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IX Jornadas de Investigación de la Facultad de Ciencia y Tecnología

UPV EHU
ZIENTZIA ETA TEKNOLOGIA FAKULTATEA
FACULTAD DE CIENCIA Y TECNOLOGÍA
50 URTE AÑOS 1968 - 2018
Biba Zientzia! Ciencia Viva

ABSTRACTS

Idatzizko Komunikazioak

Comunicaciones Escritas

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Facultad de Ciencia y Tecnología

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RESEARCH REPORT

2021-2023 TRIENNIUM

269 PhD theses

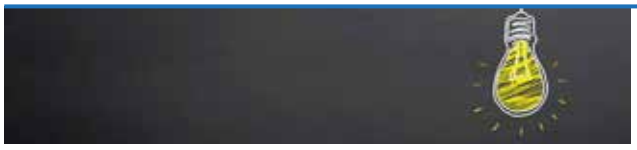
21% of the total of the UPV/EHU

2437 Articles JCR (WoS)

22% of the total of the UPV/EHU

2 ERC

30% of the total of the UPV/EHU



39 Patents

75% of the total of the UPV/EHU

6 Startups

15% of the total of the UPV/EHU

€ 44M Return of investment

35% of the total of the UPV/EHU

1 "Highly Cited" Researcher

100% of the total of the UPV/EHU

Projects
636

Contracts with companies
471

Average impact of articles (JCR)
5'94

Impact: nº of articles ≥ 50 citations
59

Biozientziak

Biociencias

Biodiversity, Ecosystem Services and Ecophysiology of Stress and Pollution in Plants: “BEZ-EKOFISKO Group”

María Teresa Gómez-Sagasti[1], José María Becerril[1], Antonio Hernández[1], Gloria Rodríguez-Loinaz[2], José Ignacio García-Plazaola[1], Beatriz Fernández-Marín[1],Igone Palacios-Agundez[2], Miren Irati Arzac[1], Unai Ortega-Barrueta[1],Unai Sertutxa[1], Lorena Ruiz de Larrinaga[1], Brenda Durand[1], Soniya Firoozi[1], Enara Alday[1], Rafael G. Lacalle[1], Lorena Peña[1], Unai Artetxe[1], Ibone Ametzaga-Arregi[1] (IP) and,Raquel Esteban[1] (IP)
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KEY WORDS: Ecophysiology, agroecosystems, biomarkers, forestry systems, soil pollution, didactics of experimental science, biotic, abiotic, Stress, biodiversity, nature-based solutions, ecosystem services

The BEZ-EKOFISKO group, led by Raquel Esteban and Ibone Ametzaga-Arregi, is a consolidated research group distinguished with the highest grade in the Basque Government classification for Scientific Groups (IT1648-22). The group consists of 12 Ph.D. researchers and 4 Ph.D. students, whose expertise and research interests align with the group's overarching objectives. These objectives are structured around three key pillars: high-quality research, training of highly skilled research personnel, and the education, dissemination, and communication of science.The main challenge of the BEZ-EKOFISKO group is to investigate essential ecophysiological processes in plants in response to both natural and anthropogenic environmental stressors. The group aims to integrate these responses at the ecosystem level, analyzing their effects on biodiversity and ecosystem services. To achieve this, our research is organized into six interconnected strategic lines, aligned with the RIS3 strategy and framed within the United Nations International Scientific Program: (i) ecophysiology of stress, (ii) phytomanagement and soil health restoration, (iii) sustainable land management, (iv) biodiversity and ecosystem services protection and conservation, (v) development of cross-disciplinary tools, and (vi) education for sustainability.

Our research employs cutting-edge methodologies, including genomics, proteomics, non-invasive techniques, physiology, biochemistry, ecosystem health assessment, and Geographic Information Systems. Through these approaches, we generate knowledge to understand ecophysiological processes and identify key mechanisms—genetic, molecular, biochemical, and physiological—driving plant responses to both biotic and abiotic environmental stressors (e.g., climate change, fungal infections, extreme weather events) and anthropogenic stressors (e.g., pollutants, heavy metals, organic compounds, antibiotics). By studying these mechanisms, we aim to: (i) identify biomarkers of plant health decline, particularly those related to photoprotection and oxidative stress;(ii) develop innovative biotechnological and methodological tools, such as remote and ground stress detection indices and plant toxicity bioassays to assess the ecotoxicological impacts of pollutants;(iii) select plant species tolerant to natural and anthropogenic stress conditions;(iv) design and develop environmentally friendly remediation strategies;(v) monitor short- and long-term forest health and track remediation processes of degraded and/or contaminated sites;(vi) implement physiological indicators to assess plant tolerance to natural stress conditions;(vii) identify ecosystem functions, evaluate conservation status, and assess biodiversity impacts at the landscape level;(viii) develop and apply indicators to assess ecosystem goods and services from social (health and well-being), ecological (environmental), and economic (green job creation, costs, and benefits) perspectives;(ix) and promote education, scientific dissemination, and public awareness, which is a fundamental and cross-cutting priority of our group.

The BEZ-EKOFISKO group has achieved national and international recognition and has established itself as a competitive research group. Our global impact is reflected in research stays in prestigious international laboratories at predoctoral, postdoctoral, and visiting professor levels; active participation in national and international projects and networks; contributions to international conferences; teaching engagements at prestigious universities; and ongoing research in collaboration with leading national and international scientists and institutions, as evidenced by joint publications and project participation. Additionally, we are committed to postgraduate education, teaching in several Master’s and Doctorate Programs with Quality Mention from the Ministry of Education. We are also dedicated to outreach activities, ensuring that our research has a meaningful impact on society.

NUtricion Management in Plant and Soil

NUMAPS – research group

Diego Tazueco, Mikel Hurtado, Daniela Salazar, Maddi Malatsetxebarria, Maitane Juárez–Murgarza, Leyre Urmeneta, Adrián Bozal–Leorri, Inmaculada Coleto, Izargi Vega–Mas, Ximena Huérfano, Daniel Marino, Teresa Fuertes–Mendizábal, Begoña González–Moro, Isabel Salcedo, Carmen González–Murua, José Mª Estavillo

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KEY WORDS: nitrogen, plant nutrition, plant molecular biology, plant physiology, soil greenhouse gases emissions, plant growth–promoting microorganisms, soil metabolism.

Nutrients are essential for plant growth and soil fertility in agriculture. Key nutrients like nitrogen (N), phosphorus, and potassium support crop development and yield. However, N is the most widely used nutrient due to its importance in plant metabolism and its scarcity in agricultural soils. Unfortunately, agriculture systems have very low N use efficiency (NUE) and more than 50% of the applied N is not used by the crops and is lost to the environment contaminating water and atmosphere. Thus, increasing NUE and sustainable fertilization management are crucial to balance productivity and environmental protection.

The rise in the use of organic waste as fertilizers and the use of nitrification inhibitors to increase NUE, pose a scenario in which crops are exposed to ammonium (NH_4^+) nutrition. High concentration of NH_4^+ in the soil leads to stress for most crops, resulting in lower growth and yield. The mechanisms leading to NH_4^+ tolerance or sensitivity are far from being understood. Thus, the identification of environmental and nutritional factors affecting NH_4^+ stress tolerance, as well as increasing the knowledge of the metabolic and molecular mechanisms involved in the response to NH_4^+ nutrition is necessary to properly address sustainable N fertilization strategies.

On the other hand, plant growth promoting microorganisms (PGP) improve crop productivity by enhancing nutrient uptake and stress tolerance. Increasing and optimizing their use favours sustainable agriculture by reducing chemical inputs and soil degradation. In a circular economy, PGPs increase nutrient use efficiency and reduce the environmental impact of agriculture.

To reach this general objective the NUMAPS research group works in three research lines:

- Environmental and productive implications of nitrogen fertilization: greenhouse gases emission mitigation strategies.
- Physiological, metabolic and molecular mechanism of mineral plant nutrition.
- Biofertilizers as a tool to optimize crop nutrient uptake, promoting more resilient agrosystems in a circular economy context.

To develop these research lines we use a wide array of different techniques that include plant growth under controlled environmental conditions (hydroponics, *in vitro*, etc.), field trials, greenhouse gases emissions determination (gas chromatography), plant physiology monitoring (photosynthesis, growth, etc.), metabolic analysis (enzyme activities, chromatography), plant transformation (CRISPR/Cas9, overexpression, etc.) and "omics" (metagenomics, transcriptomics, proteomics, metabolomics), among others.

NUMAPS is a consolidated research group distinguished with the highest grade of the Basque Government classification for Scientific Groups (IT1560-22). At present NUMAPS group is composed of 6 permanent researchers, 5 postdoctoral researchers and 5 PhD students.

FisioKlima-AgroSosT Lab. Working on the future

Aldezabal A[1], Artamendi M[1], Astigarraga J[2], del-Canto A[2], Herrero A[2], Ijurco-González I[2], Kortabarria-Perez A[1], Lacuesta M[2], Leunda M[1], López-Castro G[1], Martínez-Goñi XS[1], Mena-Petite A[2], Miranda-Apodaca J[1], Múgica A[1], Muñoz-Rueda A[1], Pardo I[1], Pérez-López U[1], Sarrionaindia E[2], Yoldi-Achalandabaso A[1]

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KEY WORDS: agroecosystems, climate change, food security, resilience, sustainability.

In the current context of climate change, sustainability, resilience, and food security are key factors that shape our agriculture and ecosystems. These are the foundation of our survival, so it is important to thoroughly understand the challenges they face and explore alternatives to address them in a resilient and sustainable environment.

In this regard, we are a multidisciplinary research team of ecologists, botanists, and plant physiologists, seeking solutions through various approaches, including precision agriculture, phenotyping, sustainability indicators, dendrochronology, resilience assessments, and paleoecology. Our work spans different levels of depth and organization, from physiological processes to species, communities and ecosystems, across various spatial and temporal scales. Specifically, our research lines are as follows:

- Search for sustainable and resilient production strategies in the face of climate change: (*i*) promoting agrobiodiversity, efficient symbiotic associations, and the cultivation of traditional varieties; (*ii*) promoting the use of biostimulants; and (*iii*) optimizing the values of vegetation index references used in precision agriculture obtained through drones.
- Ensure future food security: (*i*) evaluating the potential of alternative crops (buckwheat, sorghum, tritordeum, quinoa, among others) and traditional varieties versus conventional crops (barley, wheat, maize, and beans) under future climate scenarios combining high CO_2, high temperature, drought, and/or salinity; and (*ii*) identifying physiological mechanisms and resistance traits to abiotic stresses.
- Analyze the sustainability and resilience of dairy sheep farming (Latxa sheep) managed in extensive systems, through a multidisciplinary approach, including ecological indicators (plant biodiversity and soil microbiota), environmental indicators (greenhouse gas emissions, carbon sequestration), economic, social, and nutritional factors.
- Develop studies on forest resilience to biotic and abiotic disturbances by integrating different demographic rates (survival, growth, and recruitment) and ecological variables (e.g., soil fertility) using various sources of information (field data and national forest inventories), with an emphasis on long-term monitoring.
- Study how past climate changes and other environmental disturbances have affected plant species at centennial to millennial scales.

These research lines have led to significant contributions for the scientific community and society in general. These achievements will be presented in the poster, along with various collaborations with other researchers, companies, and entities.

You can also access more information through the following links: https://www.fisioclima.eus/es/, https://bsky.app/profile/fisioklima.bsky.social and https://x.com/fisioklima.

Marine plankton ecology

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KEY WORDS: marine ecosystems, plankton, harmful algae, invasive species, ecosystem health, time series, climate change

Research Focus Areas:

1. **Long-term variations in plankton ecosystems along the Basque coast in relation to climate change and local human activities.** This involves the analysis of time series data on plankton and environmental variables collected through monitoring programs in both marine and brackish waters, as well as hydrographic and climate data obtained from local and international public databases.
2. **Detection and impact of harmful microalgae and invasive species.** Our research examines the presence and effects of toxic microalgae and non-native zooplankton species along the Basque coast.
3. **Diversity and biogeography of microalgae**. Taxonomy of selected groups of microalgae is addressed with strains from different origins.

Rationale
Time series provide crucial insights into long-term ecological changes related to climate change and local human activities, while helping predict future trends. Plankton time series are particularly useful in tracking changes in the composition, size-spectra, abundance, and phenology of lower trophic levels in pelagic food webs, which support fisheries and commercially important shellfish. Compared to higher trophic level species, plankton are considered more reliable indicators of climate change and local environmental disturbances because of their population dynamics, being organisms with a relatively short life span, which are not subject to harvesting, unlike fish and marine mammals.

In 1998, we began plankton time series in the neritic and transitional zones of two key Basque coast estuaries (Bilbao and Urdaibai). These studies have provided valuable data to identify and analyze changes in basic environmental factors (such as temperature, dissolved oxygen, and turbidity) and plankton communities (including phytoplankton biomass, zooplankton abundance and composition) throughout the first two decades of the 21st century, allowing us to detect the effects of climate change and wastewater sanitation programs. Through international collaboration, we are comparing climate change driven changes in the zooplankton communities in our coastal waters with those in other areas in the Northeast Atlantic, particularly in trends, phenology, level of tropicalization/deborealization and changes in the size spectra. Our research is also documenting the arrival of non-native zooplankton species, from copepods to jellyfish, which have had greater success colonizing the estuary of Bilbao than that of Urdaibai.

Studies on toxic microalgae have documented potential causative species of different shellfish poisonings. Yessotoxins arise as an emerging problem, with *Protoceratium reticulatum* identified as the most likely cause and Basque strains showing warm-water affinities. *Dinophysis acuminata* has been shown to be the causative species of DSP (Diarhetic Shellfish Poissoning) toxins, which are the most prevalent in the Basque coast mussels. Twelve species of *Pseudo-nitzschia*, the causative of ASP (Amneshic Shellfish Poissoning) were identified, two of them new. Different potential PSP (Paralytic Shellfish Poissoning) toxin producers have been identified, including *Centrodinium punctatum*, which has been the last species uncovered as a toxic species. The warm-water benthic dinoflagellate genus *Ostreopsis*, of concern for the recreational use of the marine environment, was detected, for the first time in European Atlantic waters, in 2007. The genus was represented by the species *O. cf. siamensis* until 2021, when the more toxic *O. ovata* was also detected. The latter species has been shown to have warmer water affinities.

BMCC Team - Research on Microalgae: ecology and biotechnological applications

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KEY WORDS: microalgae, ecology, biotechnology.

The microalgae research group focuses on two main areas of investigation: the ecological study of phytoplankton composition and abundance across diverse ecosystems and the biotechnological applications of microalgae. Additionally, the group manages the Basque Microalgae Culture Collection (BMCC, www.ehu.es/bmcc), which comprises over 700 microalgal strains primarily isolated from ecosystems within the Basque Country. This collection, formally registered with the World Federation for Culture Collections (WFCC) in 2020, constitutes a valuable resource for the taxonomic and biotechnological study of microalgae.

In the field of ecology, the group conducts research on phytoplankton communities within estuarine ecosystems such as Urdaibai, Bilbao and Plentzia estuaries, assessing the impact of different anthropogenic pressures on community composition and ecosystem dynamics, including nutrient enrichment and challenges associated with ballast waters. Furthermore, within the context of climate change, the group participates in the European project “Ostreobila”, which investigates the dynamics of toxic benthic microalgae in coastal environments of the southwestern Bay of Biscay, evaluating their potential health risks associated with mass proliferations.

Regarding biotechnology, the BMCC is an active member of both the Spanish Network of Microorganisms (REDESMI) and the European Culture Collections’ Organisation (ECCO). The group has undertaken extensive studies on microalgal strains with industrial potential, either for their production of bioactive compounds relevant to the food, pharmaceutical, nutraceutical, and cosmetic industries, or for their capacity to capture greenhouse gases. Currently, the group is leading the PROVALGA project, funded by the Basque Government, which seeks to develop commercially valuable products from native microalgal strains and to determine their optimal cultivation conditions.

The BMCC research team collaborates with a wide network of international and national academic and technological institutions, including among others the University of Geneva, the University of Oslo, and the University of Almeria. Additionally, at the local level, it maintains active partnerships with research Centers such as AZTI, Neiker and Achucarro Center. Within the University of the Basque Country (UPV/EHU), the team collaborates with several departments, including Physical Chemistry, Pharmacy and Food Science or Cell and Animal Biology. These scientific contributions of the group are reflected in its research output, encompassing peer-reviewed publications and conference communications, as well as in its commitment to public dissemination through different initiatives, including the European Researchers’ Night, Zientzia Astea and various scientific talks and exhibitions on microalgae.

Terrestrial flora and vegetation as sentinels of global change

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KEY WORDS: climate change, community classification, human impact, functional and phylogenetic diversity, invasive species, threatened species, survey, vegetation structure

Our group has evolved over the last 30 years, from an initial focus on diversity, mapping and classification of vegetation to later incorporate taxonomic, functional and phylogenetic diversity of plant communities, macroecological studies, and monitoring and ecological modelling of biodiversity in the face of global change. We use a variety of field, laboratory, and statistical methods, as well as ecoinformatic facilities such as various in-house and international databases about plant communities, nested vegetation plots, climate, and land use. All this activity is aimed at strengthening the foundations for rational ecosystem management and conservation.

We have recently launched a **Sentinel Network for Global Change Monitoring** where we use plant diversity patterns to track changes occurring at different scales and monitor the responses of different plant communities. So far, we have incorporated permanent plots to monitor several habitats of the territory with conservation interest:

Coastal habitats as biodiversity climatic refuges

We have selected dune and estuarine habitats, which are naturally subjected to strong environmental stress, coupled with a strong human impact and the threat of rising sea levels and increased storms. In these habitats the above-mentioned impacts are combined with the expansion of several invasive species that, favoured by global change, already threaten many habitats and highly specialized native species.

Forest Diversity and Management

We have selected two types of forests that are highly fragmented and isolated in the territory: the subcantabrian mesic island oak forests and riparian hardwood ash forests. The selected plots are located in climate transition zones where a greater impact of climate change is expected. We study the effects of environment and forest management on plant diversity across different scales, with special focus on the forest understory, refuge for several endangered species. The combined analysis of physical factors, climate, forest structure and management type and intensity help us to understand and predict potential climate impacts on forest habitats and unique plant populations.

Mire Restauration and Monitoring

Peatlands not only represent a valuable fossil record where we can study events that occurred thousands of years ago but also respond rapidly to changes that are occurring today. We use permanent plots to assess changes in species composition and diversity of mire habitats after restoration actions, with control plots to track baseline changes due to climate trends. We plan to extend this network of permanent plots to the most important mire ecosystems of the territory.

Multiscale Grassland Diversity

Natural and semi-natural grasslands are highly threatened by agricultural expansion, abandonment and climate change. We focus on how land-use and climate influence grassland diversity in order to have a solid background for grassland management and conservation in the context of global change. For this, we use field samplings, international plot databases and GIS tools to analyse and model the distribution of grassland diversity at multiple spatial scales.

Ceramide 1-phosphate inhibits eosinophil migration stimulated by MCP1 derived from lung adenocarcinoma cells exposed to cigarette smoke

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KEY WORDS: Ceramide 1-phosphate, cell migration, eosinophils

Cigarette smoke (CS) is composed of many toxic compounds that can seriously alter cell homeostasis causing inflammation and cancer. In the present study, we have investigated the impact of CS on human eosinophil migration and have tested whether ceramide 1-phosphate (C1P) could counteract this action. Although neutrophils, macrophages, lymphocytes, dendritic cells and mast cells are the major cell types involved in inflammatory responses, eosinophils are particularly relevant in lung inflammation and cancer as they can migrate into inflammatory foci or into the tumor environment. We found that CS-conditioned medium from A549 lung adenocarcinoma cells (CSCM) potently stimulated migration of human eosinophils at concentrations that did not affect cell viability. Interestingly C1P, which we previously found to be anti-inflammatory in mice lungs *in vivo*, completely blocked CSCM-induced migration of eosinophils. In agreement with previous work, we also observed that CS induced the release of MCP1 in A549 lung adenocarcinoma cells, a chemokine that plays an important role in the initiation and progression of cancer. Noteworthy, C1P potently blocked MCP1 secretion by the lung cancer cells and MCP1-stimulated eosinophil migration. However, phosphatidic acid (PA), which is a natural structural analog of C1P and has pro-inflammatory properties, failed to reduce eosinophil migration. These observations indicate that C1P might be useful for developing new therapeutic strategies to treat diseases in which eosinophil migration plays a critical role.

Lipid protein interactions in autophagy

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KEY WORDS: autophagy, model membranes, ATG8.

Macroautophagy is a cellular degradation process characterized by the formation of the autophagosome (AP), a double-membrane structure that engulfs intracellular components for their degradation. AP formation involves a complex interplay of lipid transfer and vesicle incorporation, though the precise mechanisms remain unclear. The ATG8 protein family, including LC3 and GABARAP subfamilies, plays a crucial role in this process. These ubiquitin-like proteins covalently bind to phosphatidylethanolamine (PE) in the AP membrane, facilitating vesicle tethering and lipid mixing. Among them, LC3B is widely recognized as a canonical autophagosomal marker, while LC3C has been less studied but recently implicated in key cellular processes.

Our group studies the ability of LC3B and LC3C to induce vesicle tethering and fusion using model membranes. Results indicate that lipidated LC3C promotes higher levels of vesicle aggregation and lipid mixing than LC3B, a difference attributed to its unique N-terminal region. Mutational analysis confirmed that this region enhances membrane perturbation and fusion activity. We then checked if this differences *in vitro* had an effect in cells. To do so, we used HeLa HexaKO cells, with lack all six members of the ATG8 familly. In these cells, LC3C formed larger GFP-puncta than LC3B, further supporting its role in AP expansion.

Additionally, we study the involvement of ceramide (Cer), a sphingolipid known to facilitate membrane fusion, in the AP formation process. Fluorescence and spectroscopy experiments suggest that Cer enhances the vesicle tethering and fusion activities induced by GABARAP and GABARAPL1, further promoting membrane expansion. Given the suggested presence of sphingolipids in the AP, these findings provide new insights into the role of Cer in macroautophagy regulation.

In summary, LC3C displays enhanced vesicle fusion activity compared to LC3B, likely contributing to phagophore expansion, while Cer may facilitate vesicle incorporation into the growing AP. These findings suggest a specialized function for LC3C and highlight Cer as a potential modulator of autophagosome biogenesis.

Clarifying the role of disease-associated lncRNAs in autoimmunity

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KEY WORDS: lncRNA, SNP, autoimmune diseases.

Development of high-throughput techniques and next-generation sequencing (NGS) has allowed the identification of thousands of disease-associated single nucleotide polymorphisms (SNPs) throughout the genome. However, the molecular mechanisms by which these polymorphisms affect disease pathogenesis remain poorly understood. Type 1 diabetes (T1D) and celiac disease (CeD) are two complex autoimmune diseases, in which genetic and environmental factors interact to activate the immune system to specifically attack pancreatic beta cells or intestinal cells, respectively. Interestingly, the vast majority of SNPs associated to these conditions are located in non-coding regions of the genome, and especially in long non-coding RNAs (lncRNAs).

LncRNAs have traditionally defined as non-coding transcripts exceeding 200 nucleotides. While many lncRNAs undergo splicing and polyadenylation like mRNAs, others remain non-polyadenylated or originate from different RNA polymerases, introns, or repetitive elements. Genomically, lncRNAs can be intergenic (lincRNAs), intronic, or overlapping protein-coding genes, in either a sense or antisense orientation.

LncRNAs regulate gene expression at transcriptional and post-transcriptional levels through diverse mechanisms. They can modulate gene transcription by interacting with DNA and protein complexes, influence RNA splicing by facilitating splicing factor binding, participate in nuclear paraspeckle formation, and regulate mRNA stability. Additionally, lncRNAs can act as miRNA sponges, preventing miRNA-mRNA interactions, and can enhance or repress translation. Some even harbor small open reading frames capable of encoding functional micropeptides.

The presence of disease-associated SNPs within lncRNA sequences can disrupt their secondary structure, affecting their function and altering lncRNA-regulated pathways. Indeed, studies by our group have shown that T1D-associated SNPs in lncRNAs affect pancreatic beta cell viability through dysregulation of pro-inflammatory pathways. Moreover, we have also observed that SNPs associated with CeD affect the function of lncRNAs that regulate CeD-related pro-inflammatory gene expression.

Against this background, the main research line of our group is focused on the functional characterization of disease-associated lncRNAs in two immune-related diseases: T1D and CeD. To this aim, we perform in vitro functional studies in models of pancreatic beta cells and intestinal cells, ex vivo experiments using patient-derived organoids, and expression analysis and immunological studies in samples from T1D and CeD patients. In our group, we use several in silico and in vitro methods to dissect the function of the disease-associated lncRNAs, including:

1. **In Silico RNA Structure Prediction:** Computational modeling predicts SNP-induced structural alterations and the impact on lncRNA activity.
2. **RNA Immunoprecipitation (RIP):** This technique identifies RNA-protein interactions, providing insight into how SNPs affect lncRNA function or binding potential.
3. **Functional Assays in in vitro and ex vivo Models**: Overexpression and silencing of lncRNAs and SNP-specific variants to assess their effect on gene expression, signaling pathways, and immune responses.

Deciphering the functional effect of disease-associated SNPs within lncRNAs is important to understand how these genetic variants exert their effect on disease pathogenesis through lncRNA function alteration. Deciphering the molecular mechanisms by which the lncRNAs participate in disease pathogenesis at the immune-targeted tissues (pancreatic beta cells or intestinal cells) will allow developing therapeutic strategies based on lncRNA expression modulation.

Interdisciplinary approach to combat antibiotic resistance using molecular, structural and nanotechnological strategies (INTER-RA)

Itziar Alkorta[1], Sofía Ruiz-Cruz[1], Irene Beltrán de Heredia[1], Ana Rey-Sogo[1], Nagore Santos-Fernández[1], Maider Álvarez-Salazar[1], Lide Arana[2], Ianire Mate[3], Oihane Altube[2], Lucía Gallego[3], Sara Sánchez-Urtaza[3], Paola Fucini[4], Ronny Zegarra[4], Ransford Parry[4],

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KEY WORDS: Antibiotic resistance; resistance genes; bacterial conjugation; resistome; nanotechnology; solid lipid nanoparticles.

The advent of antibiotics revolutionized modern medicine, significantly extending human life expectancy and transforming the treatment of bacterial infections. However, the widespread misuse and overuse of these life-saving drugs have precipitated a crisis in which existing antibiotics are rapidly losing their efficacy. If left unaddressed, this growing antimicrobial resistance (AMR) threatens to usher in a post-antibiotic era, with mortality rates surpassing those of cancer and cardiovascular diseases. While the issue is often framed as a clinical challenge, its roots lie in the environment, where antibiotics and other emerging contaminants exert selective pressure on microbial communities. This environmental burden drives the dissemination of resistance genes among bacteria, exacerbating the global AMR crisis and underscoring the need for a multidisciplinary approach to mitigate its impact. As a result, pathogenic bacteria in hospital settings acquire these resistance genes, evolving into multidrug-resistant organisms—commonly referred to as superbugs—which exhibit resistance to nearly all known antibiotics.

Addressing this complex and multifaceted challenge requires a comprehensive, multi-tiered approach. Our research group comprises scientists with extensive expertise in diverse disciplines, including biochemistry, structural biology, nanotechnology, and clinical microbiology, enabling us to tackle antibiotic resistance through an integrated and interdisciplinary strategy. To this end, we collaborate with a network of partners who share our commitment to combating what is increasingly recognized as the 21st century's silent pandemic: antimicrobial resistance. Given the urgency of this escalating crisis, it is imperative to develop innovative solutions that both optimize the efficacy of existing treatments and explore novel therapeutic alternatives. Efforts must extend beyond the discovery of new antibiotics to encompass the development of advanced strategies aimed at preventing the dissemination of antibiotic resistance among bacterial populations.

The primary objective of this research group is to contribute to addressing the escalating problem of antibiotic-resistant bacteria through an interdisciplinary approach that encompasses: **(i) the identification of molecules capable of preventing the horizontal transfer of antibiotic resistance genes among bacteria from different ecosystems**; **(ii) the characterization of novel chemical structures and antibiotic targets**; and **(iii) the development of nanotechnological tools to enhance the efficacy and precision of existing antibiotic therapies**.The specific objectives of our group are:

Objective 1: Identification of bacterial conjugation inhibitors to control the spread of antibiotic resistance among bacteria.

Objective 2: Characterization of novel chemical scaffolds and new molecular targets for the development of antibiotics.

Objective 3: Design of Solid Lipid Nanoparticles (SLNs) as innovative solutions to enhance the efficacy and lifespan of existing antibiotics.

Objective 4: Evaluation of the impact of the proposed strategies on real clinical and environmental samples.

Molecular Biology of Cancer

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KEY WORDS: Cancer, Immunity, Cell Cycle, DNA repair, Genomic instability, Gene knockout, Genomics, Proteomics.

The main characteristic that defines cancer is the disruption of cellular homeostasis. This disruption arises from several mechanisms, including deregulation of gene expression, unchecked cell cycle progression, defects in DNA repair, metabolic rewiring, genomic instability and immune evasion, among others. A key feature of cancer progression is the deregulation of transcriptional programs, with alterations in transcription factors and epigenetic regulators driving uncontrolled proliferation, aberrant differentiation, and adaptation during metastasis, immune evasion, and therapy resistance. Cancer cells commonly exhibit deregulation of the transcriptional programs driven by the E2F transcription factors, which are critical for coordinating cell cycle progression, genome stability maintenance, differentiation, and cell death. Our research group is focused on the detailed characterization of E2F-driven mechanisms and their role in malignant transformation. Our ultimate goal is to translate the knowledge acquired into clinical applications, either by identifying prognostic markers, or by uncovering and characterizing new therapeutic targets.

Our research group is a multidisciplinary team with expertise in the areas of genetics, molecular and cellular biology, proteomics, and bioinformatics. For over a decade, we have been dedicated to the study of cancer molecular biology, a field deemed strategic by the Plan de Ciencia, Tecnología e Innovación Euskadi 2030 due to its significant biomedical and social impact. Our team has been recognized and funded by the Department of Education of the Basque Government as a "Consolidated Group" continuously since 2001.

We are applying genomic and proteomic approaches, together with classical methods of genetic, cell biology and biochemical analysis, to identify and characterize the transcriptional networks that govern cellular proliferation and cell fate, and to understand how the dysregulation of these networks contributes to oncogenesis, metastasis, resistance to therapy and immune evasion. Current areas of research in the laboratory are focused on the study of both tumor-cell intrinsic and tumor cell-extrinsic mechanisms:

1. **Tumor cell-intrinsic view:**
    a. Role of E2F factors in colorectal cancer metastasis
    b. Chromatin components of E2F transcriptional machinery
    c. Regulation of E2Fs by nucleocytoplasmic transport and post-translational modifications
    d. Regulation of centrosome cycle and cancer
2. **Tumor cell-extrinsic view: immune microenvironment:**
    a. Role of E2F factors in systemic and colonic inflammation
    b. Tumor immune surveillance in colorectal cancer

Complex Disease Precision Medicine Network

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KEY WORDS: Personalized medicine, childhood cancer, targeted therapy, molecular profiling, NGS technologies, DNA methylation profiling, cost-effectiveness.

Personalized medicine is currently emerging as a tool that seeks to make the treatment of complex diseases more effective. However, there is still a need for biomarkers to guide treatment decisions and assess response to treatment. Genetic and molecular characterization of each individual or subgroup of patients could help to overcome this situation, refining the diagnosis, improving risk-adapted management strategies and providing elements to better asses the response to treatment and disease surveillance.

In order to build the conceptual basis on which developing precision therapies, we aim to broaden our knowledge about complex diseases such as cancer, mainly analyzing the molecular profile of poorly characterized subtypes (especially those with unknown prognosis, intermediate diagnosis or non-determinant). The current possibility of performing an integrative approach that includes all data sets generated from omics studies for the identification of specific genomic signatures may be crucial to develop more specific and less harmful therapies. In addition, the genetic and molecular information obtained from these new data sets will be assembled with previously generated knowledge and clinical information, for the identification of potential new biomarkers. After the identification of biomarkers in tissue samples, in those cases in which it is particularly relevant, the suitability of liquid biopsies for identifying these markers will be also tested.

Our objectives to deal with all these important aspects are instrumentally divided in four key milestones:

- Definition of the genetic and epigenetic profile with diagnostic implications of childhood acute lymphoblastic leukemia/lymphoma, pediatric medulloblastoma and diffuse large B-cell lymphoma, through RNAseq and functional studies

- Comprehensive characterization of the molecular landscape of medulloblastoma subgroups integrating WGS, RNAseq and clinical data for the stratification and clinical implementation into the newly defined 12 medulloblastoma subgroups

- Identification of prognostic biomarkers and response to therapy in pediatric cancer through the study of the potential of non-coding RNAs as risk markers or new therapeutic targets

- Evaluation of the translational impact of using liquid biopsy in diagnosis and follow-up in cancer

This project is possible thanks to the collaborative effort between the UPV/EHU and the 4 University Hospitals with the highest volume of patients in the Basque Country, such as Cruces, Basurto, Donostia and Araba. The establishment of this Collaborative Network in our Community is being key in improving the diagnosis of cancer and the implementation of various ongoing projects and implementation of clinical trials, emphasizing the importance of collaboration between basic researchers (UPV/EHU) with clinical researchers (UPV/EHU-Osakidetza). However, these ongoing tasks must be consolidated and intensified to ensure progress in the diagnosis and treatment of these diseases. It is also very important to point out the teaching work that the group performs, tutoring doctoral theses, participating in postgraduate programs and training postdoctoral researchers.

Ecophysiology and ecotoxicology of aquatic organisms (PHYSIOTOX)

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KEY WORDS: bivalves, ecosystem services, physiology, pollution, nature-based solution, bioremediation.

Our research group, formerly known as "Physiological Energetics of Marine Bivalves", has been focused on analyzing the impact of environmental parameter variations (food availability and quality, temperature, among others) and endogenous inter-individual differences (of genetic or epigenetic origin) on the growth capacity of commercially important bivalve mollusk populations (mussels, clams, oysters, etc).

Our group has evolved into PHYSIOTOX (Ecophysiology and Ecotoxicology of Aquatic Organisms), integrating with the Ecotoxicology team to focus on Nature-based Solutions. Our current research is centered on the MIToYSTER project, which aims to evaluate the effect of pollution on the biological status of the flat oyster (*Ostrea edulis*) and its capacity to restore eutrophic ecosystems, using the Mar Menor lagoon as a case study.

THE MIToYSTER PROJECT

The Mar Menor lagoon (Murcia, Spain) is facing severe ecological degradation due to decades of intensive agricultural activity, urban development, and tourism. One of the most visible problems is the phenomenon known as "green soup", where excessive nutrient runoff, particularly nitrates from fertilizers, leads to eutrophication. This process causes massive algal blooms that turn the water green, block sunlight, and create dead zones where marine life cannot survive. In addition to nutrient pollution, the Mar Menor is also contaminated with heavy metals and emerging pollutants. Heavy metals, such as lead and cadmium, have entered the lagoon from historical mining activities. These metals accumulate in the sediment and can be toxic to aquatic life. Emerging pollutants, including pharmaceuticals and personal care products, enter the lagoon through wastewater and runoff, posing additional risks to the ecosystem. The combination of these pollutants has severely degraded the lagoon's health, making restoration efforts complex and challenging.

