Intro to LIGO

Seismic Isolation Pre-bid meeting

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LIGO/Caltech

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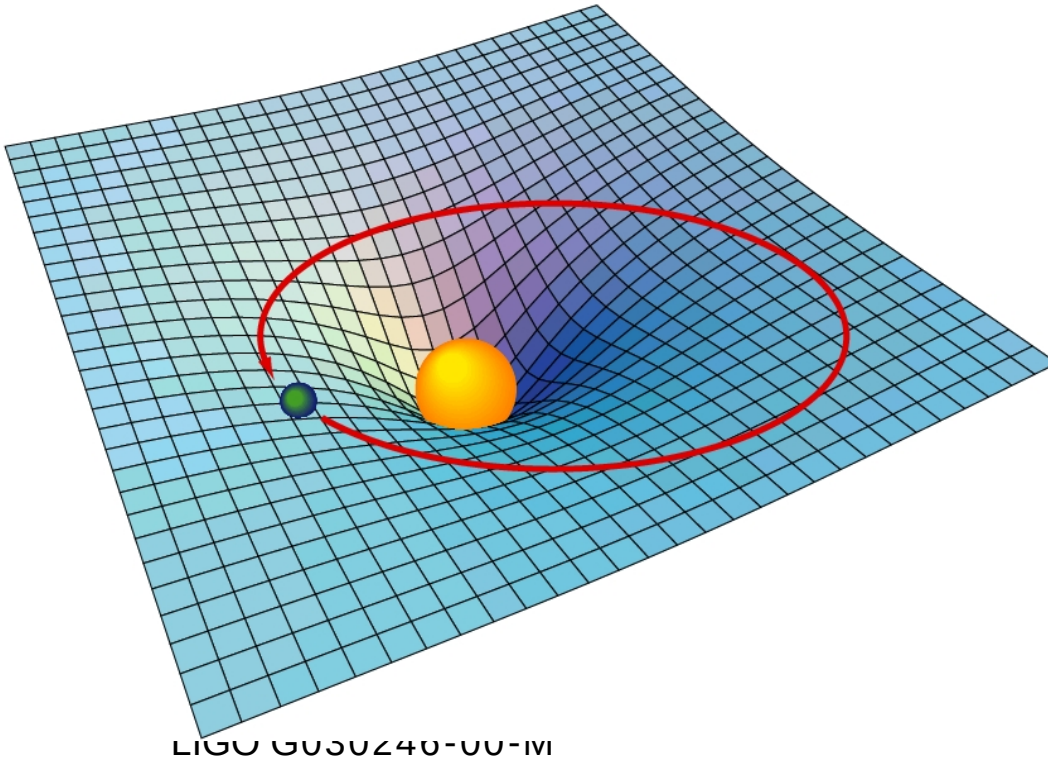
May we record the meeting and distribute transcript to all?

General Relativity

Einstein theorized that smaller masses travel toward larger masses, not because they are "attracted" by a mysterious force, but because the smaller objects travel through space that is warped by the larger object

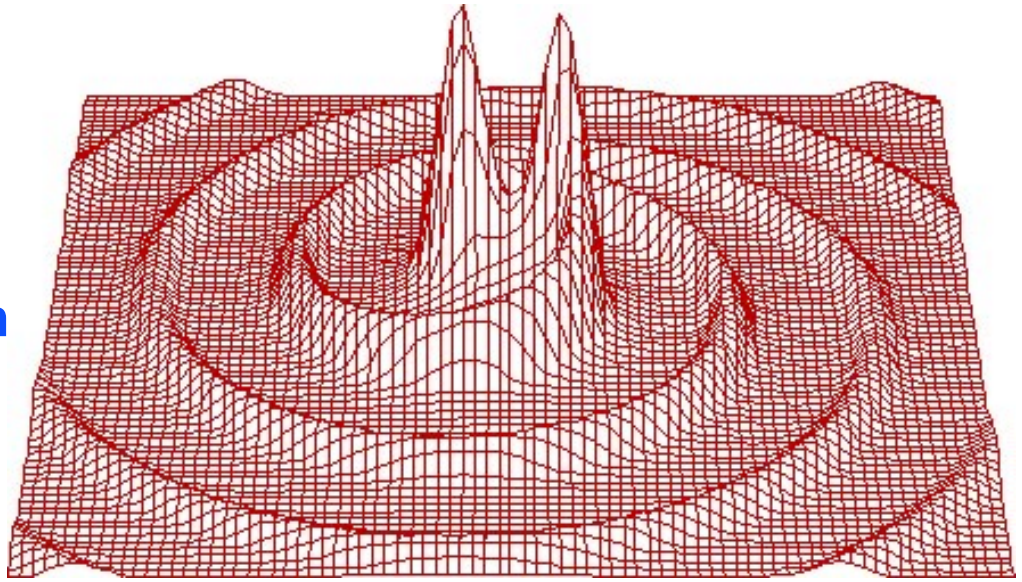


- **Imagine space as a stretched rubber sheet.**
- **A mass on the surface will cause a deformation.**
- **Another mass dropped onto the sheet will roll toward that mass.**

Gravitational Waves

- a necessary consequence of Special Relativity with its finite speed for information transfer

- time dependent gravitational fields come from the acceleration of masses and propagate away from their sources as a space-time warpage at the speed of light

