Cost-Benefit Analysis Team (CoBA)
Remote Workshop, October 28 2021

SCIENCE IMPACT FOR DIFFERENT MACRO-OPTIONS and GEOMETRY of ET

a. Methodology
b. Preliminary results

M. Branchesi on behalf of B. Banerjee, U. Dupletsa, B. Goncharov, and Jan Harms

Methodology to compare different scenarios

We evaluate:

- the impact of the different ET macro-options and geometry using **basic metrics;** detection efficiency, SNR ditribution, and sky-localization capabilities for binary neutron stars (BNSs) and binary black holes (BBHs) populations;

Possibly to do:

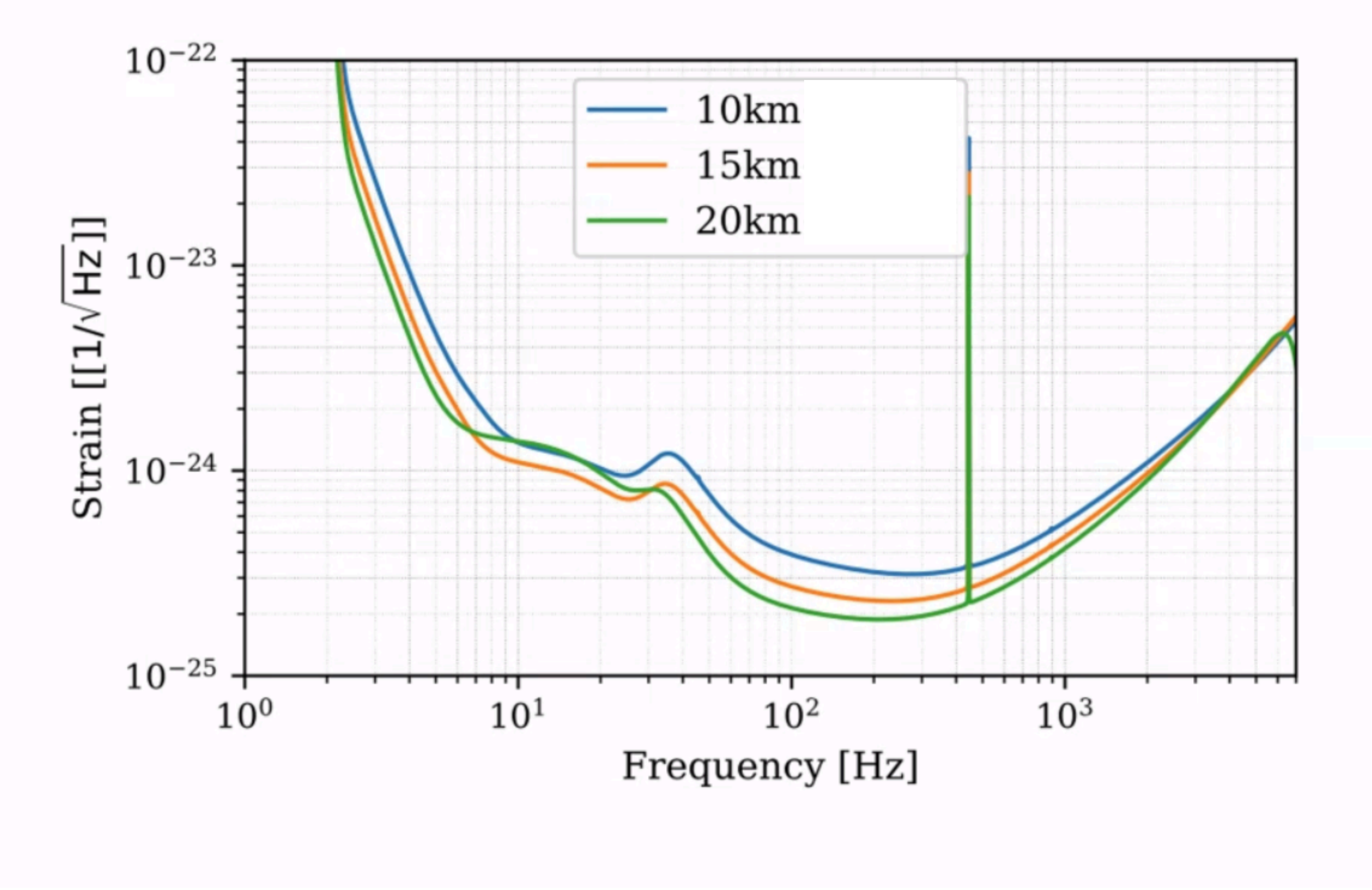
- the impact on achievements related to intermediate mass black-hole (IMBHs) and primordial black-hole (PBHs) science, MM, cosmology, NS EOS, stochastic;

DIFFERENT MACRO-OPTIONS and GEOMETRY

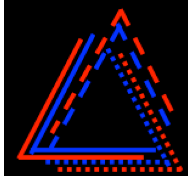
opt		A) ET-HF	B) ET-LF cryo	C) ET –LF room temperature	Cost Infrastructure
0	ET Triangle				
1	ET Triangle but 15 km side				
2	2 L x 15 km x 1 ITF x underground				
3	2 L x 20 km x 1 ITF x underground				
4	2 L x 15 km x 2 ITF x underground				
5	2 L x 20 km x 2 ITF x underground				
6	1 L x 20 km x 2 ITF x underground				
7	Surface Detector ??				

On Sunday October 17 we received from ISB
the Xylophone (HF+LF) cryogenic for 10 km, 15 km and 20 km IFO

SENSITIVITY CURVES

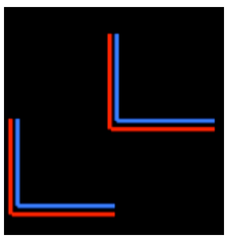


Triangle vs 2L network

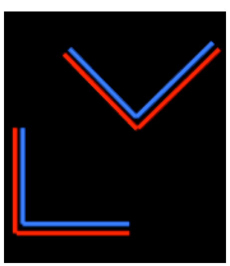


Two scenarios
- D of 10 km
- D of 15 km

Three scenarios
- 2L of 10 km
- 2L of 15 km
- 2L of 20 km



2L aligned



2L misaligned of 45°

Simulation Methodology

- Fisher matrix approach

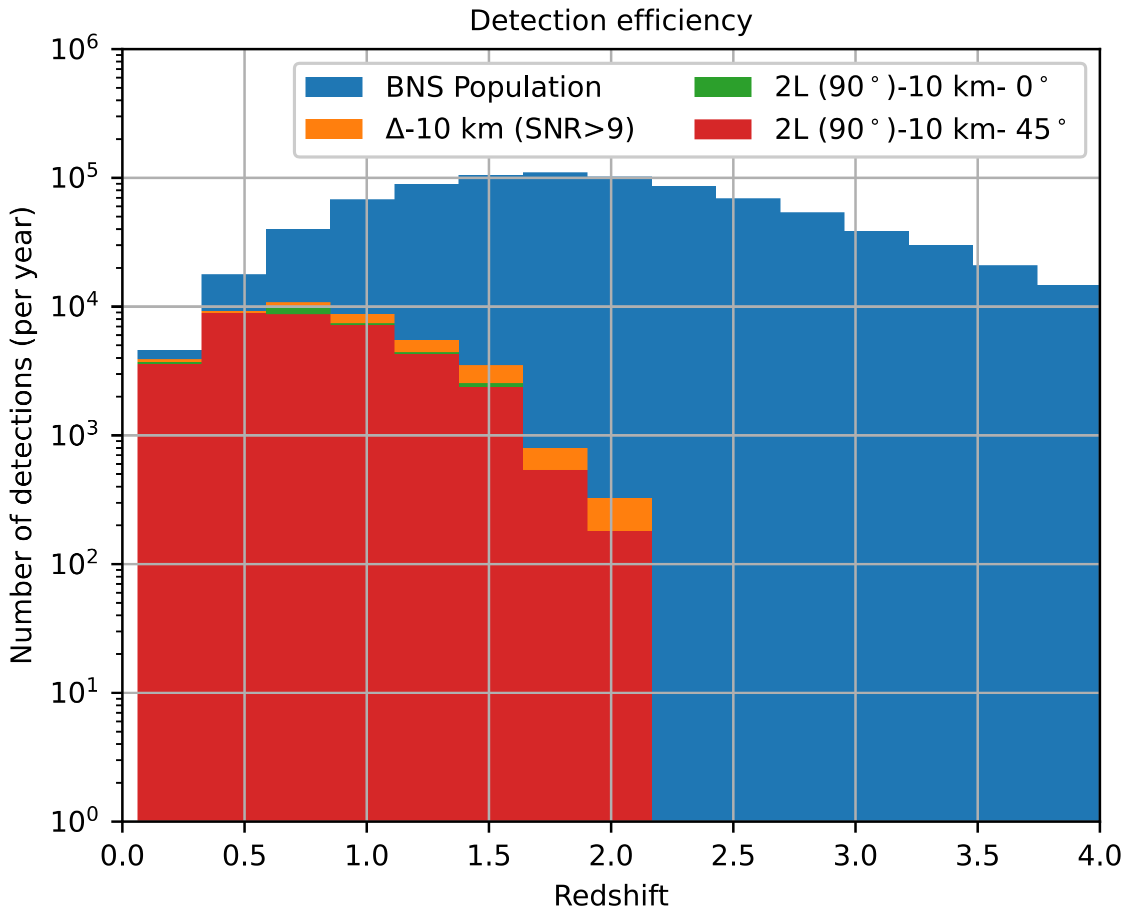
- **Astrophysical assumptions** (consistent with O3a LIGO and Virgo observations - GWTC-2):
  - BNS: rate distribution as function of z from last updates of Santoliquido et al. 2021, MNRAS, **Gaussian mass distribution** centered around ~1.3 Msun and with std ~0.1 Msun, **[1.2- 2.4] Msun**, no spin
  - BBH: rate distribution as function of z from (Regimbau et al. 2017, SF from Vangioni et al. 2015), **broken power-law mass distribution** consistent with O3a LIGO and Virgo observations (GWTC-2)

- For the injections we use TAYLORF2 waveforms

- 25k injections for each scenarios (for detection efficiency entire redshift range and for sky-localization z < 0.8)

The next slides will show preliminary results

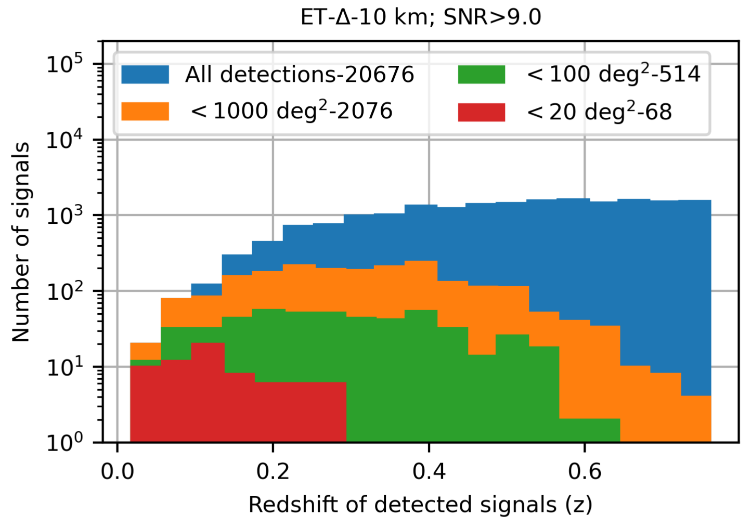
BNS: comparison delta (10 km), **2L (10 km)** aligned and misaligned



