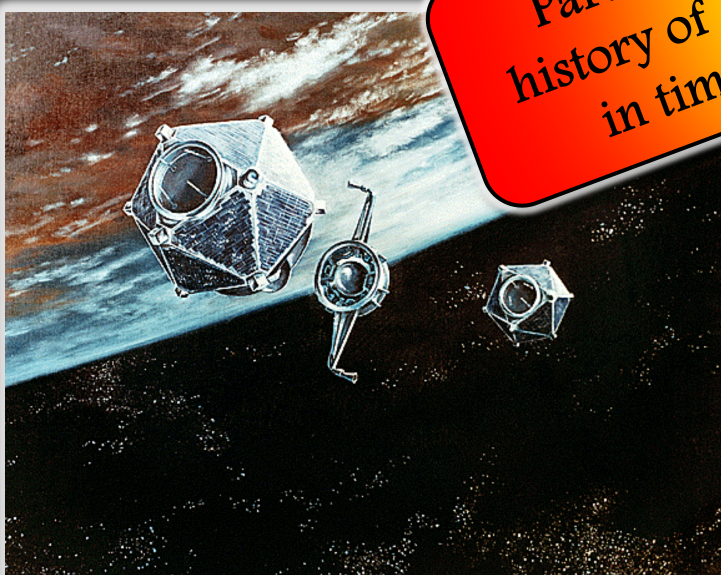
Nial Tanvir – University of Leicester

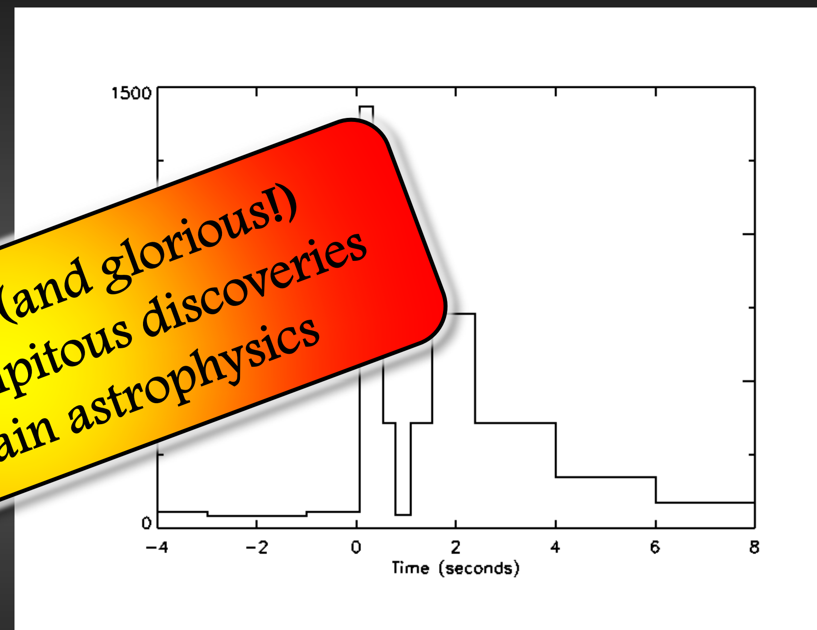
Gamma-Ray Bursts across the electromagnetic spectrum and beyond

Madrid - SCIOPS - 2019

Discovery

First known GRB detected 2nd July 1967 by US Vela 4 satellites. *Strong & Klebesadel 1993*



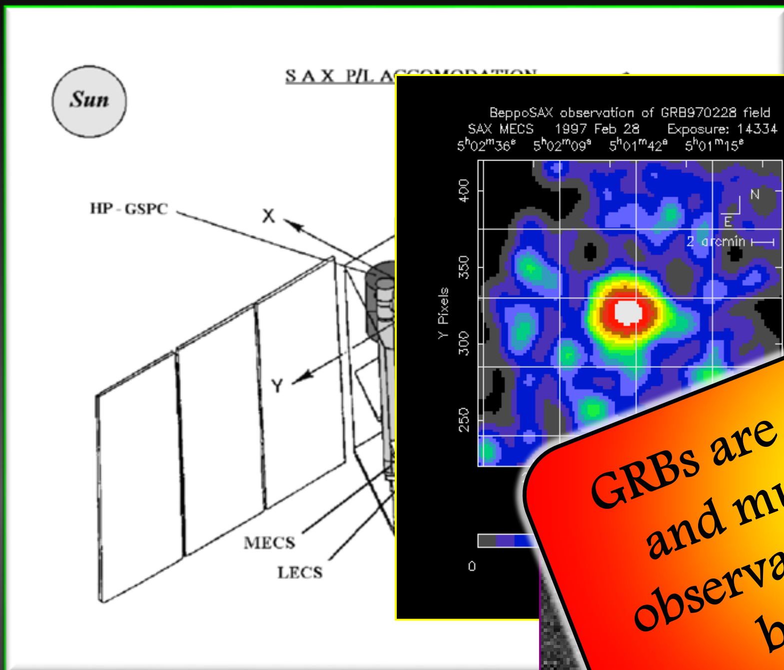


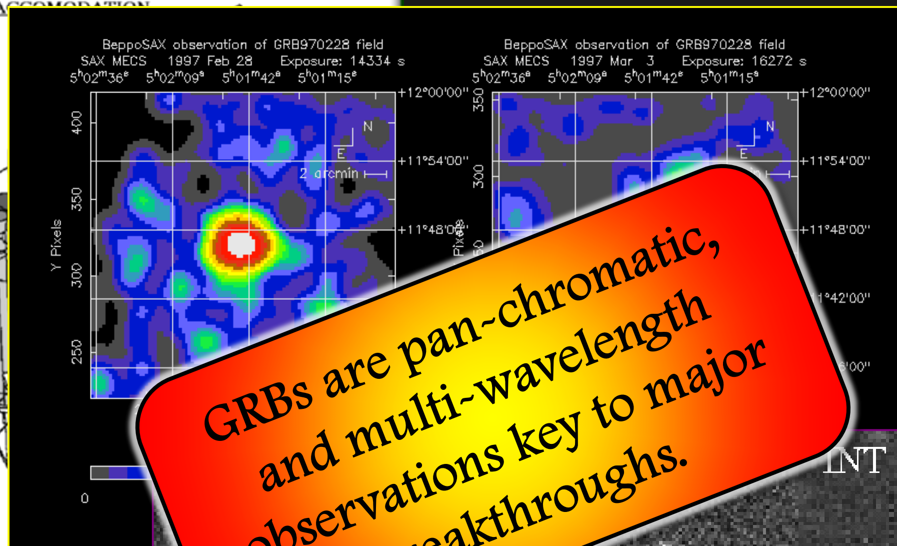
Part of the long (and glorious!) history of serendipitous discoveries in time-domain astrophysics

- Rapid variability of prompt emission (in some bursts) suggests compact progenitor.
- Compactness and non-thermal spectrum resolved if emission produced through dissipation after ultra-relativistic expansion.

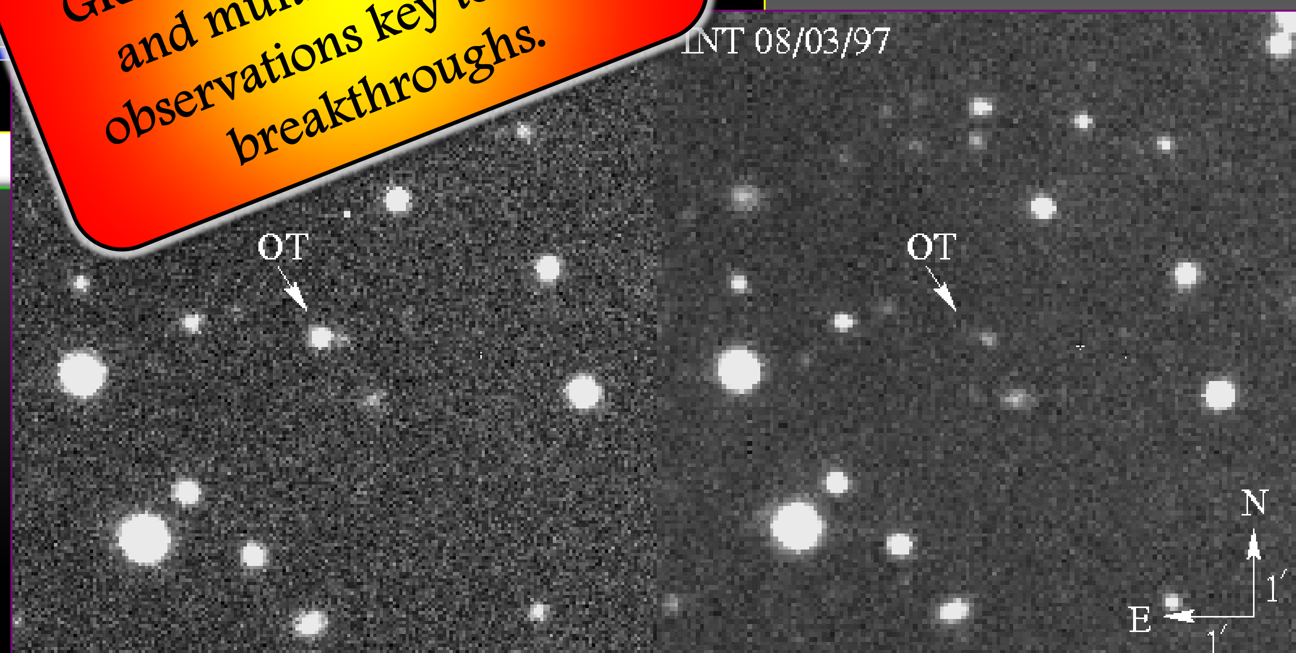
BeppoSAX and GRB 970228

X-ray positions reported within few hours leads to optical IDs.

