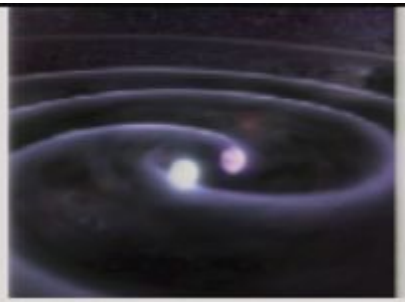
Title: Searches for coalescence of binary systems in LIGO and Virgo data

Date: Oct 28, 2010 01:00 PM

URL: http://pirsa.org/10100046

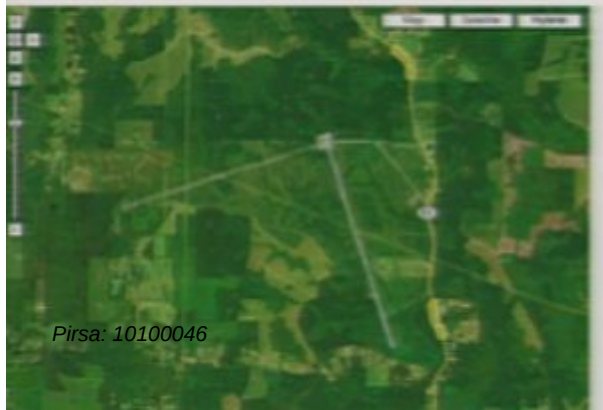
Abstract: I will present the latest results from the searches for gravitational waves from the coalescence of binary systems of neutron stars and black holes in LIGO and Virgo data. We present results on data from the Fifth Science Run LIGO run S5 from Nov 2005 to Oct 2007, which was joint with Virgo's first Science Run VSR1 from May to Oct 2007. We also show how these methods are being applied in the current LIGO S6/ Virgo VSR2 data-taking run started in July 2009, and recently ended in October 2010.

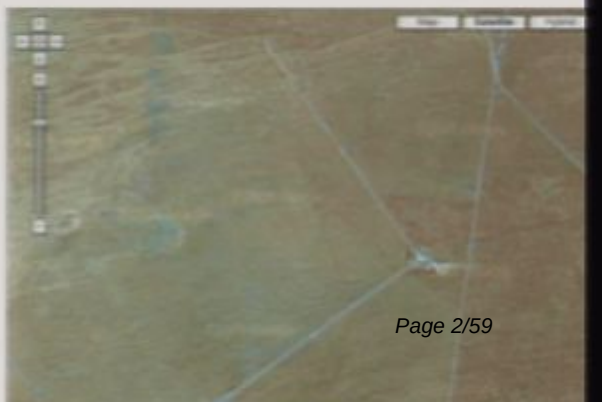


Searches for Compact Binary Coalescences in LIGO and Virgo data

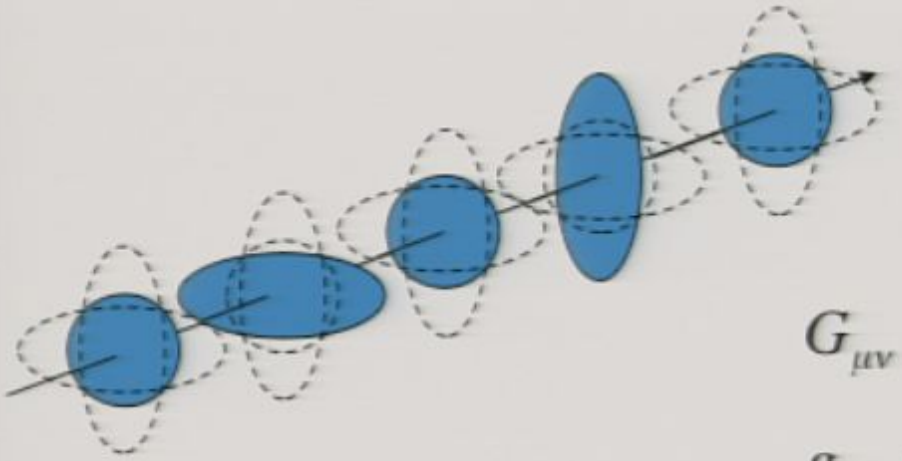
Gabriela González
Louisiana State University
For the LIGO Scientific Collaboration and the Virgo Collaboration

Perimeter Institute,
October 28, 2010
LIGO-G1001029





Gravitational waves



Gravitational waves are quadrupolar distortions of distances between freely falling masses. They are produced by time-varying mass quadrupoles.

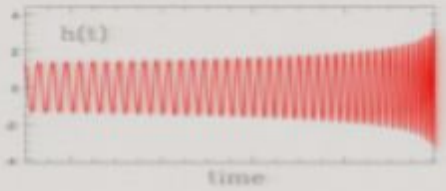
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \; (= 0 \text{ in vacuum})$$

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

$$h_{\mu\nu} = \frac{2G}{c^4 r} \ddot{I}_{\mu\nu}$$

Amplitude of GWs produced by binary neutron star systems in the Virgo cluster have $h=\Delta L/L \sim 10^{-21}$ and frequencies sweeping up to ~1400 Hz.

$$h \approx \frac{4\pi^2 G M R^2 f_{orb}^2}{c^4 r}$$



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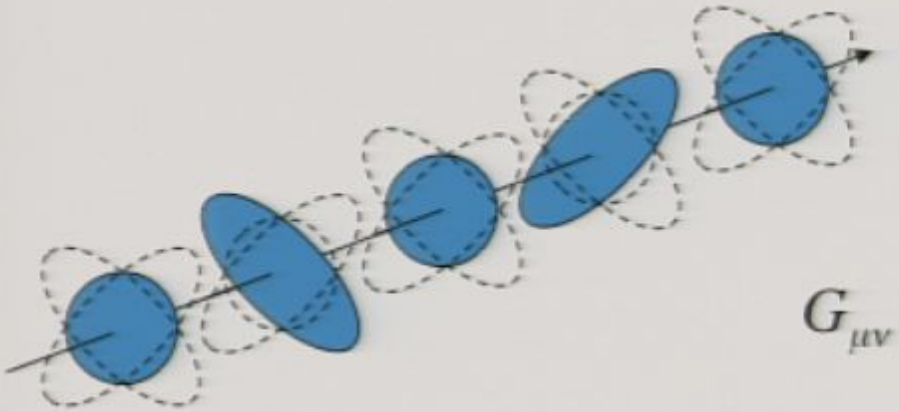

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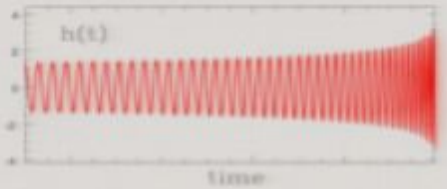

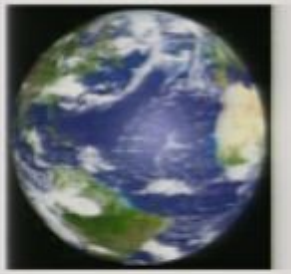

A worldwide network

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LIGO-G1001029


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University of Strathclyde
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Montana State University
PAH
University of Washington
PI
Tsinghua University
Trinity University
Louisiana Tech
San José State University
UWMilwaukee
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The Australian National University
Syracuse University
Founded AD 1870
LSU
UTB TSC
The University of Western Australia
University of Glasgow
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Goddard Space Flight Center
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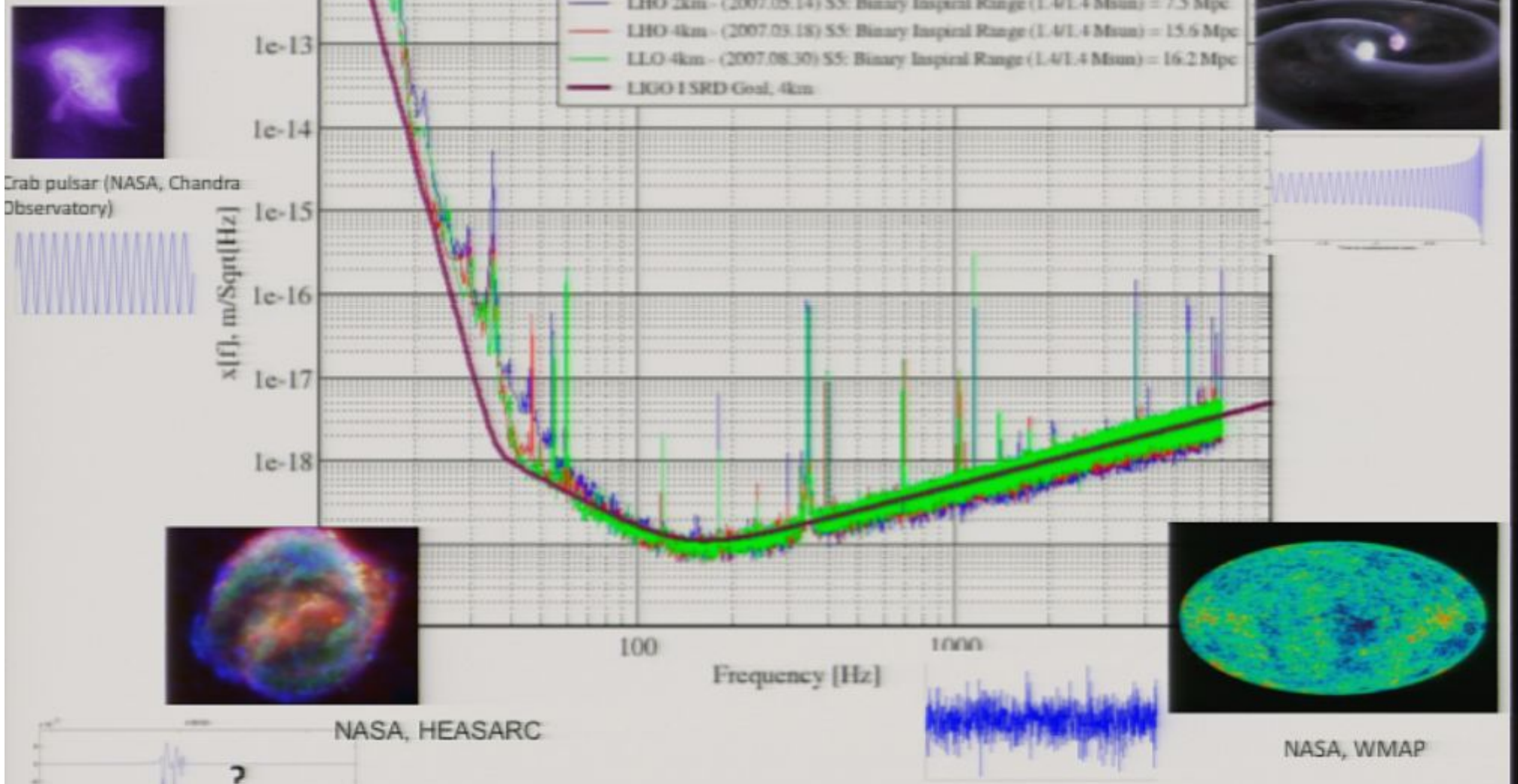
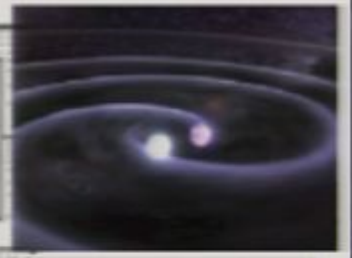
GW sources in LIGO band



Crab pulsar (NASA, Chandra Observatory)



NASA, HEASARC

NASA, WMAP

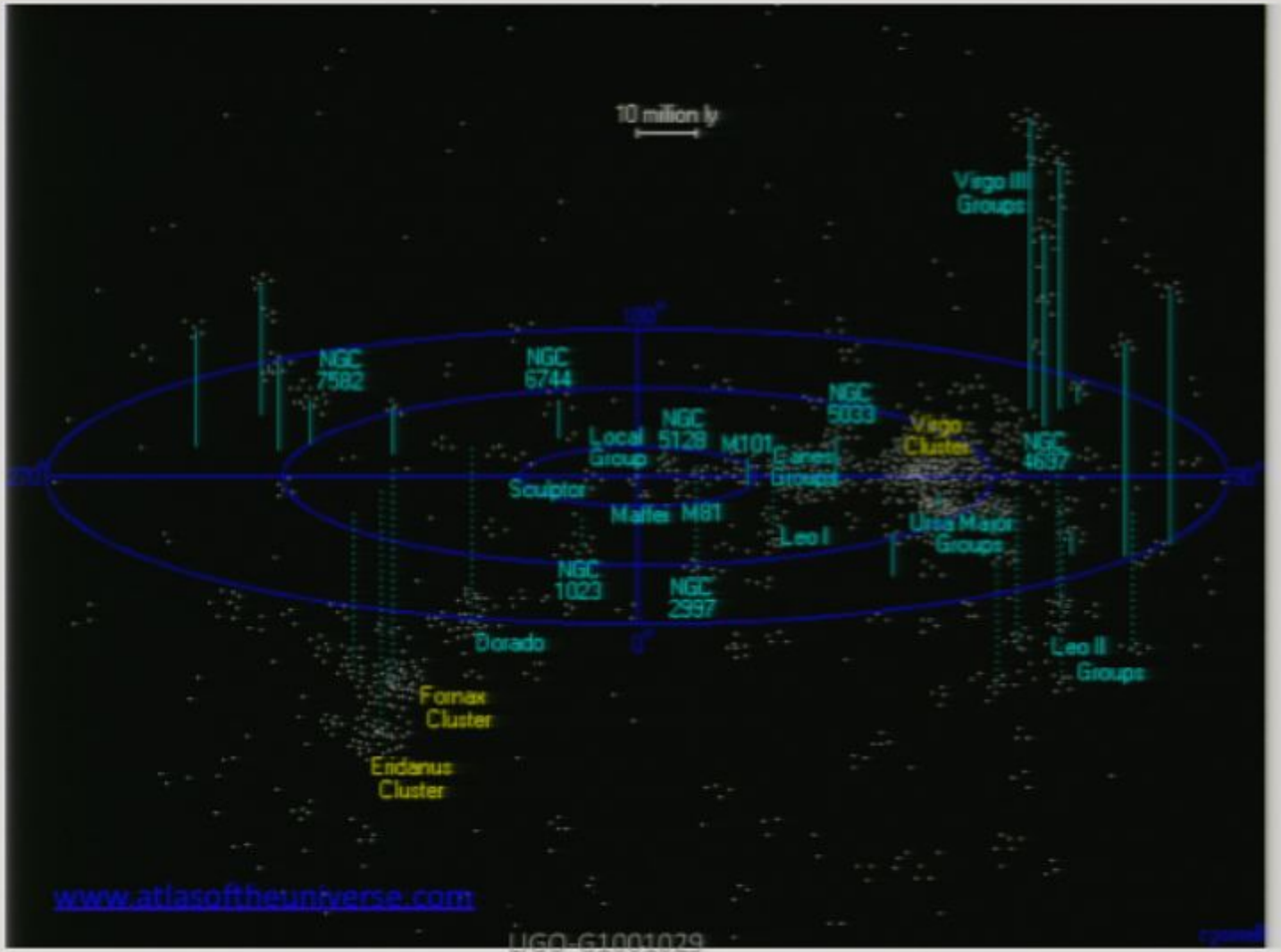
Find all LSC results in www.ligo.org

This plot in https://dcc.ligo.org/ Document ID 6563

How far can we see BNS systems?

If stars are aligned, we can see up to 100 million light years away!

With this reach, we expect neutron stars coalescing into a black hole every ~50 years



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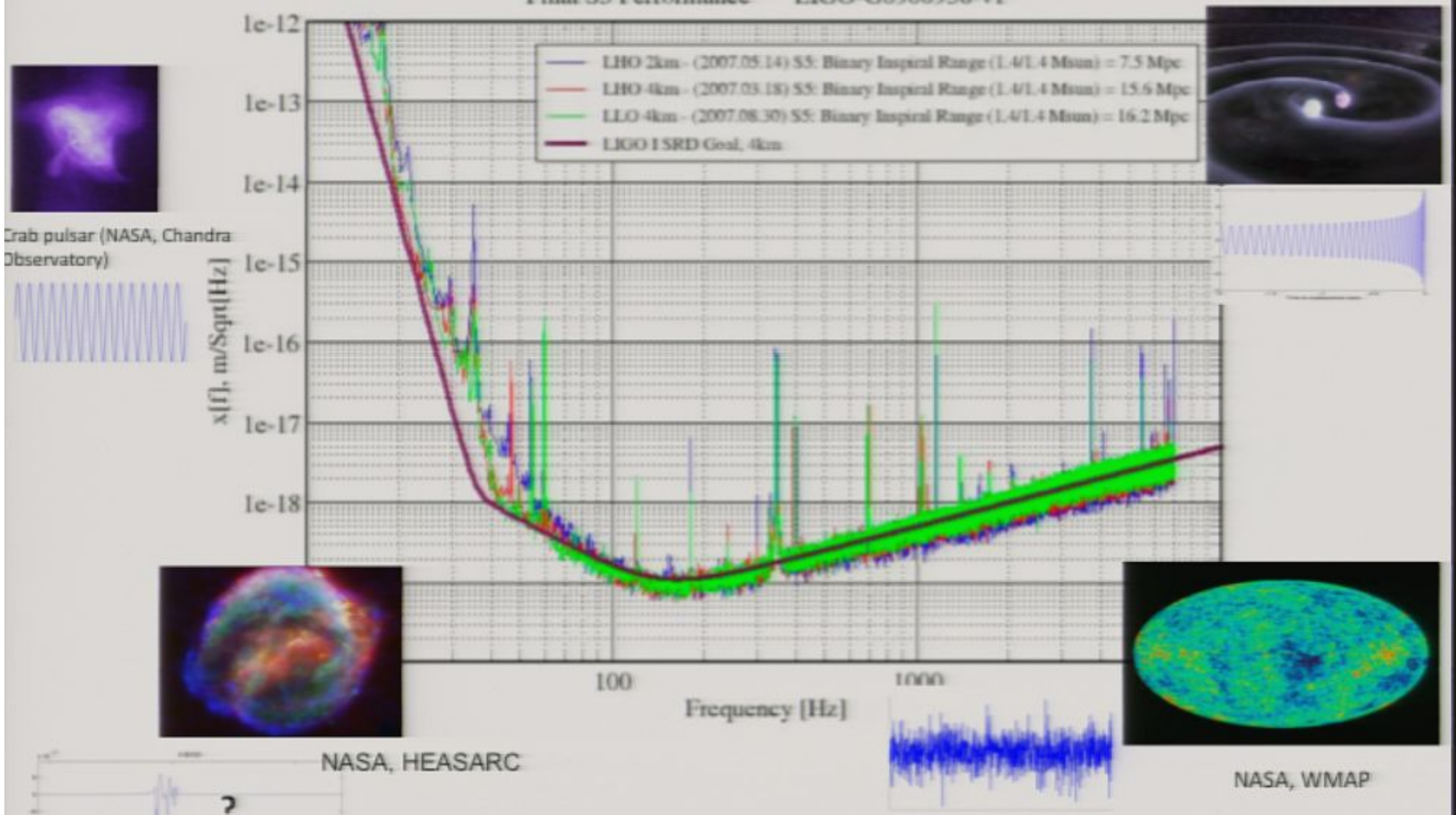

