
Time domain astrophysics
The discovery space after Swift
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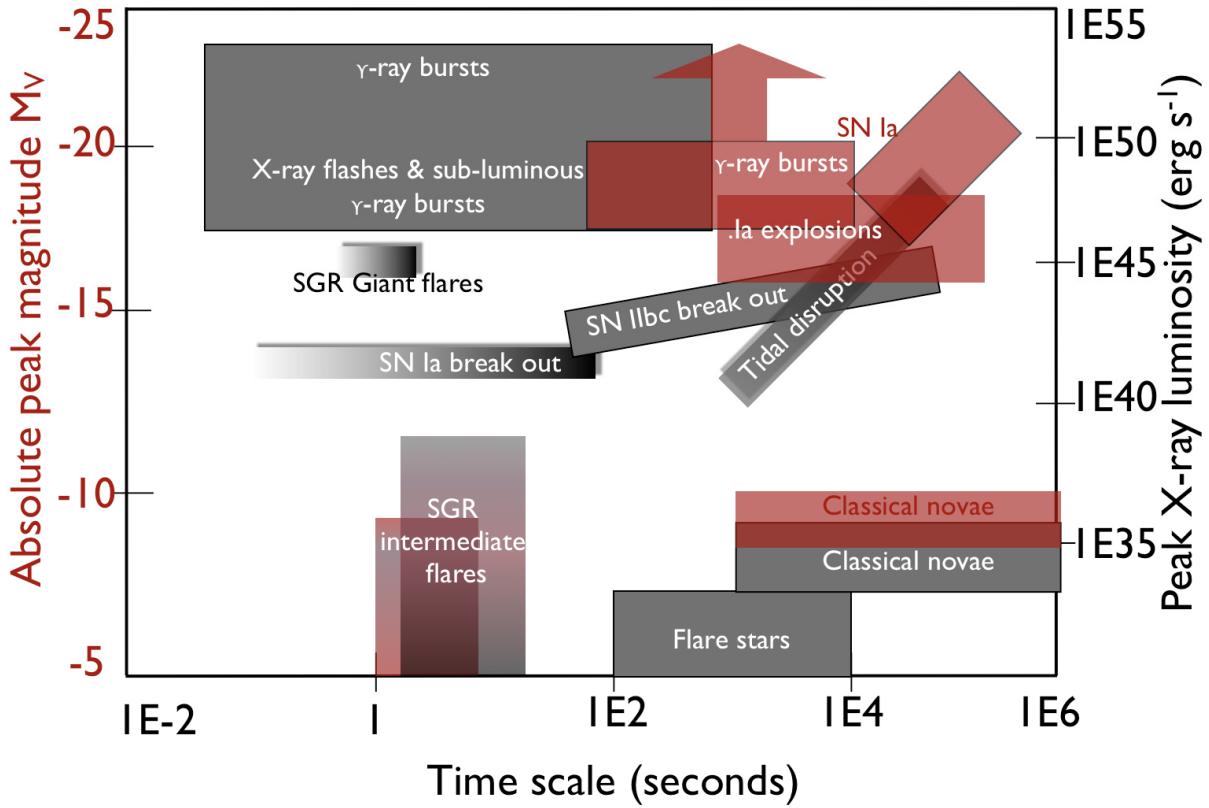
Global context

- All major "roadmap" type reviews have identified time domain astrophysics as a priority area. E.g.,
  - Chinese Space and Technology Roadmap (Guo & Wu, 2010),
  - European Union ASTRONET group (Bode et al., 2015)
  - USA National Research Council Decadal Survey (Committee for a Decadal Survey of Astronomy and Astrophysics, 2010)
  - Many national reviews (e.g. UK Programmatic science review, (O'Brien et al. 2012)
- The scale of transient science will be very different in the next decade
- Example current hot topics, e.g. GW, FRBs, relativistic TDEs etc.
- Community have come to expect information to be available right now

