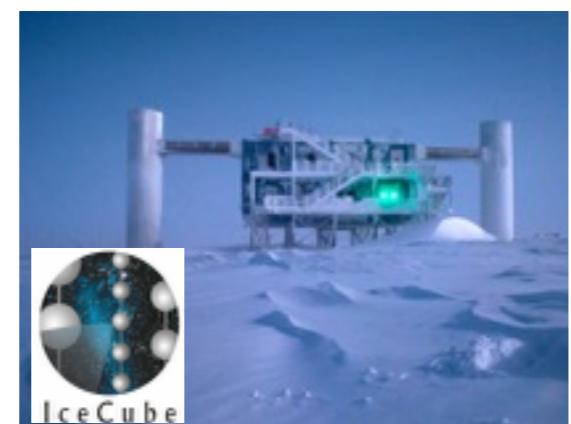
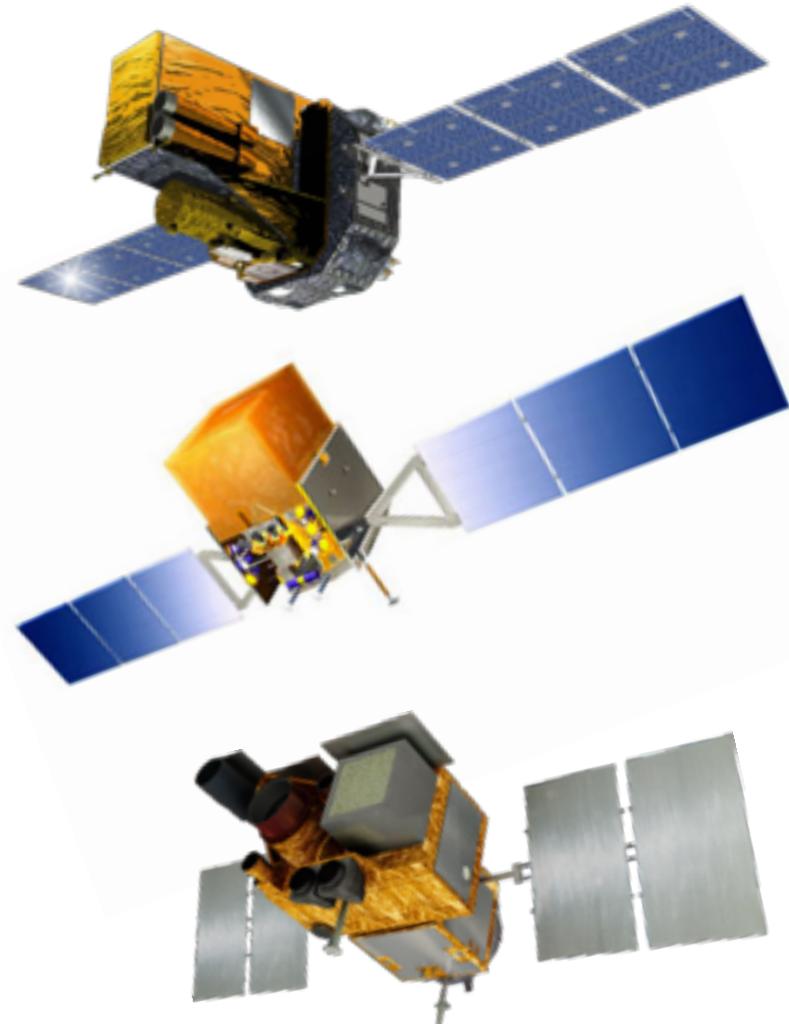
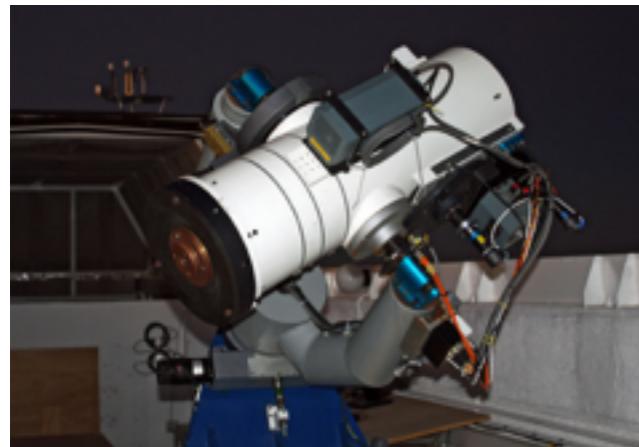


Le suivi d'alertes



Journée PNHE, 2016-03-30

Fabian Schüssler, Irfu/CEA-Saclay

100s deg²

Localisation uncertainty

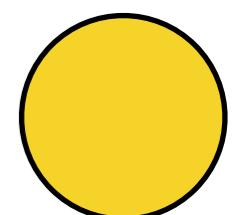
arcsec

msec

Duration

days

well established follow-ups



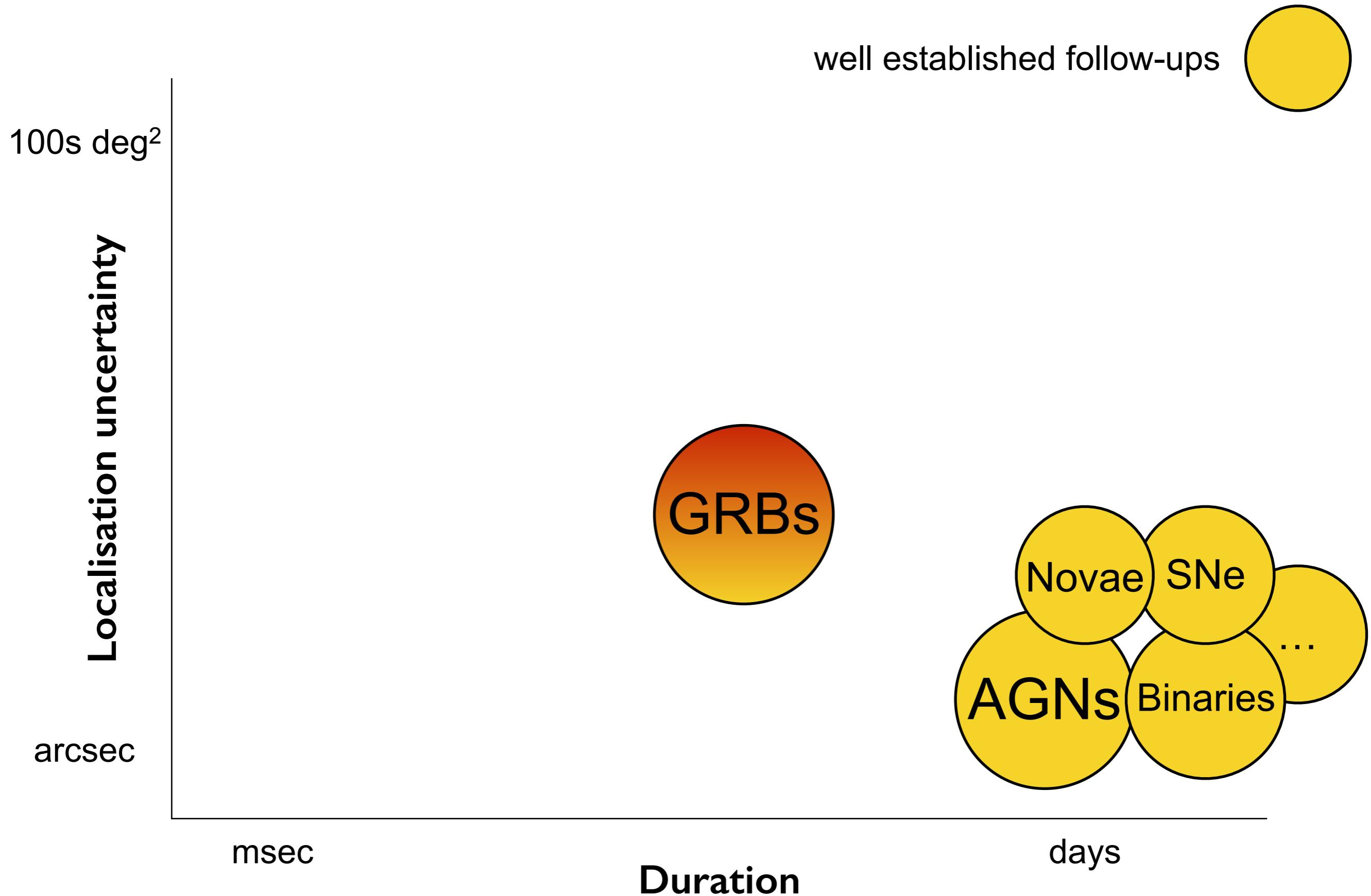
Novae

SNe

AGNs

Binaries

...



