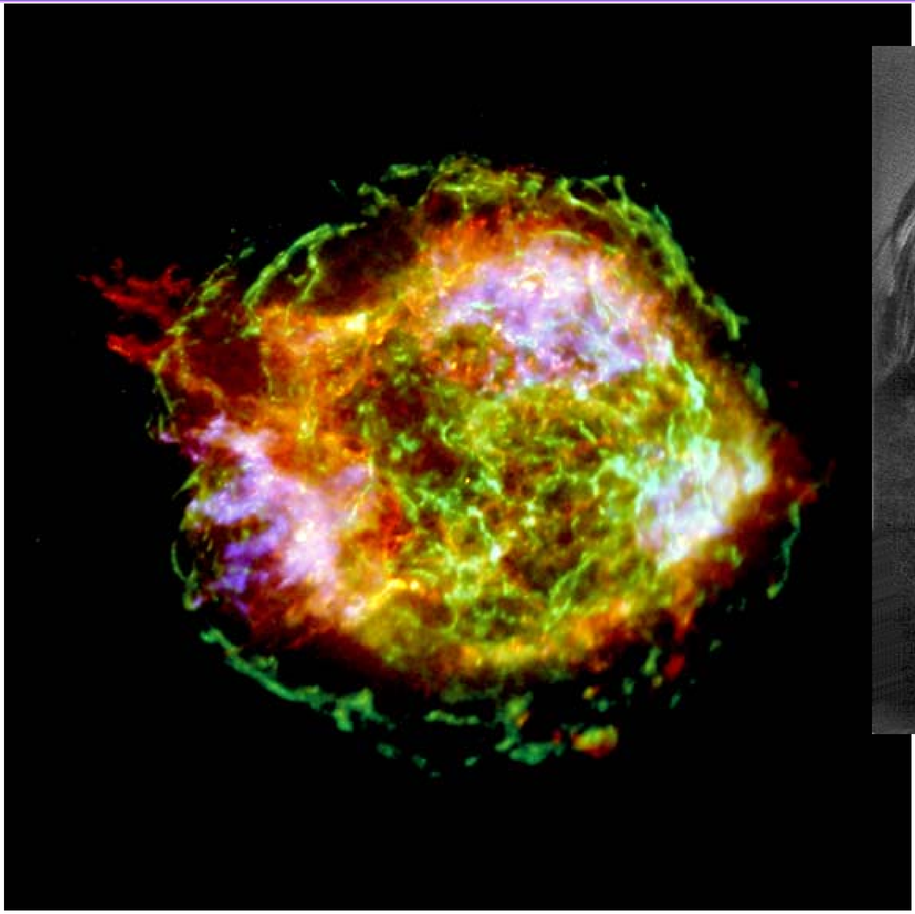
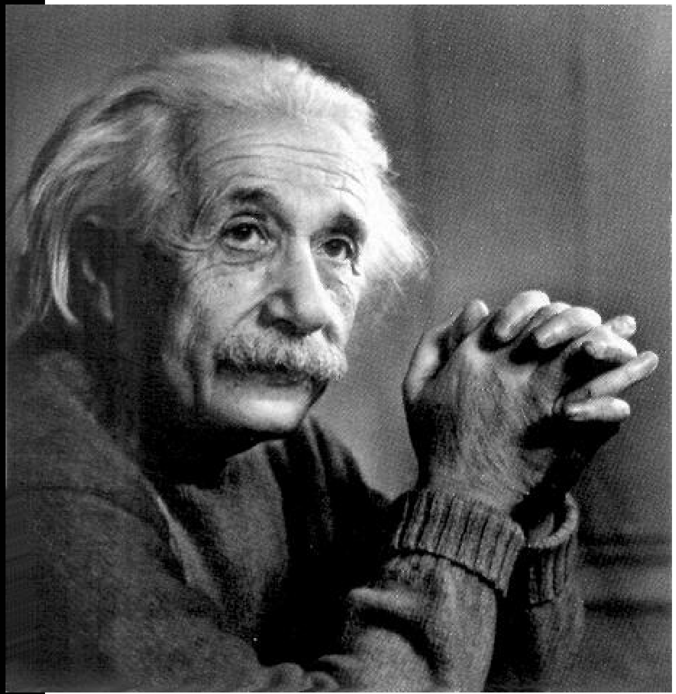
Expanding Horizons: Yours. Mine. The Universe’s



Supernova remnant Cas A
Credit: NASA/CXC/GSFC/U. Hwang et al.



Dr. Michael Landry
LIGO Hanford Observatory
California Institute of Technology

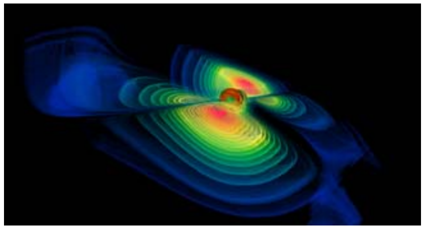
LIGO-G060230-00-Z

What this talk is about

Physics and physicists

Cool stuff about gravity, curved space, and some of the most violent events in the universe