This multidisciplinary project involves a comprehensive study of the interactions between pollution and nutrient extraction capacity of oysters, combining expertise in marine pollution assessment, physiological components of bivalves' energy balance, and chemical analysis of pollutants. The project is a collaborative effort involving several research groups, including the Marine Pollution Research Group at the Spanish Oceanographic Institute (IEO-CSIC), the Ecophysiology and Ecotoxicology of Aquatic Organisms Group at the University of the Basque Country (UPV/EHU), and the Applied Analytical Chemistry Group at the University of A Coruña (QANAP-UDC). Our group is responsible for coordinating the physiological responses of juvenile and adult oysters for assessing their nutrient extraction capacity. This year, we have commenced experimentation following a year of preliminary trials, and we expect to obtain the first results in the coming months. This includes laboratory experiments aiming to:

1. Establish the EC_{50} of Mar Menor oyster populations in response to the most common contaminants in the region.

2. Simulate eutrophication conditions similar to the "green soup" phenomenon to assess their filtration capacity during these events.

3. Evaluate the interactive effects of pollution and eutrophication on the nutrient extraction capacity of oysters.

The project pursues to contribute to the United Nations Decade on Ecosystem Restoration and the European Green Deal, as well as to the SDG 14 (life below water).

Development of a Chemical Toolkit to Unravel Protein-Lipid Interactions in Physiopathology conditions

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KEY WORDS: Lipid-protein interactions, chemical probes, biological membranes, HIV, bioorthogonal chemistry

Lipid-protein interactions play a fundamental role in cellular processes and have been implicated in various diseases, including cancer, Alzheimer's disease, and HIV infection. Understanding these interactions is crucial for developing targeted therapeutic strategies and advancing our knowledge of cellular regulation.

Our research group, based in the Department of Biochemistry and Molecular Biology and the Biofisika Institute (CSIC, EHU/UPV), focuses on elucidating the role of lipid-protein interactions in disease contexts. To achieve this, we develop and employ custom-designed lipid probes that enable high-resolution microscopy imaging of these interactions without perturbing the physiological state of living organisms. This approach allows us to study lipid-protein dynamics with unprecedented precision, providing valuable insights into their functional roles in health and disease.

In addition to investigating general lipid-protein interactions, we have a particular focus on their involvement in biological membranes, with an emphasis on the human immunodeficiency virus (HIV). Our studies have contributed to the identification of key molecules involved in viral infection and have paved the way for novel therapeutic strategies. By understanding how lipids influence viral entry, replication, and host cell interactions, we aim to uncover potential targets for antiviral interventions.

Through interdisciplinary collaboration and cutting-edge methodologies, our research aims to shed light on the intricate molecular mechanisms governing lipid-protein interactions. The insights gained from our work hold significant potential for the development of innovative therapeutic approaches, ultimately contributing to the advancement of biomedical science and the improvement of human health.

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Cancer Cell Plasticity and Epigenetics

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KEY WORDS: breast cancer, cellular plasticity, epigenetics, metabolism, methylation.

Genetic, environmental, and metabolic insults disrupt chromatin homeostasis leading to abnormal epigenetic restriction or plasticity. Such aberrant chromatin states confer oncogenic properties through repression of tumor suppressors or activation of oncogenes. Moreover, these chromatin states are often dynamic, unlocking phenotypic plasticity in cancer cells, a notion now considered an emerging hallmark of cancer. In this scenario, perturbation of epigenetic homeostasis acquires a dual role: i) as a hallmark of cancer in oncogenic processes driven by mutation of epigenetic regulators and ii) as an enabling capability upon non-mutational epigenetic reprogramming. Metabolic intermediates represent crucial substrates for chromatin-modifying enzymes, creating an interdependent communication by reflecting microenvironmental perturbations onto the chromatin status. A representative example is the methionine metabolism product S-adenosylmethionine (SAM), which is the main cellular methyl group donor and building block for DNA and histone methylation in the nucleus.

Breast cancer (BCa) is the most common cancer and the first leading cause of cancer related death among women worldwide. Of note, data simulations predict an increasing incidence rate for this disease in the next two decades, posing it as a growing socio-economic concern.
Our group is a young research team focused on studying the molecular mechanisms underlying breast cancer pathogenesis. Our research is based on our expertise in the areas of molecular and cellular biology, signaling, metabolism and epigenetics. By employing cell line and organoid models *in vitro* and subcutaneous or orthotopic xenograft mouse models *in vivo*, we aim to answer the following questions:

- How does the alteration of epigenetic regulation affect breast cancer pathogenesis?
- What is the impact of alterations in histone modifying enzymes and chromatin remodelers in breast cancer development?
- Which are the key determinants of the metabolism-epigenetic axis in breast cancer?

ONE-HEALTH_OMICs Group:
Multiomics in Human and Animal Health

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KEY WORDS: genomics, infectious diseases, vaccines, adjuvants, autoimmunity, RNA-seq, miRNAs, non-coding RNAs, metagenomics, women health

Omics techniques are comprehensive assessments of different classes of biological molecules, such as RNA, that have revolutionized modern medicine by advancing our understanding of molecular complexity in health and disease. Combining different omics can provide functional information that cannot be captured by one of them alone, enabling new understanding of the molecular complexity. Advancement in different omics technologies have enabled novel integration of different omics data, called multi-omics, to capture the complex molecular interplay of health and disease by combining the power of individual data types. In multi-omics, one omics technology can complement the shortcomings of another to provide a holistic view of molecular complexity.

Non-coding RNAs are, arguably, the enigma of the RNA transcriptome. Non-coding RNAs (ncRNAs) are molecules able to regulate cell fate both in physiological conditions and in disease by controlling transcriptional or post-transcriptional mechanisms. Originating from "the dark matter" of the genome, ncRNAs lately became increasingly crucial multipurpose regulators of all biological processes. As we begin to understand the function and regulation of this class of RNAs, strategies targeting ncRNAs could lead to improved therapeutic interventions for some conditions.

The main objective of our research group is deepening in the study of the mechanisms of infectious diseases and other complex diseases using multi-omics methodologies. Our research includes in depth knowledge of specific pathogens and diseases, along with carefully selected samples and optimally developed model systems. Among the specific objectives, and in relation to the host-pathogen interactions, the followings are addressed:

Line 1:

- Detection and characterization of genomic elements, both protein-coding genes and non-coding RNAs, involved in the immune response against infectious agents.
- Characterization of the Immune response to vaccination and vaccine adjuvants by transcriptomic analysis.

Line 2:

- Metagenomic analysis of the cervico-vaginal microbiota as a modulator of infectious diseases in women.
- Role of ncRNAs in reproductive diseases.

Our studies in Line 1 can help to identify molecular signatures activated by vaccines and their adjuvants, providing insight into the mechanism that underlie the immune response by combining the molecular information provided by the sequencing of different RNA molecules. Moreover, the analyses in line 2 can provide information for the diagnosis of cervico-vaginal diseases and other reproductive problems in women.

Evolutionary Biology and Human Health

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KEY WORDS: Wolf, Dog, Domestication, Paleogenomics, Prosociality, skin pigmentation, skin microbiome, spatial gene expression, Visium HD, single-cel

Currently, the Evolutionary Biology and Human Health group is mainly researching into the following lines:

WOLF DOMESTICATION: AN APPROACH BASED ON PALEOGENOMICS ANALYSES IN ANCIENT HUMAN POPULATIONS

Dogs, the first domestic species, are present in the fossil record from the Upper Paleolithic. During the last Ice Age, species migrated South into Eurasia, where population density increased and hunter-gatherers had to coexist with other species (such as the wolf), emerging interactions that contributed to the generation of a favorable niche that would trigger the domestication of the wolf.
In the early stages of the domestication process, changes in both wolf and human behavior can be an important clue to understanding the interaction between these two species. For this reason, an analysis of genetic variants related to behaviors that may have favored the social and biological adaptation of our species in the last ~40,000 years is being carried out. Genetic polymorphisms, related to behaviors regulated by the HPA (Hypothalamus-Pituitary-Adrenal) axis, are being studied in ancient *H. sapiens* databases from Europe and Asia in order to detect possible temporal changes in the allelic frequencies of some genes involved in the development of prosocial behaviors, that could influence the process of this domestication.

SKIN PIGMENTATION, MELANOMA and other CANCERS

Natural selection, our demographic history and chance all shape our genetic diversity and consequently determine our ability to adapt to the environment and survive as a species. Adaptations are the result of tinkering processes that occasionally may result in undesirable consequences for human post-reproductive health. For instance, light-skinned individuals are at a higher risk of developing a skin cancer. In the past, we have analyzed the genetic variation and gene expression changes associated with skin pigmentation in humans in order to infer its adaptive value and assess its biomedical implications. However, our skin can be considered a complex ecosystem, composed also of millions of bacteria, fungi and viruses, collectively known as the skin microbiota. Consequently, our present interest lies in how the human skin microbiota might contribute a protective effect against UVR and how UVR has modulated the microbiota ecosystem. As regards melanoma, and other cancer like ccRCC, we are investigating the spatial expression of genes on biopsies to analyze gene expression heterogeneity, by means of Visium HD Spatial Gene Expression at almost single cell resolution.

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Ecological and biotechnological role of marine bacteria

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KEY WORDS: marine bacteria, global change, plastisphere, resistance to antibiotics, aquaculture, extracellular enzymatic activity, bioremediation.

Marine bacteria play an important role in in the trophic webs and in the biogeochemical cycles of the oceans. On the one hand, due to global change, the oceans are changing, increasing in temperature, acting as sinks for high concentrations of pollutants such as drugs or antibiotics (and the antimicrobial resistance associated), accumulating plastics and losing much of the fish diversity due to large-scale fishing. Although several changes in the functioning of the global ocean occur, **how the bacterial communities may respond to this global changes** is uncertain. In order to try to understand the whole picture, we have focused our research on different aspects that may affect the bacterial community in a changing ocean.
In this sense, we study the temperature sensitivity of bacterial respiration, production and extracellular enzyme activities, in order to gain predictive power about the changes in the **remineralization of the organic matter under future scenarios of global warming**. We also study the possible ecotoxicological role of plastics in the oceans and their presence throughout the food chain. We also analyze the abundance, taxonomic composition, metabolic potential, and resistance to different antibiotics of the bacterial communities present in plastispheres of different types of **plastics** with the aim of determining whether, in addition to their ecotoxicological role, they may be acting **as reservoirs of pathogens and/or bacterial resistance to antibiotics**.

On the other hand, the high abundance and functional diversity of the marine bacteria represent an important biotechnological potential for solving many of the problems of the XXI century related to global change. Our work focuses on several aspects of the activity of the marine bacteria that can help to improve life and society. Our working group has managed to isolate different marine bacteria from different marine systems and under different incubation conditions, which allows us to search for bacteria with interesting characteristics in the field of biotechnology. The great metabolic versatility of the marine bacteria makes them a good bioprospecting tool for the search and production of **new chemical compounds (microbial growth inhibitors and enzymes of biotechnological interest)**. Thus, marine bacteria are a feasible source of new natural compounds with **antimicrobial activity** to confront the emergence of new diseases and pathogens resistant to antibiotics. Some of the marine bacteria analyzed have inhibitory activity against the growth of pathogenic bacteria such as *Staphylococcus aureus* or pathogenic fungi such as *Scedosporium*. In addition, some of the marine bacteria isolated and analyzed present extracellular enzymatic activities such as lipases, amylases, cellulases or laccases especially stable and active at different temperature and salinity conditions, which makes them **of great biotechnological interest** as new drugs or food additives, and useful compounds for different industrial processes. Finally, the high metabolic variability of marine bacteria allows them to be used for the **degradation or transformation of pollutants**. In this regard, the working group is analyzing the ability of some marine nitrifying bacteria to **eliminate ammonium and nitrite** and the possibility of their use in sustainable aquaculture systems. Another aspect of the applications of the metabolic potential of marine bacteria is the **bioremediation of environmental pollutants like the plastic waste**. Some bacteria are able to biodegrade microplastics, which makes them potential tools to reduce plastic pollution.

In summary, our research group aims to gain knowledge about each of these aspects, in order to obtain predictive tools about the role of marine bacteria in future scenarios of global warming or plastic pollution, and to detect bacterial compounds or metabolic capabilities useful in industrial, biomedical or environmental applications.

Bacterial resistance to stress

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KEY WORDS: *Vibrio*, pathogenicity, *Galleria mellonella*, mollusk, reservoirs, *Mytilus galloprovincialis, Magallana gigas*.

Some members of the *Vibrio* genus are potential pathogens of humans and animals and are responsible for significant economic losses worldwide. In recent years, the detection of pathogenic *Vibrio* strains and the incidence of vibriosis associated with the use and consumption of contaminated water, seafood, and other foodstuffs have increased. The Basque Autonomous Community, a predominantly coastal area with socioeconomic activities gathered around the use and enjoyment of its beaches and coasts, constitutes an area of interest for determining the distribution, survival and pathogenicity of *Vibrio* spp. in order to prevent the potential effects of global warming on the health of its inhabitants, the economy and the environment. In the last years, we have been studying the temporal and spatial distribution of *Vibrio* spp. on the Basque coast, with special attention to the Bay of Plentzia. These analysis are complemented by the enumeration and/or detection of other bacteria widely used as indicators of contamination. Meanwhile, the group has focused on other aspects related to the persistence of *Vibrio* in the environment (reservoirs) and the possible variations in its pathogenicity due to the permanence in changing aquatic environments:

1. **Invertebrates as Vibrio reservoirs**
   We ahave studied the ability of mussels (*Mytilus galloprovincialis*) and oysters (*Magallana gigas)* to act as reservoirs of *Vibrio* spp. by accumulating these microorganisms in their organs (grills, digestive glands, and gonads). Our results show that both molluscs actively remove vibrios from water, although a fraction of them is retained in their organs. In addition, we demonstrated that mollusks can concentrate *Vibrio* in the faeces and pseudofaeces, which could be a mechanism of *Vibrio* dissemination.
   Likewise, we are also analyzing the role that phytoplankton and zooplankton may play as reservoirs of *Vibrio* by attaching to the surface of these organisms.

2. **Impact of environmental factors on *Vibrio*'s survival and pathogenicity**
   We have studied how different *Vibrio* strains survive under a variety of environmental conditions (temperature, salinity, starvation) and we want to know how these conditions might affect their pathogenicity and antibiotic resistance. For the pathogenicity assays, we use *Galleria mellonella* larvae as an animal model. Prior to conducting the assays, we had to standardise the procedure in order to normalise the assay conditions, including the selection of the most appropriate larvae size to obtain homogeneous results. The results obtained thus far indicate that starvation at 20°C increases the pathogenicity of *V. harveyi* over time. Furthermore, an increase in resistance to certain antibiotics was detected after several weeks in nutrient-deprived conditions.

Invasive Candidiasis: Strategies for improving diagnosis, treatment, and prevention

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KEY WORDS: Invasive candidiasis, diagnosis, prevention, antibodies, antifungals, resistance, immunocompromised patients, risk factors.

Invasive Candidiasis (IC) is a severe and life-threatening fungal infection caused by *Candida* species, with *Candida albicans* being the most common etiological agent (50%). Immunodeficiency and invasive medical procedures are key risk factors for IC, making it a leading nosocomial fungemia. The standard diagnostic method, blood culture, exhibits limited sensitivity (50-60%) and requires 2 to 10 days for processing. Moreover, current therapeutic options are restricted to three classes of antifungals, whose efficacy is increasingly compromised by adverse effects and the emergence of antifungal resistances. Consequently, IC presents a high mortality rate (63.6%).

Therefore, the Invasive Fungal Infection Study Group (GEIFI) focuses on three research lines researching novel diagnostic, therapeutic, and protective strategies, as well as assessing antifungal resistance mechanisms.

1. **NOVEL BIOMARKERS FOR INVASIVE CANDIDIASIS DIAGNOSIS:** Given the limitations of current IC diagnostic techniques, our research aims to improve detection methods. For that purpose, our research group developed an indirect immunofluorescence assay (IFI) detecting *Candida albicans* Germ Tube Antibodies (CAGTA) in IC patients. CAGTA, indicative of invasive processes, are associated with a lower mortality rate in ICU patients, and are directed against germ-tube surface antigens of *Candida albicans*, such as agglutinin-like sequence 3 (Als3), hyphal wall protein 1 (Hwp1) and methionine synthase (Met6). Based on this premise, we work with a collection of sera registered by the Instituto de Salud Carlos III-Spain. These sera come from patients at risk for developing invasive fungal diseases. We use detection of ß-glucan, immunodetection (e.g. ELISA) or IFI techniques to evaluate different and non-invasive culture-independent diagnostic tools to improve diagnosis of an IC. In addition, we assess some antibodies for diagnosis utility. In these regards, we investigate the biological activities of the monoclonal antibodies (mAbs) C7, B9E, and Cg26, which are produced in our laboratory and could offer diagnostic potential.
   Furthermore, we are working with a λ ZAP II (Stratagene) cDNA library prepared from mRNA of the *Candida albicans* strain SC5314 growing in the mycelial phase, aiming to identify novel IC biomarkers.

2. **ASSESSMENT OF PROTECTIVE STRATEGIES AGAINST INVASIVE CANDIDIASIS** The proteins Hwp, Als3, and Met6 of *C. albicans* are antigenic targets recognised by CAGTA. Now, we evaluate their capacity to induce a protective immune response through a complex peptide approach, aiming for future vaccine development.
   Regarding monoclonal antibodies (mAbs), our findings suggest that some of them also exhibit protective and fungicidal properties, making them promising candidates for antifungal therapy and immunoprotection.

3. **MECHANISMS OF ANTIFUNGAL RESISTANCE:** As the antifungal resistance rises, we focus on characterising its molecular mechanisms. Our investigations focus on analyzing resistance-associated mutations in *Candida* spp. using RT-qPCR and sequencing techniques, as well as characterizing azole resistance mechanisms in *Candida albicans* through transformed yeast. Additionally, we analyse the susceptibility of clinical isolates to azoles and other antifungals, establishing correlations between resistance phenotypes and genetic profiles.

In summary, the GEIFI research group prioritizes the comprehensive characterization of the cellular, molecular, and genetic factors contributing to the pathogenesis of invasive candidiasis, by adopting a multidisciplinary approach.

MicrobiomicsEHU: Fungal pathogens and their infectious diseases

Nahia Cazalis-Bereicua[1], ***Lucia Abio-Dorronsoro***[1], *Oier Rodriguez-Ereñaga*[1], *Eduardo Pelegri-Martinez*[1], *Saioa Cendón-Sánchez*[1], *Maialen Areitio*[1], *Leire Aparicio-Fernandez*[1], *Leire Martin-Souto*[1], *Idoia Buldain*[1], *Aitziber Antoran*[1], *Aitor Rementeria*[1] *and Andoni Ramirez-Garcia*[1].

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KEY WORDS: *Aspergillus, Scedosporium/Lomentospora, Candida.*

The incidence of fungal infections has been increasing globally in recent years. In fact, infections caused by fungi affect millions of people every year, primarily immunocompromised patients, with mortality rates often exceeding 50%. The main factors contributing to these outcomes are delays in diagnosis due to the lack of rapid, specific, and sensitive detection methods, and the resistance of many of these fungi to available antifungals. In fact, in 2022, the World Health Organization (WHO) published a list of priority fungal pathogens, including *Candida auris, Candida albicans*, and *Aspergillus fumigatus* in the Critical Priority Group, and *Scedosporium/Lomentospora* in the Medium Priority Group due to their high resistance to antifungals and virulence.

Therefore, in the MicrobiomicsEHU Research Group of the University of the Basque Country (UPV/EHU) we focus our efforts on shedding light on the pathobiology of the most important fungal pathogens, mainly *Aspergillus*, *Scedosporium/Lomentospora*, and *Candida*, with the aim of understanding their virulence mechanisms.

In the *Aspergillus* research line, we focus on key genes involved in the virulence of the fungus. To achieve this, we use the CRISPR-Cas9 technique to generate knockout mutants and characterize the effects of the selected genes *in vitro*. In addition, in the *Scedosporium/Lomentospora* research line, based on the serum of cystic fibrosis patients, we identify new diagnosis and therapeutic targets. Finally, in the *Candida* research line, several species are studied. On one hand, we study the effect of *Candida albicans* on cancer, analysing how tumor cells change upon exposure to the fungus, as well as the underlying molecular mechanisms. On the other hand, we investigate how environmental factors influence the resistance mechanisms and virulence of *Candida auris*.

Analysis of *Vibrio* adaptation and survival in aquatic systems

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KEY WORDS: Climate change, next-generation sequencing, proteome analysis, zymography

The ubiquitous presence of microorganisms is largely conferred by their unique abilities to adapt and survive under adverse and continuously changing conditions. We use the members of the *Vibrio* genus as model organisms to study various aspects of *Vibrio* ecology by analyzing the impact of climate change on *Vibrio* adaptation and survival. Our major research lines are briefly outlined below.

1. Addressing the impact of cell size reduction on adaptation of *Vibrio harveyi* and *Vibrio kanaloae* in aquatic systems

Our recent work has revealed that adaptation of *V. harveyi* to some abiotic stress conditions could occasionally trigger cell size reduction and acquisition of coccoid-like morphology. As the mechanisms and conditions that lead to the acquisition of coccoid-like morphology by marine vibrios are poorly characterized, we are currently assessing the individual and joint contribution of environmental factors (different salinities, temperature, iron scarcity and pH) to cell size reduction. Moreover, due to potential contribution of the coccoid-like morphology to cell resistance to stress and *V. harveyi* fitness in marine ecosystems, we are employing advance fluorescent microscopy and quantitative proteomic / transcriptomic tools to address the impact of this phenotype on the capacity of *V. harveyi* and *V. kanaloae* to resist various stress factors.

2. Development and use of advanced DNA sequencing protocols for the identification and quantification of *Vibrio* spp. in environmental samples

This research line is centered on using next-generation sequencing (NGS) for analysis of metagenomic DNAs isolated from environmental samples. The developed tools will be employed to determine the interannual dynamics of the *Vibrio* populations in seawater sampled in the Bay of Plentzia in the frame of the HOBE (MICINN) and BlueAdapt (EU) projects. The results of this analysis will further be used to assess the risk of the climate-dependent appearance and spread of *Vibrio*-associated diseases.

3. Analyzing the composition and regulation of *Vibrio* secretomes

The ability of *Vibrio* species to invade various organisms or adopt to changing environments is often dependent on their capacity to produce various hydrolytic enzymes able to damage the host (e.g., cell wall) or recycle natural biopolymers (e.g., chitine) into smaller molecules subsequently used as nutrients. We are utilizing *Vibrio harveyi* and *Vibrio kanaloae* to study the effect of environmental factors on secretions of various hydrolytic activities (i.e., proteases, lipases and laccases) and identify the corresponding enzymes.

Some of the most recent results include:

- Characterization of the long-term physiological and phenotypical responses of *Vibrio harveyi* and *Vibrio kanaloae* at different salinities and pH that mimics the pH of the world ocean in the past, present and future;
- *In silico* design of gene-specific PCR primers that enable to improve differentiation of *Vibrio* species using single-locus sequence analysis;
- Determining the key gene clusters associated with cellular responses to fluoride and define its ATP-dependent stabilizing effects on transcripts containing repetitive extragenic palindromic (REP) sequences.
- Development of RepRanger, a platform for identification of bacterial and archaeal REP sequences.

Cell Biology in Environmental Toxicology + One Health (CBET+)

Maren Ortiz-Zarragoitia[1] (PI), Itziar Arranz[1], Clarissa Atzori[1], Denis Benito[1], Eider Bilbao[1], Joyanta Bir[1], Esther Blanco[1], Nagore Blasco[1], Tifanie Briaudeau[1], Evgeni Bunin[1,2], Miren P. Cajaraville[1], Ibon Cancio[1], Miren Carnicero[1], Oihane Diaz de Cerio[1], Edgar Dusacre[1,3], Pilar Ezcurra[1], Nerea García-Velasco[1], Nagore Gonzalez-Soto[1,3], Isabella Gutiérrez-Zabala[1,3], Tamer Hafez[1], Urtzi Izagirre[1], Xabier Lekube[1], Ionan Marigomez[1], Anabella Massa[1], Markel Montaño[1], Laura Noguera[1], Amaia Orbea[1], Afrin L. Parvin[1,3], Olga Rodríguez[1], Iratxe Rojo-Bartolomé[1], Pamela Ruiz[1], Mar Santos[1,4], Markel Sanz[1], Gaybrielle Smith[1,3], Manu Soto[1], Erik Urionabarrenetxea[1], Miren Bego Urrutia[5], Beñat Zaldibar[1]

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KEY WORDS: Environmental Toxicology, Ecosystem Health Assessment, Biomonitoring, Cellular and Molecular Biomarkers, Histopathology, Reproduction and Sex Differentiation, Environmental Risk Assessment, Toxicity Profiling in vitro and in vivo, Emerging Pollutants.

The Cell Biology in Environmental Toxicology + One Health (CBET+) research group has been developing research and education activities in the field of Environmental Toxicology and Health (in both aquatic and terrestrial ecosystems) since 1985. The group is recognized since 2001 as a type A consolidated research group of the Basque Government. The main field of expertise is the development and application of early warning cell and molecular biomarkers of pollution exposure and effects, and toxicity profiling of environmental pollutants using standard and novel toxicity tests in cells *in vitro* and in microalgae and invertebrate and vertebrate animal models. In view of the new trends and advances in the field of Environmental Toxicology and the relevance of a holistic environmental vision framed within the One Health concept, the CBET+ group structures its scientific activities around four related research areas within the 2030 SDGs:

1. **Biological effects of pollution and disruption of ecosystem health.**
2. **Toxicology of nanomaterials, microplastics, and other emerging contaminants.**
3. **Reproduction and sexual differentiation in aquatic organisms under environmental stress.**
4. **The "One Ocean, One Health" paradigm to address the challenges of SDG 14 and Ocean´s Decade.**

In addition, CBET+ members work in four transversal strategic actions:

- Local and international networking.
- Development and implementation of novel technologies, methods and tools.
- Higher education.
- Dissemination and visibility.

CBET+ delivers its activities in the Faculty of Science and Technology and in the Plentzia Marine Station (PiE-UPV/EHU). The level of multidisciplinarity and internationalization of CBET+ in all our scientific activities (research, higher education, outreach) is remarkable. The CBET+ deploys its mission from the local to the international scale with multiple collaborations, participating in EU funded projects and networks. Within PiE-UPV/EHU CBET+ operates marine research services offered within the European Research Infrastructure, EMBRC-ERIC. Members of the group participate in the Incubator LTC-EAR (partners) and the AquEus LTC (coordinators) and two ENLIGHT Thematic Networks H2OPE (partners) and PLASTIMPACT (coordinators). Additonally, CBET+ members are active in the EU NORMAN network and the Euroregional platform TURQUOISE. In a novel and integrative activity with the concept of One Health approach CBET+ is one of the promoters of the Plentzia Living Lab, which aims to integrate science, higher education, society, local and regional stakholders with focus on climate change, pollution and environmental health status.

Funding: Basque Government through consolidated research groups grant (IT1743-22).

Fate and Impact of Plastics - from Macro to Nano – on Planetary Health, the PLASTIMPACT ENLIGHT thematic network

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KEY WORDS: Macro, micro and nanoplastics, one health, aquatic and terrestrial environments, human health, material science, nanotechnology, degradation, life cycle analysis, science communication, citizen science, education.

Plastic pollution, on the macro, micro or nanoscale, is a planetary threat, transcending local boundaries and demanding a global response involving scientists,citizens, societal agents and governments. Although researchers have been studying plastic pollution for some decades, especially in coastal and marine ecosystems, the findings of these studies have not been sufficient to change human behaviour and decrease plastic pollution in the environment. In the ENLIGHT Thematic Network PLASTIMPACT, nine universities (Basque Country, Bordeaux, Ghent, Groningen, Galway, Bern, Tartu, Bratislava and Uppsala) have joined forces to share and spread knowledge on different aspects of plastic pollution through a planetary one health perspective. The main objectives of this network are therefore: (1) to build a community of scientists and citizens with a common interest in tackling plastic pollution, (2) to raise awareness and stimulate behaviour change in society and to share knowledge with citizens and researchers, and (3) to establish a dialogue with stakeholders to define common strategies to reduce plastic pollution. To achieve the first objective, we are organizing a symposium, to share our views on the ways to tackle the challenge of plastic pollution, and we are organizing two summer schools focusing on terrestrial environment and human health aspects and on aquatic environmental, aspects of plastic pollutionrespectively. Stakeholders will be involved in both the symposium and the summer schools. Methods to extract and measure microplastics in different environmental samples will be discussed in an attempt for standardization. For objectives two and three, we will first carry out a pilot citizen science program in each partner region. In this program, citizens will be actively involved in monitoring plastic litter in marine, freshwater, and soil ecosystems. In addition, secondary school students will be involved in microplastic sampling and analysis. A dedicated web page and educational materials will be created and datasets of macrolitter and microplastics will be produced. Through these initiatives, the network strives to raise awareness and develop innovative solutions to limit plastic pollution in the environment. At UPV/EHU, five research groups are involved in PLASTIMPACT: Cell Biology in Environmental Toxicology + One Health (CBET+), Basque Center for Macromolecular Design and Engineering, Polymerization Processes (POLYMAT), Life cycle thinking (LCT), Materials and Technologies (GMT), and Marine Ecology (ECOMAR). Together, the five teams cover a wide range of expertises contributing to PLASTIMPACT.

Acknowledgements. The ENLIGHT thematic network ETN PLASTIMACT is funded by the European University Alliance, European Commission´s Education and Audiovisual Executive Agency (Ref: INT-ERASMUS+23/07). The groups at UPV/EHU and University of Bordeaux also acknowledge funding from the Laboratory of Transborder Cooperation LTC AquEus.

Neuro-Ophthalmo Biology Group: Understanding disorders of the visual system and promoting repair and regeneration

Arantxa Acera[1], Javier Araiz[2], Sandra Beriain[1], Juan Durán[2], Alex Fonollosa[2,3], Marta Galdós[3], Silvia López-Plandlolit[2,4], Itziar Martinez-Soroa[2,5], Xandra Pereiro[1], Sergio Pinar-Sueiro[4], Laura Prieto[1], Noelia Ruzafa[1], Haritz Urcola[2,6], Javier Zabalza[2] and Elena Vecino[1]

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KEY WORDS: visual system, eye, repair, regeneration, GOBE

GOBE (Grupo de Oftalmo-Biología Experimental, www.ehu.es/gobe) is a multidisciplinary research group interested in eye research, and integrated by ophthalmologists, biologists and biochemists. Currently, GOBE has 26 members: 17 doctors and 5 PhD, 1 Master Student and 3 undergraduates. The director of the group is Prof. Elena Vecino from the Faculty of Science and Technology; the laboratory is located at the Faculty of Medicine, in the Department of Cell Biology and Histology. The group is a consolidated group that has been collaborating for over 30 years in which 40 Doctors has been formed, half of them Ophthalmologist that work in Hospitals of the Basque Country. The members of the group are also attached to BioBizkaia, BioDonosti and BioAraba. Moreover, we collaborate with national and international groups at Universities of Munich, New York, Cambridge and Bordeaux among others. We also have close collaborations with the industry like Sylentis, IMG-Pharma and Tecnalia as well as Technological Institutions like CIDETEC and POLYMAT. The group is currently funded by Grupos Consolidados Gobierno Vasco (IT1510-22) and MINECO-Retos MICIU/AEI/10.13039/501100011033 (PID2023-152778OB-I00). We have at present projects in collaboration with companies PUE, Elkartek and Hazitec. Two of our projects have end up in clinical therapies. Some of our methods and technologies developed are being used internationally. The methods and techniques that we use include animal models of glaucoma, primary cell culture, immunohistochemistry, ELISAs, proteomic, lipidomic, electron microscopy as well as the use of biomaterials.

PRINCIPAL LINES OF RESEARCH

1- **Neurodegenerative diseases and neuroprotection of the retina (Dr. Xandra Pereiro, Dr. Noelia Ruzafa and Prof. Elena Vecino).** Glaucoma, the primary cause of irreversible blindness, is a neurodegenerative disease resulting from the death of retinal ganglion cells (RGCs), the neurons in charge of communication between the eye and the brain. The supportive relationship between retinal glial cells and RGCs is crucial for normal function. Our research focuses on the molecular interactions between neurons and glia in an effort to prevent neuronal damage. In addition, other neurodegenerative diseases, such as Parkinson's disease also affect RGCs. The implication of retinal glial cells in this pathology is also being studied.

2- **Other retinal pathologies (Dr. Xandra Pereiro, Dr. Javier Araiz and Prof. Elena Vecino).** We analyze and study the composition and structure of epiretinal membranes obtained from patients. Our goal is to characterize and establish a classification for these membranes to gather information to better understand the etiology of their appearance and to identify possible therapeutic targets for the development of new treatments.

3- **Ocular Surface and neurodegeneration diseases (Dr. Arantxa Acera, Prof. Juan Durán and Prof. Elena Vecino).** The main objective is to identify biomarkers in tears, as a source of information for the ocular surface in different diseases. We are trying to characterize molecular markers of Parkinson disease from tear samples from patients in order to do an early diagnostic. In addition, we propose to design artificial tears that could promote the repair of the injured ocular surface.

Fisika eta Ingeniaritza Elektronikoa

Física e Ingeniería Electrónica

Software Technologies Working Group (GTTS, http://gtts.ehu.es)

Germán Bordel, Mikel Peñagarikano, Luis Javier Rodríguez Fuentes and Amparo Varona
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KEYWORDS: Information Retrieval for Multimedia Resources, Language and Speaker Recognition/Verification, Automatic Speech Transcription, Automatic Video Subtitling/Captioning, Speech and Language Resources for Basque, Machine Learning, Generative IA

Research at GTTS focuses on fundamental software technologies, particularly those related to speech processing and information retrieval: speech segmentation, language and speaker recognition and verification, speaker diarization, automatic speech transcription, video subtitling, etc. Part of our efforts are devoted to developing tools and prototypes for various applications in Basque. For example:

- Automatic bilingual video subtitling applied to the plenary sessions videos that the Basque Parliament posts on its website (https://www.legebiltzarra.eus/portal/web/eusko-legebiltzarra), running from September 2010 until November 2024.

Besides, we also pay special attention to the dissemination of results, both in prestigious publications and through technology transfer to companies in our area, and collaborations with other research groups. Finally, we also devote great efforts to academic training (PhD and Msc Theses).

ACTIVE and RECENTLY FINISHED PROJECTS

- ELKARTEK – Proyecto de investigación fundamental colaborativa (Basque Government): IA generativa para la resolución de vulnerabilidades de ciberseguridad en la red eléctrica inteligente (VISTA), 2025-2026 (*under review*)
- Basque Government Research Group Aholab-GTTS (IT1704-22), 2022-2025 (60.000 euros)
- Spanish MINECOR under national plan of R+D+I (PID2019-106424RB-I00) – Unsupervised methodologies for leveraging public domain data in state-of-the-art automatic speech recognition: from high- to low-resource languages (OPEN-SPEECH), 2020-2024 (35.000 euros)

RESEARCH ACTIVITY IN THE LAST 10 YEARS (2015-2025)

- Basque Government Research Group Aholab-GTTS (IT1355-19): 2019-2021 (100.000 euros)
- Projects, contracts and research fellowships: 7 (230.000 euros)
- More relevant publications: 16 (8 JCR journals, 8 peer-reviewed conferences)
- Thesis (presented): 2
- Organization of international Workshops: Odyssey 2016 – The Speaker and Language Recognition Workshop (http://www.odyssey2016.org)

TECHNOLOGY TRANSFER

- BPDB-v1: large (+1400 hours-long) bilingual Basque-Spanish speech dataset for ASR (https://huggingface.co/datasets/gttsehu/basque_parliament_1)

Magnetism and Magnetic Materials Group

[1,5]Mª Luisa Fdez-Gubieda,[1,5]Jon Gutierrez, [1,5]Alfredo García Arribas, [2]Ana García Prieto, [3]Ana Abad, [4]David de Cos, [4]Andoni Lasheras, [1,5]Patricia Lazpita, [2]Maite Goiriena, [3]Alicia Gascón, [1]Beatriz Sisniega, [5]Nerea Lete, [1]Guillermo Gestoso, [1]Danny Villanueva, [3]Alaine Urrutia

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KEY WORDS: Nanomagnetism, Magnetotactic bacteria, ferromagnetic shape memory alloys, Thin films, magnetic sensors

The Magnetism and Magnetic Materials Group (GMMM), https://www.ehu.eus/en/web/gmmmt, started working at the Faculty 30 years ago. As a result of the consistent and productive research performed, the group is acknowledged as an "A" class consolidated research group in the Basque Country and has international reputation. At present, it is an interdisciplinary group composed of Physicists, Electronic Engineers and Biologists working together.

