Multi-messenger astrophysics

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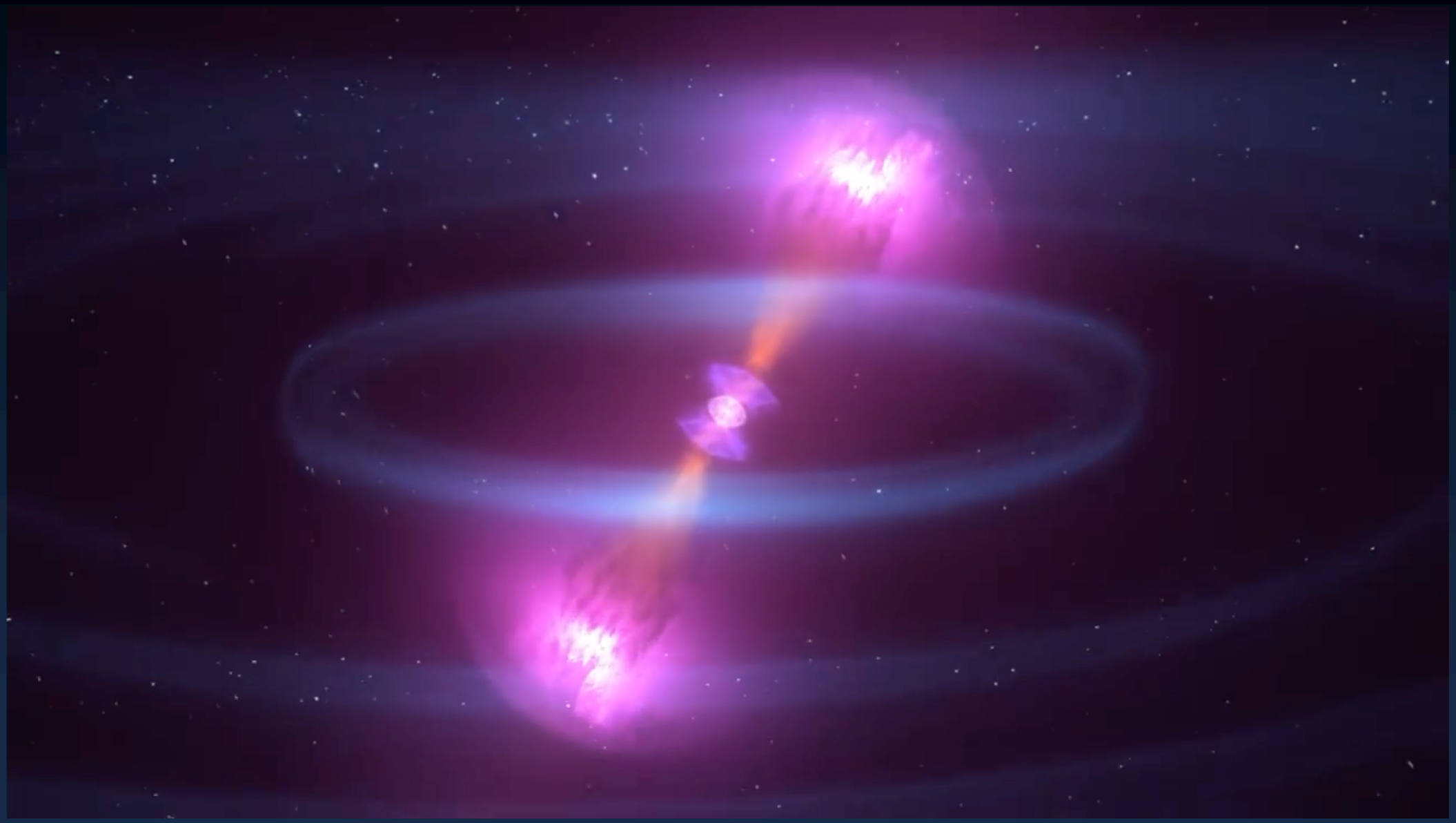
GW170817: GW + Gamma rays!

