The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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Jet precession and its observational evidence: The cases of 3C 345 and 3C 120

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Abstract. Several radio-loud objects exhibit a complex structure when observed at radio wavelengths: a stationary core, which is thought to harbour the central engine that powers the AGN phenomena, and a relativistic jet, formed by several superluminal components. In some cases, jet components are ejected with different apparent proper motions and directions on the plane of the sky. Moreover, these sources can also show signatures of long-term periodic variability in their historical optical light curve. In this work, we selected the objects 3C 120 and 3C 345, which exhibit both characteristics mentioned above, and interpret them in the framework of jet inlet precession. A brief discussion about what kind of mechanism could be responsible for jet precession is also presented.

Superluminal components of 3C 120 and 3C 345 are ejected in different directions on the plane of the sky and with different apparent proper motions (e.g., Zensus, Cohen & Unwin 1995; Walker et al. 2001). Besides, long-term periodic variability is seen in the B-band light curve of both sources (Webb 1990; Zhang, Xie & Bai 1998). These characteristics were interpreted as due to jet inlet precession (Caproni & Abraham 2004a, 2004b), using the precession model developed by Abraham & Carrara (1998).

A question that arises is what kind of mechanism drives jet precession; among the possibilities, we explore in this work the scenario of supermassive black hole binary system (SBHBS): a secondary black hole in a non-coplanar orbit in relation to the primary accretion disc induces torques in its inner parts, which consequently lead to jet precession (e.g., Romero et al. 2000). If the accretion disc precesses as a rigid body, we can calculate the outer radius of the precessing part of the disc $r_{\rm d}$ as a function of the ratio between the mass of the primary black hole $M_{\rm p}$ and the total mass $M_{\rm tot}$ ($M_{\rm tot} \approx M_{\rm p} + M_{\rm s}$, where $M_{\rm s}$ is the mass of the secondary) through (e.g., Papaloizou & Terquem 1995):

$$r_{\rm d} = \left[-\frac{8\pi}{3}\left(\frac{5-n}{7-2n}\right)\frac{(1+z)}{P\cos\Omega}\frac{r_{\rm ps}^3}{\sqrt{GM_{\rm tot}}}\right]^{2/3} \times \frac{x_{\rm p}^{1/3}}{(1-x_{\rm p})^{2/3}} \qquad (0.1)$$

where G is the gravitational constant, n is the politropic index of the gas, z is the redshift, Ω is the angle between the orbit of the secondary and the plane of the disc, $r_{\rm ps}$ is the separation between the black holes and $x_{\rm p} = M_{\rm p}/M_{\rm tot}$.

In Fig. 1, we plot $r_{\rm d}$ as a function of $x_{\rm p}$ for several orbital periods of the secondary $P_{\rm ps}$ ($r_{\rm ps}$ and $P_{\rm ps}$ are related by the third Kepler's law). This relation can be used to put an upper (lower) limit for the mass of the primary (secondary) black hole since $r_{\rm d}$ must be smaller than $r_{\rm ps}$. Specifically, we show in Table 1 the physical parameters of a SBHBS in the cases of 3C 120 and 3C 345, assuming that $P_{\rm ps}$ coincides with the median interval between consecutive ejections of jet components.

Concluding, some AGN exhibit signatures of jet precession, such as ejection of superluminal components in different directions with different apparent proper motions, and

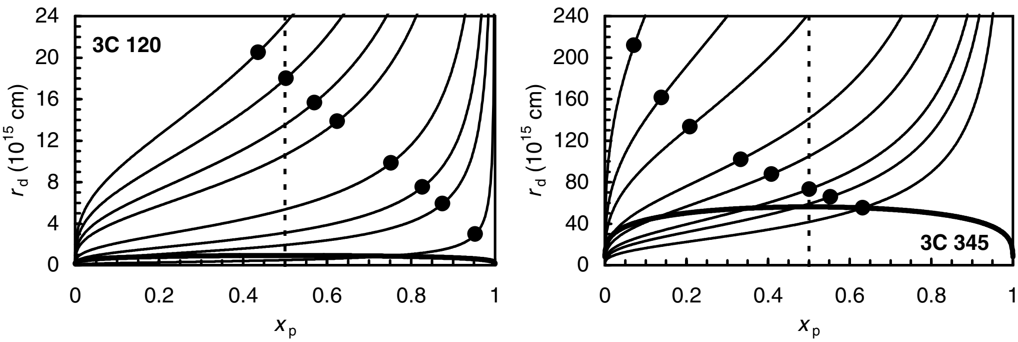

Figure 1. Outer radius of the precessing disc as a function of $x_p = M_p/M_{tot}$. Each continuous line corresponds to a different orbital period, increasing from right to left (the orbital periods measured in the observer' reference frame are 0.5, 1.4, 2, 3, 5, 6, 7.4 and 9 yr for 3C 120, and 4, 5.2, 6.1, 8, 10, 15, 20 and 30 yr for 3C 345). The big circles show the values at which the outer radius of the precessing disk equals the separation between the two black holes. The dashed line marks the position in which the masses of the primary and secondary black holes are equal. The thick line shows the behaviour of r_{ps} for a time-scale due to losses due to gravitational waves of 500 yr (solutions physically acceptable are found above this curve).

Object	P_{ps} (yr)	r_{ps} (pc)	M_p ($M_\odot$)	M_s ($M_\odot$)
3C 120	1.4	0.002	3.0×10^7	4.0×10^6
3C 345	5.2	0.021	4.4×10^9	3.6×10^9

Table 1. Parameters of a possible black hole binary system in the inner parts of the Seyfert I galaxy 3C 120 and the quasar 3C 345.

long-term periodic variability at optical wavelengths (if the underlying jet has enough intrinsic intensity to be detected by an observer). We have shown that these characteristics seen in 3C 120 and 3C 345 can be interpreted as due to precession of their jet inlets. Assuming that jet precession is tidally induced by a secondary black hole in a non-coplanar orbit in relation to the primary accretion disc, we estimated physical parameters of such binary systems in 3C 120 and 3C 345. While the mass of the secondary black hole in 3C 120 is about ten times smaller than the mass of the primary, 3C 345 seems to harbour two black holes with almost the same mass. It suggests that such binary system in 3C 345 might have been formed by a major merger in the past.

References

Abraham, Z., & Carrara, E. A. 1998, ApJ, 496, 172
Caproni, A., & Abraham, Z. 2004a, ApJ, 602, 625
Caproni, A., & Abraham, Z. 2004b, MNRAS, in press
Papaloizou, J. C. B., & Terquem, C., 1995, MNRAS, 274, 987
Romero, G. E., Chajet, L., Abraham, Z., & Fan, J. H. 2000, A&A, 360, 57
Walker, R. C., et al. 2001, ApJ, 556, 756
Webb, J. R. 1990, AJ, 99, 49
Zensus, J. A., Cohen, M. H., & Unwin, S. C. 1995, ApJ, 443, 35
Zhang, X., Xie, G. Z., & Bai, J. M. 1998, A&A, 330, 469