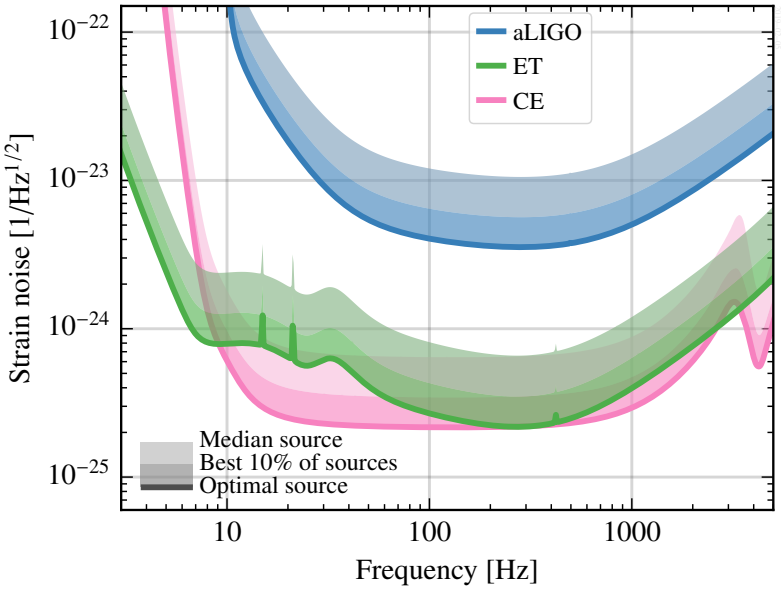
Einstein Telescope Observational Science Board (OSB)

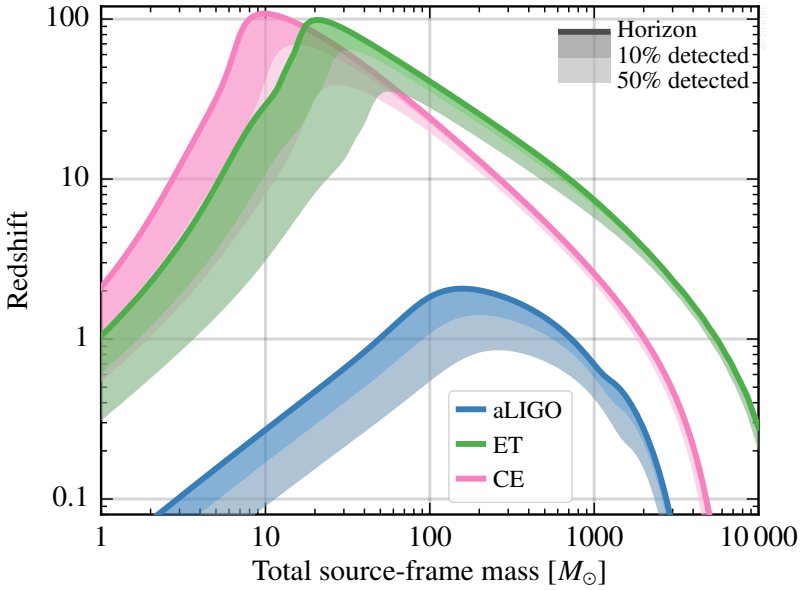
Marica Branchesi, Michele Maggiore, Ed Porter

Plan of the presentation

- Overview of ET Science (MM)
- Multimessenger observations (MB)
- Data analysis and common tools (EP)

- Structure and purpose of the OSB
- What it means to become member of the OSB





Evans and Hall 2019

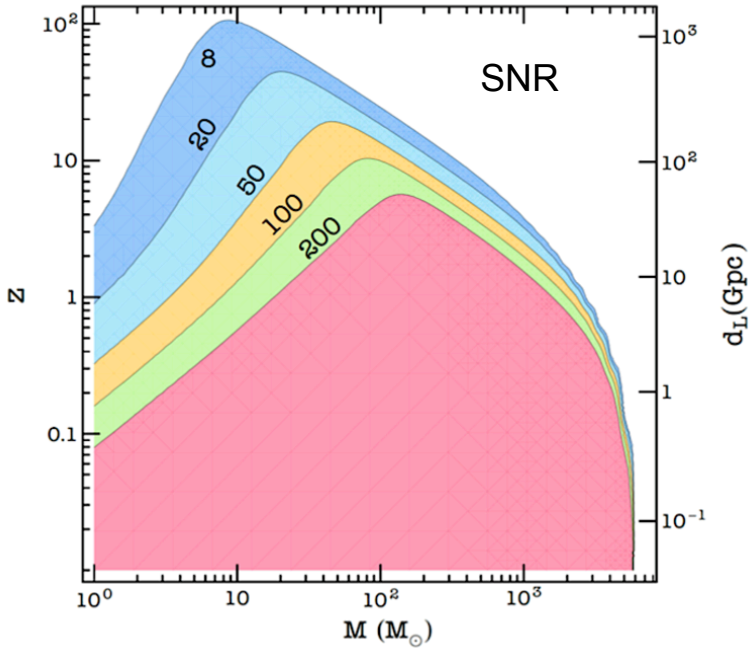
- BBH up to z ≈ 50 !!

  10^6 BBH/yr

  masses up to 10^3 $M_\odot$
- BNS to z ≈ 2 10^5 BNS/yr

  (possibly O(10-100/yr)