The main objective of the group is to prepare and characterize new magnetic materials with special properties for outstanding applications. Nowadays there are three main research lines: Magnetotactic bacteria as theranostic agents, Ferromagnetic shape memory alloys and Magnetic Sensors.

Magnetotactic bacteria as theranostic agents

Magnetotactic bacteria are aquatic microorganisms that swim along the geomagnetic field, using a chain of magnetic nanoparticles as a compass needle. The different species of magnetotactic bacteria synthesize perfectly stoichiometric magnetite nanocrystals, with genetically controlled sizes and shapes, surrounded by a biocompatible membrane, making them ideal for biomedical use. This research line is oriented in two complementary directions: first, the thorough study of the magnetic properties of these biosynthesized nanoparticles, and second, the exploitation of magnetotactic bacteria as a therapy agent as a microrobot for localized drug delivery and magnetic hyperthermia.

Ferromagnetic Shape Memory Alloys (FSMA)

FSMA are active materials that develop high recoverable shape changes under the effect of mechanical stress or magnetic field in very short times (a few milliseconds). Due to their remarkable properties in actuation, vibration damping and sensing have permeated into many industries, such as the biomedical, energy or aerospace. The main objective of this research line is the combination of applied and fundamental research to improve the material performances and the comprehension of the involved physical processes

Magnetic Sensors

We design magnetic sensors based mainly on two different phenomena Giant Magneto Impedance (GMI) and Magnetoelastic (ME) effects. GMI produces huge changes in the electric impedance of a soft magnetic material and provides excellent sensitivities to small magnetic fields. ME effect consists in the magnetic state of some materials being altered by mechanical action and vice versa. When driven to resonance it is an extremely sensitive effect that is being investigated to develop gas sensors, relying in the change of mass of an absorbing sensor coating.

Acknowledgments

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Group: Instrumentación y Control Experimental

S.Alonso, A. Anakabe, I. Arredondo, I. Badillo, J. M. Collantes, V. Etxebarria, J.Feuchtwanger, J.M. González, J. Jugo, I. Lizarraga, A. Mateo, N. Otegi, A. Perez, J. Portilla, I. Sagastabeitia, J. Vivas,

KEY WORDS: Particle Accelerators, Neutron Generation, Magnetrons, Microwave Amplifiers.

The Instrumentación y Control Experimental group works on four main research lines, which are, particle accelerators, compact neutron sources, magnetrons, and microwave amplifiers. All these lines have a common thread, and that is that the group develops the instrumentation for them, and in all cases Radio frequency plays a role in one form or another. A more detailed description of each of the lines is given bellow.

Particle Accelerators

One of the group's main projects is the design and construction of a 7 MeV proton accelerator. The accelerator is composed of an Ion Source, where Hydrogen gas is injected, and with the help of a magnetic field and 3 GHz microwaves the neutral gas is split into positively charged protons. These protons are accelerated electrostatically to 30 keV. The newly generated proton beam goes into a Low Energy beam transport, that uses magnetic optics to turn the divergent beam into a convergent one. The convergent beam enters a Radio Frequency Quadrupole that accelerates it form 30 keV to 3.5 MeV. These components have been designed and fabricated, and are in different stages of testing. Future work for this project is the design of an Inter Digitated Drift Tube Linac, to accelerate form 3.5 to 7 MeV, Two sets of magnets to control the destination of the beam and the experiment modules for the 3.5 and 7 MeV proton applications.

Compact Neutron Sources.

It is possible to generate neutrons by accelerating Deuterium ions to energies ranging from 60 to 100 keV, and making them collide with other deuterium atoms. This generates a fusion reaction that yields a He 3 atom and a neutron. The group is developing a magnetron driven Electron Cyclotron Resonance ion source to generate the Deuterium beam, and will in the future work on the generation of the neutron for their use in non-destructive compositional analysis. Most of the system has been designed and built. Initial experiments have been carried out, and the plasma generation has been successfully tested.

Magnetrons

Magnetron are common elements of daily life, the supply the microwaves used in microwave ovens. Initially developed during WWII they first saw use in radar (RAdio Direction And Range). However, they were soon replaced by other microwave generators, because of the difficulty of generation signals with a stable Frequency, Amplitude and Phase. As of late interest in magnetrons has resurged, because if properly designed they are one of the most energy efficient means of producing high power Radio Frequency signals, that with the help of modern control techniques and instrumentation can meet the requirements for powering accelerator cavities.

Microwave Amplifiers

Microwave power amplifiers for radio communications tend to generate autonomous parasitic signals due to their inherently nonlinear behaviour. These undesirable oscillations can arise depending on the input signal's power and frequency, making their detection during the amplifier design stage crucial. This issue becomes even more critical with the increasing use of active phased array antennas in modern communication systems (e.g., 5G, LEO satellites), as the removal of output isolators introduces load variations that affect amplifier stability. The primary focus of this research line is to develop advanced analysis techniques and experimental characterization platforms capable of accurately assessing the potential instability of power amplifiers, including the effects of load mismatch.

Microstructural, magnetic & spectroscopic characterization of materials with high technological applications

N. García de Iturrospe, I. Rodrigo, D. Mérida, I. Unzueta, I. Castellanos, K. Nader, N. Llanes, A. Alvarez, M. Insausti, M. J. S. Garitaonandia, J. A. García and F. Plazaola

KEY WORDS: magnetic hyperthermia, Mössbauer Spectroscopy, Positron Annihilation Lifetime Spectroscopy

Our research is divided in two main lines:

a. AC magnetometry characterization of magnetic nanoparticles
b. Mössbauer Spectroscopy and Positron Annihilation Lifetime Spectroscopy (PALS)

Magnetic hyperthermia (MH) is an innovative cancer treatment that uses magnetic nanoparticles (MNPs) exposed to alternating current (AC) magnetic fields to generate heat and destroy tumors. A key factor in this therapy is the specific absorption rate (SAR), which measures how much heat the MNPs produce per unit of mass. AC magnetometry calculates SAR by measuring the area of the AC hysteresis loop created when MNPs are exposed to a magnetic field [1].

Since 2015, our group has developed several AC magnetometers. The most recent one, operates from 100 to 1000 kHz and delivers higher field strengths than most existing devices [1]. It was designed to generate uniform magnetic fields—up to 90 mT at 134 kHz and 30 mT at 950 kHz—within a volume of 100 mm^3. Building on this experience, we have recently explored new directions by developing additional AC electromagnetic applicators tailored to specific applications. One of these systems incorporates a 520 nm laser, enabling the study of fluorescent samples for local temperature measurements. Additionally, two new setups have been designed for in vivo experiments involving rats and mice. Guided by these developments, our next objective will be to integrate magnetic applicators with optical excitation, inducing plasmonic resonance to systematically evaluate the combined therapeutic potential of magnetic hyperthermia and plasmonic photothermal therapy.

Ferromagnetic shape memory alloys (FSMA) are materials with potential applications in both engineering and biotechnology. Controlling the martensitic transformation (MT) temperature is essential for their application, which is strongly influenced by microstructure and defects. In our research group, we have investigated several of these materials (NiMnGa, NiMnSn, NiMnIn, etc.) using positron annihilation and Mössbauer spectroscopy [2-3].

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Theory of Nanophotonics

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KEY WORDS: light, nanophotonics, nanoantenna, nanoparticle, surface plasmon, plasmonic picocavity

Our group focuses on the theoretical description of new physical phenomena arising from complex light-matter interactions at the nanoscale. This research field is known as Nanophotonics and allows for the more efficient exploitation of light technology, addressing many social challenges regarding safety, energy and health.

Under illumination, metallic nanoparticles host collective oscillations of conduction electrons on their surface, known as "surface plasmons", which enable the intensification and localization of light to a few nanometers around nanostructures, acting as "collectors" or "emitters" of light at the nanoscale. For this reason, metallic nanoparticles are often considered “nanoantennas”. Typical dimensions of plasmonic nanoantennas range from several tens to hundreds of nanometers. However, it is now possible to achieve field localization in nanometer and sub-nanometer regions of space, thanks to the fabrication and use of extreme metallic morphologies, such as atomic-scale metal tips or sub-nanometer cavities, called picocavities, configurations of great relevance to the research of our group.

By adopting theoretical methods of classical Electrodynamics, Condensed Matter Physics, Quantum Chemistry, and cavity-Quantum Electrodynamics, the group describes light scattering and emission from quantum emitters and nanoscale materials in a variety of spectroscopy and microscopy configurations. We explore the interaction of plasmonic nanoparticles and picocavities with molecules, addressing the emerging quantum effects, to improve the performance of optoelectronic devices and spectroscopies such as plasmon-enhanced molecular spectroscopies (SERS, Surface Enhanced Raman Spectroscopy and SEIRA, Surface Enhanced Infrared Absorption Spectroscopy), EELS (Electron Energy Loss Spectroscopy) or Scattering type Near-field Optical Microscopy (s-SNOM). We collaborate with local and international experimental groups on the design of nanophotonic devices based on plasmonic nanoantennas and functional materials for various applications, including all-optical switches, molecular and biological sensors, magnetoplasmonic devices for active control, and novel on-chip light sources.

Ultracold Quantum Gases

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KEY WORDS: ultracold atoms, quantum simulations, optical lattices, supersolids, quantum droplets

Ultracold atomic gases provide an exceptionally versatile and tunable platform for exploring a wide range of quantum many-body phenomena, making them powerful tools for simulating complex quantum systems. For example, Bose-Einstein condensates, routinely produced at nanokelvin temperatures, behave as coherent matter waves, with all atoms occupying the same quantum state. As a result, their quantum probability distribution transforms into a measurable matter distribution, which can be directly imaged using digital techniques, making BECs ideal for studying quantum effects at macroscopic scales.

These systems — composed of either bosons or fermions — enable the implementation of effective Hamiltonians by superimposing tailored external potentials, thus realizing quantum simulators as envisioned by Feynman. Optical lattices, in particular, offer a flexible platform for simulating condensed matter models and exploring quantum phase transitions. Recently, novel quantum phases — such as supersolids made of dipolar gases and liquid-like quantum droplets, both stabilized by quantum fluctuations — have been theoretically predicted and experimentally realized.

In our group, we investigate several of these aspects from a theoretical perspective, often in collaboration with experiments performed at international laboratories. Recent work includes the study of effective topological models in driven optical lattices, the characterization of liquid-like quantum droplets and supersolids, and the simulation of quantum analogs of classical instabilities.

Physics and chemistry of cement related materials

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KEY WORDS: cement, atomistic simulation, molecular dynamics, interfaces, nucleation and growth, dissolution

The images than come to the mind of the general public when they heard the words cement or concrete are probably related to a grey, dirty and low-tech looking material, that is present everywhere from large infrastructures to small masonry works. In fact, cement composited are the most widely used material only after water. However, cement composites are also extremely complex materials composed of different chemical species, with intricate micro and nano-structures that evolve along time.

The main reasons for the widespread use of cement composites are that they can be economically produced almost anywhere in the world using only local materials and that their properties are really extraordinary. In fact, it is difficult to find any other material that can pass from powder to fluid and, finally, to a strong and durable solid at room temperature simply by mixing it with water. The complex processes that govern such evolution combine chemical reactions, nucleation and growth phenomena, ion diffusion and so on. Besides, cementitious materials are often combined with organic admixtures to tune primarily the rheological properties. In consequence, the understanding and development of novel cement composites requires the joint work of researchers from several disciplines (physics, chemists, engineers…) using a wide variety of multiscale experimental techniques and computational methods.

Work at UPV/EHU

The group of the department of physics is specialized in the use of a variety of atomistic simulation methods for the study of different aspects of the material lifetime:

- Kinetic Monte Carlo for the study of dissolution phenomena of mineral particles and surfaces.
- Machine learning development and application for the discovery of new (meta)stable crystal phases.
- Evolutionary algorithms and molecular dynamics to determine the structure of pre-nucleation clusters.
- Ab-initio (DFT) Metadynamics to determine the dissolution activation energies of cement minerals in presence of organic additives.
- Molecular Dynamics to investigate the structure and properties of non-crystalline materials and interfaces

Furthermore, we also use advanced experimental techniques (computerised tomography, x-ray diffraction, NMR, etc.) for the multi-scale characterization of cementitious materials.

Collaborations and projects

Currently we are working in two European projects: CONTRABASS (leaded by UPV/EHU) and NATURSEA-PV (leaded by Tecnalia) with a total combined budget of over €6M. We are also members of the trans-border collaboration laboratory Green Concrete composed by research institutions from the Basque Country (DIPC, Tecnalia, Polymat, CFM) and Bordeaux (CNRS and U. Bordeaux). Besides we collaborate actively with researchers from other countries as members of RILEM and INNOVANDI.

Physical and mathematical foundations of the structure of the Universe

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KEY WORDS: Cosmology, General Relativity, Quantum Gravity, Loop Quantum Gravity, Relativistic Astrophysics, neutron stars, black holes, gravitational waves, modified theories of gravity, dark matter, dark energy

Einstein's equations of General Relativity (or modifications) link the geometry of spacetime (gravity) with the physics of non-gravitational fields. They constitute the framework for the study of the Universe and very compact astrophysical objects and black holes. A better understanding of the Universe involves deepening the description of its early stages, regimes of high energies, and the principles governing the laws that govern it. Cosmology and physics directed to the description, evolution and emission of gravitational waves of relativistic systems are intimately related to the rest of the aspects of the structure of the Universe, that is to say, with more fundamental aspects, and in general of a more mathematical nature.

These theoretical aspects must also be confronted with phenomenological aspects of the Universe, both in the context of General Relativity and in the wider context of modified theories. This is an area of research in full swing thanks to the arrival of new observational data. Broadly speaking these data provide surprising conclusions about the possible components of the Universe, whose "presence" is manifested in the kinematics of the Cosmos at different scales. One of the most controversial features is the apparent acceleration of the expansion of the Universe.

Main sublines:

1. Dynamics of very compact astrophysical objects and black holes. Emission of gravitational waves, and cosmological gravitational waves. The role of the cosmological constant.
2. Quantum gravity: dynamics, semi-classical approach and physical consequences.
3. Quantum models of black holes and gravitational collapse. Quantum-gravity effects in the dynamics of the early universe.
4. Mathematical relativity; trapped and umbilical submanifolds, computer algebra, initial data characterisations and exact solutions.
5. Observational tests with large scale astrophysical data, alternate gravity theories beyond Einstein's, and future cosmological singularities.

Shape Memory Alloys, High-Temperature Intermetallic and High-Entropy Alloys at the Research Group on Physical Metallurgy and Advanced Materials, GIU-21-024

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KEY WORDS: Shape Memory Alloys, Intermetallics, Electron Microscopy, Nanotechnology, Additive Manufacturing.

The Research Group on Physical Metallurgy and Advanced Materials is focusing the activity on three different families of metallic materials, through the five different research lines shortly described here below.

1. **Shape Memory Alloys (SMA):** Ternary, quaternary and quinary Cu-Al-Ni-based SMA are being developed and patented [1] for cryogenic applications (for superconducting and quantum technologies), as well as for High-Temperature SMA for space applications. These SMA and their single crystals are produced in our laboratory following a technology which was licenced by the UPV/EHU to a Space company.
2. **Ti-Al-based Intermetallic Alloys:** Several alloys from the gamma Ti-Al system are being studied to optimize the low-pressure turbine blades for the next aeronautic engines oriented to the Clean-Sky European strategy. This is being done in collaboration with our partners from Austria, Germany and France. We are approaching fundamental research on the high-temperature diffusion mechanism and the evolution of the microstructure studied by High-Resolution Transmission Electron Microscopy [2].
3. **High Entropy Alloys (HEA):** The new paradigm of HEA appears in 2004, and at present we are moving forward to design new HEA able to exhibit shape memory behaviour, in order to merge the exceptional mechanical properties of HEA with the functional properties of SMA. Newly designed alloys are being produced and characterized in collaboration with our international partners from Germany, USA and Japan. To promote this research line, the PhD student L. Del-Río is doing a stage at the National Institute of Materials Science (NIMS), in Tsukuba, Japan.
4. **Additive Manufacturing (AM):** The new technologies of AM, in particular Laser Powder Bed Fusion (LPBF) and Laser Metal Deposition (LMD) are being applied to the production of SMA and HEA, in collaboration with our local partners from the ELKARTEK-ATLANTIS project: CEIT, LORTEK, TEKNIKER and CFAA from UPV/EHU. Through AM processing, new capabilities and performances are being obtained for the Fe-based SMA [3] and Cu-based SMA [4].
5. **Nanotechnology of SMA:** Nanotechnology techniques, like Focused Ion Beam milling and Femtosecond Laser Micro-machining are being applied to produce micro/nano pillars and small devices from SMA, exhibiting superelastic and ultra-high damping properties [5]. In-situ nano-compression tests at the electron microscopes are being used to study the superelastic behaviour in these small features [6]. In addition, active Meta-Materials are being designed by finite-element computing simulation through COMSOL Multiphysics, and tested at small scale by in-situ tests at the microscopes.

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Experimental research on the thermo-physical properties of materials

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KEY WORDS: thermo-physical properties, radiative properties, emissivity, dielectric properties

Understanding the interaction between matter and electromagnetic radiation —specifically, the absorption, emission, and scattering of electromagnetic waves by matter— is key for the research on advanced materials, optimizing industrial processes and addressing major global challenges such as the climate crisis. The research Group of Thermophysical Properties of Materials (GPTM) at the Physics Department approaches this topic through three main experimental techniques:

1. **Infrared emissometry:** The emissivity is the thermophysical property that describes the thermal radiation emitted by a material. It varies with the wavelength and direction of the emitted radiation, and it depends on the material's composition, temperature, surface condition. Infrared emissivity measurements are performed using the High Accuracy InfraRed, Leioa (HAIRL) emissometer, an internationally recognized instrument developed and recently upgraded at UPV/EHU.

2. **Thermography:** A non-invasive technique for temperature measurement that detects the heat emitted by objects and converts it into visual representations highlighting variations in temperature. It has a wide range of applications, including electronic fault detection, renewable energy technology and detection of areas of heat loss.

3. **Infrared spectroscopy:** A widely used spectroscopic technique that studies the radiation-matter interaction by means of reflectivity, absorptivity and transmittance. In this case, infrared spectroscopy is used to study the effect of the nanoscale morphology and the structure of heterogeneous materials on their optical properties, in order to tailor their optical behavior by altering their nanostructure.

The multidisciplinary expertise of GPTM covers a considerably broad spectrum of materials science and applied physics, such as physical metallurgy, advanced alloys, electron microscopy, crystallography, and structural phase transitions, among others. This extensive knowledge and experience allow us to develop research on complex materials (nanofilms, multilayers, selective absorbers, etc.) for solar applications (thermophotovoltaic and concentrating solar power), next-generation alloys for the aeronautics industry or the optimization of emerging technologies such as additive manufacturing.

GPTM maintains active collaborations with national and international scientific research centers and universities, including CNRS, CICenergigune, Tecnalia, Tekniker, and UC San Diego, as well as with industrial partners such as Sidenor and Tubacex.

Exploring ferroelectric liquid crystals

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KEY WORDS: Ferroelectric Liquid Crystals, Dielectric Spectroscopy, X-ray Diffraction, Nonlinear Optics

Liquid crystals are unique materials that exhibit characteristics of both liquids and solids. They boast anisotropy while maintaining fluidity. A wide variety of liquid crystal phases exist, such as the nematic and smectic phases, which have paved the way for many technological applications, including displays and optical devices. Among them, *ferroelectric liquid crystals* (FLCs) stand out due to their spontaneous polarization. This property allows them to respond rapidly to electric fields, making them excellent candidates for faster and more efficient optical technologies. At the Liquid Crystals Group, we investigate FLCs using a range of complementary characterization techniques. These methods help us accurately determine their structure and physical properties. Our toolkit includes polarized light microscopy, dielectric spectroscopy, X-ray diffraction, and nonlinear optical processes. Together, these techniques allow us to explore the intricate relationship between structure, molecular dynamics, and ferroelectric behavior in FLCs, emphasizing the value of a comprehensive experimental approach when studying advanced materials.

Particle Physics Group

Alessia Bongallino[1,2], Miguel G. Echevarría[1,2], Iván Esteban[1,2], Ángel Felipe[1,2], Raj Kishore[1,2], Xabier Marcano[1,2], Julius Materne[1,2], Samuel F. Romera[1,2], Gunar Schnell[1,2]

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KEY WORDS: Particle Physics, QCD, Neutrinos.

What is the fundamental structure of matter? How do elementary particles interact? How does this shape the evolution of the Universe? Many questions in fundamental physics remain unanswered. In our group, we combine theoretical calculations with experimental data to improve our understanding of the **strong interaction** and the **properties of neutrinos and dark matter**.

QCD: HADRON STRUCTURE AND FORMATION

Quarks and gluons (partons) are confined inside hadrons (protons, neutrons, etc.), therefore they are not directly observable. How do hadrons form and how quarks and gluons are arranged to contribute to the nucleon spin are some of the most fundamental questions in physics. Our group aims at answering these and other fundamental questions, in our quest for understanding the internal structure of nucleons, which, together with electrons, are the most important building blocks of ordinary matter.

The internal structure of hadrons is parameterized in terms of several multi-dimensional parton distributions. All of those encode different aspects of hadrons, correlations between the momenta and spins of the considered quark or gluon and its parent hadron. However, for now, we only have a fairly good picture in one dimension, since the multi-scale processes needed to access these multi-dimensional functions are very challenging from both the theoretical and phenomenological point of view, as well as from the experimental side.
Our group develops new tools to extract information from experiments at e.g. CERN, JLab, BNL or KEK, and future planned ones like the fixed-target experiments at CERN or the future Electron-Ion Collider in the United States.

COMPLEMENTARY FRONTIERS IN NEUTRINO AND DARK MATTER PHYSICS

Neutrinos have weak interactions and, in the Standard Model of particle physics, zero mass. This makes them a clean probe of novel physics — them having a mass is the only uncontested laboratory evidence for the existence of new interactions. It also means they have a huge penetrating power and a very long lifetime, making them a clean probe of astrophysical and cosmological environments, where they are abundantly produced.
Despite the ubiquity of neutrinos, we are just beginning to fully understand their properties. In our group, we study laboratory data, together with astrophysical and cosmological observations, to pin down neutrino properties. The rapidly improving precision of astrophysics, cosmology, and laboratory experiments is thus an opportunity.

Similarly, the nature of dark matter is among the most pressing questions in fundamental physics. Its existence has been confirmed by several independent observations, yet we do not know its fundamental nature nor how it was produced after the Big Bang. In our group, we study how the properties of small-scale astrophysical structures (as small as 50 light-years) inform us on the properties of dark matter. Our research links to current and future experiments such as Super-Kamiokande, JUNO, DUNE, IceCube, Plank, DES, DESI, or the Rubin Observatory. We extract new information from existing data, and we study the reach of future experiments.

Quantum Matter & Simulation

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KEY WORDS: Quantum, Matter, Simulation, Many-body

Quantum mechanics predicts exotic phenomena for our classical intuition. The existence of superposition and entanglement forces physicists to introduce a new formalism to describe physical phenomena at the subatomic scale. This formalism has the inconvenience of being more complex, both analytically and computationally, which hinders advances in the understanding of many-body quantum phenomena. Entanglement, a non-local correlation, promotes many-body phenomena to be of special interest in quantum mechanics because it is in these situations where the most characteristic features of quantum mechanics play a key role. The research in our group is focused on understanding the consequences of entanglement in many-body phenomena through the development of classical and quantum simulation techniques. Classical simulation can benefit substantially from the study of entanglement, as Tensor Networks have already proven, but their utility in a general setting is still to be proven. Quantum simulation has a provable advantage in some simulation tasks such as dynamical simulation, but real quantum simulators are limited by environmental noise. In our group, we study the effect of entanglement in many-body phenomena and try to develop classical and quantum algorithms to simulate them.

Geologia

Geología

Hydro-Environmental Processes research group (HGI)

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KEY WORDS: water, soil, climate, rock.

The Hydro-Environmental Processes research group (HGI, IT-1678/22), is a consolidated research group funded by the Basque Government in the 2021. *Water*, *soil*, *rock* and *climate* are the main topics of our research, with a Territory-Landscape-Heritage triaxial view under a climate change scenario. Therefore, the research projects developed during the last two years are grouped in three main research lines, some of the project being transversal to those lines.

Hydro-geo-environmental processes at river basin scale. This line consists of monitoring and understanding surface and subsurface hydrological processes in order to demonstrate the importance of hydrology in territorial management on a river basin scale, highlighting its geo-environmental implications through field data and modelling

Impacts of Global Change on the Territory. We study recent and past geological systems to understand environmental changes, natural and/or anthropogenic. The hydrology, fluvial and marine terraces, soils and speleothems register past hydrological and sea-level changes. Their understanding helps us to comprehend the current impacts of Global Change on land instabilities, hydrological changes and the adaptive land management. On the other hand, we also study the environmental impact of mining.

Integrative approach in Landscape-Heritage-Territory studies. This subject aims to characterise and recover degraded spaces, which implies a multidisciplinary analysis. Thus, it focuses in the geo-environmental understanding of the origin and evolution of landscapes, the characterisation and enhancement of singular geological spaces and the monitoring, study, consolidation and valorisation of built heritage, as well as the recovery of industrial areas.

We have developed and are involved in several projects that study the hydro-geo-environmental processes at river-basin scale concerning the impacts of Global Change on the territory: *Urbaso*, *Urlur*, *Klimatek*, *Bakio*, *Añana Gatzarana* and the *Green Ring* of Vitoria/Gasteiz. On the other hand, *Atapuerca*, *Euskarri*, *Pozalagua* and *Zugarramurdi* projects involve an integrative landscape-heritage-territory approach. Lastly, other projects in collaboration with international institutions and universities are focused on extreme (hydro)environments (extraterrestrial, archaic oceans and deep seas), by means of the study of bio-mineralisations.

We also collaborate with international cooperation activities. We recently (June 2024) carried out a new stay in the Hushe valley, this time in collaboration with BC3, with the support of the University of Baltistan-Skardu (UOBS). A hydrological monitoring network has been implemented in the valley to track environmental variables of interest as a first step to develop an adaptive strategy to climate change in high mountain conditions (Karakorum) and sampling of sediments from different geological events for dating.

The final aim of HGI is to share its research results and disseminate Geology to the society. To that end, HGI members lead, organise and collaborate in numerous conferences, field trips and science/geology dissemination activities, such as the "Geology Days for poets, myopes and the confused" in *Bizkaia Aretoa*, *Geolodía*, *Elhuyar Zientzia Azoka*, *Zientzia Astea*, ..., and collaborate with the media (press, radio, TV and social networks). We organise educational Geology dissemination activities for secondary and bachelor students. As a recognition for this effort, Arantza Aranburu was awarded with the *Lurpea* Prize 2024 for her scientific advances and dissemination work on karst. Moreover, *Rojo Ereño*, an ornamental stone valorised and promoted by HGI, was included in 2024 in the IUGS Heritage Stone international ranking.

Applied Geology for Cultural Heritage Materials

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KEY WORDS: geological approach, mineralogical and petrological characterization, mortars, plasters, bricks, pottery, glaze and iron tools, technological inputs.

This research group of geologists has been working with archaeological and architectural researchers on heritage materials for over twenty years. During this time our research group has studied ancient pottery, metals and building materials from different historical periods. The characterisation of archaeological materials provides information on the development of technology in past societies and on cultural and commercial relationships.

MORTARS
The study of mortars allows to:
(1) Identify the type of mortar manufactured and its purpose for a particular function and, determine the durability of historic building materials.
(2) Determine the date of construction and repair phases of historic buildings through radiocarbon dating.
(3) Evaluate their durability over time, assess the deterioration of buildings and formulate repair mortars and plasters compatible for use in historic buildings (Ponce-Antón, et al., 2024a).

BRICKS
The study of bricks allows to identify the provenance of raw materials and to characterise manufacturing technology and distribution of the products. Furthermore, allows to identify old workshops and old production methods (Ponce-Antón, et al., 2024b).

POTTERY AND GLAZES
The study of pottery and glazes makes it possible to identify the origin of raw materials, to characterise production techniques and to correlate them with the function of the vessels. The spatial distribution of pottery production, linked to specific workshops, allows us to understand the relationship between pottery production, inter-regional communication and consumption habits (Alonso-Olazabal, et al. 2022, 2023).

IRON TOOLS
The archaeometallurgical study of iron artefacts provides information on alloy composition and microstructure. These data can be used to determine the method of manufacture of the iron products and the level of skill of the craftsmen at different archaeological sites. The metallurgy of iron allows to distinguish different forging techniques according to the function of the piece, which in some cases demonstrates a high level of skill on the part of the blacksmiths (Rémazeilles et al., 2024, 2025).

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Behavior of B, Li, P, and other rare elements in crustal materials during the Variscan Orogeny. VARISBLIP research group - GIU 21/008

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KEY WORDS: critical raw materials, lithium-pegmatite, granite series, geochemical exploration, mineralogy, Iberian Massif.

Critical raw materials are highly important for modern society, as they play a key role in the infrastructure needed for renewable energy and other green technologies. These are essential for the energy transition and everyone's well-being. In line with the United Nations Sustainable Development Goals and the 2030 Agenda, exploring potential deposits of these materials within European territory is a priority in order to reduce dependence on other countries and promote a more circular economy. In the Iberian Massif, pegmatites of Variscan age enriched in rare elements such as Li, Sn, Nb-Ta, Be, B, F, and P, as well as industrial minerals like micas, quartz, and feldspars, are relatively common. In addition to the pegmatites themselves, associated granitic bodies and their surrounding host rocks may also hold significant potential as sources of critical raw materials. While pegmatites with simple mineralogy may constitute valuable sources of industrial minerals, the highly evolved terms could represent potential deposits of certain critical elements such as lithium, which is currently in high demand for battery production.

One focus of the research group is the study of these Variscan pegmatites from the Central Iberian Zone of the Iberian Massif, which offer important insights into the transition from magmatic to hydrothermal stages and into the geochemical behavior of these elements during the crystallization of granitic magmas. The works that the research group is dealing with include mineralogical, textural, and geochemical characterization of different pegmatites to improve the understanding of their typology and regional distribution. This contributes to broader knowledge about the petrogenesis of these mineral deposits and their economic potential. Another key line of research involves the study of the host rocks, which may help identify the source of boron (as well as other elements such as Li, Rb, Cs, Sn, and W), its possible recycling, and the redistribution during the Variscan Orogeny. Ongoing work by the research group is providing also new data on the metasomatic effects that mineralized bodies provoke on their host rocks. The geochemical halos generated around these mineralized bodies as a result of the metasomatic effect may provide useful insights in the exploration of critical raw materials in Spain and Portugal. Together, these research areas also contribute to a better understanding of the regional and historical geology of the Iberian Massif during the Variscan orogeny.

RESEARCH PROJECTS DURING THE LAST FIVE YEARS

H2020 GREENPEG project: “New Exploration Tools for European Pegmatite Green-Tech Resources”. https://doi.org/10.3030/869274

Project funded by the Spanish Ministry of Economy, Industry and Competitiveness: “Caracterización de las mineralizaciones de Li-(Nb-Ta-Sn-Be) de la Zona Centro Ibérica (España y Portugal): tipología, petrogénesis y potencial económico”.

COOPERATION WITH OTHER INSTITUTIONS

1) Department of Geosciences, Environment and Spatial Planning, University of Porto, Portugal. 2) Natural History Museum, University of Oslo, Norway. 3) Mineralogy, Petrology and Pegmatology Research Group, Maine Mineral & Gem Museum, USA. 4) Geology Department, Cadi Ayyad University, Morocco.

Palaeontology, Geology and Natural Heritage from the Mesozoic and Cenozoic of the western Pyrenees

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KEY WORDS: Palaeodiversity, Geodiversity, vertebrates, invertebrates, ecological adaptations, environments

This Research Group (IT1485-22-Basque Government/EJ) includes researchers from different fields (palaeontology, sedimentary geology and biology) from the Euskal Herriko Unibertsitatea (UPV/EHU), in collaboration with researchers from other institutions, both national and foreign.

The main goal of our research is to contribute to the better understanding of the palaeobiodiversity of western Pyrenees throughout the study of sedimentary rocks and fossils of invertebrates, vertebrates and associated biota from the Mesozoic and Cenozoic deposits of the Basque-Cantabrian region and nearby sedimentary basins. Besides, studies on living faunas are used as an actualistic approach to the understanding on fossil vertebrate communities. The obtained knowledge is of utmost importance to understand the geological processes that occurred during the history of these Pyrenean basins and to decipher how these processes affected the once living communities. The fossil record, which indeed is part of the geological record, is a non-renewable historical archive and constitutes the main tool for the study of biodiversity in an ancient changing Earth, as well as to better understanding of the today changing biosphere.

The activities of the group can be summarised into the following research lines:

1.Palaeobiology and biochronology of vertebrate faunas and related biota from the Mesozoic and Cenozoic deposits of the western Pyrenees and nearby sedimentary basins.
2.Evolutionary palaeoecology and palaeobiogeography: environmental and biotic changes.
3.Geological context, environmental analysis and taphonomy of the Mesozoic and Cenozoic biota.
4.Geological heritage and geoconservation of palaeontological sites and fossil associations from the western Pyrenees, and their social projection.
5.Socioecology and animal-environmental interactions.

Research carried out in recent years:

1) Vertebrate faunas from the Mesozoic and Cenozoic deposits of the western Pyrenees and related biota: geology, taphonomy, palaeobiology and biochronology.
2) Dinosaurs and associated biota from the Basque-Cantabrian, Cameros and South Pyrenean basins.
3) Palaeobiodiversity and palaeoecology of Iberian mammals in Eocene tropical ecosystems.
4) Human evolution and palaeocology of the Quaternary. Anatomical evolution, and first populations in the area.
5) Cretaceous sinsedimentary tectonics, hydrotermalism and biotic changes occurring in the marine environment.
6) Ammonoid associations and other sea invertebrates from the Cretaceous of the western Pyrenees.
7) Animal-landscape interactions. Landscape effects of trophic rewilding and animal responses to habitat restoration.
8) Evolution of intelligence, socioecology and ecophysiology in primates and large ungulates.
9) Geological heritage and geoconservation of palaeontological sites and fossil associations from the western Pyrenees.

More information in: https://ekoizpen-zientifikoa.ehu.eus/grupos/24737/detalle

HAREA-Coastal Geology Research Group

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KEY WORDS: environmental transformation, natural processes, anthropogenic impact, sea-level rise

The HAREA-Coastal Geology research group (www.ehu.eus/harea-geologialitoral) develops a multidisciplinary approach (sedimentology, geochemistry, micropalaeontology, topography, radiometric chronology) to characterize natural and anthropogenic processes responsible for the environmental transformation of the coastal zone during the last climate cycle (Pleistocene, Holocene and Anthropocene). Its activities can be summarized into the following research lines and recent publications:

1. Transformation of polluted coastal ecosystems: Looking back to foresee the future. The coastal area has experienced an intense human pressure that provoked its physical destruction and a significant chemical and biological transformation. The development of environmental conservation and regeneration schemes, based on scientific criteria, makes necessary to carry out geological studies to evaluate their modern characteristics, historical alteration processes and the feasibility of improvement proposals (Gardoki, J., Cearreta, A., Irabien, M.J., Gómez-Arozamena, J., Villasante-Marcos, V., García-Artola, A., Bessa, F., 2024. Recent environmental and morphosedimentary evolution of the mining-impacted Nalón Estuary (Asturias, N Spain): Disentangling natural and anthropogenic processes. Sci. Total Environ. 943, 173792. https://doi.org/10.1016/j.scitotenv.2024.173792).

