# Exploring the future of Virgo

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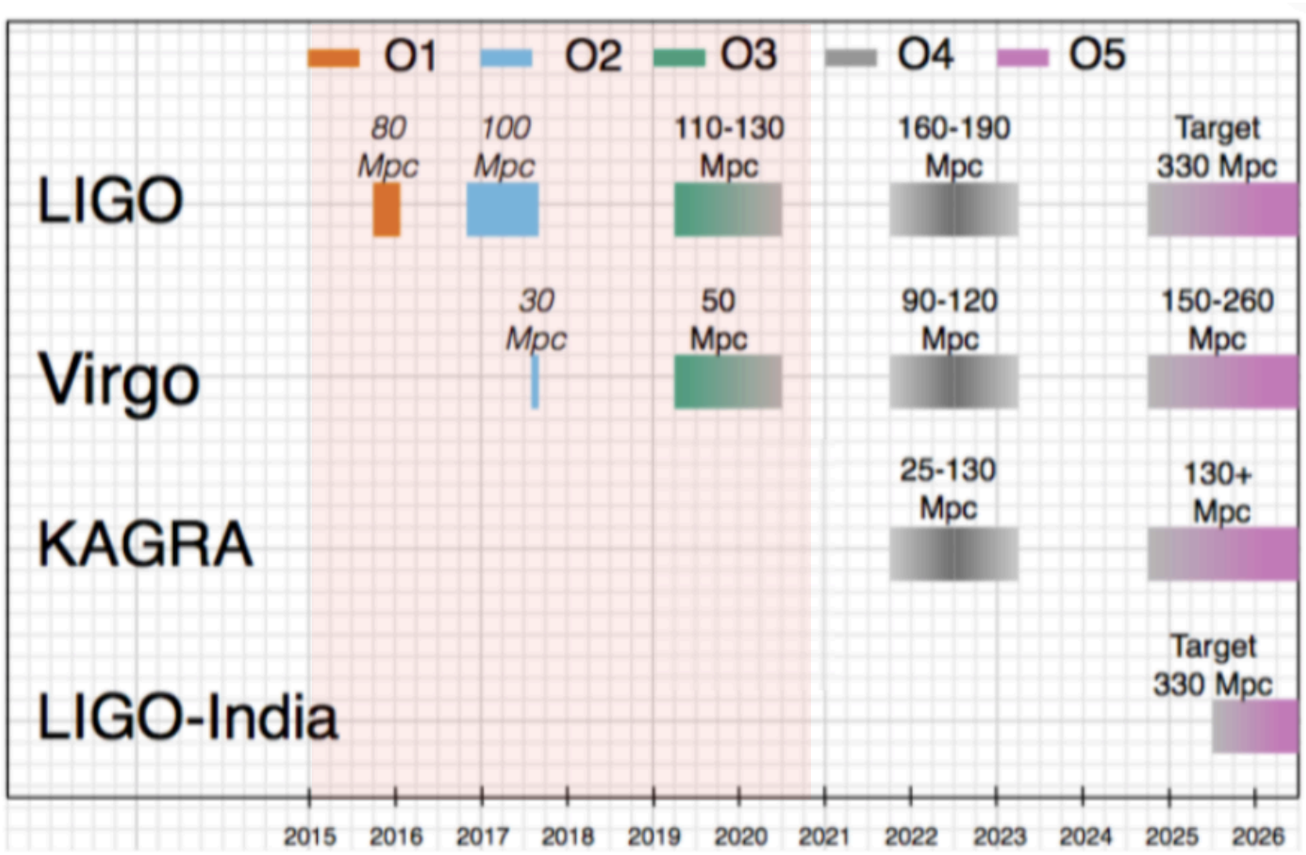
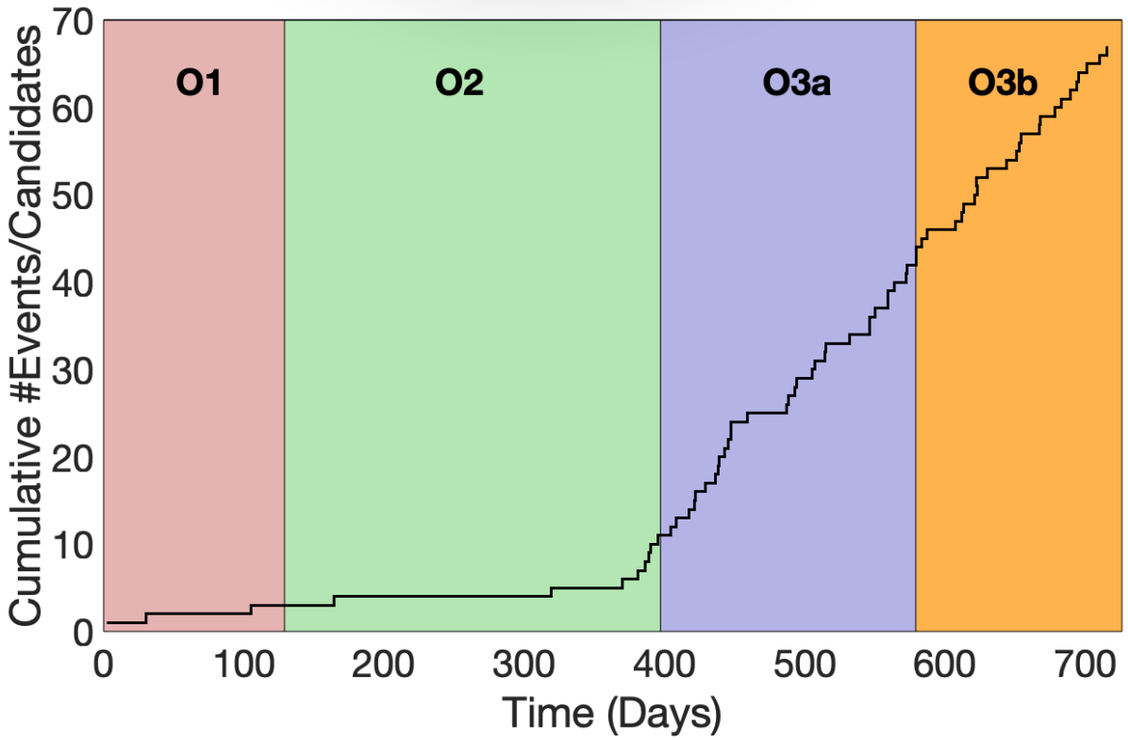
Exploratory project proposal - Scientific Committee meeting 16 nov 2020

