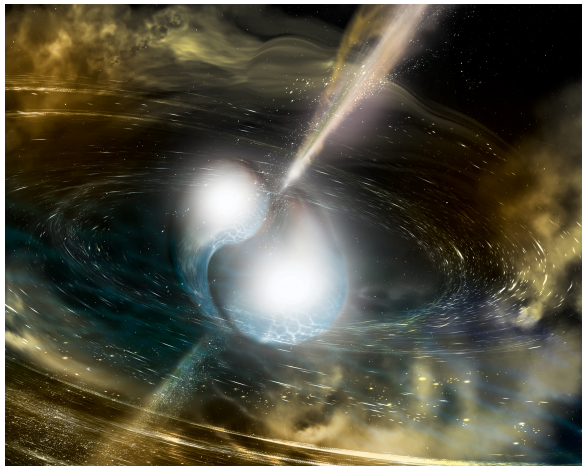


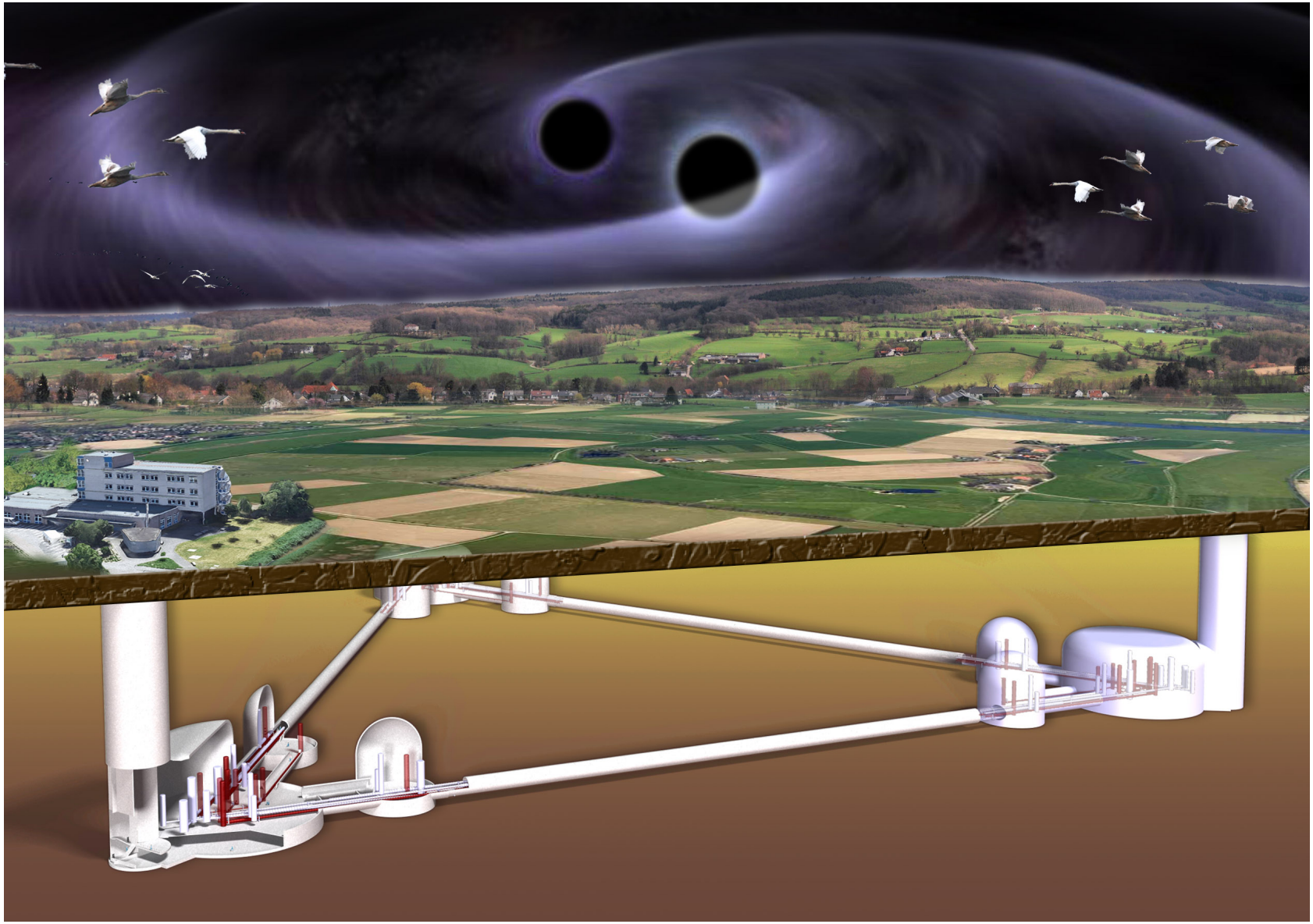
Einstein Telescope: Paving the road and prospects

