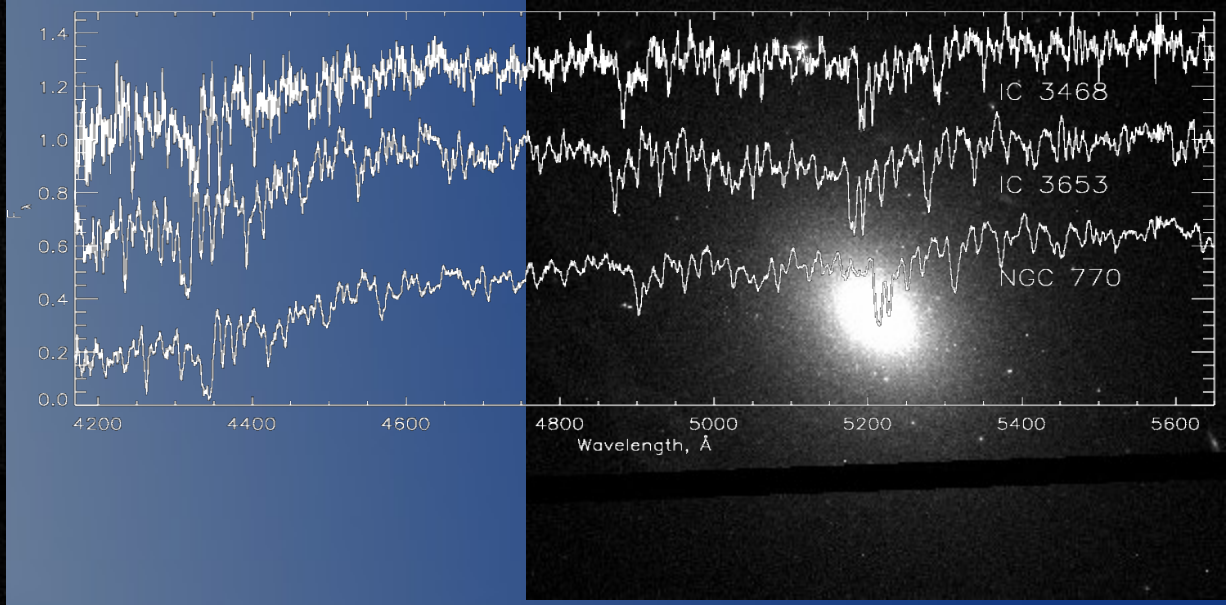
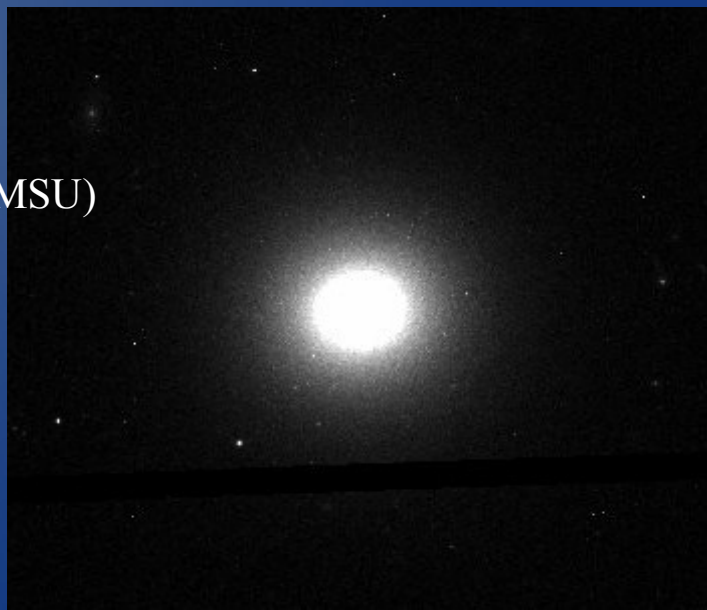


Discs in dwarf early-type galaxies



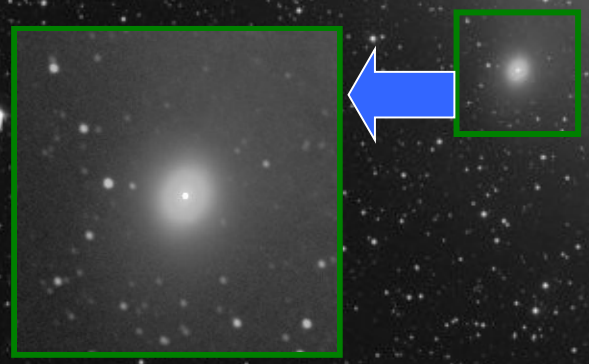
Igor Chilingarian
(Observatoire de Strasbourg / SAI MSU)

Dwarf early-type galaxies: historical prospective

M31 satellites (Baade 1944)

- NGC205: prototypical dE
- M32: prototypical cE

dE is the numerically dominant galaxy type in nearby clusters



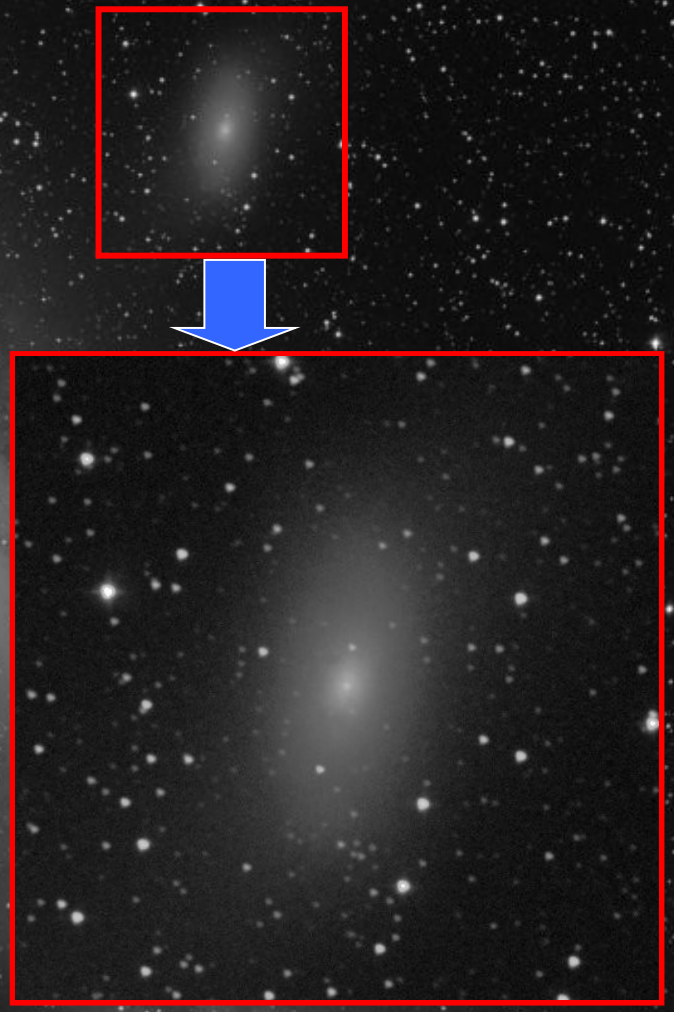
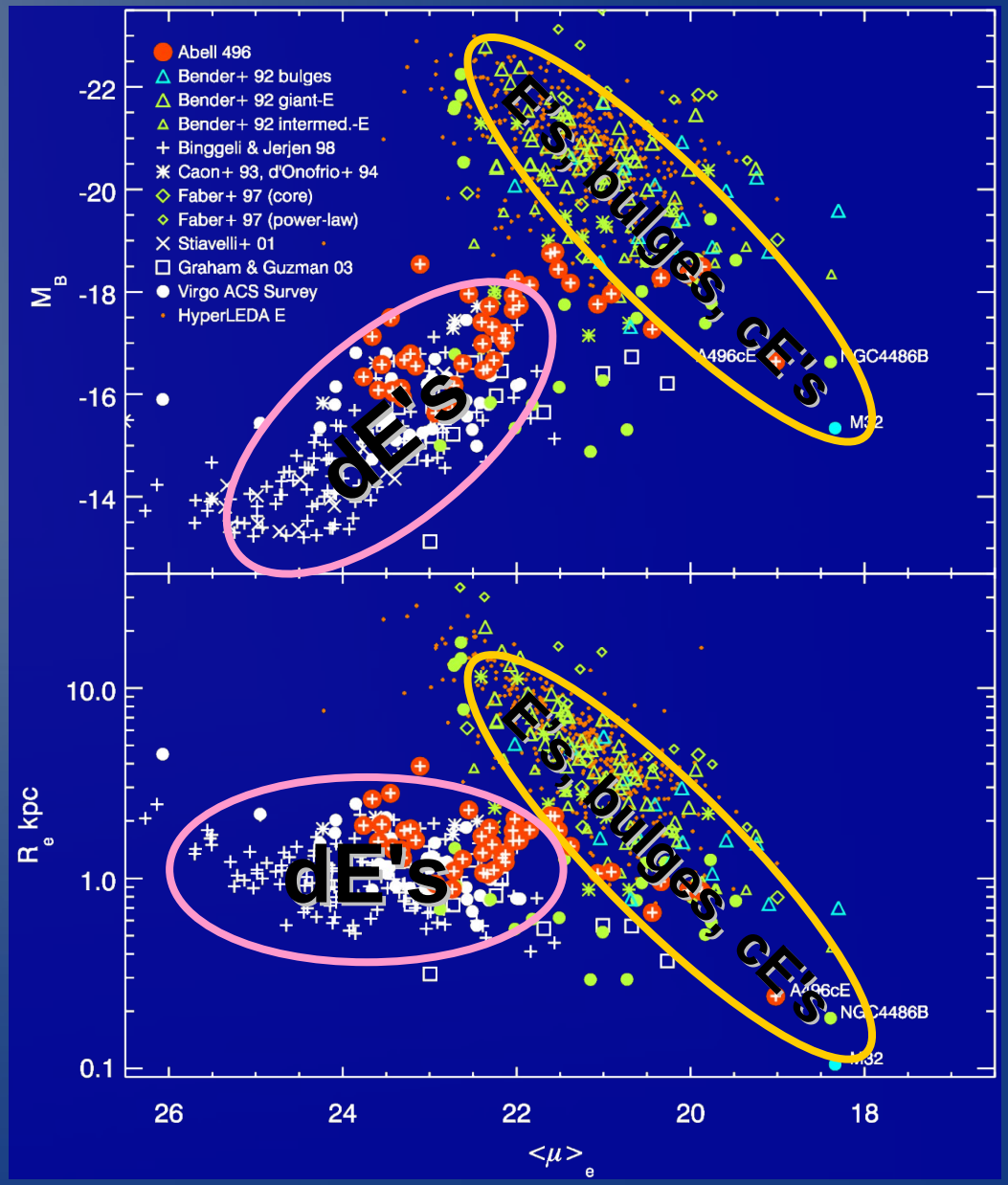


Image credits: MASTER

Properties of dwarf early-type galaxies

- Early-type morphology, M_B>-18
- exponential brightness profiles: structurally different from E or is there a smooth transition?
- No ISM, no star formation
- Fine structures in bright dEs
- Often rotationally-supported
- DM fraction ~50%
- t=3..7 Gyr, Z=-0.7..-0.2 dex

- formation and evolution:
  - Internal channels:
    - collapse + SF feedback
  - External channels:
    - ram pressure stripping of late-type dwarfs
    - gravitational harassment