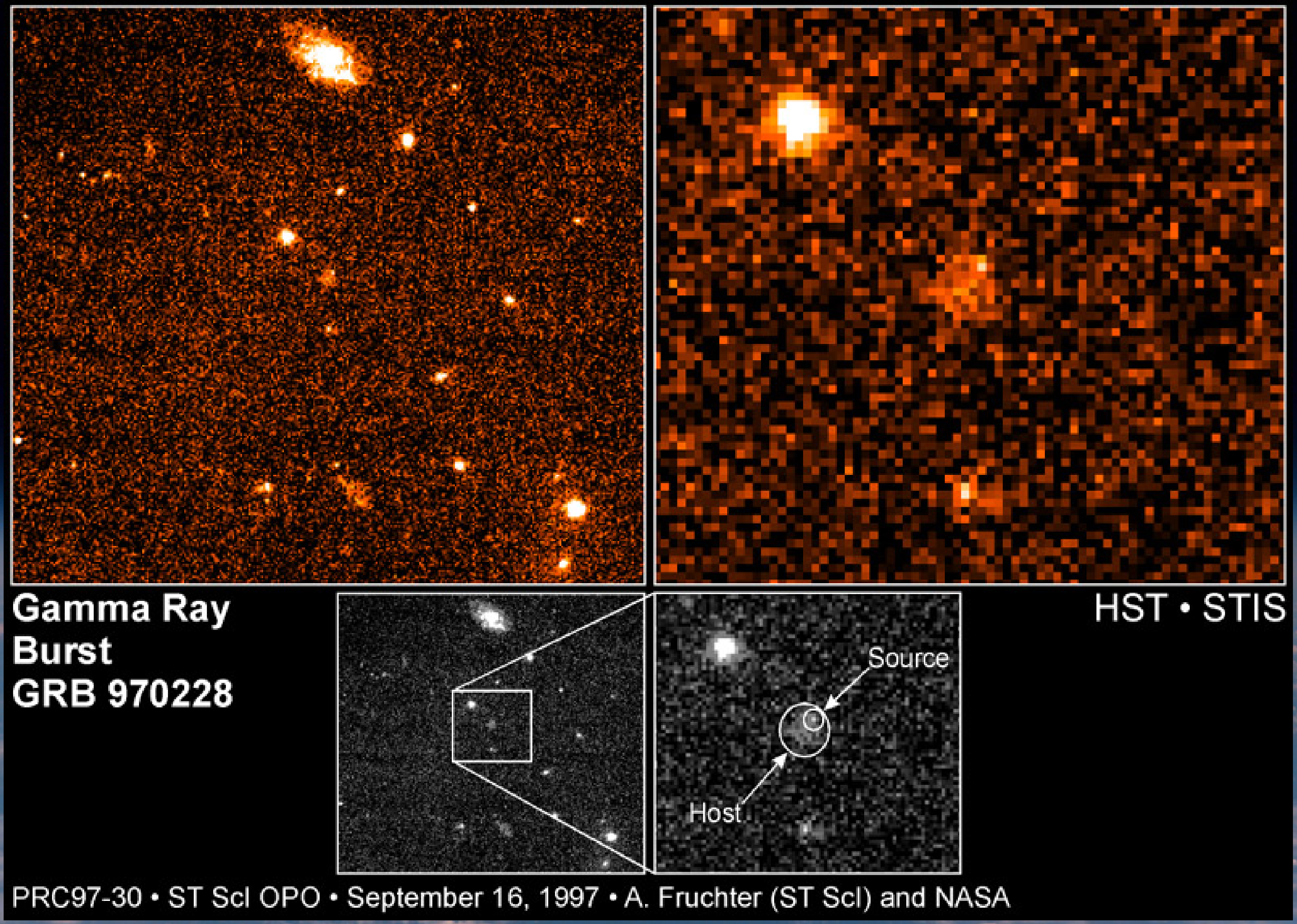




GRBs are pan-chromatic, and multi-wavelength observations key to major breakthroughs.



Later HST observations reveal host galaxy at z=0.65, which is about half way across observable universe!



GRBs by far the most luminous objects known!

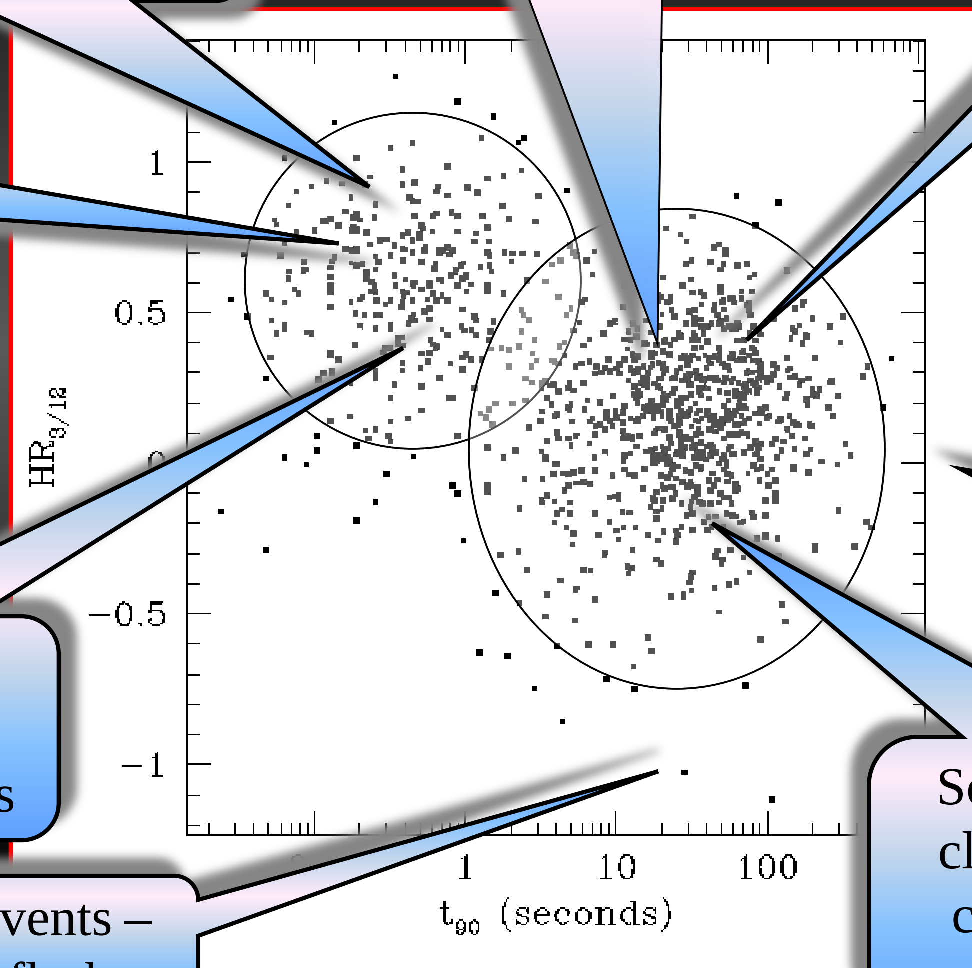
A mixed bag

Short duration bursts from compact binary mergers

Classical long bursts are associated with core collapse of H-stripped massive star

Some from SN shock breakout?

NS-NS and NS-BH?