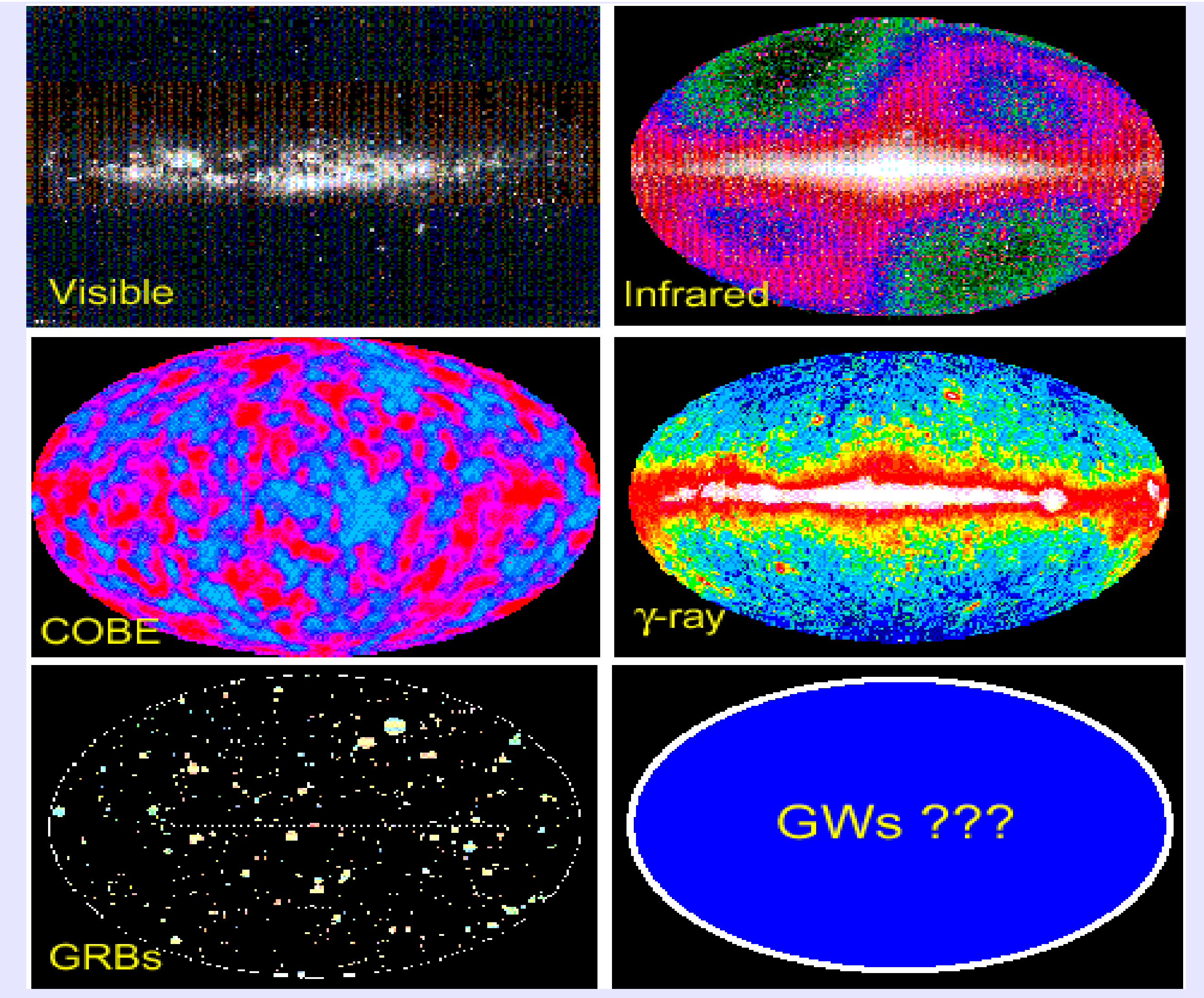
Cool women physicists that I have the privilege to know and work with



What this talk is about

LIGO Observatory: instruments for the detection of gravitational waves

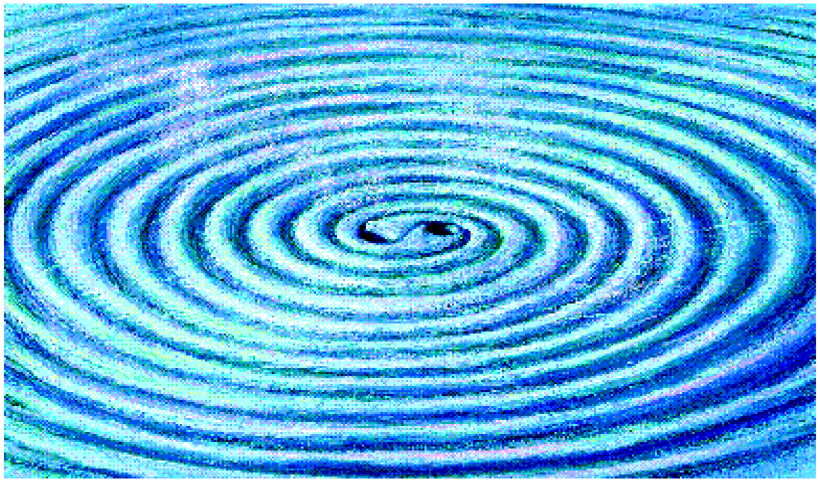
What might the sky look like in gravitational waves?



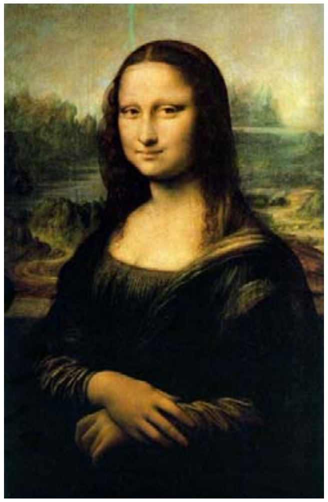
Gravitational waves

Gravitational waves are ripples in space when it is stirred up by rapid motions of large concentrations of matter or energy

Rendering of space stirred by two orbiting neutron stars:

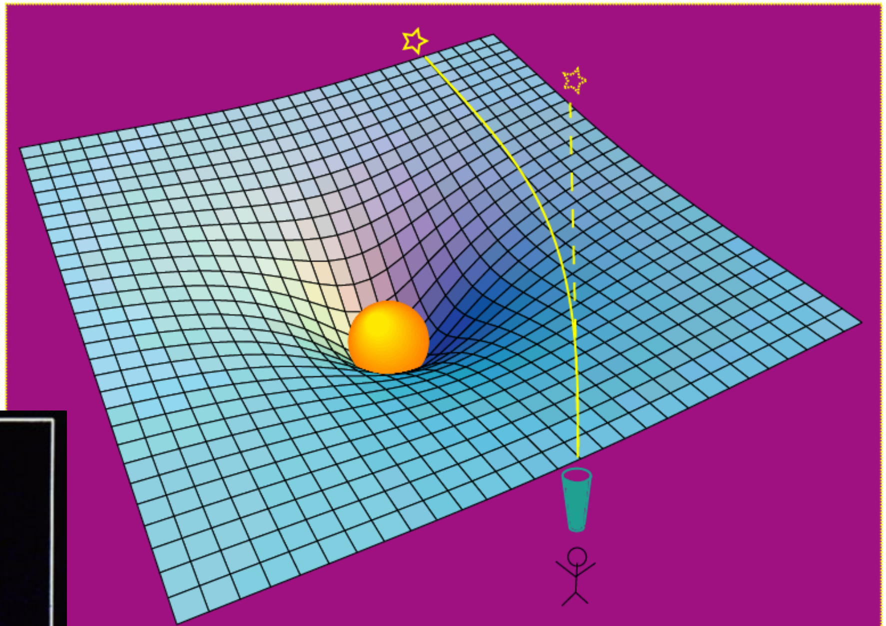


It’s space that expands and contracts

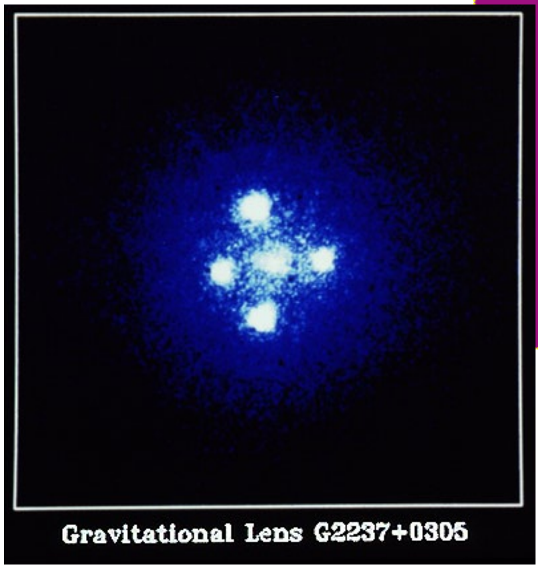


Go figure: space is curved

Not only the path of matter, but even the path of light is affected by gravity from massive objects



