Probing subgalactic dark matter using mm-VLBI and phased ALMA

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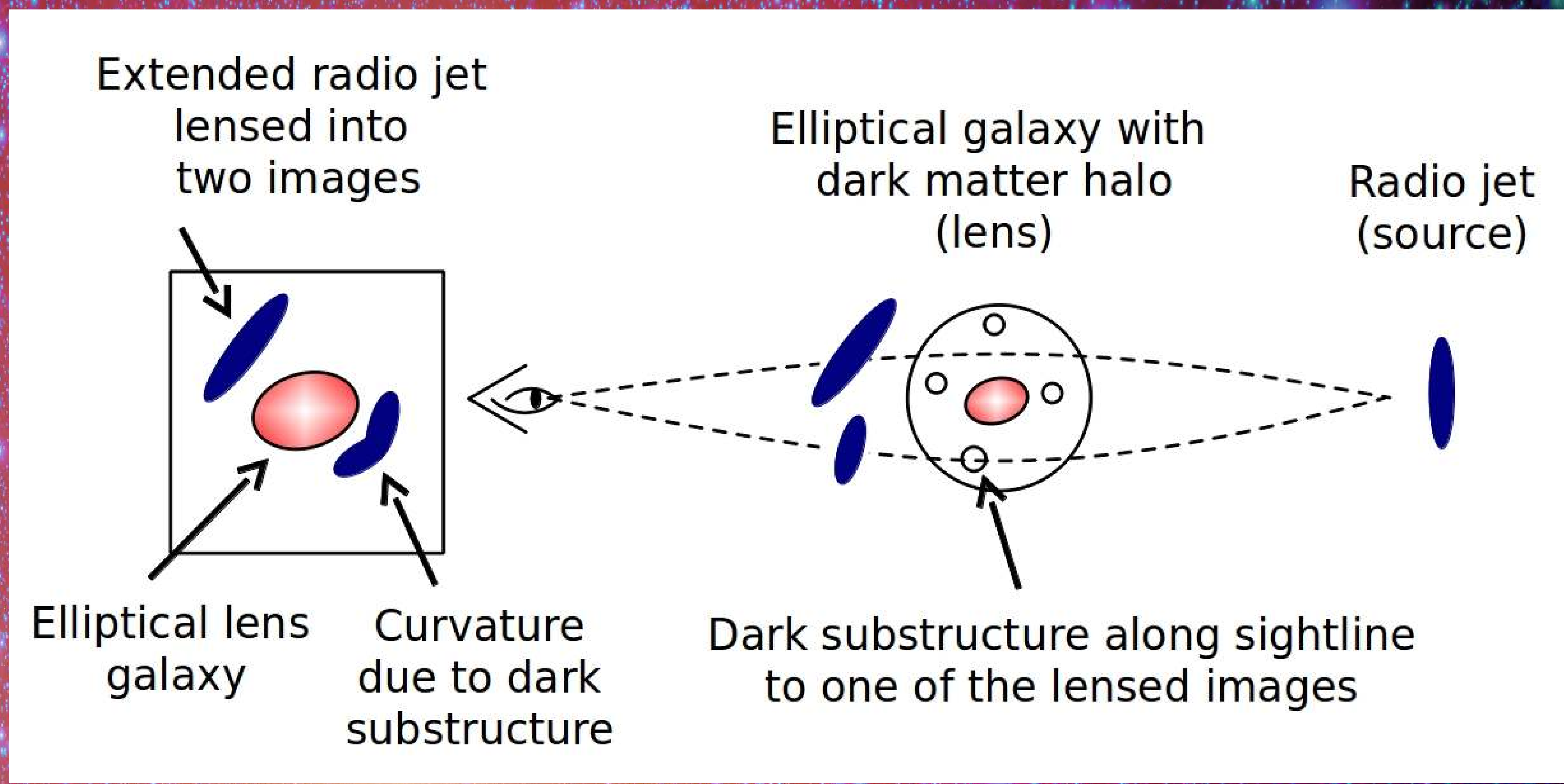
Results

