Cosmology and spacetime physics

IPARCOS Scientific Advisory Board: Bi-Annual Review 2026

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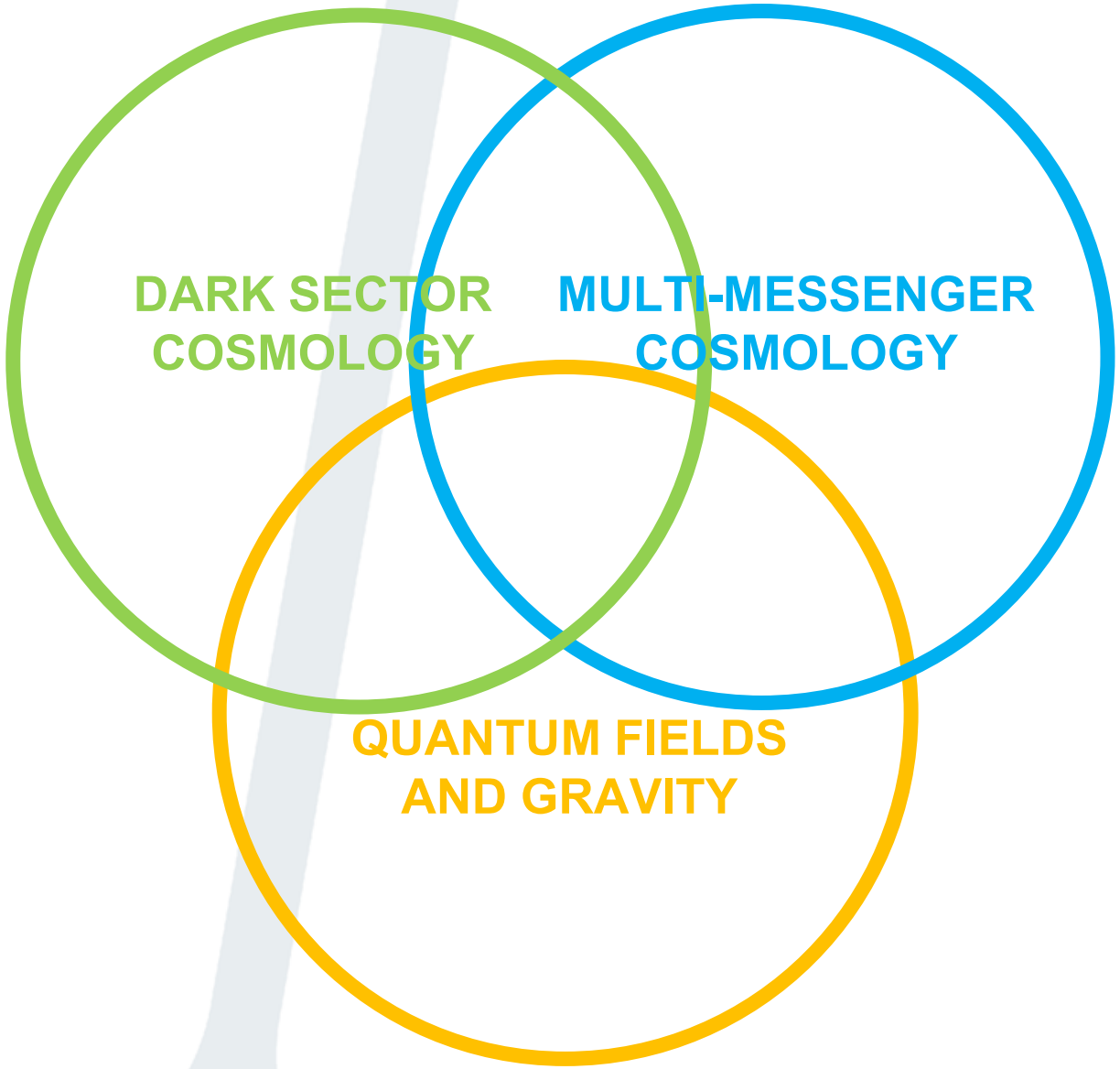
IPARCOS

UNIVERSIDAD COMPLUTENSE MADRID

Cosmology Group's Overview



Cosmology Group's Overview

Group Snapshot

- **Quantum fields and Gravity**
- **Current Size:** 4 senior + 4 junior postdocs + 4 PhD students
- **Key Personnel Changes:** Attracted one ATRAE researcher (plus 3 postdocs and 2 PhD students under his grant). One PhD student promoted to PAD.

