Transients and Time-Domain Source Science with CMB-S4

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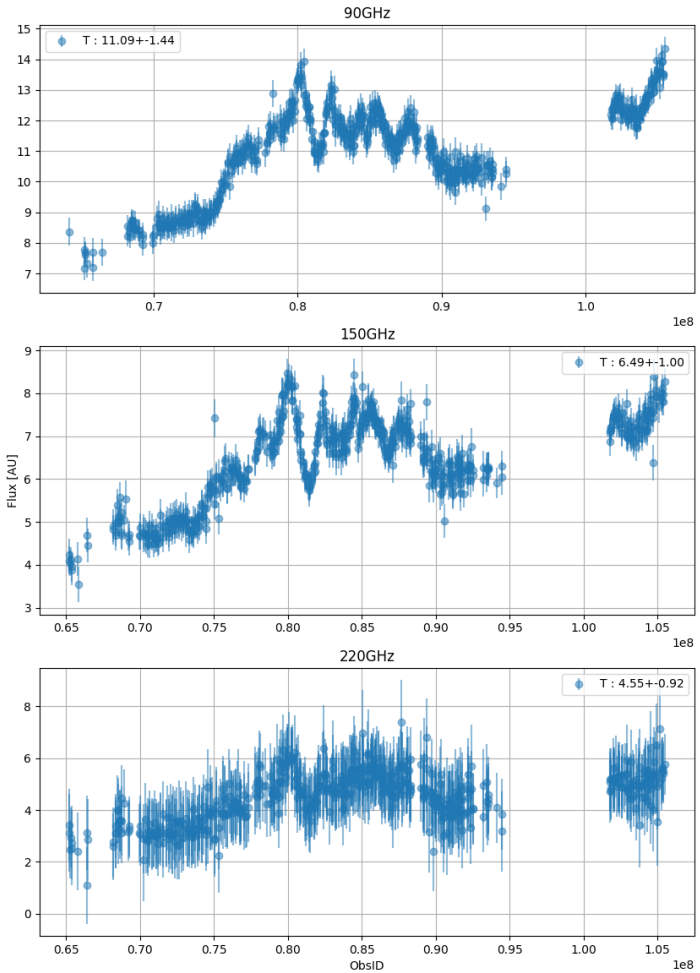
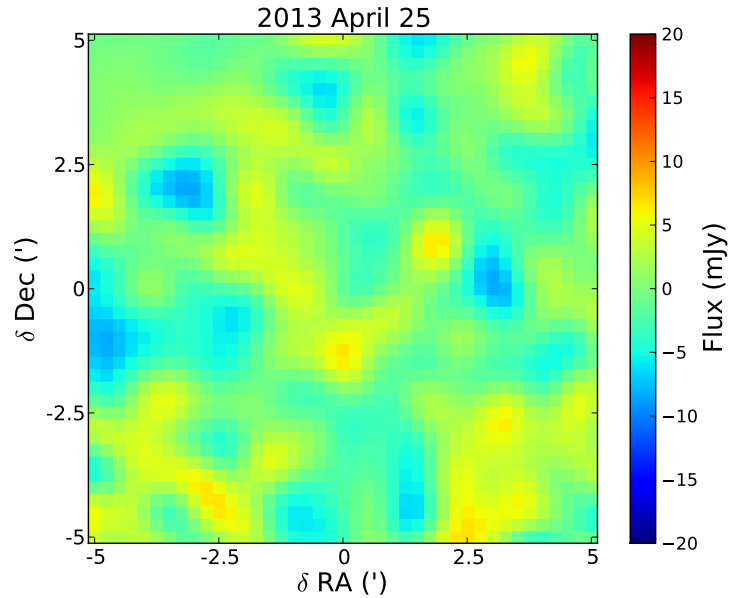
Time Variable Millimeter Sky

