

LIGO, gravitational waves and me: a wonderful life in physics with more to come!



Gabriela González,
Louisiana State University
Jan 18, 2014



THE UNIVERSITY of
MISSISSIPPI

APS Conferences for
Undergraduate Women in Physics
(APS CUWiP)

Exploring Paths in Physics

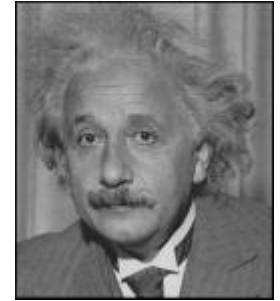


School and college in Argentina

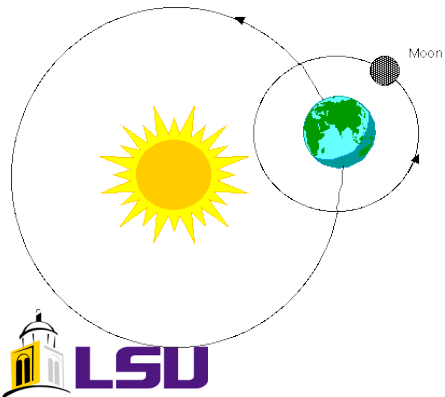
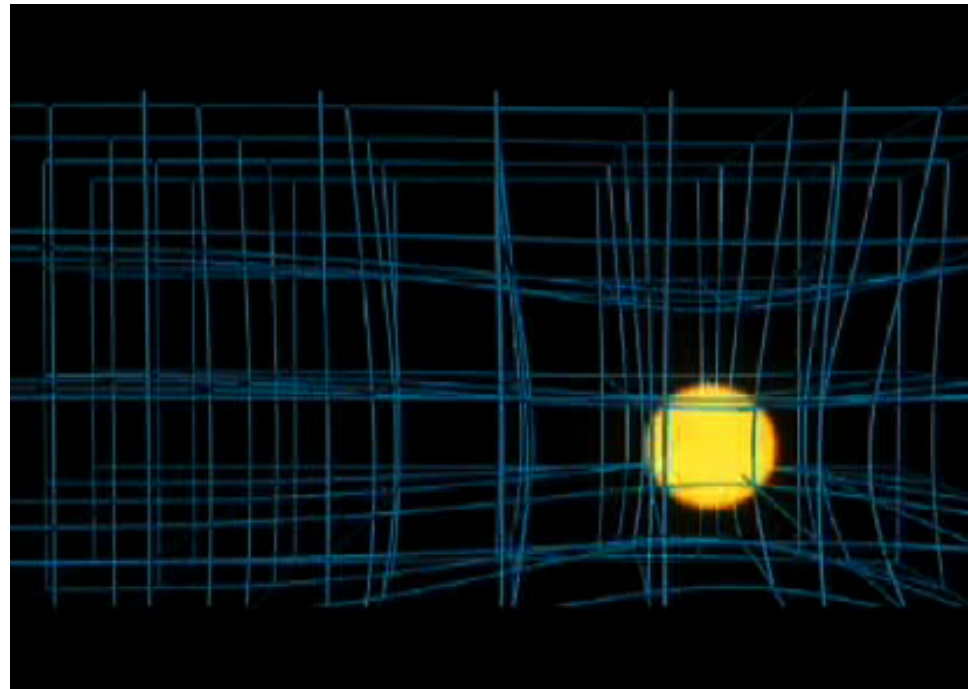


Einstein's gravity

When masses move, they wrinkle the space time fabric, making other masses move...



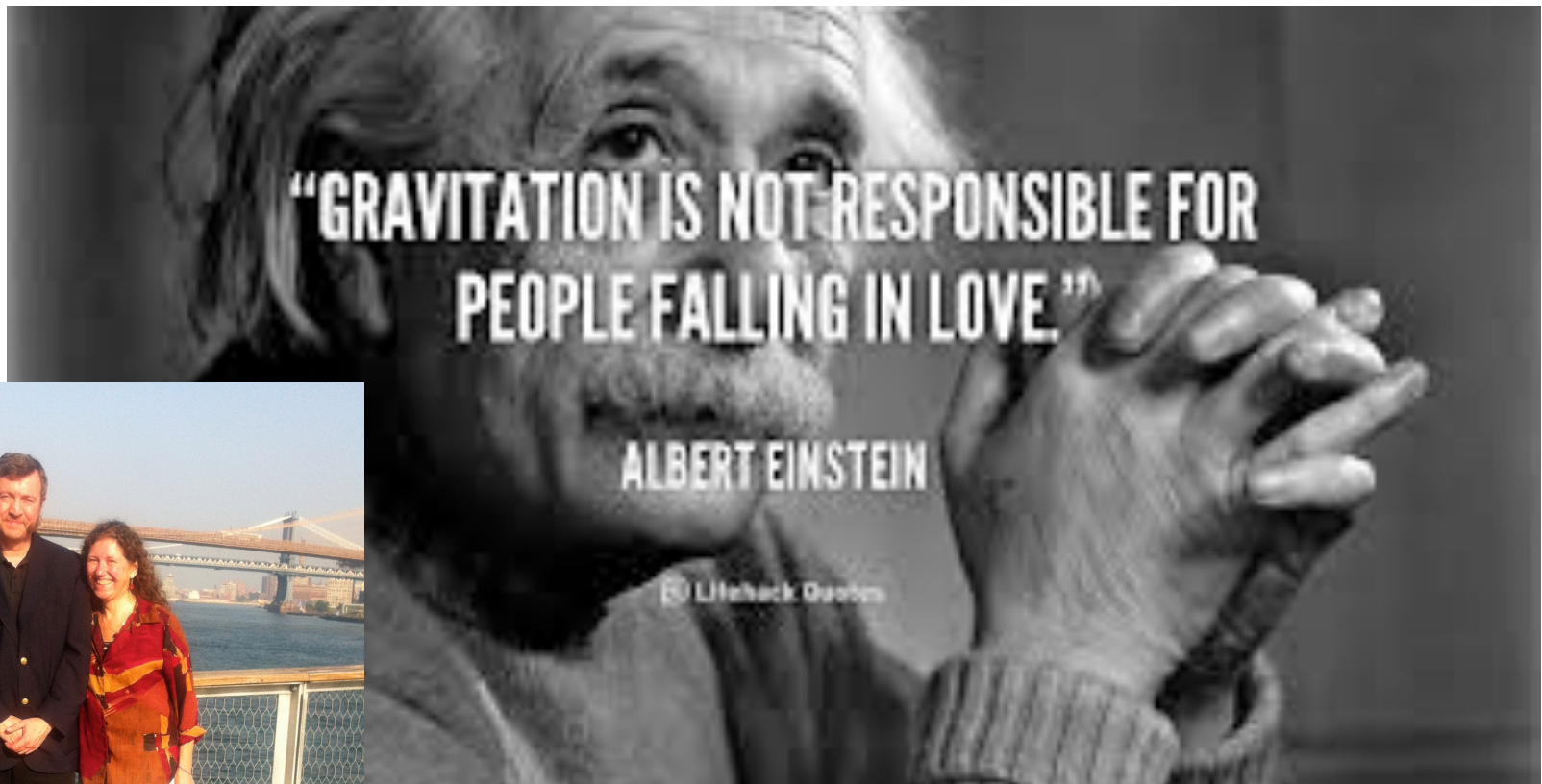
Explains just as well as Newton's why things fall and planetary motion...