Chris Van Den Broeck

Nikhef LIGO VIRGO rijksuniversiteit groningen

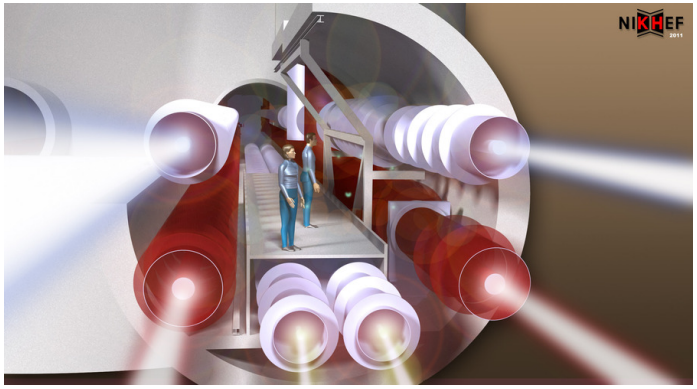
Nikhef Jamboree, Utrecht, 17-18/12/2018

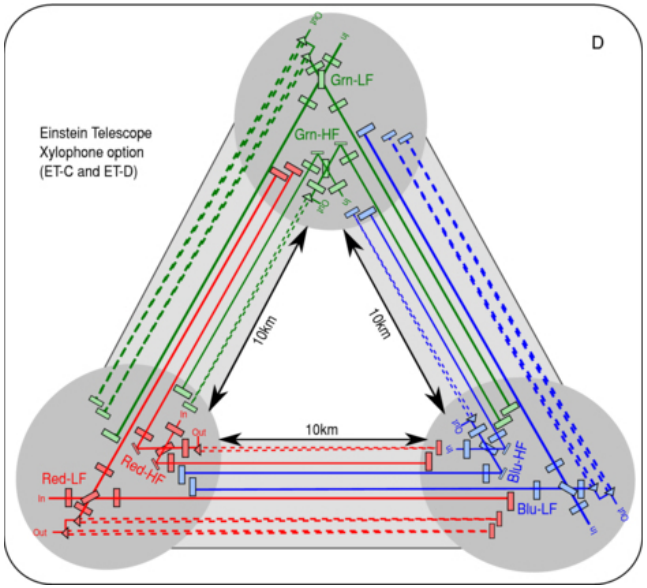
Einstein Telescope

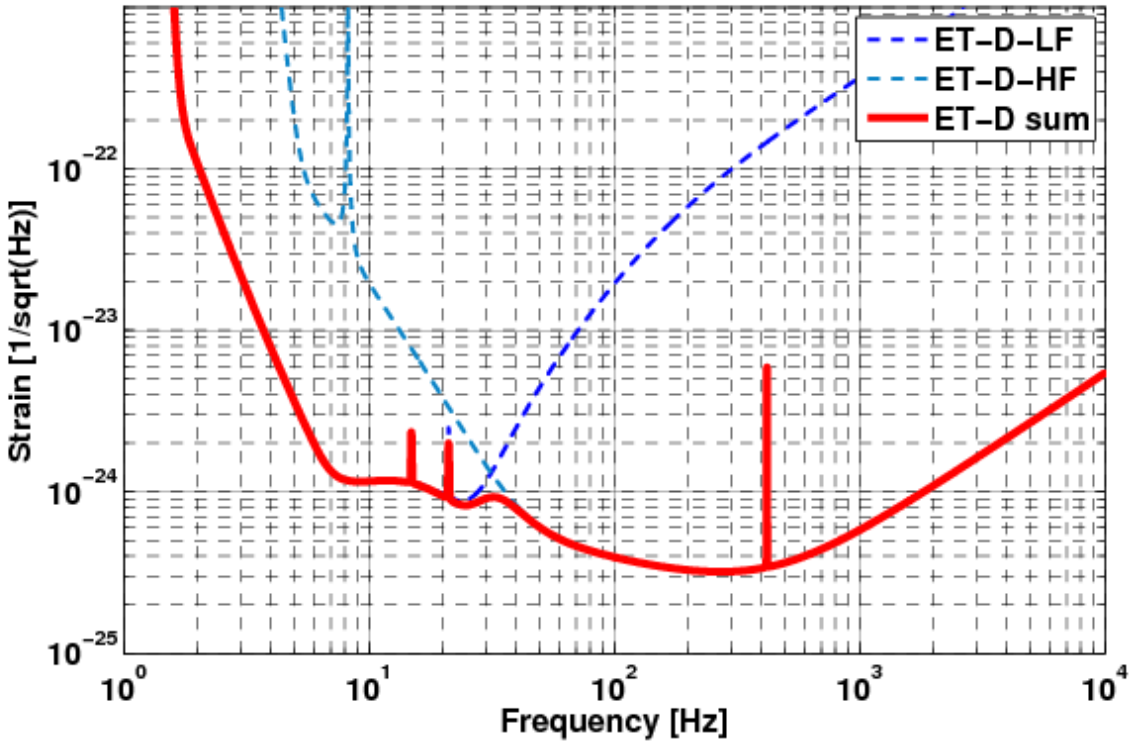


Einstein Telescope

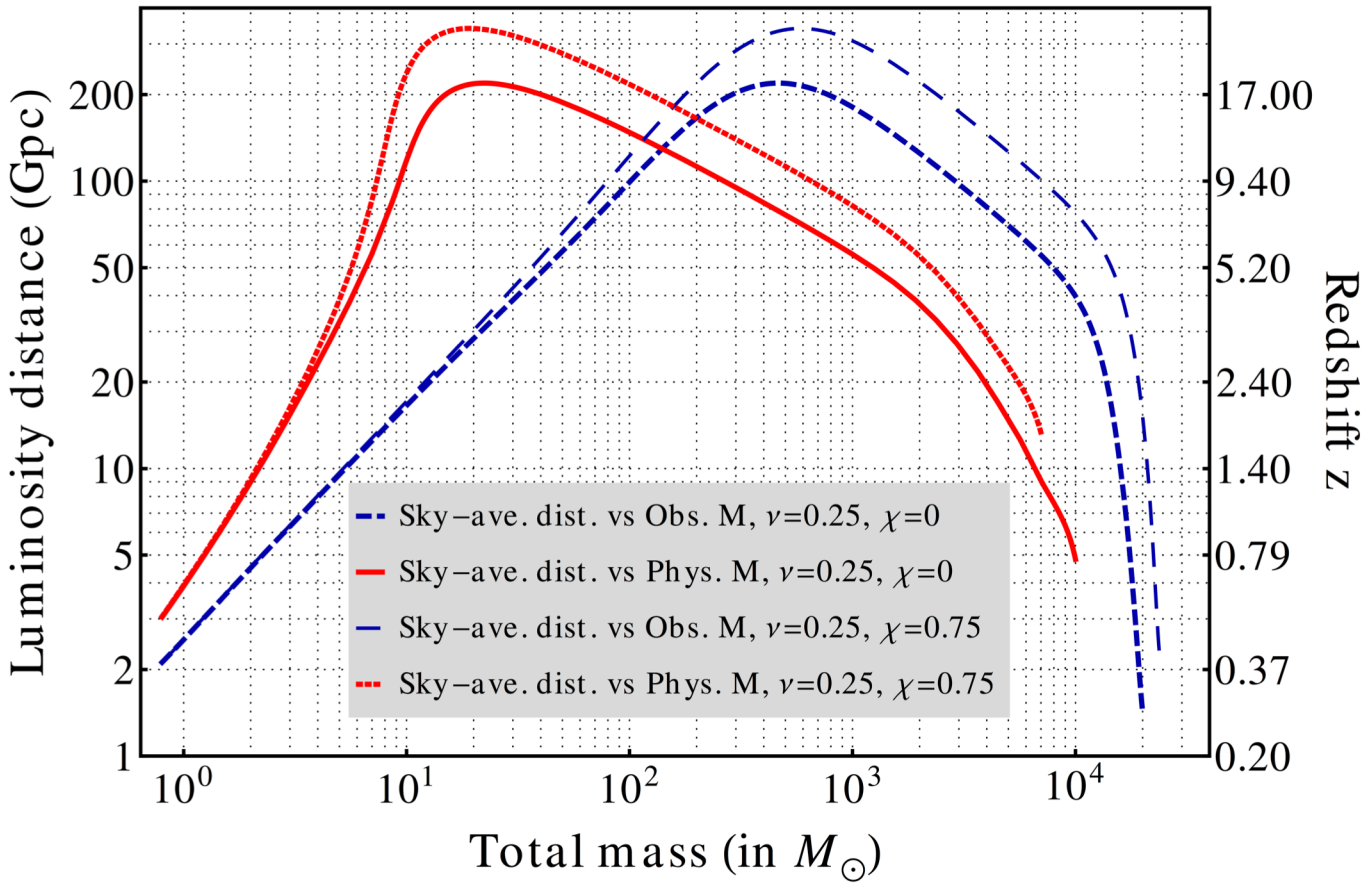
- Underground, 10 km triangle
- Xylophone design:
  - 3 low laser power, cryogenic: low-frequency sensitivity
  - 3 high laser power, non-cryogenic: high-frequency sensitivity





