LIGO

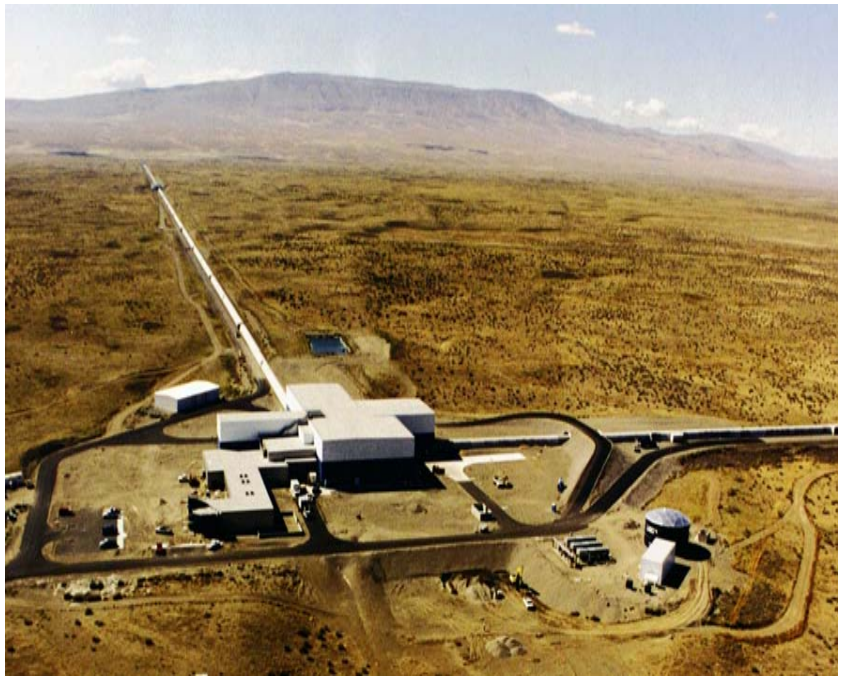
# *Status of LIGO*

*Stan Whitcomb*

ACIGA Workshop

21 April 2004

# LIGO Observatory Facilities



***LIGO Hanford Observatory [LHO]***

*26 km north of Richland, WA*

2 km + 4 km interferometers in same vacuum envelope

***LIGO Livingston Observatory [LLO]***

*42 km east of Baton Rouge, LA*

Single 4 km interferometer

# LIGO Beam Tube

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

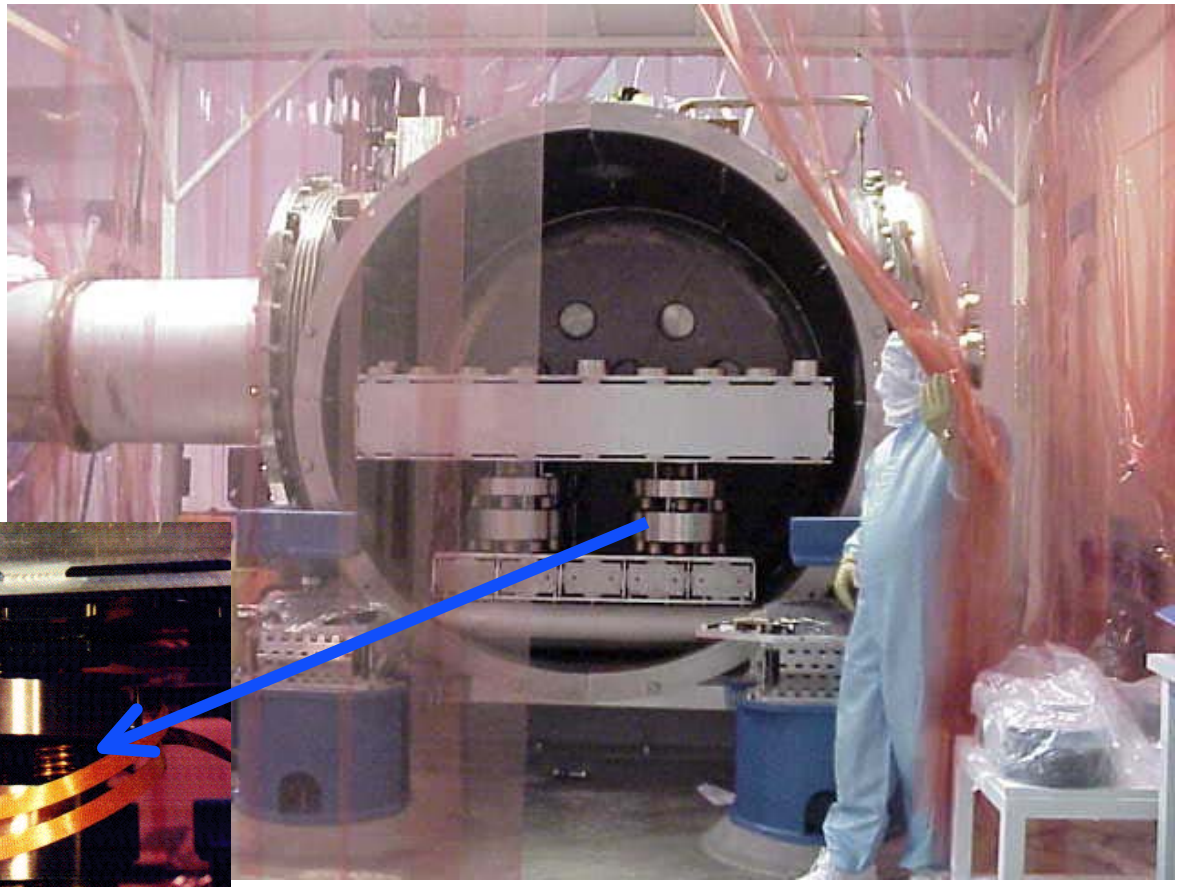
**1.2 m diameter - 3mm stainless**
**50 km of weld**

