

Prédiction et suivi des signaux multi-messagers

S.D. Vergani



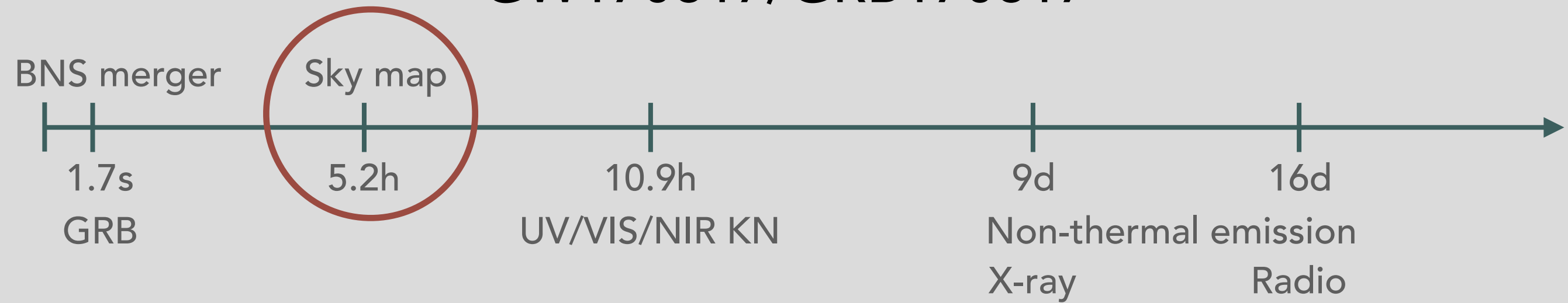
- Are all BNS similar to GW170817 (EM side)?
- Rate?
- Population?
- Are all BNS associated with SGRB?
- Are all SGRB associated with BNS?
- NSBH ?
- r-process heavy element production

GW170817/GRB170817

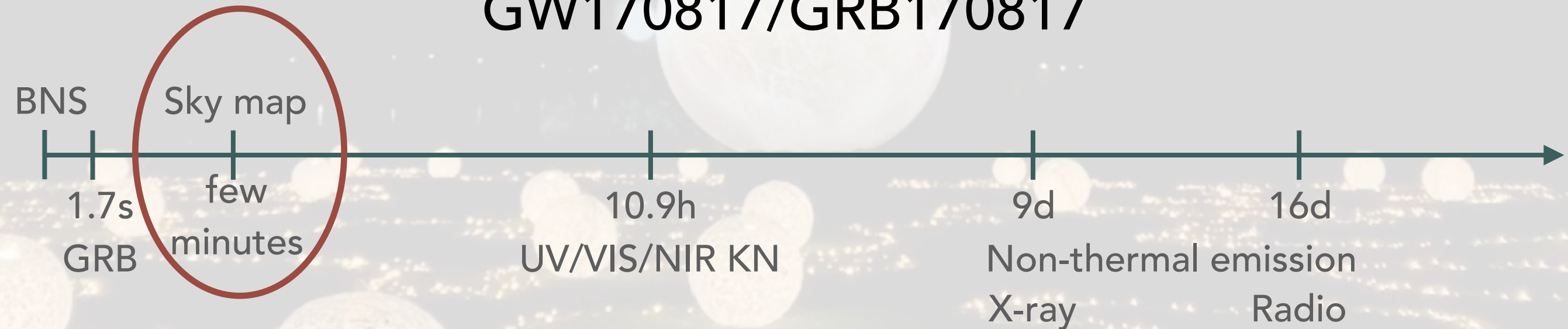
Worldwide, long-term effort is needed

We were lucky

GW170817/GRB170817



GW170817/GRB170817



**O3 & O4 runs
Faster**

Early kilonova evolution
Reverse shock?
X-ray emission?

O3 & O4 runs

LVC Observing scenario paper
<https://arxiv.org/pdf/1304.0670.pdf>

O3 Range: aLIGO 110–130 Mpc, AdV 50 Mpc, KAGRA 8–25 Mpc

O4 Range: aLIGO 160–190 Mpc, AdV 90–120 Mpc, KAGRA 25–130 Mpc

Observation Run	Network	Expected BNS Detections	Expected NSBH Detections	Expected BBH Detections
O3	HLV	2^{+8}_{-2}	0^{+19}_{-0}	15^{+19}_{-10}
O4	HLVK	8^{+42}_{-7}	2^{+94}_{-2}	68^{+81}_{-38}
		Area (deg ²) 90% c.r.	Area (deg ²) 90% c.r.	Area (deg ²) 90% c.r.
O3	HLV	250 – 320	310 – 390	250 – 340
O4	HLVK	30 – 48	48 – 69	33 – 47