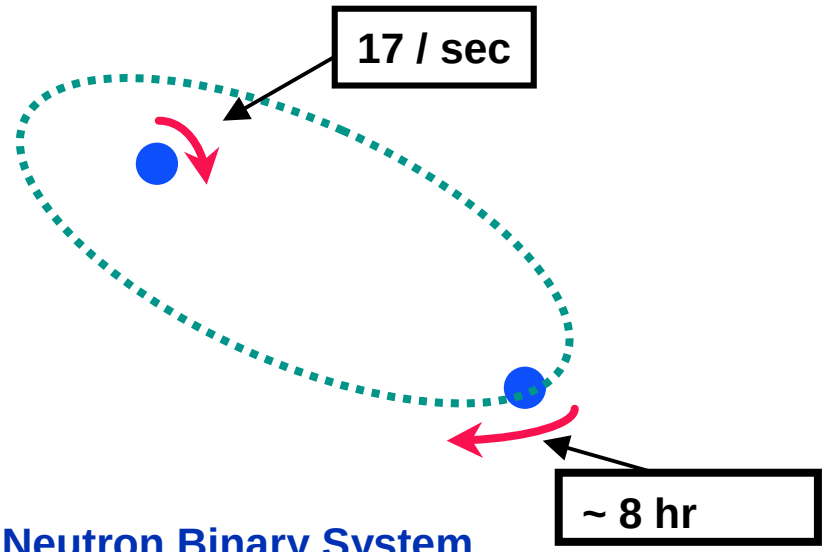


gravitational radiation from binary inspiral of compact objects

Evidence for Gravitational Waves

Neutron Binary System – Hulse & Taylor

PSR 1913 + 16 -- Timing of pulsars



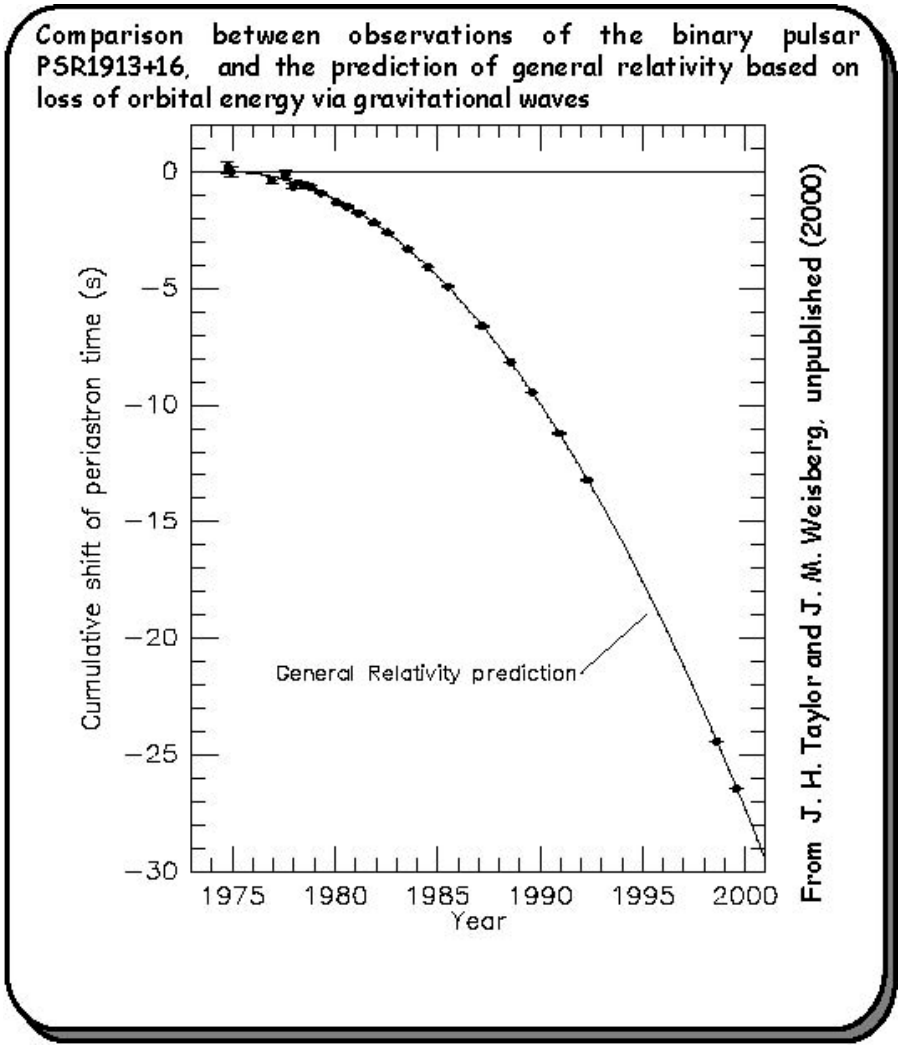
Neutron Binary System

- **separated by 10^6 miles**
- **$m_1 = 1.4m_\odot$; $m_2 = 1.36m_\odot$; $\varepsilon = 0.617$**