Ultra-long bursts (and rTDEs)

Some likely to be giant flares in extragalactic SGRs

Some bursts hard to classify and may be core collapse via a different channels

Soft events – X-ray flashes

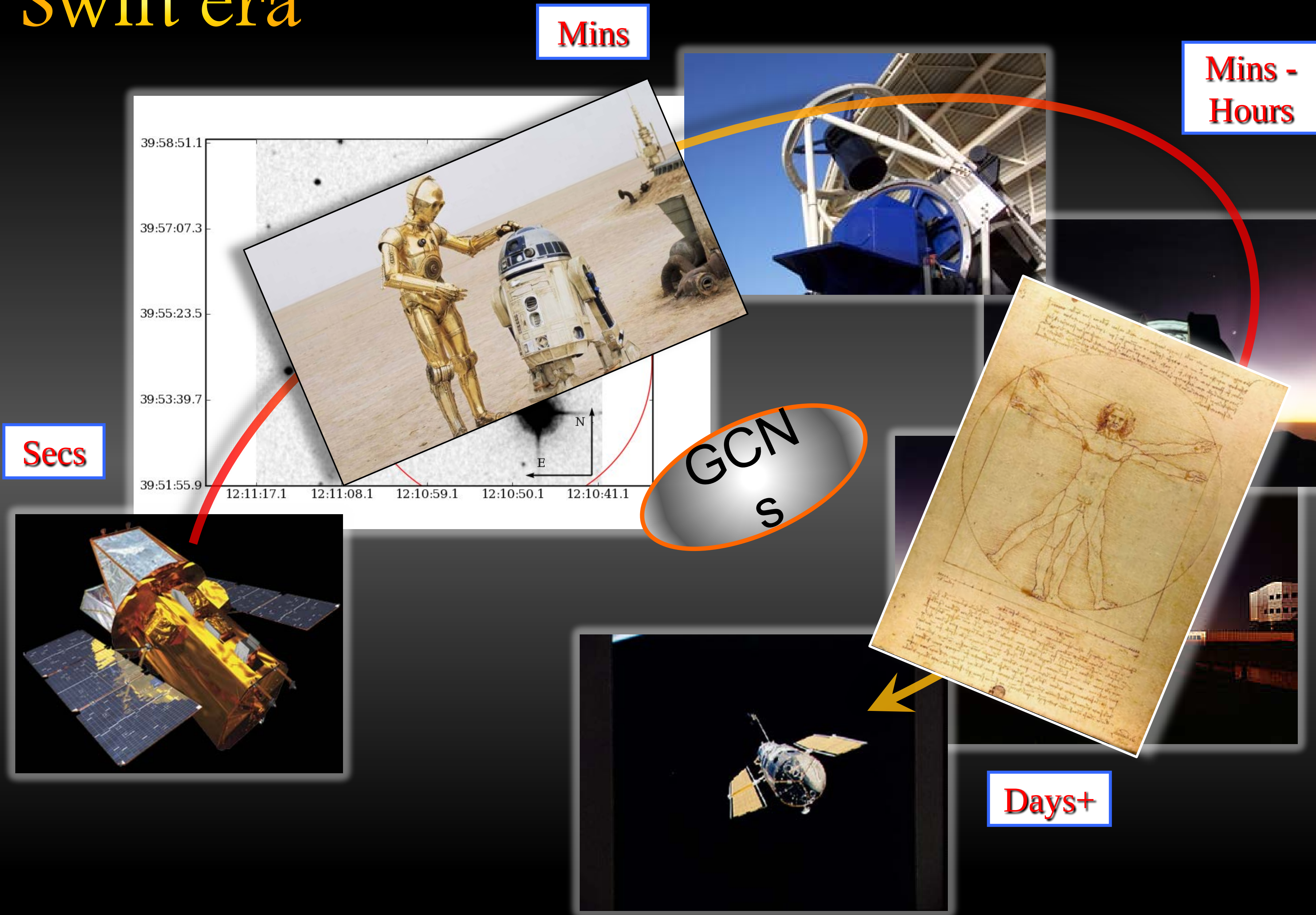
Regimes of followup

- Very early – "prompt" phase – may identify exceptional events
- Early – afterglows – light curves, spectra!
- Later – supernova/kilonovae, "jet" breaks
- Much later – hosts/environments

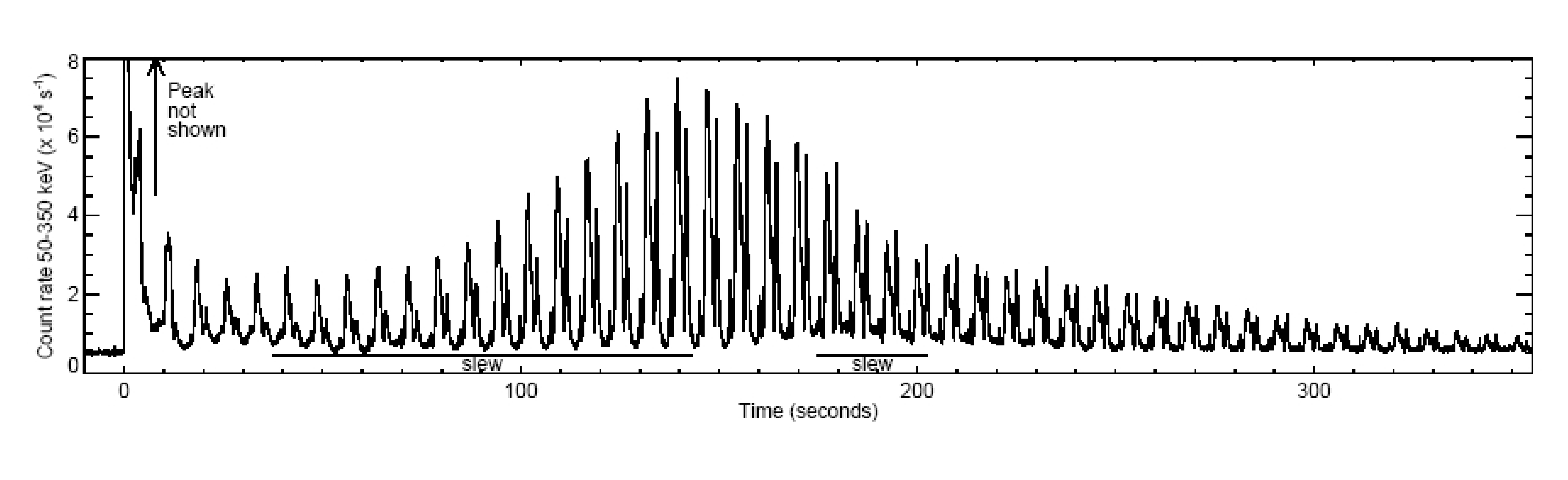
Perennial Challenges

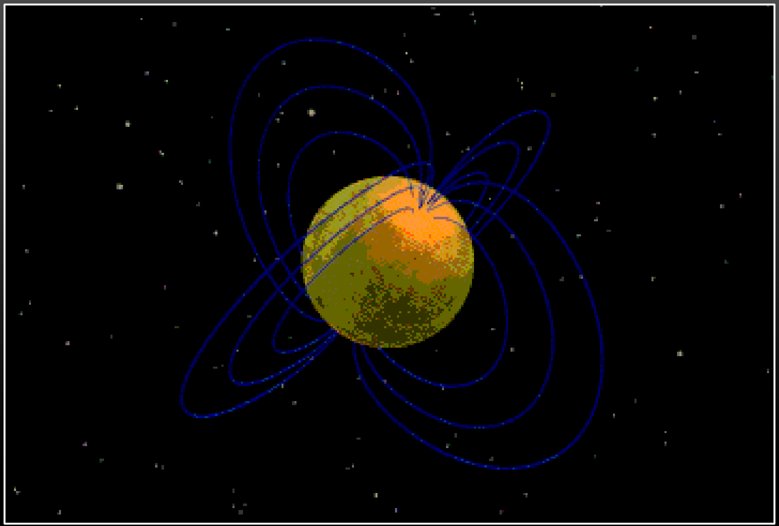
- Rapid ToO's need either good (well maintained) automation, and/or dedicated humans and responsive observatories.
- Many of the most interesting events are faint (e.g. SGRBs, high-z), and, of course, fading.
- Statistics hard: samples small, especially the sub-samples that have high redshift completeness; and data-sets rarely homogeneous. (Can be hard to explain to TACs the importance of slow build up of samples!)

Swift era


Mins
Mins -
Hours
Secs
Days+
GCN
s
39:58:51.1
39:57:07.3
39:55:23.5
39:53:39.7
39:51:55.9
12:11:17.1
12:11:08.1
12:10:59.1
12:10:50.1
12:10:41.1
N
E

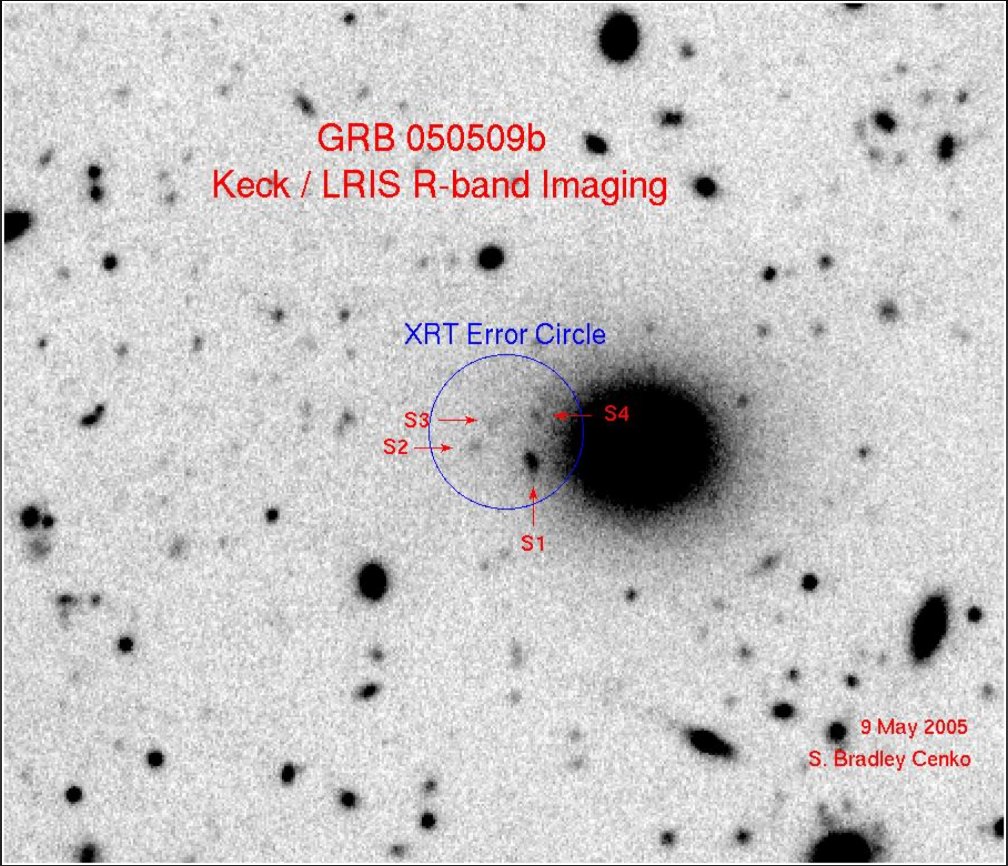
27th Dec 2004 – record-breaking flare with 0.2s initial spike.





