

GRAVITATION

APC

Composition de l'Equipe

1. **Responsable scientifique de l'équipe: BABAK Stanislav (Stas)**

2. **Budget Annuel Soutien Equipe (hors budget projets): 17100 €**

3. **Liste des chercheurs de l'équipe:**

• **8 permanents [Prénom, Nom, Qualité (Emérite, PR, DR, MCF, CR, IR-Chercheur), (HDR)]**

Stanislav Babak, DR2, HDR

Matteo Barsuglia, DR1, HDR

Eleonora Capocasa, MCF

Eric Chassande-Mottin, DR2, HDR

Eric Plagnol, Emeritus, HDR

Edward Porter, DR2, HDR

Hubert Halloin, MCF

Antoine Petiteau, MCF

• **6 post-doctorants : [Prénom, Nom, indiquer projet, origine financement, date de début, date de fin]**

Leïla Haegel, Fonds National Suisse, 1/1/20 - 31/08/22

Sylvain Marsat, LISA/AdVIRGO, CNES, 1/11/20 - 31/10/21

Agata Trovato, AdVIRGO, H2020 AHEAD, 01/10/17 - 30/09/21

Simone Mastrogiovanni, AdVIRGO, Labex, 01/01/19 - 31/12/21

Henri Inchauspe, CNES, 01/12/2019-30/11/2021

Etienne Savalle, CNES, 01/01/2021-31/12/2022

Composition de l'Equipe

3. Liste des chercheurs de l'équipe:

- **6 Doctorants: [Prénom, Nom, indiquer sujet, origine financement, directeur, codirection, cotutelle, date de début, date de fin]**
 - Catherine Nguyen, "Reducing quantum noise for Advanced Virgo gravitational-wave detector by using frequency-dependent squeezing technique with Einstein-Podolsky-Rosen (EPR) entanglement", ED STEP'UP/EGO, Matteo Barsuglia, 01/10/18 – 01/10/21
 - Aurelien Chalumeau, "Gravitational wave confusion problem across frequency bands", Dim ACAV, Stanislav Babak & Gilles Theureau, INSU, 1/11/18 – 30/01/22
 - Alexandre Toubiana, "Bayesian population study and testing General Relativity with gravitational waves from coalescing binaries", CNRS, Stanislav Babak & Enrico Barausse, 01/10/18 – 30/09/21
 - Mikel Falxa, "Detecting low frequency gravitational waves", ANR, Stanislav Babak & Antoine Petiteau, 15/10/19-14/10/22
 - Dam Quang Nam: "Simulations and associated data analysis for realistic LISA configuration", CNRS, Antoine Petiteau & Chiara Caprini, 01/11/19-31/10/22.
 - Léon Vidal, "Experimental validation of LISA interferometric performances", (50% ED STEP UP, 50% CNES), Fabien Casse & Hubert Halloin, 01/11/19 - 31/10/22

Closely connected to the Gravitation team :

- Konstantin Leyde, "Cosmology and Tests of General Relativity with Gravitational Waves", ED STEP'UP et Fondation CFM, Danièle Steer & Eric Chassande-Mottin, 01/10/20-30/09/23
- Cyril Cano, "Outils d'analyse pour la polarisation des ondes gravitationnelles", LabEx PERSYVAL-Lab et ED EEATS (Grenoble) , Nicolas Lebihan (Gipsa-lab) & Eric Chassande-Mottin, 01/10/19-30/09/22
- Julien Marchioro. "Progenitors of LIGO-Virgo sources", ED, Sylvain Chaty & Ed Porter, 01/10/2020-30/09/2023

Activités de l'Equipe

• **Coopérations/collaborations principales avec l'extérieur (avec équipes locales, nationales, internationales)**

- H2020 NEWS (Japan, USA)
- H2020 AHEAD
- COST action Machine Learning [CA17137]
- COST action Quantum Gravity Phenomenology [CA18108]
- COST action GWverse
- LIGO-VIRGO collaboration
- LISA consortium
- PTA France/EPTA/IPTA consortium
- Cooperation with KAGRA/NAOJ NEWS EU project - R&D on squeezing

• **Participations à l'enseignement, à la communication, à la vulgarization**

- Ma thèse en 180 seconds, 2019
- Podcast « Savant sachant chercher » sur les ondes gravitationnelles, 2019
- Intervention pour la semaine des ingénieurs à la Cité des Sciences, 2019
- Université Ouverte, Fev 2020 et 2021
- Participation to the European project FRONTIERS 2019-Now
- Organization of workshop for gender equality in science 2019-2021 with the PCCP.
- Table ronde au Festival des Idées de Paris: Voir l'Univers autrement (2020)
- Q&A avec le Planétarium de Vaulx-en Velin: De l'infiniment grand à l'infiniment petit (2020)
La lumière pour détecter des frissons de l'Univers (2021)

Activités de l'Equipe

•Responsabilités hors projets (laboratoire, université, sites, comités, ..)

- GdR Ondes gravitationnelles (GdR exec board, scientific committee and group lead)
- COST action "CA17137 – A network for GW, geophysics and machine learning"
- Data intelligence institute of Paris <https://u-paris.fr/diip/> (ECM adjunct director)
- PCCP responsible (MB)

•Organisations d'écoles, de workshops, conférences, .. (2018-2021)

- LISA consortium meeting (Marseille), nov 2018
- Workshop "Gravity falls – alternative theories of gravity" dec 2018
- GW open data workshop, 2018, 2020 & 2021
- PCCP Workshop on Bayesian Deep Learning for Cosmology and Gravitational waves, mar 2020
- Programme IHP GWmess'21, mar 2021
- Organization of the LIGO and Virgo open data workshops 2,3 and 4
- ISAPP school (june 2021)

Implication dans les projets: Projet AdVIRGO

Responsable scientifique de labo du (Master) Projet : Eric Chassande-Mottin (depuis jan 2019)

Liste des chercheurs de l'équipe impliqués dans le projet:

