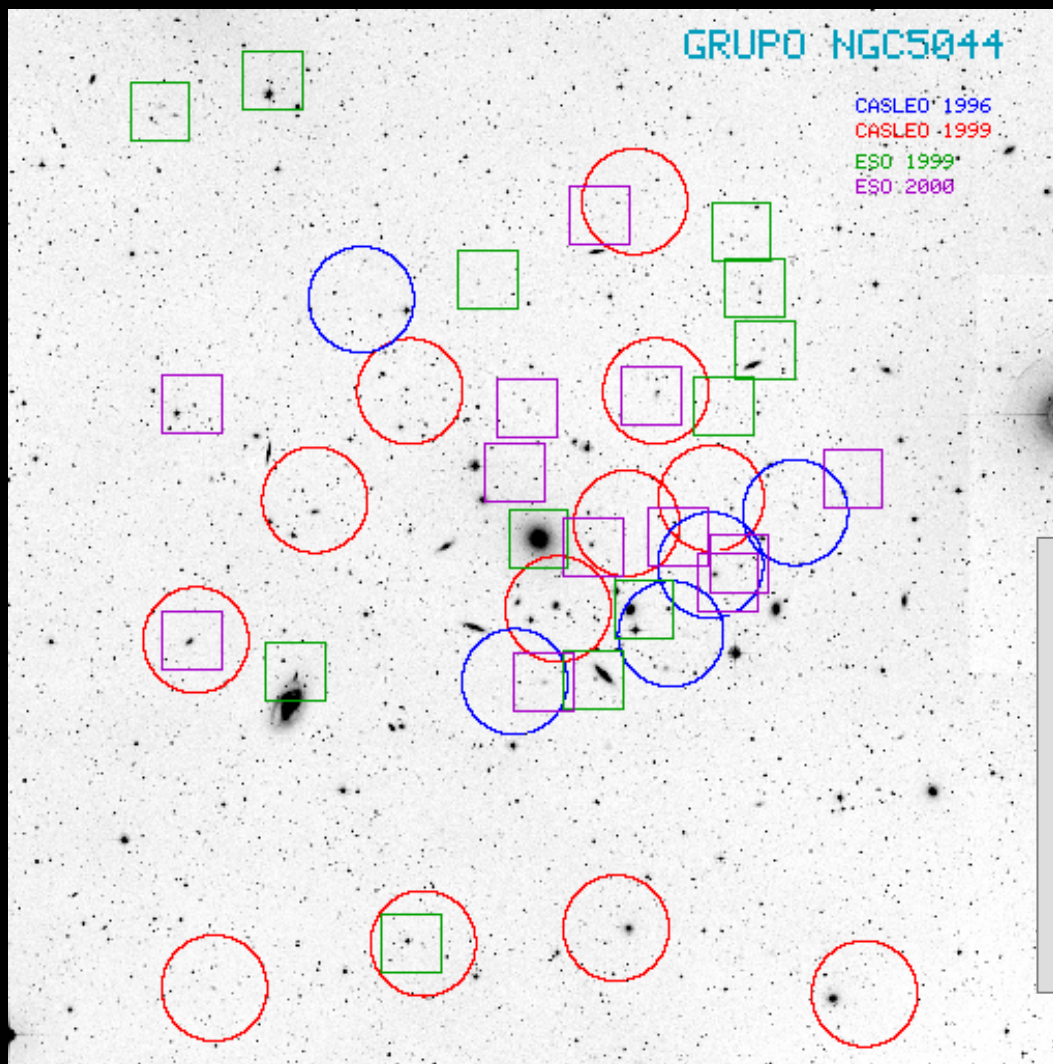


The low-luminosity galaxy population in the NGC 5044 Group

Sergio A. Cellone (Fac. Cs. Astronómicas y Geofísicas, UNLP — CONICET, Argentina)

Alberto Buzzoni (INAF — Osservatorio Astronomico di Bologna, Italy)



$m-M = 31.9$
162 members and candidates
(Ferguson & Sandage 1990, *AJ* 100, 1)
 $\langle v_r \rangle = 2461 \text{ km/s}$

Imaging: 79 galaxies

Spectra: 13 galaxies

- ESO 3.6 m + EFOSC2 (*griz*)
- CASLEO 2.15 m (*BV*)

(Cellone & Buzzoni, 2005, *MNRAS*, 356, 41; 2005 A³ Annual Meeting)

Dwarf ellipticals
(dE)

N34

N83

N42

N75

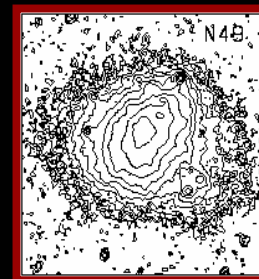
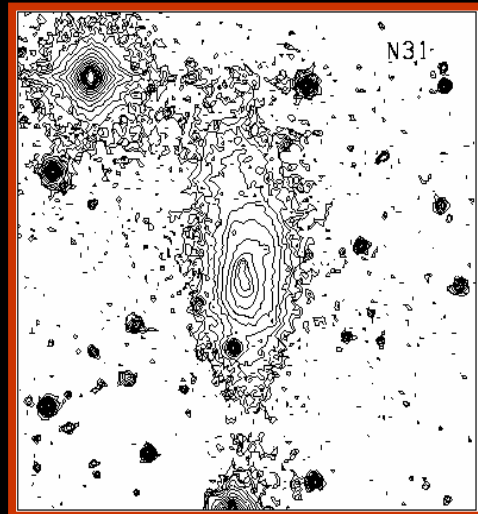
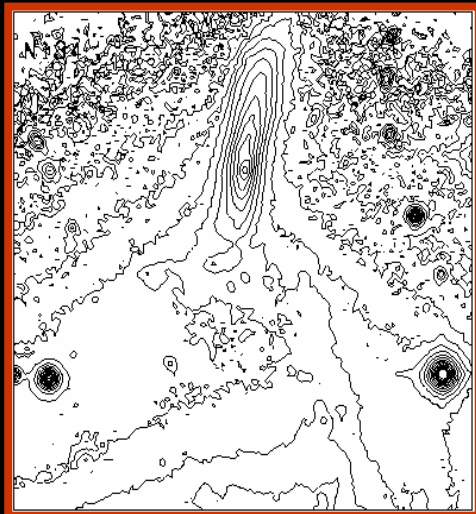
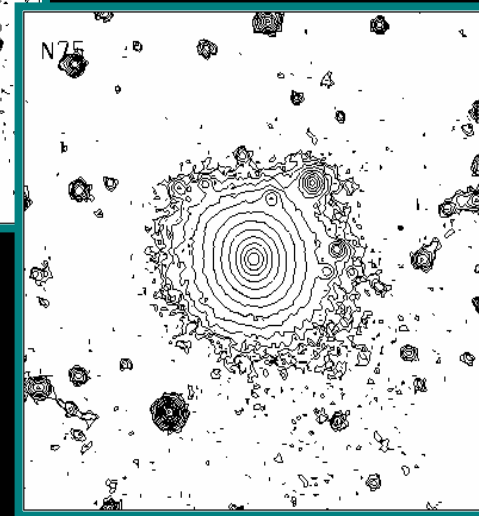
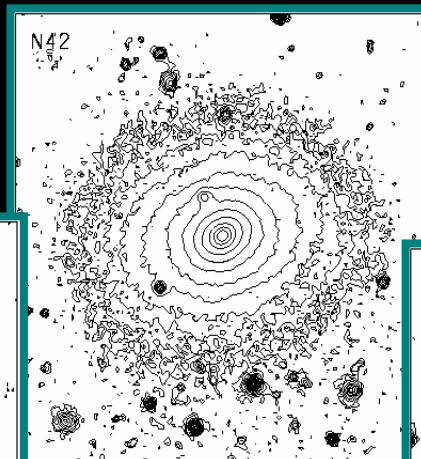
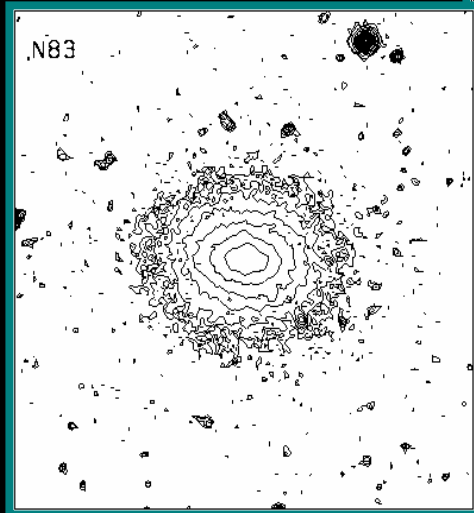
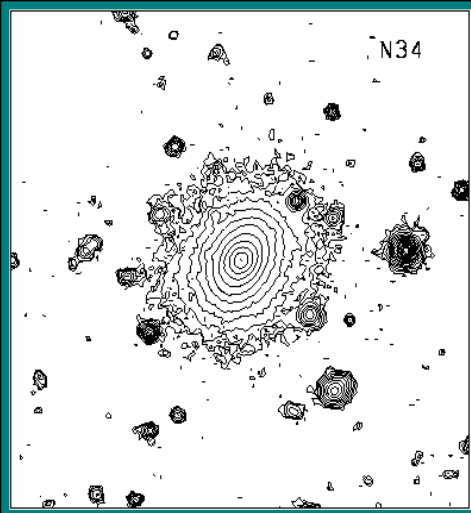
N134

N31

N49

Dwarf irregulars
(dI)

Dwarf ellipticals
(dE)



Dwarf irregulars
(dI)

Early-type dwarf galaxies with:

- embedded spiral structure, bars and/or disks
- rotation

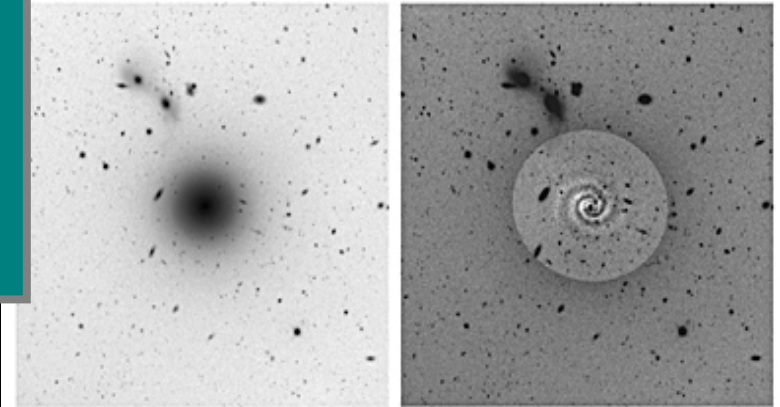
Coma

Virgo

Fornax

$$-18 < M_B < -16$$

(VLT - Keck - HST)



Spiral Pattern in Virgo Dwarf Galaxy (VLT ANTU + FORS1)

ESO PR Photo 11/00 (3 May 2000)

© European Southern Observatory



They could be remnants of
“harassed” disk galaxies.

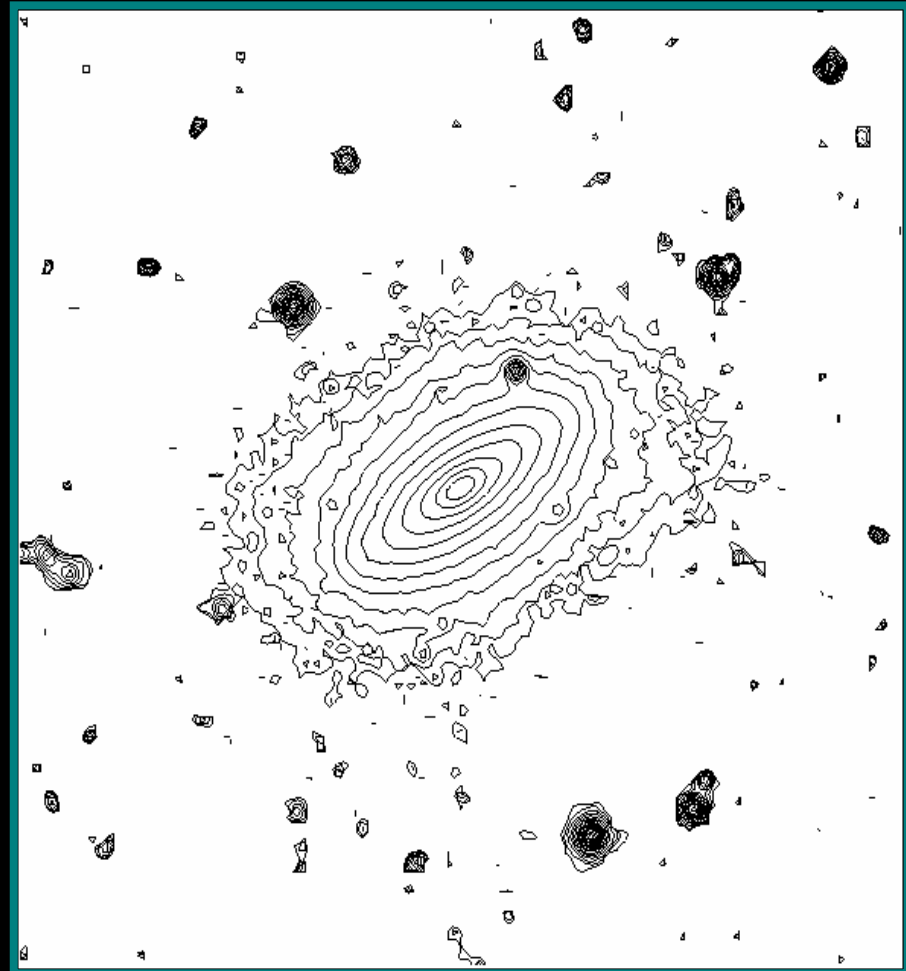
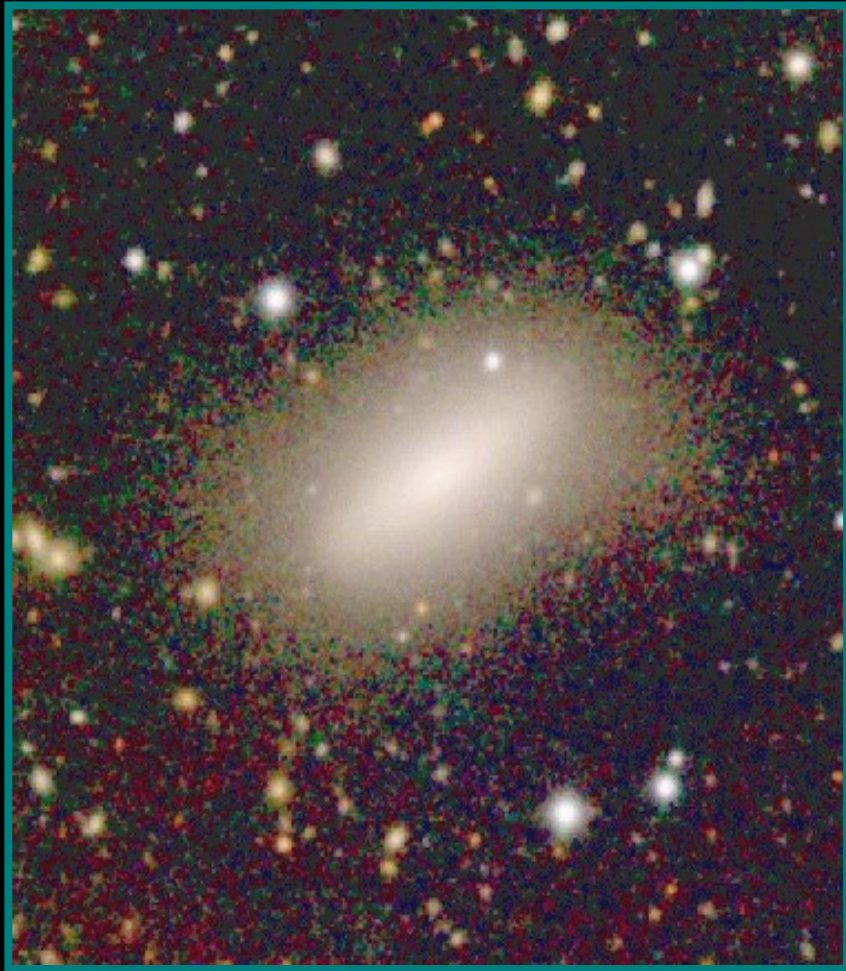
(Moore et al. 1998, *ApJ* 495, 139)

- Jerjen et al. 2000, *A&A* 358, 845
- De Rijcke et al. 2001, *ApJ* 559, L21
- Pedraz et al. 2002, *MNRAS* 332, L59
- Barazza et al. 2002, *A&A* 391, 823
- Simien & Prugniel 2002, *A&A* 384, 371
- De Rijcke et al. 2003, *A&A* 400, 119
- Barazza et al. 2003, *A&A* 407, 121
- Graham et al. 2003, *AJ* 186, 1787

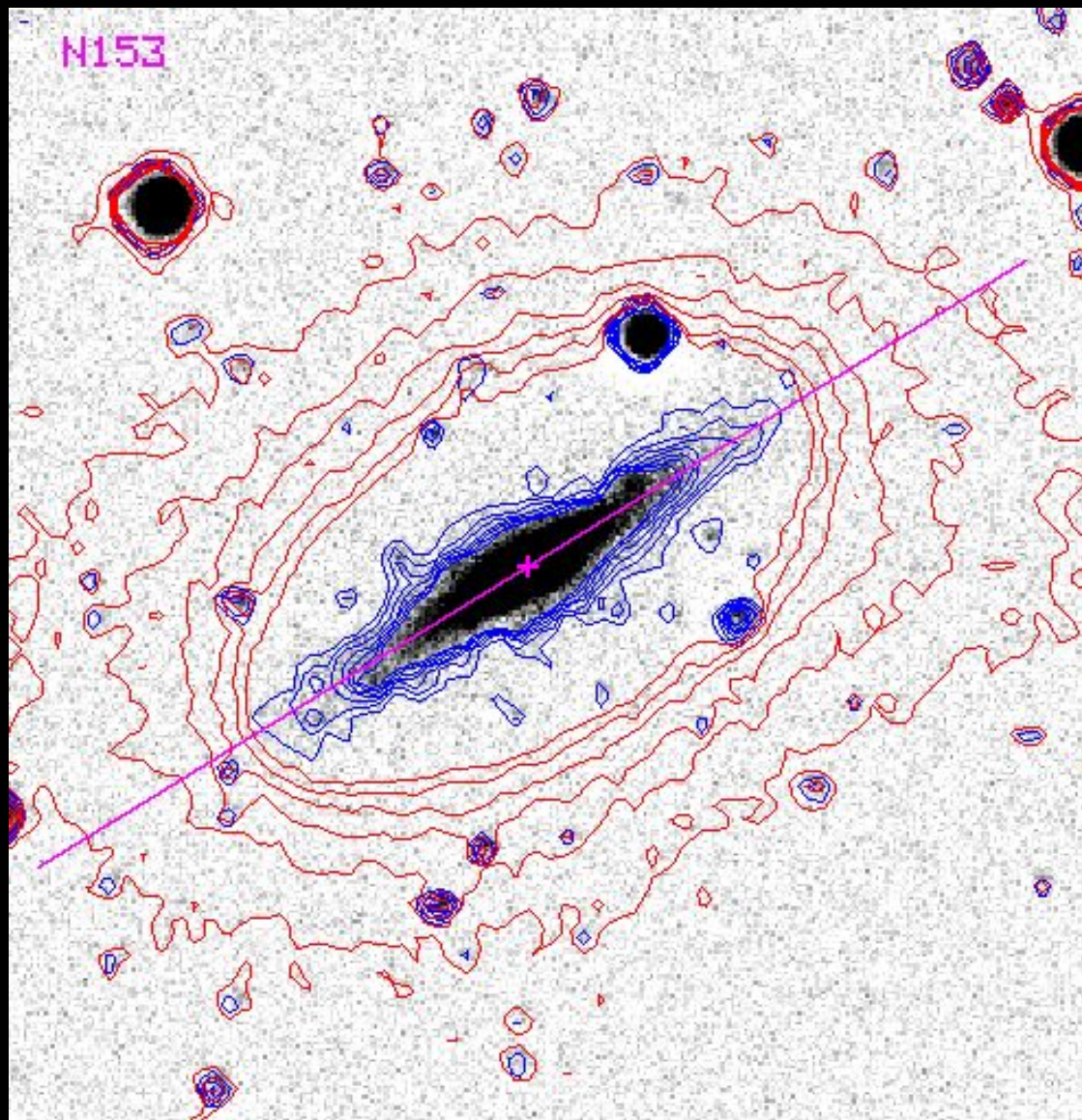
(etc.)

