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Whispers from the Cosmos: seeing the Universe in gravitational waves

Shane L. Larson
Utah State University

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Shane L. Larson
Department of Physics
Utah State University

s.larson@usu.edu

Utah State University

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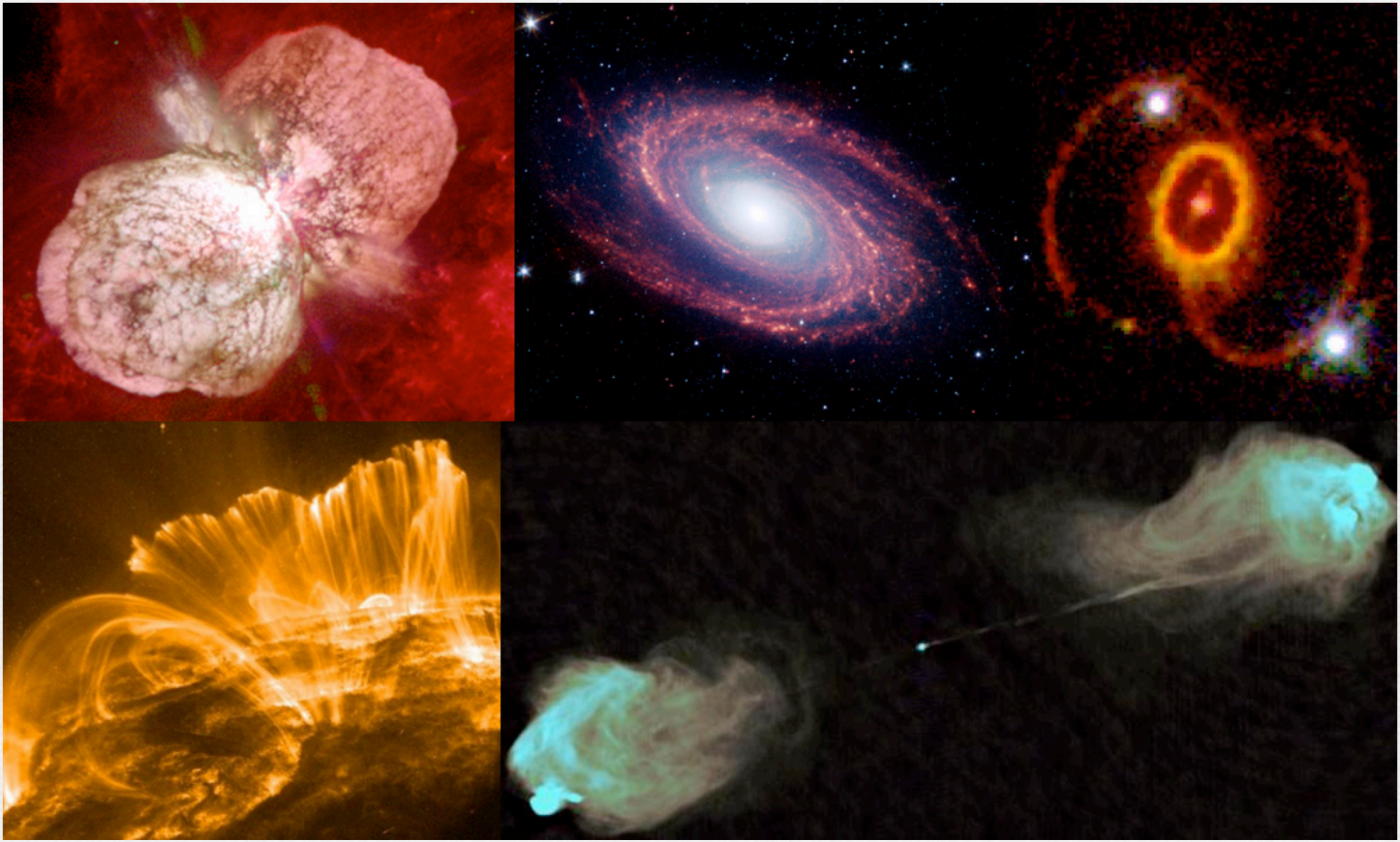
Storyline

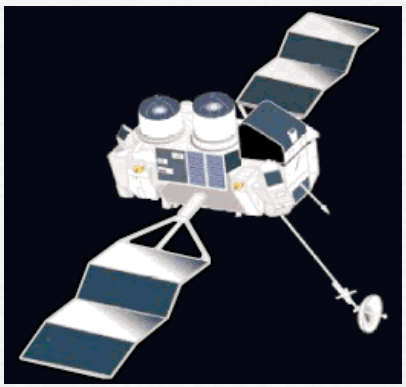
- Seeing the Universe
- Gravity, waves and observatories
- Songs of gravity
- Gravitational waves in your classrooms

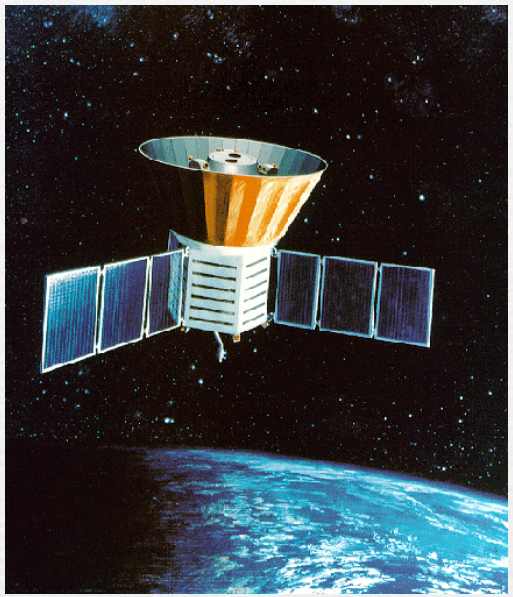
The Cosmos as we know it...



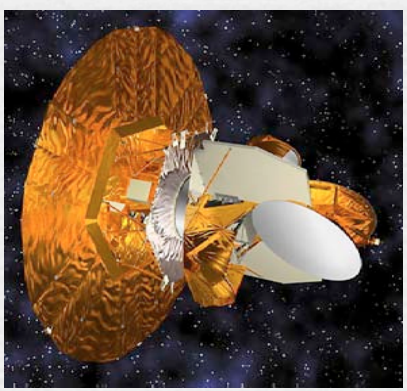
- LIGHT has been our messenger from the Universe.

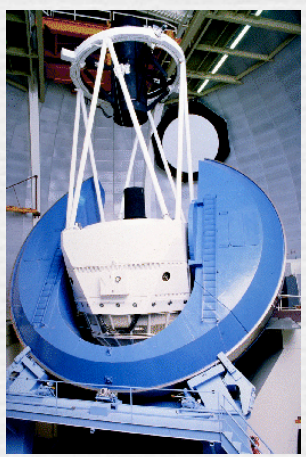
Our eyes







- Light has many forms (visible, infrared, radio, x-ray,...) and we have a myriad of instruments to detect it.

