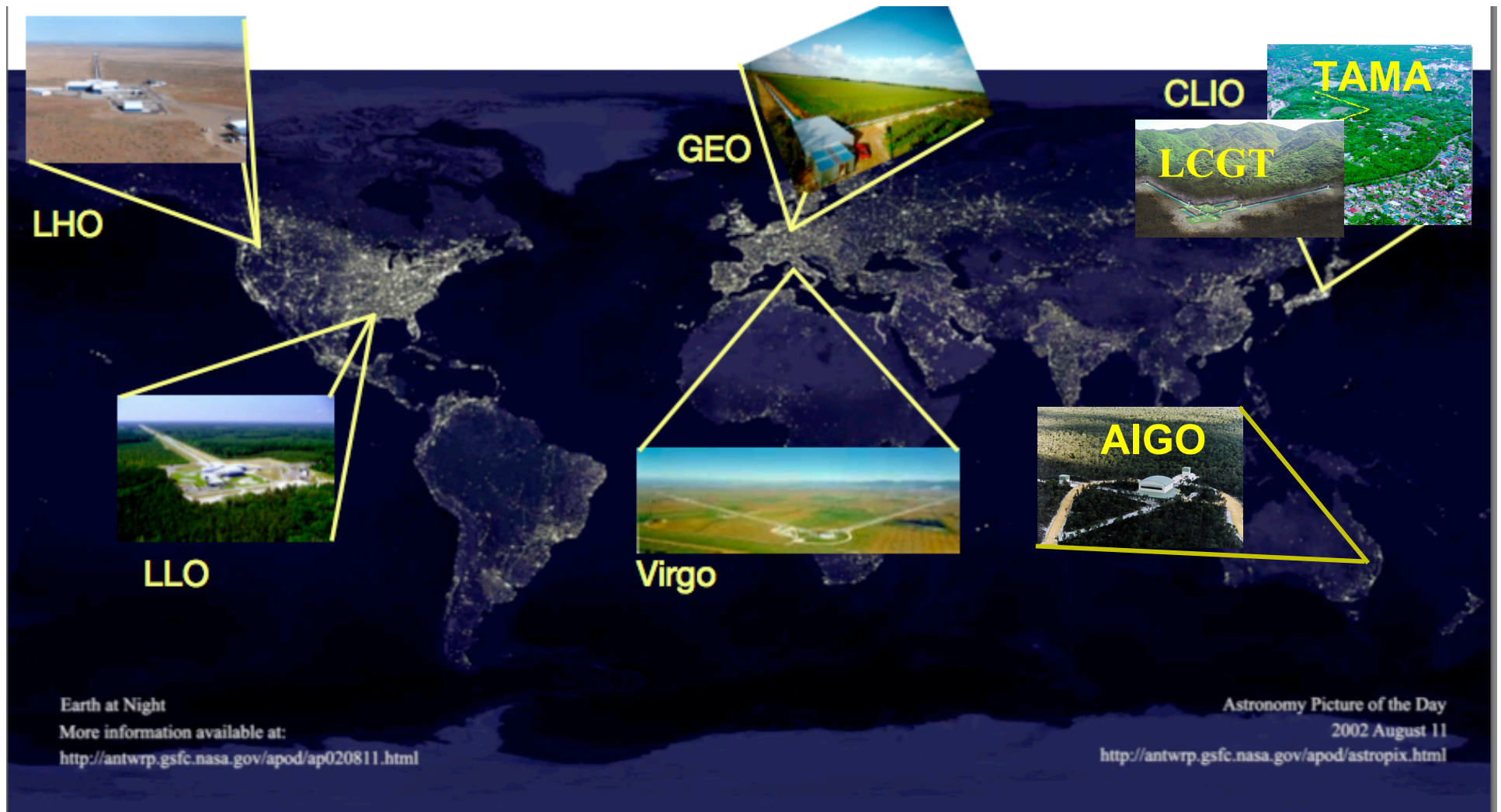

Status of Ground Based Interferometers



Gabriela González

For the LIGO and Virgo Scientific Collaborations
Louisiana State University

Worldwide network



Networks exist!

LIGO-GEO detectors, S1 (17 days in 2002)

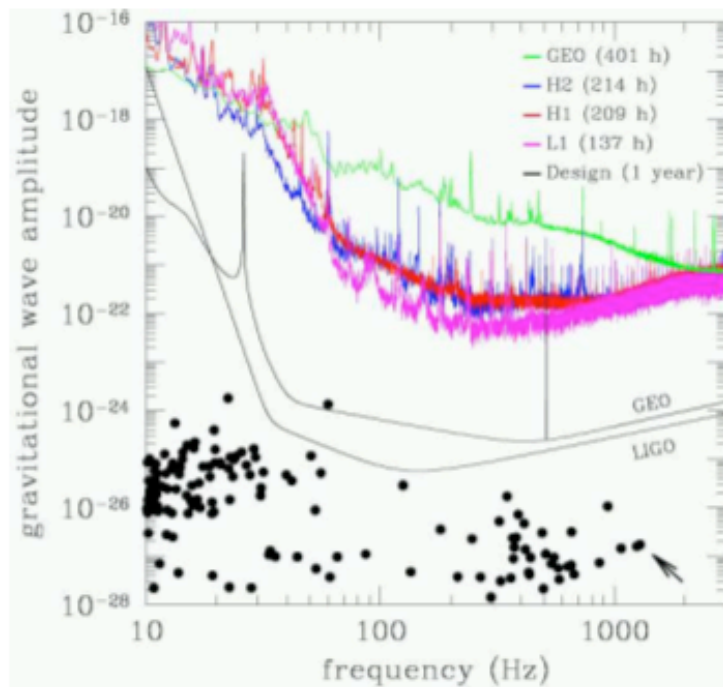


FIG. 1: Upper curves: characteristic amplitude $\langle h_0 \rangle$ of a known monochromatic signal detectable with a 1% false alarm rate and a 10% false dismissal rate by the GEO and LIGO detectors at the S1 sensitivity and with an observation time equal to the up-time of the detectors during S1 (GEO: 401 h, L1: 137 h, H1: 209 h, H2: 214 h). Lower curves: $\langle h_0 \rangle$ for the design sensitivities of the detectors for an assumed 1 y observation time. Filled circles: upper limit on $\langle h_0 \rangle$ from measured spin-down rate of known radio pulsars assuming a moment of inertia of 10^{45} g cm^2 . These upper limits were derived under the assumption that all the measured loss of angular momentum of the star is due to the emission of gravitational waves, neglecting spin-down contribution from electromagnetic and particle emission. The arrow points to the filled circle representing pulsar J1939+2134.

Phys.Rev. D69: 082004, 2004

Networks exist!

LIGO S2-TAMA DT8, 2003

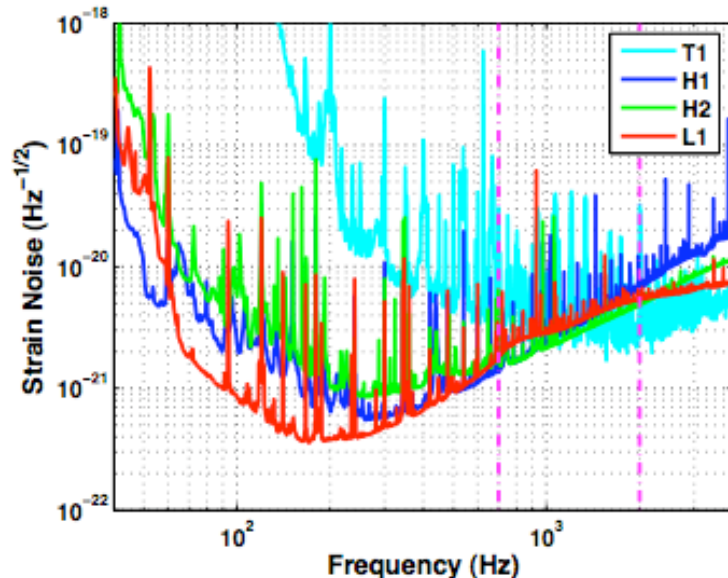


FIG. 2: S2-averaged amplitude noise spectra for the LIGO detectors, and a representative DT8 spectrum for the TAMA detector. We focus on GWBs which have significant energy in the frequency range 700-2000 Hz (indicated by the vertical dashed lines), where each interferometer has approximately the same noise level.

detector combination	observation time (hr)	fraction of total observation time
H1	1040	74%
H2	821	58%
L1	536	38%
T1	1158	82%
H1-H2-L1-T1	256	18%
H1-H2-nL1-T1	320	23%
H1-H2-L1-nT1	62	4%
network totals	638	45%

TABLE I: Observation times and duty cycles of the LIGO and TAMA detectors individually, and in various combinations, during S2/DT8. The symbol nL1 (nT1) indicates times when L1 (T1) was not operating. The network data sets are disjoint (non-overlapping).

Phys. Rev. D 72 (2005) 122004, Upper limits from the LIGO and TAMA detectors on the rate of gravitational-wave bursts.

Also: Phys. Rev. D 73 (2006), 102002 ,Joint LIGO and TAMA300 Search for Gravitational Waves from Inspiralling Neutron Star Binaries.

Networks exist!

LIGO S3-AURIGA 2003
Class.Quant.Grav.25 : 095004, 2008

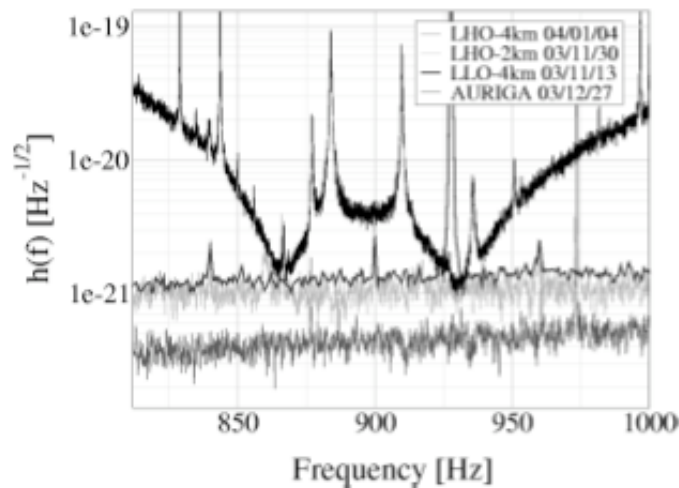


Figure 2. Best single-sided sensitivity spectra of AURIGA and the three LIGO interferometers during the joint observation. In the AURIGA spectrum, several spurious lines are visible while LIGO spectra present calibration lines at 973 Hz for the Hanford detectors (LHO-4 km and LHO-2 km) and 927 Hz for the Livingston detector (LLO-4 km).