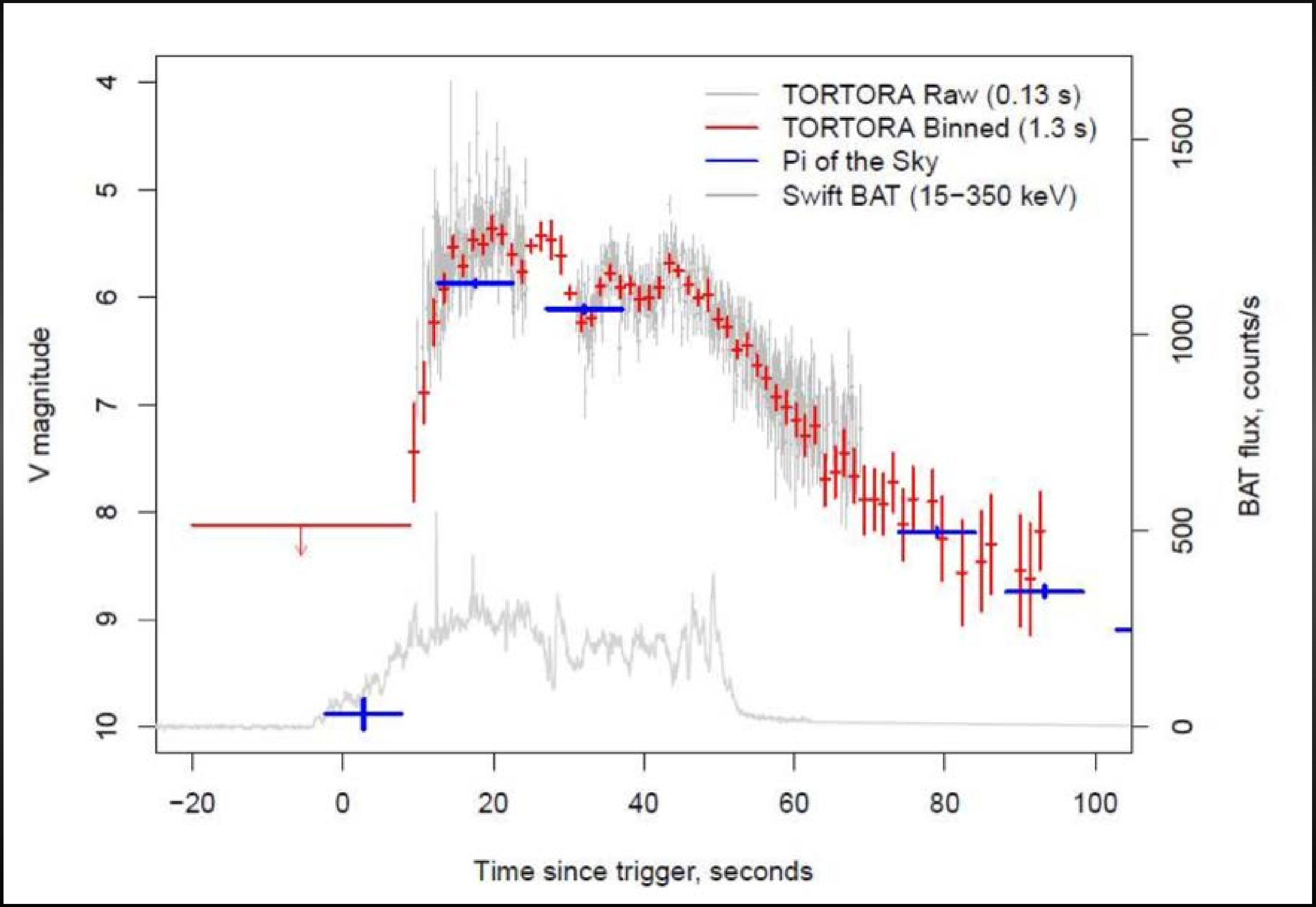
SGR 1806-20

GRB 050509B – short-burst afterglow



Thanks largely to Swift, >100 short GRBs have now been rapidly localised to few arcsec accuracy, allowing identification of likely hosts, and hence redshifts in some cases.

