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## Whispers from the Cosmos: seeing the Universe in gravitational waves

Shane L. Larson  
*Utah State University*

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# ***WHISPERS from the COSMOS: seeing the Universe in gravitational waves***

Shane L. Larson  
Department of Physics  
Utah State University

[s.larson@usu.edu](mailto:s.larson@usu.edu)

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**UtahState**  
UNIVERSITY

AAPT Summer Meeting  
Edmonton, Alberta  
22 August 2008

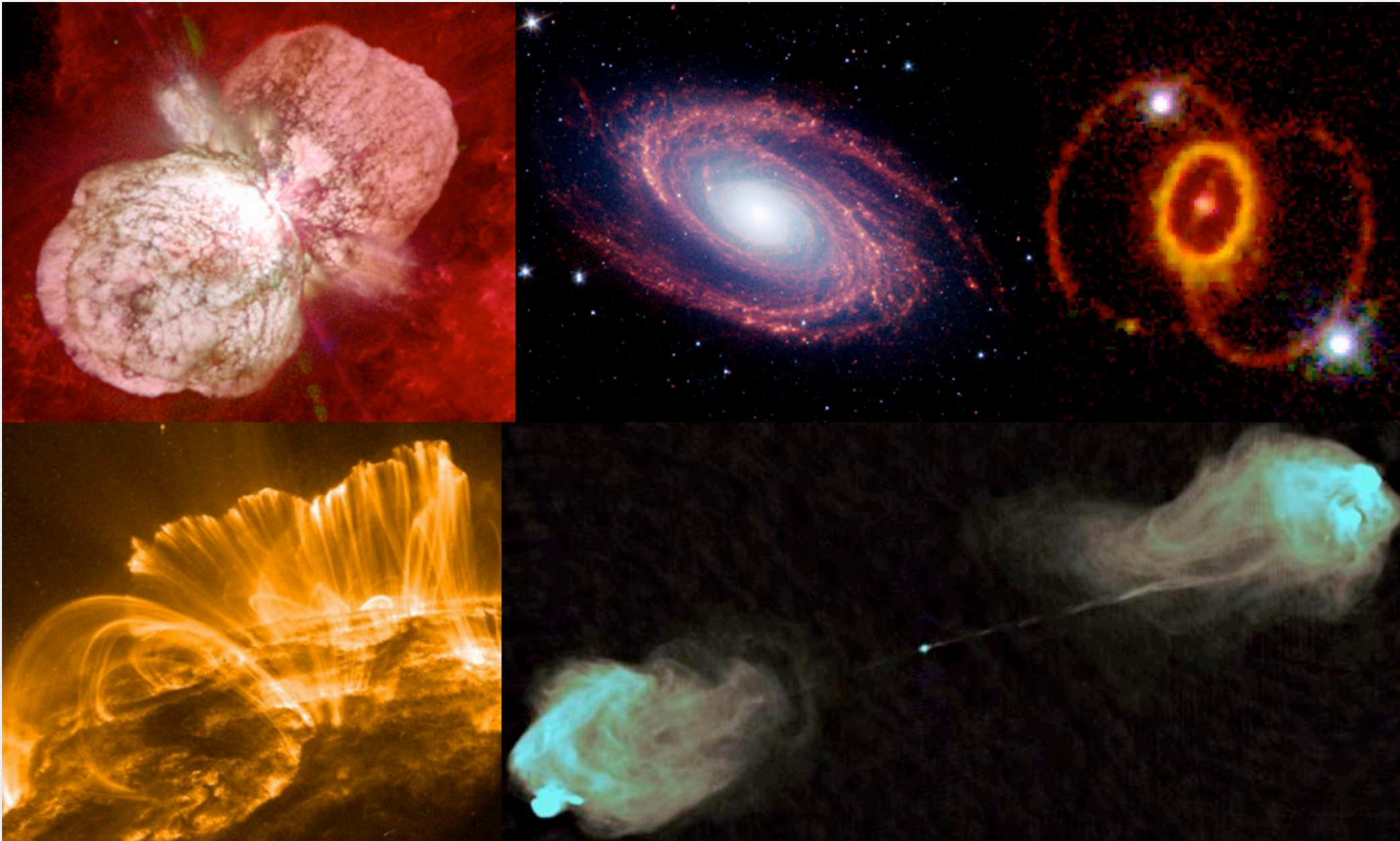