• **11 permanents :**

- Matteo Barsuglia 100% (design optique, R&D squeezing, commissioning, détection/télescopes). Responsable scientifique Virgo IN2P3. Coordination Virgo France et Einstein Telescope France.
- Eleonora Capocasa 50 % (design optique, R&D squeezing, commissioning, détection/télescope)
- Edward Porter 90% (inference CBC, Einstein Telescope OSB co-chair)
- Stanislav Babak 50% (test RG, forme d'ondes)
- Eric Chassande-Mottin (transitoires, cosmologie, science ouverte)
- Danièle Steer 70% (cosmologie, cordes cosmiques)
- Sylvain Chaty (AIM) 40% (populations et outreach)
- Benoit Revenu (Subatech) 100 % (cosmologie)
- Nicola Tamanini (L2IT) 40 % (cosmologie, lensing, test RG)
- Irina Dvorkin (IAP) 30 % (fond stochastique)
- Nicolas Lebihan (Gipsa-lab) 20 % (methodes d'analyse)

• **6 post-doctorants :**

- Leila Haegel 85 % (parameter estimation, testing GR)
- Agata Trovato 100% (donnees ouvertes, machine learning)
- Sarah Antier 50% (alertes)
- Simone Mastrogiovanni 100% (cosmologie, pulsars)
- Sylvain Marsat 40% (forme d'ondes)
- Federico Garcia 20 % (populations)

• **5 doctorants :**

- Catherine Nguyen, 100% (squeezing et R&D EPR)
- Pierre Auclair, 20% (cordes cosmiques)
- Konstantin Leyde, 80 % (cosmologie)
- Cyril Cano, 20 % (methodes d'analyse)
- Julien Marchioro (40% BBH progenitors)

Implication dans les projets: Projet AdVIRGO

Responsable scientifique de labo du (Master) Projet : Eric Chassande-Mottin (depuis jan 2019)

Liste des Ingénieurs et Techniciens du laboratoire impliqués dans le projet:

• 3 permanents

- Eric Breelle, IR, 20 % (R&D EPR/squeezing)
- Walter Bertoli, IR, 40 % (mecanique, telescope mode matching)
- Pierre Prat, IR, 60 % (electronique, photodiodes large bande)

- Giulia Vannoni 20 % (outreach)
- Cindy Pires (administration)

Associés pour l'instant au groupe APC :

Au LT2I

- Christelle Buy (LT2I), IR, 50%, (telescope mode matching)

A Subatech

- Stéphane Martinez IR (66 %) (isolateur Faraday/cellule Peltier)

Implication dans les projets: Projet LISA

A dupliquer pour chaque projet (inclus Master-Projets, ANR/ERC/CNES/Labex/.., Theorie, R&D)

Responsable theorique de labo du (Master) Projet : Antoine Petiteau/Chiara Caprini

Responsable science instrumentale de labo du (Master) Projet : Hubert Halloin

Liste des chercheurs de l'équipe impliqués dans le projet:

- **8 permanents [Prénom, Nom, %ETPT dans le projet, (responsabilité)]**
 - Antoine Petiteau 50% (LISA Board, LISA PI-France, Distributed Data Processing Centre lead)
 - Hubert Halloin 50% (LISA AIVT lead, LISA System Engineering Office, LISA project IN2P3 coordination)
 - Eric Plagnol 100% (LISA PathFinder data analysis)
 - Edward Porter 10% (LISA data analysis)
 - Stanislav Babak 50% (LISA data challenge lead, LISA data pipeline lead, LISA data analysis tools lead)
 - Chiara Caprini 50% (LISA science interpretation working group lead)
 - Daniele Steer 10% (Modelling stochastic GW signal)
 - Sylvain Chaty 10% (LISA associated scientist)
- **4 post-doctorants : [Prénom, Nom, %ETPT dans le projet, (responsabilité)]**
 - Sylvain Marsat 50% (LISA data analysis, waveform modelling)
 - Henri Inchauspe, 100% (LISA science inference, LISA simulator)
 - Etienne Savalle, 100% (LISA data analysis, LISA calibration uncertainties)
 - Alberto Mangiagli 80% (LISA science exploitation)
- **3 Doctorants: [Prénom, Nom, sujet, %ETPT dans le projet, (responsabilité)]**
 - Alexandre Toubiana 100% (LISA data analysis, Testing GR, LISA astrophysics)
 - Dam Quang Nam 100% (LISA noise reduction, LISA simulator)
 - Léon Vidal, 100% (LISA simulator, "LISA ON TABLE")

Implication dans les projets: Projet LISA

A dupliquer pour chaque projet (inclus Master-Projets, ANR/ERC/CNES/Labex/.., Theorie, R&D)

Responsable theorique de labo du (Master) Projet : Antoine Petiteau/Chiara Caprini

Responsable science instrumentale de labo du (Master) Projet : Hubert Halloin

Liste des Ingénieurs et Techniciens du laboratoire impliqués dans le projet:

- **12 permanents [Prénom, Nom, Qualité (IR, IE, AI, T), %ETPT dans le projet, (responsabilité)]**
 - Maude LeJeune 80% (LISA DDPC, System lead)
 - Cecile Cavet 30% (LISA DDPC)
 - Joseph Martino 100% (LISA simulation group lead, LISA performance group lead)
 - Philippe Bacon 40% (LISA DDPC)
 - Alexandre Boucaud 5% (LISA DDPC)
 - Thomas Zerguerras 100% (LISA AIVT, gestion de projet)
 - Pierre Prat 70% (LISA phasemeter, signal acquisition)
 - Guy Monier 30% (LISA AIVT, cableur)
 - Jean Lesrel 20% (LISA AIVT, harnais)
 - Walter Bertoli 20% (Mécanique)
 - Stéphane Dhelly 10% (Mécanique)
 - Corinne Juffroy 30% (Qualité)
- **1 CDD : [indiquer Prénom, Nom, %ETPT dans le projet, source de financement, date début, date fin]**
 - Matthieu Laporte 100% (LISA AIVT), CNES, 12/2020 - 12/2021

