Perseus in Sicily: From Black Hole to Cluster Outskirts
Proceedings IAU Symposium No. 342, 2018
K. Asada, E. de Gouveia Dal Pino, M. Giroletti,
H. Nagai & R. Nemmen, eds.

doi:10.1017/S1743921318008049

A precessing and nutating jet in OJ287

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Abstract. We re-analyzed OJ287 in 120 Very Long Baseline Array (VLBA, MOJAVE) observations (at 15 GHz) covering the time span between Apr. 1995 and Apr. 2017. We find that the radio jet motion over the sky is consistent with a precessing and nutating jet source. The variability of the radio flux-density can be explained by Doppler beaming due to a change in the viewing angle. We suggest that part of the optical emission is due to synchrotron emission related to the jet radiation. We find a strikingly similar scaling for the timescales for precession and nutation as indicated for SS433 with a factor of roughly 50 times longer in OJ287.

Keywords. techniques: interferometric, galaxies: jets, BL Lacertae objects: individual (OJ 287)

1. Introduction

OJ287 (z=0.306 Stickel *et al.* (1989), a low synchrotron peaked (LSP) BL Lac Object) has been named the Rosetta stone of blazars by Takalo (1994), expressing the hope, that deciphering this particular blazar will lead to a better understanding of the active galactic nucleus (AGN) phenomenon in general. A light-curve observed in the optical V-band since 1890 shows repeated outbursts at ∼11.65 yr intervals of this object (Sillanpää *et al.* (1988)). Sillanpää *et al.* (1988) proposed that OJ287 is a supermassive binary black hole (SMBBH) with an orbital period of 9 yr (in the rest frame of OJ287). Further works by Lehto & Valtonen (1996), Valtonen & Wiik (2012), and Valtonen *et al.* (2016) have explored the binary BH nature of this AGN in a scenario where disturbances of its accretion disc are caused by a plunging black hole (BH).

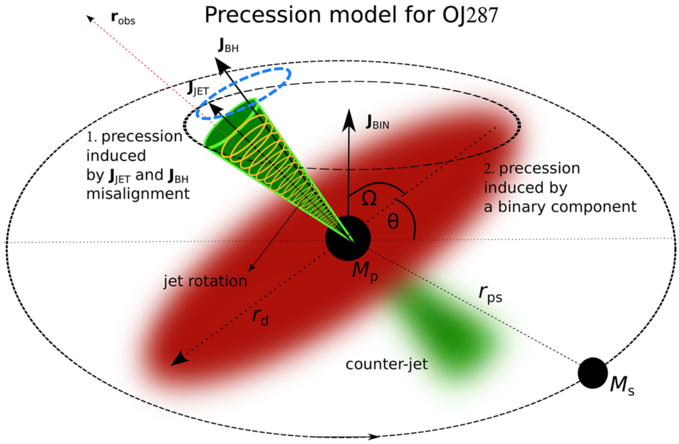

Figure 1. Sketch to illustrate two of the scenarios discussed in more detail in Britzen *et al.* (2018)): 1. The Lense-Thirring precession due to the misalignment of angular momenta of the Kerr black hole and that of the accretion disc. 2. The disc-jet precession due to the torques induced by a secondary black hole.

2. Results

We briefly list the most important results of the findings presented in detail in Britzen *et al.* (2018).

Jet stability. Despite several claims, the jet is not wobbling in an erratic way but, instead, it reveals smooth and continuous motion in the plane of the sky.

Jet precession. The jet ridge line connects all jet features modeled per Gaussian components per epoch, which reveals a precession of the radio jet on the timescale of about 22 yr. This appears to be consistent with (double of) the previously claimed OJ287 perodicity of $\sim$ 11 yr observed in the optical data.

Jet nutation. In addition to the dominant motion of the jet - the precession - a yearly motion is superimposed. This can best be explained and modeled as the jet nutation.

In summary, the radio variability on long time scales ($\sim$ two decades) can best be explained and modeled via jet precession, whereas the short term variability on timescales of a year can best be explained and modeled by jet nutation.

Physically, the *precession can be caused by a SMBBH or Lense-Thirring precession (a misaligned disc around a single black hole)*. A plunging black hole in a SMBBH scenario does not seem to be required to explain the observed jet motion phenomena. A sketch is provided to illustrate both options (Fig. 1).

References

Britzen, S., Fendt, C., Witzel, G., Qian, S.-J., *et al.* 2018, *MNRAS*, 478, 3199
Lehto H. J., & Valtonen M. J. 1996, *ApJ*, 460, 207
Sillanpää A., Haarala S., Valtonen M. J., *et al.*, 1988, *ApJ*, 325, 628
Stickel, M., Fried, J. W., & Kühr, H. 1989, *A&AS*, 80, 103
Takalo L. 1994, *Vistas in Astronomy*, 38, 77
Valtonen M. J., & Wiik K. 2012, *MNRAS*, 421, 1861
Valtonen M. J., Zola S., Ciprini S., *et al.* 2016, *ApJL*, 819, L37

https://doi.org/10.1017/S1743921318008049 Published online by Cambridge University Press