2. Climate change and Holocene relative sea-level (RSL) rise. An increase in the rate of RSL rise is potentially one of the most devastating impacts of the future climate change on coastal areas. Climate change influences the coastline at decadal and centennial scales, and these variations of the RSL are registered in the coastal sedimentary sequences. The reconstruction of Holocene RSL evolution from coastal sedimentary sequences provides a background upon which to compare modern rates of RSL rise, especially the early Holocene period of rapidly rising RSL (Li, T., García-Artola, A., Shaw, T.A., Peng, D., Walker, J.S., Cearreta, A., Horton, B.P., 2024. Vertical land motion is underestimated in sea-level projections from the Oka estuary, northern Spain. Sci. Rep. 14, 31302. https://doi.org/10.1038/s41598-024-82692-1).

3. Environmental implications of natural and human-induced sedimentary processes. Sedimentary processes in the estuarine areas are frequently altered by human-induced activities (dredgings, dumpings, reclamation, channelling) which can lead to undesirable repercussions. Geological studies contribute to understand the role of the anthropogenic influence and to establish suitable strategies for a sustainable development and harnessing (Gardoki, J., Cearreta, A., Ortiz, J.E., López-Cilla, I., Gómez-Arozamena, J., Villasante-Marcos, V., Bessa, F., García-Artola, A., Irabien, M.J., 2025. Assessing the environmental impacts of engineering and agrochemical pollution in a historically-eutrophic estuary: The Mondego case (W Portugal). Mar. Pollut. Bull. 214, 117782. https://doi.org/10.1016/j.marpolbul.2025.117782).

4. Anthropocene: a new epoch in the geological scale? Human activity is leaving a pervasive and persistent signature on Earth. Numerous anthropogenic markers of functional changes in the Earth system have been found through the stratigraphic record. These signals render the Anthropocene stratigraphically distinct from the Holocene (Summerhayes, C.P., Zalasiewicz, J., Head, M.J., Syvitski, J., Barnosky, A.D., Cearreta, A., Fialkiewicz-Koziel, B., Grinevald, J., Leinfelder, R., McCharthy, F.M.G., McNeill, J.R., Saito, Y., Wagreich, M., Waters, C.N., Williams, M., Zinke, J., 2024. The future extent of the Anthropocene epoch: A synthesis. Glob. Planet. Change 242, 104568. https://doi.org/10.1016/j.gloplacha.2024.104568).

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Mass transfers through the lithosphere: hyperextension evidences in orogenic belts

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KEY WORDS: lithosphere, delamination, tectonics, hyperextension, structural geology, transpression, extensional collapse.

Our main research topics are the mass transfers in the continental crust, a key point for the dynamics of the lithosphere. The most important processes of mass transfer through the lithosphere are due to the motion of ductile shear zones and the intrusion of huge volumes of igneous rocks. We integrate field studies of Structural Geology, rock fabric analyses, anisotropy of the magnetic susceptibility, seismic and gravity data and mapping in order to perform 3-D models. Since this approach is concerned with geological processes rather than with regional questions, we have selected any working areas which encompass the main steeps of a complete orogenic cycle:

- **Oceanic subduction** in La Puna and the Eastern Andean Cordillera (Salta, NW Argentina), with special emphasis on the Calama-Olacapato-El Toro lineament, representing a transfer zone associated to an important change in the subduction angle of the Nazca plate below the South America plate and the magmatic rheology of laccolith of Piedra Parada Mega Caldera in Patagonia. Magmatism, recent volcanism and active seismicity related to mantle delamination of the South American plate can be also tested in these areas.

- **Extensional collapse**, in Betic Cordilleras. The interest of this area is due to the presence of the Ronda peridotites, the largest outcrops of the subcontinental mantle in the world, which allows a unique chance to analyse the deformation of the lithospheric mantle at the Earth's surface.

- **Continental collision and transpression**, in the Central-Iberian Zone (Galicia) of the Iberian Variscan belt and in the western Pyrenees. In the Pyrenees the study analyses the evolution from continental collision to transpression during the Hercynian orogeny and the superposition of the Alpine orogeny. In the Basque Cantabrian Basin we are characterizing the main tectonic structures. In the Central-Iberian Zone we are mainly working in the internal structure and emplacement of granite plutons, as a way to test the influence of lithospheric delamination in old orogens.

All of these areas are suitable to test melt-enhanced deformation processes related to the interplay between shear zones and igneous melts. The members of the applying institutions, Universidad del País Vasco UPV/EHU, Burgos, and Buenos Aires, Salta, Río Cuarto y CONICET in Argentina, have the methodological and regional expertise required for this type of works. The results of this research represent a significant advance in the knowledge of both, the emplacement of granite plutons and the rheological behaviour of rocks during the nucleation, kinematics and evolution of ductile and brittle shear zones. These are essential factors for the geodynamic interpretation of orogenic belts.

Morevover, our group is also actively involved in the transfer of geological knowledge to Society, through ongoing University-Industry collaborations focused on green-exploration technologies for the evaluation of critical resources and their role in the energy transition.

Matematika

Matemáticas

Integrated Mathematical Optimization for Health, Energy, and Logistics Problems management (MATH-HELP)

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KEY WORDS: Operations Research, Applied Mathematics, Computer Science, Industrial Engineering, Green and Sustainable Science and Technology.

The proposal aims to address significant social challenges by leveraging **Operations Research and Applied Mathematics**. Specifically, the goal is to conceive data-driven robust decision-making processes for complex real-world problems. It outlines two primary intertwined objectives. Firstly, to propose new approaches by developing advanced **mathematical models** for robust decision making. Rooted on the intersection of Combinatorial and Stochastic modelling, we will leverage the potential of Distributionally Robust Optimization to mitigate the curse of dimensionality related to classical stochastic programming. Secondly, to design innovative **algorithms** hybridizing Mathematical Programming and Artificial Intelligence techniques for solving large scale problems. The resulting matheuristics and metaheuristics should be able to produce efficiently near-optimal solutions. In essence, the underlying hypothesis is that the DRO paradigm, combined to the ability of AI to generate and refine uncertainty sets, holds the potential to significantly improve the modeling and solving capacity, addressing critical social issues currently out of the reach of available technologies.

The proposal targets three key application domains aligned with the *"National Plan for Scientific and Technical Research and Innovation"* Health, Energy, and Logistics characterized by a high and system wide uncertainty.

- In **Health**, it addresses location and dispatching problems for an ambulance fleet in a stochastic and robust framework.
- Within **Energy**, it focuses on Smart Grids and Multi-Energy Systems modeling for buildings and electric vehicles.
- **Logistics** goals involve designing stochastic cross-dock infrastructures to advance modeling and computational aspects.

This interdisciplinary project merges expertise from mathematical, computational, and industrial disciplines. Moreover, the aforementioned research domains are intricately linked to the 2030 Agenda and its associated **Sustainable Development Goals**. Specifically, the alignment is evident with Goal 3, focusing on health and well-being; 7, centered on affordable and non-polluting energy; 9, emphasizing the establishment of resilient infrastructure, promotion of sustainable industrialization, and encouragement of innovation; 11, concerning sustainable cities and communities; and 13, addressing climate action. The socio-economic impact of the project is indisputable. The applications are the result of a close collaboration with key stakeholders, including the Basque Public Health System, ZIV Applications and Technology, GoiEner cooperative, ULMA group, Basque Energy Agency EVE, and BCAM. The outcomes of this project hold the potential to serve as a benchmark for other regions.

This research has been partially supported by the Spanish Ministry of Science and Innovation through the project PID2023-147410NB-I00, BCAM Severo Ochoa Accreditation CEX2021-001142-S and PRE2020-091984 Severo Ochoa grant; and by the Basque Government through the project IT-1494-22 and BERC 2022-2025.

Mathematical Analysis and Applications

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KEY WORDS: PDEs, Dynamics, Harmonic Analysis, Quantum mechanics, Numerical Analysis.

Our group focuses on several branches of Mathematical Analysis and Mathematical Physics, ranging from Fourier Analysis to Numerical Analysis. Some of the topics in which our group works are the study of: uncertainty principles and their applications; different properties of a variety of equations (Dirac Equation, Schrödinger Equation and the Vortex Filament Equation, among others) and related problems, in connection with some physical phenomena; unique continuation and Control Theory; properties of maximal operators in different situations; free boundary regularity of harmonic measure; operators which arise from Fourier theory and the study of solutions of elliptical equations such as singular integral operators and their weighted versions, in a quantitative way; the extension problem for the sublaplacian in the Heisenberg group; the analysis on the infinite dimensional torus; discrete harmonic analysis; generalized spherical means acting on radial functions and their relation to the solution of Euler-Poisson–Darboux equations; fractional and classical Poincaré-Sobolev type inequalities in relation with elliptic partial differential equations, and the study of fractional differential equations, in both the mathematical and the numerical settings.

Some particular problems

One of the objectives on which we are currently working is the study of the absence of eingenvalues of Dirac operators. By using the method of multipliers, a class of pontentials is given in order to leave invariant the spectrum of the free Dirac operator. Another interesting problem, related to fluid mechanics, is the evolution of viscous vortex filaments. Here, the aim is to build a Navier-Stokes solution around a filament evolving with the binormal flow by using an infinite vortex filament (which asymptotically approaches a straight line) as initial data. Part of the group is also involved in the study of PDEs like the Poisson equation through singular integrals known as Calderón-Zygmund operators. Our goal is to show that they are well-defined when applied to data associated to PDEs in non-classical settings, such as those with non-homogeneous data, or elliptic boundary value problems with fractional regularity. The group also carries out dissemination work, as for example, the *2M: Music and Mathematics programme*, which aims to use musical culture as a vehicle for spreading mathematical knowledge.

Our main projects are the ones listed below:

• Funded by the Basque Government: IT1615-22, Fourier Analysis and Partial Differential Equations. PI: C. Pérez.

• Funded by MCIN/AEI/10.13039/501100011033 and by “ERDF A way of making Europe”:
- PID2021-122156NB-I00, Harmonic analysis meets inverse problems. PI: P. Caro and I. Parissis.
- PID2021-126813NB-I00, Análisis matemático y numérico de ecuaciones en derivadas parciales. PI: F. de la Hoz and L. Vega.
- PID2021-123034NB-I00, Spectral theory and PDE: Real and Fourier Analysis. PI: R. Lucà and L. Fanelli.

• Excellence Acreditation "Severo Ochoa": Centre of Excellence "Severo Ochoa" CEX2021-001142-S. Host institution: BCAM. PI: L. Vega.

Matrix analysis and applications group

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KEY WORDS: matrix analysis, control theory, linear systems, structure invariants, perturbation, numerical linear algebra, inverse problems, canonical forms, eigenvalues, singular values.

The Group of Matrix Analysis and Applications (GAMA) of the University of the Basque Country UPV/EHU is the result of the evolution of a team that has been working uninterruptedly in research since 1981. The main research areas of this group are:

- Theory of matrices.
- Mathematical control theory.
- Perturbation theory.
- Numerical linear algebra.

The aim of our research is to gain insight into the structure of the linear control systems and matrices and to develop mathematical techniques in order to solve problems in these areas. The following research lines have been designed:

- Study of the structure of control systems and matrices.
- Spectral perturbation of matrices and linear systems.

These research lines are closely related. Nevertheless, in order to clarify the problems that we are interested in, we will state, in a general manner, some of them:

1. Parametrize the spectral filters of general quadratic systems, characterize the eigenvectors of classically damping systems and generalize the phase synchronization method.
2. Design a procedure to effectively construct vibrating and gyroscopic systems with prescribed dynamic behaviour.
3. Complete a rational matrix with rows (columns) so that the resulting matrix has some prescribed invariants for a given equivalence relation.
4. Progress on the characterization of the assignment of invariants under state feedback and output injection for linear control singular systems.
5. Study the regularity of the stratified manifold of controllable and observable linear systems with fixed controllability and observability indices.
6. Find necessary and sufficient conditions for the existence of polynomial and rational matrices when the minimal indices of the column and row spaces, together with other structural data, are prescribed.
7. Extend properties of polynomial matrices on one variable to several variables.
8. Complete the study of the hyperinvariant and characteristic subspace lattices.
9. Generalize Berlekamp-Massey algorithm to obtain matrix generators of minimal length for a given sequence of matrices.
10. Obtain a general characterization of the stable (A,B)-invariant subspaces.
11. Analyse the geometry of the connected components of the pseudospectra and compute their derivatives in the sense of the Hausdorff metric.
12. Provide conditions for the reduction of a non-analytic matrix function of real variable to its Jordan form under global similarity.

The methods and techniques to be used run over almost all fields of mathematics: from Linear Algebra and Matrix Analysis or Combinatorics to Differential Geometry or Commutative Algebra.

Weekly seminars are kept where the progression of the subgroups' work is shown, the difficulties are discussed and other researchers' work related to our problems is explained. This and the individual study of papers are the main methodological tools. The results are published in the most important specialised journals: Linear Algebra and its Applications, SIAM Journal of Control and Optimization, SIAM Journal on Matrix Analysis and Applications, International Journal of Control, Linear and Multilinear Algebra, Electronic Journal of Linear Algebra, etc.

More information in: http://www.ehu.eus/gama

Performance Evaluation and Learning in Complex Networks

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KEY WORDS: Markov chains; Resource-sharing problems; Reinforcement Learning.

The Internet is today the fundamental component of worldwide communications infrastructure. In recent years, the use of both the Internet and wireless services has experienced an explosive growth and has had a striking impact in the world-wide economy. Network operators and service providers anticipate further expansion, boosted by the emergence of all-optical networking as well as the convergence of wireless and Internet access, along with a fundamental trend towards service integration. It is expected that future information and communication systems will accommodate a variety of new applications with a diverse range of Quality-of-Service (QoS) requirements. This research group focuses on the modeling and performance evaluation of large-scale distributed systems. More precisely, we aim to model complex networks, analyze the performance of this model, and propose algorithms/mechanisms that improve the performance of end users.

The main challenges are the need to cope with are: (i) the management of heterogeneous resources in both data and services, due to the fact that arrival times of queries and their service requirements are unknown, and (ii) little or no knowledge of the explicit dynamics of the system. Hence, queueing theory and stochastic processes are a fundamental tool to analyze these systems. In fact, they provide a wide set of mathematical tools to define models that allow us to predict the performance of queues or waiting lines. Once the evaluation of the performance of a system has been done, one can think of the design of efficient algorithms to apply to those systems, i.e., how the system must be designed so as to ensure that its performance is as close as possible to the optimal performance that can be achieved.

Some of the current research topics covered by our group are the following:

- Performance Evaluation and Optimization of Parallel Server Systems and Matching Models
- Analysis of Queueing Games
- Optimization using the Age of Information Metric
- Learning in Queueing Systems

The main tools we use in our research are:

- The theory of Markov chains and its approximations
- Markov decision processes in discrete and continuous time
- Non-cooperative Game Theory
- Reinforcement Learning

Kimika

Química

Integrative strategies to assess global issues in human and environmental health

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KEYWORDS: environment pollutants, emerging contaminants, xenobiotics, contamination, analytical chemistry, biofluids, climate change, aquatic environment, metabolomics, endocannabinoids, bioaccumulation, toxicity, wastewater, Alzheimer, microplastics.

The use of many compounds –some of them pollutants - in our daily life inevitably leads to their release into the human and environment, without really knowing which is their fate and behavior in the environment and overlooking their effects on the living organisms and on materials. These concerns require an integrative and multidisciplinary approach to understand the processes that take part in the hazardous effects or in the degradation processes. In **IBeA (*Ikerketa eta Berrikuntza Analitikoa*)** we lead several research topics in human and environmental health analytical issues, and we collaborate actively with many national and European research groups.

Within the framework of the **OneHealth** concept, we develop high-throughput analytical methods for innovative sample treatments and bioassays, and to validate target and nontarget analytical methods for efficient (bio)monitoring of surface waters and biofluids (plasma, urine and breast milk). **AQUASOMIC** project is focused on the assessment of the occurrence of emerging contaminants in surface waters and the strategies to mitigate their effects in drinking water, or on the assessment of exposure to contaminants by analyzing biofluids and wastewater. This will allow exposomic studies to shed some light on the impact of environmental contaminants on human and environmental health. **Inmujeres** project is a collaboration work with healthcare personnel to study how exposure to xenobiotics can affect reproductive system. This is done using target and non-targeted analyses of organic compounds in follicular fluid. Moreover, the determination of endogenous modulators of the endocannabinoid system that are involved in a multitude of biological functions can be linked to different health conditions such as neurologic and reproductive alterations. **AMMONTOX** project focuses on the issue of oils spills and aims at exploring the suitability of the Adverse-Outcomes driven Whole-Mixture Toxicity Assessment approach as a better alternative to the commonly used Chemically oriented Mixture Toxicity Assessment that pursues identifying chemicals responsible of the mixture toxicity. **PLASTeMer** is a project that aims to determine the presence and impact of microplastics (MPs) in the environment and to study the interactions of these materials with other pollutants (metals and organic chemicals pollutants). Given the urgent need to standardize studies on MPs, the main objective of the **Elkartek 2021** is to develop robust technology based on analytical methods to identify MPs in biological tissues, classify them by size and quantify them. **PlasticEDAR** project arises from the Bilbao Bizkaia Water Consortium (CABB)'s interest in adapting its operations to the upcoming changes in European legislation regarding the presence of MPs in wastewater.

One of society's major concerns is health and IBeA is increasingly active in this area. **Elkartek 2023** addresses new avenues in the understanding of the innovative CART treatment for cancer, through developments based on spectroscopic and metabolomic methods combined with artificial intelligence.

For most of these works, the development of new and innovative analytical procedures based on cutting edge instrumentation is the key part of our research. In this sense, we can include the use of microfluidic devices or the development of non-target analytical methods.

Studies in Cultural Heritage and Landscape by means of Analytical Chemistry – IBeA Research Group

J.M. Madariaga, F. Amato, J. M. Amigo, F. Alberquilla, J. Aramendia, G. Arana, N. Arrieta, K. Castro, L. Coloma, I. Costantini, I. Etxebarria, O. Gómez-Laserna, G. Gorla, J. Huidobro, M. Maguregui, I. Martinez-Arkarazo, M.A. Olazabal, I. Población, N. Prieto-Taboada, S. Puente, M. Romani, I. Vázquez-de la Fuente and M. Veneranda.

KEY WORDS: Cultural Heritage, Landscape, space exploration, transdisciplinary.

IBeA research group has made an important effort in the last years to understand the chemistry behind the decaying processes that affect the cultural heritage and to develop new solutions to revert them. Our research group develops innovative analytical strategies to evaluate the impact of chemical contaminants, microorganisms and the environmental conditions on the Cultural Heritage and Landscape scenarios. The most relevant ongoing projects are:

1. **NanoCult** (Advanced Nano-solutions for consolidation and muntifunctional protection in cultural heritage): The main objective of this project is to guarantee the conservation of cultural heritage materials, stone and mural paintings, through innovative diagnostic techniques, the development of non-invasive cleaning methodologies, the formulation of consolidating and protecting products based on nanotechnology and their following application on real cases, innovative processes of solutions.
2. **SIDIRE** (Innovative solutions for the diagnosis and restoration of the built cultural heritage): This research aims at providing innovative solutions to some of the problems cultural built heritage is facing, restoration and diagnosis, with greener approaches to provide more sustainable paths.
3. **ENCLOSURE** (Eco-design of nanocelulose-based solutions for cultural heritage conservation: materials development, validation and life cycle assessment): This project aims to provide sustainable conservation solutions through the Safe and Sustainable by Design (SSbD) concept, testing nanocellulose-based materials.
4. **Rock art**: Collaboration on various projects with other institutions, aiming to contribute to the study and the conservation of rock art through a none-destructive approach. As an example, TaphArt-MSCA and PALEOPRO projects which explore the possible influence of taphonomic events in the conservation of rock art in the Middle Stone Age of Southern Africa, and Paleolithic caves from the Basque Country, respectively.
5. **Herculano and Pompeii**: A diagnostic study is being carried out on the degradations of the tuff of the archaeological park of Herculaneum (Italy), and possible materials for its restoration.
6. **FUEGO-PATAGONIA** and **ELEMENT**: Design of non-invasive analytical methodologies to study the earliest painted portable art from Patagonia and Southern Tierra del Fuego (in collaboration with CONICET-University of Buenos Aires), and the unique exemplar of a young woman life-sized bronze *togatus,* thanks to the funding of the Government of Navarra and the support of Bruker.
7. **Mars2020, ExoMars and other space missions**: Official members of Nasa's Mars2020 mission through the SuperCam instrument science group. Part of the team of the future ESA Rosalind Franklin Mission, through the RLS (Raman Laser Spectrometer) instrument. Working on other international space missions such as VMMO which aim to analyze the Moon surface from an orbit.
8. **Analysis of meteorites and terrestrial analogues**: Thanks to an agreement with NASA (Johnson Space Center), meteorites found in Antarctica for analysis using non-destructive techniques are received and analyzed. Furthermore, we have an extensive study of the east coast of Bizkaia, as Martian analog as well as La Palma latest volcano, Tajogaite, used as Martian and Moon analogue.

FarmArteM research group. From health and environment to cultural heritage conservation

R.M. Alonso[1], M.I. Maguregui[2], K. Alberdi[2], M.L. Alonso[1], E. Artetxe[2], M. Barandiarán[2], O. de la Hera[1], O. González-Mendia[2], M. Konjevod[1], I. Madariaga[2], A. Porcel[2], H. Salazar[2], I. Belza, A. Duque[1], L. Blasco[1], A. Rivas[1], J.L. Larrañaga[2], E. Tarilonte[2]

[1]Analytical Chemistry Department, Faculty of Science and Technology, UPV/EHU; [2]Department of Painting, Fine Arts Faculty, UPV/EHU.

KEY WORDS: health, environmental protection, forensics, art heritage.

The FarmArteM research group is composed of researchers from the Analytical Chemistry and Painting departments, which provides us with a strong multidisciplinary character. The main objective of our research is to address challenges of significant social relevance. Metabolomics and Drug Analysis, Environmental Analysis, Forensic Analysis and Conservation of Cultural Heritage are the four research lines of the group. The outcomes of these research efforts have an important impact on different fields such as health, environmental sustainability, dating of artworks and preservation of cultural heritage.

In order to deal with all these challenges we apply a wide range of analytical techniques In this regard, mass spectrometry coupled to chromatographic techniques as well as immunoaasays together with sample treatment procedures such as QuEChERS, solid phase microextraction or head-space procedures are the analytical methodologies mainly applied to health and environmental fields. Meanwhile, radiography, reflectography and X-ray fluorescence, together with Raman spectroscopy, X-ray diffraction, scanning electron microscopy-energy dispersive spectroscopy or Fourier transform infrared spectroscopy-attenuated total reflectance are employed for the study of cultural assets.

Metabolomics and Drug Analysis

- **The** role of short fatty acids (SCFAs) in the development and treatment of neurological diseases.
- Antibody drug conjugates (ADCs) as new strategy to fight against cancer.
- Search of schizophrenia biomarkers by Metabolomics.
- Microbiota-Gut-Brain Axis. Treatment and prevention of mental diseases.
- Resistance to antifungal drugs.

Environmental Analysis

- **Diele**ctric gas mixture of medium voltage electrical distribution cells. Alternative to SF6 use
- Protein baits control the invasive species Vespa Velutina (Asian hornet).
- Analysis of hydrogen and methane produced by green algae.
- Quality control of waters from drinking water treatment plant.
- UV filters analysis in environmental waters by low toxicity deep eutectic solvent (DES).
- Valorization of fruit industries subproducts.

Forensic Analysis

- **P**en inks and papers dating in questioned documents.
- Acrylic paints dating in contemporary artworks.
- Post-mortem interval of human skeletal remains.

Conservation of Cultural Heritage

- Characterization and conservation of contemporary artworks.
- Catalogue of the art heritage of the University of the Basque Country (UPV/EHU).
- Catalogue of Faustino Orbegozo Eizaguirre Foundation artworks.
- Polychromatic coatings on concrete.

Multifunctional Dyes and Nanomaterials for Photonics and Bioapplications

Virginia Martínez, Teresa Arbeloa, Jorge Bañuelos, Leire Gartzia, Rebeca Sola, Edurne Avellanal, Ruth Prieto, Eduardo Duque, Natalia Casado

[1]Departamento de Química Física

KEY WORDS: organic fluorophores, UV-VIS-NIR spectroscopy, nanostructured materials, computational simulations

The Molecular Spectroscopy group comprises a team of researchers and professors with expertise in molecular spectroscopy, materials chemistry and computational chemistry. The laboratory is equipped with state-of-the-art high-resolution techniques, enabling the measurement of absorption and emission signatures of photoactive systems across various states (liquid, solid, and films) and time scales (picoseconds to nanoseconds). These measurements span the ultraviolet, visible, and near-infrared regions of the electromagnetic spectrum.

The research activities within the group are structured into four interdisciplinary lines, each one addressing a specific scientific challenge:

1. **Smart probes for bioimaging and photodynamic Therapy**. BODIPY organic dye is the archetype of modern fluorophores with accessible chemistry and tunable photophysical performance. This research focuses on developing and characterising rational modifications in this molecular scaffold to render efficient and stable fluorophores photoactivated with long wavelength light and able to selectively recognise specific subcellular localization for their visualization under the fluorescence microscope in bioimaging. Alternatively, suited structural modifications allow the design of triplet state photosensitizers for the generation of reactive oxygen species like singlet oxygen for targeted photodynamic therapy.

2. **Bright and tunable emittes for lasers and circularly polarized luminescence.** Following the above exposed strategy, the chemical modifications of the chromophoric core can also be directed to modulate the absorption/emission window from the ultraviolet to the near infrared edge. Thus, a palette of glow BODIPY-based emitters are designed as photoactive media for lasers. Furthermore, these achiral dyes can be endowed with optical activity though the induction of axial symmetry or the attachment of chiral moieties leading to chiral dyes featuring circularly polarized luminescence. The induction of new photophysical processes like intramolecular charge transfer allows the modulation of the sign and strength of this chiral emission.

3.-**Functionalized nanosystems for targeted (photo)therapies**. Use of nanomaterials (silica nanoparticles, cellulose nanocrystals and nanoclays) for controlled drug delivery to target cells or microorganisms, particularly resistant bacteria. These nanocarriers are chemically functionalized to enhance stability and biorecognition, allowing for the selective localization to the malignant or infectious tissue. New approaches exploring the synergistic potential of combined mechano-bactericidal properties and photo treatments are being developed against antimicrobial resistance.

4.-**Photoactive hybrid host-guest materials for non-linear optics.** Research in this area is directed towards developing solid-state materials with tailored photonic properties for applications in photonics and in particular in non-linear optics. The focus is on rationally selecting host materials, such as zeolitic porous frameworks, and integrating them with photoactive dyes, as well as leveraging self-assembly strategies of organic molecules to optimize their functional performance.

Achieving these research objectives implies a multidisciplinary and collaborative approach, engaging experts from complementary fields. Collaboration with specialists in organic and inorganic chemistry facilitates the synthesis of dyes and solid hosts, while partnerships with physicists support advanced optical measurements, including laser technology, circularly polarized luminescence, and non-linear optics. Furthermore, biologists contribute to bioimaging studies and cytotoxicity assessments, providing critical insights that drive the iterative improvement and redesign of next-generation dyes and materials.

Quantum foundations and beyond

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KEY WORDS: *Founadtions of quantum mechanics, quantum measurements, quantum paradoxes*

We are a small research group based at the Department of Physical Chemistry and the Department of Applied Physics of the University of the Basque Country (Leioa and Bilbao campuses, respectively). This poster presentation explains, in the most general terms, who we are and which research lines we pursue.

Advanced spectroscopic and magnetic techniques in molecular and nanoscale research

Fernando Torres, Cristina Huergo, Raquel Zurbano, Izaro Solozabal, Ibai Calvo, Andrea Vázquez, Daniel Doménech, María García, Maider Parra Santamaria, Aran Insausti, Ander Camiruaga, Francisco Javier Martín, Iker Lamas, Raúl Montero, Imanol Usabiaga, Emilio J. Cocinero, José Andrés Fernández, Asier Longarte, Carolina Redondo, Rafael Morales and Francisco J. Basterretxea*
Department of Physical Chemistry, UPV/EHU.
*SGIKER Laser Facility

KEY WORDS: laser spectroscopy, microwave spectroscopy, ultrafast processes, nanomagnetism, nanostructures, lipidomics, cancer, metabolites, vaccines, nanomedicine, biosensors.

The Group of Spectroscopy, Spectrometry and Materials (**GS$_2$M**) works on research lines that comprise different subjects, all focusing on a molecular and nanometric scale. It designs and applies state of the art spectroscopic techniques to a variety of problems in chemistry that partly overlap with the fields of biology or physics. The group works in spectroscopic instrumentation to achieve high resolutions, in both time and frequency, and high control of physical and chemical properties at the nanoscale. Thus, ultrafast lasers allow detection of phenomena in the timescale of femtoseconds, whereas microwave spectrometers can resolve molecular energy levels that differ only a few kHz. On the other hand, combining nanosecond laser pulses with mass spectrometric detection it is possible to discriminate among different molecular conformers of the same species. Finally, laser lithography techniques, together with magneto-optical spectroscopy, allow fabrication and characterization of singular patterned nanostructures.

The previous techniques are well suited to investigate numerous scientific problems at a molecular and nanometric level. A brief list of the ongoing research lines of the group is given below:

- The study of *ultrafast molecular phenomena* using femtosecond laser pulses, such as dissociative processes, energy transfer among excited electronic states, or charge generation in isolated or condensed phase systems.
- *Development of methods based in short laser pulses* of a chosen time duration and spectral properties for technological and scientific applications.
- *Microwave spectroscopy* experiments, combined with laser vaporization techniques, enable to obtain molecular structures and gas-phase dynamics of biomolecular building blocks, such as sugars, of which few experimental studies free from the interation with solvent molecules can be found. These studies are also the basis for the detection of prebiotic molecules in the interstellar space.
- *Laser electronic spectroscopy* with pulsed supersonic jets and mass resolution is a powerful tool to characterize electronic and vibrational transitions of rather big molecules and can further discriminate among a usually numerous family of conformers. This techniques are adequate to study interactions between molecular moieties of interest in the biosciences, such as anesthetic-receptor, or bonding among the nitrogenated bases in DNA and RNA chains.
- More specific mass spectrometric techniques, such as *Matrix Assisted Laser Desorption Ionization* (MALDI), allow the obtention of bidimensional images of biological tissues; in this way the distributions of lipids or other substances can be monitored quickly. This technique has direct medical applications.
- Nanofabrication and characterization of structures at the nanometer scale allow designing of *magnetic nanostructures* (discs, rods and other geometries) with distinctive properties, different from those of macroscopic elements. These patterned structures have a wide application in fields such as magnetic storage of information or biomedicine, for example, cancer diagnosis, regenerative medicine and neurostimulation.
- Molecular Conformational Cartography applies advanced computational and spectroscopic studies to characterize molecular potential energy surfaces and to understand intermolecular interaction mechanisms.

Multifunctional and advanced materials: innovations for a sustainable future

A. García[1 2], A. Vélez[1], M. Díaz[1], S. Muñana[1], M. Ostovar[1], R. López[1], Y. Plasencia[1], G. Conejo[1 2], E. Pagalday[1 2], C. Pérez[1 4], G. Arrien[1], B. Gutiérrez[1], J.C. Martínez[1], J. Piñeiro[1], N. Muñoyerro[1], M. Gómez[1], P. Martinez[1], A. López[1], E. Castañeira[1], O. Sagarduy[1], L. Carranza[1], R. Teijido[1 2], J. Sánchez[1], A. Galdames[1], J. M. Laza[1], E. Hernaez[1], A. C. Lopes[1,5], I. Moreno[3], L. Pérez[1 2], L. Ruiz[1 2], A. Veloso[1], J. L. Vilas[1 2]

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KEY WORDS: hydrogels; coatings; biosensors; bio-based, additive manufacturing; soil remediation

The poster presents the key research areas of the Innovative Macromolecular Materials Group (IMACROMAT), part of the Physical Chemistry Department at UPV/EHU, led by Prof. José Luis Vilas. IMACROMAT specializes in polymeric materials and their processing for diverse applications.

Polymers play a crucial role across multiple industries, from healthcare to manufacturing, due to their versatility, durability, and tunable properties. However, the extensive reliance on petrochemical-based monomers raises significant environmental concerns, including resource depletion and pollution. To address these challenges, IMACROMAT is dedicated to the development of polymeric materials derived from renewable sources. By utilizing natural monomers such as eugenol, vanillin, tannins and oils, the group seeks to create innovative materials that not only exhibit enhanced thermal and mechanical properties but also align with the principles of green chemistry. The group also explores monomers and active compounds from natural resources, including marine sources such as local algae, expanding the potential for sustainable and biodegradable materials.

IMACROMAT's research focuses on several key areas aimed at developing sustainable and high-performance polymeric materials. One area involves photopolymerizable hydrogels derived from natural polymers like alginate and chitosan, which are used in biomedicine, tissue engineering, and wound healing due to their biocompatibility and tunable properties. The group also develops polymeric coatings with enhanced mechanical strength and anti-corrosive properties, benefiting industries such as automotive, aerospace, and construction. Another major focus is biocompatible materials for medical applications, including drug delivery systems and tissue scaffolds designed to interact safely with biological systems. IMACROMAT also researches polymeric fibers and piezoelectric hydrogels for sensor applications, enabling innovations in wearable technology, healthcare monitoring, and soft robotics. Additionally, the group works on nanoparticles for controlled drug release, bioremediation, and pollutant capture, offering solutions for both medicine and environmental sustainability. Advanced manufacturing techniques such as 3D bioprinting and electrospinning allow for the creation of complex polymeric structures with tailored properties, essential for biomedical applications and high-performance industrial materials.

Through its multidisciplinary research approach, IMACROMAT aims to develop innovative and sustainable polymeric materials that address current challenges in industry and society. By integrating renewable feedstocks, advanced processing techniques, and functional materials, the group contributes to the advancement of environmentally friendly and high-performance polymer solutions.

Organometallics in Synthesis

B. Fundora, E. Vásquez, M. Baltasar, S. He, B. Taboada, B. Muñoz, I. Zurutuza, A. Dominguezgil, F. Bani, R. Figuera, M. Rueda, C. Santiago, A. Carral-Menoyo, S. Arrasate, H. González-Díaz, N. Sotomayor, E. Lete
Departamento de Química Orgánica e Inorgánica, Facultad de Ciencia y Tecnología, UPV/EHU (www.ehu.eus/en/web/oms/home)

KEY WORDS: synthesis, catalysis, chemoinformatics, machine learning.

