Probing the Inner Density Profile of Galaxy Clusters with Strong Lensing and MUSE Spectroscopy

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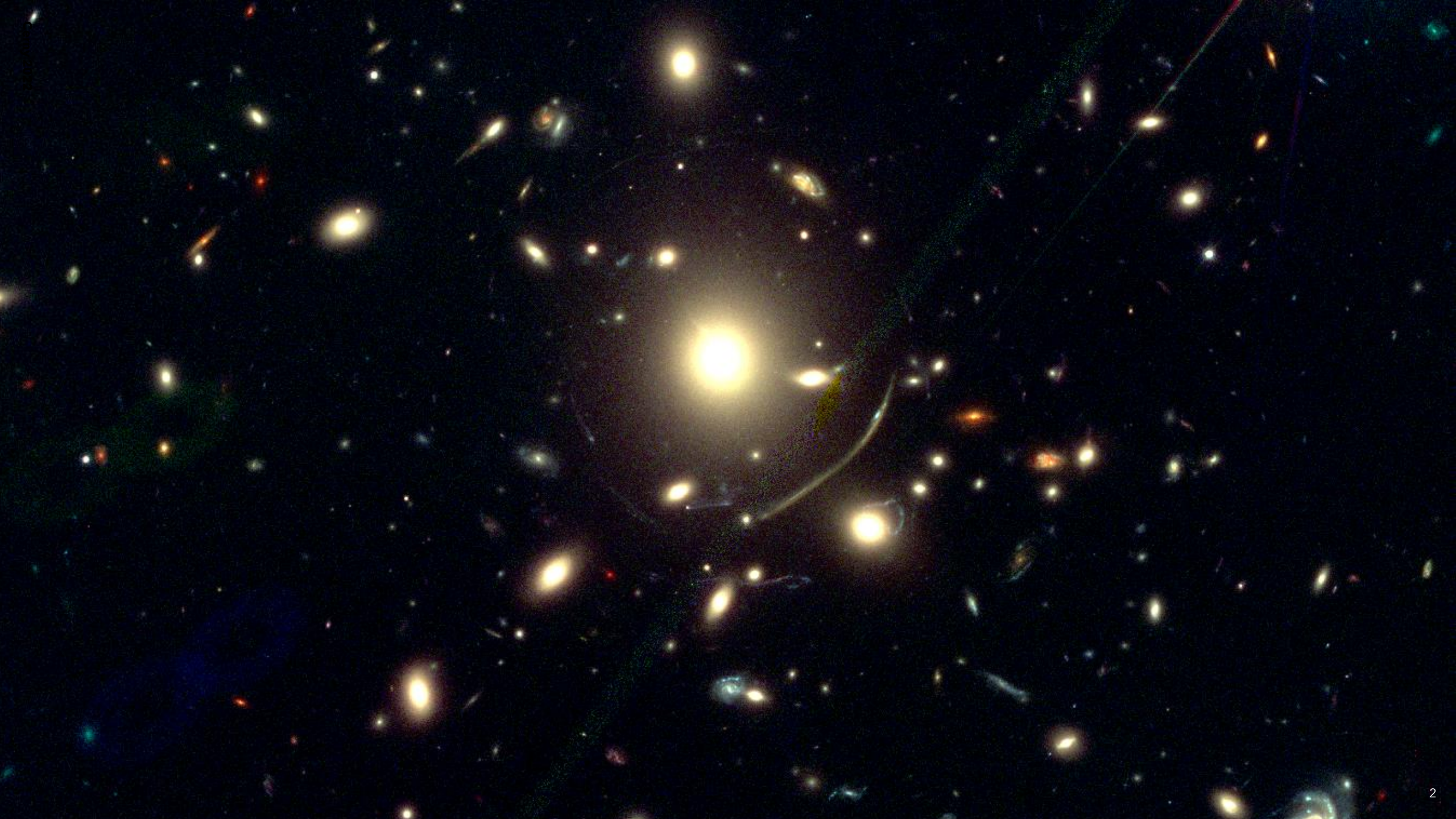
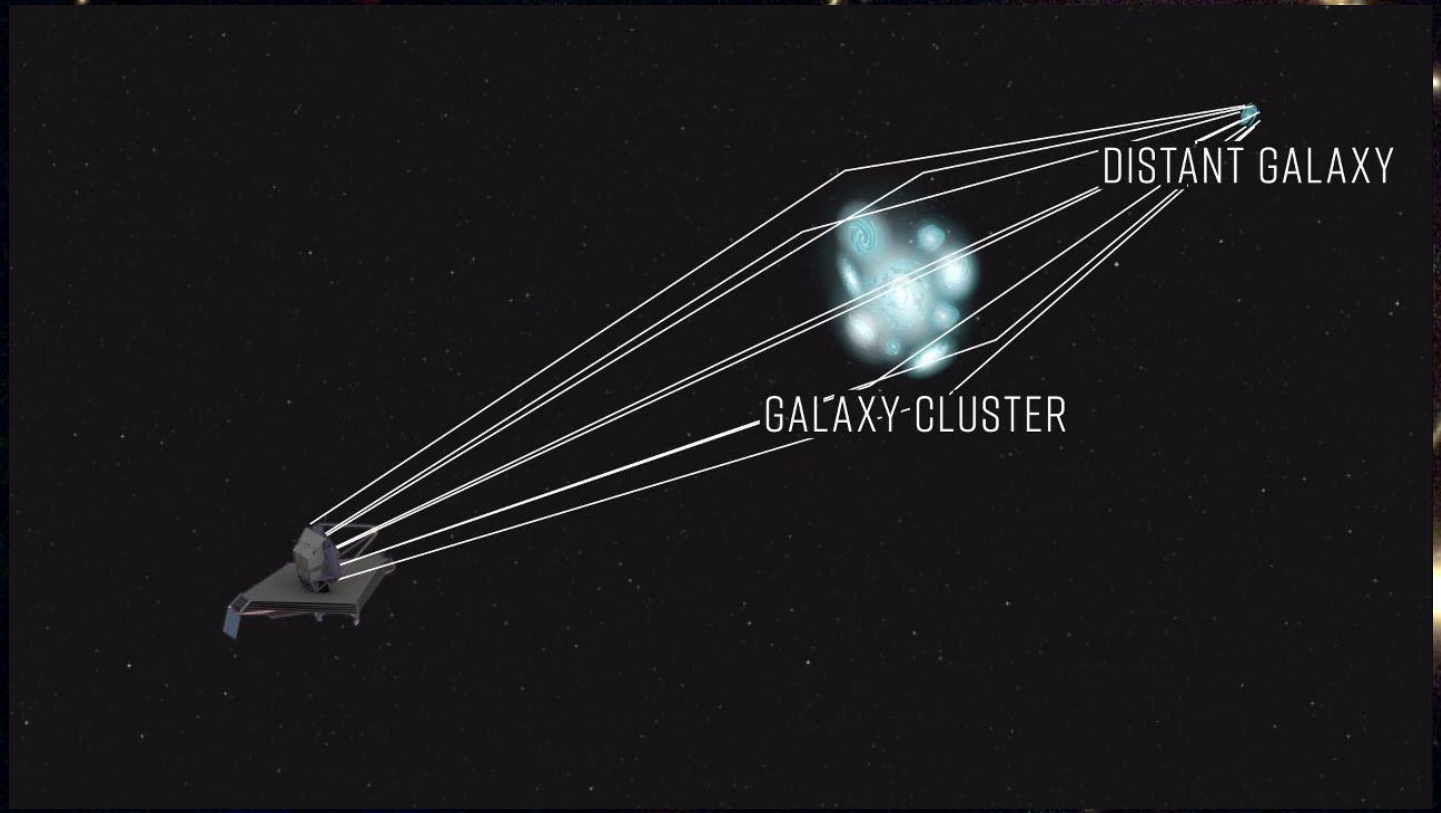
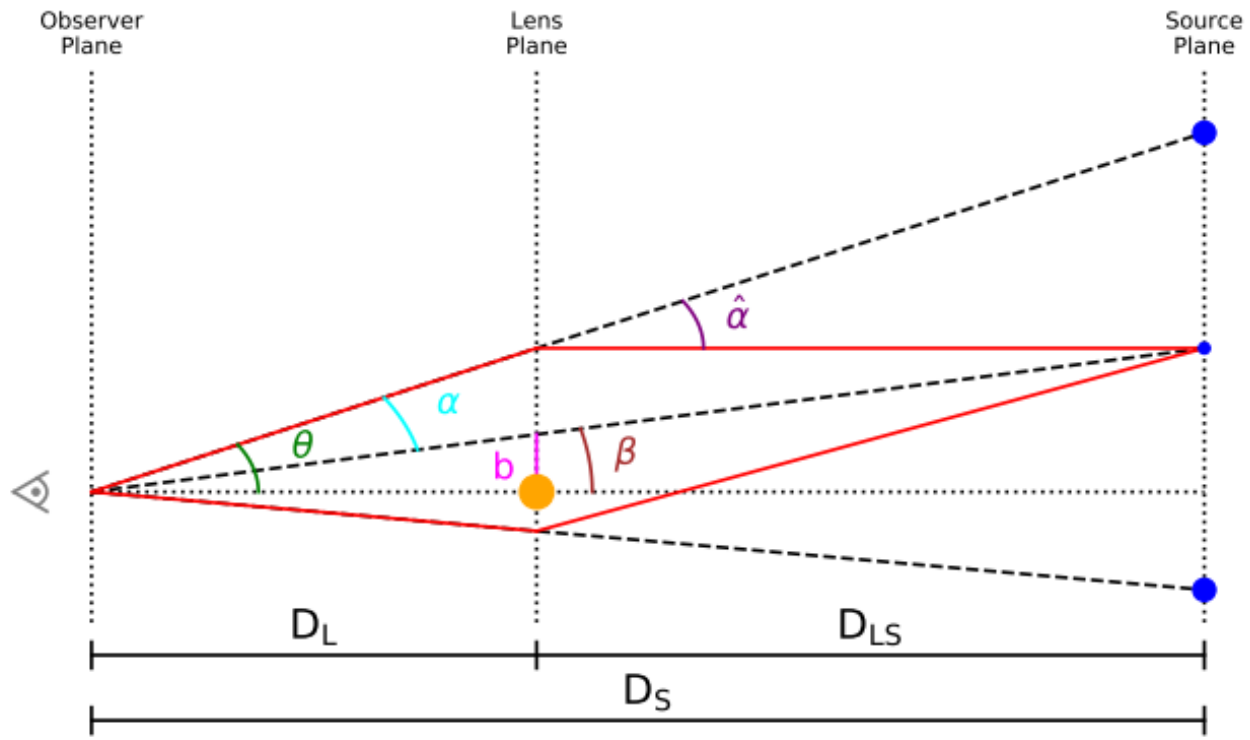
German Conference of Women in Physics 26 Nov 2022

