

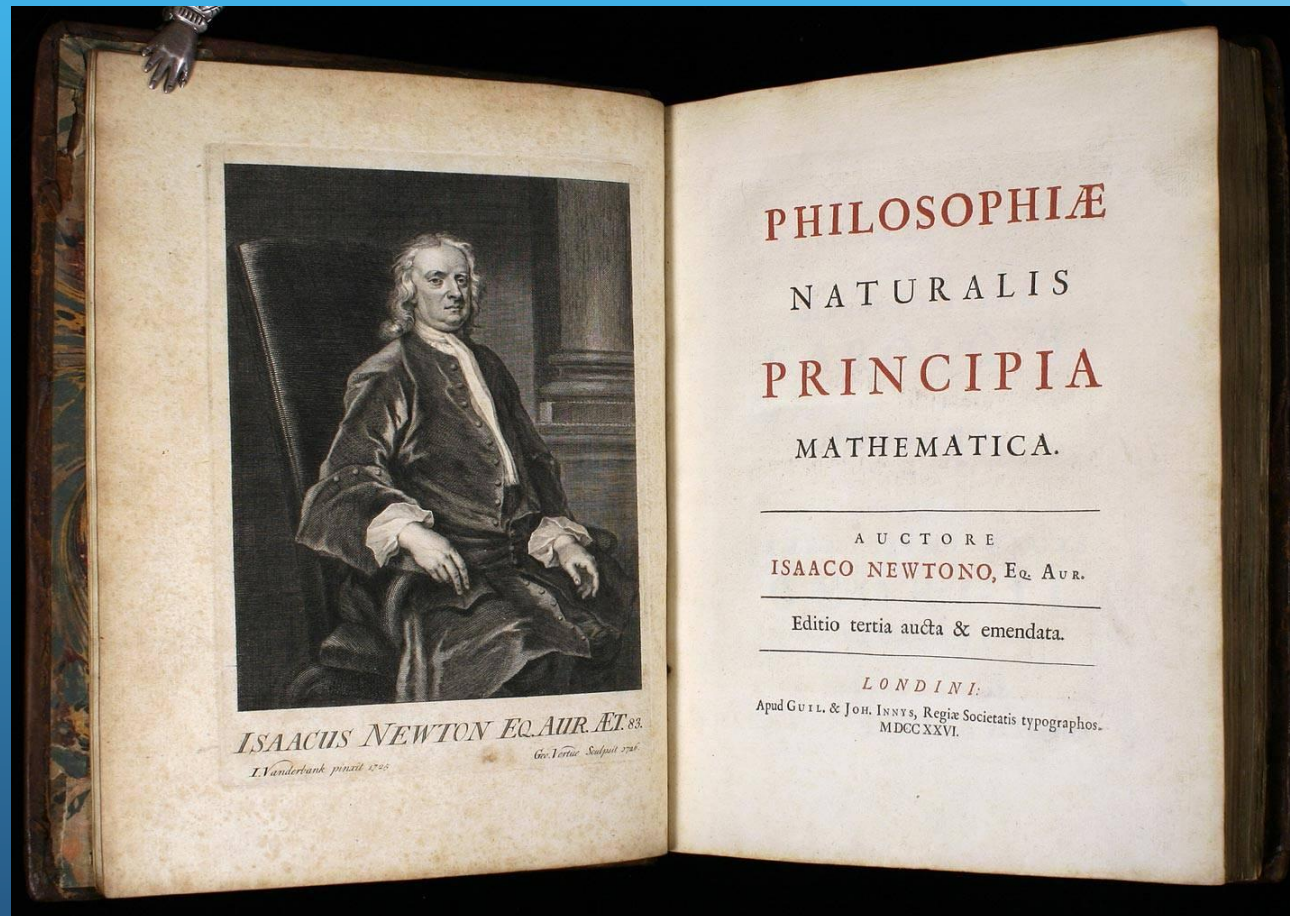
Gravity and gravitational waves

Maria Alessandra Papa

Albert Einstein Institute

(Max Planck Inst.I for gravitational Physics, Hannover, Germany)

