MULTIWAVELENGTH BEHAVIOUR OF THE BLAZAR OJ 248 FROM RADIO TO γ–RAYS

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ABSTRACT

We present an analysis of the multiwavelength behaviour of the quasar-like blazar OJ 248 (z=0.939) in the period 2006-2013. The low-energy (radio, near-infrared and optical) data were obtained by 21 observatories participating to the GLAST-AGILE Support Program (GASP) of the Whole Earth Blazar Telescope (WEBT; http://www.oato.inaf.it/blazars/webt/) a network of astronomers who in concert have the capability to obtain continuous, high-temporal-density monitoring of blazars. The high-energy data come from the Swift and Fermi satellites.
We also analyse the polarimetric and specroscopic behaviour of the source in the optical band.

The aim is to study flux and spectral variability and correlations among emission in different bands. We take account of the effect of absorption by the damped Lyman alpha (DLA) intervening system at z=0.525.

The study focuses mainly on the major flare that occurred at the end of 2012, lasting until the beginning of 2013 and detected at all frequencies. This event is compared to the previous optical outburst, occurred in 2006-2007, and to the radio outburst observed at the end of 2010 at high radio frequencies, revealing a complex radio-optical correlation.

PHOTOMETRY

The figure on the right shows the multifrequency behaviour of OJ 248 from 2006 to 2013. From top to bottom we see:

-The monthly (blue) and weekly-binned (green) γ-ray flux from Fermi in the 0.1-100 GeV energy range;

-The X-ray light curve from Swift-XRT (flux densities at 1keV)

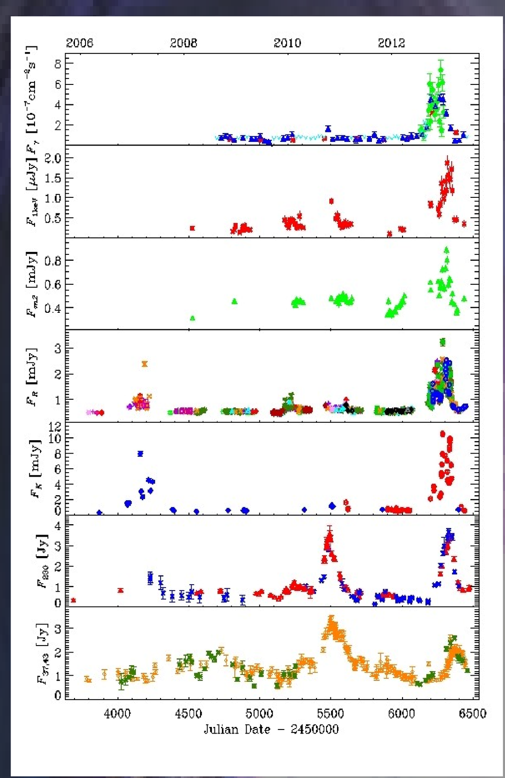
-The UV magnitudes in the Swift-UVOT m2 band (2229 Å)

-The optical photometric observations by the WEBT, which were provided by different observatories: Abastumani, Calar Alto, Crimean, Lowell, Lulin, Mt. Maidanak, Roque, Rozhen, San Petersburg, Steward, Teide (IAC80), Tijarafe, Torino (Loral) and Vidojevica.

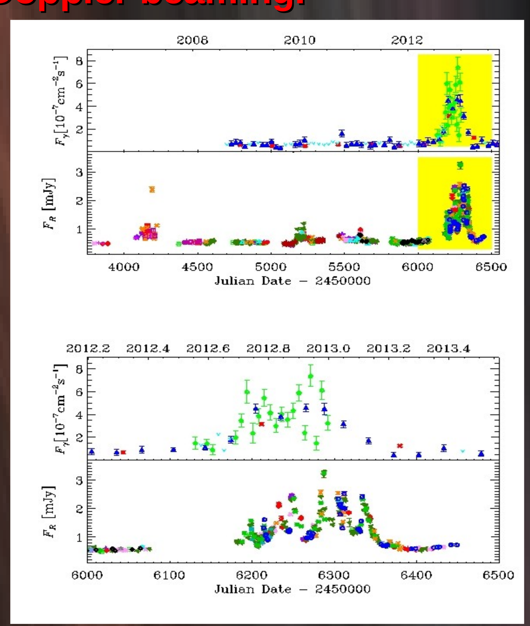
-The IR light curve from the Teide (TCS) and Campo Imperatore observatories.