# STORYLINE

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

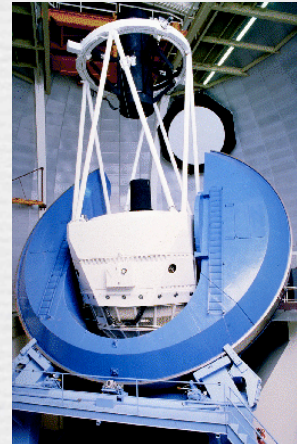
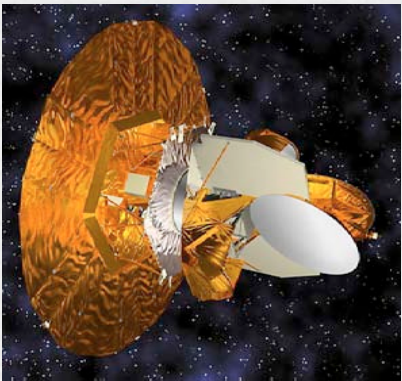
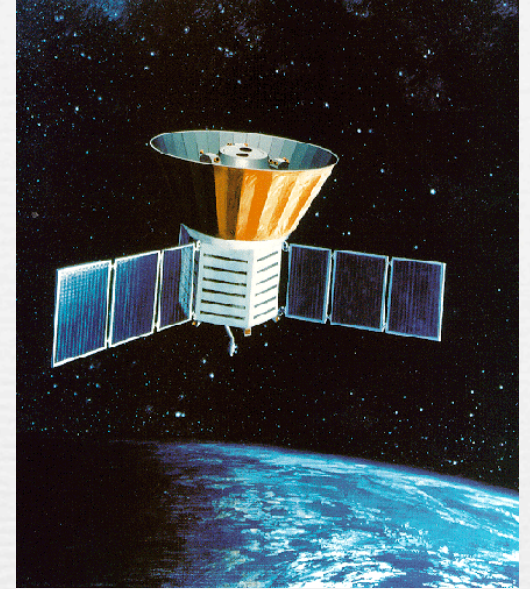
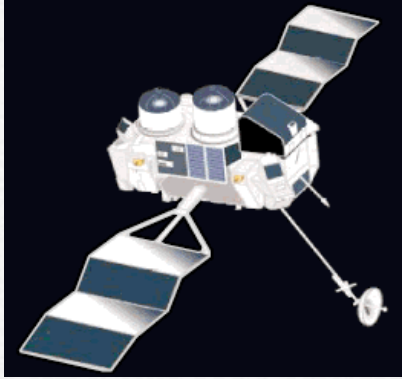
# THE COSMOS AS WE KNOW IT...



- LIGHT has been our messenger from the Universe.



# OUR EYES



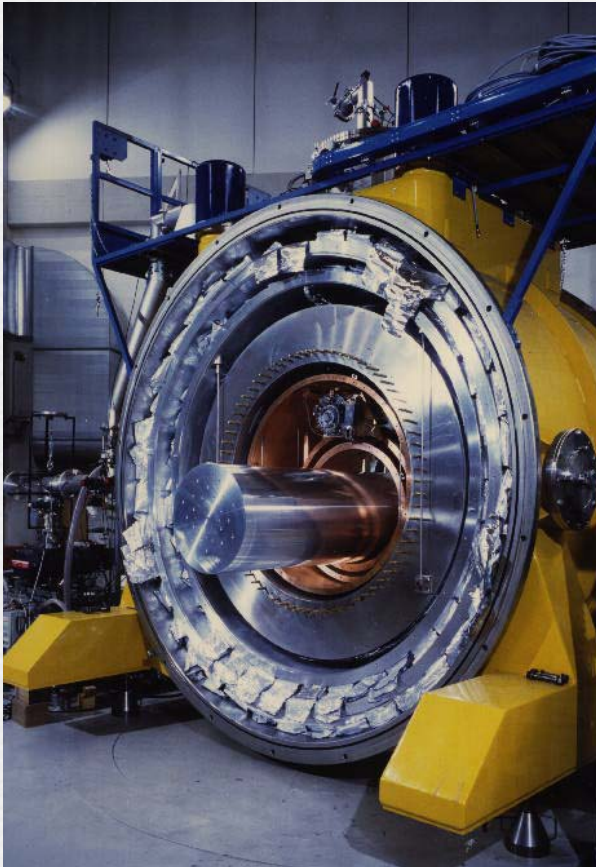
- Light has many forms (visible, infrared, radio, x-ray,...) and we have a myriad of instruments to detect it.



# A NEW KIND OF ASTRONOMY

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- 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**