Key Performance Indicators

- **High-Impact Publications:** 23 peer-reviewed papers in Q1 journals, 1 of them PRL ("No Black Holes from Light")
- **Funding Secured:** 845000 € (ATRAE, IP: D. Oriti) + 45500 € (PID2023, IPs: M. Martin-Benito, L.J. Garay)
- **Final stage of evaluation before approval:** 3.5M € (Templeton Foundation Grant, Co-IP: D. Oriti)
- **Training:** 2 PhD theses defended.

Cosmology Group's Overview

Group Snapshot

- **Dark sector cosmology**
- **Current Size:** 2 senior + 4 PhD students
- **Key Personnel Changes:** During 2024 three postdocs left IPARCOS (one for a permanent position and the others for postdocs).

Key Performance Indicators

- **High-Impact Publications:** 20 peer-reviewed papers in Q1 journals.
- **Funding Secured:** 80 750 € (PID2022, IPs: A. López Maroto and P. Martín Moruno), submission for PID2025.
- **Training:** 2 PhD theses defended.

Cosmology Group's Overview

Group Snapshot

- **Multi-messenger Cosmology**
- **Current Size:** 2 senior + 1 postdoctoral research + 5 PhD students
- **Key Personnel Changes:** 3 PhD students defended their thesis in 2024. During 2025, 1 postdoc and 2 PhD student joined the group,

Key Performance Indicators

- **High-Impact Publications:** 25 contributions, including Einstein Telescope BlueBook, CosmoVerse COST Action CA21136 White Paper and 18 peer-reviewed papers in Q1 journals.
- **Funding Secured:** 50 000 € (Leonardo BBVA Fellowship, IPs: J. Rubio): 31 000 € (PID2022, IPs: J.A.R. Cembranos and J. Rubio), submission for PID2025.
- **Training:** 3 PhD theses defended (2 IST Lisbon, 1 UCM).

Cosmology Group's Overview

Top Scientific Highlights

- **Highlight 1:** Published in Nature Astronomy (2025), the paper "Detection of an orthogonal alignment between parsec-scale AGN jets and their host galaxies," co-authored by J. Asorey among others, analyzes 6,273 galaxy–AGN pairs to reveal a significant alignment between SMBH jets and the minor axis of host galaxies.
- **Highlight 2:** The article "No black holes from light", co-authored by Á. Álvarez-Domínguez and L. J. Garay among others, was awarded for the Physical Review Letters "Collection of the Year 2024". It ranks in the top 0.3% of all-time research impact globally and is the second highest-impact paper in terms of social reach in the journal's period. The findings were featured in Nature Research Highlights and international mainstream media like Europa Press.

Leadership, Internationalization & Impact

- **Major Roles:**
  - D. Oriti: Chair of the International Society for Quantum Gravity and board member of the International Society on Loop Quantum Gravity.
  - M. Martín-Benito: Board member in the Spanish Society for Gravitation and Relativity.
  - J.A.R. Cembranos: Council member in the European Consortium for Astroparticle Theory (EuCAPT).
  - J. Rubio: Coordinator of IPARCOS members (4 of them core members) of the Laser Interferometer Space Antenna (LISA).
  - P. Martin-Moruno: Member of Euclid.
  - A.L. Maroto: Member of Javalambre Physics of the Accelerating Universe Astrophysical Survey (J-PAS).

