THE NEXT GENERATION OF GRAVITATIONAL WAVE DETECTORS

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Giovanni Losurdo

INFN Firenze – Virgo Collaboration

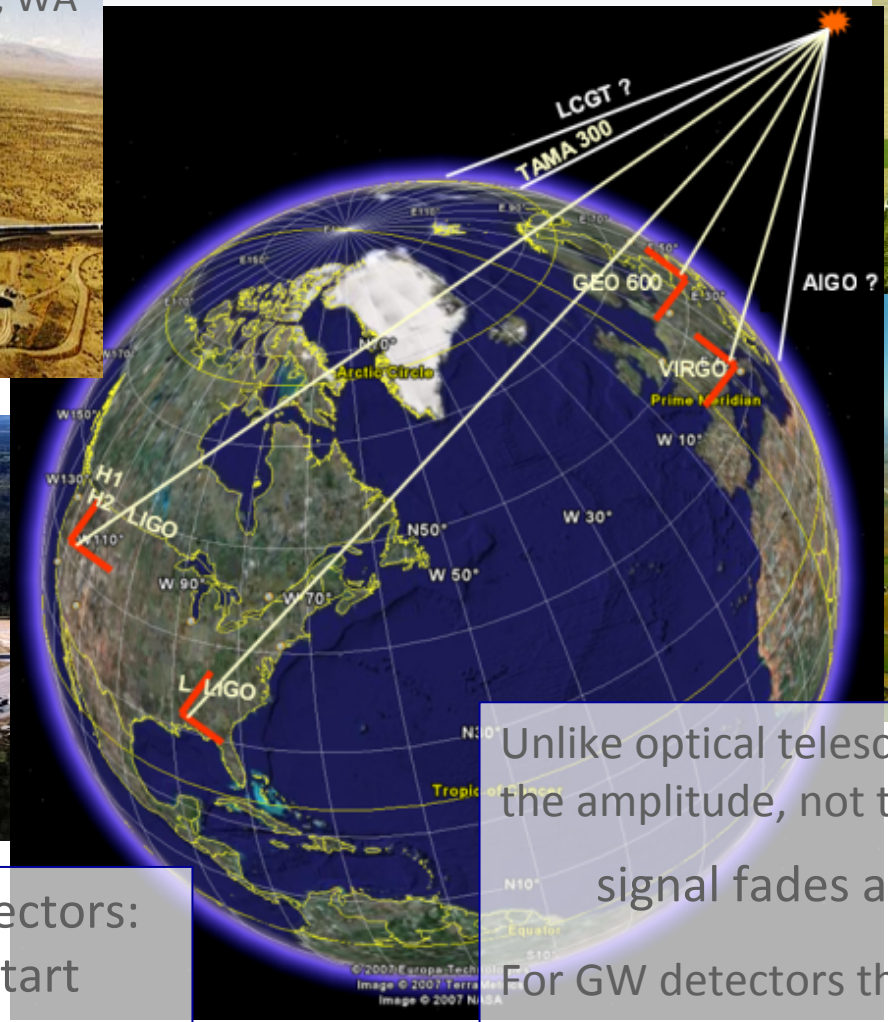
on behalf of

LIGO Scientific Collaboration

Virgo Collaboration

LIGO-G080007-00-Z

GW TELESCOPES



A network of GW detectors: upgrades needed to start GW astronomy

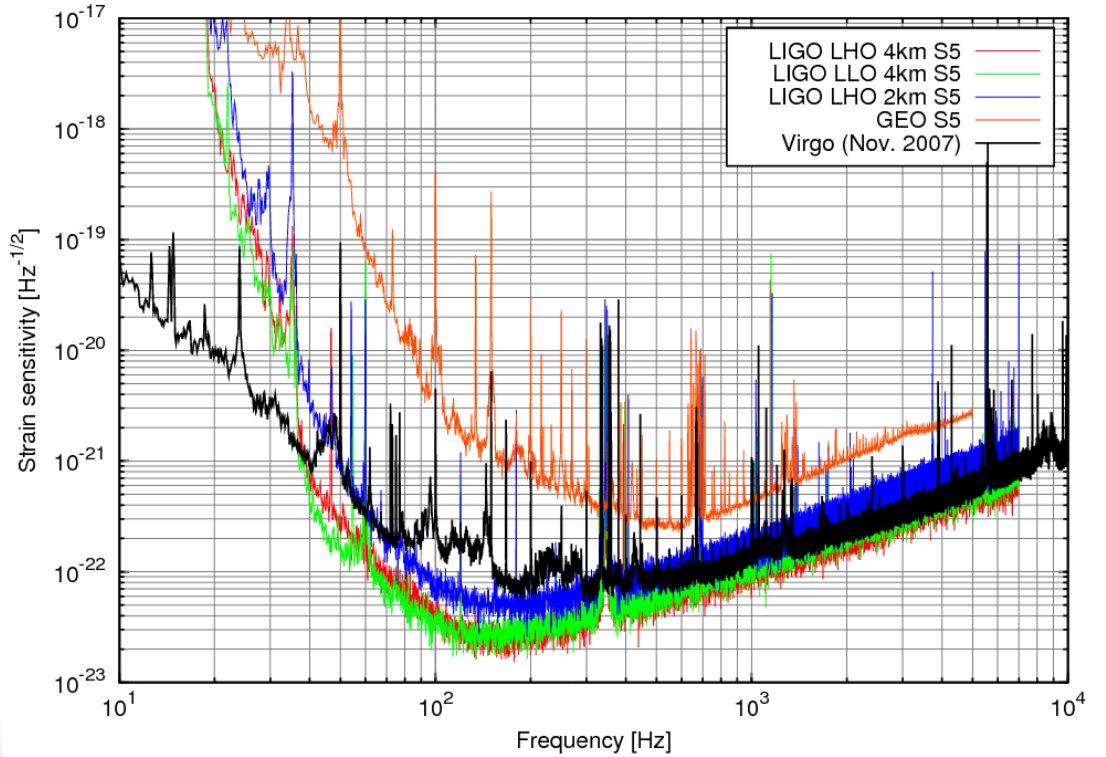
Unlike optical telescopes, these measure the amplitude, not the power:

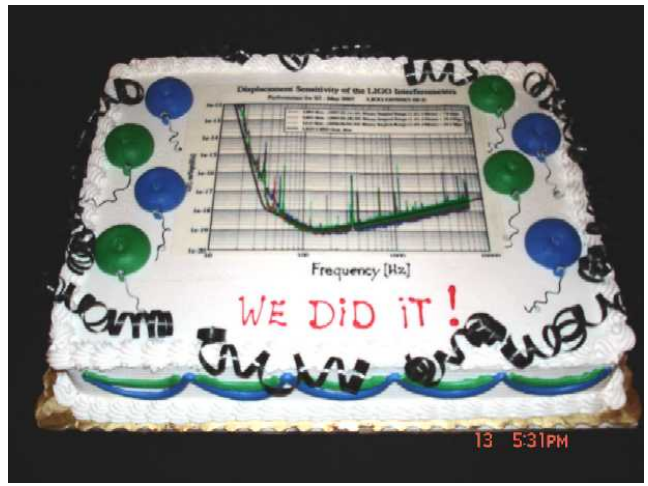
signal fades as **1/r**, not **1/r²** !

For GW detectors the number of observable sources grows as SENSITIVITY³ !

GW TELESCOPES TODAY

- LIGO at design sensitivity: technology demonstrated
- Virgo is not far. Starting to become interesting at low frequency
- GEO has successfully tested solutions for 2nd generation (signal recycling, fused silica suspensions)

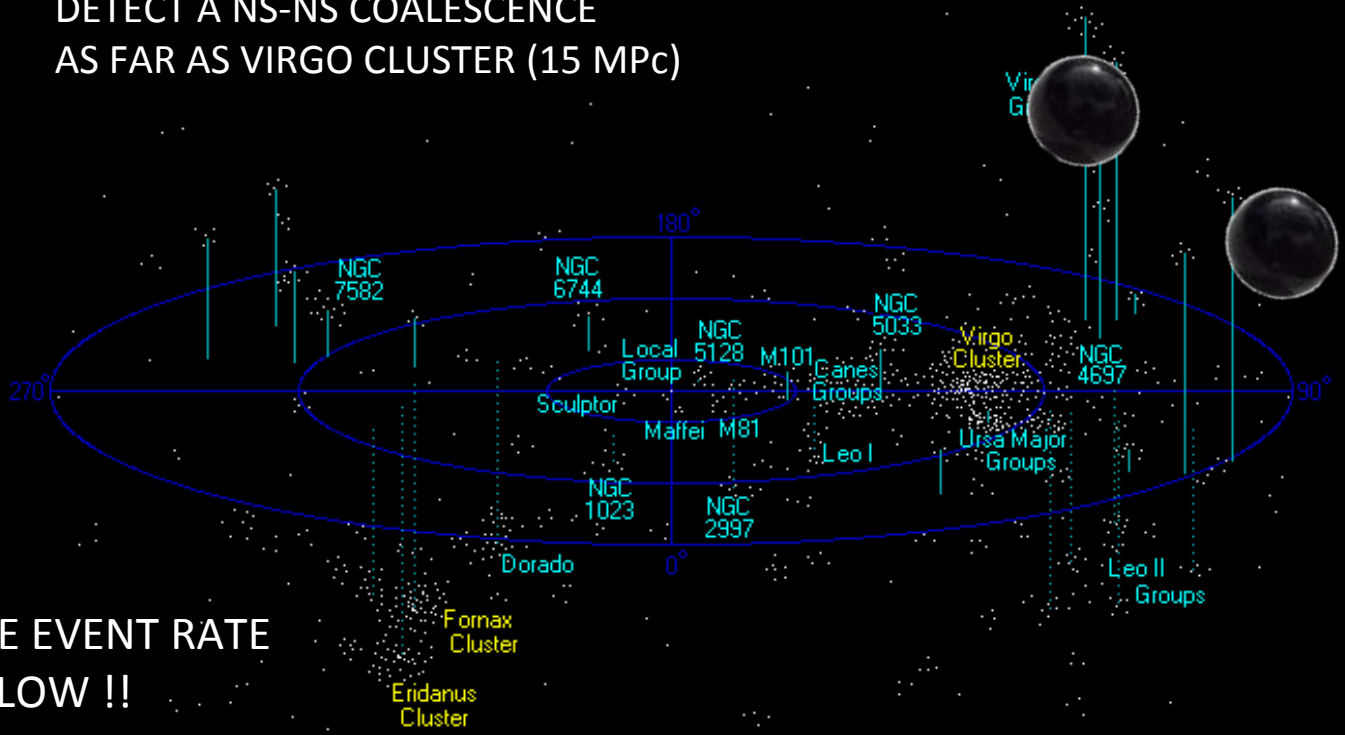




The cake for the S5 LIGO party…

1st GENERATION DETECTORS

1ST GENERATION INTERFEROMETERS CAN
DETECT A NS-NS COALESCENCE
AS FAR AS VIRGO CLUSTER (15 MPc)



BUT THE EVENT RATE
IS TOO LOW !!