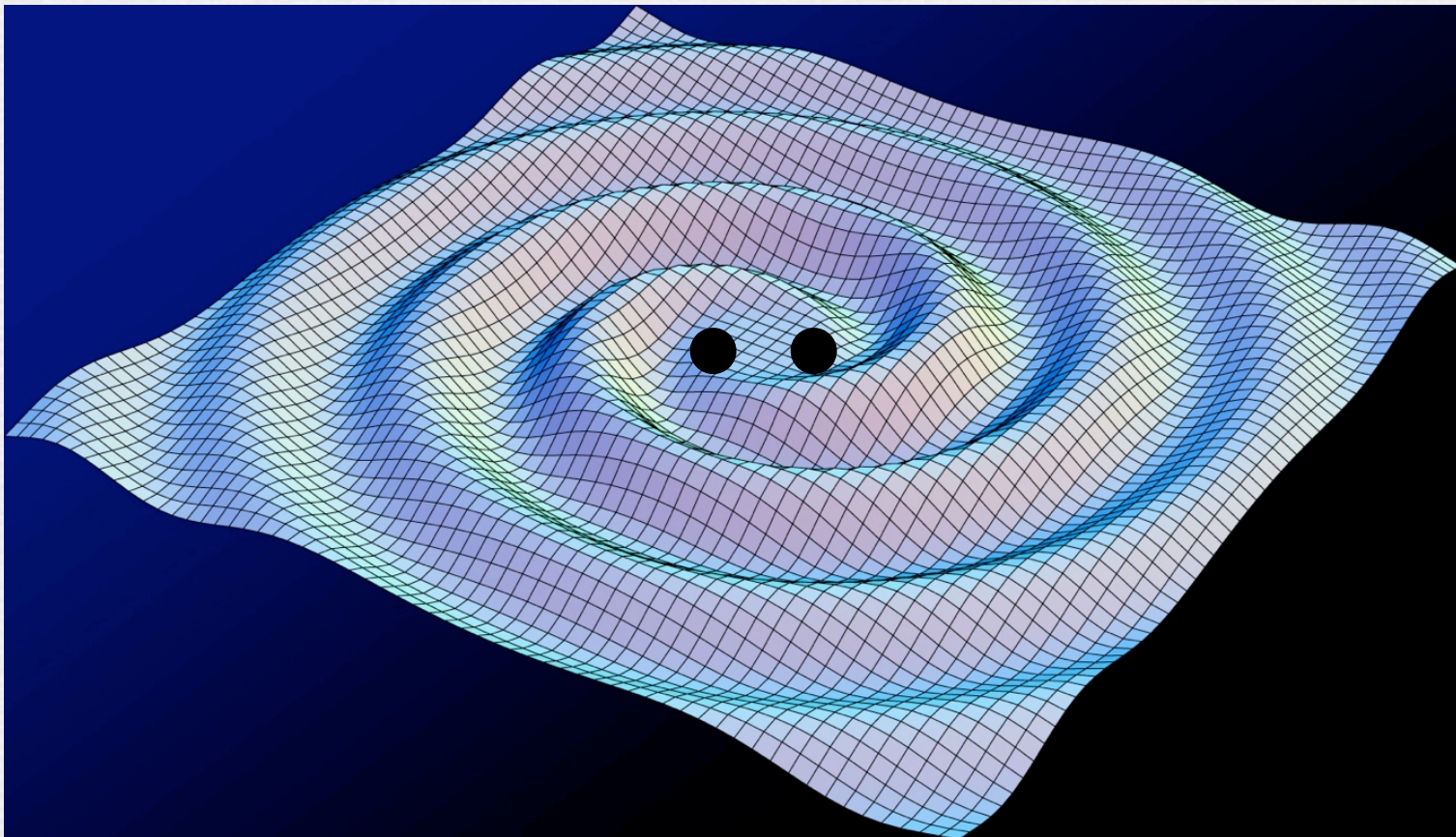




# WHAT ARE GRAVITATIONAL WAVES?

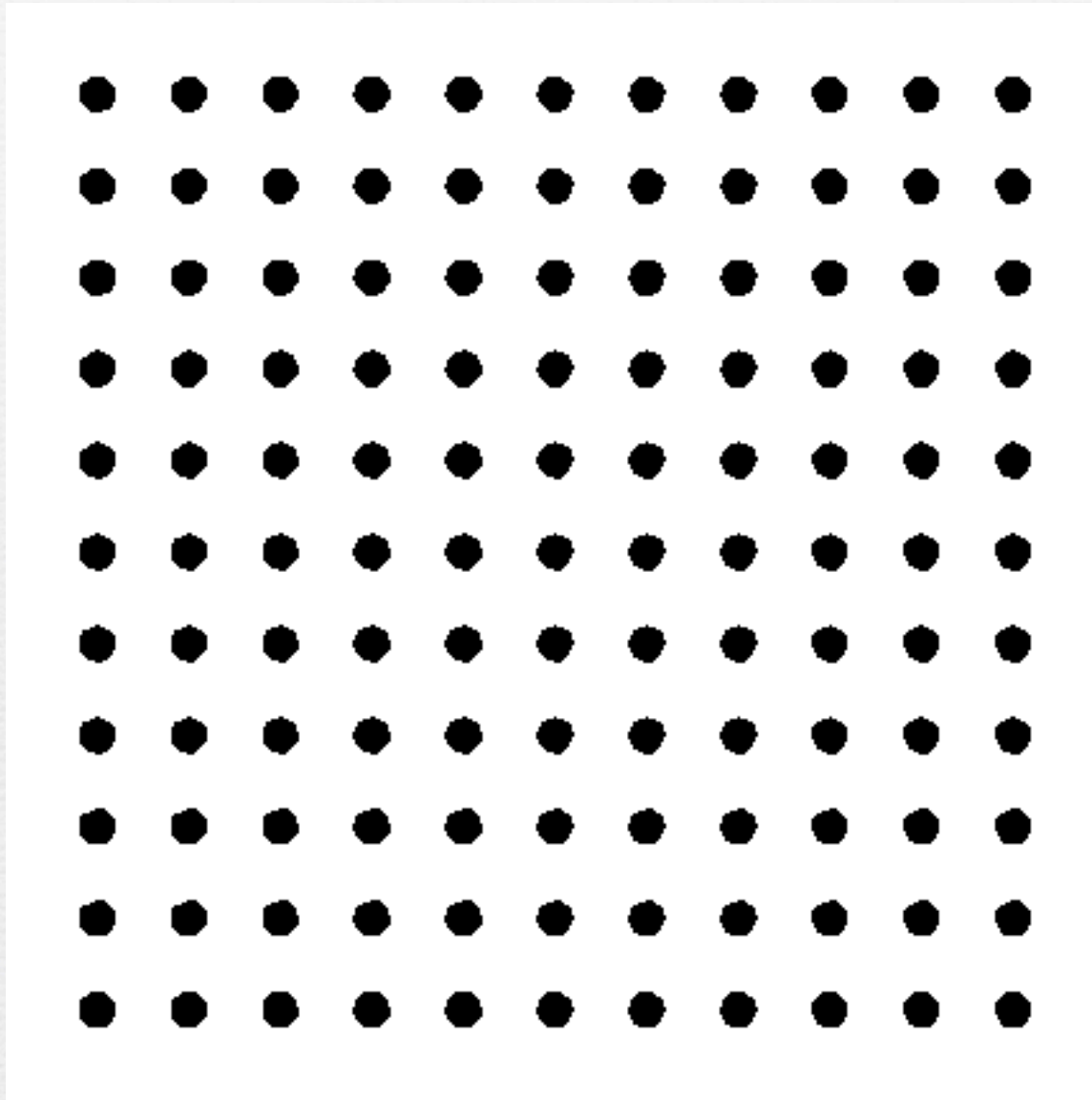
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- Einstein taught us that space and time were a single entity that forms the underlying fabric of the Cosmos
- **Gravitational waves** are ripples in the fabric of spacetime which propagate through the Universe