Implication dans les projets: Projet PTA-France (2018-2023)

A dupliquer pour chaque projet (inclus Master-Projets, ANR/ERC/CNES/Labex/.., Theorie, R&D)

Responsable scientifique de labo du (Master) Projet : Stanislav Babak

Liste des chercheurs de l'équipe impliqués dans le projet:

- **2 permanents [Prénom, Nom, %ETPT dans le projet, (responsabilité)]**
 - Stanislav Babak 10% (Coordination, PTA data analysis, IPTA GW detection executive board)
 - Antoine Petiteau 10% (PTA data analysis)
- **2 Doctorants: [Prénom, Nom, sujet, %ETPT dans le projet, (responsabilité)]**
 - Aurelien Chalumeau 100% (Pulsar noise characterization, ephemerides, stochastic GW signal)
 - Mikel Falxa 90% (PTA data analysis)
- **On INSU side (Orleans/Nançay): [Prénom, Nom, sujet, %ETPT dans le projet, (responsabilité)]**
 - Gilles Theureau (1CL) 30% (Coordination)
 - Ismaël Cognard (DR2) 20% (Instrument, Observation)
 - Lucas Guillemot (Astron. Adjoint) 20% (Observation, data reduction)
 - Siyuan Chen (CDD) 100% (PTA data analysis, astrophysics)
 - Anais Berthereau PhD student 100% (data reduction using ML)
- **Main objectives:**
 - Regular timing of stable millisecond pulsars using NRT
 - Reduction of radio observation for GW data analysis
 - Detection of GWs in the nano-Hz band
- **Results:**
 - Detection of common red noise process in EPTA data: potentially GW signal

Implication dans les projets: Labex Projet Astrophysics of Stellar binaries

A dupliquer pour chaque projet (inclus Master-Projets, ANR/ERC/CNES/Labex/.., Theorie, R&D)
Responsable scientifique de labo du (Master) Projet : Sylvain Chaty and Eric Chassande-Mottin (co-PI)

Liste des chercheurs de l'équipe impliqués dans le projet:

- **3 permanents [Prénom, Nom, %ETPT dans le projet, (responsabilité)]**
 - Eric Chassande-Mottin 30% (part of AdvIRGO activities)
 - Edward Porter 20% (part of AdvIRGO activities)
 - Sylvain Chaty (PR , 20%)
- **2 postdocs**
 - Federico Garcia (CDD, 100%, 2018-2020)
 - Francis Fortin (CDD, 100%, from 2020)
- **Summary of the project :**

Following the detection in 2015 of the first merging of binary black holes, and in 2017 of the first merging of binary neutron stars, by the LIGO-Virgo interferometers, the goldrush now goes on, with the detection of tens of binary black holes, binary neutron stars and possibly black hole and neutron star binaries. Our interface project aims at identifying the stellar progenitors which evolve in pairs, via exchange of matter and angular momentum, towards collapsing into compact objects, and eventually merging and emitting gravitational waves.

- **Results :**

First paper on the results in press:

Garcia F., Simaz Bunzel A., Chaty S., Porter E., Chassande-Mottin E., 2021, A&A in press

“Progenitors of low-mass binary black-hole mergers in the isolated binary evolution scenario” (2021arXiv210303161G)

Implication dans les projets: AHEAD 2020

A dupliquer pour chaque projet (inclus Master-Projets, ANR/ERC/CNES/Labex/.., Theorie, R&D)
Responsable scientifique de labo du (Master) Projet : Eric Chassande-Mottin (referent APC)

Liste des chercheurs de l'équipe impliqués dans le projet:

- **1 permanents [Prénom, Nom, %ETPT dans le projet, (responsabilité)]**
 - Eric Chassande-Mottin 10%
- **1 postdoc**
 - Agata Trovato 100 % (contribution on GW Open data)
- **Summary of the project : <https://ahead.iaps.inaf.it/>**

AHEAD2020's objectives is to advance further the integration of national efforts in high-energy astrophysics and to further integrate activities with the recently born **multimessenger astronomy**, boosted very recently by the discovery of gravitational waves and cosmic neutrinos and of their first high energy counterparts.

Role of APC in AHEAD is to improve the **publication of GW open data** in order to facilitate its access to other communities -- AHEAD's partners in particular.

• **Results :**

1. Completed an article on O1 and O2 open data, now published in Software X 13 (2021) 100658
2. Lead LIGO/Virgo O3a data release (being finalized, expected Apr 2021). Data curation, production of meta data and documentation, detailed review checks
3. Throughput measurement of current data distribution in Europe (using CVMFS). Working on additional regional Xcache for a faster access -- Collaboration with CCIN2P3
4. Organization of workshops about open data (next in May 2021)
5. Cooperation with WP8 on improvement with the GWOSC infrastructure

Production scientifique

- **Résultats scientifiques marquants de l'équipe (2018-2021) – 5 max**

- LISA adoption as L3 mission and finishing Phase A
- First detections with Virgo during O2 (4 BBH + 1 BNS) and Virgo observing at ~50 Mpc during O3 (Overall 50 detected GW events)
- APC leadership in AIVT (Assembly Instrument, Validation and Testing) and DDPC (distributed data processing center)
- Virgo's mode matching telescopes integrated and working at spec during O2 and O3
- Strong involvement in LVC paper writing teams for GW170814 and GW170817 discoveries, GW170817 Multimessenger, GW170817 Hubble constant paper, GW170817 EoS, GWTC1 Event rate