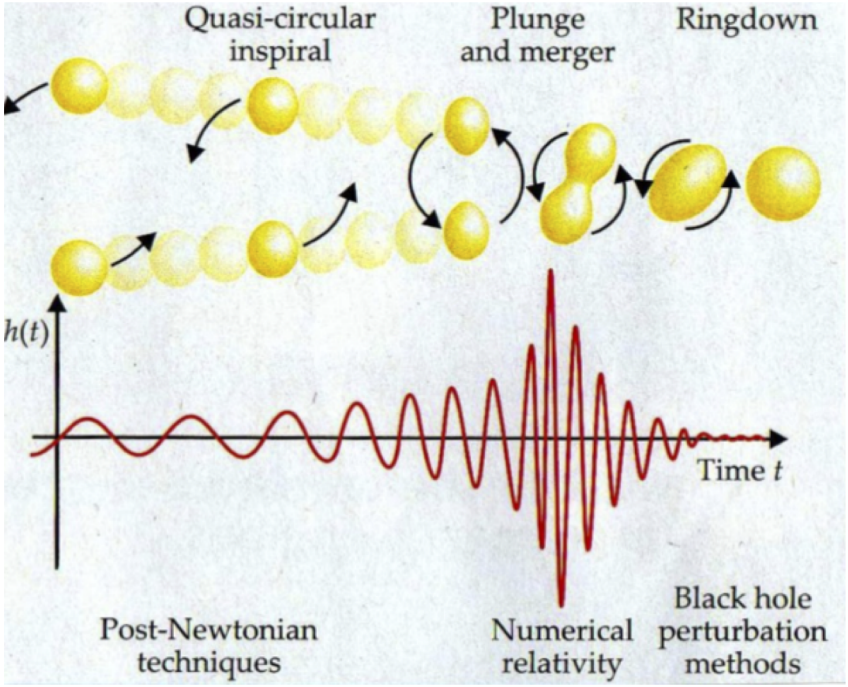


Einstein Telescope distance reach



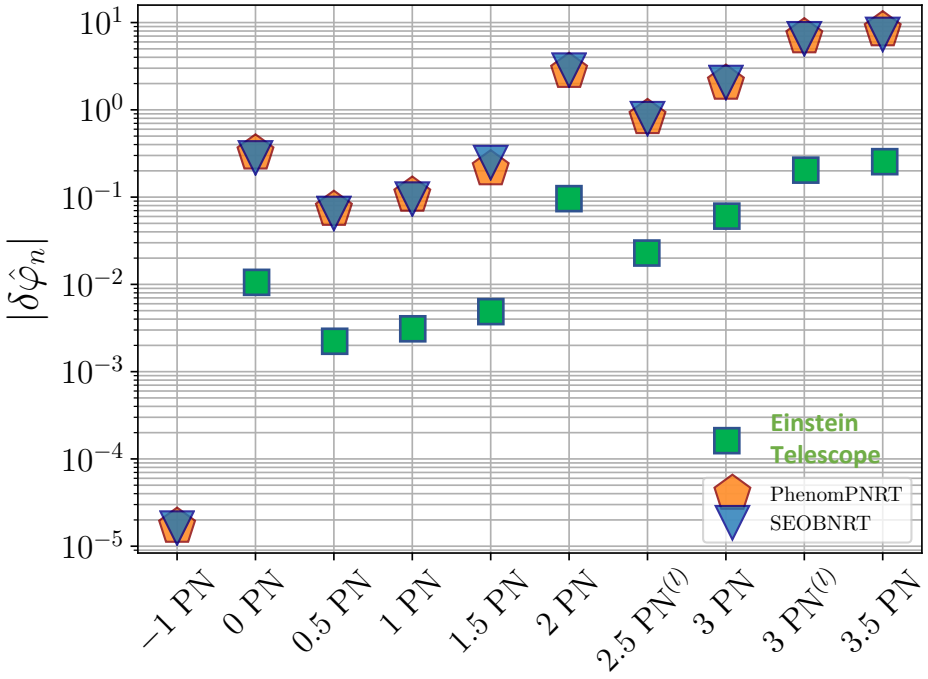
- Detection of binary black holes at times there were no stars yet (hence primordial!)
- O(10^5) binary black hole and binary neutron star mergers detected per year

Precision tests of general relativity



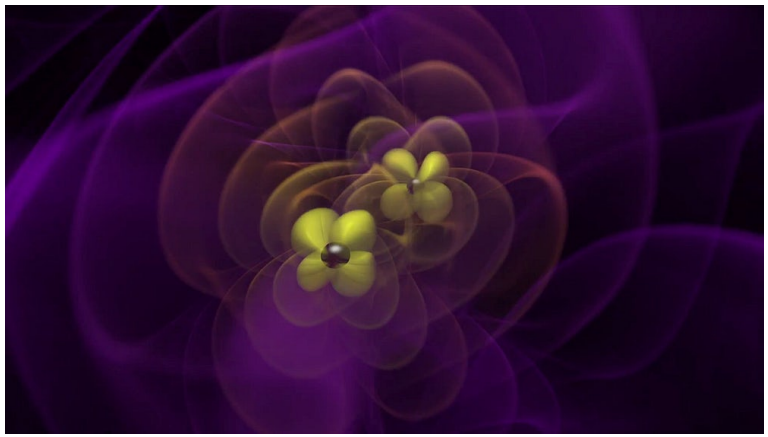
Orange, blue: GW170817

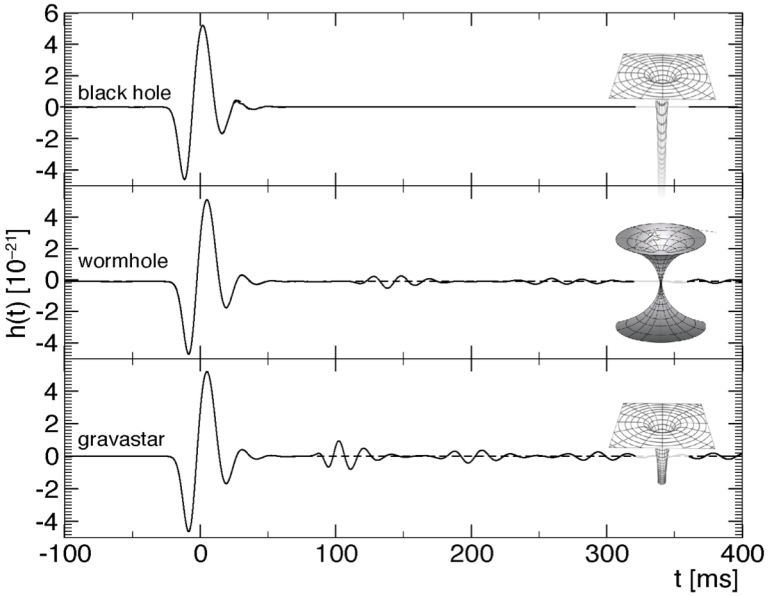
Green: Einstein Telescope after ~1 year of operation (~10^5 detections)



$$\Phi(v) = \left(\frac{v}{c}\right)^{-5}\left[\varphi_{0\mathrm{PN}} + \varphi_{0.5\mathrm{PN}}\left(\frac{v}{c}\right) + \varphi_{1\mathrm{PN}}\left(\frac{v}{c}\right)^{2} + \ldots + \varphi_{2.5\mathrm{PN}^{(l)}}\log\left(\frac{v}{c}\right)\left(\frac{v}{c}\right)^{5} + \ldots + \varphi_{3.5\mathrm{PN}}\left(\frac{v}{c}\right)^{7}\right]$$

What is the true nature of black holes?