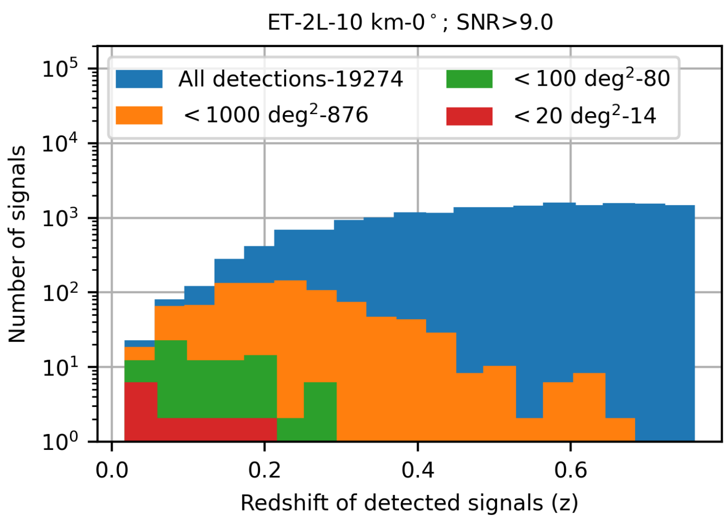
Detection efficiency

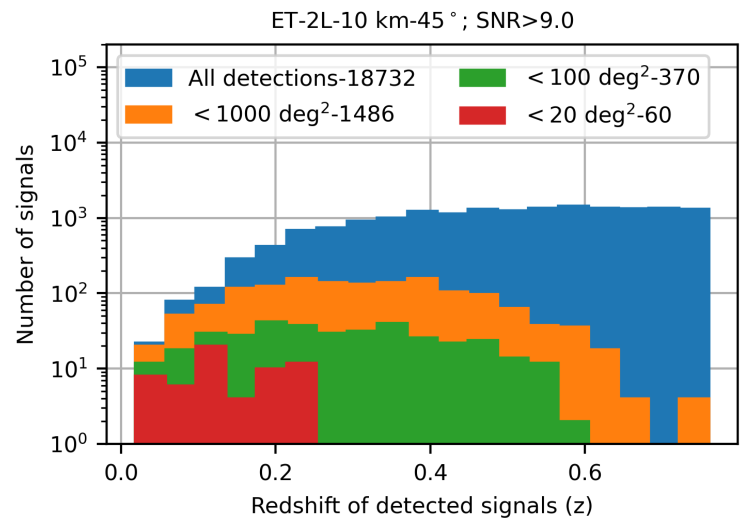
SNR > 9

BNS: comparison delta (10 km), **2L (10 km)** aligned and misaligned



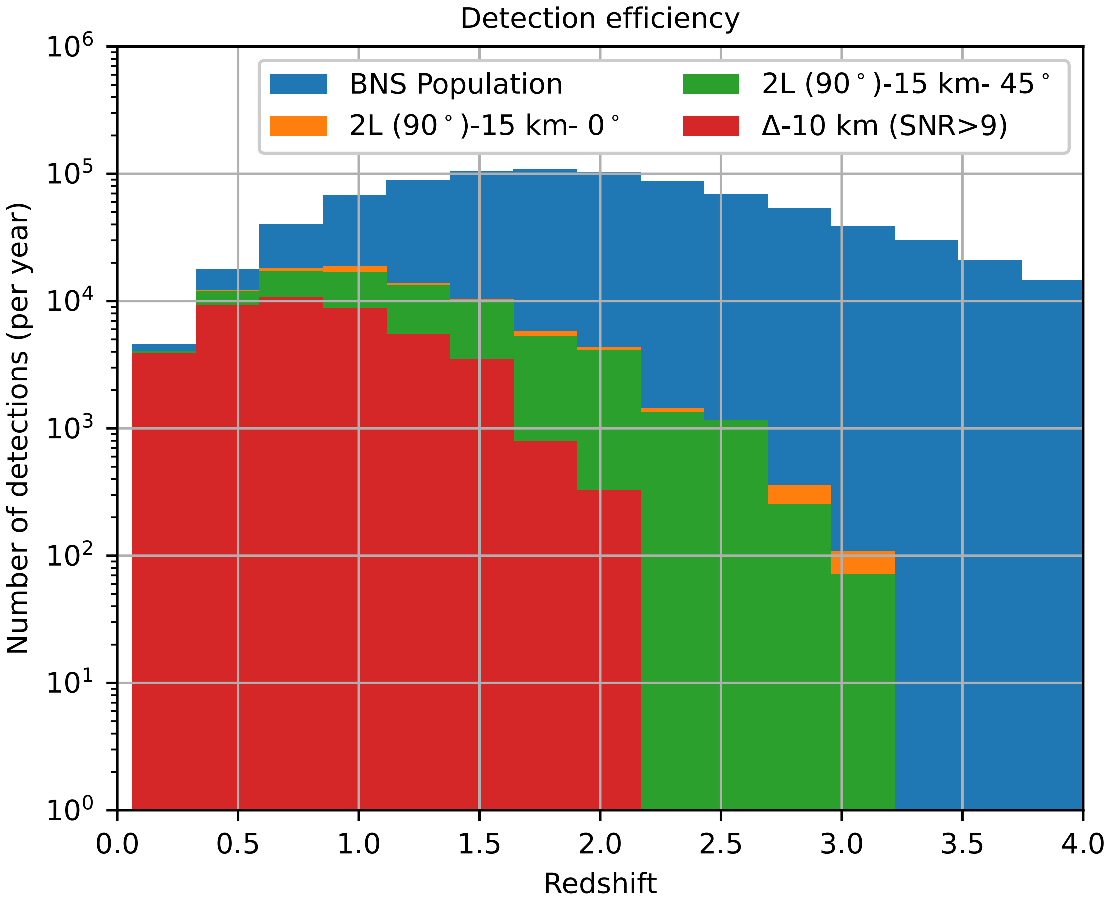
Sky-localization





SNR > 9

BNS: comparison delta (10 km), **2L (15 km)** aligned and misaligned



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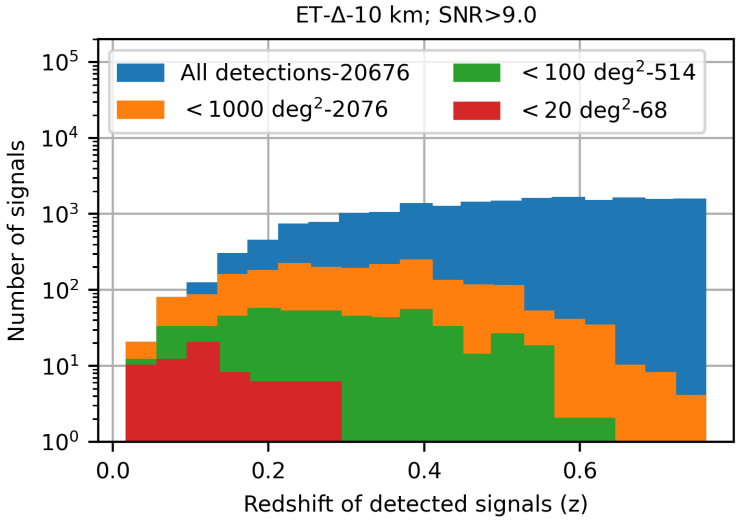
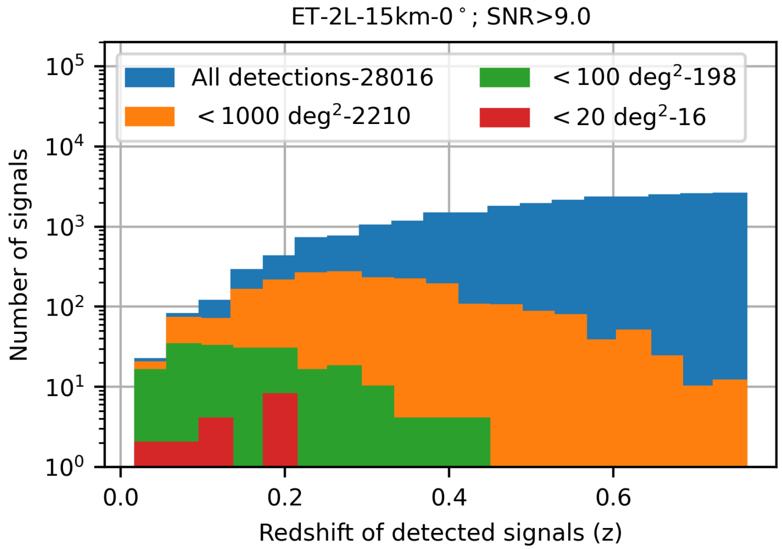
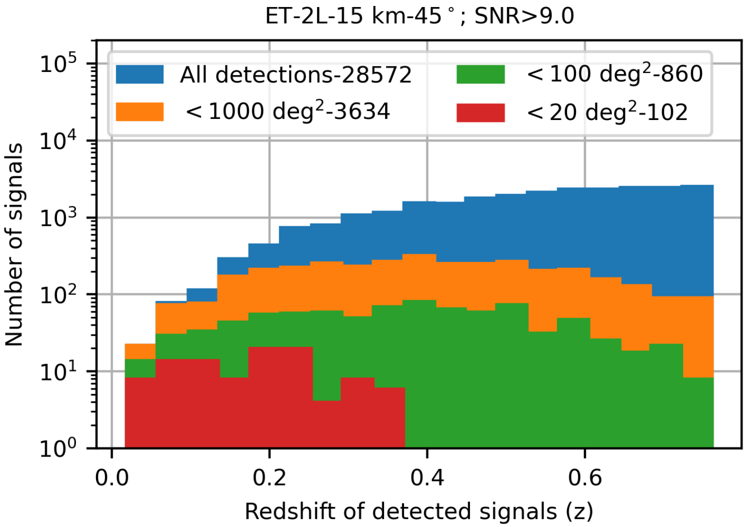


Sky-localization

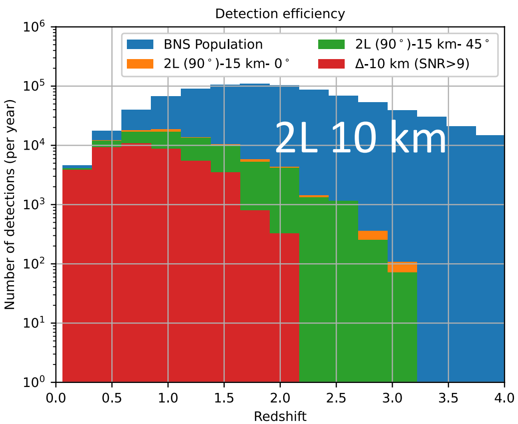




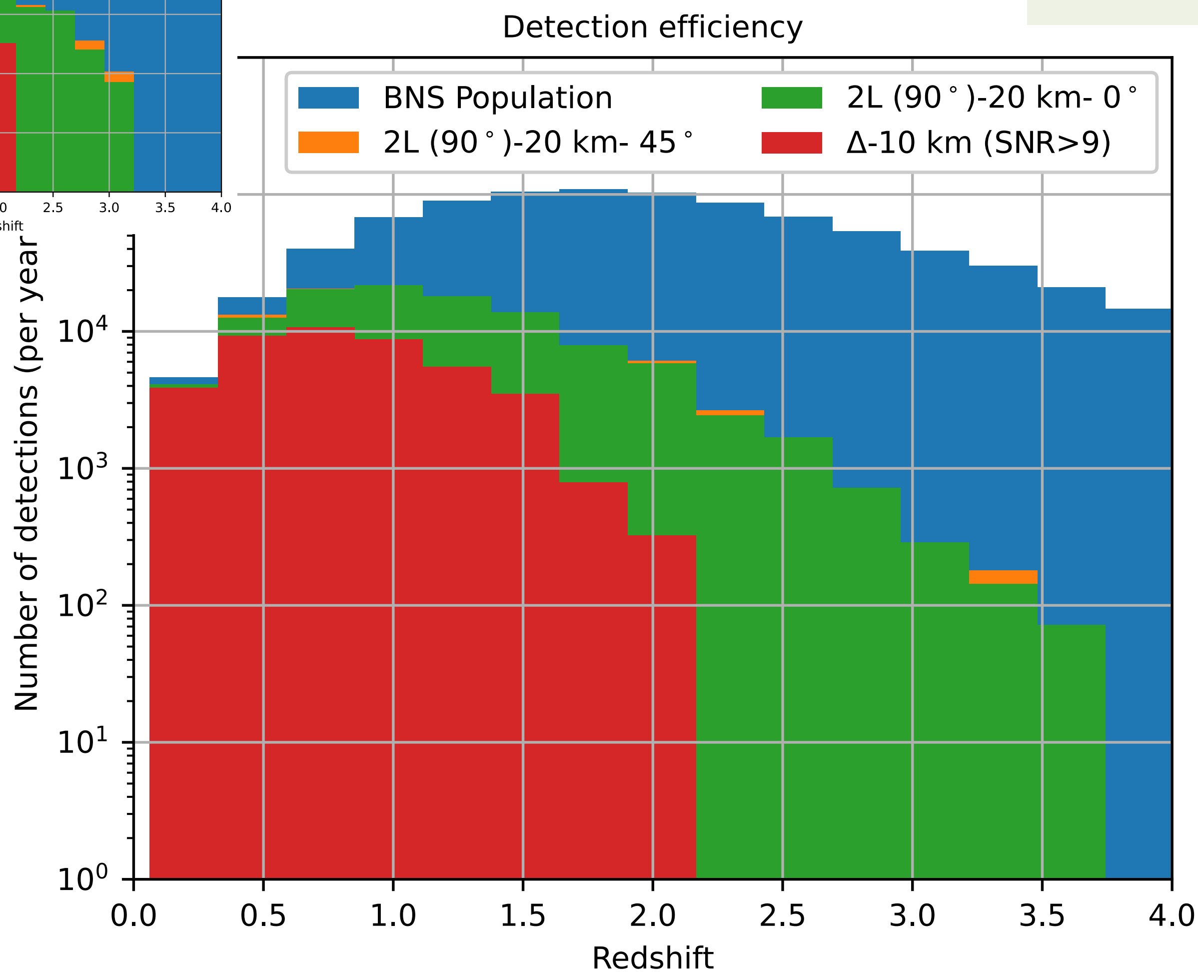
SNR > 9

Scenario	Number of detections per year	Number of detections per year Sky-loc < 20 deg^2	Number of detections per year Sky-loc < 100 deg^2
Triangle (10 km)	42732	68	514
2L(10 km) aligned	37368	14	80
2L(10 km) misaligned	35784	60	370
2L(15 km) aligned	90036	16	198
2L(15 km) misaligned	85680	102	860

BNS: comparison delta (10 km), **2L (20 km)** aligned and misaligned



Detection efficiency



SNR > 9

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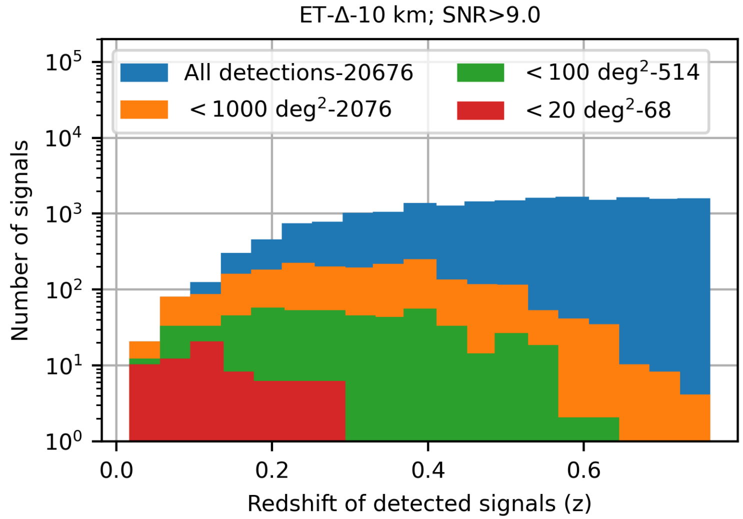
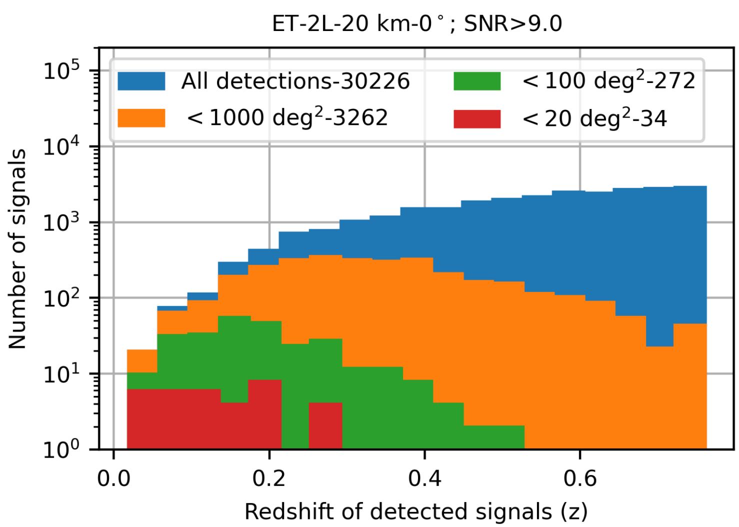
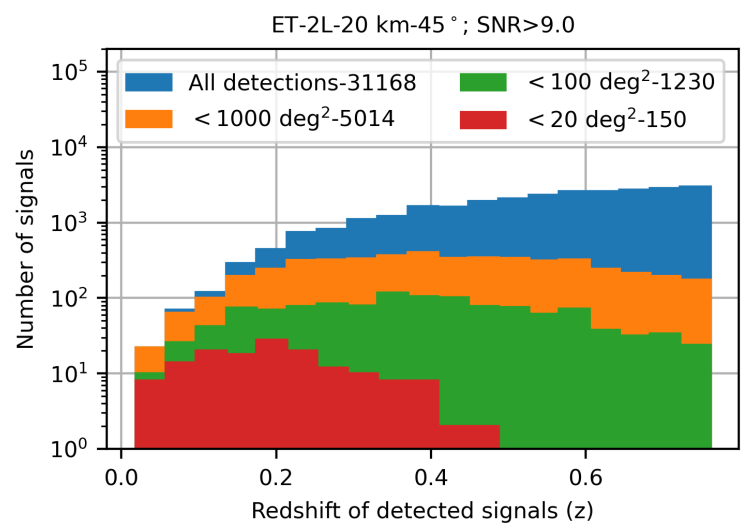