LIGO L1 S4, ALLEGRO 2004
Phys.Rev.D76:022001,2007

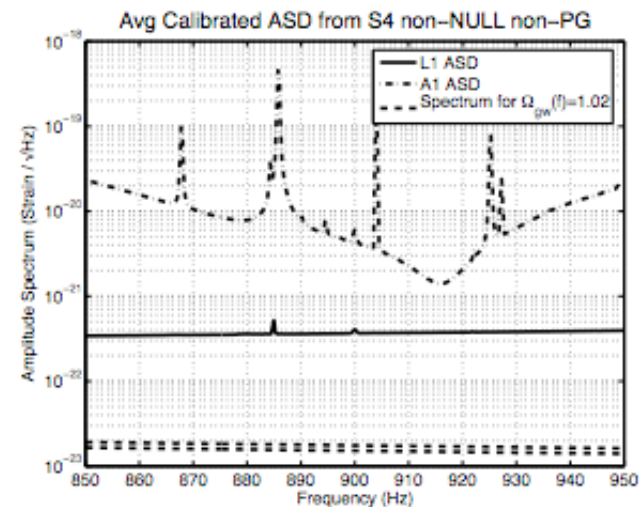
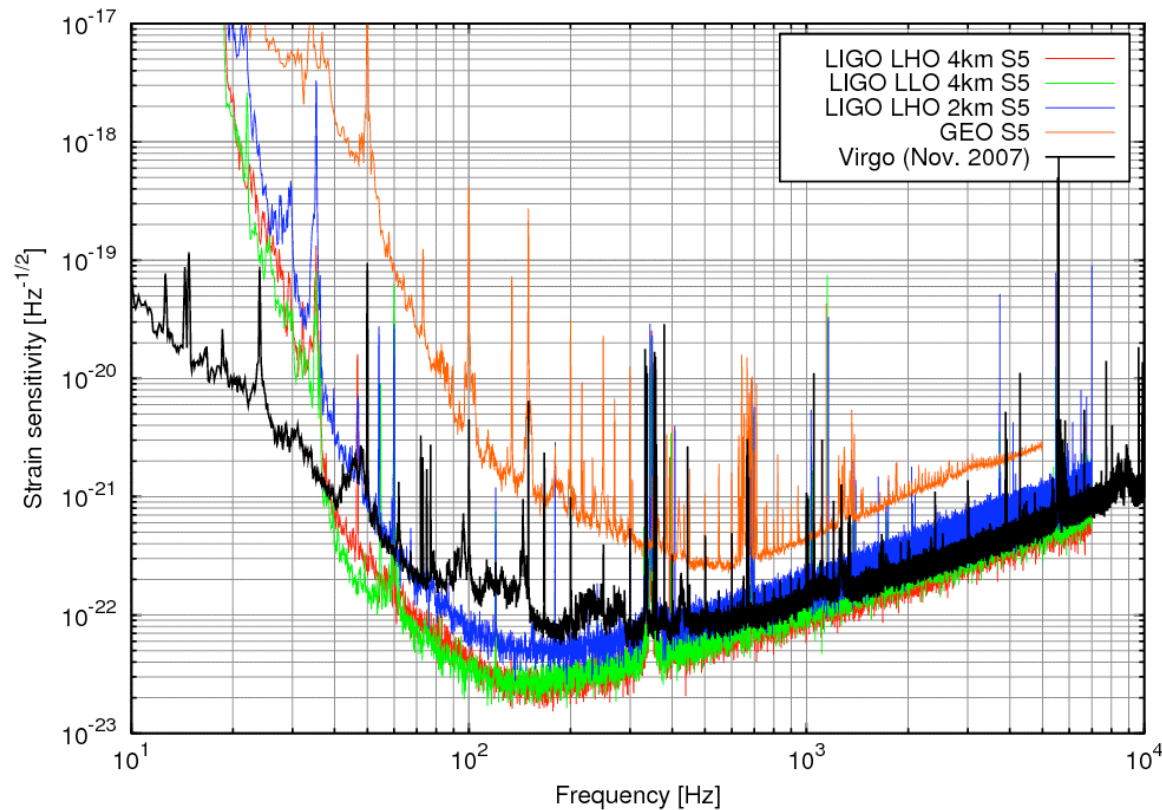


FIG. 1: Sensitivity of the LLO IFO (L1) and the ALLEGRO bar (A1) during S4, along with strain associated with $\Omega_{\text{gw}}(f) = 1.02$ (assuming a Hubble constant of $H_0 = 72 \text{ km/s/Mpc}$). (There are two $\Omega_{\text{gw}}(f) = 1.02$ curves, corresponding to the different strain levels such a background would generate in an IFO and a bar, as explained in Sec. II and [27].) The quantity plotted is amplitude spectral density (ASD), the square root of the one-sided power spectral density defined in [4.2], at a resolution of 0.25 Hz.

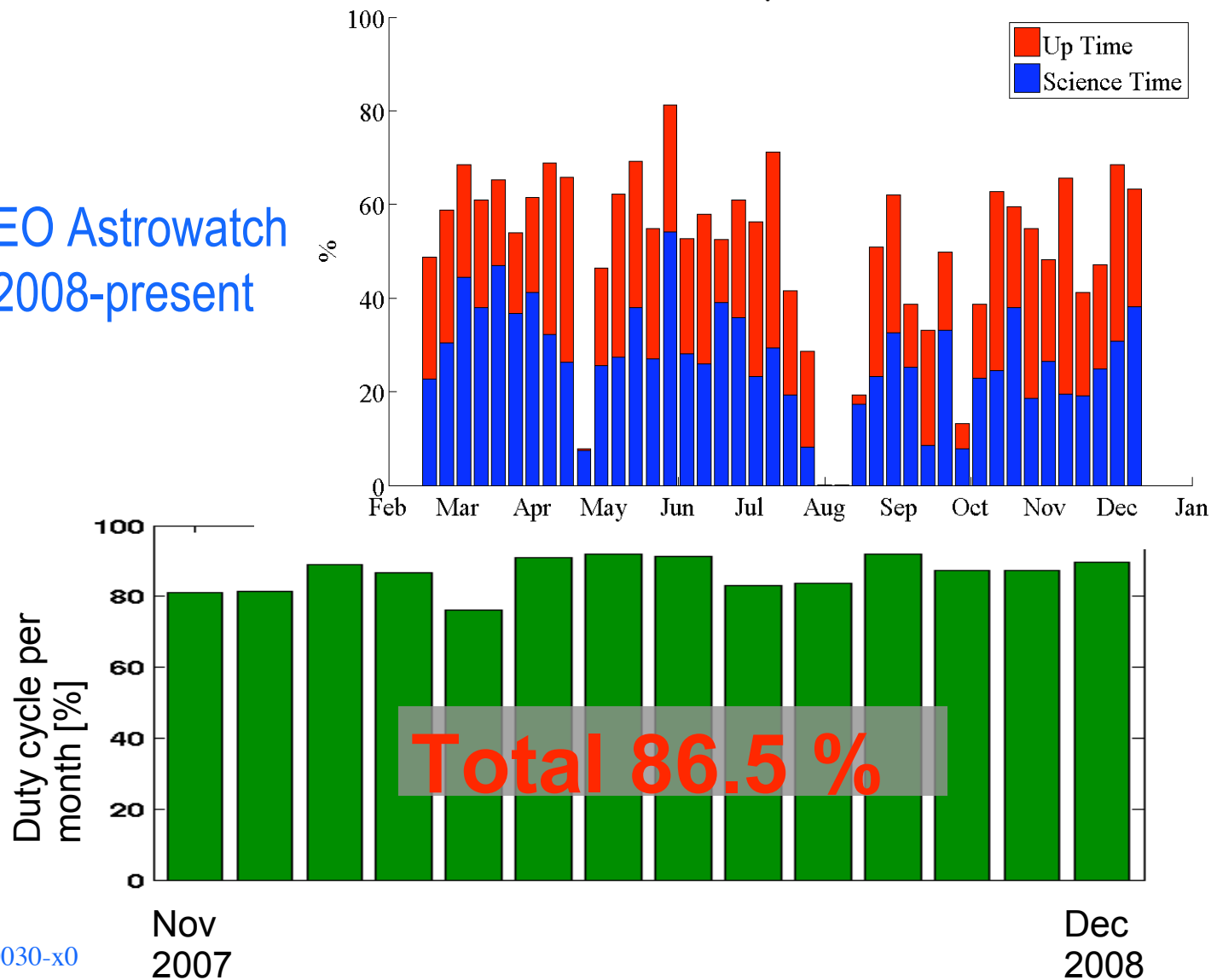
Networks exist!

LSC S5 (Nov'05-Oct'07), LVC VSR1 (May-Oct'07)
(see talks by P. Shawhan, J. Clayton on status of S5 joint searches)

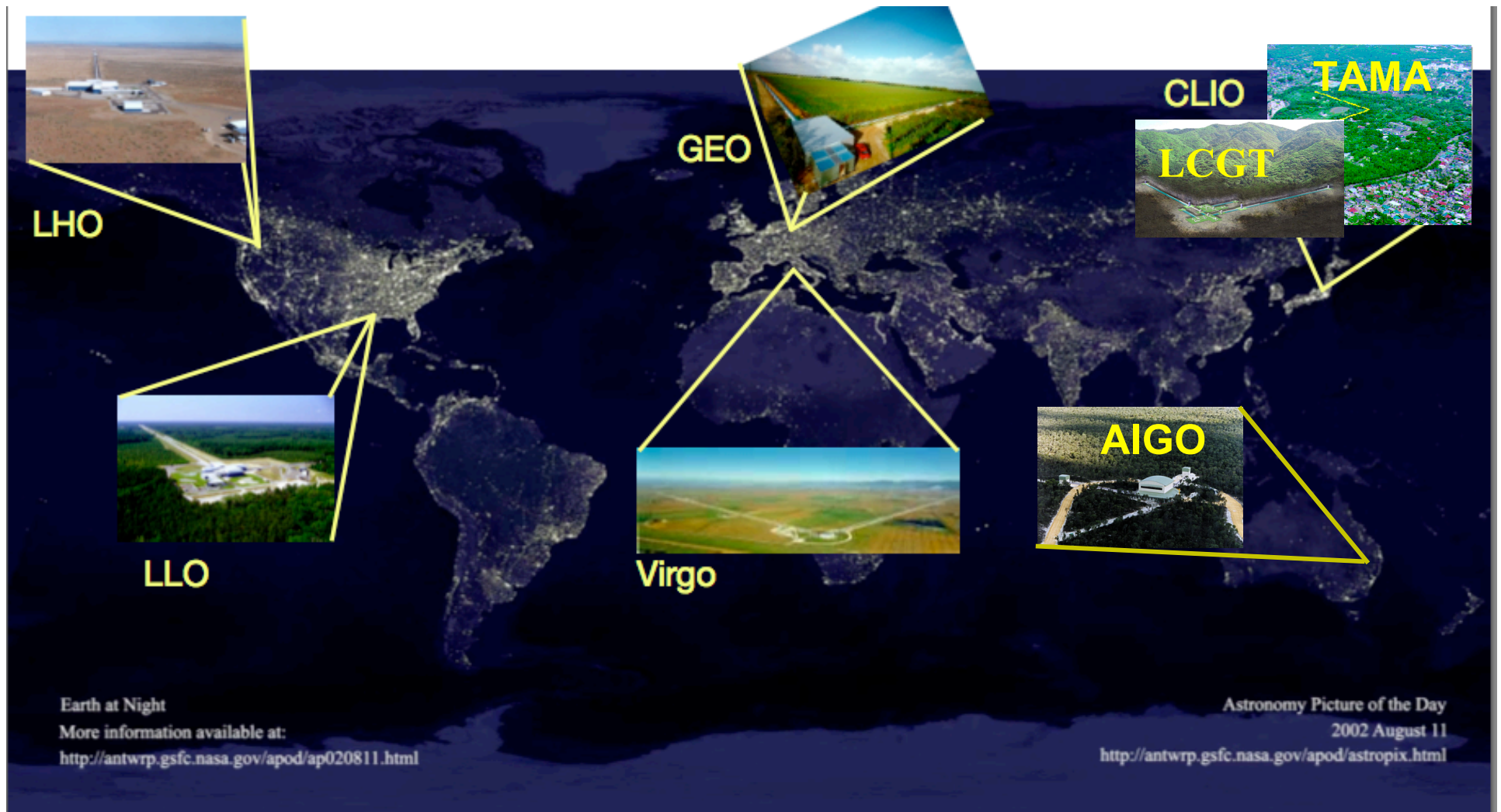


Networks exist!