# GW detector network: state of the art

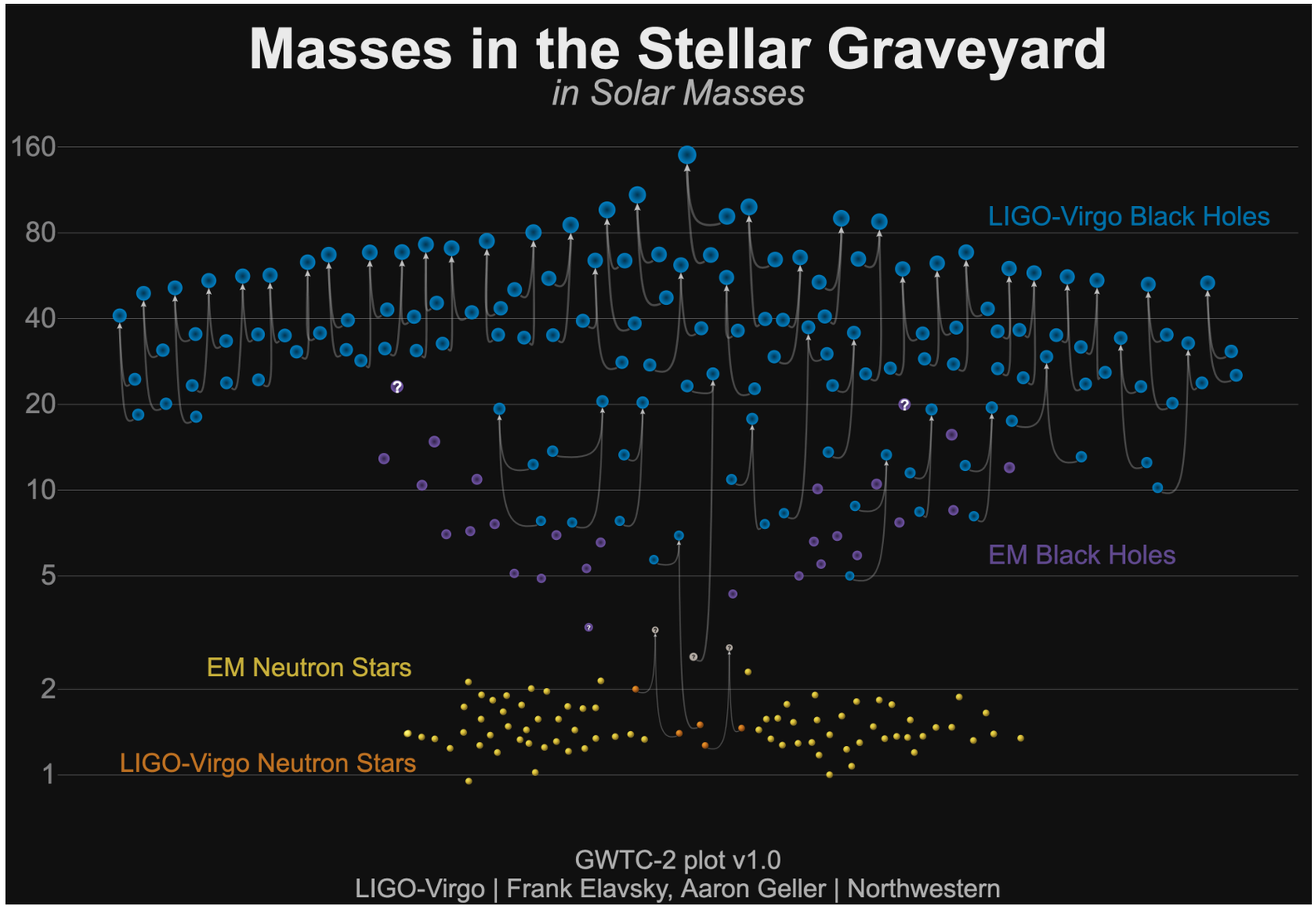




- 2G network: Virgo, LIGO and KAGRA
- 3 observation runs performed



# Observations summary




**O1-O2 (2015 - 2017)**

- 11 detections (10 BBH, 1 BNS)
- GWTC-1 first catalog of GW transient sources (2019)

