Constraining the stellar mass fraction and the quasar accretion disk size of SDSS J1004+4112 with microlensing

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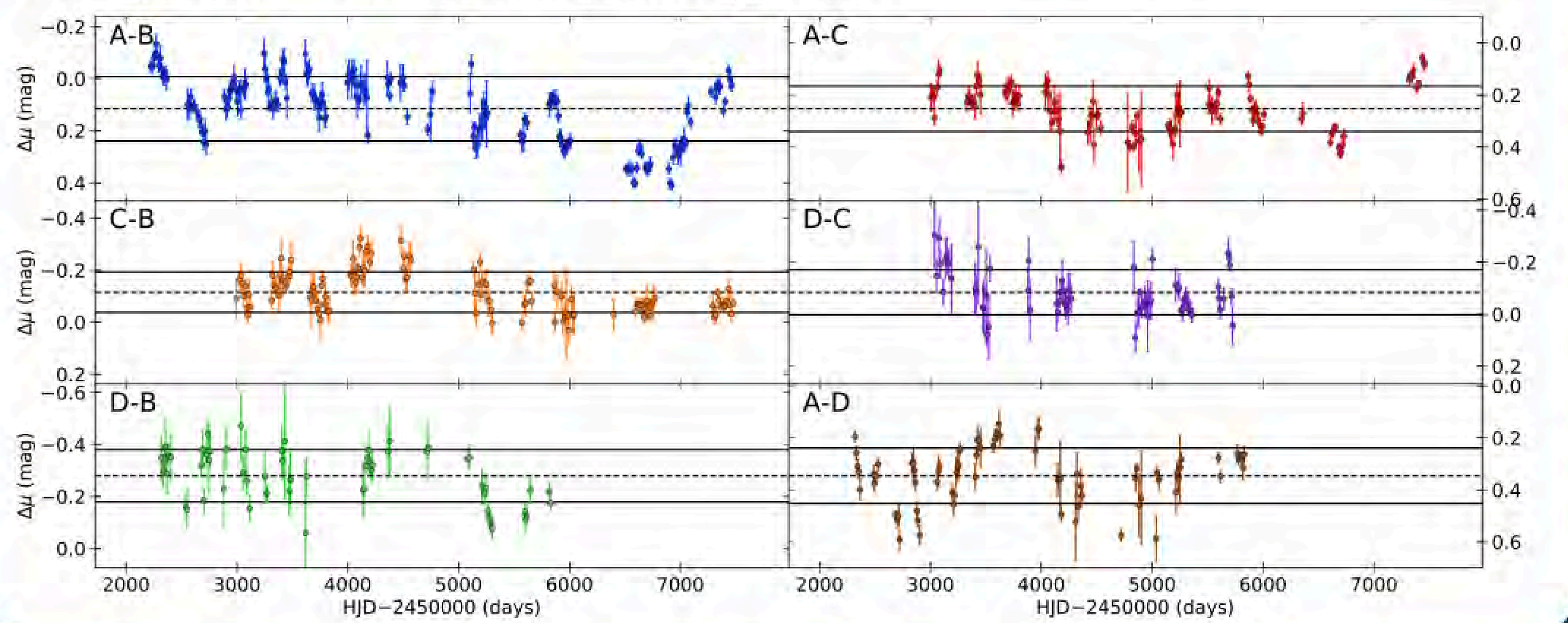
Introduction

SDSS J1004+4112 is a galaxy cluster with a background quasar lensed into five images (Inada et al. 2003). A 14.5-year monitoring campaign of the four brightest quasar images (Muñoz et al. 2022) was able to derive the time delay between the images. The light curves of the images show both intrinsic quasar variability and microlensing. From the microlensing signal, the quasar accretion disk size and the cluster stellar mass fraction can be estimated.