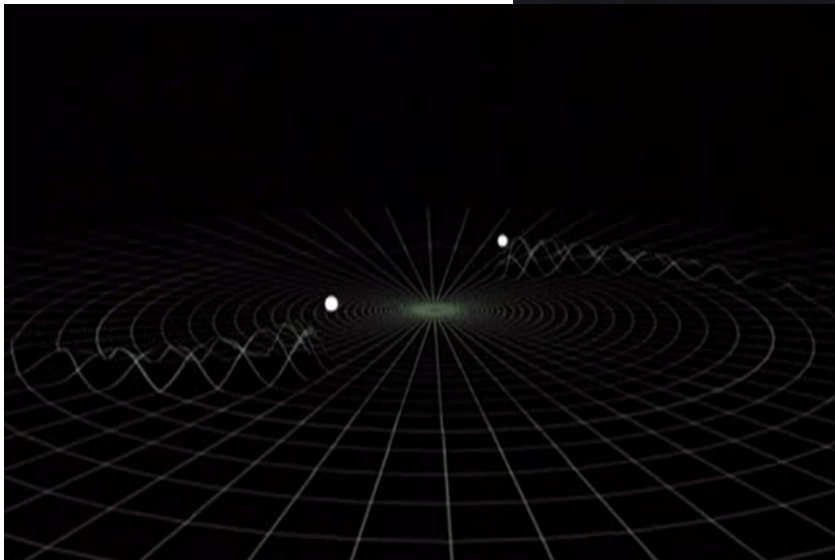
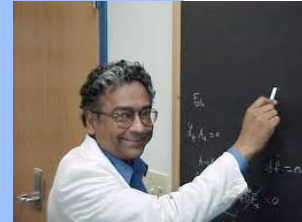
sciencebulletins.amnh.org



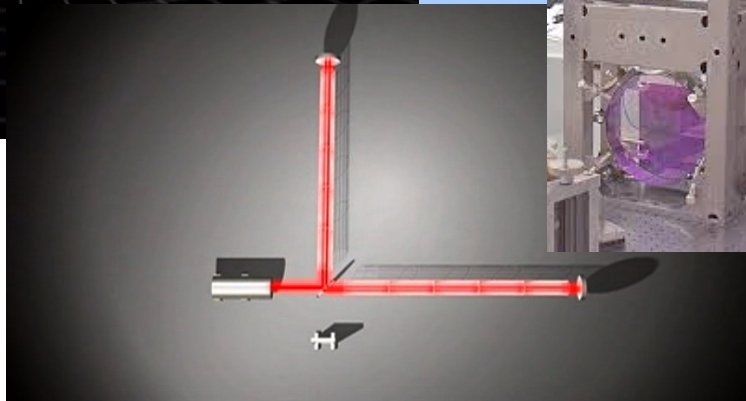
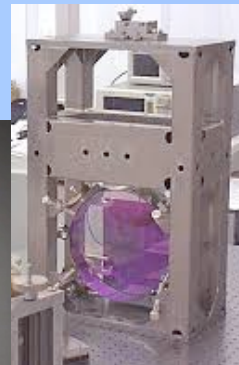
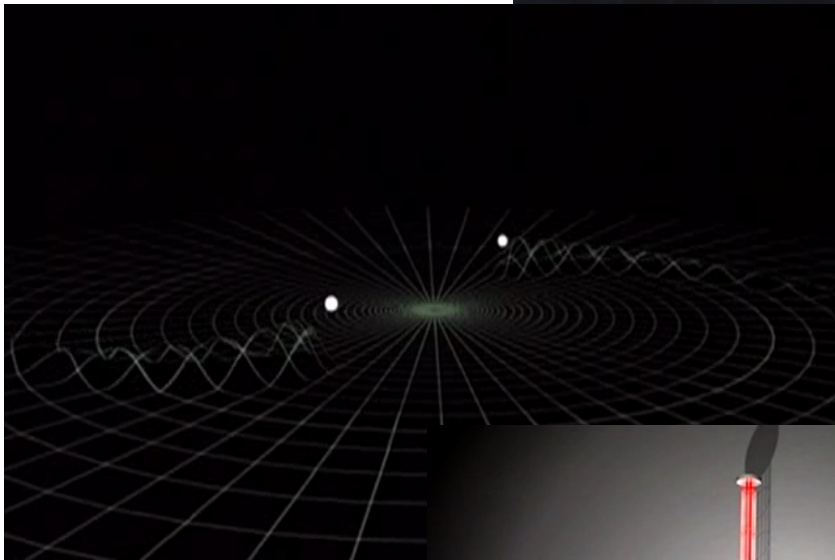
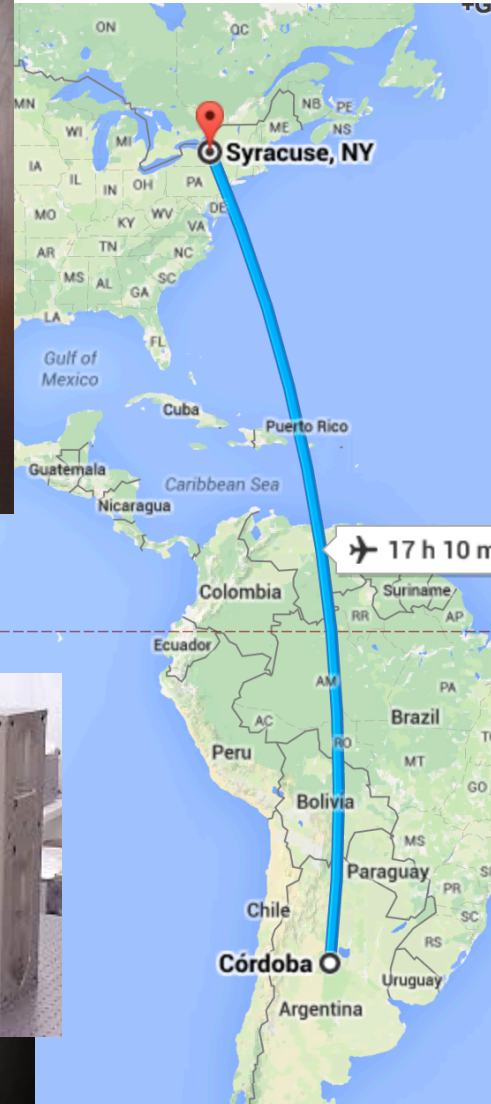
Proving Einstein wrong...



Moving to US, PhD, LIGO



Moving to US, PhD, LIGO



LIGO Observatories

LIGO Livingston, circa 1995



Welcome
to the
Inauguration
of the
National Science Foundation's
LIGO Facilities
held at
LIGO Livingston Observatory
Friday, Nov 12, 1999



LIGO Hanford, WA



LIGO Livingston, LA

From stars living in galaxies...



**Where do gravitational
waves come from?**

From stars living in galaxies...



