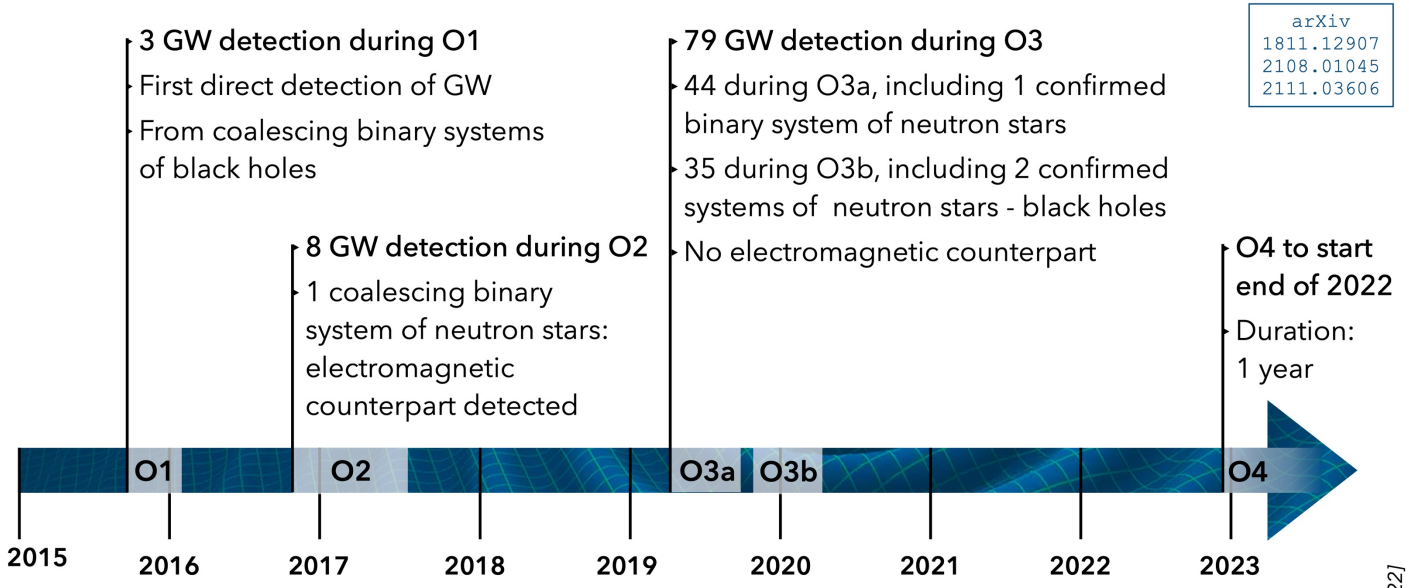
Advanced Virgo

Giovanni Losurdo – INFN Pisa
Virgo Collaboration Spokesperson

LIGO, 4 km

VIRGO, 3 km

GWTC: Gravitational Waves Transient Catalog - 3



90 GW detections reported

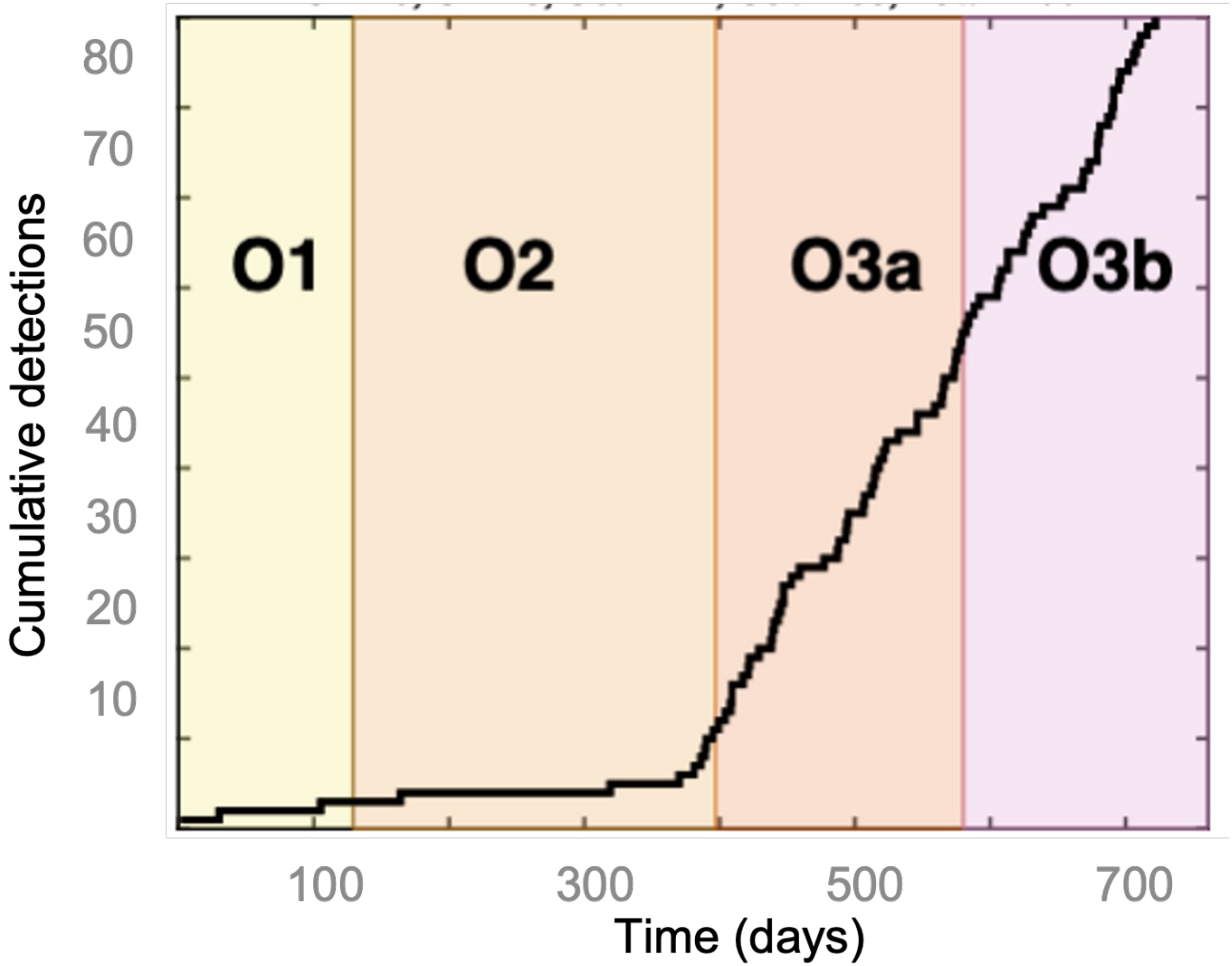
Coalescence of black holes and neutron stars

1 multimessenger event (GW + EM observation)

Mass range 1.2 → 107 $M_\odot$ (stellar)

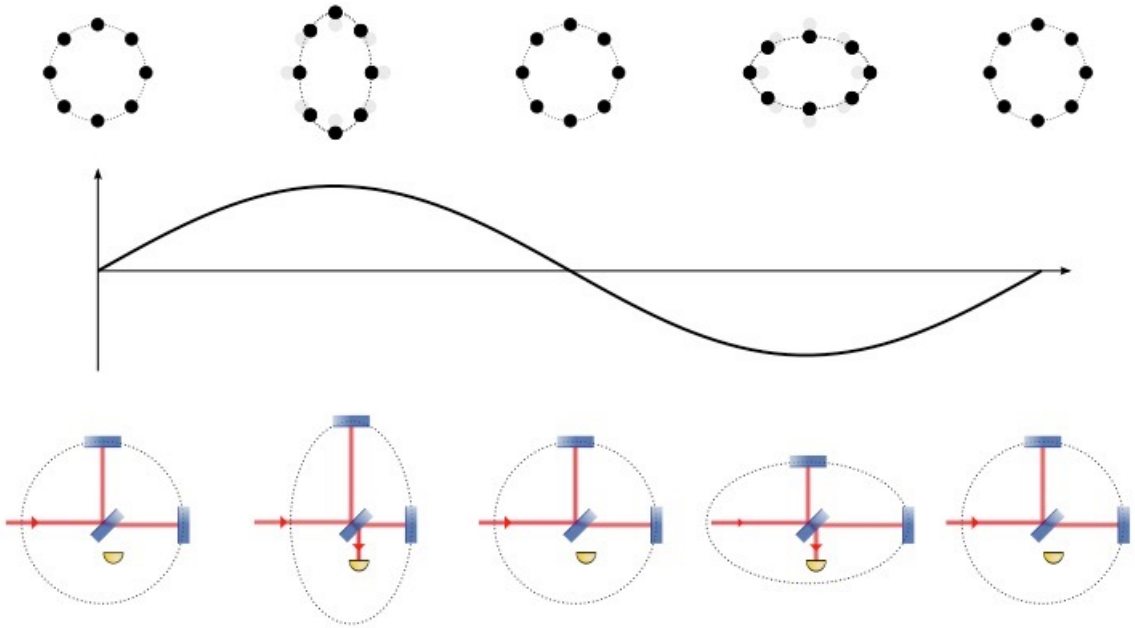
Distance range 40 Mpc → 8 Gpc (z → 1.14)

Leïla Haegel for the LVK collaboration [2022]


Cumulative detections
80
70
60
50
40
30
20
10
O1
O2
O3a
O3b
100
300
500
700
Time (days)

