Long-Term Multiwavelength Studies of High-Redshift Blazar 0836+710

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High-redshift blazar 0836+710 multiwavelength variability exhibits some complex features. The largest variability is seen at gamma-ray wavelengths.

ABSTRACT: Following gamma-ray flaring activity of high-redshift (z=2.218) blazar 0836+710 in 2011, we have assembled a long-term multiwavelength study of this object. Although this source is monitored regularly by radio telescopes and the *Fermi* Large Area Telescope, its coverage at other wavelengths is limited. The optical flux appears generally correlated with the gamma-ray flux, while little variability has been seen at X-ray energies. The gamma-ray/radio correlation is complex compared to some other blazars. As for many blazars, the largest variability is seen at gamma-ray wavelengths.

Introduction

0836+710 is a luminous, high-redshift (z=2.218) quasar of the blazar subclass. It is also known as 4C71.07 and is characterized by a flat radio spectrum (α=-0.33, Kuhr 1981). This source hosts a powerful radio jet emerging from the core and extending up to kpc scales (Hummel et al. 1992). VLBI (Very Long Baseline Interferometry) images of 0836+710 show a very complex motion pattern, with one-sided jet components moving from apparent subluminal (β_{app} = 0.5) to superluminal (β_{app} = 25) velocities (β = v/c, H_0 = 71 km/s/Mpc) (Otterbein 1998; Lister et al 2009).

Internal structure of the jet in 0836+710 has been investigated at 1.6 and 5 GHz using observations with VSOP (VLBI Space Observatory Programme, Perucho et al. 2007). These observations suggest a helical structure for the jet. See also http://www.physics.purdue.edu/astro/MOJAVE/ sourcepages/0836+710.shtml, the MOJAVE summary page for this blazar. A more recent study of this source with VLBI data presented evidence that the helical structures observed in the jet of 0836+710 are real and not generated artificially by the observing arrays (Perucho et al 2012). Blazar 0836+710 was also the subject of several X-ray studies and multiwavelength modeling (e.g. Sambruna et al, 2007).

Gamma-Ray Observations

During the Compton Observatory era, 0836+710 was detected by COMPTEL (3-10 MeV band, Collmar 2006) and EGRET (Thompson et al. 1993; 3EG J0845+7049, Hartman et al. 1999). This source was not bright enough to be included in the *Fermi*-LAT Bright Source List (Abdo et al. 2009); however, it was associated with 1FGLJ0842.2+7054 in the First LAT Catalog (1FGL, Abdo et al. 2010). Its 2FGL name is 2FGL J0841.6+7052 (Nolan et al. 2012). Its gamma-ray spectrum is steep, with a photon power-law index of 2.95±0.07 in 2FGL.

The *Fermi-LAT* data (E>100 MeV*)* considered for this analysis cover the period from 2008 August 4 to 2012 January 31. The data analysis was performed with the standard analysis tool *gtlike*, along with standard Galactic and isotropic diffuse radiation models, all provided with the *Fermi-LAT* Science Tools package (*v*9r23p1). The corresponding P7_V6 Instrument Response Functions (IRF) were used. We restricted the analysis to a region of interest centered on the source and a radius of 10°. The source model includes point sources from the 1FGL catalog (Abdo et al 2010a), a component for the Galactic diffuse emission (gll_iem_v02.fit), and an isotropic component (isotropic_iem_vo2.txt) that represents the extragalactic diffuse emission as well as residual cosmic-ray background.

Temporal Behavior

We divided the observations into two time periods: a quiescent period from 2008 August to 2010 August (matching the 2FGL catalog analysis), and an active period from 2011 March to 2012 January. The weekly light curves in Figure 1 show the integrated flux (E > 100 MeV).

