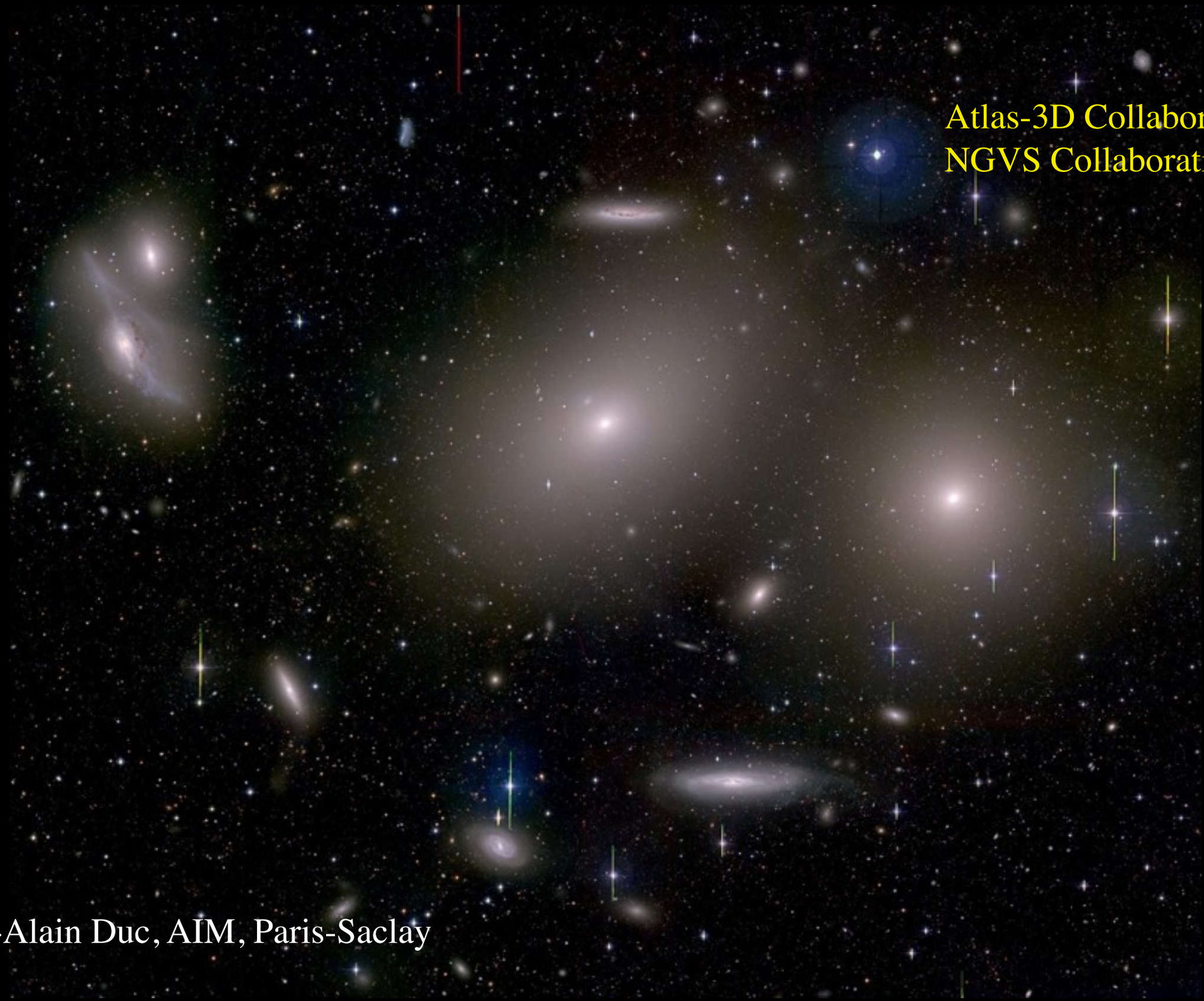
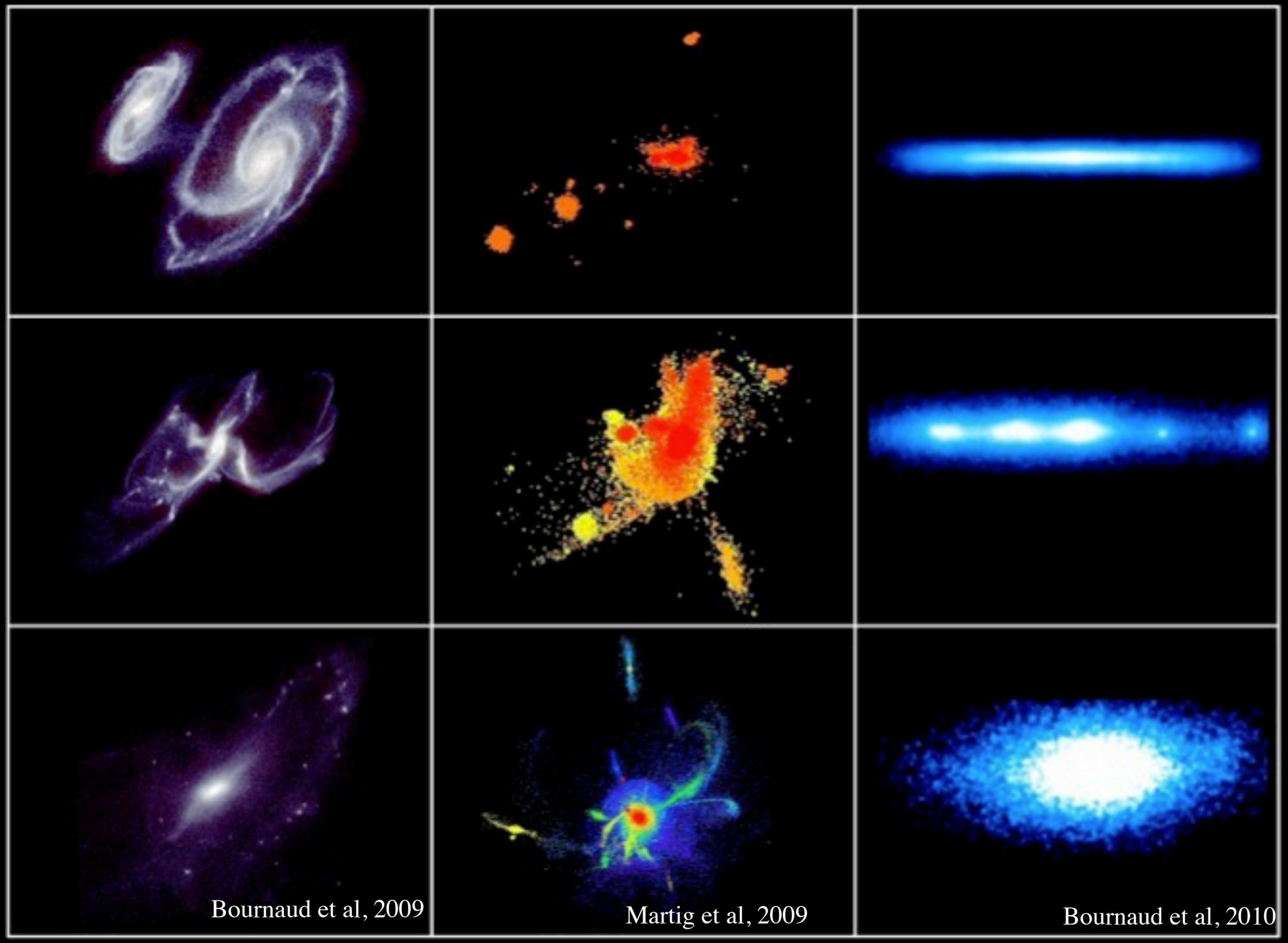
Probing the mass assembly of galaxies with deep imaging



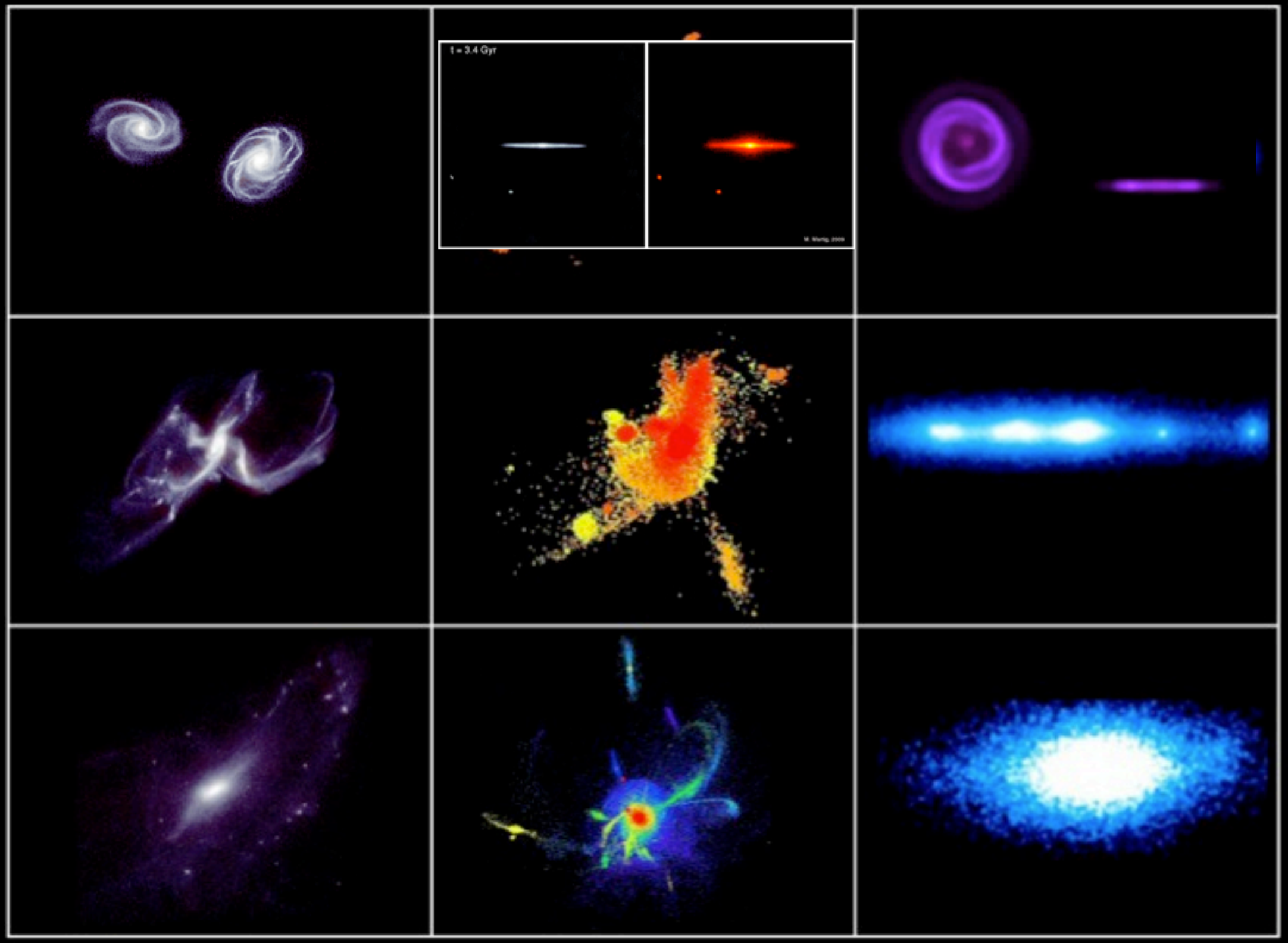
Pierre-Alain Duc, AIM, Paris-Saclay

Various scenarios to form massive galaxies



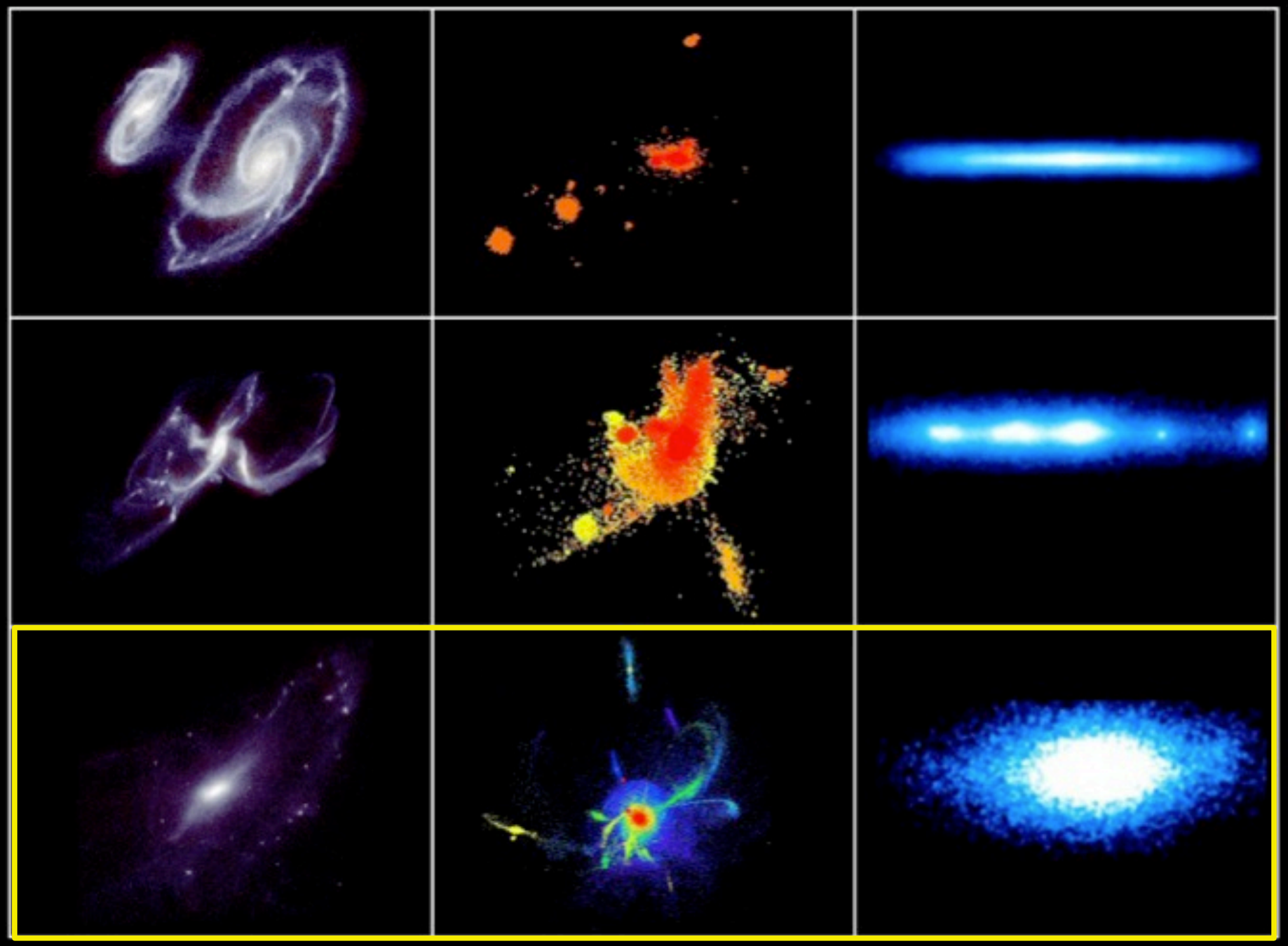
Recent major merger | Merger history | Secular evolution