The development of innovative synthetic methodology is crucial for the discovery of new active molecules in the pharmaceutical industry. New synthetic methods and reactivity patterns capable of allowing the preparation of complex molecules in a safe and environmentally compatible manner are required. Our projects are focused on the development of effective and selective methods of C-C and C-X bond formation via transition metal-catalyzed C-H functionalization reactions to provide access to biologically relevant molecules. We also carry out interdisciplinary projects that involve computational chemistry and development of Perturbation Theory Machine Learning predictive algorithms (PTML) for reactivity prediction and for the design of biologically active molecules to help in the drug-discovery process. Our research interests are summarized in the following topics:

Synthesis. Metal-catalyzed C-H activation reactions in the synthesis and functionalization of heterocycles. Transition metal-catalyzed C-H functionalization is already an essential synthetic methodology, allowing the use of non-functionalized starting materials for the construction of more complex molecules. Building on our previous experience with Pd(0) catalysis in intramolecular and cascade processes, we have developed methodologies based on Pd(II)-catalyzed C-H activation, showing that alkenylation or acylation reactions are versatile synthetic tools for the synthesis and functionalization of medium-sized rings. Currently, we continue working in this field by developing enantioselective variants with axial chirality control. We have also begun to study the use of cheaper, more abundant, and less toxic metals, such as Co(III), in catalysis to replace palladium complexes. The use of Co(III) complexes in catalysis opens up opportunities for the development of new reactivity, including asymmetric versions. We have developed hydroarylation, allylation and aminocarbonylation reactions and are currently working on the development of cascade processes and enantioselective versions.

Computational chemistry. Machine learning algorithms for prediction of chemical reactivity and biological activity. We are also developing new computational multi-target methods capable of predicting different reactivity parameters of a given reaction when structural modifications (on substrates, ligands or catalysts) or experimental conditions are carried out. On the other hand, PTML multi-target models are also being developed to determine structure-activity or structure-toxicity relationships, that may be useful tools for the prediction and discovery of more effective and safer drugs.

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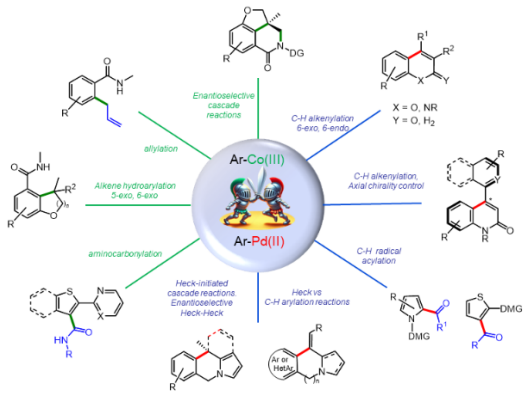
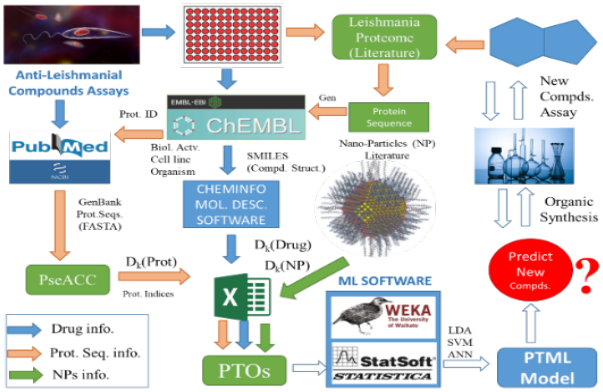




For some recent publications, see: *Eur. J. Org. Chem.* **2024**, *27*, e202301090, *Biomed. Pharma.*, **2024**, *174*, 116602; *J. Cheminformatics*, **2024**, 16, 9; *Trends Chem.* **2022**, 4, 495; *Org. Biomol. Chem.* **2022**, *20*, 852; *J. Chem. Inf. Model.*, **2022**, 62, 3928; *Eur. J. Med. Chem.* **2021**, 113458; *J. Org. Chem.* **2020**, 85, 10261

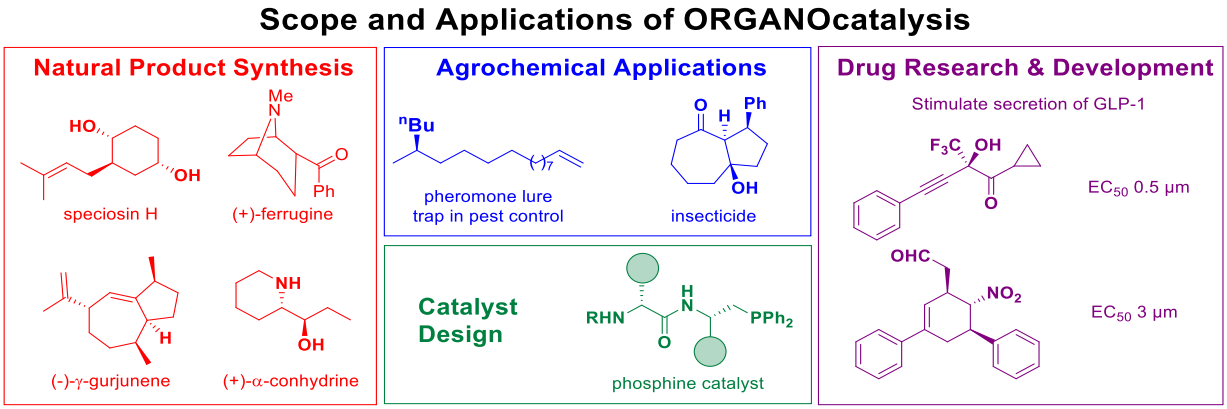
Group of Asymmetric Synthesis

Jose L. Vicario, Luisa Carrillo, Efraím Reyes, Uxue Uria, Liher Prieto, Gorka Garay, Antón Igartua, Ana Sorazu, Ixone Gamboa, Josebe Hurtado, Cristina Alonso, Anne Olarte, Uxue Aberasturi, Matteo Amico, Ager Axpe, Ibai Aner Pérez*
Department of Organic and Inorganic Chemistry, Faculty of Science and Technology, UPV/EHU

KEY WORD: Chirality - Asymmetry - Stereoselectivity - Asymmetric Synthesis.

– Is there anything but chirality? From the origin of the universe to small molecules, asymmetry is everywhere.

Our research has led us to explore various organocatalytic methodologies across different research lines, aiming to design new catalysts, synthesize natural products, and develop pharmaceuticals and other agrochemical compounds of interest in an asymmetric way. In the field of asymmetric synthesis, the catalyst must not only accelerate the reaction but also be highly stereoselective and flexible, enabling its use in the synthesis of different target molecules under benign reaction conditions. Furthermore, organocatalysts are stable in air, compatible with water, and most are commercially available, which is a major advantage when used in the pharmaceutical industry, especially in drug research, because the presence of traces of contaminating transition metals is strictly prohibited by legal regulations.



Our experience in Asymmetric Synthesis is well known and internationally recognized. Our research group provides laboratory facilities for students in the last year of degree, Master students, PhD. students or post-doctoral researchers. More information can be found in the group web page (http://www.ehu.es/gsa).

Metal-Organic Porous Materials Research Team

G. Beobide, O. Castillo (IP), M. Lanchas, A. Luque, S. Pérez-Yáñez
Postdoc: J. Pascual-Colino, R. Pérez-Aguirre, M. Perfecto-Irigaray
Predoc: N. Landaluce, N. Luengo, S. Mena-Gutiérrez, J. Napal, E. Maiza
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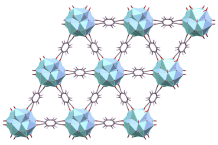
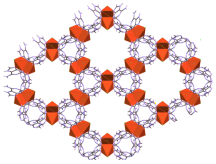
KEY WORDS: MOFs, MOGs, MOAs, Photocatalysis, CO_2 valorization, Pollutant capture, Sensors, Drug delivery.

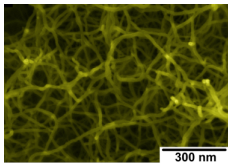
Below you can find an insight into the main lines of our research group, altogether with their applications fields:



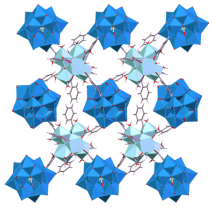
Metal–organic frameworks (MOFs). Metal–organic frameworks (MOFs) are a class of hybrid materials comprising metal ion-based vertices and organic ligands (linkers) that serve to connect the vertices into two or three-dimensional periodic structures. The structures and properties of MOFs can be carefully tailored by judicious selection of metal ion and organic linker building blocks. They encompass an area of chemistry that has experienced impressive growth during the last decades because of their various applications in catalysis, gas storage, chemical separations, sensing, ion exchange, drug delivery, and optics.



Supramolecular Metal-Organic Frameworks (SMOFs). Considering the great potential of MOFs, we decided to explore a related type of material, in which the coordination bonds are replaced with hydrogen bonds as connectors, which are also directional and predictable interactions, to sustain the three-dimensional (3D) crystal architecture displaying potentially accessible voids. Although such kind of alternative materials can arise a similar fascination to that of MOFs, the crystal engineering principles and the synthetic approach are not yet settled, and examples of this kind of material are rather scarce. We have recently proved the sensing and controlled drug release capacity of this new family of materials. Some of them being also able to capture the CO_2 dissolved in water.



Metal-organic gels (MOGs) and Metal-organic aerogels (MOAs). Metal-organic gels (MOGs), also called metallogels, have emerged as an alternative material to MOFs. Ideally, during the gel formation, the coordination polymer grows as nanoscopic primary particles that crosslink stochastically into the reaction media, creating a 3D solid network that entraps the solvent within. Gel drying by evaporation of the solvent induces a severe shrinkage of the microstructure and leads to materials called xerogel (MOX, metal-organic xerogel) with reduced porosity. Contrarily, supercritical drying of MOGs removes the solvent without collapsing their microstructure, and it leads to metal-organic aerogels (MOAs) that are hundreds of times lighter than MOFs. They have been successfully employed for the electro- and photocatalytic reduction of CO_2 into valuable chemicals.



Hybrid MOP-POMs. This new family of materials developed by us consists of cationic discrete metal-organic clusters and anionic polyoxometalates which are combined to provide a chemically and photochemically stable material. The synergistic effect between both discrete entities allows to markedly overpass the photochemical activity of the single ionic components. It is envisaged a fruitful future for this kind of material in photocatalysis, especially for the photocatalytic reduction of CO_2 into valuable chemicals.

Exploring the Power of Polyoxometalates

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KEY WORDS: Polyoxometalates, Organic functionalization, Multifunctional behaviour.

Polyoxometalates (POMs) are a well-known family of anionic metal-oxo clusters that exhibit a large structural, compositional, and electronic versatility, which renders them ideal candidates for a wide array of applications across various fields, including catalysis, material science, and biomedicine. Their unique properties, such as high thermal stability, excellent solubility in diverse solvents, and versatile redox behaviour, make POMs key components in the development of advanced functional materials. Specifically, our work is focused on three main research lines that involve the assembly of POMs with organic moieties, which leads to POM-based hybrid systems with enhanced properties for the study of their magnetic, luminescent, and structure-correlated properties, as well as their applications in biomedicine, environmental remediation and gas adsorption.

4f-metal containing POM assemblies: Extensive work has been carried out in this field due to the interesting structural and physicochemical properties that lanthanide-containing POMs might show, including their role as magnetic or luminescent systems. Regarding the first one, the intrinsic large magnetic anisotropy together with large ground-state spin values displayed by rare-earth metal ions under certain ligand fields, accompanied by the rigidity and insulating ability of POMs as ligands have been proved to result in molecular systems showing slow relaxation of the magnetization. In this sense, different 4f-containing POMs have been reported to behave as effective single-ion or single-molecule magnets (SIMs or SMMs) or spin qubits, for being applied in high-density memory-storage/sensor devices, spintronics or quantum computing. Moreover, these POM-based systems also serve as efficient antenna groups for lanthanide luminescence, overcoming the Laporte rule's restrictions and resulting in bright photoluminescent, which can be useful as optical devices.

POM-Polymer hybrids: The interaction between POMs and polymers has gained significant attention due to its ability to form robust composite materials. Organic functionalization of POMs is often required to create suitable hybrid POM-polymer platforms, which is typically based on the substitution of surface oxygen atoms of the POM clusters with those belonging to either O– or N–donor ligands. Most typical methods include the covalent attachment of trisalkoxo ligands to Anderson–Evans type polyoxomolybdates or Lindqvist–type hexavanadates. Covalent anchoring of those hybrids to classical organic polymers constitutes an optimal strategy to afford long-lived smart materials with self-healing and shape-memory behaviour. Regarding the polymerization process, recent studies comparing thermal- and photopolymerization methods have revealed that the latter is a faster, more energy efficient process, with minimal impact from the POM and aligned with green chemistry principles. Therefore, photopolymerization can be regarded as an effective approach for constructing advanced hybrid materials with enhanced functionality and environmental benefits, particularly for applications in environmental remediation and other high-impact areas such as biomedicine.

Grafting 3d-Metal Complexes onto POM anions: The grafting of 3d-metal complexes of macrocyclic ligands to POM surfaces is a key approach to form extended porous networks with permanent porosity able to exhibit interesting functionalities for selective gas absorption (such as CO_2, N_2, C_2H_2…) and heterogeneous catalyst. This family of compounds have also demonstrated the ability to undergo single-crystal-to-single-crystal (SCSC) structural transformations promoted by external stimuli, among which thermal dehydration processes stand out. Recently, some of these porous materials have also shown high water sorption capacities at low relative humidity environments (20-30% RH), with a great cyclability after 100 adsorption/desorption cycles, which endows these systems with interesting properties for their use as humidity control devices.

In conclusion, by exploring the combination of POMs with organic and metal-organic components, we can create fascinating materials with unique properties, such as enhanced magnetism, luminescence, biomedicine and environmental functionality. This strategy opens up exciting opportunities for the development of smart materials capable of addressing pressing global challenges, from environmental pollution to energy storage.

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Focusing on Efficiency and Sustainability.

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KEY WORDS: sustainable chemistry, new catalysts, upcycling.

The development of efficient and more sustainable synthetic protocols is the aim our research group (NEWSYNMETH) is working. In order to achieve this goal, we design our projects following two main strategies:

On one hand, we work for the development of efficient chemical processes that minimize the production of by-products, thus promoting catalysis, prioritizing the use of renewable reagents and benign solvents, as well as minimizing the energy cost. Therefore, our research projects focus on:

- The creation of molecular complexity and diversity from simple substrates through cascade reactions, advantageous processes that avoid several purification steps associated with traditional stepwise synthesis. Energy saving and minimization of waste are also achieved.
- Catalysis. Our catalytic systems allow us to minimize the amount of catalyst to be used, reaching infinitesimal values in some cases so that reactions become cheaper and purification of the final products is simplified. In addition, the catalytic activity of more abundant and less toxic metals such as iron, nickel, copper, etc. is also studied.
- Use of safer, non-flammable and more sustainable reaction media or even, if possible, solventless reactions are explored.
- Reducing the energy consumption. In this regard, microwave irradiation often results in better performances and reaction rates.

On the other hand, we work on the design of chemical methods for the reuse of waste. The massive use of plastics in today's society has turned the prevention, reuse and recycling of waste into key objectives of both the action plan and the waste management legislation. Accordingly, new methods for the “upcycling” of polymer waste based on its degradation and subsequent use as substrate are currently under research.

Ingeniaritza Kimikoa

Ingeniería Química

Catalytic processes for the refinery of the future

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KEY WORDS: biorefinery, biomass, hydrogen, syngas, decarbonization

The research lines of the Catalytic Processes and Waste Valorization (CPWV) group focus on the development of thermochemical and catalytic processes to obtain fuels and raw materials from alternative sources to oil. The feedstocks for the catalytic processes are the products from the thermochemical processes for valorization of wastes (lignocellulosic biomass, plastics, tires, etc.), together with CO_2 and secondary refinery streams of interest (light cycle oil (LCO), and vacuum gasoil (VGO)). The objective is to improve the management of wastes while contributing to the decarbonization of the energy sector, thus providing the framework for the development of the refinery of the future.

In the H_2 production process through the reforming of the bio-oil produced by fast pyrolysis of lignocellulosic biomass, two strategies for minimizing CO_2 emissions have been addressed. First, the sorption enhanced steam reforming process (SESR) uses a sorbent with the Ni-based reforming catalyst for the in-situ CO_2 capture so as to attain a higher H_2 yield and selectivity (the latter approaching 100%). Aspects studied include the selection of the catalyst, sorbent and operating conditions, and the reproducibility in cyclic operation. Second, the combined steam/dry reforming (CSDR, with H_2O and CO_2) is studied as an efficient route to jointly valorise bio-oil and CO_2 to produce syngas (H_2+CO), which is useful as a raw material in different catalytic processes for the production of fuels or chemicals. Aspects studied include thermodynamic studies to delimit a suitable range of operating conditions and the screening of catalysts based on their stability and regenerability. Moreover, we have developed a membrane reactor provided with a composite Pd-based H_2 selective membrane for the simultaneous reforming of crude bio-oil co-fed with ethanol for high-purity H_2 production.

The research based on the concept of Sustainable Refining combines the valorization of fossil and biogenic wastes to produce valuable fuels and compounds, with three different approaches: i) the hydroprocessing of pyrolysis liquids from plastics (including WEEE) and tires, mixed with refinery streams such as LCO or VGO, using bifunctional catalysts (PtPd and NiW on zeolites) in fixed and semi-continuous bed reactors; ii) the direct dissolution of plastics as an alternative to pyrolysis; iii) the hydrotreatment (HDO) of pine and spruce bio-oil with the aim of integrating it into a continuous hydroprocessing system. Together with the study of the deactivation and regenerability of catalysts and the kinetic modelling of the processes, the reuse of by-products such as pyrolysis char is being evaluated as a possible catalytic support.

In the research line that focuses on the production of petrochemical compounds and fuels from syngas (obtained via biomass gasification or CSDR of bio-oil), notable advances have been obtained in the development of catalysts and kinetic modeling for the direct hydrogenation of CO_2/CO into hydrocarbons with oxygenates as intermediates. Tandem catalyst (metal oxide/zeotype) are employed, for the formation of oxygenates (methanol/dimethyl ether, over the metal oxide) and their selective conversion into hydrocarbons (olefins and gasoline, over the zeotype). The current objective is to develop an original process with cascade reactors, which represents an advancement in the integration of catalytic processes, surpassing the thermodynamic and operational limitations of the processes in a single reactor and advancing towards the implementation at a large-scale of a novel and viable technology for the use of CO_2 as a carbon source. The development of highly selective and stable catalysts is key to maximizing its conversion into high-value petrochemical products. Furthermore, the production of fuels from light olefins from secondary streams via low-pressure oligomerization is being investigated as a promising route for hydrocarbon production, employing a cost-effective and energy-efficient process.

The research is carried out in collaboration with companies (Petronor, Total Energies) and other universities (INCAPE (Argentina), King Abdullah (Saudi Arabia), Western Ontario (Canada)), as reflected in the publications.

Waste valorization by thermochemical processes for hydrogen, fuels, and chemicals production

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KEY WORDS: Pyrolysis, spouted bed, gasification, waste valorization, hydrogen

Valorisation of biomass and residues of the consumer society (sewage sludge, waste plastics and tyres) contributes to solving serious environmental problems and developing eco-industry. Accordingly, the research lines of CPWV group promote the development of original and scalable technologies with great potential impact on industry. Thus, the research lines have a clear energy and environmental interest dealing with hydrogen, fuels and chemicals production by means of sustainable and environmentally friendly routes (pyrolysis, gasification and catalytic reforming), using biomass and wastes as raw materials. Moreover, these processes are associated with the development of new reaction technologies as spouted bed reactor (SBR). The research related to waste valorisation is divided in three main lines:

- Spouted bed reactor design optimization and scale up

The aim of this research line is the development of new spouted bed reactor configurations for different applications. The optimization of the reactor design is based on fundamental research involving hydrodynamic studies in different cold units, from lab scale up to a 500 kg pilot plant. Different tools are used for the monitoring of gas and solid flows in the reactor and contribute to the understanding of the reactor hydrodynamic performance under different process conditions. In this respect, gas flow pattern for different reactor design plays a key role on residence time distribution, which is critical in certain application as waste pyrolysis or gasification. In the same line, particles circulation path and rate control gas-solid contact and heat transfer rates. Therefore, improving the knowledge and understanding of reactor hydrodynamic performance is essential for the development of new applications and the scale up of this technology.

- Hydrogen production from plastics and biomass by pyrolysis and in-line reforming

The overall objective of this line is to progress on the sustainable production of hydrogen from waste plastics and biomass, by means of a versatile and scalable two-stage pyrolysis and in-line reforming process. The process combines a SBR for the fast pyrolysis step followed by a fluidized bed reactor (FBR) for the steam reforming of pyrolysis volatiles. This process ensures high hydrogen production and efficient conversion of pyrolysis volatiles. In order to overcome the high-energy requirement of the steam reforming step, the oxygen co-feeding to the reforming step is being studied to allow the reforming stage to be carried out under autothermal regime and improve the stability of the catalyst. Another challenge of the pyrolysis-reforming process is the high CO_2 emissions. In this respect, the incorporation of a CO_2 sorbent in the reforming step is proposed to overcome it. This strategy is especially interesting since, on the one hand, it increases the hydrogen production potential, and, on the other hand, it avoids the CO_2 release.

- Development of new reactor designs for thermochemical processes to produce fuels and chemicals

In the last years, the group worked in the optimization of SBR design for different thermochemical processes, specifically, pyrolysis and gasification. The design modifications incorporated have improved the performance of this technology, resulting in two patents and a contract with a multinational company. The excellent performance of optimized SBR has demonstrated its potential in different applications. In this respect, the applications of this technology is studied in three main thermochemical conversion processes: i) Biomass steam gasification for syngas with low tar contents production. ii) Catalytic pyrolysis of waste plastics over acid catalysts for the production of alternative fuels and valuable chemicals. iii) Selective recovery of light olefins and BTX from waste plastics by steam cracking.

Making biogas and biomass waste matter: the challenges of decarbonising our energy and raw materials supply

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KEY WORDS: Biomass, waste valorization, reforming processes, hydrogen production, tandem reaction

One of the main causes of climate change on our planet is the emission of gases such as CO_2 from the use of fossil fuels to produce chemicals and energy. For example, the synthesis of polymer materials consumes up to 80% of the carbon resources in the chemical industry. The most straightforward option to address the global warning challenge and the transition to a circular economy, aiming at a clean energy transition and climate change, is the use of biomass (organic waste and biogas) as a feedstock, as it is the only sustainable source of organic carbon. Our group is developing two catalytic approaches to achieve this ambitious goal, focusing on decarbonising the economy to mitigate the climate challenge. Thus, our research activities will pave the way for significant breakthroughs that will lead to robust, mature, enhanced technologies that could play a vital role in a modern, low-carbon society.

PRODUCTION OF FURFURYL ALCOHOL FROM FURFURAL BY TANDEM REACTION IN AQUEOUS PHASE

We develop advanced catalytic technology to produce high-value chemicals from lignocellulosic biomass-derived feedstocks. Specifically, we convert furfural into furfuryl alcohol using a tandem reaction approach. In this process, hydrogen is generated in situ via aqueous phase reforming (APR) of sacrificial biomass-derived molecule (methanol, formic acid or formaldehyde) and then selectively utilized to hydrogenate furfural into furfuryl alcohol, the desired product. To achieve this, we design and synthesize bifunctional catalysts based on transition metal (Ni, Co, and Cu) aluminate spinels. These catalysts facilitate hydrogen production by cleaving C–O and O–H bonds of the sacrificial molecule. In a tandem reaction, the generated hydrogen is then selectively used to hydrogenate the challenging C=O bond of furfural. Catalyst stability in aqueous-phase reactions is a major challenge due to leaching and particle coarsening, which degrade performance over time. To address this, we apply a porous carbon coating that protects the catalyst and enhances its durability.

CONVERSION OF BIOGAS TO SYNGAS BY COMBINED DRY REFORMING OVER ADVANCED NICKEL CATALYSTS

On the other hand, we are actively involved in the design of an innovative intensified chemical process for the valorisation of raw biogas (mixture of CO_2+CH_4), an increasingly abundant resource from landills and digestion of organic wastes, into high-quality syngas (CO+H_2) by combined dry reforming (with controlled amounts of O_2/H_2O) over advanced nickel catalysts supported on open cell foams operating under industrially relevant conditions. The results obtained will be valuable in advancing the industrial maturity of this catalytic reforming technology, which is hampered by high energy requirements, limited catalyst durability and the need to tune the composition of the product stream to make it efficient for renewable gas-to-liquid processes. Particularly, we are interested in lowering the reaction temperature while operating with high flow rates of CH_4-rich streams (CH_4/CO_2>1) by optimising the design of advanced spinel-derived nickel/cobalt foam catalysts; increasing the resistance to coking and poisoning by present bioimpurities; and adjusting the H_2/CO molar ratio of the product stream. These are all challenging issues that need to be addressed to bridge the gap between laboratory scale and pilot plant prototypes. In sum, our research activities will open the way to significant breakthroughs resulting in a step ahead towards robust, mature intensified technologies that could play vital role in a low-carbon modern society.

Driving CO_2 emissions to zero (and beyond) with capture and conversion to fuels and high-added value chemicals

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KEY WORDS: environmental catalysis, NOx removal, VOC removal, CO_2 capture and utilization, carbon neutrality

CO_2 UTILIZATION IN POWER-TO-GAS PROCESS

The concept power-to-gas or abbreviated as P2G, is based on the process which is able to produce hydrogen from exceeding electric energy, which is directly introduced into the transport and distribution gas network to be used when demand exists or well is utilized for production of SNG, which is also injected into the mentioned network. Wind, solar or any other renewable energy can be used in the P2G process. At TQSA, we are designing dual function materials to achieve in a single process unit the CO_2 capture and conversion for production of methane, methanol, gasoline and kerosene (jet-fuel).

DIRECT CO_2 AIR CAPTURE AND UTILIZATION

The capture of CO_2 from atmosphere together with its conversion into value-added fuels and chemical products is fundamentally essential to achieve the bright and sustainable carbon-neutrality future. In TQSA we are developing mesoporous supports functionalized with polymeric amines, evaluating their thermal stability, and optimizing their CO_2 capture and desorption capabilities as a first step toward producing carbon-neutral synthetic fuels by reacting captured CO_2 with renewable H_2. The potential of polyethylenimine-functionalized mesostructured silica SBA-15 as a CO_2 capture agent is being examined under various conditions. Also, the potential use of this material for CO_2 direct air capture and subsequent methanation with green H_2 has been successfully conducted.

CATALYTIC CO_2 ELECTROREDUCTION

CO_2 electroreduction (CO2RR) over metal-based catalysts is presented as an opportunity to take advantage of CO_2 as a raw material for high value-added products in sectors of industry highly dependent on hydrocarbons at present. Gaseous diffusion electrodes are usually composed of a porous carbon-based support on which the catalyst is deposited by impregnation with an ink containing it. At TQSA, we are synthesizing transition metal based catalysts with high selectivity towards C1+ products and preparing satisfactory inks that optimizes the selectivity of CO2RR towards the products of interest (C1+ reduction products).

CO_2 AS A SUBSTITUTE OF FOSSIL RESOURCES FOR PLASTICS PRODUCTION

CO_2 can replace fossil resources as a source of carbon for the production of plastic polymers, in particular polypropylene carbonates (PPC), polycarbonates and polyurethane. The copolymerization of CO_2 and propylene oxide (PO) is especially relevant, since PPCs thus obtained exhibit excellent biodegradable/biocompatible properties. The catalytic copolymerization of CO_2 and epoxides constitutes a technology that combines numerous economic and environmental advantages. Several catalysts, including Zn-Co double metal cyanide (DMC) and two-dimensional (2D) layered double metal cyanides (Ni-Ni, Co-Ni, Fe-Ni, Mn-Ni) with valuable and advanced structures are developed in TQSA for this technology.

CATALYTIC TECHNOLOGIES FOR PERSISTENT POLLUTANT ABATEMENT FROM INDUSTRIAL EFFLUENTS

Among the variety of pollutants present in industrial effluents, we are interested in removal of methane emissions (power plants and natural gas engines), halogenated volatile organic compounds (HVOC in PVC chemical plants, and textile, electronic and metallurgical industries) and dioxins/furanes with NOx (solid wastes incineration plants). Under this frame, TQSA develops: i) Catalysts for individual pollutant removal, such as chlorinated VOCs, or unburned methane in small engines; ii) Catalysts for simultaneous elimination of dioxins (PCCD)/furanes(F) along with NOx from municipal waste incineration plants.

PIE-UPV/EHU

Plentzia Marine Station

One Health approach in the Plentzia estuary: From a pilot project to a Living Lab

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KEY WORDS: One Health, Estuary of Plentzia, Climate Change; Environmental Contamination; Coastal Pathogens.

Plentzia Bay represents a typical situation in the European North Atlantic with strong seasonal tourism impacts. We aim to understand how climate change and environmental contamination modifies the impact coastal pathogens on human/animal/plant health from a One Health perspective. The novelty lies in basing the framework on an "extended One Health" approach that incorporates holistic concepts of nature of human, animal and ecosystem health. This requires bringing together i) a deep understanding of the physical, chemical and biological processes, ii) the resulting complexities and interrelationships, and iii) the contextual knowledge of local social, economic and political actors.

To develop the environmental survey along the Plentzia estuary, we have carried out monthly sampling for chemical profiling, Vibrio content analysis, total bacterial activity (including WWTP water), fito, zooplankton and pigment content, and metagenomic analysis. In addition, seasonal sampling of oysters and squid provided histopathology and contamination biomarker approach and information on chemical bioaccumulation. To facilitate the integrative analysis of all results, most of the data and metadata are archived in an *ad hoc* designed database.

In addition to the environmental survey, atmospheric and oceanic physical data have been provided to define both a long-term climatology and a high resolution of observations and anomalies of these variables during the aforementioned sampling campaigns. In addition, hourly photographs of the beach and the water layer will allow us to estimate the general use of the beach. Finally, social questionnaires provided information on the knowledge of climate change and the socio-economic situation of the area.

Based on these activities, we see the need to create a space where all potential actors, from academia to lay citizens, can engage in new ways of prioritizing research needs and solutions. In this sense, the Living Lab concept has emerged as an innovative strategy to address this type of complex problems in real-life contexts. This requires the integration of scientific knowledge with the participation of communities and all stakeholders. For the moment, we have incorporated Biobizkaia and the OSI of Urduliz, the city halls of Plentzia and Gorliz, the Water Counsil of Bilbao-Bizkaia, the Public Health Service, and some local NGOs. In the context of One Health, a Living Lab could become an experimental space where solutions to health governance challenges are explored using the practical and collaborative approach of this concept.

ZiForKrim

Zientzia Forenseak eta Kriminalistikoak

ZiForKrim – A Basque Hub for Forensic & Criminalistics Research

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KEY WORDS: Forensic Sciences, Criminalistics, Collaborative Research and knowledge transfer

ZIFORKRIM GELA is a collaborative space, jointly promoted by the ZTF-FCT and Ertzaintza´s Scientific Police Unit (member of the European Forensic Science Network since 2006). The financial support comes from the Basque Government, through the Basque Academy of Police and Emergencies (AVPE).

The objectives of ZiForKrim are: (1) Contribution to the research, transfer and dissemination of knowledge in the field of forensic sciences and criminalistics; (2) Cooperation in the development of Forensic Science and Criminalistics training programmes at all educational levels; (3) Promotion of interdisciplinary and international collaboration. Links have already been established with ENACIF (México), IUICP (Alcalá de Henares) and the Criminalistics Laboratory of the University of Quebec-Tres Ríos. (4) To bring the role of Forensic Science and Criminalistics closer to Basque society.

ACTIVITIES ANUALLY PROMOTED BY ZIFORKRIM

1. One of the main objectives of the creation of ZiForKrim is the realisation of collaborative research projects between researchers from the University of the Basque Country and professionals from the fields of forensic science and criminalistics.

- Student internships are accepted.
- There are currently three **active colabs**: ZFK COLAB lophoscopic crests; ZFK COLAB forensic trichology; ZFK COLAB DNA conservation.

2. **ZiForKrim FORUMS** are expert seminars, scientific conferences and specialisation courses in Forensic Science and Criminalistics.

3. **KRIMINALISTIK SIMULABS**. Oriented towards SDG 16 (Peace, justice and strong institutions), Kriminalistik Simulation Labs is an educational innovation project involving 40 experts from 4 countries (including Mexico, Quebec-Canada, and USA). Based on simulated scenarios, KSL fosters teamwork skills and critical thinking, and provides the opportunity to carry out Final Degree Projects in Criminalistics and Forensic Sciences from the perspective and methodologies of any of the Experimental Sciences.

4. **ZiForKrim IKERTZAILE GAZTEAK.** Awards competition for final undergraduate and master's projects in Criminalistics and Forensic Science.

5. **ZiForKrim IKERTZAILE TOPAKETA**. Annual conference on research activities in Forensic Science and Criminalistics.

Joint Forensic Research: Advancing Justice Through Science (ZiForKrim Colabs)

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KEY WORDS: collaborative research, forensic sciences, criminalistics.

FORENSIC SCIENCES & CRIMINALISTICS AT THE SCIENCE AND TECHNOLOGY FACULTY

The Forensic science brings together many fields of science to dilucidate the dynamics of evenys. Following domains are encompassed: (1) Crimes and illegal activities; (2) Accidents and disasters; (3) Historical events (even from prehistoric times). There are currently 5 active research lines in forensic science and criminalistics at ZiForKrim. Three of them with the Scientific Police Unit of Ertzaintza (ZiForKrim Collabs).

ACTIVE RESEARCH LINES. Student collaborators welcome – internships and final-year projects available

1. **ZIFORKRIM COLAB lophoscopic ridges.** The distinctiveness and permanence of fingerprints render them a highly effective tool in the identification of individuals. However, some latent fingerprints may not provide sufficient information to reach a conclusion (12 minutiae are needed). The objectives of this ZFK COLAB are twofold: 1) to establish the characteristics of 3rd level observable phenomena and 2) to establish the percentages of these phenomena to increase the probability of identification.

2. **ZIFORKRIM COLAB Forensic trichology.** The morphological characteristics of the hair (color and texture, the visual patterns of the medulla and the cuticle, etc.) are informative in forensic caseworks. The aim of this collaboration line is to develop a reference collection of human and animal hairs in order to ultimately help on the identification of hairs found at a crime scene.

3. **ZIFORKRIM COLAB DNA preservation.** This collaborative line explores how fingerprint reagents and surface temperatures affect DNA preservation (blood and epithelial) across various materials.

4. **Strontium and oxygen isotopes to estimate the geographical provenance of unidentified skeletal human remains (**Geology Department**).** Strontium isotopes vary based on geological materials, while oxygen isotopes reflect the isotopic signature of drinking water, which depends on factors like climate, altitude, distance from the sea, rainfall, and temperature. By comparing the isotope ratios in a tooth to those in the burial location: (1) If they match → the person is likely local. (2) If they differ → the person is considered non-local, and comparisons are made with **isotopic variation maps** to narrow down the region of origin.

5. **AI-BIOSURVEILLANCE Collaborative Project. UPV/EHU, Univ. Granada; Ertzaintza Forensic Science Unit and Alcalá University.** AI-Biosurveillance is a research project on the protection of fundamental rights in the face of the emergence of AI systems for biometric recognition of individuals. SSH and STEM experts address in detail the accuracy, robustness, and cybersecurity of biometric recognition systems, with particular attention to the interoperability that the EU has activated with respect to the bases that operate in the fields of law enforcement, justice, and border control.

SGIKER

Advanced research facilities of the UPV/EHU-SGIker

KEY WORDS: Advanced, research, facility

Advanced Research Facilities, SGIker, created by the University of the Basque Country/Euskal Herriko Unibertsitatea (UPV/EHU) were born in 2002 with the vocation to respond and provide support for research, being available to the university itself, other Public Institutions and Business.

SGIker have front-line technical and human resources and aims to offer research support at the highest level, with modern equipment and high technology equipment. This infrastructure allows SGIker to respond to a variety of problems in the field of research and technological development.

SGIker units are present in the three Campus of the UPV/EHU and are distributed in the following scientific areas:

- Materials and Surfaces
- Biotechnology and Biomedicine
- Environment
- Common Services
- Social Sciences
- Technological support

In 2023, SGIker provided 1,673 services to the university community and 1,059 to external companies and organizations, benefiting 147 public and private entities. Additionally, 17 training activities were organized.