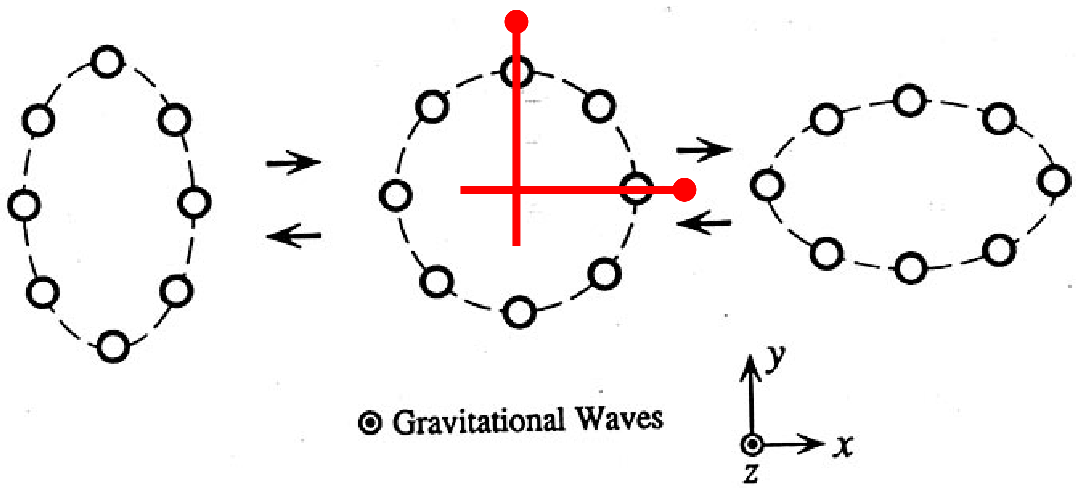
A massive object shifts apparent position of a star



Einstein Cross
Photo credit: NASA and ESA

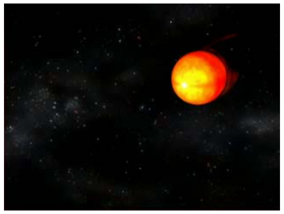
The effect of gravitational waves

Gravitational waves shrink space along one axis perpendicular to the wave direction as they stretch space along another axis perpendicular both to the shrink axis and to the wave direction.



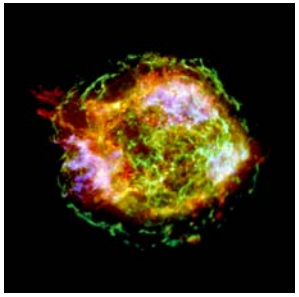
What can make gravitational waves?

Stars live…



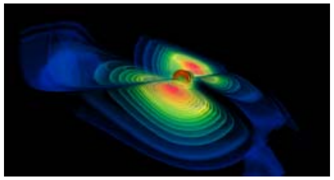
(ordinary star)

Stars die…

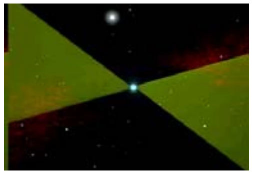


(supernova)

And sometimes they leave good-looking corpses…



(black holes)



(pulsars, neutron stars)

Supernova: death of a massive star

- Spacequake should preceed optical display by ½ day
- Leaves behind compact stellar core, e.g., neutron star, black hole
- Strength of waves depends on asymmetry in collapse
- Observed neutron star motions indicate some asymmetry present
- Simulations do not succeed from initiation to explosions

Credit: Dana Berry, NASA

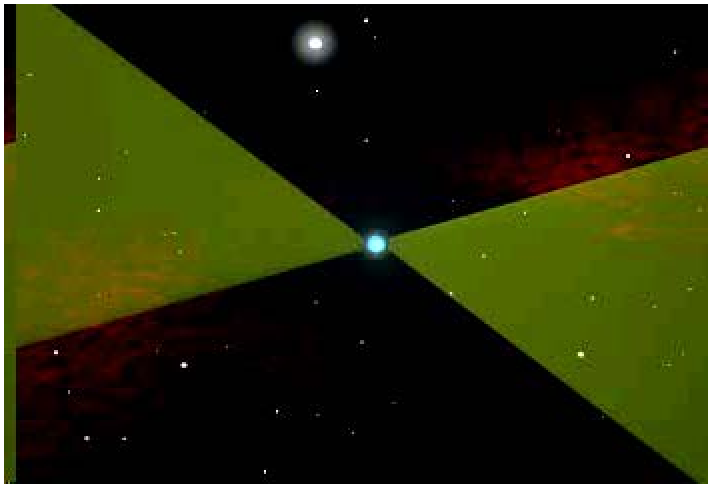
Dr. Laura Cadonati

- Born Bergamo, Italy
- Research scientist, MIT
- Specializes in data analysis for "burst" signals, such as may be given off by supernovae
- Prior to LIGO : work in the field of particle physics
- Hobbies include quilting, reading, movies, hiking

