# Intracluster Stars in the Virgo Cluster Core

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# Historical Overview

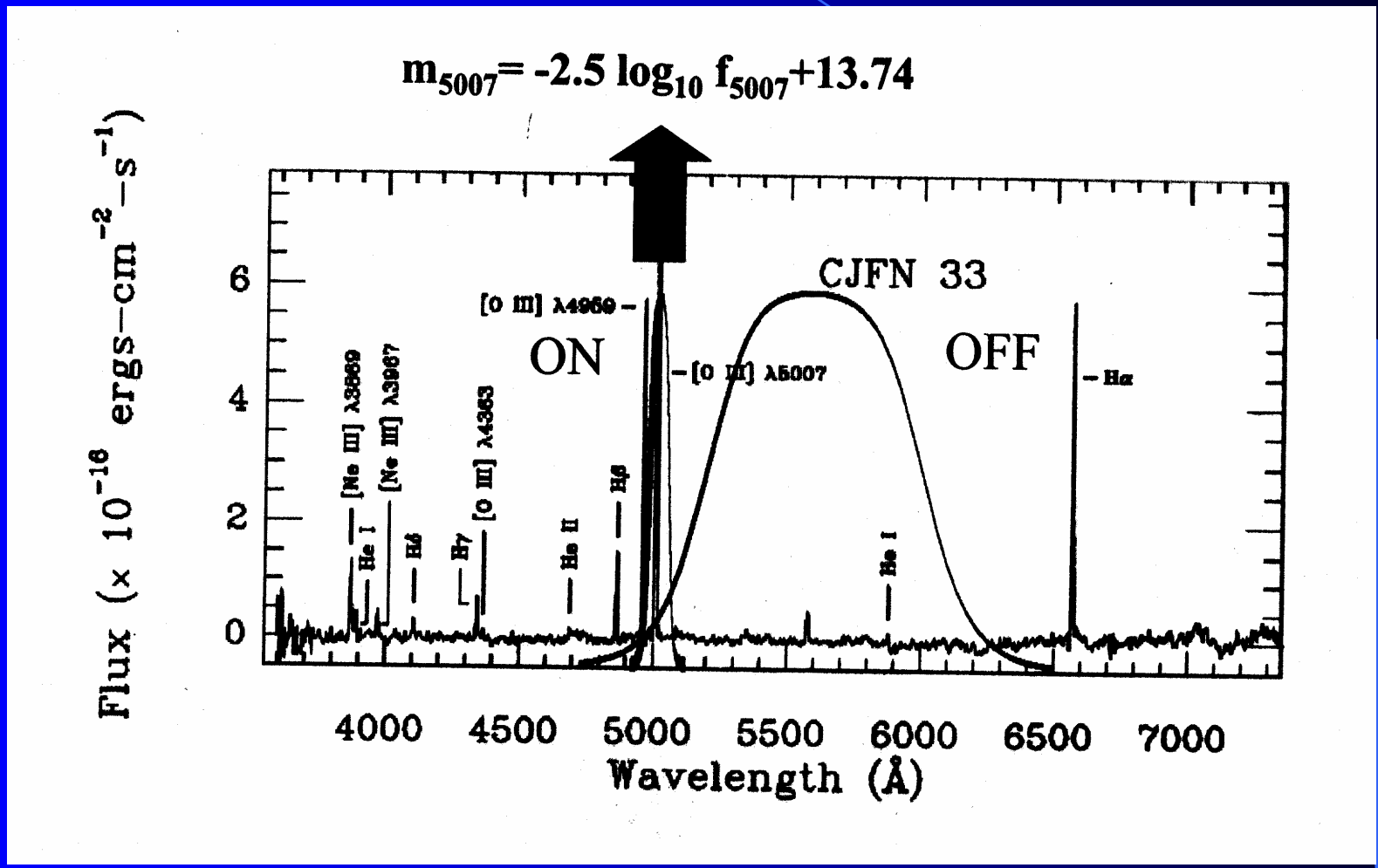
- Zwichy (1951) detected excess of light between the galaxies in Coma Cluster.
- This light has a surface brightness of about 28 mag/arcsec^2 in B, just 1% over the sky background.
- The nature of this light has been unknown during decades

LSB galaxies or cD halos.
De Vaucouleurs et al (1970);
Vilchez et al. (1994)

Globular clusters
Harris (1986);
Muzzio (1987);
West et al (1995)

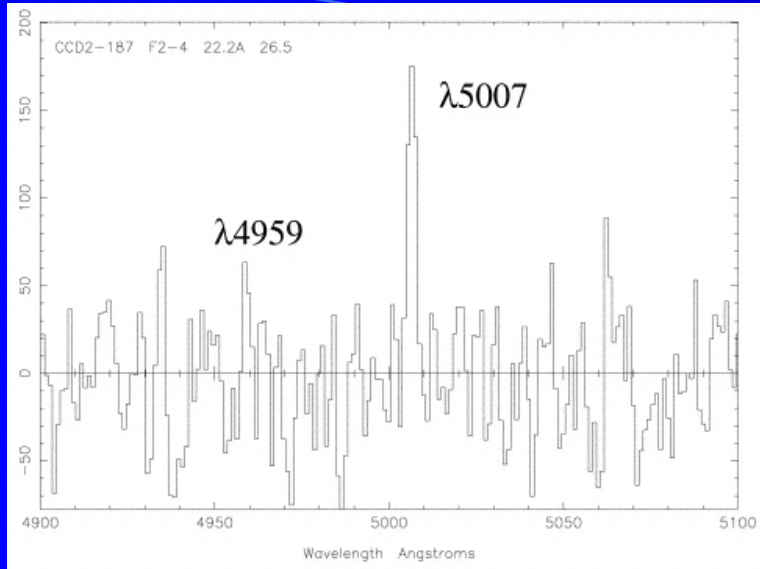
RGB intracluster stars
Ferguson et al (1998);
Durrell et al (2002)

