

The detectability of dark galaxies through image-splitting effects

E. Zackrisson^{1,2,3}, T. Riehm², H. Lietzen¹,
 O. Möller⁴, K. Wiik¹ and P. Nurmi¹

¹Tuorla Observatory, University of Turku, Väisäläntie 20, FI-21500 Piikkiö, Finland

²Stockholm Observatory, AlbaNova University Center, 106 91 Stockholm, Sweden

³Department of Astronomy and Space Physics, Box 515, 751 20 Uppsala, Sweden

⁴Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Strasse 1, D-85741 Garching, Germany

Abstract. In principle, dark galaxies in the dwarf-galaxy mass range may be detectable through additional, small-scale image splitting of quasars that are already known to be multiply-imaged on arcsecond scales. Here, we derive the image separations expected for dark galaxies with density profiles favoured by recent N-body simulations. The results are compared to the angular resolution of existing and planned telescopes at X-ray, optical, near-infrared and radio wavelengths.

Keywords. Dark matter – galaxies: halos – galaxies: dwarf – gravitational lensing – quasars: general

1. Introduction

In principle, dark galaxies (either subhalos or field halos) in the dwarf-galaxy mass range can be detected through millilensing effects. So far, most investigations of these phenomena have focused on the flux ratio anomalies of multiply-imaged quasars, i.e. the *magnification* associated with millilensing by subhalos. This is, however, an indirect method of searching for subhalos, since flux ratios can also be affected by microlensing by stars in the lens galaxy and absorption/scattering in the interstellar medium. The detection of small-scale image splitting (typically on scales of milliarcseconds) would provide a more direct proof of the existence of large numbers of low-mass halos. Yonehara, Umemura & Susa (2003) predicted that there should be a reasonable chance of detection of this effect in the individual images of multiply-imaged quasars, and Inoue & Chiba (2005a, 2005b, 2005c) have developed this idea further. Previous estimates of the resulting image separations have, however, been based on the premise that the lenses can be treated as singular isothermal spheres. This is an assumption that is difficult to justify, since neither theoretical arguments, simulations nor observations favour a density profile of this form for dark matter halos in the relevant mass range. Here, and in Zackrisson, Riehm, Möller, *et al.* (2007), we derive the image separations expected for millilensing by dark galaxies with density profiles favoured by recent N-body simulations.

2. Image separations and prospects for detection

For field halos in the dwarf-galaxy mass range, we consider Navarro, Frenk & White (1996, hereafter NFW), Moore, Quinn, Governato, *et al.* (1999, hereafter M99) and Navarro, Hayashi, Power, *et al.* (2004, hereafter N04) density profiles. For subhalos of the same

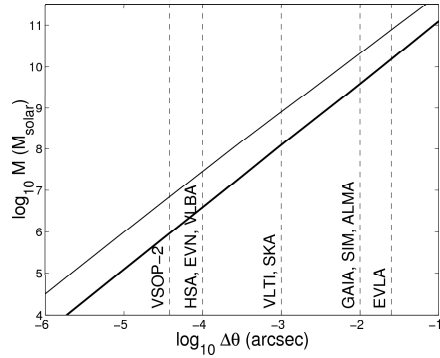


Figure 1. Image separation $\Delta\theta$ versus dark galaxy mass for SIS (thick solid) and M99 (thin solid) halo density profiles. The vertical, dashed lines represent the angular resolution of a number of current and future telescopes. A typical lens redshift of $z_l = 0.5$ and a source redshift of $z_s = 2.0$ have been assumed.

mass, we use the density profiles suggested by Hayashi, Navarro, Taylor, *et al.* (2003, hereafter H03) and Kazantzidis, Mayer, Mastropietro, *et al.* (2004, hereafter K04). We find, that the resulting image separations in all cases are substantially smaller than those predicted by singular isothermal sphere (SIS) models, thereby making the detections of dark galaxies through image-splitting effects far more challenging than previously believed. These different halo models moreover produce very disparate image separations. Whereas the image splitting by dwarf-galaxy mass halos with NFW, N04 H03 or K04 density profiles would be too small to be detectable with existing or planned telescopes, halos with an inner density cusp as steep as that of the M99 profile should be within reach of current technology.

In figure 1, we compare the image separations predicted for 10^4 – $10^{11} M_\odot$ dark galaxies with SIS or M99 density profiles to the best angular resolution attainable with various existing or planned observational facilities. For instance, the angular resolution provided by the existing European VLBI Network (EVN) should allow the detection of dark galaxies with masses as low as $\approx 3 \times 10^7 M_\odot$, provided that these have density profiles of the M99 type. The *probability* for making such a detection is, however, a different matter (see Riehm et al., these proceedings).

Acknowledgements

EZ acknowledges research grants from the Swedish Research Council, the Academy of Finland and the Swedish Royal Academy of Sciences.

References

- Hayashi, E., Navarro, J.F., Taylor, J.E., Stadel, J., Quinn, T. 2003, *ApJ*, 584, 541 (H03)
- Inoue, K.T. & Chiba, M. 2005a, *ApJ*, 633, 23
- Inoue, K.T. & Chiba, M. 2005b, *ApJ*, 634, 77
- Inoue, K.T. & Chiba, M. 2005c, *astro-ph/0512648*
- Kazantzidis, S., Mayer, L., Mastropietro, C., Diemand, J., Stadel, J., Moore, B. 2004, *ApJ*, 608, 663 (K04)
- Moore, B., Quinn, T., Governato, F., Stadel, J., Lake, G. 1999, *MNRAS*, 310, 1147 (M99)
- Navarro, J.F., Frenk, C.S. & White, S.D.M. 1996, *ApJ*, 462, 563 (NFW)
- Navarro, J.F., Hayashi, E., Power, C., *et al.*, 2004, *MNRAS*, 349, 1039 (N04)
- Yonehara, A., Umemura, M. & Susa, H. 2003, *PASJ*, 55, 1059
- Zackrisson, E., Riehm, T., Möller, O., Wiik, K., Nurmi, P. 2007, *ApJ*, submitted