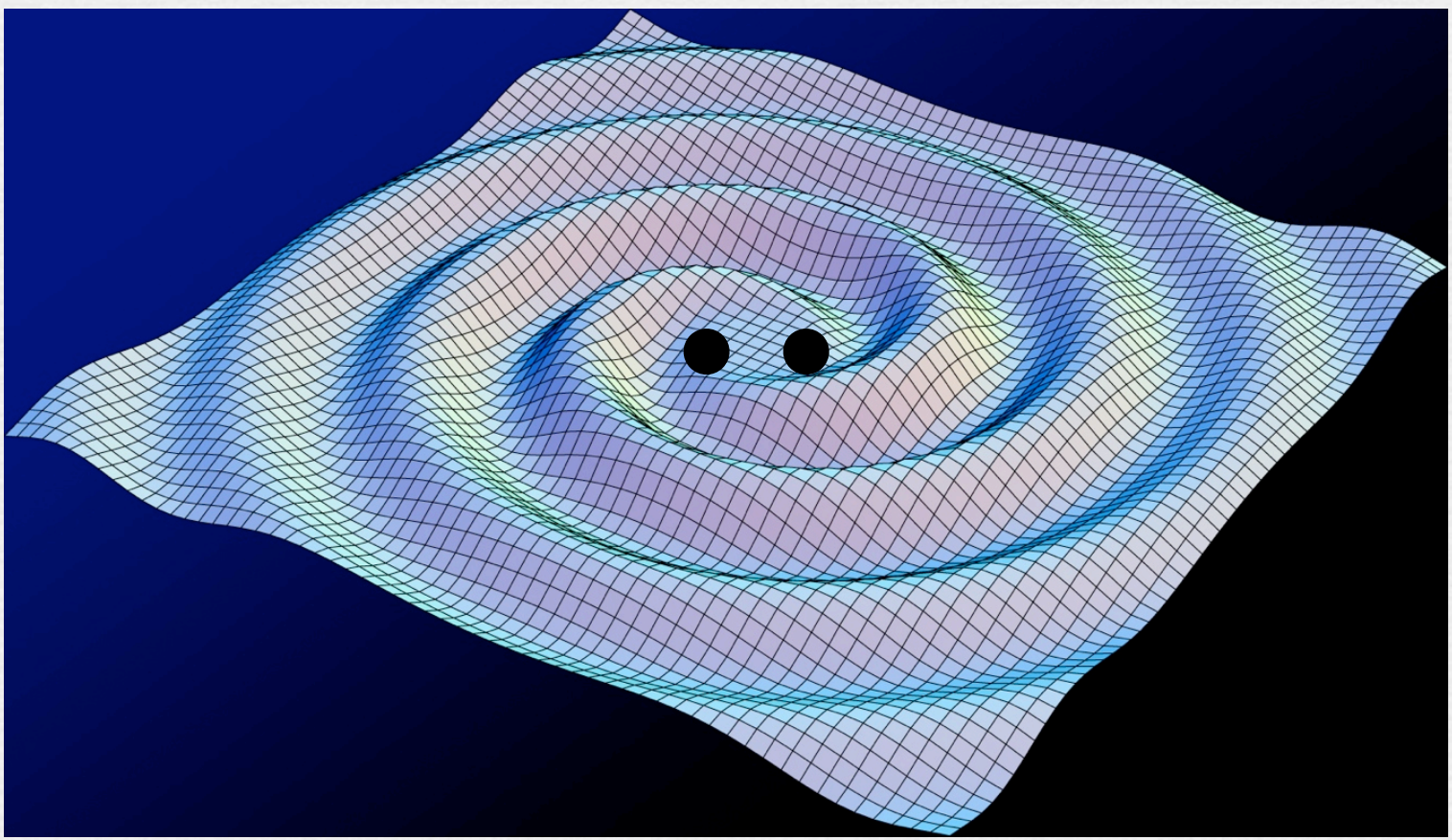
A NEW KIND OF ASTRONOMY

- Here at the start of the 21st Century we are looking at the Cosmos in a fundamentally new way
- Not with light, but with gravity

