Gravitation

Response to criticism and encouragement

Biennale APC: 23 May 2024

Stas Babak for Gravitation group

Gravitation group (current)

Permanents

1. BABAK S. (DR2) LISA, VIRGO, PTA
2. BAGHI Q. (MCF) LISA
3. BARSUGLIA M. (DR1) VIRGO, ET
4. CAPOCASA E. (MCF) VIRGO, ET
5. CHASSANDE-MOTTIN E. (DR1) VIRGO, ET
6. HALLOIN H. (MCF) LISA
7. PLAGNOL E. (Emeritus) LISA
8. PORTER E. (DR2) ET, VIRGO

- PETITEAU A. (CEA) 20%
- STEER D. (Prof) in transition to ENS
- CHATY S. (Prof) HEA

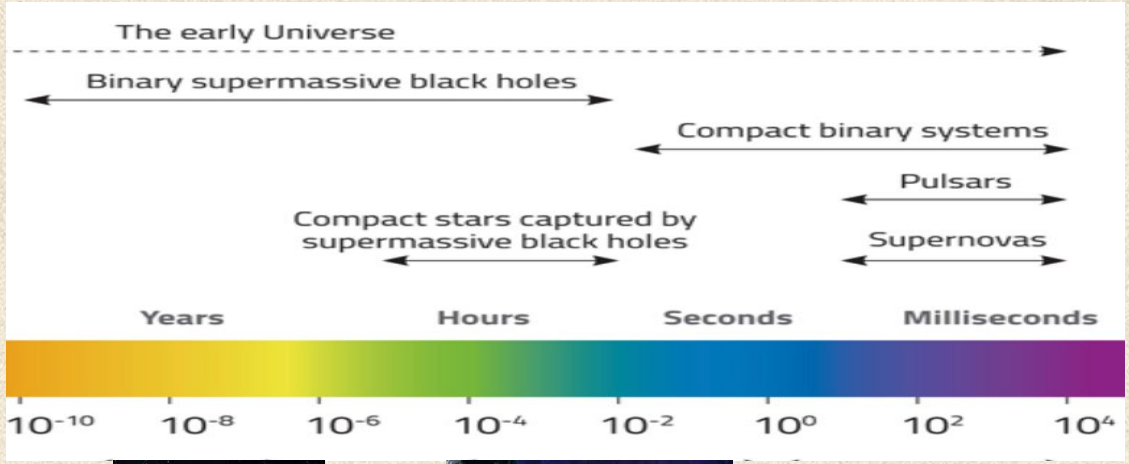
Post docs

1. FRANCHINI N. (VIRGO, LISA)
2. MANGIAGLI (A. LISA)
3. VIDAL L. (Moon)
4. ZHAO Y. (VIRGO, ET)
5. PALUD P. (VIRGO)

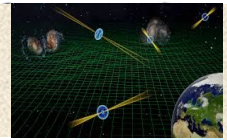
PhD Students

1. QUELQUEJAY H. (PTA, LISA)
2. DENG S. (LISA)
3. HARER Sh. (LISA)
4. PERRET J. (VIRGO, ET)
5. DING J. (VIRGO, ET)
6. VINCENT M. (LISA)
7. MANZINI S. (PTA)

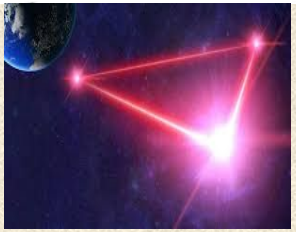
General overview



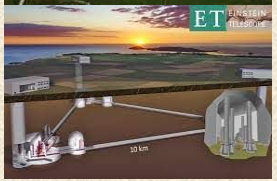
Pulsar Timing Array (PTA)



Nancay Radio telescope (NRT)



LISA: detecting GW from space



VIRGO
Einstein Telescope

Feasibility study for a moon GW detector
→ With IPGP

Context

- LISA: mission adoption in january 2024. Start project activities
  - APC is responsible for beam simulator and LISA data analysis
  - Strong support from CNES
- Einstein Telescope: future (3g) European ground-based detector: design/capability study
  - APC building the group - contribution to the squeezing activity
- VIRGO: upgrade ran into a problem of stability (due to lack of financial resources for a major upgrades during the transition Virgo→AdVirgo) during the extension of the detector (signal recycling cavity - resonance to enhance the sensitivity in a particular freq. band)
  - Delays in joining O4: joined O4b (April 2024) with sensitivity of O3 → now working and contributing to the localization (~ 1 event/3 days)
  - Hard decision making: changing the design - few years
- Virgo/LISA/ET lab in the clean room; ANR quantum-FRESCO (squeezed vacuum)!
- Small group size (permanent): 4 CNRS, 3 MCF
  - Total ~20 people: Postdocs+Docs: ~Max capacity Young Res/Perm.