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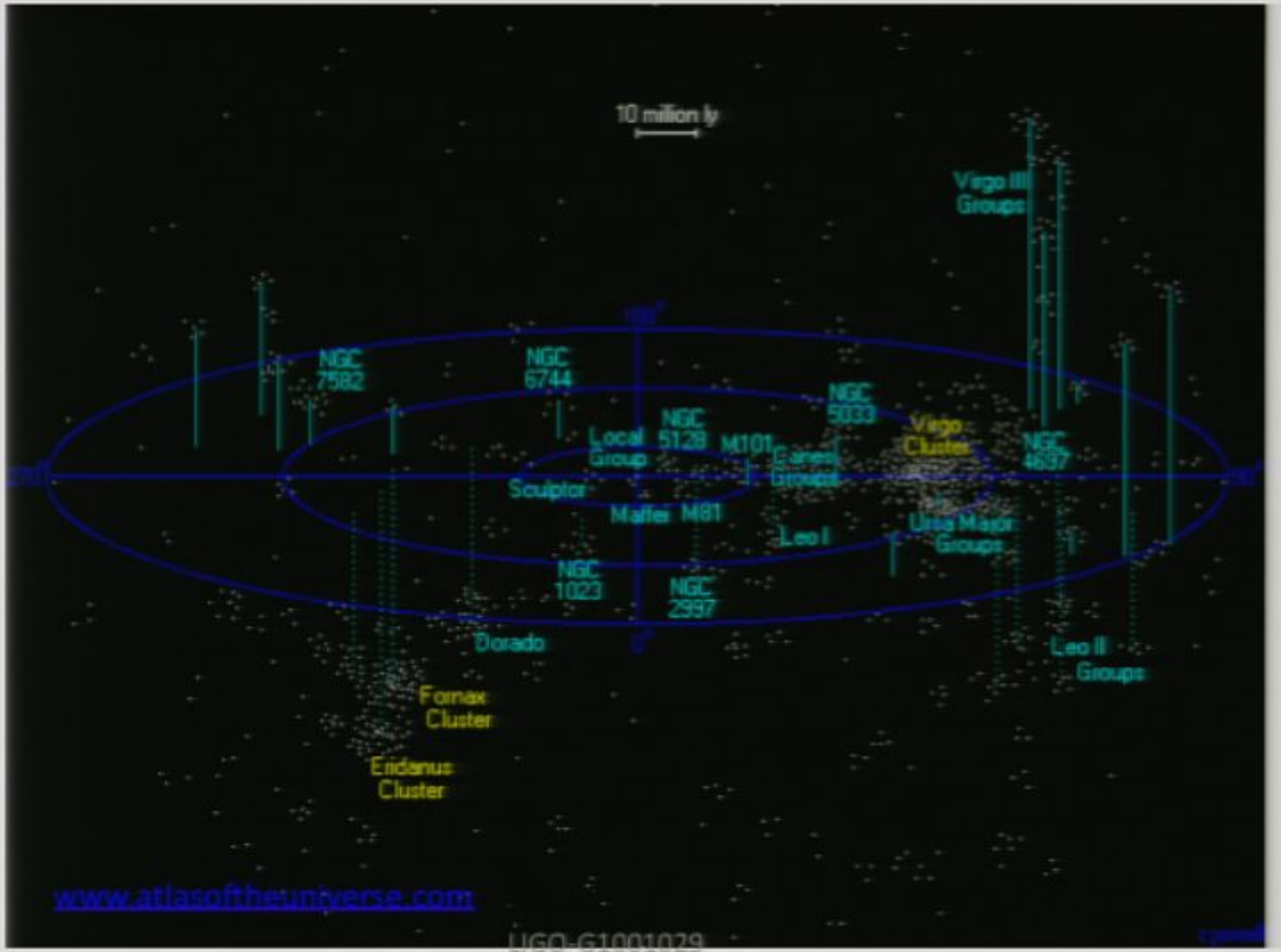

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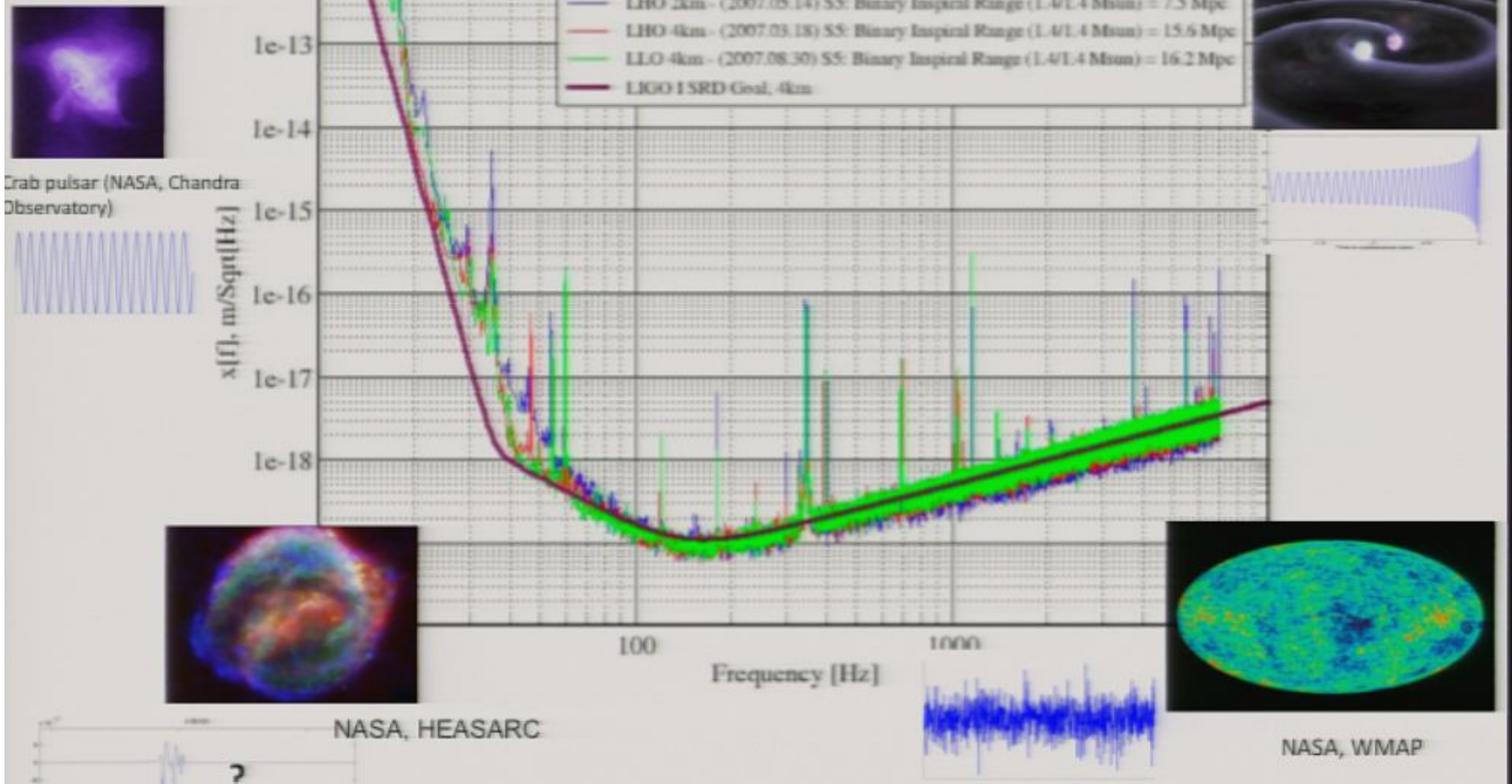

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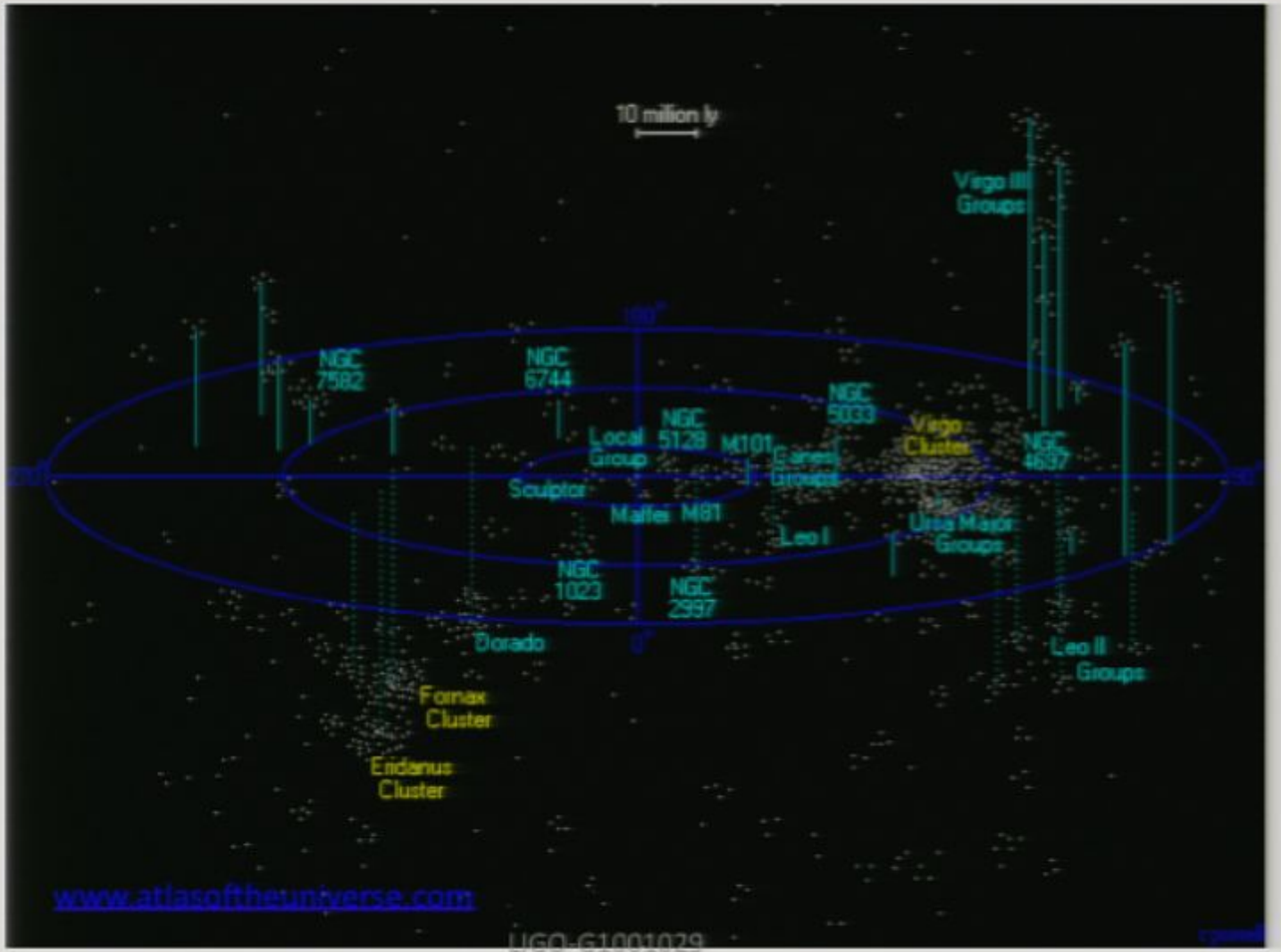
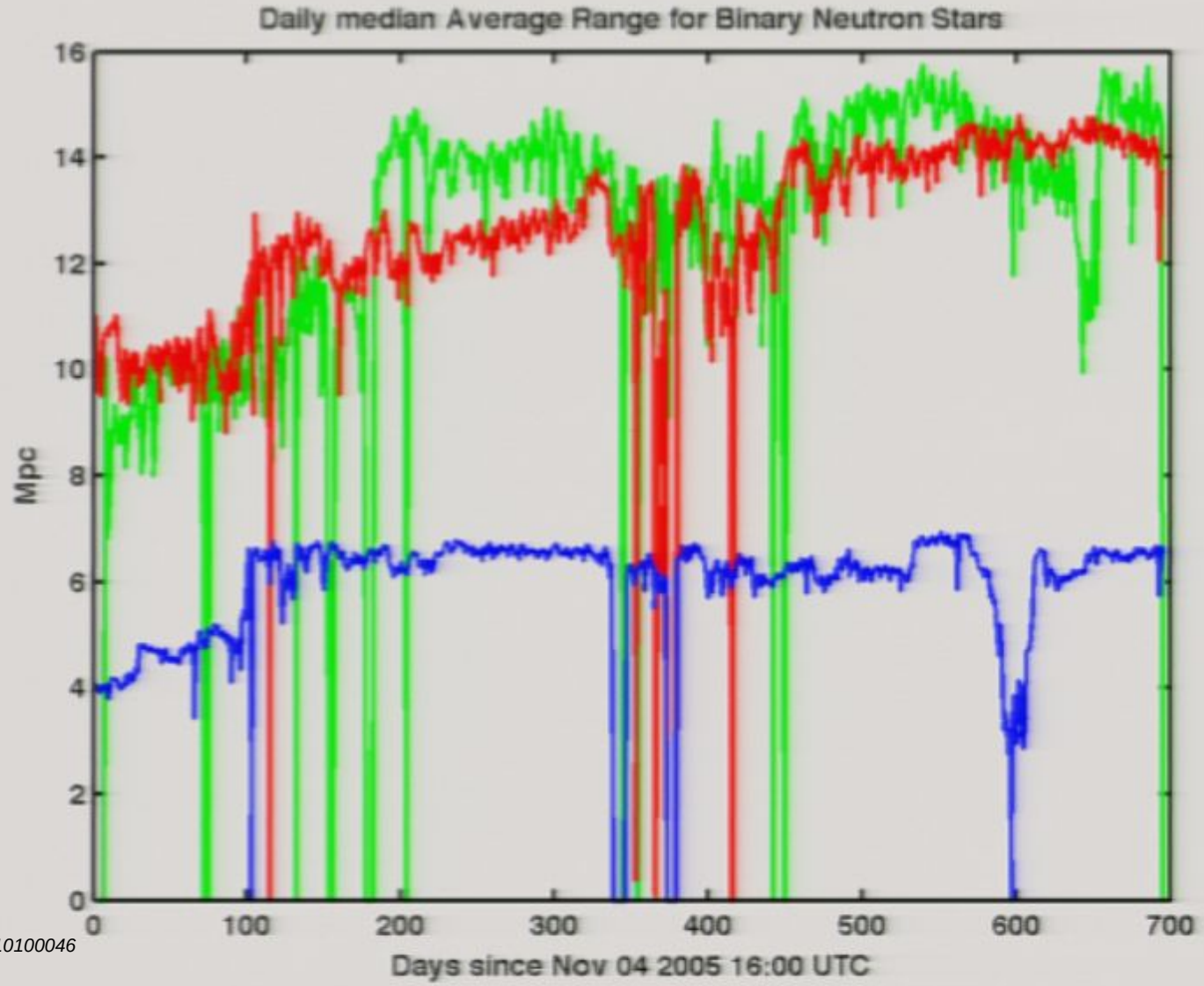
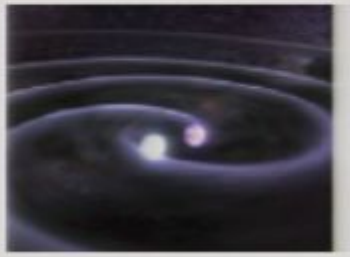


LSC S5 run (Nov'05-Oct'07)



~10% calibration uncertainty



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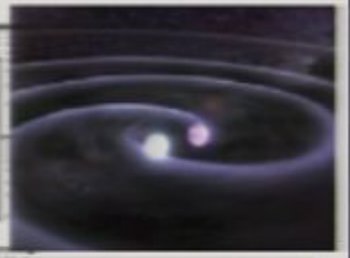

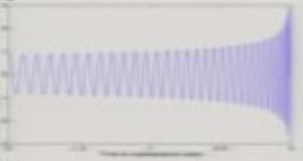

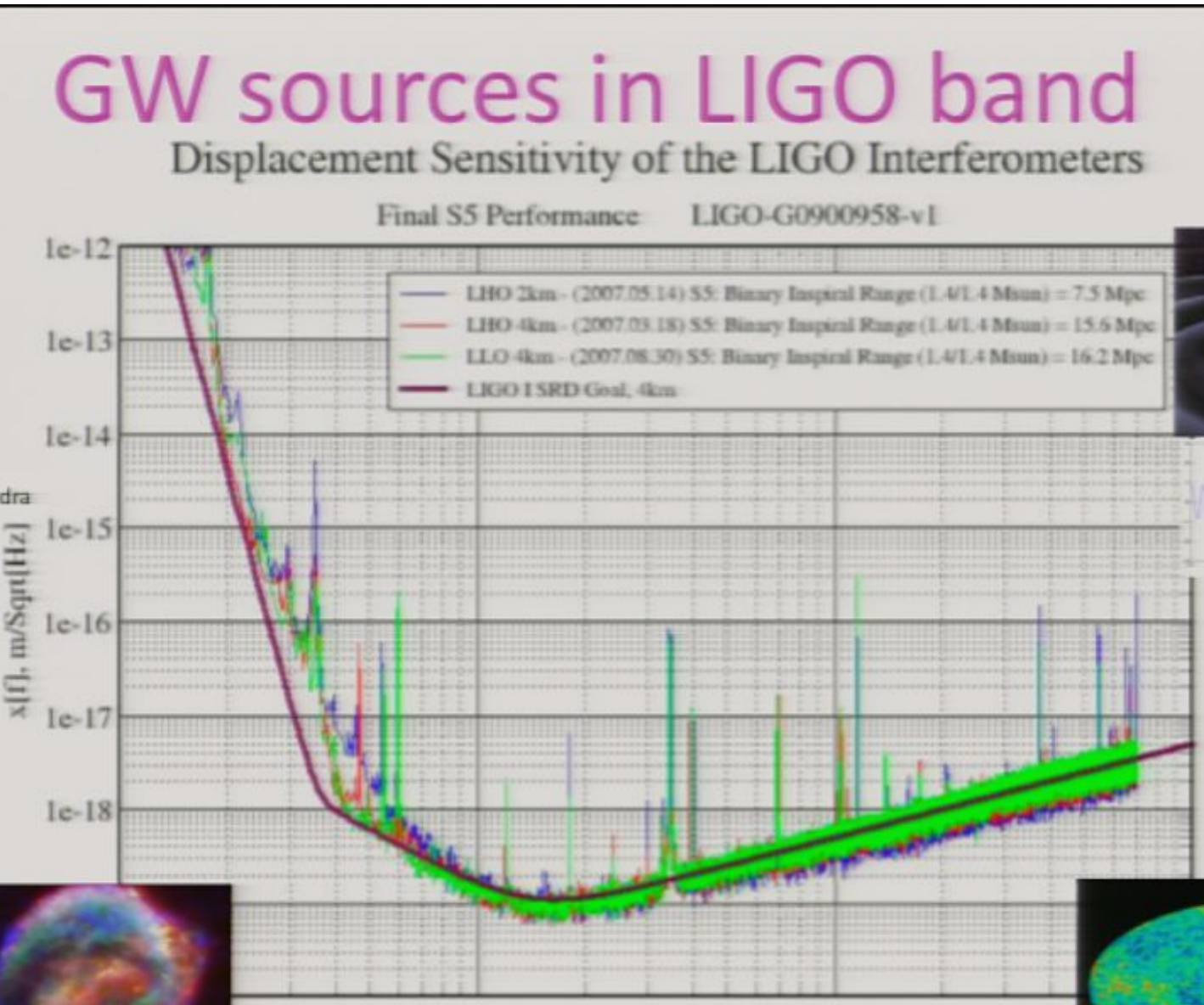

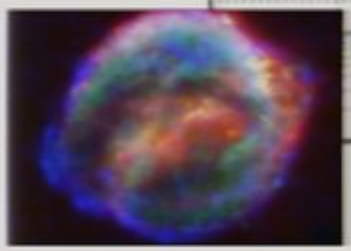

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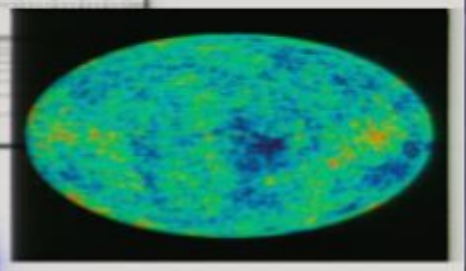

