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# Light on Dark Matter: Anomalies in Gravitational Lensing

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## Abstract

Gravitational lensing of light from distant galaxies can be used to investigate Dark Matter (DM). The currently favoured candidate for dark matter comprises of ultra-massive particles. We investigate gravitational lensing by a DM halo, and see if models based on ultra-massive particles can reproduce the positions and magnifications of multiply-lensed images of a distant supernova (SN). We find that such lens models fail to reproduce the image positions and magnifications simultaneously, adding to mounting evidence that DM does not comprise ultra-massive particles.

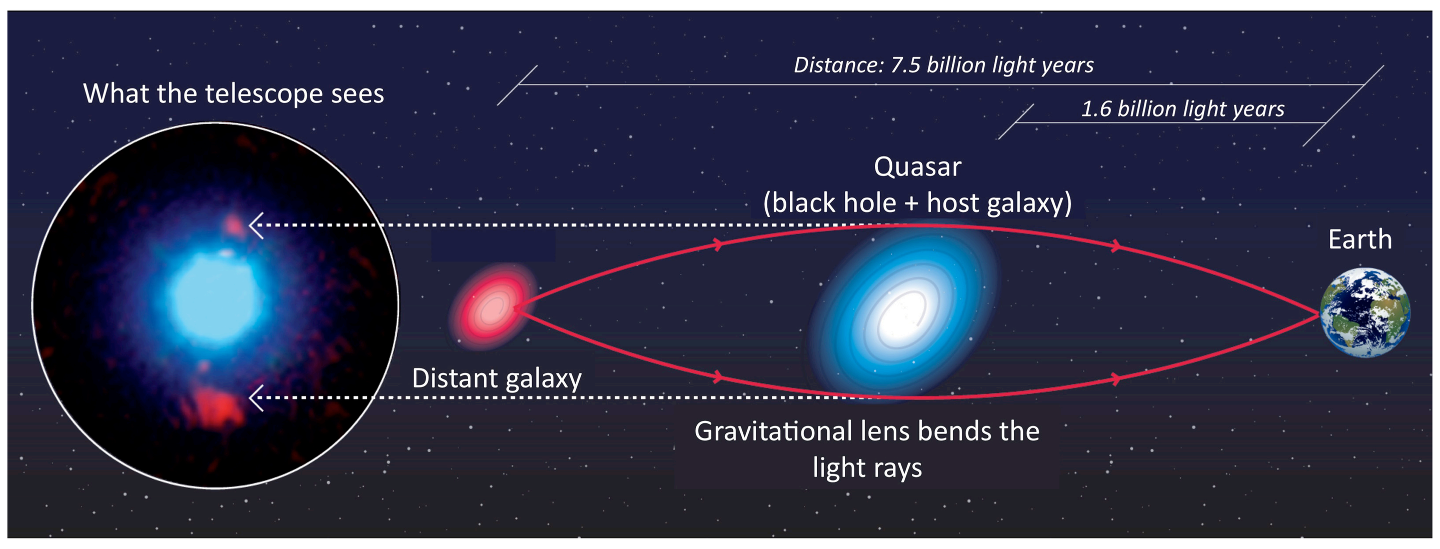




Fig. 1. Schematic of gravitational lensing, George Djorgovski

## SN Zwicky

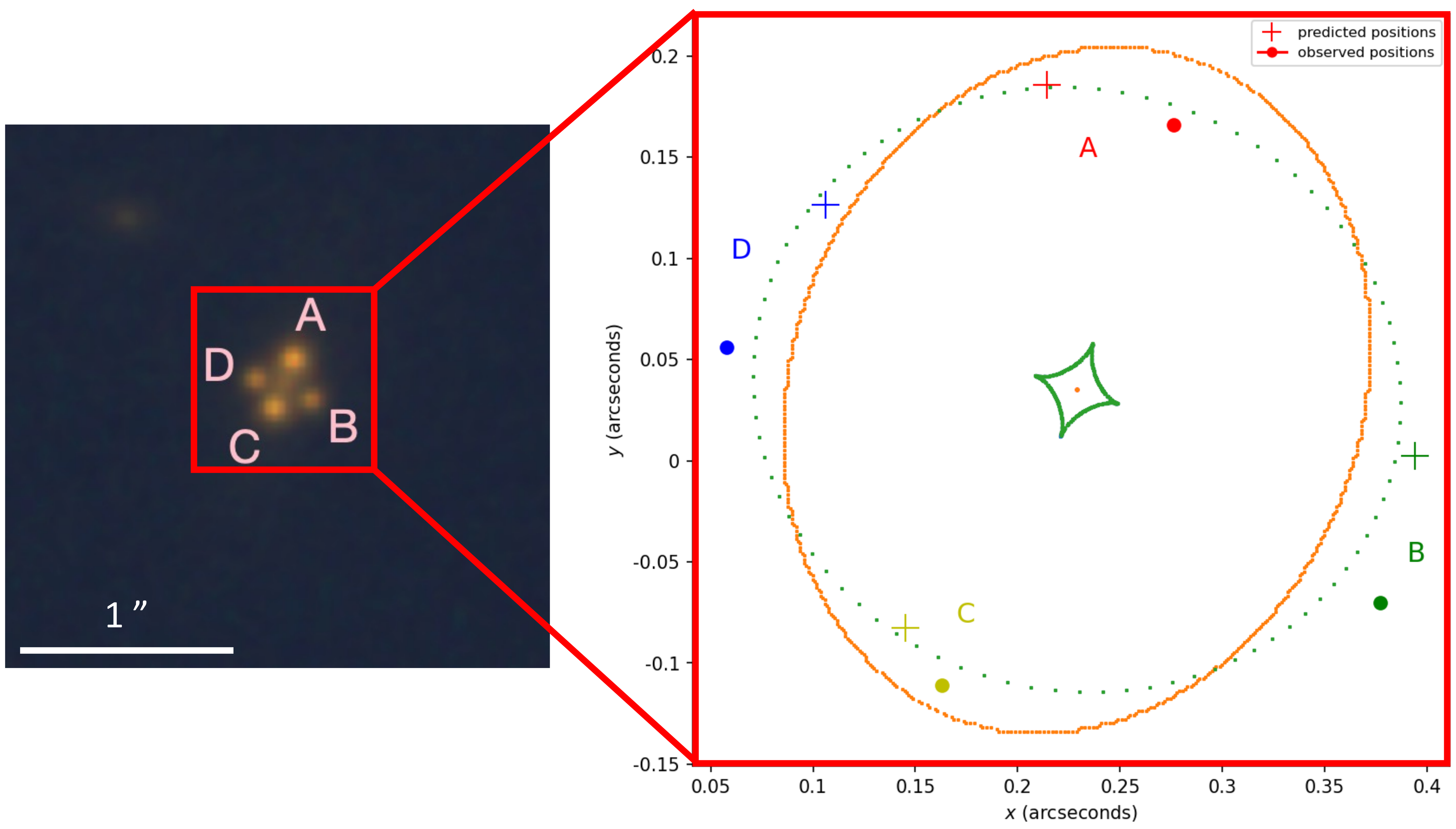
SN 2022qmx aka. SN Zwicky is the second known example of a lensed Type Ia supernova. SN Ia occur when a white dwarf in a binary system reaches a critical mass. These SN have a consistent peak luminosity and can be used as 'standard candles'. SN Zwicky is at a redshift of 0.354, which can be seen quadruply lensed by a foreground galaxy, z = 0.226, in Fig. 1