N153 – **d:S0** (dwarf? lenticular)

$M_B = -17.2$ $v_r = 2816$ km/s

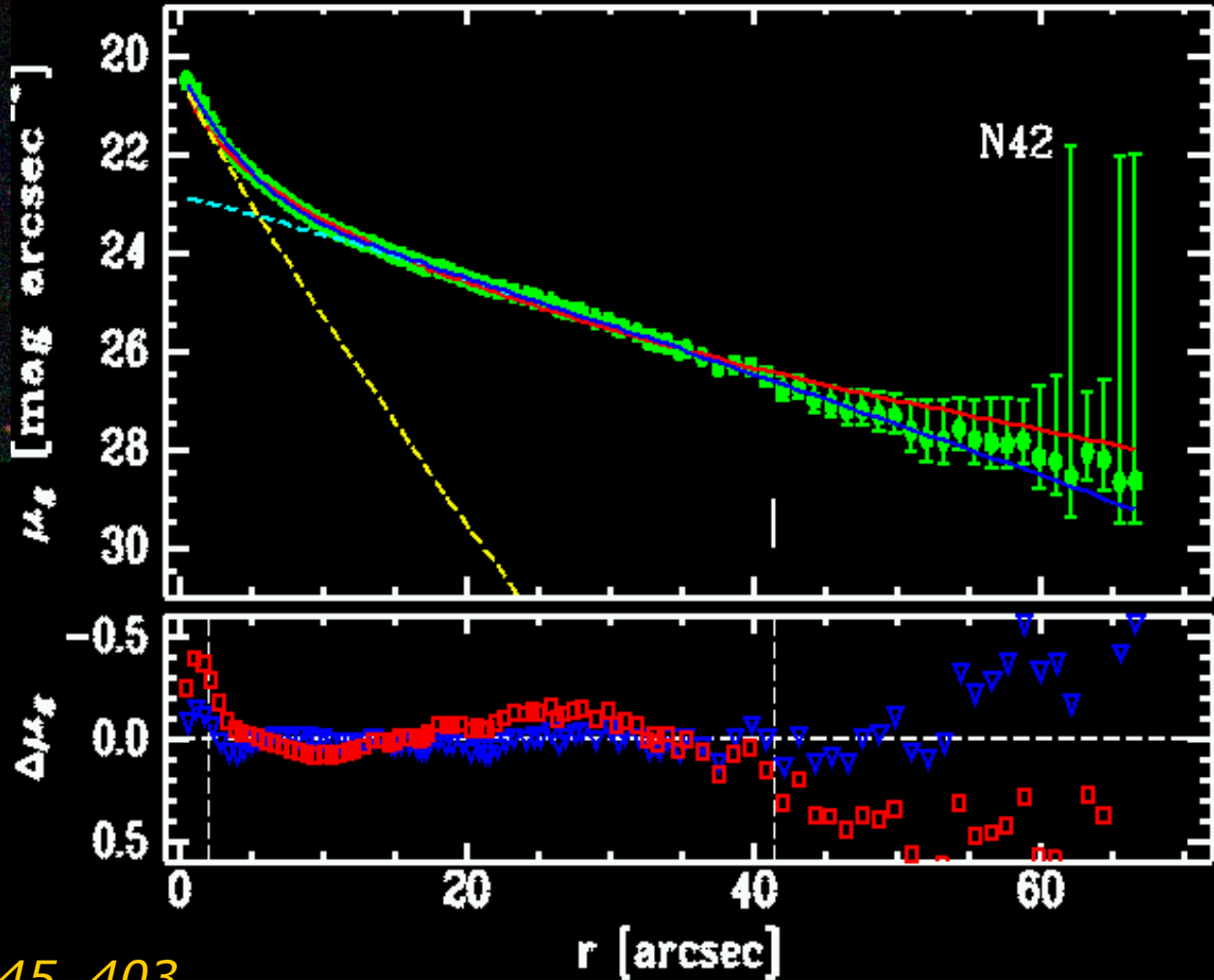


N153





$$\mu(r) = \mu_0 + 1.067 (r/r_0)^n$$

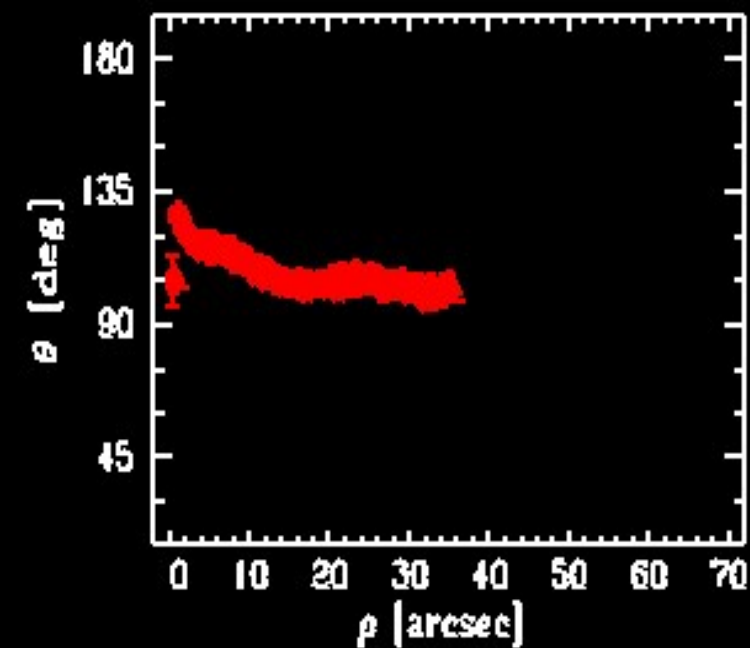
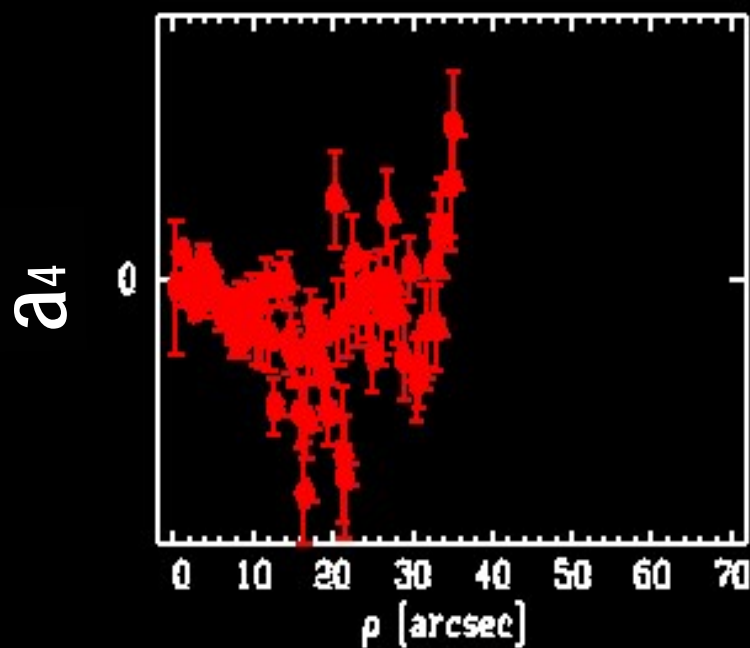
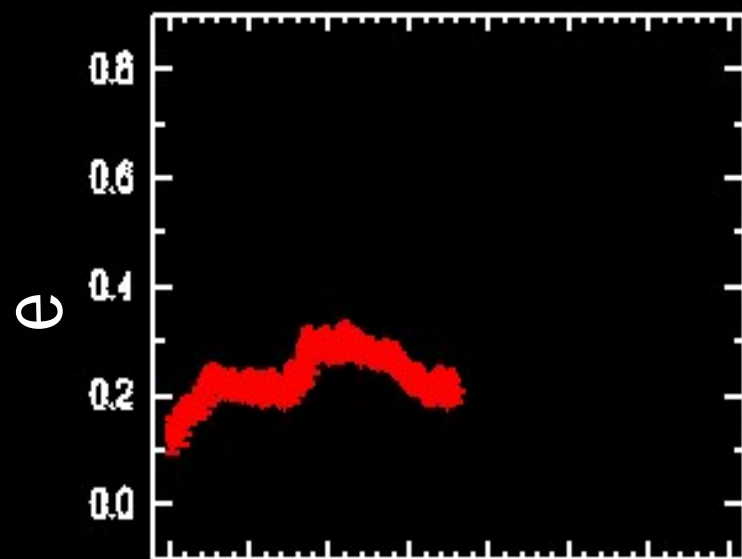
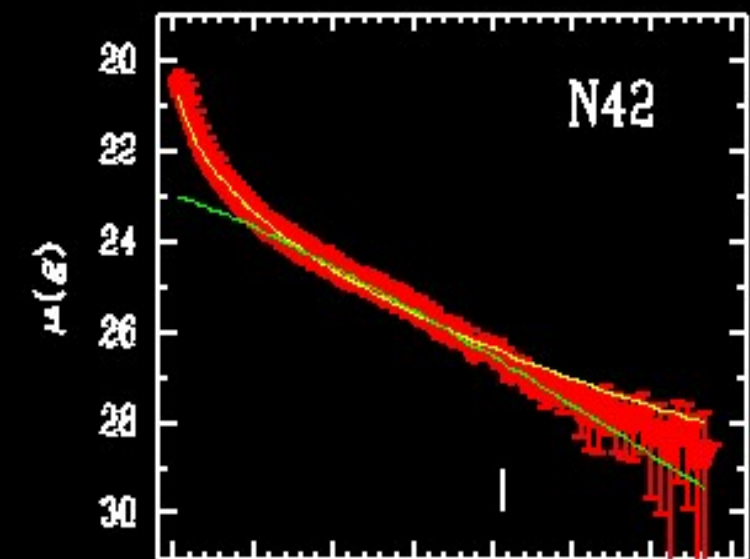


N42: dE,N
 $M_B = -16.9$
 $v_r = 2462$ km/s

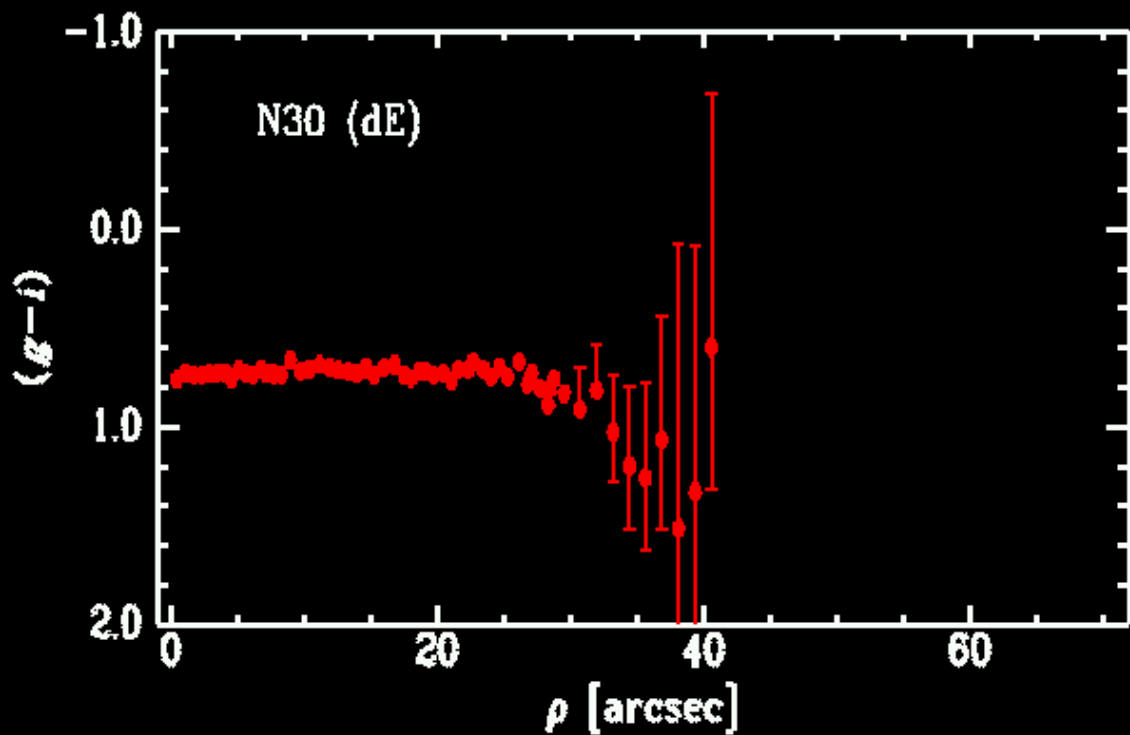
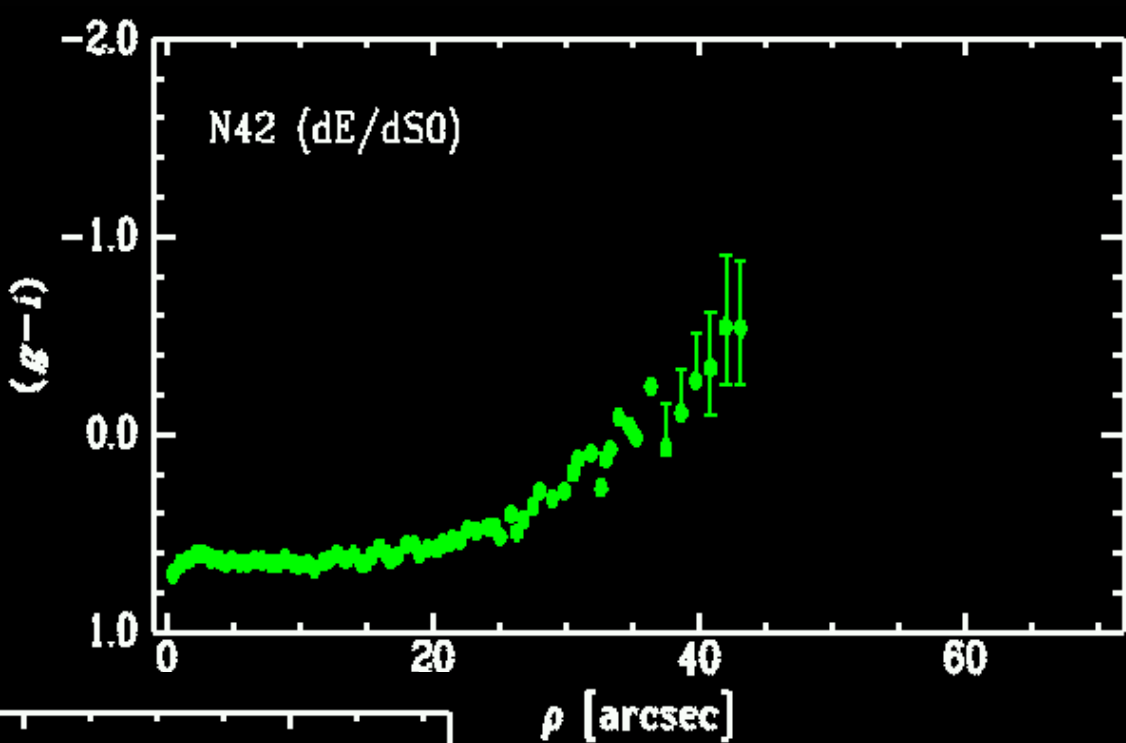
Cellone 1999, A&A 345, 403

Young & Currie 2001, A&A 369, 736

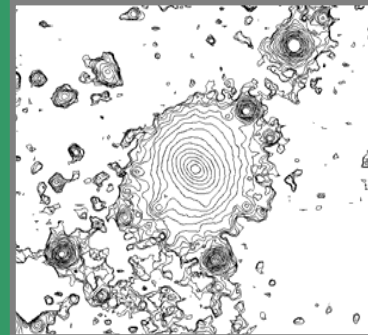
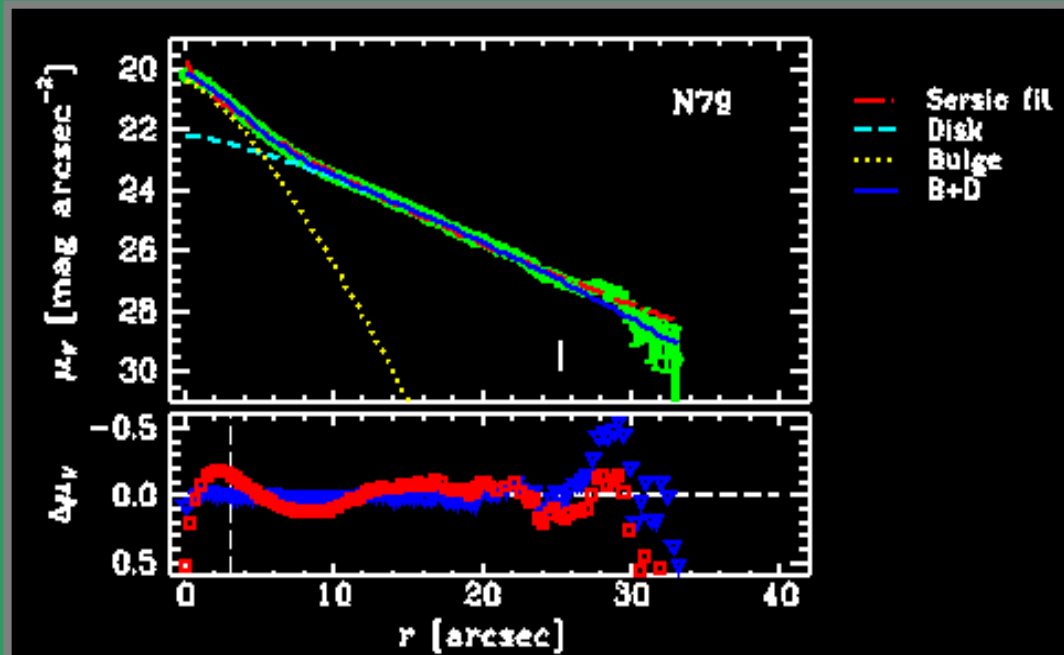
Cellone & Buzzoni 2001, A&A 369, 742



Colour profiles



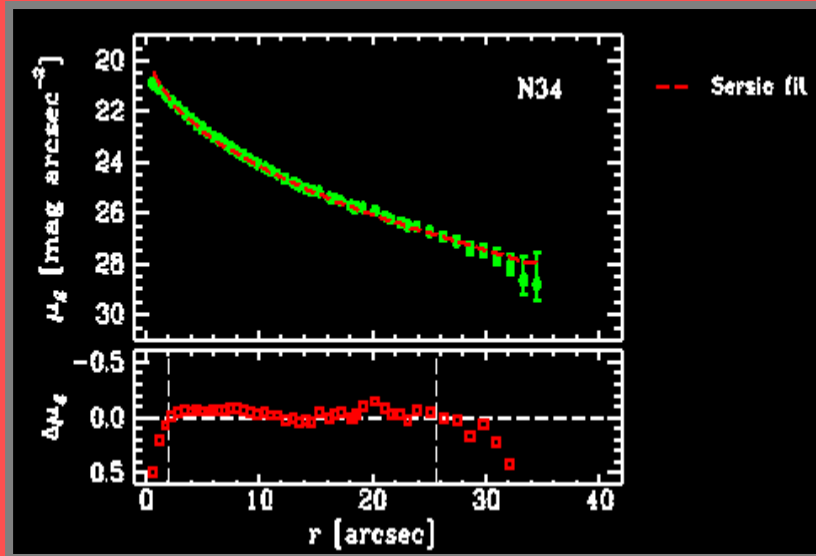
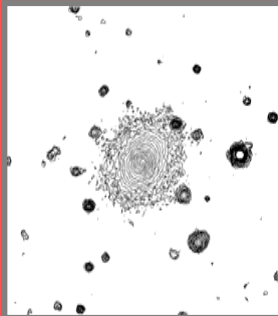
Classification



dE/dS0: their profiles **CANNOT** be fit by a Sérsic model; both positive and negative systematic residuals are left (red curve). Usually they show isophote twisting and ellipticity gradients ($\Delta\varepsilon \geq 0.1$).

A good fit is obtained with a “disk + bulge” model (blue).

