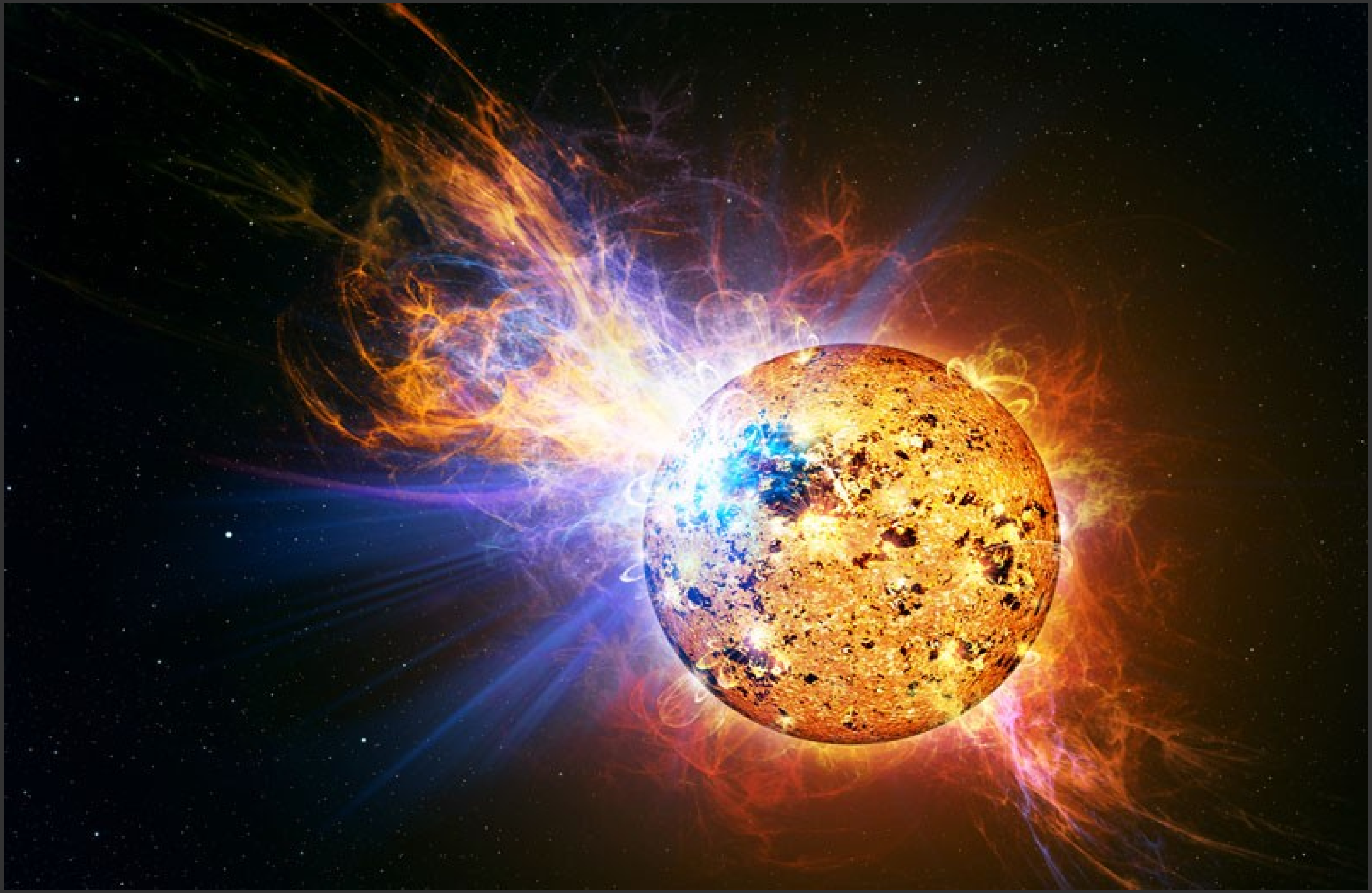
A prompt radio transient associated with a gamma-ray superflare from the young M dwarf binary DG CVn