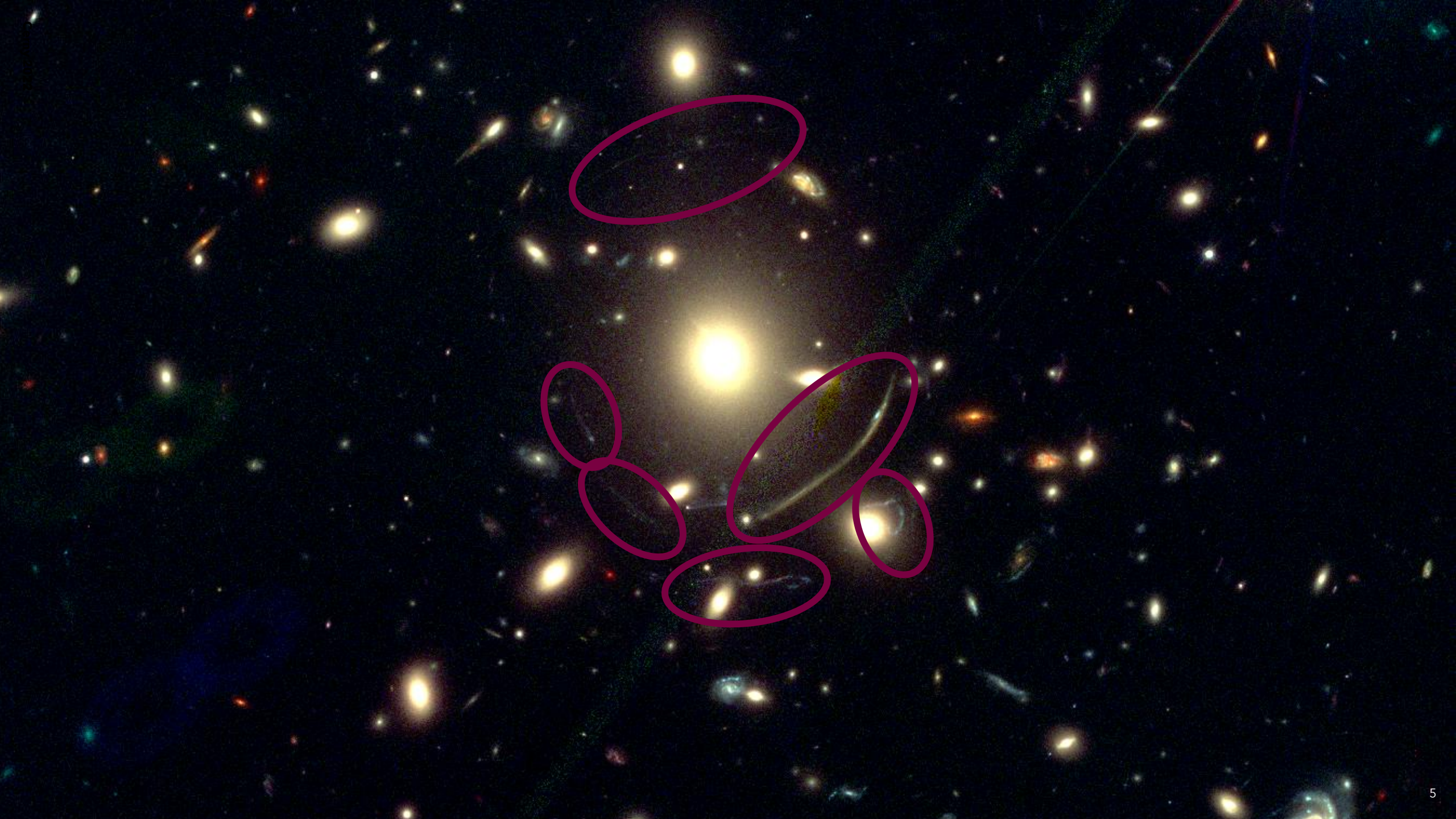


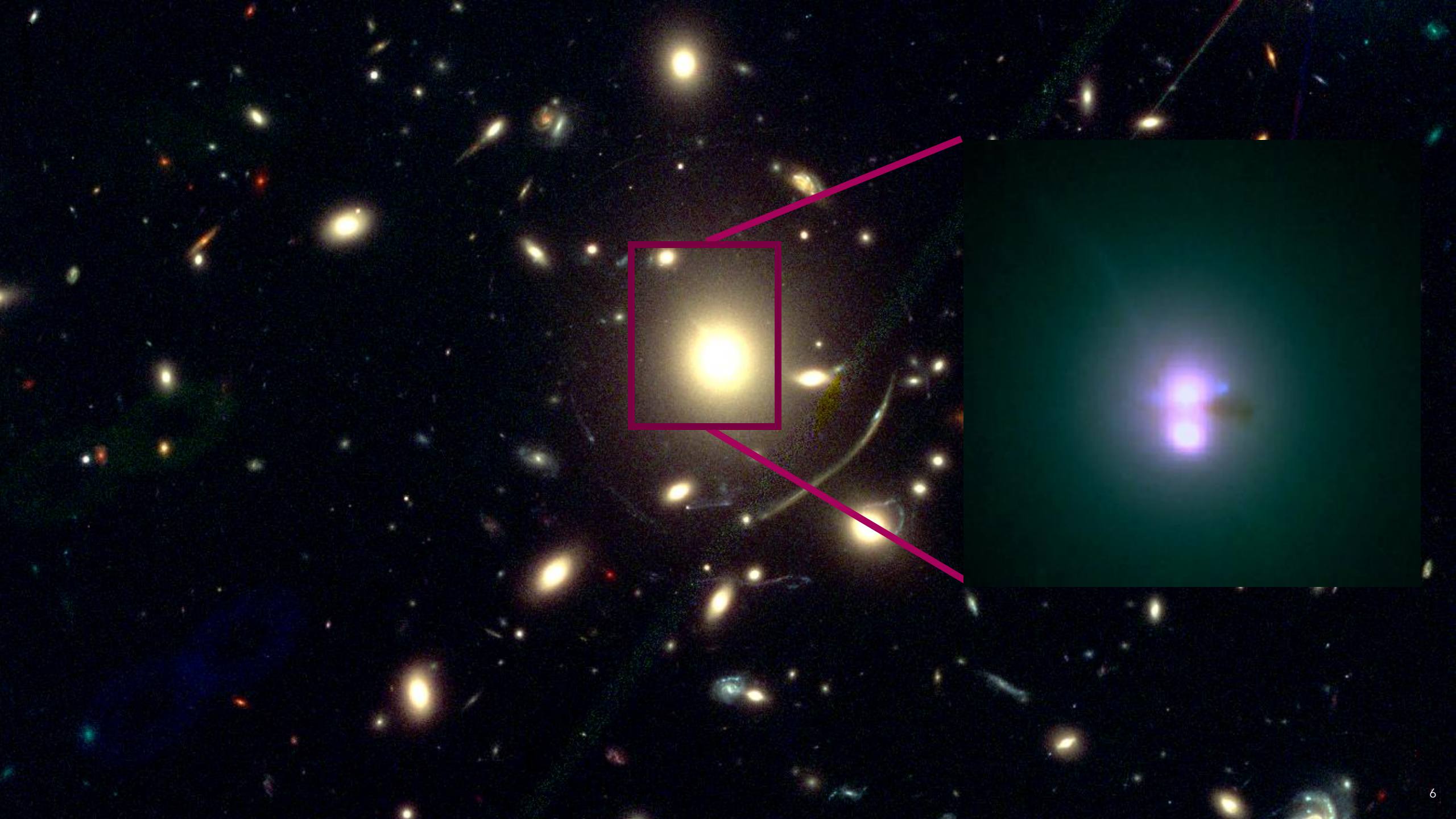


Strong lensing distorts the light from background sources to multiple positions around the cluster



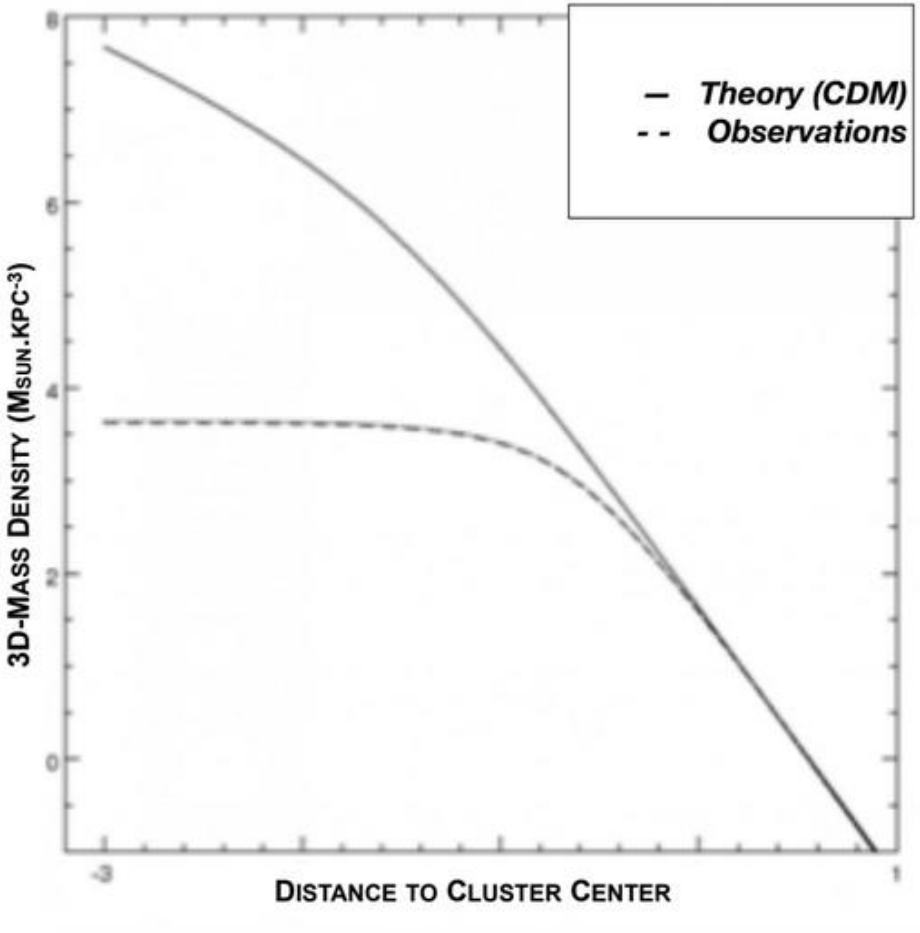
We use the positions of multiply imaged background sources to solve the lensing equation and map the mass distribution in the cluster