  with counterpart)
- high SNR



Detection distance of BBHs

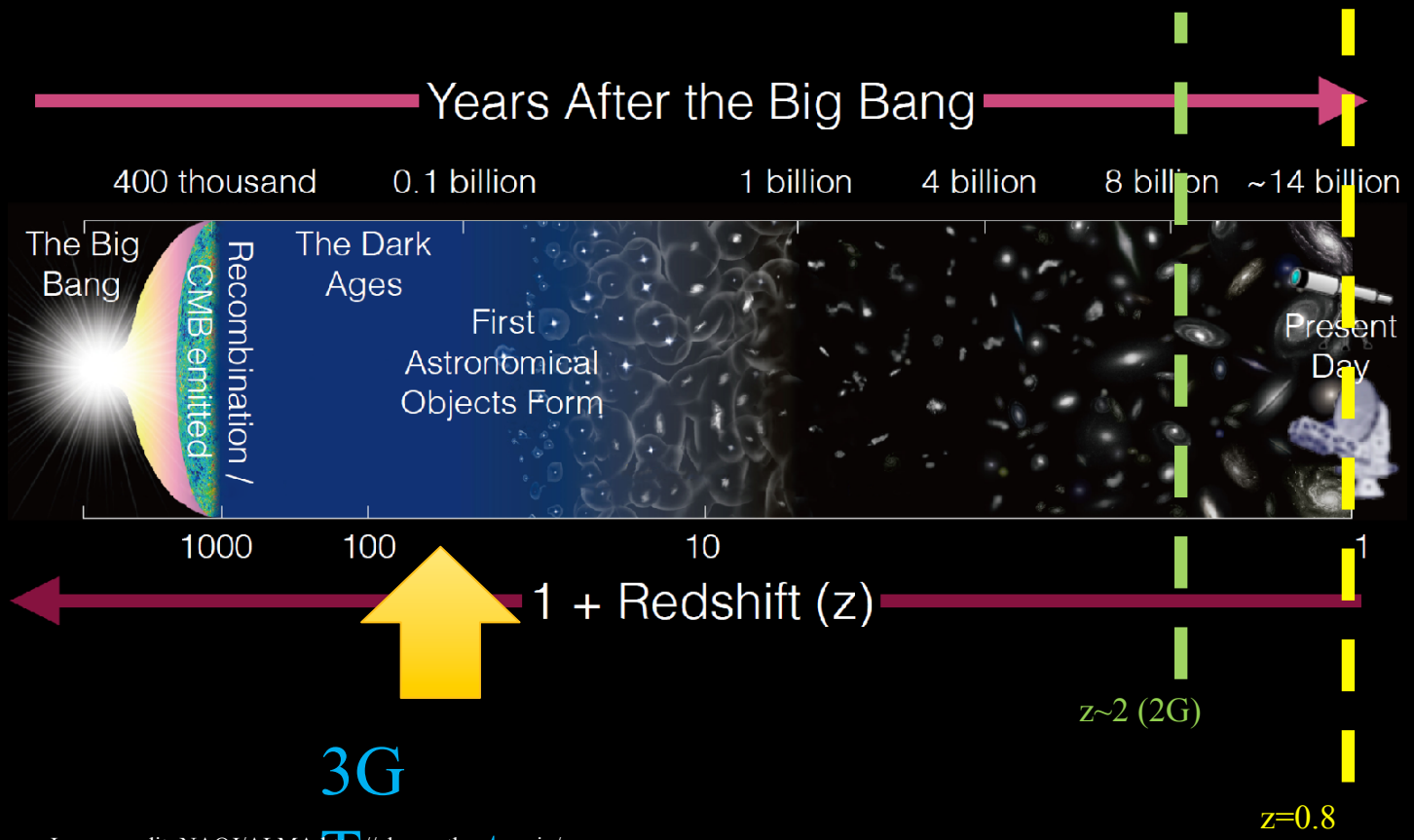


Image credit: NAOJ/ALMA http://alma.mtk.nao.ac.jp/

The combination of

- distances and masses explored
- number of detections
- detections with very high SNR

will provide a wealth of data that have the potential of triggering revolutions in astrophysics, cosmology and fundamental physics

A summary of the Science of ET

Astrophysics

MM et al. ``Science Case for the Einstein Telescope", 1912.02622, JCAP 2020

- Black hole properties
  - origin (stellar vs. primordial)
  - evolution, demography
- Neutron star properties
  - demography, equation of state
- Multi-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

- testing the nature of gravity
  - perturbative regime

    inspiral phase of BBH, post-Newtonian expansion
  - strong field regime

    physics near BH horizon

    exotic compact objects

- QCD

  interior structure of neutron stars probe:
  - QCD at ultra-high temperatures and densities
  - exotic states of matter

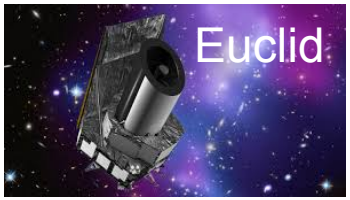
- Dark matter/new particles
  - primordial BHs
  - axions, dark matter accreting on compact objects

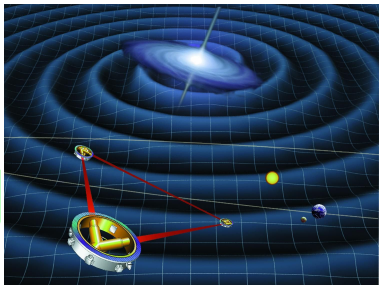
- Dark energy and modifications of gravity on cosmological scales
  - DE equation of state
  - modified GW propagation

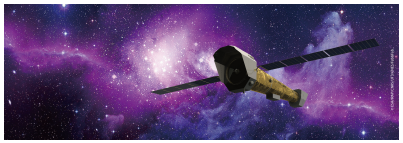
- Stochastic backgrounds of cosmological origin and connections with high-energy physics
  - inflation
  - phase transitions
  - cosmic strings
  - ...

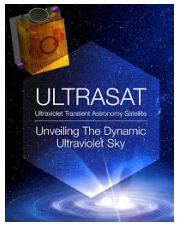
and we should not forget that ET will be a `discovery machine': expect the unexpected!