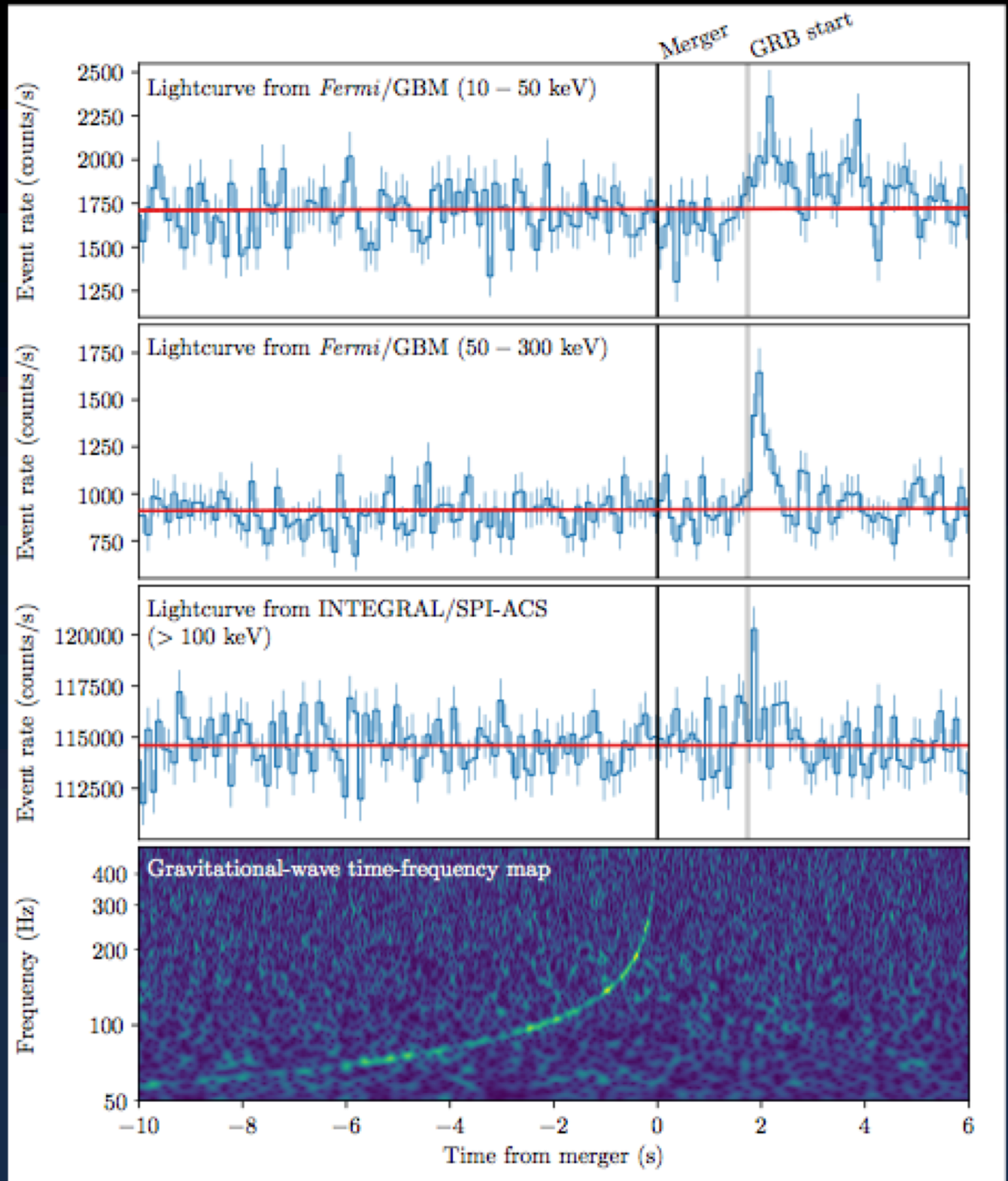


Credit: NASA/GSFC

Discovery

GW trigger:
17 Aug 2017
12:41:04 UT

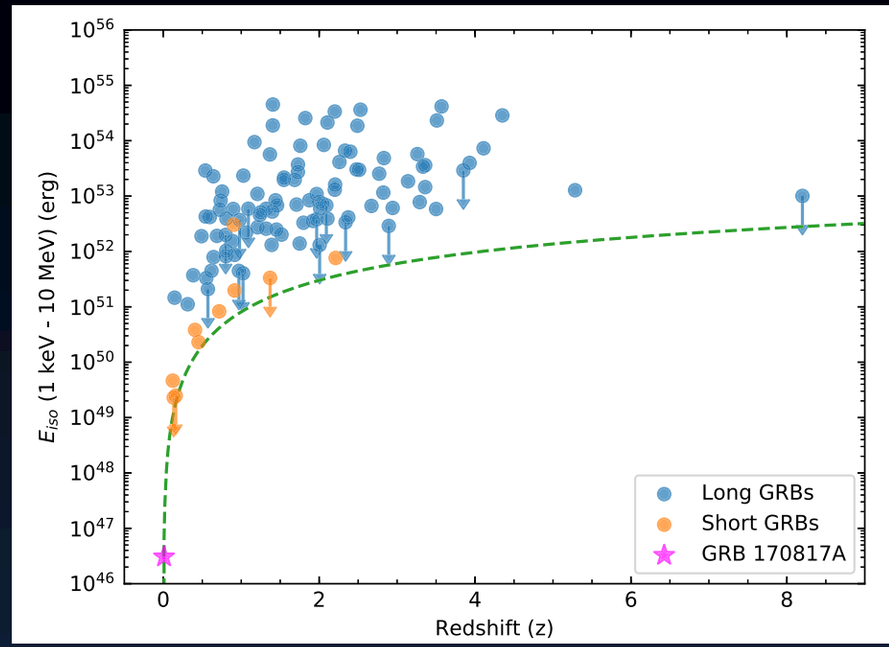
Gamma rays:
17 Aug 2017
12:41:06 UT

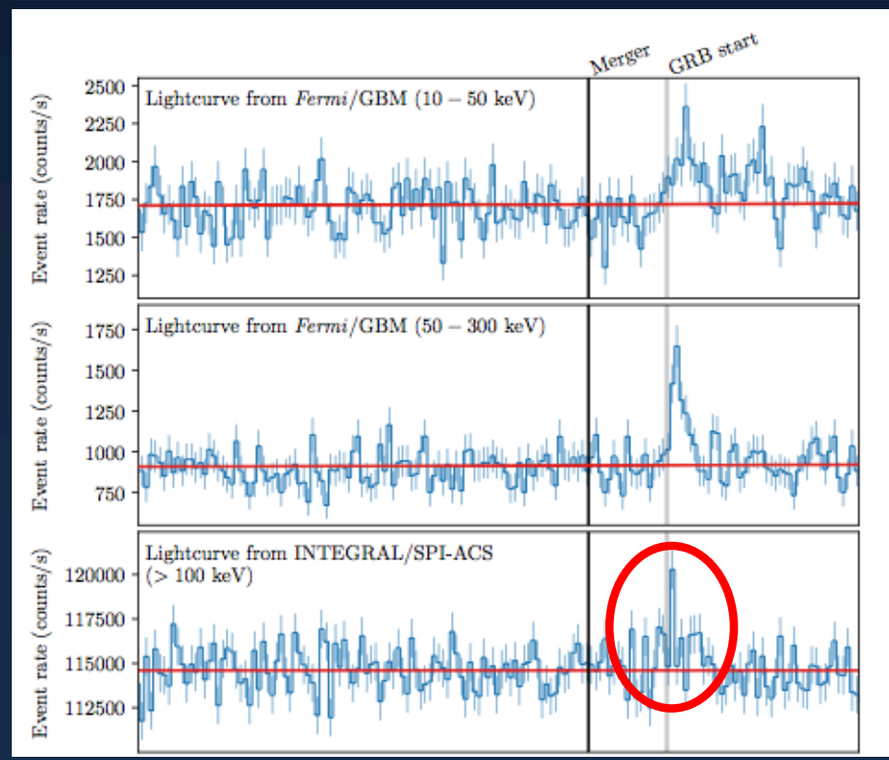


LSC et al, 2017, ApJL

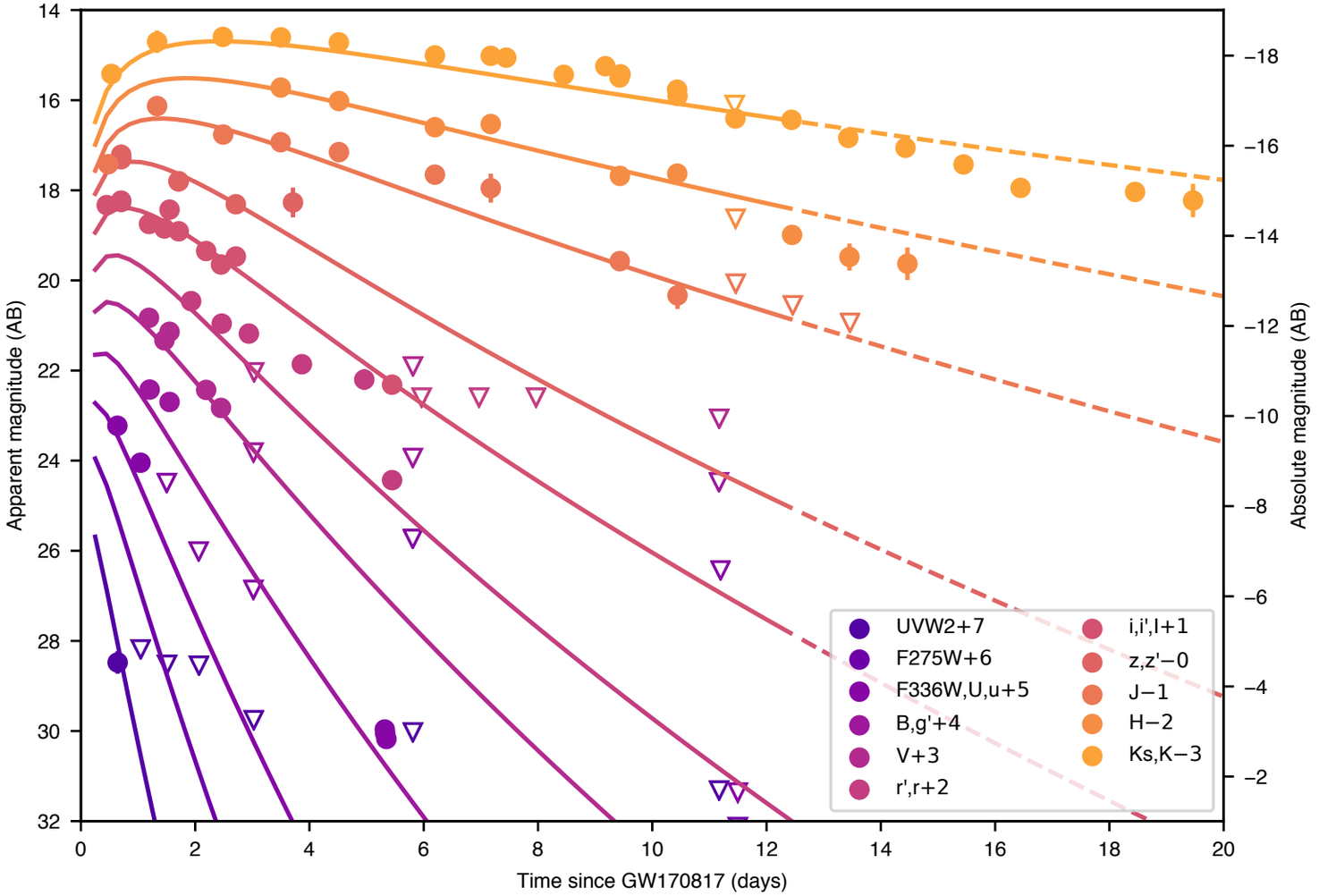
New class of bursts !