Short summary of all reports

BUT...

What is in HCERES report for Gravitation group

- *One worry can be the size of the permanent staff of some of the **teams** (eleven for Cosmology and six for the **Gravitation**) as they are almost **comparable to the number of projects** the teams plan to engage with. This is particularly true for the **Gravitation team** where the engagement in present (Virgo) and future (Einstein Telescope, LISA and Virgo_nEXT) risks to stress the small team. If additional resources become available, **this is a team which should get more***

- Increasing the group size (permanent members) is not fully in our hands
  - Priority of the lab 2023
  - We try explain our scientific strategies and how it fits in the (inter)national context (big projects) and in the broad content of current astro-particle and fundamental physics
  - Demonstrate importance and synergy of a young field of Gravitational Waves with other already established fields, underlying the forthcoming opportunities
    - Connections within the lab and with other labs at UPcite and IN2P3
- 60% of the group are docs and postdocs. We are constantly applying for external grants and have pretty good success rate.
- Responsibilities in the lab: Eric Ch-M, Matteo B.

What is in HCERES report for Gravitation group

- *LISA activities see an important leadership role of the APC group and a clear trajectory for the future. The **Virgo** part is more problematic, due to the delay in Virgo joining the current observing run with improved sensitivity. This **might call for a significant change to future plans, and will require the APC group to coordinate with French colleagues to decide the future directions for advanced Virgo and Virgo nEXT.** The group is small, and has effort **split between Virgo and ET**, and this **is not an advantage** for coping with such delicate situation that might also affect the plans **for the students' projects.***

- VIRGO project took decision to implement stable cavities in Virgo for Advanced Virgo phase 2 and the decision to postpones the large masses (and the correspondent telescopes) for Virgo_nEXT
  - APC/Virgo is re-orienting its activity about the mode-matching telescopes (former responsibility) to the re-design of the telescopes for the stable cavity.
  - APC/Virgo has a strong and visible competence in squeezing technology and this activity has been awarded by some national and regional grants (ANR and Region Ile de France), which led to a very ambitious experimental activity:

    The use of squeezed laser light (diminishing quantum photon noise) in GW detectors is valuable for Virgo_nEXT **and** for Einstein Telescope.

- We are trying to identify the projects which are transferable between the projects LISA-ET-VIRGO-PTA:
  - Scientific interpretation of GW observations: Cosmology, testing GR, Astrophysics
  - It is attractive to young researchers and increases their visibility (exposed in more than one project)

What is in HCERES report for Gravitation group

- *The Virgo upgrade situation, with the failure in joining O4 and the realisation of the limits imposed by the marginally stable cavities' put the collaboration in front of tough decisions to be taken soon.* ***The APC group should find a role to save the investment done and keep the attraction power for students and postdocs.*** *The limited consistency of the group in term of senior physicists is a big concern given the context. Furthermore, the team is now spread between* ***advanced Virgo*** *(and upgrades)* ***and*** *preparations for* ***Einstein Telescope****. Given the size of the team, it will be* ***difficult to maintain leadership roles*** *in both* ***experimental and observational science for both current and future observatories****.*

- We have mostly answered this question before… (see the projects which could contribute to several projects with minimal adjustments)
  - The past investment (mode-matching telescope) has not been lost and it will be used for Virgo_nEXT
- We have established our clear leadership within VIRGO and LISA (and PTA).
- We are attractive, very attractive but… **APC cannot only rely on our expertise and enthusiasm, we need to recruit at least 1 staff position**

What is in HCERES report for Gravitation group

- *it would be important to better* ***sketch the trajectory for the APC researchers searching for a leadership role in the ET preparation.*** *The studies performed in the PTA analysis are important and offers chances of visibility.*