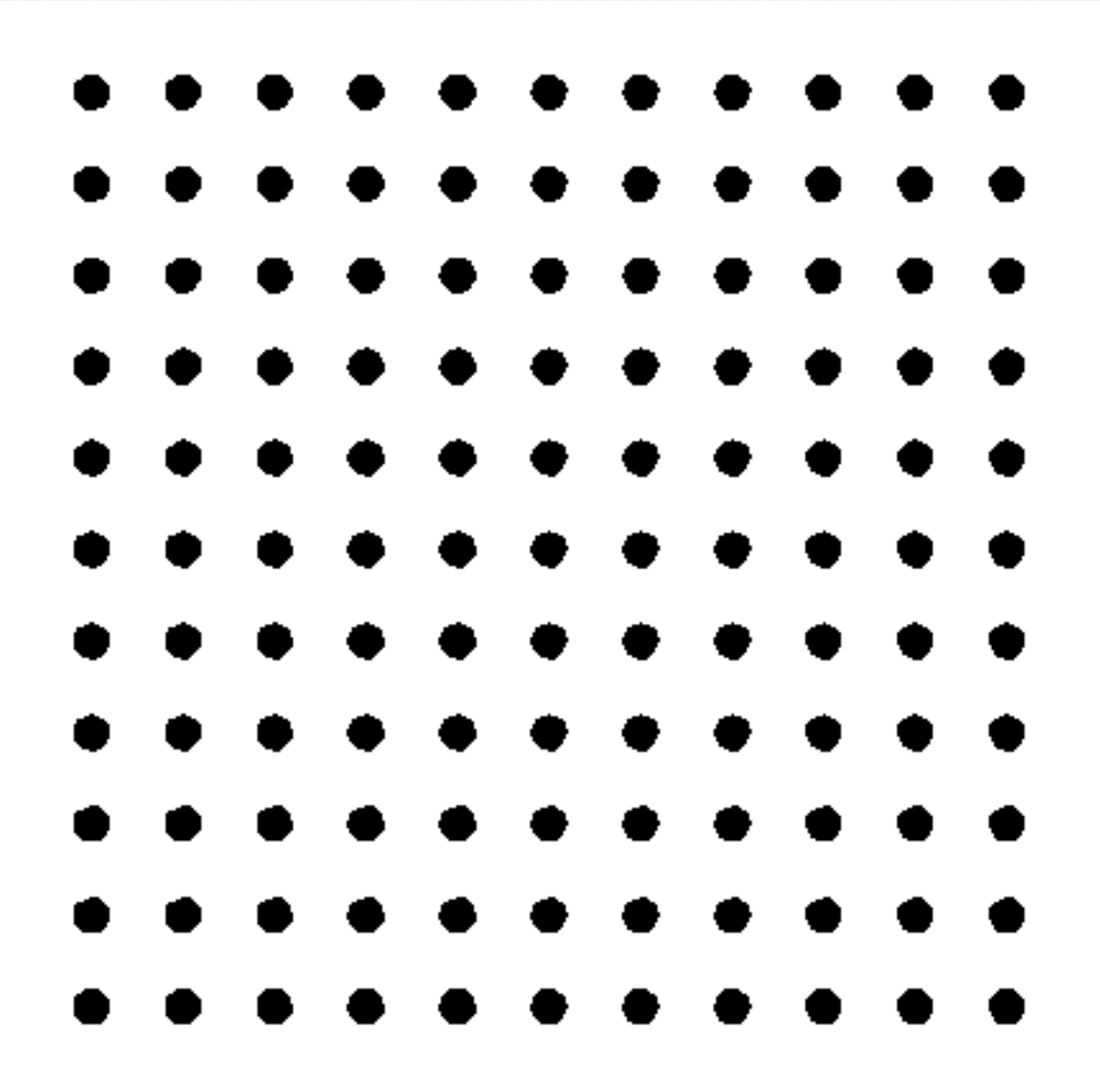


What are gravitational waves?

- Einstein taught us that space and time were a single entity that forms the underlying fabric of the Cosmos
- Gravitational waves are ripples in the fabric of spacetime which propagate through the Universe



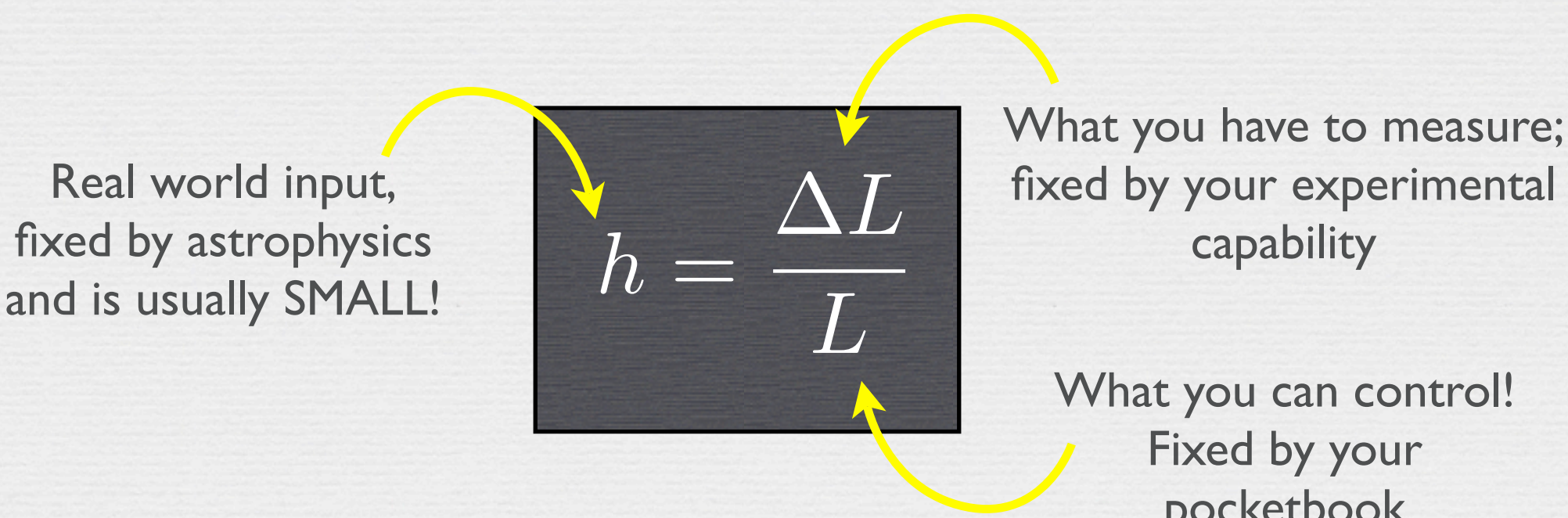
Changes in Spacetime



- Gravitational waves change the distances between different points in spacetime

Wave action on particles...

- A passing gravitational wave changes proper distances in a plane transverse to the direction of propagation
- Characterized by a **dimensionless strain h**



Typical Wave Strengths

Angry Motorist:

$$h \sim 7 \times 10^{-52}$$

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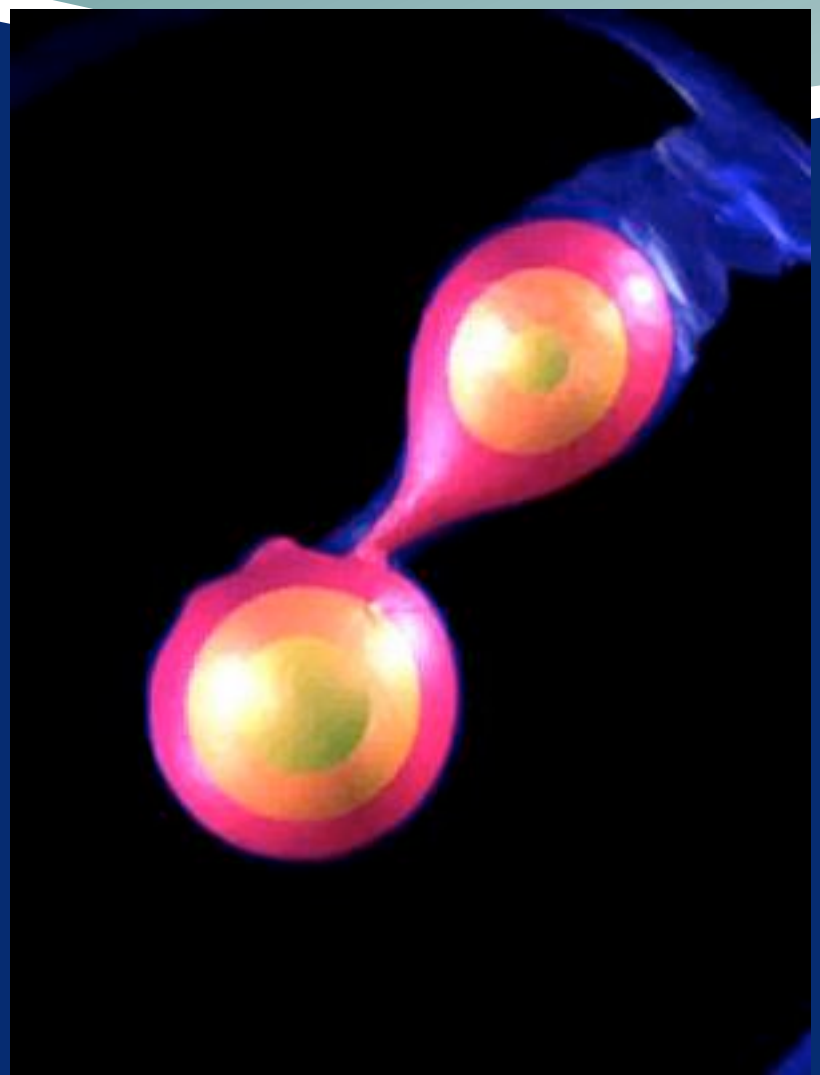
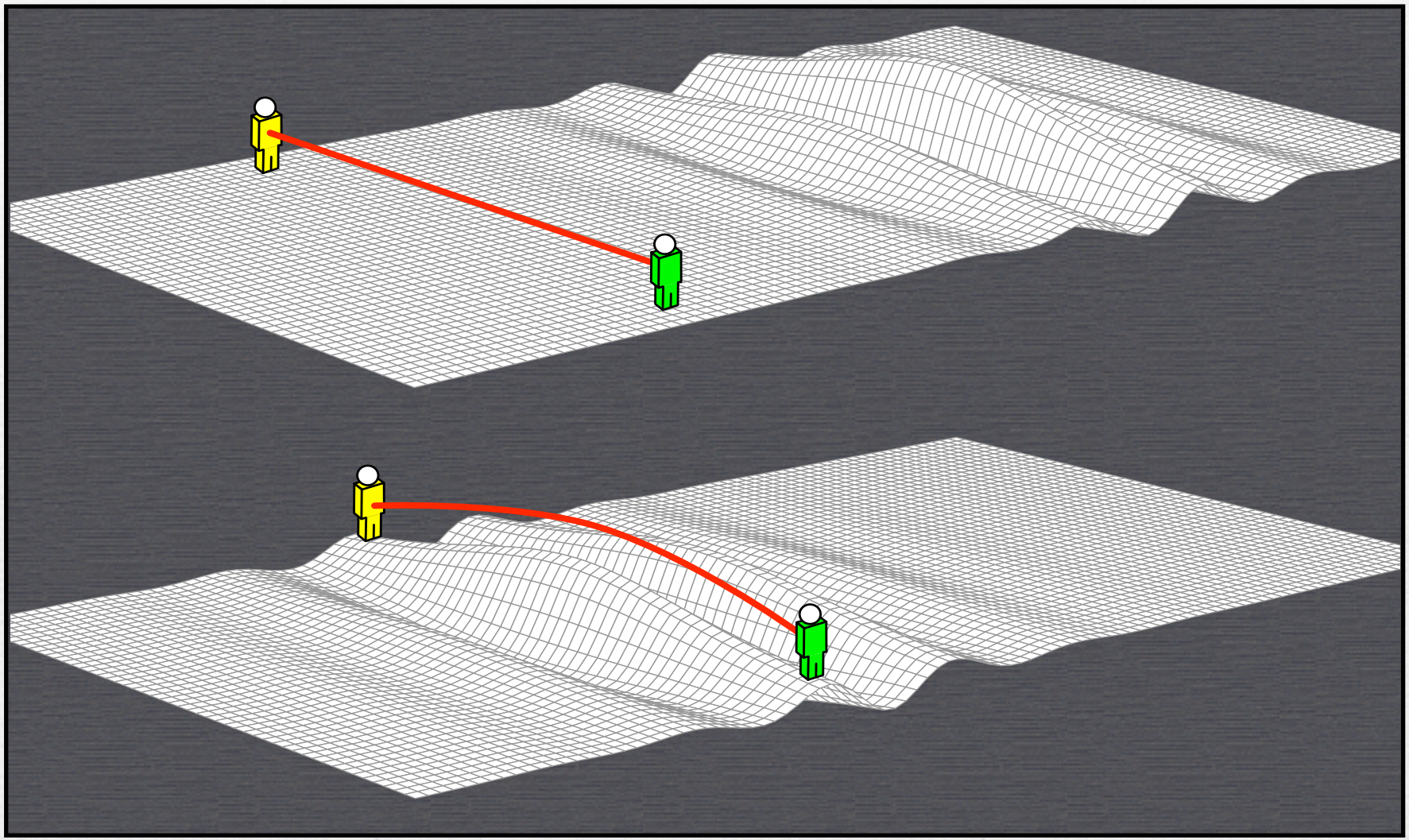
NS Binary at Galactic Center:

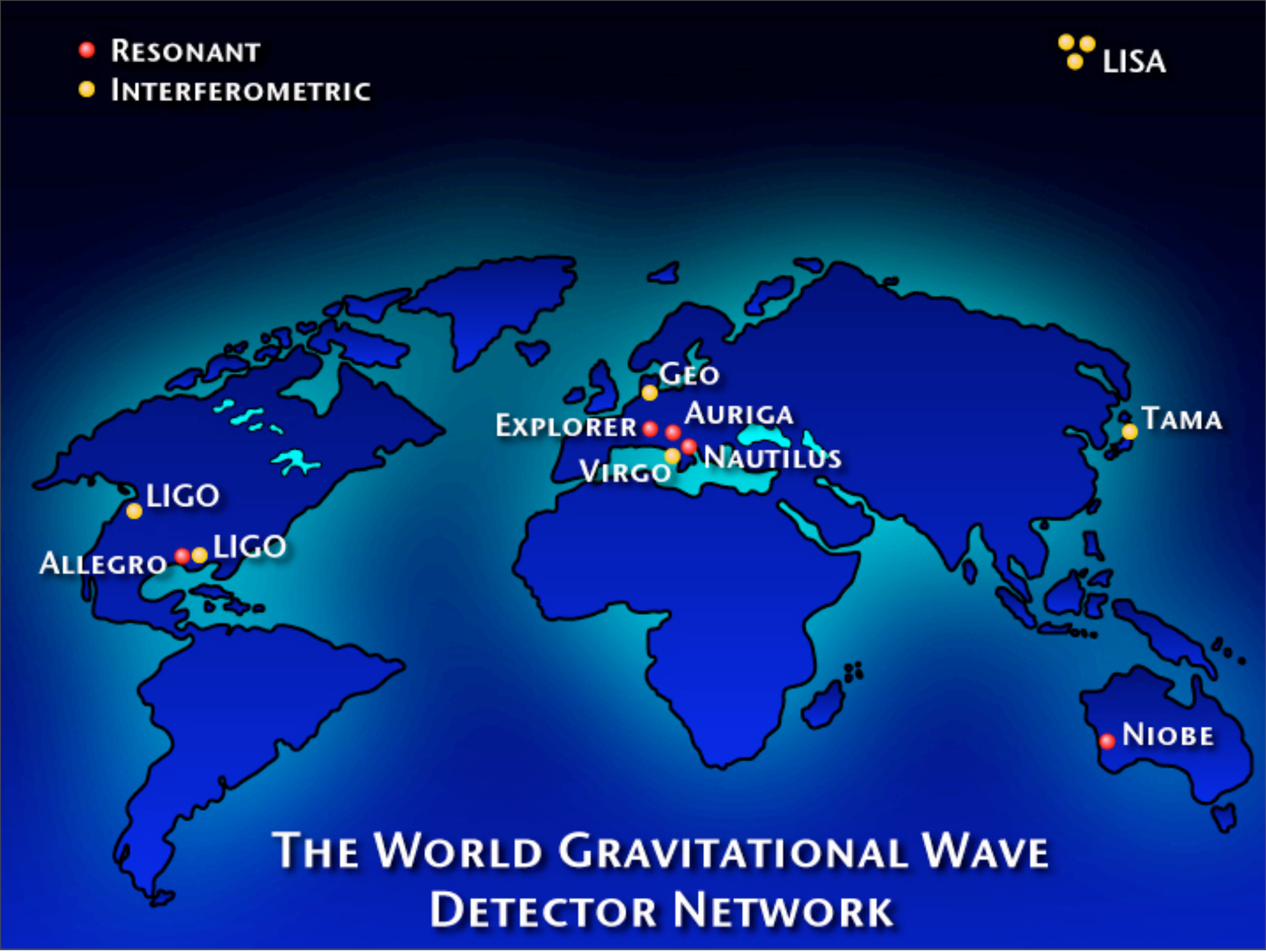
$$h \sim 5 \times 10^{-23}$$



Looking for gravitational waves

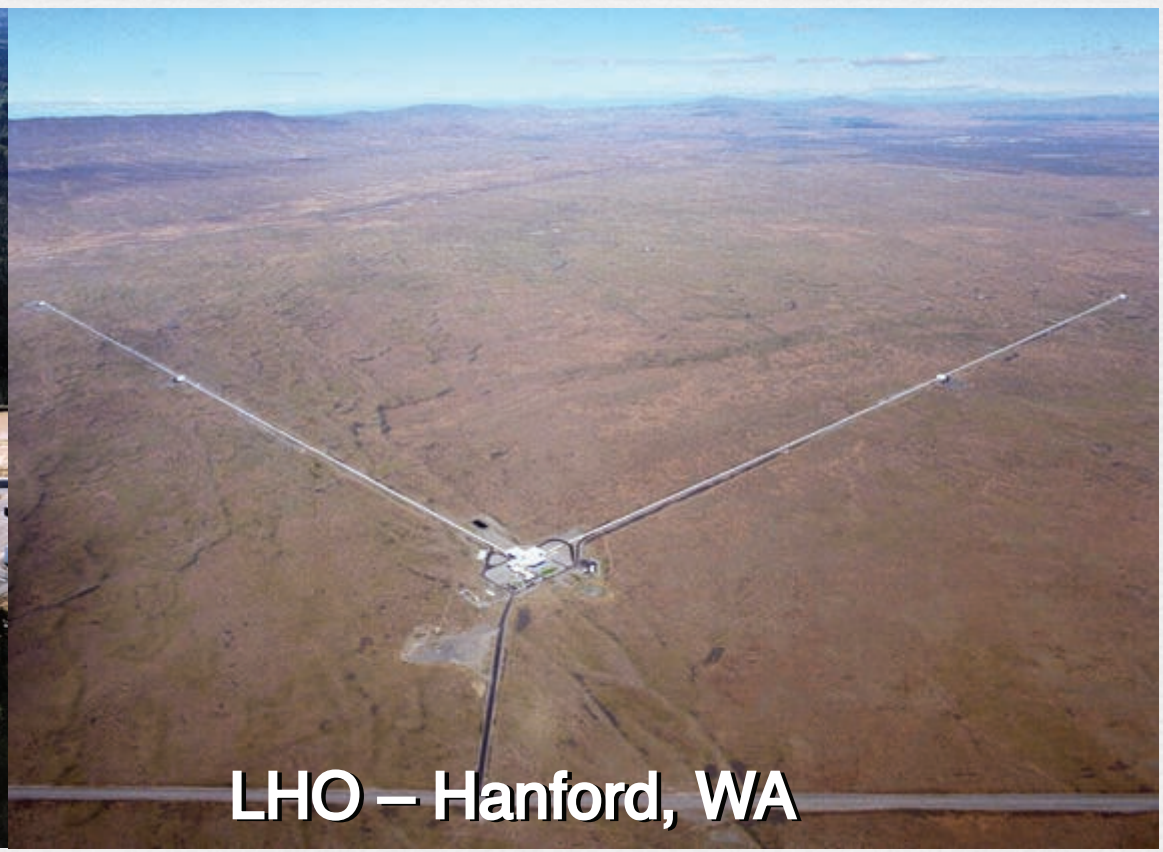


- Characterize change in distance by the strain $h = \Delta L/L$
- Typical values: $h \sim 10^{-23}$ implies $\Delta L \sim 10^{-13}$ m


Resonant
Interferometric
LISA
Geo
Auriga
Explorer
Tama
Nautilus
Virgo
LIGO
LIGO
Allegro
Niobe
The World Gravitational Wave
Detector Network

LIGO

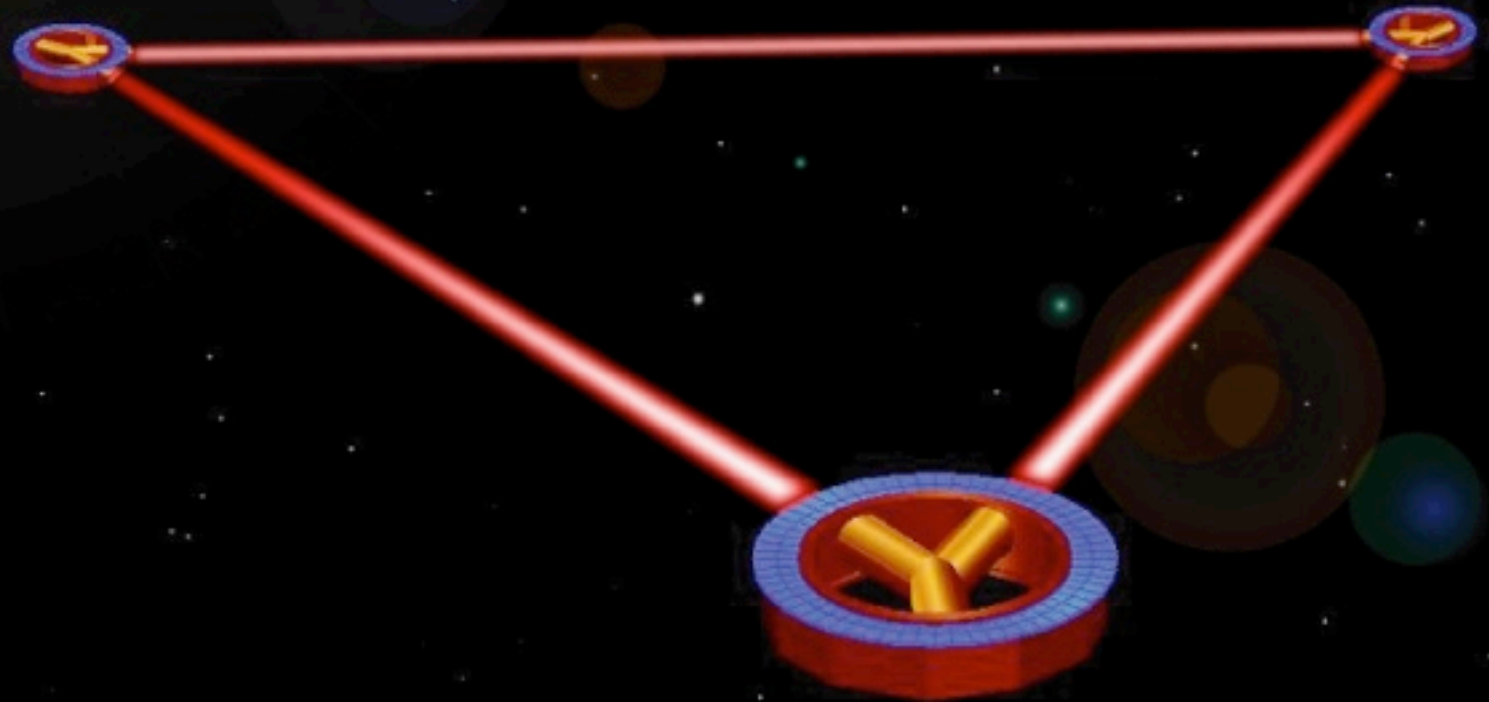
- Two 4 kilometer long laser interferometers



