# IntraClusterLight

## A probe for the large scale cluster dynamical properties

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with OAR team
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An LBC@LBT survey for faint photometry in high z cluster cores

First results from pilot observations in CL0026+17 z=0.4

ApJ, 2014, 781, 24

Visible/NIR ICL was recognized as an important component of total stellar mass in cluster cores (Zwicky 1951)

Massive clusters contain a luminous component consisting of stars residing outside cluster galaxies

Strong tidal fields by galaxy interactions are likely primary contributors

ICL is composed of stars stripped into the IC environment from the cluster galaxies

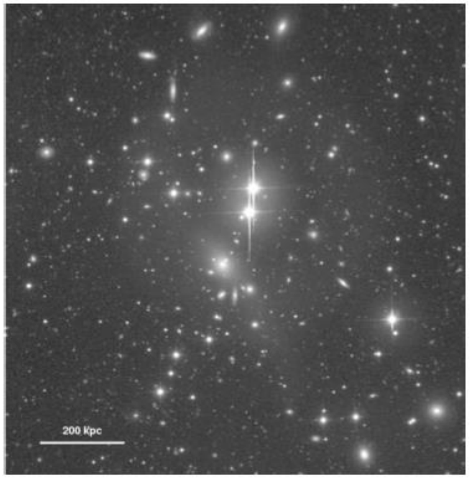
Numerical simulations suggest ~10-40% of ICL fraction for clusters at z=0-1 in broad agreement with observations
e.g. Arnaboldi et al. (1996, 2004), Zibetti et al (2005), Mihos (2005), Gonzalez et al. (2007), Krick et al (2007), Toledo et al (2001), Rudick et al. (2011)

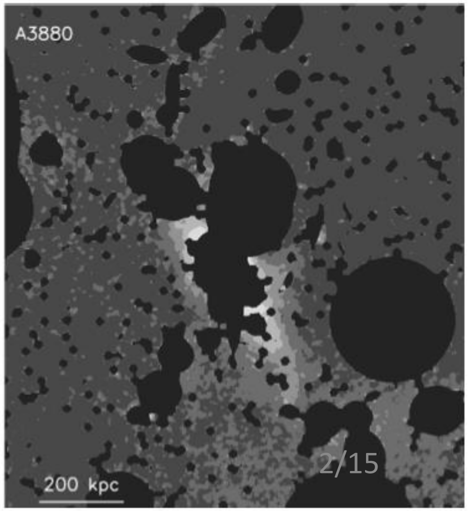
Different techniques have been used to measure ICL (e.g. isophotal limit, galaxy light subtraction)

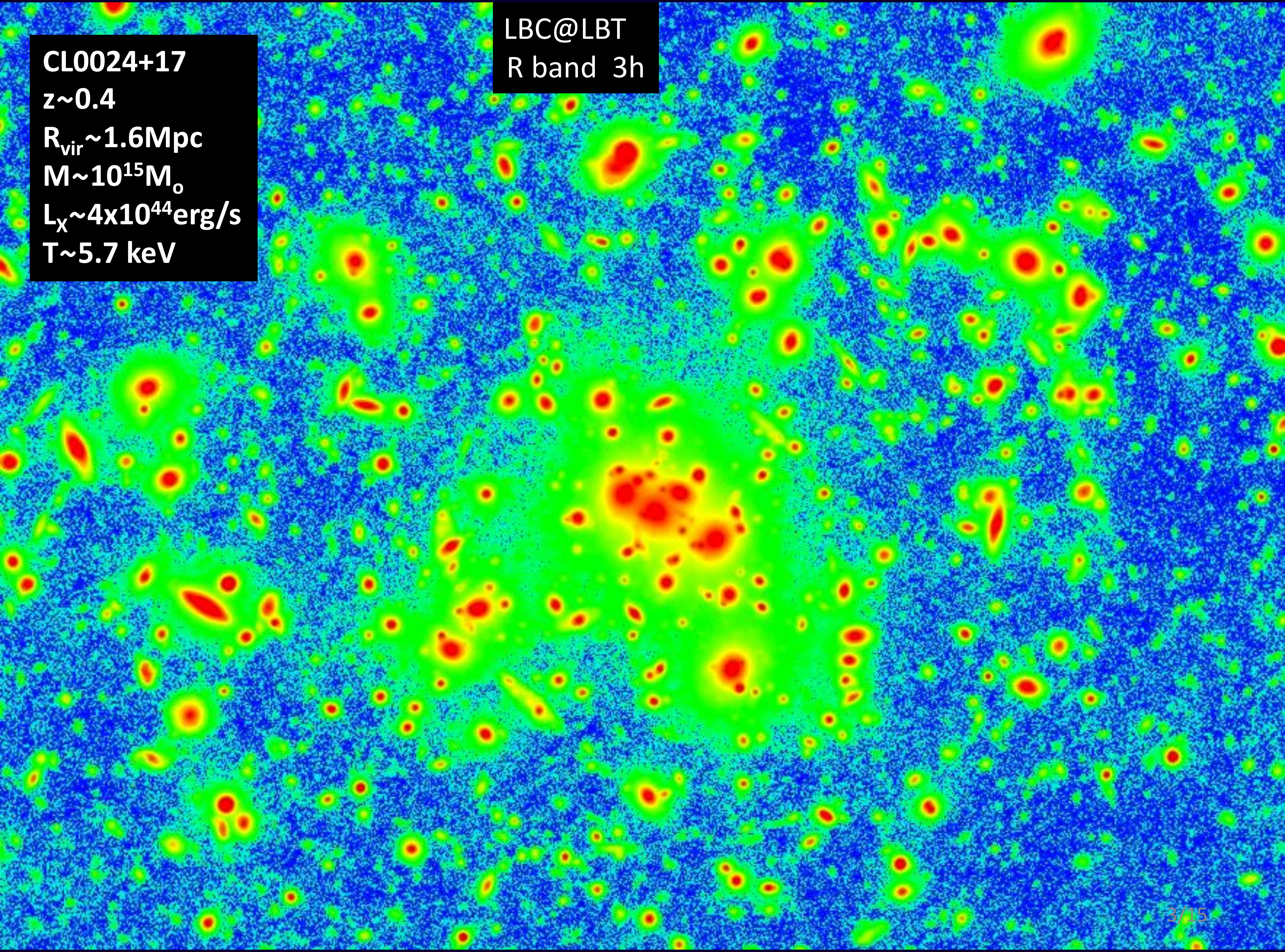
We are starting a long term program with LBC@LBT to provide homogeneous ICL measure for intermediate z clusters

