COMPACT DOUBLES: TESTING THE LENSING HYPOTHESIS

GOPAL-KRISHNA AND KANDASWAMY SUBRAMANIAN
NCRA-TIFR, Poona University Campus, Pune 411007, India.

Abstract. If a compact double (CD) is caused by lensing, the orientation and/or flux ratio of its components can substantially change in ≈ 1 year.

1. Compact doubles as gravitationally lensed images

Major surveys using VLBA are underway to find lensed radio sources with separations $\approx 1 - 100$ milliarcseconds (e.g., Patnaik et al. 1995; Wilkinson 1995). Further, it has been suggested that some of the known CDs (Phillips & Mutel 1982) may in fact be such lensed images (e.g., Ostriker 1995). The required lensing agents of $\sim 10^6 - 10^7 M_\odot$ may be remnants of a generation of pregalactic stars or dwarf galaxies. Since the individual components of CDs are ≈ 1 mas, the lensed object is likely to be the radio core of a quasar. Such cores are identified with the base of a relativistic jet pointed roughly towards us (Blandford & Konigl 1979), which is itself often resolved by VLBI into one or more bright emission knots apparently separating at superluminal velocities, $v \sim 5 - 10c$, from a nucleus near the jet's origin (e.g., Vermeulen & Cohen 1994). We suggest that such superluminal motion of radio knot(s) in the lensed source can lead to significant structural variations in the small-separation images, even on time scales of ≈ 1 yr. VLBI monitoring can thus help in distinguishing any (*milli-*) lensed CD images from genuine CDs.

2. Temporal effects in the lensing scenario

For evaluating the temporal changes we concentrate on just the superluminal components (knots); they would dominate the core structure except in the strongly self-absorbed spectral regime. Consider a superluminal knot being multiply imaged by a point-like lens of mass M. The angular positions

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TABLE 1. Evolution of PA (Φ) and flux-ratio (R) for two ejection directions (ψ).

	$\psi = 60^o$		$\psi = 120^o$			$\psi = 60^o$		$\psi = 120^o$	
t (yr)	Φ (deg)	R	Φ (deg)	R	t (yr)	Φ (deg)	R	Φ (deg)	R
0	0	1.5	0	1.5	3	37	2.4	79	1.7
1	19	1.7	30	1.4	4	41	2.8	90	2.0
2	30	2.0	60	1.5	5	44	3.4	97	2.5

of the two images, α, measured from the lens (which is the origin of our coordinate system) are related to the source position β by : $\alpha^2 - \beta\alpha - \theta_L^2 = 0$. Here $\theta_L = 5(D_{LS}/D_L)^{1/2}(D_S/1000\text{Mpc})^{-1/2}(M/3 \times 10^6 M_\odot)^{1/2}$ mas is the Einstein ring radius, and D_S, D_L and D_{LS} are the source, lens and lens-source angular-diameter distances. For a $3 \times 10^6 M_\odot$ lens located roughly midway between us and a source $\sim$ 1000 Mpc away the image separation $\Delta\alpha \sim 2\theta_L \sim 10$ mas, which is characteristic of CDs (Carvalho 1985). Another characteristic is the flux ratio of the components, $R \sim 1$ to 2 (note that $R \simeq 1.5$ if $\beta \simeq \theta_L/5$).

Now, suppose an emission knot initially located on the x-axis at $x = x_A$, moves with $v = \gamma c$ at an angle ψ to the x-axis. After a time t : $\beta^2(t) = x_A^2 + 2l x_A \cos\psi + l^2$, where $l = \dot{\theta} t = \gamma c t/D_S$ with $\dot{\theta} = 0.5(\gamma/8)(D_S/1000\text{Mpc})^{-1}$ mas/yr. The flux ratio is then: $R(t) = (2 + u(t)^{1/2} + u(t)^{-1/2})/(u^{1/2} + u^{-1/2} - 2)$, where $u = [1 + 4\theta_L^2/\beta^2]$. The position angle (or PA) $\Phi(t)$, of the line joining the two images relative to the x-axis varies as : $\tan\Phi(t) = (l\sin\psi)/(x_A + l\cos\psi)$. The evolution of these quantities is given in Table 1, assuming characteristic values $\theta_L = 5$ mas, $x_A = \theta_L/5 = 1$ mas and $\dot{\theta} = 0.5$ mas yr^{-1} (see above). Clearly, substantial variations can occur in the PA and R of the CD, if indeed it results from gravitational milli-lensing of a quasar core. Hence, by imaging a CD with VLBI arrays even $\approx$ 1 year apart one can verify if it is merely an illusion caused due to milli-lensing.

References

Blandford, R.D. & Konigl, A., 1979, ApJ, 232, 34.
Carvalho, J.C., 1985, MNRAS, 215, 463
Ostriker, J., 1995, in Quasars & AGN: High Resolution Radio Imaging, eds. K. Kellermann & M. Cohen (Proc. Nat. Acad. Sci.), in press.
Patnaik,A.R., Garrett, M.A., Polatidis, A. & Bagri, D.S., 1995, these proceedings
Phillips, R. B.& Mutel, R. L., 1982, A&A, 106, 21
Vermeulen, R.C. & Cohen, M.H., 1994, ApJ, 430, 467
Wilkinson, P.N., 1995, in Quasars & AGN: High Resolution Radio Imaging, eds. K. Kellermann & M. Cohen (Proc. Nat. Acad. Sci.), in press