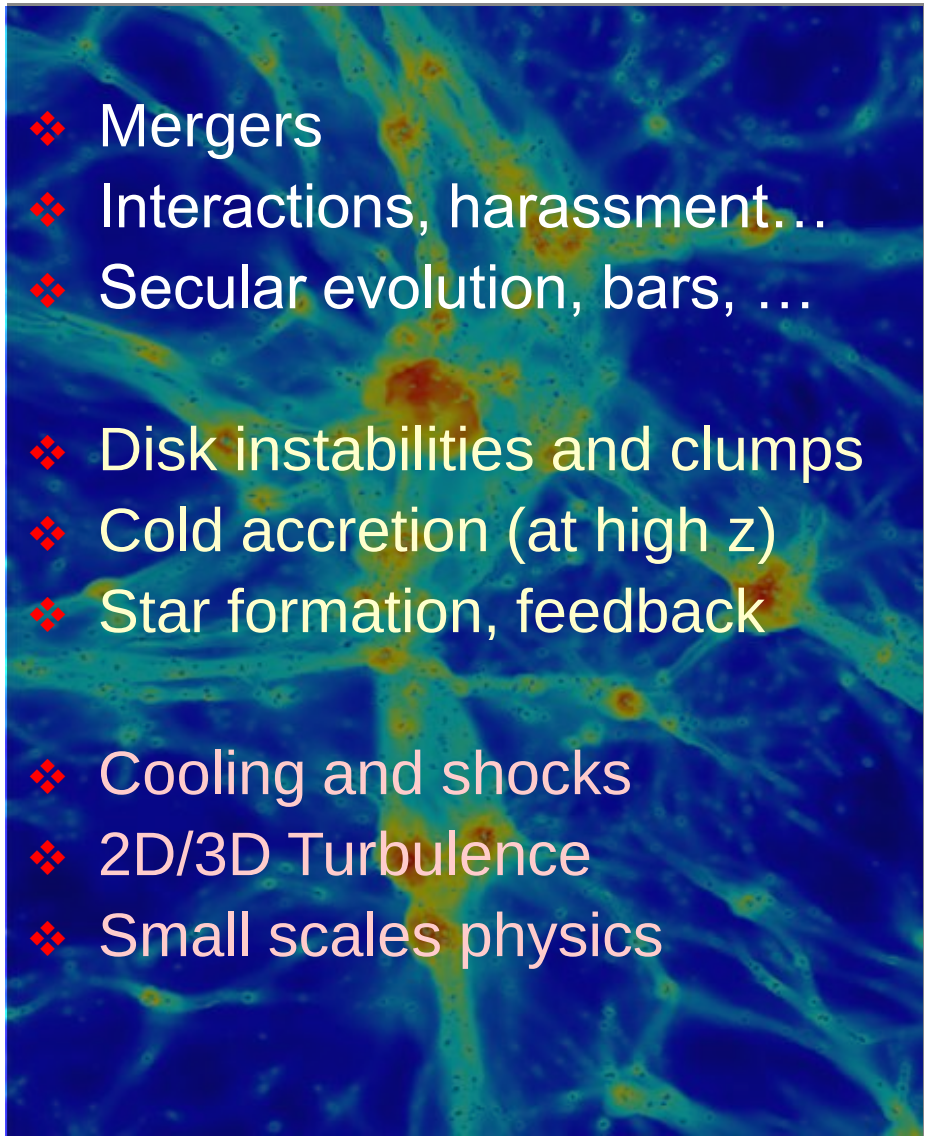
News from

the Atlas^{3D} project

Eric Emsellem

and the ATLAS^{3D} team

From DM inhomogeneities to z=0 galaxies

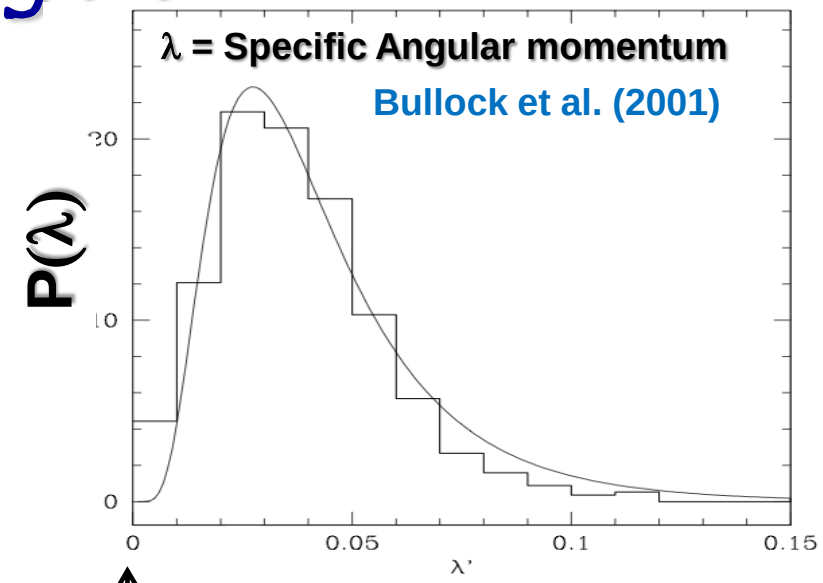


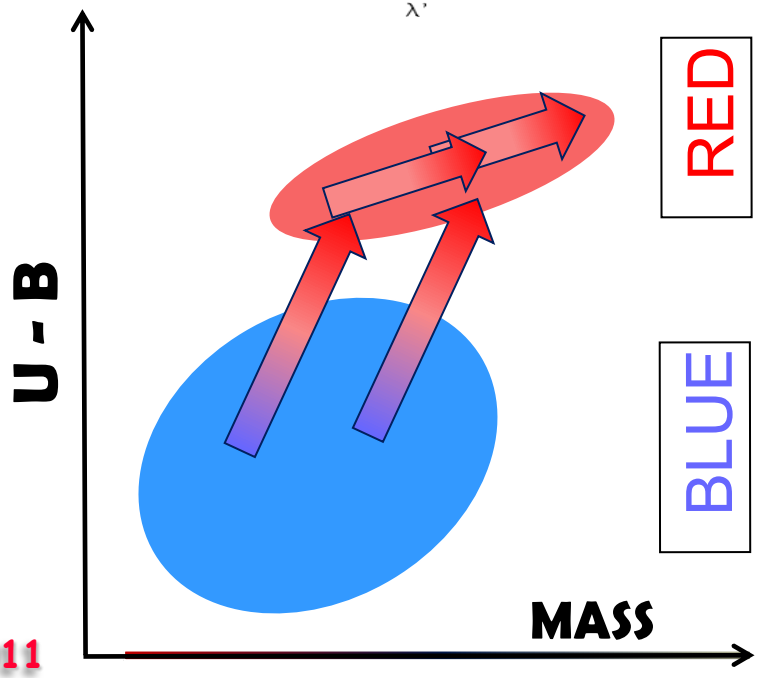
- Mergers
- Interactions, harassment…
- Secular evolution, bars, …

- Disk instabilities and clumps
- Cold accretion (at high z)
- Star formation, feedback

- Cooling and shocks
- 2D/3D Turbulence
- Small scales physics

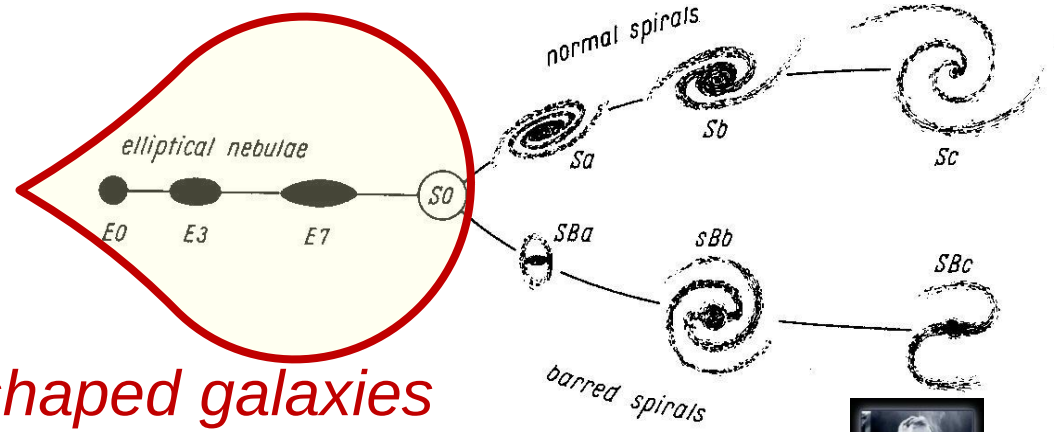
Mare Nostrum = Teyssier et al.