Sky-localization





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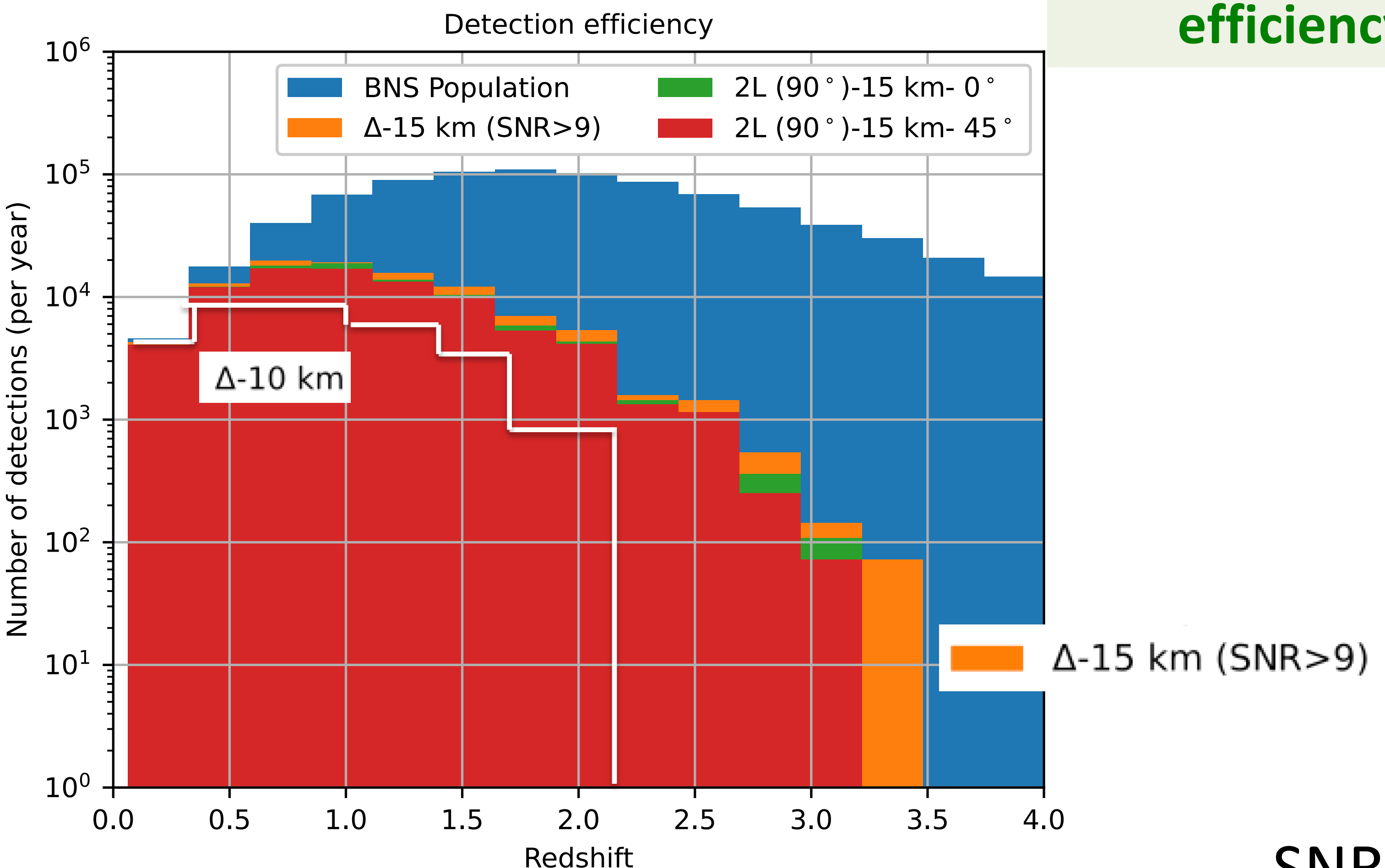
2L(20 km) aligned	109584	34	272
2L(20 km) misaligned	108072	150	1230

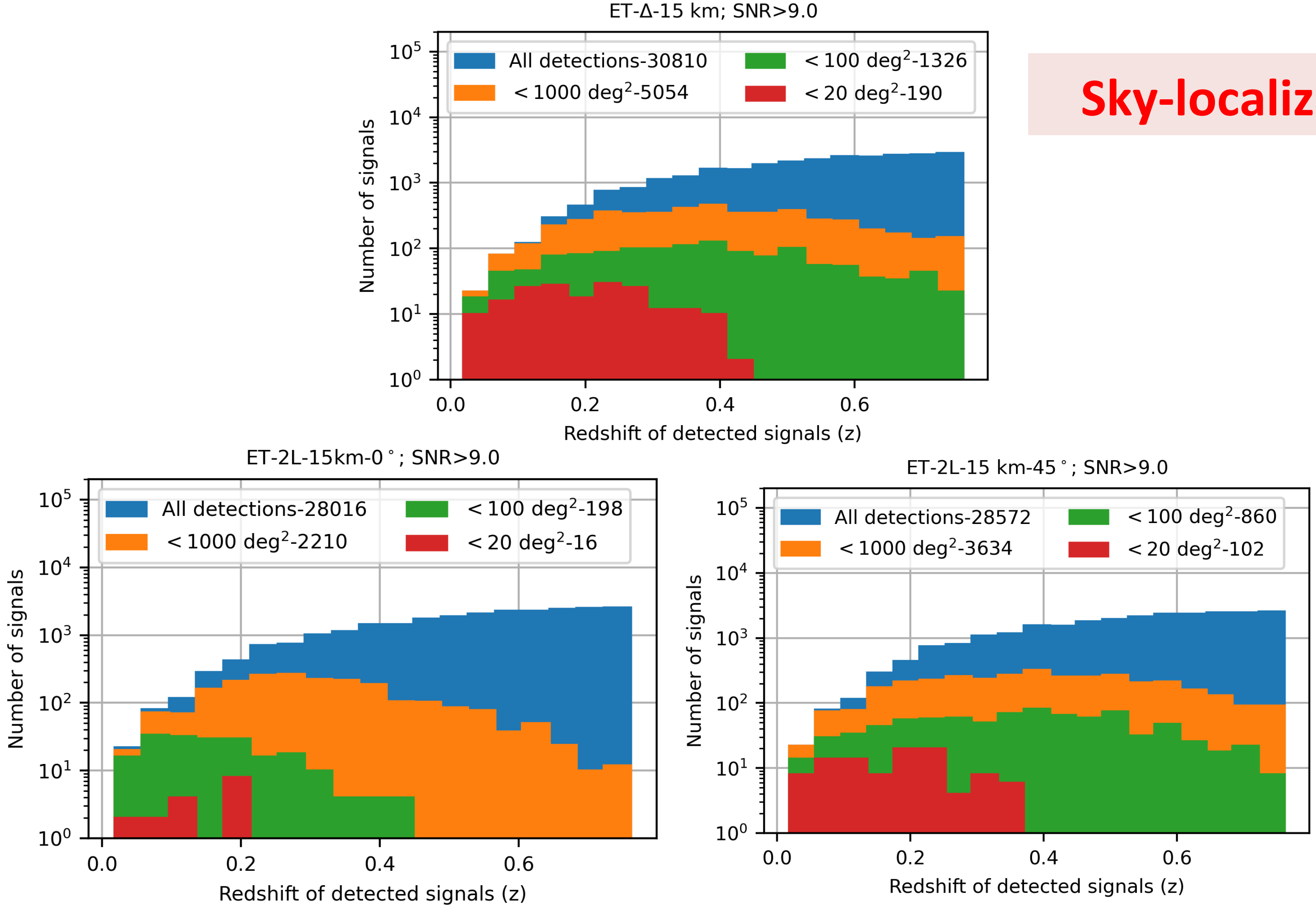
BNS: comparison delta (15 km), **2L (15 km)** aligned and misaligned

Detection efficiency



SNR > 9

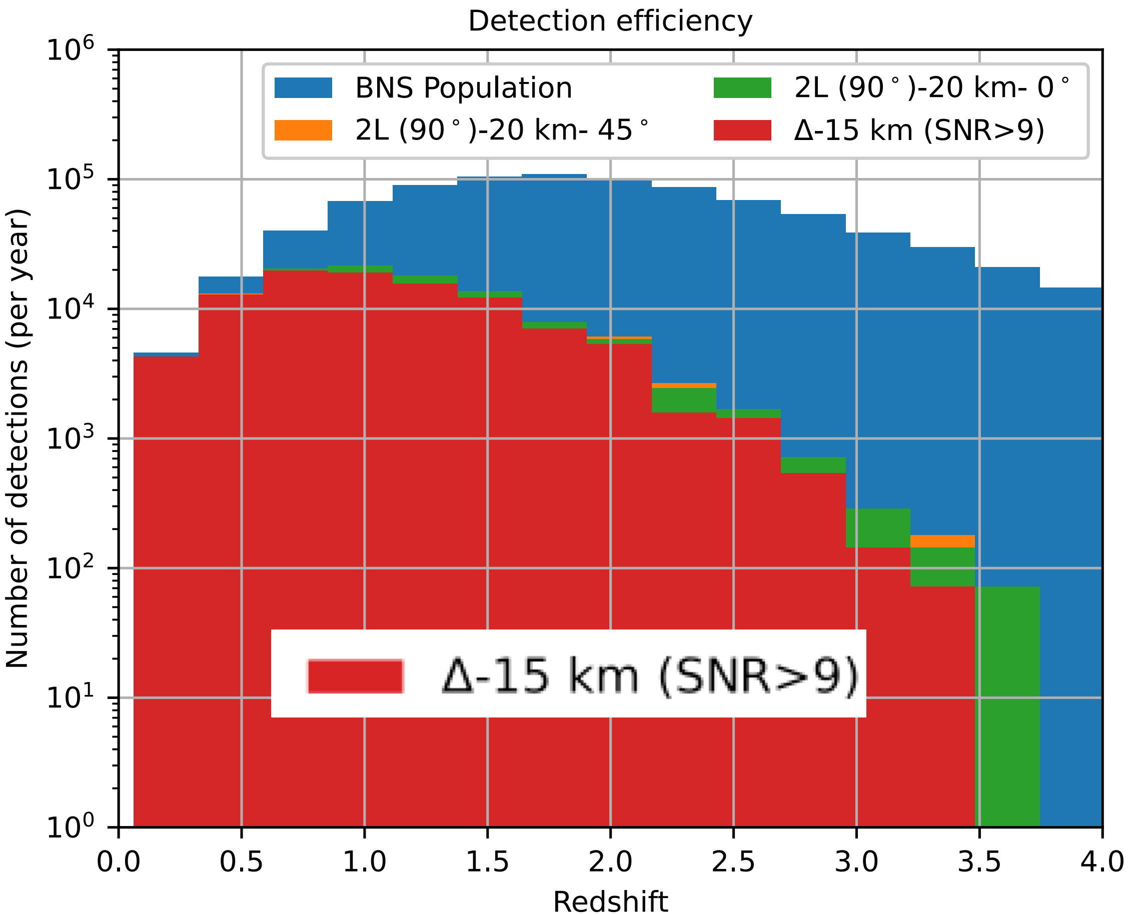
BNS: comparison delta (15 km), **2L (15 km)** aligned and misaligned



Sky-localization

SNR > 9

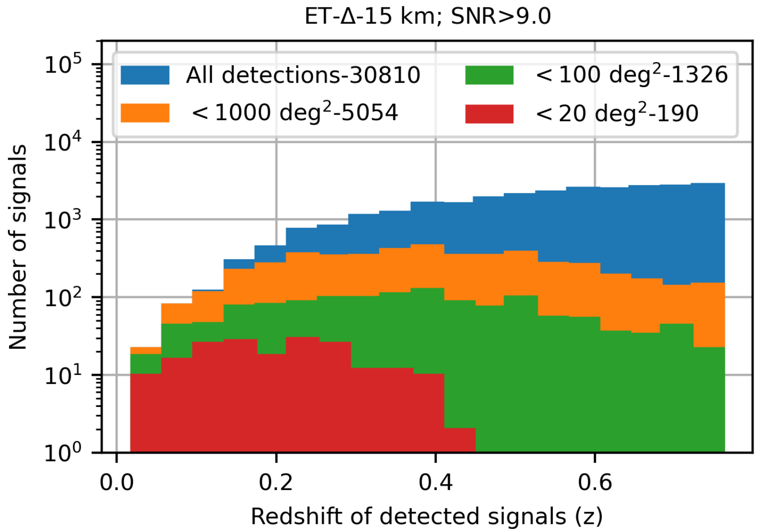
BNS: comparison delta (15 km), **2L (20 km)** aligned and misaligned