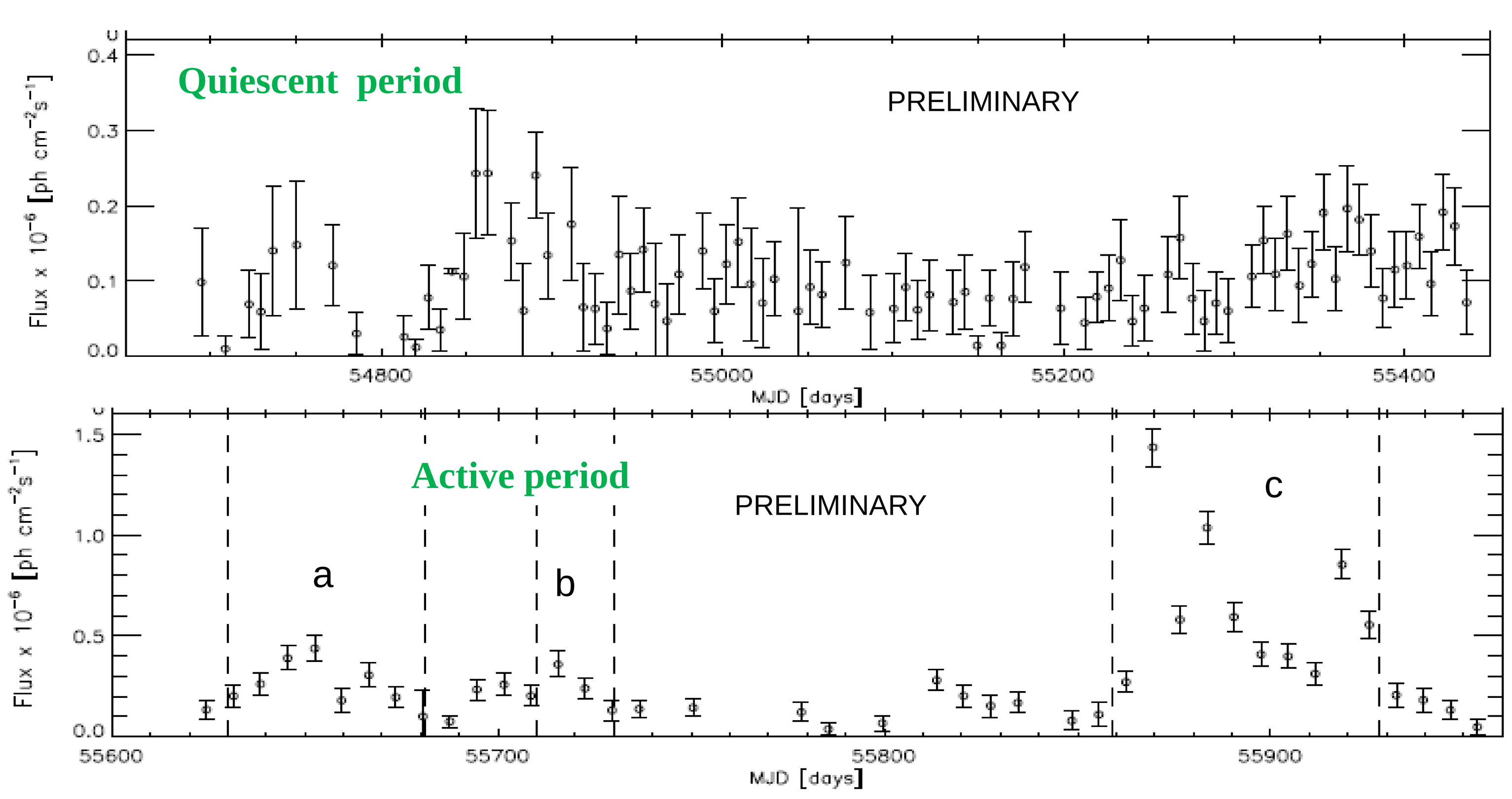

Figure 1. Light curve for 0836+710 measured by *Fermi*-LAT between MJD 54682 and 55412 (2008-08-04 and 2010-08-04) for the quiescent period (left), and MJD 55652 and 55957 (2011-04-01 and 2012-01-31) for the active period (right). In the lower panel, flares a, b, and c are delineated by vertical dashed lines.
The source variability is shown with 1 week-time binning and an integral flux E>100 MeV. A Test Statistic TS > 4 was required for a detection. Although the LAT observations are continuous, weeks in which TS < 4 are upper limits and are not shown on the figure. Note that both the time and flux scales differ between the two panels.

Gamma–ray Spectra

The spectral analyses were performed using binned (for the quiescent period) and unbinned (for the active period) maximum-likelihood estimators (gtlike). In the analysis, 0836+710 was detected with a statistical significance of approximately 19σ and an integral flux F(E>100 MeV) of 6.29±0.50×10^{-8} cm^{-2}s^{-1} for the quiescent state. During the active state, flares a, b, and c showed flux F(E>100 MeV) in the same units of 2.41±0.21×10^{-7} (17σ), 2.51±0.32×10^{-7} (11σ), and 6.45±0.22×10^{-7} (50σ), respectively. For all time intervals EXCEPT flare c, the spectrum is well fit by a power law. During flare c, spectral curvature is visible (as represented in Figure 3). A detailed spectral analysis during this time interval showed a reduced χ2 of 2.85 for a power-law fit, while a log-parabola fit produced a reduced χ2 of 0.89.

