Einstein Telescope: Synergies and Complementarities with HEPP

Belgian National ESPP meeting 2025 Feb 05

Archisman Ghosh

GHENT UNIVERSITY

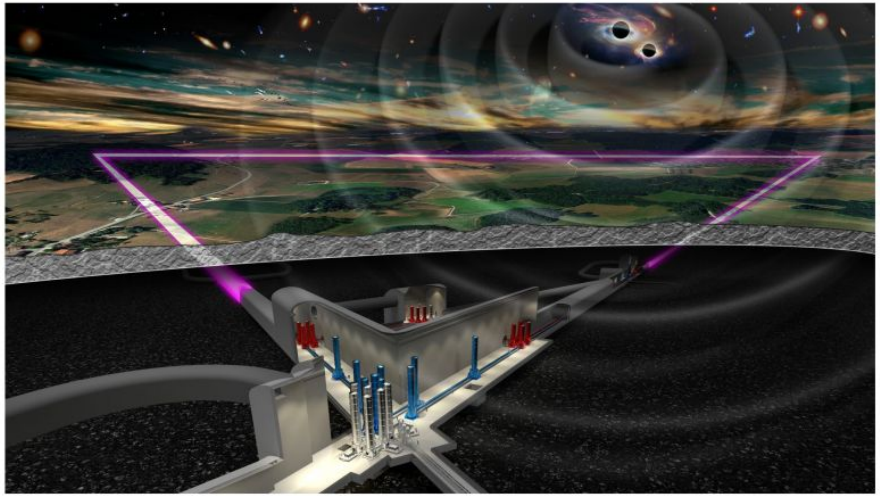
EINSTEIN TELESCOPE

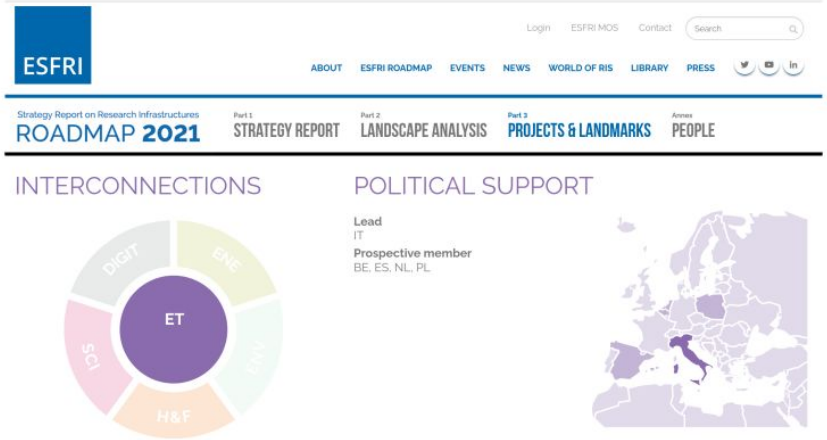
In memoriam ..