- **Thèses récentes soutenues dans l'équipe (2018-2021) :**

- **Prénom, Nom, Sujet, Directeur de thèse, financement, dates début/fin, position actuelle**
- Matthieu LAPORTE, Dir: Matteo Barsuglia (Hubert Halloin), CNES/STEP'UP, oct 2015--avr 2019, "Exploitation d'un simulateur électro optique et contribution à l'analyse système d'eLISA", CDD VIRGO (APC)
- Lucile FAYON, Dir: Ph. Lognonné (+Hubert Halloin), USPC, oct. 2014 – avr 2018, "Instrumentation sismologique spatiale : Fonction de transfert du sismomètre 6 axes InSight et développement d'un capteur de déplacement picométrique par interférométrie", Post-doc (ETH-Zurich)
- Hien Phan, Dir: Ph. Laurent (+Hubert Halloin), Gvt Vietnamien + UnivEarthS, nov 2015 – janv 2019, "Simulation and Experimental Characterization of the Scintillation Detector for IGOSat", Research Ass. (USTH, Hanoi)
- Philippe BACON, Dir: Eric Chassande-Mottin, oct 2015-oct 2018, H2020 ASTERICS, "Graphes d'ondelettes pour la recherche d'ondes gravitationnelles: application aux binaires excentriques de trous noirs". (IR Info APC)
- Marc Arene, Dir: Edward Porter, ED STEP'UP, oct 2017 - 31/03/21, "Bayesian inference for compact binary sources of gravitational waves",

Production scientifique

- **3 publications emblématiques de l'équipe dans revues à comité de lecture (2018-2021) :**

- A. Toubiana, ..., S. Marsat, S. Babak, Ch. Caprini, et. al. “*Detectable environmental effects in GW190521-like black-hole binaries with LISA*”, e-Print 2010.06056, Phys.Rev.Lett. 126 (2021)
- S. Mastrogiovanni, D. Steer, M. Barsuglia “*Probing modified gravity theories and cosmology using gravitational-waves and associated electromagnetic counterparts*”, Phys.Rev.D 102 (2020) 4, 044009, e-Print: 2004.01632
- L. Haegel et al, “*Predicting the Properties of Black-Hole Merger Remnants with Deep Neural Networks*”. Classical and Quantum Gravity (2020), 37 (2020) 13, 135005 • e-Print: 1911.01496

Jointly with the AHE group :

- Garcia F., Simaz Bunzel A., Chaty S., Porter E., Chassande-Mottin E., 2021, A&A in press “Progenitors of low-mass binary black-hole mergers in the isolated binary evolution scenario” (2021arXiv210303161G) (Press release in place)

- **3 publications récentes de conférence à forte contribution de l'équipe (2018-2021) :**

- C. Cavet, A. Petiteau, M. Le Jeune, S. Babak, M. Vallisneri, M. Lilley “Prototyping of the Distributed Data Processing Center of LISA”, Proc. of the 2019 conference on Big Data from Space (BiDS'19), doi: 10.2760/848593 (2019)
- A Trovato for the LVC, “GWOSC: Gravitational Wave Open Science Center, The New Era of Multi-Messenger Astrophysics” - Asterics 2019 25 - 29 March, 2019 Groningen, The Netherlands
- L. Haegel, S. Mastrogiovanni, ChrC.istos Karathanasis, I. Magana-Hernandez, D. Steer, K. Ault-O'Neal, J. Tasson, A. Samajdar, "Searching for new physics during gravitational waves propagation", Moriond Gravitation 2021, Proceeding to be published.

Evolution anticipée de l'Equipe (3-5 ans)

Evolution of the group 2021-2025

•Nouveaux projets en vue (inclus réponse aux calls ANR, EU, AO locaux...)

- PTA-France (2018-2023)
- ANR project RICOCHET with Gipsa-lab
- ANR project MBH-Waves with IAP
- DIM ACAV project PTA
- COST action application (LISA)
- ERC grant

•Evolution de la composition de l'équipe (départs/arrivées permanents, docs, post-docs...)

- **Permanent:** recently +1 MCF , Overall: 4DR, 1Emer, 3MCF: **Asking for CR!**
- **Post Docs.:** Currently 6 postdoc: **-4** by the end of this year: **Asking for postdoc!**
- **PhD students:** Currently 6 PhD: **-3** by the end of the year, maybe +1 starting this year:

•Evolution des expertises, compétences

- **Extended:** Testing GR, data analysis, waveform modelling
- **Extended:** Pulsar Timing Array data reduction and analysis, **GW detection**
- **Extended:** Cosmological and astro inference using GW observations (science exploitation)
- **Extended:** Optical ground support equipments for Space instrumentation / AIVT

Ground based GW astronomy

Contributions to the instrument

Hardware contributions to AdV+ phase 1 -- **delivered!**

Diffused light mitigation (Detection): **W Bertoli**, E.Capocasa, C Buy et al

Large band-pass photodiodes (ALS subsystem): **P Prat** et al

Contribution to design for AdV+ phase 2

Optical design & optimization (large mirror RoC) : **J. Baird**, **M. Barsuglia**

Preliminary optical design for the updated end bench telescopes : **C. Buy**,

E. Capocasa, C. Nguyen, M. Barsuglia, J. Baird



Baird and Barsuglia *Galaxies* 2020, 8(4) (2020)

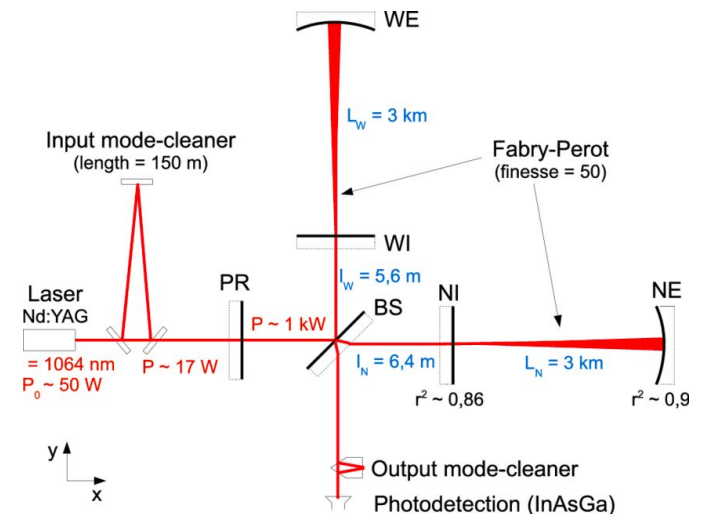
R&D and future upgrades

R&D Einstein Podolsky Rosen -- **C. Nguyen**, **M. Barsuglia**, **E.Capocasa**

C. Nguyen *et al.*, Automated source of squeezed vacuum driven by finite state machine based software, Submitted to RSI (2021)

