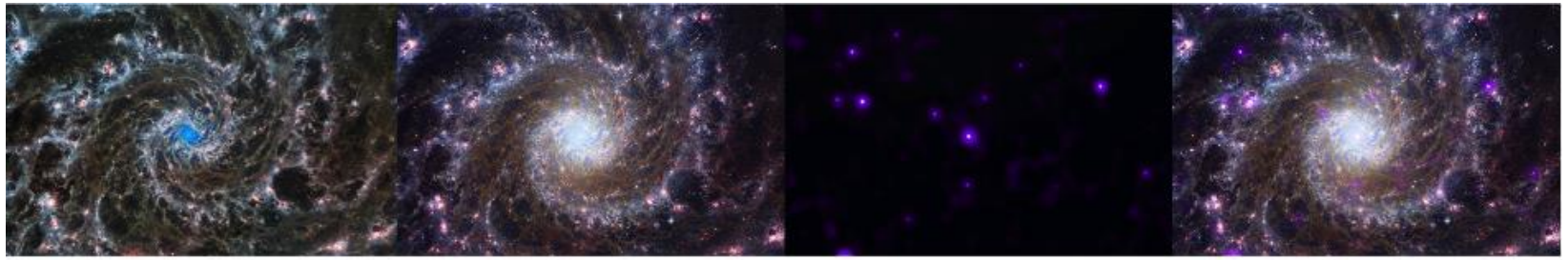
# GALAPHYS
# Axis 3: Gravitation



Cédric Deffayet (head of the “Gravitation and cosmology” team @ LPENS)

# Current scientific perimeter of axis 3 (gravitation)

- Tests and extensions of General Relativity (theory)
- Dark matter and alternatives (theory and observations)
- Observations and analysis of close environmemt of supermassive blackholes
- Gravitational waves (theory)
- Primordial black holes (theory)

# Current scientific perimeter of axis 3 (gravitation)

- Tests and extensions of General Relativity (theory)

Collège de France, LPENS, LUTH

- Dark matter and alternatives (theory and observations)

Collège de France, LERMA, LPENS

- Observations and analysis of close environmemt of supermassive blackholes

LESIA, LUTH

- Gravitational waves (theory)

LPENS, LUTH

- Primordial black holes (theory)

LPENS

# • Tests and extensions of General Relativity (theory)

Collège de France, LPENS, LUTH

## From very abstract to observational issues

Motivations for extending and modifying General relativity:

- High energy physics considerations (quantum gravity) along the superstring program
- Cosmology (as alternatives to dark matter and dark energy)
- Compact objects (as alternatives to black holes)
- Wish to find alternatives to GR to be tested against GR

M. Henneaux (CDF), A. Kashani-Poor (LPENS), C. Deffayet (LPENS),
D. Steer (LPENS), L. Bernard (LUTH), E. Gourgoulhon (LUTH).

# • Tests and extensions of General Relativity (theory)

Collège de France, LPENS, LUTH

## From very abstract to observational issues

Observational tests of General relativity and its extensions:

- Solar and galactic size tests
- Cosmological tests
- Compact objects
- Via gravitational waves

C. Deffayet (LPENS), D. Steer (LPENS), L. Bernard (LUTH), E. Gourgoulhon (LUTH), Ph. Grandclement (LUTH), A. Le Tiec (LUTH),

# • Tests and extensions of General Relativity (theory)

Collège de France, LPENS, LUTH

## Some recent highlights

JHEP

Published for SISSA by Springer

Received: *February 18, 2022*
Accepted: *February 18, 2022*
Published: *March 9, 2022*

**The final Kasner regime inside black holes with scalar or vector hair**

Marc Henneaux

*Université Libre de Bruxelles and International Solvay Institutes, ULB-Campus Plaine CP231, B-1050 Brussels, Belgium*
*Collège de France, 11 place Marcelin Berthelot, 75005 Paris, France*

