Neutral hydrogen, stellar populations and ionised gas in early-type galaxies

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HI in early-type galaxies

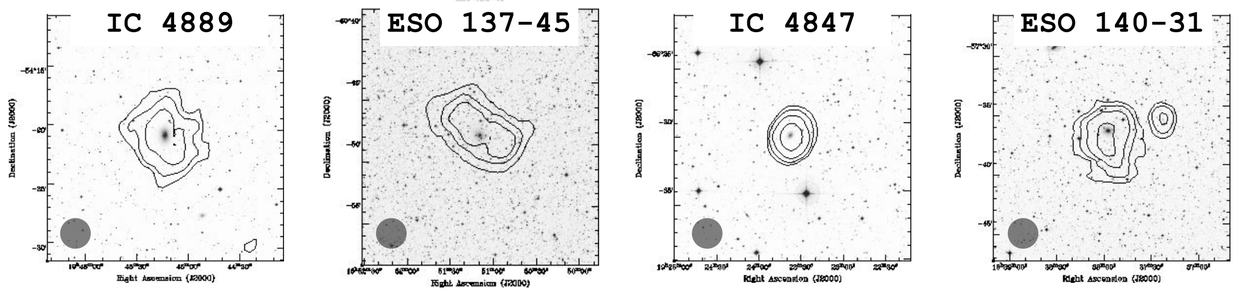
Significant fraction of the ISM

Detection rate:
>50% in the field
~few% in the cluster

$M(HI)=10^{6}-10^{10}\ M_{\odot}$
spread over tens of kpc
$n_{HI} < 10^{20}\ cm^{-2}$

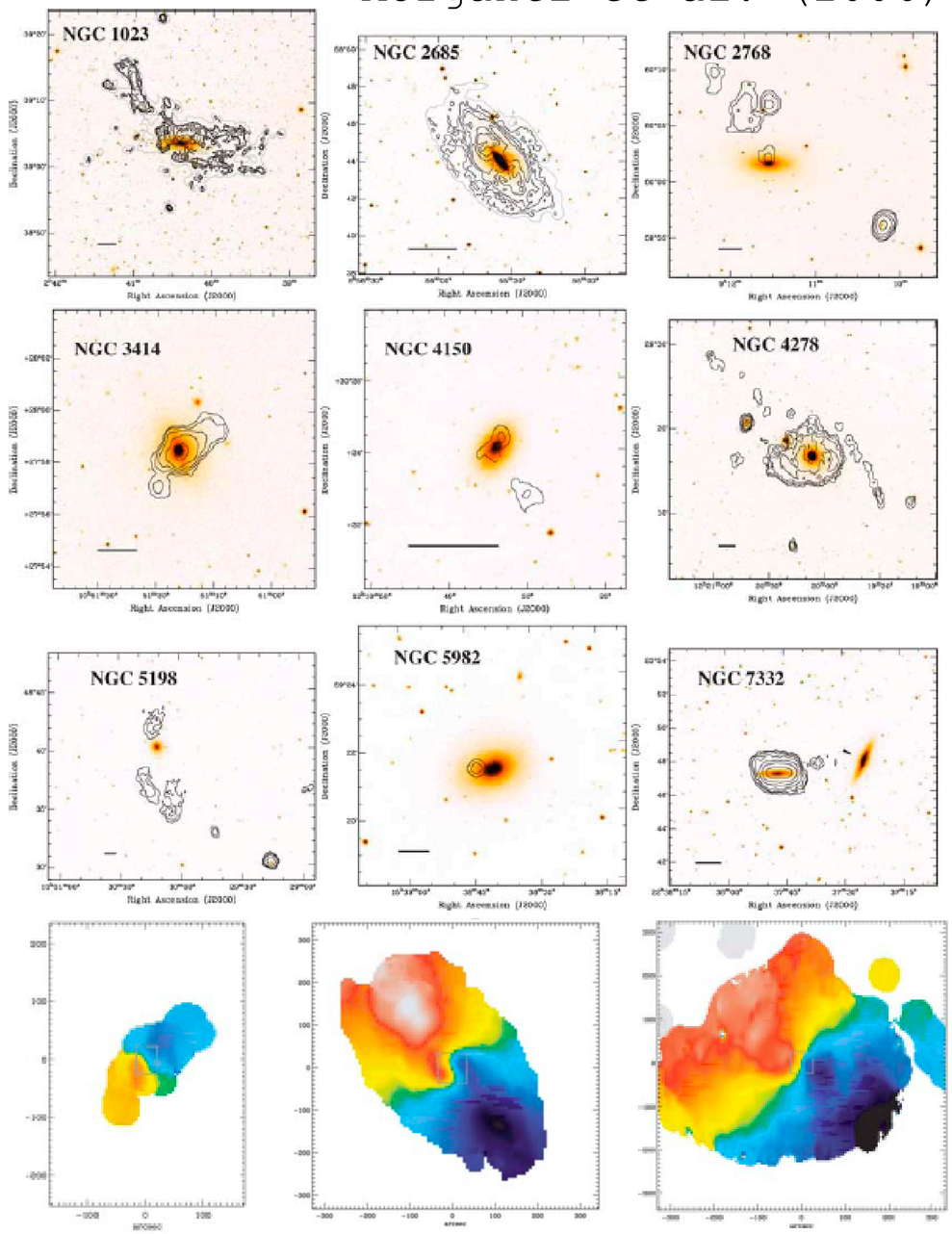
Unlike in spirals, large variety of HI morphology/kinematics and M(HI) does not correlate with L.

Large fraction of regularly-rotating, long-lived systems
T_{orbit} >1 Gyr



Oosterloo et al. (2007)

Morganti et al. (2006)

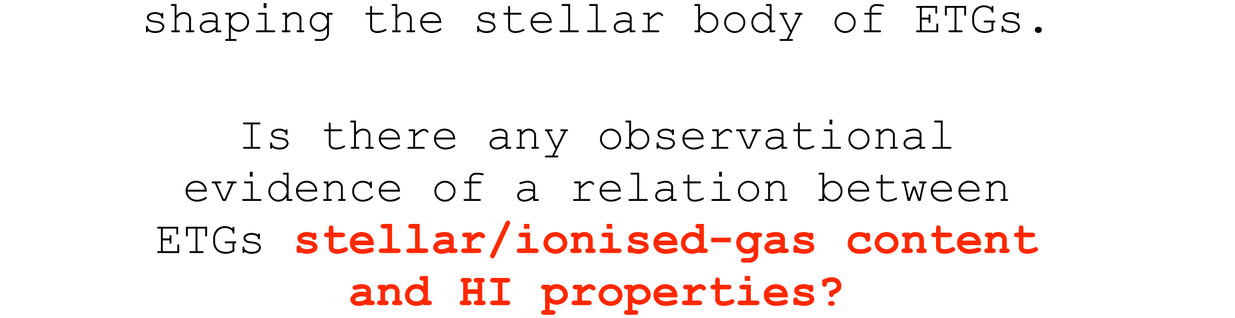


HI in early-type galaxies

Gas can play a major role in shaping the stellar body of ETGs.

Is there any observational evidence of a relation between ETGs **stellar/ionised-gas content and HI properties?**

Can we understand how this gas was accreeted? (e.g., accretion from the IGM, disc-galaxy mergers, accretion of small satellites, stellar mass-loss)



Oosterloo et al. (2007)

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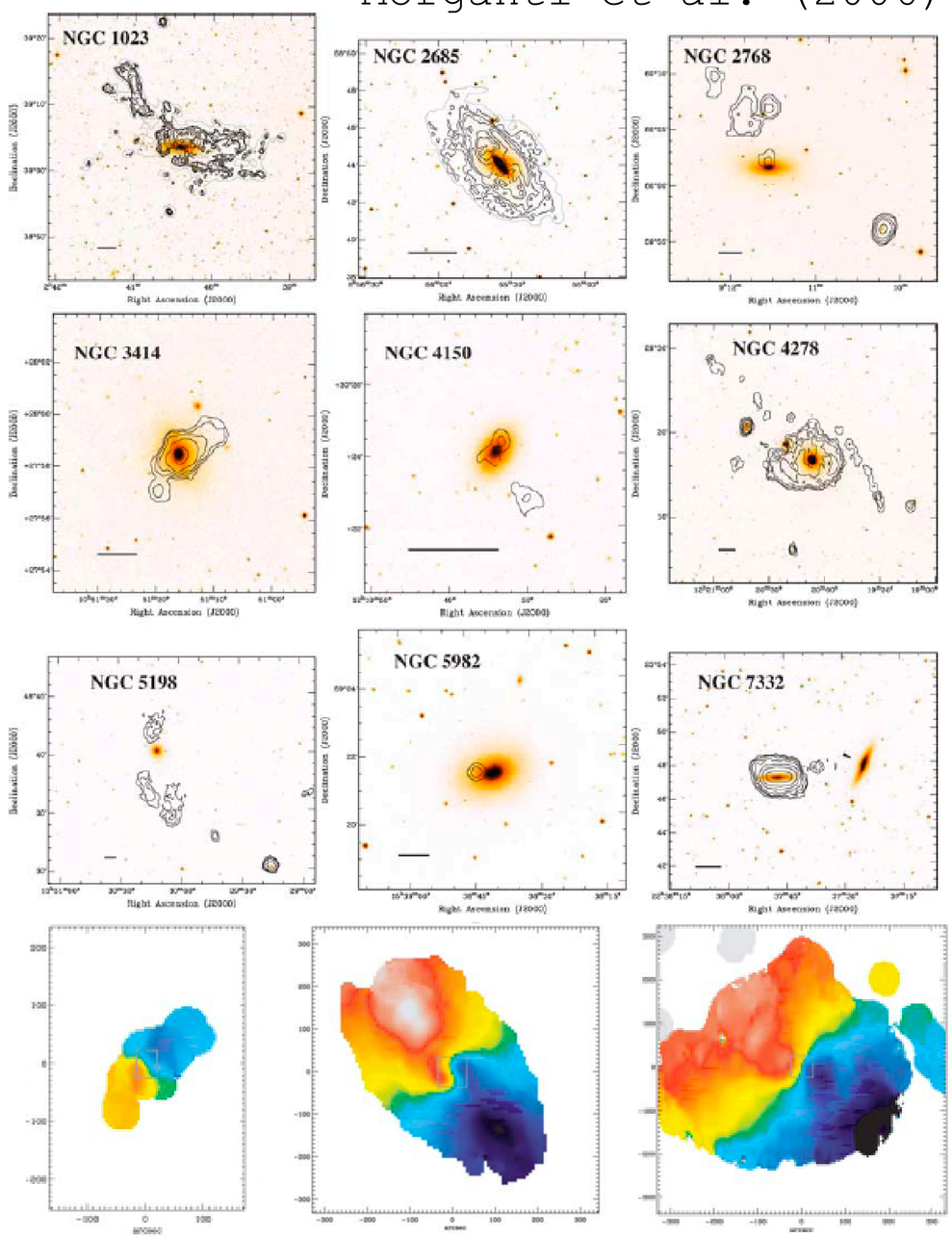
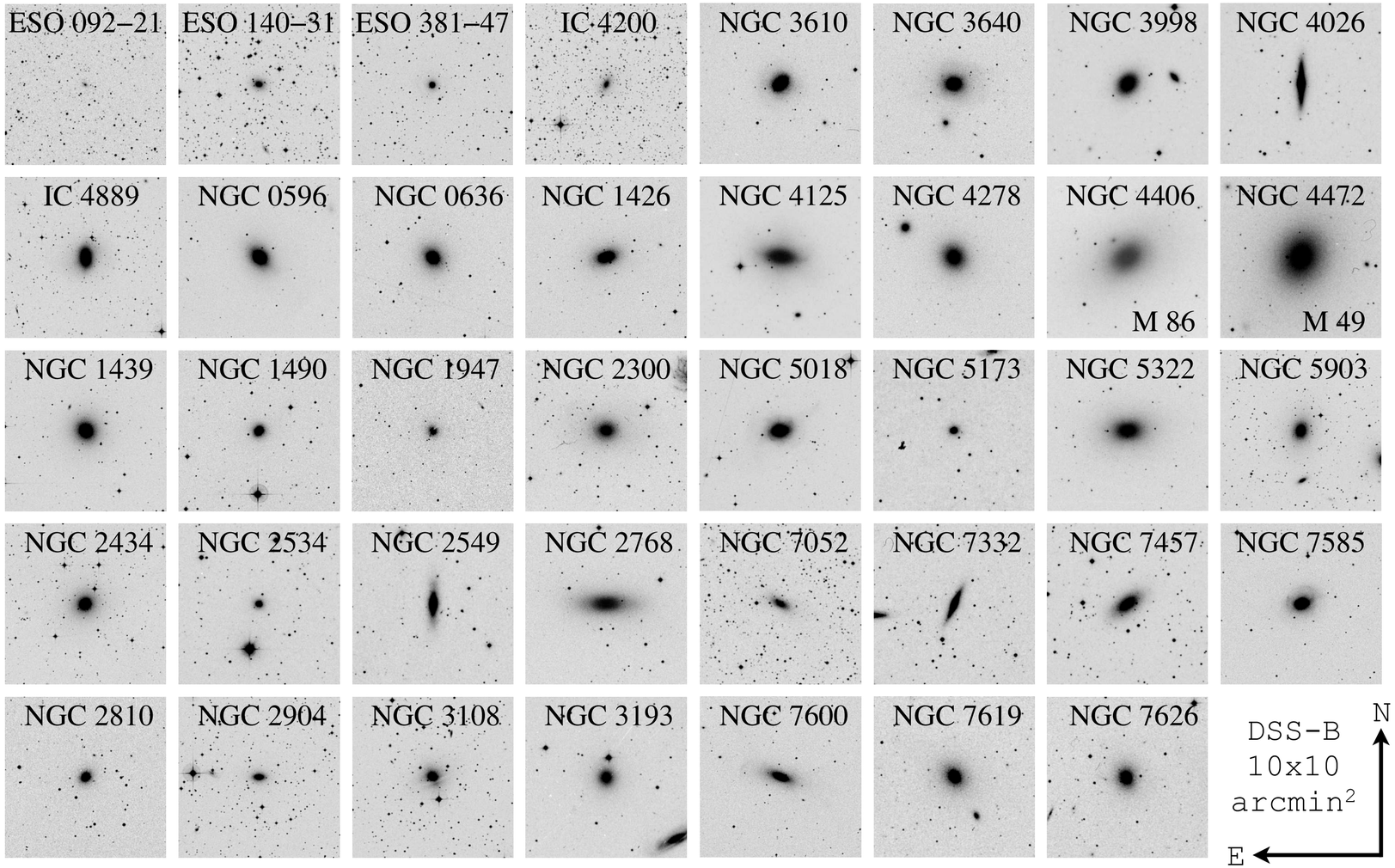