Frequency dependent squeezing (TAMA) -- **E Capocasa**, **M. Barsuglia**

Zhao, **Capocasa**, et al, *Phys. Rev. Lett.* **124**, 171101, (2020)



Ground based GW astronomy

- **Data analysis and science exploitation**

Bayesian parameter inference, testing GR, cosmology using standard sirens, machine learning -- M. Arene, P Auclair, K Leyde, S. Mastrogiovanni, A. Trovato, L. Haegel

Collaboration papers : arXiv:2101.12248 (Cosmic strings), arXiv:2010.14529 (Test GR)

Chassande-Mottin, Leyde, Mastrogiovanni, Steer Phys Rev. D 100, 083514 (2019)

G. Calcagni, S. Kuroyanagi, **S. Marsat**, et al. JCAP 10 (2019) 012

G. Calcagni, S. Kuroyanagi, **S. Marsat**, et al. Phys.Lett.B 798 (2019) 135000

Isi, **Mastrogiovanni** et al Phys. Rev. D 102, 123027 (2020)

Mastrogiovanni, Steer, Barsuglia, Phys. Rev. D 102, 044009 (2020)

A. Toubiana, S. Babak, E. Barausse, L. Lehner Phys.Rev.D 103 (2021) 064042

Mastrogiovanni, Haegel, Steer et al arXiv:2010.04047

Mastrogiovanni, Duque et, arXiv:2012.12836

Mastrogiovanni, Leyde, et al, arXiv:2103.14663]

- **Multimessenger astronomy**

Contributions to the GW alert system -- S. Antier

[J. Heinzl,.. **S. Antier**, et al. Mon.Not.Roy.Astron.Soc. 502 (2021) 2, 3057,

M. Coughlin, **S. Antier**, et al Nature Commun. 11 (2020) 1, 4129;

I Tews, .. **S. Antier**, et al. Astrophys.J.Lett. 908 (2021) 1, L1,

T. Dietrich,... **S. Antier** Science 370 (2020) 6523, 1450

M. Coughlin, ... **S. Antier**, et al *M.N.R.A.S.* 492 (2020) 1, 863

M. Coughlin, ... **S. Antier**, *Phys.Rev.Res.* 2 (2020) 2, 022006

- **Open data science**

Preparation, validation and release LVC data -- A. Trovato

[Abbott et al, SoftwareX 13, 100658 (2021)]

- **Waveform modelling**

S. Marsat, L. Haegel

[**Haegel** et al, Class. Quant. Grav. 37 (2020) 13, 135005 (2020)

Cotesta, **S. Marsat**, M. Pürrer, Phys.Rev.D 101 (2020) 12, 124040

T. Marchand, Q. Henry, F. Larrouturou, **S. Marsat**, G. Faye et al Class. Quant. Grav. 37 (2020) 21, 215006

S. Ossokine, A. Buonanno, **S. Marsat**, R. Cotesta, **S. Babak** et. al Phys.Rev.D 102 (2020) 4, 044055]

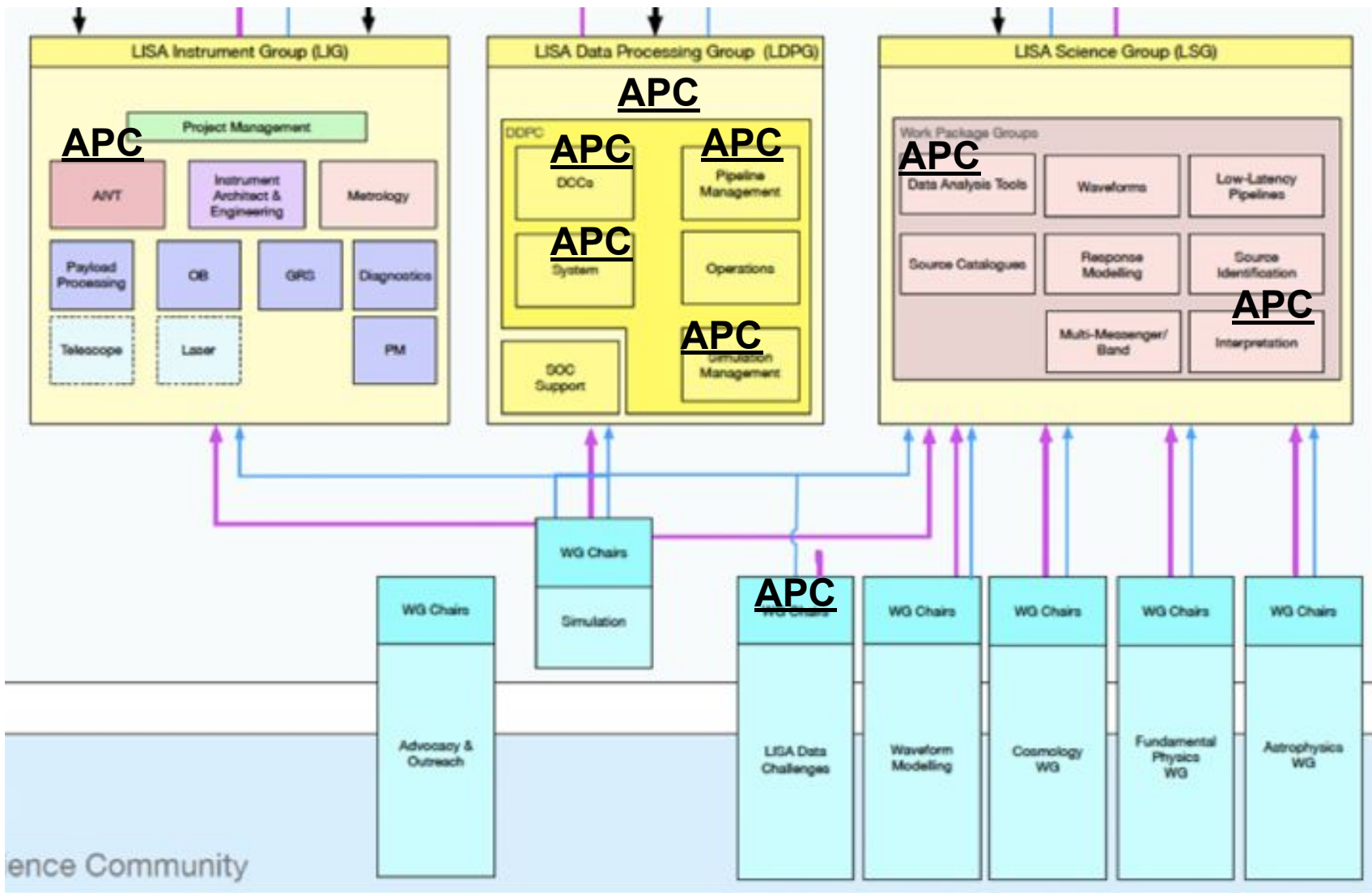
Ground based GW astronomy: Vision on science

