Lenticular galaxies of the Local Universe: Effect of environments

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What is lenticular galaxies?

- De Vaucouleurs, G., in Handbuch der Physik, v. 53, pp.275-310, 1959:

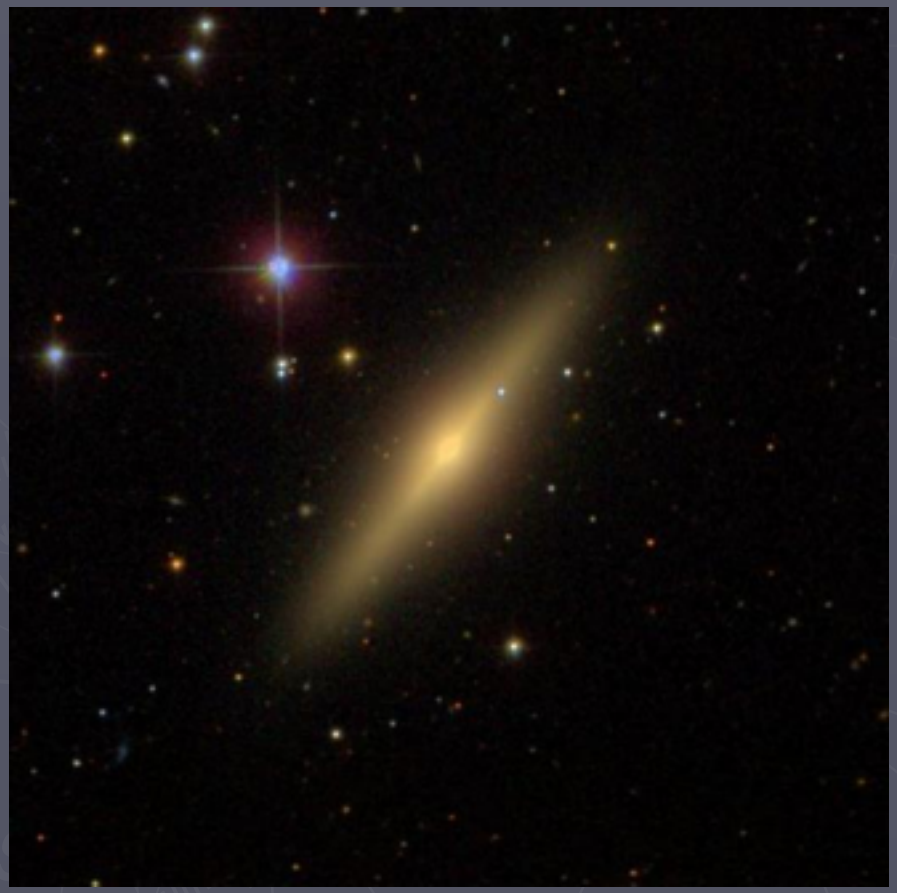
Referring ('courtesy of') to A. Sandage collecting the notes by Hubble after 1935: "S0 objects have the smooth appearance of ellipticals, but a luminosity distribution more like that of spirals, although no spiral arms are visible…"

Hubble distinguished two groups of S0s:

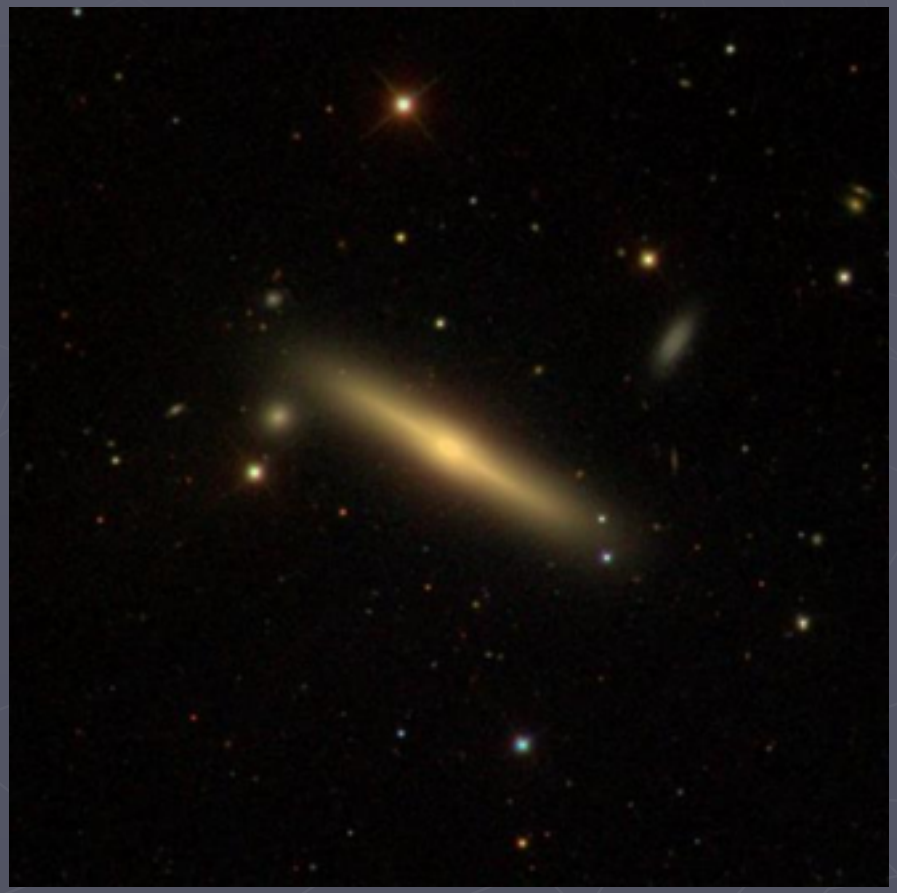
S0(1): smooth lens and envelope;

S0(2): some structure in the envelope in the form of a dark zone and ring.

