Observing Dark Matter through Strong Gravitational Lensing Using Next-Generation Space Telescopes

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Introduction & Background

In modern physics and astronomy, we have significant evidence that dark matter exists throughout the universe, yet it is still extremely difficult to detect. One of the key ways to observe dark matter substructure is through Strong Gravitational Lensing (SGL), due to dark matter being revealed through the bending of light by gravity.

Modern telescopes are now capable of observing halos and Einstein rings through SGL. We can use the previously found Einstein rings in combination with computer simulations to predict the capabilities of next-generation space telescopes in detecting dark matter substructure. Observing ideal halos also allows us to determine how much dark matter is affecting the curve of the light ring.

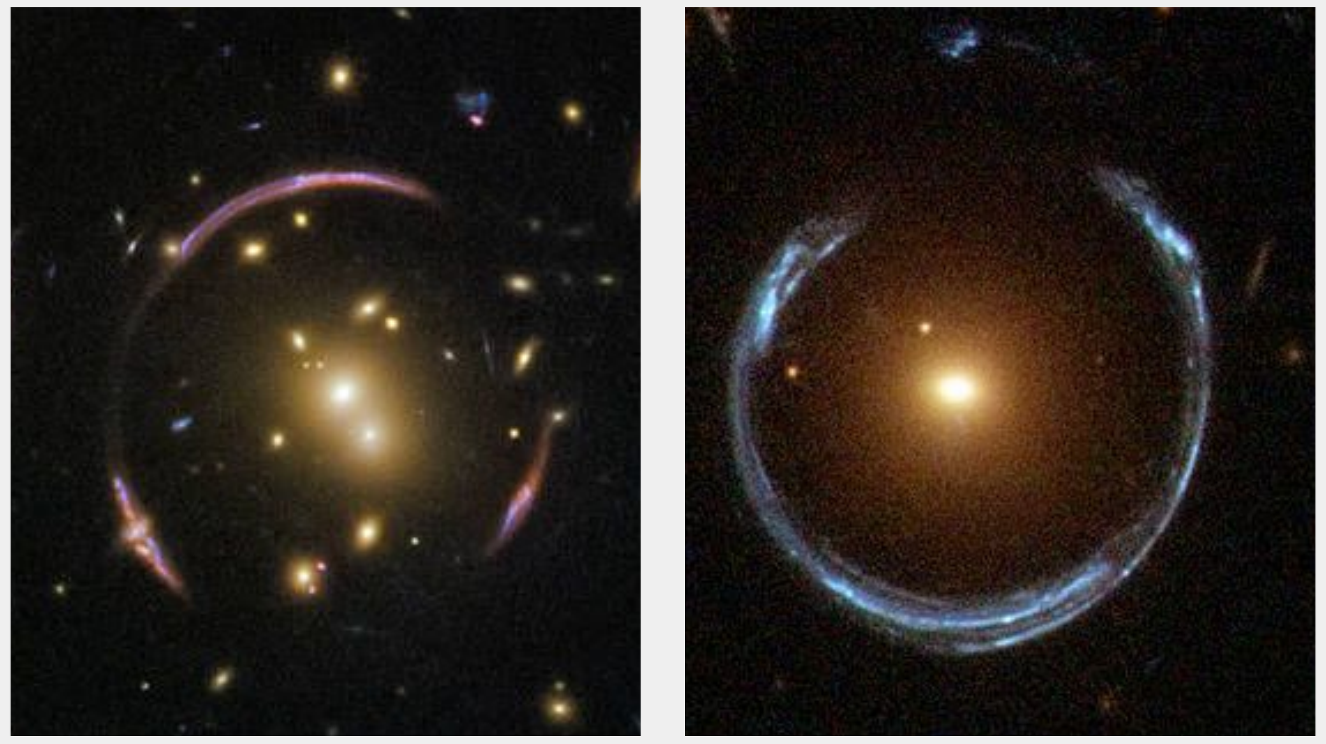

Figure 1: Images of Einstein Rings taken by Hubble Space Telescope, which show the bending of light around the lens source. The strength of the bending could not be caused by visible matter alone, strongly suggesting the evidence of dark matter. [1]

Methods & Results

Research about the substructure of dark matter such as cold, warm, or ultra-light dark matter provides important information for accurately generating populations of subhaloes in simulations. [2] Repositories designed in Jupyter notebooks allow for the generation of these halo populations along with the manipulation and analysis of the data they generate. The two primary repositories used to generate these simulations of halos are lenstronomy and pyHalo. [3,4] lenstronomy generates realistic models with substructure and turns it into realistic data using a point spread function (PSF). pyHalo generates populations of subhalos using lenstronomy to make observation and perform data analysis on. By combining code from these two repositories, we can create a Gaussian halo and adjust individual parameters including shear, gamma, and position to change the shape and thinness of the arc. We can also observe how far the observed object is from the critical arc, which provides important information on how the position of the source, lens, and observer play key roles in the resolution and clarity of these halos (Fig. 2).