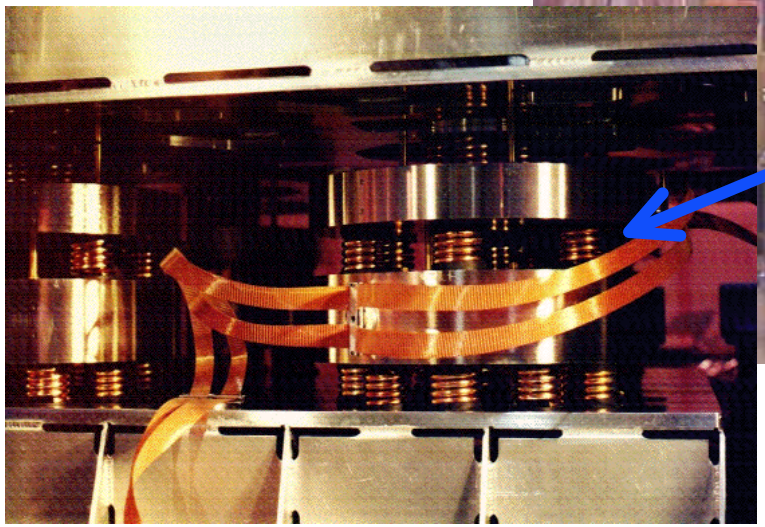
**NO LEAKS !!**

# Vacuum Equipment

# Seismic Isolation System

Tubular coil springs with internal constrained-layer damping, layered with reaction masses

