Available online at www.sciencedirect.com
SCIENCE DIRECT
New Astronomy Reviews 47 (2003) 633–635
New Astronomy Reviews
www.elsevier.com/locate/newastrev

Multi-epoch VSOP observations of 1928+738

D.W. Murphy[a,*], R.A. Preston[a], H. Hirabayashi[b]

[a] Jet Propulsion Laboratory, MS 238-332, 4800 Oak Grove Drive, Pasadena CA 91109, USA
[b] Institute of Space and Astronautical Science, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan

Abstract

We have undertaken a series of eight VSOP observations of the relatively low-redshift ($z = 0.3$) core-dominated quasar 1928+738 in order to test the claims by Roos et al. [AJ 409 (1993) 130] that on the pc-scale this source shows evidence of a super-massive binary black hole system in the form of a precessing ballistic relativistic jet. We have detected a wide range of proper motions from nearly stationary (0.02 mas/yr or 0.5c) to relatively fast (0.82 mas/yr or 19c). We also find that the observed kinematics are more consistent with a ballistic precessing relativistic jet model than a relativistic helical jet model.

Keywords: Radio continuum: galaxies quasars: individual (1928+738)

1. Introduction

Roos et al. (1993) proposed that a massive binary black hole (MBBH) system is responsible for the sinusoidal jet ridge line observed in 1928+738 by Hummel et al. (1992) at 22 GHz over a 5-year period. The phase of this sinusoid, in the plane of the sky, varies by $\approx$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 (Roos et al., 1993). 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.

We decided to undertake a VSOP monitoring campaign on this source due to its interesting nature (as described above) and for the practical reason that due to its high ecliptic latitude it always meets the HALCA solar constraints.

2. Observations

In Table 1 we present a summary of our eight epochs of 5 GHz VSOP observations. For the seventh epoch of data (e7) no HALCA data was obtained due to a recorder failure at the tracking station. As can be seen we typically observed the source for about 2 HALCA orbits using the 10-element VLBA in combination with other northern hemisphere radio telescopes. In Figs. 1 and 2 we show VSOP images and ground-only images respectively. In the VSOP images, a pronounced S-shaped bend can be seen a few mas from the core (assumed to be located at the northern most point of the jet)

*Corresponding author. Tel.: +1-818-393-4992; fax: +1-818-354-3437.
E-mail address: david.w.murphy@jpl.nasa.gov (D.W. Murphy).

1387-6473/03/$ – see front matter
doi:10.1016/S1387-6473(03)00110-6

Table 1
Observation summary

Epoch	Observation date	Observation length (h)	Ground radio telescope array[a]
e1	22 Aug 1997	11.8	VLBA + EF + TR
e2	16 Dec 1997	8.0	VLBA + EF + UD
e3	19 Apr 1998	15.0	VLBA + EF + NT + UD
e4	09 Jul 1998	16.0	VLBA + EF + GB
e5	16 Jun 1999	16.0	VLBA + EVN(6) + GB
e6	07 Sep 2000	12.0	VLBA + UD
e7[b]	27 Feb 2001	10.0	VLBA + EF
e8	03 Sep 2001	10.0	VLBA + EF

[a] Telescope codes: EF = Effelsberg; EVN(6) = EVN (with 6 elements used); GB = Green Bank 140′; NT = Noto; TR = Torun; UD = Usuda; VLBA = 10-element VLBA.
[b] No HALCA data for e7 (due a tracking station recorder hardware failure).

whose properties are changing with time. In the ground-only images we can trace the jet much further from the core than on the VSOP-images due to the enhanced surface brightness sensitivity.

3. Discussion

We have undertaken extensive model-fitting on the images presented in Figs. 1 and 2 and have compared our observed results to the predictions of both ballistic relativistic jet and helical relativistic jet models. In 1928 + 738 we have measured a large range of component proper motions. Futhermore, near the core components move in quasi-straight lines with no single unique trajectory. In particular, components do not move around the bend which is located about 2 mas from the core. These result favor the ballistic relativistic jet model compared to the helical relativistic jet model and indicate the jet collimation must be occurring further down the jet than the apparent jet bend at 2 mas (≈20 pc) which we interpret as an illusion as opposed to a real bend seen in projection.

4. Summary

In 1928 + 738 we have detected a wide range of proper motions/speeds with components moving in roughly straight lines (but not the same straight line). Our model-fitting shows that a relativistic variable speed ejecta ballistic jet model, with variable-speed ejecta, is preferred over a relativistic helical jet model. Furthermore, the jet is being collimated at a projected distance beyond the bend located at ≈ 20 pc from the core and not in the core region itself.