Optical spectroscopy of an HI-selected ETG sample



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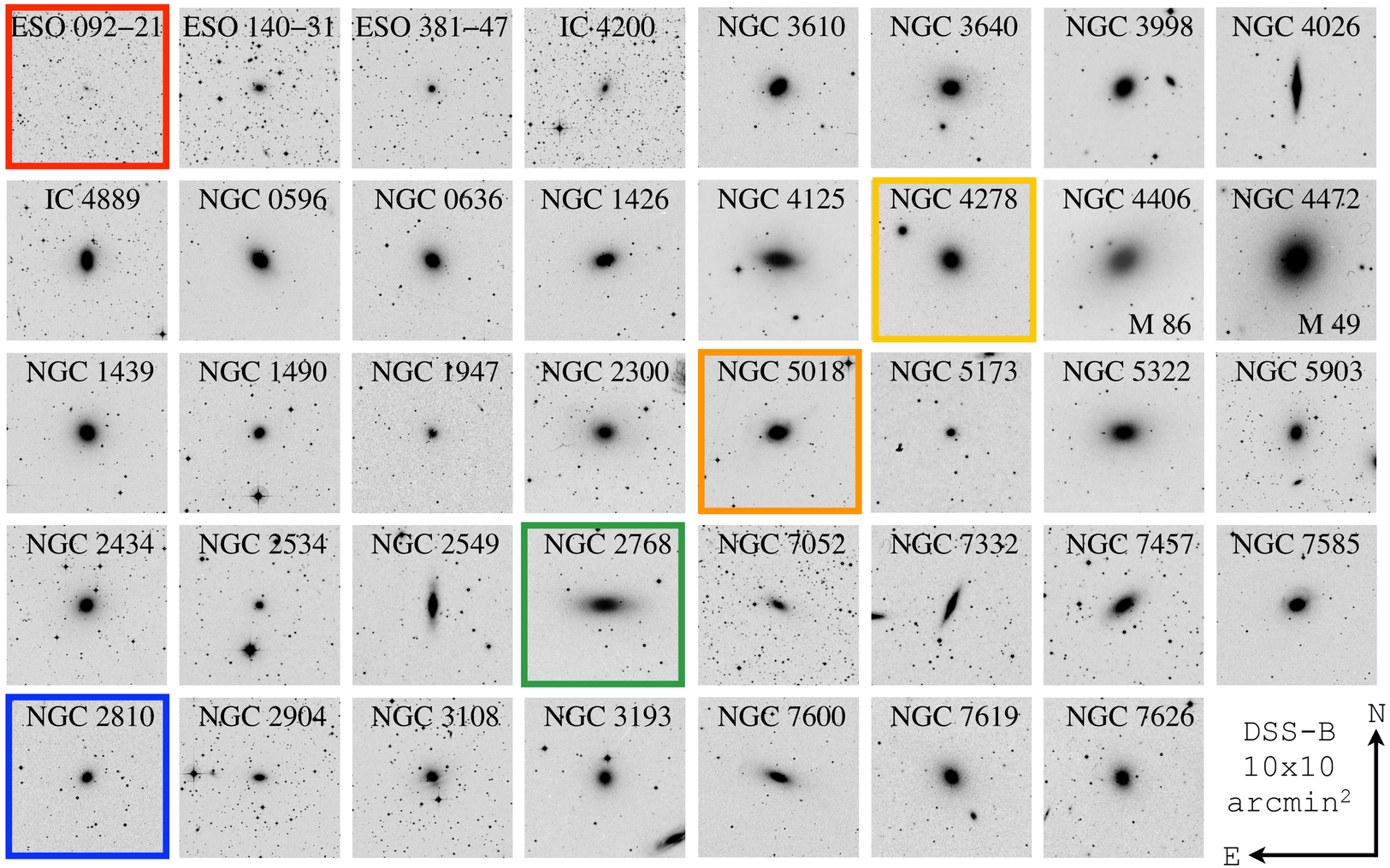
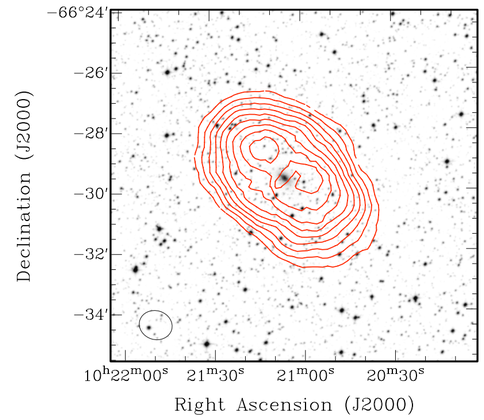
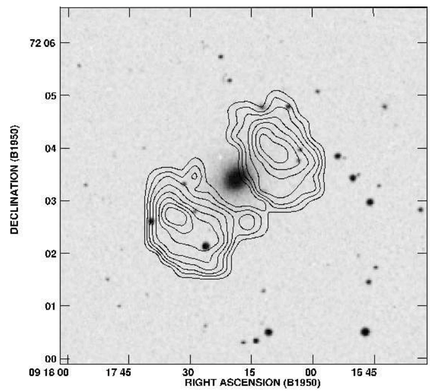
Optical spectroscopy of an HI-selected ETG sample



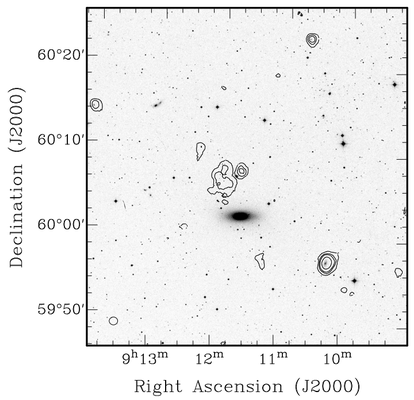
ESO 092-21



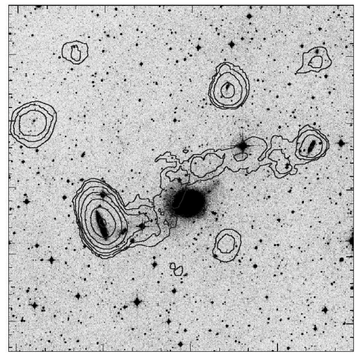
NGC 2810



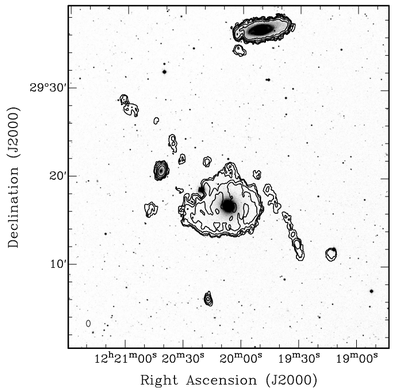
NGC 2768



NGC 5018



NGC 4278



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Ionised gas
(Serra et al. 2008)

60% of galaxies detected

Extended emission

LINER-like emission-line ratios at any radius (so not just star formation)

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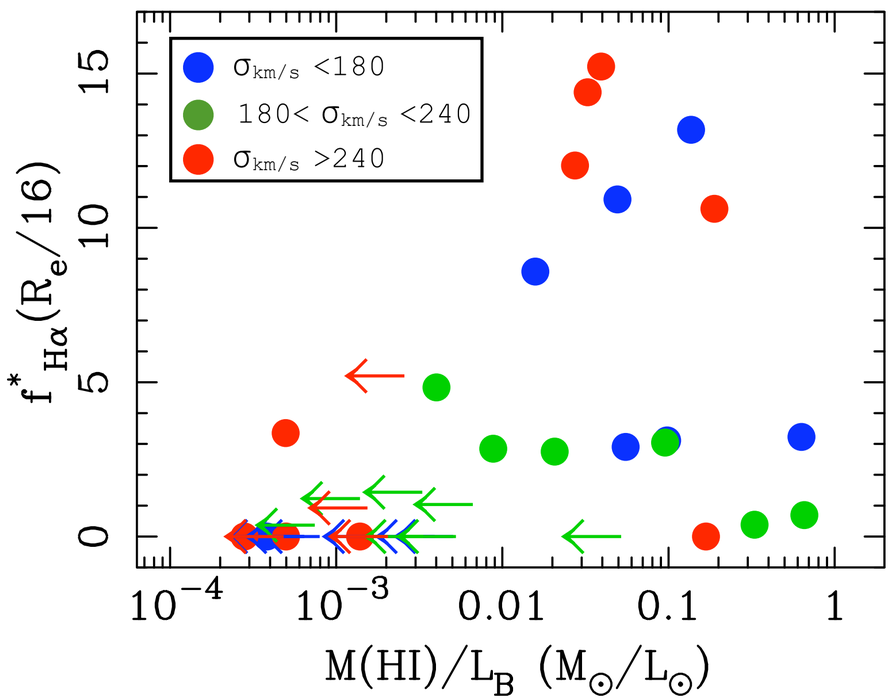


Large M(HI) necessary (but not sufficient) to have bright ionised gas. Very different physical scales!!!