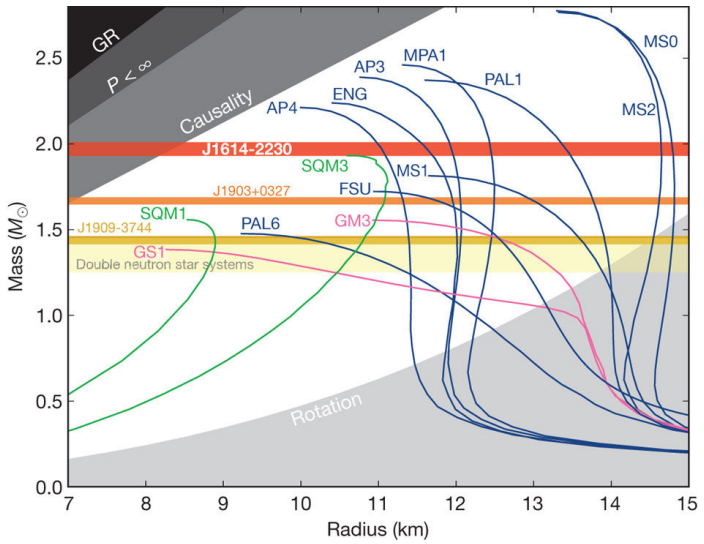




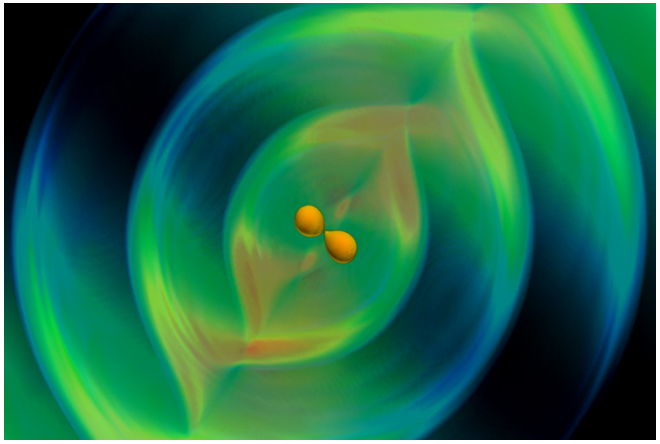
- Black hole no-hair conjecture
  - Stationary black holes only determined by mass and spin
  - "Ringdown" modes of newly formed black hole:
    - Frequencies, damping times only depend on mass and spin
    - Einstein Telescope will test these dependences for individual modes with sub-percent accuracy

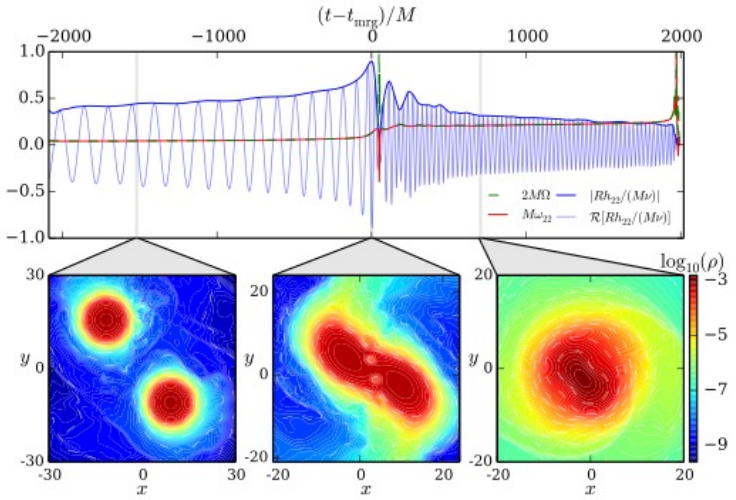
- Signatures of quantum gravity?
  - Prompted by Hawking's information paradox:
    "Firewall" instead of horizon
  - Leads to gravitational wave "echoes"

Probing the interiors of neutron stars

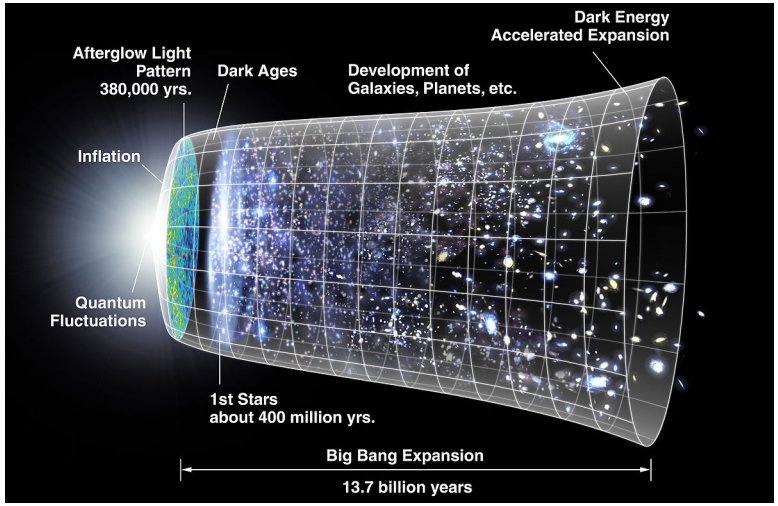


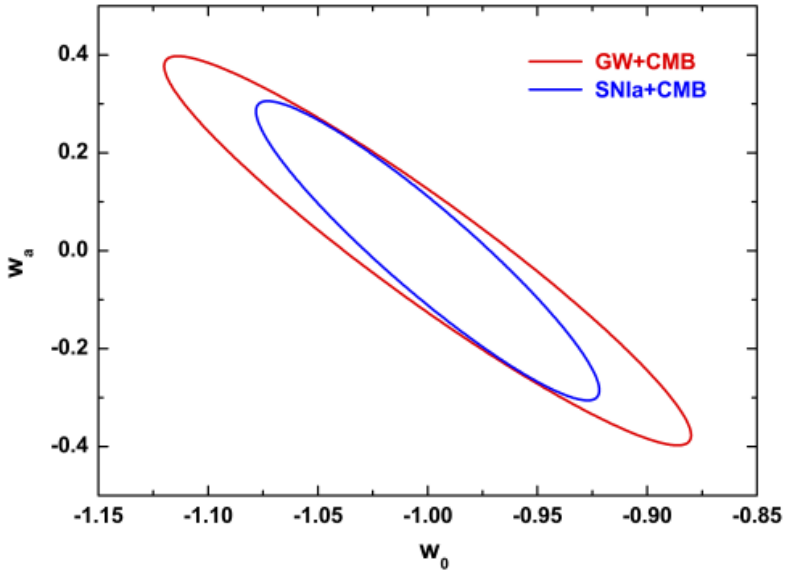
- Widely differing theoretical predictions for **equation of state**
- LIGO, Virgo: exploit tidal effects to gain information on internal structure
- Einstein telescope:
  Also access to the post-merger regime
  - Detailed mapping of neutron star interiors



