

Report on Moriond Gravitation session 2022

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DPhP 22 May 2022

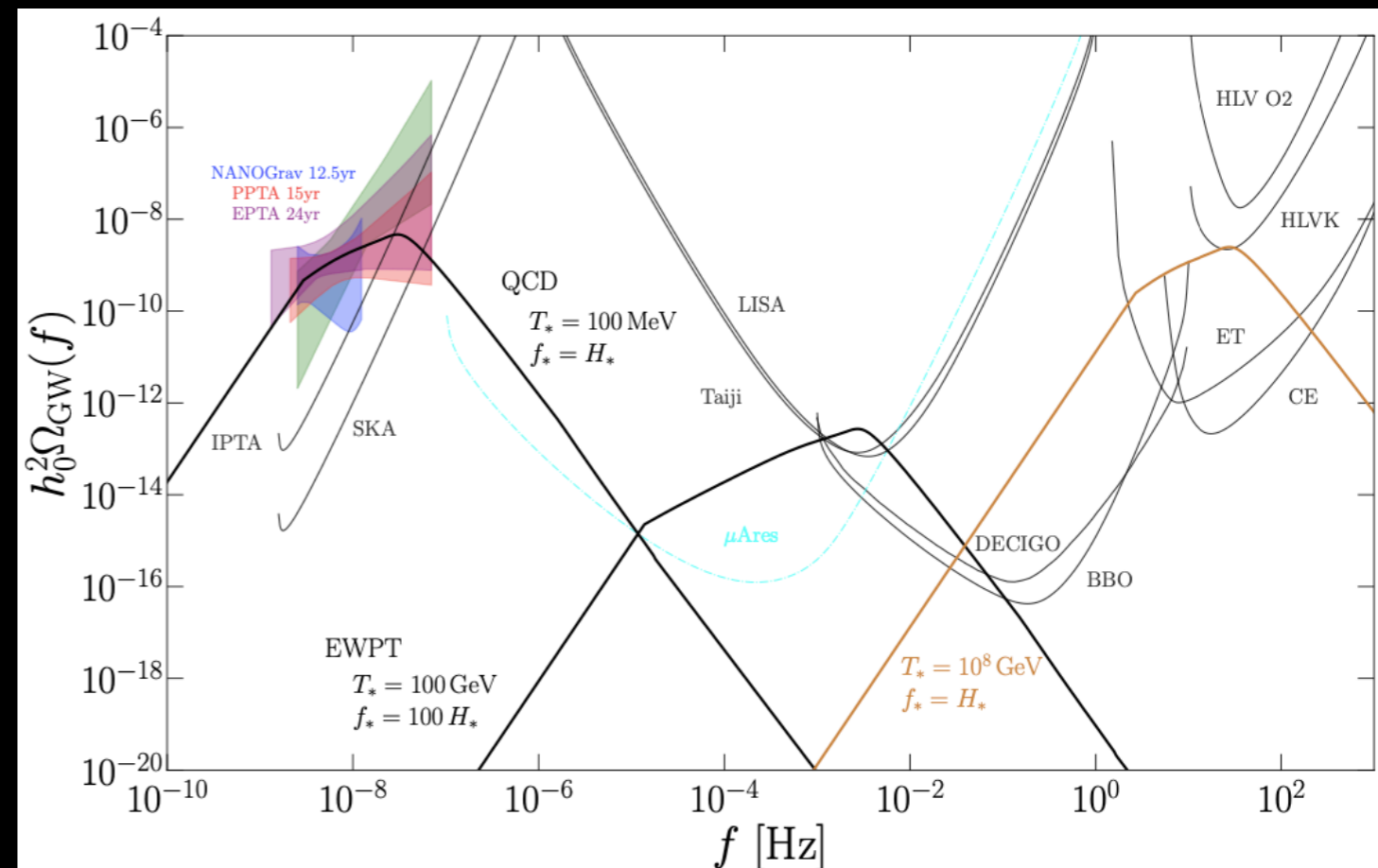
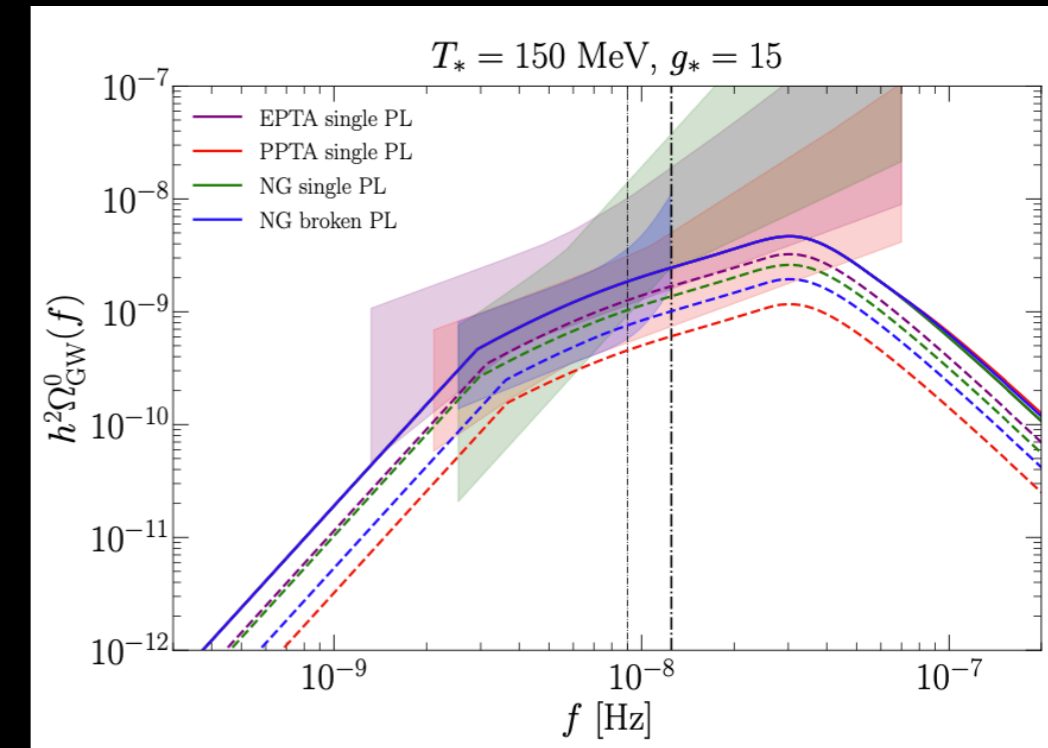
Overview

- ▶ **Gravitational Waves (GW) (7/14 sessions):**
 - Sources and waveforms
 - Searches in available data: PTA and LIGO-Virgo-Kagra
 - Observatories: LIGO-Virgo-Kagra, LISA, ET, very high frequency
- ▶ **Gravitation with cold atoms ($\sim 2/14$ sessions)**
- ▶ **Test of equivalence principle (1/14 session)**
- ▶ **Test of Gravitation ($\sim 0.5/14$ session)**
- ▶ **Dark matter ($\sim 0.5/14$ session)**
- ▶ **Neutrons and Anti-hydrogen (1/14 session)**
- ▶ **Theory (2/14 sessions)**

GW: sources, waveforms, population

► Stochastic backgrounds

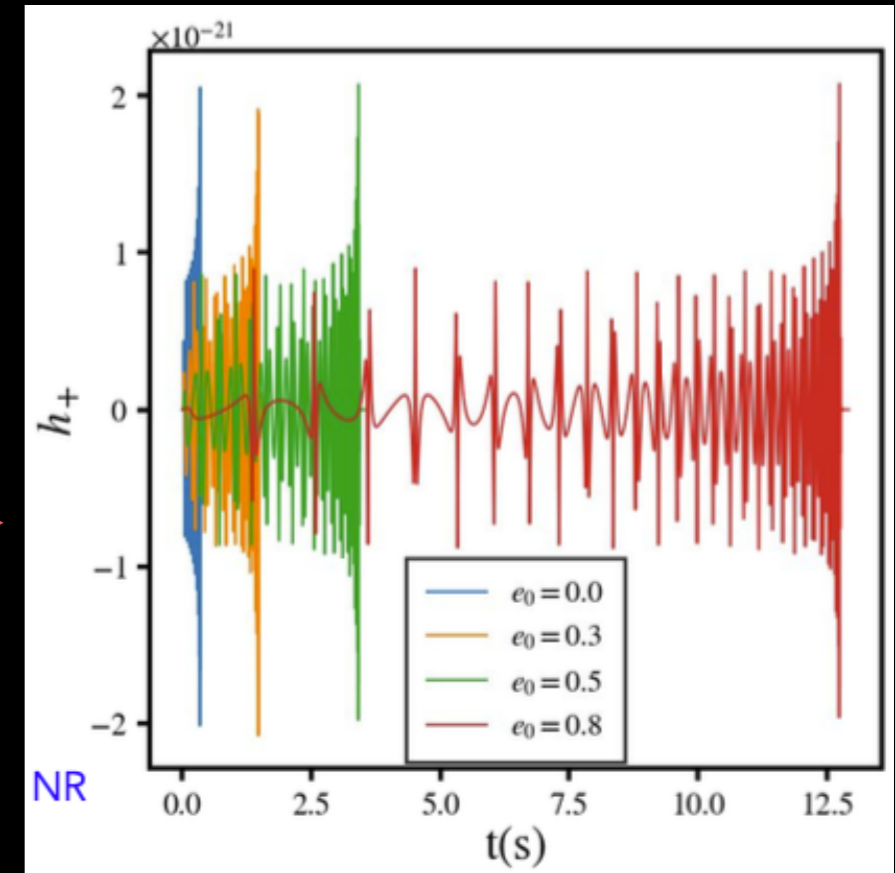
- **[A. Roper Pol]** Impact of primordial magnetic field in the early Universe on first order phase transition backgrounds \Rightarrow constrain on the primordial magnetic field with PTA observations.



