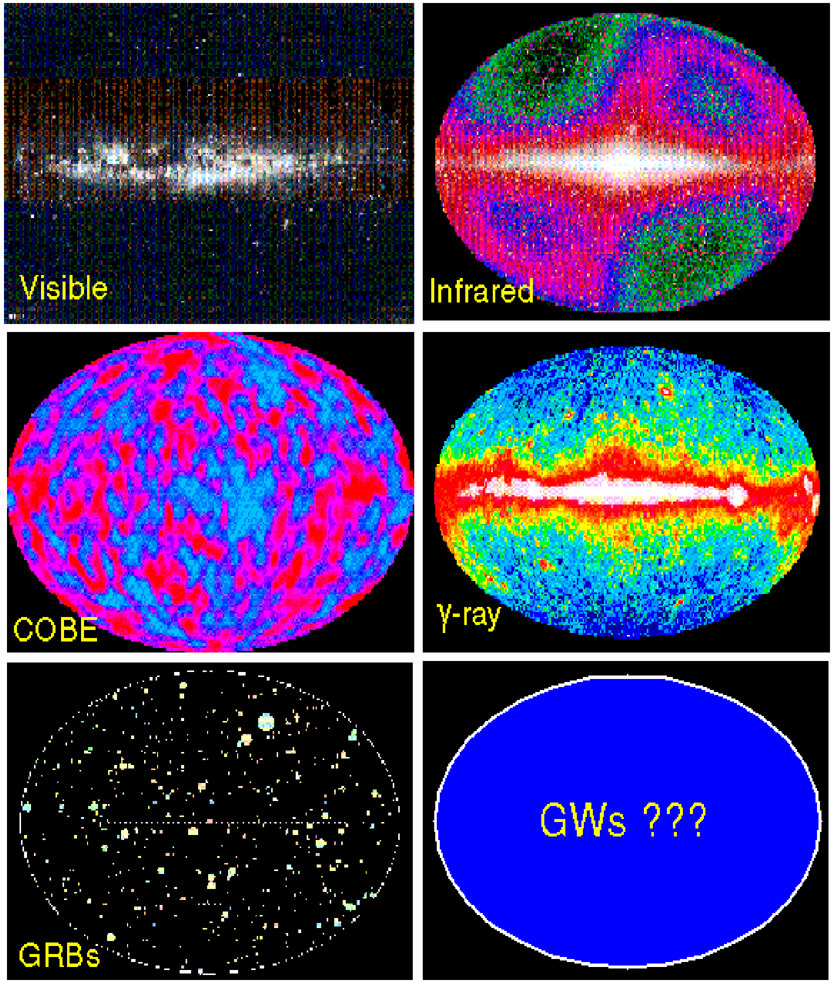
Astronomical Goals of LIGO



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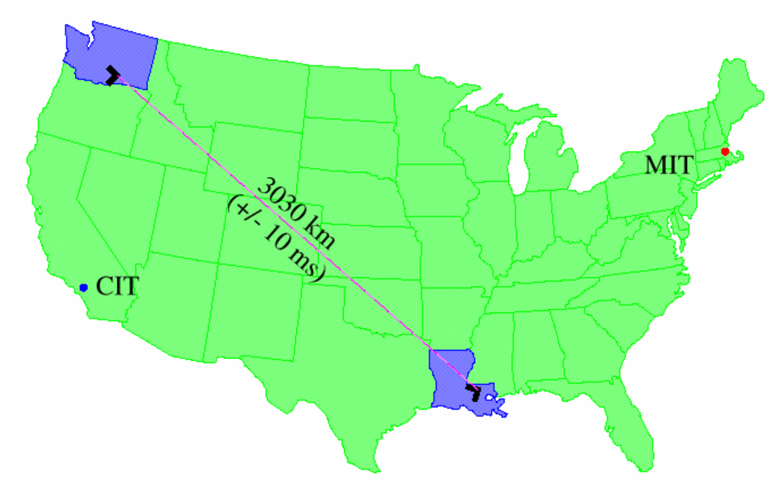
April 15, 2005

