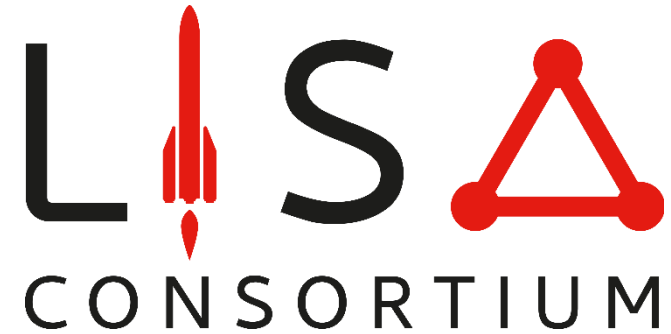


LISA @ ICCUB (Cosmology)

Jacopo Fumagalli

09/04/2026

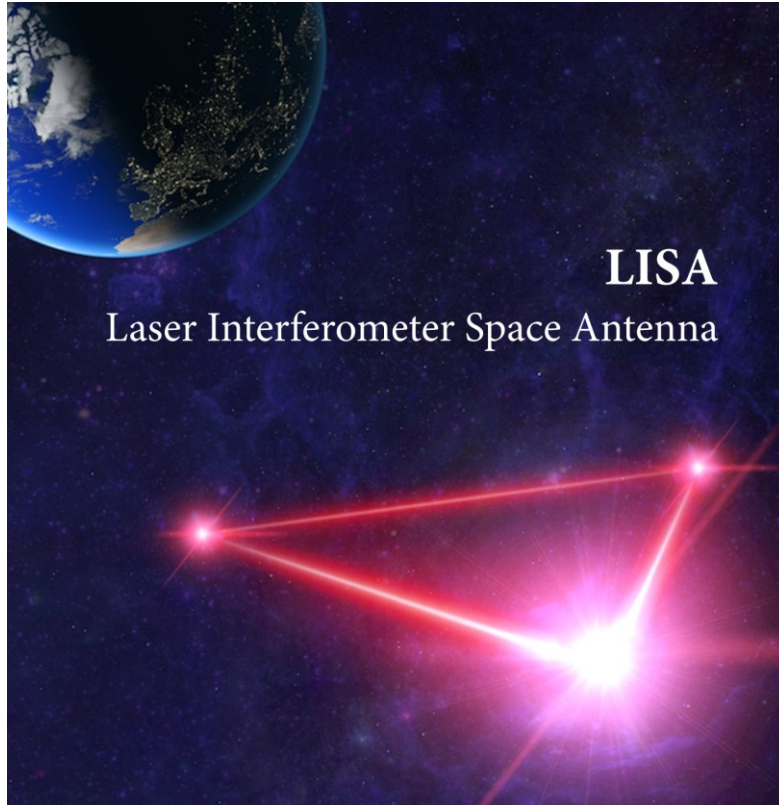
ICC – GW workshop



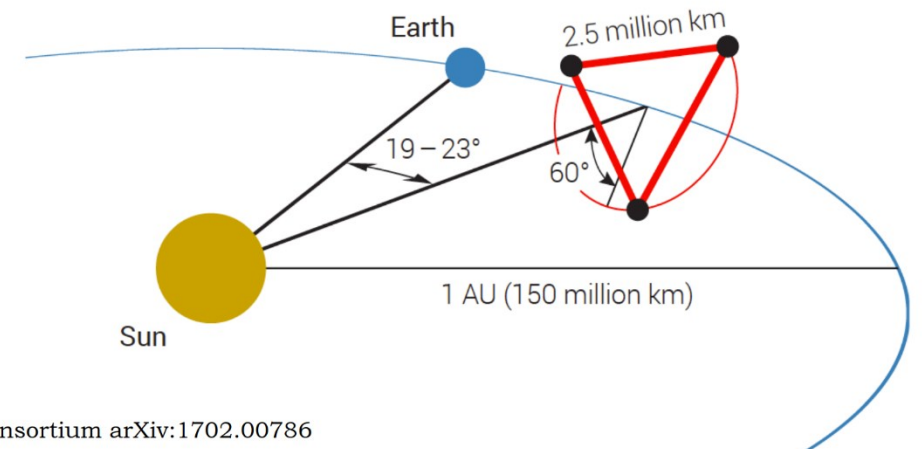
Institut de Ciències del Cosmos
UNIVERSITAT DE BARCELONA

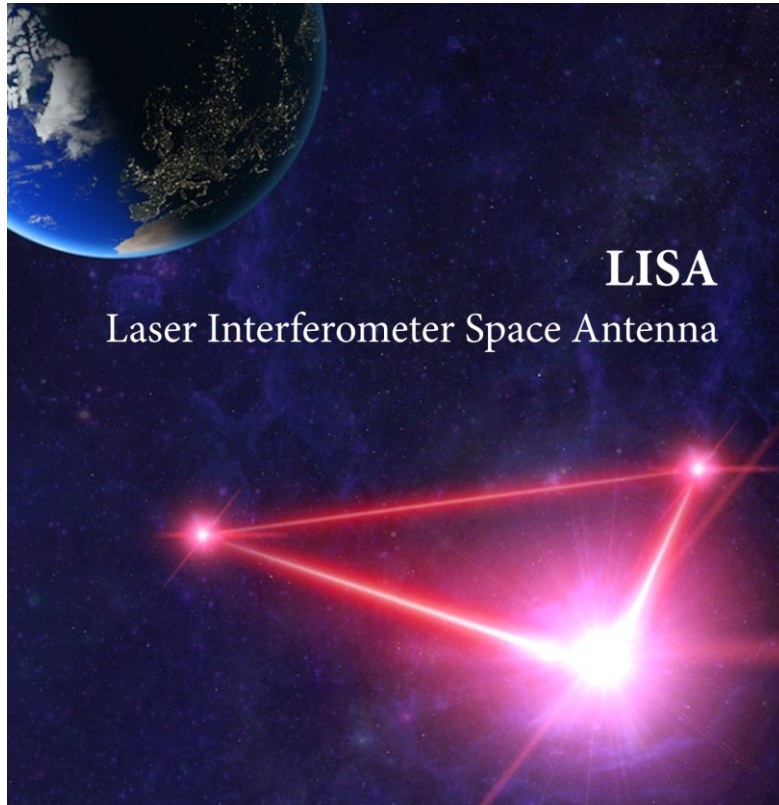
Outline

- Current efforts at ICCUB directly and indirectly related to LISA
- Current efforts within the LISA Cosmology WG directly and indirectly related to ICCUB activities (biased by my works)
- Brief description of the LISA Cosmology Working group (how to get actively involved, sign up etc)



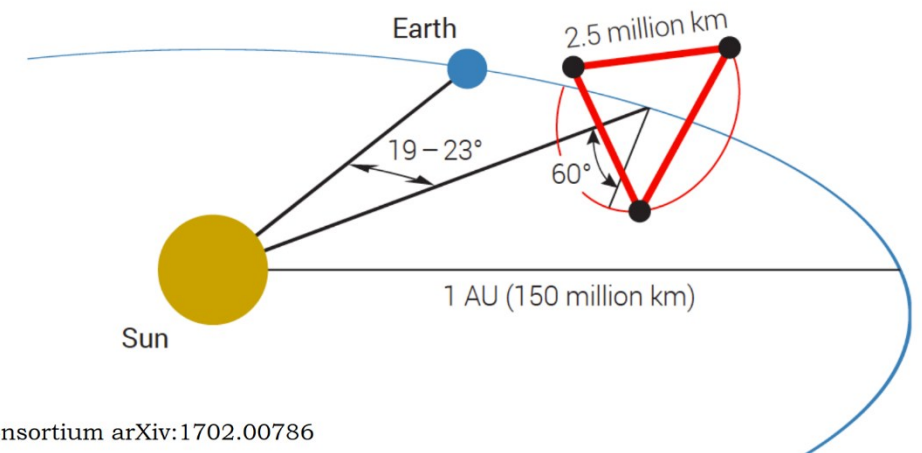
- Three satellites at 2.5 million km distance in eliocentric orbit
- Adopted in January 2024, i.e. ESA starts to build the experiment.
- Expected launched in 2035
- Recent reboot of the all consotrium in 2025 (many opportunities NOW)