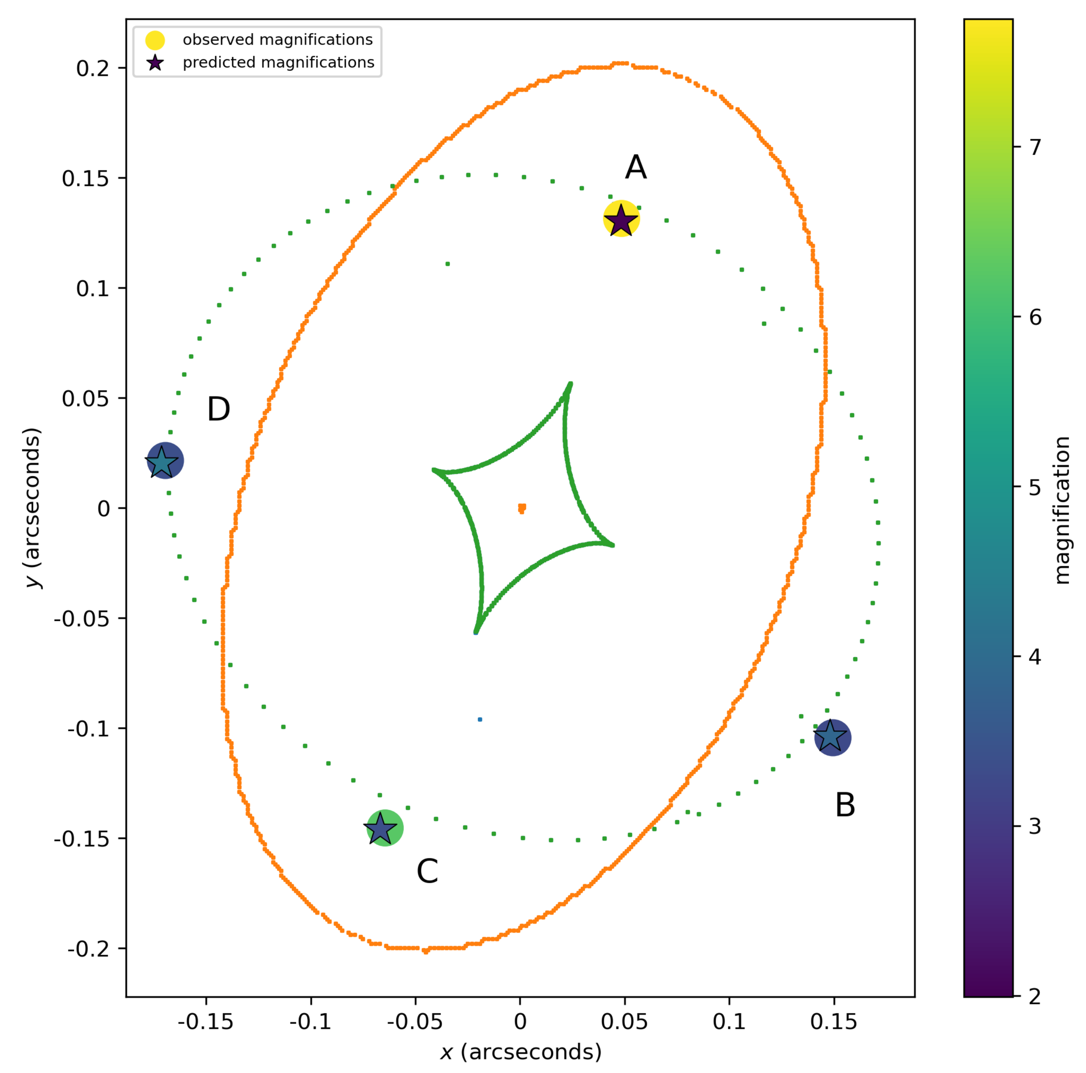
## Method and Results

We carried out model fitting using an open-source code, GLAFIC, with three commonly used dark matter models, giving a wide range in the density slope of the dark matter halo. Models were found using just observed positions as constraints, only magnifications as constraints and with both positions and magnifications jointly as constraints. Observation data for positions and magnifications were taken from the HST. The parameters for each model are determined by the code using chi-squared fitting. Some of the results are visualised in Fig. 2,3,4. The critical curves, which correspond to regions of high magnification, are plotted in orange.

## Discussion

None of the models used in the work, with any combination of constraints, were able to simultaneously predict the positions and magnifications of the observed images. An example of this can be shown in Fig. 4, where we have good predictions of magnifications within 1σ but incompatible position predictions. Fig.3 has excellent agreement in positions but the magnifications are wildly different. The next steps are to insert dark matter composed of ultra-light particles, an alternative description of dark matter, into the models and determine if there is improvement in the predictions made.