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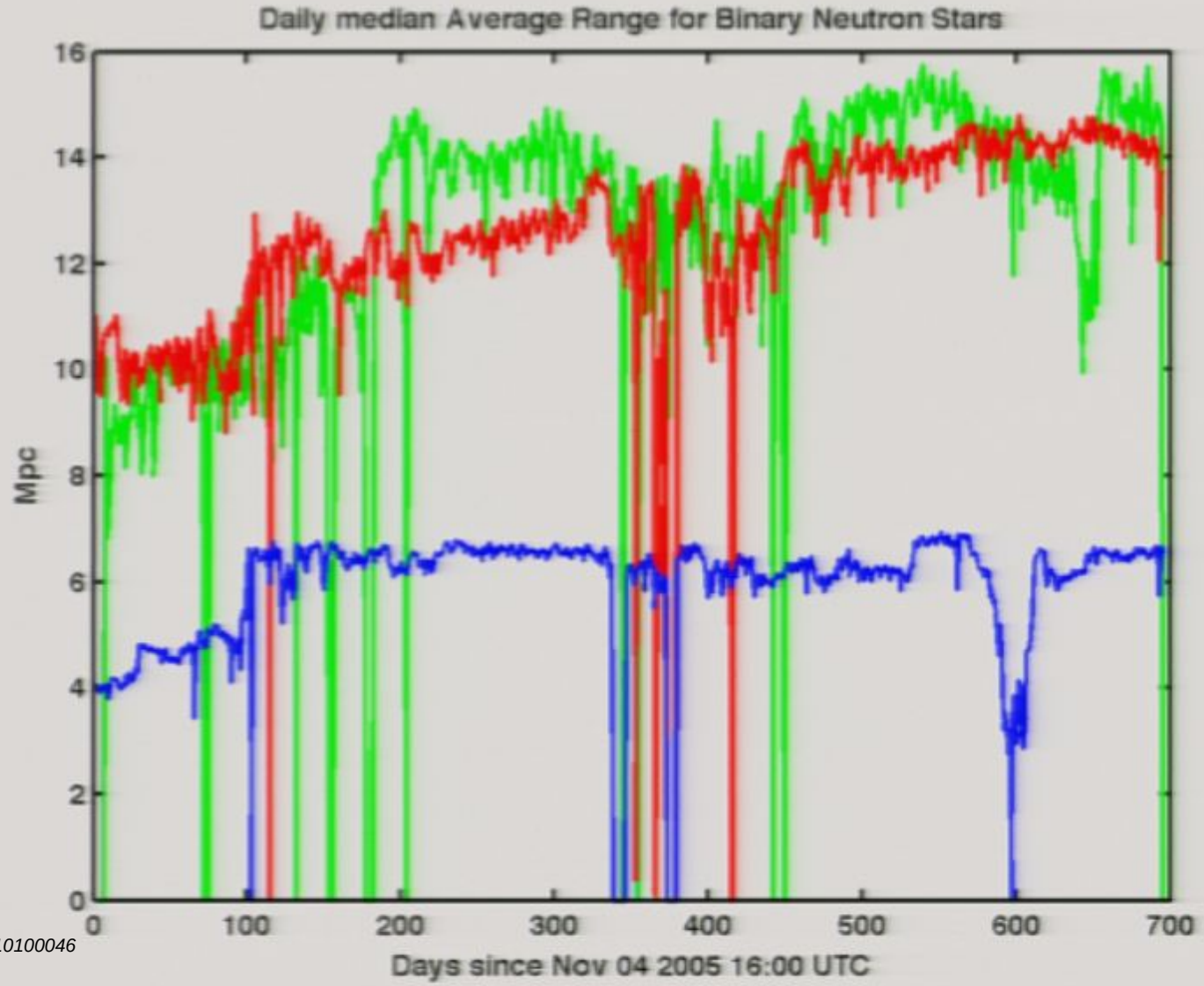

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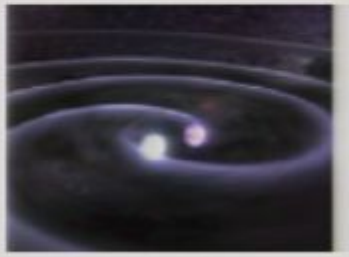

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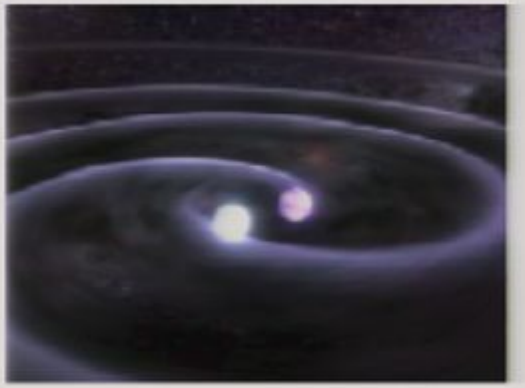
Overview of a Search Pipeline



Overview of a Search Pipeline

- Generate a template bank
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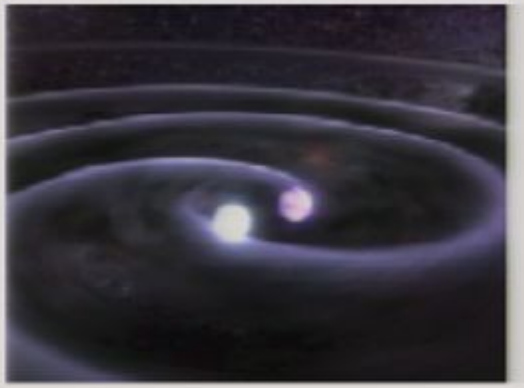

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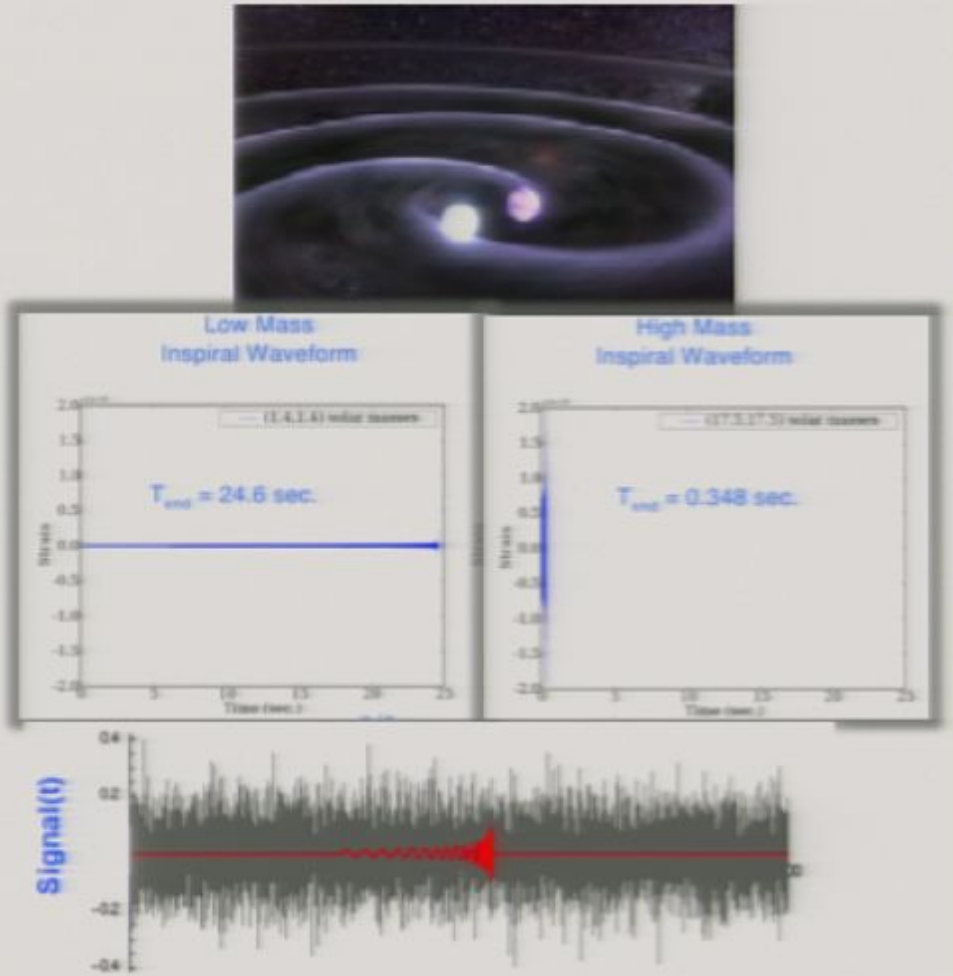

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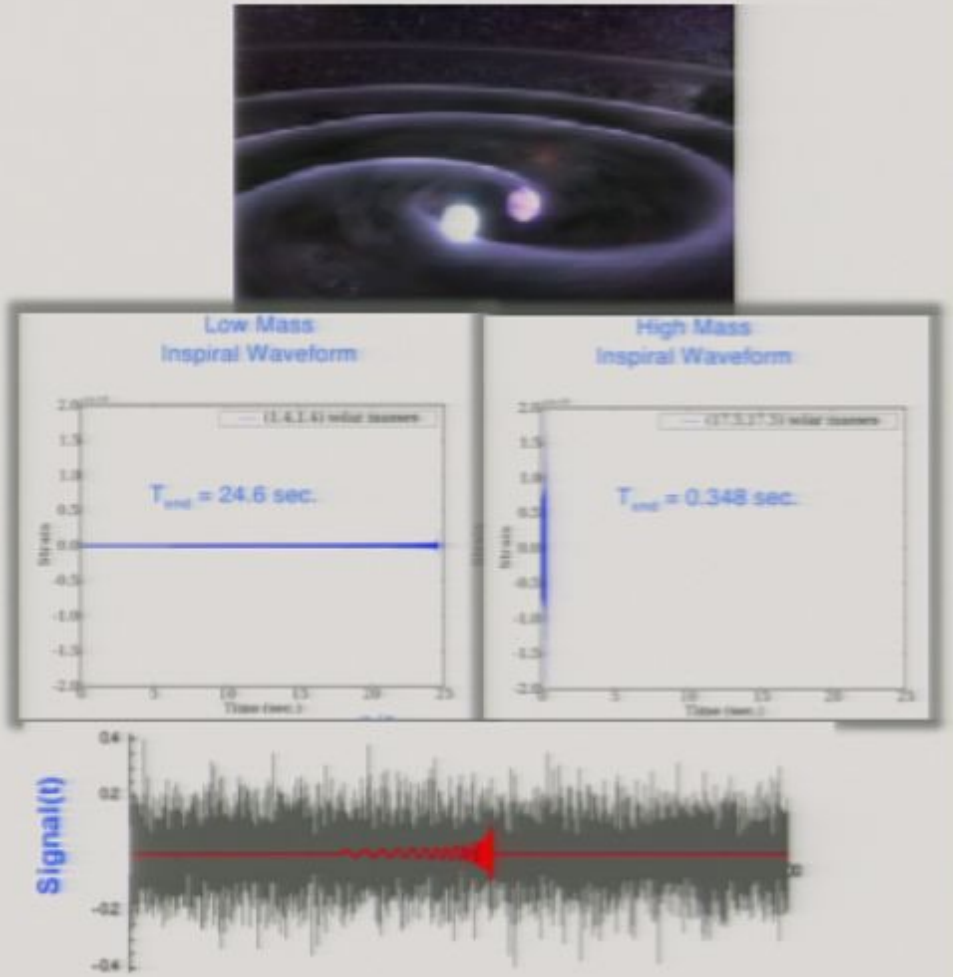

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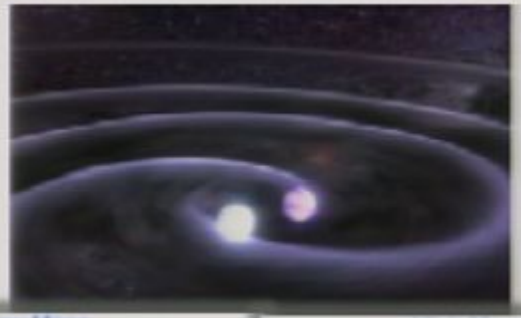

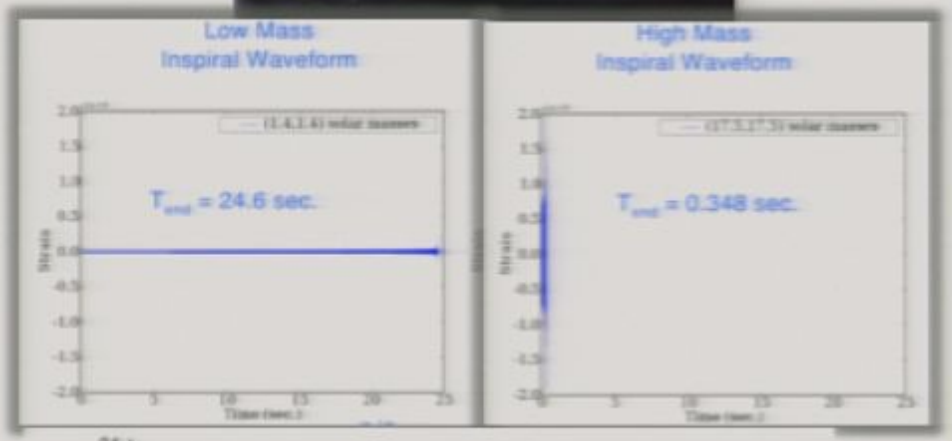

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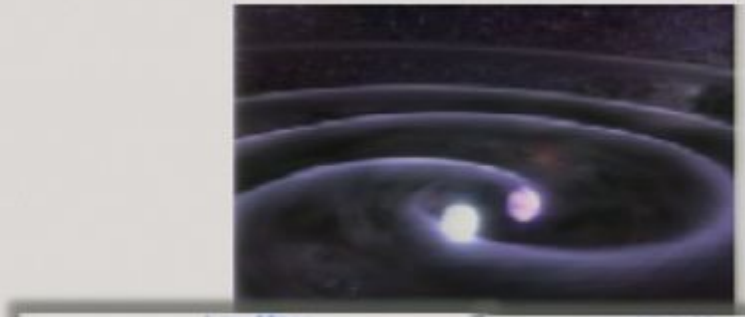

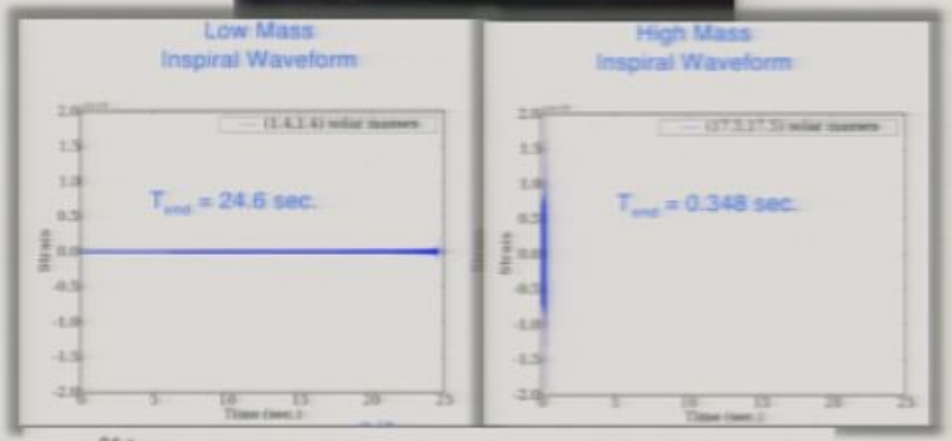

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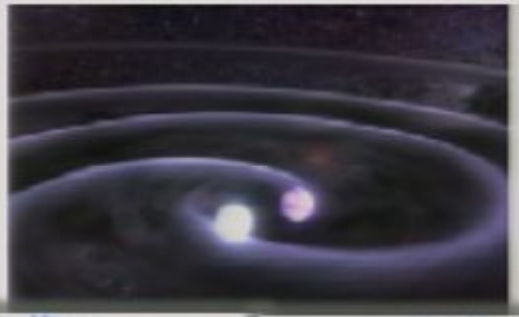

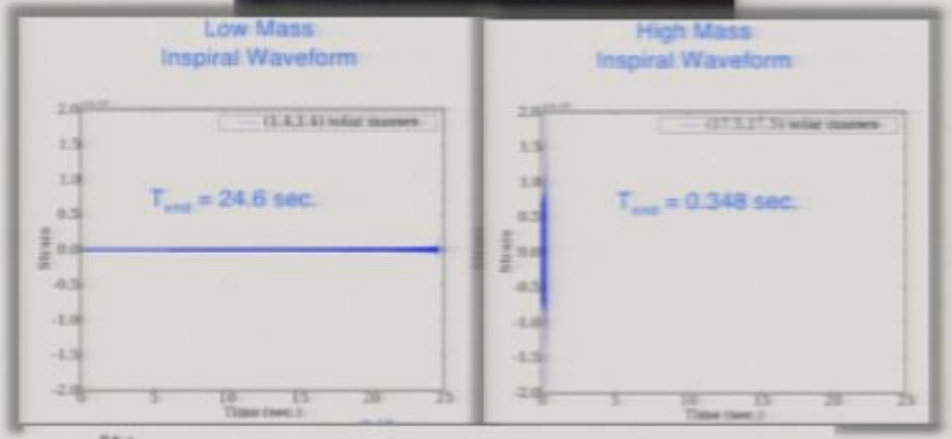

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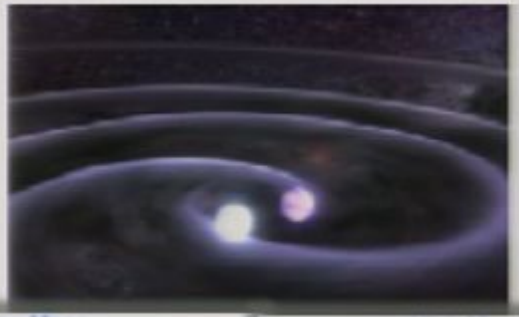
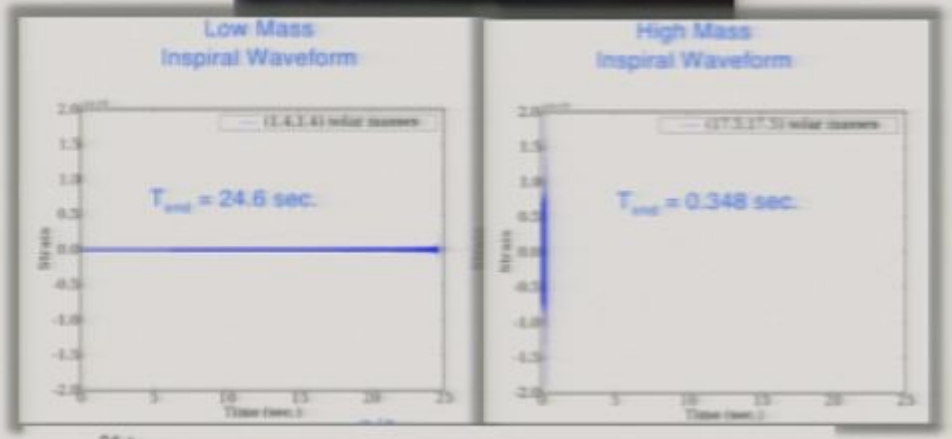
  - Use χ^2 parameter





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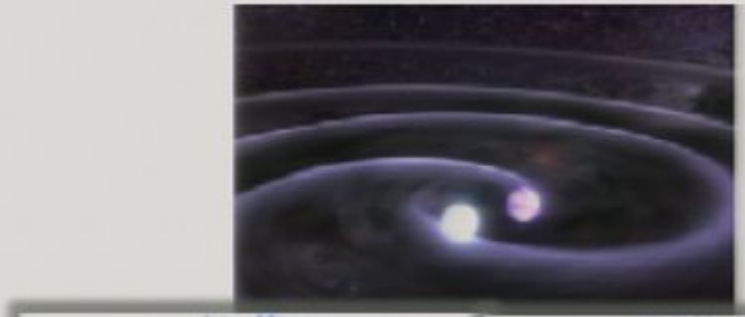
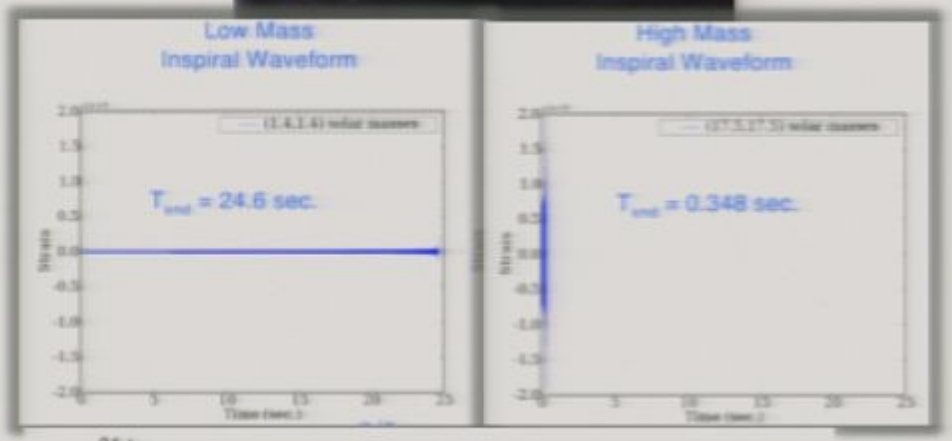
- Apply data quality
- Signal consistency checks
  - Use χ^2 parameter
- Calculate a false alarm rate