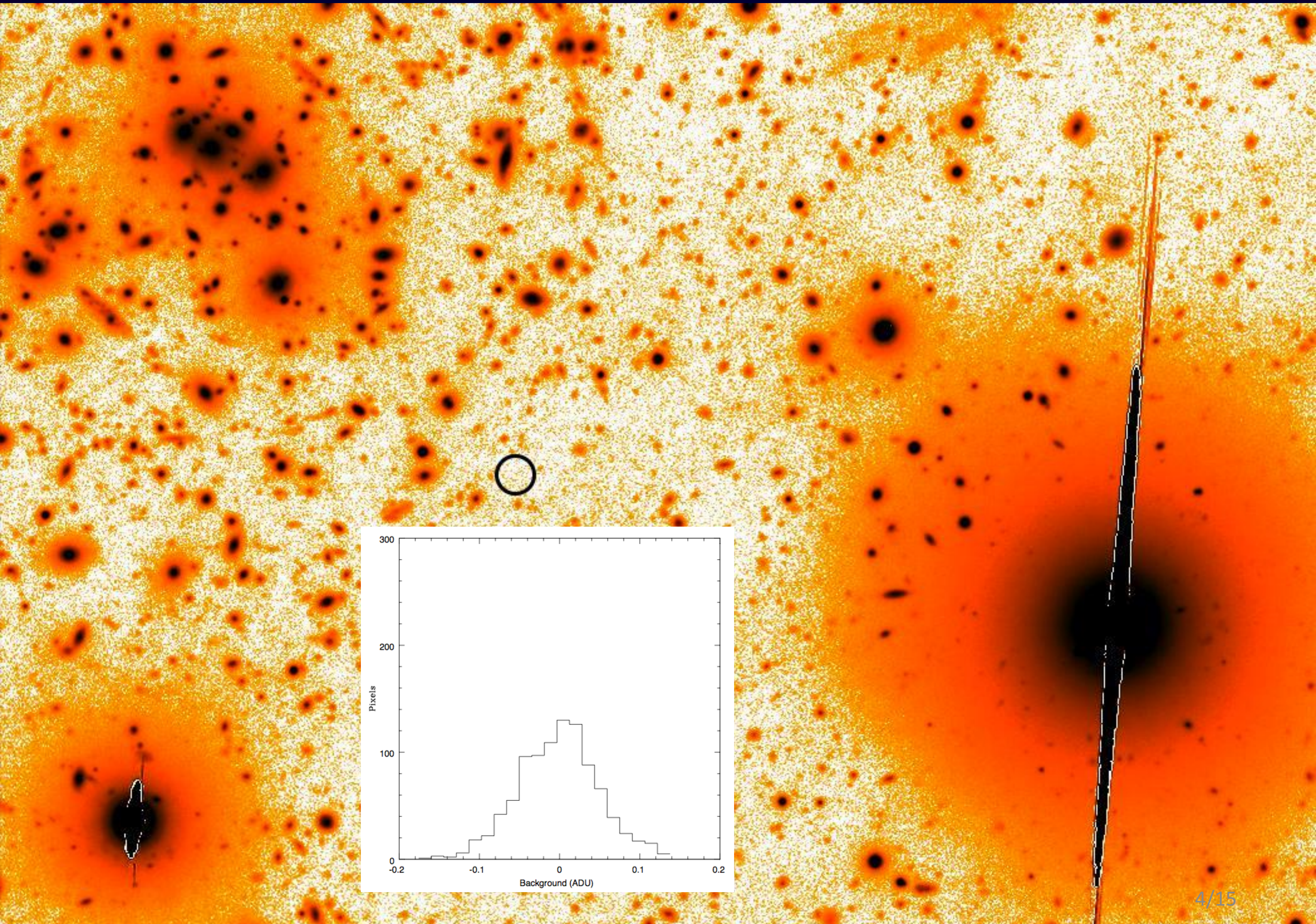
Previous measures on small telescopes or HST
More recently at Subaru and VLT

Krick & Bernstein 2007 Las Campanas 2.5m




LBC@LBT
R band 3h
CL0024+17
z~0.4
R$_{vir}$~1.6Mpc
M~10$^{15}$M$_o$
L$_X$~4x10$^{44}$erg/s
T~5.7 keV