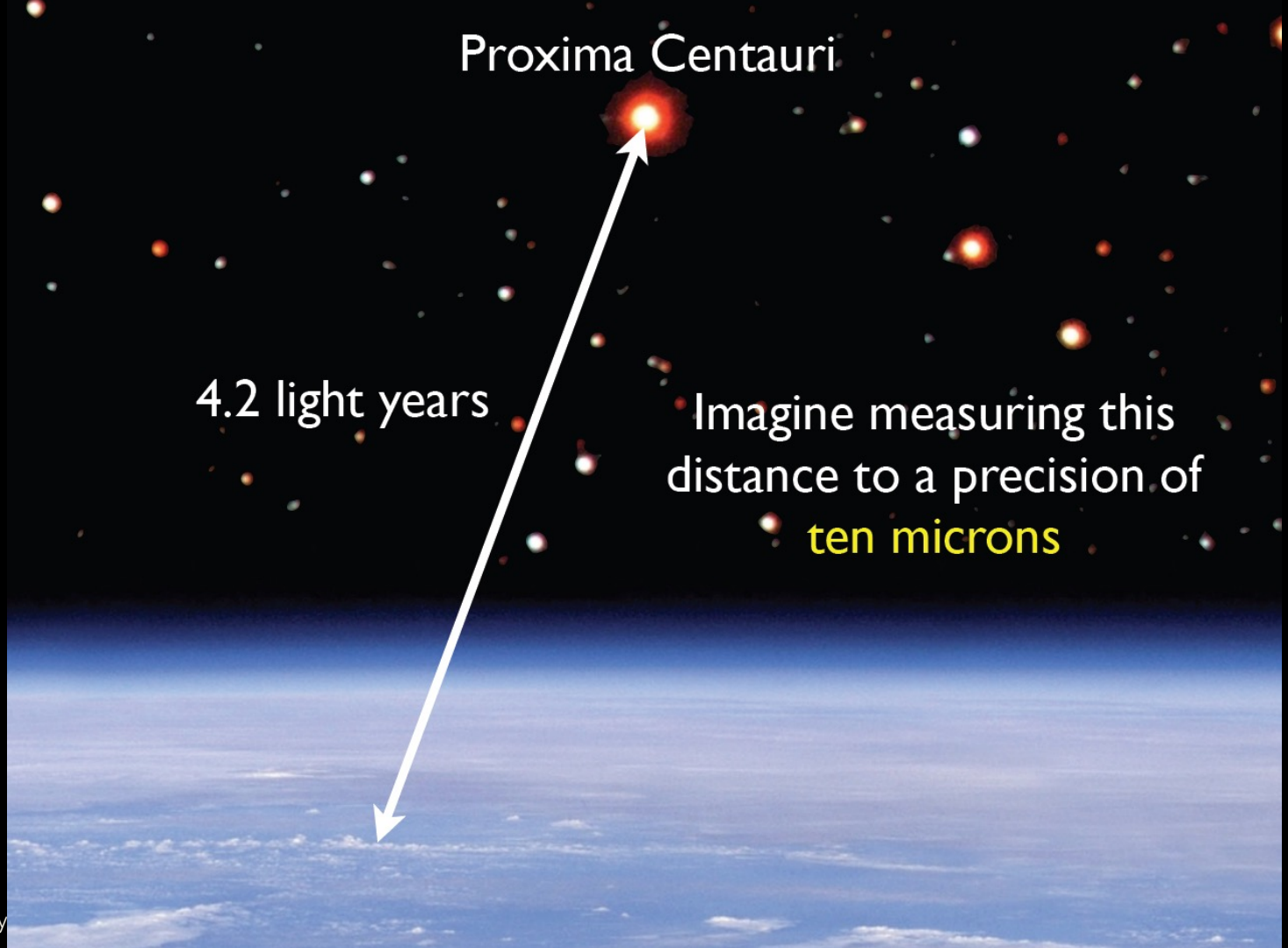
LOOKING BACK

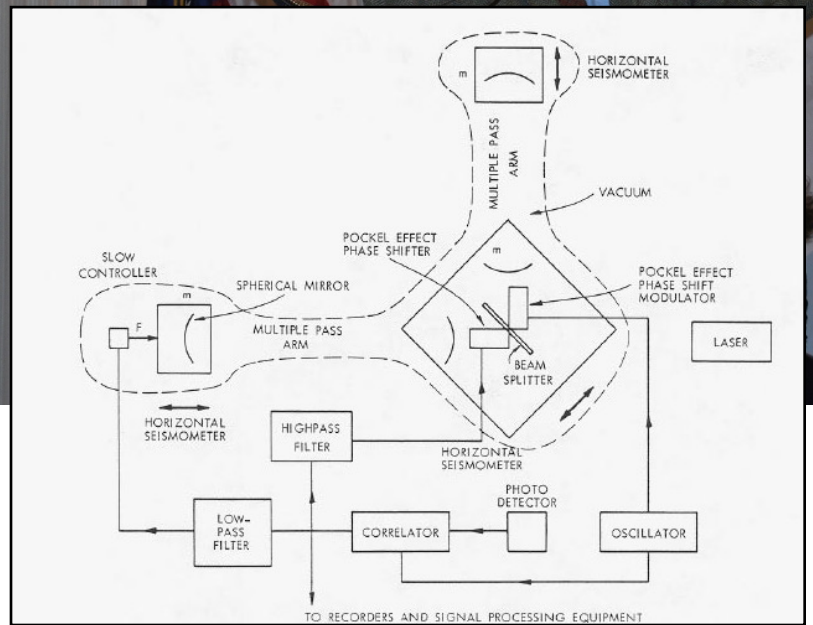
CONCEPT



~10^{-18} m

$$\Delta L = \frac{1}{2} hL$$


Proxima Centauri
4.2 light years
Imagine measuring this distance to a precision of ten microns



QUARTERLY PROGRESS REPORT

No. 105

APRIL 15, 1972

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
RESEARCH LABORATORY OF ELECTRONICS
CAMBRIDGE, MASSACHUSETTS 02139

(V. GRAVITATION RESEARCH)

B. ELECTROMAGNETICALLY COUPLED BROADBAND GRAVITATIONAL ANTENNA

1. Introduction

The prediction of gravitational radiation that travels at the speed of light has been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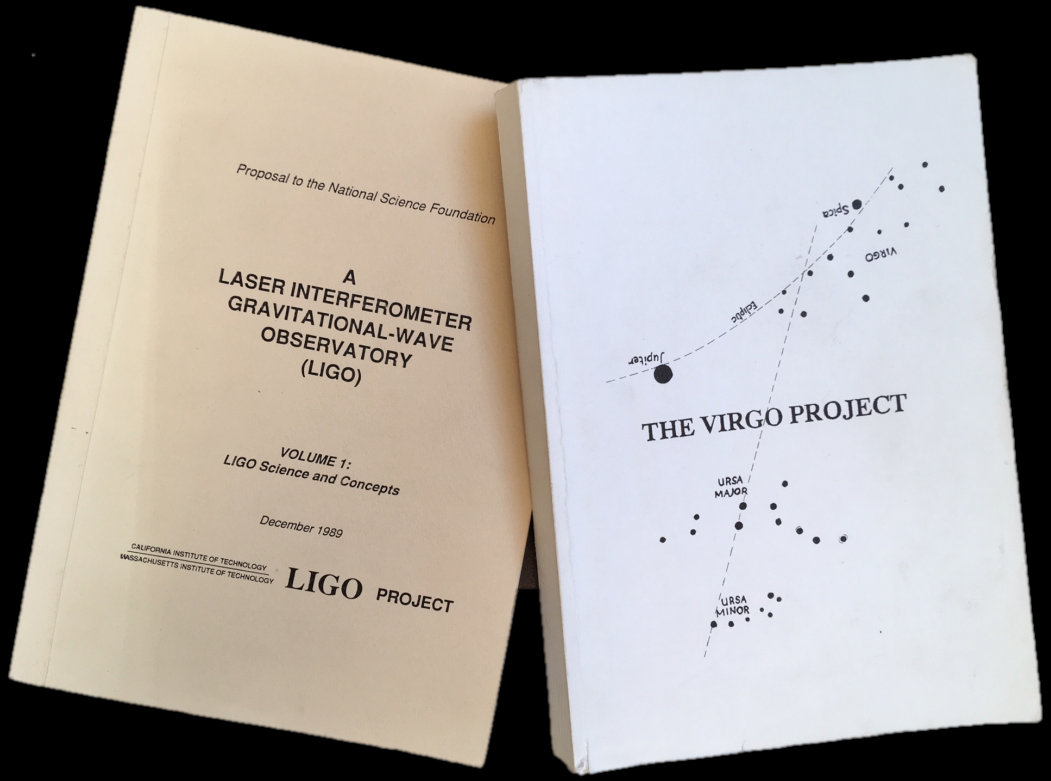
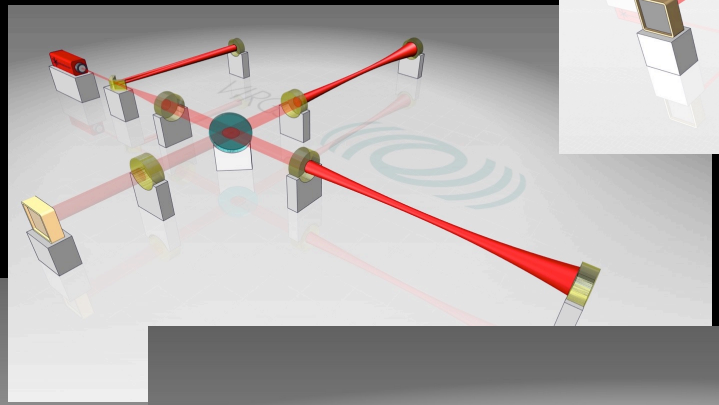
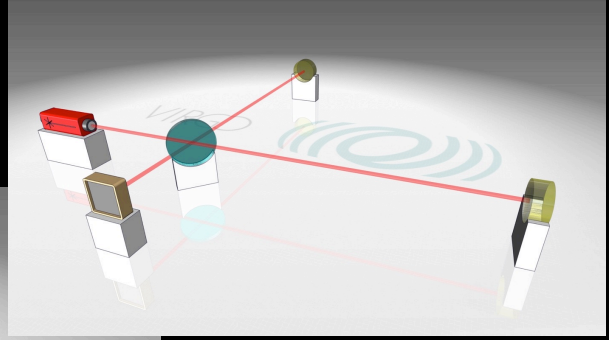
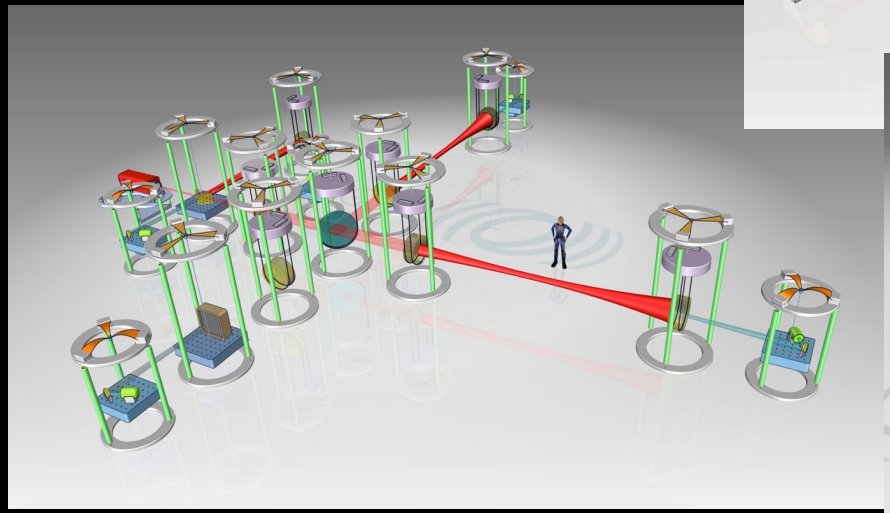
PISA, 1984