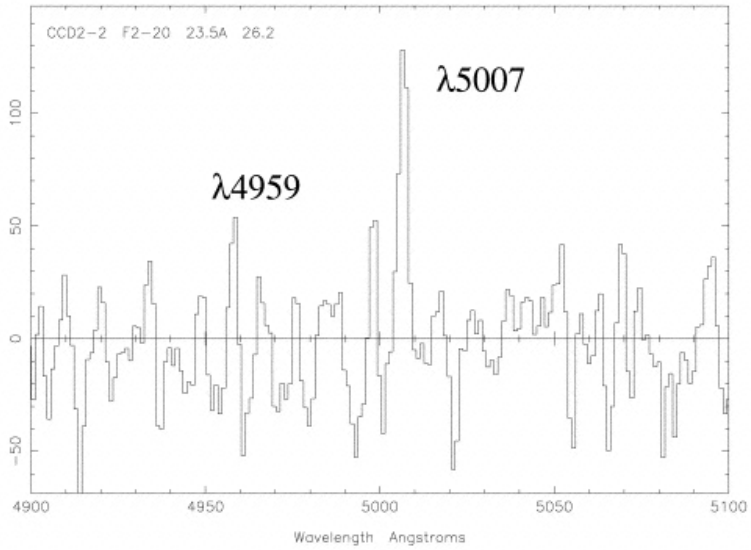
Intracluster Pne: Arnaoldi et al (1996), Mendez et al (1997), Feldmeier et al (1998), Aguerri et al (2005)

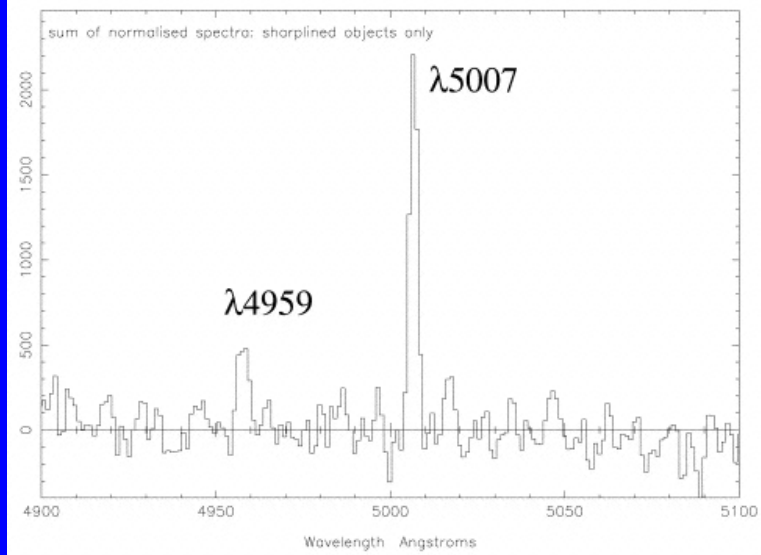

$m_{5007}$= -2.5 $\log_{10}$ $f_{5007}$+13.74
Flux (× $10^{-16}$ ergs−cm$^{-2}$−s$^{-1}$)
CJFN 33
ON
OFF
[O III] λ4959
[O III] λ5007
[Ne III] λ3869
[Ne III] λ3967
He I
Hδ
Hγ
[O III] λ4363
He II
Hβ
He I
Hα
0
2
4
6
4000
4500
5000
5500
6000
6500
7000
Wavelength (Å)

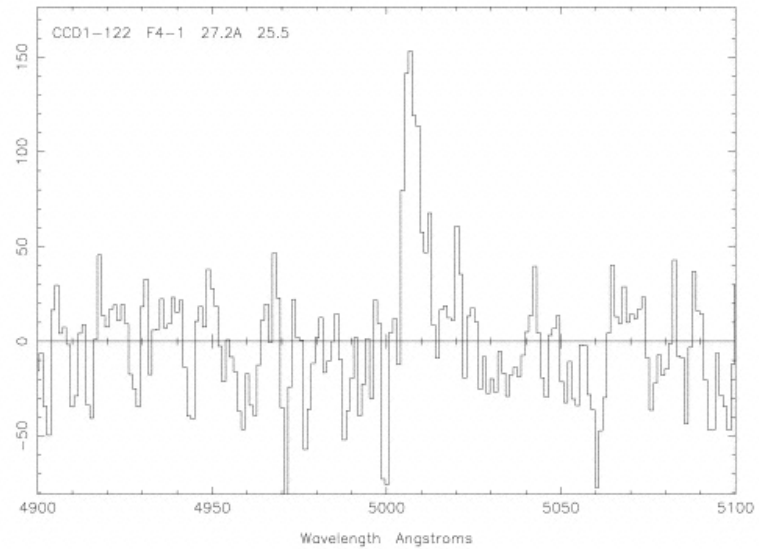
# Previous Work....

- Photometrical Samples:
  - Previous works detected ICPNe by eye. Just blinking the off- and on-band images
  - They were also based on small field of view fields.
    - Feldmeier et al. 1998: 16'x16'....160 ICPNe
    - Méndez et al. 1997: 8'x8' ..... 11 ICPNe
- Firsts Spectroscopical confirmation
  - Freeman et al 2000: The brightest ICPNe candidates from Feldmeier et al and Méndez et al.
    - 50% No detection or faint stars
    - 50% emision line objects: 75% real ICPNe and 25% Lyalpha
  - Kudritzki et al 2000: The faintest ICPNe.
    - No ICPNe, all galaxies at z=3.1