EXPECTED EVENT RATE:
0.01-0.1 ev/yr (NS-NS)

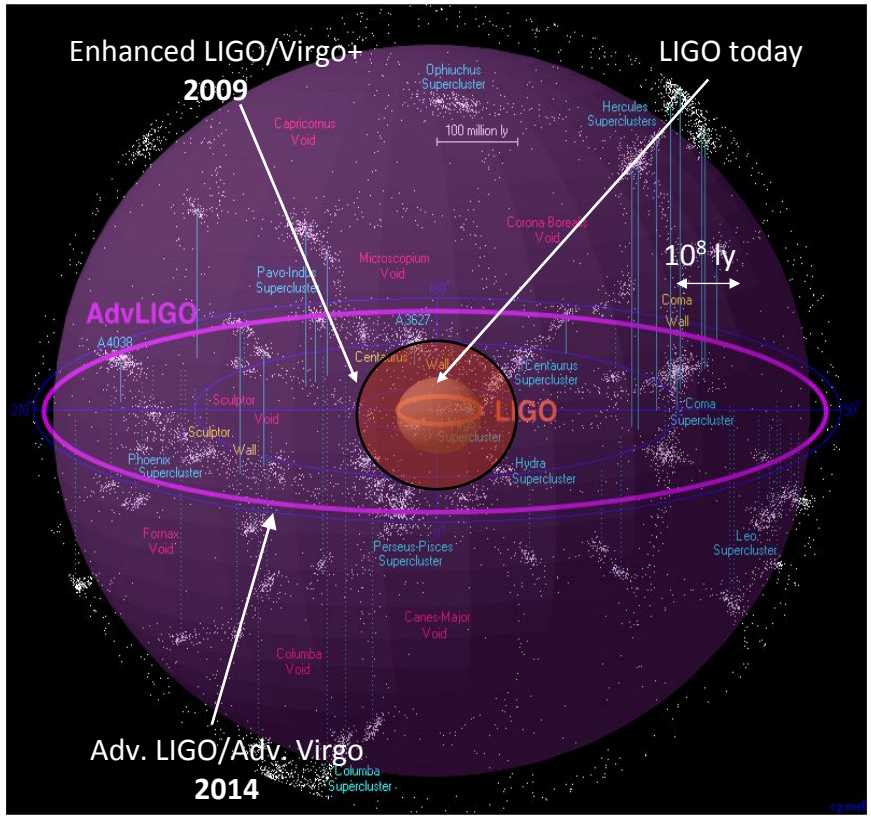
FIRST DETECTION:
POSSIBLE BUT UNLIKELY

FROM DISCOVERY TO ASTRONOMY

2nd generation detectors:
Advanced LIGO, Advanced Virgo

GOAL:
sensitivity 10x better →
look 10x further →
Detection rate 1000x larger

Intermediate step:
Enhanced LIGO, Virgo+, GEO HF



Credit: R.Powell, B.Berger

THE PATH TO 2nd GENERATION

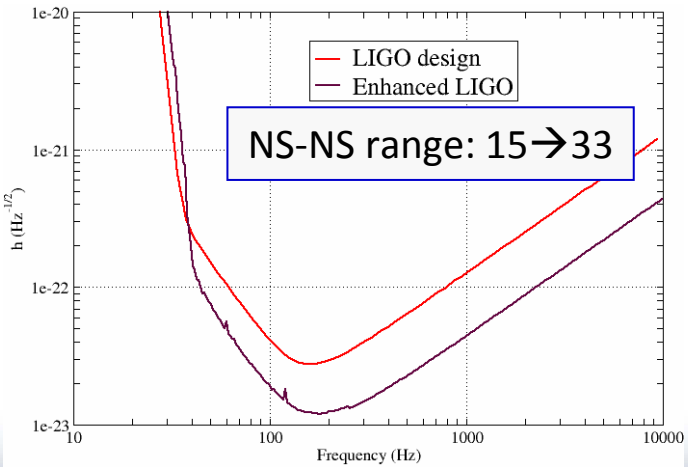
Exploit available technology to enhance the sensitivity by 2-3x.
Increase the detection probability by about one order of magnitude.
Test solutions for the 2nd generation detectors.

ENHANCED LIGO

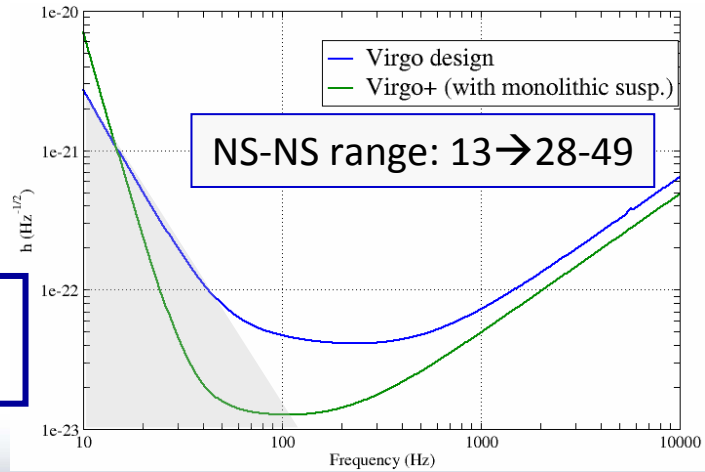
- Increase the laser power
- Reduce the effect of environmental noise
- Direct (homodyne) readout of GW

