

Dark Matter in the Hubble Frontier Fields

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Jeremy Lim, Dan Coe, Sandor Molnar, Txitxo Benitez, ...

J.M. Diego



Lam et al. 2014, ApJ, 797, 98

A Rigorous Free-Form Lens Model of A2744 to Meet the Hubble Frontier Fields Challenge

Diego et al. 2015, MNRAS, 447, 3130

Free-form Lensing Implications for the Collision of Dark Matter and Gas in the Frontier Fields Cluster MACS J0416.1-2403

Diego et al. 2015 MNRAS, 451, 3920

Hubble Frontier Field Free-Form Mass Mapping of the Massive Multiple-Merging Cluster MACSJ0717.5+3745

Diego et al. 2015 MNRAS, 449, 588

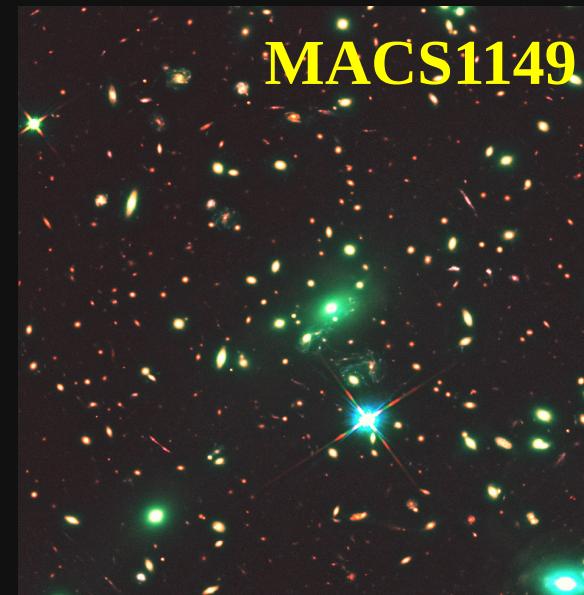
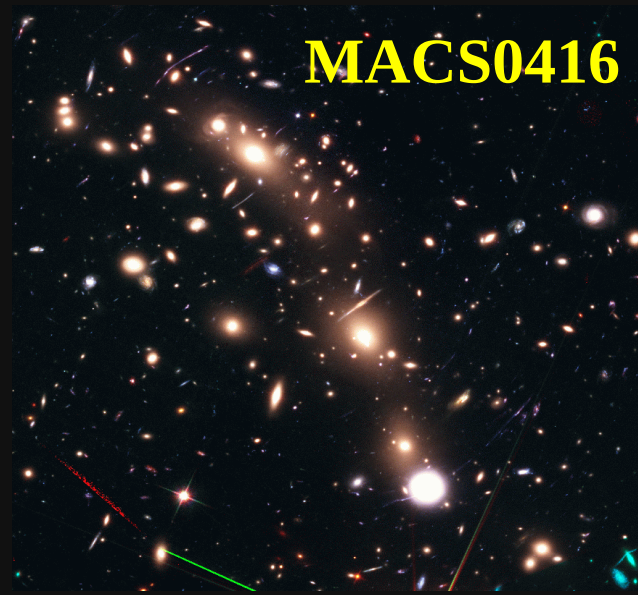
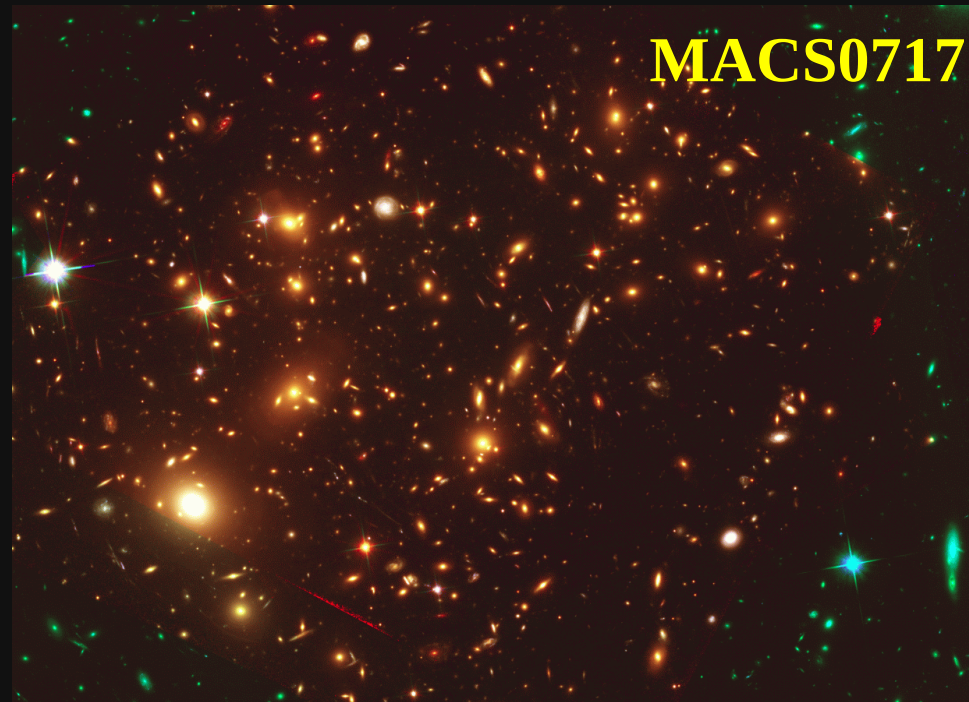
The Orthogonally Aligned Dark Halo of an Edge-on Lensing Galaxy in the Hubble Frontier Fields: A Challenge for Modified Gravity

Diego et al. 2015, MNRAS, accepted

A Free-Form Prediction for the Reappearance of SN Refsdal in the HFF Cluster MACS1149

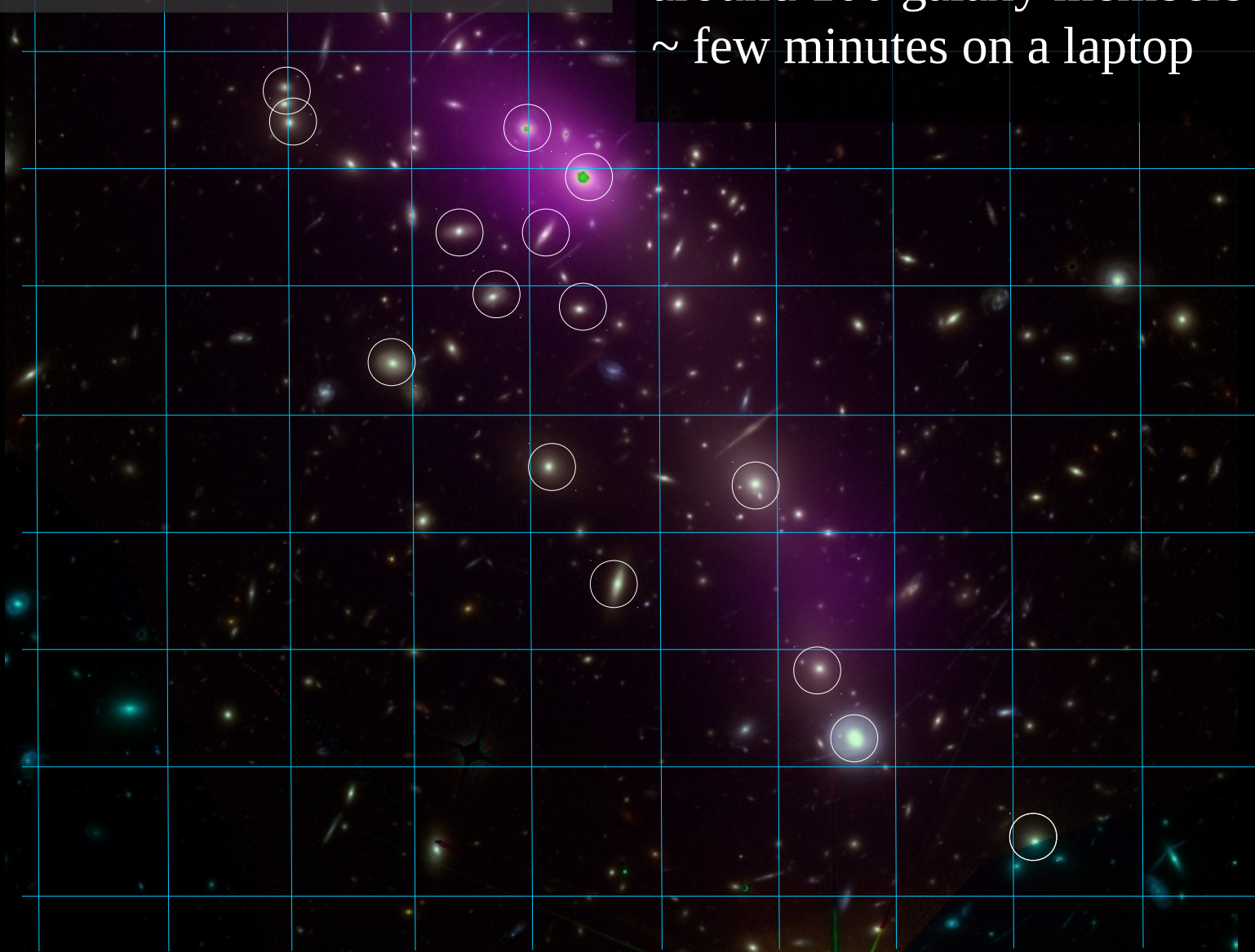
Hubble Frontier Fields Program

- 4 (+2) clusters
- ~ 150 orbits per cluster
- 7 bands from ~ 0.4 - 1.6 micron
- Typically ~ 100 arcs (strong lensing)
- Deep HST *through* a natural telescope