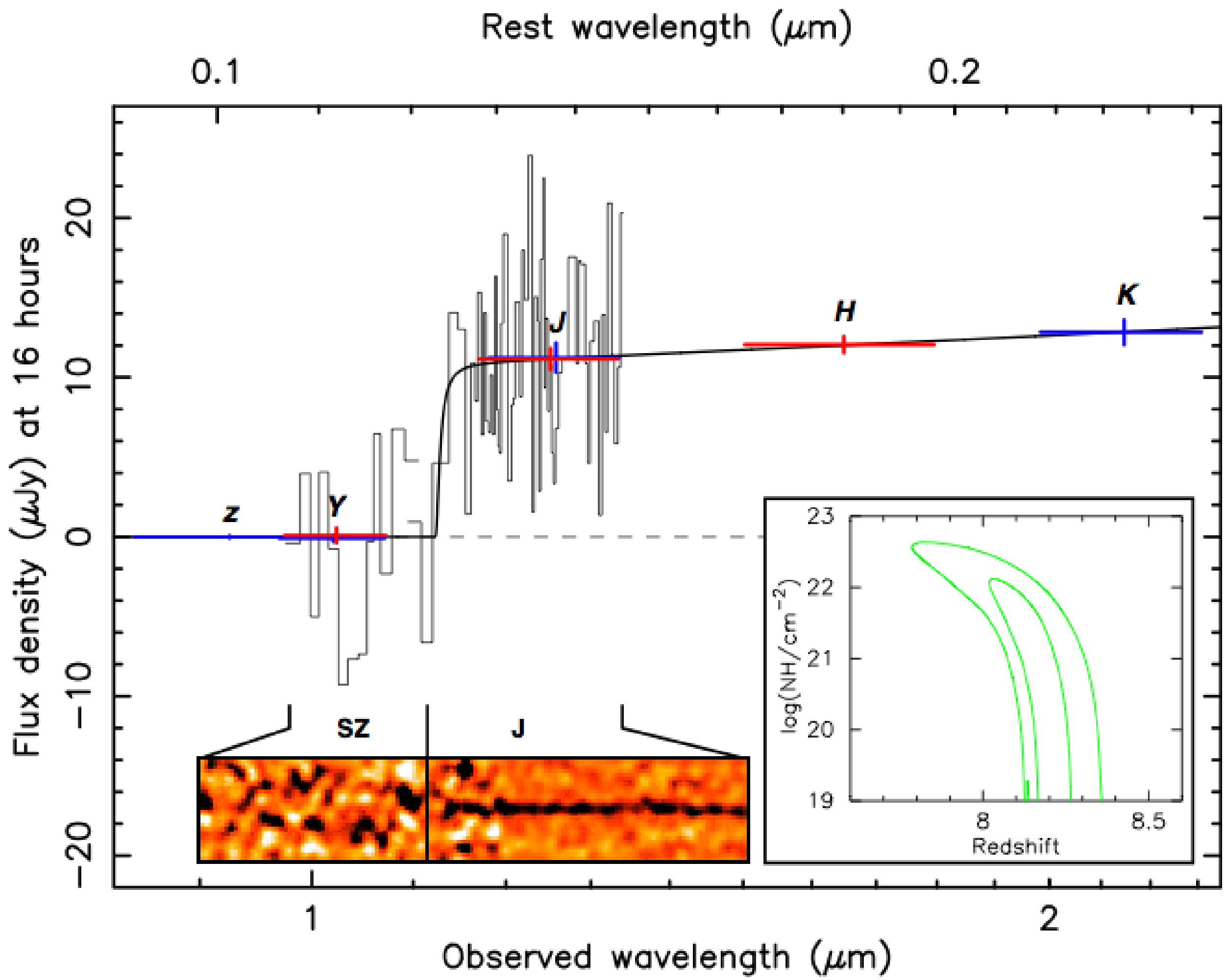
GRB 080319B – naked eye burst



Bertolini et al. 2009

GRB 090423

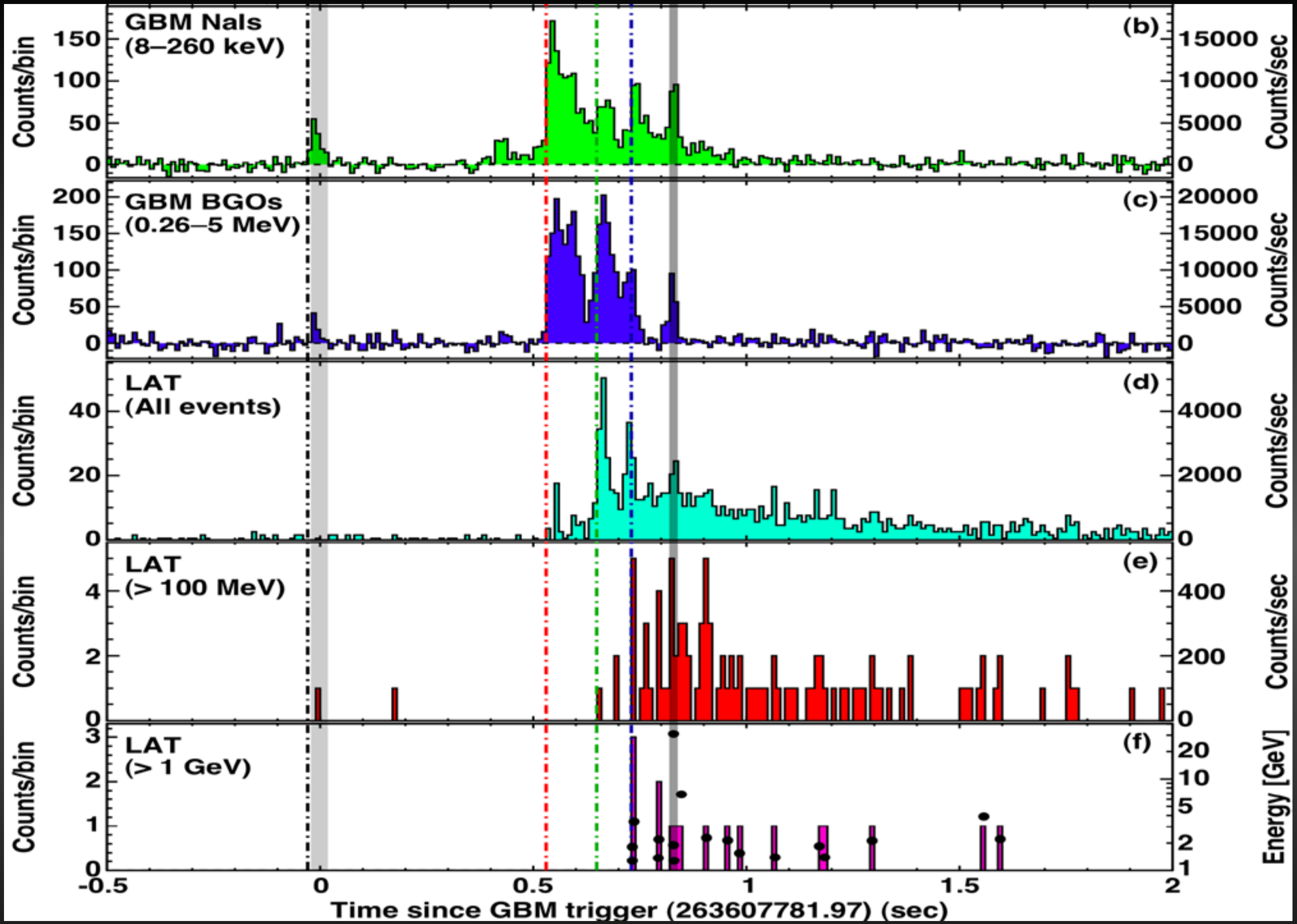
$z = 8.23 \pm 0.08$



VLT

Tanvir et al. 2009

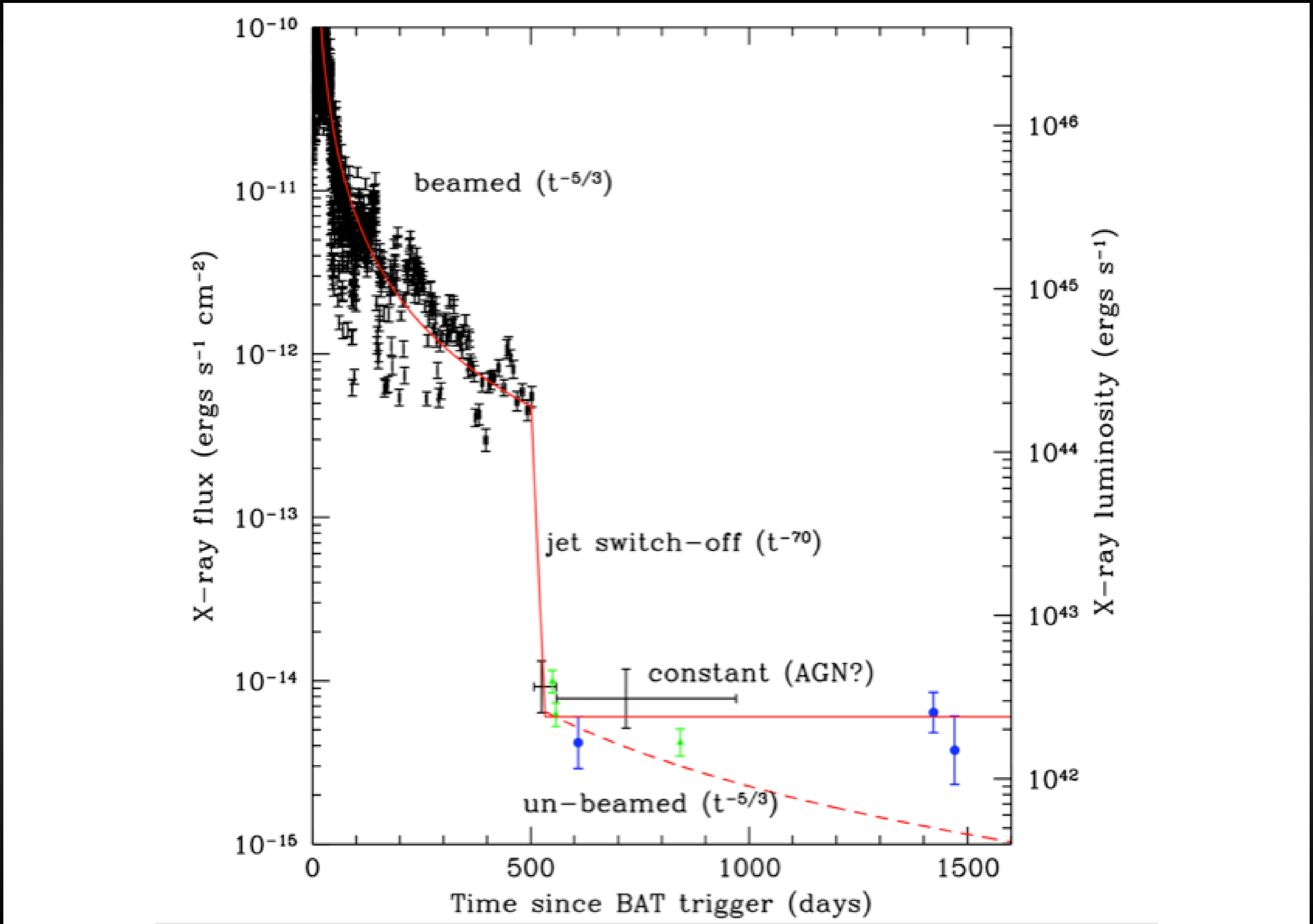
GRB 090510 – fundamental physics



Abdo + Fermi team 2010

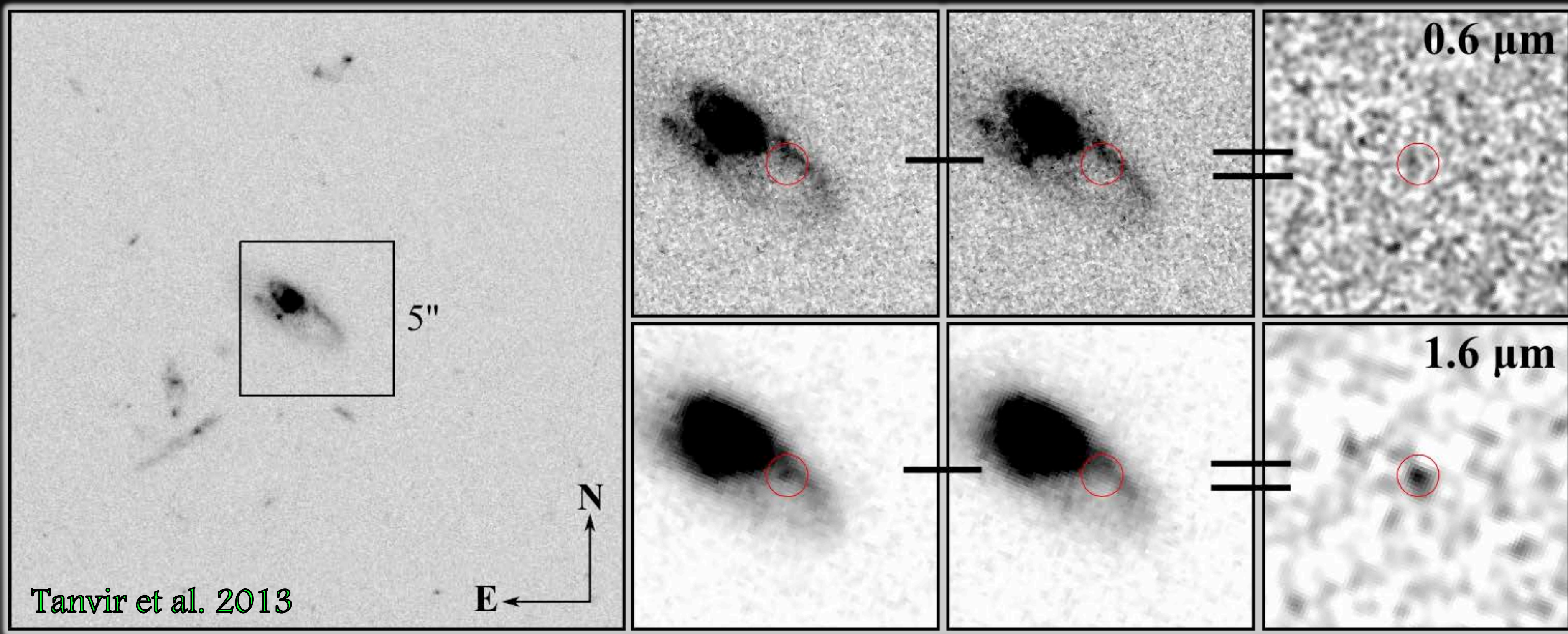
Coincidence of arrival times of highest energy gamma-ray photons with peaks in light curve at lower energies limits quantum gravity effects (Lorentz violation)

Swift J1644+57