# CHANGES IN SPACETIME

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- 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**

Real world input,  
fixed by astrophysics  
and is usually SMALL!

$$h = \frac{\Delta L}{L}$$

What you have to measure;  
fixed by your experimental  
capability

What you can control!  
Fixed by your  
pocketbook



# TYPICAL WAVE STRENGTHS

Angry Motorist:

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





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Battleships Colliding:

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Io orbiting Jupiter:

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# TYPICAL WAVE STRENGTHS

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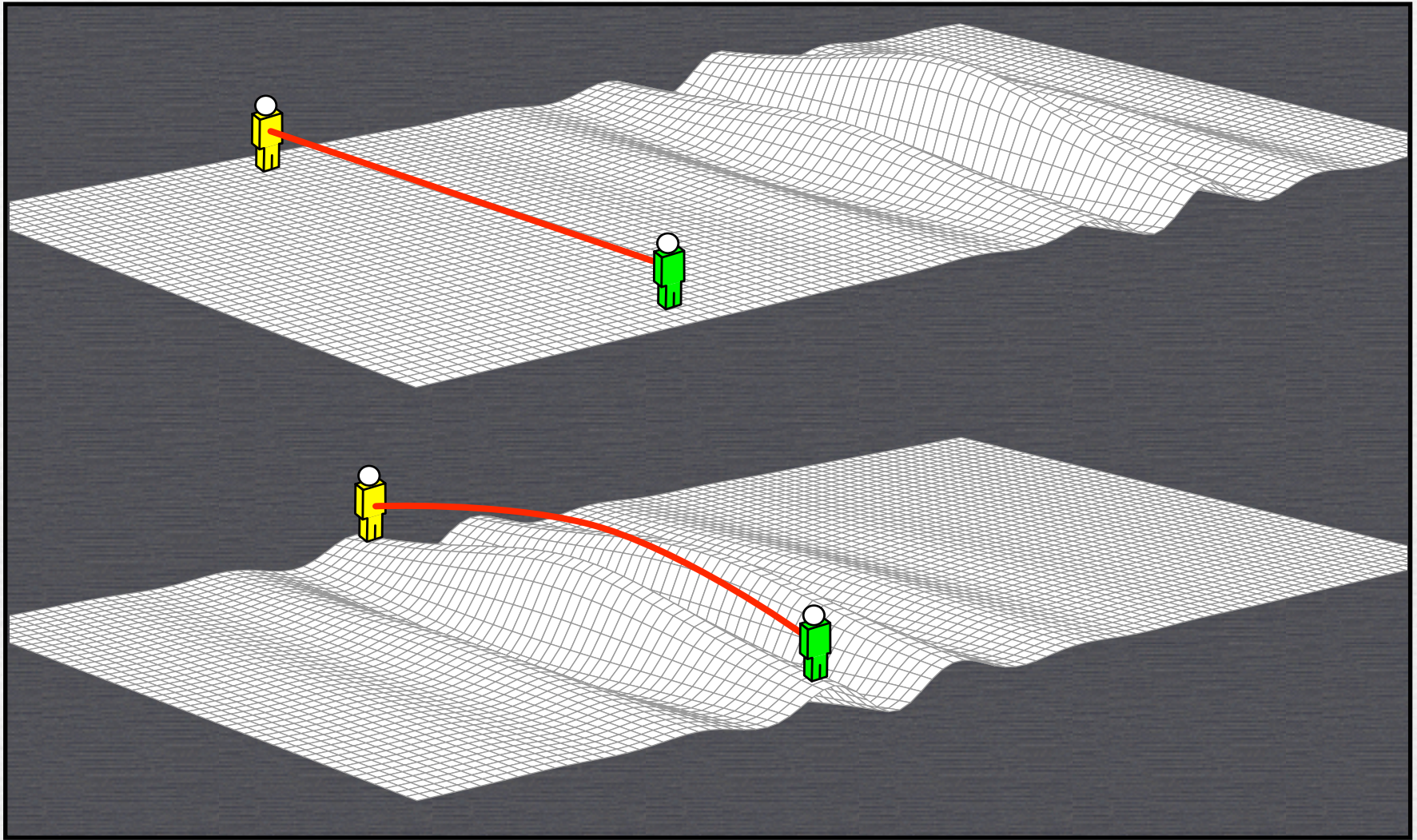
NS Binary at Galactic Center:

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





# 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



# THE WORLD GRAVITATIONAL WAVE DETECTOR NETWORK



# LIGO

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- Two 4 kilometer long laser interferometers



