The universal structure of spherical galaxies

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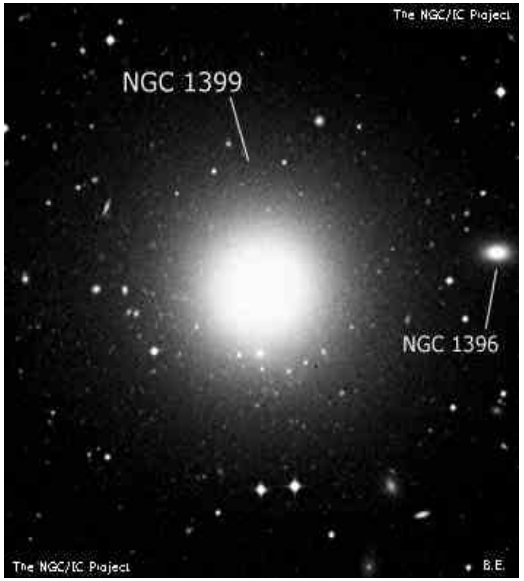
isolated

centre of the Fornax cluster



Structure → luminosity profile

Structure → mass profile

Issues

- isolated elliptical galaxies and central galaxies in galaxy clusters
- the Modified Hubble Profile and its universality
- What has this to do with MOND?
- the Baryonic Tully-Fisher Relation for early-type galaxies and deviating galaxies
- remarks on clusters of galaxies

Galaxy Sample

isolated ellipticals

NGC 6411 Richtler+in prep.
NGC 7796 Richtler+2015
NGC 7507 Lane+2015
NGC 5812 Richtler+subm.
NGC 4240 Richtler+ in prep.

central galaxies

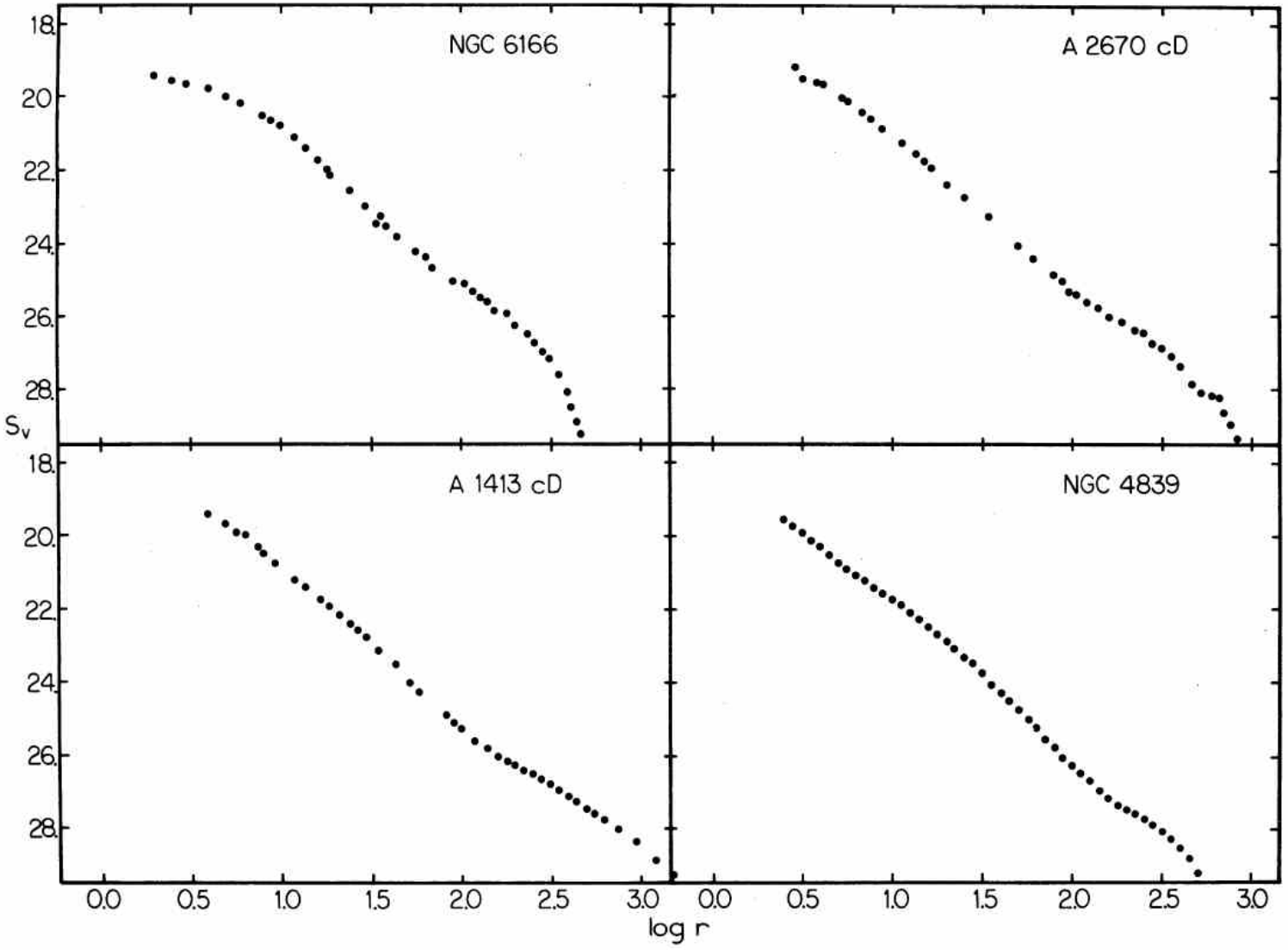
NGC 1399 Fornax Schuberth+2010
NGC 4486 Virgo Murphy+2014
NGC 3311 Hydra I Richtler+2011,
2020
Hilker+ 2018
NGC 6166 Abell 2199 Bender+2015

Kormendy+2009: 42 Virgo galaxies

Oemler 1976: the structure of ellipticals and cD galaxies (333 citations)

influential paper in establishing the myth of cD halos

4 central galaxies



The masses of elliptical galaxies

M87-Virgo cluster

No disk assumption of spherical symmetry is necessary

Observational parameters:

Integrated galaxy light

  projected velocity

  projected velocity dispersion

Dynamical tracers: radial velocities of globular clusters planetary nebulae

X-rays: assumption of hydrostatic equilibrium, structureless gas

Central galaxies have rich globular cluster systems

NGC 1399 in the Fornax cluster

Very Large Telescope (Cerro Paranal)

Approx. 6000
globular clusters

Schuberth et al. 2010

The most popular elliptical galaxy luminosity profiles

Reynolds 1913 – Andromeda nebula $I(r) \sim r^{-2}$

Hubble 1930 $(1 + r/rc)^{-2}$

de Vaucouleurs 1948 $-b_n \left[\left[\frac{R}{R_e} \right]^{\frac{1}{n}} - 1 \right]$

Sersic 1963

Jaffe 1983 3-D profile $\rho(r) \sim \left(\frac{r}{r_0} \right)^{-2} \left(1 + \frac{r}{r_0} \right)^{-2}$

Hernquist 1990 3-D profile $\rho(r) \sim r^{-1} \left(r + r_0 \right)^{-3}$

why so many different profiles?

observational reasons – better photometry of galaxy components

theoretical reasons – finite mass, analytical potential-density pairs, analytical deprojection

Less popular: the modified Hubble profile (MHP)

$$I(r) \sim \left[1 + \left(\frac{r}{r_c} \right)^2 \right]^{-1}$$

Textbook: Binney & Tremaine – Galactic Dynamics

The cored isothermal sphere (CIS)

Variables

$$\tilde{\rho} = \frac{\rho}{\rho_0} \qquad \tilde{r} = \frac{r}{r_0} \qquad r_0 = \sqrt{\frac{9\sigma^2}{4\pi G \rho_0}}$$

"King-radius"
Zwicky 1957
Rood et al. 1972

structure equation for the cored isothermal sphere

$$\frac{d}{d\tilde{r}}\left[\tilde{r}^2 \frac{d \ln \tilde{\rho}}{d\tilde{r}}\right] = -9\tilde{r}^2\tilde{\rho}$$

numerical solution: BT, 1987, p.229

the modified Hubble profile is a good representation of the CIS out to a few King radii

