GdR Ondes Gravitationnelles

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http://gdrgw.in2p3.fr/

Groupement de recherche
Ondes gravitationnelles

cnrs
dépasser les frontières
IN2P3
Les deux infinis

History of the GdR

- Founded by Pierre Binétruy at the end of 2016 with IN2P3 funding
- Scientific context:
    - First direct detections of GW from BBH collisions by LIGO/Virgo
    - Flight of LISA Pathfinder and preparation of the LISA mission
    - Birth of a new science, need to form and structure the French community
- Activities started in 2017
- *Chiara Caprini*, director -> end 2021
- New edition, 2022->2026. Director: *Danièle Steer*, Directeur-adjoint: *Filippo Vernizzi*

Main role of the GdR

- Provide a common environment for the french scientific community with interest in GW physics: astrophysicists, theorists, experimentalists, data analysts...
- Organise meetings, in the form of "assemblées générales" and "rencontres thématiques"
  - present latest progress and discoveries in the field.
  - where community can meet and exchange,
  - where young researchers are encouraged to present their work
- Promote new collaborations and projects (the GdR is organised in 8 *Working Groups*)
- The budget is devoted exclusively to meetings organisation, no research financing

Structure of the GdR, 2022-2026

– ~310 membres

– Directors : Danièle Steer + Filippo Vernizzi

– Comité de Pilotage (10): directeurs + responsables principaux des 8 groupes de travail

Formes d'Onde : Luc Blanchet
Population des sources : Irina Dvorkin
Prédiction et suivi des signaux multi-messagers : Sylvain Chaty
Cosmologie : Nicola Tamanini
Étoiles a neutrons, supernovae, et synthèse des éléments lourds : Jerome Novak
Méthodes et analyse de données : Eric Chassande-Mottin
Tests de la relativité générale et théorie alternatives : Karim Noui
Développement des détecteurs : Joseph Martino

– Conseil scientifique (21): comité de pilotage + membres externes
(représentants des différents programmes nationaux concernés, et pour s'ouvrir à des sujets scientifiques non représentés au conseil de pilotage, p.ex atom interferometry)

– 8 groupes de travail

GdR working groups

Waveforms

coordinators : Luc Blanchet, Guillaume Faye, Eric Gourgoulhon, Alexandre Le Tiec

- MBHB, stellar origin BHB, NSB et WDB
- Numerical relativity (BHB, relativistic hydrodynamics...)
- Analytical methods (PN, EoB, Phenom, effective field theories...)

Sources populations

coordinators : Irina Dvorkin, Gilles Theureau, Marta Volonteri, Astrid Lamberts

- Binaries origin and formation (MBHB, stellar origin BHB, IMBHB...)
- Stochastic foregrounds from binaries
- Complementarity ground/space: multi-wavelength GW observations

Prediction and follow-up of multi-messenger signals

coordinators : Sylvain Chaty, Olivier Godet, Tito del Canton

- Multi-wavelength follow-up of GW emitting events
- Observational prediction and interpretation of the detections
- Counterparts: NSB, MBHB, stellar origin BH-NS binaries...

Cosmology

coordinators : Nicola Tamanini, Tania Regimbau, Giulia Cusin

- early universe signals (stochastic backgrounds)
- cosmological parameters (standard sirens)
- angular correlation, large scale structure
- Weak and strong lensing
- Cosmic- (super-) strings
- Primordial BHs

Tests of GR and of modified gravity theories

coordinators : Karim Noui, Luc Blanchet

- tests of the inspiral, waveforms in GR and in alternative theories
- physics of the horizon, tests of the no-hair theorem
- tests of GW propagation and polarisations
- cosmological modified gravity theories

Neutron stars, supernovae and nucleosynthesis

coordinators : Anthea Fantina, Jérôme Novak

- Internal structure and equation of state of NS
- Heavy elements synthesis
- supernovae