- GRB was very faint: 3-4 orders of magnitude lower than SGRBs
  next will be fainter!
- Broadband: seen from few keV to hundreds of keV
- Missed by Swift, AstroSat, CALET…





UVOIR Light Curve

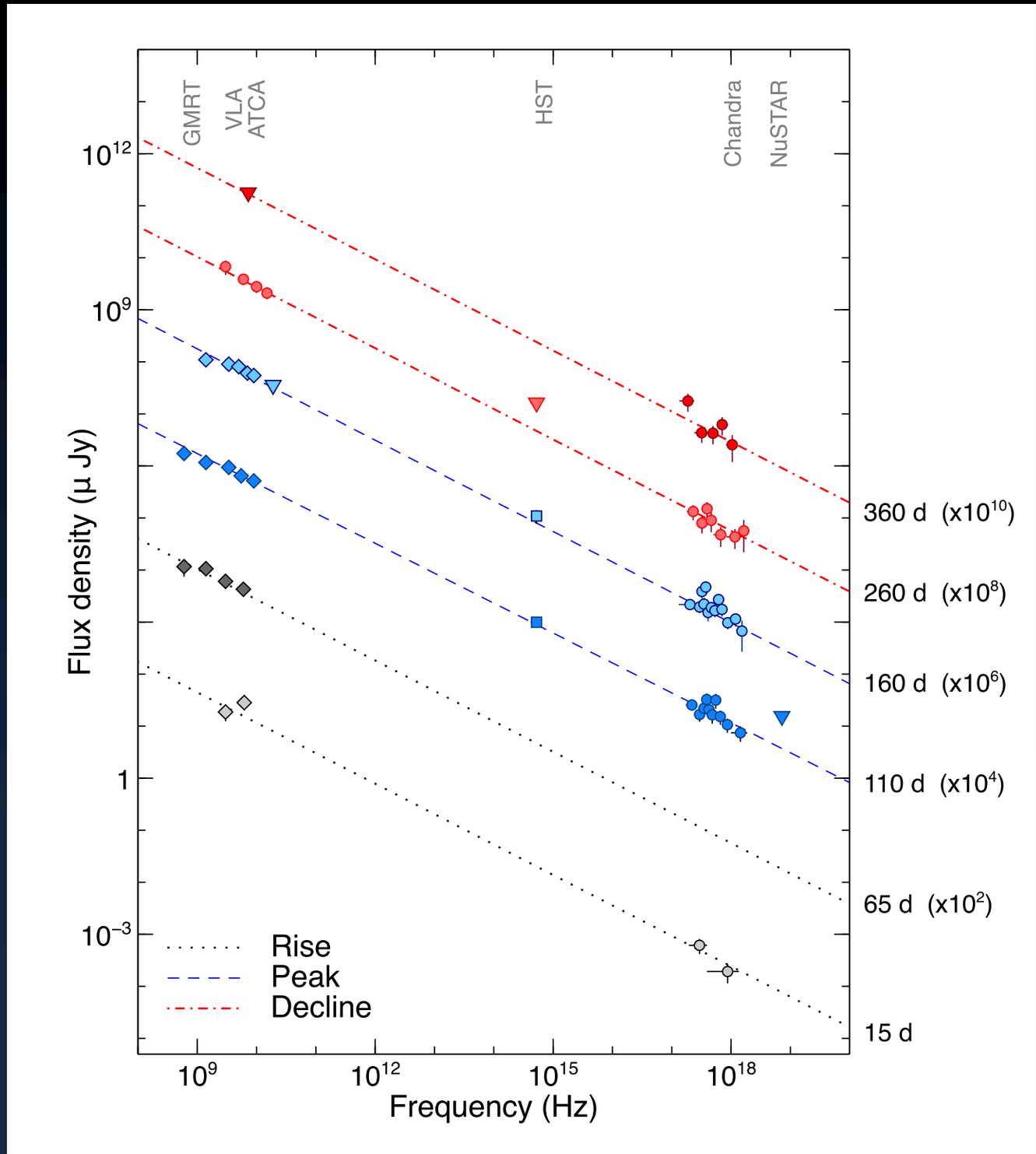


See also:
Andreoni et al. 2017
Arcavi et al. 2017
Cowperthwaite et a. 2017
Coulter et al. 2017
Drout et al. 2017
Lipunov et al. 2017
Lyman et al. 2017
Pian et al. 2017
Soares-Santos et al. 2017
Smartt et al. 2017
Tanvir et al. 2017
Utsumi et al. 2017
Villar et al. 2017