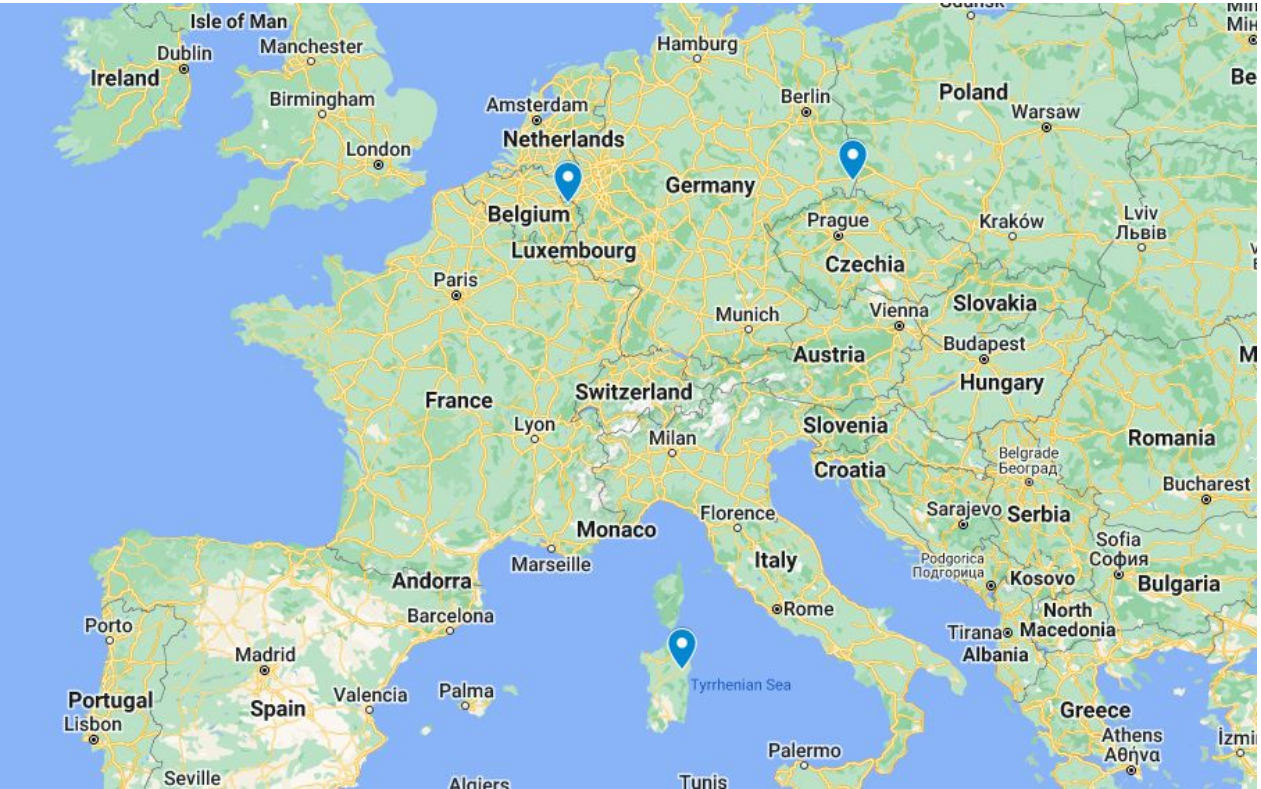
Paul Kuijer (1957–2025)

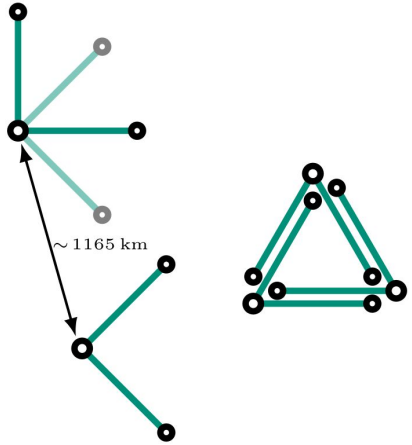
Plan of the talk

- Brief overview of the ET
- Fundamental science synergies and complementarities
- Technological synergies
- Computing and software




ESFRI
Login
ESFRI MOS
Contact
Search
ABOUT
ESFRI ROADMAP
EVENTS
NEWS
WORLD OF RIS
LIBRARY
PRESS
Strategy Report on Research Infrastructures
ROADMAP 2021
Part 1
STRATEGY REPORT
Part 2
LANDSCAPE ANALYSIS
Part 3
PROJECTS & LANDMARKS
Annex
PEOPLE
INTERCONNECTIONS
DIGIT
ENE
ET
SCI
H&F
POLITICAL SUPPORT
Lead
IT
Prospective member
BE, ES, NL, PL





Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

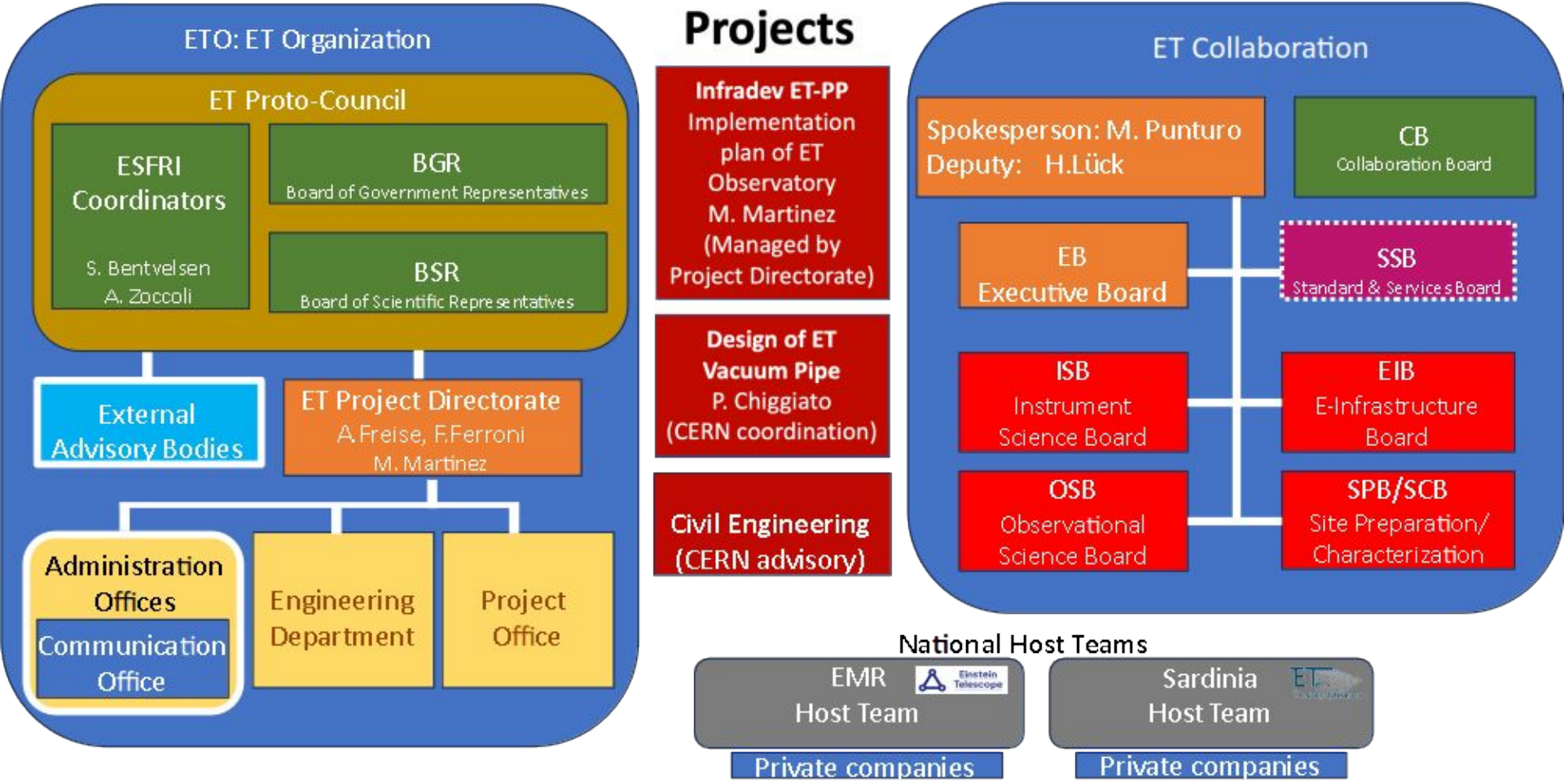
Science with the Einstein Telescope: a comparison of different designs

Marica Branchesi,[1,2,*] Michele Maggiore,[3,4,*] David Alonso,[5]
Charles Badger,[6] Biswajit Banerjee,[1,2] Freija Beirnaert,[7]
Enis Belgacem,[3,4] Swetha Bhagwat,[8,9] Guillaume Boileau,[10,11]

