Laboratori Nazionali del Sud
Università degli Studi di Sassari

INFN UNISS Role

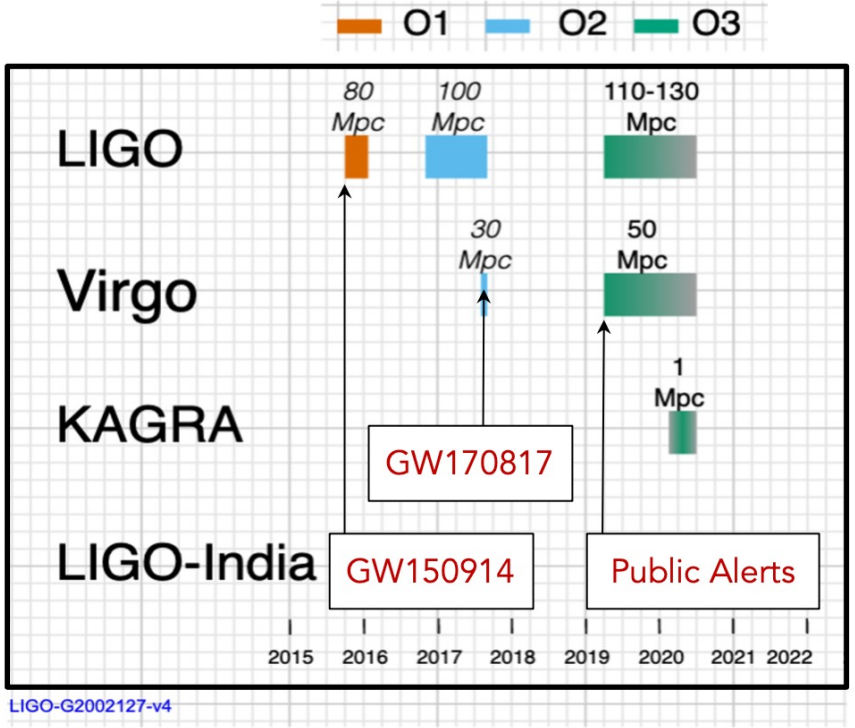
- VIRGO: Data analysis. Search for Burst Multi-messenger event candidates and application of Machine Learning to data analysis

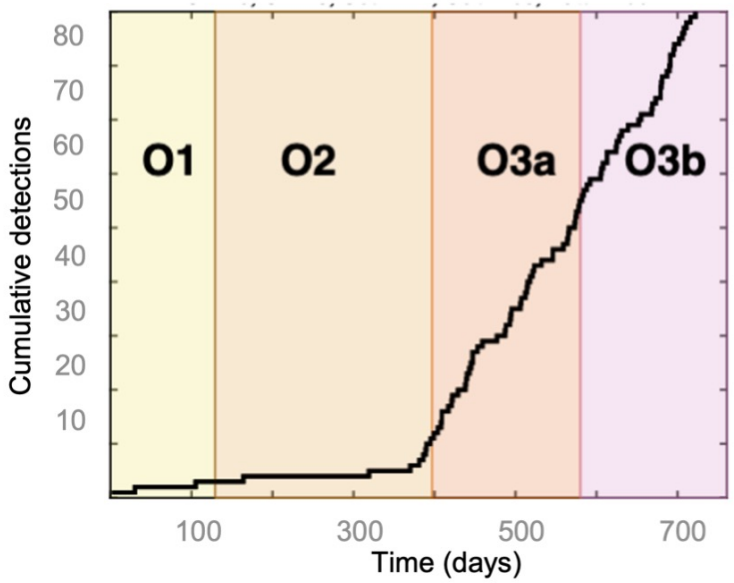
- ET: Sos Enattos Characterization and Candidature. R&D Super Attenuator

Virgo Collaboration

- ~770 members, ~450 authors, 131 institutions from 15 countries
- 34 Groups:
  - 32 full members
  - 2 in the first year (L2I Toulouse, KU Leuven)
- 9 countries represented in the VSC

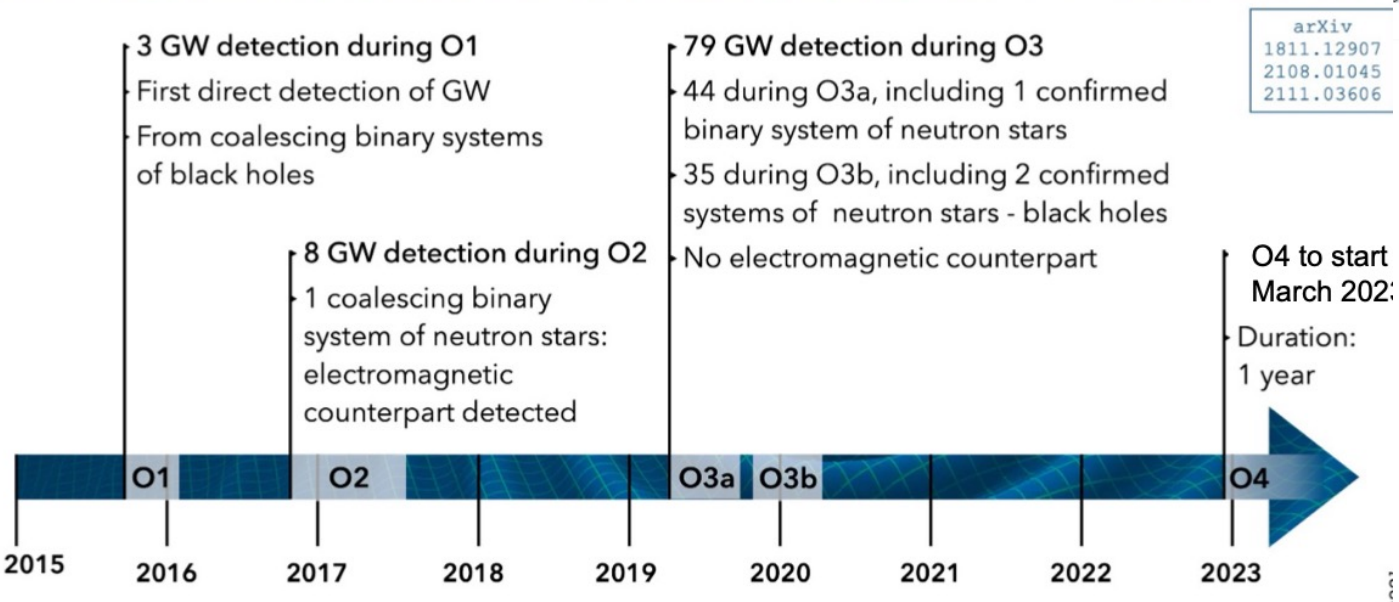
Past Obs. RUN





O3 binary detection rate ~ 1/(5 days)