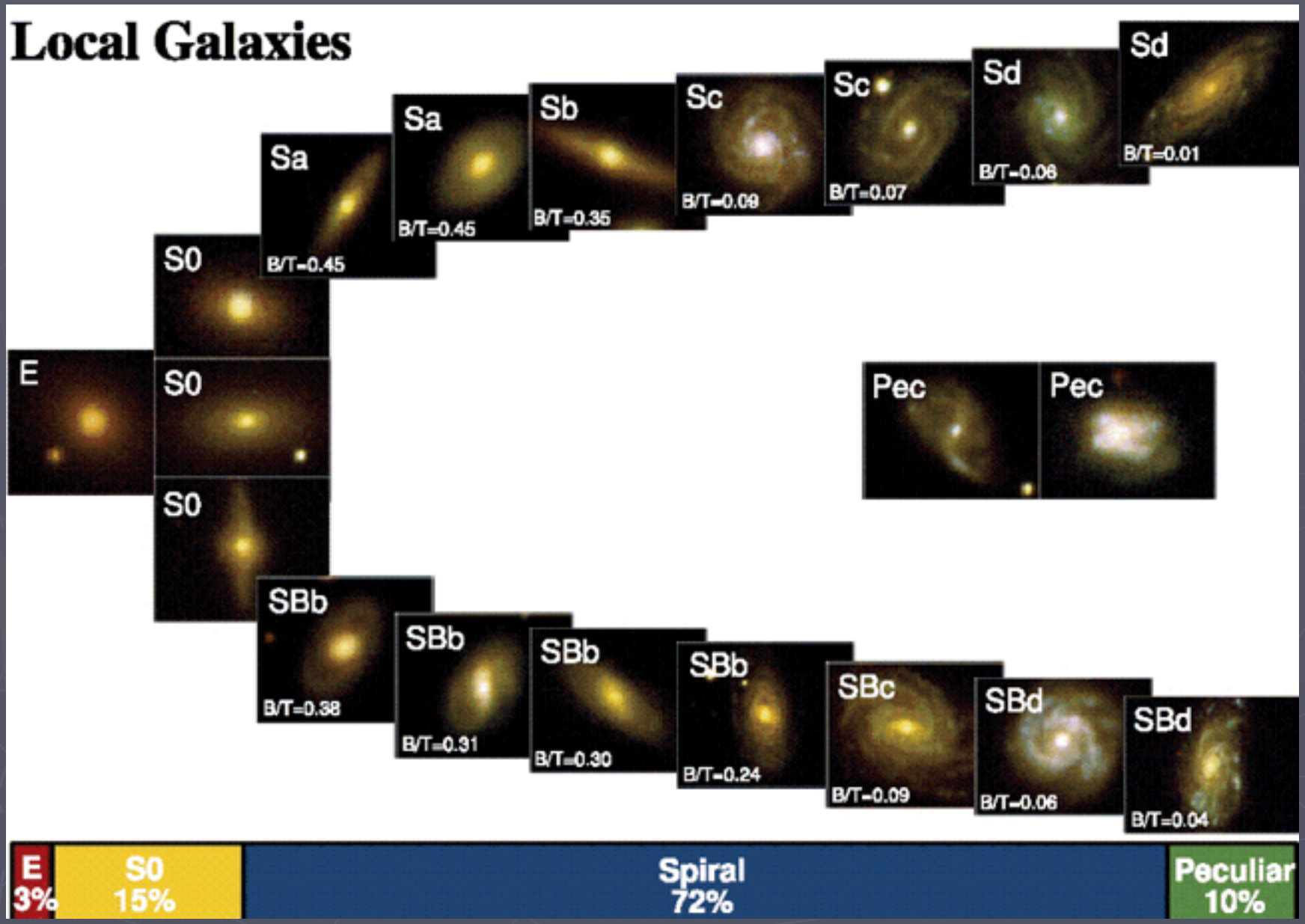
S0: red disks, ANY-sized bulges



NGC 4179



NGC 5308


Local Galaxies
E
S0
S0
S0
Sa
B/T=0.45
Sa
B/T=0.45
Sb
B/T=0.35
Sc
B/T=0.09
Sc
B/T=0.07
Sd
B/T=0.06
Sd
B/T=0.01
Pec
Pec
SBb
B/T=0.38
SBb
B/T=0.31
SBb
B/T=0.30
SBb
B/T=0.24
SBc
B/T=0.09
SBd
B/T=0.06
SBd
B/T=0.04
E
3%
S0
15%
Spiral
72%
Peculiar
10%

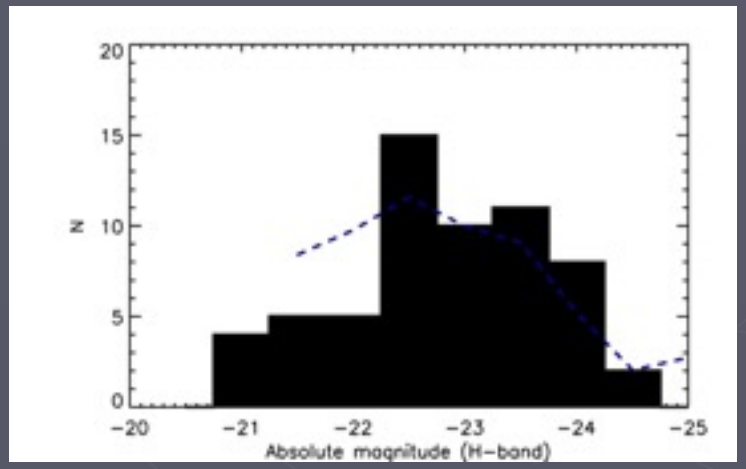
Observations

- Multi-band photometry: LCO robotic 1m telescope network (Cerro Tololo, Sutherland, Siding Spring, MacDonald…)
- SDSS-filters g and r, exposure times 900x3 (g) and 600x3(r) s
- 26 arcminute field of view, seeing 1.2” to 2.5”, 0.39”/px
- Long-slit spectroscopy: SALT/RSS and BTA/ Scorpio

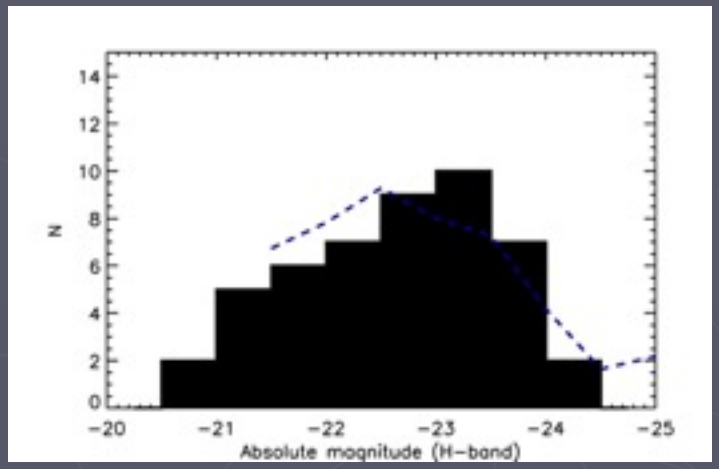
Sample

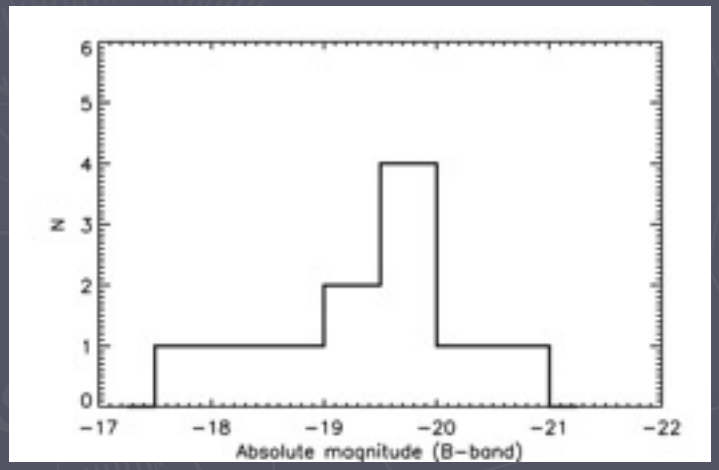
- Photometry: 60 S0 galaxies in the clusters (Fornax, Hydra, Centaurus, Antlia, …) and 42 isolated S0s (II>2.5) – Silchenko, Kniazev, Chudakova (2018, 2019) .
- Long-slit spectroscopy: 23 S0 galaxies in the (same) clusters and 20 isolated S0s – Silchenko et al. in preparation, Katkov et al. (2014, 2015).
- Honestly, only the isolated S0 sample is sampled within the Local Universe (v_r <4000 km/s); the clusters are up to D=70 Mpc.

