Coeval Observations of a Complete Sample of Blazars with Effelsberg, IRAM 30m, and Planck

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Project Objective

Highly time resolved multifrequency observations of blazars are the key to our understanding of the extreme physics of supermassive black holes and their jets. In this project, we use the synergies of the long term blazar radio-millimetre monitoring program F-GAMMA (Fuhrmann et al. 2007, 2014), the continued scanning of the millimetre-submillimetre sky by the *Planck* satellite (Tauber et al. 2010, Planck Collaboration I 2011), together with several dedicated observing programs at the Effelsberg 100m telescope, to obtain a data sample unprecedented in both time resolution and frequency span.

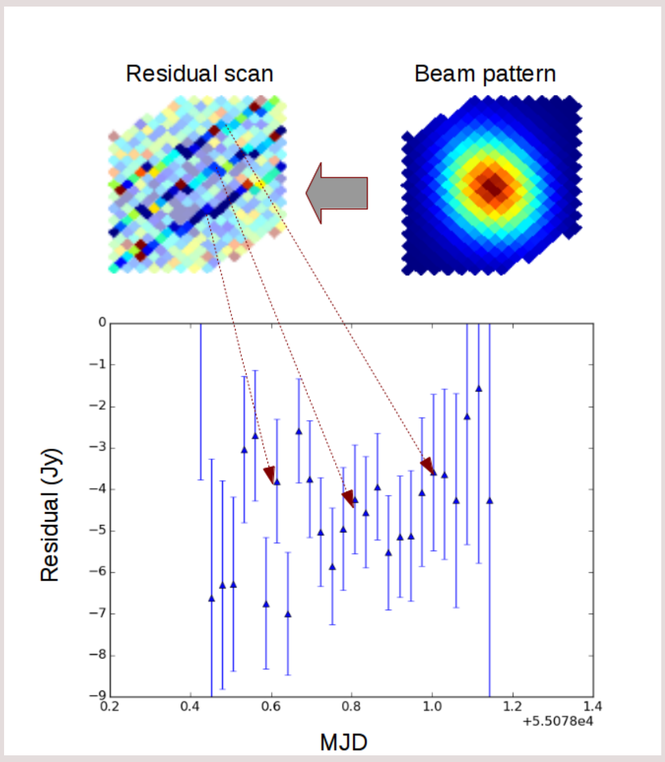
Sample Selection

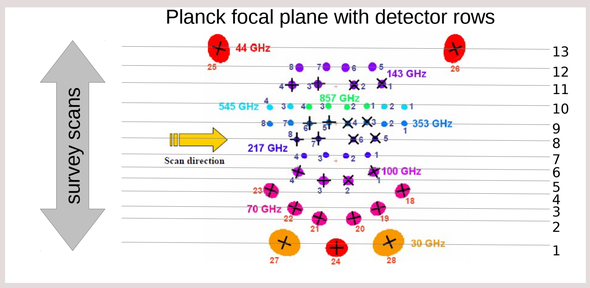
Our main target list is based on a sample derived from the CRATES catalog, applying the spectral index cuts $\alpha_{<4.8\mathrm{GHz}} > -0.3$ and $\alpha_{<8.4\mathrm{GHz}} < 0.1$, a flux limit $F_{8.4\mathrm{GHz}} > 1.0$ Jy, and declination $\delta > -10°$. These criteria focus on sources with flat cm-spectra, but exclude GPS objects. To ensure observability by Planck, we further required $F_{\geq 143\mathrm{GHz}} > 700$ mJy, for which we used the Planck ERCSC at 143 and 217 GHz (Planck Collaboration VII 2011). The total sample of 33 sources was observed with the Effelsberg 100m telescope between April 2011 and February 2012, following the Planck scans during the 4th and 5th sky survey. The sample has a considerable overlap with the F-GAMMA sample and also with the Metsähovi sample of northern radio sources (see Planck Collaboration XV 2011). F-GAMMA data are used to complement and extend the observations of the Planck target sample.