100s deg²

Localization uncertainty

arcsec

msec

Duration

days

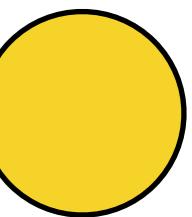
well established follow-ups

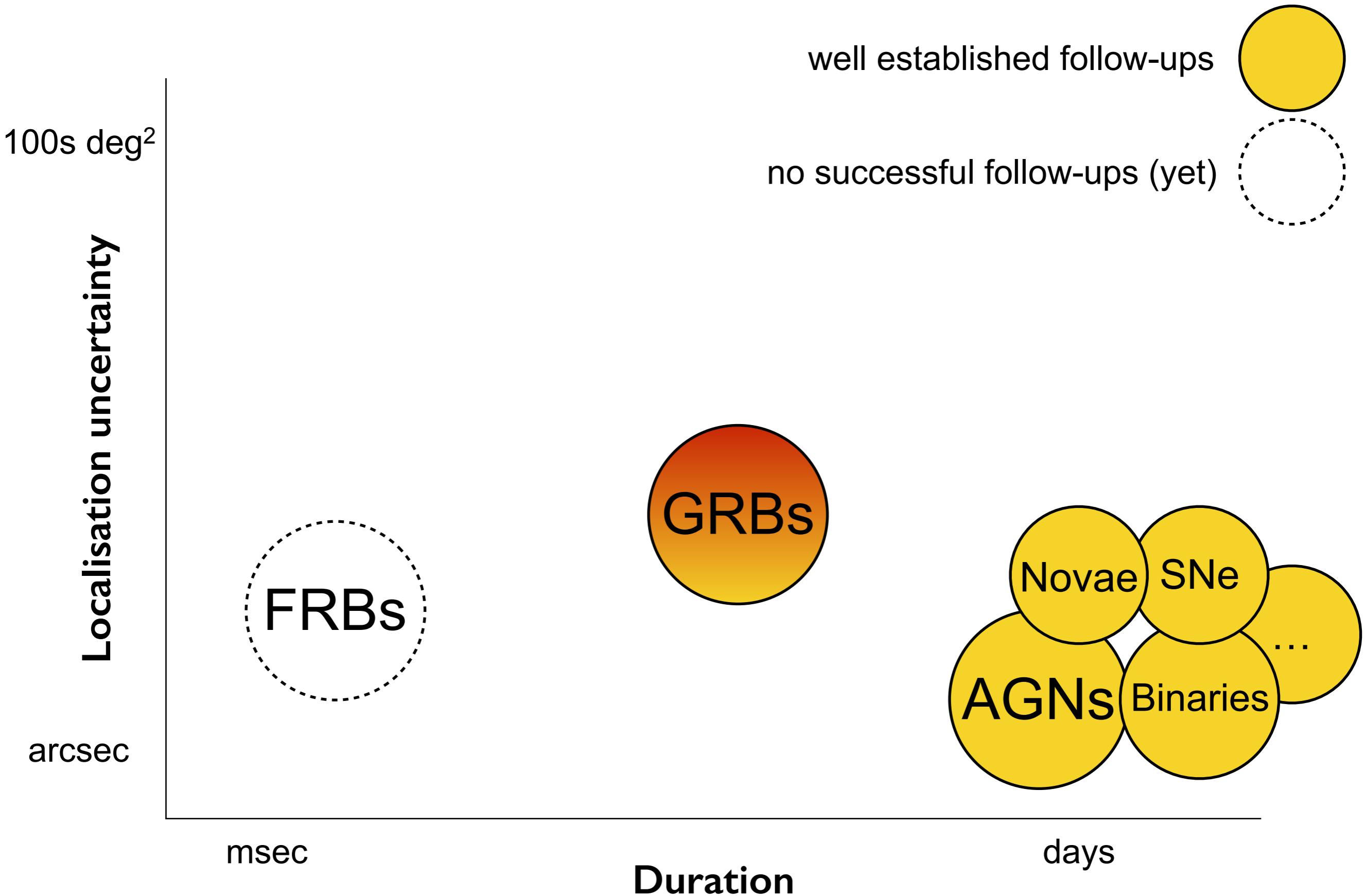
GRBs

Afterglow follow-up

Novae SNe

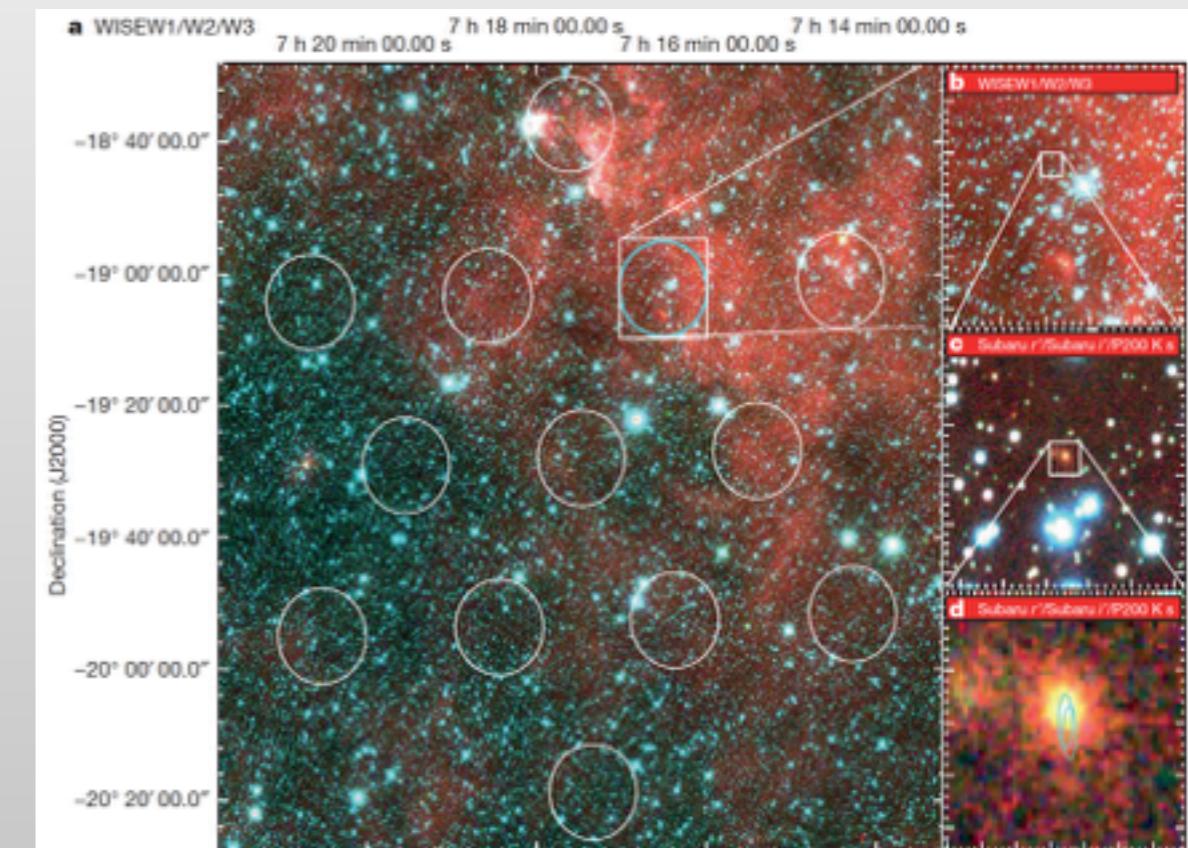
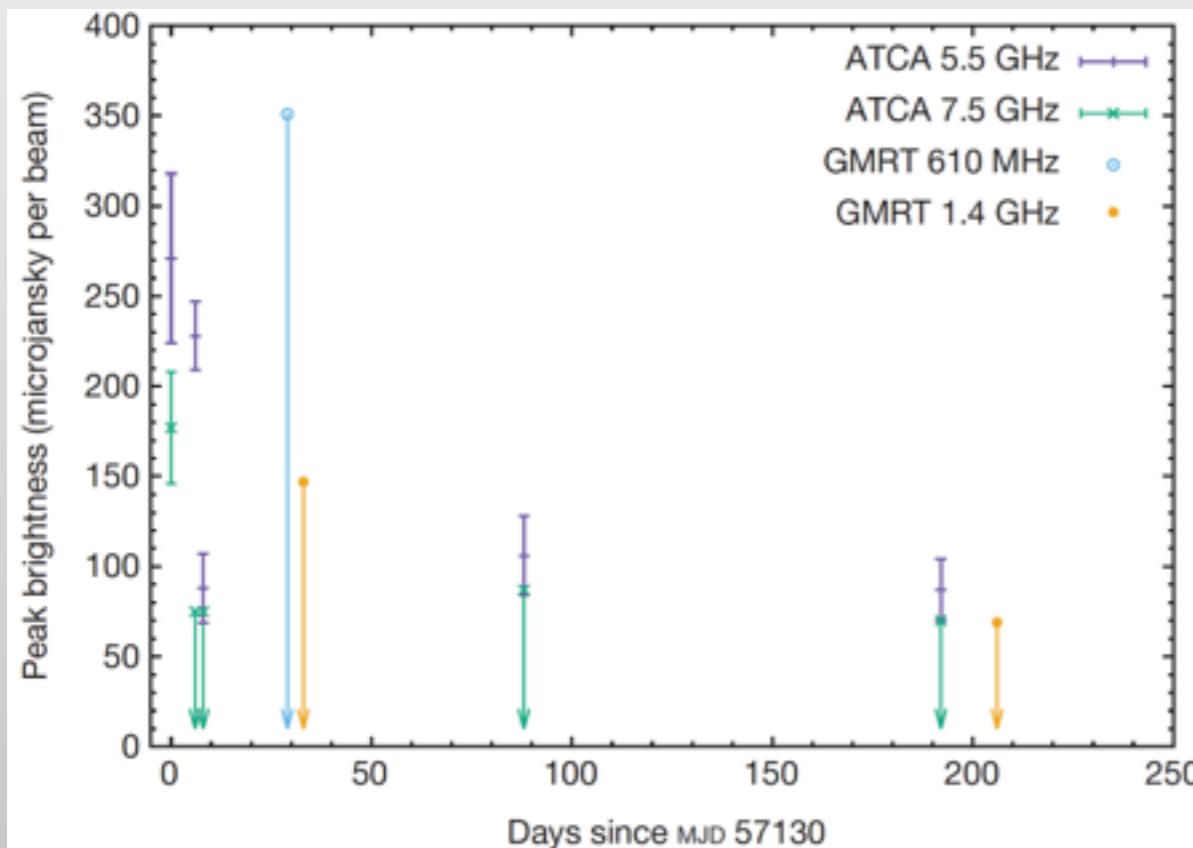
AGNs Binaries