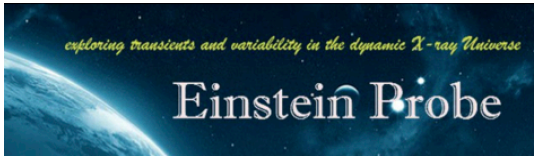
Multi-band and -messenger Observations

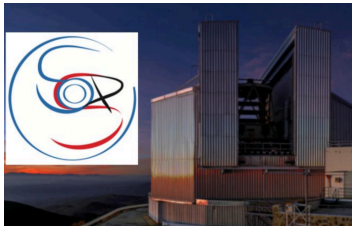


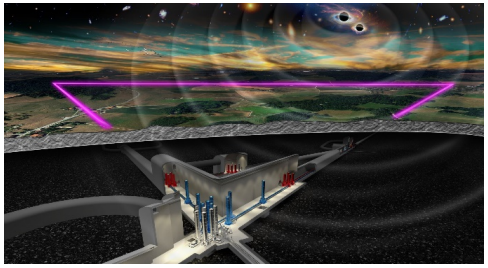


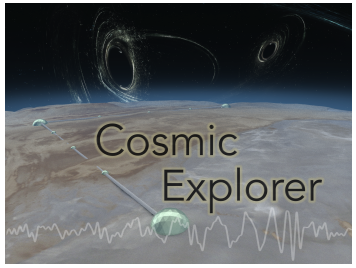


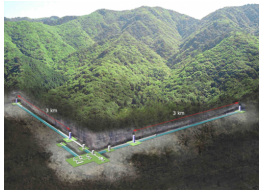


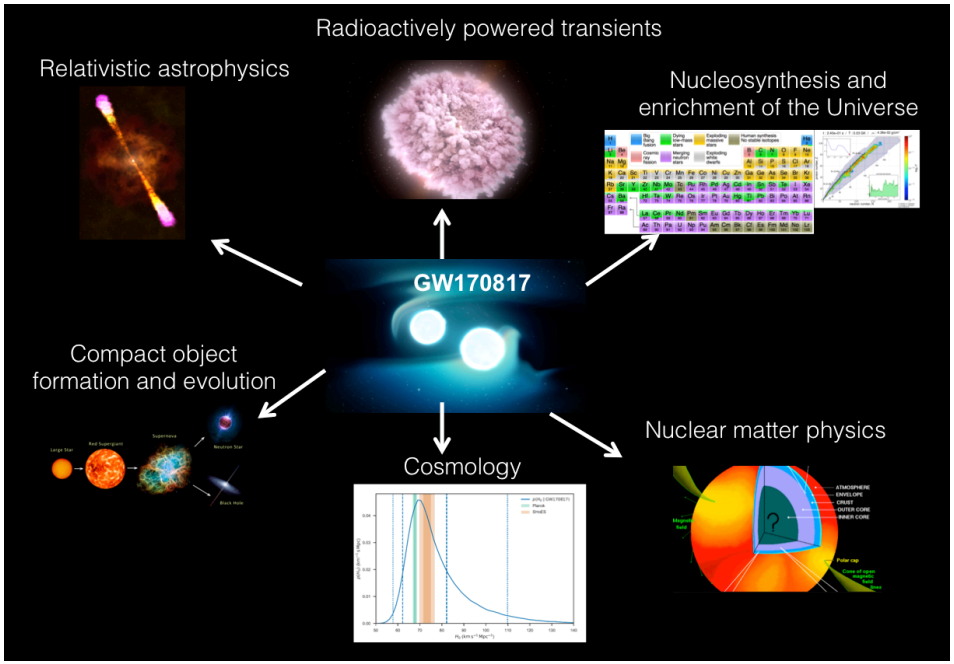












- Large increase of detection rate
  - population of BNS/NSBH/BBH
  - detections along the cosmic history
- Better parameter estimation

- Higher chance to detect other sources and counterparts: core-collapse SN, new-born neutron stars, magnetars, FRBs, neutrinos