- We are at the origin of ET in France:
  - Ed Porter has been co-chair of the observatory science board for 3 years
  - Matteo Barsuglia has been scientific responsible for Virgo/ET at IN2P3 for 4 years.
  - Matteo Barsuglia coordinated the organization of the ET community during the formation of the Virgo Collaboration, and the participation of France to the answer to ET-PP call (with ~900 K€ granted to France);
- The focus of the group will be on LISA and VIRGO projects for the next ~5years:
  - We intend to progressively move/extend our involvement in ET (including leadership positions)
  - This is the natural transition for the VIRGO activity in general
  - Inevitable simbios (multiband) of future GW observations from nano-Hz (SKA) to milli-Hz (LISA) to kilo-Hz (ET)

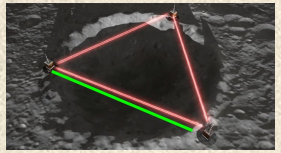
Tourniquet: Gravitation

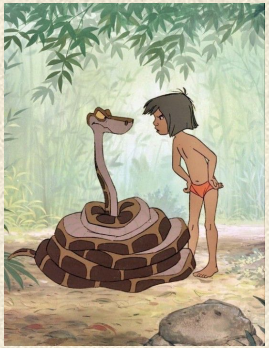
- *Le groupe est impliqué dans toutes les expériences de détection des ondes gravitationnelles, ce qui représente une situation unique en France mais aussi un challenge. Le dynamisme du groupe doit être maintenu avec des financements style bourse ANR* ***en attendant de pouvoir recruter un CRCN****. Le groupe a un futur bien défini structuré autour de LISA et Virgo/Einstein Telescope et les* ***liens avec le groupe théorie et AstroHE doivent être maintenus*** *pour maximiser le retour sur investissement dans ces projets.*

- Currently 3 active ANR in the group
- Connection to theory:
  - Co-advising PhD students and postdocs
  - We still maintain connection to Chiara Caprini and Daniele Steer. Increasing (slowly) interaction with Luca Santoni. Collaboration with D. Semikoz on interpretation of PTA observations
  - Multimessenger observations with AstroHE group (Alexis Coleiro (Athina), Peggy Varniere, Raphael M-R): LISA and PTA
    - Observing merging massive black holes embedded in gaseous environment
    - Observing a small black hole(s) in the accretion disk around massive black hole

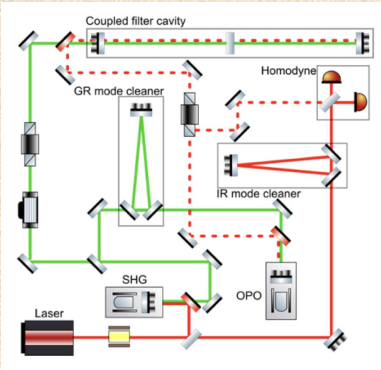
Trajectory

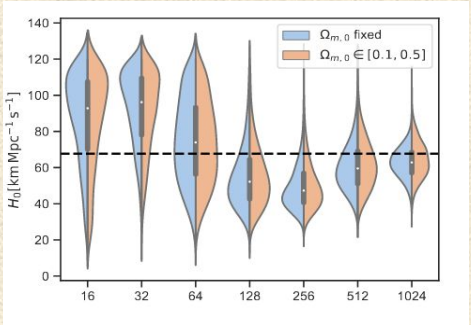
- Ground (Earth) based: VIRGO → Virgo_nEXT → Einstein Telescope
  - *Advanced* mode-matching telescopes
  - Quantum squeezing (Quantum-FRESCO)
  - Machine learning techniques
  - Test of GR & Cosmology ?





