# Generating Catalogues of Lensed Galaxies to Test Weak Lensing Pipelines

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# Weak Lensing Formalism

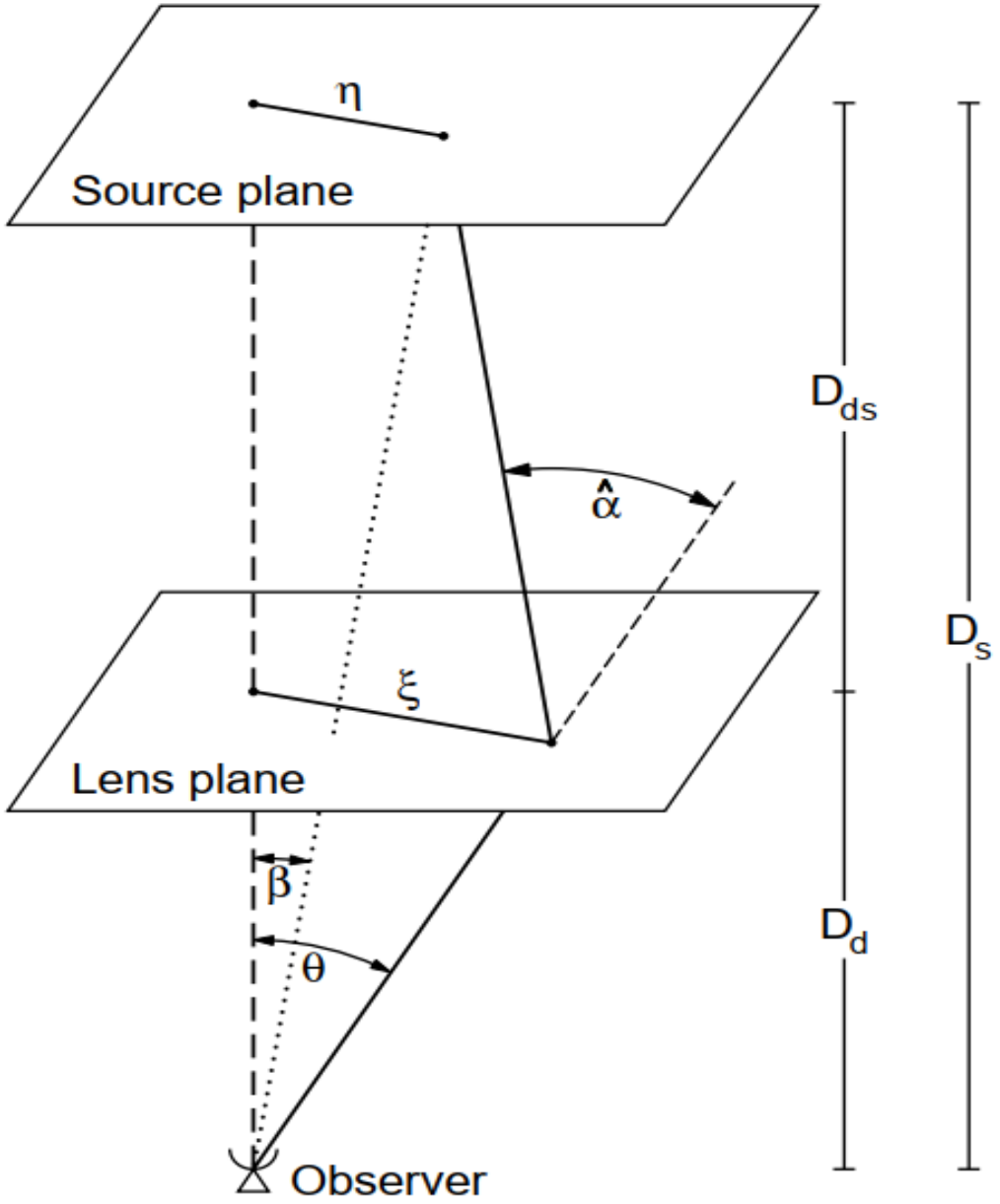
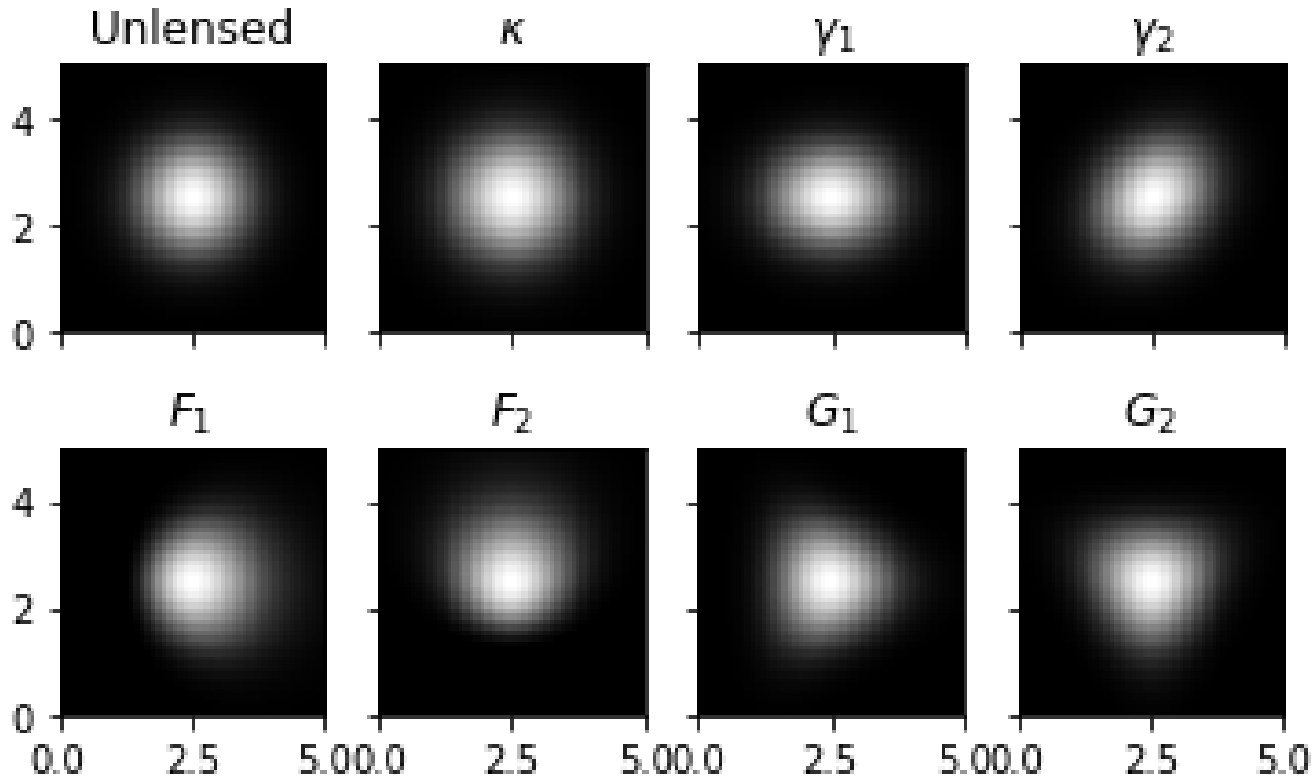