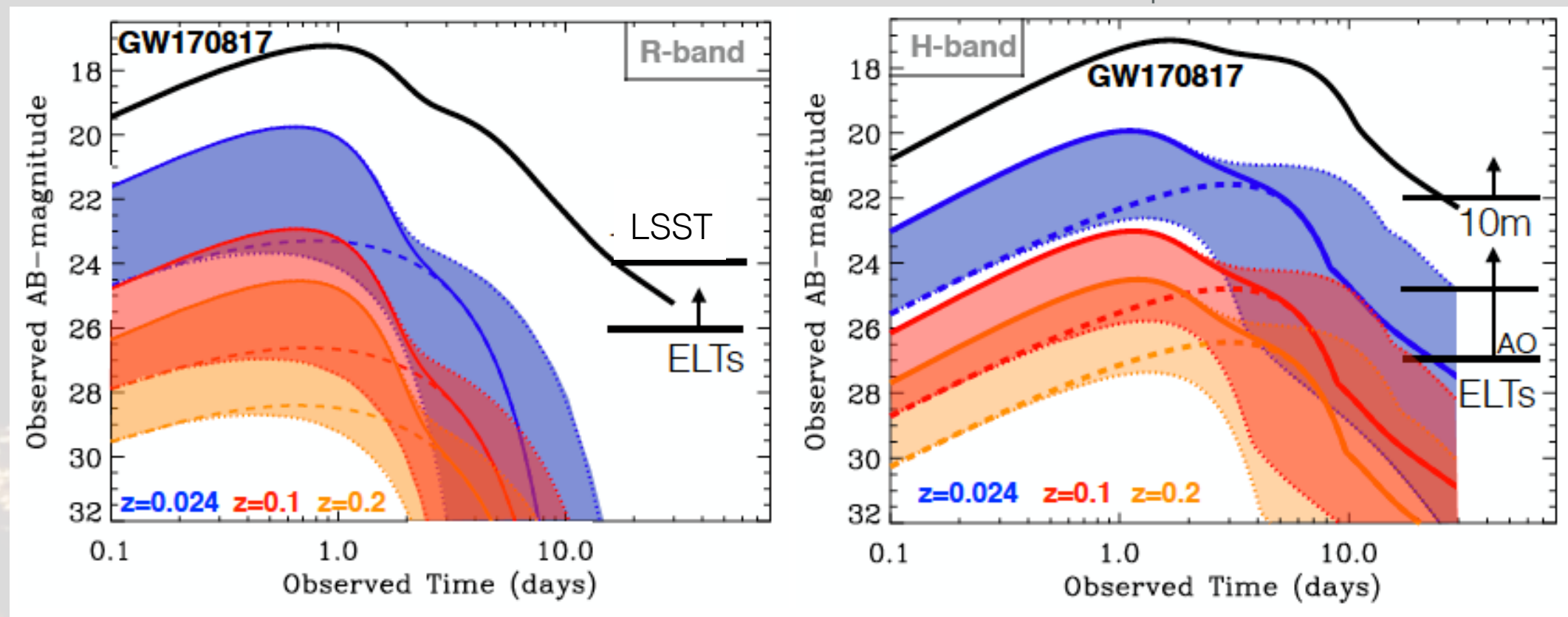
10-14 % < 20 deg²
 2-4 % < 5 deg²

38-44 % < 20 deg²
 11-15 % < 5 deg²

Kilonova

Research based on galaxy catalogues, challenging at larger distances

adapted from Chornock+2019

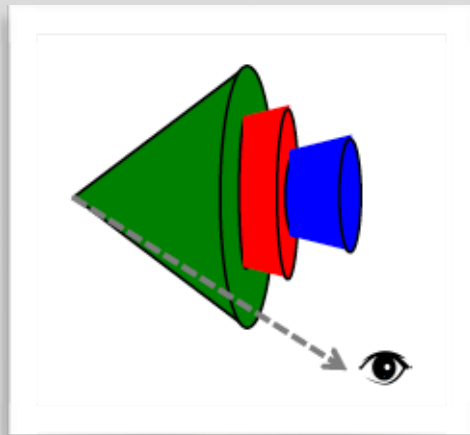


Too faint? Too many candidates? Only photometry?