**O3a (2019)**

- 39 detections
- GWTC-2 second catalog of GW transient sources just published

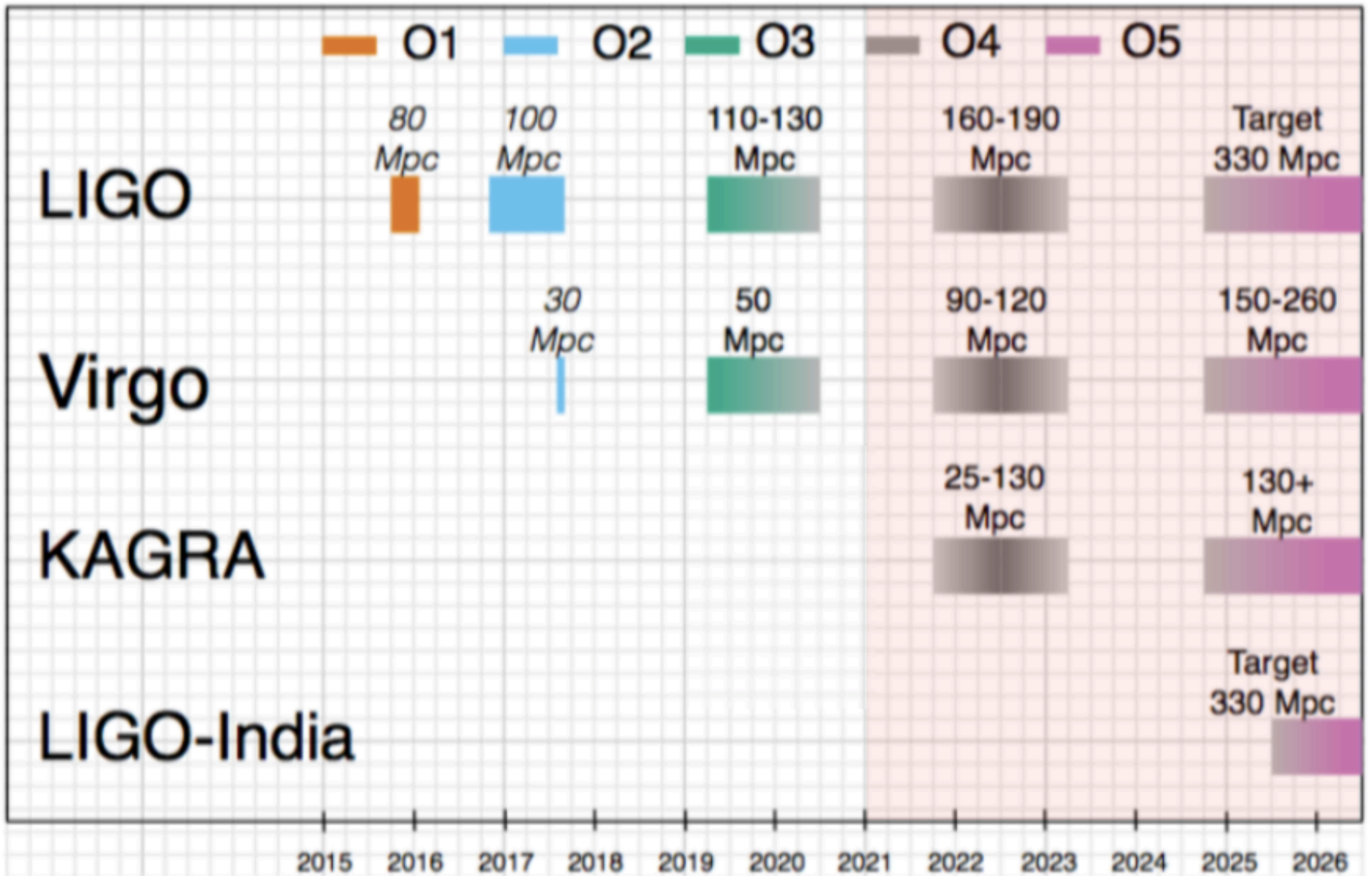
**O3b (2019 - 2020)**

- 30 alerts
- Analysis on-going

# Scientific results from GW detections so far

- General Relativity
  - Test of GR in strong field regime
  - Properties of GW in agreement with GR
- Astrophysics and cosmology
  - Compact binary parameters (mass, spin, rate)  and populations
  - First observation of an intermediate mass black hole
  - Detection of EM counterpart (and associated phenomena) thanks to sky-localization
  - Origin of short gamma-ray burst and heavy elements
  - Independent measurement of Hubble constant
  - Constraints on neutron stars equation of state