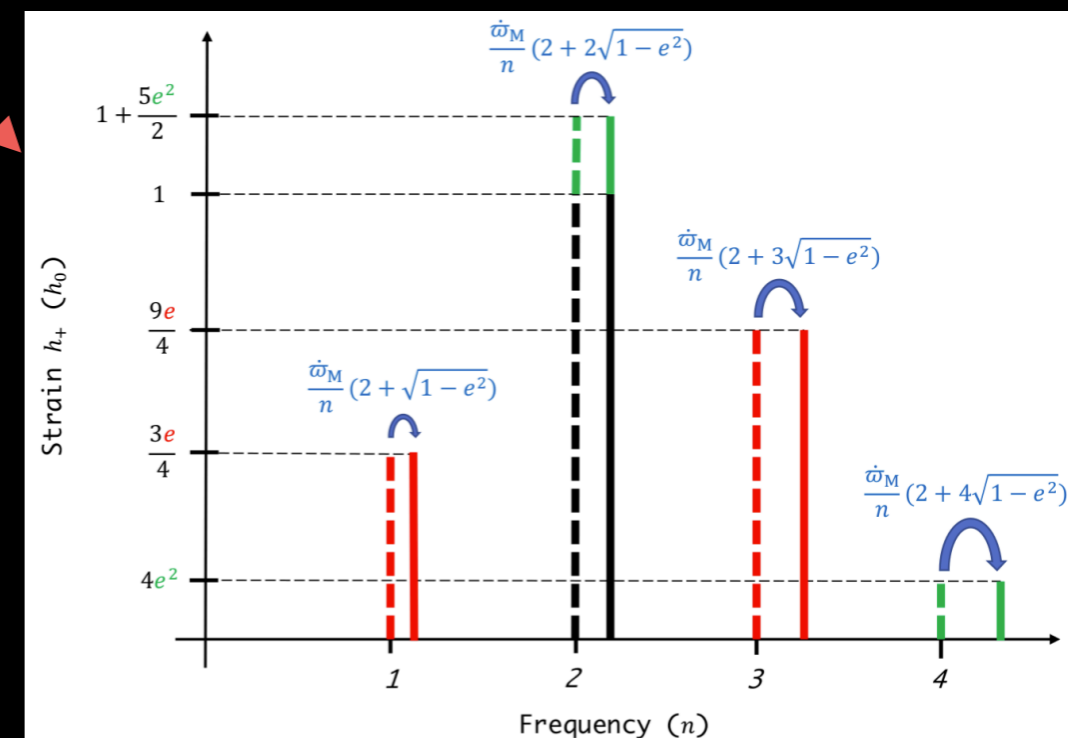
GW: sources, waveforms, population

► Binaries:

- Eccentricity for BH binaries: [A. Ramos-Buades] Development of waveform with eccentricity and multiple harmonics in the Effective One Body approach.
- Magnetic field in white dwarf binaries: [A. Bourgoin] possibilities to measure it with LISA.



- Importance of the LISA and PTA observations to constrain the population of SMBHBs and the formation models [M. Curylo]



GW: searches in available data

► Stochastic GW backgrounds (SGWB) :

- Importance of SGWBs for astrophysics and cosmology. Hope in future detectors.

- With PTA:

- Evidence of common red-noise in EPTA.

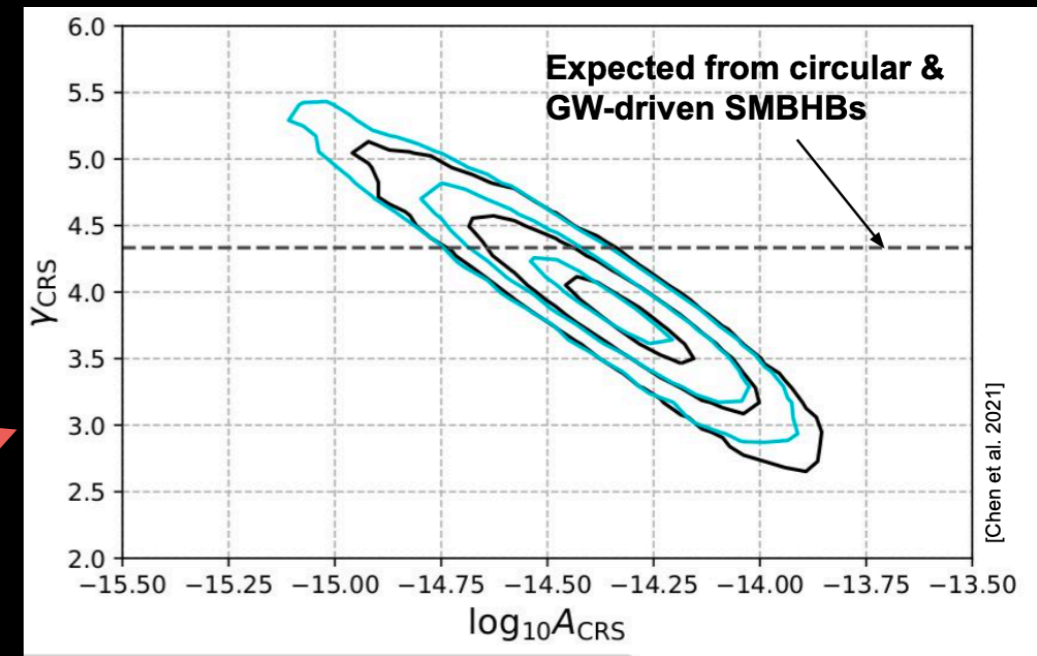
[A. Chalumeau]

- On-going search for anisotropies. [Y. Ali-Haimoud]

- With LVK:

- No detection in LVK O3 but constrains. BH Binaries background should be detected in the coming years. [T. Regimbau]

- Upper limit with multiple components for the anisotropic background. [J. Suresh]



α	Ω_{GW}	$H(f)$	Max SNR (% p-value)				Upper limit range (10^{-9})	
			HL(O3)	HV(O3)	LV(O3)	O1+O2+O3 (HLV)	O1+O2+O3 (HLV)	O1 + O2 (HL)
0	constant	$\propto f^{-3}$	1.6 (78)	2.1 (40)	1.5 (83)	2.2 (43)	3.2–9.3	7.8–29
2/3	$\propto f^{2/3}$	$\propto f^{-7/3}$	3.0 (13)	3.9 (0.98)	1.9 (82)	3.7 (1.7)	1.9–9.7	6.5–25
3	$\propto f^3$	constant	3.9 (12)	4.0 (10)	3.9 (11)	3.2 (60)	0.56–3.4	1.9–11

GW: searches in available data

► Compact Binaries Coalescing (LVK):

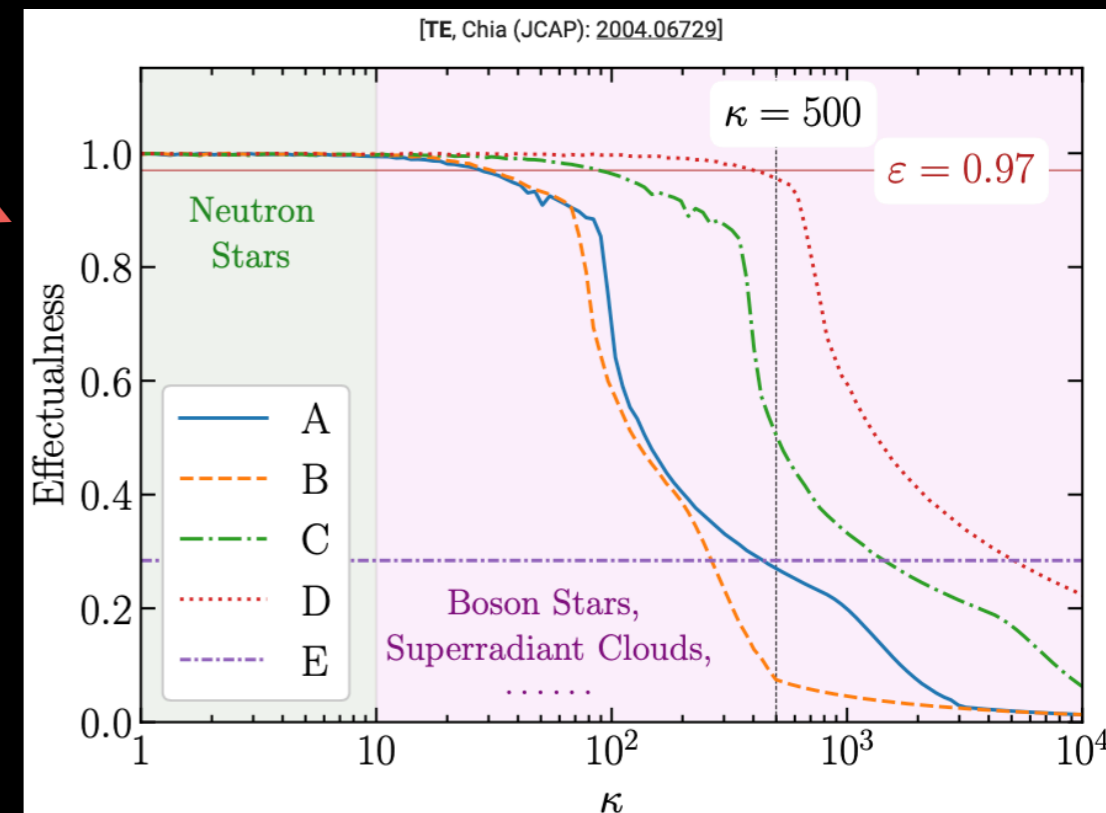
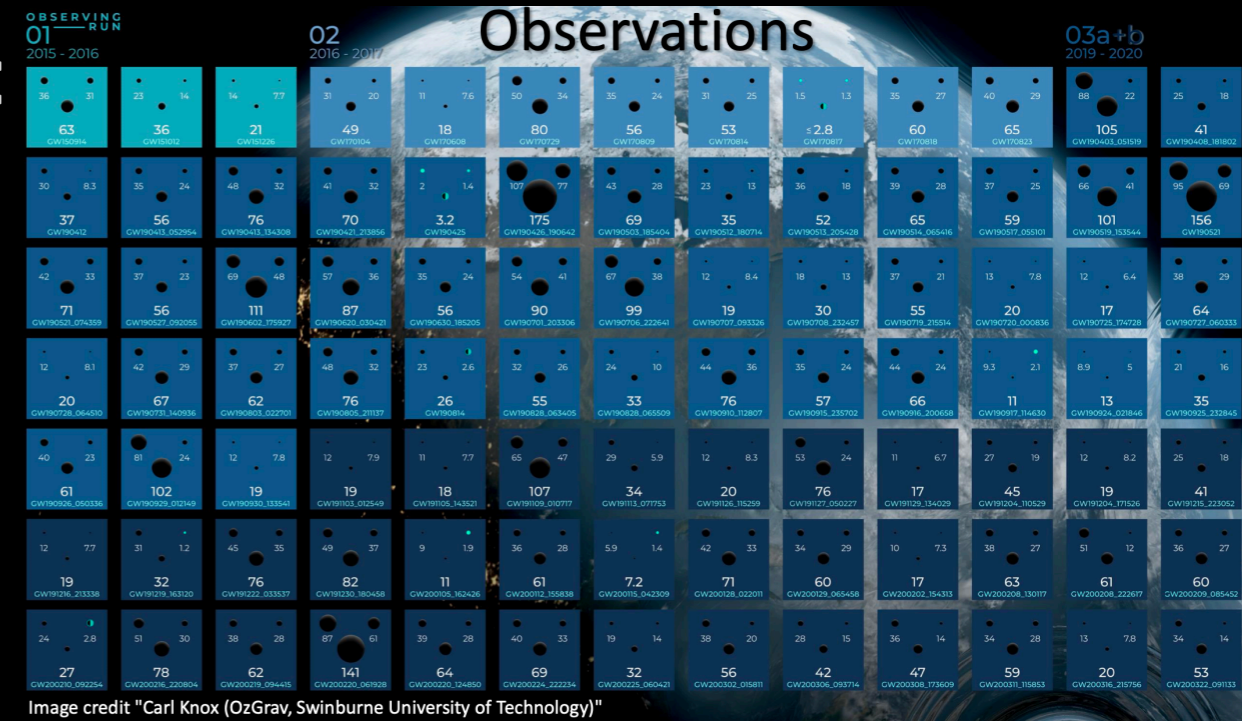
- Overview talks about particular sources from the LVK catalogs [S. Fairhurst]: detection of higher harmonics, NS-BH, statistic on population.

