ADVANCED VIRGO

Giovanni Losurdo – INFN Pisa
Advanced Virgo Project Leader

for the Virgo Collaboration and EGO

Tweet   Tweet e risposte   Contenuti

EGO - Virgo

EGO-Virgo @ego_virgo · 8 ott

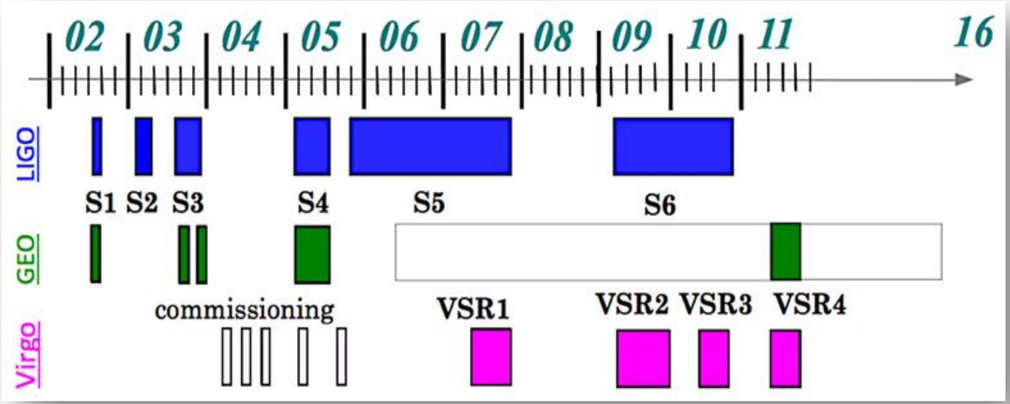
See this spot? This Thursday we locked for the first time the 3-km Advanced Virgo interferometer on the dark fringe!

27   41

Virgo central hall
SPRING 2013

1^{st} GENERATION DETECTORS

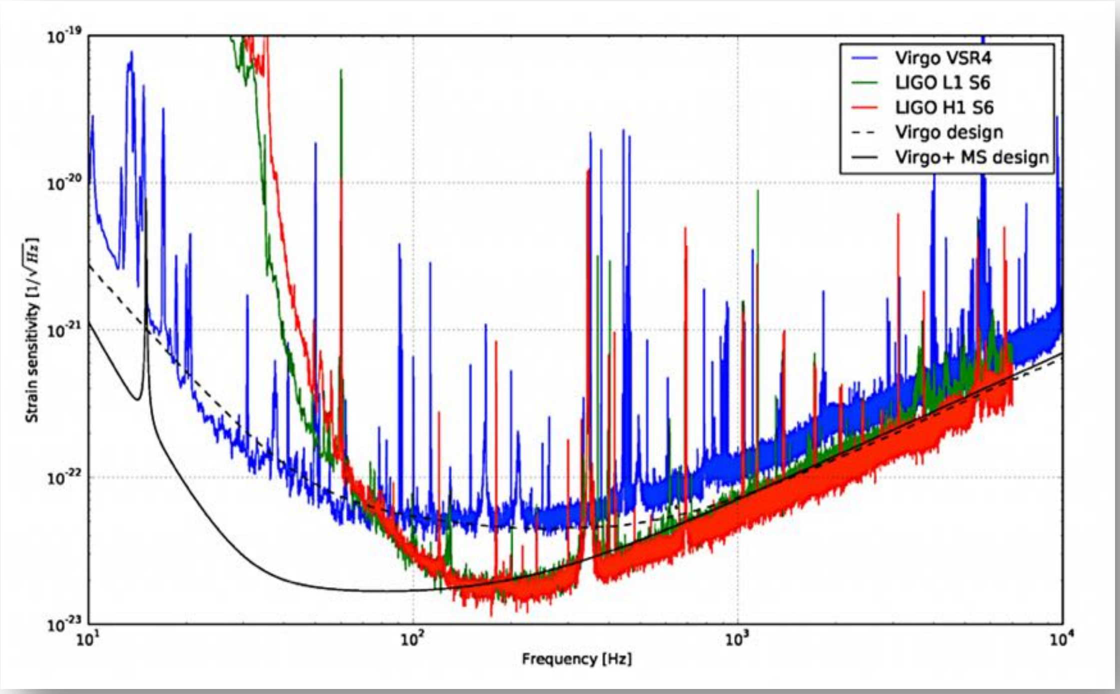
- The interferometers of the 1t generation (LIGO, Virgo, GEO600) have run in the 1^{st} decade of 2000's

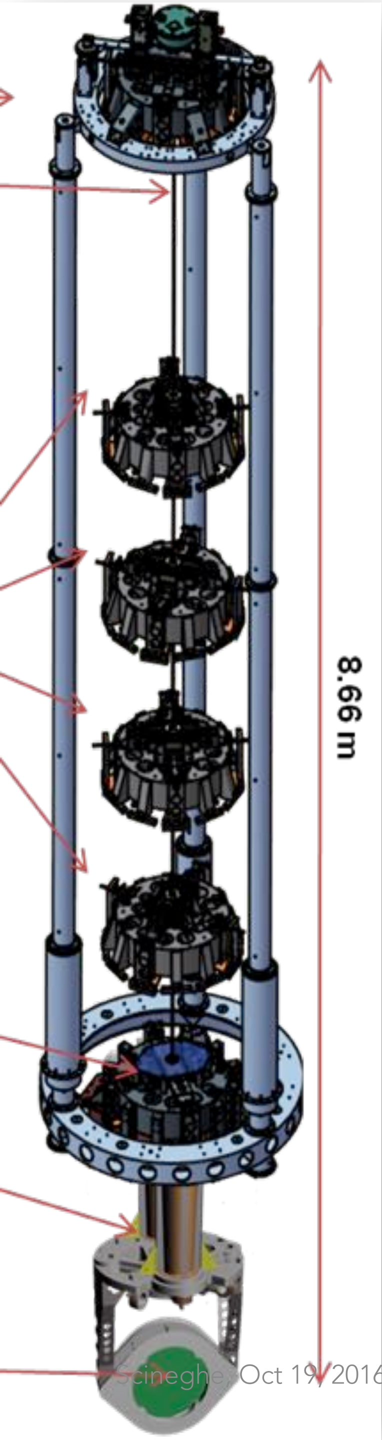


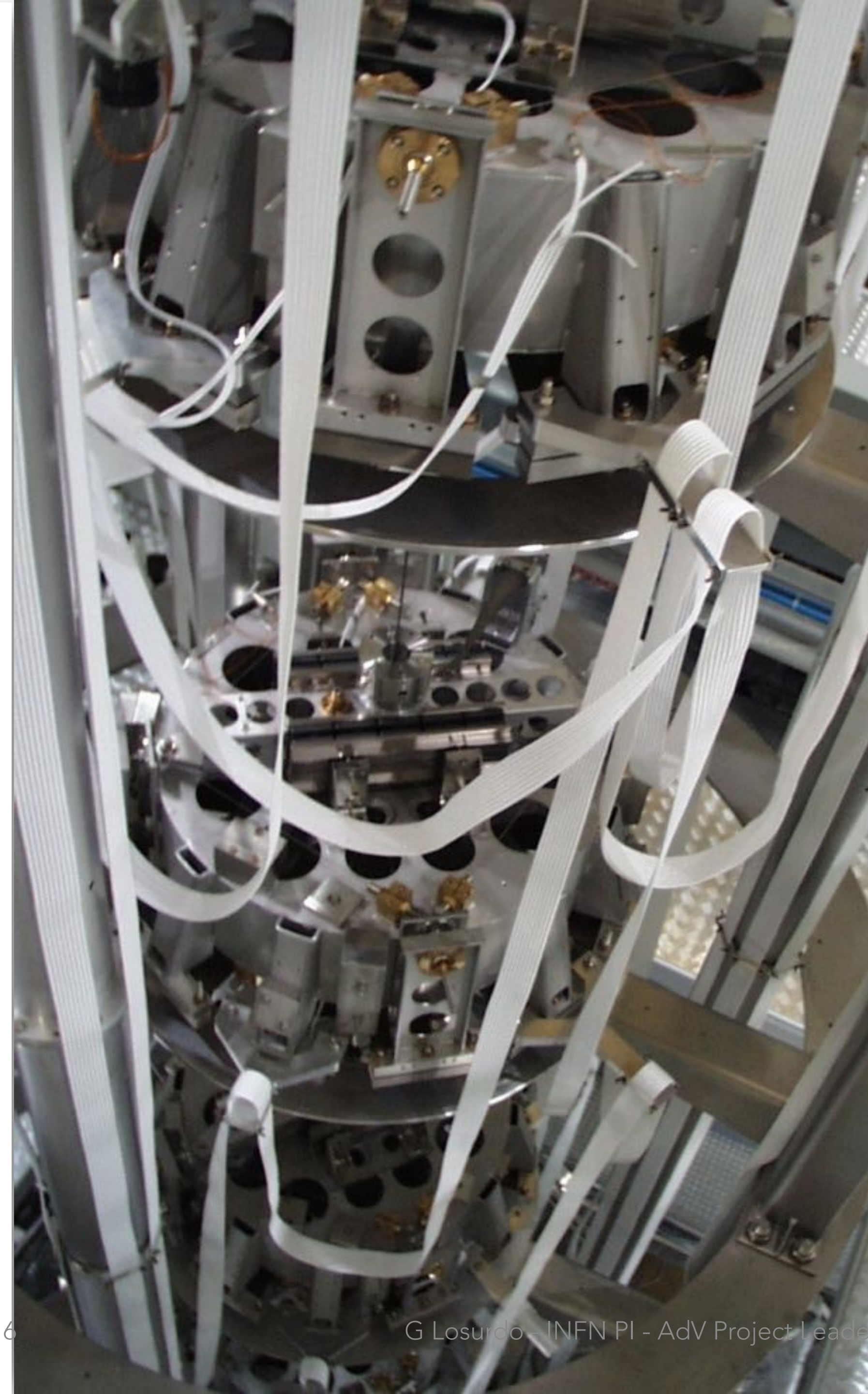
- The sensitivity finally achieved was enough to detect a coalescing BNS in ~100 galaxies…
  - …but such events happen ~1/10000 yr per galaxy…
- No detection done but a rich legacy has been left.

NOISE AND SENSITIVITY

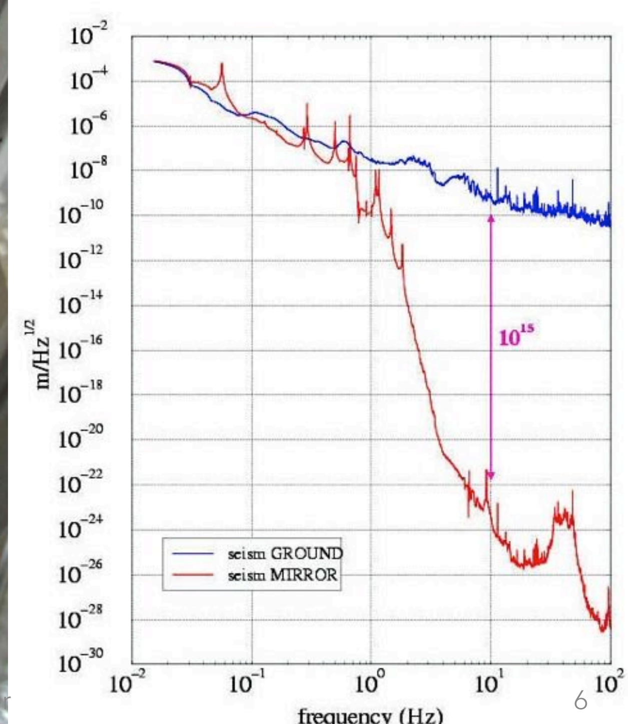
- The noise has been mostly understood
- The 1st generation design sensitivities have been approached closely (and somewhere exceeded upon detector upgrades)
- Excellent duty cycle (~80%): reliable instruments!