- The LIGO project
- Astronomical sources
  - » Binary inspirals
  - » Burst sources
  - » Periodic sources
  - » Stochastic backgrounds
- Status and future plans

The LIGO Project

LIGO: Laser Interferometer Gravitational-Wave Observatory

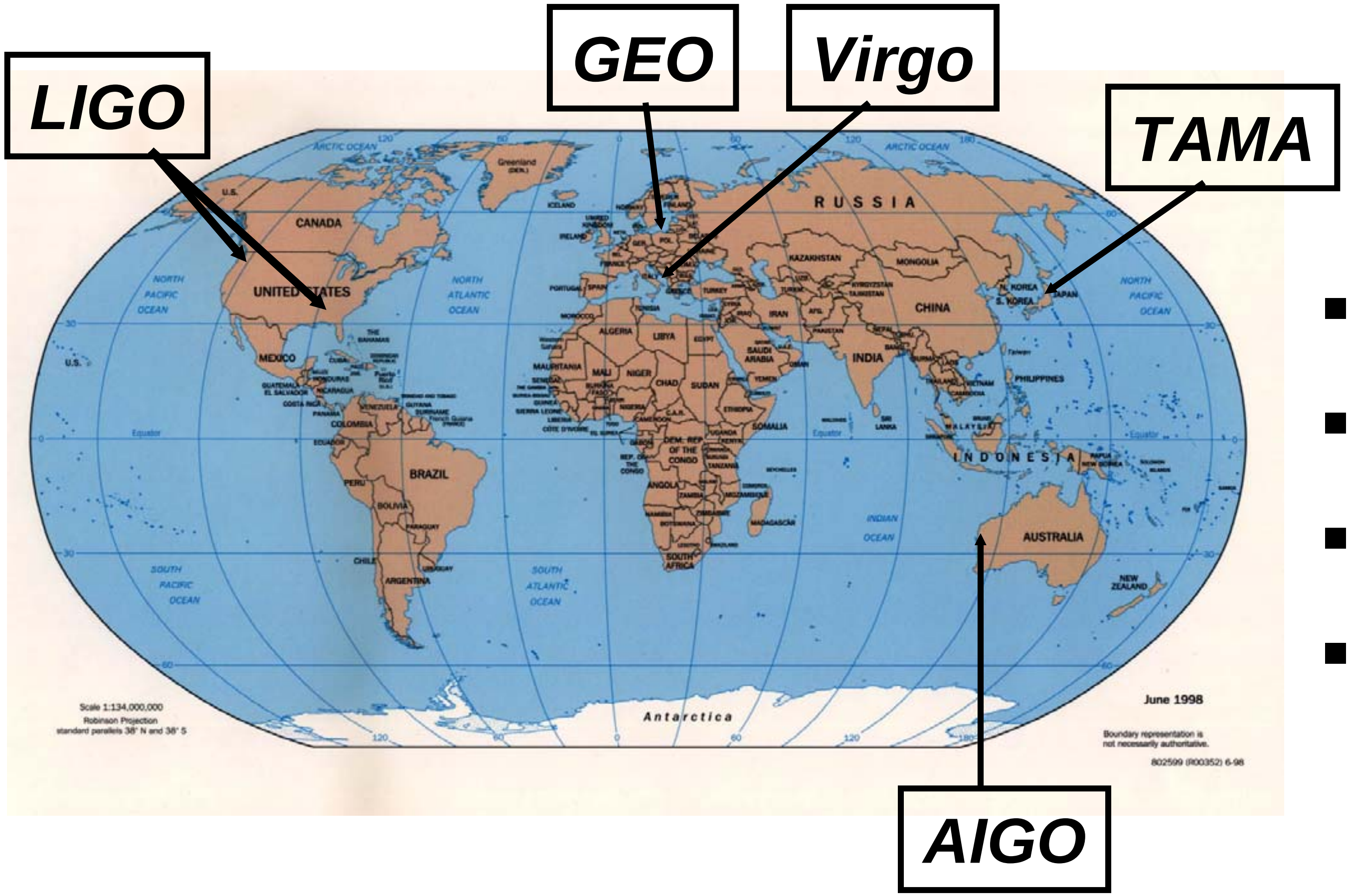
- US project to build observatories for gravitational waves (GWs)
- Initial detection, followed by astronomy of GWs
- Collaboration of ~40 institutions
- Funded by US National Science Foundation



