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A new quadruple-image gravitational lens in an edge-on disk galaxy at z=0.0956

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BACKGROUND AND DISCOVERY

Strong gravitational lensing is invaluable as a probe of the mass distribution within galaxies, providing insights into both the mass-to-light ratio of stellar populations and the structure of dark-matter halos, especially when combined with stellar dynamical measurements (e.g. Auger et al. 2010). Most strong-lens samples are dominated by massive early type galaxies, which are favoured by several selection effects. However spiral lenses, in particular those with edge-on disks, are keenly sought, since their rotation curves provide relatively direct kinematic information to constrain more complex lens models (e.g. Treu et al. 2011).

In order to refine the input catalogue for the Taipan Galaxy Survey (da Cunha et al. 2017) optical image cutouts from a variety of legacy surveys, e.g. Pan-STARRS PS1 (Chambers et al. 2016), are being visually inspected by one of us (JRL). From this work we have previously published the discovery of two quadruple systems (Lucey et al. 2018), both of which have been confirmed spectroscopically as lensed quasars (Rusu et al. 2018).

Here we report the further serendipitous discovery of a quadruply-lensed source at the core of a $z = 0.0956$ edge-on disk galaxy, 2MASXJ13170000–1405187. Features suggestive of a lensing configuration were initially noted in the inspection of PS1 data, and confirmed in K-band imaging from the VISTA Hemisphere Survey (VHS; McMahon et al. 2013). We subsequently obtained deeper optical observations with LDSS3 at the 6.5m Magellan Clay telescope in g, r and i (360 sec in each band), with FWHM $\approx 0\overset{''}{.}6$. Extracts from these images are shown in Figure 1.

PROPERTIES OF THE LENS GALAXY

2MASXJ13170000–1405187 is an edge-on disk galaxy, with a redshift of $z = 0.0956$ (6dFGS, Jones et al. 2009). The galaxy spectrum is continuum-dominated, with the strong metal lines and weak Balmer absorption typical of old stellar populations. There is weak emission at [O II] 3727 Å and [N II] 6584 Å.

The Magellan imaging shows that the galaxy has a bright central bulge with radius $\sim1''$ (1.8 kpc) and an extended disk with low surface brightness, traceable to a radius of $\sim15''$ (27 kpc). The g-band image reveals a prominent dust ring at a major-axis radius of $\sim9''$. The apparent axial ratio suggests a disk inclination of $i \gtrsim 80°$.

LENSING CONFIGURATION AND PRELIMINARY MODELLING

The four lensed images (A–D) are observed at radii 1.0–1.5 arcsec from the bulge centre. The images are clearly extended, showing that the background source is a galaxy, not a quasar. All of the lensed features, as well as the