Prompt gamma-ray emission

GW170817/GRB170817

Gamma-ray detection (FERMI & INTEGRAL)



gamma-ray emission from the sheath of slower material surrounding the jet core and moving towards us

O3 & O4:

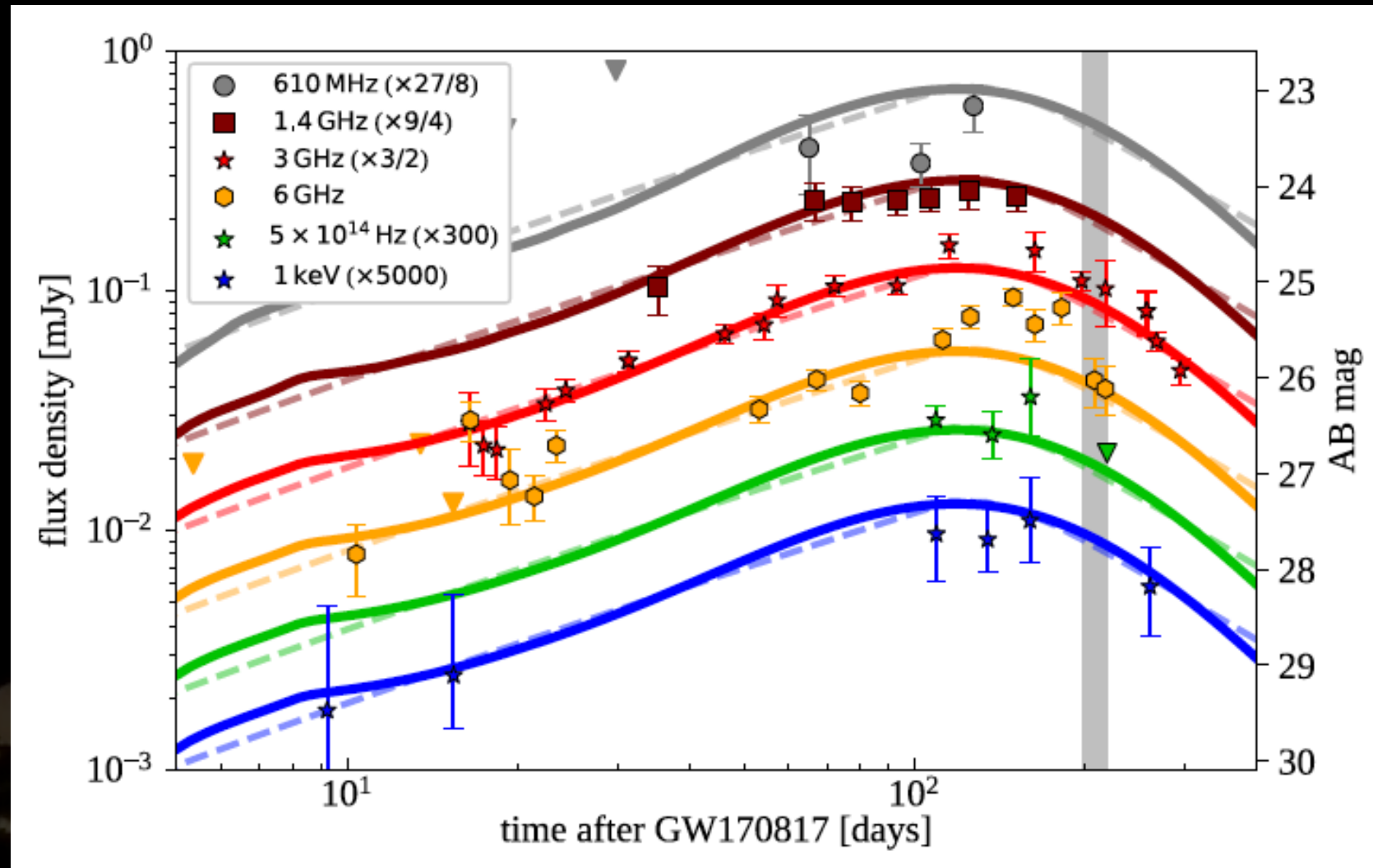
on-axis: good! ...but rare

(Swift GRB: great!... but even rarer)

off-axis: larger angles than GW170817
too faint?