Evans et al. 2017, Kasliwal et al. 2017c

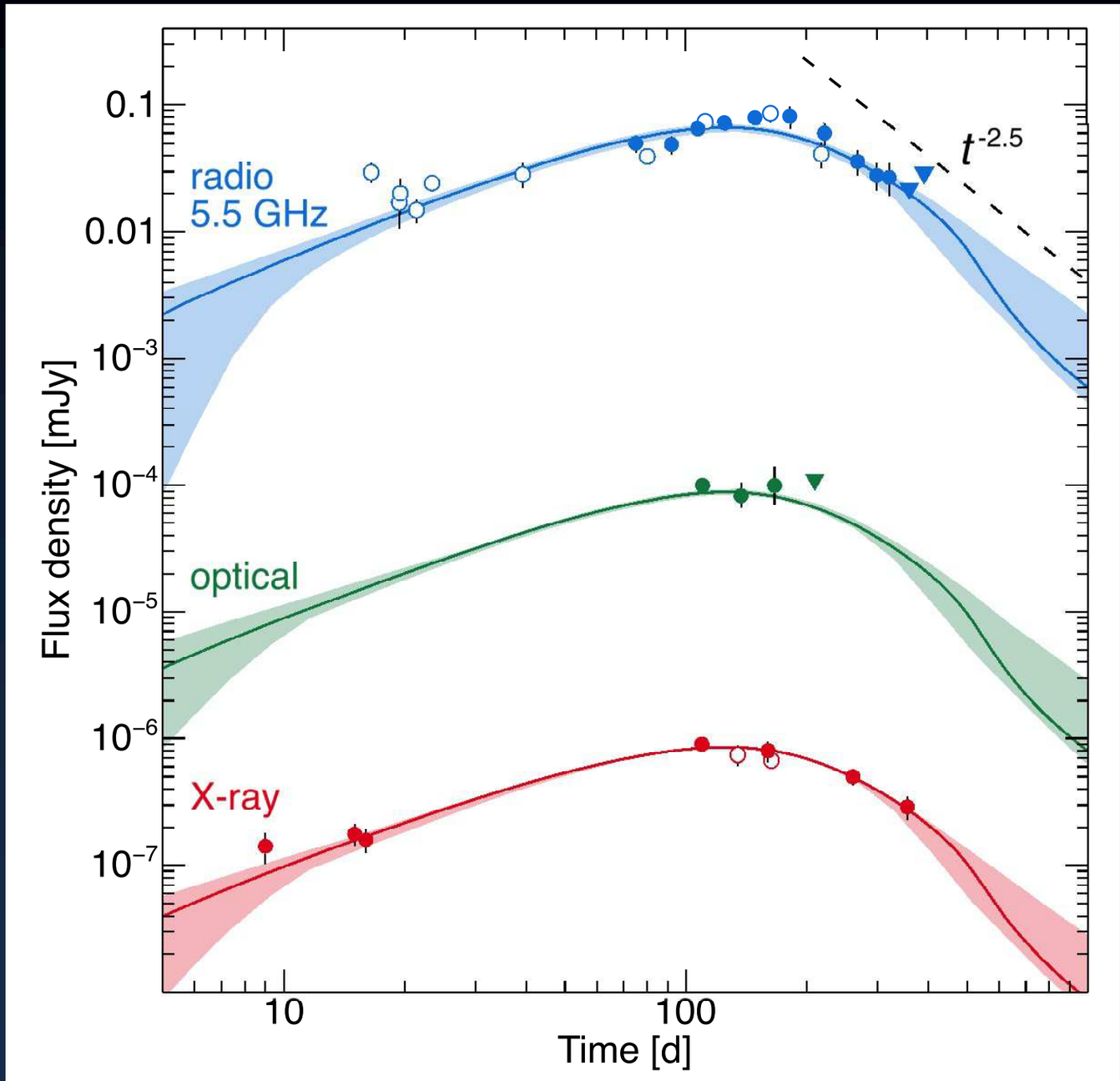
The afterglow spectrum

- Consistent with a constant slope, β=0.585±0.005
- No intrinsic absorption (only MW)
- Consistent with synchrotron (p=2.17)
- $\nu_c > 1$ keV (90% cl) at 260 d, $\nu_c > 0.1$ keV at 360 d.
- Troja et al., 2019 (arXiv:1808.06617)



Lightcurve evolution

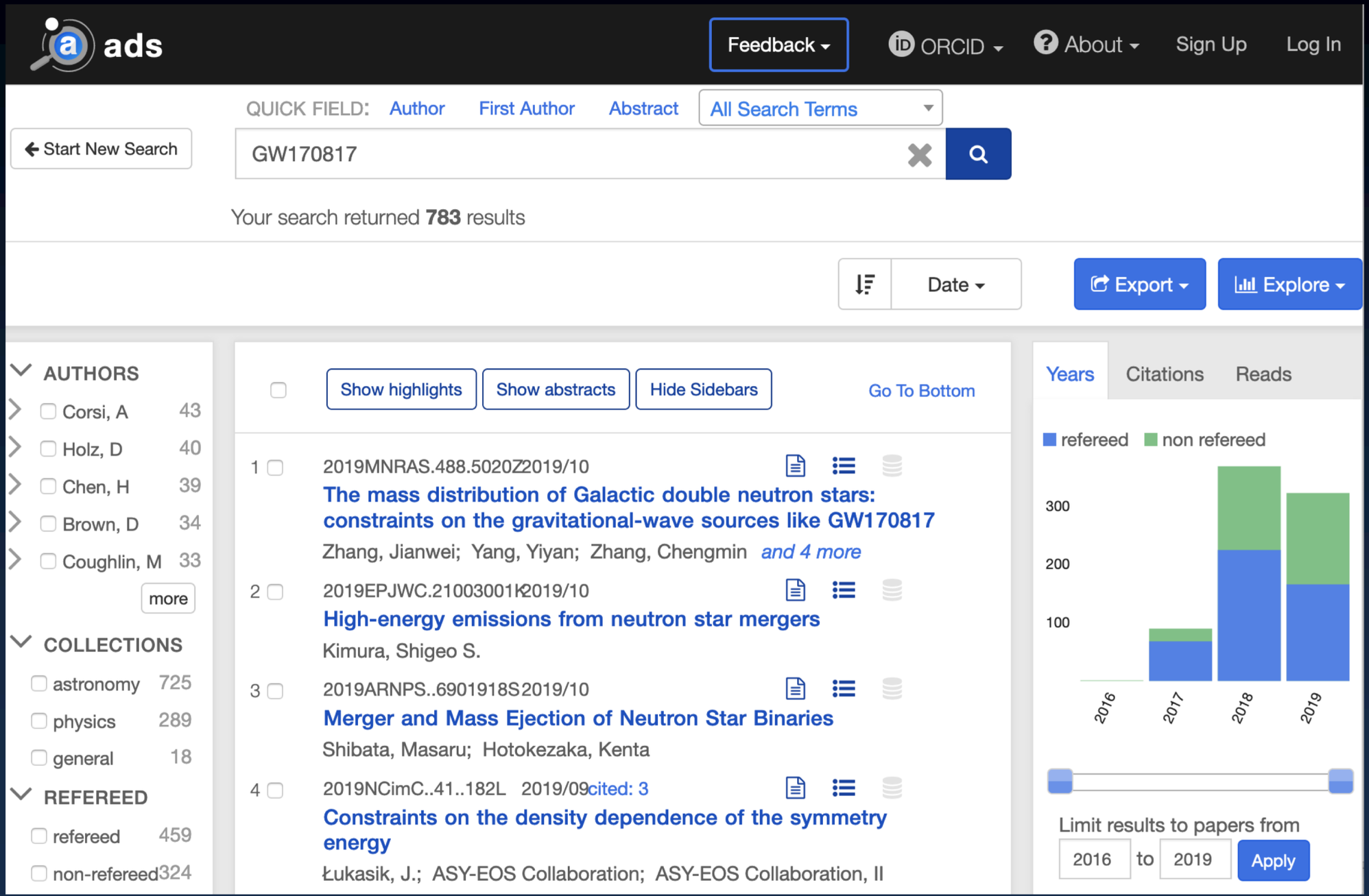
- Slow rise, now rapid decline
- Consistent with a Gaussian jet viewed off-axis
- Far off-axis viewers may see more absorption