Fender, Anderson, Osten, Staley, Rumsey, Grainge, Saunders
(MNRAS in prep)

Roboticisation of AMI-LA GRB follow-up
Automatic observation of *Swift* GRBs

γ

Timescale from *Swift* detection of first photon to observing command sent to follow-up telescope: **30s**

NASA GSFC

VO Event

four π sky

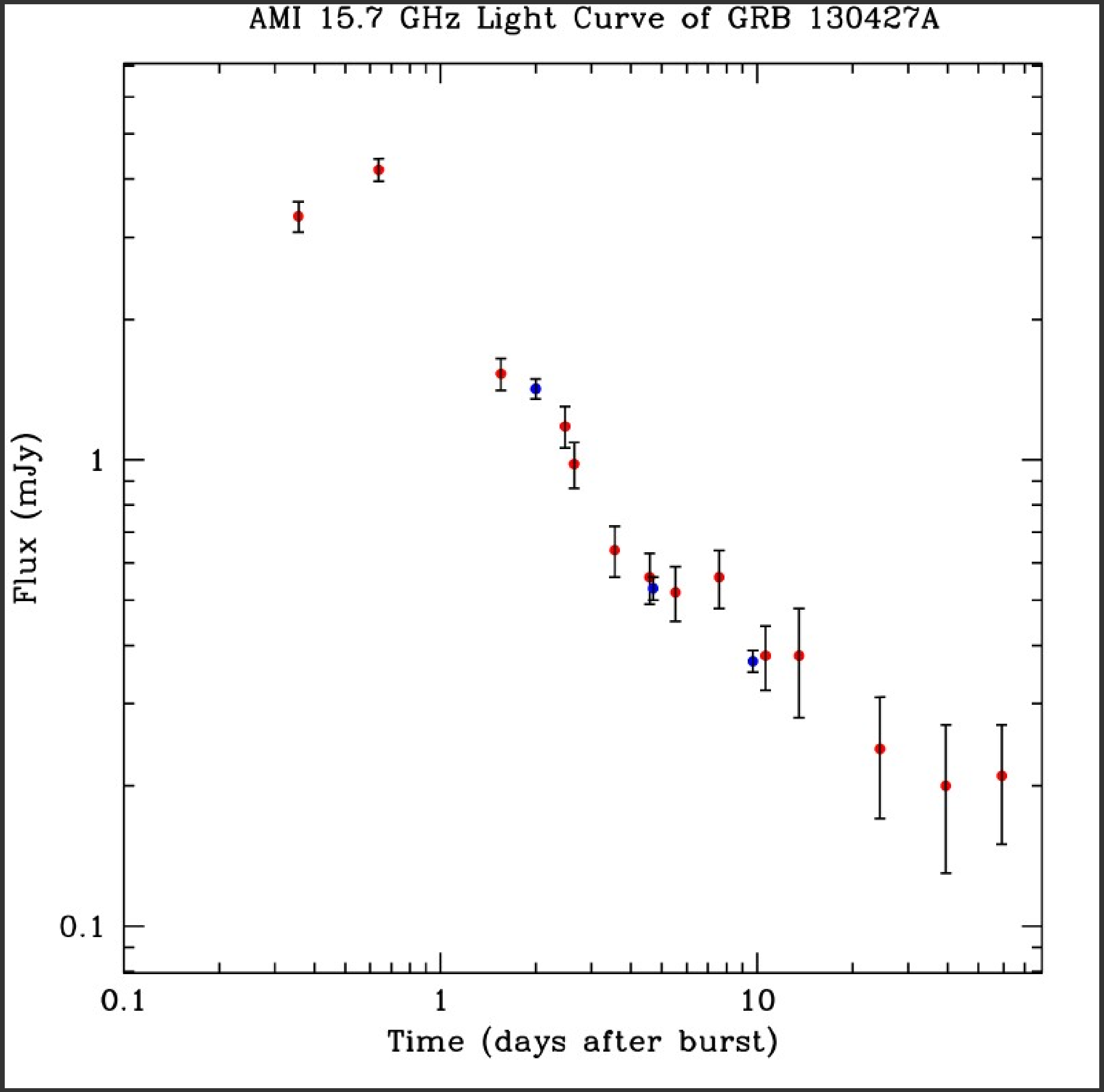
AMI-LA

AMI on-target typically ~**4min**

Staley, Titterington, Fender et al. (2013)