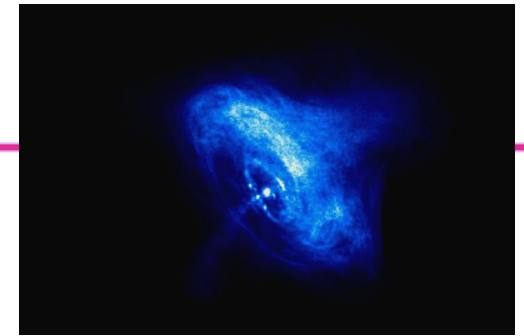
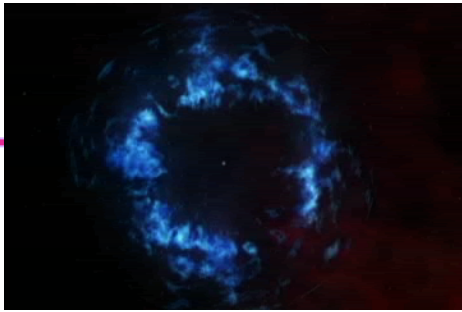
Supernova explosions
(that form a BH or a NS)



**Where do gravitational
waves come from?**



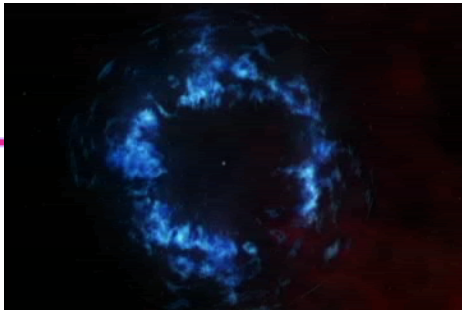
From stars living in galaxies...



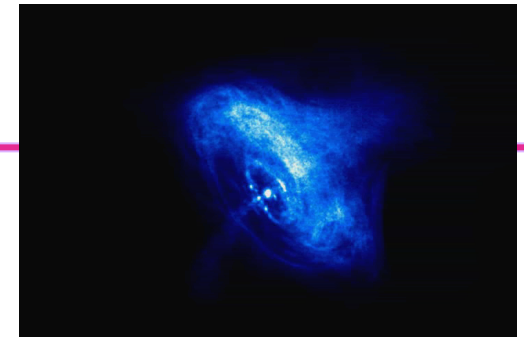
Rotating stars (pulsars)

Where do gravitational waves come from?

From stars living in galaxies...

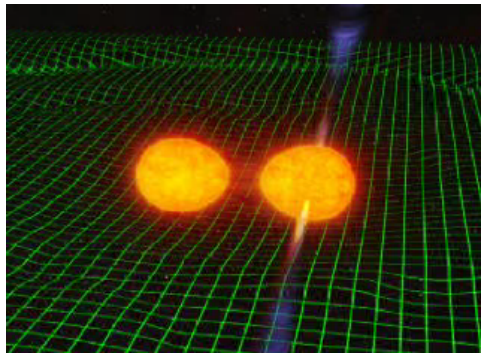


Supernova explosions



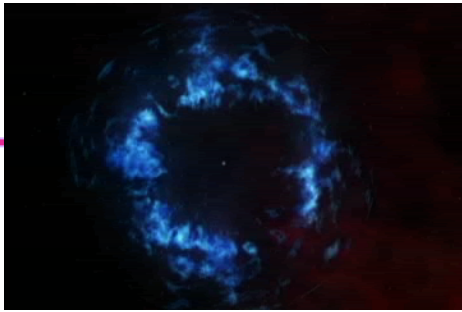
Rotating stars (pulsars)

Where do gravitational waves come from?

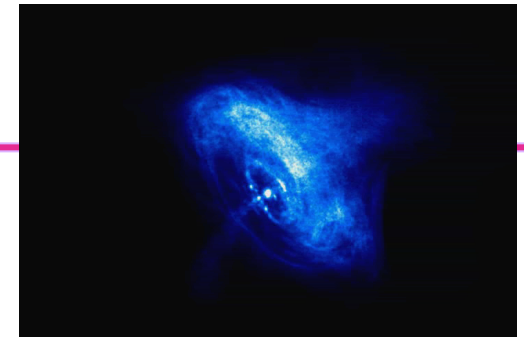


Binary systems coalescing into a black hole

From stars living in galaxies...



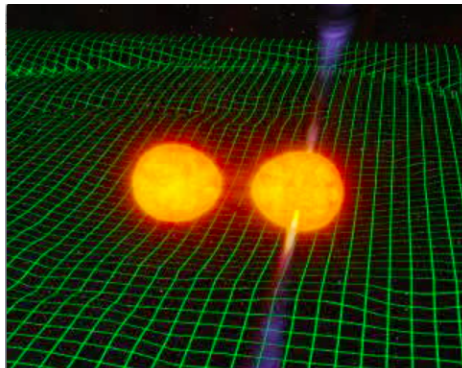
Supernova explosions



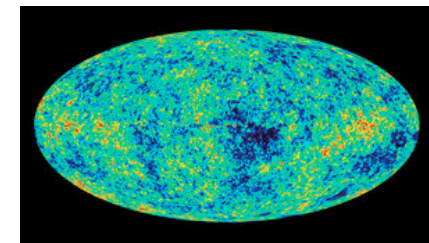
Rotating stars (pulsars)

Where do gravitational waves come from?

..and from the beginning of the Universe!

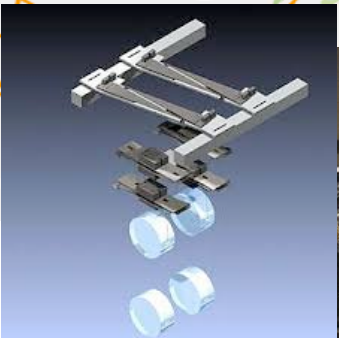
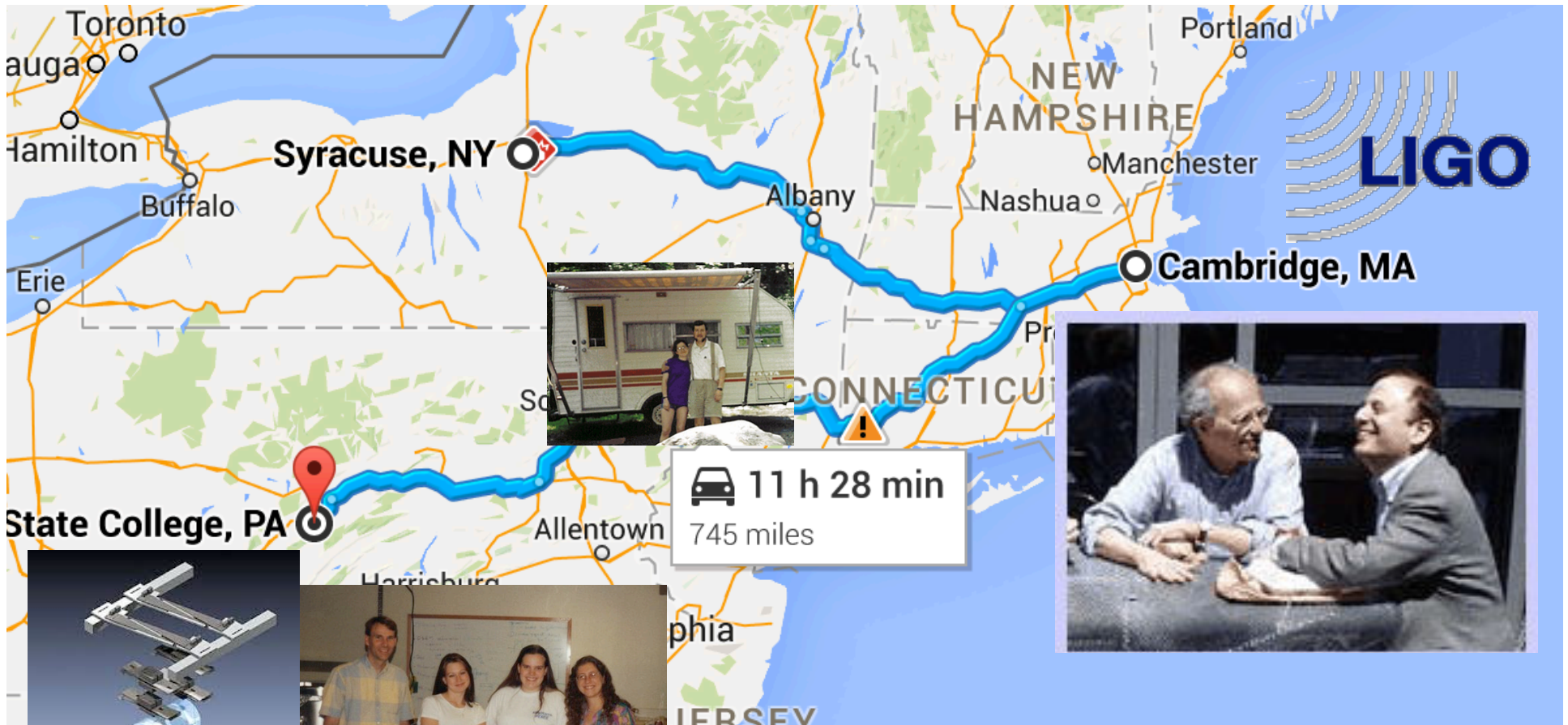