Relativistic jet

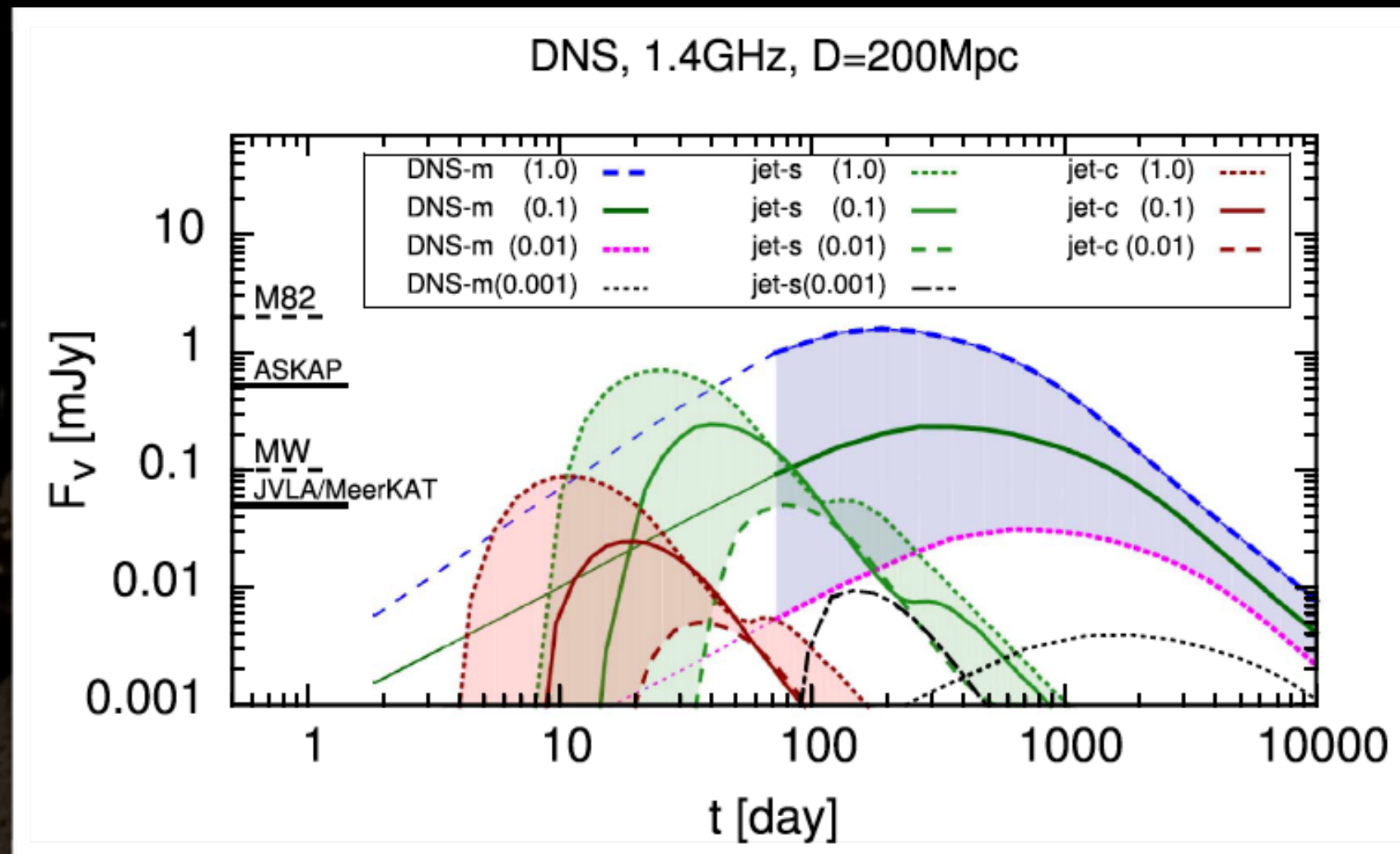
Ghirlanda+2019, Science



> viewing angle \rightarrow fainter
 let's hope for a denser medium

very late time emission

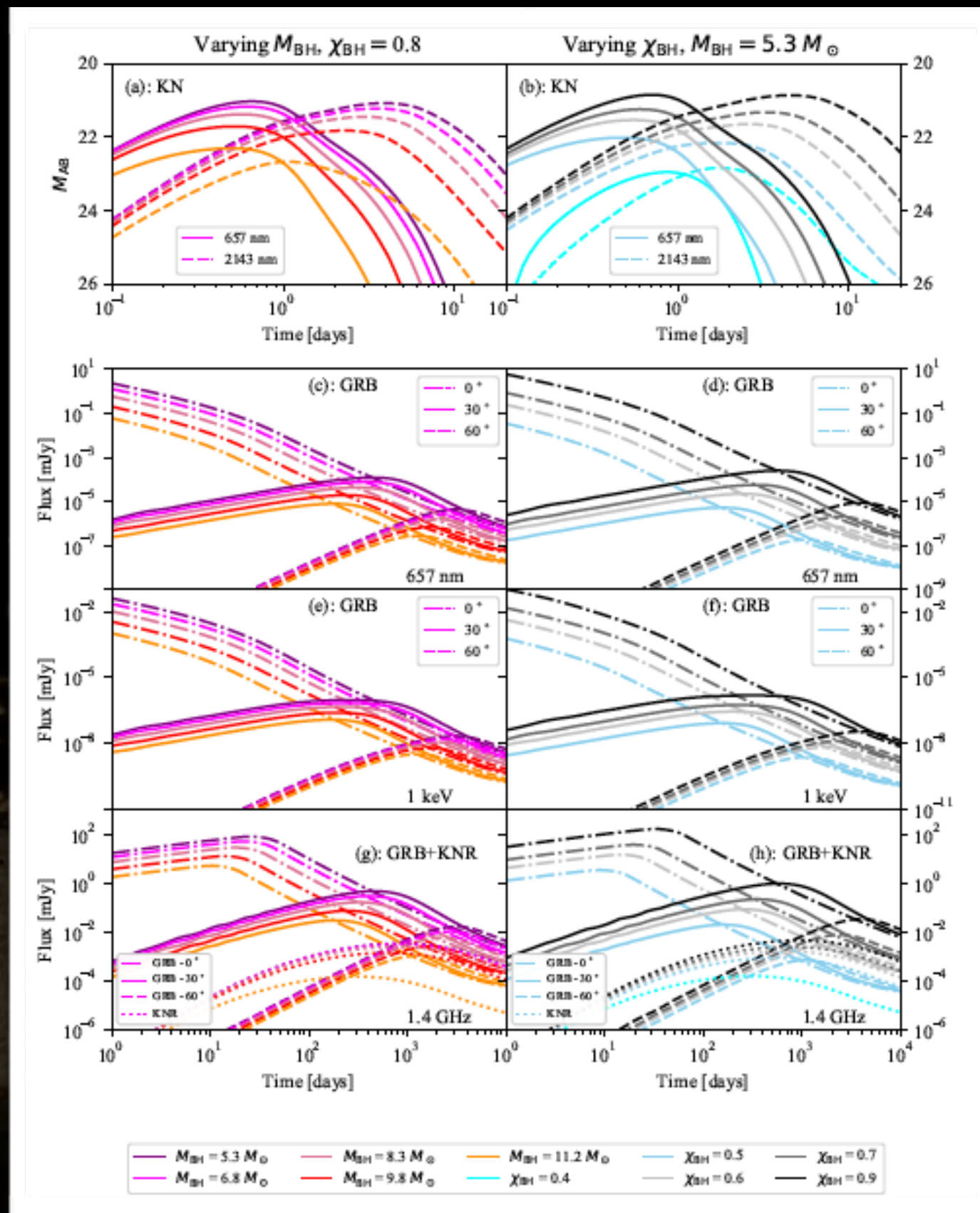
- dynamical ejecta
- tidal tails

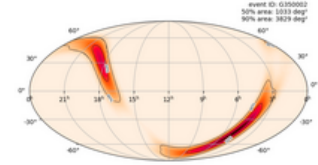
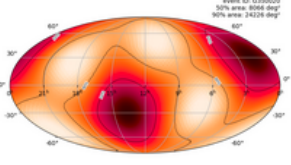
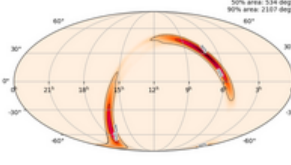
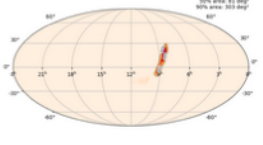
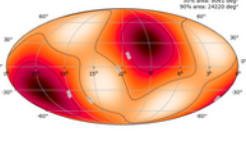