15 deg/minute slew speed

GRB 130427A: very early time radio emissions



Early time radio emission from bright GRB (~0.3 day)

Probably associated with reverse shock in jet (rarely seen in radio)

Anderson et al. (2014)
Van der Horst et al. (2014)

Automatic observation of *Swift* GRBs: early results

- Demonstrated rapid follow-up with scientifically useful measurements was useful (Staley et al. 2013)

- Detected very early time (reverse shock) flare from GRB 130427A (Anderson et al. 2014)

- Over 100 GRBs now followed up, 10+ detected → best constraints on early time emission, possibly supports bimodality of GRB radio loudness (Anderson et al. *in prep*)

- In parallel, AMI survey archive to be searched for high-frequency transients (Anderson et al.)

ALARRM (AMI-LA Rapid Response Mode)

Now:

- Follow-up of **all** *Swift* alerts (not just GRBs)

- Follow-up of iPTF transients

Soon:

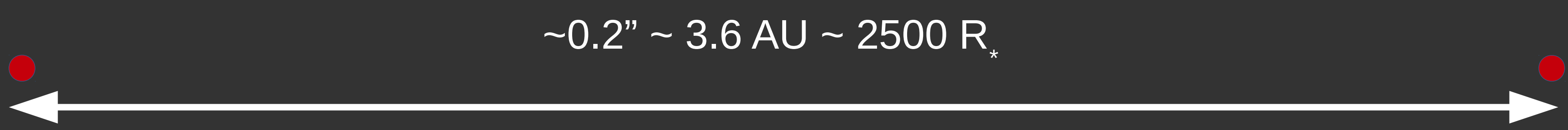
- Follow-up of GAIA transients

- Synchronized with pt5m optical follow-up [?]

[See also Palaniswamy et al. 2014 for related, single-dish, robotic GRB follow-up]

DG CVn: nearby, young, active M-dwarf binary

- Nearby M-dwarf binary, not well studied
- Distance: 18pc
- Binary: two M dwarfs
- Very young: probable age <30 MY
- Rapid rotation: 50 km s^{-1}



April 23, 2014: very bright gamma-ray flare detected from DG CVn by *Swift*

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Swift Detection of a Superflare from DG CVn

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*on **5 May 2014; 18:45 UT***
Credential Certification: Kim Page (kpa@star.le.ac.uk)

Subjects: Optical, Ultra-Violet, X-ray, Gamma Ray, Star, Transient

The Swift team reports the detection of a superflare from one of the stars in the close visual (0.17â) dM4e+dM4e flare star binary system DG CVn (G 165-8AB). The Burst Alert Telescope (BAT) triggered on DG CVn at 2014-04-23T21:07:08UT = T0 (trigger 596958 reported in GCN Circ. 16158), resulting in an automatic slew to the source. The partial coding was 93%. The hard X-ray source had a peak intensity in the BAT 15-50 keV band of ~300 mCrab or 0.06 count/cm^2/s. The BAT data cover the period from T0-239 to 963 s. The mask-weighted lightcurve shows a single peak from ~T0-40 s to 120 s and another weaker peak from ~T0+200 to 240 s. The time-averaged spectrum from -29 to 337 s is well fit by either a simple power-law or a bremsstrahlung model. The power law index of the time-averaged spectrum for the former model is 2.62+/-0.33, while the temperature of the latter is 26(+12,-8) keV. The fluence in the 15-150 keV band is (8.4+/-1.5)e-7 erg/cm^2 for the power-law model.

