SPT AGN Monitoring System:

Simultaneous Millimeter-wave, Gamma-ray, and Optical Monitoring of the Blazar PKS 2326-502 During a Flaring State

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with the South Pole Telescope, ACT & CMB-S4 collaborations

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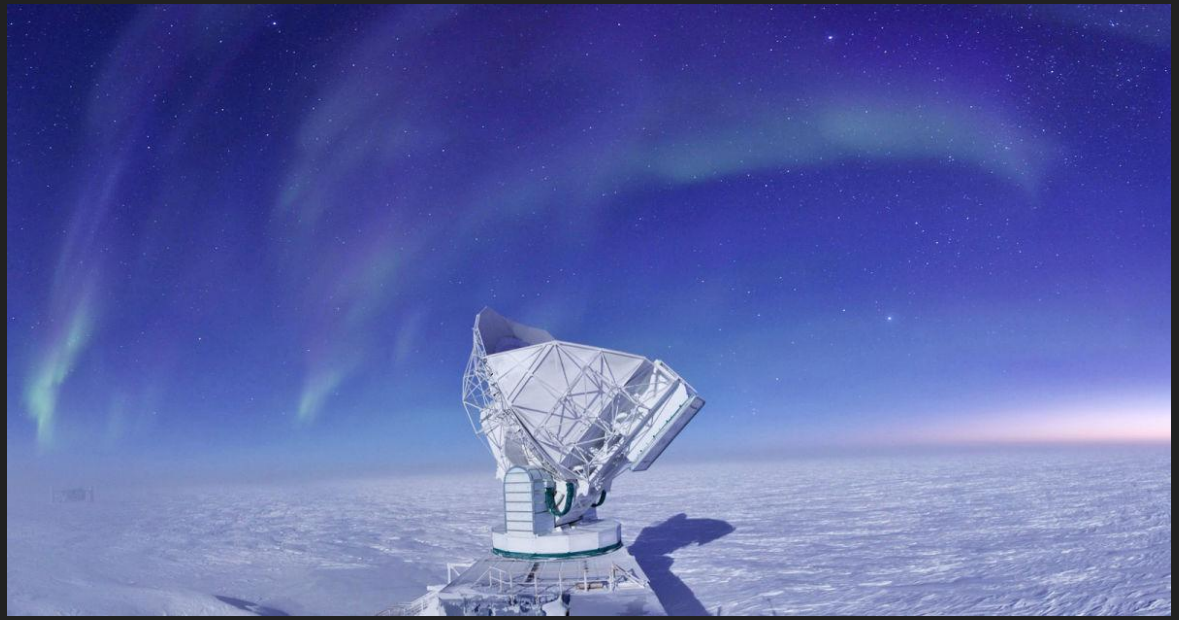
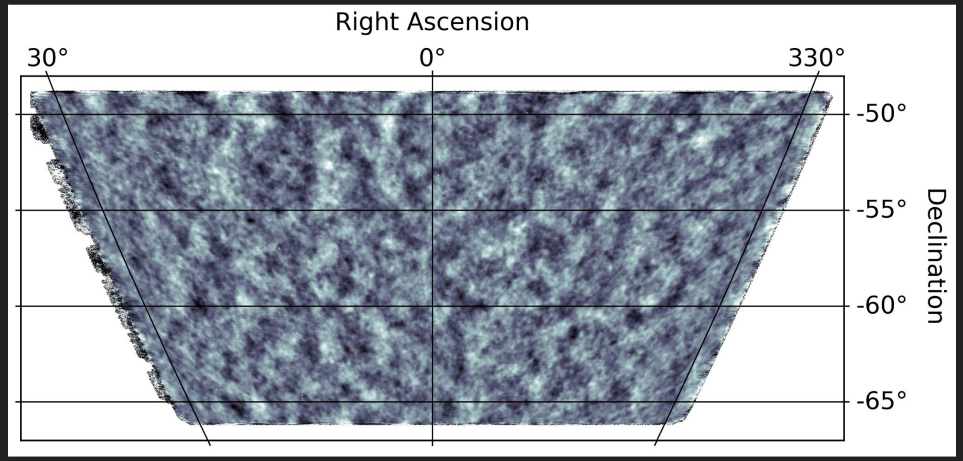
South Pole Telescope (SPT)

