

Astronomy in a 4-D

Universe

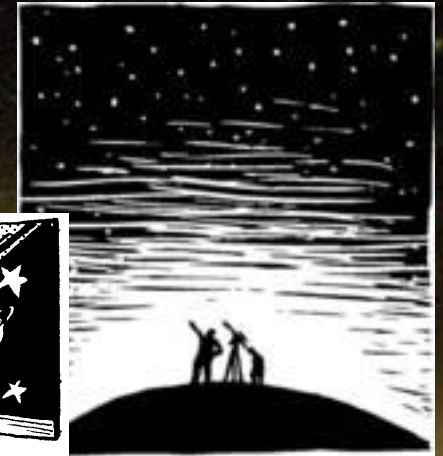
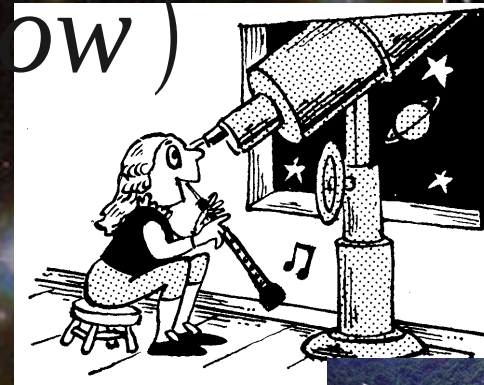
Gravitational Waves:

What are they and How Do We
find them?

Cristina Valeria Torres
LIGO Livingston Observatory

Astronomy Snapshot

- Observations by ancient cultures
- 85 AD: Ptolemy, first theory built on known observations
- 1564 AD: Galileo births observational astronomy
- 1905 AD: Jansky fathers radio astronomy
- . . .



McDonald Observatory(NASA)



Arecibo Radio Telescope

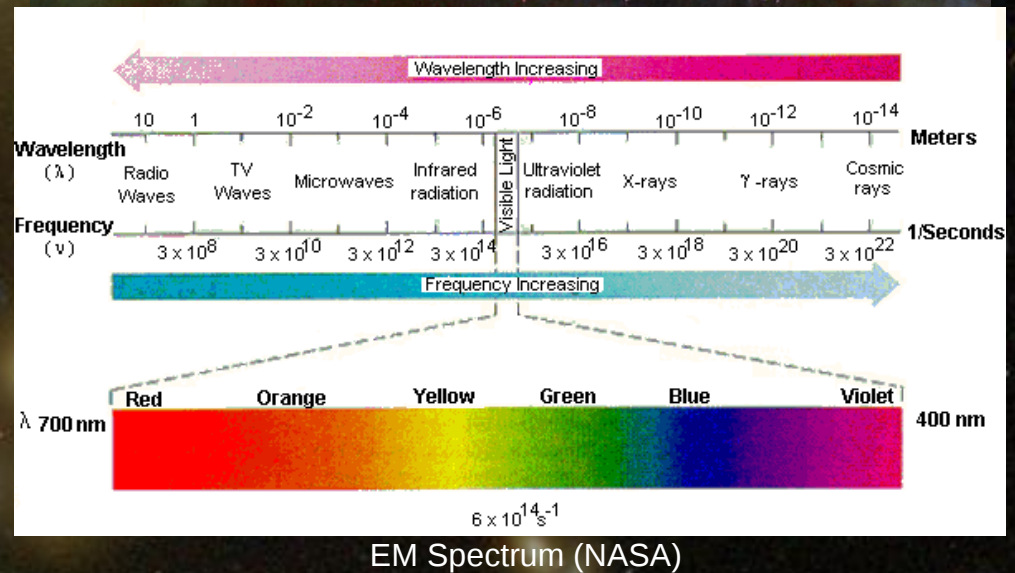
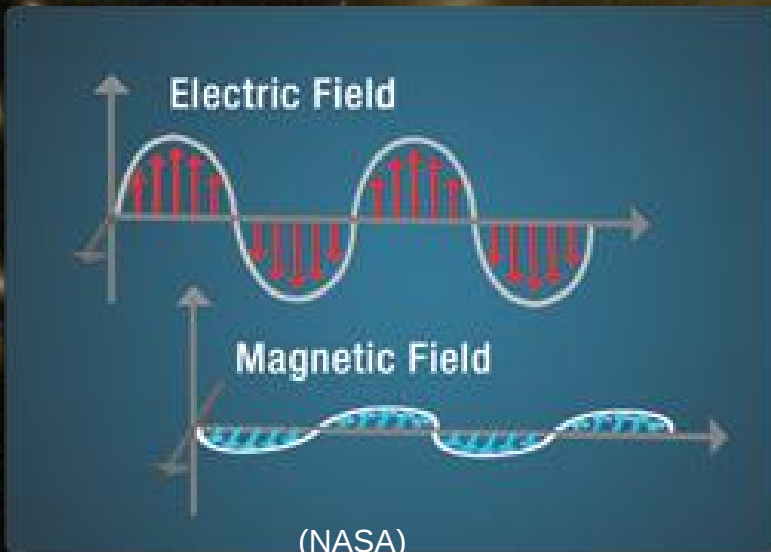


+ Much much more, astronomy is a content rich field

Light

our observational standard

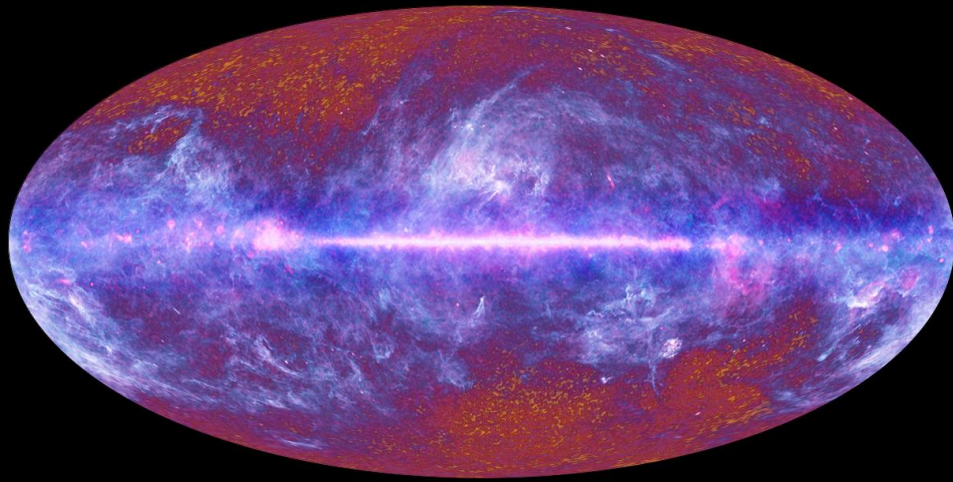
- Also known as electromagnetic waves
- Spans more than visible spectrum
- By-product of charged particle **acceleration/motion**



Light Sources

Stellar Dust to Stellar Cores

- Stellar formation/reactions are gravity powered...
- Motion induced ionization causes electromagnetic radiation