GWTC: Gravitational Waves Transient Catalog - 3



90 GW detections reported

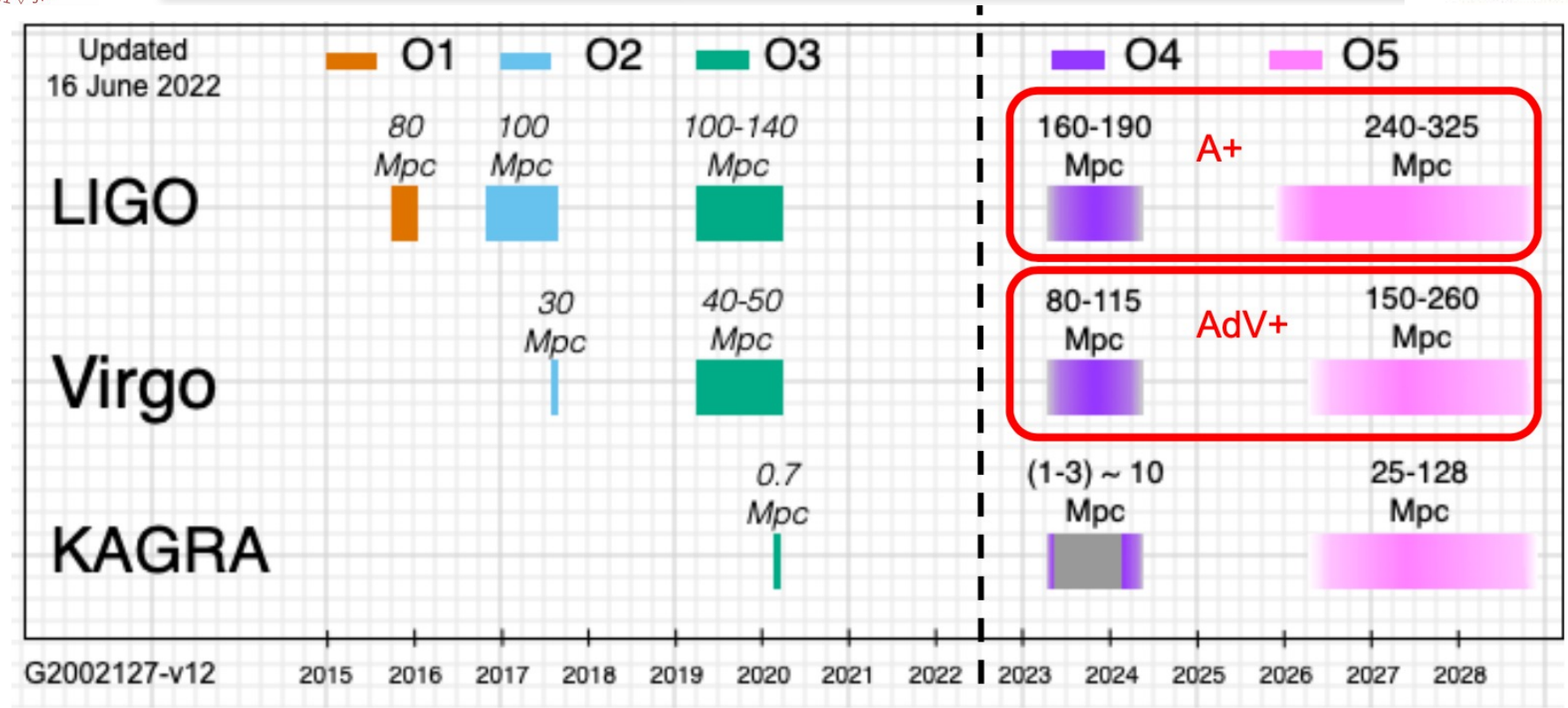
Coalescence of black holes and neutron stars

1 multimessenger event (GW + EM observation)

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

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

Future Obs. RUN



Advanced Virgo+

- Two phases project
  - Phase I (before O4 run/2023)
    - ✓ Mainly an upgrade to reduce quantum noise: no mirrors change
    - ✓ Reduction of technical noises
    - ✓ Preparation of Phase II
  - Phase II (before O5 run/2025)
    - ✓ More invasive upgrade to reduce thermal noise: mirrors change
- What Post –O5 ????

Towards O4

- Installation of main interferometer completed in December 2020
  => Commissioning of main interferometer started in January 2021
- Installation of quantum noise reduction system completed in April 2021
  => Commissioning of quantum noise reduction system started in May 2021

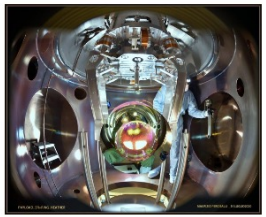
- Great effort to complete the installation during the pandemic
- Now working at the commissioning of the detector

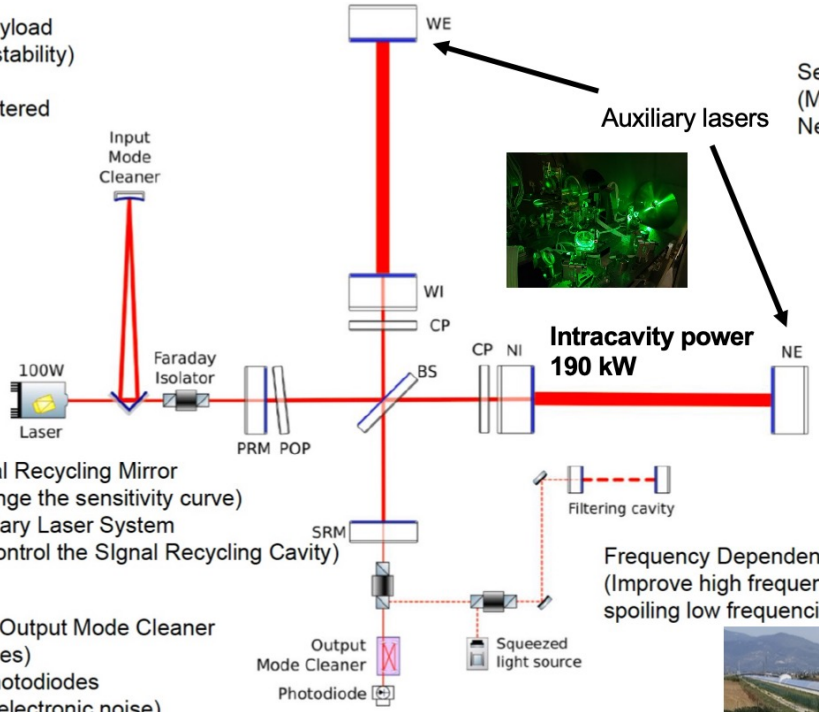
Towards O4

Reducing quantum noise – hit against thermal noise

New Input Mode Cleaner Payload
(Improve controllability and stability)
Instrumented Baffle
(Direct measurement of scattered light)