The "universality" of galaxy light profiles

- galaxy centres show pronounced individuality

  dust
  recent star formation
  cusps
  non-stellar continuum

- round galaxies do not need to be spherical

- with these caveats: outside the very centre
  galaxy luminosity profiles of (presumably) spherical
  galaxies are universal

Photometry

NGC 1399 – Dirsch+2004

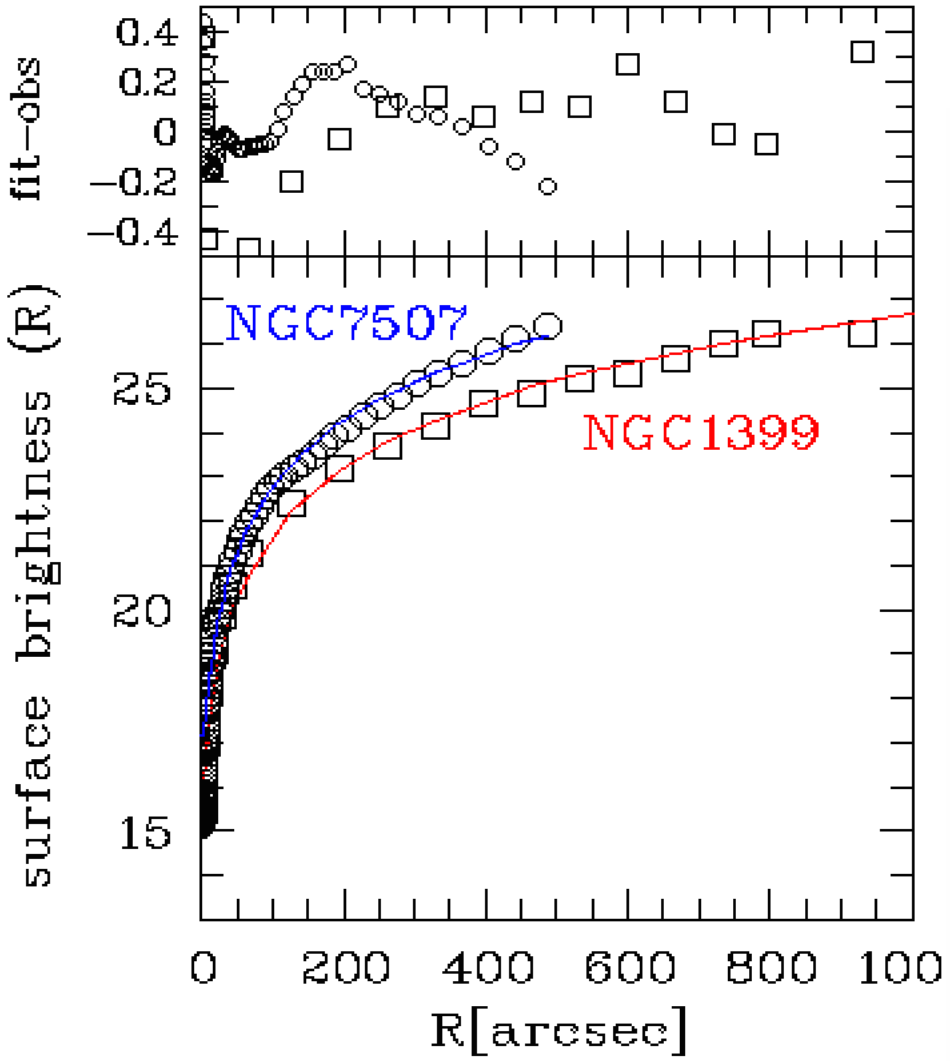
NGC 7507 – Lane+2015

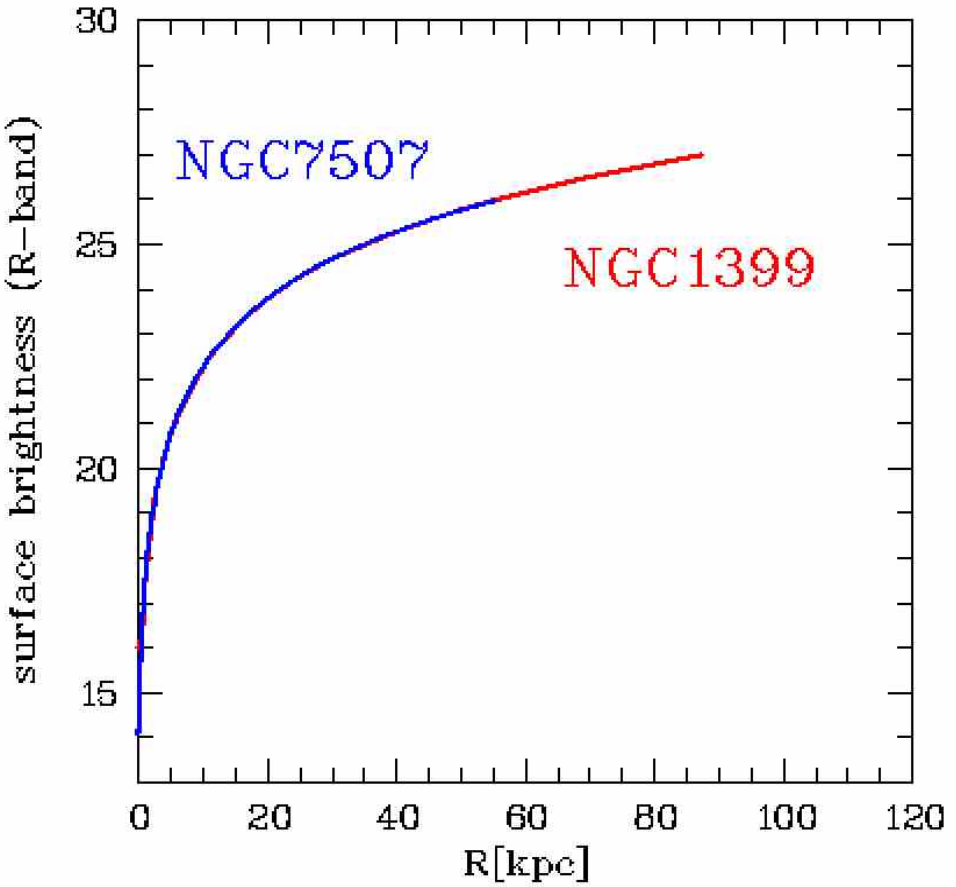
distances:

NGC1399 18 Mpc

NGC7507 28 Mpc

shifting NGC 7507 by 0.54 mag

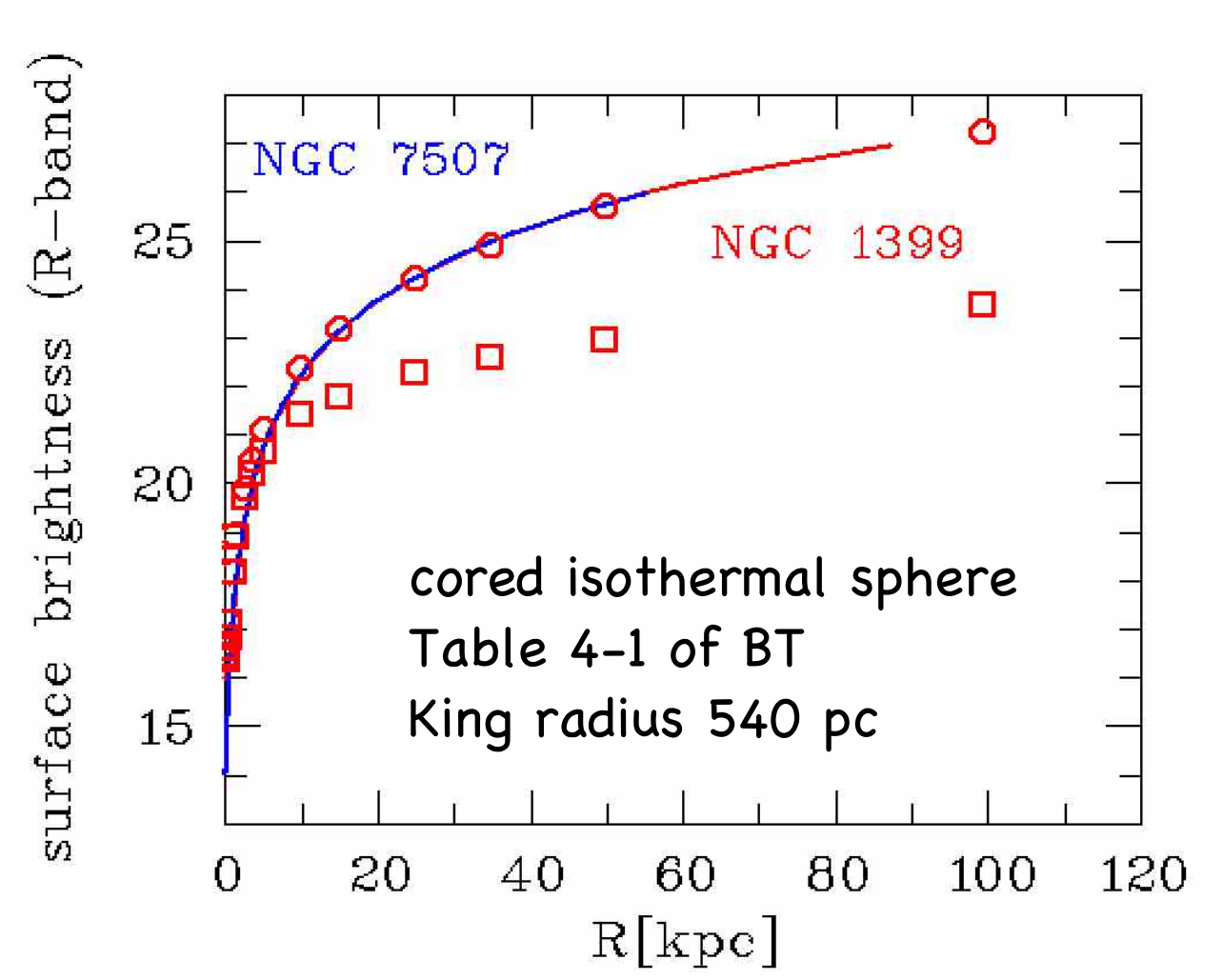




There is no sign of a photometric cD-halo !

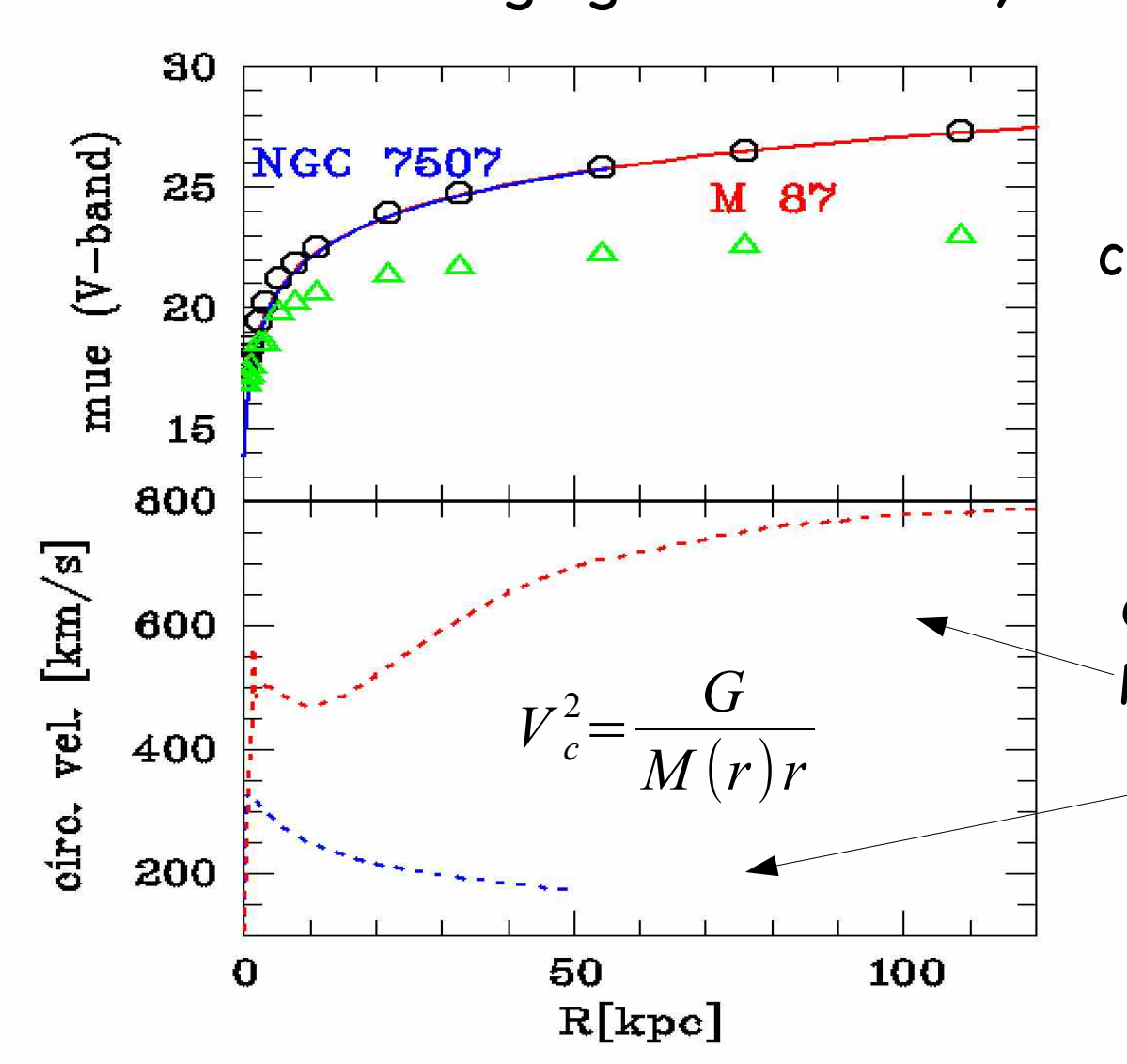
There is no photometric sign of a transition to DM dominance!

NGC 1399 – a MONDian cored isothermal sphere?



MOND
with mass-to-light ratio

Exchanging NGC 1399 by M87



cored isothermal sphere

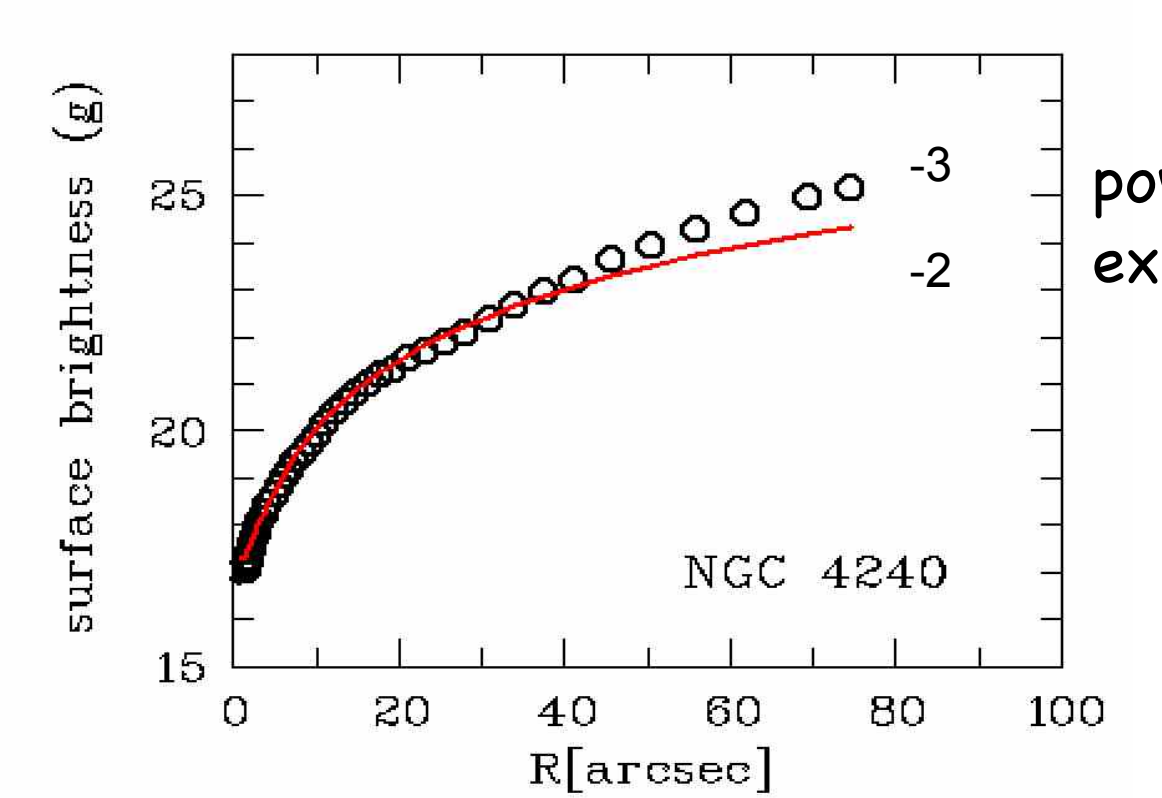
circular velocities for M87 and NGC7507

luminosity profiles miss signatures of the mass profiles !