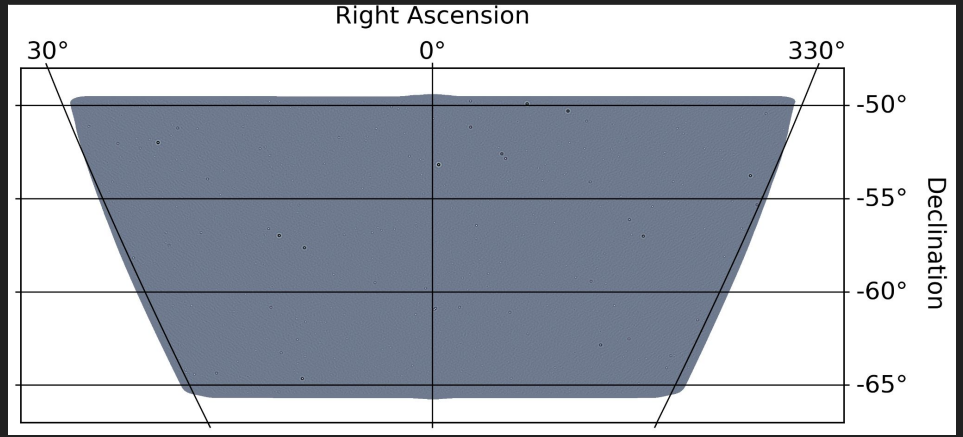
- Built in 2007 to observe the CMB.
- Three different cameras
  - SPT-sz (2007-2011)
  - SPTpol (2012-2016)
  - SPT-3G (2017 - present)
- We use data from the second generation camera SPTpol.

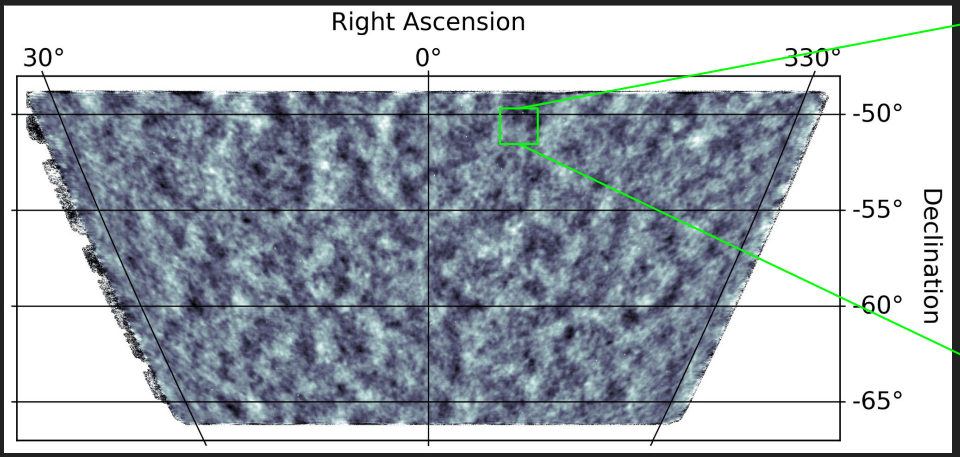


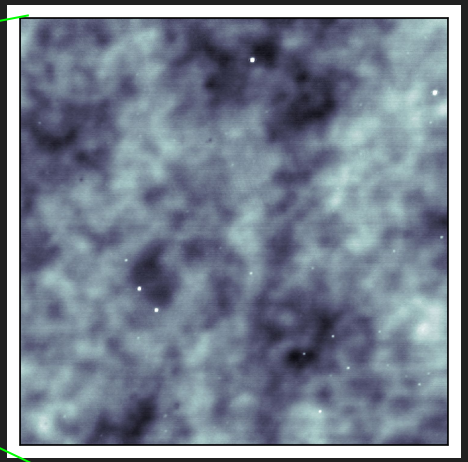
SPTpol 500 deg^2 survey

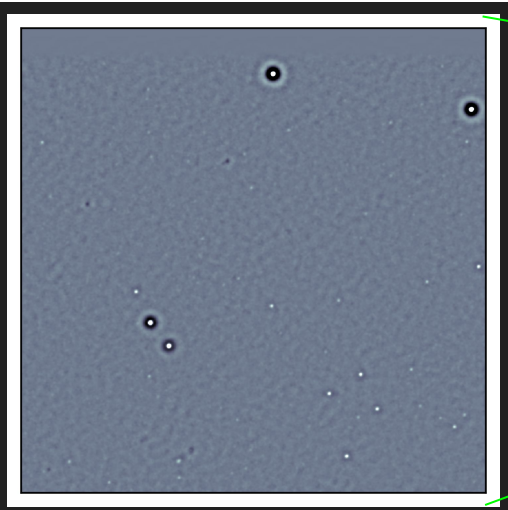
- SPTpol: second generation camera used to observe the CMB intensity and polarization
- ~3500 observations over ~9000 hours at high Galactic latitude, covering 22^h to 2^h in right ascension and -65° to -50° in declination.
- Two frequencies observed:
  - 90 GHz
  - 150 GHz
- Repurposing CMB maps for this study