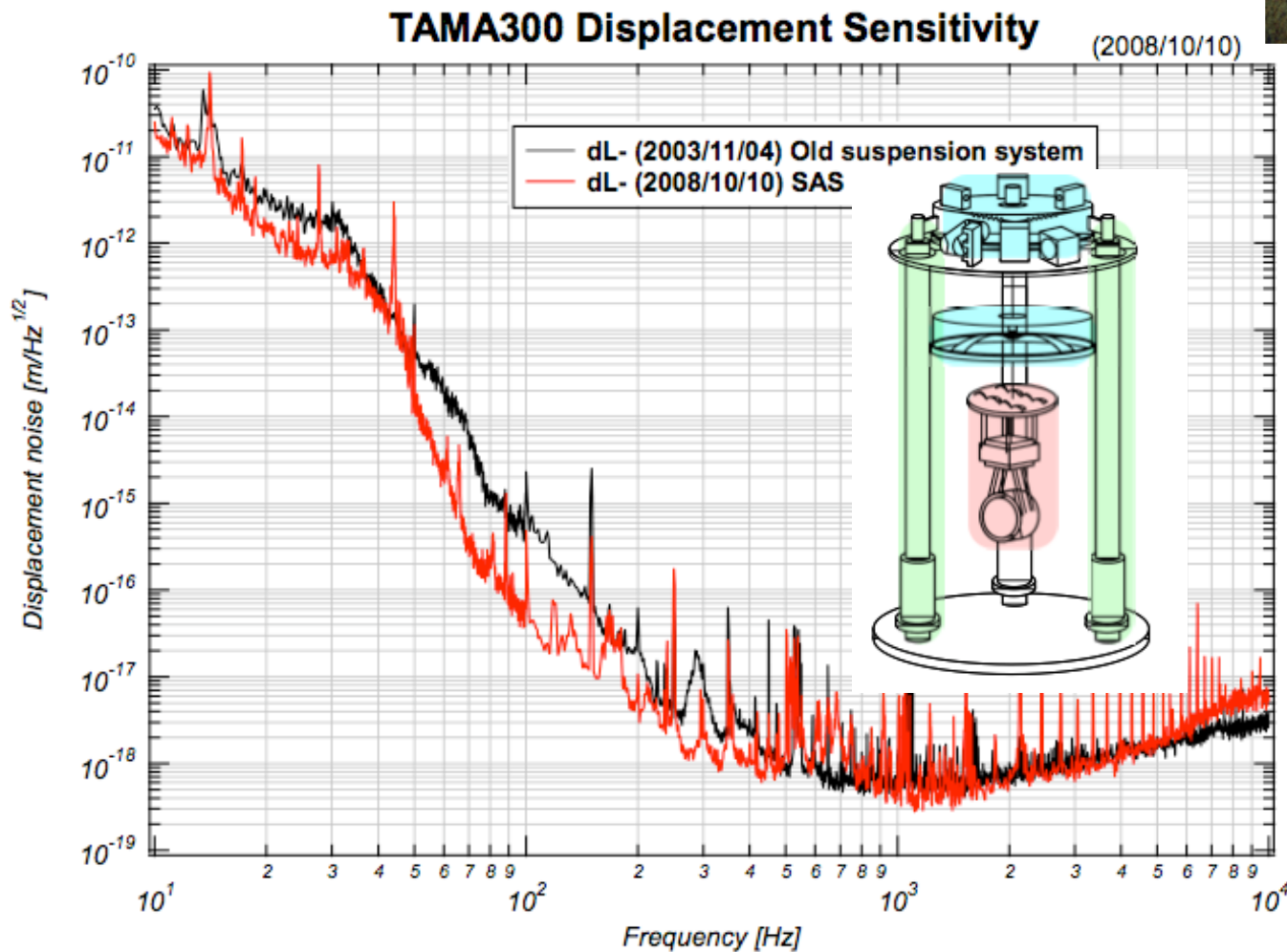
H2-GEO Astrowatch
Jan 2008-present



Worldwide network



TAMA 300

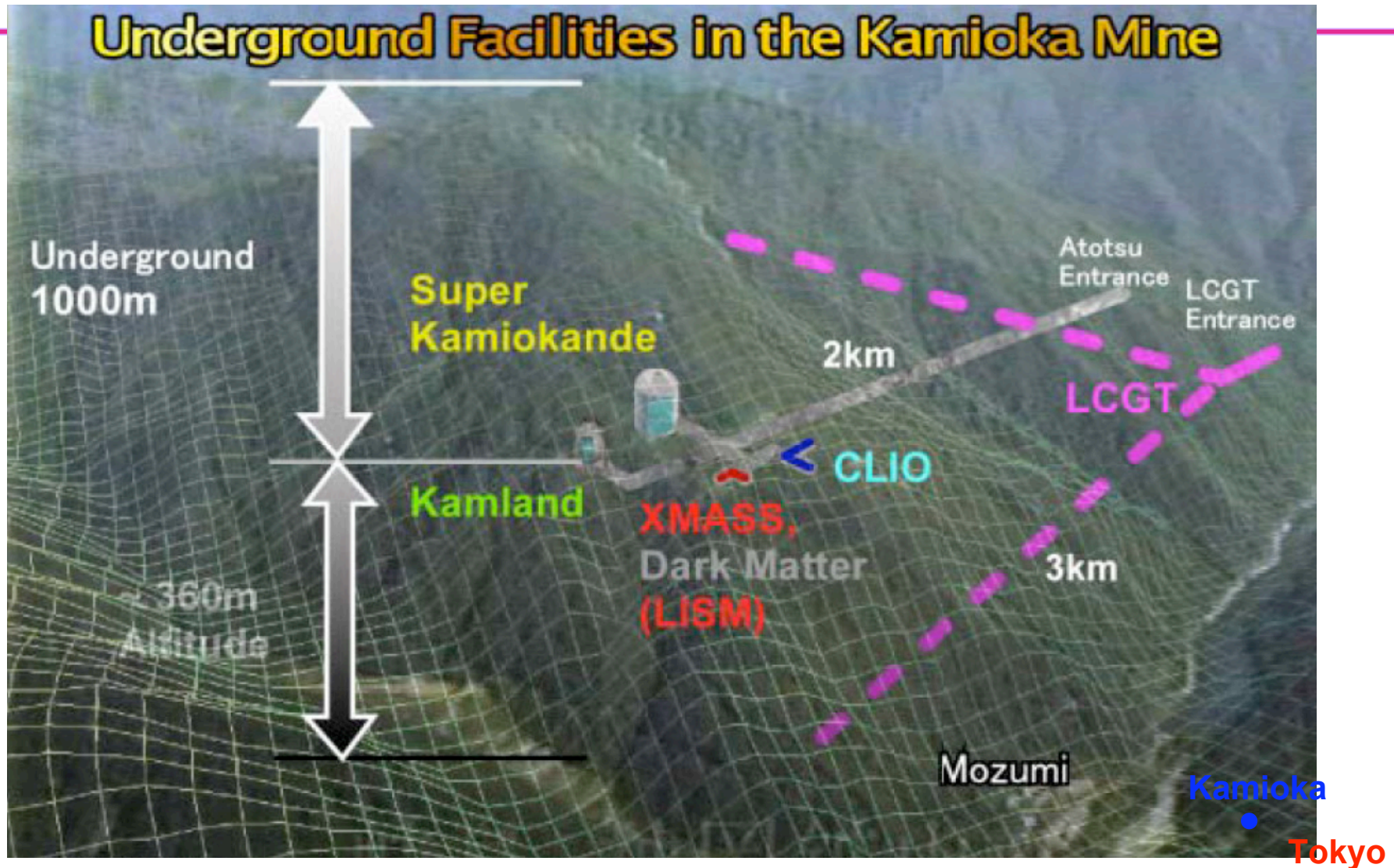


floor level
@1kHz

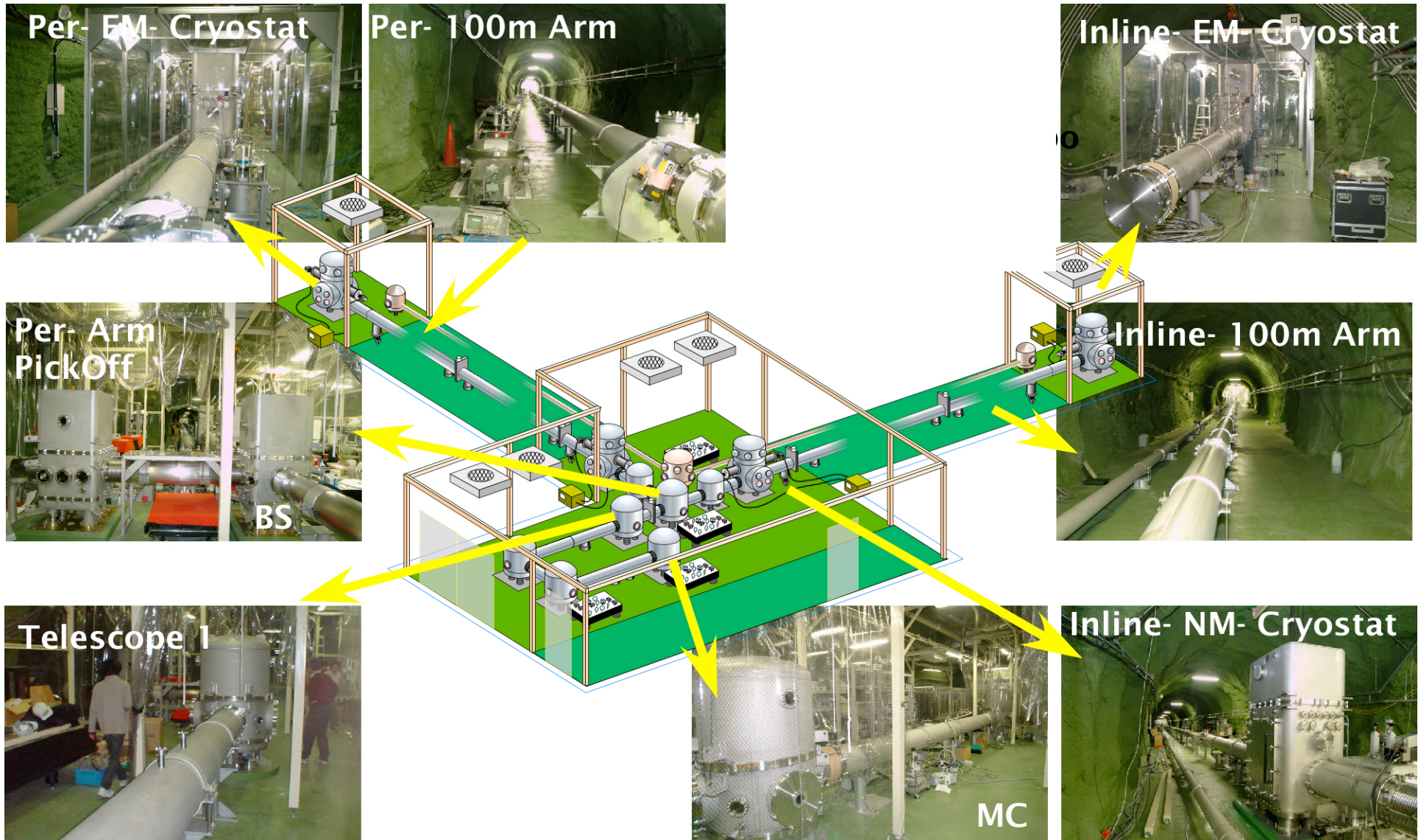
displacement
 $dL=4 \times 10^{-19}$
[m/rtHz]

strain
 $h=1.3 \times 10^{-21}$
[/rtHz]