The Horizon

- **Next Big Milestone:** LISA CosWG project on "Reinterpreting GW Signals from PTs in Particle Physics Model Parameter Space"

Cosmology Group's Overview

Leadership, Internationalization & Impact

- **Recognitions and invited plenary talks (selection):**
  - D. Oriti: "Gravitational dynamics in analogue systems: a proposal", Quantum Gravity in the lab, Heidelberg University, Heidelberg (Germany) Jun 2024.
  - A.L. Maroto, "Cosmology with broken diffeomorphisms". ATHens symposium on EXploring the unIverSe ATHEXIS, Athens (Greece), Jun 2024.
  - M. Martín-Benito: "Loop Quantum Cosmology and the trans-Planckian problem", XXVI SIGRAV Conference on General Relativity and Gravitation, University of Milano–Bicocca, Milan (Italy) Sep 2025.
  - J.A.R. Cembranos: "Hidden Gravitons Phenomenology", Ultralight Dark Matter and observable phenomena Focus Week, SISSA & IFPU, Trieste (Italy), Oct 2025.
  - J. Rubio: "Hubble-induced phase transitions in the Standard Model and Beyond", workshop "High Energy, Cosmology and Astroparticle Physics" at NYU Abu Dhabi (Emirates), Jan 2026.
  - D. Oriti: "Emergent spacetime and cosmology from quantum gravity", workshop "Concepts of quantum and spacetime" at KEK, Tsukuba (Japan), Mar 2026.
  - J. Rubio: "Inflationary Cosmology: "Theory, Data, and Future Probes", "LIII International Meeting on Fundamental Physics" at Granada Univ., May 2026.
- **Tech Transfer / Outreach**
  - Service and Learning project: APSCONCIENCIA: Promotion of STEM vocations in underrepresented social groups
    Funding entity: Complutense University of Madrid. Years: 2024-2026.
  - COSMOCINE: Activity of the Madrid Science Week at UCM. Dates: November 2024, November 2025.
  - Members of the Scientific Theater CSIC Group: TeatrIEM sponsored by FECYT project.
  - Participation in the outreach book: ¿Y si el Universo no es como pensamos? SEGRE edited.
  - M. Martin-Benito is Dean's Delegate for sustainability (e.g. coordinator of female mentorship program).

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Research lines

Scientific results: Quantum Fields & Gravity

QFT in nontrivial backgrounds

- Progress in our understanding of particle creation phenomena in QFT, such as in the context of the Schwinger effect: No black holes from light in realistic circumstances.
- Consideration of modified dispersion relations in cosmology: new regularization scheme for the two-point correlation function (adiabatic regularization does not work in general with MDRs)
- Analysis of spatial curvature effects and uncertainties in gravitational production, development of covariant pointer variables and detector responses in non-trivial backgrounds
- Weyl transverse gravity from the thermodynamics of stretched light cones, Loop Quantum Gravity to cosmology via vertex models and no-hair results for ultracompact objects

Quantum gravity hydrodynamics and emergent cosmology

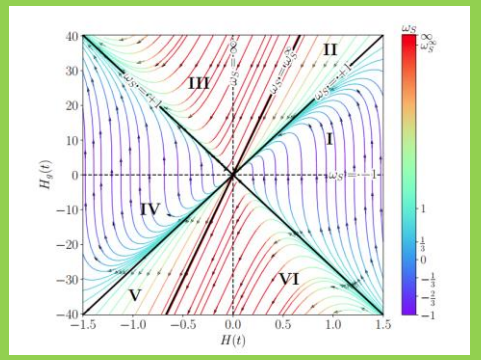
- Development of general strategy for extracting effective cosmological dynamics from quantum gravity models, treated as quantum many-body systems
- Cosmic Acceleration from Quantum Gravity: Emergent Inflation and Dynamical Dark Energy
- Effective dynamics for cosmological perturbations, incorporating quantum gravity effects