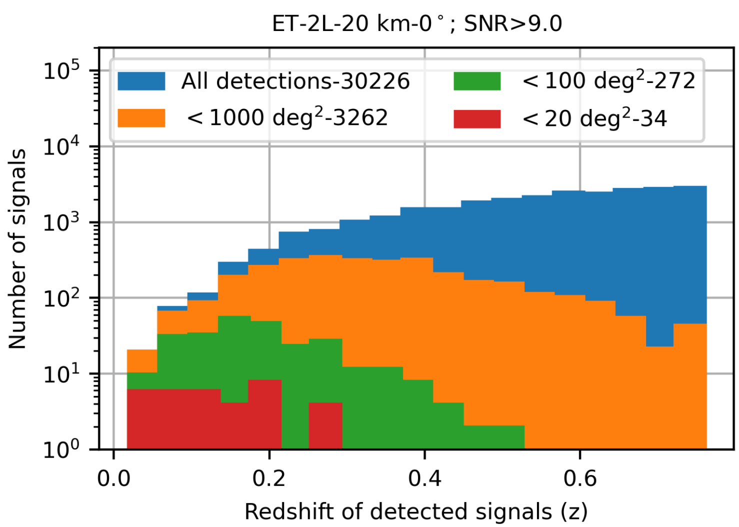
Detection efficiency

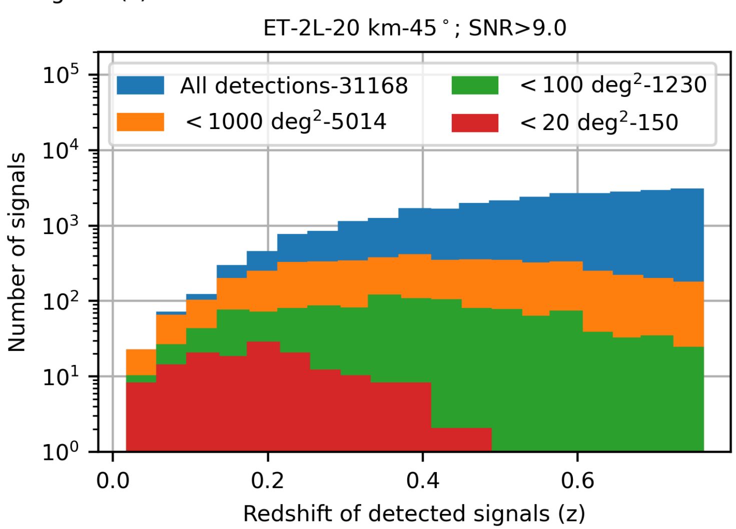
SNR > 9

BNS: comparison delta (15 km), **2L (20 km)** aligned and misaligned



Sky-localization





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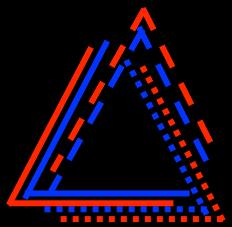
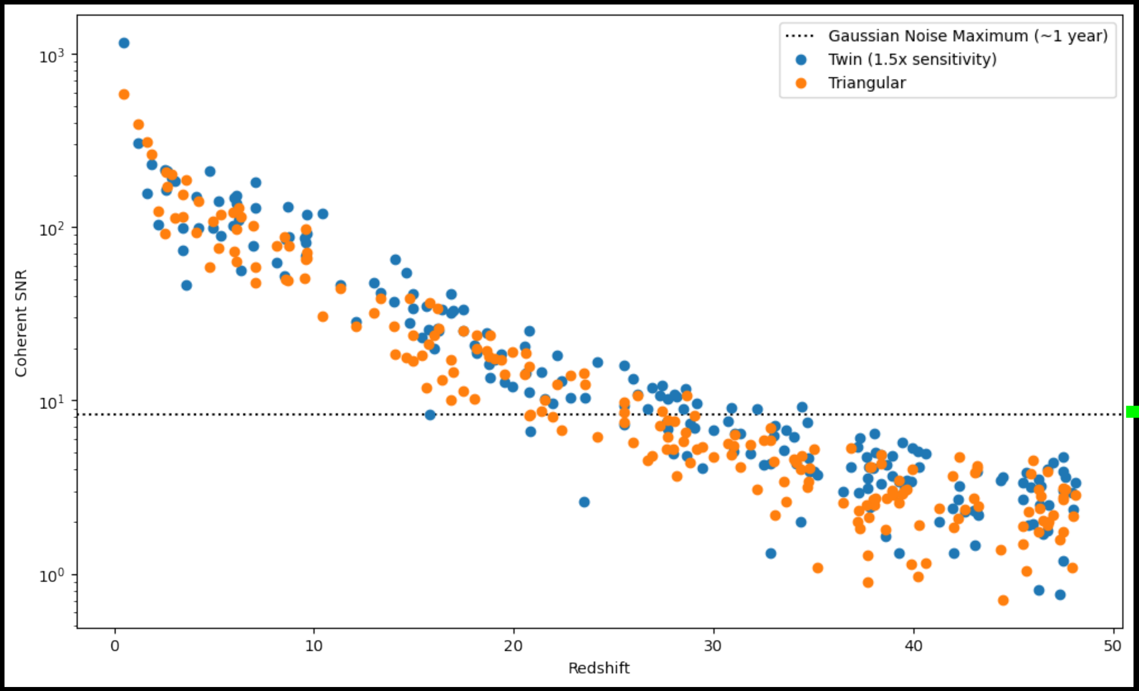
Null- Stream study

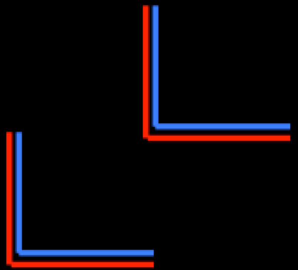


BBH source-frame mass= 50-100 Mo



fiducial detection threshold (SRN≈8)

produced by Boris with the help of Alex Nitz, with PyCBC code



NULL STREAM:

- contribution will depend on the rate of non-Gaussian noise, which is not clear at the moment
- expect it to be a higher level and possibly increasing towards higher redshifts.

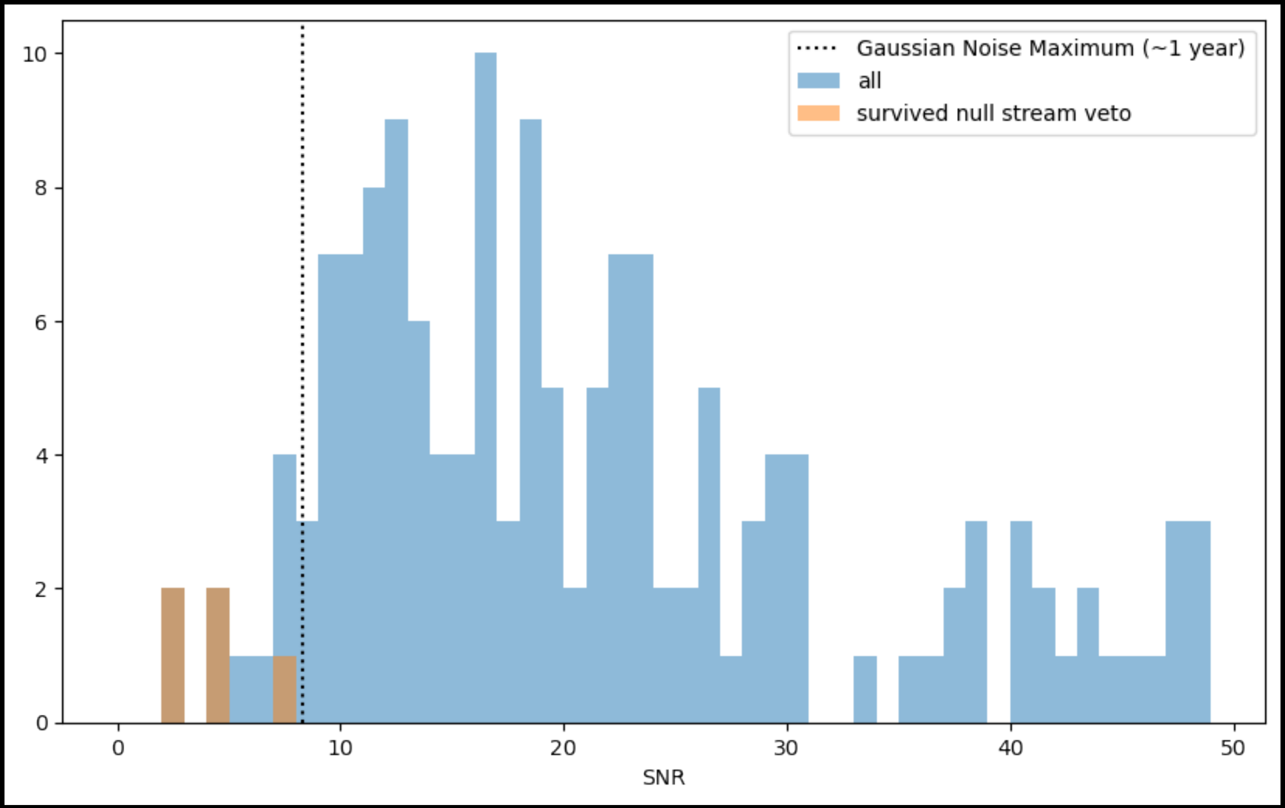
The null stream has a potential to:

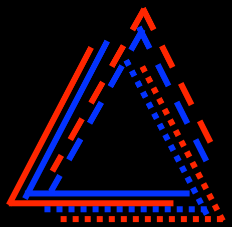
(a) remove the non-Gaussian noise;

(b) Decrease the detection threshold;

(c) to push the BBH detection horizon further in redshift, where a lot of interesting physics happens

Null- Stream study

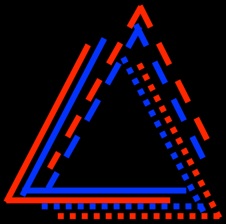


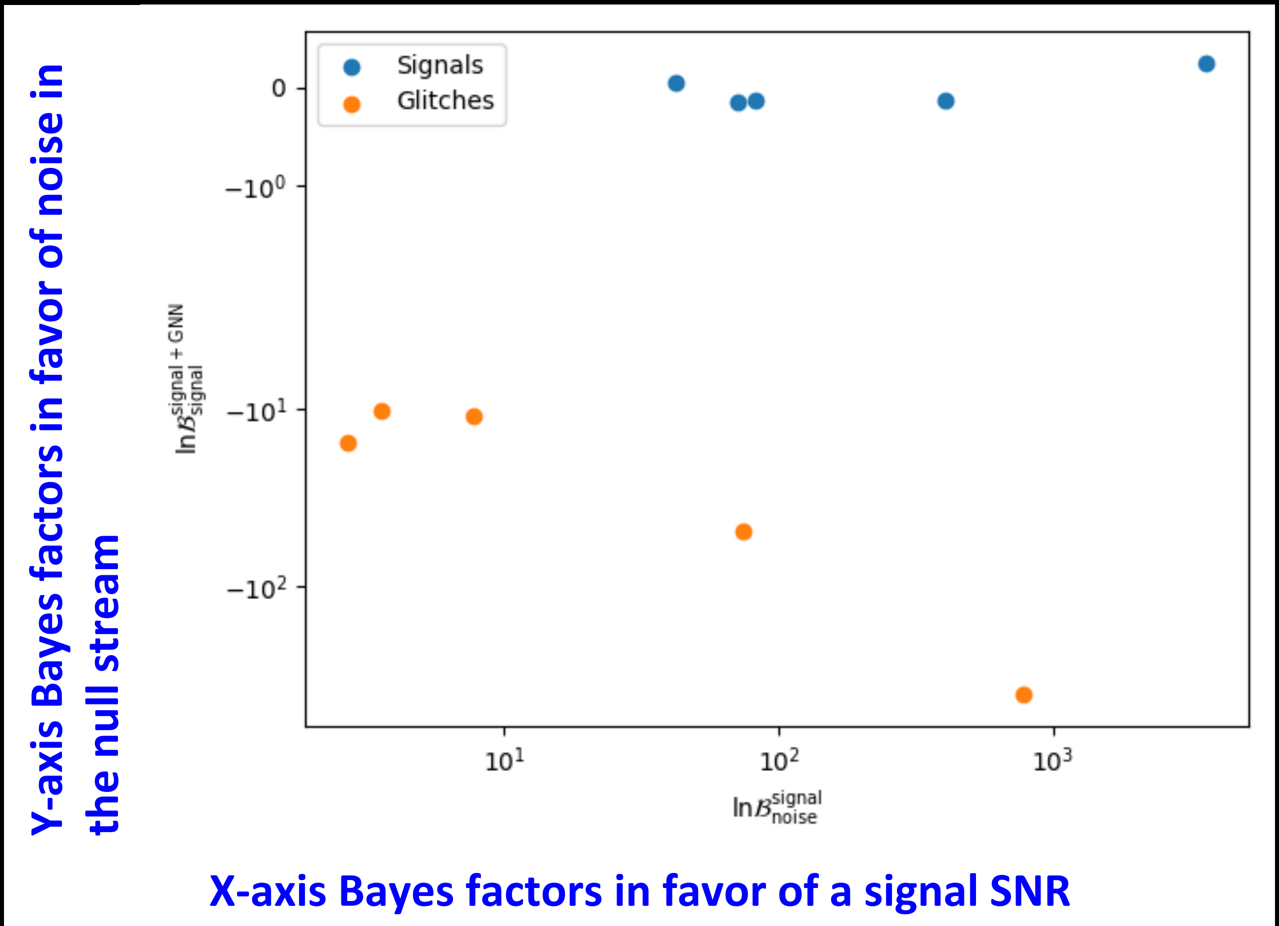


produced by Boris with the help of Alex Nitz, with PyCBC code

SNR for population of glitches (=incoherent signals in one detector) glitches in orange are the ones which survived a veto based on the null stream - "survived" glitches are below Gaussian noise levels.