-The millimetre flux density light curve built with data acquired by the SMA and IRAM

-The radio flux density light curve built with data acquired at Metsähovi and Noto



The correlation between the optical and radio outbursts is clear in 2012-2013, while the optical counterpart of the 2010-2011 radio outburst is difficult to identify. Something likely changed in the source in the period between the two outbursts, one possibility being a slightly better alignment of the optical emitting region with the line of sight with the consequent increase of the Doppler beaming.

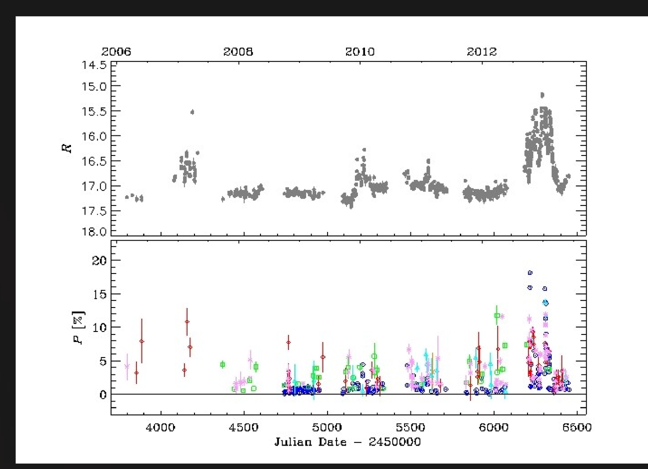


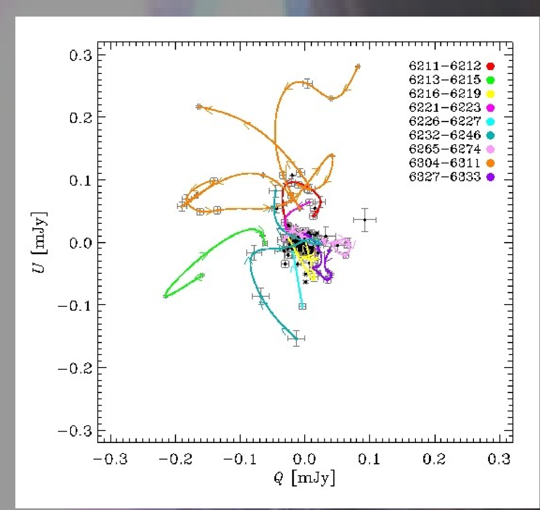
γ-ray and optical light curves on the whole period (upper plot) and during the 2012-2013 outburst (lower plot). Sub-weekly-binned γ-ray fluxes (green) are superposed to the monthly-binned (blue) ones. In both bands the outburst appears formed by many fast flares. A delay of the optical flux changes with respect to the γ ones is evident.

OPTICAL POLARIMETRY

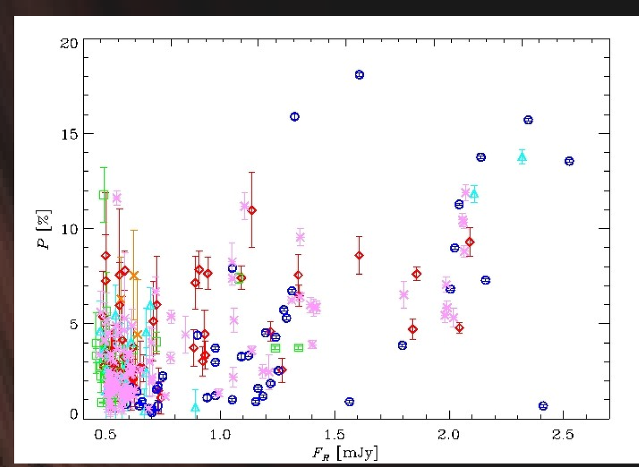
The polarimetric data were provided by the Calar Alto, Crimean, Lowell, San Pedro Martir, St. Petersburg and Steward observatories.

