The massive relic galaxy NGC 1277 is dark matter deficient

Comerón et al. (2023, A&A, 675, A143)

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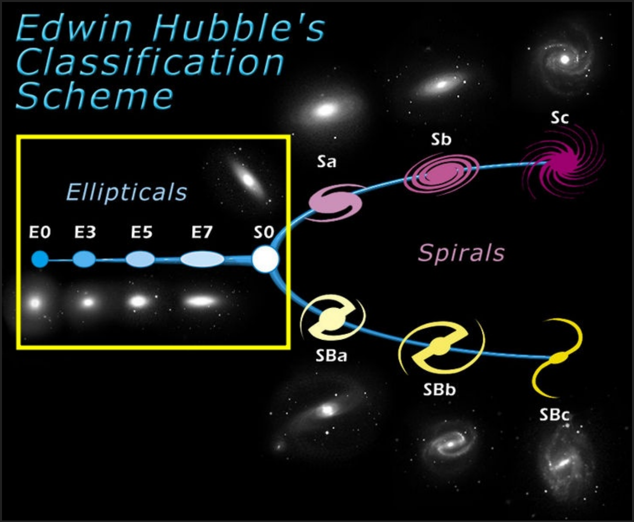
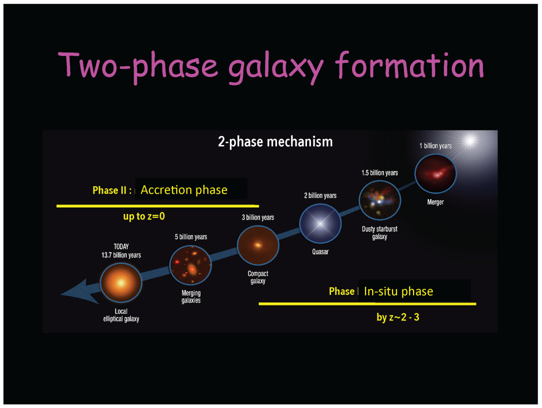
Early-type galaxies



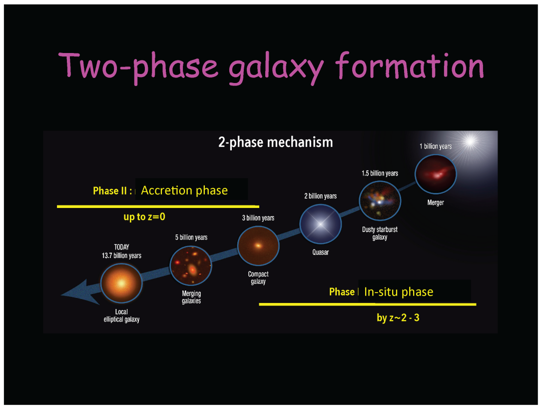
Relics within the ETG two-phase formation scenario



NASA, ESA, S. Toft, A. Feild, A. Ferré-Mateu

- Massive ETGs are born as a compact in-situ core and then accrete an envelope through mergers

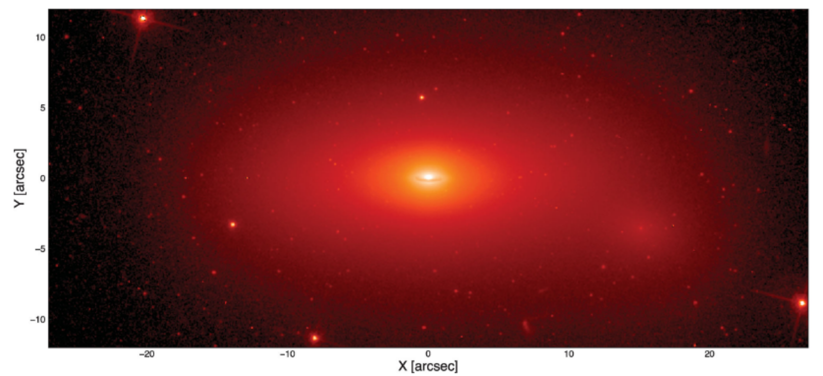
Relics within the ETG two-phase formation scenario



