The UV view of Early-Type galaxies: insight from SPH simulations

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Early type galaxies (ETG)

- The UV data for E and S0 galaxies
- The UV data for ETG with peculiar features
- The UV and the orientation
- SPH simulations to fully describe the evolutionary path of some cases
- Conclusions

Burstein et al. 1988 (IUE data)

The UV spectra of quiescent galaxies can be modeled as a sum of two components: a normal, cool stellar population of main sequence and giant stars plus a very blue population having a steeply rising UV flux below 2000 A

Results based on 97 IUE spectra of 31 ETG

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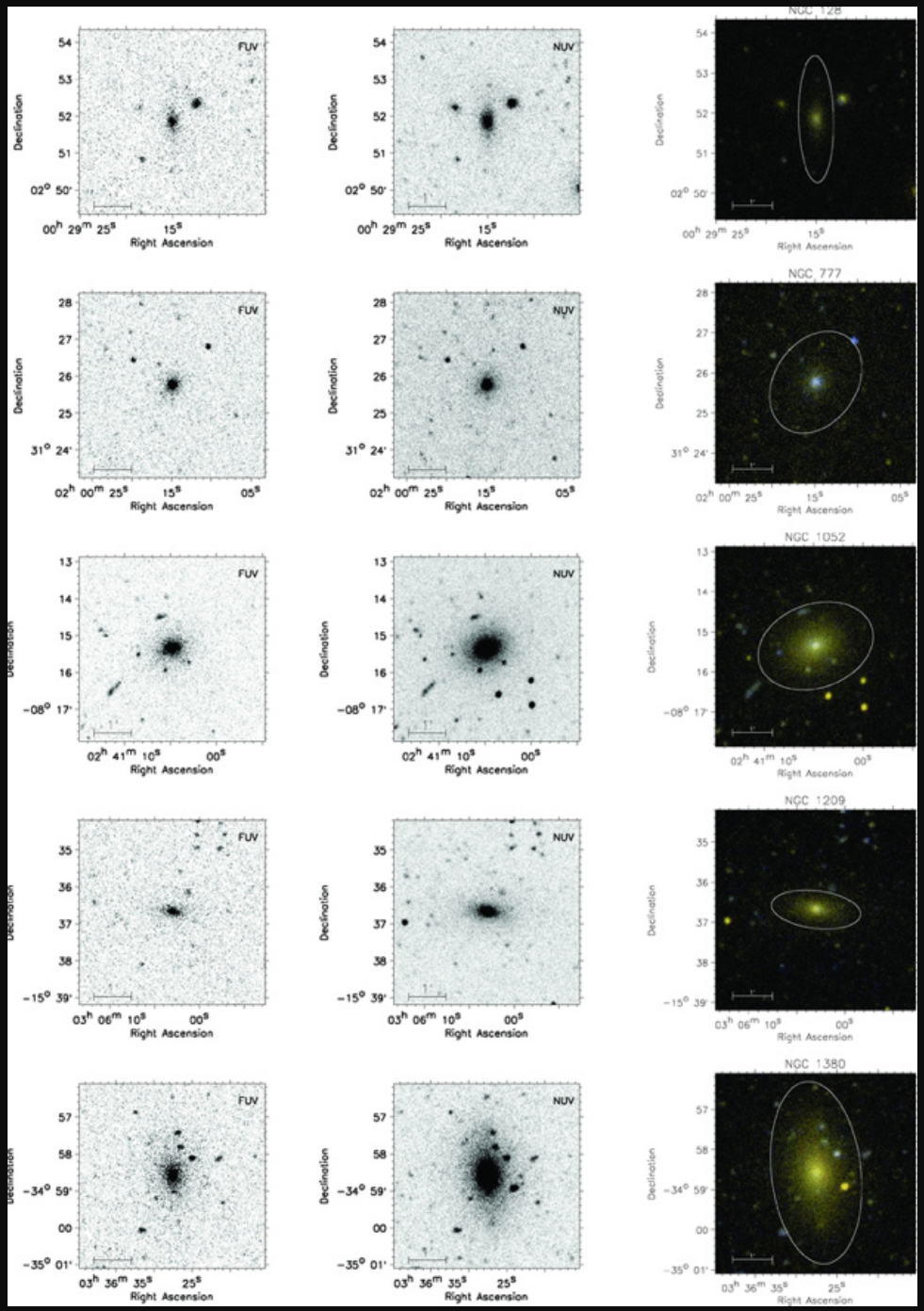
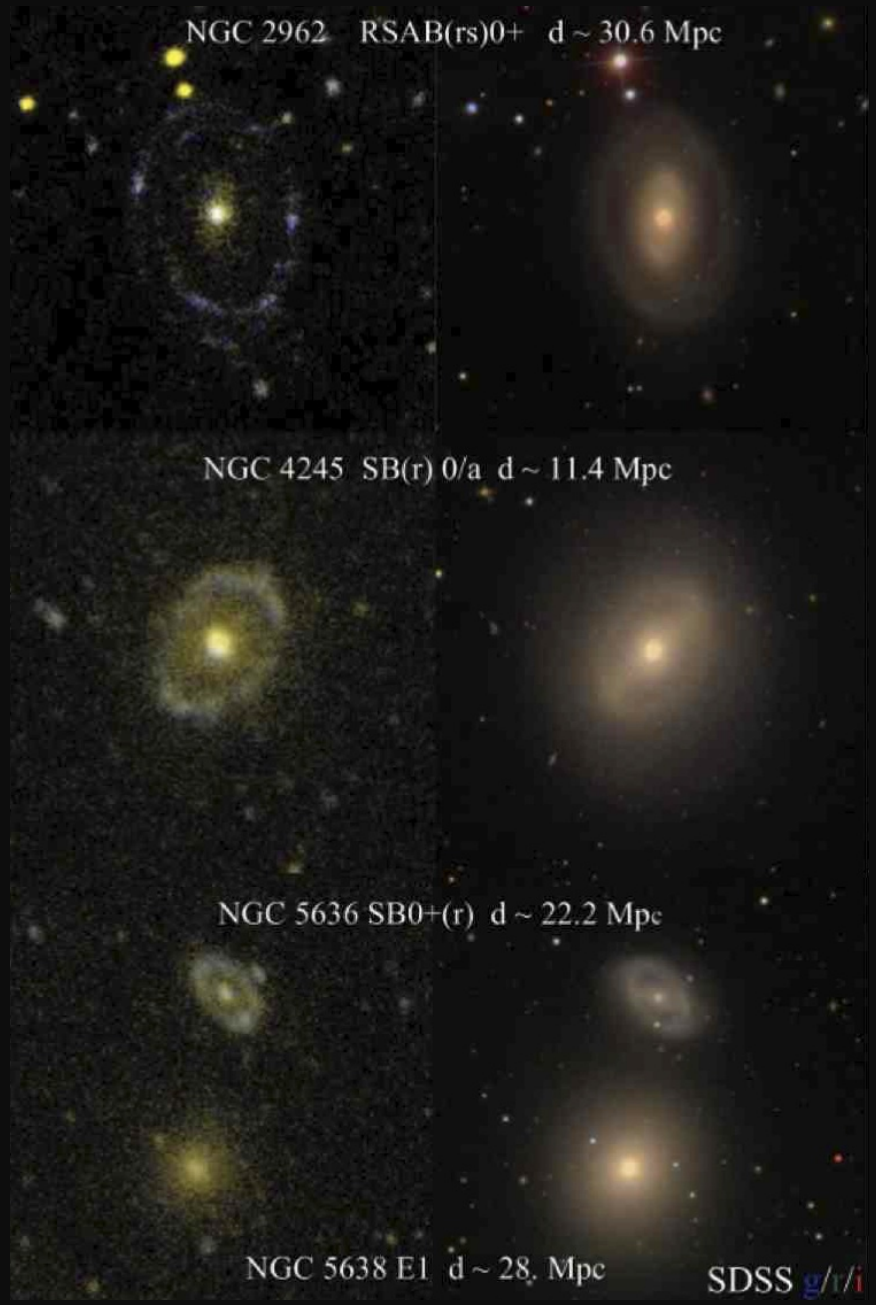
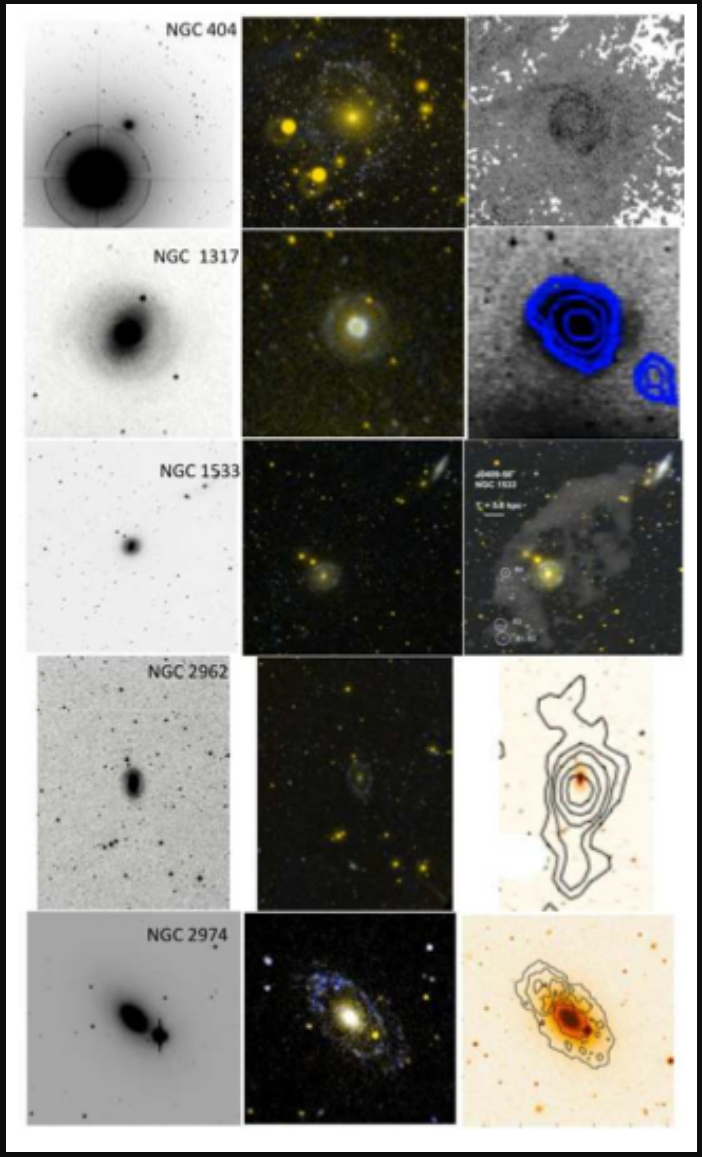
Later Donas et al. (2007) and Schawinski et al. (2007) showed that up to ~30% of the ETGs imaged in the UV with GALEX show signatures of such rejuvenation episodes, even after excluding classical UV-upturn candidates.