Relativistic jet from tidal disruption event.

GRB 130603B ~ kilonova

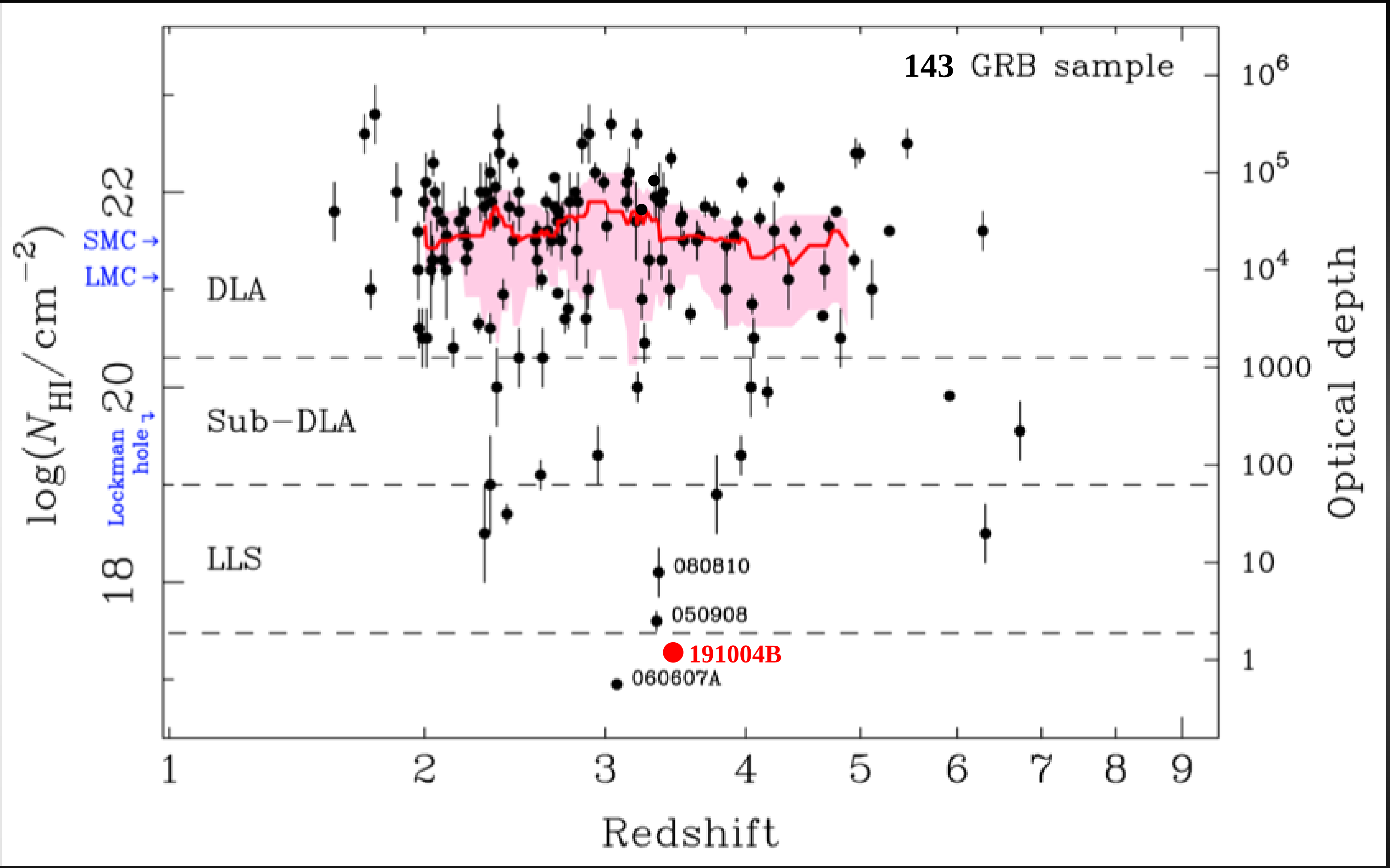


Transient emission seen in near-infrared in *HST* imaging at 9 days post-burst.

Consistent with high opacity line-blanketing of optical light.

HI column density evolution

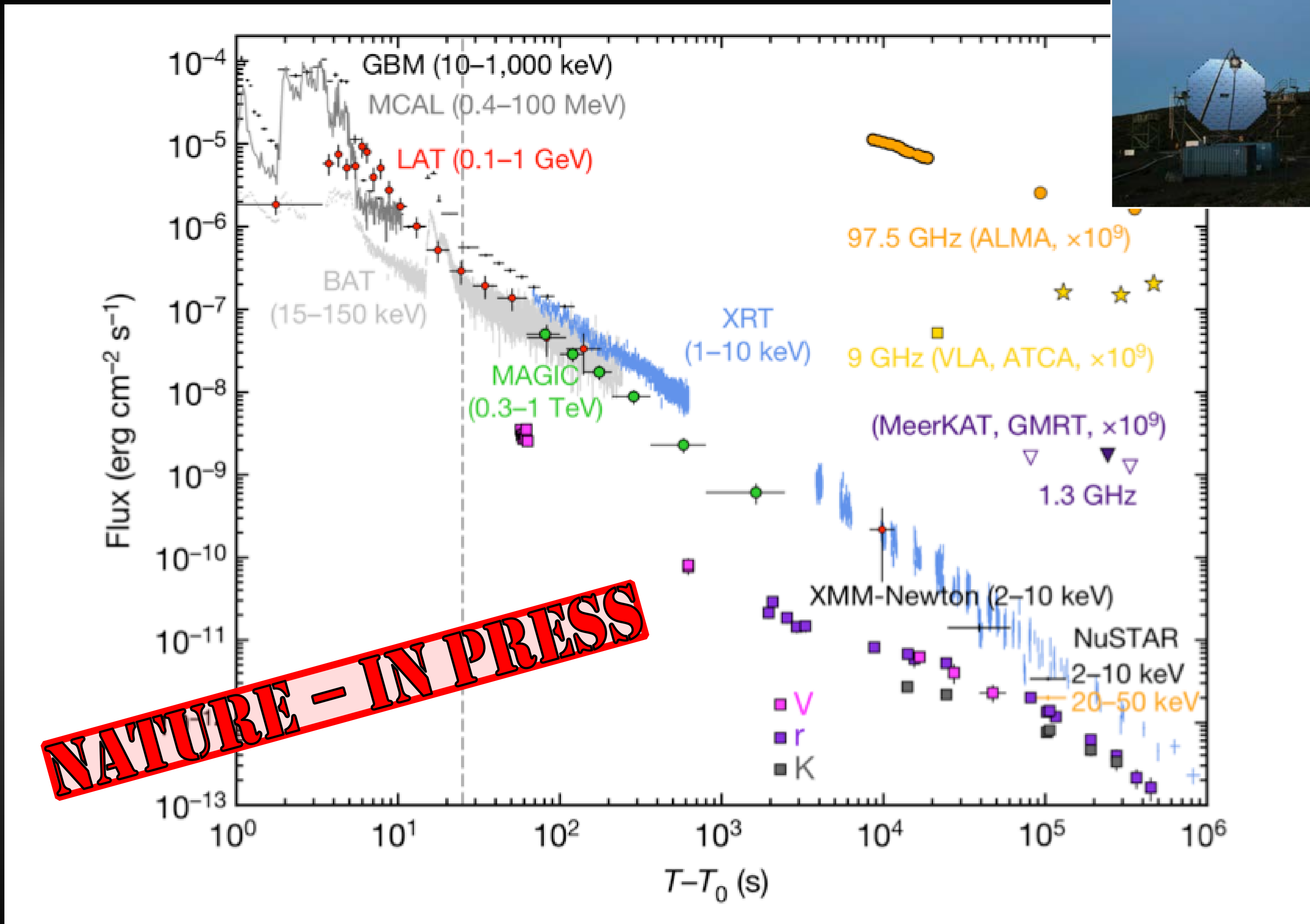
NT et al. (2019)



Reionization requires escape fraction >~10%

High column densities seen in optical spectra of most 2<z<5 GRBs suggest escape fractions for *these stellar pops* of <2 %.