Binary systems coalescing into a black hole

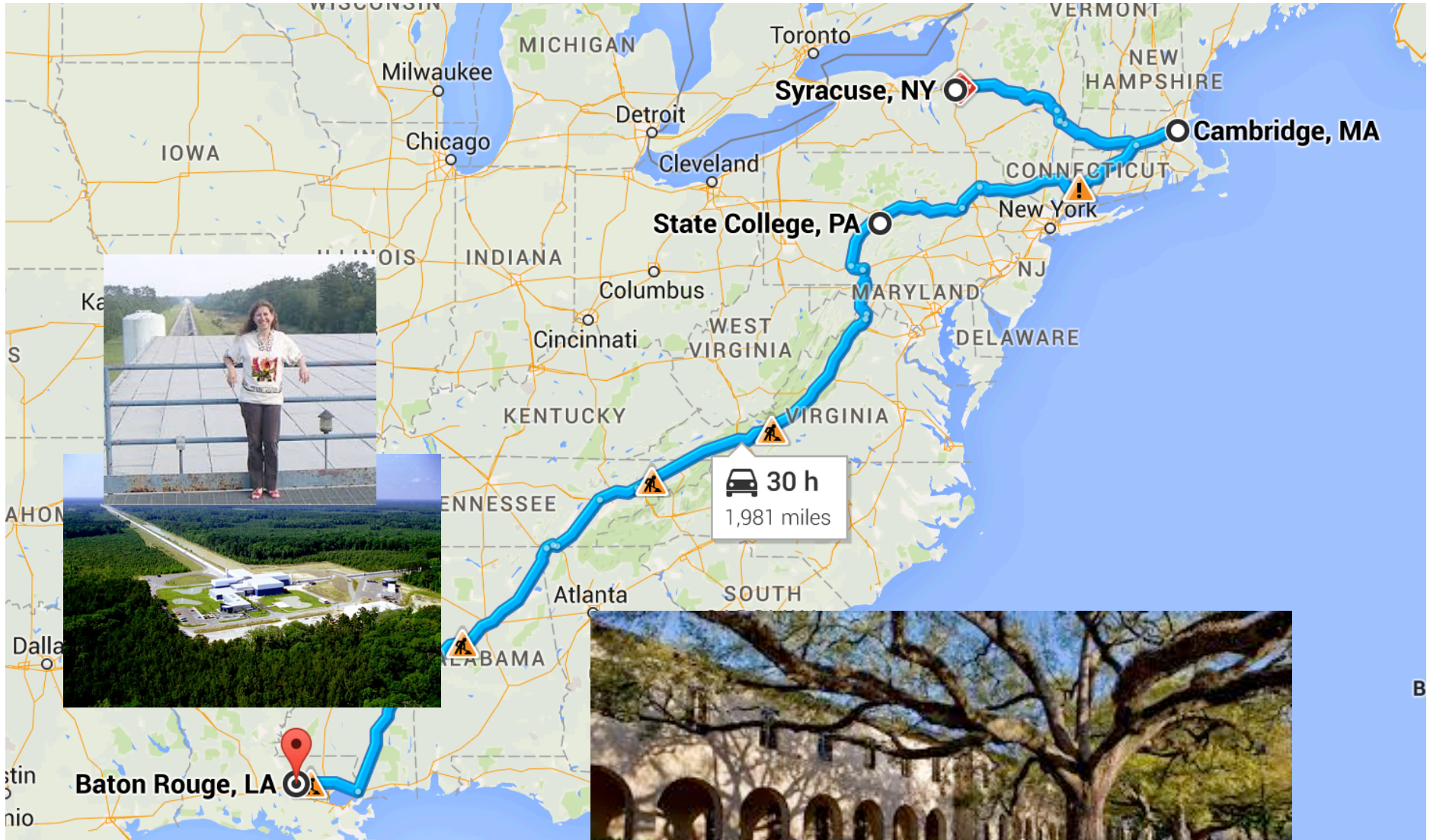


Credit: NASA/WMAP

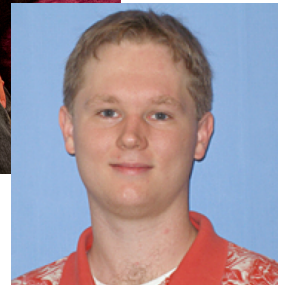
Moving around



Our home since 2001



Students, postdocs, friends



Gravitational

Astrophysical sources are the
For LIGO most likely source
coalescence which has known

$$h_0 = \frac{4}{r} \left(\frac{GM_c}{c^2} \right)$$

$$\tau = 9.829 \times 10^6 \text{yrs} \left(\frac{T_0}{1\text{hr}} \right)^{8/3} \left(\frac{M_\odot}{m_1 + m_2} \right)^{2/3} \left(\frac{M_\odot}{\mu} \right)$$

$$f_{\text{GW}} = 134\text{Hz} \left(\frac{1.21 M_\odot}{M_c} \right)^{5/8} \left(\frac{1\text{s}}{r} \right)^{3/8}$$

Time	Long Duration		Short
Waveform	Known	Unknown	Known
Signal Character	Continuous	Stochastic	Inspirals
Example	Pulsar	Big Bang	NS-NS
Distance	galactic	-	extragalactic