Marino et al. 2011, MNRAS, 411, 311

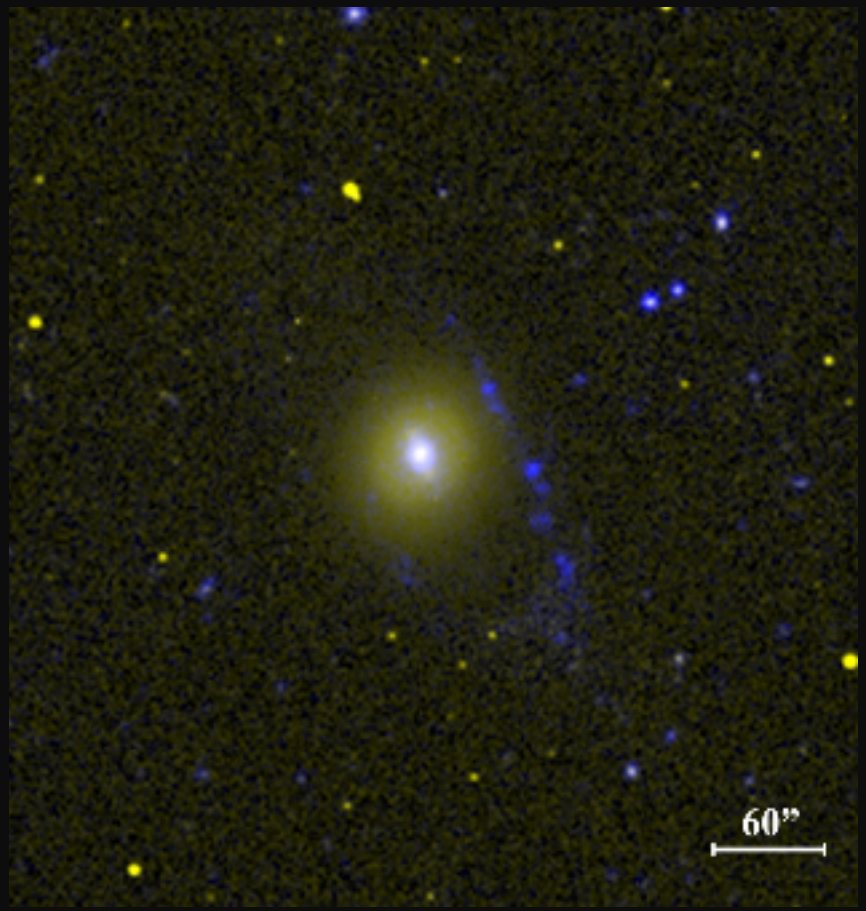


Marino et al. 2011 ApSS, 335,243



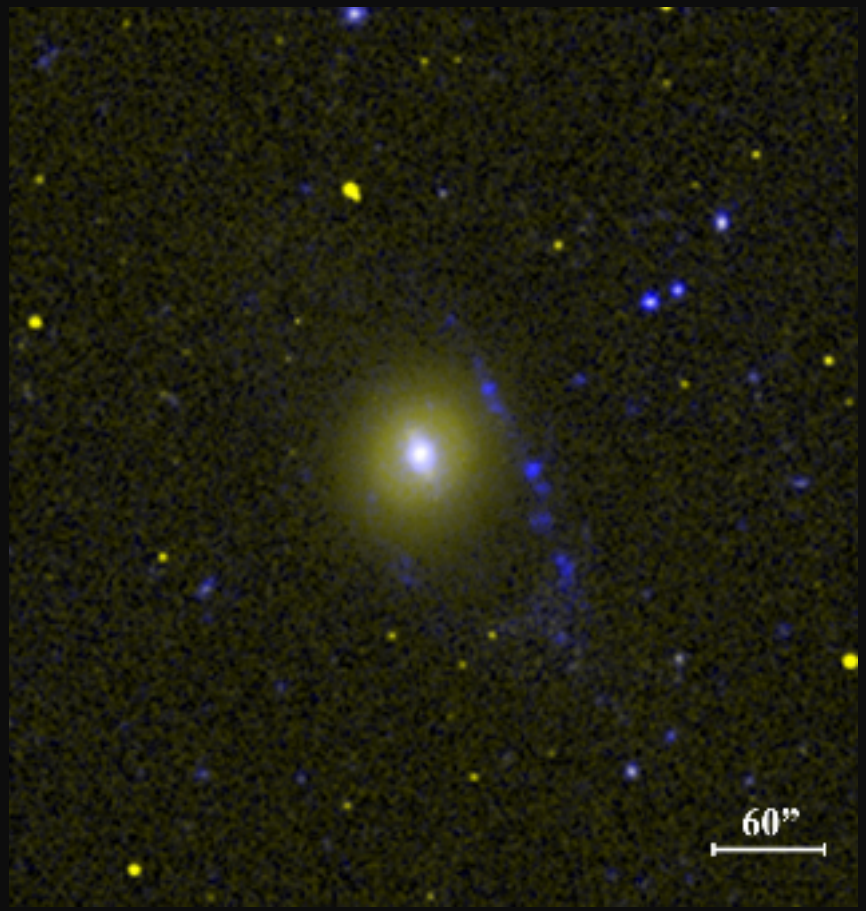
optical (left), UV two colours FUV (blue) and NUV (yellow) composite images (mid), and HI distribution or contours (right)

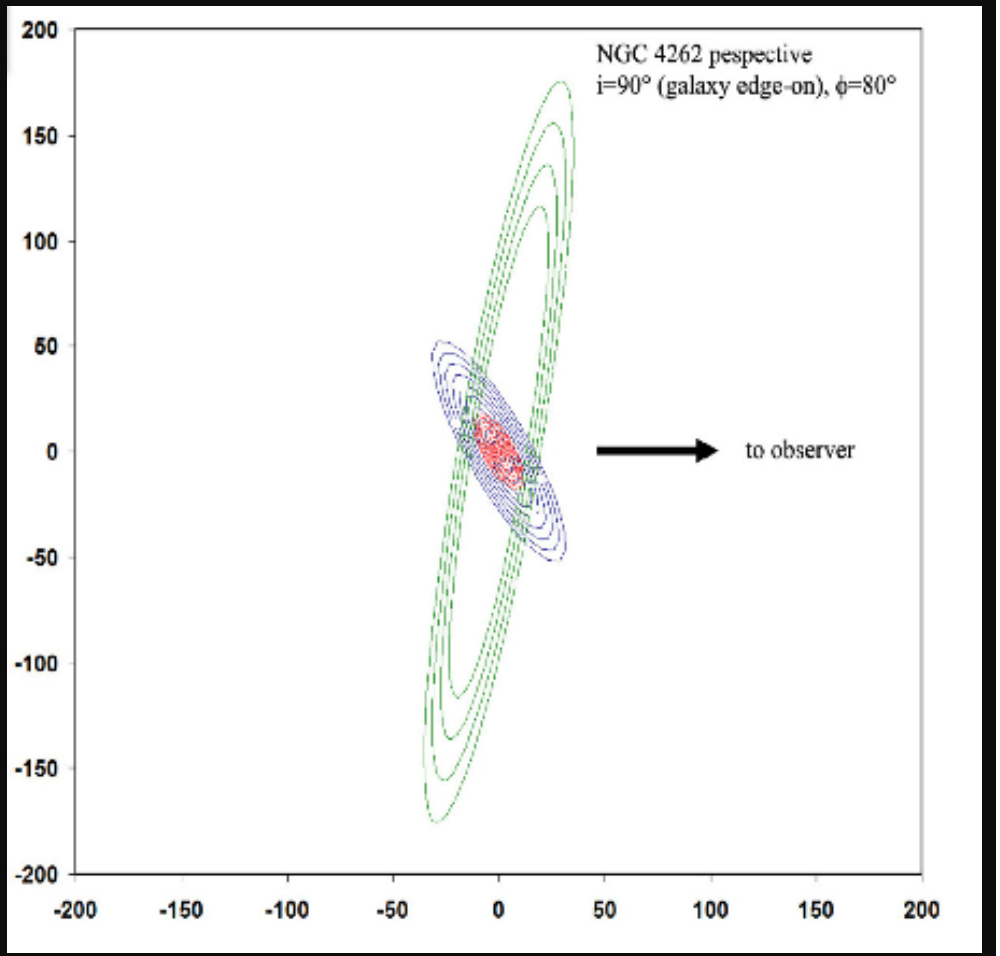
Marino et al. 2011, MNRAS, 411, 311



NGC 4262

NGC 4262





Bettoni et al. 2010

ETGs with peculiar features

Galaxies with counter-rotation

Galletta (1996), Bertola & Corsini (1998)

"Counter-rotation is a physical phenomenon for which two part of a galaxy rotate with opposite spin"

POLAR-RING Galaxies (PRG)

Whitmore et al. (1990), Moiseev et al. (2011)

"galaxies in which an outer ring of gas, stars and dust orbit in a nearly perpendicular plane to the equatorial one of the central galaxy"