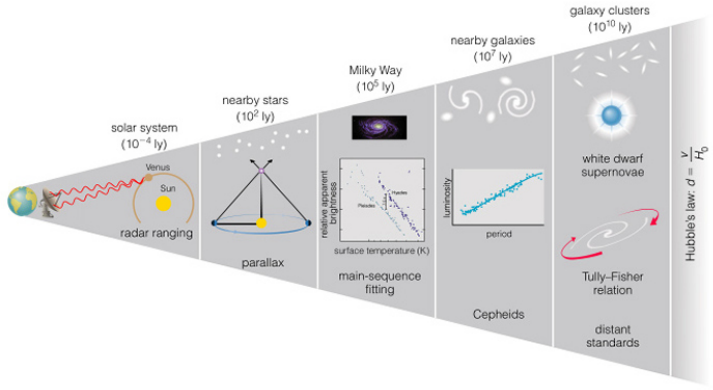


Mapping the large-scale evolution of the Universe





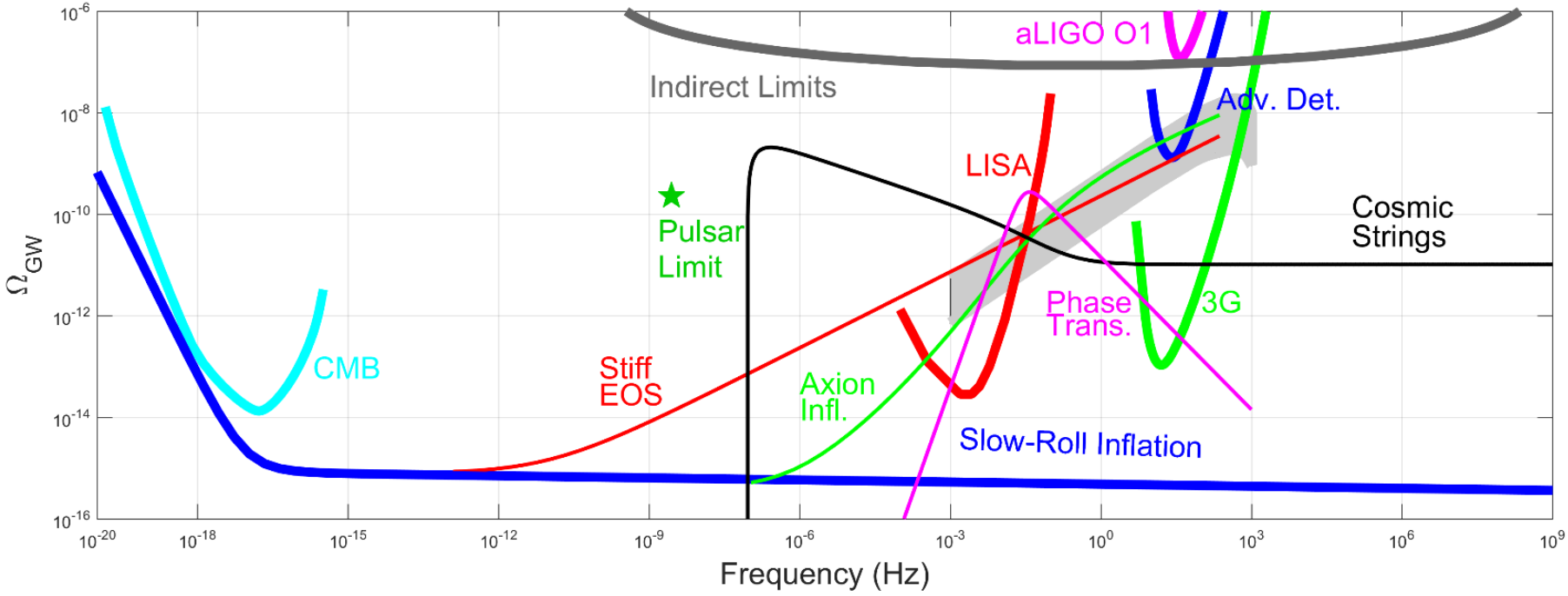
- With a network of detectors, can extract **distance** directly from gravitational wave signal of binary inspirals
- No need for a "cosmic distance" ladder with one type of object calibrating the other



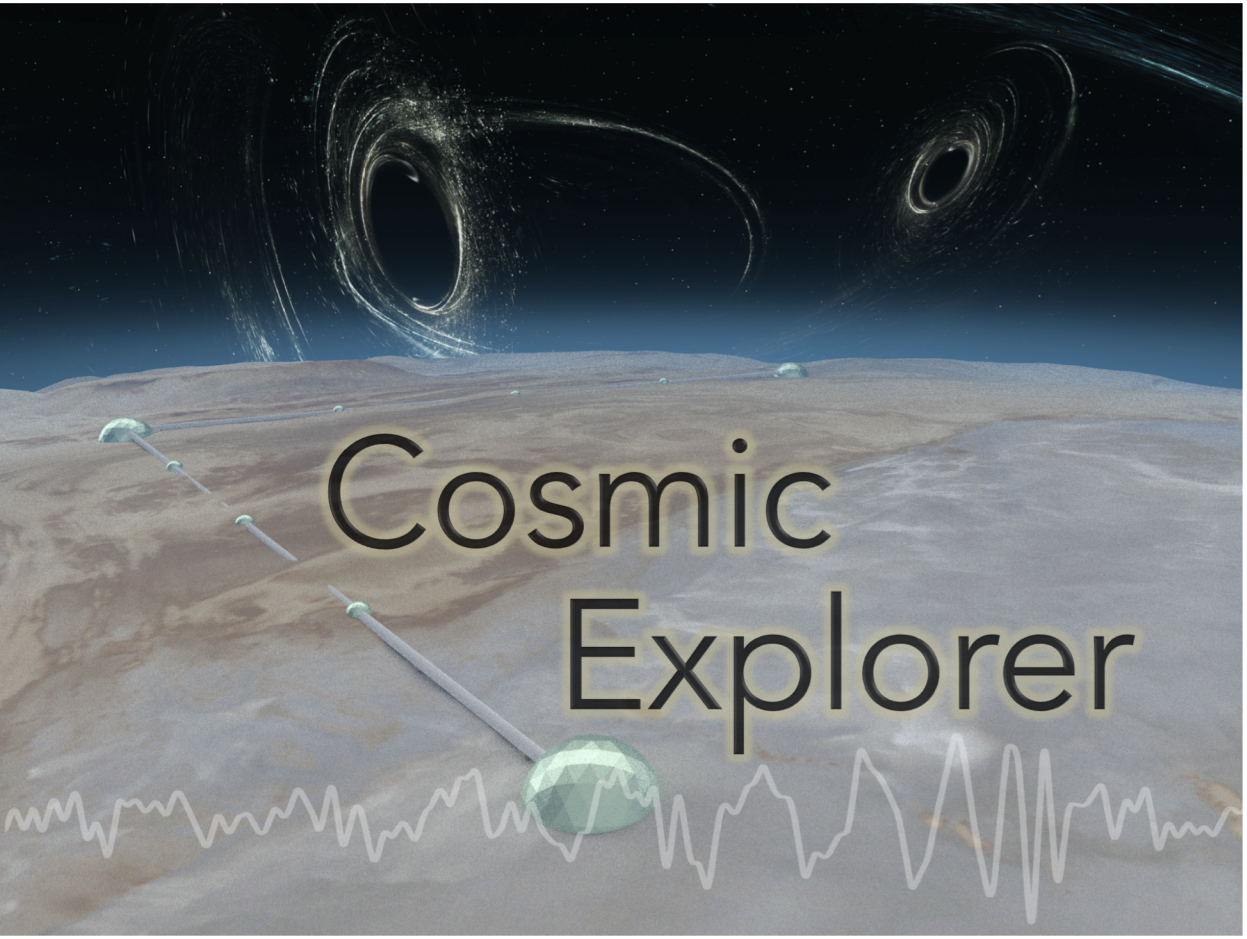
- LIGO/Virgo: independent measurement of Hubble constant
- ET: independent measurement of the nature and time evolution of **dark energy**

