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Prominent activity of the blazar OJ 287 in 2005.
XMM-Newton and multiwavelength observations

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Abstract. Two guest-observer XMM-Newton pointings of the blazar OJ 287 in 2005 are introduced, along with part of the radio, mm, near-IR, and optical data obtained during a coordinated and intensive WEBT campaign, during longer-term monitoring observations performed by teams of the ENIGMA network, and during other independent observing programs (like VLBA observations). In that year OJ 287 showed an interesting variable behavior in the optical band. An optical outburst, well matched by our WEBT observations, is claimed in the period Oct.-Nov. 2005, and the XMM-Newton X-ray observations are performed in correspondence with two active optical states (an intermediate flare and such outburst). X-ray data indicates different flux levels, spectral slopes, and emission components, and VLBA radio maps are consistent with a jet precession model. This appreciable observing effort is still ongoing (a further XMM-Newton pointing is planned in 2008), joined with further parallel/multi-monitoring observing programmes devoted to this interesting object.

Key words. BL Lacertae objects: general – BL Lacertae objects: individual: OJ 287 – quasars: individual: OJ 287 – X-rays: galaxies – radio continuum: galaxies – galaxies: jets – galaxies: photometry – radiation mechanisms: non-thermal

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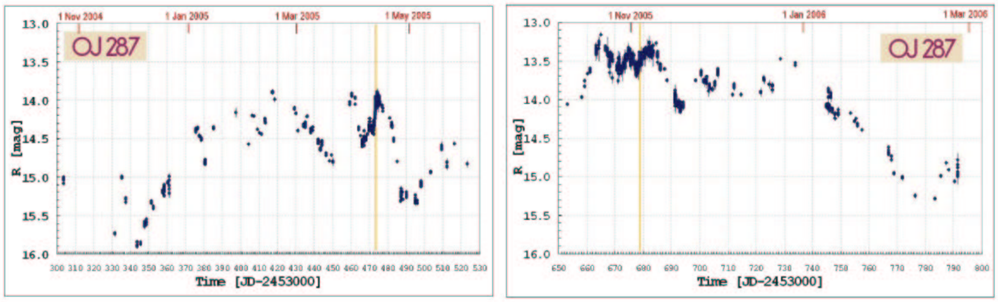

Fig. 1. Optical (*R*-band magnitude) light curve obtained during the coordinated, intensive and short MW campaign by the Whole Earth Blazar Telescope (WEBT) consortium, and during longer-term monitoring observations (ENIGMA network observatories, plus other independent programmes and observatories), requested or triggered by the 2 XMM-Newton pointings in 2005. This light curve covers two optical observing seasons for the blazar (Oct.2004 - Mar.2006). The XMM-Newton space observatory pointed OJ 287 twice (Apr.12 and Nov.3-4, 2005, vertical lines in the figs.) following our granted GO AO-4 proposal. X-ray observations were coincident with two main active stages in the optical band (a mild flare in Apr. and an outburst in Oct.-Nov.). The second X-ray observation was performed during an optical enduring (~ 20 days) and time-structured (3 major symmetric wiggles) outburst (R_{max} ~ 13.3). The whole dataset of radio, mm, near-IR, and multiband optical observations has been collected by more than 30 ground-based observatories. The intensive coordinated WEBT campaign covers a period of about 1 week around the first XMM-Newton pointing in Apr.2005, and about 1 month around the second pointing of Nov.2005.

1. The OJ 287 campaign in 2005

The high-energy and variable flux, the broad-band synchrotron and inverse Compton (possibly connected) emission components, make blazars ideal targets for multiwavelength (MW) campaigns, involving both space-borne observatories and ground-based facilities. In particular the blazar OJ 287 (PG 0851+202, 3EG J0853+1941, $z = 0.306$) is an optically highly-variable (> 3 mag variations) and low/intermediate-energy peaked BL Lac object (LBL/IBL), interesting mainly for a twofold reason. First, this source is historically among the best observed AGN in the optical/radio bands, having a very good database of observations (see Pursimo et al. 2000; Takalo 1994, for a review of earlier observations), hence allowing a more significant statistical investigation, and a wider study of the parameter space of variability (Wagner 2007). Secondly it is one of the very few extragalactic sources, where a major periodical or quasi-periodical signature is claimed (e.g., Valtonen 2007; Nilsson et al. 2006), and the search for supermassive binary black holes should become a major research field in the next years.