Shell Galaxies

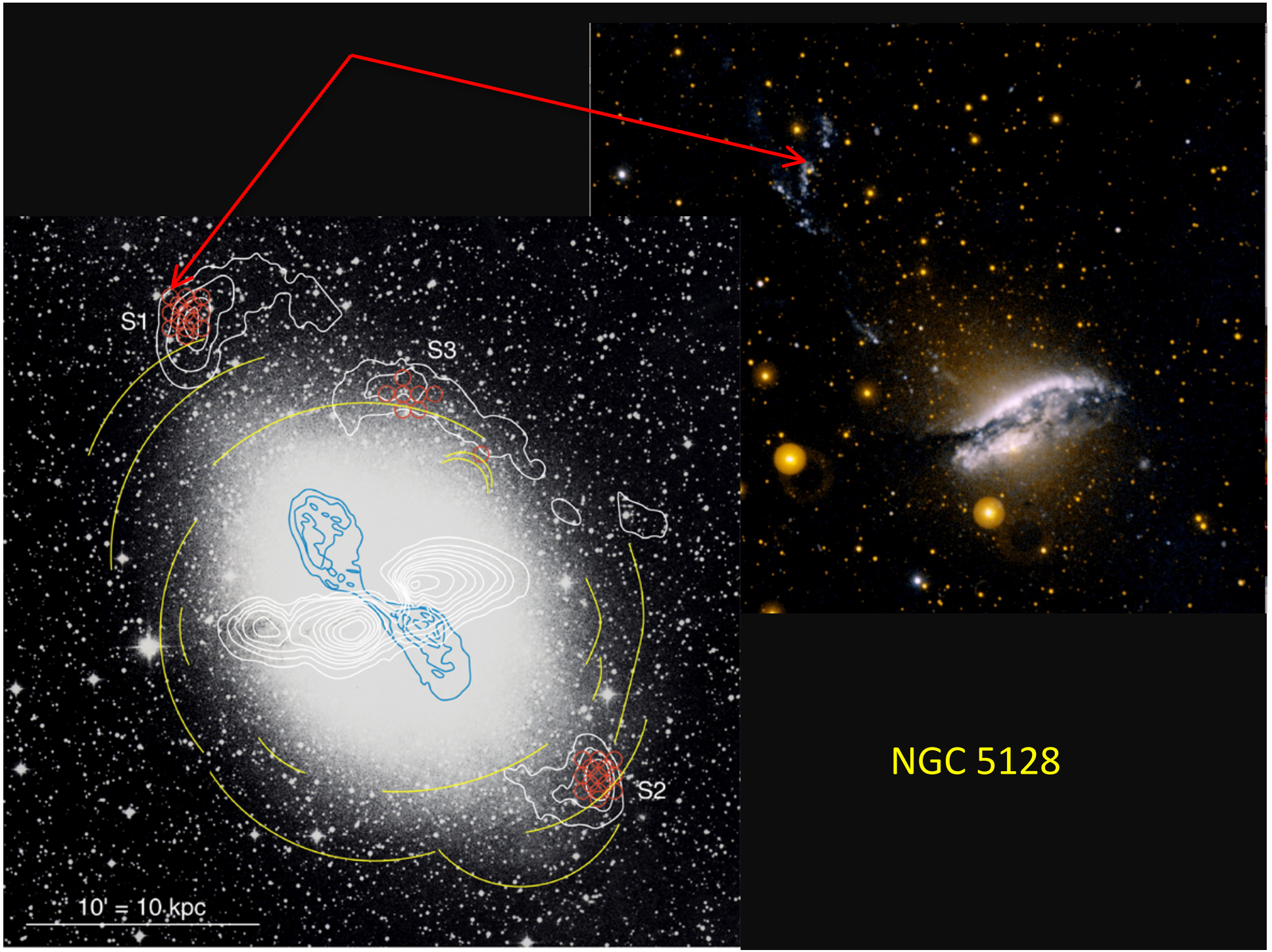
Malin & Carter (1983), Schweizer (1993)

shells are faint, sharp-edged stellar features of the field ETGs

Rampazzo et al. (2007) and Marino et al. (2009) showed that ETGs with shell structures (indicative, according to simulations, of recent accretion episodes) host a “rejuvenated” nucleus. Similar results have been obtained by Jeong et al. (2009) for the SAURON galaxy sample (de Zeeuw et al. 2002)

Outer rings consist of young (<200 Myr old) stellar populations, accounting for up to 70% of the FUV flux but containing only a few % of the total stellar mass

If we consider the sample of galaxies with counter-rotation the percentage of ETG with signatures of rejuvenation episodes jump at ~50%


S1
S3
S2
10' = 10 kpc
NGC 5128

NGC 2685

The chemo-photometric SPH simulations

We have obtained a grid of SPH simulations spanning a large set of masses and input parameters (Mazzei et al 2013, ASP in press, astro-ph/: 1306.0777; Bettoni et al. 2012)

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Simulations provide the synthetic SED, based on evolutionary population synthesis (EPS) models, at each evolutionary stage, i.e. at each snapshot. The time-step between each snapshot is 0.037 Gyr. The SED accounts for chemical evolution, stellar emission, internal extinction and re-emission by dust in a self-consistent way. This extends over four orders of magnitude in wavelength at least, i.e., from 0.06 to 1000 micron.

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Results for two galaxies: NGC 3626 and NGC 5173

NGC 3626

RSA type..... Sa
RC3 type.....RLAT+
$D_{25}xd_{25}$.....2.69'x1.95'
BT_0.....11.75
(U-B).....0.30
(B-V).....0.81
V(km/s).....1493
Distance (Mpc)..... 24
LB($10^{10}L_{\odot}$) 1.8
m_B.....11.91±0.04
m_V.....11.11±0.02
m_R.....10.59±0.02
ε.....0.32±0.02
P.A. (deg)..... 164±3
B/D_R.....0.37