Danger! Danger!

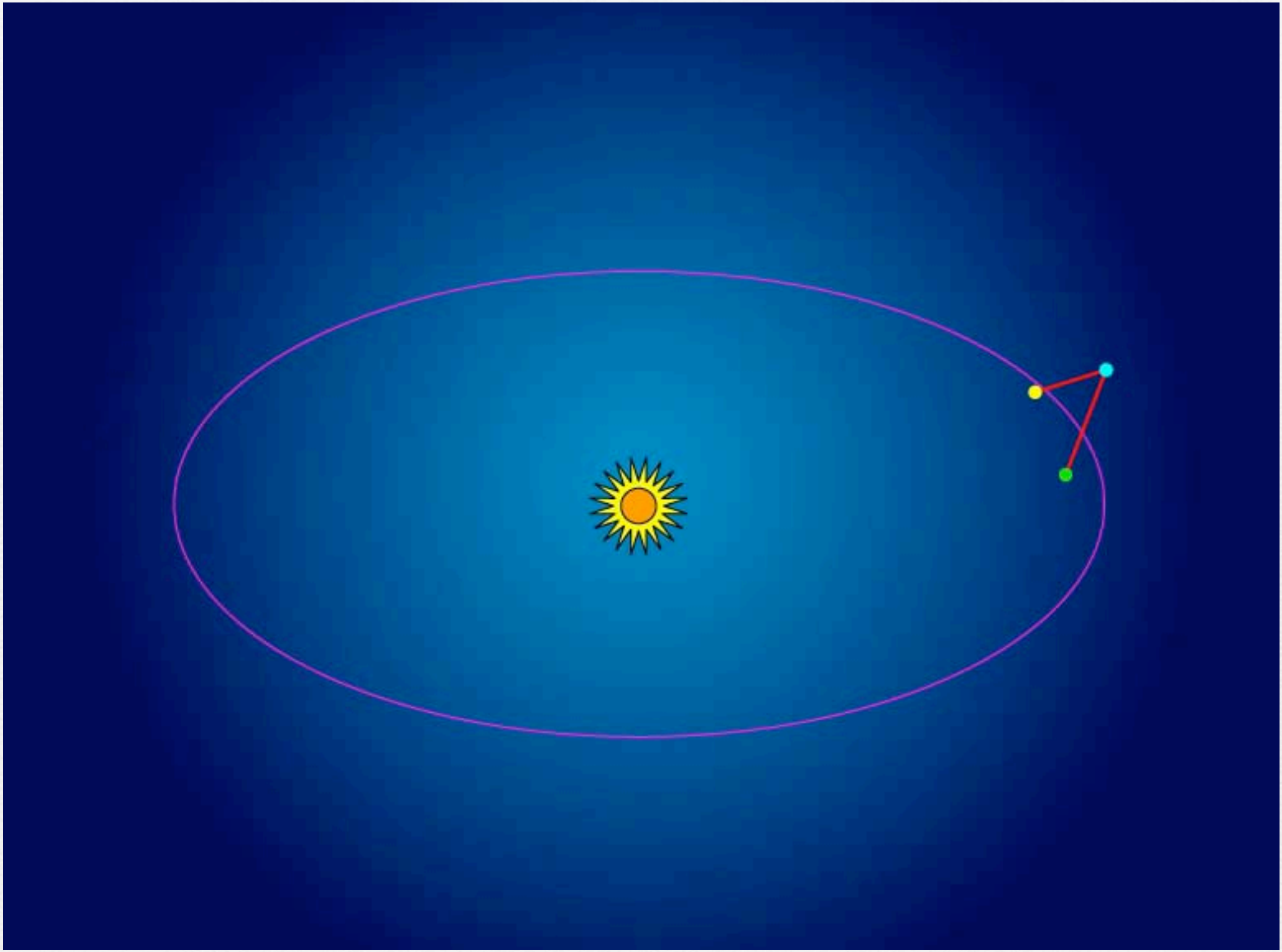
- Unforseen dangers of being a gravitational wave astronomer