The Planck one-year all-sky survey

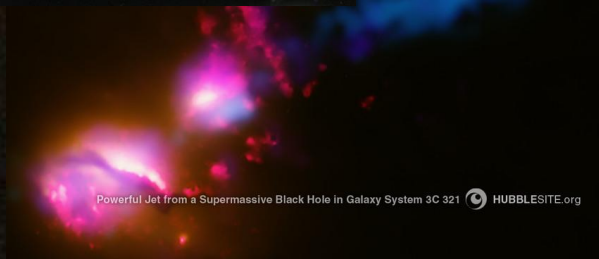


(c) ESA, HFI and LFI consortia, J

- Bulk masses are also accelerating..
 - *Is there a gravitational analogue to radiation emission from accelerated charges?*



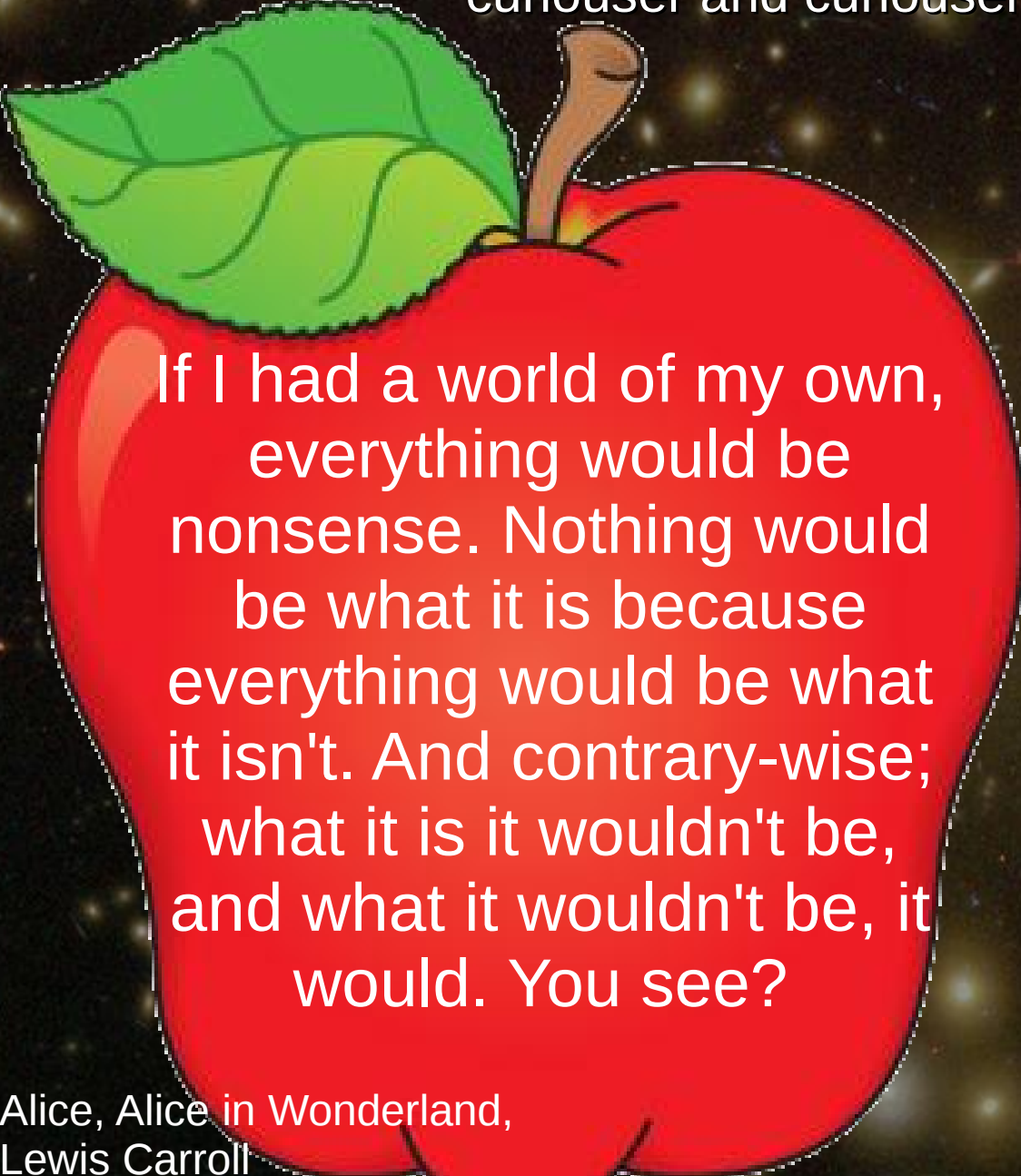
The Mice: Colliding Galaxies with Tails of Stars and Gas — NGC 4676 © HUBBLESITE.org



Powerful Jet from a Supermassive Black Hole in Galaxy System 3C 321 © HUBBLESITE.org

General Relativity

curiouser and curiouser views of gravity

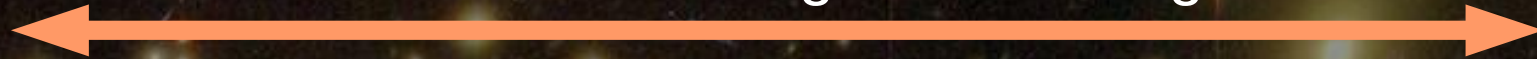


If I had a world of my own,
everything would be
nonsense. Nothing would
be what it is because
everything would be what
it isn't. And contrary-wise;
what it is it wouldn't be,
and what it wouldn't be, it
would. You see?

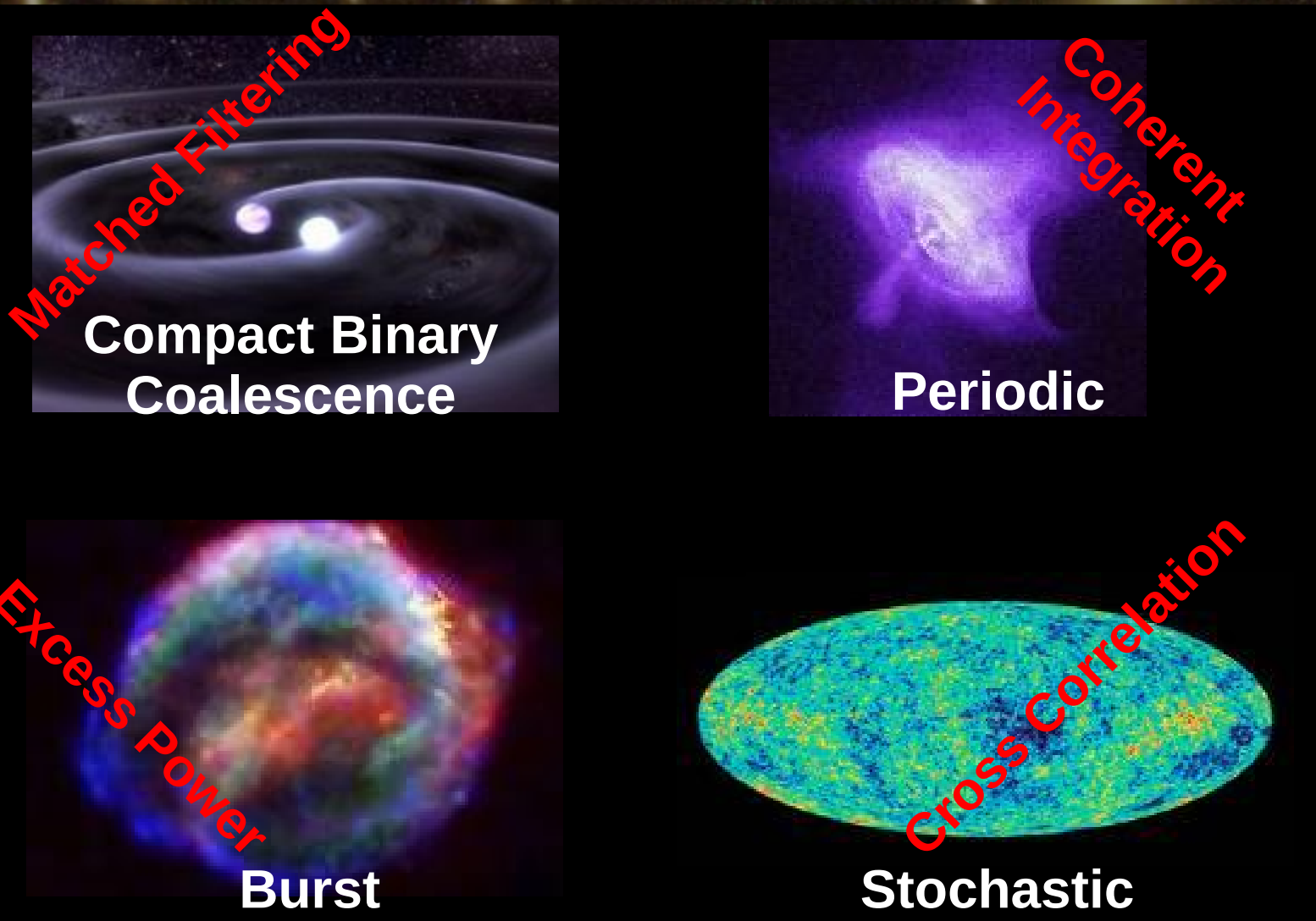
- Newton's Gravity
 - Instantaneous (action at a distance)
 - A force (mechanical)
- Einstein's Gravity
 - Limited by speed of light!
 - Geometrical
- What about every day gravity?