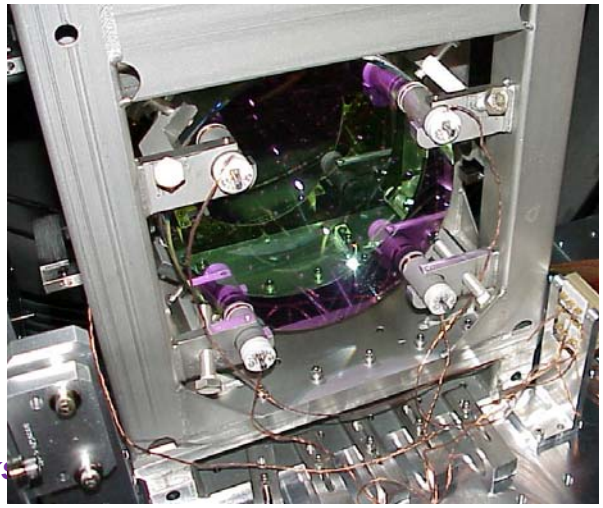




Isolation stack in chamber

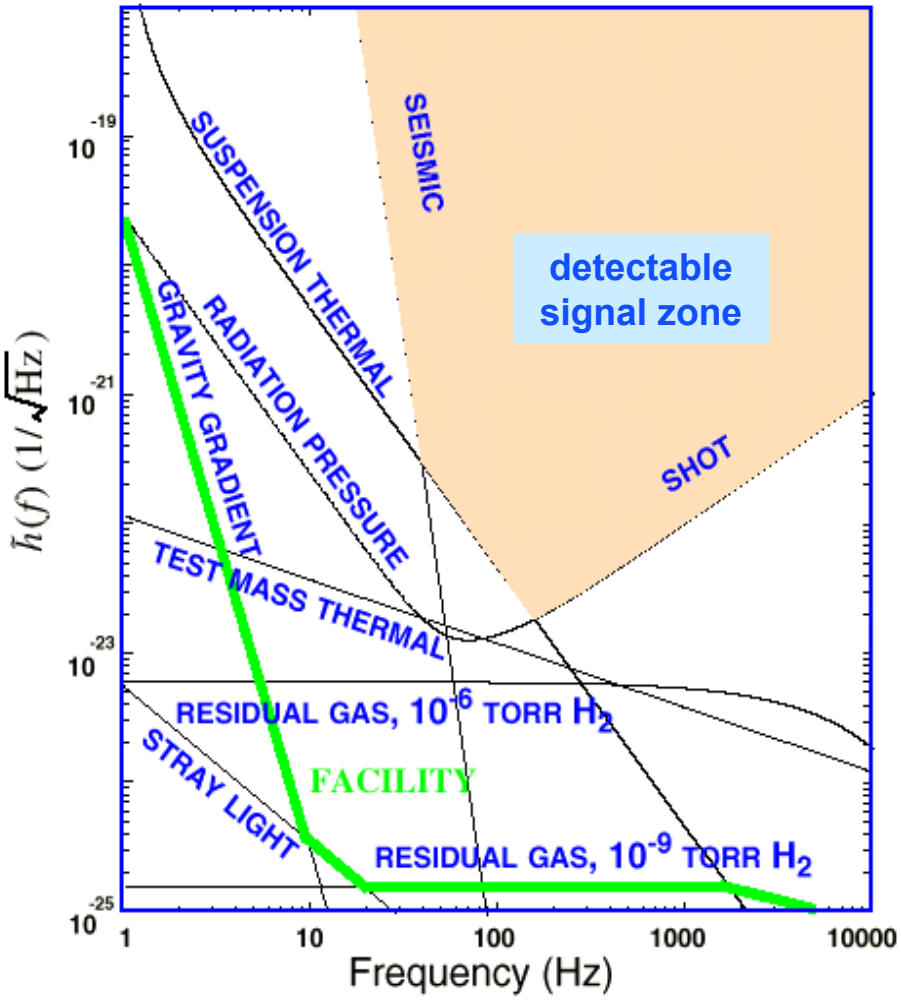
