Flaring Activity from 0836+710 (4C+71.07): What Can We Learn With Limited Multiwavelength Coverage?

A. Akyüz
University of Cukurova, Department of Physics, 01330 Adana, Turkey, and NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

D. J. Thompson
NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

D. Donato
CRESST, Department of Astronomy, University of Maryland, College Park, MD 20742, USA, and NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

L. Fuhrmann†, K. Sokolovsky
Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69 53121 Bonn, Germany

O. Kurtanidze
Abastumani Observatory, 383762 Abastumani, Republic of Georgia

After a long period of quiescence in γ rays, blazar 0836+710 (4C+71.07) flared in the Spring of 2011. We found only limited multiwavelength coverage of the source. An indication of correlated optical/γ-ray variability is not surprising for a Flat Spectrum Radio Quasar (FSRQ) like this one. Radio observations at high frequencies, however, had seen a flare in 2010, well offset from possible γ-ray activity. The 2011 γ-ray activity comes during a period of rising radio emission, a pattern that has been seen since the EGRET era.

I. INTRODUCTION

The luminous high-redshift (z=2.218) quasar 0836+710 (also known as S5 0836+71 or 4C+71.07) is characterized by a flat radio spectrum (α=−0.33). It hosts a powerful one-sided radio jet emerging from the core and extending up to kiloparsec scales. Very Long Baseline Interferometry (VLBI) images of the source show a complex motion pattern, with one-sided jet components moving from apparent subluminal to superluminal velocities. Monitoring with MOJAVE has shown apparent speeds up to \( \beta_{app} = 25 \), with \( \beta = v/c \), \( H_0 = 71 \text{ km s}^{-1} \text{ Mpc}^{-1} \), \( \Omega_m = 0.27 \), \( \Omega_\Lambda = 0.73 \). Internal structure of the jet in 0836+710 has been investigated at 1.6 and 5 GHz using observations with the VLBI Space Observatory Programme (VSOP), showing details of the curved jet. VLBA observations also suggest a spine-sheath structure for the jet of this source. See also the MOJAVE and Boston University summary web pages for this blazar. Blazar 0836+710 was also subjected to several X-ray studies and multiwavelength modeling to understand how X-ray emission is produced and the relationship between X-ray emission and other bands.

II. GAMMA-RAY OBSERVATIONS

In the 1990’s this blazar was detected and shown to be variable by EGRET on the Compton Gamma Ray Observatory (CGRO) at 100 MeV γ-ray energies, with the name in the Third EGRET Catalog 3EG J0845+7049. Data from other CGRO instruments, BATSE, OSSE, and COMPTEL at lower γ-ray energies showed that the peak of the Spectral Energy Distribution (SED) falls in the MeV energy range. A new era in γ-ray astrophysics began with the launch of the Fermi Gamma-ray Space Telescope (Fermi) in June, 2008. This source was not bright enough to be included in the Fermi Large Area Telescope (LAT) Bright Source List; however, it was associated with 1FGLJ0842.2+7054 in the First LAT Catalog (1FGL, 1) and first LAT Active Galactic Nuclei (AGN) Catalog (1LAC, 1). Regular γ-ray monitoring by Fermi-LAT showed that the source was not active until recently. An exceptional outburst from the source on 2011 April 3 was noted by the Fermi-LAT (1). Preliminary analysis of observed γ-ray flare indicated that 0836+710 was in a bright state with an average daily flux of \( F_{E>100\text{MeV}} \approx (1.2\pm0.3)\times10^{-6} \text{ photons cm}^{-2}\text{s}^{-1} \). The reported flux is an order of magnitude greater than the average flux value in the 1FGL catalog. Its 2FGL name is 2FGL J0841.6+7052 (1). Its γ-ray spectrum is steep, with a photon power-law index of 2.95±0.07 in 2FGL.