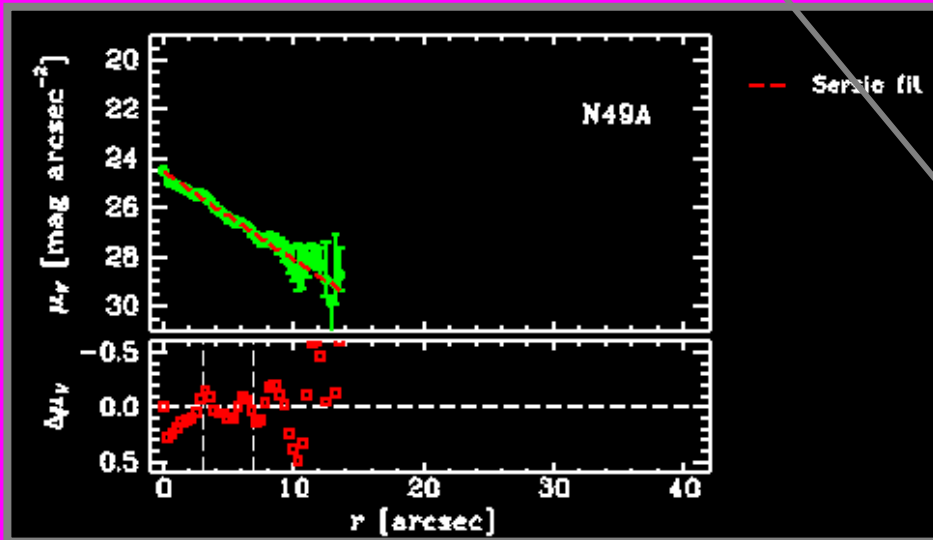
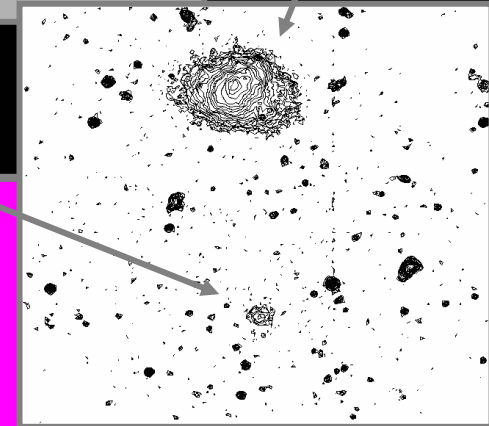
(See also Aguerri et al. 2005, AJ 130, 475)

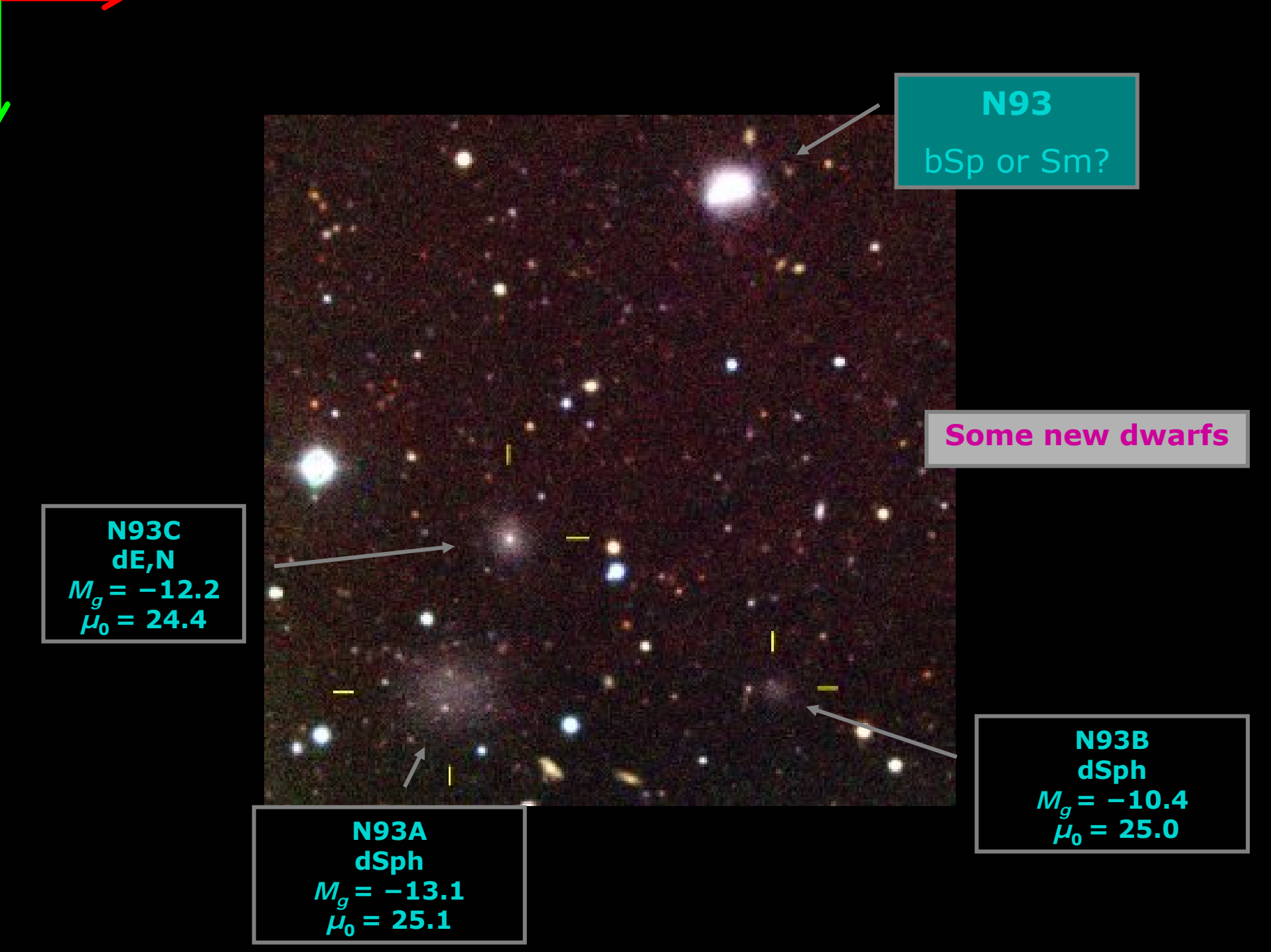


dE: their profiles are well fit by a Sérsic model. In general, no isophote twisting is detected.

Im: Magellanic irregulars .

dSph: mostly uncatalogued objects, with central surface brightnesses ≥ 24 mag arcsec⁻² and absolute magnitudes $M_g \geq -12$.





N93
bSp or Sm?

Some new dwarfs

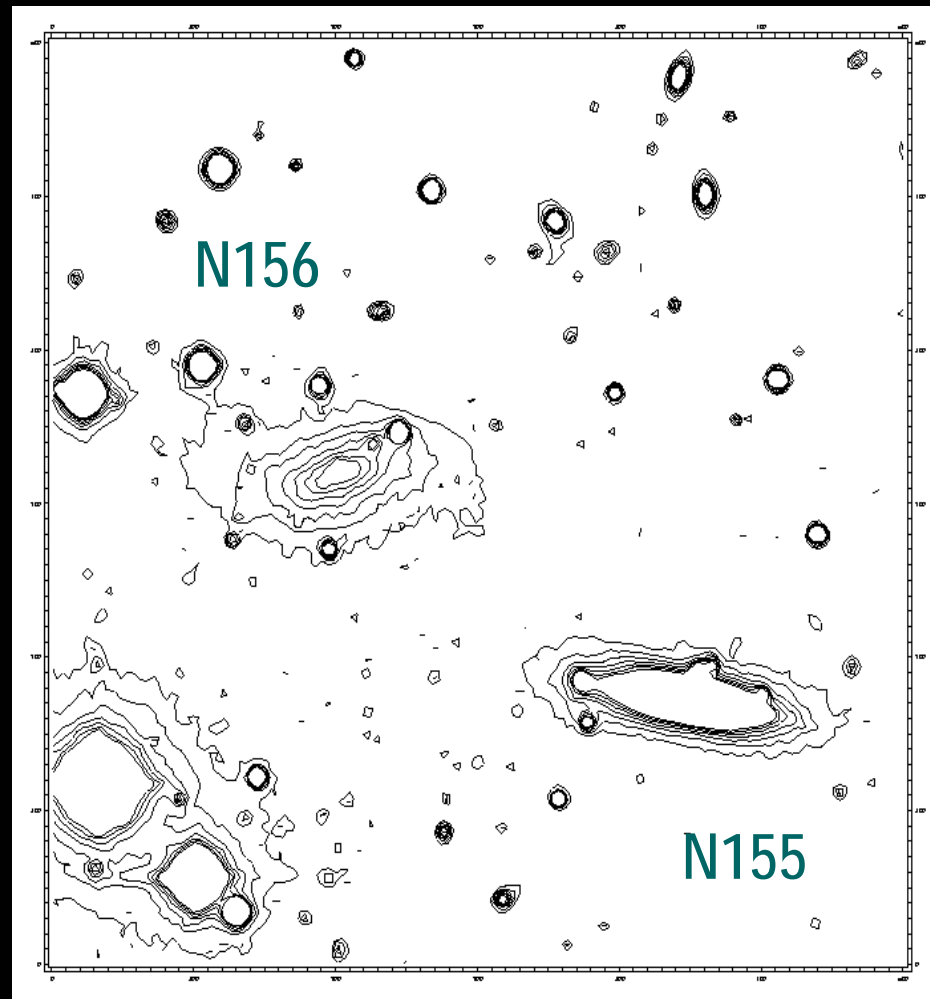
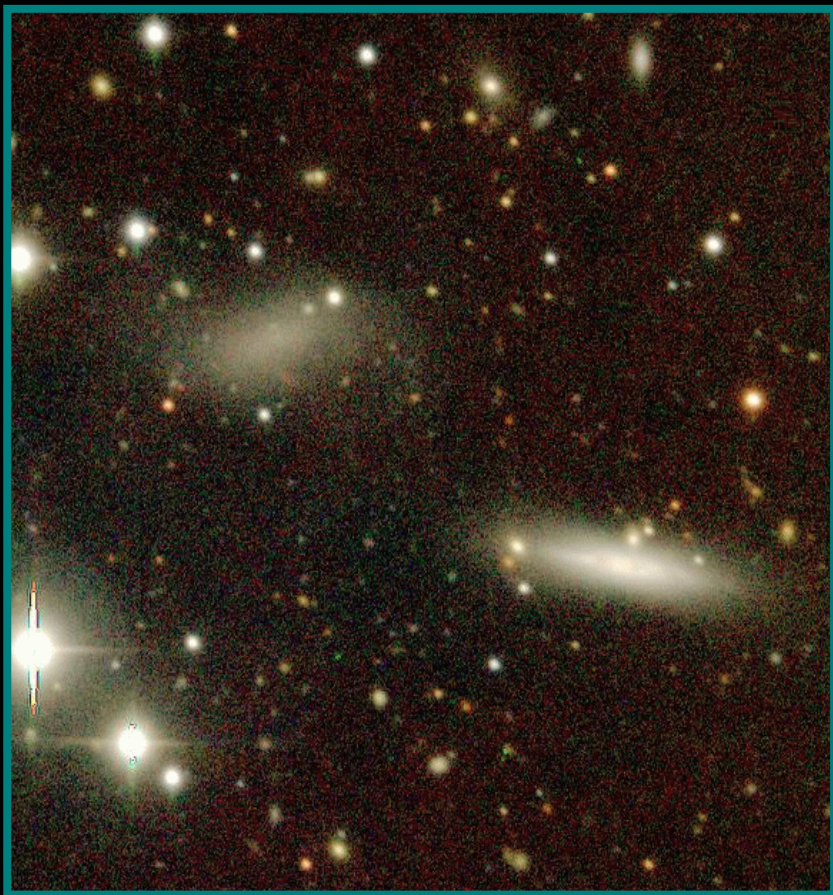
N93C
dE,N
 $M_g = -12.2$
 $\mu_0 = 24.4$

N93A
dSph
 $M_g = -13.1$
 $\mu_0 = 25.1$

N93B
dSph
 $M_g = -10.4$
 $\mu_0 = 25.0$

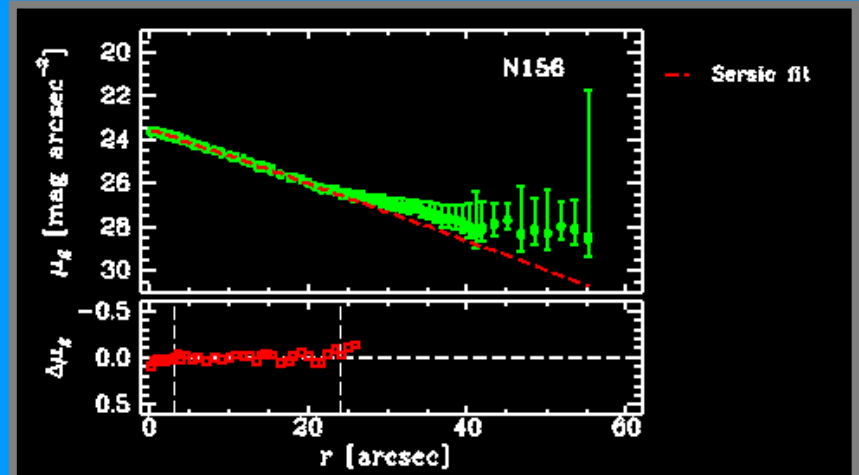
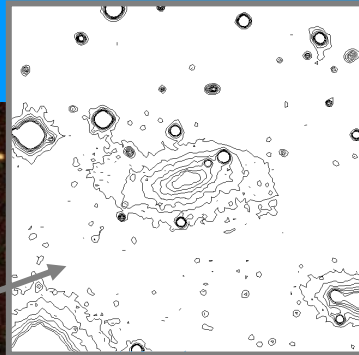
N156: dE

$$M_B = -15.1$$

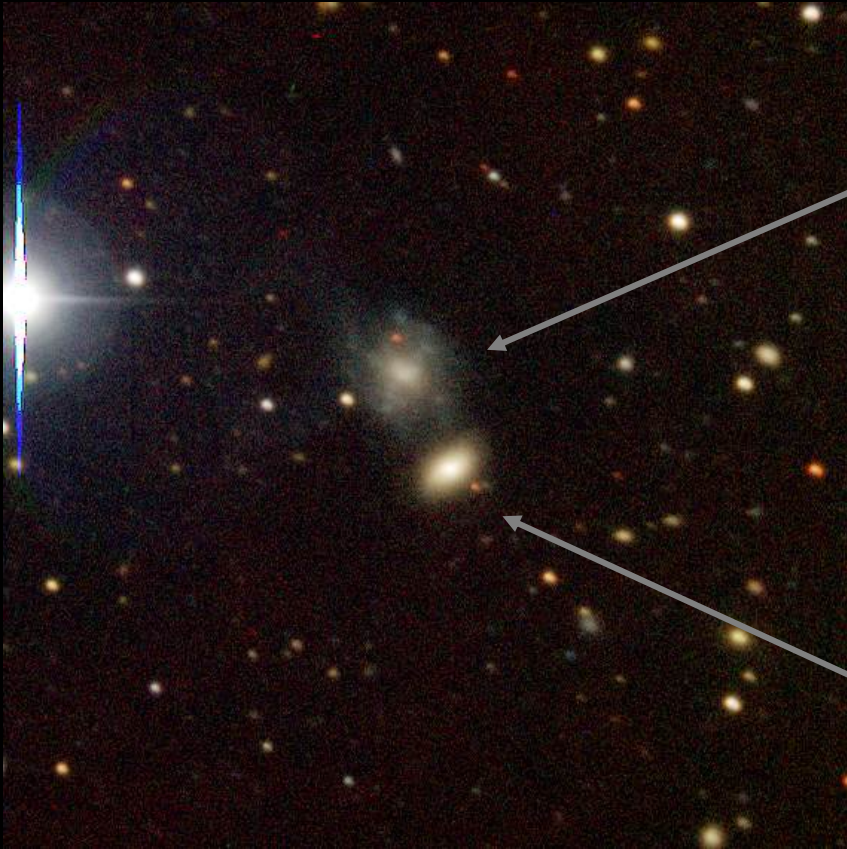


dI/dE: very low surface brightness objects; their profiles are nearly exponentials (Sérsic index $n=1$), and very extended.

No direct evidences of recent star formation; however, some show peculiar structures ("arms").



Background galaxies



N109: dE,N

Definite member (m=1)

$v_r = 5409$ km/s

Sdm (near background)

Uncatalogued galaxy

$v_r > 28000$ km/s


E (background)