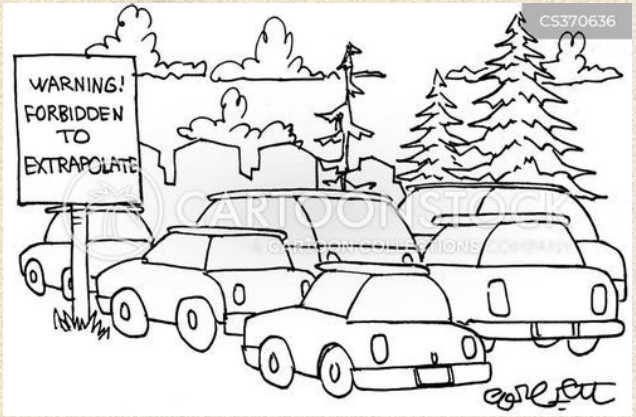
- Moon based: Feasibility study of a lunar GW detectors (MOWGLI)
  - Study of the performances and scientific potential of a strainmeter detector
  - Assess the ecological impact of the project
  - Collaboration with IPGP

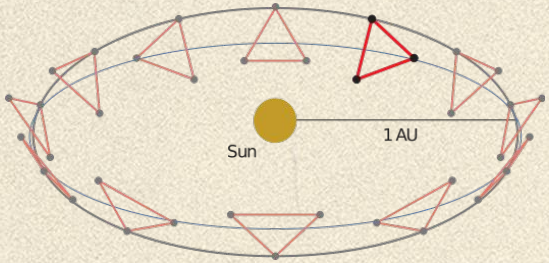


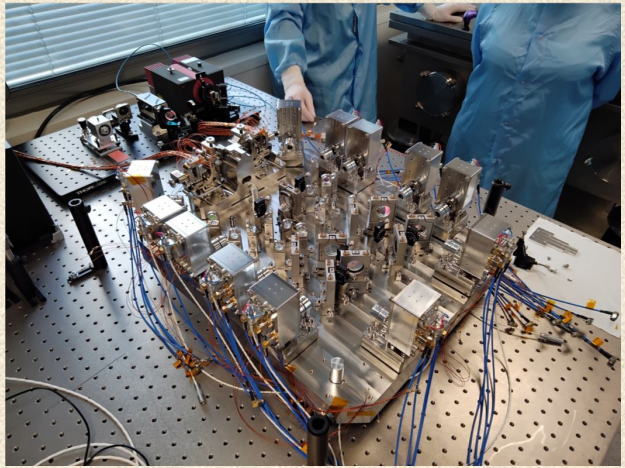


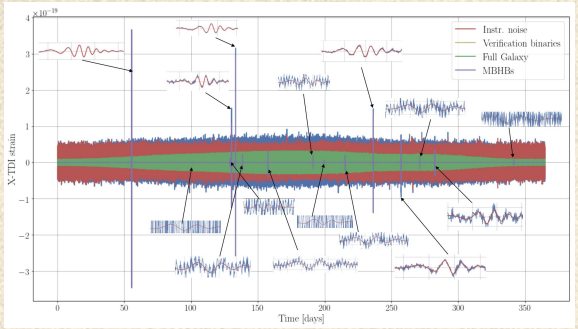
Trajectory

- Space-based: LISA
  - DDPC
  - Beam simulator
  - Scientific interpretation of GW observations (?)