Data Analysis

coordinators : Eric Chassande-Mottin, Sylvain Marsat, Antoine Petiteau, Viola Sordini

- Data quality and noise analysis
- parameter estimation
- Bayesian methods
- Un-modelled sources
- Non-gaussianity, non-stationarity
- Foreground subtraction
- De-noising, machine learning

Detectors development

coordinators : Joseph Martino, Eleonora Capocasa, Walid Chaibi

- LIGO/Virgo and LISA
- Development of ET France from the instrumental point of view and in light of the scientific context
- Atom interferometry: ground and space

Science of the GdR

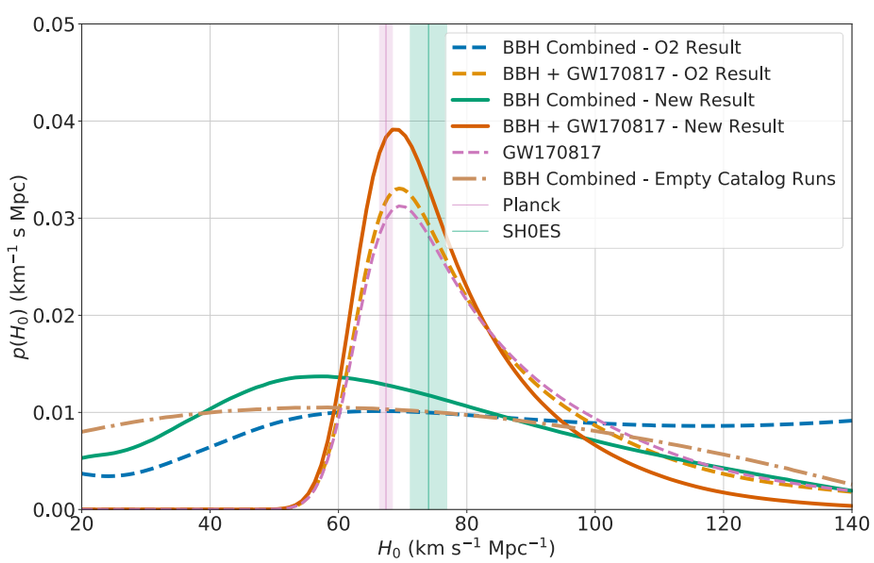
Fundamental physics

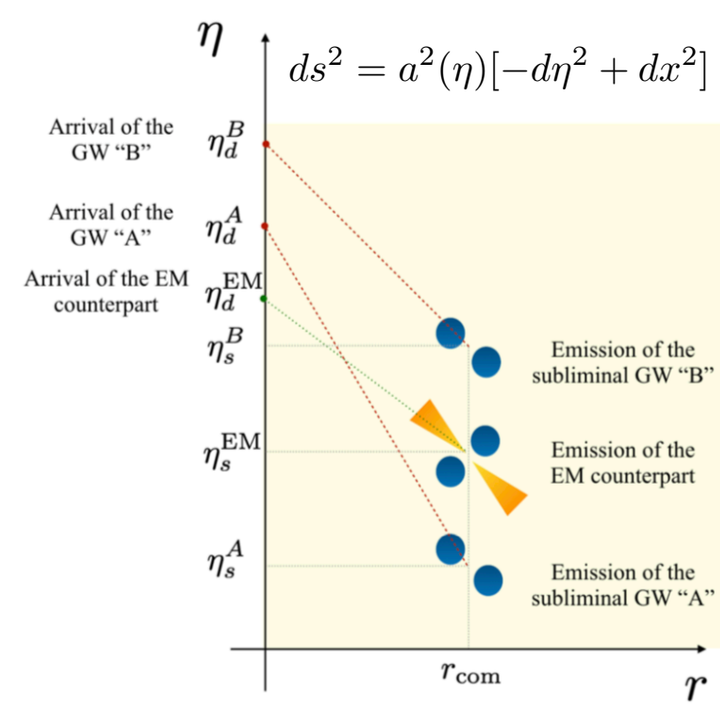
- GW from binaries: waveforms (order 4.5PN), propagation...
- Tests of General Relativity and of modified gravity theories: strong field, propagation modes, exotic objects...
- cosmology: standard sirens and measurement of cosmological parameters,
  stochastic GW background + its anisotropies

➔ *connection with CMB physics, dark matter, populations of stellar/supermassive BH*

- physics beyond the standard model of particle physics: symmetry breaking, string theory...