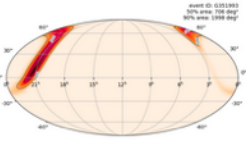


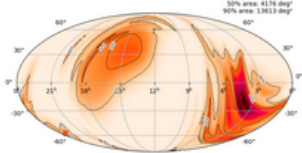

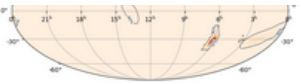
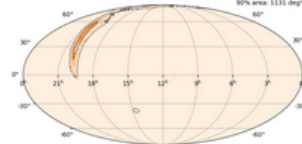
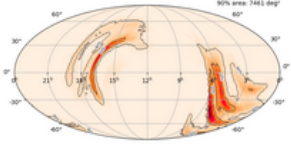
NSBH

Barbieri+2019

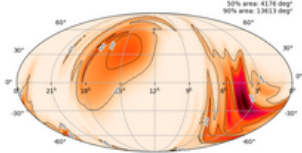

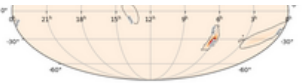
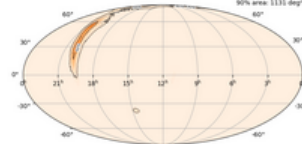
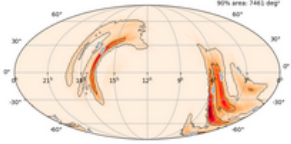
$z=0.054$
 $n=10^{-3} \text{cm}^{-3}$