LIGO

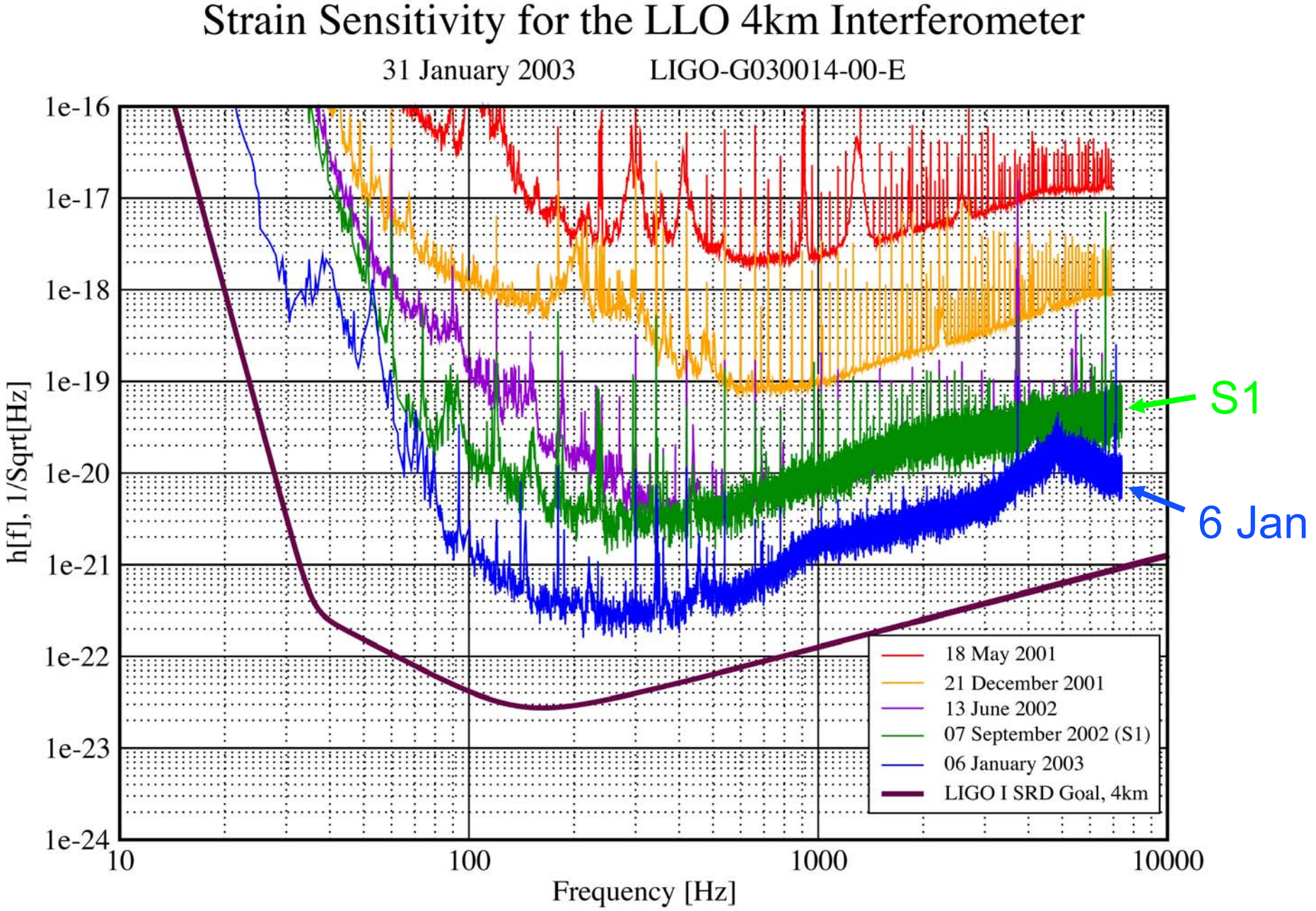
# Core Optics Suspensions
## *installation and alignment*