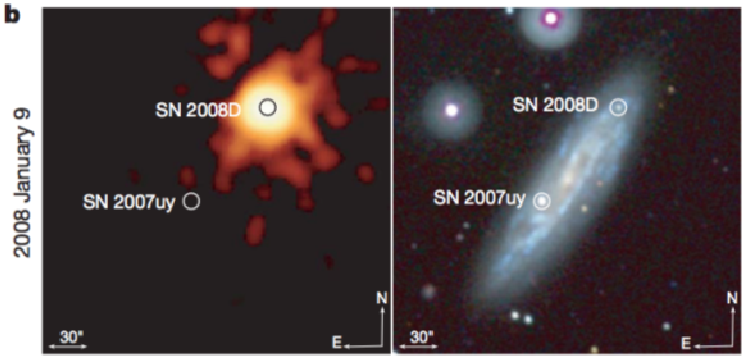
Explosive transients



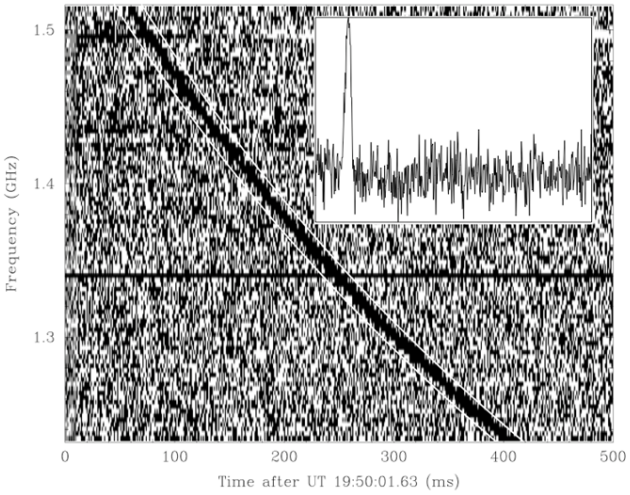
Jonker, O'Brien et al., 2013 arXiv1306.2336

GRBs and TDEs are the most luminous (rare) transients, but SVOM can access many transient types at low redshifts. Almost all types are bright across multiple parts of the EM spectrum. And the multi-messenger era has begun.

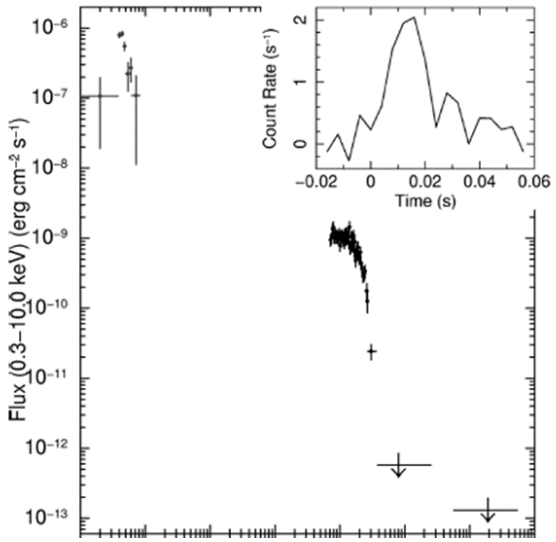
Anything can happen



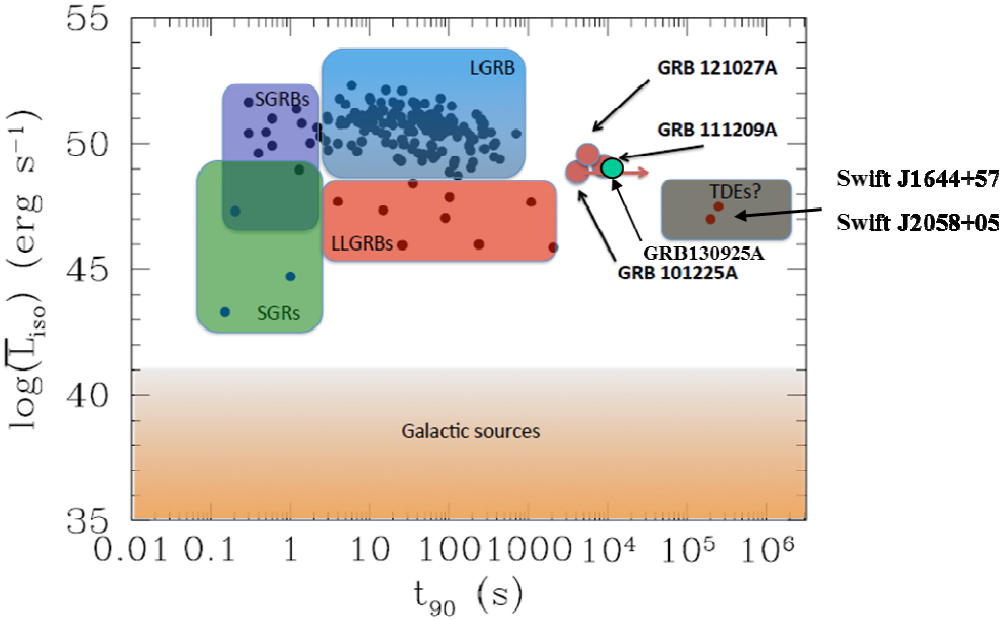
SNe shock breakout
(Soderberg et al. 2006)



Fast Radio Bursts
Lorimer et al.
(2007)