4 km

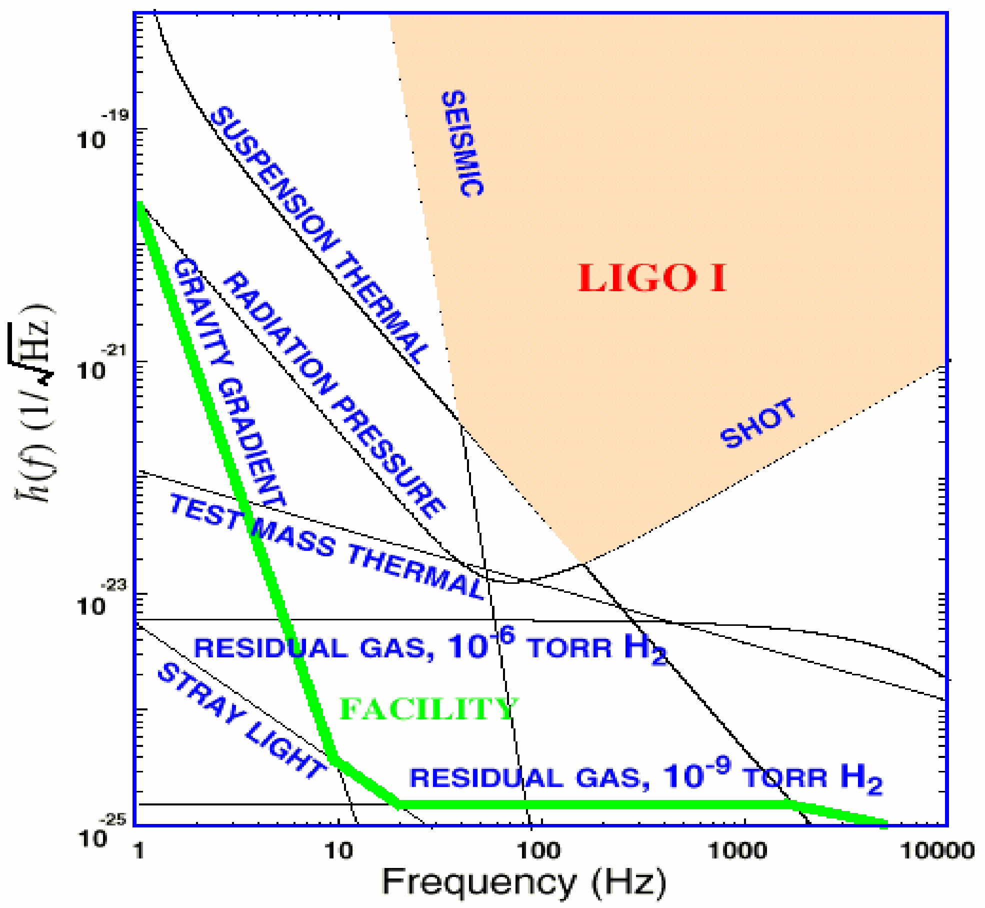
International Network

Simultaneously detect signal (within msec)



- Detection confidence
- Locate sources
- Speed of propagation
- Polarization of GWs