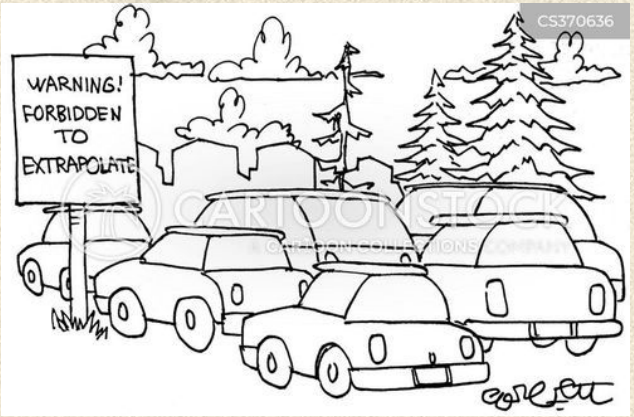


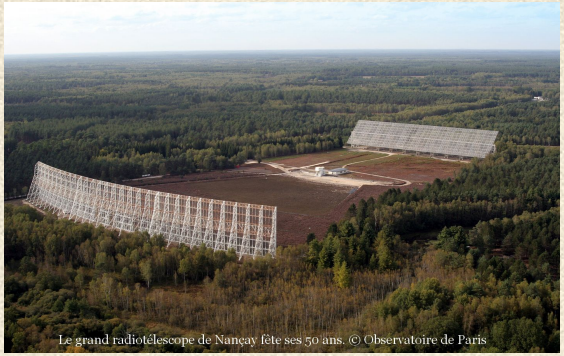


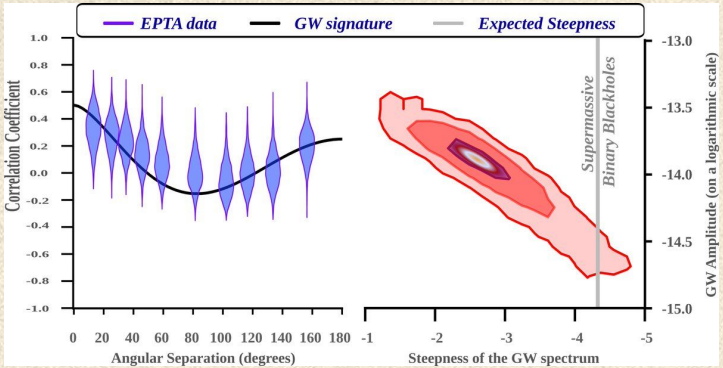


Trajectory

- PTA
  - Discovery of GW in the nano-Hz band
  - From discovery to interpretation







Future....

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(Matteo): thanks for raising this point

The previous answers should have clarified our trajectory. Let us insist on the following points:

- The decision to move to stable cavities and the fact to postpone the large masses, allowed us to focus now stable cavity telescopes. The past investment has not been lost and it will be used for Virgo_nEXT
- The beginning of recent squeezing projects and enlargement of the squeezing team allows us to attract students and post-docs
- Students and post-docs trained on our local squeezing project are trained to work in Virgo and ET and become future leaders for ET.

Despite our efforts the attractiveness of APC cannot only rely on our expertise and enthusiasm, we need to recruit on these themes at least 1 staff position

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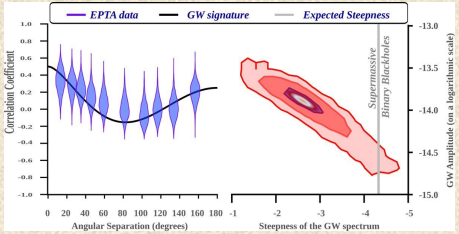
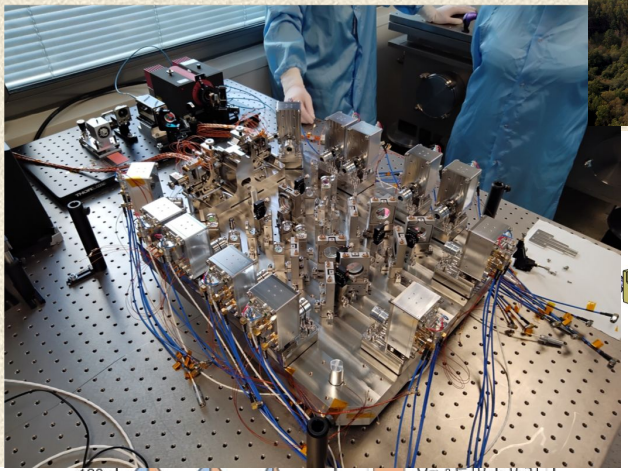
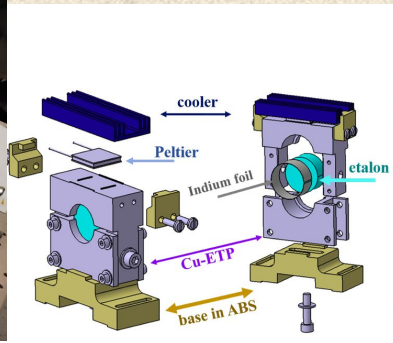
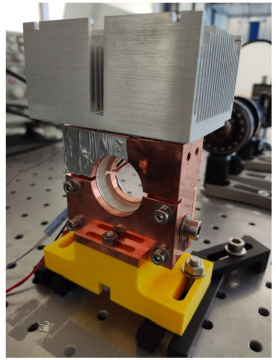
For the future, we would like to keep visible contributions in the Virgo development, design and commissioning. We believe that the best strategy is keeping this focus for the next ~5 years, but progressively (and starting from now) be more involved in ET and take more important roles in the future.