Long-term Multiwavelength Light Curve

Although 0836+710 is monitored regularly by radio telescopes, its coverage at other wavelengths has been fairly sparse in recent years. Figure 2 summarizes the long-term flux history of the source; in the top panel the results from *Fermi*-LAT with 4-week binning, in the second panel from *Swift* X-Ray Telescope, in the third panel from the *Swift* Ultraviolet/Optical Telescope, in the fourth panel from R-band optical data (Abastumani Observatory), in the fifth and sixth panels from the F-GAMMA collaboration (using the Effelsberg and IRAM telescopes) .

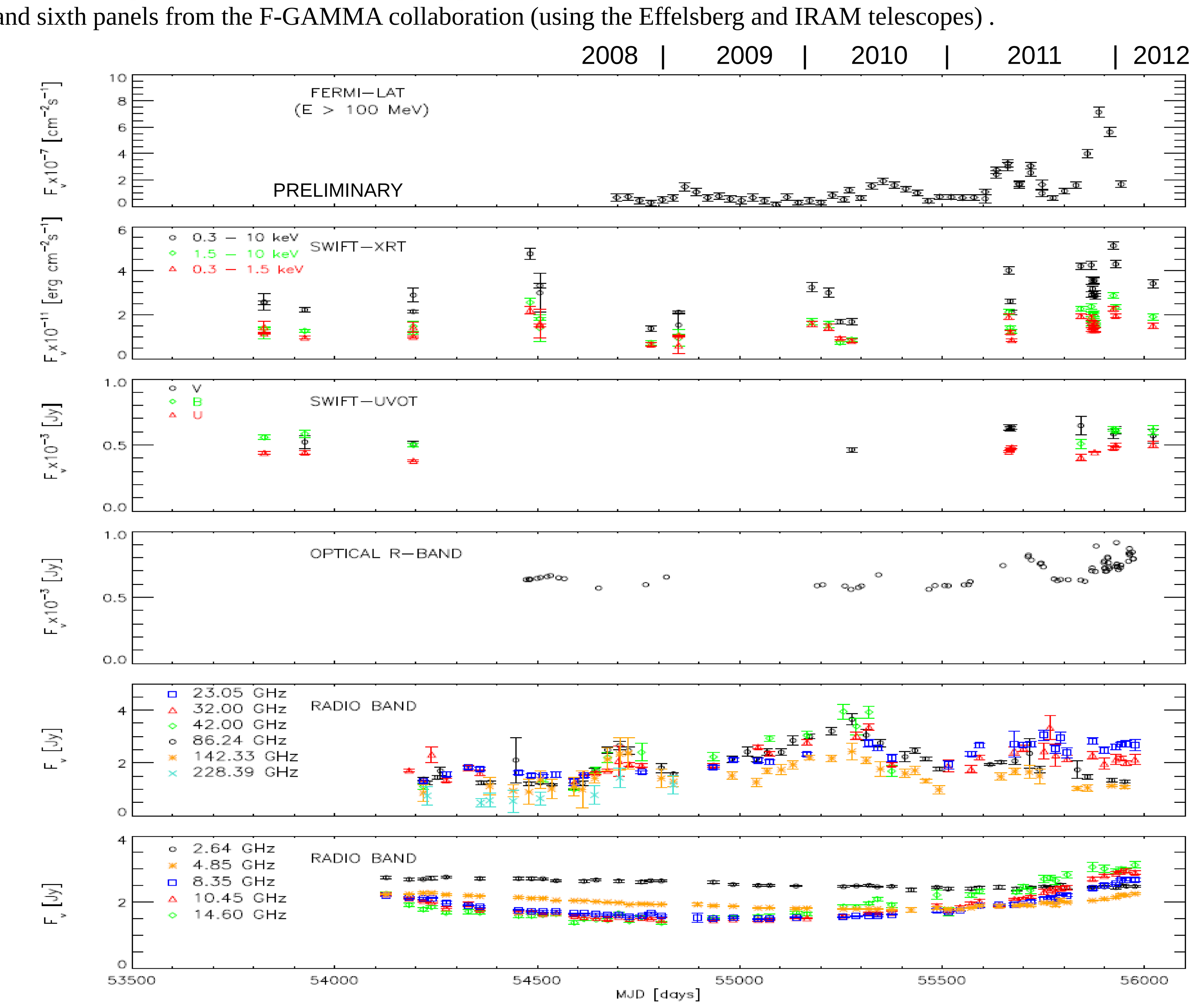

Figure 2. Long term multiwavelength light curve of 0836+710.