PHYSICAL REVIEW D
*covering particles, fields, gravitation, and cosmology*

Highlights Recent Accepted Collections Authors Referees Search Press About

High precision numerical sequences of rotating hairy black holes

Gustavo García, Eric Gourgoulhon, Philippe Grandclément, and Marcelo Salgado
Phys. Rev. D **107**, 084047 – Published 28 April 2023

PHYSICAL REVIEW D **100,** 101701(R) (2019)

Rapid Communications

**Theory for multiple partially massless spin-2 fields**

Nicolas Boulanger,[1] Cédric Deffayet,[2,3] Sebastian Garcia-Saenz,[2] and Lucas Traina[1]

[1]*Service de Physique de l'Univers, Champs et Gravitation, Université de Mons, UMONS Research Institute for Complex Systems, Place du Parc 20, 7000 Mons, Belgium*
[2]*Sorbonne Université, UPMC Paris 6 and CNRS, UMR 7095, Institut d'Astrophysique de Paris, GReCO, 98bis Boulevard Arago, 75014 Paris, France*
[3]*IHES, Le Bois-Marie, 35 Route de Chartres, 91440 Bures-sur-Yvette, France*

# • Gravitational waves (theory)

LPENS, LUTH

- Wave forms in General Relativity for binary objects
- Wave forms in extended theories of gravity (scalar tensor in particular)
- Primordial gravitational waves

D. Steer (LPENS), L. Bernard (LUTH), E. Gourgoulhon (LUTH),
Ph. Grandclement (LUTH), A. Le Tiec (LUTH).

# • Gravitational waves (theory)

LPENS, LUTH

## Some recent highlights

PHYSICAL REVIEW D
covering particles, fields, gravitation, and cosmology

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Search for continuous gravitational wave emission from the Milky Way center in O3 LIGO-Virgo data

R. Abbott *et al.* (LIGO Scientific Collaboration, Virgo Collaboration, and KAGRA Collaboration)
Phys. Rev. D **106**, 042003 – Published 9 August 2022

Journal of Cosmology and Astroparticle Physics

PAPER

Gravitational waves in scalar-tensor theory to one-and-a-half post-Newtonian order

Laura Bernard[1], Luc Blanchet[2] and David Trestini[1,2]
Published 8 August 2022 • © 2022 IOP Publishing Ltd and Sissa Medialab
Journal of Cosmology and Astroparticle Physics, Volume 2022, August 2022
**Citation** Laura Bernard *et al* JCAP08(2022)008
**DOI** 10.1088/1475-7516/2022/08/008

PHYSICAL REVIEW D
covering particles, fields, gravitation, and cosmology

Highlights Recent Accepted Collections Authors Referees Search Press About

On the importance of source population models for gravitational-wave cosmology

S. Mastrogiovanni, K. Leyde, C. Karathanasis, E. Chassande-Mottin, D. A. Steer, J. Gair, A. Ghosh, R. Gray, S. Mukherjee, and S. Rinaldi
Phys. Rev. D **104**, 062009 – Published 20 September 2021

# • Primordial black holes (theory)

LPENS

- Formation of primordial black holes and inflation
- Primordial black holes and gravitational waves

K. Petraki team (LPENS), V. Vennin (LPENS)

# • Primordial black holes (theory)

LPENS

## Some recent highlights

Journal of Cosmology and Astroparticle Physics

PAPER

### Primordial black holes from stochastic tunnelling

Chiara Animali[1,2,3] and Vincent Vennin[3]

Published 22 February 2023 • © 2023 IOP Publishing Ltd and Sissa Medialab

Journal of Cosmology and Astroparticle Physics, Volume 2023, February 2023

**Citation** Chiara Animali and Vincent Vennin JCAP02(2023)043

**DOI** 10.1088/1475-7516/2023/02/043

### Primordial black holes as dark matter: Interferometric tests of phase transition origin

Iason Baldes (LPENS, Paris), María Olalla Olea-Romacho (LPENS, Paris) (Jul 21, 2023)

e-Print: 2307.11639 [hep-ph]