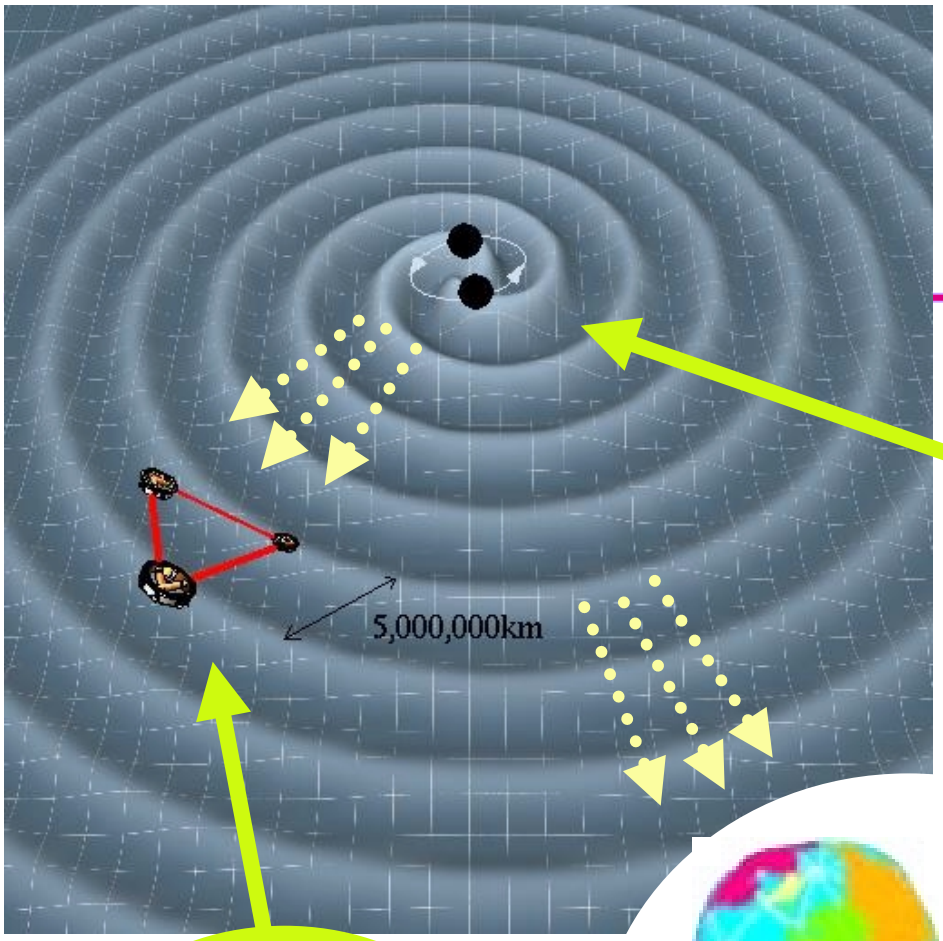
Prediction from general relativity

- **spiral in by 3 mm/orbit**
- **rate of change orbital period**

Emission of gravitational waves



Direct Detection



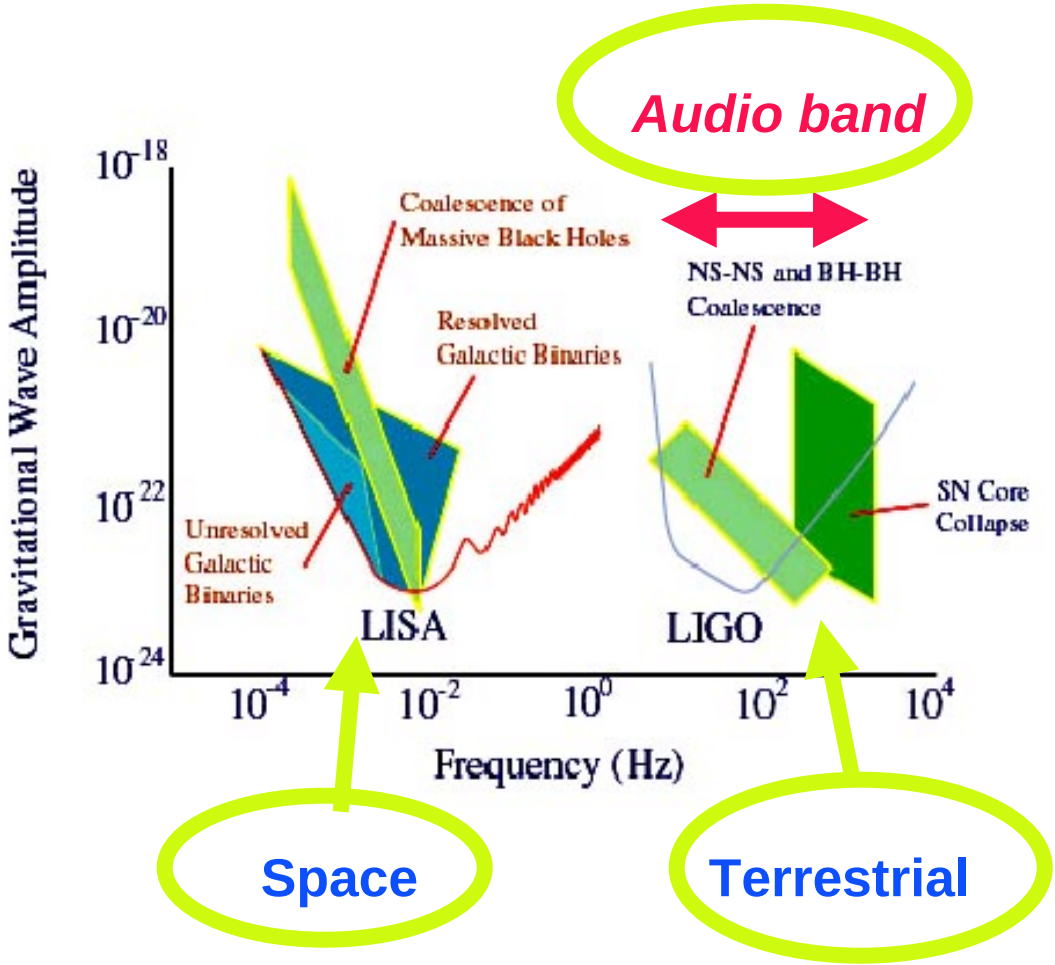
Gravitational Wave Astrophysical Source

Detectors in space
LISA

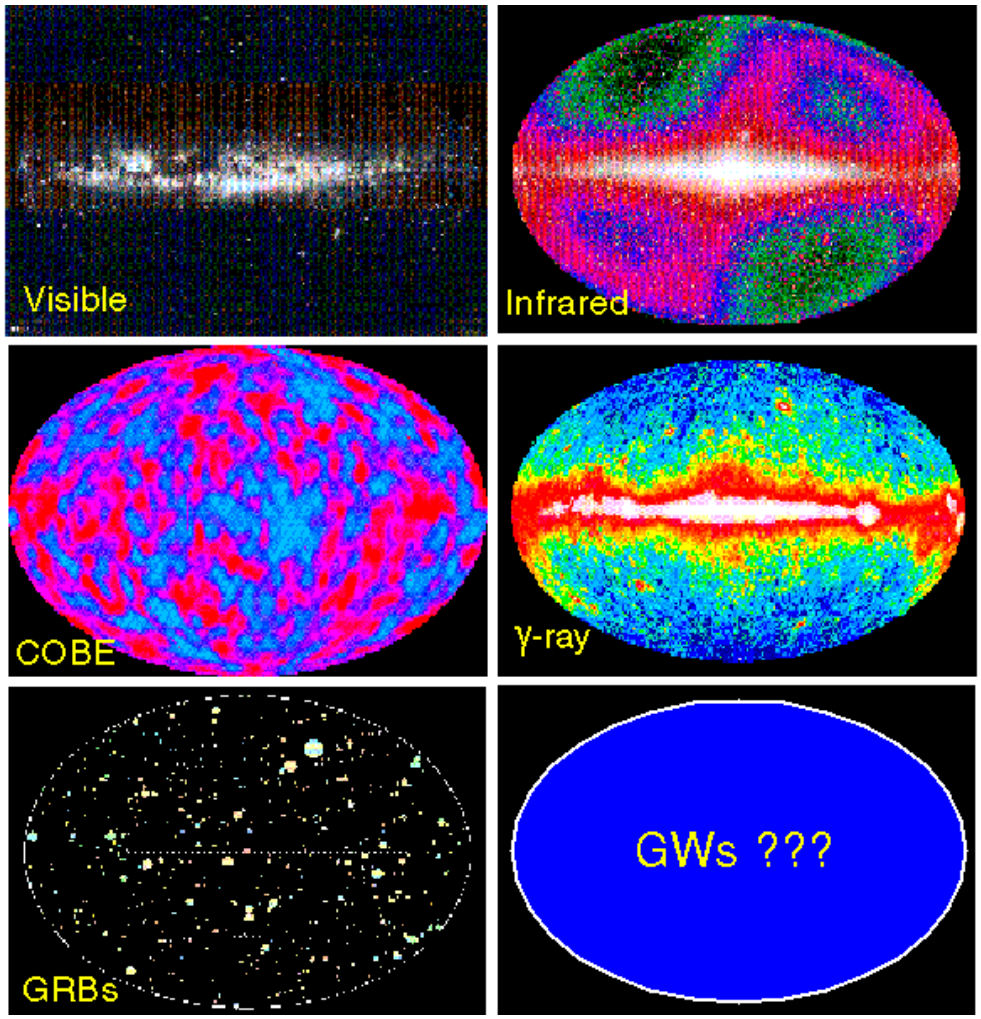
Terrestrial detectors
LIGO, GEO, TAMA, Virgo