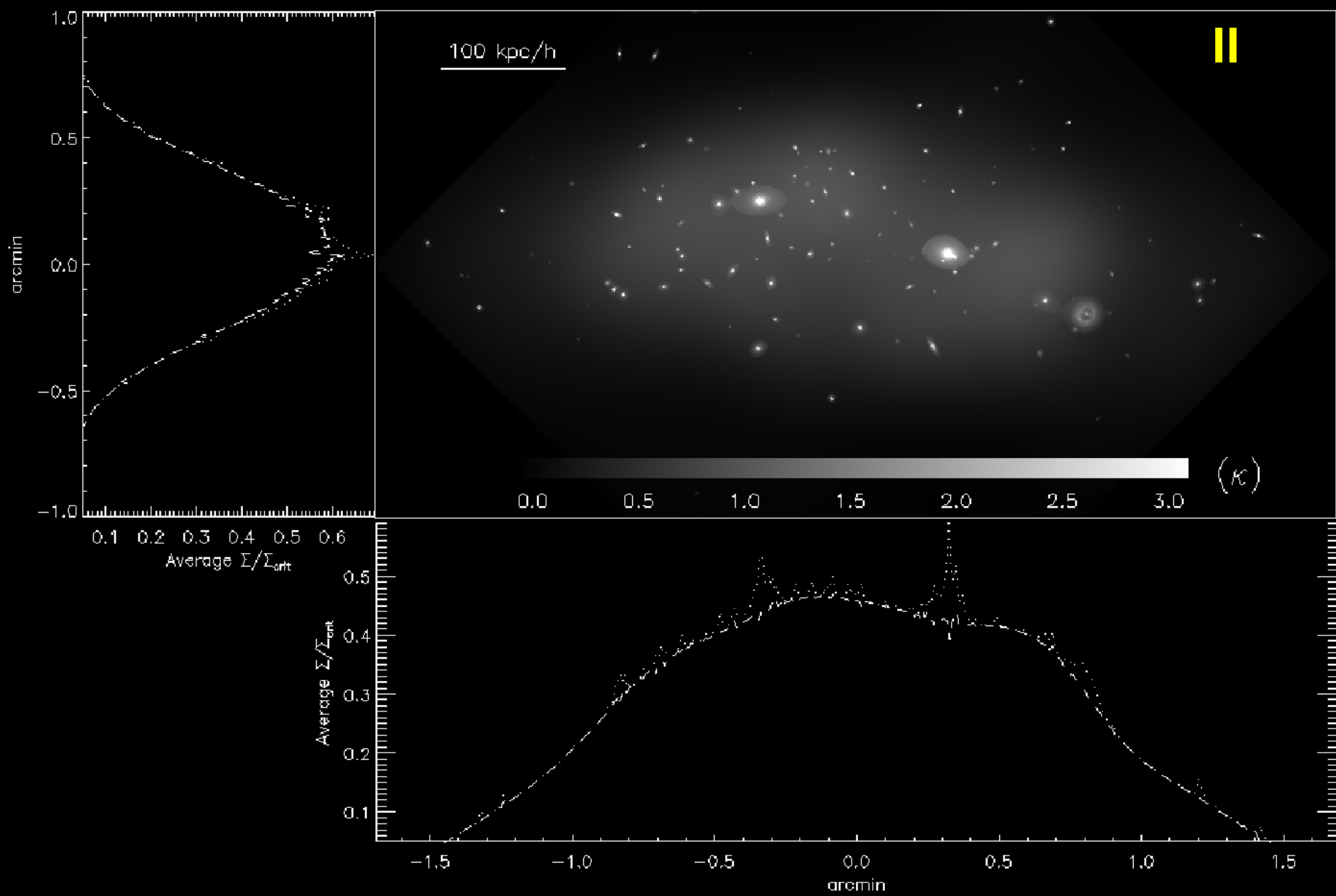
WSLAP+ (Diego et al. 2005,2007)
A Fast Free-Form method