300
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Pixels
-0.2
-0.1
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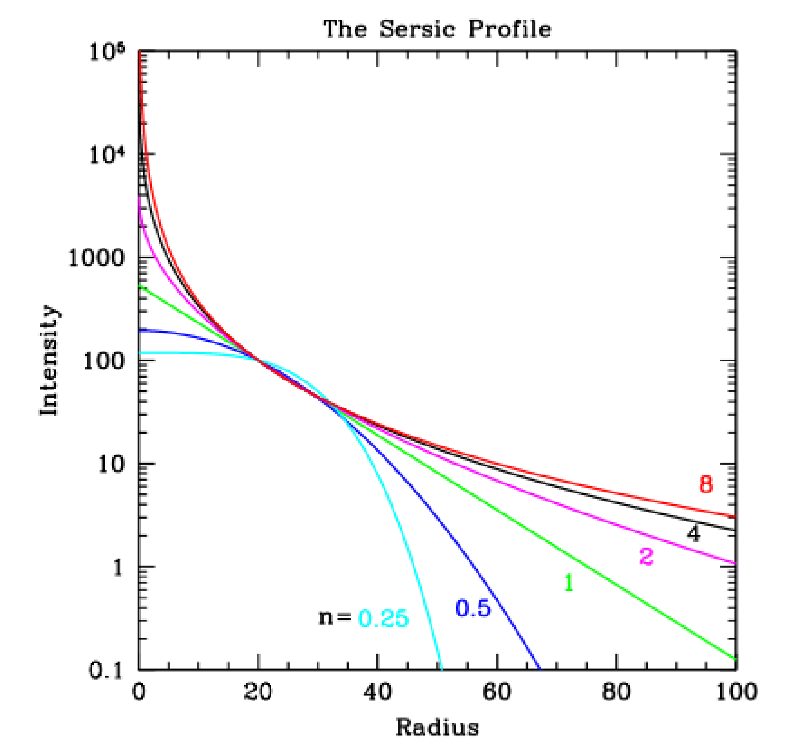
Background (ADU)

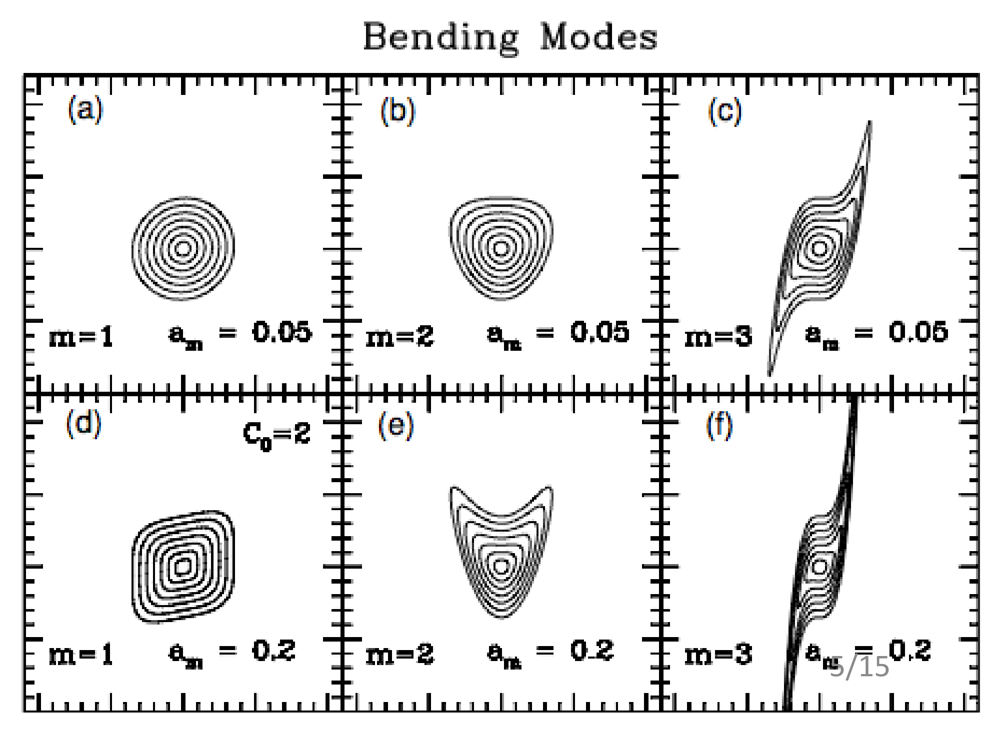
