Astrophysical Phenomena Revealed by Space VLBI
H. Hirabayashi, P.G. Edwards and D.W. Murphy (eds.)

VSOP Monitoring of 1928+738

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Abstract

In the paper we present the results from a VSOP monitoring campaign on the low redshift (z=0.3) circumpolar superluminal quasar 1928+738. Our five epochs of data show that there have been substantial structural changes in this source near the core on the time-scale of a few months.

1 Introduction

1928+738 is in the S5 polar cap sample and has been well studied on both the arcsecond-scale and mas-scale. Proper motions have been detected in several distinct jet components with values that lie in the range 0.27–0.36 mas yr^{-1} (Hummel et al. 1992; Ros et al. 1999) which leads to apparent speeds in the range 4.8–6.5 c for $H_0 = 65\,km\,s^{-1}\,Mpc^{-1}$. The 22 GHz work of Hummel et al.(1992) showed that the motion of the VLBI components in 1928+738 was not consistent with simple linear expansion along a fixed position angle (PA) for all components. Indeed, 1928+738 was one of the first sources for which helical jet motion was proposed. Expanding upon this work, Roos et al. (1993) proposed that a massive binary black hole (MBBH) system is responsible for the sinusoidal jet ridge line observed at 22 GHz over a 5 year period. The phase of this sinusoid, in the plane of the sky, varies by ≈ 0.28 mas yr^{-1}, which implies a period in the rest frame of the quasar of 2.9 years within the framework of a ballistic relativistic jet model. A period this short is unlikely to be caused by geodetic precession of the primary black hole as the implied gravitational lifetime is then extremely short (~10 years!). A more realistic scenario is to assume that the observed period is associated with the binary orbital period. An alternative to the ballistic relativistic jet model is to assume that the observed wiggles in the jet are caused by Kelvin-Helmholtz (KH) instabilities also driven by the orbital motion of the MBBH system.

2 1928+738 VSOP Images

Figure 1, and Color Figure 3, show 5 GHz images of the core and inner jet region of 1928+738 from our five epochs of data. These epochs are 1997 August 22, 1997 December 16, 1998 April 29, 1998 July 9 and 1999 June 16. Each image has a size of 6 mas by 6 mas and our typical observation included the use of HALCA, the VLBA, Effelsberg and a second European antenna.

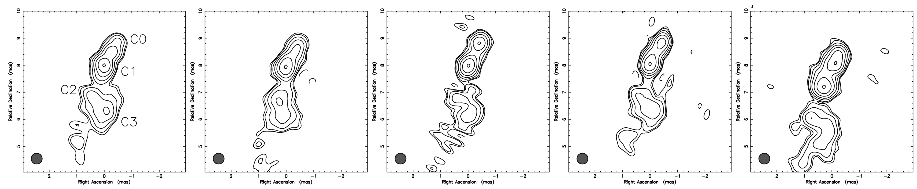

Figure 1: 5 GHz images from the 5 epochs of 1928+738 monitoring.

As can be seen, there are very distinct structural changes in this region during the period of our monitoring observations. The core is located in the northern most part of the image and is not a bright feature on the early images. In the later 3 epochs the core can be seen to be flaring and in the last epoch there is evidence of the ejection of a new component. However, at a distance of roughly 2.3 mas from the core the jet goes through a large apparent bend followed by another large bend after which the jet has roughly the same position angle as the initial jet direction.

3 Component Properties

We have model-fitted the core region of 1928+738 using 4 components which we call C0, C1, C2, and C3. The location of these components are shown in the first image in Figure 1. C0 is the core while C1, C2, C3 are jet components located progressively further down the jet from the core. Figure 2 shows the proper motion of these components with respect to the core. Least squares fitting gives proper motion of the components C1, C2, and C3 to be 0.34 ± 0.07, 0.09 ± 0.08, and 018 ± 0.07 mas $^{-1}$ respectively. For $H_0 = 65$ km s^{-1} Mpc^{-1}, this corresponds to apparent speeds (in units of c) to be 6.1 ± 1.3, 1.6 ± 1.4, and 3.2 ± 1.3 for components C1, C2, and C3 respectively. These speeds are similar to what has been derived in previous studies of this source (Hummel et al. 1992 and Ros et al. 1999). The behavior exhibits several features which are now seen in increasing numbers of VLBI sources. Namely, we have both stationary (C2) and moving components (C1, C3). Furthermore there is evidence that the apparent speed increases as we go away from the core since the speed of C3 is higher than that of C1. This may be explained as either real acceleration of the jet or by simple projection effects namely that the jet is curving slightly away from our line of sight as the it leaves the core. An examination of the position angle (PA) variations of the components, as displayed in Figure 3, shows that C1 and C3 are moving away from the core at different PAs. There is some evidence for the PA of each component to be changing with time and for there to be oscillations about this linear PA evolution. Such PA changes seem to rule out simple ballistic motion for the components and oscillations in a helical jet seems an attractive explanation worth pursuing further.