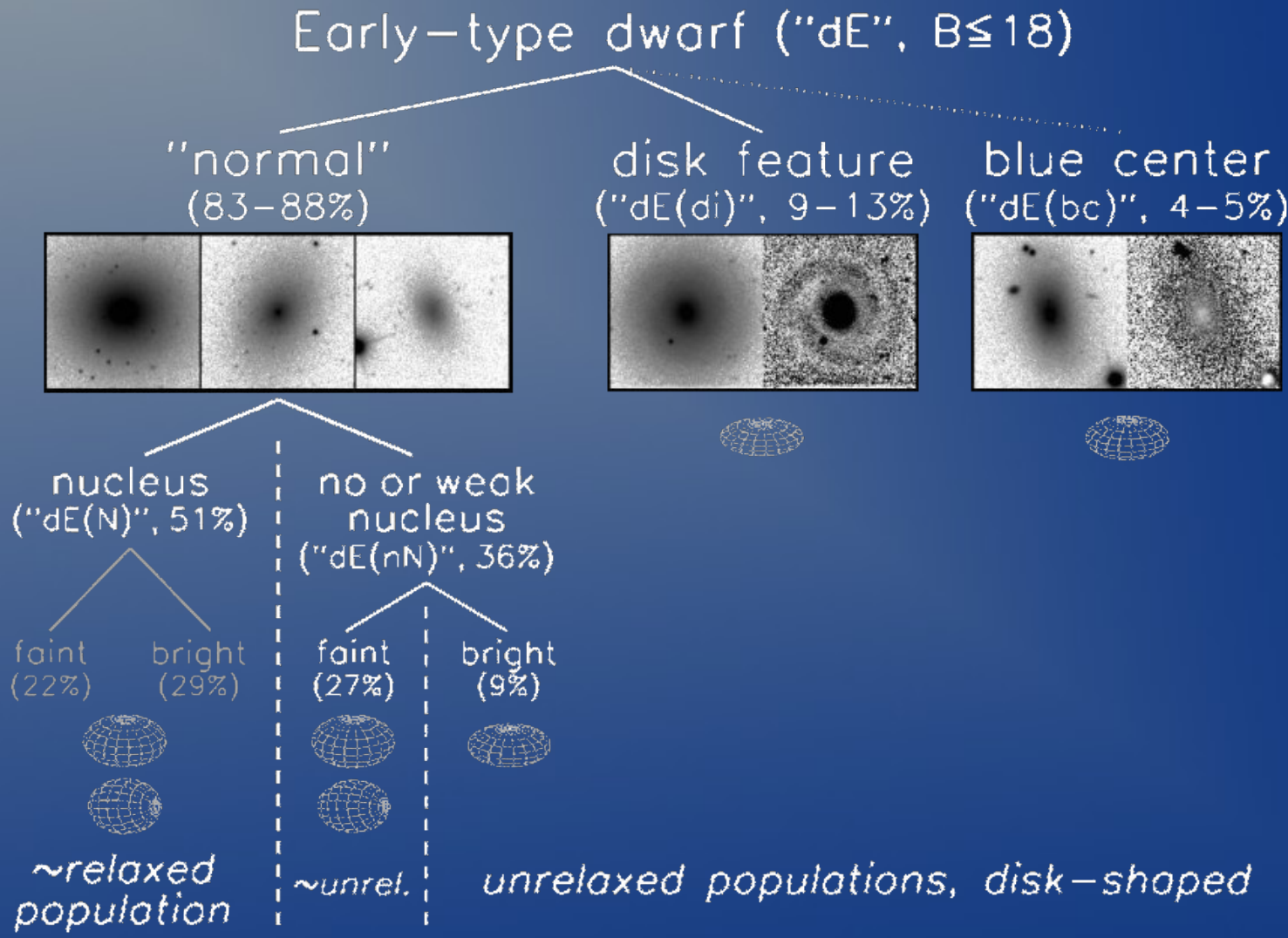


Dwarf vs non-dwarf galaxies

- Lower masses: stronger environmental effects on their evolution, but: smaller sizes, therefore less probable mergers
- Lower densities: lower SFE and SFR
- Lower metallicity, velocity dispersion, and surface brightness, therefore observational difficulties
- Correlation of surface brightness with luminosity, therefore observational biases

dE/dS0 classification

(Lisker et al. 2007)



1. Virgo cluster

- Photometric study using SDSS *(Lisker et al. 2006)*
  - Unsharp masking with elliptical smoothing
- Spectroscopy *(Chilingarian et al. 2007ab, Chilingarian 2009)*
  - Optical IFU spectroscopy
    - MPFS @ BTA 6m
    - PMAS @ Calar-Alto 3.5m
  - Optical MOS (SDSS)
  - Optical long-slit spectroscopy (archival data):
    - Palomar 5m (Van Zee et al. 2004)
    - 1.93m at OHP (Simien & Prugniel 2002)
    - GMOS-S at GEMINI

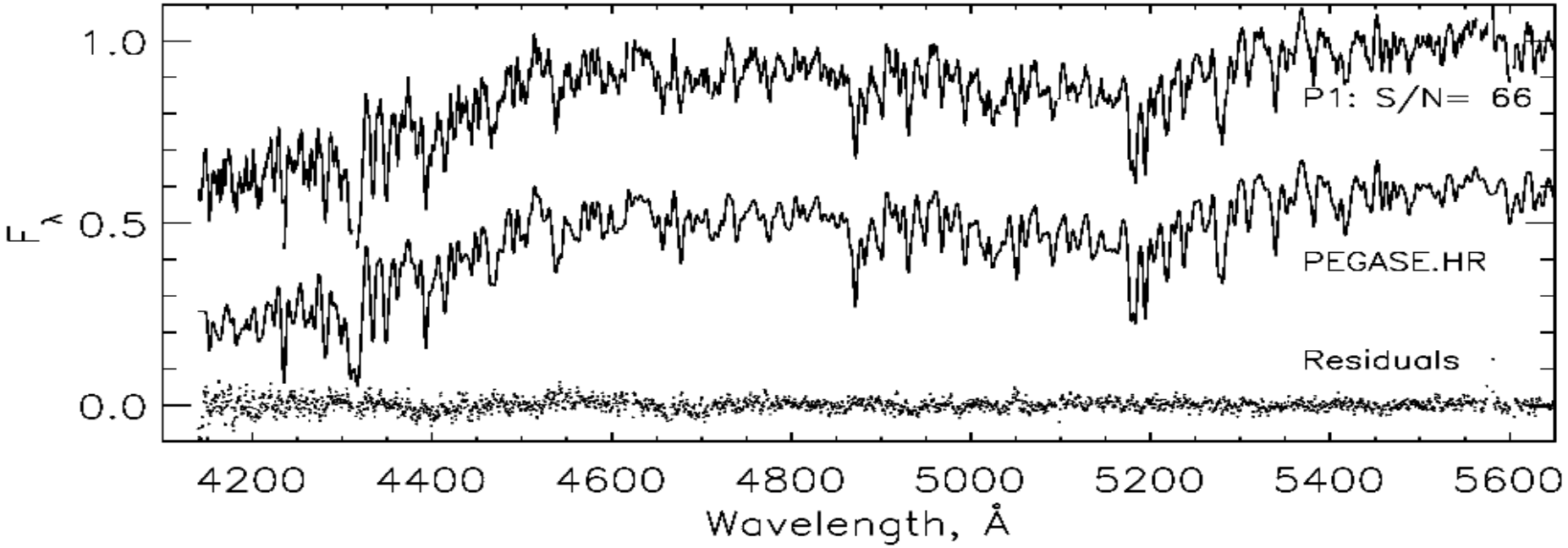
Data Analysis: full spectral fitting (*NBursts*)

Classical Approach:

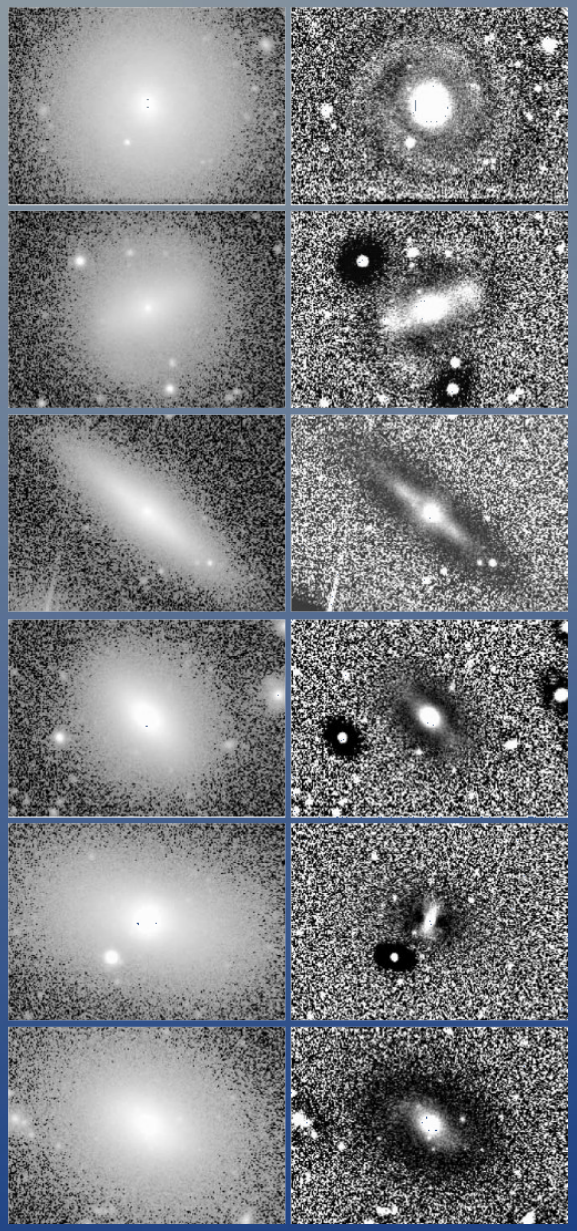
- Internal kinematics:
  - Cross-correlation
  - Fourier-based techniques
  - Spectral fitting (pixel space)
- Stellar populations: Lick indices

Our Approach:

- Internal kinematics and stellar populations simultaneously from full spectral fitting (PEGASE.HR)
- Avoiding degeneracies, minimizing template mismatch, increasing precision (factor 3-6)