Milgrom 1984: MONDian isothermal sphere has finite mass!

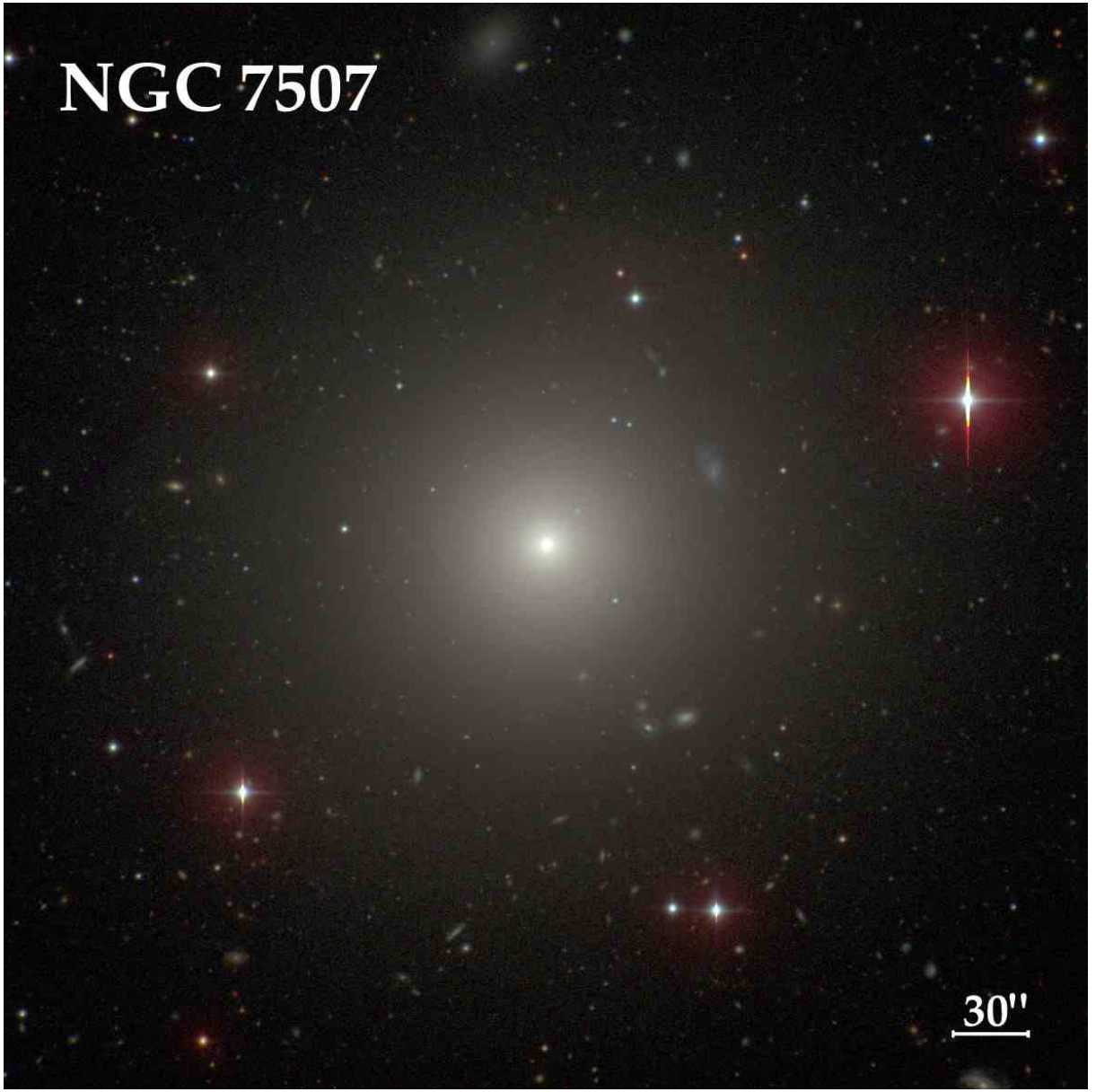
 MHP can describe the part with power-law -2

NGC 4240 – a faint isolated elliptical galaxy (Salinas+2015)