Arnaboldi et al 2002

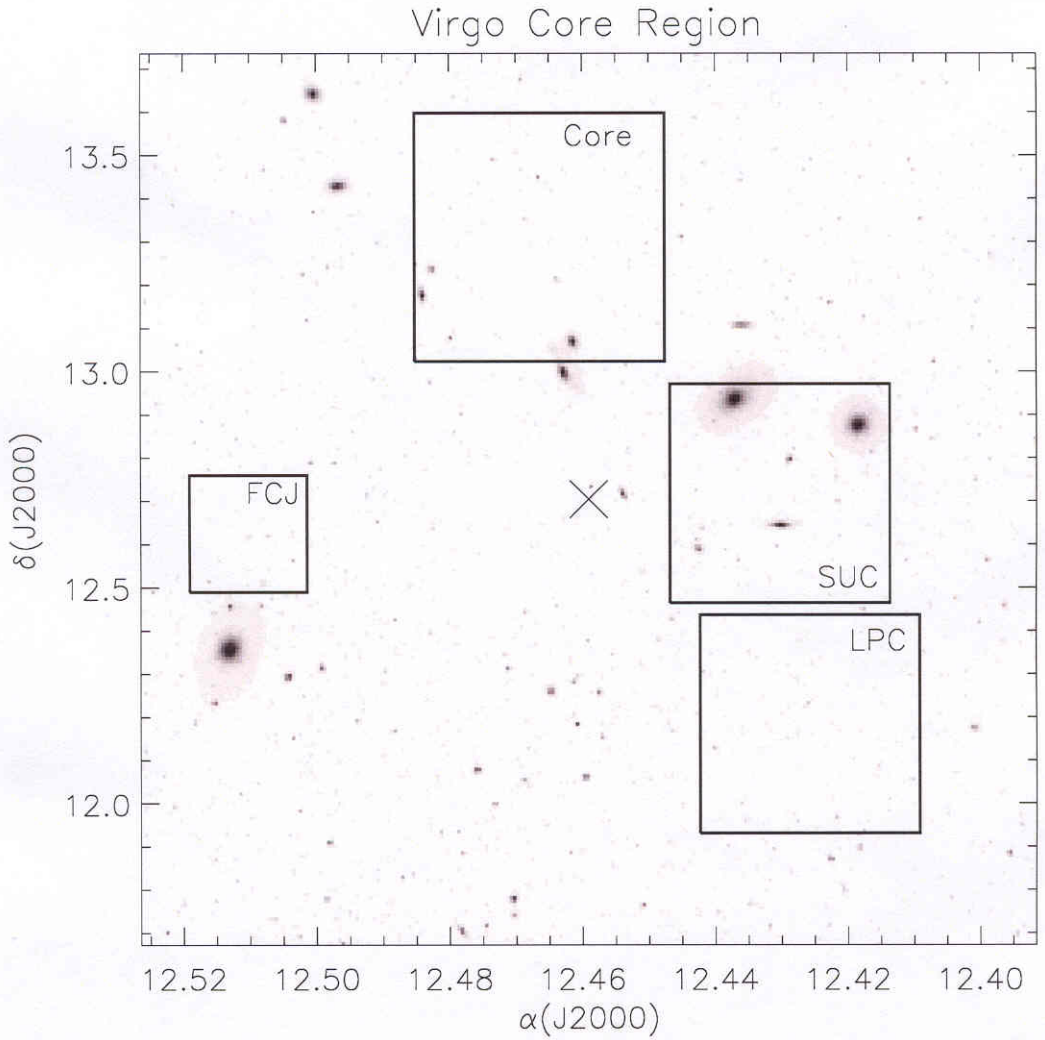
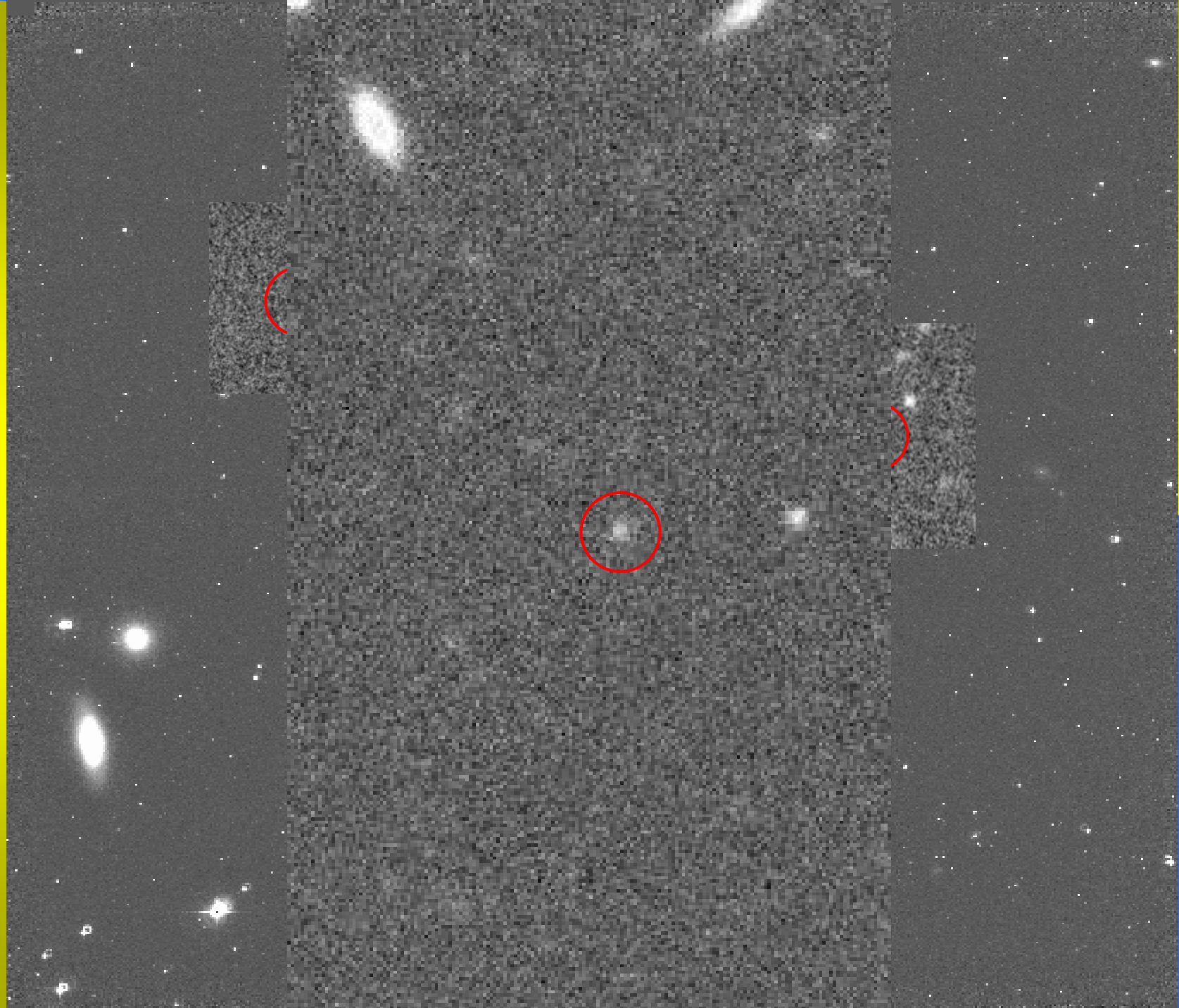