1687 AD

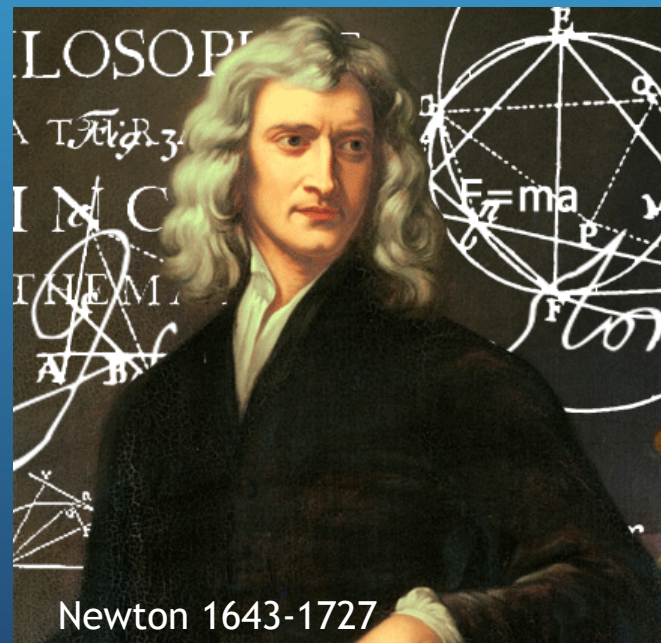




Brahe 1546-1601



Kepler 1571-1630

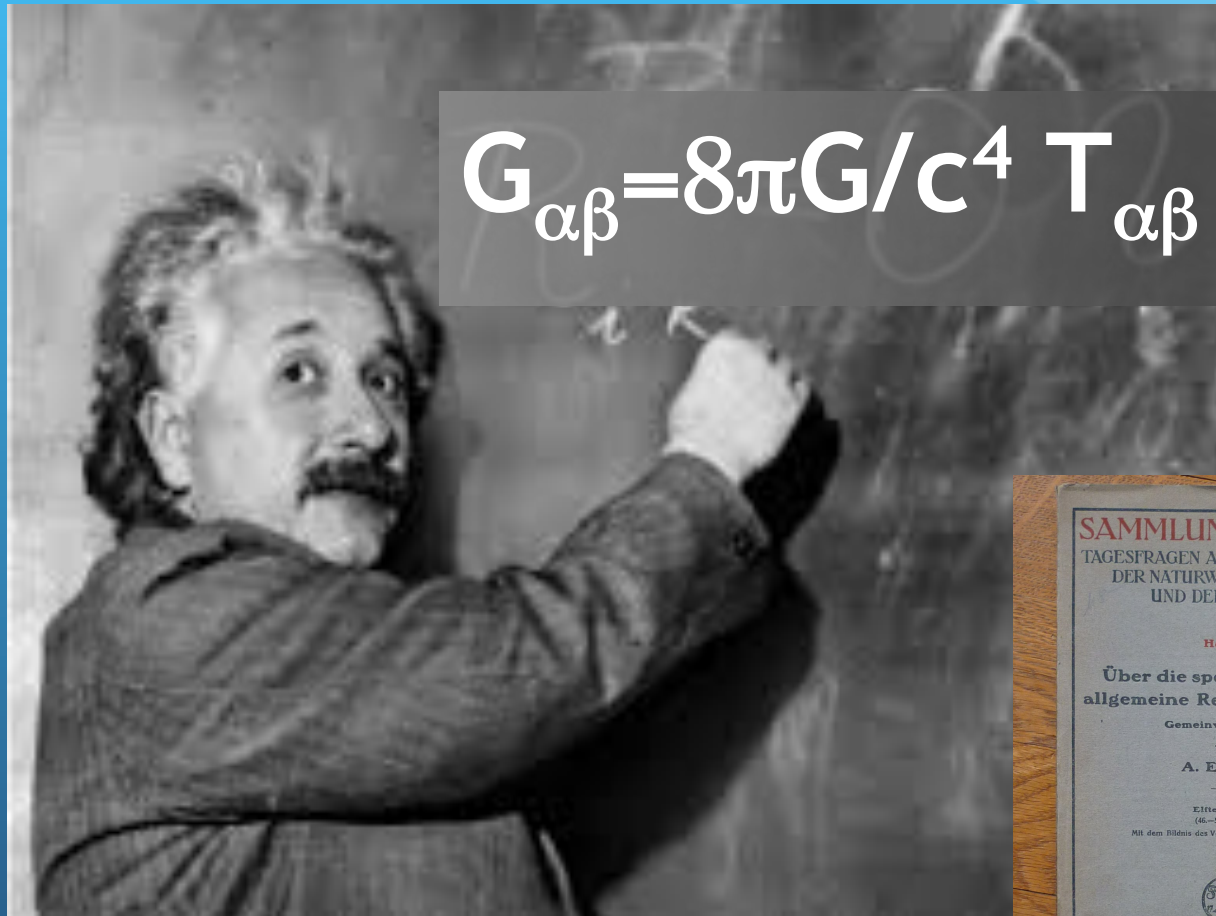


Newton 1643-1727

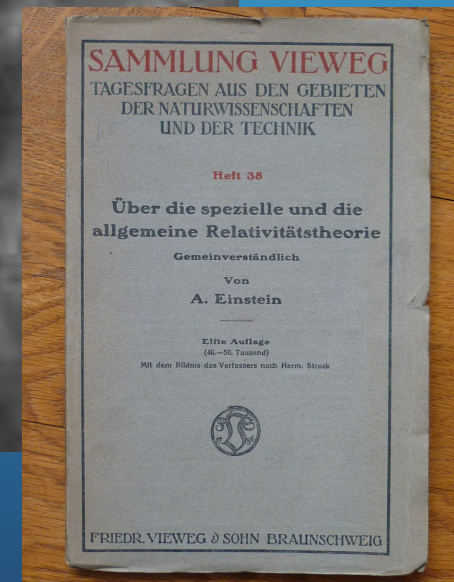
$$\frac{GMm}{R^2}$$



1916



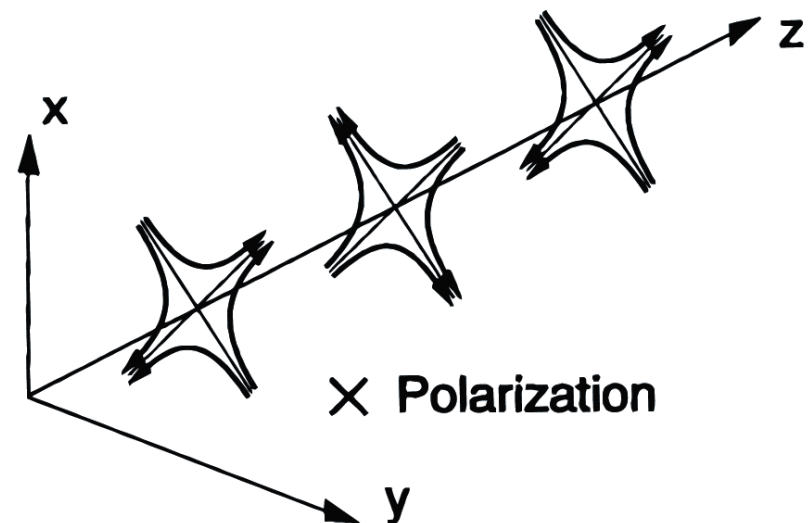
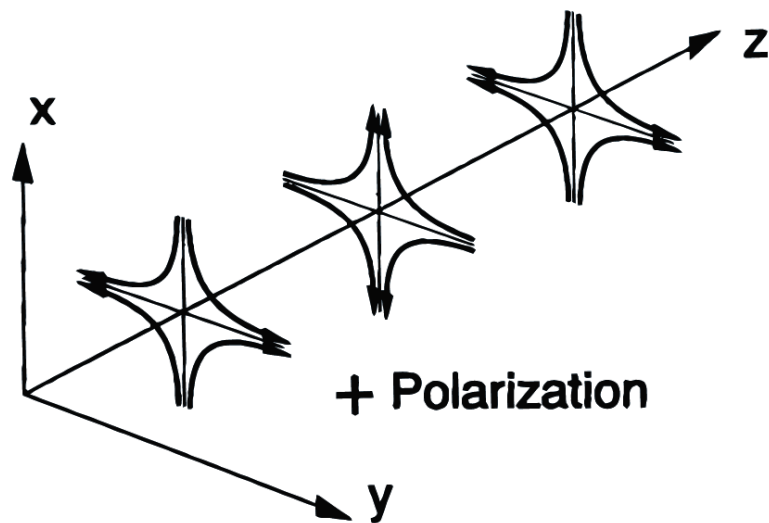
$$G_{\alpha\beta} = 8\pi G/c^4 T_{\alpha\beta}$$



1916

Gravitational waves

- Solution of Einstein's linearized equations
- Transverse waves
- Two polarizations



Gravitational waves

- Solution of Einstein's linearized equations
- Transverse waves
- Two polarizations



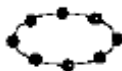





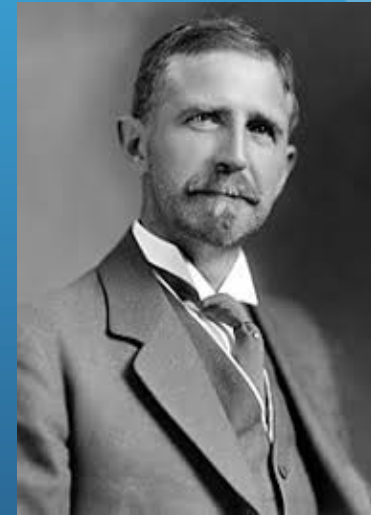
ωt	h_+	h_\times
0		
$\pi/2$		
π		
$3\pi/2$		

Fig. 1.1 The deformation of a ring of test masses due to the $+$ and \times polarization.

The controversy: are GWs real ?

- 1920s: Einstein, Rosen, Eddington (“conversations” with Schwarzschild, Born) -- NO
- 1930s: Robertson (referee for PRD who criticised Einstein’s paper), Infeld -- YES
- 1956: Pirani -- YES
- 1957: Chapel Hill conference
 - New institute, directed by Bryan DeWitt
 - Inaugural conference
 - Feynmann’s sticky bead argument
- 1960: Joe Weber, ideas for detection