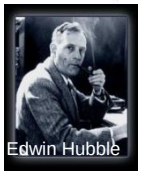
The paradigm

Early-type galaxies ≡



~50% of E's ≡ *spheroid-shaped galaxies*

~50% of S0s ≡ *bulge dominated disk galaxies*



- E + S0s **~ 40%** of (SDSS) mass **Bernardi et al. 2010**
- E/S0s are overall red, S0s can have young stars
- ***Mergers*** ➔ important to build E's
- Two flavours of E's ? **Davies/Nieto/Kormendy/Bender/Lauer**…
  - Boxy with flat cores or light deficit, anisotropic, oblate
  - Disky with cusps or light excess, isotropic, triaxial

The Team

PIs: Michele Cappellari, Eric Emsellem, Davor Krajnović, Richard McDermid

Cols :

Katey Alatalo, Leo Blitz, Maxime Bois, Frederic Bournaud, Martin Bureau, Alison Crocker, Roger Davies, Tim Davis, Tim de Zeeuw, Pierre-Alain Duc, Sadegh Khochfar, Harald Kuntschner, Pierre-Yves Lablanche, Raffaella Morganti, Thorsten Naab,Tom Oosterloo, Marc Sarzi, Nicholas Scott, Paolo Serra, Lisa Young, Anne-Marie Weijmans

Associates: Estelle Bayet, Jean-Charles Cuillandre, Jesus Falcon-Barroso, Gijs Verdoes-Kleijn, Marie Martig, Leo Michel-Dansac, Kristina Nyland, Krysten Shapiro, Remco van der Bosch, Glenn van de Ven

Atlas^{3D}: the sample

Cappellari, EE, DK, et al., 2011 (P1)

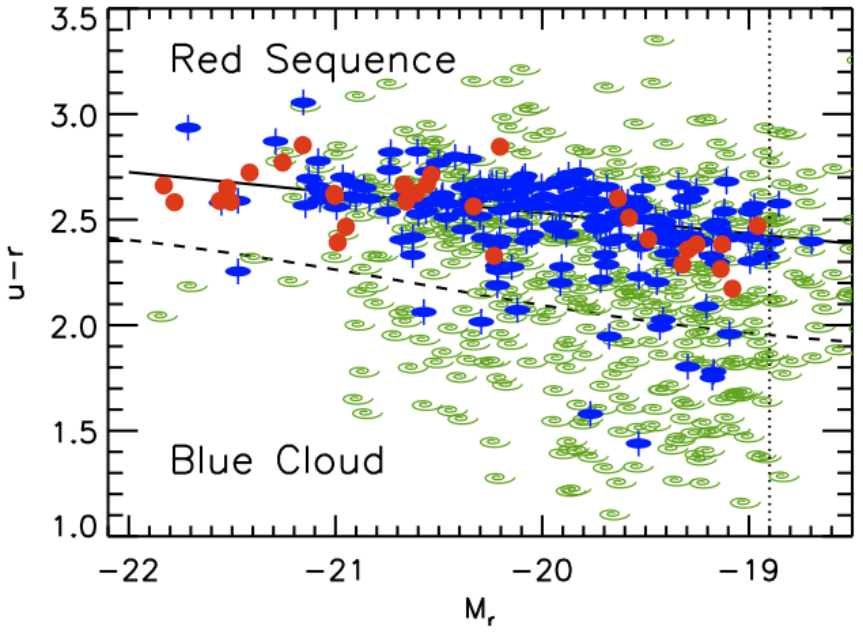
➔ **Observe a complete volume-limited sample of ETGs**

$M_K < -21.5$, $D < 42$ Mpc
$|\delta - 29| < 35^o$, $|b| > 15^o$

➔ **Parent sample: 871 nearby galaxies**

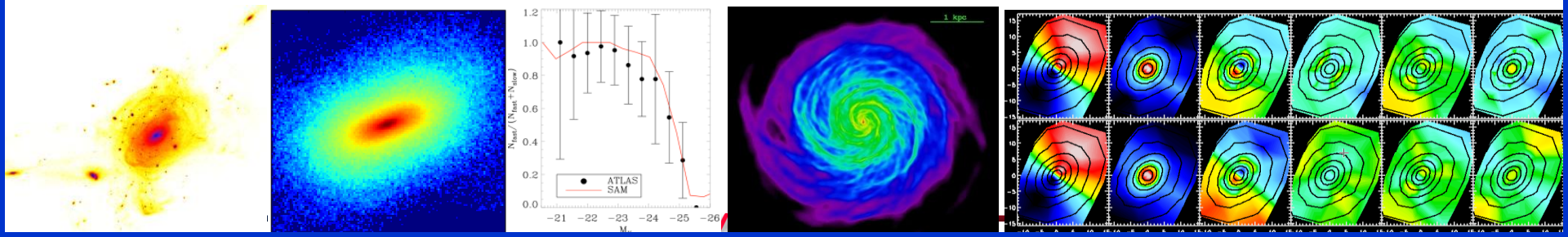
"*No spiral structure*" (SDSS/DSS2/INT)

➔ **260 galaxies**



- *2D-spectroscopy* (SAURON-WHT)
- *Single-dish + interferometric CO* (IRAM 30m, CARMA PdB)
- *HI survey* (WRST, excl. Virgo)
- *Multi-band and Deep Photometry* (INT, 2MASS, SDSS, MegaCam)
- *eVLA, X-ray, Spitzer, …*

- *Stellar populations & Dynamical modelling* (JAM)
- *Suite of high-resolution numerical simulations of mergers*
- *High resolution simulations of gas in ETGs*
- *Simulations in a cosmological context*
- *Semi Analytic Modeling* (SAM)