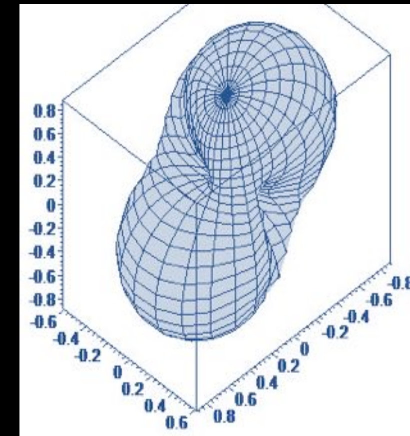




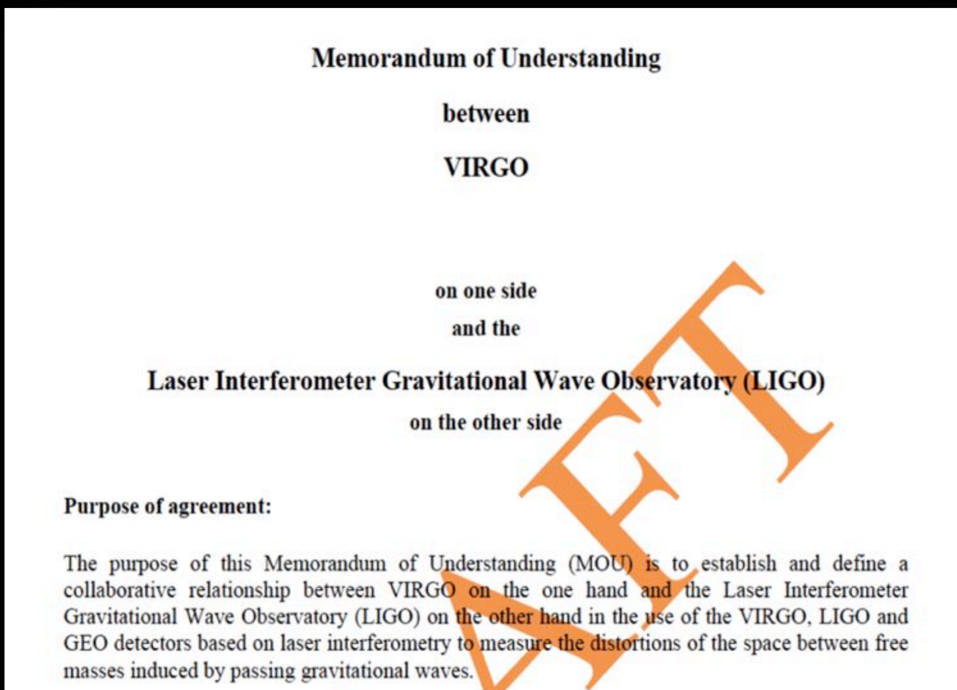
A Giazotto
INFN



NETWORK



A MAJOR STEP TOWARDS GW ASTRONOMY



Memorandum of Understanding

between

VIRGO

on one side

and the

Laser Interferometer Gravitational Wave Observatory (LIGO)

on the other side

Purpose of agreement:

The purpose of this Memorandum of Understanding (MOU) is to establish and define a collaborative relationship between VIRGO on the one hand and the Laser Interferometer Gravitational Wave Observatory (LIGO) on the other hand in the use of the VIRGO, LIGO and GEO detectors based on laser interferometry to measure the distortions of the space between free masses induced by passing gravitational waves.

GW “TELESCOPES”
CANNOT BE POINTED

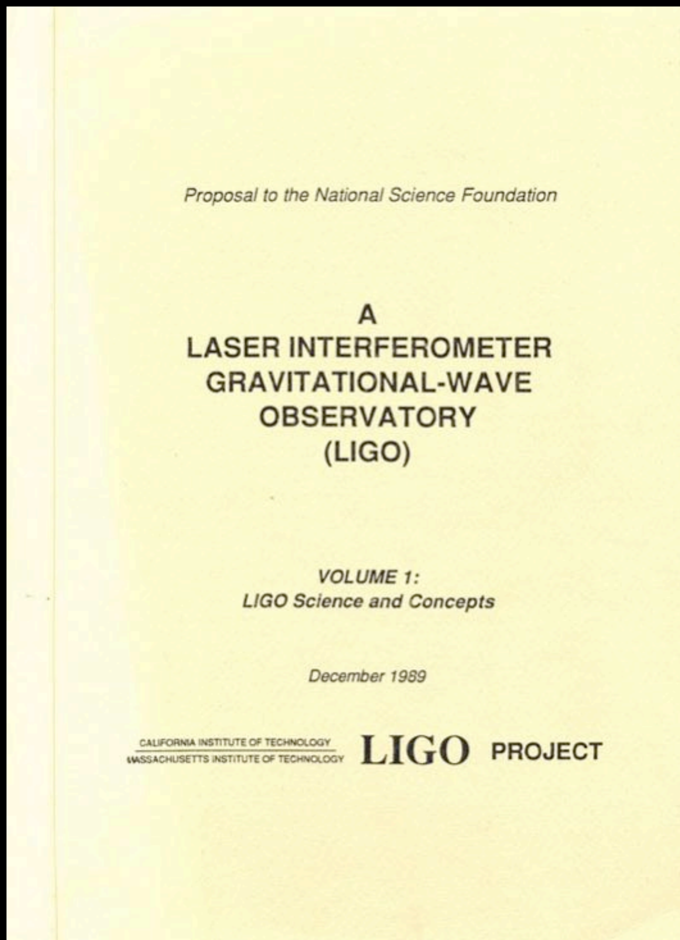
SOURCE LOCALIZATION
REQUIRES NETWORKING

SINCE 2007: LIGO, VIRGO, GEO
WORKING AS A SINGLE MACHINE

MOU RENEWED IN 2014.

NETWORK

1989

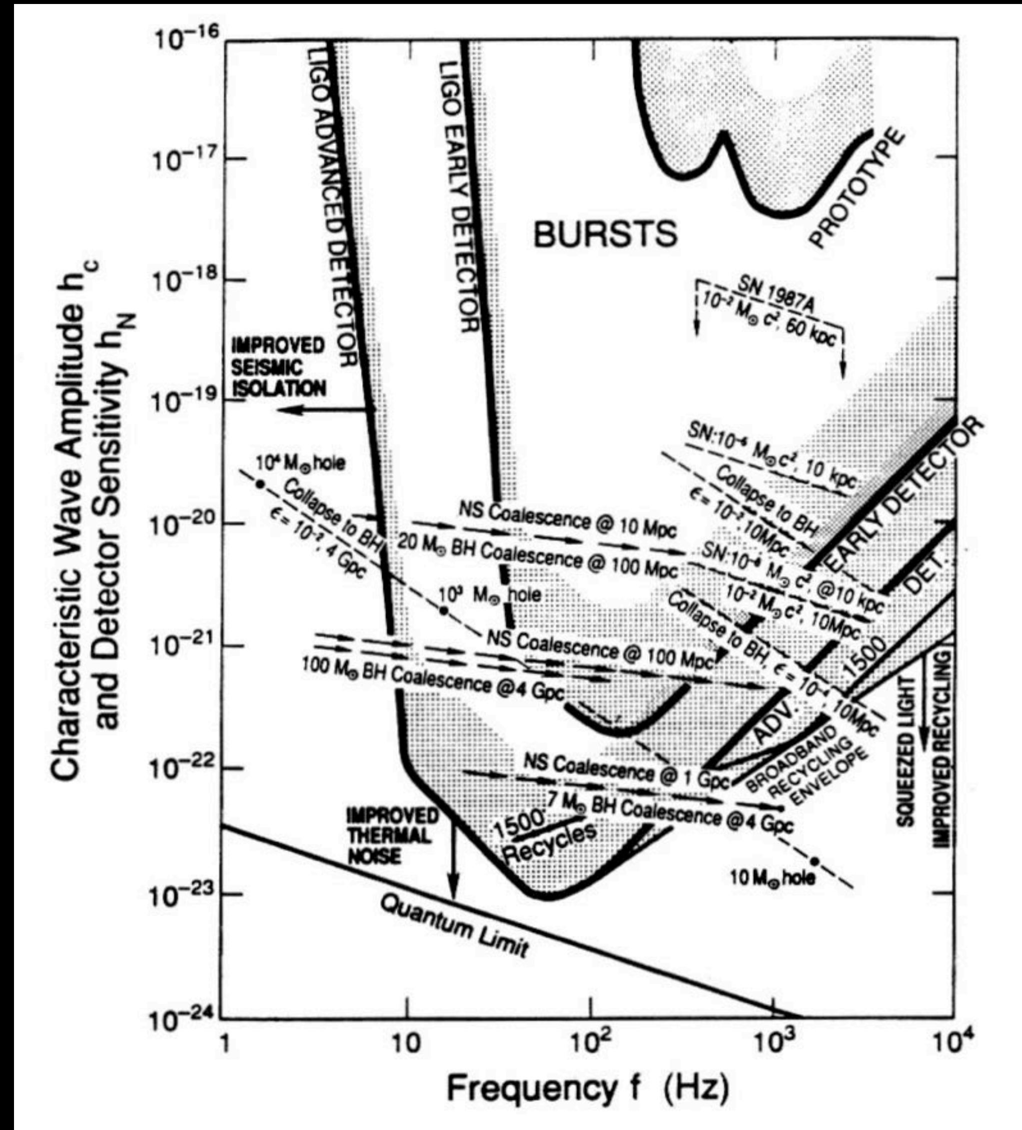

Proposal to the National Science Foundation

A
LASER INTERFEROMETER
GRAVITATIONAL-WAVE
OBSERVATORY
(LIGO)