Formation of the ET Collaboration, Budapest, June 2022

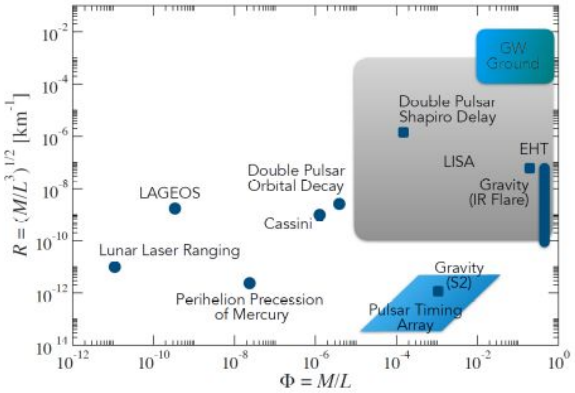
EINSTEIN TELESCOPE

GHENT UNIVERSITY


ETO: ET Organization
ET Proto-Council
ESFRI Coordinators
S. Bentvelsen
A. Zoccoli
BGR
Board of Government Representatives
BSR
Board of Scientific Representatives
External Advisory Bodies
ET Project Directorate
A.Freise, F.Ferroni
M. Martinez
Administration Offices
Communication Office
Engineering Department
Project Office
Projects
Infradev ET-PP
Implementation plan of ET Observatory
M. Martinez
(Managed by Project Directorate)
Design of ET Vacuum Pipe
P. Chiggiato
(CERN coordination)
Civil Engineering
(CERN advisory)
ET Collaboration
Spokesperson: M. Punturo
Deputy: H.Lück
CB
Collaboration Board
EB
Executive Board
SSB
Standard & Services Board
ISB
Instrument Science Board
EIB
E-Infrastructure Board
OSB
Observational Science Board
SPB/SCB
Site Preparation/ Characterization
National Host Teams
EMR
Host Team
Einstein Telescope
Private companies
Sardinia
Host Team
ET
Private companies

Fundamental science: testing gravity

- Is Einstein's GR the ultimate theory of gravitation?
  - Testing gravity in strong-field dynamical regime



- Are the observed compact objects really black holes?
  - GR meets quantum mechanics near the event horizon of black holes

EINSTEIN TELESCOPE

GHENT UNIVERSITY

What is the nature of dark matter?

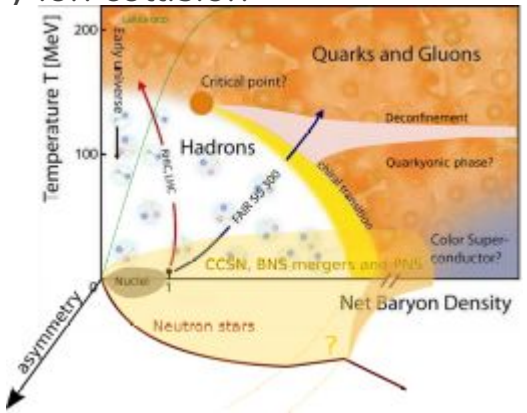
- Standard heavy dark matter models (MeV-TeV) predict halos and spikes near astrophysical BHs, which affect the dynamics of binary systems
    - effects are negligible for LIGO/Virgo but will be relevant for next-generation detectors
- Ultralight bosonic dark matter (< 10 eV) such as axions and dark photons, induces phenomena near BHs via superradiance
    - mass-spin gaps, continuous GW signals, detectable environmental effects
- Interiors of neutron stars are natural catalysts of DM interactions
- Primordial black holes (PBH) are unique DM candidates

EINSTEIN TELESCOPE

GHENT UNIVERSITY

QCD at overcritical density

- Low-temperature high-density regime of QCD probed by NS mergers is quite complementary to the regime probed by heavy ion collision experiments (such as in ALICE).
  - EoS models feature large uncertainties
  - plethora of models:
  - plain npeμ matter, hyperons, pion condensates, quarks, etc.



- GW170817 already ruled out very stiff EoS (large tidal deformabilities)
  - just a single detection with ET will rule out several families of EoS
  - discriminate between EoS with similar softness but distinct microphysics

What is dark energy?

- Whether gravity is modified at cosmological distances
- Stochastic background of GWs in ET bandwidth
  - Window into the primordial universe and fundamental phenomena:
  - primordial inflation, phase transitions, the formation of primordial BHs, DM relics

- Synergies with particle physics is of prime importance
  - new dynamics (inflation, modified gravity, baryogenesis...) or new forms of matter!

EINSTEIN TELESCOPE

GHENT UNIVERSITY

Technology: vacuum pipe system

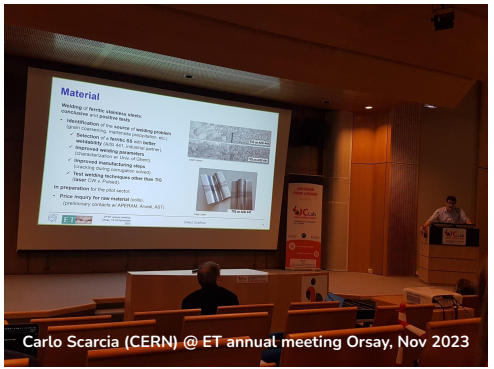
- ET: 120 km of vacuum pipe, internal diameter of 1m, satisfying following requirements (from CERN TDR)

Gas species	Maximum residual gas pressure [mbar]
H_2	10^{-10}
H_2O	5×10^{-11}
CO	10^{-11}
N_2	10^{-11}
C_xH_y with more than 100 amu	$< 10^{-14}$

- In addition, few hundred vacuum chambers to host ET suspended optics

Technology: vacuum pipe system

- New technological solutions to enhance feasibility and reduce expected costs!
- The vacuum team of CERN committed
    - to produce TDR of ET vacuum pipe system
    - to develop an R&D facility to test innovative solutions in terms of design and materials.