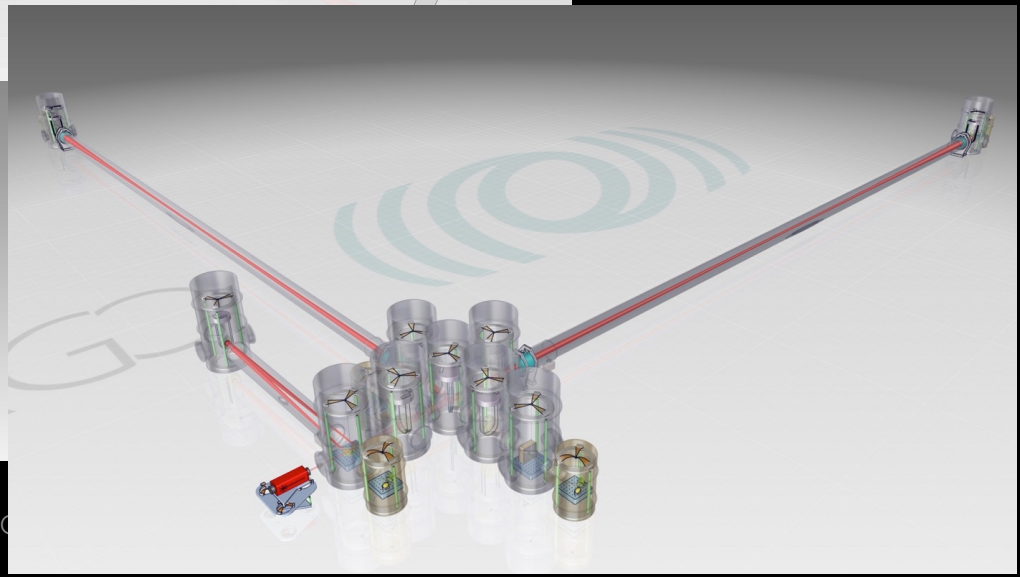
From CONCEPT to PROJECT



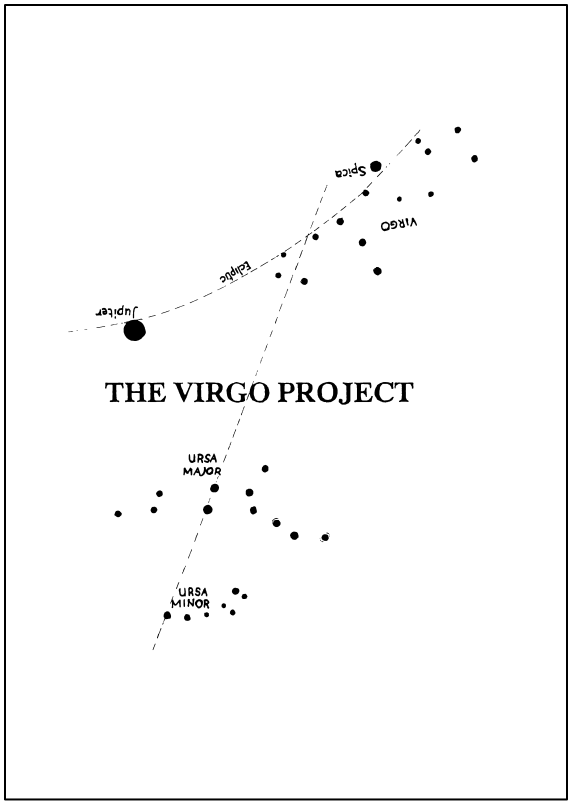








1989

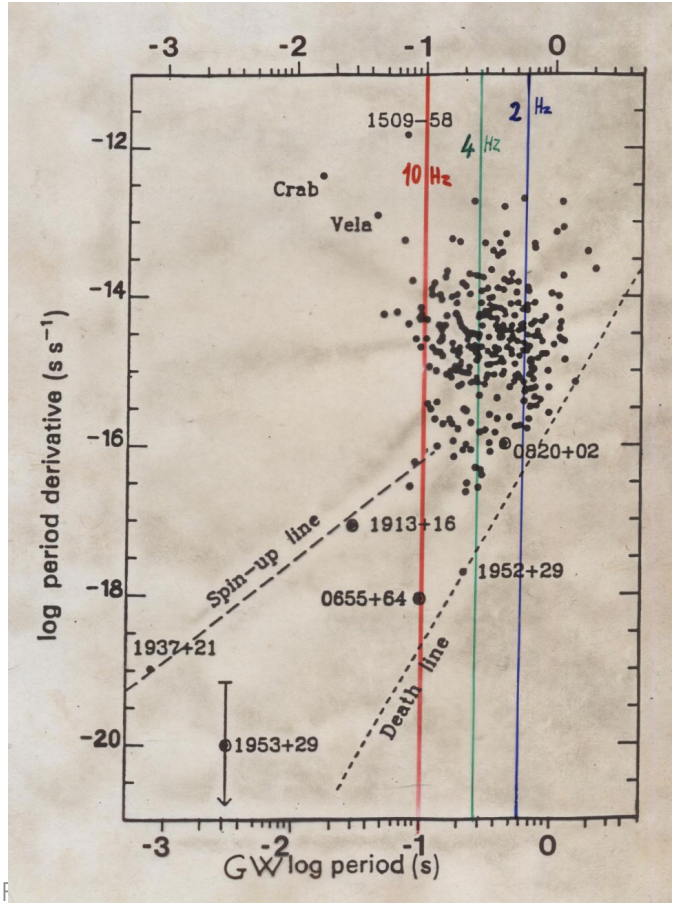


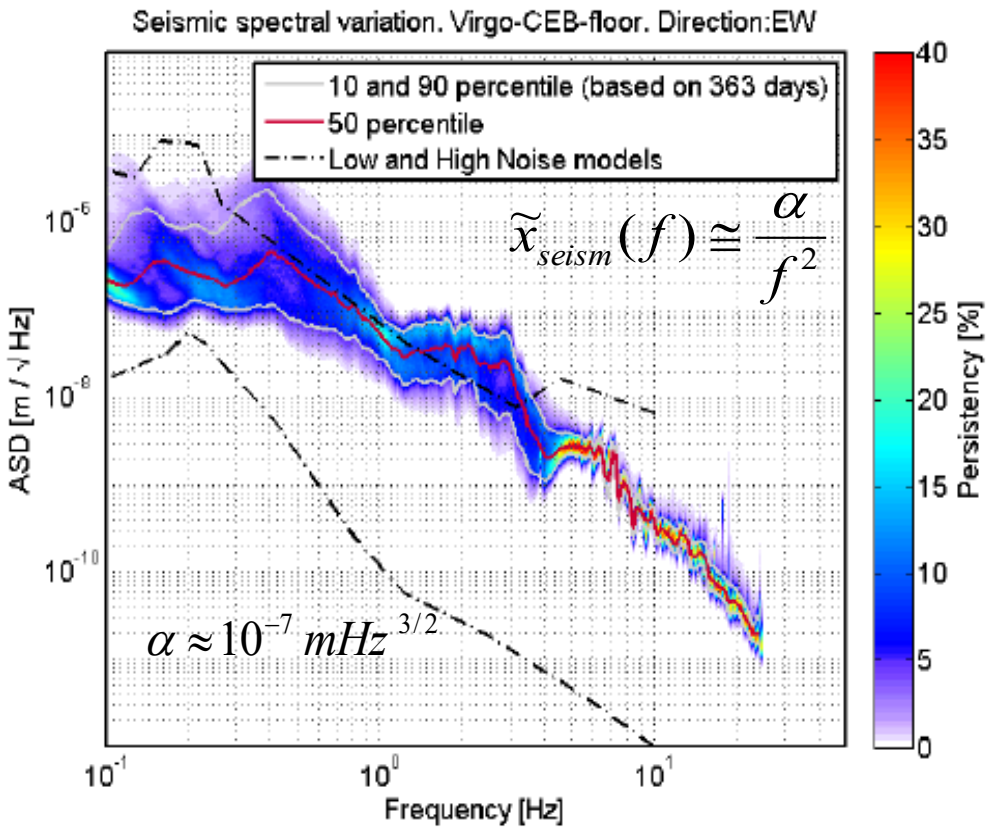
VIRGO must be considered both as an experiment and as a step towards a future observatory. The immediate goal of the VIRGO experiment is to realize, or to participate in, the first detection of gravitational radiation, but it also has the long term goal of being one component of the gravitational wave detectors network which will involve other detectors in other countries, and provide data of astrophysical interest. These goals imply a collaboration with the other groups having similar projects, without excluding some competition. The group leaders from Italy, France, Germany, Scotland, and the USA have agreed to exchange all information and to collaborate on all the aspects of the construction of large interferometers in order to generate the international effort required by the birth of gravitational astronomy.

A BRILLET & A GIAZOTTO

A Giazotto, 1980

- A Giazotto was the first who conceived a detector with low frequency threshold at ~10 Hz
- He was thinking about detecting continuous sources (pulsars)
- And he thought he had the right idea to achieve the goal





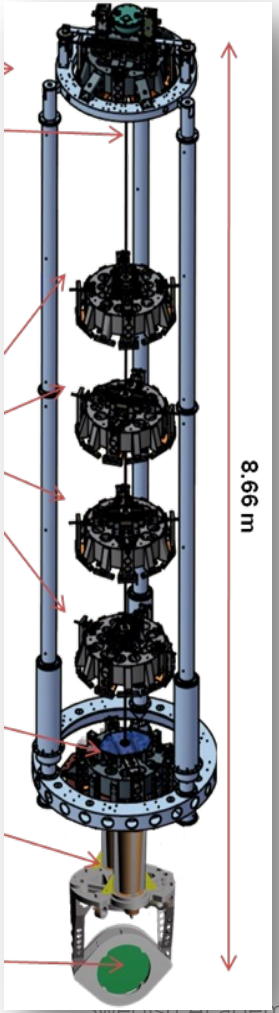
In detection band (>10 Hz) a point on ground moves by

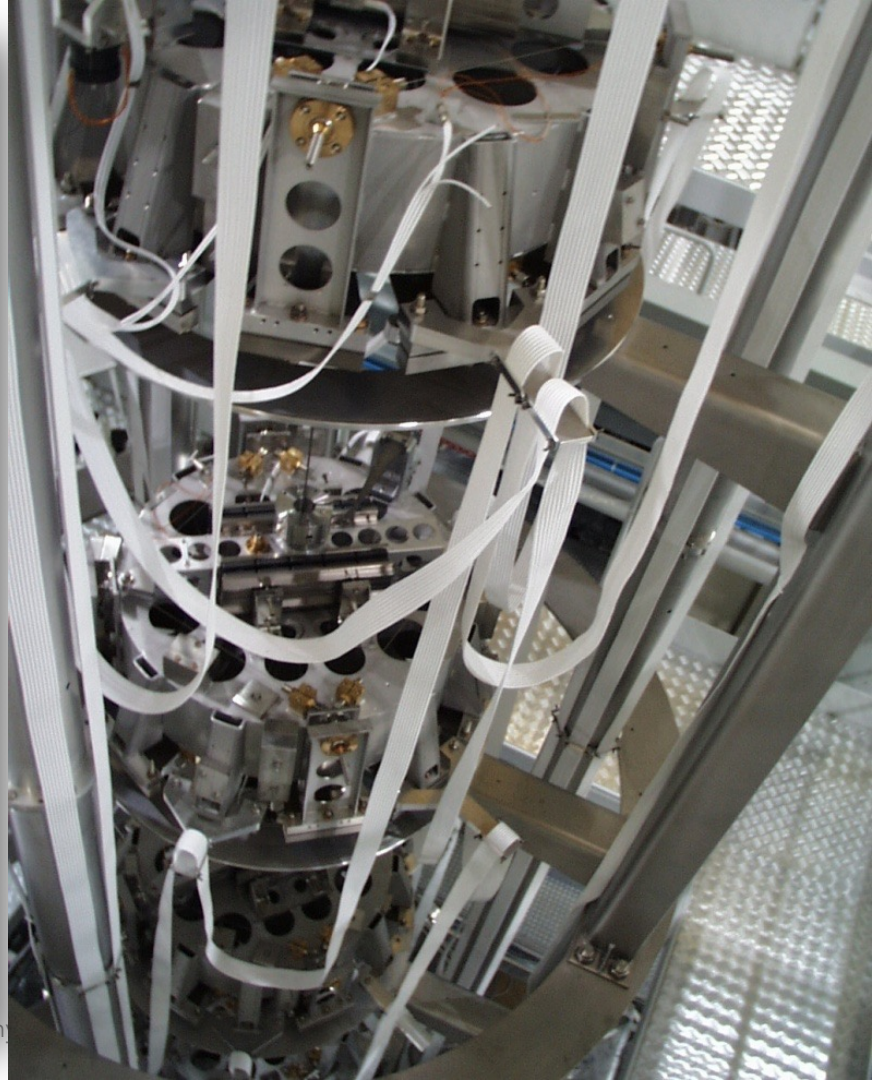
$$\tilde{x}_{seism} \approx 10^{-9}\ m/Hz^{1/2} \qquad f \approx 10 Hz$$

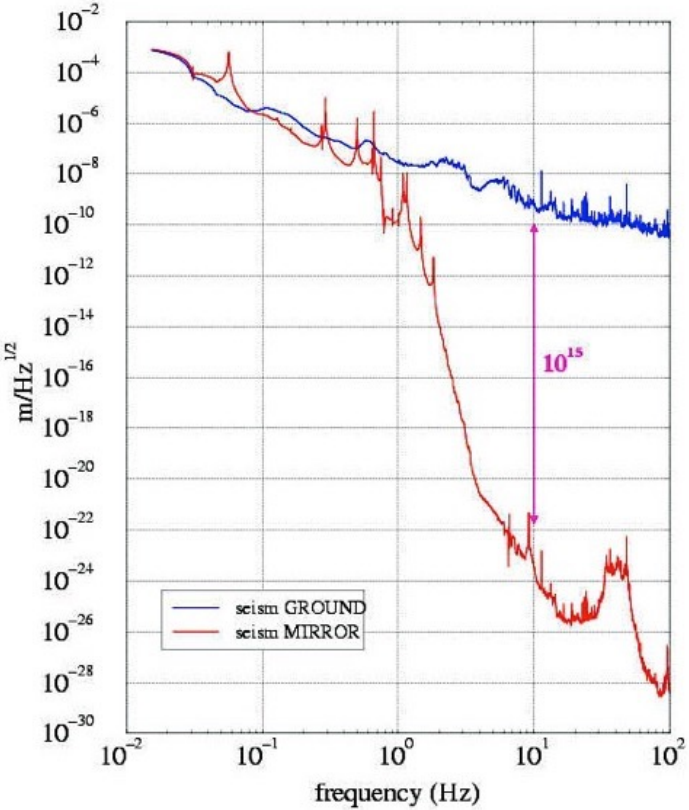
To detect the little displacement caused by a GW

$$\tilde{x} \approx 10^{-18}\ m/Hz^{1/2}$$

a seismic suppression of ~ 10 orders of magnitude is needed!!!