Typically 1000 cells and
around 100 galaxy members
~ few minutes on a laptop

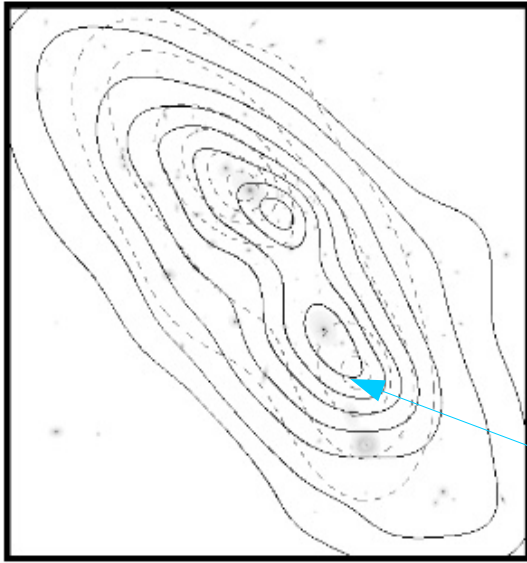


MACS J0416

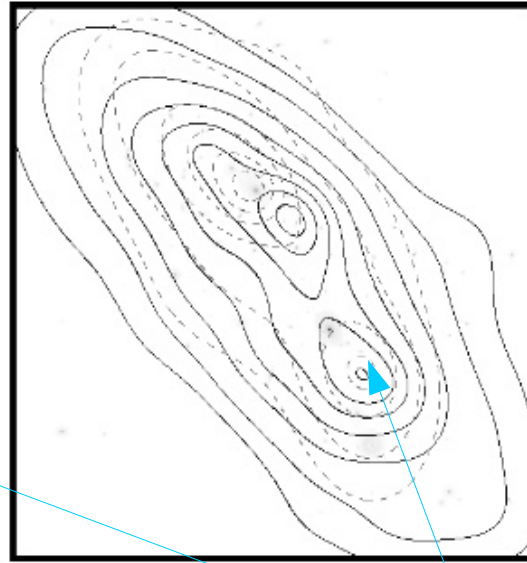




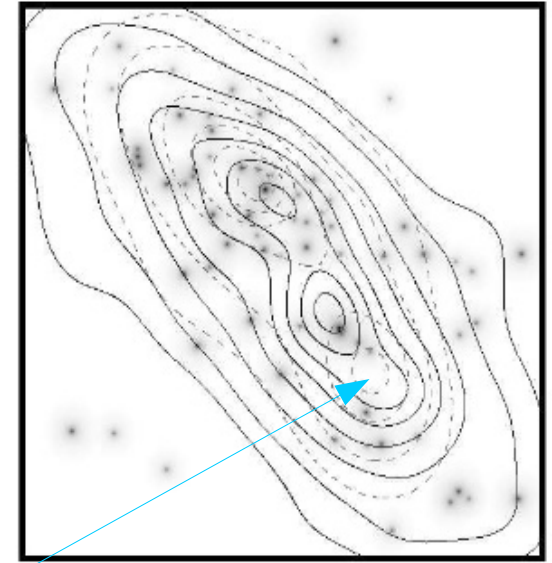
Case I



Case II

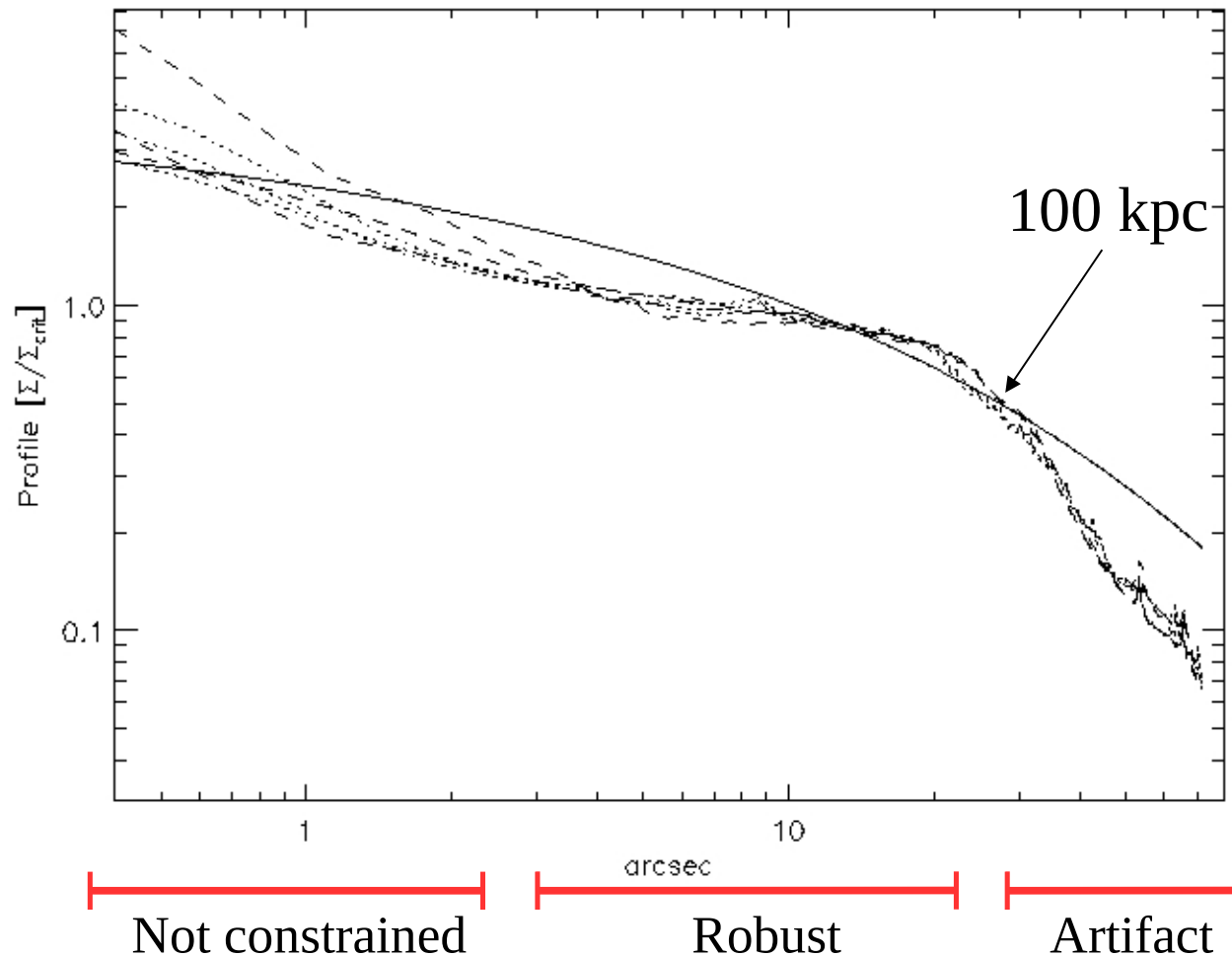


Case III



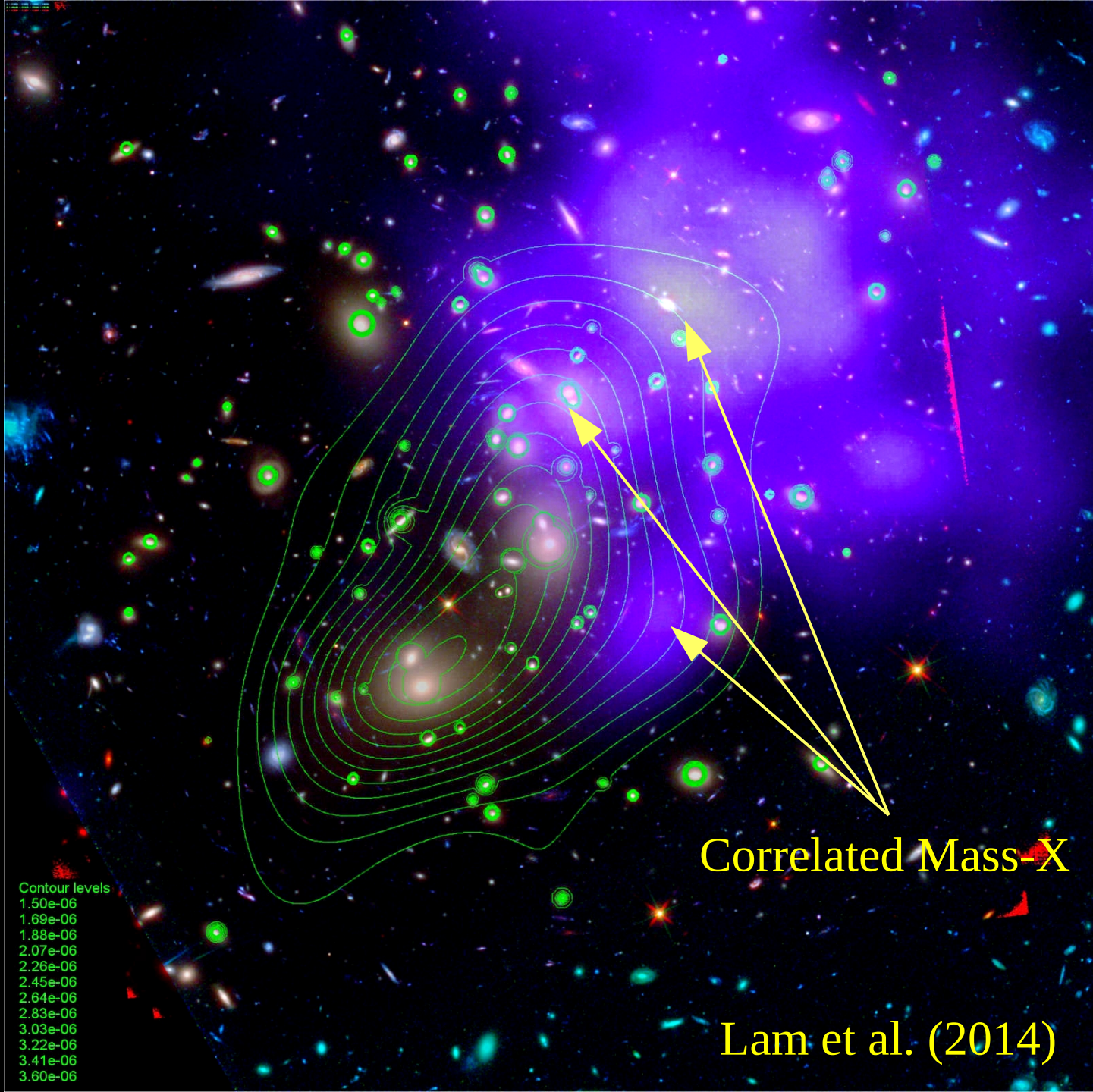