dE(di) from photometry *(Lisker et al. 2006)*



VCC308

VCC1896

VCC1304

VCC990

VCC1183

VCC2019

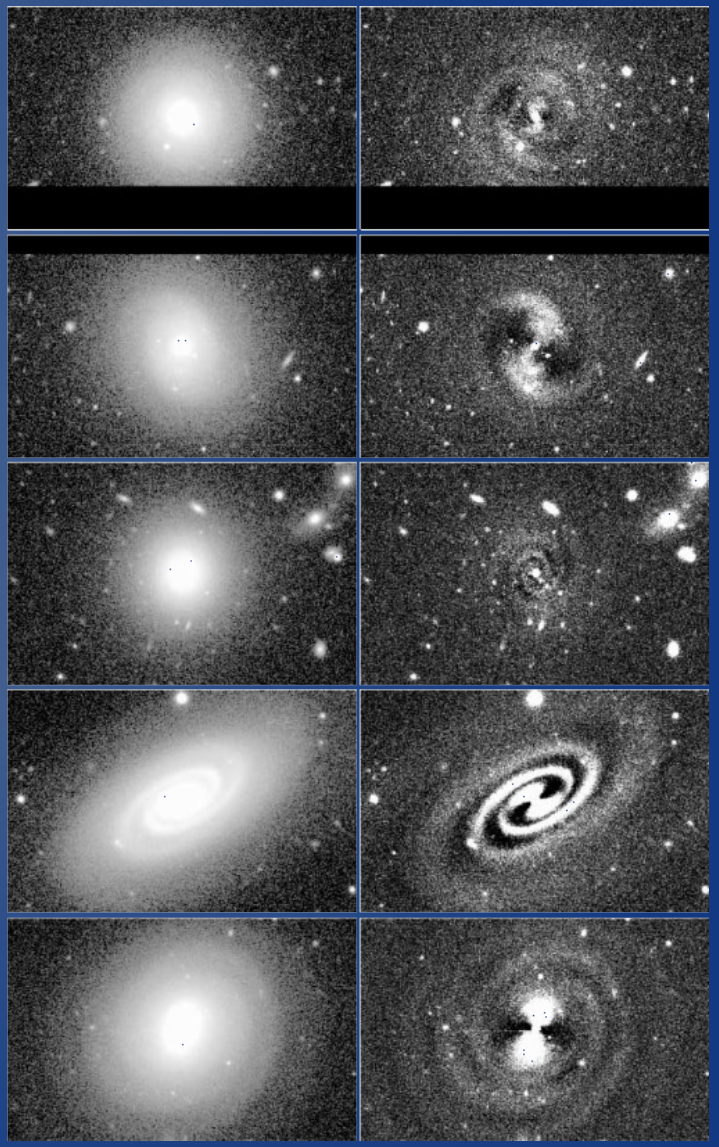
VCC308

VCC490

VCC856

VCC522

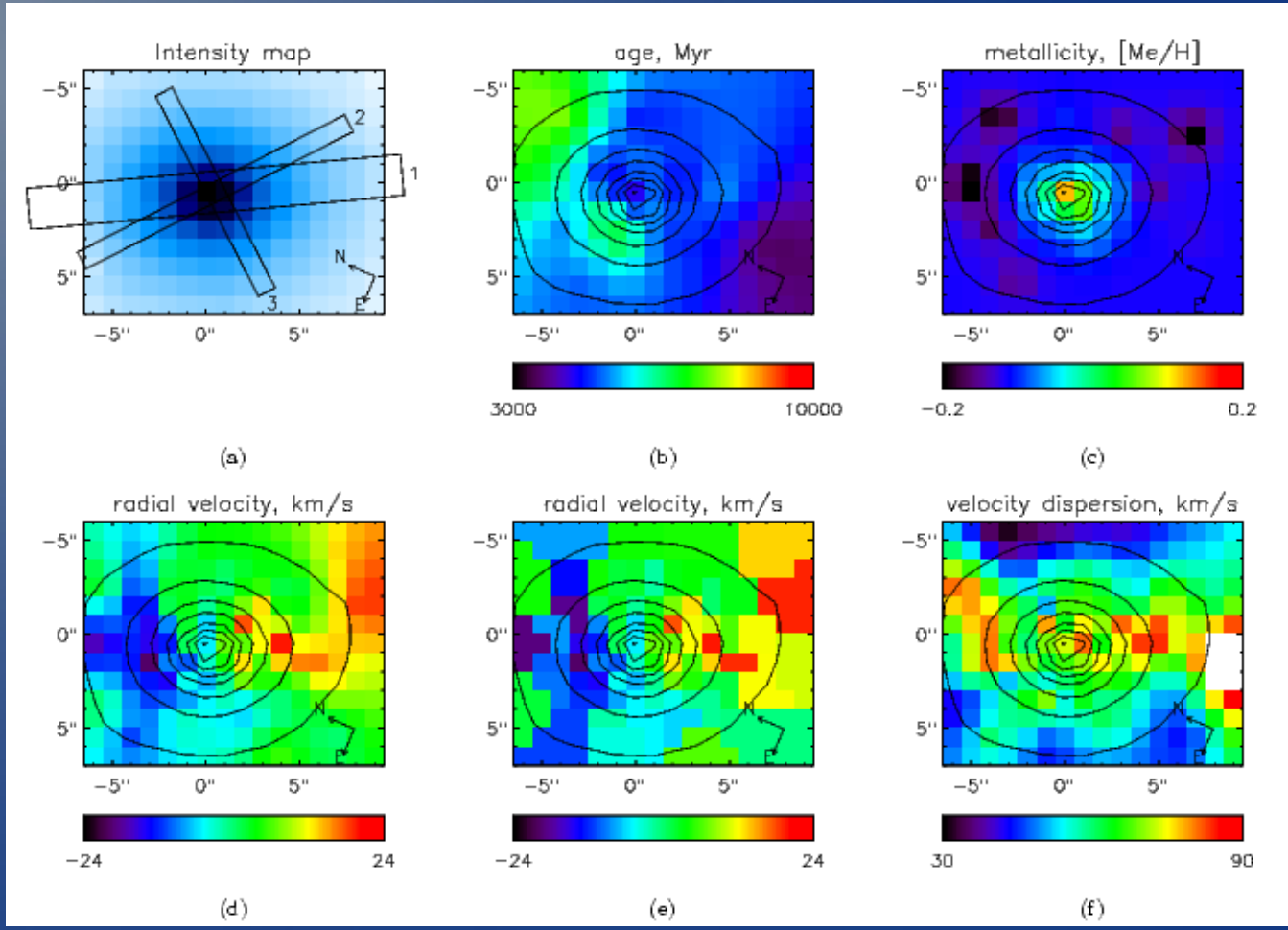
VCC1902



VCC 1871 (“bright”)

M_B = -16.8	σ = 70 km/s	[Fe/H] = 0.0	Age =5 Gy

- Embedded disc
- Metal-rich nucleus
- Intermediate age



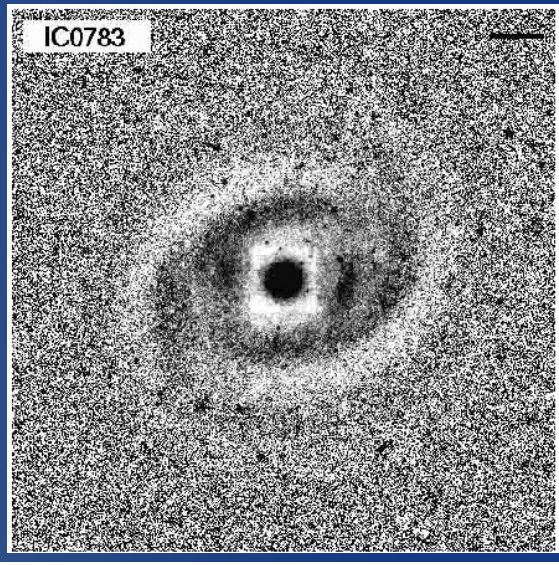
Chilingarian et al., 2007, MNRAS

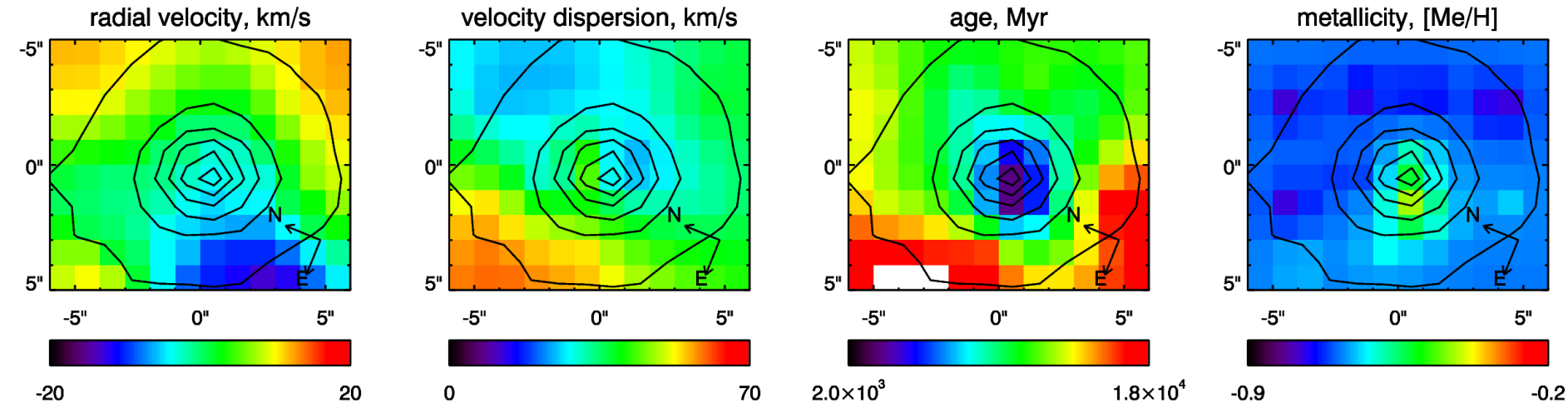
Chilingarian et al., 2007, AstL

VCC 490 (“spiral”)

M_B = -16.3	σ = 30 km/s		
age_{cnt}=3.3 Gyr	$[Fe/H]_{cnt}$=-0.35	age_{out}=13 Gyr	$[Fe/H]_{out}$=-0.8

- Rotation in the inner region
- **Young nucleus (3 Gyr)**
- Low metallicity
- Two consequent crossing of the cluster centre?



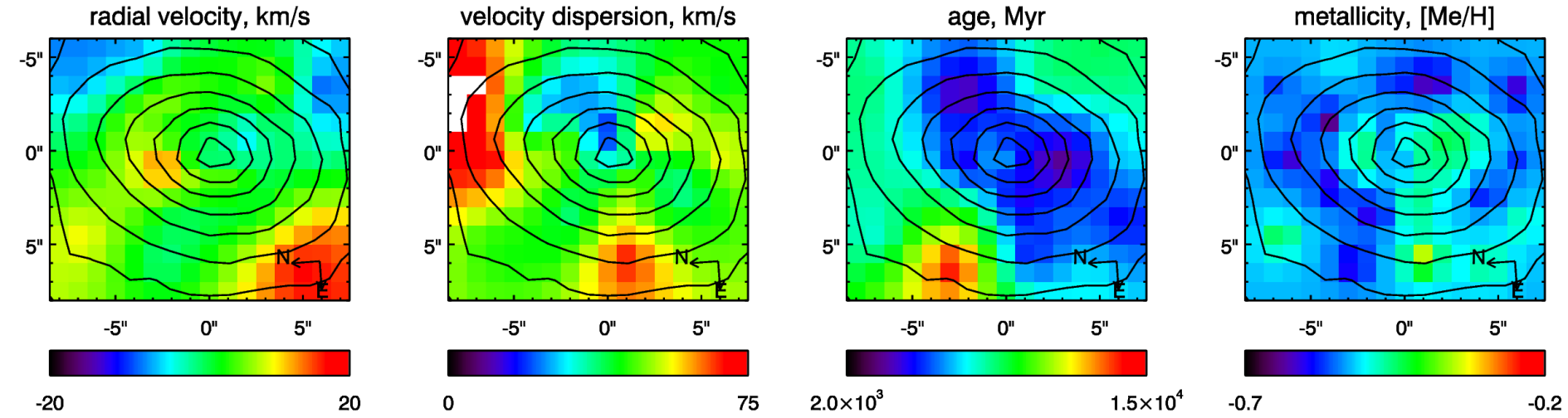


Chilingarian et al., 2007, AstL

VCC 1422 (“barred”)

M_B = -16.7	σ = 40 km/s		
age_{cnt}=5.3 Gyr	$[Fe/H]_{cnt}$=-0.4	age_{out}=8.6 Gyr	$[Fe/H]_{out}$=-0.6

- Kinematical axis is turned by 35-40 degrees off the photometric one. HST images reveal faint warped structure, corresponding to this orientation
- Intermediate-age extended embedded structure (disc)
- Velocity dispersion map shows a dip, corresponding to this “disc” (or “bar” according to Barazza et al. 2002)

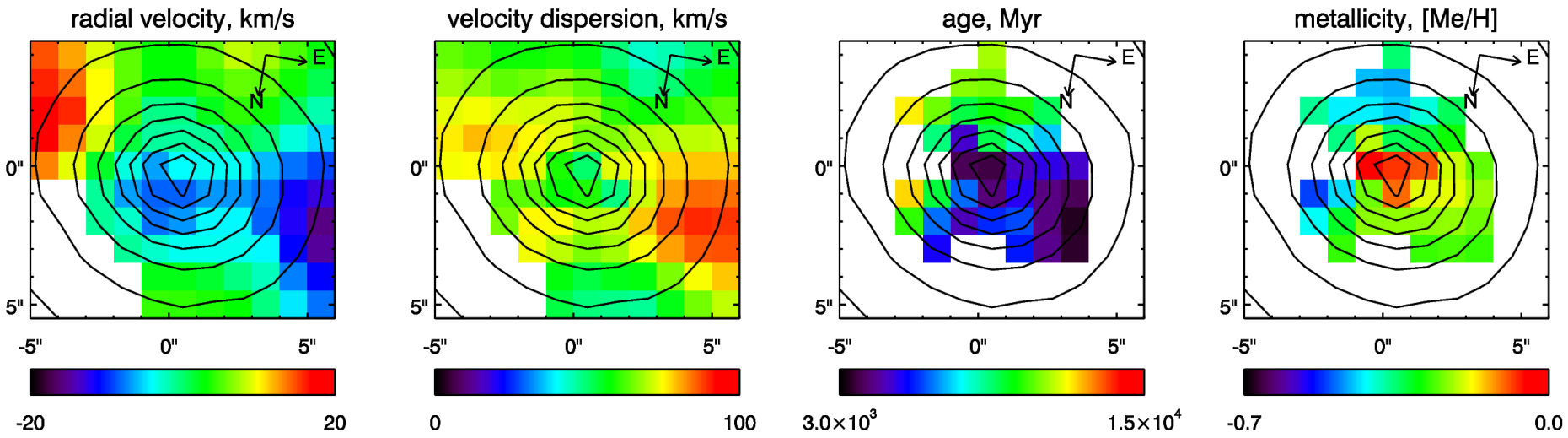


Chilingarian et al., 2007, AstL

VCC 1545 (“classical”)

M_B = -16.2	σ = 50 km/s		
age_{cnt}=4.1 Gyr	$[Fe/H]_{cnt}$=-0.0	age_{out}=7.8 Gyr	$[Fe/H]_{out}$=-0.4