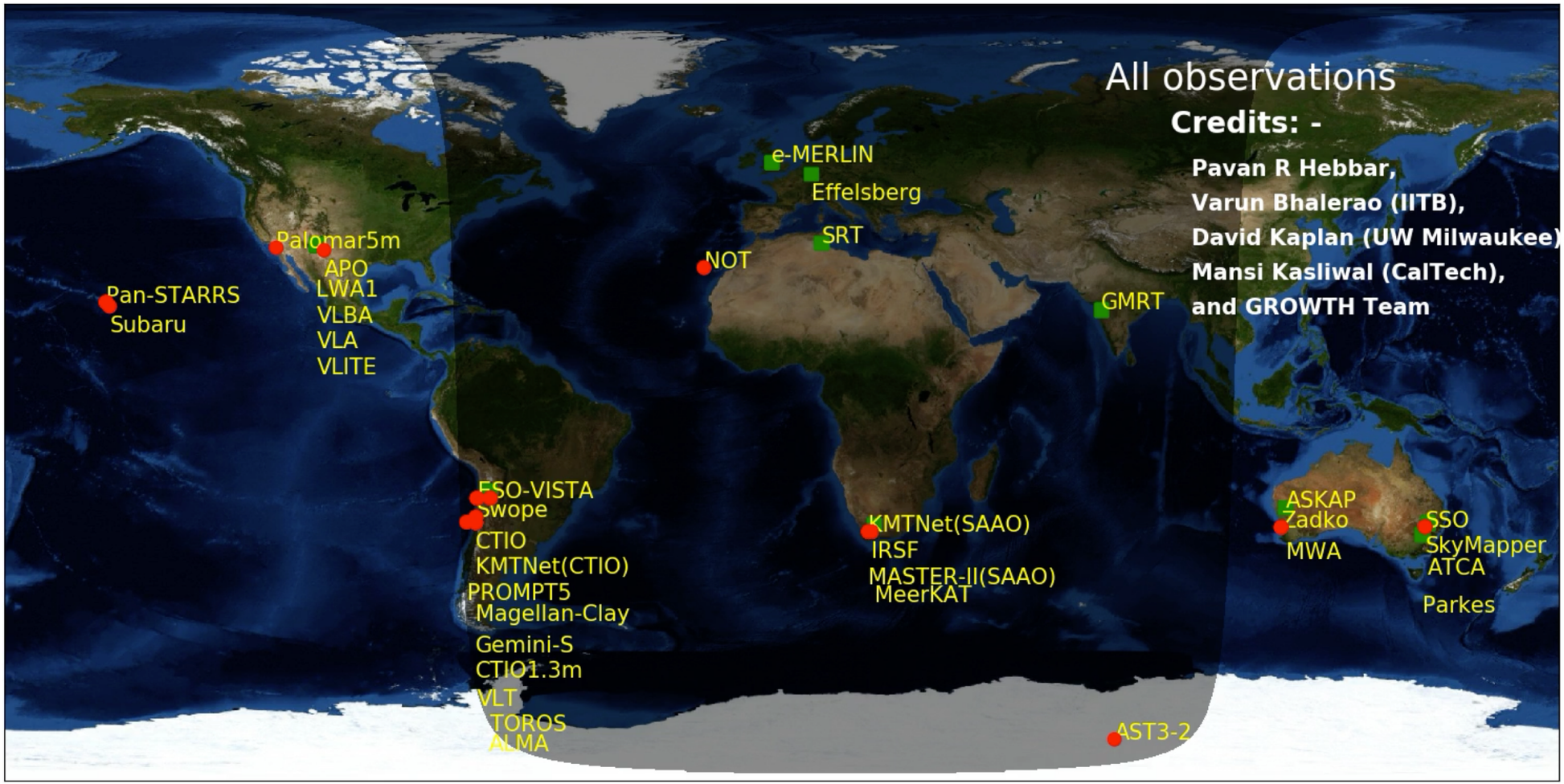
Troja et al., 2019 (arXiv:1808.06617)