Gravitational Wave Sources

Short Duration to Long Duration Signals

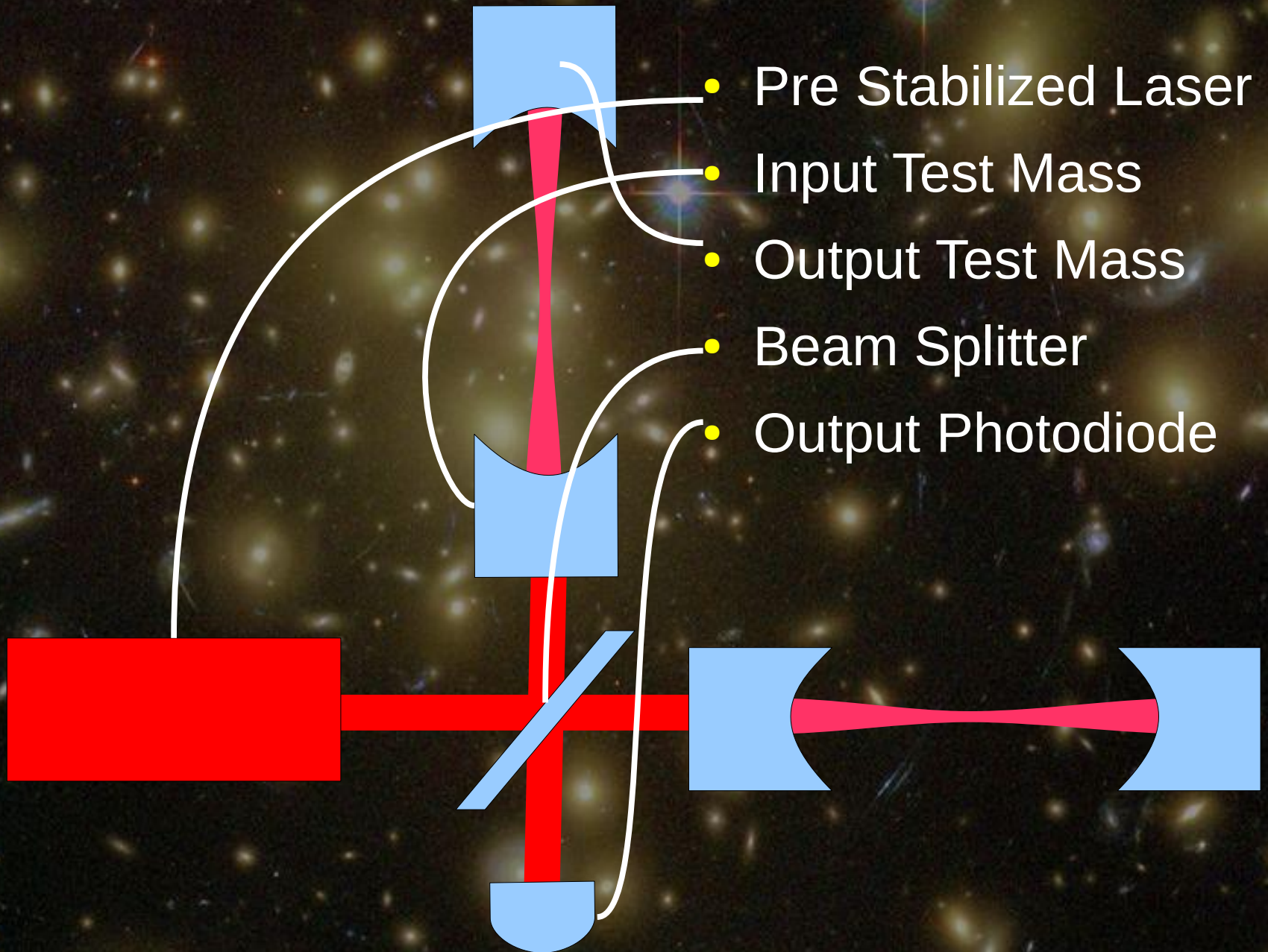


Unknown Waveform to Known Waveform



Gravitational Radiation Antenna

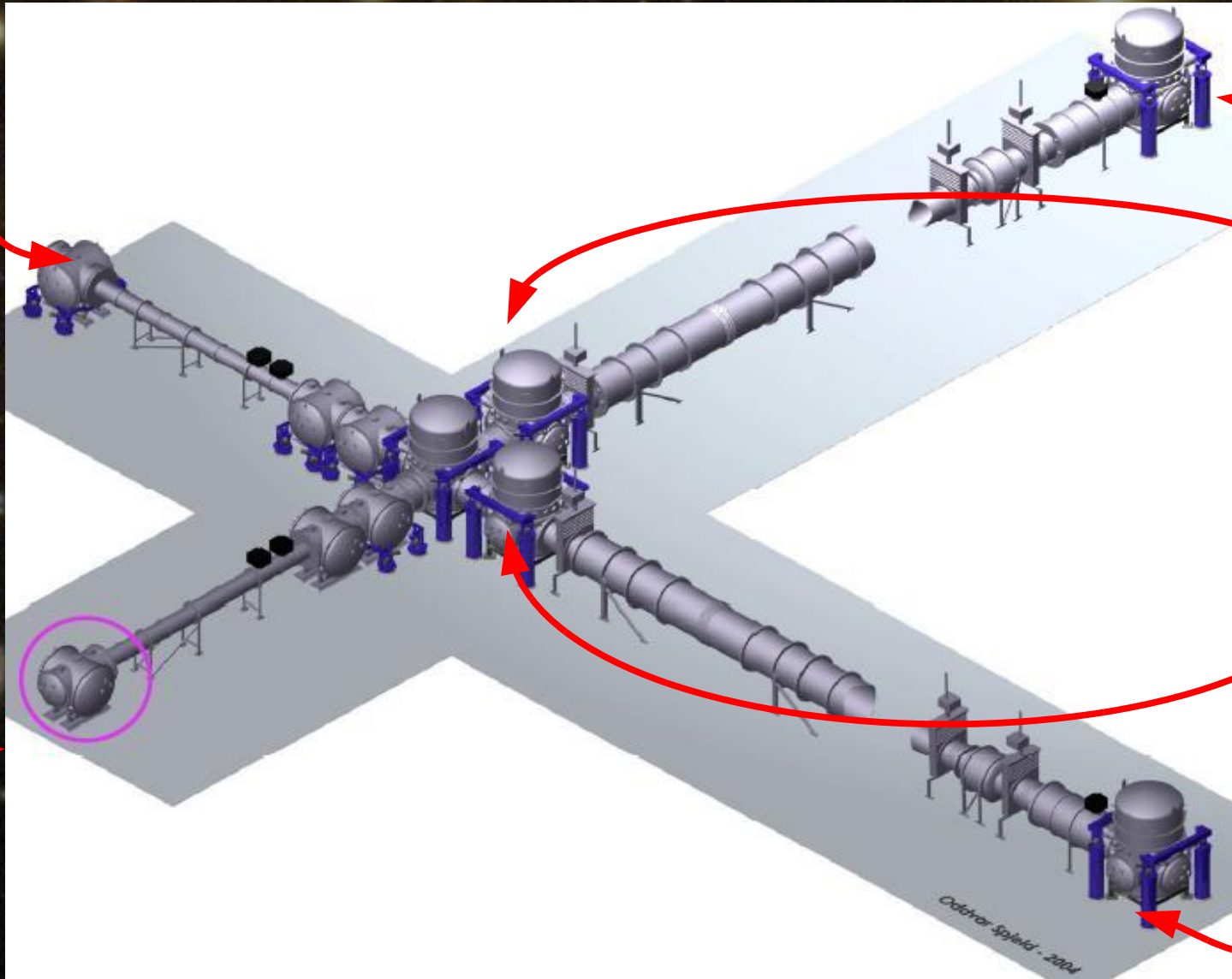
simplified



Gravitational Radiation Antenna

NOT so simplified

Input
Laser
Housing



Large
Optics
Housing

Output
Photo-diode
Housing

October 2014