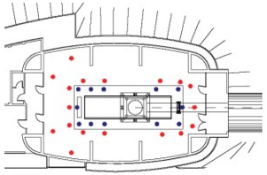
High-power Laser
(Increase the circulating power)



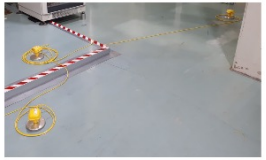


Auxiliary lasers

Seismometer Array
(Measurement and cancellation of Newtonian Noise)



WEB



Intracavity power
190 kW

Signal Recycling Mirror
(Change the sensitivity curve)
Auxiliary Laser System
(To control the SIgnal Recycling Cavity)

Frequency Dependent Squeezing
(Improve high frequencies without spoiling low frequencies)

Goal: 4.5 dB

High-finesse Output Mode Cleaner
(Reduce losses)
Low-noise photodiodes
(Reduce the electronic noise)

VIRGO: UniSS/LNS Contribution

- Burst Multi-messenger events: Search for transient GWs signals associated with GRB and FRB during LIGO-Virgo third observational run => paper "Search for Gravitational Waves Associated with Fast Radio Bursts Detected by CHIME/FRB During the LIGO–Virgo Observing Run O3a" e-Print: 2203.12038

- Use of machine learning techniques to search for GW events => contribution to a review paper under preparation

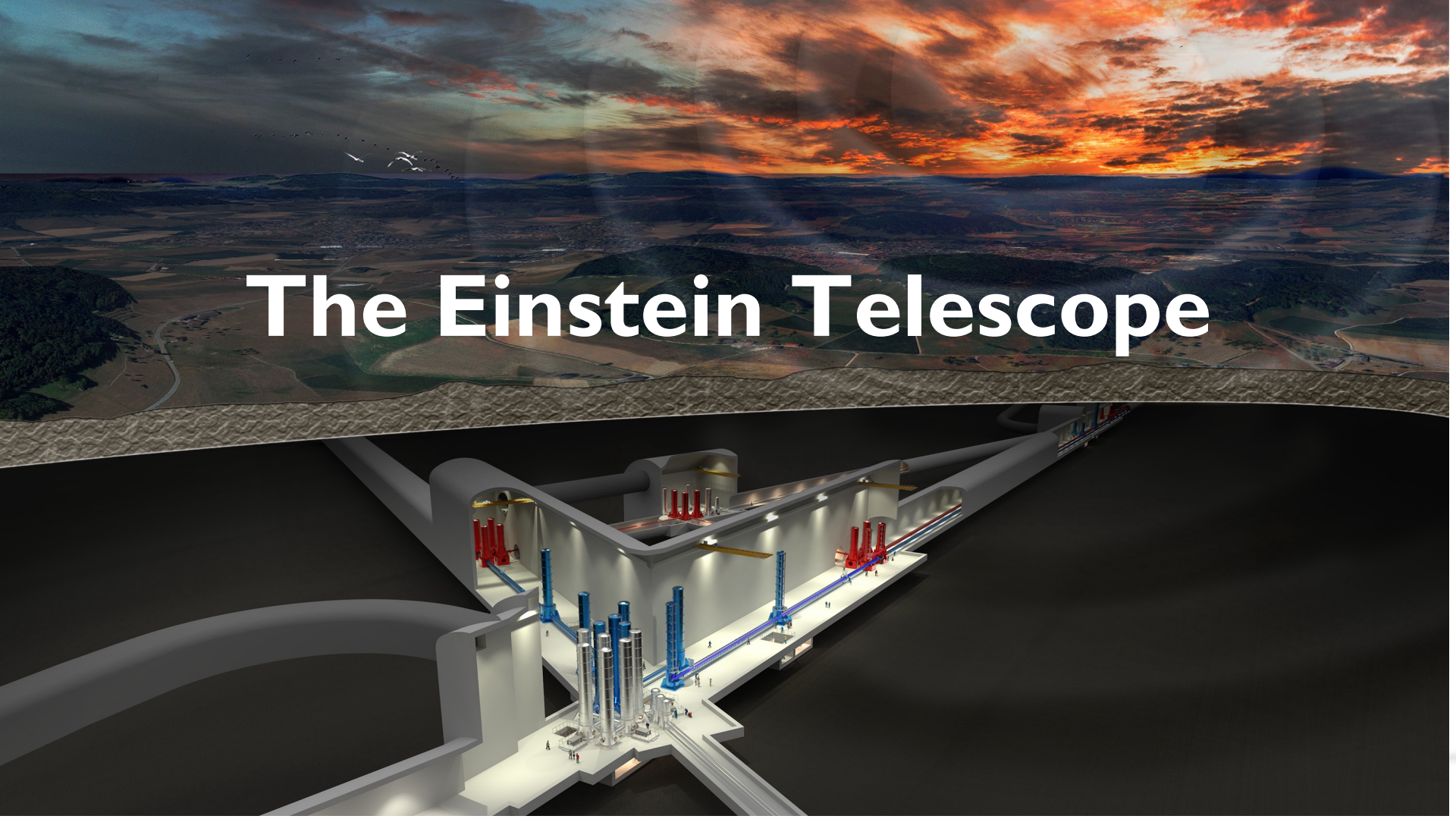
VIRGO: Machine Learning Analysis

- Implementation of pre-filter trigger to distinguish event candidates by means of machine learning techniques
  - Hierarchical approach
  - Test on Monte Carlo data

VIRGO: Anagrafica/Richieste 2021

Personel	Virgo FTE
Massimo Carpinelli	0.50
Domenico D'Urso	**0.50**
Daniele Dell'Aquila	0.40
Davide Rozza	0.50
Valeria Sipala	0.40
Iara Tosta e Melo	0.50
Tot	**2.8**

				(kEuro)
Missioni	N. 6 Meeting Nazionali 1 fisico x 3 gg (meeting di gruppo)			5
	N. 3 Meeting Internazionali 1 fisico x 3 gg (meeting di gruppo e/o 1 conferenza)			7
Tot				**12.0**