- Search for new compact objects. [M. Edwards]

- AGN flares counterpart of BBH in galaxy centres? [A. Palmese]

- 3 bodies interactions [A. Palmese]

- Deformability of Neutron Stars [A. Perot]



GW: searches in available data

▶ SuperMassive Black Hole binaries

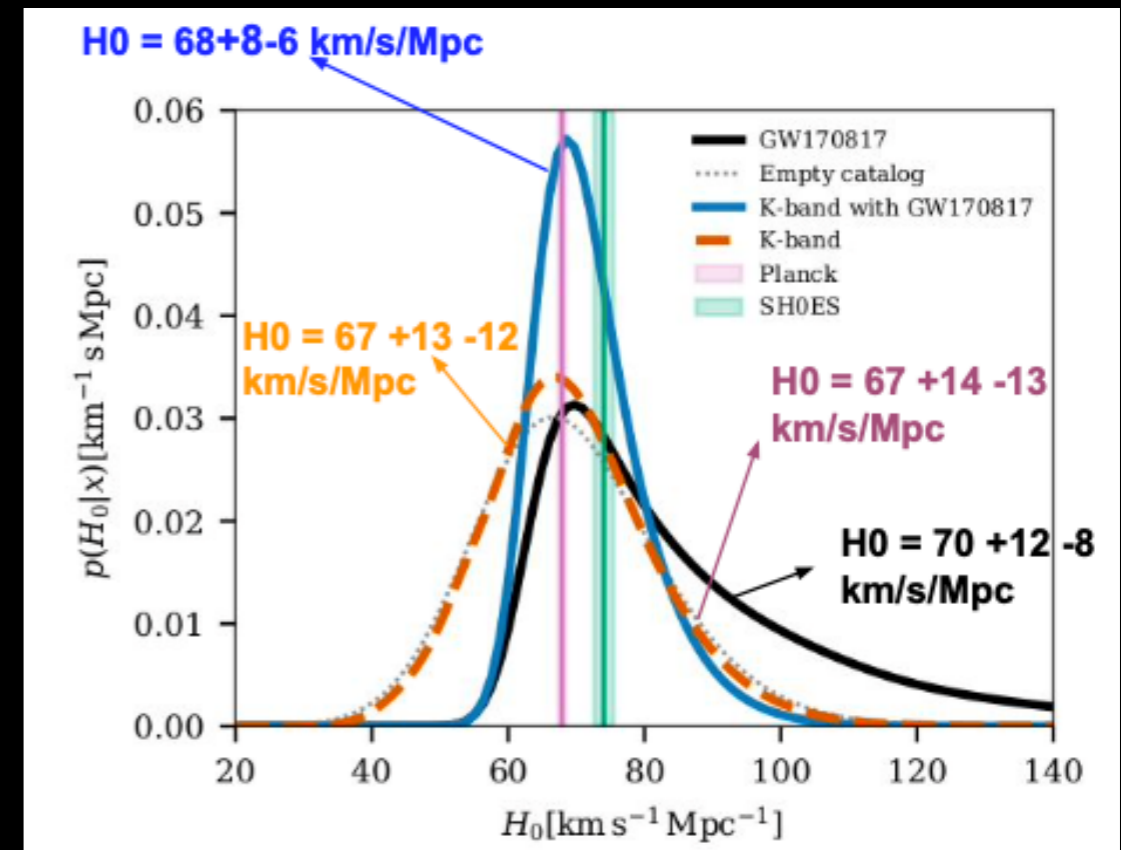
- Search with IPTA [M. Falxa]: discussion about the nature of observed features.


▶ Cosmology with GWs:

- Constrain on H_0 from LVK O3 [S. Mastrogiovanni]
- Modified gravity and cosmology with dark sirens [S. Mancarella & F. Iacovelli]

▶ Multimessenger:

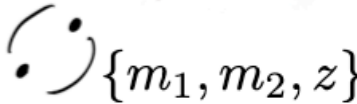
- Targeted searches associated to GRBs: no detection but exclusion distance [J.G. Ducoin]





$d_L^{\text{GW}}(z; H_0, \Xi_0, \dots)$

$m_i^D = m_i \times (1+z)$



$\{m_1, m_2, z\}$

$$d_L^{\text{gw}}(z) = \left[\Xi_0 + \frac{1 - \Xi_0}{(1+z)^n} \right] \times \frac{c}{H_0} (1+z) \int_0^z \frac{dz'}{\sqrt{\Omega_M(1+z')^3 + \rho_{\text{DE}}(z', w_0, w_a)/\rho_0}}$$

MODIFIED GW PROPAGATION

— Dominant effect at largish z & beyond Λ CDM

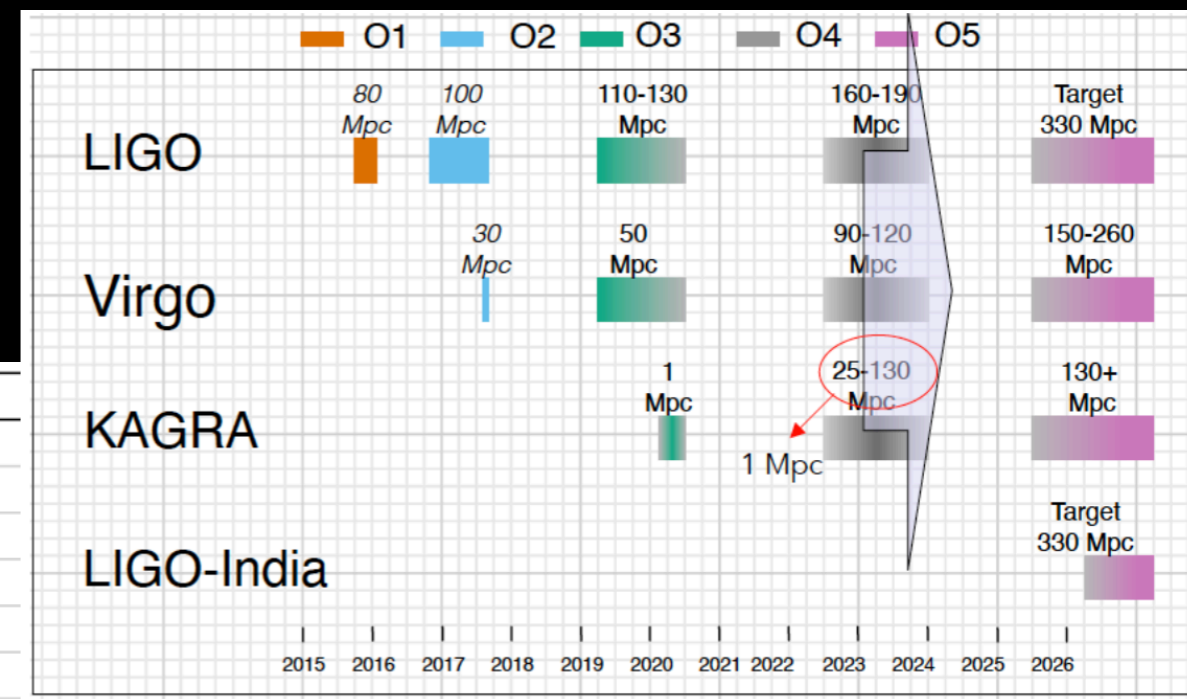
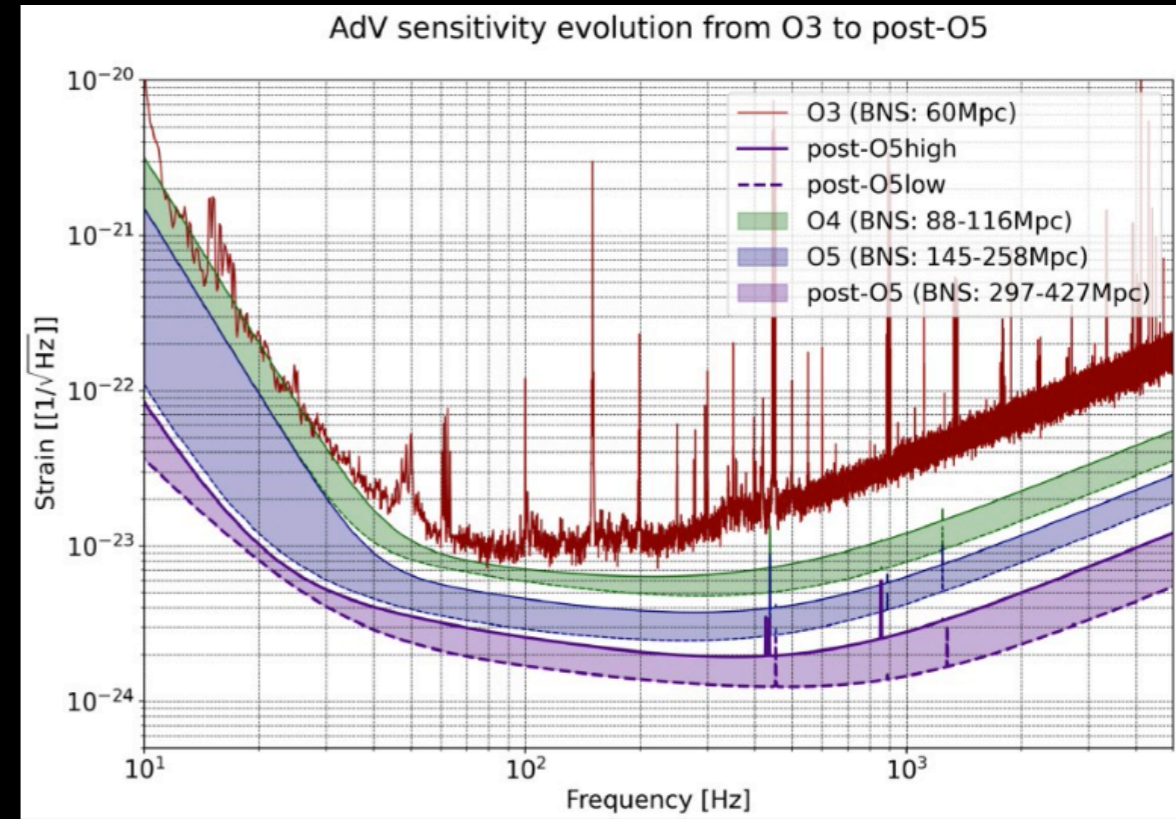
USUAL (ELECTROMAGNETIC) LUMINOSITY DISTANCE

— Dominant effect at low redshift &/or in Λ CDM only;

— Small effect &/or constrained by EM observations

GW: current ground based obs.