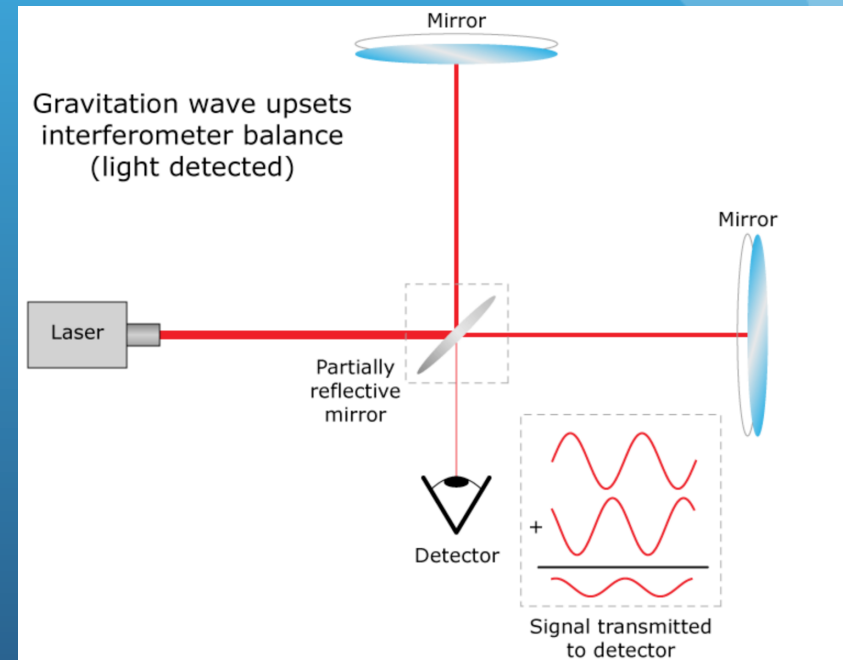
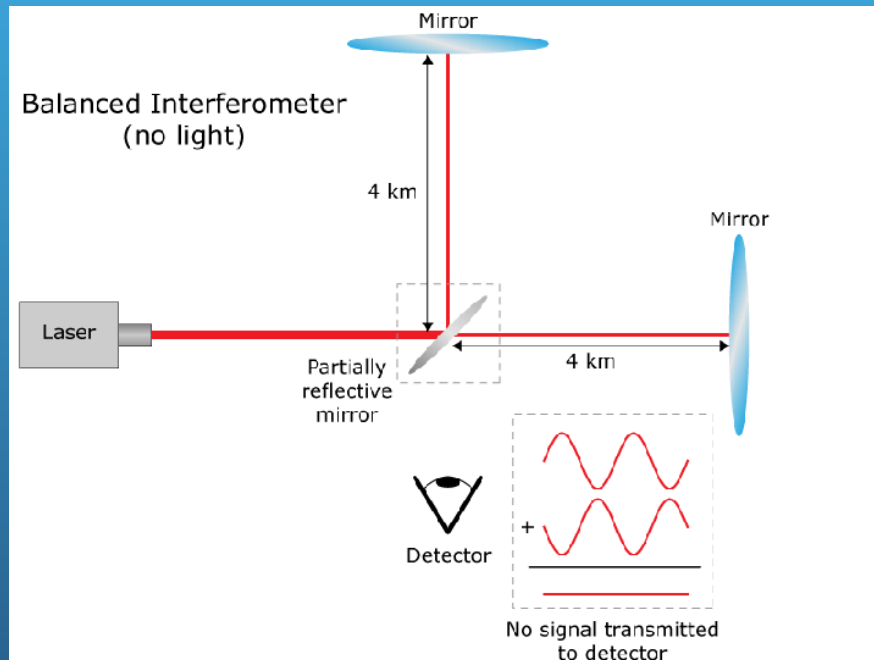
Babson 1875-1967

Resonant bar detectors

- Joe Weber 1960s
- Many followed in the 60s, 70s, 80s
- Cryogenic detectors
 - Stanford and LSU
 - Rome and CERN
 - U. Western Australia
 - Legnaro
 - Maryland
 - Moskow State U.
 - U. Maryland



Interferometers: principle of detection



VIRGO

- Failure of conclusive observations with bars
- Late 1970s: Brillet
- 1984: Hulse & Taylor observations
- 1985: Giazotto and Brillet meet at MG meeting in Rome
- 1989: Virgo proposal submitted to CNRS and INFN
- 1993/1994: Project approved
- 2000 EGO was created

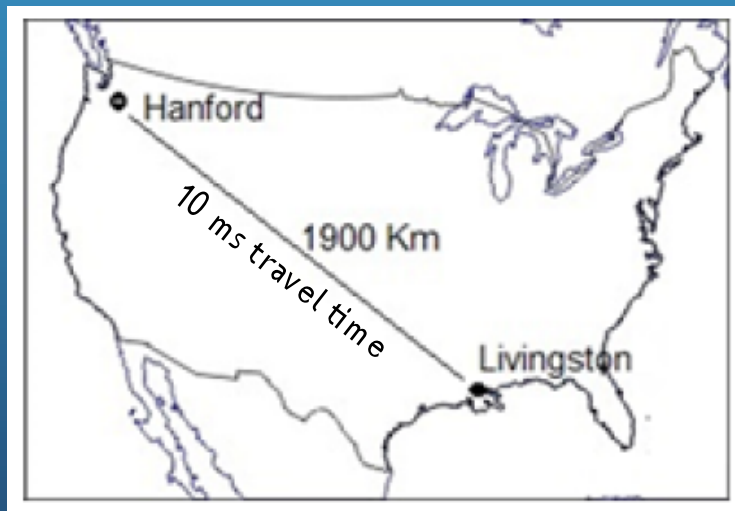
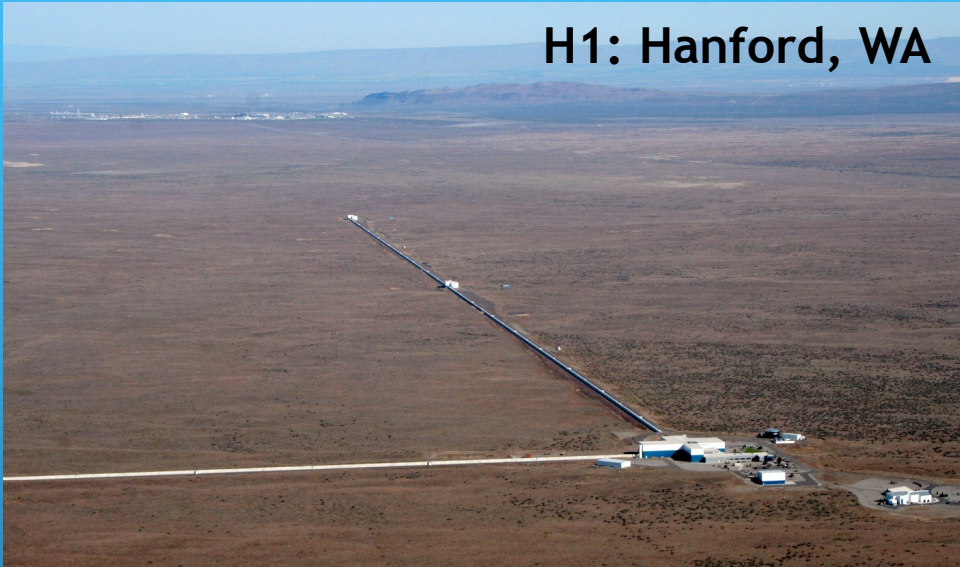


LIGO

- Failure of conclusive observations with bars
- R. Weiss, “Electromagnetically Coupled Broadband Gravitational Antenna”, in MIT Research Lab of Electronics Quarterly Progress Report no. 105, April 1972
- 1975 Weiss and Thorne share a hotel room: shortly after, a GW experimental group was established at Caltech
- 1984: Hulse & Taylor observations
- R. E. Vogt, R. W. P. Drever, K. S. Thorne, F. J. Raab and R. Weiss (Caltech & MIT), “Construction, operation, and supporting research and development of a Laser Interferometer Gravitational-wave Observatory”, proposal to NSF, 1989. Approved in 1990.
- NSF started funding LIGO in 1992
- LIGO Scientific Collaboration (LSC) was born in late 90s.

