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Towards a determination of H_0 in JVAS B1030+074: a detection of the VLBI jet in both images

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We have recently measured the time delay between the two images of the gravitational lens system JVAS B1030+074 using archival VLA monitoring data. Impressive polarization variability gives a value of 146 ± 6 d for this long sought-after parameter. In principle, it is now possible to determine H_0 with this lens and focus must now turn to improving the lens model. VLBI can potentially provide modelling constraints if the lensed source contains a radio jet, but although a prominent example is seen in the brighter image, its counterpart in the fainter (and therefore smaller) image has never been convincingly detected. We have performed our own analysis of the existing VLBI 1.7-GHz data and demonstrate that in fact the jet in image B is observable and see similar structures in multiple epochs. We also discuss prospects for detecting the third image in this system.

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1. Introduction

A measurement of the time delay between pairs of images in gravitational lens systems allows a single-step measurement of H_0 and can, in these times of tension [2], help to resolve the discrepancy between the latest CMB and Cepheid-based determinations. We recently began a systematic reanalysis of large amounts of VLA monitoring data from the period covering approximately 1996 to 2002 with an emphasis on calibrating the polarization response of the antennas and producing variability curves of percentage polarization and EVPA.

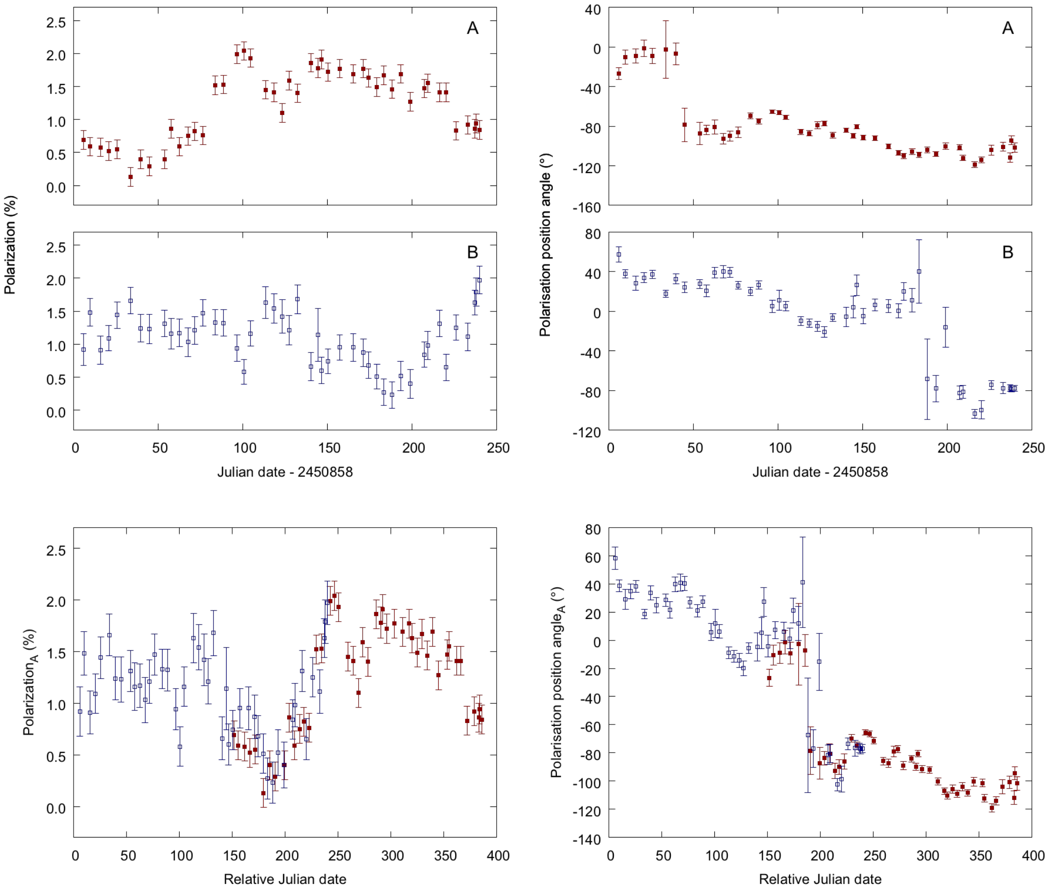

Figure 1: Top: Percentage polarization and EVPA of image A (red) and B (blue) as derived from VLA 8.4-GHz monitoring data. Bottom: Combined A and B plots after removal of the time delay.

As hoped for, the magnitude of the polarization variability is generally greater than that in total intensity and has resulted in the first measurement of the time delay in the two-image lens system JVAS B1030+074 [4]. The total flux density variations seen by the VLA at 8.4 GHz during 1998 were previously published [3] and we find the same result: no variations are visible that are common to the two images, A and B. In stark contrast, the pattern of the percentage polarization variability is the same in each image, but with a clear time delay. Most strikingly, the EVPA undergoes a rapid 90-degree swing corresponding to a minimum in the magnitude of polarization and this is obvious in both images. Biggs report a time delay of 146 ± 6 d (1 σ). The percentage polarization and EVPA variability curves are shown in Fig. 1.

JVAS B1030+074 now becomes a candidate for measuring H_0. However, this can only be done if a good model for the mass distribution in the lens can be found. The predicted time delay from initial mass modelling (112 d for $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$) was very different to the measured value, indicating that the model is not a good representation of the lensing mass. Two-image systems give few model constraints and thus we must find an additional way of constraining the mass model.

