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OBSERVATIONS OF BLAZARS IN OUTBURST WITH THE INTEGRAL SATELLITE

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RESUMEN

Desde el lanzamiento de INTEGRAL en 2002 hemos trabajado en un proyecto de blazares como fuentes de oportunidad. En abril de 2004 observamos el BL Lac S5 0716+714, que había aumentado su brillo en óptico. INTEGRAL/IBIS detectó la fuente entre 30 y 60 keV, con un flujo marginalmente más alto que aquel detectado antes en el PDS en Beppo SAX. Una observación simultánea con XMM-Newton detectó variabilidad en rayos X. Debido al gran campo de visión de IBIS, la imagen incluía otro blazar S5 0836+710 ($z = 2.172$), que fue claramente detectado entre 20 y 100 keV. Esto demuestra que INTEGRAL puede detectar en forma eficiente chorros relativistas durante episodios de actividad y permite la exploración de fuentes de rayos gamma a altos corrimientos al rojo.

ABSTRACT

Since the launch of the INTEGRAL satellite in October 2002, we are pursuing a project of observations of blazars as Target-of-Opportunity. In April 2004 we observed the BL Lac S5 0716+714, which had reached a high optical state. The INTEGRAL/IBIS instrument detected the source in a limited energy band, 30-60 keV, with a marginally higher flux than previously detected by the PDS instrument onboard BeppoSAX. A simultaneous XMM-Newton campaign has detected variable X-ray emission. Thanks to the large field-of-view of the IBIS detector, the IBIS image included the position of another blazar, the Flat Spectrum Radio Quasar S5 0836+710 ($z = 2.172$). This was serendipitously detected by IBIS with good significance between 20 and 100 keV. These observations demonstrate that INTEGRAL can be effective in the investigation of the blazar relativistic jets during active states and in the exploration of gamma-ray sources up to high redshifts.

Key Words: **GAMMA-RAYS: OBSERVATIONS — GALAXIES: ACTIVE — BL LACERTAE OBJECTS: INDIVIDUAL (S5 0716+714, S5 0836+710)**

1. INTRODUCTION

Blazars represent the most luminous and dramatically variable subclass of Active Galactic Nuclei (AGN). They emit over the entire electromagnetic spectrum, however, it is at gamma-ray wavelengths that the maximum of their spectral energy distribution is often located. The blazar spectrum is produced by synchrotron radiation at low frequencies (radio-to-X-rays) and by inverse Compton scattering at higher frequencies. Occasionally, the synchrotron tail extends to the hard X-rays (∼100 keV). In general, the region of blazar spectra covered by the IBIS instrument is the rising portion of the inverse Compton component. Its exploration, especially during bright, active states, makes it possible to constrain the frequency location of the inverse Compton peak and to follow the temporal evolution of the broadband spectrum, when gamma-ray data are combined with multiwavelength information. So far, INTEGRAL has observed a number of blazars, including the known hybrid source 3C 273 (Courvoisier et al. 2003) and the EGRET AGNs 3C 279 (Collmar et al. 2005) and 3C 454.3 (Pian et al. 2005b).

We present here the results of the INTEGRAL observations of S5 0716+714 in April 2004, when the source was detected in an unusually high optical state, which triggered the activation of our program for blazars in outburst. Upon start of the INTEGRAL monitoring, we also activated our XMM-Newton program. The results of the observations with the IBIS, SPI and JEM-X observations have already been presented in Pian et al. (2005a). The XMM-Newton results will be published in Foschini et al. (2005), along with the optical data acquired with the INTEGRAL OMC.

2. INTEGRAL OBSERVATIONS OF THE FIELD OF S5 0716+714

In Spring 2004, S5 0716+714 underwent a dramatic optical flare, monitored by many ground-based telescopes (Figure 1). INTEGRAL (Winkler et al. 2003) observed S5 0716+714 starting from 2004 April 2nd, 20:49:25, and ending on 2004 April

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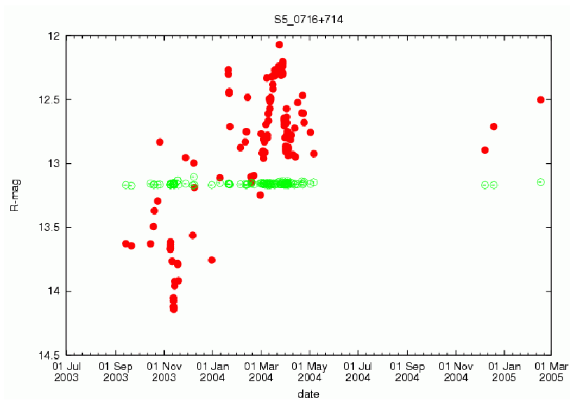

Fig. 1. Historical optical light curve of S5 0716+714 obtained with many ground-based telescopes (filled circles). The flare of Spring 2004 is evident. The open circles represent the optical flux of a comparison star.

