1 Science case

The dark matter is one of the most poromient open questions in physics. Wbhile existing searches are restricting conventional models, there is increasing interest in alternative models and lensing is a way to test such models.

The proposed MERLIN observations are a part of the larger project with the overall goal to search for rare lensing events in the lens mass range of $10^6 M_\odot$ to $10^{10} M_\odot$. Such lensing effects will results in separations 3–300 mas. The abundance of lensing events depends on the model of the dark matter contribution to the gravitational field. Therefore, detecting gravitational lenses at such separations will allow us to constrains models of dark models.

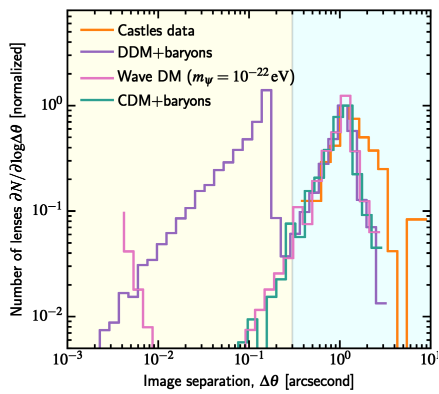


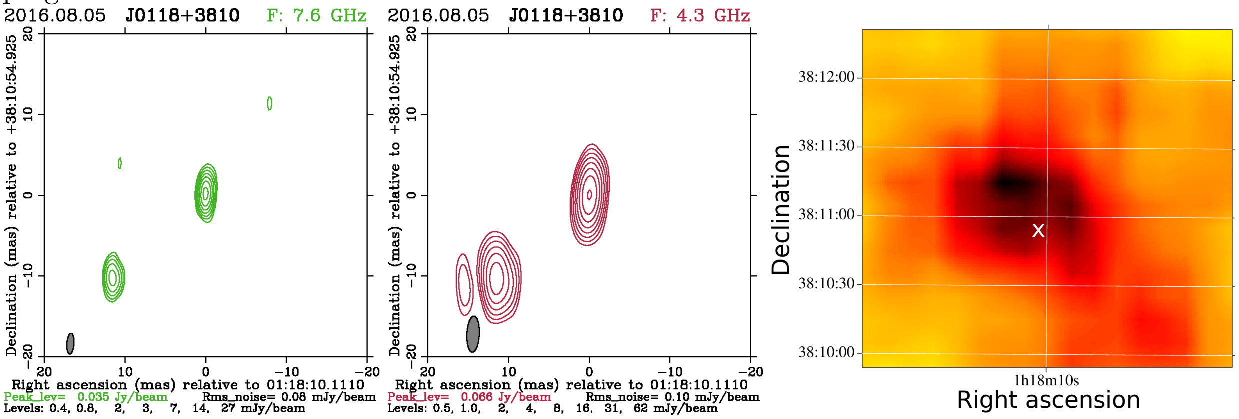
Fig. 1: Image separation distribution for various dark matter models. The right hand part (cyan background) shows the resolution range of existing large-scale lens surveys that probe halos with mass $10^{11} M_\odot$. Currently, viable dark matter models agree on such large scale and high halo masses. The left hand region (yellow background) is the VLBI regime where the models may be distinguished.

Dissipative dark matter (DDM) models posit that DM is composed of dark-sector particles that follow dissipative dynamics similar to baryons. While the supernova feedback from the postulated kinetic coupling of DM to photons is sufficient to maintain extended halos in galaxies more massive than 1011 M , at lower masses DM is expected to collapse into an exponential disk much in the same way baryons form galaxies (Foot and Vagnozzi, 2016). We simulated this collapse, maintaining mass and angular momentum conservation (see e.g. Mo et al., 1998, sec 2.3), and find that if 10% of matter is dissipative 100 mas scale lenses will be found by this survey with rates comparable to existing arcsecond-scale surveys (see Fig. 1).

The previous searches of gravitation lenses were based on surveys with VLA and MERLIN. Such searches could not help finding lenses with separations shorter than VLA and MERLIN resolutions. We used the Radio Fundamental Catalogue of 16,845 sources detected with VLBI[1] and identified 741 visually binary objects, i.e. objects with two or more distinct components in their VLBI images at 3–300 mas separations. Further, we stroke out the objects that had multiple components with obviously different surface brightness, or spectral indices between components, or whose morphology was not consistent with lensing. Among remaining objects, we selected those that are considered the most promising for being classified as gravitational lenses. We observed 12 visually biniary objects with VLBA in 2018 at 15 and 23 GHz. We have detected two compact components in six of them. We have been awarded 140 hours at the EVN in 2019 for observing 43 gravitational lenses at 5 and 22 GHz in order to get high fidelity images, estimates of the spectral index and determine the frequency dependent position shift between components.

[1] Available at http://astrogeo.org/rfc

Fig. 2: Target source J0118+3810. *Left* and *center* images are made with VLBA. The position angle of the symmetry axis is 312°. *Right* image is made at VLA at 2–4 GHz under VLASS program. White cross denotes the source core detected with VLBI.



2 Proposed observations

We propose complimentary L-band MERLIN observations of eight candidate gravitational lenses sources with declinations $> -20°$. Of them, six show several components at 15 and 23 GHz and the 7th, J0118+3810, shows extended structure at VLASS image, and the 8th, J0348+3353, is tripple. We do not see a jet in neither VLBA observations because a jet is resolved out, not in VLASS images because of their insufficient resolution. Proposed Merlin observations will help us to detect jets. Jet detection and determination of its direction will help us to classify the sources understand their nature.