F-GAMMA Observations

The *Fermi*-GST related monitoring program of gamma-ray blazars (F-GAMMA) closely coordinated Effelsberg 100m observations with the more general flux monitoring at the IRAM 30m telescope between 2008 and 2014. Effelsberg measurements were conducted with the secondary focus heterodyne receivers at 2.64, 4.85, 8.35, 10.45, 14.60, 23.05, 32.00 and 43.00 GHz, performed quasi-simultaneously with cross-scans, slewing over the source position in azimuth and elevation direction with an adaptive number of sub-scans (for details see: Fuhrmann et al. 2007, 2014; Angelakis et al. 2015). IRAM 30m observations were carried out with calibrated cross-scans using the EMIR horizontal and vertical polarisation receivers operating at 86.2 and 142.3 GHz. The opacity corrected intensities were converted into the standard temperature scale and finally corrected for pointing offsets and systematic gain-elevation effects. The conversion to standard flux densities was done using frequently observed primary (Mars, Uranus) and secondary (W3(OH), K3-50A, NGC 7027) calibrators.

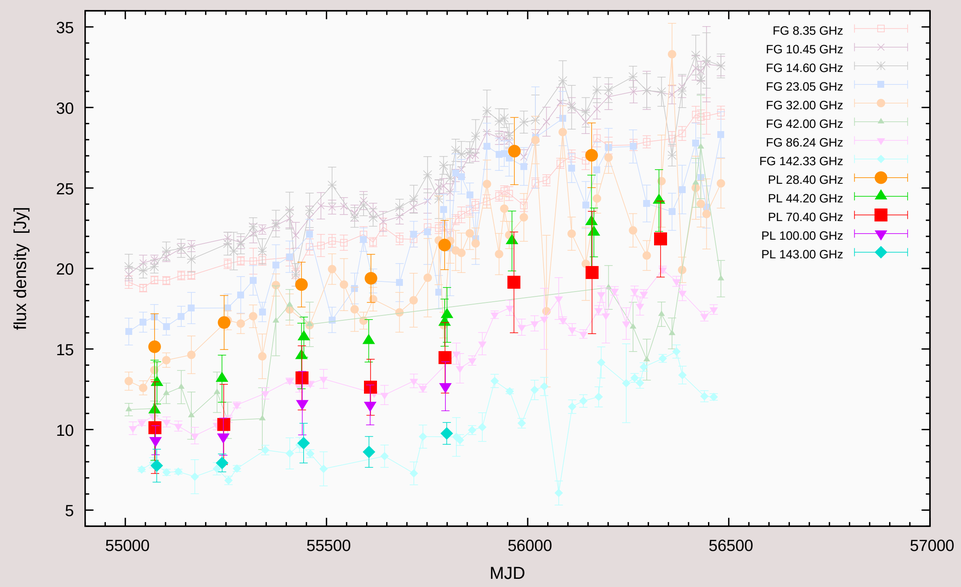
Planck time resolved fluxes with MATTI





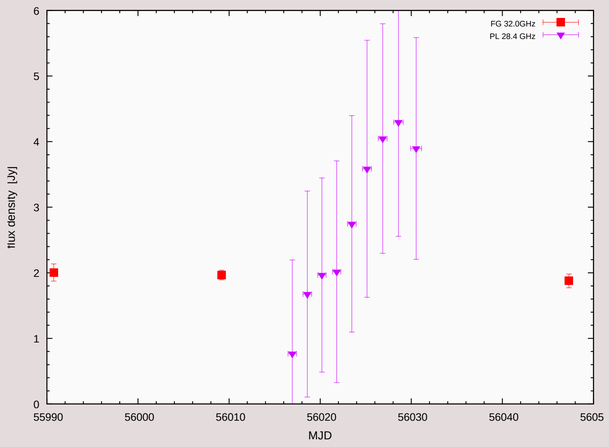
Unlike other work where fluxes of point sources detected by cosmology probes are extracted from time-restricted all sky maps (e.g., Planck Collaboration XV 2011, Chen et al. 2013), Planck fluxes used here are produced by the Mapping Tool for Time Ordered Information (MATTI, see poster FM5p.32). MATTI, based on the beam-deconvolution code ArtDeco (Keihänen & Reinecke 2012), detects flux *variations* in a given sky position and associates it with bright, variable sources within the beam. For every pointing ID (PID) and each detector, a source flux is estimated by deconvolving with the detector beam. While sweeping over the source, Planck thus produces a *survey scan* profile with roughly one hour time resolution. Obviously, the method relies on our knowledge if the beam profile, and is prone to noise and systematic detector effects, apparent from the large variation of single PID fluxes in the survey scan.