NASA, ESA, S. Toft, A. Feild, A. Ferré-Mateu

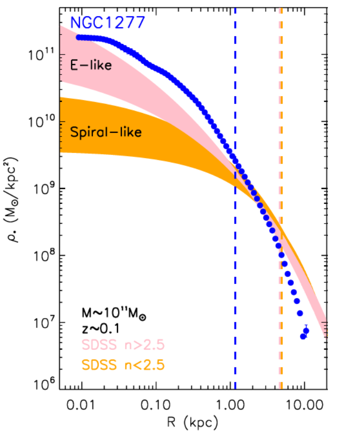
- Relic galaxies have avoided accreting an envelope and are the pristine remains of massive galaxies at $z \sim 2$
- Only three relic galaxies within 100 Mpc (Ferré-Mateu et al. 2017)

Our protagonist: NGC 1277



F625W *HST* image from Emsellem (2013)

What did we know about NGC 1277?

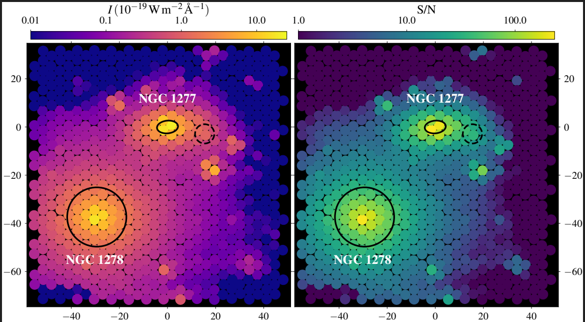


Trujillo et al. (2014)

- The first known example of a relic galaxy
- As massive as a massive elliptical ($M_\star \approx 1.2 \times 10^{11}\,\mathrm{M}_\odot$)
- But much more compact ($R_\mathrm{e} \approx 1.2\,\mathrm{kpc}$ versus $R_\mathrm{e} \sim 5\,\mathrm{kpc}$)
- Single stellar population (old, α-enhanced)

New GCMS IFU data

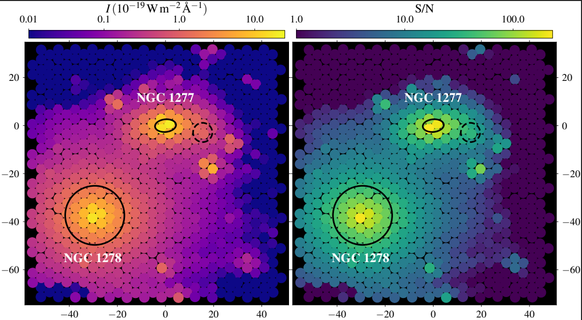
SDSS DR 14



- 2.5 hours per position in the 2.7 m Harlan J. Smith telescope from the McDonald Observatory
- Fibre size of 4.″16
- 4400 – 6800 Å spectral coverage at a spectral resolution of 5.3 Å

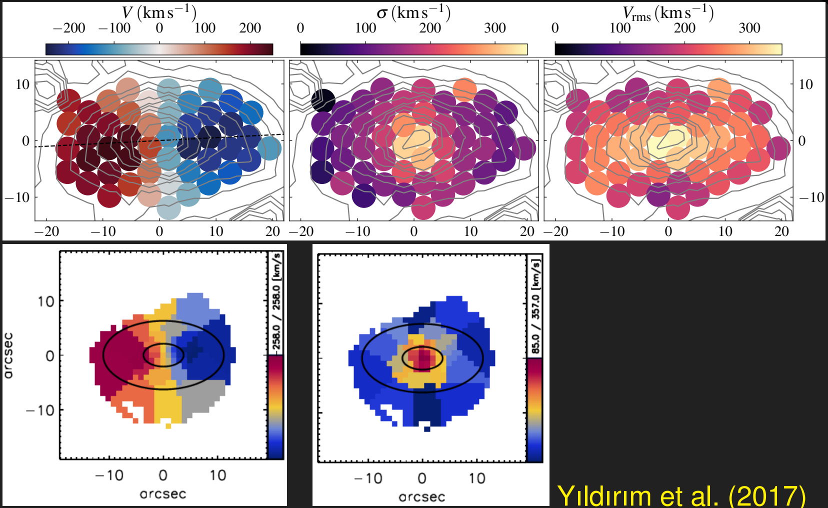
Advantages over other datasets

SDSS DR 14



- Deepest IFU data so far for this galaxy
- A fully-evolved galaxy with a similar mass in the FOV (NGC 1278)