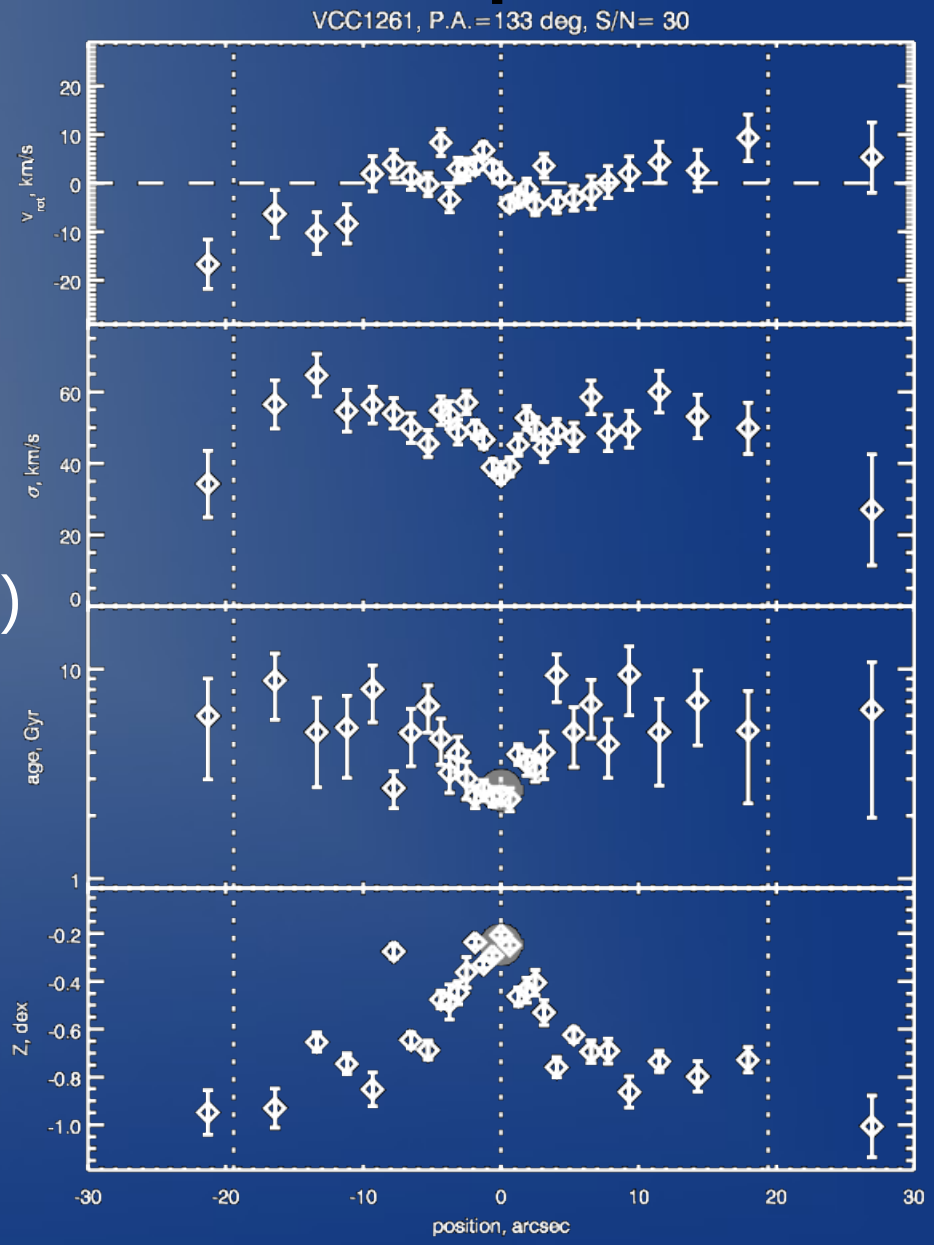
- Was chosen as a “prototypical” dE: without photometrically detected bar, disc or spirals
- Rotation along two perpendicular directions. Kinematical appearance looks very similarly to giant E NGC4365, where it was explained as a projection of orbits in a 3-axial potential (without need for embedded structure)
- Rather young (4 Gyr) metal-rich ([Fe/H]=0) nucleus



Chilingarian, 2009, MNRAS

VCC1122: KDC inside a spheroid

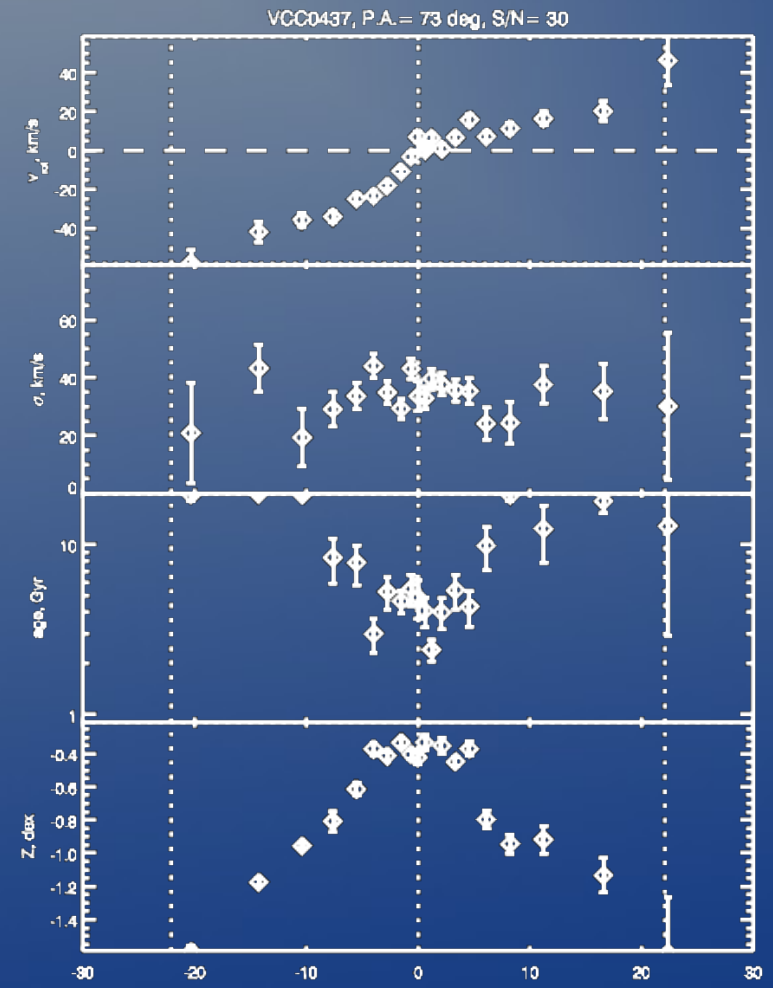
- Nothing detected in SDSS
- Rotating inner component
- Young and metal-rich
- σ-drop in the centre
  - Inner disc (dynamically cold)
  - Dissipative merger?

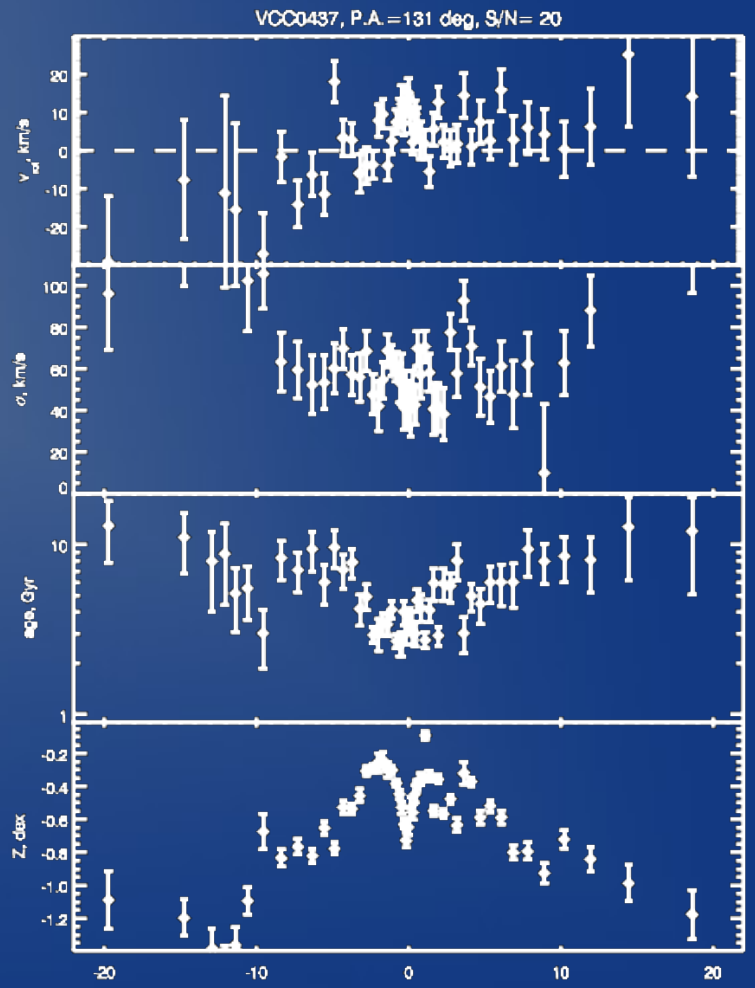


Chilingarian, 2009, MNRAS

VCC437: face-on inner disc

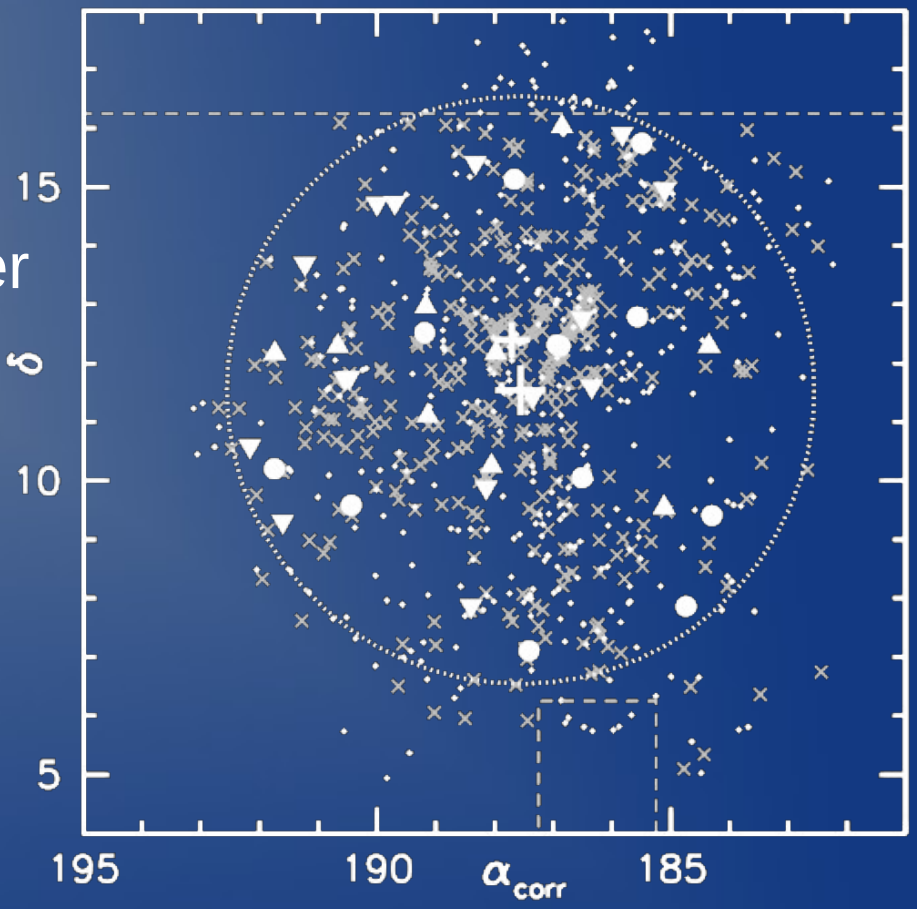
- Break in the colour profile in the peculiar central part
- Extreme metallicity gradient (>1 dex per eff. radius)
- Metal-poor nucleus (right plot: GMOS-S data)





dE(di): spatial distribution

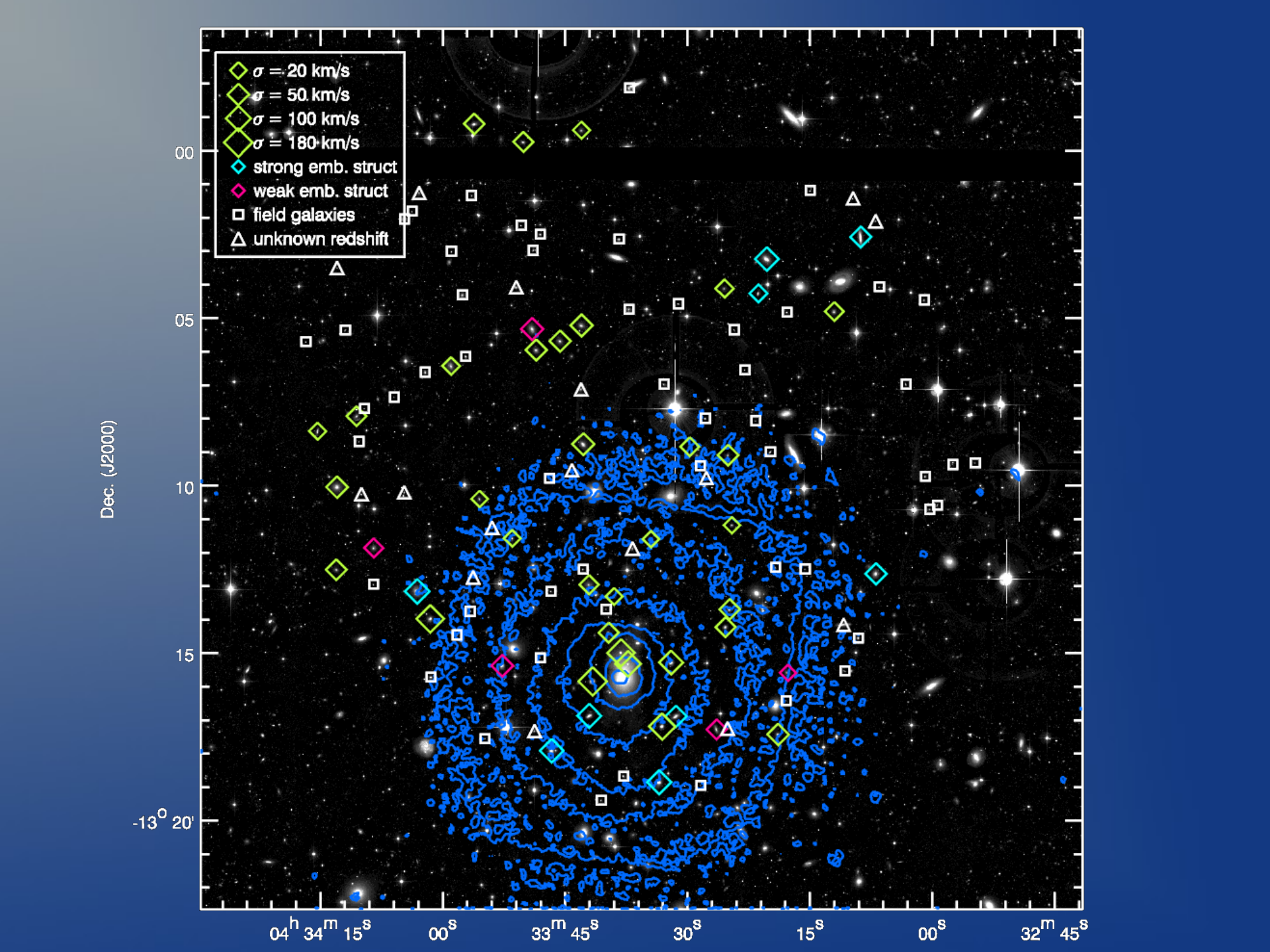
- ~10% of all Virgo dEs belong to the dE(di) class, most of them are bright (M_B<-16.8)
- Unlike dE(N), dE(di)s form an unrelaxed system in the cluster
- Most of them where spectra were available to us, have intermediate ages and moderately subsolar metallicities of their stellar populations
- This suggests that they were formed quite recently from infalling galaxies