The figure shows the evolution of the polarization percentage P compared with the R-band light curve. The average value of P is 3%, but during the brightening phase of the 2012-2013 outburst it reaches 19%, suggesting a correlation between P and brightness typical of FSRQs (Smith 1996; Raiteri et al. 2013).

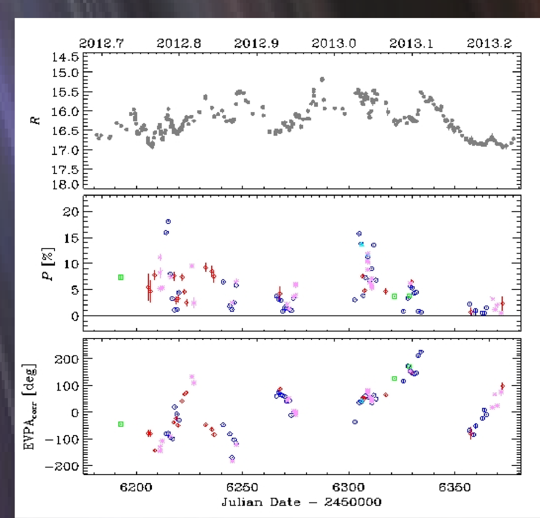




The different lines connect subsequent data belonging to the periods listed in the legend (JD–2450000). The direction is indicated by the arrows.

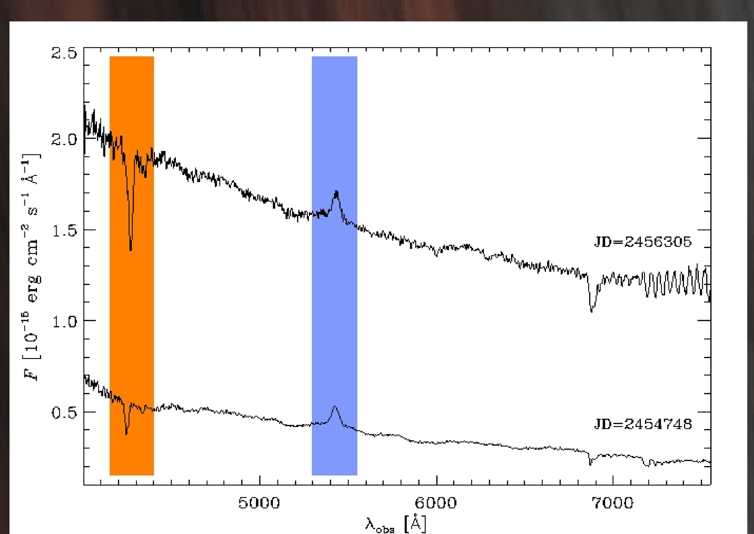


For any value of the flux there is a large dispersion of P, but the highest values of P (>13%) are reached when the source is bright (F_R > 1.3 mJy).



Wide rotations of the electric vector polarisation angle (EVPA) can be reliably detected only during the 2012-2013 outburst and they occur in both directions, suggesting a complex behaviour of the magnetic field in the jet, possibly due to turbulence and/or a complex jet structure involving spiral paths (Marscher 2014).