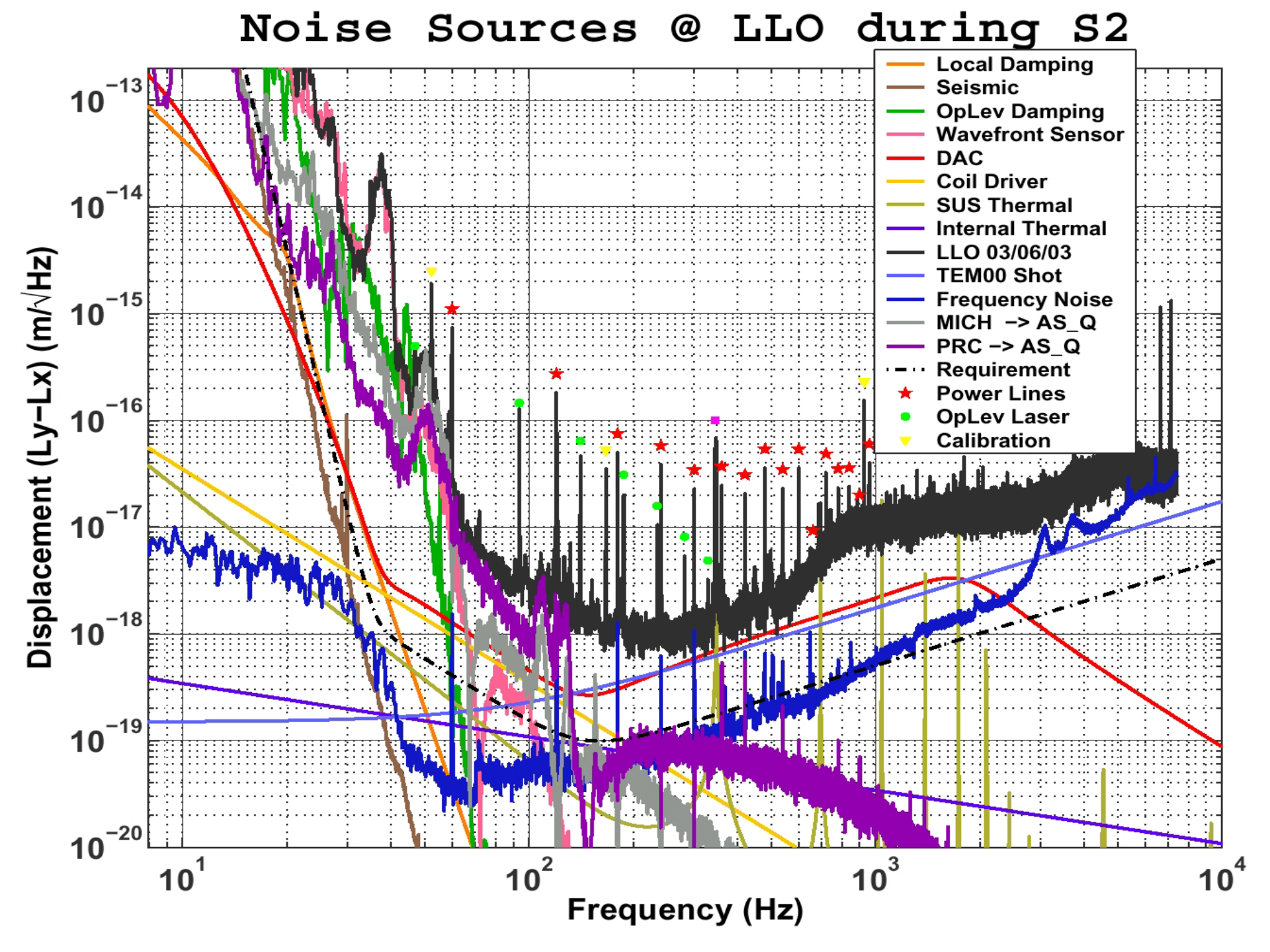


# *Interferometers: design noise budget*

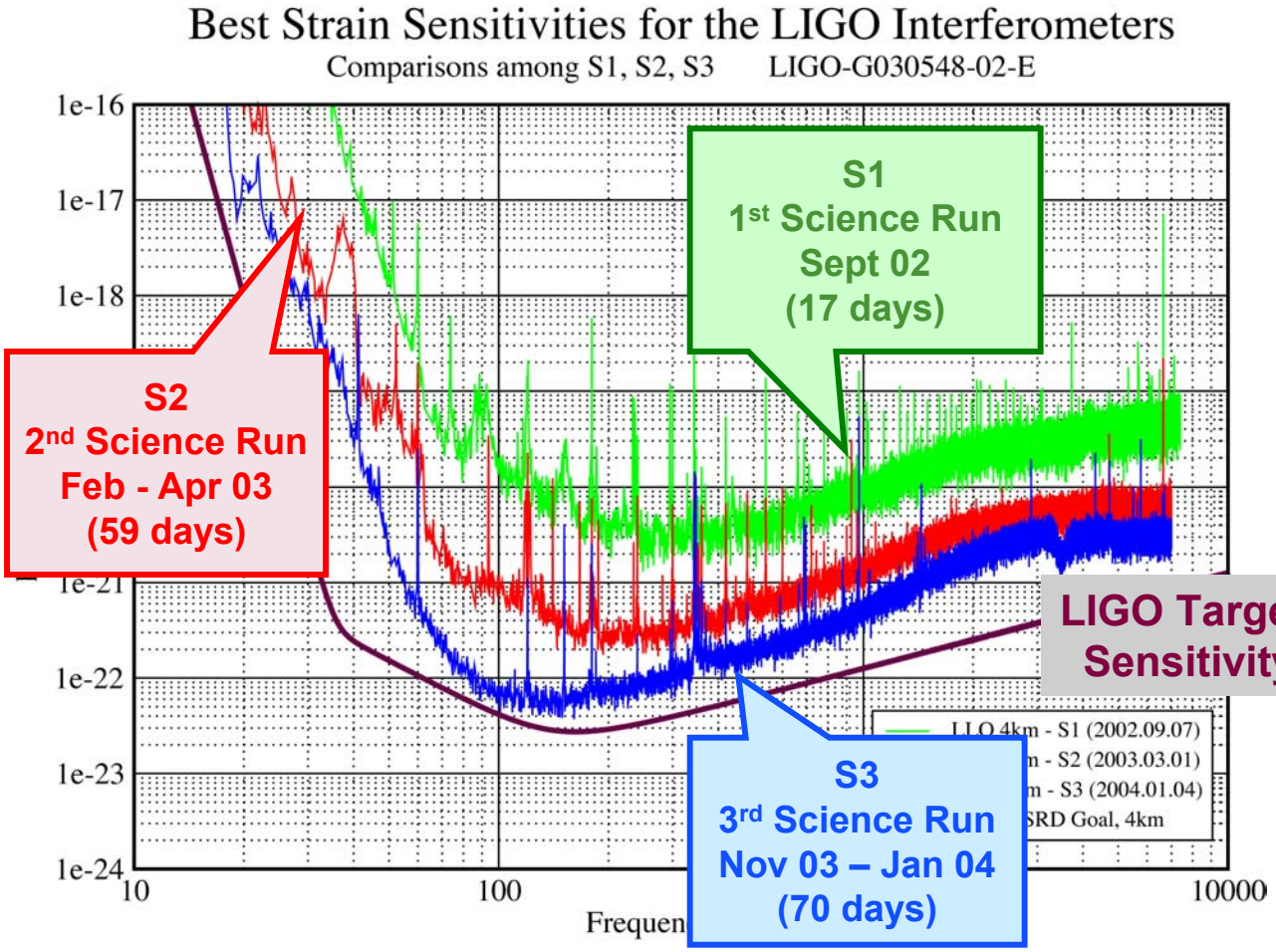
- Calculated "fundamental" limits determined design goal
  - **seismic** at low frequencies
  - **thermal** at mid frequencies
  - **shot noise** at high frequencies
- Other "technical" noise not allowed above 1/10 of these
- Facility limits much lower to allow improvement as technology matures