Gravitational waves detectors in space:

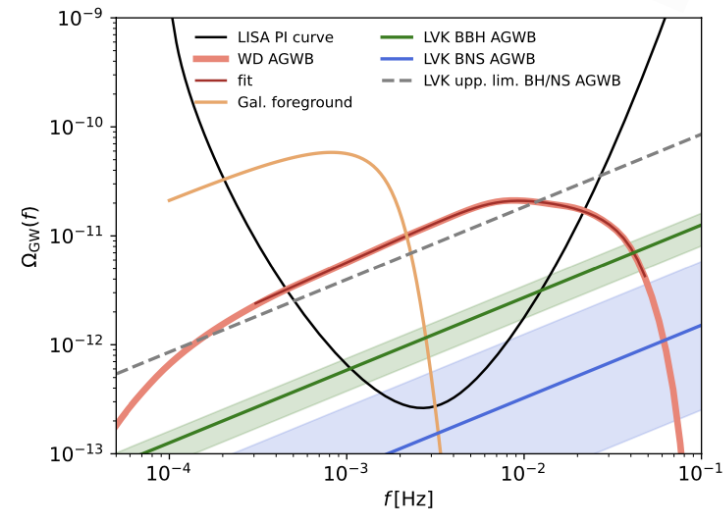
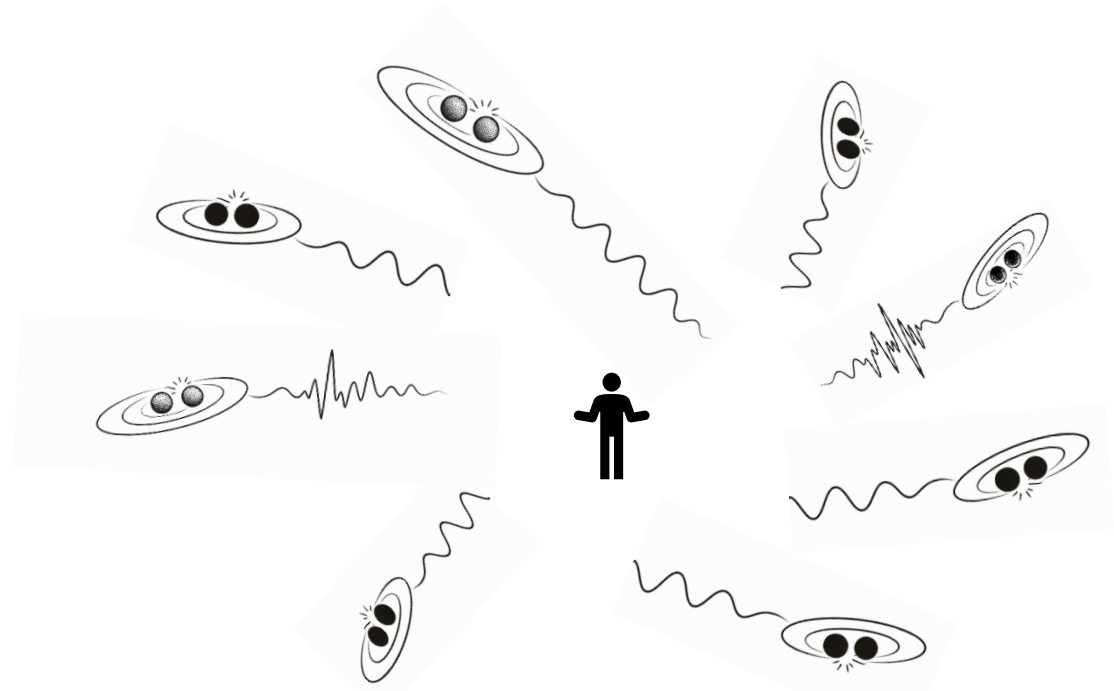
- No seismic noise
- Longer arms
- Lisa band: $10^{-4} \text{ Hz} < f < 1 \text{ Hz}$



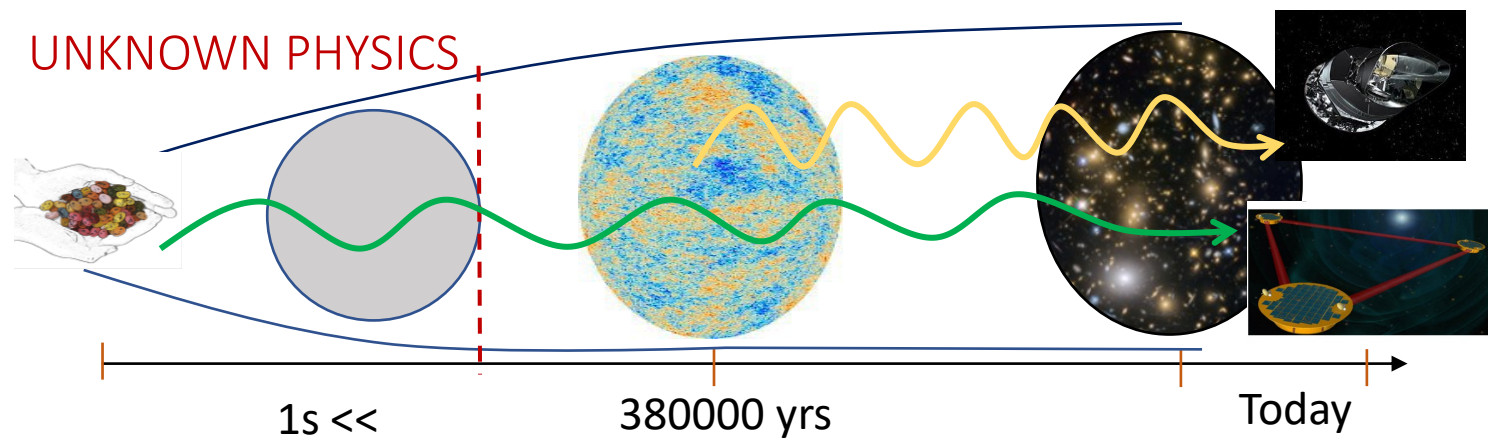
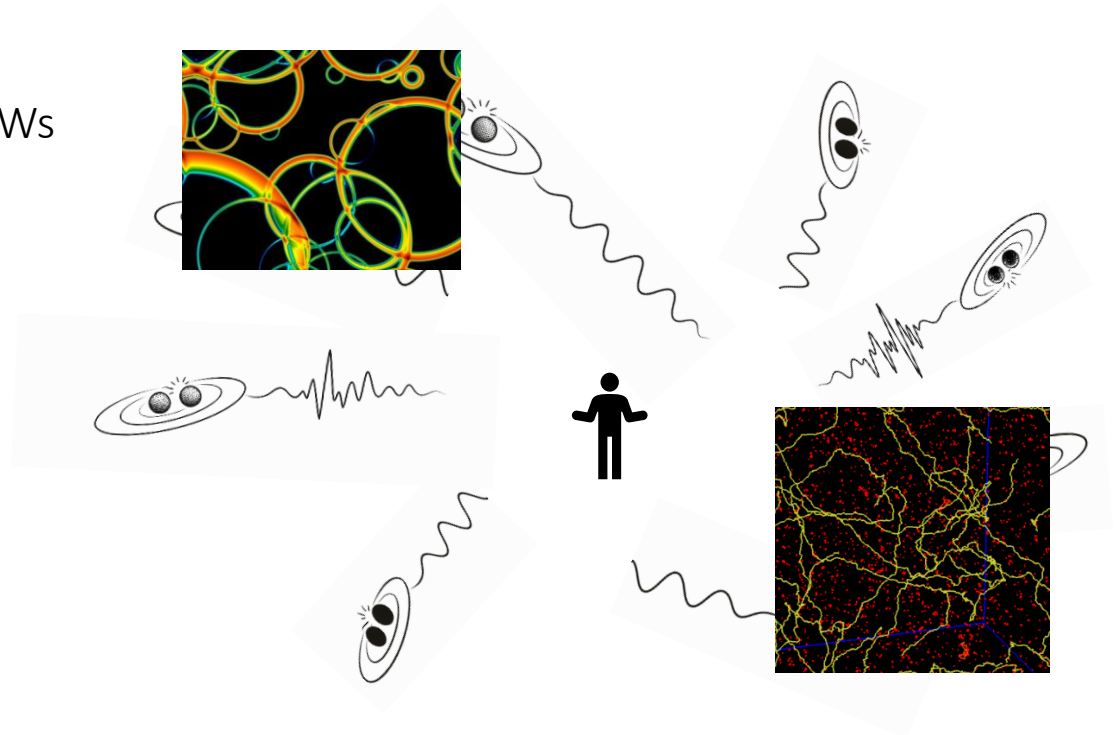
LISA consortium arXiv:1702.00786