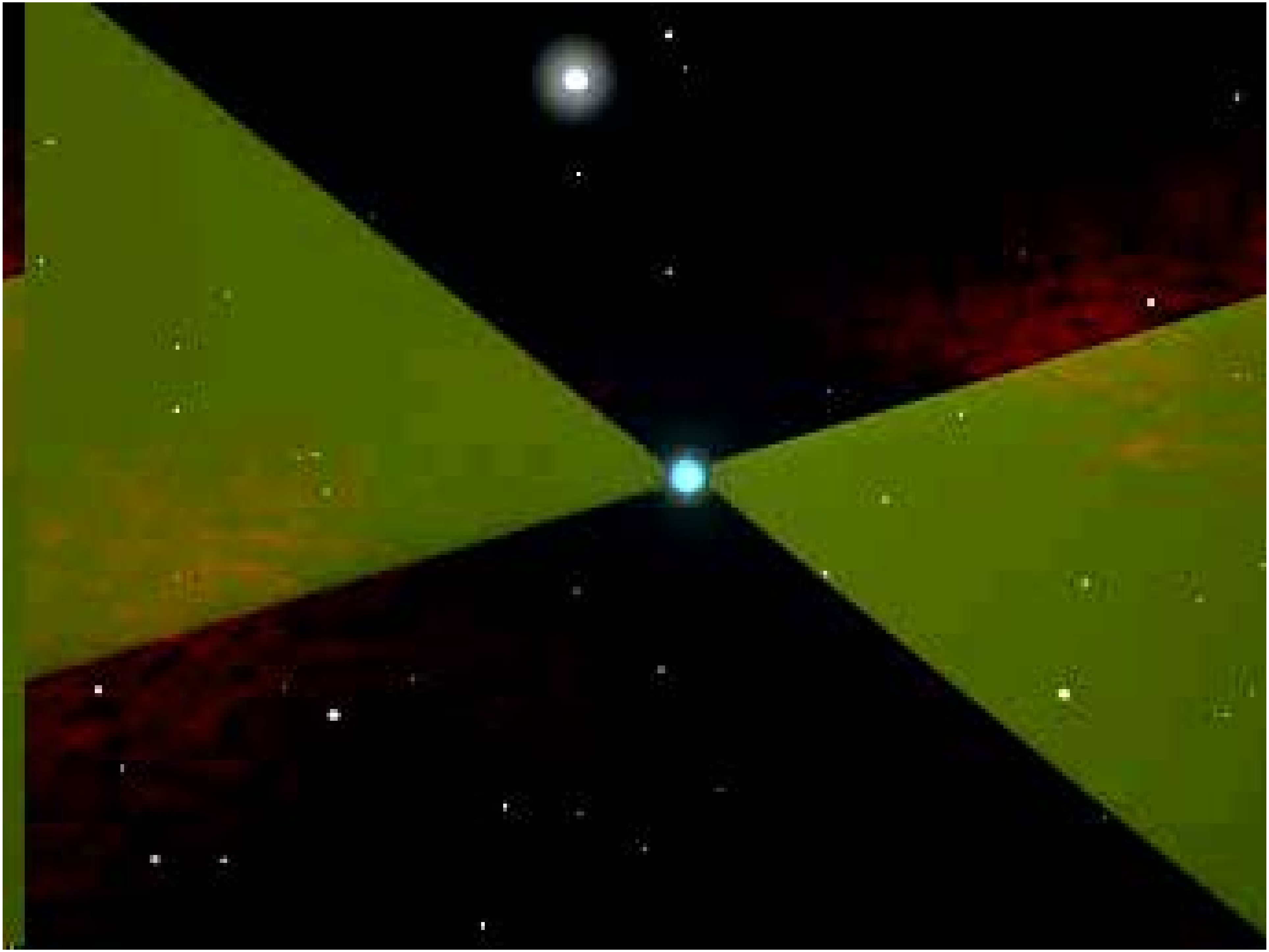
Supernovae specialist

The "Undead" corpses of stars: neutron stars and black holes

- Neutron stars have a mass equivalent to 1.4 suns packed into a ball 10 miles in diameter, enormous magnetic fields and high spin rates
- Black holes are the extreme edges of the space-time fabric