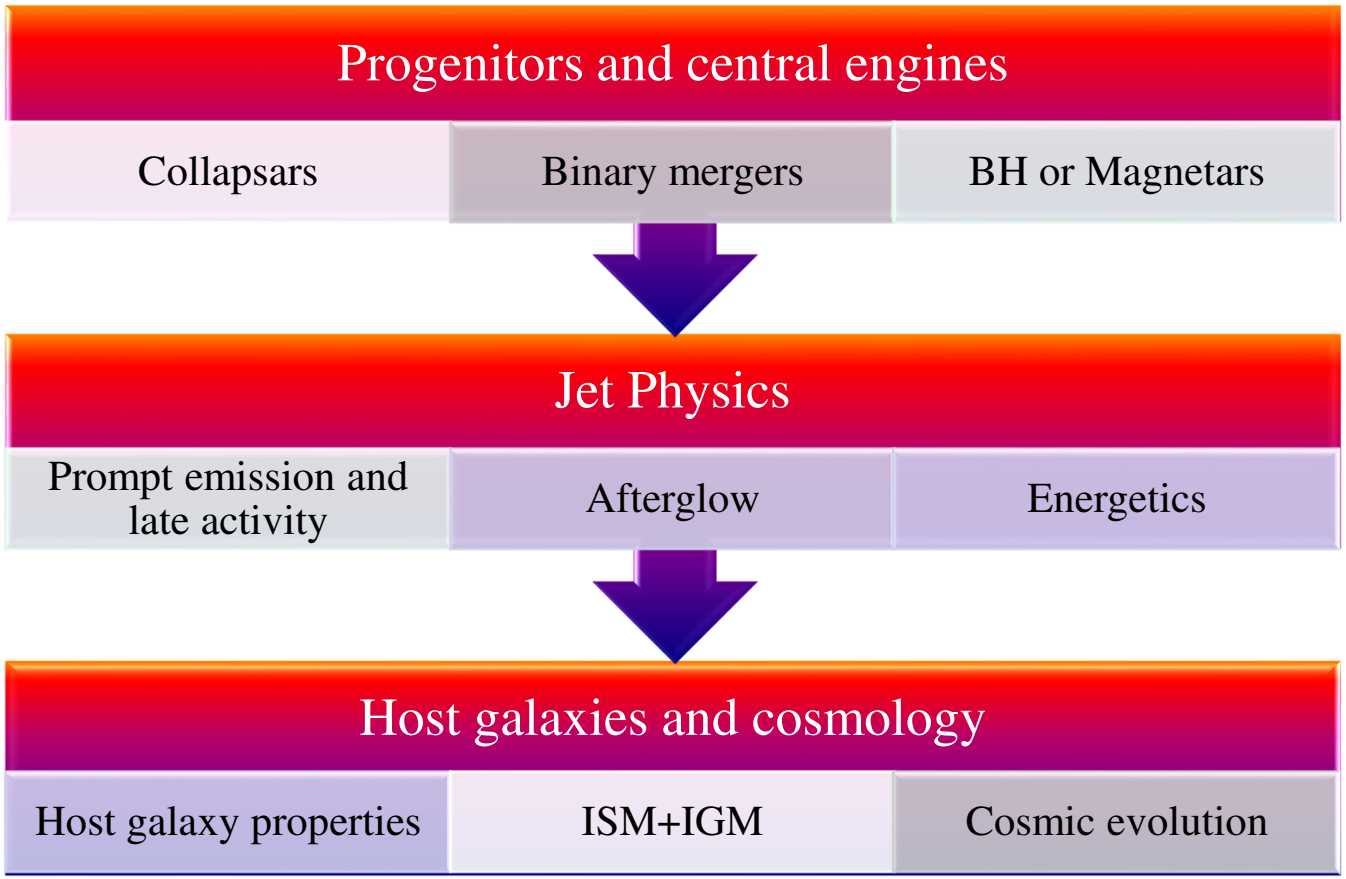


Rapid decline GRBs
Rowlinson et al. (2010)



Rel. TDEs and Ultra-long GRBs
Levan et al. (2014)

GRB (+other) science areas

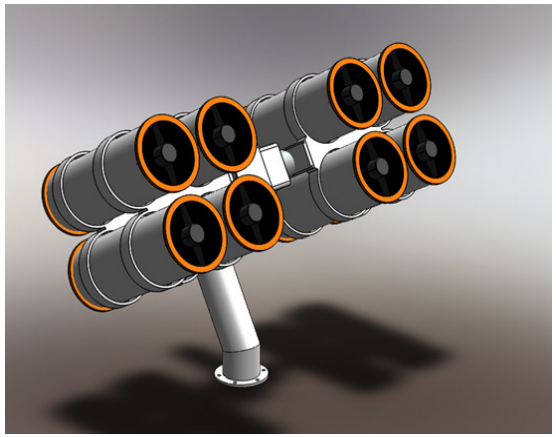


Require triggers, localisation & multi-wavelength/multi-messenger capability

Swift, Fermi etc. have made a huge difference, but many new, powerful complimentary facilities coming, e.g. JWST, 30m telescopes etc.