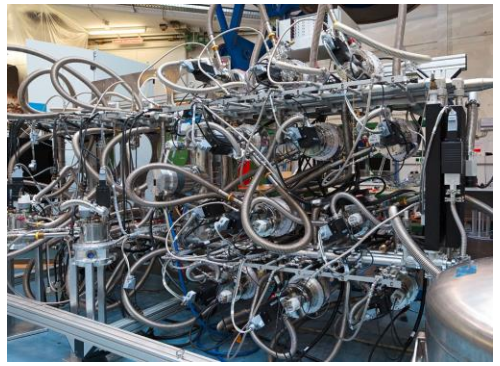
THE 'CORE-CUSP' PROBLEM

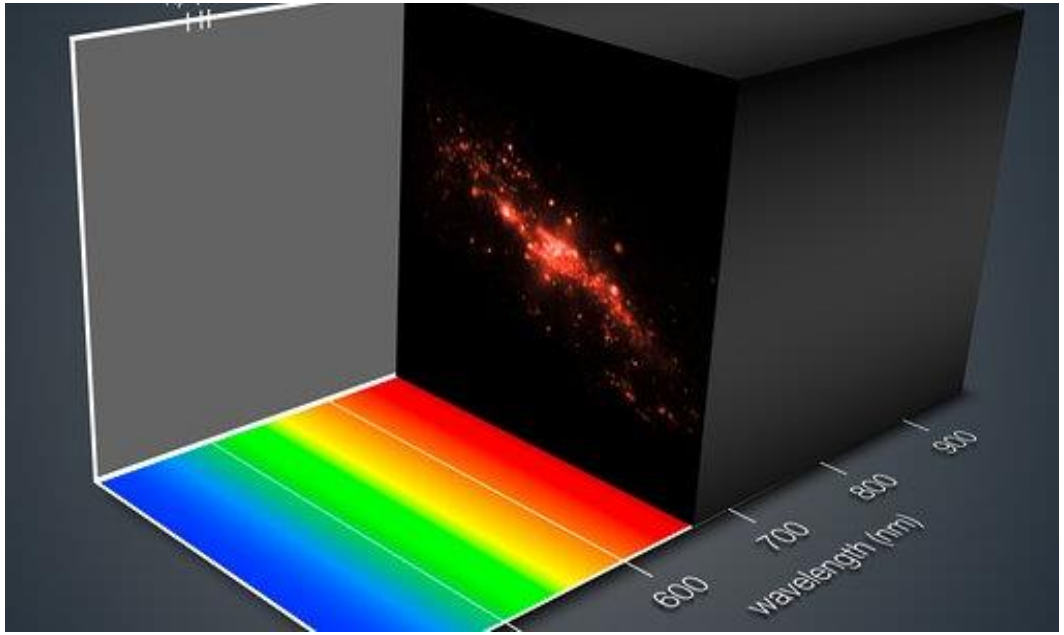
- Observations suggest constant-density 'core'
- CDM simulations predict increase into a 'cusp'
- Hydrodynamical simulations like BAHAMAS, Cluster-EAGLE, FIRE, etc. demonstrate that the central baryon concentration cannot be neglected (see McCarthy et al. 2017, He at al. 2020, Bose et al. 2019, etc)
- Need more observational data points to compare against simulations!



MUSE

- MUSE: Multi Unit Spectroscopic Explorer
- Integral Field Spectrograph
- Located at the Very Large Telescope (VLT)
- 24 identical spectrographs sample the same ~1 arcmin FoV over nearly the entire optical domain (~480-930 nm)
- 3D views with a spectrum for each pixel as the third dimension





GIANT RADIAL ARCS

- Six galaxy clusters with giant radial arcs, four new models
- Clusters are ~relaxed with a nearly circular BCG (axis ratio *b/a*~0.8), good to compare with simulations with equilibrium DM halos

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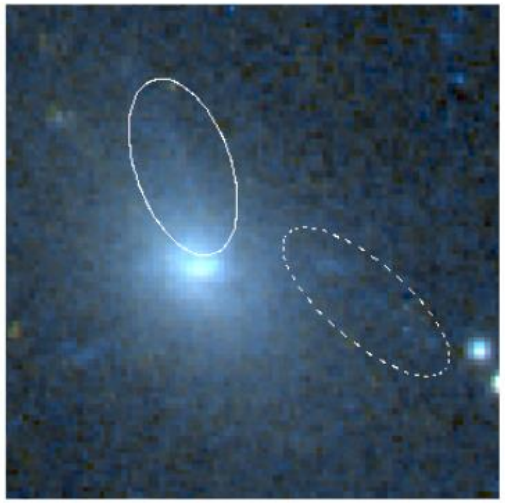

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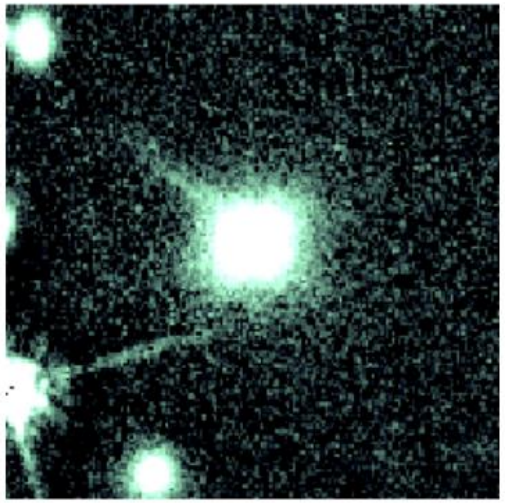

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GIANT RADIAL ARCS

- Six galaxy clusters with giant radial arcs, four new models
- Clusters are ~relaxed with a nearly circular BCG (axis ratio *b/a*~0.8), good to compare with simulations with equilibrium DM halos
- NEW: MUSE *Kaleidoscope* Survey
  - Spectroscopic redshifts for radial arcs
  - Cluster member identification
  - Stellar kinematics of BCG

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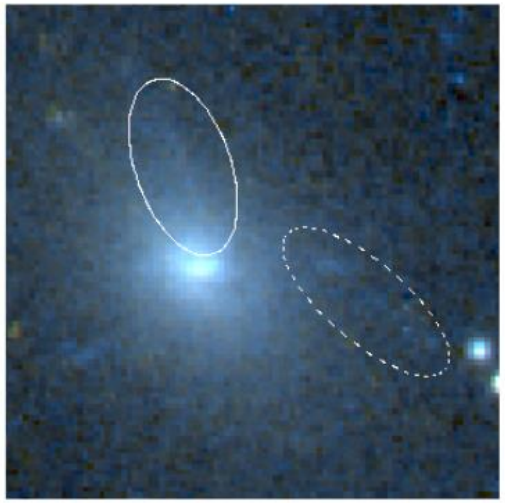