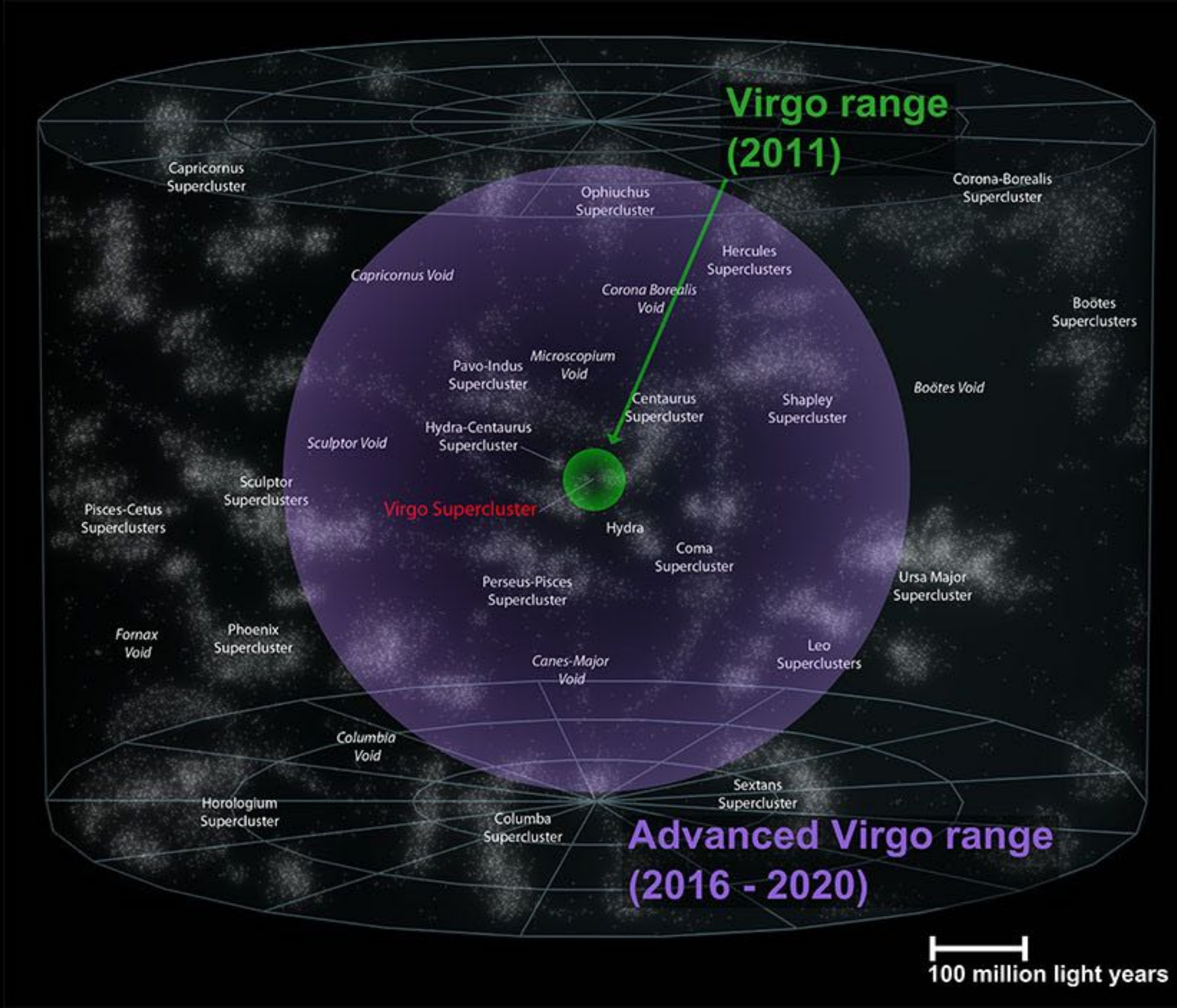
VOLUME 1:
LIGO Science and Concepts

December 1989

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LIGO PROJECT



THE CONCEPT OF AN “ADVANCED” DETECTOR IS ALREADY IN THE LIGO PROPOSAL TO NSF


Virgo range
(2011)
Capricornus
Supercluster
Ophiuchus
Supercluster
Corona-Borealis
Supercluster
Hercules
Superclusters
Capricornus Void
Corona Borealis
Void
Boötes
Superclusters
Microscopium
Void
Pavo-Indus
Supercluster
Boötes Void
Centaurus
Supercluster
Shapley
Supercluster
Hydra-Centaurus
Supercluster
Sculptor Void
Sculptor
Superclusters
Pisces-Cetus
Superclusters
Virgo Supercluster
Hydra
Coma
Supercluster
Ursa Major
Supercluster
Perseus-Pisces
Supercluster
Phoenix
Supercluster
Fornax
Void
Leo
Superclusters
Canes-Major
Void
Columbia
Void
Sextans
Supercluster
Horologium
Supercluster
Columba
Supercluster
Advanced Virgo range
(2016 - 2020)
100 million light years

ADVANCED VIRGO

- Advanced Virgo (AdV): upgrade of the Virgo interferometric detector
- Participated by scientists from France and Italy (former founders of Virgo), The Netherlands, Poland and Hungary
- Funding approved in Dec 2009 (21.8 ME + Nikhef in kind contribution)
- End of installation: July 2016
- Part of the international network (MoU with LSC)
- Short-term goal: join O2b in ~March 2017

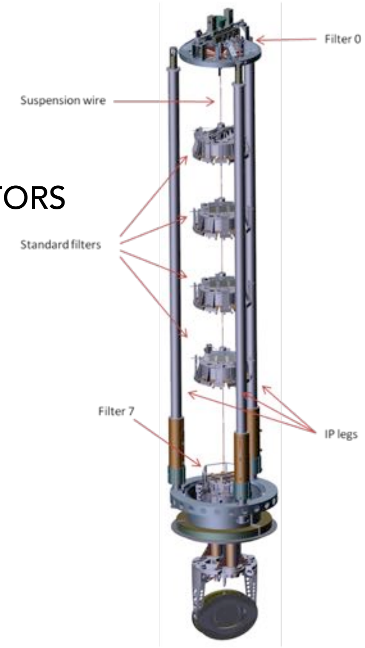
6 European countries
20 labs, ~250 authors

APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata
INFN Trento-Padova
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW(Poland)
RADBOUD Uni. Nijmegen
RMKI Budapest
Univ. of Valencia

HEAVIER TEST MASSES

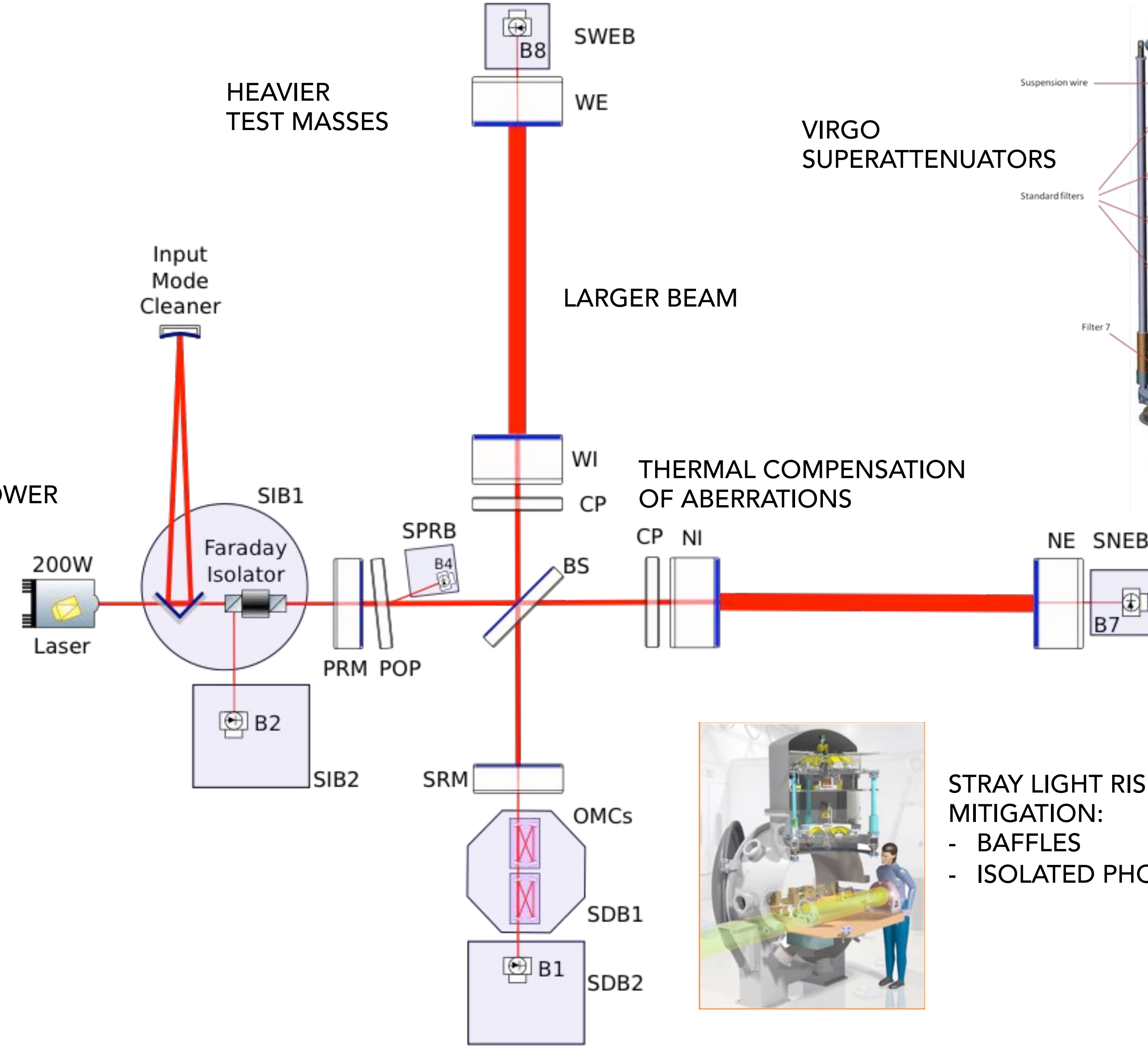
LARGER BEAM

VIRGO SUPERATTENUATORS



HIGH POWER LASER

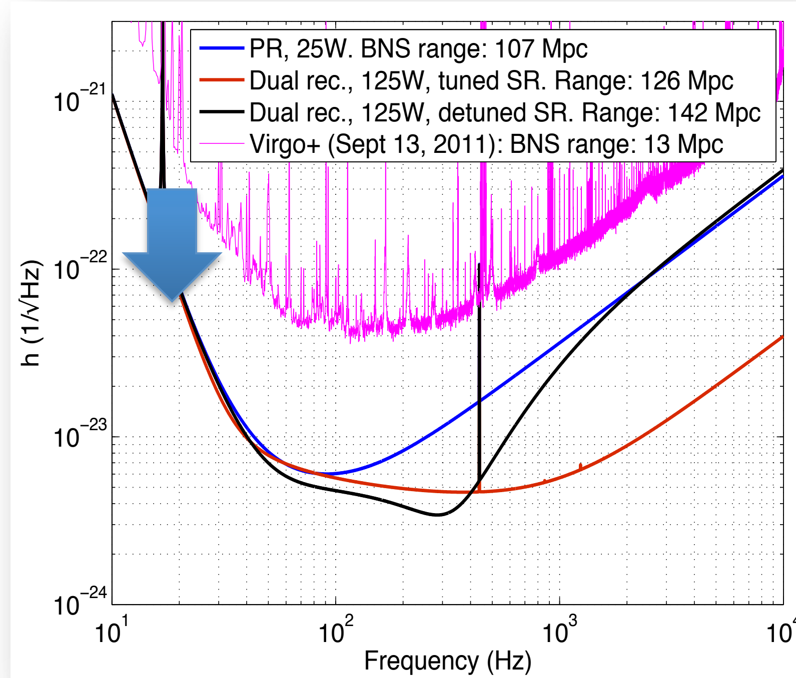
THERMAL COMPENSATION OF ABERRATIONS



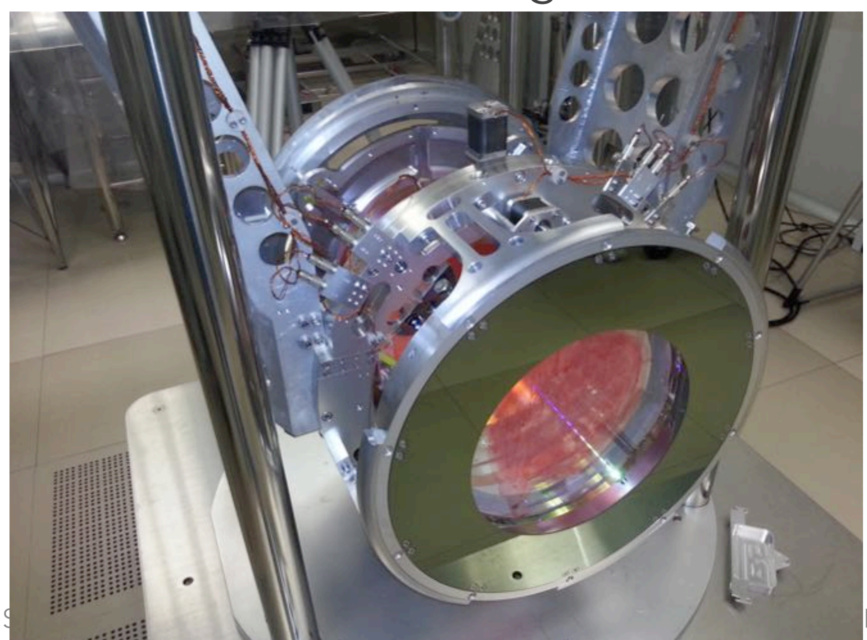
STRAY LIGHT RISK MITIGATION:

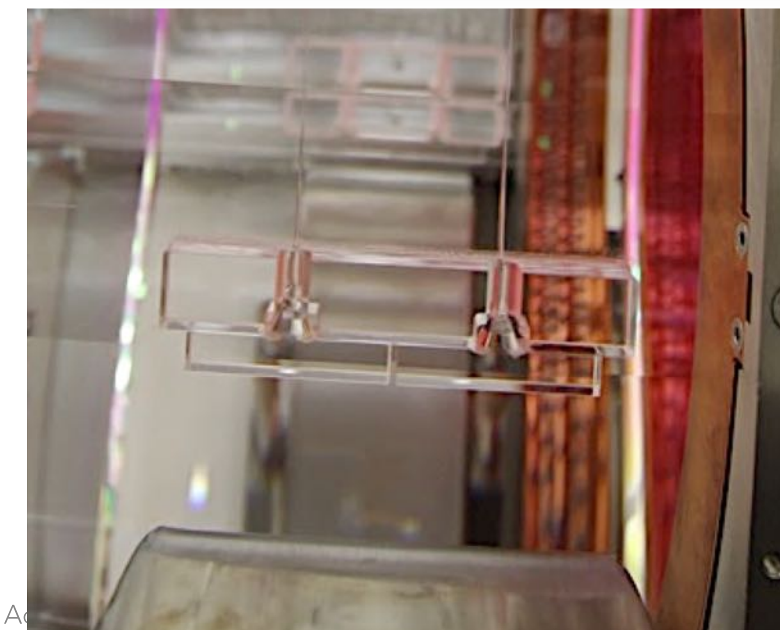
- BAFFLES
- ISOLATED PHOTODIODES

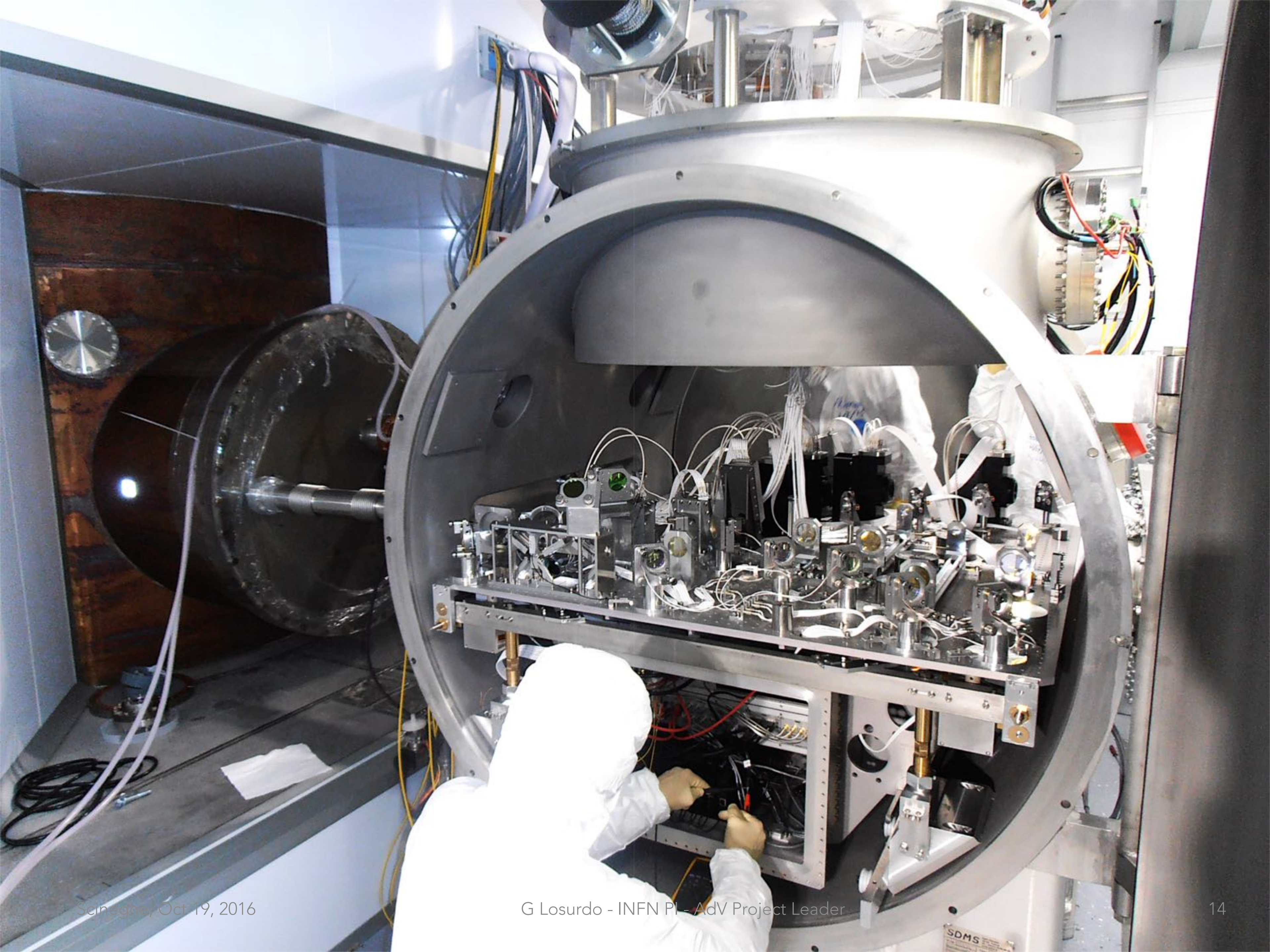
TECHNOLOGIES



- Virgo Superattenuator already compliant with 2nd generation
  - Some upgrades to support heavier payloads
  - New control electronics!
- Improve monolithic suspension
- Prevent scattered light

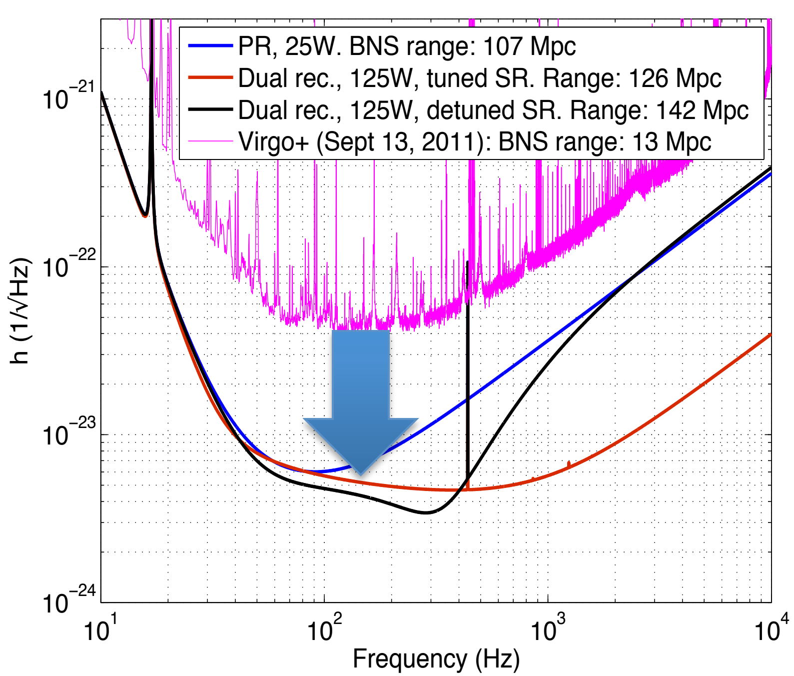


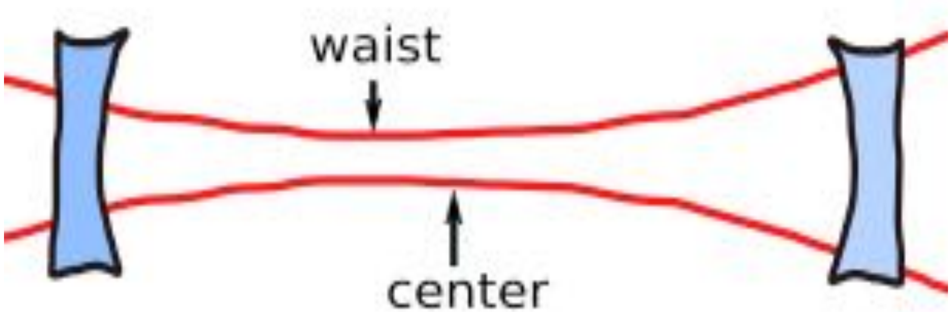


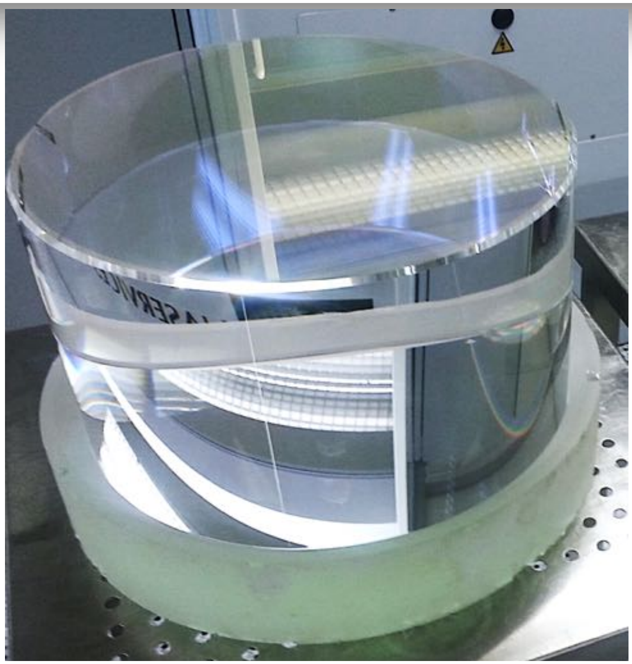

SDMS

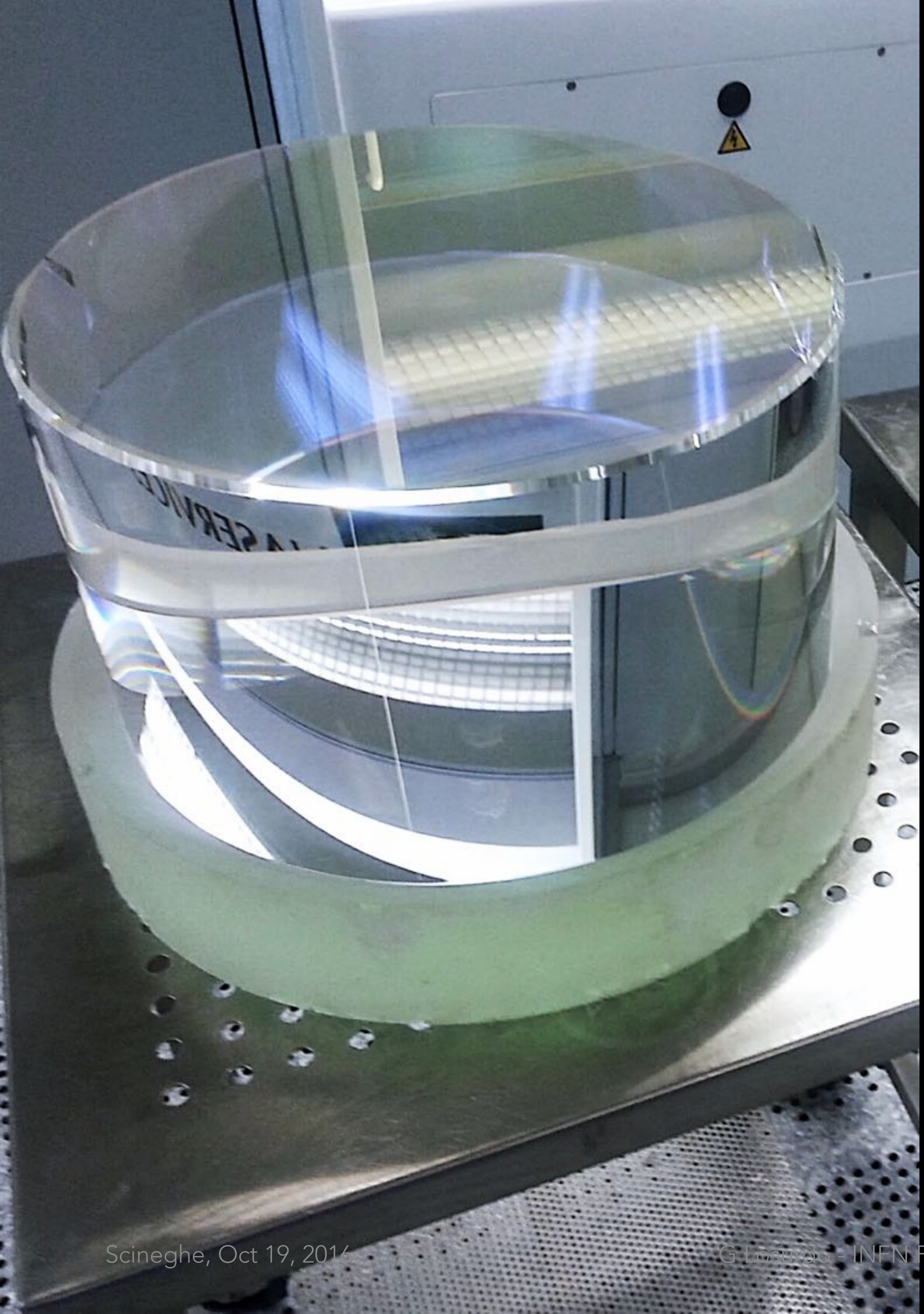
TECHNOLOGIES

- Dominated by thermal noise of mirror coatings
- Reduced by:
  - Improved optical configuration: larger beam spot
  - Mirror coatings engineered for low losses