To measure the ICL we decided to fit the galaxy profiles removing the galaxy halos light

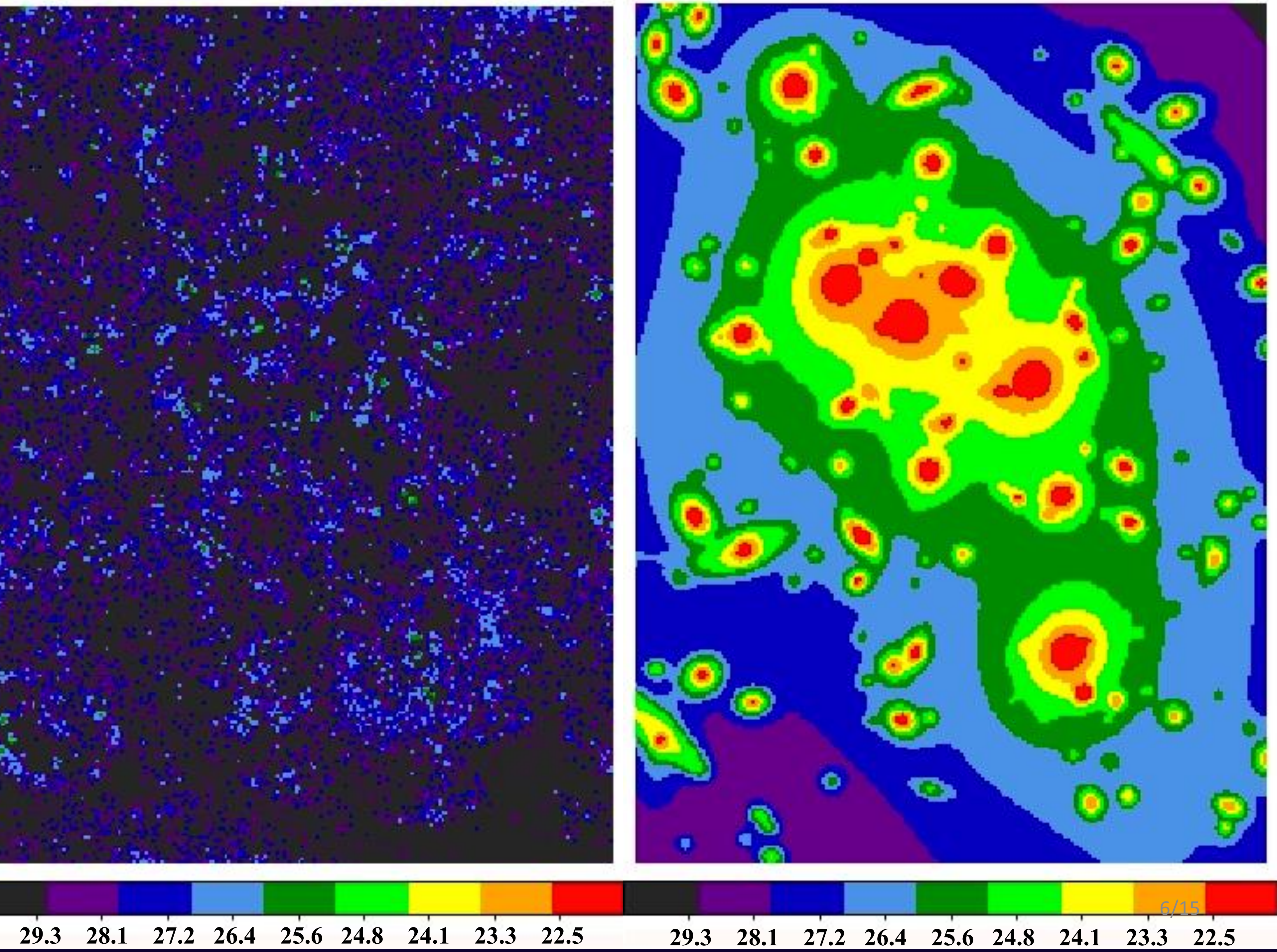
Galfit (Peng et al. 2010) package has been adopted for all galaxies down to R=27 within 200 kpc