Some current/near-future optical survey machines



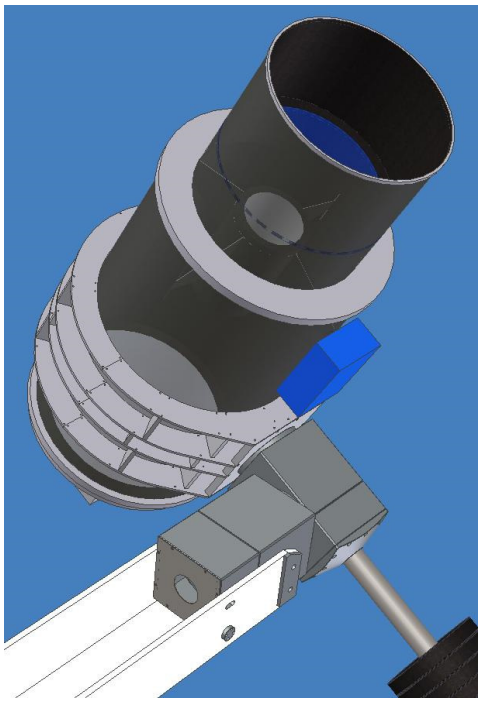



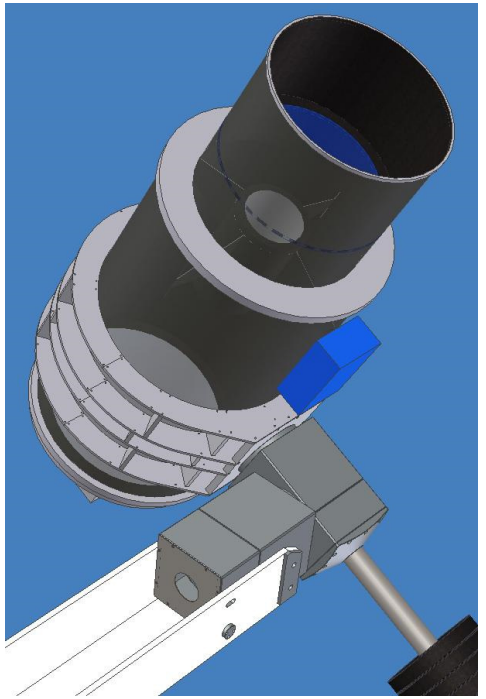

Many survey machines built for different purposes, e.g. PS1+2, Sky Mapper, NGTS, ZTF, ASSASN, ATLAS, GOTO, GWAC, GAIA, etc.
Some of these can survey large sky areas every day monitoring & finding transients.

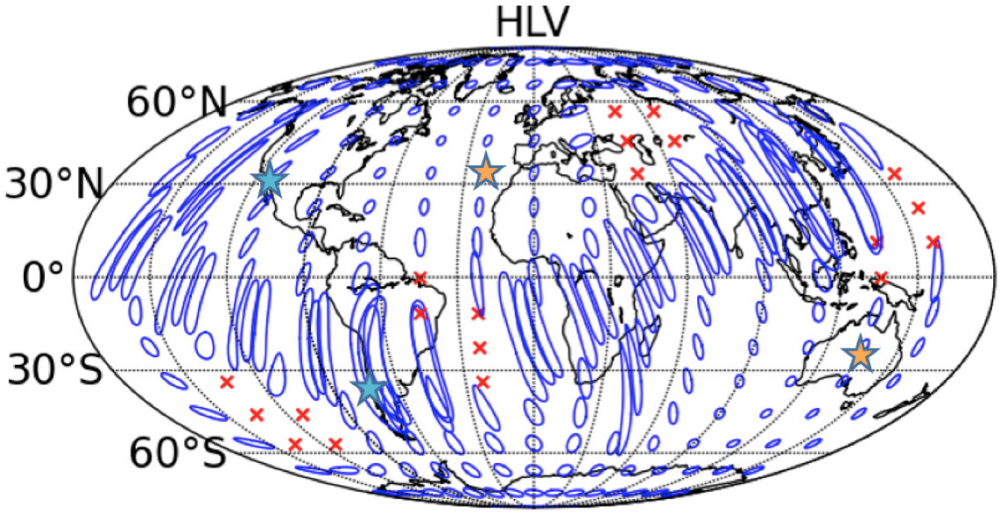
ATLAS
Asteroid Terrestrial-impact Last Alert System

Project funded by NASA to find dangerous asteroids

- Two 0.5m telescopes covering 30 deg^2 (5.4° x5.4°) producing ~2.5" images.
- One telescope on Maui (Haleakala), one telescope on Hawaii (Mauna Loa)
- Optimized for maximum survey speed (per unit cost) and fast cadence.
- Broad filters (cyan~g+r and orange~r+i) provide improved sensitivity for normal search but retain color information.
- 16 filters overall, including
  - c, o, u, v, g, r, i, z, B, V, R, I, Hα, [OIII]
- Expect to observe ~60,000 deg^2 at m~20, i.e. entire visible sky 3 times per night.