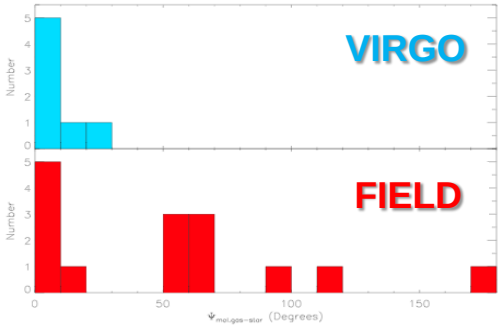
Atlas^{3D} Project : First results

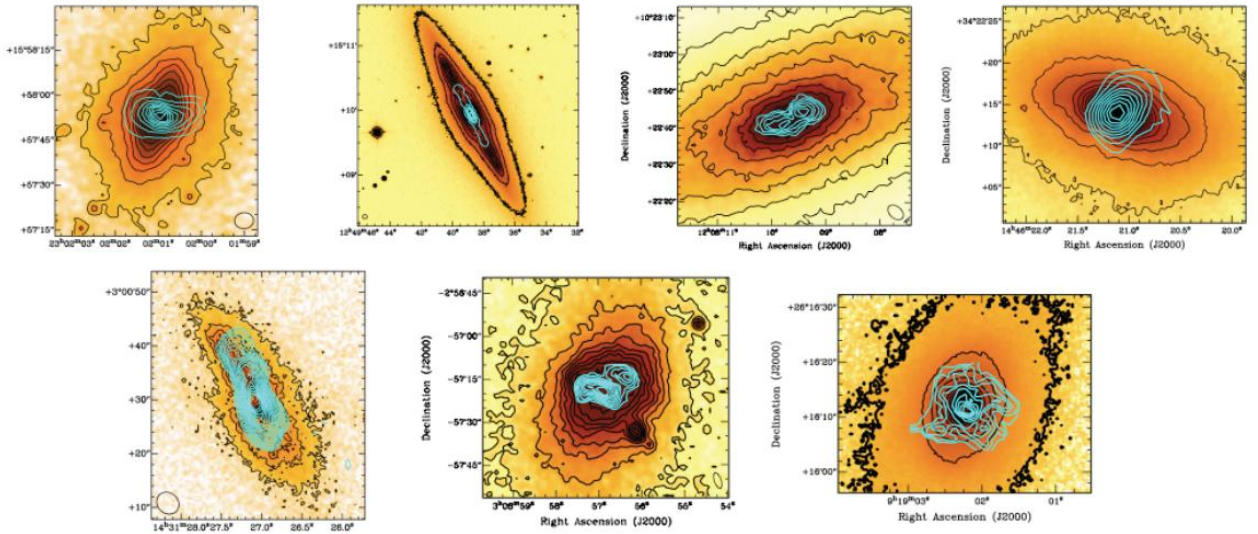
I. Cappellari , Emsellem, Krajnović, McDermid et al. 2011 (Sample)
II. Krajnović, Emsellem, Cappellari et al. 2011 (Kinematic properties)
III. Emsellem, Cappellari, Krajnović et al. 2011 (Angular momentum)
IV. Young, Bureau, Davis et al. 2011 (CO Singe dish)
V. Davis, Bureau, Young et al. 2011 (CO Tully–Fisher relation)
VI. Bois, Emsellem, Bournaud et al. 2011 (Binary disk mergers)
VII. Cappellari , Emsellem, Krajnović, McDermid et al. 2011 (Environment)
VIII. Khochfar, Emsellem, Serra, et al. 2011 (SAM)
IX. Duc, Cuillandre, Serra, et al. 2011 (Deep Imaging)
X. Davis, Alatalo, Sarzi, et al. 2011 (Origin of ionised/molecular gas)
XI. Crocker, Kripps, Bureau et al. 2011 (Dense molecular gas)
XII. Lablanche, Cappellari, Emsellem et al. 2011 (M/L recovery)
XIII. Serra, Oosterloo, Morganti et al., 2011 (HI content)

+ Bois, Bournaud, Emsellem et al. 2010 (Numerical resolution)
+ Alatalo, Blitz, Young et al. 2011 (Large-scale AGN outflow in NGC1266)

Molecular Gas

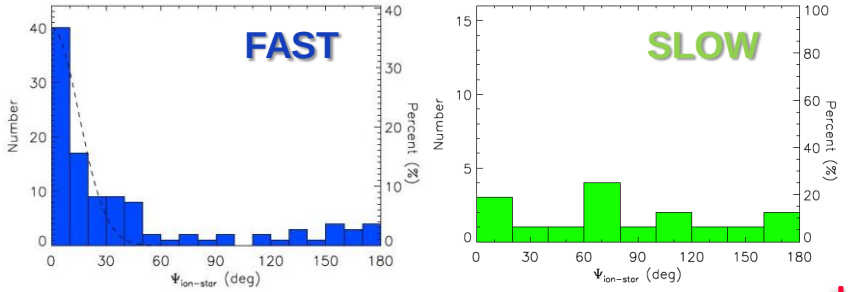
- **CO (1-0)/(2-1) + CARMA: detection rate of 23 %**
  - Same in clusters or outside, or from -21.5 < M_K < -26
  - *No CO in slowly rotating galaxies*