The Einstein Telescope

ET Science Case in a nutshell

ASTROPHYSICS

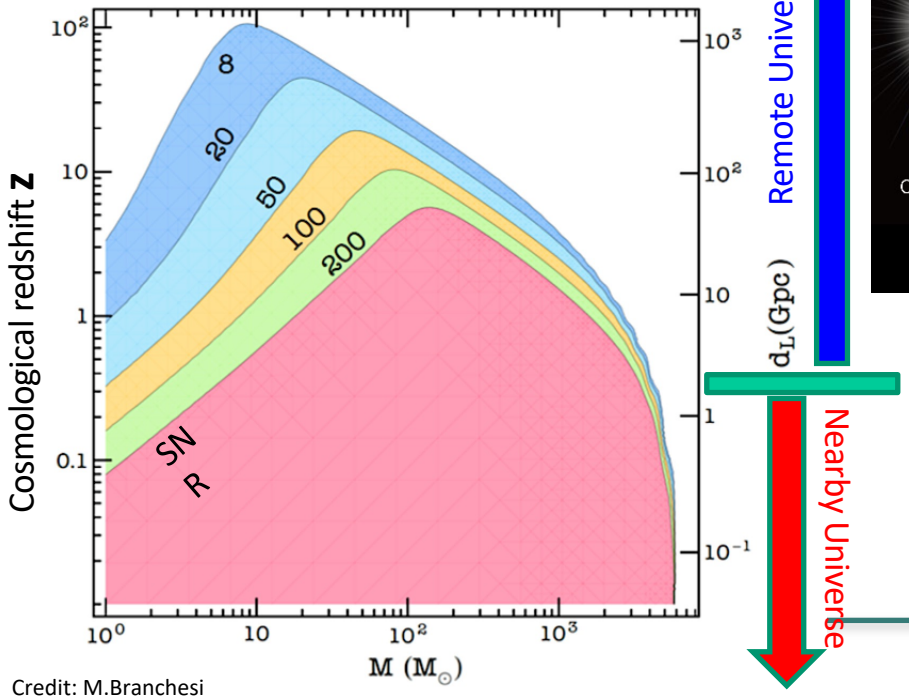
- **Black hole properties**
  - origin (stellar vs. primordial)
  - evolution, demography
- **Neutron star properties**
  - interior structure (QCD at ultra-high densities, exotic states of matter)
  - demography
- **Multi-band and -messenger astronomy**
  - joint GW/EM observations (GRB, kilonova,...)
  - multiband GW detection (LISA)
  - neutrinos
- **Detection of new astrophysical sources**
  - core collapse supernovae
  - isolated neutron stars
  - stochastic background of astrophysical origin

FUNDAMENTAL PHYSICS AND COSMOLOGY

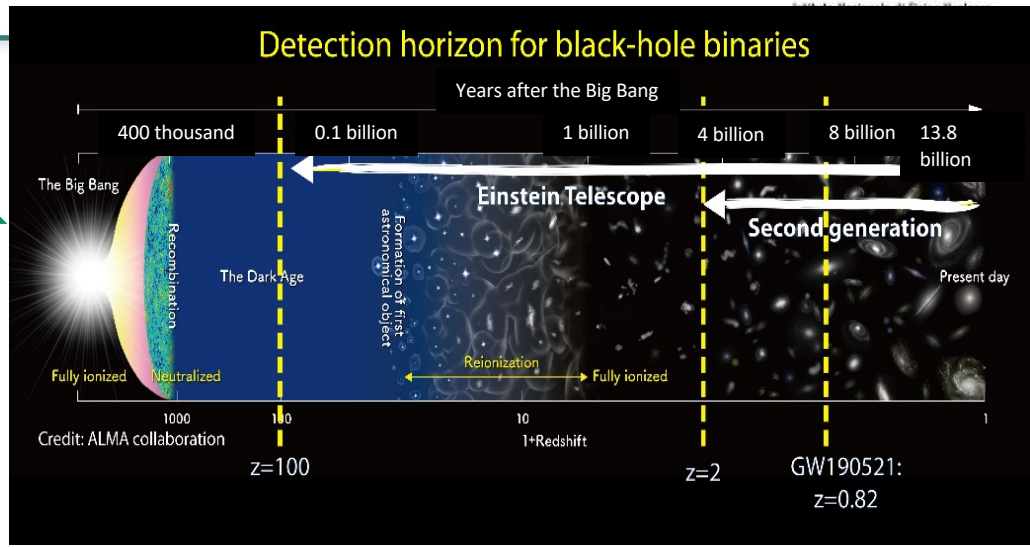
- **The nature of compact objects**
  - near-horizon physics
  - tests of no-hair theorem
  - exotic compact objects
- **Tests of General Relativity**
  - post-Newtonian expansion
  - strong field regime
- **Dark matter**
  - primordial BHs
  - axion clouds, dark matter accreting on compact objects
- **Dark energy and modifications of gravity on cosmological scales**
  - dark energy equation of state
  - modified GW propagation
- **Stochastic backgrounds of cosmological origin**
  - inflation, phase transitions, cosmic strings

ET Science in a nutshell: double nature

- ET will be a new discovery machine:
  - ET will explore almost the entire Universe listening the gravitational waves emitted by black hole, back to the dark ages after the Big Bang