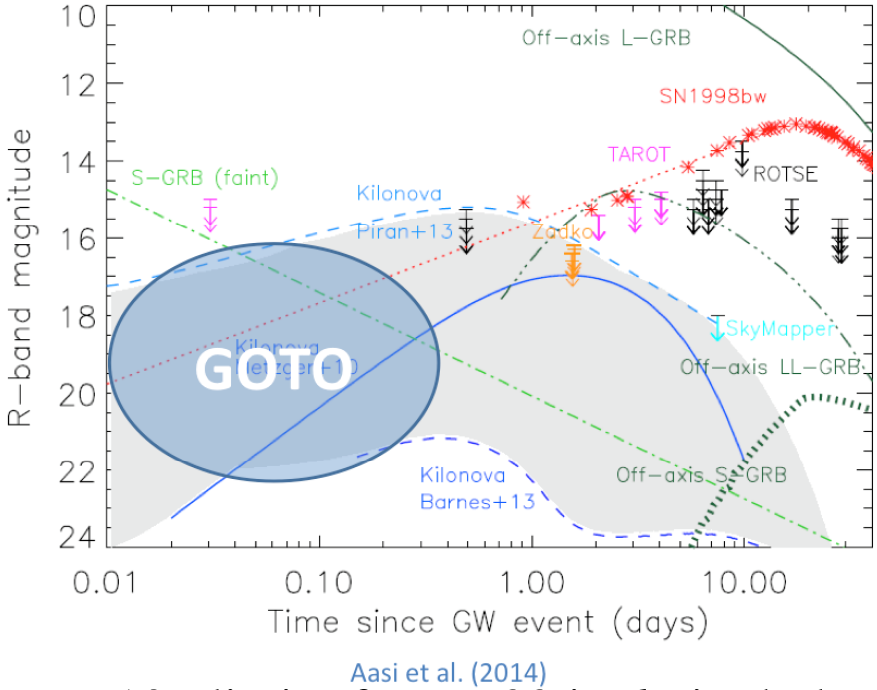






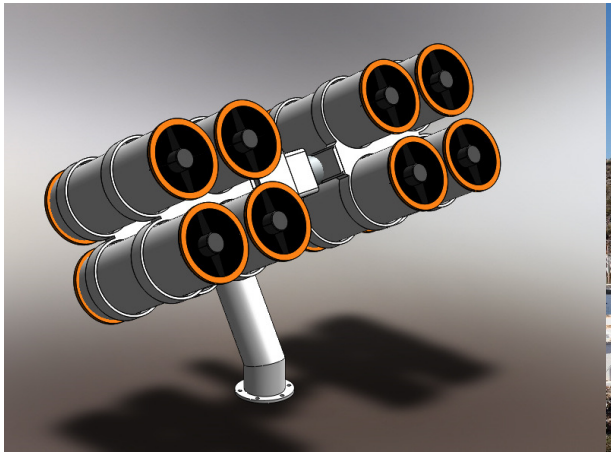
Aasi et al. (2013)

Located on La Palma, one of the best sites in the world and in a HLV “sweet spot”

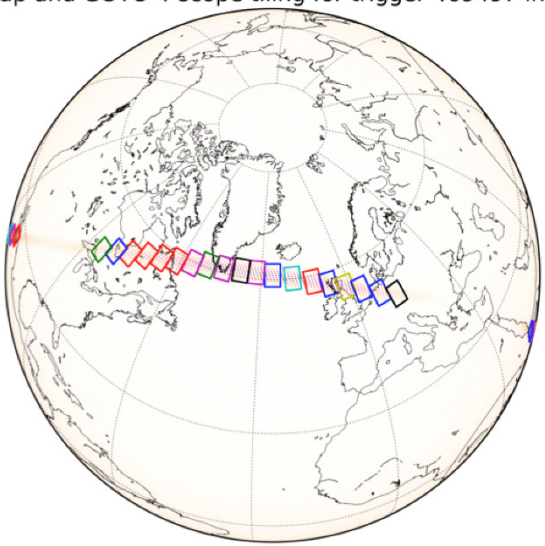


Aasi et al. (2014)

10σ limit of mag~22 in 6min dark time

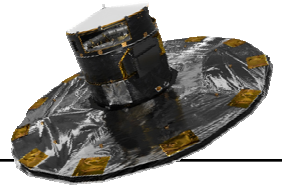


A battery of telescopes on a single mount in a clamshell dome. Starting with 18 sq. deg. FoV



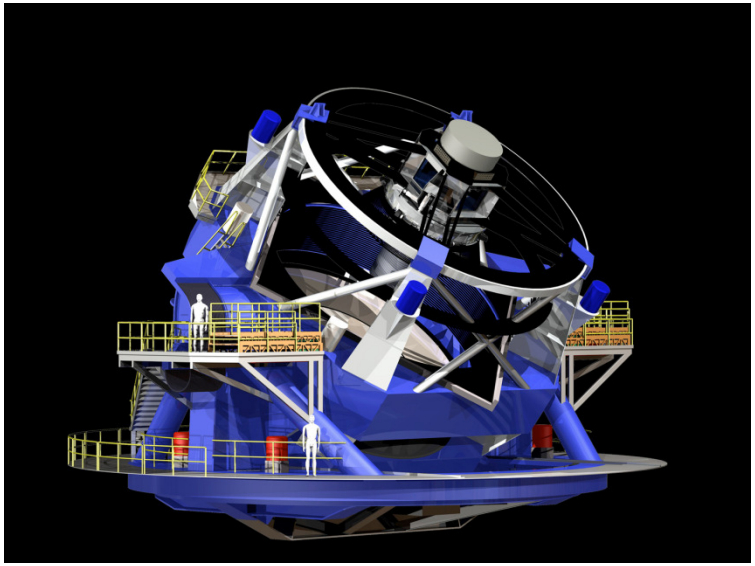
Each 0.4m/f2.5 astrograph equipped with 28Mpix CCD

(some) Transient surveys



	Gaia	OGLE-IV	Catalina Sky Survey	PTF	LSST
$deg^2\ day^{-1}$	≈ 1230	150	1200	1000	5000
Avg Cadence	≈ 30 days	20min– 5d days	14 days	5 days	4 days
Limiting mag	20 (21?)	22	19.5	21	r=24.7
f_{sky}	all sky	0.07	0.6	0.2	<0.48

Large Synoptic Survey Telescope (LSST)



- 6-band imaging survey over 20,000 square degrees; observe each object ≈1000 times over 10 years. Find thousands of ‘transients’ each night.