The GW Detector Network~2020

Advanced LIGO
Hanford



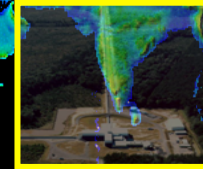
GEO600



Advanced
Virgo



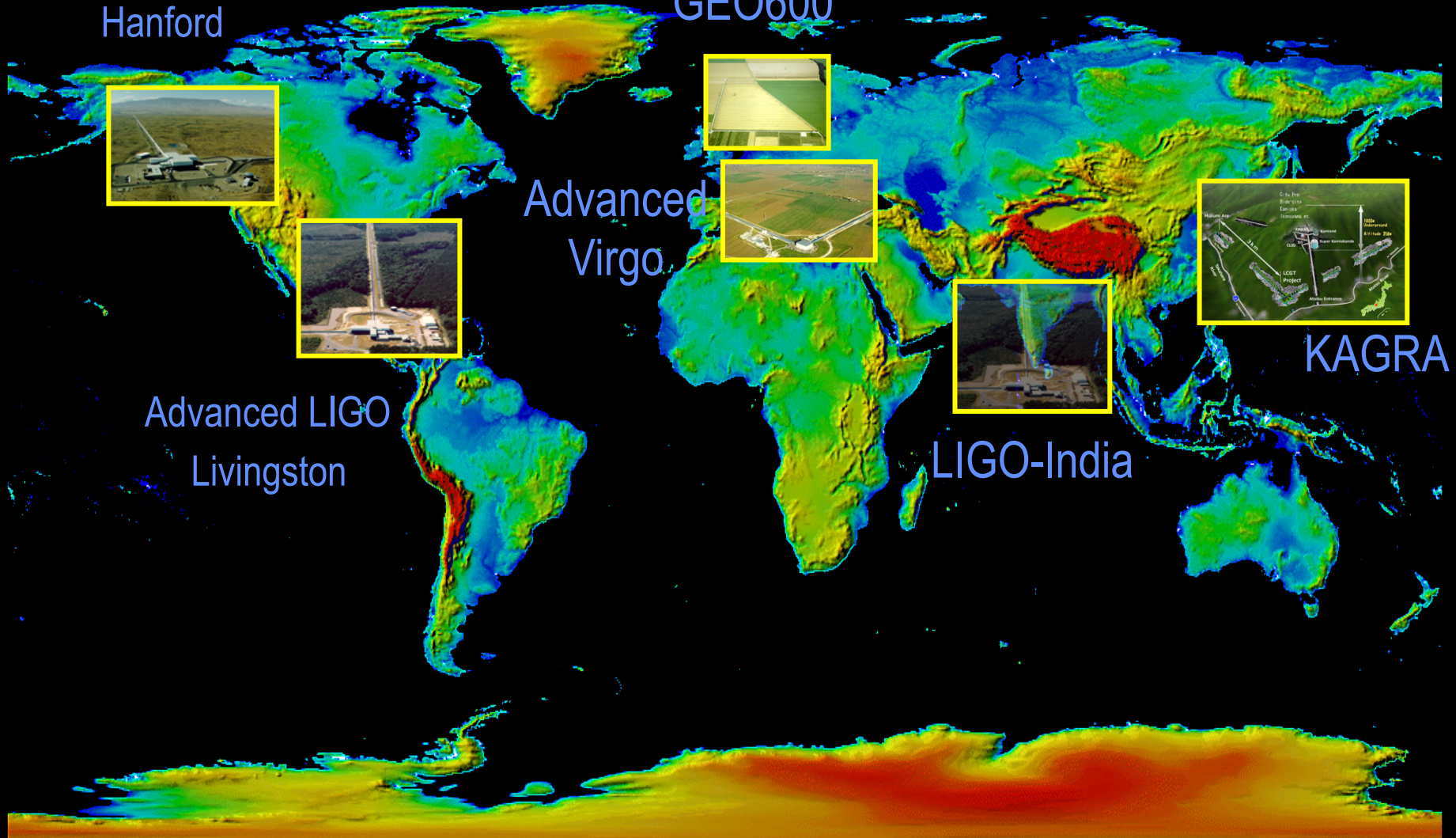
Advanced LIGO
Livingston



LIGO-India



KAGRA



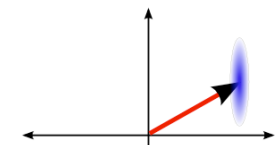
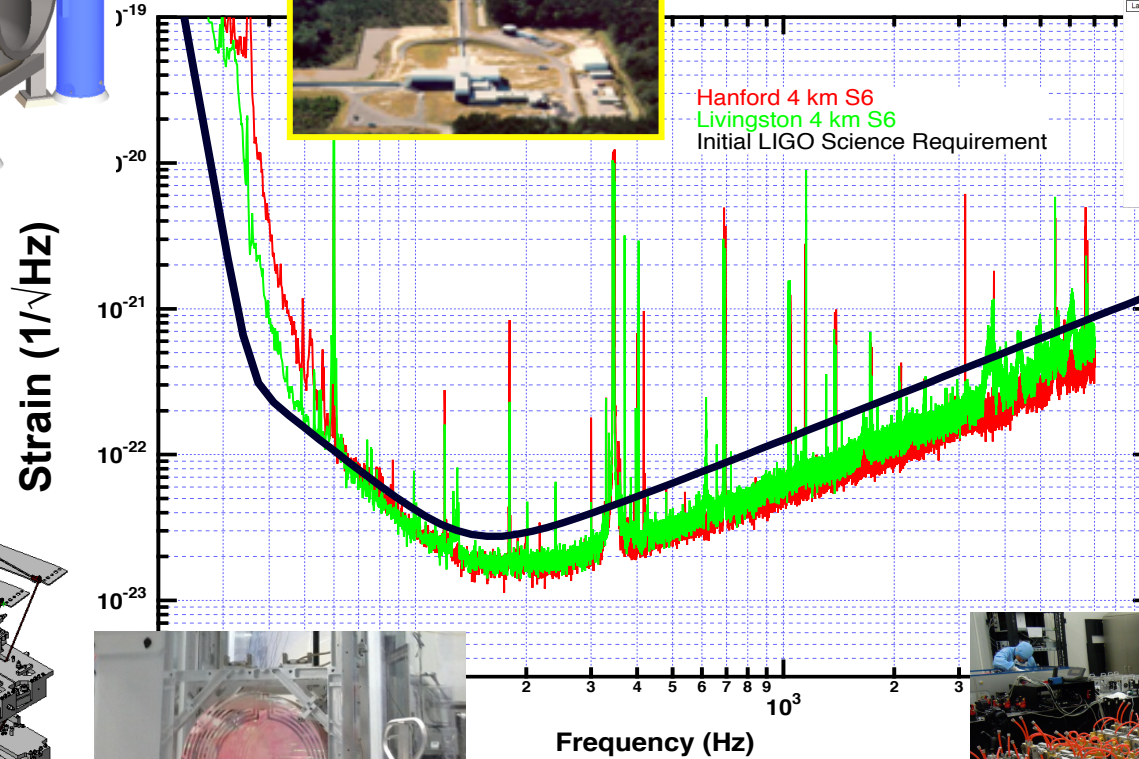
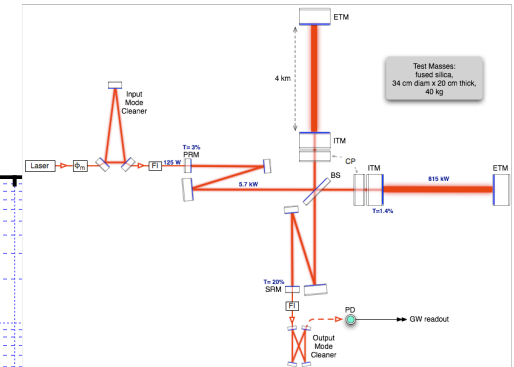
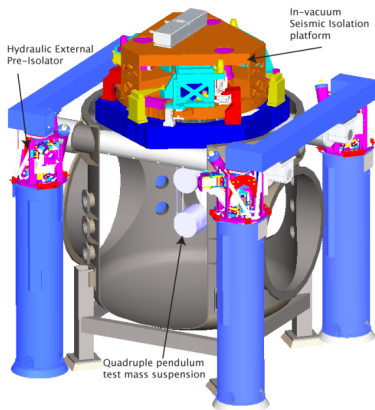
LIGO Scientific Collaboration