Early-type galaxies have surprising amounts of H_2 and HI

MISALIGNMENT Angle

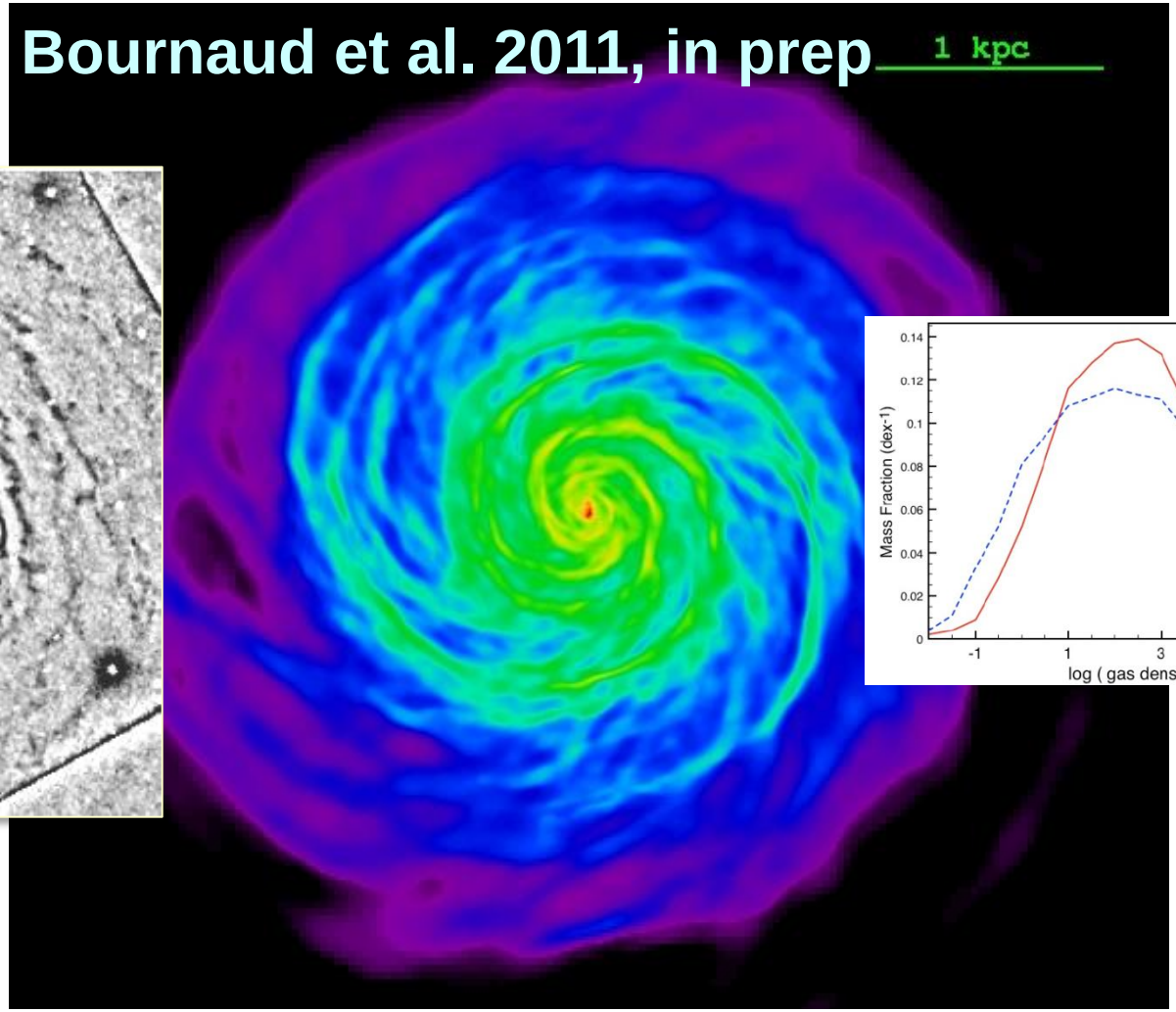


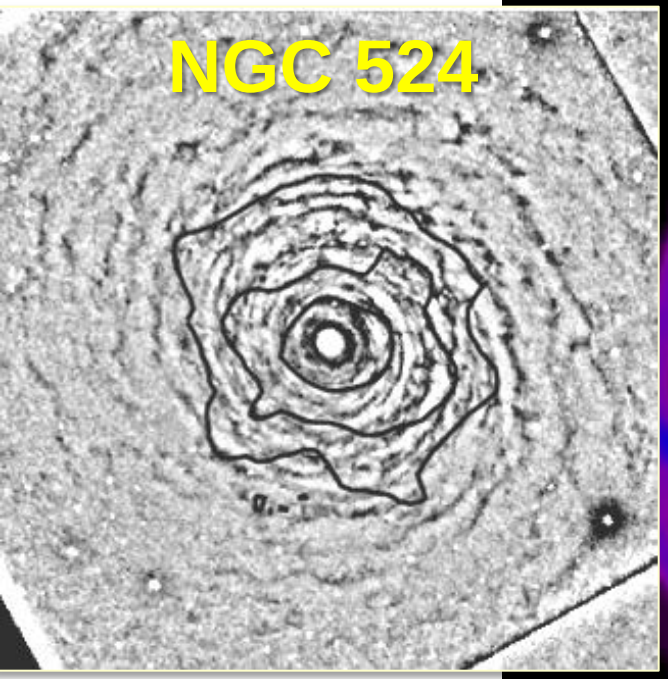
Young, Bureau, Davis et al. , 2011 (P4)
Davis, Bureau, Young et al. ,2011 (P10)
Alatalo et al., 2011, in prep.

Morphological Quenching

(Martig et al. 2009)

- **Gas in ETGs at very high resolution (~ 5pc)**





Gas in an Isolated Galaxy

- What is already there:
  - Spatial resolution: ok (convergence at ~2-5 pc)
  - Gas phases (cooling, etc), star formation, feedback, mass loss: various recipes exist

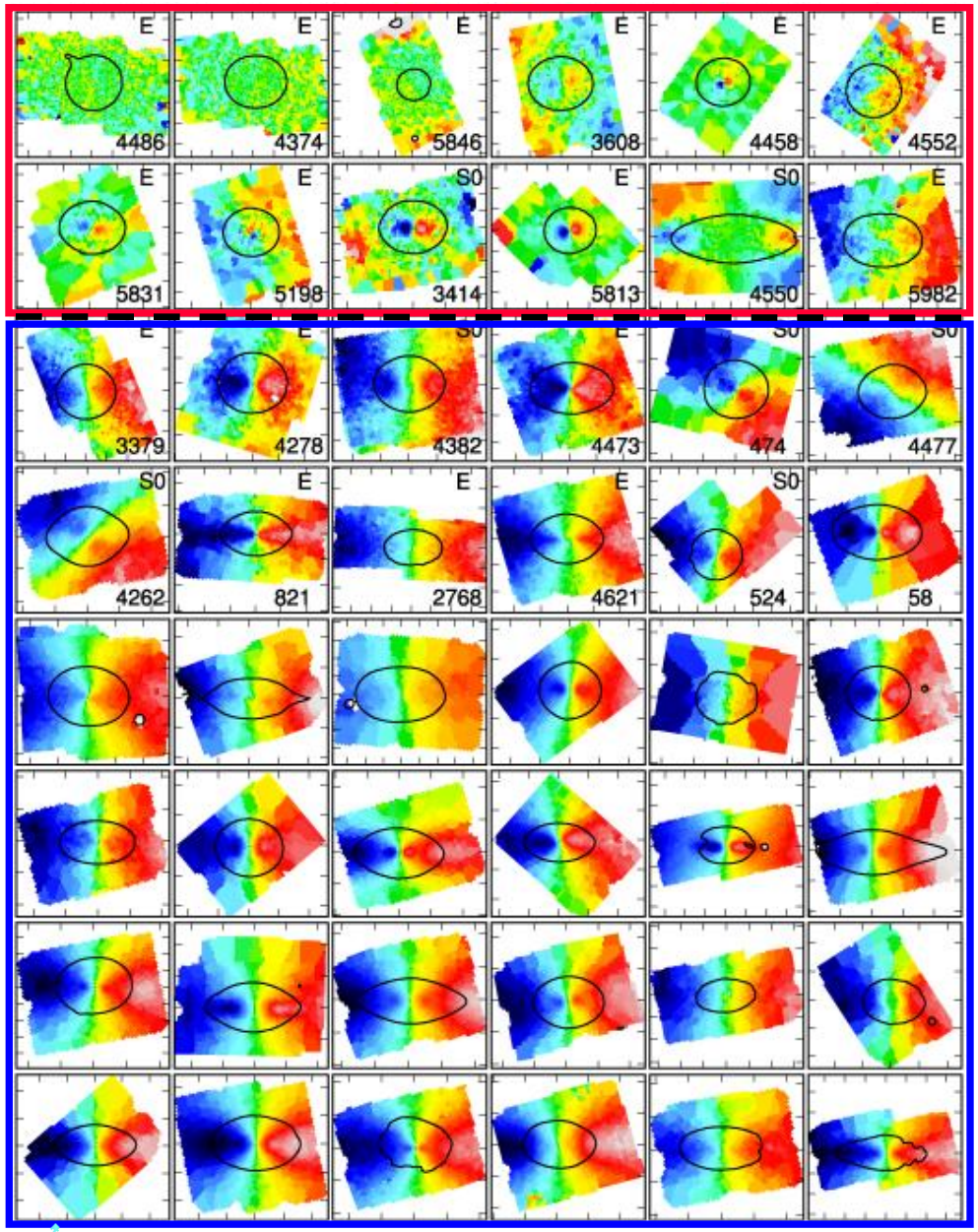
- What we need now :
  - EVOLUTION on a long time-scale (few Gyr) to study
    - Dynamical evolution and link with Star formation
  - Role from individual processes:
    - e.g., cluster potential, stripping, cold accretion

Slow rotators

λ_R=0.1

$$\lambda_R \equiv \frac{\langle R \cdot |V| \rangle}{\langle R\sqrt{V^2+\sigma^2} \rangle}$$