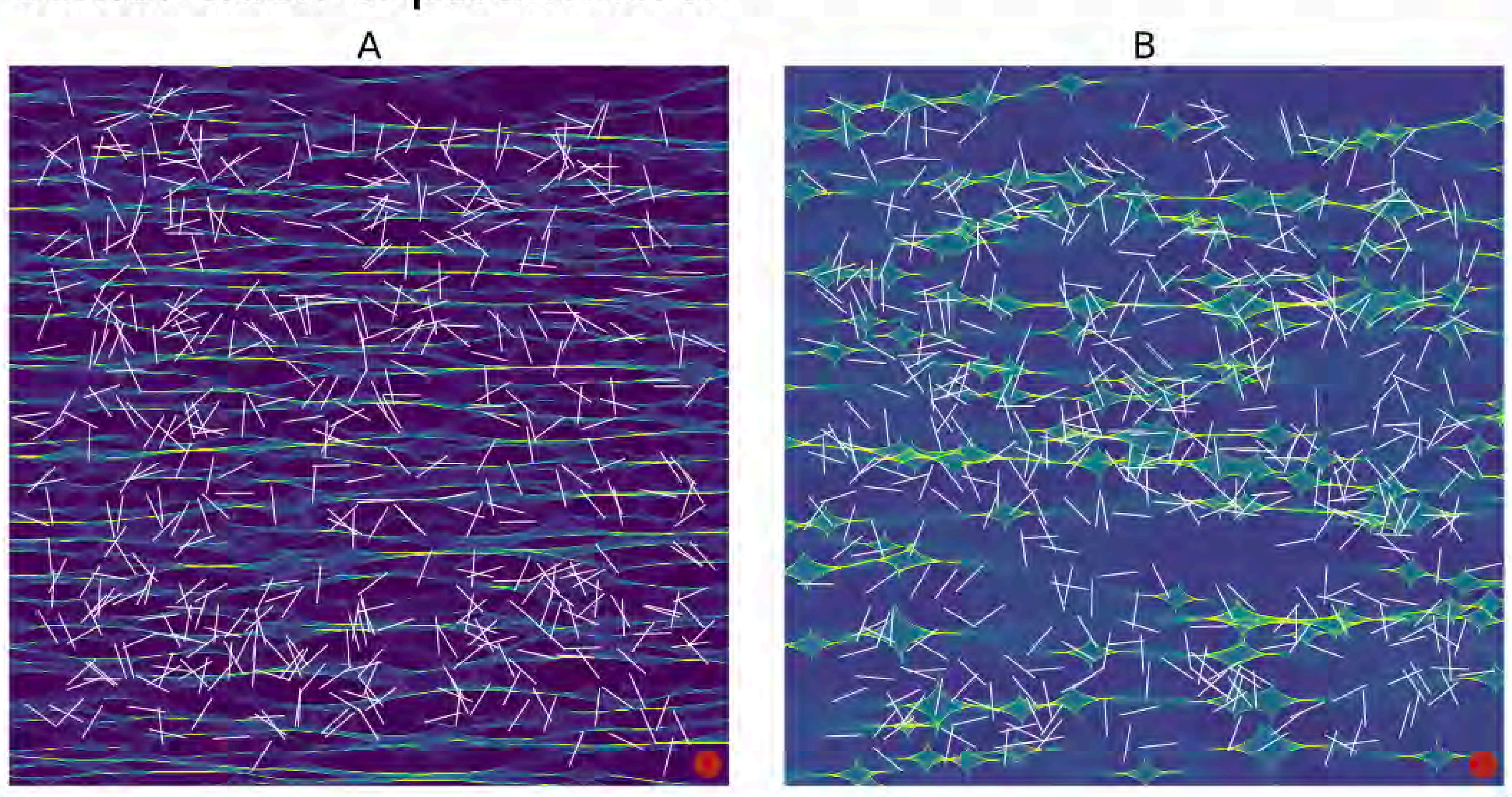
Observational data

In order to remove the intrinsic quasar variability, the six posible difference light curves are computed after shifting by the corresponding time delays and correcting by macro-magnification. From these difference light curves, histograms of micro-magnification are built to be compared with model histograms.