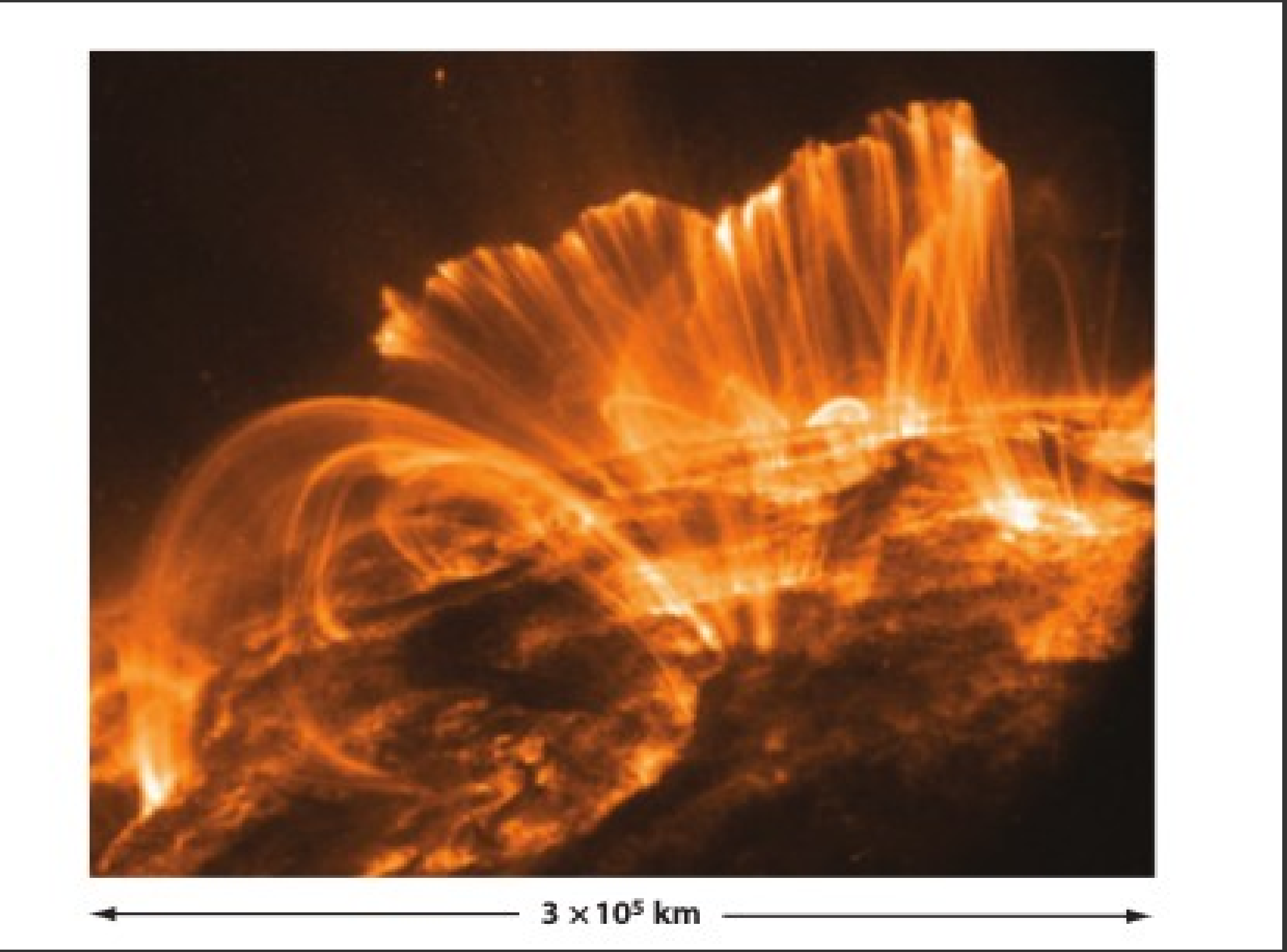
When the Swift X-Ray Telescope (XRT) started observing at T0+117 s, the soft X-ray 0.3-10 keV rate of DG CVn was ~100 count/s, corresponding to 5e-9 erg/cm^2/s, and then decayed moderately, reaching a count rate of ~50 count/s by ~328 s after the trigger. After a 4.2 ks gap in XRT observations of this field, the soft X-ray emission had declined to a level of 4-15 count/s, but, after a further gap, at T0+11 ks DG CVn was observed to have had a second, smaller flare back to a level of ~30 count/s. The source then decayed monotonically for ~10 days, with a power-law of alpha = 1.39+/-0.01 fitting the data after T0+10 ks, ignoring a third, much smaller flare (peak rate 0.7 count/s) which occurred at T0+460 ks. By the end of this period, the count rate had declined to ~0.07 count/s (swift.ac.uk/DGCVn.gif) or a soft X-ray flux of DG CVn of 3e-12 erg/cm^2/s, similar to the levels of previous detections of this source by ROSAT and XMM-Newton. Preliminary spectral analysis of the XRT data from T0+120 to 600 ks using a 3T APEC fit yields a temperature of 27(+6,-8) keV for the dominant high-T component in the first observation (T0+117 to T0+328 s), in agreement with the initial BAT measurement. The derived temperatures for this component