# Near future observation plan



# Near term upgrades: AdVirgo+ and ALIGO+

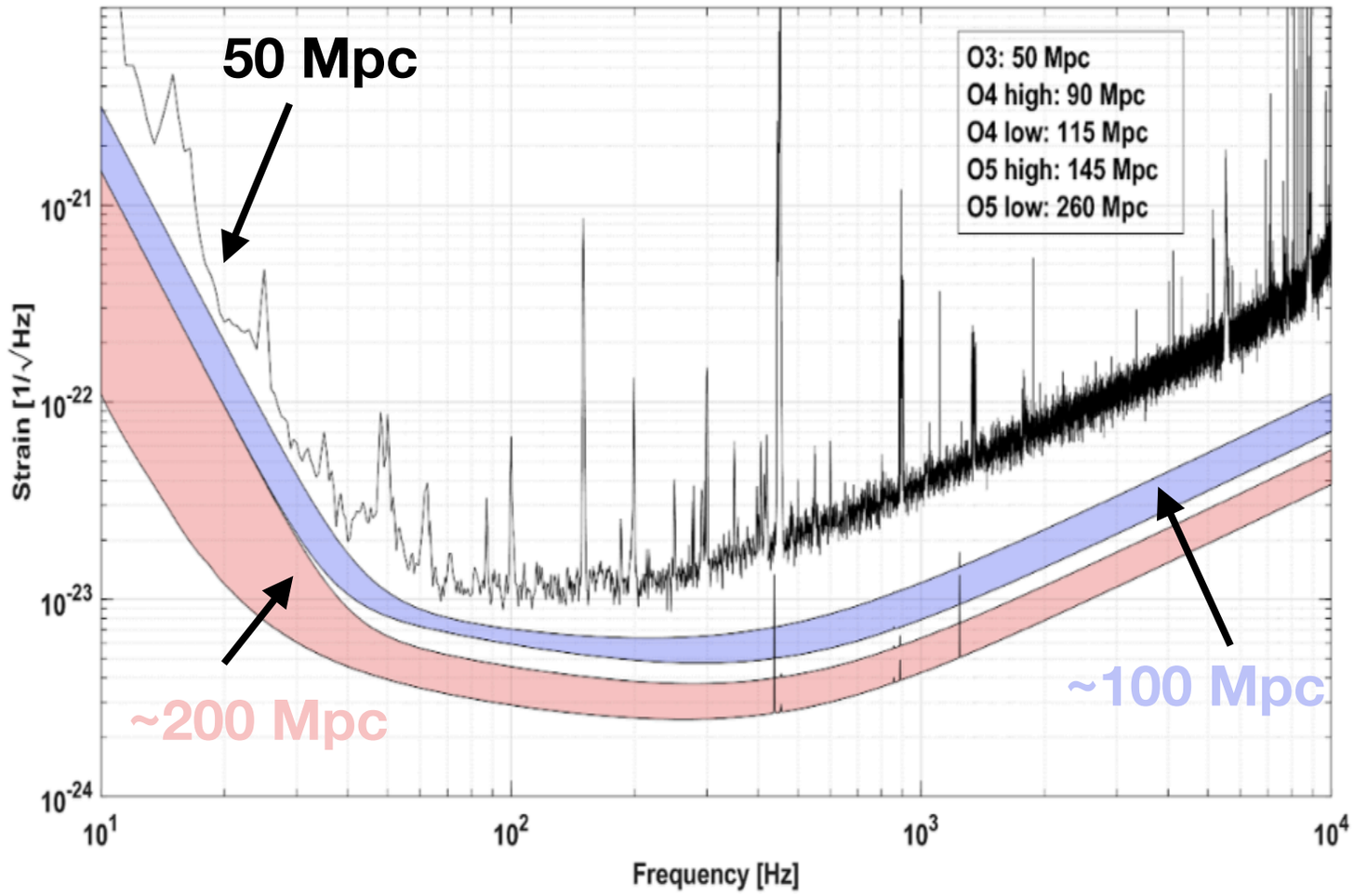
## AdVirgo+

**PHASE I (04) - up to 2023**

- Reduction of quantum noise

**PHASE II (05) -up to 2026**

- Reduction thermal noise