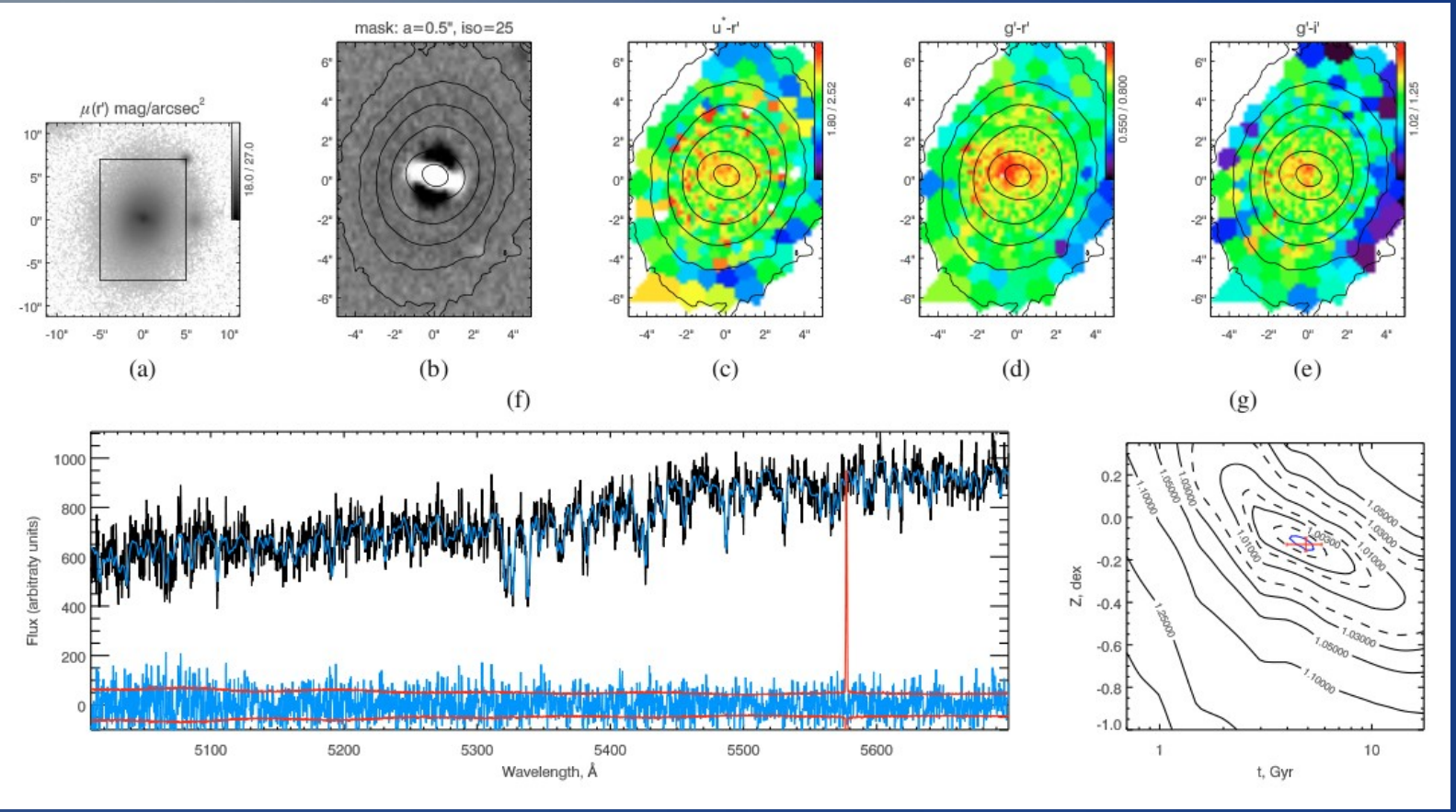
2. Abell 496 (d=131 Mpc)

(Chilingarian et al., 2008, A&A)

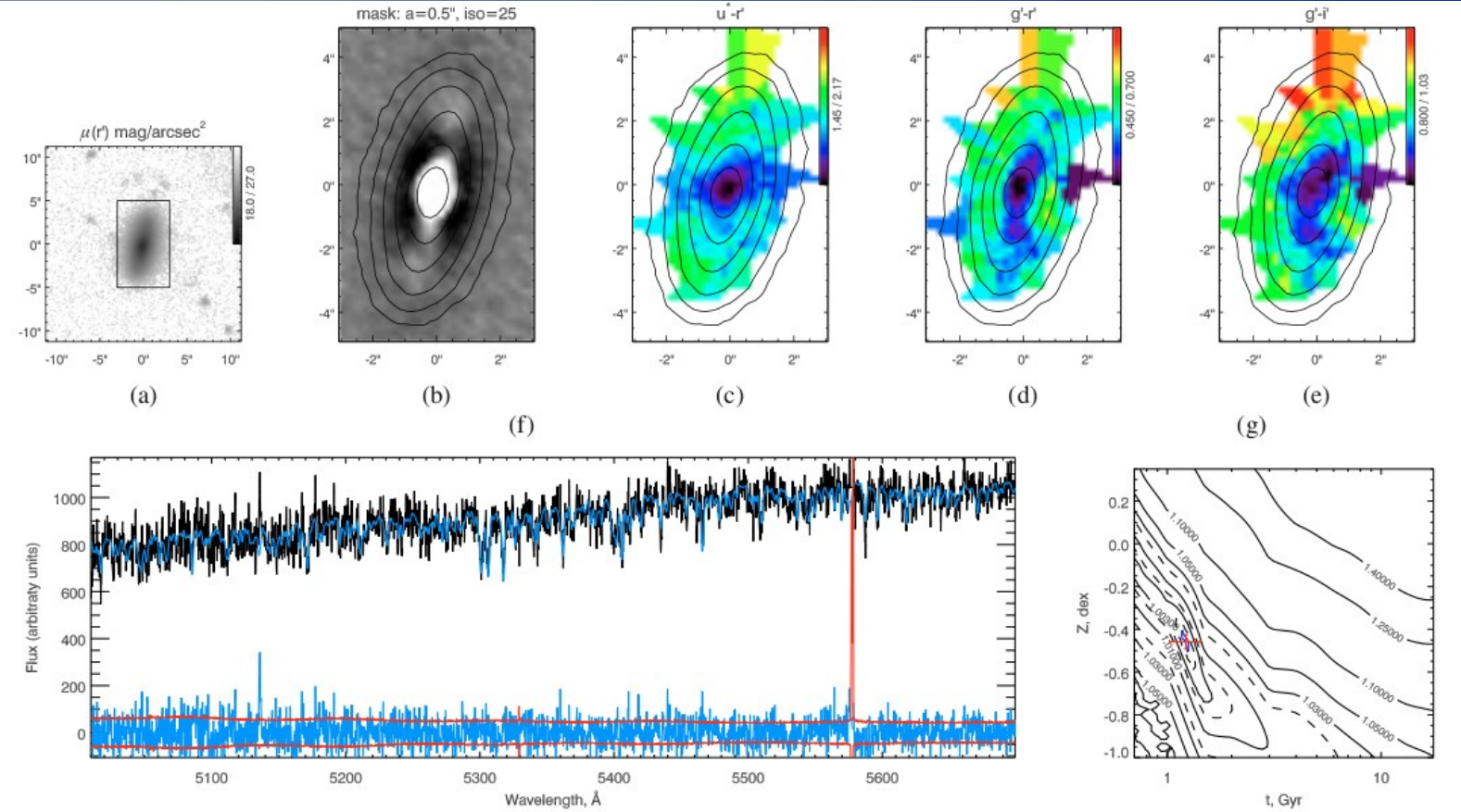
- Data:
  - Imagery (u*, g', r', i') using MegaCam @ CFHT
  - Spectroscopy: 3 fields with VLT FLAMES/Giraffe
- 110 spectra. 48 cluster members (46 sufficient S/N ratio):
  - 36 dEs/dS0s, 2 SBs, 10 low-luminosity E/S0/Sa
  - Accurate internal kinematics
  - [Mg/Fe] abundance ratios by measuring Lick indices
  - Estimations of age and metallicity for the luminosity-weighted population (single burst)
    - Mapping relations between stellar populations and velocity dispersions in the low-σ regime
- Colour maps for 48 galaxies
- Unsharp masking for 48 galaxies to detect fine structures


σ = 20 km/s
σ = 50 km/s
σ = 100 km/s
σ = 180 km/s
strong emb. struct
weak emb. struct
field galaxies
unknown redshift
Dec. (J2000)
00
05
10
15
-13° 20'
04h 34m 15s
00s
33m 45s
30s
15s
00s
32m 45s