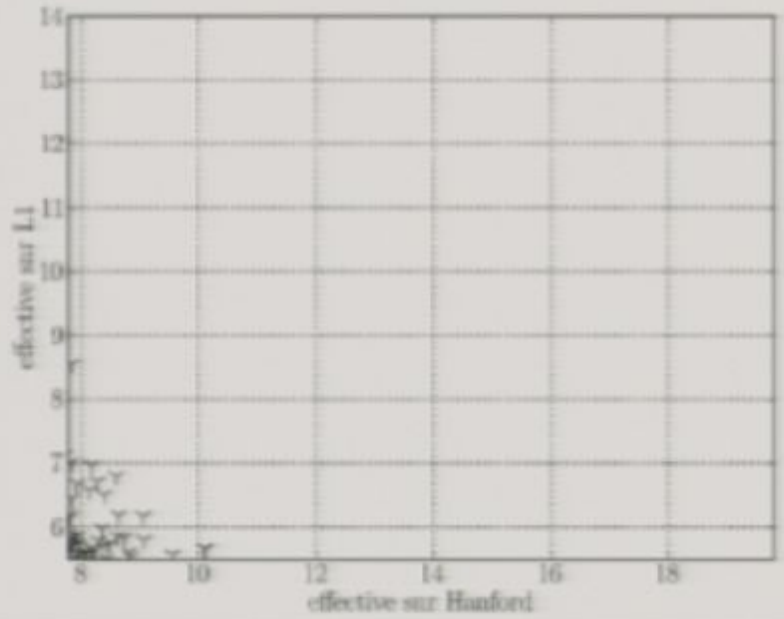




False alarm rates (FAR)

- Estimate looking for coincidences with unphysical time delays.
- 2 ifo background coincidences are more likely than 3 or 4 ifo coincidences
- We combine results using FAR, not SNR

H1H2L1 Triggers



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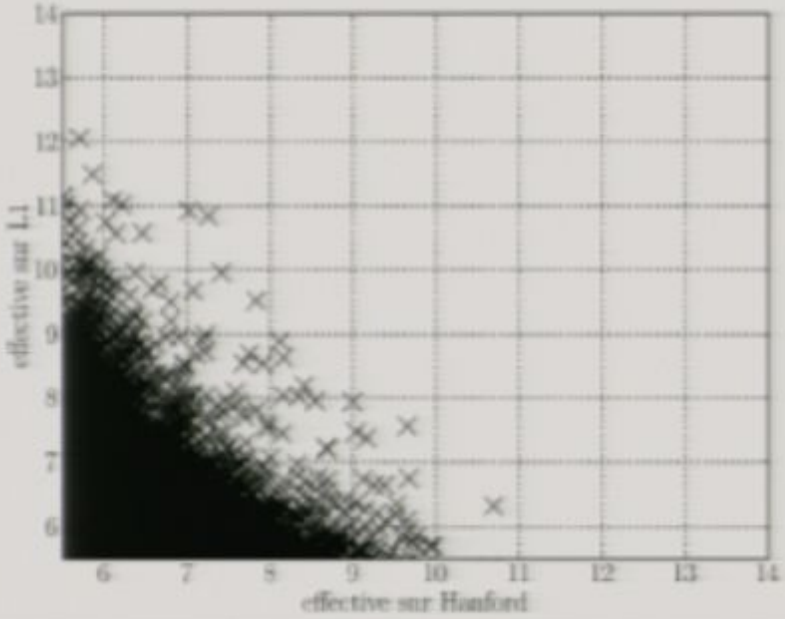
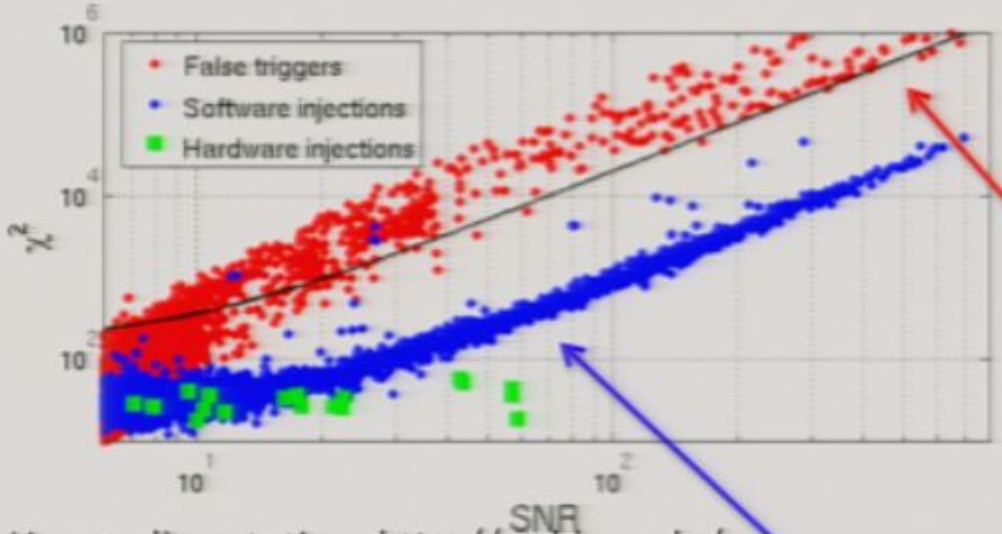
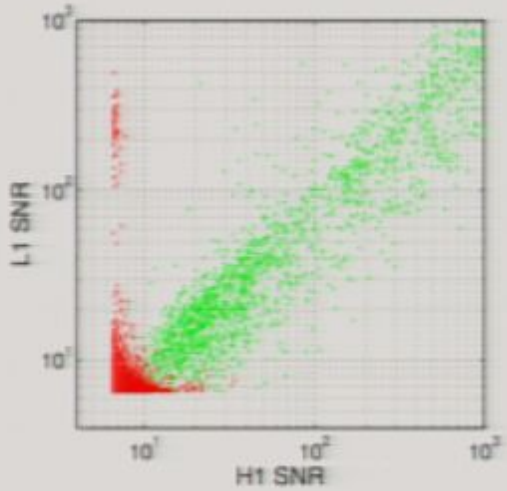
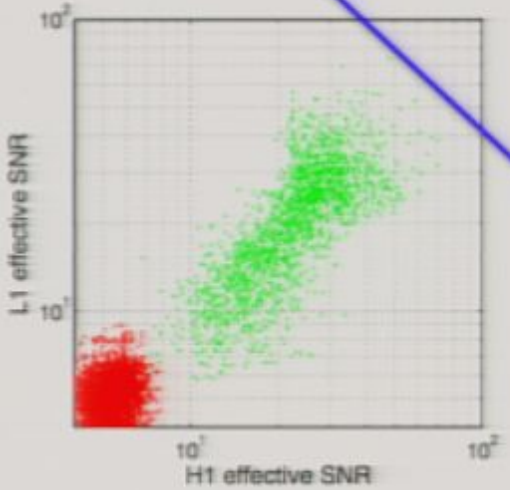


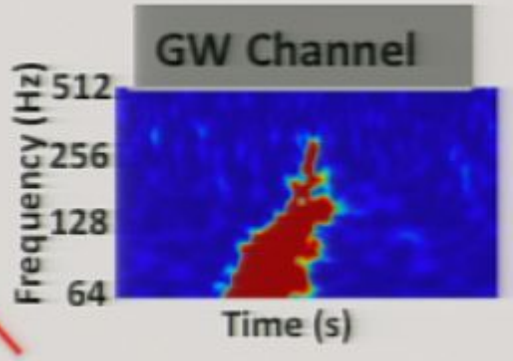
Improving the search: χ^2



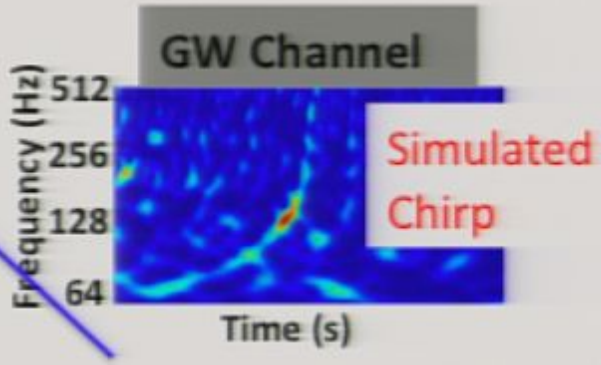
C. Hanna dissertation, http://etd.lsu.edu/







Very high SNR, high χ^2



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[Phys. Rev. D 77 (2008) 062002]

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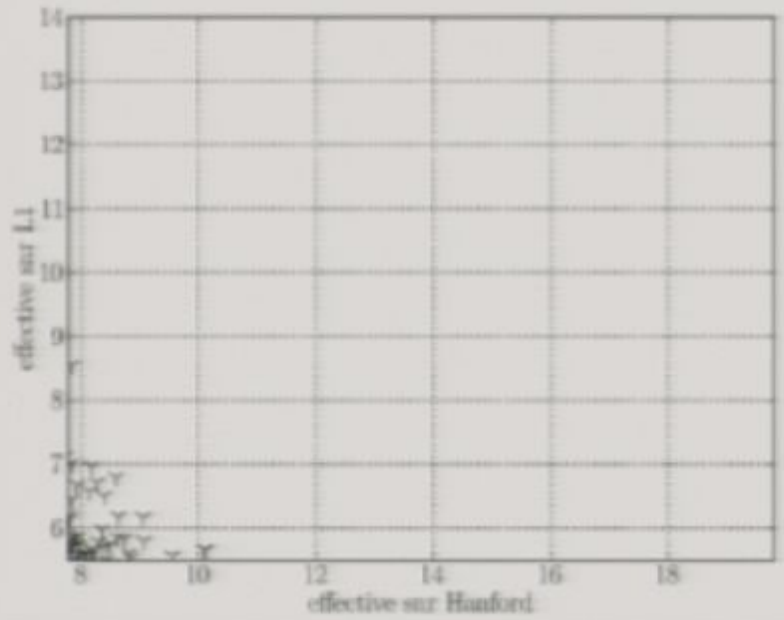
H1H2L1 Triggers



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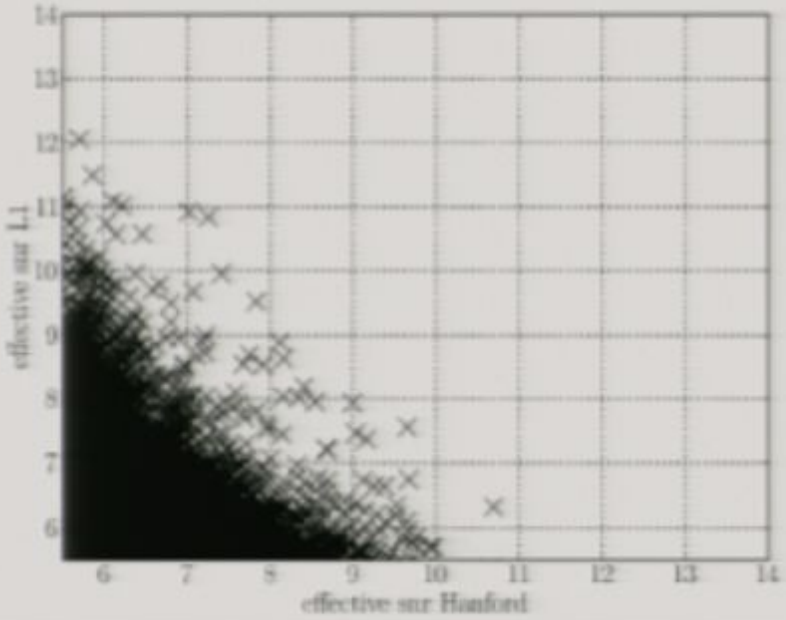
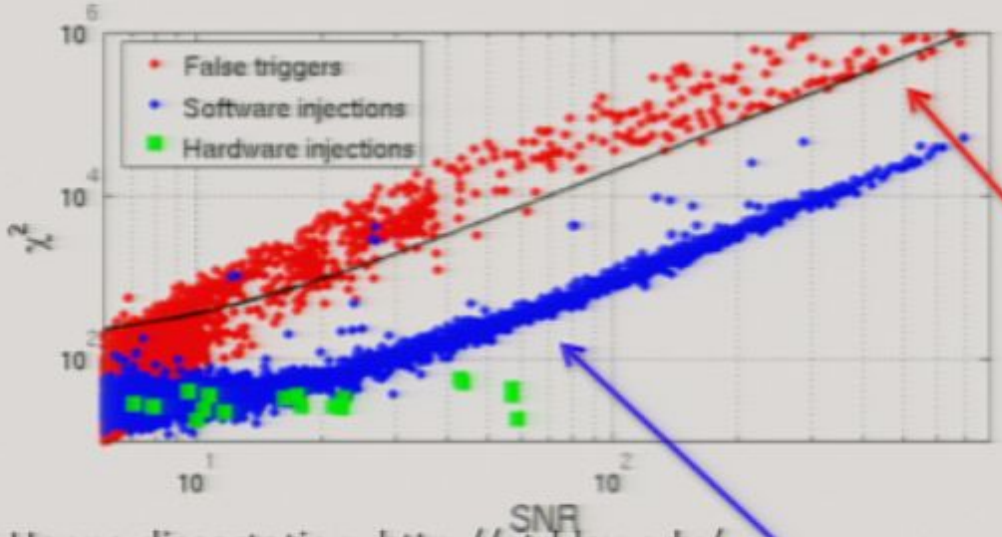
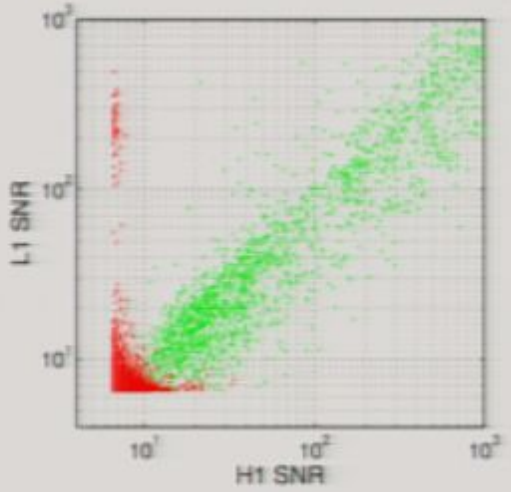
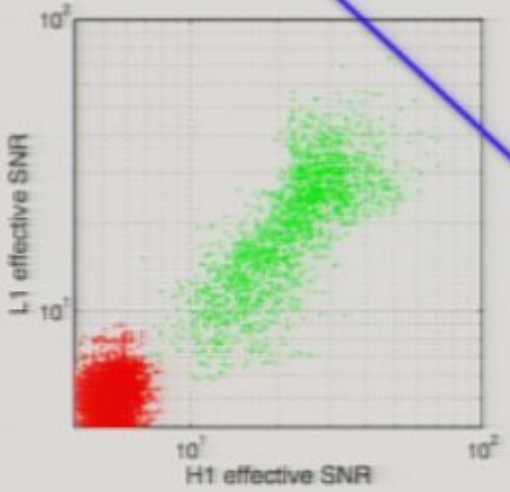


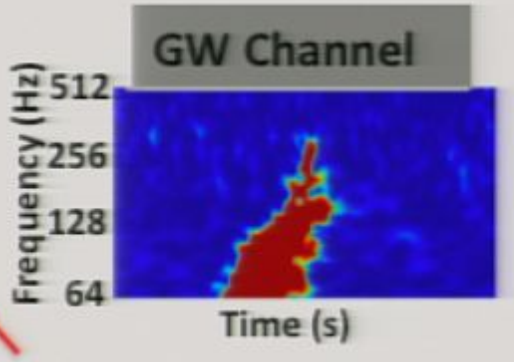
Improving the search: χ^2



C. Hanna dissertation, http://etd.lsu.edu/







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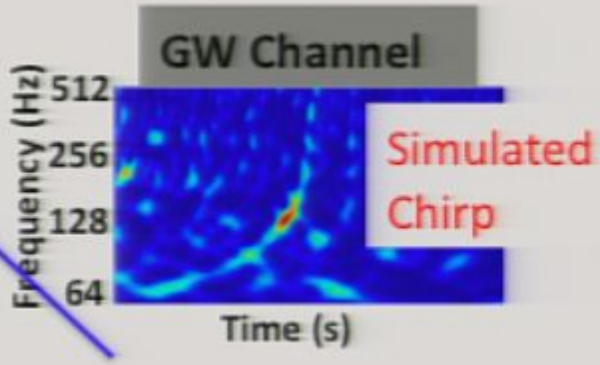

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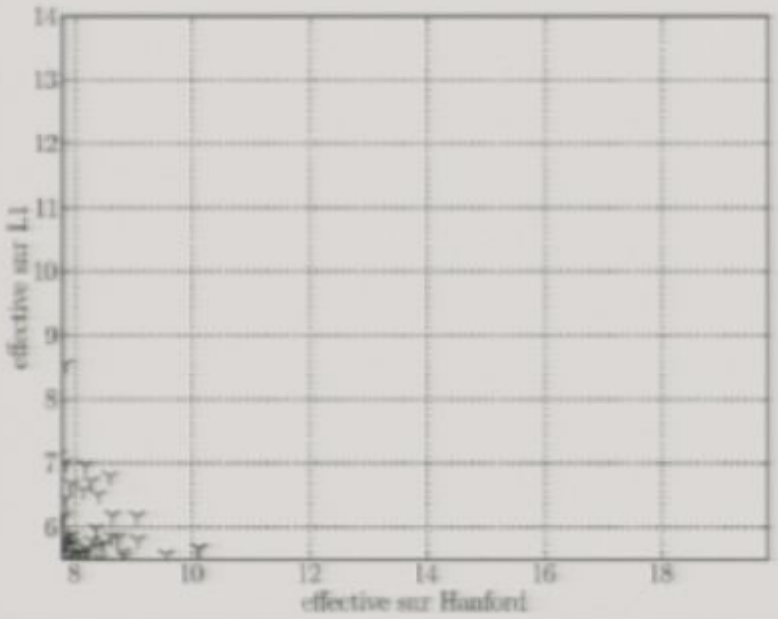

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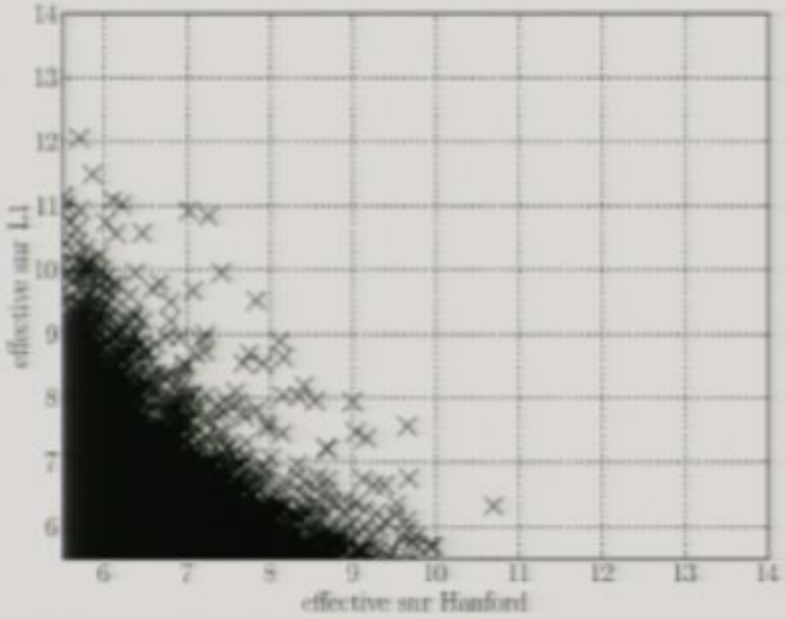

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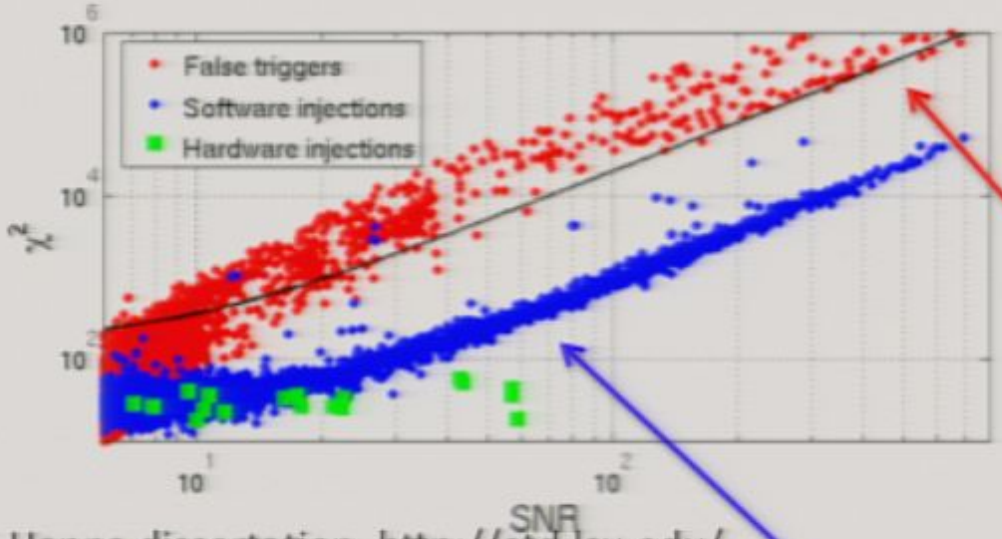