Laser Interferometer GW Observatory

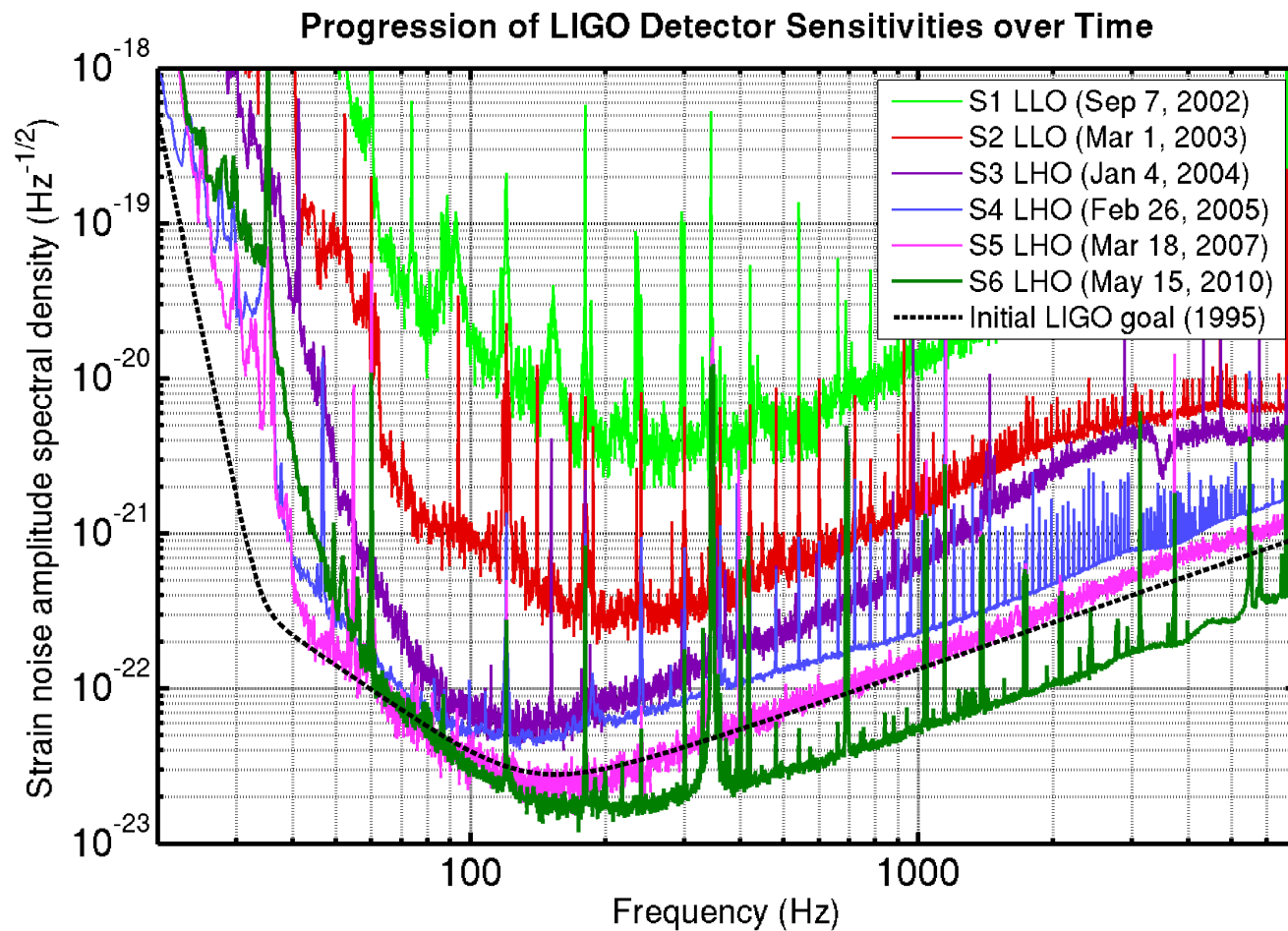
H1: Hanford, WA



L1: Livingston, LA

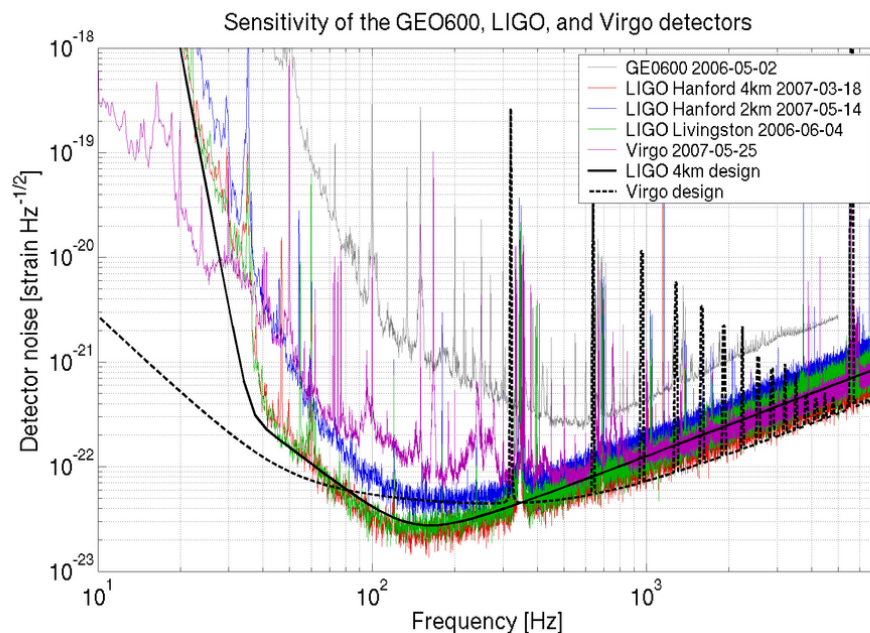


The initial detectors

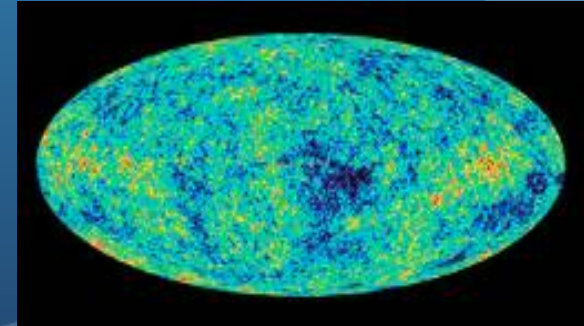
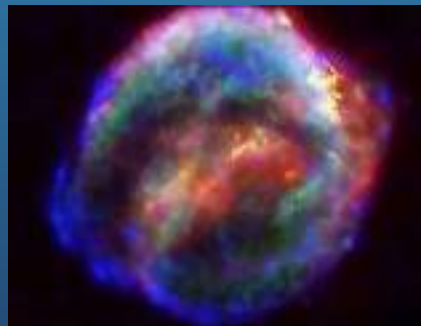
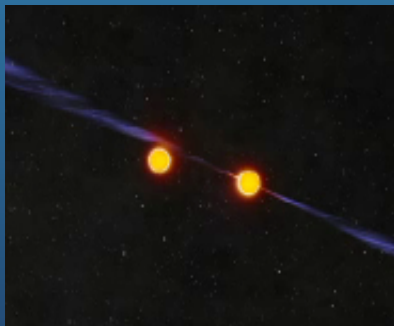


What signals may be detectable ?

time scales of ms to s, compact objects,
high accelerations:



- from inspiraling compact objects
- bursts , typically arising from catastrophic events
- continuous quasi-periodic waves
- stochastic background of gravitational radiation



Summer 2015: Out of the “Dark Ages”

16



credit P. Shawhan

Scrambling in September 2015

- Both LIGO detectors were operating pretty well by late August, when Engineering Run 8 began
- Observing run O1 was scheduled to begin on Sept 14 at 15:00 UTC
- Still lots of details to transition to observing:
 - Calibration studies
 - Real-time data stream production
 - Hardware signal injection tests
 - Low-latency data analysis automation and testing
 - Event candidate alerts and rapid response procedures
 - Environmental noise coupling studies
- On Sept 11, start of O1 was delayed to Sept 18
- Calibration stable and well-measured by Sept 12, still working on some of the other things...