NGC 5044 Group members

17

 dE


13

 S0 + dE/dS0

21

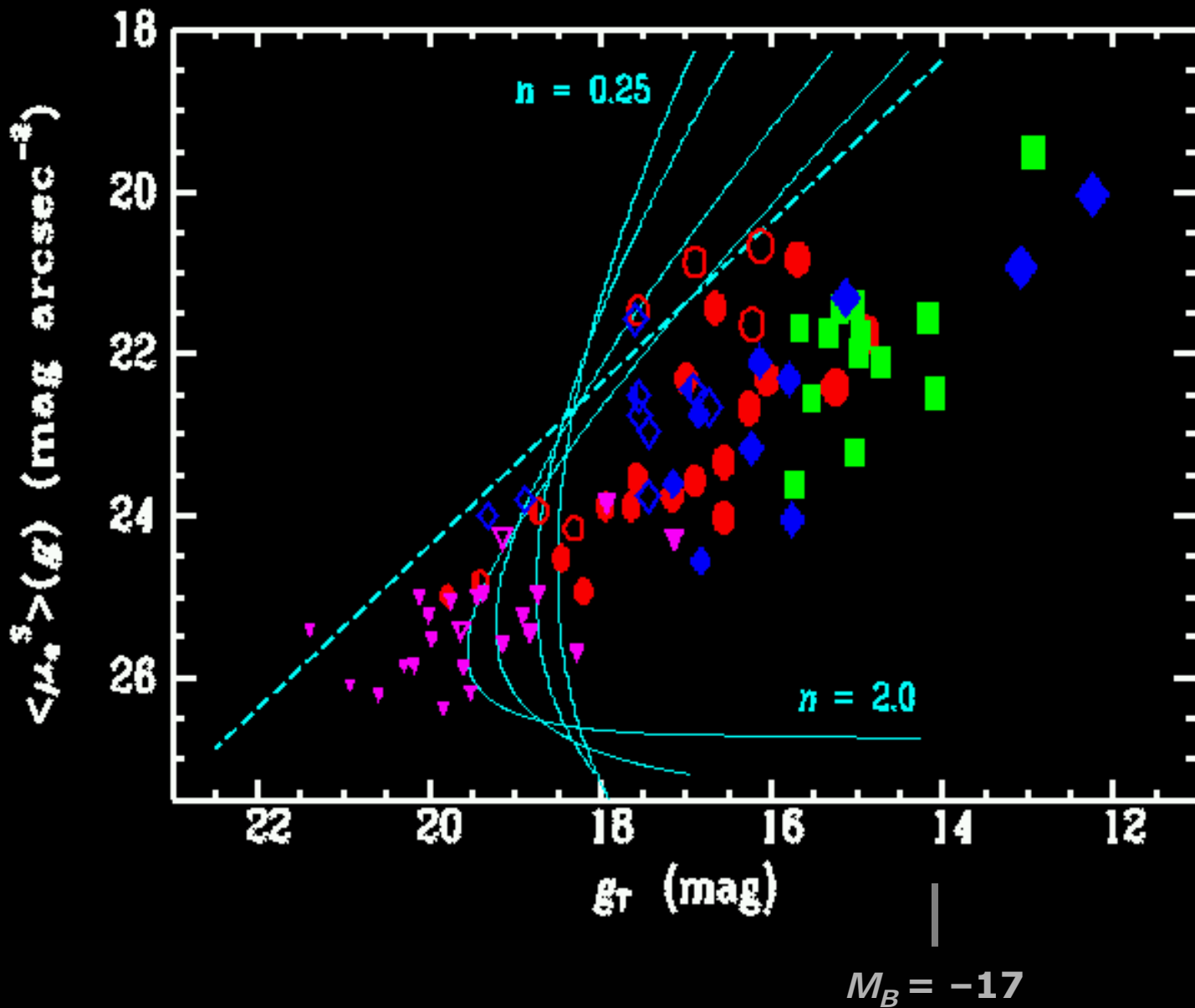
 dSph

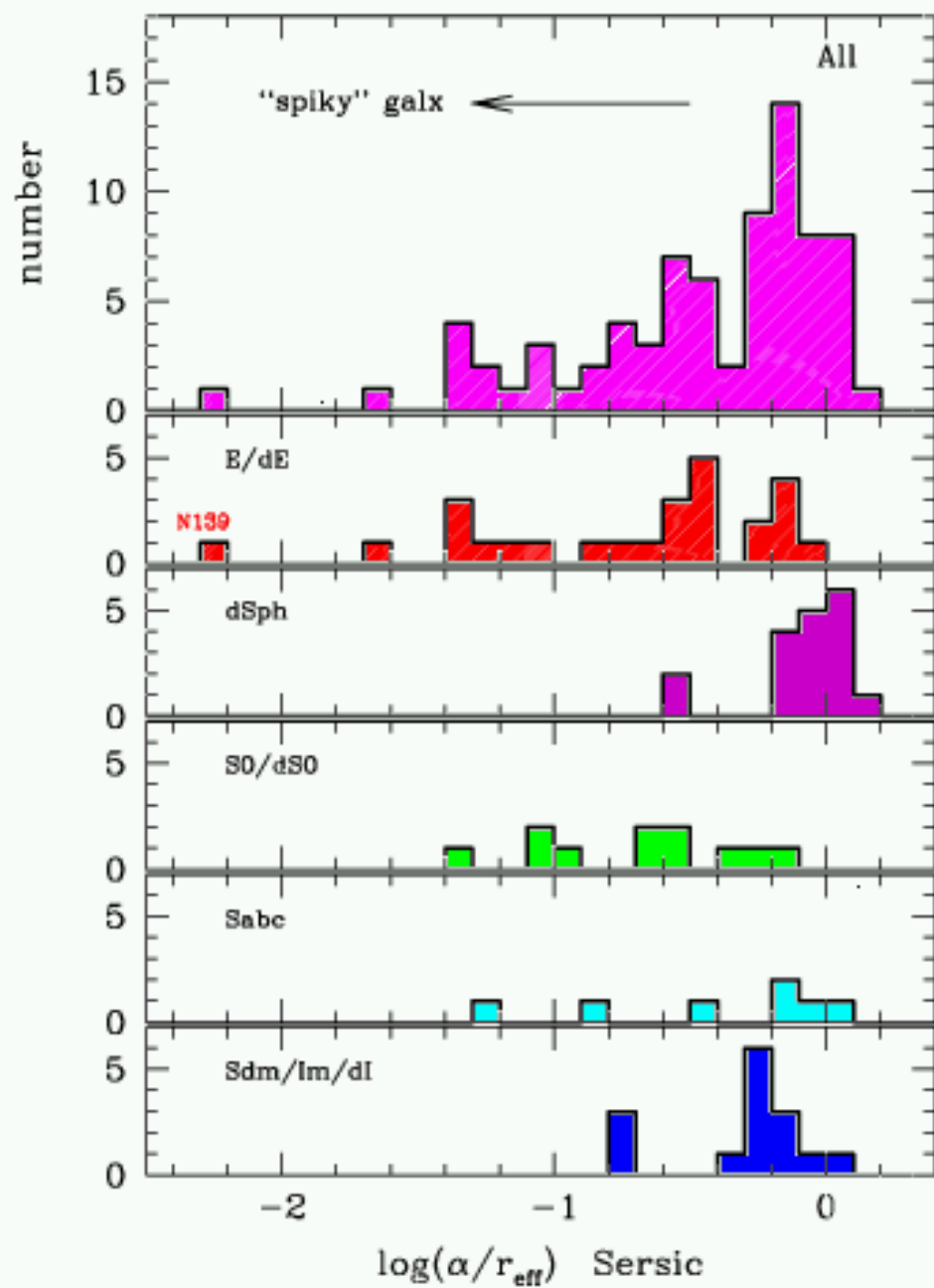
10

 S-Im + dI/dE

(18 background galaxies)

Magnitude — surface brightness





Distribution of radial velocities

Shown in colour:
dwarf galaxies
($B_T > 15$ mag).

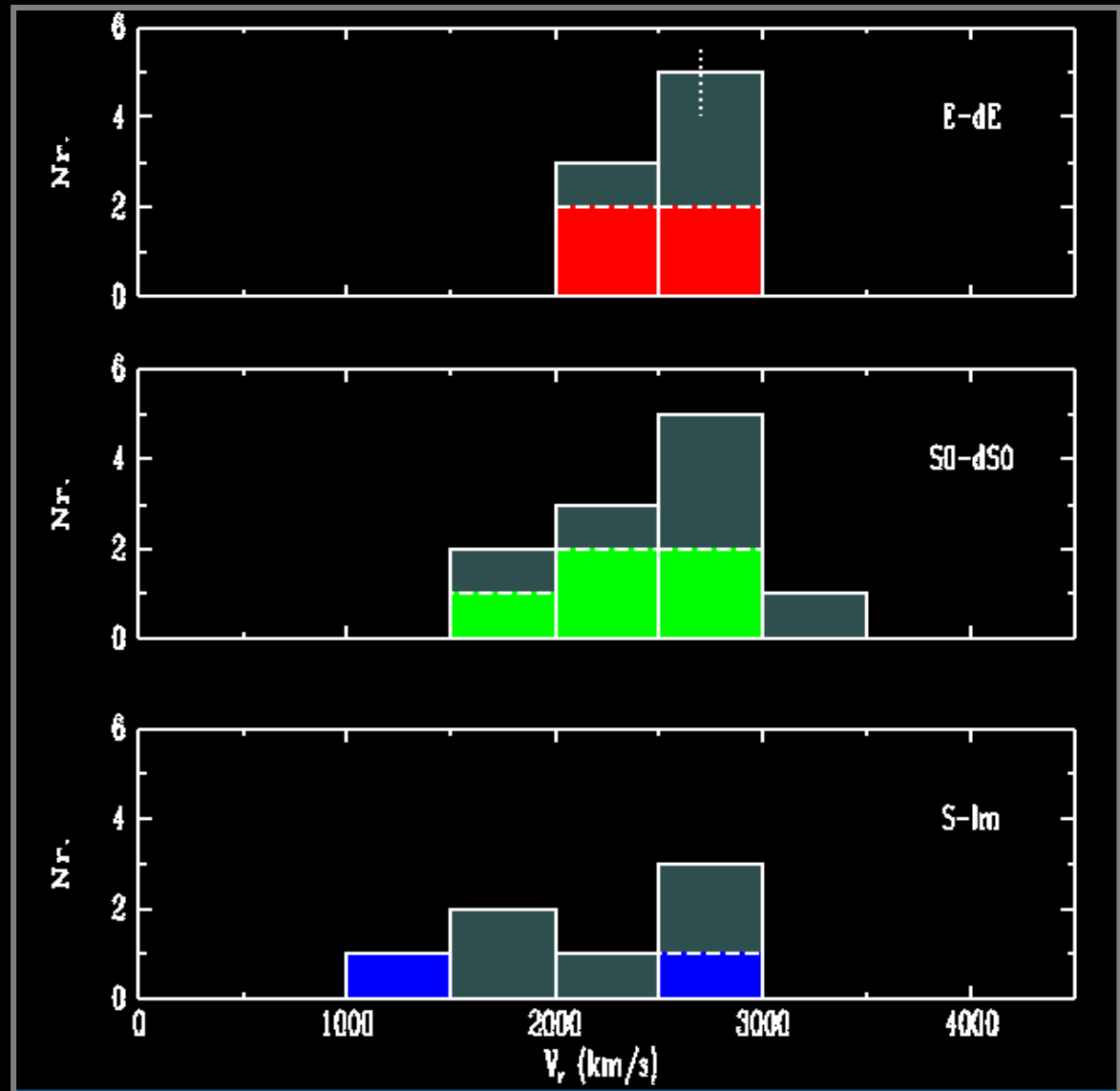
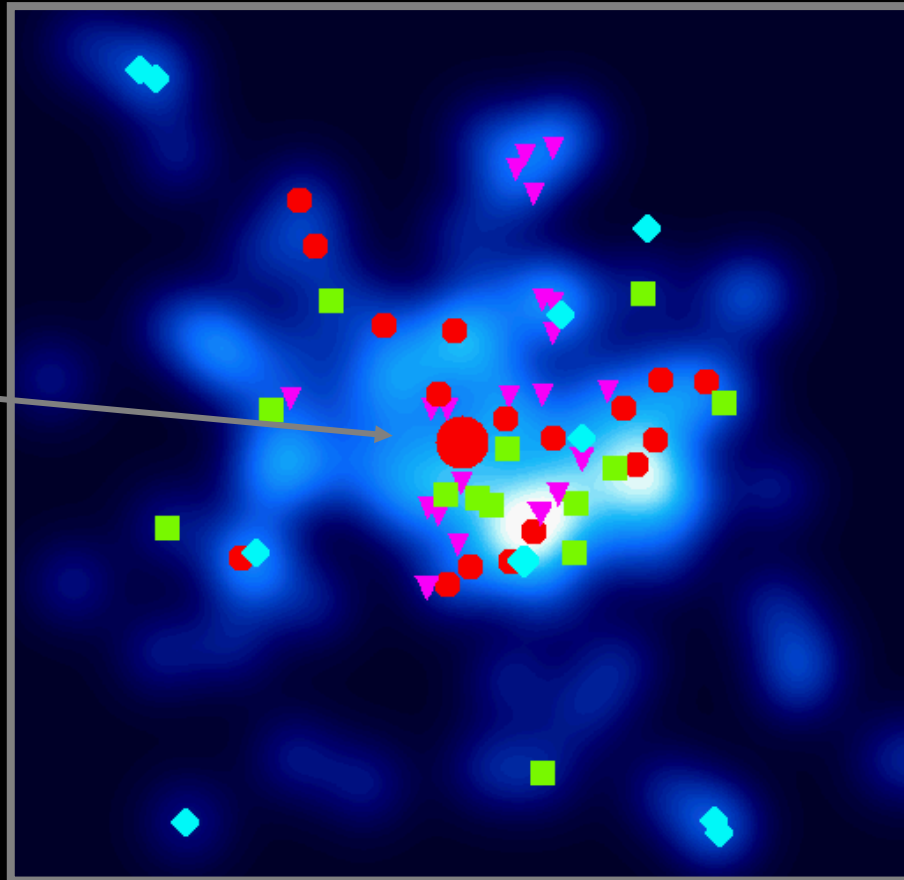


Table 4. Kinematic properties.

Type	Nr.	no weights		L weighted	
		$\langle v_r \rangle$ km s ⁻¹	σ_{v_r}	$\langle v_r \rangle$ km s ⁻¹	σ_{v_r}
E-S0	9	2488 ± 96	287	2590 ± 87	262
dE-dS0	9	2487 ± 98	294	2493 ± 97	292
Sa-Im	8	2404 ± 241	681	1982 ± 245	693
All	26	2461 ± 84	431	2281 ± 98	501

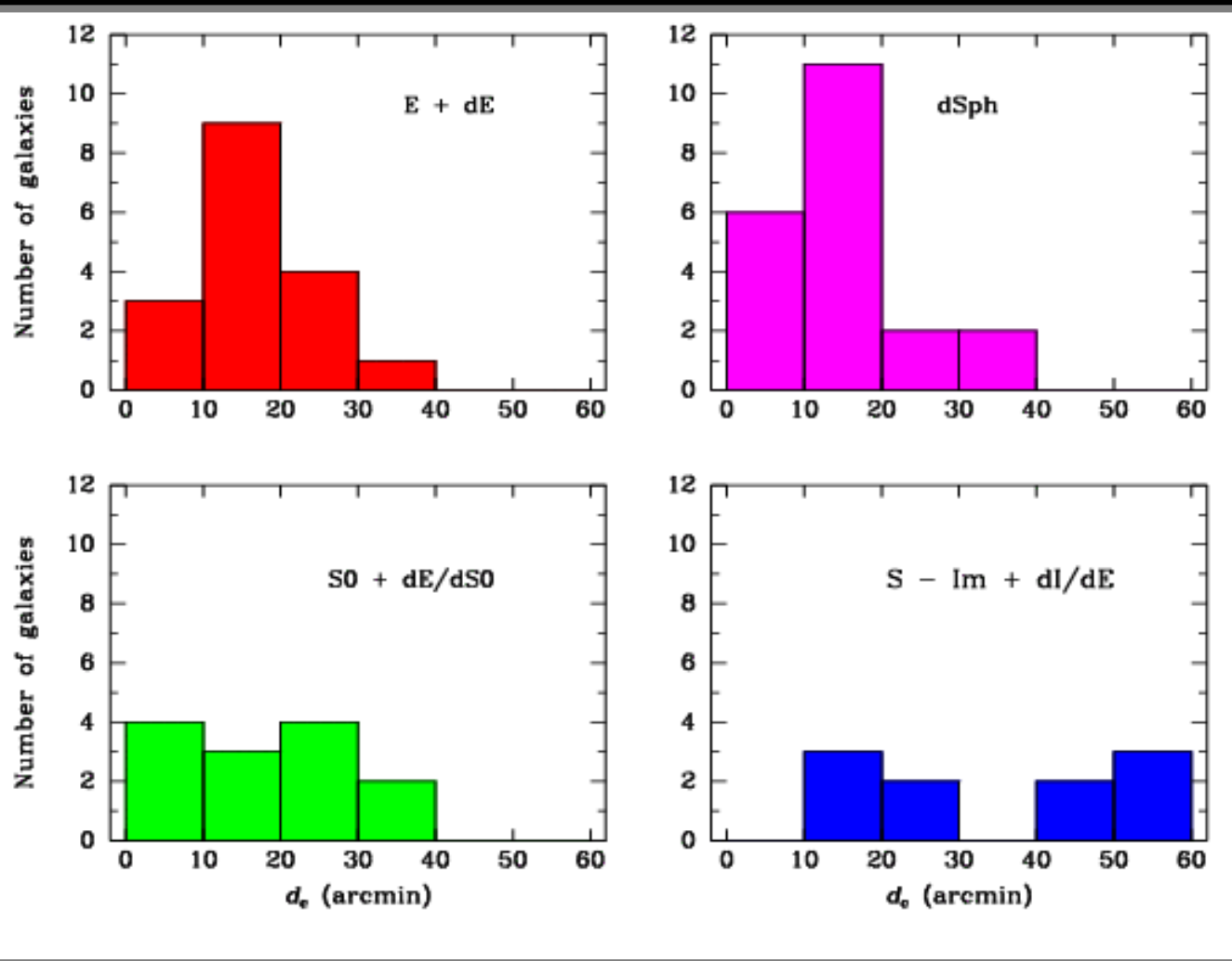
Spatial distribution

NGC 5044

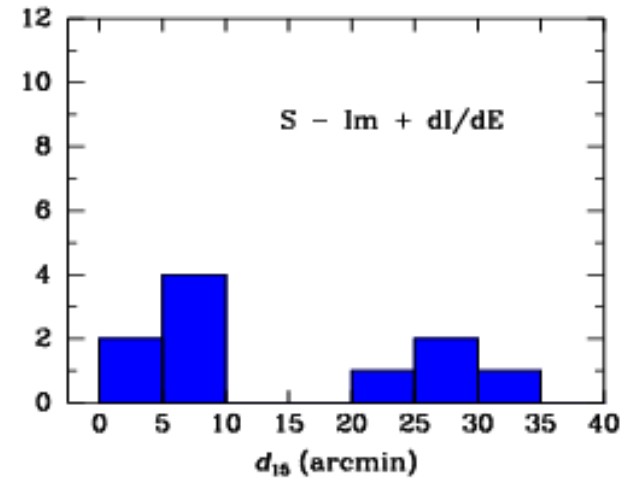
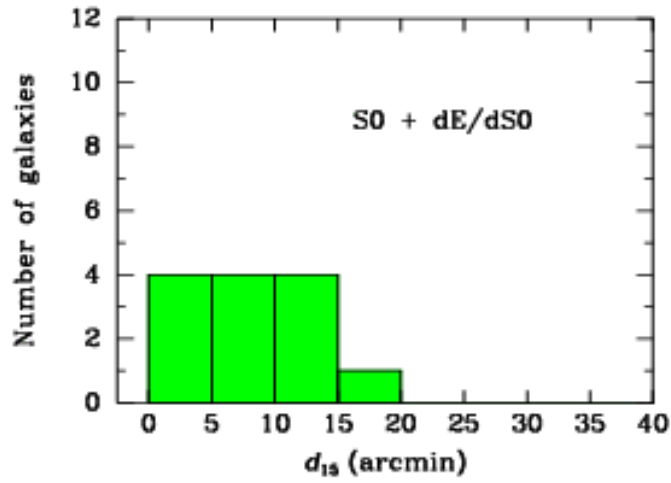
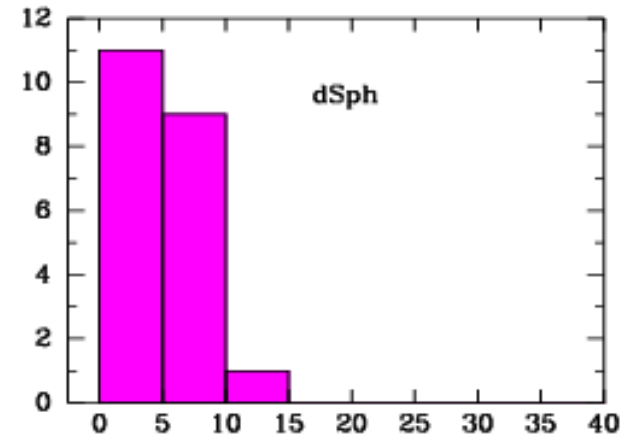
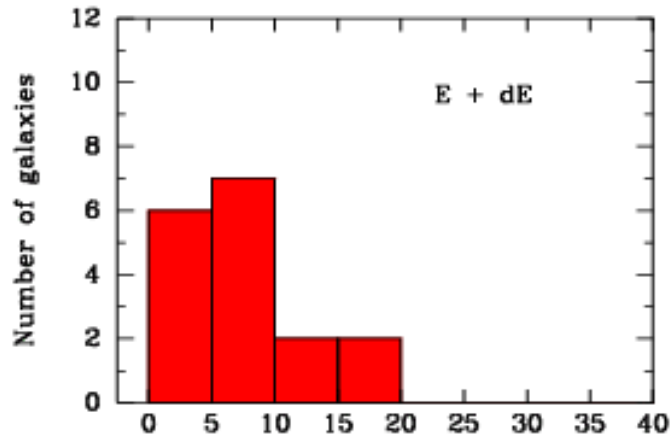


- dE
- S0 + dE/dS0
- ▼ dSph
- ◆ S-Im + dI/dE

Projected density map ($1^{\circ} 40' \times 1^{\circ} 40'$).



Distribution of projected distances (arcmin) to the Group centre (10 arcmin = 63 kpc).