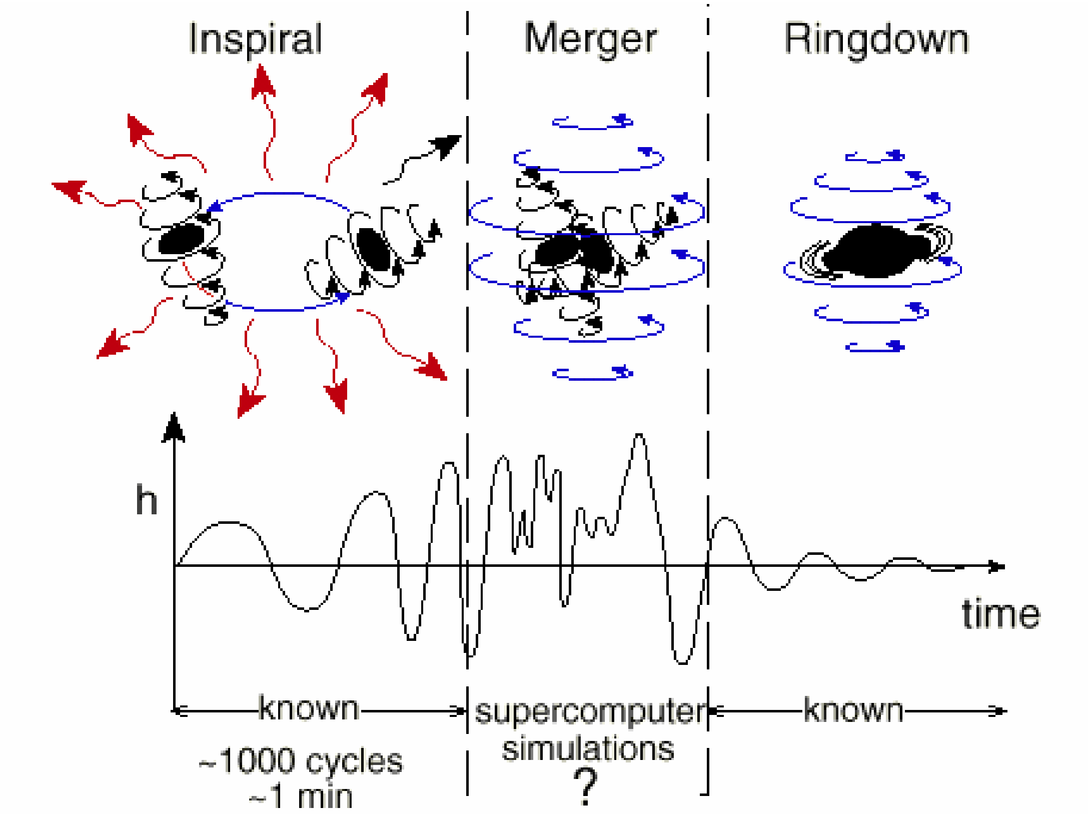
What We Can/Can't See



- Sensitive to $h \sim 10^{-21}$–10^{-22}
- Effective bandwidth of 40 Hz – 1 kHz
- Many sources are lower frequency
  - » Hulse-Taylor binaries
  - » Supermassive black holes