Gravitational Radiation Antenna

NOT so simplified

- Very susceptible to environmental effects
 - Wind
 - Rain
 - Ground Motion



(LIGO.org)

Gravitational Radiation Antenna

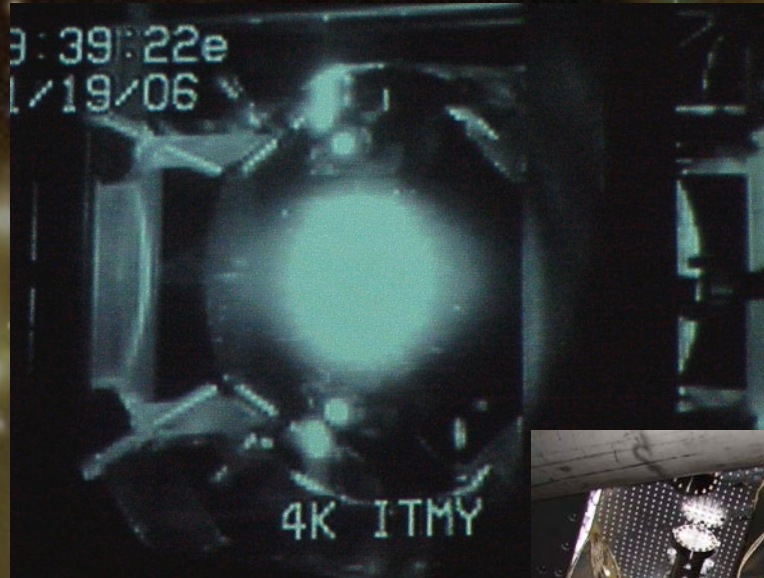
NOT so simplified

- New technologies for ultra-high precision measurements
 - Ultra stable laser
 - New optical coatings
 - Complex isolation control servos