That year, SGIker expanded its infrastructure by installing an X-ray Computed Tomography system. In 2024, it secured 4.5 M€ in research infrastructure funding through the 2021-2023 National R&D Plan. This investment will enable the acquisition of six advanced instruments: an ultrashort-pulse laser source, a multi-quadrupole ICP-MS, a computing cluster, an atomic force microscope, an imaging platform, and a mass spectrometer. These new resources will enhance research excellence, foster collaboration, and drive innovation across various scientific and technological fields.

SGIker remains strongly committed to quality, with 16 units certified under ISO 9001 and two laboratories accredited under ISO 17025. Its circular economy strategy has also facilitated the reuse of furniture and equipment.

These achievements have been made possible thanks to the efforts of the SGIker team, other university departments, the Basque Government, and the relevant Spanish Ministry.

ABSTRACTS

Ahozko Komunikazioak

Comunicaciones Orales

Biozientziak

Biociencias

Photosynthesis in Extreme Environments: Research in Antarctica

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KEY WORDS: photosynthetic organisms, Antarctic Base, hidden precipitation, snow algae.

During five weeks as part of the POPEYE team, I had the opportunity to work at the Spanish Antarctic Base on Livingston Island. This is an overview of how various scientific projects take place during the four months the base is operational, during the austral summer. Our project in particular focuses on photosynthetic organisms with high photosynthetic rates living in such extreme environments. Specifically, we focused on studying the effects of "hidden precipitation" and elevated CO2 in the Antarctic tundra and the physiology of snow algae. All this research and scientific progress would not be possible without the dedicated support of the base personnel from the BAE, whose expertise and commitment are essential to the success of these projects.

From mussels to oysters: a necessary transition in biomonitoring sentinel species on the Basque coast

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KEY WORDS: *Magallana gigas*, *Mytilus galloprovincialis*, biomarker, Basque coast, biomonitoring.

In the last decades, the distribution of *Mytilus* spp. in the Atlantic Ocean has considerably changed, and different mortality events have been reported in the area, leading to a decrease in mussel population possibly due to multifactorial reasons (i.e. parasites prevalence, global warming, alien species pressure and anthropogenic impact among others). This raises the need for a change in the employed environmental contamination monitoring sentinel organism in the Basque Coast and oysters (*Magallana gigas*) have been considered a suitable alternative to mussels. Within this context, the aim of the present study is to determine if *Magallana gigas* and *Mytilus galloprovincialis* cell and tissue level responses to general stress are comparable for environmental pollution monitoring programmes, considering biomarkers accepted and established for mussels. In order to achieve this, the approach of the present work is set in four different lines, which include:

1. A preliminary comparison of cell and tissue level biomarkers in mussel and oyster samples gathered in sampling points with different anthropogenic impact in the coast of Biscay.
2. A study in depth of the reproductive cycle of *Magallana gigas* in the Basque Coast to establish a schedule for collecting samples that avoids spawning periods and, thus, a confounding factor that could affect measured biomarkers.
3. A laboratory experiment of exposure to pollutants to mussels and oysters, through which cell and tissue level responses to stress will be assessed and compared in both organisms.
4. An oyster sampling campaign to compare the health status of the organisms in different locations of the Basque Coast with different contamination history.

The work done up to the present has been mainly focused on the biomarker comparison between both species at cell and tissue level. Preliminary results show a worse health status in mussels, including higher levels of digestive epithelium atresia and higher presence and prevalence of parasites, and demonstrate the need to expand the knowledge regarding oyster biology to fully understand and interpret the results obtained in future biomonitoring programmes.

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FOREST ON THE EDGE! Impacts of habitat fragmentation and global change on the vegetation diversity of Basque-Navarran mesic oak and floodplain forests

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KEY WORDS: fragmentation, herb layer, edge effect, forest specialists, microclimate, northern Spain, deciduous forest, southwestern Europe.

Forest fragmentation and global change are widely recognized as one of the main causes of the current biodiversity crisis, often resulting in a loss of forest diversity. There are different mechanisms underlying this biological decline, mostly linked to the edge effect, which involves outcomes such as the alteration of microclimatic conditions, increased external disturbance, or biological invasions. Since a high percentage of the world's forest areas lies near of a forest edge, it is crucial to deepen our understanding of how edge affects forest diversity.

The main objective of this PhD is to study various aspects of plant diversity at different spatial scales in a biogeographical boundary (Eurosiberian to Mediterranean) particularly affected by global change. We will focus on mesic oak forests and riparian ash forests in the Basque-Navarran subcantabrian region, where they form a fragmented forest, with a continuum from ash forests to oak forests, hereinafter referred to as island forests. In this study, we pretend to understand the patterns and processes that structure the nemoral flora of the Basque-Navarran island forests, as well as to evaluate the importance of all plant communities associated with these forests (fringe herbaceous communities, clearings, hedgerows…). Additionally, we aim to establish the scientific basis for efficient management of these endangered habitats, ensuring the maintenance of the ecosystem services they provide, as well as the protection of populations of rare and threatened vascular plant species.

At this moment, we are trying to evaluate how forest type and environmental and human factors (climate, soil, forest fragmentation and other human disturbances) affect patterns of taxonomic, functional, and phylogenetic alpha diversity of generalist and specialist forest species, as well as the spatial dependence of this effect. We are also analyzing the changes in plant alpha and beta diversity along the forest edge-interior gradient and their relationship with microecological changes in temperature, soil and humidity conditions. In addition, we are trying to unravel the relation of the degree of forest fragmentation with the changes in microecological conditions and plant diversity.

During the fieldwork of this research, we sampled eight patches of mesic oak forests and six patches of floodplain forests in the inner valleys of Basque Country and Navarre. In each forest patch, we have set three permanent plots of 200 m^2 (10 m x 20 m). In these plots, we estimated the cover of all vascular plants at 200 m^2 and, additionally, recorded the presence of the species occurring in the herb layer at sizes 0.0001, 0.001, 0.01, 0.1, 1, 10 and 100 m^2. We also measured topographic, soil and structural variables. In summary, we have diversity, topographic, soil and structural data for 42 plots of 200 m^2 (14 forest patches x 3 plots) in the subcantabrian area.

In order to determine the edge effect in the island forests of this region we selected three mesic oak forests and placed six NW-SE transects in each of them. In each transect, we sampled six plots of 10 m^2 (3.16 m x 3.16 m). The distance between quadrats progressively increased towards the interior of the forest (0 m, 1.5 m, 4.5 m, 12.5 m, 36.5 m, and 99.5 m). In each quadrat, we recorded all the vascular plants occurring in the herb layer with their percentage cover value, collected soil samples as well as various environmental variables such as humidity and air temperature by means of dataloggers. Summarizing, we have diversity data for 108 plots of 10 m^2 in three different mesic oak forests (3 forests x 6 transects x 6 plots).

Impact of sewage treatment plant effluents on estuarine sediments: Microbial indicators of the environmental health

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KEY WORDS: microbial ecotoxicology, Basque coast, integrated environmental assessment, environmental health

River estuaries are vital transitional ecosystems that experience significant anthropogenic pressure, leading to the accumulation of pollutants in sediments. While the ecological impacts of treated sewage discharges on river sediments have been previously studied, estuarine ecosystems pose additional challenges due to their dynamic physico-chemical properties. To address properly threats to ecosystem resilience posed by an individual sewage treatment plant (STP) in a contaminated estuarine environment, integrated, multiple-organism-based risk assessment is required.

The study aims to discover and test a reliable set of structural and functional bioindicators for assessing the impact of three STPs with different pollution loads (Bayonne, Bilbao-Galindo, Guriezo), on estuaries from the southeastern Bay of Biscay region. We will verify the effectiveness of the microbial bioindicators and biomarkers in the assessment of estuarine environmental health by comparing toxicity endpoints from established ecotoxicological models (microalgae, rotifer, polychaeta and fish) with the microbial community alterations in space (three different estuaries with gradient sampling) and time (two seasons). To achieve this, we will:

1. perform targeted chemical analysis of the sediment-associated pollutants and characterize sediment physico-chemical properties;
2. evaluate the deterioration degree of STP-impacted ecosystems by integrating ecotoxicological endpoints from multiple organization level of exposed model organisms;
3. characterize the microbial communities inhabiting STP-impacted estuarine sediments using *in-silico* and *in-vitro* methods;
4. validate the microbial bioindicators in microcosm experiments with sediments continuously exposed to a model STP effluent.

The work done up to present has mainly focused on the ecotoxicological profiling of sediments using rotifer *Brachionus calciflorus* and ragworm *Hediste diversicolor* models at multiple levels of biological organization. The results revealed heightened toxicity endpoints at the discharge and downstream sites in both organisms highlighting the impact of sediment-associated contaminants on the health of benthic organisms. Future research will enhance understanding the impact of STP effluents on estuarine sediments and offer a valuable set of easy-to-apply bioassays to characterize bacterial community structural and functional alterations as a proxy for assessing the STP activity impact.

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The effect of *Candida albicans* on the metastatic capacity and the activation of metabolic pathways in melanoma cells

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KEY WORDS: cancer, *Candida albicans*, metastasis.

Candida albicans is an opportunistic pathogenic fungus that is part of the human microbiota, commonly colonizing areas such as the oral cavity, intestinal tract, and skin. Recently, several studies have identified a potential relationship between the presence of this fungus and the development of cancer and metastasis, particularly in the colon and oral cavity. However, its direct impact on tumor cells has been poorly explored, and in the specific case of melanoma, no research has been conducted to date. Therefore, the aim of this study was to investigate the effect of *C. albicans* on melanoma tumor cells both *in vitro* and *in vivo*.

First, the effects of *C. albicans* on the pro-tumoral phenotype of melanoma cells were evaluated through *in vitro* assays, including cell migration, adhesion to endothelial cells, and pro-angiogenic capacity, using melanoma cells exposed to *C. albicans*. In this context, all processes showed a significant increase upon contact with the fungus, suggesting the development of a more aggressive tumor phenotype. Next, *in vivo* assays were conducted using C57BL/6 mice, which were intra-splenically inoculated with melanoma cells previously stimulated with *C. albicans*. After two weeks, the livers extracted from mice inoculated with fungus-stimulated cells exhibited an increased metastatic area. Finally, to understand the molecular responses triggered in melanoma cells, RNA-seq gene expression analysis was performed on melanoma cells exposed to *C. albicans*, revealing the overexpression of genes linked to inflammatory signalling pathways and metabolic reprogramming.

In conclusion, *C. albicans* promotes phenotypic changes in melanoma tumor cells, leading to increased pro-tumoral and metastatic capacity.

Fate and effects of microplastics, nanoplastics and additives from the degradation of fishing nets in the Bay of Biscay

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KEY WORDS: Fishing gear; Micro and nanoplastics; Additives; Artificial degradation; Leachate ecotoxicity.

Fishing activities account for 17% of human consumption of animal proteins. On the other hand, this sector, upon which approximately 550 million individuals globally rely for their livelihoods, could also play a significant role in marine pollution due to the use of plastic fishing gear (FG). Scientific studies on how plastic FG contributes to global pollution of microplastics (MPs), nanoplastics (NPs) and additives and their toxicological effects are scarce. In this context, we selected6 oil-based FNs (one made of polysteel and 5 of polyamide (PA)) and 2 partially biobased/biodegradable FNs (made of polybutylene succinate-polybutyrate adipate terephthalate (PBS-PBAT)) used in the Southeastern Bay of Biscay to investigate their degradation and toxicityon different aquatic species. We also quantified the operated and lost FG in the studied area. The degradation of FNs was analyzed through artificial aging in order to quantify the production of MPs, NPs, and associated chemicals. Then, the effects of leachates containing these degradation products were studied through acute, subacute and subchronic toxicity assays on bacteria *Aliivibrio fischeri*, microalgae *Tisochrysis lutea*, copepods *Acartia tonsa* and fish *Oryzias latipes*.

Using published models and sociological data, we estimated that the fishing fleet of the Southeastern Bay of Biscay operated 211 tons of FG in 2023 and lost 6 tons of them. In the same period, we estimated through field sampling and statistical analysis that 3 tons of abandoned, lost, or otherwise discarded FG (ALDFG) were washed up on the beaches of the area. We found no correlation between the number of FG beached seasonally and the surface and length of FG operated seasonally. However, we found a significant and negative correlation between the quantity of ALDFG beached seasonally and the surface area and length of FG lost in the Southeastern Bay of Biscay.

The artificial aging of FNs revealed FN-dependent production of MPs, NPs, organic compounds and heavy metals. Production of these degradation products increased with aging time, although not linearly. Three aged oil-based FNs produced a significant amount of MPs ranging from $3.4x10^5$ MP/g of FN to $1.0x10^7$ MP/g of FN. NPs were produced from the FNs, although we did not quantify them. Significant amounts of four heavy metals (Cu, Fe, Pb, Zn) were quantified in the leachates. In addition, we identified 27 organic compounds (additives, non-intentionally added substances or degradation by-products) and quantified 8 of them.

Each of the 4 species exposed to FN leachates experienced varying degrees of effects. The bioluminescence inhibition of *A. fischeri* was significantly impacted by most FNs, but more especially by the PBS-PBAT ones. Concerning *T. lutea*, the density of microalgae cells was not significantly affected after 72 h of exposure, but an aged PA FN caused a significant growth delay after 24 h. Most tested FNs significantly disrupted the behavior of Japanese Medaka larvae, usually behavior alteration increasing with FN aging. The survival of adult copepods was decreased by one aged PA FN and by one new and aged PBS-PBAT FN. Looking at the survival of juvenile copepods; most of the FNs caused a significant decrease, with the lowest EC_{50} estimated for a new PA (1.32±1.14 g/L) and a new PBS-PBAT FN (1.55±0.82 g/L). Subchronic exposure of copepods did not show effects on survival, but significant effects on cumulated egg production, daily egg production and hatching success were recorded. Globally, these results highlighted that FNs contribute to MPs, NPs and chemical pollution of the oceans. However, their hazard is dependent on their composition and aging. Biobased/biodegradable FNs could offer a solution to better manage end-of-life FG and to reduce ghost fishing when lost, but their current polymeric and chemical composition needs to be improved to reduce their toxicity.

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Relevance of E2F factors in the interface between cell cycle and centrosome cycle

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KEYWORDS: E2F factors, cell cycle, centrosome cycle, TEDC2

The centrosome is the main site for microtubule nucleation and organization in animal cells. This non-membranous organelle consists of two orthogonal centrioles, joined by a linker, and surrounded by a protein matrix called pericentriolar material (PCM). Just like DNA is replicated when a cell is going to go through cell division, the centrosome also needs to duplicate. This duplication process, named centrosome cycle, has to occur in parallel to the cell cycle. During S phase, a procentriole in generated in each centriole's wall, which will get elongated throughout S and G2 phases. Once duplicated, parental centrioles disjoin from one another in late G2 and, upon mitotic entry, each centrosome localizes to one cell pole to generate the mitotic spindle and achieve chromosome segregation.

Research from many groups has demonstrated that proper regulation of the centrosome cycle is essential for cellular homeostasis, and that aberrant centrosomes may contribute to the development of malignant phenotypes. A key regulatory point occurs at the G1/S transition, where the transcriptional program regulated by E2F transcription factors plays a central role. While this transcription factor family is well-known for regulating the expression of genes involved in DNA replication, growing evidence suggests that they also regulate organelle biogenesis, including centrosome duplication. Indeed, several genes involved in centriole duplication have been identified as E2F targets, although this list remains incomplete.

In this work, we have identified an additional centrosome-related gene, TEDC2, as a novel target of E2F factors, regulated at the transcriptional level through E2F binding motifs found in its promoter. The protein encoded by this gene has recently been reported to play a role in centriolar architecture and stability, as part of a tetrameric complex with TEDC1 and δ- and ε-tubulins. However, its precise biological role remained largely unexplored. Using a combination of biochemical approaches and high-resolution microscopy, we demonstrate that TEDC2 localizes specifically to the PCM at the proximal region of both mother and daughter centrioles, and plays a critical role in centriole duplication. Together, these findings provide new insights into the interplay between the centrosome and cell cycles and, at the same time, enhance our understanding of the centriole duplication pathway

Transcriptomics in pediatric hematologic cancers: biomarker discovery for prognostic prediction at diagnosis

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KEY WORDS: Pediatric cancer, Acute lymphoblastic leukemia, prognostic biomarker, long non-coding RNA.

Acute Lymphoblastic Leukemia (ALL) is the most common pediatric malignancy, accounting for 25% of all childhood cancers, and is a leading cause of death in children. It is a highly heterogeneous hematological malignancy, arising from transformed B-cell (B-ALL, ≈ 85%) or T-cell (T-ALL, ≈ 15%) precursors. Over the past decades, survival rates for both subtypes have significantly improved, with event-free survival (EFS) and overall survival (OS) exceeding 85% in contemporary clinical trials. However, the prognosis for relapsed patients remains poor, with survival rates below 25% in relapsed T-ALL cases. Therefore, accurate identification of high-risk patients at diagnosis is crucial, highlighting the urgent need for novel biomarkers and predictive tools to improve risk stratification.

In this context, our aim was to identify new prognostic biomarkers in pediatric ALL through a total RNA sequencing (RNA-seq) approach, a methodology that allows the detailed exploration of the transcriptomic landscape, including a wide range of long non-coding RNAs (lncRNAs), novel candidates with great potential.

For B-ALL cases, two pediatric cohorts were analyzed: 50 Spanish patients from three different hospitals (seven relapses), and 72 Canadian patients (12 relapses). RNA-seq was performed on the NovaSeq 6000 platform, and reads were aligned to the hg38 reference using STAR. All protein coding and non-coding genes included in lncRNAKB annotation (enriched in lncRNAs) were quantified, which were used to develop a gene expression-based 5-year EFS prediction model (surviBALL); selecting the most informative variables with univariate Cox proportional hazards analyses and an ALASSO regression. For T-ALL cases, RNA-seq was conducted on nine patient samples diagnosed in Cruces University Hospital (three relapses). Additional post-alignment analyses included, among others, variant calling and annotation performed with VarScan and Annovar, respectively. Candidate biomarkers identified through downstream analyses were assessed for prognostic potential using Kaplan-Meier (KM) survival curves and Cox proportional hazards models. Additionally, publicly available cohorts were used to validate our results: TARGET (B-ALL, n = 177) and Kids First + TARGET (T-ALL, n = 1335).

The filtering of candidate biomarkers for the B-ALL EFS prediction model resulted in five lncRNAs, with which surviBALL was developed. Patient stratification into three risk groups revealed significantly poorer EFS in high-risk patients across both cohorts and the TARGET validation cohort (*P* < .001).

In T-ALL cases, *USP7* emerged as a frequently mutated gene, with three out of nine patients harboring at least one alteration—two of whom experienced an event. Due to the small sample size, analysis of Kids First and TARGET cohorts revealed 70 single nucleotide variants (SNVs) in 49 patients (3.67%), with a higher event frequency in *USP7*-mutated patients, nearing statistical significance in children under 15 years at diagnosis in KM analysis (*P* = .081). When analyzed together with other relevant variables in multivariate Cox proportional hazards analysis, *USP7* SNVs, Central Nervous System status 3 and positive minimal residual disease were identified as independently significant poor prognosis markers, which combined, could identify a very high-risk group of T-ALL patients.

These findings highlight the power of RNA-seq in discovering novel biomarkers. surviBALL could enhance current risk stratification by identifying high-risk B-ALL patients at diagnosis, potentially guiding treatment decisions. Additionally, *USP7* mutations may represent a key novel prognostic marker in pediatric T-ALL. Together, these results support the integration of RNA-seq into clinical practice to improve personalized therapy in pediatric ALL.

Use of reconstituted HDL for the theragnostic of cardiovascular disease

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KEY WORDS: Cardiovascular disease, reconstituted HDL, Reverse cholesterol efflux.

Cardiovascular diseases (CVD) are the leading cause of mortality in industrialized countries, representing a major public health challenge. These diseases are closely linked to cholesterol accumulation and inflammation in the arteries, which together drive the formation of atheroma plaques. These plaques progressively narrow the vascular lumen, restricting blood flow and increasing the risk of severe cardiovascular events such as heart attacks, strokes, or pulmonary embolisms.

One key mechanism that protects against the progression of atherosclerosis is reverse cholesterol transport (RCT), a natural process that mobilizes excess cholesterol from peripheral tissues back to the liver for elimination. High-density lipoproteins (HDL) play a central role in this protective mechanism by facilitating cholesterol efflux from foam cells, which are lipid-laden macrophages found in atherosclerotic plaques. Improving cholesterol efflux capacity is considered a promising strategy to reduce the risk of cardiovascular events.

Our project explores an innovative therapeutic strategy based on the sequential administration of recombinant high-density lipoprotein nanoparticles (rHDL) loaded with antagomir-33a, a specific inhibitor of miRNA-33a. This two-step strategy first delivers antagomir-33a to silence miRNA-33a expression, thereby boosting ABCA1 and ABCG1 transporter activity in macrophages. This step primes foam cells for efficient cholesterol efflux. The second phase involves administering rHDL particles enriched with DPPC, which effectively mobilizes the accumulated cholesterol, facilitating its transport to the liver for clearance.

This innovative approach offers a promising new avenue for the treatment and prevention of atherosclerosis by combining miRNA modulation with enhanced cholesterol clearance. By improving HDL functionality and promoting cholesterol crystal removal, this strategy holds potential to reduce plaque burden, stabilize vulnerable lesions, and lower the risk of cardiovascular events in affected individuals.

The principle of detecting an undectable organism

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KEY WORDS: Biological monitoring, Detectability, Elusive and rare species, Reliability, Frailty models

The world is facing serious environmental challenges, such as climate change, biodiversity loss and pollution. This means it is very important to manage the environment effectively. One strategy that is used a lot is biological monitoring. This uses indicator species to check the health of an ecosystem. These species can seem like a random choice, but they give us reliable information if they are chosen and used in the right way.

Recent studies highlight the importance of indicator species in assessing the impacts of climate change, focusing on semi-aquatic mammals. These animals eat other animals or insects, and they have specific adaptations that make them highly sensitive to environmental changes. If these animals are declining, it can be a sign of bigger problems in the ecosystem. And, because they live in water and on land, they are more likely to be at risk of extinction than animals that only live in water or on land.

Our research team is also studying how species move and change in numbers within networks like rivers or cave systems. These networks create unique patterns that are important for understanding how ecosystems work in these habitats. We are developing a new approach that uses reliability analysis techniques from industry to improve monitoring. This method uses frailty models that take into account the spatial dependencies and specificities of each monitoring site. The aim is to improve the cost-effectiveness and accuracy of monitoring semi-aquatic mammals. This will support better ecosystem management.

Epitranscriptomics in Autoimmune Diseases: Unraveling RNA Modifications in Immune Dysregulation

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KEY WORDS: epitranscriptomics, autoimmunity, type 1 diabetes, celiac disease.

Epitranscriptomics, the study of chemical modifications in RNA molecules, has emerged as a crucial layer of gene regulation with significant implications for immune function, inflammatory processes, and disease development. Among these modifications, N6-methyladenosine (m6A) is the most extensively studied; however, other less abundant modifications have been identified and investigated in recent decades. These include pseudouridylation (Ψ or Y) and N7-methylguanosine (m7G), among others. Such modifications play essential roles in RNA stability, splicing, translation, and degradation. Consequently, the dysregulation of these finely tuned processes has been implicated in the pathogenesis of autoimmune diseases.

Notable examples of autoimmune diseases include type 1 diabetes (T1D) and celiac disease (CD), both of which arise from a complex interplay of genetic and environmental factors. In T1D, the immune system targets and destroys pancreatic beta cells, leading to impaired insulin production, hyperglycemia, and associated metabolic complications. Meanwhile, CD is a chronic, immune-mediated inflammatory disorder triggered by gluten ingestion in genetically predisposed individuals. The resulting proinflammatory response primarily affects the small intestine, leading to villous atrophy and crypt hyperplasia. The absence of curative treatments highlights the urgent need for further research into the molecular mechanisms underlying these diseases.

Epitranscriptomic modifications are increasingly recognized as key players in autoimmune disease pathogenesis, as aberrant RNA modification patterns can influence cytokine production, immune cell function, and chronic inflammation. Understanding the regulatory mechanisms governing RNA modifications in immune cells and target tissues may facilitate the identification of novel biomarkers and therapeutic targets for autoimmune disorders. Advancements in high-throughput techniques have enabled the characterization of RNA modifications and their functional consequences. Notable methodologies used in our research group include:

1. **Modified RNA Immunoprecipitation:** This technique utilizes antibodies specific to RNA modifications to selectively enrich modified RNA species from total RNA extracts, which are subsequently analyzed via qPCR or RNA sequencing. Using this approach, we have identified *PSME2* and *IFNAR1* as transcripts harboring internal m7G methylation in intestinal and beta cells, respectively.

2. **Dot Blot Analysis:** By employing antibodies specific to m6A, m7G, or Ψ, this technique quantifies the bulk levels of RNA modifications. Here, RNA is crosslinked to a positively charged nylon membrane, followed by detection using a primary anti-modification antibody and a secondary reporter antibody. Our findings indicate a reduction in internal m7G modifications in beta cells following an 8-hour incubation with proinflammatory cytokines or viral infection mimics.

3. **BID-seq:** Some RNA modifications, such as Ψ, can undergo chemical conversion for detection. Specifically, Ψ can be transformed into a bisulfite (BS)-induced adduct, which generates deletions upon sequencing. This technique allows for the systematic identification of Ψ-modified sites, facilitating the development of a comprehensive database for further study.

Collectively, these advances in epitranscriptomic research offer novel insights into the molecular basis of autoimmune diseases and present promising avenues for therapeutic intervention. Further studies are warranted to elucidate the precise mechanisms through which RNA modifications influence immune and inflammatory response dysregulation and disease progression.

Functional and structural biophysical characterization of a CdiA-CT effector

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KEY WORDS: CDI, TPSS, bacterial toxin.

Contact dependent growth inhibition (CDI) is a bacterial mechanism that uses a TPSS-like secretion system. This system functions similarly to a molecular syringe by directly injecting toxins into neighbouring cells, inhibiting their growth. CDI has been found in several gram-negative bacteria, including important human pathogens such as *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Neisseria meningitidis*. In the face of the growing problem of resistance to antibiotics, toxins and mechanisms that can be important pathogen virulence factors have become of great interest.

The CDI+ phenotype is mediated by the cdiBAI gene cluster. It consists of two proteins, CdiA and CdiB. CdiB is involved in the secretion of CdiA by translocation. It is believed that CdiA can diffuse about 30 nm from the surface of a CDI+ cell to bind to a specific receptor on the target cell. CdiA self-cleaves to release its effector fragment (CdiA-CT). Although most of the CdiA and CdiB domains have been conserved during evolution, we can find immense diversity among Cdia-CT effectors. This project is focused on the functional and structural characterization of a CdiaA-CT effector.

CdiA-CT toxin

Our object of study is a CdiA-CT effector. Studies to date have shown that it can form pores in the inner membrane of gram-negative cells, for which it needs AcrB together with the pump.

Despite its hydrophobic nature, in our laboratory we have managed to express and purify this toxin by a personalized method, expressing it inside a barrel of rhs. For this purpose we have designed plasmids pET29a(+) containing the rhs barrel, replacing the original C-terminal with the corresponding CdiA-CT toxin. The Rhs barrel has a histidine tail at the N-terminus, so using high concentrations of urea, we separate the barrel from the toxin by affinity chromatography.

Once the toxin has been purified, the ability of the toxin to penetrate biological membranes is measured, first by Langmuir balance and then by electrophysiology. Their dependence on AcrB is also intended to be studied in these experiments. The final objective is to solve the atomic structure of the pore produced by the toxin by means of cryo-electron microscopy.

Fisika eta Ingeniaritza Elektronikoa

Física e Ingeniería Electrónica

Exploring the fate of the universe through dark energy with transient dynamics

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KEY WORDS: dark energy

Over the course of the last century, cosmological data has unveiled that we live in a Universe composed mainly of cold dark matter and an enigmatic dark energy (DE) content, responsible for late-time accelerated expansion. The dominant interpretation of a non-evolving DE, modelled by the so-called cosmological constant, has been challenged by recent surveys pointing towards DE being a dynamic entity. My research activity mainly focuses on developing new mechanisms to mimic evolving DE, which could determine the fate of the universe, while also exploring novel tests to distinctly unravel its signatures. Theoretical models are meticulously evaluated against the most up-to-date data sets, in our pursuit of clues pointing to new and exciting physics.

Particle physics at UPV/EHU: exploring the fundamental structure of matter

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KEY WORDS: Particle Physics, QCD, Neutrinos.

What is the fundamental structure of matter? How do elementary particles interact? How does this shape the evolution of the Universe? Many questions in fundamental physics remain unanswered. In our group, we combine theoretical calculations with experimental data to improve our understanding of the **strong interaction** and the **properties of neutrinos and dark matter**.

QCD: HADRON STRUCTURE AND FORMATION

Quarks and gluons (partons) are confined inside hadrons (protons, neutrons, etc.), therefore they are not directly observable. How do hadrons form and how quarks and gluons are arranged to contribute to the nucleon spin are some of the most fundamental questions in physics. Our group aims at answering these and other fundamental questions, in our quest for understanding the internal structure of nucleons, which, together with electrons, are the most important building blocks of ordinary matter.

The internal structure of hadrons is parameterized in terms of several multi-dimensional parton distributions. All of those encode different aspects of hadrons, correlations between the momenta and spins of the considered quark or gluon and its parent hadron. However, for now, we only have a fairly good picture in one dimension, since the multi-scale processes needed to access these multi-dimensional functions are very challenging from both the theoretical and phenomenological point of view, as well as from the experimental side.
Our group develops new tools to extract information from experiments at e.g. CERN, JLab, BNL or KEK, and future planned ones like the fixed-target experiments at CERN or the future Electron-Ion Collider in the United States.

COMPLEMENTARY FRONTIERS IN NEUTRINO AND DARK MATTER PHYSICS

Neutrinos have weak interactions and, in the Standard Model of particle physics, zero mass. This makes them a clean probe of novel physics — them having a mass is the only uncontested laboratory evidence for the existence of new interactions. It also means they have a huge penetrating power and a very long lifetime, making them a clean probe of astrophysical and cosmological environments, where they are abundantly produced.
Despite the ubiquity of neutrinos, we are just beginning to fully understand their properties. In our group, we study laboratory data, together with astrophysical and cosmological observations, to pin down neutrino properties. The rapidly improving precision of astrophysics, cosmology, and laboratory experiments is thus an opportunity.

Similarly, the nature of dark matter is among the most pressing questions in fundamental physics. Its existence has been confirmed by several independent observations, yet we do not know its fundamental nature nor how it was produced after the Big Bang. In our group, we study how the properties of small-scale astrophysical structures (as small as 50 light-years) inform us on the properties of dark matter. Our research links to current and future experiments such as Super-Kamiokande, JUNO, DUNE, IceCube, Plank, DES, DESI, or the Rubin Observatory. We extract new information from existing data, and we study the reach of future experiments.

Exploring Ferroelectric Liquid Crystals

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KEY WORDS: Ferroelectric Liquid Crystals, Dielectric Spectroscopy, X-ray Diffraction, Nonlinear Optics

Liquid crystals are materials that combine properties of both liquids and solids, exhibiting molecular order in certain directions (anisotropy) while maintaining fluidity in others. Many phases of liquid crystals exist, such as the nematic and smectic phases, which have enabled the development of numerous applications, including displays and optical devices. Within this family, ferroelectric liquid crystals (FLCs) stand out due to their spontaneous polarization, allowing them to respond rapidly to electric fields and opening possibilities for faster and more efficient optical devices.

At the Liquid Crystals Group, we study FLCs using various characterization techniques that provide complementary information to accurately determine their structure and properties such as polarized light microscopy, dielectric spectroscopy, X-ray diffraction, and nonlinear optical processes. This combination of techniques allows us to unravel the complex relationship between structure, dynamics, and ferroelectric properties in FLCs, highlighting the importance of a comprehensive experimental approach in the study of advanced materials.

Numerical cosmology: simulations of the early Universe

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KEY WORDS: Cosmology, Simulations, Numerical, Axions, Inflation Black Holes, Gravitational Waves, Domain Walls, Topological Deffects.

The development of modern physics, such as General Relativity or Quantum Field Theory has profoundly transformed our understanding of the Universe. Applying this knowledge to the earliest stages of cosmic evolution has provided answers to age-old questions, such as the origin of the cosmic microwave background (CMB), the distribution of elements, and the formation of the Universe's large-scale structure. At the same time, it has brought new fundamental questions to the forefront, including the nature of dark matter, the existence of gravitational waves, and the ultimate fate of the cosmos. Moreover, the early Universe serves as a natural laboratory for exploring physics at energy scales far beyond the reach of terrestrial experiments. While particle colliders probe high-energy interactions up to the TeV scale, the extreme conditions of the early cosmos open a unique window into physics at much higher energies, where phase transitions, symmetry breaking and the formation of topological defects take place. To investigate these processes, numerical simulations have become an indispensable tool, enabling us to model the non-linear dynamics of fields and particles in regimes where analytical approaches fall short. In our group, we integrate theoretical models with computational techniques to simulate early Universe scenarios, with a particular focus on topological defects and axion inflation models.

Computational methods in condensed matter systems: relativistic effects due to periodically driven perturbations

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KEY WORDS: condensed matter physics, computational methods, Density Functional Theory, electron-phonon interaction, spin-orbit coupling, relativistic effects, Rashba model, periodically driven perturbations

The computational condensed matter physics group [1] focuses on the physical properties arising from many-body interactions. In particular, we work on problems where electrons, vibrations (phonons) and magnetism (spins) are coupled. Computational methods permit us to simulate condensed matter systems and to understand the properties that arise from many-body interactions. As a starting point, we generally use Density Functional Theory (DFT) [2] to compute the electronic structure of solids; this provides an accurate description of many of their properties. On top of DFT, we also introduce new methodological developments to tackle different scenarios of many-body interactions, such as strongly correlated systems and relativistic effects.

As an example of our work we present here the problem of the interplay between a non-magnetic surface with sizeable spin-orbit coupling (SOC) and a local, non-magnetic and periodically driven perturbation. Many interesting effects can arise from the interaction of surfaces with strong SOC and external perturbations: on the one hand, magnetic impurities can induce Friedel oscillations in the magnetization density of a Rashba electron gas [3, 4]; on the other hand, and more unexpectedly, phonons can induce an oscillating magnetization density in surfaces with strong SOC, even if the corresponding material is non-magnetic [5]. Both phonons and our impurity model share their time-periodic nature, even though the latter is now a localized perturbation. In this manner, we aim to understand and determine whether a local, non-magnetic and time-dependent perturbation can induce a magnetic response in a non-magnetic surface with SOC.

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Quantum Sensors for Nuclear Magnetic Resonance

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KEYWORDS: magnetic resonance, nitrogen vacancy, quantum technology.

Nuclear Magnetic Resonance (NMR) consists of a bunch of techniques widely used in physics, chemistry, and biomedical sciences for probing molecular structures and dynamics. The foundation of these is the precession of spins in a magnetic field, emitting a signal with amplitude proportional to the initial polarization of the sample, and a frequency decomposition dependent on the probed species. Conventional NMR suffers from low sensitivity, as nuclear spin polarization is inherently weak under standard thermal conditions. This limitation has driven the exploration of alternative methods to enhance signal detection, including the use of quantum defects, such as the nitrogen vacancy center. These offer unprecedented magnetic field sensitivity, even at the nanoscale regime, where the probed volumes are on the order of nm^3. This talk will cover a brief introduction to the topic and the motivation for the group's research line.