8.66 m



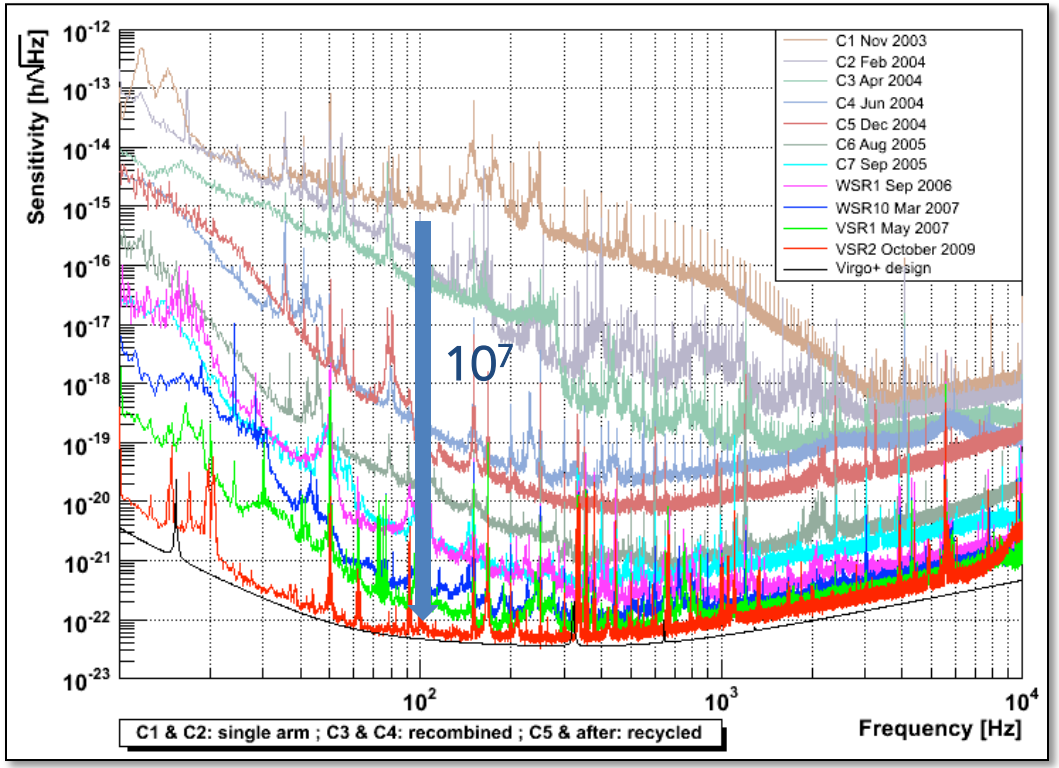

10^{15}
seism GROUND
seism MIRROR
m/Hz$^{1/2}$
frequency (Hz)

- 1994: Virgo approved
- In 1994 the struggle for the land starts
  - Several owners went to court to stop the expropriation
- The construction of the central area could only start in 1996


G Losurdo - INFN Pisa

VIRGO COMMISSIONING

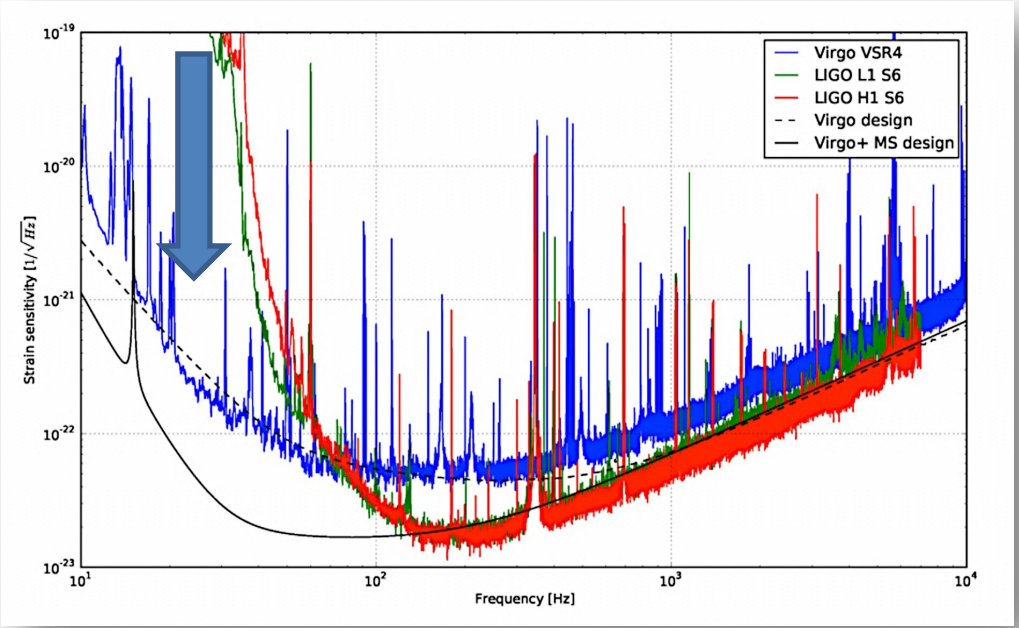
6 YRS FROM FULL LOCK (2005)
TO DESIGN SENSITIVITY



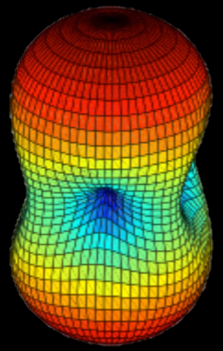
1st GENERATION SENSITIVITIES

- LIGO and Virgo both reach design sensitivity but…no detections

Virgo opens the way to low frequency



2007: LSC-Virgo MoU



2007: LSC-VIRGO MoU for a "SINGLE MACHINE"
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.

DRAFT

IMPROVING EVENT SIGNIFICANCE AND LOCALIZATION, SKY AND TIME COVERAGE

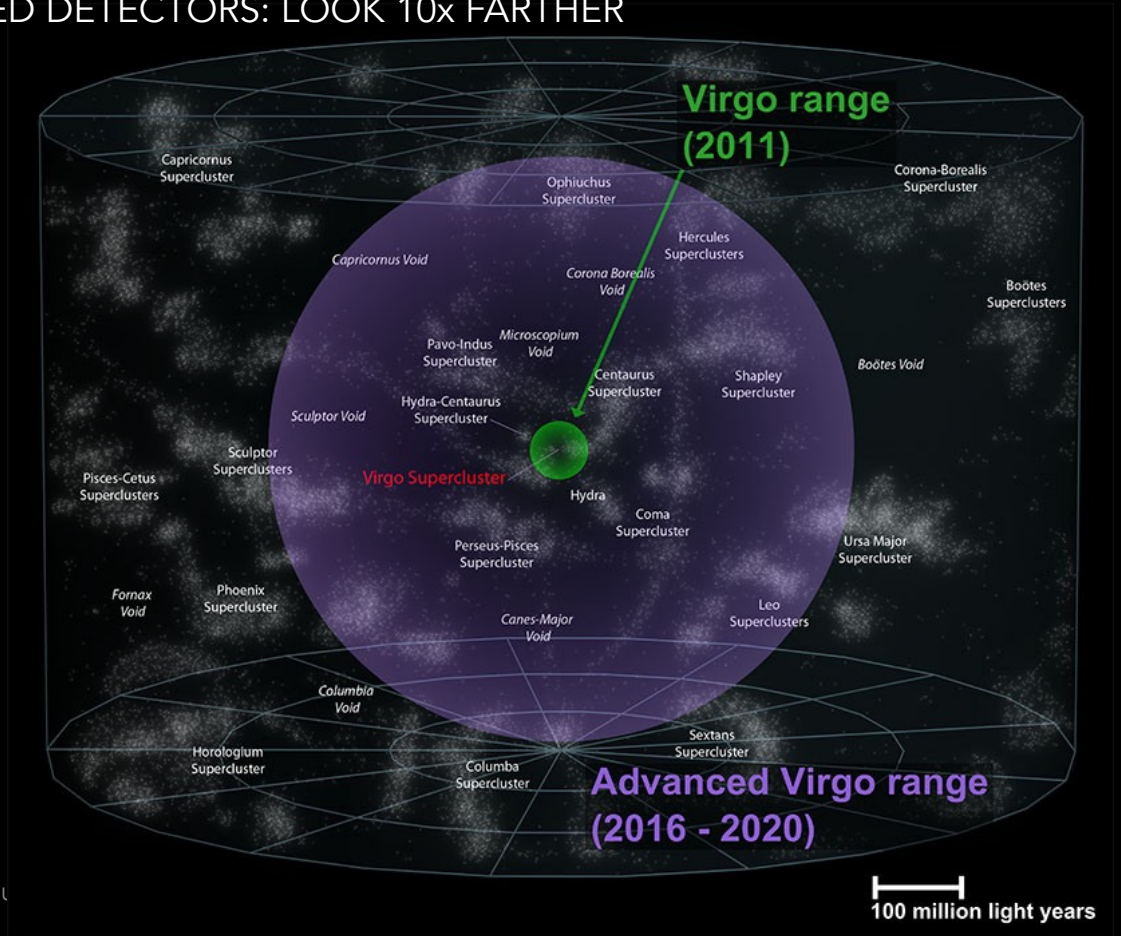
THE CASE FOR BETTER DETECTORS

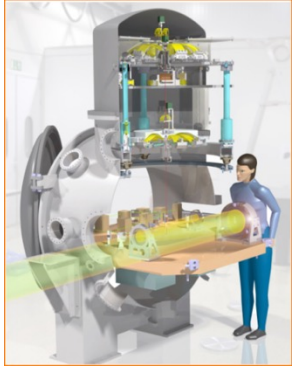
$$\#\ \text{EVENTS} \propto d^3\, T$$

Observing for a long time is good,
improving the sensitivity further is better.