VIRGO+

- Increase the laser power and compensate for thermal lensing
- Increase the arm cavity finesse
- *Possibly reduce the thermal noise of the suspension wires*

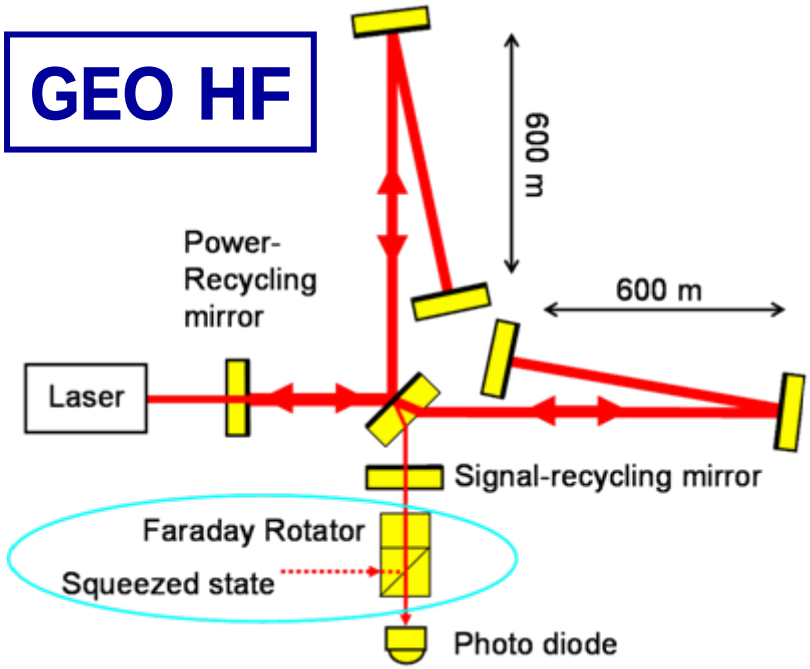


2009



THE PATH TO 2nd GENERATION

- EMPHASIZE HIGH FREQUENCIES: provide scientifically interesting data with GEO until 2014
- Be up during the LIGO/Virgo upgrade to 2nd generation
- Perform developments and tests towards third generation detectors



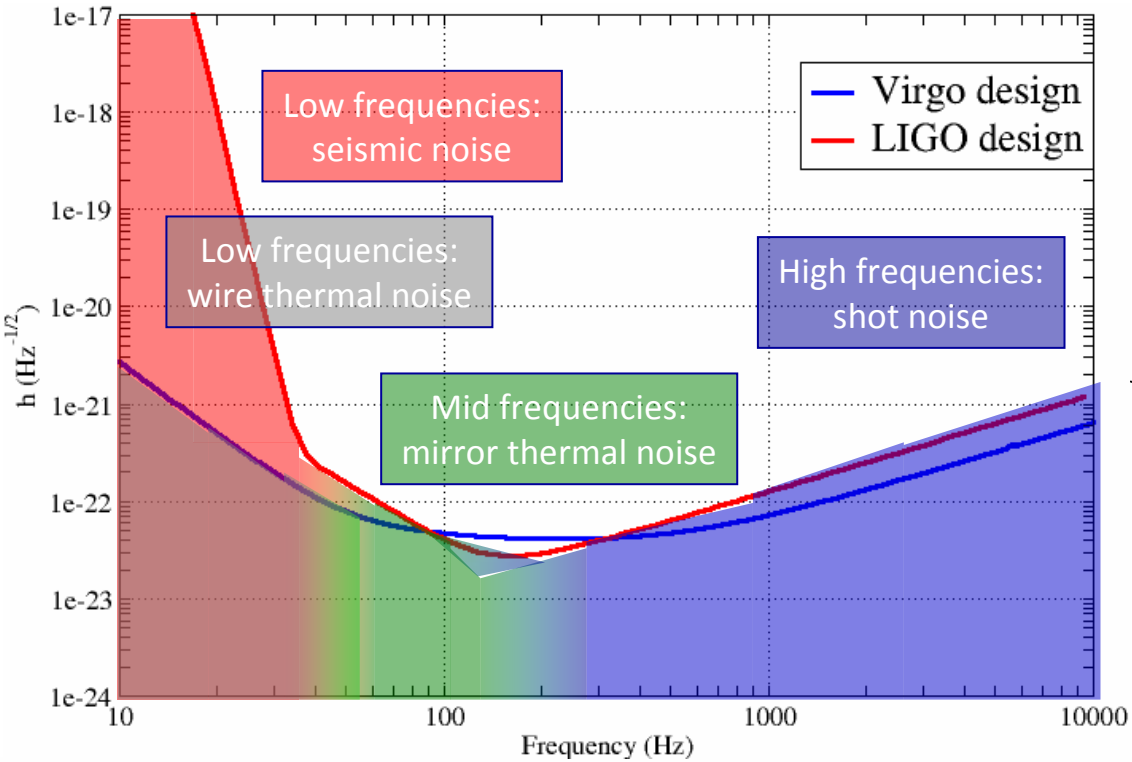
GEO-HF UPGRADES

- Increase the laser power
- Reduce coating thermal noise
- DC detection
- **Inject squeezed light**