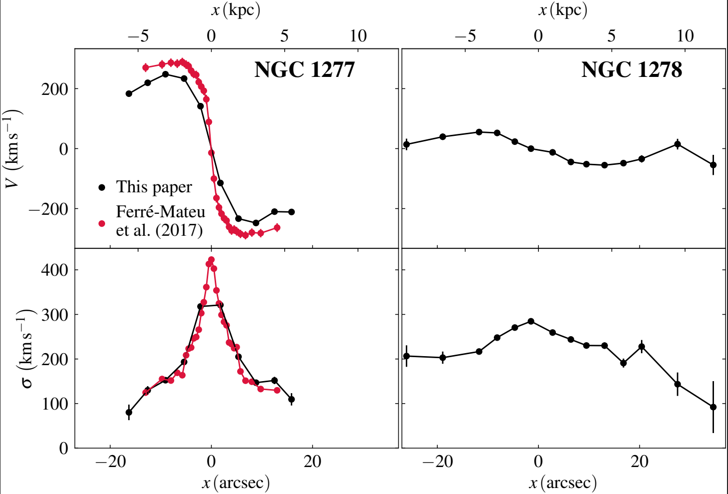
NGC 1277 kinematic maps



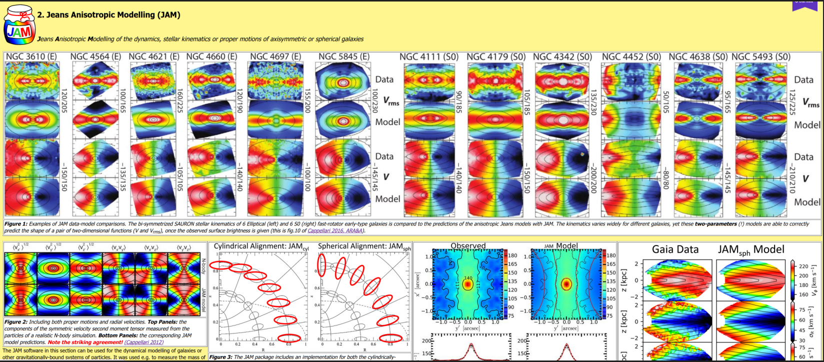
Yıldırım et al. (2017)

- To mitigate the lack of angular resolution we have NIFS AO data of the inner 1.″6 × 1.″6 from Walsh et al. (2016)

A first comparison between NGC 1277 and NGC 1278

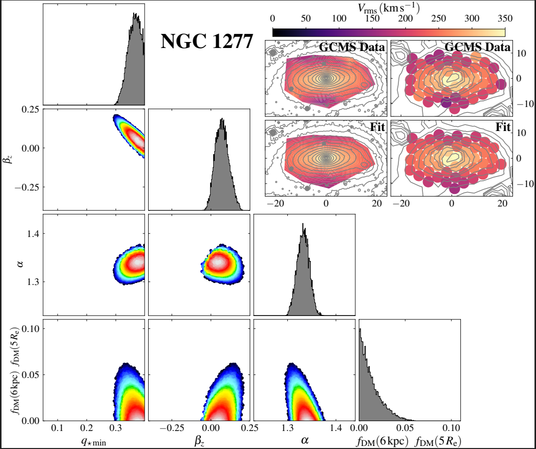


Jeans anisotropic modelling (JAM)