Distribution of DM seems to trace the gas, suggesting that the SL data may be sensitive to the mass of the plasma.

A Very Shallow Profile?



Possible explanations include tidal forces (no cusp?), SMBH (small scales only?), self-interaction DM (no head on collision?), DM+gas combined profile?

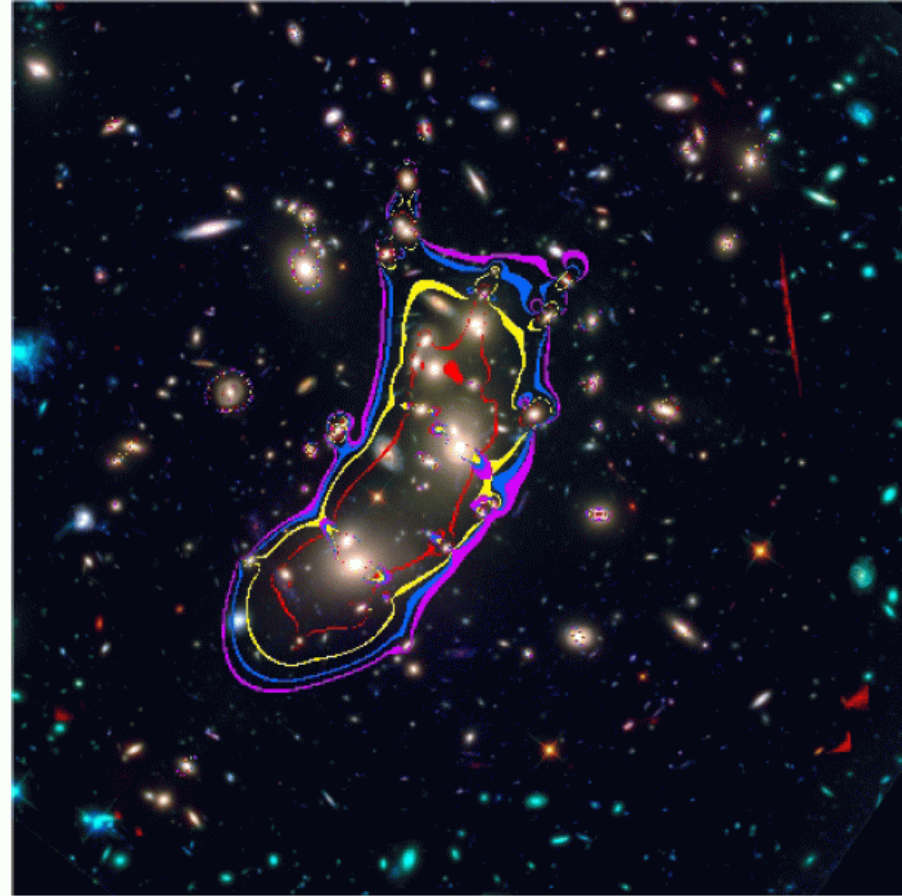
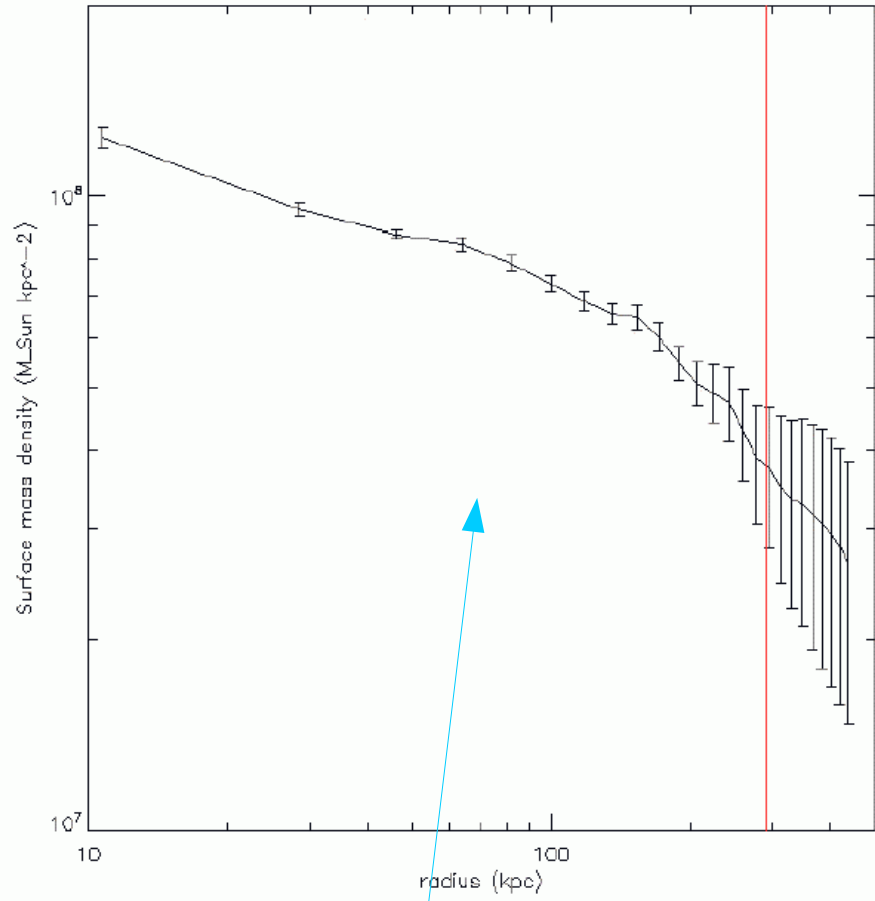
A2744