LISA



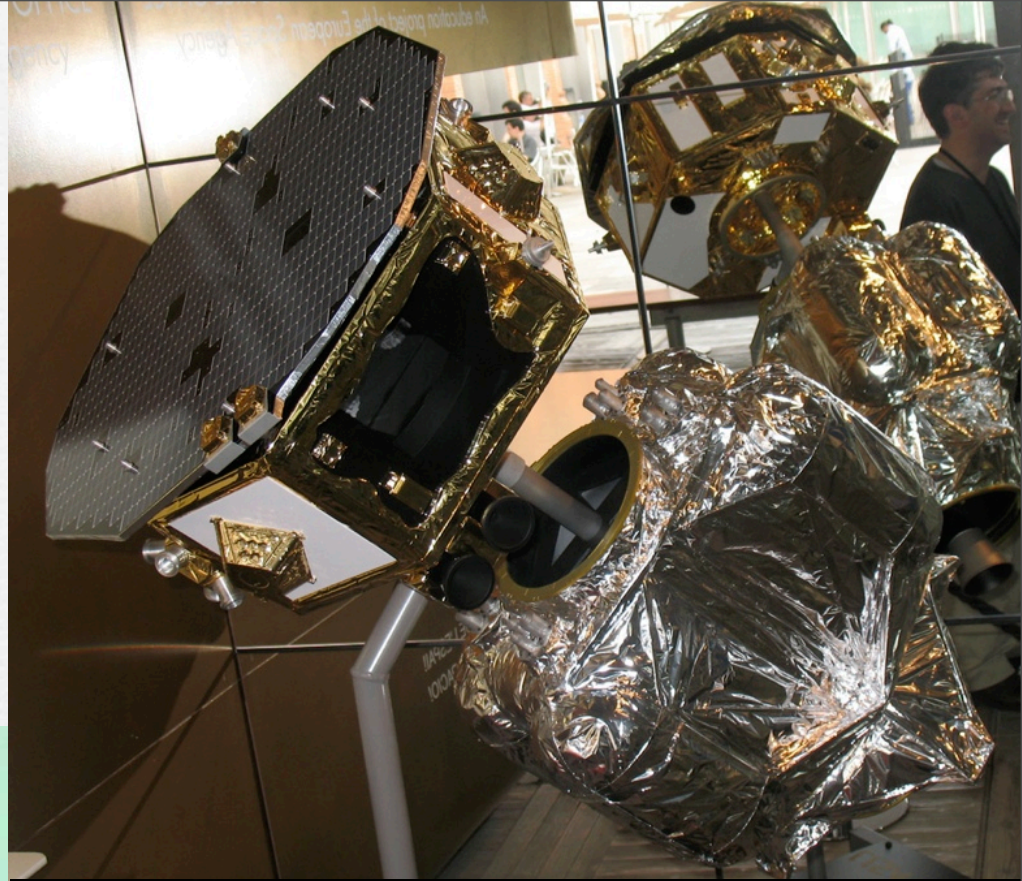
- 5 million kilometer laser interferometer in space

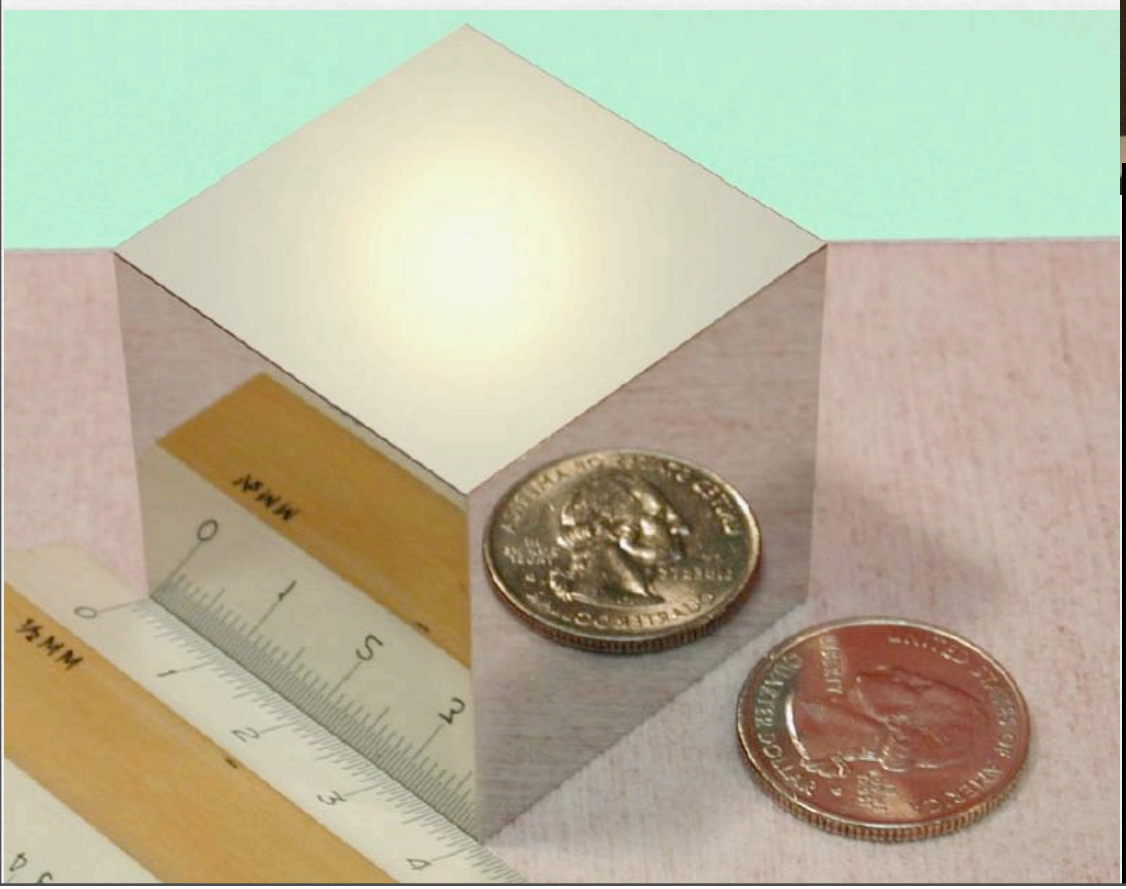
Guaranteed sources of gravitational waves