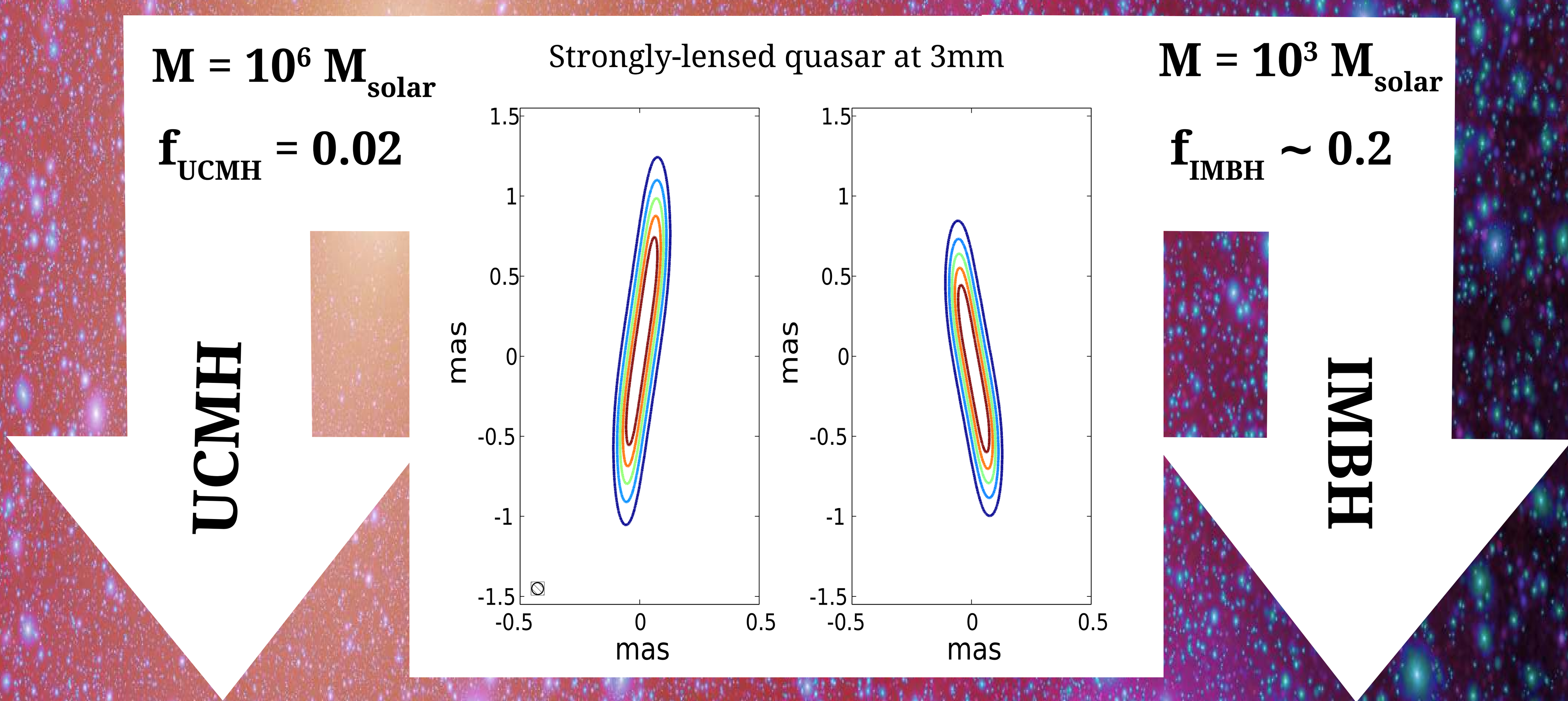
Alternative structure formation scenarios predict that galactic halo substructure comes in more compact forms like *intermediate-mass black holes* or *ultracompact minihalos*[1,2]. Through strong lensing simulations, we show that by mapping approximately five strongly lensed radio jets, phased ALMA joining the mmVLBI array, should be possible to detect or robustly rule out primordial black holes in the 10^3-10^6 M_{solar} mass range if they constitute ≥1% of the dark matter in these lenses, and ultracompact minihalos of 10^6-10^8 M_{solar} if they constitute ≥10% of the dark matter. However, observations of this type would not be sensitive to standard CDM subhalos but requires a source area ~10^3 times of radio jets.



Introduction

Cosmological N-body simulations based on ΛCDM model show a number of disagreements with observational evidence in the local group; systematic inconsistencies that have not been solved with a single recipe (baryonic feedback, alternative dark matter particle, etc.). Two of the challenges for the ΛCDM model, addressed with this technique are the following.