Kilonova/GW - EOS constraints

Kilonova/GW - Nucleosynsthesis

GRBs – BNS/NSBH merger up to high z

Relativistic jet properties

Jet-less/jet GRBs

GRB/stable NS remnant

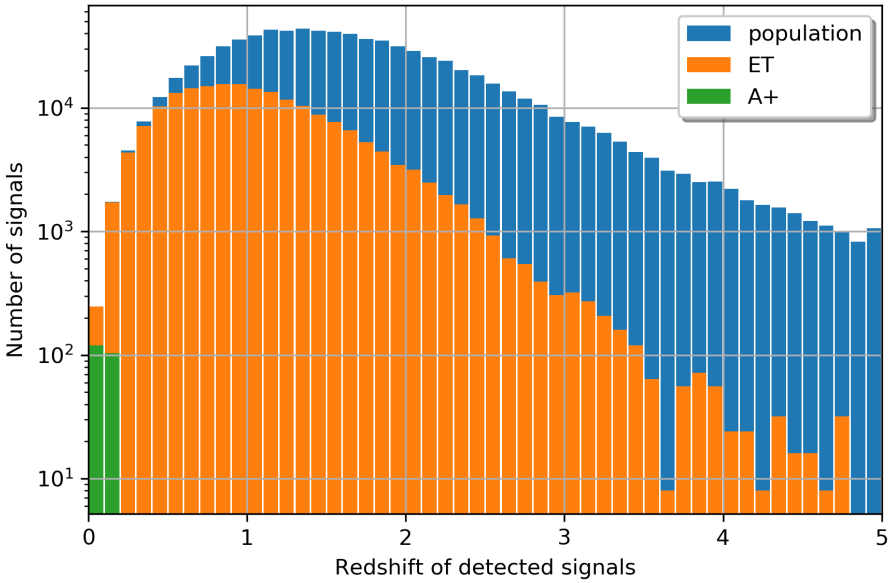
Link to Star Formation History

Emission mechanism

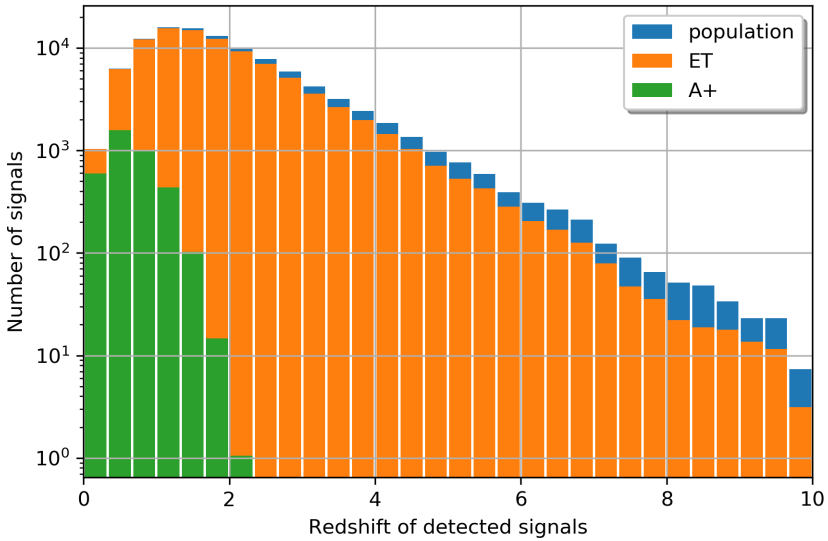
Cosmology

COMPACT OBJECT BINARY POPULATIONS

BINARY NEUTRON-STAR MERGERS



BINARY BLACK-HOLE MERGERS

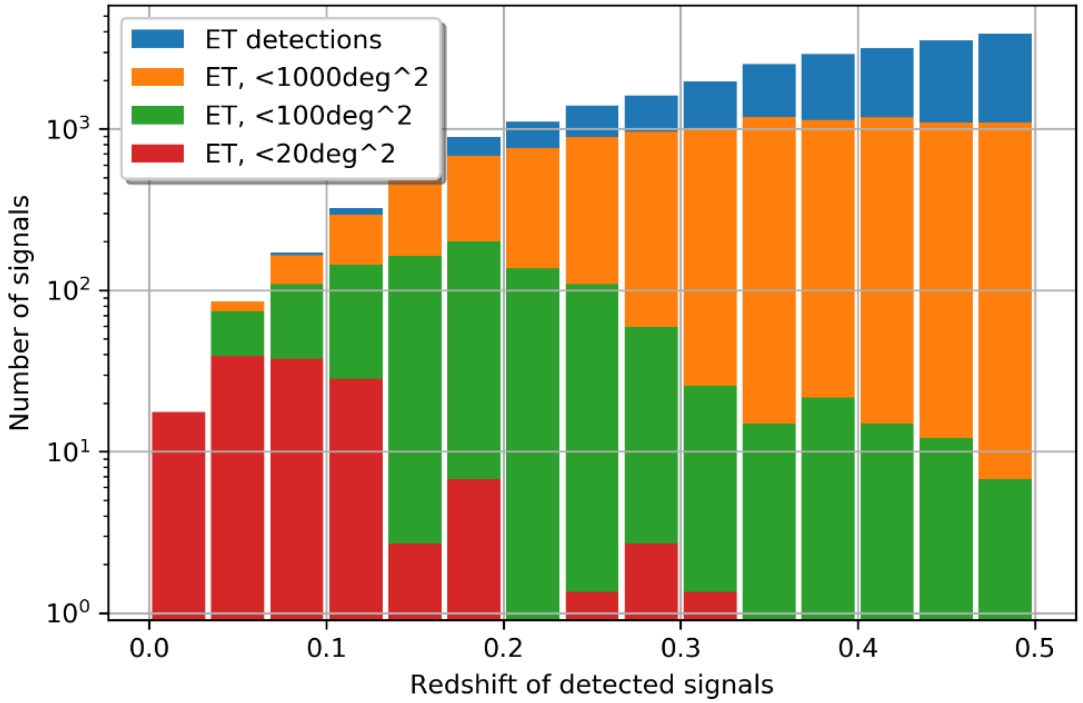


Sampling **astrophysical populations** of binary system of compact objects along the cosmic history of the Universe

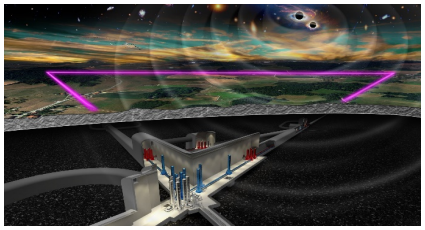
10^5 BNS detections per year

10^5 BBH detections per year

ET sky-localization capabilities

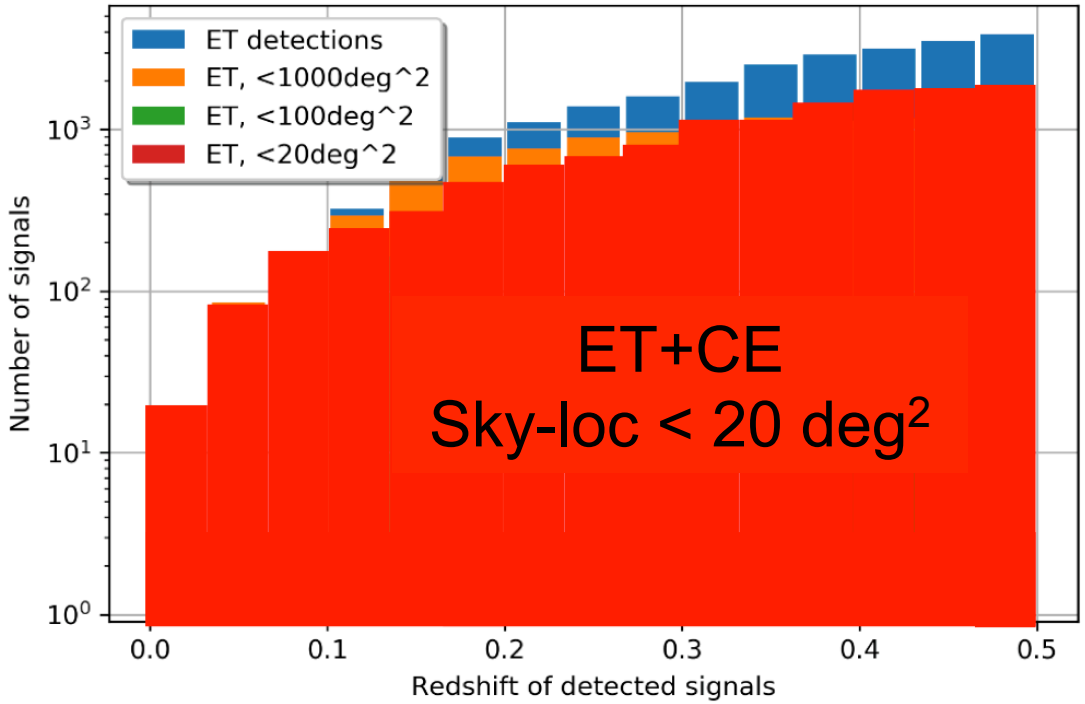


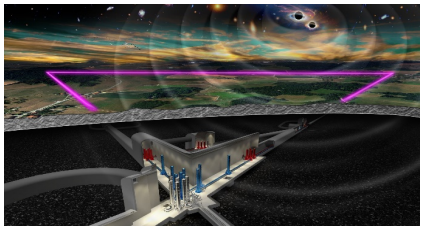
1 year of observation

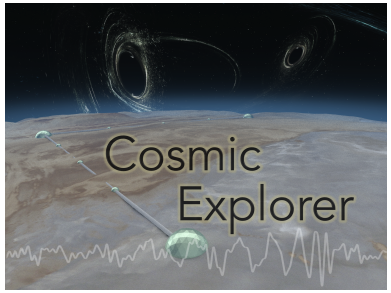


- 100 detection per year with “well” sky-localization < 20 sq. degrees
- early warning of hours-minutes

