Polarisation Observations of Gravitational Lenses

A. R. Patnaik\textsuperscript{1}, K. M. Menten\textsuperscript{1}, R. W. Porcas\textsuperscript{1}, A. J. Kemball\textsuperscript{2}

\textsuperscript{1}Max-Planck-Institut für Radioastronomie, Bonn, Germany
\textsuperscript{2}National Radio Astronomy Observatory, Socorro, USA

Abstract.

We present multi-frequency VLA polarisation observations of nine gravitational lenses. The aim of these observations was to determine Faraday rotation measures (RM) for the individual lensed images, and to measure their continuum spectra over a wide range of frequencies.

1. Introduction

Radio polarisation observations of gravitational lenses provide important information about the properties of the lens as well as the background radio source. Such observations give two measurable quantities – the degree and position angle (PA) of polarisation. Both are unaffected by the gravitational potential of the lens. However, the magneto-ionic medium in the lens can cause Faraday rotation of the radiation, which may be different for each of the ray paths. The magnitude of this differential rotation measure (RM) may provide clues to the nature of the lensing galaxy; a gas-rich lens is expected to give rise to a larger value than a gas-poor one. The polarisation properties can also be used to discriminate between candidates in surveys for gravitational lenses. In addition, given that both the degree and PA of polarisation in a compact radio source may vary in time, permits independent measurements of the time delay.

There are, however, difficulties in the interpretation of polarisation measurements, which arise mainly because many radio sources have extended structure, and the spectral and polarisation characteristics change across the source. Polarisation variability, and the existence of time delays between images, may combine to make difficult a comparison of their properties at a single observing epoch.

2. Observations and Results

We observed 9 radio lensed systems in which a compact core is multiply imaged. The observations were made on 1998 May 22/23 using the NRAO VLA in A-configuration in the 1.4, 5, 8.4, 15, 22 and 43-GHz bands. Here we provide only a summary of our results; further details will be published elsewhere. References for individual sources are available at the CASTLES web-site for gravitational lenses [http://cfa-www.harvard.edu/glensdata/] maintained by C.S. Kochanek, E.E. Falco, C. Impey, J. Lehár, B. McLeod and H.-W. Rix.
B0218+357 Our fits of RMs to the present data yield $-8920 \pm 250$ rad m$^{-2}$ for image A, and $-7920 \pm 220$ rad m$^{-2}$ for B. These values differ from earlier measurements (Patnaik et al., 1993). However, a fit to the PA difference between A and B at 15, 22 and 43 GHz gives a differential RM of $980 \pm 10$ rad m$^{-2}$, similar to the value previously reported.

MG0414+0534 This source is remarkably unpolarised, although small but significant polarisation (0.2%) is detected from the A1–A2 image complex at 5 GHz. Image C was not detected at 43 GHz.

0957+561 We find a RM for image A of $-61 \pm 1.0$ rad m$^{-2}$, and for B $-91 \pm 1.0$ rad m$^{-2}$, with equal intrinsic PAs (i.e. PA at zero wavelength). For A our value agrees with that given by Greenfield et al. (1985) but for B it differs considerably from their $-164.6 \pm 4.5$ rad m$^{-2}$. This could indicate a possible 180° PA ambiguity error at 1.4 GHz in the earlier value, or a real change in RM along the path close to the lensing galaxy G1.

B1422+231 The measured RMs of A, B and C are $-4230 \pm 80$, $-3440 \pm 80$, $-3340 \pm 80$ rad m$^{-2}$, respectively; their intrinsic PAs are $90° \pm 10°$, $57° \pm 10°$ and $59° \pm 10°$. It is quite surprising that the RMs are so large, given that the lens galaxy is reported to be an elliptical.

B1600+434 The RMs of the two images are low in this source, 44 and 40 rad m$^{-2}$ for A and B, respectively. Comparing this source to B0218+357, it is curious that the lens, a spiral galaxy, does not give rise to large RM.

B1608+656 The images are unpolarised (<0.5%) at all the frequencies we observed.

PKS1830−211 This is the most difficult source to characterise, as the PAs of the two images, measured at the brightness peaks at each frequency, do not follow a $\lambda^2$–law. This result is not surprising due to differing resolutions at different frequencies and the frequency-dependent structures near the cores.

B1938+666 The three bright polarised emission regions, A, B and C, have RMs of $665 \pm 90, 465 \pm 90$ and $530 \pm 90$ rad m$^{-2}$, respectively. The source was not detected at 43 GHz.

2016+112 The source was not detected in polarised emission.

In summary, we detect polarised emission from 7 of the 9 lensed systems. The image flux ratios are generally independent of frequency. We detect steepening of the spectra of many sources towards high frequencies (e.g. 22 and 43 GHz). Although the difference in RM is expected to reflect the nature of the lensing galaxies, our results do not clearly show this. The lack of large RM in B1600+434 and the presence of large RM in B1422+231 are especially puzzling.

Acknowledgments. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

References

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