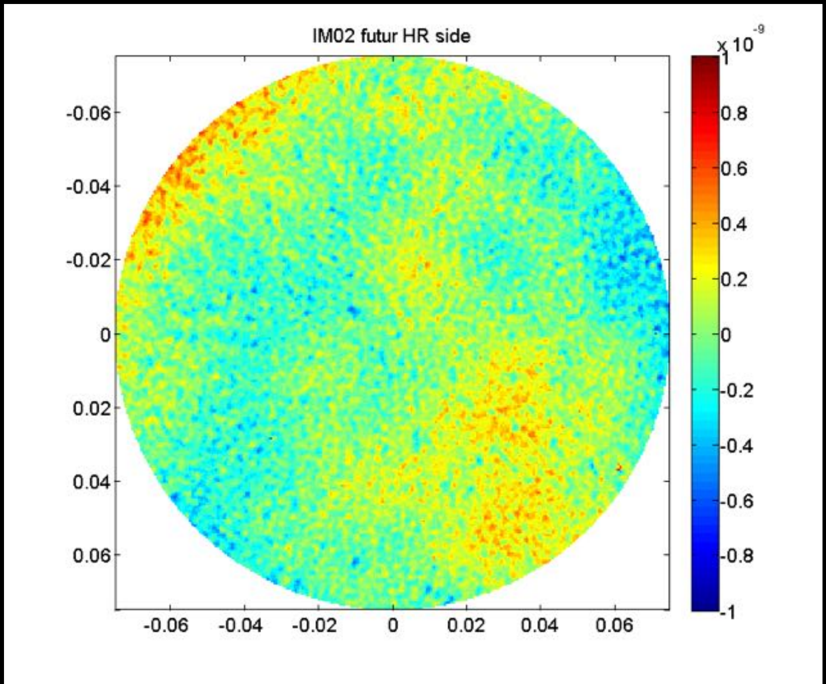


EXTREME MIRROR TECHNOLOGY:

- Low losses
- Low absorption
- Low scattering:

FEATURES:

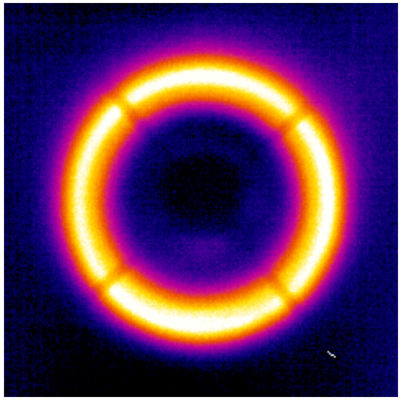
- 42 kg, 35 cm ⃠, 20 cm thick
- Flatness < 0.5 nm rms
- Micro-roughness: 0.1 nm rms
- Optical apbsorption < 0.5 ppm

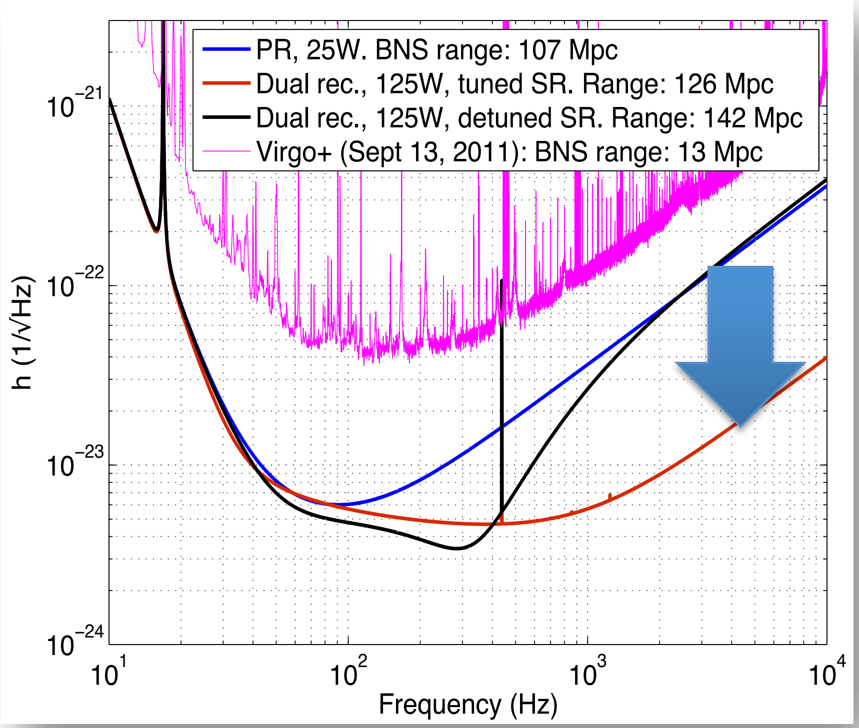


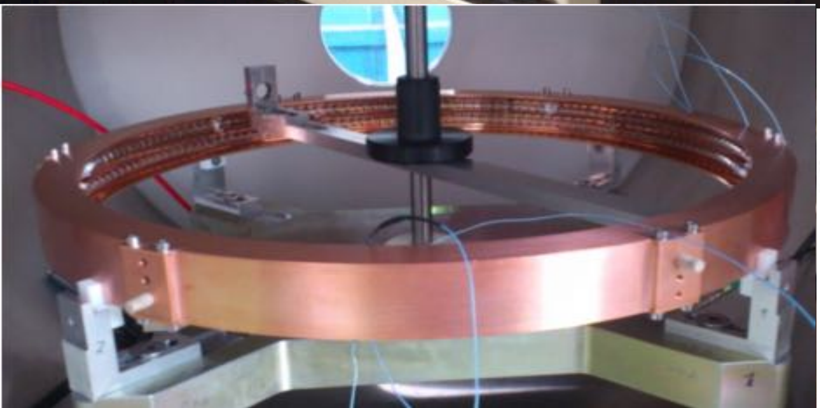
TECHNOLOGIES

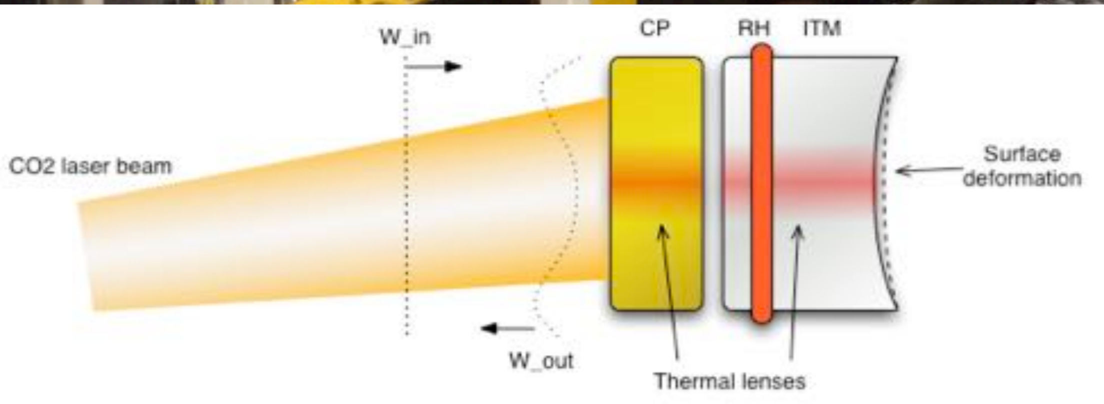
BEATING THE SHOT NOISE LIMIT

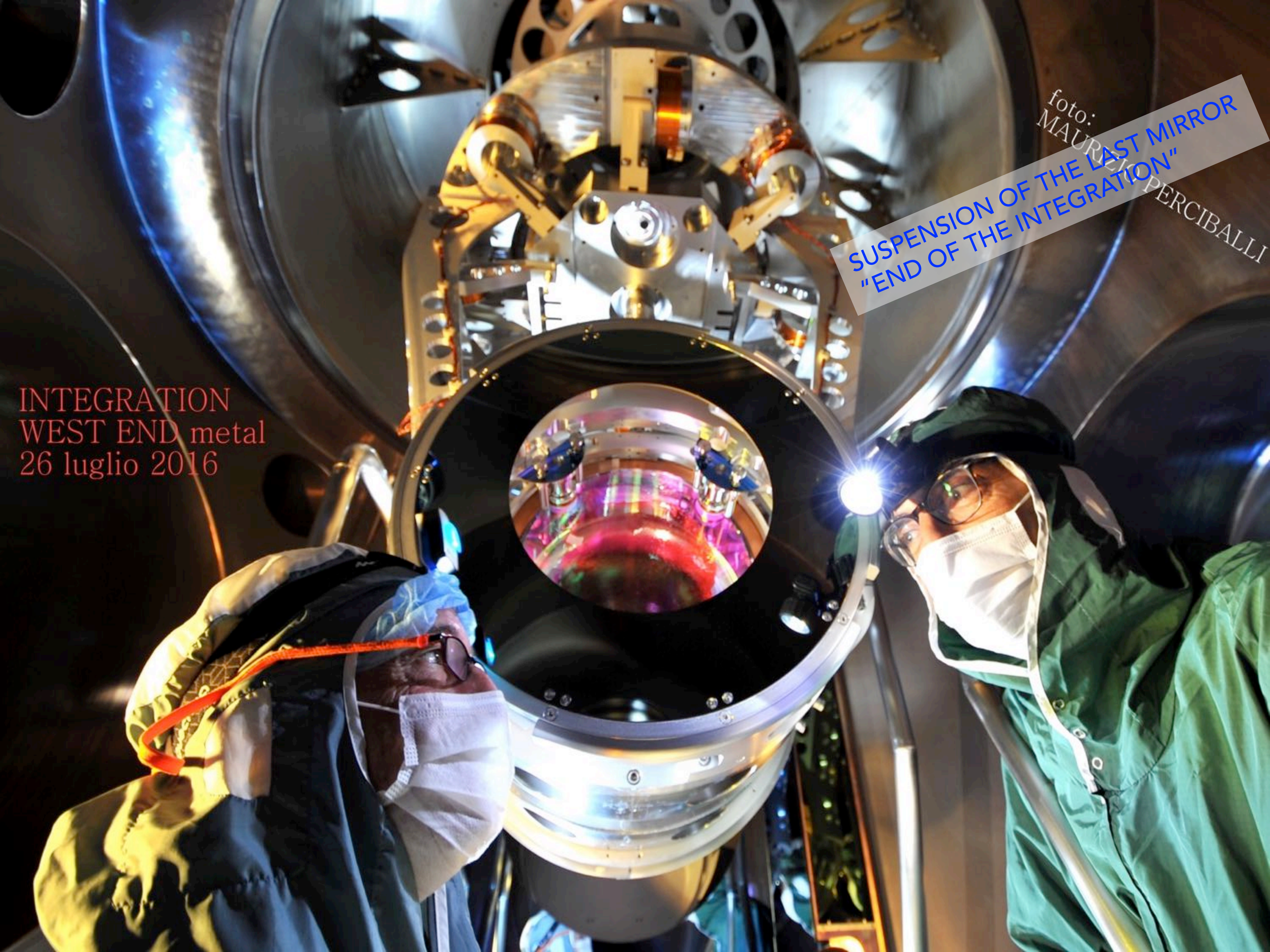
- Increase of laser power 10x
- Requires:
  - Heavier mirrors
  - Low absorption optics
  - Compensation of thermal aberrations
- Alternative/complementary approach: use of squeezed light