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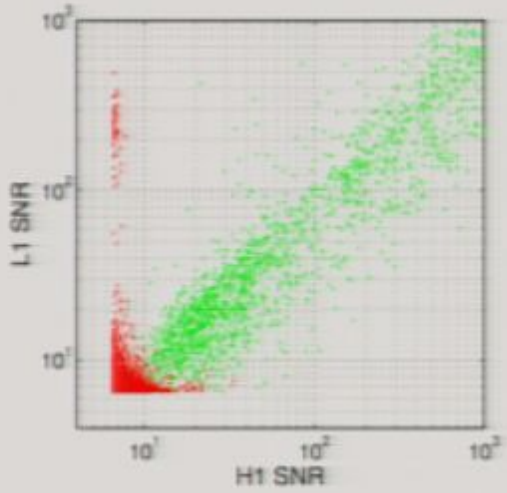

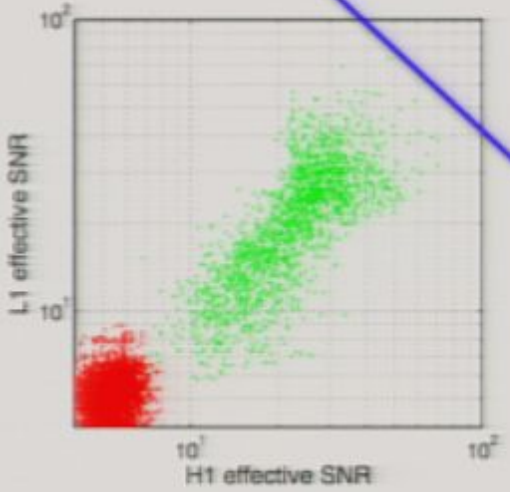

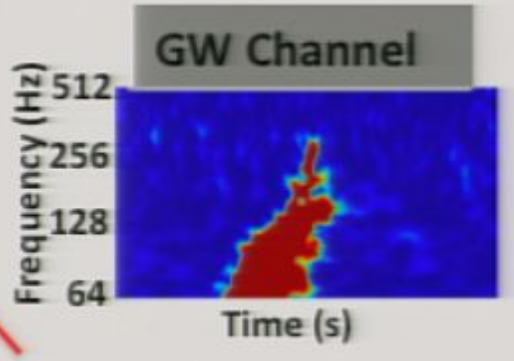

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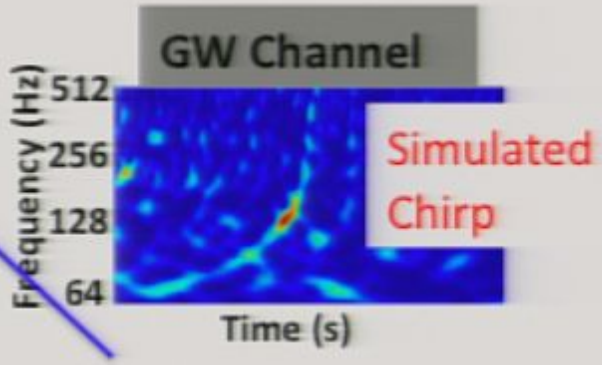

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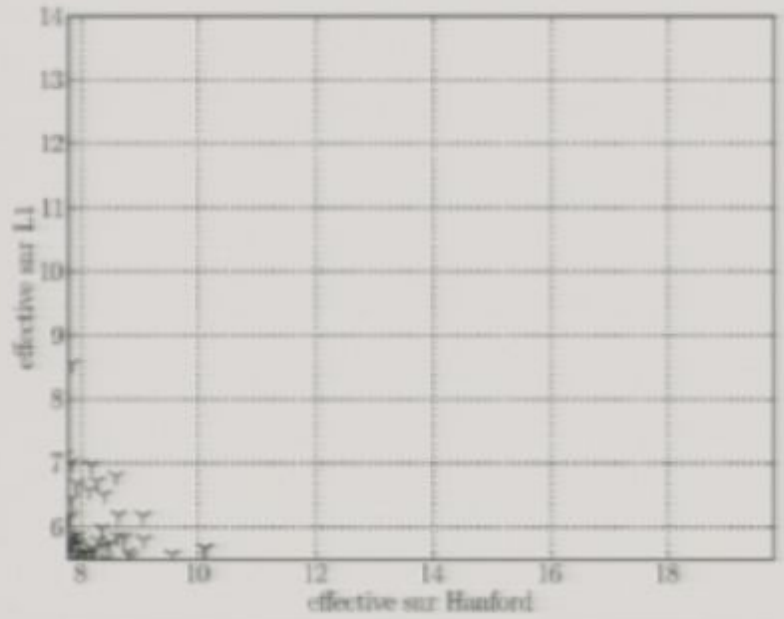

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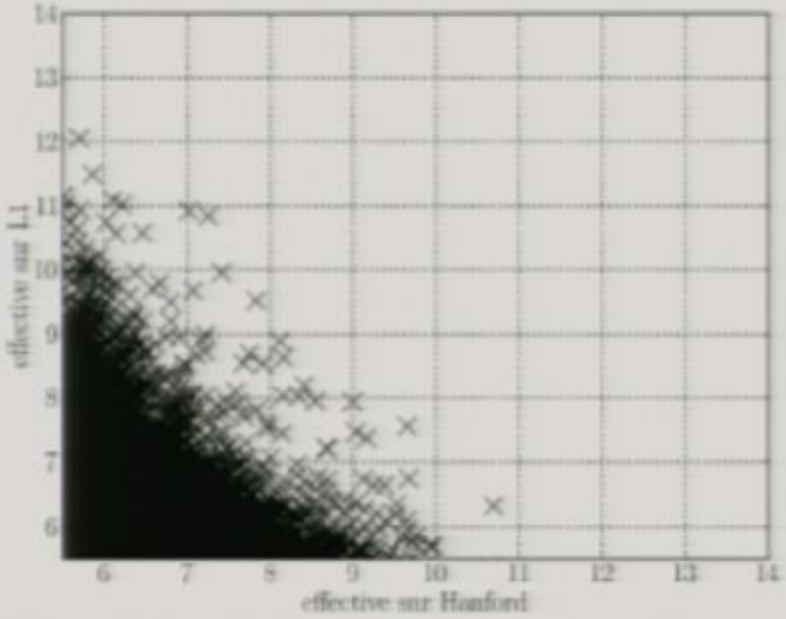
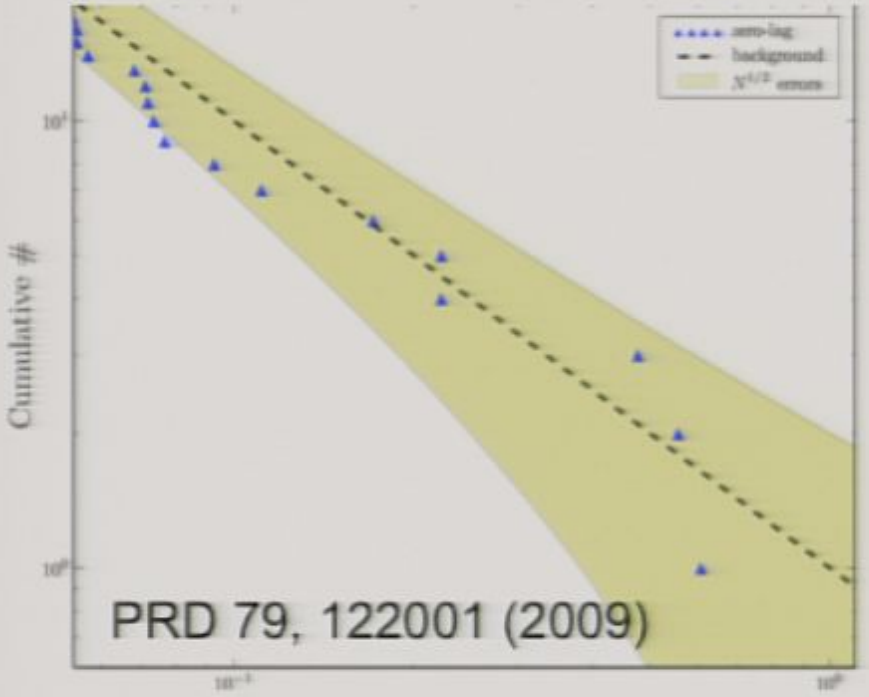


Low Mass Results

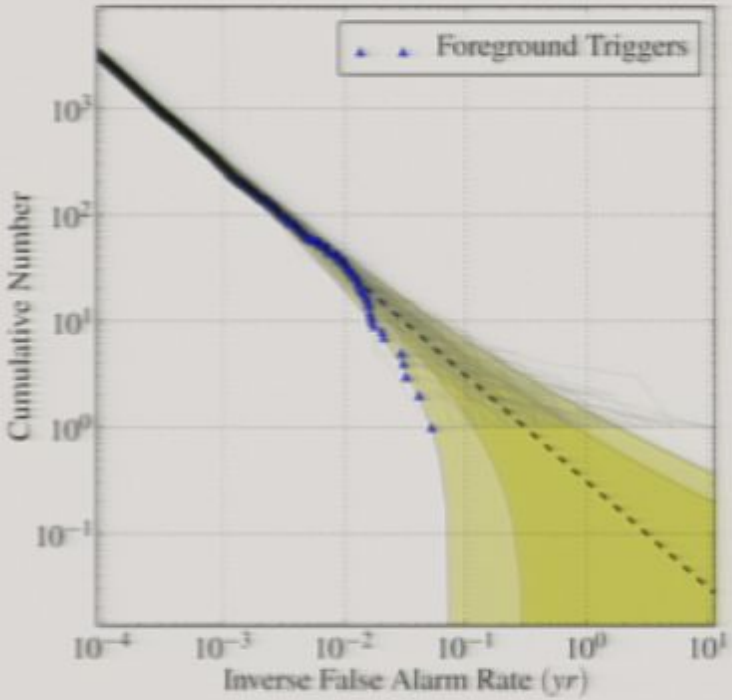
Loudest triggers

S5 1st year low mass



1/FAR

S5 LIGO-Virgo run



Our conclusion is that no gravitational wave candidates were found in these searches ☹

S5/VSR1 search included a "blind injection"

No detection ➡ upper limits

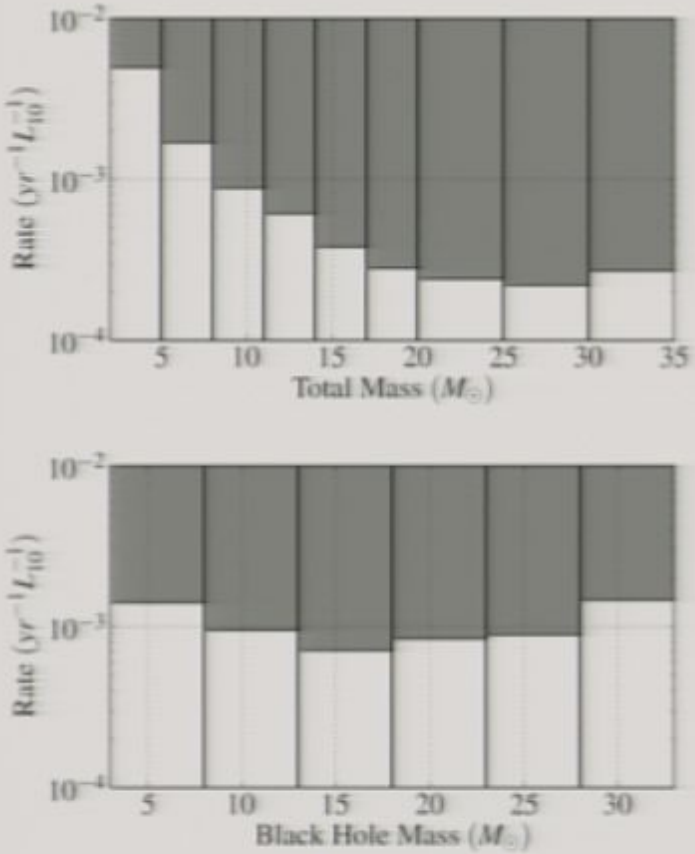


FIG. 4: The 90% rate upper limits as a function of mass. The first figure gives the upper limit on the rate of coalescence from BBH system as a function of the total mass of the system. The second figure gives the BHNS upper limit as a function of black hole mass, assuming a fixed neutron star mass of 1.35 $M_\odot$.

Table 1. Rate statement terminology.

Abbreviation	Rate statement	Physical significance
$R_{\max}$, $\dot{N}_{\max}$[a]	Upper limit	Rates should be no higher than …
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Table 2. Compact binary coalescence rates per Milky Way Equivalent Galaxy per Myr.

Source	R_{low}	R_{re}	R_{high}	$R_{\max}$
NS–NS (MWEG^{-1} Myr^{-1})	1 [1][a]	100 [1][b]	1000 [1][c]	4000 [16][d]
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arXiv:1003.2480

http://arxiv.org/abs/1005.4655

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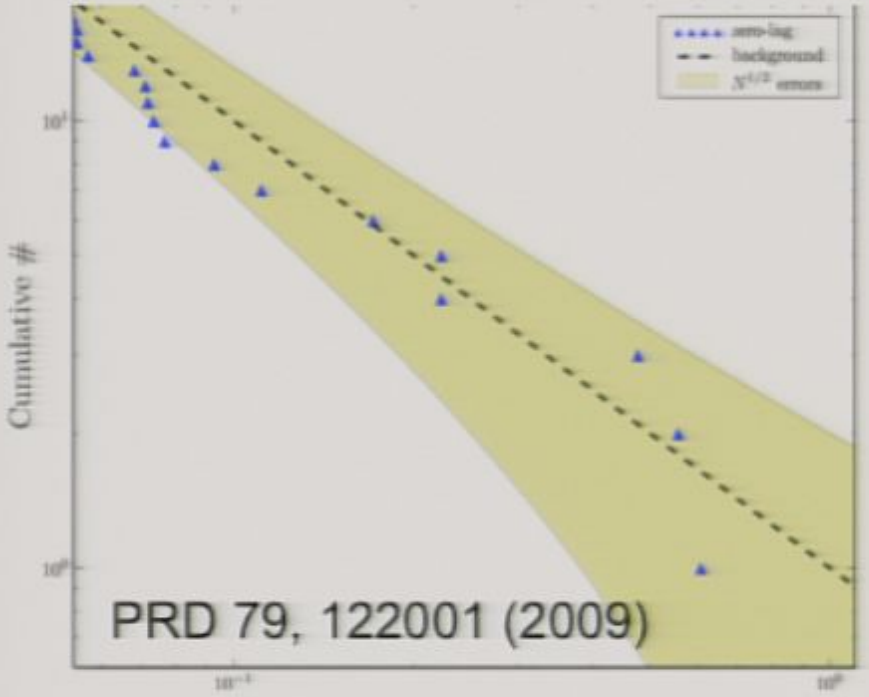

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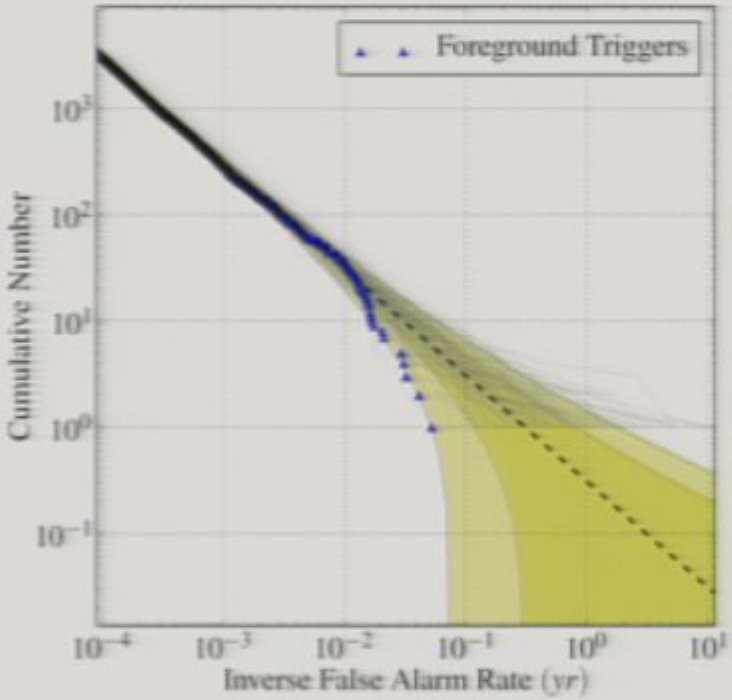

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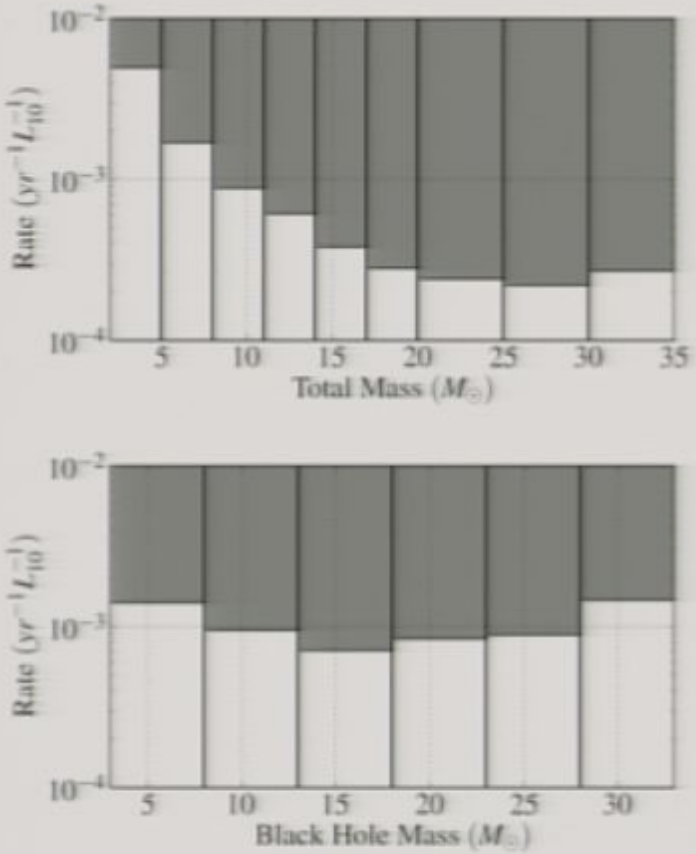

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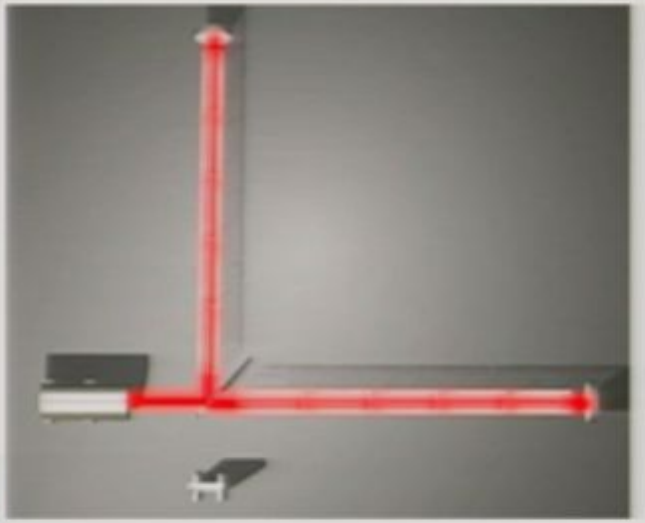
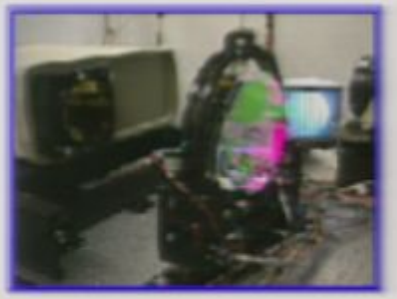
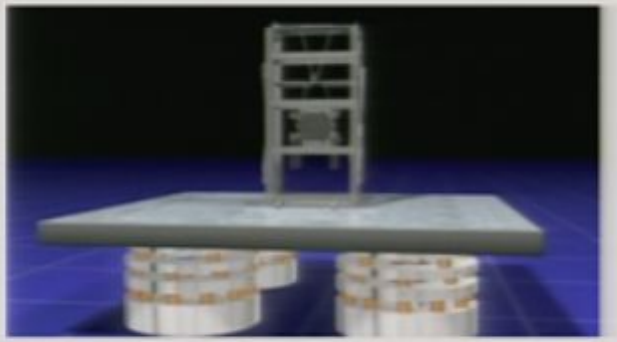
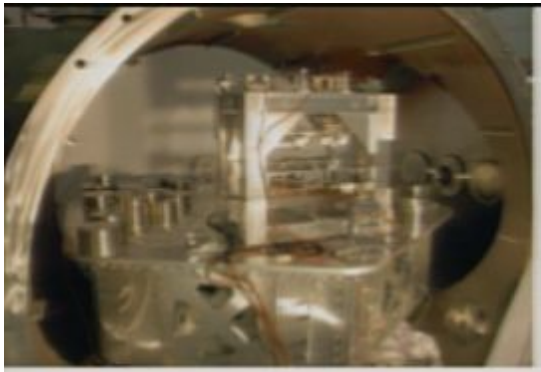
GW Detection:
a difficult and fun experiment