* on behalf of the Fermi LAT Collaboration
† on behalf of the F-GAMMA Collaboration, http://www.mpifr-bonn.mpg.de/div/vlbi/fgamma/fgamma.html

2012 Fermi & Jansky Proceedings - eConf C1111101
III. SPECTRAL ENERGY DISTRIBUTION

Simultaneous or near-simultaneous SEDs of many Active Galactic Nuclei, including 0836+710, were recently constructed from the Planck Early Release Compact Source Catalog (ERCSC) [20], using a wide range of ground-based and space-based observatories, including Swift (optical/ultraviolet/X-ray) and Fermi. The result for 0836+710 is shown in Figure 1, with simultaneous observations shown in red and historical data in gray. The Planck scan for this figure began on 2010 March 17. During the 2-month interval centered on this scan, the detailed energy spectrum of the blazar was not measurable by Fermi-LAT (shown as upper limits), because it was still in its quiescent state. The well-known double peak spectra for blazars is seen in the historical data, and the second order polynomial fits to the low-frequency (synchrotron) peak and high-frequency (inverse Compton) peak are shown as dotted lines.

In the absence of a strong detection in the Fermi-LAT band during this quiescent period and the lack of broadband simultaneous coverage at times when the γ-ray emission was detectable, we chose not to attempt a physical model of the SED for this early analysis. Modeling should be more practical when results from later observations are available (see below).

IV. FERMI-LAT ANALYSIS

The Fermi-LAT data (E>100 MeV) considered for this analysis cover the period from 2008 August 4 to 2011 July 4. Only “diffuse” LAT events, those likely to be photons, were used. To avoid contamination from the γ-ray-bright Earth limb, the selection of events with zenith angle <105° was applied. 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 (v9r23p1) [22]. The Instrument Response Functions (IRF) P6 V3 DIFFUSE 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 [15], a component for the Galactic
diffuse emission (gll_iem_v02.fit), and an isotropic
component (isotropic_iem_v02.txt) that represents the
extragalactic diffuse emission as well as residual back-
ground, largely from mis-identified cosmic-ray parti-
cles.

Despite the short, bright γ-ray flare in April,
0836+710 was too faint in most of the LAT data for
detailed studies on short time scales. We chose, there-
fore, to concentrate on the long-term behavior. In the
top panel of Figure 2, the source variability is shown
by producing a light curve with 4-week time binning
and at E>100 MeV, starting with the beginning of
Fermi science operations. Because this is a known
source, we calculated flux values for all bins with a
Test Statistic (TS) greater than 4, where TS = 2Δ
log(likelihood) between models with and without
the source. As the figure shows, all the bins exceeded this
level, indicating that 0836+710 has a continual low-
level emission of γ radiation. The γ-ray light curve
shows three broad peaks of emission, centered on MJD
54875 (2009 February), 55360 (2010 June), and 55660
(2011 April). No significant variation in the shape of
the γ-ray energy spectrum was seen during the obser-
vations, although the uncertainties are large for these
low-level detections.

V. 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, anchored in the
top panel by the results from Fermi-LAT and in the
bottom two panels by the large F-GAMMA (Fermi-
GST AGN Multi-frequency Monitoring Alliance) ra-
dio data program [21].

Contributions to this multiwavelength light curve,
in addition to the LAT γ-ray results, are:

- Second panel: Swift X-Ray Telescope observations
are taken from the Swift team automated
monitoring program for Fermi sources [26], with
manual checks on the results near the time of
LAT flaring.
- Third panel: Swift Ultraviolet/Optical Tele-
scope observations have been made sporadically
in the U, B, and V bands. We analyzed the public
data using the standard tools from the Swift
Center of HEASARC [27].
- Fourth panel: R-band optical data come from the
blazar monitoring program of the Abastu-
manli Observatory, reduced using their standard
software.
- Fifth panel: High radio frequency radio data,
from the F-GAMMA collaboration, come from
the Instituto de Radio Astronoma Milimétrica
(IRAM) 30-m telescope (142 and 86 GHz) and
the Effelsberg 100-m telescope (42, 32, and 23
GHz).
- Sixth panel: Lower radio frequency radio data,
also from the F-GAMMA collaboration using the
Effelsberg telescope.

Key features of the long-term light curves:

1. The coverage is sparse except for γ rays and
radio; therefore the emphasis is on long-term
rather than short-term correlations.