GW detectors underground

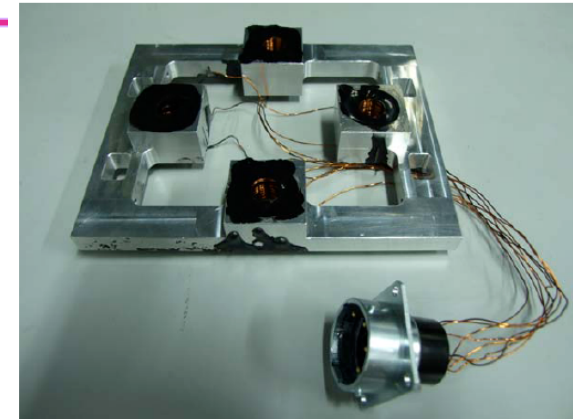
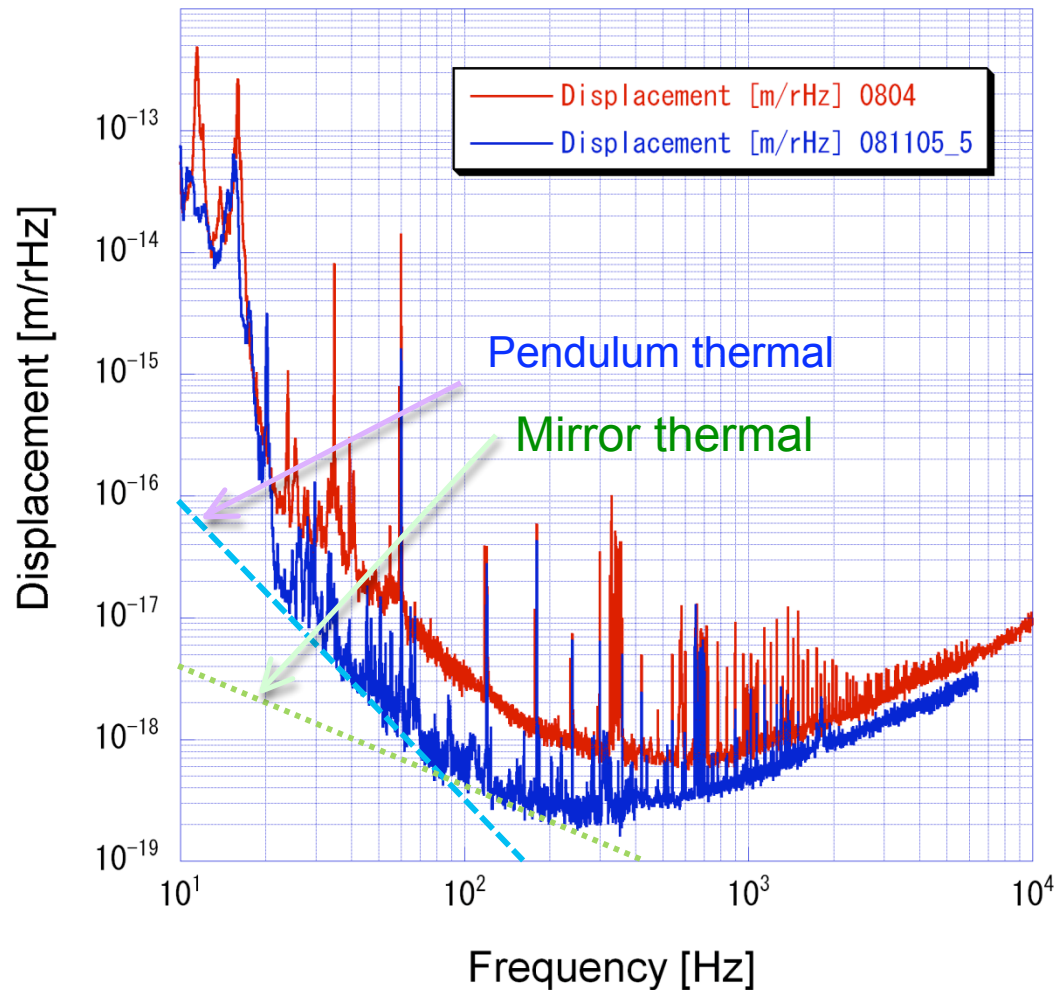


CLIO in Kamioka mine

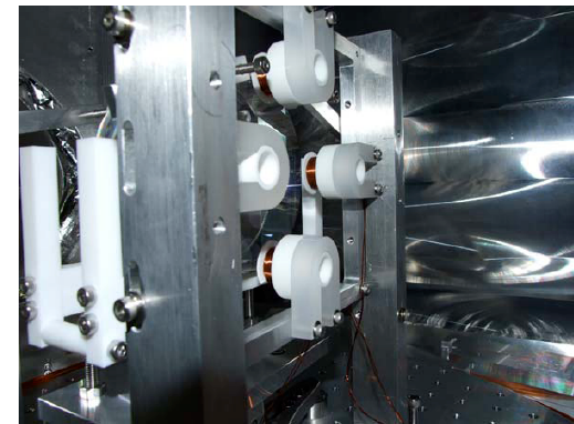


CLIO current spectrum

**CLIO Displacement Noise Improvement
from April/2008 to December/2008**

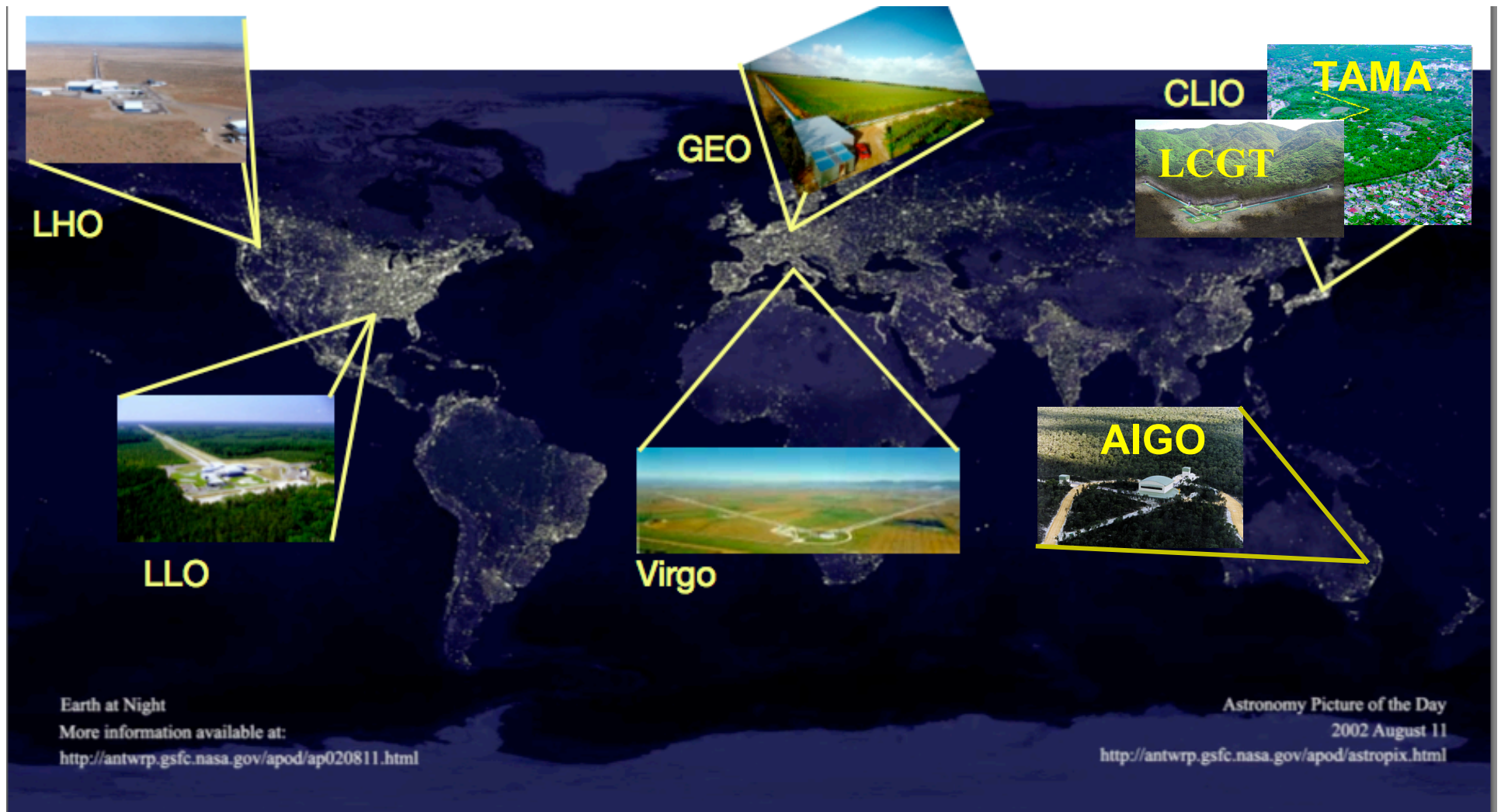


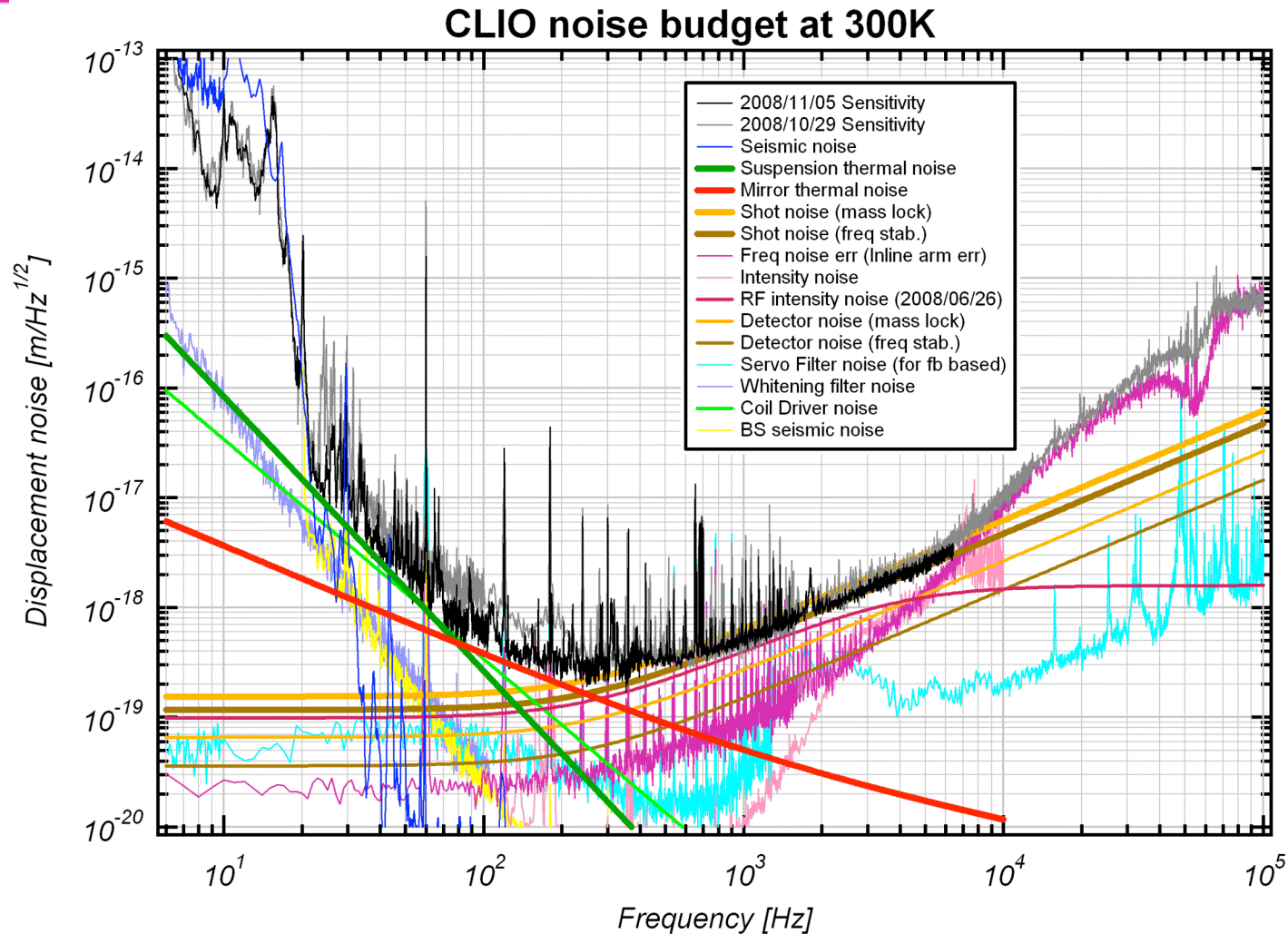
Problem: Eddy current in aluminum coil holders induced by magnets attached on mirror added mechanical loss on pendulum thermal noise



Solution: Aluminum holders were exchanged to ceramic and daifron holders.