Enhanced LIGO

- Improved sensitivity over initial LIGO
- New readout scheme
  - DC (homodyne)
  - Suspended output mode cleaner + seismic isolation
  - In-vacuum detection diodes
- Higher laser power → 35 W
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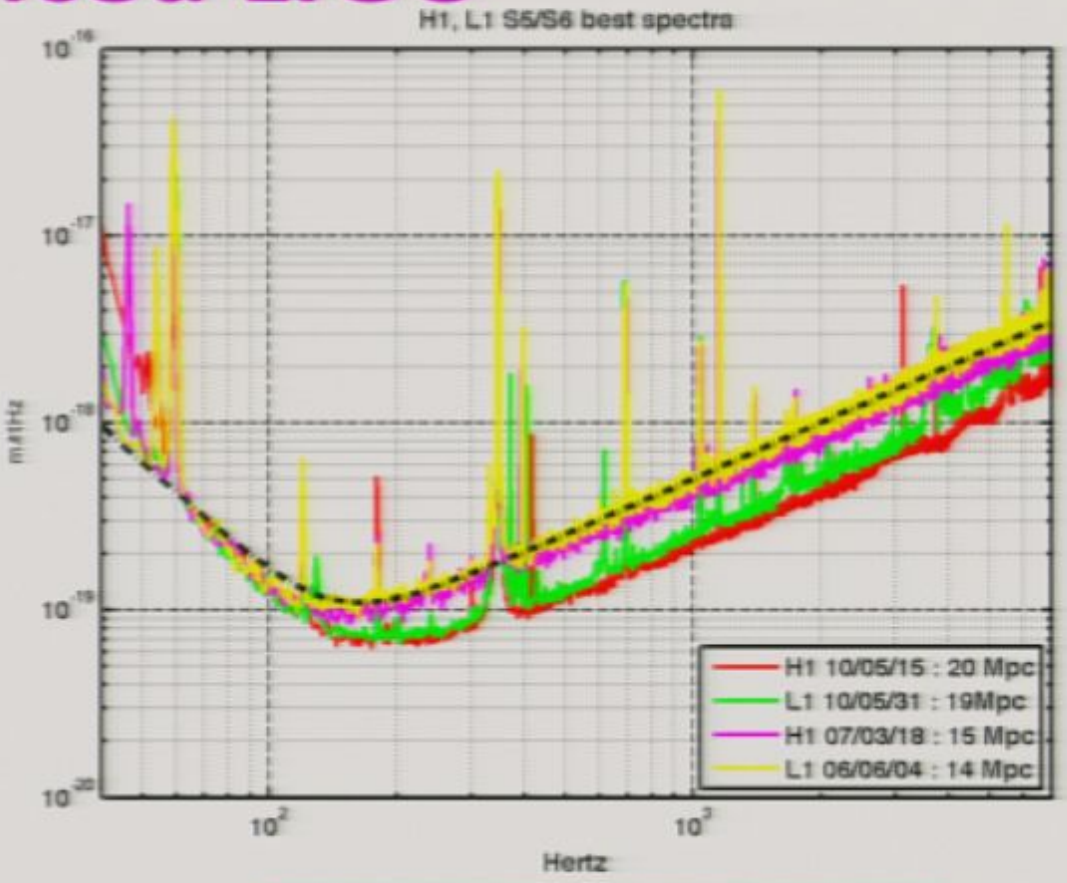
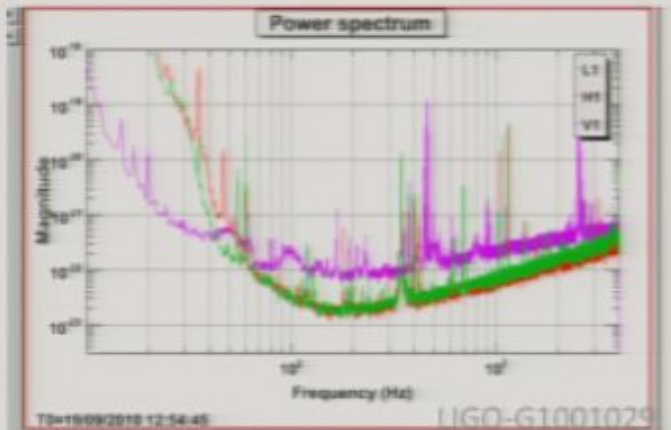
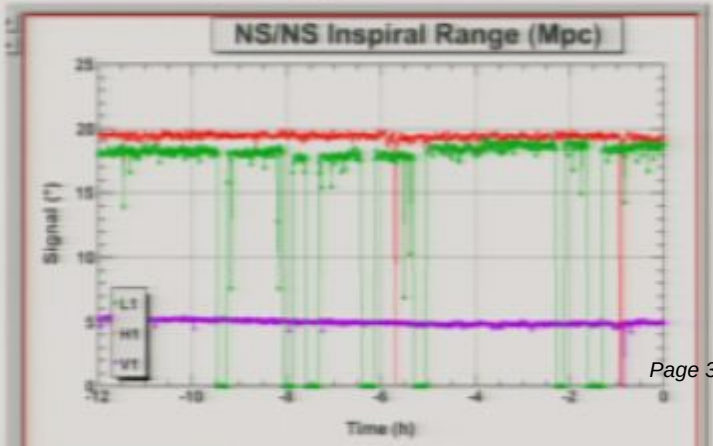
- Science Run S6 began July'09, ended Oct 20 10







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Vacuum system is the same!

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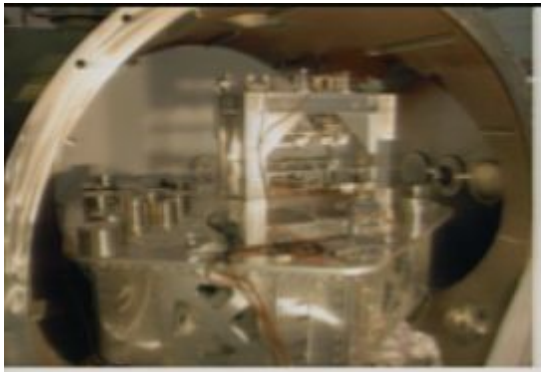
EGO started funding Advanced Virgo in 2009
1st hour lock for all expected in ~2014



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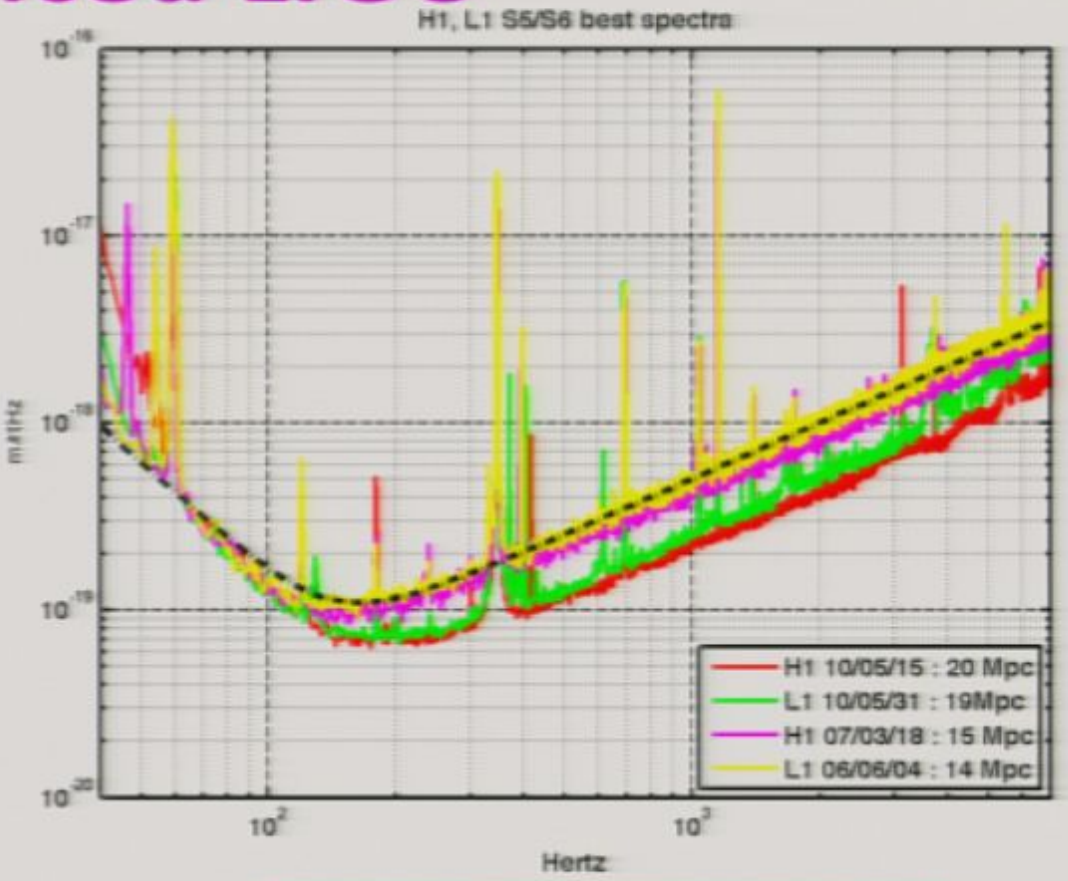

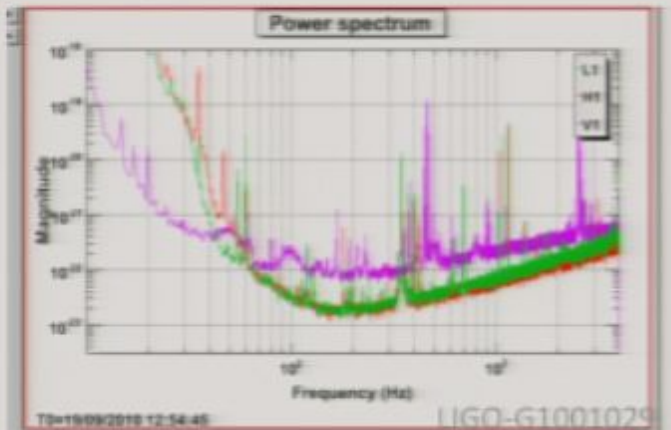

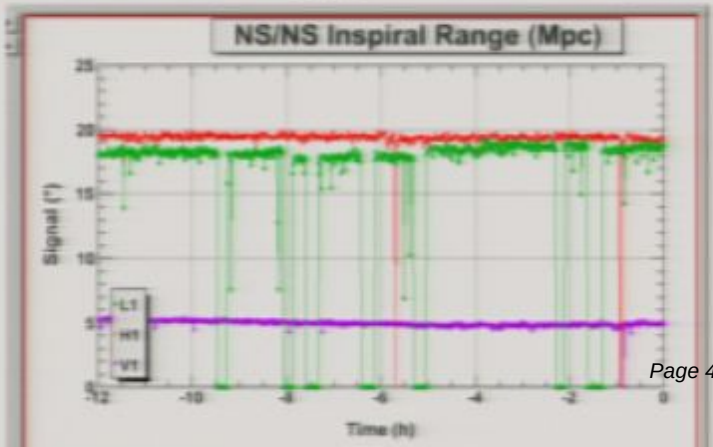

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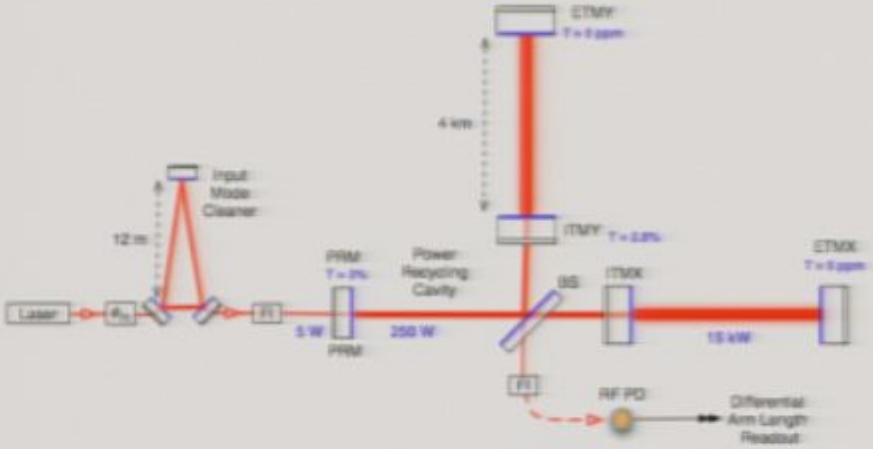
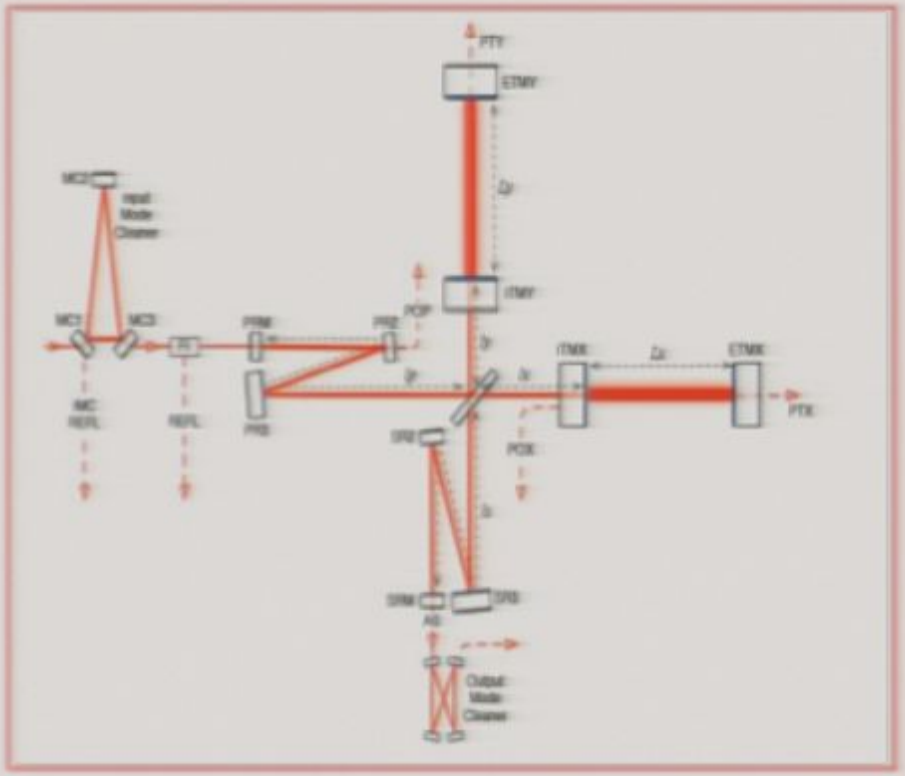
Optical layout: includes signal recycling (tested in GEO), DC readout with output mode cleaner (tested in S6).





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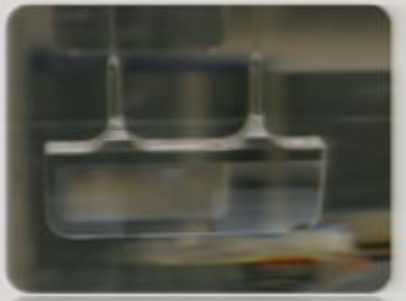
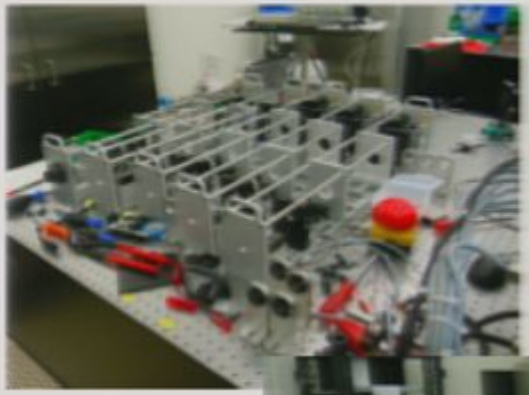


Simple pendulums become
monolithic, quadruple pendulums
with better quality optics
Prototypes being tested, optics are polished

Initial vs Advanced LIGO

Lasers become more powerful: 10W -> 200 W
30W tested in S6, 200W exists in Zentrum, Hannover



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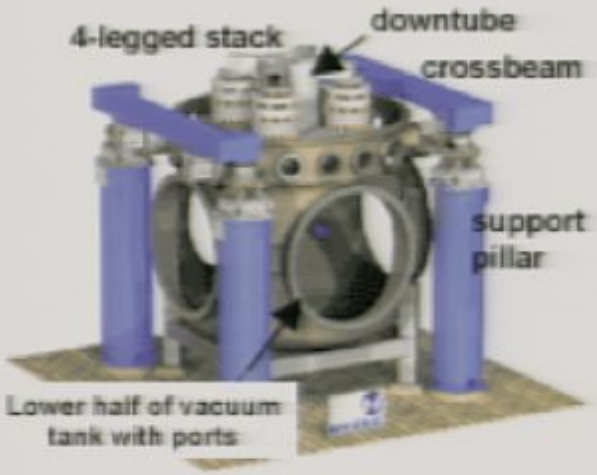
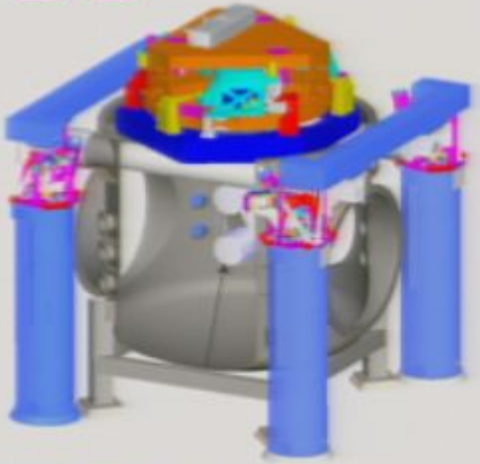
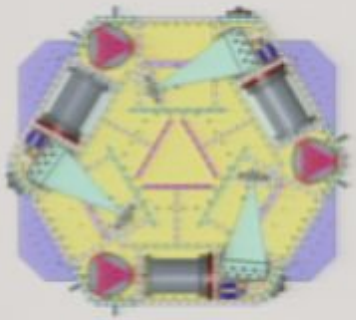
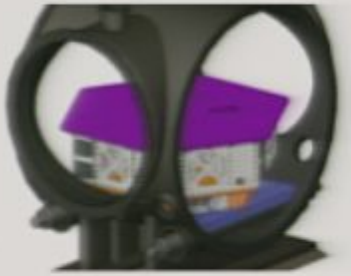