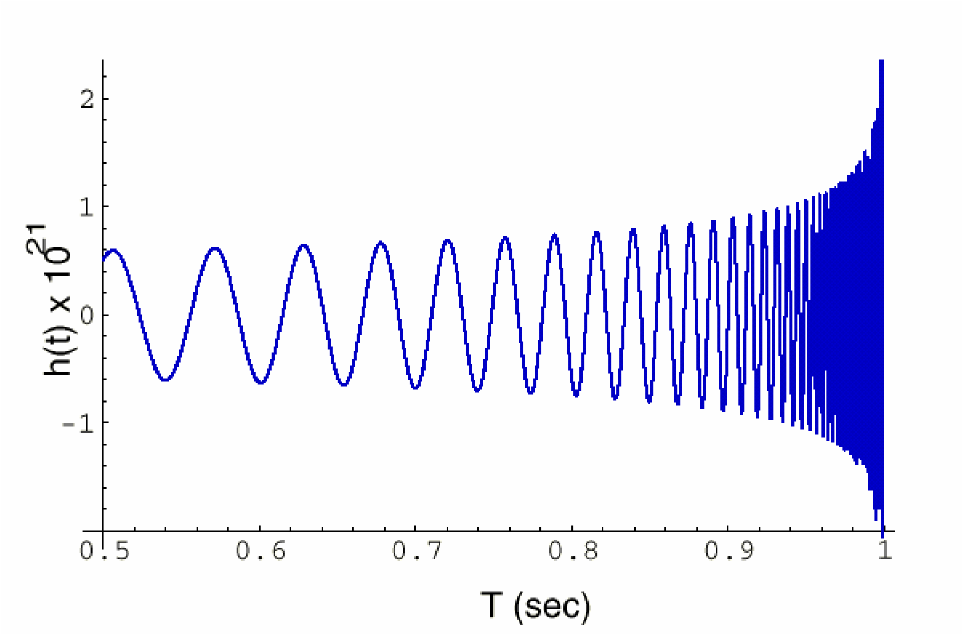
Binary Inspirals

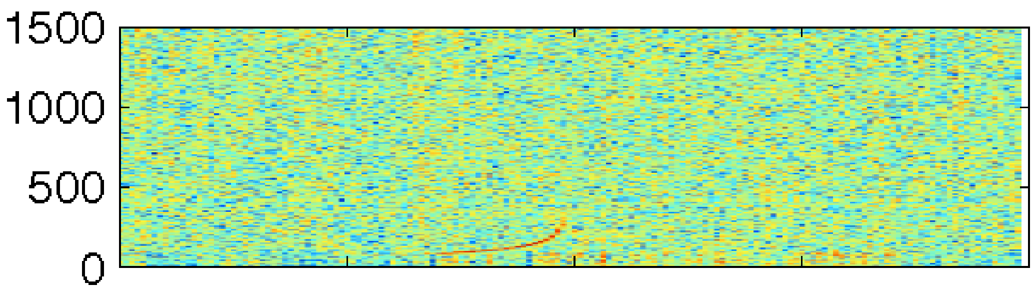
- LIGO should be sensitive to neutron star and black hole binary inspirals in the last 0.01-0.1 seconds before collision
- Known to exist and to be emitting gravitational waves (Hulse-Taylor)
- Excellent opportunity to do astronomy



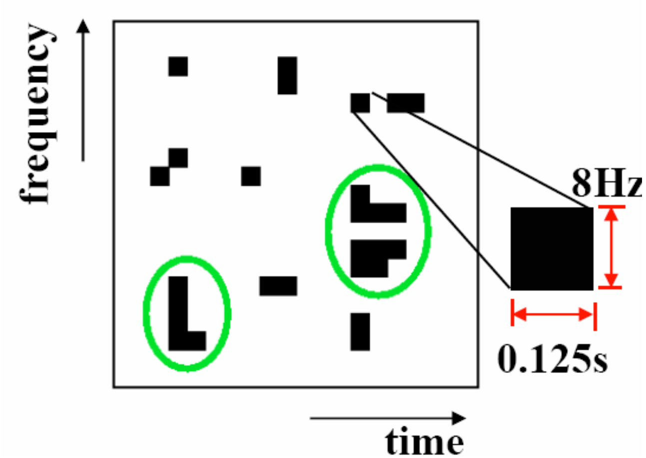
Matched Filtering

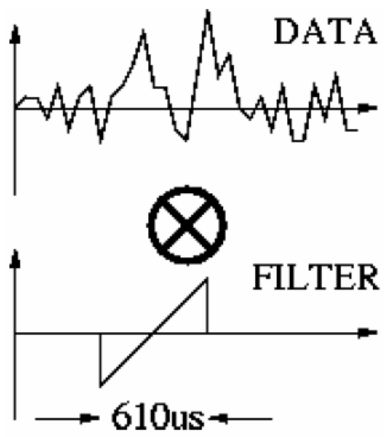
- Inspiral waveform can be modeled for different masses, positions, orbits
- ASIS – Astrophysical Source Identification and Signatures
- Use matched filtering to correlate each modeled waveform to data