LIGO/VIRGO HAVE OBSERVED UP TO ~50 Mly. NOT ENOUGH FOR GW DETECTION

ADVANCED DETECTORS: LOOK 10x FARTHER





STRAY LIGHT RISK MITIGATION:
- BAFFLES
- ISOLATED PHOTODIODES

HEAVIER TEST MASSES

LARGER BEAM

THERMAL COMPENSATION OF ABERRATIONS

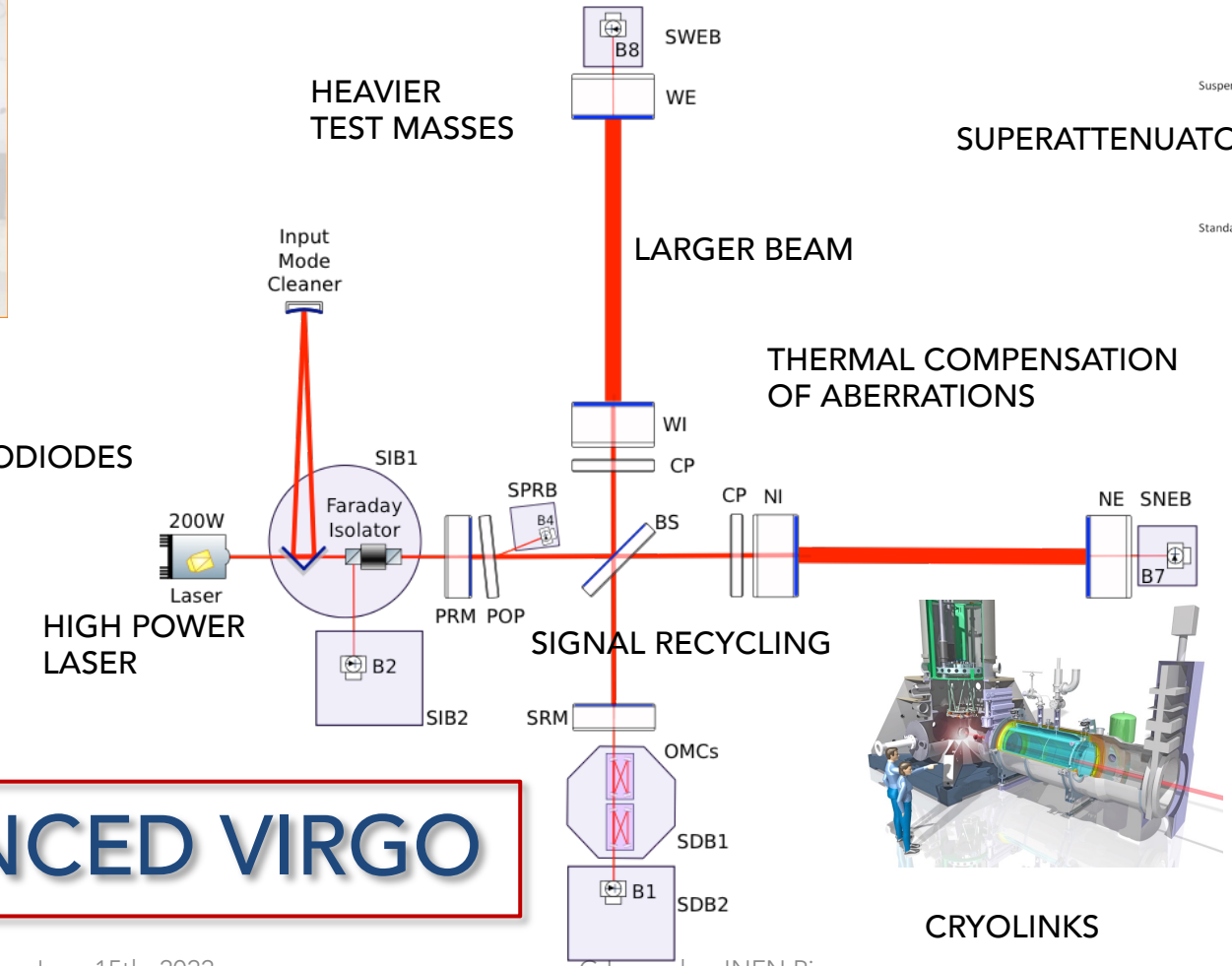
HIGH POWER LASER