SPECTROSCOPY



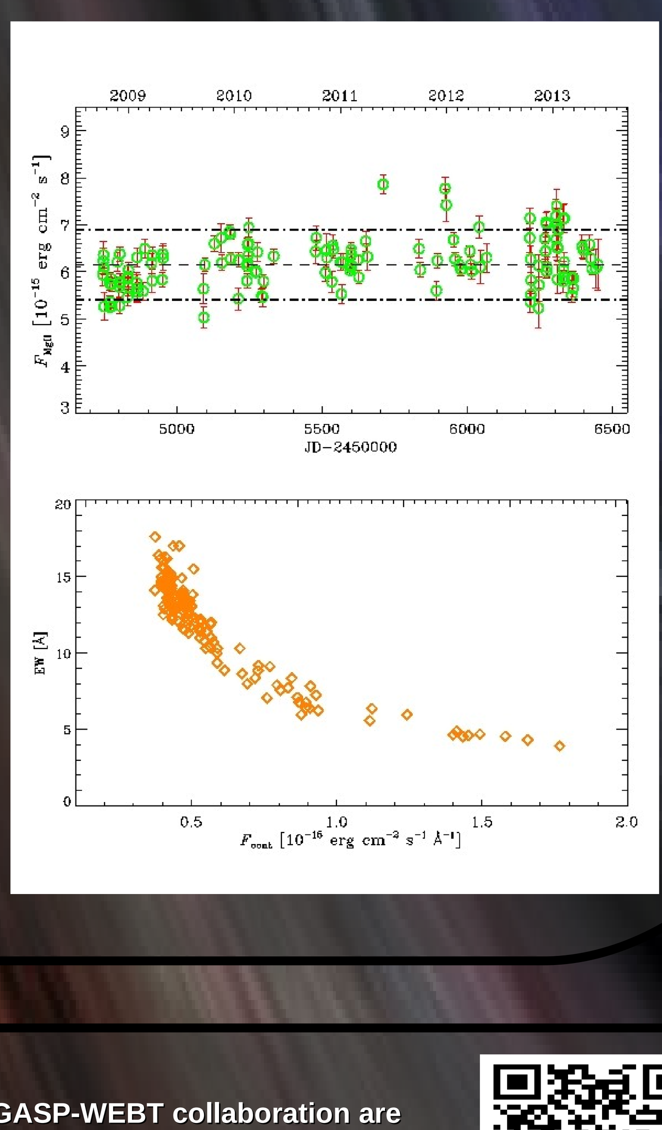
We show two of the spectra corresponding to different brightness states obtained at the Steward Observatory. We can see the source Mg II broad emission line at z=0.939 (blue) and a Mg II absorption line at z=0.525 (orange) due to an intervening DLA system

The flux of the Mg II emission line is basically stable, and this is true also during the 2012-2013 outburst period, when the continuum flux increased by a factor ~6.

Moreover, no delayed line flux increase was detected also after the outburst. Hence, the enhanced jet activity responsible for the outburst did not affect the BLR.

The average velocity of the gas clouds in the BLR is 2053 km/s, with a standard deviation of 305 km/s. The corresponding de-projected gas velocity depends on the geometry and orientation of BLR (Decarli, Dotti & Treves 2011).

The EW decreases when the source brightens, which confirms that the jet is not the ionizing source of the BLR. According to the classical definition (Stickel et al. 1991) if the rest-frame EW is less than 5 Å **blazars are** classified as BL Lacs; in OJ 248 this happens when the observed EW goes below 9.7**Å**. This underlines the limit of the classical distinction between BL Lacs and FSRQs based on the EW, which depends on the source brightness.



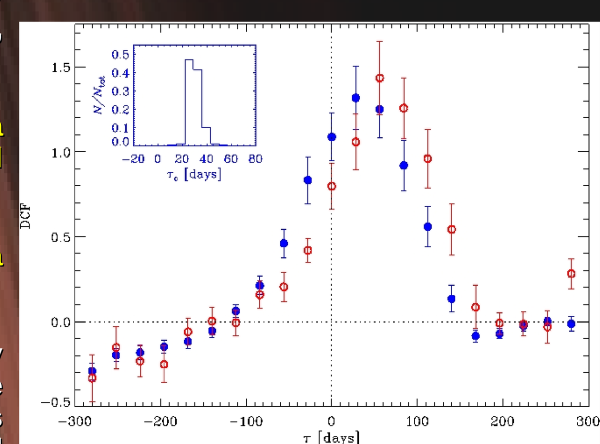
CROSS-CORRELATION

We investigated the correlations between flux variations in different bands by means of the discrete correlation function (DFC; Edelson & Krolik 1988, Hufnagel & Bregman 1992).

The DCF between the γ-ray fluxes and the R-band light curve (blue) shows a peak at a lag of 28 days, which indicates strong correlation with the optical variations following the γ-ray ones after four weeks.

The DCF between the γ-ray fluxes and the X-ray flux density (red) suggests a delay of the X-ray variations of about 2 months.

