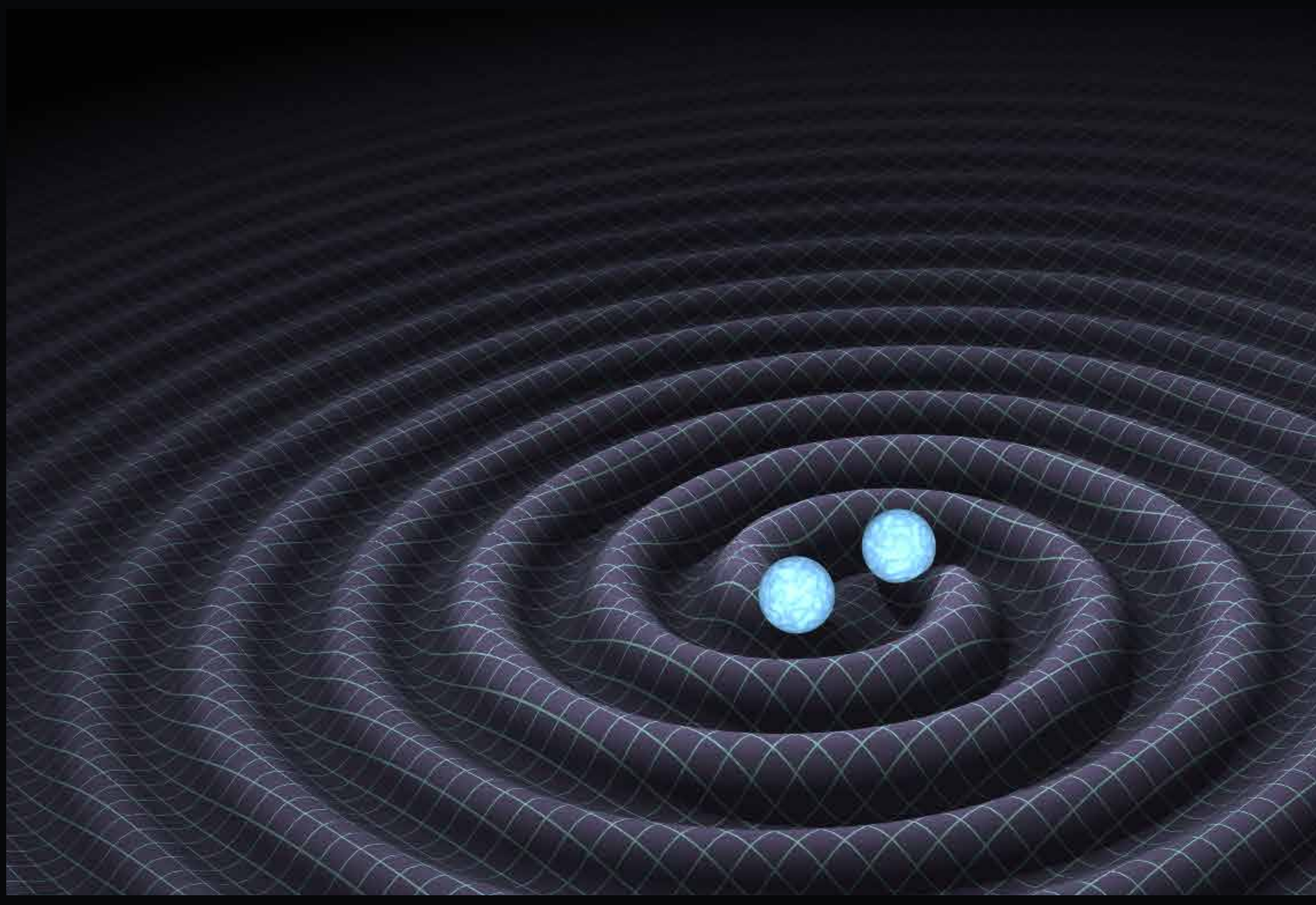
ITALY

Einstein Telescope



GRAVITATIONAL WAVES

ET will study gravitational waves, a physical phenomenon predicted by the general relativity theory, formulated by Albert Einstein over a century ago, discovered in the year 2015 by the scientific collaborations LIGO and Virgo.
Gravitational waves are infinitesimal vibrations of spacetime, produced by the motion of accelerating masses, like black holes and neutron stars, which propagate at the speed of light through the Universe. They are invaluable cosmic messengers carrying to the Earth, where it could eventually be revealed by the interferometers, the information about their sources and the deep universe where they were produced.