Stepping back: a bird's-eye view

783 papers and counting…

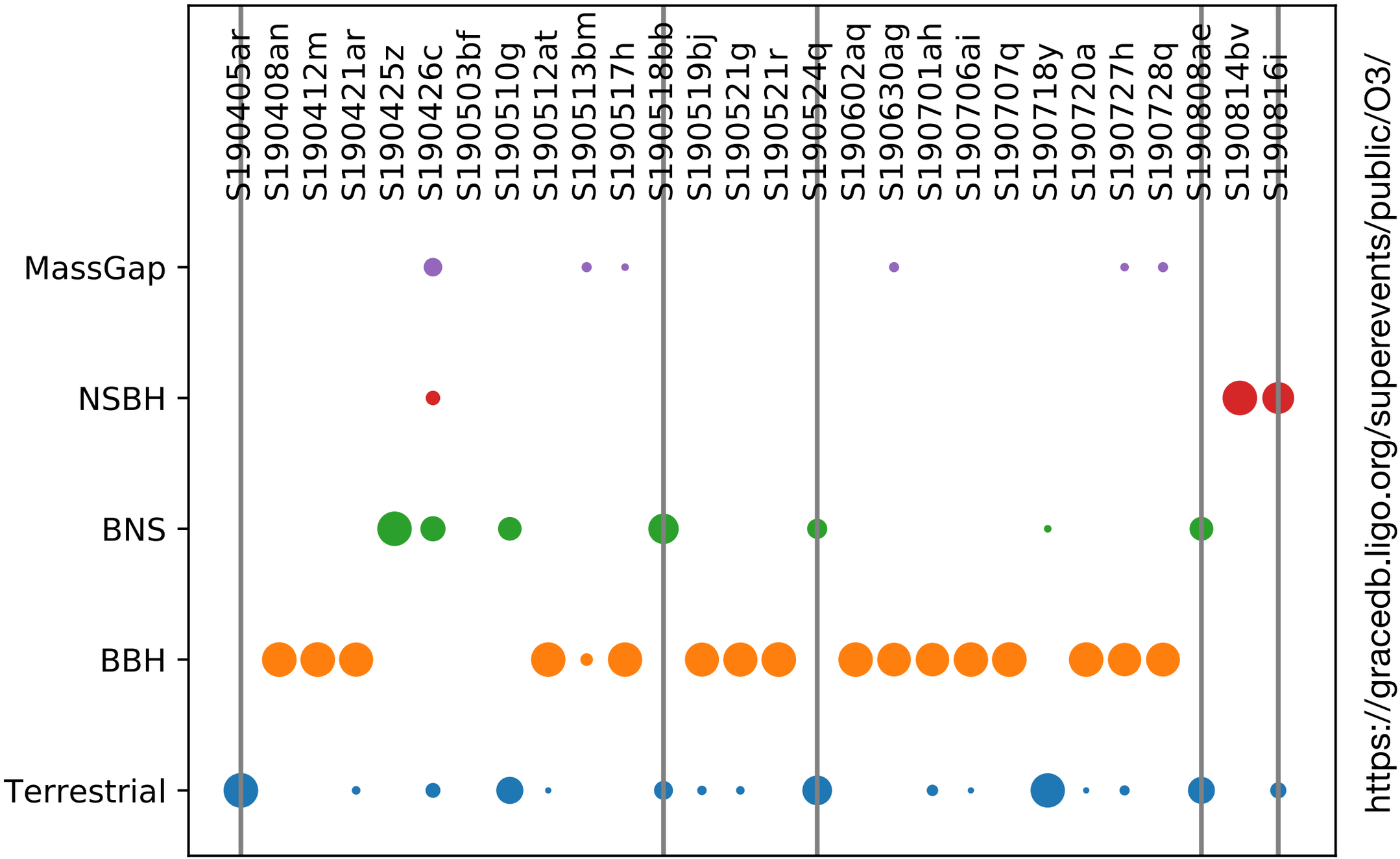


Ground-based follow-up



Credits: Pavan Hebbar, Varun Bhalerao (IITB), David Kaplan (UW Milwaukee), Mansi Kasliwal (Caltech), GROWTH collaboration

O3 candidates



O3 NS candidates

Name	Type	Distance (Mpc)	90% area (sq deg)	Counterpart
S190425z	99% BNS	156 ± 41	7461	No
S190426c	49% BNS, 13% NSBH, 24% Gap, 14% Terrestrial	377 ± 100	1131	No
S190510g	42% BNS, 58% Terrestrial	227 ± 92	1166	No
S190718y	2% BNS, 98% Terrestrial	227 ± 165	7246	No
S190814bv	100% NSBH	267 ± 52	23	Not yet?
GW170817	100% BNS	41	31	Yes

GW170817-like scaling

Name	Type	Distance (Mpc)	90% area (sq deg)	Optical	IR (Ks)	X-ray (10 keV-1000 keV)
S190425z	99% BNS	156 ± 41	7461	20	21	5e-8
S190426c	49% BNS	377 ± 100	1131	22	23	9e-9
S190510g	42% BNS	227 ± 92	1166	21	22	2e-8
S190718y	2% BNS, 98% Terrestrial	227 ± 165	7246	21	22	2e-8
S190814bv	100% NSBH	267 ± 52	23	21	22	2e-8
Fake event	100% BNS	500	–	22	23	5e-9
GW170817	100% BNS	41	31	17	18	7e-7

Scaling from Kasliwal et al. (2017) and Abott et al 2017 (Fermi + Integral +LVC)

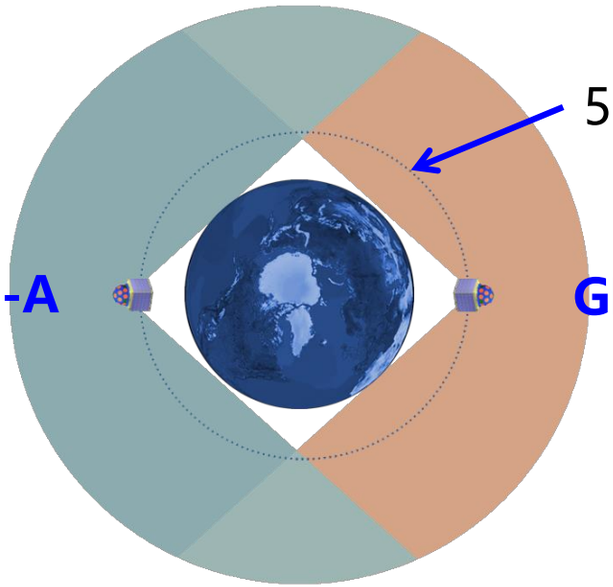
Typical optical surveys reach ~21 mag (ZTF, PanSTARRs), ~23 DECam
IR ~ 17.5 (Gattini), X-ray / Gamma ray ~ few e-7

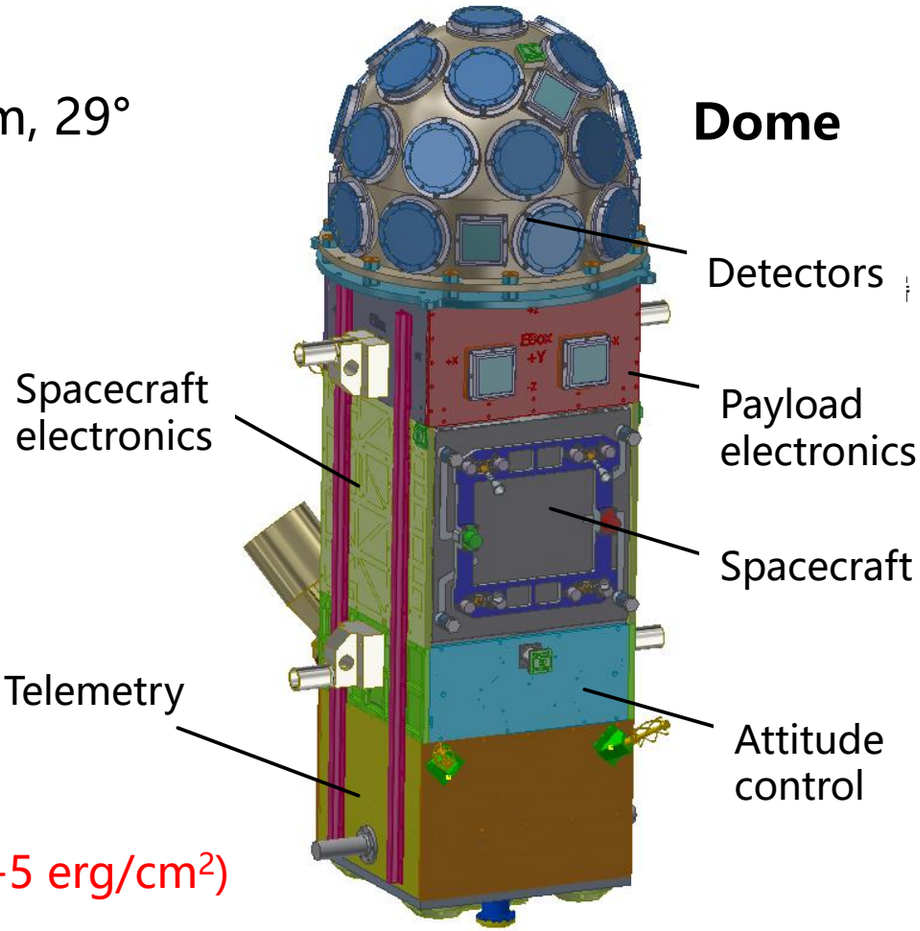
Is anyone looking?