$7^{\rm th}$, 00:14:08 UT. The total duration of the observation was of 280 ks, but the effective exposures of the various INTEGRAL detectors were shorter, due to telemetry gaps, dead time corrections, and to technical problems specific to this observation. For details on the observations and the data reduction and analysis we refer to Pian et al. (2005a).

Only the observations with the IBIS/ISGRI instrument yielded significant source detection: S5 0716+714 was detected with signal-to-noise ratio of 4.5 in the energy band $30-60$ keV, for a count rate of 0.11 ± 0.04 counts $\rm s^{-1}$. Since the source was better detected in the first part of the INTEGRAL observation, indicating that it was declining, we selected and accumulated the individual pointings of the early portion of the monitoring, for which the signal-to-noise ratio at the position of the blazar is larger than 1. This reduces the useful exposure to a total of 84 ks, but allows us to improve the significance of the detection of S5 0716+714 to 6.5σ in the $30-60$ keV energy range. The flux in this energy range is 3.1×10^{-11} erg s−1 cm−2 (see Figure 2). No signal is detected above 60 keV.

The large field of view of IBIS ($19° \times 19°$ at half response) allowed us to observe serendipitously other AGNs. In particular, in the IBIS/ISGRI image we detected the Flat Spectrum Radio Quasar S5 0836+710 ($z = 2.172$). The flux of this source was higher than that of S5 0716+714, so that the detection is more significant, and a spectrum could be extracted between 20 and 100 keV. Its shape is fitted by a rather flat power-law, with a photon index of $\Gamma = 1.3 \pm 0.3$ (Figure 4).

The IBIS detections of both S5 0716+714 and S5 0836+710 had insufficient signal-to-noise ratio

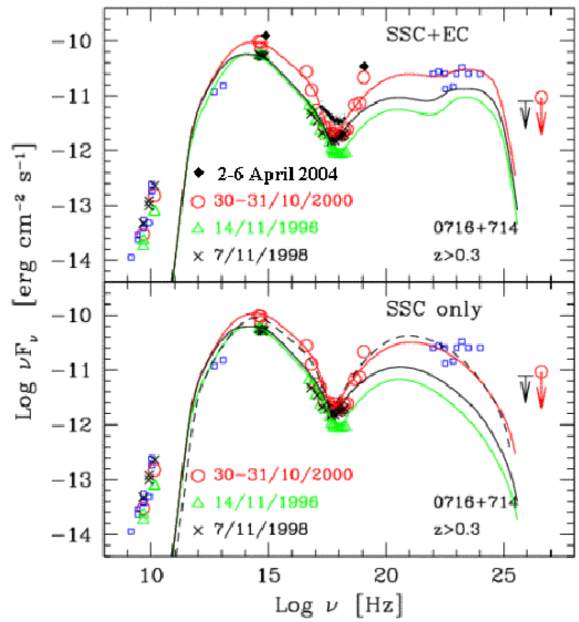

Fig. 2. Spectral energy distributions of S5 0716+714 at various epochs (from Tagliaferri et al. 2003). In the top panel, the XMM-Newton (Foschini et al. 2005) and INTEGRAL/IBIS (Pian et al. 2005a) simultaneous observations during the flaring state of April 2004 are reported as filled diamonds. The overplotted model curves represent a synchrotron radiation model at the radio-to-soft-X-ray frequencies, and inverse Compton scattering of relativistic particles off synchrotron photons in the jet (synchrotron self-Compton) and off photons external to the jet, such as broad emission line or accretion disk photons (external Compton). In the bottom panel are reported the same multiwavelength spectra as in the top panel (except the 2004 data), with a synchrotron and pure synchrotron-self-Compton model, with no external Compton contribution.

to allow time-resolved spectroscopy or even the construction of a light curve in a given energy band. The data of the other INTEGRAL detectors, IBIS/PICsIT, SPI and JEM-X, were also accumulated into final images. However, no sources are detected in those data. Upper limits are reported in Pian et al. (2005a).