- After 4 runs (**Ruxandra's talk**), approx. more than 200 binaries detected by LVK
- We learn a lot: fundamental physics/astrophysics...
- Several weak sources expected (one/per minutes to a few per hour)

→ Random signal produced by many independent and unresolved sources (pop-corn)



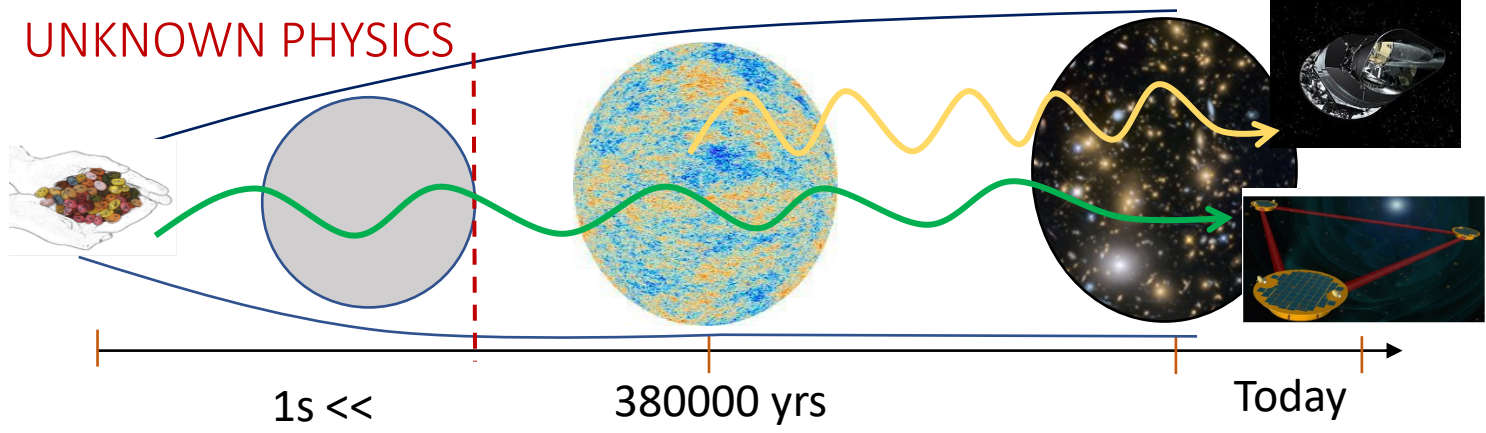
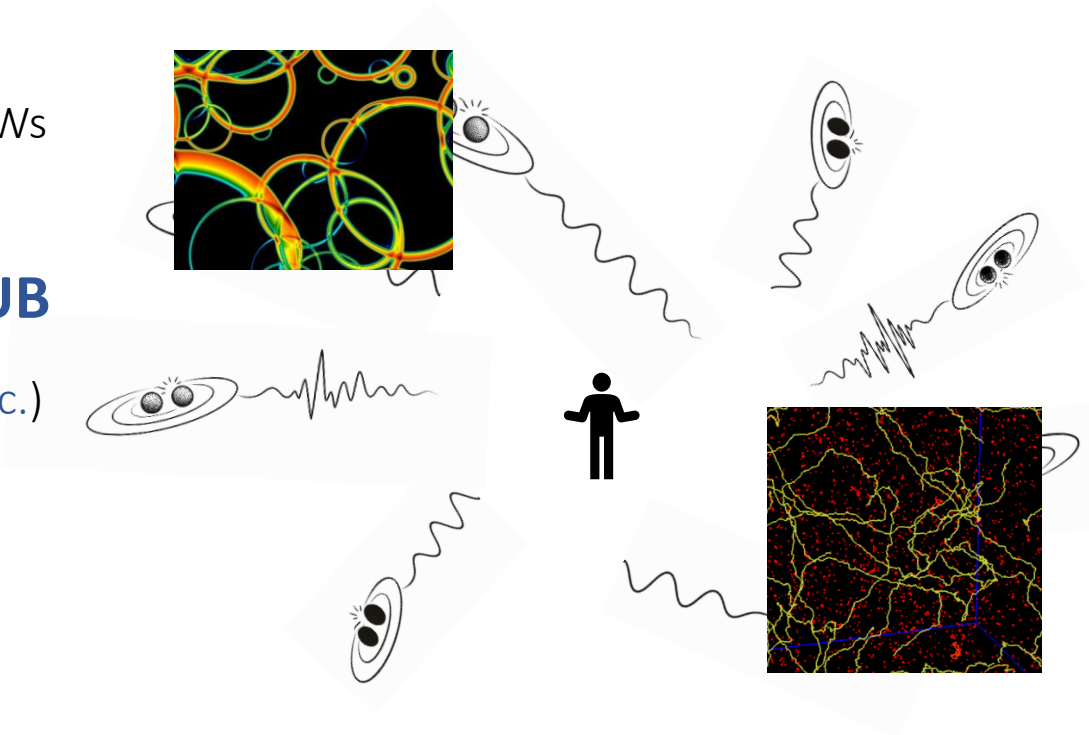
- LISA WILL TARGET THE DETECTION OF PRIMORDIAL GWs



- LISA WILL TARGET THE DETECTION OF PRIMORDIAL GWs

Cosmological sources (see J. Miralda's talk): [@ICCUB](#)