Various scenarios to form massive galaxies



Recent major merger | Merger history | Secular evolution

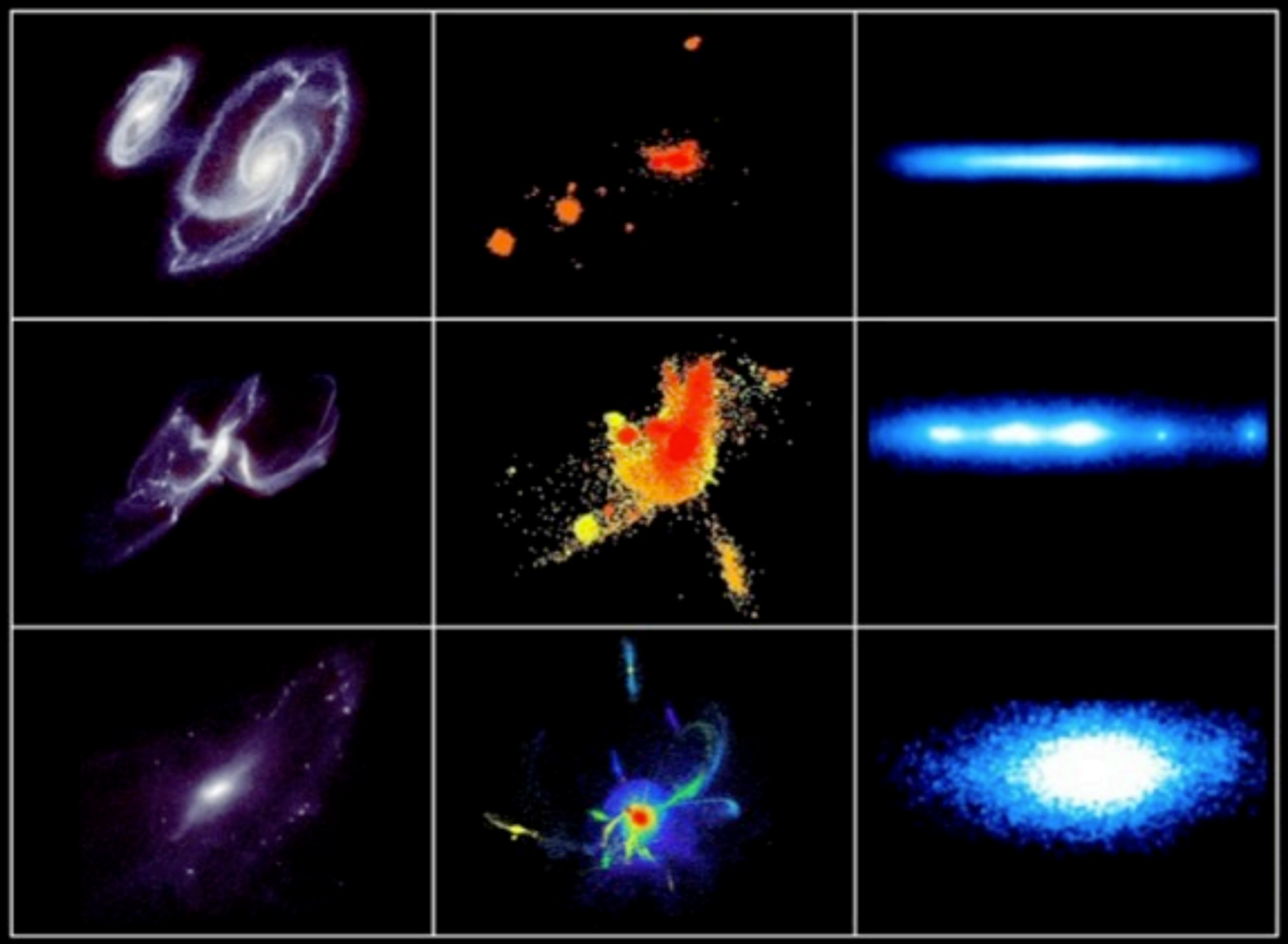
Various scenarios to form massive galaxies



Recent major merger | Merger history | Secular evolution

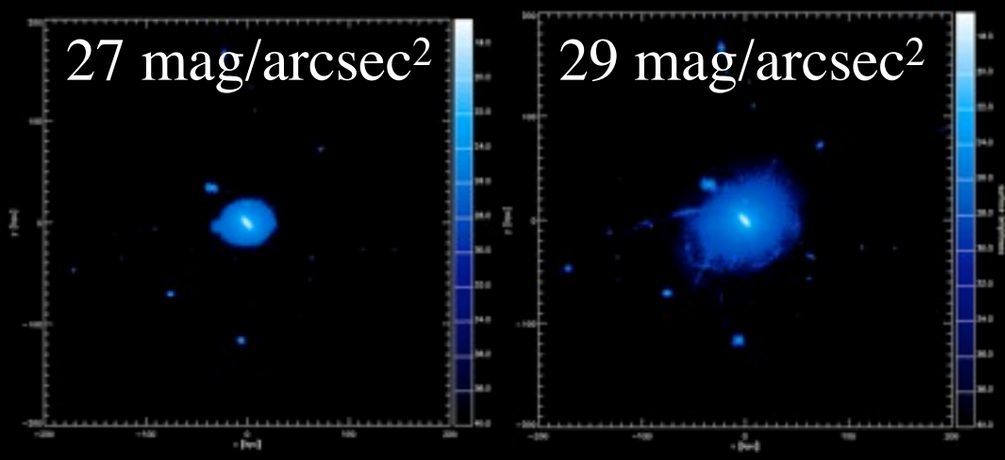
... that produce various types of fine structures: tails, plumes, streams, shells, etc...

Various scenarios to form massive galaxies



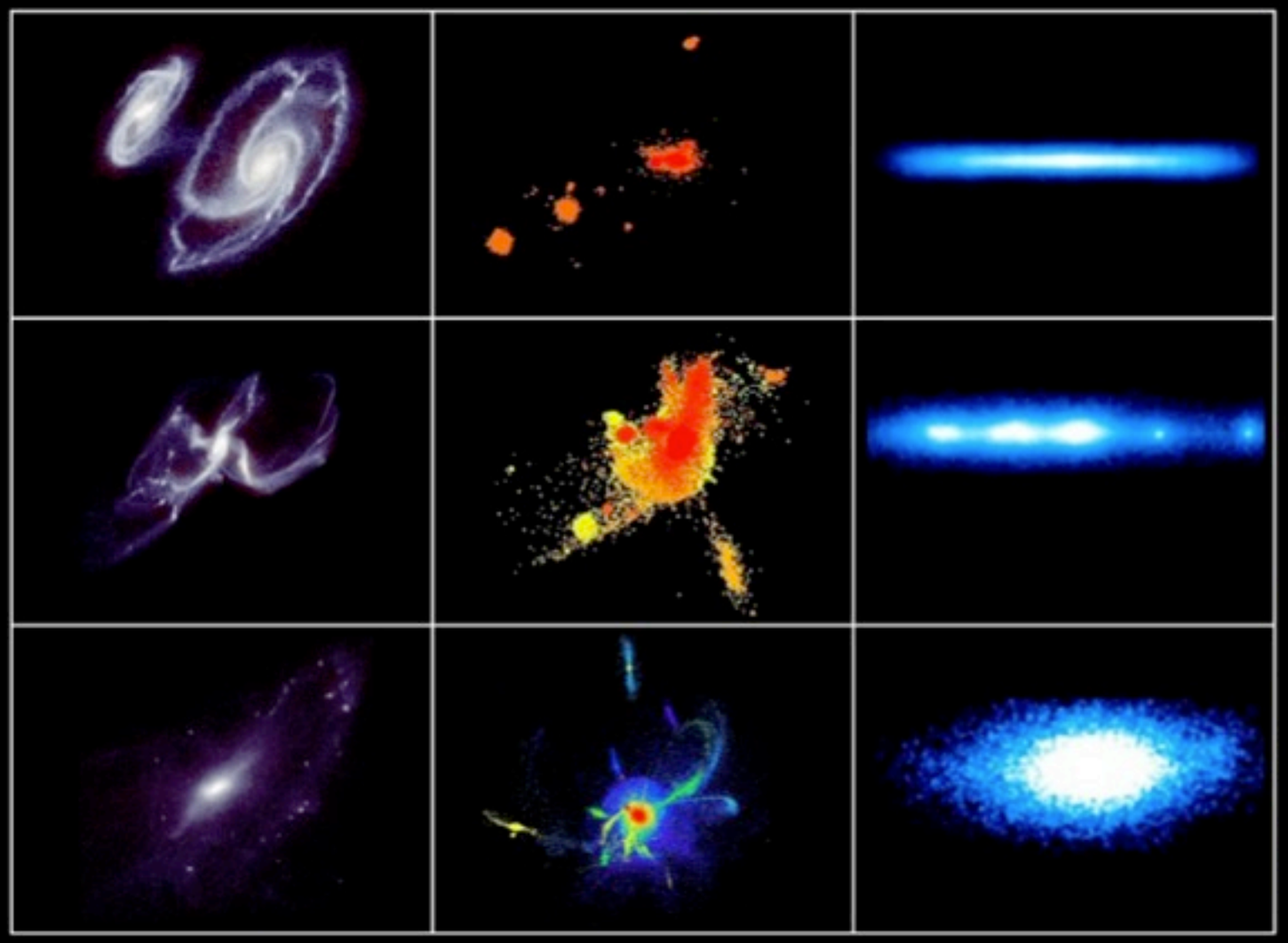
Tracing the origin of ETGs with fine structures

- Issues:
- how to detect the fine structures?



Using specific observing methods, and dedicated pipeline (Elixir-LSB), MegaCam can now do it!

Various scenarios to form massive galaxies



Tracing the origin of ETGs with fine structures

• Issues:
- how to detect the fine structures?

- the memory of past accretion might be lost:
✓ with time

addressed by numerical simulations

✓with the environment (e.g. in clusters)

two MegaCam surveys of nearby ETGs
✓*field, groups: Atlas-3D - 50 objects*
✓*cluster: NGVS - 60 objects*

The Next Generation Virgo Cluster Survey



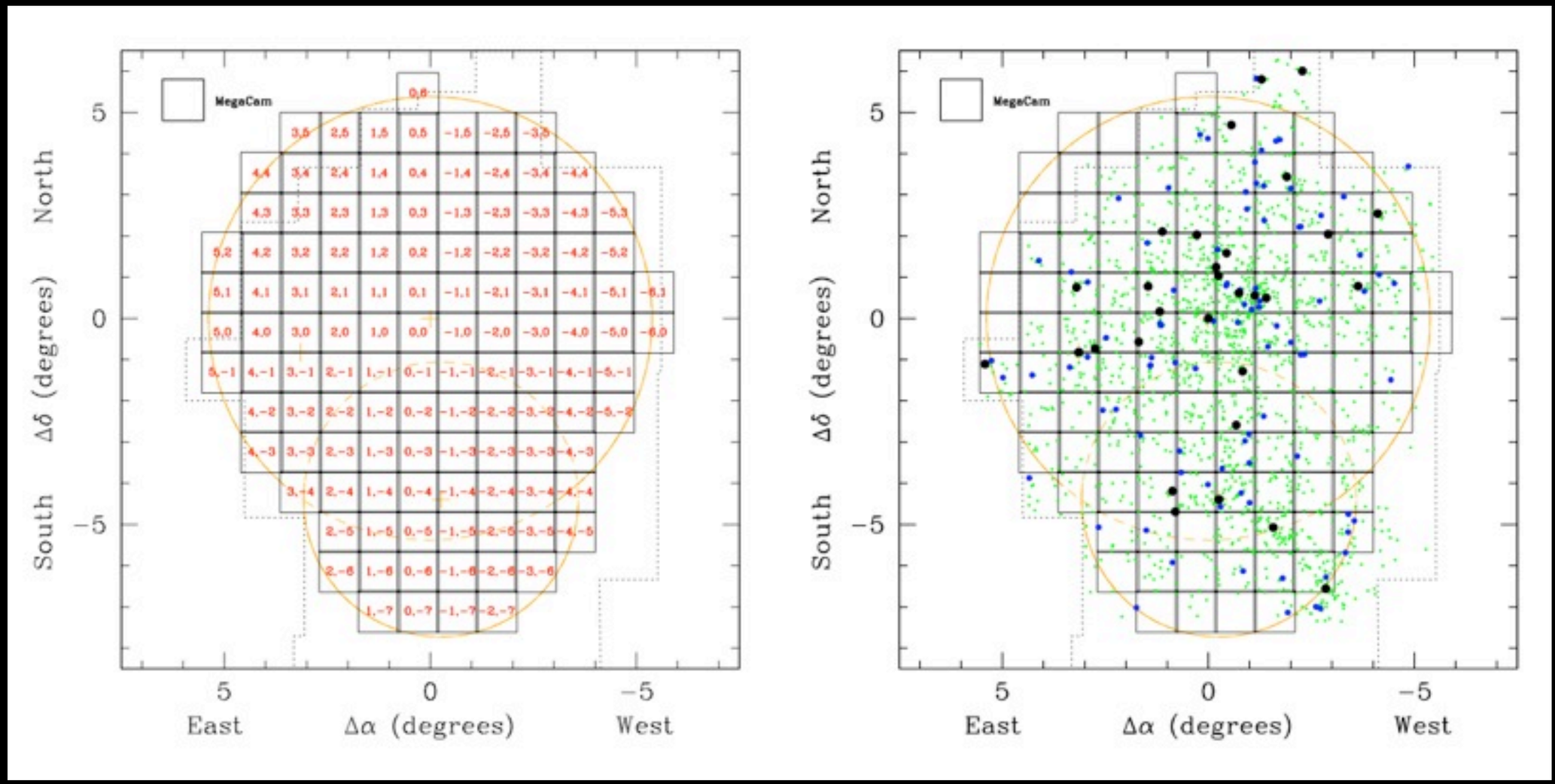


A Large Programme with CFHT / MegaCam
(771 hours over semesters 2009A-2012A

- 104 square degrees in 5 bands (u,g,r,i,z)

- seeing(i)<0.6”
- *g*~25.7 AB mag
- SB (g)< 29 mag arcsec^{-2}

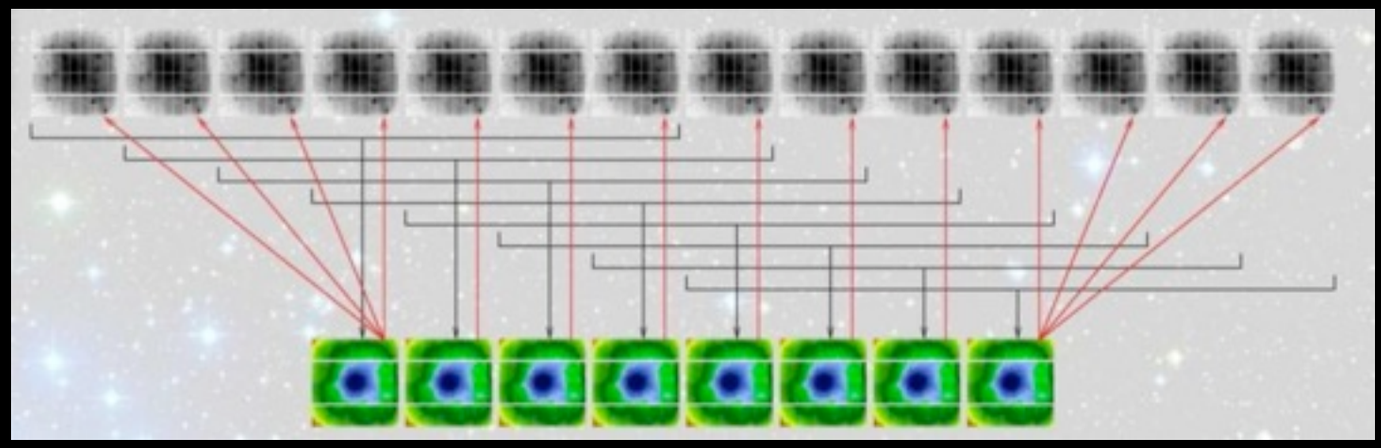
u=6400 s
g=3200 s
r=4800 s
i=2050 s
z=4400 s