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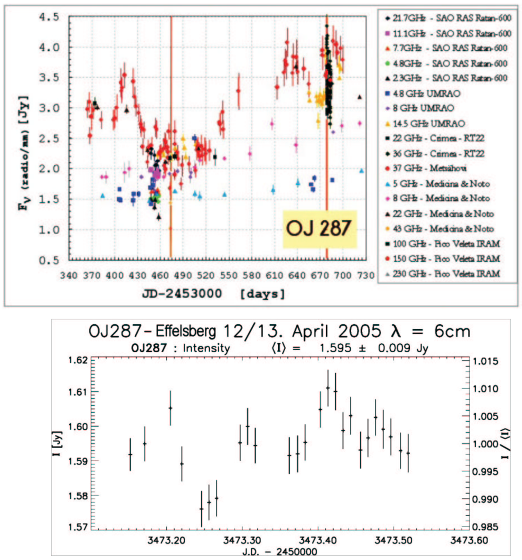

Fig. 2. *Upper panel*: The Nov.2004-Dec.2005 multiband light curves of the radio/mm fluxes of OJ 287 (observing bands spans from 2.3 to 230 GHz), obtained during the extended coordinated campaign. *Lower panel*: preliminary radio (6cm) intensive light curve of OJ 287 obtained on Apr.12-13, 2005 (9h almost simultaneous to the first XMM-Netwon pointing) with the Effelsberg 100m radio telescope. The source showed a fast and significant radio intra-day variability (IDV) of 2-3% (see Fuhrmann et al. 2007)

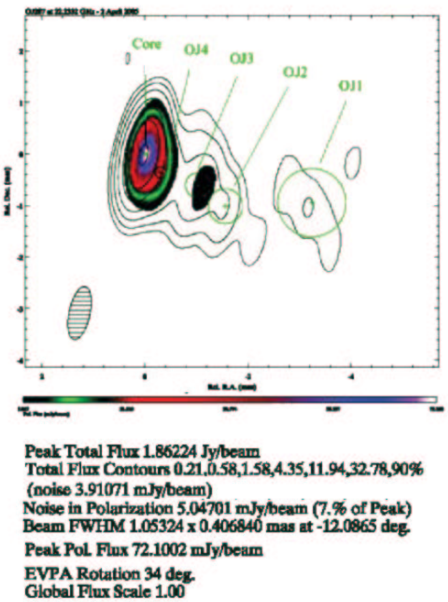

Fig. 3. 22 GHz VLBA image of OJ 287 obtained in Apr.02, 2005. Contours represent the total intensity, the colour scale the polarized intensity, and the superimposed sticks the orientation of the polarization electric vectors. The positions of the fitted Gaussian components are indicated by the crosses, whereas the circles (of radius equal to the FWHM of each Gaussian) symbolize their size. The 22 GHz image convolving beam is $(1.05 \times 0.41)\,\mathrm{mas}^2$, with major axis position angle at $-12°$.

Two X-ray snapshots of OJ 287 by XMM-Newton (performed in Apr.12, 2005 and Nov.3-4, 2005) are brielfy reported here, together with radio, mm, near-IR, optical preview data obtained by a coordinated WEBT campaigns, by longer-term observations obtained within the ENIGMA Network, and by further independent observing programs. The more recent X-ray observations of OJ 287 were performed by ASCA (Isobe et al. 2001) and *Beppo*-SAX (Massaro et al. 2003). The X-ray spectra obtained by the EPIC camera (pn-MOS1 and MOS2 detectors) on board of XMM-Newton, and part of the multiwavelenght data are shown, and described in more detail in the caption of the Figures 1-5. Among the most interesting results we summarize the following ones: (i) an enduring, symmetrical, and time structured optical outburst observed in Oct.-Nov. 2005; (ii) a broken power-law X-ray spectrum (i.e. a two-component, synchrotron + IC spectrum, typical signature of intermediate blazars, or a thermal tail end) discovered by the EPIC instrument on Nov.3-4; (iii) a clear frequency dependence of the mean structural position angle of the radio-jet in VLBA maps, consistent with a ballistic jet precession model, and a polarization structure mostly concentrated on the emission core. A more detailed analysis will be available in (Ciprini et al. 2007).