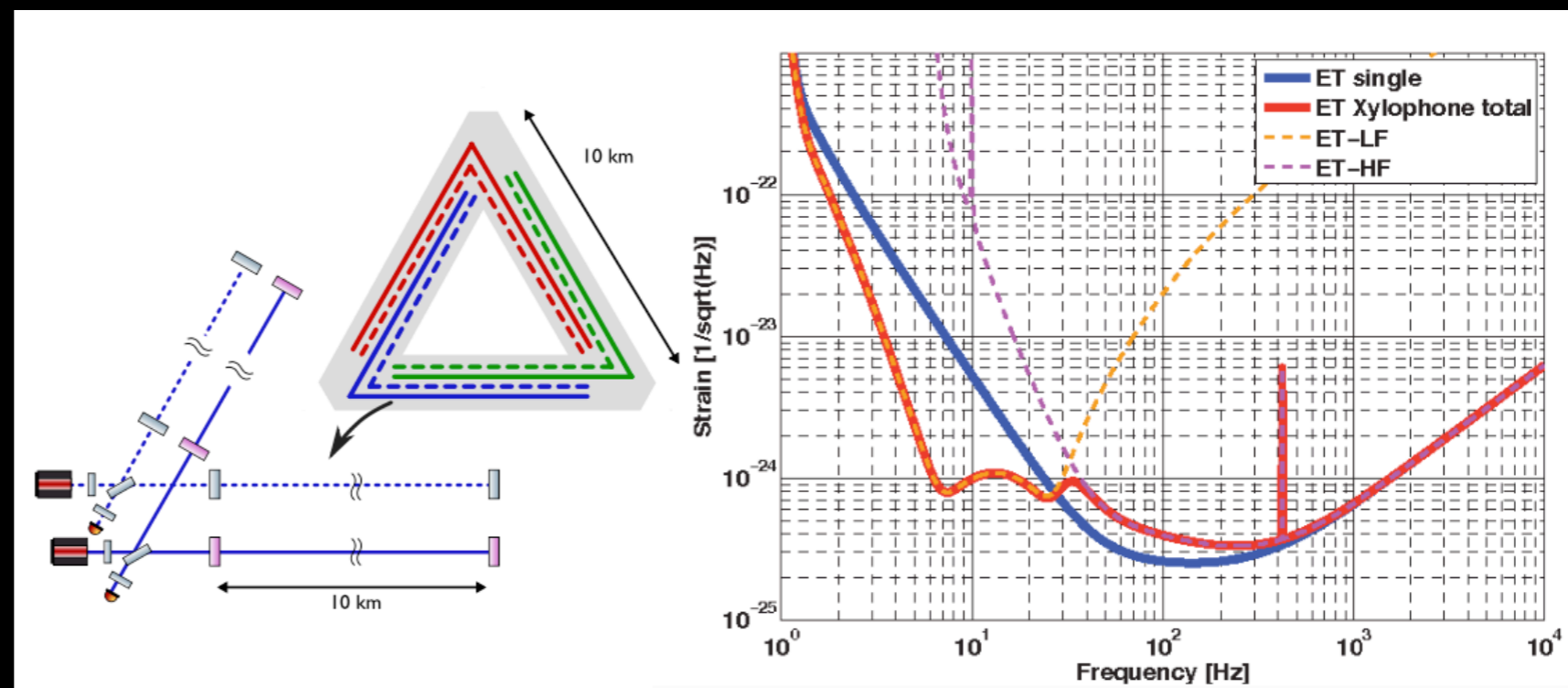
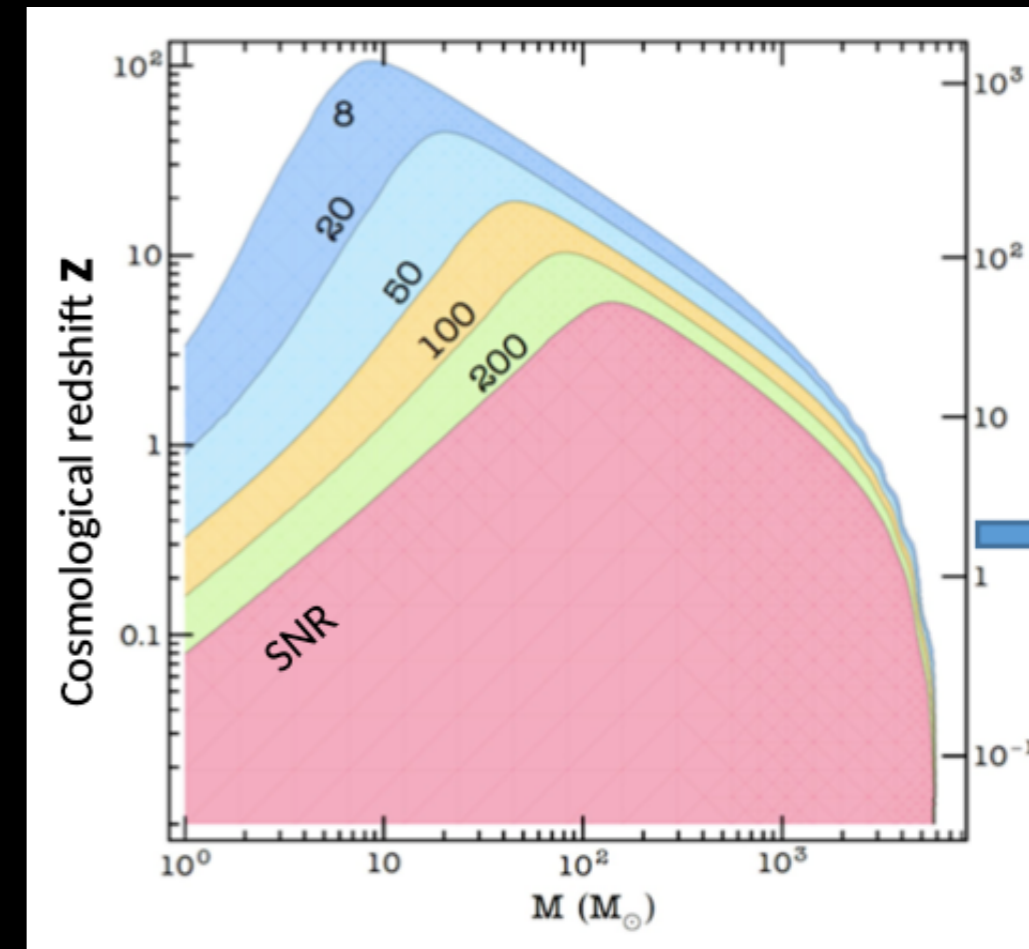
- ▶ Virgo: update on upgrade; O4 plan to December 2022 [A.-M. Bizouard]
- ▶ Frequency dependent squeezing [A.-R. Schnabel]



	2019	2020	2021	2022	2023	2024	2025
O3	O3						
AdV+ Phase I	Construction and Preparation Phase II		Installation	Commissioning			
O4				O4	O4		
AdV+ Phase II	Construction					Installation	Commissioning
O5							O5