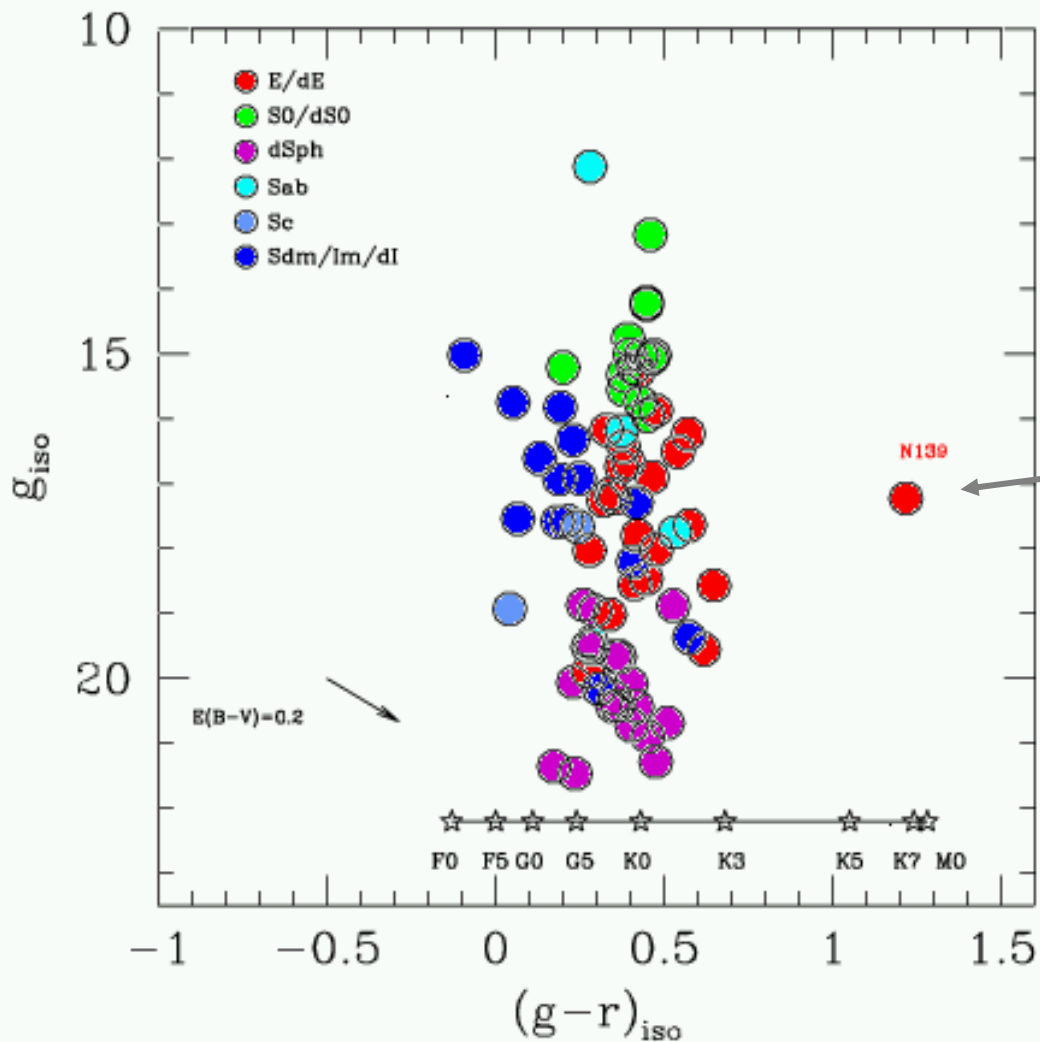


Distribution of projected distances (arcmin) to the closest bright ($B_T \leq 15$) galaxy (10 arcmin = 63 kpc).

Table 2. K-S statistic (D) for cumulative distributions of Σ_{25} , d_c , and d_{15} .

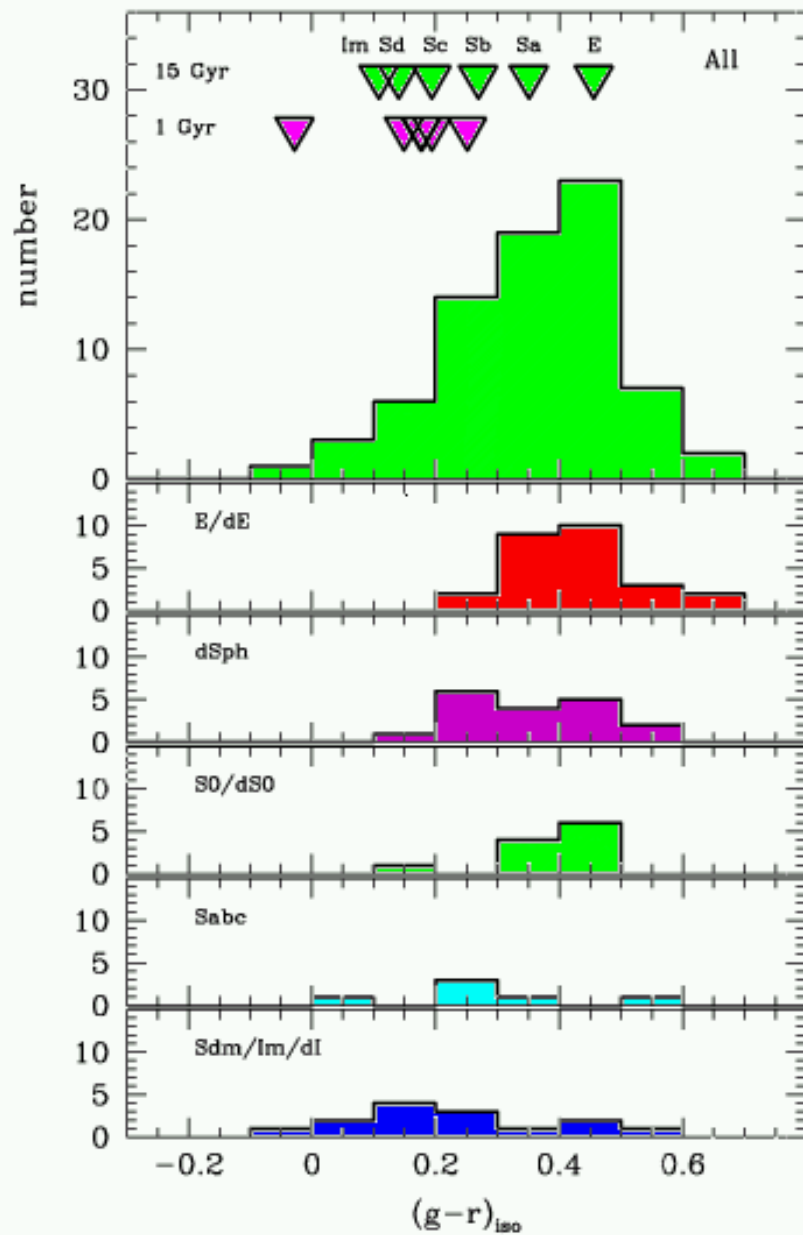
Set 1 (Nr.)	Set 2 (Nr.)	Σ_{25}	d_c	d_{15}
E (17)	dSph (21)	0.2213	0.2997 (69%)	0.3053 (71%)
E (17)	S0 (13)	0.3032 (57%)	0.1900	0.1900
E (17)	S-I (10)	0.3882 (77%)	0.5412 (97%)	0.4000 (80%)
dSph (21)	S0 (13)	0.3480 (77%)	0.2711 (47%)	0.3370 (74%)
dSph (21)	S-I (10)	0.5048 (96%)	0.5095 (96%)	0.4571 (92%)
S0 (13)	S-I (10)	0.4385 (83%)	0.5000 (92%)	0.4154 (79%)

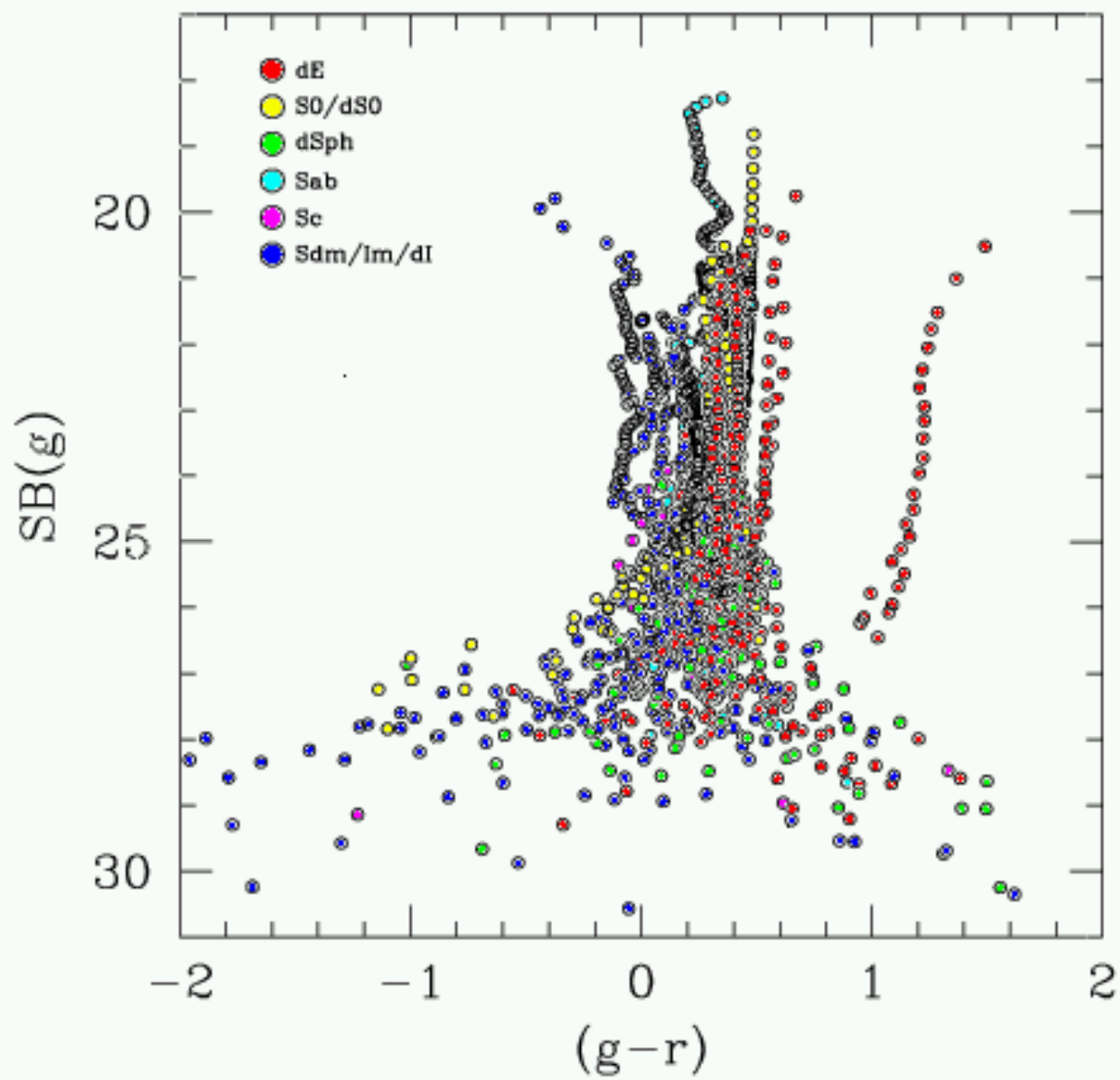
Colour — magnitude diagram



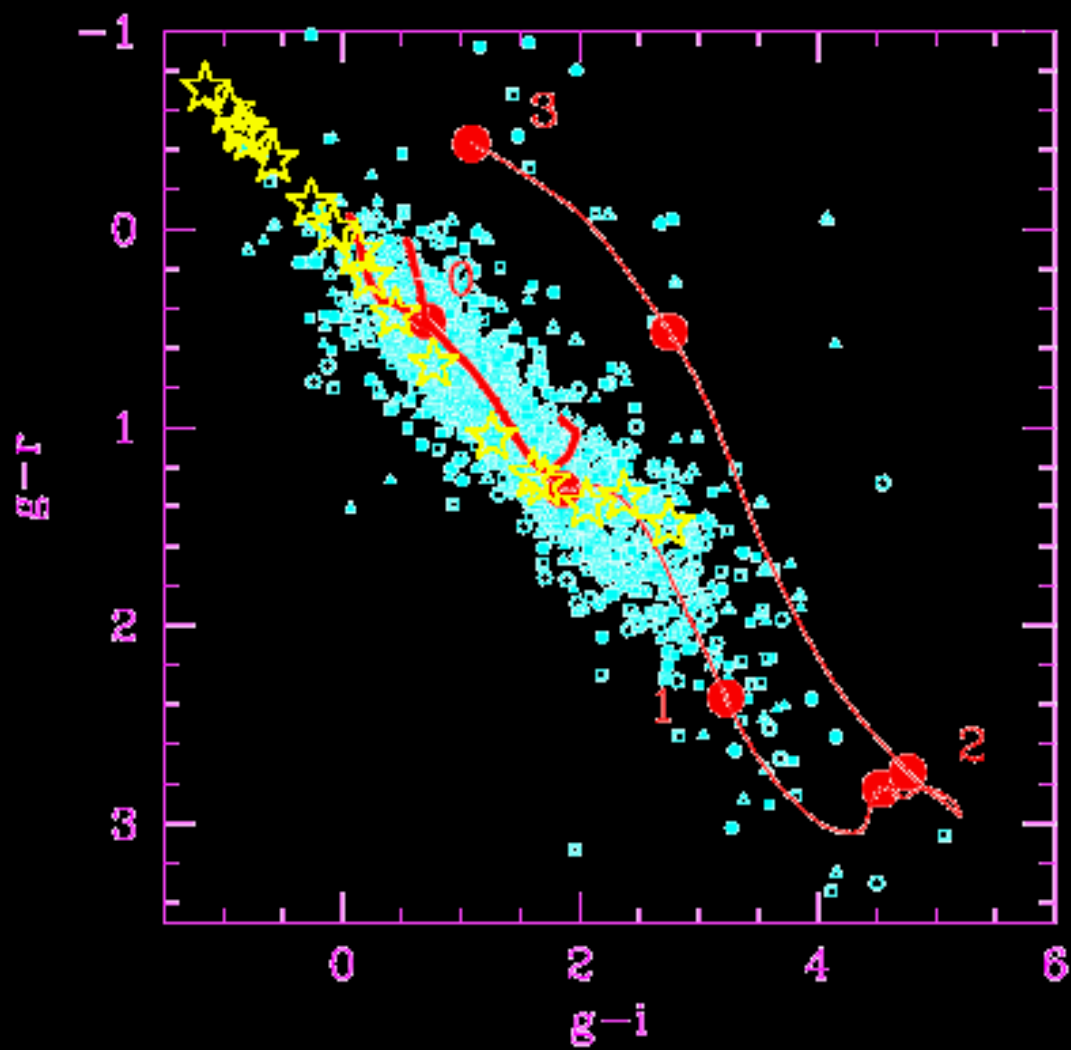
N139: $z \sim 0.4$

(See also Lisker, Grebel & Binggeli 2005, astro-ph/0505048)