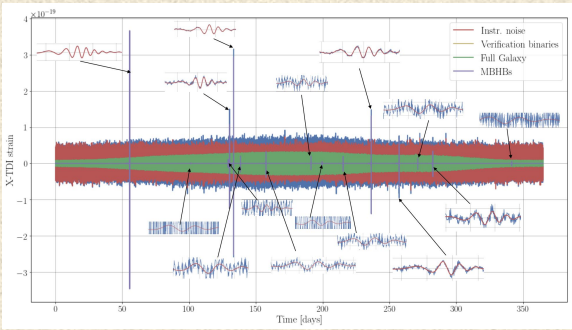

EPTA data
GW signature
Expected Steepness
Correlation Coefficient
GW Amplitude (on a logarithmic scale)
Supermassive Binary Blackholes
Angular Separation (degrees)
Steepness of the GW spectrum

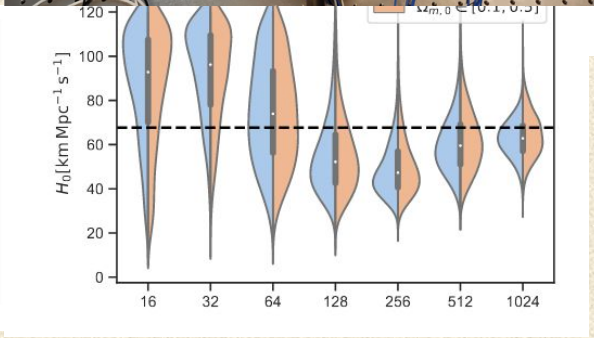

Le grand radiotélescope de Nançay fête ses 50 ans. © Observatoire de Paris

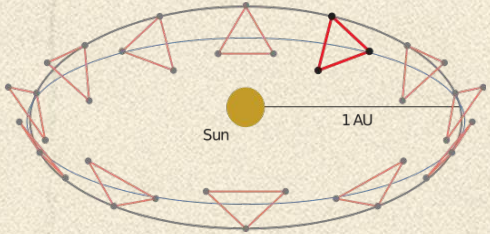



cooler
Peltier
Indium foil
etalon
Cu-ETP
base in ABS




Instr. noise
Verification binaries
Full Galaxy
MBHBs
X-TDI strain
Time [days]


H_0[km Mpc^{-1} s^{-1}]


Sun
1 AU

Continue…

- *There is room for the group to grow, particularly in analysis of current GW data*

We are involved in analysis of LVK data: ring-down analysis.

(Matteo): We agree and we are doing our best to 1) explain our scientific strategy and the importance of our research in the broader context of astroparticle physics and fundamental physics, 2) explain the synergies between our research and other researches of the lab at UPcité and IN2P3 (data-analysis, squeezing etc…), 3) increase the visibility and attractiveness of APC for young post-docs, PhD students and candidates of CR and MCF positions
(Hubert): 2b) demonstrate the importance of the Gravitation field for multi-messenger astronomy and advocate for permanent positions from IN2P3 and UPCité to match with the forthcoming opportunities

60% of the groups are Doc & postdocs. We are constantly applying for external grant and have pretty good success rate. LISA's support by CNES.

Other responsibilities taken by the group: Eric Ch-M, Matteo

(Matteo): thanks for raising this point

The Virgo group is re-orienting its activity about the **mode-matching telescopes**, after the decision to implement stable cavities in Virgo for Advanced Virgo phase 2 and the decision to postpones the large masses (and the correspondent telescopes) for Virgo_nEXT. we are focusing now our activity on the re-design of the telescopes for the stable cavity.

The Virgo group has developed strong and visible competences in **squeezing technology,** which is valuable for Virgo_nEXT and for Einstein Telescope. This activity has been granted by some national and regional grants (ANR and Region Ile de France), which allowed starting a very ambitious experimental activity in the Virgo lab at APC. This experimental activity already proved to attract students and post-doc, while training them to work in Virgo_nEXT and ET.

In conclusion: the last decisions taken in Virgo (stable cavities, postponing large masses) and the grant obtained on squeezing make us believing that we have and we can continue both activities, though it is clear that a reinforcement of the size of the group is mandatory.

Continue…

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