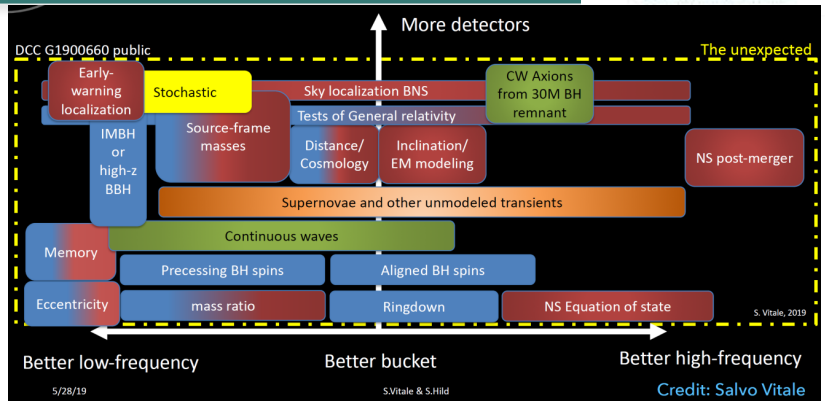
Credit: M.Branchesi

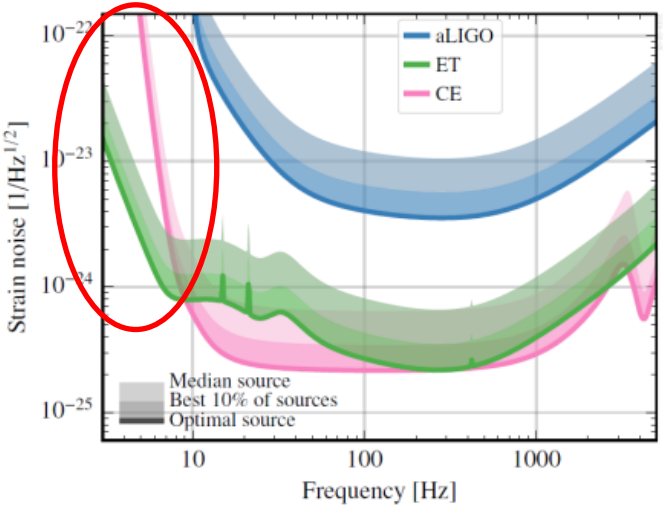


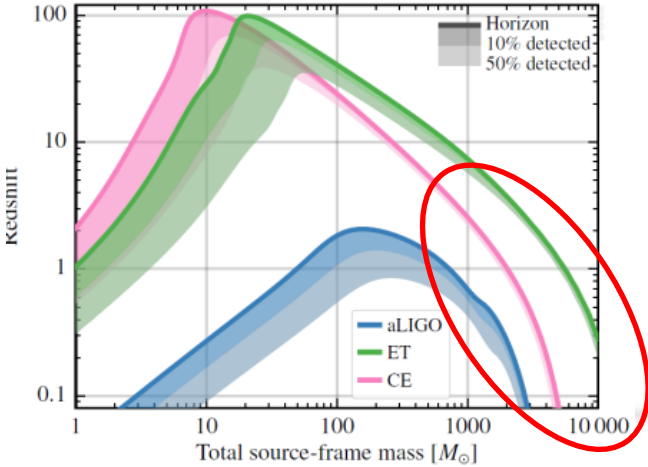
- ET will be a precision measurement observatory:
  - ET will detect, with high SNR, hundreds of thousands coalescences of binary systems of Neutron Stars per year, revealing the most intimate structure of the nuclear matter in their nuclei

ET Science in a nutshell: double nature

- GW science targets are almost equally distributed in the frequency range accessible by terrestrial GW detectors (but technical difficulties aren't)
- We want to have access both to low and high frequency targets
  - ET will be a wide band observatory with a special focus on (intermediate) massive compact object:
    - **Low frequency!**







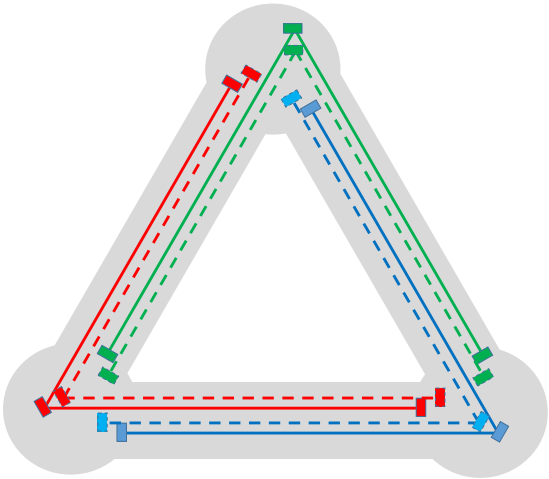
ET Design: key elements

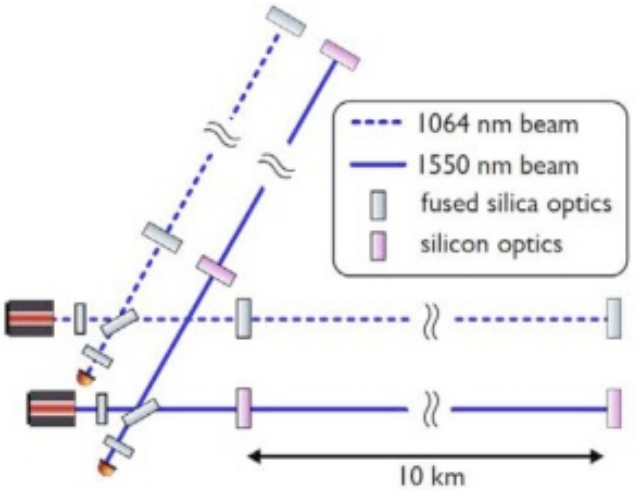
Requirements

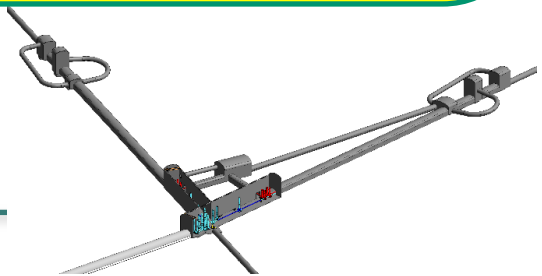
- Wide frequency range
- Massive black holes (LF focus)
- Localisation capability
- (more) Uniform sky coverage
- Polarisation disentanglement
- High Reliability (high duty cycle)
- High SNR

Design Specifications

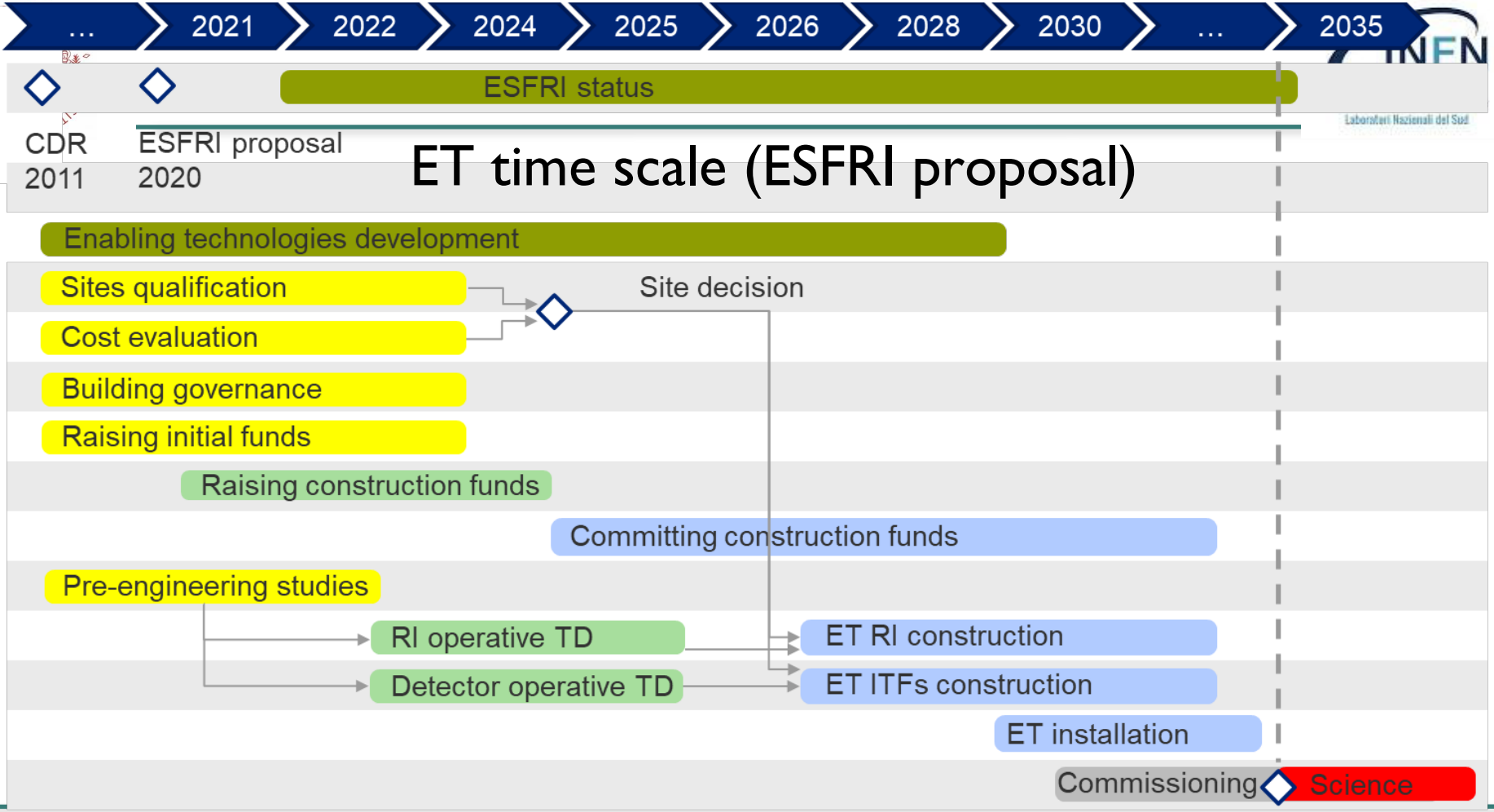
- Xylophone (multi-interferometer) Design
- Underground
- Cryogenic
- Triangular shape
- Multi-detector design
- Longer arms