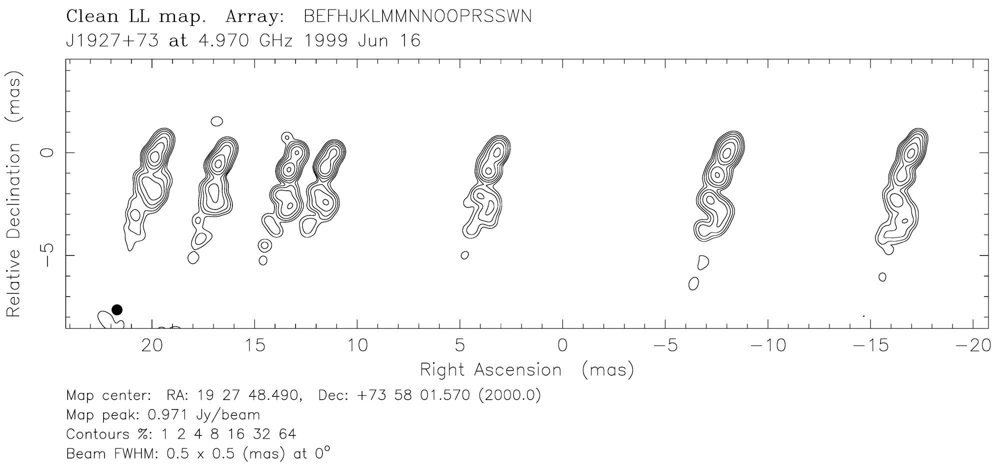

Fig. 1. VSOP images from the seven epochs of 5 GHz observations for which HALCA data was obtained. Images are shifted westwards by 9.1 mas times the time elapsed in years between the observation epoch and the first epoch. A 0.5 mas circular restoring beam is used for all images.

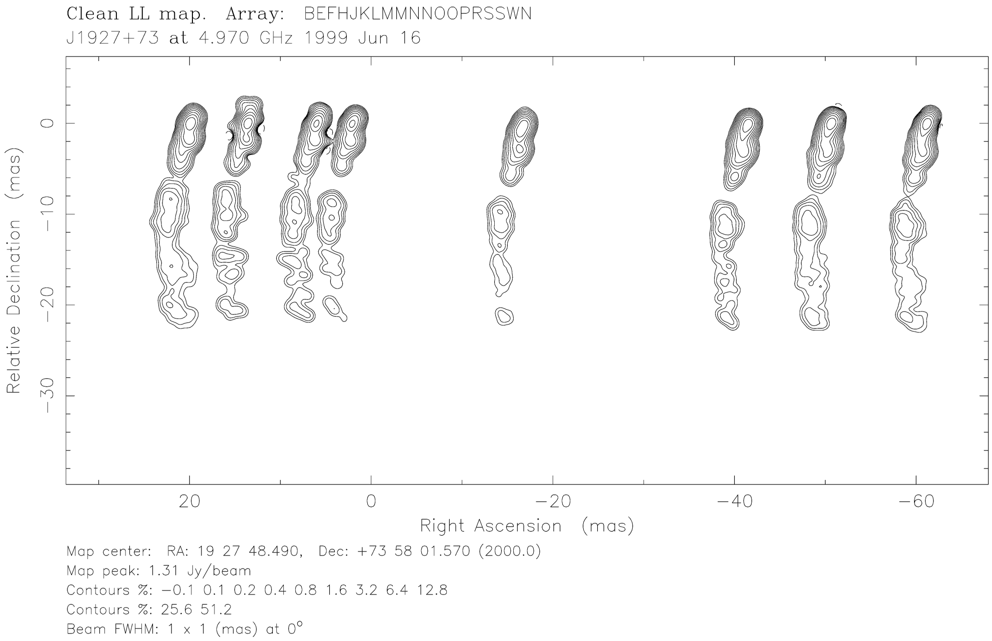

Fig. 2. Ground-only images from the eight epochs of 5 GHz observations. The images are shifted westwards by 20.1 mas times the time elapsed in years between the observation epoch and the first epoch. A 1.0 mas circular restoring beam is used for all images.

Acknowledgements

Part of this research was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA. 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

Hummel, C.A., Schalinski, C.J., Krichbaum, T.P., Rioja, M.J., Quirrenbach, A., Witzel, A., Muxlow, T.W.B., Johnston, K.J., Matveenko, L.I., Shevchenko, A., 1992. A&A 257, 489.

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