Strain Sensitivity for the LLO 4km Interferometer
31 January 2003
LIGO-G030014-00-E
h[f], 1/Sqrt[Hz]
1e-16
1e-17
1e-18
1e-19
1e-20
1e-21
1e-22
1e-23
1e-24
10
100
1000
10000
Frequency [Hz]
18 May 2001
21 December 2001
13 June 2002
07 September 2002 (S1)
06 January 2003
LIGO I SRD Goal, 4km
S1
6 Jan


Noise Sources @ LLO during S2
Local Damping
Seismic
OpLev Damping
Wavefront Sensor
DAC
Coil Driver
SUS Thermal
Internal Thermal
LLO 03/06/03
TEM00 Shot
Frequency Noise
MICH -> AS_Q
PRC -> AS_Q
Requirement
Power Lines
OpLev Laser
Calibration
Displacement (Ly−Lx) (m/√Hz)
Frequency (Hz)
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20
10^1
10^2
10^3
10^4

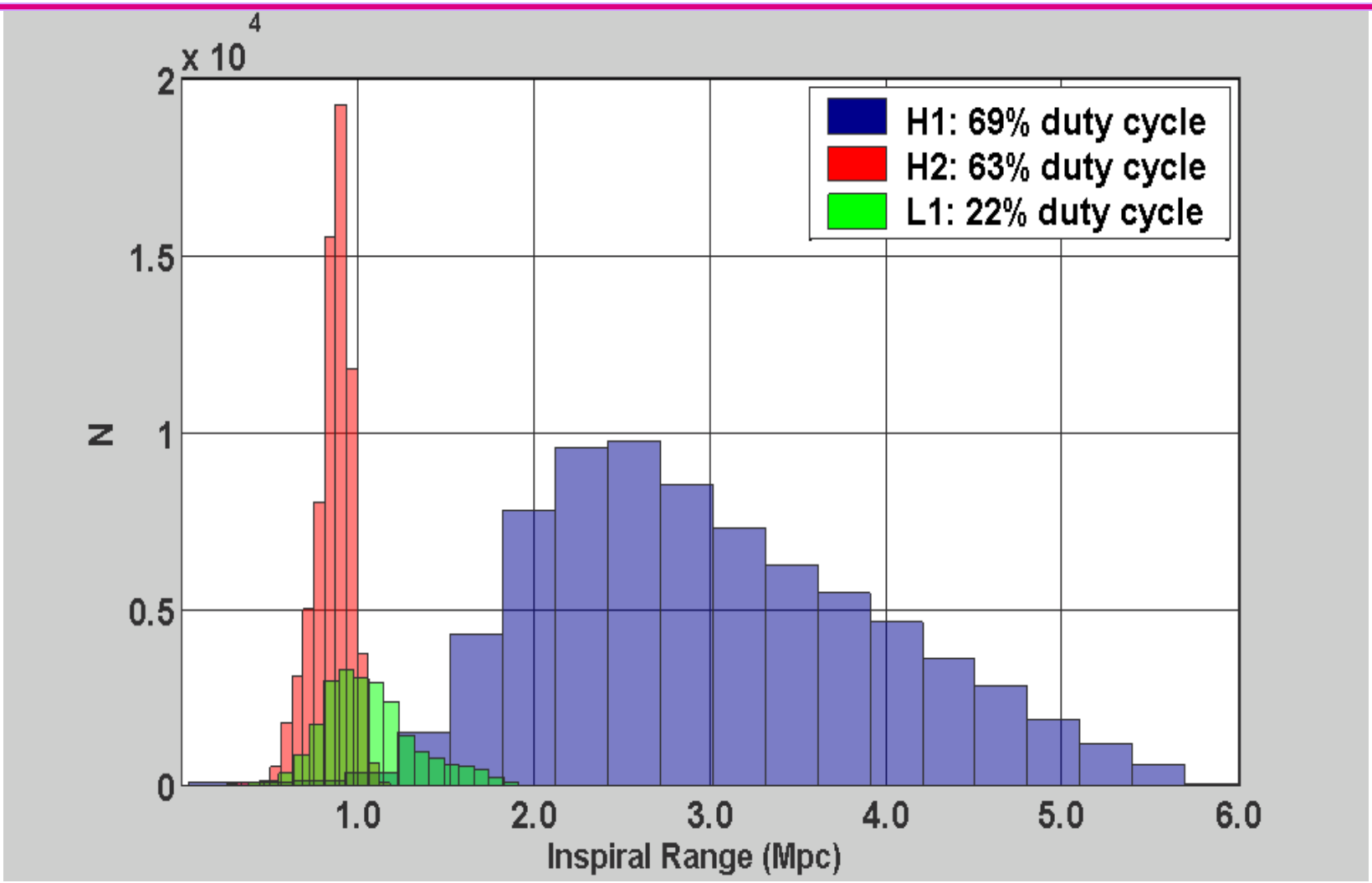
# LIGO Science Runs




| S3 Duty Cycle | |
|---|---|
| Hanford 4km | 69% |
| Hanford 2km | 63% |
| Livingston 4 km | 22%* |

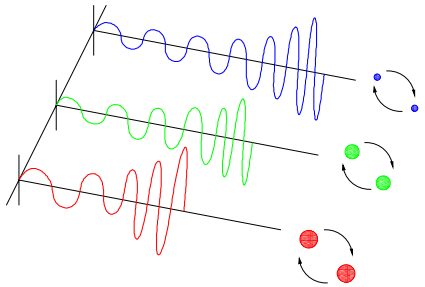
*Limited by high ground noise—upgrade currently underway

# S3 Range and Stability

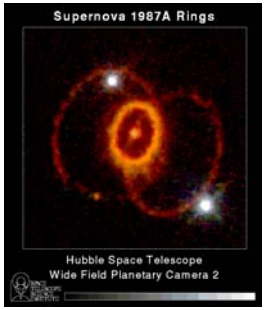


# Astrophysical Searches with LIGO Data

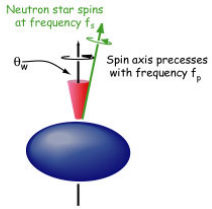
- Compact binary inspiral: *"chirps"*
  - » NS-NS waveforms are well described
  - » BH-BH need better waveforms
  - » search technique: matched templates



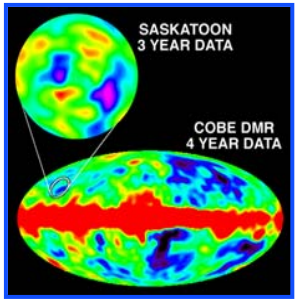
- Supernovae / GRBs: *"bursts"*
  - » burst signals in coincidence with signals in electromagnetic radiation
  - » prompt alarm (~ one hour) with neutrino detectors




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




- Cosmological Signals *"stochastic background"*



# "Results" Papers

*LIGO Science Collaboration (~370 authors, 40 institutions):*

Papers based on S1 data:

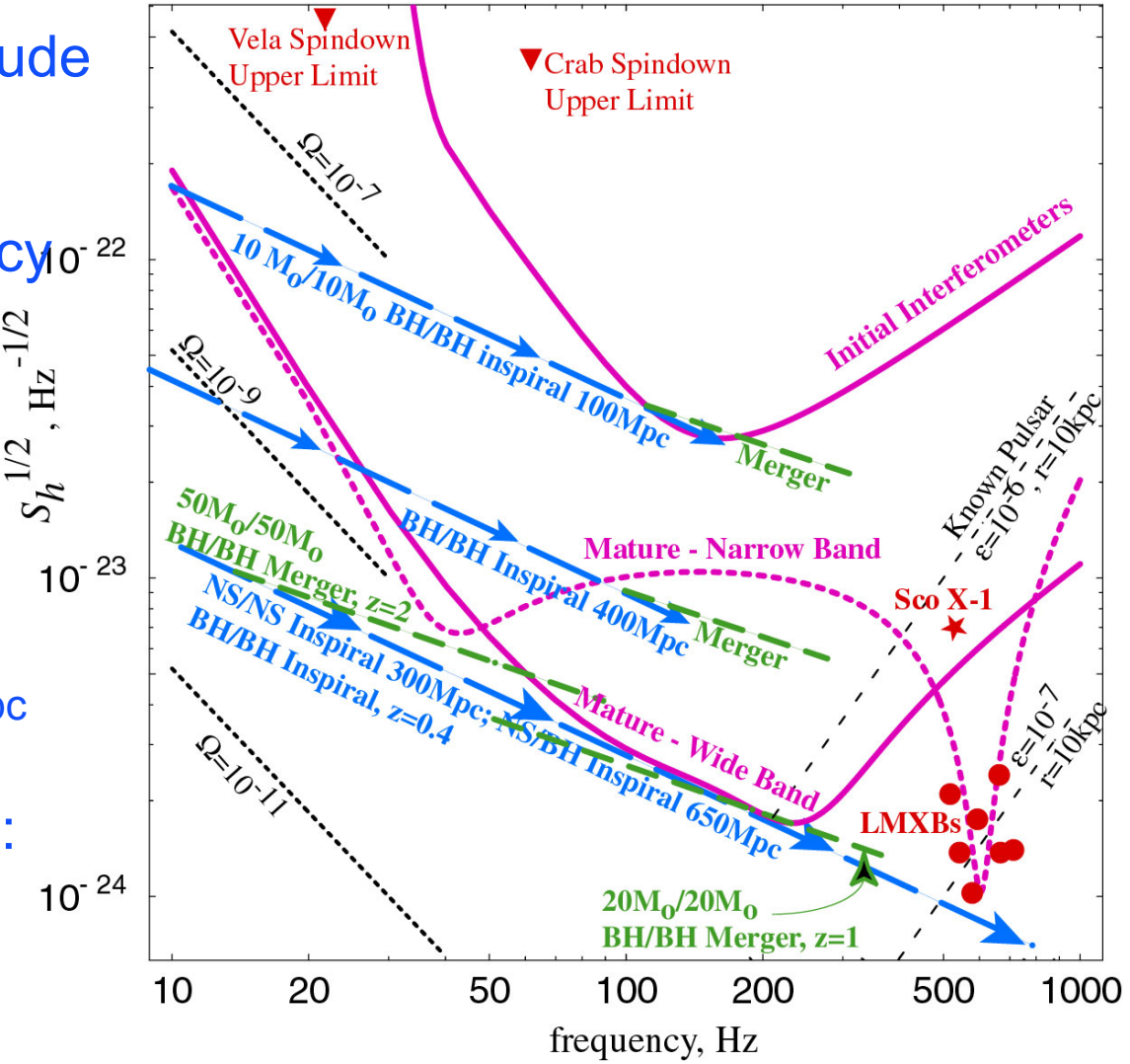
- "*Setting upper limits on the strength of periodic gravitational waves using the first science data from the GEO600 and LIGO detectors*" gr-qc/0308050, accepted for publication in PRD
- "*Analysis of LIGO data for gravitational waves from binary neutron stars*", gr-qc/0308069, accepted for publication in PRD
- "*First upper limits from LIGO on gravitational wave bursts*", gr-qc/0312056, accepted for publication in PRD
- "*Analysis of First LIGO Science Data for Stochastic Gravitational Waves*", gr-qc/0312088, under review by PRD

Papers based on S2 data nearing maturity:

- GRB030329
- "All" known pulsars > ~50Hz
- Binary neutron star inpirals

# Advanced LIGO vs. Initial LIGO

- Factor 10 better amplitude sensitivity
  - » (Reach)$^3$ = rate
- Factor 4 lower frequency bound
- NS Binaries: for three interferometers,
  - » Initial LIGO: ~20 Mpc
  - » Adv LIGO: ~350 Mpc
- BH Binaries:
  - » Initial LIGO: 10 $M_o$, 100 Mpc
  - » Adv LIGO : 50 $M_o$, z=2
- Stochastic background:
  - » Initial LIGO: ~3e-6
  - » Adv LIGO ~3e-9



# Summary

- LIGO construction complete and expect to be near design sensitivity by year's end
- First results are published
- 2005 will bring first long duration (~6 month) Science Run
- Proposal for Advanced LIGO is a major step toward gravitational astronomy