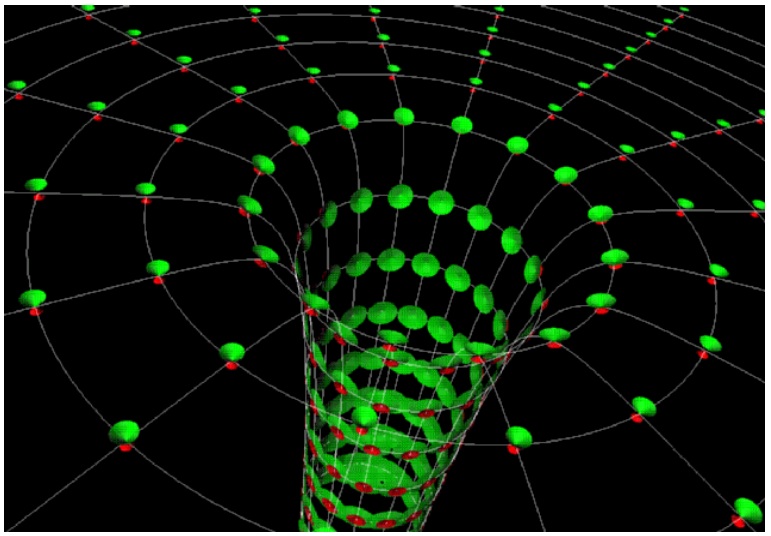
Astrophysics Sources by Frequency

- EM waves are studied over ~20 orders of magnitude
  - » (ULF radio –> HE γ-rays)
- Gravitational Waves over ~10 orders of magnitude
  - » (terrestrial + space)



A New Window on the Universe

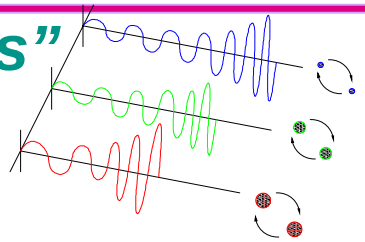




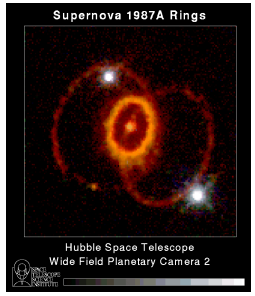
Gravitational Waves will provide a new way to view the dynamics of the Universe

Astrophysical Sources of Gravitational Waves

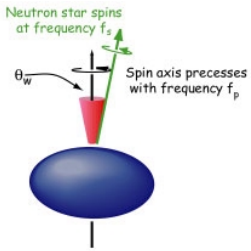
- Compact binary inspiral: ***"chirps"***
  - » NS-NS waveforms are well described
  - » BH-BH need better waveforms
  - » search technique: matched templates



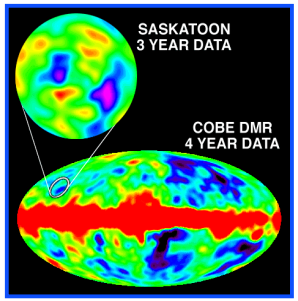
- Supernovae / GRBs: ***"bursts"***
  - » burst signals in coincidence with signals in electromagnetic radiation
  - » Challenge to search for untriggered bursts



- Pulsars in our galaxy: ***"periodic signals"***
  - » search for observed neutron stars (frequency, doppler shift)
  - » all sky search (computing challenge)
  - » r-modes

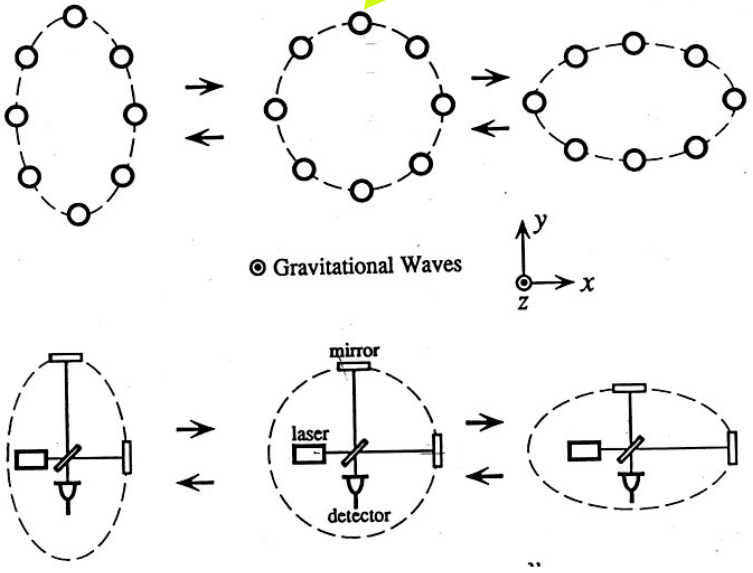


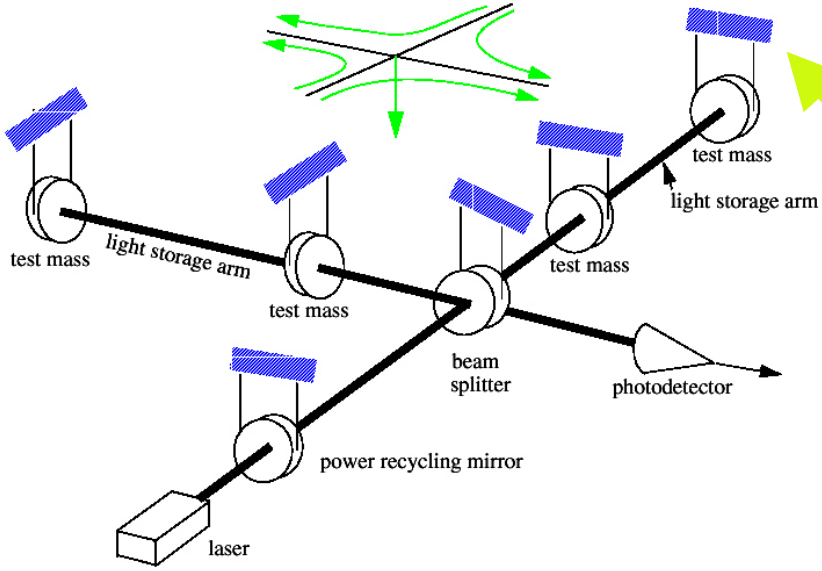
- Cosmological Signals ***"stochastic background"***