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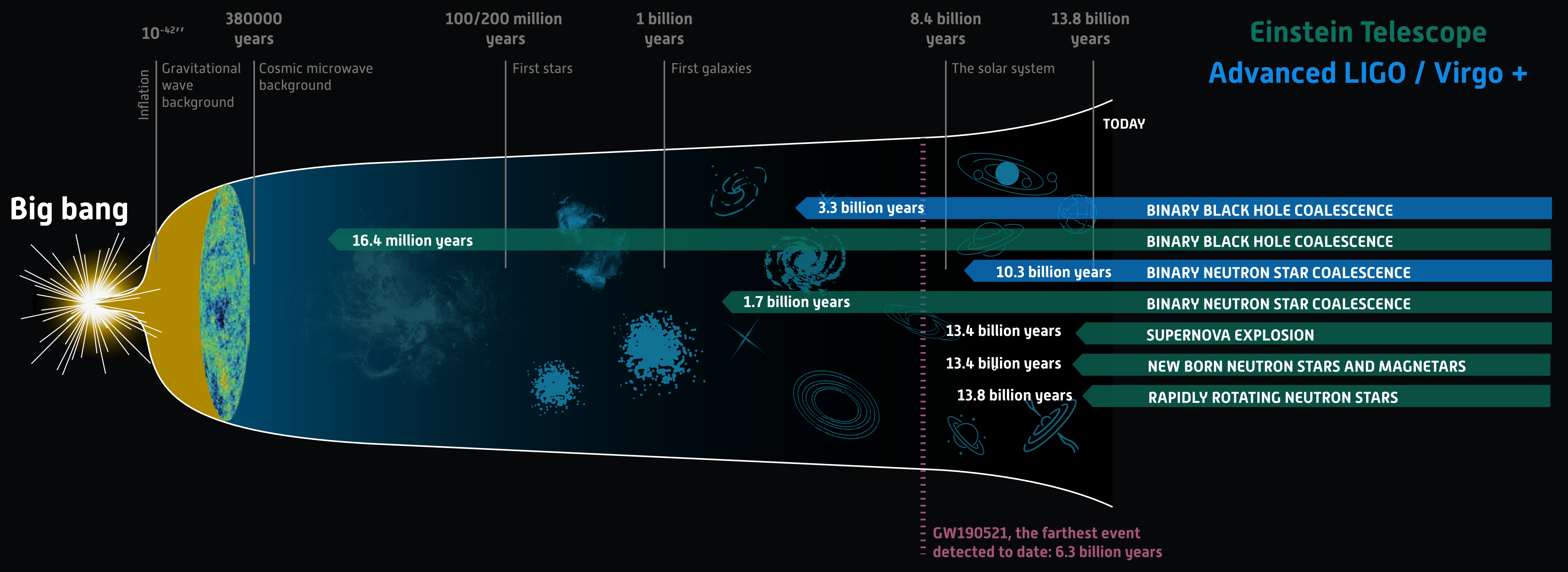
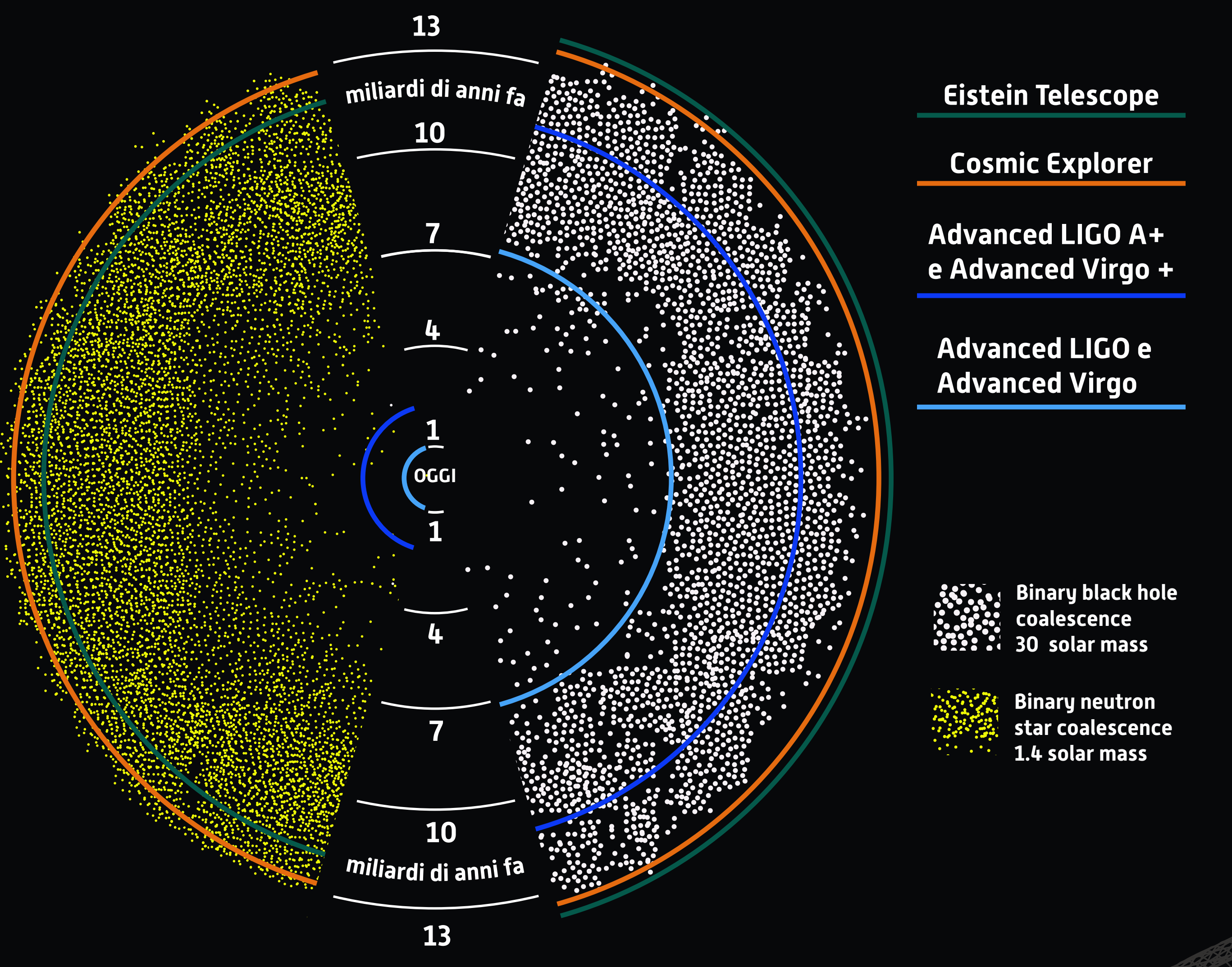
A BACK IN TIME JOURNEY