LLO – Livingston, LA



LHO – Hanford, WA



# DANGER! DANGER!

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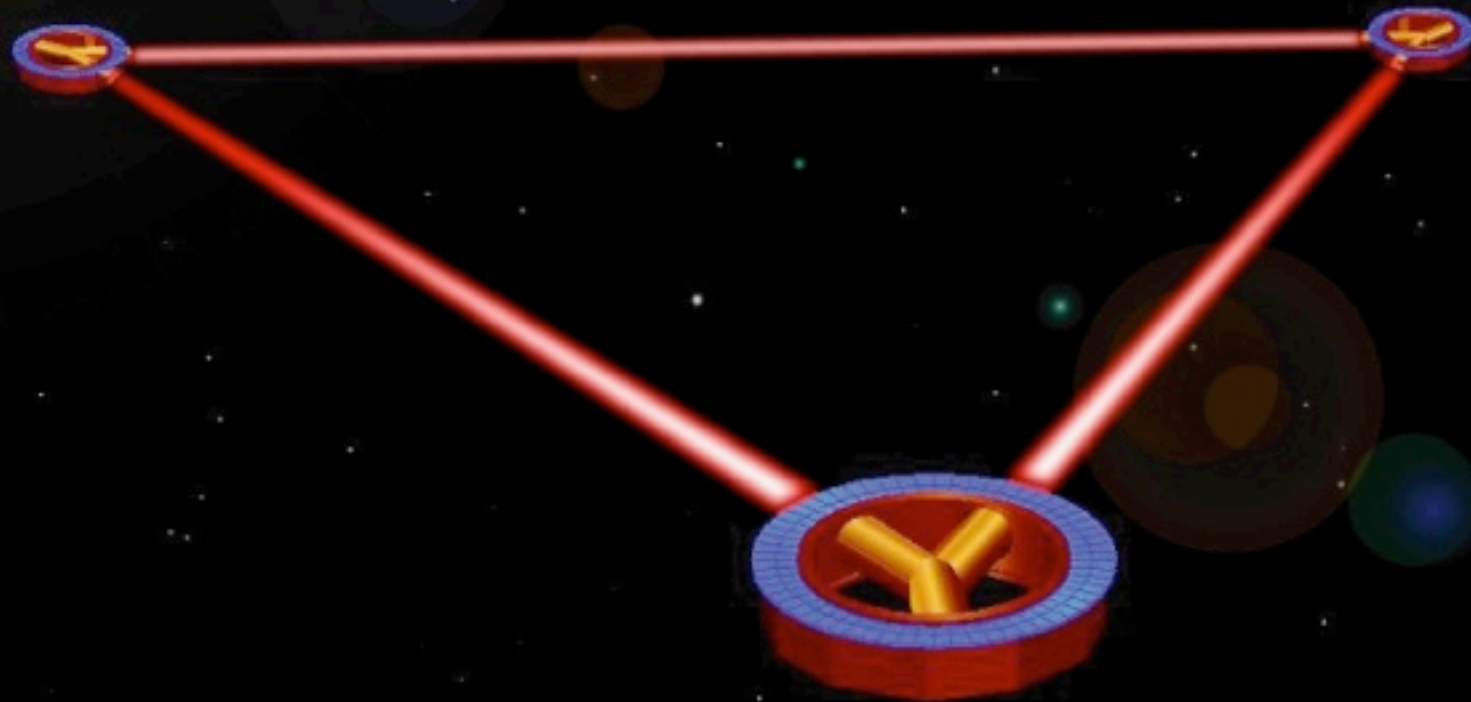
- Unforeseen dangers of being a gravitational wave astronomer