Terrestrial Interferometers

International network (LIGO, Virgo, GEO, TAMA) of suspended mass Michelson-type interferometers on earth's surface detect distant astrophysical sources



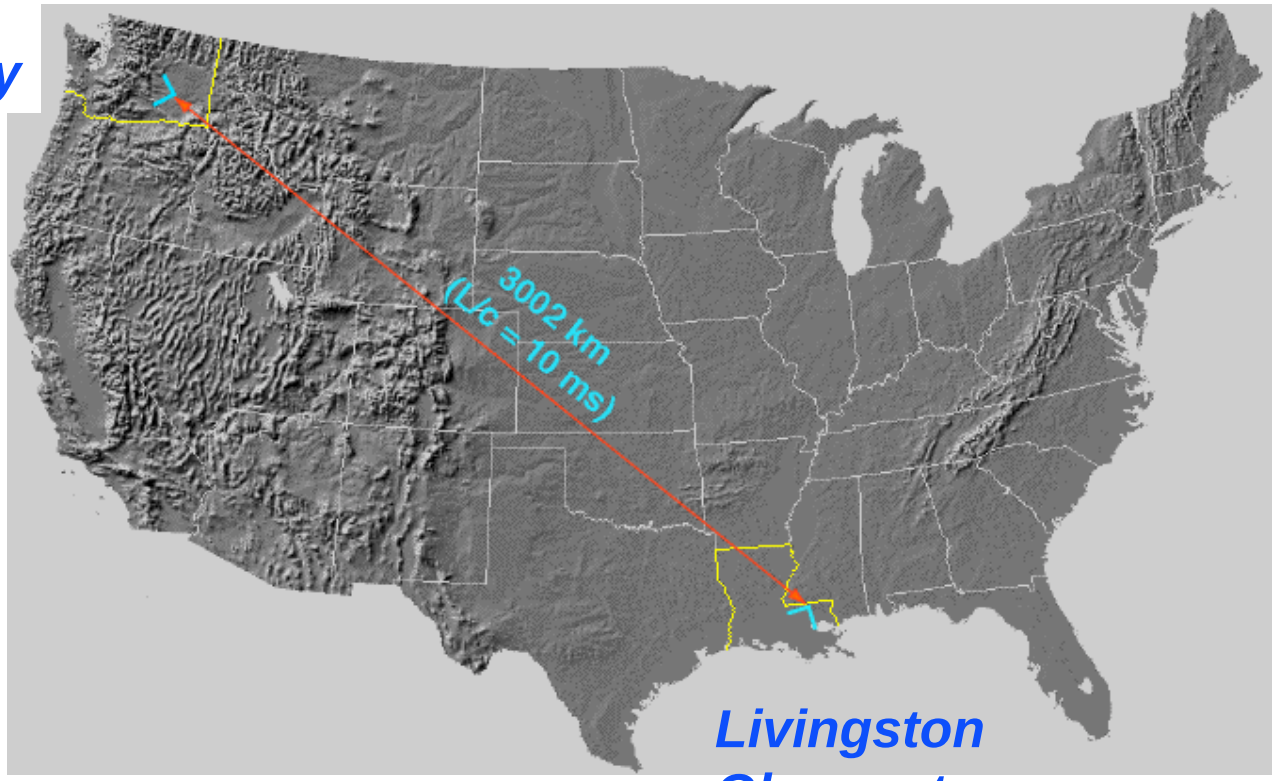


suspended test masses

The Laboratory Sites

Laser Interferometer Gravitational-wave Observatory (LIGO)