Event ID	Possible Source (Probability)	UTC	GCN	Location	FAR	Distance (Mpc)
S190910d	NSBH (98%), Terrestrial (2%)	Sept. 10, 2019 01:26:19 UTC	GCN Circulars Notices VOE		1 per 8.5248 years	606+/-197
S190910h	BNS (61%), Terrestrial (39%)	Sept. 10, 2019 08:29:58 UTC	GCN Circulars Notices VOE		1 per 0.88 years	241+/-89
S190923y	NSBH (68%), Terrestrial (32%)	Sept. 23, 2019 12:55:59 UTC	GCN Circulars Notices VOE		1.5094 per year	438+/-133
S190924h	MassGap (> 99%)	Sept. 24, 2019 02:18:46 UTC	GCN Circulars Notices VOE		1 per 3.5493e+10 years	548+/-112
S190930t	NSBH (74%), Terrestrial (26%)	Sept. 30, 2019 14:34:07 UTC	GCN Circulars Notices VOE		1 per 2.0536 years	709+/-191
S190930s	MassGap (95%), Terrestrial (5%)	Sept. 30, 2019 13:35:41 UTC	GCN Circulars Notices VOE		1 per 10.534 years	108+/-38

Event ID	Possible Source (Probability)	UTC	GCN	Location	FAR	Distance (Mpc)
S190901ap	BNS (86%), Terrestrial (14%)	Sept. 1, 2019 23:31:01 UTC	GCN Circulars Notices VOE		1 per 4.5093 years	242+/-81
S190814bv	NSBH (>99%)	Aug. 14, 2019 21:10:39 UTC	GCN Circulars Notices VOE	50% area: 5 deg ² 90% area: 23 deg ² 	1 per 1.559e+25 years	267+/-52
S190510g	Terrestrial (58%), BNS (42%)	May 10, 2019 02:59:39 UTC	GCN Circulars Notices VOE	50% area: 31 deg ² 90% area: 1166 deg ² 	1 per 3.5872 years	227+/-92
S190426c	BNS (49%), MassGap (24%), Terrestrial (14%), NSBH (13%)	April 26, 2019 15:21:55 UTC	GCN Circulars Notices VOE		1 per 1.6276 years	377+/-100
S190425z	BNS (>99%)	April 25, 2019 08:18:05 UTC	GCN Circulars Notices VOE		1 per 69834 years	156+/-41

Extremely rare to have a nearby event as GW170817

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S190425z	BNS (>99%)	April 25, 2019 08:18:05 UTC	GCN Circulars Notices VOE	50% area: 1178 deg ² 90% area: 7461 deg ² 	1 per 69834 years	156+/-41

No EM counterpart yet, but tens of (more or less) possible candidates
999 GCNs

Detectable → detected → identified

Detectable : is it bright enough? (distance, viewing angle)

Instrument sensitivity

Detectable → detected: are we able to cover the large sky map with instruments sensitive enough?

Sensitive, large field of view / surveys instruments

Detectable → detected → identified: are we able to characterize all the candidates?

Deep multi-wavelength / spectroscopic observations

Time limited!

Detectable → detected → identified

- ZTF
- ATLAS
- Pan-STARRS
- ...

detected

- GROWTH
- ENGRAVE
-

identified (and followed)



Electromagnetic counterparts of gravitational wave sources
at the Very Large Telescope
<http://www.engrave-eso.org/>





Governing Council

- Marica Branchesi
- Enzo Brocato
- Paolo D'Avanzo
- Jens Hjorth
- Peter Jonker
- Elena Pian
- Stephen Smartt (Chair)
- Jesper Sollerman
- Danny Steeghs
- Nial Tanvir

Executive Committee

- Stefano Covino
- Andrew Levan (Chair)
- Kate Maguire
- Daniele Malesani
- Susanna Vergani

>200 members



Large Programme @ VLT

~ 230hr to follow-up EM candidate counterparts
photometry, spectroscopy, polarimetry

“Spin-off” radio-mm and HST awarded programs



Weekly on-call Operations Team & Writing Team

WG: imaging, spectroscopy, polarimetry, theory,
infrastructure, epo, external

Many ENGRAVE members have time
at different facilities to search for the EM counterpart

Situation in ~2025 (Phase Plus)