ET will study the universe through gravitational waves, even, for some kind of sources, up to cosmological distances. Through the observation of gravitational waves produced by the merger of black holes (30 solar masses each) and neutron stars (1.4 solar masses each) and of other extreme astrophysical events, ET will be able to trace the evolutionary history of the universe on a journey which arrives back to the Big Bang. In the figure below, the comparison of the ET sensitivity (green) to that of the II generation detectors (blue) is given, in terms of their capability to go back in time, for different types of gravitational wave events. Some of these events have already been observed with current detectors (black hole and neutron star mergers), others are still undetected or even out of the horizon of current detectors.





REWORKED IMAGE FROM [FONTE ASTRO-PH 2109.09882]

COMPARISON OF INTERFEROMETERS

ET will perform population studies of black holes and neutron stars, thus reconstructing our universe demography. The figure indicates the astrophysical horizon, in terms of age of the universe, for the detection of signals from the merger of binary black holes of 30 solar masses and neutron stars of 1.4 solar masses, with II generation detectors and with ET and Cosmic Explorer CE (III generation detectors). The dots represent a simulated population for each of the two source groups. The progress in sensitivity that will be obtained using ET and CE is evident. Their sensitivity is such that an observatory consisting of both detectors will be able to reveal the merger of binary systems throughout cosmic time, back to the origin of star formation. In future, an observatory composed of ground and space detectors, making use of ET, CE and of the LISA satellite interferometer, will also be able to make "multiband" detections, managing to follow a same compact objects merger during different phases of the evolution.