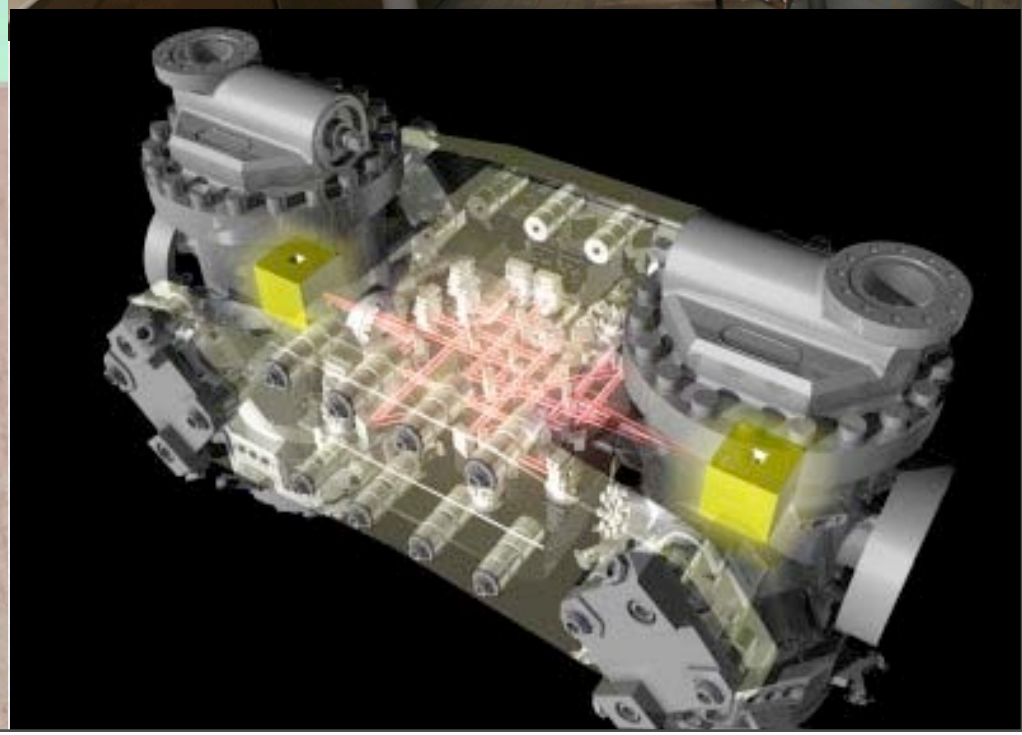


LISA Timeline

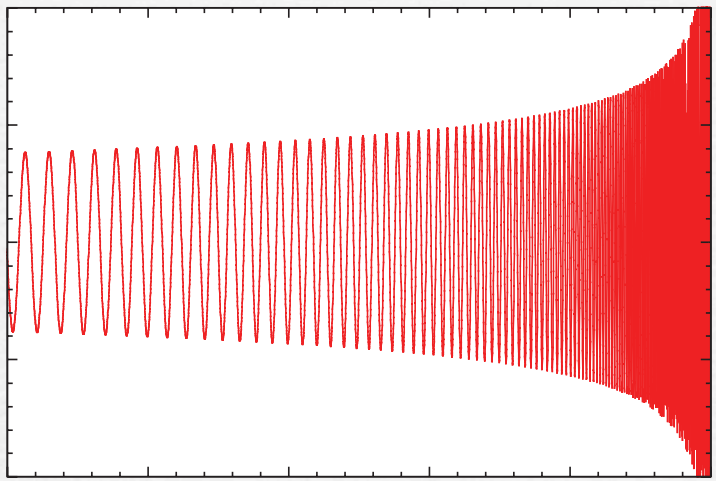
- LISA Pathfinder is due to launch in 2010, and will test the core LISA sensor technology
- LISA will follow in ~2015-2018 timeframe

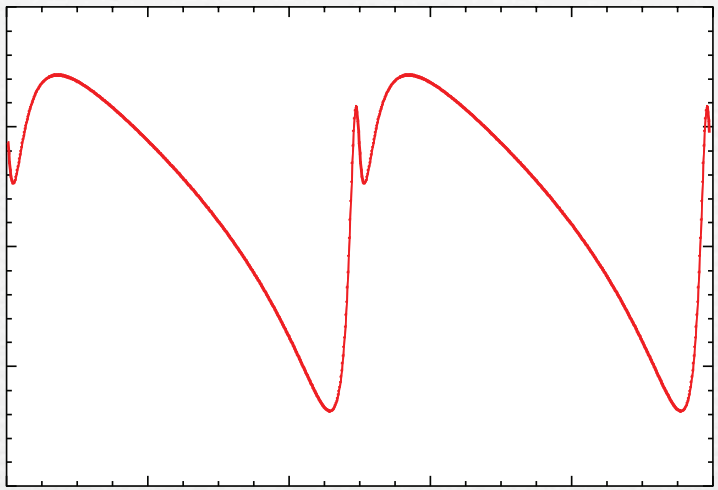


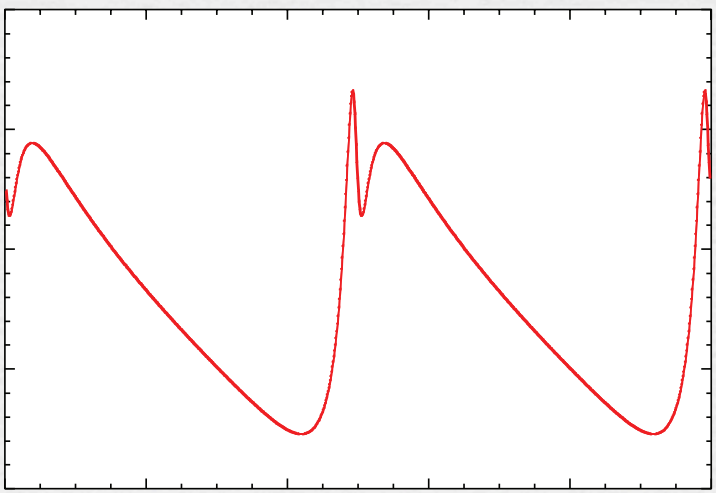


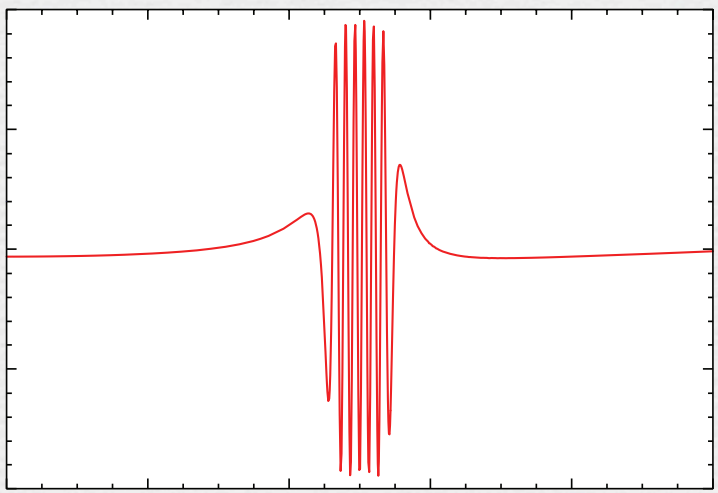


Waveform Zoology









- Gravitational waves encode astrophysical information!
- They aren't good for making pretty pictures! :-(

The Songs of Gravity

10 Msun BH + 10,000 Msun BH
circular orbits

10 Msun BH + 10,000 Msun BH
eccentric orbits

In your classrooms

- Resources are emerging that allow you to introduce gravitational waves alongside normal astronomy concepts

  Rubbo, Larson, Larson, & Zaleski, *Physics Teacher* **44**, 420 [2006]
  Larson, Rubbo, Zaleski & Larson, *Physics Teacher* **44**, 416 [2006]
  Rubbo, Larson, Larson & Ingram, *American Journal of Physics*, **75**, 597 [2006]

  - http://cgwp.gravity.psu.edu/outreach/activities/
  - http://www.einsteinsmessengers.org/

- Einstein@Home: http://einstein.phys.uwm.edu/
- Einstein Online: http://www.einstein-online.info/en/

Last Thoughts...

- Technology is providing us with new ways to see the Cosmos
- We can see things with gravity that cannot be seen with light!
- Within the next decade, gravitational wave astronomy will change our view of the Universe as radically as expansion into non-visible spectrum did in the last century

- Thanks for coming!