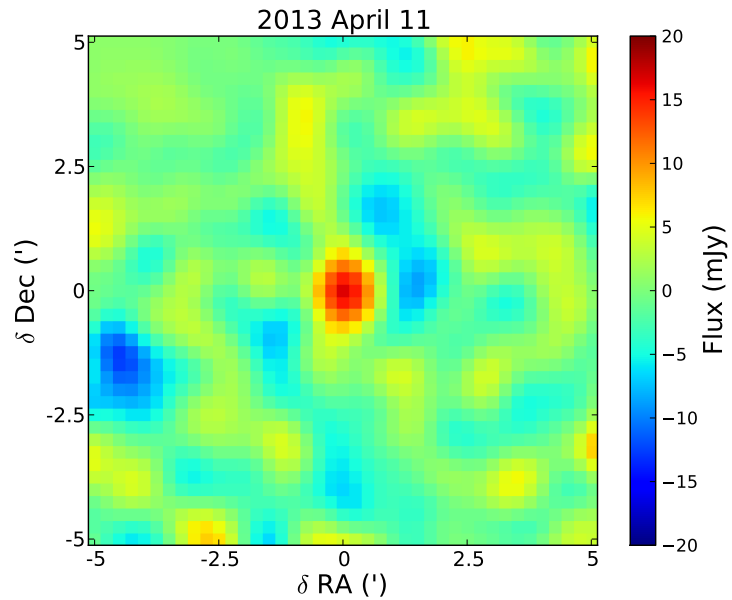
AGN



All data from SPT

????

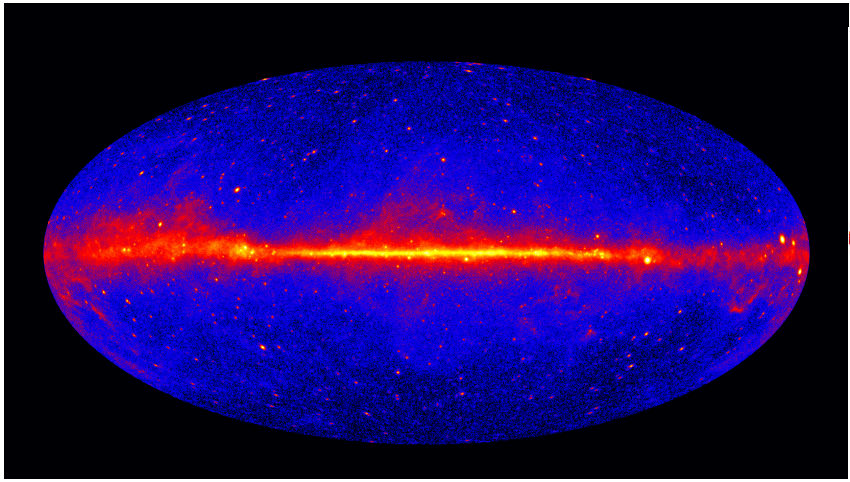


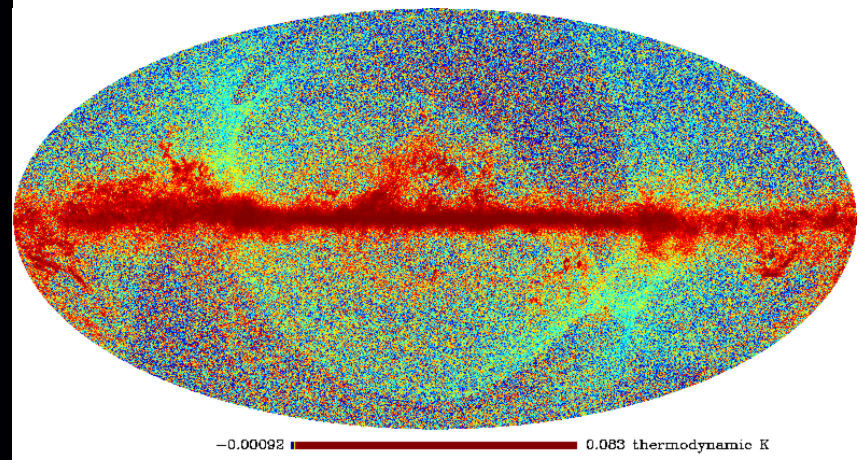


Things in the Millimeter Sky

- 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

Gamma Rays and Millimeter





Which one is Planck and which one Fermi-LAT?

