

Einstein Telescope

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What is Einstein Telescope (ET)?



- ET is the project aiming to realise the European 3rd Generation Gravitational Wave observatory
- ET has been a pioneer idea that defined the concept of 3rd generation GW observatory:
 - A sensitivity at least 10 times better than the (nominal) advanced detectors on a large fraction of the (detection) frequency band
 - Wideband (possibly wider than the current detectors) accessing the frequency band below 10Hz
 - High reliability and improved observation capability
- ET has a long and important history that formed first the ET community and now the ET project
- ET is now becoming also a (formal) scientific collaboration

ET long path





European Strategy Forum on Research Infrastructures

Einstein Telescope



https://www.et-gw.eu/



Project submitted by:

- Italy (Lead Country)
- Netherlands
- Belgium
- Spain
- Poland

Entered in the roadmap the 30/06/2021

ET CA signed by 41 institutions
INFN and Nikhef are the coordinators of the ESFRI

consortium

Portogallo



- Content of the proposal Mar Balt
 - ET proposal questionnaire

ET

- ET Cost Book through the evaluation of two external companies for the excavation costs
- ET Science¹ and Technology²
- ET services and communities

Bu

Pare ET planning including site selection milestone Franeia

¹Michele Maggior^{®®}*et al* JCAP03(2020)050 ²Einstein Telescope, Instrument Science and Design (ET-0018A-20)

ET timeline

- ET timeline presented to ESFRI
 - As expected, the ESFRI approval boosted the activities at all the levels: S

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· >	2021 🔰 20	022 🔰 2024 🍃 202	5 🔪 202	6 > 2028	> 2030 >		2035
\diamond \diamond		ESFRI status					
CDR ESF	RI proposal						i
2011 202)						1
Enabling t	echnologies	development					1
Sites qual	fication	S	ite decision				1
Cost evalu	ation						1
Building g	overnance						1
Raising in	tial funds						1
Raising construction funds							i
		Comm	tting constr	uction funds			1
Pre-engin	ering studie	<mark>s</mark>					i
		RI operative TD		ET RI const	ruction		1
	L	Detector operative TI		ET ITFs cor	struction		
ET installation						tion	I.
Commission							Science
ESFRI Phases	: Design	Preparatory		Implementa	tion		Operation



- Scientists
- Agencies
- Governments

5

ET collaboration current organisation



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ISB: Instrument Science Board

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The ISB mandate (from ET-085A-20)

Boosted by financial availabilities at national level

- The first objective of the team is to deliver the ET Technical Design Report (ET-TDR) of the infrastructure and of the detectors starting from the ET Conceptual Design Report (ET-CDR). The ET TDR production will be an iterative process and will go through intermediate steps:
 - Q3 2022: Pre-engineering definition of the Research Infrastructure (including an updated costs evaluation).
 - Q4 2022: Pre-engineering definition of the detector (including an updated costs evaluation).
- The level of detail of the design must be sufficient to allow the customization of the design for the two different sites, in order to prepare the site bids.
 - Q4 2025: RI operative TDR full engineering (including costs evaluation). This activity will probably be transferred to (or shared with) an external company.
 - Q2 2026: Detector operative TDR (including costs evaluations).
- Further intermediate internal release of the TDR will be needed in order, for example, to inform external agencies or committees.
- The second objective of the whole team is to identify the missing technologies and suggest a plan for R&D activities. This must be a living plan, regularly updated.
 - The first delivering of this plan is expected in early 2022.

ET Key ingredients

Factor 10 better sensitivity in a wide range of frequency with a specific attention to low frequency (<10Hz)

• Einstein Telescope is a 3rd generation Gravitational Wave Observatory

It is, first of all, a new Research
 Infrastructure

- Capable to host ET and its upgrades
- Capable to host 4G, ...



Einstein Telescope Xylophone option (ET-C)

Each detector (red, green and blue) consists of two Michelson interferometers. The HF detectors need one filtercavity each, while the LF detectors require 2 filter cavities each due to the use of detuned signal recycling. Number of 'long' suspensions = 21 (ITM, ETM, SRM, BS, PRM of LF-IFOs) of which 12 are crogenic.

Grn-LF

Number of 'normal' suspensions (PRM, BS, BD and FC) = 45 for linerar filtercavities and 54 for triangular filter cavities

Beams per tunnel =7

Observation (rather than detection) is the core business:

10km

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

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Q1: Enabling Technologies

• The multi-interferometer approach asks for two parallel technology developments:

New technology in optics

Challenging

engineering

New

technology in

cryo-cooling

New laser technology

High precision mechanics and low noise controls

High quality optoelectronics and new controls



- Underground
- Cryogenics

ET-LF:

- Silicon (Sapphire) test masses
- Large test masses
- New coatings
- New laser wavelength
- Seismic suspensions
- Frequency dependent squeezing

• ET-HF:

- High power laser
- Large test masses
- New coatings
- Thermal compensation
- Frequency dependent squeezing

Advanced detectors and their development programmes are a crucial de-risking factor for ET-HF Evolved laser technology

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Evolved technology in optics

Highly innovative adaptive optics

High quality optoelectronics and new controls

A network of new R&D infrastructures ET

- The technological evolution requested by ET is stimulating the grown of a series of new facilities and infrastructures where ET R&D is performed:
 - ET pathfinder