ACHIEVING THE SENSITIVITY GOAL

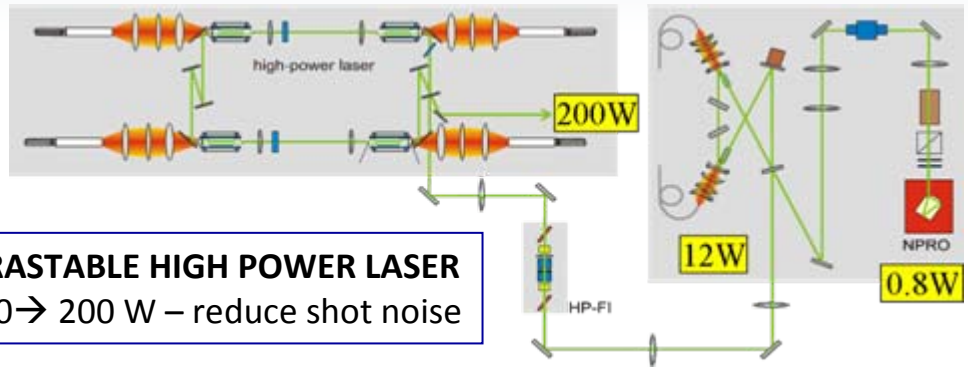
Achieving a sensitivity 10x better is ambitious.

Act on different noise sources: new ideas and a wide R&D program have been necessary



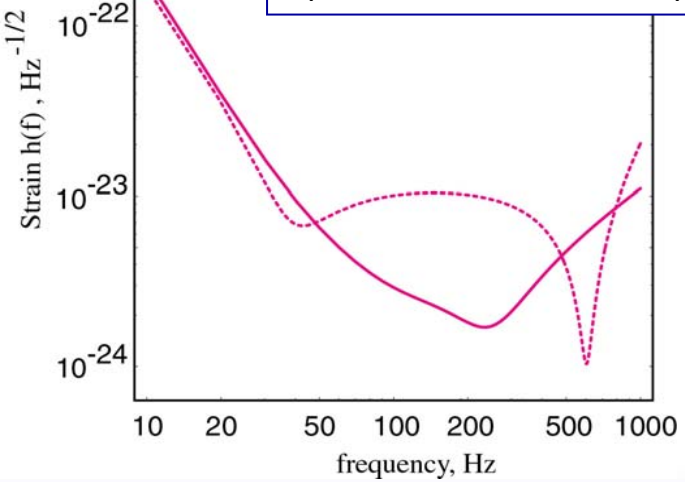
IMPROVING THE SENSITIVITY

MID-HIGH FREQUENCIES: TACKLING THERMAL AND OPTICAL READOUT NOISE

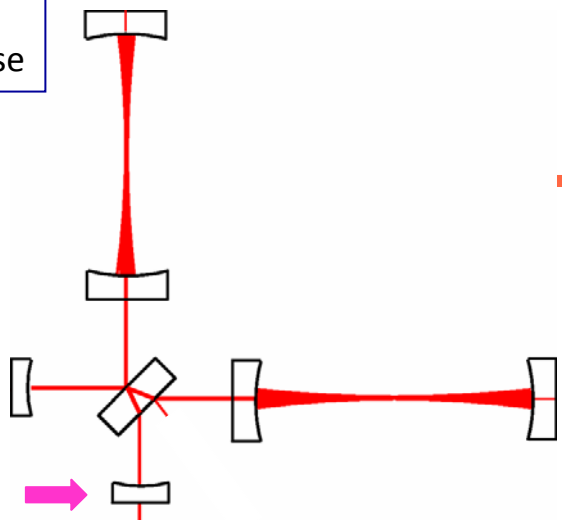


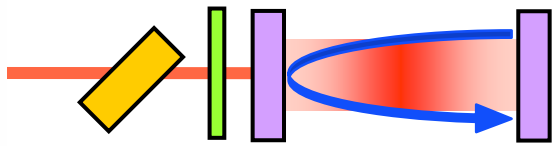
ULTRASTABLE HIGH POWER LASER
10/20→ 200 W – reduce shot noise

GERMANY - capital investment of Max Planck Inst. for Adv. LIGO



A new optical configuration: DUAL RECYCLING, permits to optimize the detector response

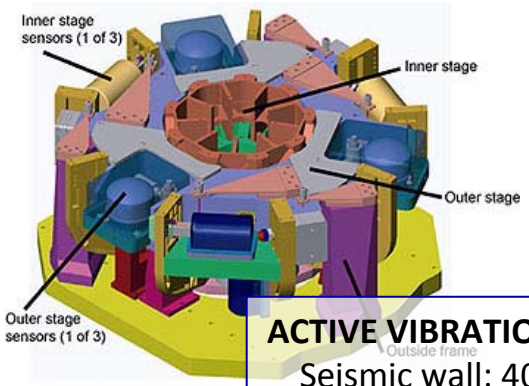




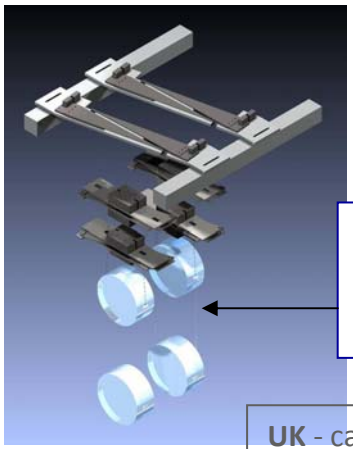
LARGER BEAM SIZE
on test masses to reduce thermal noise