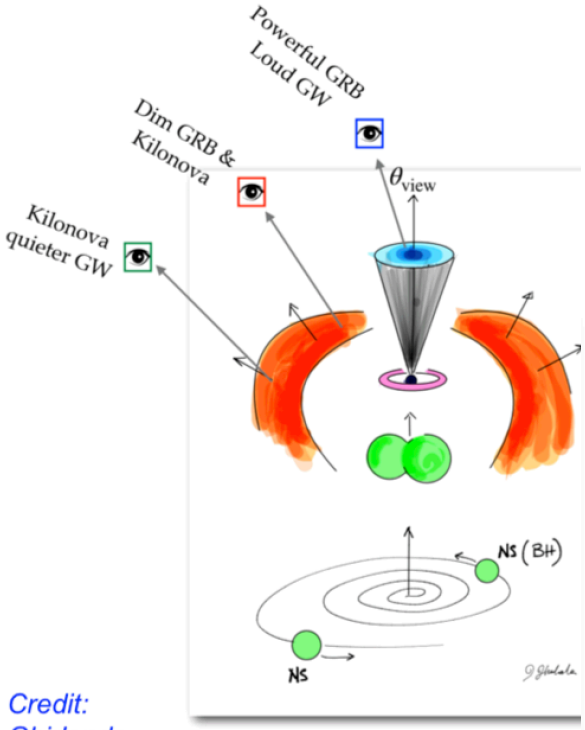
Network sky-localization capabilities



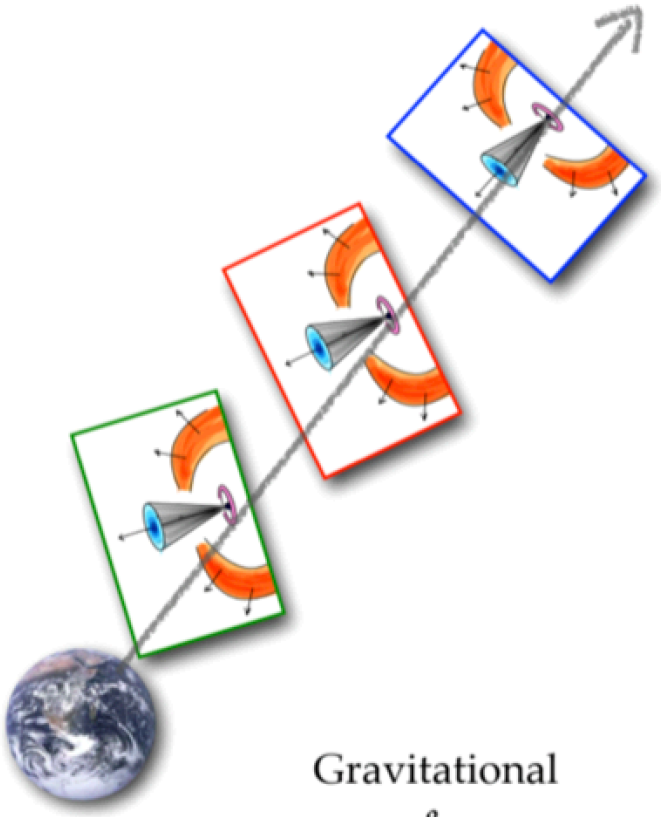




SEARCH PHASE: two regimes **nearby Universe** and **distant Universe**



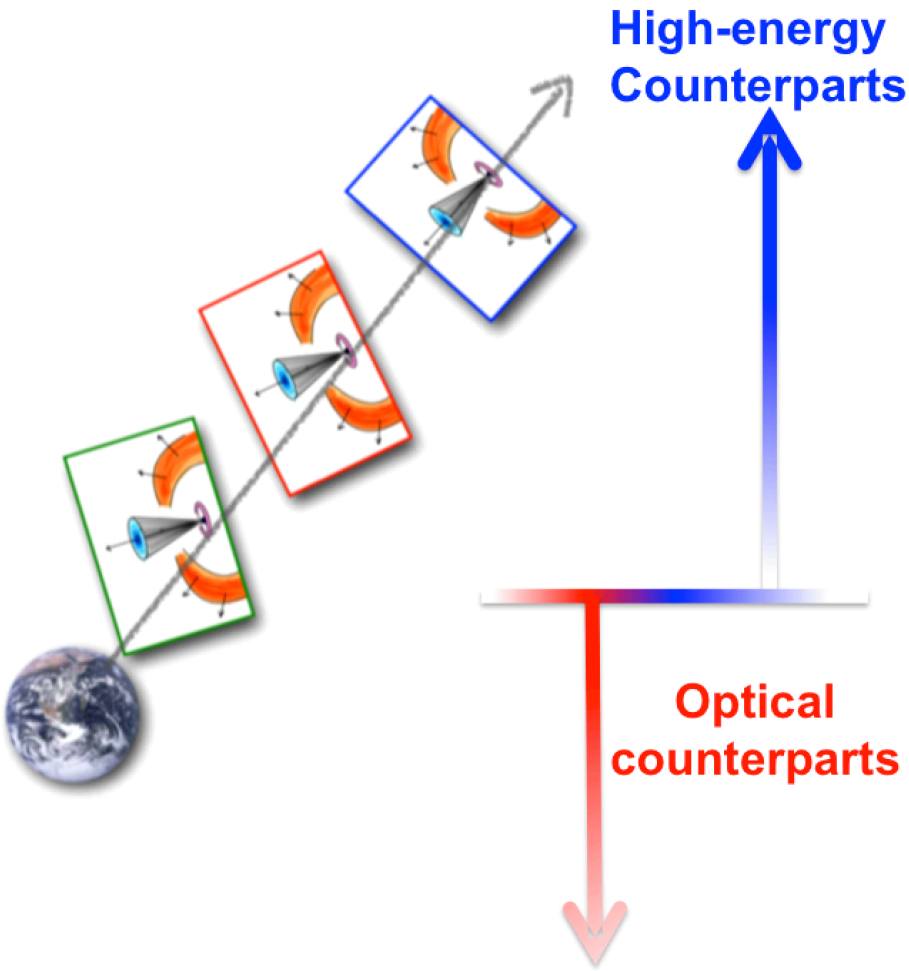
Credit: Ghirlanda



Gravitational
&
Electromagnetic
ranges

High-energy Counterparts