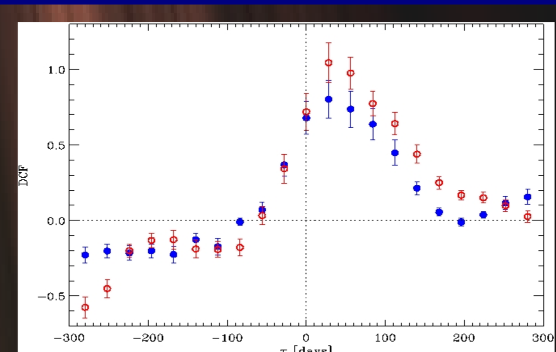
γ-ray flux changes leading the optical ones by several days were found e.g. by Hayashida et al. (2012) in 3C 279. They suggested that the energy density of the external seed photons for the inverse-Compton process producing the γ-rays decreases faster along the jet than the energy density of the magnetic field producing the synchrotron optical emission. Alternatively, the complex optically correlation may be explained by considering the effects of turbulence in the jet (Marscher 2014).



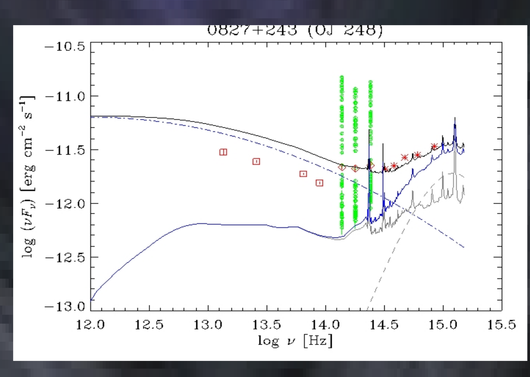
The DCF between the R band and the 230 GHz flux densities (blue) indicates that the time lag of the mm variations after the optical ones is about 1 month.

Hence, the X-ray and mm radiation are likely produced in the same region, with the X-ray emission due to inverse-Compton on the mm photons.

The DCF between the 230 GHz and the 37 GHz flux densities (red) shows a delay of the lower frequency flux changes of 40-50 days.



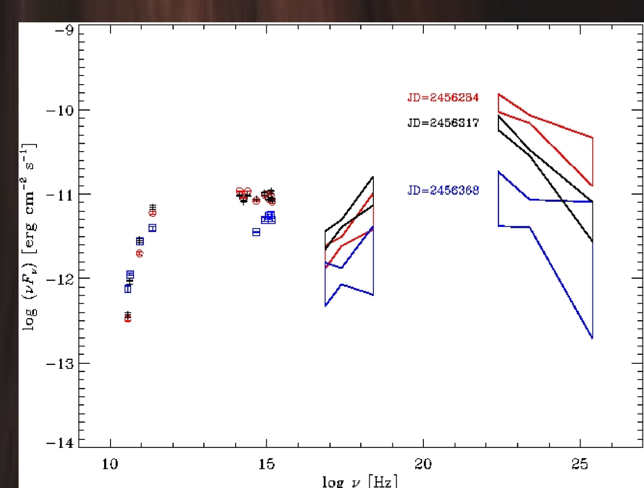
BROAD-BAND SED



Data in the figure are taken from WISE (squares), 2MASS (diamonds) and SDSS (asterisks); the green circles represent data from the GASP-WEBT archive. The contributions from synchrotron (dot-dashed line) and QSO-like (solid line) emission are displayed in blue.

In the right figure three broad-band SEDs corresponding to the peak of the γ-ray emission, to the peak of the X-ray emission, and to the the post-outburst epoch are shown.

The emission in the optical-UV receives an important contribution from the accretion disc radiation, whose signature is more evident in the faint, post-outburst SED. The concave shape of the near-IR spectrum is due to the intersection between the disc contribution and the non-thermal jet emission (left figure, from Raiteri et al. 2014).



The data collected by the GASP-WEBT collaboration are stored in the GASP-WEBT archive; for questions regarding their availability, please contact the WEBT President Massimo Villata (villata@oato.inaf.it).

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