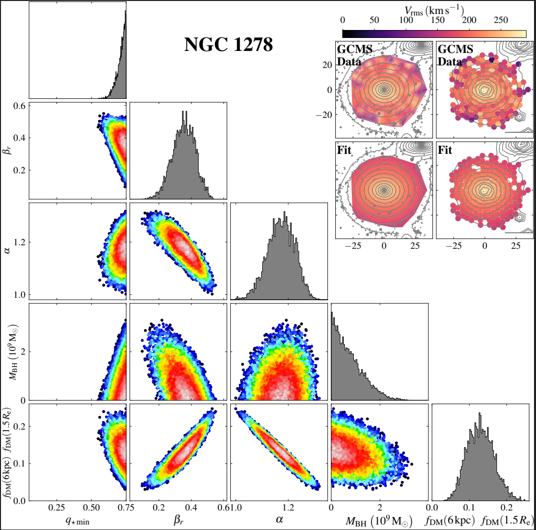
Cappellari et al. (2008, 2022)

Jeans modelling of NGC 1277 with JAM



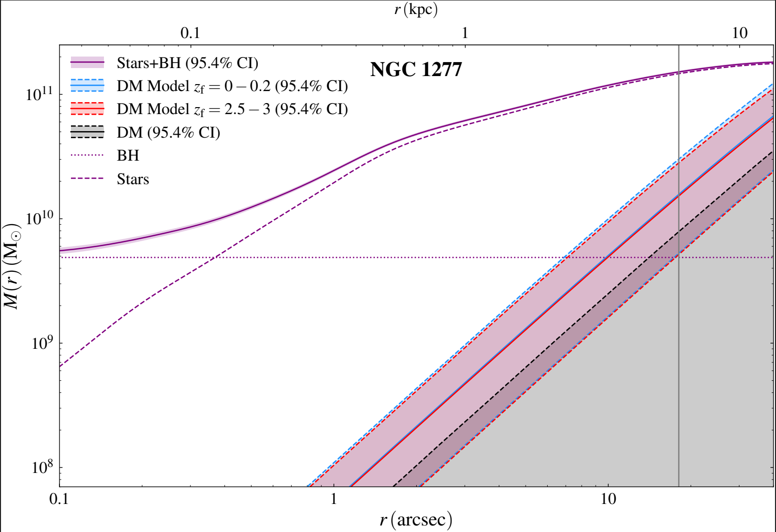
- Large mass-to-light ratio ($M/L_r \approx 7\,\mathrm{M}_\odot/\mathrm{L}_{r,\odot}$)
- Virtually no dark matter within the radius covered by the data
- $f_{\mathrm{DM}}(6\,\mathrm{kpc}) < 0.05$ (two sigma)

Jeans modelling of NGC 1278 with JAM



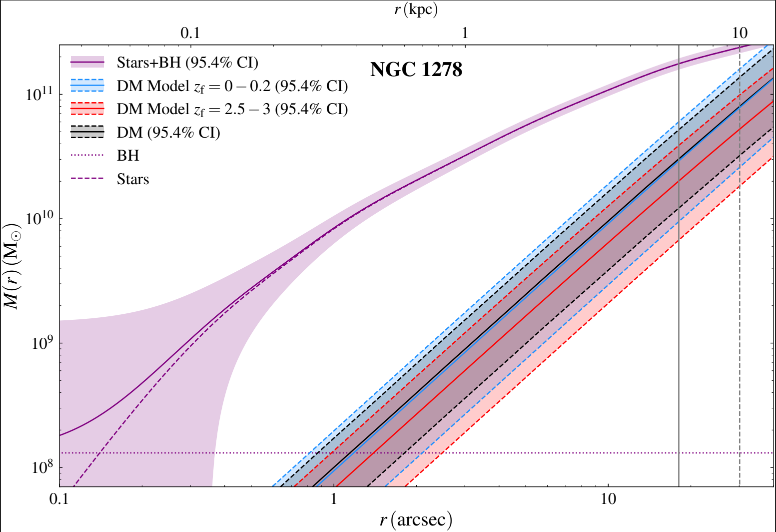
- An IMF less bottom-heavy than that of NGC 1277
- A significant amount of dark matter within the explored radius
- $f_{DM}(6\,\mathrm{kpc}) = 0.14 \pm 0.08$ (two sigma)