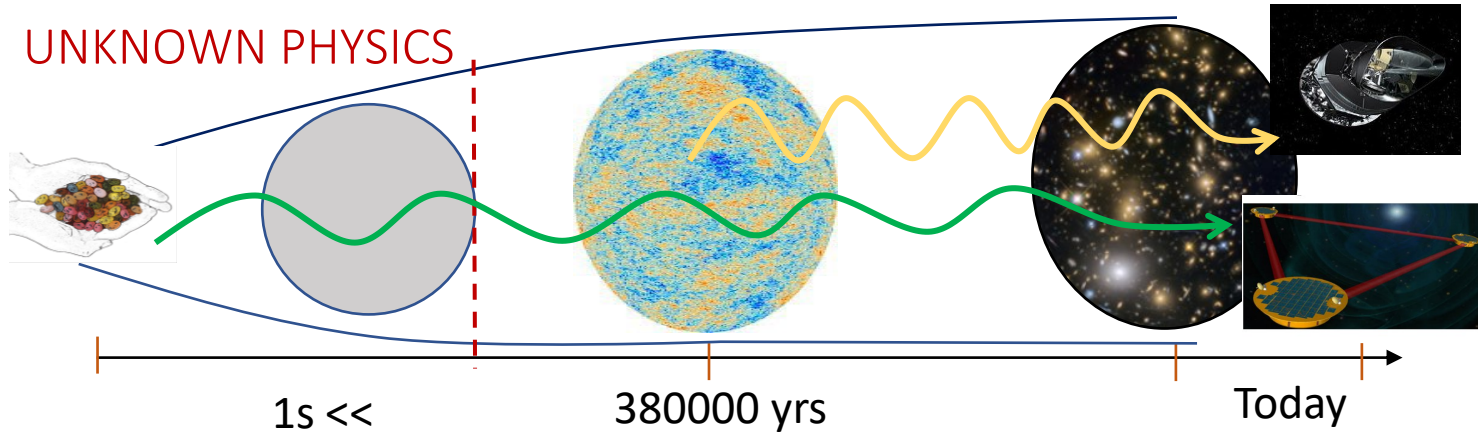
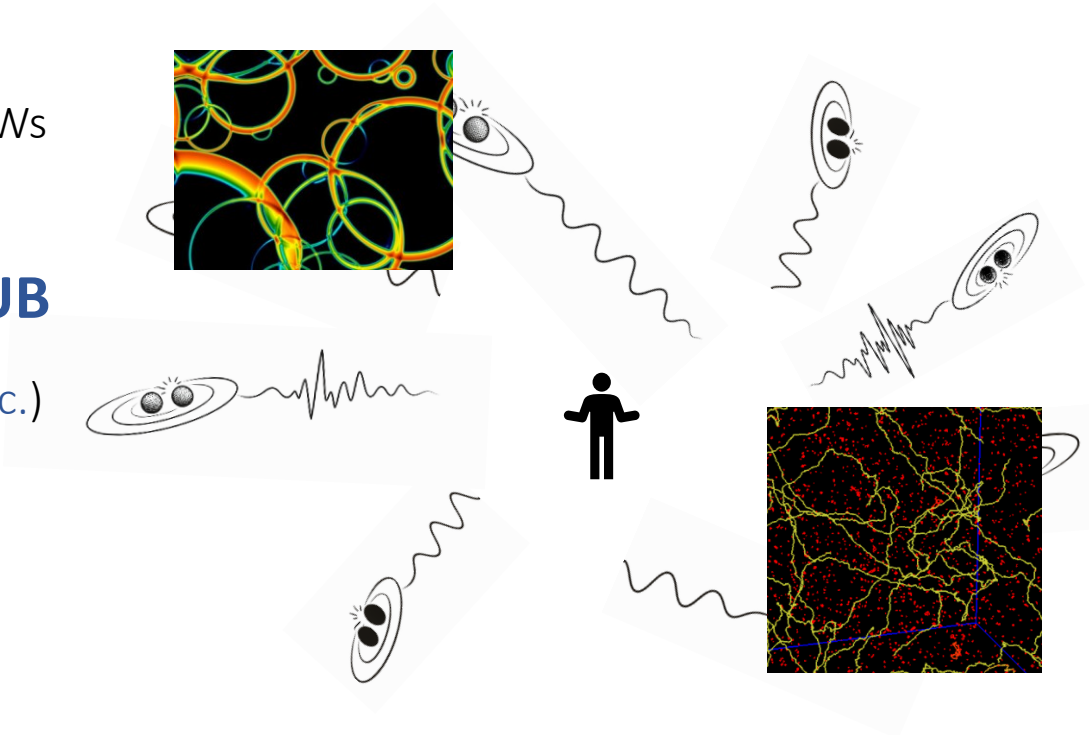
- Phase transitions (D. Mateos, M. Vanvlasselaer, etc.)
- Domain walls (A. Notari, F. Torrenti)
- Cosmic Strings
- Inflation (J. Fumagalli, J. Garriga, C. Germani..)



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Cosmological sources (see J. Miralda's talk): **@ICCUB**

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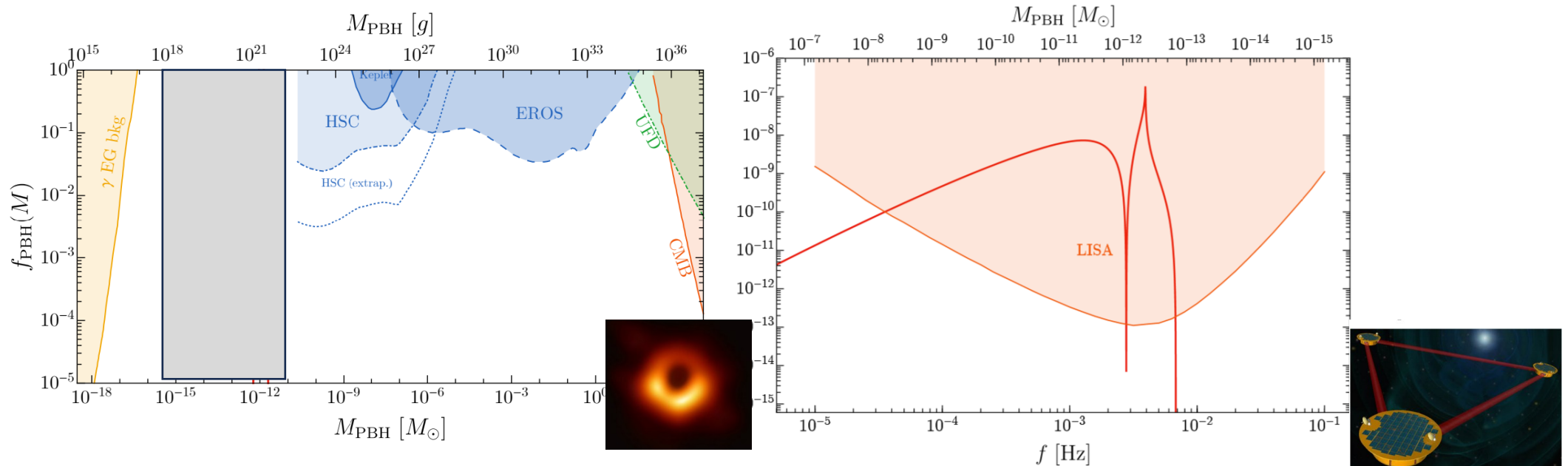


EXAMPLES: PBH / GWB & LISA COINCIDENCE

LISA Serendipity:

Primordial black holes can be the whole dark matter in a specific mass window,
That will imply GWs in the mHz!