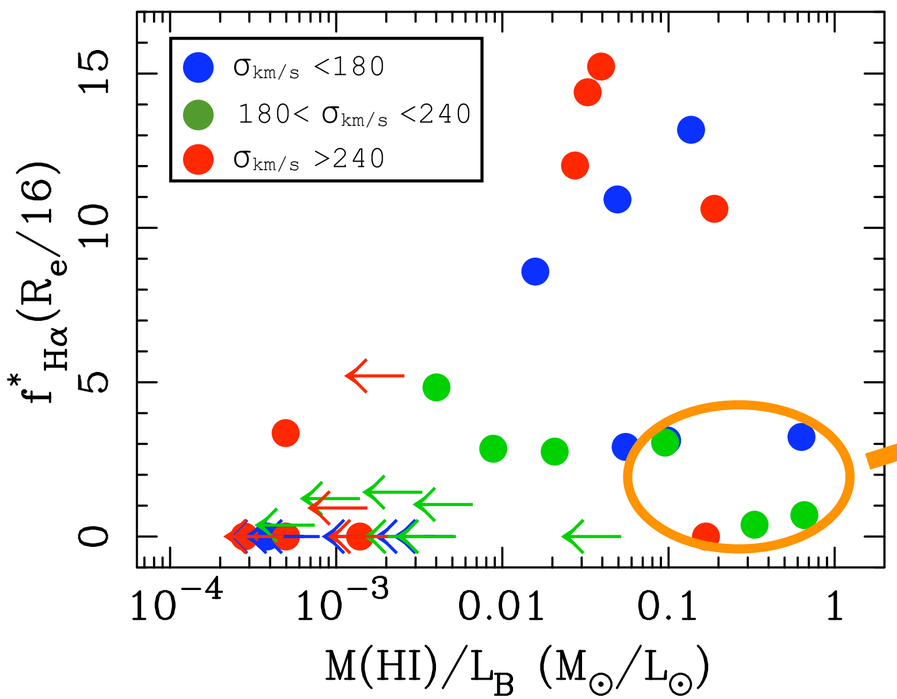
Regular HI extending down to the stellar body => bright ionised gas whose kinematics is consistent with that of the inner HI.

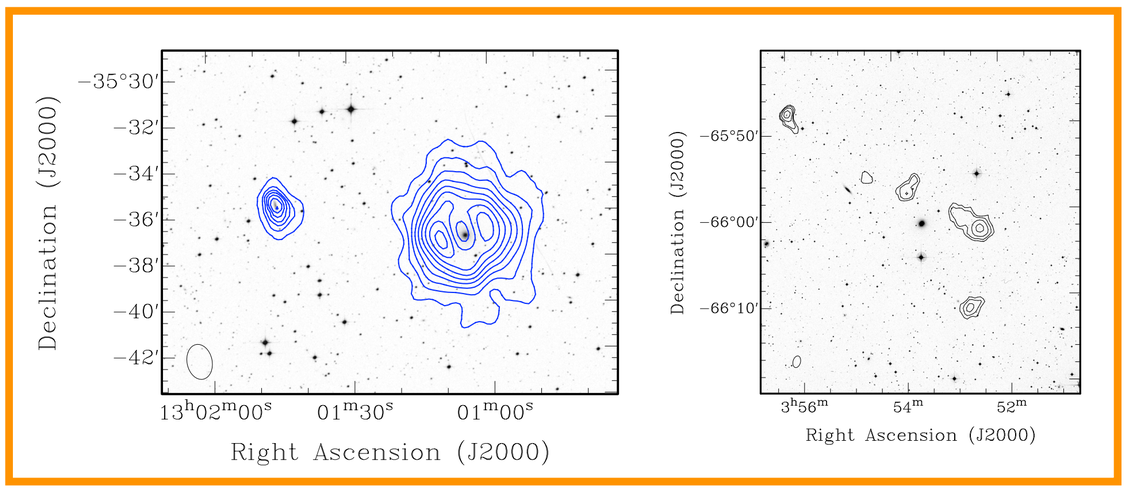
Ionised gas
(Serra et al. 2008)

60% of galaxies detected

Extended emission

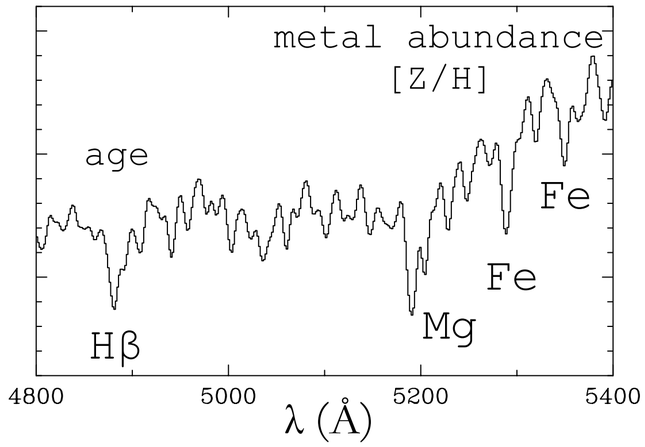
LINER-like emission-line ratios at any radius (so not just star formation)

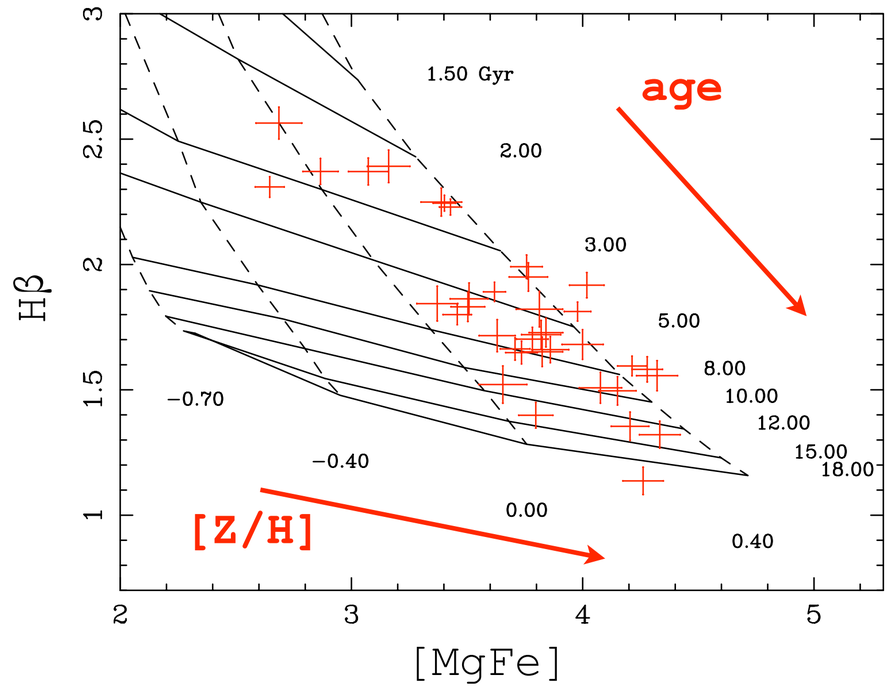




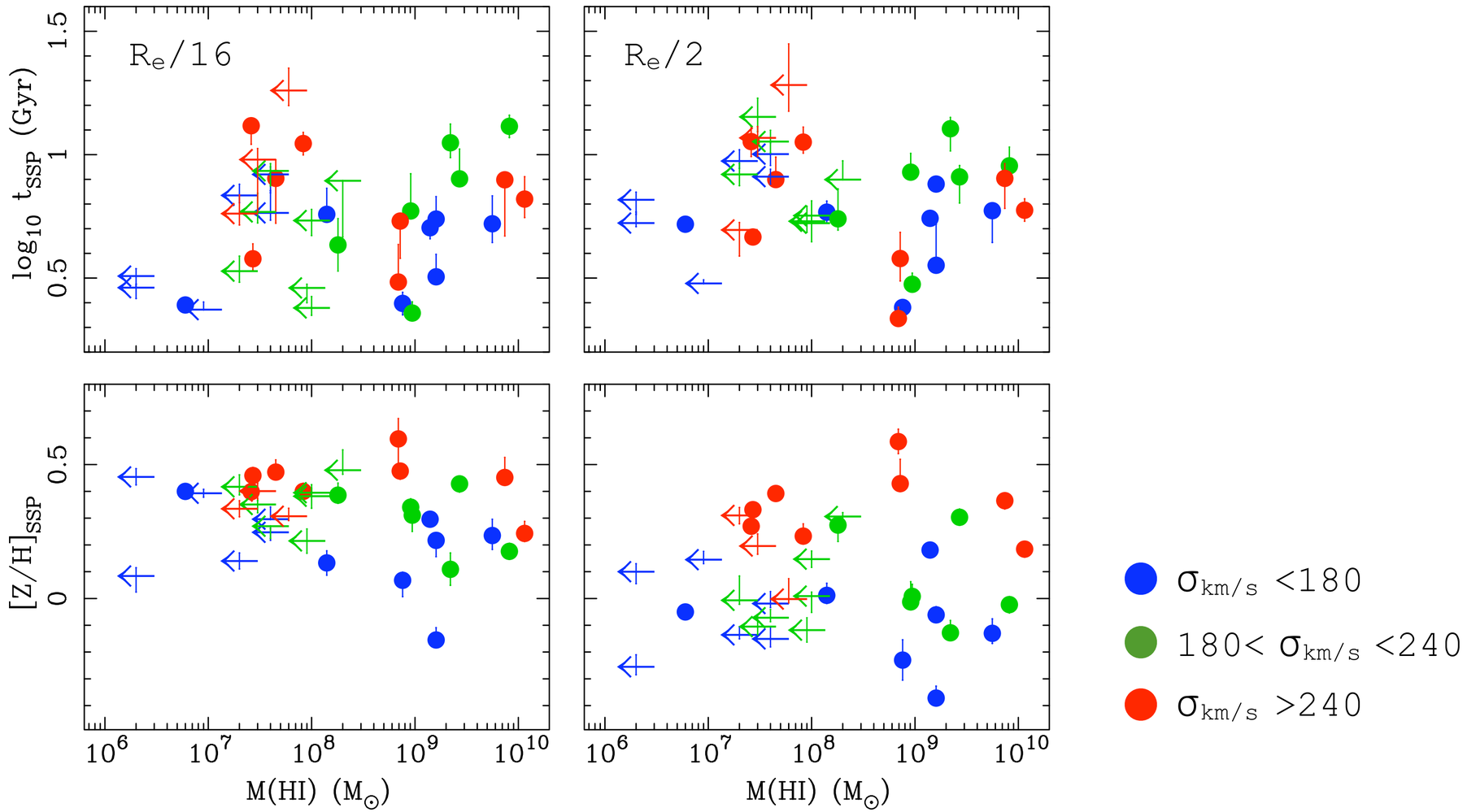
Galaxies where the HI does not extend down to within the stellar body