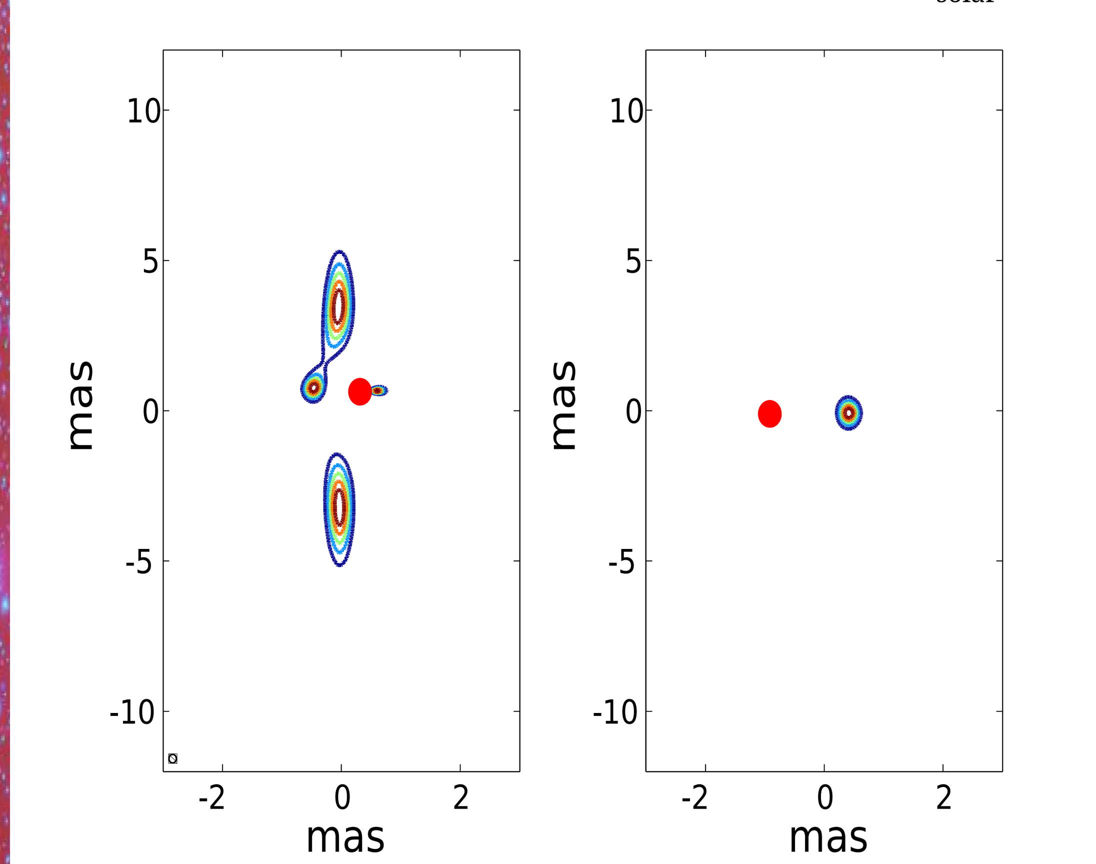
- *missing satellite problem*[3, 4]:
  The dark subhalo abundance of a Milky Way-sized halo in simulations greatly outnumber the dwarf satellites around the Milky Way and Andromeda.
- *too big to fail problem*[5, 6]:
  The most massive subhalos of simulated local group halos are too massive and too dense to host the most massive satellites, in contrast with the expectation that the most massive subhalo structures is unlikely to remain devoid of stars.