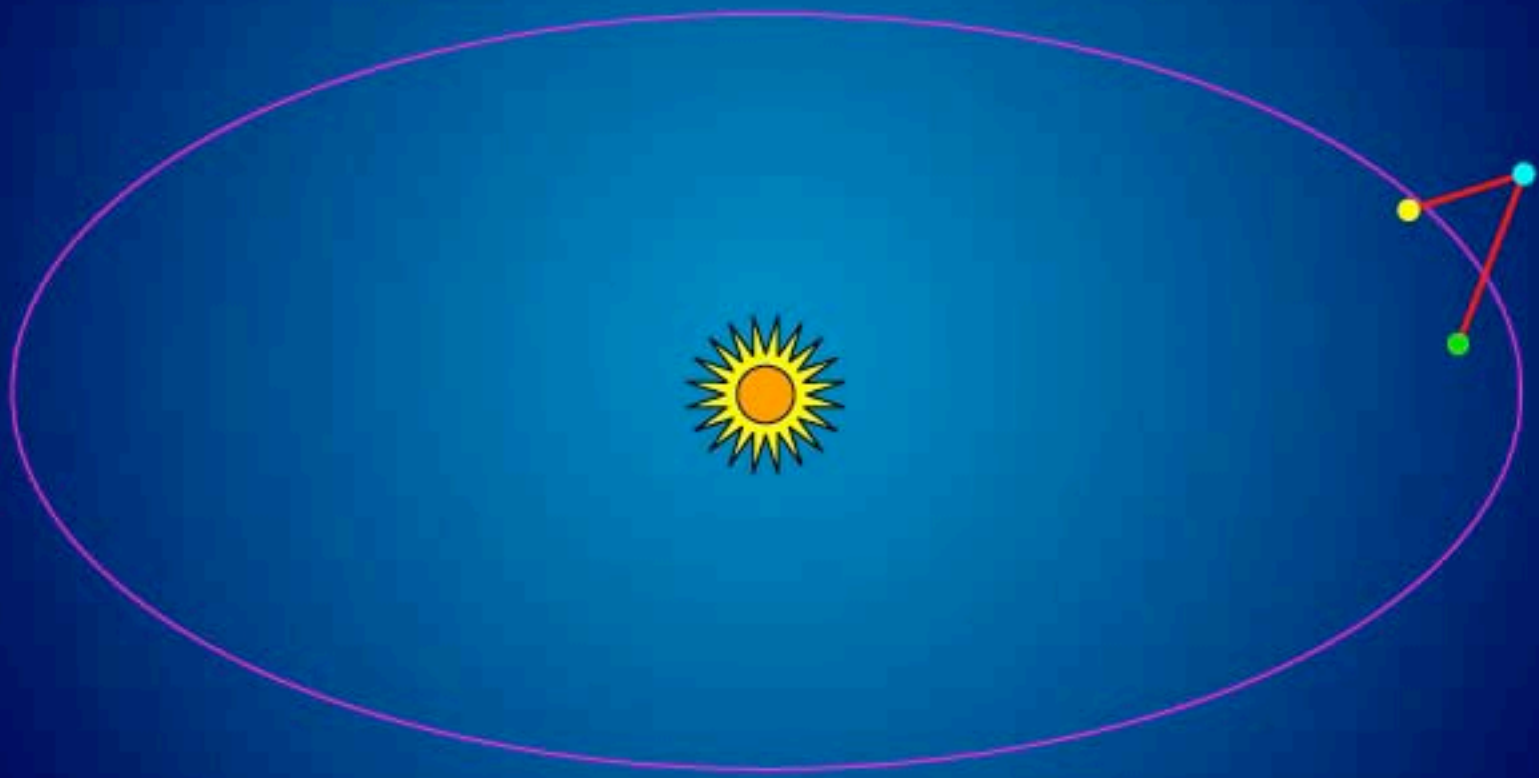


# LISA

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- **5 million kilometer** laser interferometer in space  
*Guaranteed sources* of gravitational waves