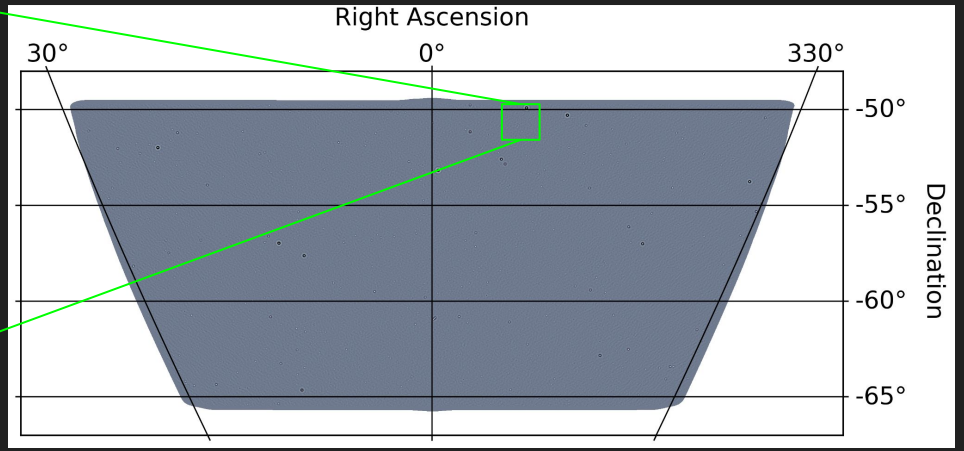





Right Ascension
30°
0°
330°
-50°
-55°
-60°
-65°
Declination

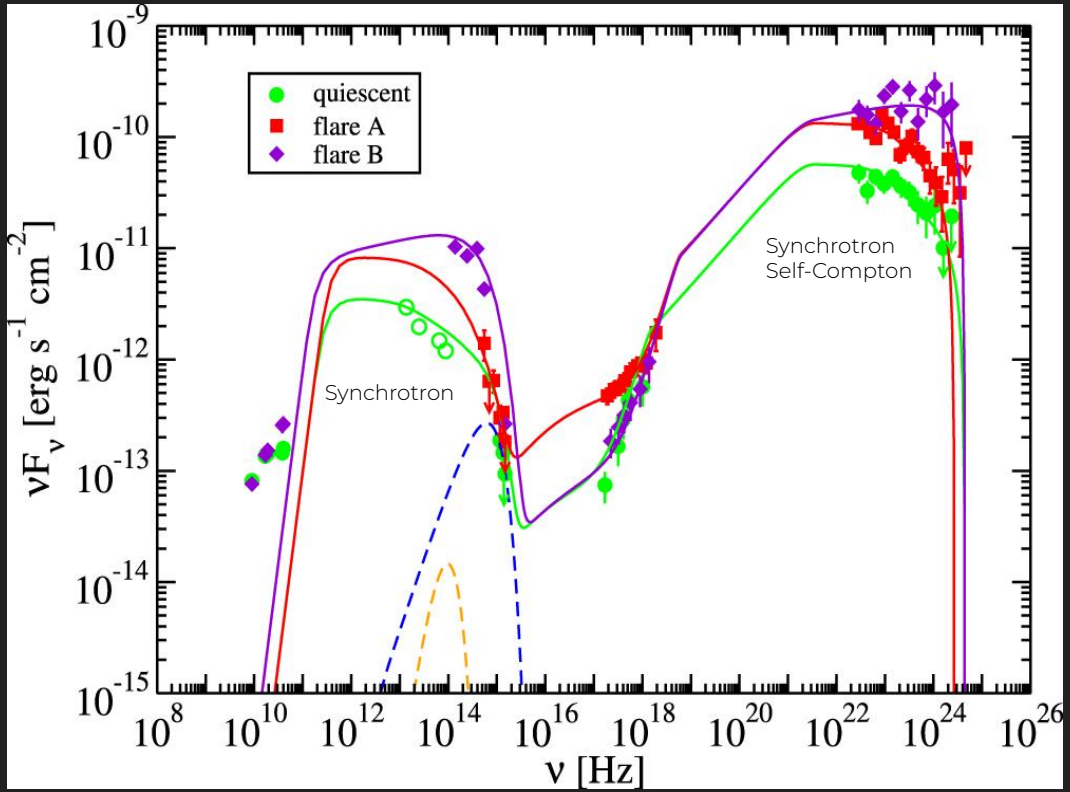




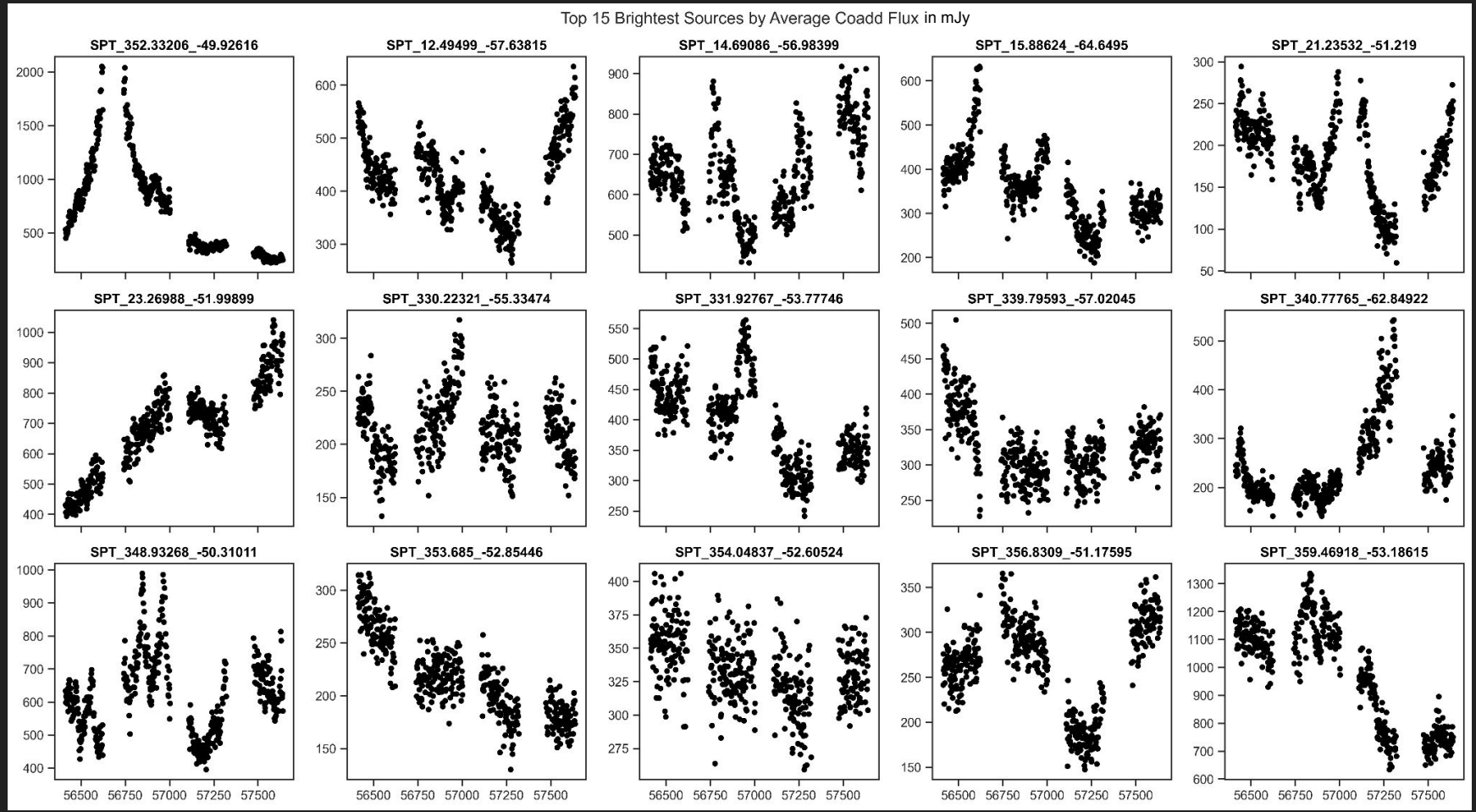

Right Ascension
30°
0°
330°
-50°
-55°
-60°
-65°
Declination

Why study AGN in Millimeter?

- Do the physical mechanisms that cause gamma ray and optical emissions also produce the mm-wave emissions?
- Are there any correlations of millimeter, optical and γ-ray emissions?



Dutka et al. 2017


Top 15 Brightest Sources by Average Coadd Flux in mJy
SPT_352.33206_-49.92616
SPT_12.49499_-57.63815
SPT_14.69086_-56.98399
SPT_15.88624_-64.6495
SPT_21.23532_-51.219
SPT_23.26988_-51.99899
SPT_330.22321_-55.33474
SPT_331.92767_-53.77746
SPT_339.79593_-57.02045
SPT_340.77765_-62.84922
SPT_348.93268_-50.31011
SPT_353.685_-52.85446
SPT_354.04837_-52.60524
SPT_356.8309_-51.17595
SPT_359.46918_-53.18615
56500 56750 57000 57250 57500

Observations Used

Photo Credit: Jeff McMahon

South Pole Telescope

Mm-wave (150 GHz)

SPTpol

Photo Credit: NOIRLab/NSF/AURA

SMARTS

Optical (R-band)