2. The Swift X-ray Telescope observations show
fading X-ray emission following the bright April
2011 γ-ray flare. Because the X-ray observa-
tions were started after the short γ-ray flare,
a detailed correlation of the time variability in
these two bands was not feasible.

3. The optical data indicate a correlation with
the γ-ray flaring in both 2010 and 2011. The
correlation establishes an identification of the
γ-ray source with 0836+710, but coverage is
not good enough for a detailed cross-correlation
analysis before the 2011 flare.

4. The high-frequency (> 23 GHz) radio observa-
tions also show strong variability with up to a
factor of 4 at mm-bands. Some features:
a) There is a long-term increasing trend starting
before the beginning of the LAT light curve
and continuing throughout the overlapping
observations.
b) There are also 3 radio flares similar to those
seen in γ rays, although the cross-band relative
timing and correspondence (1:1 correlation) is
unclear at the moment. Quantitative analysis of
the amplitudes, shapes, and time offsets
should be possible in the near future.
c) If the 2010 radio peak (∼MJD 55275) is
associated with the γ-ray peak that same year
(∼MJD 55360), then the radio would have to
lead the γ-ray emission by a significant amount
(months). The observed radio-γ-ray offset
is even longer between the 2008 radio peak
(∼MJD 54700) and the 2009 γ-ray maximum
(∼MJD 54875). Detailed correlation studies
are in progress.
d) The stronger γ-ray flaring activity in 2011
(after MJD 55600) does appear to coincide with
a rising flux in the radio, a pattern that has
been seen since the EGRET era, e.g. [22].

5. 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, at least through the middle of 2011.

On Nov. 1, 2011, 0836+710 flared in γ rays to a flux above 100 MeV greater than $3 \times 10^{-6}$ photons cm$^{-2}$s$^{-1}$, nearly 40 times brighter than the average flux in the 2FGL catalog. The rise was a factor of 5 in 24 hours or less. A follow-on paper to these proceedings will incorporate these recent results.
Acknowledgments

The Fermi LAT Collaboration acknowledges generous ongoing support from a number of agencies and institutes that have supported both the development and the operation of the LAT as well as scientific data analysis. These include the National Aeronautics and Space Administration and the Department of Energy in the United States, the Commissariat à l’Energie Atomique and the Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules in France, the Agenzia Spaziale Italiana and the Istituto Nazionale di Fisica Nucleare in Italy, the Ministry of Education, Culture, Sports, Science and Technology (MEXT), High Energy Accelerator Research Organization (KEK) and Japan Aerospace Exploration Agency (JAXA) in Japan, and the K. A. Wallenberg Foundation, the Swedish Research Council and the Swedish National Space Board in Sweden.

This research is partly based on observations with the 100-m telescope of the MPIfR (Max-Planck-Institut für Radioastronomie) at Effelsberg. This work has made use of observations with the IRAM 30-m telescope.

[1] Kühr, H. 1981, A&AS, 45, 367
[2] Hummel, C. A., et al. 1992, A&A, 266, 93
[3] Otterbein, K., et al. 1998, A&A, 334, 489
[4] Lister, M. L. et al. 2009, AJ, 138, 1874
[5] Lobanov, A. P. et al. 1998 A&A, 340, L60
[6] Asada, K. et al. 2010 ApJ, 720, 41
[7] Fang, T., et al. 2001, ApJ, 555, 356
[8] Foschini, L., et al. 2006, A&A, 453, 829
[9] Gianni, S., et al. 2011, Mon. Not. R. Astron. Soc., 411, 2137
[10] Thompson, D. J. et al. 1993, ApJ, 415, L13
[11] Hartman, R. C., et al. 1999, ApJS, 123, 79
[12] Malizia, A. et al. 2000, ApJ, 531, 642
[13] Collmar, W., 2006, Blazar Variability Workshop II: Entering the GLAST Era, ASP Conference Series, 350
[14] Abdo, A. A., et al. 2009, ApJS, 183, 146
[15] Abdo, A. A. et al. 2010, ApJS, 188, 405
[16] Abdo, A. A., et al. 2010, ApJ, 715, 429
[17] Ciprini, S., 2011, The Astronomer’s Telegram, 3260,