Stellar populations from line-strength indices





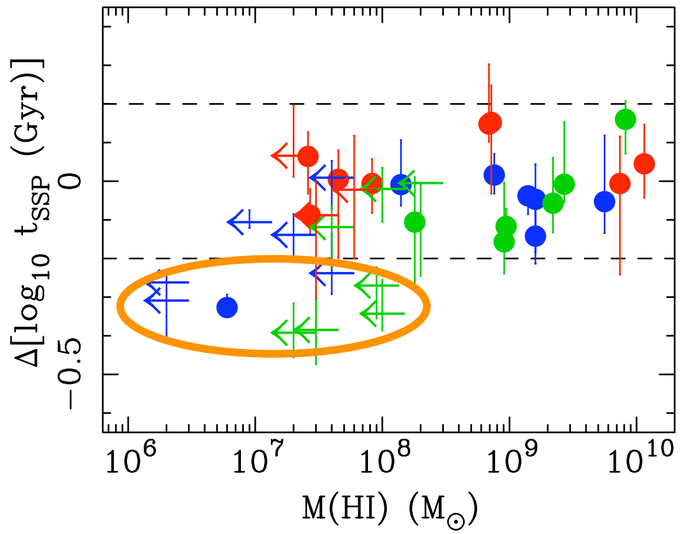
Stellar populations vs. HI
(Serra et al. 2008)



The stellar populations of ETGs do not depend on HI mass

Stellar populations vs. HI
(Serra et al. 2008)

- $\sigma_{km/s}$ <180
- 180< $\sigma_{km/s}$ <240
- $\sigma_{km/s}$ >240



stars younger in the centre than at larger r

~50% of ETGs with M(HI)<10^8 $M_\odot$ become younger when moving towards the galaxy centre; **none** of the HI-rich objects do

Stellar populations vs. HI
(Serra et al. 2008)

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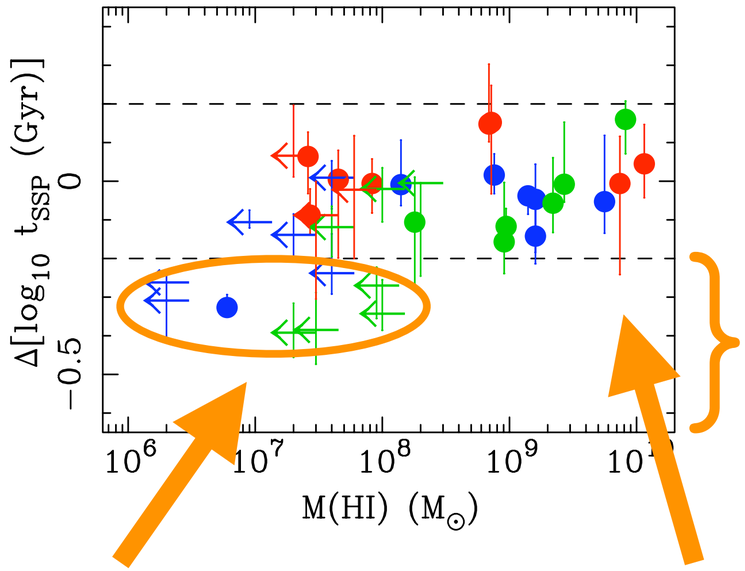

stars younger in the centre than at larger r

low-angular-momentum gas-rich mergers

vs.

high-angular-momentum gas-rich mergers

?

quantitative comparison to merger simulations needed!!!

Stellar populations vs. HI
(Serra et al. 2008)

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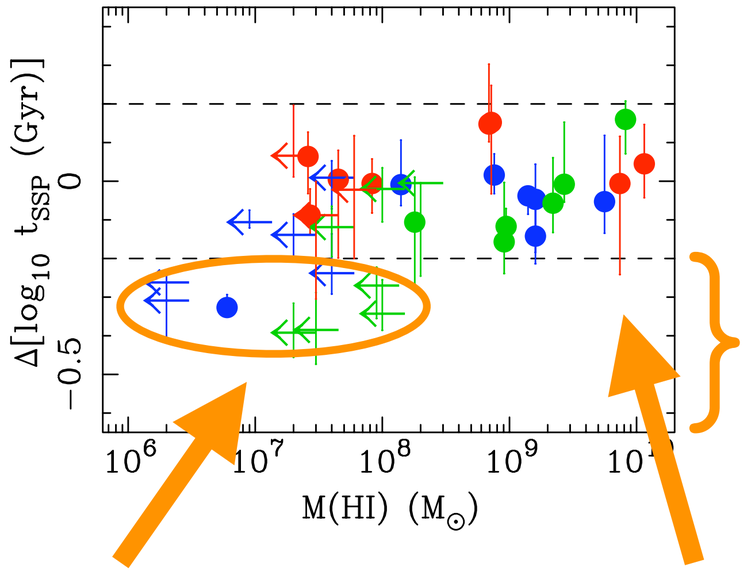

stars younger in the centre than at larger r

low-angular-momentum gas-rich mergers

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Main limitations of this and other works:
sample size and selection

21-cm interferometry of a complete, representative sample is still missing!

A multi-wavelength, **volume-limited** survey of ~260 nearby early-type galaxies

Optical integral-field spectroscopy (WHT/SAURON)
Optical imaging (INT)
CO (IRAM)
HI (WSRT)
+ archival 2MASS, GALEX, SDSS
+ archival XMM-Newton, Chandra
+ simulations

PIs: Cappellari and Kranjovic (Oxford), Emsellem (Lyon), McDermid (Gemini)

Atlas^{3D} WSRT HI survey

DEC>+10 deg

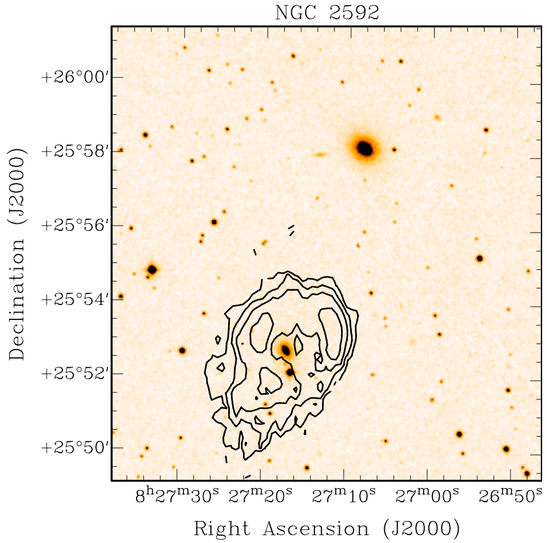
~100 Atlas^{3D} galaxies with no deep WSRT data nor Alfalfa upper limit on M(HI)
(=> mostly field galaxies)

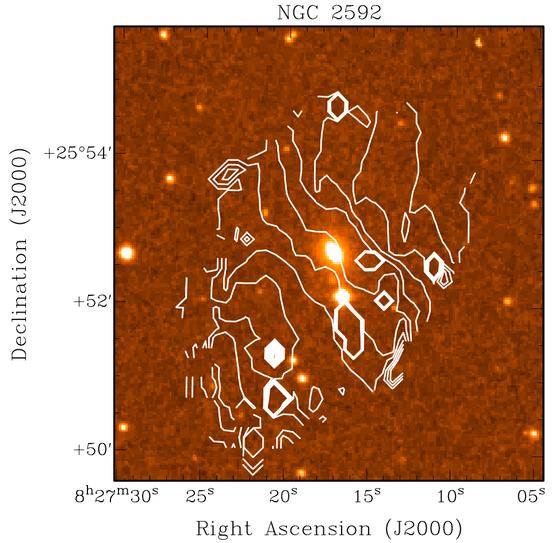
1x12 h/galaxy with WSRT
(possible 3x12-h follow-up of detected galaxies)

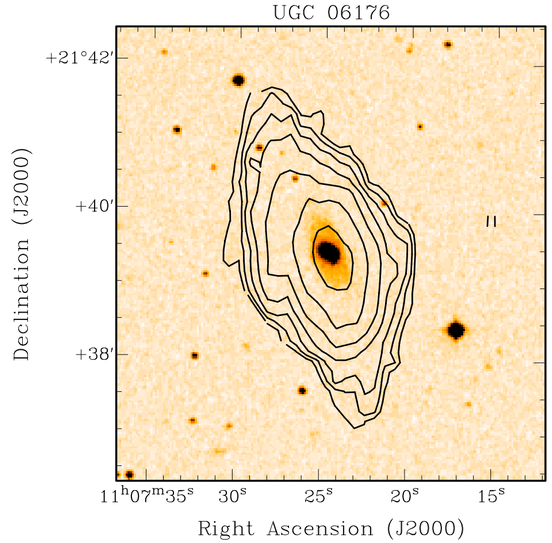
12/26 field galaxies detected
(~50% detection rate including 20 SAURON field galaxies)

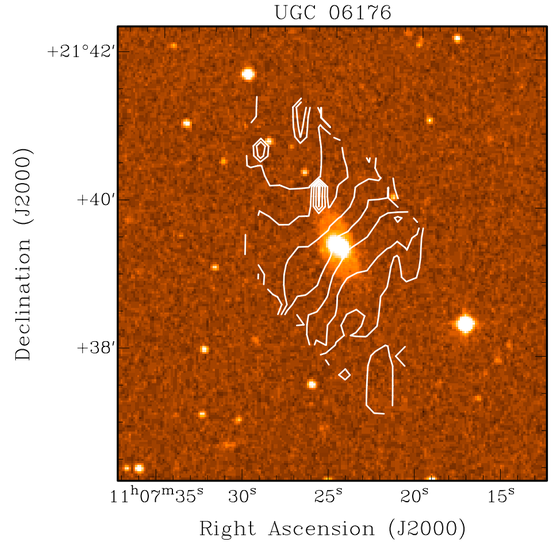
observations completed by June 2009

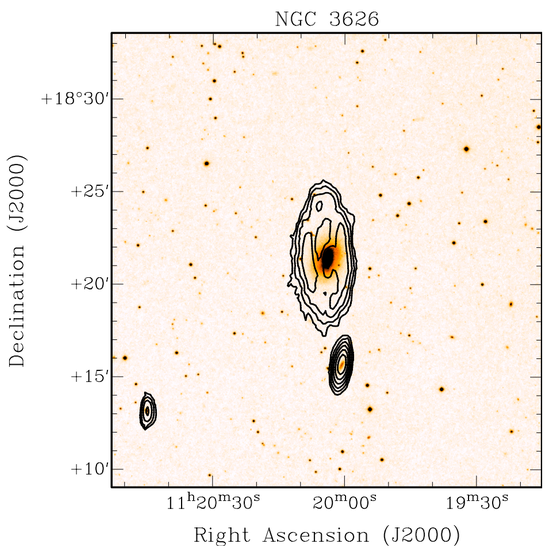
Atlas^{3D} WSRT HI survey (preliminary results)