A network of new R&D infrastructures

The technological evolution requested by ET is stimulating the grown of a series
of new facilities and infrastructures where ET R&D is performed:



Slide P.Rapagnani

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A network of new R&D infrastructures

- The technological evolution requested by ET is stimulating the grown of a series of new facilities and infrastructures where ET R&D is performed:
 - ET pathfinder
 - Amaldi Centre, Rome
 - Sar-Grav lab in Sardinia
 - Other sites under preparation





The SarGrav Laboratory

- Founded with 3.5 M€ by the Regione Autonoma della Sardegna (RAS) to host low seismic noise underground experiments (low seismic noise experiments, cryogenic payloads, low frequency and cryogenic sensor development)
- ~ 900 m² surface Laboratory
- 3 Underground stations equipped for measurements at different depths
- ~ 50 m² underground area available
- planned a 250 m² underground Lab
- First experiment: Archimedes (founded by INFN)



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ET site(s)

- Currently there are two sites, in Europe, candidate to host ET:
 - The Sardinia site, close to the Sos Enattos mine
 - The EU Regio Rhine-Meusse site, close to the NL-B-D border
- A third option in Saxony (Germany) is under discussion, but still too preliminary to be a candidate



SPB: ET sites under characterisation

10⁻¹⁹

10⁻²⁰

strain//(Hz) 55-01/(Hz)

10⁻²³

10⁻²⁴

10-25 10^{0}

Euregio Meuse-Rhine

- A 250-m deep borehole has been excavated and equipped
 - Seismic data under acquisition and analysis
- 3-5 other boreholes expected
- Extensive active and passive site characterisation with sensor arrays in 2021
- Good seismic noise attenuation given by the particular geological structure
- Characterisation funded through Interreg grants



 10^{1}

Frequency (Hz)

H.Lueck – GWADW 2021

10-10

Soumen Koley, GWADW 2021

ground level

250 m deep

- Peterson LNM/HNM

 10^{1}

250 m deer

Surface

Sun

(b) Vertical component

Frequency (Hz)

E

Sat

10

1.0 - 10.0 Hz

SPB: ET sites under characterisation



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Sardinia

- Long standing characterisation of the mine in one of the corners continuing
 - Seismic, magnetic and acoustic noise characterisation ongoing at different depth in the mine
- Underground laboratory under construction (SarGrav)
- Two ~290m boreholes have been excavated, equipped and data taking is ongoing
- Intense & international surface investigations programme in Summer/Fall 2021
- Characterisation funded on regional and national funds



Characterisation funded on regional and national funds

-L.Naticchioni e tal., *Characterization of the Sos Enattos site for the Einstein Telescope*, JPCS1468,2020 -M.DiGiovanni et al., *A seismological study of the Sos Enattos Area-the Sardinia Candidate Site for the Einstein Telescope*, SRL,2020https://doi.org/10.1785/0220200186

-A.Allocca et al., Seismic glitchness at Sos Enattos site: impact on intermediate black hole binaries detection efficiency, EPJP, 2021https://doi.org/10.1140/epjp/s13360-021-01450-8

SPB Site Preparation Board Site Studies **Environmental studies** Geophysical studies Data management std. Analysis tools and data comparison **Detector Optimisation** Community relations Costs and socioeconomic impact Legal

Site Preparation Board

- The SPB has the mandate to characterise, qualify and compare the two sites.
- The global reorganisation of the ET project has partially disturbed and delayed its formal definition, but the technical activities are progressing at full speed
 - Characterisation at the sites
 - Definition of common tools and methods
 - SPB Workshop 8-11 November 2021



SPB Workshop



https://agenda.infn.it/event/28070/

E-Infrastructure Board



- The mandate of the e-Infrastructure board (ET-0323A-21) is to design, create and operate an evolving, efficient and functional e-infrastructure environment at a reasonable cost for the collaboration. Initially the focus will be the development of a Computing Model for the ET.
- Current Chairs: S.Bagnasco (INFN), A.Stahl (Uni Aachen), P. Verdier (IN2P3)
- Current activities are:
 - Definition of the IAM (Identity and Access Management) architecture and requirements
 - Support and work from Cyfronet, INFN, EGI and Géant
 - Definition of the collaboration support tools (e.g. member database, web services,...) and MoU with EGO
 - E.g. evaluation of alternative collaborative editing and sync&share tools proposed by BSC
 - Aiming at a kick-off meeting in November
 - Possible date: Nov 19 (Friday of the Virgo Week), to be confirmed
 - Hopefully in person, at EGO or in Pisa



OSB: Observation Science Board



EXERN ET Science in a nutshell

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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 Structure - 2020

ESFRI



• Before ESFRI approval: A broad ET scientific community;





Summary

- ET is now an ESFRI project
 - Important and increasing support of national governments
 - Important funding possibility currently under discussion
 - Perspective of EU funding for specific activities
 - Specific ESFRI calls under preparation
- Agencies and institutions are working to define the ET project governance
- The ET collaboration is going toward its formalisation
 - ET wants to be open to all the scientific and technical contributions, but this so challenging effort needs commitment by its members
- Huge amount of technical, scientific, political and financial activities is progressing



What are you doing?

ET Wants You!