Worldwide network





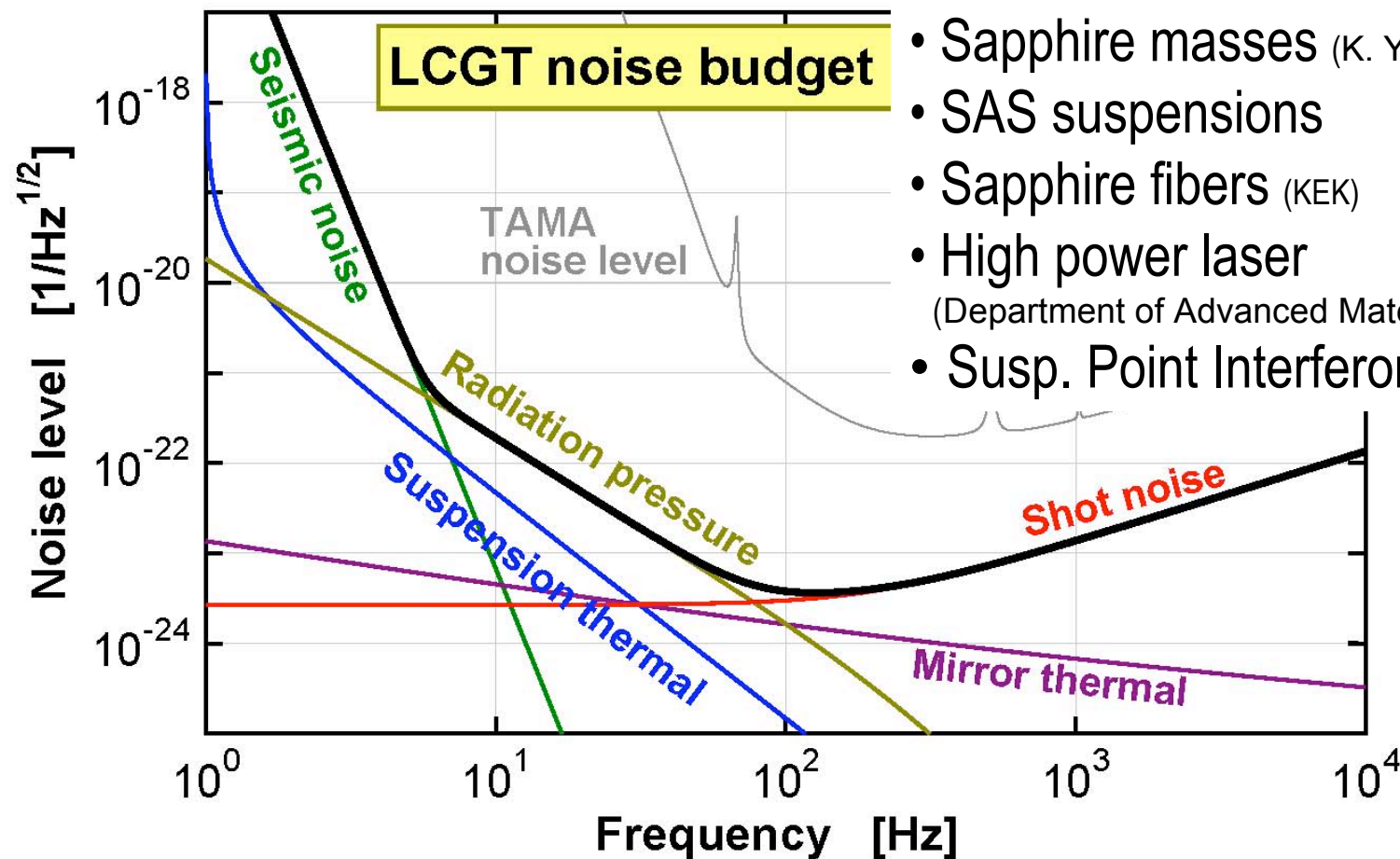
Start *cooling* in this spring to see improved thermal noise!

14

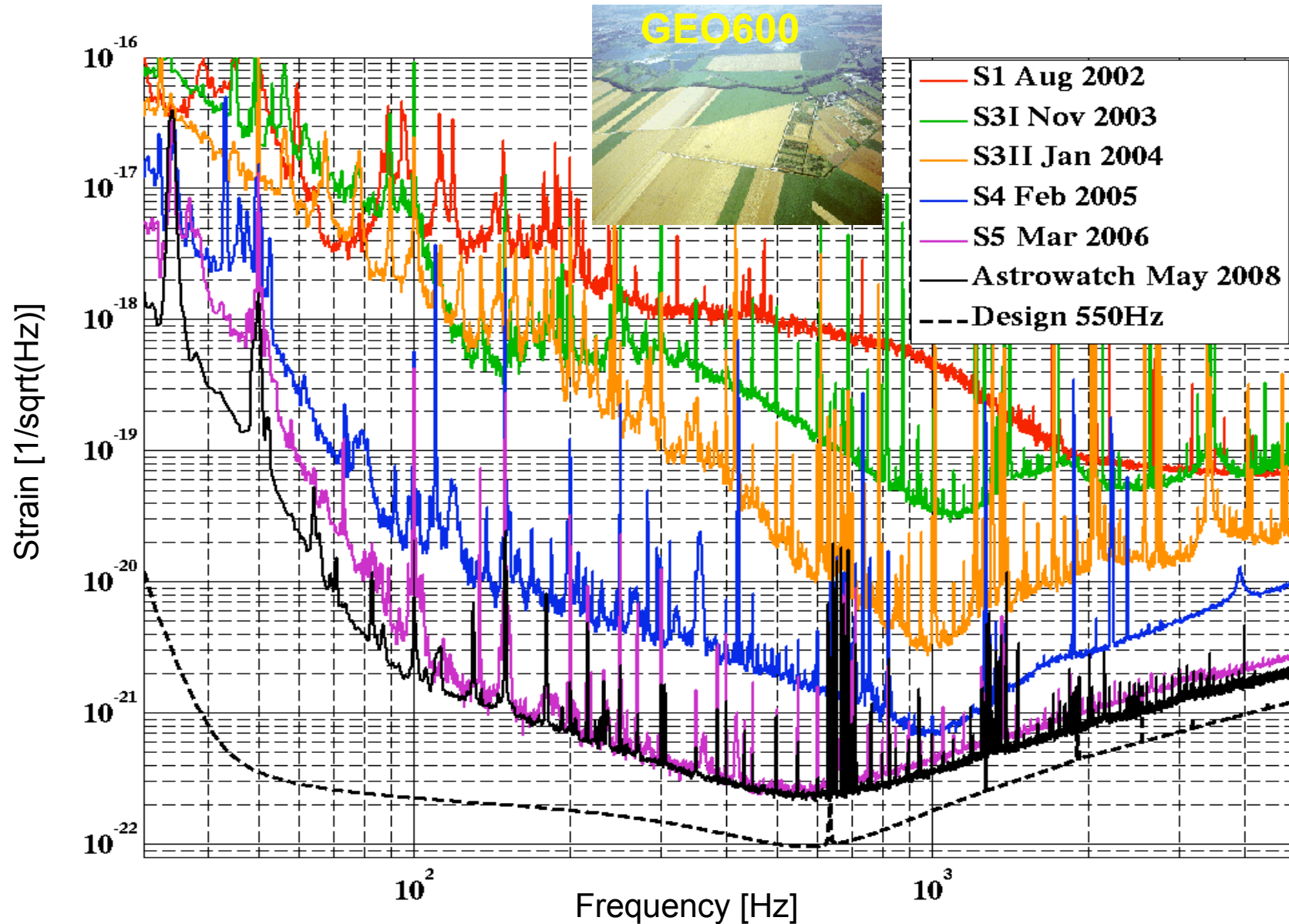
LCGT Design Sensitivity



- *Underground*
- *Cryogenic system*
- RSE control scheme (NAOJ)
- Sapphire masses (K. Yamamoto's talk)
- SAS suspensions
- Sapphire fibers (KEK)
- High power laser
(Department of Advanced Materials Science, UT)
- Susp. Point Interferometer