- LIGO - Virgo - KAGRA - LIGO India
- NSNS (rate: ?) ~ *15 times current volume*
- sky regions ~few/ten square degrees

- GW alert

Nearby or on-axis events —> “easy cases”

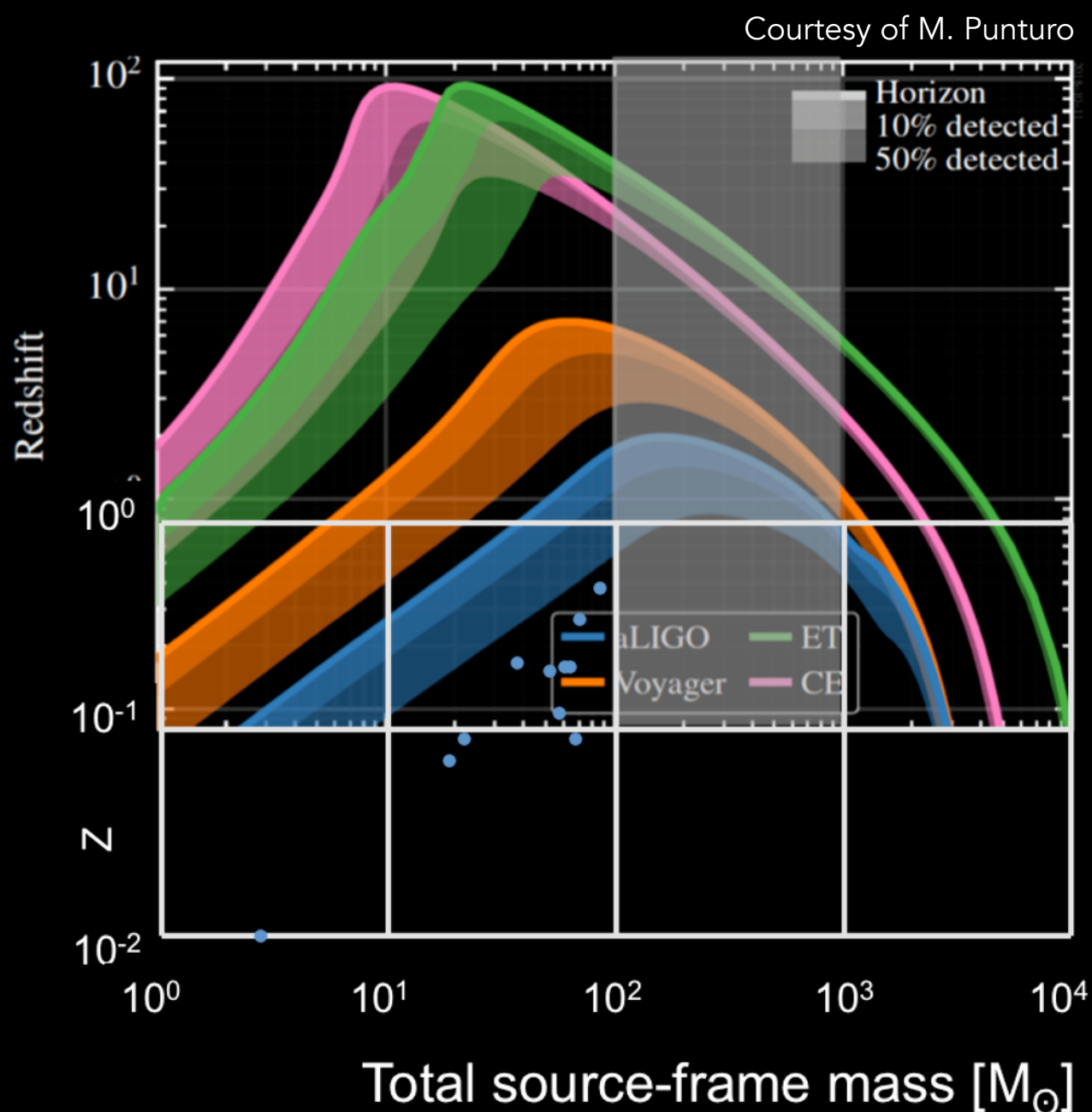
Higher redshift (+ larger error region) —> ?

No major evolution expected in EM instruments

Less time available?

