Millimeter to γ-Ray Variability of AGN found in the SPTpol 500 degree^2 field

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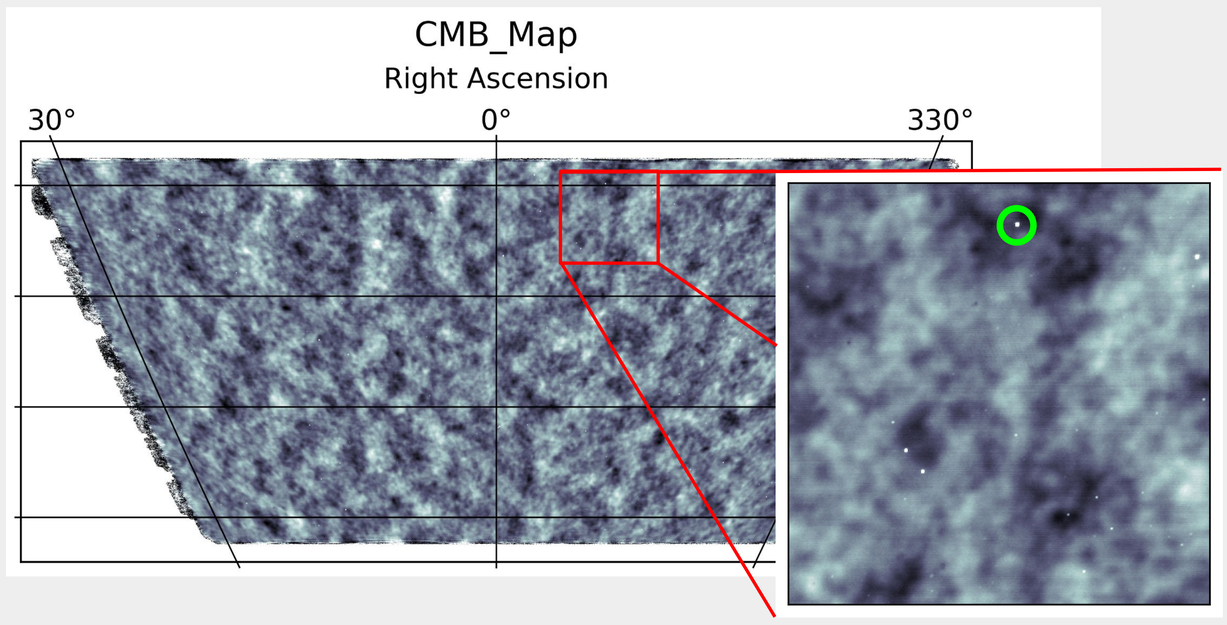
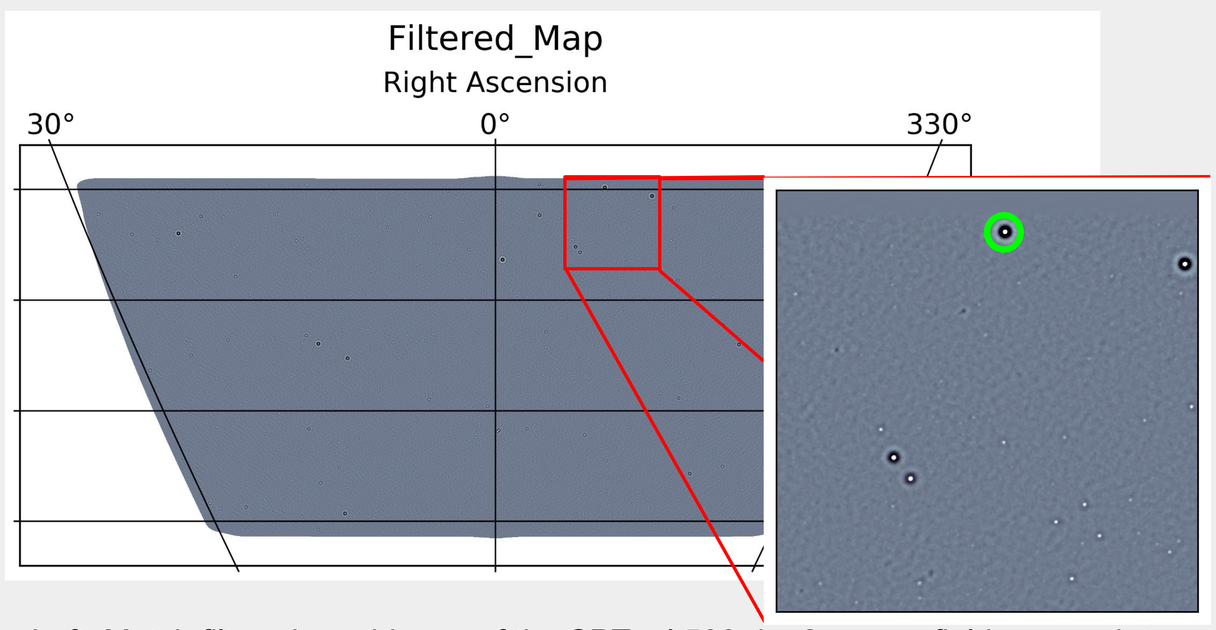
Abstract: Cosmic Microwave Background (CMB) telescopes are now providing an option for daily monitoring of these objects within limited fields of view. While continuous, high-cadence monitoring of active galactic nuclei (AGN) is now common at gamma-ray, optical, and radio frequencies, AGN monitoring in the millimeter (mm) band has mostly been restricted to short campaigns on targeted sources. Here we use the South Pole Telescope (SPT), which was designed to observe the CMB at arcminute and larger angular scales, to monitor AGN. Between 2013 and 2016, the SPTpol instrument (the second-generation mm-wave camera mounted on the SPT) was used to continuously scan a 500 deg^2 field, covering the entire field several times per day with detectors sensitive to polarization and radiation in bands centered at 95 and 150 GHz. This data set enables the monitoring of tens of mm-bright AGN on timescales from years to days at high signal to noise (S/N > 10 in a 36-hour coadd). We use SPTpol 150 GHz observations to monitor the variability of the sources in the mm-waveband and directly compare that to other frequencies. In a pilot study, we focus on the source PKS 2326-502, which has extensive, day-timescale monitoring data in gamma-ray, optical, and now mm-wave data between 2013 and 2016. We present a search for evidence of correlated variability between SPTpol (150 GHz), SMARTS (O/IR) and Fermi (gamma-rays) observations. This pilot study is paving the way for AGN monitoring with current and upcoming CMB experiments like SPT-3G, SO and CMB-S4, including multi-wavelength variability studies with upcoming facilities such as VRO-LSST.