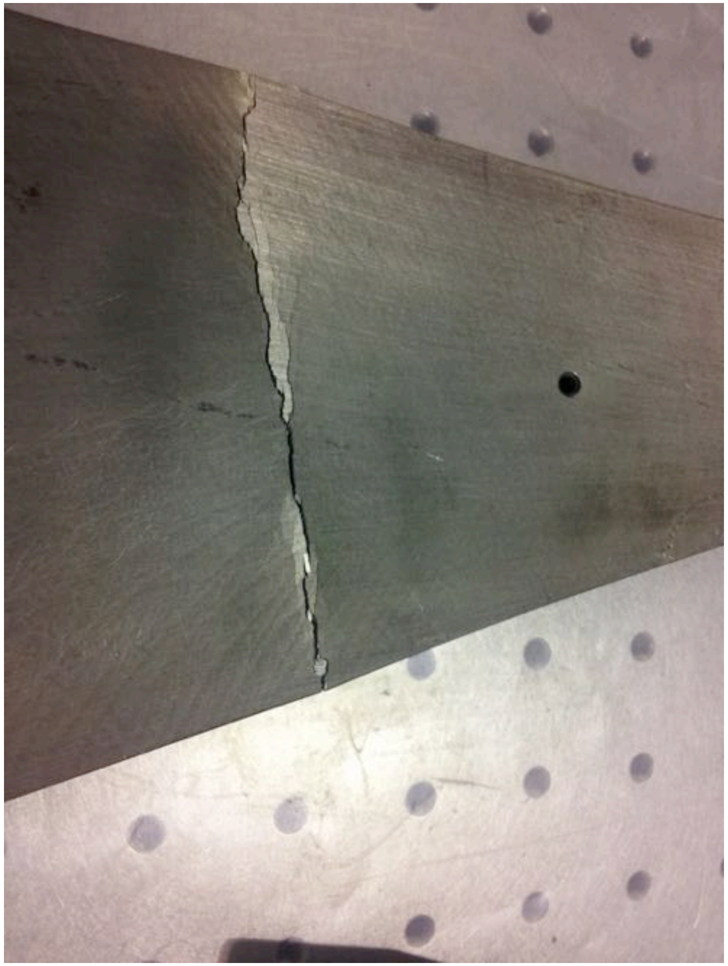





W_in
CP
RH
ITM
CO2 laser beam
Surface
deformation
W_out
Thermal lenses


INTEGRATION
WEST END metal
26 luglio 2016
foto:
MAURIZIO PERCIBALLI
SUSPENSION OF THE LAST MIRROR
"END OF THE INTEGRATION"

MAIN INTEGRATION ISSUES

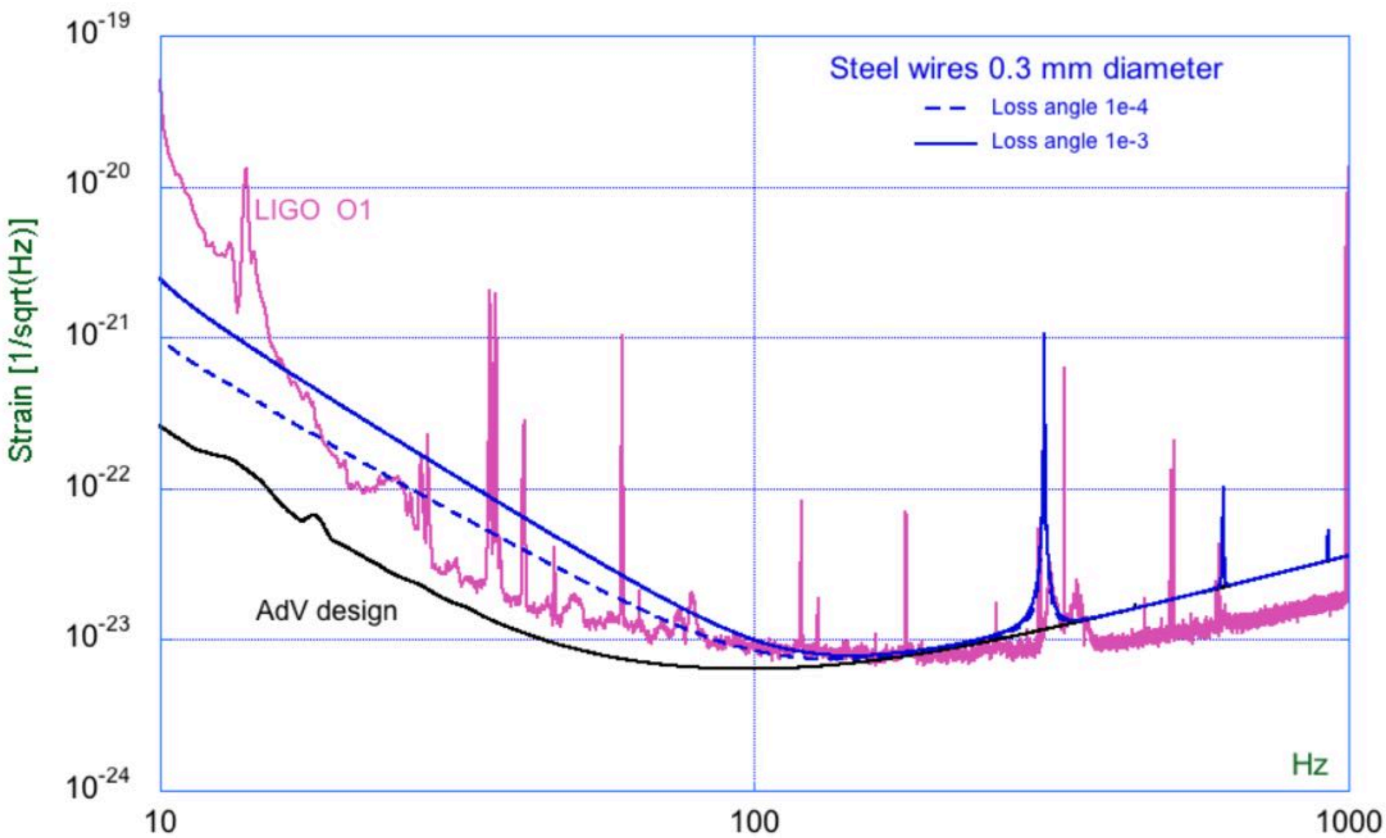


BROKEN SUPERATTENUATOR BLADES

BROKEN MONOLITHIC SUSPENSIONS


TEST MASSES SUSPENDED
WITH STEEL WIRES
14.07.2016 17:55

TARGET O2 SENSITIVITY



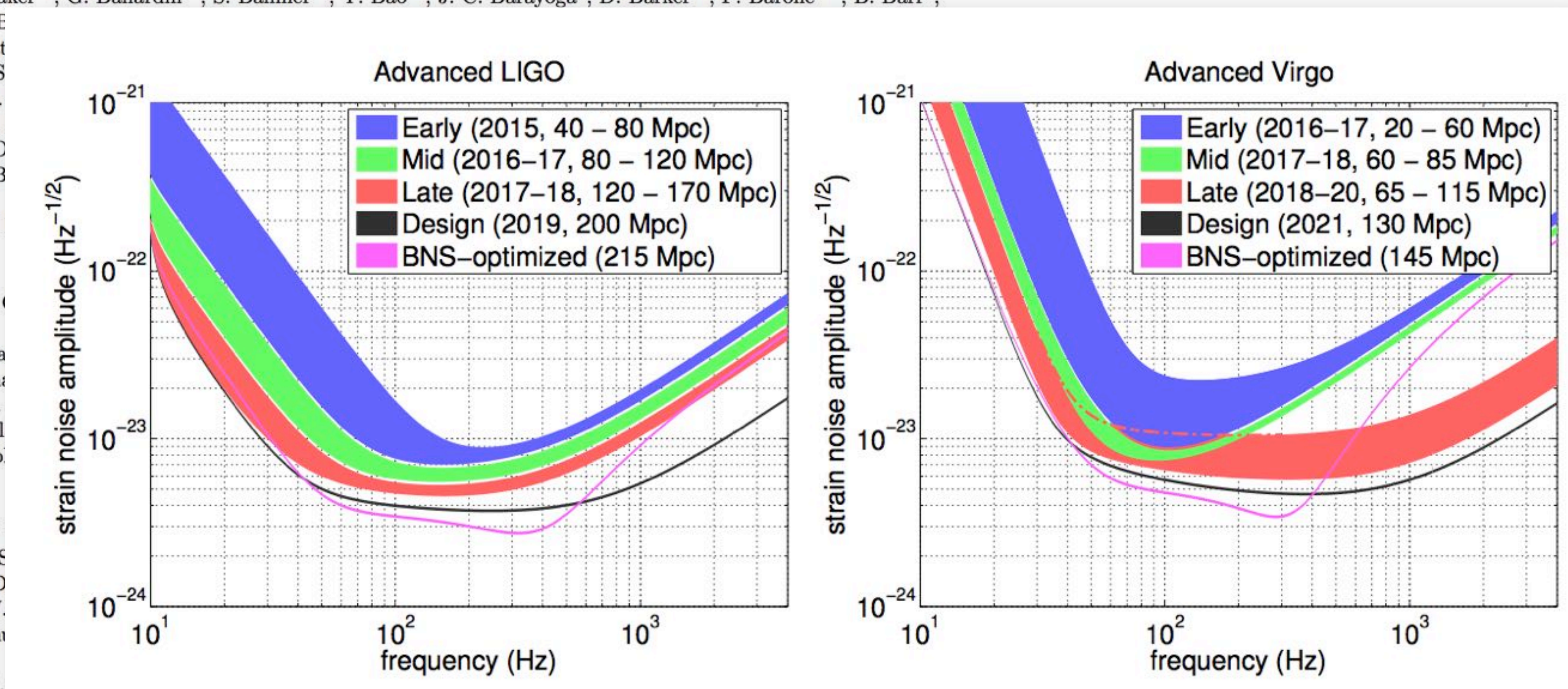
Inspiral range (Mpc), steel wires on 4 TM, ϕ = 1e-4 (1e-3)	
BNS	60 (45)
BBH	313 (202)