- **50 GW signals detected so far and expect a total > 80 for O3**
 - **Black-hole binaries**
 - First indications on the population and formation channels
 - A couple of objects falling in the *lower mass gap* (heavy NS or light BH ?)
 - GW190521 is a very heavy BBH in the *upper mass gap* -- Intermediate mass BH !
 - **Other sources (with neutron stars)**
 - BNS rate is in the lower end of the anticipated range
 - Electromagnetic counterparts more difficult to find than expected based on GW170817
 - **Interesting prospects in related areas**
 - A lot of activities on GW cosmology and tests of GR
- **O3 data raises fundamental questions about BH formation**
 - **Observations contradict well accepted theories** on BH formation such as *pair instability supernova*
 - Indications for **multiple BBH formation channels** -- What are they?
- **Few hundreds GW signals expected for O4**
 - **Good characterisation of the BBH population up to $z \sim 1$**
 - Able to decide on formation channel?
 - More hints on IMBH ?
 - **Multimessenger astronomy may get more lucky?**

Ground based GW astronomy: Vision on experiment

- **AdV+ phase 1 in its final stage**
 - Commissioning started on January 2021. On schedule so far.
 - On track for O4 with a expected start in ~ June 2022
- **AdV+ phase 2 2023-2025 in preparation**
 - Large mirrors impact optical layout → APC contribution with new mode-matching telescopes
- **Post-O5 (post 2026) scenario**
 - Under study -- Strategy to be defined and agreed with international partners. A Virgo committee has been set-up.

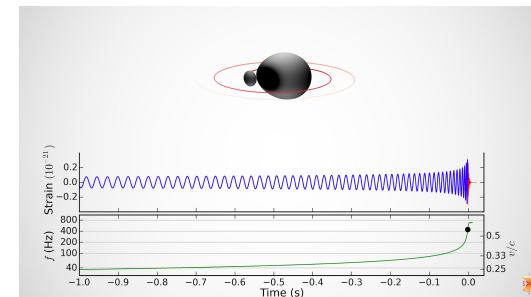
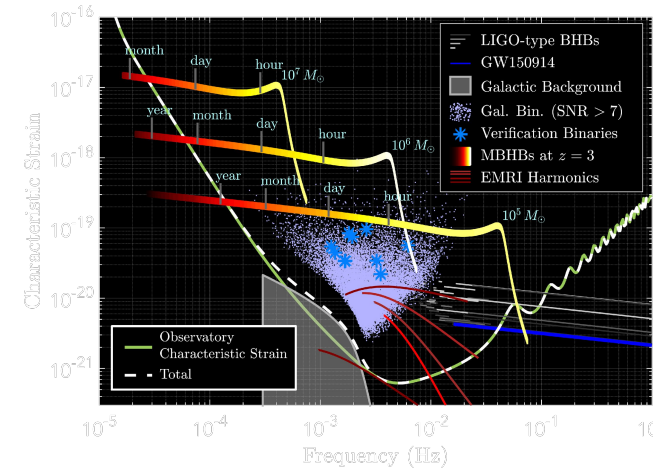
Space based GW astronomy



Space based GW astronomy

LISA data analysis:

- **LISA data simulation:** S. Marsat (CDD), H. Inchauspe (CDD), A. Toubiana (doct), E. Savalle (CDD), M. Lejeune (IR), J. Martino (IR), Ph. Bacon (IR), S. Babak (DR), A. Petiteau (MCF)
 - simulating Universe in GWs: astro population of sources, GW models
 - simulating instrument: orbit, response, noise budget
- **LISA data analysis:** S. Marsat (CDD), H. Inchauspe (CDD), A. Toubiana (doct), E. Savalle (CDD), S. Babak (DR), A. Petiteau (MCF), A. Mangiagli (CDD), E. Plagnol (Emer)
 - building algorithms for extracting GW signals
 - exploring scientific abilities of LISA (parameter estimation)
 - inference of cosmological and astrophysical models (expansion of Universe, MBH formation)
- **Results:**
 - 2020: 20 papers
 - 2021: 7 papers (including 1 PRL) + 2 e-Prints



Space based GW astronomy

Building Distributed Data Processing Center:

- **Implementation of tools:** S. Marsat (CDD), E. Savalle (CDD), M. Lejeune (IR), Ph. Bacon (IR), S. Babak (DR), A. Petiteau (MCF)
 - data analysis tools, signal processing tools, GW response
- **Prototyping data analysis pipeline:** M. Lejeune (IR), Ph. Bacon (IR), S. Babak (DR), A. Petiteau (MCF), E. Plagnol (Emer).
- **Distributed computing and common development environment:** C. Cavet (IR), M. Lejeune (IR), A. Petiteau (MCF)