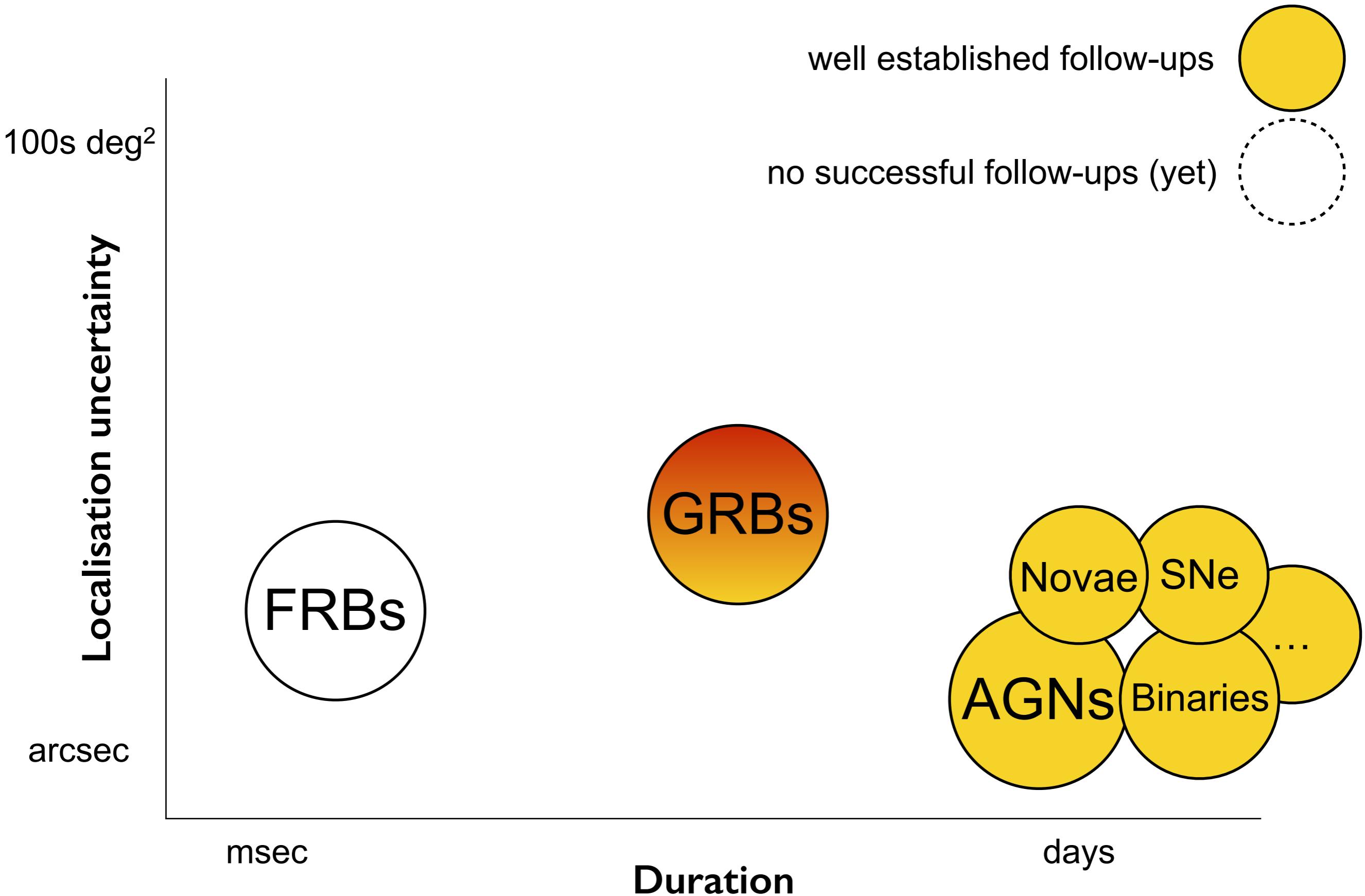


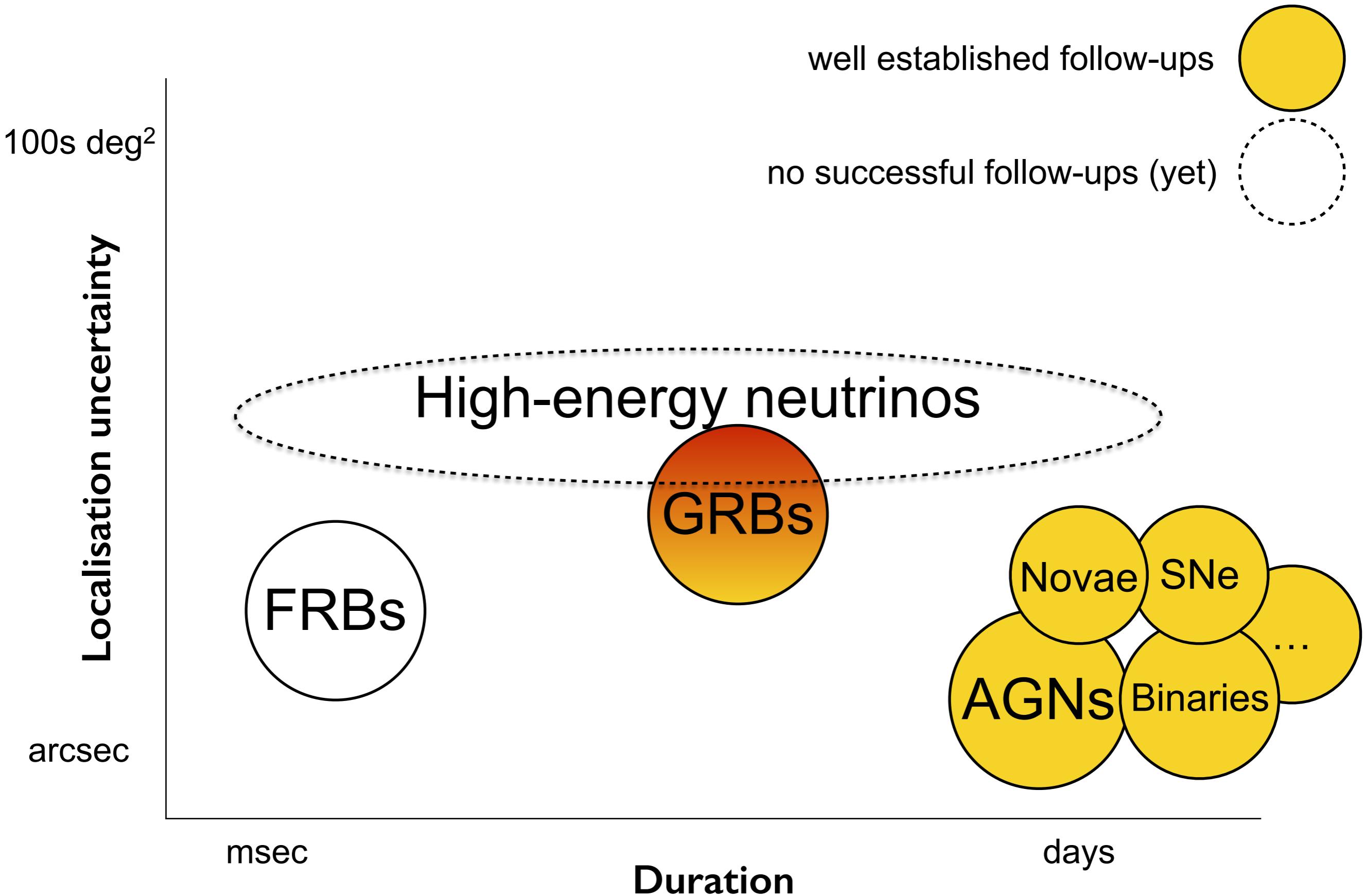
Keane et al., Nature 530: The host galaxy of a fast radio burst

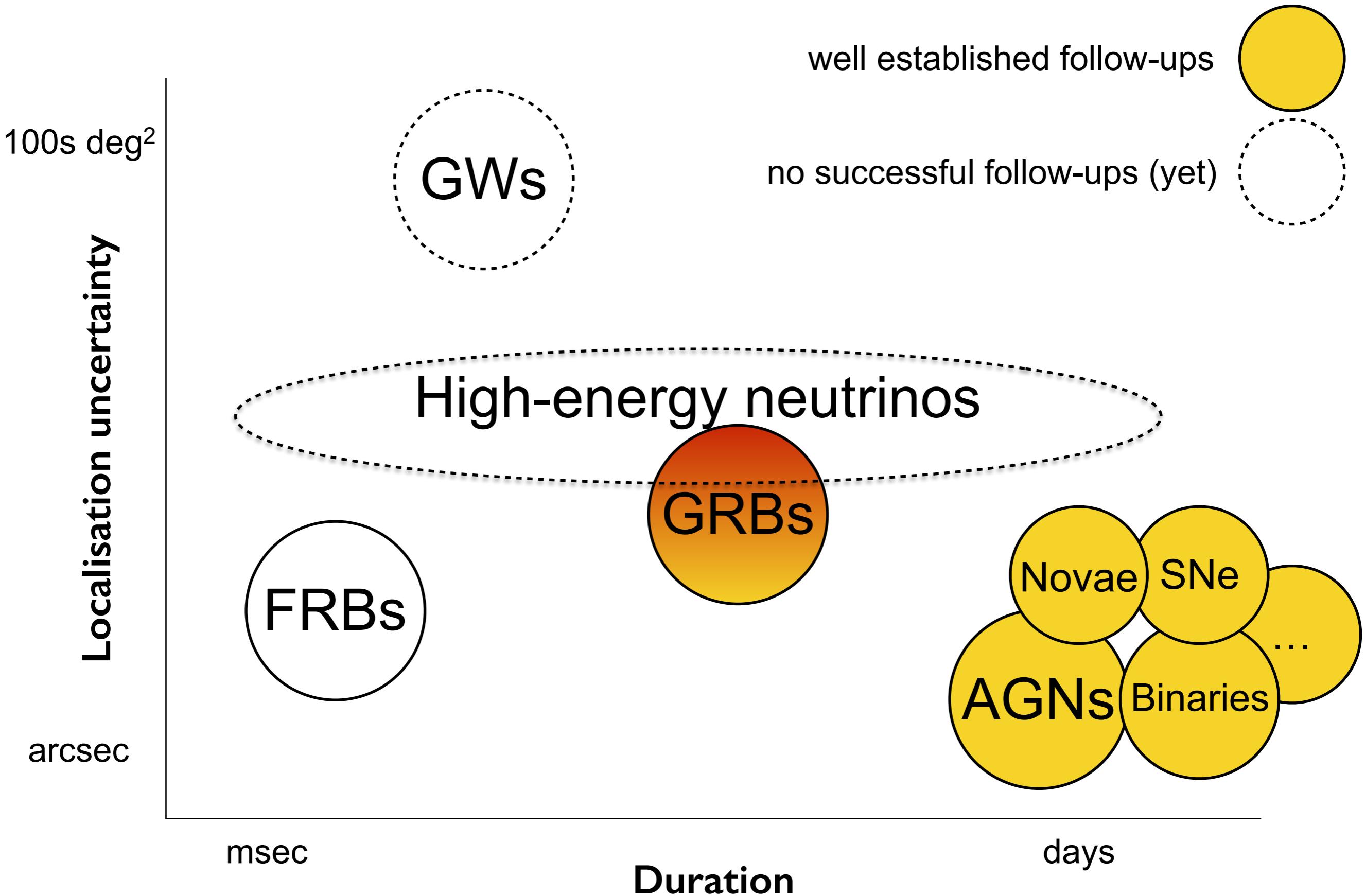
- SUPERB@Parkes: detection of FRB150418
- ATCA follow-up: detection of afterglow emission (up to 6days)
- Subaru: identification of galaxy + redshift $z \sim 0.492$



William et al., ATEL 8752, arXiv: 1602.08434
VLA observations: radio afterglow due to AGN unrelated to FRB