power-law exponents

NGC 7507 – an isolated elliptical galaxy



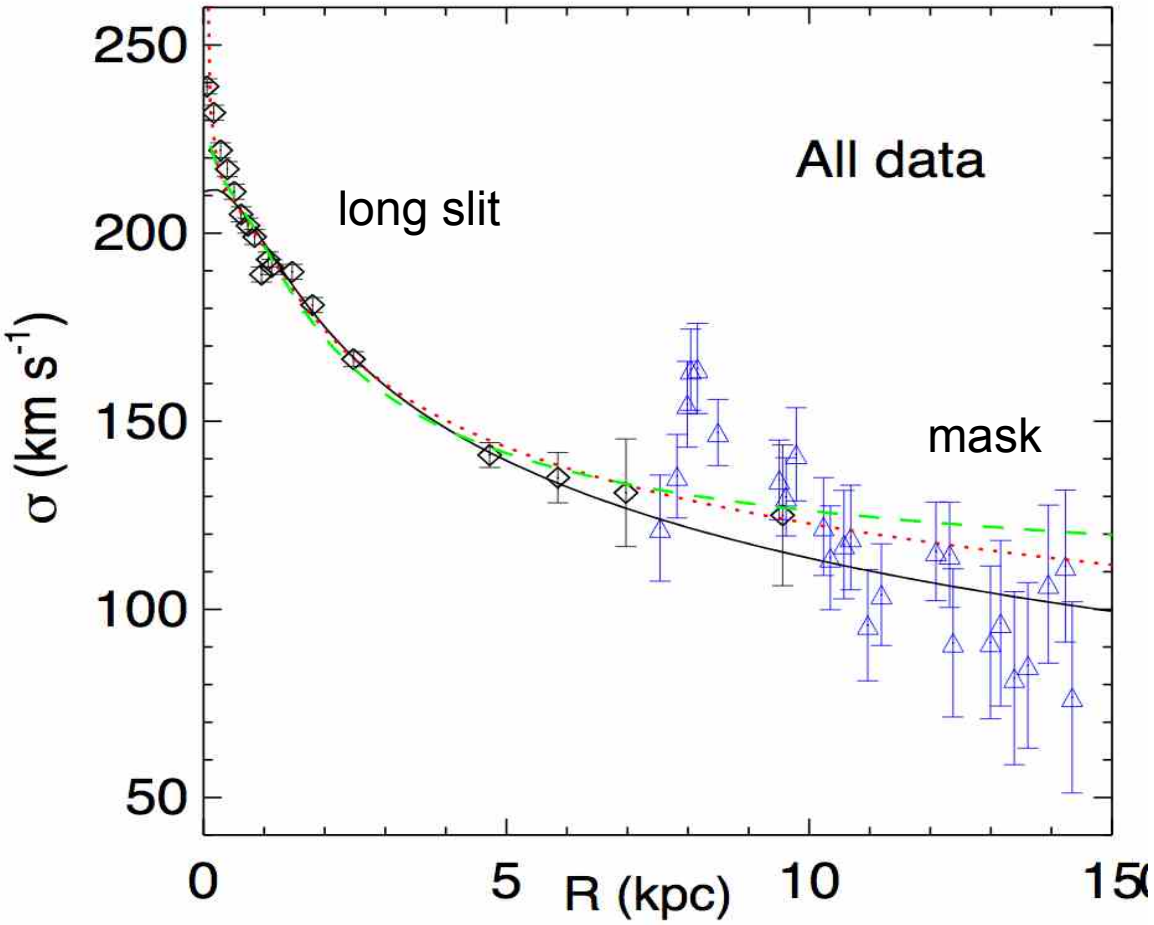
Salinas et al. 2012
Lane et al. 2015

distance 23 Mpc

$M_V = -21.6$

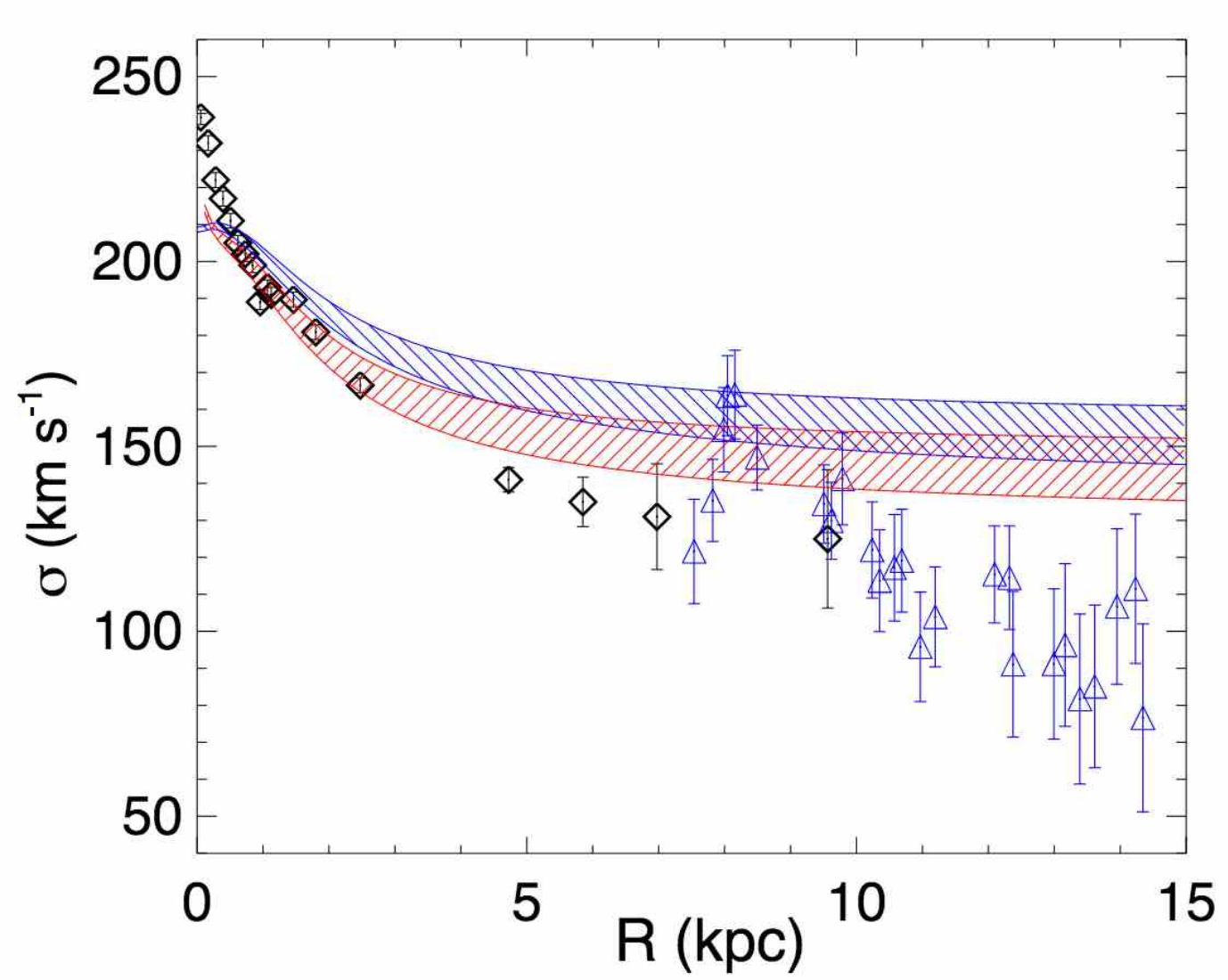
NGC 7507: a galaxy without dark matter!