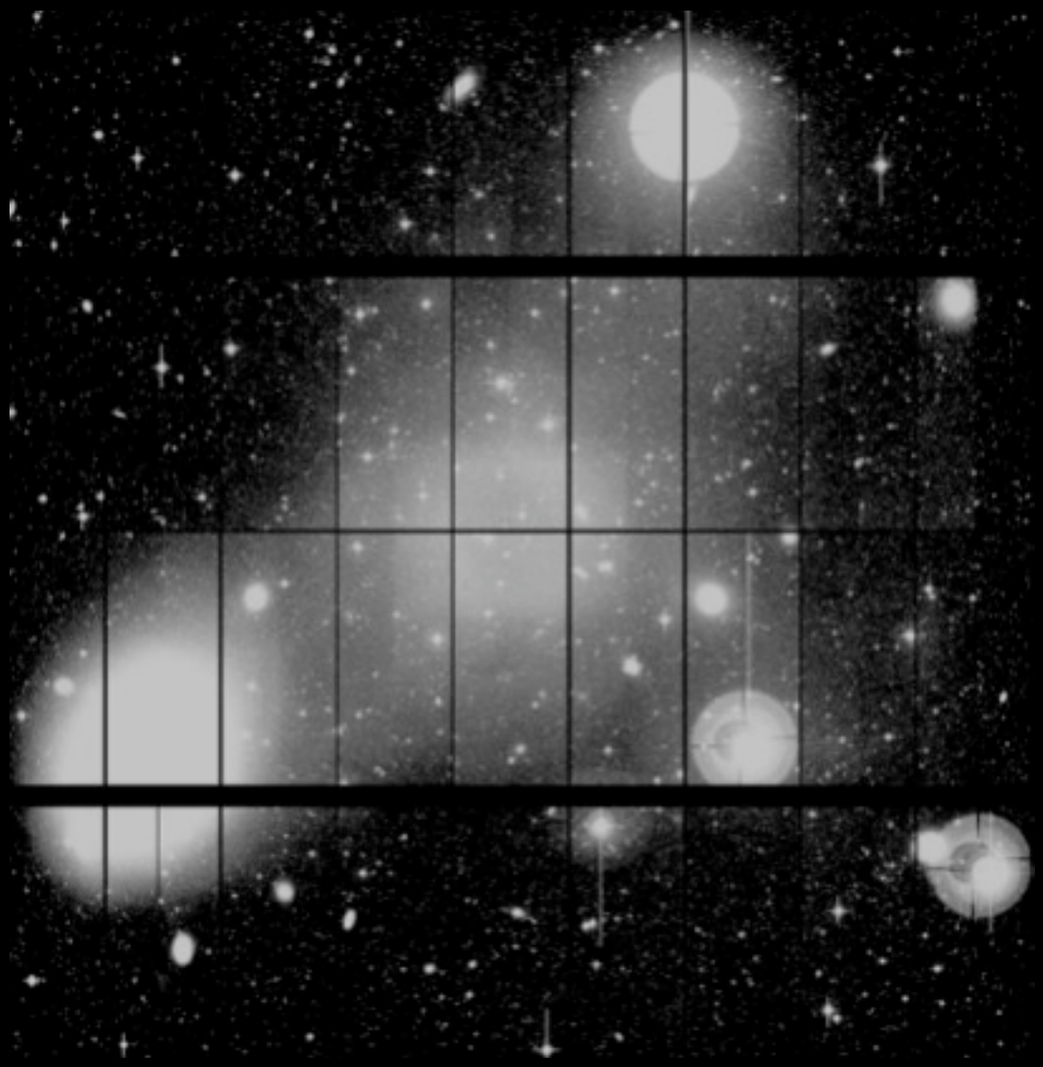
Ferrarese et al, 2011

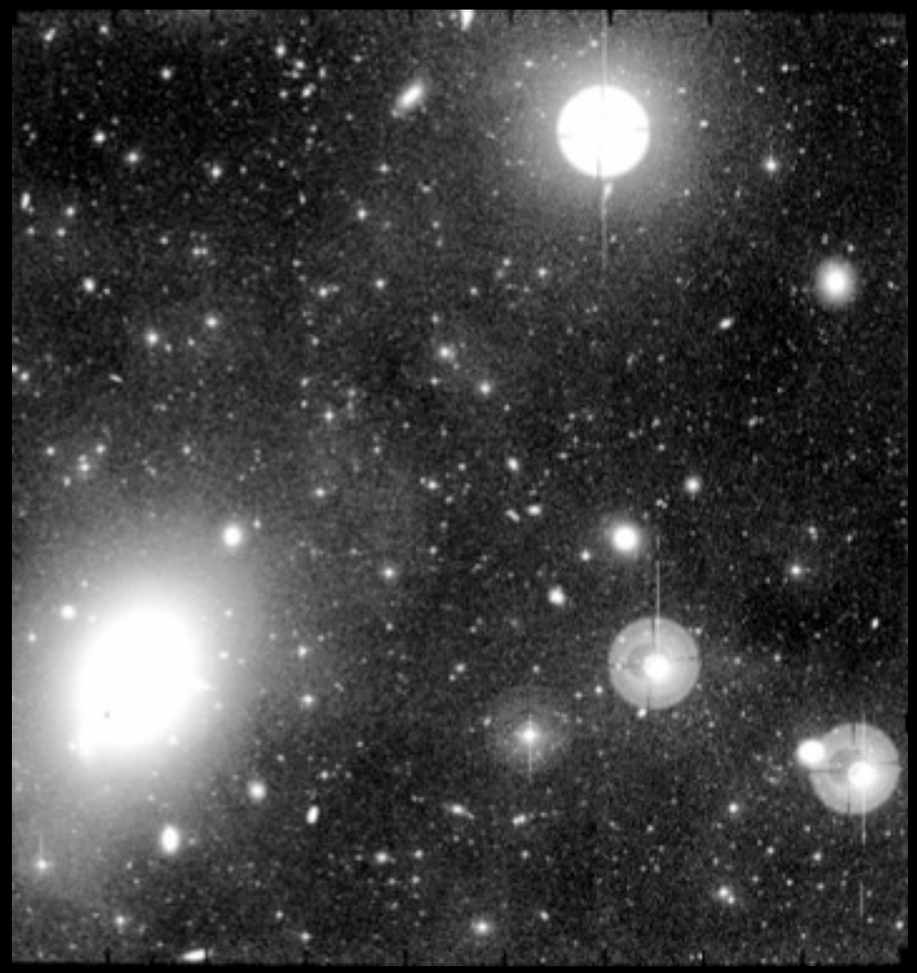
Dealing with the complex optics of MegaCam



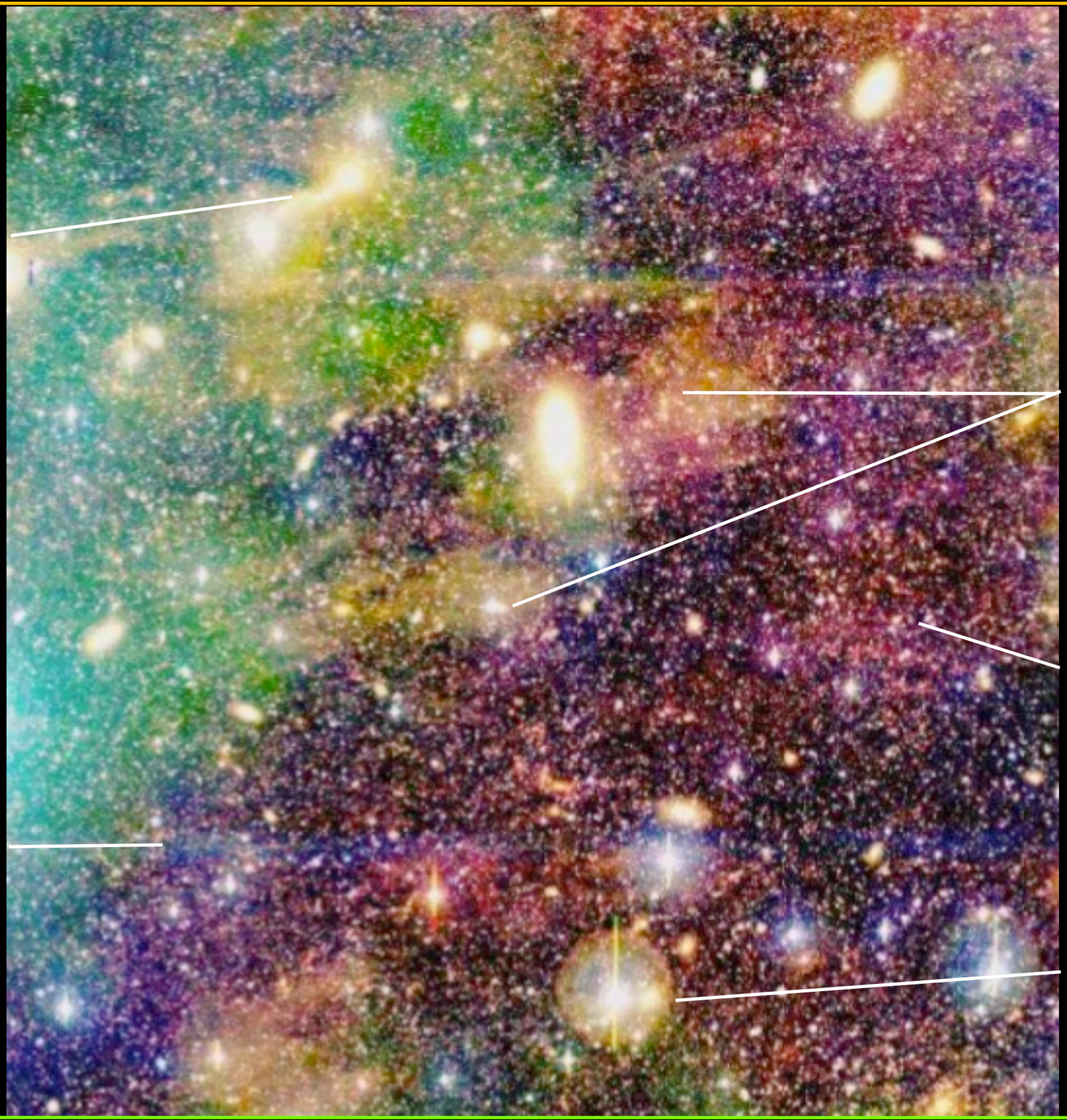


• scattered light removed by an ad-hoc observing strategy and pipeline (Elixir-LSB)





Trouver ses petits...