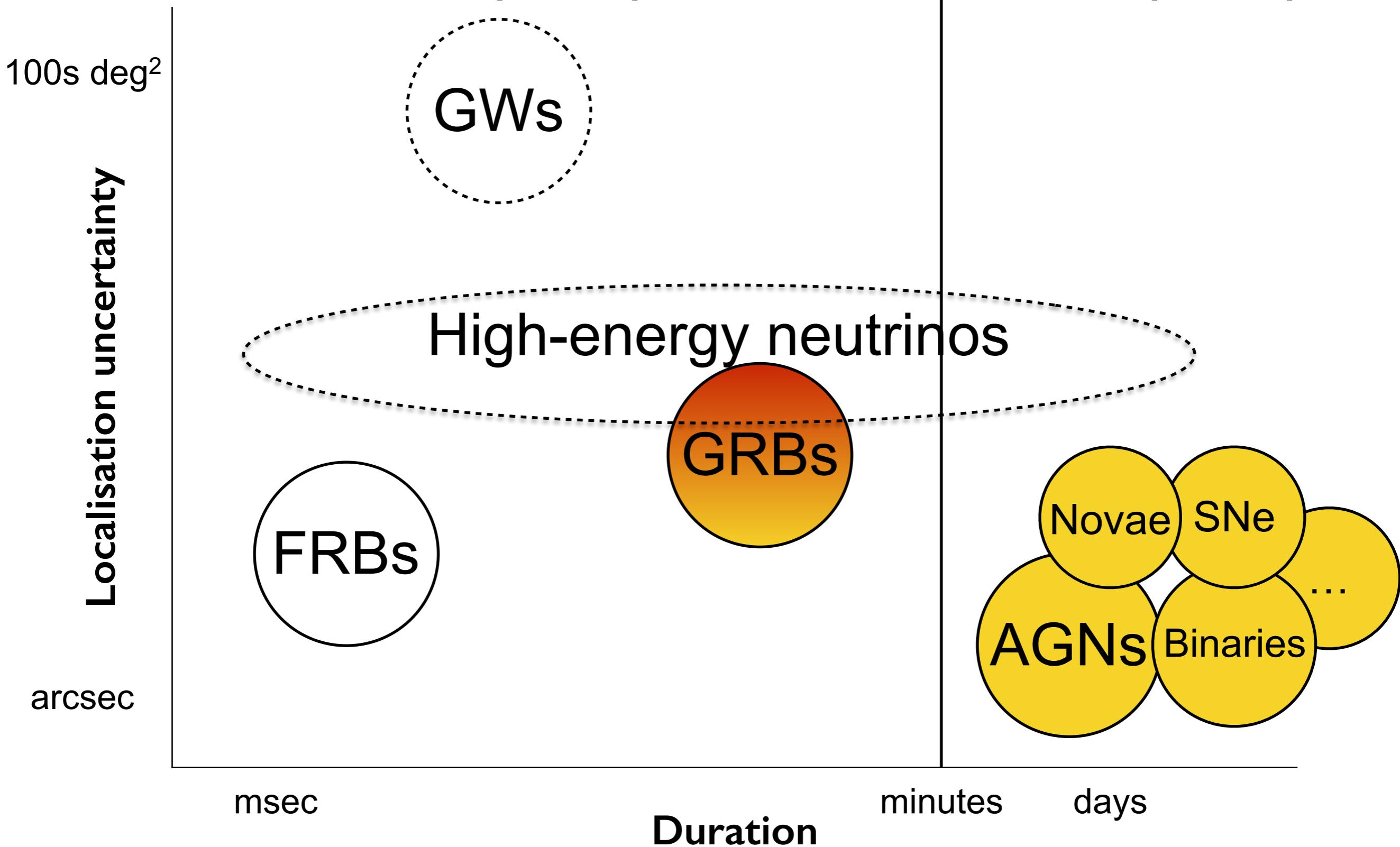






prompt alerts

Non-prompt



Alert emission

- Typically from monitoring instruments with large field of view
 - radio: SUPERB@Parkes, ...
 - optical: ASAS-SN, Pan-STARRS, MASTER, ... (LSST)
 - X: Swift, (SVOM)
 - Gamma: Fermi, HAWC, (CTA, LHASSO)
 - HE-Neutrinos: IceCube, Antares, (KM3NeT)
 - GW: Ligo/Virgo
- Additional alerts found during pointed observations
 - all instruments, all wavelengths/messengers
- Prompt alert distribution via the GCN network + VoEvents messages
 - efficient, fast and reliable
 - main delays due to event reconstruction + data transmission (satellite downlinks, etc.)
- Non-prompt alerts
 - ATELs
 - Emails (e.g. Fermi light-curve analyses, AGN flares between TeV instruments, etc.)

Alert follow-up

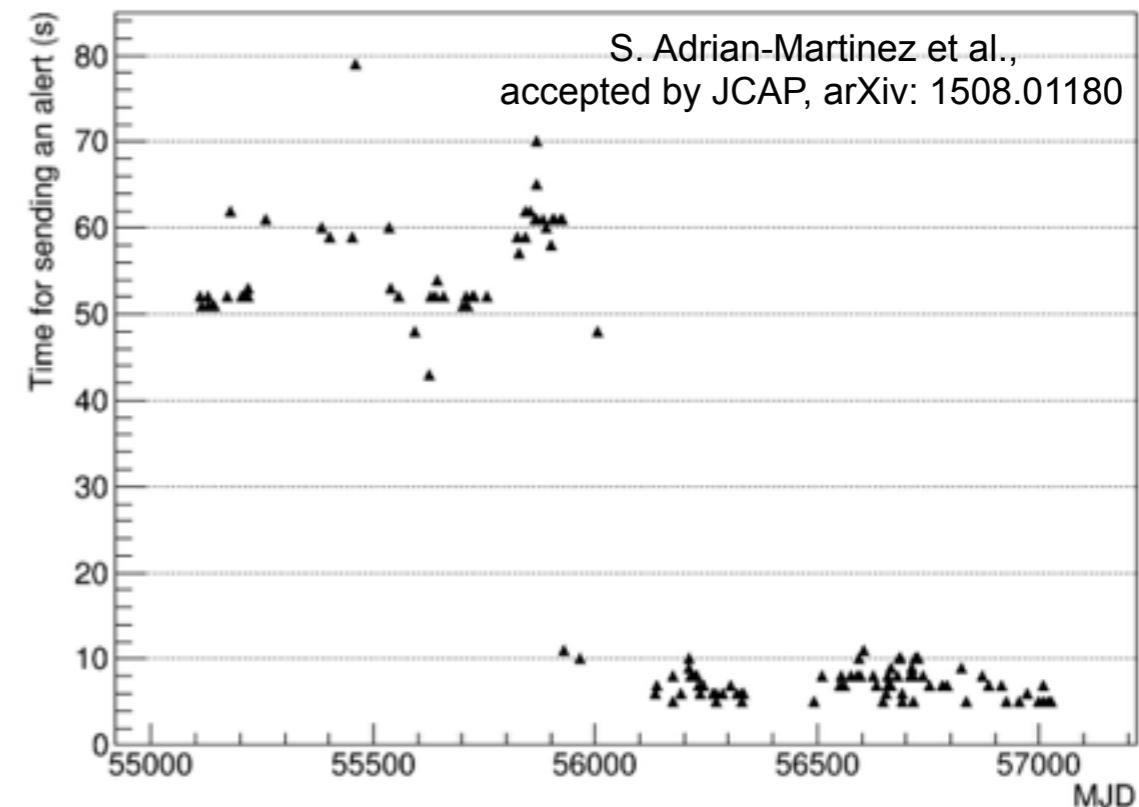
- Very active field, many observatories actively taking part
- currently good coverage of (almost) all wavelengths
 - many optical robotic telescopes: TAROT/Zadko, Master, iPTF, LCOGT, GFT/GWAC@SVOM
 - missing sensitive MeV instrument



Lessons learned from recent events (I)

