Multi-Frequency VLBI Observations of Gravitational Lens B2016+112

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Introduction:
The gravitational lens system B2016+112 has intrigued astronomers since its discovery in 1981 (Lawrence et al. 1984). This wide angle separation (4" across) lens system comprises three components viz. A, B and C as shown in Figs. 1 and 2. Although A and B are associated with an AGN at z=3.273 lensed by a galaxy D (Fig. 3) located near the centroid of A, B and C at z=1.01 (Schneider et al. 1985), the redshift of the elongated structure C has not been successfully determined yet. Components A and B are each further resolved into two sub-components (A1, A2, B1 and B2) whereas C is resolved into four sub-components (C11, C12, C13 and C2, Garrett et al, 1996).

Koopmans et al. Model:
The most recent model by Koopmans et al. (2002)
a) explains the radio and optical positions qualitatively
b) describes the lens as a quadruply imaged system
c) proposes that C11-C12 and C13-C2 are two partial but highly magnified images of a part of the background source which lies on the north-west edge of A2 and B2 (but is unresolved in A and B).
d) predicts the spectral index distribution of each of the components observed.

In this work, we make an attempt to verify the model.

Observations & Results:
Simultaneous MERLIN and Global VLBI observations of B2016+112 were made at 18 and 6 cm. The purpose of the observations was to analyze the spectrum of the sub-components especially of the complex structure C.

Figs. 4, 5 and 6 show high resolution VLBI maps at 18 cm of the lens system. The phased VLA and 70 m dishes Robledo and Goldstone were included for better sensitivity. However, only single polarisation (LCP) observations (Feb ‘02) were made. Figs. 7, 8 and 9 are from the VLBI 6 cm dual polarisation observations (Nov’01), Arecibo included. To avoid bandwidth smearing the data was unaveraged in frequency.

The spectra of components A1, B1, C11 and C2 are found to be steep and those of A2, B2, C12 and C13 are found to be flat which is in agreement with the Koopmans model. The spectra of the outermost sub-components of the structure C, according to the model should have similar spectral indices. However, the spectral index value for C2 is much steeper than C11, as is evident from Fig. 6 and 9.

Future work:
Determination of the spectral index using data at two frequencies is not a robust estimate hence further observations will be made at 3.6 cm with the VLBI High Sensitivity Array (HSA). We also propose to make infrared observations to determine the redshift of the arc-like C structure shown in Fig. 3.

References:
Lawrence, C.R. et al, 1984, Science, 223, 46

Discussions:
The difference observed in the spectrum of the outermost sub-components of C can be due to various effects, including scattering or free-free absorption along the line of sight to one of the images, or the interaction of a frequency-dependent source size with a local magnification gradient caused by mass substructure. Possible evidence for the latter is the different separations between C11-C12 and C13-C2.

References:
Lawrence, C.R. et al, 1984, Science, 223, 46