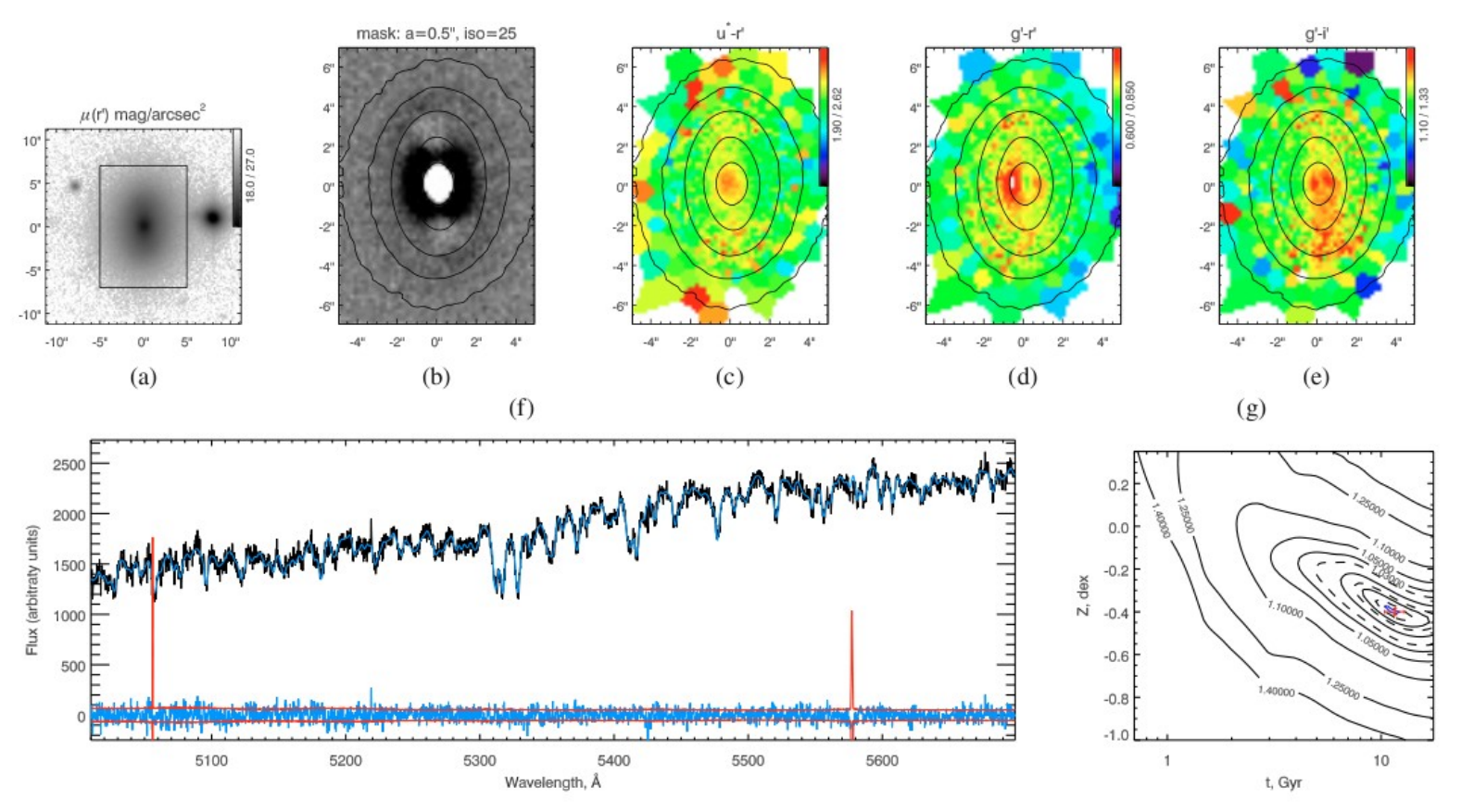
Example 1: bar



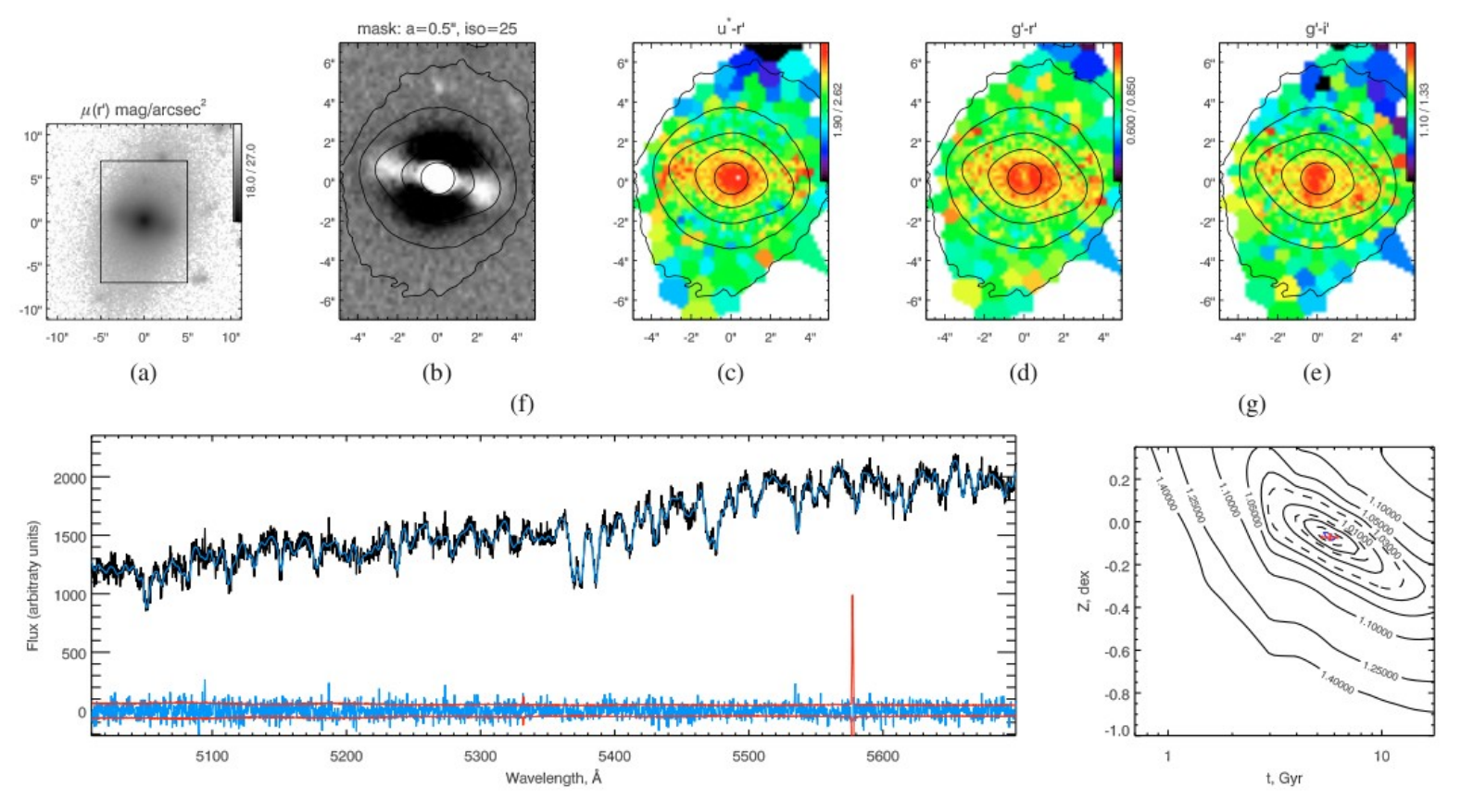
Example 2: disc + blue core



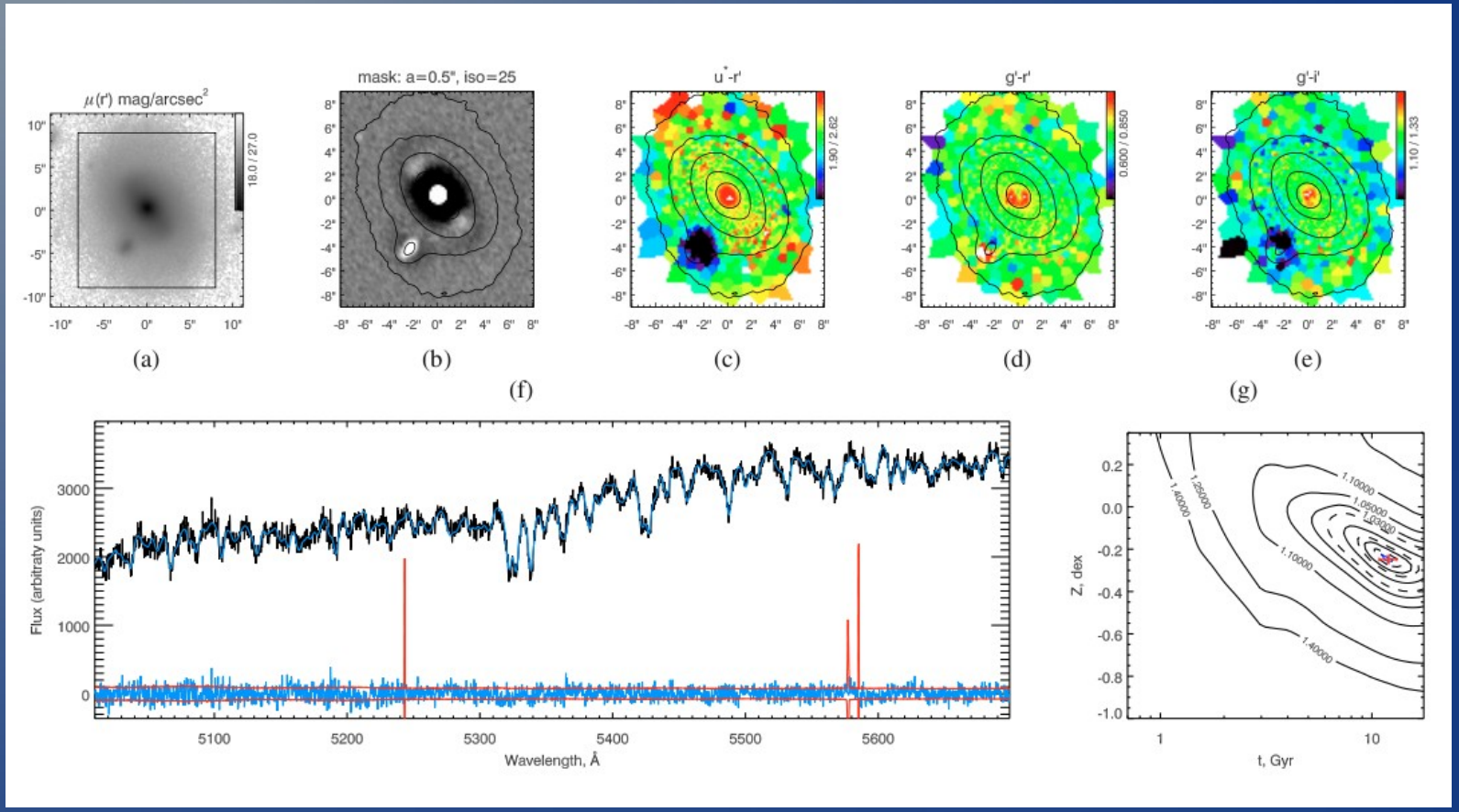
Example 3: spiral + bar



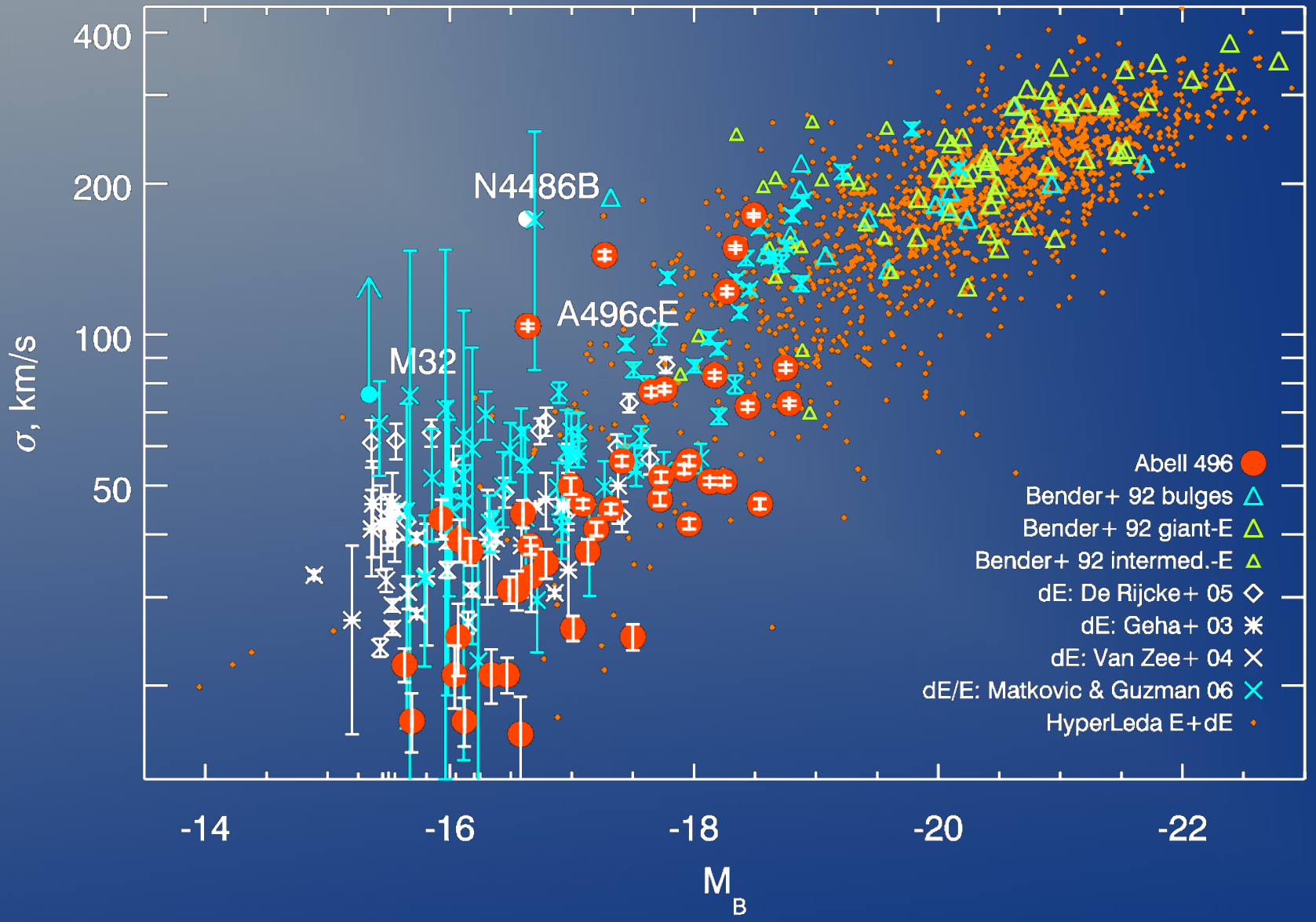
Example 4: strong bar



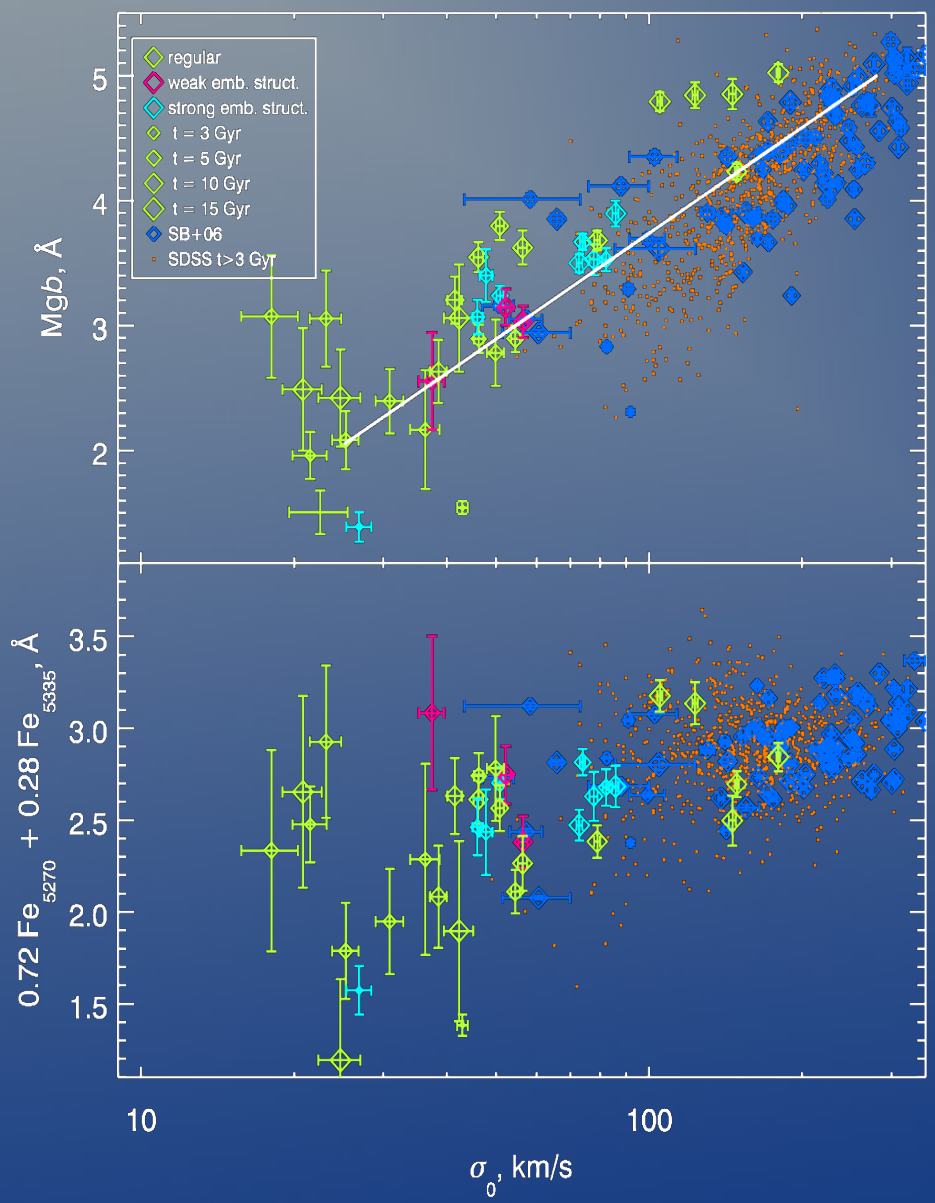
Example 5: old bar + spirals

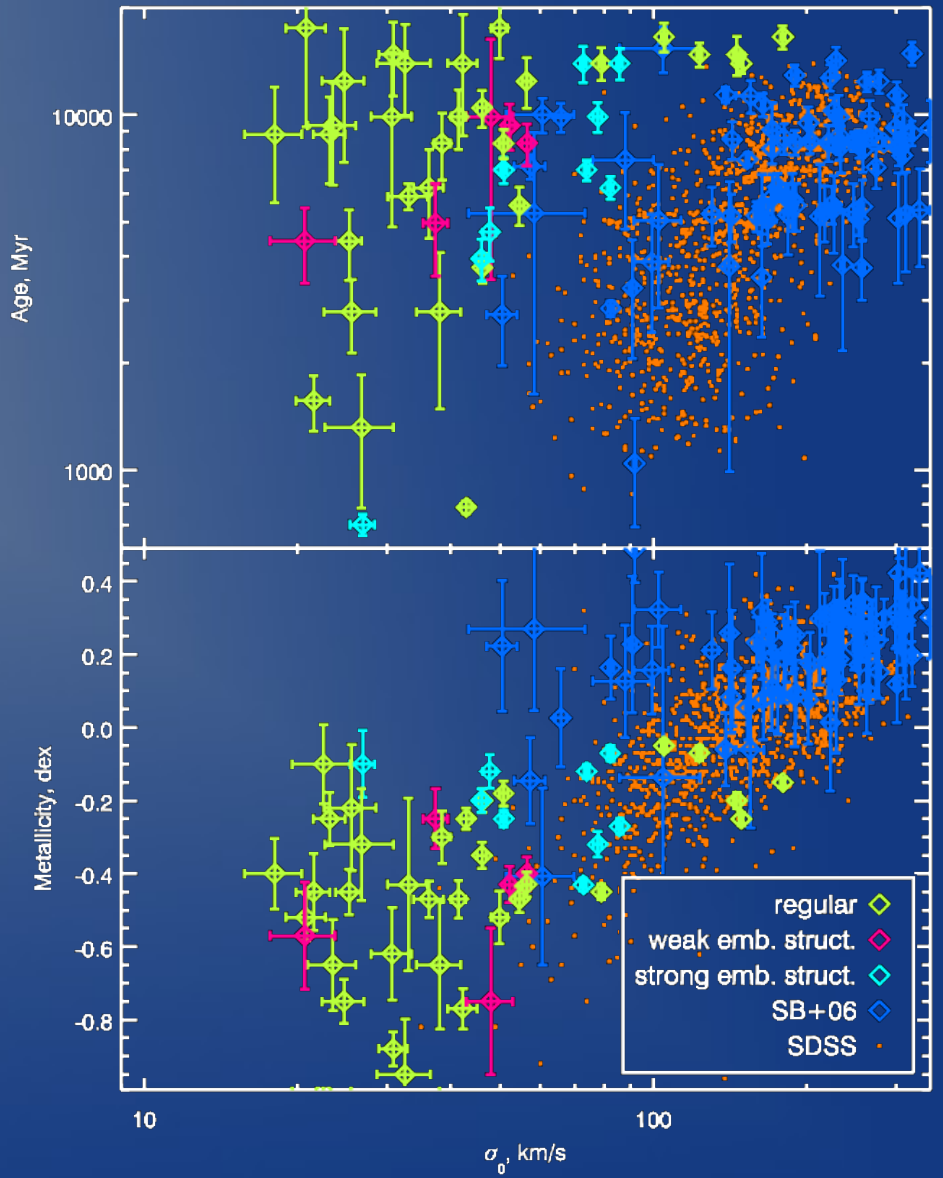


