THE RADIO JET IN 3C418 +

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ABSTRACT

Models are here presented interpreting the arcsecond radio structure found in the quasar 3C418 as a precessing jet. No simple solution exists and it has been found necessary to complicate the model geometry by allowing the precession cone-angle to increase with time. The timescales suggest the presence of a close binary black-hole system within the quasar core. The modelled behaviour of the precession cone close to the core is explained either by interaction of the jet with the surrounding galactic material or by the observation of the source during the capture of one black-hole by the other.

INTRODUCTION

Much recent interest has arisen regarding precessing jets in radio-galaxies and quasars following the work of Gower et al. (1982) who suggest that a number of extragalactic radio sources may possess ballistic precessing jets similar to those found in the galactic source SS433. For the quasars in their sample, they derive jet velocities near 0.7c together with precession timescales of order 10^4 years. Begelman, Blandford and Rees (1980) have shown that such periods can be produced by a close binary black-hole system within the quasar core; and that a system undergoing mutual capture could account for those cases where the precession cone-angle increases on timescales comparable with the precession period.

MODELLING

We have attempted to account for the highly curved arcsecond radio structure seen in the quasar 3C418 (z=1.69) with a twin-sided precessing jet model: assuming that the jet velocity remains constant throughout its length and that the precession period and angle between the precession axis and the line of sight do not vary. Since the jet may not be intrinsically smooth, we have concentrated on explaining the observed geometry, the detailed radio brightness distribution being considered to be of secondary importance.

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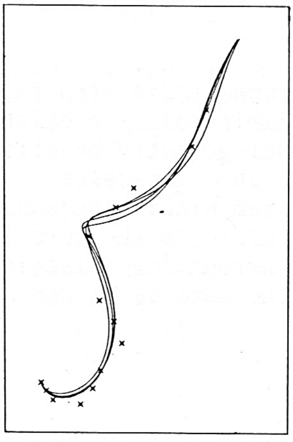
R. Fanti et al. (eds.), VLBI and Compact Radio Sources, 141–143.

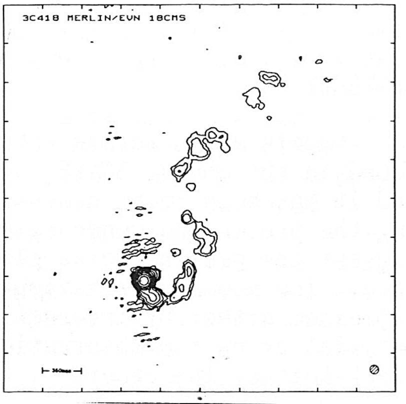
https://doi.org/10.1017/S0074180900077895 Published online by Cambridge University Press

No satisfactory geometrical solution was found for a simple precessing jet, since the extreme curvature of the observed structure within 1 arcsec of the core could not be reconciled with the small degree of curvature in its outer regions. We have thus found it necessary to introduce an additional model parameter: we have allowed the precession cone-angle to increase close to the quasar core (i.e. increase with time). This allows the line of sight to lie within the precession cone for the inner jet region which appears highly curved, whilst lying outside it for the outer jet where the apparent bending is much less pronounced. With the increased complexity of our revised model, no unique solution exists. Many satisfactory fits to the geometry were found. Four representative solutions are shown here (γ= 1.05, 1.41, 2.10, 5.00).



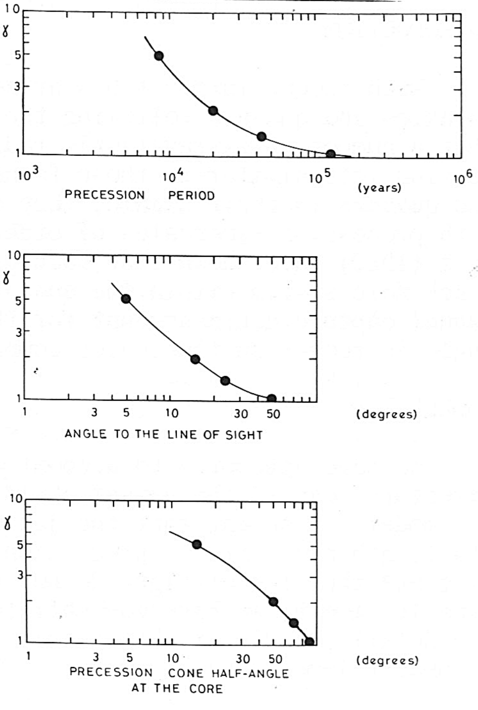
Left:
Ridge-line geometries for the illustrated four solutions overlayed upon component positions taken from the MERLIN/EVN map.

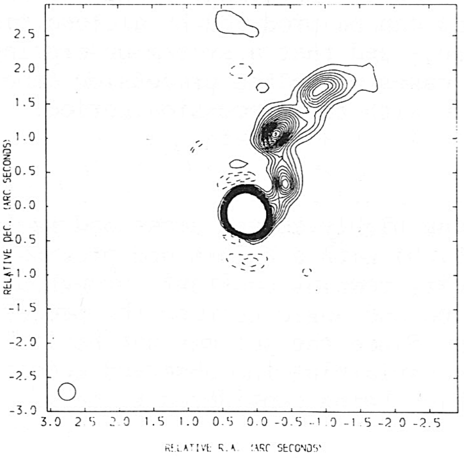
Right:
MERLIN/EVN map at 1.7GHz.



Right:
Model parameters for the illustrated solutions.

Below:
MERLIN map at 1.7GHz.





DISCUSSION

The precession angle opens rapidly within ≃0.2 cycles of the core for all the solutions. At greater distances this angle drops to a few degrees. The slow solutions lie substantially in the plane of the sky, must be intrinsically one-sided, and constitute a short jet with a large precession angle at the core. (The γ=1.05 jet is some 15 kpc in length and has an opening half-angle of precession at the core of 90°), whereas the fastest solutions have jets of length in excess of 100kpc with a much reduced cone-angle at the core. Both the line of sight and precession cone-angles decrease with increasing jet speed. The geometry of the fastest (γ=5.00) solution is compatible with the scheme of Orr and Browne (1982) to unify steep and flat spectrum radio quasars. The precession periods in these solutions are such that they could be produced by a close massive binary black-hole pair within the quasar core.

If the jet motion is purely ballistic, then the behaviour of the precession cone close to the core requires that the cone-angle be changing on timescales of order or shorter than the precession period. This could occur if the black-hole pair were undergoing mutual capture. This, however, places our observations at a very specific epoch in the source history which would seem somewhat contrived, although the probable promotion to a short lived high luminosity state which may be associated with such an event could account for our detection. Alternatively, we may identify the cone-angle behaviour as evidence for non-ballistic motion in the surrounding galactic material. Such bending might arise from fast winds or buoyant refraction. We can estimate the required pressure gradients from the radius of curvature and the observed internal energy density of the jet in this region (≃100mas from the core). Assuming that the jet contains no thermal material we find that in all cases we require that $\nabla p \simeq 10^{-29} Nm^{-3}$. This is insensitive to γ because the faster solutions have lower values of internal energy density and larger radii of curvature. It is possible to envisage circumstances where such a high value of pressure gradient could exist; they do however lie outside the range of environments found in known galaxies.

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https://doi.org/10.1017/S0074180900077895 Published online by Cambridge University Press