Hard X-ray flare peaked at ~300 mCrab

$L_X \sim 10^{32}$ erg s^{-1}

→ for a period of a few minutes the X-ray emission from this flare outshone all the light from its parent star

What happened? Particle acceleration in magnetic loops (probably)



April 23, 2014: very bright gamma-ray flare detected from DG CVn by *Swift*

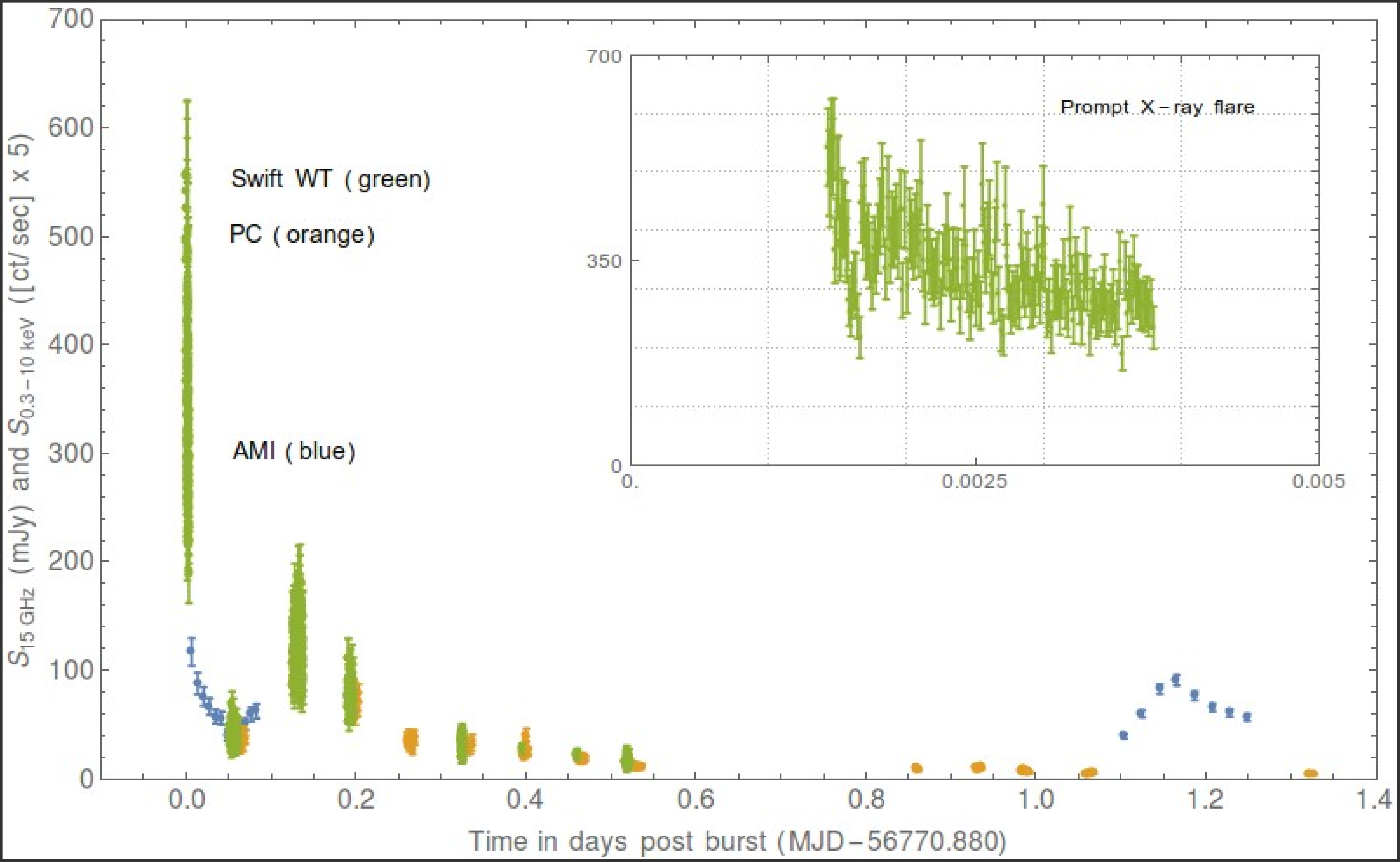
1	21:08:25	Initial *Swift* BAT timestamp (VOEvent, marked as GRB), *Swift* starts slewing
2	21:08:29	4 Pi Sky Bot activated
3	21:08:30	AMI receives request email, ALARRM mode
4	21:08:35	AMI starts slew to phase cal.
5	21:10:33	**Swift on target**
6	21:10:34	AMI on phase cal., wai
7	21:12:26	AMI phase cal. obsser
8	21:14:06	phase cal. obs complet starts slew to DG CVn
9	21:14:21	AMI DG CVn observati