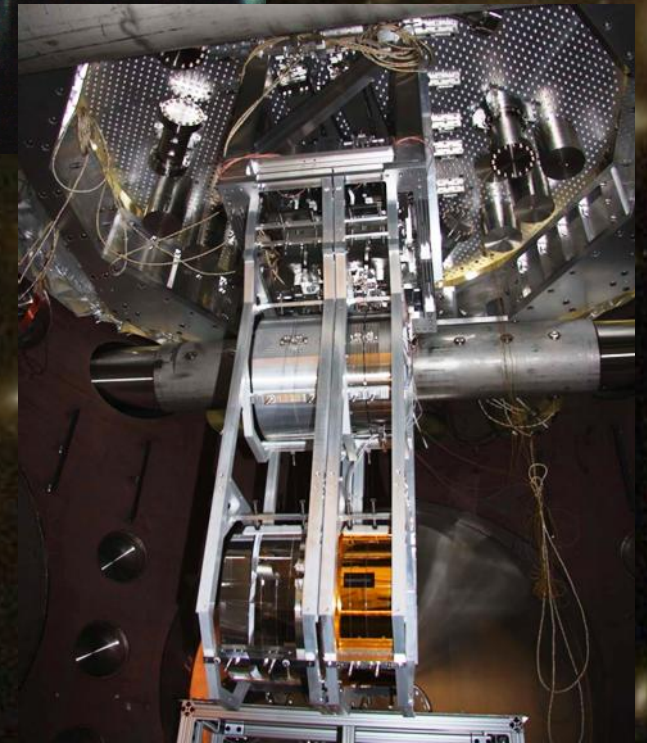


Gravitational Radiation Antenna

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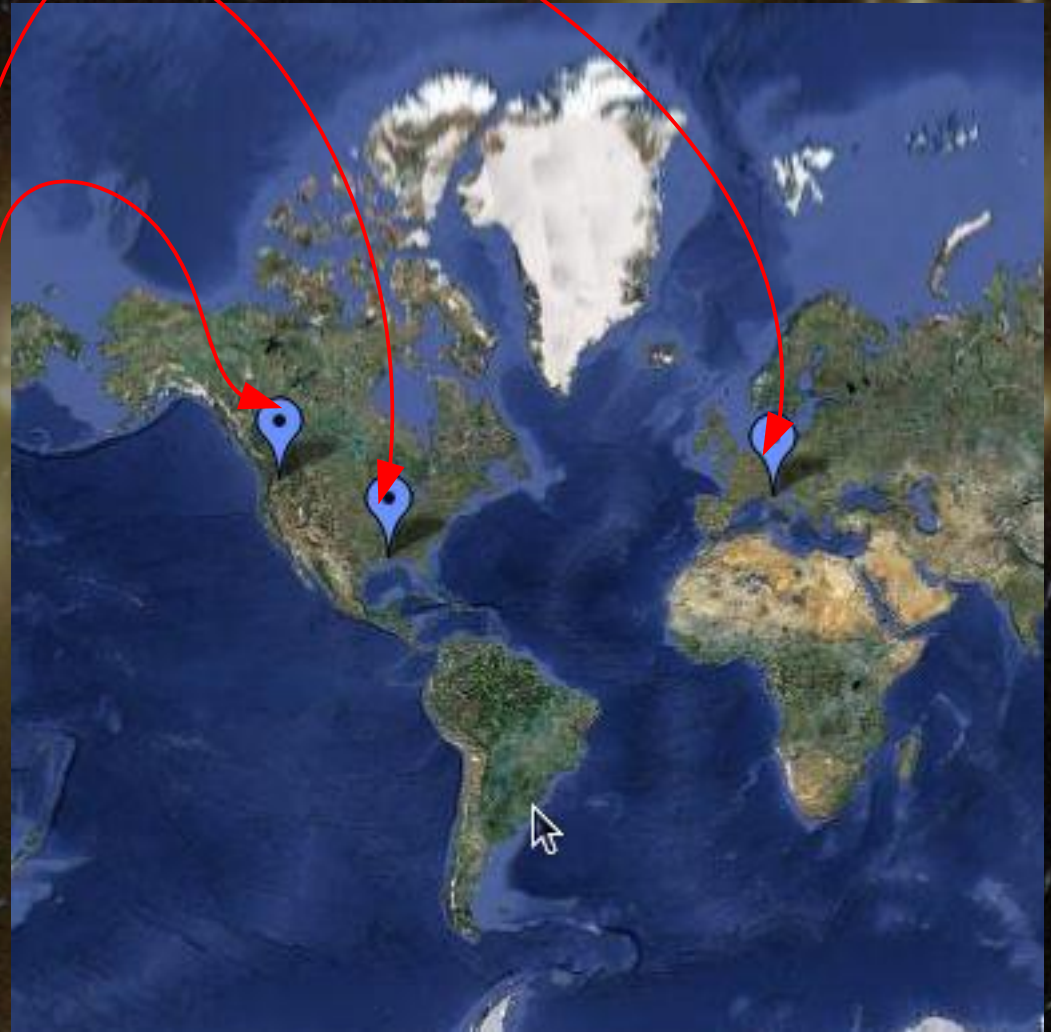


- For required high precision measurements new technologies developed
 - Ultra stable laser
 - New optical coatings
 - Complex isolation control servos



Global GW Detector Network

- LIGO (United States)
 - 4km (Livingston)
 - (4km & 2km) Hanford
- Virgo (French/Italian)
 - 3km (Cascina)
- GEO (German/British)
 - 600m (Sarstedt)
- TAMA (Japan)
 - 300m (Tokyo)
 - LCGT



LIGO Livingston Observatory

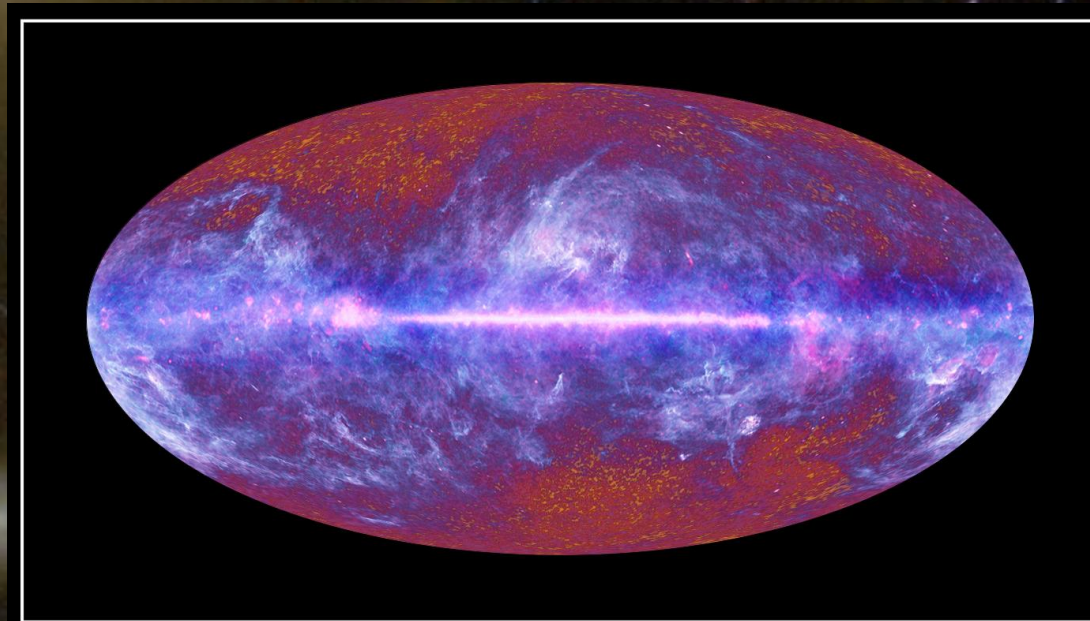


LIGO Hanford Observatory



Gravitation Wave Astronomy

- Fundamentally Different... How so?
 - Doesn't rely on light
 - Source physics travels universe undisturbed
 - Generated by all dynamical astronomical size systems (several solar masses and above, and dense!)
- Observing the Sky!
 - Omni-directional
 - Poor sky resolution of potential sources
 - Observatory network needed