Lane et al. 2015: GMOS/Gemini spectroscopy



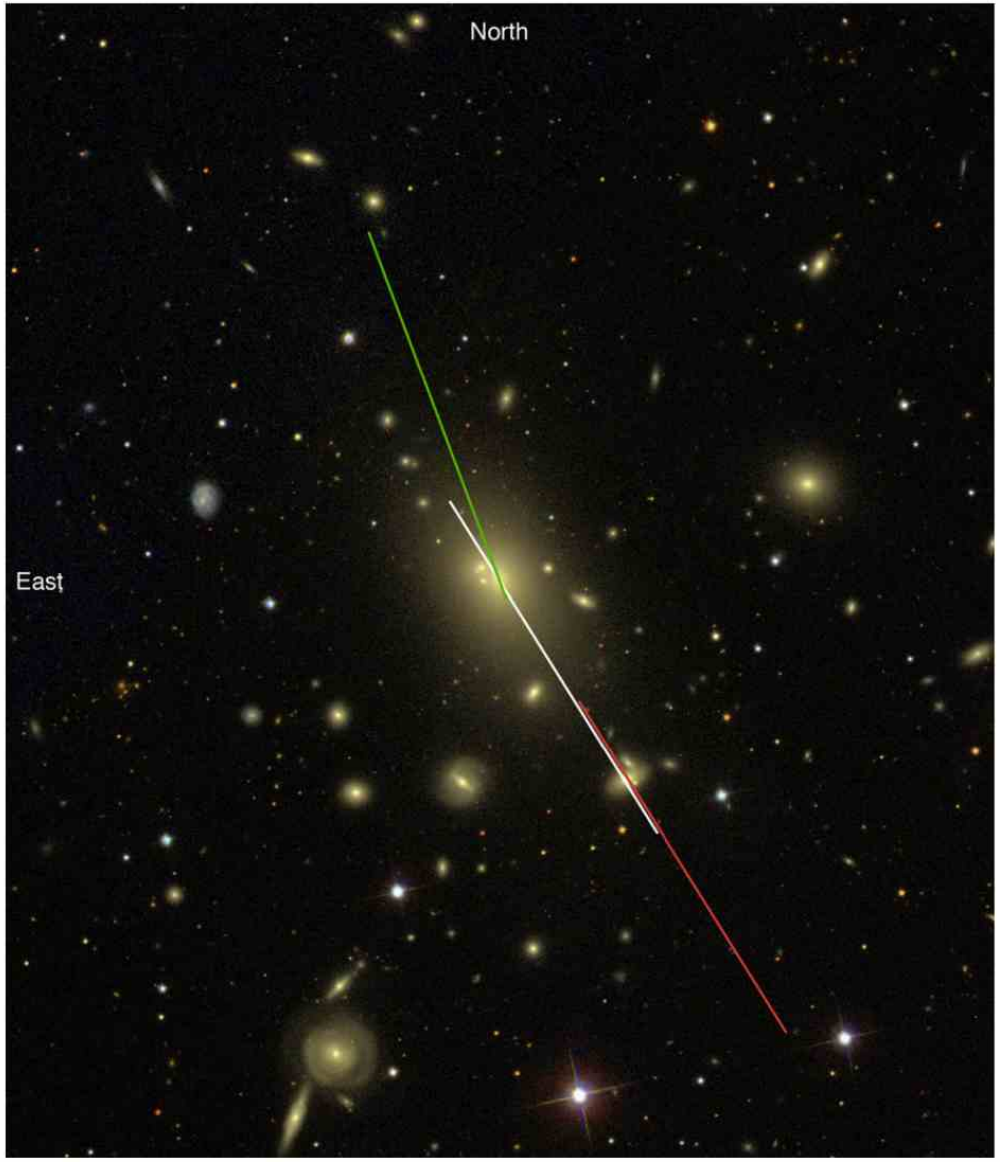
stars only

MOND models



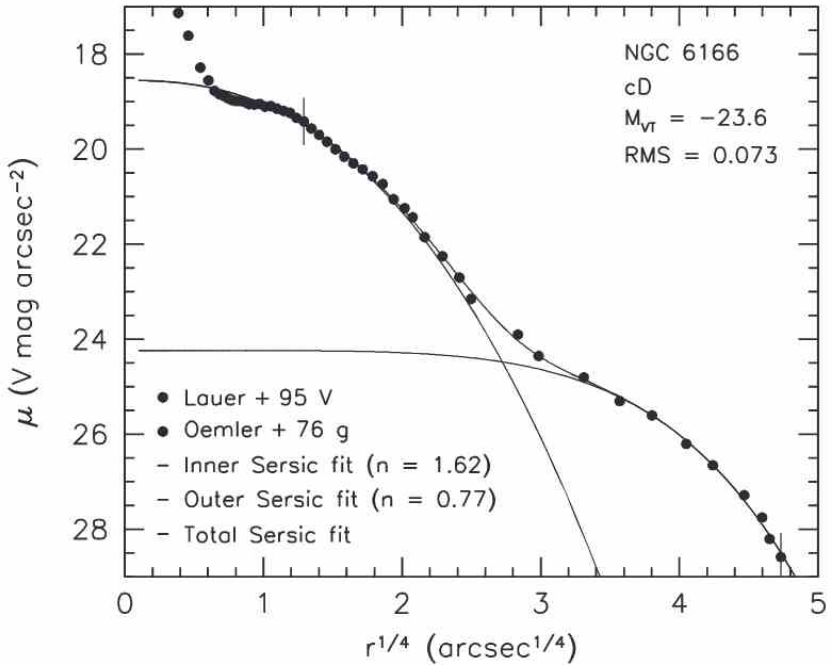
flattened along the line-of-sight?

NGC 6166 – central galaxy of Abell 2199



Bender et al. 2015

old photometry

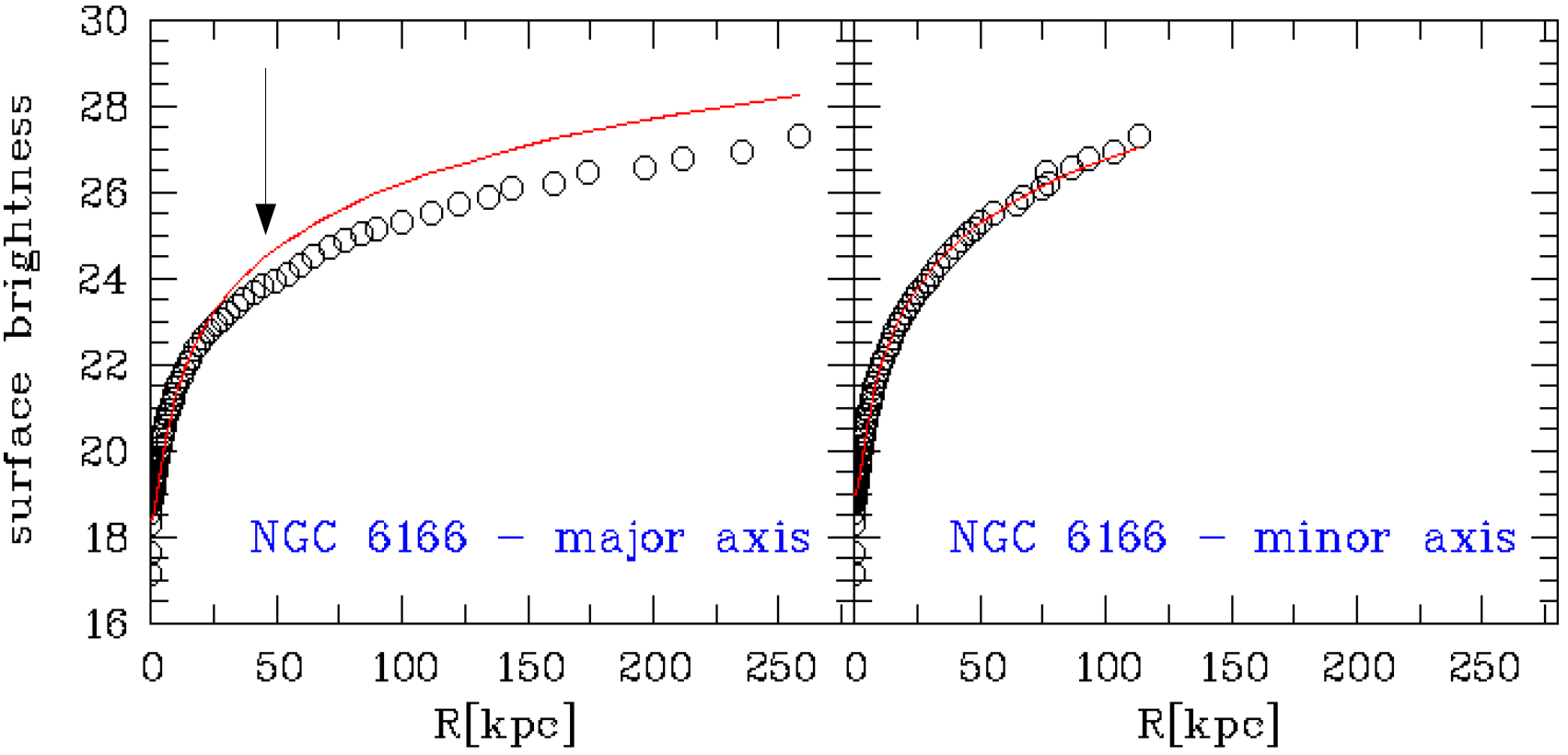


Bender et al. 2015:

This photometry is errorneous!
There is no photometric cd-Halo

Bender+2015

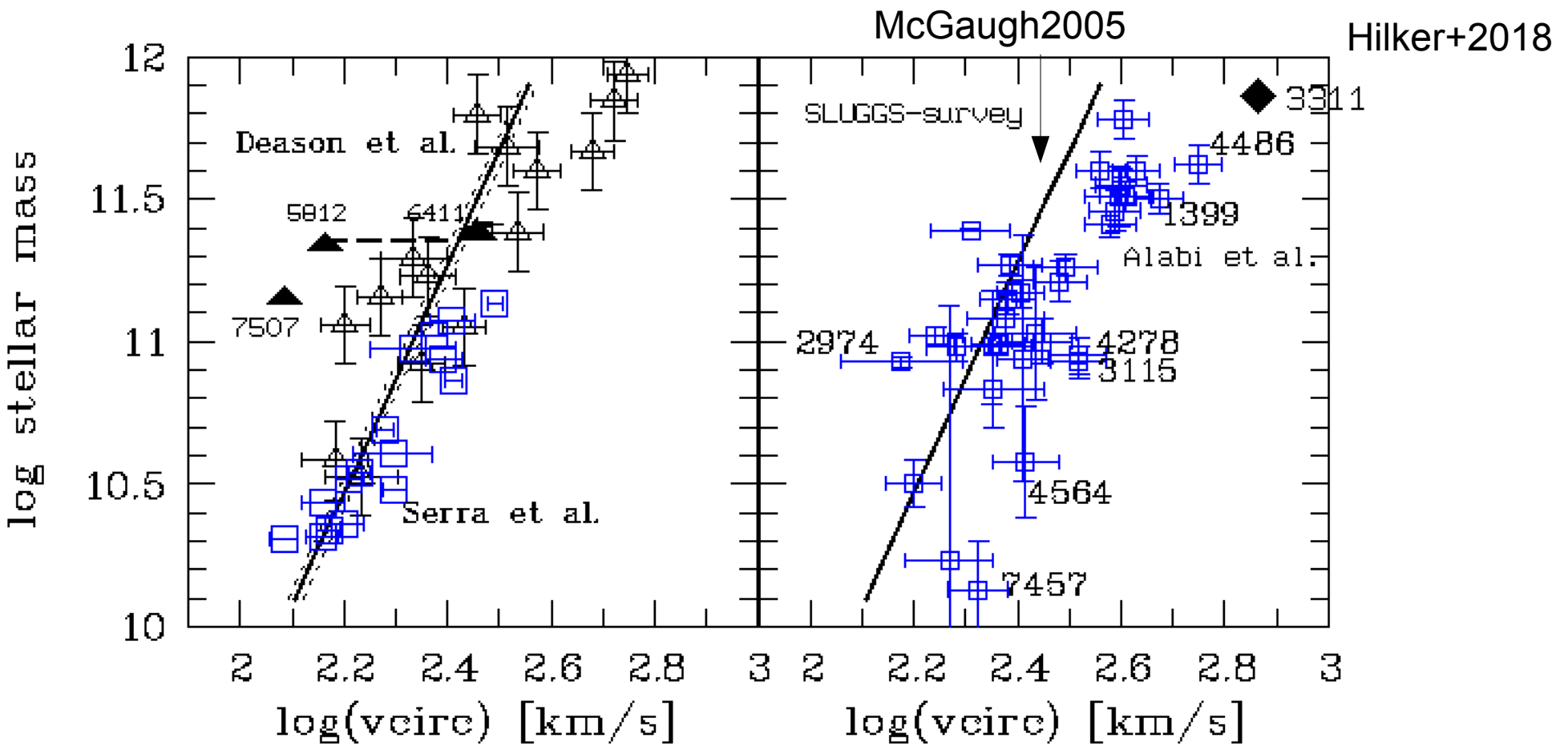
NGC 6166 – the modified Hubble profile



NGC 6166 is elongated and anisotropic!