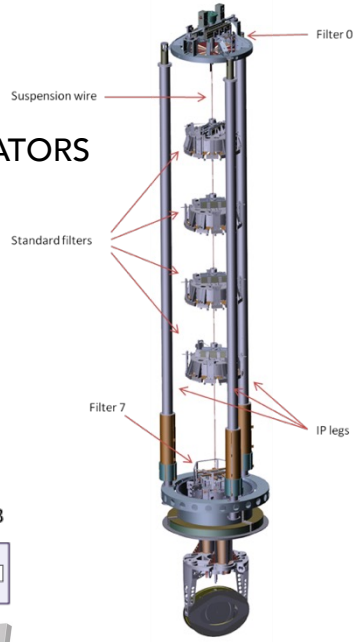
SIGNAL RECYCLING

SUPERATTENUATORS

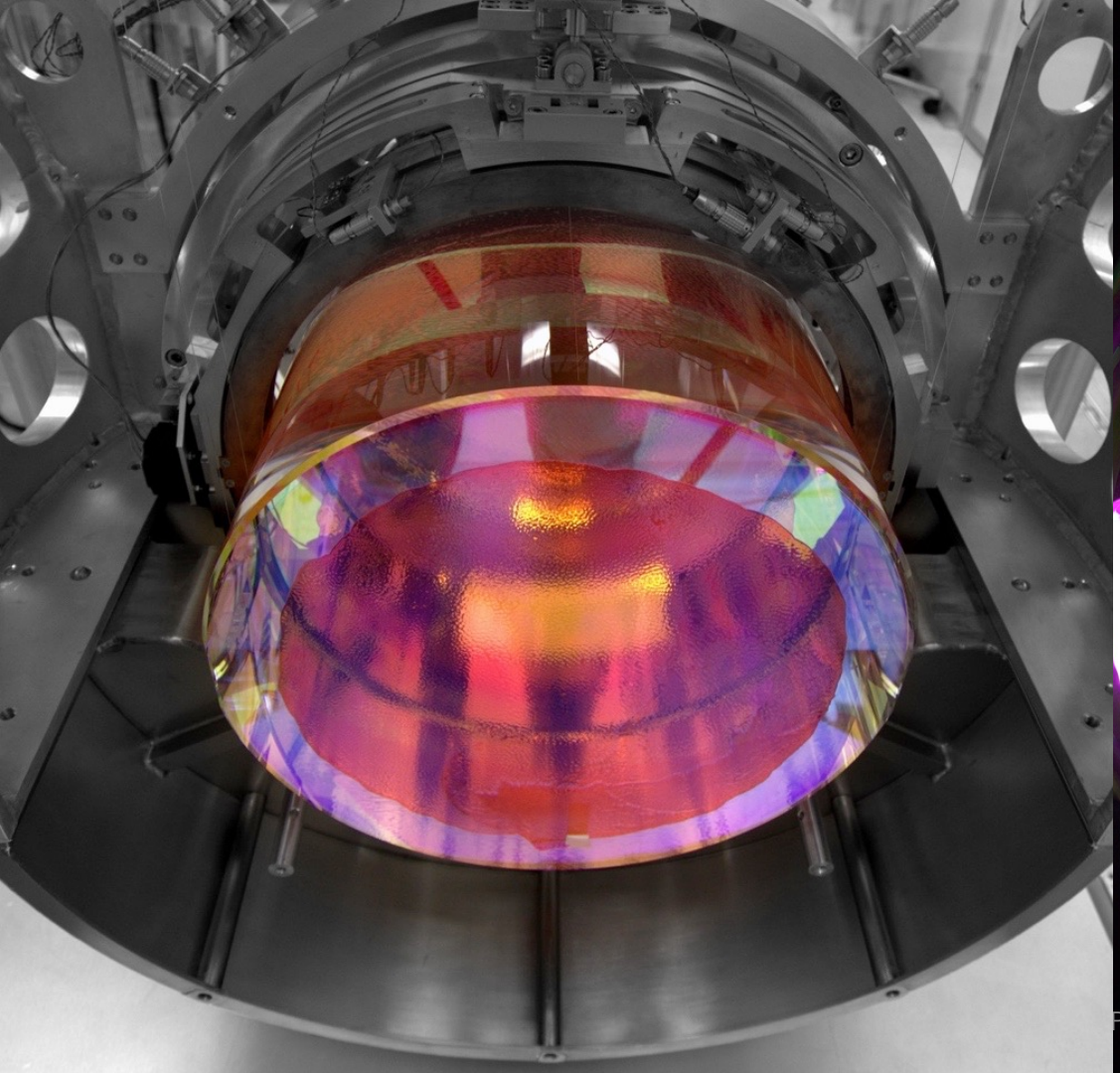
NEW PAYLOADS, MONOLITHIC SUSPENSIONS

CRYOLINKS





ADVANCED VIRGO



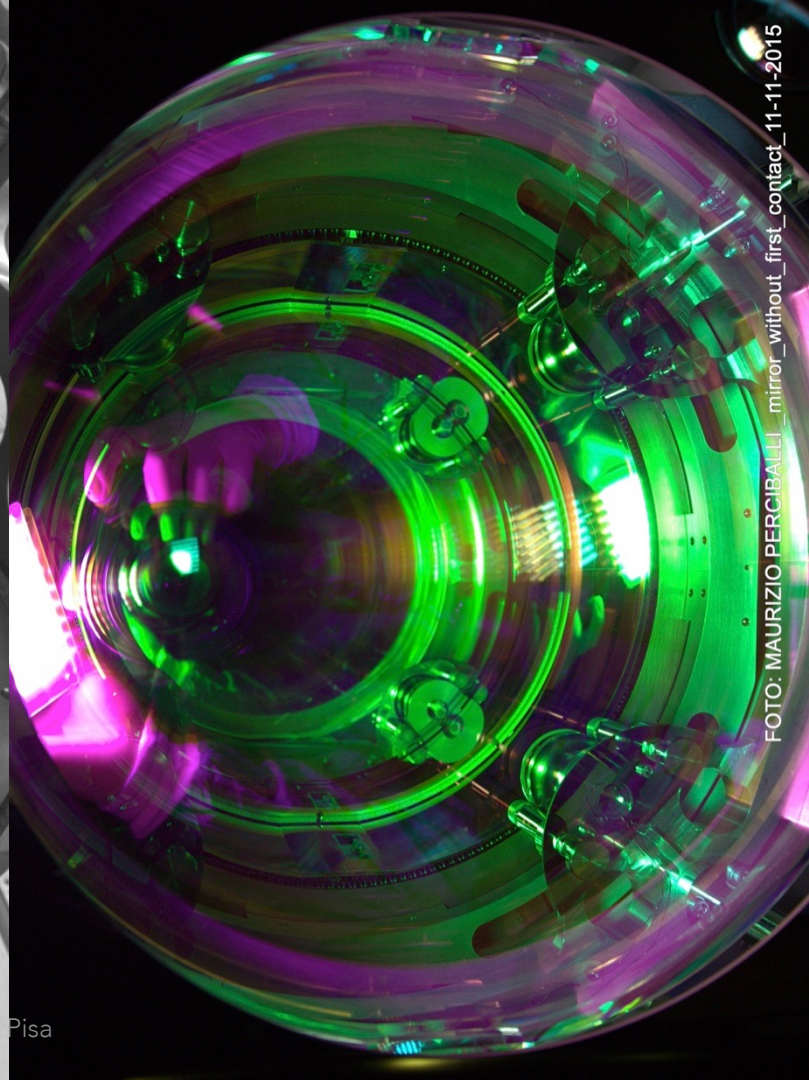
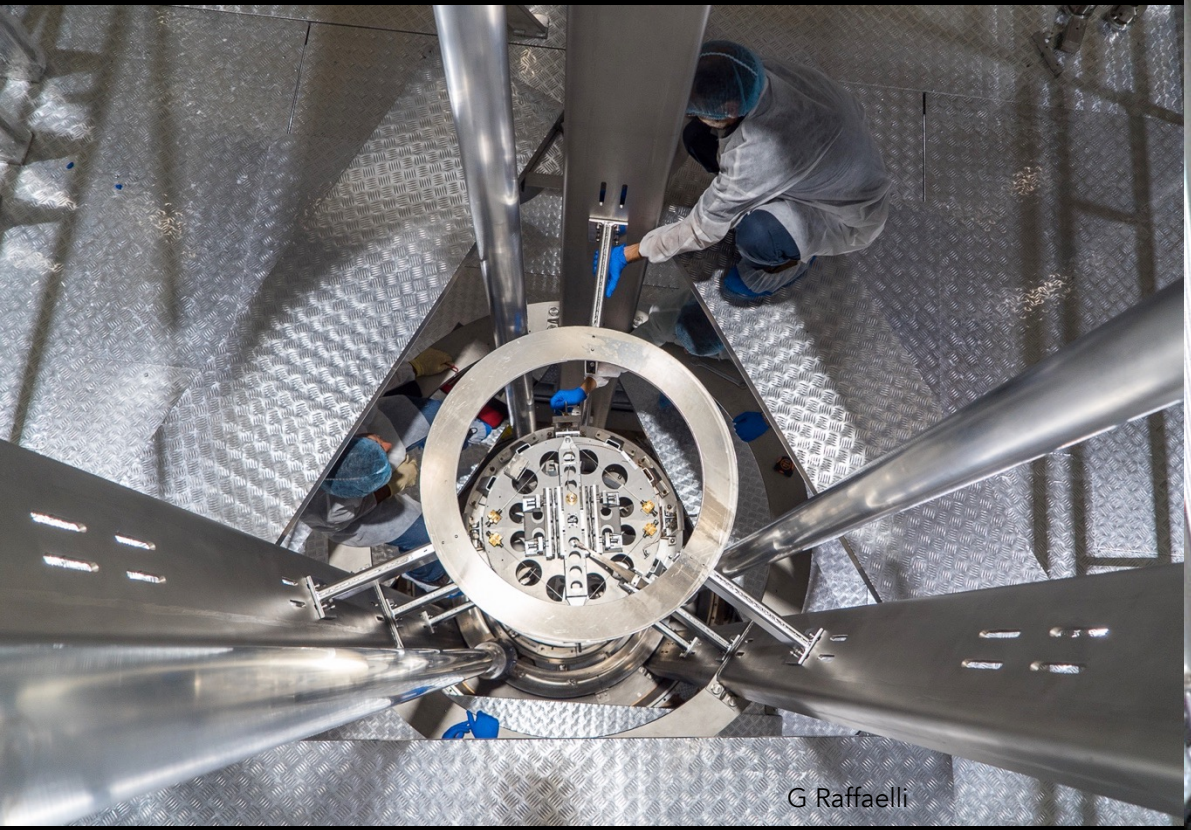
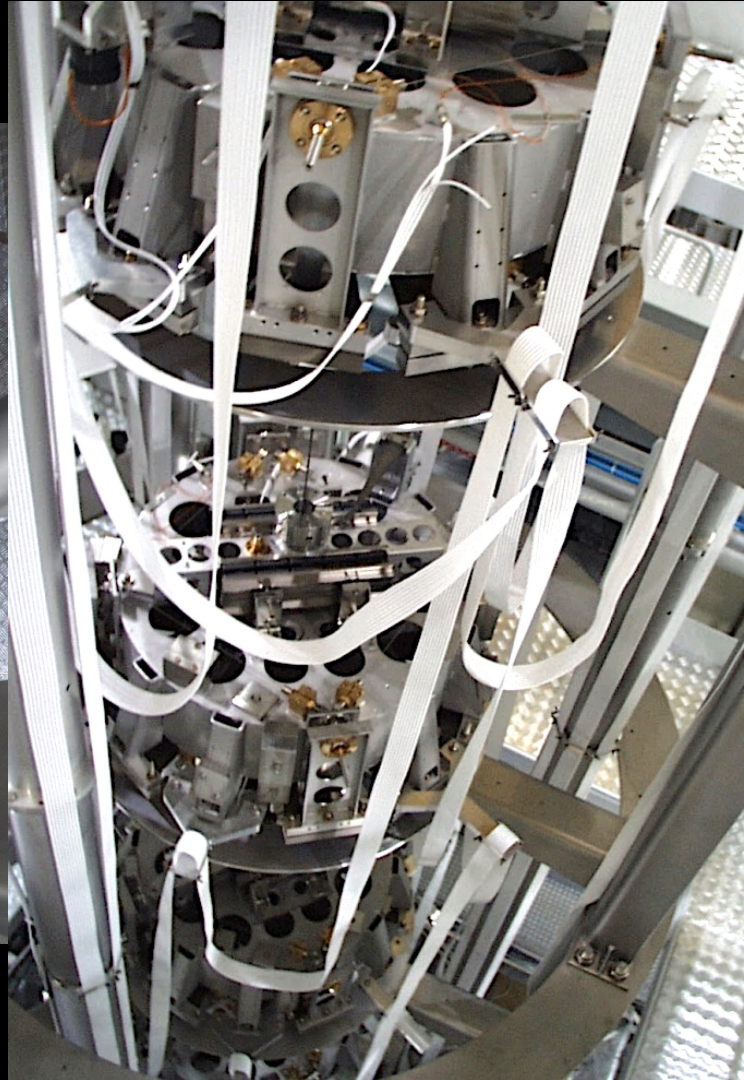