Null- Stream study

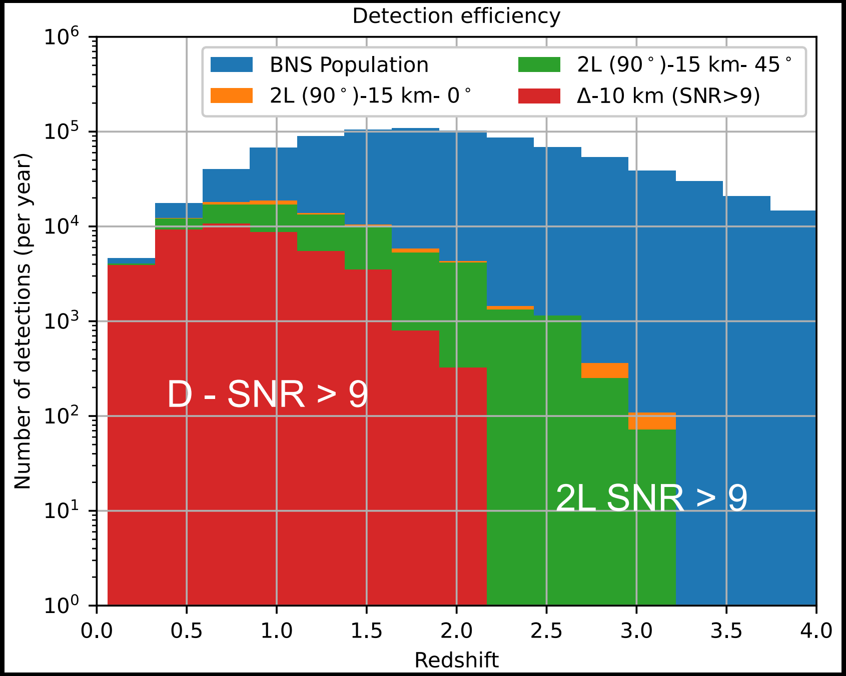




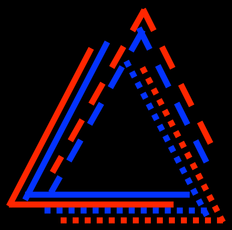
No Gaussian noise

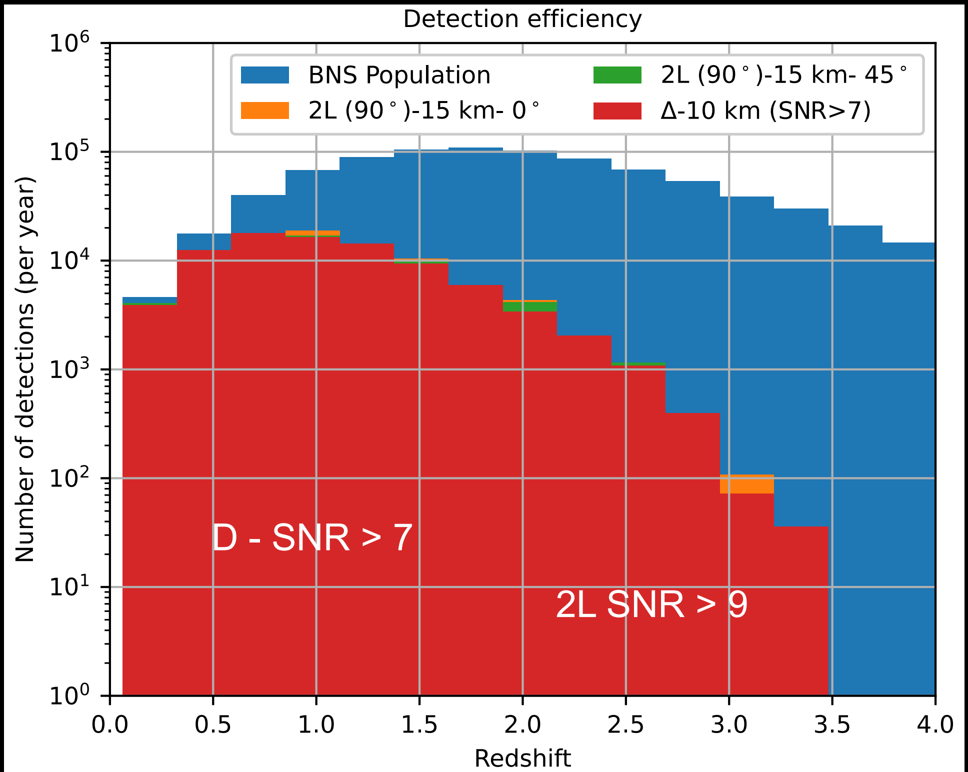
produced by Boris based on the Bayesian approach to null stream, with Bilby

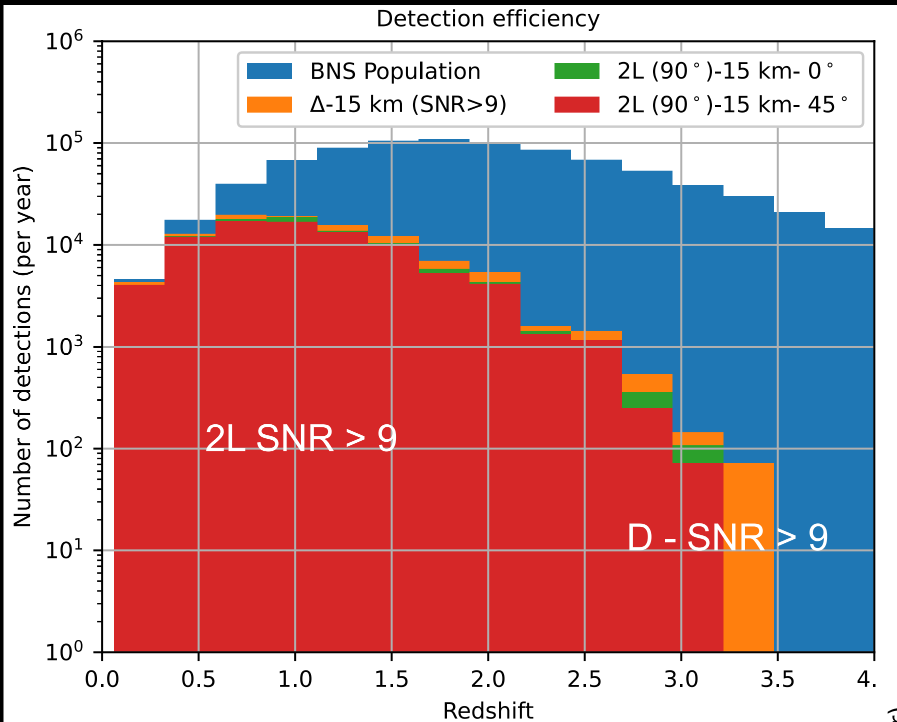
Detection efficiency



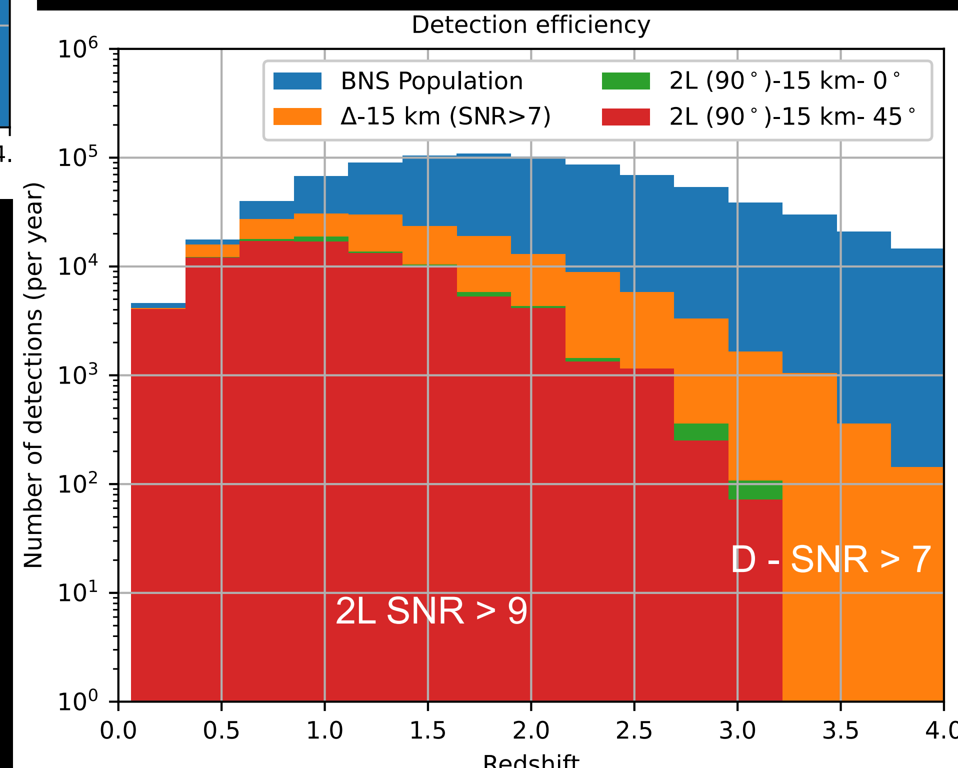
Triangle 10 km



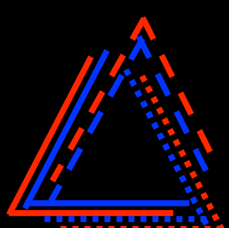


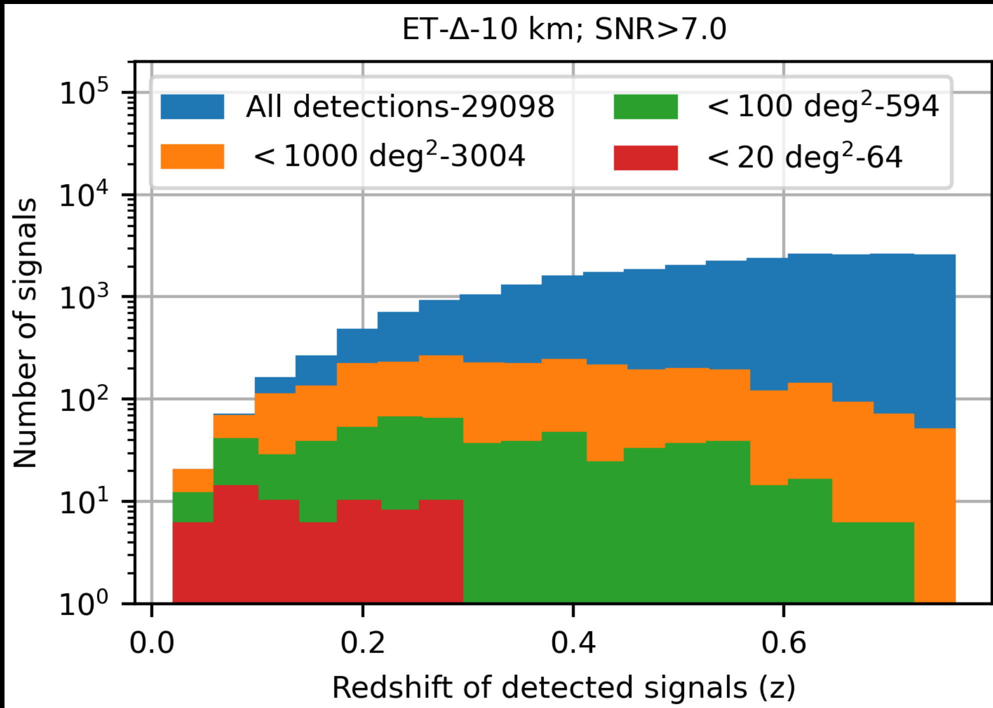


Detection efficiency

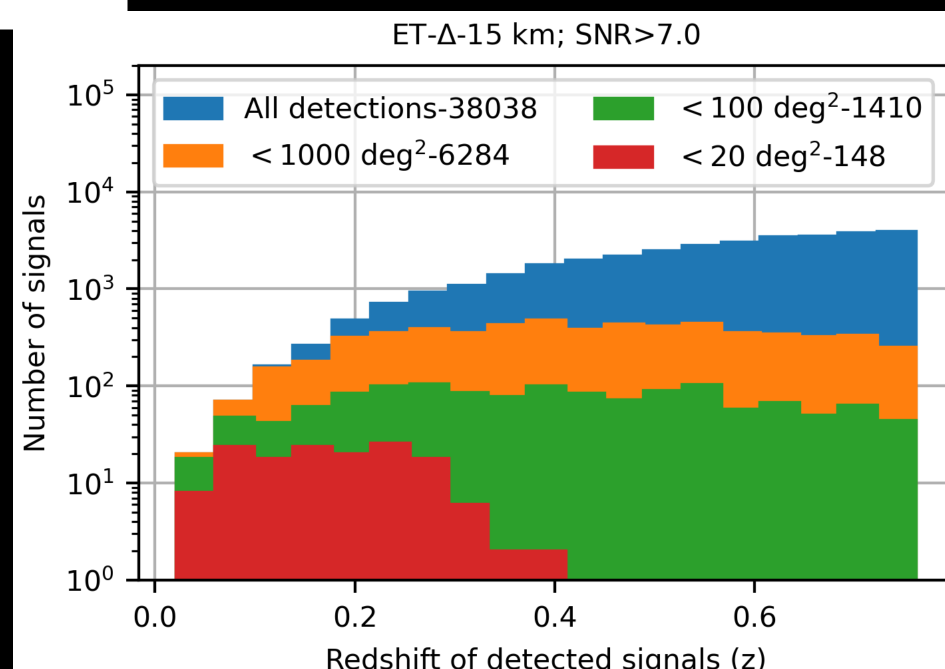


Triangle 10 km





Sky-localization



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Triangle (10 km)	87696	64	594
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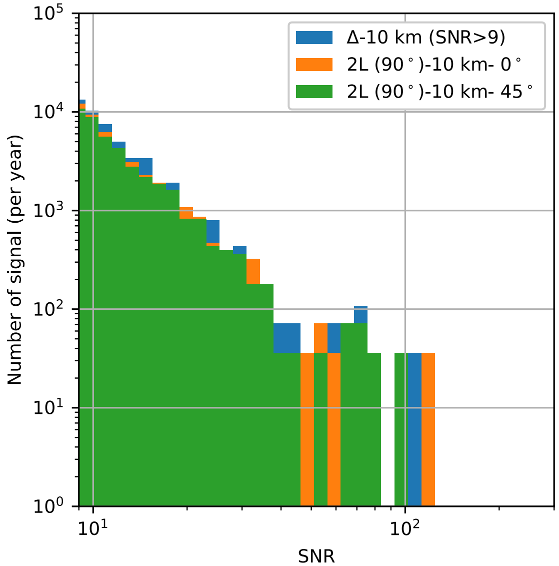
2L(20 km) misaligned	108072	150	1230