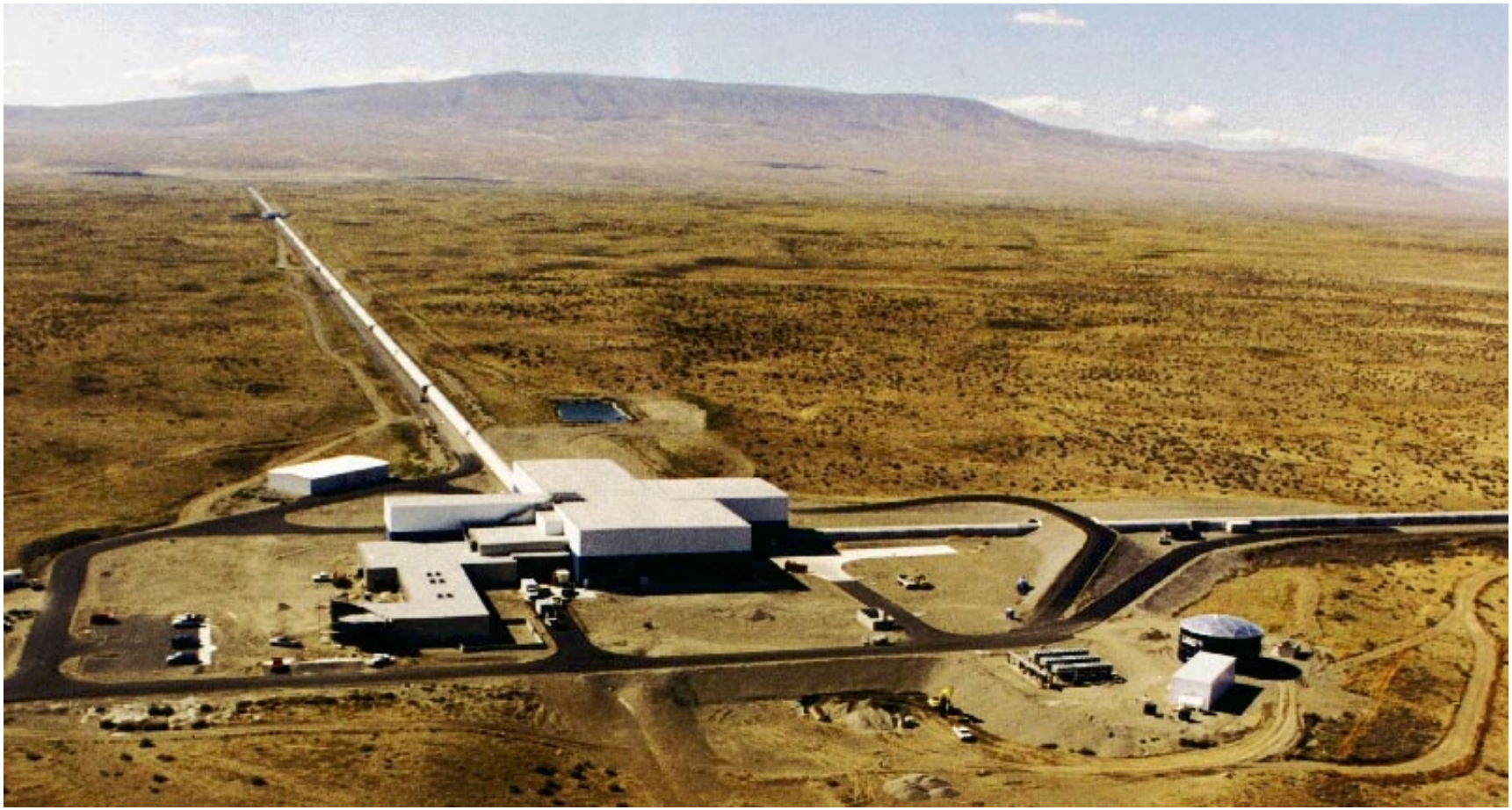
Hanford Observatory



Livingston Observatory

LIGO Livingston Observatory

LIGO Hanford Observatory



LIGO Beam Tube

1.2 m diameter - 3mm stainless
50 km of weld

NO LEAKS !!

- LIGO beam tube under construction in January 1998
- 65 ft spiral welded sections
- girth welded in portable clean room in the field