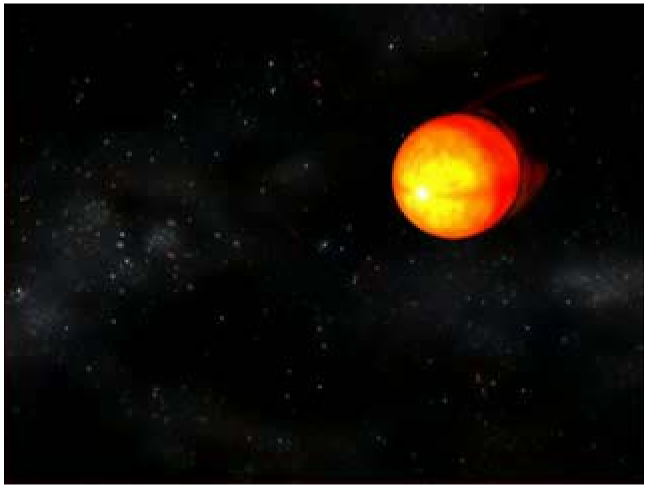


Artist: Walt Feimer, Space Telescope Science Institute

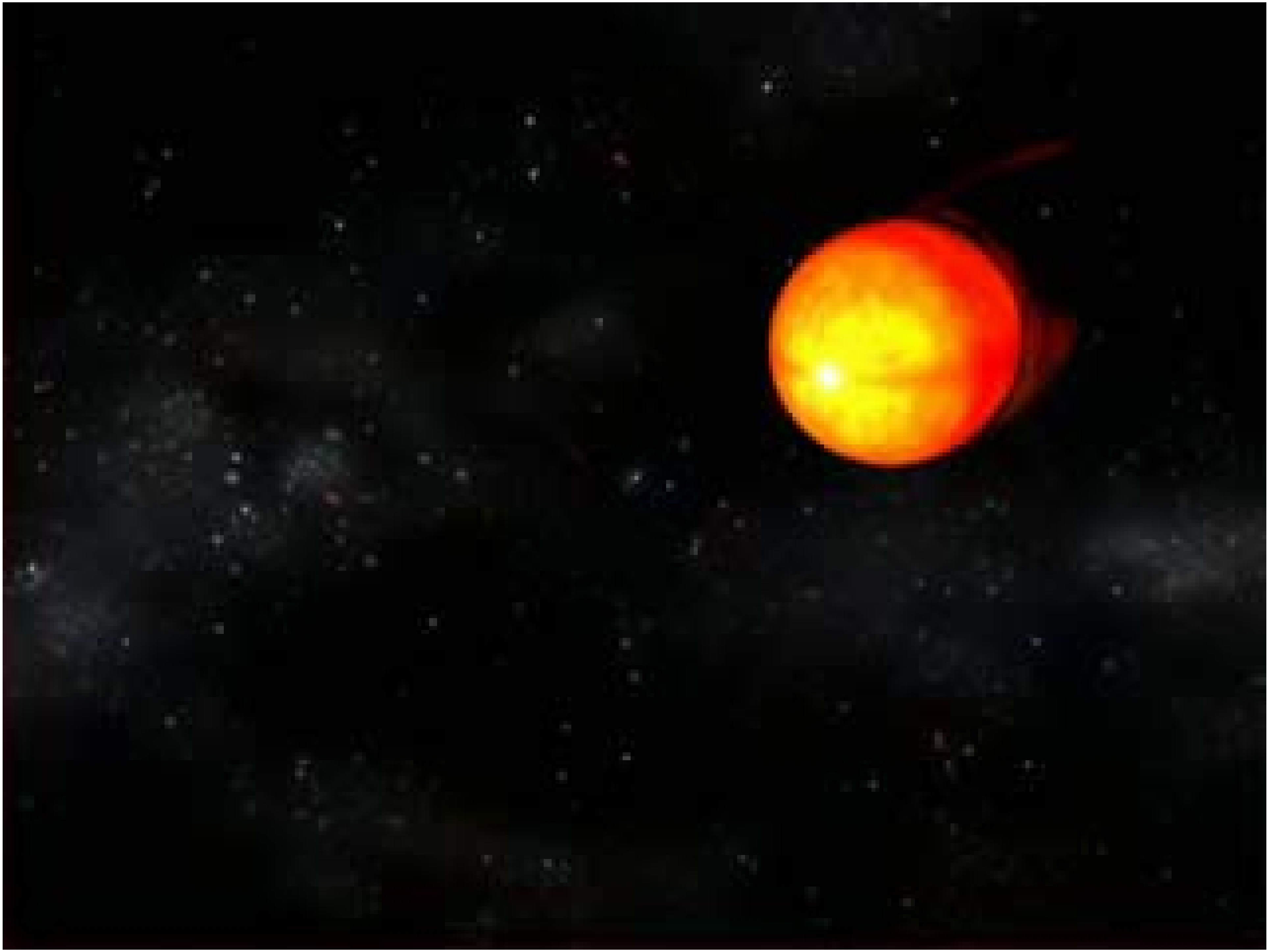


Neutron stars with an ordinary companion

- Like a figure skater pulling her arms in, neutron stars spin faster when they accrete matter from a companion
- Observed neutron star spins "max out" at ~700 times/second
- Gravitational waves are suspected to balance angular momentum from accreting matter



Credit: Dana Berry, NASA



Dr. Marialessandra Papa

- Born Rome, Italy
- Senior Scientist, UWM/AEI
- Data Analysis chair GEO & LIGO, leads pulsar group
- Specializes in analyses of data for gravitational waves from spinning neutron stars
- Hobbies include dance, jazz and choral singing, cooking

Pulsar specialist

Sounds of compact star inspirals

Neutron-star binary inspiral: 

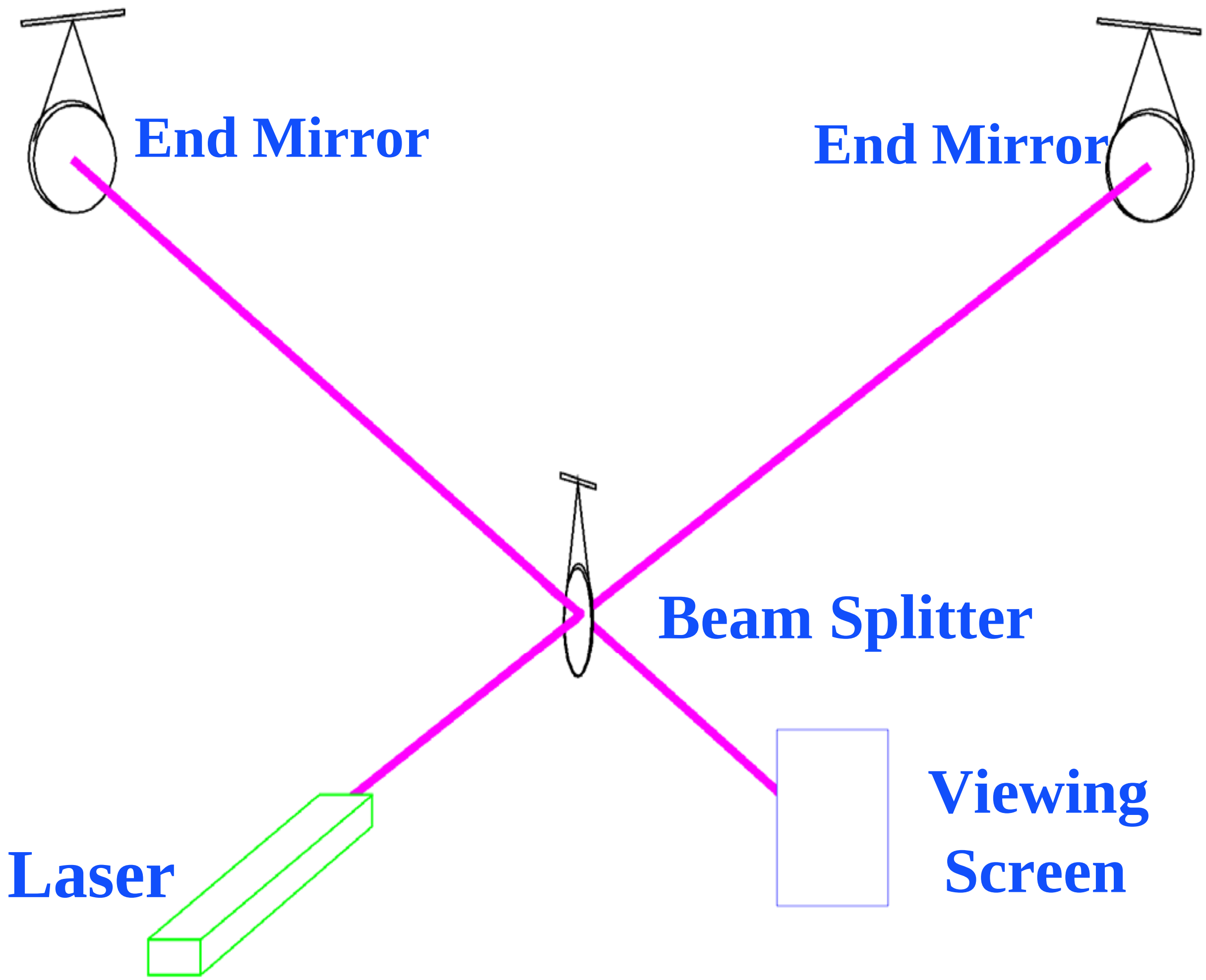
Black-hole binary inspiral: 

Dr. Gabriela González

- Born Cordoba, Argentina
- Associate Professor of Physics, LSU
- Design and implementation of many key subsystems of the Livingston interferometer
- Work on calibration: just how small a motion can we detect?
- Leads a group searching for binary inspirals