OBSERVING SCENARIO

Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories

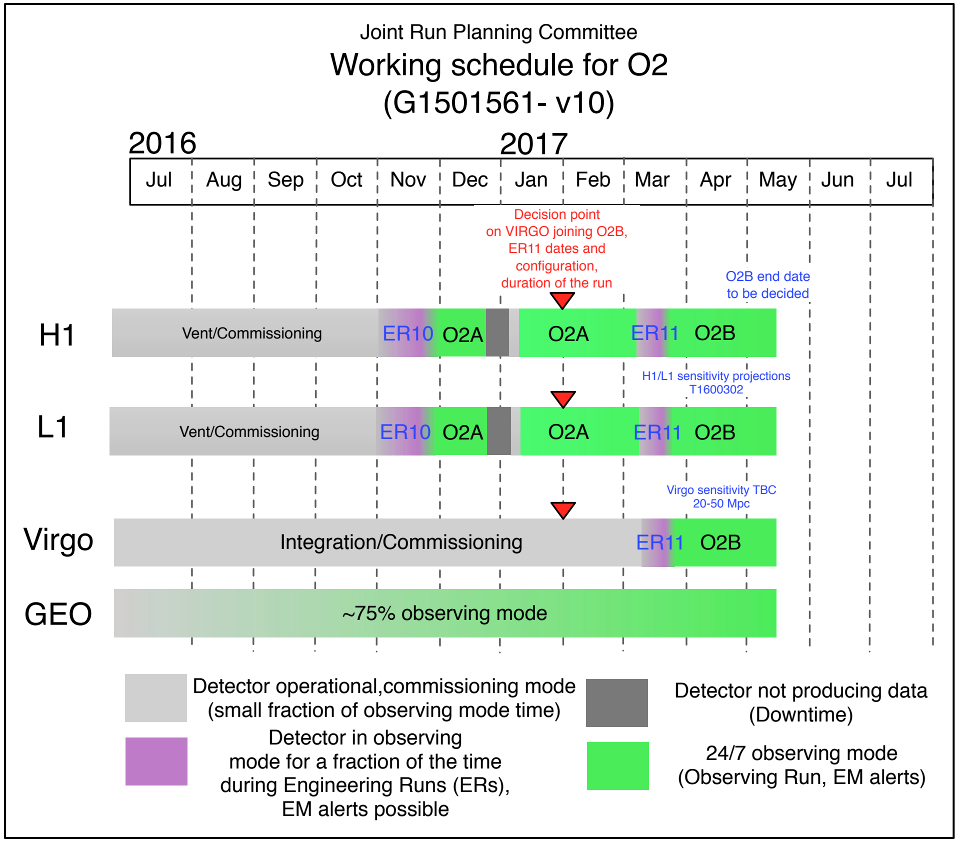
J. Aasi[1], J. Abadie[1], B. P. Abbott[1], R. Abbott[1], T. D. Abbott[2], M. Abernathy[3], T. Accadia[4],
F. Acernese[5ac], C. Adams[6], T. Adams[7], P. Addesso[8], R. X. Adhikari[1], C. Affeldt[9,10], M. Agathos[11a],
O. D. Aguiar[12], P. Ajith[1], B. Allen[9,13,10], A. Allocca[14ac], E. Amador Ceron[13], D. Amariutei[15],
S. B. Anderson[1], W. G. Anderson[13], K. Arai[1], M. C. Araya[1], C. Arceneaux[16], S. Ast[9,10], S. M. Aston[6],
P. Astone[17a], D. Atkinson[18], P. Aufmuth[10,9], C. Aulbert[9,10], L. Austin[1], B. E. Aylott[19], S. Babak[20],
P. Baker[21], G. Ballardin[22], S. Ballmer[23], Y. Bao[15], J. C. Barayoga[1], D. Barker[18], F. Barone[5ac], B. Barr[3],

arXiv:1304.0670v1 [gr-qc] 2 Apr 2013



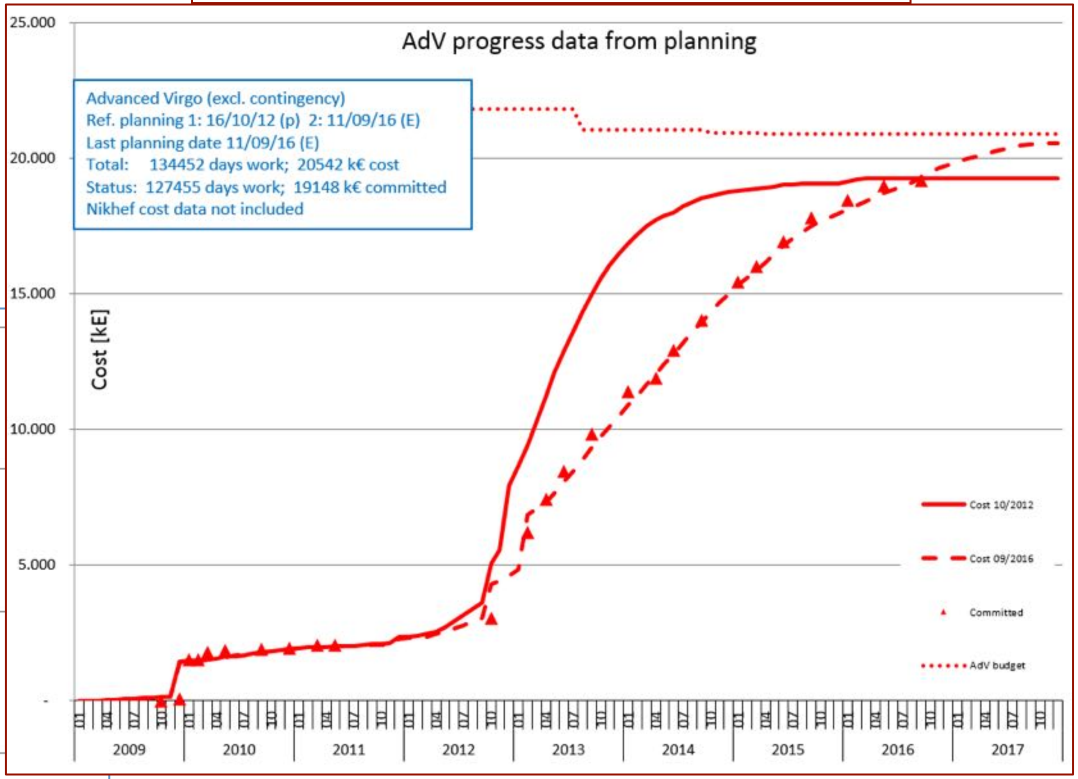
TOWARDS O2

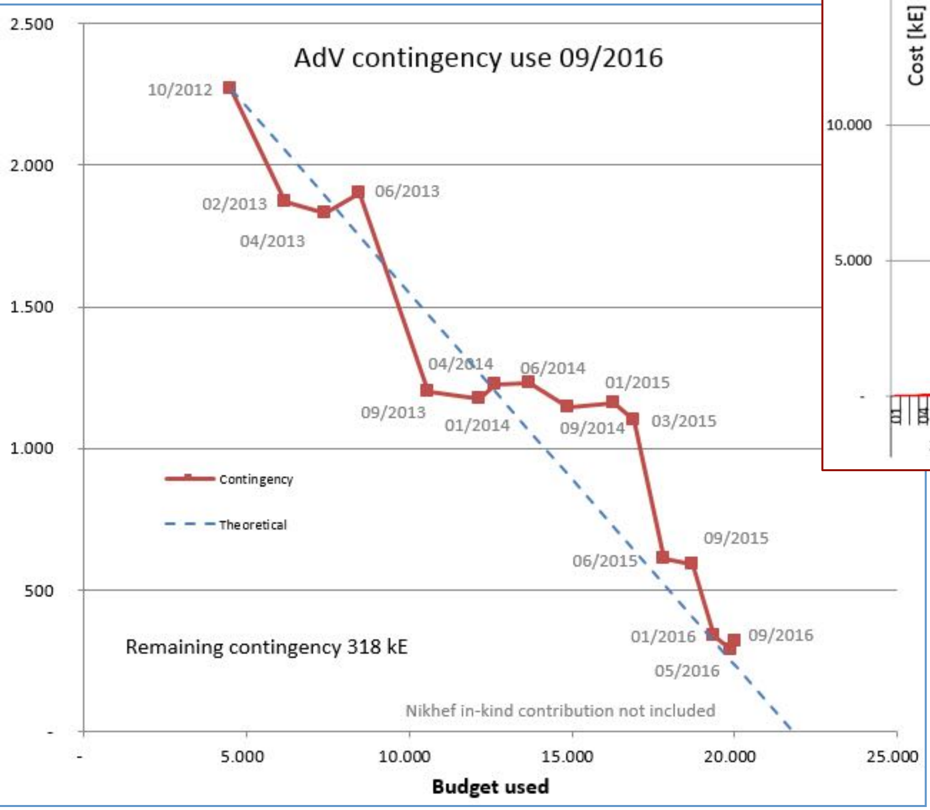
- Short-term goal: join LIGO in O2b (~03/17)
- Starting data taking will mark the official end of the AdV project



BUDGET

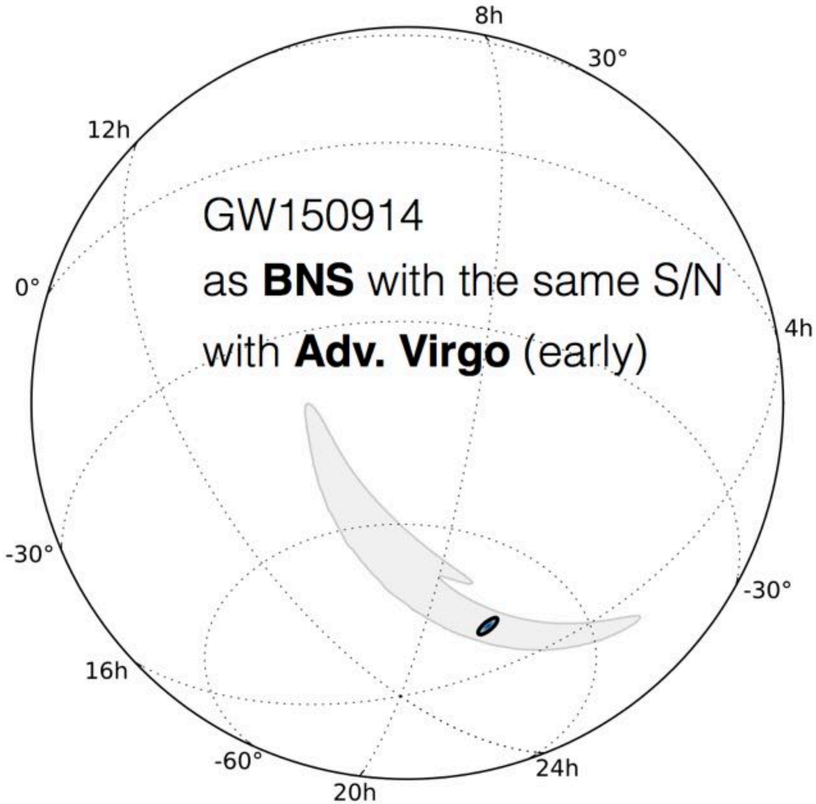
93% of project cost committed





PROJECT BEING COMPLETED ON BUDGET

THE NEED FOR ADV



from L SINGER, G1601468

Even with "early" sensitivity, Advanced Virgo can **fundamentally transform** the character of GW observations.

Area (deg^2)	GW 150914	NSBH	NSNS
HL	400	300	200
HLV	11	11	5
HLI	6	7	4

GLOBAL FRAMEWORK

Category⁺ (⁺Color code: scaled from aLIGO / new engineering)	ROM Estimate (FY'17k$)*
Core optic coating pathfinder	3,546
Core optic production	4,266
FC facility mods	1,023
FC vacuum	1,761
FC seismic isolation	4,728
FC suspensions	990
Balanced homodyne readout	339
Sensing & control	214
Other equipment	601
Labor	5,648
Contingency (25%)	5,779
Total	**28,896**

PRELIMINARY

LIGO-G1601435

A+

- An incremental upgrade to aLIGO that leverages existing technology and infrastructure, with minimal new investment and moderate risk
- Target: factor of 1.7* increase in range over aLIGO
  ➔ About a factor of 5 greater event rate
- Stepping stone to future 3G detector technologies
- Link to future GW astrophysics and cosmology
- Could be observing within < 6.5 years (mid-2022)
  – with prompt funding (FY'19 or earlier)
- "Scientific breakeven" within 1/2 year of operation
- Incremental cost: *a small fraction of aLIGO*

*BBH 20/20 $M_{\odot}$: 1.64x
*BNS 1.4/1.4 $M_{\odot}$: 1.85x

LIGO-G1601435 A+ LIGO DAWN II WORKSHOP ZUCKER 7

AdV: WHAT NEXT?