LIGO Vacuum Equipment

A LIGO Mirror

Substrates: SiO_2

25 cm Diameter, 10 cm thick

Homogeneity < 5×10^{-7}

Internal mode Q's > 2×10^{6}

Polishing

Surface uniformity < 1 nm rms

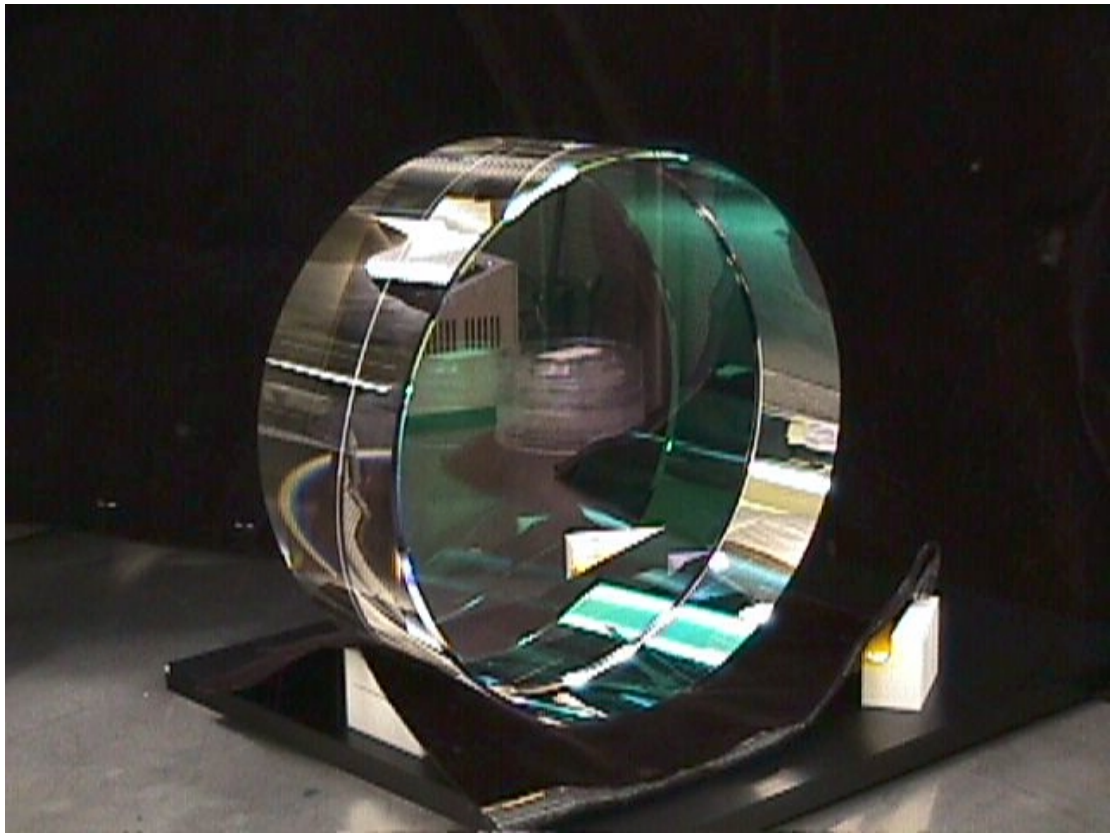
Radii of curvature matched < 3%

Coating

Scatter < 50 ppm

Absorption < 2 ppm

Uniformity <10^{-3}

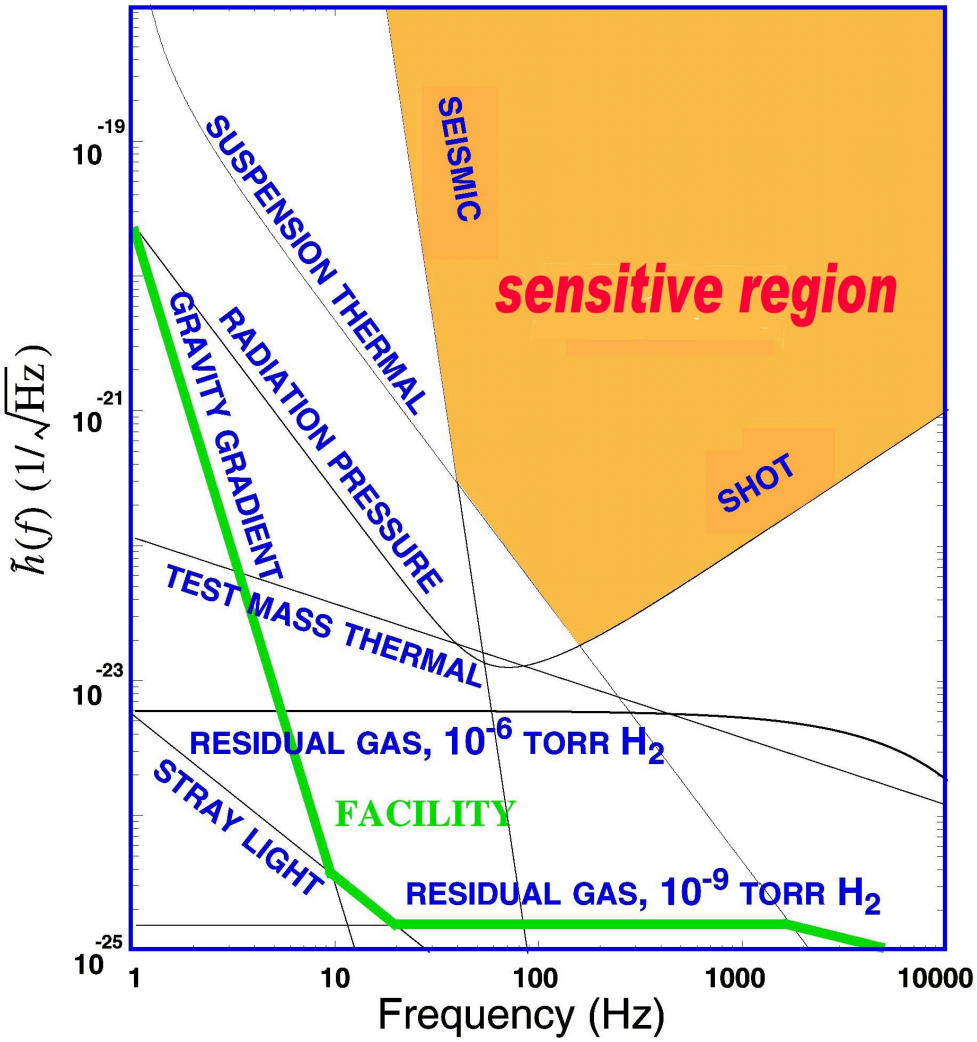


Core Optics

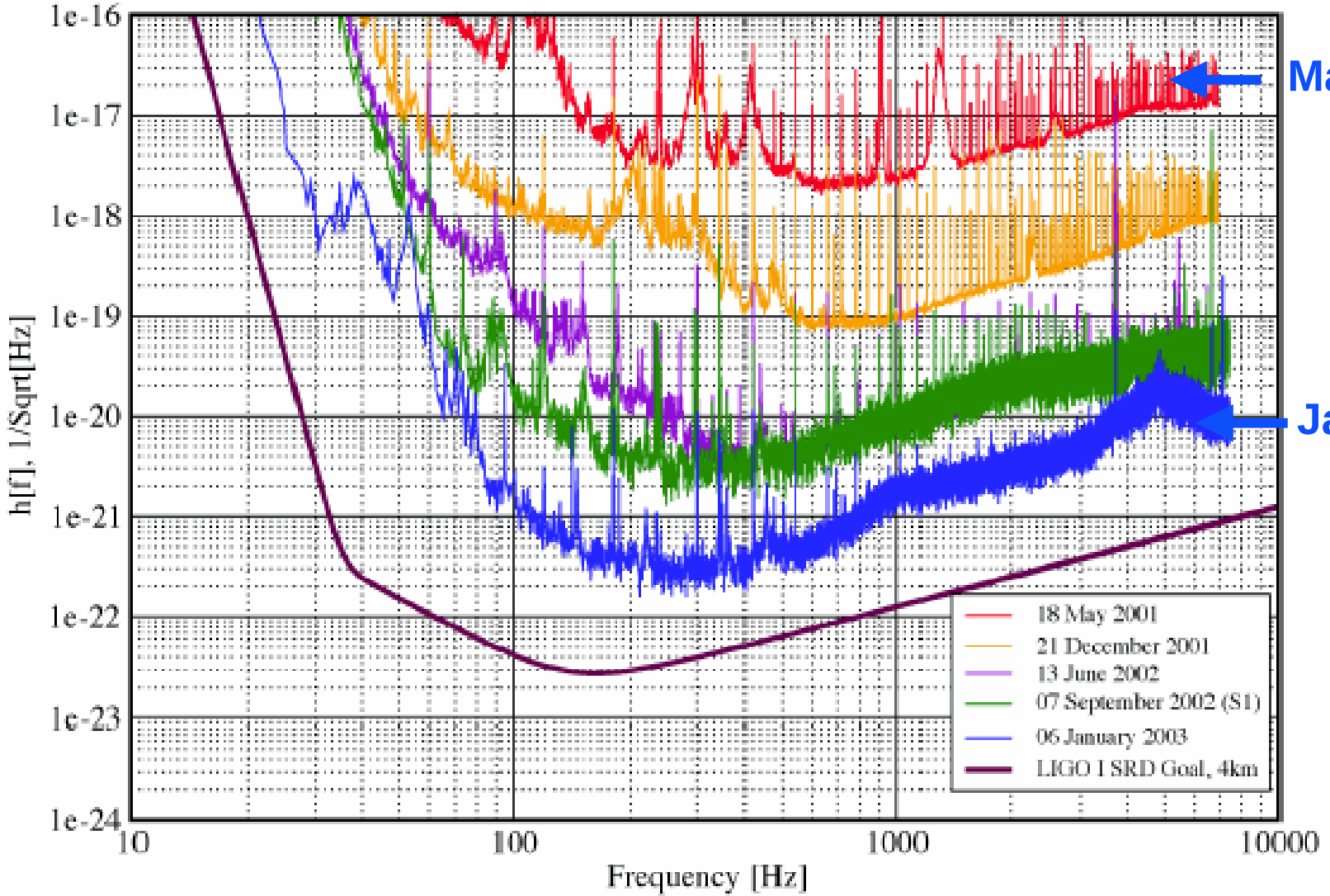
installation and alignment

What Limits Sensitivity of Interferometers?

- Seismic noise & vibration limit at low frequencies
- Atomic vibrations (Thermal Noise) inside components limit at mid frequencies
- Quantum nature of light (Shot Noise) limits at high frequencies
- Myriad details of the lasers, electronics, etc., can make problems above these levels