Bartolo et al. '18

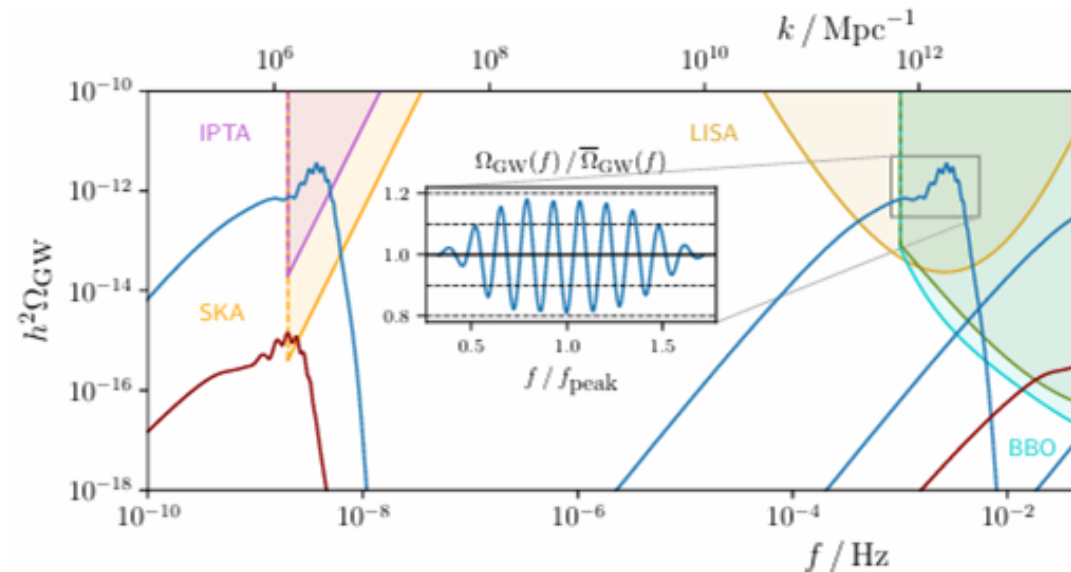


@ICCUB PBHs statistics: C. Germani, J. Garriga, V. Atal, A. Escriva, J. Fumagalli, L. Montella' ...

EXAMPLES – Primordial signals from inflation

Scalar induced GWs / primordial features:

$$\square h_{ij} = S_{ij}^{TT} \sim (\partial\zeta)^2$$



@ICCUB

JF, S. Renaux-Petel, L. Witkowski, '20 '21 '22 '23
+ G. Domenech, S. Sypsas, G. Palma, C. Zenteno
JF, A. Caravano in progress.

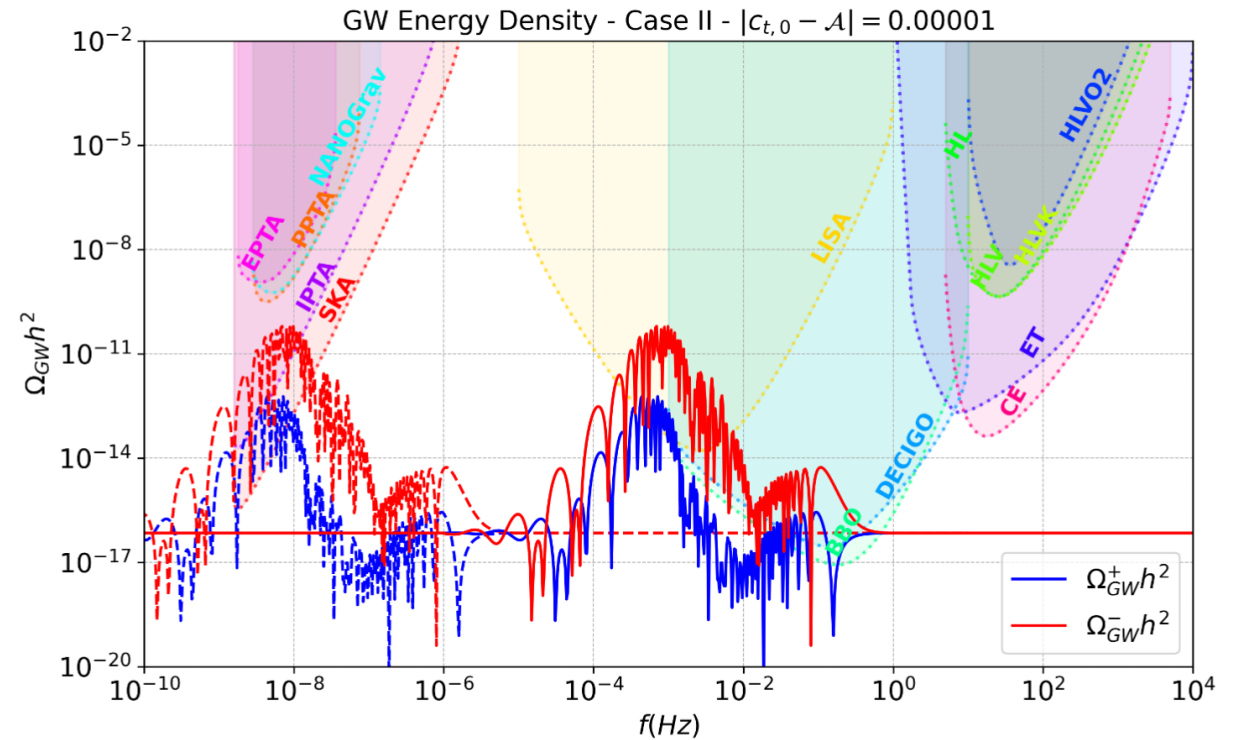
EXAMPLES – Primordial signals from inflation

Scalar induced GWs / primordial features:

$$\square h_{ij} = S_{ij}^{TT} \sim (\partial\zeta)^2$$

Extra spin-2 field:

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EXAMPLES – Primordial signals from inflation

Scalar induced GWs / primordial features:

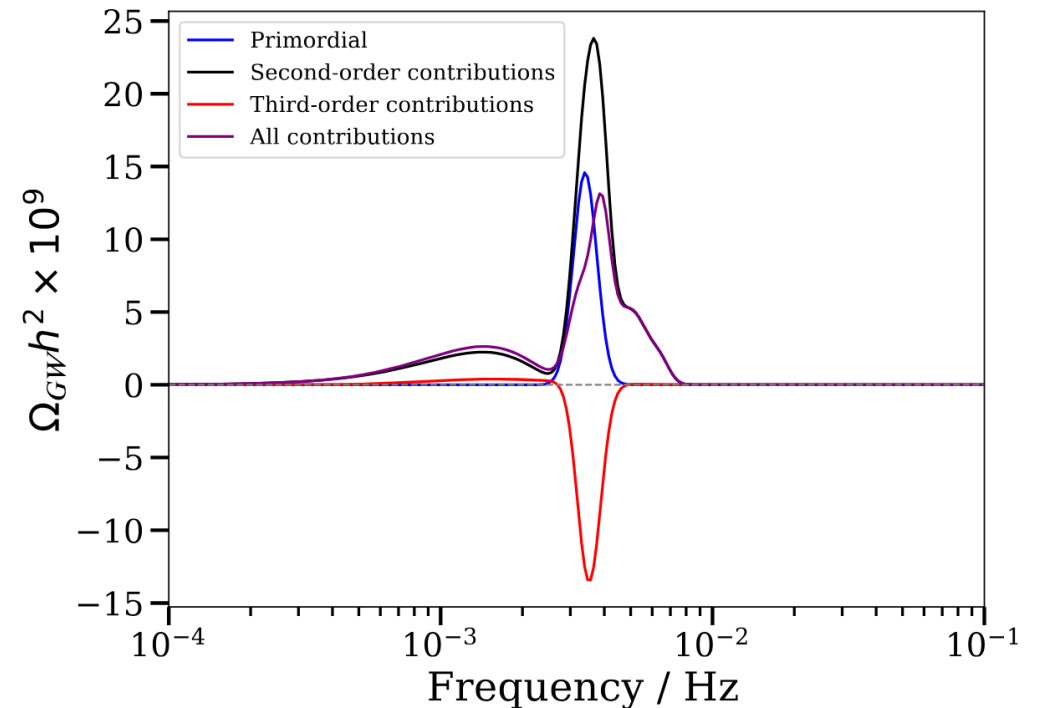
$$\square h_{ij} = S_{ij}^{TT} \sim (\partial\zeta)^2$$