Gravitation Wave Astronomy

- Type Ia Supernova events



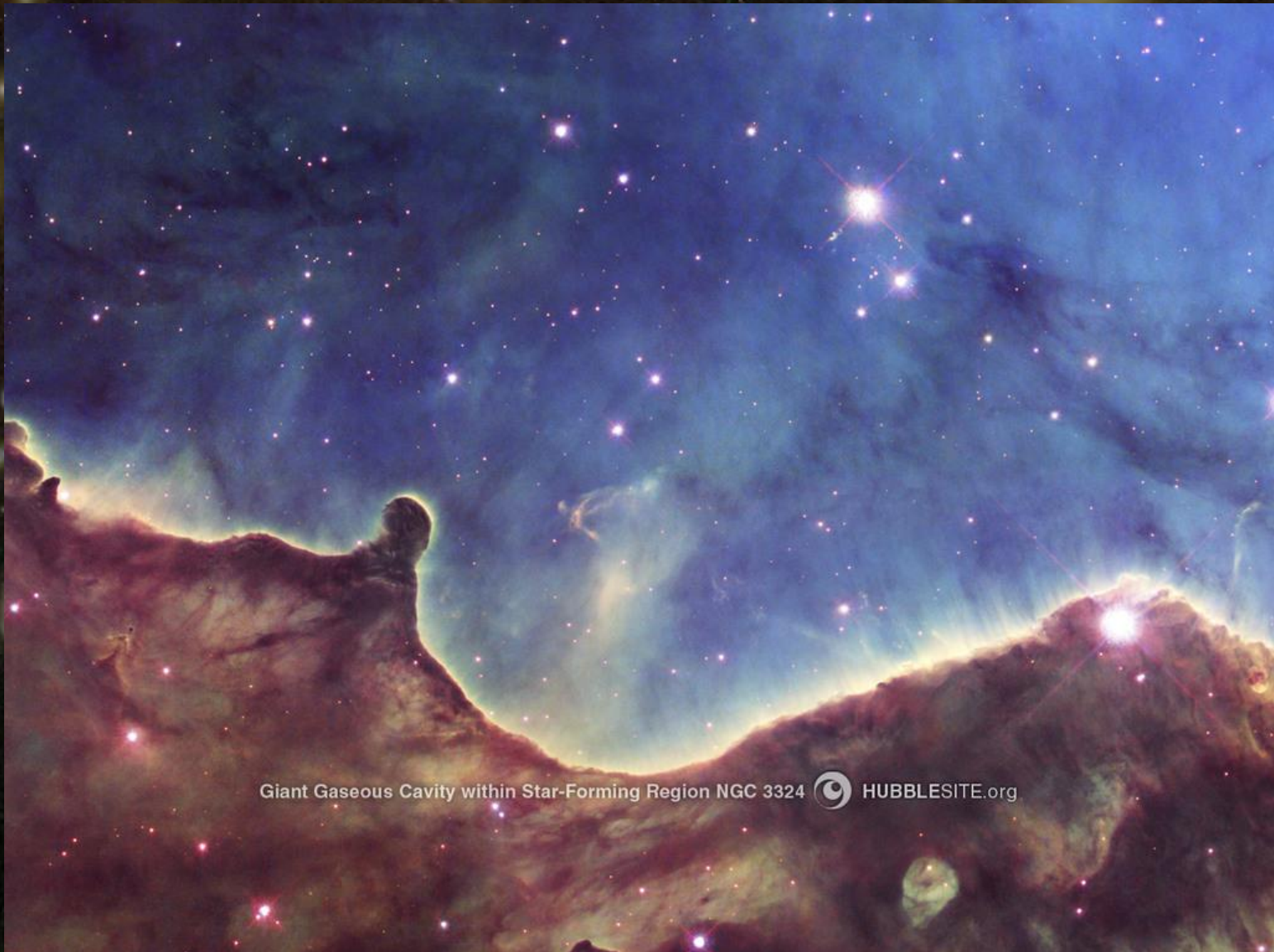
Gravitation Wave Astronomy


- Millisecond Pulsar



Gravitation Wave Astronomy

- Exotic unknown phenomena



Giant Gaseous Cavity within Star-Forming Region NGC 3324  HUBBLESITE.org

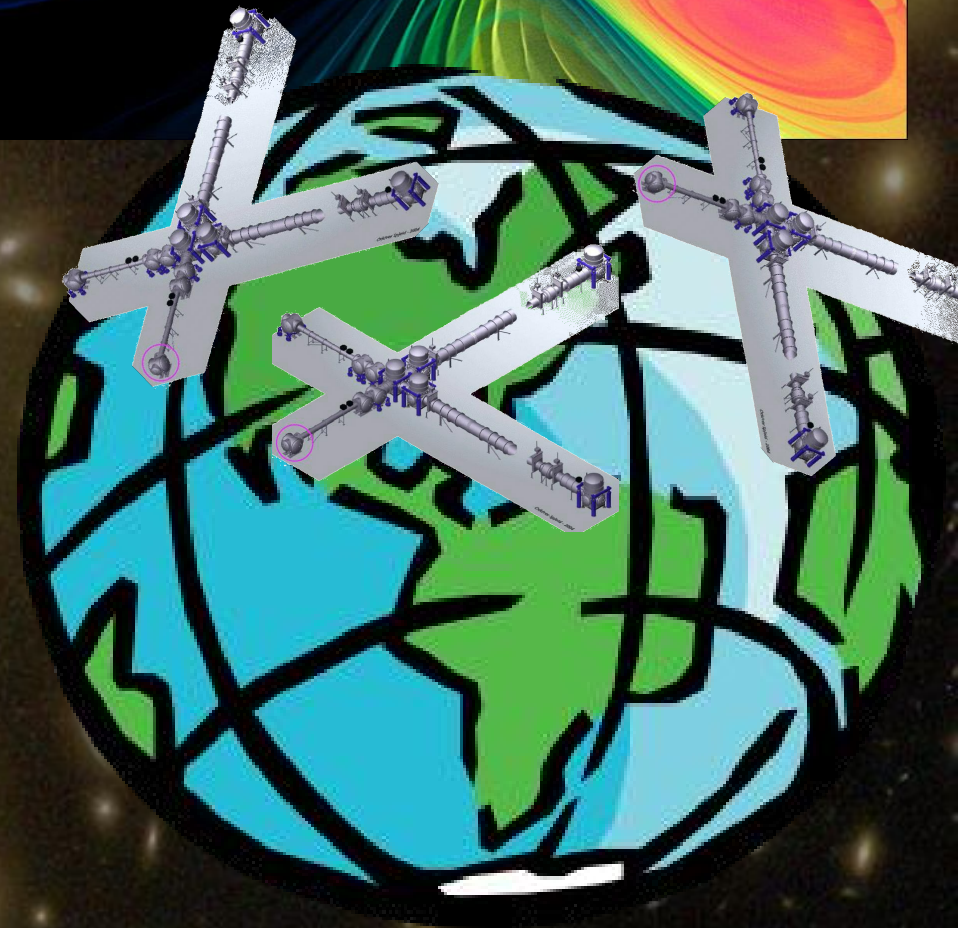
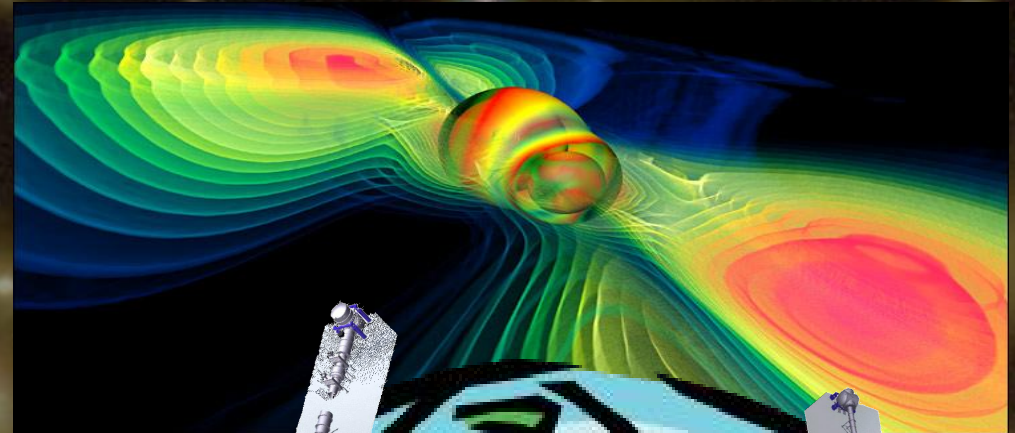
Mechanics of GW Searches

- Search Types
 - Match Filtering
 - Excess Power
 - Coherent Integration
 - Cross Correlation
- Observatories Involved
 - No less than 2 sites