- LSST will address many science areas: dark energy, dark matter, galactic structure, transients, solar system…

Radio transients: FRBs etc.

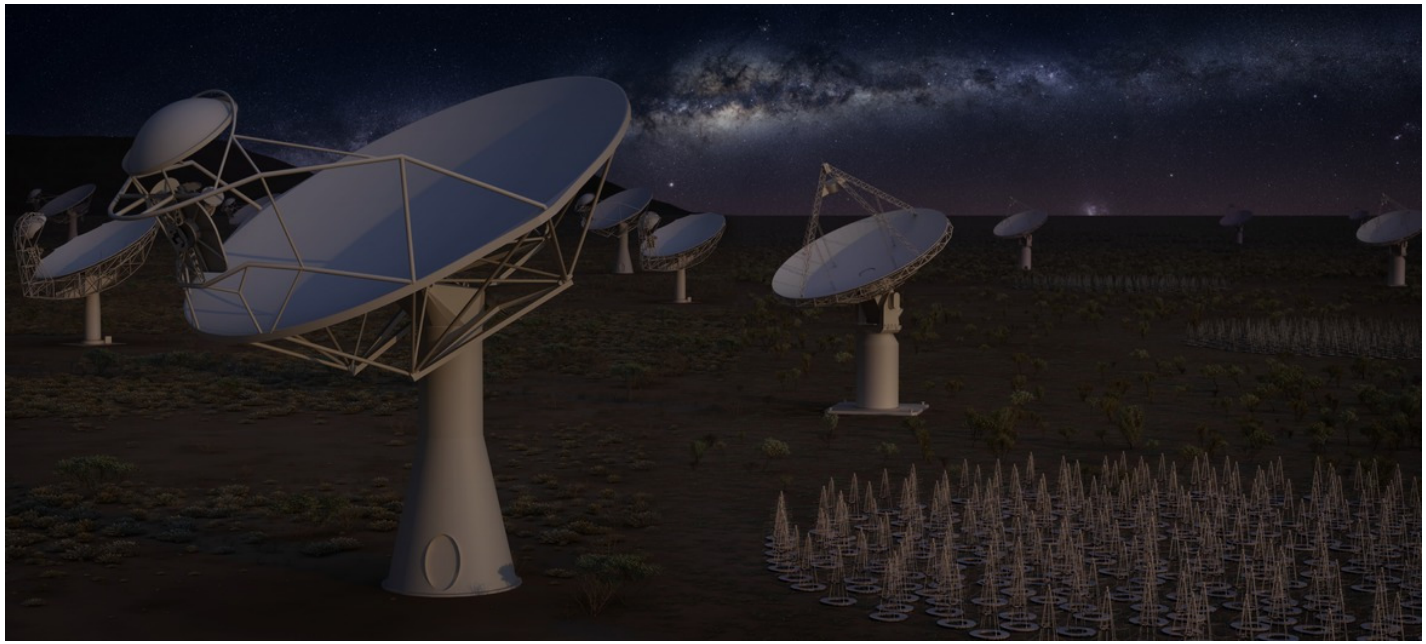
Westerbork (WSRT) upgrade (APERTIF) with FoV ~8 deg^2 (1-1.7GHz)

Sky survey starts 2016 but will also search for transients – the ARTS project

LOFAR – has found transients in "old" data (transient durations of several minutes).

The real-time pipeline is coming very soon (2016)