Stellar streams

Galactic cirrus

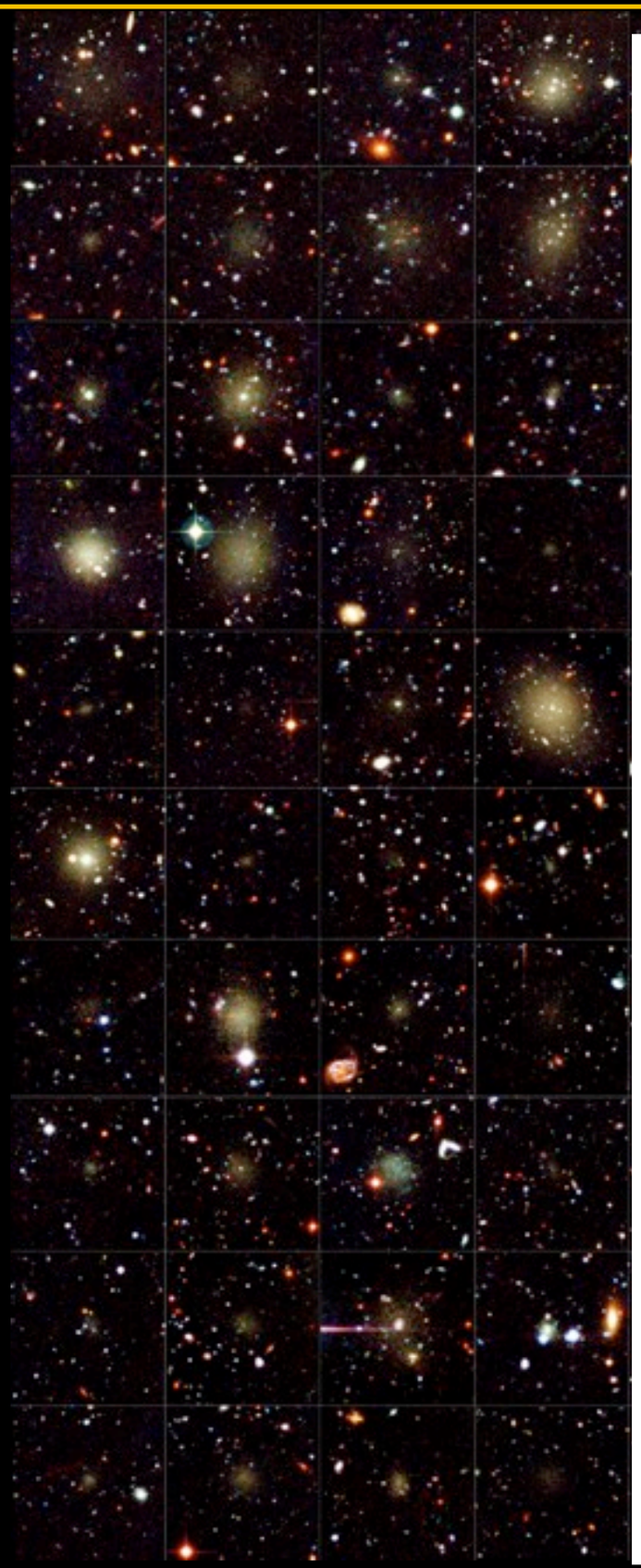
Faint foreground stars

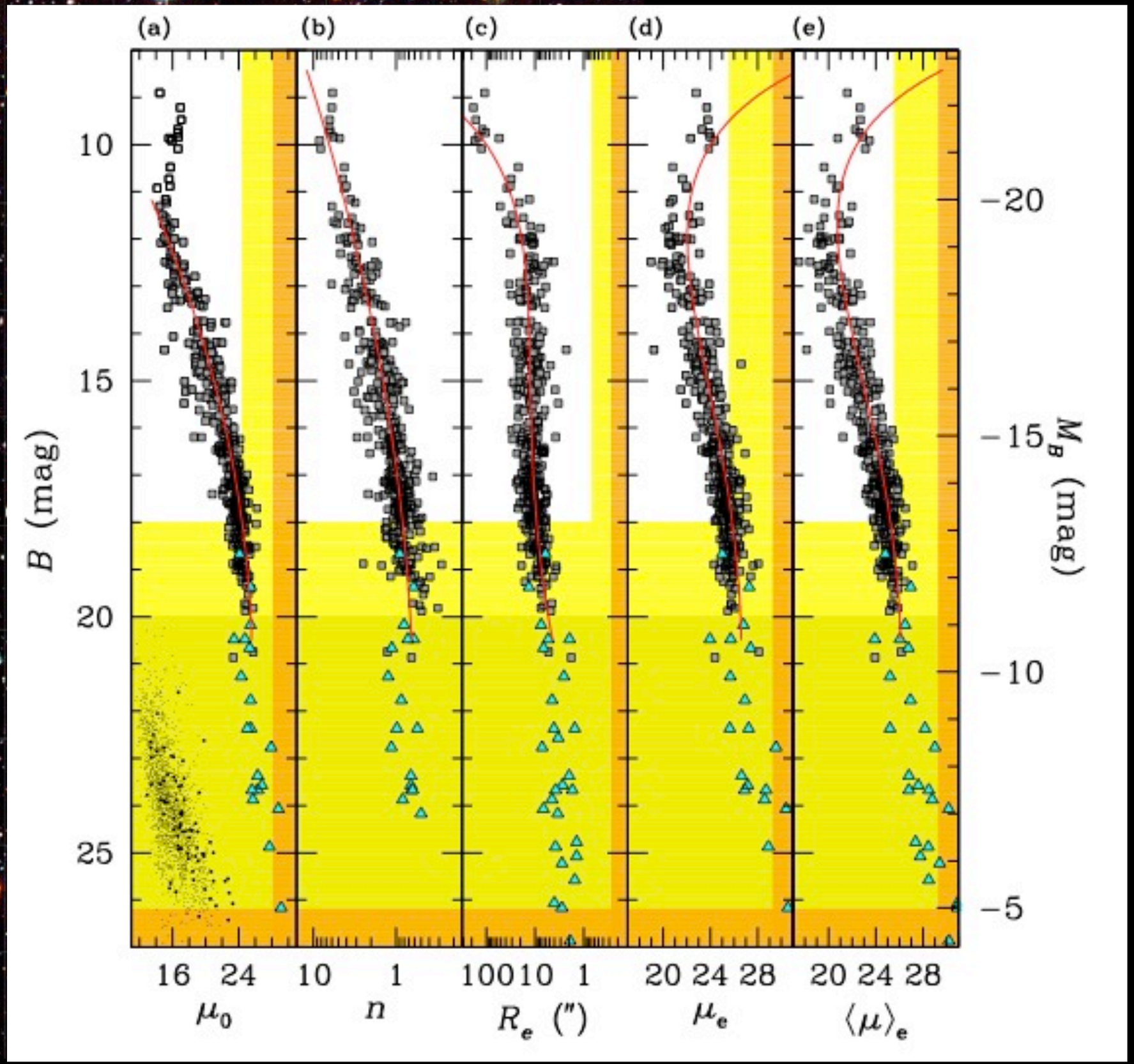
Instrumental artifacts

Halos of bright stars

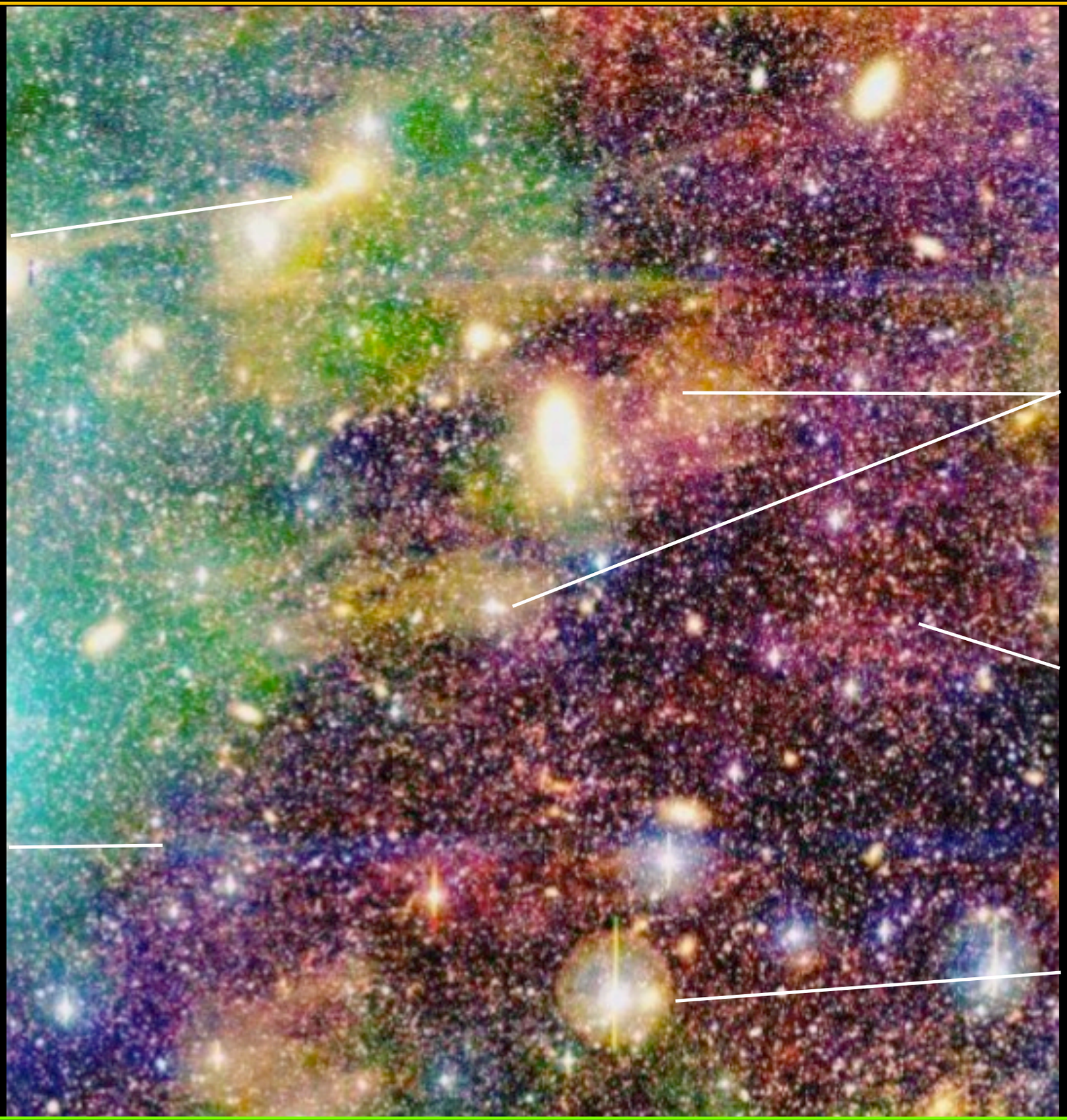
Plus galaxies

Ultra faint dwarfs in the NGVS





Trouver ses petits...



Stellar streams

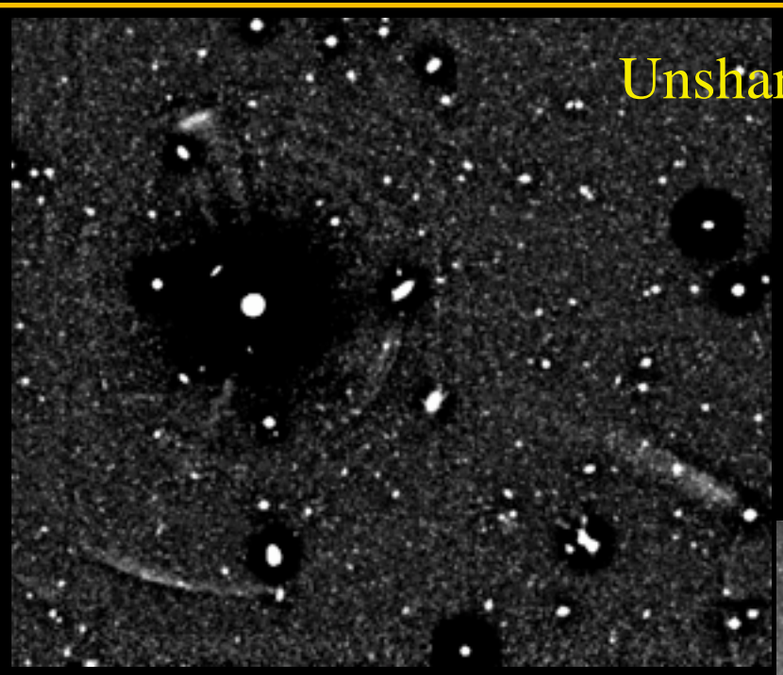
Galactic cirrus

Faint foreground stars

Instrumental artifacts

Halos of bright stars

Detection of fine structures: testing different algorithms

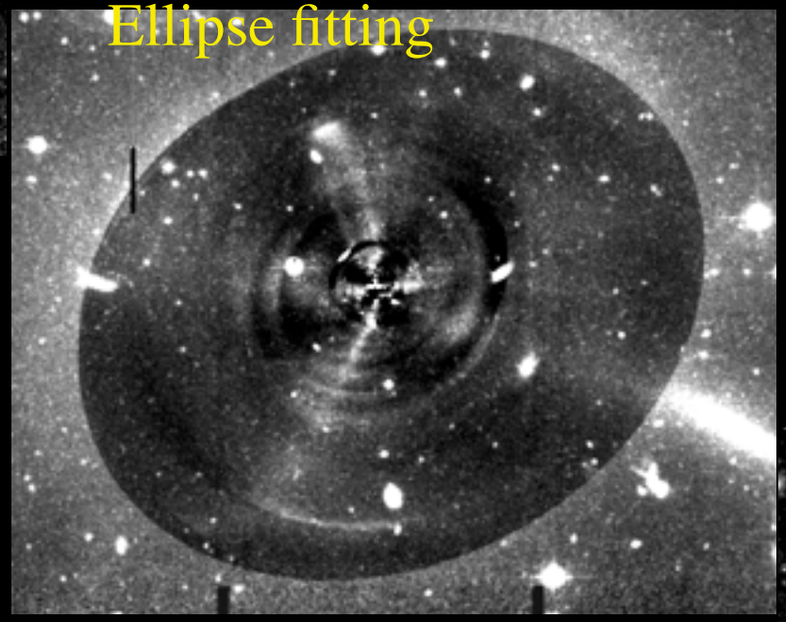


Unsharp masking

Fast
Automatic

Slow
Resource incentive
Manual fine tuning

Ellipse fitting



Detached fine structures

Enhance
diffuse component
Real?

Profile fitting (galfit)

Analysis of fine structures: quantification

- Determination of a fine structure index
-> count number of structures

$$\Sigma = S + \log(1+n) + J + B + X,$$

Schweizer & Setzer, 1992

- Determination of a tidal index
-> RMS of residual maps

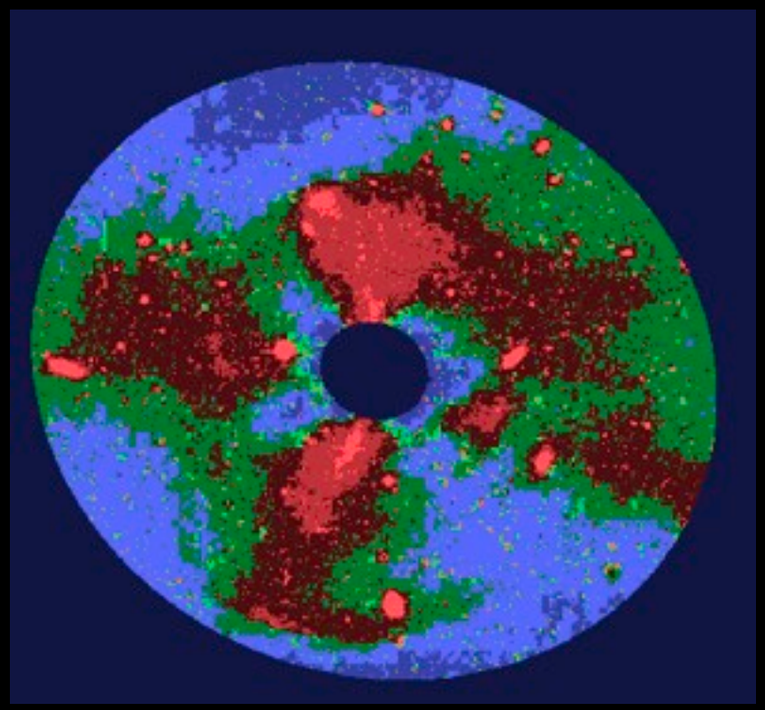
$$T_{\text{galaxy}} = \overline{\left| \frac{I_{x,y}}{M_{x,y}} - 1 \right|},$$

Tal et al., 2009

- Photometry measurements
-> aperture photometry

Janowiecki et al., 2010

- Measurement of the “filling factor” for each MARSIAA class



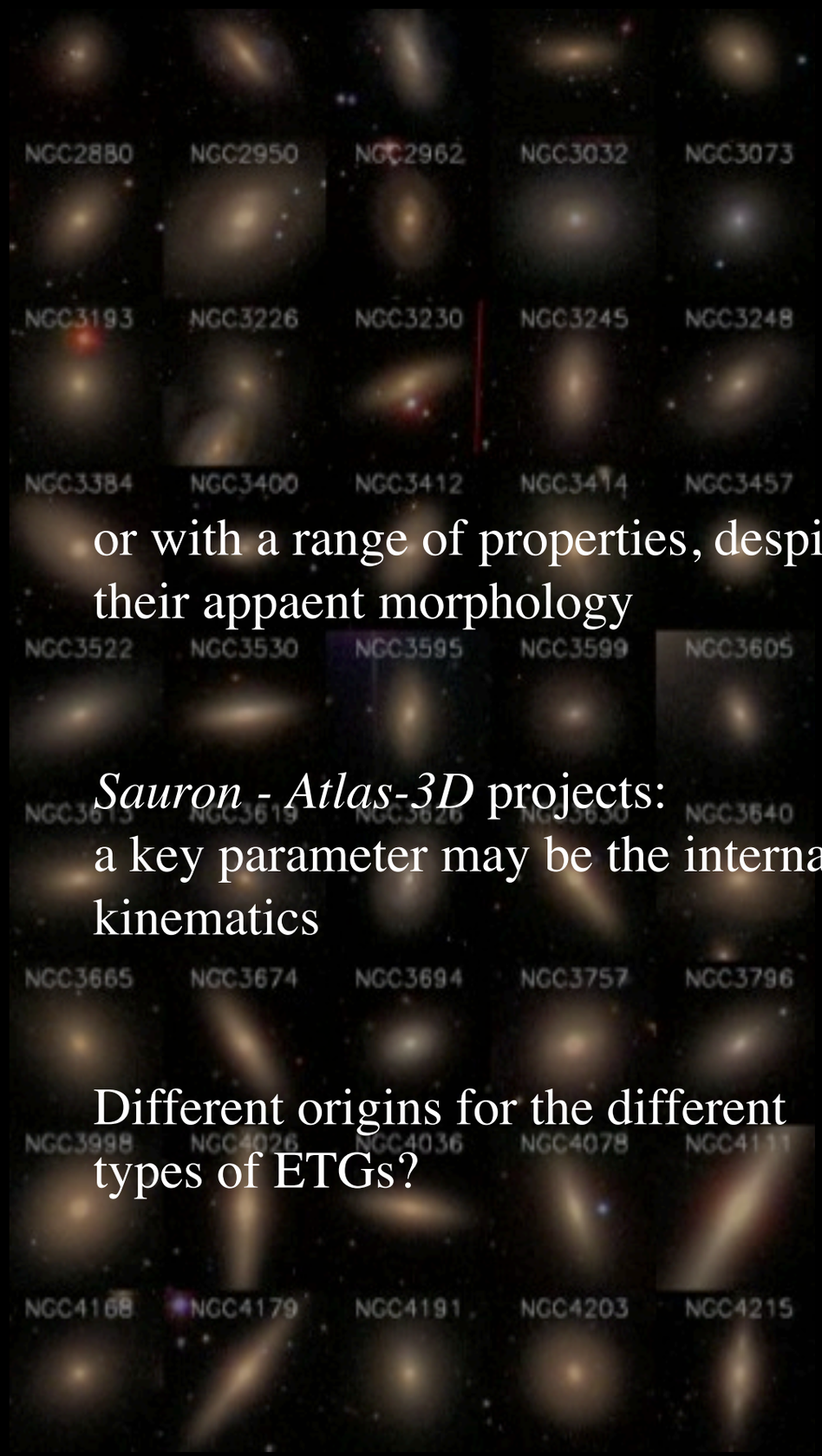
Early-type galaxies...



- For some, *Red and dead*

- For others, *the high mass end of dEs*
... following universal scaling relations

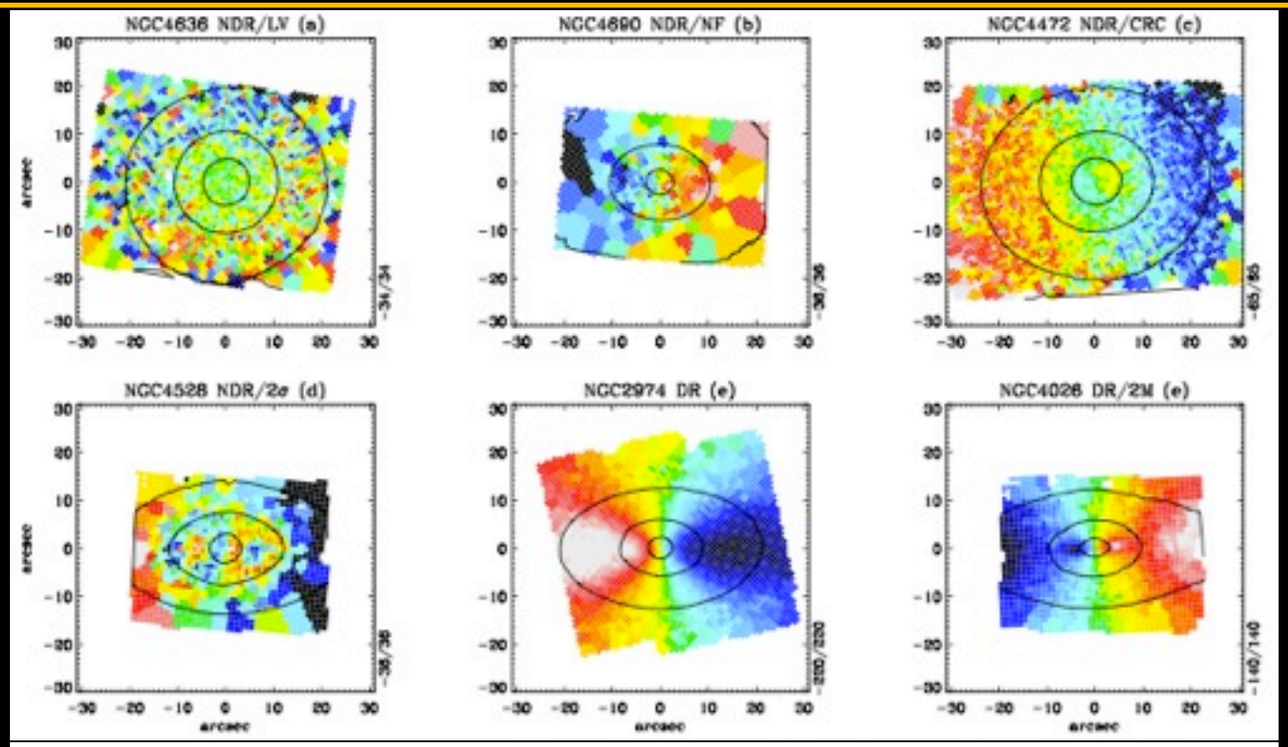
Early-type galaxies...