1.3m ANDI-Cam

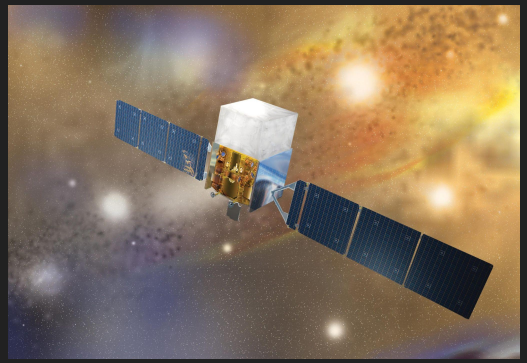


Photo Credit: NASA

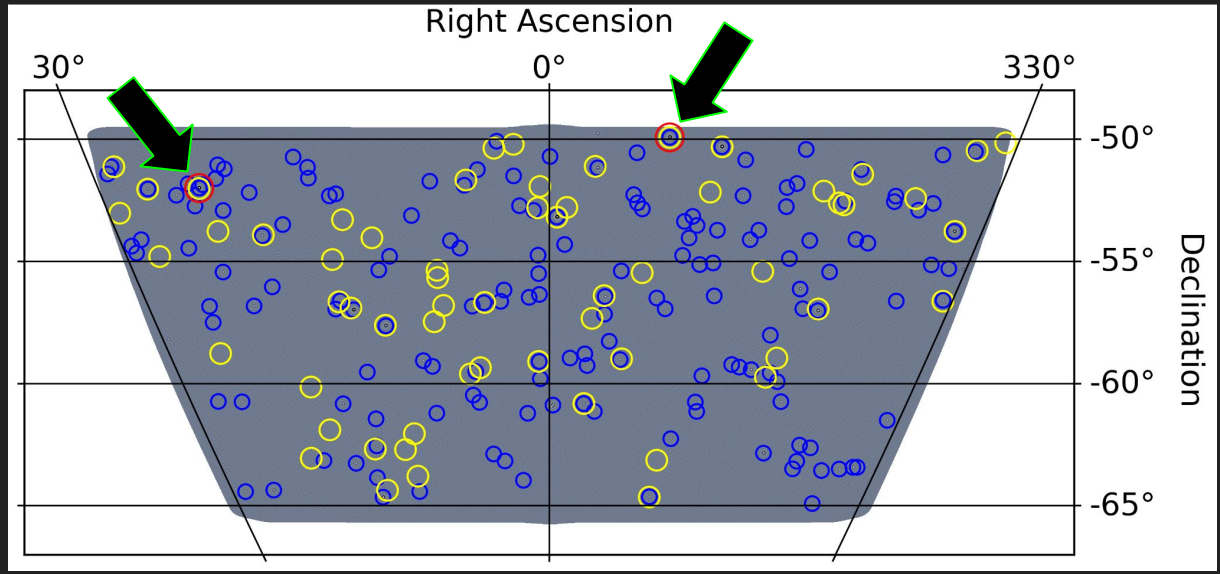
Fermi

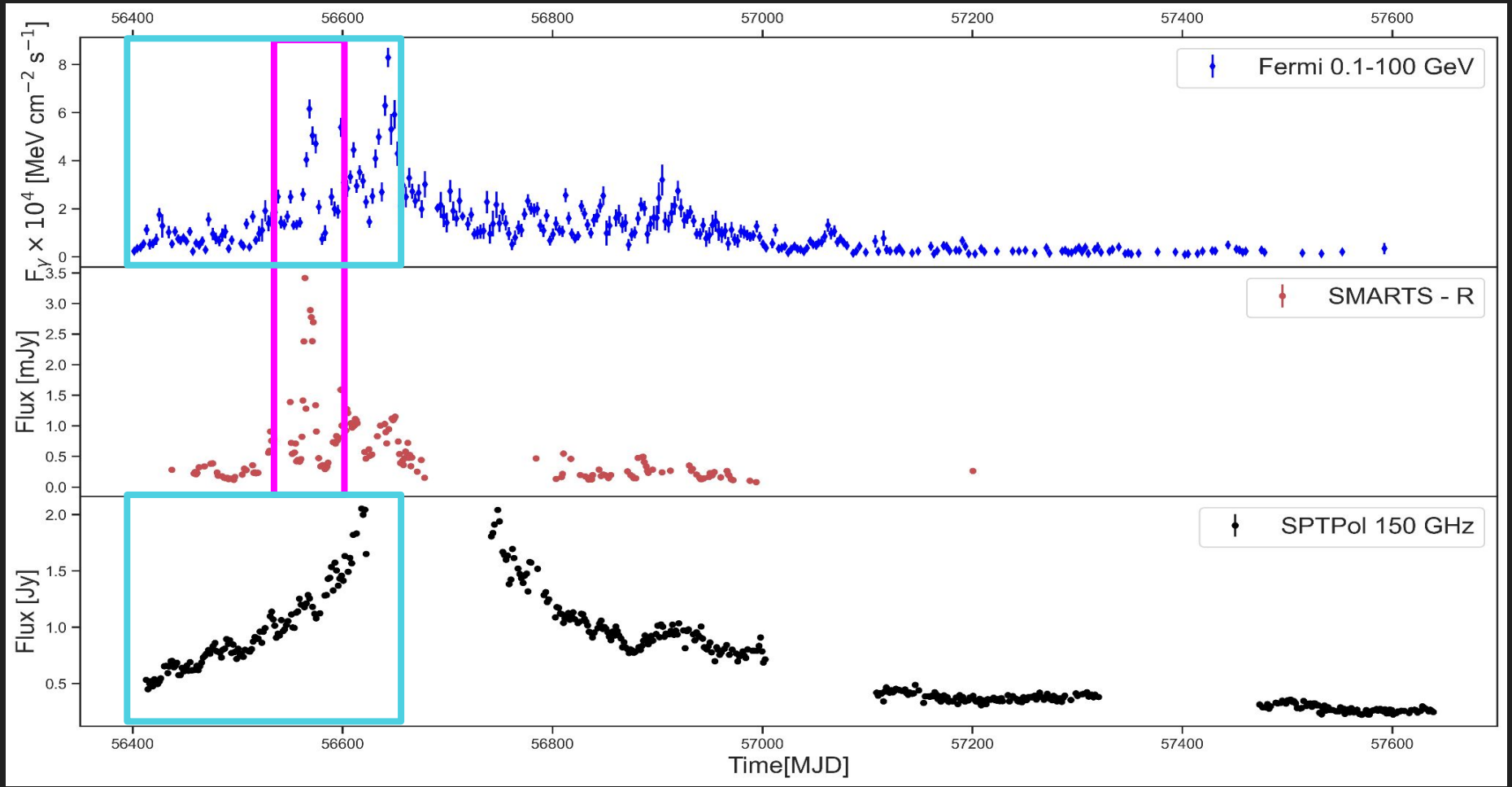
γ-Ray (0.1-300 GeV)