www.ligo.org

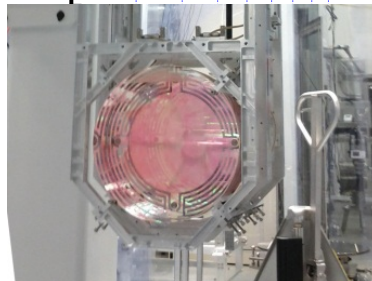
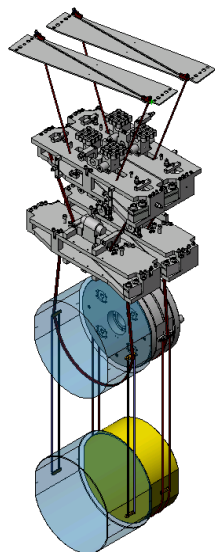
- 900+ members, 85+ institutions, 16 countries



LIGO Detectors Technology

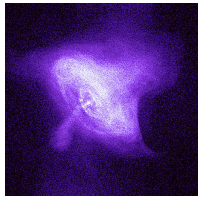


See K. Dooley's talk 3:45pm

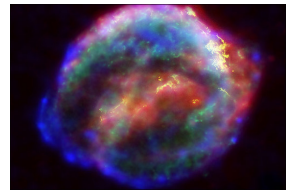
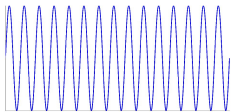


LIGO-T1400316 (dcc.ligo.org).

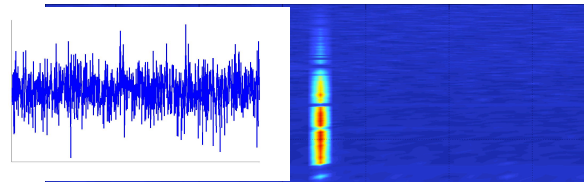
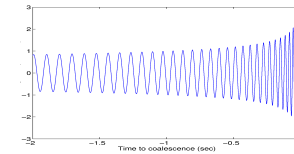
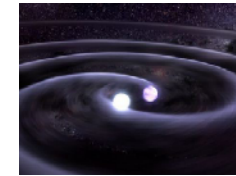
LIGO Data Analysis



Crab pulsar (NASA, Chandra Observatory)

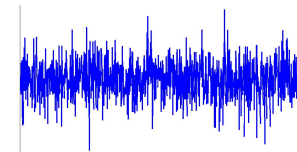
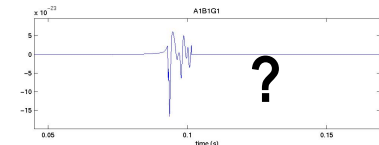
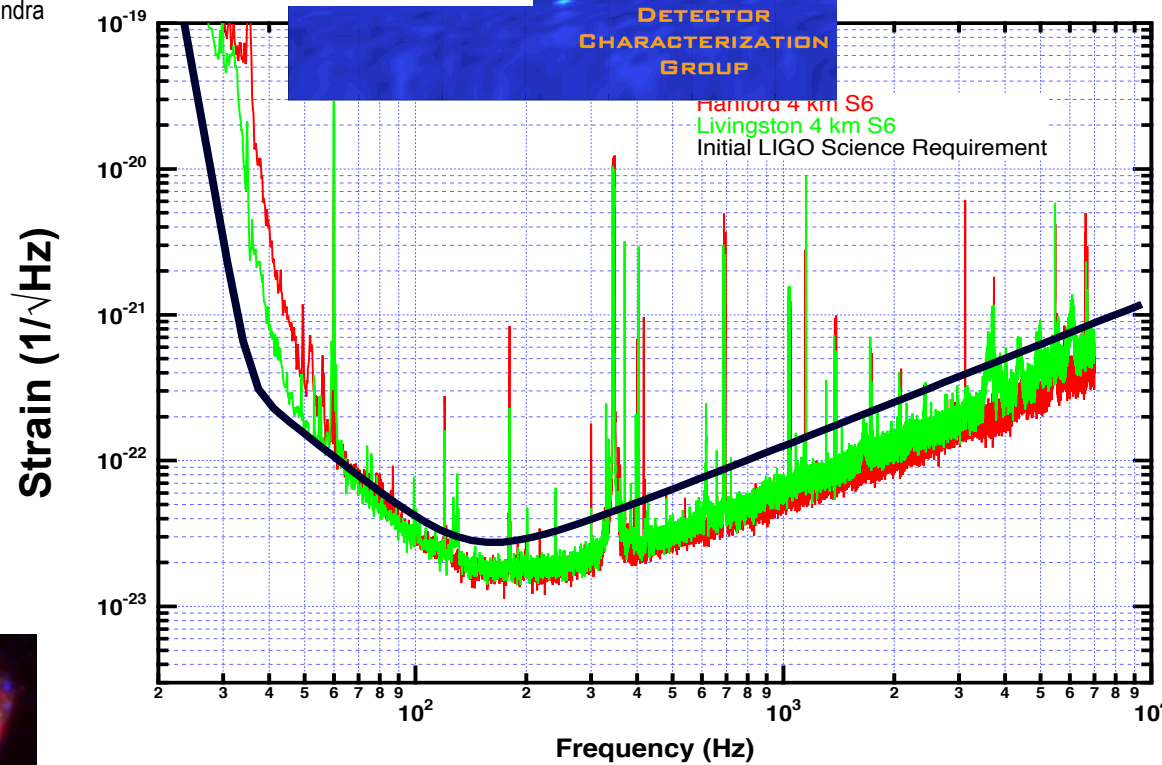


NASA, WMAP



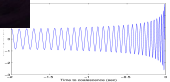
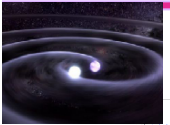
DETECTOR CHARACTERIZATION GROUP

Hanford 4 km S6
Livingston 4 km S6
Initial LIGO Science Requirement



LIGO-T1400054 (dcc.ligo.org).