POSSIBLE FUTURE DISCOVERY SCENARIOS

The main scientific objectives of ET concern different research fields: multimessenger astronomy, astrophysics, cosmology, particle physics, fundamental physics. In the diagram below, some of the main research topics within the ET reach, are presented. They are ranked according to the probability of being discovered or studied by the future III generation interferometer.

CERTAIN

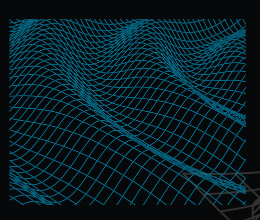
- detection of signals from the coalescence of compact binary systems (black holes, neutron stars, mixed)
- detection of signals form the coalescence of binary neutron stars or mixed systems, with an electromagnetic counterpart
- general relativity tests
- study the nature of gravity in extreme regime environments
- study the nature of compact objects
- demography and comprehension of neutron star's structure
- study the black hole mass distribution and other black hole properties
- improved determination of cosmological parameters, as for example those related to the expansion of the universe and to dark energy

EXPECTED

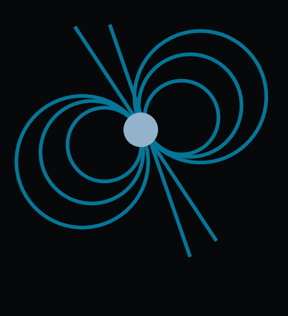
- detection of signals from core-collapse supernova explosions
- detection of signals from rapidly rotating neutron stars
- multiband astronomy, in coincidence with lisa (laser interferometer space antenna)
- coincidences between gravitational waves and neutrinos
- astrophysical stochastic background detection

POSSIBLE

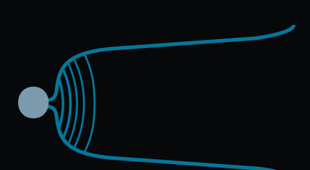
- detection of signals from unexpected compact objects
- cosmological stochastic background detection, verification of inflationary models, cosmic strings and phase transitions
- modified gravity models
- dark matter studies: measures and verification of models related to primordial black holes, ultra-light boson clouds, dark photons
- quantum gravity
- unexpected phenomena, surprises, relevant to the comprehension of the cosmological model



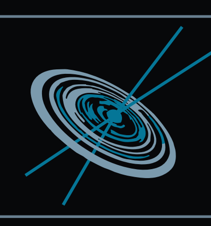
Fundamental physics and general relativity: accurate tests of general relativity, identification of possible deviations from general relativity, both in extreme gravity conditions and on cosmological scales. Formulation of alternative general relativity models, with the possibility of detecting quantum gravity effects.



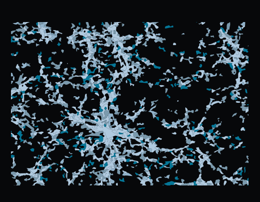
Fundamental physics, nuclear physics, and astrophysics: study of compact objects - black holes and neutron stars- properties, population studies, mass distributions, formation channels, evolution history. Exotic objects identification. Studies of extreme conditions nuclear matter (neutron stars equation of state). Nucleosynthesis and chemical evolution history of the universe. Identification and study of not yet revealed gravitational wave events: for example, supernova explosions, rapidly rotating neutron stars, newborn neutron stars (after coalescence, magnetars), stochastic background of astrophysical origin.



Cosmology: detection of numerous signals from the merger of compact binary systems, possibly with electromagnetic counterpart, to measure cosmological parameters related to the evolution and expansion of the universe. Identification of possible deviations from general relativity at cosmological scales. Contributions to the understanding of the nature of dark energy, which is responsible for the accelerated expansion of the universe.
Cosmological model verification and identification of possible alternatives to general relativity. Detection of the cosmological stochastic gravitational waves background, studies of the first life moments of the universe, studies of different inflation scenarios and of very high energy physics phenomena, otherwise inaccessible. Identification of possible alternatives to the standard cosmological model.



Multimessenger astronomy: physics of compact objects, relativistic jets, nucleosynthesis, mechanisms of supernova explosion, cosmology.



Dark matter: possible verification of some dark matter models, through their gravitational wave emission, like that expected from the coalescence of primordial black holes or from ultralight boson clouds around black holes. Measure of the "dark photon" effect on the interferometer detectors.