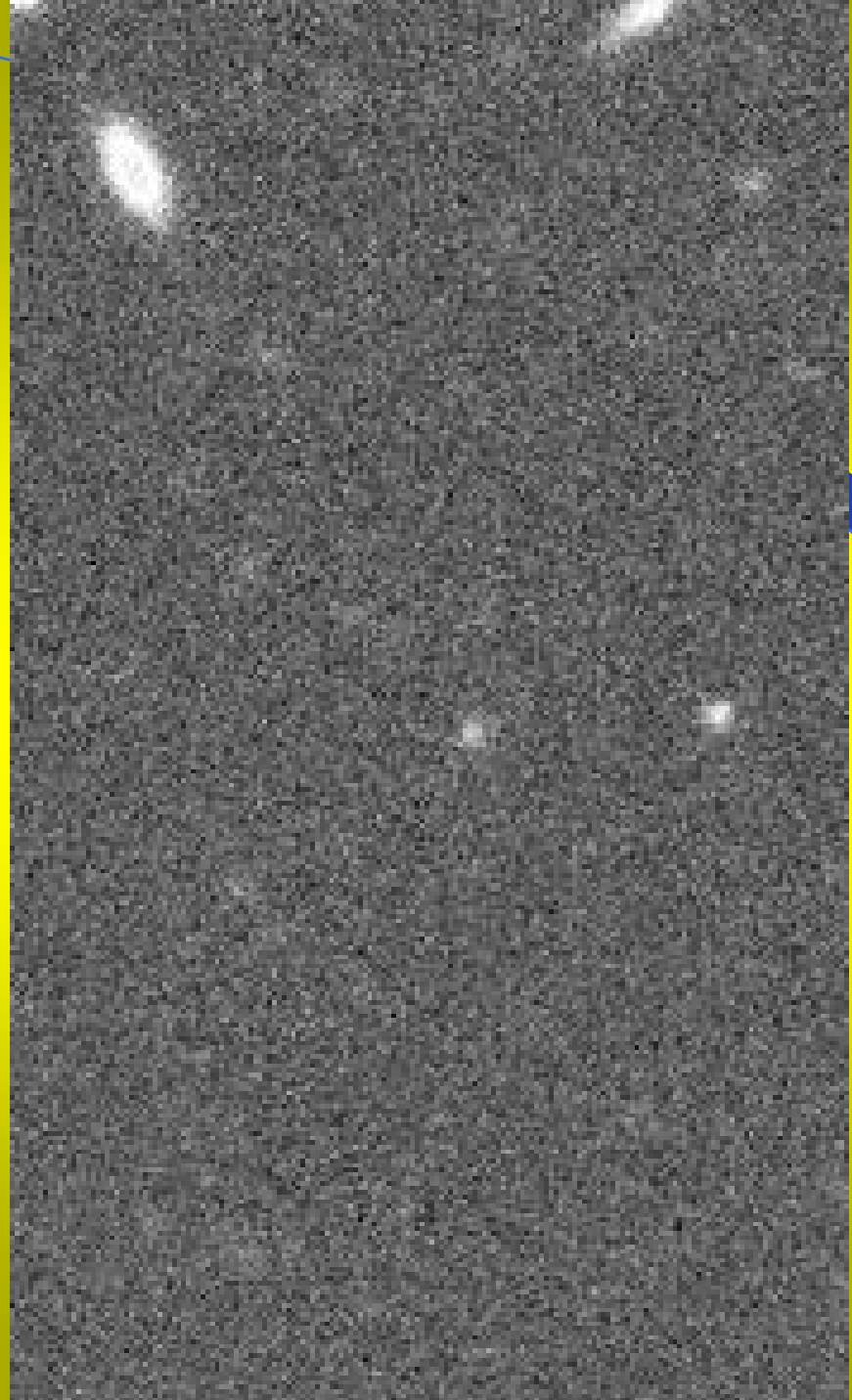

Fig. 1.— Virgo cluster core region with the positions of the fields studied in this work. The cross represent the adopted center for Virgo cluster (see text for details).