Carlo Scarcia (CERN) @ ET annual meeting Orsay, Nov 2023

University of Antwerp

GHENT UNIVERSITY

- Crucial pathfinder toward the vacuum system of a future CERN collider and a key synergy for the future of GW research and Particle Physics.

GHENT UNIVERSITY

Computing and software

- High performance computing, federated infrastructures, software employing machine learning and artificial intelligence
- Joint ECFA-NuPPECC-APPECC meetings
  - increased need for discussions on strategy and implementation of European computing at future large-scale research facilities.
- European Open Science Cloud (EOSC)
  - GW science actively contributing to this European effort.
- ET in ESCAPE Science Cluster
  - brings together European Research Infrastructures in particle and astroparticle physics to develop software and computing solutions for Open Science

EINSTEIN TELESCOPE

GHENT UNIVERSITY

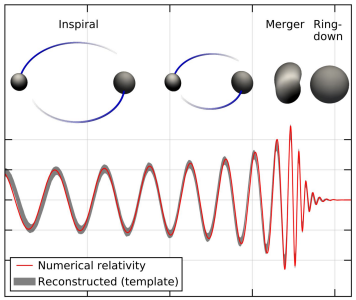
Other synergies

- Data management
- Civil infrastructures
- Governance

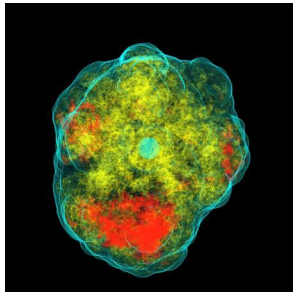
Extra slides

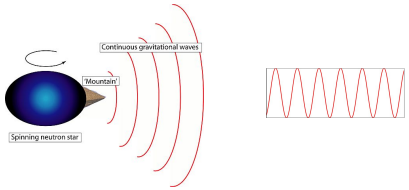
GW sources

Mergers of binaries of black holes and neutron stars

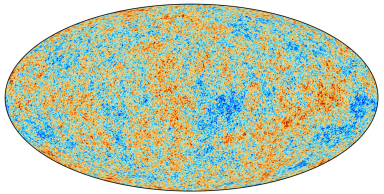


Bursts (supernovae)





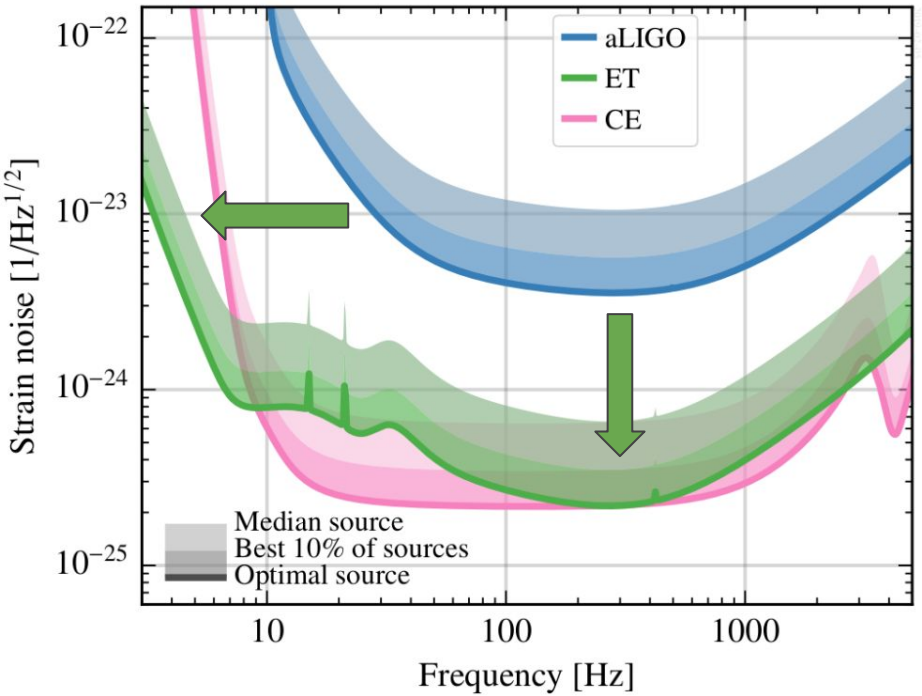
Spinning neutron stars



GW background (astrophysical and cosmological)