We can improve Response:

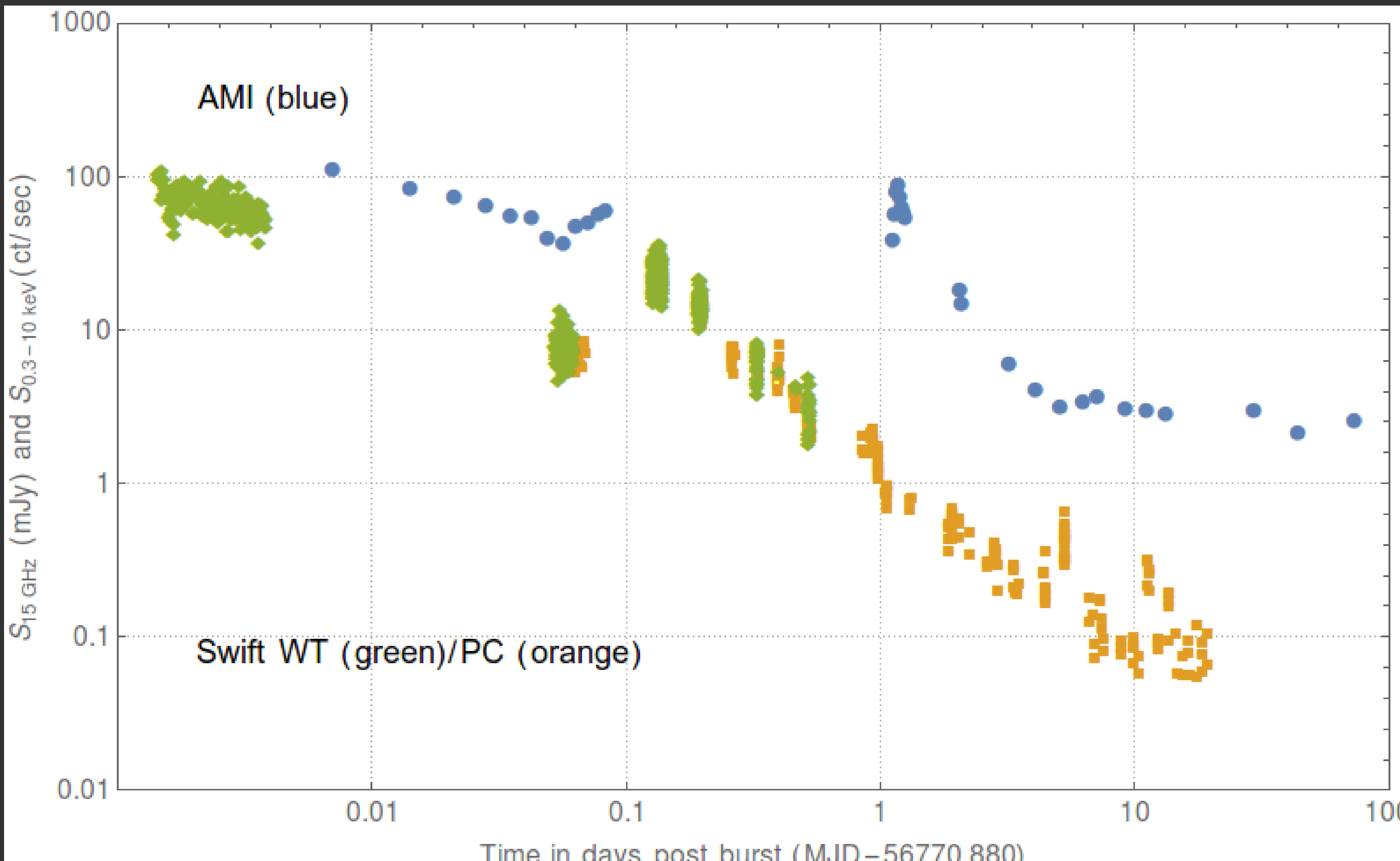
1. go straight to target
2. remove “wait”
3. SKA dishes will slew faster than AMI

→ get to events at same time/before *Swift*

DG CVn: radio / X-rays (linear)



DG CVn: radio / X-rays (logarithmic)



DG CVn: why the superflare?

Binarity is unlikely to be the cause:

- Magnetic loops typically or order ~1 stellar radius

- Binary separation ~2500 stellar radii

More likely:

- Extreme youth (30MY) and rapid rotation

DG CVn: what did we learn with AMI?