FOTO: MAURIZIO PERCIBALLI _mirror_without_first_contact_11-11-2015

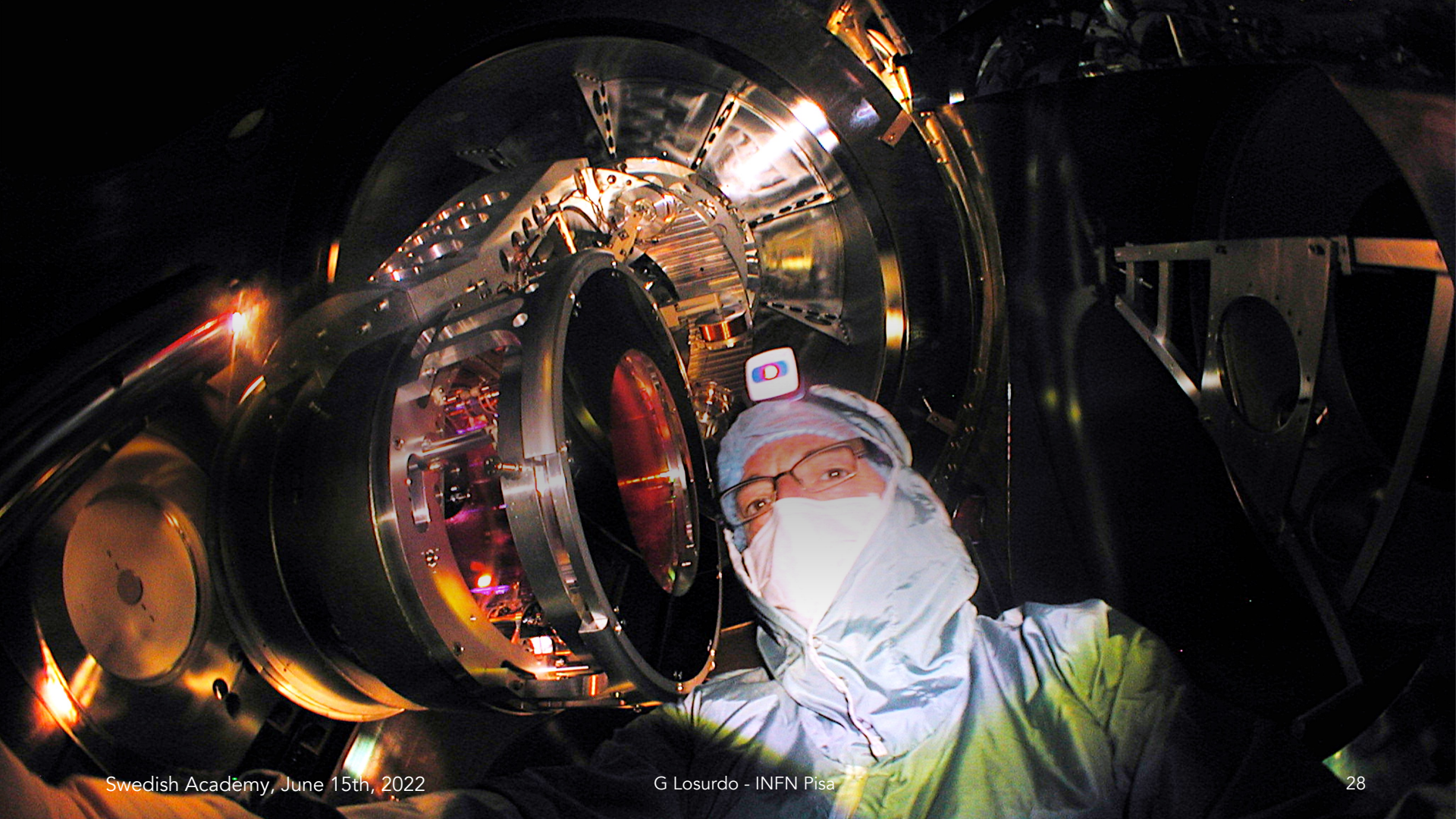
Pisa

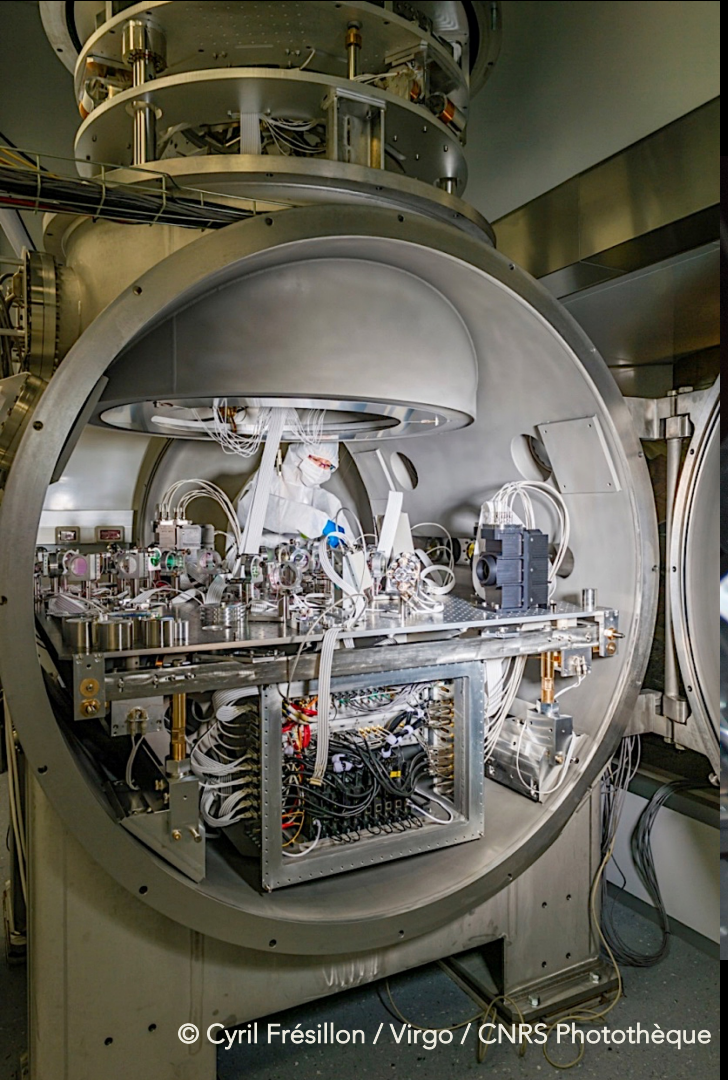


G Raffaelli

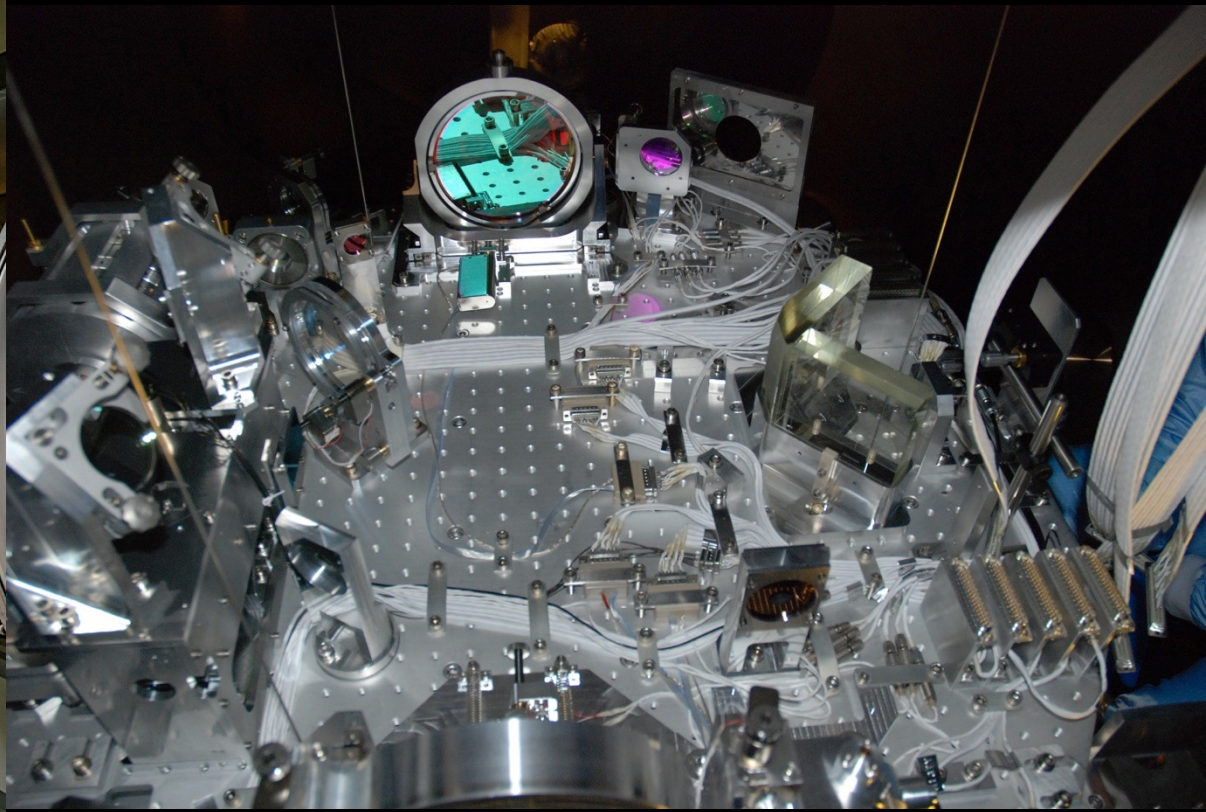


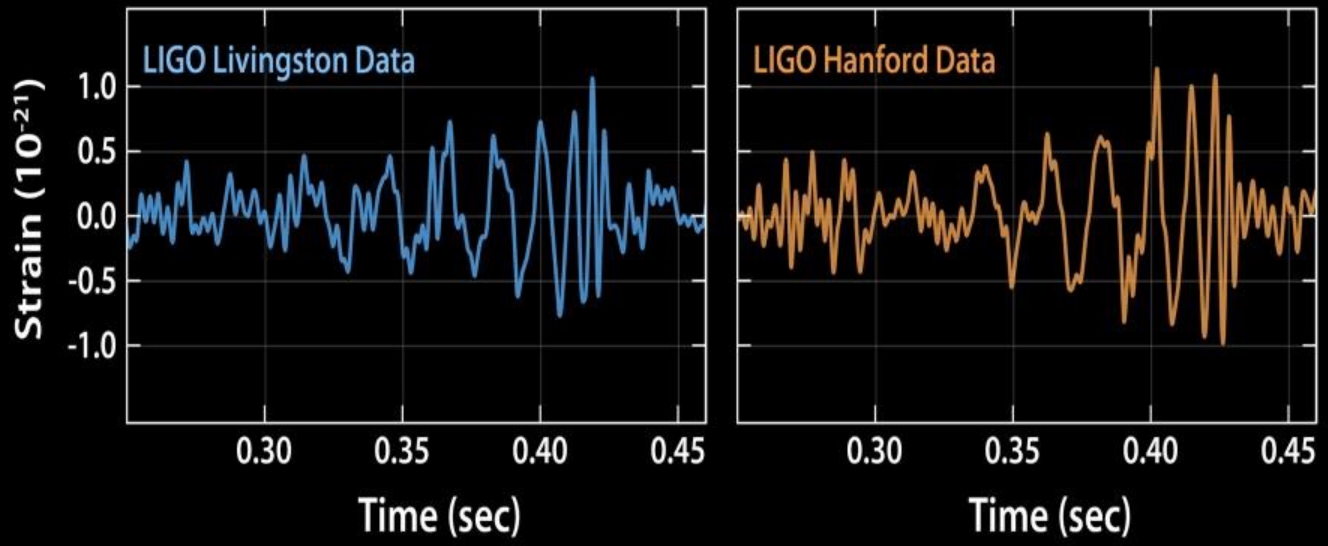
Swedish Academy, June 15th, 2022



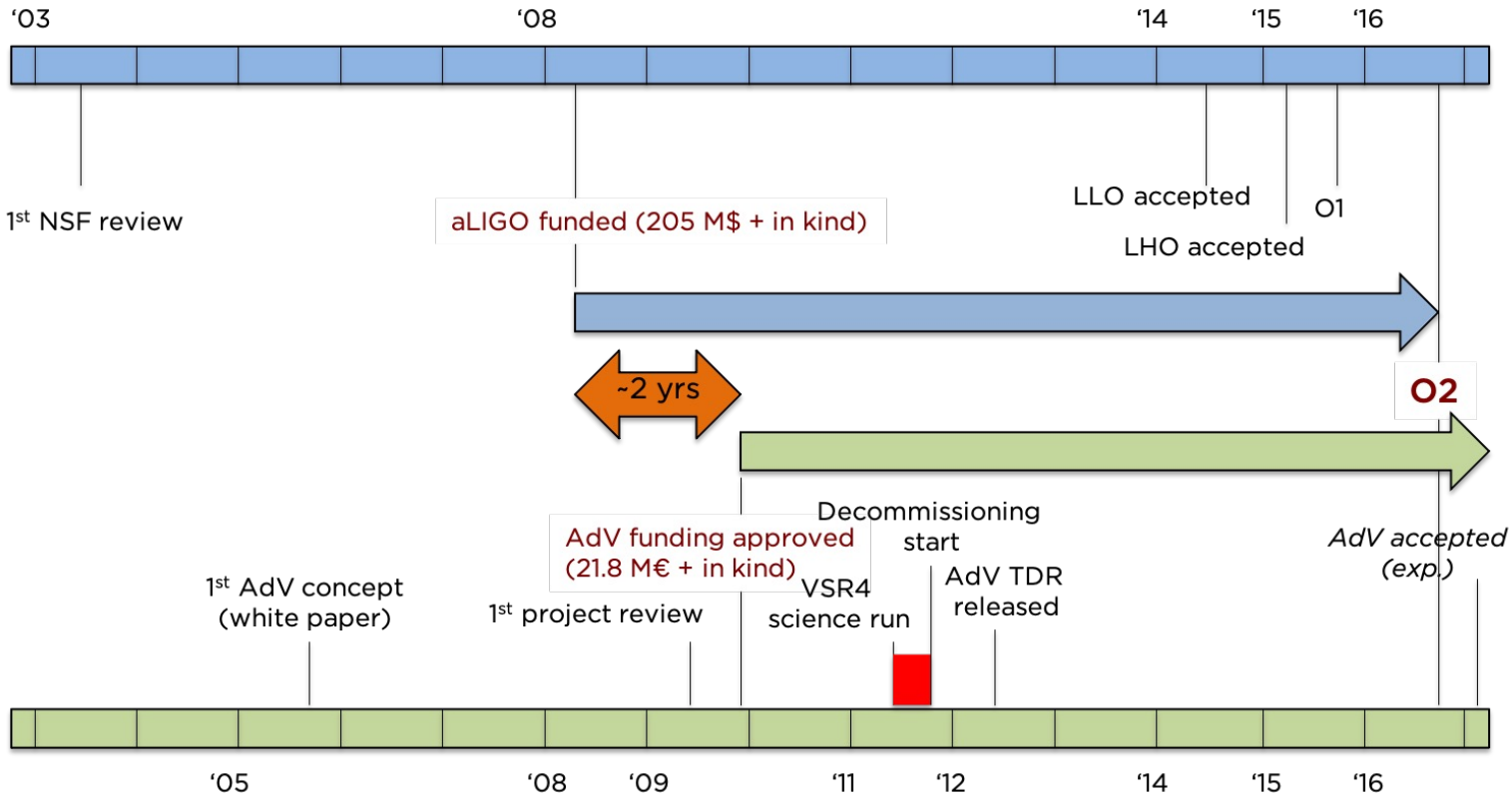


© Cyril Frésillon / Virgo / CNRS Photothèque




LIGO Livingston Data
LIGO Hanford Data
Strain (10-21)
1.0
0.5
0.0
-0.5
-1.0
0.30
0.35
0.40
0.45
Time (sec)
0.30
0.35
0.40
0.45
Time (sec)

Advanced LIGO/Virgo timelines



	AdV	aLIGO*
Date of approval	Dec 2009	Apr 2008
End of integration	Aug 2016	Oct 2014 (LHO)
First stable lock	Mar 2017	Feb 2015 (LHO)
Run start/1st GW	Aug 2017	Sep 2015