# • Dark matter and alternatives (theory and observations)

Collège de France, LERMA, LPENS

- Theoretical model building and constraints on standard and exotic dark matter
- Observational constraints on dark matter
- Modified gravity as alternative to Dark matter (MOND) : theory and observations

F. Combes and LERMA, K. Petraki (LPENS),
C. Deffayet (LPENS)

# • Dark matter and alternatives (theory and observations)

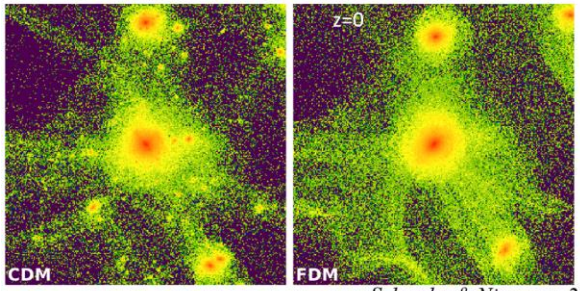
Collège de France, LERMA, LPENS

## Some recent highlights

**Is there an alternative to MOND?**

COLLÈGE DE FRANCE 1530

*Chaire Galaxies et Cosmologie*




Ultra-Light Axions (ULA)

Scalar-field, non-interacting

*Schwabe & Niemeyer 2022*

Françoise Combes

*June, 2023*

l'Observatoire de Paris — LERMA

Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique


ELSEVIER

Physics Letters B

Volume 833, 10 October 2022, 137323

# Saha equilibrium for metastable bound states and dark matter freeze-out

Tobias Binder [a], Anastasiia Filimonova [b], Kalliopi Petraki [b c], Graham White [a]

Show more

Do old globular clusters in low mass galaxies disprove modified gravity?

Michal Bílek (LERMA, Ivry and College de France and Strasbourg Observ.), Hongsheng Zhao (St. Andrews U.), Benoit Famaey (Strasbourg Observ.), Srikanth T. Nagesh (Strasbourg Observ.), Françoise Combes (LERMA, Ivry and College de France) et al. (Jul 5, 2023)

Contribution to: IAUS379 • e-Print: 2307.03202 [astro-ph.GA]

# • Observations and analysis of close environmemt of supermassive BH

LESIA, LUTH

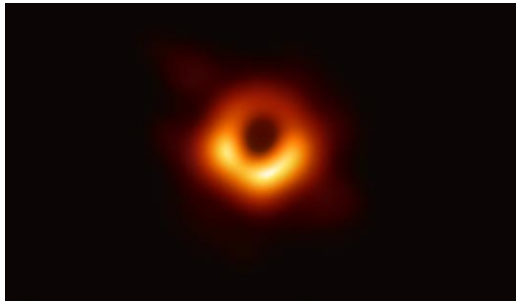
- Experimental developments for GRAVITY (PI. France G. Perrin) and GRAVITY + (PI. France T. Paumard)
- Scientific interpretation using in particular the code GYOTO which is a radiative transfer code allowing to evaluate the emissions around compact objects jointly developped with LUTH
- Modelling of accretion disks around supermassive BH in line with Event Horizon Telescope