GRB 190114C



MAGIC collab + 2019

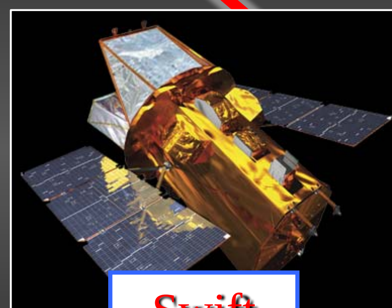
First reported TeV emission from GRB

The developing landscape

8m

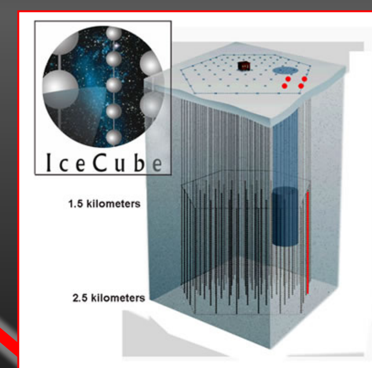
HST

XMM, CXO



Swift

ALMA



Radio

LIGO, Virgo

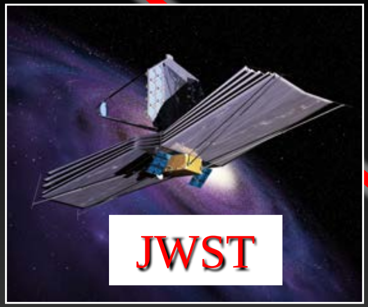
Now

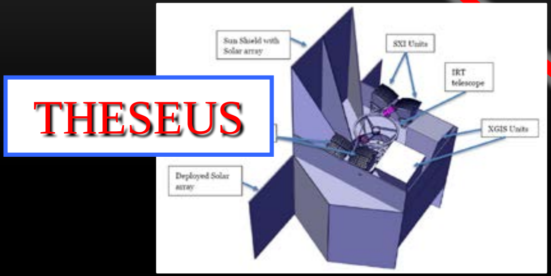
Lessons and thoughts

- GRBs (and related phenomena) have been a huge success story for coordinated, rapid, multi-wavelength and now multi-messenger astrophysics.
- Regularly spring new surprises, and whole new fields that were not known about when instruments/telescopes originally designed – common user facilities have been as important as specialised ones!
- Requires access to the most powerful follow-up facilities, therefore crucial that they have the necessary flexibility.
- This includes fast response; large field-of-regard (and geographical coverage for ground); range of observing modes and speed of switching; fast safety checking; *fast calibration and return of data*.
- Basic considerations: more useful follow-up likely to be obtained at lower declinations, higher galactic latitudes, greater Sun angles (darker moon phases)
- Robots very useful, *but* high cost of development/maintenance and human judgement/approval likely still to be required for triggering expensive common-user facilities (although robotic assistance still invaluable).