ET sensitivity

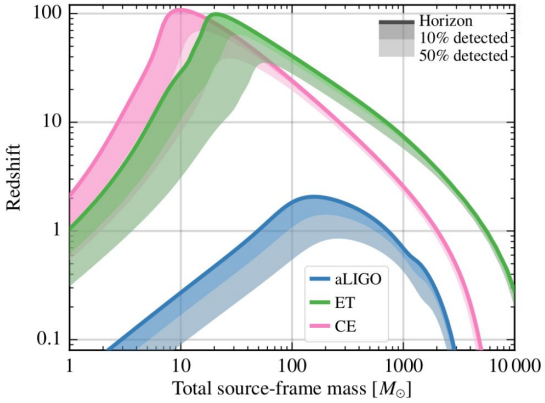
- 10 × current detectors
- Low-freq improvement

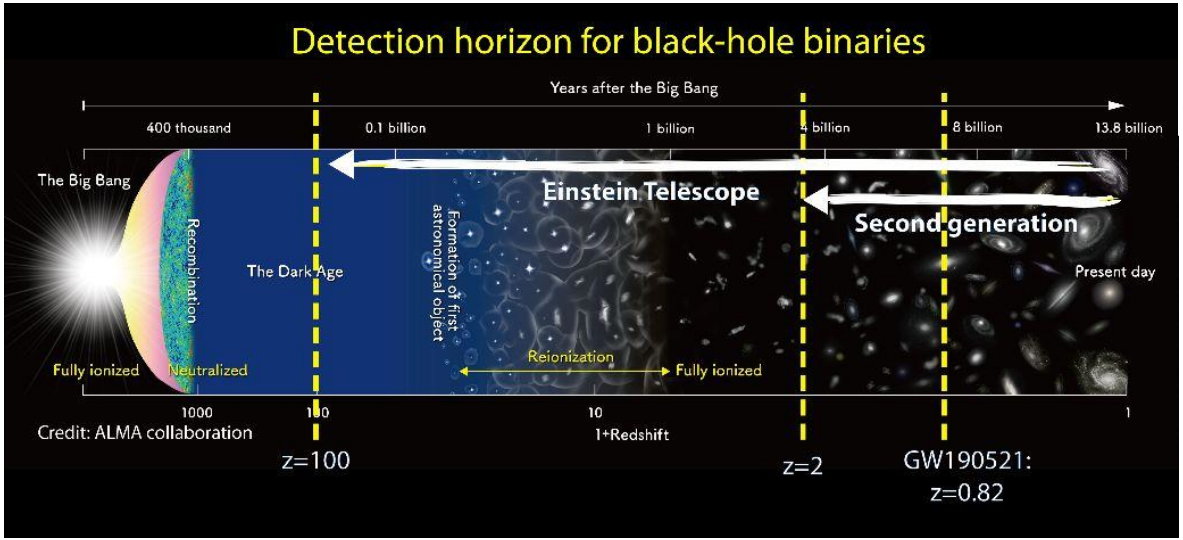


EINSTEIN TELESCOPE

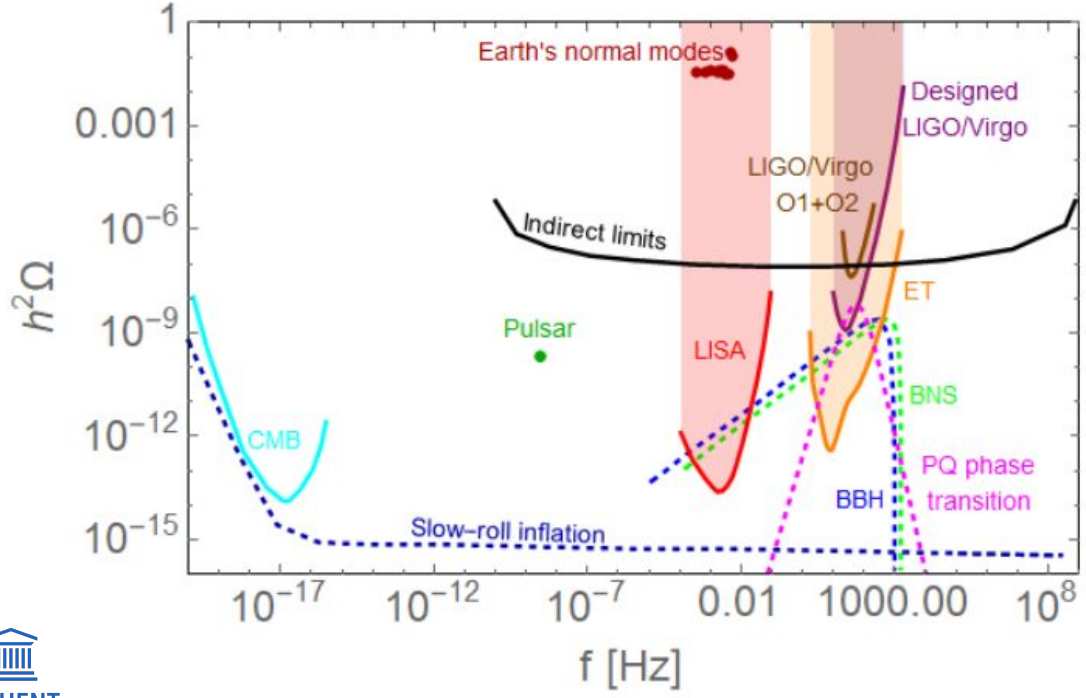
GHENT UNIVERSITY

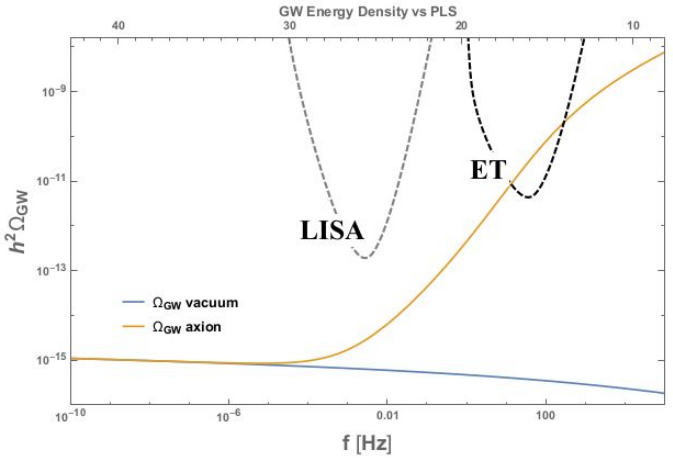
ET detection capability: binary mergers





ET detection capability: GW background



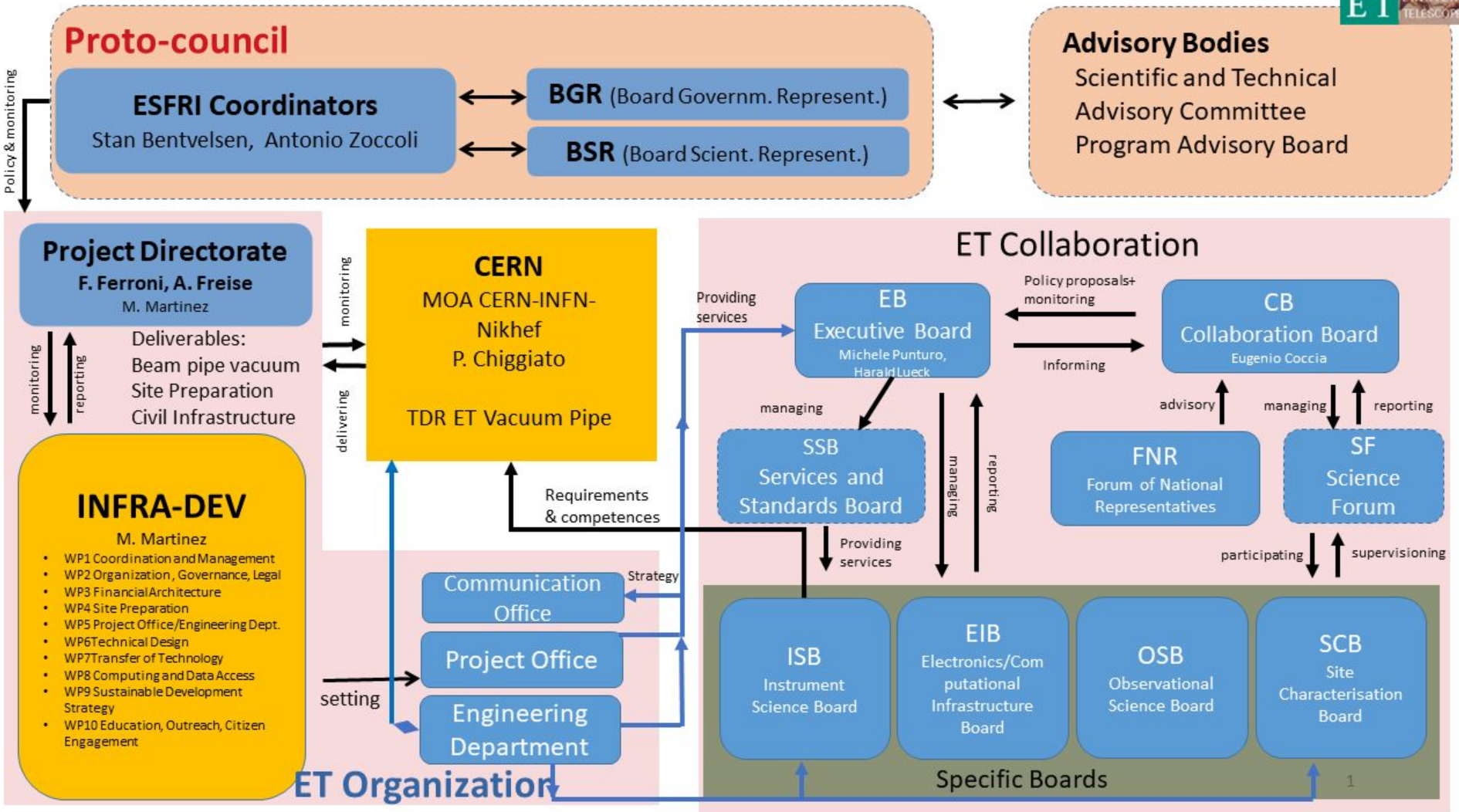


Topological defects, phase transitions ...

ET science

- Black hole properties: origin (stellar / primordial), evolution, demography
- Near-horizon physics, probing the nature of compact objects
- Neutron star properties: strongly coupled matter, QCD, exotic matter
- Multimessenger astronomy
- Dark matter: primordial black holes, axion clouds, ...
- Dark energy and modifications of gravity at cosmological scales