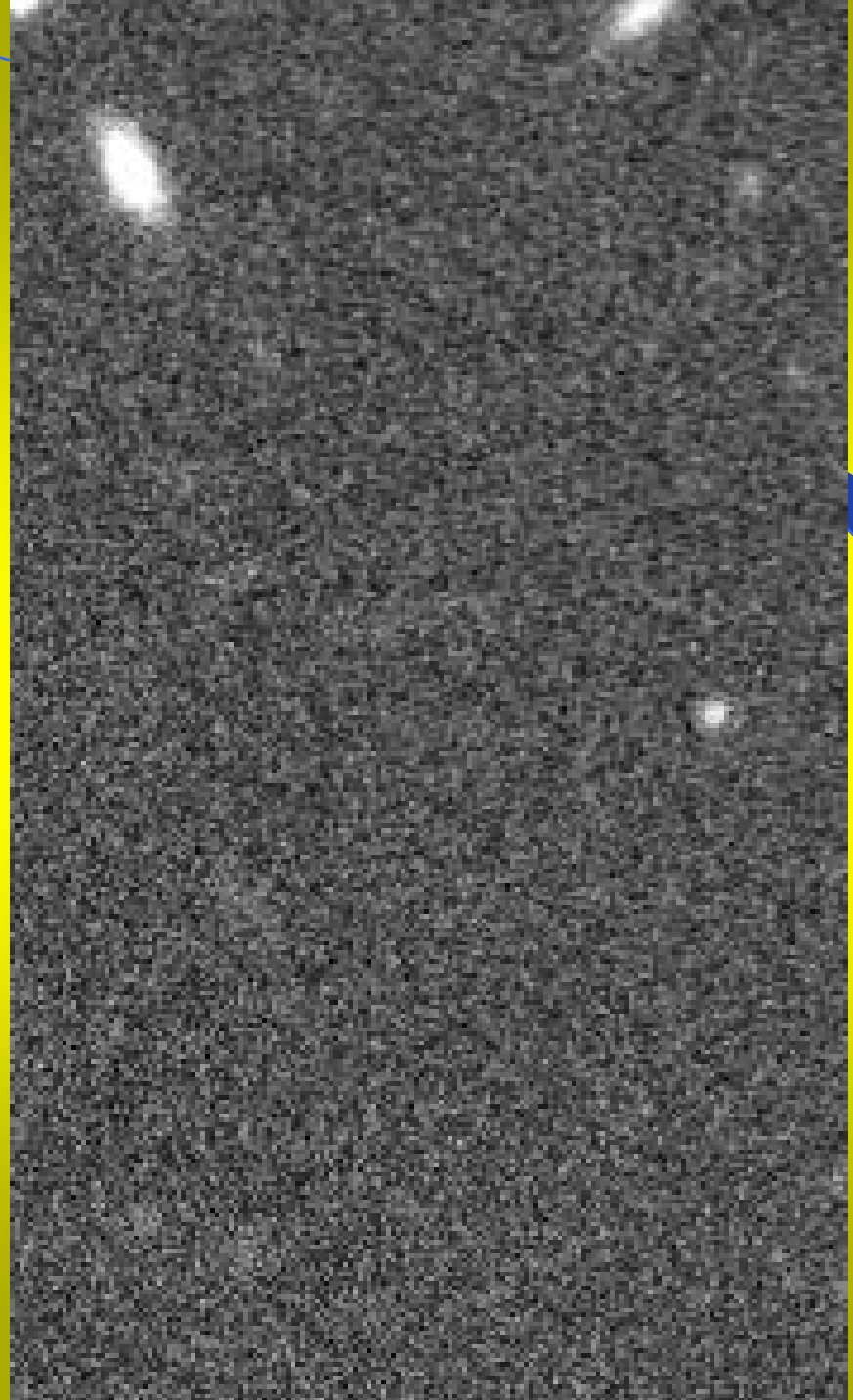
Aguerri et al 2005

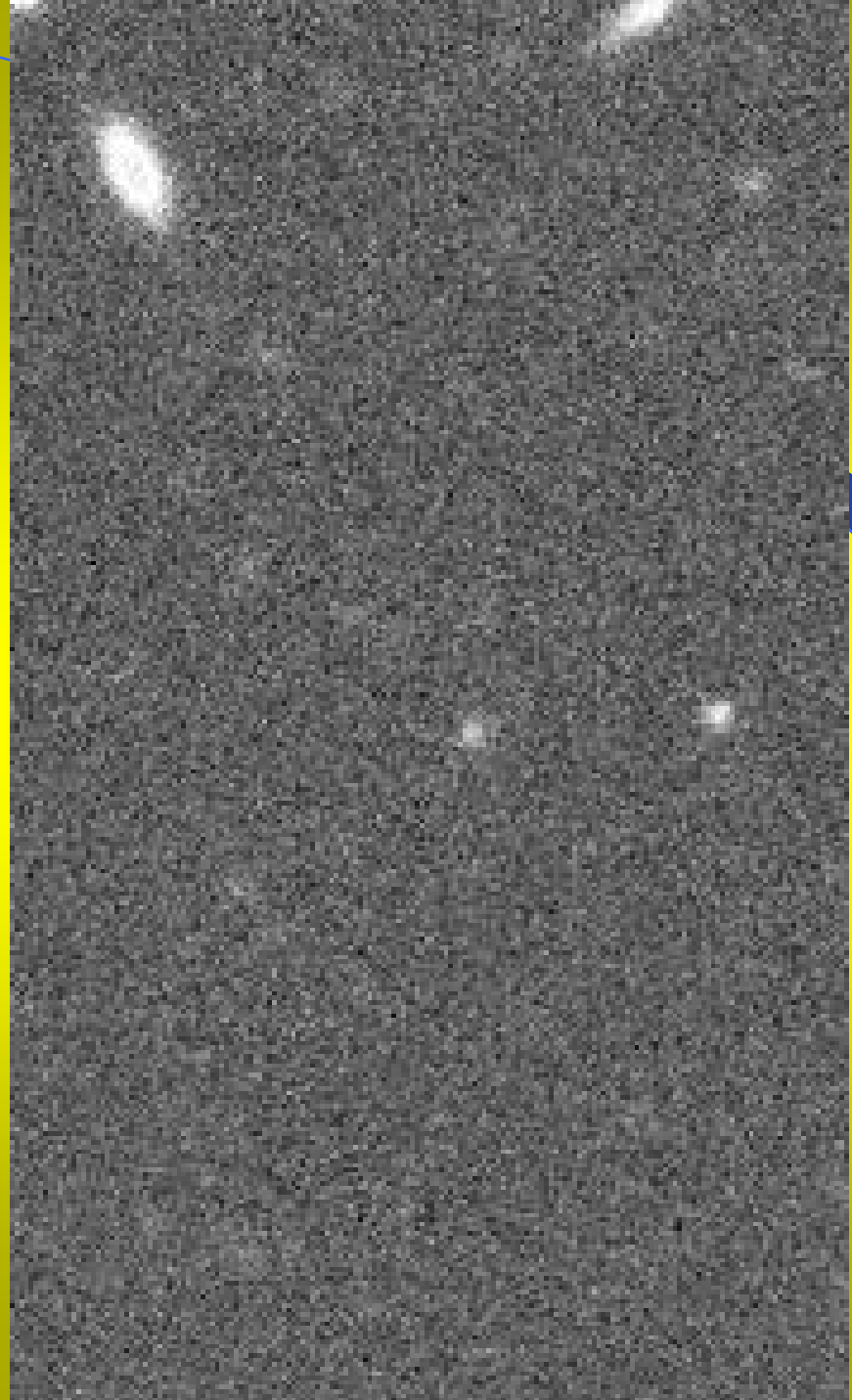
# Automatical detection method

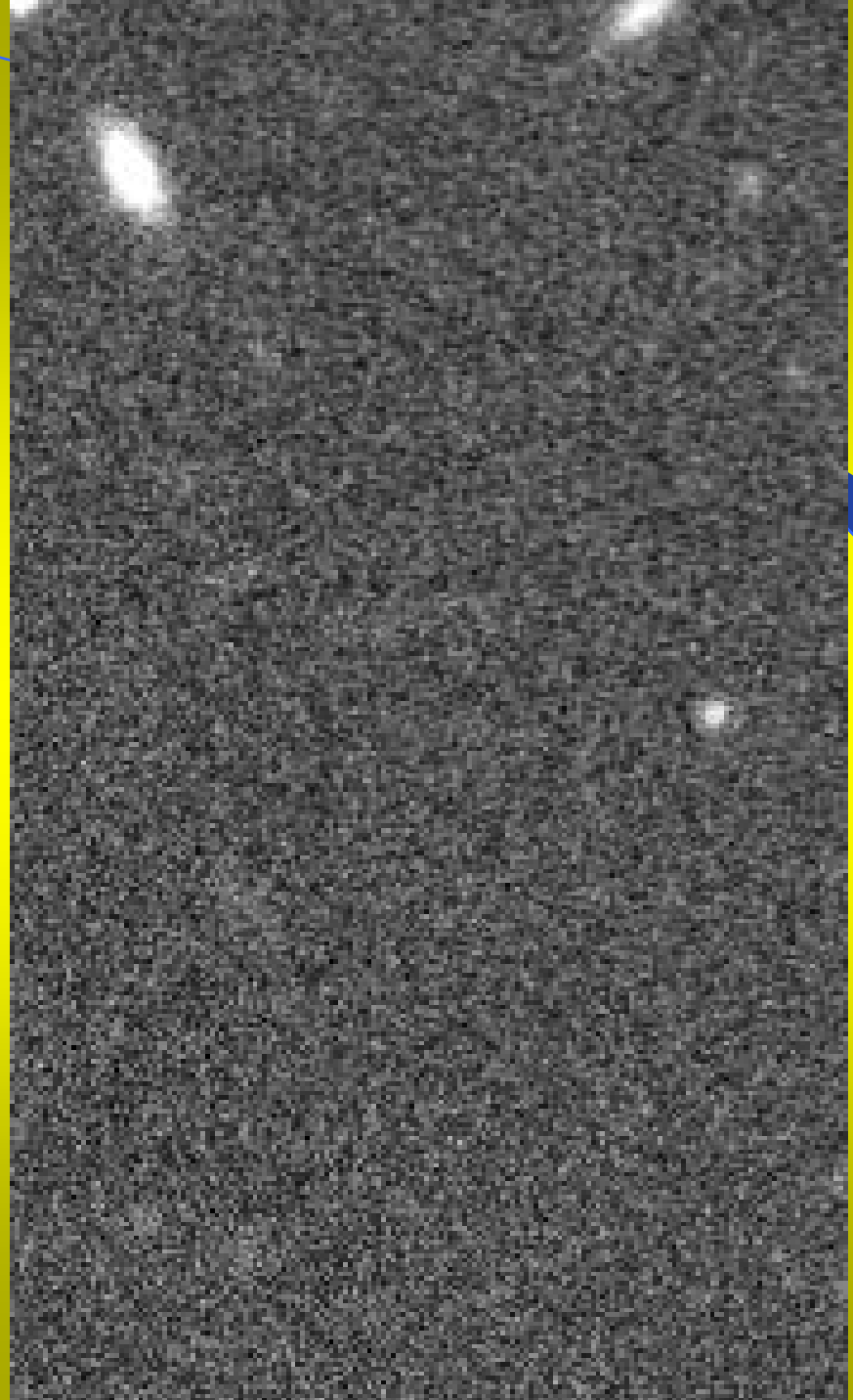
- Automatical detection methods of ICPNe are needed due to the large field of view of the new wide field cameras (WFI 2.2m ESO; WFC 2.5m INT).
- It is based on:
  - 1.- Automatical extraction of the candidates.
  - 2.- Automatical classification of the objects.











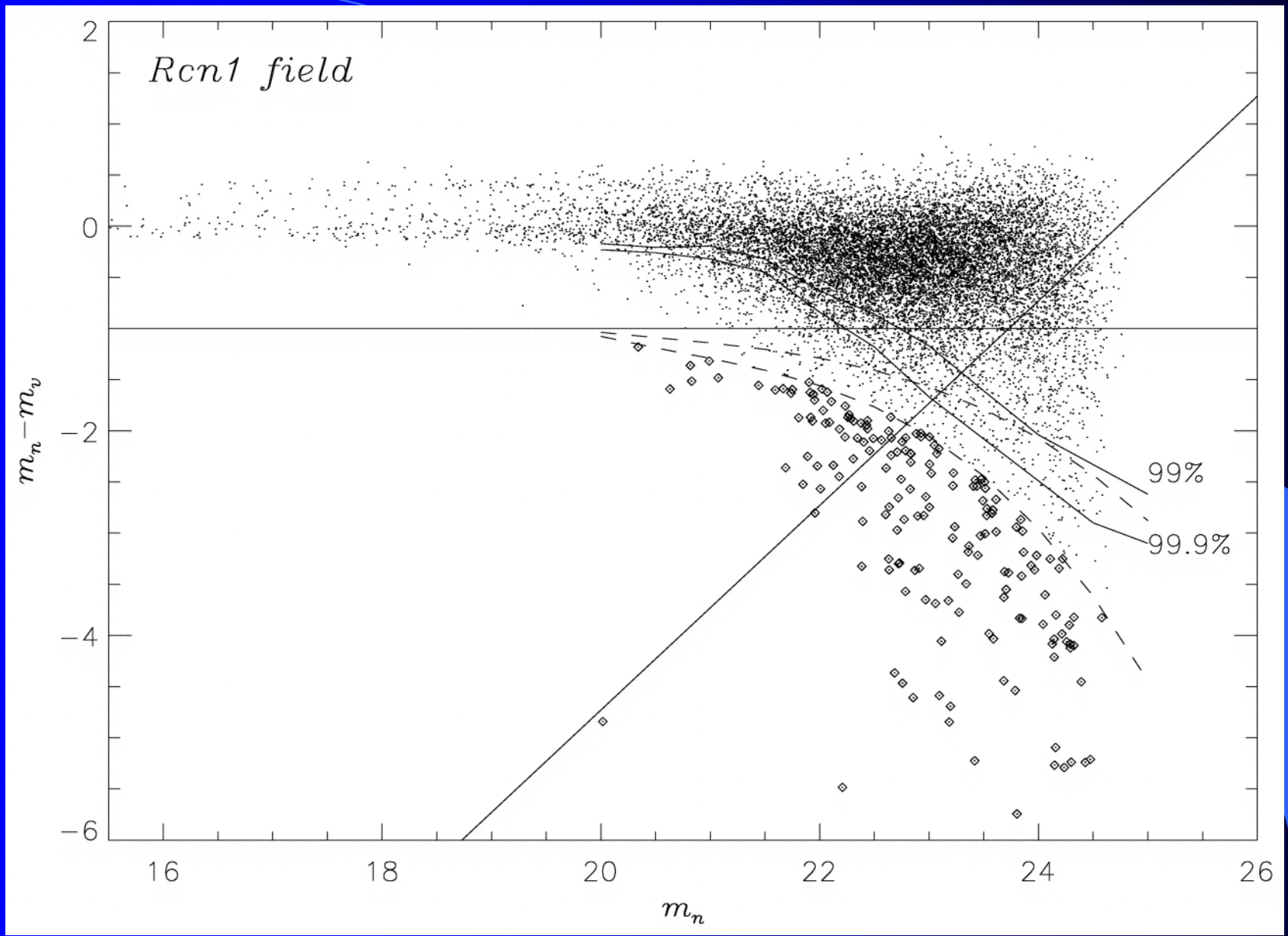
# Extraction of the objects

- The objects are automatically extracted from the images, using SExtractor.
- The imput parameters of Sextractor are tested based on simulations of point-like objects.