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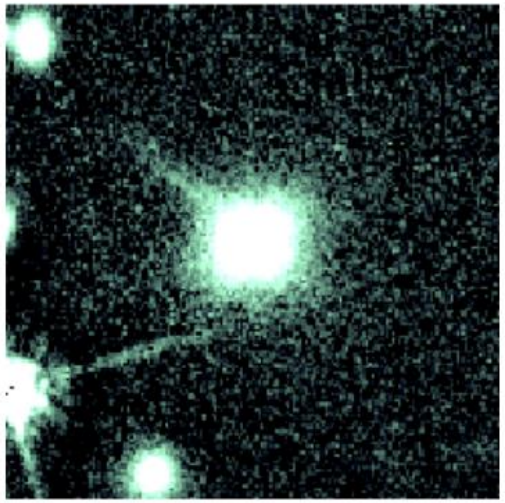

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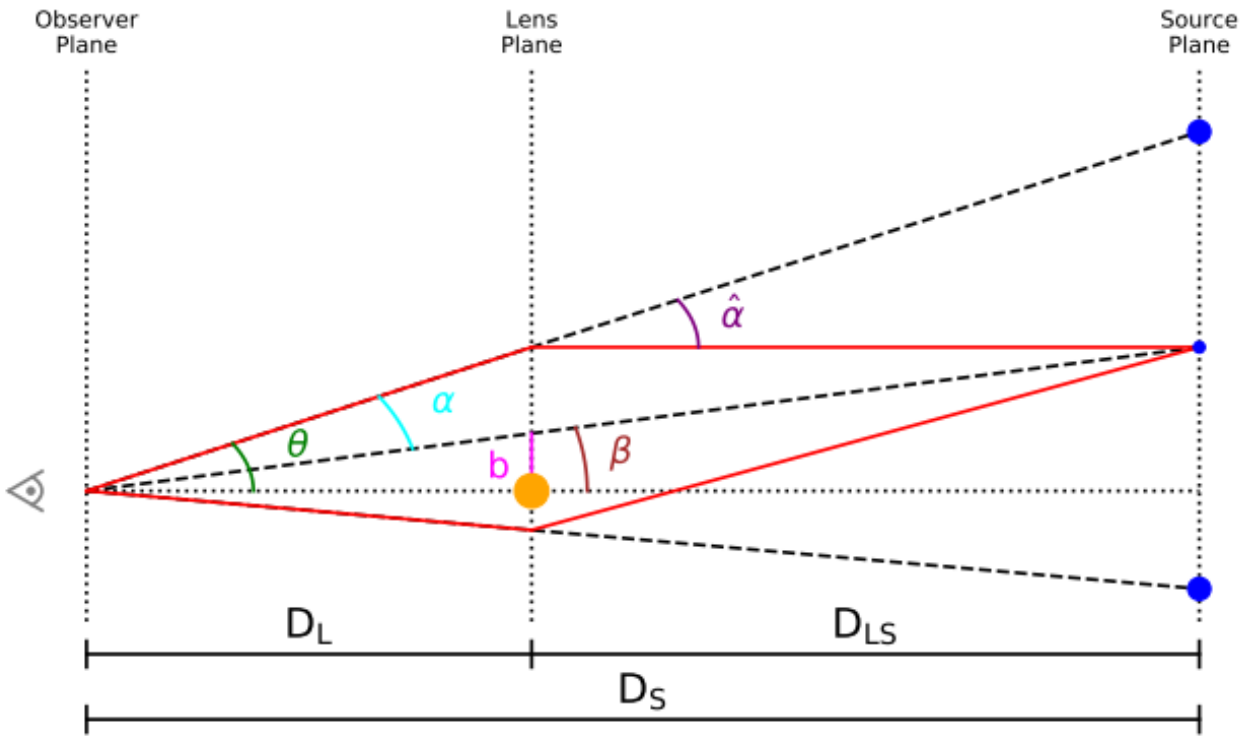
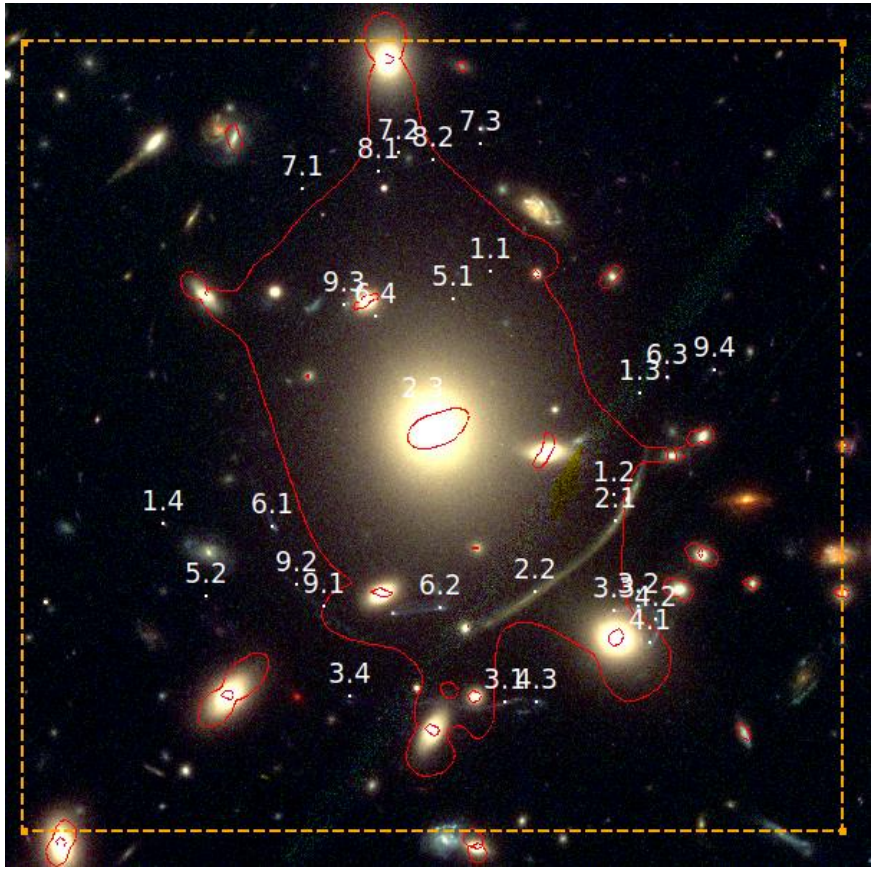
LENSTOOL MODELING