IMPROVING THE SENSITIVITY

Advanced LIGO setup



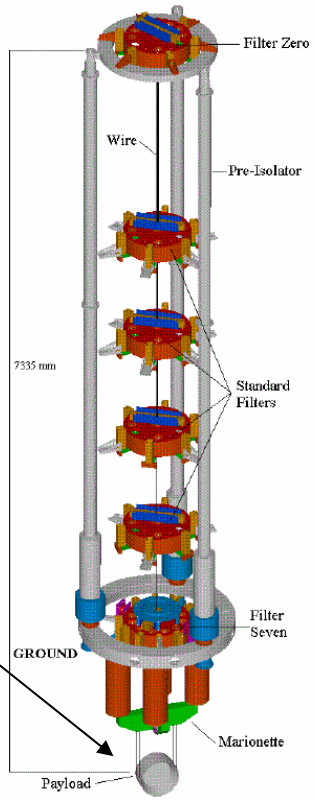
ACTIVE VIBRATION ISOLATION
Seismic wall: 40 Hz→10 Hz



SILICA FIBERS
to suspend the mirror:
LOWER THERMAL NOISE

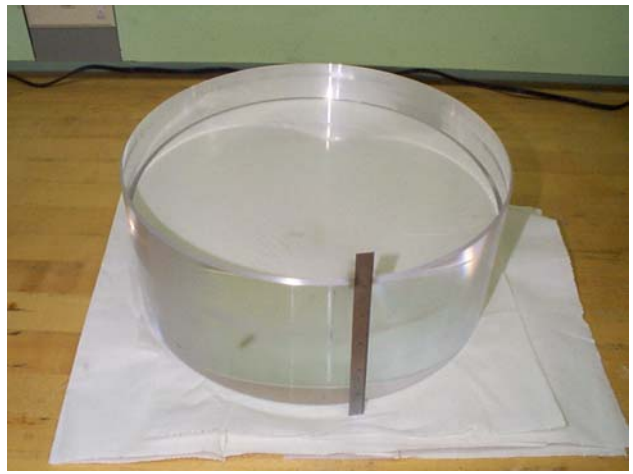
UK - capital investment of Science & Technology Facilities Council for Adv. LIGO

Virgo/Adv. Virgo Superattenuator



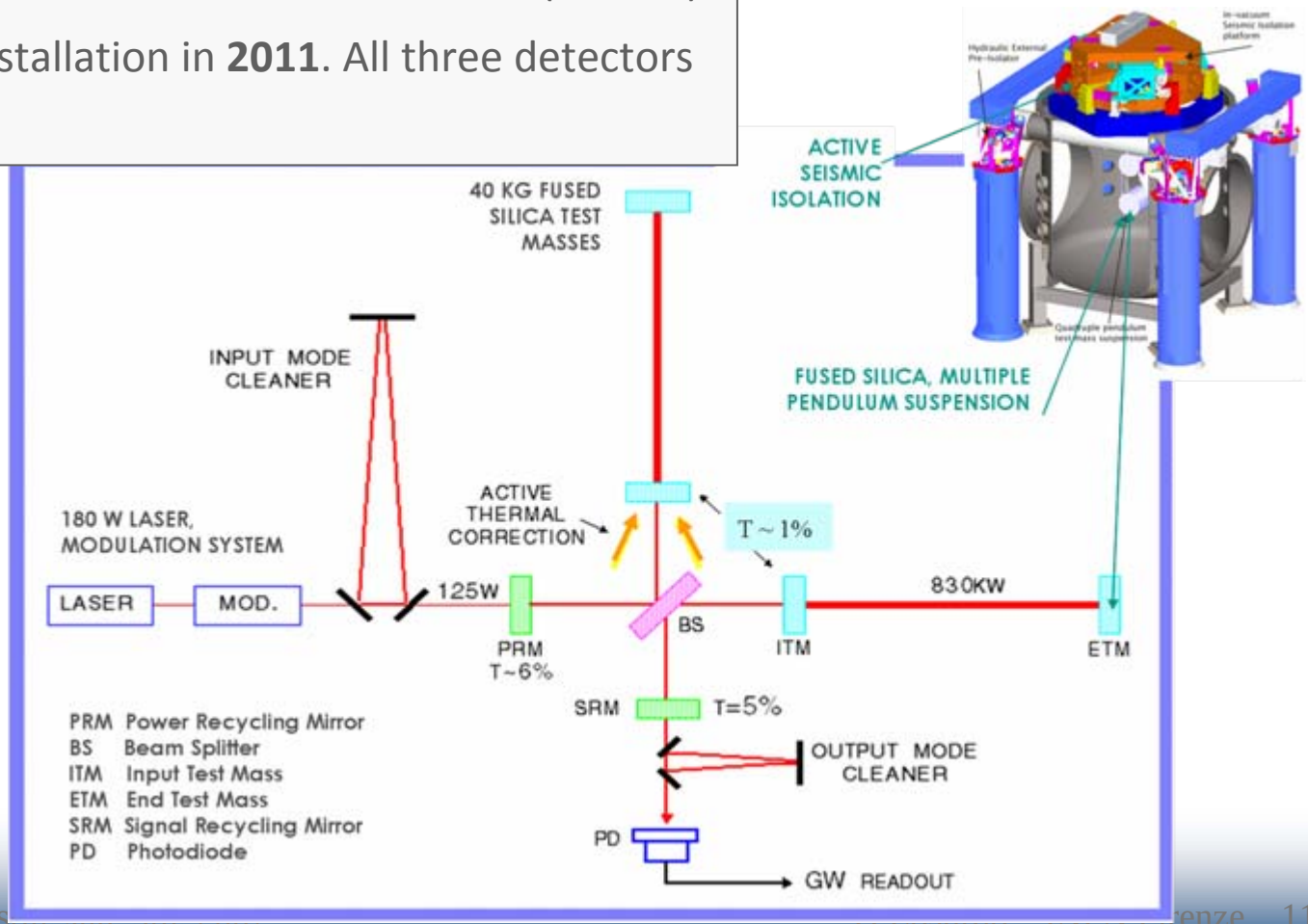
LOW-MID FREQUENCIES: TACKLING SEISMIC AND THERMAL NOISE