Samples

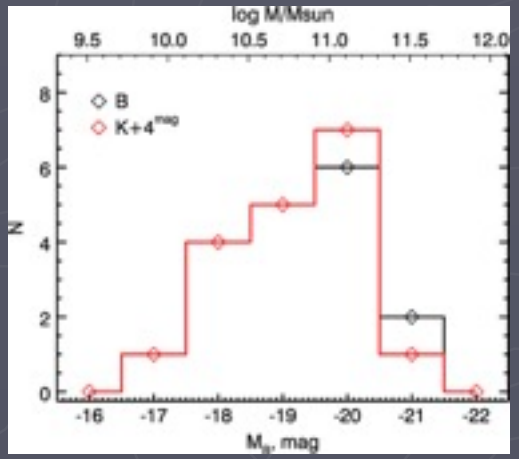


Photo





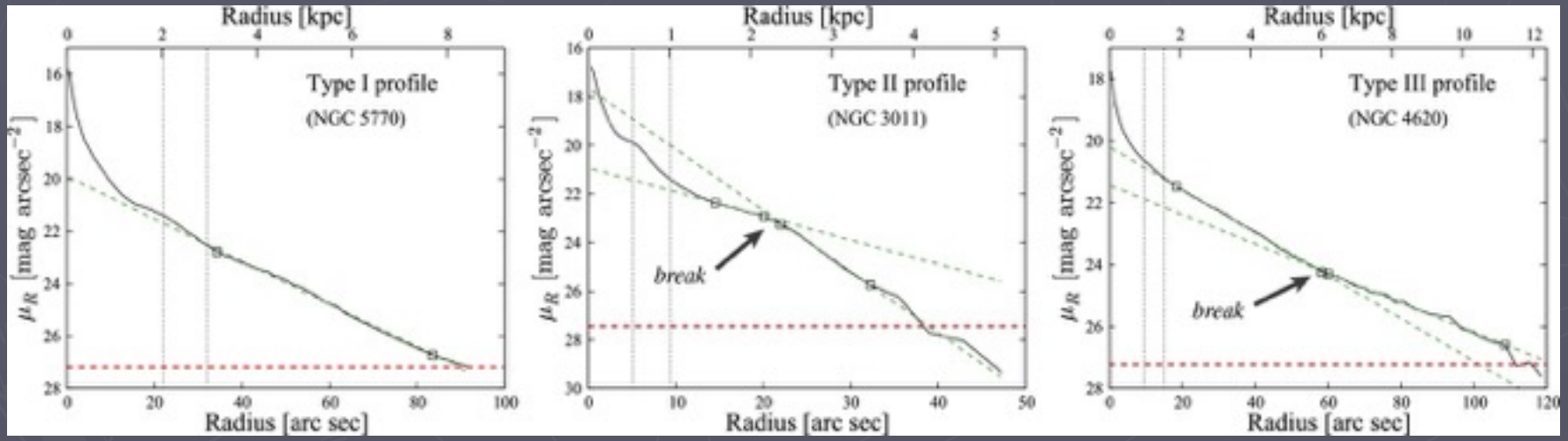
Spectro



Clusters

Isolated

Photometry: radial structure

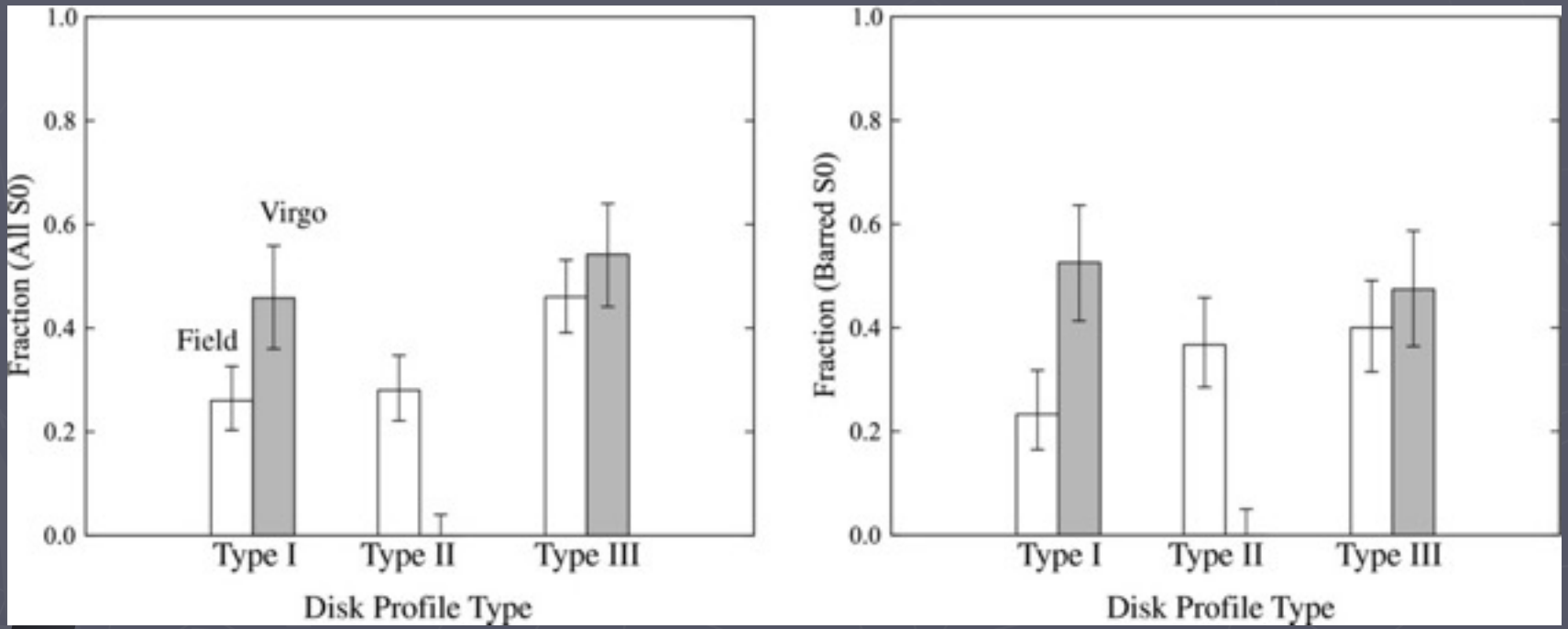


Erwin et al. 2012

Origin of different radial-profile types

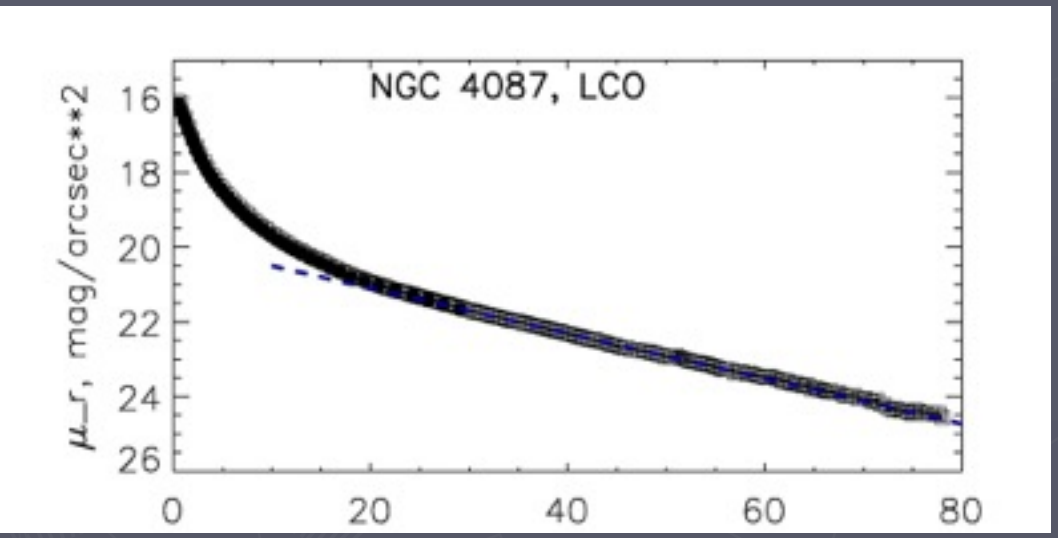
- Initial conditions or evolution?
- Struck & Elmegreen (2017): initially exponential gaseous disks, then stellar disks keep the shape.
- Evolution: I type → III type, Younger et al. (2007) – pure stellar dynamics.
- Evolution: II type → I type, Clarke et al. (2017) – gaseous dynamics, dense environments.