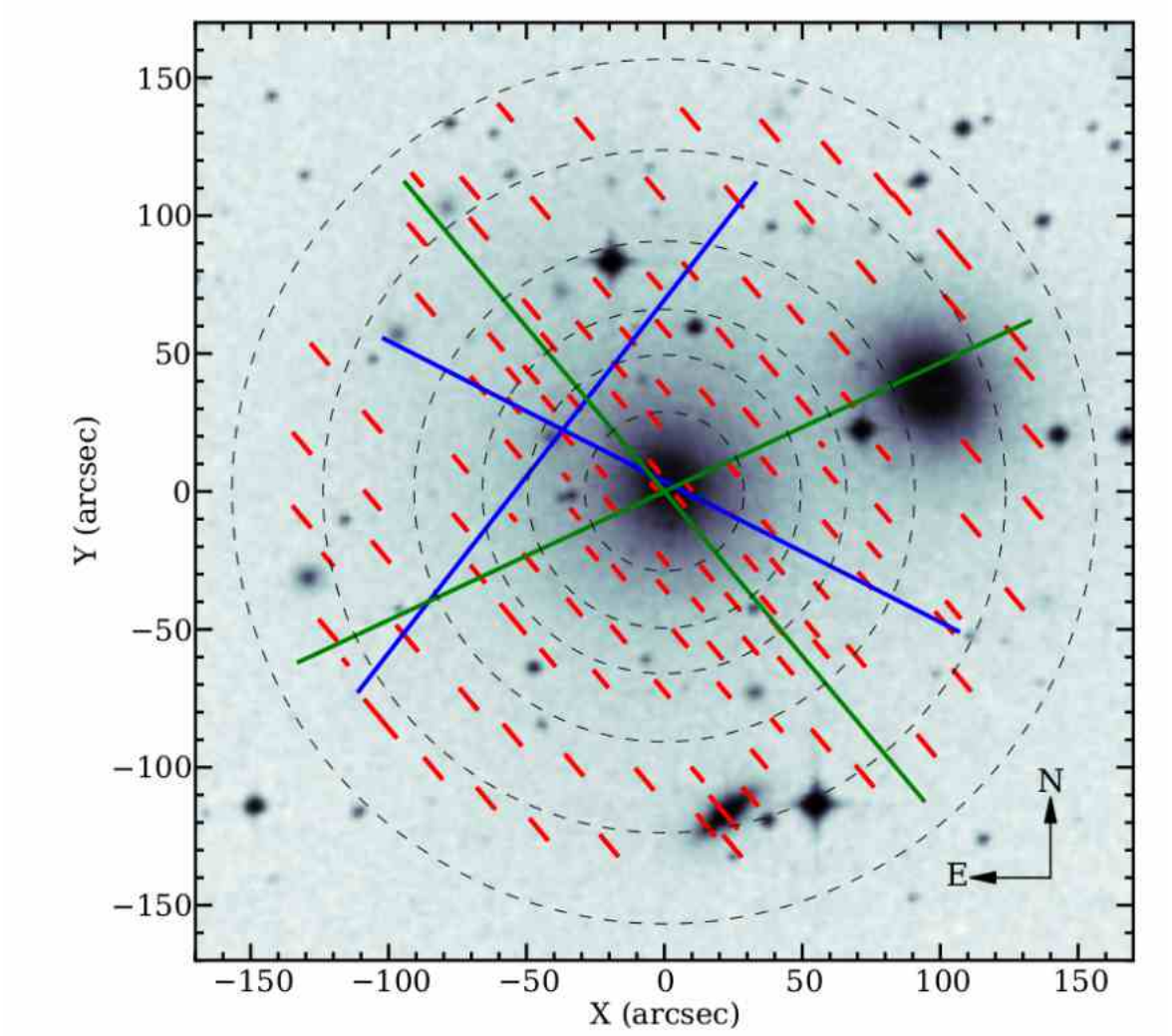
The Baryonic Tully-Fisher Relation
- early-type galaxies

Samples of early-type galaxies with masses: Deason+2012
Serra+2016 (with HI disks)
SLUGGS survey: globular cluster velocities Alabi+2016



Slit spectroscopy around NGC 3311 - VLT/FORS2

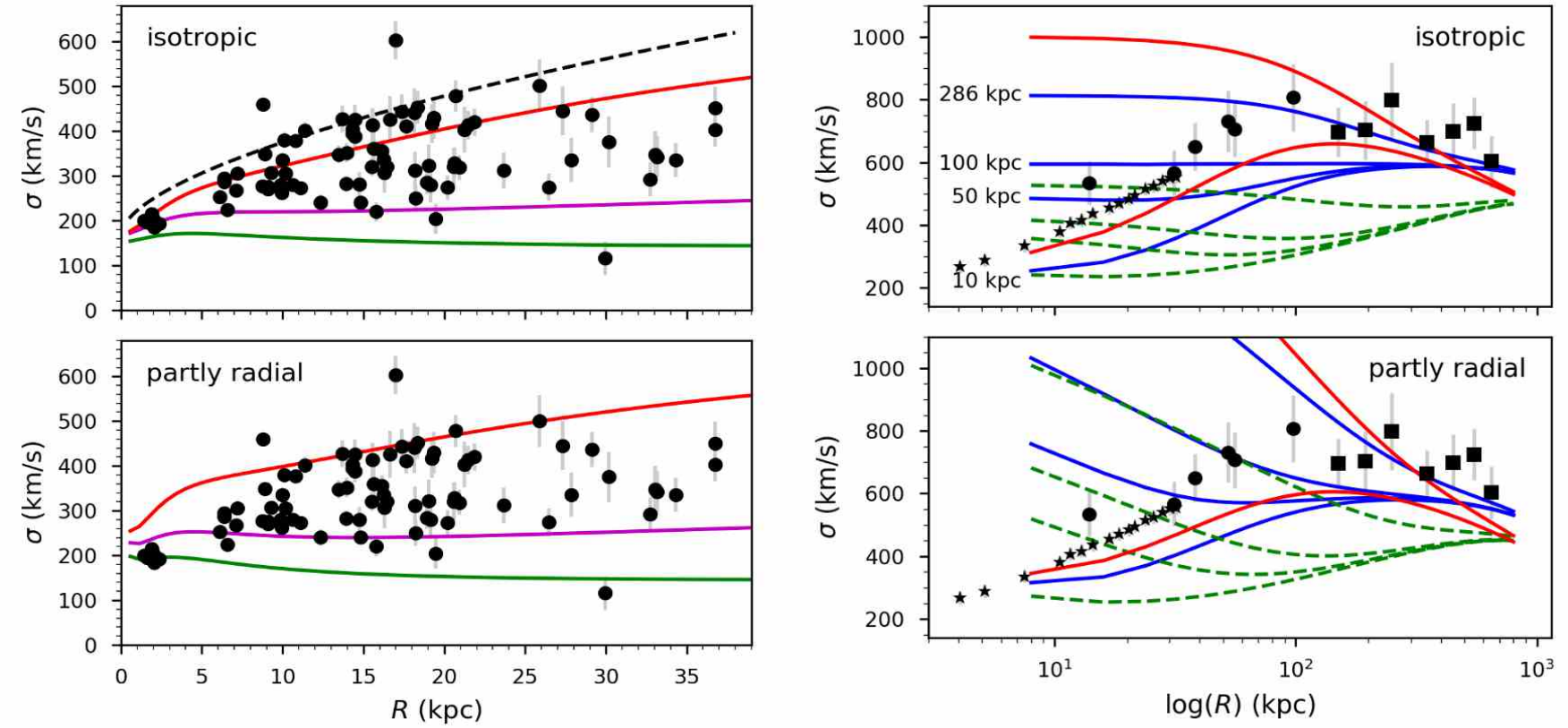
Hilker+2018



NGC 3311: Field of velocity dispersion of the stellar light, globular clusters and cluster galaxies

inner region – the galaxy

outer region – the cluster



There is no unique tracer population

Comments on the kinematic complexity around NGC 3311

- folding all dispersion data into one radial coordinate produces a radially rising velocity dispersion fakes a dark halo