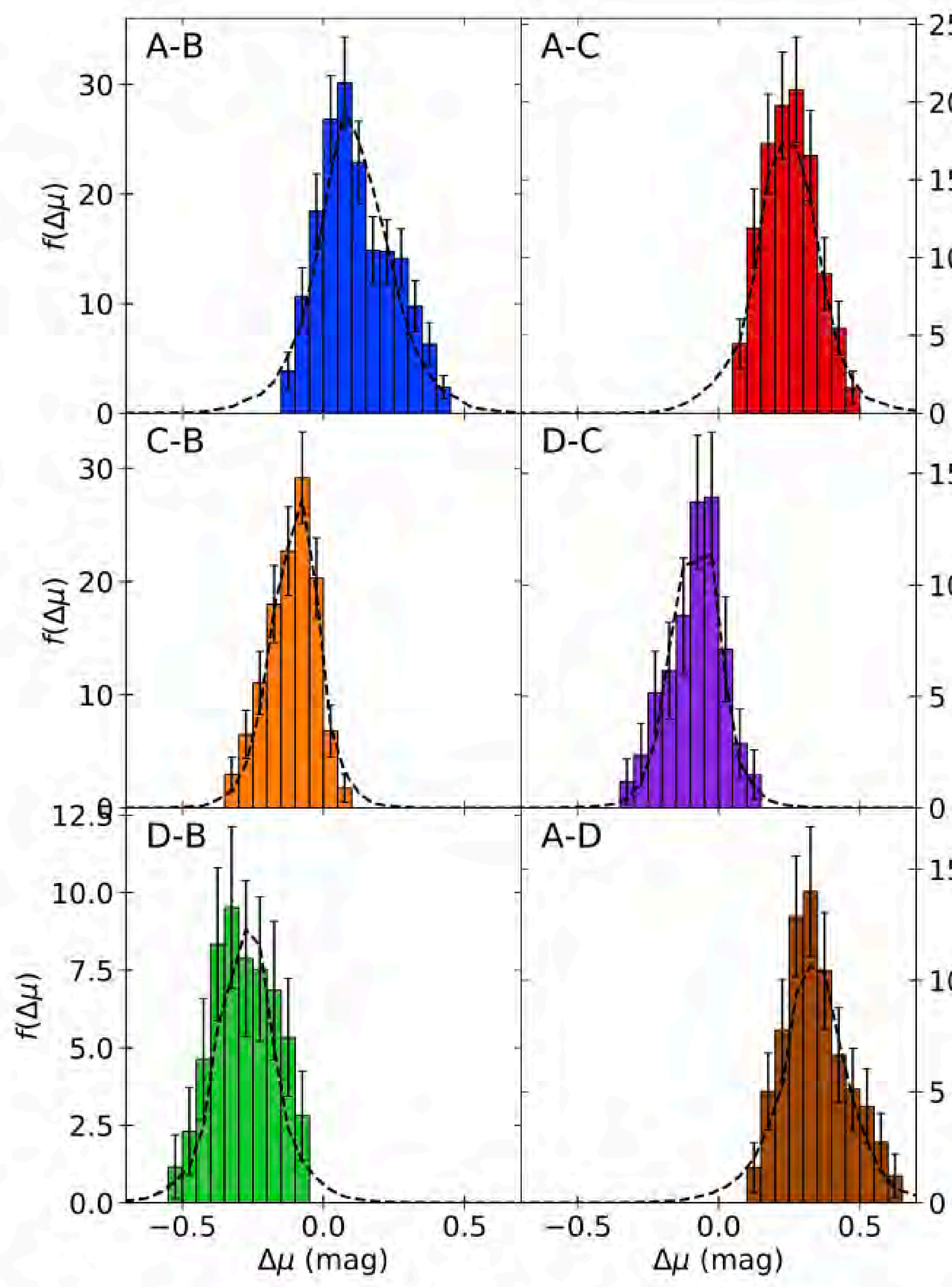
Model histograms

From the cluster mass model of Forés-Toribio et al. (2022), magnification maps are computed for different mass fractions and convolved with Gaussian sources of different sizes. Then, 500 pairs of tracks of the same length and with the same mean difference as the observational data are selected and averaged for each combination of parameters.



Results

Using a χ^2 test, we fit the observed difference histograms and compute the probability distribution functions of the model parameters. We use a logarithmic prior for the source size and a uniform prior for the stellar mass fraction.



We infer a quasar disk half-light radius of $R_{1/2} = 6.4^{+0.5}_{-0.8}\sqrt{M/0.3M_\odot}$ light-days at 2407Å in the restframe and stellar mass fractions at the quasar image positions of $\alpha_A = 0.075^{+0.030}_{-0.035}$, $\alpha_B = 0.048^{+0.049}_{-0.035}$, $\alpha_C = 0.033^{+0.013}_{-0.033}$ and $\alpha_D = 0.066^{+0.068}_{-0.034}$ for a fixed source half-light radius of 6.4 light-days.

Conclusions

Our source size estimate is in tension with the determinations of Hutsemekers et al. (2023), Mosquera & Kochanek (2011) and Fohlmeister et al. (2008) who derived a smaller disk size. On the other hand, our value is compatible with the determinations of Fian et al. (2016), Jiménez-Vicente et al. (2014) and Motta et al. (2012).

Regarding the stellar mass fractions, numerical and observational estimations place the intracluster stellar content at 1-3% (Kravtsov et al. 2018, DeMaio et al. 2018 and Henden et al. 2020). The stellar mass fractions at all quasar images are compatible with these estimates, but we infer a slightly larger fraction at image A, in line with the spectroscopic microlensing detections (Fian et al. 2023). This might suggest the presence of an undetected galaxy cluster member in this region.

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