Match Filtering to Extract Source Flux

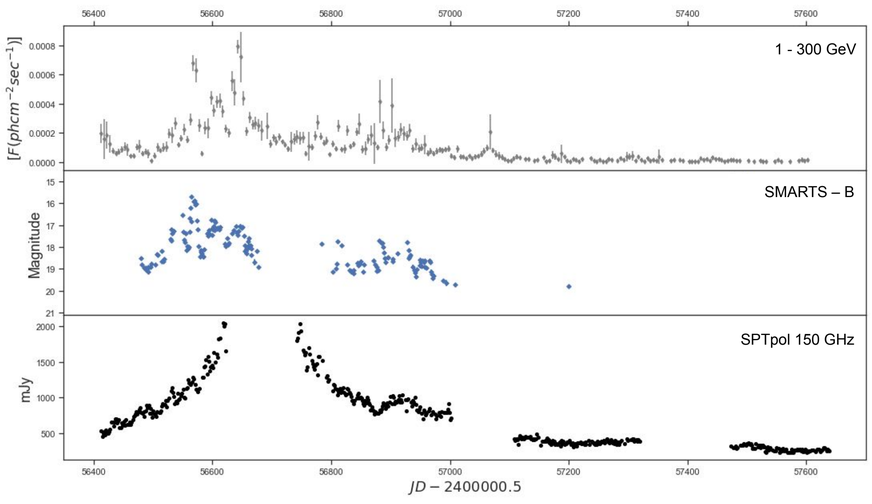


Left: Minimally filtered coadd map of the SPTpol 500 deg2 survey field, used to study the anisotropies of the CMB. Right: 5x5 degree zoom in, point sources here show as white dots in the foreground are typically masked out to prevent contamination. The green circle here highlights the target source PKS 2326-502