Radial profiles differ in the field and in clusters



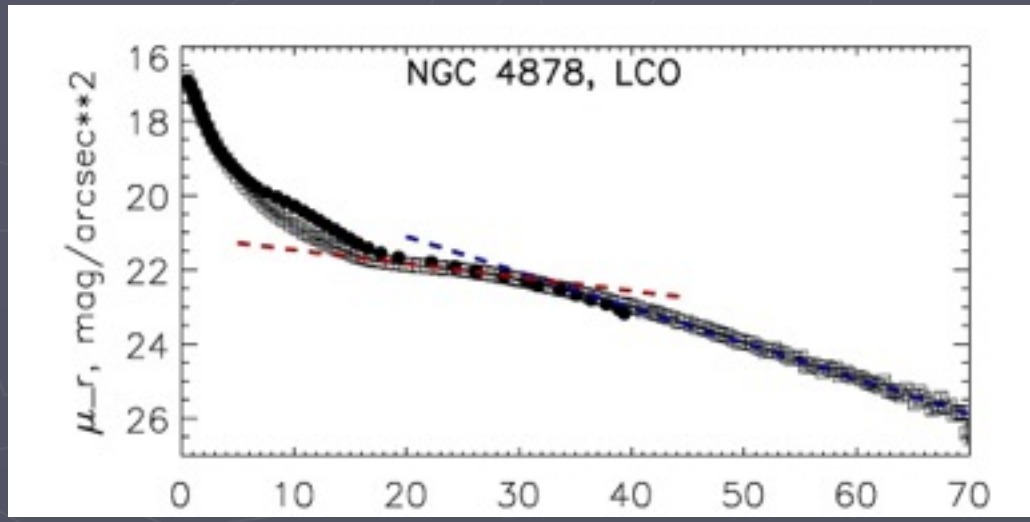
Erwin et al. 2012, 24 S0 in the Virgo cluster

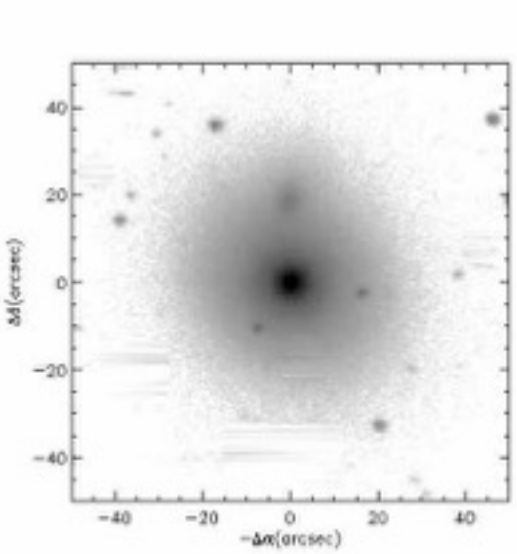
Our analysis of the radial profiles

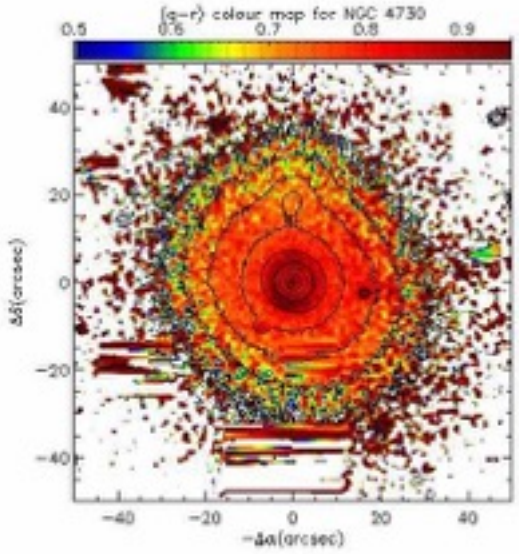


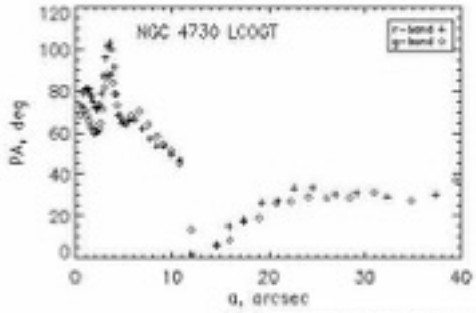
Single-scale exponential profile

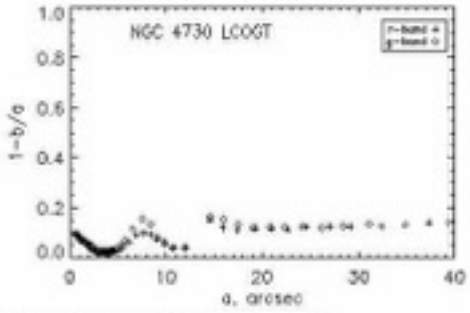
- Truncated profiles, Type II

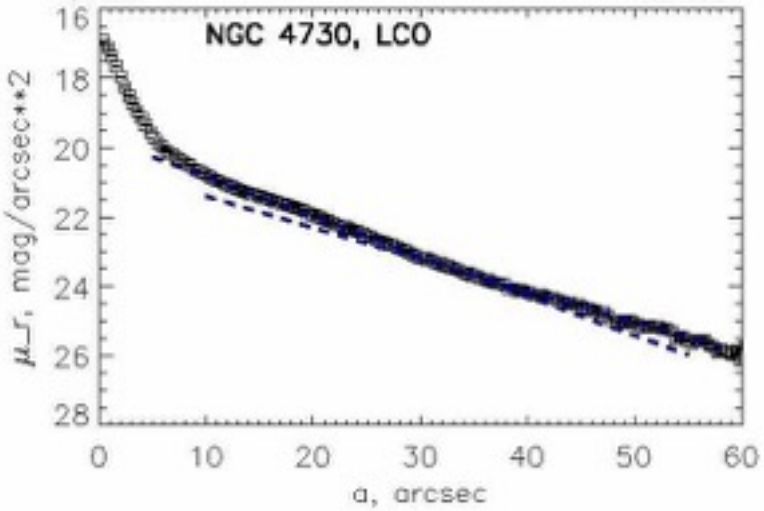



Δδ(arcsec)
−Δα(arcsec)


(g−r) colour map for NGC 4730
0.5
0.6
0.7
0.8
0.9
Δδ(arcsec)
−Δα(arcsec)


NGC 4730 LCOGT
r−band +
g−band ○
PA, deg
a, arcsec


NGC 4730 LCOGT
r−band +
g−band ○
1−b/a
a, arcsec


NGC 4730, LCO
μ_r, mag/arcsec**2
a, arcsec

Radial profile type proportions:

Clusters:

- Type I – 45% +/- 6% (46%+/-10% Virgo after Erwin et al. 2012);
- Type II – 5%+/-3% (0%+/-4% Virgo after Erwin et al. 2012).

Isolated:

- Type I – 28%+/-7% (26%+/-6% Erwin+ in the field).
- Type II – 17%+/-6% (28%+/-6% Erwin+ in the field).
- SO THERE IS AN EFFECT OF ENVIRONMENT!

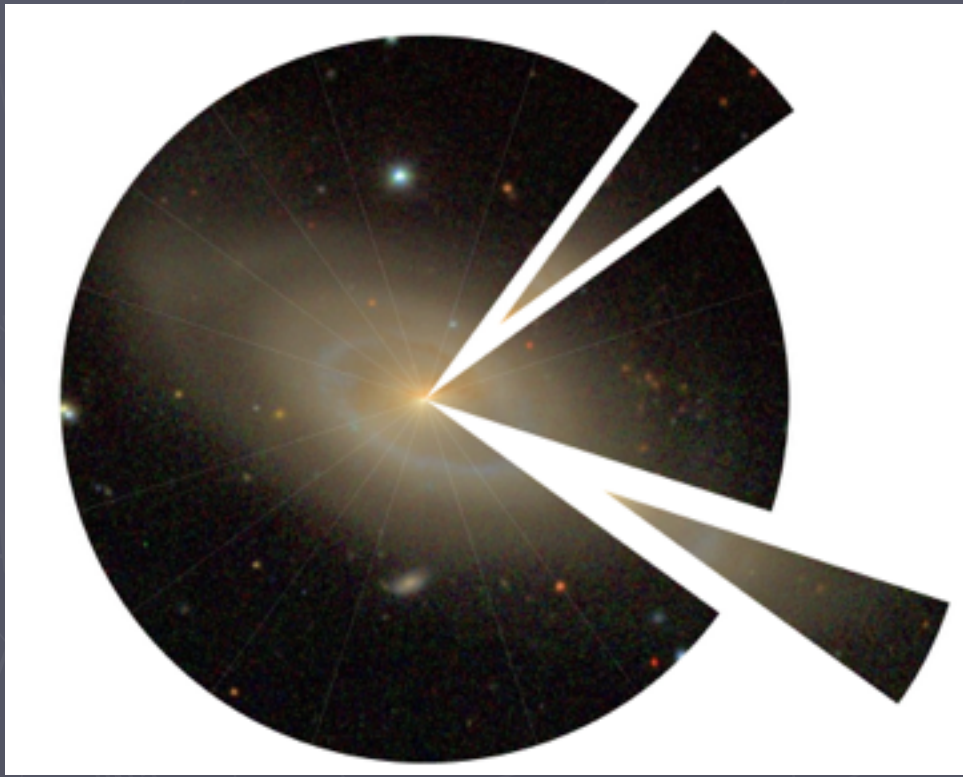
Inclination of a thick round disk:

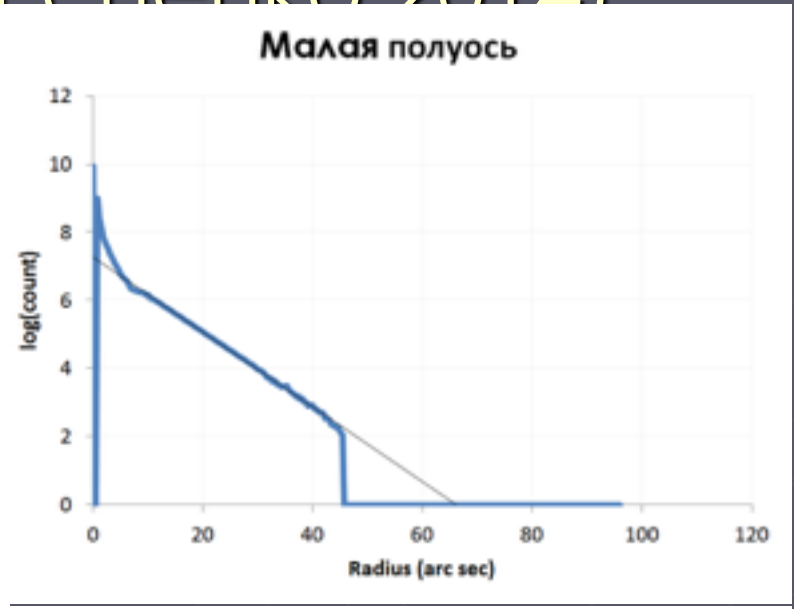
$$\sin^2 i = \frac{1-(b/a)^2}{1-q^2}$$

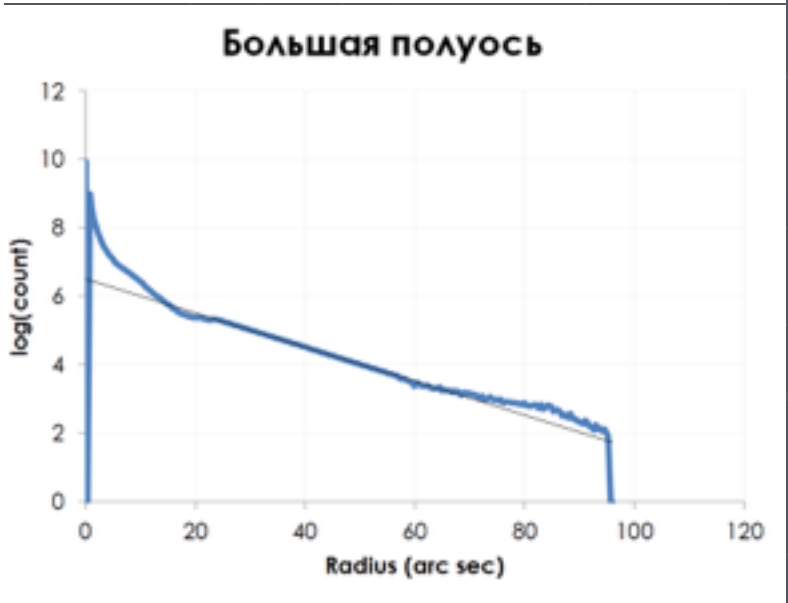
where b/a – the isophote axis ratio,

q – the relative thickness of a disk (in terms by E. Hubble 1926)

New approach to determine inclination (Chudakova and Sil'chenko 2014)







By confronting isophote ellipticity and ellipticity of the h azimuthal distribution:

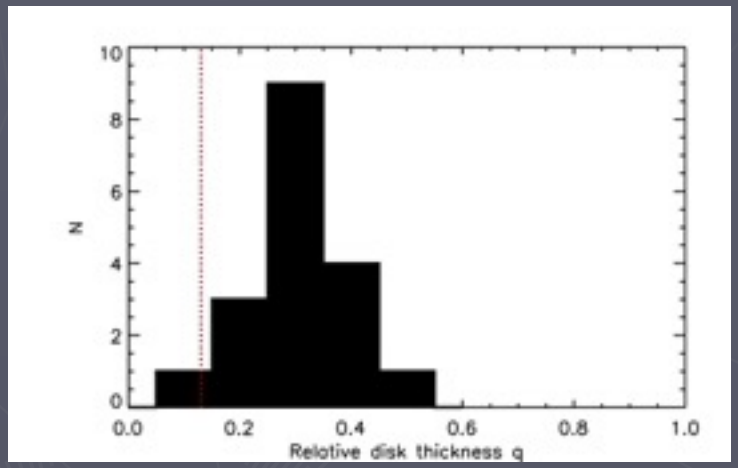
$$q = \sqrt{1 - \frac{2e_I - {e_I}^2}{2e_h - {e_h}^2}}$$

- Относительная толщина диска вычисляется из соотношения эллиптичности изофоты и масштабного коэффициента

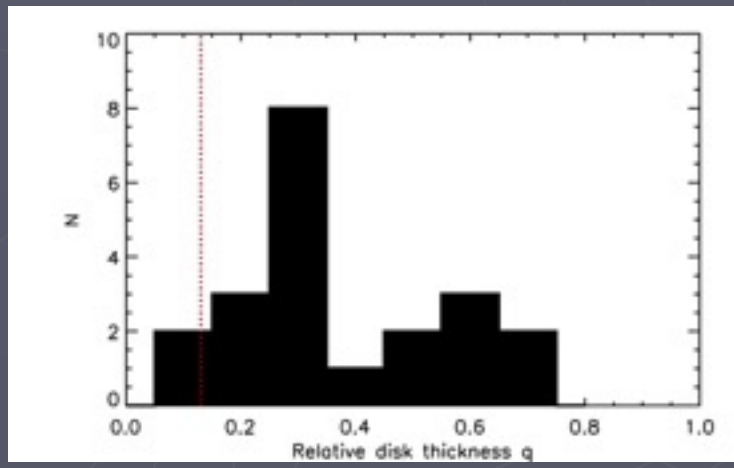
To compare disk thicknesses in S0s in clusters and isolated ones

