S4 Transient Cadence

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September 29, 2020

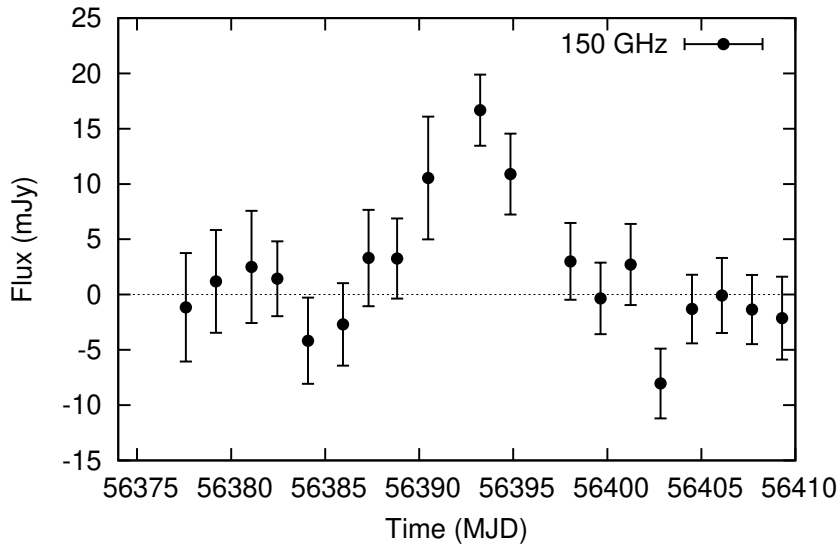
Things in the Millimeter Sky

- Tight connections to high-energy astrophysics: millimeter and gamma-ray skies tightly correlated
- Millimeter observations provide a different view of *same processes in the same objects* as high-energy probes
- Millimeter band a useful probe of otherwise hard-to-see sources – very common for follow-up, but limited fields of view from ALMA make surveys hard
- No wide-area surveys with time-domain capabilities extant or planned from 10 GHz to IR – we have a unique shot at this

Science Targets of CMB-S4

What kinds of things can we see?

1. GRB afterglows
2. AGN Flaring and Variability
3. Multimessenger Astronomy
4. Supernovae and TDEs?
5. Stellar flares
6. New and unexpected things



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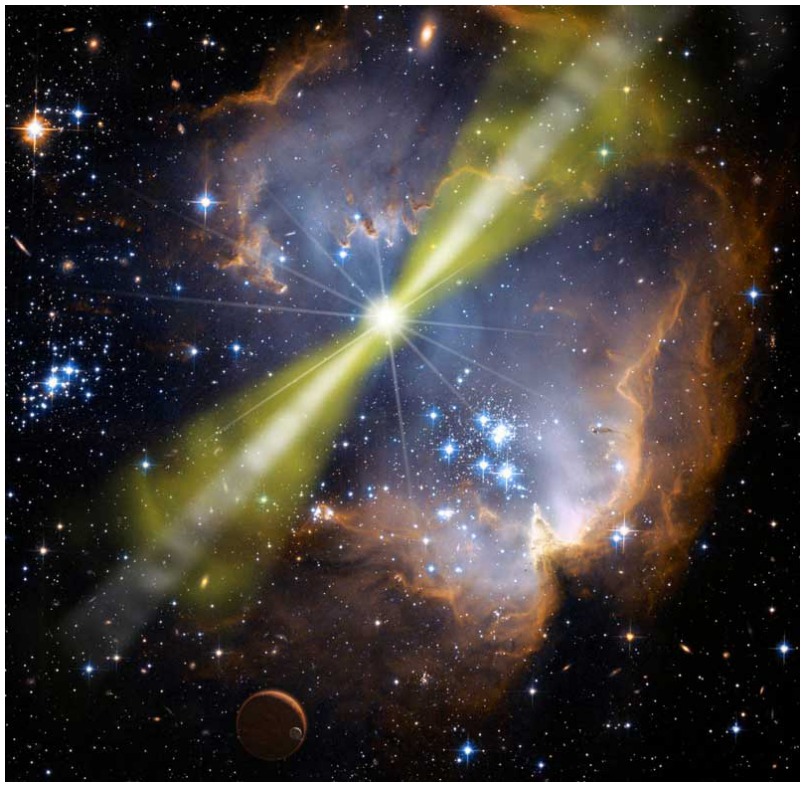
Timescales of Interest

- AGN flares: day – month scales
- Nearby GRBs ($z < 2$): $\sim 3 - -7$ days long, structure on ~ 1 day scales
- Distant GRBs ($z > 2$): Scaled by z, up to 6 months ($z \sim 30$)
- Supernovae: Lasts for weeks, key information in first day
- Stellar flares: hours up to $\sim$ a day (cm-band + ALMA, small statistics)
- New and unexpected things: ?



NASA/Swift

Likely Targets

- AGN flares: $\sim$ all AGN in the field are variable. First shot at statistical understanding of long-wavelength flares, cross-correlation with gamma rays. Key multimessenger/multiwavelength science
- Nearby GRB afterglows: Should see a few of these, would be major breakthrough if we do. Need structure on a $\sim$ 3-day lightcurve.
- Far-away GRB afterglows: Likely from Pop-3 stars, *major* science result if seen, but totally unclear if we see any. Very slow, no cadence implications.
- Stellar flares: Hours to days $\rightarrow$ faster is better
- New things: AT2018cow lasts for weeks
- Historical (SPTpol): likely detection of 5-day source

Re-observation Cadences

Sub-day:

- Gives structure in rising part of light curve
- Catches all event classes except very short-duration stellar flares

Every day:

- Minimum two detections for GRBs $\rightarrow$ confidence for follow-up
- Some stellar flares still, but one detection each $\rightarrow$ satellite backgrounds and glitches compromise results
- AGN science largely unaffected

Every other day:

- One detection per GRB, some start being missed $\rightarrow$ no lightcurve structure, satellite backgrounds become large
- Majority of stellar flares missed
- Rapid structure in AGN lightcurves missed, but most AGN science goes on

Other considerations: follow-up latency

- Transient science with S4 relies on follow-ups: our own sensitivity is too poor to understand objects in detail.
- Usually short-wavelength instruments (gamma-rays, X-rays, optical) trigger follow-up with long-wavelength instruments (optical, IR, radio)
- Sources (usually) dim faster at longer wavelengths, which makes going the other way harder
- Low latencies important: long cadence statistically impacts latency and few data points make it hard to know whether you are too late.
- Not totally clear what the right answer here is, but something to think about.

Summary

- Breaking open a fundamentally new view of the sky, especially with time-domain information
- Strong complementarity to other 2020s planned projects (LSST, LIGO, SKA, upgraded IceCube, etc.) using other wavelengths and messengers
- Faster is better, sensitivity degrades fast after every-day and some science (GRBs) entirely lost after every-other-day.
- Few glimpses of this unexplored territory – we know there are things there waiting!

For the science here, faster is always better. Sub-day would be great, day-scale is mostly fine, two-day cadence starts really eating into our science. Slower than that kills most of the things we want to do.