Contour levels
1.50e-06
1.69e-06
1.88e-06
2.07e-06
2.26e-06
2.45e-06
2.64e-06
2.83e-06
3.03e-06
3.22e-06
3.41e-06
3.60e-06

Correlated Mass-X

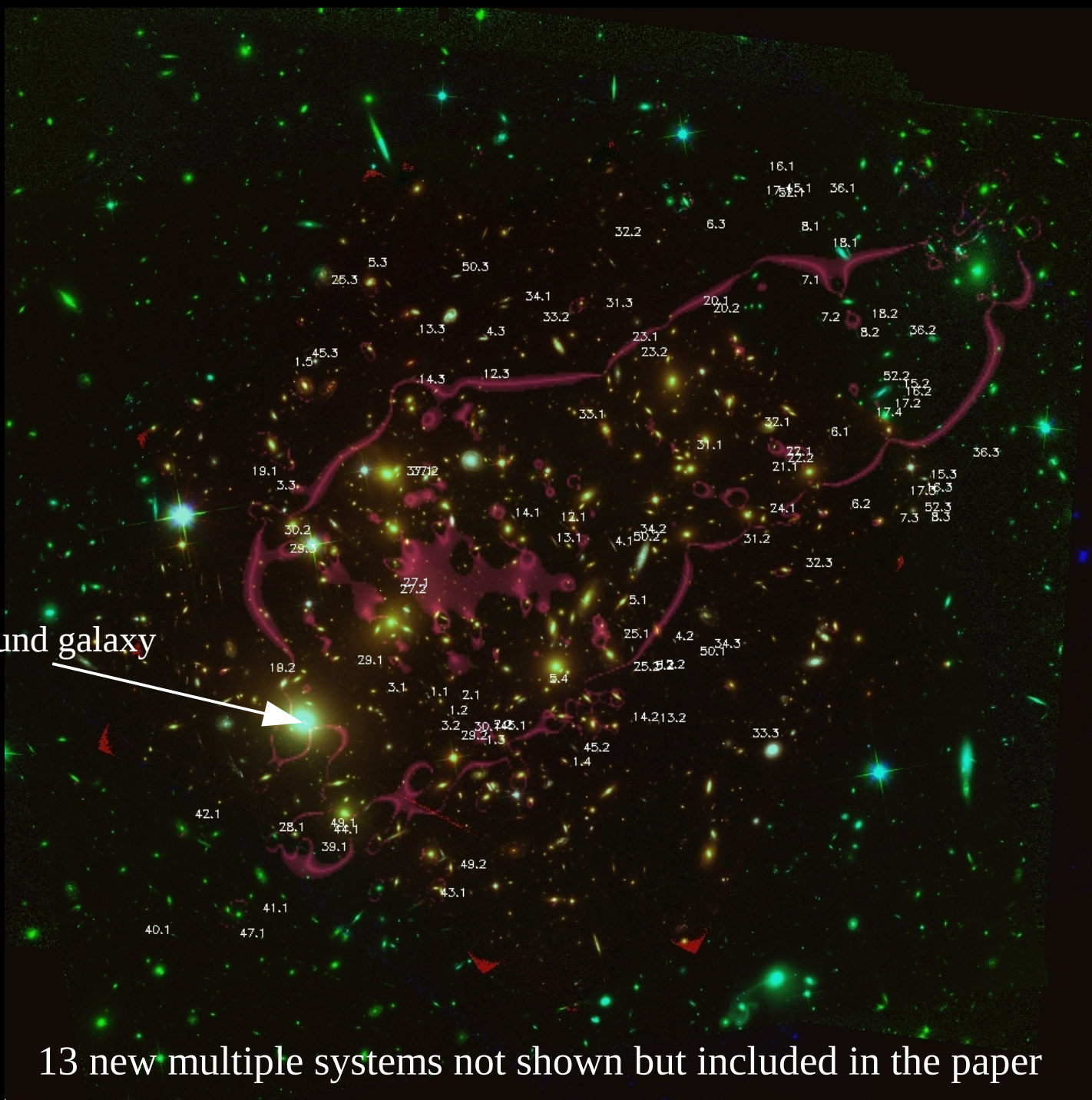
Lam et al. (2014)



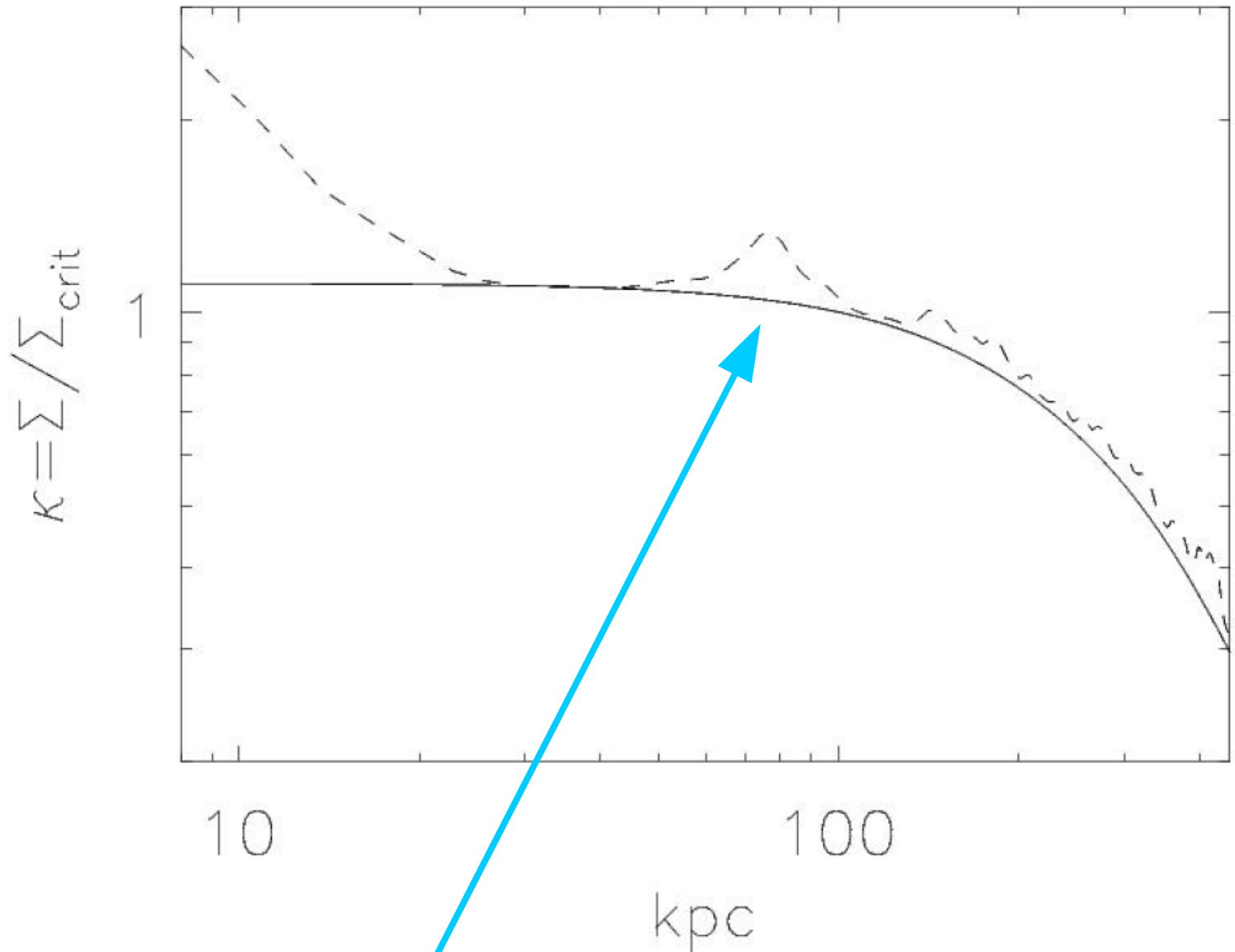
No shallow profile ?