Cummulative mass profiles of NGC 1277



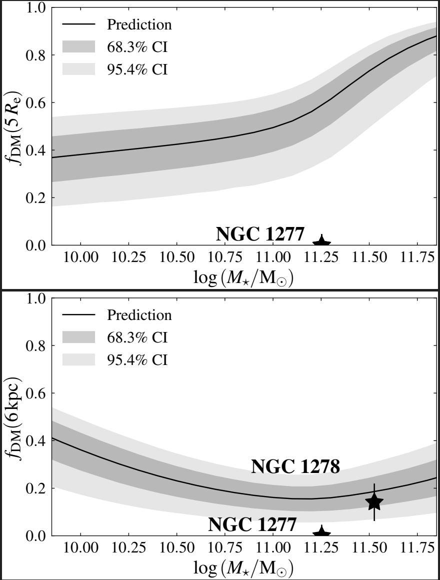
- Tension between fitted DM profile (black line and grey shades) and expectation (red line)

Cummulative mass profiles of NGC 1278



- NGC 1278 has about the expected amount of dark matter

NGC 1277 is indeed dark matter poor

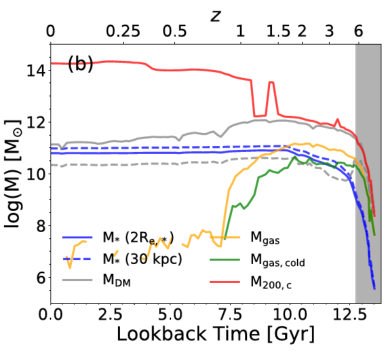


Lack of dark matter explains lack of envelope: dynamical friction

$$F \propto \frac{M^2 \rho}{v^2}$$

- If the halo surrounding the galaxy has a vanishing small density ($\rho \to 0$), nearby galaxies undergo parabolic flybys instead of being cannibalised
- Either NGC 1277 lost its dark matter halo early before it accreted an envelope or it was dark matter poor ab initio

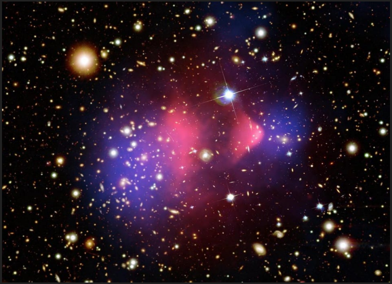
How do we make a galaxy without dark matter?



Flores-Freitas et al. (2022)

- Galaxies undergo dark matter halo stripping as they fall into a cluster (Flores-Freitas et al. 2022)
- Because of their elliptical orbits, dark matter particles are easier to strip than stars in circular orbits (Moreno et al. 2022)

How do we make a galaxy without dark matter?



X-ray: NASA/CXC/CfA/M.Markevitch et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.

- Merger of gas-rich proto-galactic fragments forming NGC 1277 with dark matter with sufficient velocity to escape the system
- Required relative velocities of $\sim 2000\,\mathrm{km\,s^{-1}}$, which might be achieved in a massive proto-cluster (Ferragamo et al. 2022)

Summary

- The relic galaxy NGC 1277 is the first giant galaxy found not to have much dark matter

The massive relic galaxy NGC 1277 is dark matter deficient

From dynamical models of integral-field stellar kinematics out to five effective radii★

Sébastien Comerón[1,2], Ignacio Trujillo[2,1], Michele Cappellari[3], Fernando Buitrago[4,5], Luis E. Garduño[6], Javier Zaragoza-Cardiel[6,7], Igor A. Zinchenko[8,9], Maritza A. Lara-López[10,11], Anna Ferré-Mateu[2,1], and Sami Dib[12]

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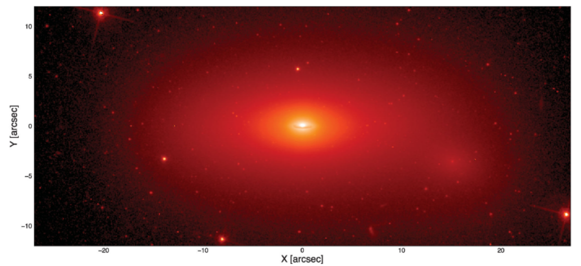

Emsellem (2013)