~6.5 yrs

~7.5 yrs

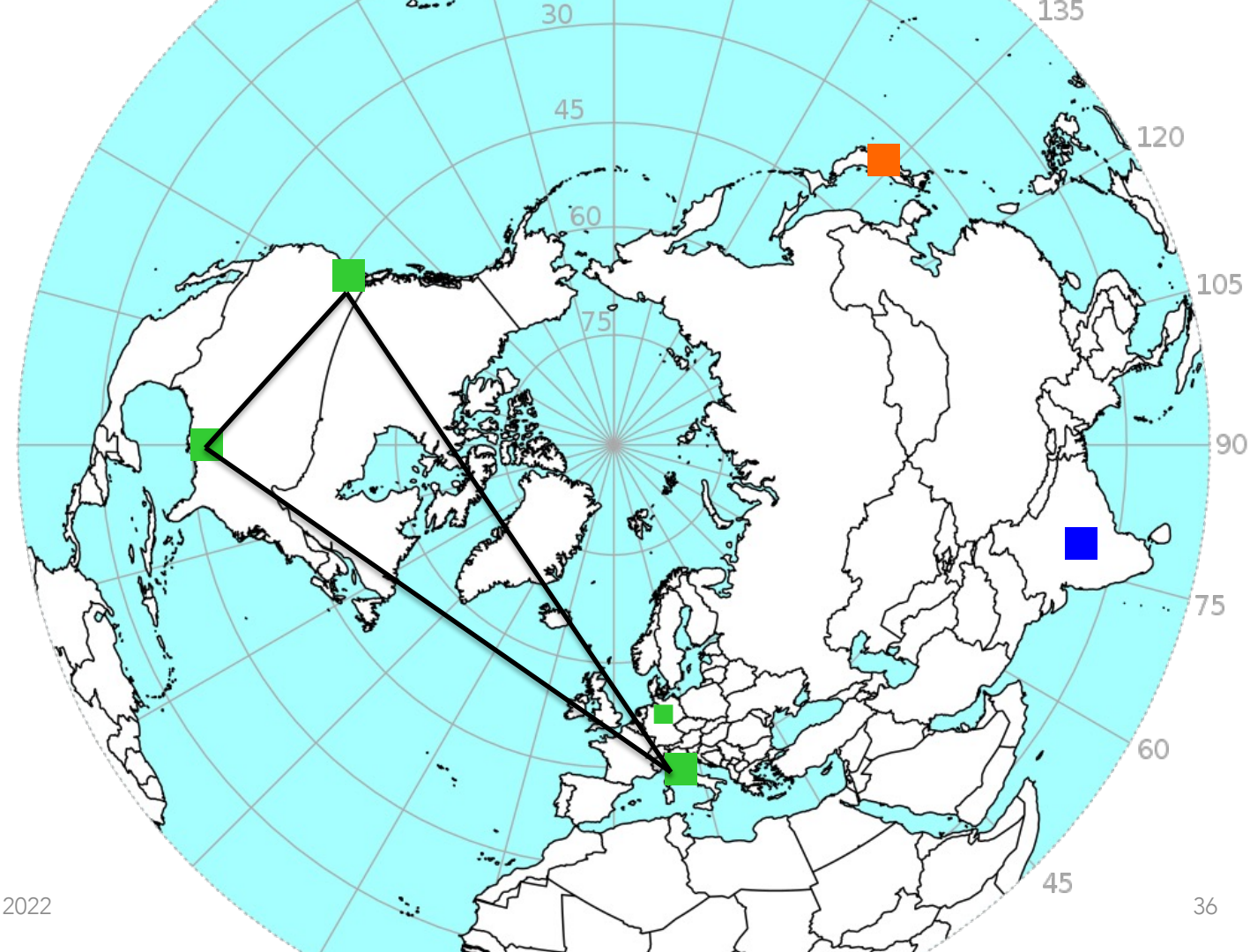
*LIGO data from **LIGO-L1400164-v3**

August 1st, 2017

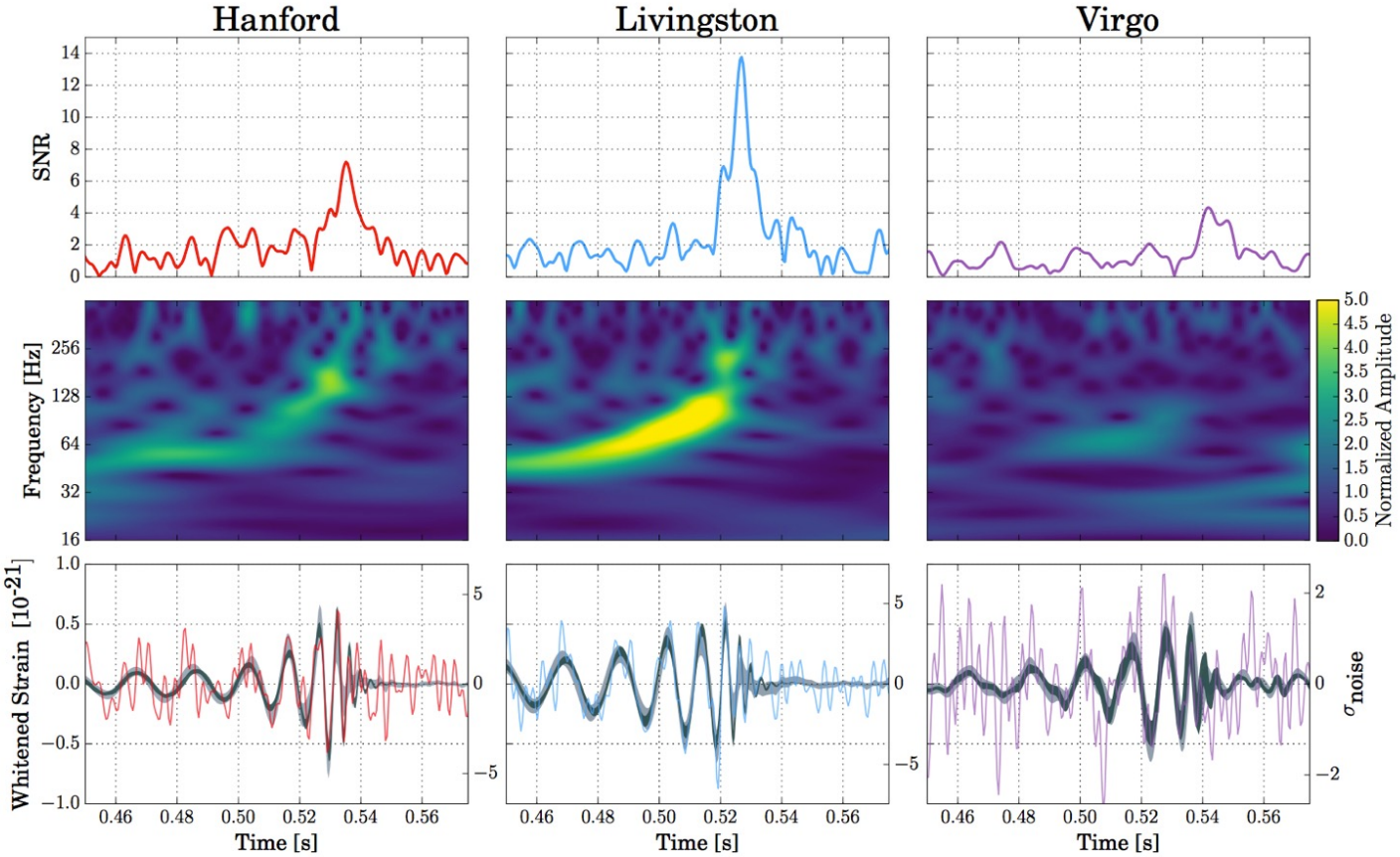
VIRGO JOINS LIGO IN THE OBSERVATION RUN O2

THREE 2G DETECTORS ACTING AS A “SINGLE MACHINE”

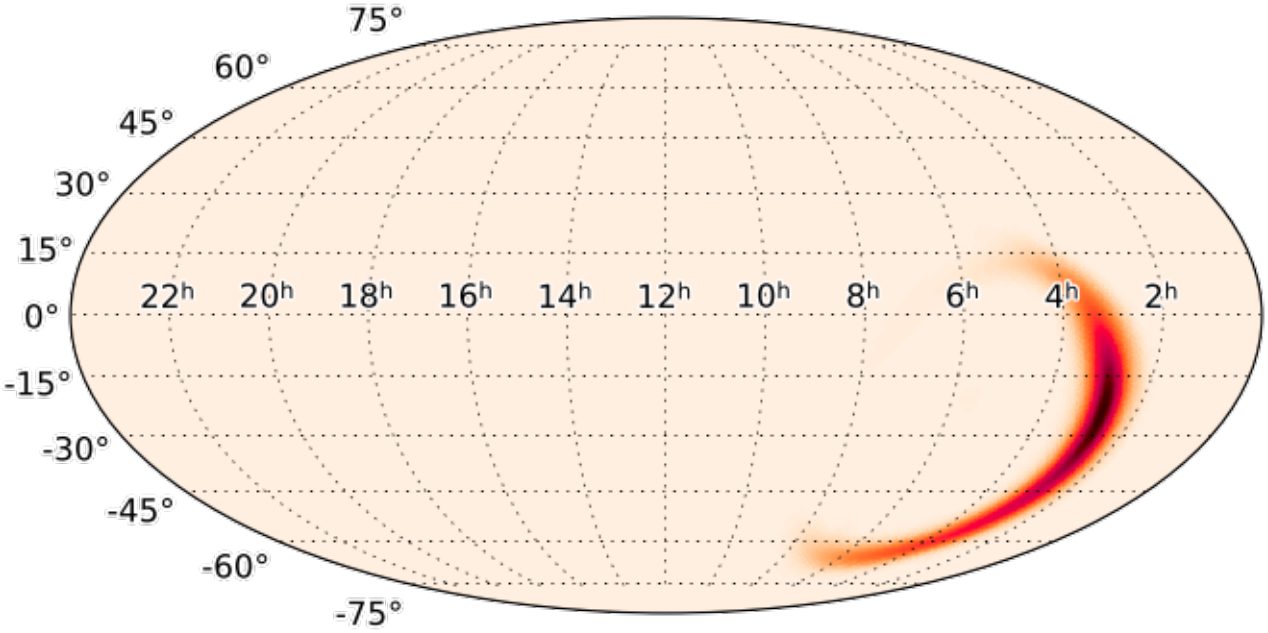
- OPERATION
- COMMISSIONING
- CONSTRUCTION
- APPROVED



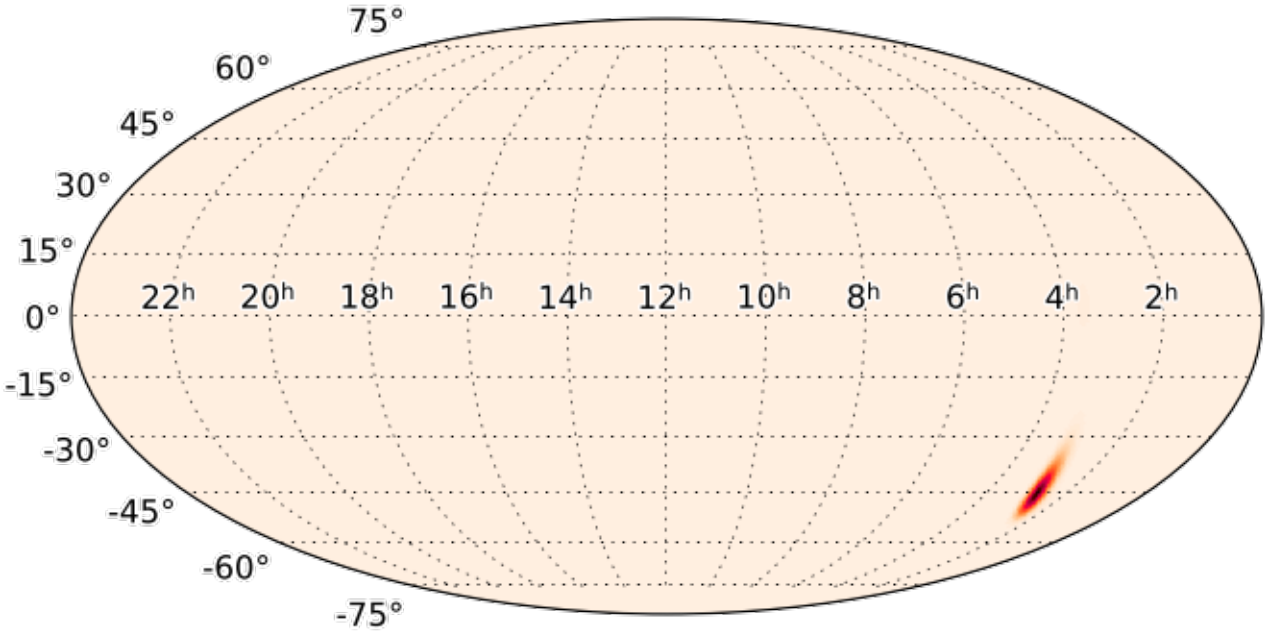
GW170814


Hanford
Livingston
Virgo
SNR
Frequency [Hz]
Normalized Amplitude
Whitened Strain [10^-21]
σnoise
Time [s]

LOCALIZATION: **WITHOUT** VIRGO



LOCALIZATION: WITH VIRGO



“DETECTING GRAVITATIONAL WAVES

NO IDEA COULD BE CRAZIER”

ADALBERTO GIAZOTTO