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# The CLASS Gravitational Lens Search

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**Abstract.** To exploit gravitational lensing for cosmology large, reliable and statistically complete surveys are required. With the Cosmic Lens All-Sky Survey (CLASS) we have set out to achieve these goals. We pre-select targets to be flat spectrum radio sources and map every source with the VLA at 200mas resolution. Candidates having multiple compact components with flux density ratios $\leq$10:1 and separation in the range 0.3 to 15 arcsec are followed up with high resolution MERLIN and VLBA observations, eliminating those candidates which do not match strictly defined surface brightness and morphological criteria. A complete sample of 11685 sources have been surveyed and nineteen lens systems have been found.

## 1. Introduction

Finding multiple image gravitational lens systems is not easy; creating a reliable and complete sample of such lens systems is even harder. The aims of CLASS are to create a large, reliable and statistically complete survey for galaxy-mass lens systems, to find ones that are suitable for time delay measurements and to identify lensing galaxies and study their properties (Myers et al., 1997; Browne et al., 2001). To achieve these goals we look for lensed images of compact radio cores amongst a sample of radio sources pre-selected to have flat radio spectra. This approach has several advantages: (1) flat spectrum radio sources have structures dominated by a single compact radio core and thus multiple imaging events are easy to recognize, (2) being compact, the probability of multiple imaging of radio cores depends only on the lens cross-section and not on the angular extent of the lensed object, (3) most flat spectrum radio sources are quasars and therefore at high redshift, thus maximizing the lensing cross section, (4) most flat spectrum radio sources are time variable and, if multiply imaged, are suitable for time delay measurements and Hubble constant determination, (5) the targets are free from any bias arising from extinction in the lensing galaxy, something that affects the completeness of optical lens searches and (6) high resolution radio follow up with MERLIN and VLBI is possible to provide extra constraints on the lens model from extended radio structure.

The collaboration involves groups at the Jodrell Bank Observatory, NRAO, the University of Pennsylvania, Caltech, NFRA and the University of Groningen.



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## 2. Sample Selection, Lens Candidate Selection and Follow-up

Our final complete sample was selected using GB6 and NVSS; starting with GB6 we picked sources stronger than 30 mJy and looked for their counterparts in NVSS rejecting all those with two point spectral indices steeper than -0.5. A total of 11,685 GB6 sources meet our selection criteria. Each source was observed with the VLA in its A-configuration at a frequency 8.4 GHz resulting in a map with a resolution of 200 mas and a dynamic range of $\geq$50:1. All data were mapped and model-fitted automatically using a script in DIFMAP.

A critical step is the selection of candidates to follow up with further higher resolution observations. The CLASS philosophy is to be cautious and follow up all objects meeting the selection criteria, even when our initial conclusion from the VLA maps was that they were unlikely to be multiply imaged systems. Because of this meticulous follow up procedure we believe our lens sample is complete within the well-defined selection criteria we set out below. We emphasize that in our statistically complete sample we count only cases in which we see multiple images of compact radio cores. Complete sample candidates must meet the following criteria: (1) the source must have multiple compact components with size $\leq$170 mas, (2) the component separation must be between 300 mas and 15 arcsec (3) the component flux density ratio must be $\leq$10:1 and (4) the total 8.4 GHz flux density in the components must be $\geq$20 mJy.

Candidates were selected visually and checked against an automatically generated list based on the results of modelling each source in DIFMAP. We followed up candidates (about 300 in total) with various stages of filtering, systematically increasing the resolution as we went. Candidates are rejected if the surface brightnesses of the putative images are different, if the structure is inconsistent with lensing; e.g. if the map shows a clear core plus jet or if the spectral indices and/or their percentage polarizations are very different. The first stage of filtering is MERLIN 5 GHz snapshot observations with a resolution of 50 mas. Surviving candidates are then observed with the VLBA at 5 GHz - resolution 3 mas – again in snapshot mode. By this stage all but a hand-full of the candidates can be classified unambiguously.

The Current Status of CLASS is that the follow up of candidates is virtually complete. Nineteen lens systems have been found so far.

## 3. Acknowledgements

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