Imput parameters

Pericentric distance = 101 Kpc

v_1=273km/s v_2=546 km/s

$M_1=2x10^{12}$ $M_{\odot}$ $M_2=1x10^{12}$ $M_{\odot}$

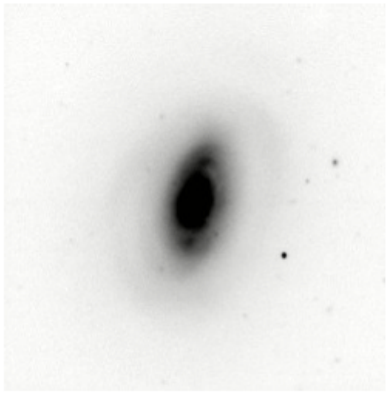
f_{gas} =0.1

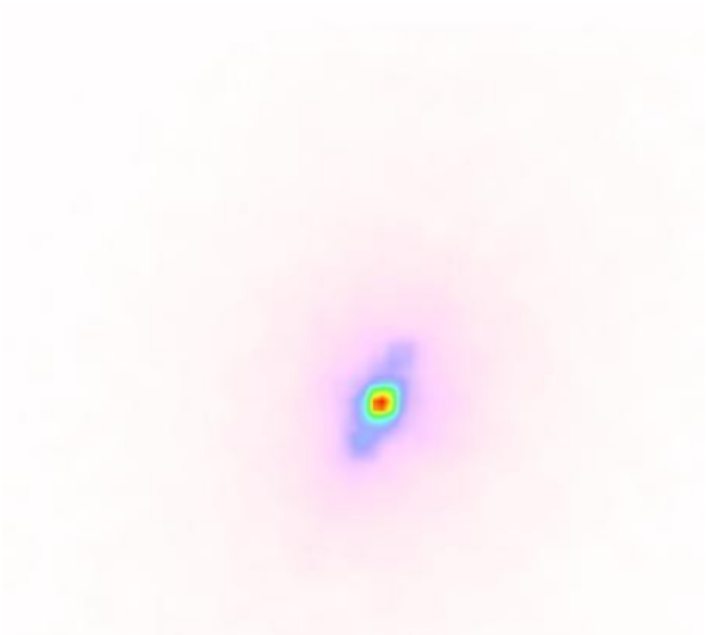
Ciri et al. 1995,

Garcia-Burillo et al. 1998

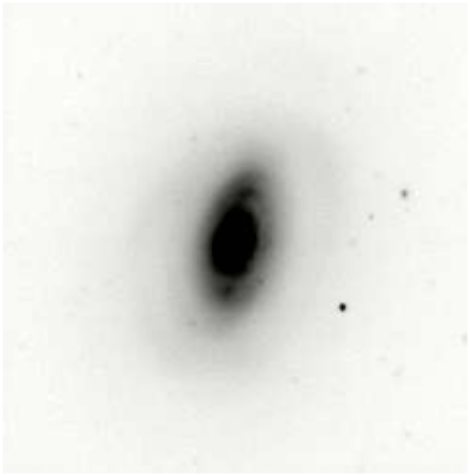
Haynes et al. 2000

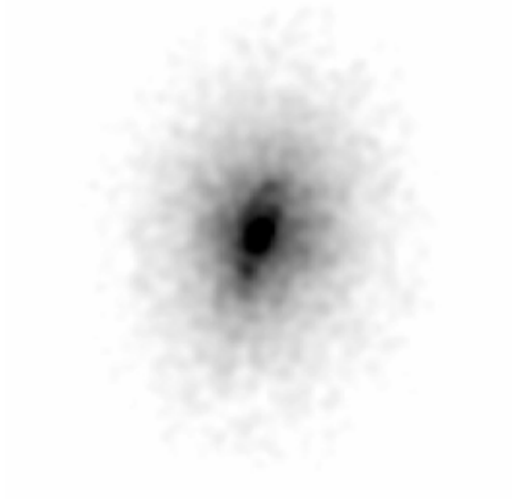
2'.9x2.' 9 J map of NGC3626 compared with our simulated map on the same scale

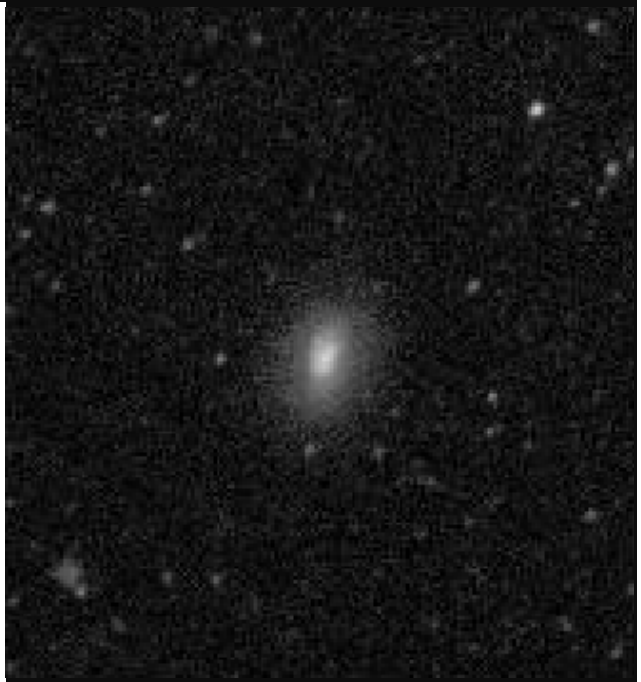




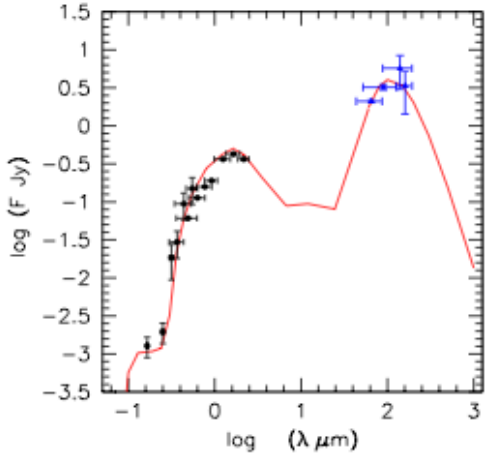
NGC 3626

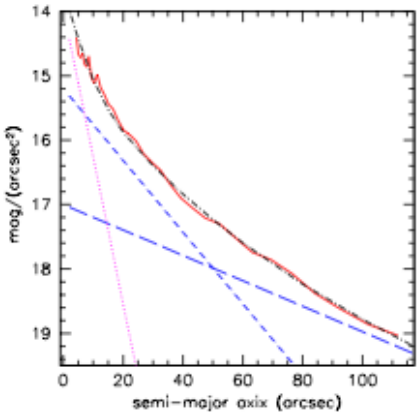






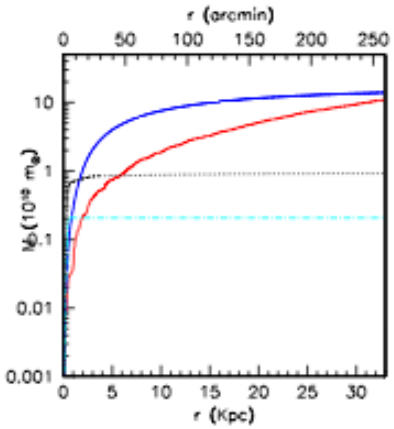
GALEX NUV

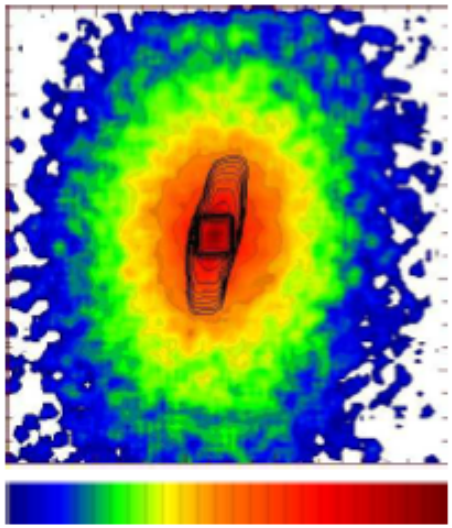




Mazzei et al. 2013, COSPAR

Mass distribution





NGC 3626

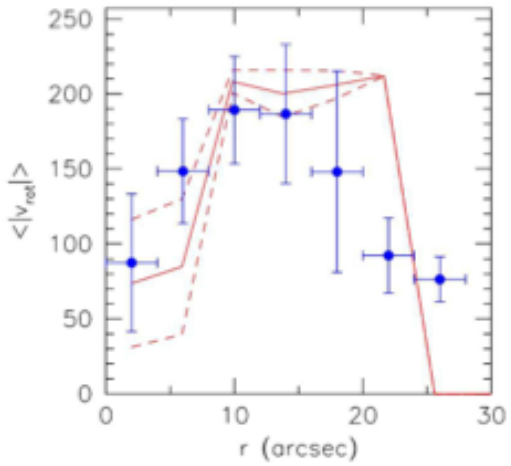
--- Dark Matter

---- Stars

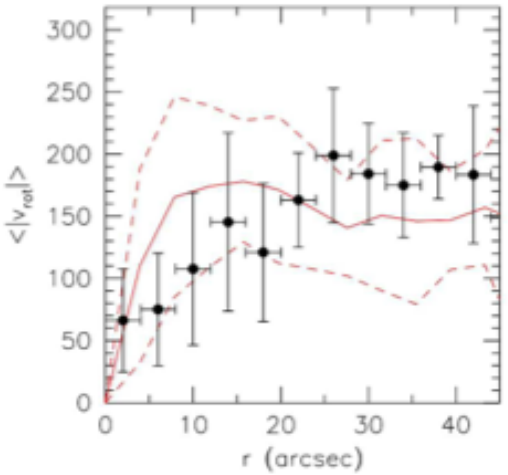
---- Gas

---- Cold gas ($T<10^4$ K)