Extra spin-2 field:

$$\square h_{ij} = S_{ij}^{TT} \sim t_{ij}$$

Beyond leading order: (ongoing TFG) @ICCUB

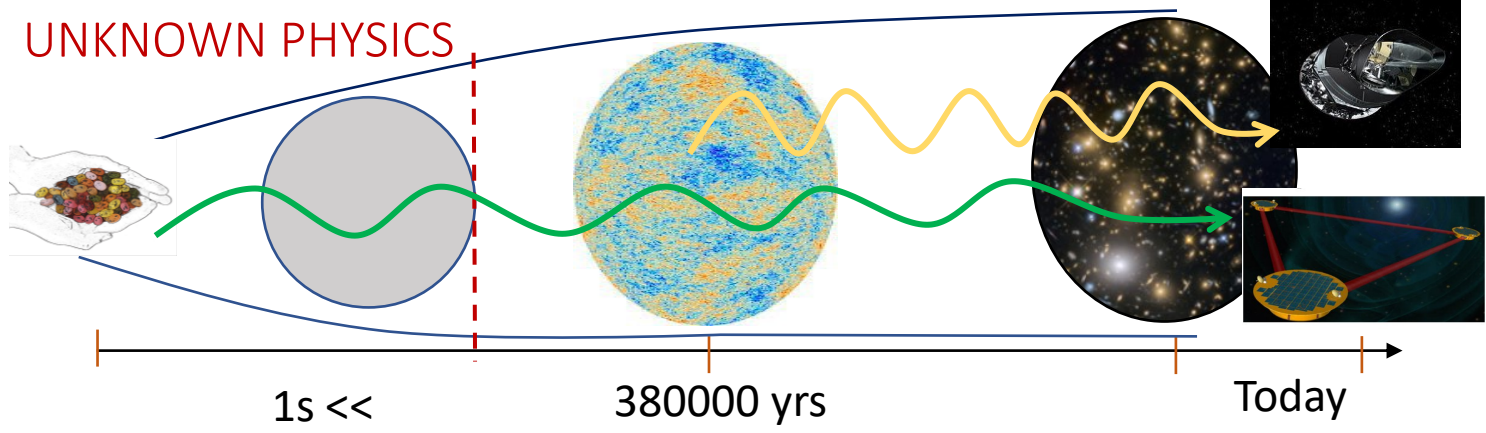
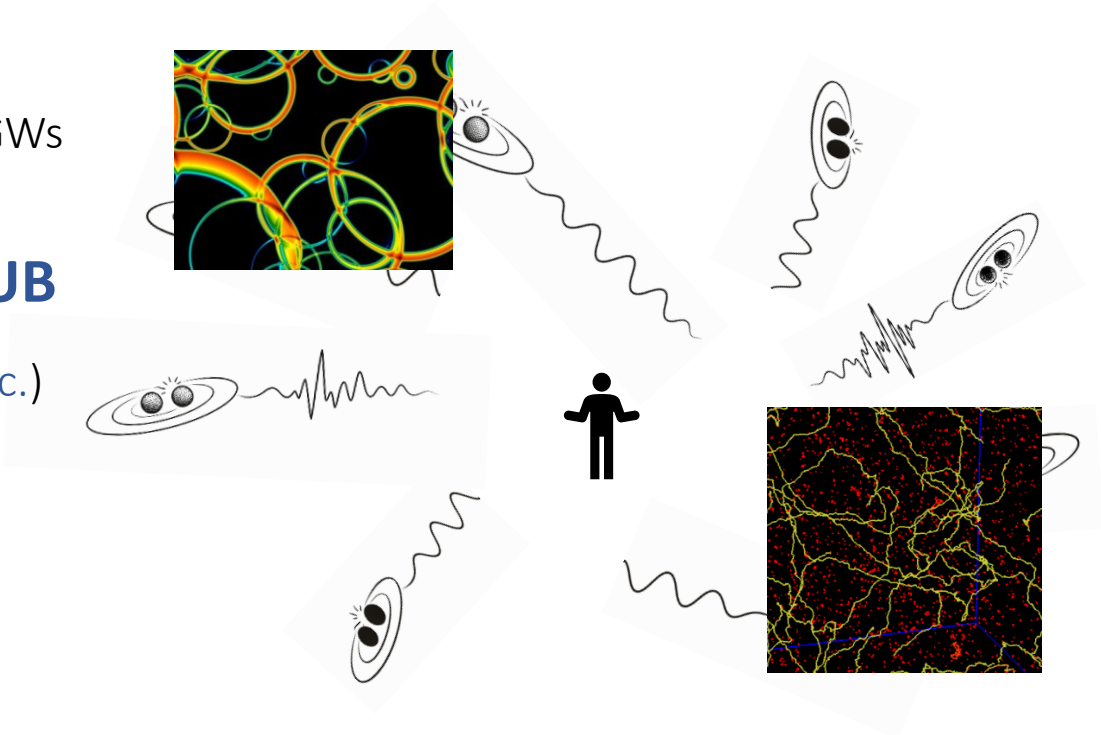
$$\square h_{ij} = S_{ij}^{TT} \sim \underline{h\zeta\zeta} + \dots$$



- LISA WILL TARGET THE DETECTION OF PRIMORDIAL GWs

Cosmological sources (see J. Miralda's talk): @ICCUB

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- LISA WILL TARGET THE DETECTION OF PRIMORDIAL GWs
- Cosmological sources triggered a lot of activity within the LISA COSMOLOGY WORKING GROUP



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CERN-TH-2024-072

Gravitational waves from inflation in LISA: reconstruction pipeline and physics interpretation

Matteo Braglia^{1,a}, Gianluca Calcagni^b, Gabriele Franciolini^c, Jacopo Fumagalli^{2,d}, Germano Nardini^{3,e}, Marco Peloso^{4,f,g}, Mauro Pieroni^{5,c}, Sébastien Renaux-Petel^h, Angelo Ricciardone^{i,j,f}, Gianmassimo Tasinato^{l,m}, Ville Vaskonen^{f,g,n}



Gravitational waves from first-order phase transitions in LISA: reconstruction pipeline and physics interpretation

Chiara Caprini,^{a,b} Ryusuke Jinno,^c Marek Lewicki,^{d,1} Eric Madge,^{e,2,*}
Marco Merchand,^{f,g} Germano Nardini,^{h,3} Mauro Pieroni,^{b,4} Alberto Roper Pol,^a
Ville Vaskonen^{i,j,k}



CERN-TH-2024-085

Gravitational waves from cosmic strings in LISA: reconstruction pipeline and physics interpretation

Jose J. Blanco-Pillado,^{a,b,c} Yanou Cui,^d Sachiko Kuroyanagi,^{e,f} Marek Lewicki,^{g,1}
Germano Nardini,^{h,2} Mauro Pieroni,ⁱ Ivan Yu. Rybak,^{j,k,l} Lara Sousa,^{k,l} Jeremy
M. Wachter^m

- LISA WILL TARGET THE DETECTION OF PRIMORDIAL GWs
- Cosmological sources triggered a lot of activity within the LISA COSMOLOGY WORKING GROUP
- Specific project on enhanced scalar fluctuations (Inflation)



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Reconstructing Primordial Curvature Perturbations via Scalar-Induced Gravitational Waves with LISA

Jonas El Gammal^{1,a}, Aya Ghaleb^b, Gabriele Franciolini^{2,c}, Theodoros Papanikolaou^{d,e,f},
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- LISA WILL TARGET THE DETECTION OF PRIMORDIAL GWs
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- Specific project on enhanced scalar fluctuations (Inflation)
- Motivated by Primordial Black holes dark matter



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Primordial black holes and their gravitational-wave signatures