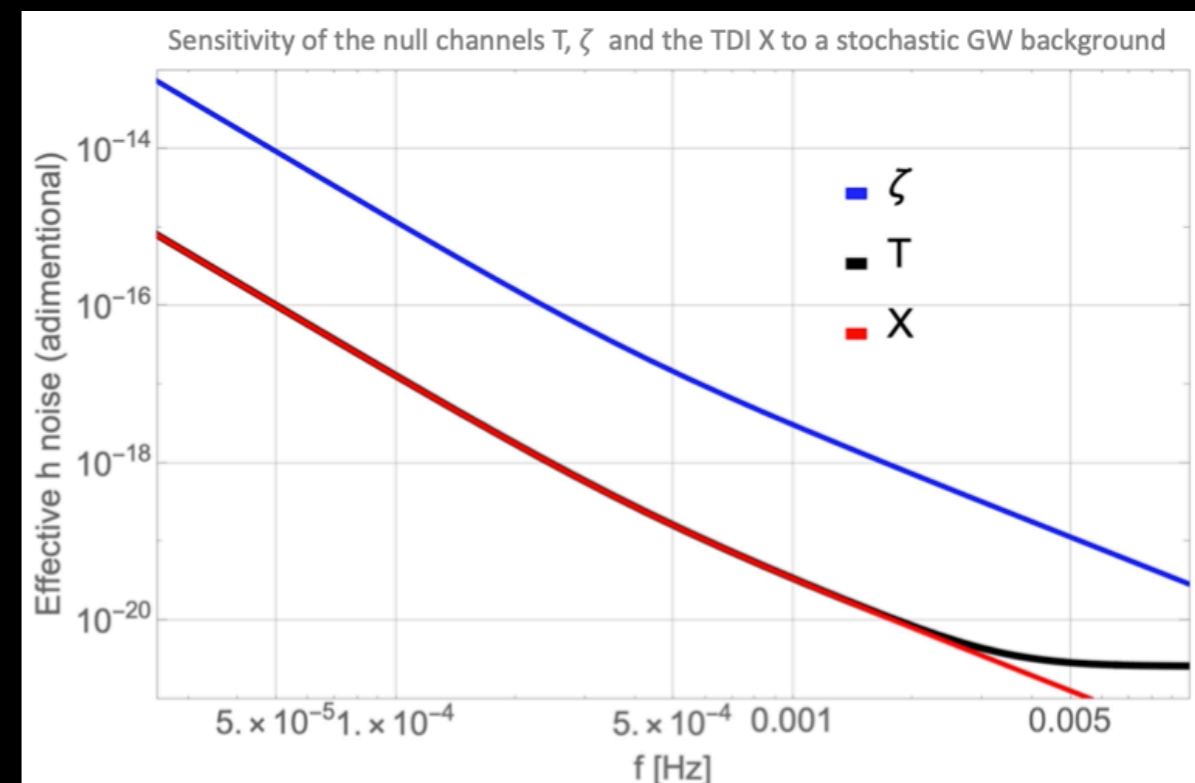
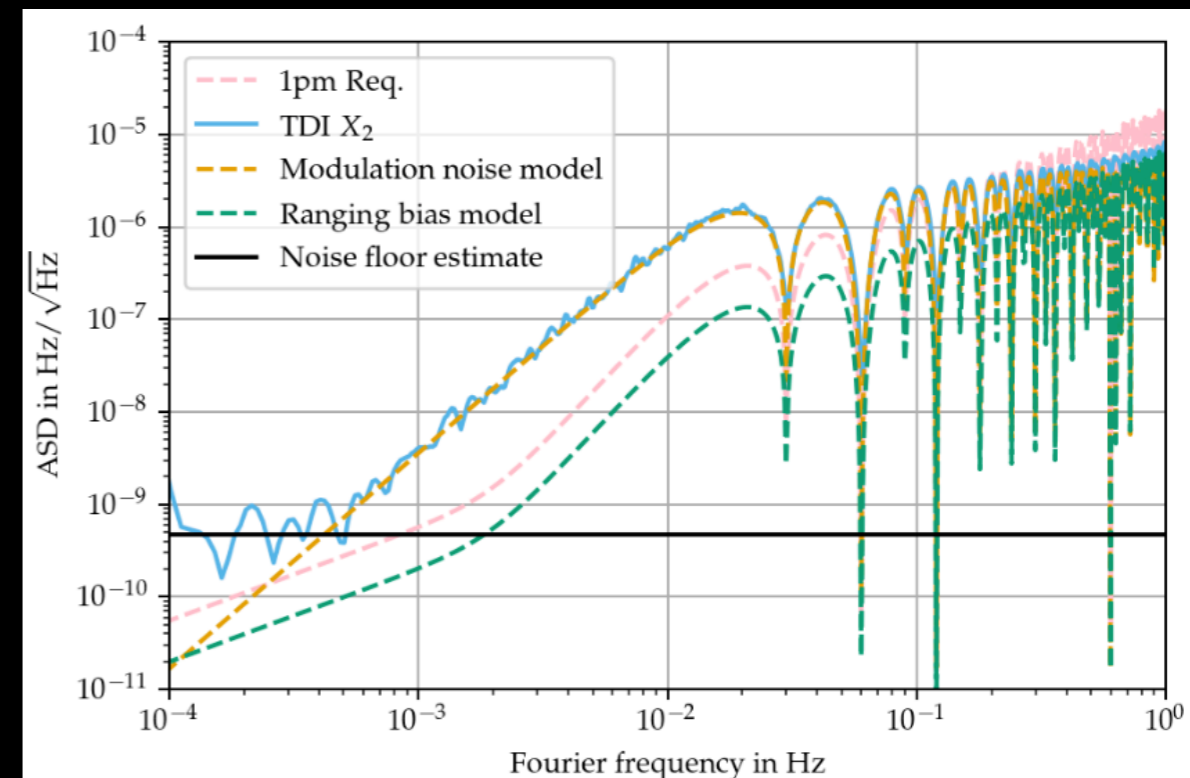
GW: Einstein Telescope

- ▶ Status of the project [T. Bulik]:
 - Localisation will be decided in 2 years with building starting in 2026
 - Possible multi-wavelength with LISA
- ▶ They are starting to work on data analysis using mock data, etc. [N. Singh]
- ▶ Constrain on pop. of compact objects [T. Bulik]



GW: LISA

- ▶ Status of the mission [A. Petiteau]
- ▶ LISA Data Challenges [Q. Baghi]
- ▶ Time Delay Interferometry (on ground processing of noises):
 - New version of the TDI algorithm working directly from the unsynchronised data [O. Hartwig]
 - Use of specific TDI channel for noises characterisation: new null channel [M. Muratore]
- ▶ LISA Pathfinder results and update on the on-going analysis (low frequency excess noise, long-lasting glitches, etc) [L. Sala]

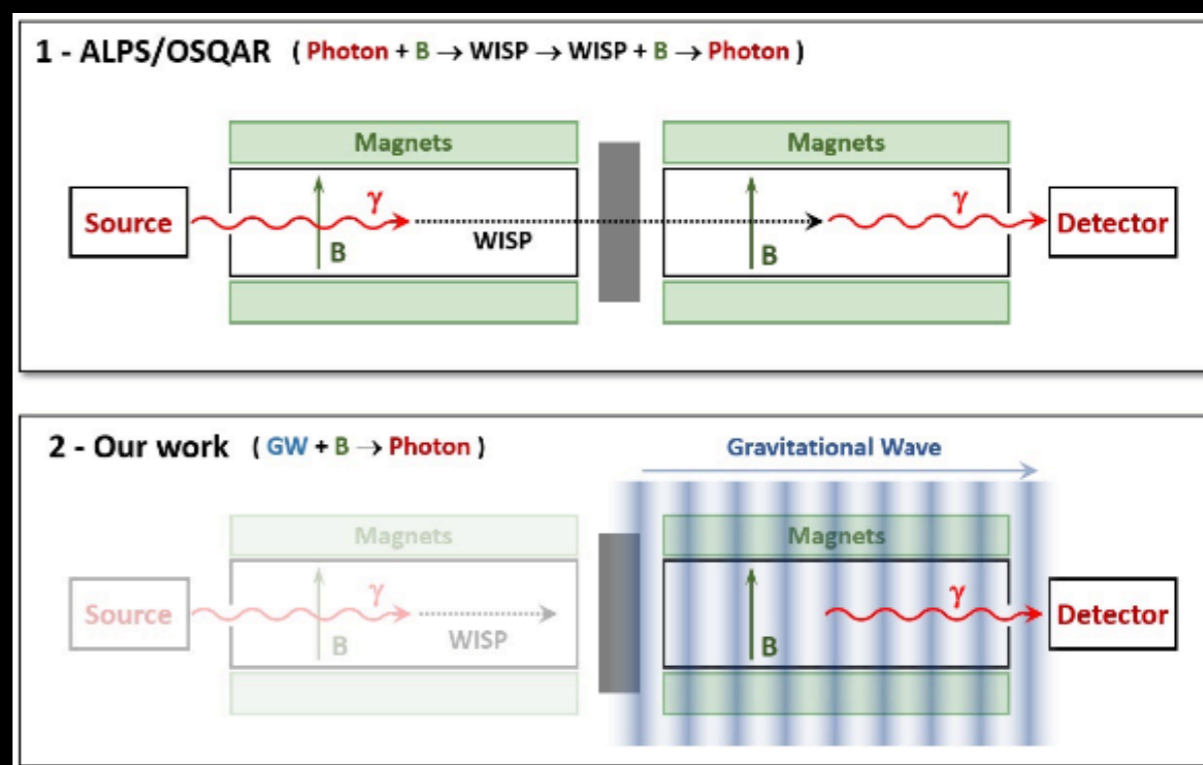
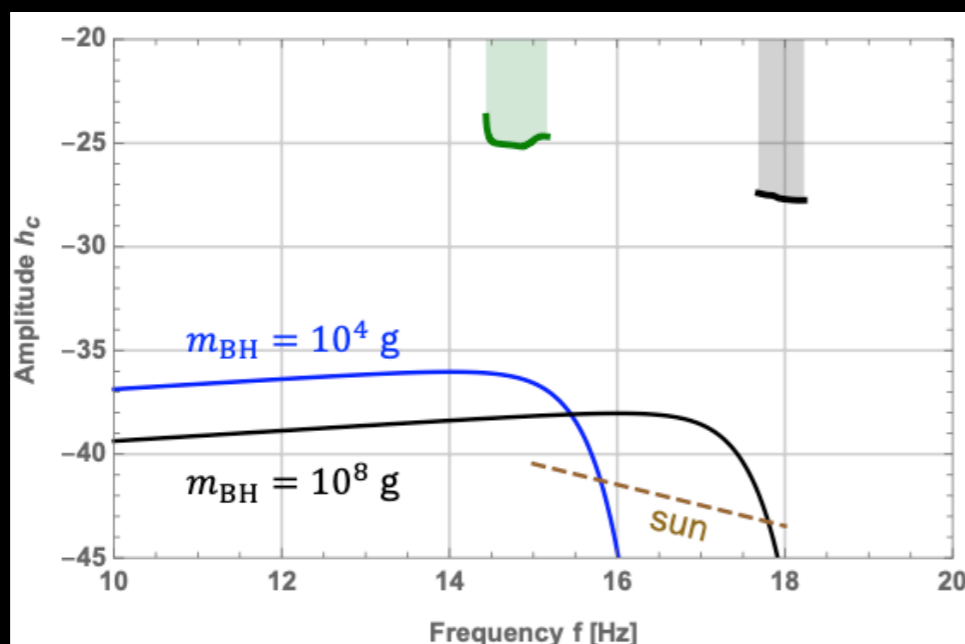
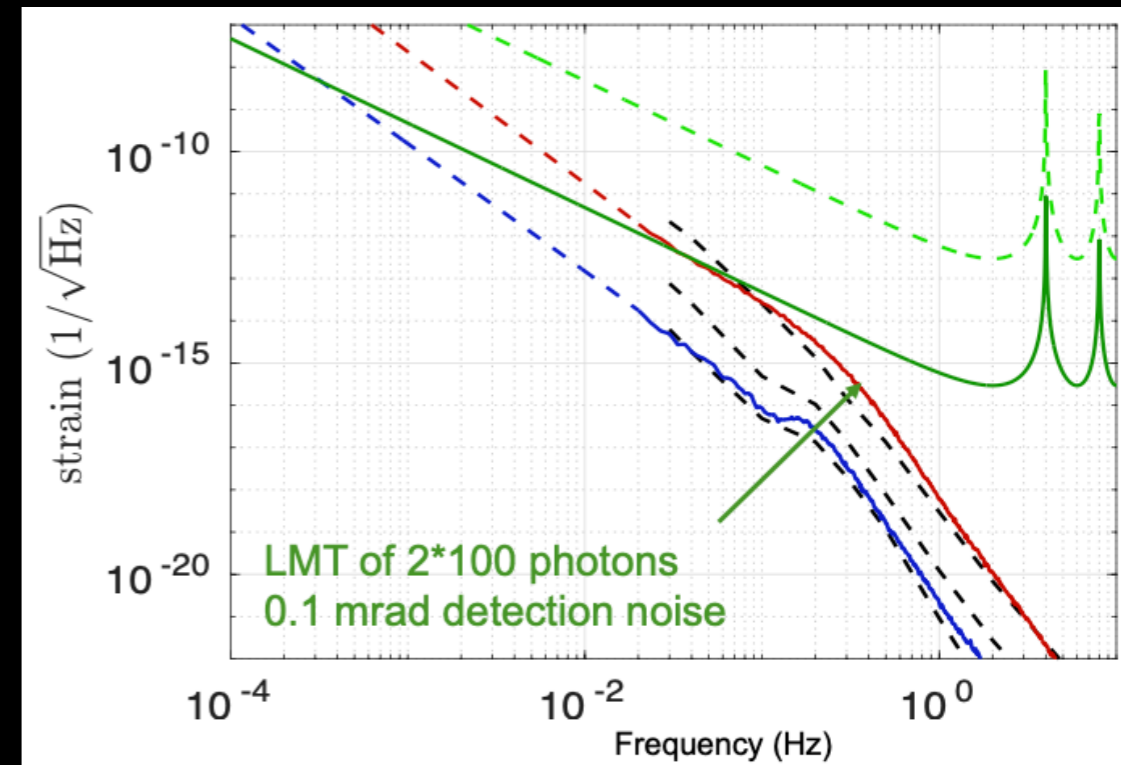