Binary star specialist

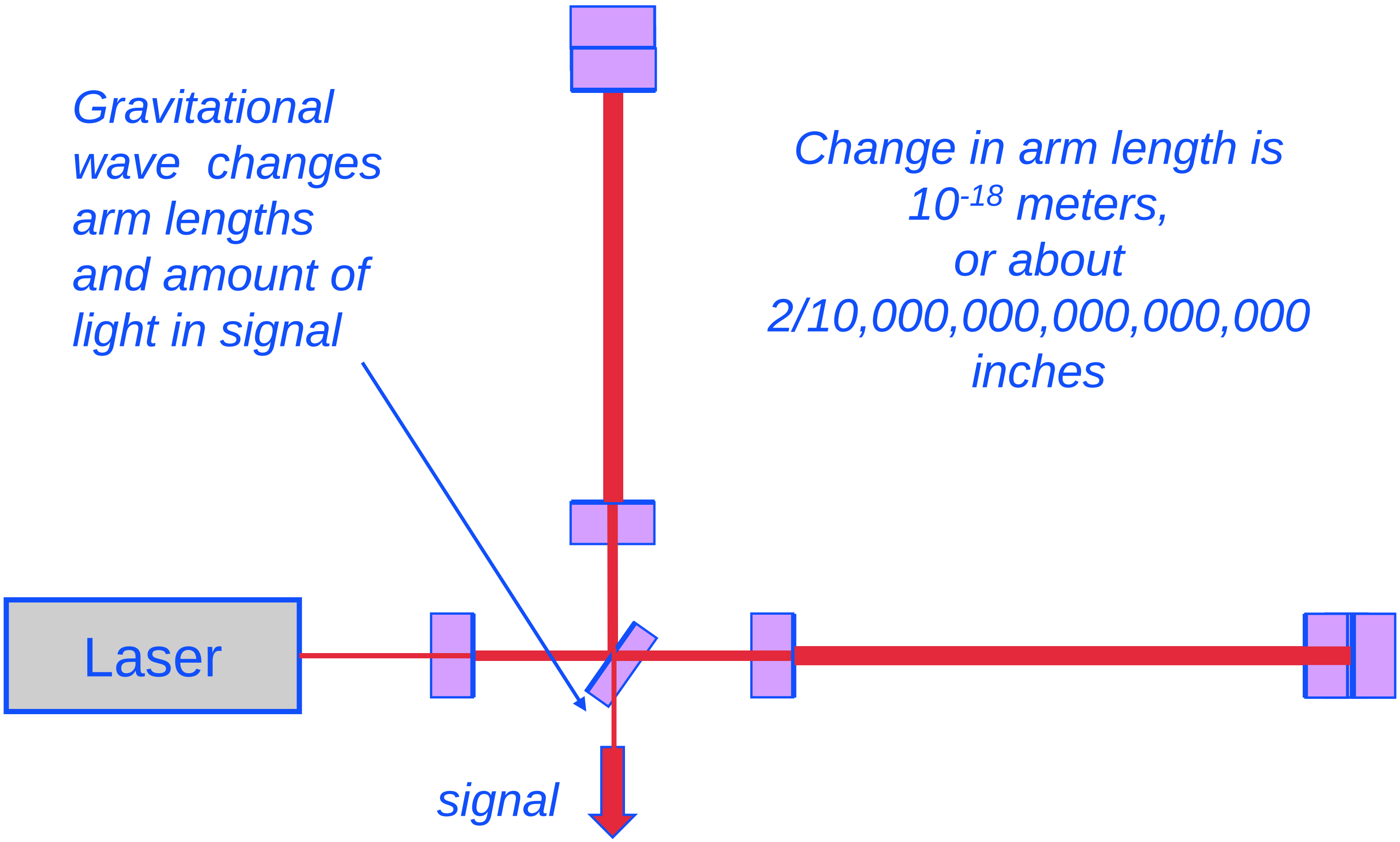
Sketch of a Michelson interferometer



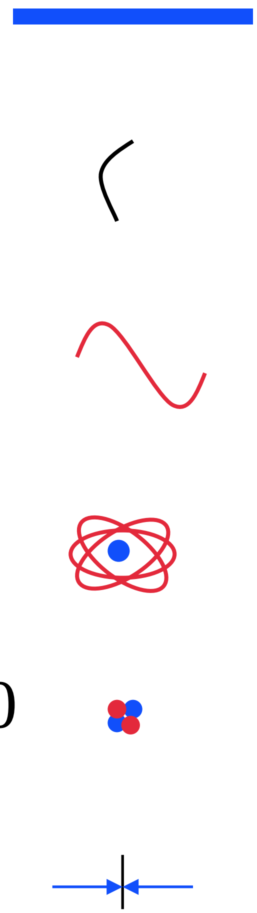
Sensing the effect of a gravitational wave

Gravitational wave changes arm lengths and amount of light in signal

Change in arm length is 10^{-18} meters, or about 2/10,000,000,000,000,000 inches



How small is 10^{-18} meter?



	One meter, about 40 inches
÷10,000	*Human hair, about 100 microns*
÷100	*Wavelength of light, about 1 micron*
÷10,000	*Atomic diameter, 10^{-10} meter*
÷100,000	*Nuclear diameter, 10^{-15} meter*
÷1,000	*LIGO sensitivity, 10^{-18} meter*

Dr. Nergis Mavalvala

- Born Karachi, Pakistan
- Professor of Physics, MIT
- Experimental gravitational wave detection and quantum measurement
- Design and implementation of many of the key subsystems that make our current detectors run so sensitively
- cycling, running, squash, political activism

interferometer specialist

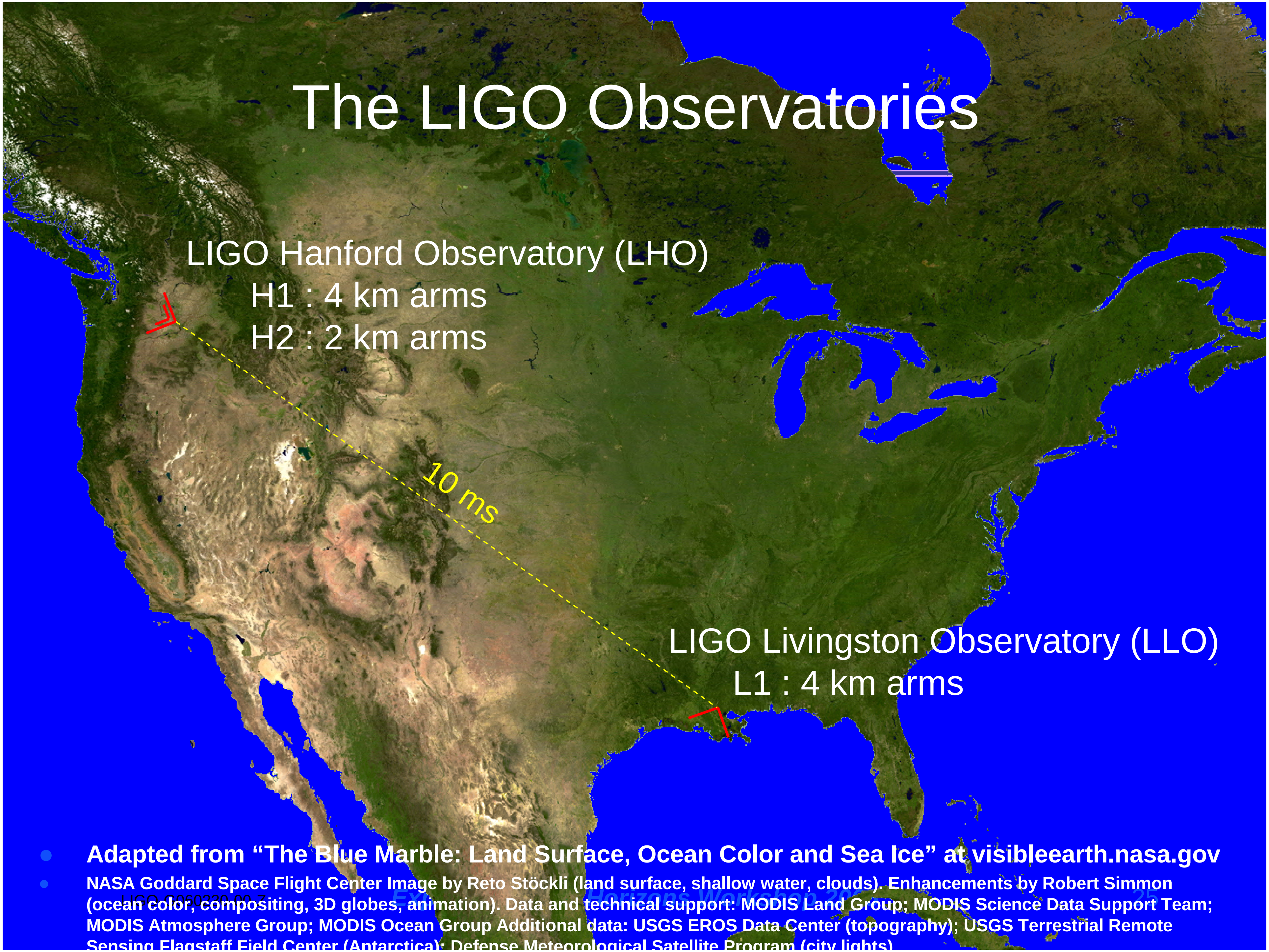
The Laser Interferometer Gravitational-Wave Observatory