Optical counterparts



RELATIVISTIC JET PHYSICS,
GRB EMISSION MECHANISMS,
COSMOLOGY and MODIFIED GRAVITY

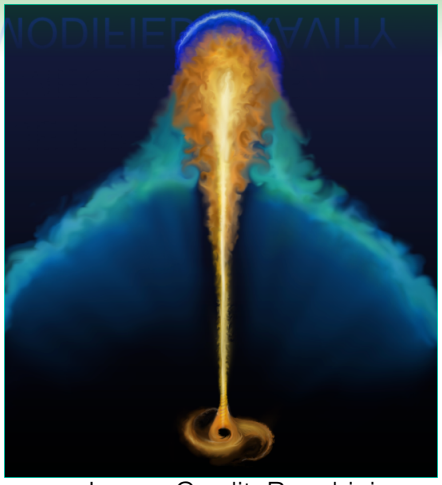


Image Credit: Ronchini

KILONOVA PHYSICS,
NUCLEOSYNTHESIS, NUCLEAR
PHYISCS and H0 ESTIMATE

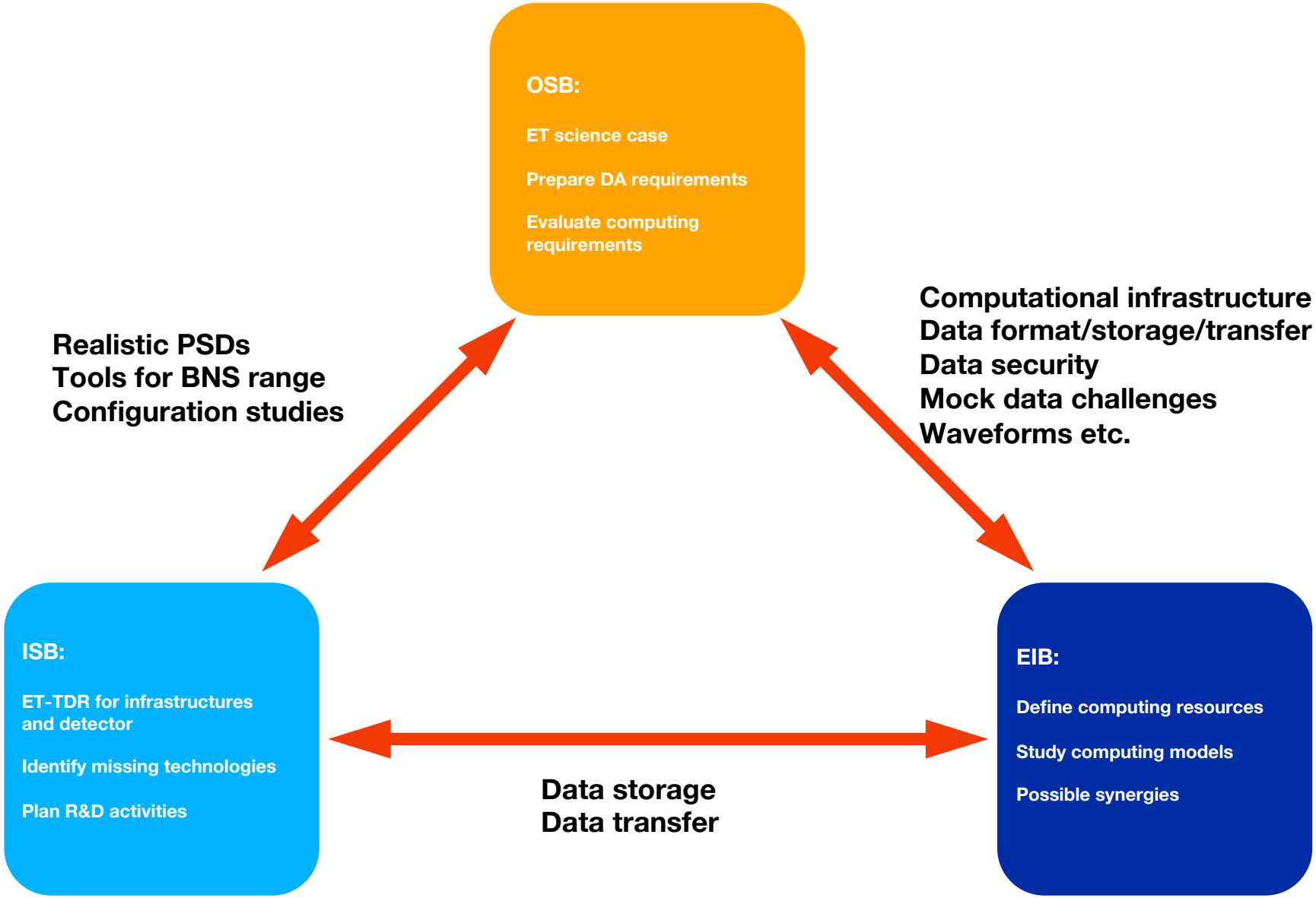
Image credit: NASA Goddard Space Flight Center