GW: Other observatories

► MIGA: GW Obs. With atom interferometry
[B. Canuel]:

- Infrastructure and main elements ready
- Assembly and commissioning
- Starts mid-2022

► Ultra-high frequency GW from graviton to photon conversion (axion-like partial experiments) [A. Ejlli]; sources: primordial BH evaporation, Sun



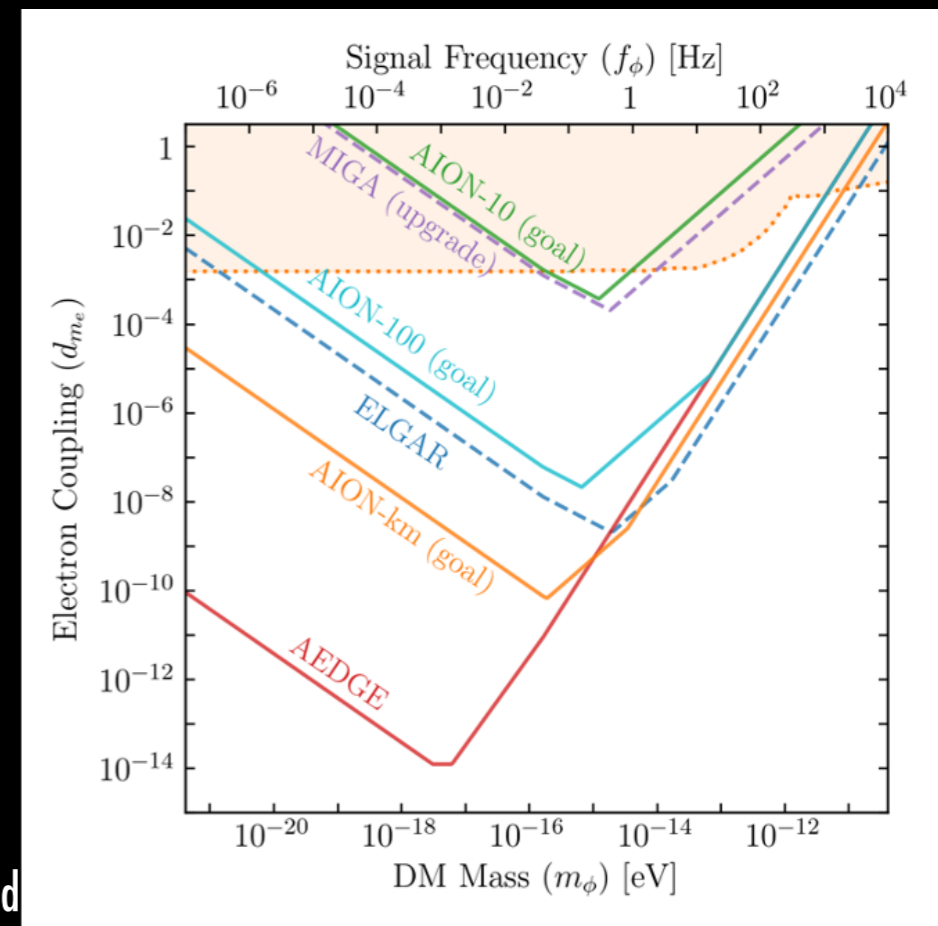
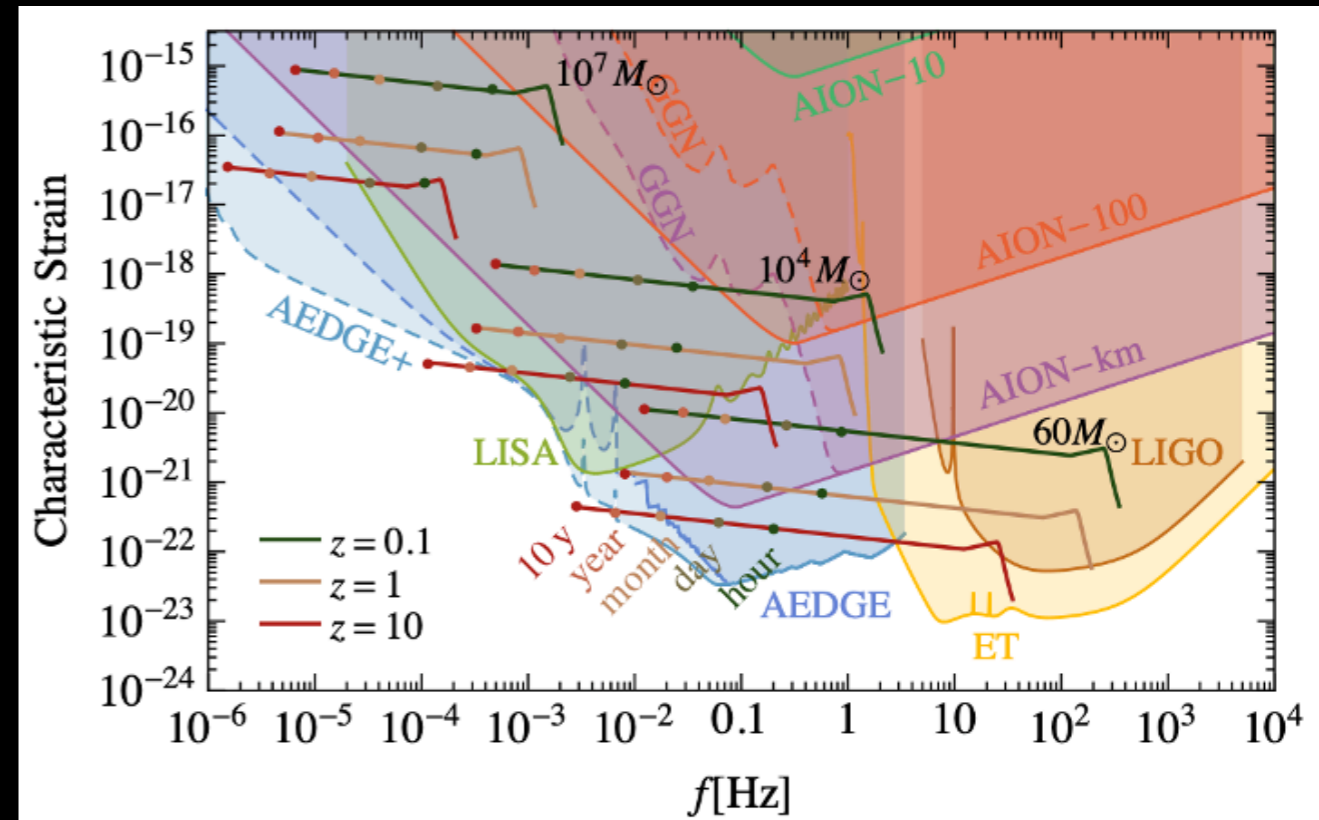
Gravitation with cold atoms

▶ AION (Atom Interferometer Observatory and Network) & AEDGE [O. Buchmueller]:

- space mission: pair of satellites with very long baseline; long-term but roadmap at ESA
- GW & Ultra-Light Dark Matter

▶ CARIOQA [P. Wolf & Q. Beaufils]:

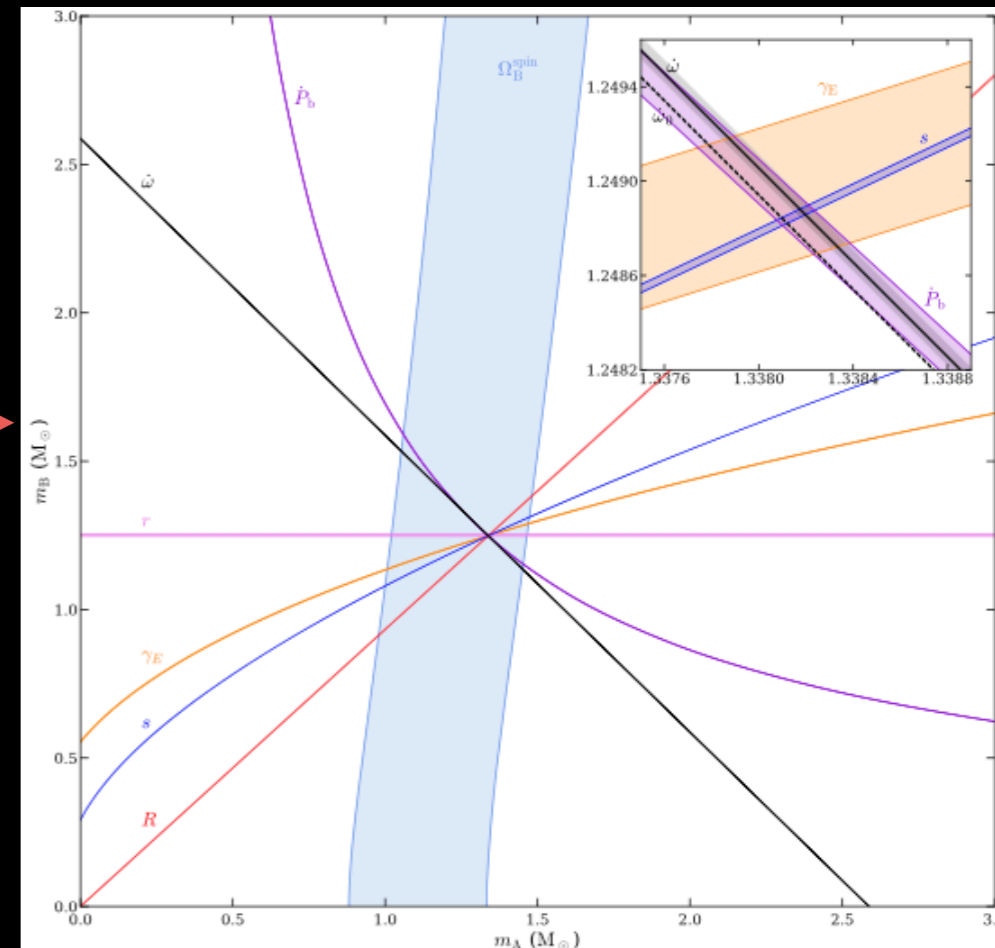
space mission for cold atom interferometer;
seconds long interferometers;
accelerometer