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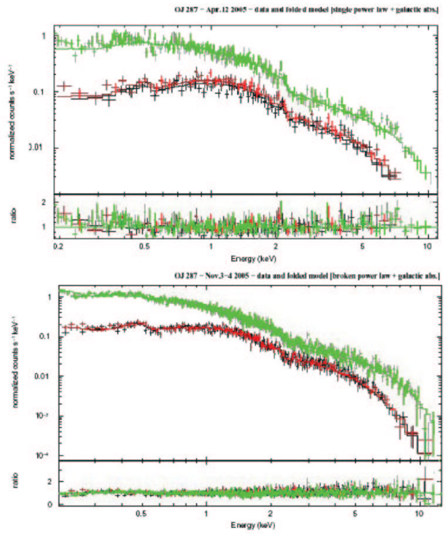

Fig. 4. XMM-Newton combined EPIC (pn, MOS1 and MOS2 detectors) X-ray spectra of OJ 287, belonging to the two observations performed on Apr.12, and Nov.3-4, 2005. Upper panel: the Apr.12 spectrum can be described by a simple power-law + galactic absorption, $N_H = 3.09 \times 10^{20}$ cm^{-2}, $\Gamma = 1.63 \pm 0.02$, $\chi^2_r = 1.03$ $d.o.f. = 367$, $F_{2-10\mathrm{KeV}} = (2.5 \pm 0.8) \times 10^{-12}$ erg s^{-1} cm^{-2}. Lower panel: the Nov.3-4 spectrum can be described by a broken power-law + galactic absorption, $N_H = 3.09 \times 10^{20}$ cm^{-2}, $\Gamma_1 = 2.65^{+0.12}_{-0.07}$, $\Gamma_2 = 1.79 \pm 0.02$, $E_{br} = 0.69^{+0.04}_{-0.05}$ keV, $\chi^2_r = 1.03$ $d.o.f. = 927$, $F_{2-10\mathrm{keV}} = (1.82 \pm 0.07) \times 10^{-12}$ erg s^{-1} cm^{-2}.

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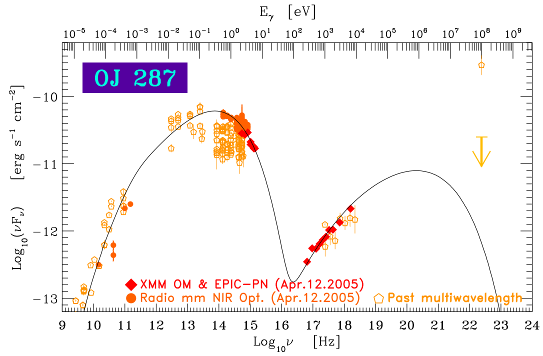

Fig. 5. The overall spectral energy distribution (SED) of OJ 287 quasi-simultaneous to the first XMM-Newton observation of Apr.12, 2005 (OM and EPIC-pn spectral data reported), assembled with radio, mm, near-IR and optical data collected around the satellite pointing date (filled red/orange symbols). A synchrotron self-Compton (SSC) model for this epoch is reported (black line). The SSC fit attempt reported is a first approximation model (one-zone, homogeneous region with injection of a power law energy distribution of accelerated electrons, characterized by cooling and escape times), taking into account also the radio emission, and providing the following parameters: $\gamma_{min} = 135$, $\gamma_{max} = 6.2 \times 10^4$, $p = 1.8$, $k = 0.05$, $B = 0.4$Gauss, $R = 9.5 \times 10^{16}$cm, $\mathcal{D} = 6$, $z = 0.306$. In this date XMM-Newton data suggests a pure inverse-Compton origin for the X-ray emission. On the other hand data referring to the Nov.3-4, 2005 pointing (not reported here), suggests a different situation. More details can be found in Ciprini et al. (2007).

References

Ciprini S., Raiteri C.M., Rizzi N., et al., in prep.

Fuhrmann L., Ciprini S., Marchili N., et al., in prep

Isobe N., Tashiro M., Sugiho M., & Makishima K. 2001, PASJ, 53, 79

Massaro E., Giommi P., Perri M. et al. 2003, A&A, 399,

Nilsson K., Takalo L.O., Sillanpää A., & Ciprini S. 2006, ASP Conf. Ser. 350, 47

Pursimo, T., Takalo, L.O., Sillanpää A., et al. 2000, A&AS, 146, 141

Takalo, L.O., 1994, Vistas in Astron., 38, 77

Valtonen, M. J. 2007, ApJ, 659, 1074

Wagner, S. J., 2007, AIP Conf. Proc., in press