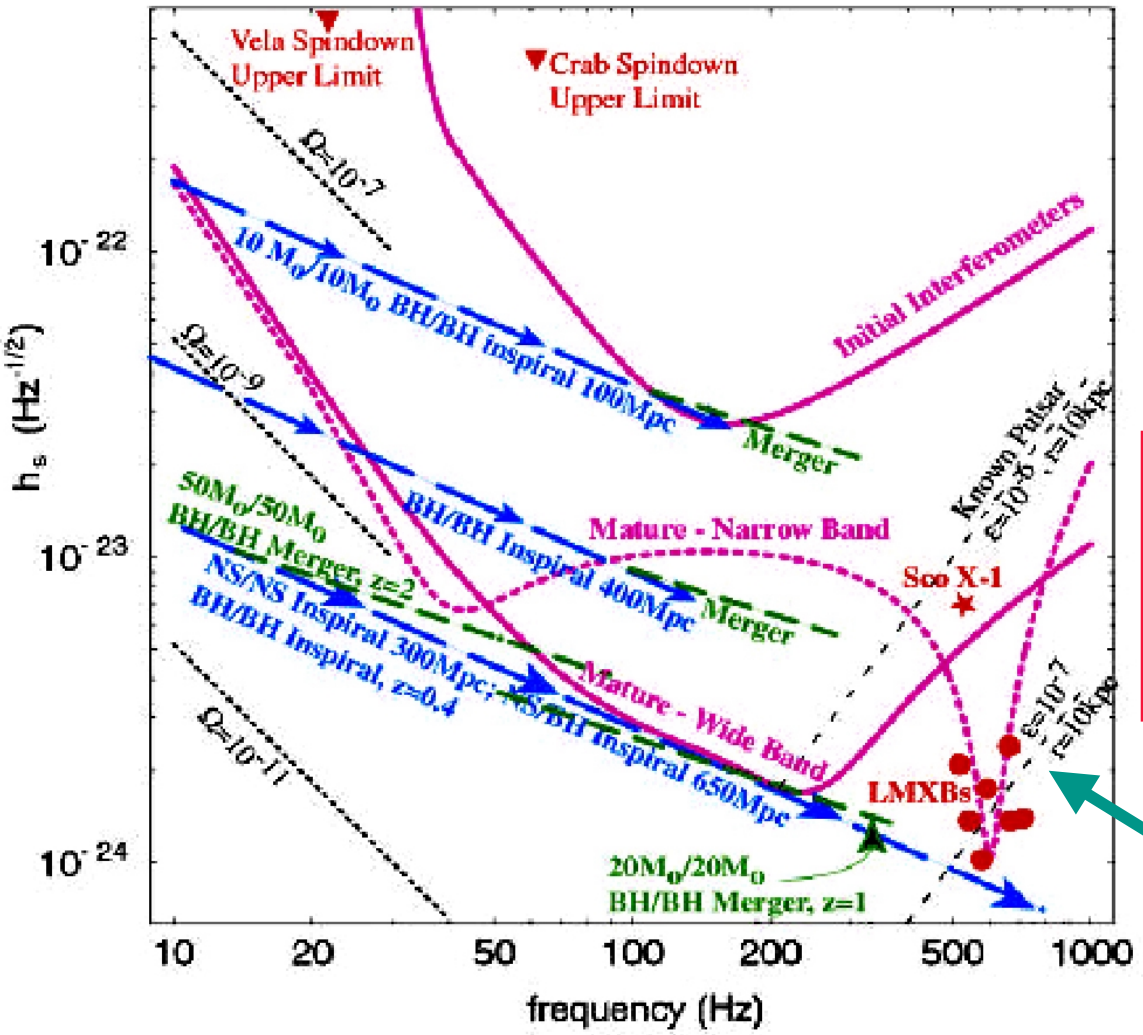


LIGO Sensitivity
Livingston 4km Interferometer



Advanced LIGO

2007 +



Enhanced Systems

- laser
- suspension
- seismic isolation
- test mass

Improvement factor in rate

~ 10^4

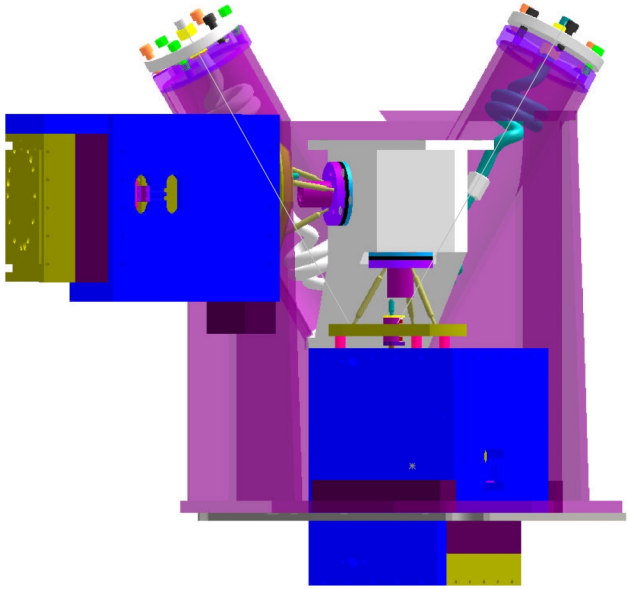
+

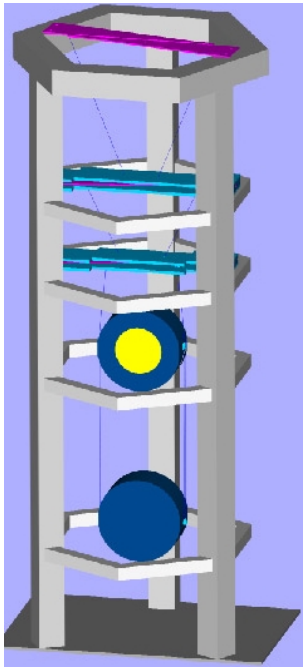
narrow band optical configuration

Advanced LIGO Development Underway

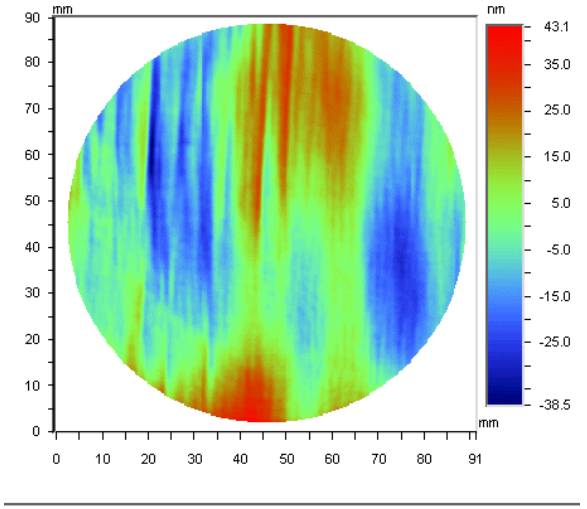
Multiple Suspensions

Active Seismic





Sapphire Optics



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Time: 13:59:18
Wavelength: 1.064 um
Pupil: 100.0 %
PV: 81.6271 nm
RMS: 13.2016 nm

X Center: 172.00
Y Center: 145.00
Radius: 163.00 pix
Terms: None
Filters: None
Masks:

Higher Power Laser