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Radio-Optical Study of Double-Peaked AGNs.
I. 3C 390.3

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J. León-Tavares[*12†], **A.P. Lobanov**[2], **V.H. Chavushyan**[1] **and T.G. Arshakian**[2]
[1]*Instituto Nacional de Astrofísica, Optica y Electrónica*
AP 51, 72000 Puebla, México
[2] *Max-Planck Institut für Radioastronomie*
Auf dem Hügel 69, 53121 Bonn, Germany

E-mail: `fleon@inaoep.mx`, `alobanov@mpifr-bonn.mpg.de`,
`vahram@inaoep.mx`, `tigar@mpifr-bonn.mpg.de`

We aim to test the model proposed to explain the correlation between the flux density at 15 GHz of a stationary component in the parsec-scale jet and the optical continuum emission in the radio galaxy 3C 390.3. In the model, the double-peaked emission from 3C 390.3 is likely to be generated both near the disk and in a rotating subrelativistic outflow surrounding the jet, due to ionization of the outflow by the beamed continuum emission from the jet. This scenario is chosen since broad-emission lines are observed to vary following changes in the inner radio jet. For recent epochs we have imaged and modelled the radio emission of the inner jet of 3C 390.3, which was observed with very long baseline interferometry at 15 GHz, 22 GHz and 43 GHz, to image the inner part of the parsec-scale jet, locate the exact region where the bulk of the continuum luminosity is generated and search for the mechanism that drives the double-peaked profile emission. We present the preliminary results of testing the model using data from 11 years of active monitoring of 3C 390.3.

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1. Inner Jet Structure in the Double-Peaked AGN 3C 390.3

Among the variety of types and species in the AGNs "zoo", there is a small fraction of AGNs showing unusual broad and double-peaked profiles of Balmer and Mg II emission lines, hereafter double-peaked (DP) AGNs. The widths of the DP profiles range from several thousands to $\sim$ 40000 km s^{-1} . The first DP emission line profile was discovered in the Hβ profile of the broad-line radio galaxy 3C 390.3, whose parsec-scale radio jet has been monitored at 15 GHz since 1995 with the Very Long Baseline Array (VLBA). The compact jet can be modelled by circular Gaussian components (see Figure 1). The features **D** (at r=0 mas), **S1** (at r=0.3 mas) and **S2** (at r=1.5 mas) are stationary components, whilst the other features are moving. We have measured flux densities of all the jet components and used back-extrapolation of linear fits to the component trajectories to calculate the epochs of ejection from the nucleus (**D**) and the epochs of passage through the closest stationary feature (**S1**). Most of the observations with very long baseline interferometry (VLBI) have been extracted from the MOJAVE survey [3].

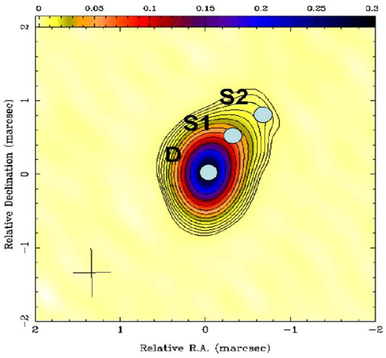

Figure 1: Radio structure of 3C 390.3 Observed in October 2006 with the VLBA at 15 GHz. The synthesized beam plotted as a cross in in the bottom left corner is 0.56 mas × 0.44 mas oriented at an angle of 1.34°. The peak of the flux density in the image is 304 mJy/beam and the rms noise is 0.45 mJy/beam. The contours are drawn at 1, $\sqrt{2}$, 2, ... times the lowest contour shown at 0.9 mJy/beam, the color scale is in Jy. The structure observed is quantified by a set of two dimensional, circular Gaussian features (*filled circles*) obtained from fitting the visibility amplitudes and phases. Features **D**, **S1**, and **S2** are stationary components.

2. Results

Arshakian et al. (2006) found a significant correlation with the flux density at 15 GHz of the stationary component **S1** in the parsec-scale jet and the optical continuum emission in 3C 3903. This strongly implies that the jet emission from component **S1** is the main source of the optical continuum driving the DP emission line variability. We imaged and model fitted the VLBI data at 15 GHz for recent epochs (2001-2007), finding four new features (**C8, C9, C10, C11**). We used measures of the Hα broad line [2] to follow the variations between the jet components and the nuclear optical emission. We back-extrapolated the trajectories of the features identified in the jet, the components **C5**-**C10** passed through the location of the stationary feature **S1** shortly after local $H\alpha$ optical maxima (*green line* in Figure 2). The null hypothesis that this happens by chance is rejected at a confidence level of 99.99 % . The Hα light curve shows a correlation with the flux density of the stationary feature **S1** at a high confidence level, whilst there is no such correlation for any other component. In Figure 2 is shown the apparent anticorrelation between the flux variability of the component **D** at the base of the jet and the stationary component **S1** becoming dramatic for the most recent epochs.