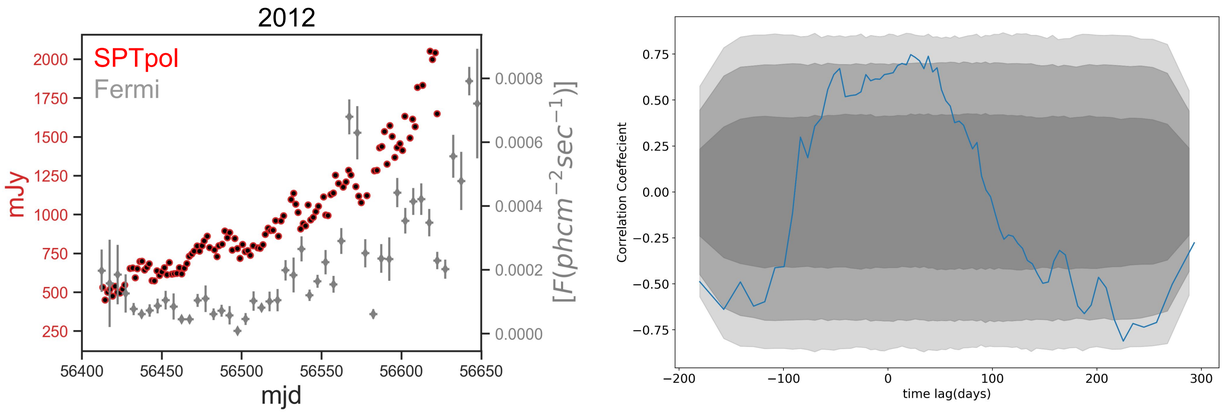
Left: Match filtered coadd map of the SPTpol 500 deg2 survey field, now point source matched filtered to allow the extraction of source fluxes without CMB contamination. Right: 5x5 degree zoom in, point sources here show as white dots with rings around them. The green circle here highlights the target source PKS 2326-502.

PKS 2326-502 Light Curves



Light curves for FSRQ PKS 2326-502 / J2329-49. top: Fermi-LAT; middle: SMARTS Optical B; bottom: SPTpol 150GHz. Shown here we can see long time scale correlation between millimeter and γ-Ray observations and short scale correlations between the Optical and γ-Ray observations.

MM→γ-ray Light Curve Correlations

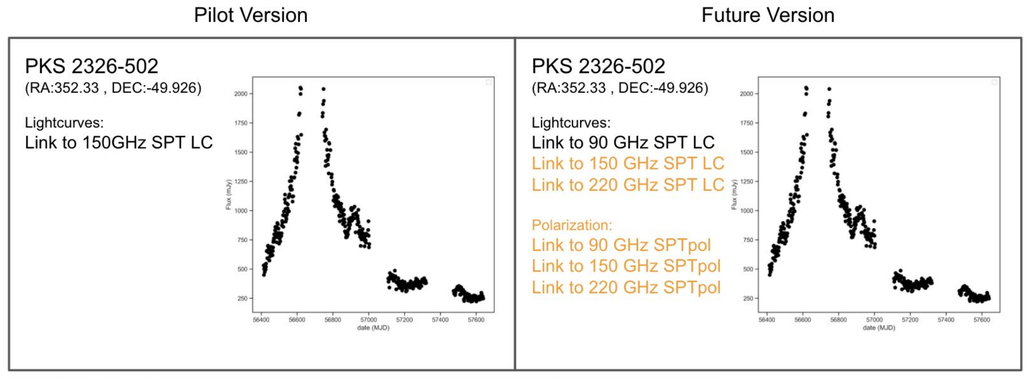


Preliminary results showing correlations that cover the first year of observations (2012) for the Fermi and SPTpol instruments. Right: Millimeter and γ-ray light curves. Left: (2012) indicates year one has a 2.1 sigma significance that there is a 0.6 correlation. The shaded regions represent the 68\%,95\%,and99\% errors (from dark to light) derived from simulated light-curves with similar power spectra as the collected data.

Future Work

I will develop a systematic way to conduct similar analysis using the current generation SPT camera, SPT-3G. With the larger 1500 deg^2 field of view of the SPT-3G, we will increase the number of AGN within the current survey field by a significant amount. Therefore providing a strong foundation for a starting point for running a similar study with data from the CMB-S4 and SO experiments which are expected to cover ~70 percent of the sky. This wide sky coverage will not only be extremely valuable for the study of AGN variability but also for newer studies involving multi-wavelength variability studies with upcoming facilities such as VRO-LSST.

In addition I will be working to create an outward facing public server that will house daily updated millimeter wave light curves for our monitored source list of AGN. This server will be open for anyone to view and will have options to download the necessary data of a researcher's choosing. While originally it will only have the 150 GHz SPTpol data, it will later be updated to also include the 90, 150 GHz SPTpol and 90, 150 and 220 GHz flux and polarization data from SPT-3G.



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