Primordial gravitational waves

- Range of scenarios for primordial gravitational waves originating from immediately after Big Bang:
  - Phase transitions
  - Axion inflation
  - Resonant pre-heating
  - Cosmic strings
  - …

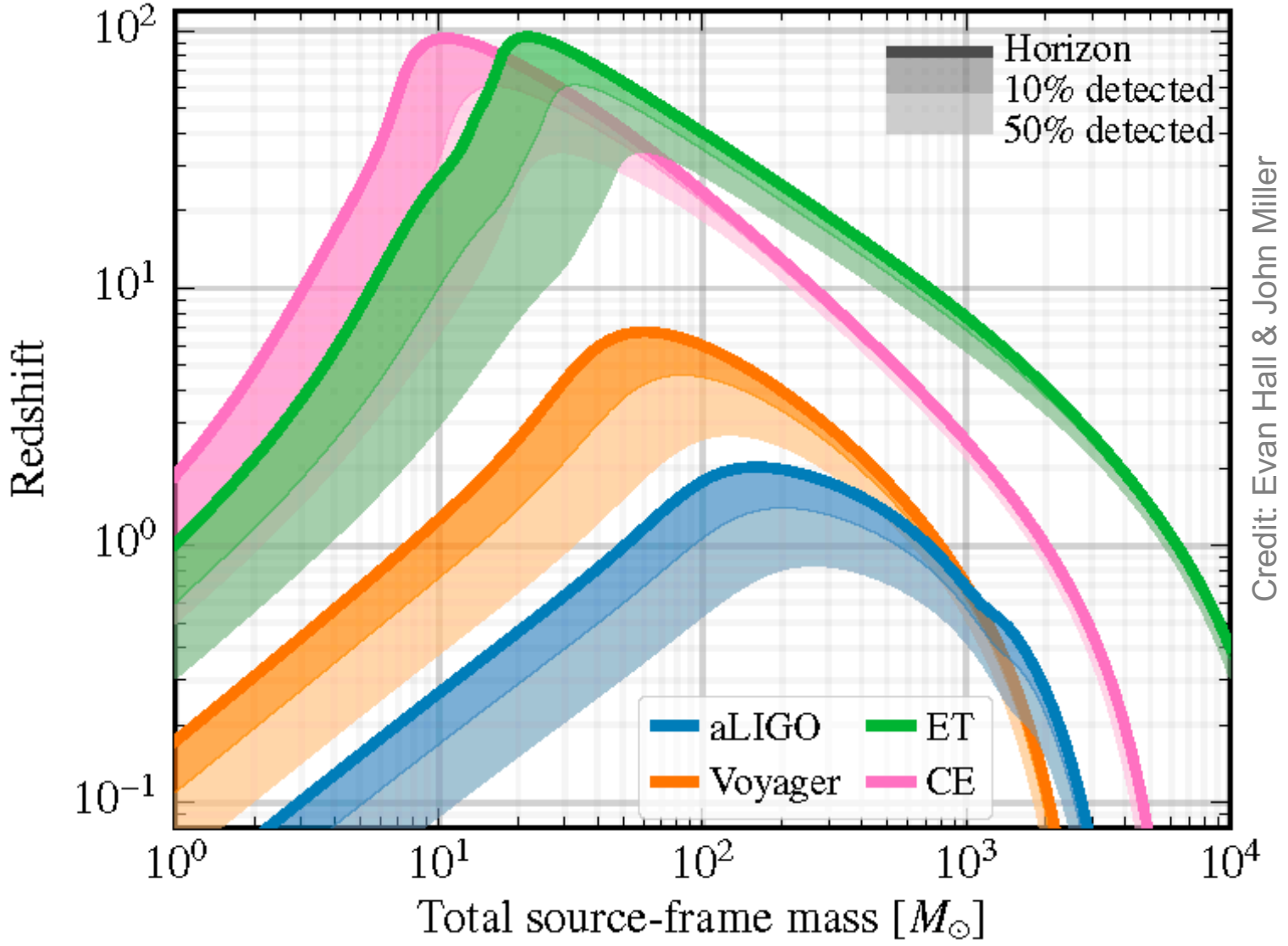


Plans in the United States: Cosmic Explorer

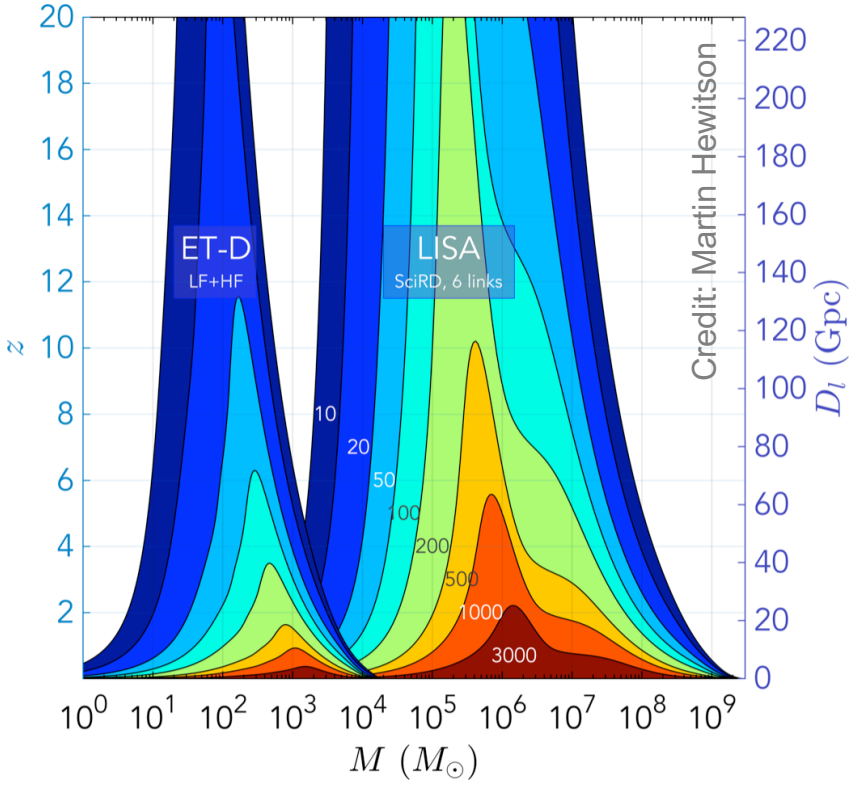


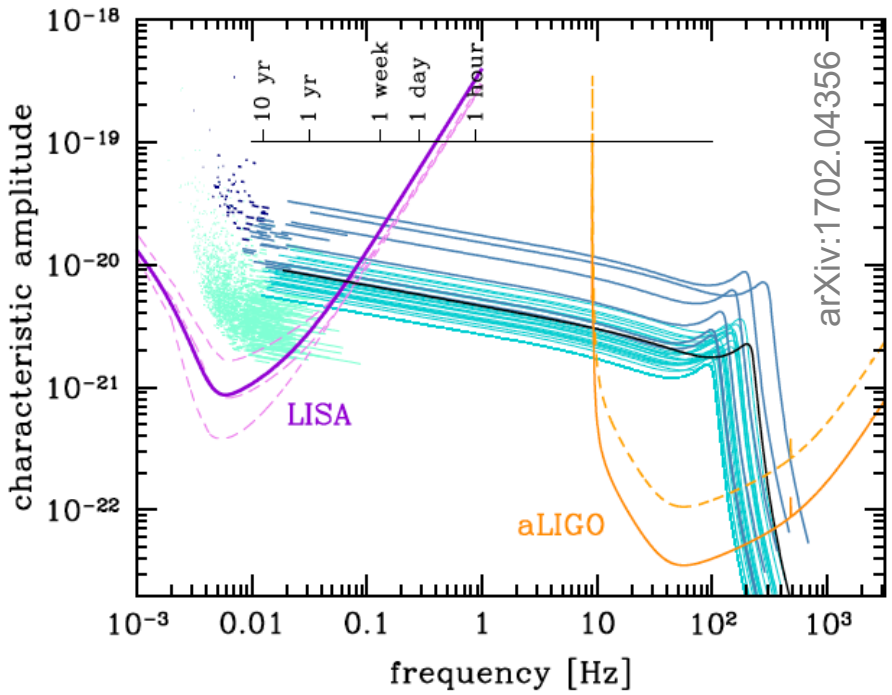
- 40 km arm length
- (Mostly) above ground
- Single L-shaped detector
  - Or two, in different locations
- Partially cryogenic
- Recent idea (after first detection)
- Together with ET: **sky localization**

Plans in the United States: Cosmic Explorer



Advantages in having Einstein Telescope, Cosmic Explorer running at the same time as LISA





