



## What's up with LIGO?

Fred Raab, LIGO Hanford Observatory, on behalf of the LIGO Scientific Collaboration 25 Aug 2011 MARCIA BARTUSIAK







## Outline

- LIGO's Mission
- Initial LIGO (iLIGO) achievements (before retirement)
- Advanced LIGO (aLIGO) construction ongoing
- LIGO Science Education & Public Outreach
- Reflections on the future





Empty space and time are things, with real physical properties. Space has a shape, a stiffness and a maximum speed for information transfer. Raab: What's Up With LIGO?



Initial LIGO

## From Discovery to Astronomy



LIGO

Credit: R.Powell, B.Berger





## Gravitational waves deform a circle of space into an ellipse



### The LIGO Observatories

LIGO Hanford Observatory (LHO) H1 : 4 km arms H2 : 2 km arms

LIGO Livingston Observatory (LLO)

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 echoica (Suppost: MCDNS Lance 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).





## The Laser Interferometer Gravitational-Wave Observatory

#### LIGO (Washington)



#### LIGO (Louisiana)



Owned by the National Science Foundation; operated by Caltech and MIT; the research focus for 850 LIGO Scientific Collaboration members worldwide. Now engaged in joint operations with Virgo.

LIGO-G1100905





### **Interferometers in Europe**

#### GEO 600 (Germany) 600-m



Operated by GEO, member of LIGO Scientific Collaboration



Virgo (Italy)

**3-km** 

CNRS/INFN collaboration; has joint operating agreement w/ LIGO

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# iLIGO was the most sensitive machine on Earth

- ✓ Typical Strains <  $10^{-21}$  at Earth ~ 1 hair's width at 4 light years
  - Resolve displacement fluctuations of 4-km arms at the millifermi level (1/1000<sup>th</sup> of a proton diameter)
- ✓● Control km-scale arm lengths to 1/1000<sup>th</sup> of atomic diameter
  - Detect optical phase changes of billionths of a degree
  - Hold mirror alignments to millionth of a degree in angle
- Engineer structures to mitigate recoil from atomic vibrations in suspended mirrors
  - Do all of the above 7x24x365
    - ✓ S5 science run 14Nov05 to 30Sep07
    - ✓ S6 science run 08Jul09 to 20Oct10





## **GRB 070201**

- Short gamma-ray burst
- IPN error box included M31!
- Exclude any compact binary progenitor in our simulation space at the distance of M31 at > 99% confidence level
- Exclude compact binary progenitor with masses

1  $M_{\odot}$  <  $m_{1}$  < 3  $M_{\odot}$  and 1  $M_{\odot}$  <  $m_{2}$  < 40  $M_{\odot}\,$  with D < 3.5 Mpc away at 90% CL

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## Moving on to aLIGO

- Two decades of LIGO-driven R&D and lessons learned from Initial LIGO have resulted in:
  - » Superior laser, mirror and optical technology
  - » Superior vibration isolation technology
  - » Superior control-system technologies
  - » Refinements in understanding and reducing manifestations of atomic motion
- Funding for Advanced LIGO construction began in 2008
- 2011 is peak year of construction and beginning of installation
- 2014 delivery for operational detectors, followed by commissioning to design sensitivity
- At design sensitivity, expect monthly to weekly detections of black hole formations





## aLIGO installation in progress



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### LIGO outreach programs at Observatories connect the public to LIGO science



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### Inquiry-friendly exhibits illustrate breadth of "LIGO science", tied to state standards



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# What will be the legacy of LIGO discoveries?

- Attempts in the 19<sup>th</sup> century to explain why the sky is blue, sunsets red and clouds white led to the 20<sup>th</sup> century economy:
  - » Atomic and nuclear physics and modern materials
  - » Modern chemical and pharmaceutical industries
  - » Modern electronics and computer industries
  - » Unraveling the structure of DNA and other bio-molecules, leading to modern biochemistry and gene therapy
  - » Development of almost all medical diagnostic machines
  - » Also a new phrase, "Blue-sky research"
- LIGO discoveries likely will revolutionize our understanding of space, time, matter and energy, as well as redefine what people can imagine and build





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