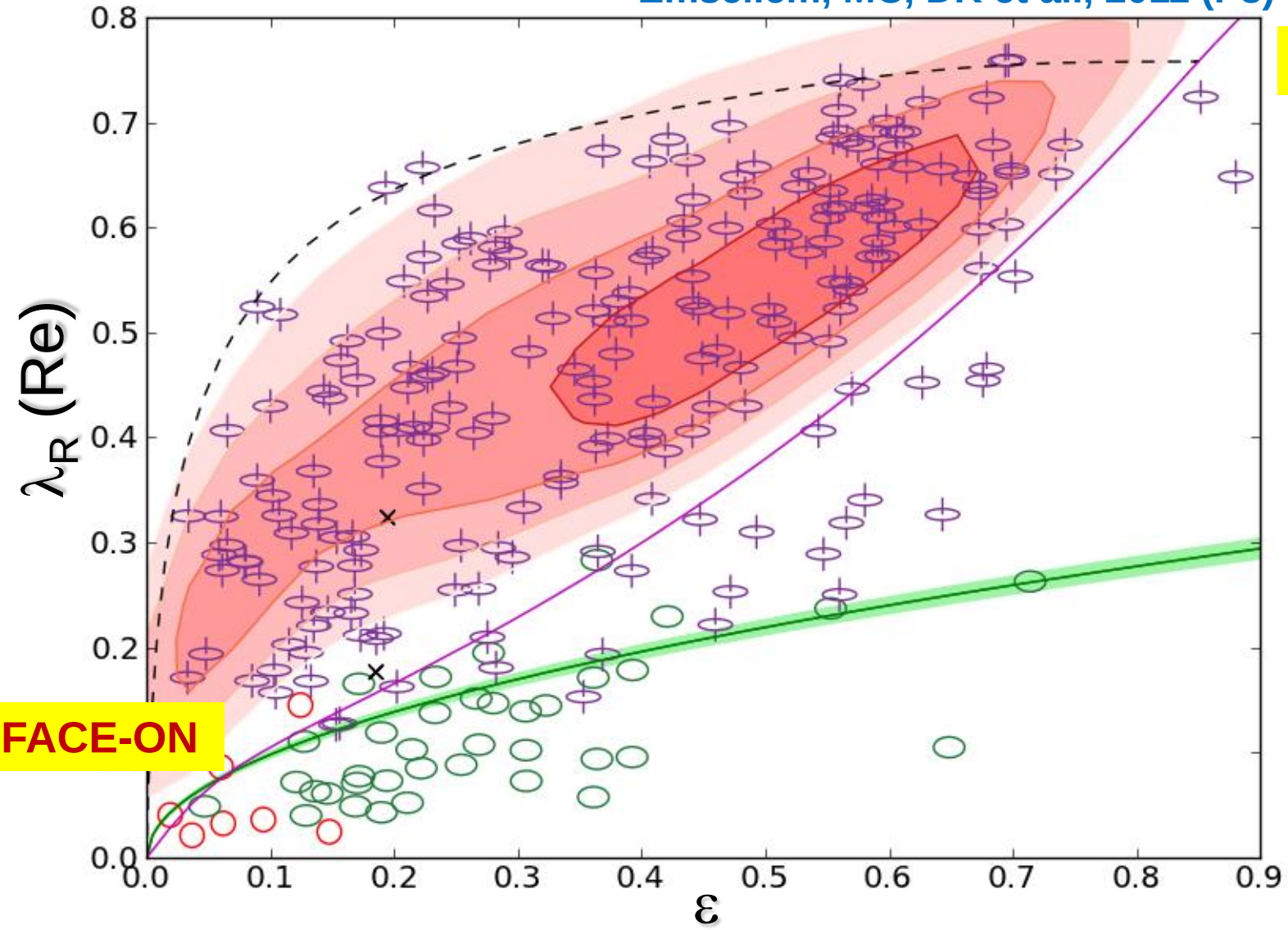
Fast rotators



Emsellem et al., 2007

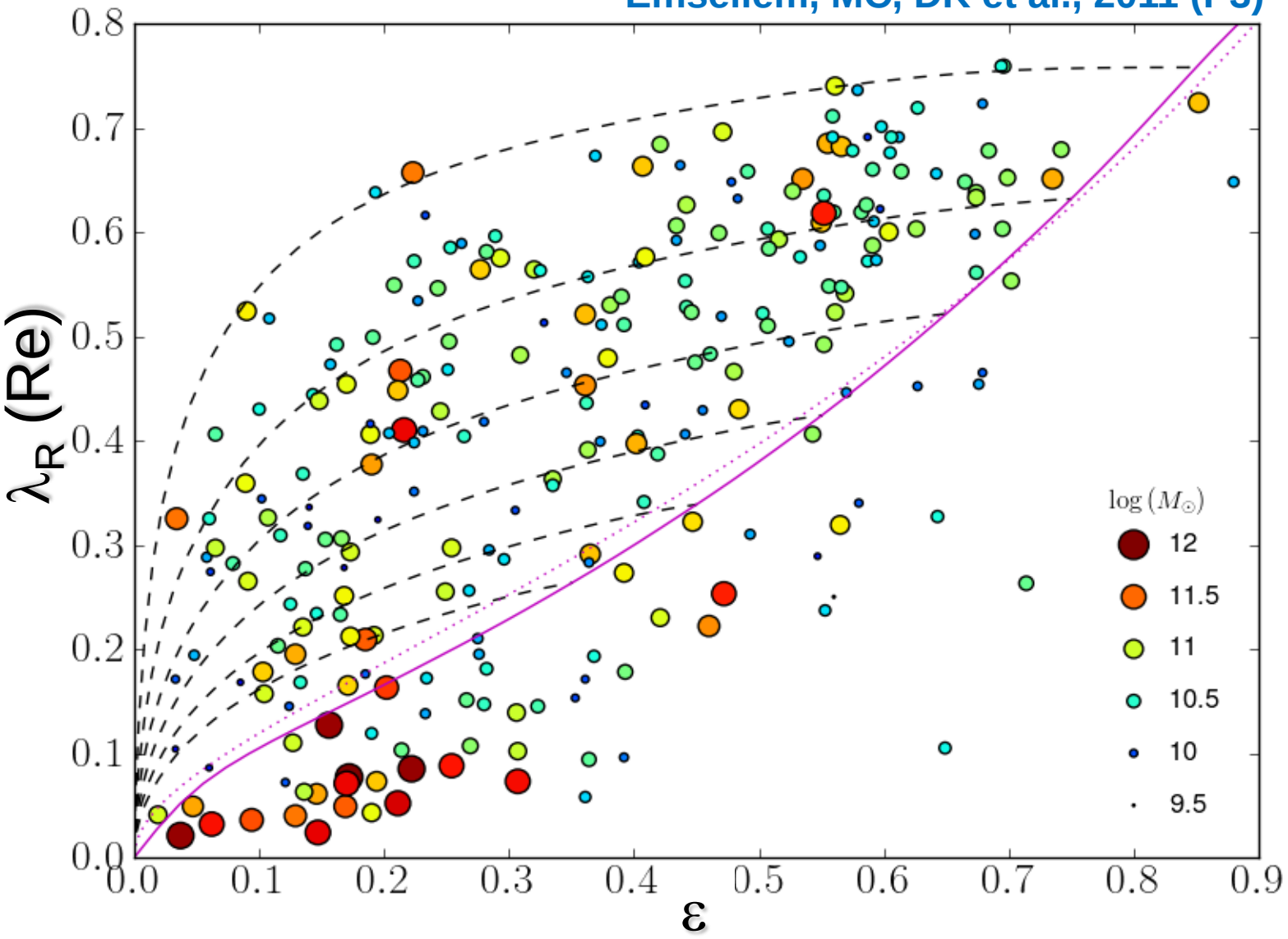
Fast Rotators ➔ Family of oblate rotators

Emsellem, MC, DK et al., 2011 (P3)