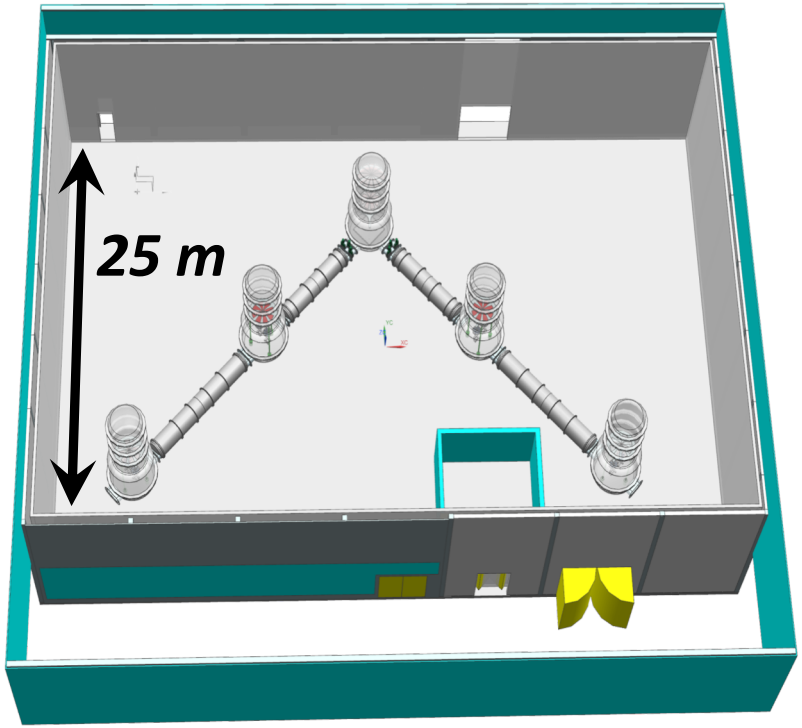
- LISA has a planned launch in 2034
- Make sure ET and CE have consistent timelines

Joint science case for ET and CE

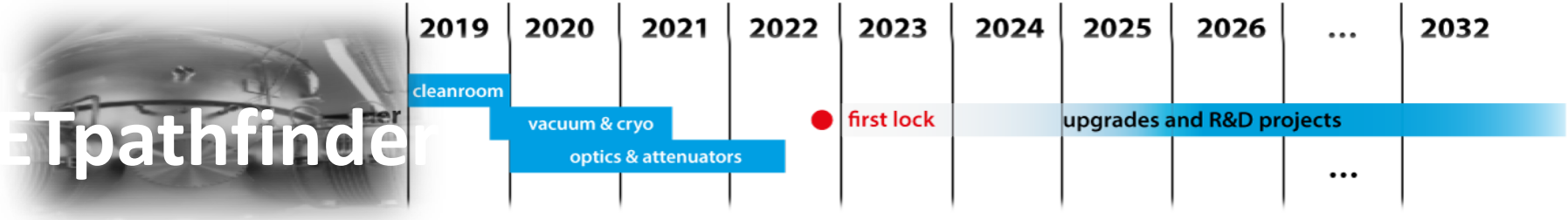
- Einstein Telescope Conceptual Design Study dates from 2011
  - How do we optimize a detector network that includes Cosmic Explorer?
  - Need to involve instrumentalists, data analysists, theorists: **community building/expansion**
- New science case document to be produced in 2019
  - Under aegis of the Gravitational Waves International Committee (GWIC)
  - October 2018: meeting of the writers and editors in Potsdam, Germany
  - Significant Dutch presence/input