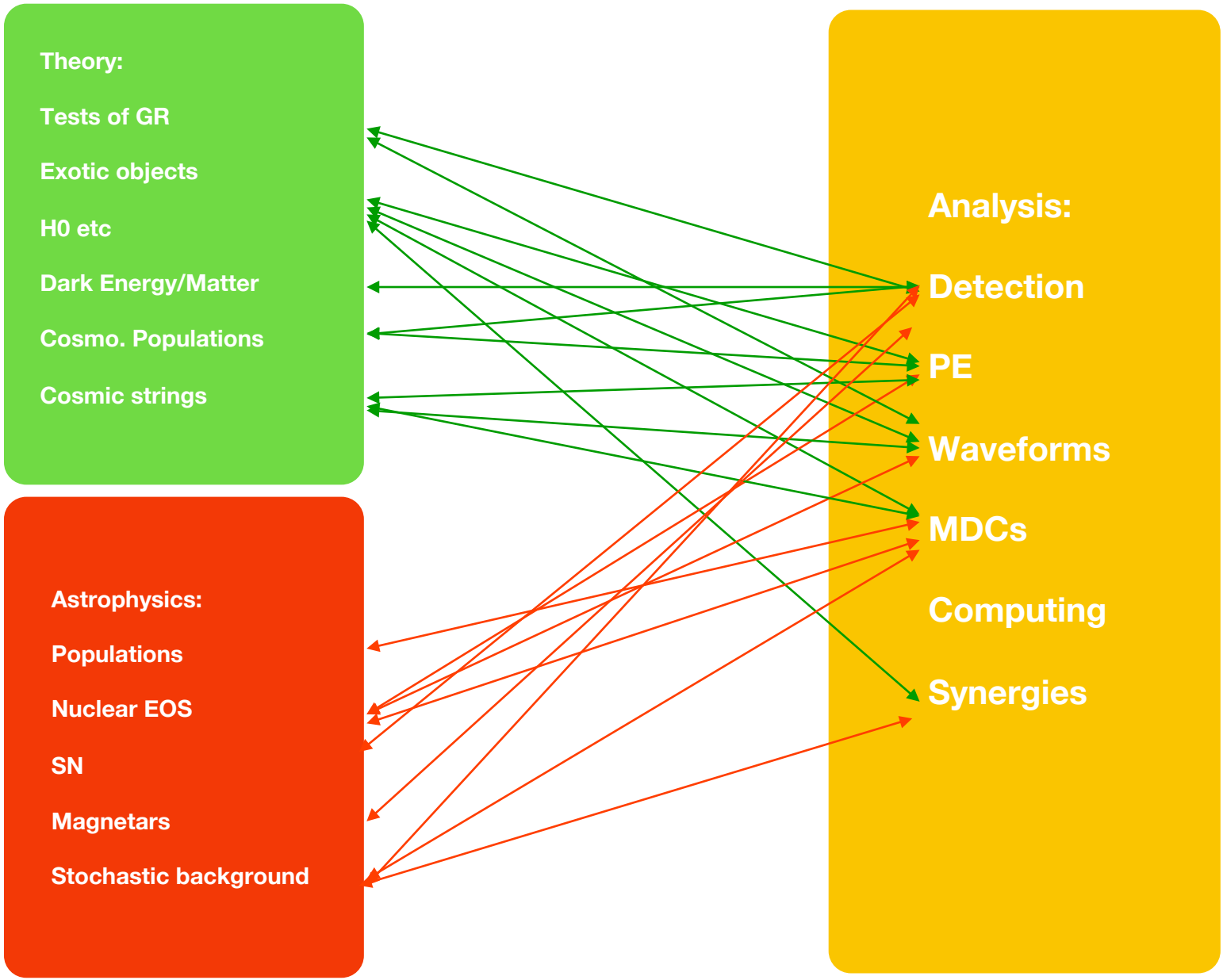
Data analysis and common tools

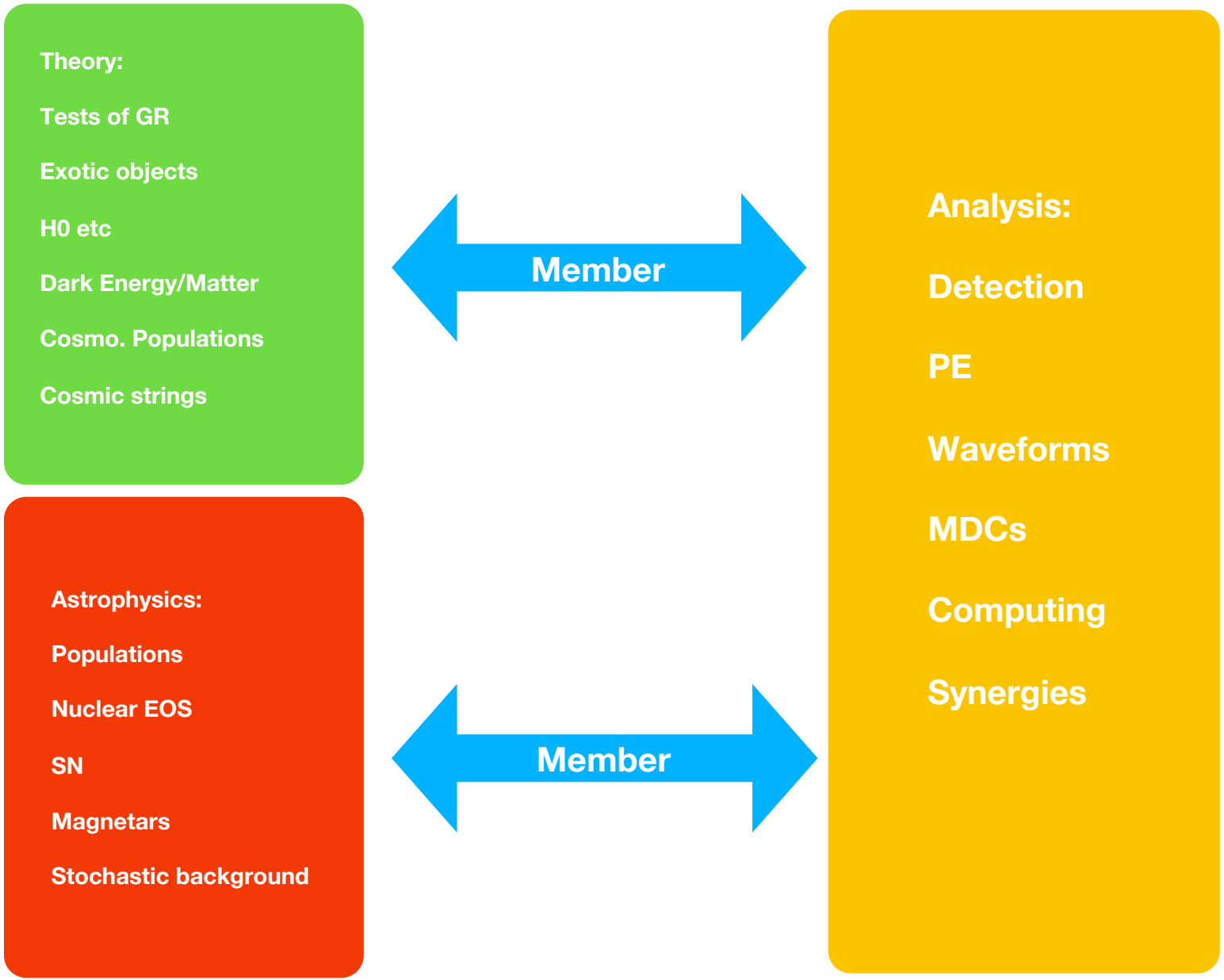
The data analysis development is a cross division - cross board effort

The goal is not only to prepare for science extraction, but also to investigate new and innovative methods

This includes the investigation of new technologies.