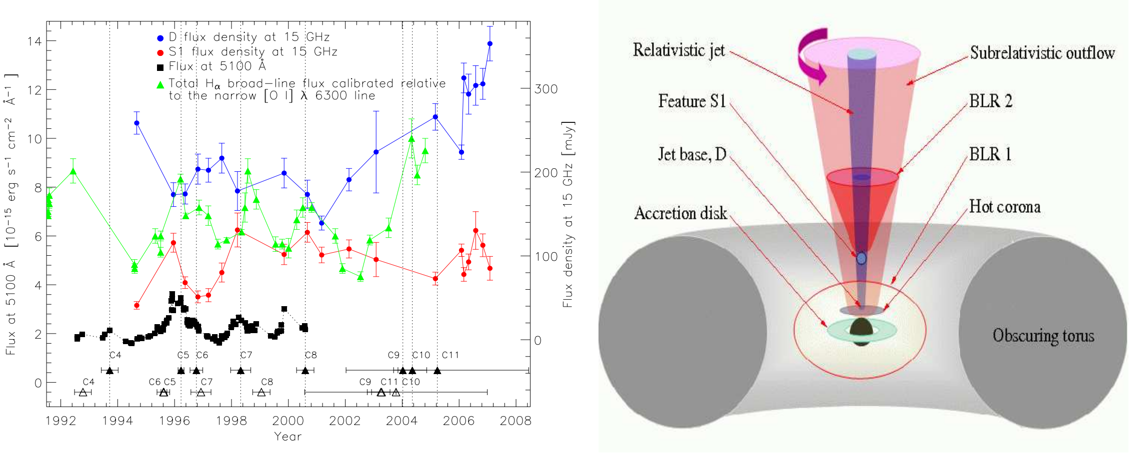

Figure 2: **Left panel:** Flux variations of the inner jet stationary components and the optical emission. *Black-squares*: Optical continua flux at 5100 Å[4]. *Green-triangles*: Total Hα broad-line flux calibrated relative to the narrow [O I] λ6300 line [2] (the flux scales in the plot do not apply to this measures). *Filled-circles*: Flux density of the inner-jet features **D** (*blue*) and **S1** (*red*). The ejection epochs (*open-triangles*), and the epochs of passages through the stationary feature (*filled-triangles*) **S1**. **Right panel:** A sketch of the nuclear region in 3C 390.3 (the drawing is not to scale and shows only the approaching jet). The broad-line emission is likely to be generated both near the disk (BLR1, ionized by the emission from a hot corona or the accretion disk) and in a rotating subrelativistic outflow surrounding the jet (BLR2, ionized by the emission from the relativistic plasma in the jet). BLR2 is evident in the broad-line emission near the maxima in the optical light curve, when the jet emission dominates the optical continuum. BLR1 may be manifested in the broad-line emission around the epochs of minima in the optical flux, when the jet contribution to the ionizing continuum is small.

3. Discussion and Future work

We found a correlation between the **S1** jet component and the Hα optical emission using 11 years of VLBI and Hα broad-emission line monitoring, supporting the idea that the optical nuclear emission in 3C 390.3 has a non-thermal origin. Figure 2 shows the suggested scheme that explains the basic properties of the optical emission (continuum and broad Hα) driven by the inner jet. The multi-frequency analysis and the spectrophotometric monitoring for 3C 390.3 still in progress.

References

[1] T. G. Arshakian et al., *The Source of Variable Optical Emission is Localized in the Jet of the Radio Galaxy 3C 390.3*, in proceedings of *Relativistic Astrophysics and Cosmology - Einstein's Legacy* meeting, November 7-11, 2005, Munich, Germany, eddited by B. Aschenbach, V. Burwitz, G. Hasinger, and B. Leibundgut (2005) [astroph/06020016]

[2] S. Gezari et al., *Long-Term Profile Variability of Double Peaked Emission Lines in Active Galactic Nuclei* (2007), ApJS 169 167

[3] K.I. Kellerman et al., *Sub-Milliarcsecond Imaging of Quasars and Active Galactic Nuclei. III. Kinematics of Parsec-Scale Radio Jets* (2004), ApJ 609 539

[4] A.I. Shapovalova et al., *Intermediate Resolution of Hβ and Photometric Monitoring of 3C 390.3. I.Further Evidence of a Nuclear Accretion Disk* (2001), A&A, 376 775