“Un-modeled” Bursts



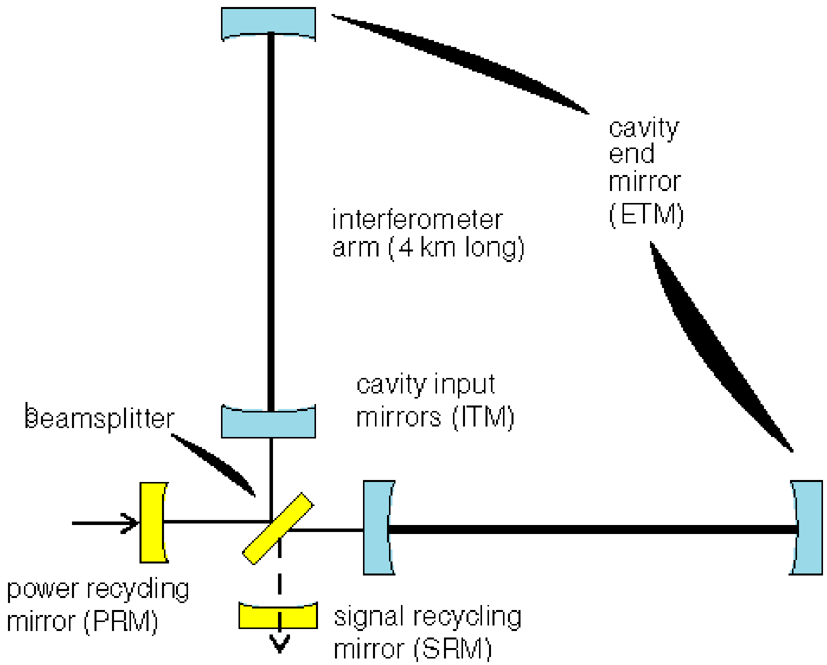


- Unlike inspirals, look for waveforms for which we have no accurate prediction (i.e., asymmetric supernova)
- Time-frequency search – look for connected regions of excess power
- Time domain search – look for rapid amplitude increase over certain rise time

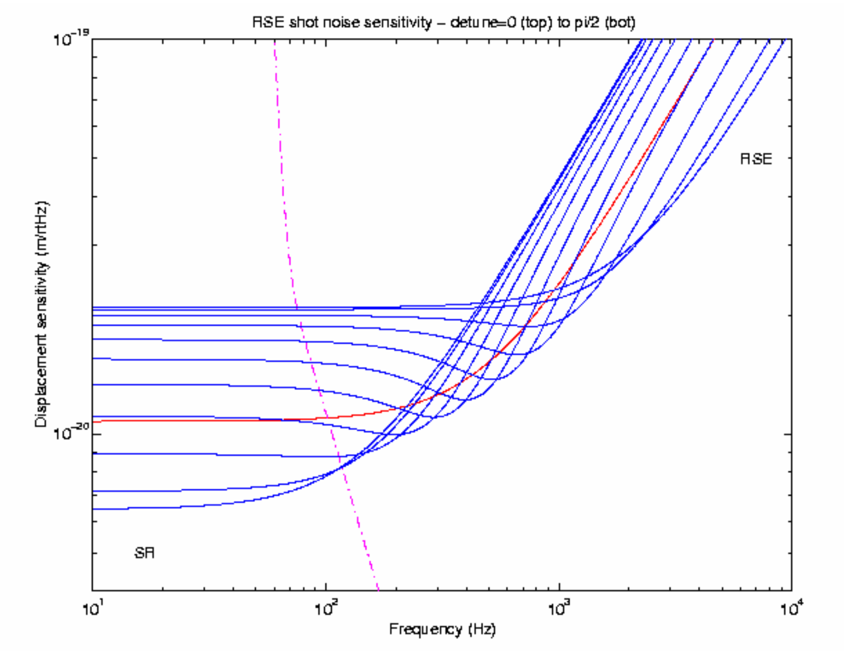
Periodic Sources (Pulsars)