3. DISCUSSION

We observed the blazar S5 0716+714 with INTEGRAL while it was undergoing a major optical outburst and detected the source with IBIS/ISGRI in a somewhat higher (about a factor of 2) gamma-ray state than observed in October 2000 (Tagliaferri et al. 2003, see Figure 2). At that epoch the optical flux was slightly lower ($R \simeq 12.5$) than that observed in

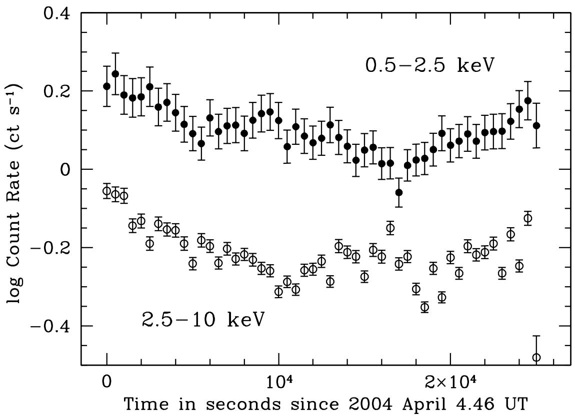

Fig. 3. XMM EPIC-MOS Light curves of S5 0716+714 obtained in April 2004. The light curve in the 2.5-10 keV range has been upshifted by a factor 4. A maximum variability amplitude of ∼50% is observed in both energy ranges (from Foschini et al. 2005).

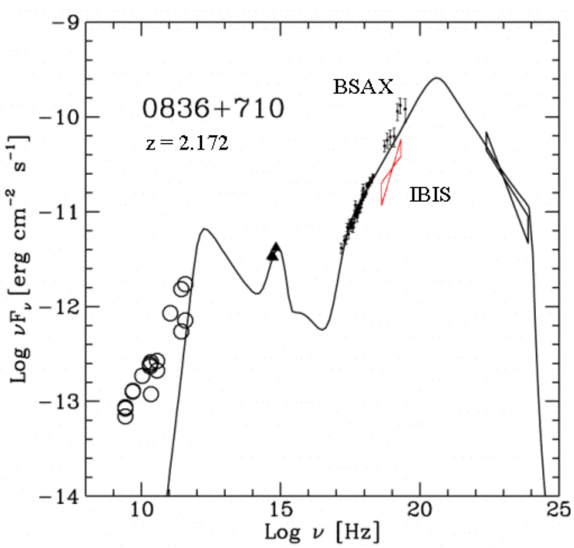

Fig. 4. Spectral energy distribution of S5 0836+710. In evidence are the BeppoSAX PDS data and the INTEGRAL IBIS spectrum with its 1-σ confidence range. The curve represents a synchrotron and external Compton model in a homogeneous region (from Tavecchio et al. 2000).

March 2004 at maximum brightness. The *BeppoSAX* PDS spectrum suggests that the soft gamma-rays are due to inverse Compton scattering of relativistic particles (Tagliaferri et al. 2003; Giommi et al. 1999).

Simultaneously with INTEGRAL, we also observed S5 0716+714 with XMM-Newton (Foschini et al. 2005). The EPIC light curves in two different energy ranges are shown in Figure 3. The X-ray spectrum integrated over the duration of the observation is reported in Figure 2. Its concave shape and the X-ray variability indicate that the X-ray detectors sample the spectral region of S5 0716+714 where the synchrotron and inverse Compton component overlap. A concave X-ray spectrum has already been observed both in this source at previous epochs (see Figure 2) and in other sources (Ravasio et al. 2003; Tagliaferri et al. 2000).

In the INTEGRAL IBIS image of our primary target we also detected the high redshift blazar S5 0836+710. The spectral index of S5 0836+710 is consistent with that determined through *CGRO* BATSE (Malizia et al. 2000) and *BeppoSAX* PDS (Tavecchio et al. 2000) observations during higher emission states (our measured flux is a factor of ∼3 lower than found by both BATSE and *BeppoSAX*, see Figure 4). The flat spectral slope favours the interpretation of the high energy spectrum as Compton scattering of relativistic electrons off external radiation, as opposed to synchrotron-self Compton.

Our observation of S5 0716+714 and serendipitous detection of S5 0836+710 proves INTEGRAL to be effective in the study of bright extragalactic sources at high Galactic latitudes and underscores the importance of instruments with a large field of view and good angular resolution for the investigation of gamma-ray-loud AGNs.

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