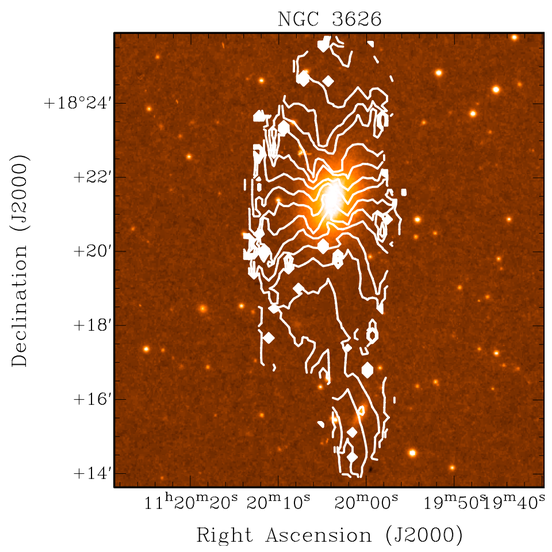


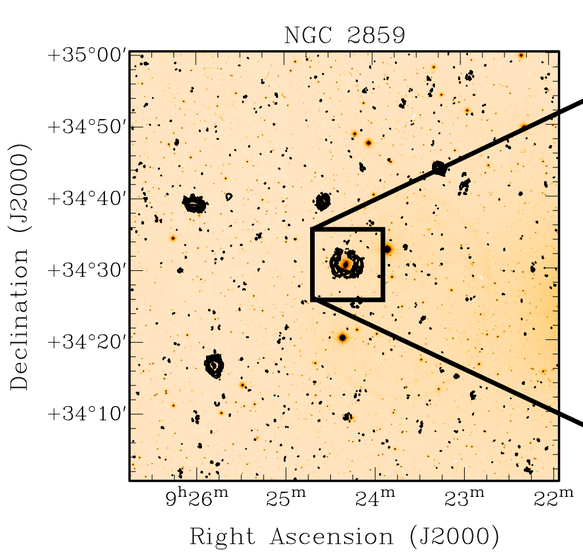


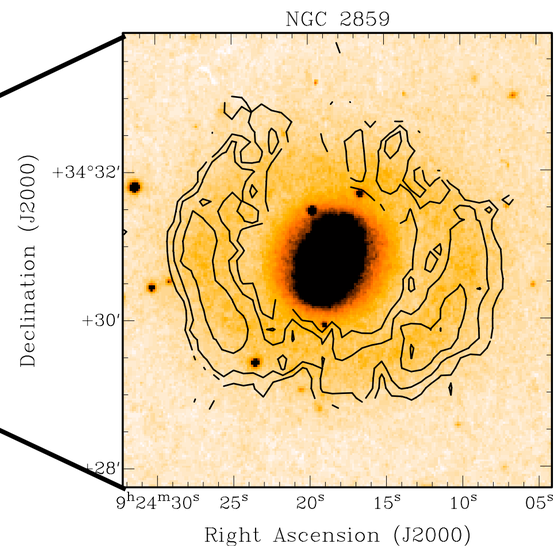












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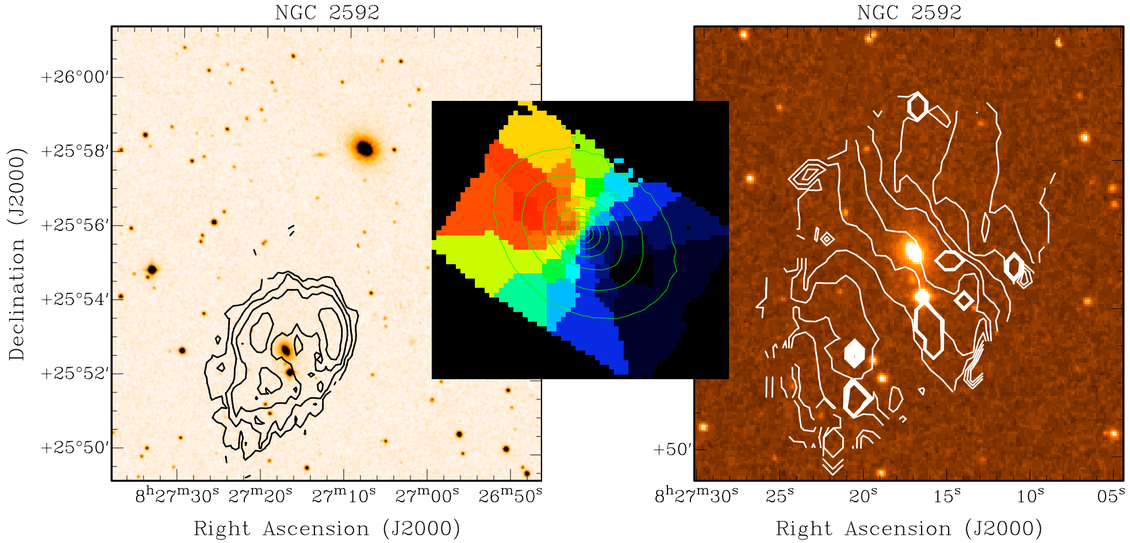
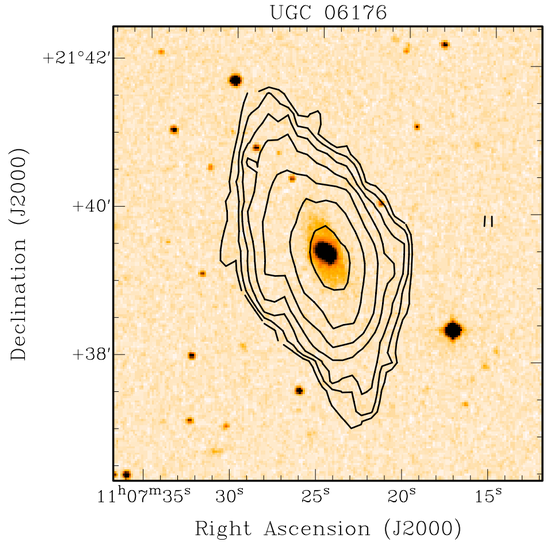
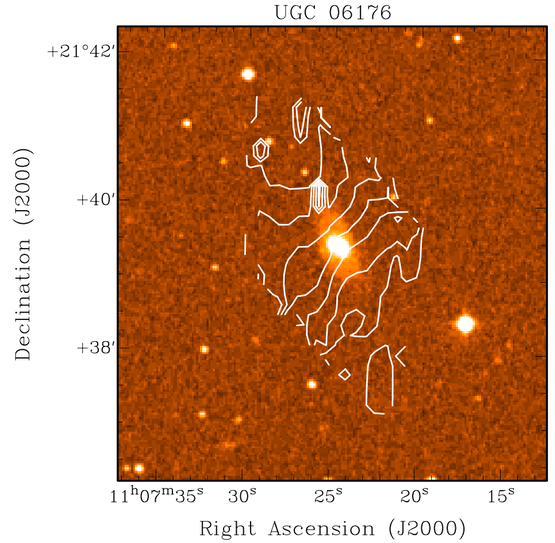
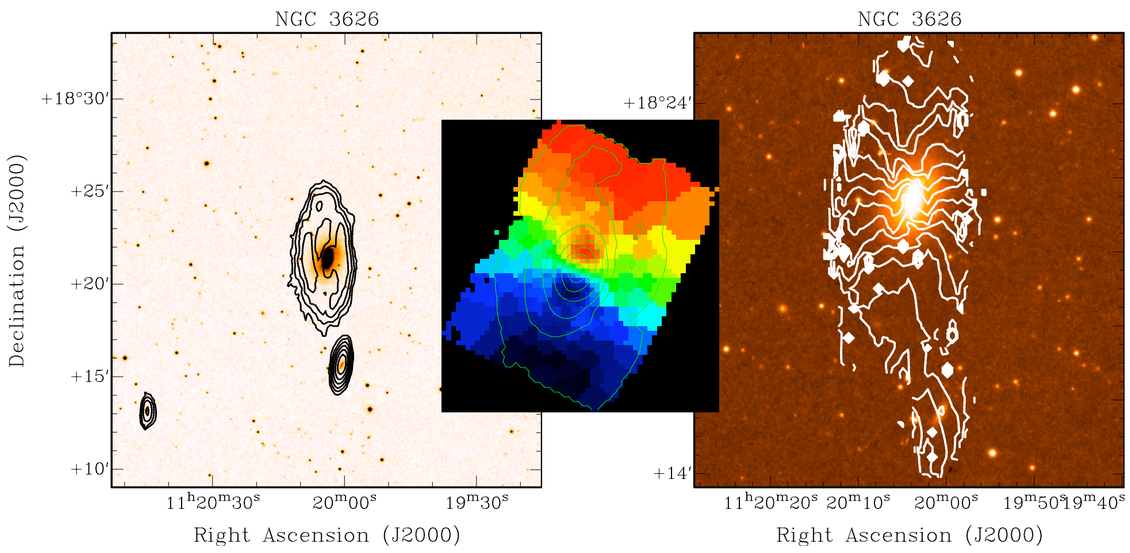
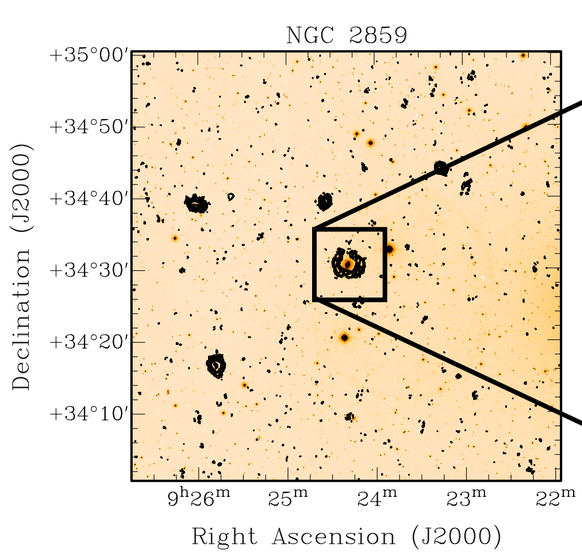
Atlas^{3D} WSRT HI survey (preliminary results)