PSF convolved Sérsic profiles were adopted (n=4 DeVaucouleur , n=1 exp. Profiles)

Fourier modes and bending modes were used to add azimuthal perturbations to the radial profiles (useful for distorted lensed images and for ICL shaping)

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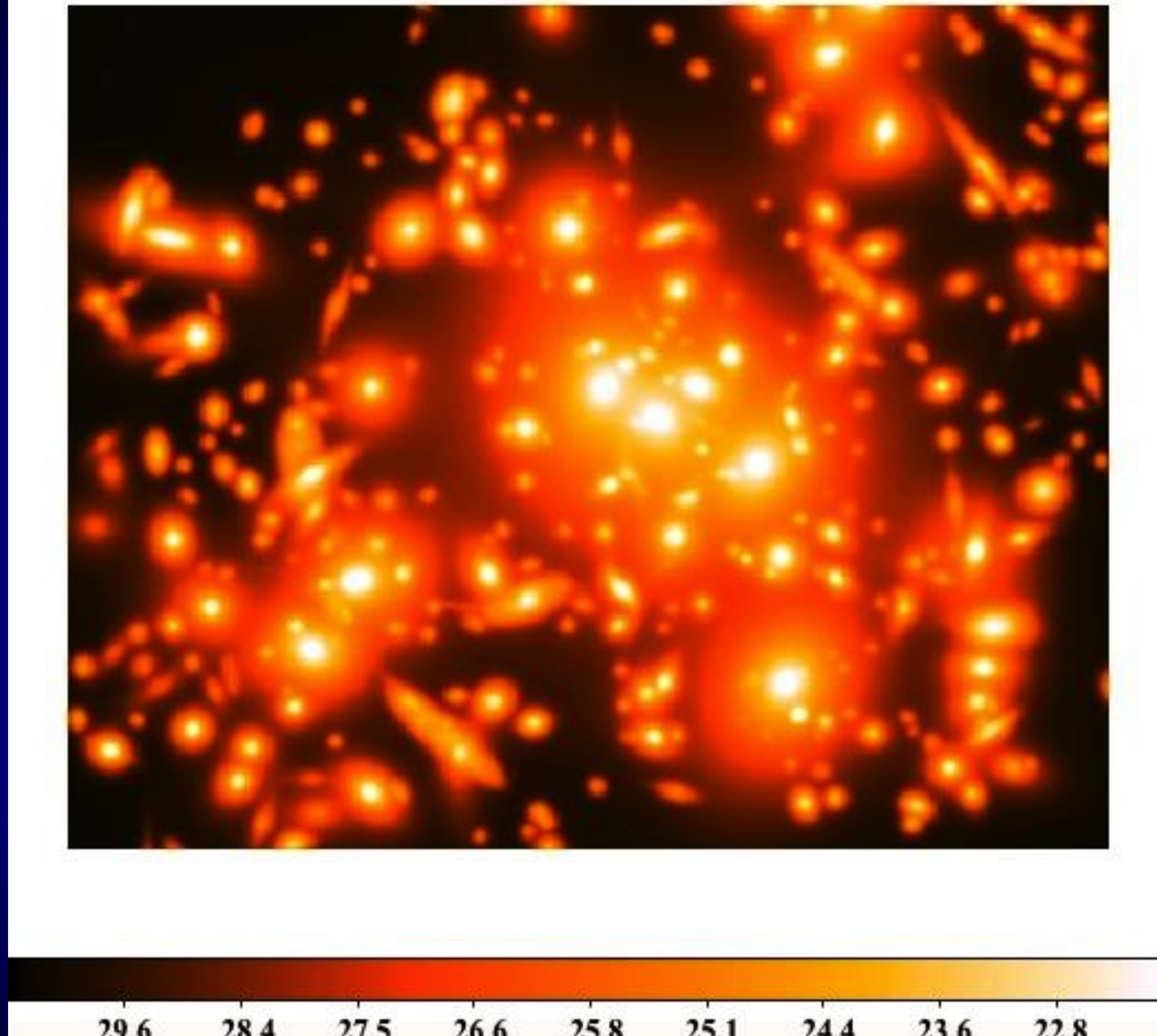
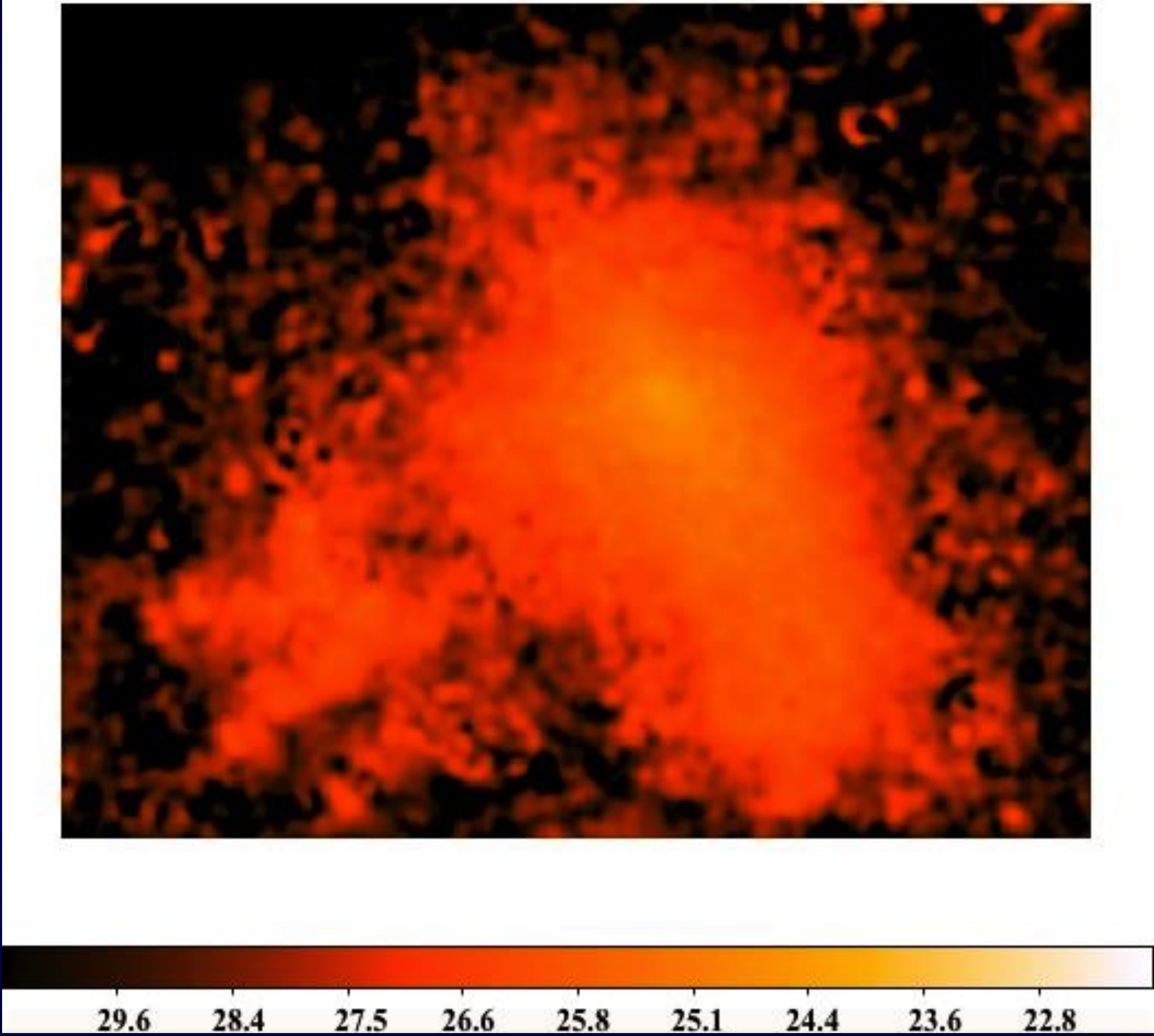



R (mag/arcsec$^2$)