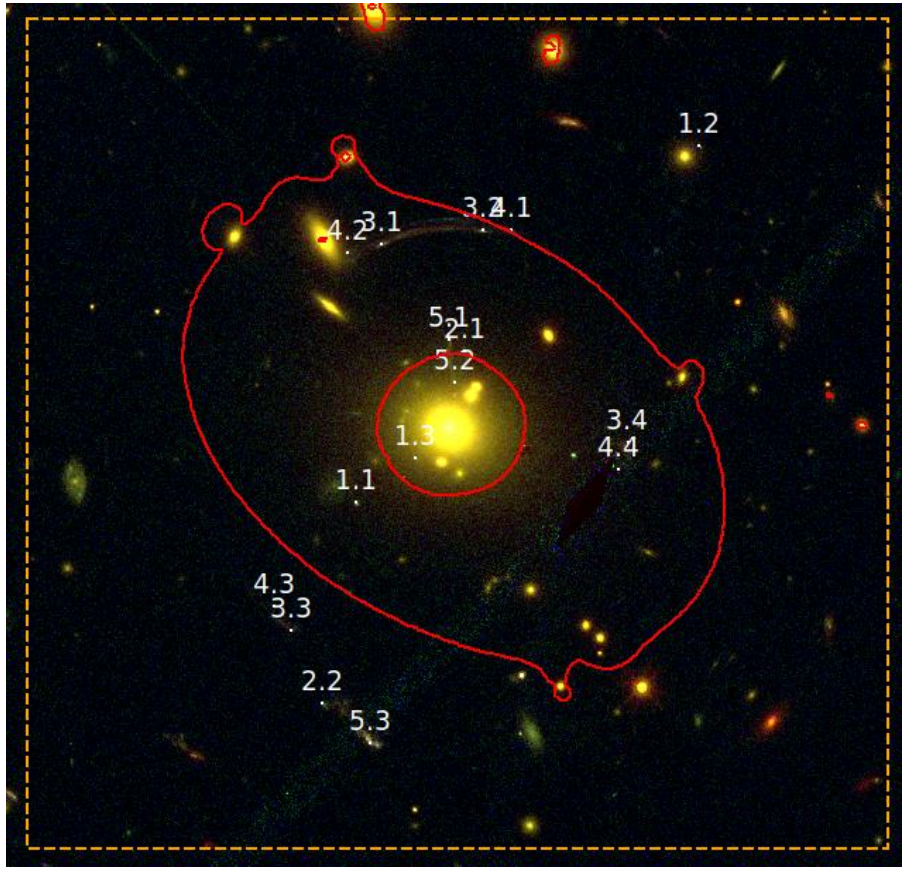


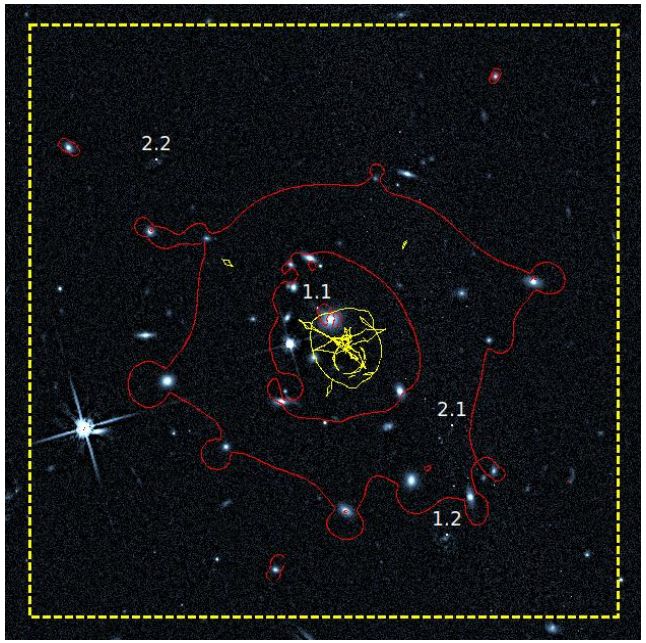
- Parametric MCMC modeling
- Positions and redshifts of multiply-imaged arcs are constraints
- Three components of mass:
  - 1) Cluster-scale DM halo
  - 2) Galaxy-scale DM halos in areas with strong lensing
  - 3) Cluster galaxies modeled with pseudo-isothermal ellipsoidal mass distribution (PIEMD) halos

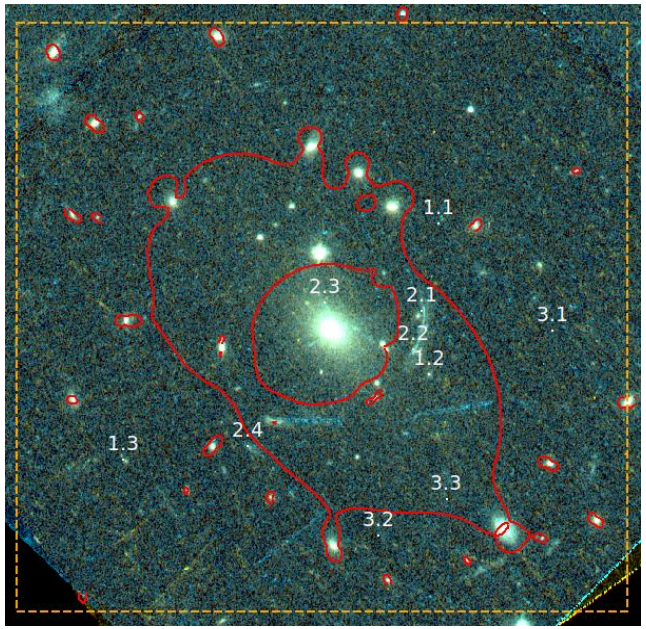
STRONG LENS MODELS

- Modeled with Lenstool (parametric MCMC)
- Three components: cluster-scale DM halo, galaxy-scale perturbers, cluster member galaxies









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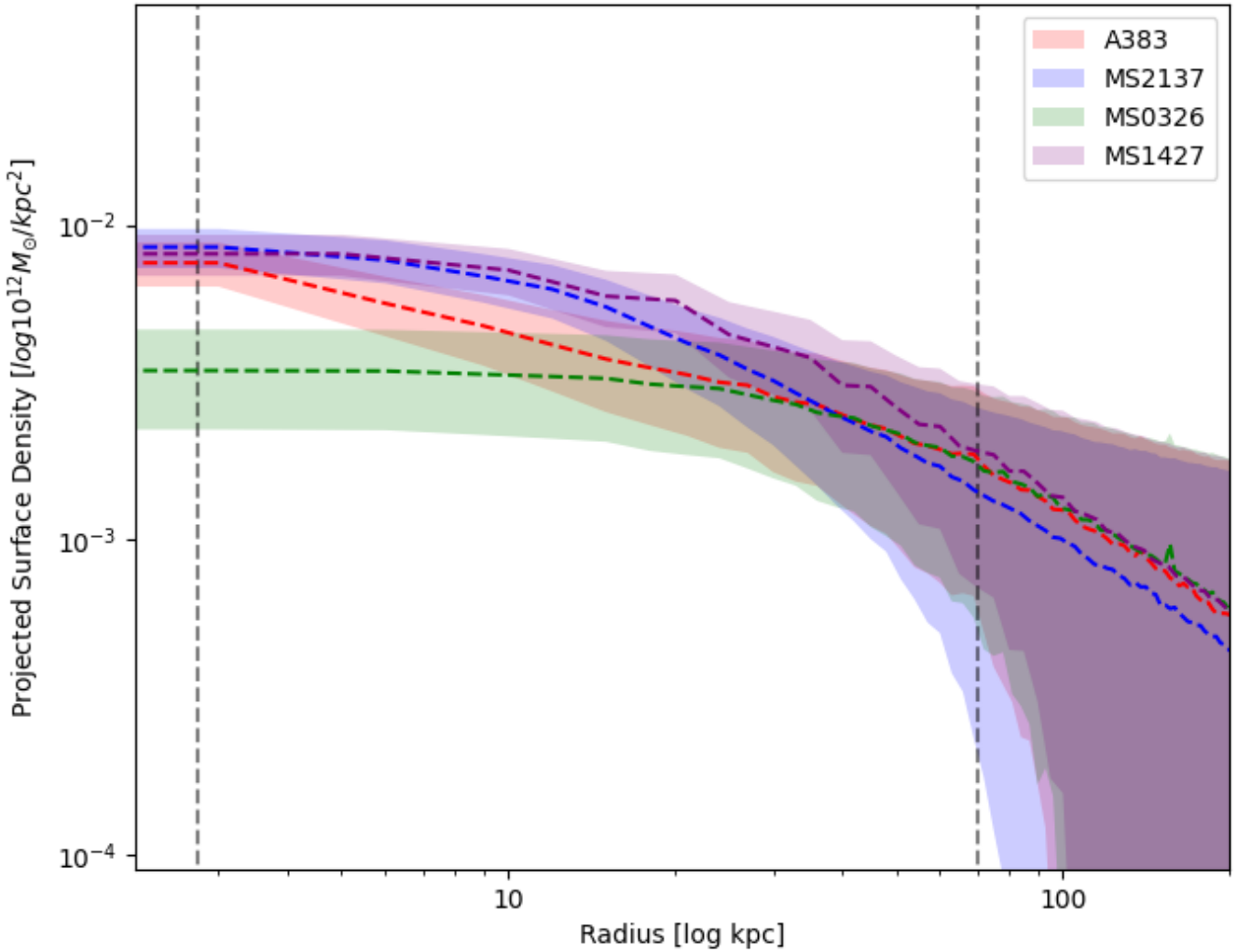
DENSITY PROFILE