Some interesting results 2005-2011



[Astrophys. J. 681 \(2008\) 1419](#)

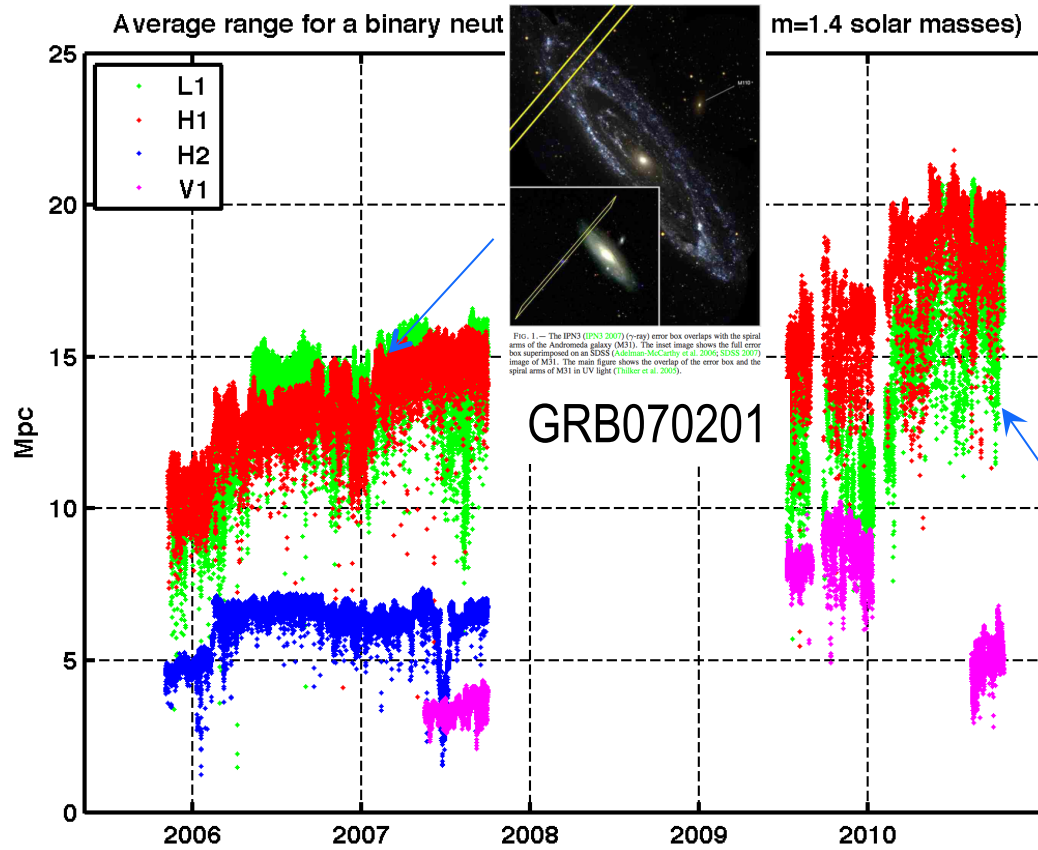
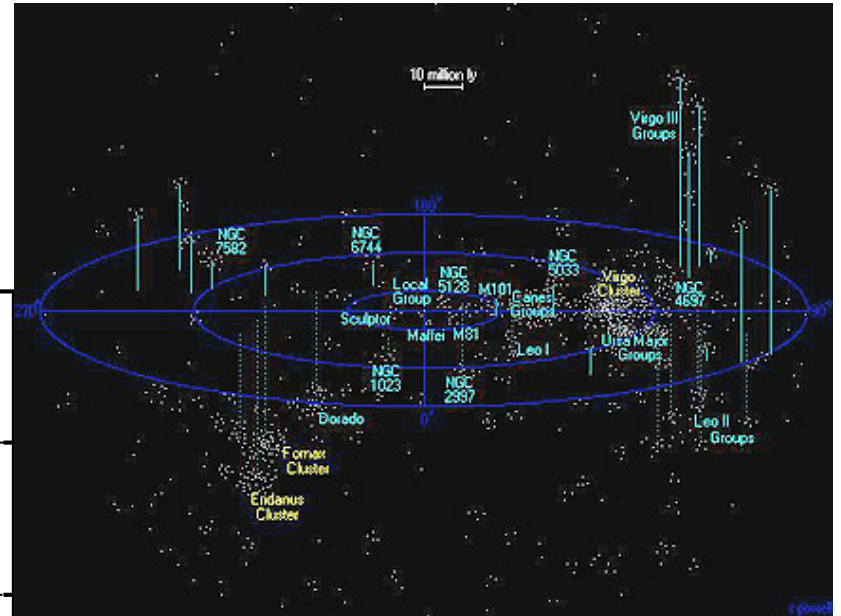


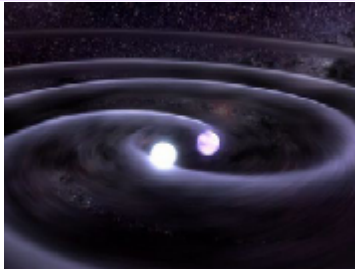
FIG. 1 — The IPNS (PNS 2007) error box overlaps with the spiral arm of the Andromeda galaxy (M31). The inset image shows the full error box superimposed on an SDSS (Chabouni-McCarthy et al. 2006; SDSS 2007) image of M31. The main figure shows the overlap of the error box and the spiral arm of M31 in UV light (Thirier et al. 2009).



GW100916

[Phys. Rev D85 \(2012\) 082002](#)

What will Advanced LIGO see ?



Neutron Star Binaries:

Initial LIGO:

Average BNS reach ~ 15 Mpc \rightarrow
rate $\sim 1/50$ yrs

Advanced LIGO: ~ 200 Mpc

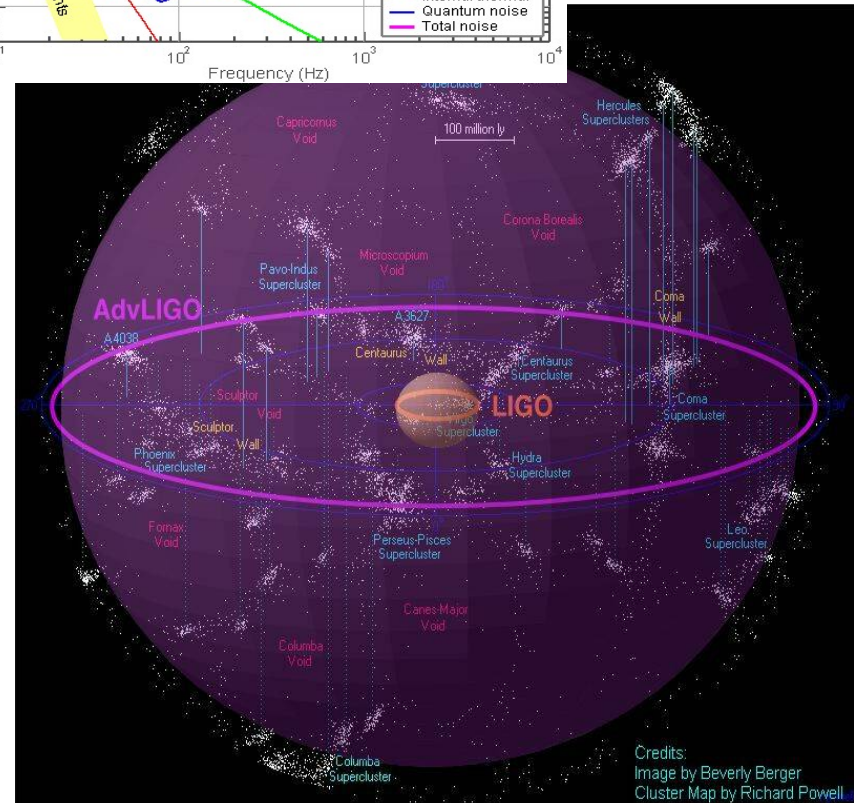
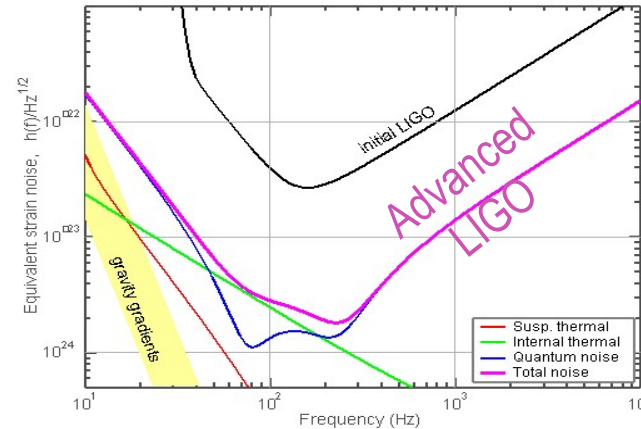
“Realistic rate” ~ 40 /year (but can be 0.4
or 400)