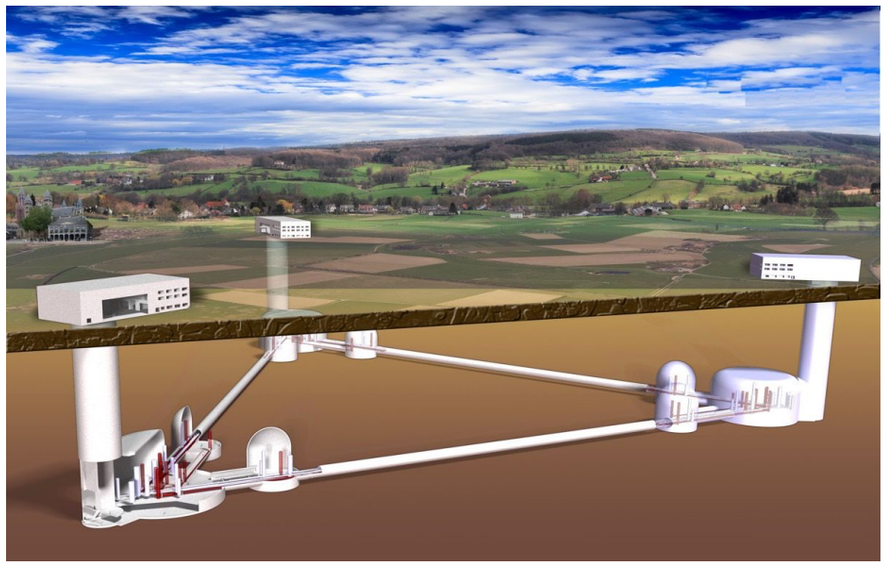


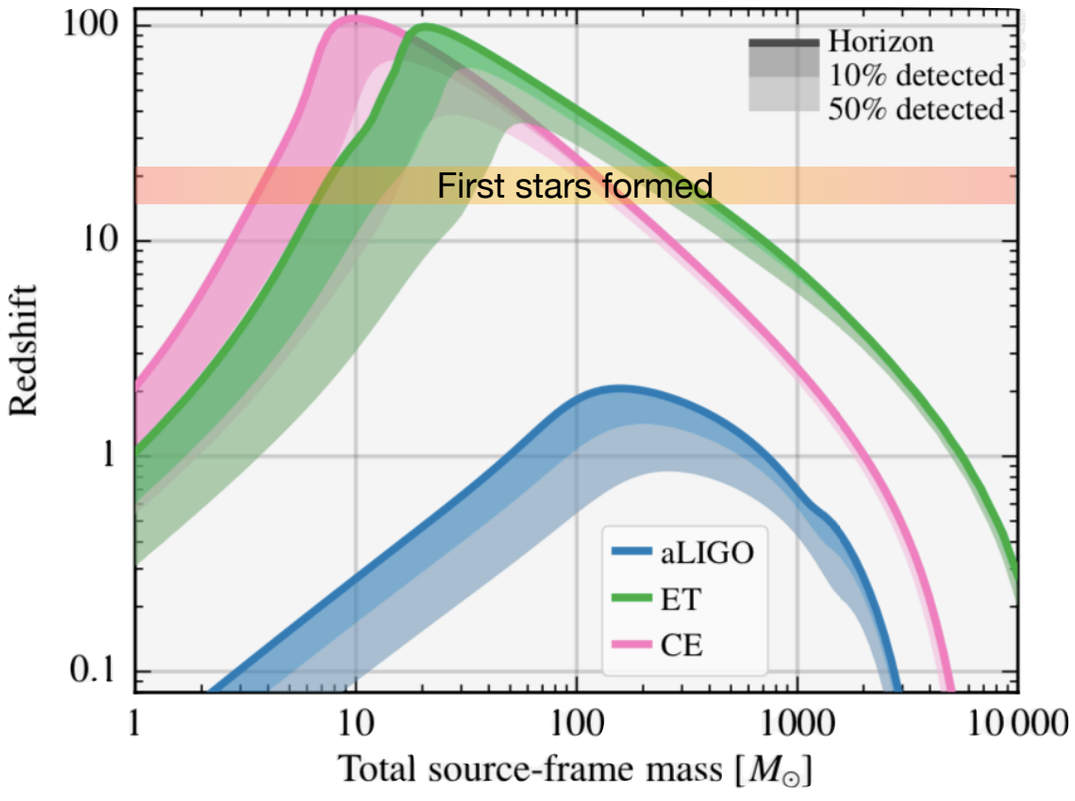

- LIGO upgrade A+ with the same schedule
- KAGRA online with a better sensitivity (>25 Mpc)
- LIGO India is expected to join the network in 2025
- ~1000 detections per year expected during O5