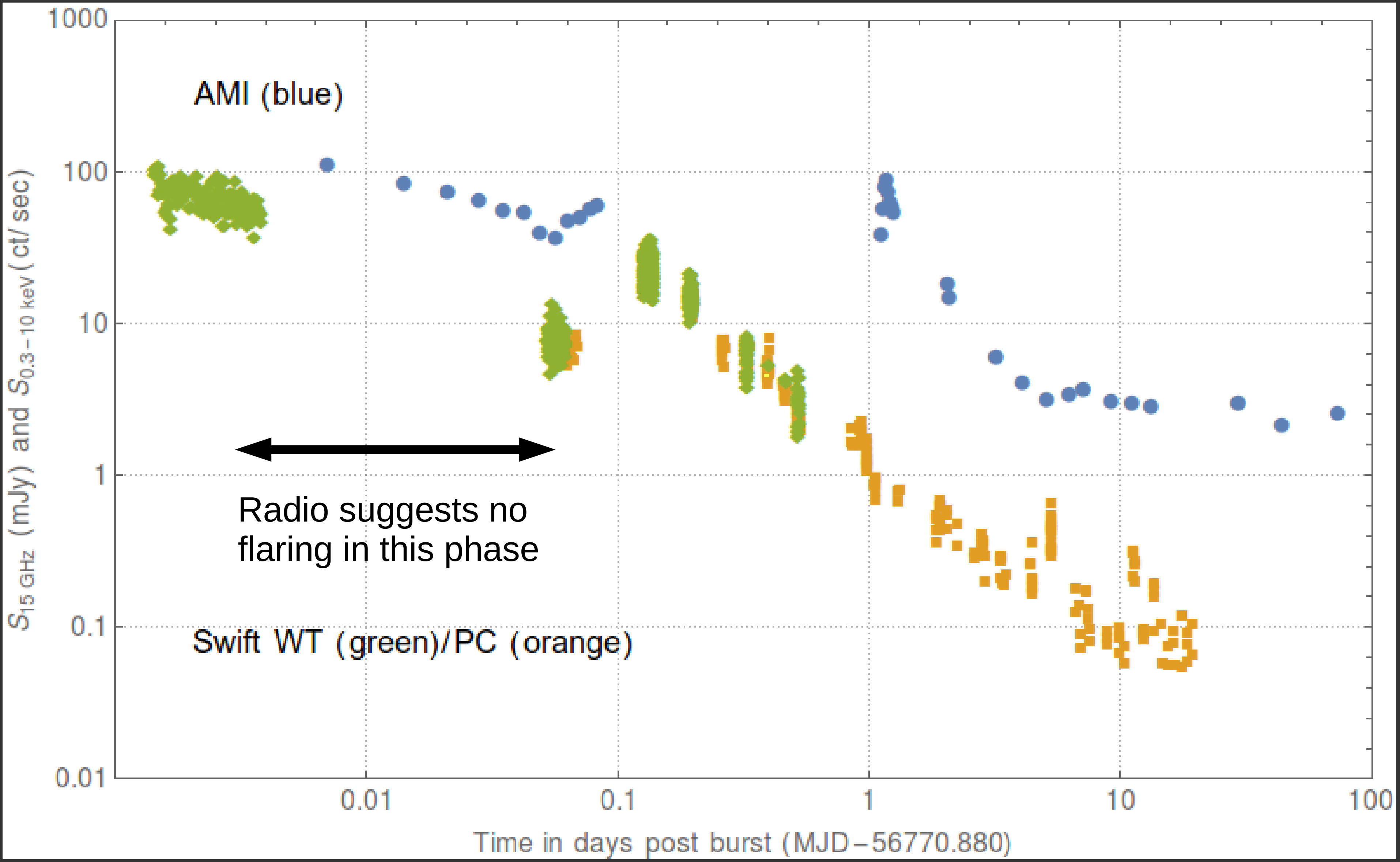
The AMI observations occupy a unique niche:

- Radio peak (~100 mJy) is by factor 20 most luminous radio flare ever seen from an M dwarf

- Despite this, radio:X-ray ratio actually rather low

- Very small lag (if any) between X-ray ↔ radio (Neupert effect) constrains particle acceleration

- AMI observations in first hour during gap in *Swift* coverage indicate no secondary flares during this period


AMI (blue)
Radio suggests no
flaring in this phase
Swift WT (green)/PC (orange)
$S_{15\,GHz}$ (mJy) and $S_{0.3-10\,keV}$ (ct/sec)
Time in days post burst (MJD−56770.880)
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100

Implications for what we want for SKA

Rapid response one of our top requests for Transients science with SKA

- No major objections from SPO but noted that *“rapid response is yet to be demonstrated”*

I would contend that if we can do it with a decades old telescope and a few weeks' work by two developers (admittedly highly competent ones) we can do it for SKA → real objections likely to be cultural/political (but caveat LOFAR discussion yesterday)

[so next, let's demonstrate real-time commensal...]

Conclusions

AMI-LA Rapid Response Mode (ALARMM) is now working on all *Swift* triggers (+ iPTF, soon GAIA, +pt5m)

In April 2014 we triggered on a gamma-ray superflare from DG CVn and measured a bright, prompt radio flare already at burst +6min. There **are** prompt radio transients.

This is a unique observation for flare star research, corresponds to the brightest radio flare ever observed from a M dwarf, probes early-time particle acceleration

It furthermore demonstrates the feasibility and scientific potential of rapid response modes for radio telescopes