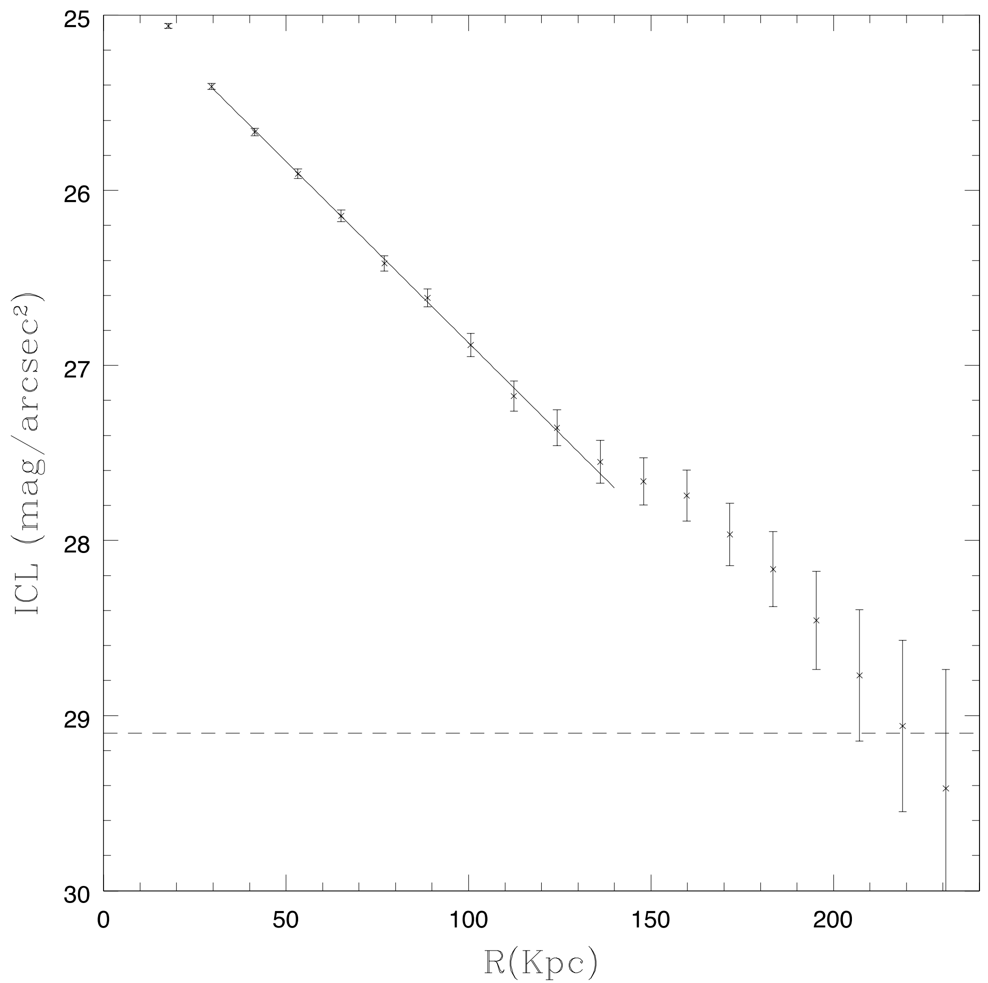

R (mag/arcsec$^2$)

Radial ICL profile up to 200 kpc

Exponential radial profile

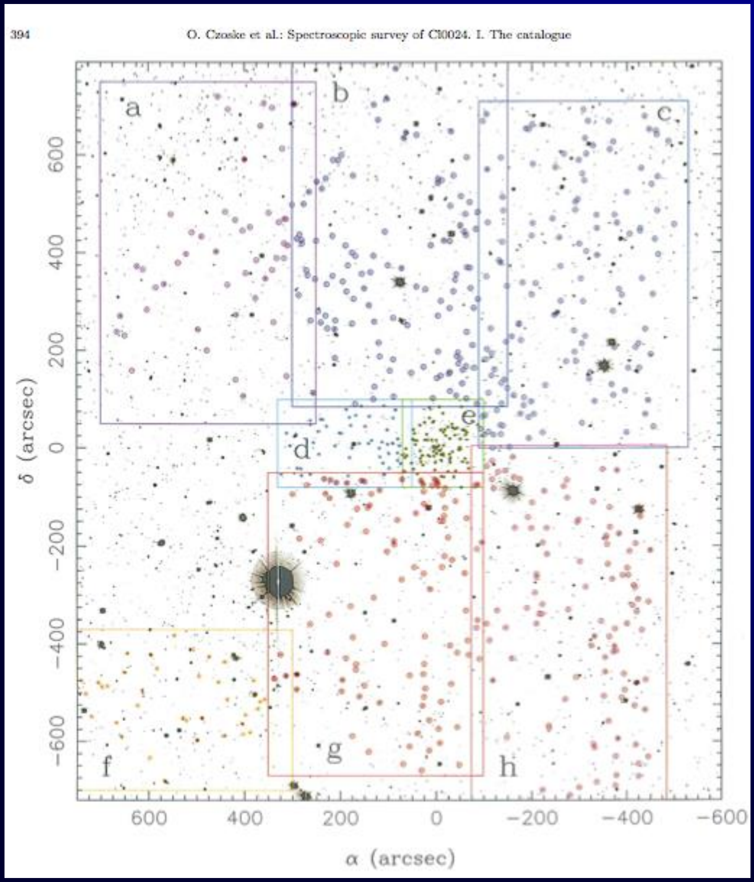
Small deviation at 150 kpc (group)

Exponential decrease consistent with CDM models expectations



Cluster membership ensured by means of the large photometric (BVRIJK) and spectroscopic database available for this cluster which provide reliable spectroscopic and phot. redshifts down to R=23 (33/43 spec. R<21.5 within 200kpc)

From R=23 to R=27 we assumed cluster membership for all the galaxies in the cluster core (within 200 kpc)



# ICL Predictions from Tidal Stripping (Simple Analytic Estimate)

$$r_t = \left( \frac{G\,m_s}{\omega^2 - \frac{d^2\phi}{dr^2}} \right)^{1/3}$$

King 1962, Taylor & Babul 2001

$$\rho(r) = \rho_0\, f(x)$$

$$x \equiv r/r_c$$

$$r_c = r_v/c.$$

NFW profiles.

$$r_t = \frac{\sigma_s}{\sigma}\, x\, r_c\, A(x)$$

$$A(x) \equiv \left\{ \frac{[I(x_s)/x_s]^{3/2}}{[I(x)/x]^{1/2} \left[ [2\,I(x)/x] + x\,\frac{d}{dx}[I(x)/x] \right]} \right\}^{1/3}$$

$$I(x) \equiv \int_0^x f(x')\,x'^2\,dx'$$

In the isothermal case $f(x) = x^{-2}$ $\quad r_t = (\sigma_s/\sigma)\,r/2^{1/3}$

$$m_{lost} = \int_{r_t}^{\infty} 2\pi\,\Sigma_0\, e^{-\frac{\xi}{r_d}}\,\xi\, d\xi$$

Assuming exp. Disk profile
$r_d$ is the disk scale radius

$$m_{lost} = m_*\, G(x, \lambda, c)$$

$$G(x, \lambda, c) \equiv \left[1 + \frac{x\,A(x)}{\lambda\, c}\right] exp\left[-\frac{x\,A(x)}{\lambda\, c}\right]$$

$$M_{lost}(x) = \int dm_* N(m_*)\, w(x)\, x^2\, m_*\, G(x) = \overline{m_*}\, w(x)\, x^2 G(x)$$

$\lambda = r_d/r_{vs} = 0.1$ is the canonical spin parameter (Mo, Mao, White 1998)

$$M_*(x) = \int dm_* N(m_*)\, w(x)\, x^2\, m_* = \overline{m_*}\, w(x)\, x^2$$

$$\mathcal{F}_{ICL}(x) \approx \frac{M_{lost}(x)}{M_*(x) - M_{lost}(x)} = \frac{G(x)}{1 - G(x)}$$

Result assuming circular orbits

Since simulations suggest ε≈0.8 (Ghigna et al. 1998)
Numerical results are similar to the latter analytical computation

The ICL fraction mainly depends on the gravitational profile of the cluster and it is a probe of the large scale cluster physical properties

Previous eq. should be projected perpendicular to the l.o.s.