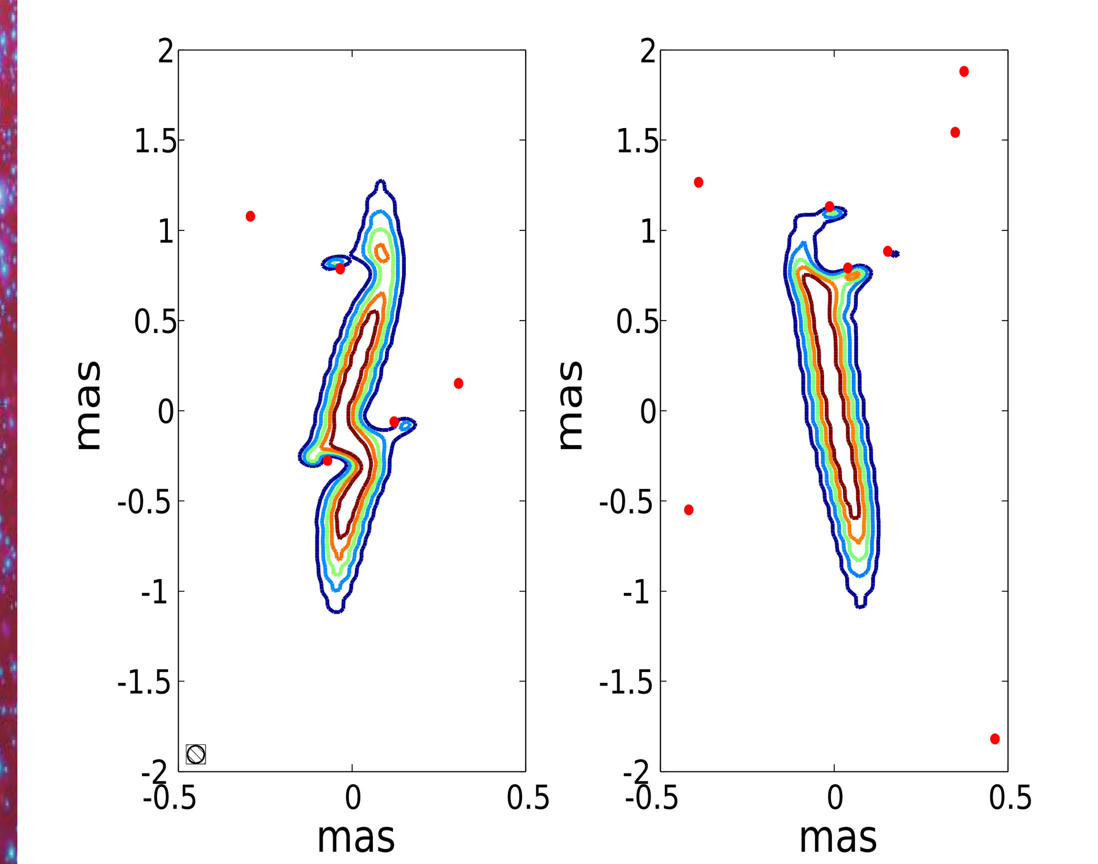
Method

An extended source is assumed to be multiply-imaged by a foreground galaxy, and the lens equation is used to determine the lens plane positions of the corresponding macroimages. A small region around each such macroimage is then populated with randomly distributed dark halo substructures and simulated in greater detail. The deflection angles (with contributions from both substructures and the macrolens) are computed for every pixel within this region and converted into a numerical surface brightness map of the macroimage. These maps are initially generated with a very fine pixel scale, but are then convolved with a Gaussian filter to match the finite resolution of the mm-VLBI array connected to the phased ALMA; FWHM = 0.05 mas.

Ultracompact minihalo with M=10^6 M_{solar}



Point-like perturbers with M=10^3 M_{solar}



References

[1] Mack, Ostriker & Ricotti 2007, ApJ, 665, 1277
[2] Ricotti M., Gould A., 2009, ApJ, 707, 979
[3] Klypin et al. 1999, ApJ, 522, 82
[4] Moore et al. 1999, ApJ, 524, L19
[5] Boylan-Kolchin et al. 2011, MNRAS, 514, L40
[6] Boylan-Kolchin, et al. 2012, MNRAS, 422, 1203

Results are based on the paper:
Zackrisson E. et al., 2013, MNRAS, 431, 2172 **(Available below, in a few copies)**

Summary

Dark halo substructure may reveal itself through secondary, small-scale gravitational lensing effects on light sources that are macrolensed by a foreground galaxy. Gravitational lensing, therefore, provides a test for the presence and properties of dark halo substructures, regardless of the microphysics of dark matter particles.

Using simulations of strongly lensed quasar jets using phased ALMA connected to the global 3mm array, we argue that very dense forms of halo substructure (intermediate-mass black holes and ultracompact minihalos) within the main lens may reveal itself through small-scale morphological distortions in the macroimages. Such distortions can be distinguished from intrinsic source features by obtaining data at multiple epochs.