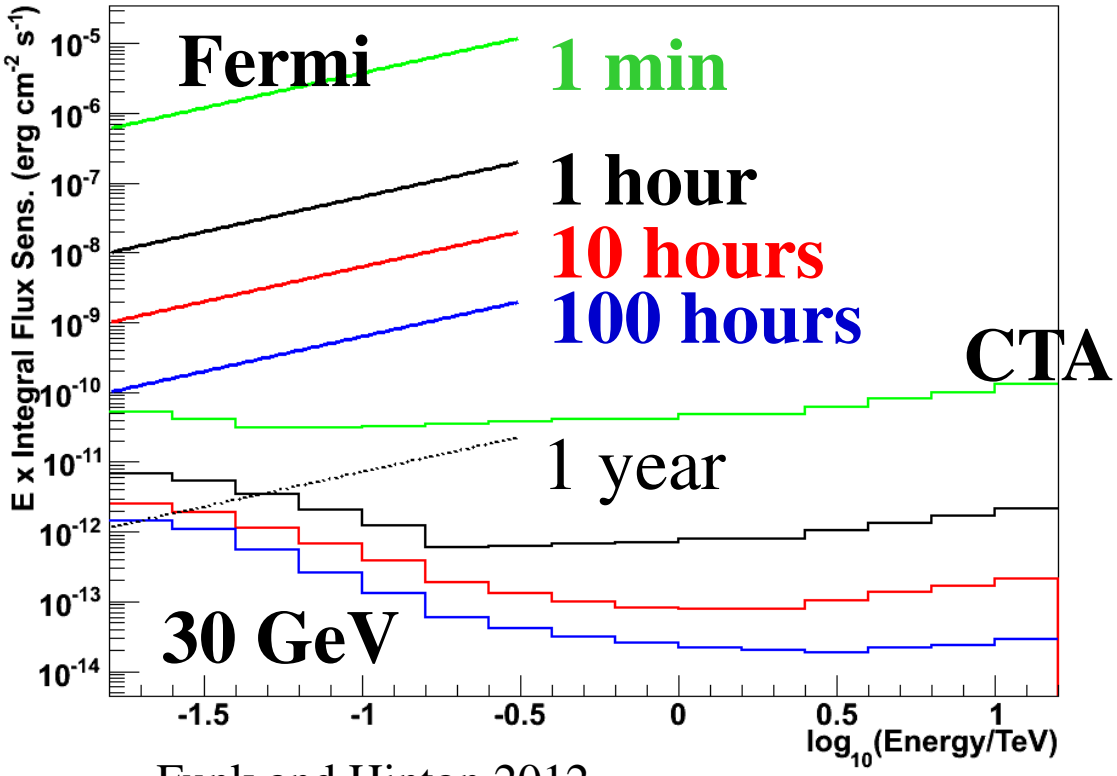
Square Kilometre Array



- Pathfinders exist: LOFAR, MWA, ASKAP, MeerKAT
- SKA phase 1 coming soon (2018-2023); first science ~2020
- Full phase 2 deployment (?-2030?) depends on funding level
- SKA will find many transients, both coherent (e.g. FRBs) and incoherent emission (generally slower explosive events)
- Transients rates poorly determined at present, but likely many day^{-1}

Cherenkov Telescope Array

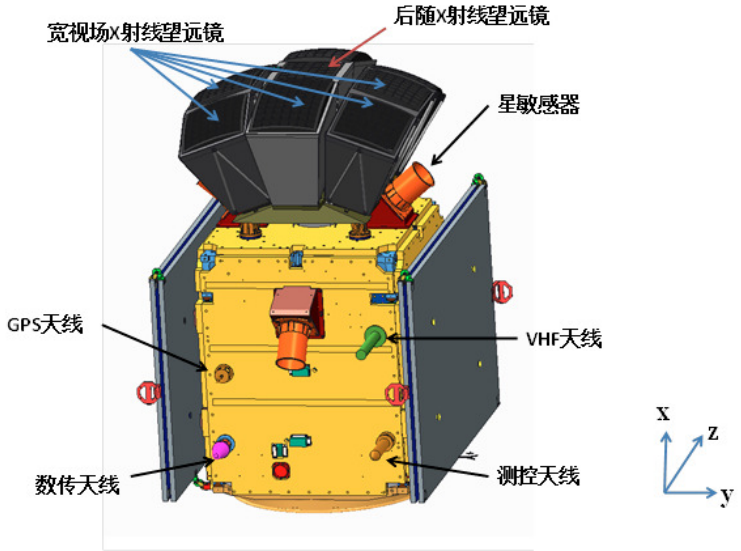
- >10x more sensitive than current IACT instruments
- Wider energy coverage, substantially better angular and energy resolution and wider field of view
- Can find transients in real time and respond fast (tens of seconds)
- Build in 2017-2023
- Two sites: La Palma & Paranal



Funk and Hinton 2012

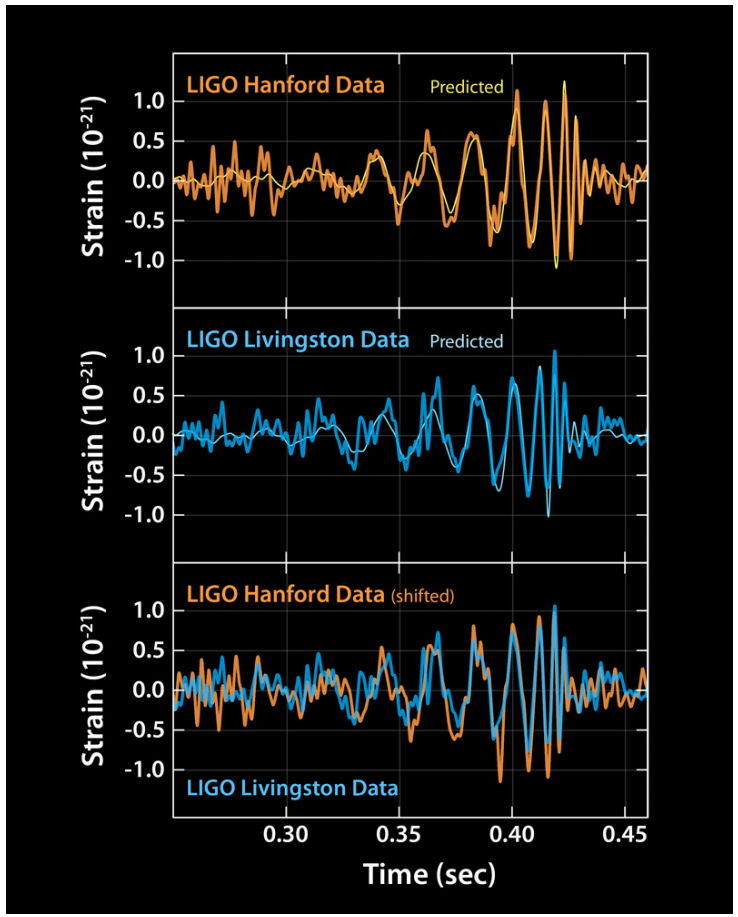
Einstein-Probe (+others)?