➔ *connection with particle physics*



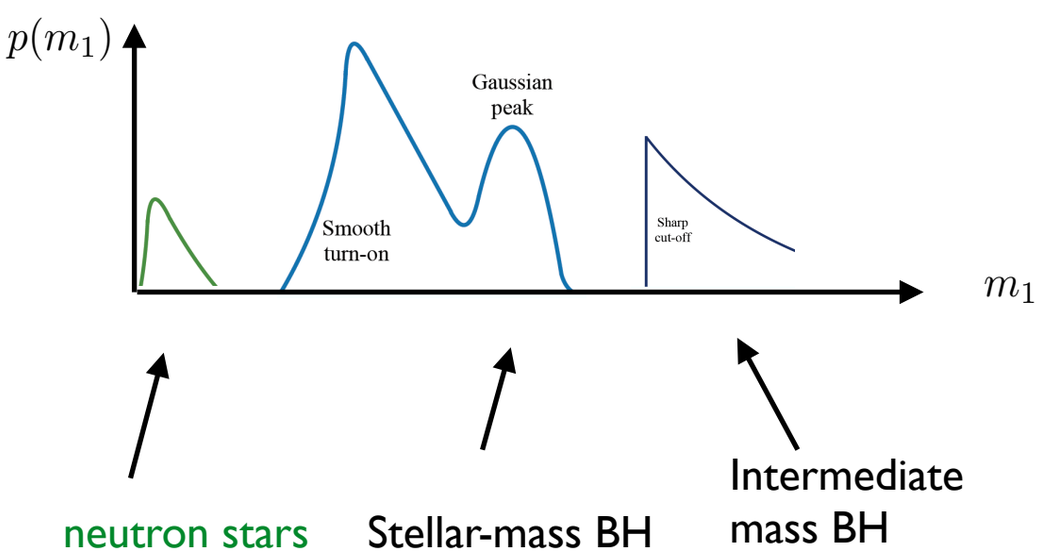


Science of the GdR

Astronomy and astrophysics

- Massive BBH: population, origin, binary formation, connection with structure formation, counterparts...
- Stellar origin BBH: population, origin, binary formation...
- Neutron stars: population, equation of state, counterparts of mergers (gamma-ray bursts, kilonovae...)
  - ➔ *connection with astrophysics, astroparticle physics, nuclear physics, cosmology*
- Counterparts and multi-messenger: electromagnetic: optical, X/ gamma-ray, radio...
  - ➔ *connection with science of astronomical observatories; neutrinos observatories*

➔ *connection with astrophysics and fundamental physics*



[SMBH: relativistic MHD simulations: 2102.06712]