Faber-Jackson Relation

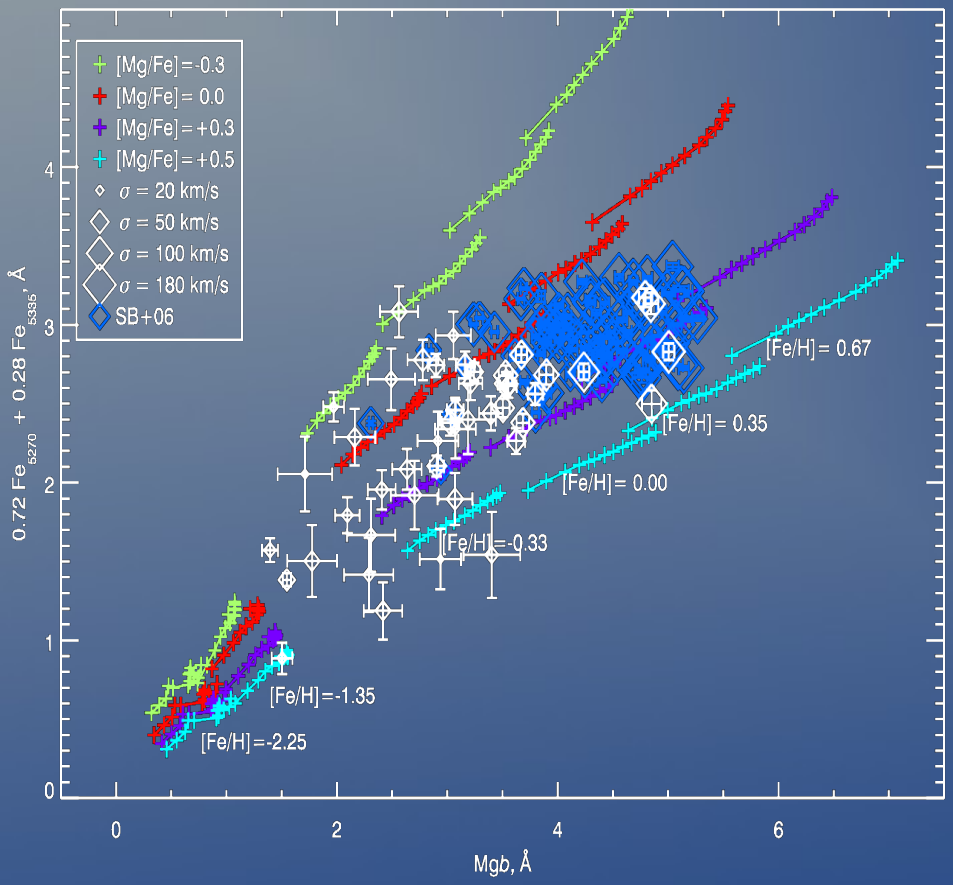


Stellar Populations: age, [Fe/H]





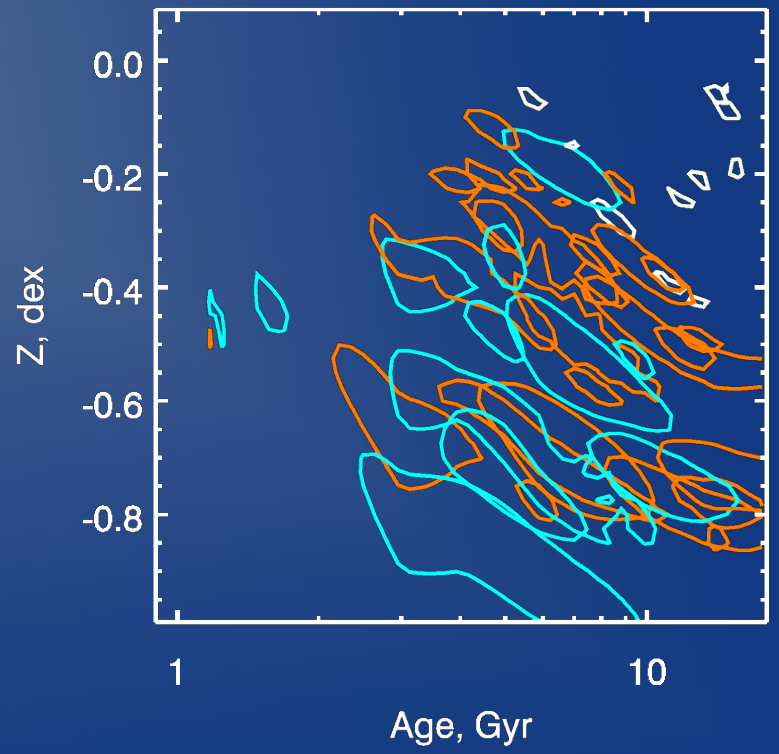
Stellar populations: [Mg/Fe], t vs Z



What we see:

- Strong correlation in [Fe/H]-σ
- Much less clear on the age-σ plot
- [Mg/Fe]=0 for low-luminosity galaxies

Age-metallicity degeneracy??? NO!