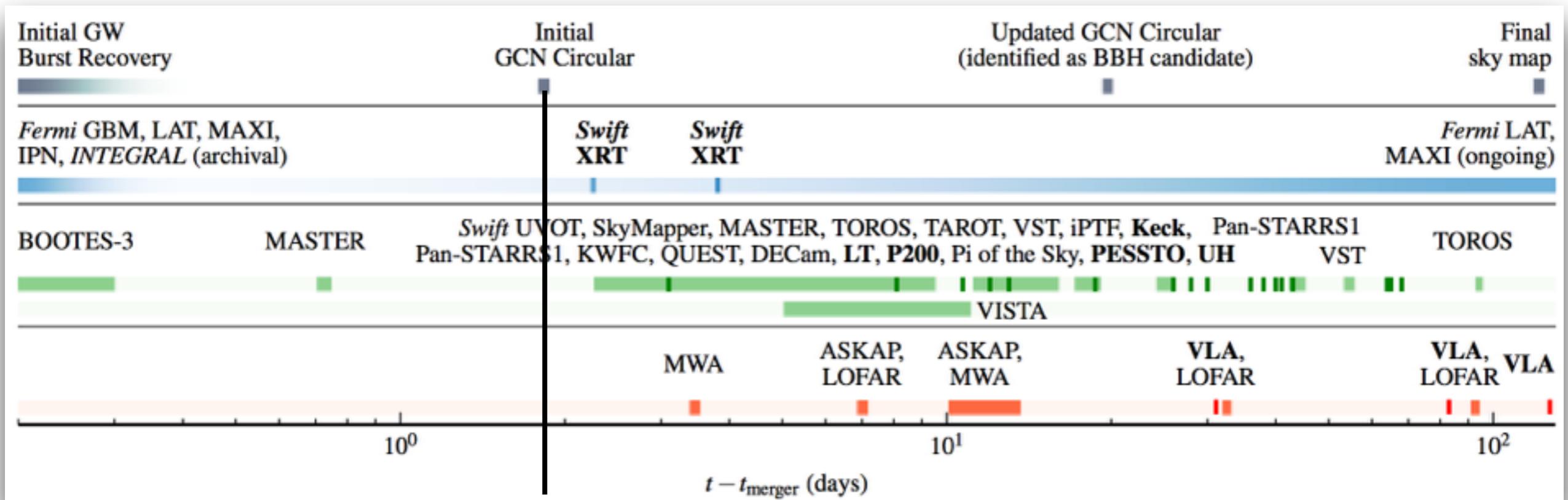
■ High-energy neutrinos

- astrophysical flux detected by IceCube => **neutrino event/alerts become ‘meaningful’**
- no localized excess found by neutrino telescopes
- need for correlations with additional information from other messengers
 - input from MWL observations (e.g. searches for neutrinos around GRB detections, ...)
 - alerts from neutrino telescopes followed by MWL observations
 - example: TAToO@ANTARES: alerts emitted within a few seconds
 - EM-follow up covering the full spectrum (radio - optical - X-ray - gamma-rays)
 - significant interest, e.g. [ATEL 7987](#)
- low latency publication of IceCube HESE events coming very soon



Lessons learned from recent events (II)

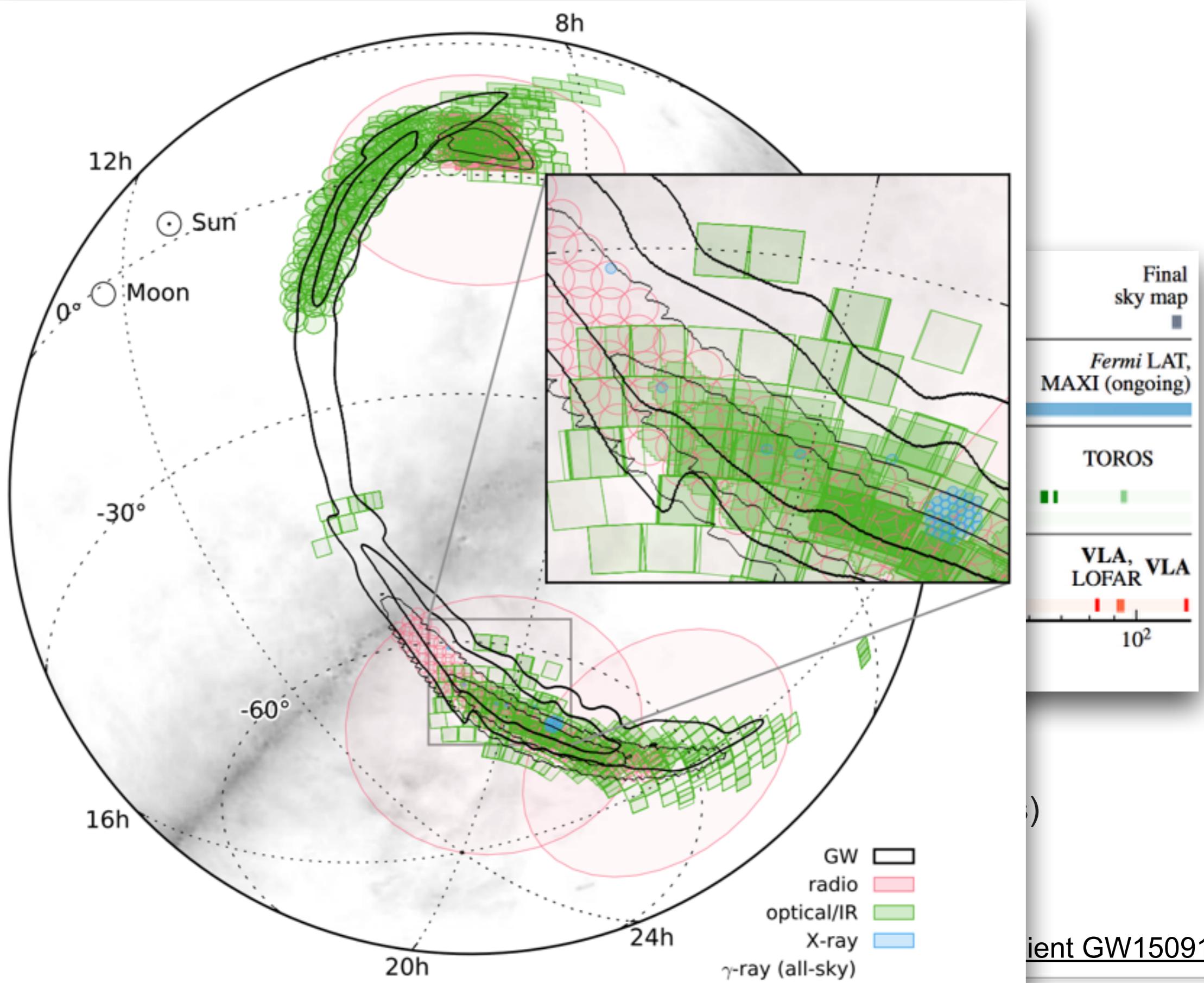
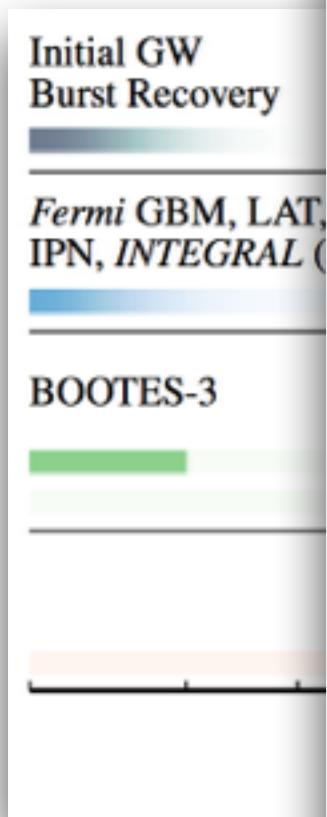
- Gravitational waves (GW150914)
 - (private) alert emission two days after the GW detection



- EM follow-up difficult due to large localization uncertainties (+ systematic shifts)