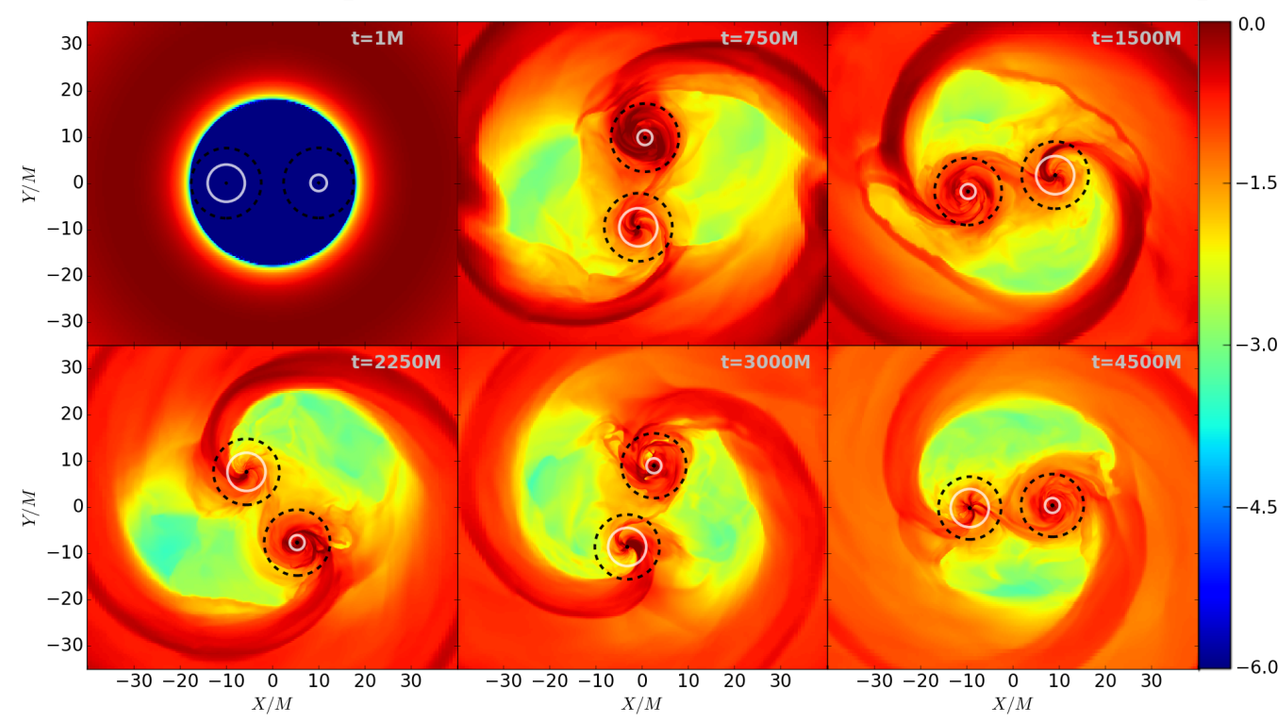


FIG. 1.— Rest-mass density in the equatorial plane for the χ_{+-} model. A persistent minidisk quickly forms around the $\chi_1 = +0.75$ black hole, but no disk forms around the $\chi_2 = -0.75$ black hole. The Hill spheres (black dashed circles) and the ISCO radii (white circles) are shown around each black hole (assuming each BH was in isolation). For the $\chi_1 = +0.75$ black hole the Hill sphere is significantly larger than the ISCO, but for the $\chi_1 = -0.75$ they are more comparable in size.

GdR Ondes Gravitationnelles v2

- Crucial to continue having an environment in which the French community interested in GW science can exchange.

  Multiple important aspects to discuss: e.g.

  - multi-messager astronomy (SVOM, ATHENA…)
  - preparation of Einstein Telescope, instrument design, preparation of data analysis, role of french community.
  - synergies LISA – Einstein Telescope (multi-wave length physics, common experimental aspects…)
  - interpretation of future LIGO/Virgo/KAGRA O4 et O5, (multiple events at cosmological distances.)
  - LISA scientific objectives (will influence the final design of LISA, and GW astronomy from space until mid-century!),
  - Low frequency GWs (PTA europe, Nancy Radio Telescope)
  - Virgo post-O5