- New sources: supernovae, isolated neutron stars, stochastic background!

From: ET Design Report 2020 Update ET-0007B-20


Proto-council
ESFRI Coordinators
Stan Bentvelsen, Antonio Zoccoli
BGR (Board Governm. Represent.)
BSR (Board Scient. Represent.)
Policy & monitoring
Advisory Bodies
Scientific and Technical Advisory Committee
Program Advisory Board
Project Directorate
F. Ferroni, A. Freise
M. Martinez
monitoring
reporting
Deliverables:
Beam pipe vacuum
Site Preparation
Civil Infrastructure
monitoring
delivering
CERN
MOA CERN-INFN-Nikhef
P. Chiggiato
TDR ET Vacuum Pipe
INFRA-DEV
M. Martinez
WP1 Coordination and Management
WP2 Organization, Governance, Legal
WP3 Financial Architecture
WP4 Site Preparation
WP5 Project Office/Engineering Dept.
WP6 Technical Design
WP7 Transfer of Technology
WP8 Computing and Data Access
WP9 Sustainable Development Strategy
WP10 Education, Outreach, Citizen Engagement
Requirements & competences
Communication Office
Strategy
Project Office
setting
Engineering Department
ET Organization
ET Collaboration
Providing services
EB
Executive Board
Michele Punturo, Harald Lueck
Policy proposals+ monitoring
Informing
CB
Collaboration Board
Eugenio Coccia
managing
advisory
managing
reporting
SSB
Services and Standards Board
managing
reporting
FNR
Forum of National Representatives
SF
Science Forum
Providing services
participating
supervisioning
ISB
Instrument Science Board
EIB
Electronics/Computational Infrastructure Board
OSB
Observational Science Board
SCB
Site Characterisation Board
Specific Boards
1