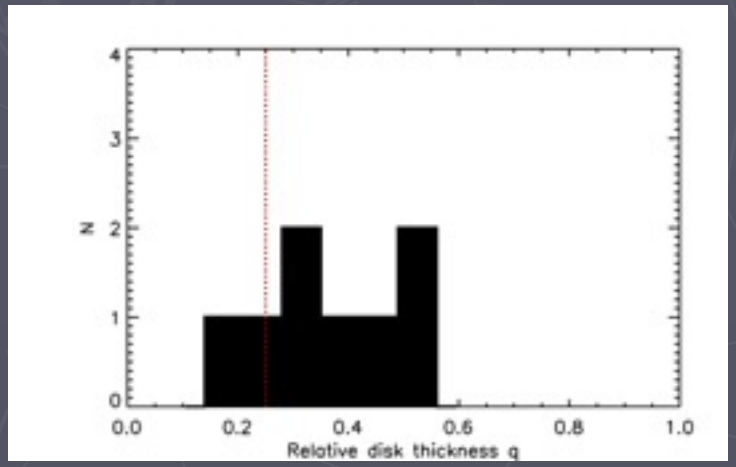
Type I

Type III

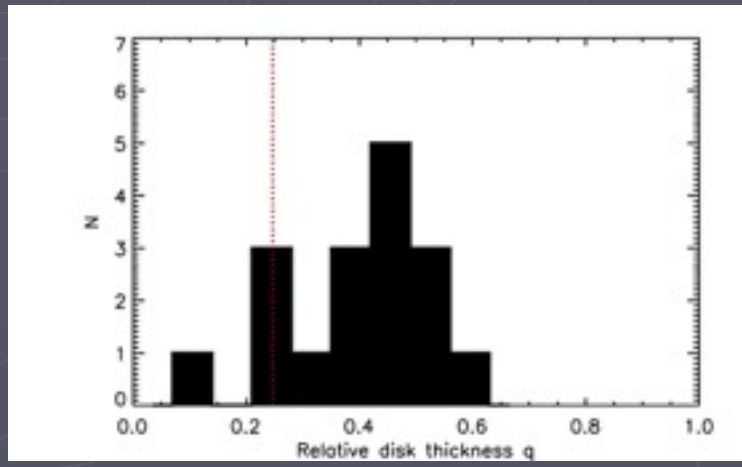


Clusters





Isolated

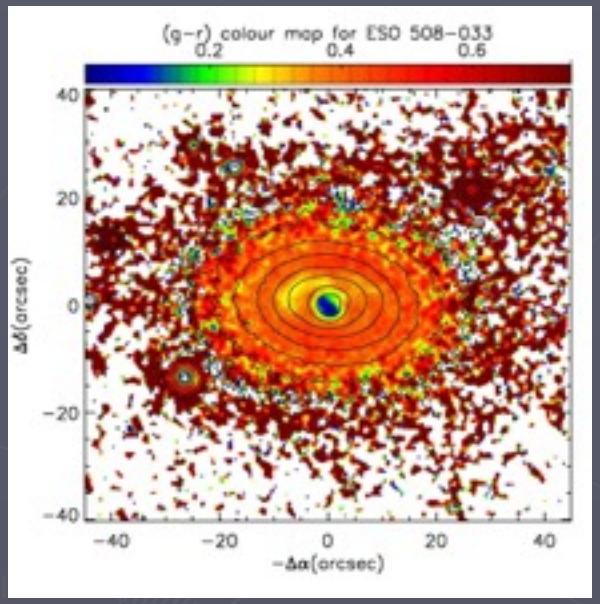


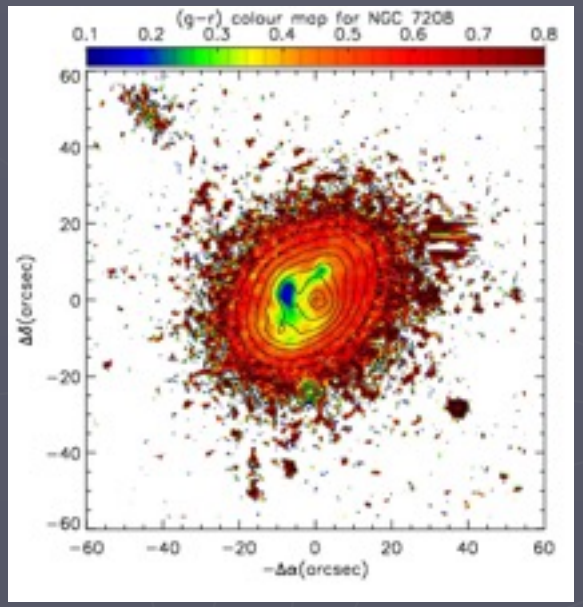
(red vertical lines – inner segments of the Type II type)

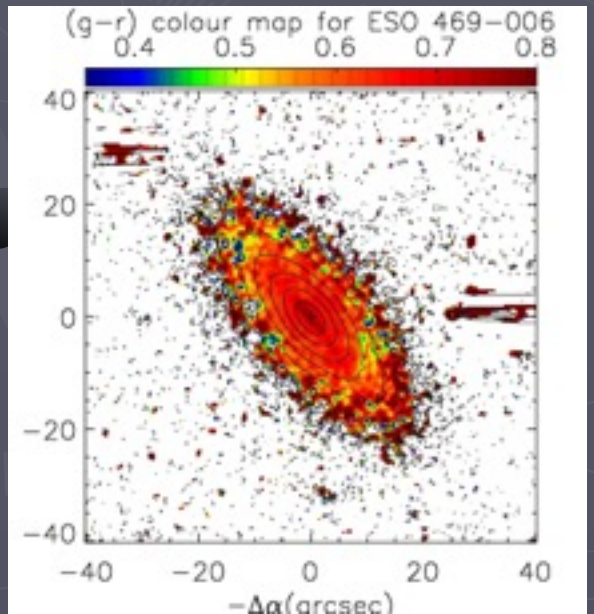
Environment effect:

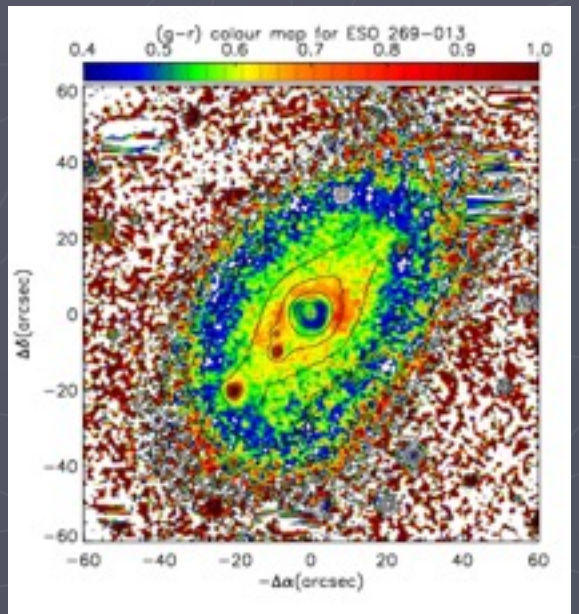
- Isolated S0 are thicker than those in clusters!
- Clarke et al. (2017) dynamical evolution: no cluster (tidal or ram pressure) effect on the disk thickness.
- Accretion?