Other binary systems:

NS-BH: 0.004/yr \rightarrow 10/yr

BH-BH: 0.007/yr \rightarrow 20/yr

Class. Quant. Grav. **27**, 173001 (2010)



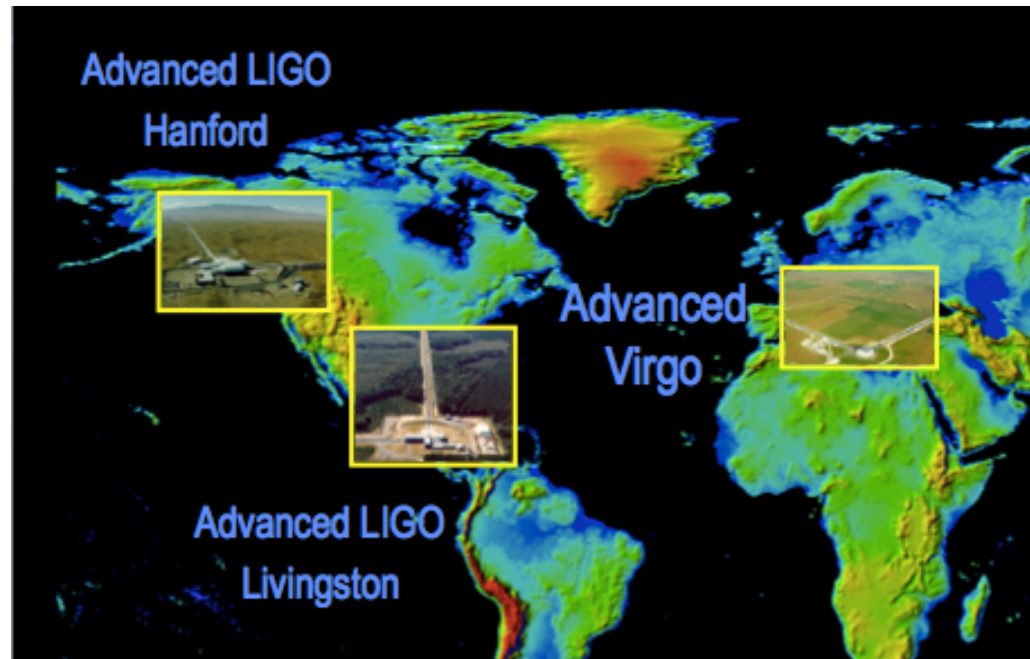
Credits:
Image by Beverly Berger
Cluster Map by Richard Powell

Are we there yet?

Soon!!!

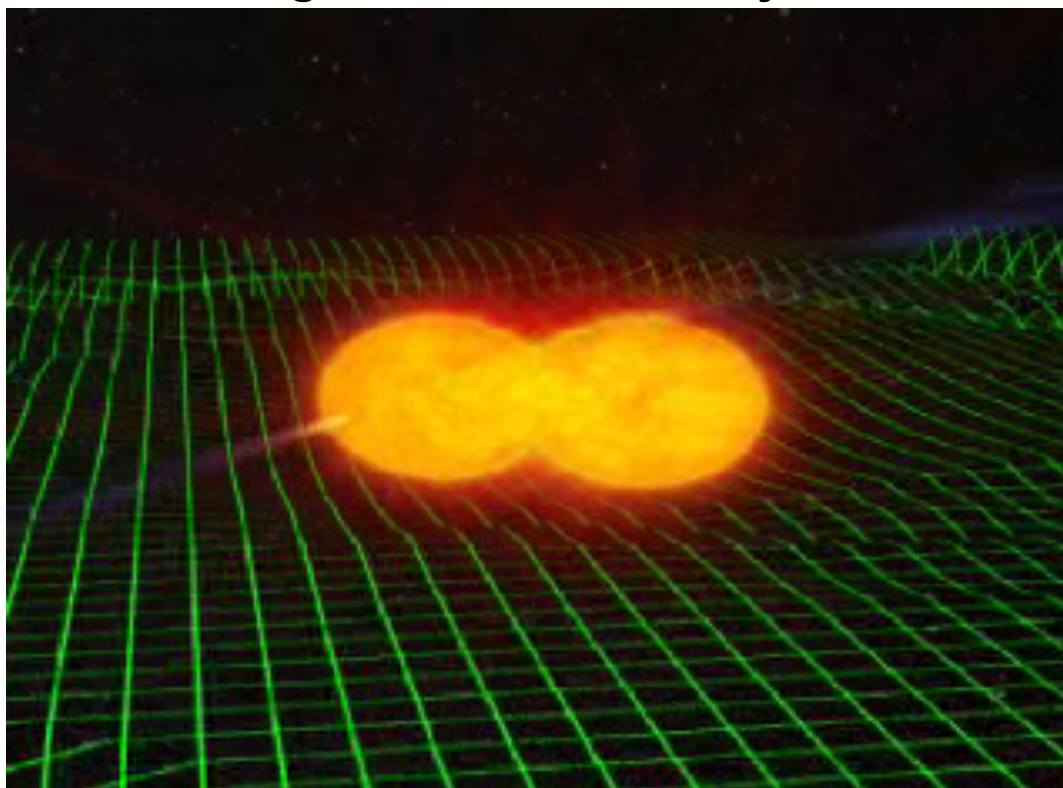
Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_{\odot} c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections
		LIGO	Virgo	LIGO	Virgo	
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200
2022+ (India)	(per year)	105	80	200	130	0.4 – 400

[arXiv:1304.0670](https://arxiv.org/abs/1304.0670)



Life in Physics is Fun

And there's a lot of gravitational waves excitement coming to a theater near you!



To learn more about LIGO : www.ligo.org

To ask me (any!) question: gonzalez@lsu.edu