# Objects Classification

- The objects are classified according with:
  - Point-like or extended objects
  - Position in the color magnitudes plots.
  - Observed Equivalent Width (EW)

ICPNe
- Objects with mO3-mV<<0
- EW>80 Amstrongs
- mV<1 rms
- Point-like objects




Arnaboldi et al. (2002)

# Background contamination

- We can still have some contamination from Lyalpha background galaxies. In order to removed such contamination we have computed the number of Lyalpha galaxies brighter than our limiting magnitudes from Lyalpha surveys with similar characteristics in the selection criteria: Castro-Rodriguez et al. (2002), Ciardullo et al (2002). This contaminations goes from 10% to 100%.

| Field | N(ICPNE) | N(Lyalpha) |
|---|---|---|
| Core | 77 | 20/26 |
| LPC | 14 | 22/16 |
| FCJ | 20 | 2/4 |
| SUC | 36 | |
| RCN1 | 55 | 3/15 |

# Spectroscopical confirmation

- For the Core, FCJ and SUC fields we have run a spectroscopical confirmation of all ICPNe candidates brighter than m(5007)=27.2, using FLAMES spectrograph (Arnaboldi et al 2004).
- The confirmations (expected) rates are: 84%(80%), 32%(17%) and 72%(100%), for Core, FCJ and SUC fields respectively.

# Amount of ICL in the Core of Virgo cluster

- The amount of intracluster light associated with the number of ICPNe from the value of luminosity specific planetary nebulae density ($\alpha$). The theory says that this number do not depends of the population age or inital mass function (Renzini & Buzzoni 1986).
- The measurement values go from: 50x10^9 PN/L seen in dwarf ellipticals (Bursten et al 1987) to the value of 7x10^9 PN/L observed in giant ellipcitals in Virgo.
- We took three different values:
  - The value from the Pne LF corresponding to the bulge of M31 (Ciardullo et al (1989)
  - The value computed from the RGB intracluster stellar population (Durrell et al 2002)
  - The value from the color of Virgo galaxies in the fields, assuming the color relation from Hui et al (1993)

# Percentage of the ICL

- We compare the luminosity of the ICL at the positions of the fields with the luminosity from Virgo galaxies
- The luminosities of the galaxies was computed in two ways
  - Globally: From the Binggeli et al (1989) radial luminosity plot for Virgo cluster
  - Locally: From images of the fields.
- The percentage of intracluster light is defined: L(ICL)/(L(ICL)+L(galaxies))

Table 5. Contribution of the ICL at the different fields.

| Field | $\alpha_{1.0,B}$ ($\times 10^{-9}$) | $L_{ICL}/arcmin^2$ ($\times 10^6 L_{\odot,B}/arcmin^2$) | $\mu_B$ (mag/arcsec$^2$) | $\%Local^a$ | $\%Global^b$ |
|---|---|---|---|---|---|
| Core | 9.40 | 1.91/1.06 | 29.48/30.12 | 10/6 | 6/4 |
| | 13.30 | 1.35/0.75 | 29.85/30.49 | 7/4 | 5/3 |
| | 10.59 | 1.70/0.94 | 29.61/30.25 | 9/5 | 6/3 |
| FCJ | 9.40 | 3.19/2.77 | 28.92/29.07 | 6/5 | 10/9 |
| | 13.30 | 2.26/1.95 | 29.30/29.46 | 4/4 | 8/7 |
| | 7.46 | 4.02/3.49 | 28.67/28.82 | 7/6 | 13/11 |
| LPC | 9.40 | 0.11/0.11 | 32.57/32.57 | 0.5/0.5 | 0.4/0.4 |
| | 13.30 | 0.08/0.08 | 32.92/32.92 | 0.3/0.3 | 0.3/0.3 |
| | 25.44 | 0.04/0.04 | 33.68/33.68 | 0.2/0.2 | 0.1/0.1 |
| SUC | 9.40 | 2.13 | 29.36 | 2 | 7 |
| | 13.30 | 1.50 | 29.74 | 1 | 5 |
| | 3.46 | 5.78 | 28.28 | 5 | 17 |
| RCN1 | 9.40 | 5.74/2.77 | 28.28/29.07 | 55/37 | 41/25 |
| | 13.30 | 4.06/1.95 | 28.66/29.45 | 47/30 | 33/19 |
| | 15.00 | 3.60/1.73 | 28.79/29.59 | 44/27 | 30/17 |

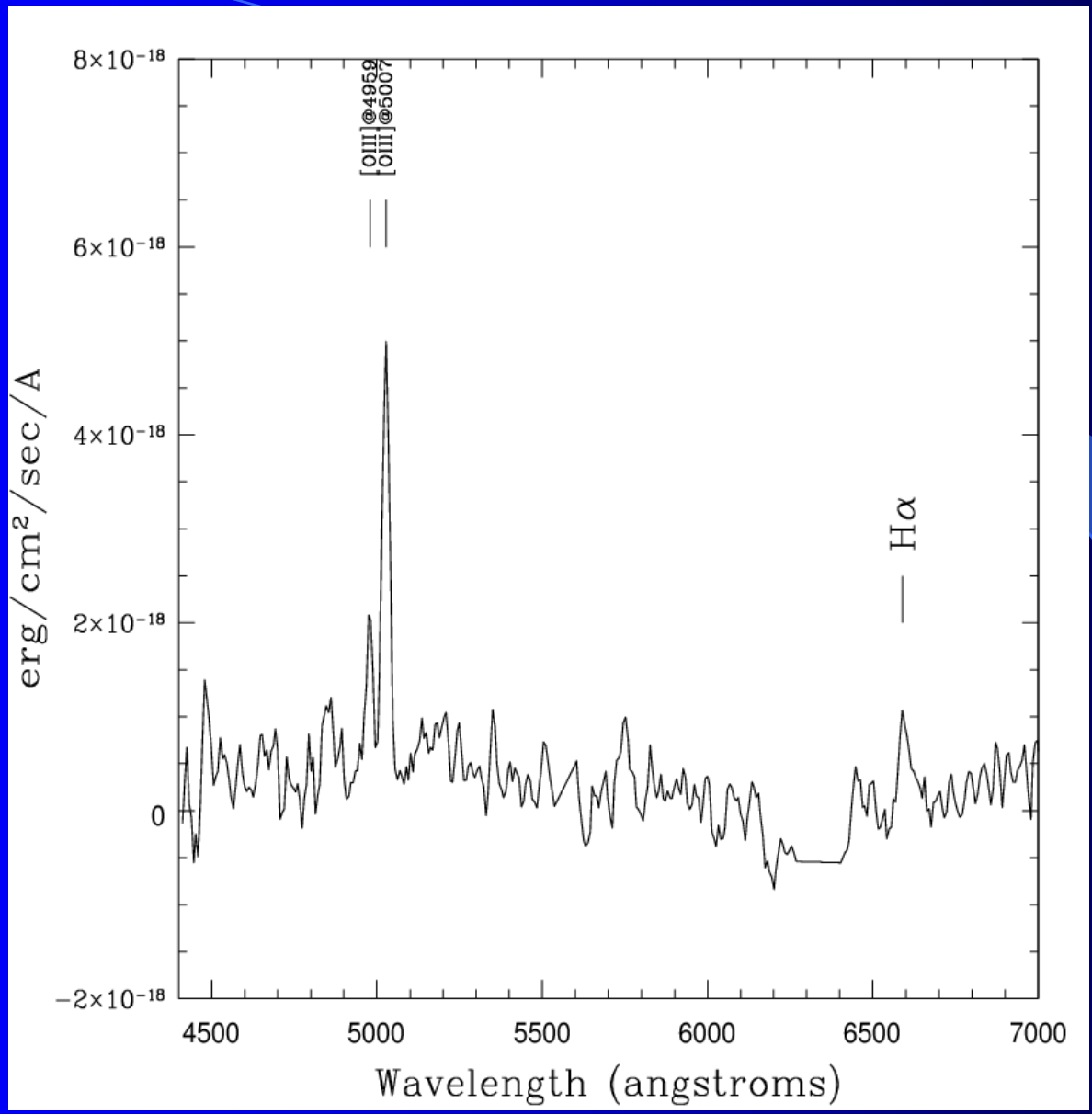
[a]Contribution of the ICL to the total light assuming that the light of the Virgo galaxies is from those around the field positions

