The intra-cluster light as a tracer of the total matter density distribution: a view from simulations

Isaac Alonso Asensio[1,2], Claudio Dalla Vecchia[1,2], Yannick M. Bahé[3], David J. Barnes[4], Scott K. Kay[5]

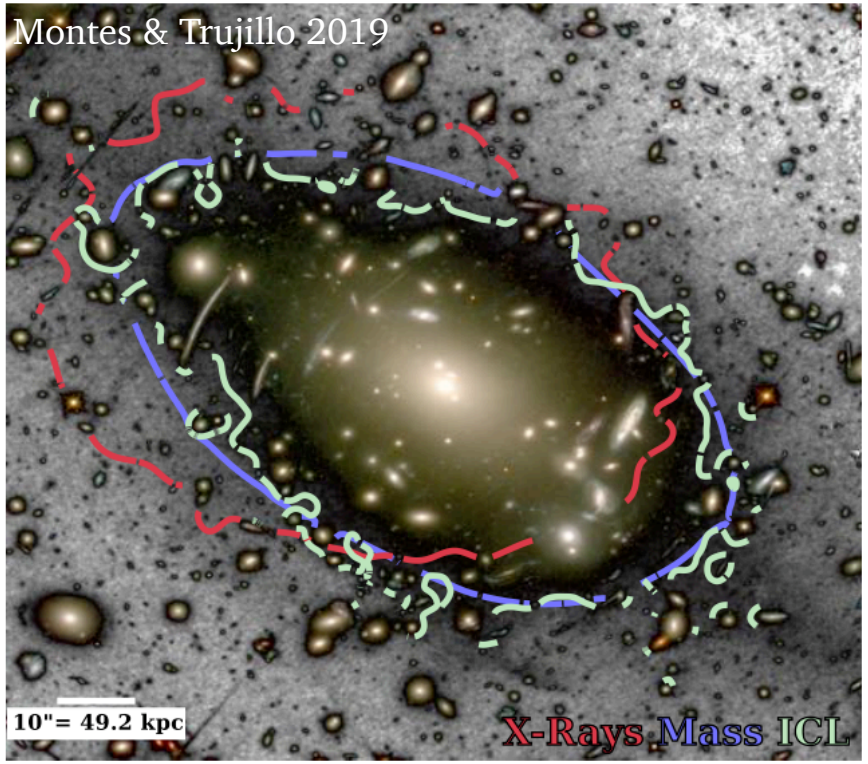
[1] *Instituto de Astrofísica de Canarias, Spain*
[2] *Departamento de Astrofísica, Universidad de La Laguna, Spain*
[3] *Leiden Observatory, Leiden University, the Netherlands*
[4] *Department of Physics, Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, USA*
[5] *Jodrell Bank Centre for Astrophysics, Department of Physics and Astronomy, The University of Manchester, UK*

By using deep observations of clusters of galaxies, it has been recently found that the projected stellar mass density closely follows the projected total (dark and baryonic) mass density. In this work, we aim to test these observations using the Cluster-EAGLE simulations. We find that the shape of the stellar mass distribution follows that of the total matter even more closely than observed, although their radial profiles differ substantially. The ratio between stellar and total matter density profiles in circular apertures shows a slope close to -1, with a small dependence on the cluster's total mass. We propose an indirect method to calculate the halo mass and mass density profile from the radial profile of the intra-cluster stellar mass density.