Compact Binary Coalescence

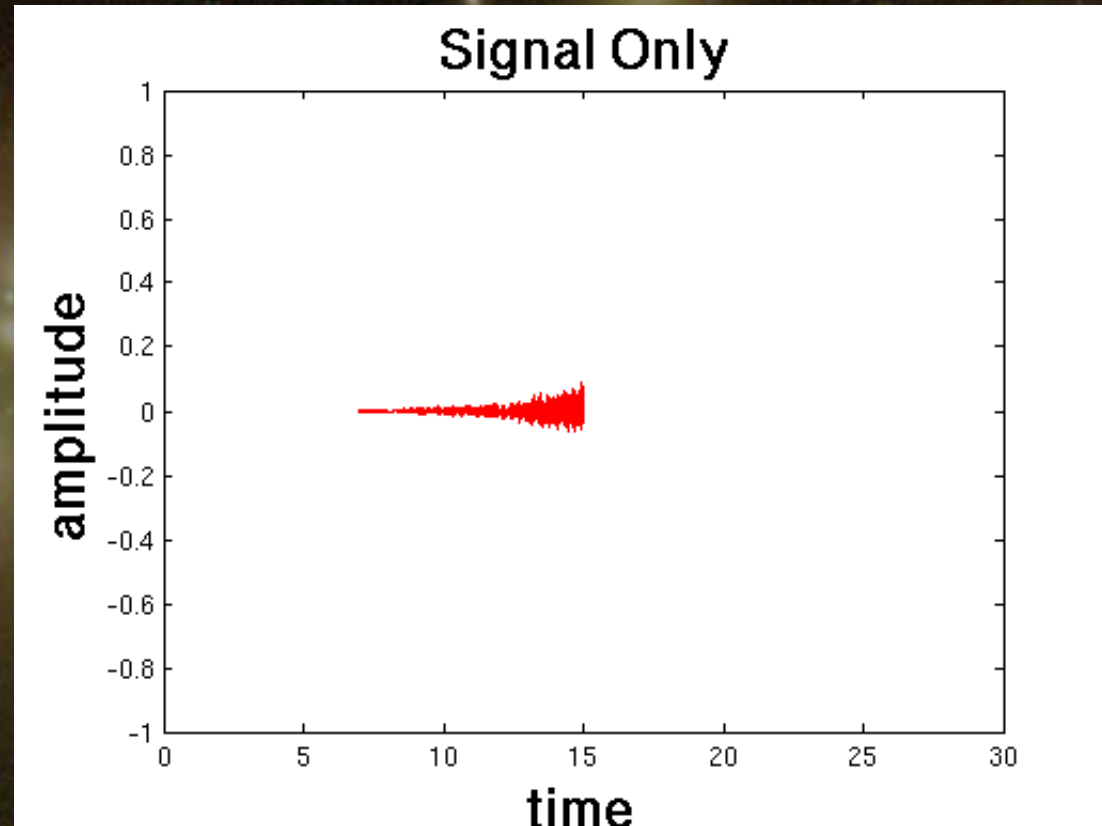
- Use theoretical knowledge to construct signal models
- Compare models to observatory data
- Account for environment
- Compare common interesting events
- If events pass criteria...



DETECTION

Compact Binary Coalescence

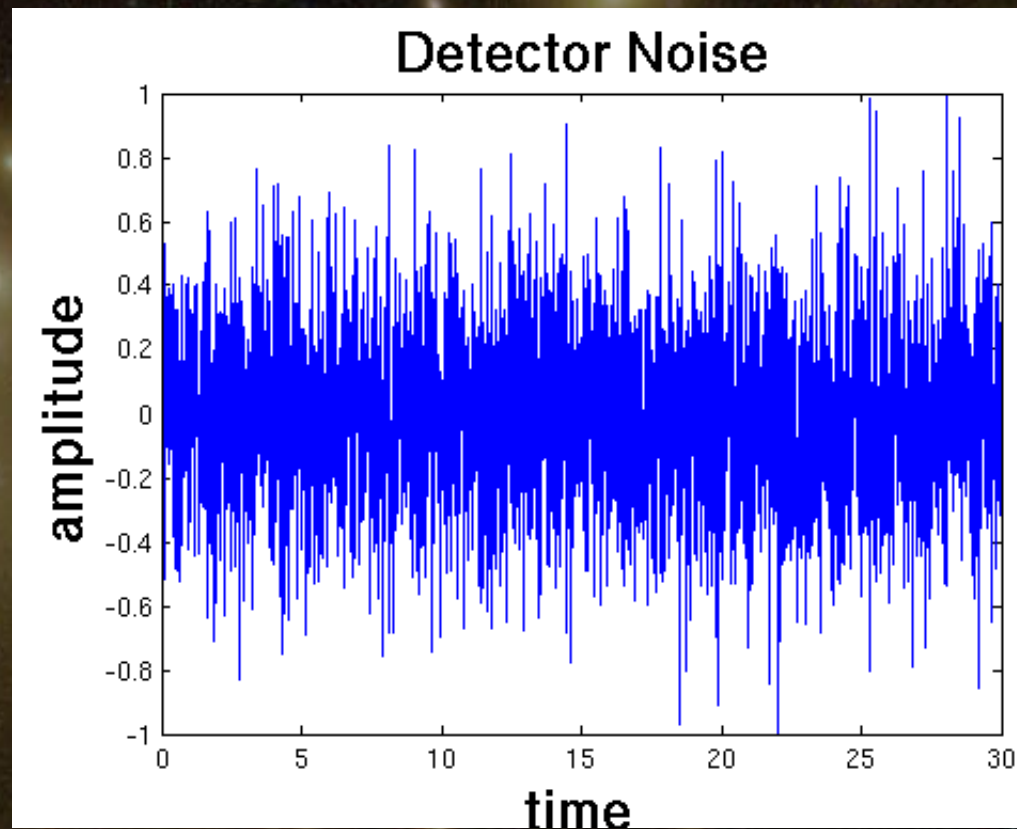
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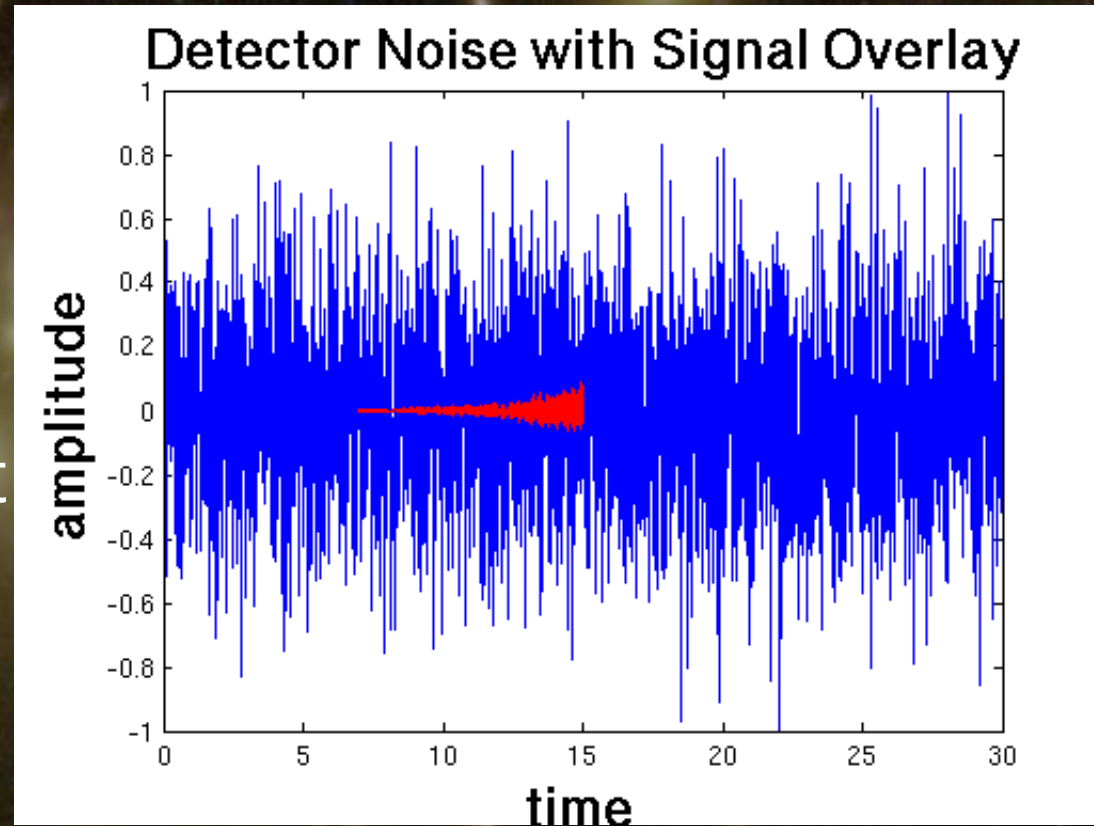
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Compact Binary Coalescence