ET EINSTEIN TELESCOPE


…
2021
2022
2024
2025
2026
2028
2030
…
2035
ESFRI status
CDR 2011
ESFRI proposal 2020
ET time scale (ESFRI proposal)
Enabling technologies development
Sites qualification
Cost evaluation
Site decision
Building governance
Raising initial funds
Raising construction funds
Committing construction funds
Pre-engineering studies
RI operative TD
Detector operative TD
ET RI construction
ET ITFs construction
ET installation
Commissioning
Science

Birth of ET Collaboration

09 GIUGNO 2022

NASCE LA COLLABORAZIONE SCIENTIFICA EINSTEIN TELESCOPE

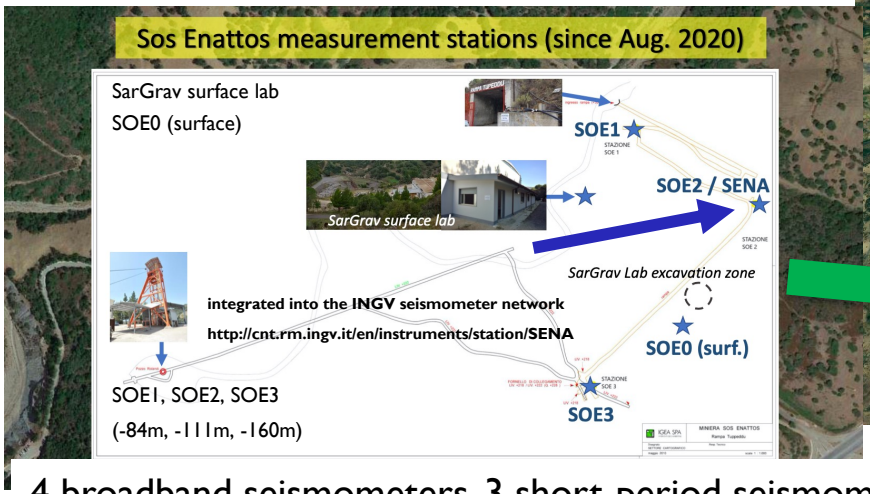
La comunità che lavora al progetto ET Einstein Telescope per la realizzazione del futuro pionieristico osservatorio di onde gravitazionali europeo ha formalmente sancito la nascita della Collaborazione scientifica Einstein Telescope, nel corso del XII Simposio di ET che si è tenuto all'Accademia ungherese delle Scienze di Budapest, il 7 e 8 giugno.

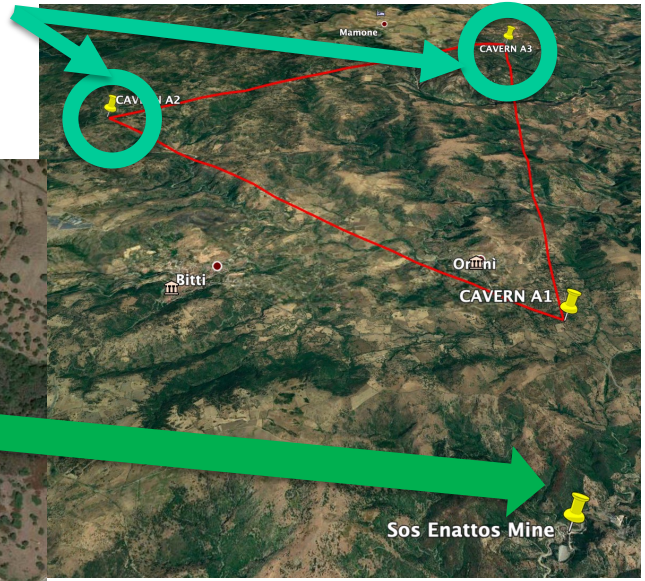
"Il XII Simposio di Einstein Telescope che si è appena concluso rappresenta un passaggio cruciale nel percorso del progetto perché ha segnato la nascita della vera e propria Collaborazione scientifica ET", ha commentato **Michele Punturo**, ricercatore dell'INFN che è stato fino ad ora alla guida della comunità di ET e adesso ricoprirà il ruolo di portavoce della collaborazione. "Eravamo una comunità scientifica, oggi siamo una collaborazione scientifica, ossia un sistema strutturato e organizzato che lavora seguendo regole condivise per il raggiungimento del comune obiettivo: la realizzazione di Einstein Telescope, una grande infrastruttura di ricerca europea che ci porterà al centro della scienza mondiale e ci consentirà di mantenere la leadership scientifica e tecnologica in questo promettente settore di ricerca della fisica fondamentale. Questo è dunque per tutti noi un momento di grande soddisfazione e motivazione", conclude Punturo.