In comparing with observations we can probe different DM profiles

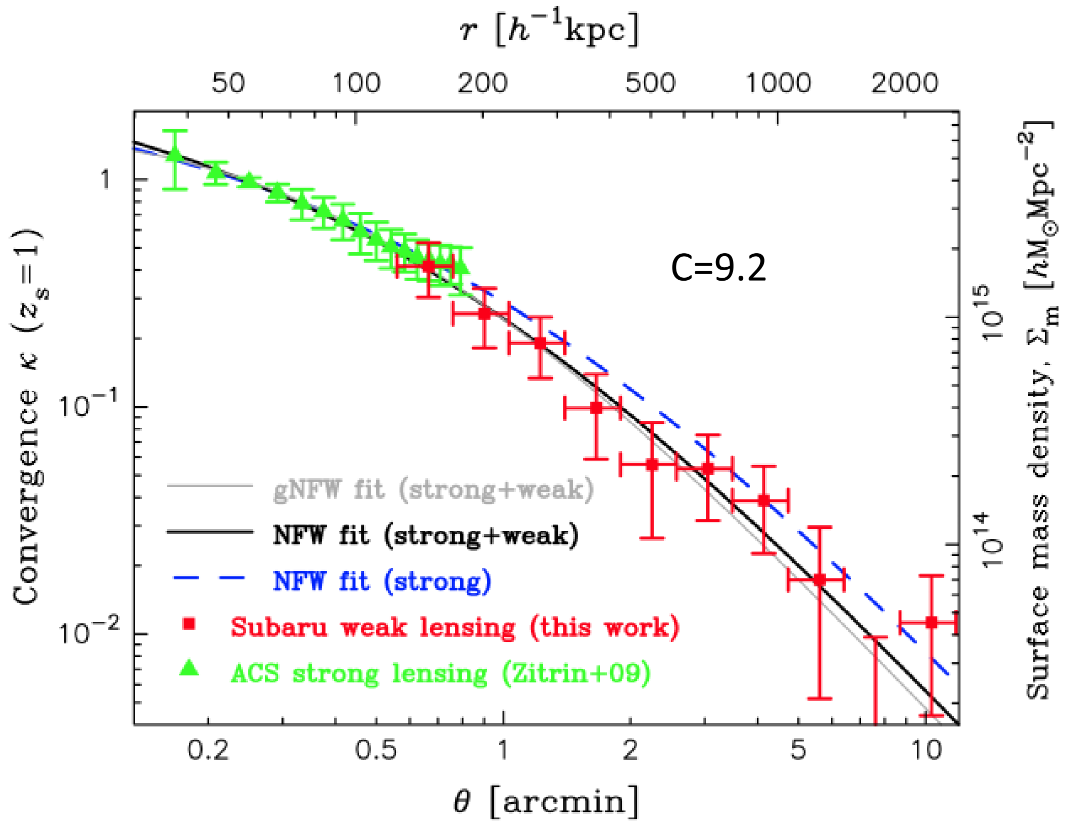
We adopted for CL0024+17 the observed 1.6Mpc virial radius. For fixed $r_v$ the ratio depends on c

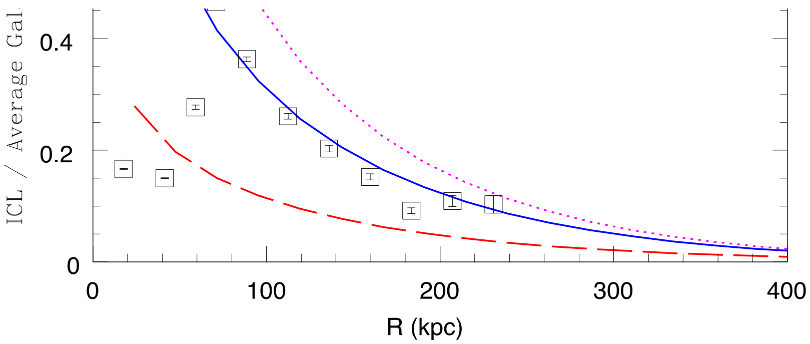
Interestingly the best agreement is obtained for a NFW profile with c=9

This is very close to the value c=9.2 derived from gravitational lensing analysis on CL0024

Note: in previous equations we assumed $c=c_s=9$ (same profile for satellites and cluster) which is reasonable for this cluster BUT not true in general

However, differences between satellites and clusters $c_s-c\approx0.5$ change by less than 5% the results derived assuming $c_s=c$