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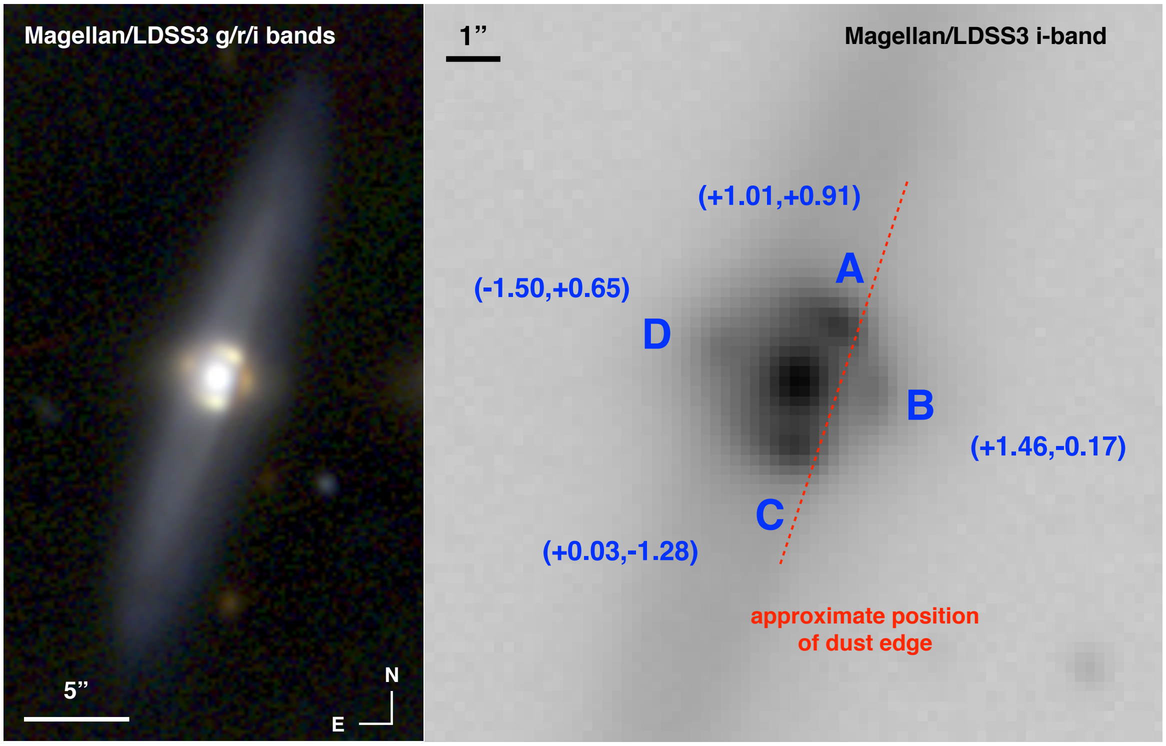

Figure 1. Left: Pseudo-true-colour image of 2MASXJ13170000–1405187 from Magellan *gri* imaging. Right: Zoomed *i*-band image. Source positions are in arcsec relative to the bulge centre, derived from the VHS K-band data.

galaxy nucleus and inner disk, would have contributed to the 6dFGS spectrum (fibre 6.″7 diameter), but no background source lines can be identified in the spectral range covered (3950–7550 Å).

Images B and D lie behind the dust ring identified in the *g*-band image, and are both subject to significant reddening. Images A and C extend into the dust ring at their western ends, which hampers deriving accurate positions to use in modelling the lens. To mitigate against this, we use positions measured from the VHS K-band image, derived by PSF-fitting following Schechter et al. (1993), and summarized in Figure 1.

We use LENSMODEL (Keeton 2001) to fit a simple lensing model to the VHS-derived positions, using Monte Carlo realisations to propagate positional errors of 0.25 pixels. The model is a singular isothermal ellipse with free centre, ellipticity, position angle, and normalisation. The best-fitting model has ellipticity $1-b/a = 0.4\pm0.1$ at position angle $19\pm2°$ (consistent with the disk orientation). The circularized Einstein radius is $1.44\pm0.05''$ (2.57 ± 0.09 kpc), corresponding to a projected mass of $(9.4\pm0.6)\times10^{10}\,M_\odot$ (assuming the background source is much more distant than the lens).

The observed K-band luminosity within the Einstein radius is $24\times10^{10}\,L_\odot$, which overestimates the galaxy contribution as it includes substantial flux from the lensed images. Using the higher-resolution *i*-band image to estimate this contamination, our best estimate of the Einstein aperture luminosity of the lens galaxy itself is $L_K = 18\times10^{10}\,L_\odot$. The resulting mass-to-light ratio range of $\sim0.5\,(M/L_K)_\odot$ is consistent with intermediate-age solar-metallicity stellar populations, e.g. 4 Gyr with Kroupa IMF, or 2.5 Gyr with Salpeter IMF (Maraston 2005).

FUTURE PROSPECTS

Future exploitation of 2MASXJ13170000–1405187 will require spectroscopy to establish the background source redshift, and to constrain better the stellar populations in the lensing galaxy. High-resolution imaging in the infra-red, to reduce the impact of the dust obscuration, will be essential for pixel-based lens modelling. Adaptive optics observations should be possible, as there is a $r \approx 14$ star located 30″ south of the target.

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Facilities: PS1, ESO:VISTA, Magellan:Clay

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