Situation in ~2035

3G instruments for GW Einstein Telescope & Cosmic Explorer



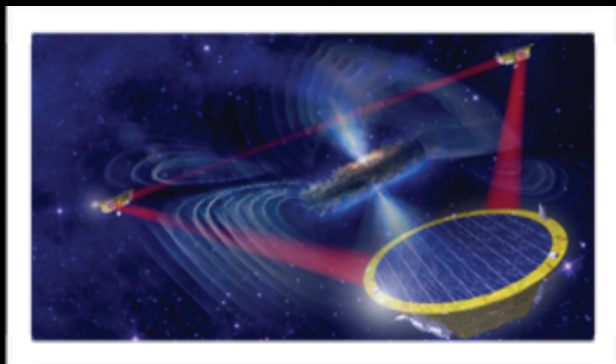
Rely on wide field space missions
able to identify high-energy emission
with good localization



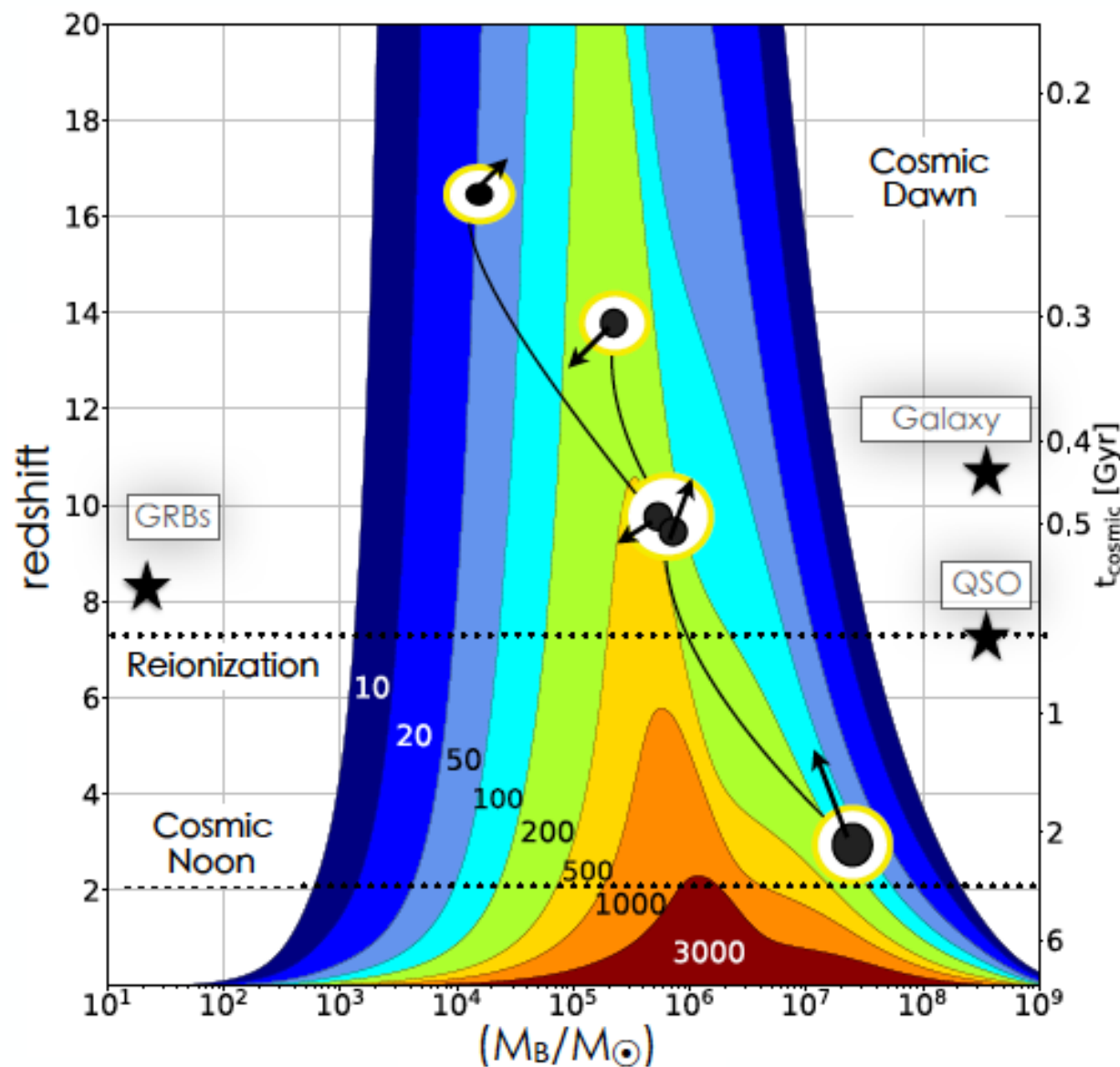
<https://www.isdc.unige.ch/theseus/>

Situation in ~2035

LISA



Colpi+2019



Merger of galaxies

$z=2$

1 day before : 100 deg²
 merger time : 1 deg²



Merci