Research lines

Scientific Results: Dark sector cosmology

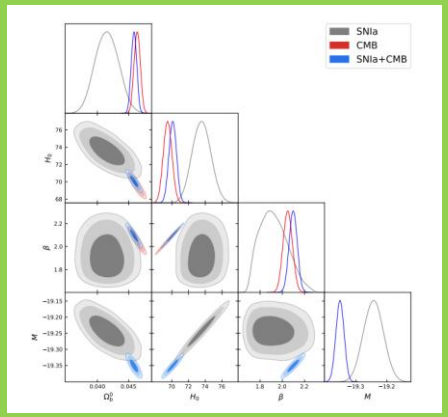
Unveiling the fundamental physics of the dark sector:

- Symmetries of the dark sector: development of models with broken diffeomorphisms. Stability and energy conditions. Generalized TDiff theories for spin 0, 1, ½ and 2. TDiff cosmological perturbation theory.
- Non-canonical Lagrangians: shift-symmetric Lagrangians with non-canonical kinetics terms



Phenomenology of the dark sector:

- Interactions of the dark sector: TDiff models with several scalar fields. Confrontation with SNIa, CMB and LSS data. Broken diffeomorphisms in the visible sector: TDiff Maxwell theory and the origin of cosmological magnetic fields.
- Compact objects and cosmic singularities: gravitational implications of violations of energy conditions
- Gravitational waves: effects of broken symmetries in the generation, propagation and polarizations of GW.



Testing the dark sector with extragalactic surveys:

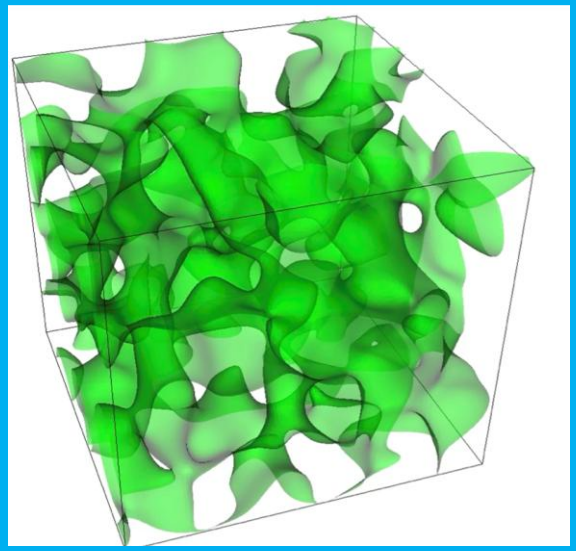
- Testing the dark sector with J-PAS; forecasts for dark energy and neutrino masses
- Testing the dark sector with radio continuum surveys and 21 cm intensity mapping: testing dark energy with SKAO Pathfinder, cross correlation with DESI and Euclid

Research lines

Scientific results: Multi-messenger Cosmology

Early-Universe dynamics and gravitational waves

- Non-linear post-inflationary dynamics in extended gravity: reheating, oscillon formation, gravitationally induced phase transitions and primordial GW backgrounds.
- Gravitational-wave propagation as a probe of modified gravity, including massive spin-2 fields and their detectable imprints in current and future GW observatories.
- Higgs vacuum stability, non-minimal gravitational couplings and early-Universe instabilities as sources of observable GW signals.
- Participation in LISA-oriented efforts to reinterpret stochastic GW signals from cosmological phase transitions in terms of particle-physics model parameters.



Dark matter and cosmological probes

- Gravitational and non-thermal dark matter production after inflation: freeze-in, curvature-induced mechanisms and phase-transition-driven scenarios.
- Cosmological and astrophysical signatures of dark sectors: ultralight DM, sterile neutrinos, axion-like particles, WISPs and gamma-ray/GW signals.
- Collider and precision observables of DM candidates.
- Data-driven confrontation of fundamental-physics models with current and future cosmological surveys through inference and forecasts.