GAS



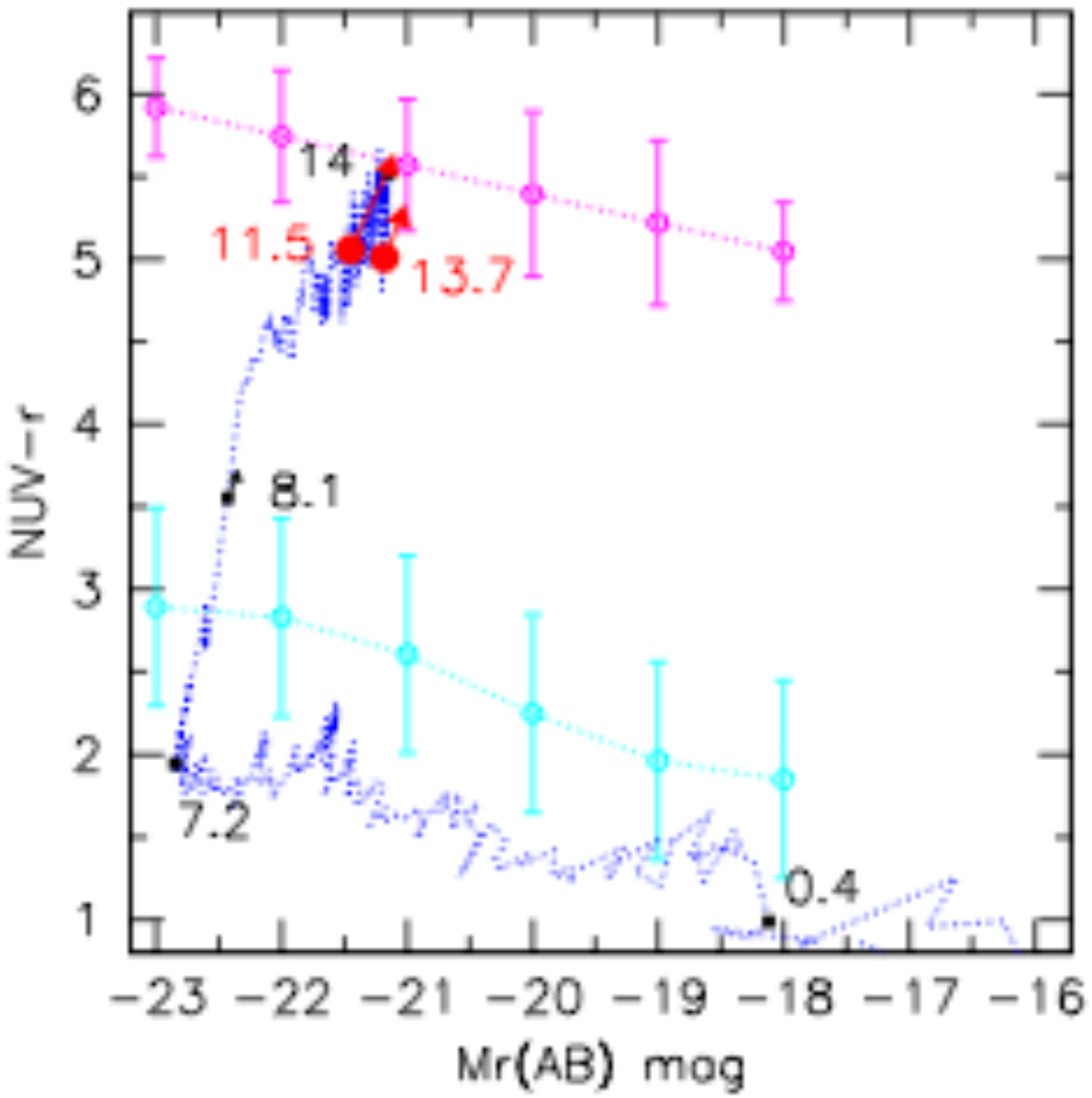
STARS



The merging of two halos with mass ratio 2:1, initially just composed of DM and gas, well match the observed SED, the surface brightness profiles and the overall kinematics.

The residual star formation today rejuvenating the ring/arm like structures in NGC 3626 is then a mere consequence of a major merger, i.e. this is a phase during the merger episode.

The peculiar kinematical features, e.g. gas-stars counter rotation in NGC 3626, depends on the halos initial impact parameters.