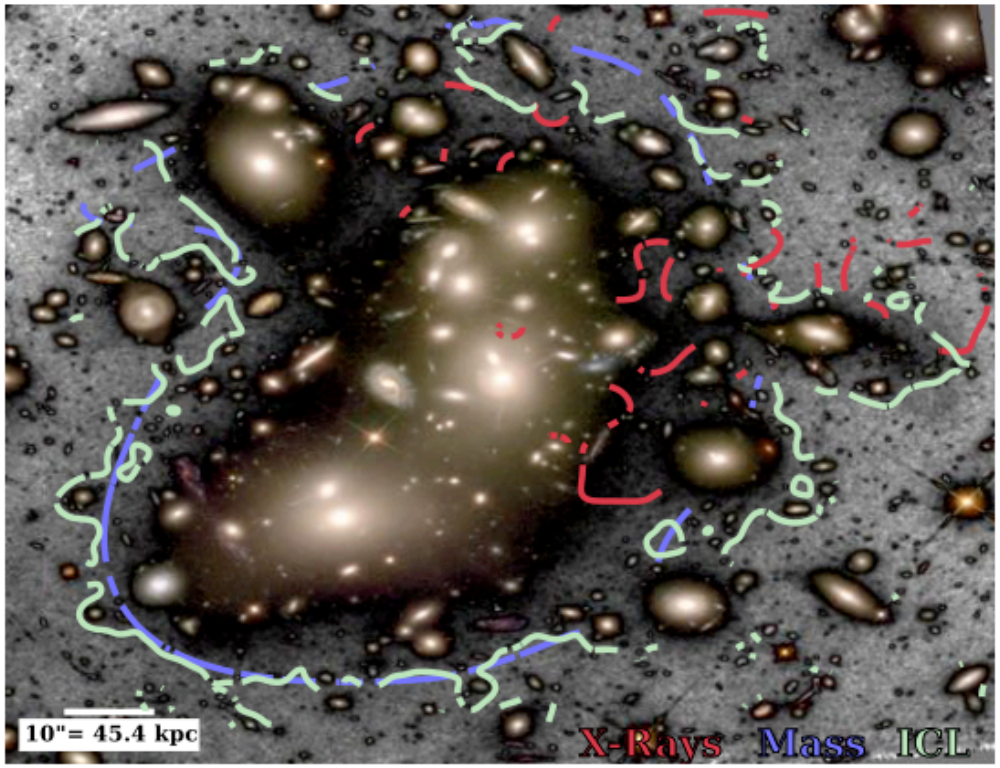
Context

Montes & Trujillo 2019 showed that the projected stellar mass distribution, calculated from ICL maps, follows remarkably well that of total matter:

AS1063



A2744



The main source of errors were the weak lensing mass, and the maximum radial distance was limited by the ICL detection.

Methodology

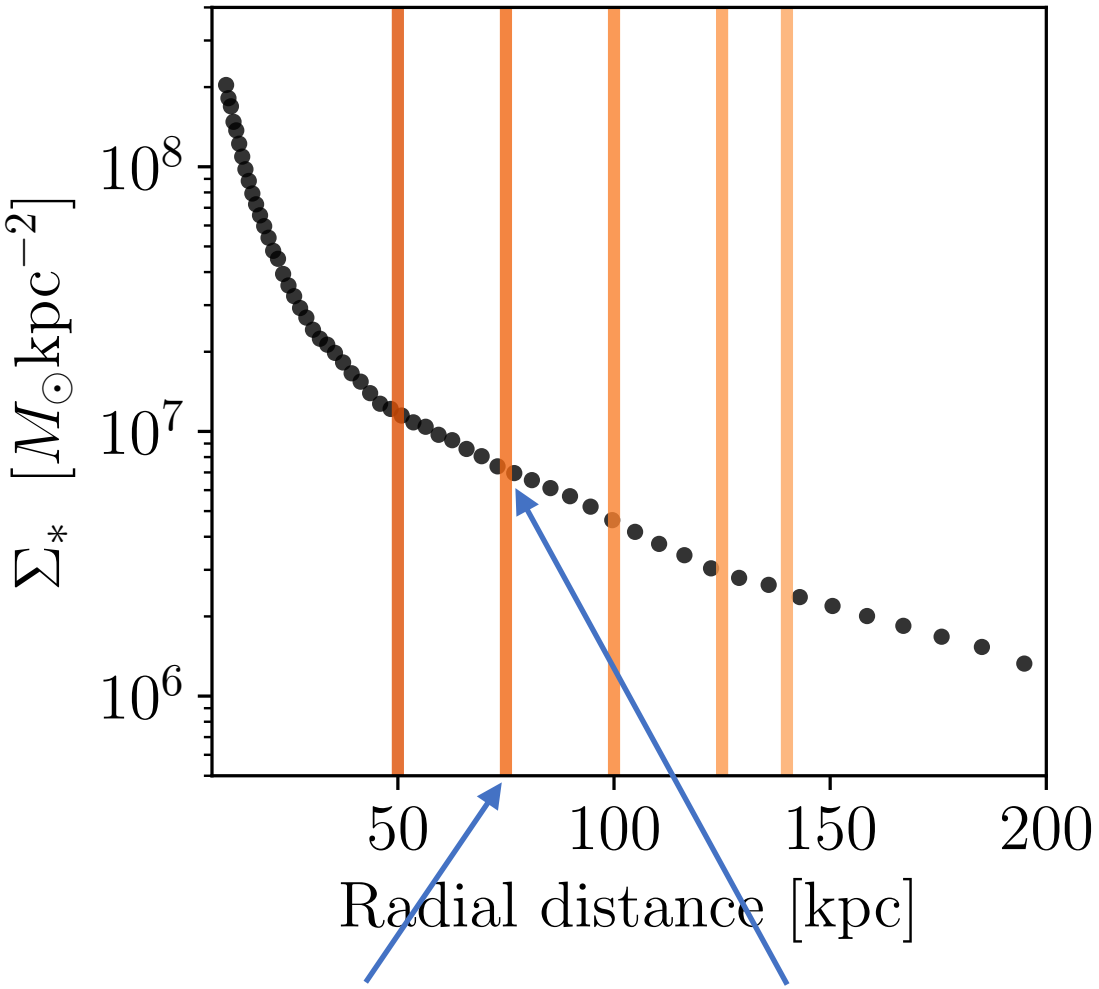
We have used the set of 30 simulations of the Cluster-EAGLE project (Barnes et al. 2017, Bahé et al. 2017). The analysis is summarised in the following:

1. We define that a star particle is part of the ICL if:

   - it belongs to the largest subhalo in the Friends-of-Friends group, i.e., the central galaxy of the cluster;
   - it belongs to the same Friends-of-Friends group, but is not associated with any other subhalo

2. We create projected stellar and total mass density maps and compute their isodensity contours following the same procedure as in Montes & Trujillo 2019

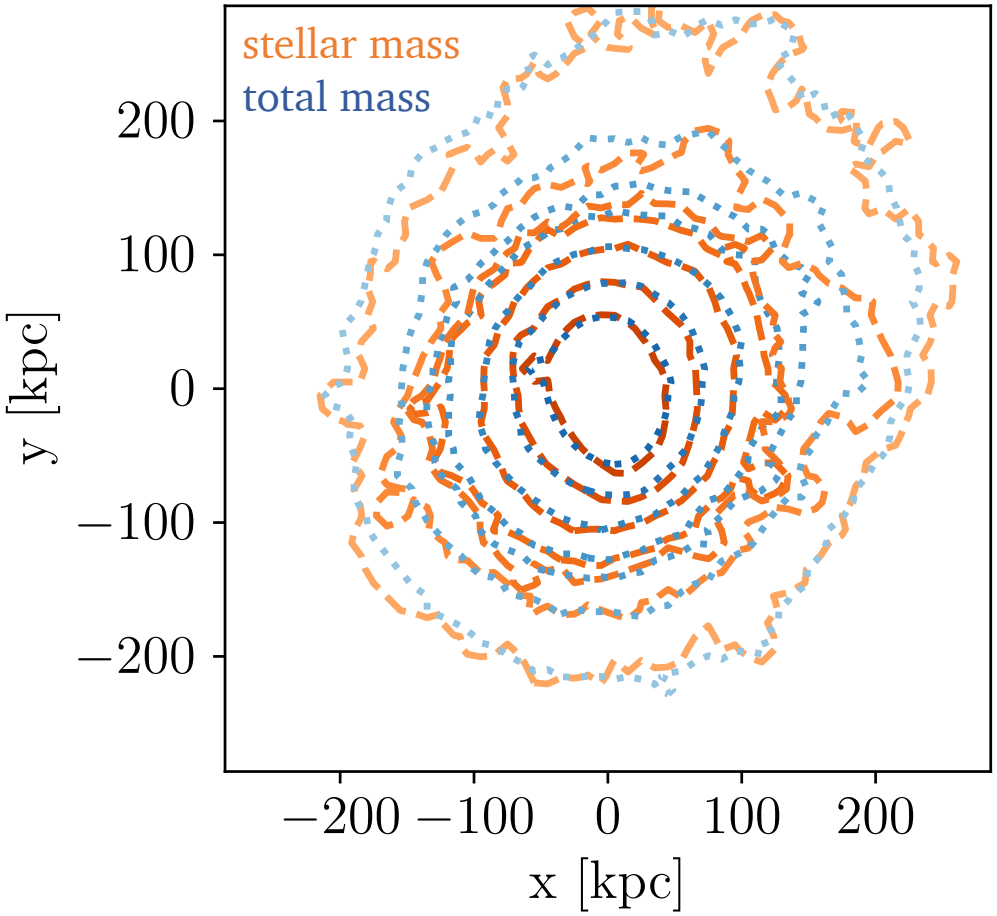
3. We apply the Modified Haussdorf Distance metric to assess the similarity between isodensity contours of stellar and total mass