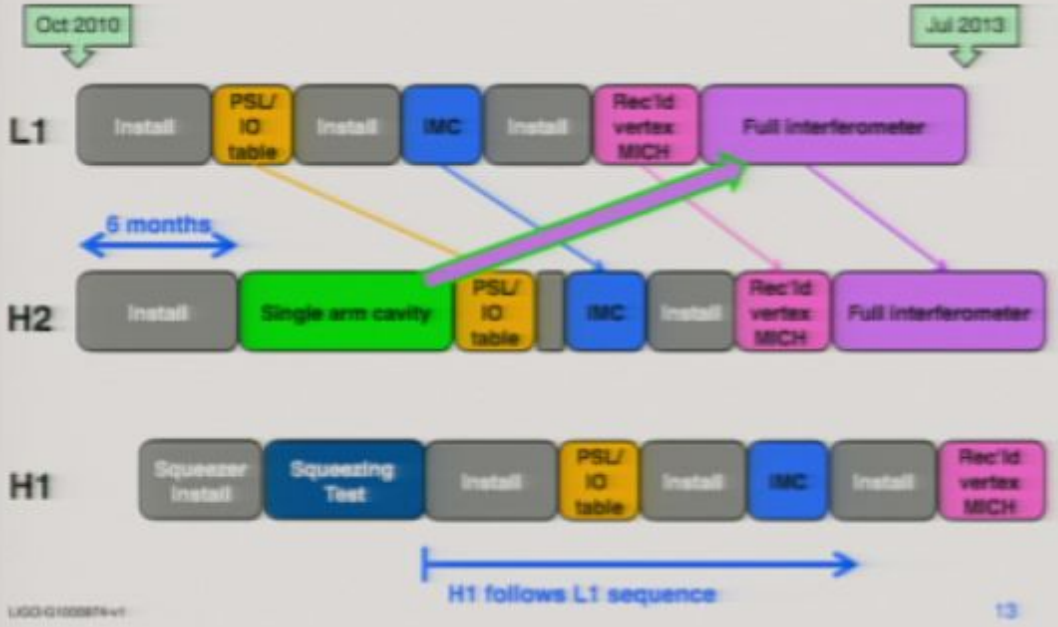
Seismic isolation goes from passive to active
HAM SEI tested in S6

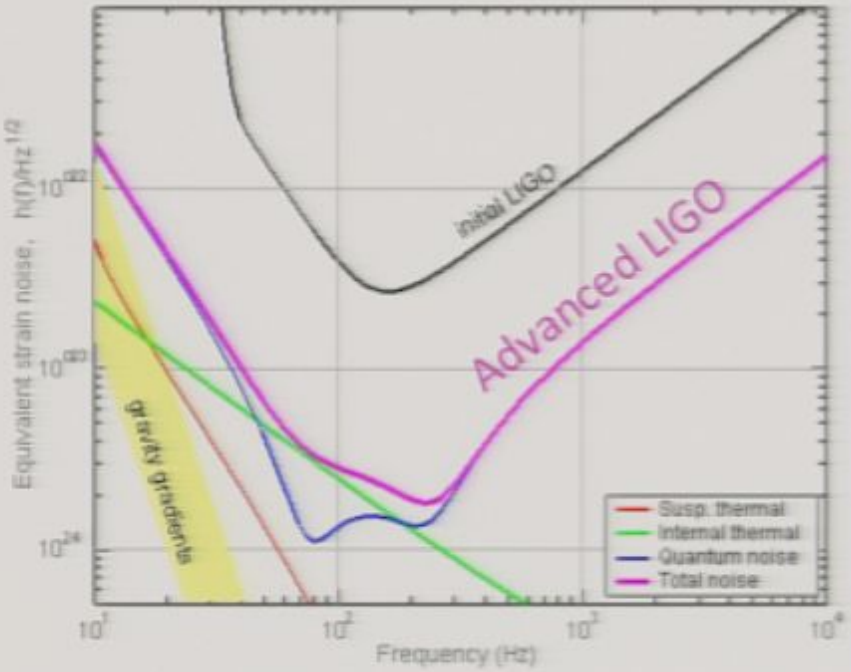






Advanced LIGO schedule





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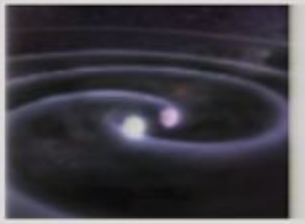

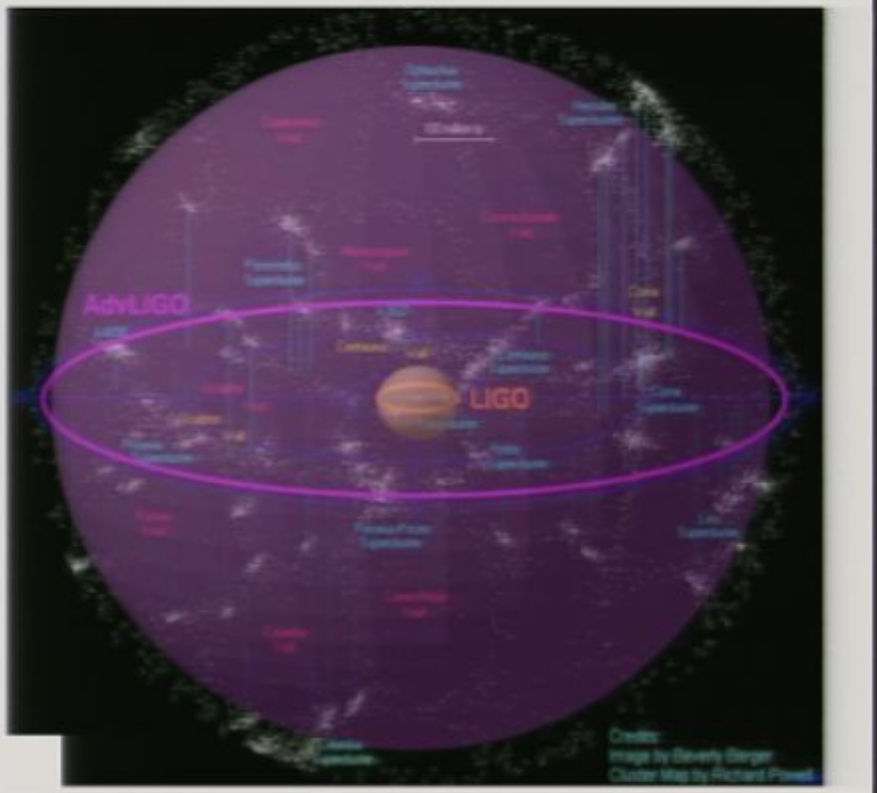

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LIGO-G1001029

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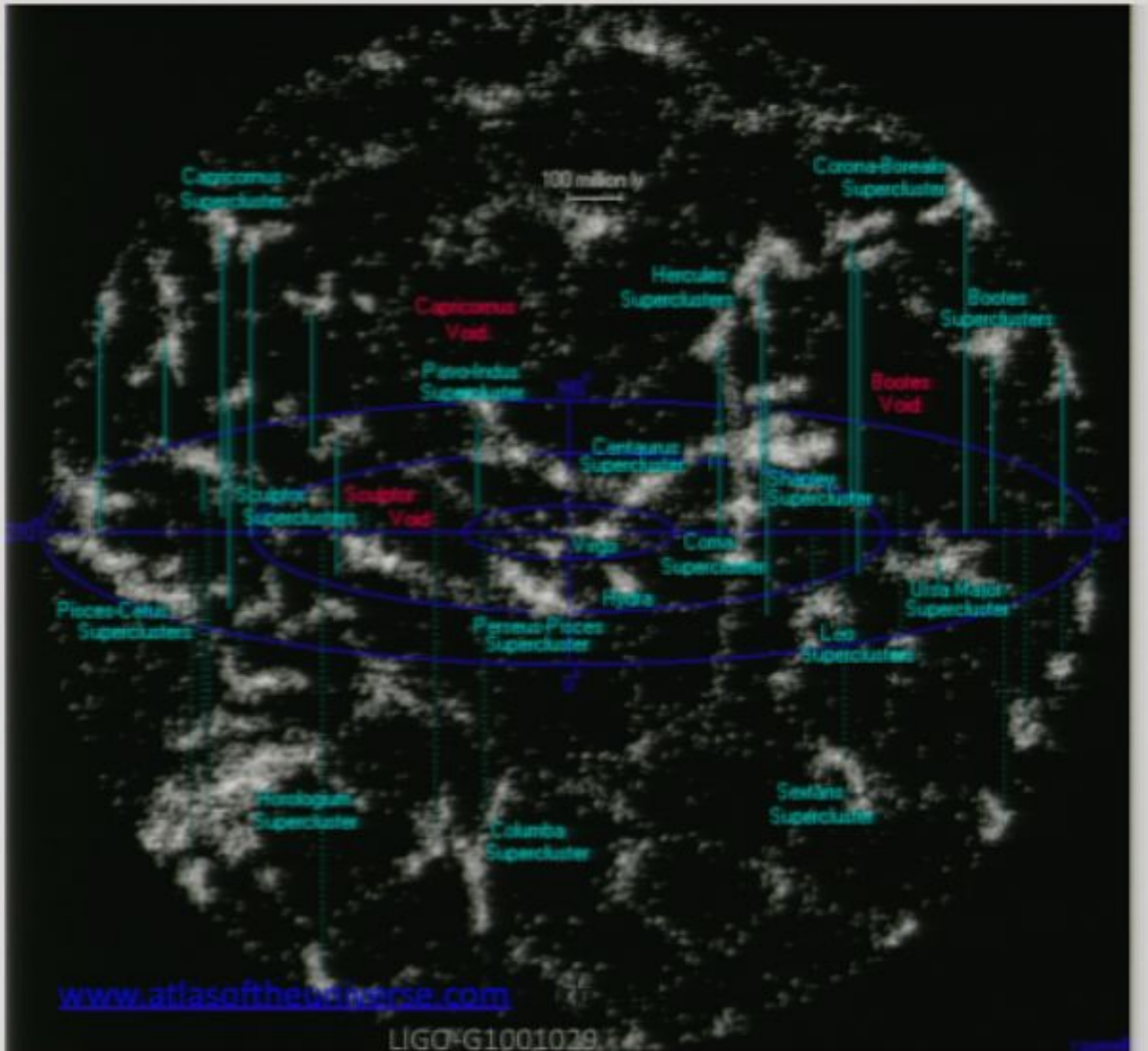
Gravitational waves are in your near future!



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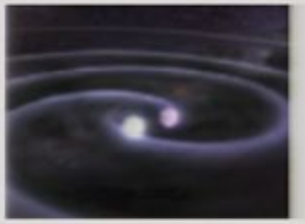

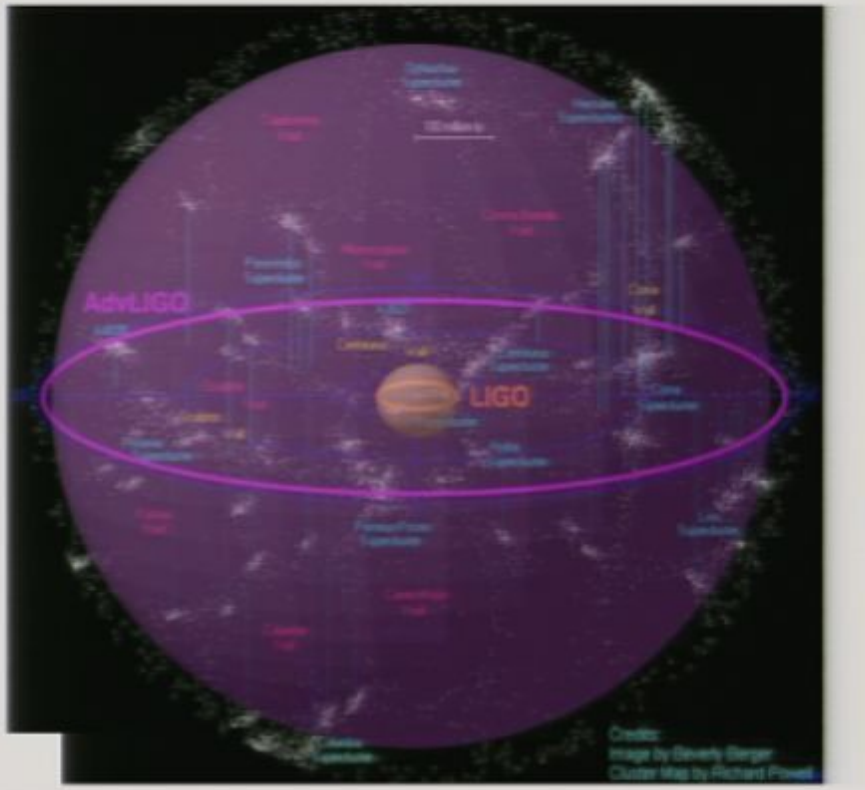

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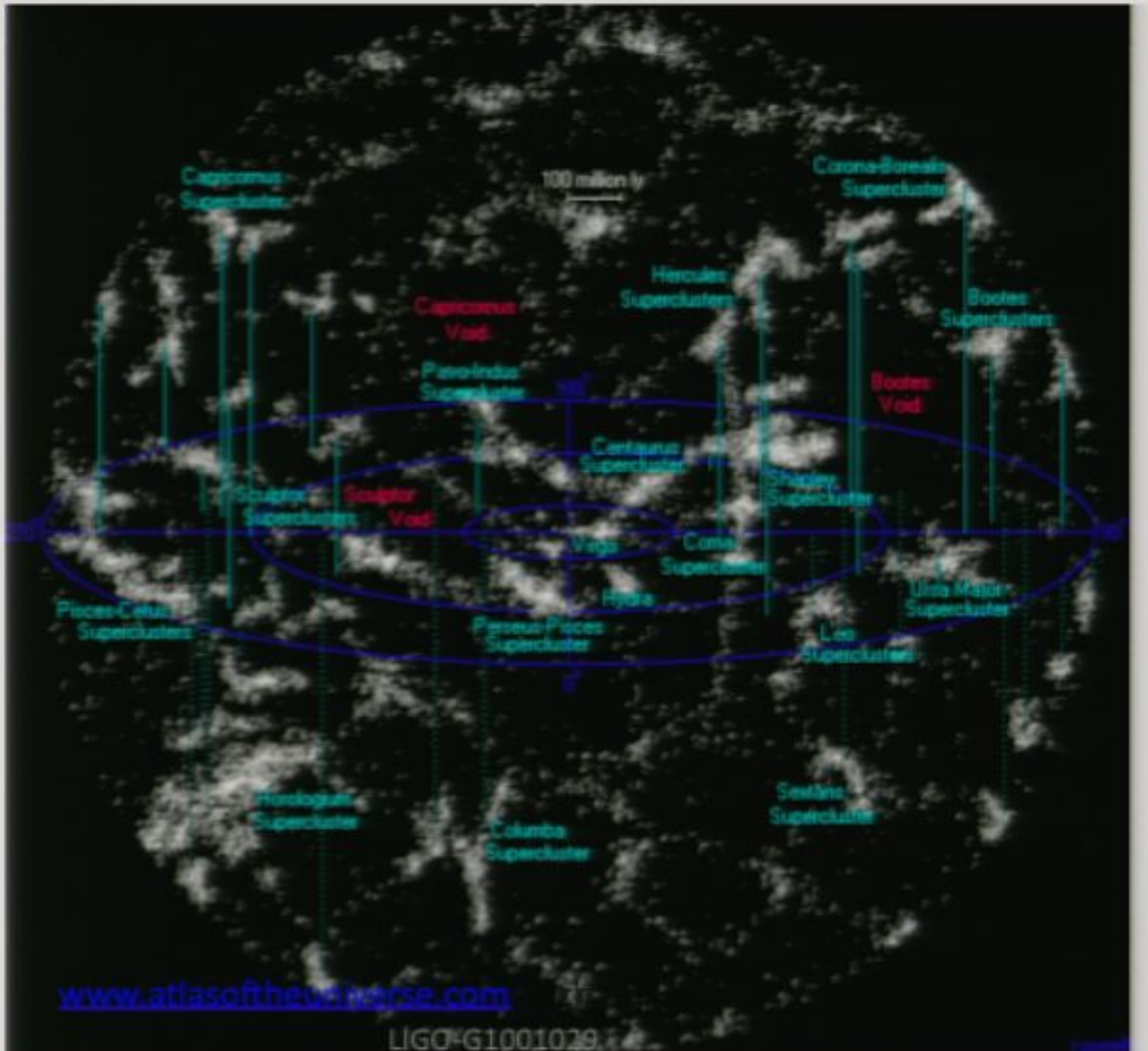

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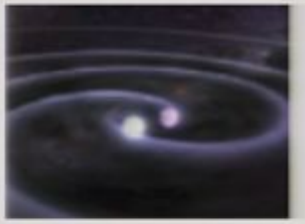

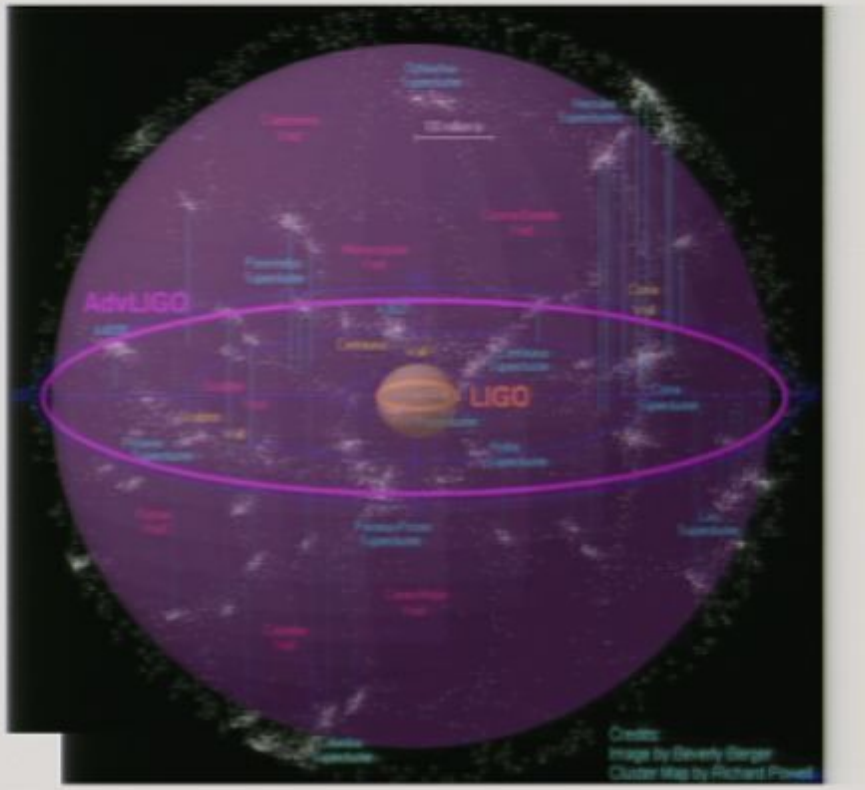

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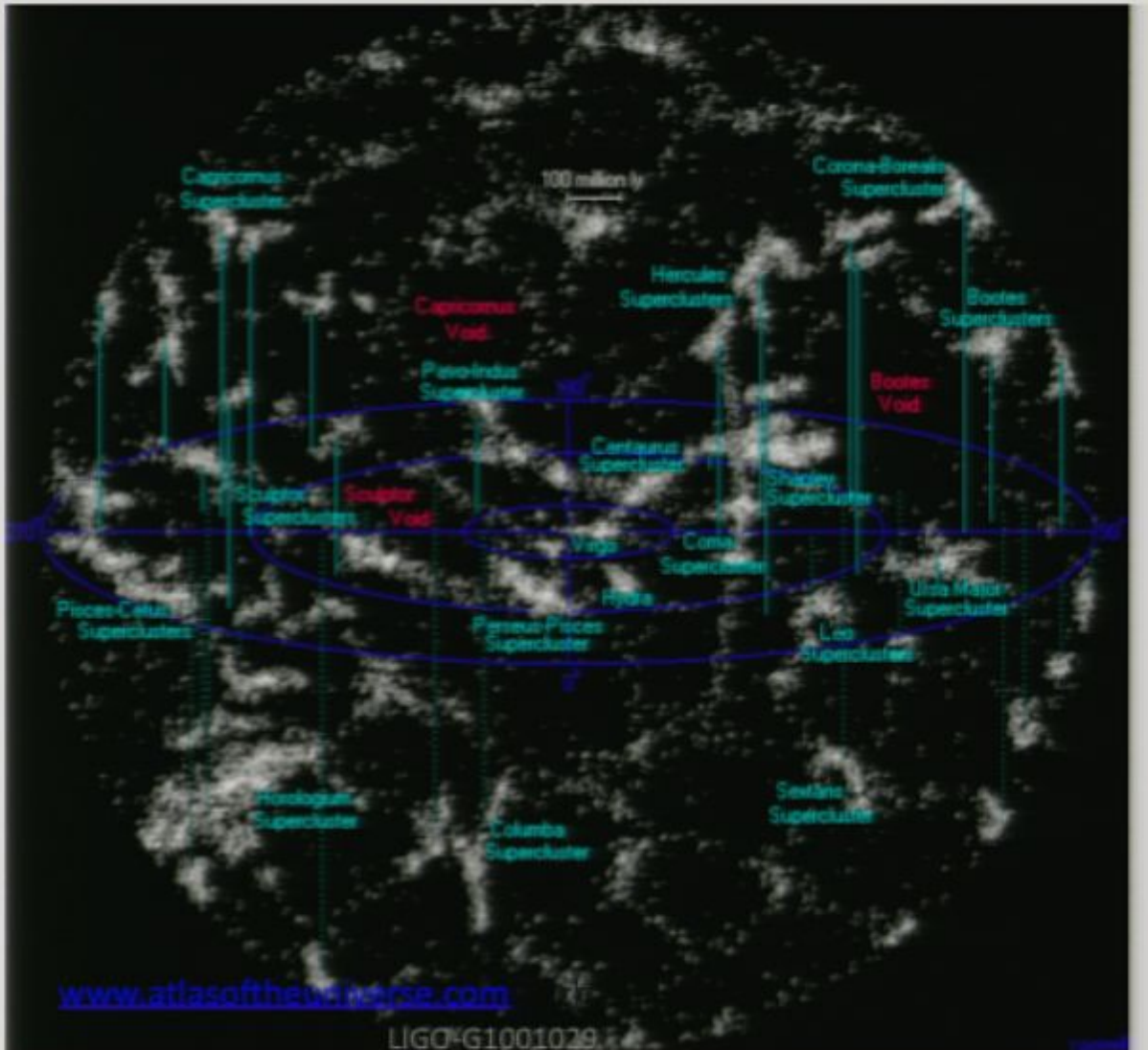