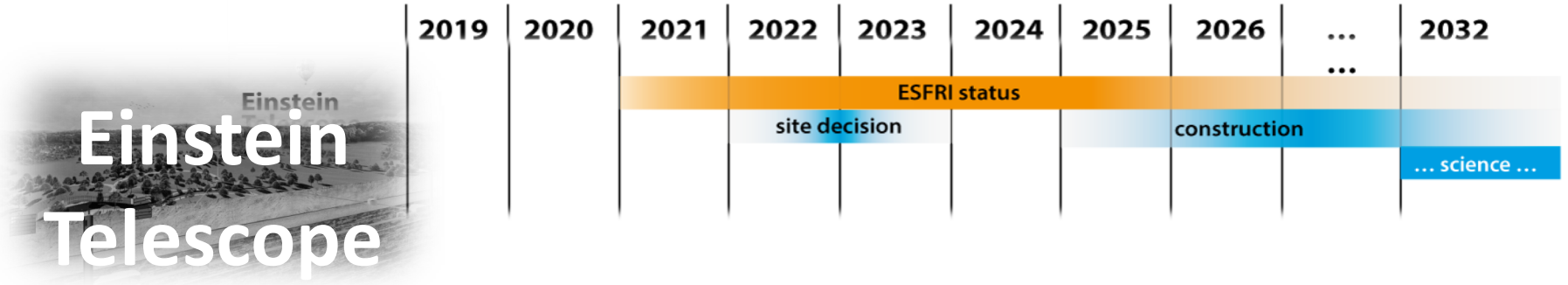
ETpathfinder in Maastricht

- R&D facility
- 20 meter interferometer
- Funded through Belgian-Dutch-German “Interreg” project
- Possible lab location found in Maastricht



Desirable timelines

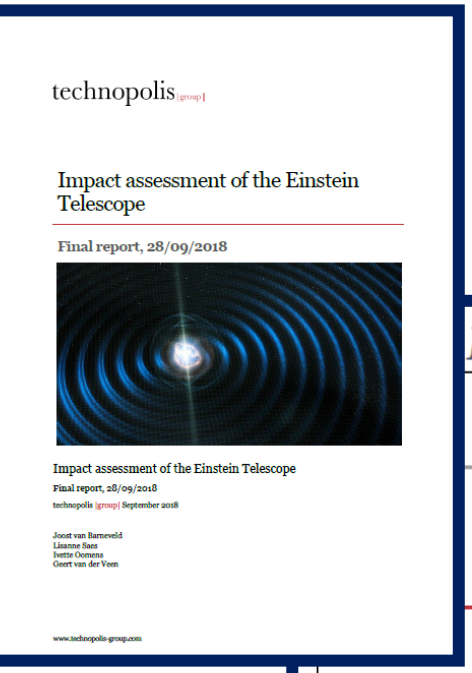




Einstein Telescope in Europe and Belgium/Netherlands/Germany

- April 2018: the ET Collaboration!
  - Letter of Intent: http://www.et-gw.eu/index.php/letter-of-intent
  - Now ~600 members

- Belgium/Netherlands/Germany, September 2018:
  - MoU between all Belgian universities, many Dutch, some German



Impact study for the Eindhoven-Leuven-Aachen triangle

Impacts of ET investment

	ETpathfinder	Einstein Telescope (ET)	
Scenarios	ETpathfinder	ET-ELAt	ET- elsewhere
Investments (rough estimate**)	Limited (M€10-30)	Very large (M€400-700)	Large (M€100-325)
Operational costs (rough estimate**)	M€0,1-0,2/y	M€ 10-20/y	M€7-13/y
Regional economic effects	Limited	Large	Limited
Organisational impact	Can be fairly large	Very Large	Large
Visibility, reputation	Limited	Large	Limited
Scientific impact	Limited	Very Large	Large
Innovation impact and long term economic impacts	Possibly large	Possibly very large	Possibly very large

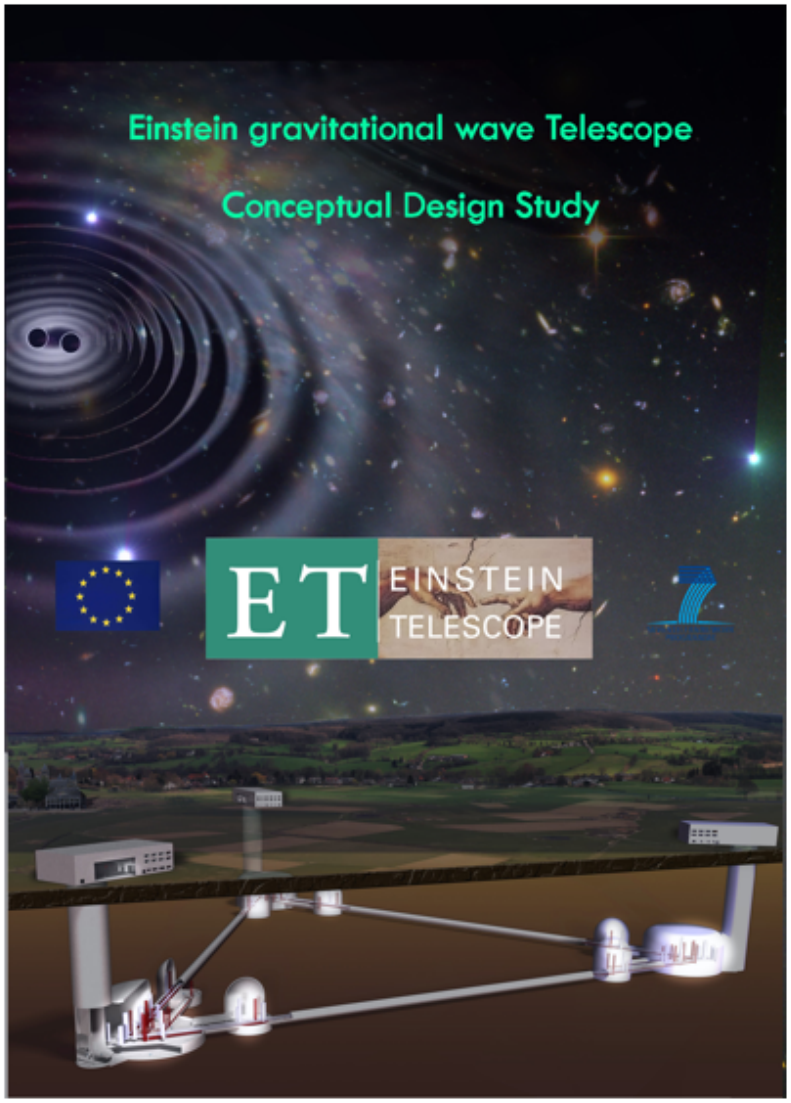
Roadmaps

ET 1 out of 33

ET 1 out of 13

ET "game changer"

What next?



ESFRI

2020

- Technical design study needed
  - Detailed cost scrutiny
  - Realistic exploitation cost estimate
- Governance structure
  - Management structure of the ET Collaboration to be finalized early 2019
- ET proposal for 2020 update of **ESFRI roadmap**
- Decision in ~2021 whether to submit a joint Belgian-Dutch-German bid for **hosting Einstein Telescope in the Eindhoven-Leuven-Aachen region**