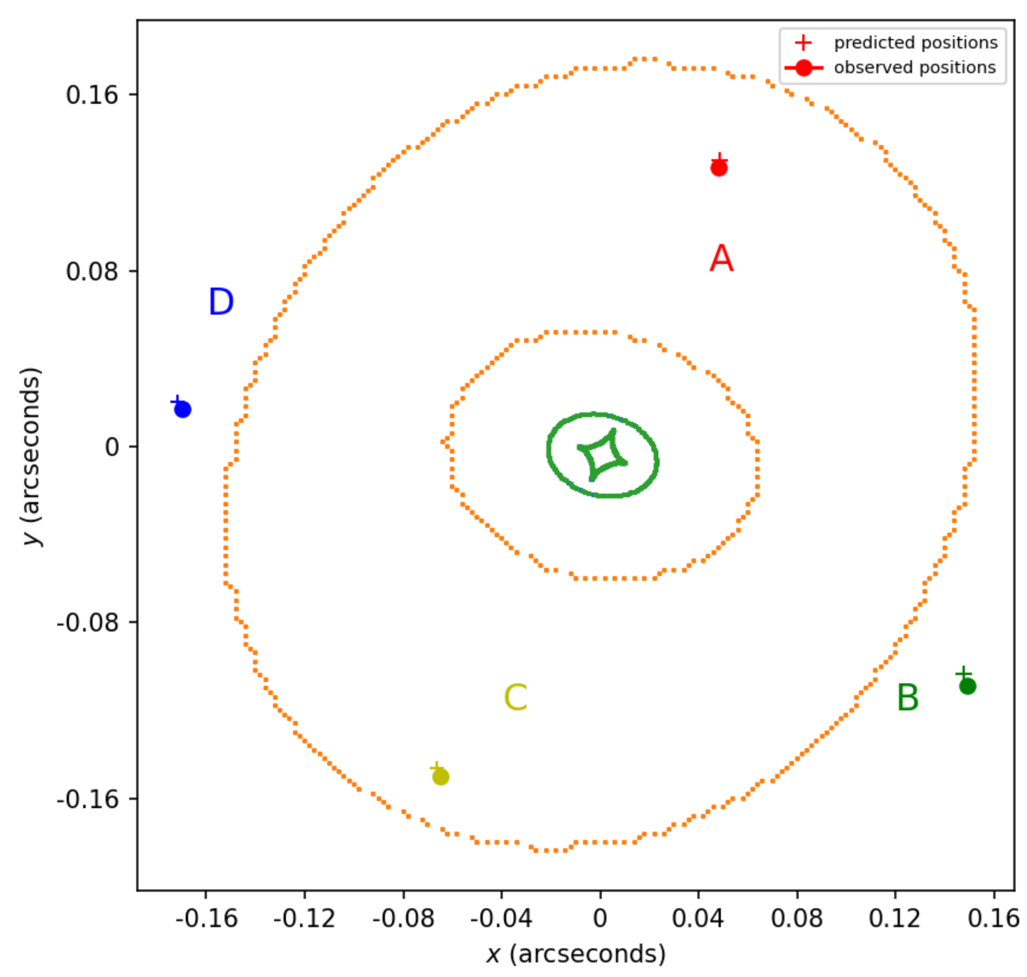




Fig. 3,4&5 LEFT: observations of the supernova images, labelled A-D, J.D.R.PIEREL et. al. CENTRE: SIE model output when only magnifications are used as constraints, with clear position differences. TOP RIGHT: SIE model with positions as constraints. The image positions align well but there is a large difference between predicted and observed magnifications. BOTTOM RIGHT: NFW model with both positions and magnifications as constraints; there is a reasonable agreement of positions but magnifications are too different to be plotted on the same graph.

## Key References


[1] Goobar et. al, 2022, arXiv Astro-ph
[2] Pierel et. al, 2022, arXiv Astro-ph



## Acknowledgements

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