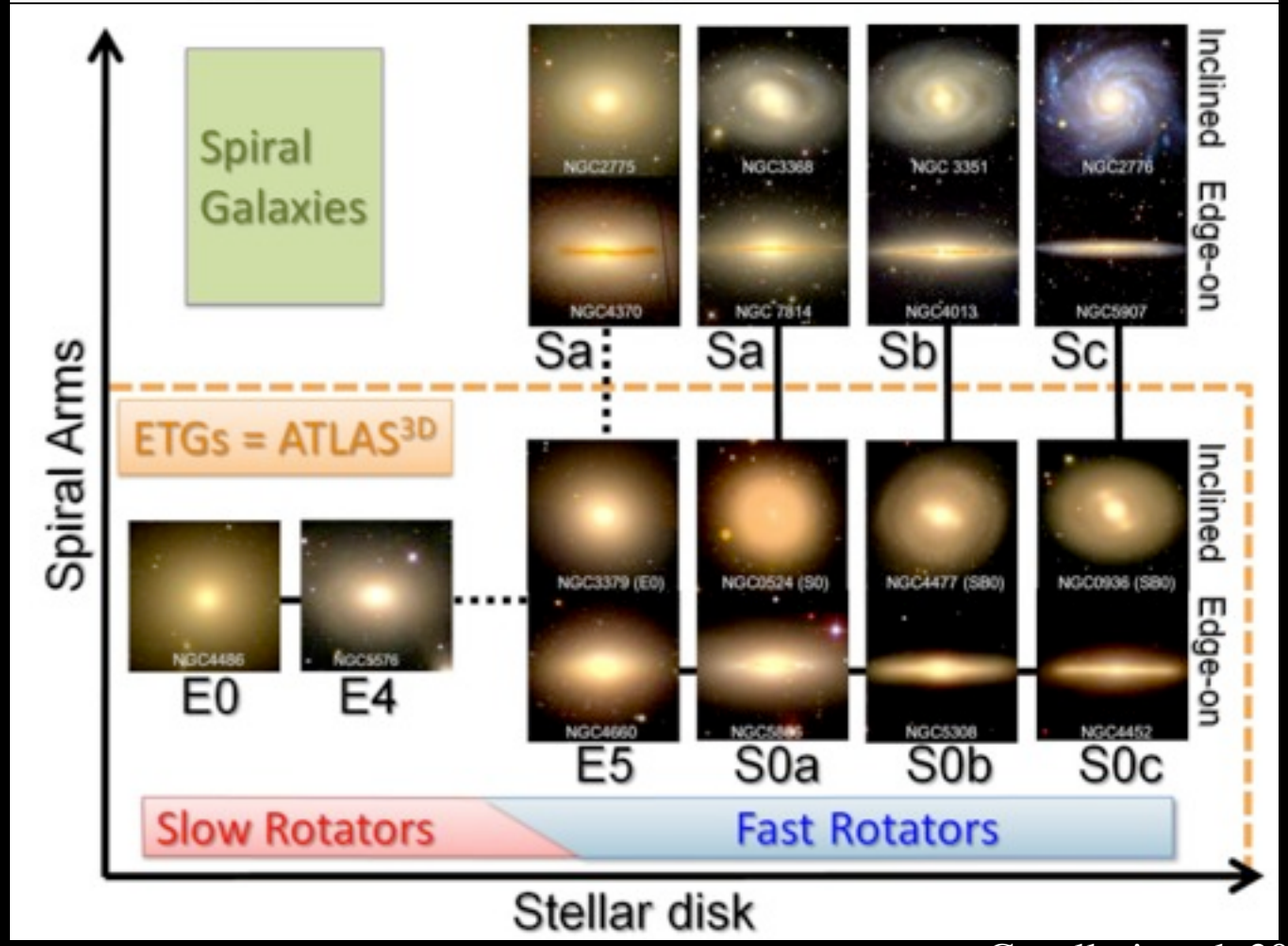


or with a range of properties, despite their appaent morphology

Sauron - Atlas-3D projects:
a key parameter may be the internal kinematics

Different origins for the different types of ETGs?



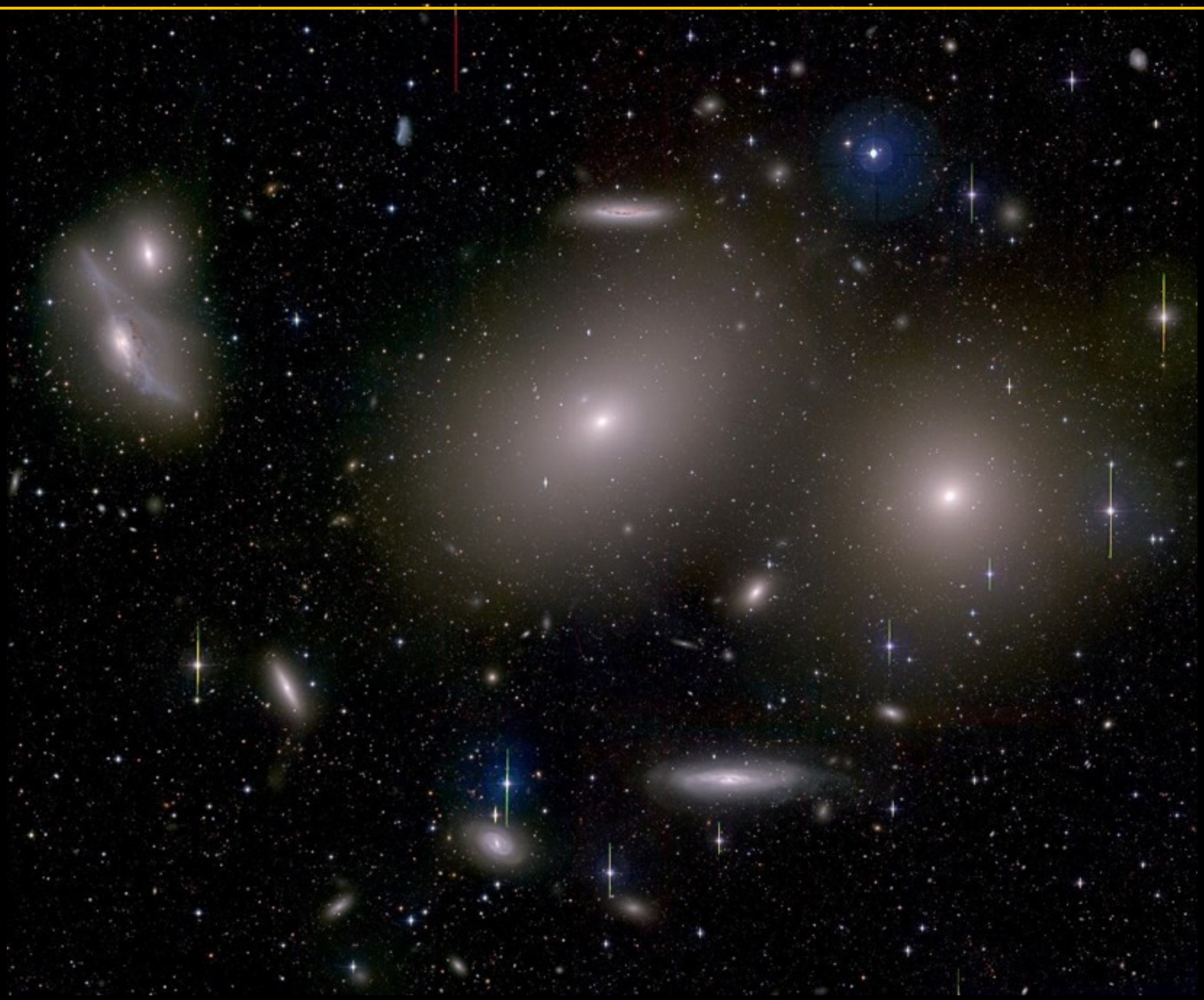


Capellari et al, 2010

Center of Virgo: the SDSS view



Center of Virgo: the NGVS view

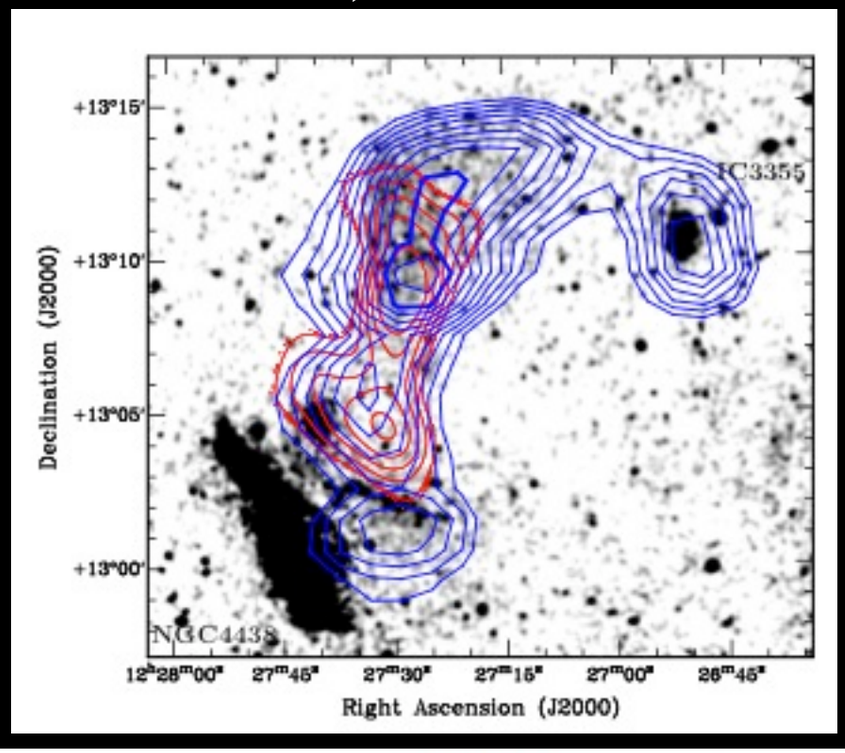


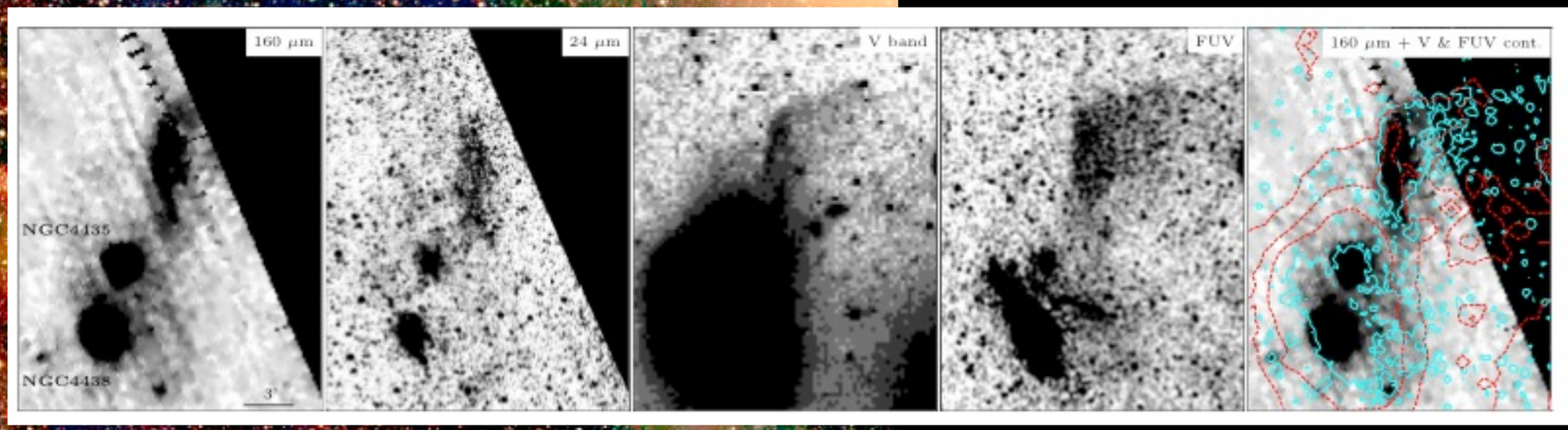
✓Cirrus

-1+1

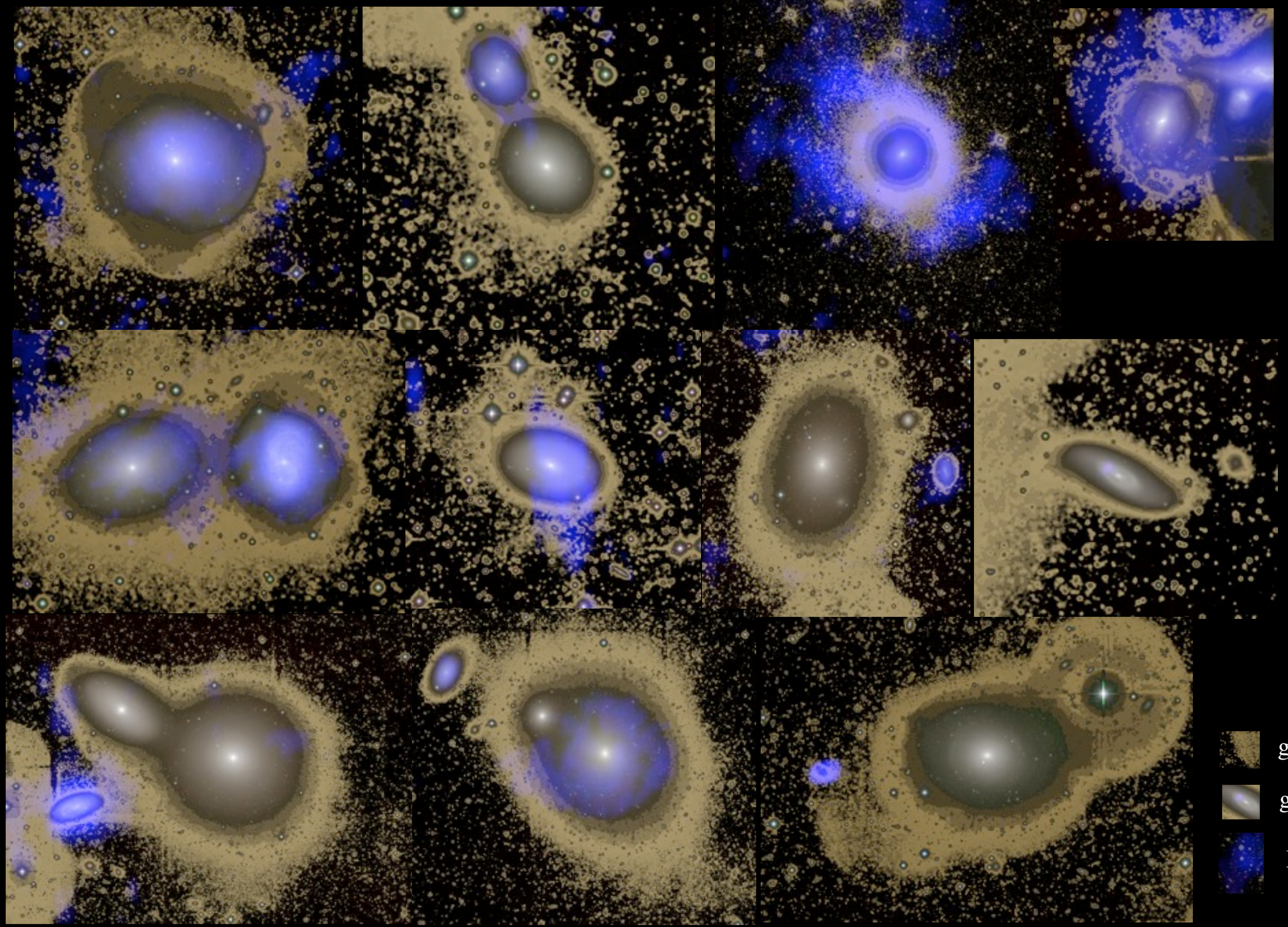
Not a star-forming tidal tail

Cortese et al., 2010

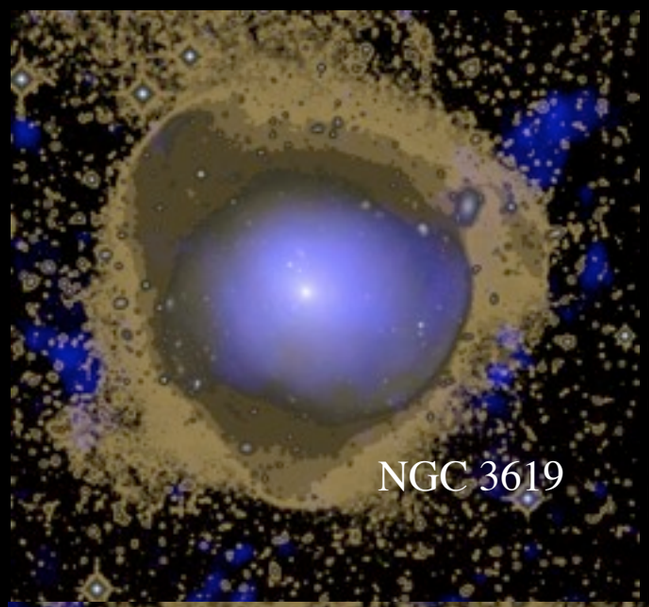


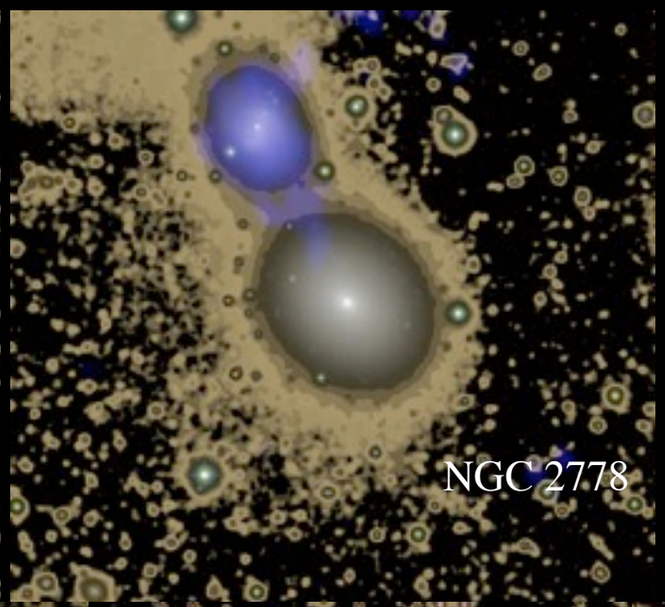


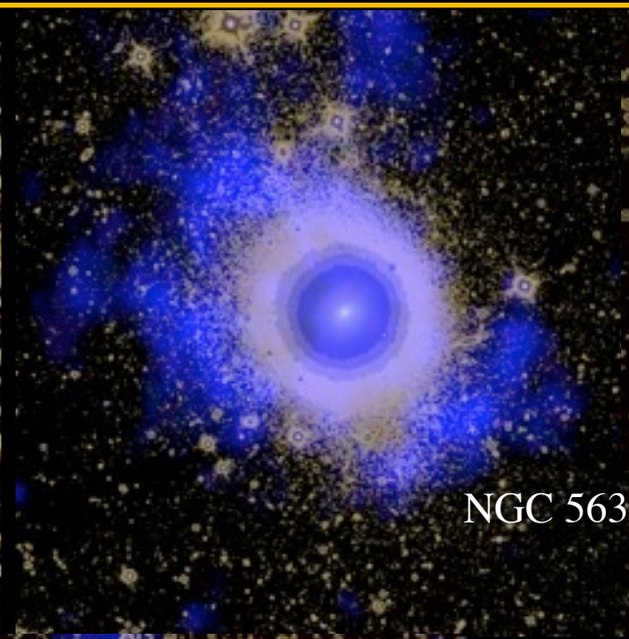
Deep imaging of Early-Type Galaxies with MegaCam