signal arrived at 9:50 UTC, 11:50 in
Hannover, spotted ~ immediately

Marco Drago

daswg

14. September 2015 at 12:55

[DASWG] Very interesting event on ER8

To: lvc-burst@sympa.ligo.org,

Cc: cbc@ligo.org Binaries Group, The LIGO Data Analysis Software Working Group, Calibration,
dac@sympa.ligo.org, <burst@ligo.org>, <detchar@sympa.ligo.org>, losc-devel@ligo.org,
lsc-all@ligo.org,

Reply-To: daswg@ligo.org



Hi all,
cWB has put on gracedb a very interesting event in the last hour.
<https://gracedb.ligo.org/events/view/G184098>

This is the CED:

https://ldas-jobs.ligo.caltech.edu/~waveburst/online/ER8_LH_ONLINE/JOBS/112625/1126259540-1126259600/OUTPUT_CED/ced_1126259420_180_1126259540-1126259600_slag0_lag0_1_job1/L1H1_1126259461.750_1126259461.750/ ▼

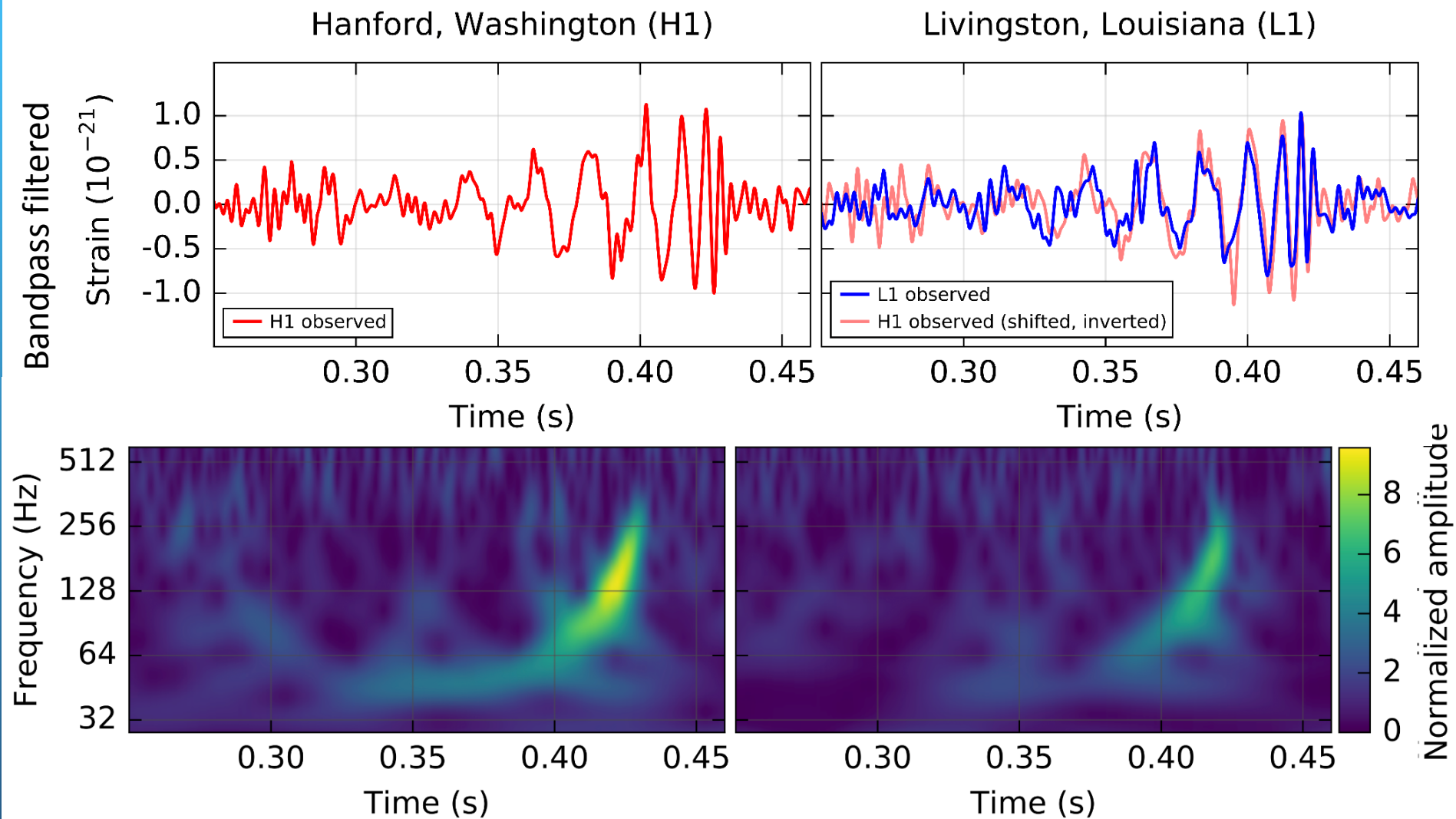
Qscan made by Andy:

https://ldas-jobs.ligo.caltech.edu/~lundgren/wdq/L1_1126259462.3910/
https://ldas-jobs.ligo.caltech.edu/~lundgren/wdq/H1_1126259462.3910/

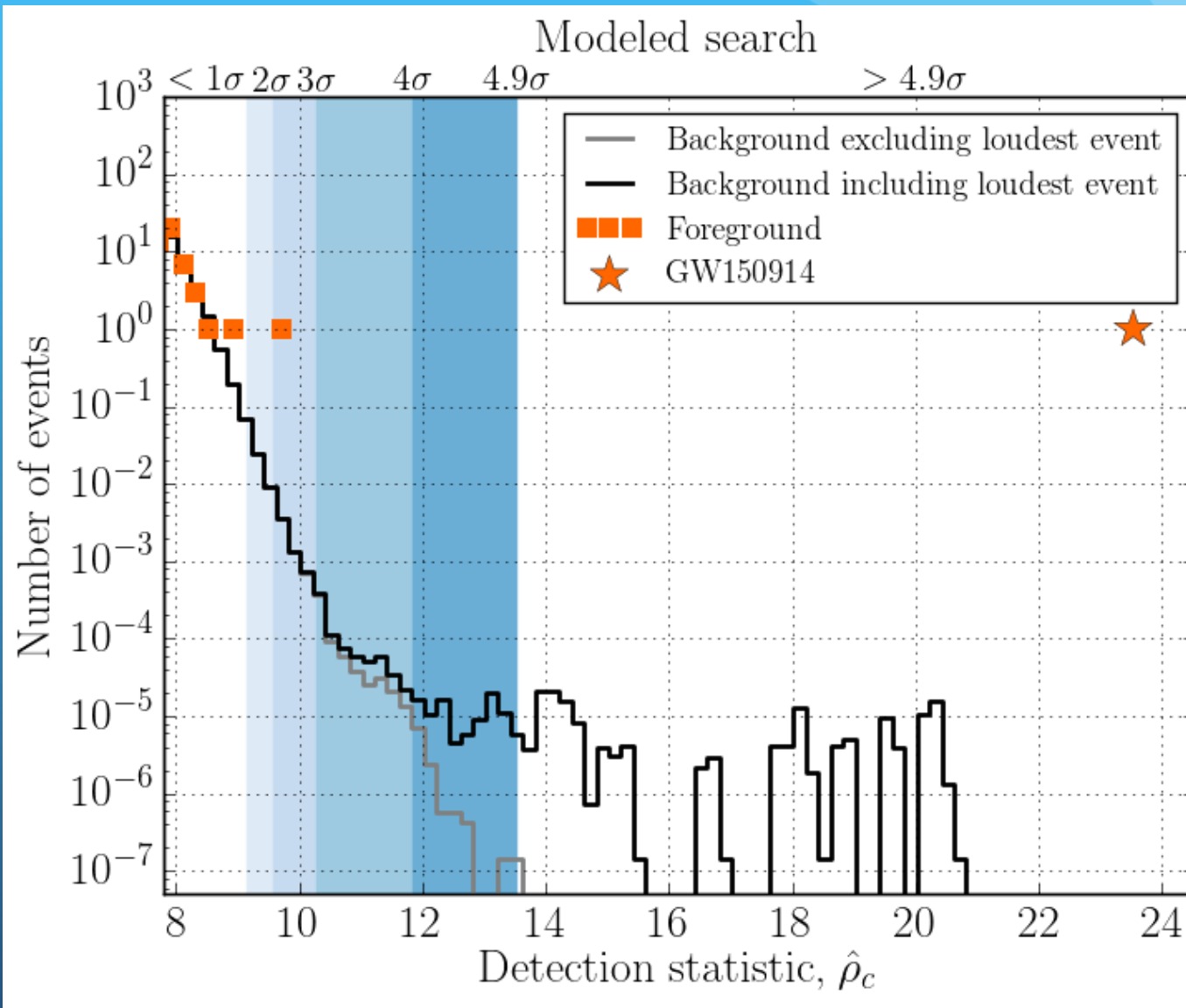
It is not flag as an hardware injection, as we understand after some fast investigation. Someone can confirm that is not an hardware injection?