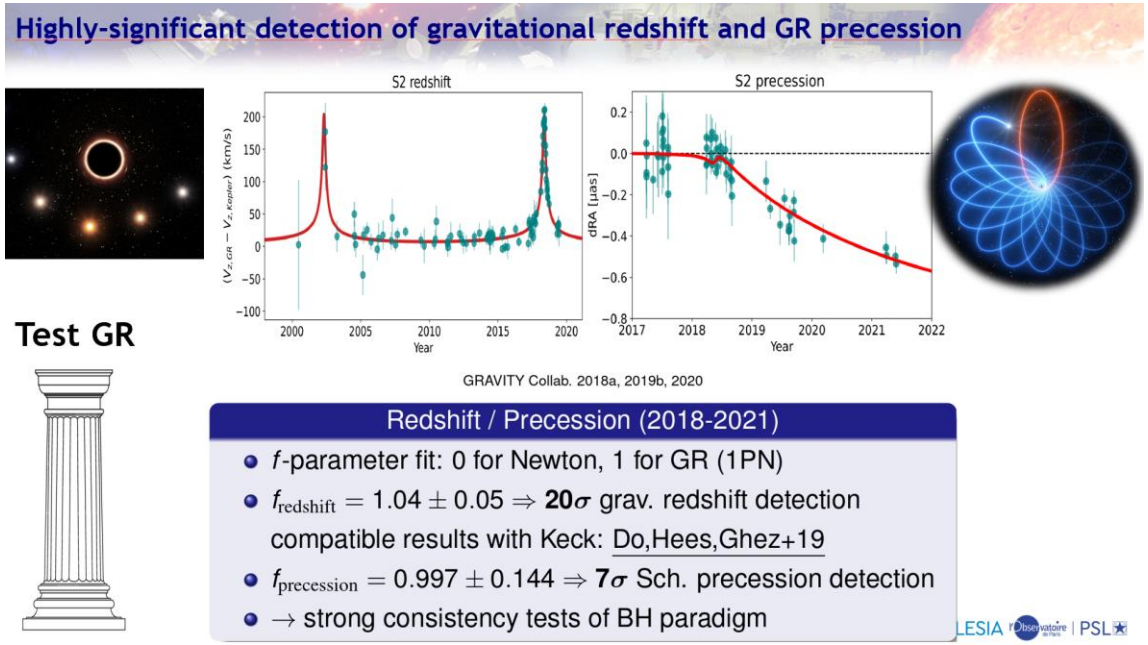
T. Paumard (LESIA), G. Perrin (LESIA), F. Vincent (LESIA), E. Gourgoulhon (LUTH).

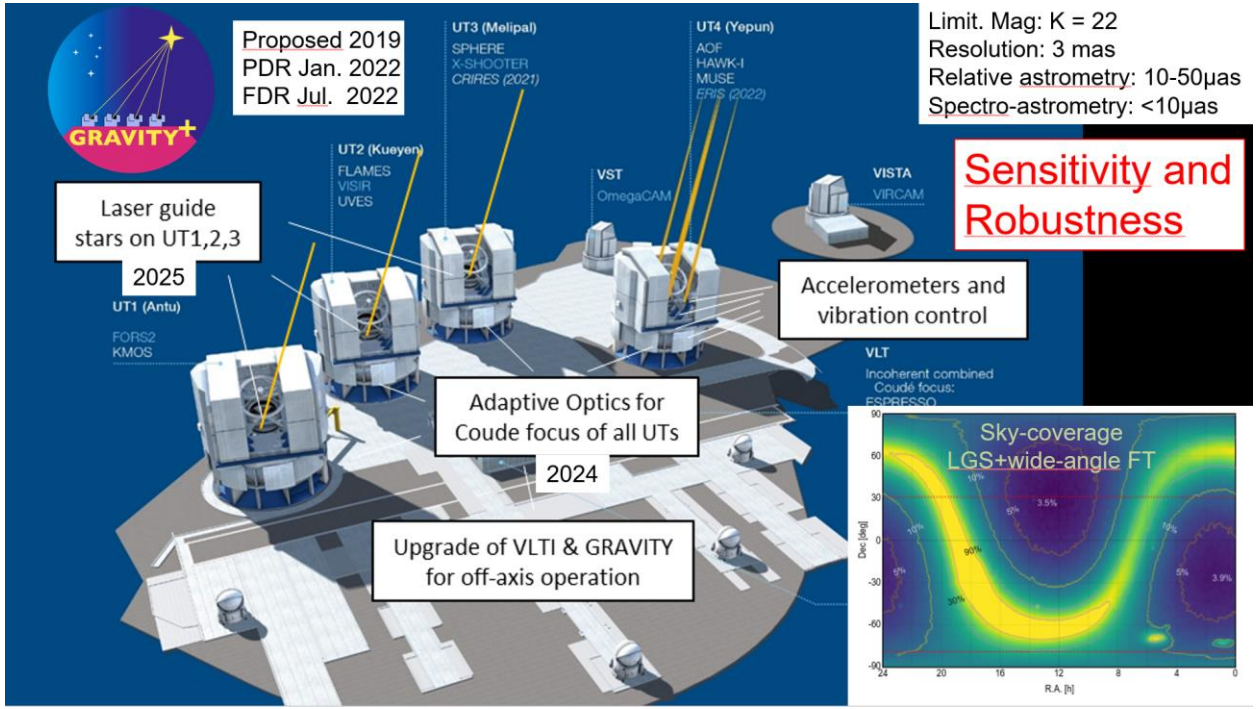
# • Observations and analysis of close environmemt of supermassive BH