Wyder et al. (2007) fits of the blue (cyan) and red (magenta) sequences

NGC 5173

Type E0

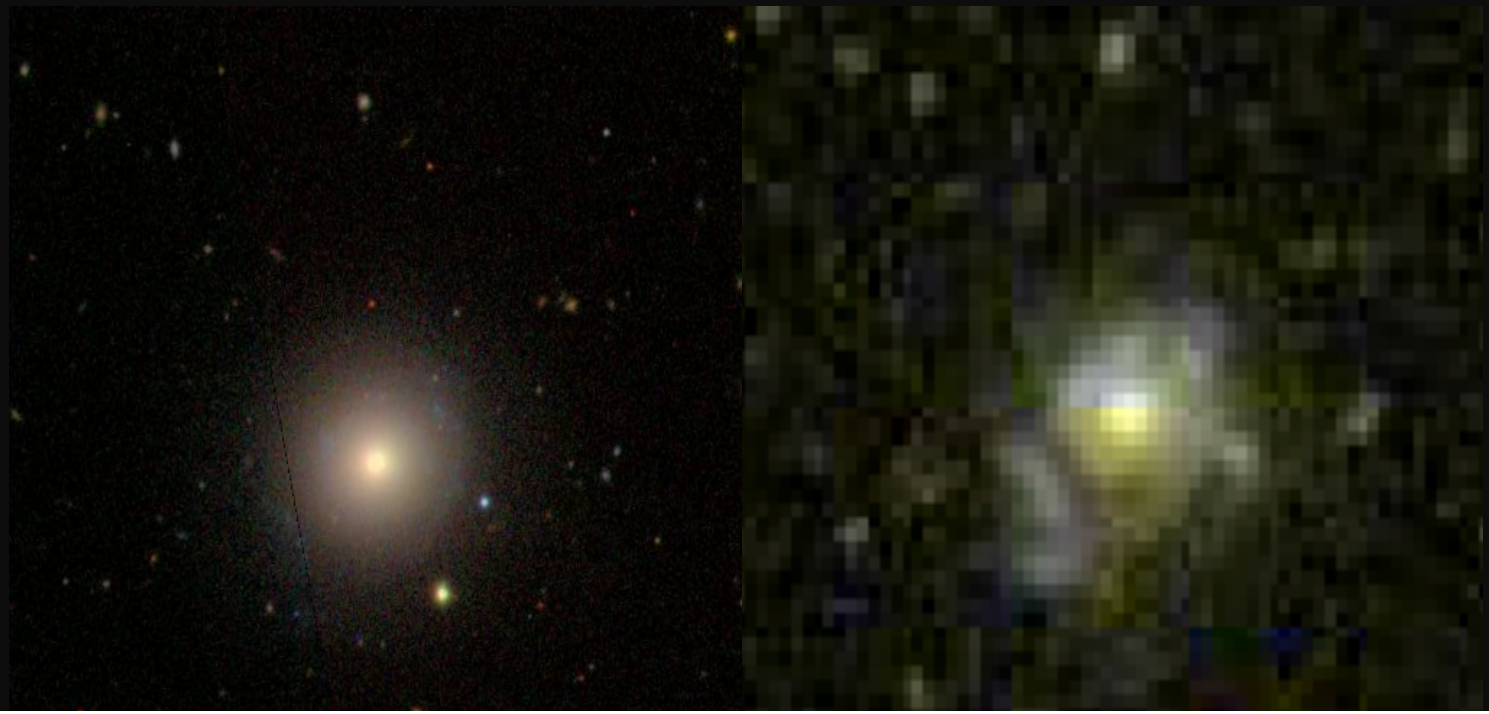
R_e = 1.8 Kpc

M_B=-19.2

PA=100

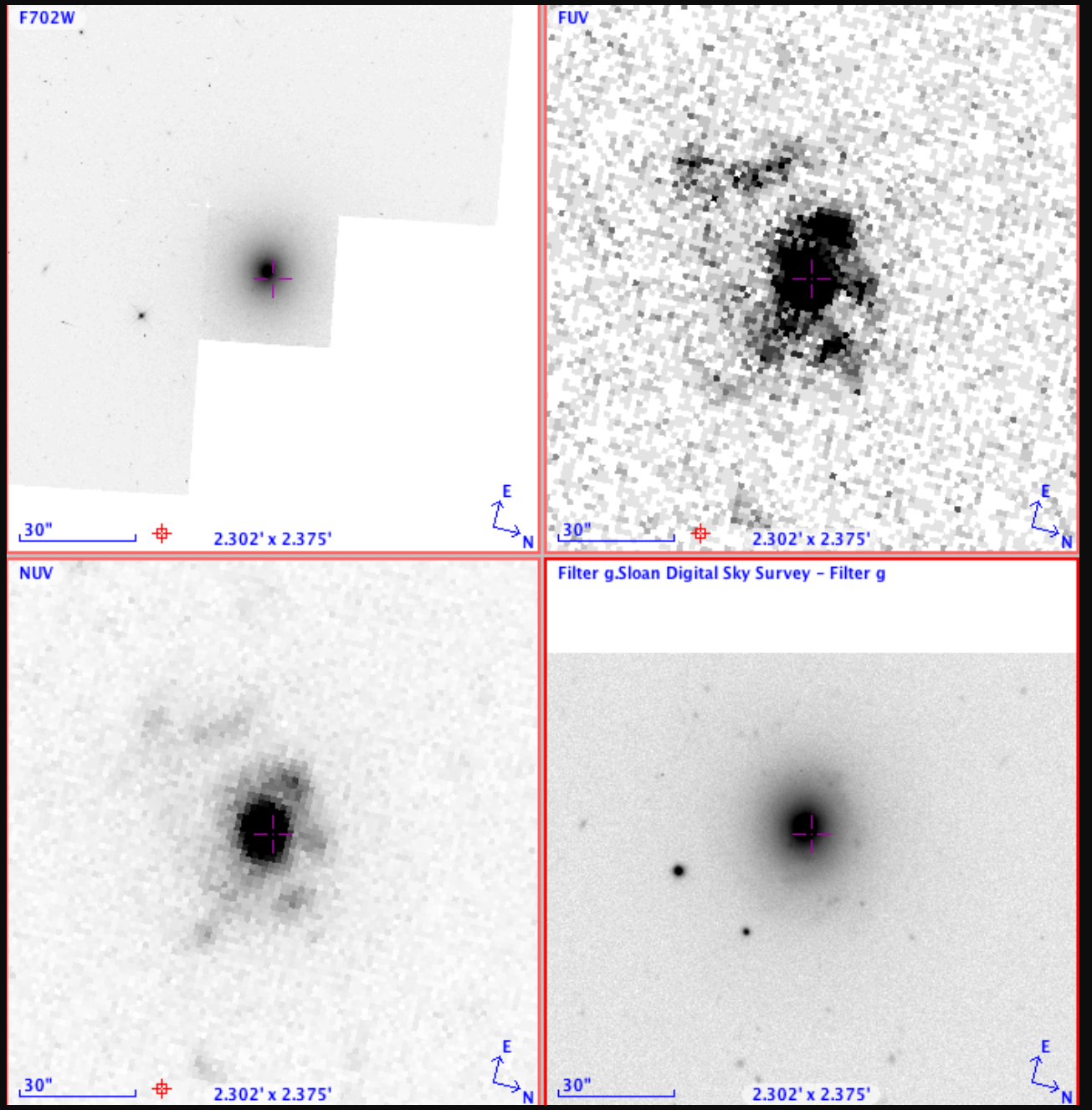
ε =0.01

NGC 5173

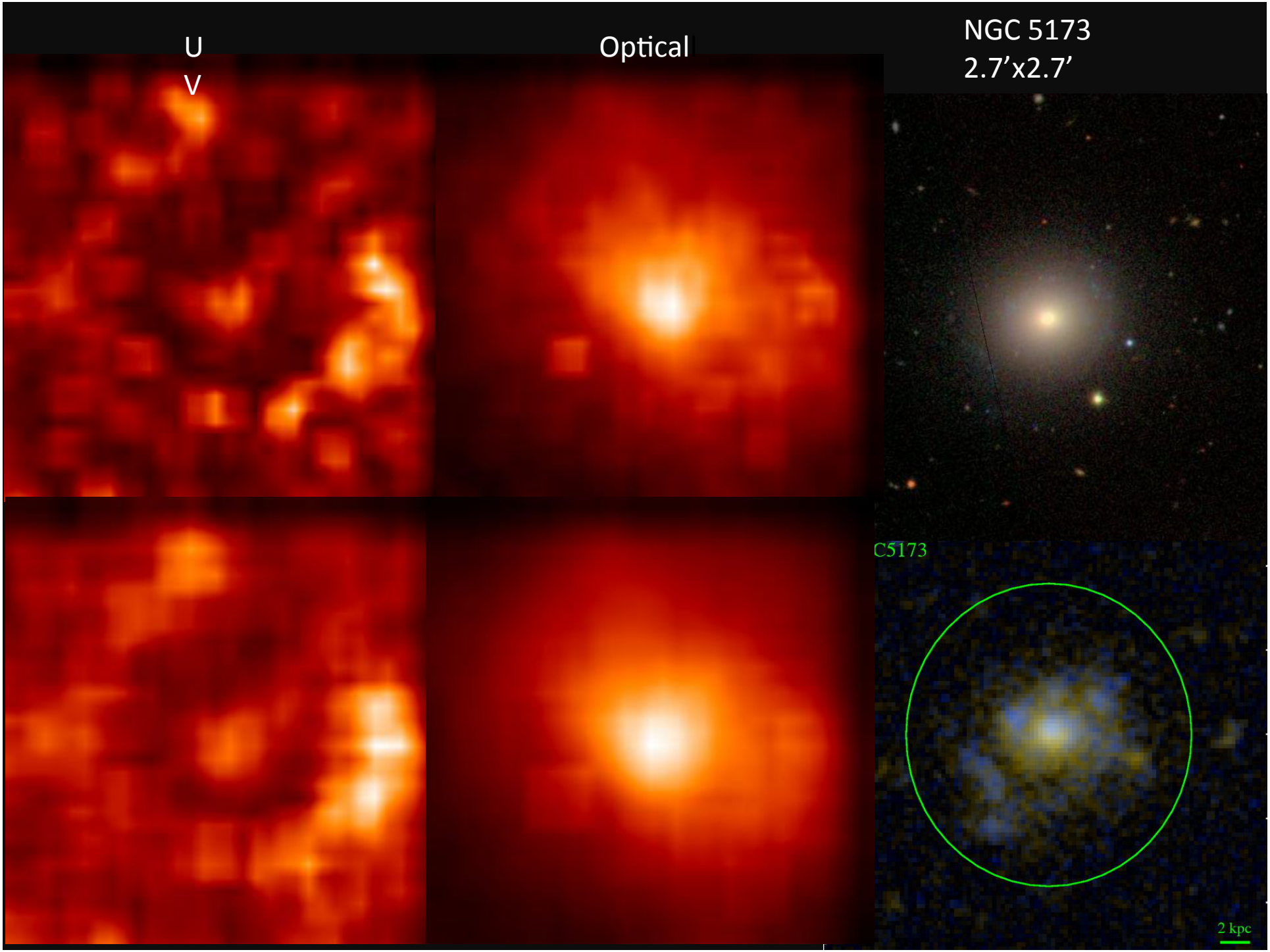


Kannappan & Fabricant. 2001

NGC 5173

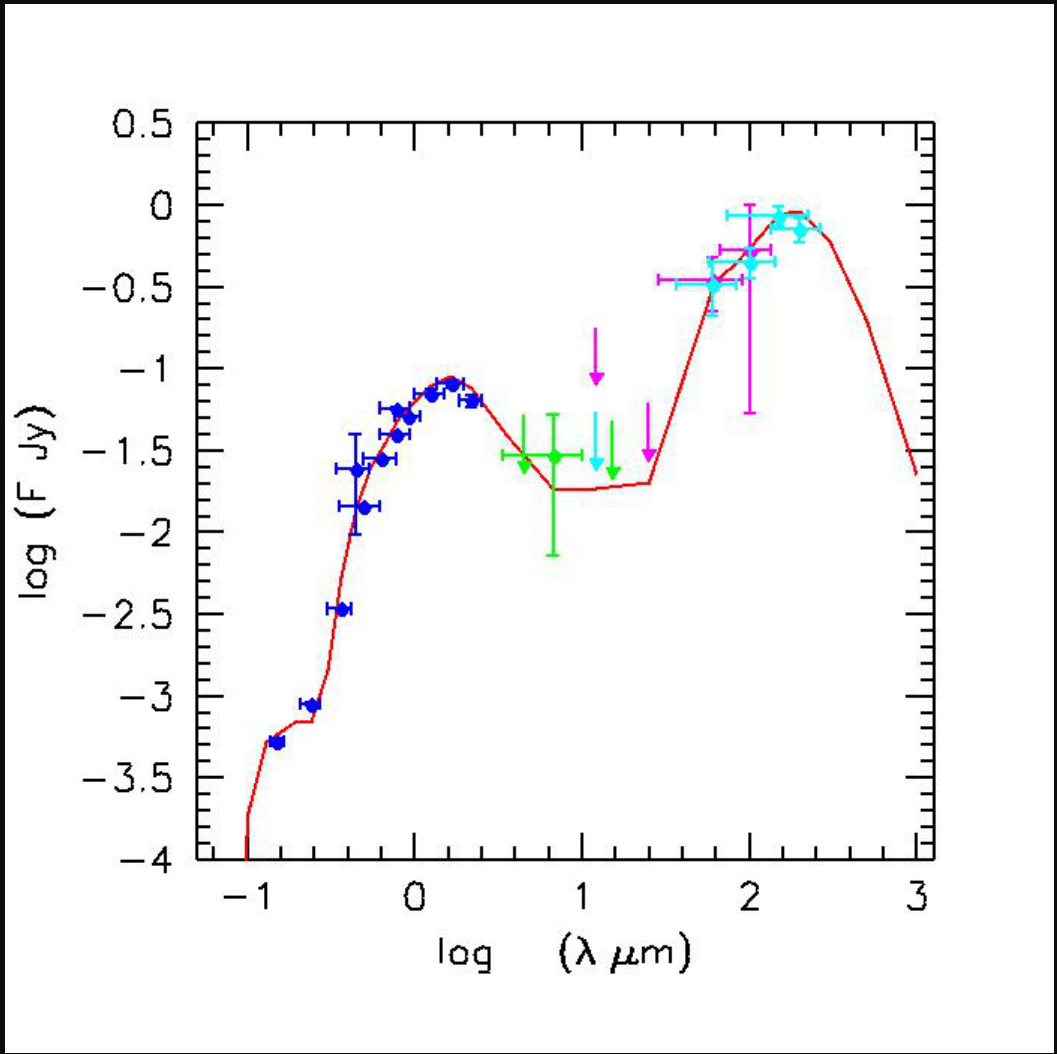

F702W
30"
2.302' x 2.375'
E
N
FUV
30"
2.302' x 2.375'
E
N
NUV
30"
2.302' x 2.375'
E
N
Filter g.Sloan Digital Sky Survey – Filter g
30"
2.302' x 2.375'
E
N

SDSS and UV (two colors, FUV (blue) and NUV (yellow)) composite images of NGC 5173, 2.7'x2.7' are compared, on the same scale, with simulated maps (res 5'' and density contrast 15; both maps have been normalized to the total flux within the simulated image) at the age of 13.8 Gyr.


U
V
Optical
NGC 5173
2.7'x2.7'
C5173
2 kpc

The simulation which best-fit its total SED, from FUV to 200 micron, total B absolute magnitude(-17.48+-0.31 from Hyperleda) and morphology at an age of 13.8 Gyr, corresponds to a galaxy encounter (1:1) from two triaxial halos, initially composed of dark matter and gas, with total mass $4x10^{12}$ solar masses and relative positions and velocities, $r_1=-r_2=888$ kpc, $v_1=-v_2=61$ km/s

The FIR SED includes two dust components: warm dust (HII regions) and cold dust (heated by the diffuse interstellar field) both including PAH molecules (e.g. Bettoni et al 2012, A&A 538, a72); the warm/cold ratio is double than in average for Es (Mazzei et al, 1994, ApJ 422, 81), i.e. 1 instead of 0.5



data are collected from NED, in particular:
green are ISO data from Xilouris et al. 2004, (A&A 416,41),
magenta are IRAS data and
cyan are from Temi et al. 2004 (ApJS, 151 237)
Continuos line shows predictions from our chemo-photometric simulation at 13.8 Gyr

Conclusions

Our chemo-photometric SPH simulations, allow us to trace, in a fully consistent way, the evolutionary path of NGC 3626 and NGC 5173. The transition from the blue sequence, along which these galaxies evolved for about 7-8 Gyr, and before they became mature and red ETGs, lasts about 4-5 Gyr.

Our results show that another mechanism of gravitational origin, the merging of two haloes, is a viable mechanism to generate S0s today found in the red sequence.

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UV data at fainter surface brightness and at higher resolution could be a “smoking gun” for the study of the formation and evolution of ETG


Thank you