Quantum world: From textbook to tech

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KEY WORDS: quantum physics, quantum communication, quantum machine learning

Quantum physics seems to be full of mysteries and paradoxes, being perhaps the least intuitive branch of science. Nevertheless, for over a century, advances in this field have brought us a better understanding of the Universe and the structure of matter around us. Moreover, in the last decades, advances in quantum science have made new technological applications possible, in areas such as quantum communications and quantum computing. We are living in a fascinating time right now, in which we are able to bring ideas that we used to only know through textbooks into practical and tangible applications.

Quantum Many-Body Hamiltonians embedding in the MPO formalism

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KEY WORDS: Quantum Many-Body Physics, Tensor Networks, Matrix Product Operators.

Quantum Hamiltonians are paradigmatic objects for the study of complex models ranging from condensed matter to particle physics.

Tensor Networks, even if they are classical in the computational sense, constitute a natural framework for the study of these models.

In this short talk, we show the Matrix Product Operator (MPO) tool and a procedure (called finite state automata) to build it smoothly.

Development of deuterium-deuterium compact neutron source

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KEY WORDS: neutrons, ECR plasma, deuterons.

In the present work, we will present the status of the deuterium-deuterium (D-D) neutron source that is being developed in collaboration between the University of Granada and the University of the Basque Country (Spain).

Our neutron source consists of an ECR ion source which accelerates a deuteron beam towards a deuterated target. The ionization to achieve the deuterium plasma is achieved by radiating the cylindrical ERC plasma chamber with a magnetron 2.45 GHz signal and an 875 G magnetic field generated by 6 NdFeB magnets located around the plasma chamber. Moreover, a cylindrical alumina RF window is used to keep the vacuum status from the ambient pressure condition inside the WR340 and help the plasma to ignite.

Once the plasma is generated, the deuterons are extracted from the plasma chamber using a Pierce electrode geometry and three other electrostatic lenses, fixed to different negative potentials. The beam is accelerated towards copper target disk with a deuterated titanium mesh fixed to -100 kV which generates the desired neutron radiation.

There are several applications of D-D neutron sources across scientific and industrial domains. In case of the University of Granada and its deep relation with IFMIF-DONES neutron source, it is worthy to mention that we plan to carry out experiments for determining the cross-sections of relevant isotopes in the studies of IFMIF-DONES to a better simulation of the behaviour of such material under high neutron flux irradiation.

Magnetrons: from Popcorn to Protons

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KEY WORDS: Particle accelerators, Magnetrons, Phase-locking, RF control

Linear accelerators (LINACs) play a fundamental role in particle acceleration for a wide range of scientific and technological applications. Within these systems, precise control of Radio Frequency (RF) signals is essential for the correct operation of resonant cavities, such as RFQs and DTLs. These cavities require high-power RF signals with high accuracy in amplitude, frequency, and phase to ensure efficient particle acceleration and manipulation.

Magnetrons, on the other hand, are autonomous devices capable of high-power outputs. These devices offer significant advantages, including their ability to generate high power levels, their efficiency, and their relative cost-effectiveness compared to other RF power sources. Their application extends to various fields where a robust and efficient power source is required. However, the use of magnetrons without phase control techniques, commonly known as phase-locking, presents critical limitations. The inherent instability in the frequency and phase of uncontrolled magnetrons, along with the associated noise, can severely compromise the performance and precision of the control of resonant cavities. These instabilities can negatively affect the quality of the particle beam generated by the LINAC.

Phase-locking emerges as an effective solution to mitigate these limitations. This technique consists of injecting a low-power signal into the magnetron, which causes its output to become much more stable and controllable in frequency and phase. This improvement in control, achieved by phase-locking, allows the use of magnetrons as cost-effective and highly efficient sources of the needed RF power for resonant cavities and, consequently, an effective control of the particle beam.

The implementation of these phase-locking techniques requires the use of control loops and LLRF (Low Level Radio Frequency) systems to ensure that deviations generated by external phenomena, such as microphonics or thermal drifts, are effectively corrected. These systems are essential to maintain the stability and precision of the acceleration system.

In summary, this talk highlights the potential of magnetrons as RF power sources specifically in particle accelerators, while emphasizing the critical need to implement phase-locking techniques and LLRF control systems to optimize their performance. The application of these strategies allows maximizing the potential of magnetrons, driving significant advances in accelerator physics and its various applications.

Matematika

Matemáticas

Efficiency of Symmetric Nash Equilibria and of Reinforcement Learning-based Algorithms for Epidemic Models

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KEY WORDS: SIR model, Symmetric Nash equilibrium, Machine Learning.

The SIR model is one of the simplest and most studied stochastic models. It allows to represent the dynamics of a virus spread in complex networks. The recent COVID-19 pandemic has put in evidence the big importance of carrying our research in this topic. In this work, we consider that an extension of the SIR model where, in a population of size N, susceptible elements can be vaccinated and a recovered element is again susceptible after a random time. We consider that susceptible elements can avoid getting the infection with some probabilty. We assume that each infected element incurs a cost per unit of time and the susceptible population incurs a cost which is decreasing and linear on the lockdown probability.

We first formulate a non-cooperative game where each player is an element of the population that can select its lockdown probability and aims to minimize its expected cost. We formulate the best response lockdown strategy of one player to the strategy of the rest of the players as a Markov Decision Process, which combined with a simple fixed point algorithm, allows us to compute a symmetric Nash equilibrium. Our results show that symmetric Nash equilibria and the global optimum strategy (i.e., the lockdown strategy that minimizes the cost of the whole population) are very similar; as a result, we have symmetric Nash equilibria that are almost-efficient.

We then investigate the problem of finding the optimal lockdown strategy of this model from a reinforcement learning perspective, i.e., without assuming that the costs and the transition rates of the model are known. We first prove that a Q-learning algorithm with a single episode does not converge to the optimal strategy. Then, leveraging the structure of the underlying model, we present an algorithm that outperforms the Q-learnign algorithm with multiple episodes, specially when the size of the episodes is very large. We provide numerical experiments that confirm our theoretical findings.

Weighted Poincaré-Sobolev inequalities via fractional integration

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KEY WORDS: Riesz potential, weighted inequalities, weighted Poincaré-Sobolev inequalities.

In this talk, we will discuss weighted Poincaré-Sobolev type inequalities with an explicit analysis on the dependence on the A_p constants of the weight. We obtain inequalities of the form

$$\left(\frac{1}{w(B)}\int_B |f(x)-f_B|^q w(x)dx\right)^{\frac{1}{q}} \leq C_w r(B)\left(\frac{1}{w(B)}\int_B |\nabla f(x)|^p w(x)dx\right)^{\frac{1}{p}},$$

with quantitative estimates for the exponent q and the constant C_w where $f_B = \frac{1}{|B|}\int_B f$ is the average of f over a ball B, $r(B)$ is the radius of B and $1 \leq p \leq q < \infty$. We prove this estimates as a consequence of the study of weighted local bounds for the fractional integral operator I_α and the classical subrepresentation formula

$$|f(x)-f_B| \leq c_n I_1(|\nabla f|\chi_B)(x).$$

We show that the obtained dependence of C_w on the A_p constant is sharp. We answer positively to a conjecture proposed by Pérez and Rela [Trans. Amer. Math. Soc. 372 (2019)] related to the sharp exponent in the A_1 constant in the (p^*, p) Poincaré-Sobolev inequality with A_1 weight. Our method allows us to prove Poincaré-Sobolev inequalities for high-order derivatives and fractional Poincaré-Sobolev inequalities with the BBM extra gain factor $(1-\delta)^{\frac{1}{p}}$.

Self-improving properties of generalized Poincaré inequalities

Iker Gardeazabal Gutiérrez

In this talk we will discuss a method to obtain extensions of the classical Poincaré-Sobolev inequalities. These results are obtained as applications of the self-improving property of generalized Poincaré inequalities, which will be the content of the first part of the talk. In the second part we will see how to use these results to obtain higher order derivative and fractional Poincaré-Sobolev type inequalities, including cases with more general measures as for example non-doubling weights.

Global AUC(t) estimation proposal for multistate models

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KEY WORDS: Multistate models, discriminative ability, time-dependent AUC.

The motivation for my PhD arises from clinical data from the DIVINE project, where patients hospitalized due to COVID-19 are followed through several states. One of the aims of this project was to analyze the evolution of those patients, and for that, a complex multistate model (MSM) was designed. This MSM allows us to analyze the risk factors for the different events of interest (e.g. non-invasive mechanical ventilation (*NIMV*), invasive mechanical ventilation (*IMV*), or death) as well as to predict the course of the disease for new patients, but we realized that we didn't know how to analyze its discriminative abiltity. Therefore, the main objective of my PhD is to evaluate the discriminative ability for MSM, and for that, the area under the time-dependent ROC curve ($AUC(t)$) can be used.

In this work we focus initially in those patients with severe pneumonia who can transition to two competing events: the need for *NIMV* or *IMV*; and we propose an estimator for the global $AUC(t)$ for a competing risk model. Under competing risk models, different estimators can be used to estimate the (partial) $AUC(t)$ of each transition $AUC_k(t), k = 1, 2$. In this work, we propose an estimator $\widehat{AUC}_{CR}(t)$ for the global $AUC(t)$ ($AUC_{CR}(t)$) for a competing risk model as a weighted sum of $\widehat{AUC}_k(t), k = 1, 2$ with each $AUC_k(t)$ being weighted by the probability of experiencing that event k before time t. We have proved that $\widehat{AUC}_{CR}(t)$ is consistent and asymptotically normal.

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Study on estimating the Remaining Useful Life (RUL) of batteries

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KEY WORDS: degradation, Physics-informed, neural networks.

The rapid advancement of technology is driving the shift towards renewable energy, particularly lithium-ion batteries, due to the shortage of fossil fuels. While these batteries offer high energy density and long lifespans, their performance degrades over time, making battery health management a key concern. Various data-driven methods have been developed to predict battery behavior without requiring domain knowledge, but their effectiveness depends on extracted features. Meanwhile, physics-based models are accurate but computationally expensive due to battery diversity. To balance accuracy and efficiency, Physics-Informed Neural Networks (PINNs) integrate physical laws and empirical data to enhance battery performance predictions. These hybrid technologies have demonstrated their capabilities as state estimators, incorporating physics knowledge with minimal or even no real data—an increasingly critical advantage in the current data-driven era.

The main goal of the present study is the design of a physic-based model capable of accurately predicting the remaining useful life of a battery, while being confidently transferable to batteries with different chemical compositions or features. To achieve this, the main objectives are:

1. **The design of a Neural Network based on PDEs** that models the system for estimating a Health State. Among the different methods, the most utilized for solving the forward problem is adding the Cauchy problem to the loss function.

2. A second model capable of outputting **the decay rate of this Health State** parameter.

3. The study of the **capability of the model to be transferable** to different chemical composition.

FIRST APPROACHES

After an initial exploration of the field of study and a thorough review of the existing literature, some preliminary analyses have been developed. To address the main objectives mentioned above, the first step has been to predict the total number of remaining cycles. The following steps were taken:

- The automation of the data cleaning process. The data used is a publicly available NASA dataset, widely cited in the literature. However, a cleaning process has been required due to the presence of outliers.
- Utilization of data-driven methods based on the discharge process and degradation curves knees to predict total life cycles and the point at which the degradation will decay exponentially.
- Comparison of all these methods and the explainability of the results.

Flow equation with application in quantum field theory

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KEY WORDS: flow equations for operators, Brocket-Wegner flow, quadratic operators.

SUBTITLE

The so-called Brockett-Wegner flow, or double-commutator flow is a differential equation on the space of operators introduced in the nineties independently both in the physical and mathematical community. On the mathematical side it was used to diagonalize matrices and solve optimization problems while on the physical side it was used to implement continuous families of specific unitary transformations.

We will present this equation and the challenges it raises in view of physical applications. Indeed, not only do we need to show the existence and uniqueness of the solution but also some properties required to achieve our goal: the N-diagonalization of quadratic Hamiltonians in many-body quantum fields theory. Consequently, we will investigate the nice general properties of this flow when considering initial data that are matrices and take advantage of this study to present the tool used. Finally, once we understand the matrix case, we can look at more complicated cases going toward the quadratic Hamiltonians that are unbounded operators.

Spectral stability of Dirac operators

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KEY WORDS: Dirac operator, absence of eigenvalues, method of multipliers.

The Dirac operator is fundamental in quantum mechanics as it incorporates relativistic effects, allowing for the description of spin-½ particles such as electrons. A natural question in spectral theory is understanding how its spectrum behaves under perturbations, particularly in the presence of external magnetic and electric fields. In this talk, I will discuss the spectral stability of the Dirac operator, showing that under small enough perturbations, its spectrum remains unchanged, and in particular, this kind of potentials do not generate eigenvalues.

Neural Networks & PDEs: a Garlerkin method approach

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KEY WORDS: Neural Networks, PDEs, Galerkin Method.

We start by giving a quick overlook on Neural Networks: focusing on their mathematical definition and their use for numerically solving PDEs. Then, we construct a Neural Network that approximates the matrix multiplication operator for any activation functions for which there exist a Neural Network which can approximate the scalar multiplication function. In particular, we use the Strassen algorithm for reducing the number of weights and layers needed for such Neural Network. This allows us to define another Neural Network for approximating the inverse matrix operator. Finally, by relying on the Galerkin method, we apply those Neural Networks for resolving parametric elliptic PDEs for a whole set of parameters at the same time.

This talk is based on a work in collaboration with Jon Asier Bárcena Petisco, which can be found in arXiv: https://arxiv.org/abs/2501.06539.

On the Performance of Dynamic Matching Models with Threshold-based Policies

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KEY WORDS: Markov chains, Steady-state distribution, Product-form distribution.

We consider the W-shaped discrete-time dynamic matching model, with two sets of queues, $A_1=\{1,2,3\}$ and $A_2=\{a,b\}$, where queues *1* and *3* are compatible with queues *a* and *b* respectively, and queue *2* is compatible with both queues of A_2 (see Figure 1). We consider synchronised arrivals where at each time slot a job arrives to each set of queues. An A_2-set job is of either class with equal probability, as well as for job classes *1* and *3*. We focus on a threshold-based policy that prioritises matching outer edges, and matches the inner edges only when the number of per class waiting jobs in queues A_2 are greater than the given threshold value.

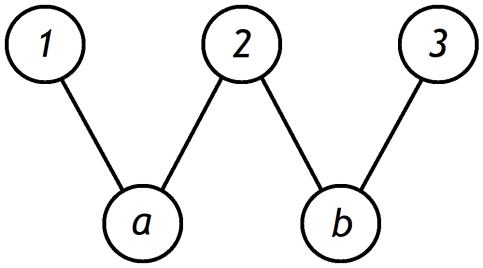

Figure 1: The W-shaped dynamic matching model's compatibility graph.

We characterise the steady-state distribution of the model when the threshold value is equal to 1, 2 or 3. Among those three threshold values, we prove that, when considering the mean queue length of queues *1* and *3*, the optimal threshold-based policy will be that of threshold value 3; whereas the optimal policy when the mean length of all queues is considered will depend on the arrival probabilities. For a threshold value equal or larger than 3, we assume partially unobservable queues; that is, the class of the waiting jobs in A_2 is unknown when queues *1* and *3* are empty. For this case, the obtained results are twofold: (i) we obtain a partial product-form steady-state distribution, which we successfully characterise, and (ii) we provide an approximation of the whole steady-state distribution, whose accuracy is studied numerically.

Geologia

Geología

Environmental anomalies in carbonate platforms during the Cretaceous hyperextension (Basque-Cantabrian Basin)

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KEY WORDS: Microbialite, Glauconite, Carbonate Platform, Cretaceous, Basque-Cantabrian Basin.

Carbonate platforms are of vital importance for understanding environmental changes throughout Earth's history, as they preserve traces of ecosystem variations. These shallow marine environments are characterised by the accumulation of sediments predominantly composed of calcium carbonate ($CaCO_3$). These sediments are primarily constituted by fragments of various living organisms that (bio)precipitate this mineral, including corals, algae and molluscs. Characterised by a high biodiversity, carbonate platforms are highly sensitive to environmental changes and record these changes preserving traces of ecosystem alterations. The variations in carbonate production and mineral precipitation provide insights into the origin, duration and ecological impact of natural environmental anomalies. The study of carbonate platforms facilitates the reconstruction of palaeoenvironmental conditions, thereby enabling understanding the response of shallow marine ecosystems to environmental disturbances.

During the Lower Cretaceous (125–100 Ma), the Basque-Cantabrian Basin (BCB) experienced an extensive carbonate platform development. The formation of these carbonate platforms occurred during the separation of the Eurasian and Iberian tectonic plates or rifting process. During this rifting, the lithospheric crust was extremely thinned, resulting in a process known as hyperextension, including mantle uplift, crustal breakup and the eventual exhumation of the mantle into the basin floor. Furthermore, the activity of extensional normal faults not only controlled the sedimentation but also facilitated the infiltration and circulation of seawater forming hydrothermal fluid-flow.

In the carbonate platforms of the BCB that developed during the active extensional phase have been identified two significant anomalies. On the one hand, there is a pronounced increase in microbial carbonate sedimentation (microbialites), which replaced typical carbonate-fixing benthic communities and filled dissolution cavities. On the other hand, an anomalous enrichment of glauconitic authigenic minerals appear as localized enrichments within certain geological formations. Both anomalies suggest the occurrence of environmental or chemical changes in the sedimentary and early diagenetic environments of the carbonate platforms.

The present study aims to investigate the environmental and geodynamic factors driving these anomalies, their impact on marine ecosystems, and their implications for basin-wide and/or local chemical changes. The main hypothesis suggests that hydrothermal discharges, facilitated by the hyperextension fault systems, altered both seawater and early diagenetic environmental waters, creating favourable conditions for microbialite proliferation and glauconite precipitation.

A combined approach of fieldwork and laboratory analyses will be used to characterise and contextualise these anomalies. Geological mapping will establish their stratigraphic and structural framework, while petrographic, geochemical and isotopic analyses will provide insights into their formation processes and environmental conditions.

Understanding these anomalies will enhance our knowledge of how carbonate platforms respond to extreme geodynamic conditions, with broader implications for palaeoenvironmental reconstructions in hyperextended sedimentary basins worldwide.

Environmental assessment and historical contamination of estuaries and rías from the northern Atlantic Iberian margin – A geological perspective

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KEY WORDS: environmental transformation, natural processes, pollution, anthropogenic impact, global change.

Estuaries and rías, located at the land-ocean interface, are complex coastal environments providing numerous ecosystem services. Since ancient times, owing to their location and their generally flat geomorphology, these transitional ecosystems have been optimal areas for human settlements, holding more than 40% of the world's population nowadays. The intense anthropogenic transformation of coastal systems leaves distinguishable biological, chemical, and physical imprints in their sedimentary record, which can be traced accurately. The northern Atlantic Iberian margin, featuring diverse ecosystems, is an exceptional natural laboratory to explore the relationship between natural and human-induced processes over the last centuries as recorded in its coastal sedimentary archives. Through a high-resolution multidisciplinary perspective, involving micropaleontological, sedimentological, geochemical, and physical indicators, this research examines the recent sedimentary record of three estuaries (Avilés, Nalón, and Mondego) and two rías (Ferrol and Vigo) to complete the following key objectives:

- To define the current environmental conditions governing these estuaries and rías.
- To reconstruct the recent environmental transformations and quality evolution of these estuaries and rías.
- To provide a comprehensive framework of the role played by anthropogenic and natural forcing factors.
- To evaluate the stratigraphic distribution and historical accumulation of legacy contaminants in coastal sedimentary archives.
- To examine the response of benthic foraminifera to current environmental conditions and historical forcing factors, both natural and anthropogenic.
- To assess the potential for ecosystem recovery following cumulative anthropogenic impacts.

Results – Five key coastal systems

The results reveal distinct transformation patterns with diverse response pathways among estuaries and rías, characterized by diachronous, localized and, in certain cases, cumulative anthropogenic impacts. Since the 19th century, mining, industrialization, aquaculture, intensive agriculture and engineering works have significantly altered the hydrological, environmental, and sedimentary dynamics of these coastal environments. Despite the cessation of disposals, many coastal systems exhibit a long-lasting contamination fingerprint stored in their sediments, including mercury, zinc, organochlorine pesticides, and microplastics. These legacy pollutants, often concentrated in shallow sediment layers, pose ongoing ecological risks due to their potential remobilization by natural factors (e.g., fluvial activity and floodings) and anthropogenic interventions (e.g., dredging), further serving as secondary sources of contamination. Natural processes, such as fluvial influence, tidal patterns, and extreme hydrological events have shaped recent estuarine evolution. These processes often interact with anthropogenic impacts, leading to amplified sedimentary and ecological disruptions. Benthic microfauna exhibits diverse responses to environmental stressors throughout time. While changing natural drivers determine assemblage composition and abundances in these coastal settings, foraminiferal species seem to adapt to pollution, despite toxicity thresholds often being exceeded. Finally, evidence of ecosystem resilience and partial recovery highlights the potential for regeneration following the cessation of anthropogenic activities or the implementation of mitigation measures. However, persistent pollutants and historical sedimentary fingerprints demand continuous environmental monitoring, as well as science-based and adaptive management, to mitigate potential risks, particularly in the context of global climate change.

Carbonate lake and wetland systems in the Cenozoic of the Miranda-Trebiño basin (N Iberia)

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KEY WORDS: Cenozoic, lacustrine, Miranda-Trebiño.

Studies on continental carbonates have grown worldwide in the last decade since they are excellent indicators of climatic and tectonic changes at different temporal scales. The continental carbonates develop in inland bodies of water and according to their context of development they can be classified as: lacustrine, palustrine, fluvial and associated carbonate deposits, travertines, tufas, calcretes and karst carbonates. This work focusses on the study of the Cenozoic continental carbonate deposits of the Miranda-Trebiño basin and, more specifically, on their stratigraphic architecture, palaeoenviromental reconstruction and evolution with time. The analysis comprises lacustrine and palustrine successions, calcareous paleosols (calcretes) and fluvial-associated tufas. For this purpose, field work has been carried out (mapping, stratigraphic logging, hard and soft rock sampling), laboratory work (thin section analysis, C and O stable isotope studies, SEM…) and office studies (synthesis of results, bibliographic search and preparation of scientist articles). The study also encompasses the analysis of continental carbonates from other areas, such as the lacustrine deposits of the Bardenas Reales de Navarra (Spain), Cerro Químal (Chile) and Cuyana Basin (Argentina), in order to learn the working methods used by other research groups and to better understand the formation processes of these complex and varied facies.

The Miranda-Trebiño Basin is a relatively smaller (approximately 40 km wide and 20 km long) syncline depositional trough that evolved as a piggyback basin in the southern Basque Pyrenees during the emplacement of the south Pyrenean thrust front. It was filled with up to 3000 m of terrigenous and carbonate deposits of ages between middle Eocene to Late Miocene corresponding to four consecutive syn- to post-tectonic depositional megasequences. The main continental carbonate systems in the basin are the following: 1) The Loza-Portilla Formation (middle-upper Eocene), up to 300 m thick marginal alluvial siliciclastics grading to palustrine-lacustrine carbonates and evaporites; 2) the Moraza-Moriana Formation, made of metric-scale calcretes intercalated with proximal to distal alluvial detrital deposits; 3) the Trebiño Formation (late Oligocene-Early Miocene succession),up to 700 m thick succession made of three consecutive lacustrine carbonate members; and 4) the Peña Adrian Formation (Upper Miocene),up to 150 m thick alluvial to lacustrine succession very rich in fossil gastropods. The study of these systems has made it possible to establish the paleogeographic evolution of the successive palaeowater bodies over time and to observe significant changes in the tectonic and climate regimes. Several Quaternary tuff deposits associated to the Inglares river have also been analysed, providing a better understanding of the deposition of freshwater carbonate deposits across this poorly-known continental basin of northern Iberia.

Cyclostratigraphic, paleoclimatic and paleoenvironmental analysis of middle/upper Eocene hemipelagic deposits from the Northern Iberian continental margin (Pamplona Marl Formation, Western Pyrenees)

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KEY WORDS: Eocene (Bartonian/Priabonian), chronostratigraphy, Milankovitch cycles, magnetostratigraphy, calcareous nannofossils.

A common goal of the Intergovernmental Panel for Climate Change (IPCC) and the International Union of Geological Sciences (IUGS) is the study of sedimentary records that were influenced by astronomically paced periodic climate-change cycles (Milankovitch cycles) in ancient times of intense greenhouse effect, as this information may provide insights into the future consequences of the ongoing global warming. Most studies are carried out using ocean drilling cores, but these cores commonly present low sedimentation rates and hiatuses, hence the information must be complemented with the study of expanded terrestrial outcrops.

During the Mesozoic and Cenozoic the northern continental margin of the Iberian peninsula was characterized by the accumulation of thick deep marine sedimentary successions which are now exposed in accessible outcrops of both the Basque-Cantabrian and South Pyrenean regions. Given their former location at a paleolatitude of 25º-35ºN, these sedimentary successions registered reliably the climate changes of the time. This doctoral thesis aims to determine the influence of orbitally forced climate-change episodes (Milankovitch cycles) on the middle/upper Eocene (Bartonian/Priabonian) Pamplona Marls Formation throughout several outcrops of the western Pyrenees.

To this end, a high-resolution study of several paleoclimatic proxies has been conducted on the Pamplona Marls outcrops located in the Jaca-Pamplona basin, more precisely in the area of the Yesa water reservoir (province of Zaragoza) to the south of the overthrusting belt of the Leyre mountain range. The succession consists of a conspicuous alternation of marl and marly limestone metric layers. The magnetostratigraphy and calcareous nannofossil biostratigraphy of most of the layers, combined with the spectral analysis of the magnetic susceptibility of more than 500 rock samples, yielded a detailed astrochronological and cyclostratigraphic framework which can be correlated with other geological sections of the same age and compared with global astronomical solutions. This has shown that the lithological alternation was caused by seasonality variations driven by precession cycles of 21,000 years, and these were modulated by climate-change episodes driven by eccentricity cycles of 100,000 years. Thus, the precise age model obtained in the studied succession substantially exceeds the resolution of the astronomical solutions calculated by mathematical models for the same time interval. This will allow the improvement of the astrochronological time scale following the guidelines of the IUGS and the International Commission on Stratigraphy (ICS).

Following the astrochronological analysis, a detailed paleoenvironmental analysis of the most characteristic cycles will be conducted in order to understand the relationship between variations in the intensity/frequency of different paleoclimatic parameters (e.g., temperature, rainfall, runoff, etc.) and hemipelagic sedimentary processes (e.g., variations in biological productivity, carbonate dissolution due to lysocline rises, or terrigenous dilution produced by increased rates of continental weathering). The assessment of climatic and environmental feedback (both positive and negative) will increase our understanding of climate change processes in greenhouse conditions, which is one of the main research lines promoted by the IPCC. Consequently, although this doctoral thesis is focused in the middle/upper Eocene of the Basque-Cantabrian Basin, the results will have global applications in the development of both the astronomical time scale and models of marine sedimentation under changing climates.

Preliminary insights from the middle-upper Oligocene alluvial deposits of the Medina de Pomar Basin (Western Pyrenees, N Spain)

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KEY WORDS: Oligocene, alluvial, calcretes.

During the 70s and 80s an intensive hydrocarbon exploration was conducted on the Mesozoic substratum in the Western Pyrenees, resulting in the acquisition of several seismic lines and the drilling of exploratory wells. One of the exploration targets was the Medina de Pomar Basin (Burgos, N Spain), a NW-SE oriented synclinal trough of approximately 500 km² emplaced within the Pyrenean fold and thrust belt. Its filling consists of almost 3000 m of purely continental deposits overlying the Upper Cretaceous and lower Paleogene marine to transitional units. These deposits are divided into four macrosequences (M1 to M4), bounded by discontinuities mostly defined by marked facies shifts, which chronostratigraphically span from the upper Eocene to the Middle-Upper? Miocene. Within these successions, the alluvial-fluvial systems play a significant role and will be the main focus of this doctoral thesis. The sedimentological analysis of these deposits, combined with surface and subsurface stratigraphic data and integrated with other techniques (paleontological, geochemical, etc.), will help to:

1. Make paleoenvironmental and paleoclimatic inferences. Disentangle the tectonic, climatic, and autocyclic controls on sedimentation and develop sedimentary models accordingly.

2. Reconstruct the paleogeographic evolution of the region in the context of the tectonically uplifting Western Pyrenees.

THE MIDDLE-UPPER OLIGOCENE MACROSEQUENCE

In the Tobalina Valley, SE of the basin, the M2 macrosequence is exposed across the synclinal closure, reaching a maximum measurable thickness of nearly 740 m. The moderate to good exposure of the M2 allows for a detailed study, including facies association mapping, architectural reconstruction, and paleocurrent analysis.

Architectural and facies analysis reveals a proximal alluvial association dominated by debris flows, primarily along the northern basin margin, transitioning basinward into a SE-trending fluvial system. This system is characterized by ribbon-shaped, low-sinuosity channels with limited interconnectivity and lateral floodplains marked by widespread calcrete development. Calcrete occurrence becomes particularly prominent in the northern marginal zone, where six continuous marker horizons can be traced for distances of up to 5 km. The sequence evolves vertically into a mixed carbonate-siliciclastic facies assemblage, occasionally carbonaceous, indicative of a freshwater lacustrine environment. This assemblage includes faunas characteristic of the Chattian stage (late Oligocene).

The present succession exemplifies the interaction between peripheral alluvial fans and an axial fluvial system, together with the distribution of paleosol development within floodplain deposits in a setting that was largely controlled by compressional salt tectonics, which created axially asymmetric differential accommodation space. This is evidenced by the large-scale wedging and onlapping of the M2 against the basin margins. Differential subsidence caused local variations in sediment supply: the axial channelized area received greater sediment influx, whereas the less subsiding northern marginal floodplain recorded more extensive paleosol development. The developed fluvial style suggests a relatively rapid base-level rise, indicating that sedimentation rates were likely sufficient to compensate for high subsidence. Nevertheless, sedimentation was episodic, primarily indicated by the widespread calcrete development, which is also characteristic of semi-arid climates, typical of the Oligocene in this region.

Kimika

Química

Antibody-drug conjugates (ADCs), a promising therapeutic strategy for the treatment of advanced and metastatic cancers. Analytical challenges

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KEY WORDS: ADC, cancer, analysis.

Cancer is one of the main public health problems worldwide. The tumors with the highest mortality rate are those that have developed beyond the organ in which they originated, in a process called "metastasis".

In recent years, successful progress has been made in the early diagnosis and treatment of early stages of many tumors. However, the development of anti-tumor therapies with reduced systemic toxicity remains a challenge.

Antibody-drug conjugates (ADCs) have emerged in response to this challenge. They are a new class of highly potent biological drugs that are synthesized by attaching a small molecule cytotoxic drug (payload) to an antibody via a chemical linker agent. Thus, the coupling of the cytotoxic drug to a monoclonal antibody represents a method of combining the specificity of the antibody for its target (tumor cell) with the potency of the payload.

The structural complexity of the molecule makes it difficult to obtain a pharmacokinetic profile. Therefore, it is necessary to develop several analytical techniques that are capable of quantifying the different parts of the ADC, as well as the changes they may undergo in vivo.

Liquid chromatography coupled to mass spectrometry (LC-MS) and immunoassay (ELISA) are the most frequently analytical techniques used for the knowledge of the fraction of total antibody and free payload as well as the conjugate.

Herein the optimized and validated methods for the quantification of these three fractions of the ADC have been carrying out. In this sense, LC-MS/MS has been applied to the determination of total antibody and free payload, and an ELISA method has been developed for the determination of the conjugated fraction.

The ultimate purpose of this research is to be able to support the analysis of samples from cancer patients participating in a Phase I clinical trial to determine the pharmacokinetic profile of the new ADC under study.

Analytical Chemistry in the Exploration of Mars and the Moon

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KEY WORDS: analytical chemistry, Mars, Moon.

Analytical chemistry is the branch of chemistry concerned with the characterisation and identification of the elements and/or compounds that constitute a sample. This renders analytical chemistry of considerable interest to a broad spectrum of disciplines, ranging from environmental studies to space science. A notable strength of analytical chemistry lies in the non-destructive and non-invasive nature of its methodologies. This characteristic ensures that the composition of a specimen can be ascertained without compromising its integrity.

In the context of the space science, the most accessible samples for study are meteorites, which can originate from different planets or spatial bodies, including Mars or the Moon. The scarcity and high value of meteorites on Earth underscores the importance of preserving them, making non-destructive techniques crucial for their analysis. The employment of such techniques facilitates the acquisition of a comprehensive characterisation of meteorites, encompassing their chemical and mineralogical composition and the detection of diverse organic molecules. Consequently, the composition of the planet of origin of these meteorites can be determined.

In the field of meteorite analysis, a distinction can be made between elemental and molecular techniques. The elemental analysis are utilised to ascertain the elemental composition of the specimen, enabling the acquisition of point by point measurements or images that reveal the spatial arrangement of elements on the sample surface. Examples of this type of technique include X-Ray Fluorescence (XRF) and Scanning Electron Microscopy coupled to Energy Dispersive Spectroscopy (SEM-EDS).

Conversely, molecular techniques, such as Raman or infrared spectroscopy, facilitate point by point measurements and imaging, akin to elemental techniques. The molecular composition of the sample surface and its spatial distribution can be determined by these techniques.

Despite the fact that meteorites represent the only samples present on Earth, they are not the unique means by which the chemical and mineralogical composition of a planet can be determined. In recent years, several space missions have been carried out in which a rover lands on the surface of a planet, mainly Mars. These rovers are equipped with various instruments that facilitate direct measurement of the surface, employing methodologies analogous to those utilised in terrestrial laboratories. A notable example is the Mars2020 Perseverance rover. This particular rover is currently operating on the surface of Mars, conducting daily measurements with the various instruments on board. These instruments include a Raman spectrometer and an IR spectrometer among others, which are utilised to ascertain the mineralogical composition of Mars and to detect organic molecules.

Following the characterisation of a meteorite or the surface of a planet, it is possible to establish different relationships between the minerals detected and propose a hypothesis of formation. These hypotheses can be tested by conducting laboratory experiments, given that the formation of one mineral from another typically occurs through various chemical reactions.

In conclusion, analytical chemistry plays a fundamental role in determining the chemical and mineralogical composition of planets and other spatial bodies in the Solar System, as evidenced by its current presence in various missions, particularly those focused on the planet Mars.

Eco-Innovation in Materials: Bio-Based Polyurethanes Reinforced with Nanotechnology Anticorrosion and Antifouling

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KEY WORDS: bio-based polyurethane, nanotechnology, anticorrosion, cathodic protection, antifouling

Corrosion of metals represents a significant global economic challenge, particularly in offshore applications where marine environments accelerate material degradation. In offshore wind farms, corrosion accounts for 43–68% of premature failures, and maintenance costs can be up to 15 times higher than those of onshore installations. These high costs, combined with the absence of on-site maintenance personnel, demand protection systems that are durable, low-maintenance, and easy to apply—capable of withstanding extreme temperatures, UV exposure, humidity, and mechanical stress.

At the same time, current protective coatings often degrade under these extreme conditions, losing adhesion, cracking, or allowing water ingress over time. Moreover, conventional coatings contain volatile organic compounds (VOCs) or leach harmful substances, posing risks to marine ecosystems. Thus, growing environmental concerns highlight the urgent need for more sustainable and eco-friendly solutions.

Bio-Based Polyurethane Coating Strategy

In this context, bio-based PU composite coatings offer a sustainable and high-performance solution by combining excellent corrosion resistance with enhanced mechanical durability.

These polyurethanes are synthesized using bio-based components, such as diols derived from vegetable sources and industrial by-products, replacing conventional petrochemical monomers. This approach not only reduces environmental impact but also aligns with circular economy principles. The resulting coatings form a robust barrier that protects steel from degradation while maintaining flexibility, strong adhesion, and resistance to cracking under extreme conditions.