MIRRORS
Large and heavier (10/20→40 Kg)
Low scatter/absorbtion
Low loss coating



ADVANCED LIGO

- Approved by NSF. Budget submitted to the President, waiting for signature
- Undergone a positive NSF "readiness review" (Nov 07)
- READY to start installation in **2011**. All three detectors up in **2014**.



Advanced Virgo BASELINE

heavier mirrors
(42 kg)

high finesse

larger beam waist

signal recycling

high power SSL
(200 W)

DC detection

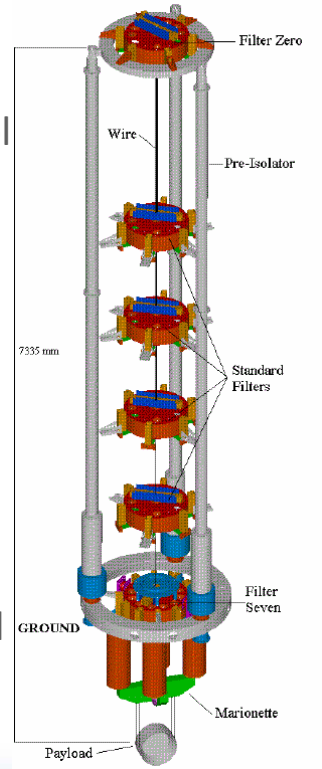
Conceptual design and preliminary cost plan submitted to the funding agencies (INFN-Italy and CNRS-France): well received

NIKHEF (Holland) interested in the project.