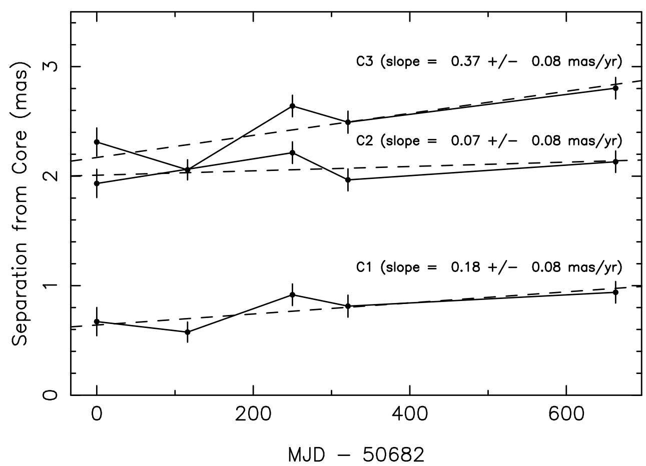

Figure 2: Separation of components from the core (C0).

4 Summary

We have imaged 1938+378 at 5 epochs that span a time range of almost 2 years. In that time, we have observed a variety of structural changes in the inner jet region near the region. As is the case for an increasing number of sources real jet motions can be very different from the simple

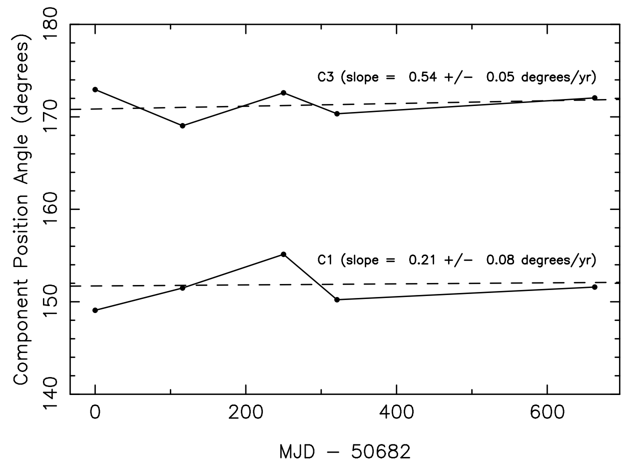

Figure 3: Position angle evolution for C1 and C3.

model of a straight jet with components moving at constant apparent speed. In 1928+738, we have examples of a variety of different phenomena: stationary components, components moving with different speeds along different position angles which themselves are changing with time. More work is needed to clarify under what new framework the diverse motions exhibited by the inner jet components of this source can now be explained.

Acknowledgements. We gratefully acknowledge the VSOP Project, which is led by the Japanese Institute of Space and Astronautical Science in cooperation with many organizations and radio telescopes around the world.

References

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Roos, N., Kaastra, J.S., & Hummel, C A. 1993, *AJ*, **409**, 130

Ros, E., Marcaide, J. M., Guirado, J. C., et al. 1999, *A&A*, **348**, 381

Corrections to VSOP Symposium Proceedings
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* In the contents, the author list for the paper starting on page 79
  is incomplete and should read
  "Ignas Snellen, Wolfgang Tschager, Richard Schilizzi et al."

* In the preface, "Orian-KL" should be "Orion-KL"!!!

* The caption to Color Figure 3 refers to the source 1928+734,
  which should be 1928+738.

* In the summary section on page 49 (Murphy et al.), the sentence
  "In that time, we have observed a variety of
   structural changes in the inner jet region near the region."
  should read
  "In that time, we have observed a variety of
   structural changes in the inner jet region near the core."

* In the references on page 175 (Fomalont et al.) and page 182
  (Moellenbrock et al.) "Fomalont et al. 2000" should be updated to
  "Fomalont, E.B., Frey, S., Paragi, Z., Gurvits, L.I., Scott, W.K.,
  Edwards, P.G., Hirabayashi, H., 2000, ApJS, 131, 95"

* On page 217 (Lovell et al), the fourth line of the final paragrpah of
  section 1 should say "(see figure on page xviii)"

* In the references on page 233 (Sambruna) an extraneous "439"
  was introduced during the editing process into the reference
  for Catanese 1999.

* In the First Author List on page 327 (in the Index), the following
  line is missing
  Junor, W.   13