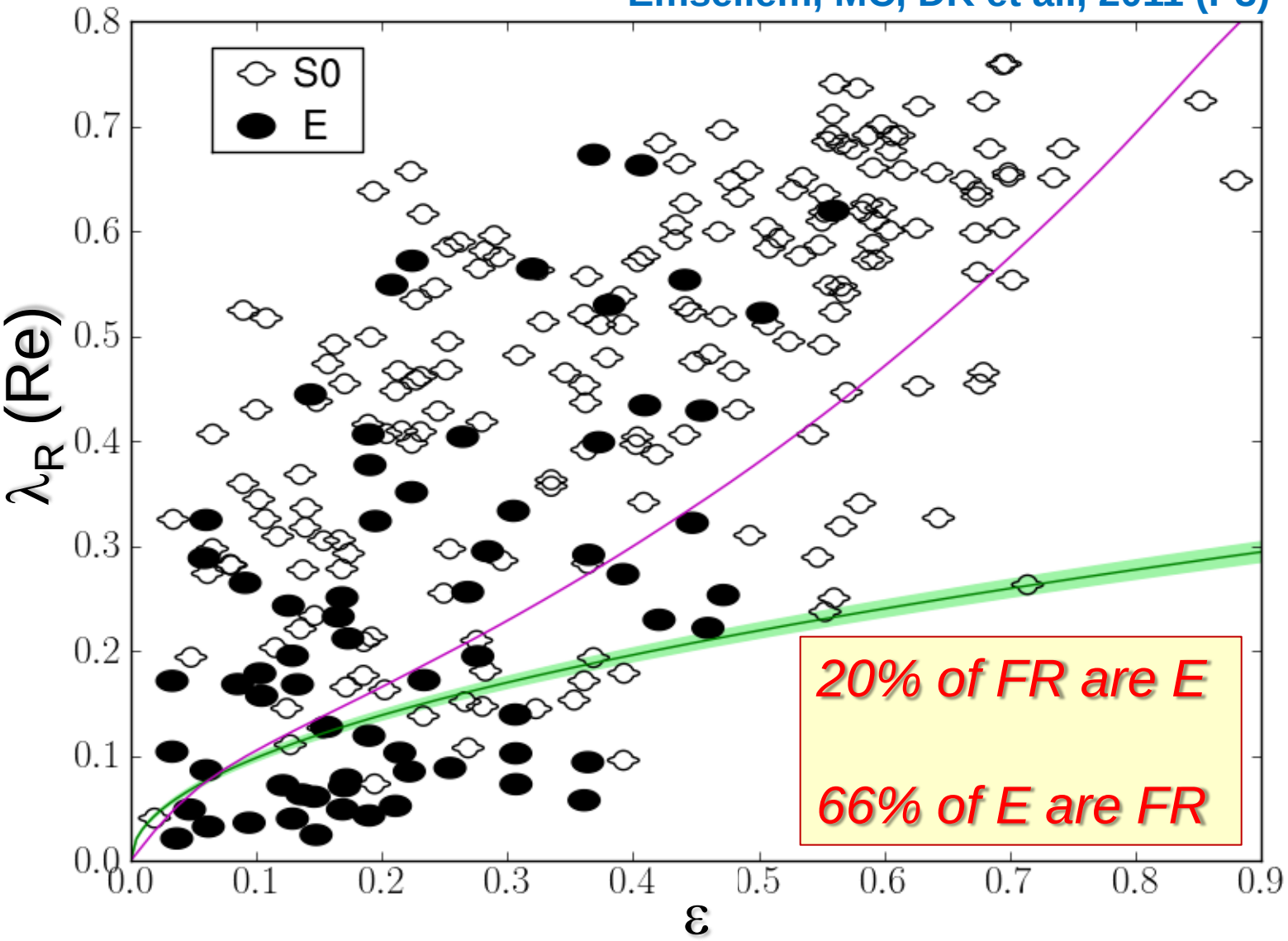
Trend with Mass

Emsellem, MC, DK et al., 2011 (P3)

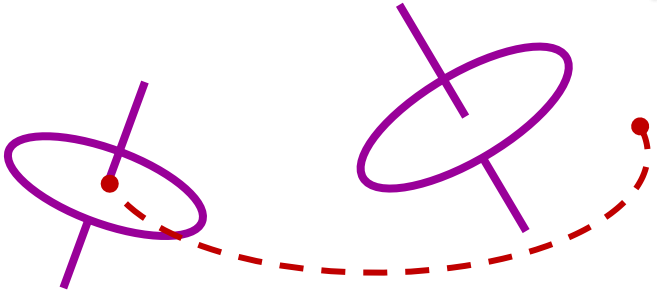


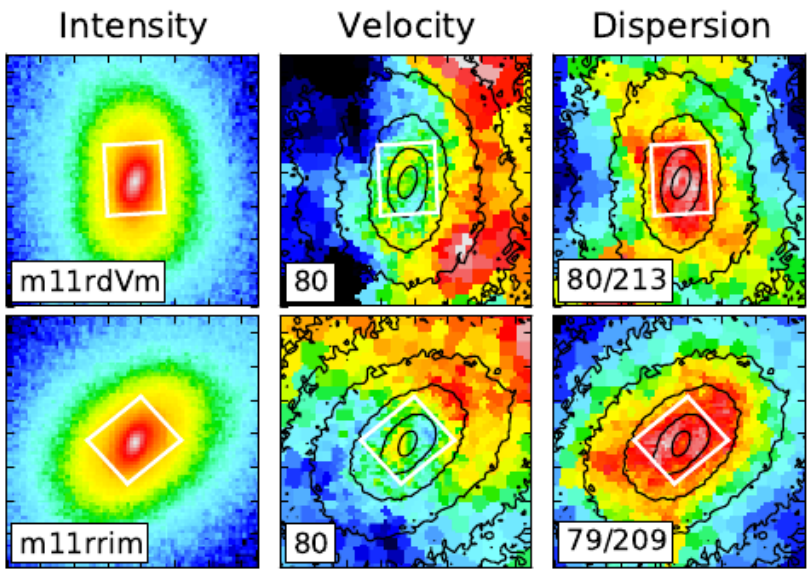
What about E's and SO's ?

Emsellem, MC, DK et al., 2011 (P3)

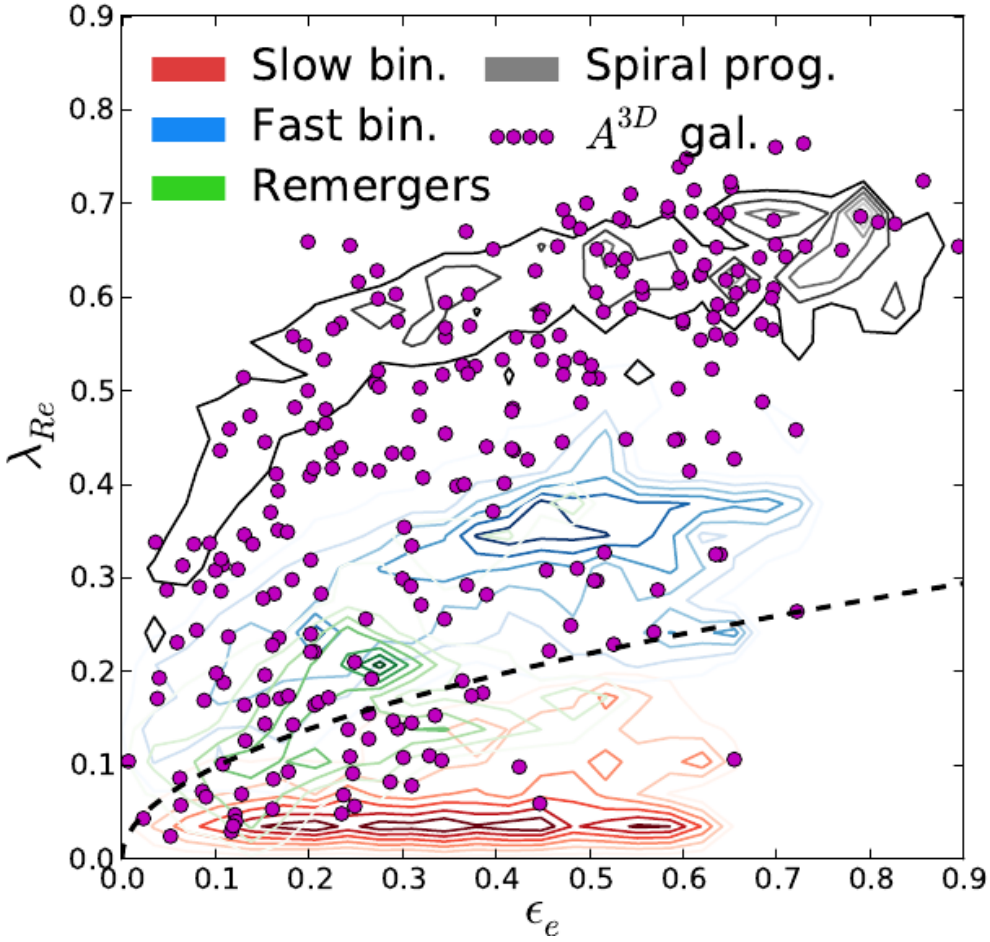


Generic Simulations: Binary mergers





Bois, EE, FB et al. 2011 (P6)