A496: older and more massive then Virgo

- Dwarf early-type galaxies are slightly older than in Virgo
- A fraction of galaxies with embedded structures is about 25% (comparable to bright Virgo dE/dS0s)
- Environmental effects are stronger (the cluster is more massive and dense): the brightest galaxy with a detected embedded structure has $M_B = -16.5$

Simulations

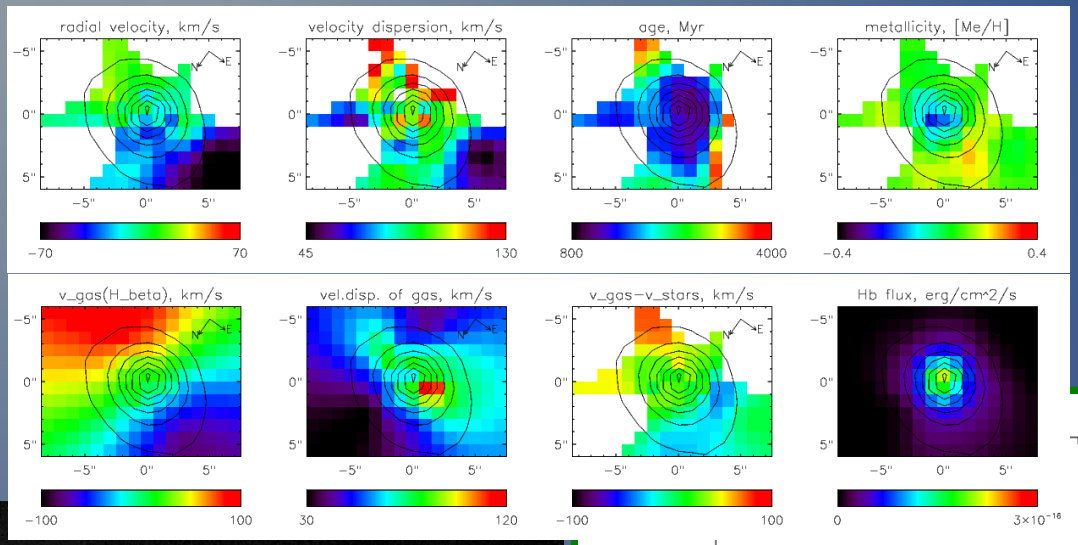
- Ram-pressure stripping of discs in clusters and groups *(Abadi et al., 1999; Marcolini et al. 2003)*
  - Too weak forces to dramatically change the morphology: just SF cessation
- Gravitational harassment *(Mastropietro et al., 2005)*
  - Strong morphological transformations
  - Interactions may induce bar formation
  - Discs are never completely destroyed
    - Movies *(credits: Chiara Mastropietro and Ben Moore)*

Formation of discs in dE/dS0s

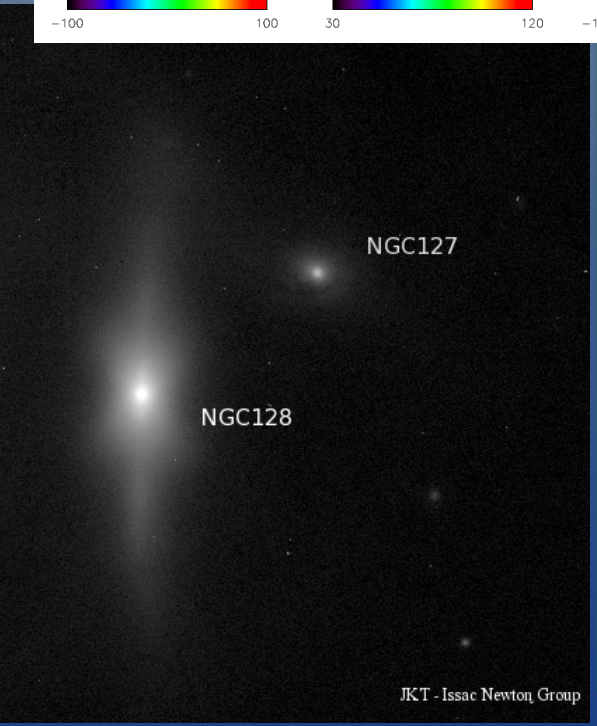
- Large-scale discs had probably formed a long time ago before galaxies entered the cluster, i.e. at the “dIrr/dS” stage
- Small embedded discs in brightest dE/dS0 (VCC437, VCC1261) could have formed already during their lifetime inside the cluster
  - Dissipative minor mergers: (is it feasible?)
  - Cold accretion from gas-rich companions: this mechanism should be important in groups

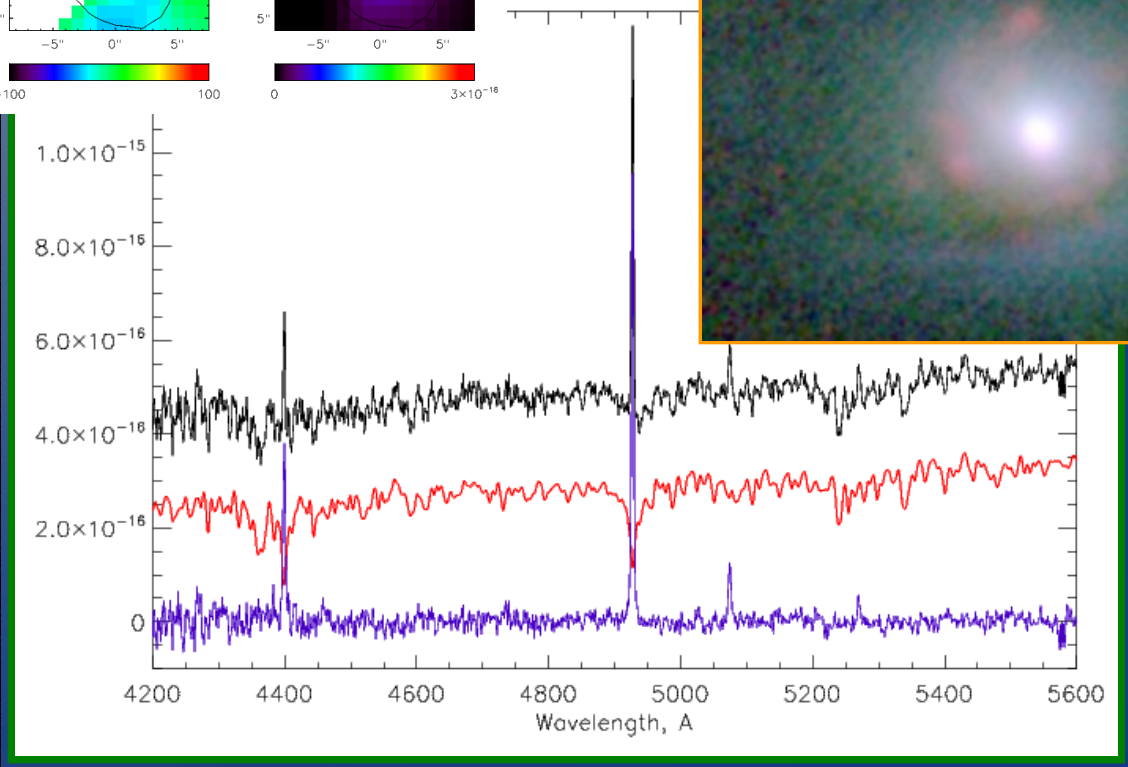
NGC127 (NGC128 group)

M_B = -18.2	σ = 90 km/s	[Fe/H] = -0.2	Age = 0.8 Gy



Ongoing accretion from NGC128 on the dwarf satellite





Summary

- Embedded discs suggest early type progenitors. We see them in at least 20% of bright dwarf early-type galaxies. At least a third of the remaining 80% are oblate
- Ubiquitous evolutionary decoupled cores
- Only brighter galaxies exhibit embedded structures: environmental effects are important for less massive galaxies and in more dense environments
- Wide range of ages, but mostly intermediate

Main conclusion: “external” channel of dE formation (ram pressure stripping + harassment) is the most important mechanism, while SN winds (though required to explain mass-[Fe/H] relation) fail to reproduce observed α-enrichment.

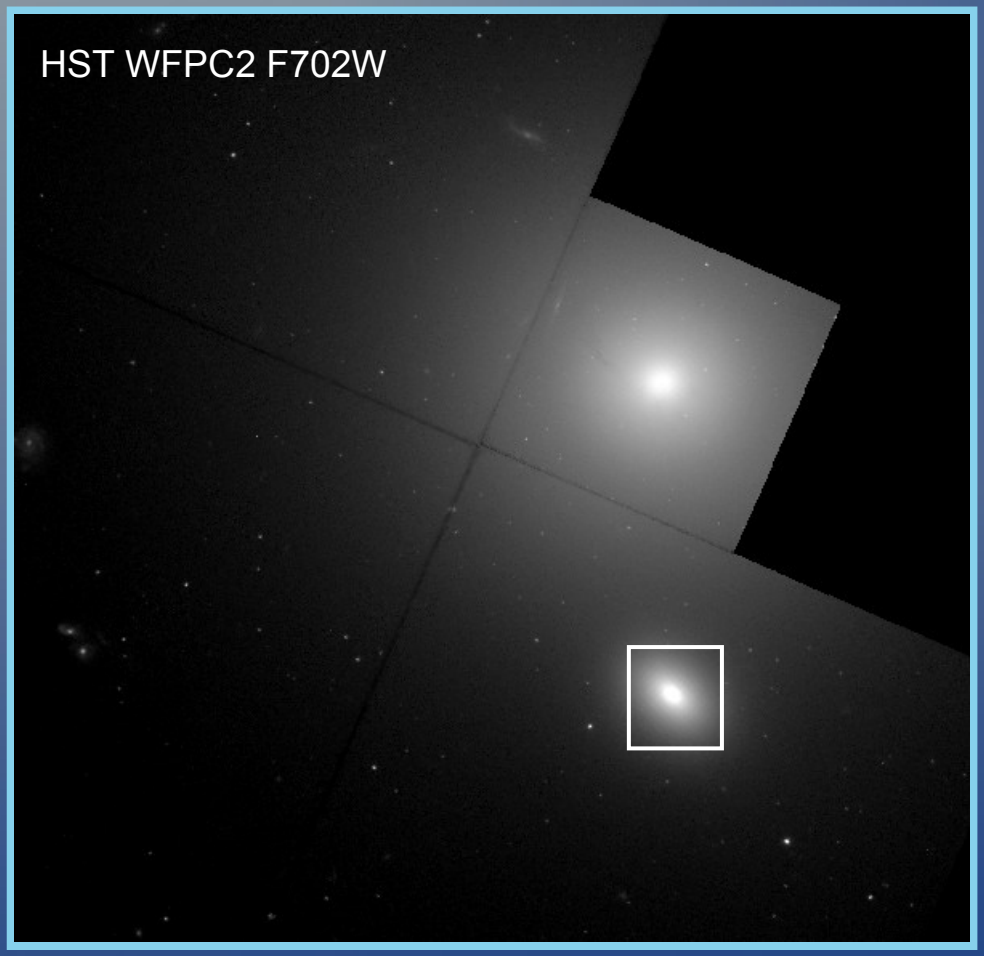
Be aware while studying discs (not only in dwarfs):

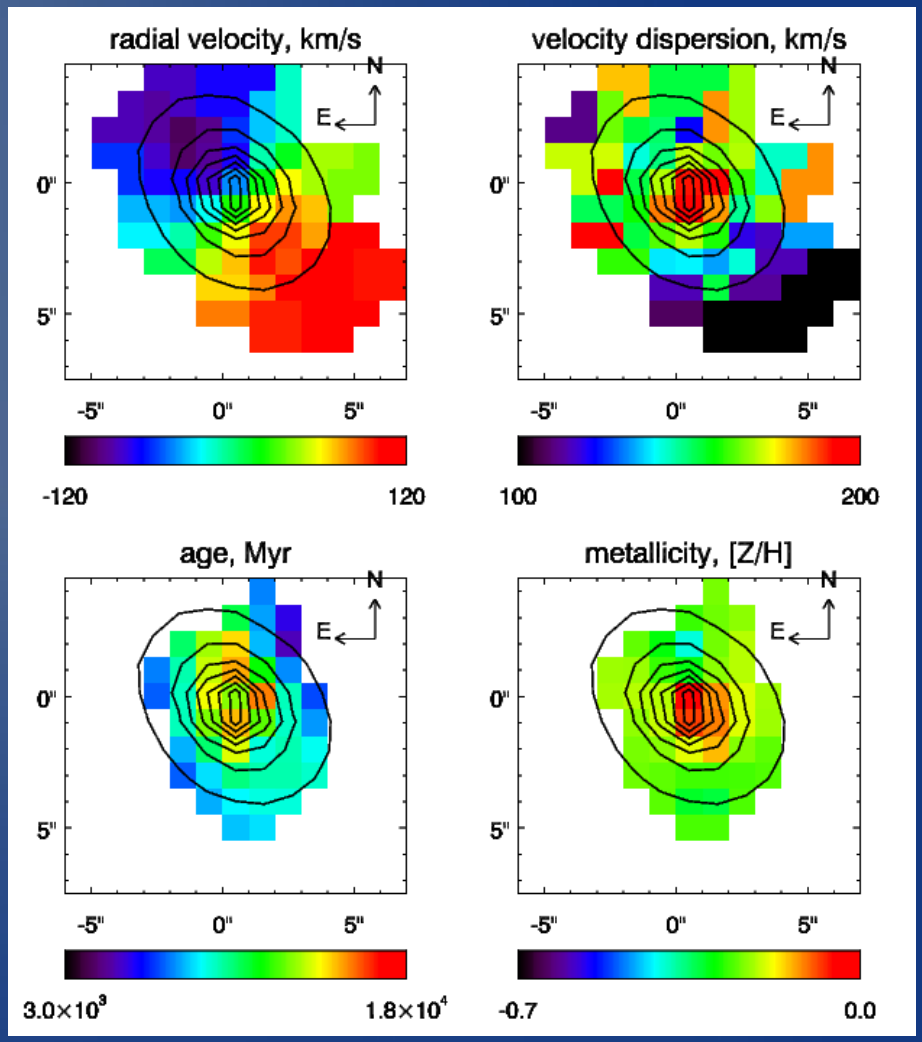
- Mass does NOT follow light
  - metallicity and age gradients
- Flat colour profile in any optical band does NOT mean “stellar population (and M/L) does not change”
- Ages from Lick indices will be wrong (probably overestimated) if faint emission lines present in the spectra and they are not taken into account properly

Thanks for your attention!

NGC 5846A (PMAS Calar-Alto 3.5m)

M_B = -19.5	σ = 190 km/s	[Fe/H] = -0.0	Age = 12 Gy





Simulations of tidal stripping