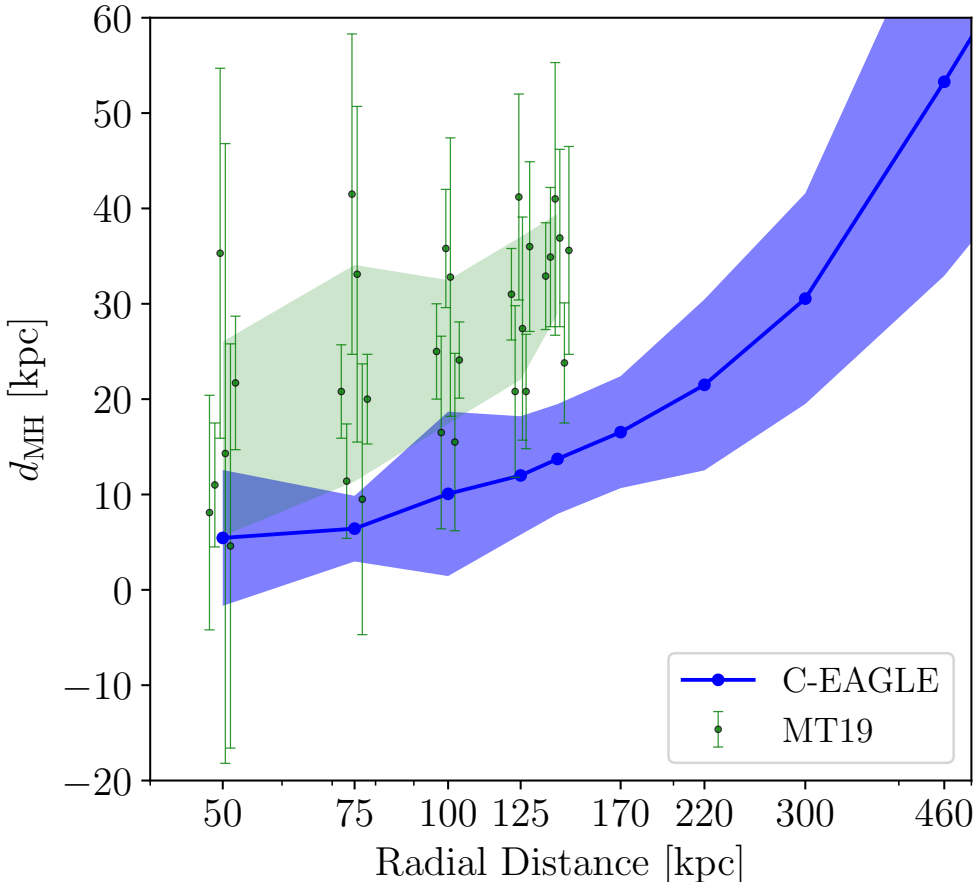


We compute density contours for the average surface densities at fixed radial distances

Results I

We obtain that the projected distribution of stellar mass follows closely the projected distribution of total matter, with a tighter relation than as seen in observations