Eleni Bagui^a, Sebastien Clesse^{1,a}, Valerio De Luca^b, Jose María Ezquiaga^c, Gabriele Franciolini^d, Juan García-Bellido^{2,e}, Cristian Joana^{f,g}, Rajeev Kumar Jain^h, Sachiko Kuroyanagi^{e,i}, Ilia Musco^{j,k}, Theodoros Papanikolaou^{l,m,n}, Alvisè Raccanelli^{o,p,q,d}, Sébastien Renaux-Petel^r, Antonio Riotto^s, Ester Ruiz Morales^{e,t}, Marco Scalisi^u, Olga Sergijenko^{v,w,x,y}, Caner Unal^{z,a2,b2}, Vincent Vennin^{e2}, David Wands^{d2}

- LISA WILL TARGET THE DETECTION OF PRIMORDIAL GWs
- Cosmological sources triggered a lot of activity within the LISA COSMOLOGY WORKING GROUP
- Specific project on enhanced scalar fluctuations (Inflation)
- Motivated by Primordial Black holes dark matter
- All that currently results in a LISA-ET synergy project



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cos-wg-2025-06

LISA-ET Synergy project on SGWB

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- 1) Initiate a motivated template bank
- 2) Estimate LISA accuracy and parameter reconstruction IF
 - Good noise model from ESA
 - Astro foregrounds modelled
 - Residual from binary waveform that not mimic a SGWB



JF + LISA CosWG
2407.04356

CERN-TH-2024-072

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JF + LISA CosWG
2501.11320

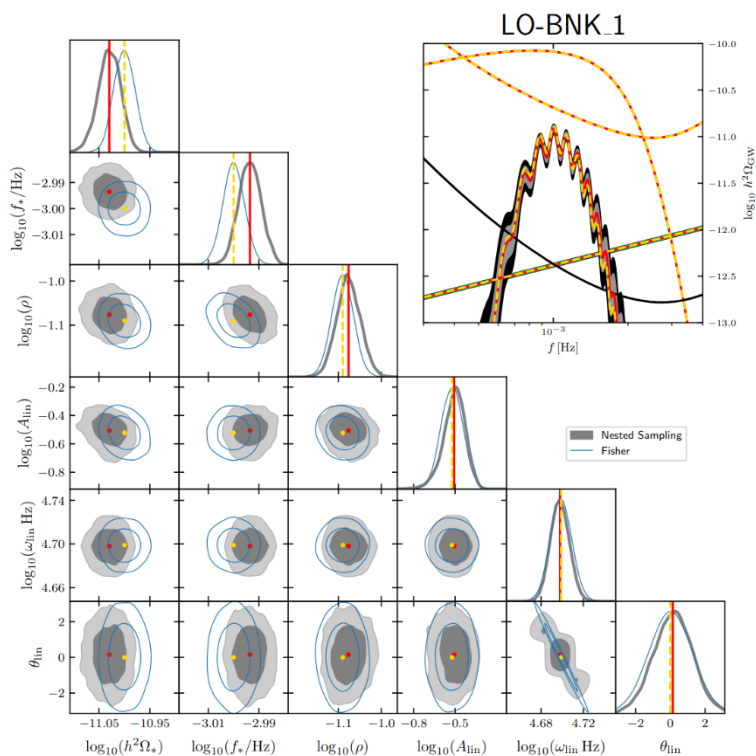
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IF the IF are met, excellent signal reconstruction



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1) Initiate a motivated template bank

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- Good noise ~~model~~ from ESA
- Astro foregrounds modelled
- Residual from binary waveform that not mimic a SGWB

M. Muratore, J. Gair, L. Speri '23

Alternative strategies to reconstruct a stochastic signals...



JF + LISA CosWG
2407.04356

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Gravitational waves from inflation in LISA: reconstruction pipeline and physics interpretation

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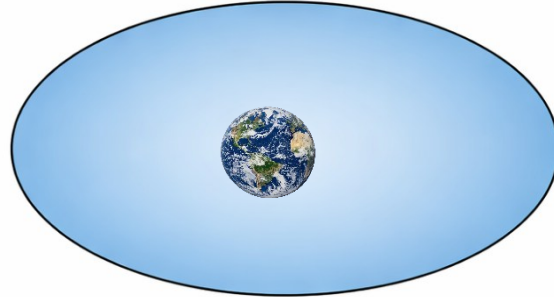
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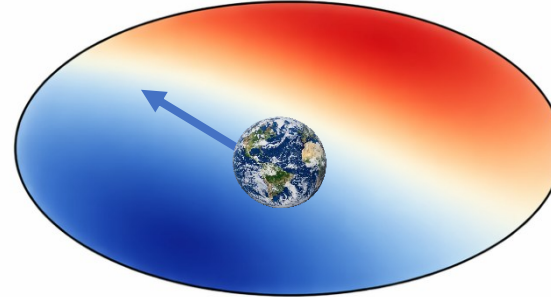
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PROBING KINEMATIC DIPOLE WITH LISA

Cosmic frame

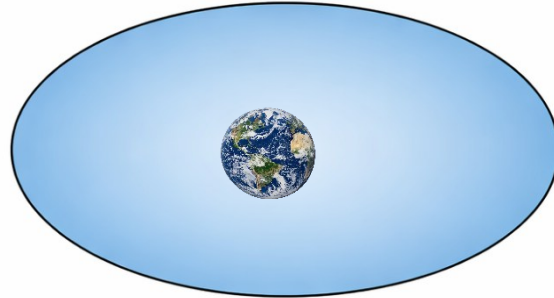


Detector frame

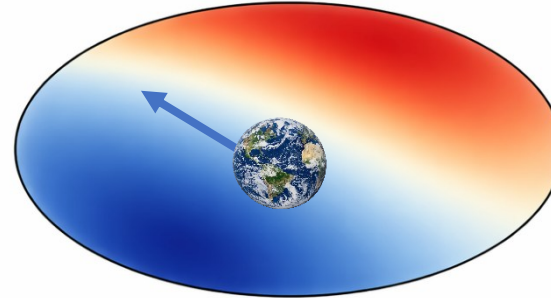


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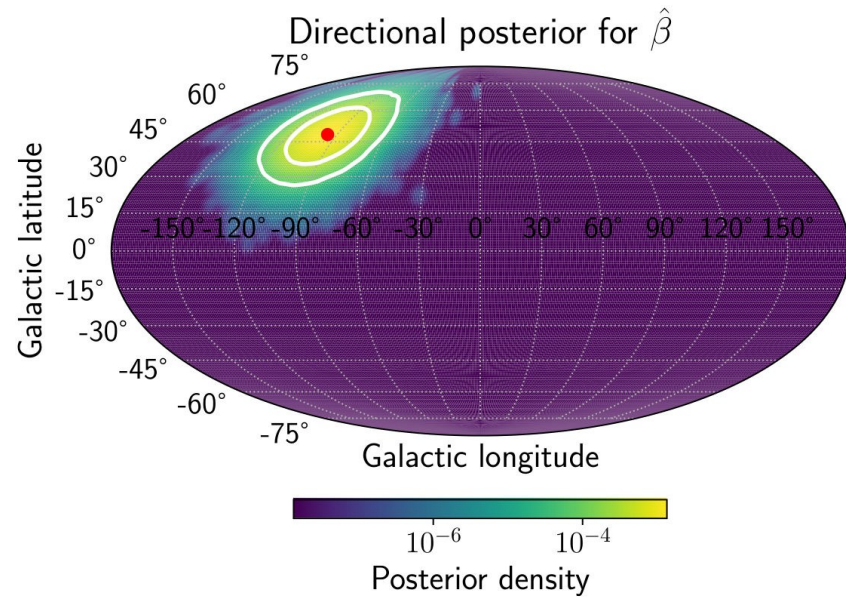
Cosmic frame