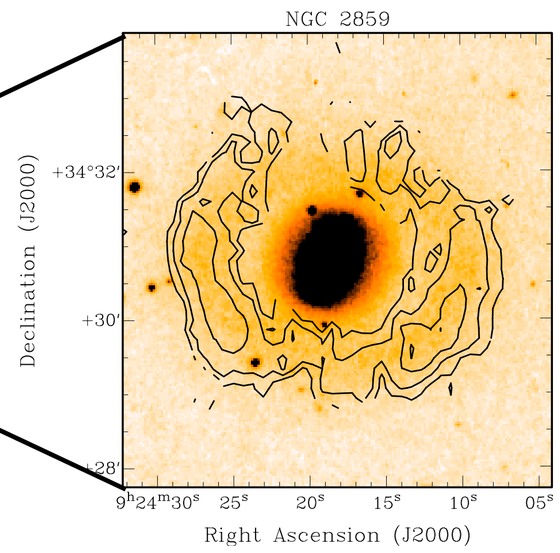












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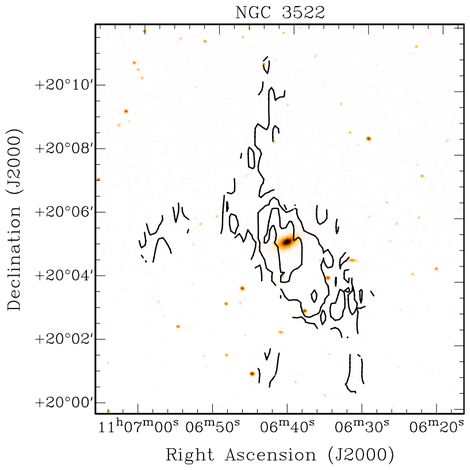
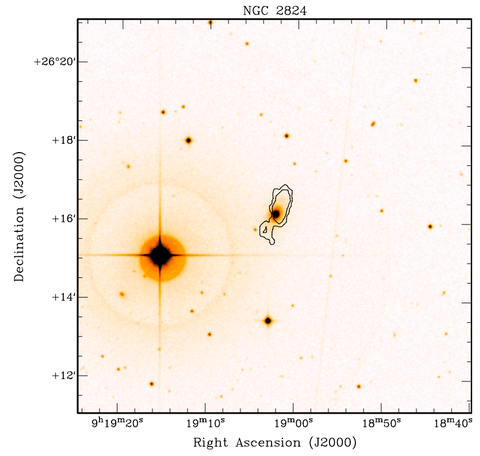
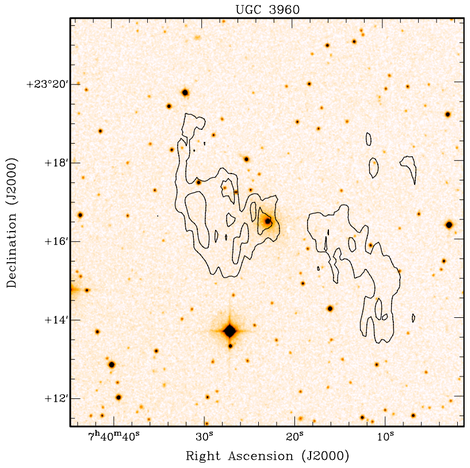
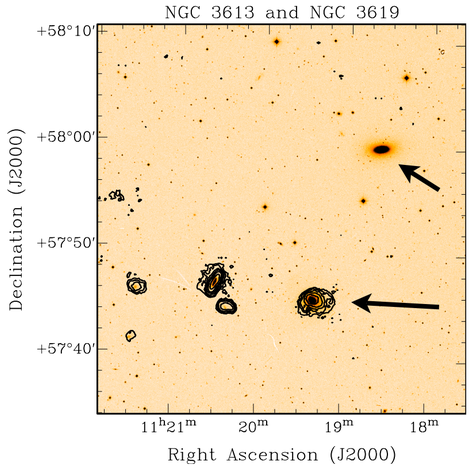
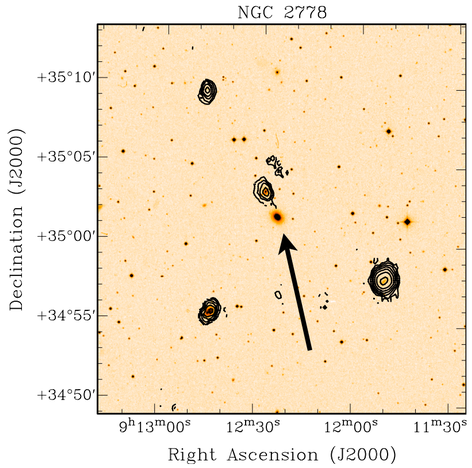
Atlas^{3D} WSRT HI survey
(more preliminary results)

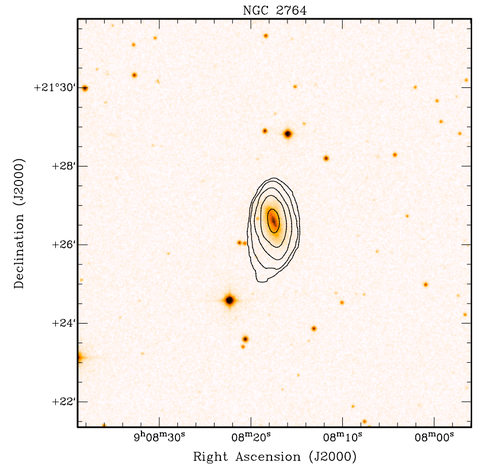


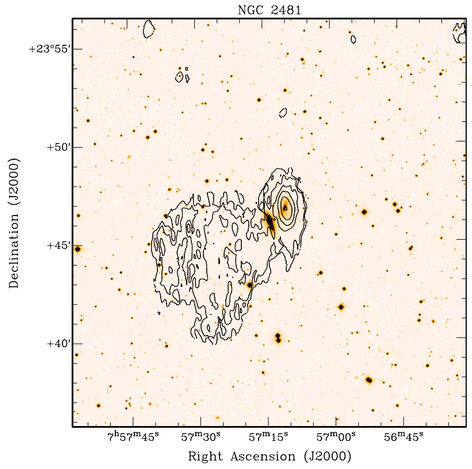


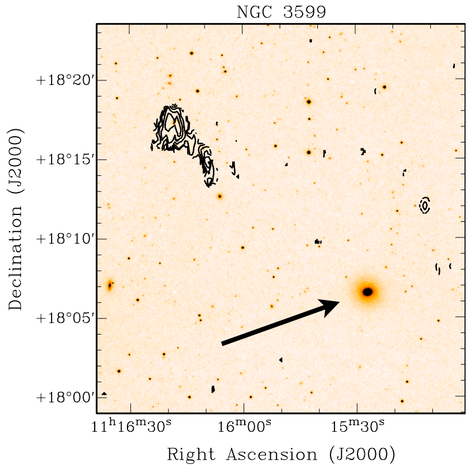


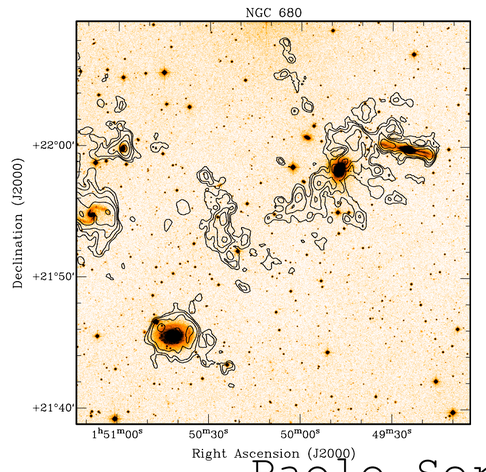












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Summary

- Early-type galaxies can be gas-rich! HI is detected in a large fraction (~50%) of field ETGs when going down to n_{HI}~10^{19} cm^{-2}.
- Ionised gas detected in 60% of galaxies. It is extended and kinematically linked to the HI. Emission-line ratios are LINER-like.
- No clear relation between HI and stellar populations.
- Possibly, there is a connection between the HI mass and the presence of a stellar age gradient: ~50% of the HI-poor ETGs get younger in their centre, while none of the HI-rich ETGs do. This may be interpreted in terms of disc-merger origin, but more data/ analysis are needed!
- A WSRT survey of HI in a volume-limited, representative sample of ETGs is on-going at ASTRON as part of the multi-wavelength Atlas^{3D} project.

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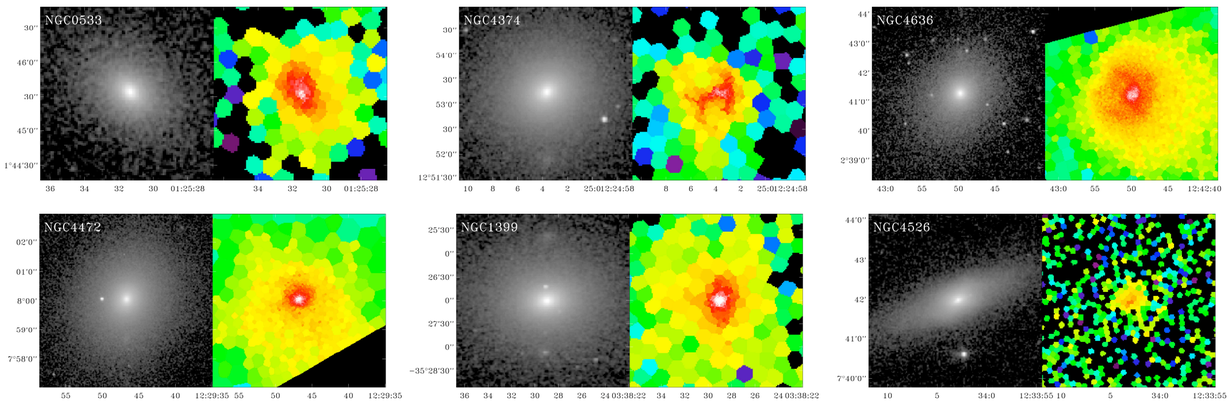
Gas in early-type galaxies

X-ray

$M_X = 10^8 - 10^{10}\ M_\odot$

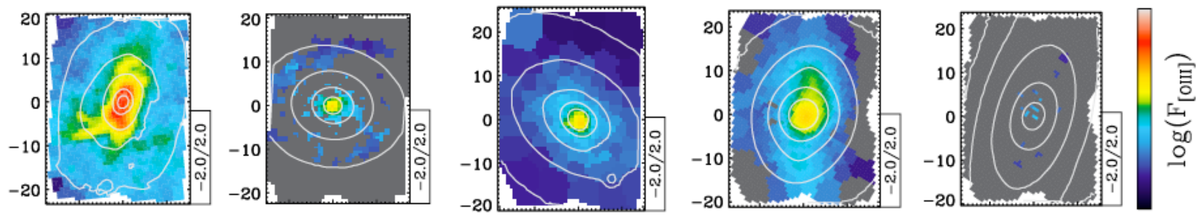


Diehl & Statler (2007)

Optical emission lines

$M_{ion} = 10^4 - 10^6\ M_\odot$

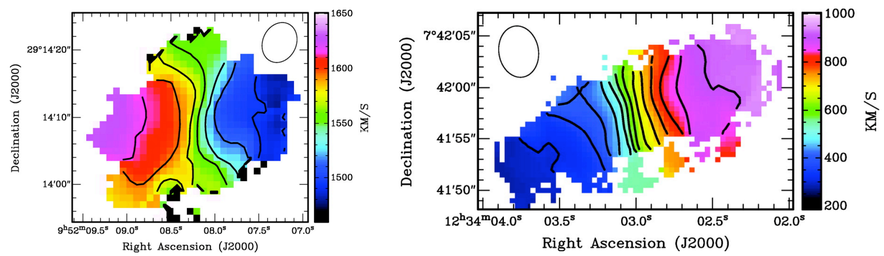
Sarzi et al. (2006)



Molecular gas

$M(H_2) = 10^7 - 10^9\ M_\odot$

Young et al. (2008)



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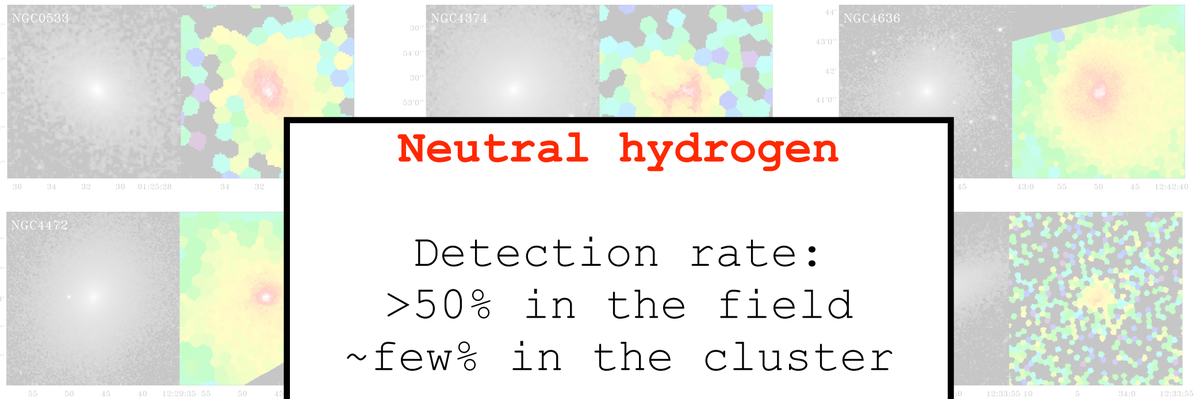