Test of Gravitation

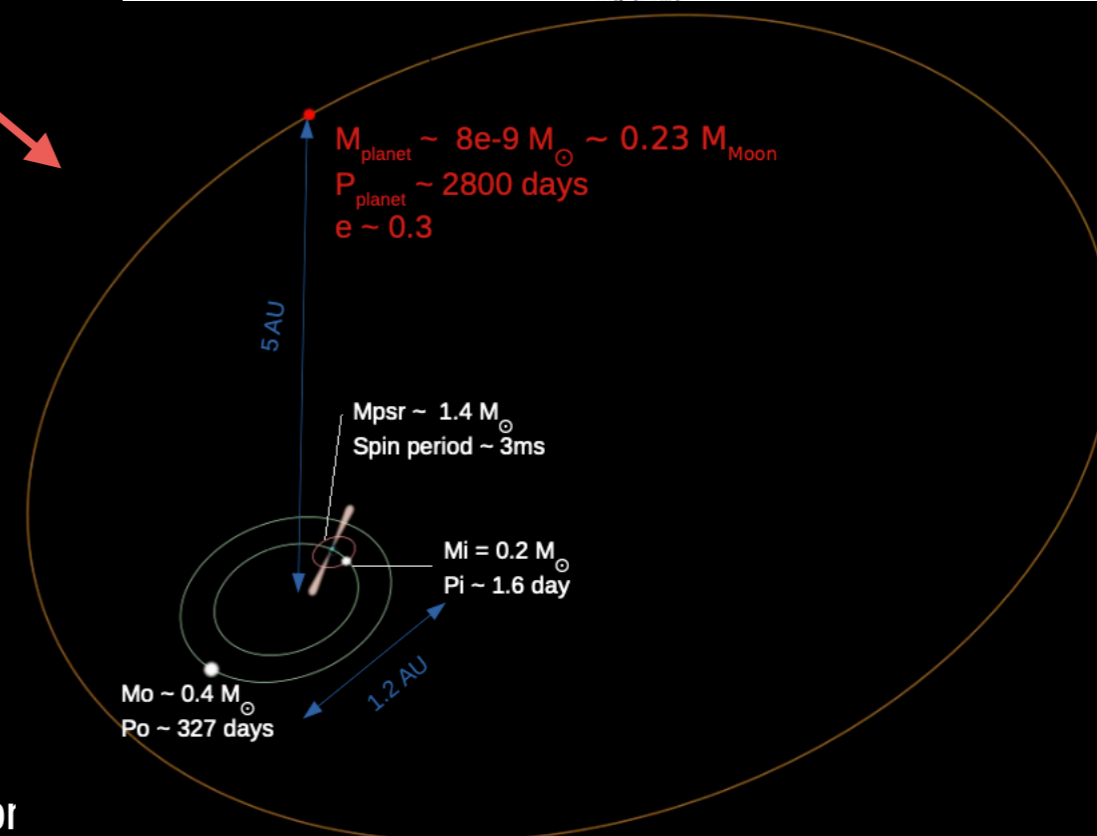
► With pulsars:

- The double pulsars agrees with GR;
No dipolar GW emission [P. Freire]
- Pulsar in triple systems + planets
(?): test strong equivalence
principle [G. Voisin]



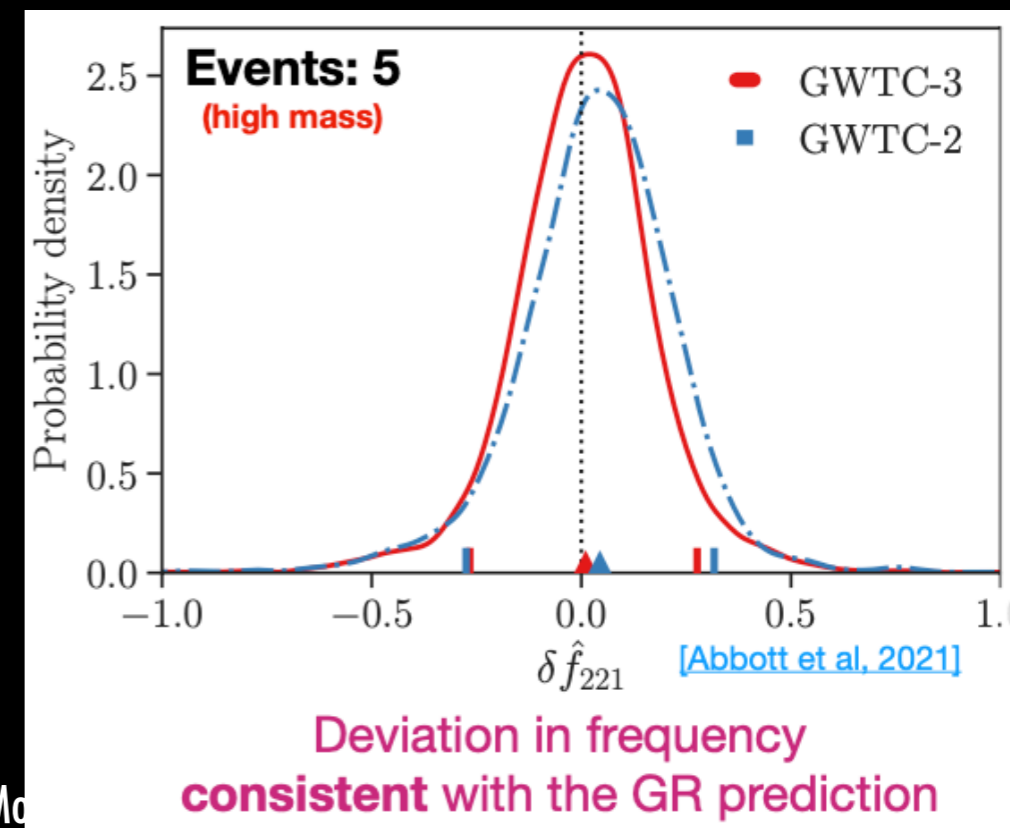
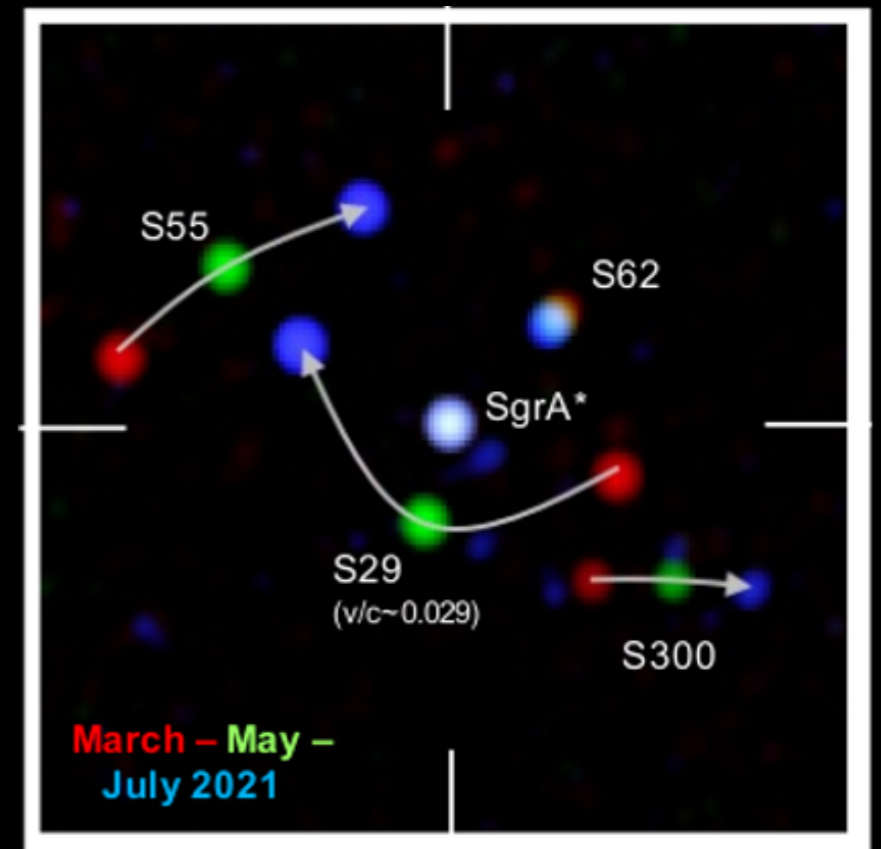
► With planets ephemerides [A. Fienga]: INPOP in the frame of the BepiColombo mission:

- Massive graviton
- Massless dilaton



Test of Gravitation

- ▶ Galactic center, GRAVITY@VLT [G. Perrin]: constrains from stars orbiting around SgrA*: test of relativistic precession:
 - Einstein confirmed at 7 sigma
 - Extended mass less than 0.1 %
- ▶ Using the catalog LVK O3 [A. Ghosh]: 9 different methods, in particular the test of the BH ringdown: no detection of significant deviation from GR.
- ▶ Test using QuasiNormal Modes [F. Bombacigno]

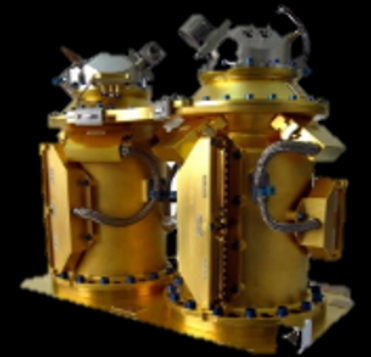
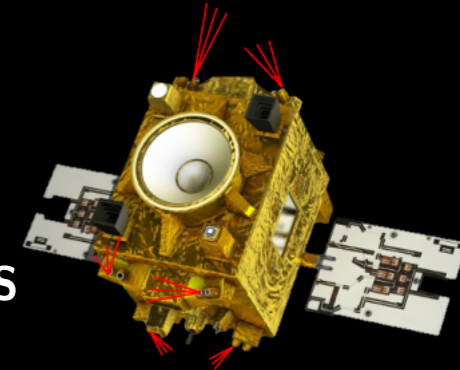