LESIA, LUTH

## Some recent highlights



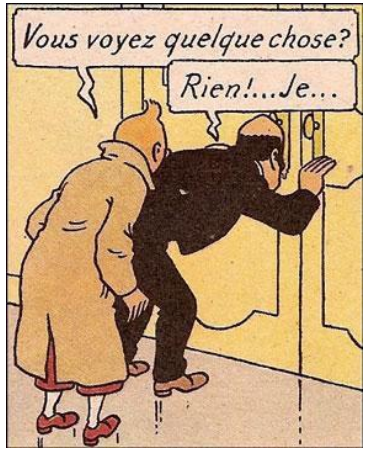


# Possible synergies between labs and team inside axis 3

## My personal view based on the PhD project of Irène Urso (just starting)

- From the « petit bout de la lorgnette »




- Phd Under (the main) direction of F. Vincent (LESIA) and my own codirection on « Constraining the nature of compact objects via the interferometric observation of black holes »
- Fostered already many interesting discussions and cross information between Frédéric and me, even though we are of very different backgrounds

# Possible synergies between labs and teams of other axes

## Some obvious directions for interactions

- Members of other axes (interstellar medium, galaxies) have been cited above
- Some personal ideas:
  - Can the statistical methods developped the Galaxy axis be used to extract some interesting information on gravity ?
  - Constraints on primordial black holes and dark matter using galactic scale observations (Galaxy and interstellar medium axes) ?

# Challenge: how to foster these synergies (intra and inter axis)

## Ways to go, my personal view

- Working groups/ working days etc…
  for some identified directions

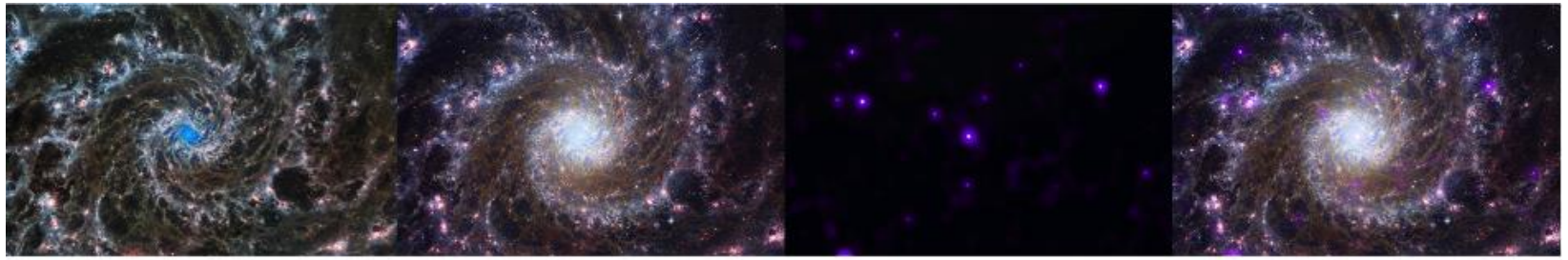
- We have to find our own ways:
  an important question to solve
  very concretely

# Challenge: how to foster these synergies (intra and inter axis)

## Ways to go, my personal view

- Working groups/ working days etc… for some identified directions
- We have to find our own ways: an important question to solve very concretely
- My own prejudice: benefit from our small size to keep it small scale inside our small size

# Thank you for your attention



Special thanks to Françoise Combes and Guy Perrin for slides communications