**What's next?**

# 3G detectors: Einstein Telescope and Cosmic Explorer

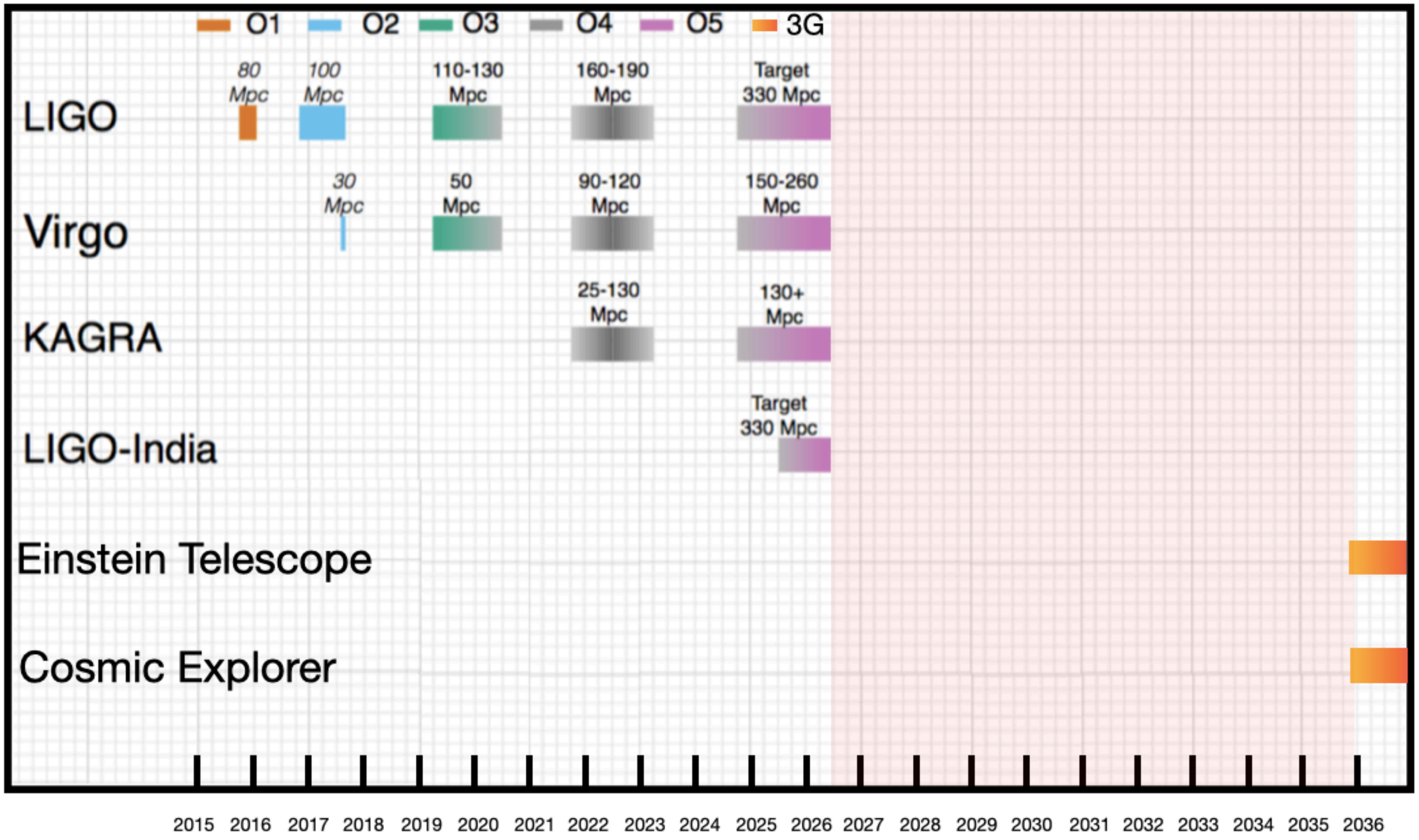
- Target: tenfold improvement in the sensitivity with respect to 2G
- **ET**: 10 km, xylophone configuration, cryogenic, underground
- **CE**: scale LIGO to 40 km