new IP
tilt control

new payload

fused silica
suspensions

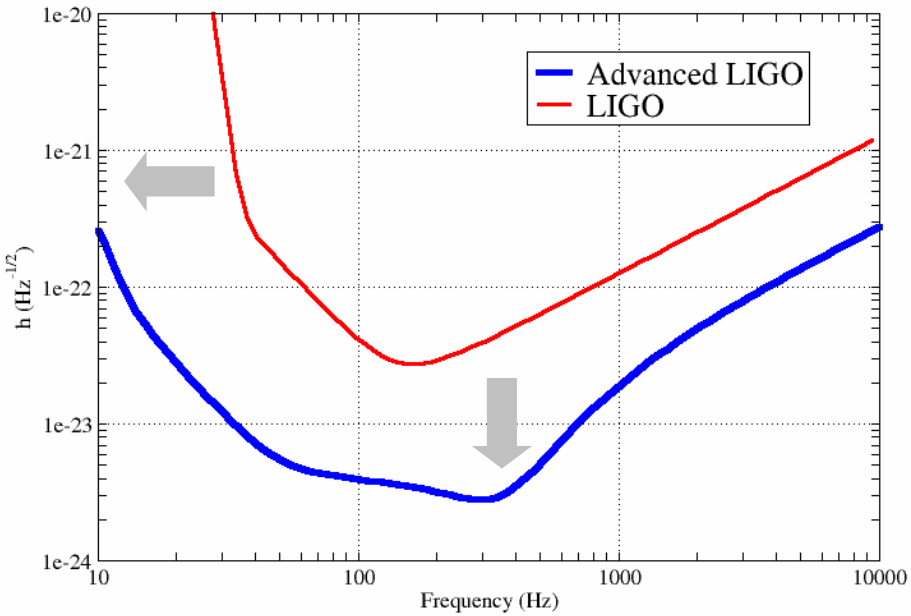


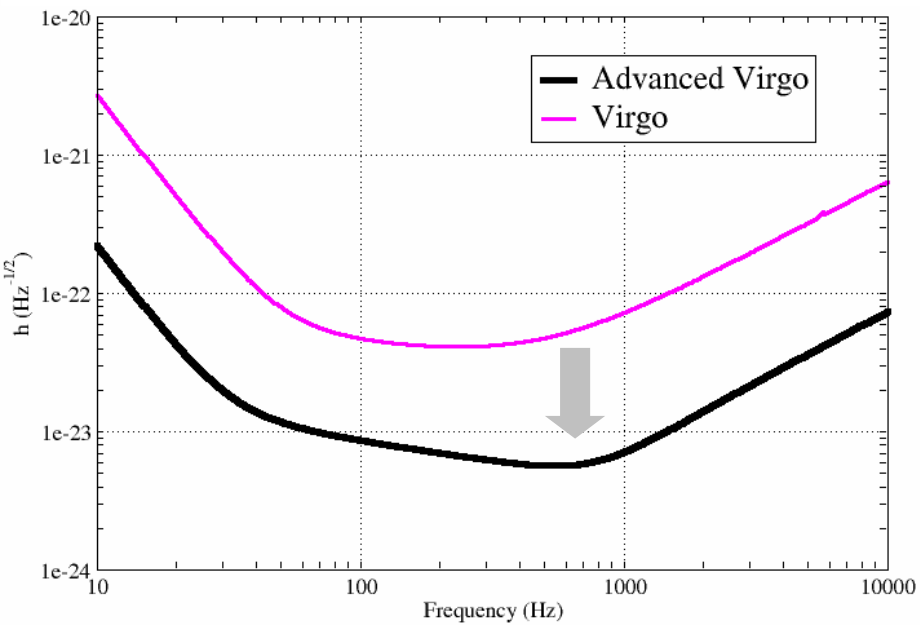
ACHIEVABLE SENSITIVITY

NS-NS detectable as far as 300 Mpc

BH-BH detectable at cosmological distances

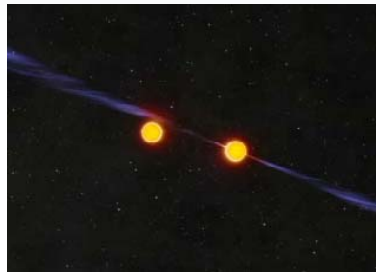
10s to 100s of events/year expected!





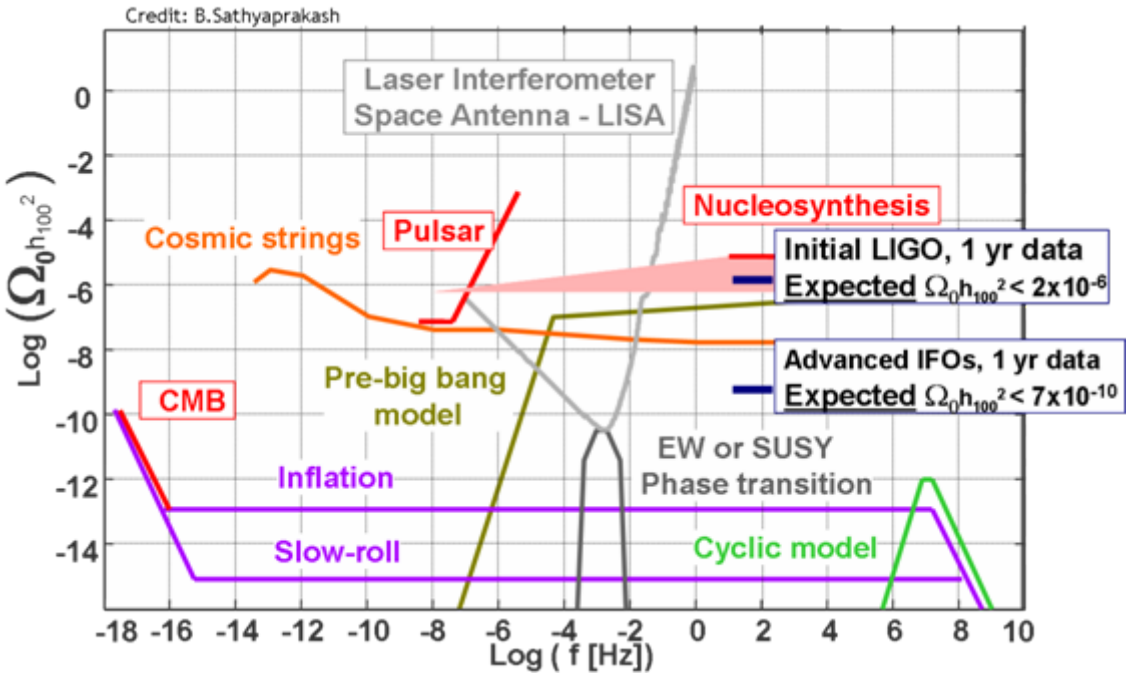
THE ASTROPHYSICS: COALESCING BINARIES

- A significant rate of detection of coalescing binaries will constrain the binary population synthesis models. A non-detection will have a big impact on the theories of binary evolution
- In NS-BH coalescence, the tidal disruption of the NS determines the waveform cutoff and provides information on the NS equation of state [Vallisneri, Phys.Rev.Lett., 2000]
- BH-BH binaries can be sources with high SNR and allow precise waveform measurements, testing GR predictions in strong field regime
- NS-NS are standard *sirens.* 10 events of simultaneous detection with GRBs would allow to measure H_0 to 2-3% [Dalal et al., Phys.Rev.D, 2006]



THE SCIENCE: STOCHASTIC GW

- Detection of primordial GW can probe the inflationary epoch
- Standard inflation scenarios generate spectra too low to be detected
- A class of string models (properly tuned) could lead to measurable spectra
  [Buonanno et al., PRD, 97]



CONCLUSIVE REMARKS

- The installation of the 2nd generation GW interferometric detectors will start soon
- They will provide a factor 10 sensitivity enhancement with respect to LIGO/Virgo
- The detection rate for Advanced LIGO/Virgo will be 1000 times larger: a rate of 10s-100s ev/year is expected
- The resulting volume of data will allow the birth of GW astronomy
- Intermediate step (2009): Enhanced LIGO/Virgo+

The LIGO Scientific Collaboration and Virgo have started a common walk. They will be working together to maximize the science outcome of the upgrades.