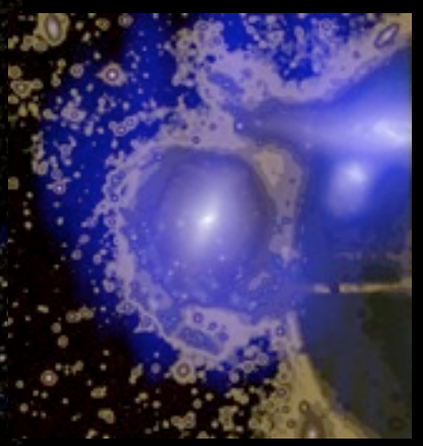


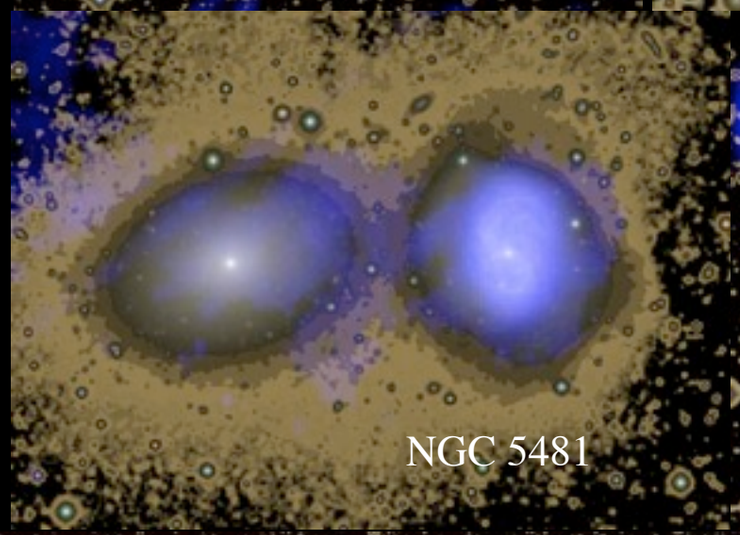
MegaCam observations of a sample of Atlas-3D galaxies

