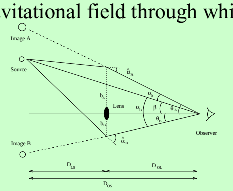
Time Delay Monitoring of Gravitational Lens MG2016+112

D. B. Haarsma and K. J. Hoekema (Calvin College), J. N. Hewitt (MIT), and G. I. Langston (NRAO)

Introduction

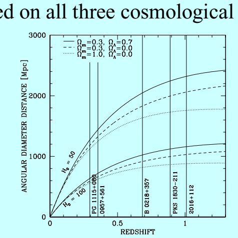
- A gravitational macro-lens produces multiple images of a background source as the light ray bends in its gravitational field.
- The light travel time differs for each image, due to differences in path length and in the strength of the gravitational field through which it passes.



- In the lens MG2016+112 (Lawrence et al 1984), the source is a quasar at z=3.27. The lens is a radio-quiet elliptical galaxy at z=1.01 and its surrounding cluster (Soucail et al 2001).
- The current best model of the lens (Nair & Garrett, 1997) predicts a delay of 1.3 years between the A and B images, independent of the interpretation of the complicated C image (Garrett et al 1994).

Cosmological parameters

- The figure below shows the dependence of angular diameter distance on redshift and three cosmological parameters: H_o, the mass density, Ω_m, and the cosmological constant Ω_Λ.
- The time delay and a complete model of the lens mass distribution allow a measurement of the angular diameter distance of the lens (Narayan 1991).
- MG2016+112 has the largest redshift of macro-lenses discovered to date (Kochanek et al 2001), and the lens distance depends strongly on the cosmological parameters.
- If accurate time delays and lens models could be determined for several lenses, firm limits could be placed on all three cosmological parameters.

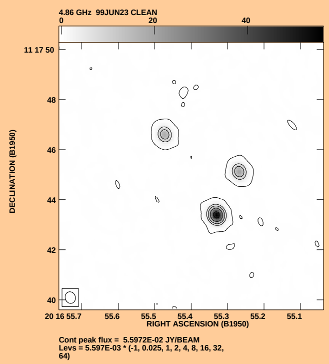


New Data:

- Monthly observations at the VLA during favorable arrays June 1999 – present.
- 19 observations at 6 cm, 23 at 3.6 cm.

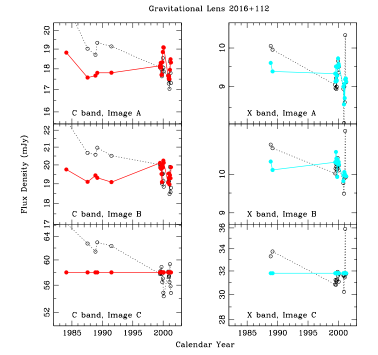
Archive Data:

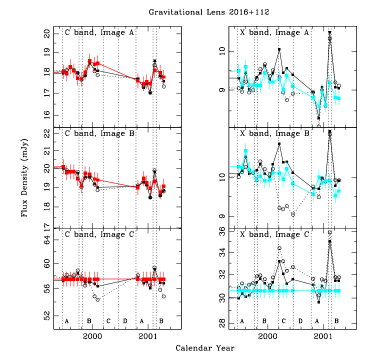
- Occasional observations in 1980s and 1990s (PIs Langston and Hewitt).
- 10 at 6 cm, 12 at 3.6 cm. (Due to differences in pointing positions and calibrators used, only some are included in the light curves here).



Data Reduction Procedure

- Hoekema (junior at Calvin College) wrote a detailed script in AIPS for reduction of the new data in a uniform fashion. The steps include:
- Amplitude calibrate to 3C48 at 6 cm using the standard "Cookbook" method, and at 3.6 cm using a full-synthesis "clean-component" model of 3C48 (courtesy of C. Walker).
- Apply two iterations of deconvolution and self-calibration.
- Subtract the C image to allow better flux density measurement of the A and B images.
- Measure the flux density of an image by summing its "clean components".





References

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17-year Light Curve

- Open symbols & dotted lines: Archive data were reduced following the same procedure as the new data. Data from 3.6 cm C-array is not shown due to large deconvolution errors (corrected later by null model, see below)
- Colored symbols & solid lines: To remove lingering amplitude calibration problems, the C image was assumed to be of constant flux density. The altered light curves show the *relative* variability of the A and B images
- **CONCLUSION: little intrinsic variability on time scales of several years**

2-year Light Curve

- For each data set, make a corresponding "null" data set with the same UV coverage but known source fluxes. Run the null data through the basic data reduction, and use the ratio of the input and measured flux to find the systematic errors due to the deconvolution and self-calibration procedure (Moore & Hewitt 1997, Moore 1996).
- Open symbols: results from basic data reduction procedure
- Solid symbols: basic result corrected for deconvolution using null data. The largest corrections are in C-array at 3.6 cm.
- Colored symbols: basic result, corrected by null data, and divided by the C image flux density. Arbitrary 2% error bars are shown for reference.
- **CONCLUSION: little intrinsic variability on time scales of a few months**

Further work:

Since there is no evidence for strong variability, the delay can not be determined from these data. The remaining tasks are:

- Include all archive data sets
- Quantify the limit on low-level variability