Capabilities of CMB-S4

Small-area survey:

- Twice daily view of 4% of the sky
- Bands from 20–270 GHz
- Prelim. map noise in central 95–150 GHz of 4 mJy
- Linear polarization sqrt(2) higher

Large-area survey:

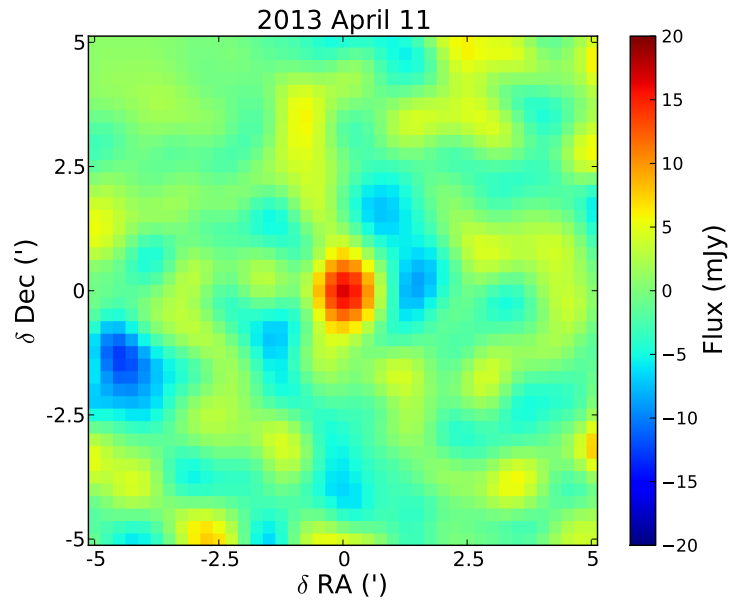
- Twice daily view of 50% of the sky
- Bands from 30–270 GHz
- Prelim. map noise in central 95–150 GHz of 7 mJy
- Linear polarization sqrt(2) higher

(LATs Only: rapidly time-variable sources are, by nature, small)

Science Targets of CMB-S4

What kinds of things can we see?

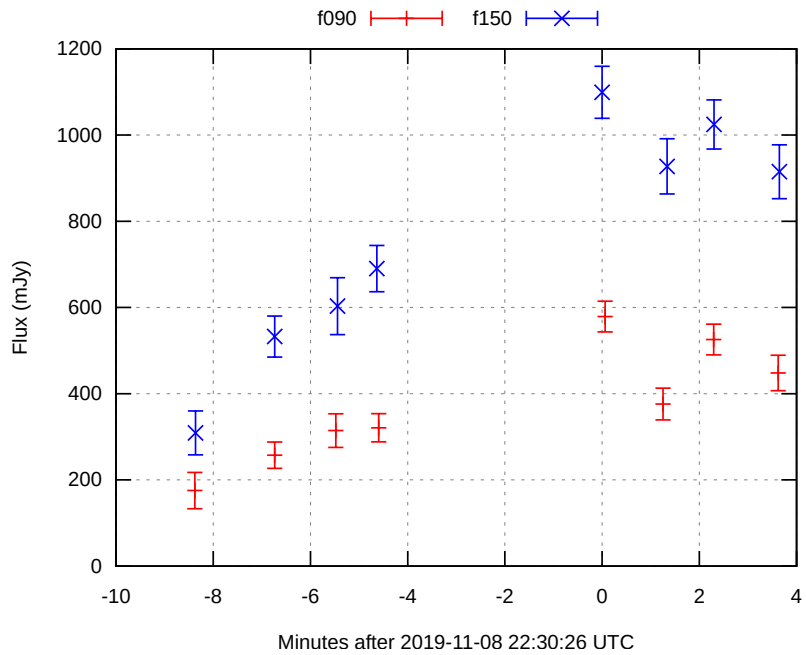
1. GRB afterglows
2. AGN Flaring and Variability
3. Multimessenger Astronomy
4. Supernovae and TDEs
5. Stellar Flares
6. New and unexpected things



1604.03507

Things We Know from ACT

- Three stellar flares
- Last minutes
- Peak fluxes of ~ 1 Jy
- Resolution of minutes from in-observation rescan