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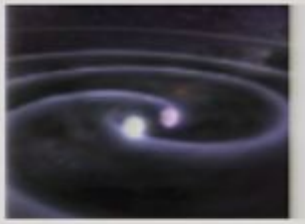

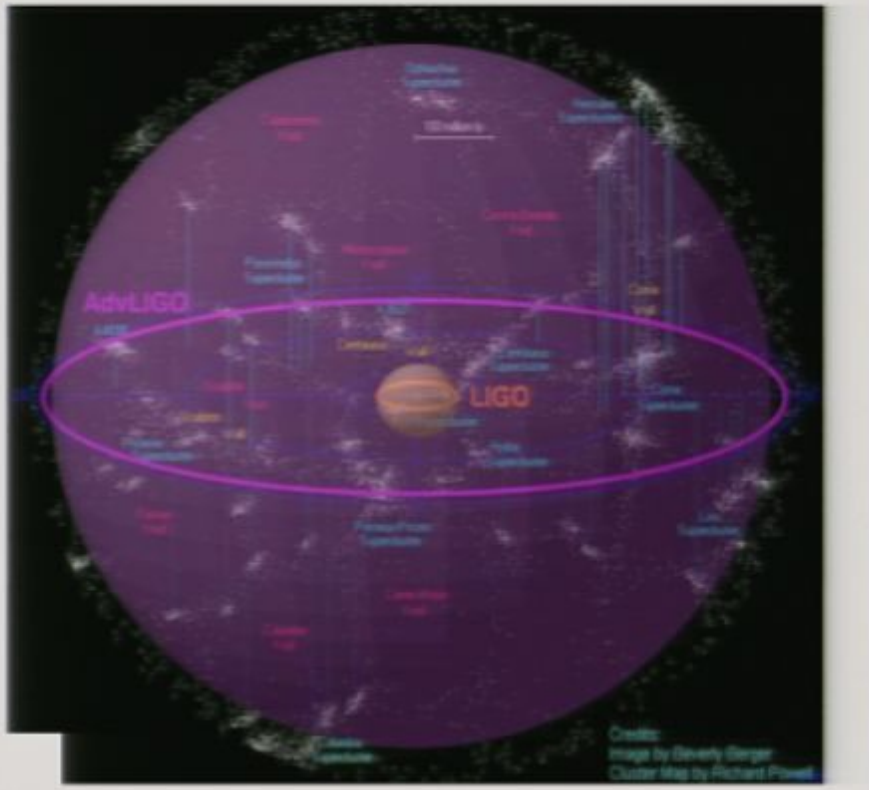

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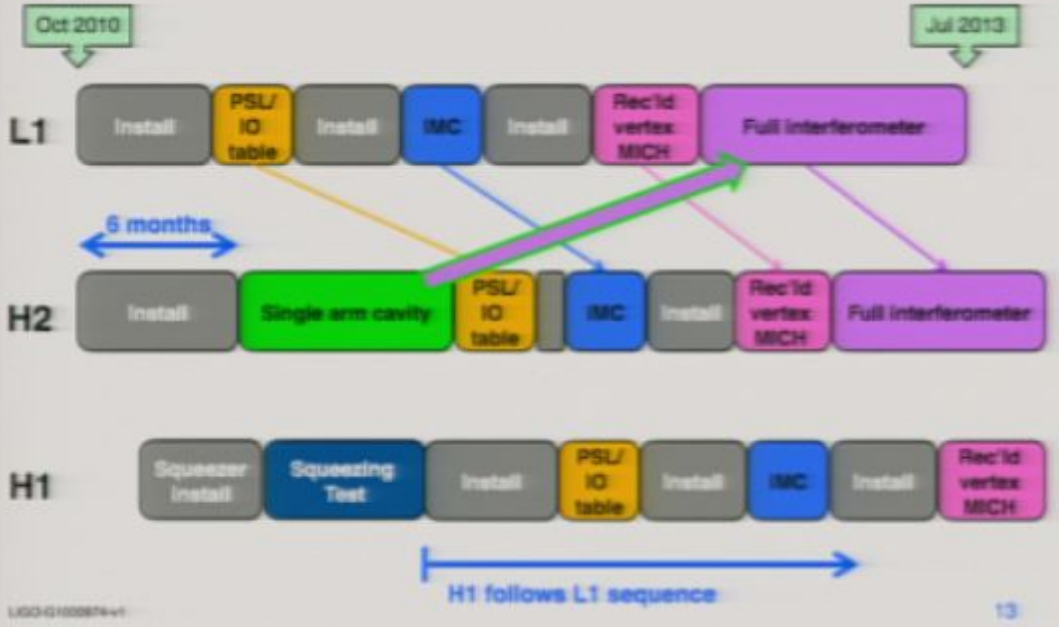
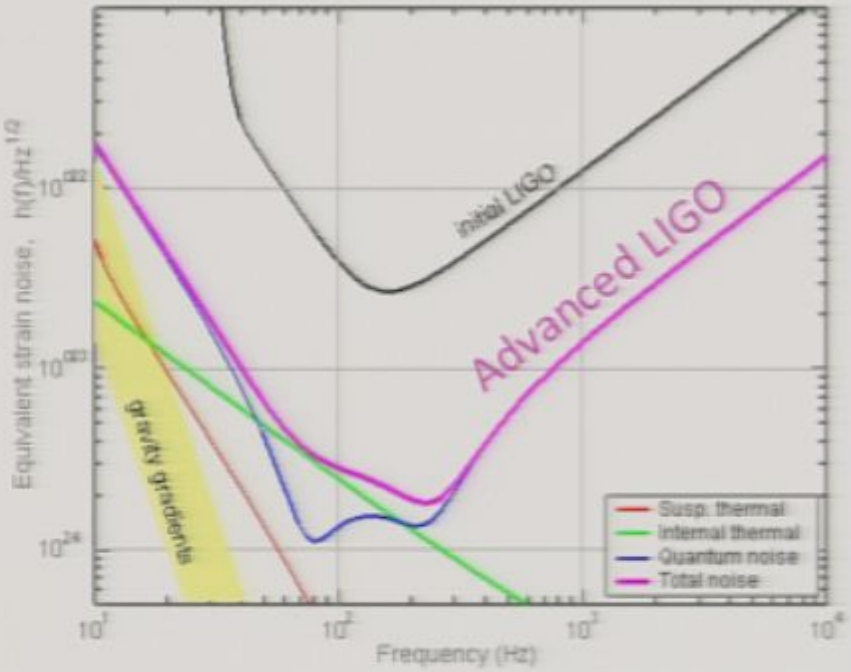
Advanced LIGO schedule





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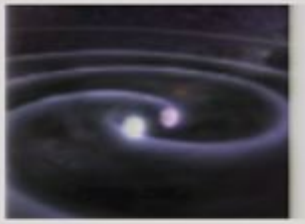

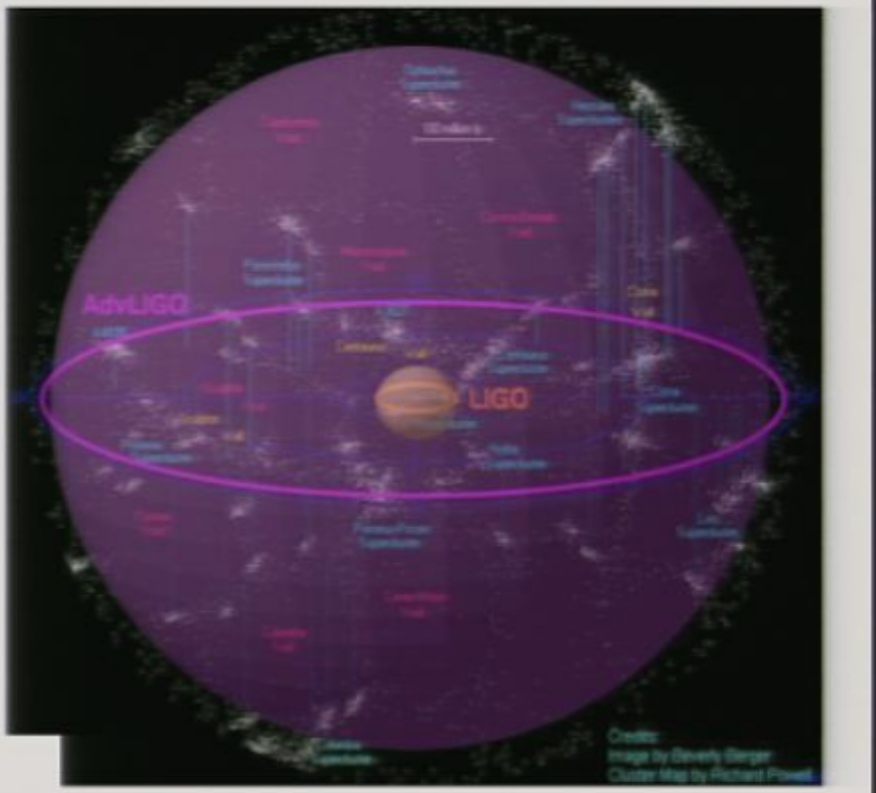

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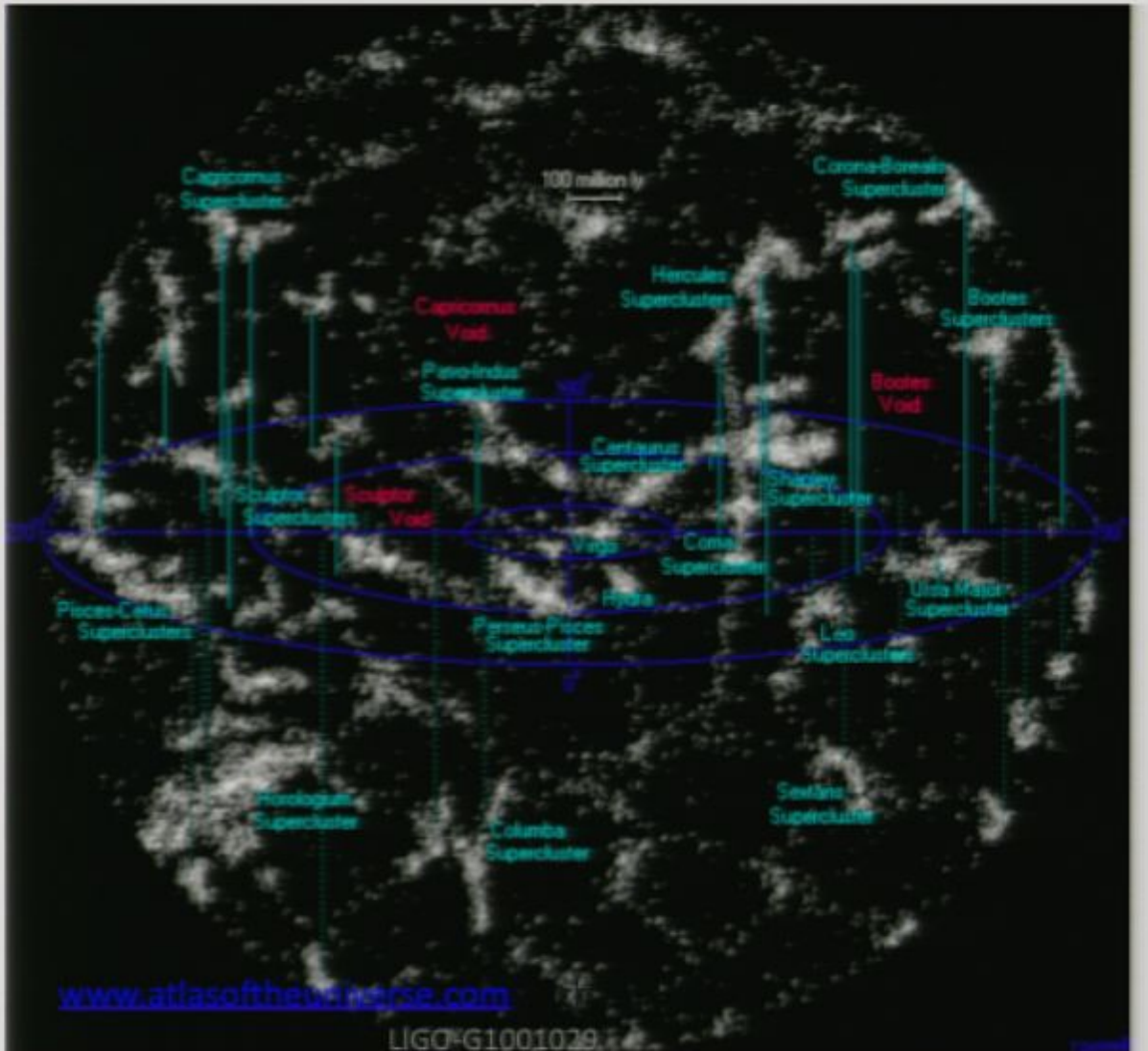

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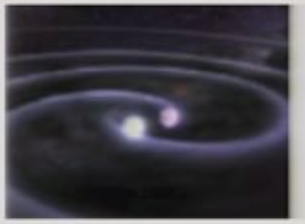

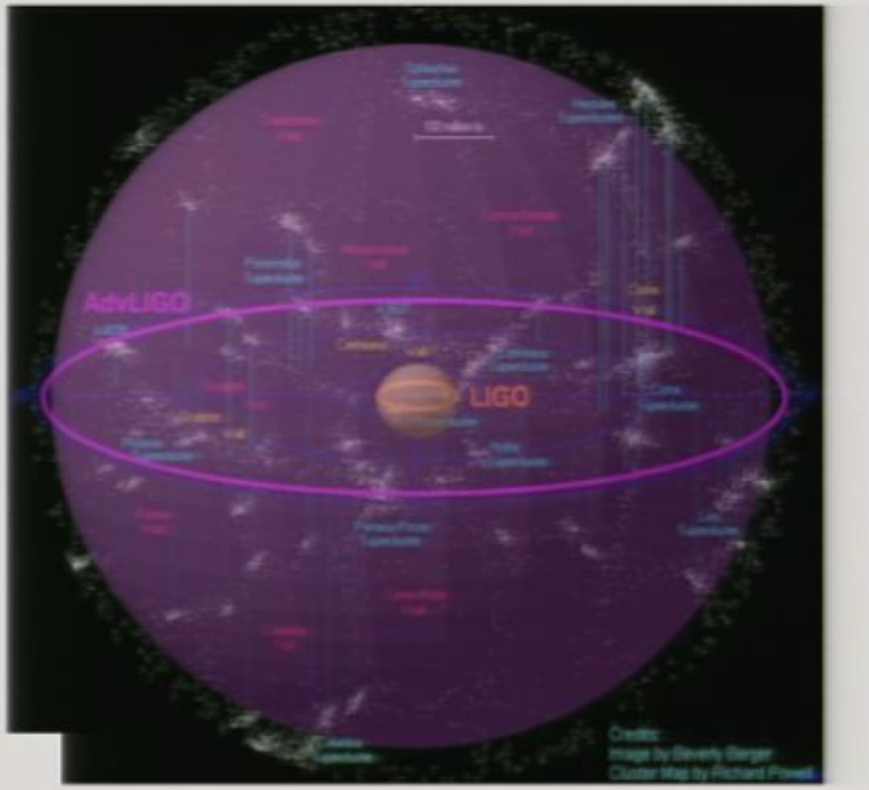

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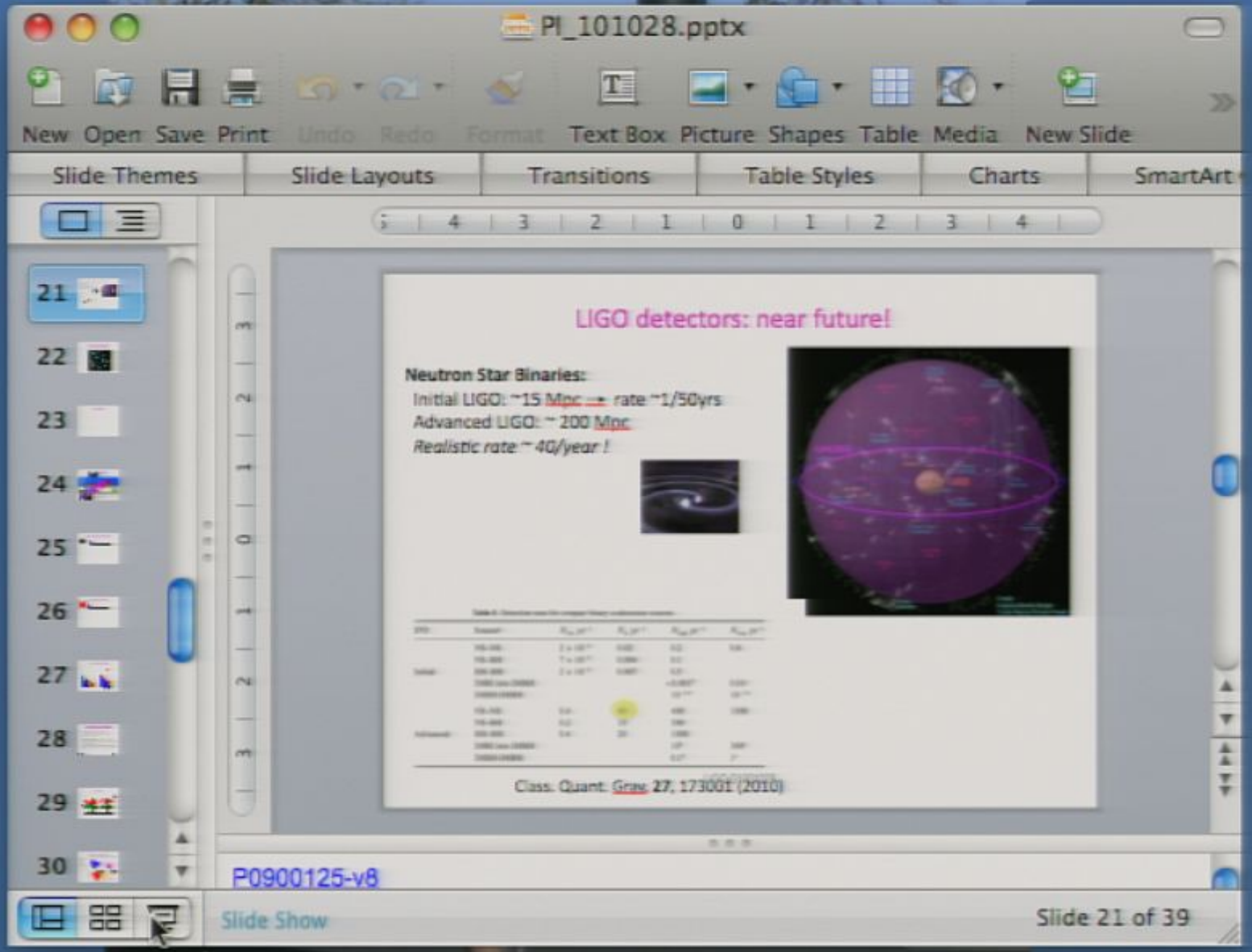
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