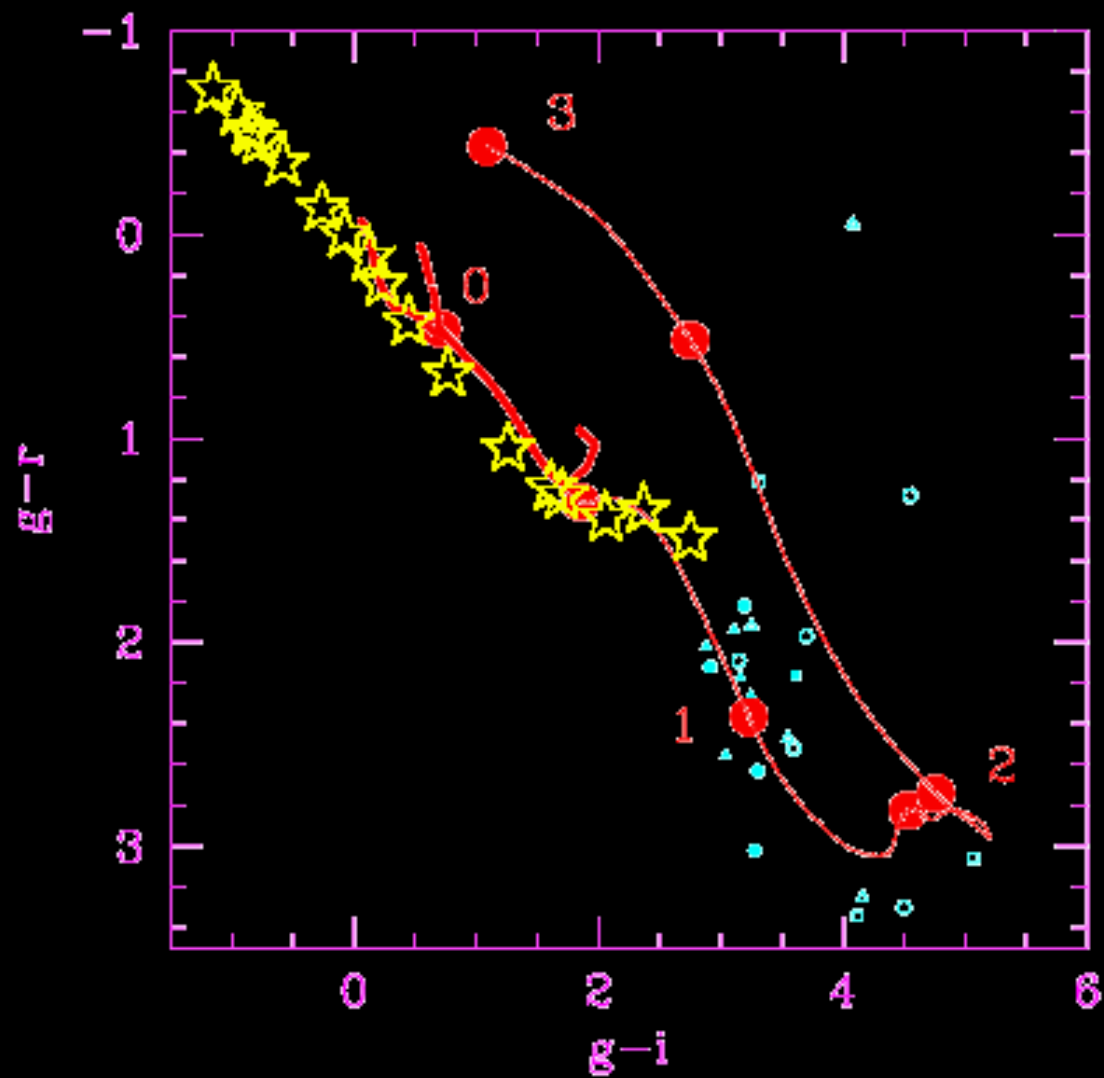




Searching for $z > 1$ Ellipticals

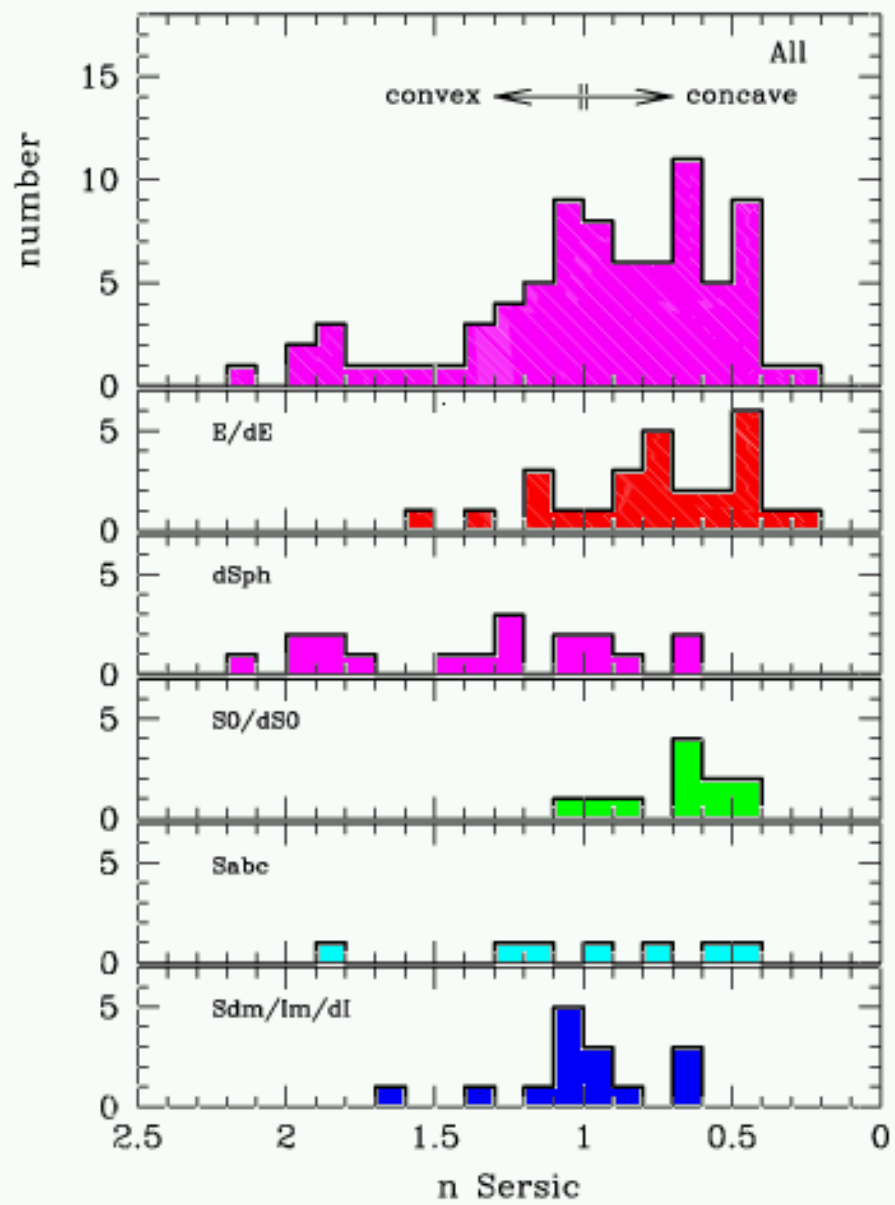


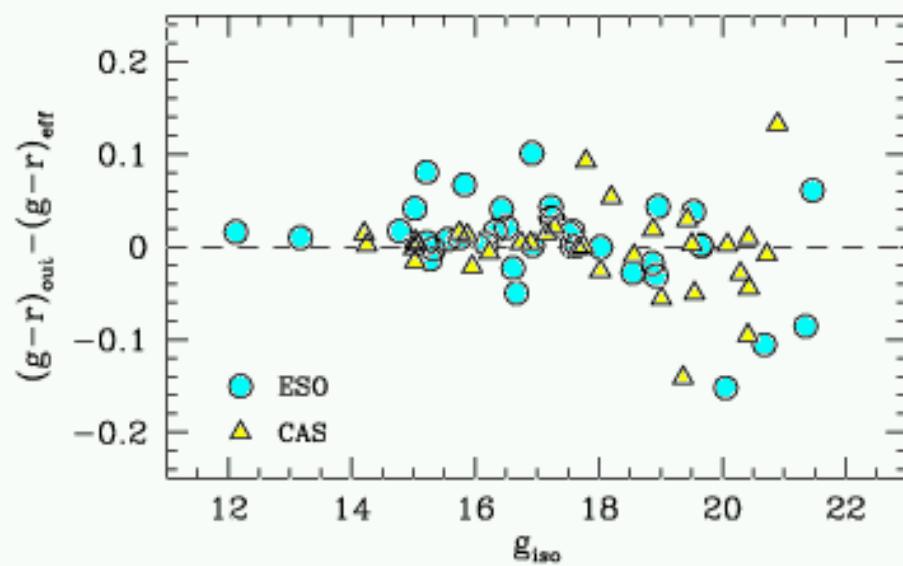
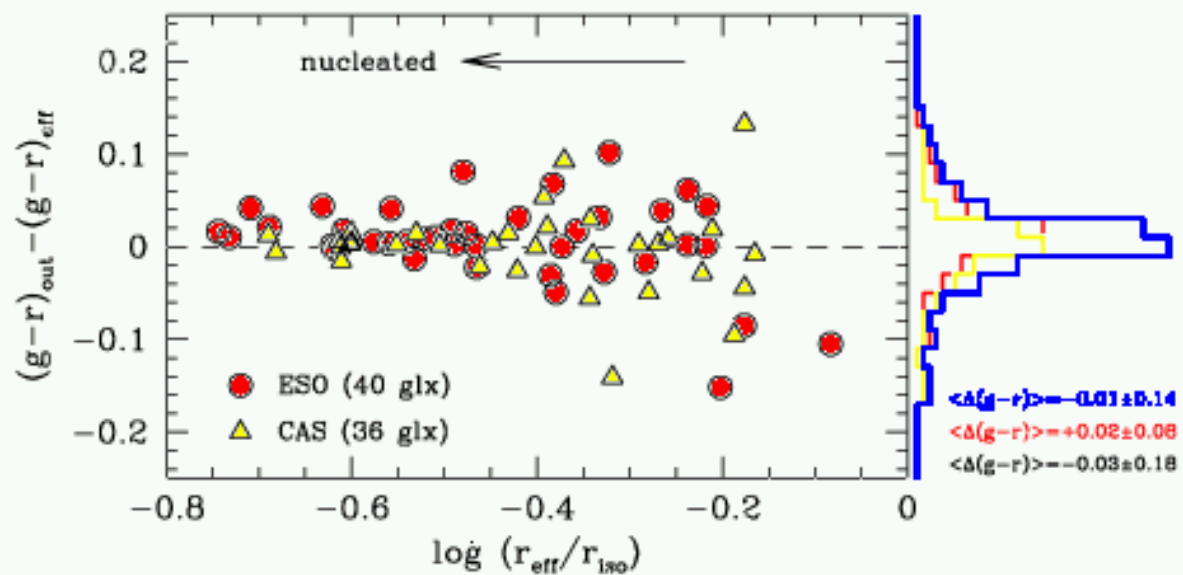
Searching for $z > 1$ Ellipticals

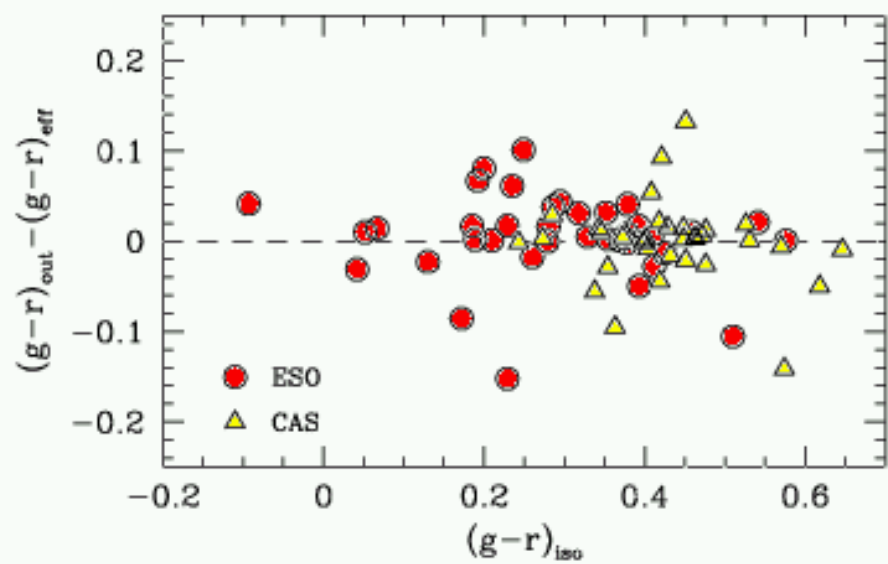
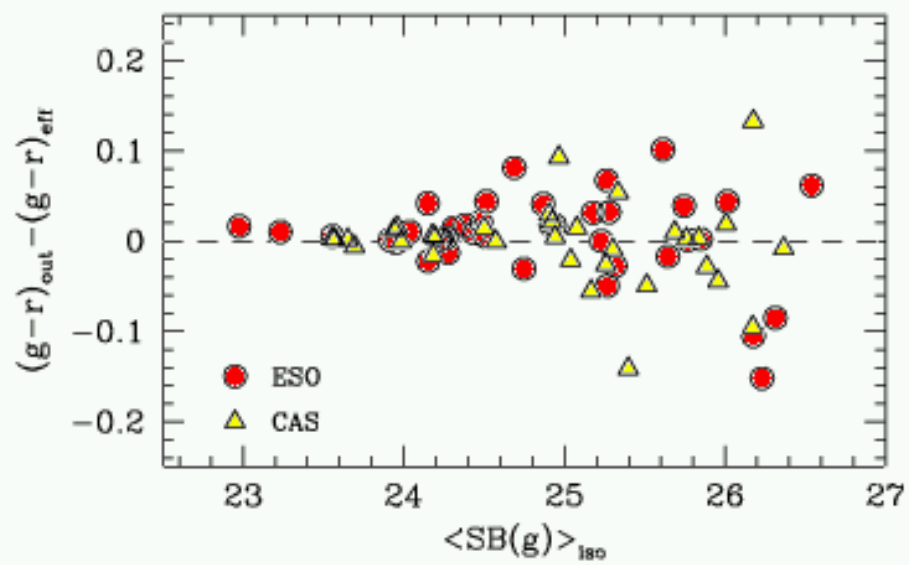


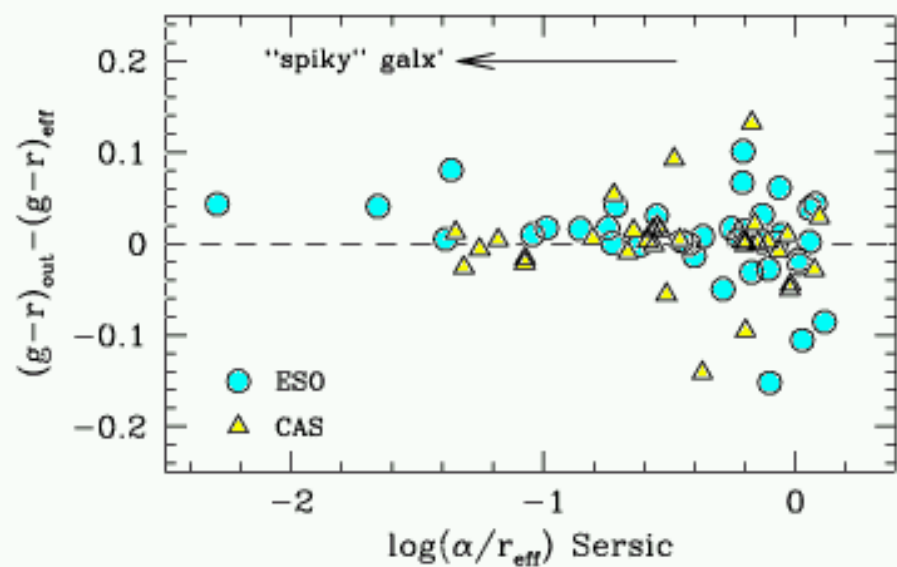
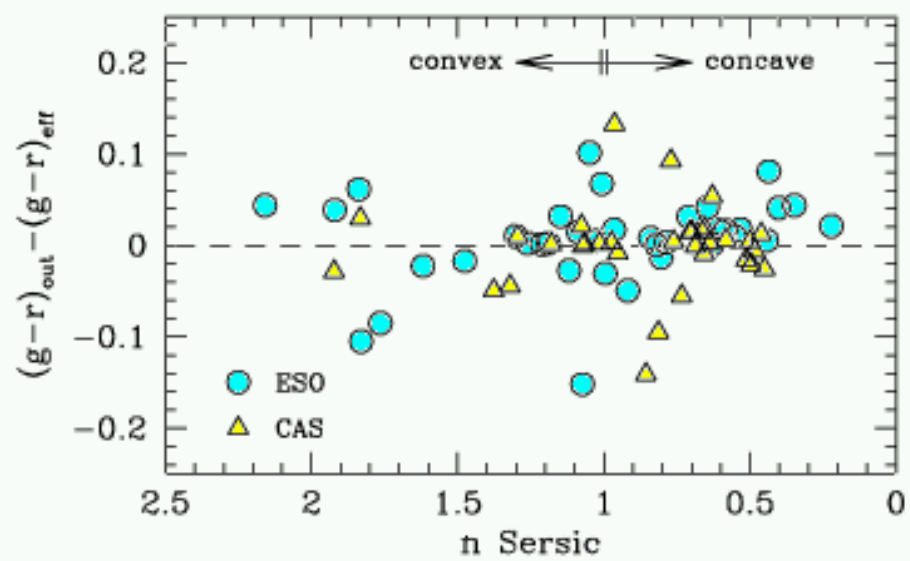
Conclusions

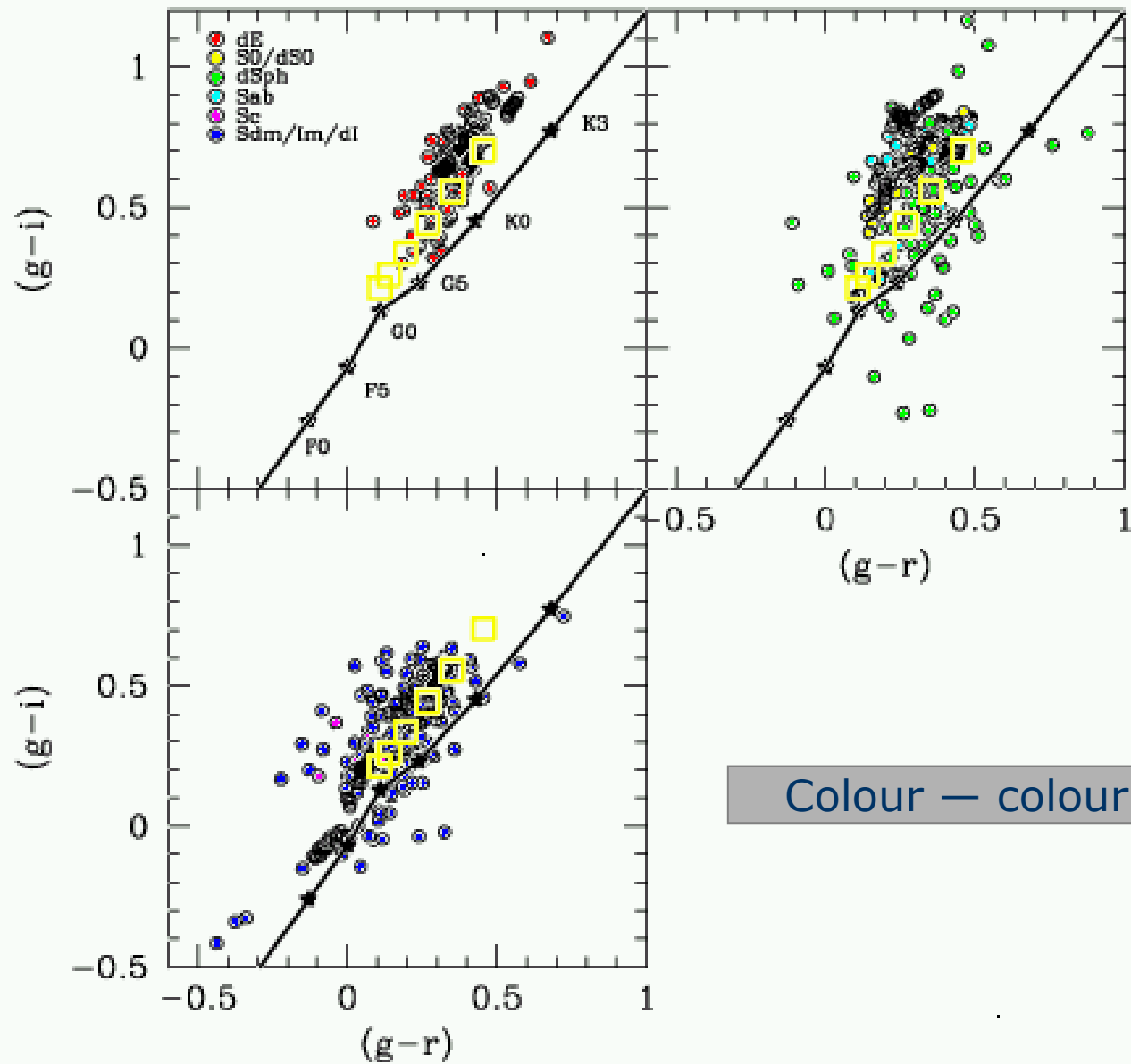
- There are hints (poor statistics!) for S0+dE/dS0's having:
 - Broader distributions than E+dE's, both in radial velocity and projected position.
 - Bluer colours at the same luminosity.
- dSph's are preferentially (almost exclusively) found near bright galaxies.
- Early-type dwarfs and giants have very similar radial velocity distributions.





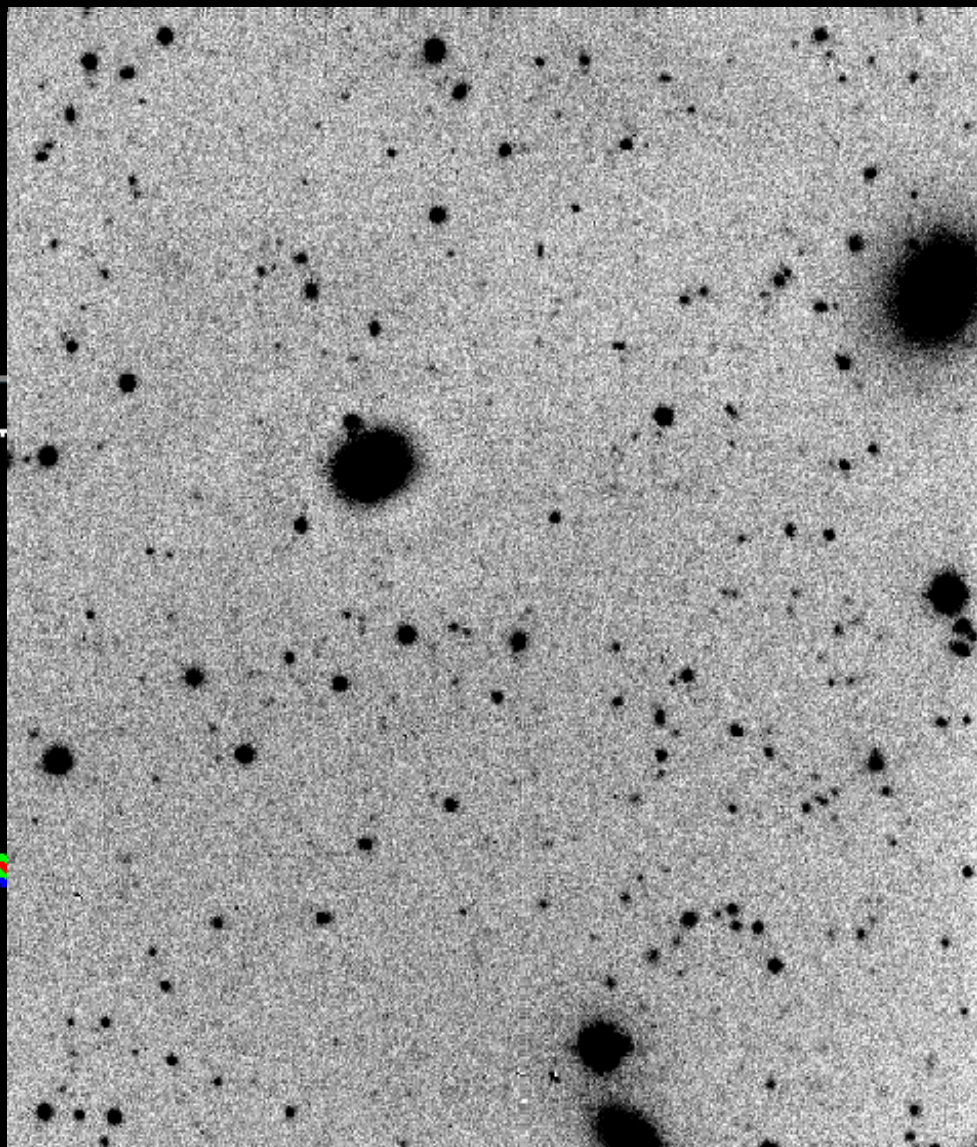
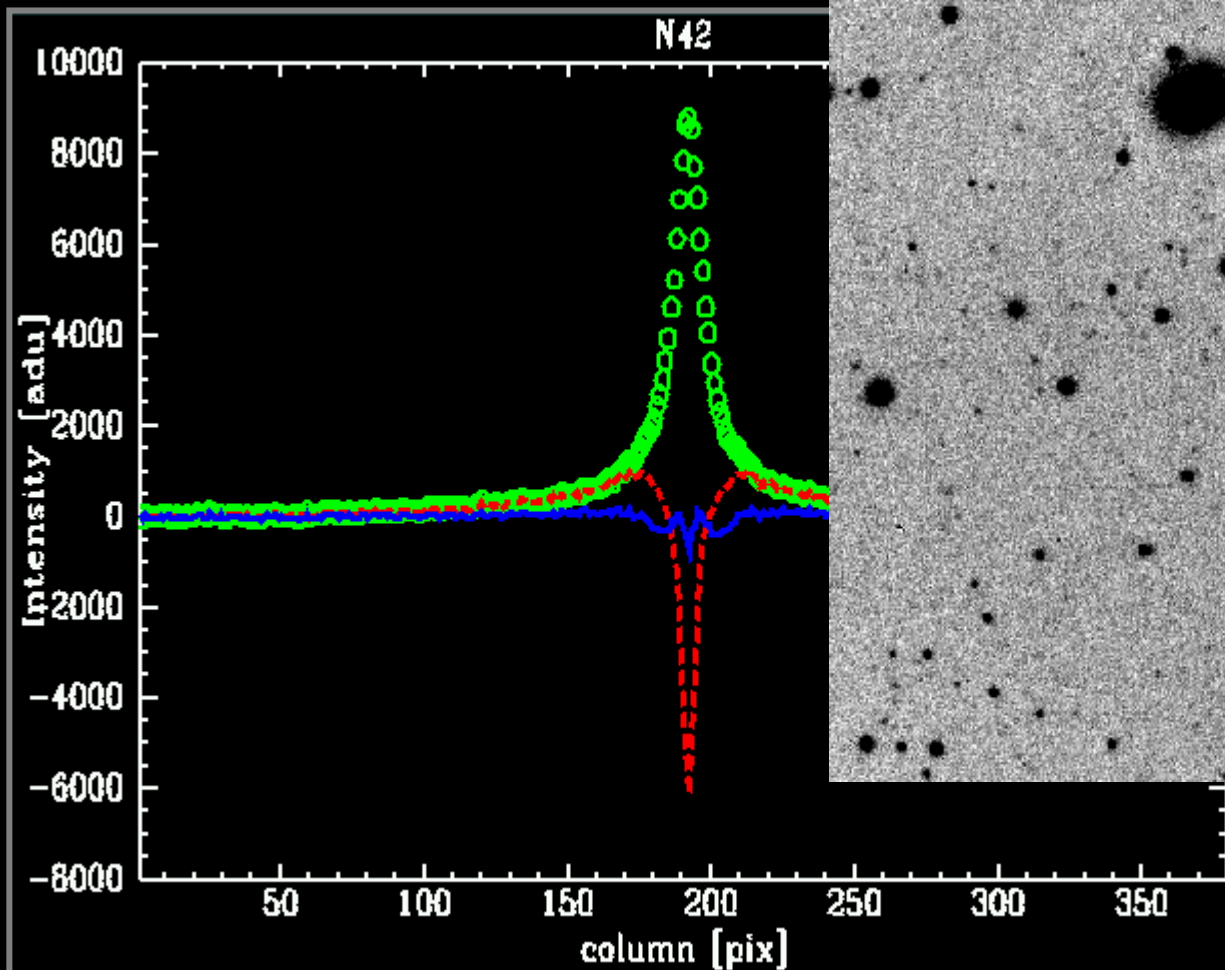