Diehl & Statler (2007)

Neutral hydrogen

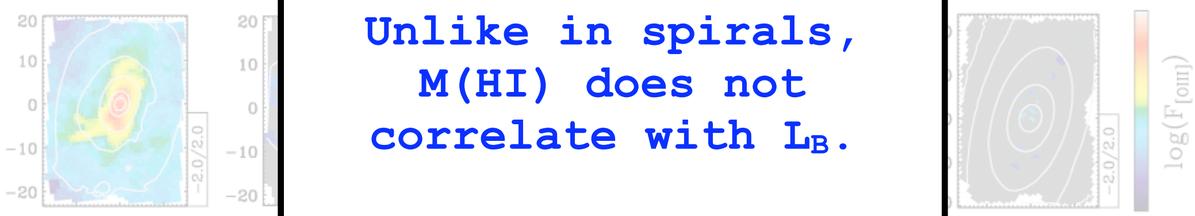
Detection rate:
>50% in the field
~few% in the cluster

$M(HI)=10^6-10^{10}\ M_\odot$
spread over tens of kpc
$n_{HI}<10^{20}\ cm^{-2}$

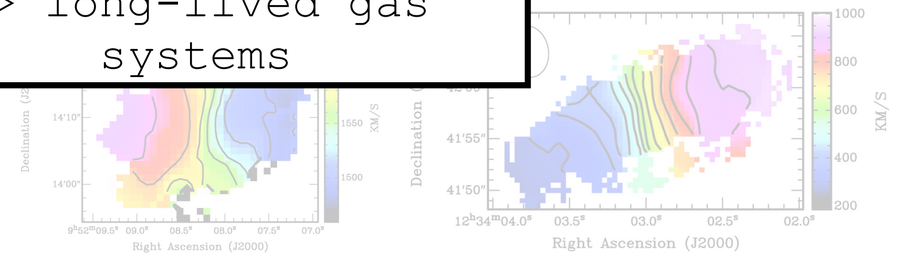
Unlike in spirals, M(HI) does not correlate with L_B.

Regular rotation
T_{orbit} >1 Gyr
=> long-lived gas systems

al. (2006)



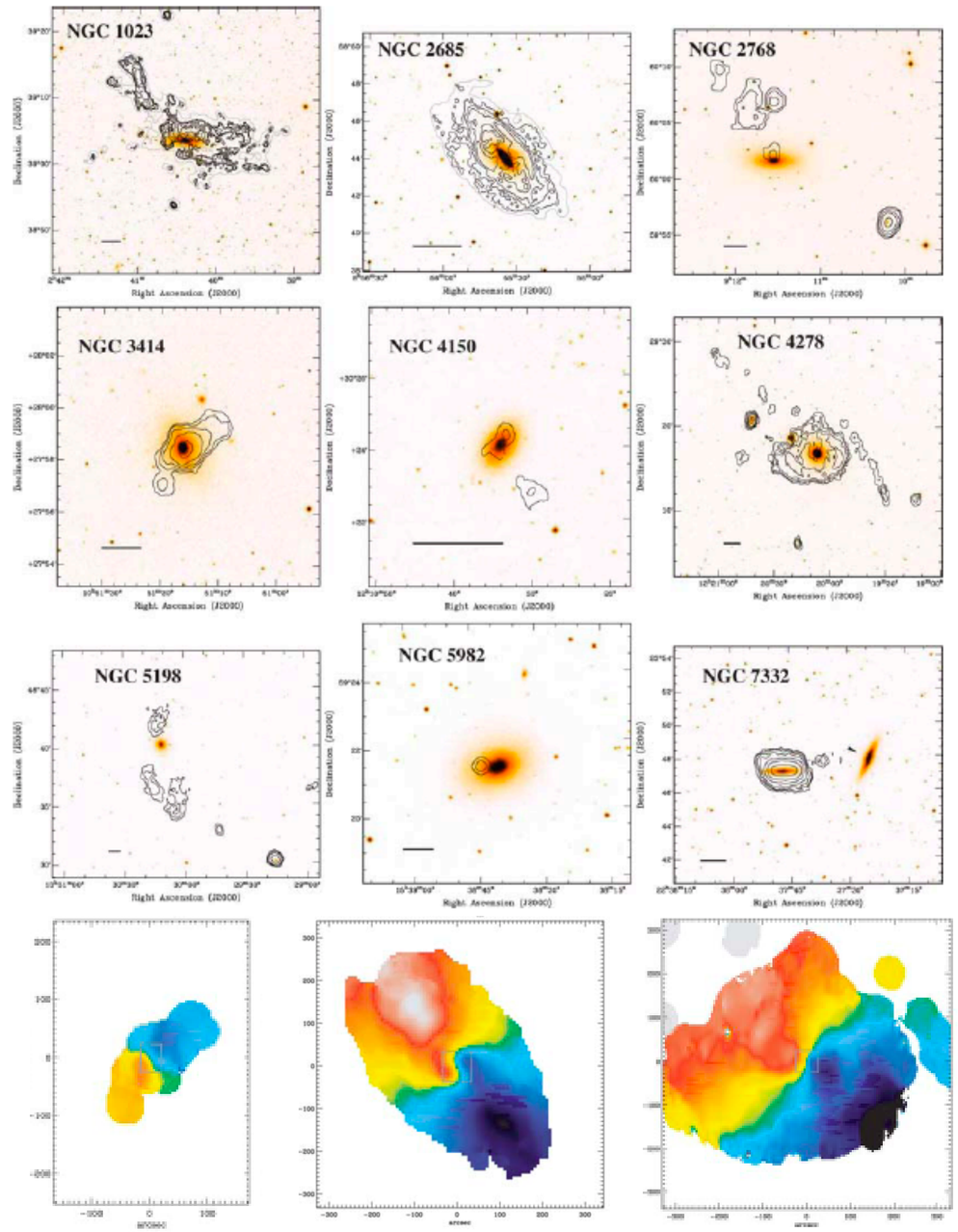
g et al. (2008)



Molecular

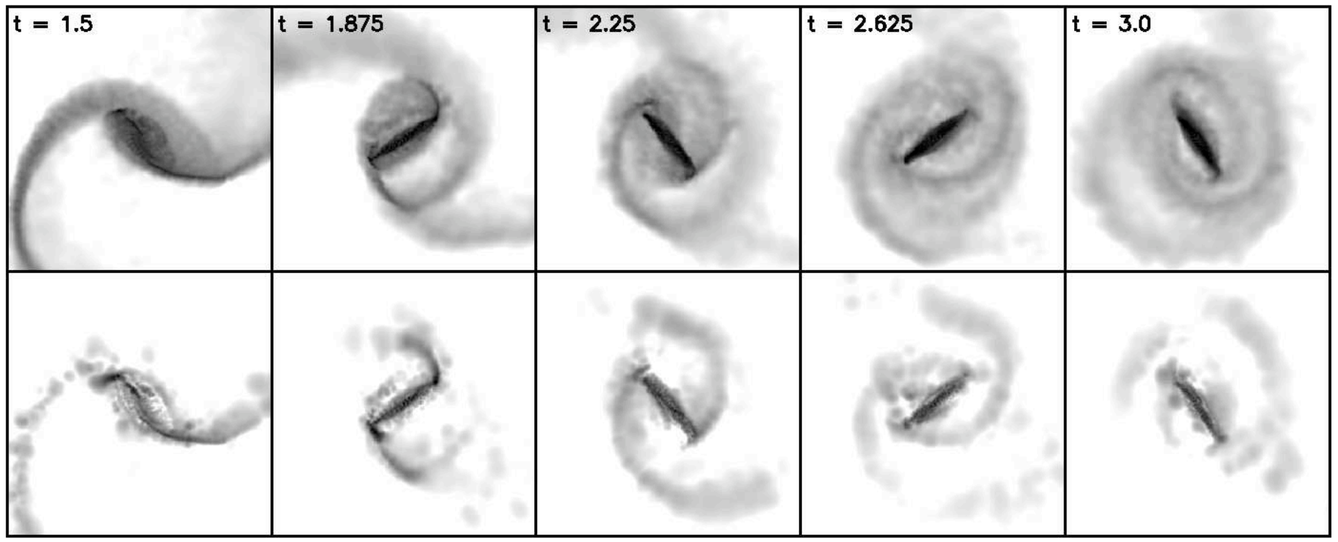
$M(H_2)=10^7-10^9\ M_\odot$

Morganti et al. (2006)



The role of gas in the evolution of early-type galaxies

(gas-rich mergers, gas inflow, accretion)



Barnes (2002)

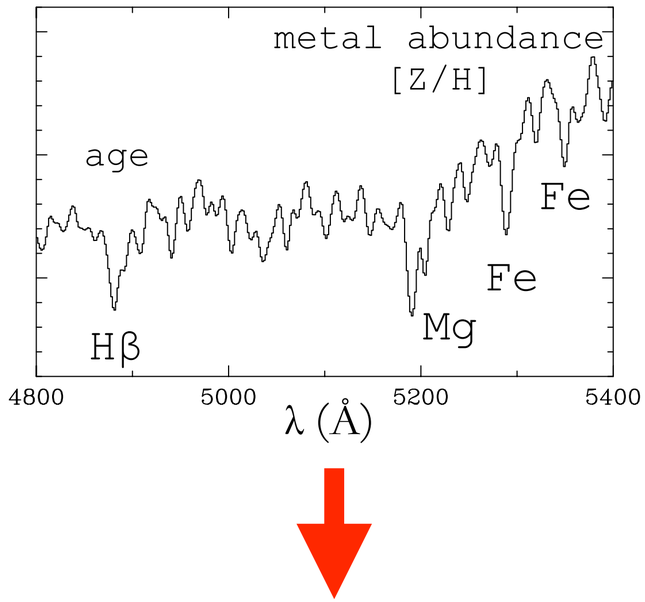
Gas can play a major role in shaping the stellar body of ETGs.

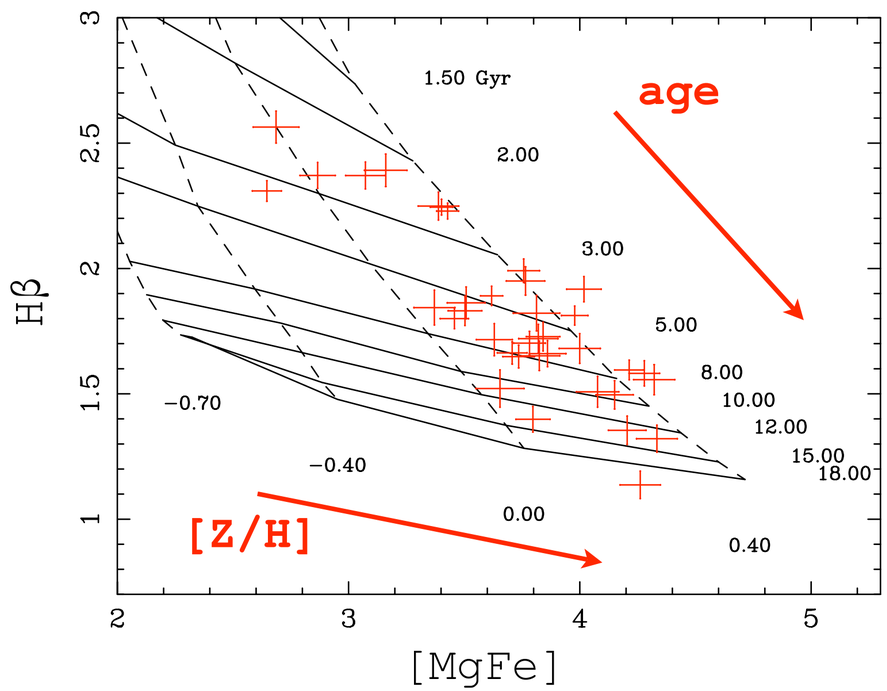
- bursts of SF in the centre => affects stellar populations
- accretion on SMBH => ISM heating (red galaxies)
- formation of extended gas structures (e.g., HI)
- flattening due to kinetic-energy dissipation
- stellar orbit modulation

Is there any observational evidence of such relation in terms of ETGs

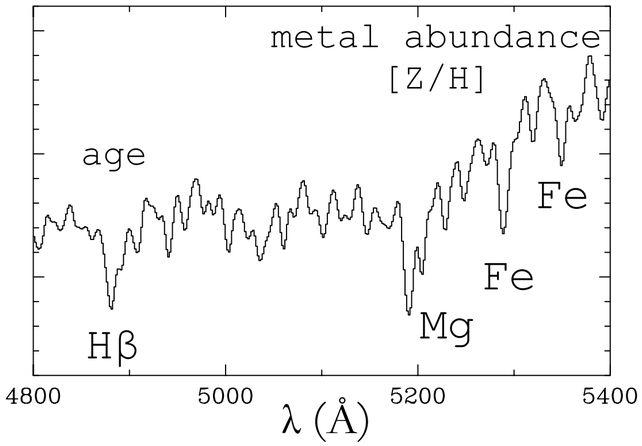
stellar content and HI properties?