MACS J0717

Foreground galaxy

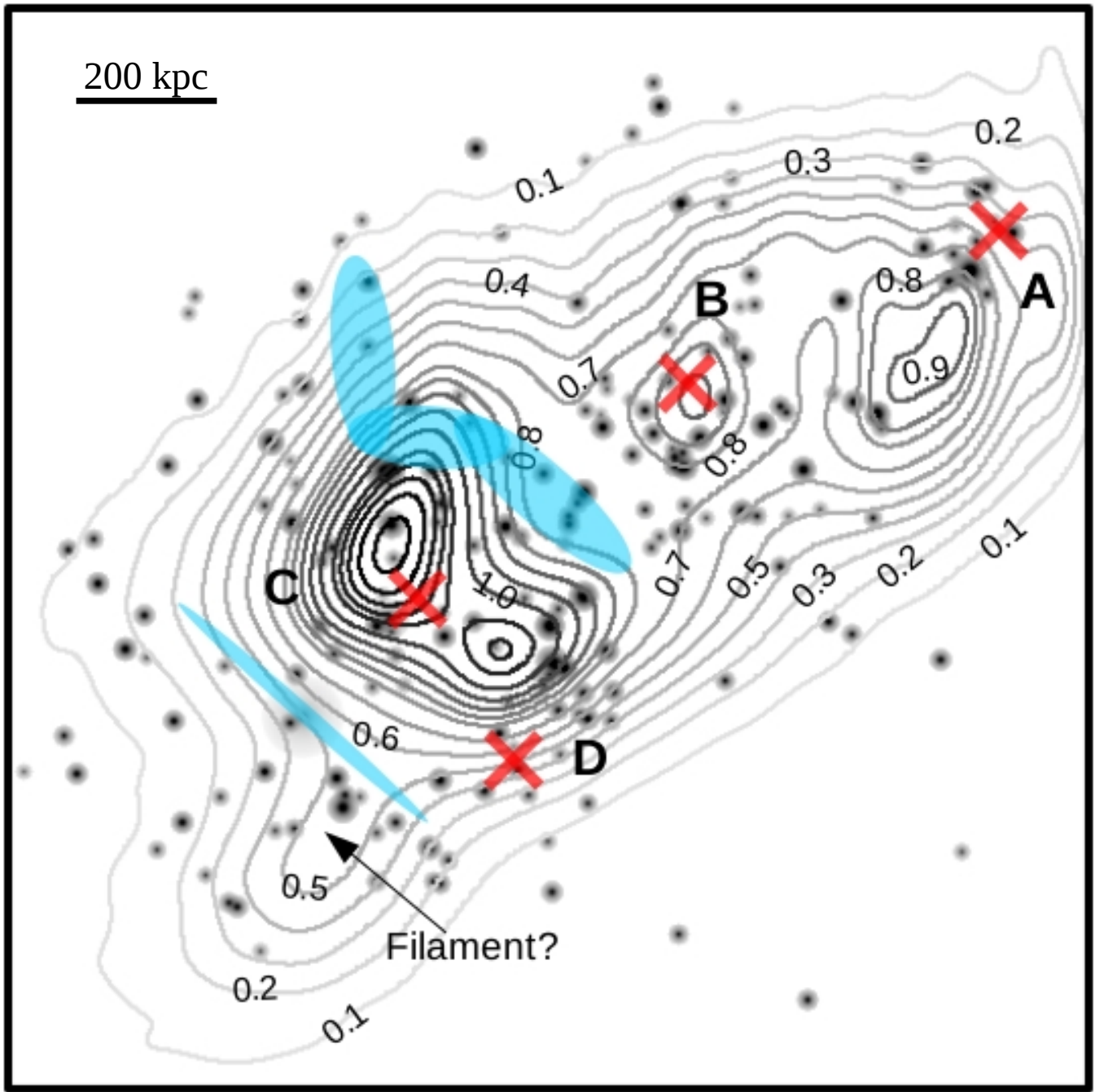


13 new multiple systems not shown but included in the paper

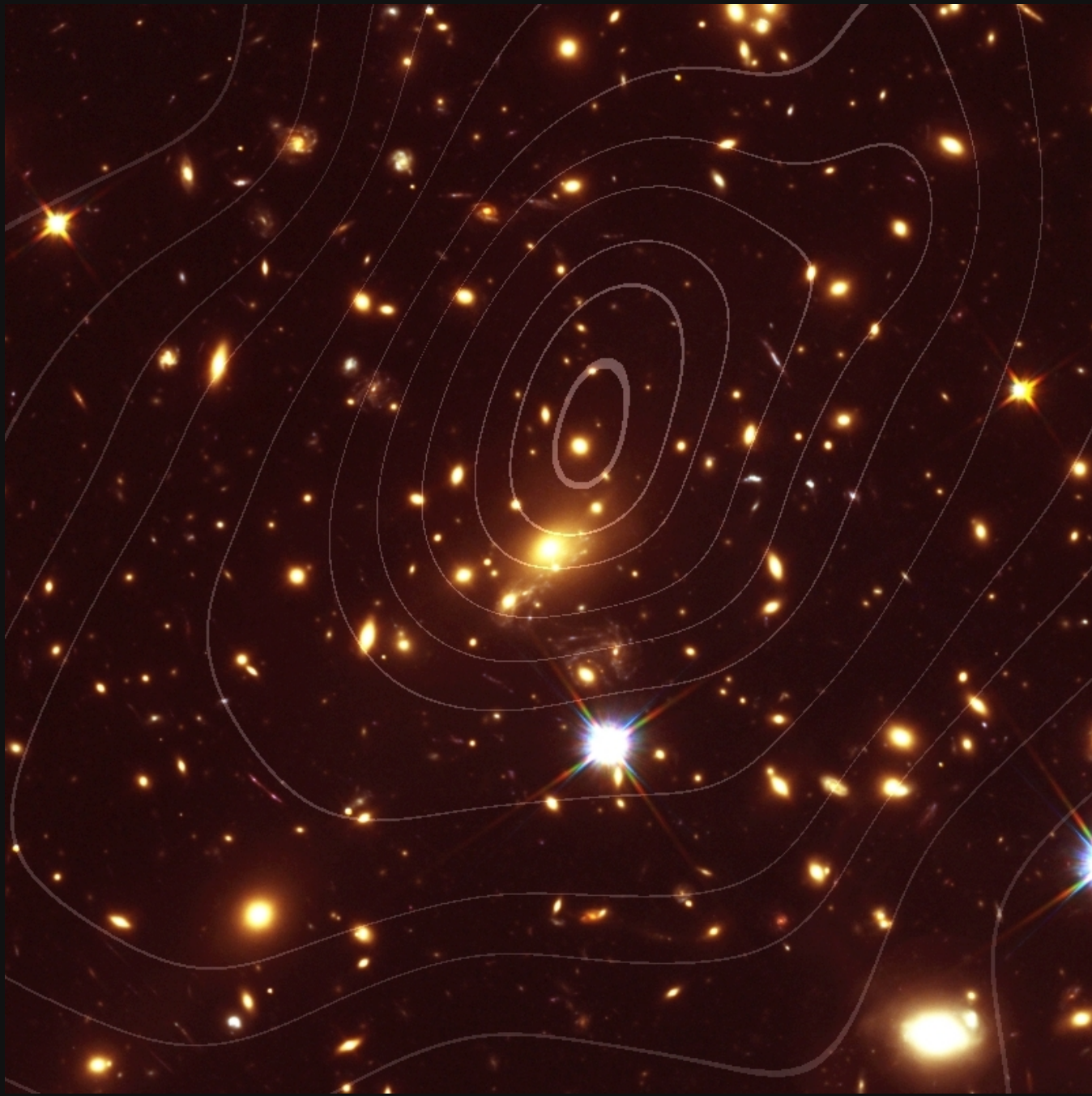


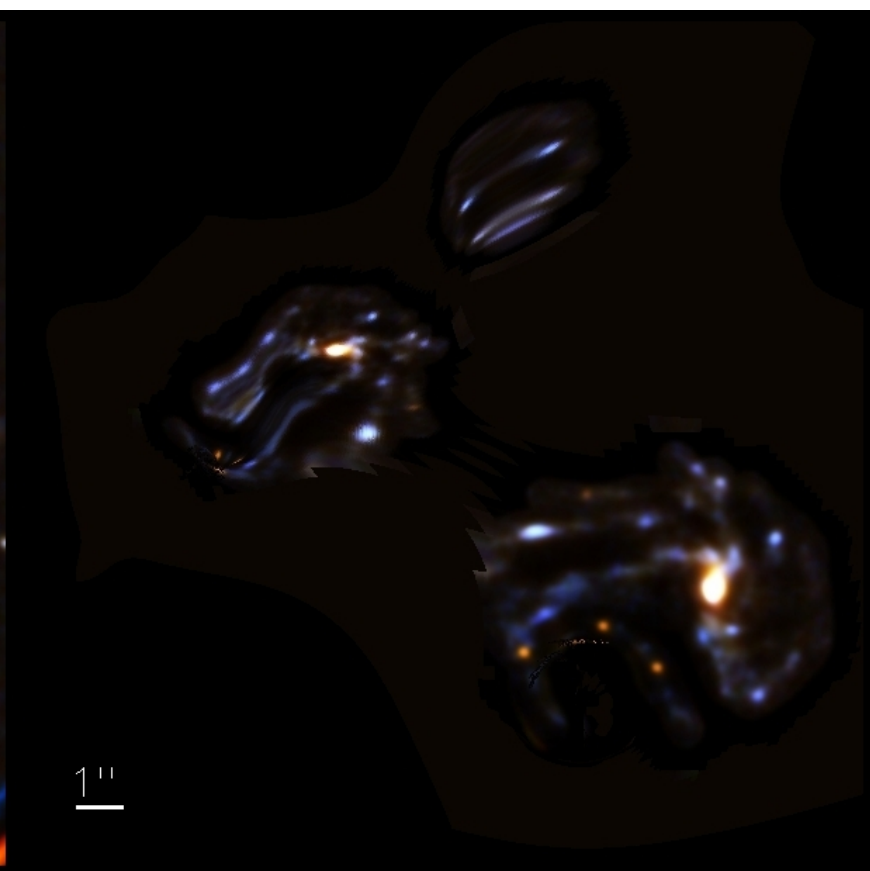
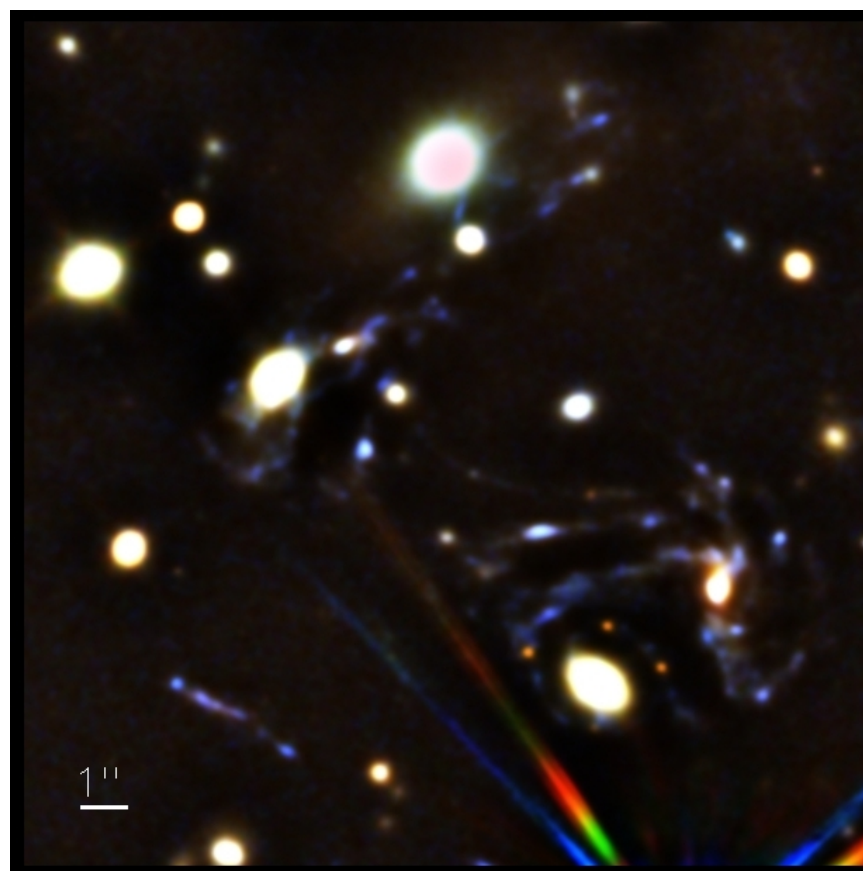
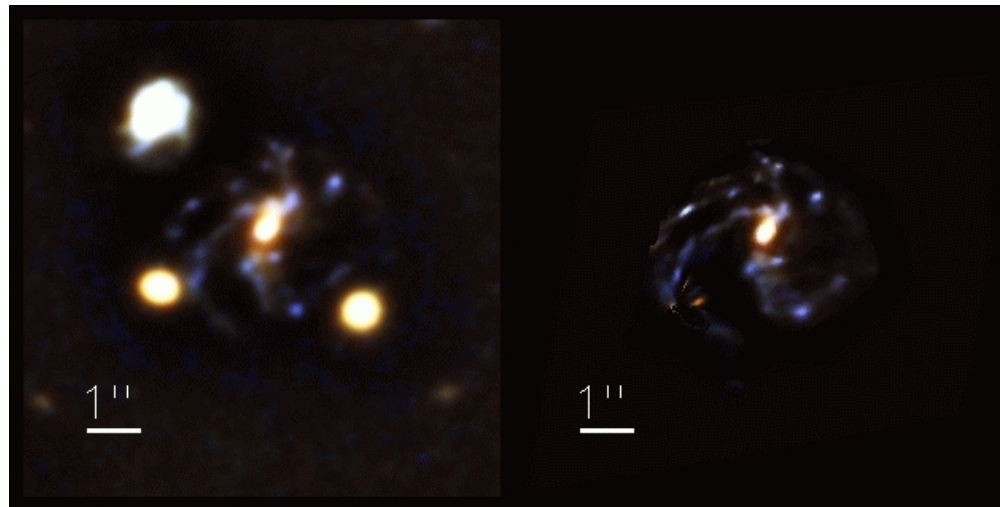
Shallow profile to 100 kpc. Due to complex structure?