Colour — colour diagram

*Residuals:
observed profile – model*



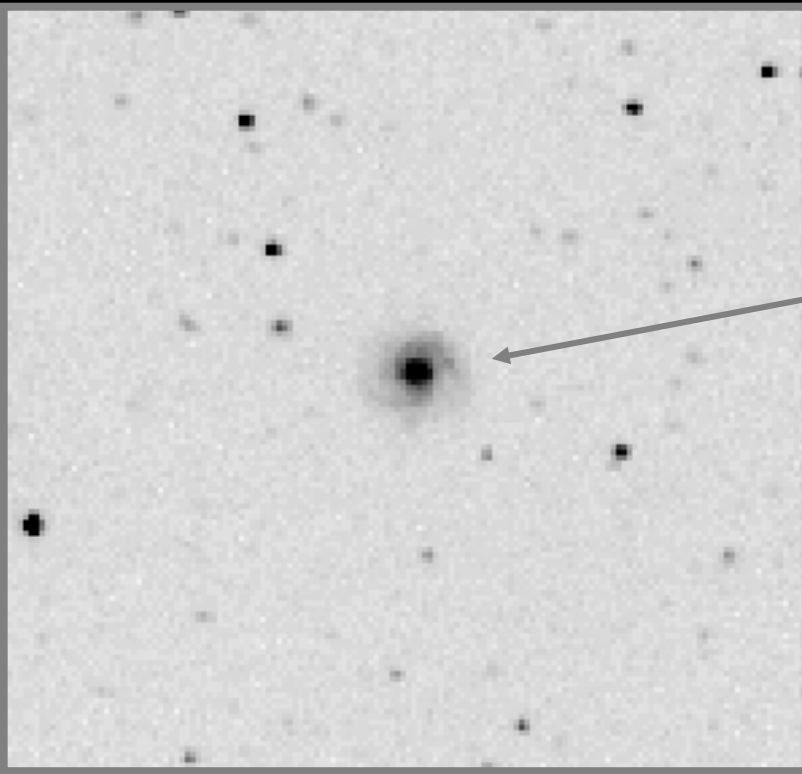
Ellipticity distributions

Table 1. K-S statistic (D) for cumulative distributions of ϵ .

Set 1 (Nr.)	Set 2 (Nr.)	ϵ
E (17)	S0 (13)	0.2579 (35.8%)
E (17)	S-I (10)	0.7412 (99.9%)
S0 (13)	S-I (10)	0.5923 (97.9%)

Future:

Search for “hidden” structure in dE galaxies	“Unsharp masking” and model subtraction on CCD images
Internal kinematics	High-resolution spectra
Relation between structure and stellar populations	Multicolour photometry and spectra



N46: dE,N

Likely member (m=2)

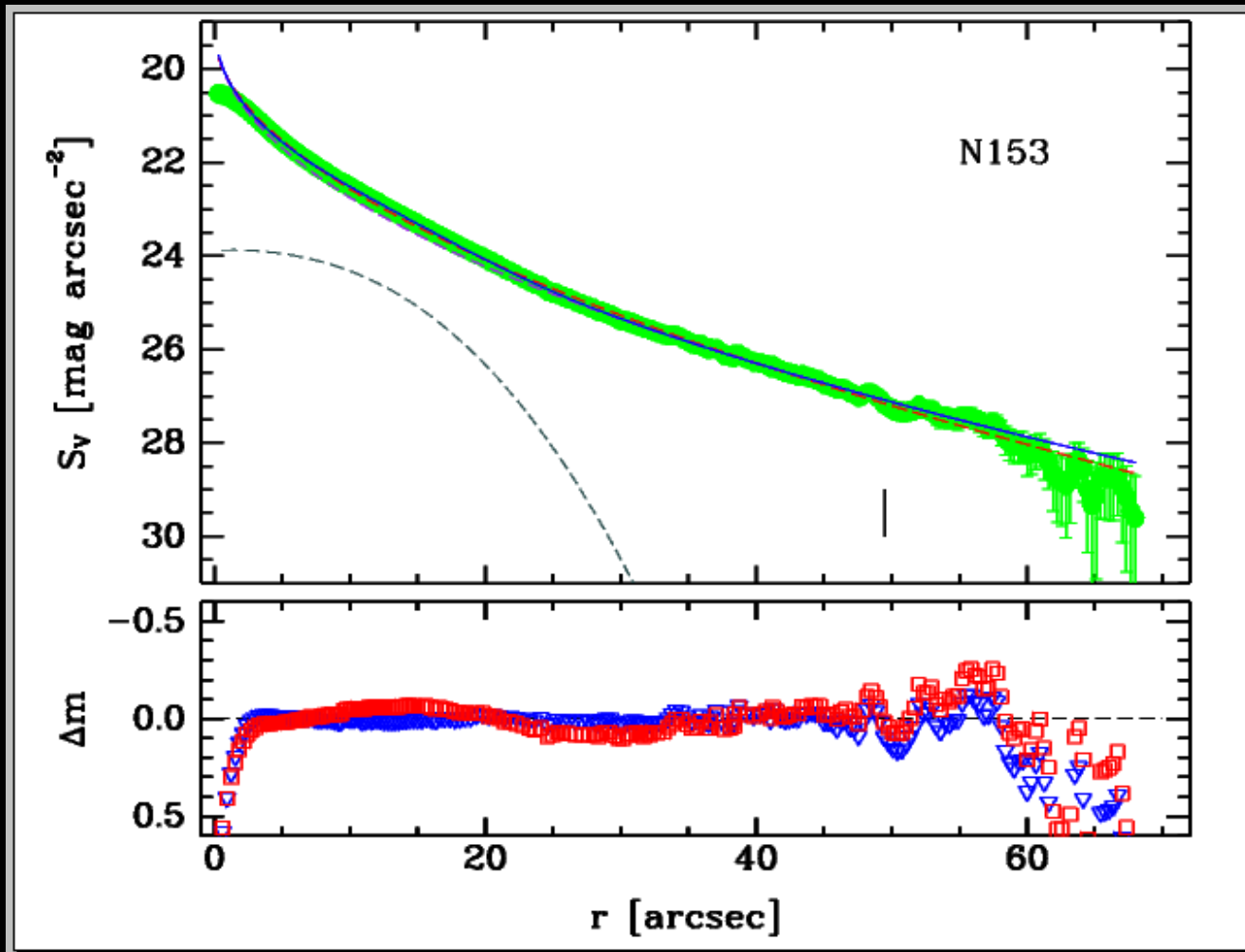
S (background)

Systematic residual from Sérsic fit are quantified by:

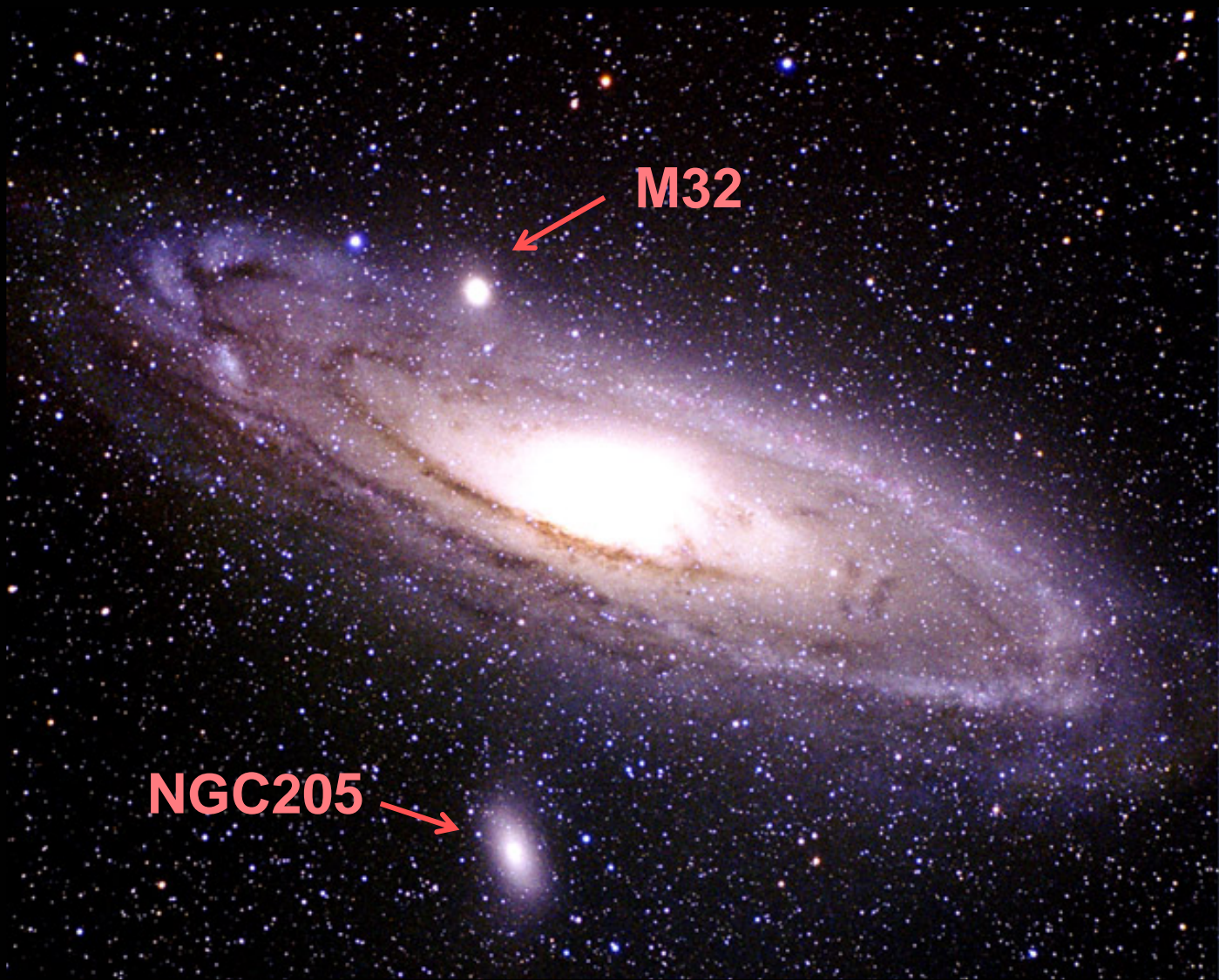
$$R = \int_{\rho_1}^{\rho_2} (I(\rho) - S(\rho)) 2\pi\rho \, d\rho$$

$$\Sigma_R = \sum |R_i| k_i,$$

where $I(\rho)$ is the observed profile, $S(\rho)$ is the Sérsic fit, and $k=1$ if $|R_i| > 1\%$ while $k=0$ otherwise.



$$\mu(r) = \mu_0 + 1.067 (r/r_0)^n$$



“The Andromeda galaxy (M31)”

“The humble dwarf galaxy is one of the most interesting objects in the universe.”

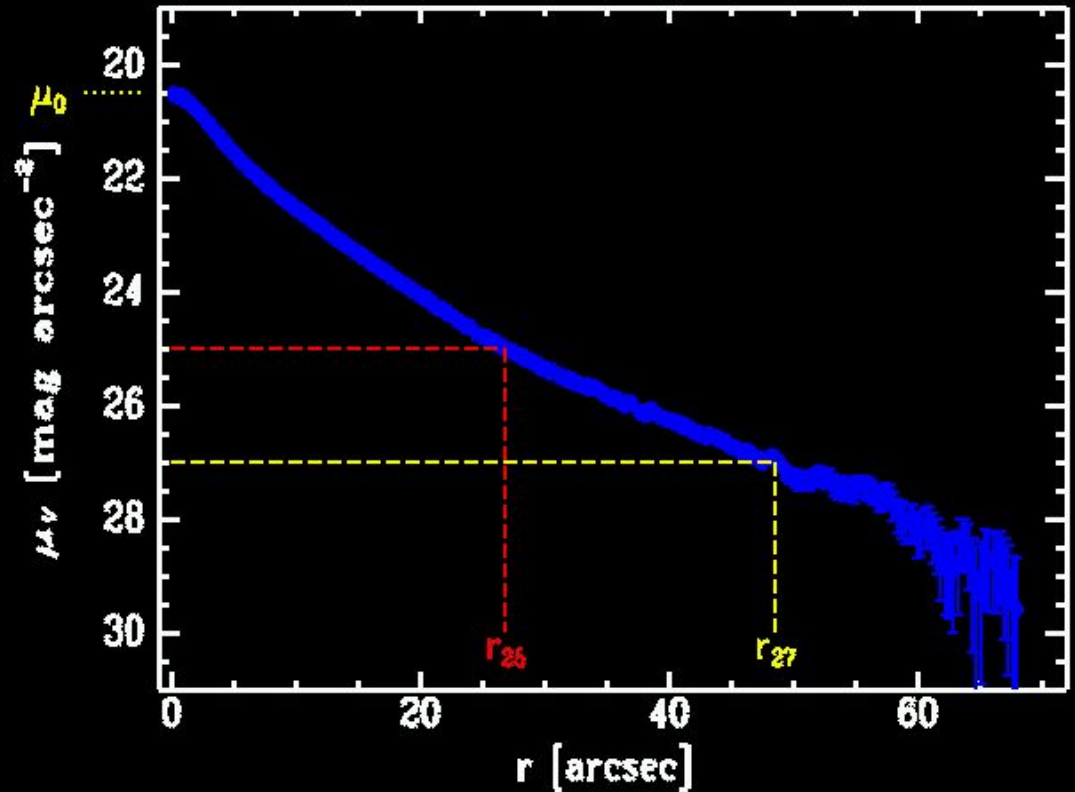
... dwarf galaxies may hold the key to many questions of galaxy formation, structure and evolution.

... dwarfs are expected to trace the mass in hierarchical theories of galaxy formation ...

Impey et al. (1988, ApJ 330, 634)

- building blocks for the formation of more massive galaxies.
- remnants of interactions.
- relatively simple systems: test benches for theories of galaxy formation and evolution of stellar populations.
- etc.

Surface brightness profiles

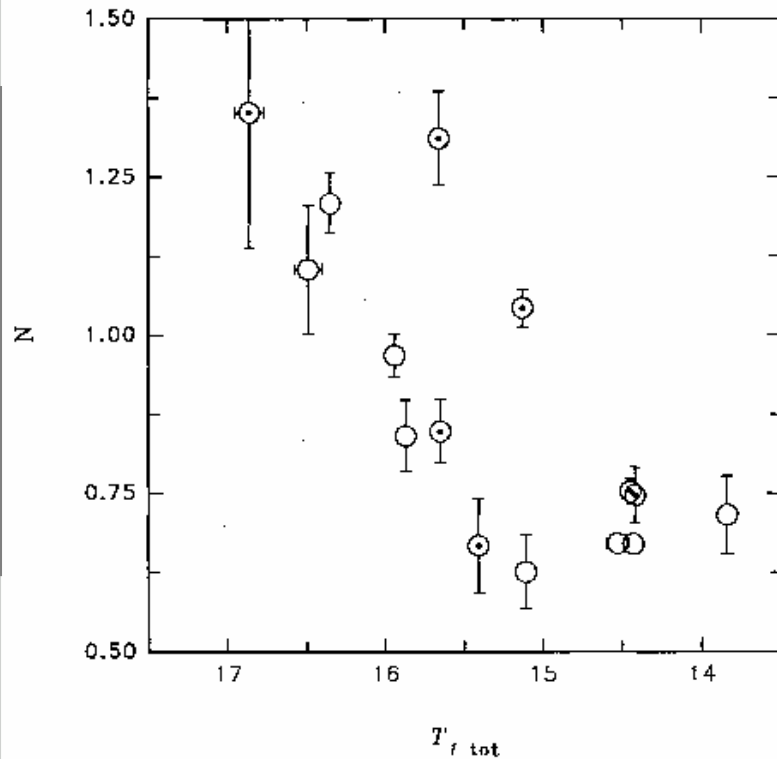


Sérsic Law:

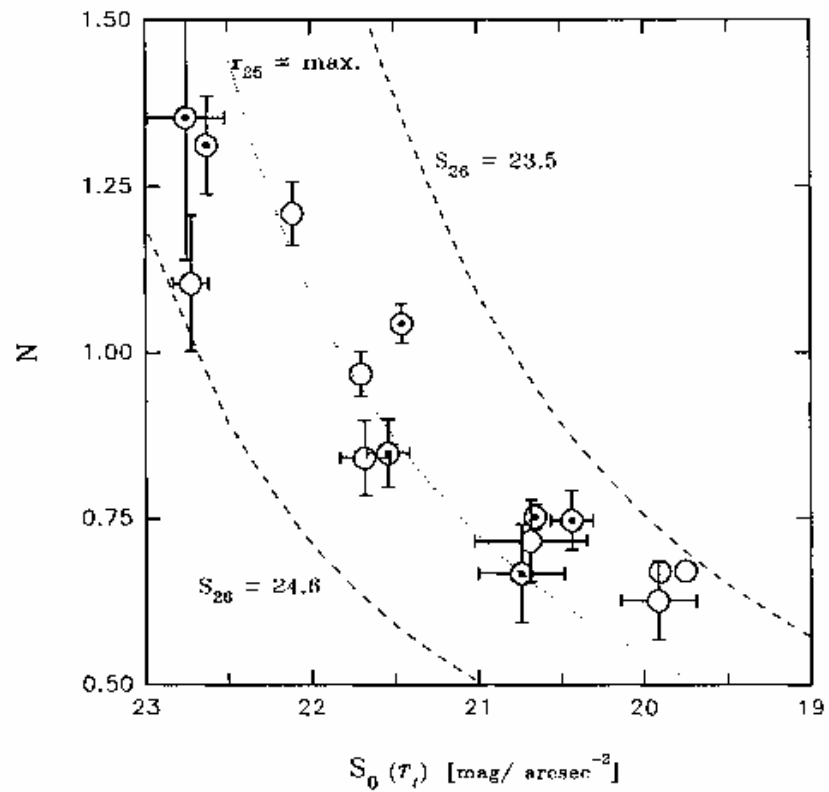
(José Luis Sérsic, 1968, *Atlas de Galaxias Australes*, Obs. Astronómico de Córdoba, Argentina)

$$\mu(r) = \mu_0 + 1.067 (r/r_0)^n$$

n (profile shape)