Many blue details inside the isolated S0s

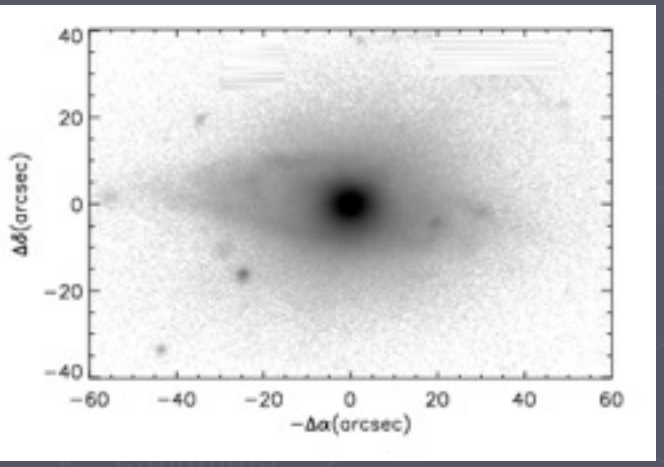




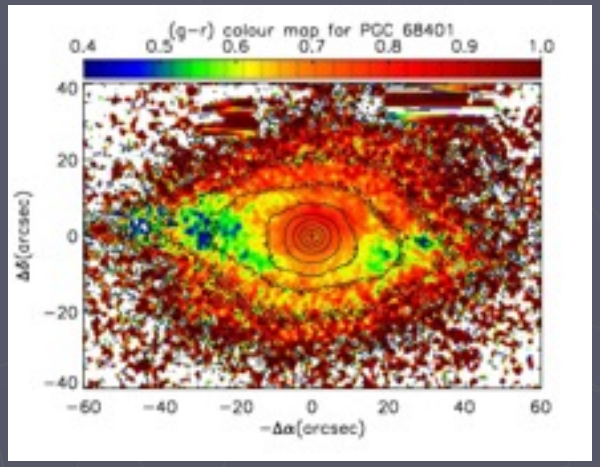




(Minor)merger features in the isolated S0s



PGC 68401

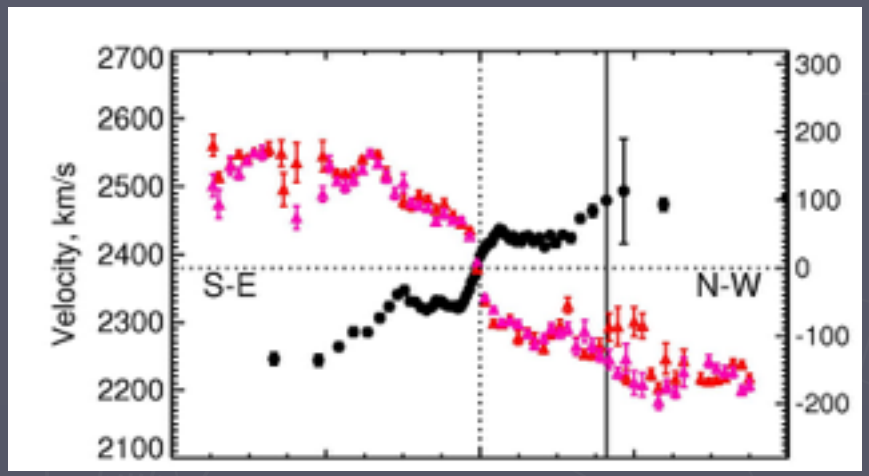


SDSS composite

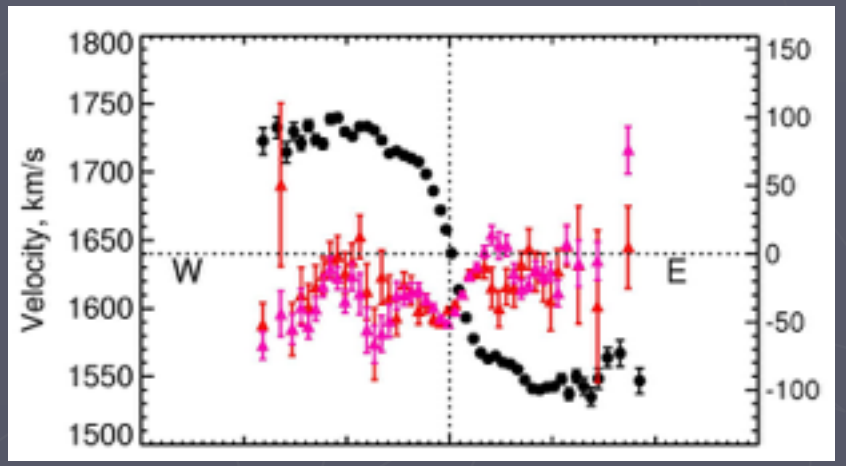
NGC 270

NGC 6014

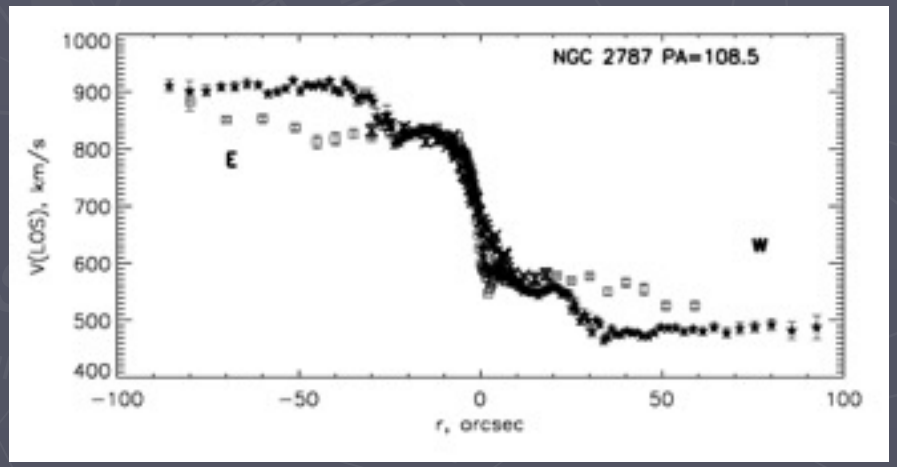
Spectral features of accretion in the isolated S0s: counterrotating or polar gas (Katkov et al.2014,2015)