- PI: Weimin Yuan (NOAC), +IHEP, Tsinghua Uni & MicroSat (+LU)
- Chinese medium class mission proposal promoted in Jan 2014 to a two-year "Advanced Study Phase" (phase A/B)
- Science case:
  - Find quiescent SMBHs through tidal disruption events
  - Find the EM counterparts to Gravitational Wave sources
  - Systematic census of the X-ray transient sky
- All-Lobster payload
  - WXT: 1 sr FOV (total: 8 modules)
  - FXT: 1 degree FOV
- Rapid slew and fast alert downlink
- If approved could launch ~2021



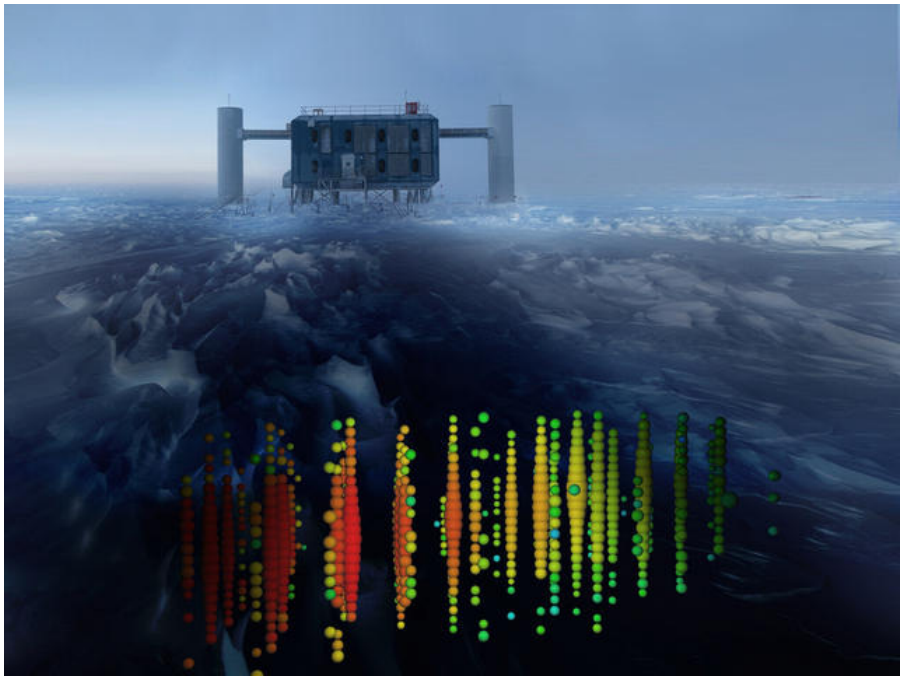
Gravitational waves

- Now have first published GW detection
- How many will have an EM signal?
- Localisation will improve (Virgo, Kagra (2019?) and LIGO-India (2020-21?)
- Much larger reach (volume) by 2021
- Design predicted rates 10s – 1000s yr^{-1}
- SVOM will have smaller regions to search (e.g. for NS-NS median error 5-10 deg^2)



Abbott et al. (2016)

Neutrinos



- IceCube and Antares – operational and will be improved
- Evidence for astrophysical neutrinos, but from what/where?
- We may know some cosmic neutrino sources by time of SVOM
- Could KM3NeT be ready in time for SVOM?

The data wave is coming…

How do we decide what to observe?

Some of the issues

- Time domain astronomy era is really just starting. The need for on-orbit capability will be greater than ever when SVOM flies
- New facilities will be transformative – but also need access to existing facilities for photometry, spectroscopy, multi-wavelength etc.
- How should the SVOM project be organised for science?
  - Key projects?
  - MOUs?
  - Apply for telescope time?
  - Guest investigators?
- What science topics will be the most critical in 2021+ ?
- SVOM is not Swift – fewer ToOs, no UV but more sensitive optical, softer X-ray wide-field (high-z, X-ray transients…)
- Need to be able to tile the sky for some science areas
- Given number of alerts, follow-up will need to be smart (rapid data processing, classification, automation…but will still need humans!)