Image credit Bartelmann and Schneider, (1999)

$$\vec{\beta} - \left(\vec{\theta} - \alpha(\vec{\theta})\right) = 0$$

# Lensing Parameters




Data produced from current work

$$\beta_i = A_{ij}\theta_j + \frac{1}{2}D_{ijk}\theta_j\theta_k$$

$$A_{ij} = \begin{pmatrix} 1-\kappa-\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1-\kappa+\gamma_1 \end{pmatrix}$$

$$D_{ij1} = -\frac{1}{2}\begin{pmatrix} 3F_1+G_1 & F_2+G_2 \\ F_2+G_2 & F_1-G_1 \end{pmatrix}$$

$$D_{ij2} = -\frac{1}{2}\begin{pmatrix} F_2+G_2 & F_1-G_1 \\ F_1-G_1 & 3F_2-G_2 \end{pmatrix}$$

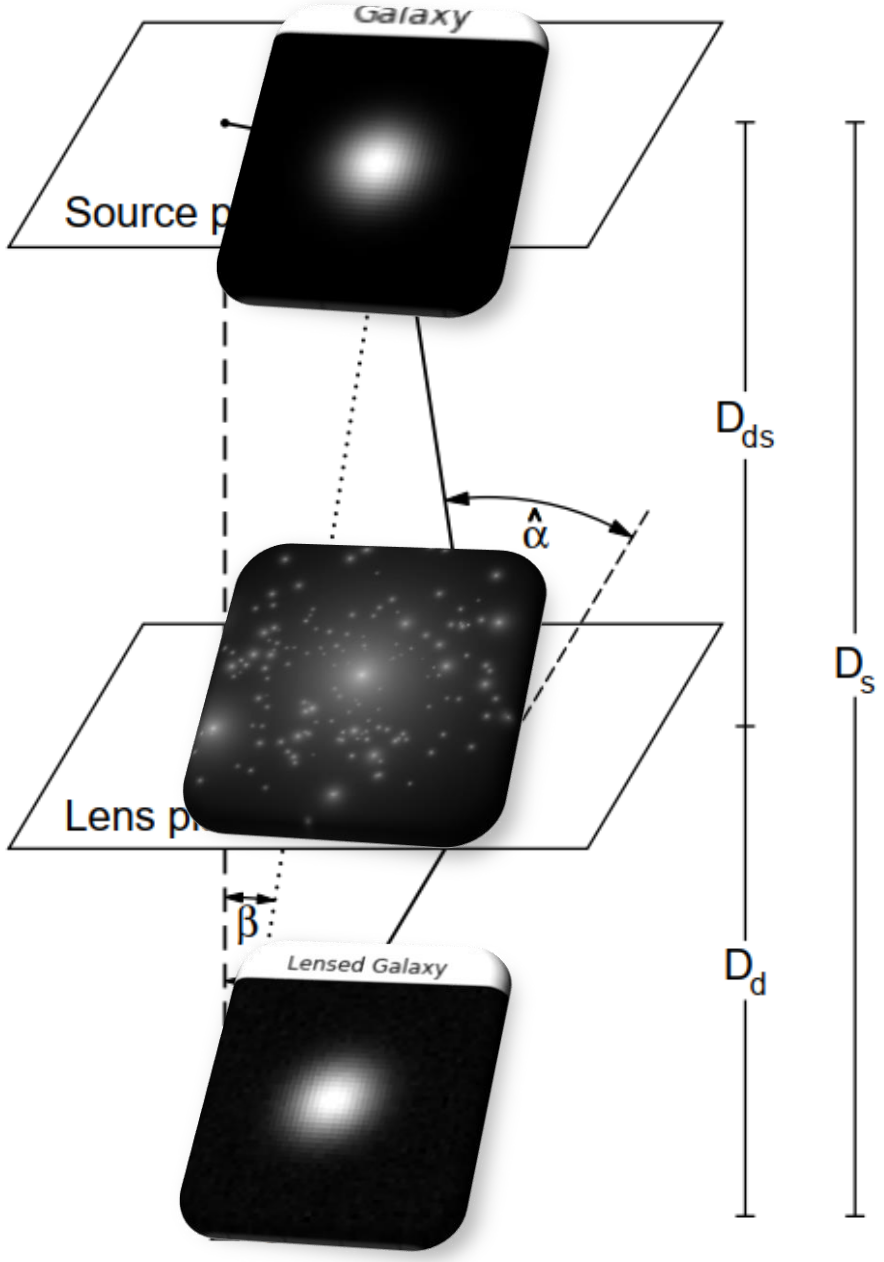



Image credit Bartelmann and Schneider, (1999)

Develop realistic galaxy images, incorporating observational features found in image data.

Produce a realistic cluster gravitational lensing potential.