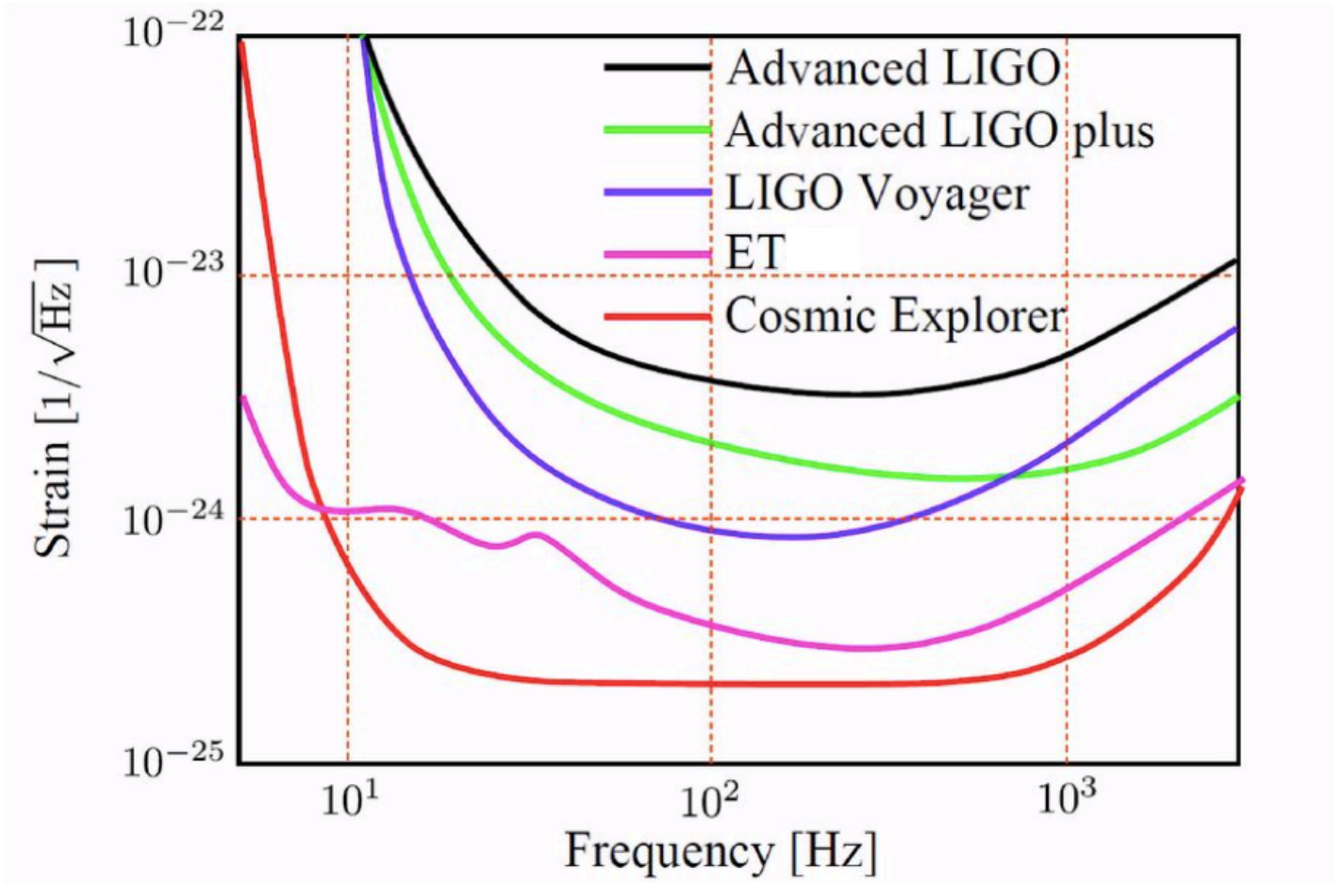

- 3G data **taking will start in 2036** at the earliest

# Near future observation plan



# LIGO Voyager

- Intermediate step on the way to ET/CE network
- Use of LIGO infrastructure
- 3G technologies (cryogenic, different wavelength)
- Operation expected in the early 30 and continue in parallel with Cosmic Explorer




What about Virgo?

# Goal of the project: exploring Virgo's possibilities after O5

Many questions to be answered

**Science**

- Which are the scientific targets within the reach of a 2G network after O5?
- What can be the contribution of Virgo?

**Instrument**

- What are the possible upgrades for the instrument?
- Should we focus on the R&D in preparation for ET?

# Contributions to the science

- Observe further away (higher redshift)
  - Improve cosmological parameters estimation
- Increase the total number of signals
  - Population studies
  - More stringent constraints on the binary evolution scenarios
- Higher SNR and post-merger signals
  - Neutron star equation of state
  - General relativity tests
- Better localization for multi messenger astronomy
- Possible other sources (e.g. supernovae)

# Instrument upgrades

What is the best upgrade strategy?

- Optimization of the sensitivity with current technologies and configuration (back scattering mitigation, higher power, loss reduction..)
- Testbed for ET: cryogenic operation, new wavelengths..
- High-frequencies detector: optimized for post merger signals
- Continue the data taking to accumulate statistics and possibly exploit multi messenger opportunities

# Methodology and deliverables

- Local working group gathering people with different expertise (theory, data analysis and instrument) to tackle both science case and instrument upgrades

- The team will work in close relationship with Virgo-LIGO- KAGRA collaborators

- Organization of workshops and invitation/visit of experts for joint work and discussions

- Two stages (for the first year):

    1. Neutron star oscillation modes signature in GW (LUTH)
    2. Sensitivity simulation for different possible configurations (APC)