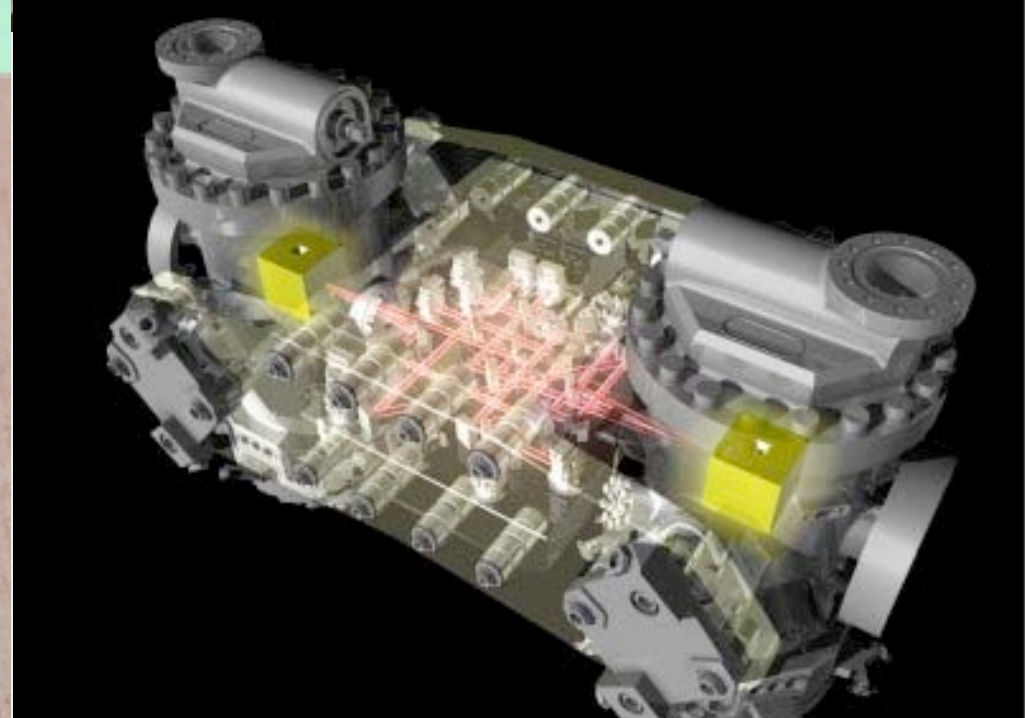
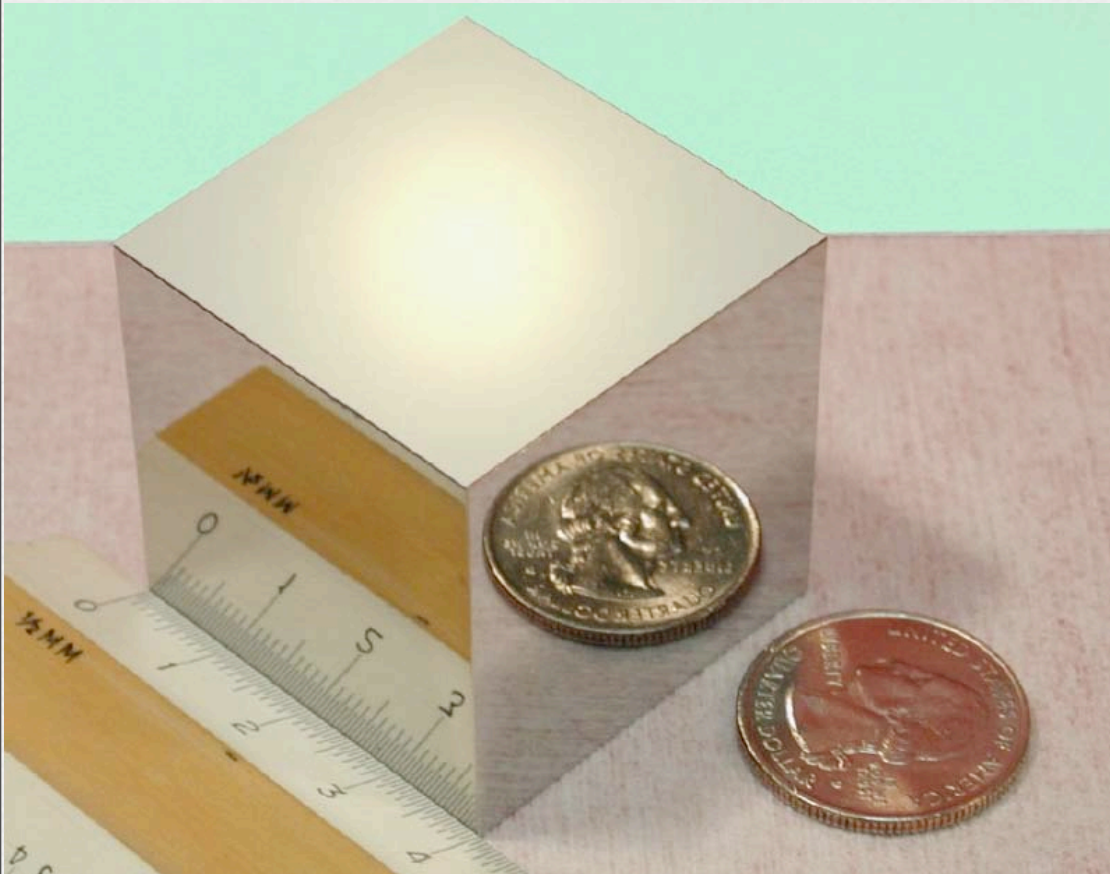
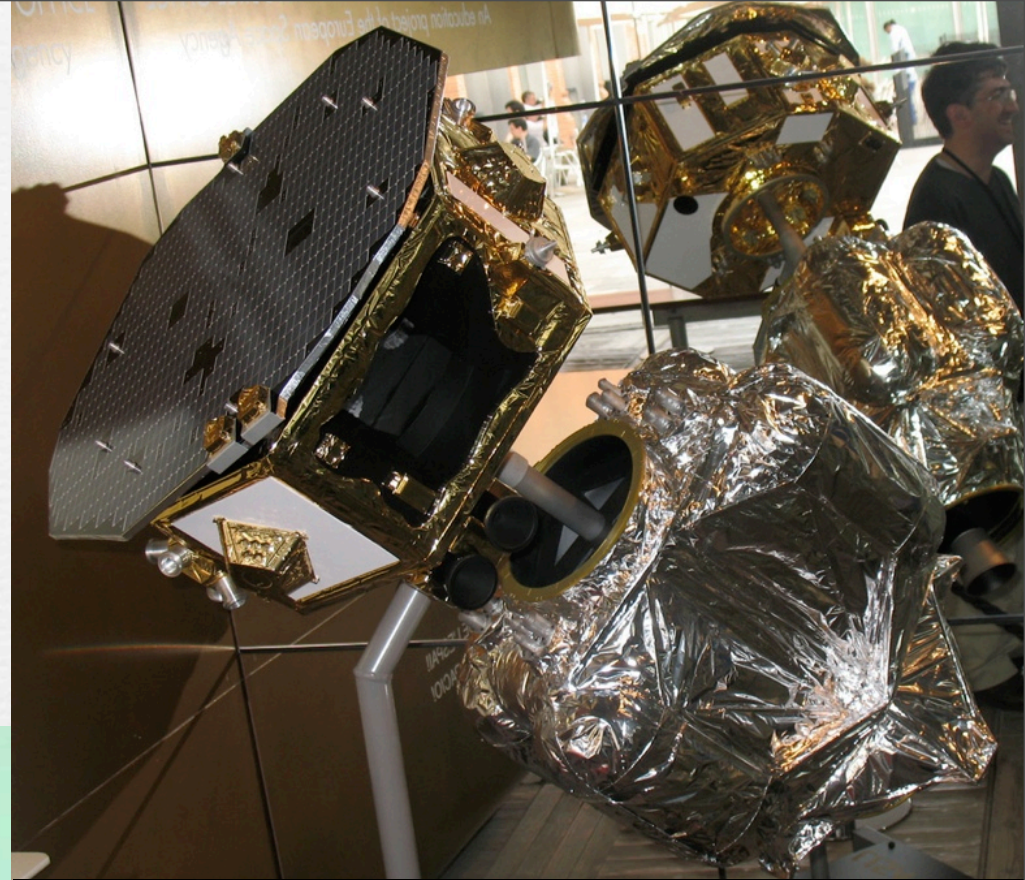