- Unusual search due to a known nearby candidate
  - » PSR J1939+2134, neutron star rotating at 641.93 Hz, 3.6 kpc away
- Look for signals at twice pulsar rotation frequency
- Lack of signal puts upper limit on ellipticity of pulsar

Signal Recycling



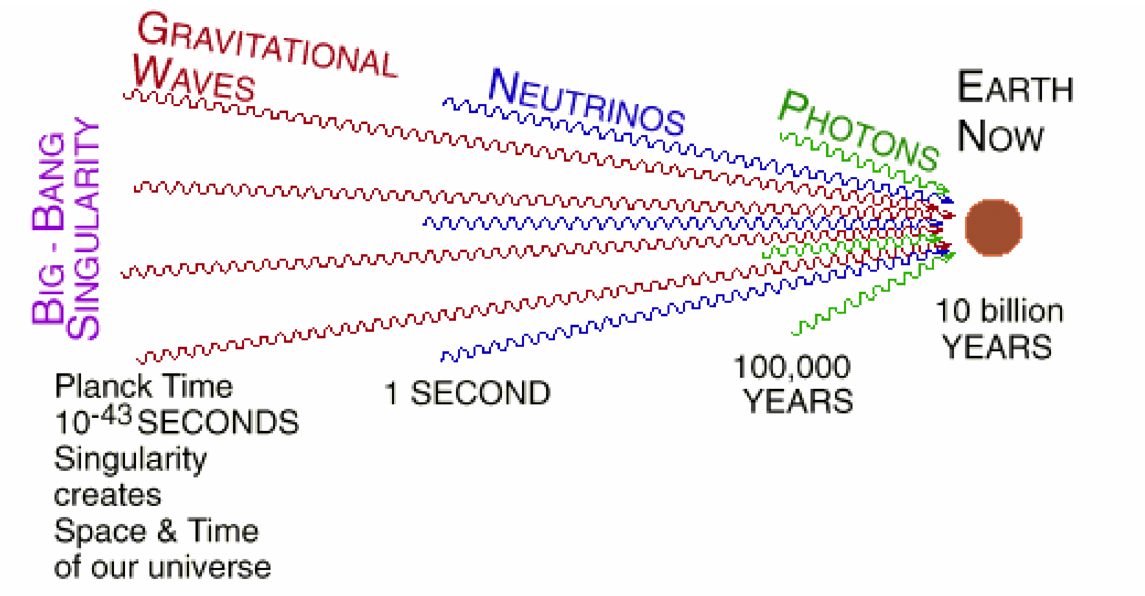
Adv. LIGO will include signal recycling, in which a mirror is added at the output, creating a cavity resonant for the beats between the laser frequency and a periodic signal.



By tuning the length of this cavity, we can enhance our sensitivity at a specific frequency.