Radial arcs allow Lenstool to reach into the inner ~20kpc

Lenstool cannot break degeneracy between baryonic stellar mass and cluster DM

Inner 10kpc can be improved with…

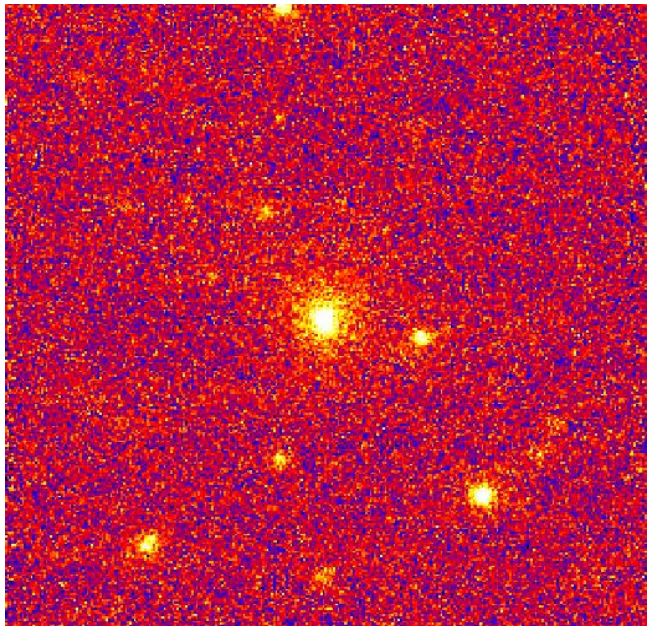
1. Stellar Kinematics (MUSE)
2. Photometry (HST)

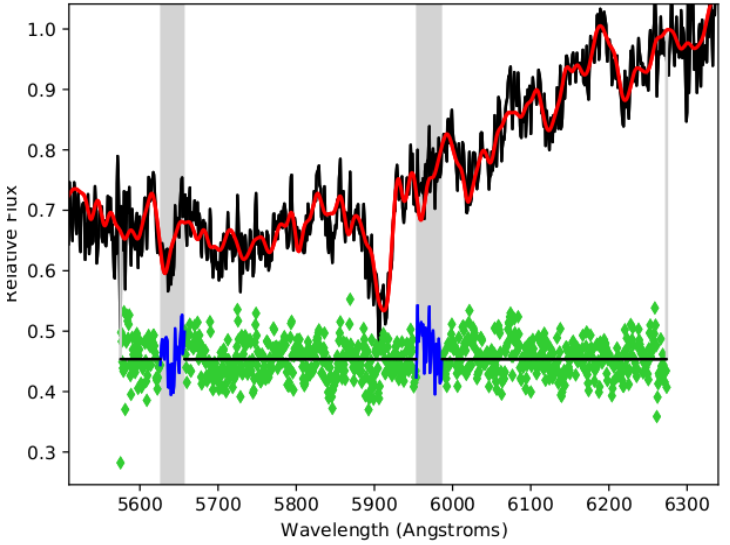


STELLAR KINEMATICS

Effectively probes mass distribution from star-dominated to DM-affected areas

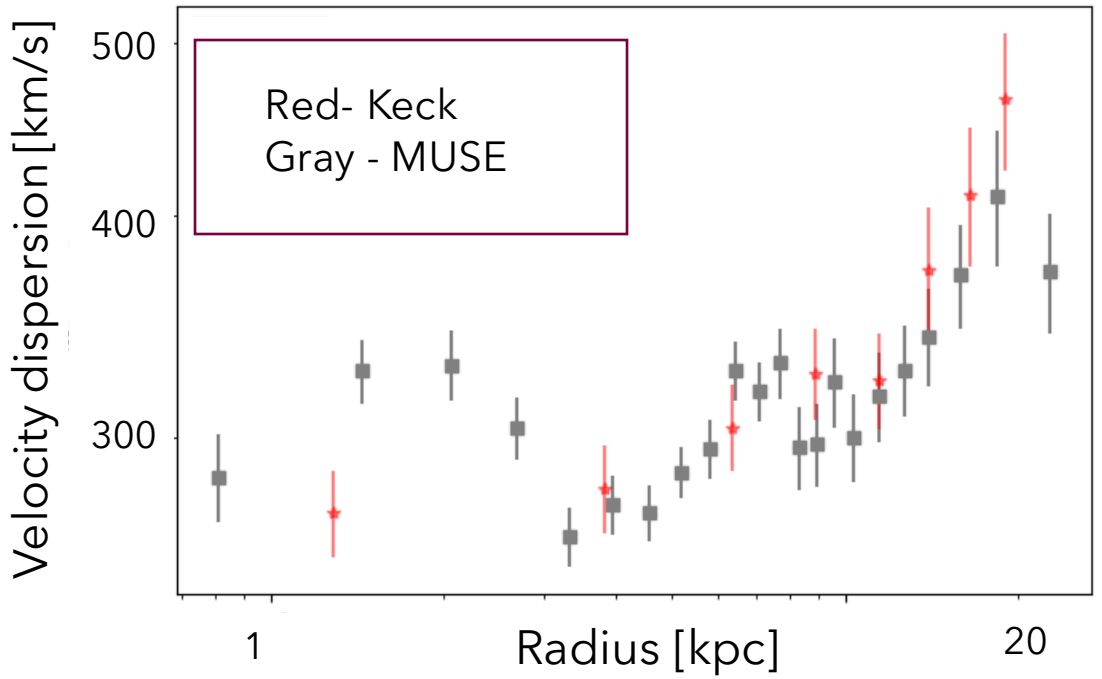
- pPXF used to fit spectra
- Indo-US Stellar Template Fitting
- Experimented with creating various apertures and selecting kinematic features to improve S/N of spectroscopic fit