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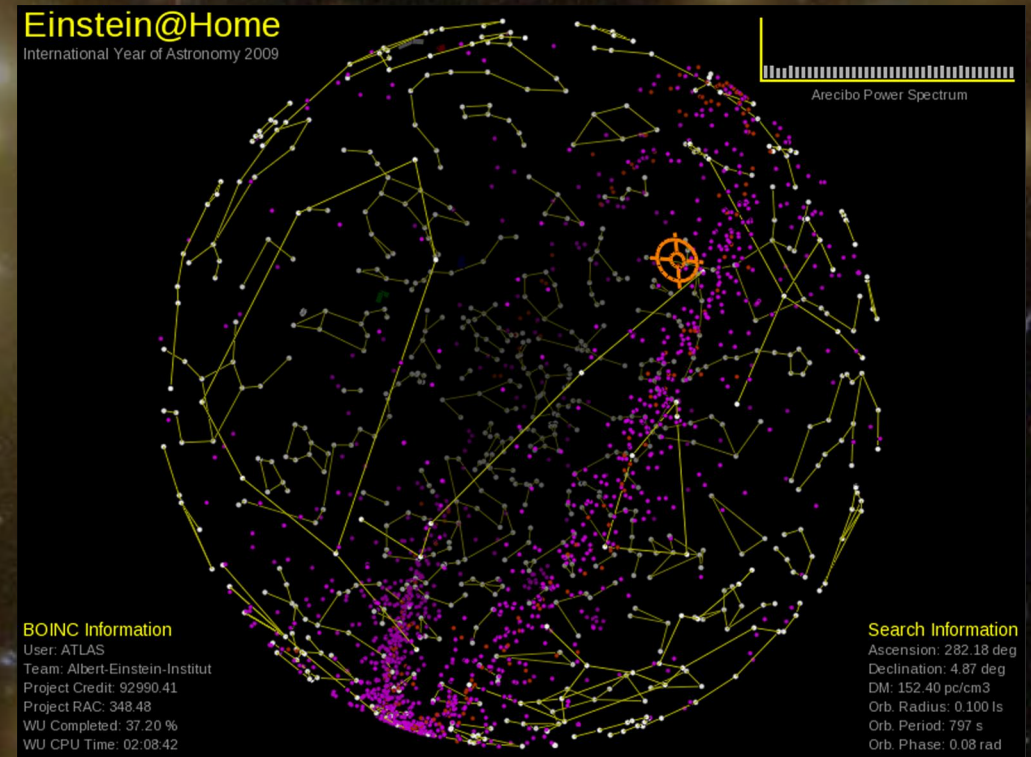


DETECTION

Ask not what GWs can do for you...



- Search Target Sources
 - Continuous wave sources
 - Radio Pulsar identification
- Computing
 - Multi-OS
 - Social network of users



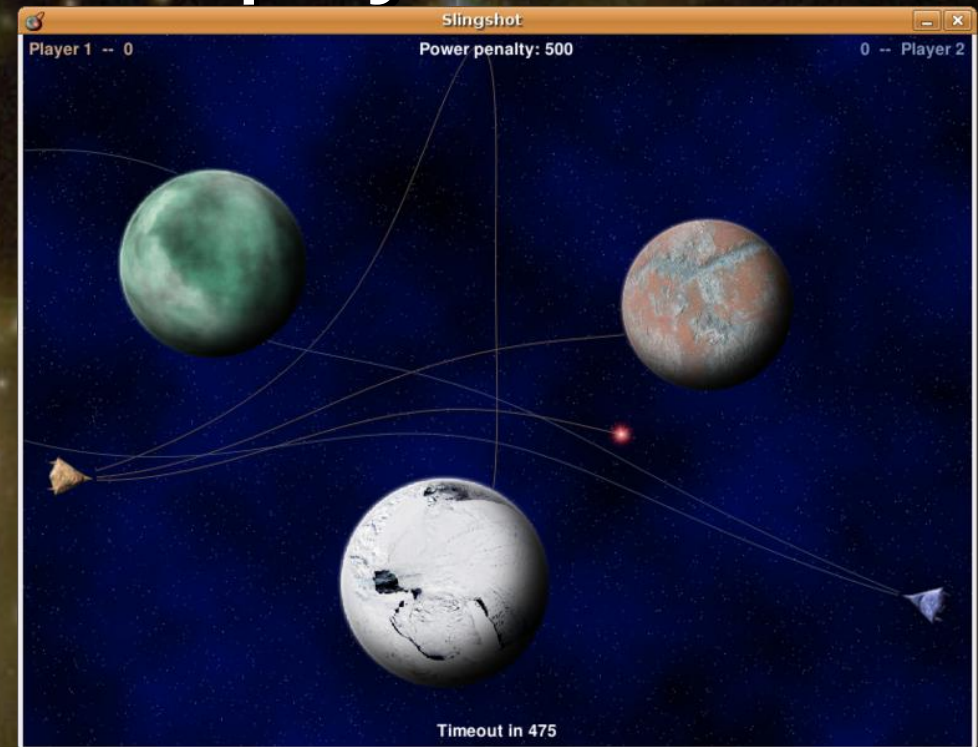
What is ahead in our field?

- Major instrumental upgrades to increase sensitivity (3-5yrs)
- Advanced LIGO, 1000X observational volume increase
- All observatories in network in simultaneous upgrade
- Regular observations will start occurring..



Relaxing as a GW physicist

- Playing video games
 - **Slingshot** →
 - **Spacetime Quest** ↘
- Public Outreach
 - Educational activities
 - Observatory tours
- Run of the mill activities



We Can Do It!



J. J. Mordant

POST FEB. 15 TO FEB. 20



WAR PRODUCTION CO-ORDINATING COMMITTEE

Interesting Links

- Light - <http://missionscience.nasa.gov/ems/>
- LIGO Project - www.ligo.org
- Einstein's Messengers - <http://youtu.be/yHkMYpKExh8>
- Slingshot - <http://slingshot.wikispot.org/>
- Spacetime Quest -
http://www.gwoptics.org/processing/space_time_quest/
- AI's Relativistic Adventures ('05 Pirelli Relativity Challenge)