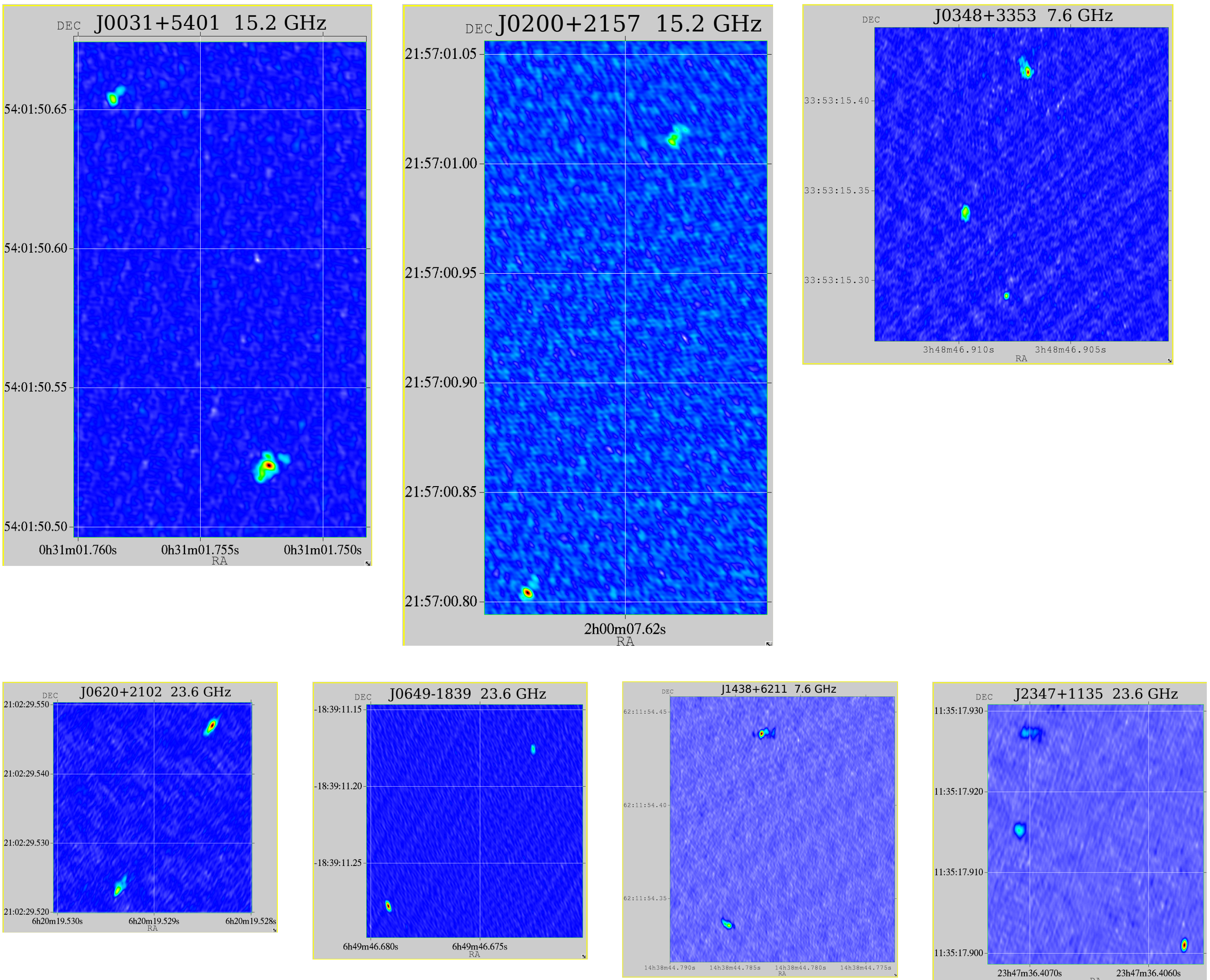
The goal of the proposed observations is to get images of kiloparsec structure of these objects with a resolution of 150 mas. These images will help us to understand the nature of visually binary sources. Among visually binary objects there are sources with core/hot-spot morphologies, compact symmetric objects (CSO), binary black holes, and gravitational lenses. We expect the most common class is core/hot-spot. For such objects we expect jet directions from the kiloparsec structure be in general aligned with the direction of their parsec-scale structure, i.e. the direction between components at their VLBI images. Assuming compact symmetric objects are young, no kiloparsec scale structure is expected for these objects. Detection of an X-shape jets will be a strong argument in favour of true binary.

MERLIN provides resolution intermediate between VLA and VLBI. Compact features within 150 mas of the central part will be captured with VLBI, although extended features will be resolved out. MERLIN images will show extended emission at scales 0.15–100 arcsec.

Our major concern in the search of gravitational lenses is that we may fail to weed out sources with core/hot-spot morphology. Resolution of VLASS is insufficient to trace features smaller than 4–5″. A curved jet may explain a misalignment of kiloparsec scale features and parsec-scale features. We select the low frequency in order to better trace jets. A jet along the symmetry axis of VLBI images will indicate that the second component at the VLBI image is likely be a hot spot at jet. A jet with significant misalignment will support the hypothesis that a given object is a gravitational lens or a binary black hole.

VLBA images of proposed targets

Fig. 3: VLBA images of seven visually binary targets at X, U and K bands



3 Bibliography

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Mo H J, Mao S and White S D M, 1998 MNRAS 295, 319–336.