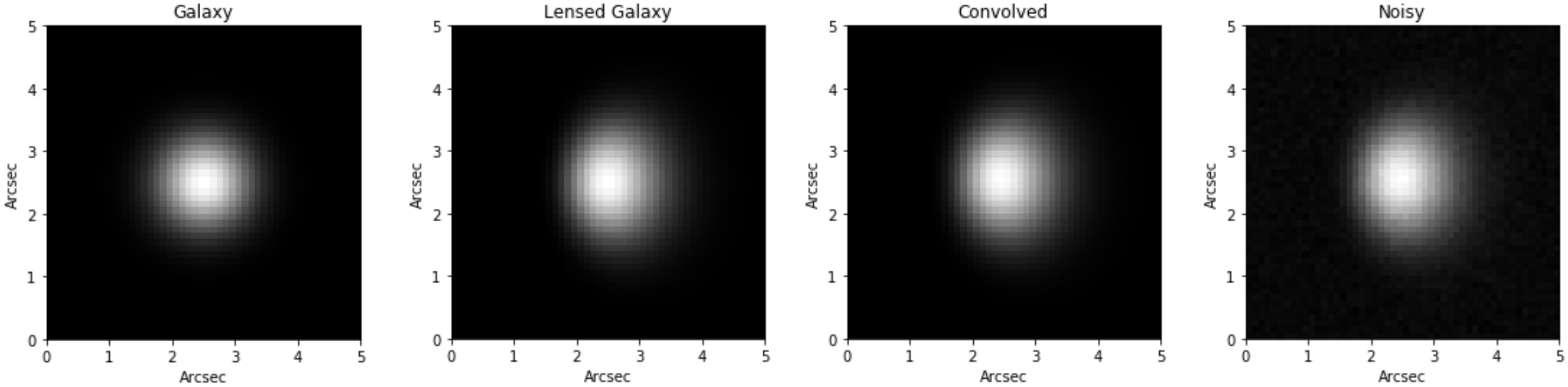
Use lensing potential to transform galaxies from source to lensing plane.

# The Multidark N-Body Simulation

| Data Field | Description |
|---|---|
| MainHaloID | Unique cluster identifier |
| HaloMass | Mass of dark matter halo, in solar masses |
| GalaxyType | Distinguishes between primary halo and subhalos |
| NFWConcentration | NFW concentration of halo |
| x | X position of halo (in Mpc) |
| y | Y position of halo (in Mpc) |
| z | Z position of halo (in Mpc) |

- An N-body simulation run in 2013.
- Particle number: $3840^3$
- Box size: 1 $h^{-1}$ Gpc
- Mass resolution: $1.5 \times 10^9 M_\odot$
- 10 million halos downloaded from the SAG catalogue.

(Knebe et al, 2016)