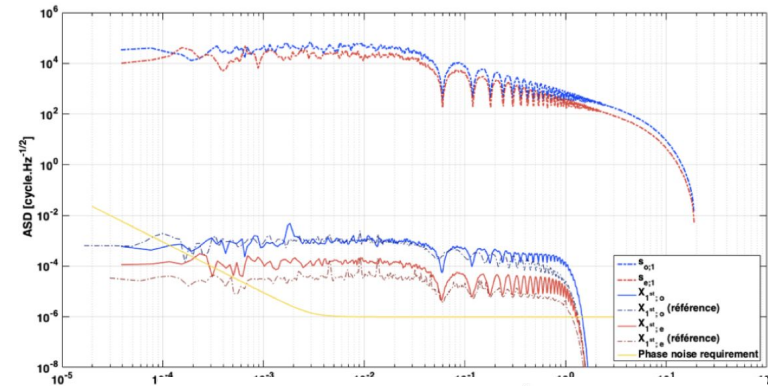
LISA Figures of merit

- **Pipeline aiming at assessing abilities of LISA to achieve science objectives:** S. Marsat (CDD), E. Savalle (CDD), H. Inchauspe (CDD), M. Lejeune (IR), Ph. Bacon (IR), S. Babak (DR), A. Petiteau (MCF), A. Toubiana (Doc)
 - Steering/assessment of evolving LISA configuration during the phase A
 - Assessing impact of calibration uncertainties and model systematics on the the LISA's science
- **Results:**
 - Software (LDC: <https://gitlab.in2p3.fr/LISA/LDC>, FoM: <https://gitlab.in2p3.fr/LISA/lisa-fom>)
 - Documentation.

Space based GW astronomy

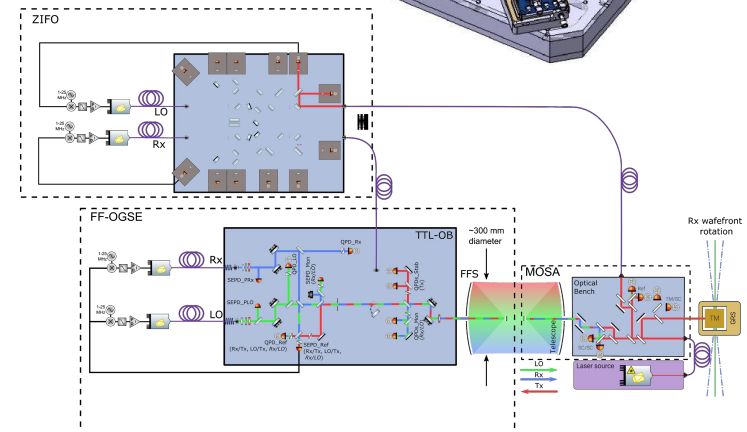
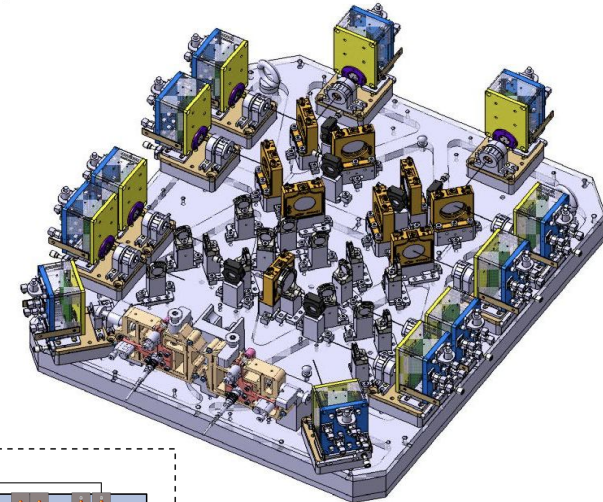
Optical/electrical simulations of LISA signal :

- **LISA On Table experiment :** L. Vidal (PhD), H. Halloin (MCF)
 - Validation of noise reduction algorithms on realistic data
- **Results:**
 - Demonstration of noise reduction factor of 8 orders of magnitude on simplified setup



Assembly Instrument, Verification and Testing:

- **OGSE prototyping : Metallic & Zerodur interferometers (MIFO/ZIFO)** H. Halloin (MCF), Th. Zerguerras (IR), M. Laporte (CDD IR), P. Prat (IR), J. Martino (IR), W. Bertoli (IR), ...
 - Development of an ultra-stable optical bench for demonstrating the on-ground characterisation capabilities
- **Design of the future AIVT GSEs** H. Halloin (MCF), Th. Zerguerras (IR), J. Martino (IR)
 - Test philosophy, design requirements and key technologies prototyping for critical Optical Ground Support Equipments for LISA
- **LISA scientific performance modeling** J. Martino (IR), H. Halloin (MCF), A. Petiteau (MCF)
 - Modeling and requirements breakdown for the LISA consortium
- **Results:**
 - Metallic OGSE prototype completed and tested by end 2021, Zerodur version by end 2022
 - Preliminary LISA OGSE definition by end of Phase A (Sept. 2021)
 - Periodic releases LISA performance model to the Consortium



Space-based GW astronomy: Vision

- **LISA in Phase A (2018-2021)**
 - Importance of LISA simulator
 - Noise budget evaluation
 - Figures of merit: scientific abilities of LISA
 - Simulating LISA data
 - Building data analysis tools
 - Completion and tests of the metallic IFO prototype (MIFO)
 - Optical ground support equipments definition
 - Requirements
 - Preliminary design
 - Lab contributions (work distribution)
- **LISA enters Phase B in 2022**
 - Demonstration of LISA data analysis
 - LISA operation and data processing implementation
 - Improving GW signal modelling
 - Building catalogue of LISA sources
 - Science exploitation with LISA
 - Completion and tests of the zerodur IFO prototype (ZIFO)
 - Prototyping of critical technologies for AIVT Optical ground support equipments