- Goal for the next decade: maximize the scientific output of AdV
  - Maximize data taking
  - Minimize downtime

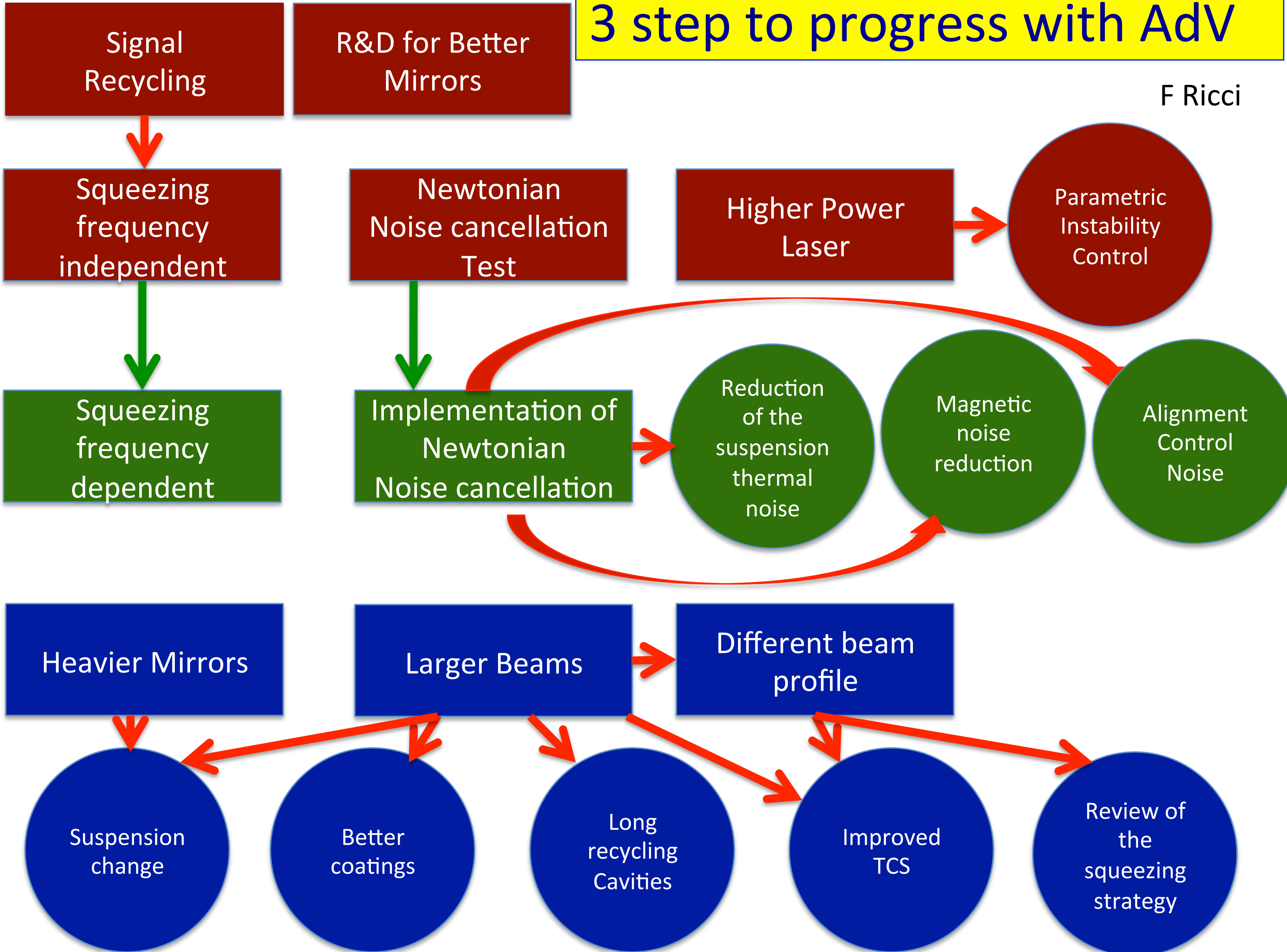
- PHASE 1 (2017):
  Post-O2 upgrades

- PHASE 2 (2018-2022):
  pushing toward the nominal sensitivity of AdV

- PHASE 3 (>2022)
  Actions to further enhance the AdV sensitivity, exploiting the limits of the present infrastructure and useful in view of a new 3G infrastructure

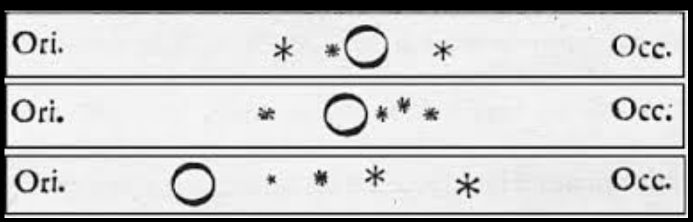
3 step to progress with AdV

F Ricci



- A "Vision Document", to present the strategy for the Virgo upgrades is being released to the agencies
- It is crucial to restart a significant R&D program with a ~10 yrs perspective to keep the pace of the 2G network progress
- In parallel, plans for 3G being pursued in Europe and US (see talk by M Punturo later)

400 years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Occ.
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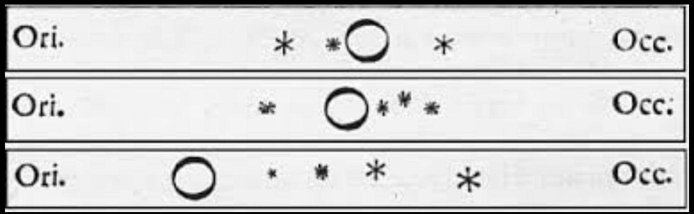
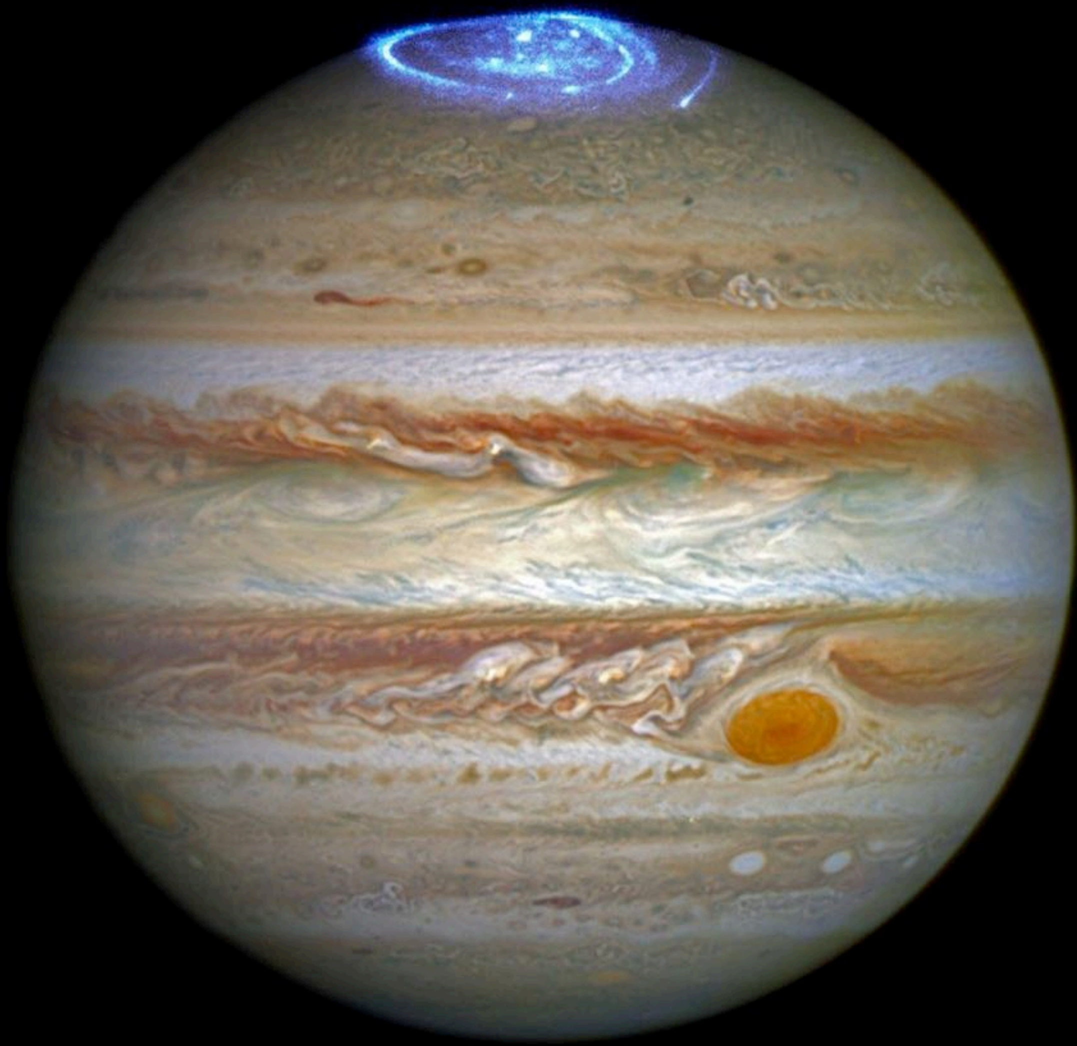
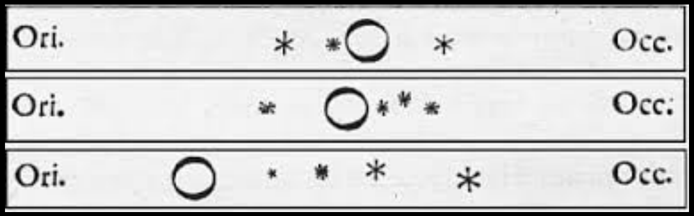




Credit: NASA/Hubble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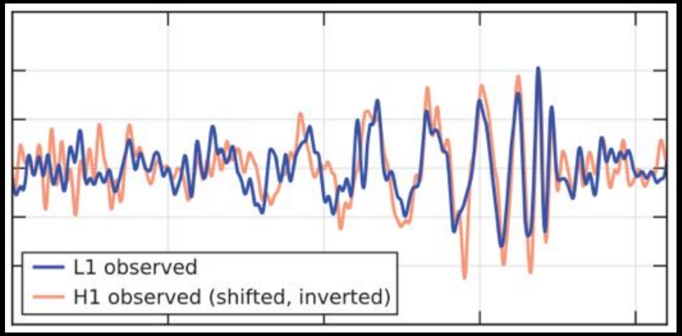
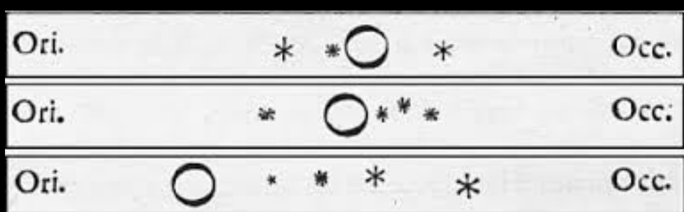

L1 observed
H1 observed (shifted, inverted)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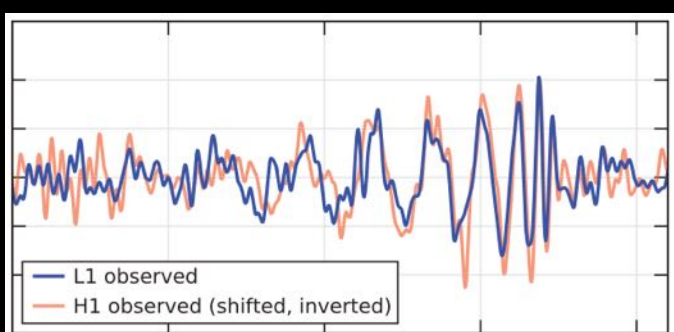
L1 observed
H1 observed (shifted, inverted)

?