- Require interdisciplinary links, between experimentalists, theorists, experts on data analysis etc, to exploit and interpret the new data from LVK and PTA

activities 2022

- Réunion du Groupe de Travail “Méthodes d’analyse des données”, IP2I Lyon, 15 novembre 2022.
- Sixième assemblée générale du GdR, Université Paul Sabatier, Toulouse, 10-12 octobre 2022
- Réunion jointe des Groupes de Travail “étoiles à neutrons et supernovae” du GdR Ondes Gravitationnelles, et “Astrophysique Nucléaire” du GdR RESANET, Observatoire de Paris, 28-29 juin 2022
- Réunion jointe des Groupes de Travail “Cosmologie” et “Tests de la relativité générale et théories alternatives”, IJCLab à Orsay, 20 juin 2022
- Réunion jointe des Groupes de Travail “Populations des sources” et “Prédiction et suivi des signaux multi-messager”, Besançon, 7-8 juin 2022
- Réunion du Groupe de Travail “Développement des détecteurs”, en ligne, 14 février 2022

activities in 2018-2021

Première assemblée générale : Paris, 18-19 octobre 2018, 98 participants
https://indico.in2p3.fr/e/GdROG
Building the GdR community, creating contacts between theorists and experimentalists, meeting, discussing, presenting the last advancements in the field

Deuxième assemblée générale : Lyon, 10-11 octobre 2019, 76 participants
https://indico.in2p3.fr/e/GdRAssembleeLyon
Building the GdR community, ... + provide an event in which young researchers can present their work

Troisième assemblée générale : on line, 14-15 octobre 2020 140 participants
https://indico.in2p3.fr/event/20835/

"Gravitational waves: a new messenger to explore the universe" 1 march - 9 april 2021
Six-weeks thematic programme at the Centre Emile Borel de l'Institut Henri Poincaré
Organisation: Chiara Caprini, E. Chassande-Mottin, G. Faye, F. Vernizzi, M. Volonteri
Structure of the thematic programme
- Theoretical aspects of gravitational-wave science (March 1-12)
- Astrophysics and cosmology (March 15-26)
- Gravitational-wave detectors and data analysis (March 29-April 9)

Quatrième assemblée générale : on line, 30 mars -1 avril 2020, 272 participants
https://indico.math.cnrs.fr/event/5766/overview

Cinquième assemblée générale : Annecy, 11 -12 October 2021, 81 participants
https://indico.in2p3.fr/event/24548/

activities in 2018-2021

Working Groups meetings

- *Développement des détecteurs* : Paris, juin 2018 ; Paris, juin 2019 ; en ligne avril 2021
- *Analyse des données* :
  - joint meeting with working group "Méthodes d'Analyse des Données" du *GdR ISIS* de l'INS (Information, Signal, Image, Vision), Paris oct 2018
  - "Gravitational wave open-data workshop", Paris avril 2019
  - en ligne, nov 2020
- *Etoiles à neutrons* :
  - Paris, mai 2019
  - joint meeting with working group "Astrophysique nucléaire" du *GdR RESANET* (physique nucléaire), Paris sep 2018 ;
  - en ligne, juin 2020
- *Cosmologie* : Paris, nov 2019 ; on line, jan 2021
  - *Tests de la relativité générale et théories alternatives* : Gif-sur-*Yvette, jan 2019*
  - *Formes d'ondes :* Meudon, mai 2019
- joint meeting: *Tests de la relativité générale et théories alternatives* + *formes d'ondes :* Paris, fév 2020
- joint meeting:, *Population des sources et prédiction et suivi des signaux multi-messager* : mars 2021
- organisation of 2 "ateliers" at the "journées de la Société Française d'Astronomie et Astrophysique", 2018 et 2019

First GDR: Support to the community / News / Highlights

- The GdR allowed a new community to form, federate and strengthen
- The GdR meetings and assemblies allowed dozens of students and postdocs to present their work to the national community
- GdR provided support to the Einstein Telescope project, and more generally the GdR spoken — though a unique voice — for the importance of GW physics at the level of the Instituts of the CNRS.
- GdR managed to maintain a regular activity during the pandemic
- The 1st version of the GdR received a very positive outcome and evaluation by IN2P3
- The connection with the astrophysics community needs to be reinforced, in particular concerning multi-messenger aspects but also at the level of sources populations