- BurstCube (NASA GSFC ++)
  - » 1/20 collecting area (52 cm^2)
  - » CsI: 10 keV – 1 MeV
  - » Launch: 2022/23
- HERMES (Italy)
  - » 1/20 collecting area (50 cm^2)
  - » CsI / LaBr3: 3 keV – 50 MeV
  - » Unfunded
- Few lobster-eye concepts (ISS-TAO, China, Theseus)

GECAM

Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor





GECAM satellite (~140 kg for each)

- **Characteristics**
  - **FOV:** 100% all-sky
  - **Sensitivity:** ~2E-8 erg/cm^2/s
  - **Localization:** ~1 deg (1-σ stat., 1E-5 erg/cm^2)
  - **Energy band:** 6 keV – 5 MeV
- **Planned to launch by the end of 2020**
  - since LIGO will reach the design sensitivity around 2020 to 2021

Slide from Shaolin XIONG, Institute of High Energy Physics (IHEP), Chinese Academy of Sciences (CAS)

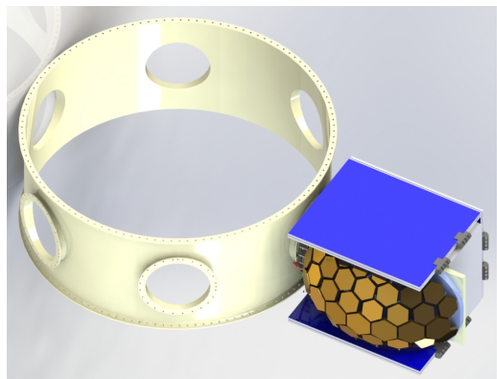
Slide from Eric Grove

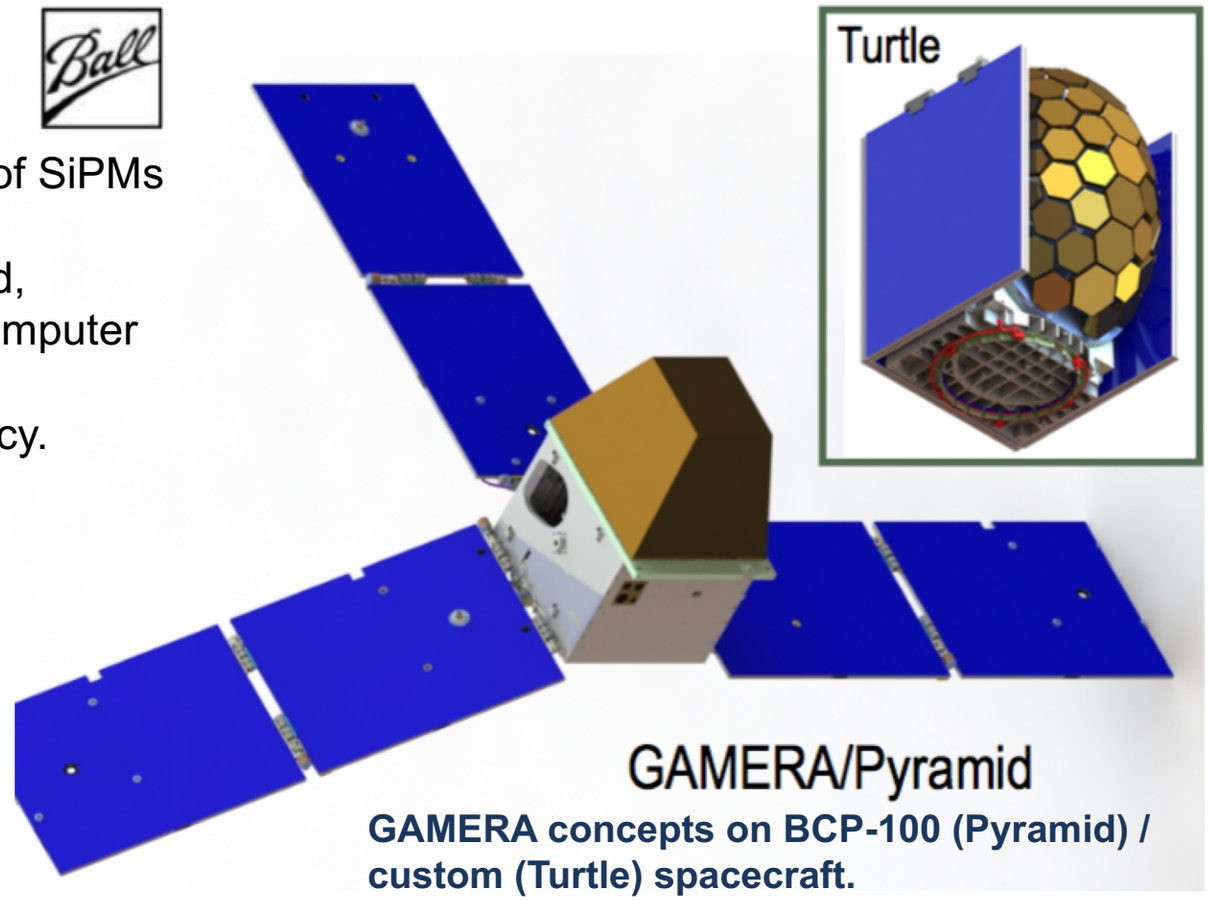
GAMERA Mission Concept – Instrument

GAMERA/Pyramid truncated pyramid CsI array (base 60x50 cm, height 40 cm). Dimensions fill ESPA volume and mass limit and are compatible with a standard SmallSat bus. Total instrument masses are ~70 kg.

GAMERA/Turtle ellipsoidal dome array spanning the longer ~90x60 cm dimensions of the ESPA volume. More efficiently exposes detector area to the sky, but requires a modified spacecraft bus layout.