Stochastic Background

- "Random" GW signal produced by a large number of weak, independent GW sources

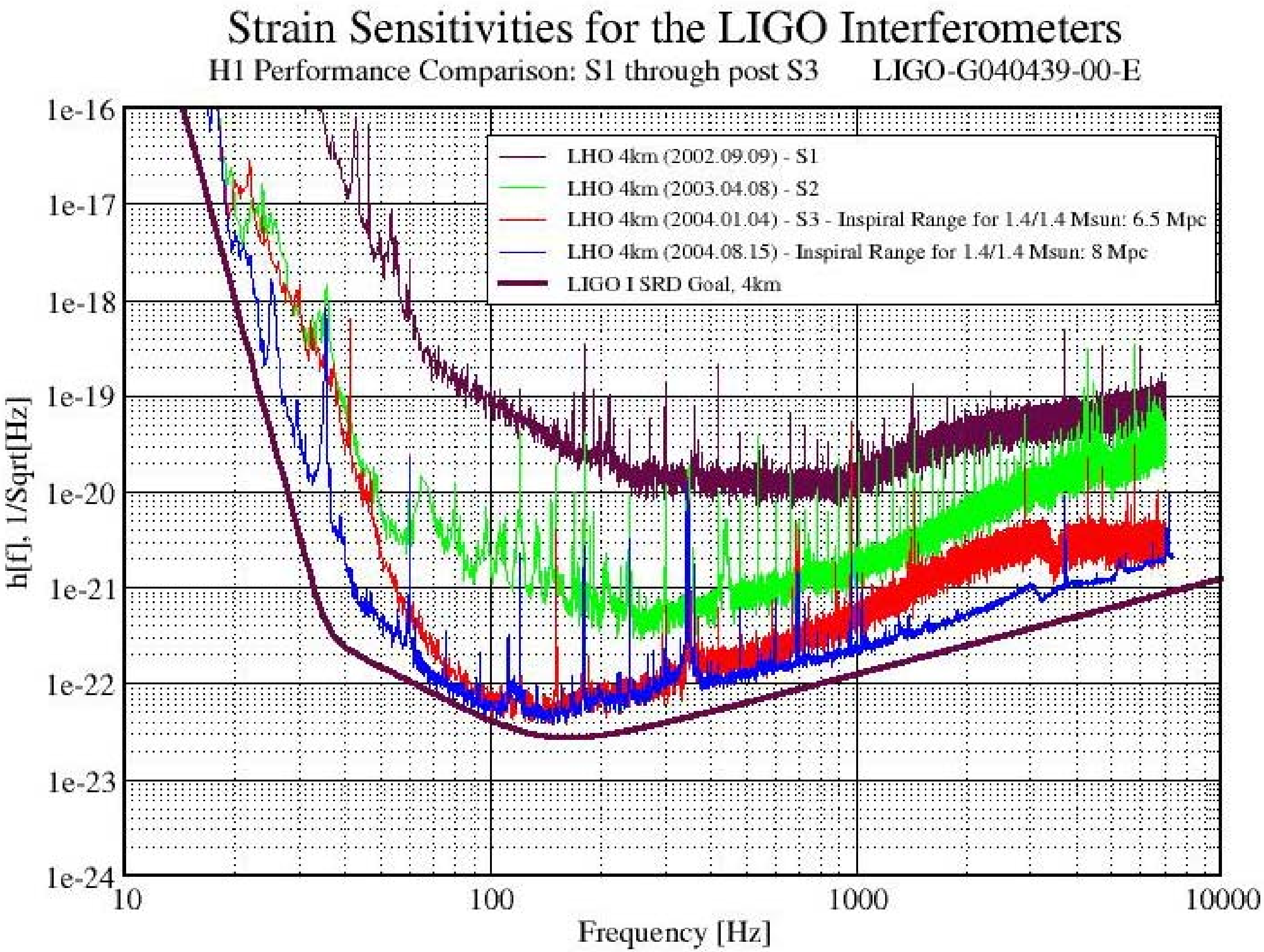


- Detected by cross-correlating the outputs of multiple interferometers

- Described by dimensionless spectrum $\Omega_{GW}(f)$:

$$\Omega_{gw}(f) = \frac{f}{\rho_c}\frac{d\rho_{gw}}{df}, \ \rho_c = \text{crit. density} = \frac{3c^2 H_0^2}{8\pi G}$$

LIGO Noise Curve



LIGO Timeline

- First science run completed September 2002
- Data analyses published in Phys. Rev. **D69**
  - » Inspirals – pg. 122001
  - » Bursts – pg. 102001
  - » Periodic – pg. 082004
  - » Stochastic – pg. 122004
- Fourth science run completed March 2005
  - » Analyses underway
- One year of integrated data taking to begin late fall 2005

Summary

- The LIGO project consists of 3 interferometers sensitive to GW strains of $h \sim 10^{-21}$ from 40 Hz – 1 kHz
- Expected GW sources include:
  - » Binary inspirals of neutron stars/black holes
  - » Un-modeled burst sources
  - » Periodic sources (pulsars)
  - » Stochastic backgrounds
- Full-time running at design sensitivity expected to begin late fall 2005