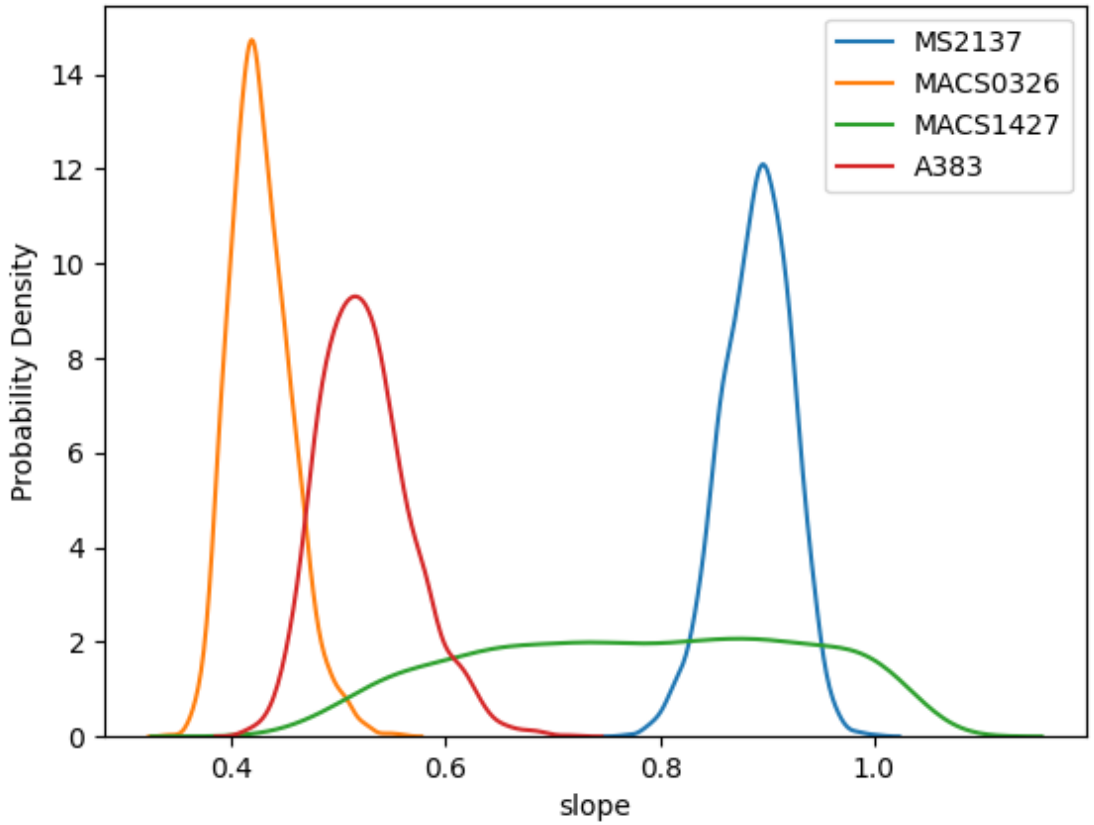


STELLAR KINEMATICS

- Measure velocity dispersion profile of stars in BCG
- Profile from MUSE (IFU, 1hr exposure, variable quality) is comparable to the quality of data from Keck (long-slit, 8hr exposure, high quality)



INNER SLOPE MEASUREMENTS



$$\gamma_{\rm tot} = -d\log\rho_{\rm tot}/d\log r$$

- Measured between ~5-50kpc
- Incorporate all constraints via Bayesian analysis to generate a PDF for the inner density profile slope
- These slopes are all fairly 'core-like'
- A more statistical analysis of the rest of the clusters in the survey (over 150!) will yield interesting results

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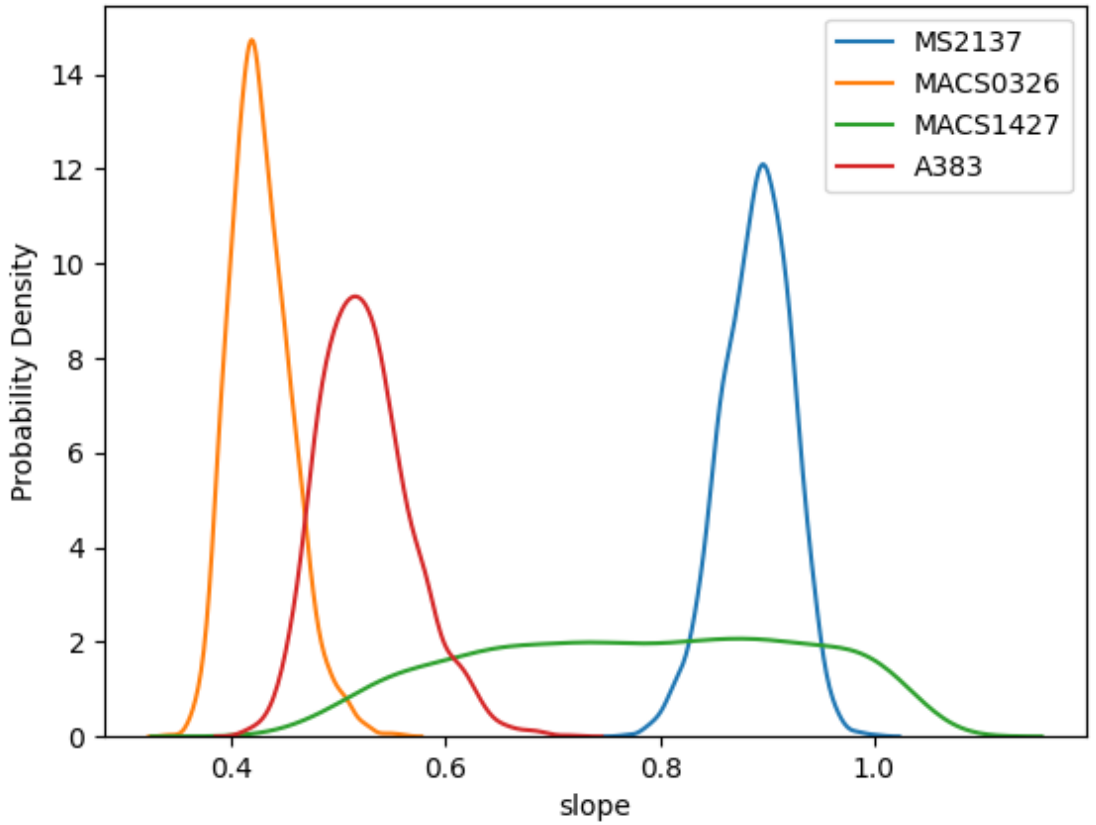

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THANKS FOR LISTENING!