Evolution anticipée de l'Equipe (3-5 ans)

• Attente vis-à-vis de l'IN2P3

• Overall: Gravitation group

• Small but very active group

- Wide expertise (with overlaps!): hardware, experimental design and simulation, data analysis, science interpretation, testing GR, GW modelling
- **7.5 (!) PhD students**: GW Astronomy is a rising star -> Importance to train new generation
- Very productive : ~40 papers in the last 2 years
- Gravitation group led two proposals within IN2P3 Prospectives
- Very **strong ties with Theory group**: sharing supervision (2 PhD students), co-authored papers. **Building links with High energy group** (population, multimessenger, Athena)
- Aiming at building the strongest group for the future multimessenger and multiband (LISA+ET) GW astronomy

• LISA and space-based astronomy

- A. Petiteau French LISA PI; H. Halloin is LISA project responsible within IN2P3
- Leading in setting up Distributed Data Processing Center (LISA ground segment) and AIVT within LISA Consortium.
- One of the strongest data analysis group world-wide
- LISA is a very integral mission: symbiosis of instrumental science, LISA simulator, developing of data analysis pipeline and methodology on the scientific data exploitation (27 papers in 2020-2021)
- Strong support/connection with CNES

Evolution anticipée de l'Equipe (3-5 ans)

•Attente vis-à-vis de l'IN2P3

• Ground based astronomy (Virgo and ET)

- M. Barsuglia: Virgo scientific responsible for Virgo and Einstein Telescope
E. Porter: co-chair of ET observational science board
- Long experience and important results in optics, control, squeezing, commissioning, data analysis and science exploitation
- High visibility within LIGO-Virgo: led several collab publications, and participate in public presentation and press-releases
- We aim to **continue a strong involvement in Advanced Virgo**, to contribute to its upgrades, data exploitation of O4 and O5 and prepare the post-O5 phase
- We can/want to **play an important role for the preparation of Einstein Telescope** (design, optics and squeezing, data analysis preparation)

• We need reinforcement

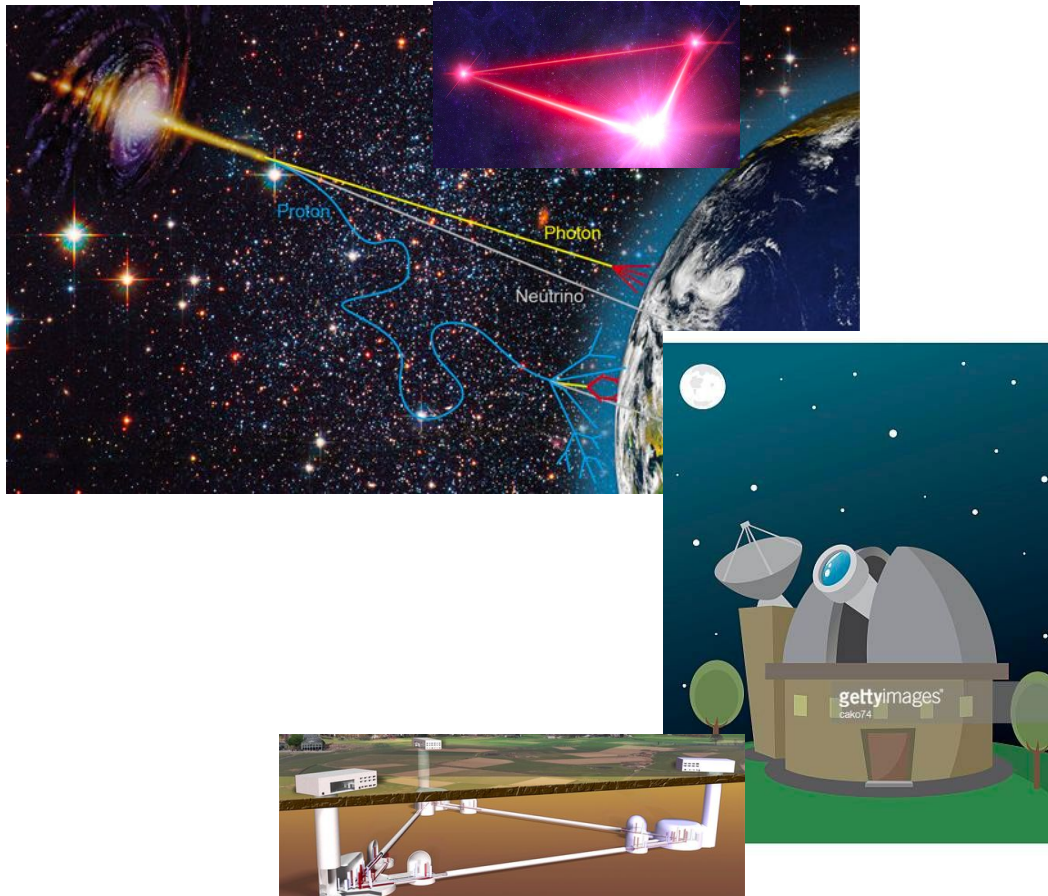
- **Young researcher (CR)** on scientific interpretation of GW observations: testing GR, inference of astrophysical and cosmological models. Overlapping research between ground- and space-based GW astronomy.
- **Postdocs** on Virgo data analysis [Gravitation group is losing 5 postdocs this year]
- **MCF** to support LISA instrumental group
- **PhD students (2)** to maintain continuity in bringing up new researchers in GW astronomy.
- Our request is strongly endorsed by CS of IN2P3

BACKUP

[+ Tous les documents jugés utiles pour la discussion]

BACKUP

Multimessenger astronomy: Vision



Quite big:

European Center for
Multimessenger astronomy

- A physical center around VIRGO/ET and LISA data with the accent on the multimessenger part. The purpose of such a center is coordination of the multimessenger operation and collaboration between different projects/consortia. It could be used to organize meetings, schools, conferences. Equiped with CDF.
- Joined with other EU countries: MPG, INFN?