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S5 0836+710 A Kelvin-Helmholtz Unstable Jet on Parsec Scales?

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Abstract. The highly redshifted quasar S5 0836+710 (z = 2.172) displays an outstanding one sided jet with complex morphology. The continuous jet shows several remarkable lateral displacements (kinks) of its ridgeline on various length scales. Despite the strength of these distortions the jet is not destroyed by them and remains well collimated. We investigated the possibility to explain the displacements by Kelvin-Helmholtz instabilities.

Observations conducted at 5 GHz and 22 GHz were analysed for this investigation. In addition 1.7 GHz/326 MHz maps (Hummel et al. 1992, Krichbaum et al. 1990) were used to determine the ridge line at larger distances from the core. The high resolution image at 22 GHz showed two lateral displacements (B3, C1, Otterbein et al. 1997) which were not resolved by previous experiments conducted at lower frequencies.

Lateral displacements of the jet axis in S5 0836+710 appear over a range of 0.3 mas − 110 mas (1.4 pc − 440 pc). Thus, it seems to be unlikely that locally implied distortions to the jet are responsible for their appearance. A more general mechanism must be at work. One possible explanation for the appearance of the kinks might be the presence of Kelvin-Helmholtz instabilities. In the following the growth of the displacements along the jet will be studied and interpreted in the framework of KH-instabilities. The displacements will be identified with the helical fundamental KH-mode.

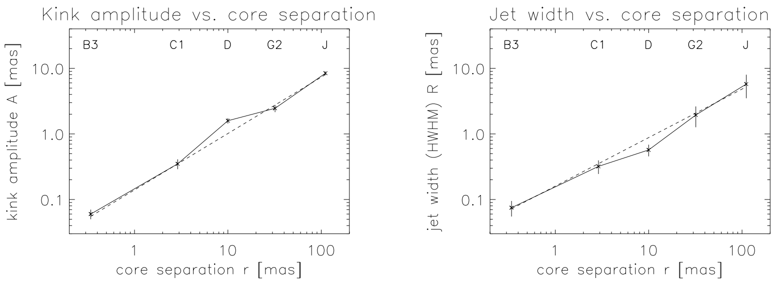

Figure 1. The amplitude of the displacements (left) and width of the jet at the position of the kinks (right) both versus core separation. Except for the D kink the amplitude and the width of the jet increase while following power laws (dashed lines).

In Figure 1 the growth of the amplitude of the displacements and the increase of the jet width are plotted, both versus distance. Both quantities follow power laws ($A = 0.14 \cdot (r/r_0)^{0.86}$ and $R = 0.16 \cdot (r/r_0)^{0.74}$). Following Hardee

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(1987, Eq. 17b) from the power law growth of the amplitude and assuming a relativistic plasma ($\mathrm{M} = \sqrt{2} \cdot \Gamma$) a lower limit to the plasma flow could be estimated: $\Gamma > \left[\mathrm{r_0}/(\sqrt{2} \cdot \mathrm{d_n} \cdot \mathrm{R_0})\right]^{1/2} \Longrightarrow \underline{\Gamma > 2.3}$ in agreement with the Lorentz factor of the jet components ($\Gamma_{\mathrm{comps}} \sim 10$).

Kink D: Obviously the kink at the position of the D component has a higher kink amplitude than given by the power law, indicative of a higher growth rate of the instability. According to Hardee (1987) the growth rate of the instabilities depends on the jet geometry: For a cylindrical jet growth is exponential ($\mathrm{A} = \mathrm{A_0}\ \exp(\mathrm{r}/\mathrm{l_e})$) instead of a power law as for an expanding jet. From Krichbaum et al. (1990) there is evidence for a constant jet width in the range of 5 mas $\leq$ r $\leq$ 10 mas. Also indicated by the smaller width of component D in Figure 1 (right). Thus, the higher kink amplitude of D might result from a change of the jet geometry. The e-folding length of the jet could be estimated assuming that the jet stopped expanding and the instability started to grow exponentially at $\mathrm{r_a} = 5\,\mathrm{mas}$. Calculating the kink amplitude at $\mathrm{r_a}$ from the power law and measuring the present day amplitude from the maps the e-folding length is: $\underline{\mathrm{l_e} = 4.8\,\mathrm{mas}}$. Following Hardee, Cooper & Clarke (1994, Eq. 17) and assuming again a relativistic jet plasma temperature one can estimate a lower limit of the Lorentz factor of the jet flow from the e-folding length: $\Gamma^2 = \mathrm{l_e}/(\sqrt{2} \cdot \mathrm{R}) \Longrightarrow \underline{\Gamma > 1.8}$ which agrees with the previously obtained value.

The density ratio η (jet to external medium): From the above determined e-folding length a rough estimation of the density ratio $\eta = \varrho_{\mathrm{j}}/\varrho_{\mathrm{ISM}}$ could be calculated. Following Hardee (1982, Eq. 28; 1987, Eq. 16 and $\Gamma = \mathrm{b_n} \cdot \mathrm{r_0}/(\mathrm{d_n} \cdot \mathrm{M_{j,0}} \cdot \mathrm{R_0})$ η is given by: $\eta^{1/6} = \mathrm{R_0}/\mathrm{R} \cdot \mathrm{l_e}/\mathrm{r_0} \cdot \pi/(1.6 \cdot \mathrm{d_n}) \cdot (\mathrm{r}/\mathrm{r_0})^{(2\varepsilon - \mathrm{a})/2} \Longrightarrow \underline{\eta = 84}$. The approximations used neglect the specific enthalpy one has to take care of in a relativistic jet plasma and the value obtained for η has to be corrected by the (unknown) ratio of the enthalpies: $\mathrm{h_j}/\mathrm{h_{ISM}}$ (Martí et al. 1994). Thus, the value of η might be reduced. However, even a reduced value of η argues for a "heavy" jet ($\Gamma^2\eta \gg 1$) due to the high apparent velocities observed.

In summary, applying the theory of Kelvin-Helmholtz instabilities seems to be capable of describing the jet of S5 0836+710 reasonably well. However, given the presence of a strong magnetic field (Hutchinson & Cawthorne, these proceedings, p. 125) a magneto-hydrodynamical theory might provide a more accurate description of the jet.

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