Mass models vs X-ray vs Radio

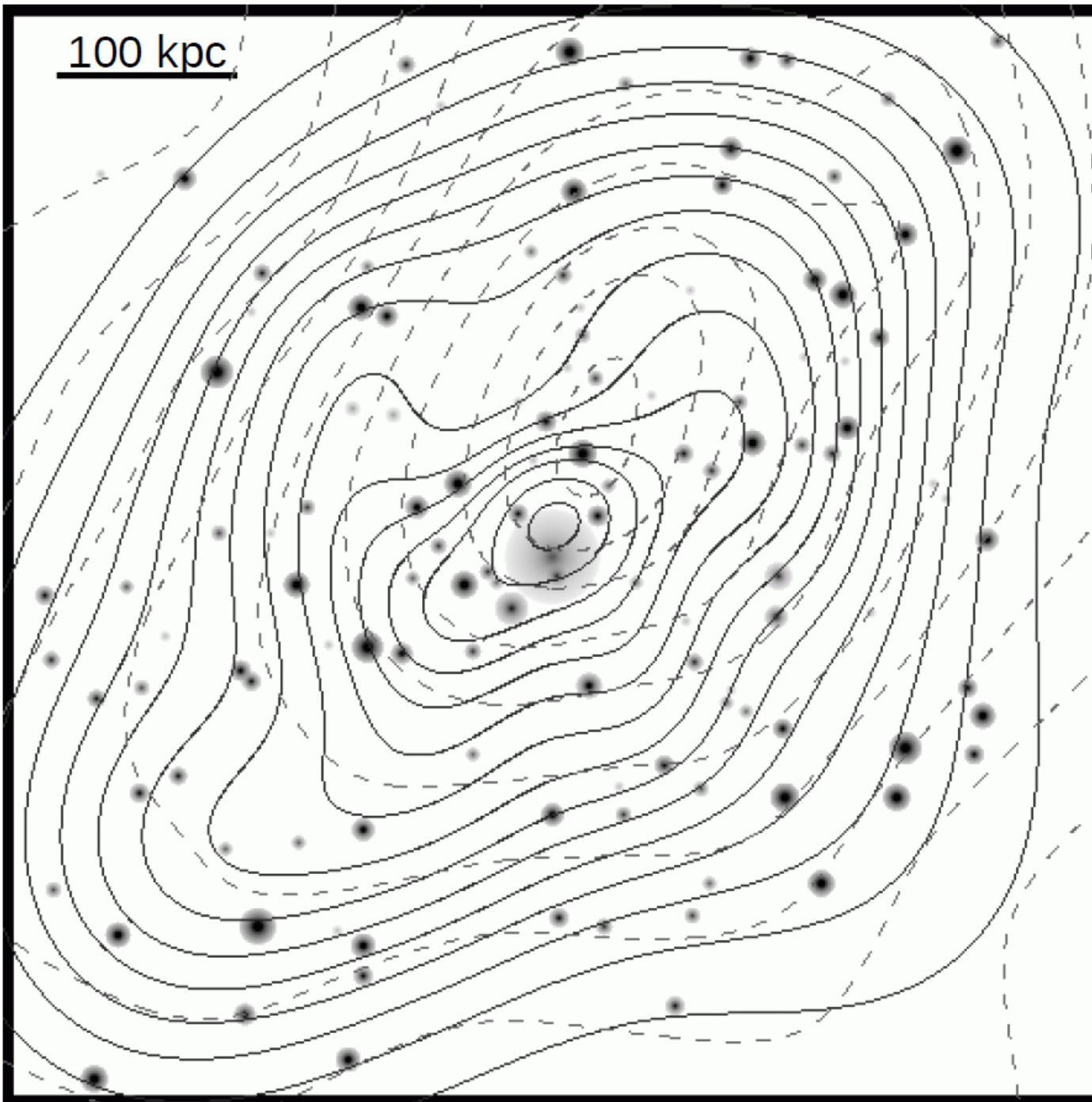


MACS1149

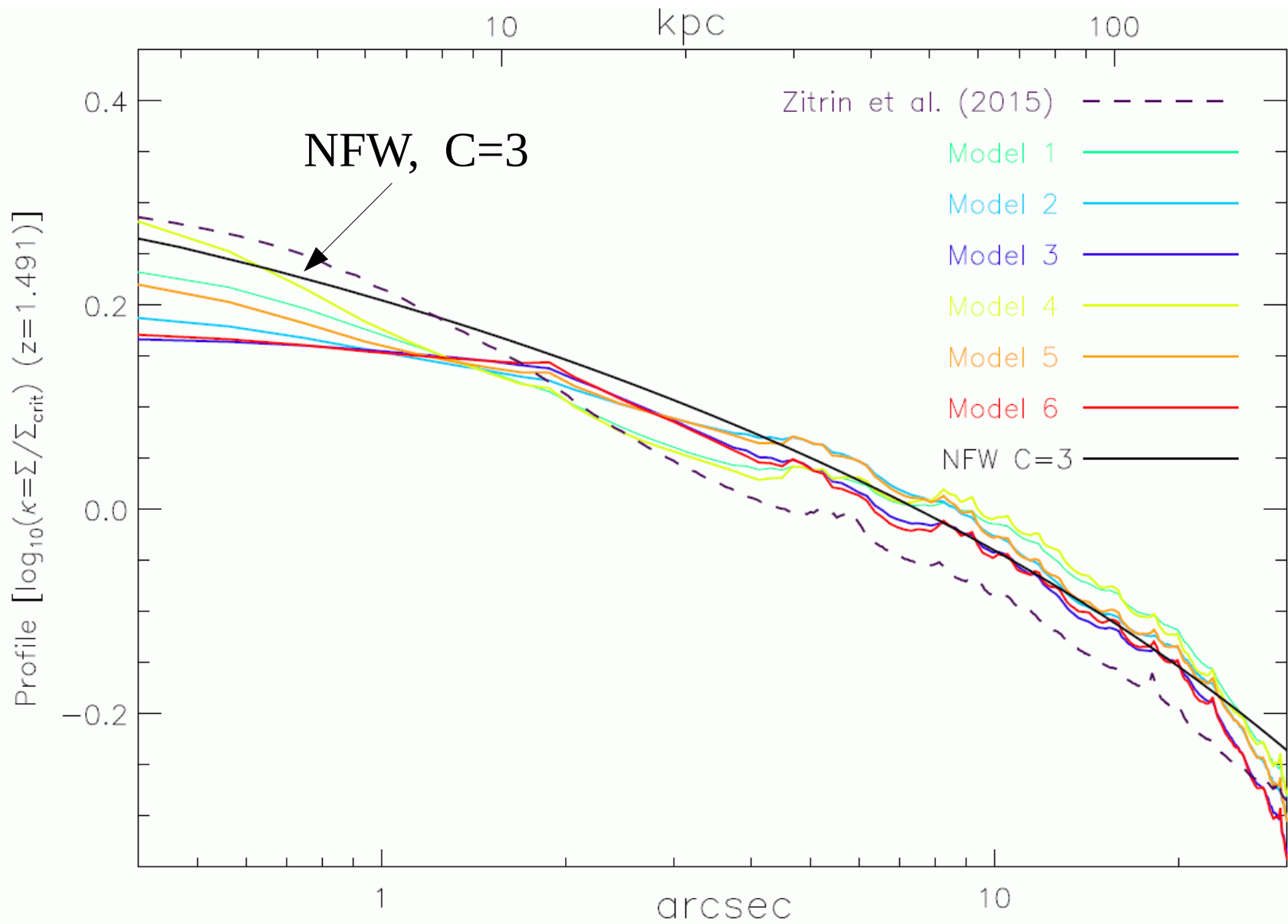




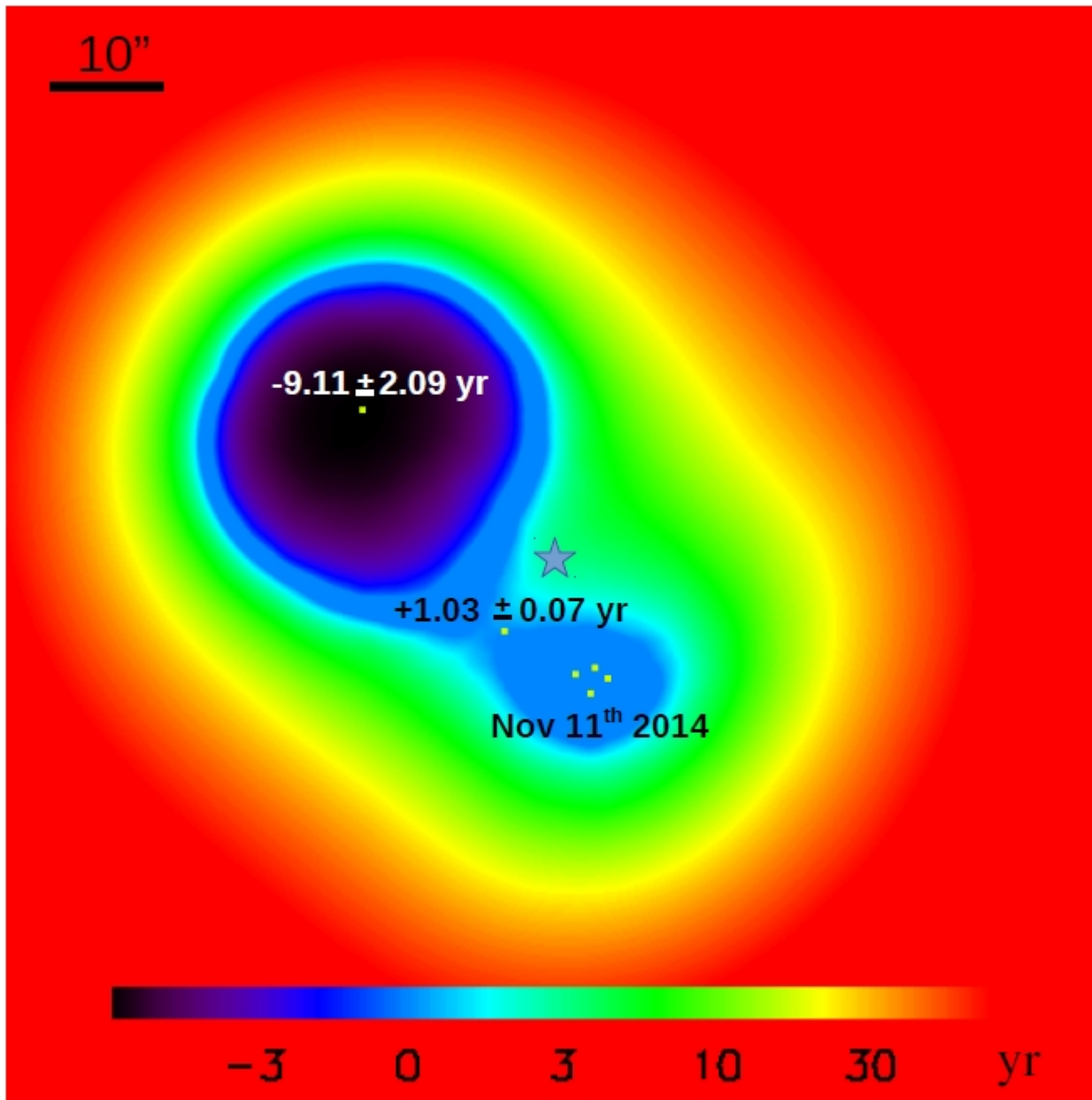
100 kpc



Projected profile in MACS1149



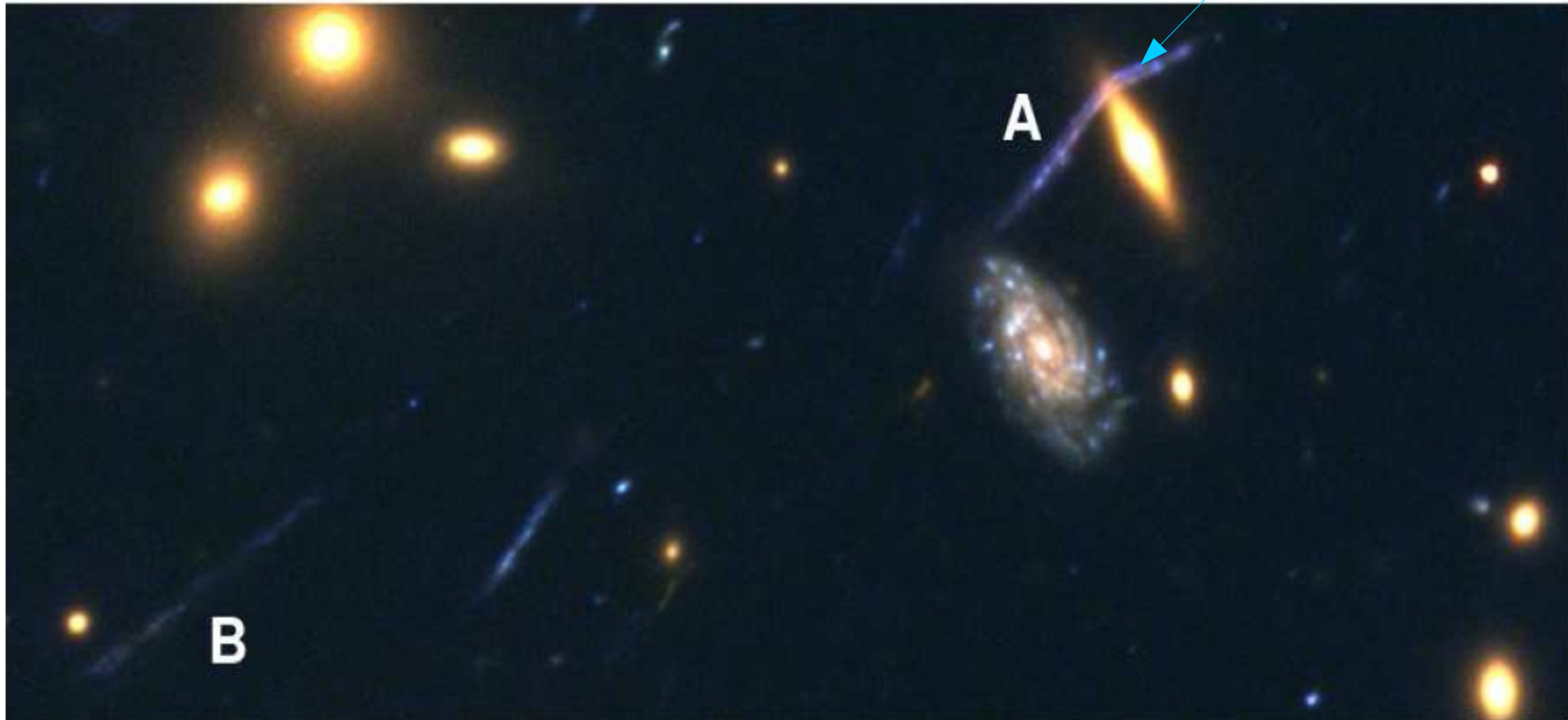
Time Delays for SN Refsdal

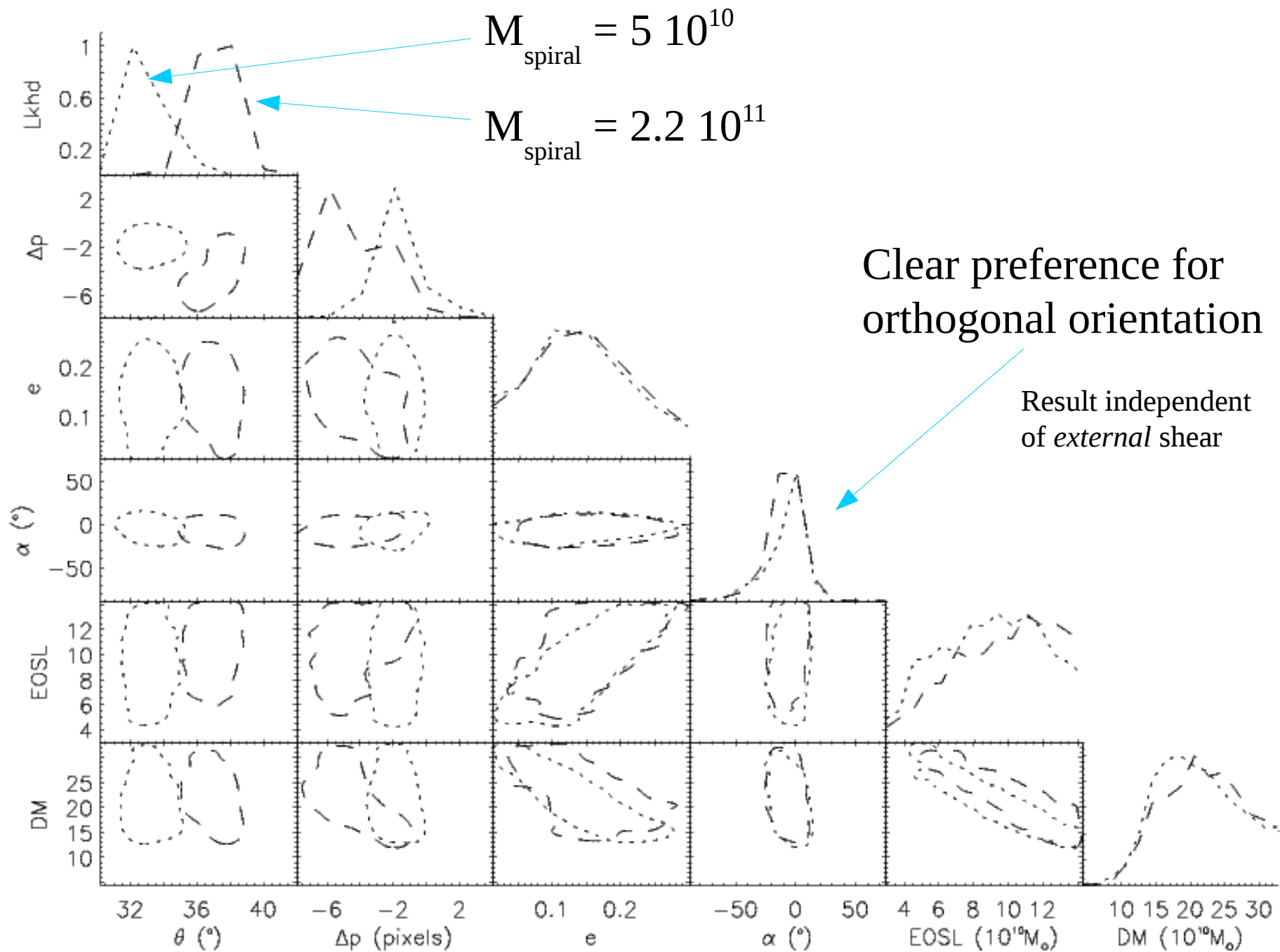


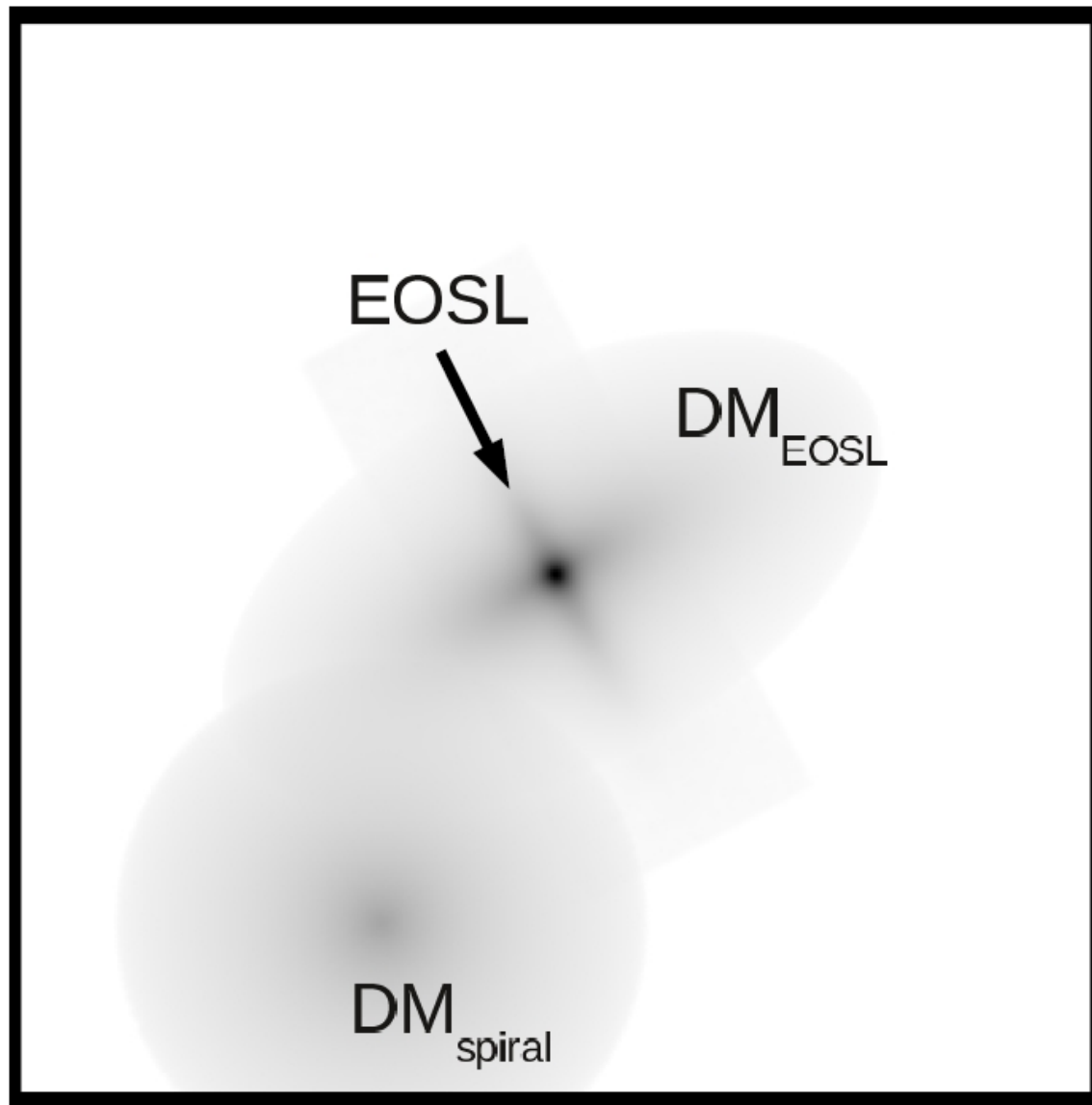
A Secondary Edge-On Galaxy in MACSJ0416

A test case for gravity models

Dragon Kick galaxy







The geometry *seems to be* inconsistent with MOND models.

Is it? Real MOND-like modeling still needed

*A **Dragon Kick** galaxy in action !*



SUMMARY

- **Free-form reconstruction** gives competitive and comparable results to parametric methods but from an completely different approach.
- **Strong lensing data** seems to suggest sensitivity to the gas mass seen in XR (A2744 and MACS0416).
- **Some Profiles** seem to be very shallow pointing towards interesting physics. Could also be due to the complex structure in the core region
- **MACSJ0717** multiple merger of at least 4(5?) massive halos. Evidence for the filament?
- **Offset between DM and baryons**
- **Dragon Kick galaxies** are useful (and powerful) probes of gravity.
- **HFF is awesome!** Future data will reveal very interesting results but more work is needed to understand the degeneracies in the lensing models.
- **Not discussed here but ...** Independent confirmation of low reionization z (as suggested by Planck) may come from the HFF data.