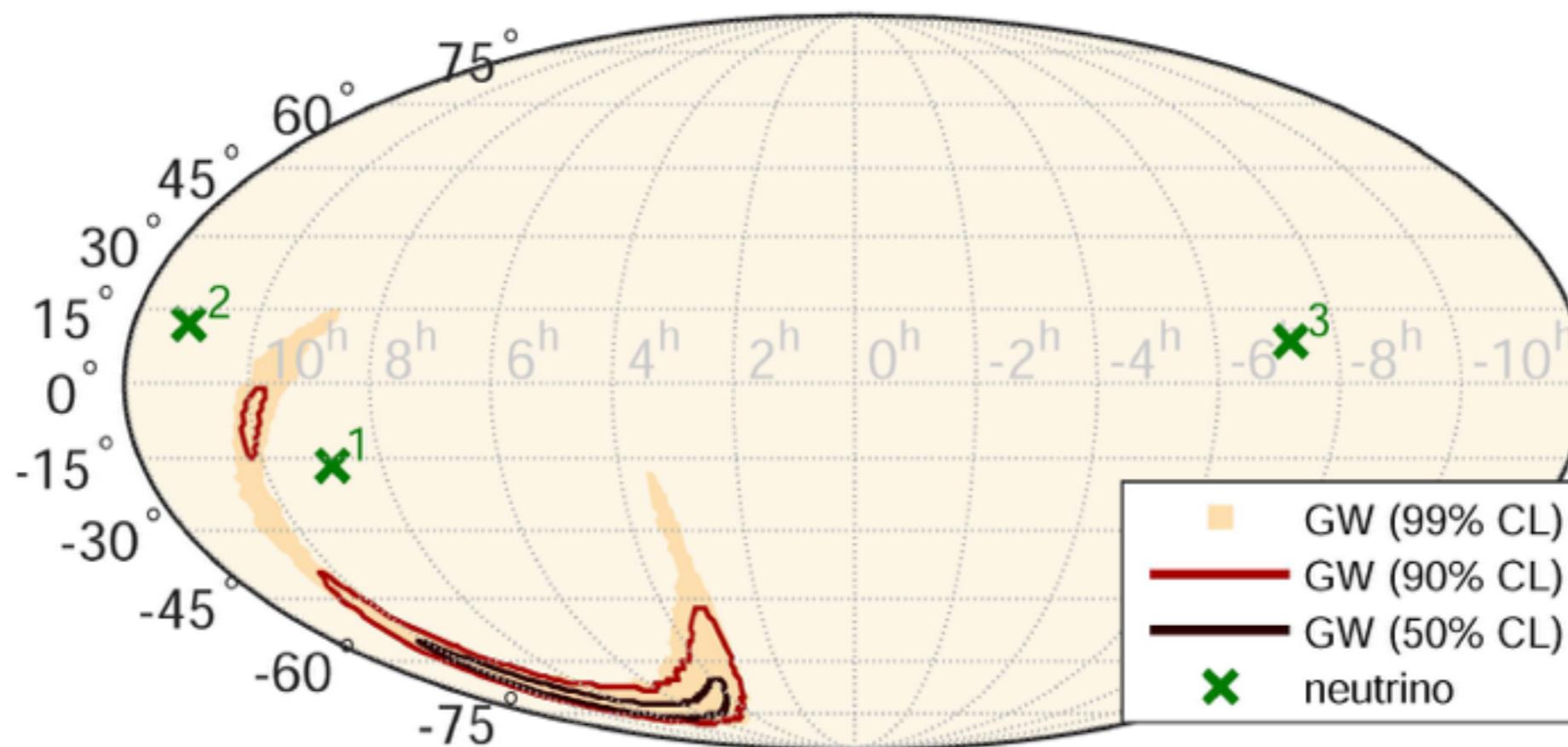
Lessons

- Gravitational waves
- (private)



Combining these two recent breakthroughs

- Searching for high-energy neutrinos in coincidence (± 500 s) with GW150914
 - IceCube: 3 neutrinos outside the LIGO localisation
 - ANTARES: no neutrino within time window
 - compatible with atmospheric background expectations



"High-energy Neutrino follow-up search of Gravitational Wave Event GW150914 with IceCube and ANTARES"

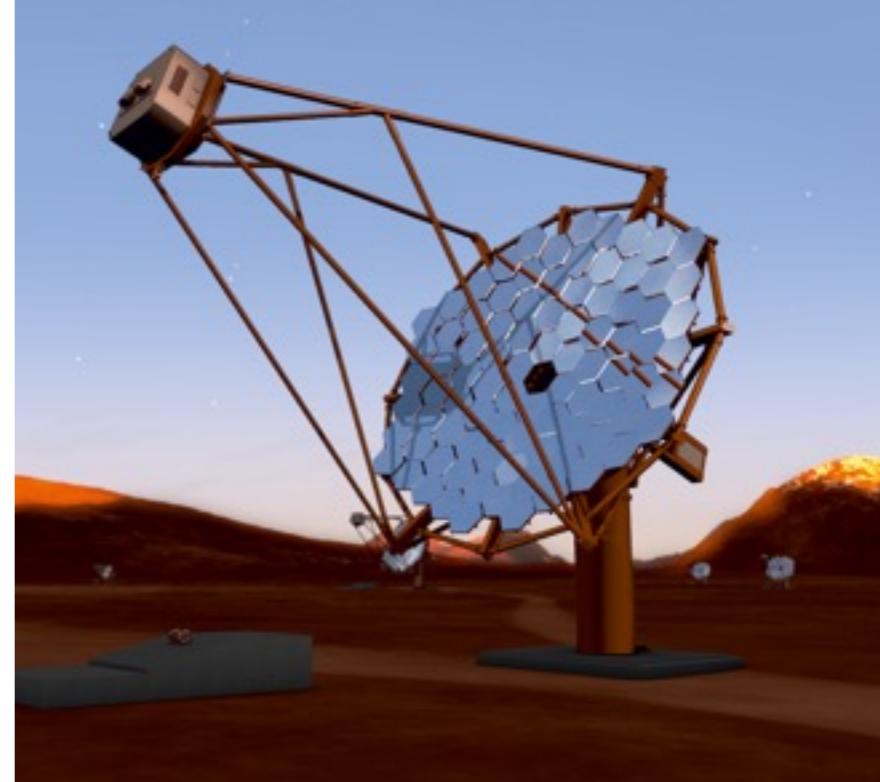
Alert follow-up: future observatories

- Rapid follow-up of transient events crucial for most science cases
 - GRBs: redshift determination (cosmology, GRB population, etc.)
 - Gamma-rays: SED determination (leptonic-hadronic scenarios, etc.)
 - GWs: detailed source studies (connection with sGRBs, etc.)
 - HE-Neutrinos: source localisation (connection with UHECR, etc.)
 - ...
- Major futur facilities are preparing for MWL+MM follow-up
 - two examples:
 - ground-based: Cherenkov Telescope Array (CTA)
 - space-based: Space-based multi-band astronomical Variable Objects Monitor (SVOM)

CTA alert/ToO program

- Key Science Project "Transients"

- Gravitational waves
- High-energy neutrinos
- Serendipitous transients during CTA observations
- Gamma-ray bursts
- Optical and radio transients (transient factories, FRBs,...)
- Galactic transients (binaries, PWNe flares, ...)



- preparations for alert reception and handling

- learning from + testing with current observatories (e.g. H.E.S.S.-II)
 - GCN listener dedicated to GRBs
 - new system: versatile VoEvent based ToO/alert handling
 - connected to GCN + IceCube + Antares + ...
 - prioritization of (multiple) alerts, regular observations, etc.

