Gravitational lens time delays using polarization monitoring

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Gravitational lens time delays provide a means of measuring the expansion of the Universe at high redshift (and therefore in the "Hubble flow") that is independent of local calibrations. It was hoped that many of the radio lenses found in the JVAS/CLASS survey would yield time delays as these were selected to have flat spectra and are dominated by multiple compact components. However, despite extensive monitoring with the VLA, time delays have only been measured for three of these systems (out of 22). We have begun a programme to reanalyse the existing VLA monitoring data with the goal of producing variability curves in polarized flux and polarization position angle, either to improve delay measurements or to find delays for new sources. Here we present the first preliminary results on the lens system B1600+434 which demonstrate the presence of correlated and substantial polarization variability in each image.

Introduction

The JVAS and CLASS surveys observed over 16,000 flat-spectrum radio sources with the VLA at 8.4 GHz and identified 22 of these as gravitational lens systems through higher-resolution follow-up. The flat-spectrum criterion was designed to select sources that were dominated by compact emission and which would therefore be a) easily identifiable as lens systems and b) likely to vary in brightness as a function of time. It was hoped that monitoring observations would allow the measurement of the time delays in many of these systems and thus allow multiple determinations of H_0. However, despite many monitoring campaigns (the majority with the VLA at 8.4 GHz) time delays have only been measured for three of the 22 systems: JVAS B0218+357 (Biggs et al. 1999, Cohen et al. 2000), CLASS B1608+656 (Fassnacht et al. 2002) and CLASS B1600+434 (Koopmans et al. 2000).

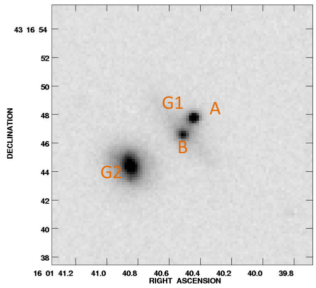
The case of B0218+357 is interesting as the lensed source is highly polarized (≤10%) and the variability of the polarized flux density is particularly pronounced (see Thursday's talk by A. Biggs). Other JVAS and CLASS lenses are also polarized, but monitoring of the polarization seems to have been discounted by most observers as a method of measuring the time delay, probably due to the very low polarized flux densities involved and the need to include dedicated polarization calibrators during the typically short monitoring observations. B0218+357 therefore remains the only lens system for which a time delay has been measured using polarization data. However, given the fact that radio sources are often more variable in polarization than in total flux density, we have begun an analysis of archival VLA data to investigate whether these can be used to measure additional time delays via polarization variability. Here we present preliminary results on B1600+434.

B1600+434

B1600+434 is a two-image lens system (Koopmans et al. 1998) for which time delays were originally measured in the radio (47±6 days, Koopmans et al. 2000) and the optical (51±4 days, Burud et al. 2000). However, no correlated features were present in the radio data and the published delay was reliant upon a measurement of the flux ratio from a previous, unpublished monitoring campaign. Also, both the optical and radio data show evidence of variability that is not intrinsic to the lensed source (even in the radio this might be due to microlensing – Koopmans & de Bruyn 2000) which complicates the time-delay determination.

A much more robust time delay has since been measured with further seasons of VLA monitoring (Berciano Alba 2009) but the question arises as to whether the delay could have been measured more efficiently using polarization monitoring. The lensed source is polarized although this has received very little attention in the literature.