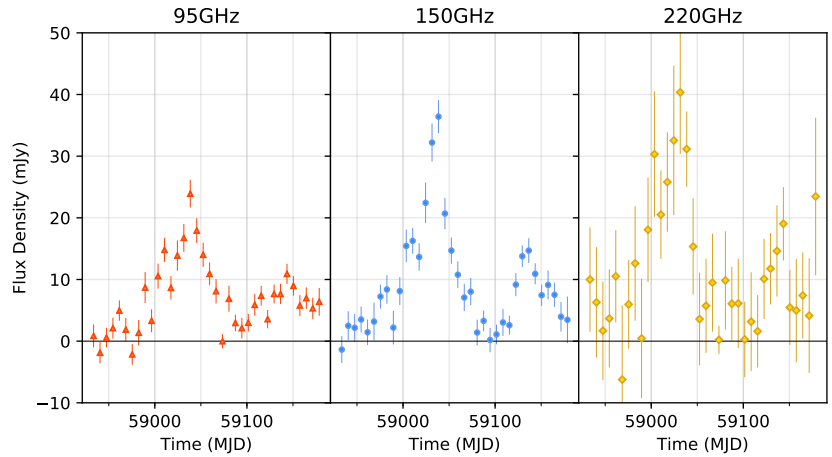


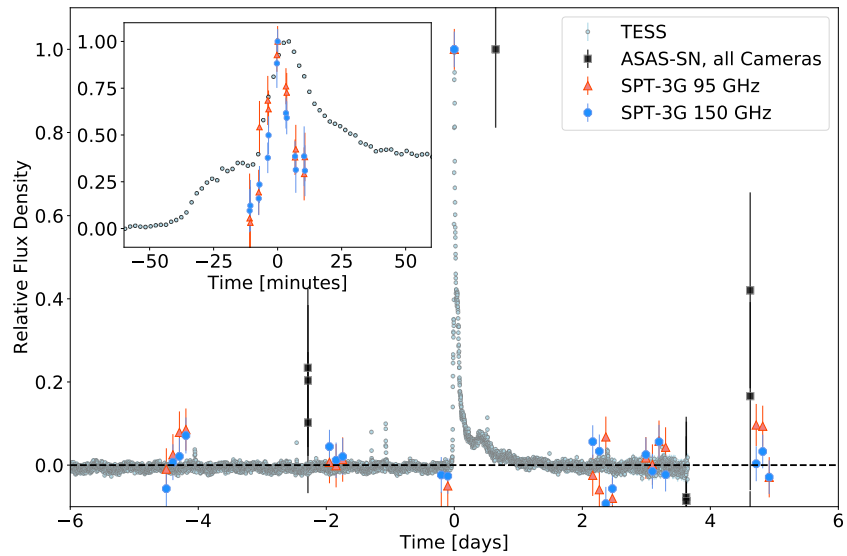
ArXiv:2012.14347

Parallel talk by K. Huffenberger

Things We Know from SPT

- Thirteen (minutes–hours) fast stellar flares
- Two slow (weeks) extragalactic events (extreme AGN flares? something else?)
- Real-time program operating



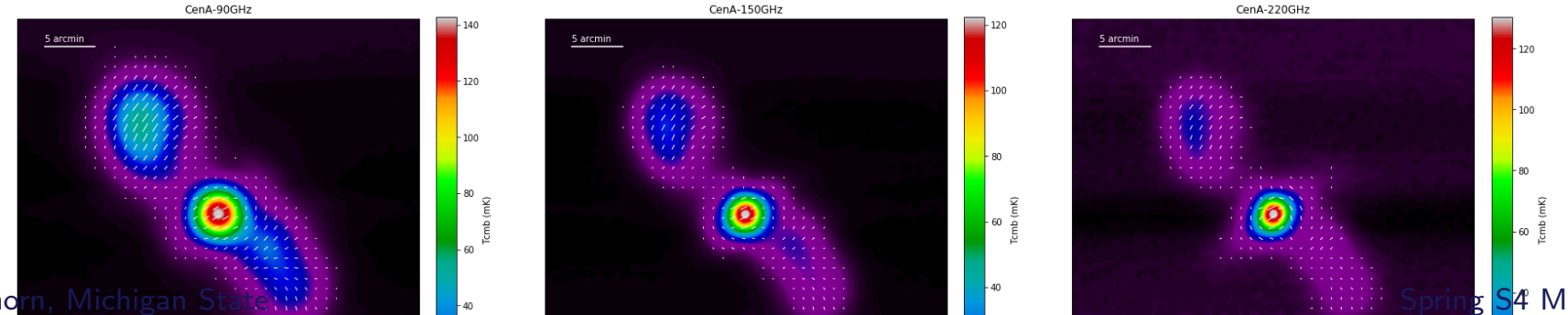


ArXiv:2103.06166

Parallel talk by S. Guns

Unprobed but Interesting: AGN

- Huge number ($\gg 1000$) of AGN in S4
- CMB instruments continuously monitor all sources in the field
- Large (2x) fluctuations in temperature and *polarization* on day- to month-long timescales
- Same physics as the high-energy emission
- Questions to answer:
  - Cross-correlation with Fermi-LAT: how flares evolve at late times? Emission usually moves to long wavelengths
  - Statistics of fluctuations at long wavelength **unknown**
  - Major obstacle to multi-messenger correlation analyses – no idea what sources do when we aren't looking at longer wavelengths
- Multiple orders of magnitude extension in number of AGN monitored at this granularity