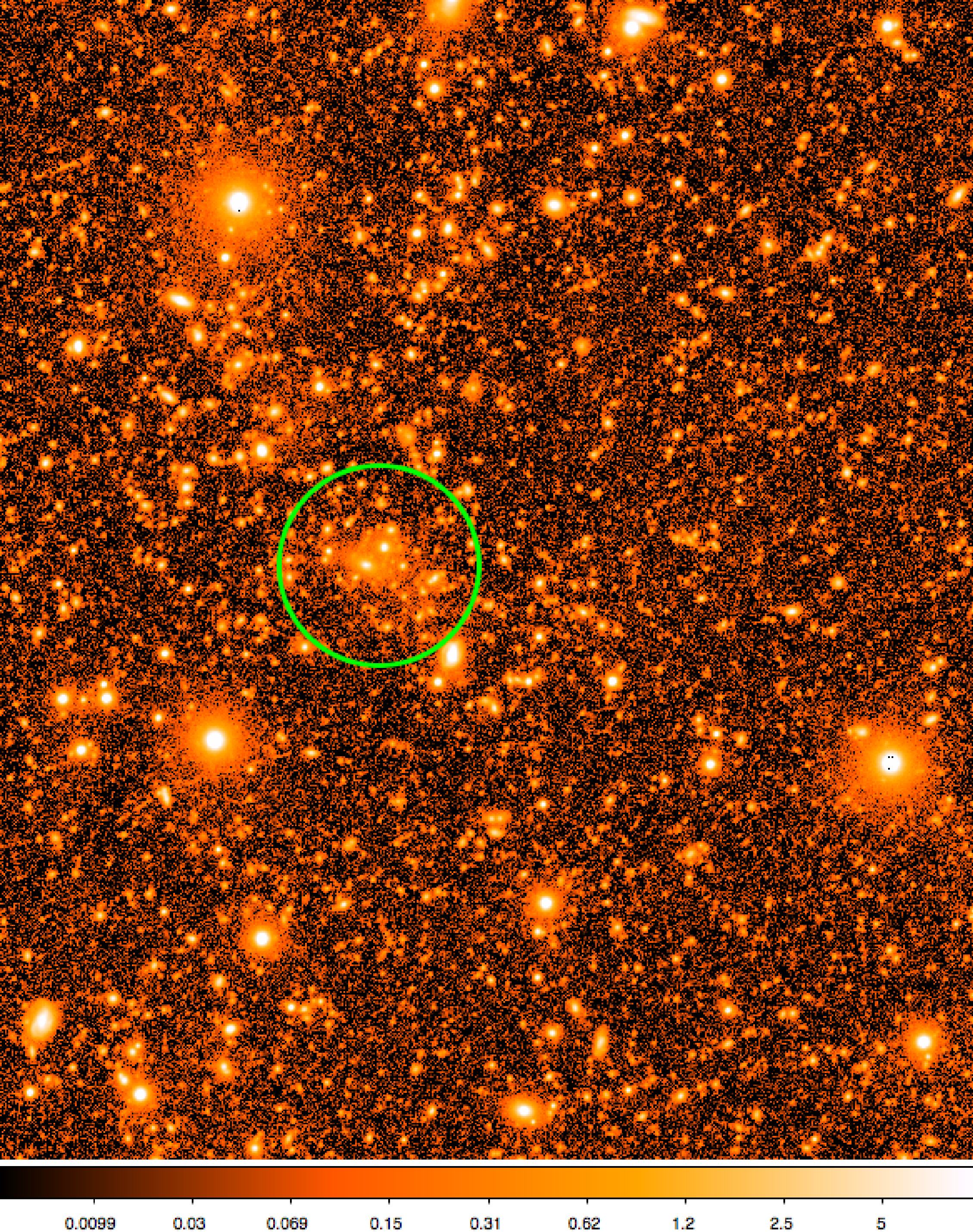
RXJ0926.6+1242

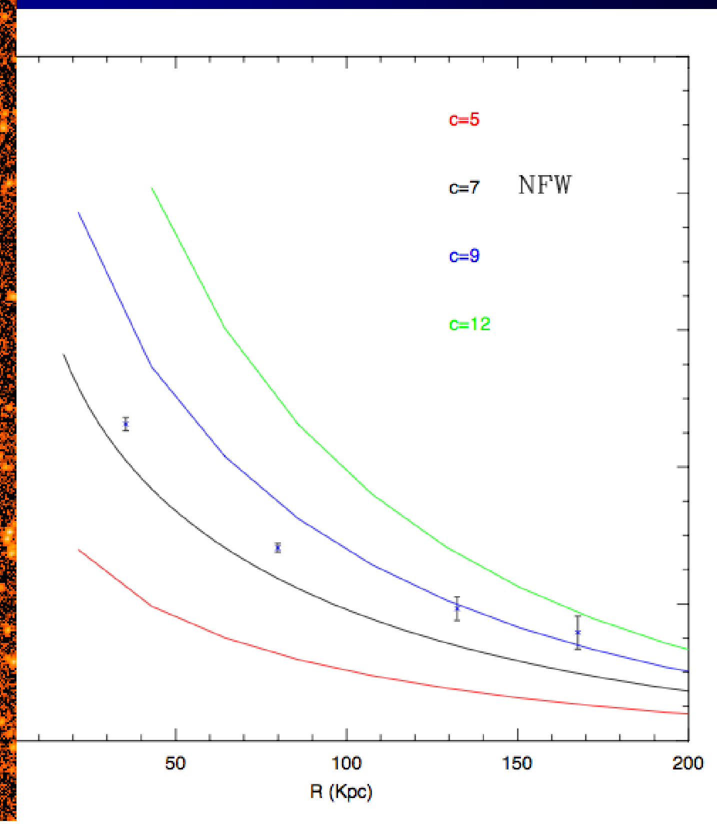
R band 2h

z~0.5

$L_X$~2x $10^{44}$ erg/s

M~2x $10^{14}$ $M_o$



# Ongoing LBC Observations:

## New LBC program pointing two HST Frontier Fields galaxy clusters (MACS 0717.5  MACS J1149.5)

- Detection of ultra faint lensed z~3 Lyman break galaxies
  (faint end LF, probe sources responsible for high-z reionization)
- Star formation, dust and metallicity content of ultra faint galaxies at z~2
- 20h per target in UV and R binocular mode requested
- Less than 1h exp time obtained so far for MACS0717 this winter
  More time will be requested for the next LBT call

## CONCLUSIONS

Imaging of galaxy clusters at intermediate z with LBC can probe very low surface brightness spatial distribution and adds crucial UV information to probe both the cluster dark matter distribution and the faint high redshifts lensed background sources (2015-2016)