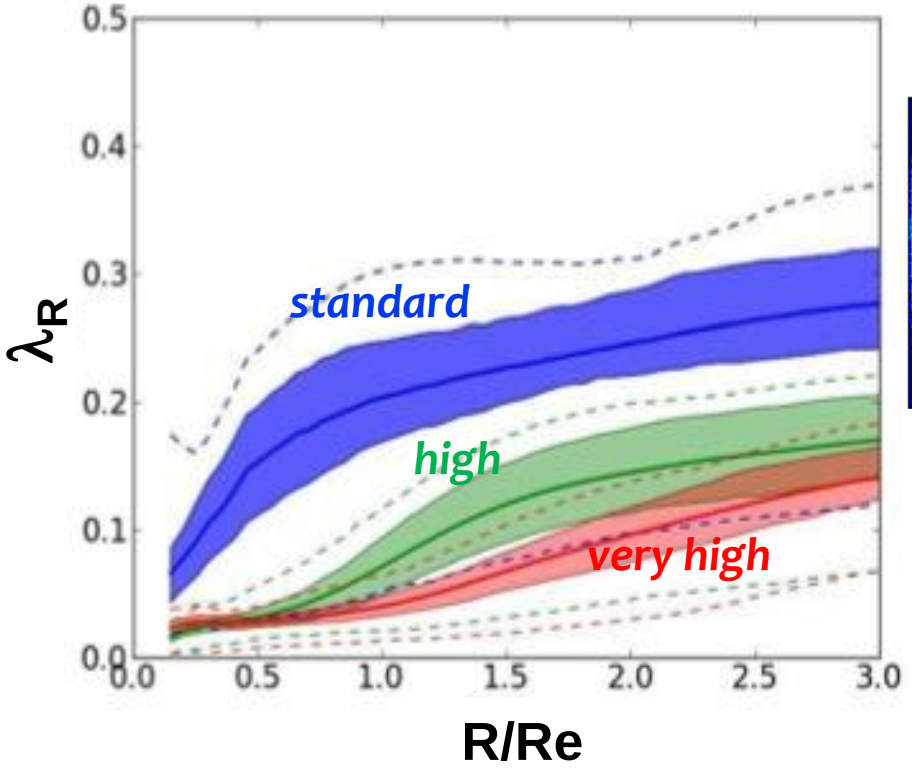


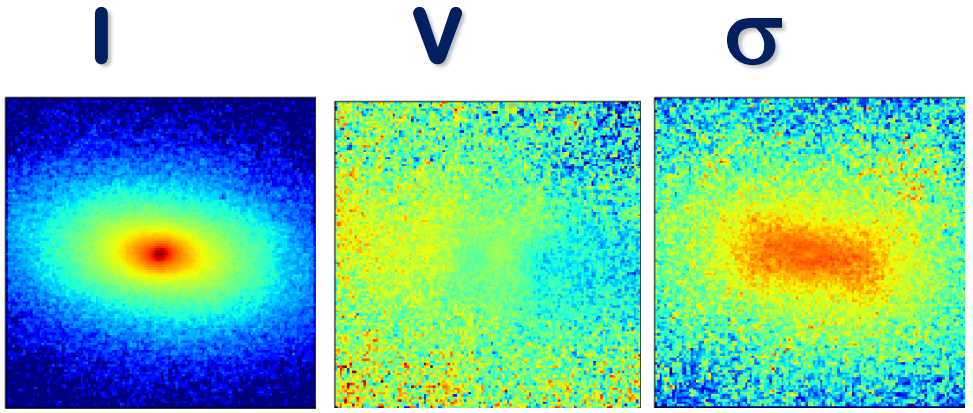
- Fastest ETGs are as spirals (λ_R)
- Most binary mergers ➔ Fast Rotators
- Slow rotators have KDCs, but are **TOO flat**

Generic Simulations

Label	Softening Length	Particles / component	Total particles
standard	180 pc	10^5	6×10^5
high	80 pc	10^6	6×10^6
very high	32 pc	6×10^6	3.6×10^7