2. VLBI Imaging of the radio jet in JVAS B1030+074

Initial VLBI imaging at 5 GHz [4] demonstrated that image A (the brighter image) contained a prominent radio jet. Subsequent imaging (mainly with global VLBI arrays) at 1.7 GHz detected more of the jet and had much higher sensitivity and improved (u, v) coverage. However, no convincing detection of the counterpart to the jet in image B proved possible [5]. The reason for this is straightforward – the flux ratio (A/B) is an impressively large 12.5. This ratio corresponds to the ratio of the surface areas of each image and thus image B is 12.5 times smaller than A. This makes detecting the jet in image B very difficult.

B1030+074 has been observed many times by VLBI arrays at various frequencies, predominantly at 1.7 GHz. Given the new detection of the time delay it seemed worthwhile to perform our own analysis and as such we have begun a programme to recalibrate and image all the existing VLBI data. Here we present the first results of this exercise, namely maps made from project GX007 observed in February 2001 at 1.7 GHz. Our new maps are shown in Fig. 2 and demonstrate fairly conclusively that the jet in image B has been detected to the south-west of the core. The synthesized beam is unfortunately very elliptical due to the low declination and thus we also show a map restored with a circular beam – this shows the jet more clearly.

3. Conclusions and future work

We have presented what we believe to be the first reliable detection of the radio jet in image B of JVAS B1030+074. Imaging of the remaining VLBI data will continue, including VSOP data at 5 and 1.7 GHz which have never been published. We have also been awarded time to observe this source with the EVN at 5 GHz in the October 2018 session. These new data will greatly surpass the previous data in terms of sensitivity and should yield the clearest image yet of the jet in image B.

The new maps will hopefully lead to a better lens model for this system and the possibility of an H_0 determination. At the same time, the new EVN data in particular will be used to search for the third image. For most lenses only an even number of images are seen, but an additional image located close to the lensing galaxy should be present. The brightness of this image can be used to place constraints on the slope of the mass distribution at the centre of the lensing mass [6].

References

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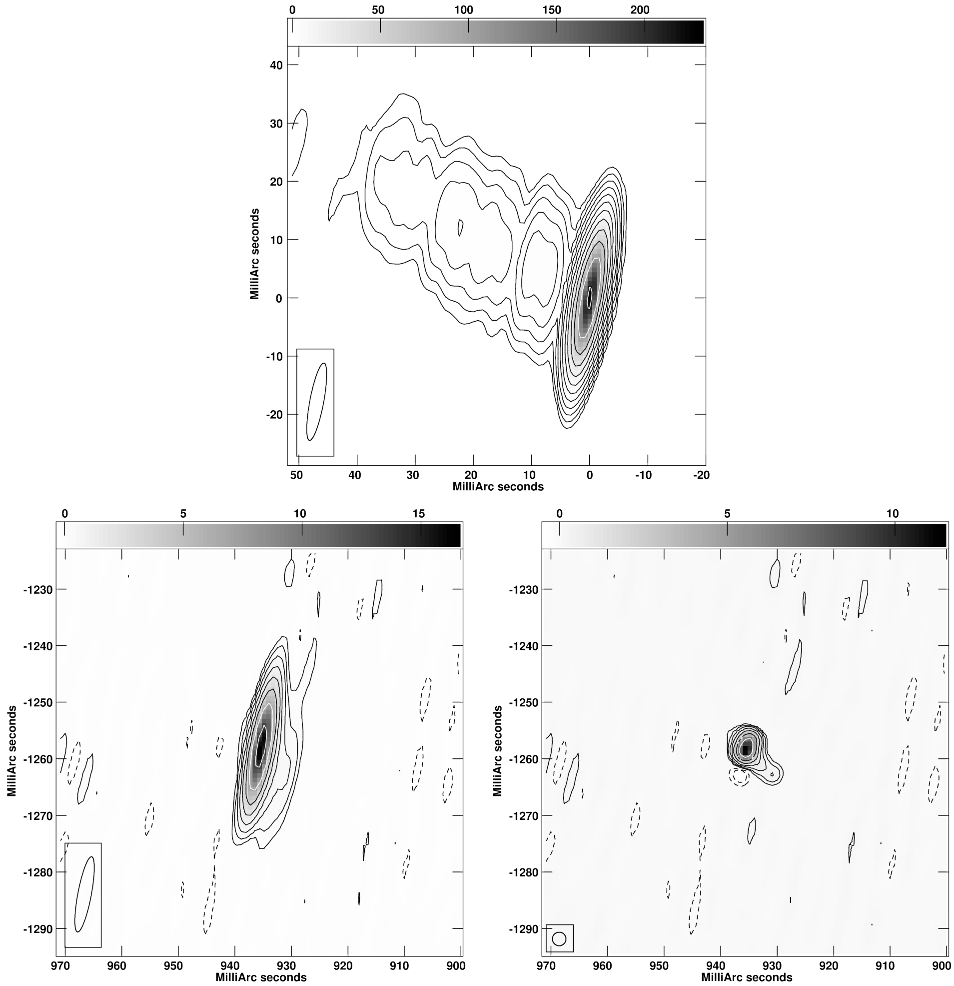

Figure 2: Global VLBI 1.7-GHz images of image A (top) and image B (bottom) of JVAS B1030+074. In our reanalysis of these data there is a distinct bulge in image B at a position angle of 180 degrees relative to that seen in image A. To show the jet more clearly we have also restored image B's clean components with a circular beam of equal to the minor axis of the real beam (right). Contours increase in powers of two from 3 times the rms noise (34 μJy beam^{-1}).

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