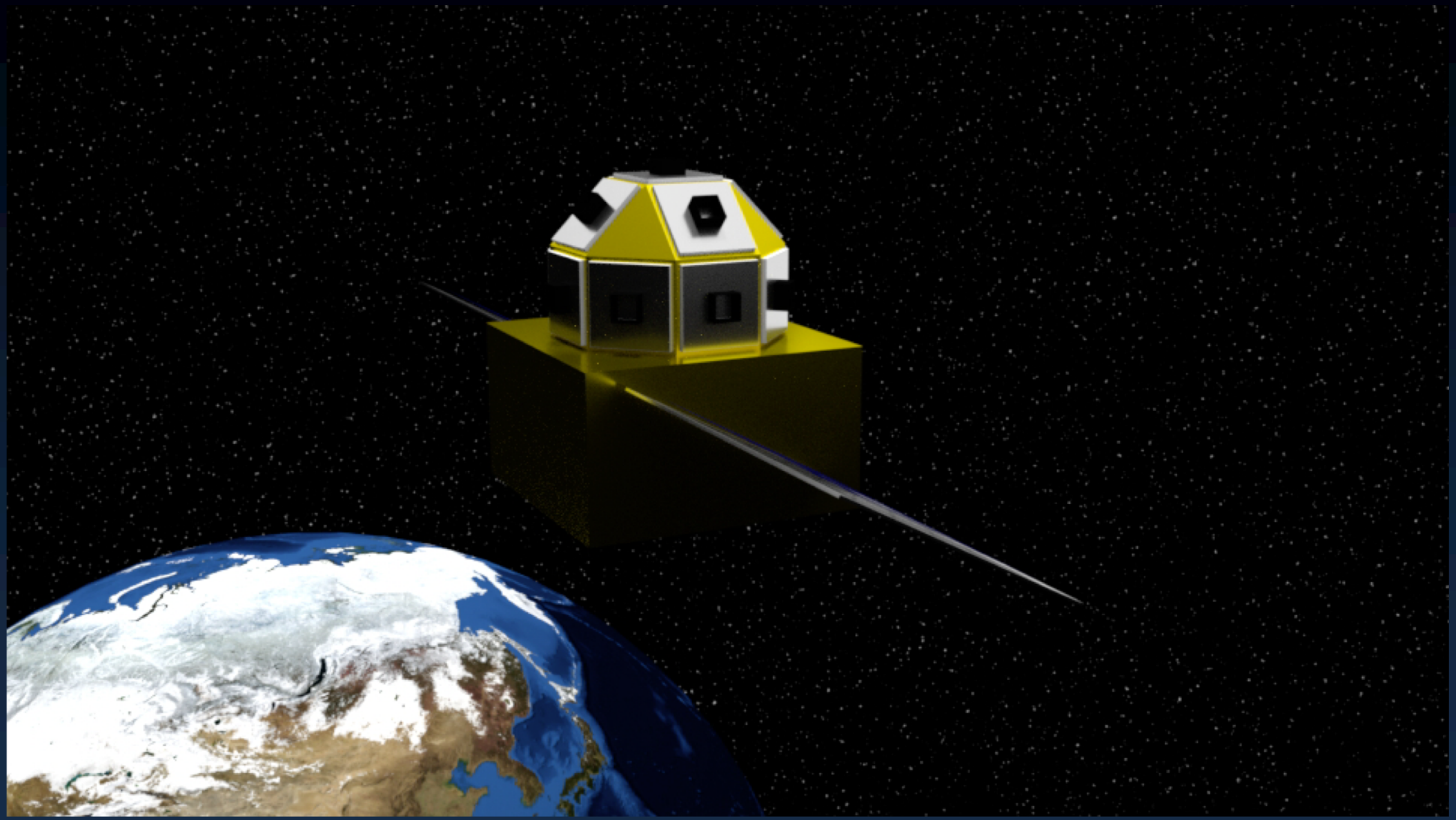
- Scintillator modules read out with an array of SiPMs digitized by a multichannel analyzer.
- Time-tagged pulse-height data are collected, processed, and stored by a single-board computer that interfaces with the spacecraft bus.
- GPS provides absolute time with μs accuracy.





GAMERA concepts on BCP-100 (Pyramid) / custom (Turtle) spacecraft.

Daksha



On alert for high energy transients

What can we do?

- Best detection bet: Optical / X-ray

- Data available:
  - » Prompt high-energy
  - » Lightcurves
  - » X-ray afterglows / OIR spectra will be rare

What can we learn from:

- X-ray detection / non-detection?
  - » Flux / broadband spectrum / polarisation?

- Optical detection / non-detection?
  - » Just lightcurves and upper limits?

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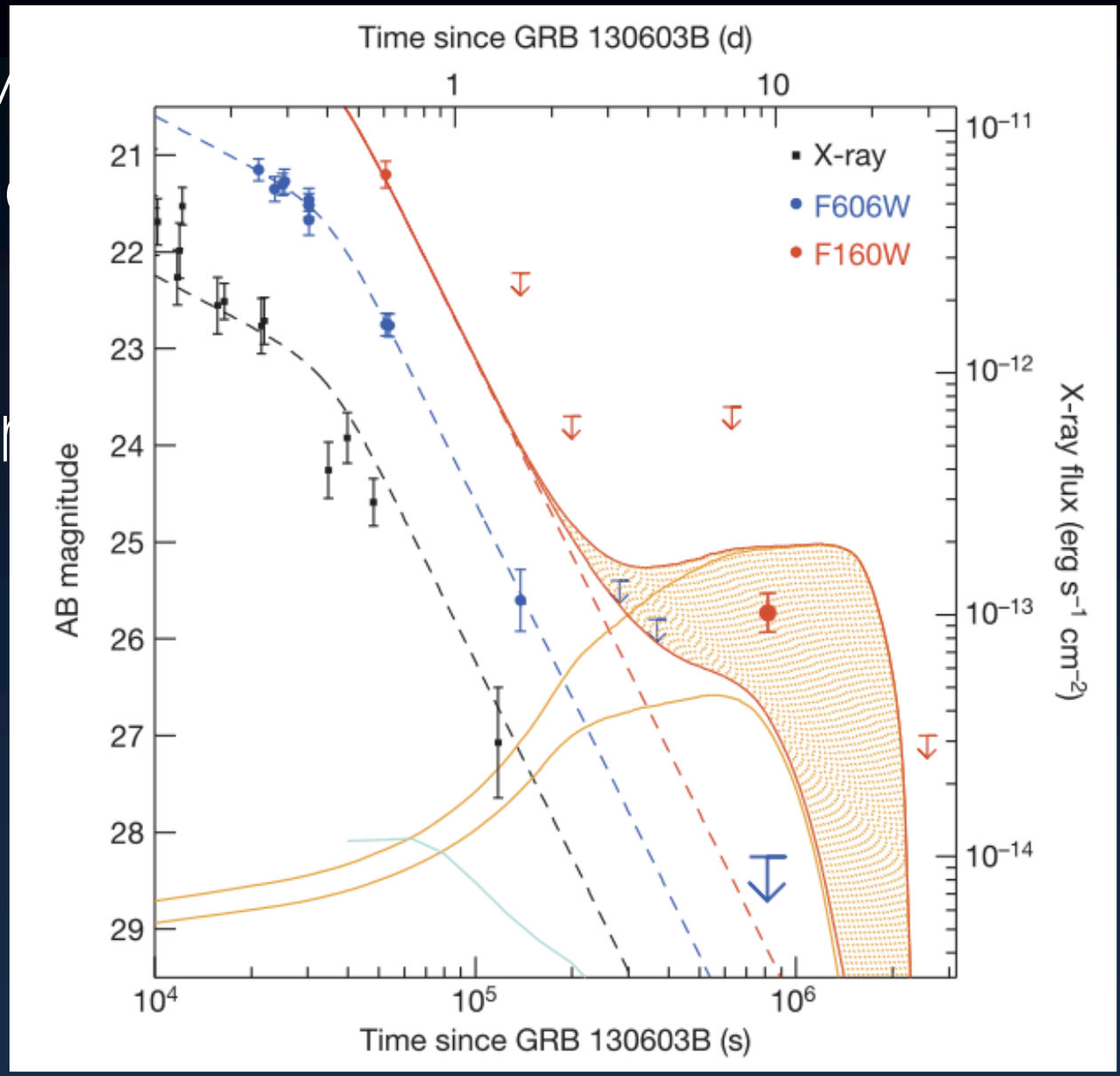
- X-ray detection /
  - » Flux / broadban
- Optical detectio
  - » Just lightcurves



What can we learn from:

- X-ray detection / non-detection?
  - » Flux / broadband spectrum / polarisation?
- Optical detection / non-detection?
  - » Just lightcurves and upper limits?
- How to prioritise “Gold” events for maximum physics?