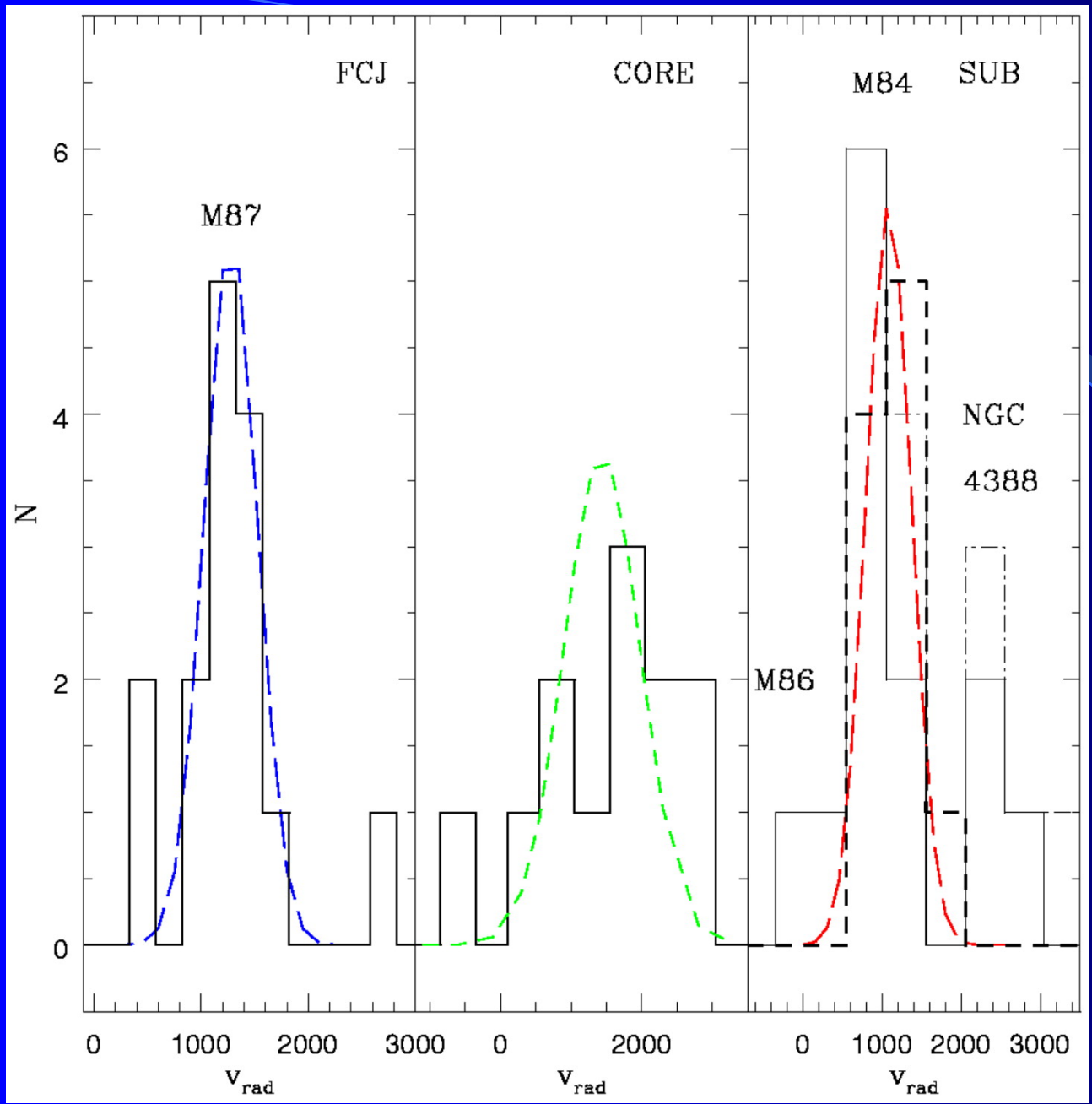
[b]Contribution of the ICL to the total light assuming that the light of the Virgo galaxies is the global galaxy distribution in Virgo.

Aguerri et al. (2005)

# Line-of-sight velocity distribution

- The spectroscopical confirmation allows us to obtained for the first time the line of sight velocity distribution and use this in order to investigate the dinamical state of Virgo cluster.


8×10⁻¹⁸
6×10⁻¹⁸
4×10⁻¹⁸
2×10⁻¹⁸
0
−2×10⁻¹⁸
erg/cm²/sec/A
[OIII]@4959
[OIII]@5007
Hα
4500
5000
5500
6000
6500
7000
Wavelength (angstroms)




Most of the ICPNe in FCJ is compatible with being in M87 halo.

Core shows a gaussian distribution. Pure relaxed intracluster population.

SUB compatible with velocities from the bright galaxies

Arnaboldi et al (2004)