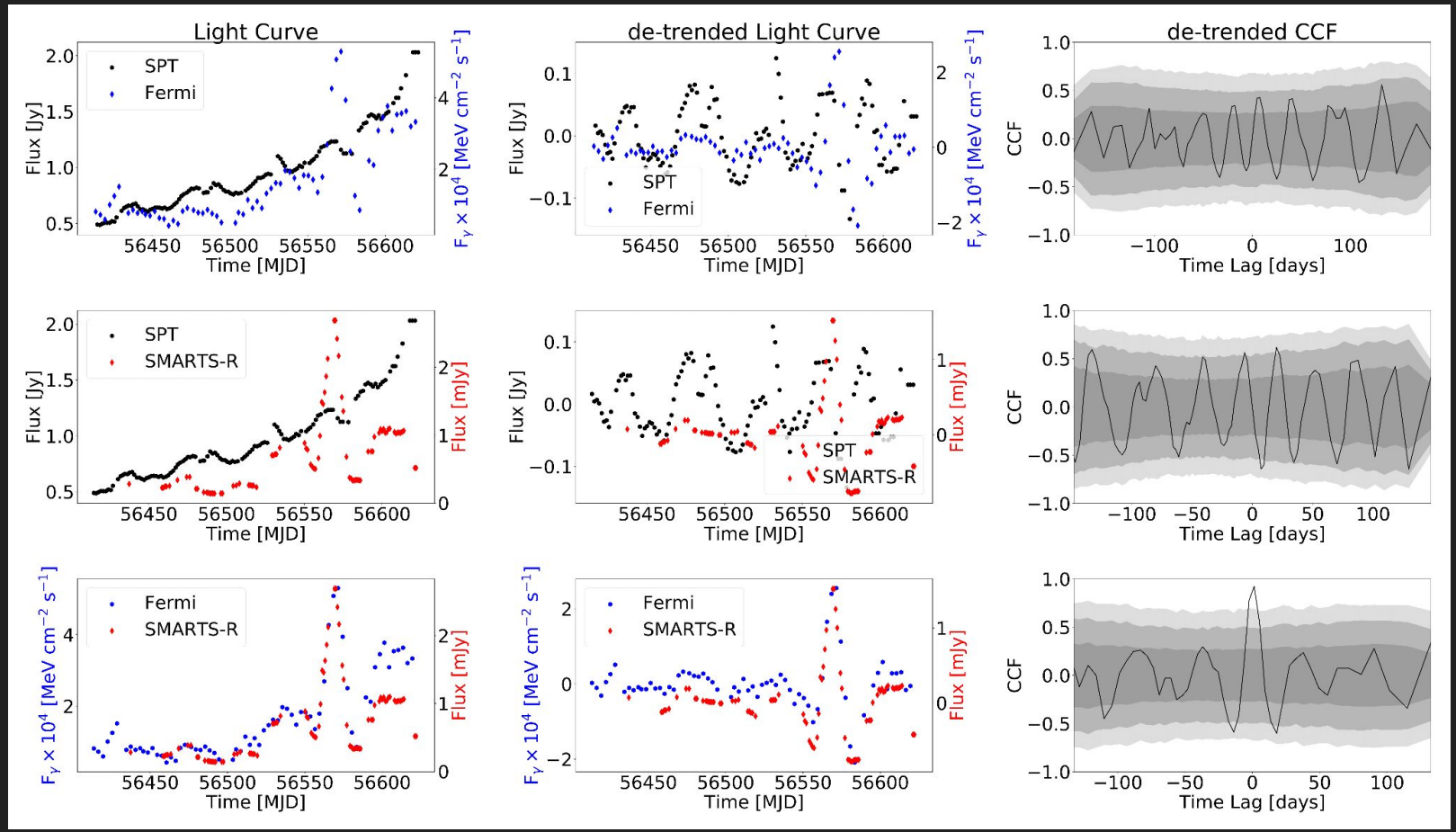
LAT

Finding Sources

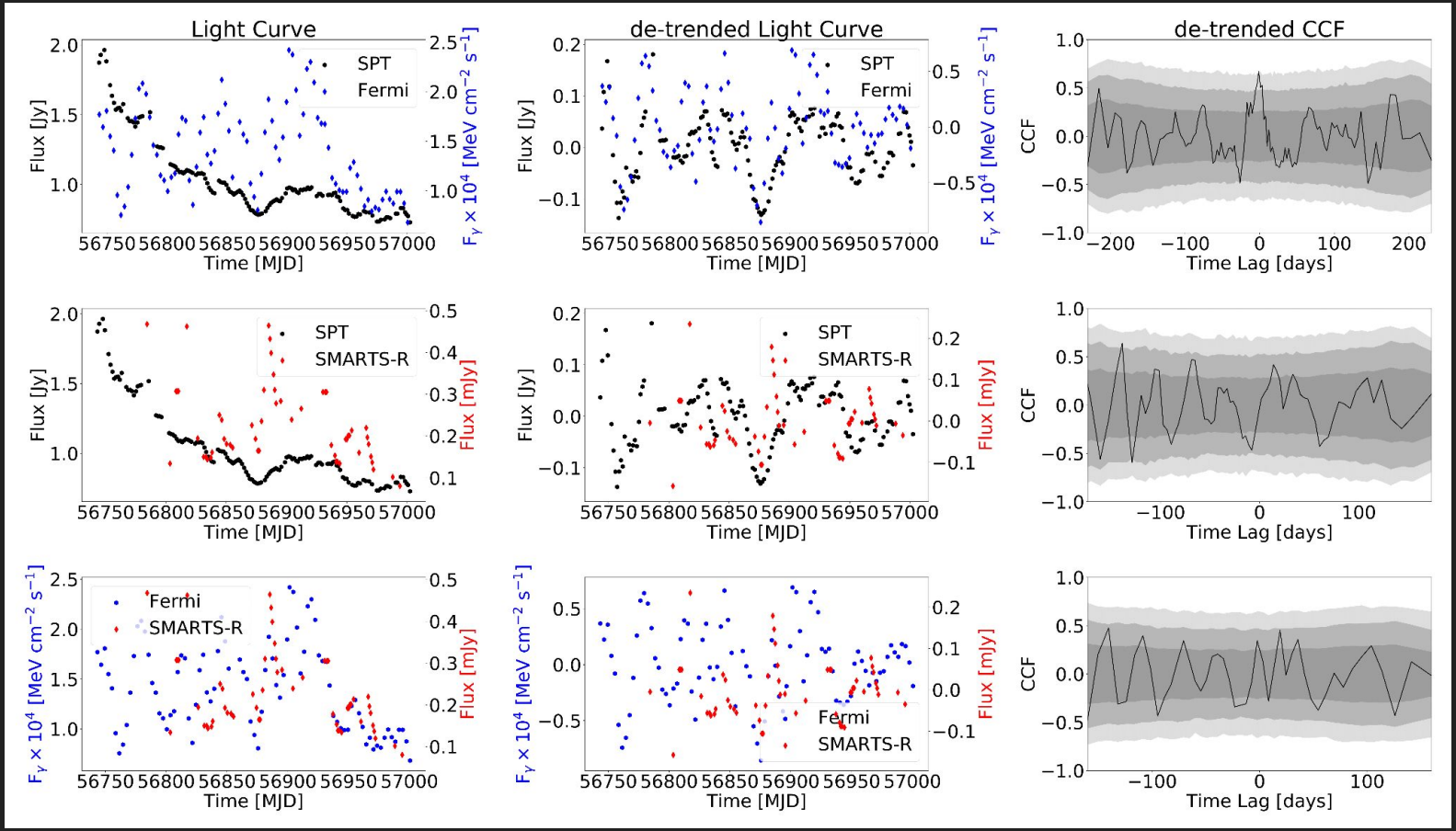
Circles mark known AGN in the field across 3 different surveys:
Yellow - FERMI 4FGL
Red - SMARTS
Blue - SPT x AT20G
(AT20G: Australia Telescope 20 GHz catalog)
The selected source for this pilot study: PKS 2326-502




Fermi 0.1-100 GeV
SMARTS - R
SPTPol 150 GHz
$F_\gamma \times 10^4$ [MeV cm^{-2} s^{-1}]
Flux [mJy]
Flux [Jy]
Time[MJD]
56400
56600
56800
57000
57200
57400
57600



Hood et al 2023



Hood et al 2023

Quantitative Results

- P(CCF,τ=0) is the zero lag p-value. ★
- Published in ApJ Letters, March of this year: https://iopscience.iop.org/article/10.3847/2041-8213/acbf45