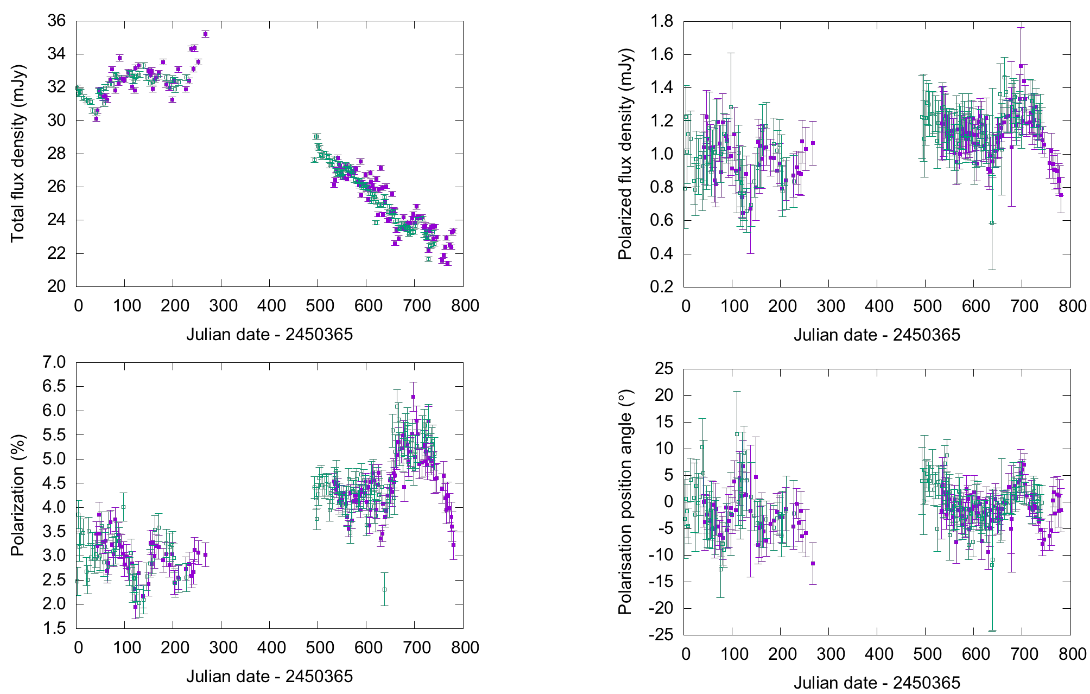
Here we present a preliminary reduction of two seasons of the VLA 8.4-GHz monitoring data for B1600+434, including polarization. The first season corresponds to the unpublished data mentioned above, whilst the second season is the published data of Koopmans et al. (2000).



Right: I-Band Nordic Optical Telescope image of B1600+434 showing the two lensed images A and B, the main lensing galaxy (edge-on spiral) and a secondary lensing galaxy (Koopmans et al. 1998). Both galaxies are at z=0.4144.

Data reduction and results

The data were calibrated in AIPS and the image flux densities measured via modelfitting to the u,v data in Difmap. No traditional polarization calibrators were observed during the second season, but one of the flux-density calibrators (1943+546) is an unpolarized Compact Symmetric Object (CSO) which we have successfully used to derive the polarization leakage (D-terms) using PCAL. The polarization position angle (PPA) was calibrated using 3C286 for the first season, whilst for the second season we have used another CSO which appears to be non-variable in polarization. Although weak (polarized flux ≅ 10 mJy) this is significantly brighter than either image of B1600+434 and seems to work well as a PPA calibrator.



Above: Variability curves of B1600+434 in total flux density (top-left), polarized flux density (top-right), percentage polarization (bottom-left) and PPA (bottom-right). In each case, a time delay of 40 days has been assumed to shift the A data (purple) relative to B. Externally induced variability of image A is responsible for the larger scatter of that image's total flux density.

Conclusions and future work

We have shown that significant short-term polarization variability (by a factor of two) was present during the first two seasons of monitoring of B1600+434 with the VLA, despite the total flux density displaying little correlated variability. It has been possible to measure this despite the very low polarized flux density (≅1 mJy) and a complete absence of standard polarization calibrators. We strongly recommend that future monitoring campaigns include sources suitable for polarization calibration.

It is our intention to analyse VLA archival data on other lens systems without robust time delays to search for variations in the polarization properties of each image. Very preliminary analyses of JVAS B1422+231 (Patnaik et al. 1992) and JVAS B1030+074 (Xanthopoulos et al. 1998) suggest that such variability is ubiquitous.

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