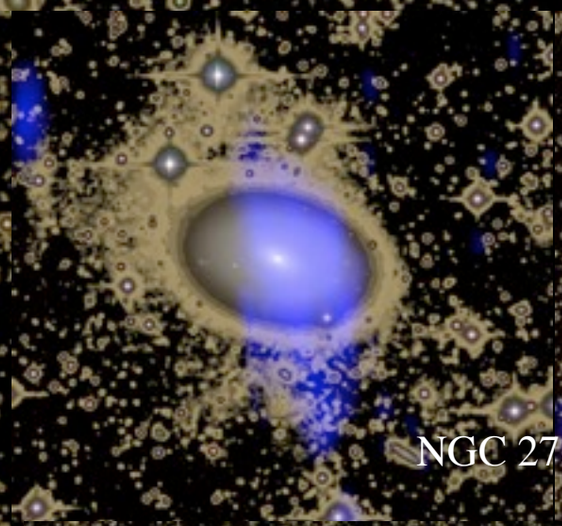

NGC 3619

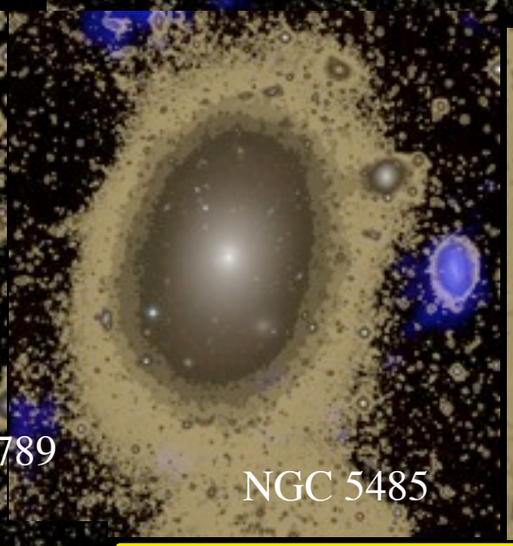

NGC 2778

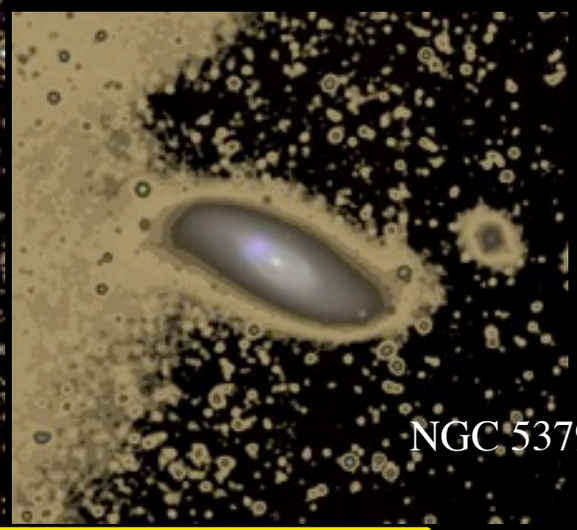

NGC 5631

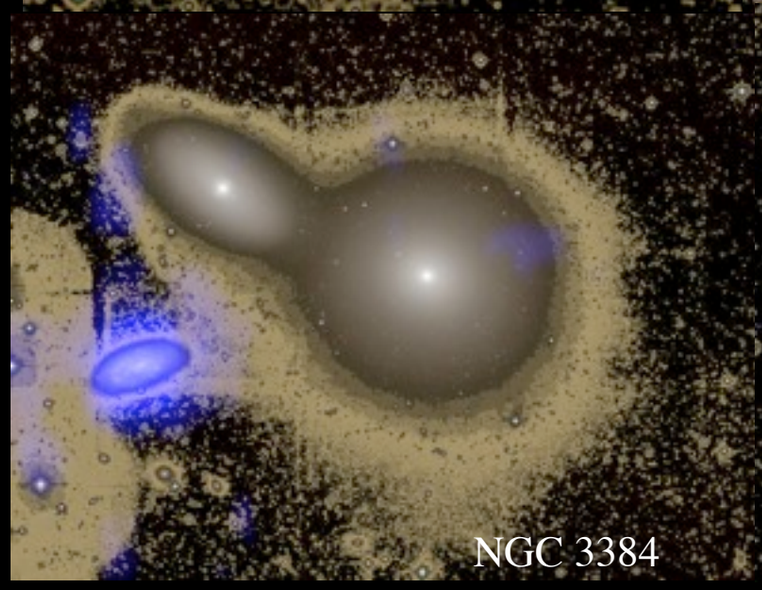

NGC 7465

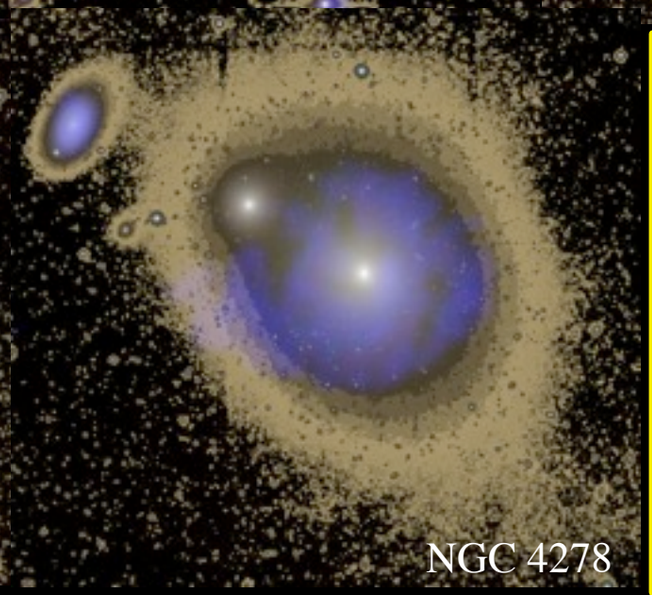

NGC 5481

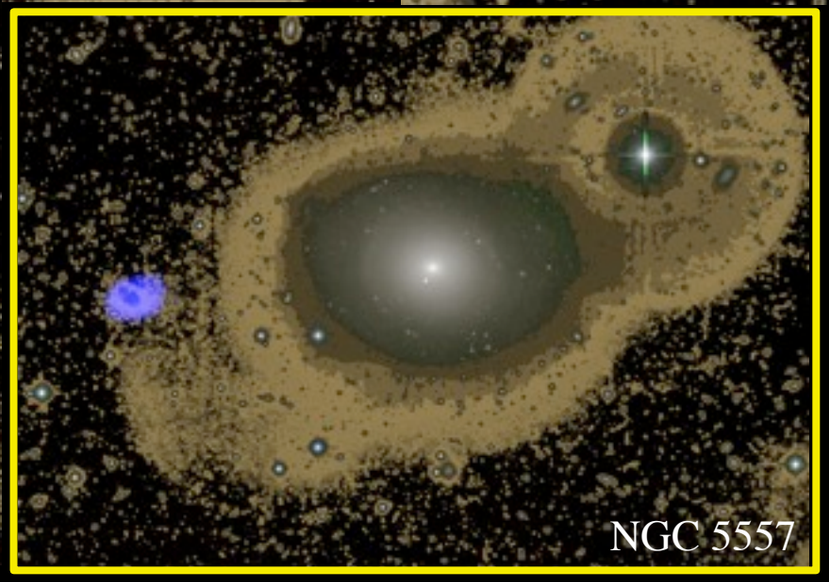

NGC 2789


NGC 5485


NGC 5379


NGC 3384


NGC 4278

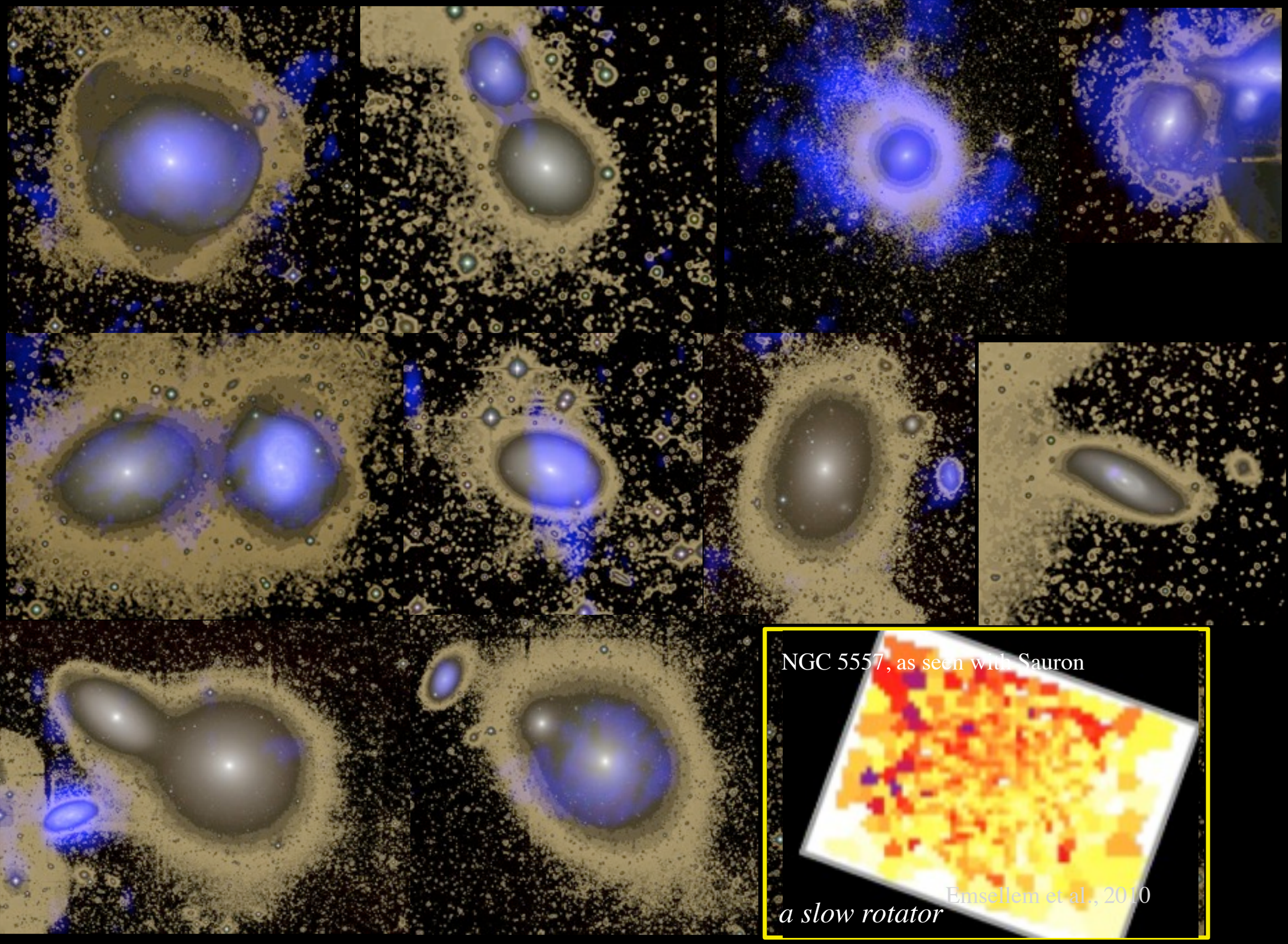

NGC 5557

MegaCam observations of a sample of Atlas-3D galaxies

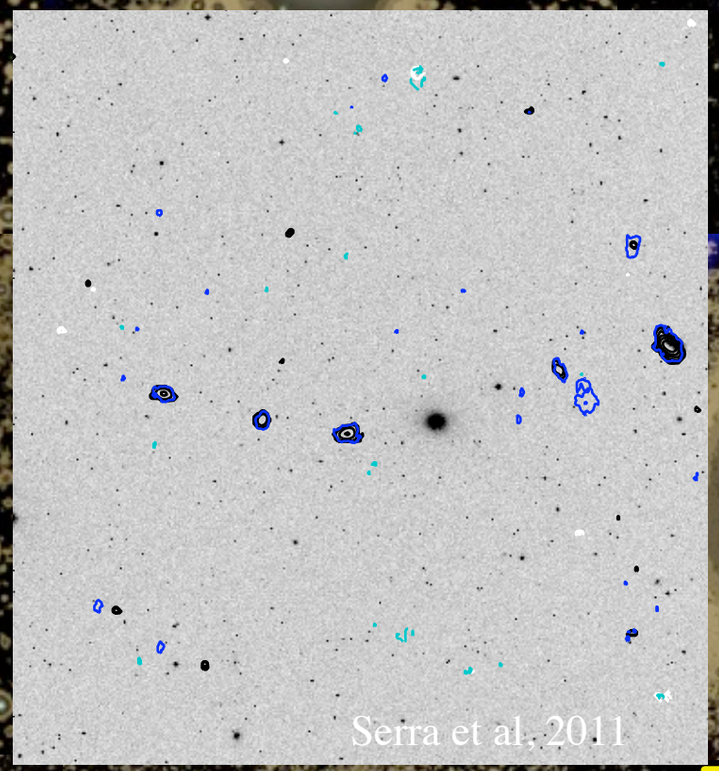
NGC 5557, as seen with SDSS

old, relaxed

MegaCam observations of a sample of Atlas-3D galaxies



MegaCam observations of a sample of Atlas-3D galaxies... with extended HI





NGC 5557 as seen by MegaCam



Duc et al., 2011

NGC 5557 as seen by MegaCam + WSRT/HI

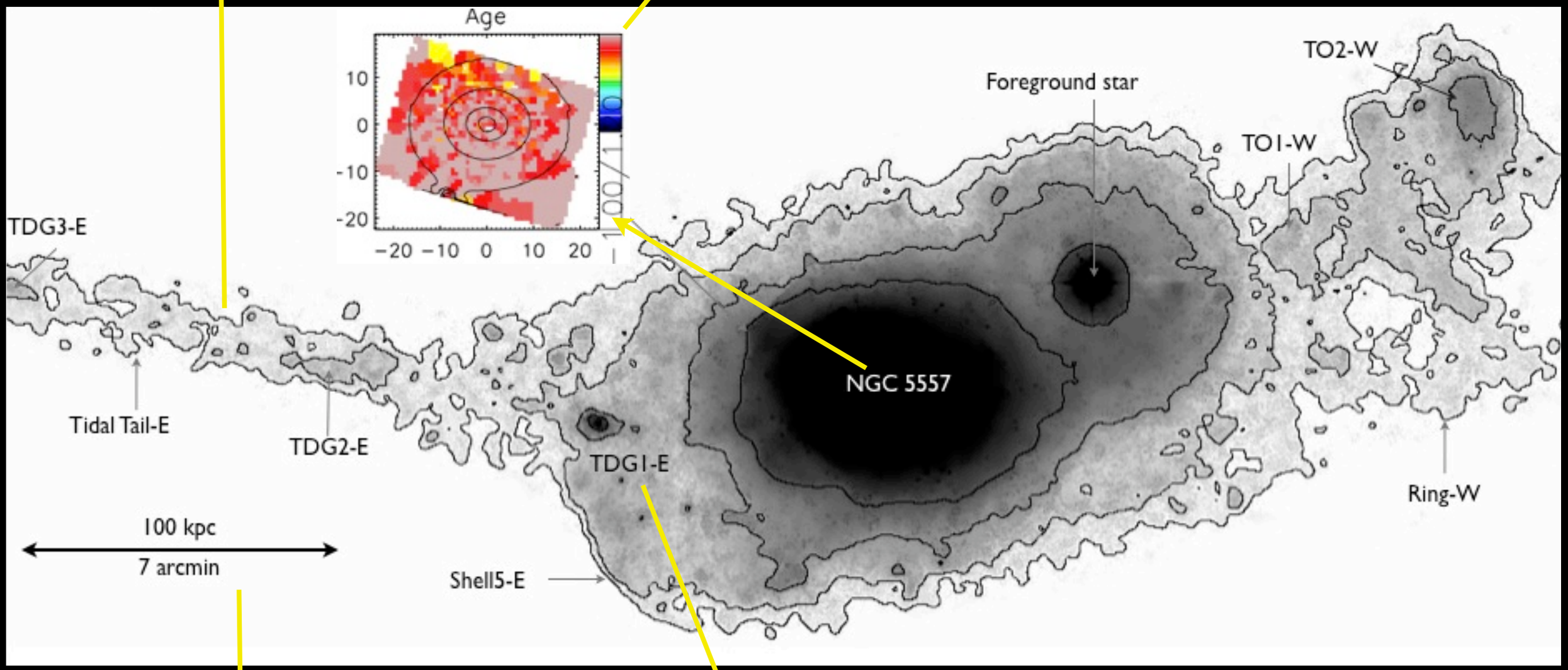


Duc et al., 2011

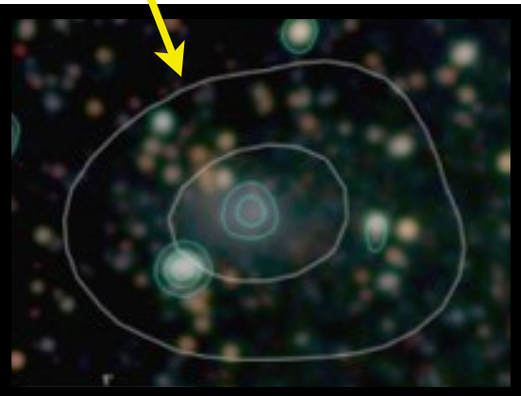
NGC 5557: an old major merger

the tidal tails reveal a wet relatively recent major merger et the originof the ETG

the absence of young stars / gas in the remnant tell that the merger is at least 1-2 Gyr old



one of the largest stellar structure known in the nearby Universe



one of the oldest surviving Tidal Dwarf Galaxy so far know

MegaCam observations of a sample of Atlas-3D galaxies

NGC 3619

NGC 2778

NGC 5631

NGC 7465

NGC 5481

NGC 2789

NGC 5485

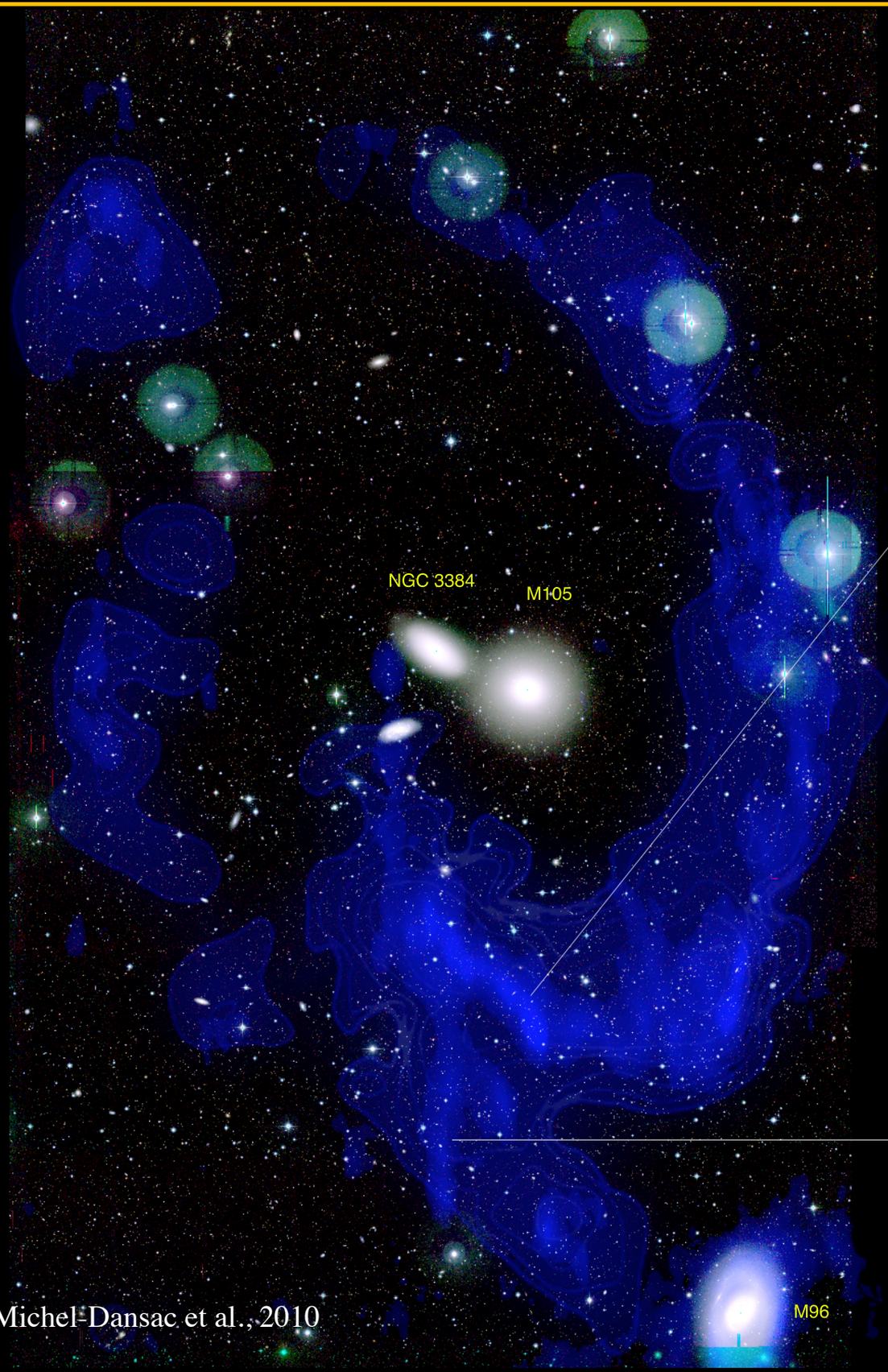
NGC 5379

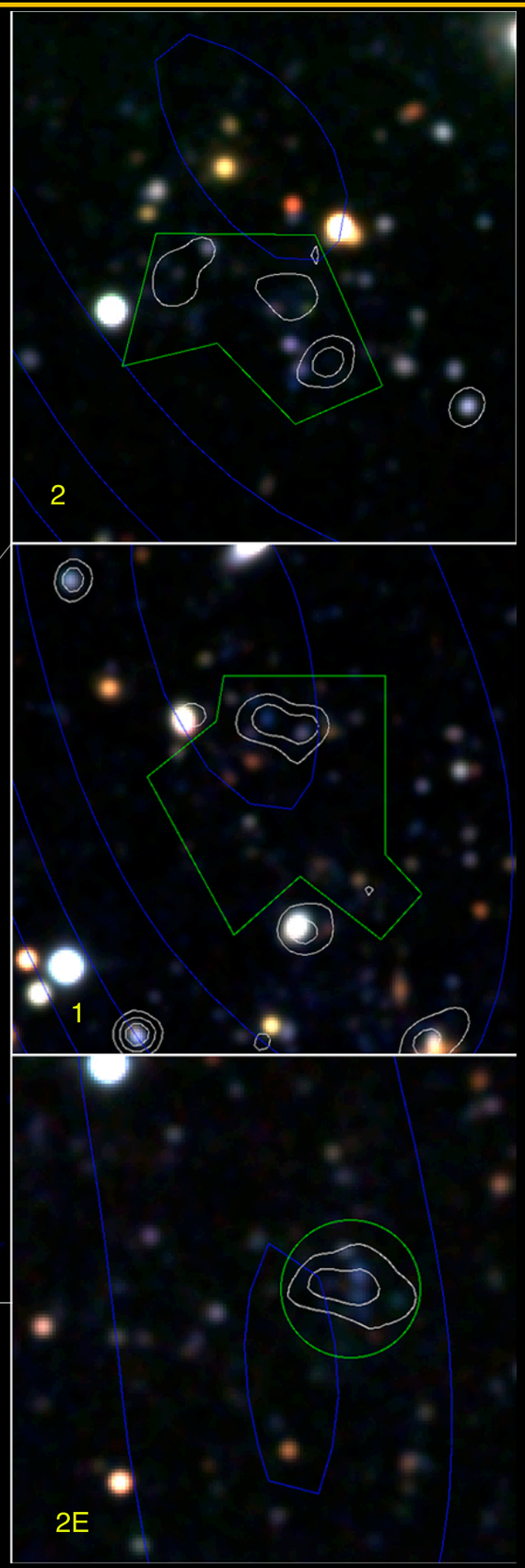
NGC 3384

NGC 4278

NGC 5557

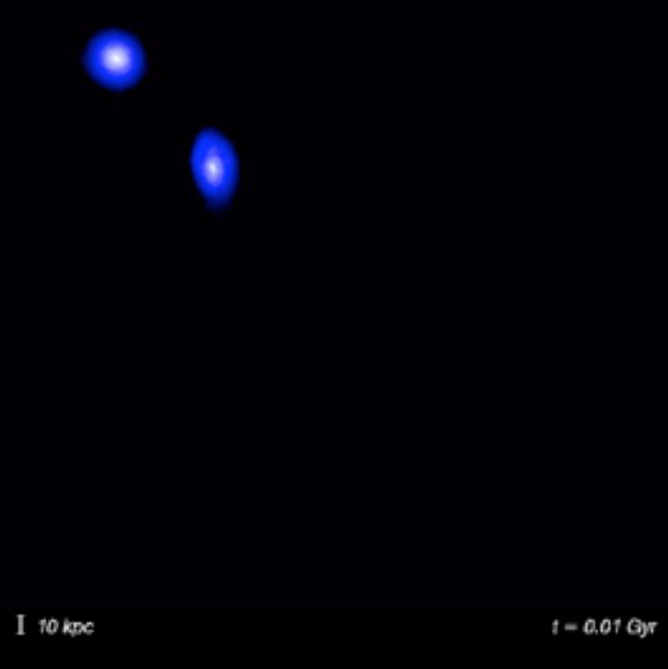
NGC 3384: a collisional origin for the Leo Ring





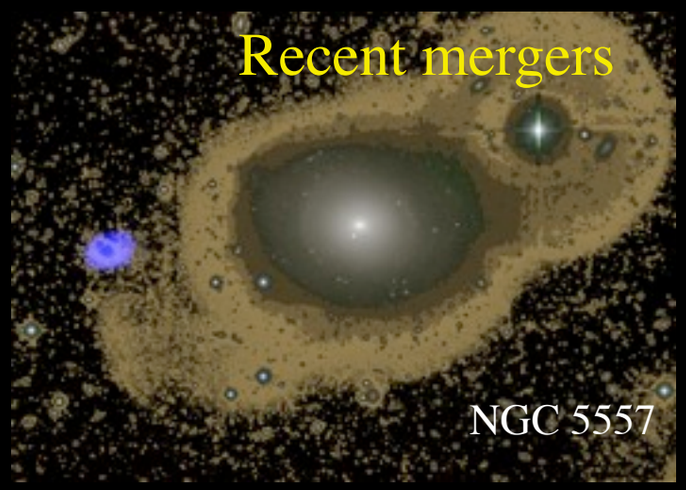
Michel-Dansac et al., 2010

- The gas in the Leo Ring is not primordial
- Young stars along it detected for the first time in the optical with MegaCam

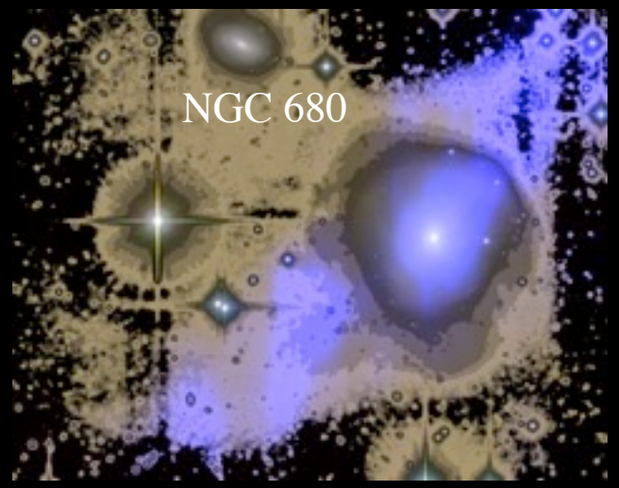


What is the fraction of major mergers among the various types of ETGs?