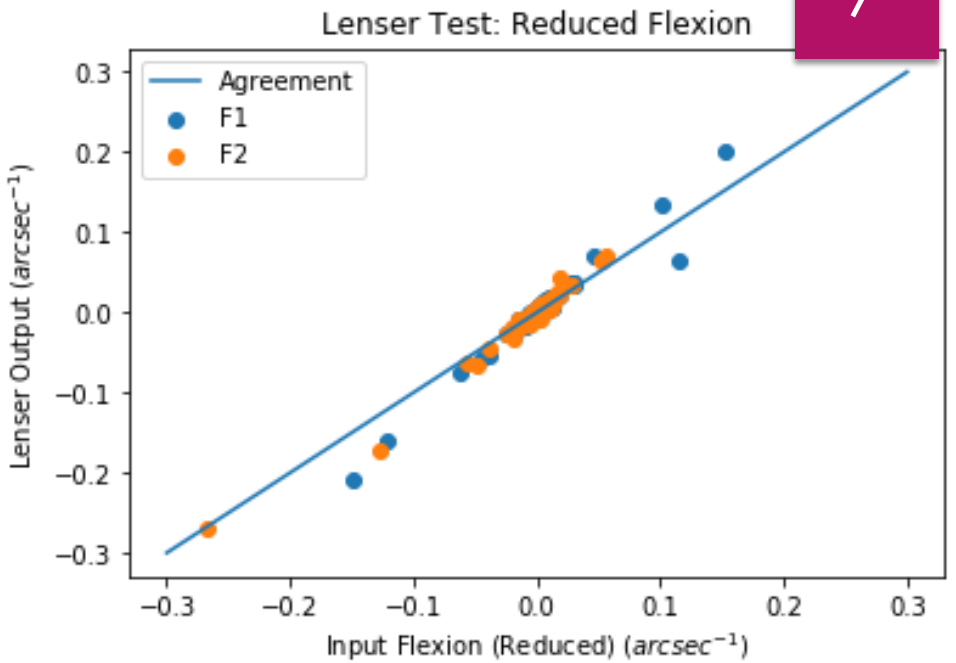


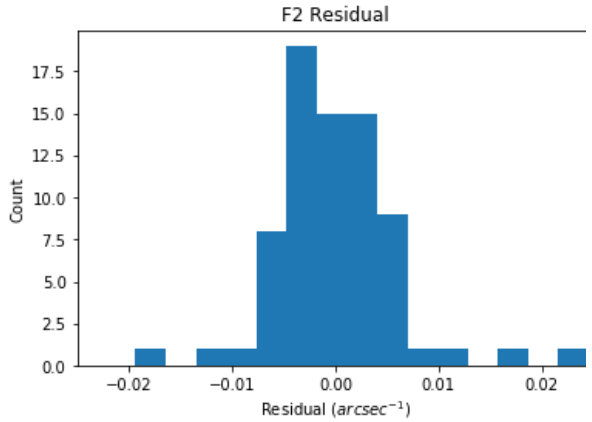

# Following One Galaxy

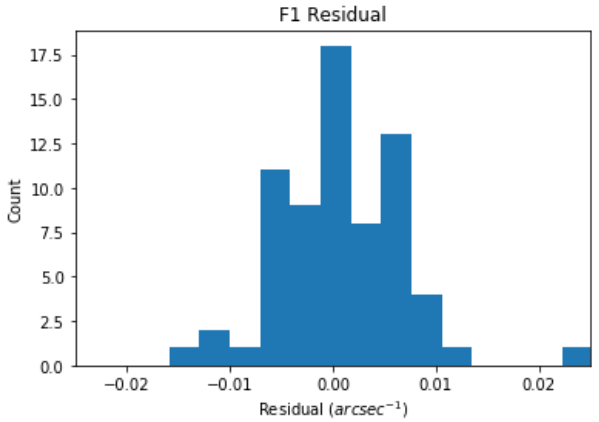
Images produced from current work

# Lenser Tests

- Lenser was used to process 100 generated images (around an SIS profile), extracting their flexion.
- I compare inputted flexions to the flexion measured by Lenser.
- Residuals have RMS values of
  - $F_1$: $0.0136\ arcseconds^{-1}$
  - $F_2$: $0.0077\ arcseconds^{-1}$




Data produced from current work

# Future Work

- This tool generates catalogues to model specific lensing scenarios. This will provide a valuable resource to lensing pipelines which extract information from lensed galaxies.
- There are more tests to be run with Lenser, with larger catalogues, more complex lensing profiles, and a larger distribution of input flexions.
- There are additional potential selection criteria for MultiDark clusters that will allow specific physical systems to be modeled.

# Thank You!

Image credit: NASA / ESA / Hubble

# Acknowledgements


- Thank you to
  - Jake Delano, for using Lenser to analyze *many* hundreds of test images.
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  - Dave Goldberg, for constant advice and insight.
- The MultiDark database was developed in cooperation with the Spanish MultiDark Consolider Project CSD2009-00064.

# References


- D. J. Bacon, D. M. Goldberg, B. T. P. Rowe, and A. N. Taylor. Weak gravitational flexion. Monthly Notices of the Royal Astronomical Society, 365(2):414–428, 2006.
- Matthias Bartelmann and Peter Schneider. Weak gravitational lensing. Physics Reports,340:291–472, 1999.
- P. Schneider and X. Er. Weak lensing goes bananas: what flexion really measures. Astronomy and Astrophysics, 485(2):363–376, 2008.
- Julio Navarro, Carlos Frenk, and Simon White. A universal density profile from hierarchical clustering. Astrophysics, 490:493–508, 1997.
- Aaron D. Ludlow and et. al. The mass-concentration-redshift relation of cold dark matter halos. Monthly Notices of the Royal Astronomical Society, 441(1):378–388, 2013.
- Charles R. Keeton and Leonidas A. Moustakas. A new channel for detecting dark matter substructure in galaxies: Gravitational lens time delays. The Astrophysical Journal, 699(2),2009.
- Jesus Zavala and Carlos Frenk. Dark matter haloes and subhaloes. Galaxies, 7(4), 2019.
- Antonio Gao and et. al. The statistics of the subhalo abundance of dark matter haloes. Monthly Notices of the Royal Astronomical Society, 410(4):2309–2314, 2011.
- Alexander. Knebe and et al. Multidark-galaxies: data release and first results. Monthly Notices of the Royal Astronomical Society, 474(4):5206–5231, 2018.
- Lenser: https://github.com/DrexelLenser/Lenser