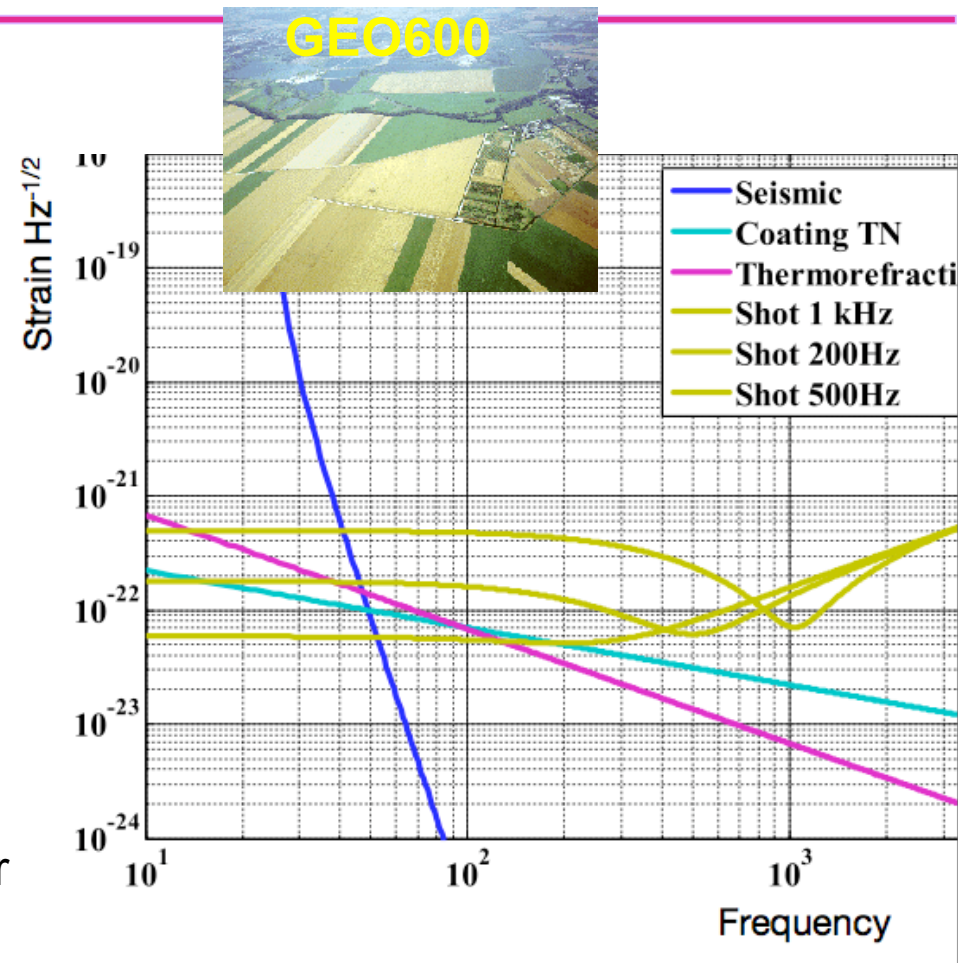


GEO Sensitivity

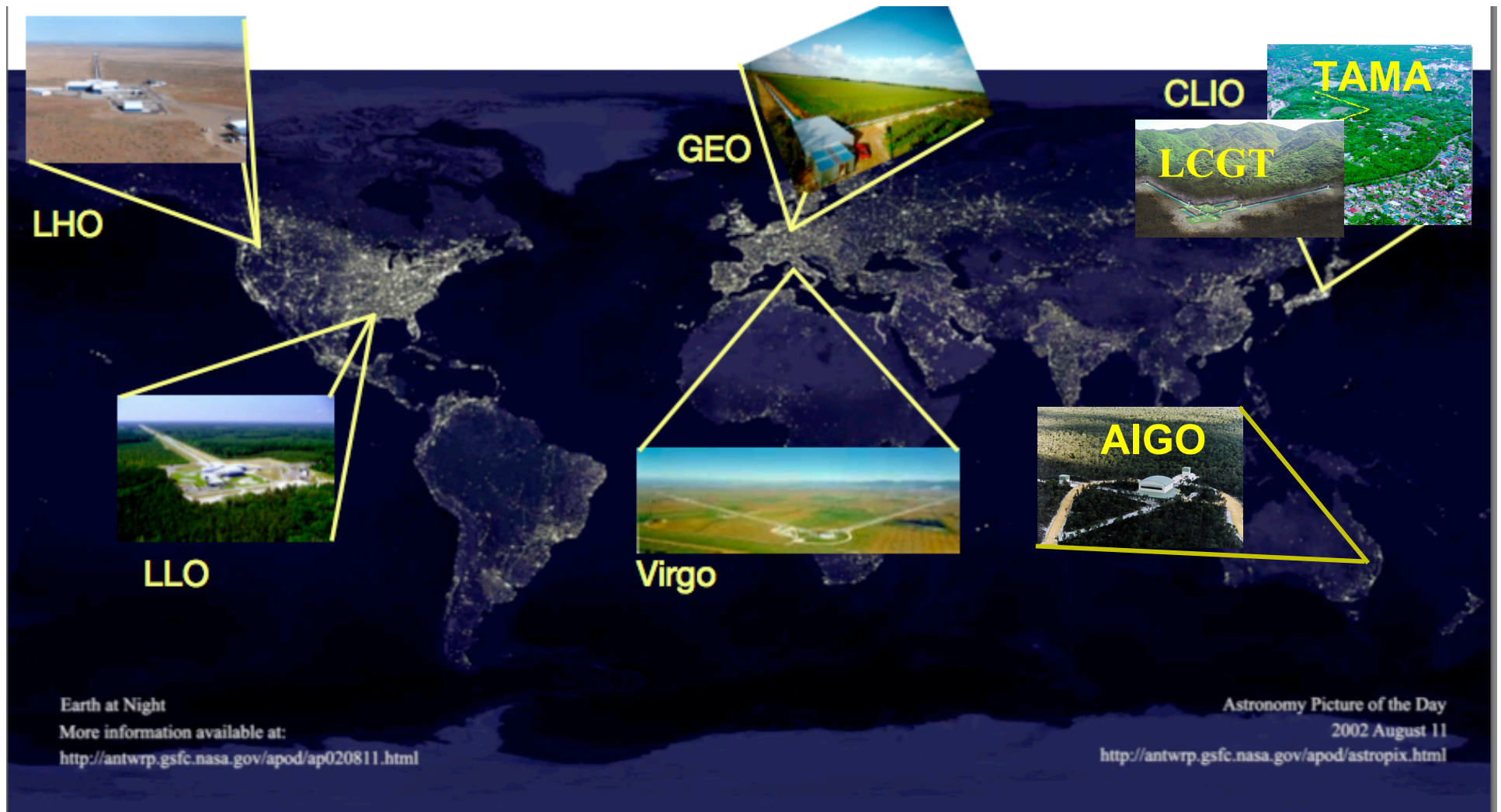


GEO Plans / Timeline

- Spring 2009:
 - New vacuum tank, with suspended platform, for in-vacuum readout
 - DC readout (with *tuned* signal recycling)
 - Injection of squeezed vacuum
 - OMC
- 2010: Increase laser power
 - Exchange IMC mirrors
 - implement thermal comp. scheme for main beamsplitter
 - upgrade laser to 30W system

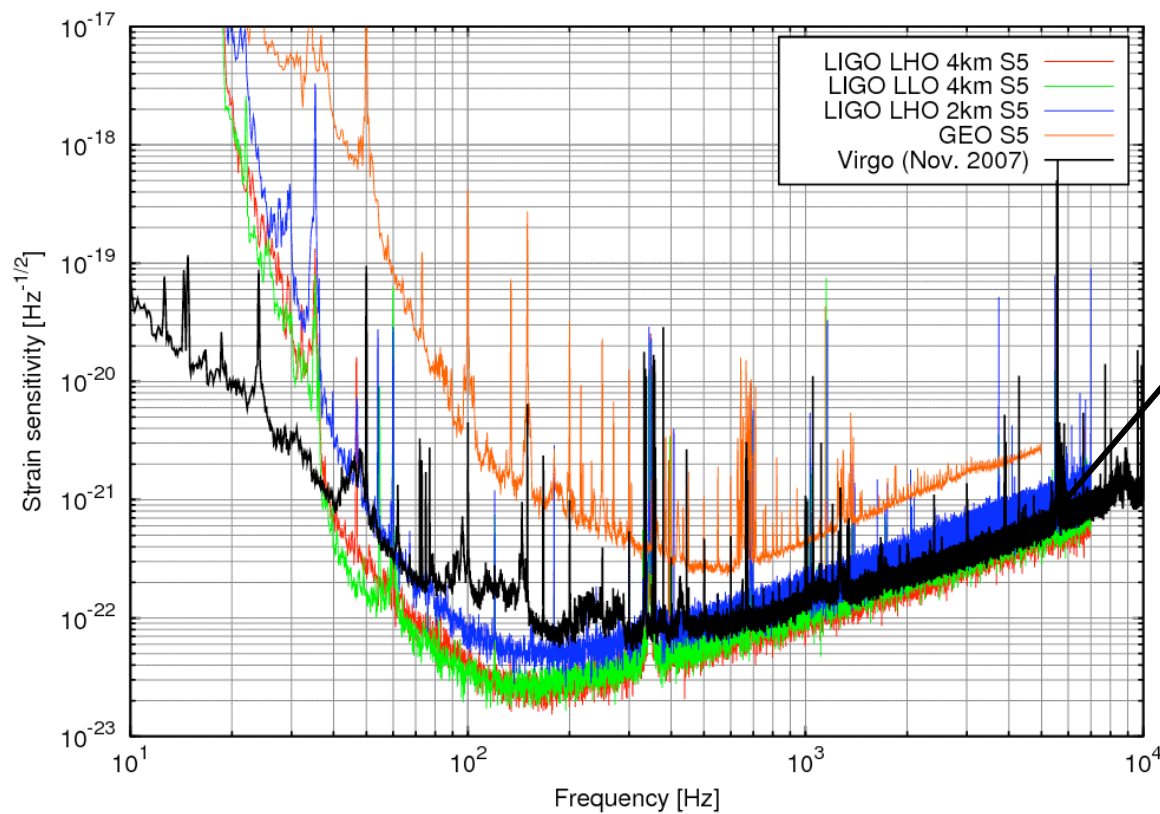


Worldwide network



Networks exist!

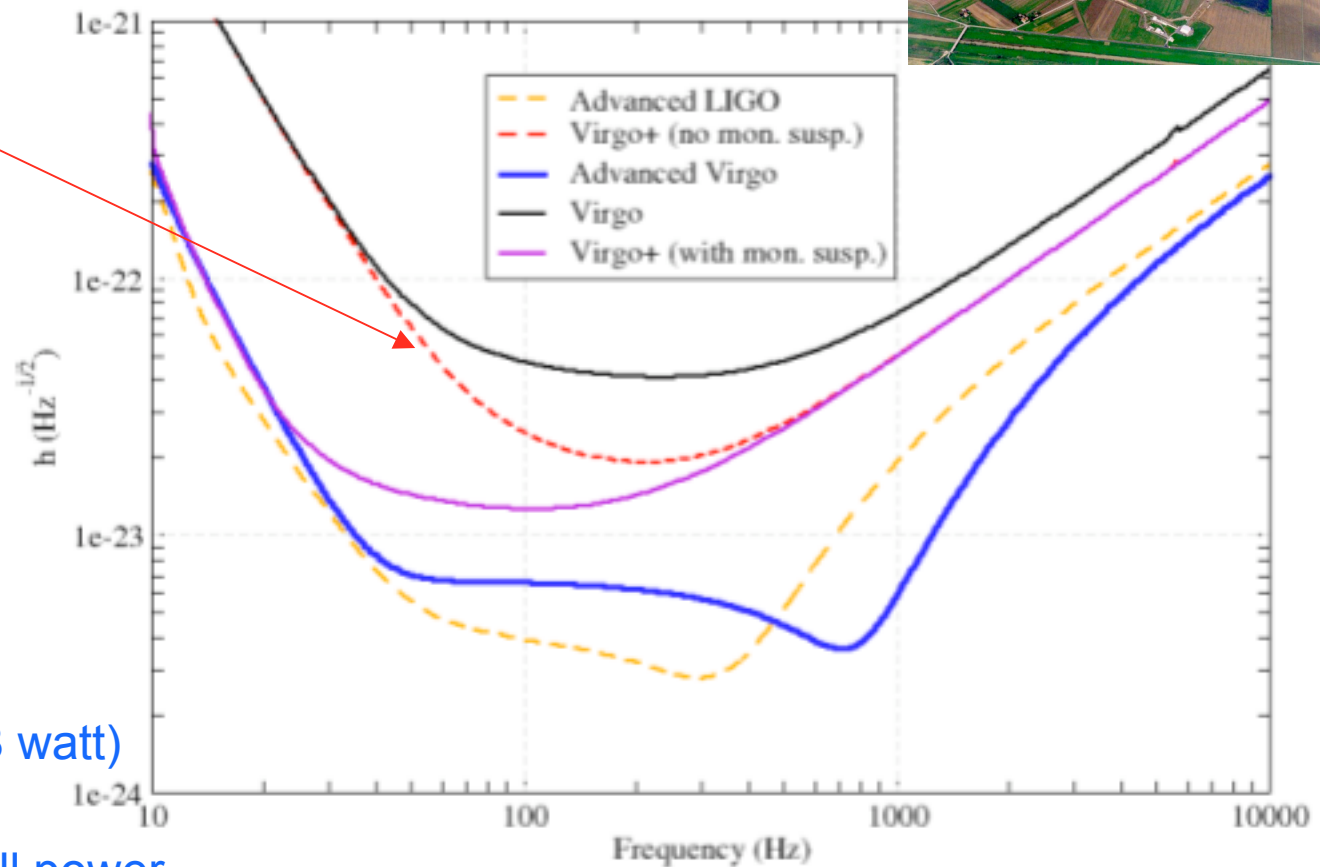
LSC S5 (Nov'05-Oct'07), LVC VSR1 (May-Oct'07)



Virgo detector



VSR2, June 2009

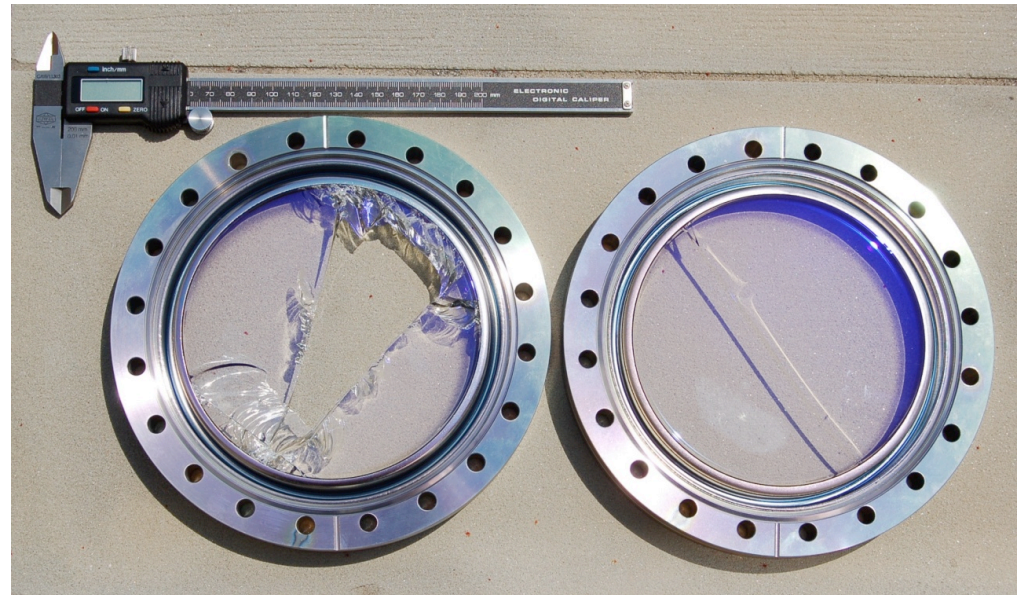


Steps to VSR2:

- 1) First Virgo+ Locking
(8 watt) $\checkmark$
- 2) Aberrations free
interferometer (8 watt)
- 3) High sensitivity @full power

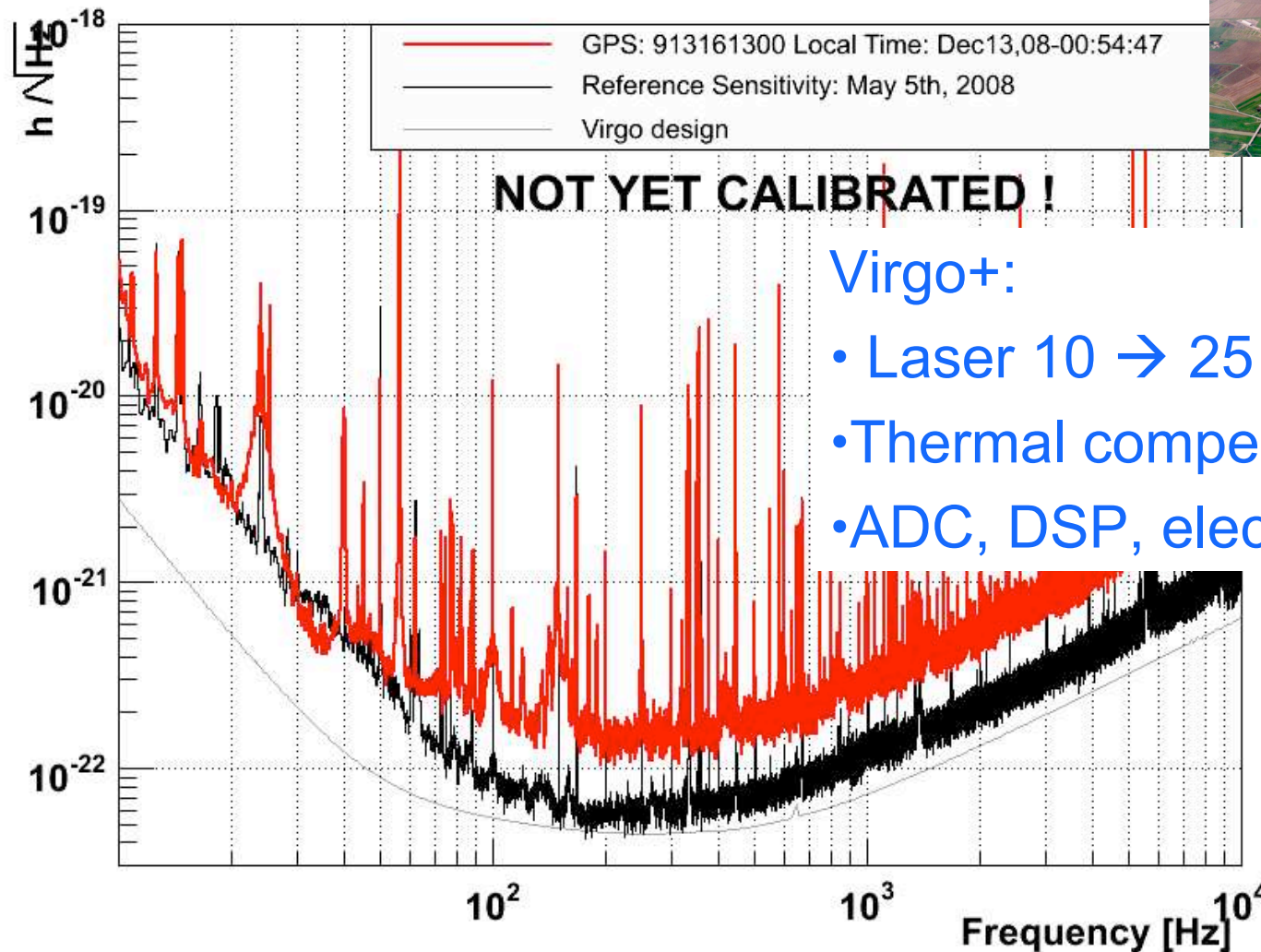
VIRGO NE accident recovery

- The last window was installed on October 15th
- The new mirror and payload installed on October 8th and commissioned in following two 2 weeks



- On November 3th the commissioning restarted
- First lock (not in low noise) after two weeks

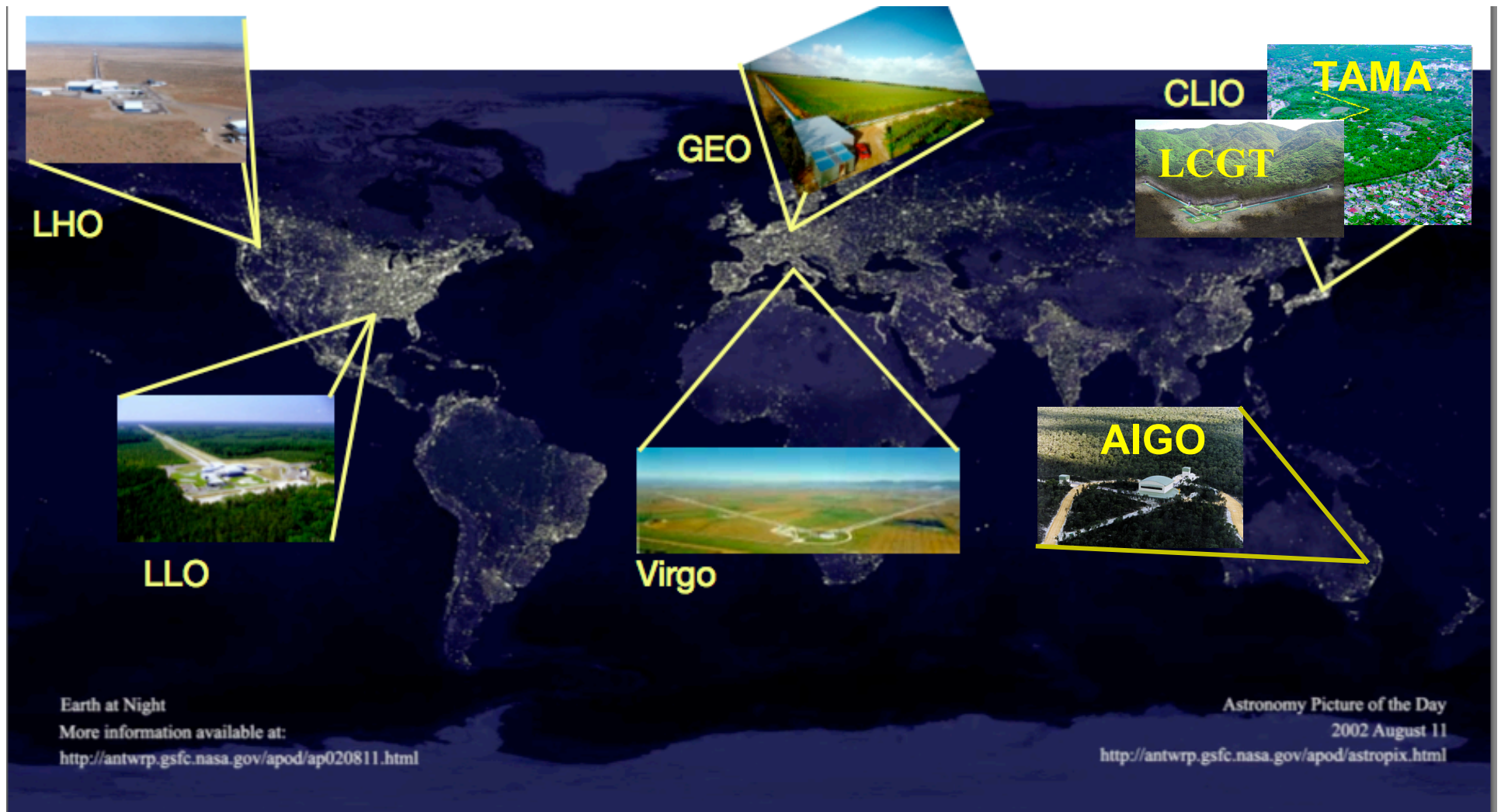
Virgo+ current spectrum



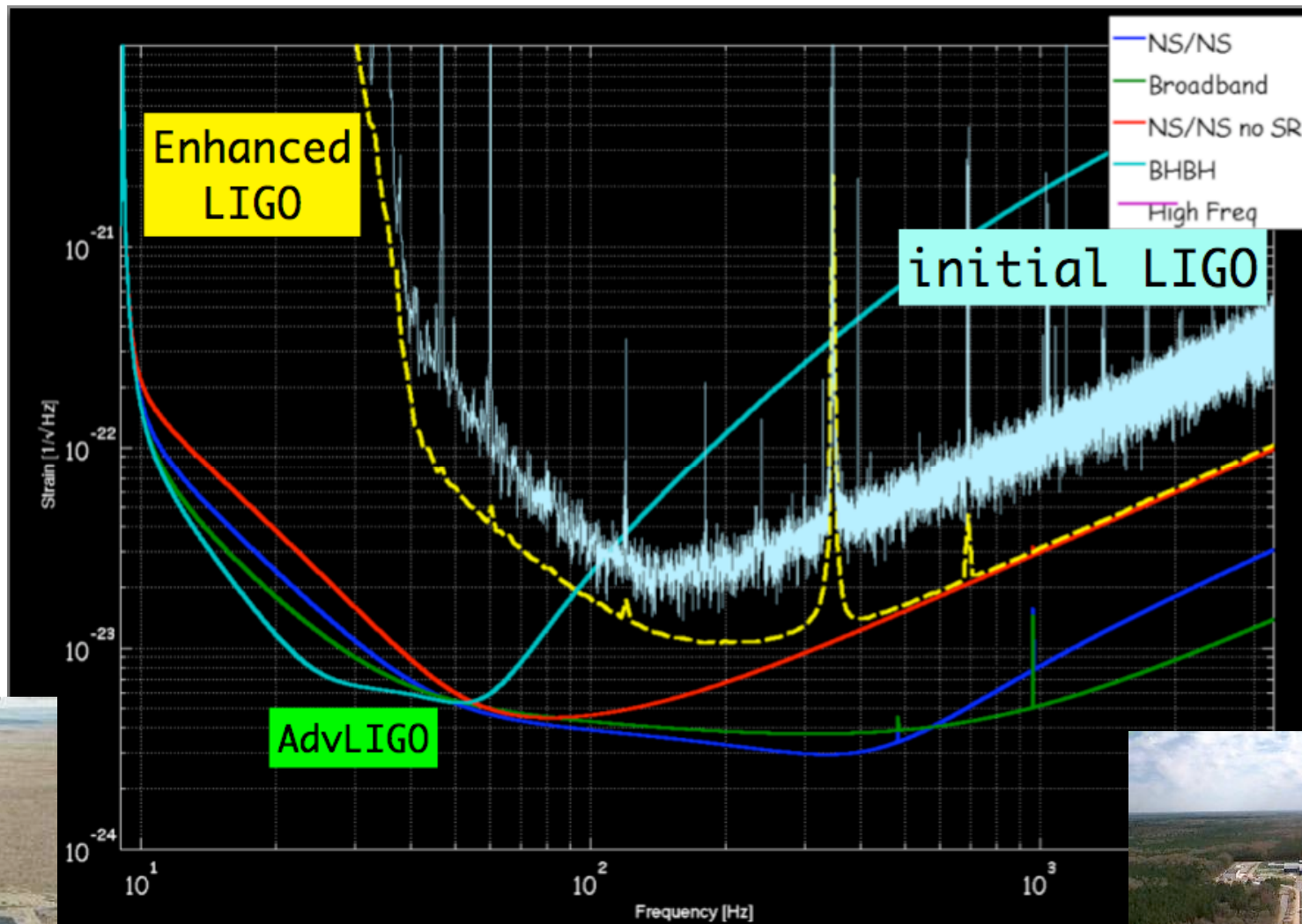
Virgo+:

- Laser 10 → 25 watt
- Thermal compensation system
- ADC, DSP, electronics

Worldwide network



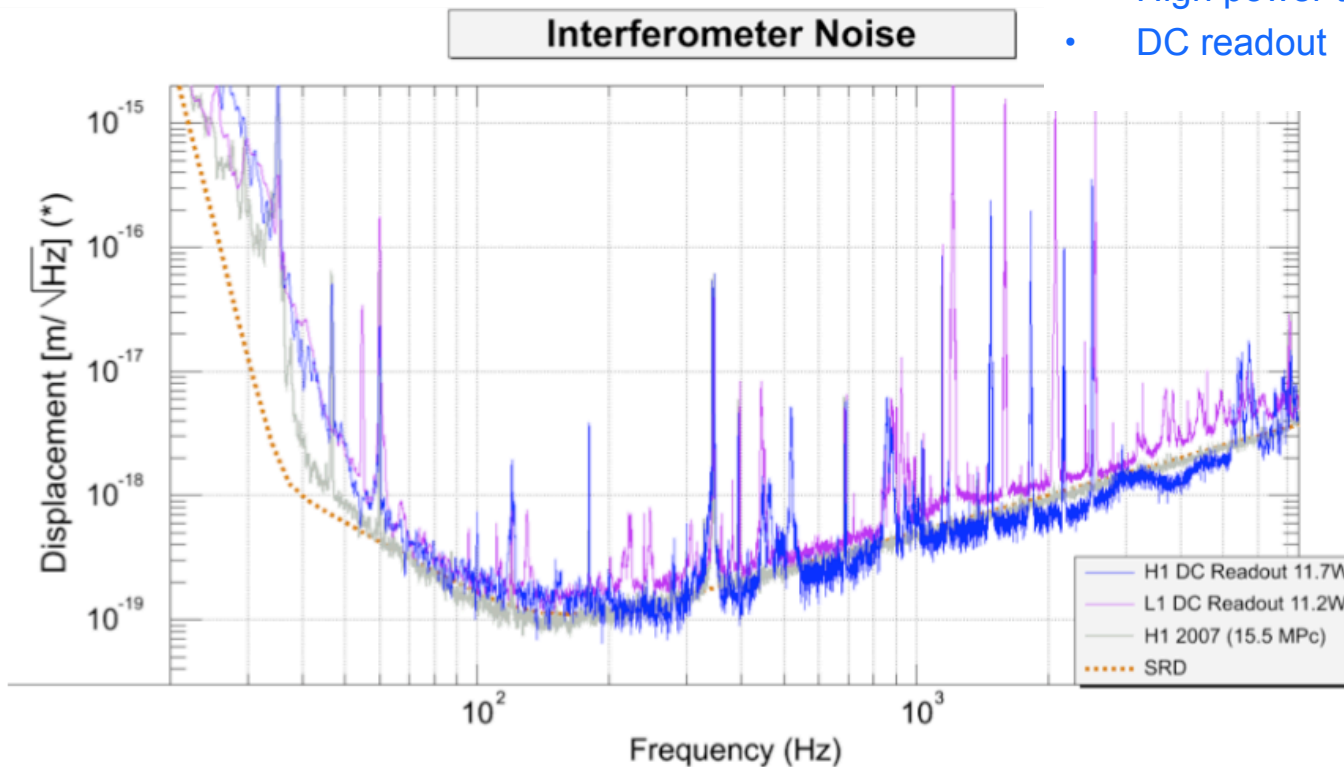
LIGO: past, present, future



Enhanced LIGO

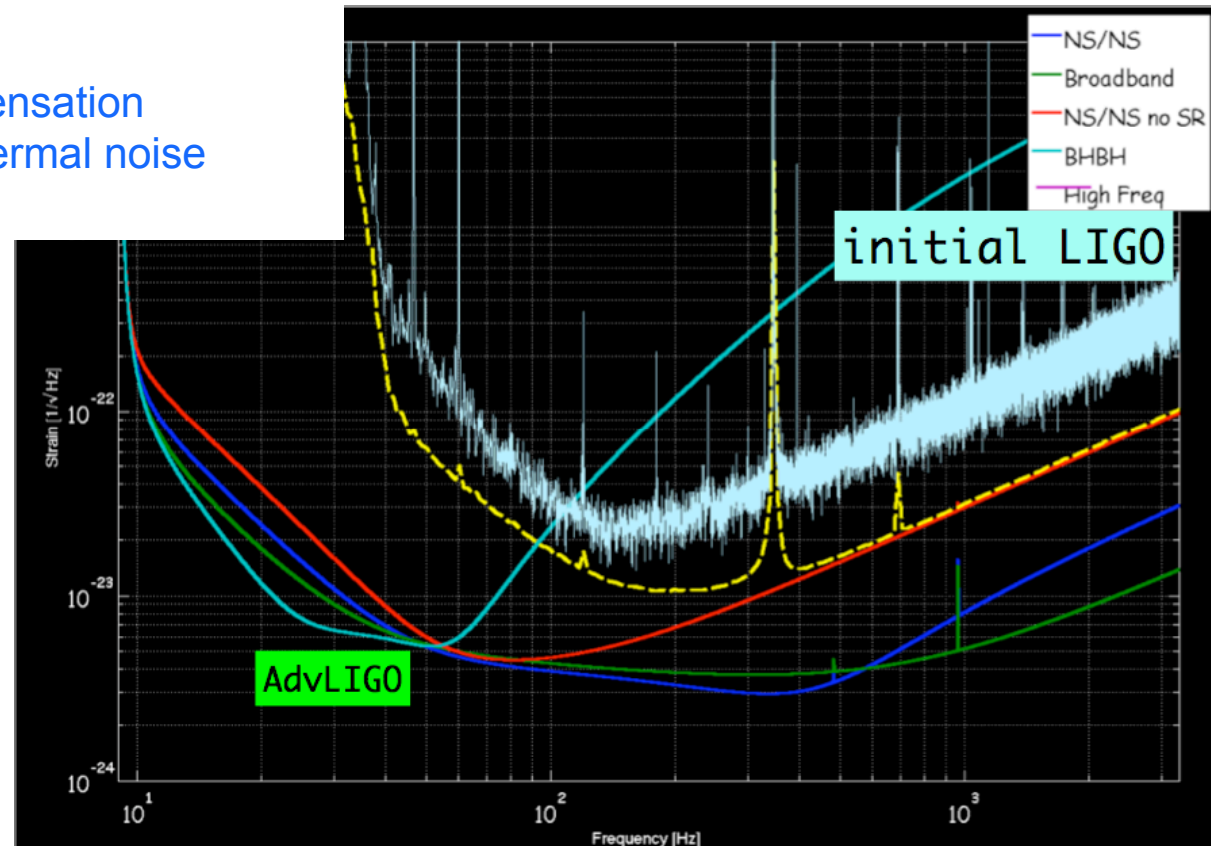
Most hardware changes
in place already
Noise hunting in progress!

- Higher laser power: 35 W
- High power Faraday isolator
- Suspended output mode cleaner
- Better magnets on test masses
- In-vacuum, active seismic isolation
- High power thermal control of test masses
- DC readout



Advanced LIGO

- Active seismic isolation
- Quadruple pendulums
- Monolithic suspensions
- Signal recycling
- Increased laser power
- Adaptive thermal compensation
- Heavier mirrors, low thermal noise coatings



Advanced LIGO

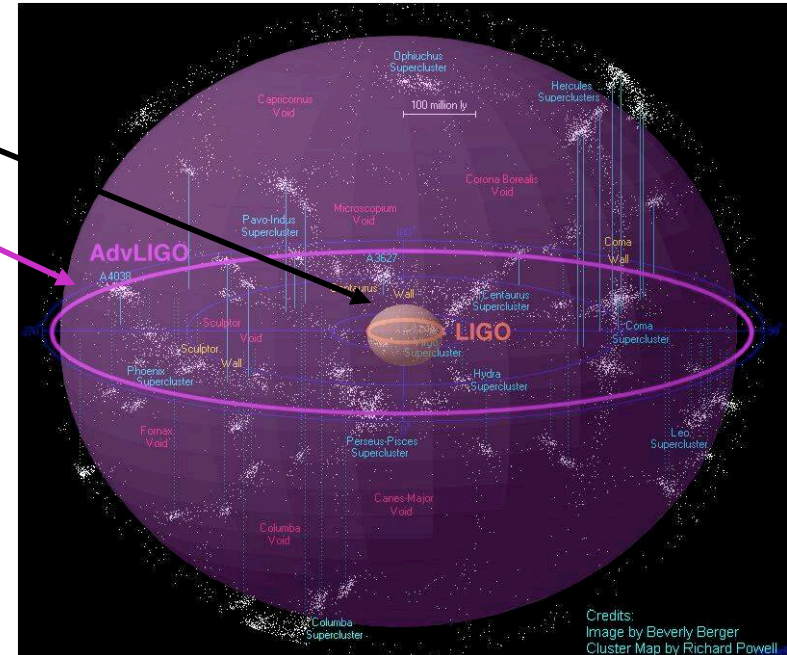
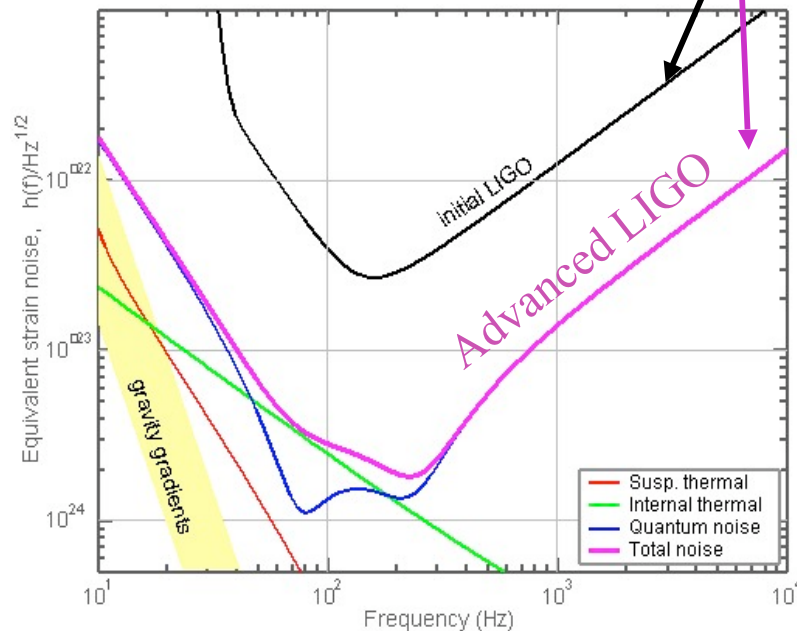
Neutron Star Binaries:

Initial LIGO (S5): ~ 15 Mpc $\rightarrow$ rate $\sim 1/100$ yrs

Adv LIGO: ~ 200 Mpc $\rightarrow$ rate ~ 40 /year !!

Black Hole Binaries:

probably similar rates
(we'll measure them!)



x10 better amplitude sensitivity

$\Rightarrow$ **x1000** rate= $(\text{reach})^3$

$\Rightarrow$ 1 year of Initial LIGO

< 1 day of Advanced LIGO !



UK, Germany provided funding for AdL; US NSF started funding AdL in 2008, Australia will also contribute funds.

Will start taking data in ~ 2014

Worldwide network