OSB:
ET science case
Prepare DA requirements
Evaluate computing requirements
Realistic PSDs
Tools for BNS range
Configuration studies
Computational infrastructure
Data format/storage/transfer
Data security
Mock data challenges
Waveforms etc.
ISB:
ET-TDR for infrastructures and detector
Identify missing technologies
Plan R&D activities
Data storage
Data transfer
EIB:
Define computing resources
Study computing models
Possible synergies


Theory:
Tests of GR
Exotic objects
H0 etc
Dark Energy/Matter
Cosmo. Populations
Cosmic strings
Astrophysics:
Populations
Nuclear EOS
SN
Magnetars
Stochastic background
Analysis:
Detection
PE
Waveforms
MDCs
Computing
Synergies


Theory:
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Member
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Populations
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SN
Magnetars
Stochastic background
Member

LIGO Livingston

LIGO Hanford

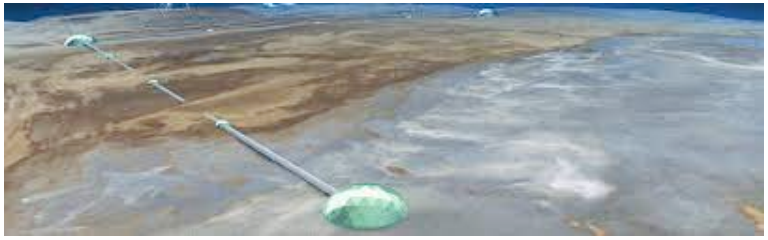
Virgo

KAGRA

Data analysis
Synergies

LISA

Cosmic Explorer



Structure of the OSB

- **Div1: Fundamental Physics**
  Chris van den Broeck, Paolo Pani, Rafael Porto

- **Div2: Cosmology**
  Archisman Ghosh, Mairi Sakellariadou, Angelo Ricciardone

- **Div3: Population studies**
  Giulia Cusin, Michela Mapelli, Antonio Riotto

- **Div4: Multimessenger observations**
  Giancarlo Ghirlanda, Stephen Smartt, Susanna Vergani

- **Div5: Synergies with other GW observatories**
  Nelson Christensen, Samaya Nissanke, Bangalore Sathyaprakash

- **Div6: Nuclear Physics**
  Tim Dietrich, Tanja Hinderer, Michaela Oertel

- **Div7: Transient GW sources**
  Marie-Anne Bizouard, Enrico Cappellaro, Pablo Cerda-Duran

- **Div8: Waveforms**
  Laura Bernard, Harald Pfeiffer, Patricia Schmidt

- **Div9: Scientific potentials of different detector configurations, and common tools**
  Michal Bejger, Ik Siong Heng, Andrea Maselli

- **Div10: Data analysis platform**
  Chris van den Broeck, Elena Cuoco, Tania Regimbau, John Veitch

each researcher working on the data analysis for specific science cases or gravitational-wave sources will be asked to be member of both Div10 and the relevant(s) physics/astrophysics Divisions (Div1 to Div8).

Div-Synergy

M. Branchesi, M. Maggiore, Ed Porter

Forum to communicate, coordinate and collaborate with other neutrino and electromagnetic observatories. See talk tomorrow

Purpose of the OSB

The Observational Science Board (OSB) envisages to develop the Einstein Telescope science case, to start building the scientific community around it, and to bring it to a scientific maturity to exploit the data taken when ET will start operation. The OSB main goals, for an estimated timeline of the next four years, can be summarized as follow:

- Develop the ET science case to help the instrument technical development and implementation, and later to fully exploit the specific capabilities of the ET detector;
- Stimulate the interest of the scientists going beyond the gravitational wave community, for example involving cosmologists, nuclear physicists, high-energy physicists, astronomers and astrophysicists;
- Build the synergy, collaboration and coordination with other gravitational-wave, electromagnetic, neutrino observatories which will operate together with ET or observatories able to give complementary insights into the ET science;
- Identify the specific data analysis and computing needs for ET and begin the development of data analysis tools and algorithms.
- Involve students, post-doc and early career researchers, and contribute to training the young community which will lead the ET data analysis and scientific interpretation when it will be operative;
- Contribute to generate broad public interest in the ET science.

The development of the Science Case will be structured around a `Blue Book', a living document that summarizes and updates original work related to ET

Each division will contribute to one chapter

(timescale: 4yr)

The coordinators will organize the activity in each division (key problems, work packages, regular meetings,…) and eventually select the most relevant results

What it means to be member of the OSB

- Belong to the community that develops the ET Science in a structured and coherent manner
- Profiting from (and contributing to) a scientific dynamics, feedback, discussions
- Visibility of own's activities related to ET
- Direct access to standardized tools, new experimental developments
- Opportunity to work together with experimentalists to identify instrument science requirements based on specific science cases
- Commit a fraction of your working time to the ET science

`Obligations and rules'

a rather minimal set of rules needed to define a collaborative effort

The principles that inspire the publication policy of the OSB are, on the one hand, to guarantee the complete freedom needed for theoretical work (intended in a broad sense as work leading to papers without real ET data) and, on the other hand, to foster a spirit of collaboration within the OSB

- Members of the OSB are free to work and publish separately their original results according to their standard procedures. The members of the OSB are highly encouraged (but not obliged) to share on-going projects and to make use of the pool of expertise within the OSB

- Upon termination of a project leading to a publication relevant for ET, OSB members have to circulate their draft within the ET Collaboration, at least one week before posting it to the arXiv
  - Receiving feedback, making everybody aware of activities in the OSB
  - In some cases, a way to try to resolve internal controversies, so that the ET OSB does not speak to external communities (including funding agencies) with contradictory voices

- One week before posting the paper to the arXiv, authors are also required to provide the draft to the coordinators of their division
  - allow the division coordinators to be aware of results that could be selected and inserted in the Blue Book
  - division coordinators are asked to perform a check that there are no sensitive collaboration issues that might be harmful to the ET project

- Papers that have gone through this will have an ET preprint number that qualifies them as `official' papers of the ET-OSB and will be added to a publicly accessible database
  - give to the paper extra visibility and authority

- Code of conduct (under development with the collaboration policy)

A link on the workshop web page (available after the end of the workshop) will allow the interested scientists to join the OSB

- publication policy
- OSB organization document
- form for joining

Recording of the talks will be available