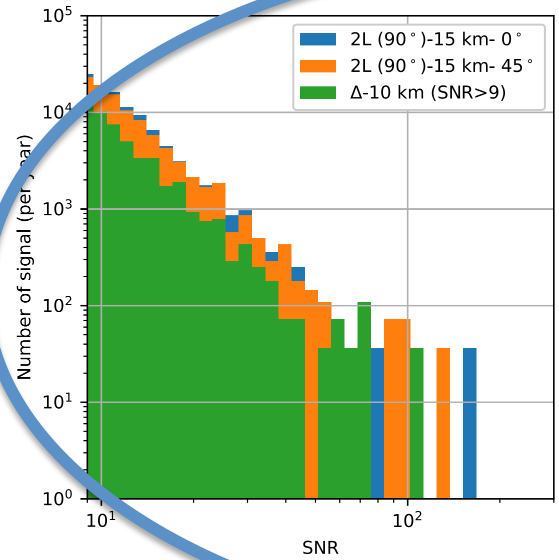
SNR > 9

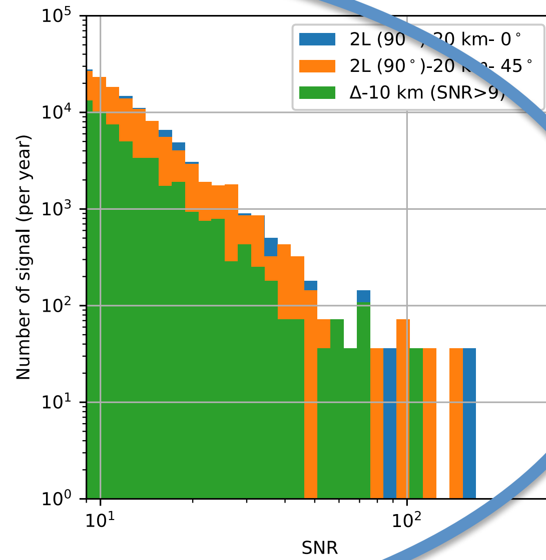
SNR > 7

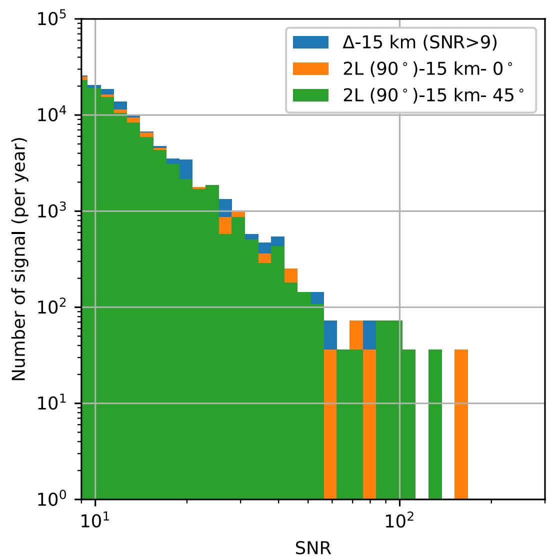
Warning
SNR >9
SNR > 7
Different
injected
population