LIGO (Washington)

LIGO (Louisiana)

Brought to you by the National Science Foundation; operated by Caltech and MIT; the research focus for more than 500 LIGO Scientific Collaboration members worldwide.

The LIGO Observatories



- **Adapted from "The Blue Marble: Land Surface, Ocean Color and Sea Ice" at visibleearth.nasa.gov**
- **NASA Goddard Space Flight Center Image by Reto Stöckli (land surface, shallow water, clouds). Enhancements by Robert Simmon (ocean color, compositing, 3D globes, animation). Data and technical support: MODIS Land Group; MODIS Science Data Support Team; MODIS Atmosphere Group; MODIS Ocean Group Additional data: USGS EROS Data Center (topography); USGS Terrestrial Remote Sensing Flagstaff Field Center (Antarctica); Defense Meteorological Satellite Program (city lights).**

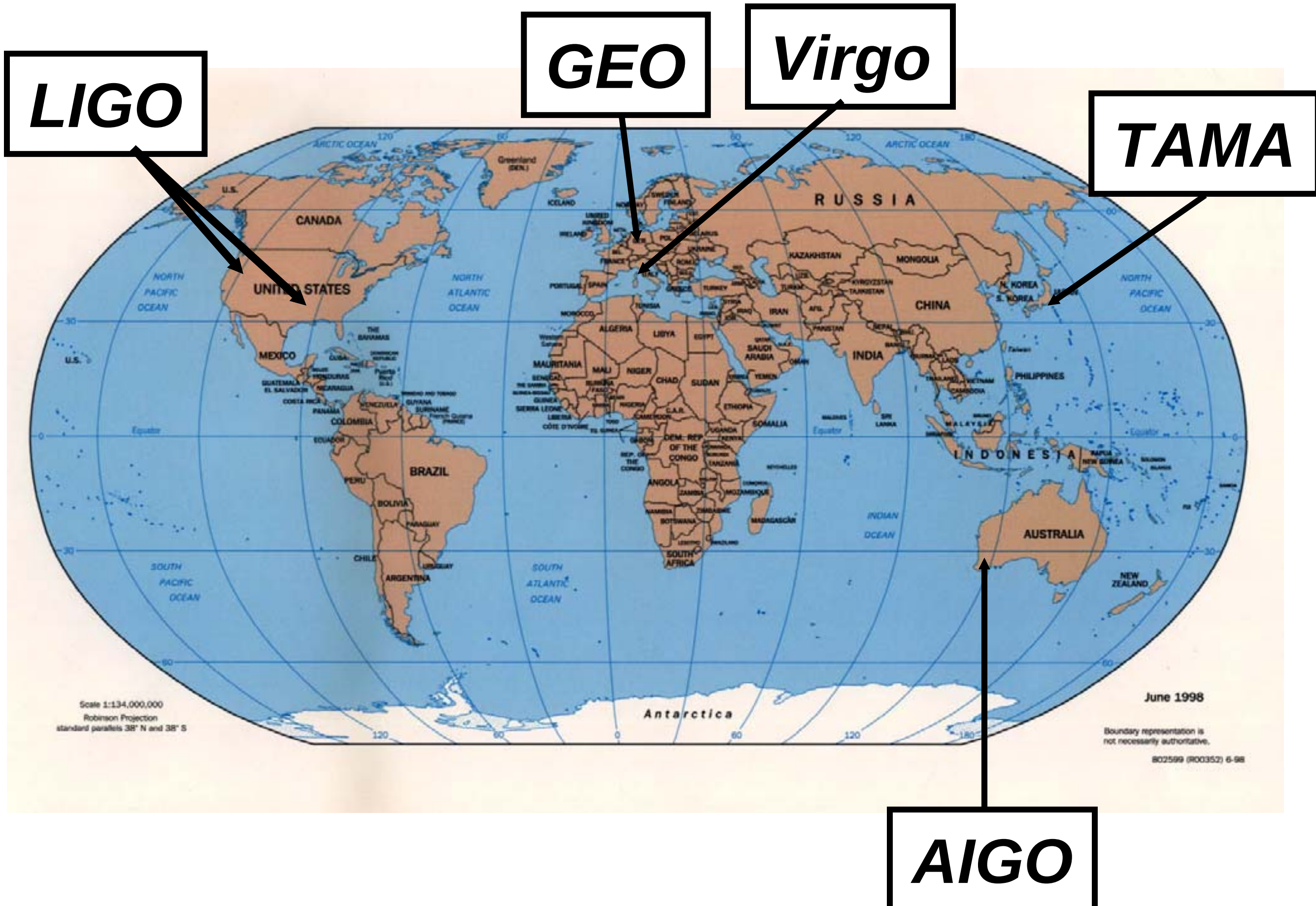
Betsy Bland

- Born Portland, OR
- Operator/Assistant Engineer, LIGO Hanford Observatory
- Works on operations and controls of interferometers, installed most of the key optics in the detectors
- Husband Mack, son Theo (2), enjoy boating on the Columbia

optics specialist

Part of future international detector network

Simultaneously detect signal (within msec)



detection confidence

locate the sources

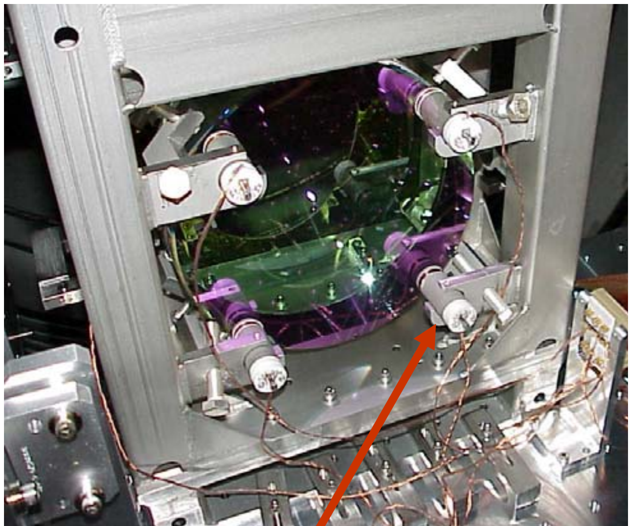
decompose the polarization of gravitational waves