At the end of the project we expect to deliver a document where **different post O5-scenarios for Virgo are quantitatively evaluated** in term of their impact on the science and their practical feasibility

# Work-package personnel

| Name | Lab | Grade / Employer | Expertise |
|---|---|---|---|
| Eleonora Capocasa | APC | MCF UdP | Instrumentation |
| Matteo Barsuglia | APC | DR CNRS | Instrumentation |
| Eric Chassande-Mottin | APC | DR CNRS | Data analysis and population studies |
| Sylvain Chaty | AIM/APC | Prof UdP | Population studies and binary evolution |
| Danièle Steer | APC | Prof UdP | Cosmology |
| Simone Mastrogiovanni | APC | Postdoc APC | Cosmology |
| Micaela Oertel | LUTH | DR CNRS | Neutron-star and supernova physics |
| Jérôme Novak | LUTH | DR CNRS | Neutron-star and supernova physics |

# Budget request - 1st year

| Item description | Required budget |
|---|---|
| 2 long internships (LUTH and APC) | 6 k€ |
| Missions for WP members, organization 2 workshops, invitation of colleagues from KAGRA, LIGO, Virgo | 6 k€ |
| Total costs | 12 k€ |

# Summary

- The GW astronomy has already brought a wealth of scientific results and more are expected in the future
- Current plan: 10 year gap in the data taking for the European detectors (2026-2036)
- This project aims to create a local team to explore how to exploit at best Virgo after 2026
- The team work both on the science and instrumental aspects in close relationships with Virgo, LIGO and KAGRA collaborators
- It is expected to deliver a document where different post-O5 scenarios are evaluated in term of scientific impact and technical feasibility

# BACK UP SLIDES

# Budget request - 2nd year

| Item description | Required budget |
|---|---|
| 2 long internships (LUTH and APC) | 6 k€ |
| Missions for WP members, organization 2 workshops, invitation of colleagues from KAGRA, LIGO, Virgo | 6 k€ |
| Consumables for the R&D lab activity at APC * | 8 k€ |
| Total costs | 20 k€ |

* Activity possibly selected according to the outcomes of the R&D review performed the first year

# Voyager - Cosmic Explorer timeline