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Superluminal Motion in the Parsec-Scale Jet of 3C 380

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Abstract. Multi-epoch VLBI observations of the quasar 3C 380 reveal a bent parsec-scale radio jet with complex substructure and superluminal motion out to ~100 pc from the core.

1. Superluminal Motion and Apparent Acceleration

The quasar 3C 380 (B1828+487) has a complicated, convoluted structure on kiloparsec scales which is consistent with it being a moderate-sized classical double source seen approximately end on (Wilkinson et al. 1991). We have embarked on a long-term study of its nuclear jet using multi-epoch, multi-frequency (λ 1.3, 6 cm, 18 cm) global VLBI observations (Wilkinson et al. 1990, Polatidis & Wilkinson 1997) enlarging the time coverage of our study using previous λ 6 cm and 18 cm VLBI observations from the literature.

Our five epoch λ 6 cm images from 1982.9 to 1993.4 (the 1990.8 image appears in Figure 1a) reveal a highly complex, filamentary, structure which exhibits rapid local brightness changes over its entire $\sim$ 100 pc length. Motion in three regions of the jet can be measured: component **C12**, at a distance 4.5-$5h^{-1}$ pc from the core **C** appears to move outwards with a velocity $0.85 \pm 0.5\ h^{-1}$ c. The bright component **A**, at a projected distance of $20h^{-1}$ to $30h^{-1}$ pc from **C**, moves with an apparent velocity v_{app}= $4.4 \pm 0.5 h^{-1}$ c. Further along the jet, the peak of emission in the region **F**, at $\sim 100h^{-1}$ pc from the core, appears to move with an apparent velocity of $v_{app} = 6.04 \pm 0.3 h^{-1}$ c (Figure 1b).

2. Changes in the Bright Knot

The most dramatic changes in the mas-scale jet of 3C 380 have taken place in the region around the bright component **A** at a projected distance of $20h^{-1}$ to $30h^{-1}$ pc from the **C**. Nonetheless for most of the period between 1982.9 and 1993.4 **A** moved outwards from **C** along P.A. $330 \pm 1°$ with little change in the speed or the direction of the apparent velocity vector. In 1988.4 however, **A** had doubled in brightness and apparently became dissociated from the underlying jet pattern appearing edge-brightened towards the East. This change was accompanied by an apparent deceleration by almost 50%. Between 1988.4 and 1990.8 **A** apparently accelerated again but its brightness barely changed and by 1990.8 its brightness peak had shifted back to its "standard" P.A. and continued in this direction through 1992.7 and 1993.4 with no significant changes in the velocity and only a slight decrease in flux density. The apparent acceleration from $v_{app} \simeq 0.85h^{-1}$ c at a few pc to $\simeq 6.0h^{-1}$ c at $\sim 100h^{-1}$ pc is similar to that seen in the best-studied superluminal source 3C 345 (Zensus, Cohen, & Unwin 1995) and can similarly be accounted for as a simple kinematic effect if the base of the jet is at a small angle $< 1^\circ$ to the line of sight and then the jet bends $\sim 10^\circ$ away as it dips below our detection threshold, but the changes in **A** cannot be accounted for in such a simple kinematic effect (Polatidis & Wilkinson 1997).

3. Rapid Local Brightness Changes

The most surprising feature of our maps is that there are gross changes in the brightness structure of the jet taking place very quickly. For example in three epochs (1988.2, 1990.8 and 1993.4) the jet appears to be bifurcated or edge-brightened in regions **B** and **D** while in others it is center-brightened. These changes seem to occur on a timescale shorter than one year (e. g., between 1992.7 and 1993.4) and our time-sampling was insufficient to characterize them in detail. The maps bear a marked resemblance to the numerical jet simulations of Hardee & Norman (1989) who showed that rapid growth of sinusoidal modes can disrupt a jet and produce a rich spectrum of moving oblique shocks. We therefore, suggest that the rapid brightness changes may be due to phase effects at the intersection of these shocks (see Polatidis & Wilkinson 1997).

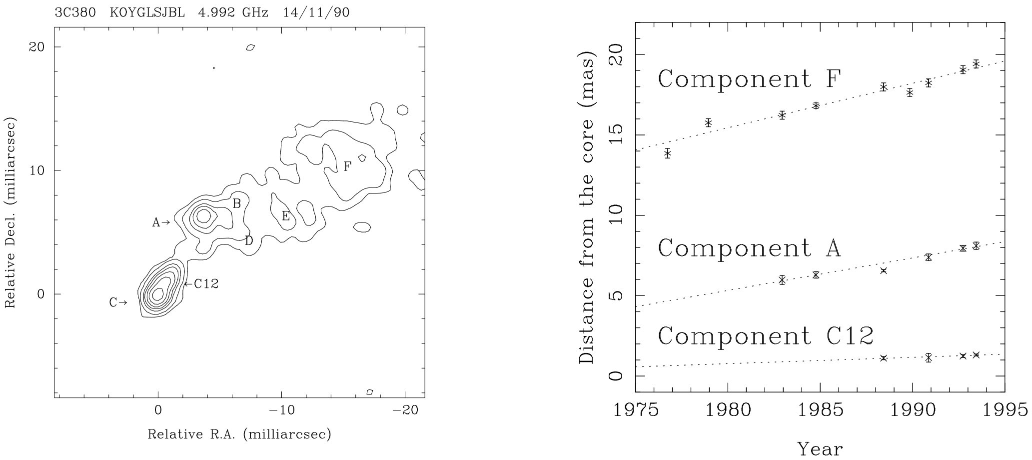

Figure 1. (a) The λ 6cm VLBI map from 1990.8 convolved with a 1mas circular beam, (b) Distance of components C12, A and F from the core as a function of time. The lines represent weighted least squares fit to the distance.

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