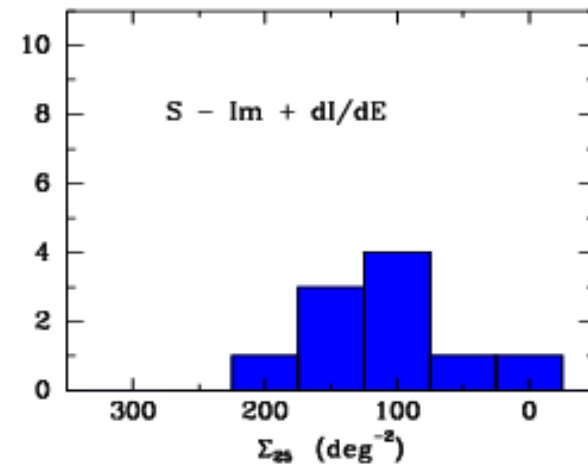
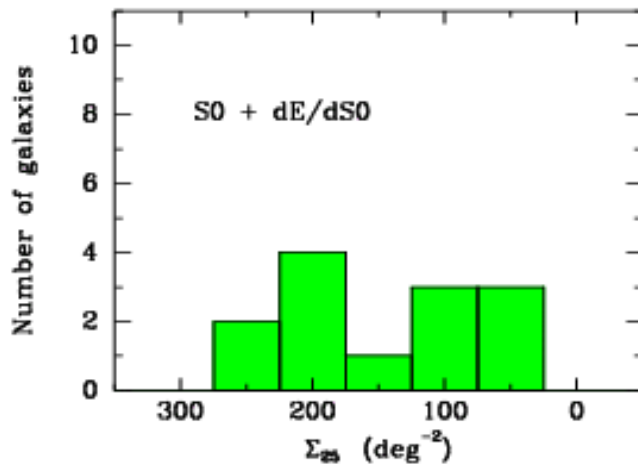
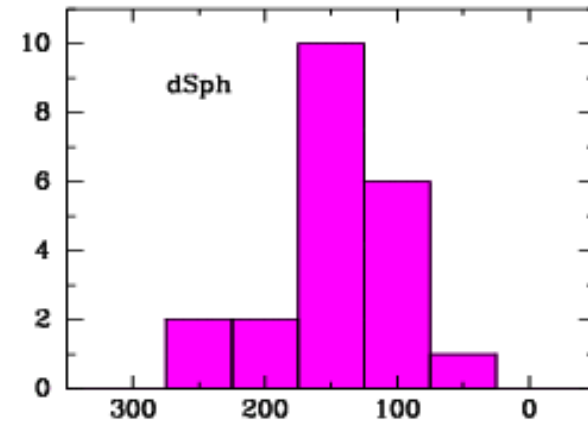
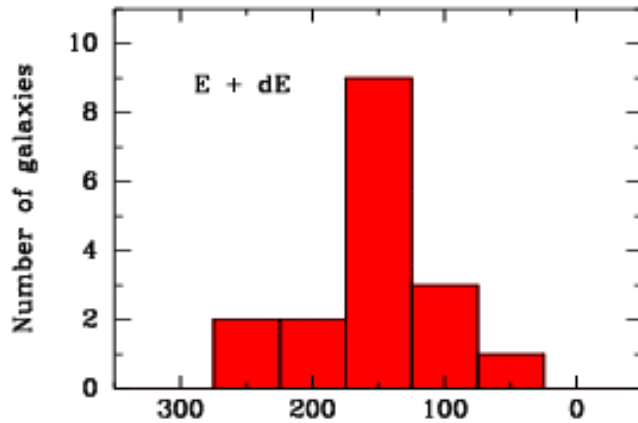
magnitude



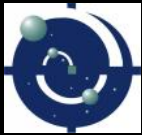
central surf. brightness

Luminosity – n (profile shape) relation

Cellone, Forte, & Geisler (1994, ApJS 93, 397)



Projected density distribution (deg^{-2}) around each galaxy.



Research Group on
Globular Clusters & Dwarf Galaxies

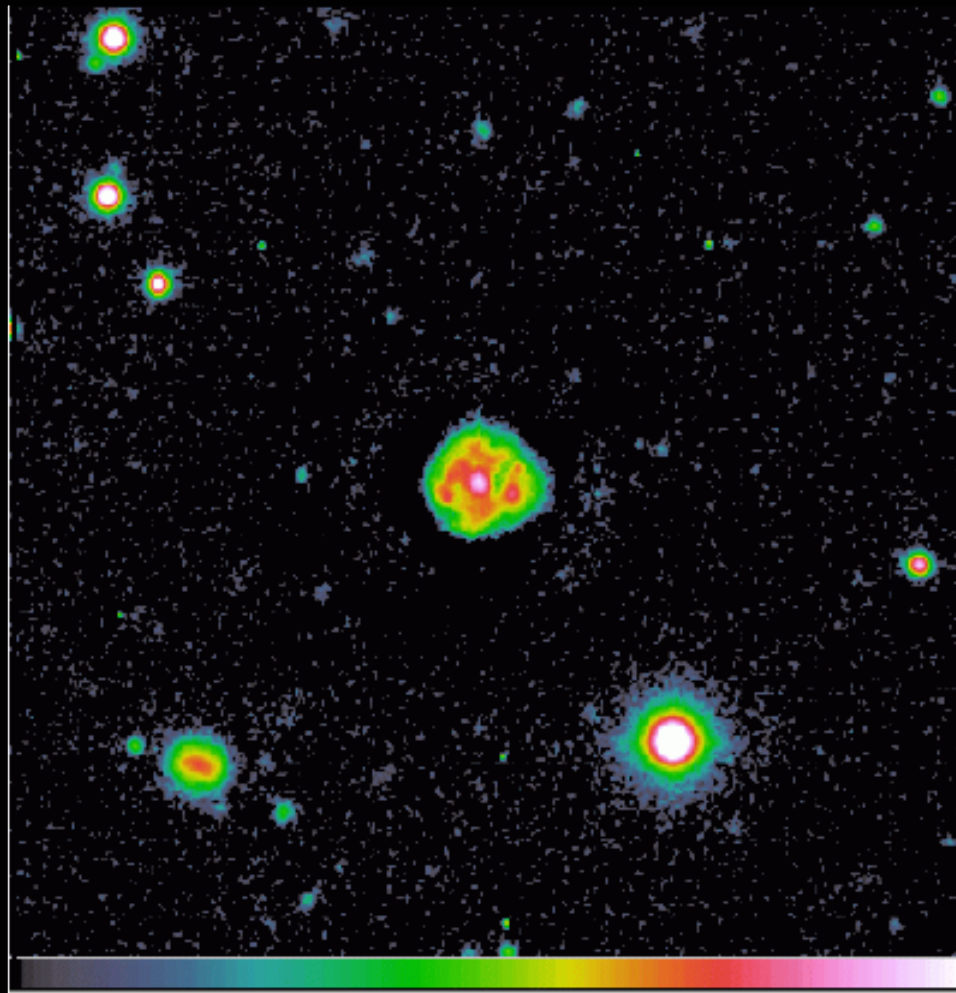
<http://www.fcaglp.unlp.edu.ar/CGGE>

Members

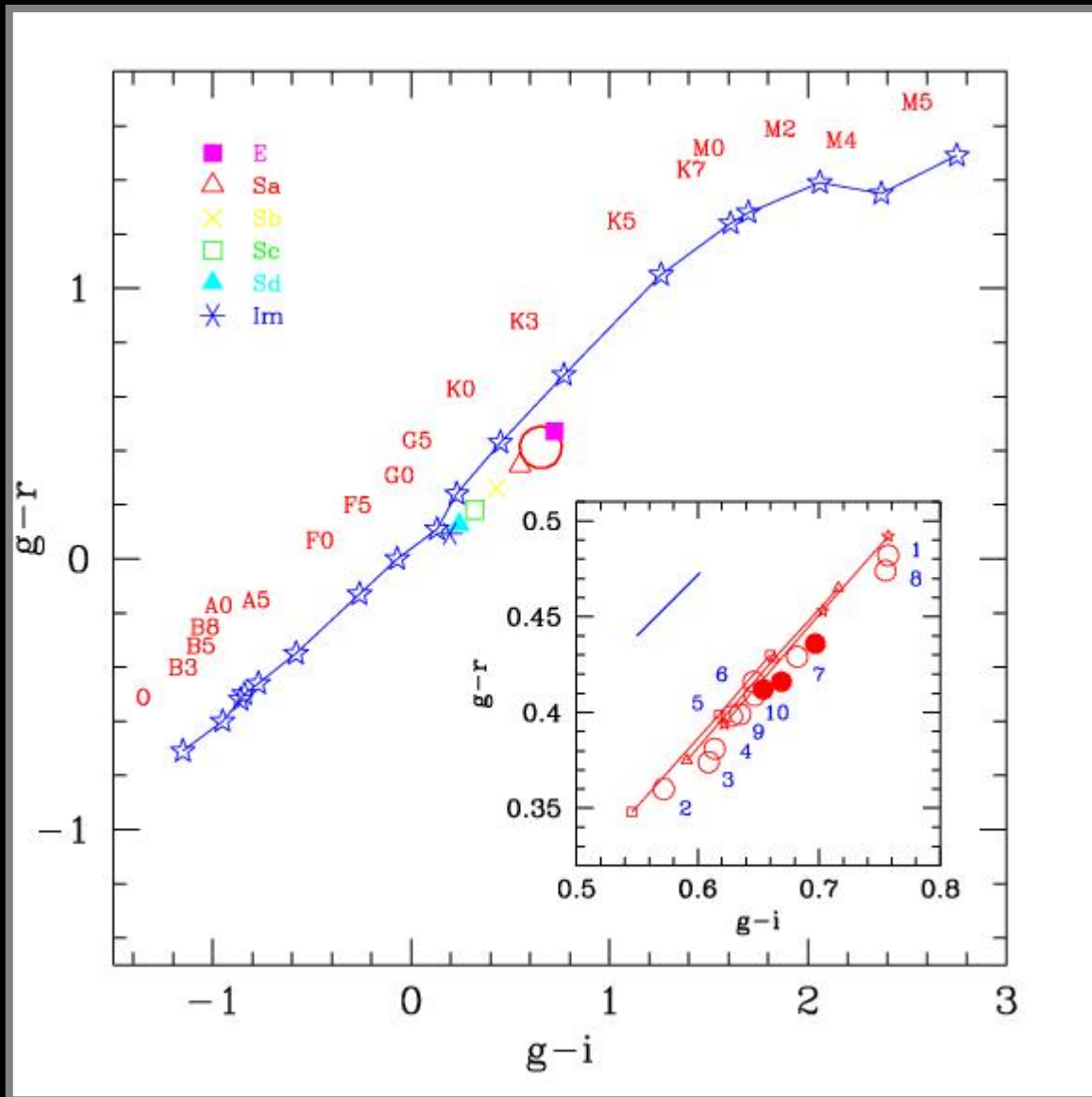
- *Dr. Juan Carlos Forte* Full Professor, UNLP – Principal Researcher, CONICET
- *Dr. E. Irene Vega* Professor, UNLP – Researcher, CONICET
- *Dr. Lilia P. Bassino* Professor, UNLP – Researcher, CONICET
- • *Dr. Sergio A. Cellone* Professor, UNLP – Researcher, CONICET
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- *Lic. Analía Smith Castelli* Lab. Assistant, UNLP – Fellow, CONICET
- *Lic. Alejandro Cifuentes* Thesist

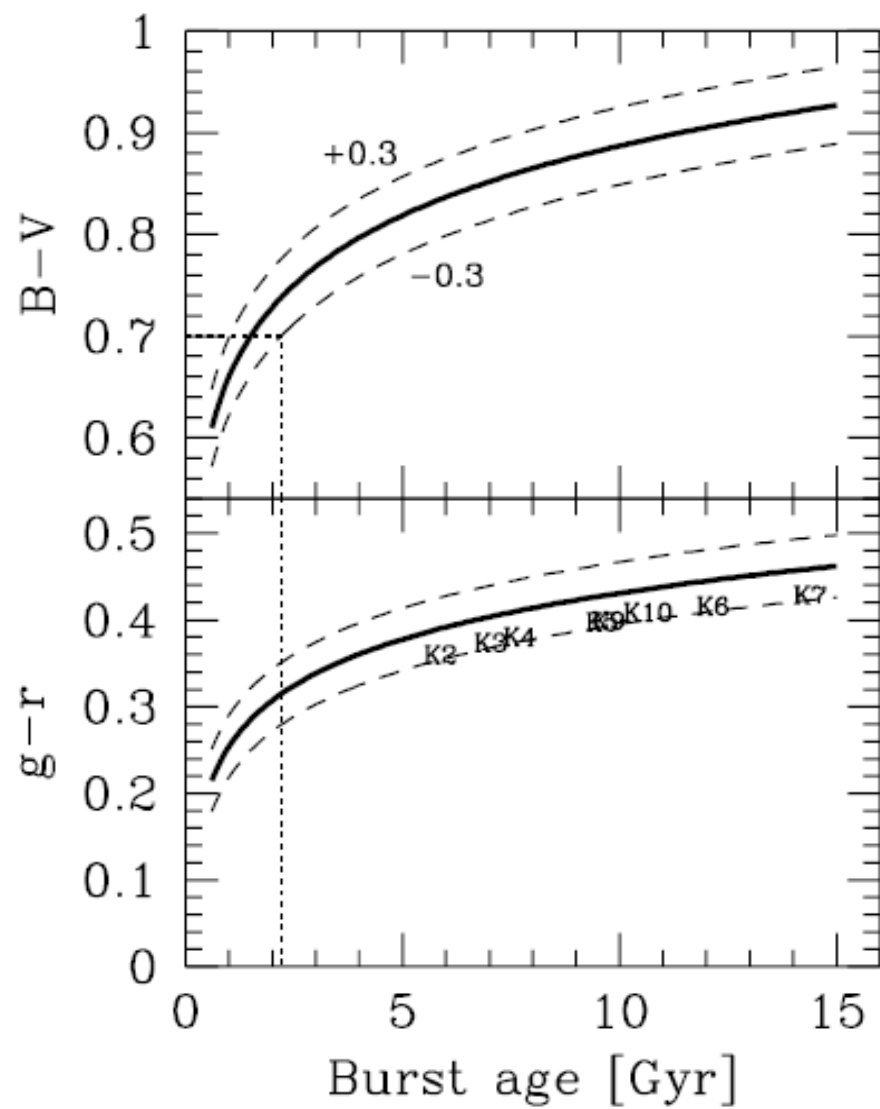
External Collaborators

- *Dr. Alberto Buzzoni* Osservatorio Astronomico di Bologna, Italia
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- *Dr. Tom Richtler* Universidad de Concepción, Chile
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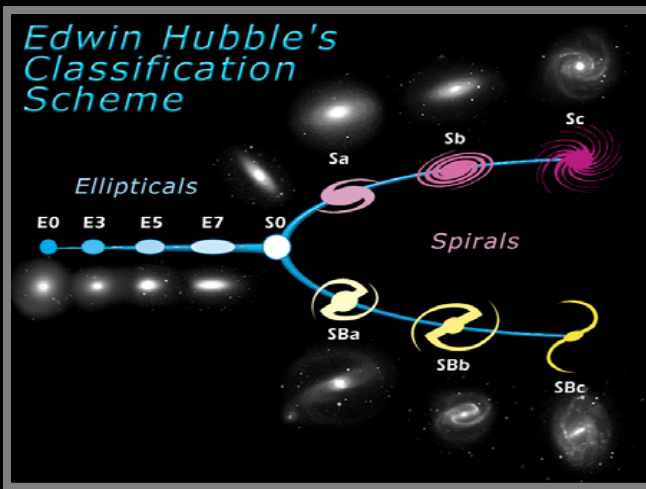


Galaxy N50, NGC5044 Group
Cellone & Buzzoni (2001, A&A 369, 742)



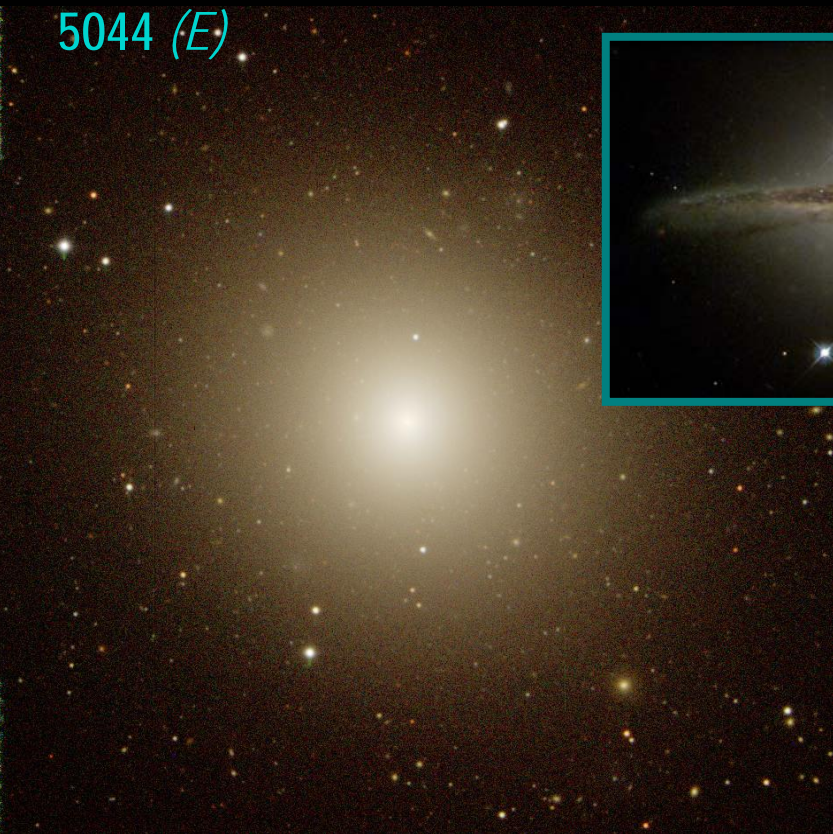


Edwin Hubble's
Classification
Scheme



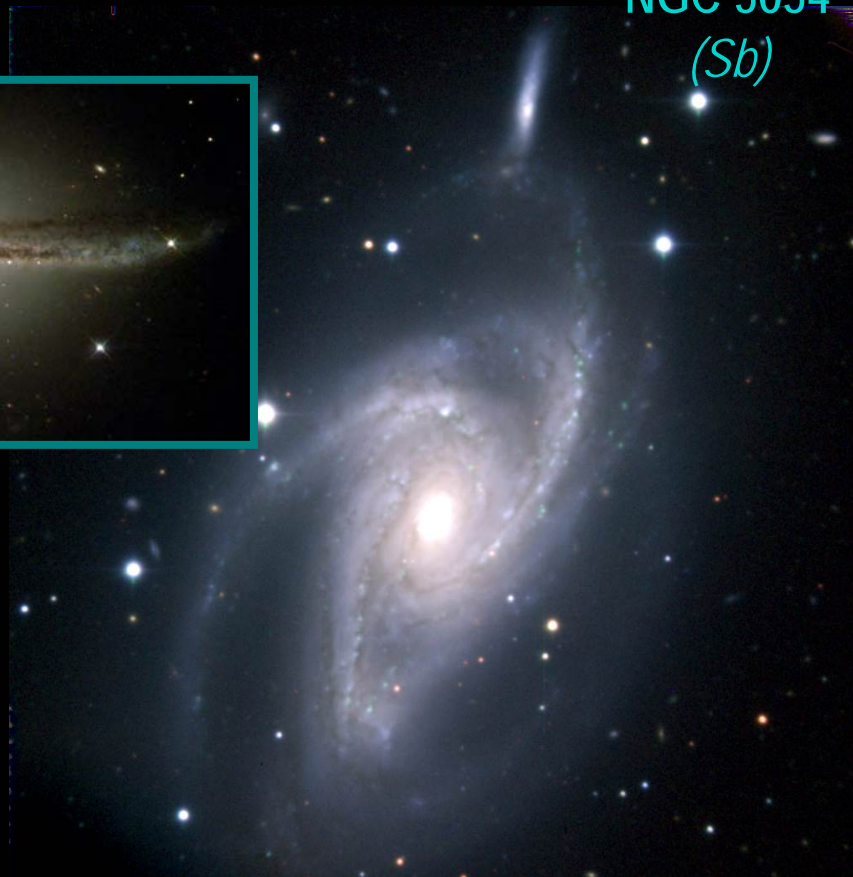
- Morphological continuity S0 / SB0 – E
(bars and disks)
(eg.: Nieto et al. 1992, A&A 257, 97)

NGC
5044 (E)



ESO 510-G13
(© HST)

NGC 5054
(Sb)



Colour — magnitude diagram

Dashed-line: Coma Cluster dwarfs (Secker et al. 1997, PASP 109, 1377).
Open symbols: background objects.