The developing landscape

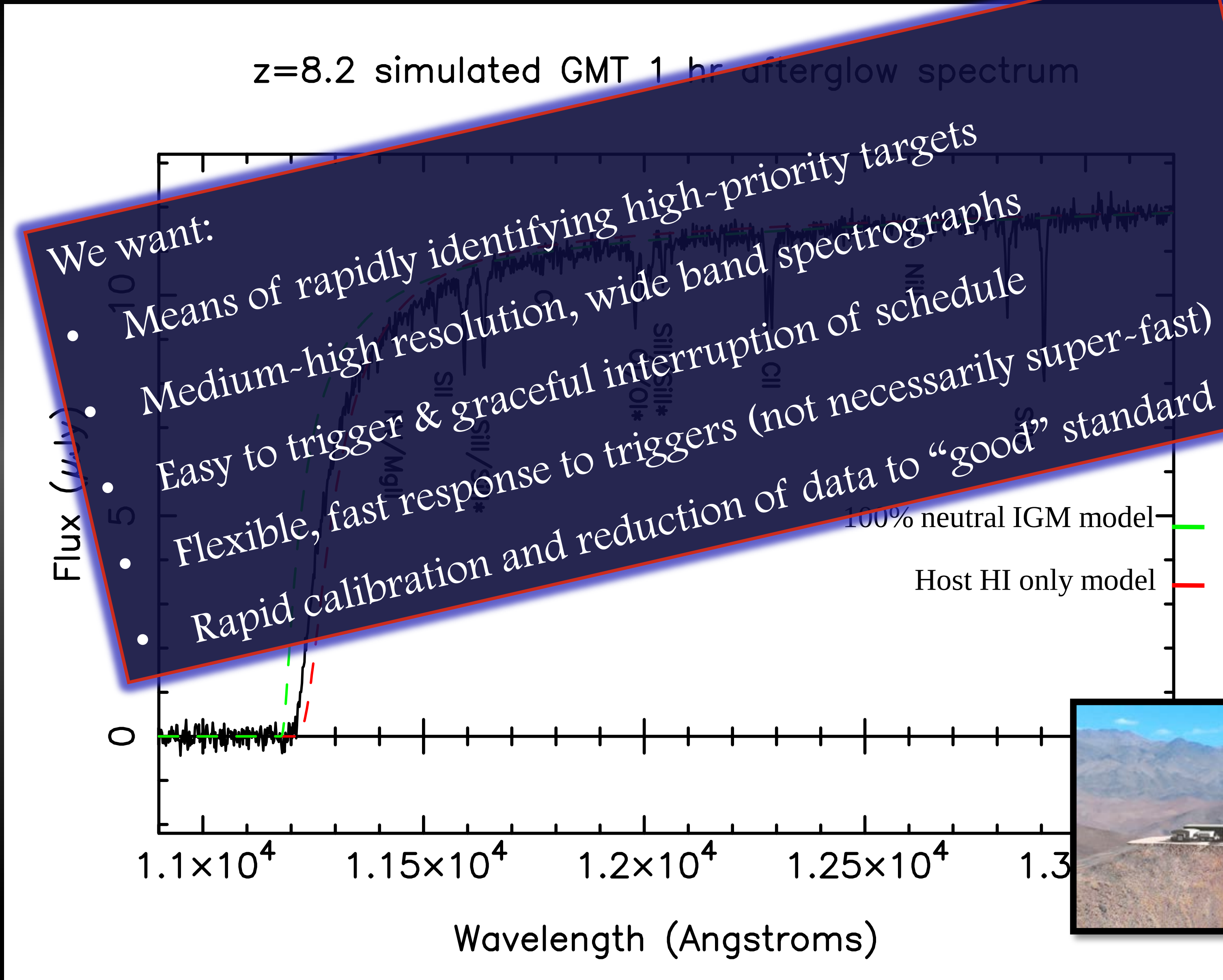
Now





2030s

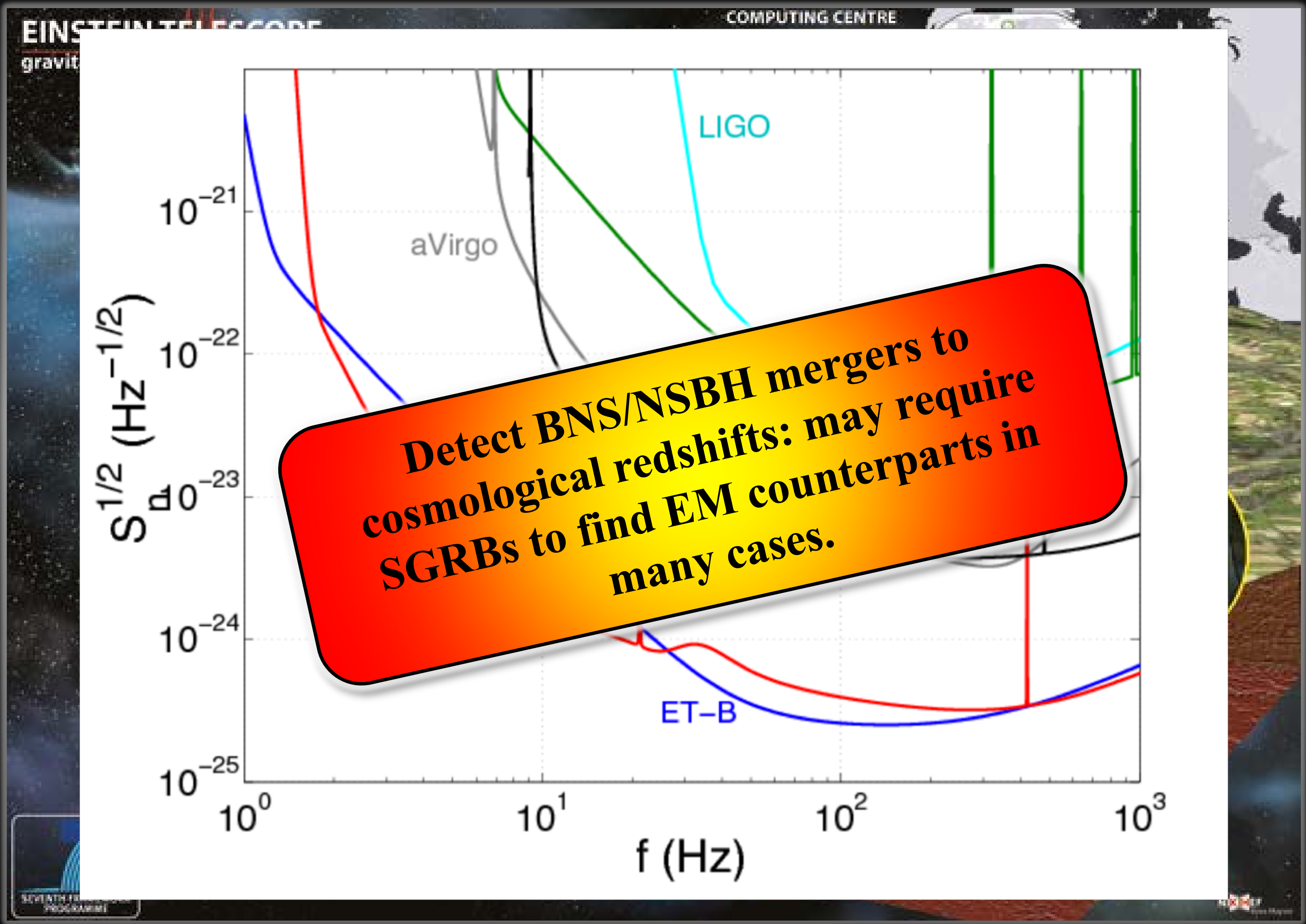
30 m class spectroscopy



We want:

- Means of rapidly identifying high-priority targets
- Medium-high resolution, wide band spectrographs
- Easy to trigger & graceful interruption of schedule
- Flexible, fast response to triggers (not necessarily super-fast)
- Rapid calibration and reduction of data to "good" standard

THESEUS in era of Einstein Telescope



Cultural issues

- Don’t be entirely hung up on today’s science cases!
- Find ways of making 24/7/365 personnel and rapid interruption an affordable cost (also funding the follow-up!).
- Simplify/smooth the interfaces – e.g. minimise the amount of bookkeeping that triggerer must do. (and remember, return path for data is also important *and/or* more “On-board” or “At telescope” intelligence?)
- Is the time-allocation process optimal?
  - E.g. 6-monthly periods does not lend itself to rare events.
  - E.g. initial follow-up for characterisation is more analogous to wide field surveys in sense of multiple possible science goals.
  - E.g. benefit in having common TAC process for multiple facilities.
- Consider options for coordinated pointing e.g. wide-field monitors following same pointing strategies; overlapping fields-of-regard.
- Competition vs. collaboration: ensuring key information is reported promptly; apportioning credit; rush to publish; public data…

Conclusion and some final questions

Many opportunities in the coming 10-20 years – probing exotic physics and evolution of the universe – but some could be missed if we build in obstacles!

How to avoid being swamped by triggers (how to aid selection)?

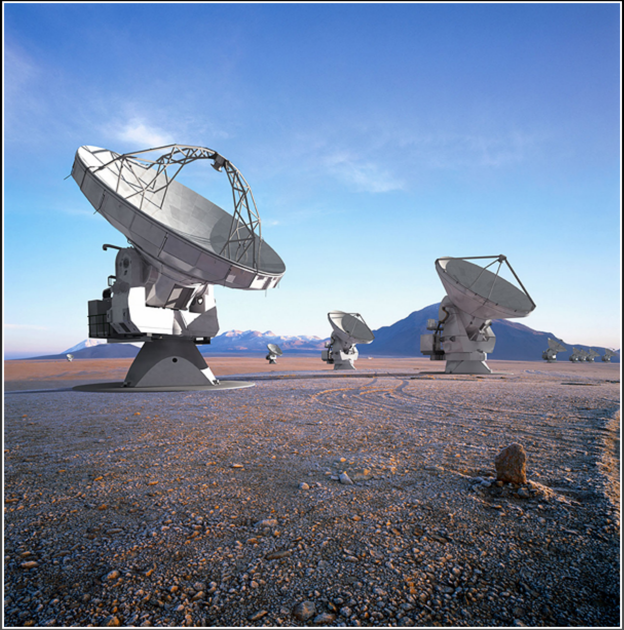
How to avoid being swamped by information? Can the required investments in automation be made?

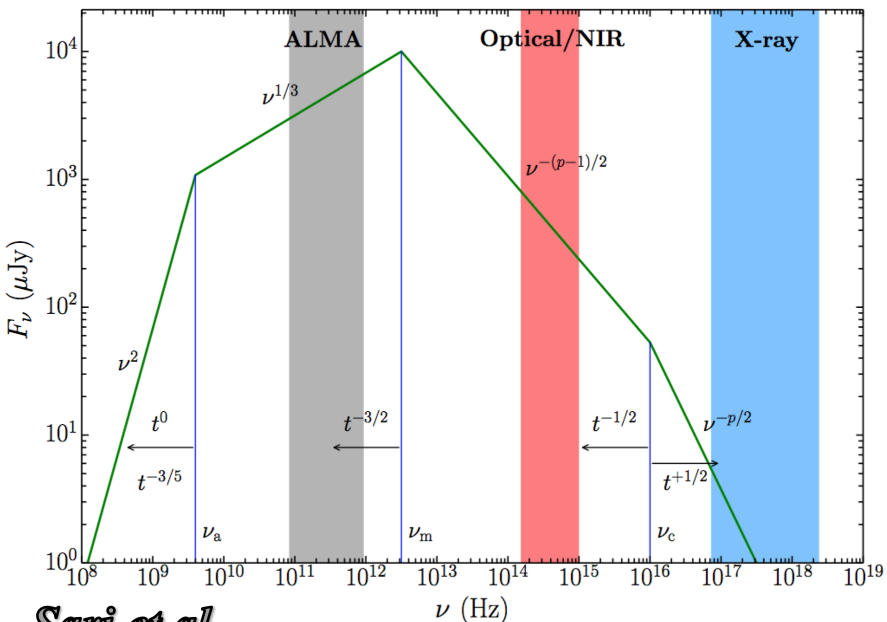
Is the publication process optimal? Would "living" publications be more appropriate for some results in these areas of science?

Will we have to work in larger collaborations?

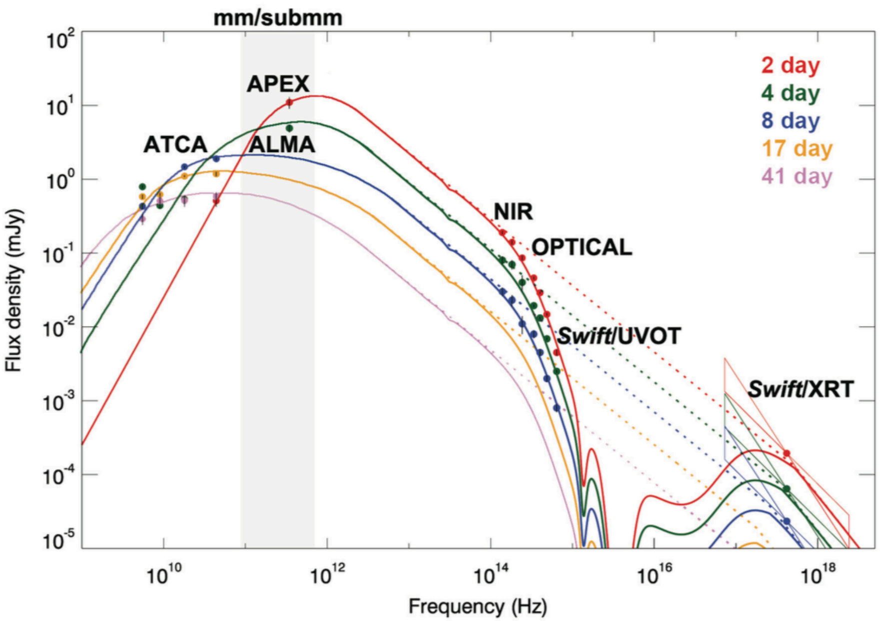
ALMA

In external shock, synchrotron model, peak of SED goes through mm/submm in days following burst. In combination with (much more regularly obtained) X-ray and O/IR data, should provide strong tests of models and more robust parameter estimation.





Sari et al.



GRB110715A; Sanchez-Ramirez et al. in prep.

Time variable absorption.

Vreeswijk et al. 2007

Due to either absorber size or ionization and dust destruction effects of prompt UV/X flash/afterglow.

e.g. GRB 060418 showed evidence of time variable fine structure lines (FeII and NiII), which were well fitted by absorption from a distant absorber excited by UV/X from the GRB itself.