Vacuum chambers: quiet homes for mirrors

View inside Corner Station

Standing at vertex beam splitter

Core Optics



Optics suspended as simple pendulums

Local sensors/actuators provide damping and control forces

Mirror is balanced on 1/100th inch diameter wire to 1/100th degree of arc

Cheryl Vorvick

- Born Vancouver, Canada, raised in Seattle
- Operator at LIGO Hanford Observatory
- Works in interferometer operations, specializes in laser thermal compensation
- Hobbies include drawing and sailing
- NASA internship: Star Spangled Banner composite image used by Polo Ralph Lauren

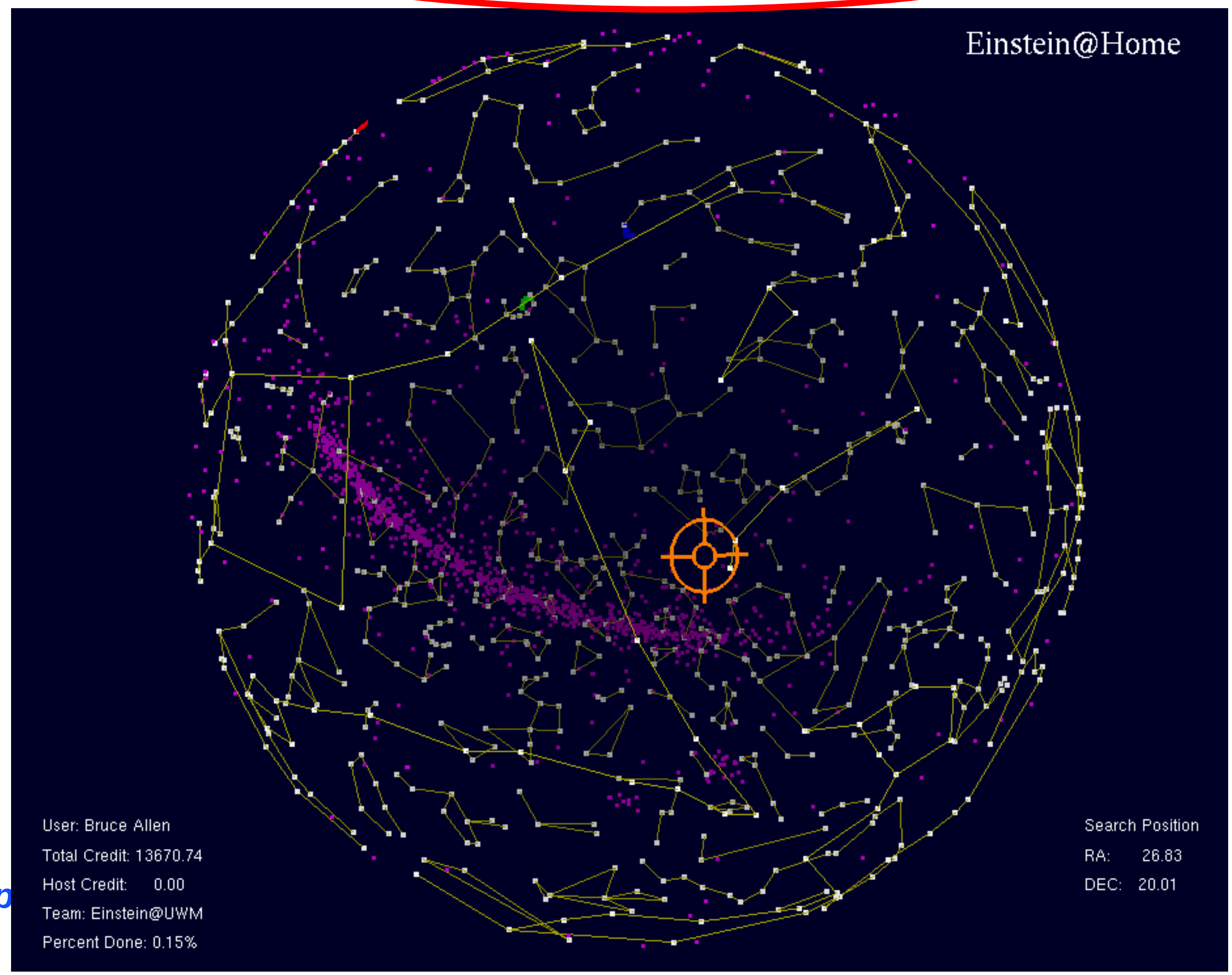
laser specialist

Einstein@home

Public Launch date:
Feb 19, 2005

- Like SETI@home, but for LIGO/GEO data
- Goal: pulsar searches using ~1 million clients. Support for Windows, Mac OSX, Linux clients
- From our own clusters we can get thousands of CPUs. From Einstein@home hope to many times more computing power at low cost

http://einstein.phys.uwm.edu/



Exp

Why ask for volunteers?

- e.g. searching 1 year of data, you have 3 billion frequencies in a 1000Hz band
- For each frequency we need to search 100 million million independent sky positions
- pulsars spin down, so you have to consider approximately one billion times more “guesses” at the signal
- Number of templates for each frequency: ~100,000,000,000,000,000,000,000
- Clearly we rapidly become limited in the analysis we can do by the speed of our computer!

Einstein@home!!!

a.k.a. Distributed computing

Quinn Simone Landry

- Born May 19, 2006 in Richland WA, about 19 hours ago
- ???

nursing specialist

On the horizon

- LIGO is searching for gravitational waves; this or future experiments should find them
- Humbling fact: we have little idea of what 96% of the universe is made of
  - 4% ordinary matter
  - about 26% dark matter (ghostly particles? Failed stars?)
  - About 70% “dark energy”, looks kind of like antigravity, and is completely mysterious
- Experiments on the horizon will reveal the nature of gravitational waves, dark matter, dark energy, and many other key questions of science: plenty of help needed!
- If this interests you: talk to teachers, scientists. Get an internship: do interesting things and meet fascinating people. Take college and university courses in math, physics, engineering…