# LISA TIMELINE

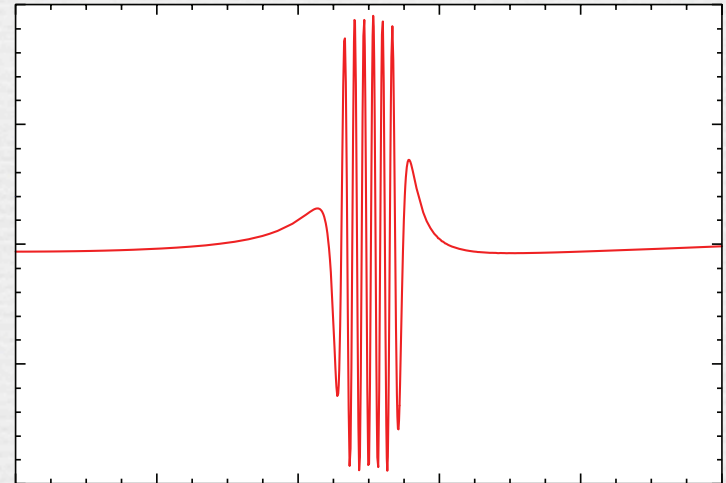
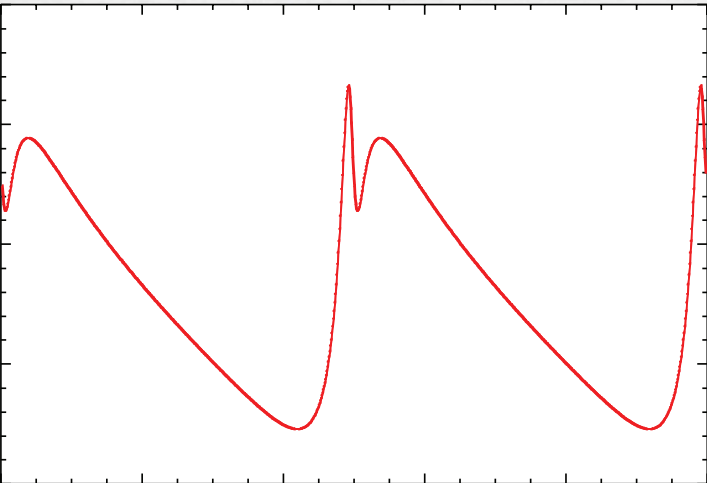
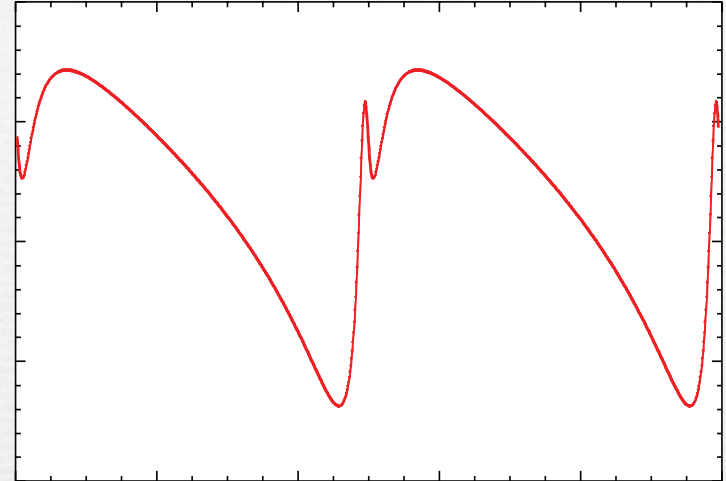
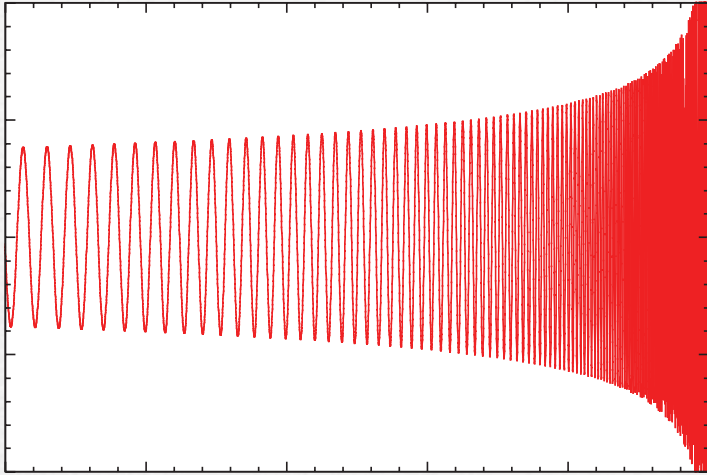
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- LISA Pathfinder is due to launch in 2010, and will test the core LISA sensor technology
- LISA will follow in ~2015-2018 timeframe



# WAVEFORM ZOOLOGY

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



# THE SONGS OF GRAVITY

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10  $M_{\text{sun}}$  BH + 10,000  $M_{\text{sun}}$  BH  
circular orbits

10  $M_{\text{sun}}$  BH + 10,000  $M_{\text{sun}}$  BH  
eccentric orbits

# IN YOUR CLASSROOMS

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- 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...

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- 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!