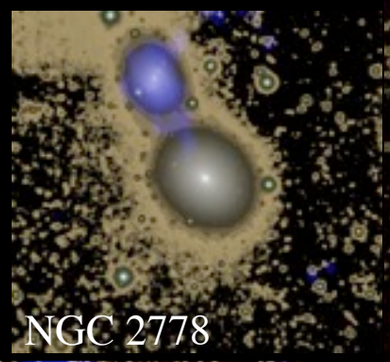

NGC 3619


Recent mergers

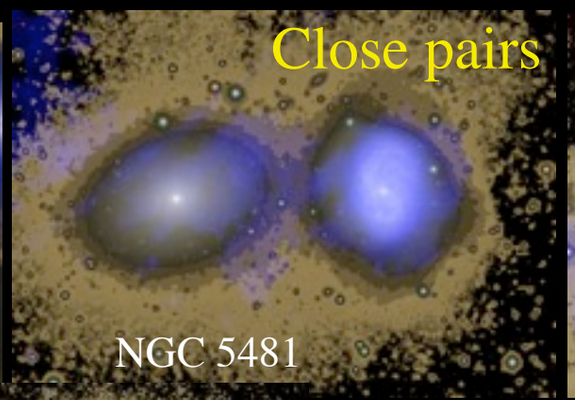
NGC 5557


NGC 680

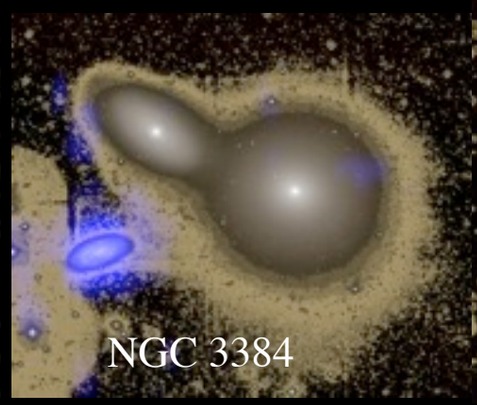

NGC 7332

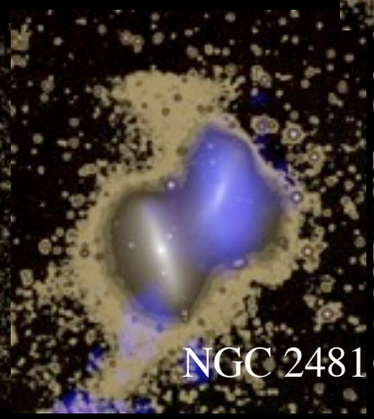

NGC 2778

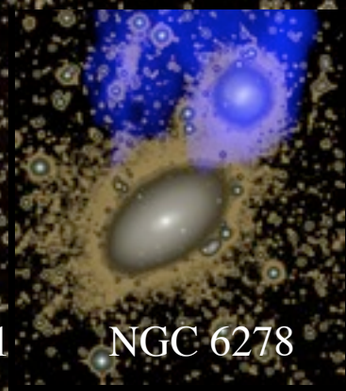

NGC 7465

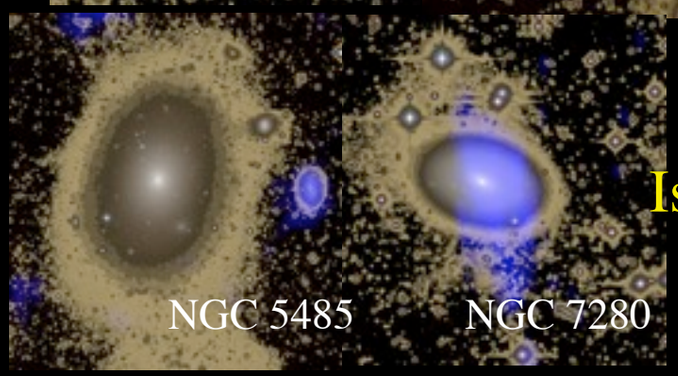

Close pairs

NGC 5481

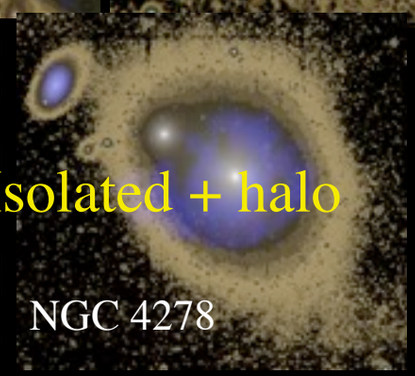

NGC 3384


NGC 2481

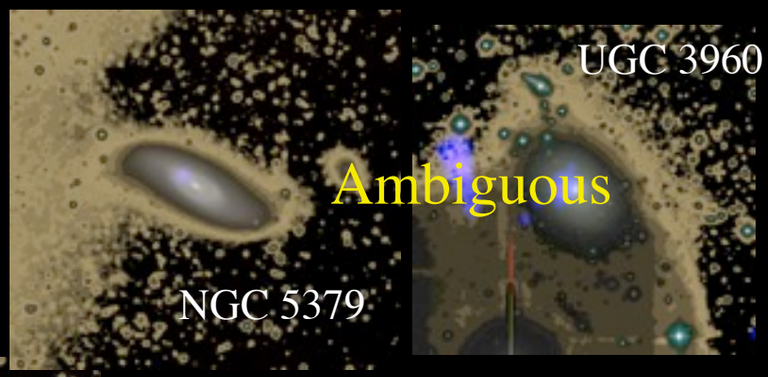

NGC 6278


NGC 5485

NGC 7280

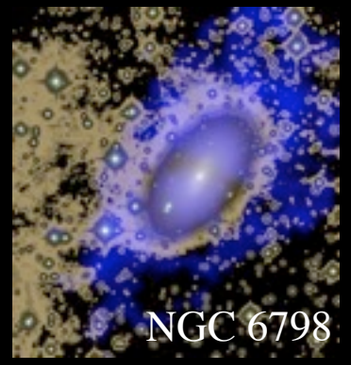

Isolated + halo

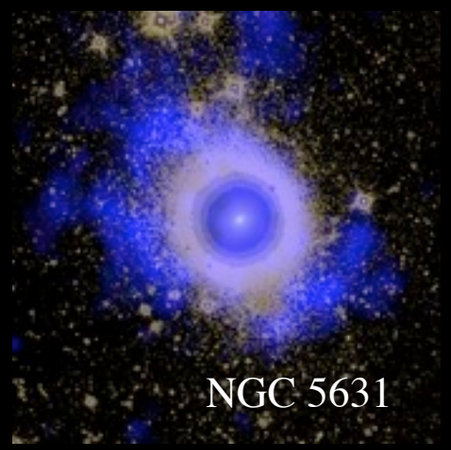
NGC 4278


Ambiguous

NGC 5379

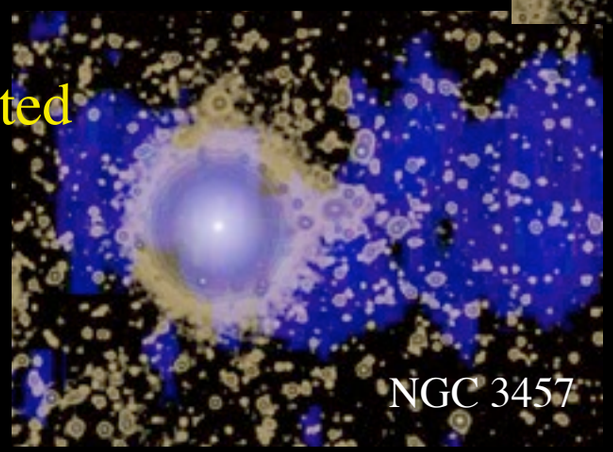
UGC 3960


NGC 6798


NGC 5631


Isolated

PGC050395


NGC 3457

about 60 ETGs in the field
+ 60 ETGs in Virgo (NGVS)

Fine structures in the field vs in clusters

about 60 ETGs in the field
+ 60 ETGs in Virgo (NGVS)

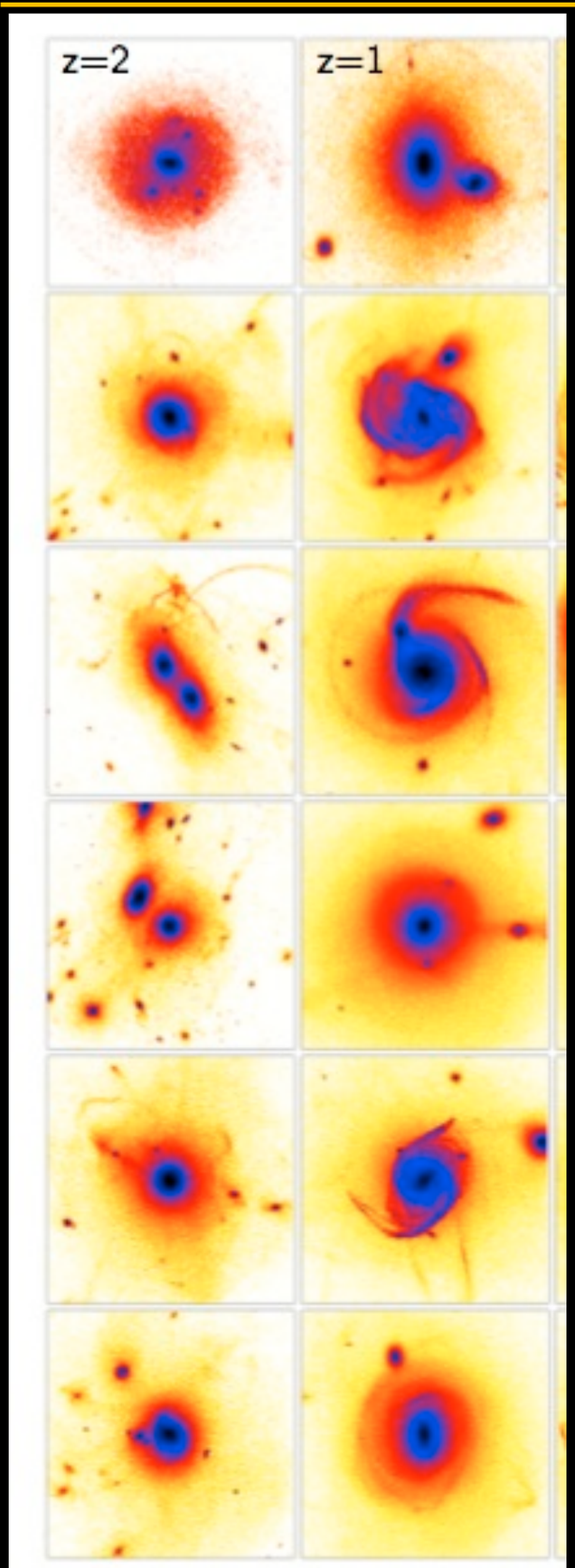
Fine structures in the field vs in clusters

Systematic differences

- 2/3 of field ETGs show some level of perturbations
- 1/3 of Virgo galaxies look perturbed

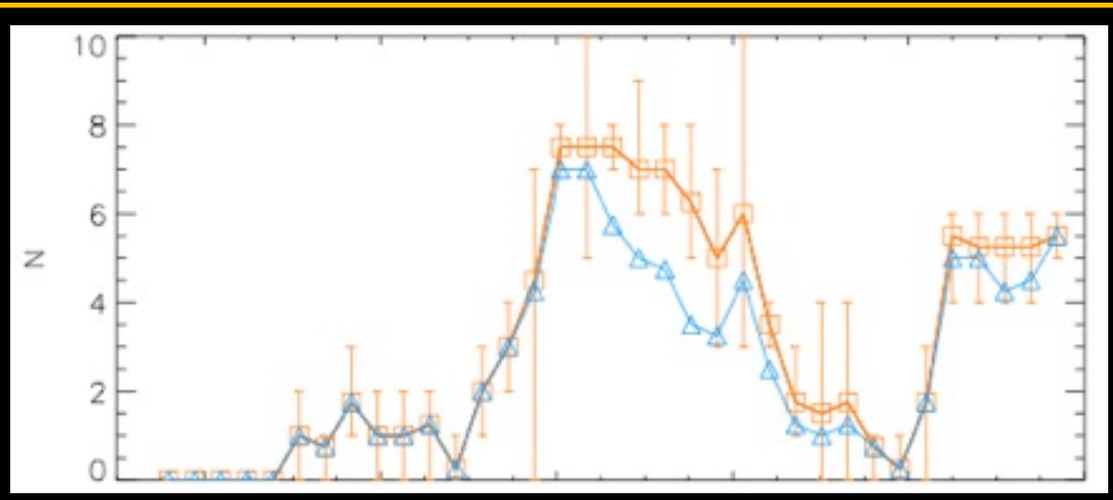
✓ Age effect: cluster ETGs are older, and the memory of their past mass accretion has been lost
✓ History effect: the mass assembly is different in the field or clusters
✓ Local environment effect: tails and fine structures are destroyed in clusters (contributing to the ICL)

Survival of fine structures (simulations)

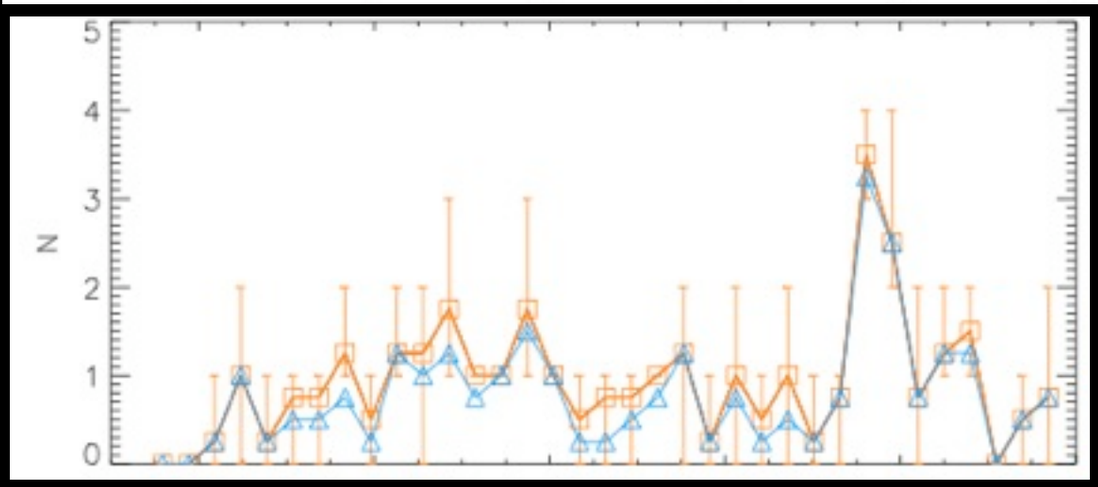


Martig et al, 2009

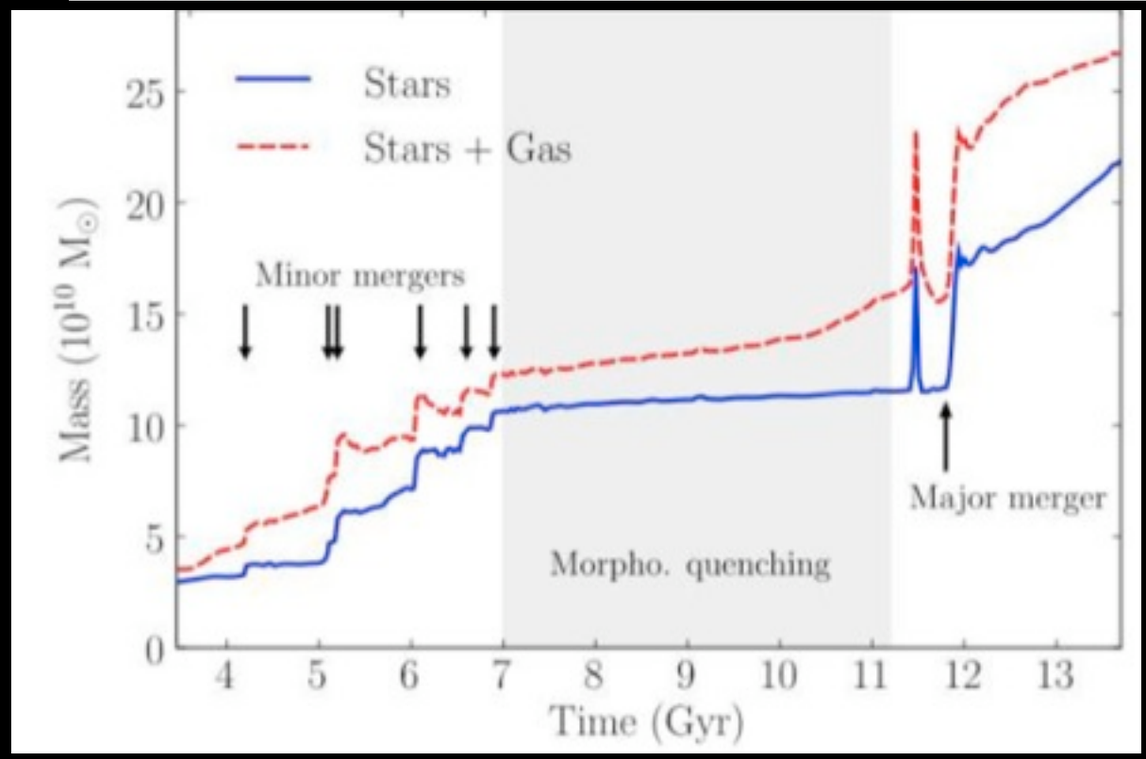
Number of shells



Number of tidal tails



Mass assembly



NGC 474