Test of equivalence principle

- ▶ MICROSCOPE [Q. Baghi]: final results using 1642 orbits to be published (first results published over 120: $1.9e-14$)
- ▶ Interesting discussion about the need to go deeper in precision for the tests of equivalence principle [P. Wolf]: hypothesis of equivalence, not a fundamental symmetry
- ▶ Tests with atomic clocks and atom interferometer [F. Di Pumpo & P. Asenbaum]
- ▶ Test around Super Massive Black Hole using stars orbiting around SgrA* [A. Hees]:

- Relativistic redshift consistent with GR
- No variation of fine structure constant

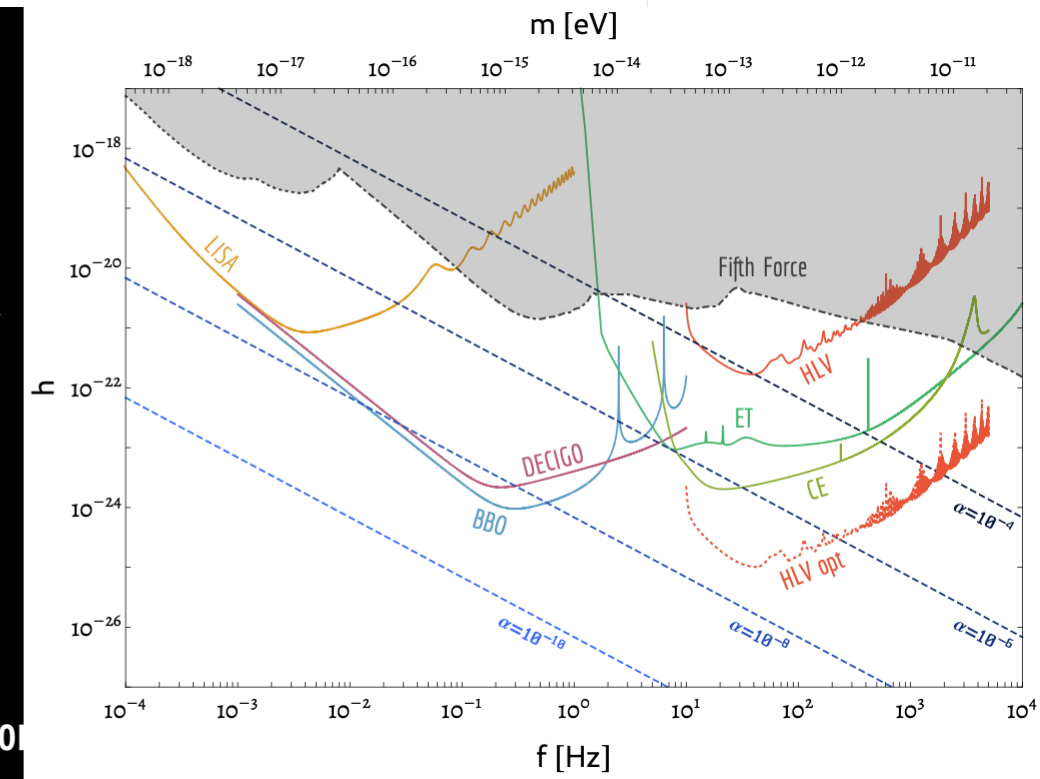
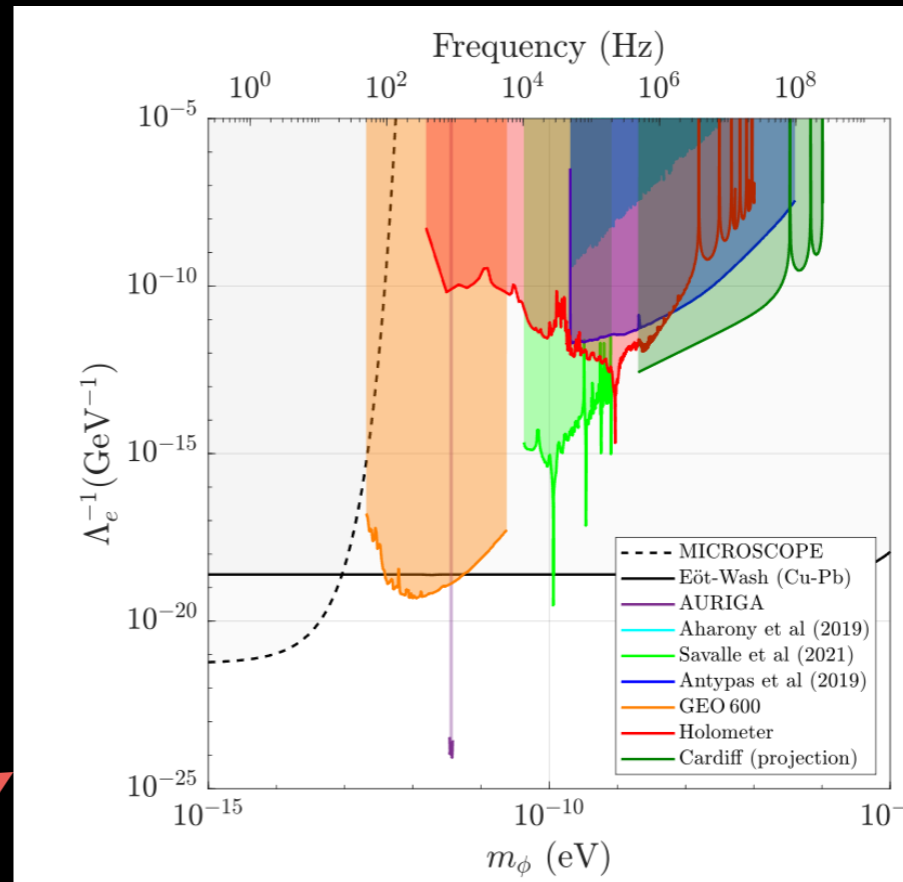
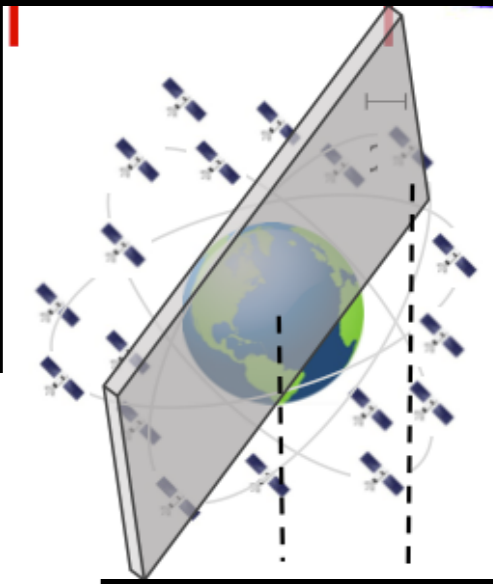
$$\eta_{AB} = 2 \frac{a_A - a_B}{a_A + a_B}$$



Class	Elements	η	Year [ref]	Comments
Classical	Be - Ti	2×10^{-13}	2008 [67]	Torsion balance
	Pt - Ti	1×10^{-14}	2017 [4]	MICROSCOPE first results
	Pt - Ti	(10^{-15})	2019+	MICROSCOPE full data
	$M_A - M_B$	10^{-17}	2035+	Adv. MICROSCOPE, macroscopic masses M_i TBD
Hybrid	$^{133}\text{Cs} - \text{CC}$	7×10^{-9}	2001 [69]	Atom Interferometry
	$^{87}\text{Rb} - \text{CC}$	7×10^{-9}	2010 [70]	and macroscopic corner cube
	$At_A - M_B$	10^{-17}	2035+	Adv. MICROSCOPE, atomic species At_A TBD
Quantum	$^{39}\text{K} - ^{87}\text{Rb}$	5×10^{-7}	2014 [71]	different elements
	$^{87}\text{Sr} - ^{88}\text{Sr}$	2×10^{-7}	2014 [72]	same element, fermion vs. boson
	$^{85}\text{Rb} - ^{87}\text{Rb}$	3×10^{-8}	2015 [73]	same element, different isotopes
	$^{85}\text{Rb} - ^{87}\text{Rb}$	3.8×10^{-12}	2020 [74]	≥ 10 m towers
	$^{85}\text{Rb} - ^{87}\text{Rb}$	(10^{-13})	2020+ [75]	
	$^{170}\text{Yb} - ^{87}\text{Rb}$	(10^{-13})	2020+ [76]	
	$^{41}\text{K} - ^{87}\text{Rb}$	10^{-17}	2035+	Atom Interferometry mission
Antimatter	$\bar{\text{H}} - \text{H}$	(10^{-2})	2020+ [77, 78]	under construction at CERN

Dark matter

- ▶ On going study of the GAIA data to test the existence of a sea of DM particles surrounding the Galaxy [B. Famaey]: complex modelling !
- ▶ Search DM using the Galileo satellites [P. Delva]: DM transients, evidence for high SNR events but systematics need to be studied
- ▶ With interferometers:
 - Direct limits for Scalar Field DM from the GEO600 GW detectors [S.M. Vermeulen]
 - Search for ultra-light bosons of spin 2 which looks like persistent quasi-monochromatic GW [F. Urban]
 - Holometer: correlated Michelson interferometers [L. Aiello]



Neutrons and Anti-hydrogen

- ▶ GBAR [P. Blumer]: "quantum free fall" of anti-hydrogen: status and plans
- ▶ qBounce [J. Bosina, J Micko]: Gravity Resonance Spectroscopy using Ultracold neutrons: ongoing measurements and analysis ($\delta g/g \sim 10^{-4}$)
- ▶ AEgIS (Antimatter Experiment: Gravity, Interferometry, Spectroscopy), test weak EP using anti-atoms [R. Caravita]: status and prospects: work in progress on higher rate of \bar{H}^* , pulsed beam of low energy \bar{H}^* , ...

Theory

- ▶ Talks on multiple theories, modified gravity, boson stars, ...
- ▶ Quentin's highlight on theory talks:
 - Proposition on entangled relativity which reinforces the link between matter and gravitation [O. Minazzoli]
 - The big bang could not be a singularity, but simply a bounce. For that we would need to observe a non-zero curvature of the universe (not favored by Planck) + an inflation mechanism. [C. Renevey]
 - ...

Thanks!