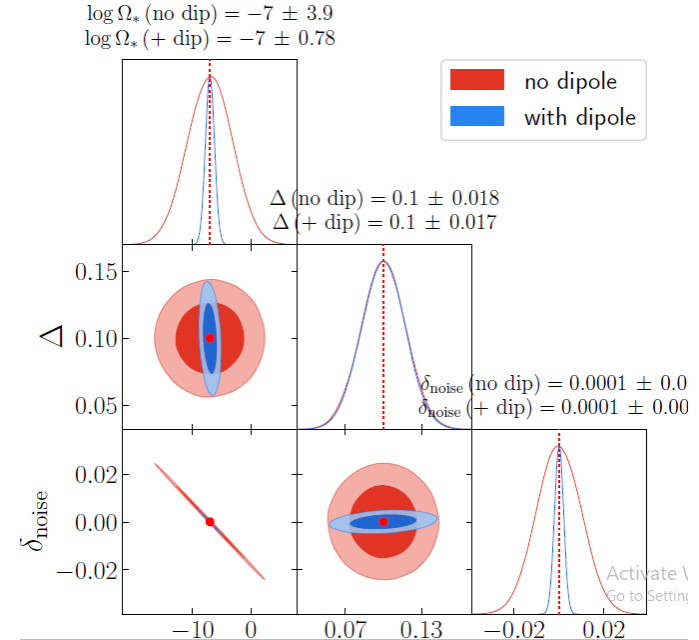
Detector frame



1) Independent measurement of our peculiar velocity



2) Dipole to disentangle a primordial signal



Outline

- Current efforts at ICCUB directly and indirectly related to LISA
- Current efforts within the LISA Cosmology WG directly and indirectly related to ICCUB activities (biased by my works)
- Brief description of the LISA Cosmology Working group (how to get actively involved, sign up etc)

The LISA Consortium

is a *scientific collaboration*. It *represents the community of researchers that will do science with LISA data*.

<https://directory.lisamission.org/register>

If you are not in anymore or you have never been, two options:

- **CORE member**; actively involved (1 deliverable per yr: project/ service role)
- **COMMUNITY member**; just to be informed (wait and see mode)



LISA Consortium sign-up

IMPORTANT: READ THIS BEFORE APPLYING

Please read the [Membership Quick Guide](#) for more details on sign-up, pledges, Member Groups and projects. It's shorter than you think!

→ We manually review each application and it takes time to process everybody's sign-up. Please wait until we approve your sign-up before submitting your pledge or creating a Member Group.

Once your membership is activated, the following data will be viewable by all users in the LISA Directory.

Type of membership*

- Community member** **Core member**
I mainly want to be informed I will work on Consortium deliverables

E-Mail address*

email address

Working Groups

- Consortium is organised in working group which are organised into projects.
- Current science WGs: Astrophysics, **Cosmology**, Fundamental Physics, Instrumentation, Data Analysis and Research Development, Instrument Simulation and Processing, Waveform.
- Other WGs: communications, early career scientists (LECS)

Cosmology WG: aims to develop methodologies and models to use LISA data to test cosmological theories and probe the Universe on large scales **~200 core members, ~190 community members**

- Early Universe (inflation, phase transitions, topological defects...) (SGWB)
- Late Universe (cosmography, tests of GR, large-scale structure...) (astro sources)
- Data analysis (build tools mainly for SGWB searches)

Contact: chairscoswg@gmail.com, cos-wg-chairs@lisamission.org

Wiki <https://wiki-lisa.in2p3.fr/LSGCWG/LSGCWG>

Cosmology WG: Projects

- **List of projects:** <https://wiki-lisa.in2p3.fr/LSGCWG/Projects> (forms, coordinators, deliverables)
- **Past projects:** Since 2019, 1 white paper + **14 completed** collaborative **projects**
- **Currently 8 Ongoing projects:**
 - LISA-ET synergy project (Jan 26)
 - Reinterpreting GW signals from Phase transitions in particle physics model parameter space (Jan 26)
 - Rapid testing of cosmological SGWB models against Global Fit residuals (Jan 26)
 - Strong lensing with LISA (Nov. 2025)
 - *Cosmic strings beyond minimally-coupled models*: characterize GWBs beyond vanilla models (Dec. 24)
 - *Standard Sirens cosmology with LISA*: a pipeline to infer late-time cosmology parameters with LISA (Feb. 24)
 - *Tests of additional GW polarisations*: using massive BH binaries and stellar BH binaries (Nov. 23)
 - *Primordial black holes toolkit*: develop a numerical toolbox to compute GWs signatures of PBHs (Jun. 22)

Cosmology WG

Ongoing actions/meetings:

- Regular telecons associated to collaborative projects
- Monthly online meetings: always a round of updates on the ongoing collaborative projects
- Yearly in-person workshop (12 editions already): next one will be here at [@ICCUB](#) !

Cosmology WG

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<https://indico.icc.ub.edu/event/677/>

13th LISA COSMOLOGY WORKING GROUP WORKSHOP
Barcelona 1-5 June

<https://indico.icc.ub.edu/event/677/>

Topics:
Gravitational wave backgrounds from the early universe
Detection challenges for stochastic backgrounds searches
Characterization of isotropic and anisotropic GWB components
Standard sirens and cosmological tests of the late universe
Cosmological probes of general relativity
Primordial black holes and dark matter
Gravitational-wave lensing
Synergies with the Einstein Telescope, LVK, and ultra high frequencies

Invited speakers:
Diego Blas, Giulia Cusin, Daniel Figueroa, Juan Garcia-Bellido, Srasthi Goyal, Otto Hannuksela, Henri Inchauspe, Antonio J. Iovino, Macarena Lagos, Konstantin Leyde, Eric Madge, Sylvain Marsat, Alberto Mangiagli, Germano Nardini, Mauro Pieroni, Carlos Sopena, Juan Urrutia, Luka Vujeva, Jeremy Wachter

Organizing Committee:
(SOC) Jacopo Fumagalli, Alice Garoffolo, Danny Laghi, Marek Lewicki, Licia Verde, Miguel Zumalacárregui
(LOC) Anna Argudo, Esther Pallarés, Alexandra Bondarescu, Helena Ubach Raya, Anna Moreso-Serra, Alberto Revilla-Pena, Roque Márquez-Rodríguez

ICCUB
INSTITUT DE CIÈNCIES DEL COSMOS
UNIVERSITAT DE BARCELONA

EXCELENCIA
NACIONAL
DE INVESTIGACIONES CIENTÍFICAS

LISA
CONSORTIUM

MINISTERIO DE CIENCIA E INNOVACIÓN

REDONGRA
Red Española de Física de Unidades Gravitacionales
Unidad Asociada al Observatorio Astrofísico de Madrid

Outlook

- Birdseye view of current efforts at ICCUB related to LISA → Mainly related to early universe
- Institutional presence within the LISA collaboration → May potentially and easily grow. Also several key actors in Spain, Barcelona (ICE) etc.
<https://redongra.github.io/website/>
- Expand synergies to address the scientific priorities and strategy of the ICCUB → For the discussion..

Cosmology WG: Projects

Research interdisciplinary projects following [CosWG rules: link](#)

Sketch for the steps to propose and coordinate a project (any member can be a coordinator):

- **Initial idea:** Mention to the chairs, brainstorming typically done (but not exclusively) at Cosmology working groups and/or monthly calls.
- **Proposing the project:** By filling a (blue) form the proposer(s) outline main objectives, tasks, required expertise and propose a timeline.
- **Open call to all CosWG members to contribute:** Each member can participate by filling a simple (green) form outlining in general terms their contributions and the contributed expertise.
- **Development of the project:** project coordinators is responsible to organize regular calls, progress reported at monthly calls and at the working group workshops, Chairs monitor to avoid extreme delays.
- **Concluding a project:** author lists (2 tiers) whose contributions is summarized in a section, internal PnP review, LISA stamp.