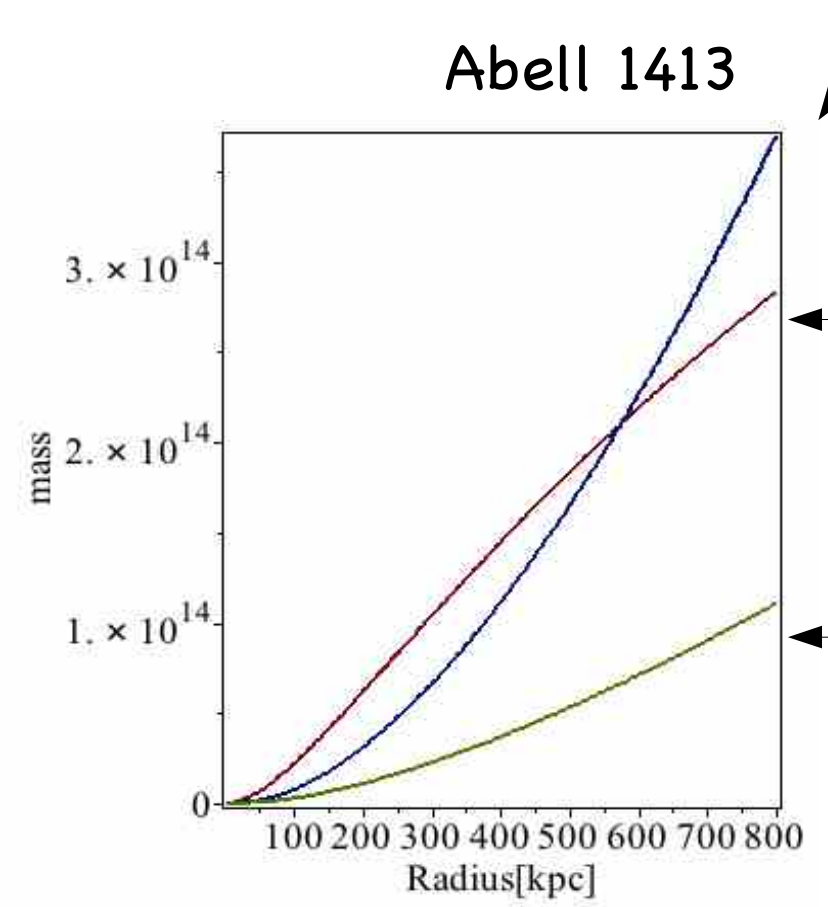
- no "ideal Jeans world"
  superposition of multiple tracer populations

- no direct possibility to measure the underlying potential

- no evidence for "cluster dark matter"

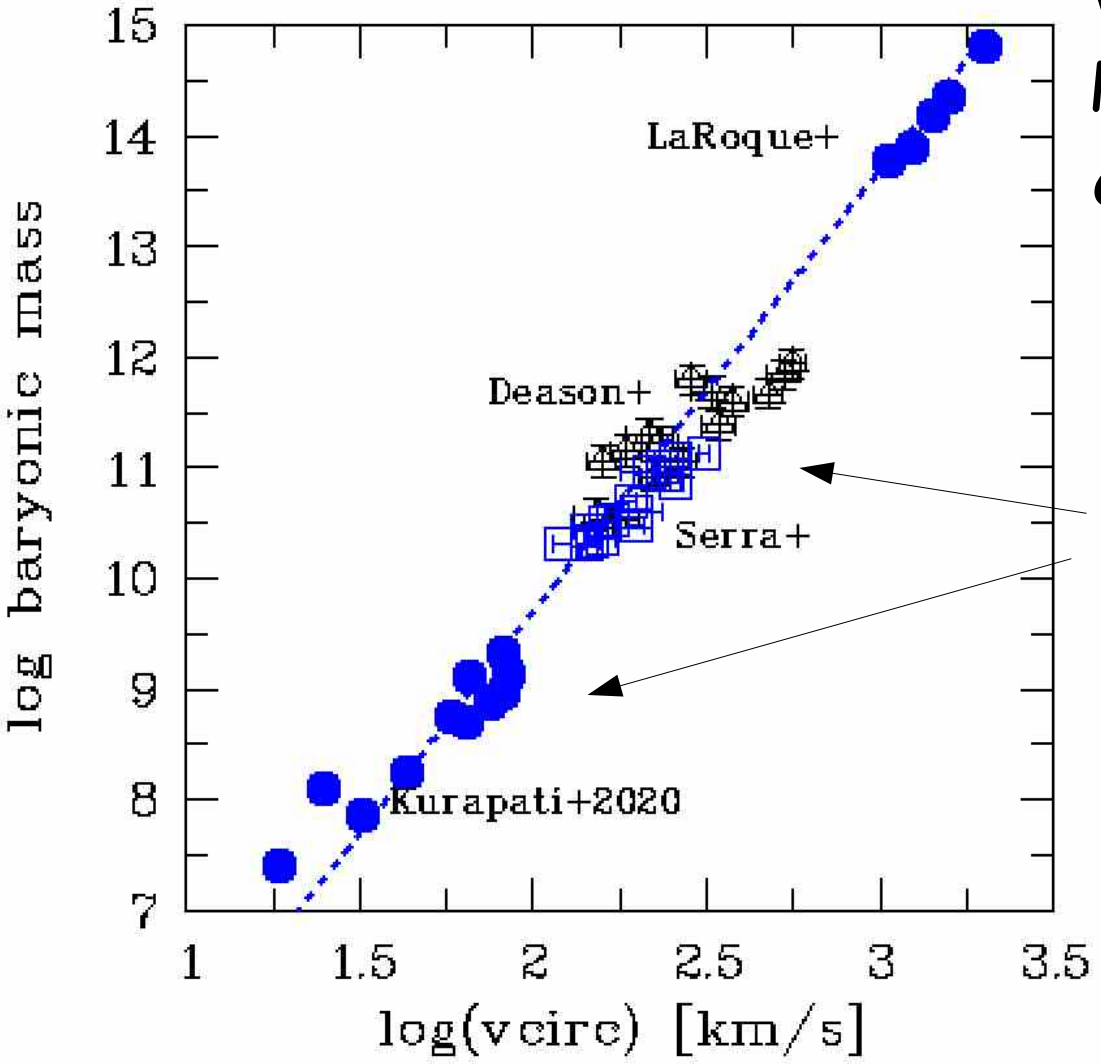
- what we need: rich tracer population without complications
  NGC 4636 (Schuberth+2012) MONDian

38 galaxy clusters (Laroque+2006): gas densities from X-rays and SZ-measurements



- cluster gas is a multiphase medium
- baryonic estimate correct?
- hydrostatic equilibrium may overestimate the mass by an unknown amount

The baryonic Tully-Fisher relation with galaxy clusters from LaRoque+2006, and the void dwarf galaxy sample of Kurapati+2020



where dynamical and MONDian ghost halos agree

at 5 R_eff

Conclusions

- bright spherical galaxies show universality, expressed by the Modified Hubble Profile

- conjecture: spherical galaxies are "cored MONDIan isothermal spheres"

- precise masses of central galaxies by the complexity of tracer kinematics difficult (or impossible) to measure

- there is no hard evidence for dark matter in galaxy clusters beyond the MONDian expectation