Marco

GW150914

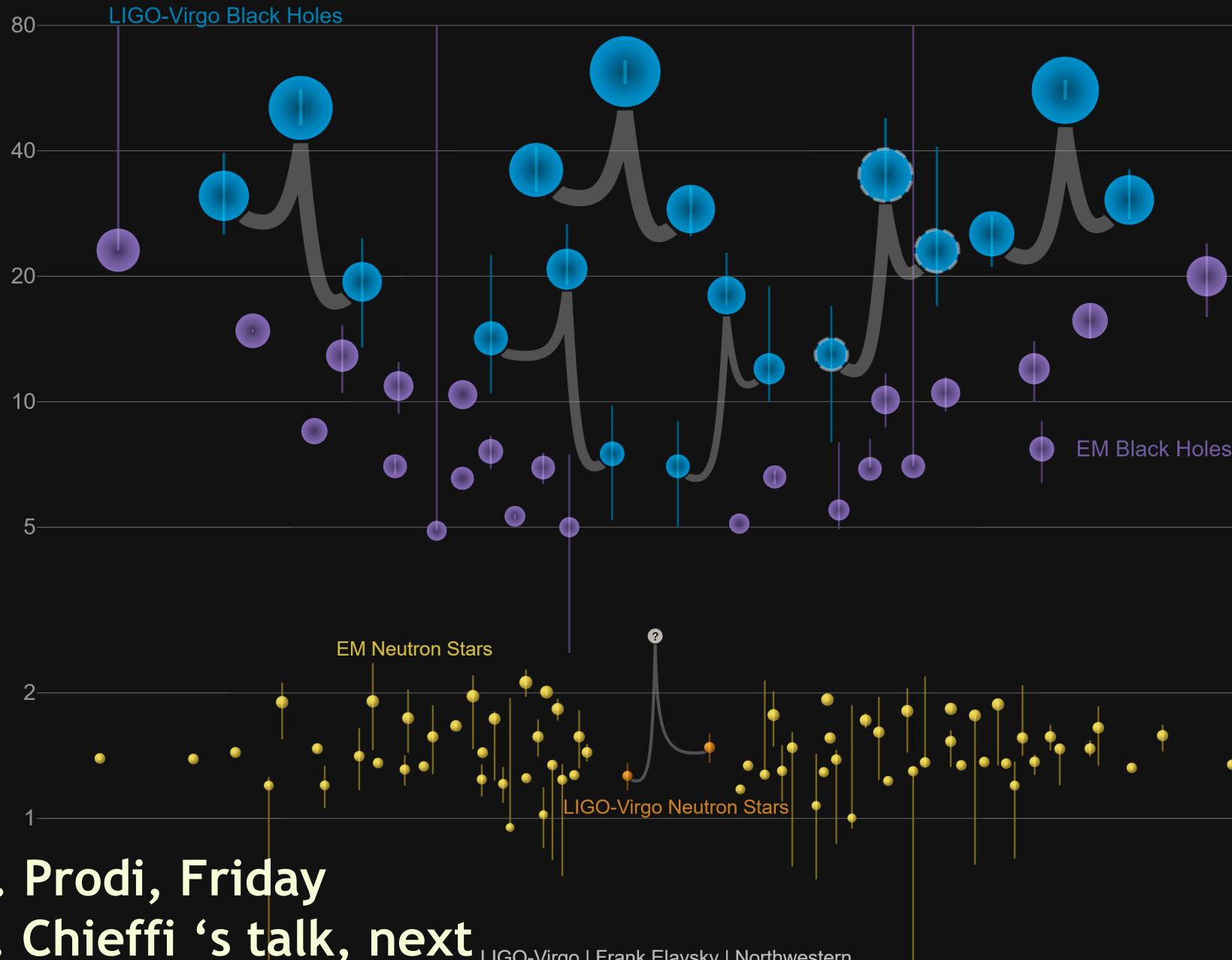


GW150914



Masses in the Stellar Graveyard

in Solar Masses

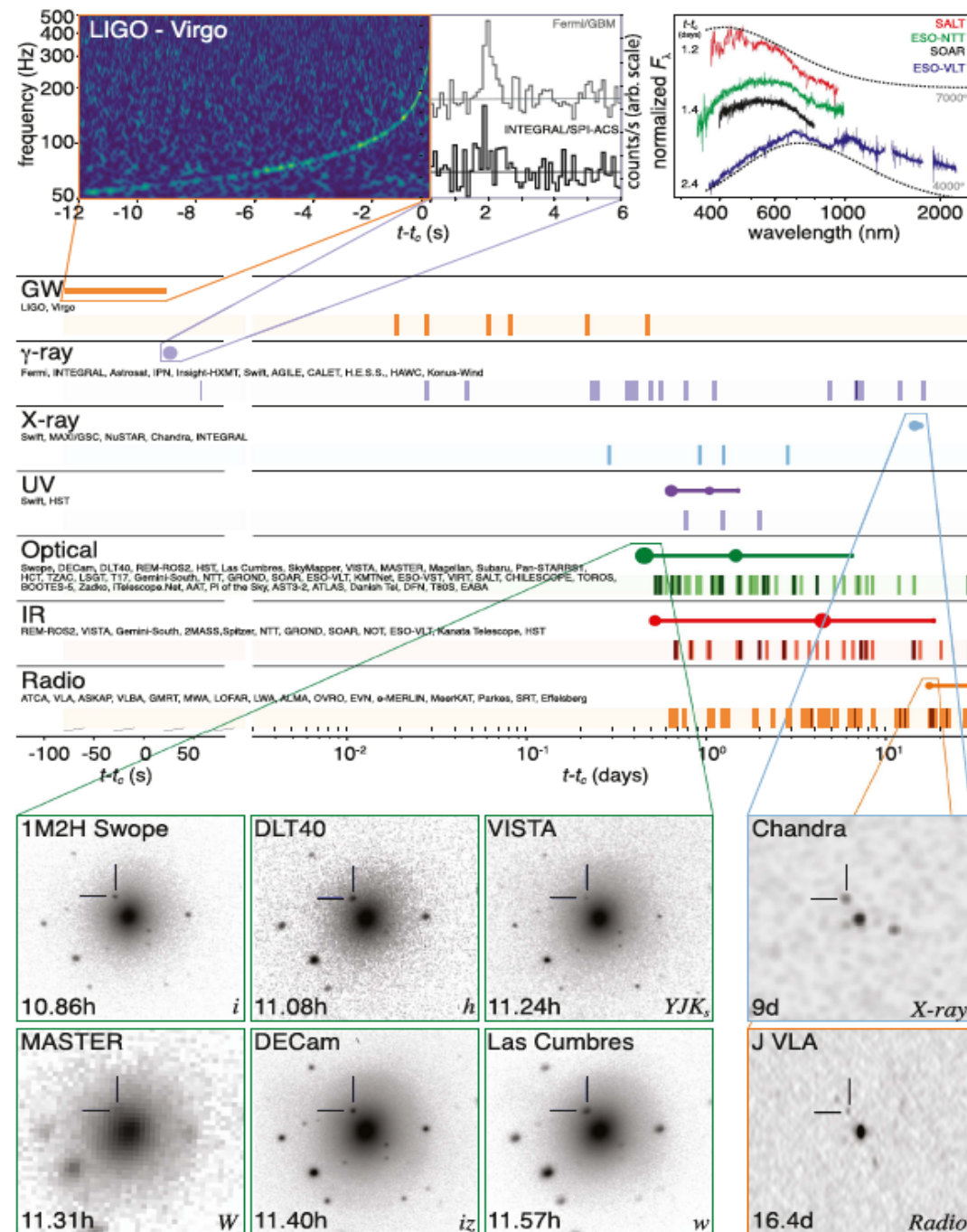


G. Prodi, Friday
A. Chieffi 's talk, next

GW170817

Next session:
M. Branchesi's
C. Kopper
E. Troja
C. Fryer
H. Van Eerten

Friday:
A. Corsi
P. Ubertini

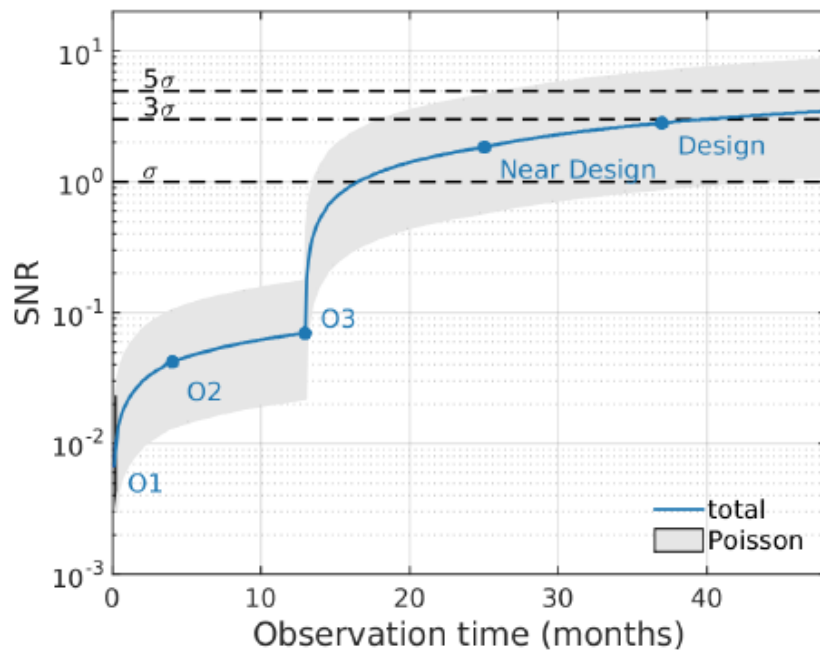


B. Abbott et al, ApJ Lett 848:L12 (2017)

The yet-to-be seen

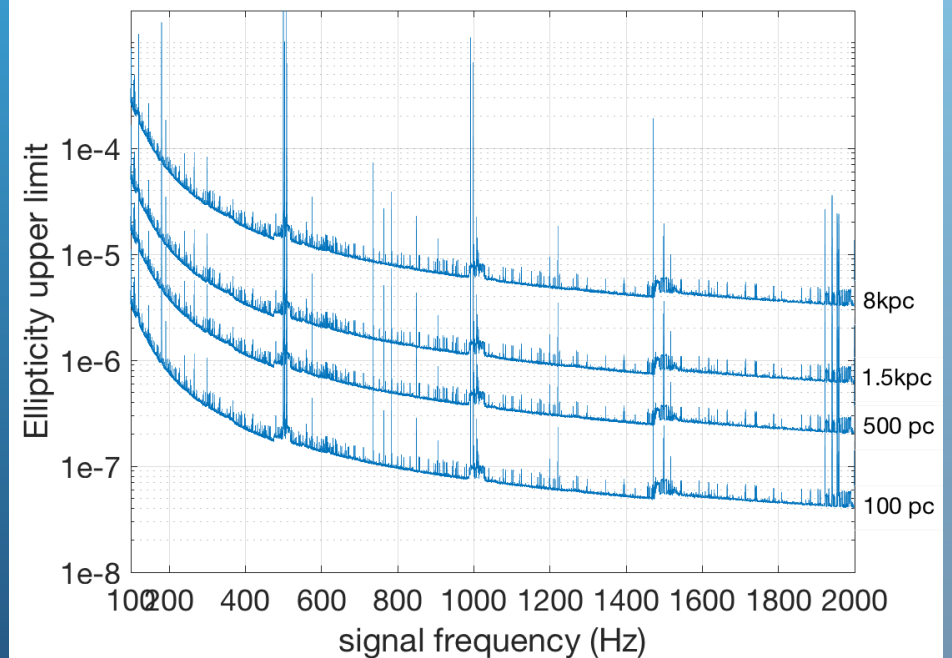
Stochastic background

P. Abbott et al, Phys.Rev.Lett. 120 (2018) no.9, 091101

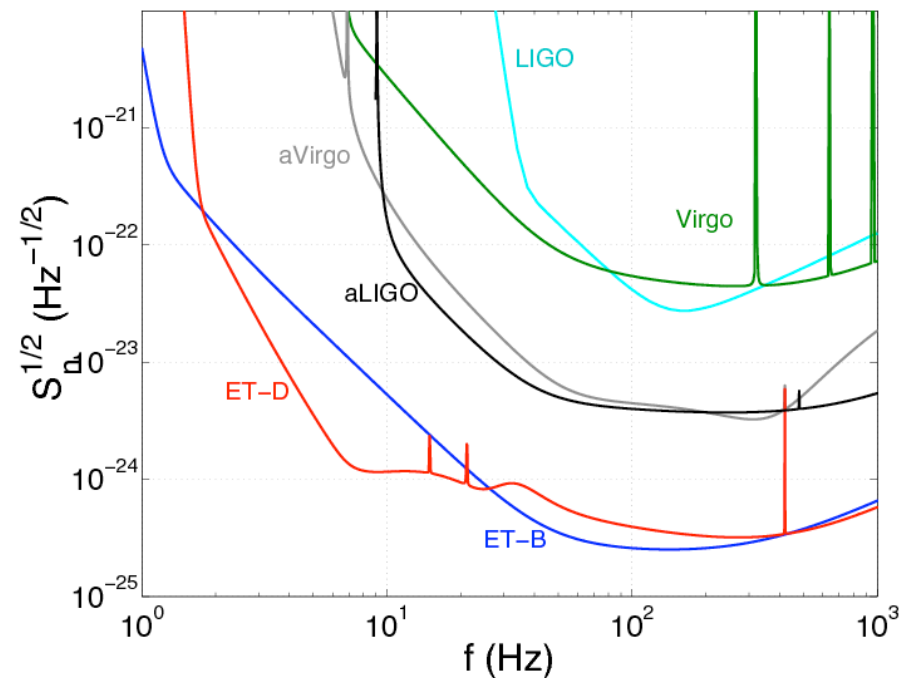


Persistent GW signal