- The Swift X-ray Telescope observations do not show significant flaring activity following the bright gamma-ray flares.
- The optical data indicate a correlation with the gamma–ray flaring in both April and November, 2011, with indications of correlations before. The correlation establishes an identification of the gamma-ray source with 0836+710, but coverage is not good enough for a detailed cross-correlation analysis before the 2011 flares.
- The high-frequency (> 23 GHz) radio observations also show strong variability with up to a factor of 4 at mm-bands. Correlations with the gamma-ray data are not clear and are the subject of ongoing work.
- The lower-frequency radio bands do not exhibit any significant flaring activity. Except at the lowest (2.64 GHz) radio frequency, all the radio bands show a generally rising trend during most of the *Fermi* observations

Spectral Energy Distribution (SED)

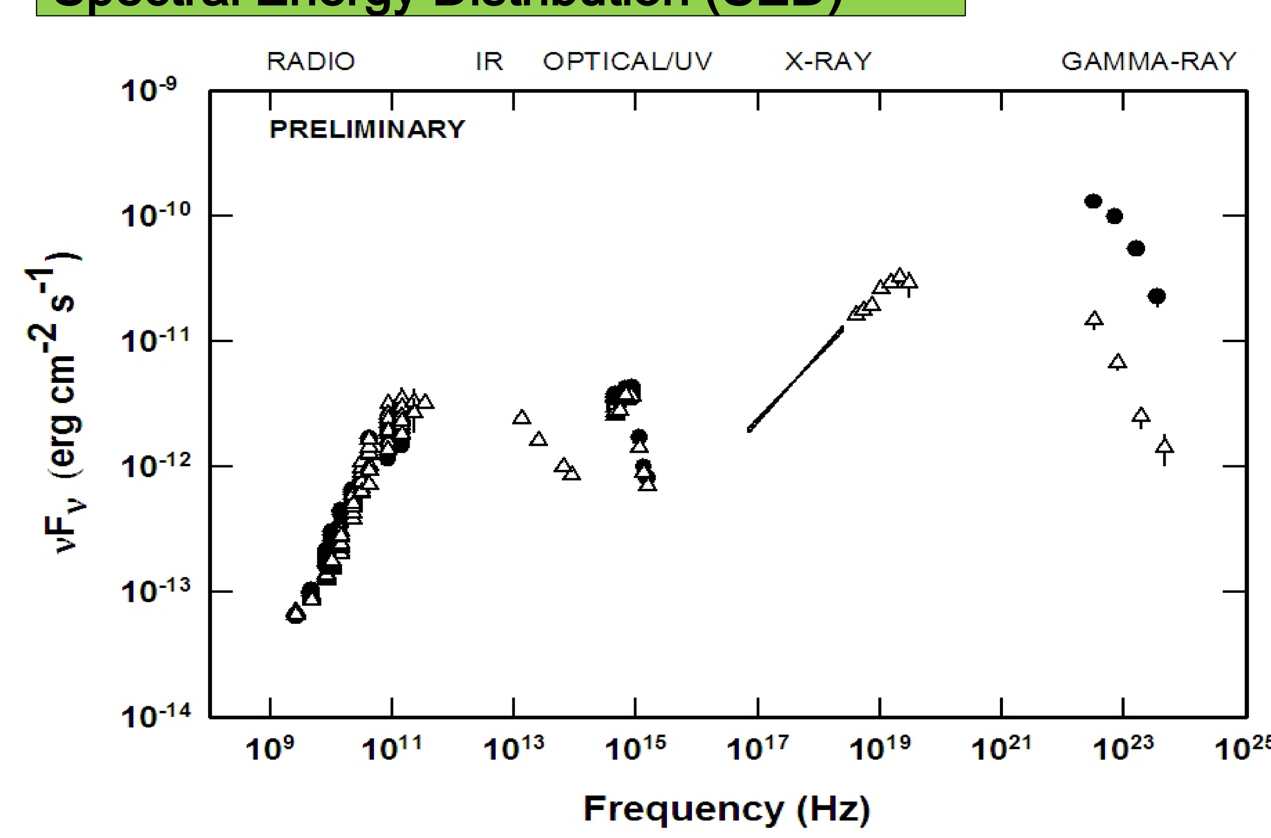

Figure 3. Broadband SED of blazar 0836+710. Filled circles: active state in 2011. Open triangles: quiescent state. Data are contemporaneous but not all simultaneous. The *Fermi*-LAT data are shown for the brightest flare (Flare c, see Fig. 1) and the quiescent state. Variability in gamma rays is significantly larger than that seen in other wavelengths. The optical/UV observations, compared with the WISE IR data, show a "blue bump" contribution from the accretion disk.