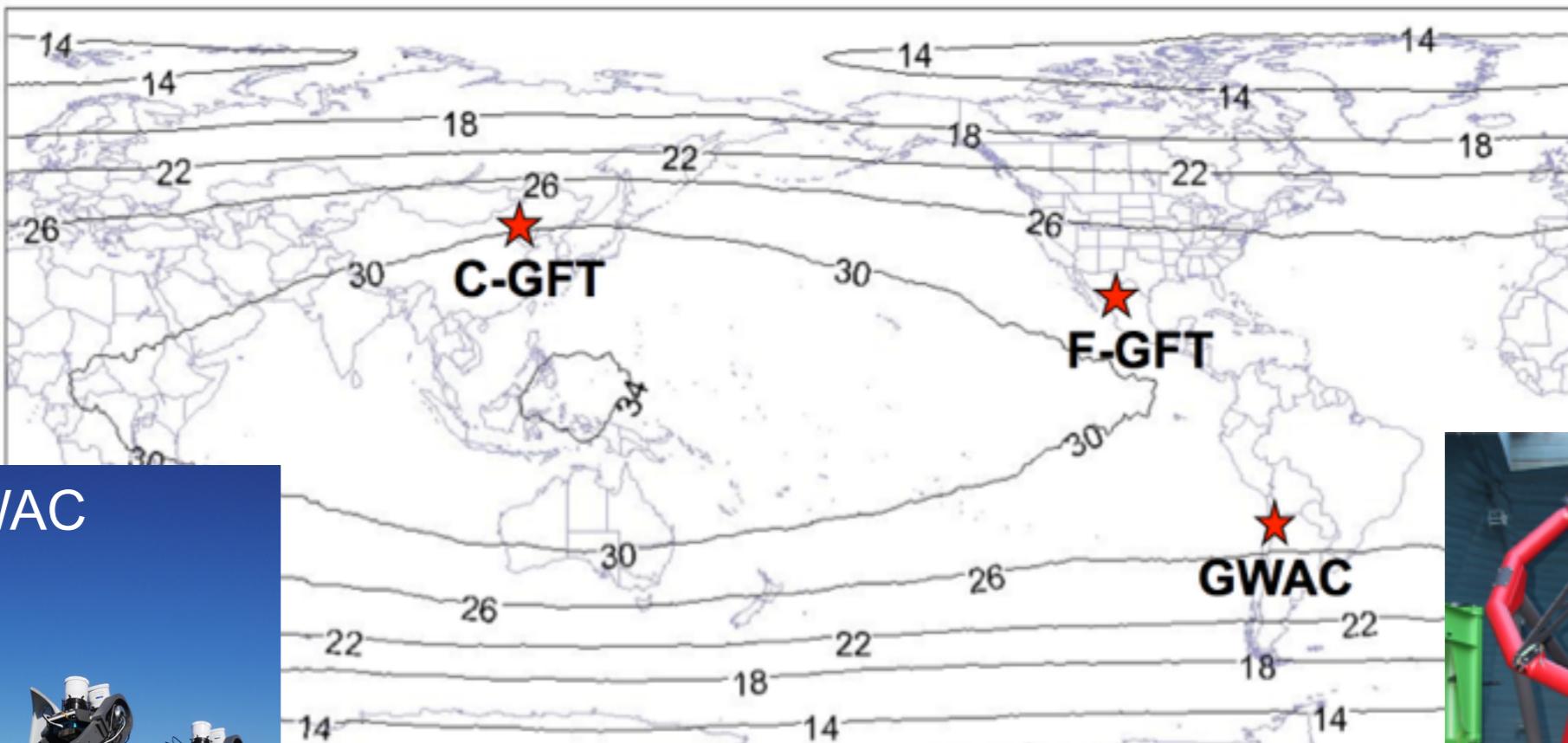
ATOM@HESS



- dedicated on-site optical telescopes (~80cm) under discussion

SVOM follow-up program

- Dedicated ground-based follow-up program included in the mission profile
 - GWAC: wide-field, optical instrument(s) tracking the FoV
 - GFTs: two 1m-class visible+NIR telescopes in China and Mexico

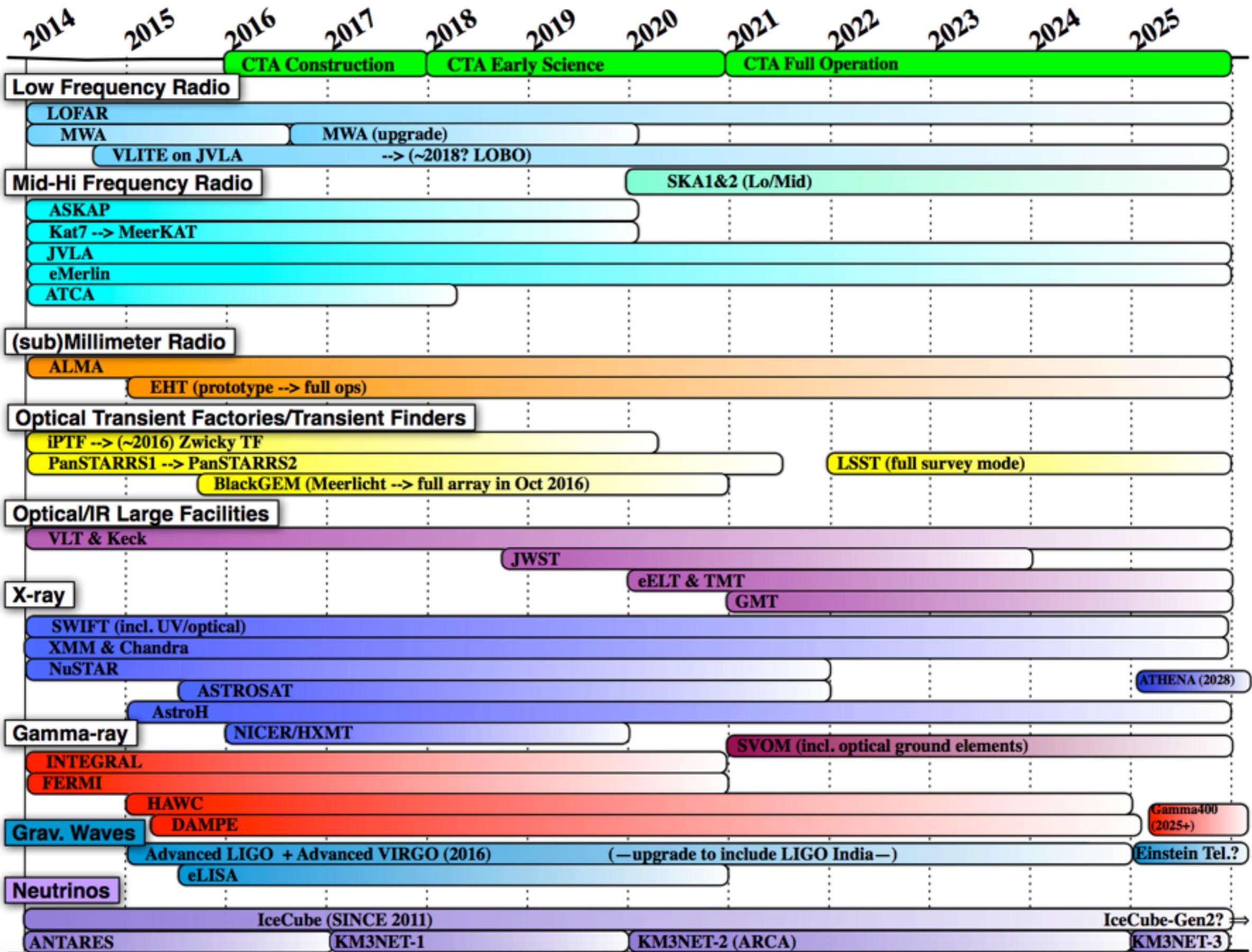


Mini-GWAC



Bright prospects

- new monitoring instruments (many with strong French contributions)
 - CTA: order of magnitude more sensitive than current TeV instruments
 - SVOM: dedicated ground follow-up program + rapid alert emission
 - KM3NeT: continuing the ANTARES-TAToO program
 - LSST: thousands of optical transients per night
 - SKA
 - LHASSO
 - ...
- new approaches
 - AMON: correlations between low-level data of different messengers (e.g. neutrino + gamma-rays)
 - 4 Pi of the Sky: automated detection of radio transient with different observatories
 - ...
- A lot of coordination necessary to fully benefit from these opportunities
 - transverse programs like PNHE essential



Sera Markoff, CTA Science TDR