Statistics		
Dataset	zero-lag correlation	zero-lag p-value
SPT x Fermi year one (de-trended)	0.0745	0.3519
SPT x Fermi year one (smoothed)	-0.0488	0.5688
Smarts x Fermi year one (de-trended)	0.7249	$< 10^{-4}$
Smarts x Fermi year one (smoothed)	0.9223	$< 10^{-4}$
SPT x Smarts year one (de-trended)	0.0106	0.4880
SPT x Smarts year one (smoothed)	-0.0479	0.5657
SPT x Fermi year two (de-trended)	0.4625	0.0054
SPT x Fermi year two (smoothed)	0.6698	0.0009
Smarts x Fermi year two (de-trended)	0.2432	0.1011
Smarts x Fermi year two (smoothed)	0.3444	0.0874
SPT x Smarts year two (de-trended)	0.0378	0.4353
SPT x Smarts year two (smoothed)	0.0605	0.4135

★

$$P(CCF, \tau = 0) = \frac{N_{sims}(CCF, \tau = 0 > CCF_{data,\tau=0})}{N_{sims}}$$

Aidan Simpson

Current Findings/ Conclusions

- Long time scale correlations with Fermi and SPT.
- Short time scale correlations with Fermi and SMARTS.
- Short time scale correlations with Fermi and SPT.
- No measurable correlation with SPT and SMARTS.

This lends support to the Synchrotron Self Compton model of gamma-ray synchrotron photons in blazars.

But it also implies that the synchrotron photons responsible for mm-wave emissions in this source are produced separately from photons responsible for optical emissions.

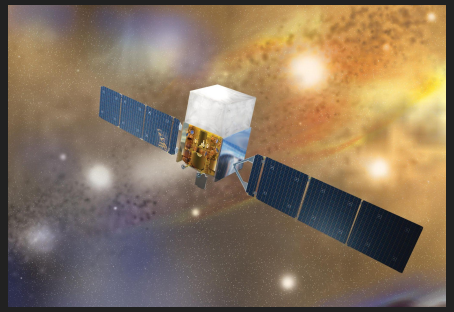


Photo Credit: NASA

Photo Credit: Jeff McMahon

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Photo Credit: NOIRLab/NSF/AURA

Next Steps

- Begin building light curves for other AGN in the field
- Include polarization data for both 90 and 150 GHz bands in analysis
- Build public facing website where others can download usable data for each source
- Deploy similar point source analysis pipelines with ACT, SO, and CMB-S4.
- Expand optical observations to other observatories.

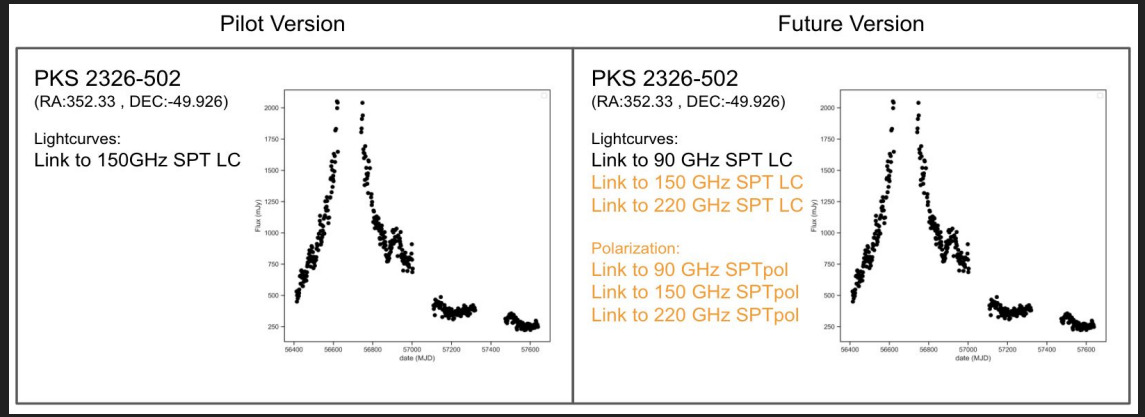

Photo credit: Debra Kellner

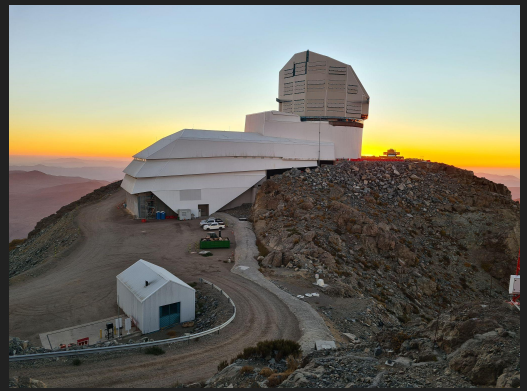

Photo credit:Rubin Obs/NSF/AURA

Thank You!