P. Abbott et al, Phys.Rev. D97 (2018) no.10, 102003

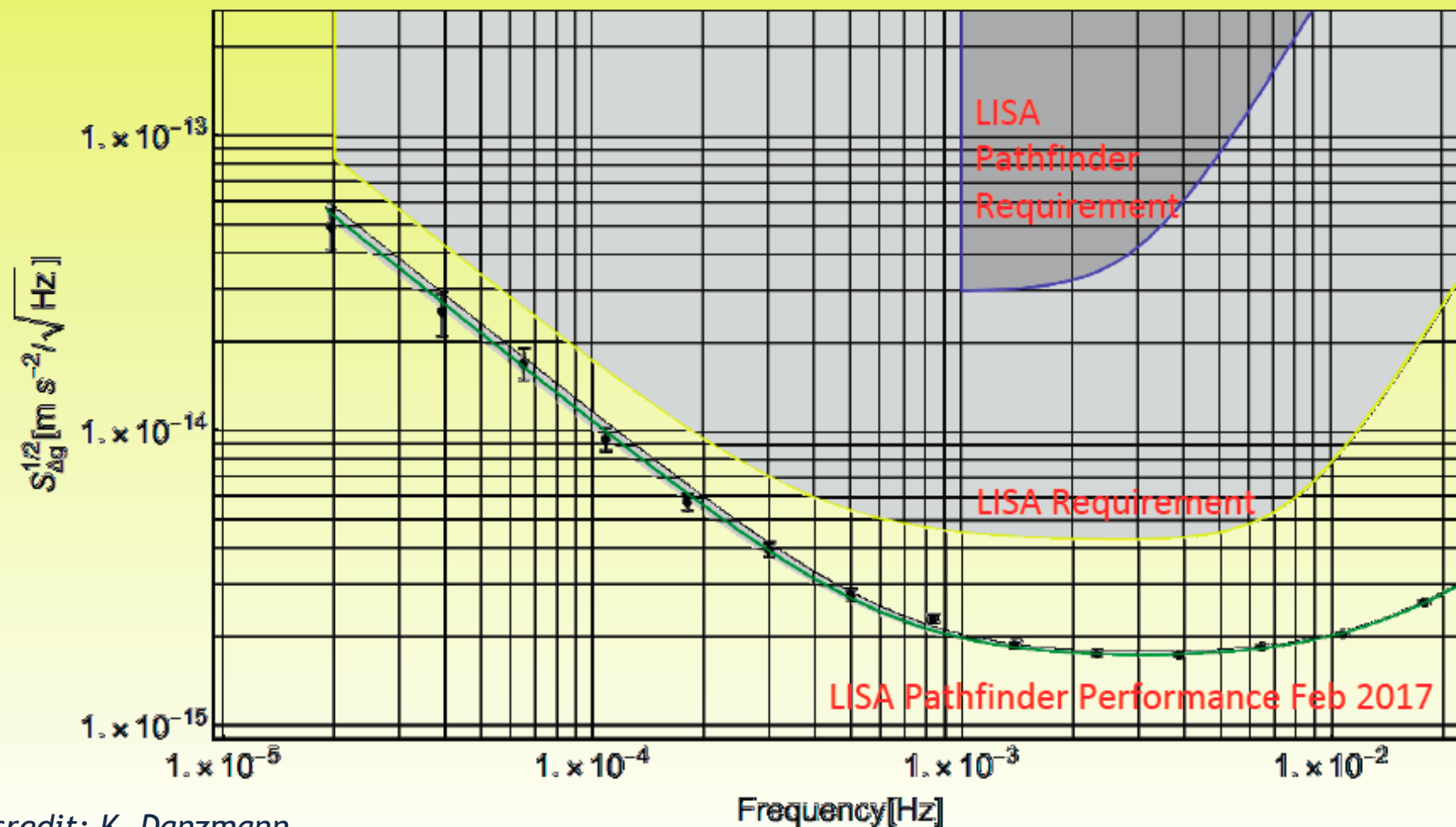


Next
generation:
down in
the ground

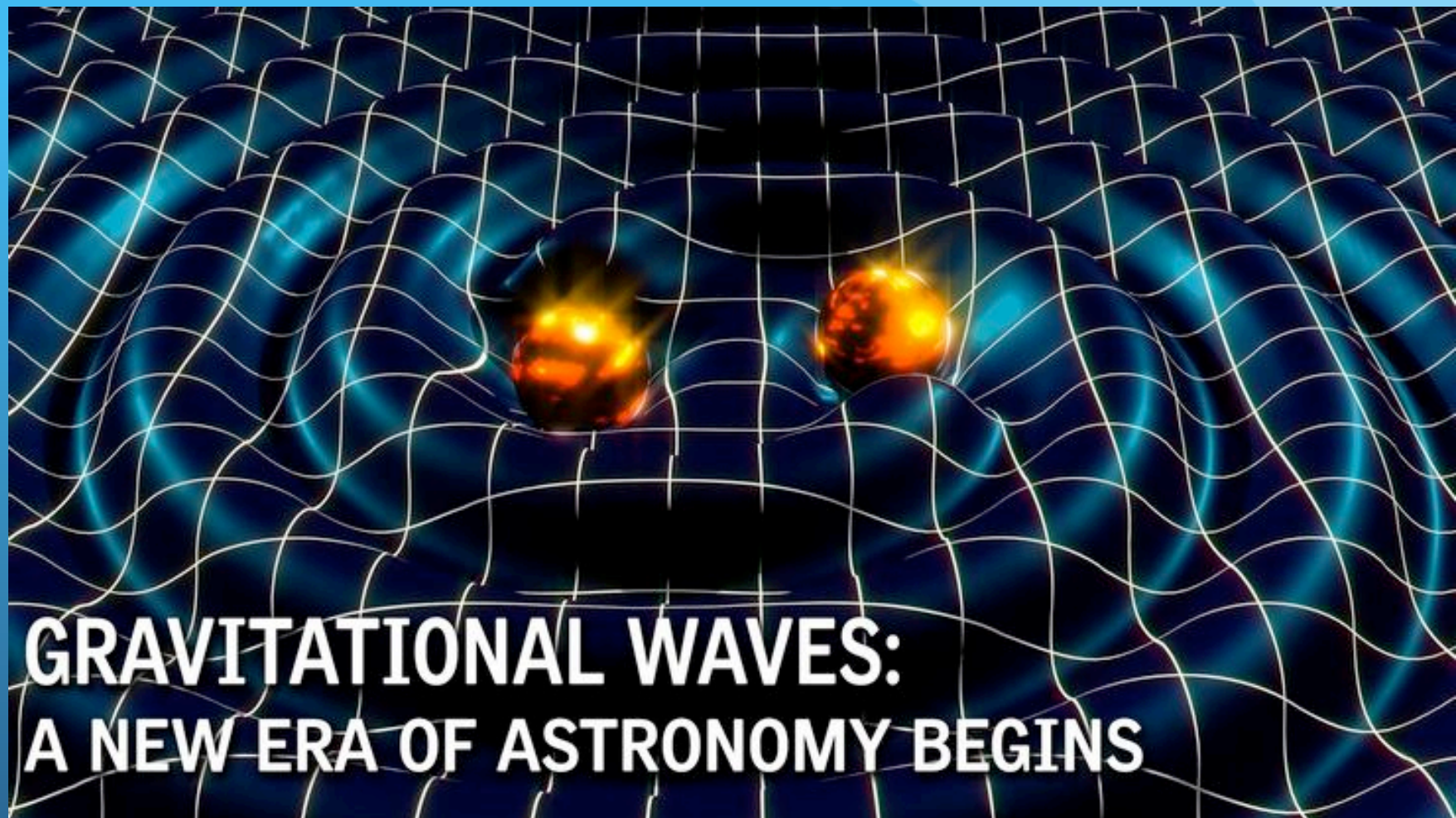


... and LISA up in the sky

@18:15 today
Rita Dolesi



credit: K. Danzmann



V. Fafone's talk, next



Thank you!