More then 1200 researchers from Europe, USA and Japan

Sardinia one of Candidate Site: Measurement on going

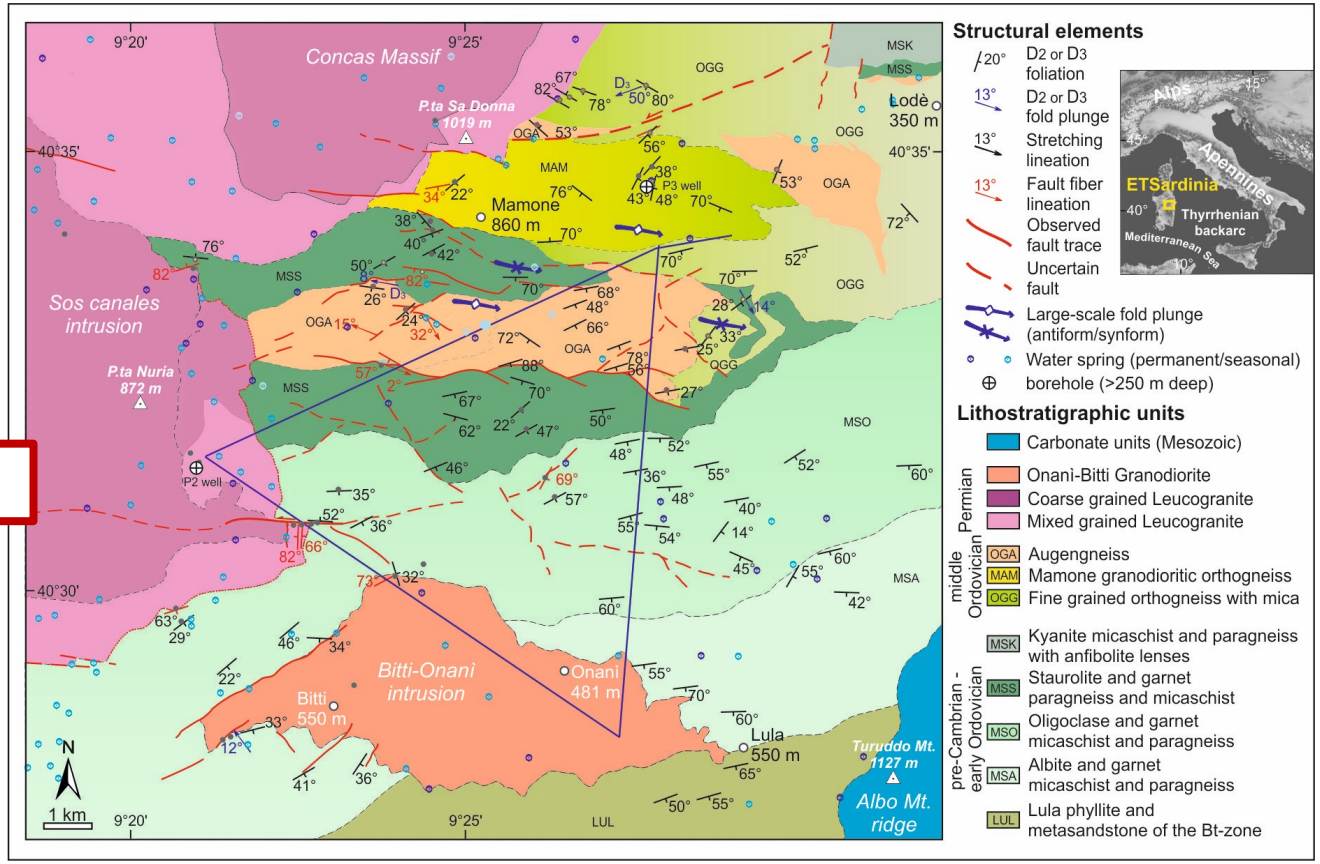
Characterization of the Bitti and Onanì corners:
Surface and underground seismic and environmental measurements





4 broadband seismometers, 3 short-period seismometers, 2 magnetometers, 1 tiltmeter distributed over underground and surface stations, 1 infrasound station

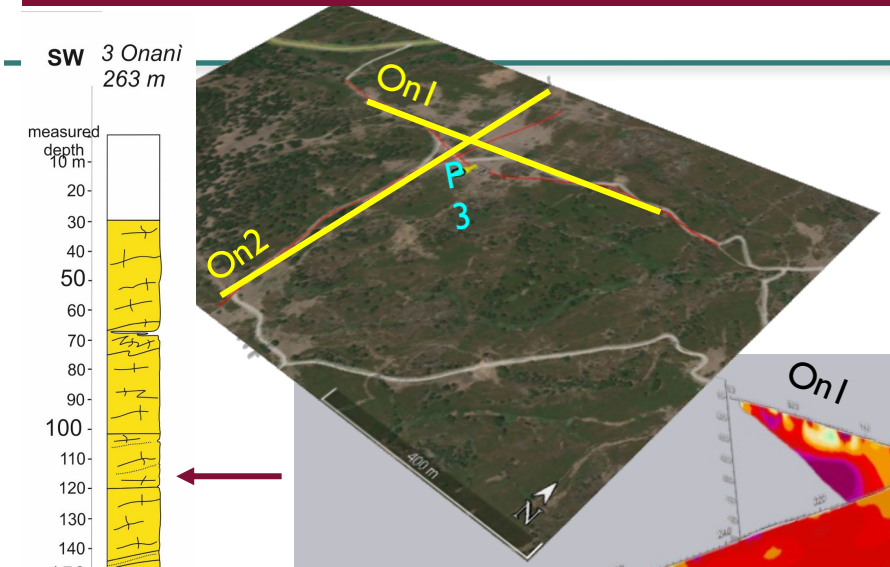
A NEW STRUCTURAL MAP



Courtesy of G.L. Cardello et al.

We have merged the lithologic information from published maps (also by comparing satellite images) and added new data collected in the field.