Implications for S4

- Minimum alert rate for ACT/SPT-like sources is 500/year
- Most of these will be new (not triggered by other observatories)
- SPT and ACT analyses not yet fully optimized, factor of ~ 2 in sensitivity to S4
- Likely S4 detection rate is $\gtrsim 1000$ per year, mostly stellar flares but certainly with a large fraction of other things

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- Need to plan for:
  - Fast cadence
  - Fast response
  - Tiered interestingness of alerts: no one will follow up an alert every 8 hours

Baseline Design

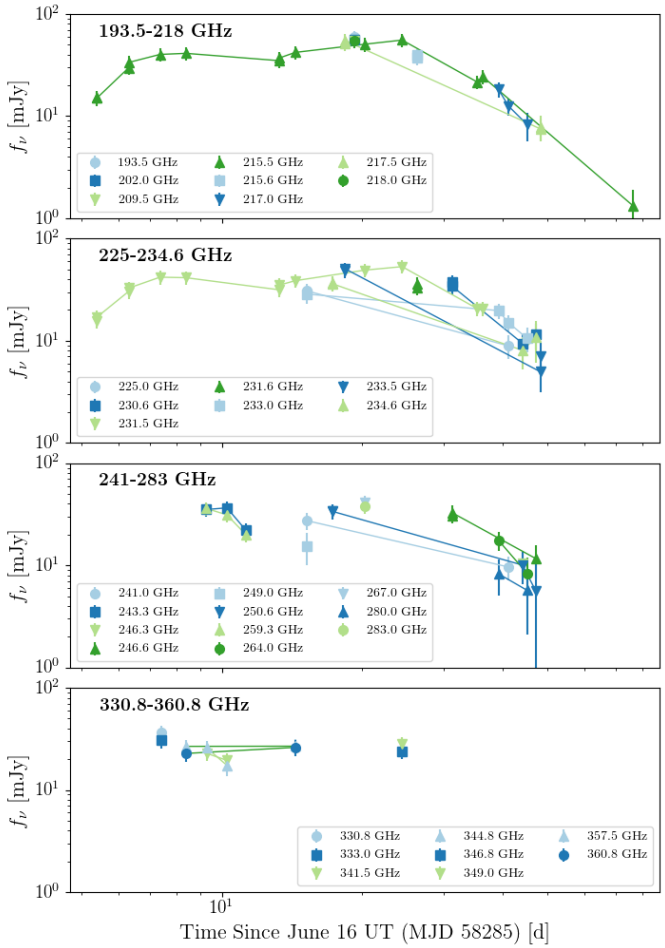
- Alert pipeline, based on S3 design (baselining SPT, which has real-time alerts already
  - Straightforward application of existing, tested strategy
- Alerts based on line-generated maps, then distributed to the community
  - Maps made at pole for SPLAT, US for Chile
  - Working on distribution strategy and contents of alerts
  - Do we include AGN flares? Which ones?
- Open question: we now know there are *lots* of sub-day sources we could see. Do we need to revisit planning for short-scale sources?

Parallel Session

Times central.

- 14:30: **Kevin Huffenberger** on ACT Results
- 14:50: **Sam Guns** on SPT Results
- 16:10: **Tarraneh Eftekhari** on Theory

Tantalizing Hints of New Discoveries



AT2018cow 1810.10880 (Ho+ 2018)

- Extraordinarily bright/weird/crazy supernova-esque object (potentially CCSN)
- Found by chance in optical survey
- Are there more like it? No good way to tell.
- CMB-S4 would see this at $10 - 20\sigma$ every day for three weeks anywhere in the survey region

Huge discovery potential in time-domain—and it comes almost for free

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
- Similar optimization to N_{eff}—science comes at little cost
- At least daily revisits of the field and large primary mirrors are key—faster is better
- Few glimpses of this unexplored territory—we know there are things there waiting!