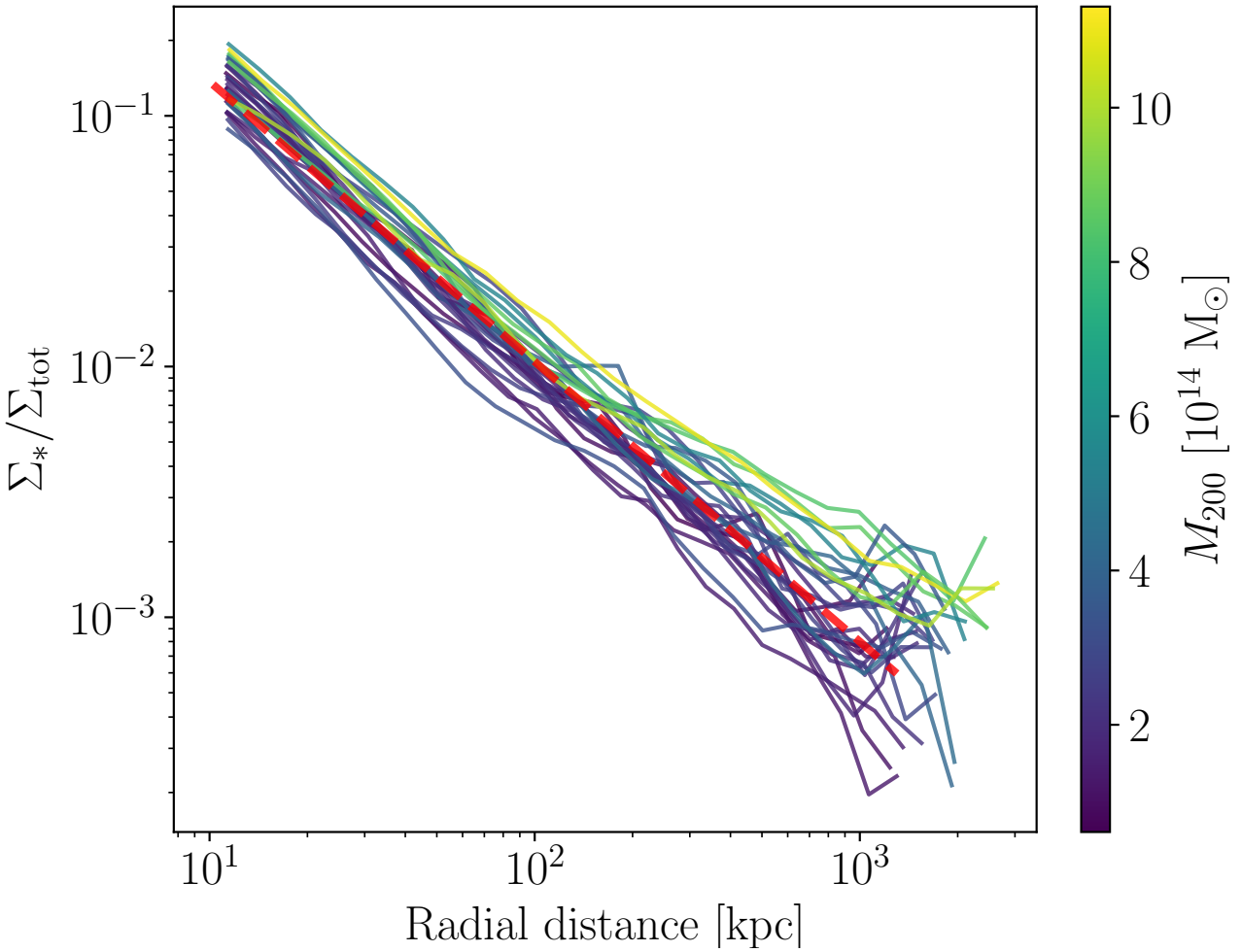


Results II

We find a tight relation between the stellar and total mass projected density profiles. This can be used to infer the total matter density profile from observed ICL profiles:

$$\log_{10}\Sigma_{\rm tot} = \log_{10}\Sigma_{\star} + \\ +(1.115 \pm 0.005) \times \log_{10} r - (0.25 \pm 0.01),$$

which in turn can be used to **estimate the total mass of the cluster**.



Impact and prospects for the future

1. The similarity between ICL and total matter density distributions

- It is systematically stronger in simulations.
- Deeper observations and more precise lensing modelling could improve the observational estimate.
- Could be the difference the sign of new physics (e.g., self-interacting dark matter)?

2. The relation between $\Sigma_{\star}$ and $\Sigma_{\rm tot}$

- How our results compare with those from other simulations? (see Pillepich et al. 2018)
- How does this mass estimate compare with other mass proxies?
- What is the physical motivation for this relation?