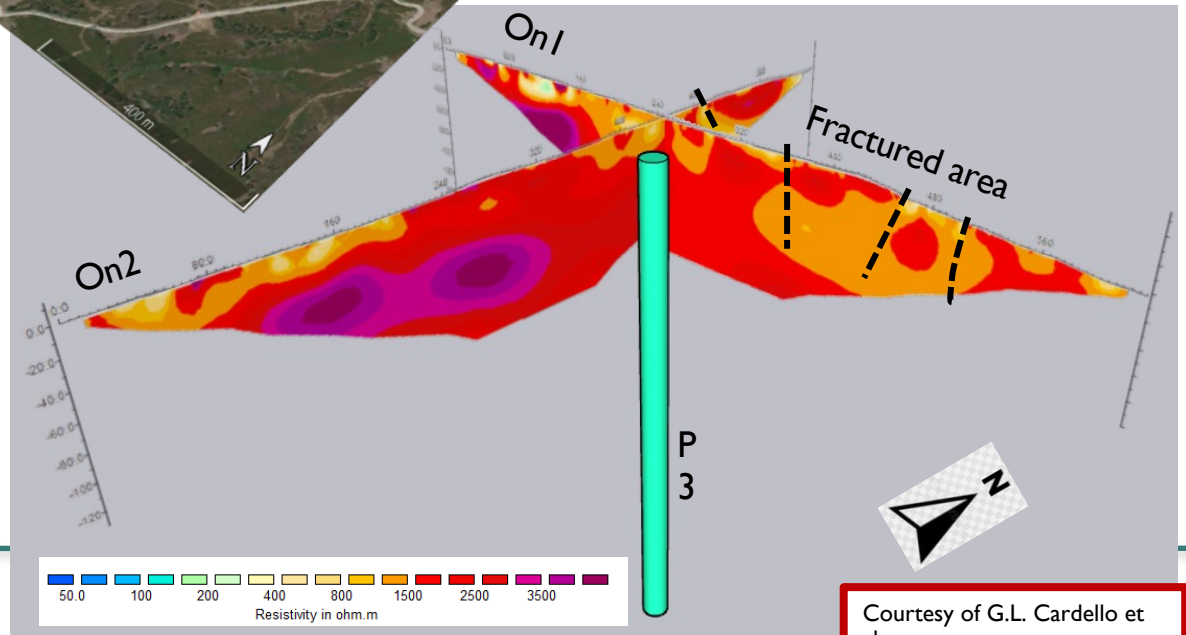
ERT RESULTS AT ONANI' BOREHOLE



conductive layer occurs either as:

i) a discontinuous and well-localized layer near the surface (up to 20 m thick), or as

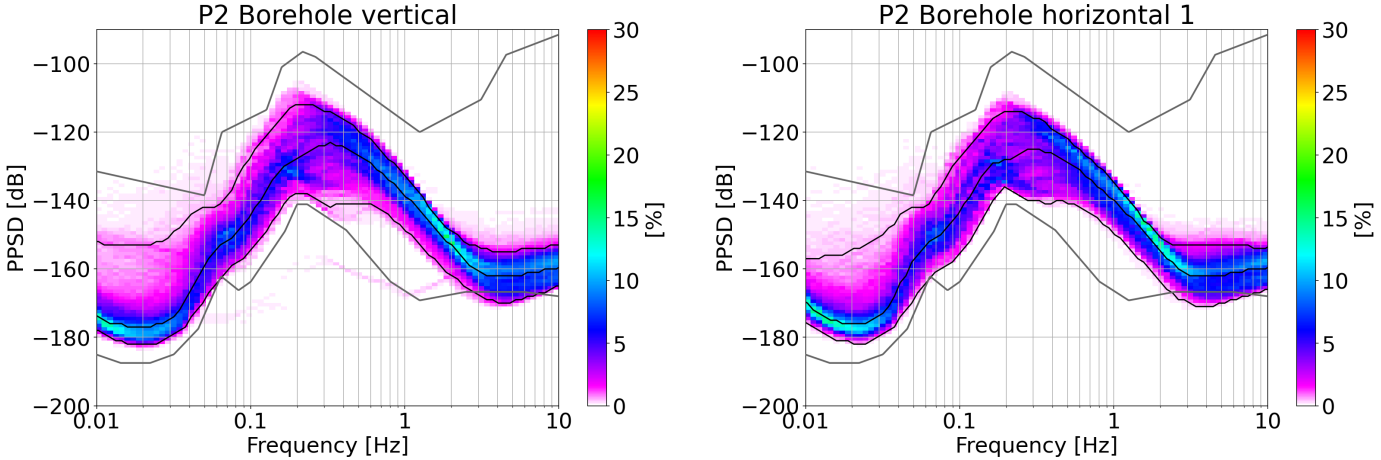
ii) a broader anomaly zone of values around 1000 Ωm that locally occurs at a depth of 30-90 meters.



Courtesy of G.L. Cardello et

Updates from P2 and P3

About half-year of continuous underground seismic measurements from the P2 and P3 boreholes, e.g.:



P2 (-264m) : 01 October 2021 – 20 March 2022

Courtesy of L. Naticchioni et al.

ET: LNS-UNISS Role

- Site Characterization Activity Coordination
- Infrastructure design and feasibility study
- Sensor Instrumentation and maintenance
- Acquisition system and mechanics of the Archimedes tiltmeter
- Data analysis and ET sensitivity estimation

ET: Sos Enattos Candidature
Next Steps

- Geology:
  - Geophysical campaign (geoelectrics and seismic lines along roads)
  - Complete the structural review of the area => Field survey
  - Hydrogeological model
  - Characterize fracture system => from LIDAR images
  - Perform microstructural studies => thin sections
  - Collect new samples for dating and chemical characterization
  - 3D geological modelling
- Site Measurements
  - Complete the long-term measurements
  - two additional magnetometer stations: SOE3 and P3
  - Interaction with windmills
- PNRR projects supporting ET in Sardinia:
  - INFN: a Reference System Network for geodetic survey (in coll. with ASI), strainmeter, Environmental Impact Assessment, Feasibility Design for surface works, Feasibility Design for technological systems, Feasibility Design of the Underground works
  - INGV: realization of a geophysical lab in the Sos Enattos area with additional 6 boreholes

ET Anagrafica/Richieste 2022

Personel	ET FTE
Giovanni Luca Cardello	1.00
Leonardo Casini	0.50
Domenico D'Urso	0.20 (+0.2 NGSA)
Luca Deidda	0.50 (ass. in corso)
Luca Pesenti	0.70 (+0.3 NGSA)
Davide Rozza	0.10 (+0.1 NGSA)
Valeria Sipala	0.00 (+0.1 NGSA)
Iara Tosta e Melo	0.20 (+0.3 NGSA)
Gaetano Schillaci	0.5
Daniele Cittadino	0.5
Tot	**4.2 (+1 NGSA)**

Richieste

Def. Preventivi in Corso

- R&D, first meeting on June 30th 11am
- Site Characterization, first meeting on July 1st 12pm

				(kEuro)	S.J. PNRR
Missioni	Missioni sul sito per installazioni manutenzione sensori e misure in loco (commissioning, montaggi e misure)			30	+10
	Missioni sul sito per la definizione e la valutazione della localizzazione delle infrastrutture			20	+30
	Partecipazione a Meeting di Coordinamento, di Collaborazione e working group			10	
Apparati	Stazione sismometrica			20	
Consumi	Materiale di consumo per I sismometri di superficie			20	
Servizi	Servizio di sorveglianza (dal 2022)			20	
Tot				**120.0**	**+40**