To further enhance performance, nanotechnology is being integrated into the PU matrix. The incorporation of metal or metal oxide nanofillers aims to improve impact resistance and enable sacrificial protection mechanisms, without releasing harmful substances into the marine environment.

Preliminary results from thermal, mechanical, and electrochemical characterization are highly promising, and future work will focus on optimizing the formulation and validating its performance under real marine conditions.

Suspect analysis in environmental samples

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KEY WORDS: Suspect screening, non-target, environmental samples, emerging contaminants

Historically, environmental sample monitoring focused primarily on compounds regulated by law, which limited the scope to a small group of chemicals and ignored other potentially harmful chemicals. Nevertheless, advances in the analytical instrument sensitivity and selectivity, combined with improvements in software and data treatment, have enabled a shift beyond the target analysis of a limited number of compounds. This shift is known as suspect and non-target analysis (SNTA), which allows a more comprehensive approach that is not limited to regulatory constraints.

Within this framework, the IBeA group conducts research on a variety of topics, including the study of emerging contaminants in drinking water and wastewater effluents in the Basque Country, contaminants adsorbed onto microplastics, the potential link between environmental pollutants and health issues such as infertility and congenital anomalies of the kidney and urinary tract, and the impact of marine pollution from oil spills on ecosystems, among other concerns. In order to carry out these studies using suspect and SNTA approaches, specific analytical strategies must be considered. The first requirement is the use of high-resolution mass spectrometry, such as the LC-Orbitrap available at the Plentzia Marine Station of the University of the Basque Country. The second consideration is the type of measurement, which varies depending of the chromatographic technique. In liquid chromatography, data dependent analysis is the most popular option, while in gas chromatography it is scan data analysis. Once the analysis is complete, the results obtained after the appropriate data analysis are reported with different levels of confidence, which vary depending on the approach. In liquid chromatography the Schymanski scale[1] is used, while in gas chromatography it is not established and we are currently developing one.

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Smart Soil Renediation: Blending Biopiles, Plants and Nanotech

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KEY WORDS: Biopile, Phytoremediation, Nanotechnology

Soil pollution poses a critical environmental challenge which resulting from industrial activities, agricultural practices, and improper waste disposal. Contaminated soils threaten ecosystems, human health, and food security, making effective and sustainable remediation techniques essential. Among these approaches, nature-based solutions have gained increasing attention due to their ecological compatibility and long-term effectiveness. Biopile technology, a cost-effective bioremediation method, harnesses microbial activity to degrade organic pollutants in contaminated soils. Despite its effectiveness, optimizing biopile performance remains crucial to enhance degradation efficiency and ensure consistent results across varying environmental conditions.

This PhD project focuses on improving the biopile remediation process through the integration of advanced methodologies to optimize contaminant breakdown. This research emphasizes the use of polysaccharide-based amendments to enhance microbial activity, thereby accelerating bioremediation. Additionally, the project employs micro-amendments to stimulate phytoremediation, employing plant-assisted contaminant degradation. To maximize these effects, precise delivery of amendments and moisture control is essential. For this purpose, Electrical Resistivity Tomography (ERT) is integrated to monitor real-time moisture distribution within the biopile, coupled with subsurface drip irrigation for controlled water delivery.

By combining these innovative approaches, the project aims to enhance the efficiency of biopile systems at both laboratory and field scales. This multidisciplinary strategy is expected to provide real-time insights, improve microbial and plant-assisted degradation processes, and contribute to the development of more sustainable and effective bioremediation techniques. The outcomes of this research will advance biopile technology, offering scalable solutions for mitigating soil pollution and promoting environmental restoration.

Key Highlights:

- Integration of Electrical Resistivity Tomography (ERT) for monitoring water content
- Implementation of subsurface drip irrigation to ensure precise moisture control
- Utilization of nano/micro-encapsulated nutrients to enhance microbial activity
- Application of phytoremediation to promote plant-assisted contaminant degradation
- Evaluation and optimization of biopile technology at both laboratory and field scales
- Contribution to sustainable and effective soil remediation practices

Acknowledgement

This PhD Project is supported by European Union's Horizon Europe (SYMBIOREM Grant agreement ID: 101060361), which provides essential funding and resources to advance biopile technology and foster the development of sustainable bioremediation strategies.

Nanotech-Enhanced Biopolymer Coatings: Revolutionizing Anticorrosion & Antifouling Performance for Offshore Environments

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KEY WORDS: Biopolymer, nanotechnology, antifouling, bio-epoxy, anticorrosion, offshore marine environments, corrosion resistance, sustainability.

Corrosion in aggressive marine environments presents a significant challenge to offshore structures, leading to elevated maintenance costs and compromised structural integrity. This study investigates the synthesis and performance evaluation of advanced bio-epoxy coatings that integrate nanotechnology with renewable biopolymers for enhanced anticorrosion and antifouling protection. Harsh environmental conditions including high salinity, persistent humidity, and biofouling accelerate corrosion processes, necessitating innovative coating solutions.

The developed formulation leverages a synergistic approach by combining epoxidized soybean oil and tannic acid both derived from natural and residual biomass with demoulding secondary streams as functional additives. This integration enhances the impermeability and antifouling properties of the coatings while promoting environmental sustainability through the valorization of industrial byproducts and a reduction in reliance on petroleum-based raw materials.

The research emphasizes the use of secondary resources, such as biomass-derived compounds and other industrial byproducts, in line with circular economy principles. Future investigations will focus on further optimization by incorporating bio-based antioxidants, 2D fillers as barrier enhancers, and additional specialized anticorrosion additives. Bio-based epoxy resins, synthesized from renewable sources and modified with tailored functional additives, ensure that the final coating system achieves both high performance and environmental responsibility.

Challenges remain, including variability in biomass quality affecting formulation consistency, the need for effective pre-treatment of secondary streams to ensure compatibility, and the complexities of scaling production without performance compromise. Additionally, establishing a stable supply chain and managing the processing costs associated with renewable and secondary-stream materials are critical for industrial implementation.

Overall, this research not only addresses the pressing issue of corrosion in marine environments but also advances sustainable and circular industrial practices. The confluence of advanced nanotechnology and renewable resources marks a significant step toward the development of eco-friendly anticorrosion solutions with far-reaching implications for both environmental stewardship and industrial efficiency.

Co(III)-Catalyzed Synthesis and Functionalization of (Hetero)arenes

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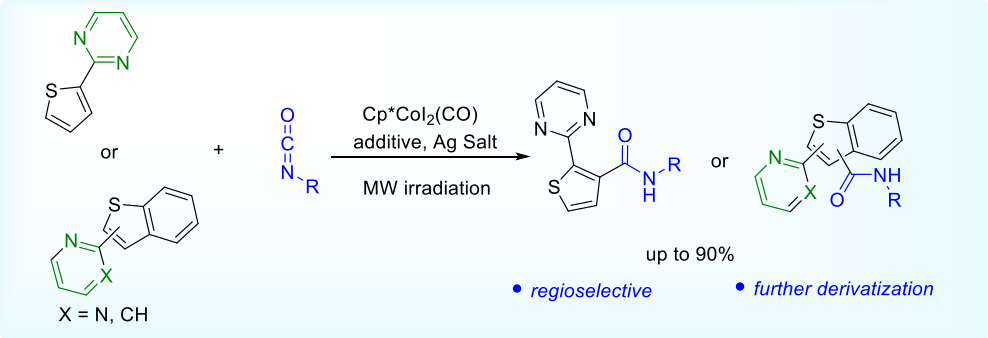
KEY WORDS: C-H activation, cobalt, asymmetric catalysis

Transition metal-catalyzed C-H functionalization has become an essential synthetic tool, which allows the use of non-functionalized starting materials for the construction of more complex targets. In this context, the development of C–H functionalization methods using earth-abundant first-row transition metals to replace more classical methods based on Pd, Ir, Rh or Ru catalysts, which are expensive, less abundant and more toxic, is a challenging area [1]. For some time now, cobalt has emerged as one of the most promising 3d metals for this purpose. Our group has contributed to this field reporting the first intramolecular Cp*Co(III) catalyzedhydroarylation of alkenes to obtain dihydrobenzofurans [2]. We now report a mild and efficient Cp*Co(III)-catalyzed C-H aminocarbonylation procedure for thiophenes and benzo[*b*]thiophenes, using pyridine and pyrimidine directing groups to control site selectivity, under MW assisted conditions. The introduced amide group can act as directing group in further iterative C-H functionalization reactions, allowing the diversification of the heterocyclic structures. In a different approach, simple cobalt salts can also be used as catalysts for the generation of more complex heterocyclic frameworks forming two rings via cascade C-C and C-N bond forming reactions ina single reaction step. A quaternary stereocenteris generated, with complete control of enantioselectivity using a chiral ligand for cobalt. Details of these transformations will be given.



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Blue Revolution: From Marine Waste to Innovation in Packaging

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KEY WORDS: BIO-films, SEAREFINERY, Blue Economy.

The excessive use of single-use plastics in the packaging industry poses a significant environmental challenge due to their slow degradation and accumulation in marine and terrestrial ecosystems. The urgent need for sustainable alternatives has driven the development of biodegradable and bio-based polymers, with marine biopolymers emerging as a promising solution.

Within this framework, this PhD research is part of the **SEAREFINERY** project, which focuses on valorizing marine resources and aquaculture by-products to develop innovative materials. The thesis explores the extraction and application of polysaccharides and bioactive compounds derived from marine algae—such as alginate, chitosan, carrageenan, and polyphenols—in the formulation of **active packaging** or **active materials** with functional properties for food preservation.

The study optimizes sustainable extraction processes to enhance the yield of these biopolymers and active compounds, achieving efficiencies above 85%. Using these materials, three types of packaging solutions will be designed: an edible coating, an active film with antioxidant and antimicrobial properties, and a biodegradable nanofiber. These innovations aim to improve thermal stability, oxygen barrier properties, and mechanical strength while extending food shelf life and reducing food waste.

This research integrates multidisciplinary approaches in biotechnology, material chemistry, and circular economy, aligning with European sustainability strategies. Through this work, the potential of marine biopolymers as a viable and eco-friendly alternative to conventional plastics will be demonstrated, supporting the transition toward a more sustainable blue bioeconomy.

Acknowledgments
This work is carried out within the framework of the **SEAREFINERY** project, which aims to enhance the blue economy by valorizing marine waste and developing innovative biopolymers.

Ingeniaritza Kimikoa

Ingeniería Química

CO_2 methanation with Green Hydrogen for Clean Energy Production and Environmental Sustainability

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KEY WORDS: CO_2 methanation, Renewable Energy, Catalyst Supports, Metals, Industrial Applications

The global transition toward renewable energy and the increasing demand for sustainable chemical processes have sparked significant interest in developing efficient technologies for CO_2 utilization. Among them, the catalytic CO_2 methanation, a process which converts CO_2 and hydrogen into methane, has emerged as a promising approach for renewable energy storage and carbon recycling. Methane, the primary component of natural gas, offers an energy-dense and cleaner-burning fuel alternative that can be integrated into existing natural gas infrastructure, including pipelines, storage facilities, and combustion systems. This adaptability makes NG production through catalytic CO_2 methanation an attractive strategy. Furthermore, methanation can play a key role in Power-to-Gas (PtG) technologies, through storing surplus renewable electricity generated from intermittent sources such as solar and wind in the form of synthetic natural gas (SNG).

The CO_2 methanation reaction is thermodynamically favored at low temperatures; therefore, the use of a catalyst is essential to overcome kinetic barriers and enable the reaction under mild temperatures. Therefore, the development of active and selective catalysts is essential for the methanation process. The efficient formulations must be able to achieve CO_2 conversions close to the thermodynamic equilibrium at relatively low temperatures (< 500 ºC) [1-3]. Ni-based catalysts are widely used owing to their high specific activity and lower cost compared with noble metals. However, they usually suffer from a rapid deactivation due to a loss in their surface active sites, which is considered a major drawback. In this sense, it would be essential the design of Ni catalysts exhibiting suitable metal-support interactions in order to provide highly dispersed and resistant active phases. In our group, many studies have been carried out to address these challenging issues. Our recent reports shed light on the importance of the choice of an adequate support as well as the syntheis method used for the deposition of the active phase.

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Acknowledgements

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Conical spouted beds: hydrodynamics and applications towards industrial implementation

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KEY WORDS: Conical spouted bed, Scaling up, Particle Tracking Velocimetry, Cycle times, CO_2 Capture.

The spouted bed technology is a gas-solid contact method widely used in different thermochemical applications, which allows handling particles of a wide variety of sizes and properties. The most characteristic feature of this technology is the cyclic motion of the particles, which plays a crucial role in promoting an efficient gas-solid contact and improving heat and mass transfer rates. This performance makes it suitable for applications such as gasification, torrefaction, pyrolysis and combustion. Among the different spouted bed geometries, the conical one has been extensively studied in numerous chemical processes, demonstrating their versatility and operational effectiveness.

However, the above mentioned applications are mainly limited to laboratory scale unit, which emphasizes the need to understand the hydrodynamic behaviour of the system prior to its industrial implementation. The scaling up challenges of this technology are largely associated with the complex gas-solid interactions, and therefore with the system operational stability. The use of internal devices is particularly useful in this context, as they enhance both gas and solid flow distribution and improve the stability of the spouting behaviour. Nevertheless, further research is necessary to gain an overall knowledge of the spouting dynamics for its successful scaling up.

With the aim of studying the internal gas-solid interaction, a variety of techniques have been proposed to obtain detailed experimental data. Thus, the CPWV research team has proposed Particle Tracking Velocimetry (*PTV*) to ascertain several parameters of uttermost importance. This optical set-up is composed of a high speed camera fitted to a borescopic system, which is introduced into the contactor and allows tracking particles. Nevertheless, when one camera is used only a two-dimensional velocity may be calculated, and therefore a second camera must be implemented in order to assess the three-dimensional (3D) displacement of particles, which is known as Stereo PTV technique. However, this set-up is still under development, with ongoing efforts focused on improving its accuracy for detailed particle tracking.

An additional key aspect in spouted bed hydrodynamic characterization is the determination of particle cycle times and their distribution, which provide information about gas-solid contact quality. Accordingly, four wide-angle lens RGB high speed cameras are used and placed above the bed. These cameras record the bed surface and detect three traced particles painted each one in one of the RGB (Red, Green, Blue) channels. In this way, the starting and ending point of the cycle is registered and the time that particles require to describe the whole cycle is calculated.

Furthermore, a novel line of this group is focused on studying strategies for reducing CO_2 emissions by its capture and mineral carbonation in a conical spouted bed. The conventional carbonation of CaO with CO_2 requires operating at temperatures typically over 600 ºC, but the aqueous carbonation proposed by this group reduces considerably the operating temperature (below 100 ºC). In this process, alkali reactants contained in slurry solutions are fed into the reactor, where CO_2 dissolves in the water and then reacts with the alkaline reactants, resulting in the formation of stable calcium and magnesium carbonates. The oxides required for the reaction are mostly present in wastes from the steel industry. This way, mineral carbonation provides the dual benefit of utilizing industrial waste, as well as contributes to reducing CO_2 emissions.

In summary, the research conducted in this line of CPWV group explores the complex dynamics of the spouted bed technology, focusing on key challenges and developing innovative methods, such as Stereo PTV, to enhance its hydrodynamic characterization. By extending this understanding to larger scales and exploring parallel pathways like mineral carbonation for CO_2 mitigation, the group contributes significantly to the development of scalable, efficient, and environmentally sustainable solutions for thermochemical and chemical engineering processes.

Intensified dry reforming of biogas: closing the organic waste recycling loop

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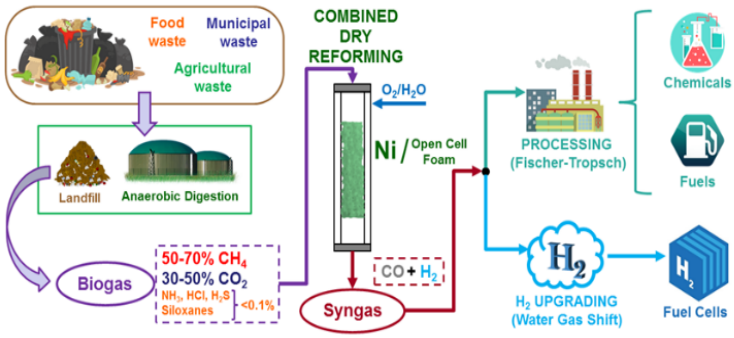
KEY WORDS: Dry reforming of biogas, Syngas, CO_2 and CH_4 valorisation, Structured reactors

The most pressing environmental challenges currently facing society are undoubtedly climate change and its attendant effects, including increases in greenhouse gas emissions. Nevertheless, the regulated production, conversion, and utilisation of these gases for energy generation can play a crucial role in mitigating climate change. Biogas has emerged as a promising renewable energy source with significant potential to accelerate socio-economic development. Comprising methane, carbon dioxide, and water vapour, biogas offers diverse applications, including direct use as an energy source or conversion into value-added chemicals, making it a viable alternative to natural gas.



The focus of our research topic is the chemical valorisation of raw biogas (CH_4+CO_2) through dry reforming of methane (DRM), a process that yields syngas (H_2+CO), a pivotal intermediate product. The primary objective is to synthesise and explore advanced catalysts supported over open cell foams that can operate under industrial conditions. This innovative approach is poised to make a substantial contribution to the valorisation of greenhouse gases, as it employs two of these gases as renewable reactants. The results will advance reforming technology by addressing high energy demands, limited catalyst durability, and the need for precise product stream composition. This enhancement will make it suitable for renewable gas-to-liquid processes while improving economic viability and carbon efficiency.

In order to achieve these objectives, the present research is centred on the industrial implementation of dry reforming of raw biogas, with the aim of lowering its reaction temperature, given that it is a highly endothermic reaction. The experimental setup involves the operation of the process at high flow rates, while simultaneously reducing coke formation. Coke formation is recognised as a primary concern affecting the durability of the catalysts. In addition, we are optimising the design of state-of-the-art multimetallic catalysts, utilising nickel as the active metal derived from spinel. We employ promoters to enhance the characteristics of the resulting catalyst. It is also important to note that these secondary metals increase the H_2/CO molar ratio of the product stream, producing a syngas of higher quality. These challenges must be overcome to transition from lab-scale development (TRL 1-3) to pilot-scale implementation (TRL 4-5). Our research aims to drive significant breakthroughs, thereby progressing towards a robust and mature technology that can fulfil a an essential role in a low-carbon modern society.

Dry reforming of raw biogas is a highly promising approach for producing energy carriers, particularly as it utilizes greenhouse gases as feedstock. However, large-scale adoption for renewable syngas production is dependent on the successful resolution of several technical and economic challenges. These challenges encompass the optimization of catalytic reactor design at both microscopic (nanosized metallic sites) and macroscopic (structured foam catalysts) levels, the mitigation of catalyst deactivation, and the precise modulation of the H_2/CO molar ratio in the product stream.

Our research addresses these critical challenges by facilitating the integration of renewable technologies into energy systems and advancing the deployment of renewable fuels and bioenergy. We are developing advanced $NiAl_2O_4$-based nickel ceramic foam catalysts and assessing their kinetic performance for combined dry reforming of raw biogas under realistic conditions. This includes the smart utilisation of multiple oxidants to optimize syngas composition, managing impurities, and ensuring stable operation with short residence times.

Sustainable valorization of refinery by-products, plastics, and bio-oil into valuable resources in the Waste-Refinery

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KEY WORDS: Waste Refinery, catalytic cracking, hydroprocessing, plastics, bio-oil

Our society still depends on oil for energy and for the production of essential products such as fuels and plastics. Moreover, the production and consumption of these products is expected to continue to grow in the coming years, while the quality of the raw materials is expected to decline. This dependence not only makes us vulnerable to fluctuating oil prices and international geopolitics, but the mass production of commodities contributes to the accumulation of waste and environmental impacts.

The Waste Refinery is emerging as a strategy to minimize this dependency and move towards a more sustainable refining model. Its aim is to valorize the waste of the consumer society, originally derived from oil, by transforming it into fuels and products with high added value [1]. This not only reduces the amount of waste generated but also optimizes the use of fossil resources within a circular economy approach. The aim is to involve refineries in the recycling or recovery of products originally derived from oil, such as plastics, to make the processes more sustainable and try to minimize landfill and incineration. The benefits are obvious.

Moreover, this concept can be extended to the recovery of waste from biomass, the conversion of which into fuels makes it possible to close the carbon cycle in a near carbon-neutral way. The key is to integrate these waste streams into existing refinery units, using their infrastructure to develop more sustainable processes without the need for disruptive investments. Two key processes in this regard are catalytic cracking and hydrocracking, given their high capacity and versatility to handle a wide range of feedstocks.

Our research line has been investigating for many years both processes for the production of fuels from waste from the consumer society, mainly used tires and plastic waste, either using pure polymers (HDPE, PP, PMMA, PS and PET) or liquids obtained from the pyrolysis of HDPE. Progress has been made to the extent that the hydrocracking of actual plastic waste is now being investigated, in particular the hydrocracking of a pyrolysis liquid from waste electrical and electronic equipment (WEEE). Regarding bio-residues, the hydrotreating of bio-oil is also being addressed, as biomass-derived waste also falls within the scope of waste refining.

The difference between model compounds and real feeds is the amount of components and heteroatoms present. For this reason, real feeds are not usually studied, as their valorization is a major challenge. In addition to the operational complications associated with working with real feeds, the number of reactions involved in the process is multiplied. This makes it really difficult to analyze the reaction products and obtain results. However, what may be a problem for some is a challenge and an opportunity for us to develop and improve processes.

At the laboratory scale, our work focuses on studying and proposing different strategies for developing sustainable processes that respond to the needs of our society, identifying possible problems and proposing useful solutions that allow the processes to be scaled up on an industrial scale.

In practice, one of our research lines is investigating whether it is feasible to produce fuel directly from WEEE pyrolysis liquids or whether it is better to blend it with a refinery side stream. So far, we have seen that this plastic by-product contains significant concentrations of halogens (Cl and Br). Some of these are intrinsic to the structure of some polymers, such as PVC, but others come from additives or flame retardants from electrical and electronic equipment. If these compounds are not removed during processing, they can pose a risk to human health and the environment, so part of our current work is focused on finding a solution to this problem.

In summary, our research plays a key role in the development and optimization of processes in line with the Sustainable Development Goals, contributing to technological advances that favor a more efficient and sustainable future.

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From Waste to Resource: Producing Sustainable Furfuryl Alcohol by aqueous phase catalysis

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KEY WORDS: Furfural, Furfuryl alcohol, Catalyst.

The search for sustainable alternatives in chemical production, with a focus on renewable sources, has been driven by the environmental challenges posed by the consumption of fossil fuels. Biomass, as the sole sustainable source of organic carbon, is an ideal pathway to mitigate global warming and transition towards a circular economy. Among biomass-derived chemicals, furfural stands out as a key platform molecule, ranking among the top biomass-derived platform chemicals according to the U.S. Department of Energy. Derived from lignocellulosic biomass, furfural is an aromatic aldehyde with a molecular structure containing a carbonyl group (C=O) attached to a furan ring. Furfural is a versatile precursor for numerous valuable chemicals, including furfuryl alcohol.

To produce furfuryl alcohol, the aldehyde group (C=O) must be hydrogenated while preventing both furan ring hydrogenation and over-reductions that lead to unwanted byproducts. Furfural hydrogenation can occur in either the gas or liquid phase, with the latter offering higher selectivity. Traditionally, the required hydrogen is supplied externally. A more sustainable and atom-efficient alternative is to generate hydrogen in situ via aqueous-phase reforming (APR) of organic compounds, enabling a tandem APR + hydrogenation reaction. We are working on the influence of the metal (Ni, Co, Cu, and their combinations), the reforming substrate (methanol, formic acid, formaldehyde), and operation conditions (T, P, residence time, …) on furfuryl alcohol yield in this tandem process.

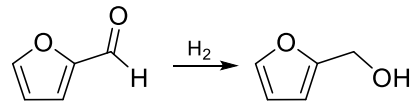
H_2 production

$CH_3OH + H_2O \rightarrow CO_2 + 3H_2$

$HCOOH \rightarrow CO_2 + H_2$

$HCHO + H_2O \rightarrow CO_2 + 2H_2$

Selective hydrogenation



Furfural Furfuryl Alcohol

In terms of heterogeneous catalysis, the catalyst must fulfill a dual function: (I) generate hydrogen through Aqueous Phase Reforming (APR) and (II) facilitate the selective hydrogenation of the carbonyl group (C=O). To achieve this, the catalytic activity of selected metal aluminates is evaluated. Upon reduction, these materials generate highly dispersed metal nanoparticles. The reactions are carried out in a fixed bed down-flow reactor to improve the H_2 residence. We optimize the substrate/furfural ratio, operating temperature, pressure, contact time, and correlate these variables with the catalyst structure.

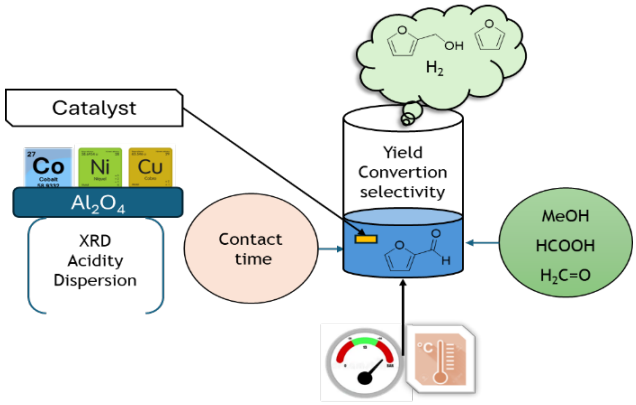


Figure 1. Catalytic optimization by APR + SH.

Figure 1 shows a flow diagram of a catalytic process, related to the aqueous reforming of furfural and the conversion into chemical products of interest, analyzing the structure using techniques such as X-ray diffraction (XRD), acidity and metal dispersion, among other characteristics. Additionally, the influence of contact time, temperature, and pressure is emphasized, as these factors significantly impact yield, conversion, and selectivity.

CO_2 direct air capture and conversion to CH_4: towards a carbon-neutral energy system

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KEY WORDS: CO_2 capture, direct air capture, polyethylenimine, SBA-15, carbon capture and utilization, CO_2 sorption and conversion to CH_4, modeling and simulation.

Climate change is one of the most pressing global challenges, driven primarily by the steady rise in greenhouse gas (GHG) emissions, particularly carbon dioxide. To avoid an energy and environmental crisis, it is necessary to create a sustainable energy system. This implies a profound change in energy sources, moving away from a system based solely on fossil fuels. However, renewable energies are being implemented slowly and there is a clear need to develop alternative technologies that reduce CO_2 emissions.

Thereby, the development and deployment of effective carbon capture technologies is crucial. The captured CO_2 can be used as a feedstock in the production of fuels, chemicals or building materials, as proposed by the carbon capture and utilization (CCU) approach. CCU technology can also provide a pathway to store large amounts of renewable energy through energy vectors. It is widely accepted that relying on renewable energy resources is the most promising method to free ourselves from dependence on fossil fuels in the near future. However, one of the main drawbacks of renewable energy is the intermittent nature of its source. As a result, energy storage technologies will become an essential part of future energy systems.

More specifically, surplus renewable electricity can be used to produce green hydrogen through electrolysis. H_2 has a high calorific value, but its storage and transport imply many challenges. Therefore, the catalytic conversion of renewable H_2 and captured CO_2 into methane, to form synthetic natural gas (SNG), i.e. power-to-methane (PtM) technology, appears to be a more suitable approach. These technologies convert CO_2 into value-added products, closing the carbon balance with net zero emissions if the CO_2 has a renewable source to avoid the delayed emission of fossil CO_2 when the fuel is burned. The direct air capture (DAC) strategy proposes extracting CO_2 directly from the atmosphere, which implies capturing it from highly diluted CO_2 streams, around 416 ppm, at ambient temperature.

Solid sorbents have a major energy advantage over traditional CO_2 capture methods using aqueous amines since they require less heat for their regeneration as there is no need to heat a liquid. Sorbents based on amine-functionalized mesoporous silica are suitable materials for this purpose. In this work, the mesostructured silica SBA-15 is used as the sorbent support due to its uniform structure, large specific surface, and large pore volume. On the other hand, polyethylenimine (PEI) is selected as functionalizing amine because of its high amine content and stability. In the development of our work, those sorbents have been synthesized and successfully tested as CO_2 DAC sorbents. The CO_2 capture and catalytic conversion into methane process has also been performed in a two fixed bed system. The sorbent, located in the capture unit, is saturated with CO_2 under DAC conditions, then the CO_2 is released by increasing the temperature and fed to the catalytic reactor together with H_2 to produce CH_4 and water.

The complexity of the CO_2 capture and conversion system and the thermodynamic difficulties of the methanation reaction, make plant design a critical factor for its optimal operation. Therefore, computer modeling and simulation of the process can be of great help to optimize reactor design while minimizing resources. Thus, in this work we have also simulated both, the CO_2 capture and conversion stages to take the first steps towards process optimization.

Thermochemical processes for waste valorization

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KEY WORDS: pyrolysis, waste, gasification.

Exponential population growth and the improvement of living standards in recent decades have led to an increase in energy demand, which has been largely supplied by fossil fuel energy [1]. The production of energy from this source is not only limited, but also very detrimental to the environment, as it is one of the main causes of both air and water pollution and global climate change [2]. The development of thermochemical processes (such as pyrolysis and gasification) is not only an alternative route to mitigating greenhouse gas emissions but also for waste valorization.

In our research line, the pyrolysis and gasification of biomass (sawdust, orange peel, rice husk, microalgae and sewage sludge) and plastics (HDPE, LDPE, PP, PS and PET) have been studied, as well as the pyrolysis of tires. Additionally, pyrolysis volatiles have been treated through subsequent stages of reforming, cracking, or CO_2 capture. For this purpose, pilot plants consisting of a first stage in a conical spouted bed reactor where pyrolysis, gasification or cracking take place and a fixed or fluidized bed reactor for the second stage have been used (Figure 1).

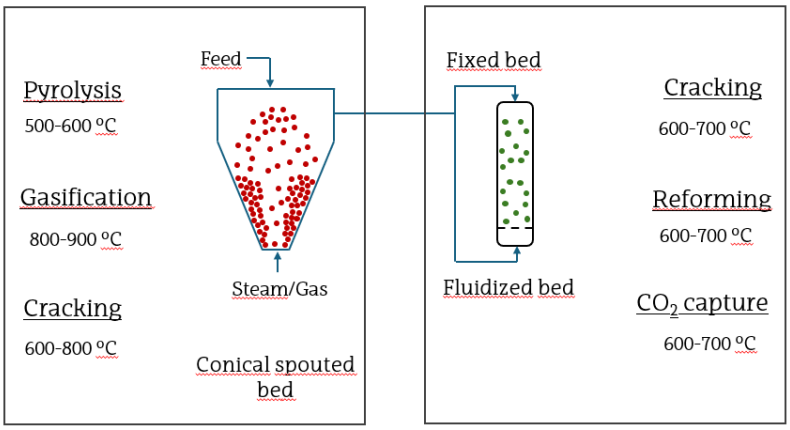

Figure 1. Schematic representation of the two-stage system.

Regarding the main products obtained from these processes, H_2, syngas, olefins and BTX are the most relevant ones. The main applications for these products are:

- H_2: Refining processes, ammonia production, fuel cells.
- Syngas: Energy generation, production of synthetic fuels (Fischer-Tropsh, methanol and DME synthesis).
- Olefins and BTX: Polymer and chemical product production, blending with conventional fuels or substituting them, production of plastic and synthetic fibers, industrial solvents and raw materials for pharmaceuticals and cosmetics.

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Cascade Reactors Strategy for Olefin Production from CO and CO_2

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KEY WORDS: Cascade reactors, Olefins, CO_2

Mitigating climate change requires reducing energy and carbon intensity while advancing on CO_2 capture and utilization technologies. The viable valorization of CO_2, to compensate for the cost of its capture and storage, consists in its conversion into added value products, through routes capable of activating the stable structure of CO_2. Among these routes, catalytic processes for the production of liquid fuels and petrochemical raw materials such as olefins and aromatics present the best prospects. One of the most promising strategies is the direct production of olefins (CTO) using a bi-functional OX-ZEO catalyst (metal oxide-zeolite), in which the metallic function catalyzes the synthesis of methanol/DME, while the acid function converts these oxygenates in situ into olefins. Nevertheless, this process faces limitations due to the difficulty of unifying the reaction conditions of both stages [1]. To address this limitation, this work proposes a two-stage approach with cascade fixed-bed reactors: one for the conversion of CO/CO_2 into methanol and dimethyl ether, using CuZn/ZrO as a metal catalyst, and another for the transformation of methanol into olefins (MTO), using SAPO-34 (silicoaluminophosphate) and SSZ-13 (aluminosilicate zeolite) as acid catalyst [2].

The runs have been carried out in a fixed bed reactor (Microactivity Reference, PID Eng. Tech.) connected on-line to a Varian CP4900 micro gas-chromatograph for the continuous analysis of the products. A wide range of reaction conditions has been tested. For the first step, the reactions were carried out at 280-260 ºC and 20-30 bar. Space time was varied from 2.5 to 7.5 g h mol_C^{-1}. The feed gas composition consisted of a $CO_2/(CO+CO_2)$ ratio of 0.5-1, and a $H_2/(CO+CO_2)$ ratio of 3 (time on stream, up to 60 h). At the maximum methanol yield, the output from this first stage was fed to the second reactor for the MTO reaction. SSZ-13 and SAPO-34 activity was studied at 350-450 ºC and 1-30 bar. All runs for MTO reactions were conducted with a space time of 30-60 g h mol_{MeOH}^{-1} respectively (time on stream, 20 h or complete deactivation). Figure 1 shows a maximum of 10% methanol in the first reactor for a $H_2/CO/CO_2$=3/0.5/0.5 feed. Using this product distribution as a reference to feed the second reactor, Figure 2 shows the evolution with time on stream of the yields of products in the second reactor, where a maximum of 70% yield of olefins was obtained.

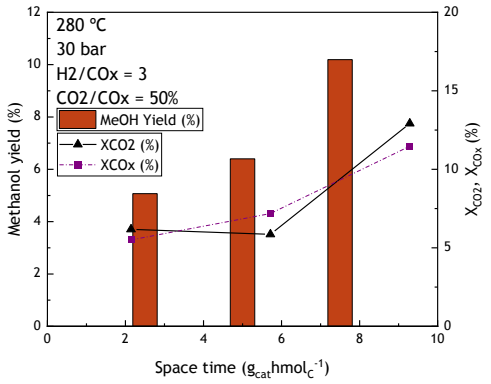

Figure 1. Effect of space time on the methanol yield using as feeds: $H_2/CO/CO_2$: 3/0.5/0.5. Reaction conditions: 280°C; 30 bar.

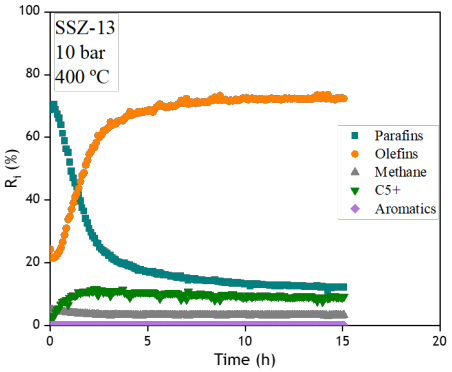

Figure 2. Evolution with time on stream of the yields of the final products Reaction conditions: 400°C; 10 bar; Catalyst: SSZ-13. Feed: $H_2/CO/CO_2/MeOH/H_2O$

Acknowledgements
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