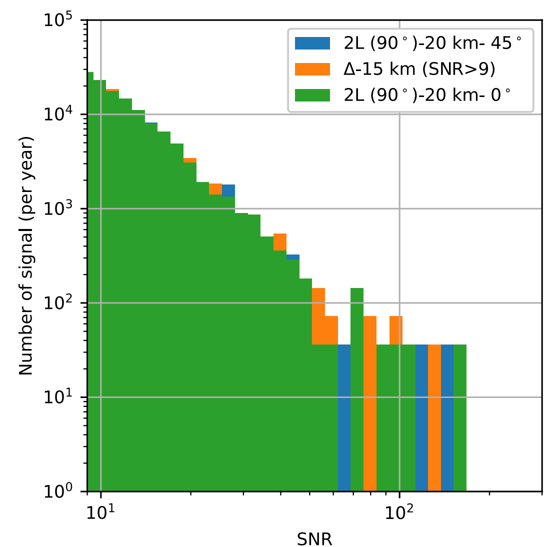
SNR distributions





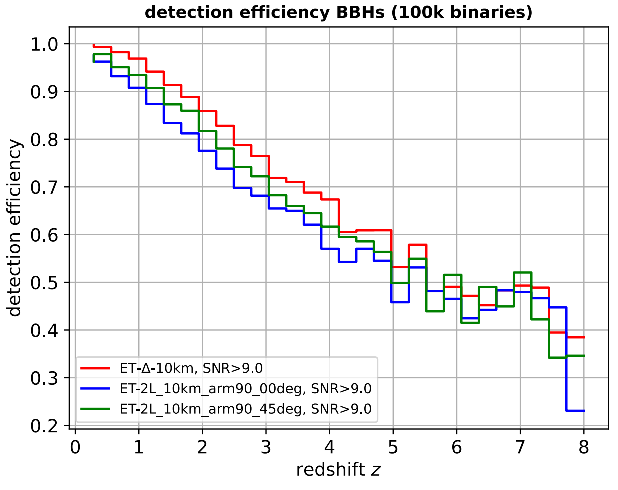


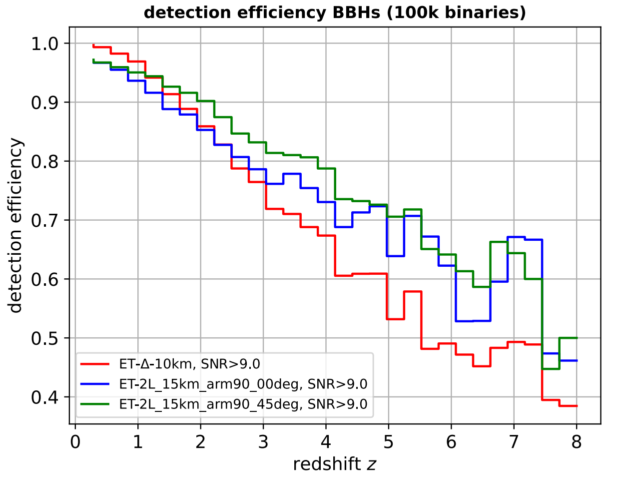


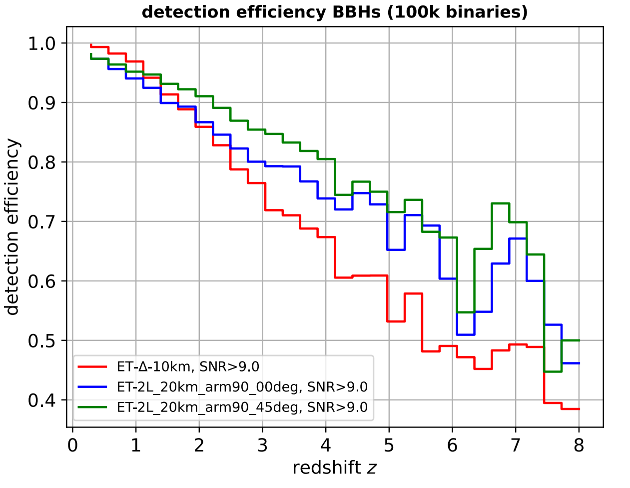


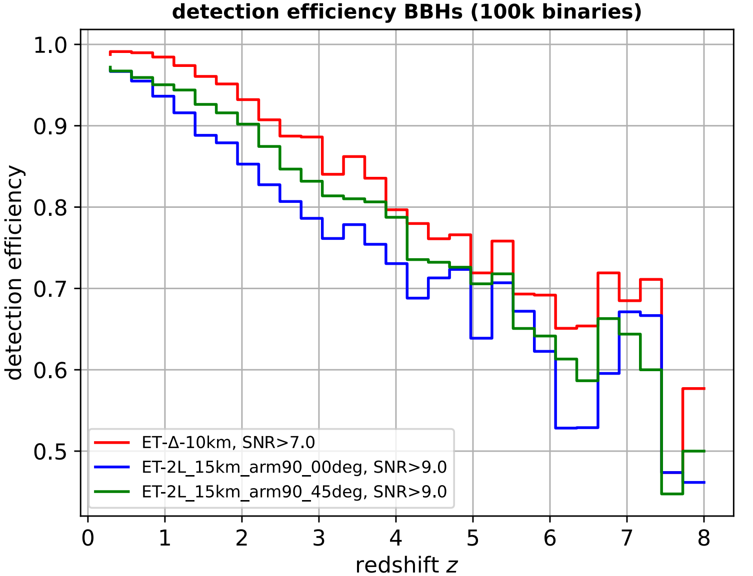
BBH simulations

SNR >9 **Triangle 10 km**, SNR >9 2L







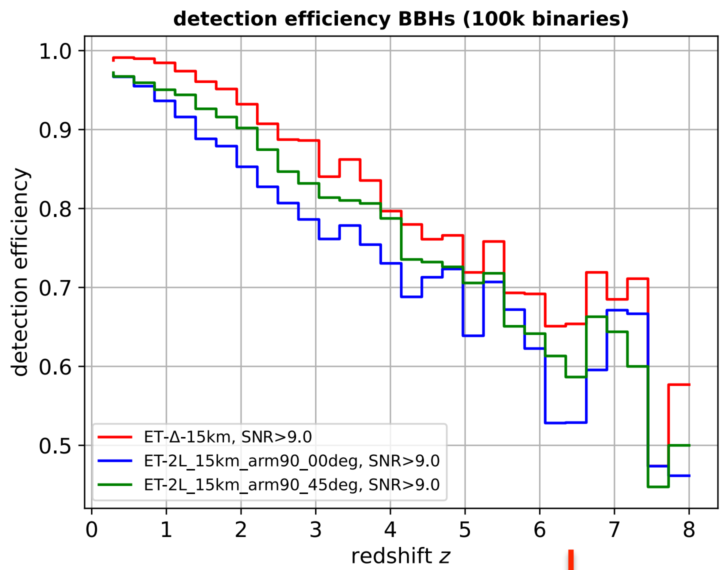


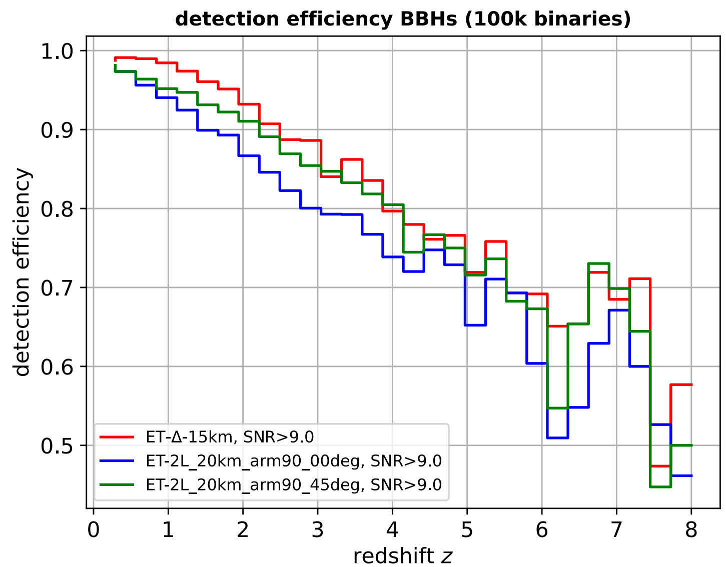
SNR >7 Triangle

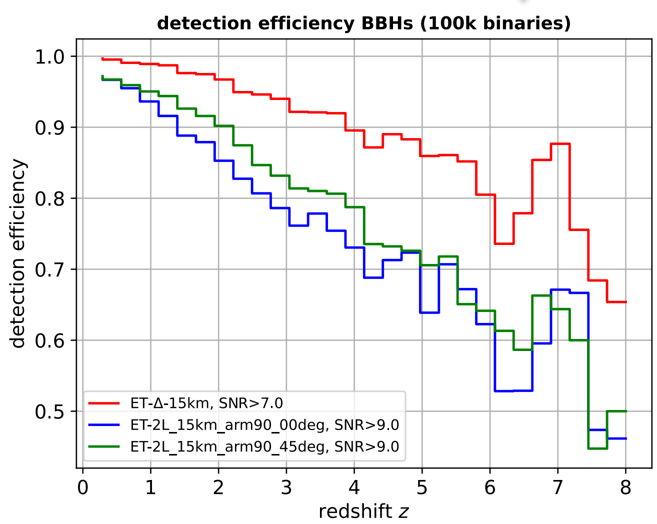
SNR >9 2L

BBH simulations

SNR >9 **Triangle 15 km**, SNR >9 2L

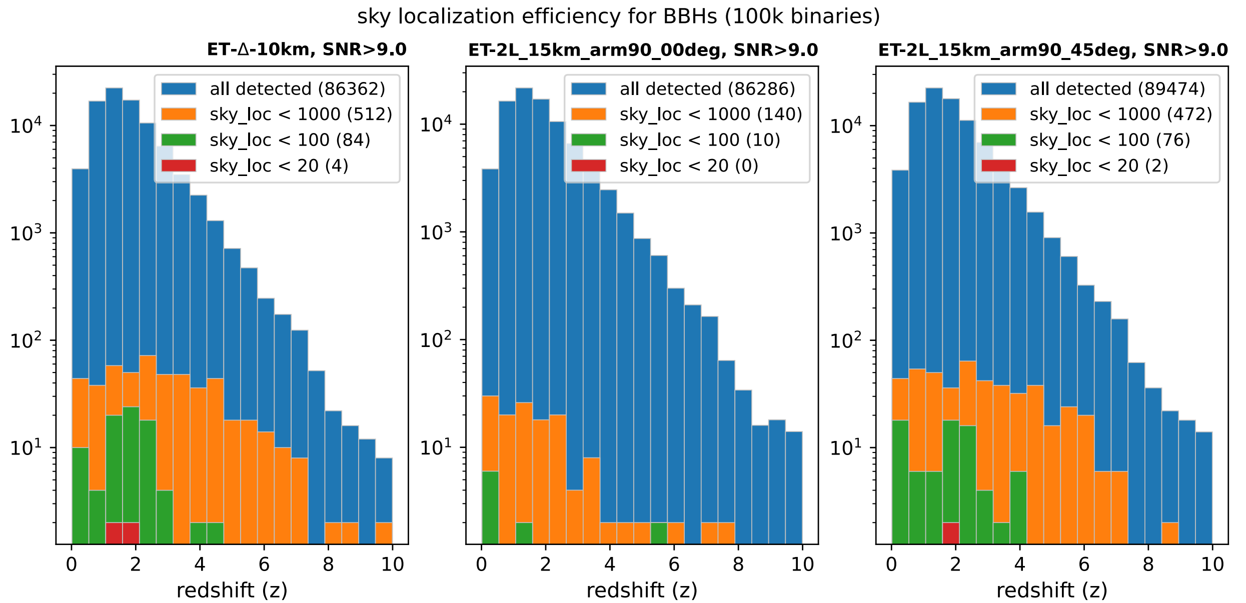


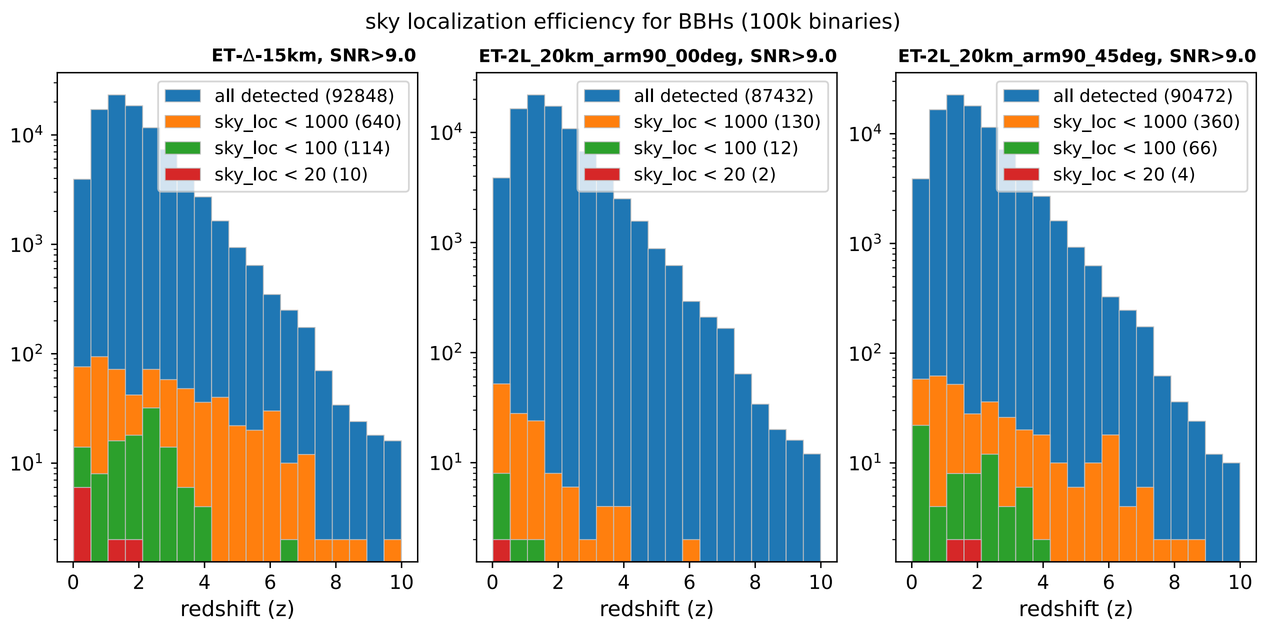




SNR >7 Triangle
SNR >9 2L 15 km

BBH simulations – Sky localization





To agree on:

- Simulation procedure?
- Metrics
- Null-stream? SNR thhreshold?
- IMBH, PBH, Stochastic, Hubble constant, NS EOS, joint detections?

ESFRI

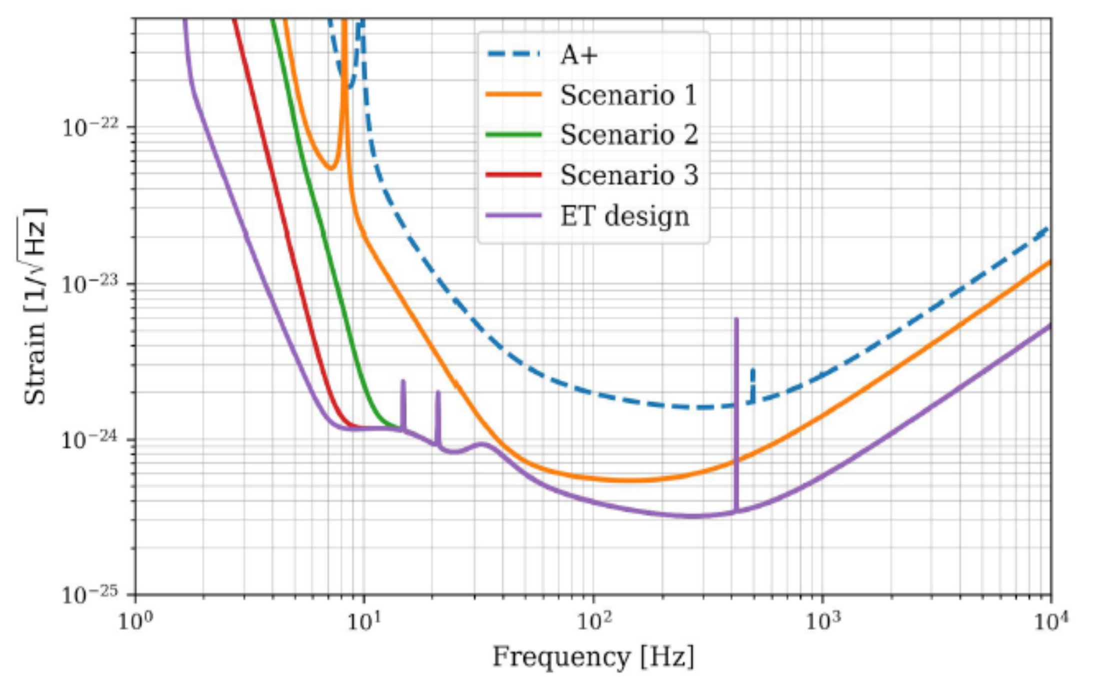
EINSTEIN TELESCOPE

WORK DONE FOR ESFRI

ESFRI

Evolution scenarios

ET EINSTEIN TELESCOPE



ET: evolutionary scenarios

- Scenario1:
  - High power + squeezing issues affecting ET-HF performance
  - ET-LF missing
- Scenario 2:
  - ET-HF full sensitivity
  - ET-LF affected by severe noise issues
- Scenario 3:
  - ET-HF full sensitivity
  - ET-LF affected by some noise issues

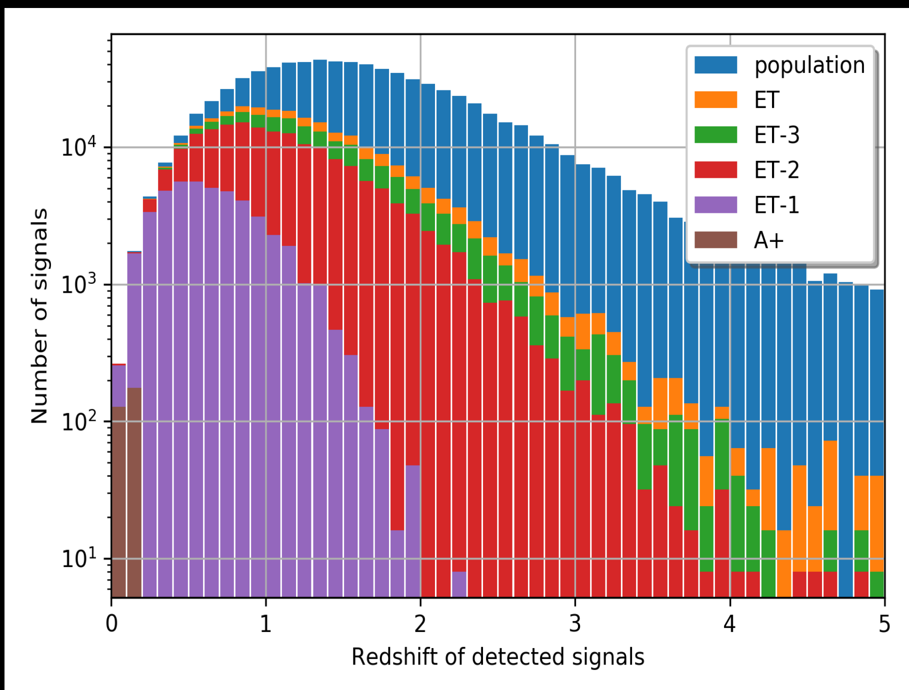
Science Impact

ESFRI

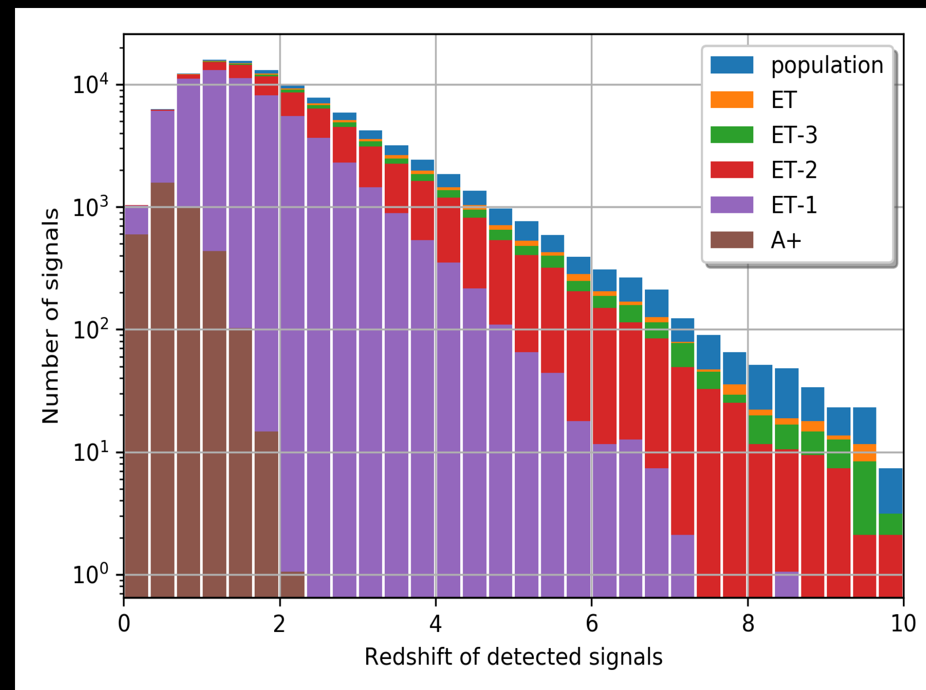
ET EINSTEIN TELESCOPE

COMPACT OBJECT BINARY POPULATIONS

BINARY NEUTRON-STAR MERGERS



BINARY BLACK-HOLE MERGERS

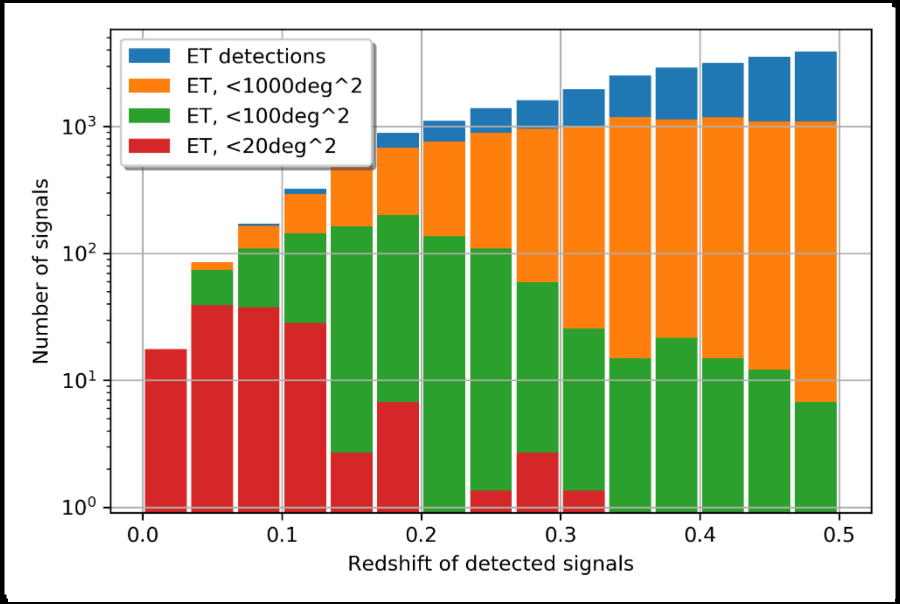


Sampling **astrophysical populations** of binary system of compact objects along the cosmic history of the Universe

Science Impact

ESFRI

ET EINSTEIN TELESCOPE

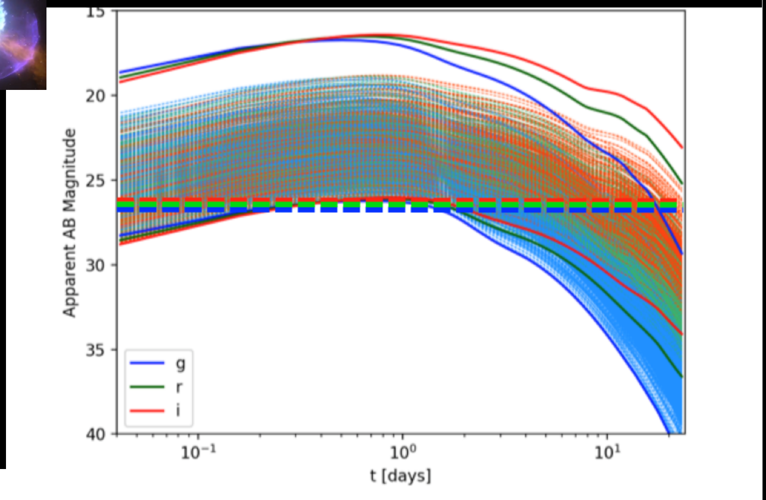


BINARY NEUTRON-STAR SKY LOCALIZATION

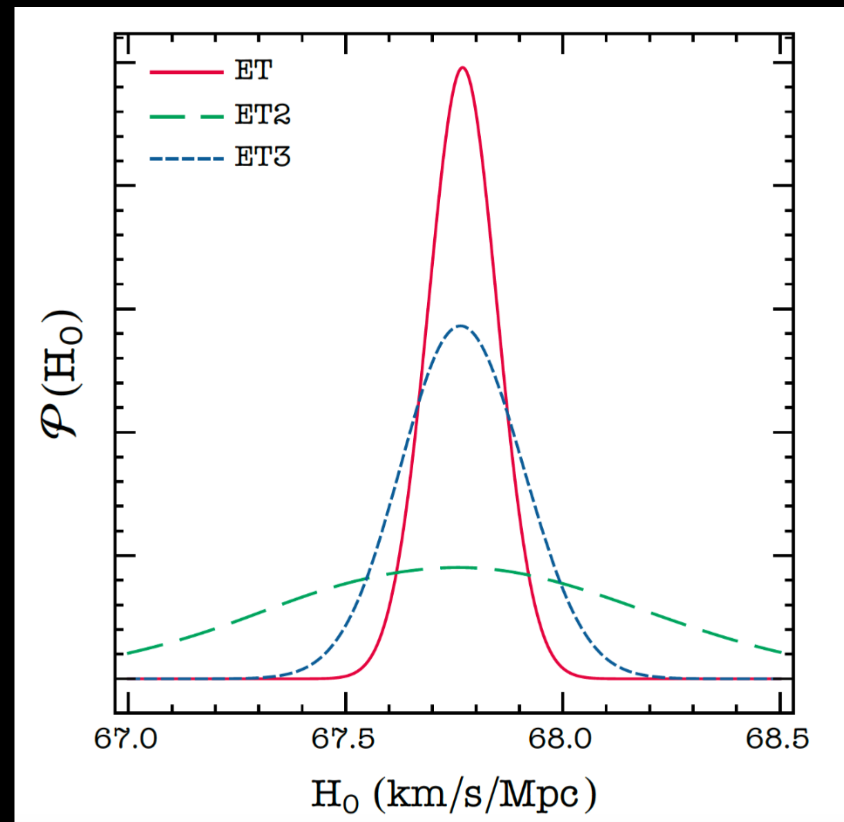
#events	sky-localization < 20 deg^2	< 100 deg^2
ET-S1	3	8
ET-S2	10	60
ET-S3	40	290
ET	150	1110