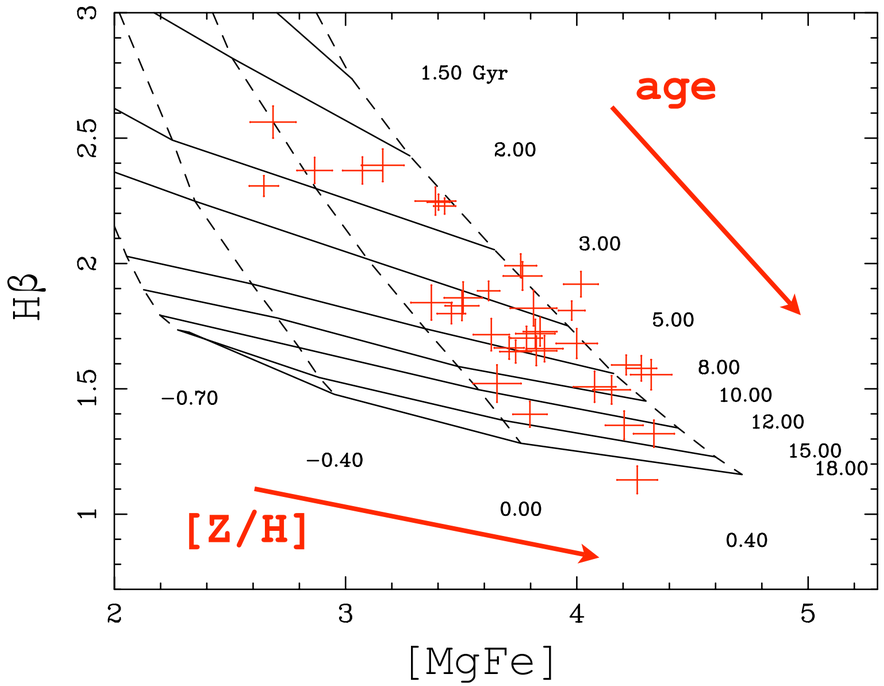
Stellar populations from line-strength indices

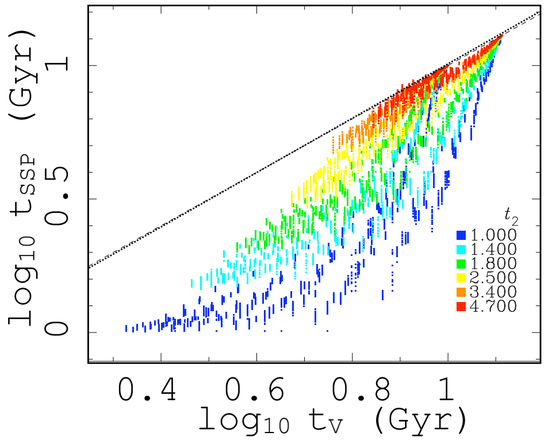


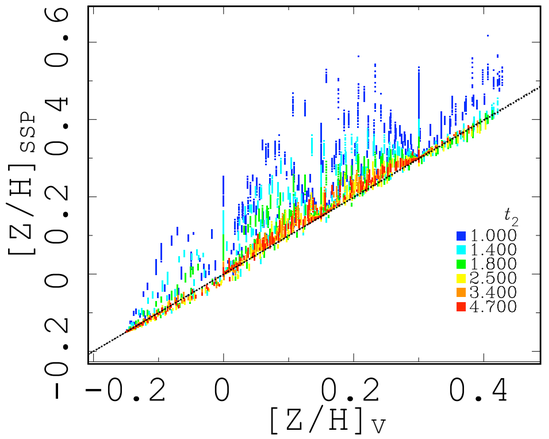


Stellar populations from line-strength indices









Serra & Trager (2007)

SSP-equivalent t, [Z/H]

In case of multiple populations

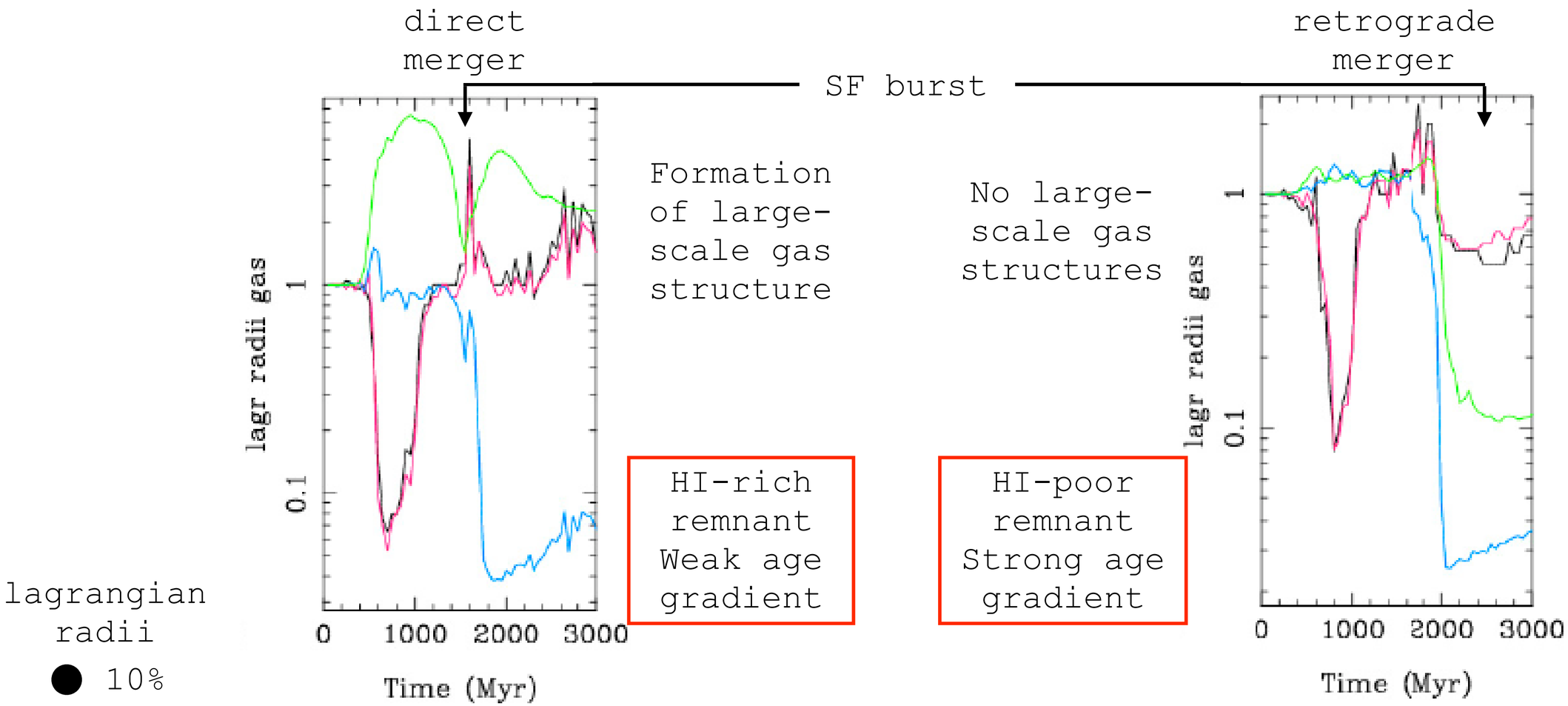
t_{SSP} biased towards t_{young}

$[Z/H]_{SSP} \sim [Z/H]_V$

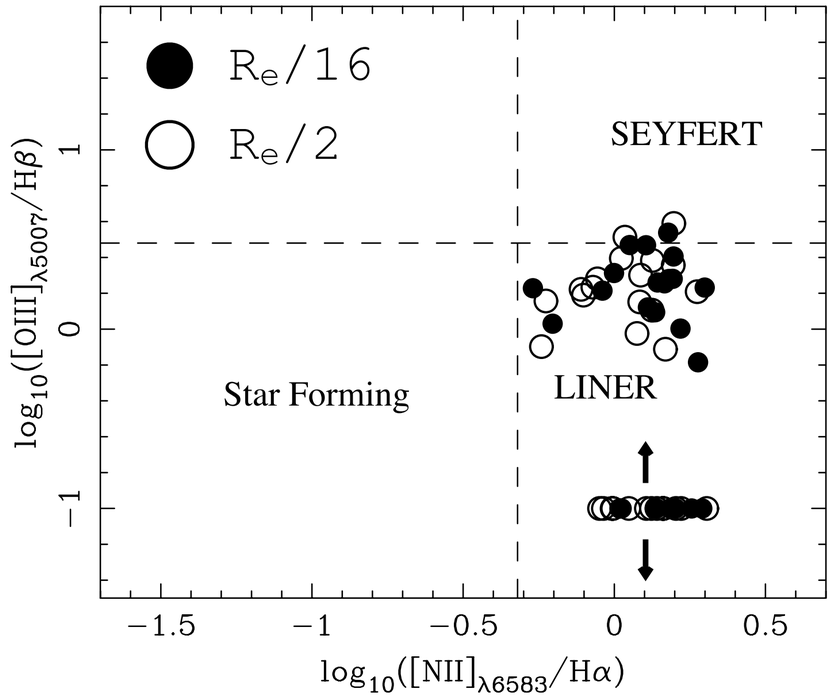
$[E/Fe]_{SSP} \sim [E/Fe]_V$

Paolo Serra ASTRON

Central rejuvenation of HI-poor ETGs from gas-rich galaxy mergers?



Di Matteo et al. (2007)


Re/16
Re/2
SEYFERT
Star Forming
LINER
1
0
−1
−1.5
−1
−0.5
0
0.5
log10([OIII]λ5007/Hβ)
log10([NII]λ6583/Hα)

- First view of HI morphology and kinematics over a complete, representative sample of ETGs down to $n_{HI}=2x10^{19}$ cm^{-2}
- Connection to Atlas^{3D} optical morphology, integral-field stellar kinematics and populations, ionised-gas, molecular gas
- Dynamical studies out to large radii (dark matter, MOND?)