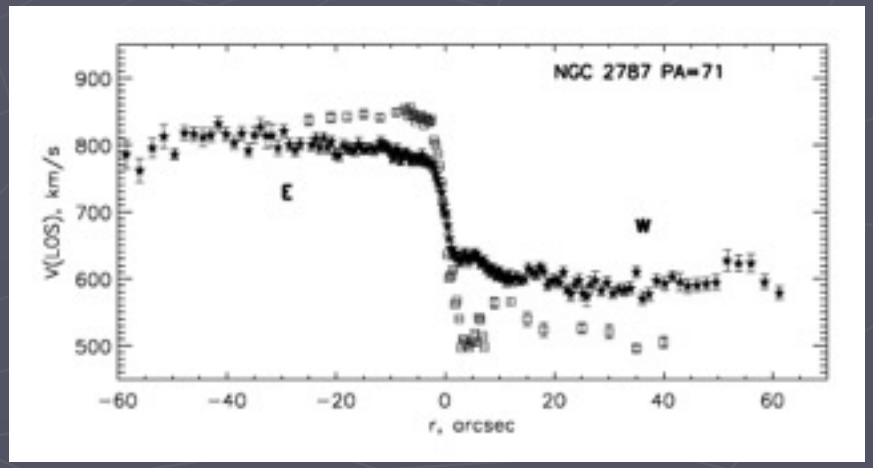


NGC 6798

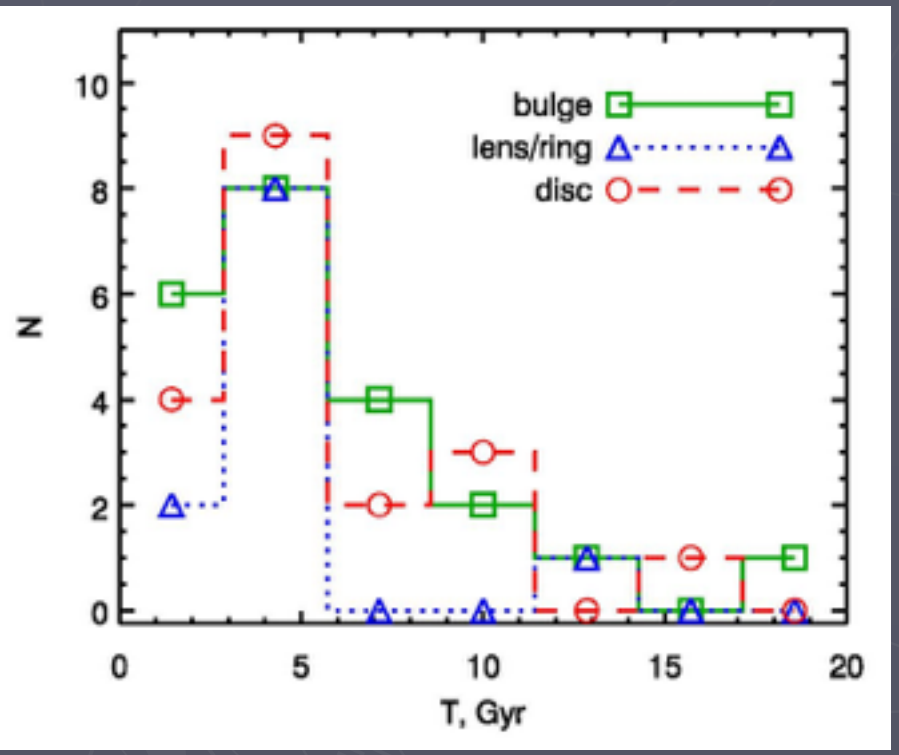


UGC 9519

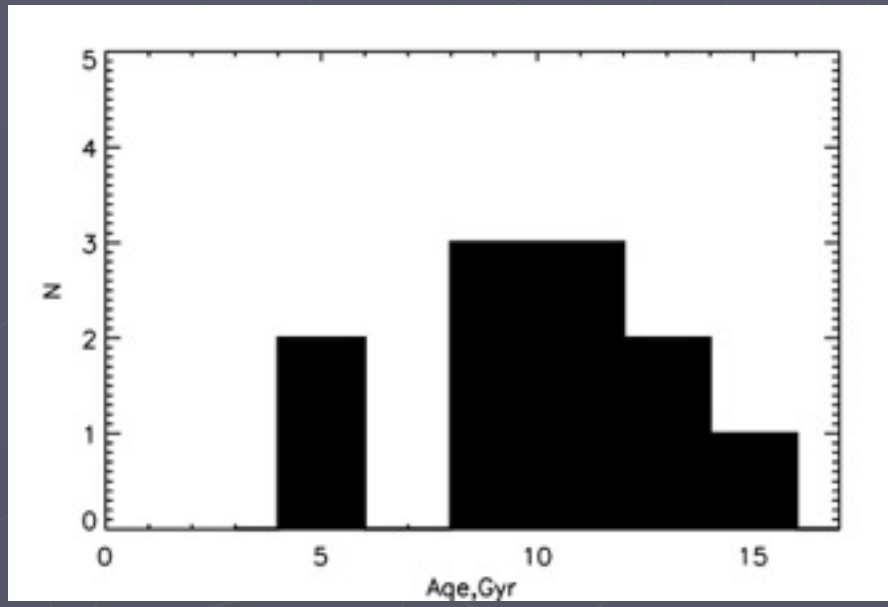




Spectral features of accretion in isolated S0s: disk age distributions



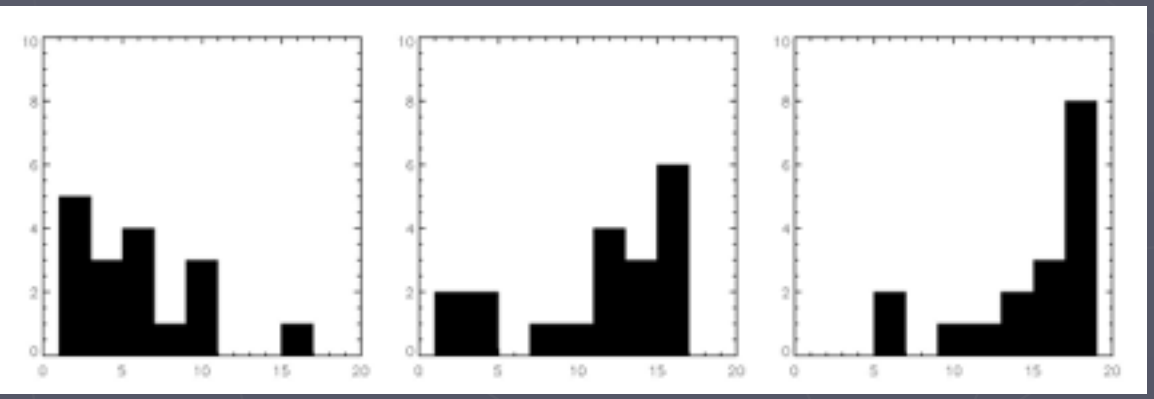
VS



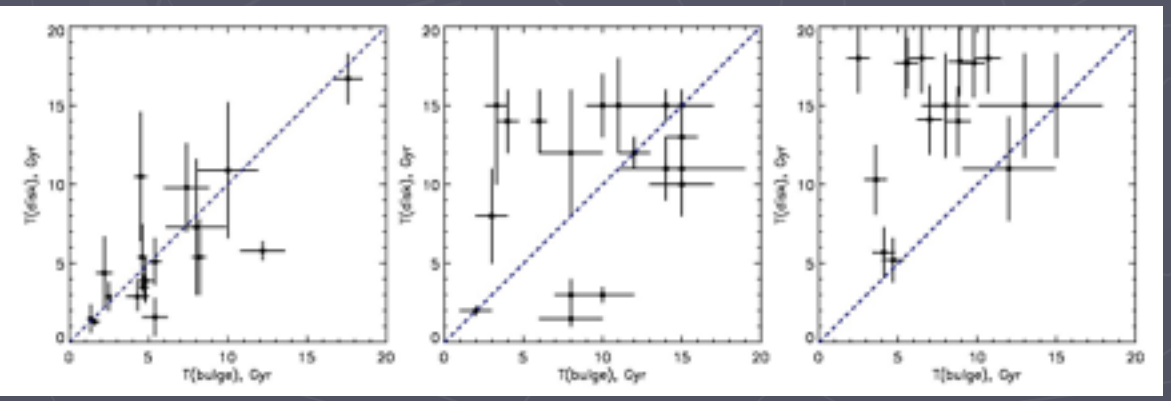
Isolated

Nearby clusters

Disks are even older than the bulges among the S0s in dense environments



Isolated In groups Virgo



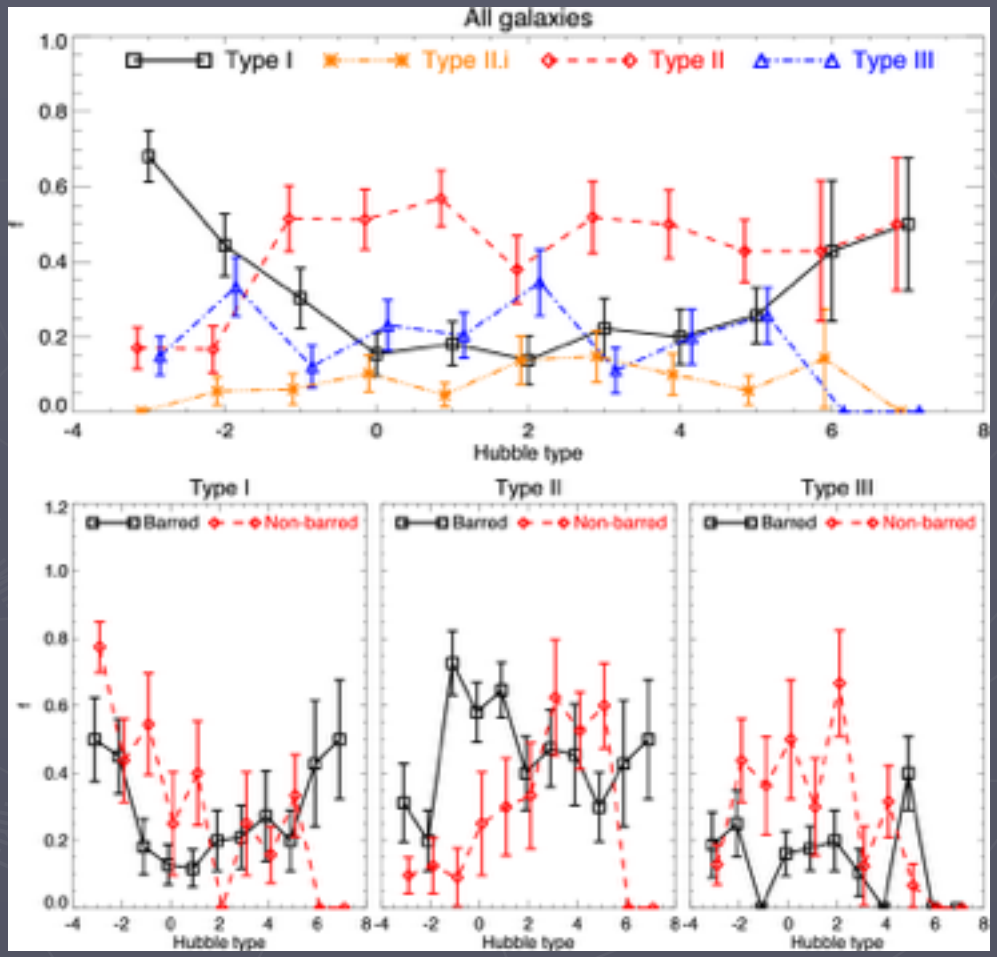
- Three samples:
- Isolated S0s (Katkov, Kniazev, Sil'chenko 2015);
- S0s in rich groups (Sil'chenko et al. 2012 and after that);
- - S0s in Virgo (Johnston et al. 2014 + 4 S0s observed with the SCORPIO-2).

S0 evolution in different environments:

- After initial star formation in the disks at z~2, any quenching –> thick stellar disks with the present ages > 10 Gyr.
- In clusters, there is no outer gas accretion → old stellar disks remain intact.
- In the field, accretion of outer cold gas is common → secondary star formation in the disks (in rings).
- Minor merging → disk thickening (e.g.Walker et al. 1996).


N
NW
NE
W
E
S
SE

Пропорции типов у галактик поля



Laine et al. 2014

(S4G)