Science Impact

KILONOVA EMISSION



HUBBLE COSTANT



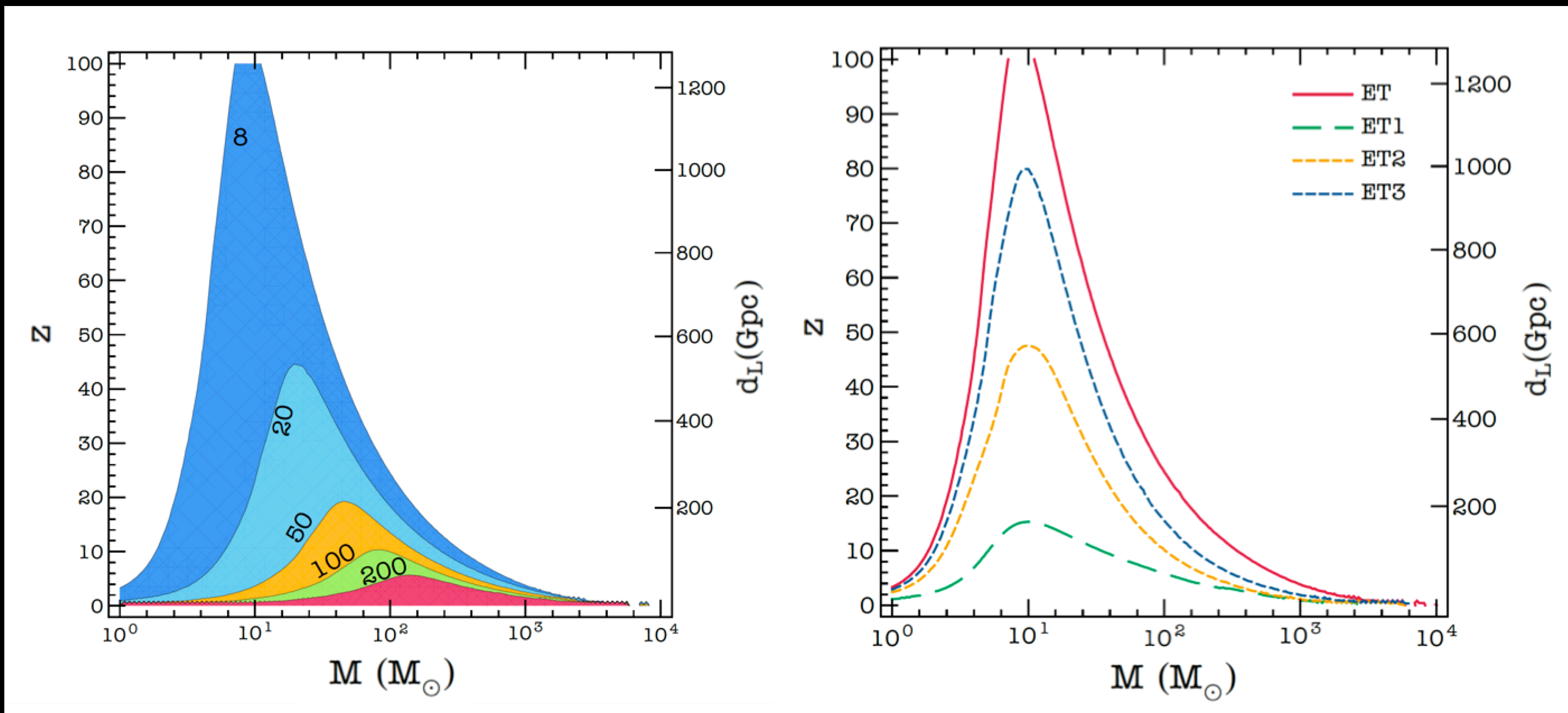
Cosmology: Hubble constant measurements from GW standard sirens

Science Impact

ESFRI

ET EINSTEIN TELESCOPE

MASS COVERAGE and INTERMEDIATE MASSIVE BHs

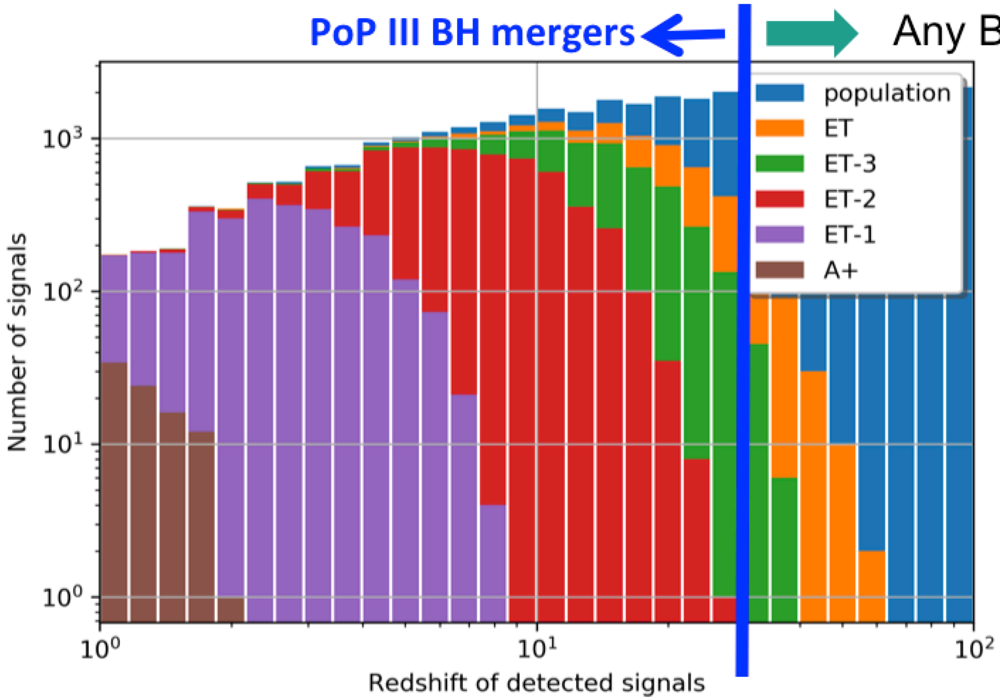


Detecting **intermediate massive BHs** in the volume of the Universe where these rare events are expected to happen

Science Impact

PRIMORDIAL BLACK-HOLES

Disentangle astrophysical PoPIII from primordial BHs



Any BBH merger at z>30 will be of primordial origin

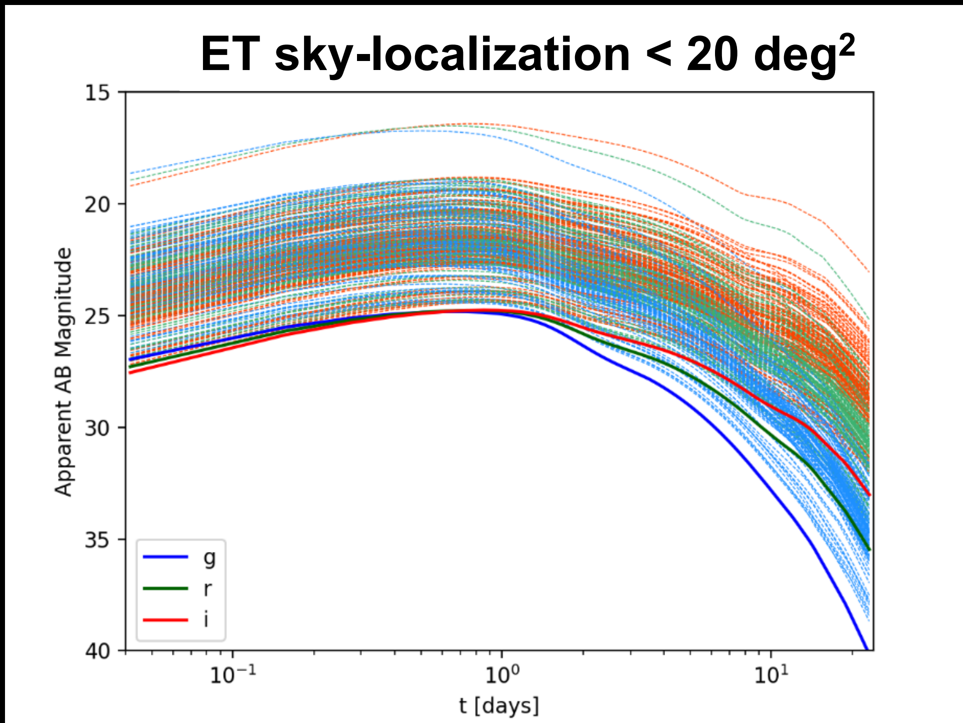
Precise redhsift estimates and statistics to confidentially detect **primordial black-holes**

ALL THE SIMULATION USE SNR=8

THERMAL EMISSION - KILONOVAE

KILONOVA PHYSICS, NUCLEOSYNTHESIS, NUCLEAR PHYISCS and COSMOLOGY

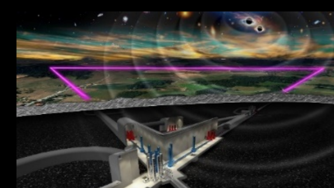
ET+Vera Rubin synergy



Credits: Loffredo

VERA RUBIN OBSERVATORY ToO:

- three epochs of 600s observations in two filters
- detection efficiency is larger than 99% up to z=0.3



VERA C. RUBIN OBSERVATORY

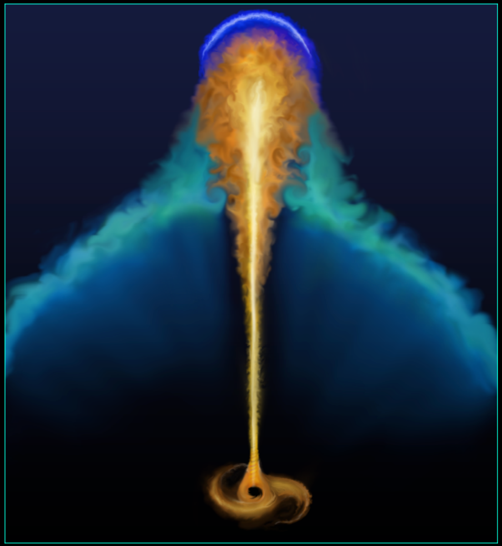
	Joint ET/VRO detections per year	Fraction of VRO telescope time
ET	60	6%
ET+2G	170	17%

COSMOLOGY: Hubble constant measurement from GW standard sirens with sub-percent precision!

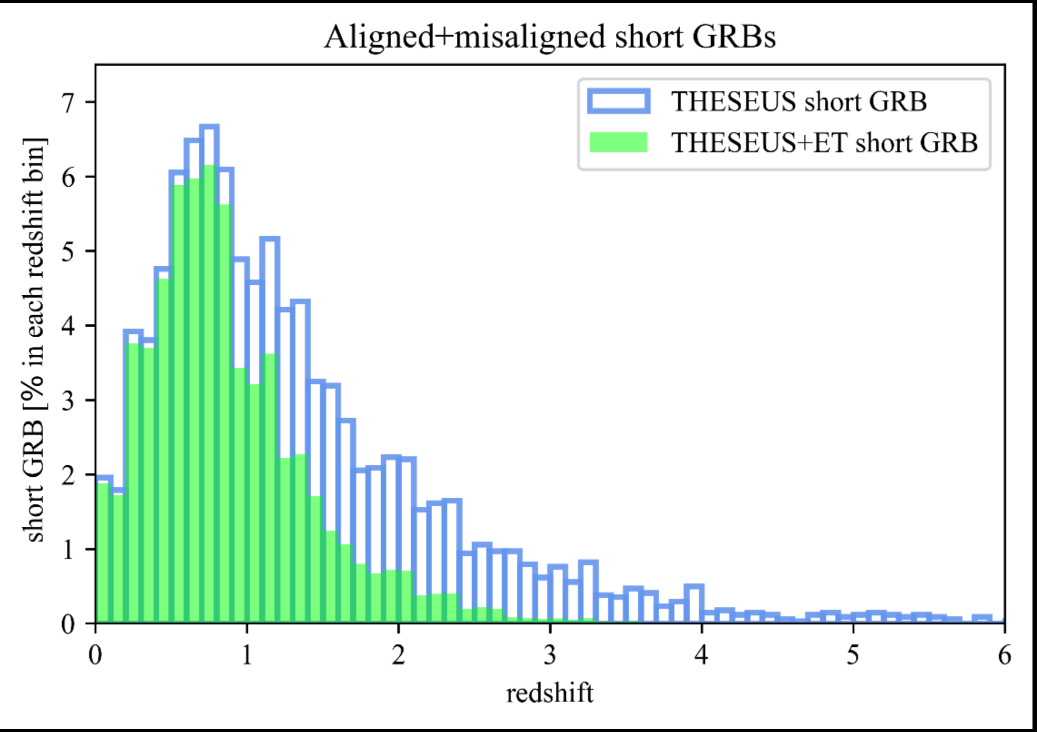
HIGH-ENERGY

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

ET+THESEUS synergy



Credits: Ronchini



THESEUS-ET joint detections
13 per year