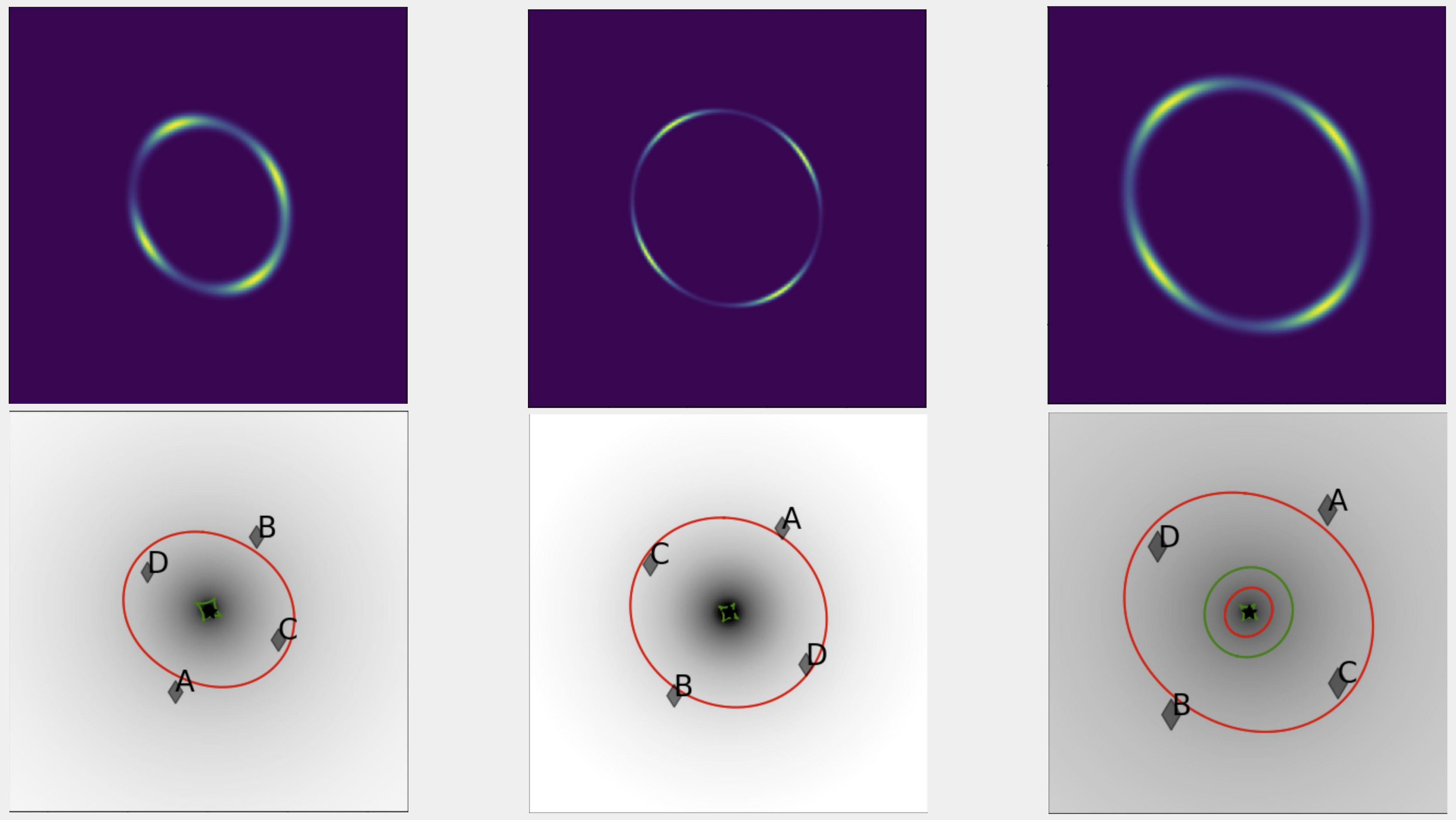

Figure 2: Gaussian halos generated by adjusting individual parameters for the size, distortion, and noise of the image to produce varieties of long, thin arcs.

Conclusion & Next Steps

As we move towards the next generations of space telescopes such as LUVOIR (Fig. 3), these simulations serve as excellent examples of the potential capabilities of the lenses in the future. In the interim, we are able to simulate both realistic galaxies and ideal Gaussian Einstein rings in ways that allow us to further explore hypotheses about the existence and structure of dark matter.

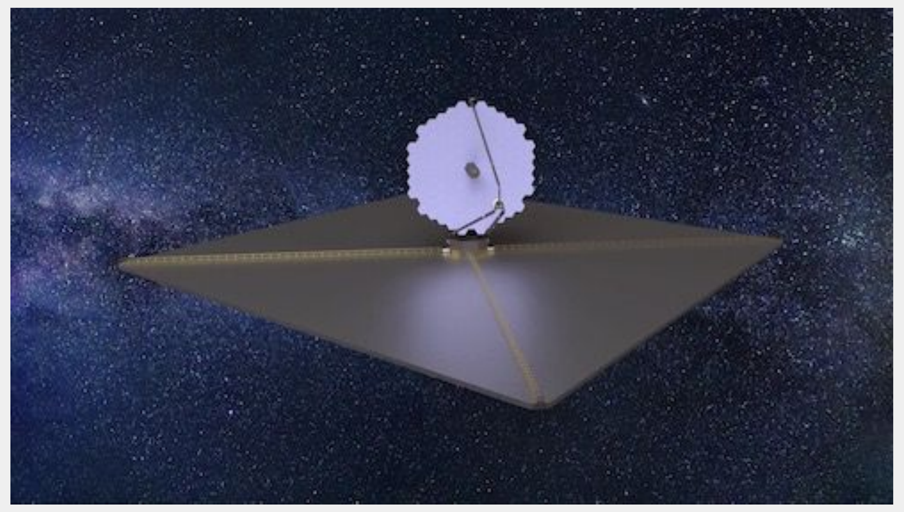

Figure 3: Concept design of the Large UV Optical Infrared telescope, a multi-wavelength, serviceable observatory. [5]

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References

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