Example: light curve of 3C84



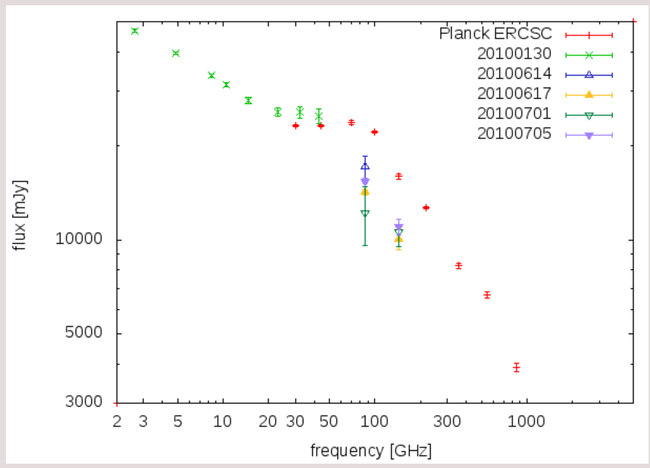
F-GAMMA light curves from 8.35 to 142.3 GHz for the bright blazar 3C84 between Aug 2009 and Dec 2013, with MATTI derived fluxes of the Planck LFI 30, 44, and 70 GHz radiometers, HFI 100 GHz PSBs and HFI 143 GHz SWBs, noted at their central bandpass frequencies as listed in Planck Collaboration I (2013). The fluxes shown here are weighted averages over full scans and all detectors at one frequency combined. Their errors express the rms scattering of the single PID fluxes during each scans, thus consider both statistical and systematic deviations. Total fluxes are determined by adding the measured average deviation to the to the source flux listed in the Second Planck Catalogue of Compact Sources (Planck Collaboration XXVI 2015).

Added value: short time scales . . .



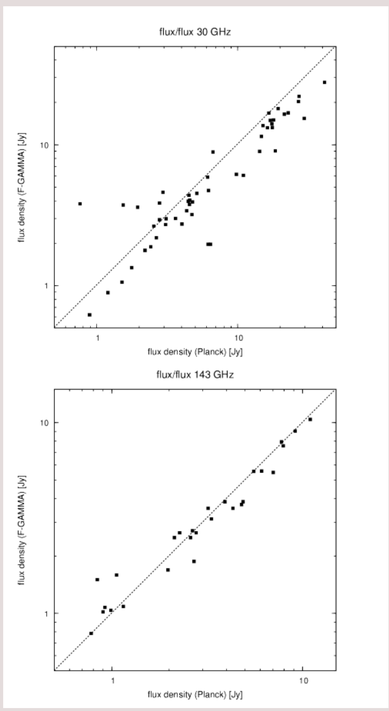
Excerpt of the 30GHz light curve of the blazar S5 1803+78, which is located in the Planck deep field at the ecliptic north pole, and thus irregularly scanned by the Planck detector rows. Fluxes of such sources can easily be subject to systematic errors, but during the rise of the flux after MJD 56020 (Apr 2, 2012) the source was stable in the central beam of both LFI 30GHz radiometers. If confirmed against further checks, this would be a rare observation of a blazar flare with doubling time scale below one week (see also Fuhrmann et al. 2008). Planck data points are cuts through a continuous scan of the source, errors express rms scattering of single PID fluxes.

. . . and large bandwidth



F-GAMMA and Planck span 2.5 orders of mag. in wavelength, from 10cm to 0.3mm, demonstrated by this quasi-simultaneous spectrum of 3C273 (Chen et al., 2013). It is the goal to produce several such spectra for each source of the Planck-Effelsberg sample and many other F-GAMMA targets.

Consistency



Flux-flux comparison; top: Effelsberg 32GHz vs. Planck LFI 30GHz; bottom: IRAM 30m 142GHz vs. Planck HFI 143 GHz, measurements taken within 20 days. The upper panel shows systematically higher Planck fluxes, the reason is under investigation.

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