Bois et al. 2010



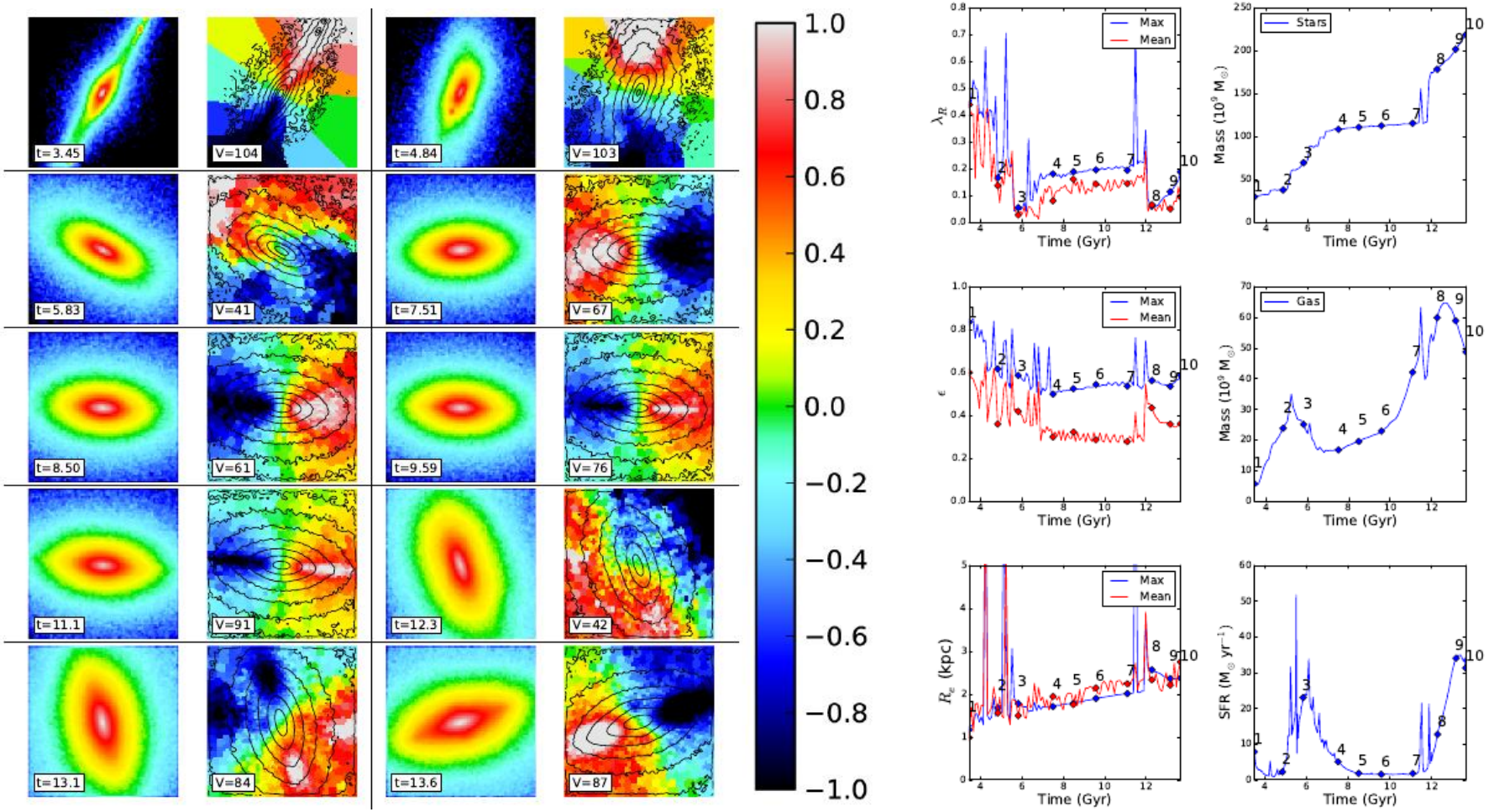


Slow rotators

➔ requires 50-100 pc

Cosmological context : first approach

Martig+Bois et al., in prep



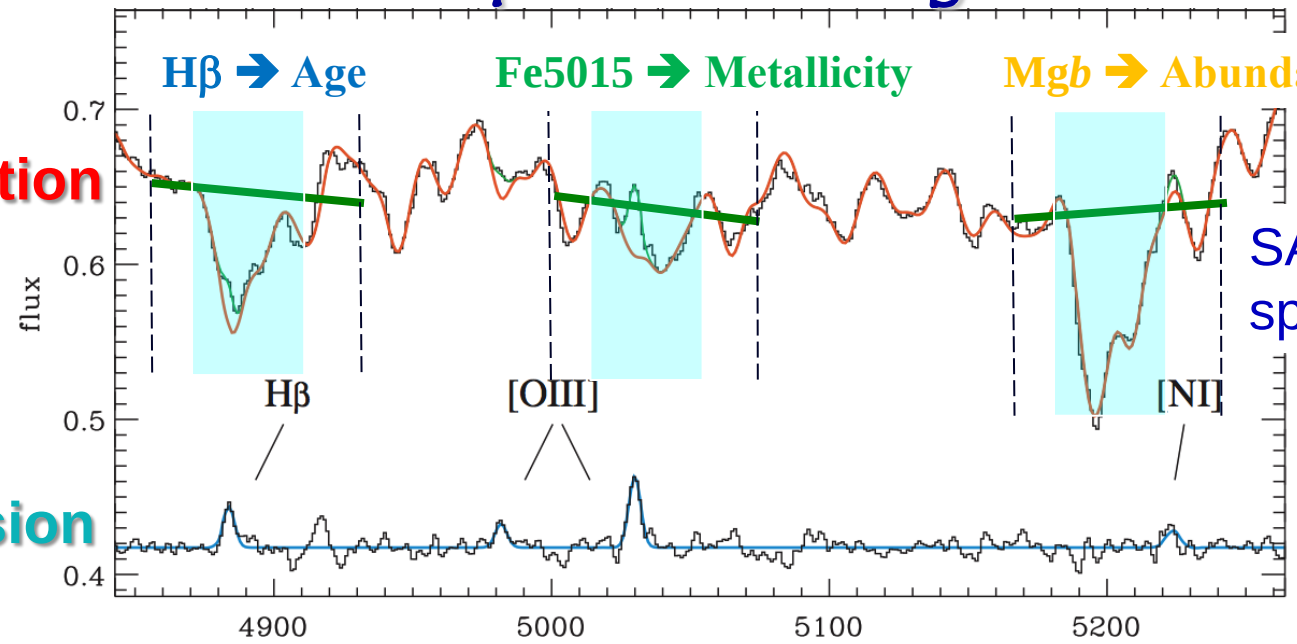
- A first look at the evolution of basic quantities (ϵ, λ_R)

From binary mergers to cosmological context

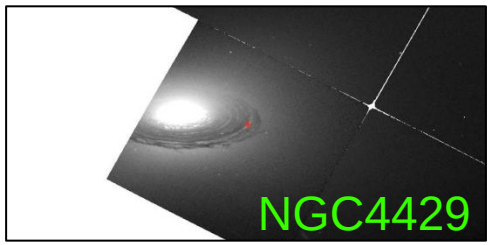
- **Compromise** between resolution and realistic context
  - Cannot handle both at the same time
  - ➔ We need to choose what we wish to study

- What we need now :
  - ~ 50pc cosmological studies with main physics
  - Studies of dedicated samples (e.g., environment, mass)
  - Stellar populations !
  - Intermediate environments: groups (Maxime Bois)
  - Understand the GC population

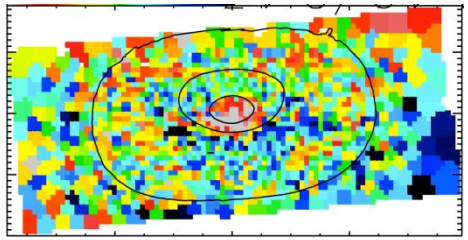
Stellar Population Diagnostics



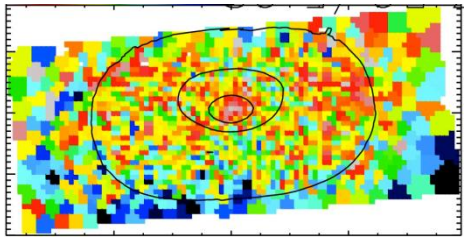
HST F606W



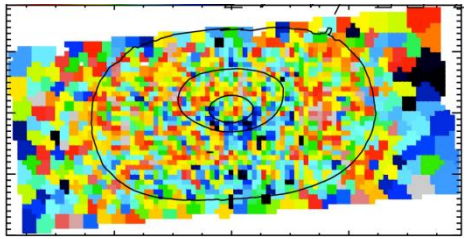
Hβ



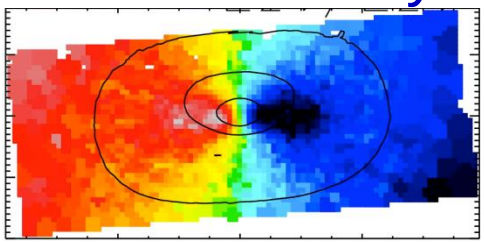
Fe5015



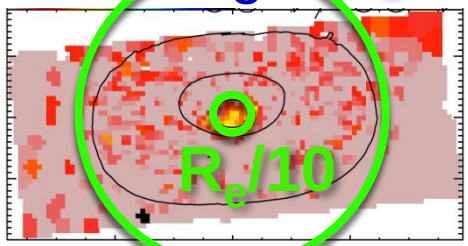
Mg*b*



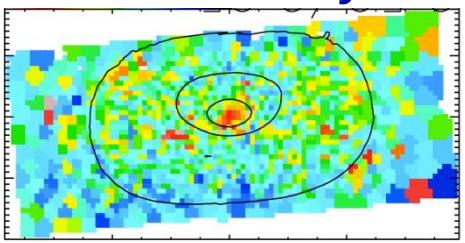
Stellar Velocity



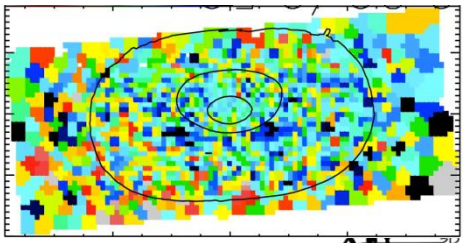
Age



Metallicity

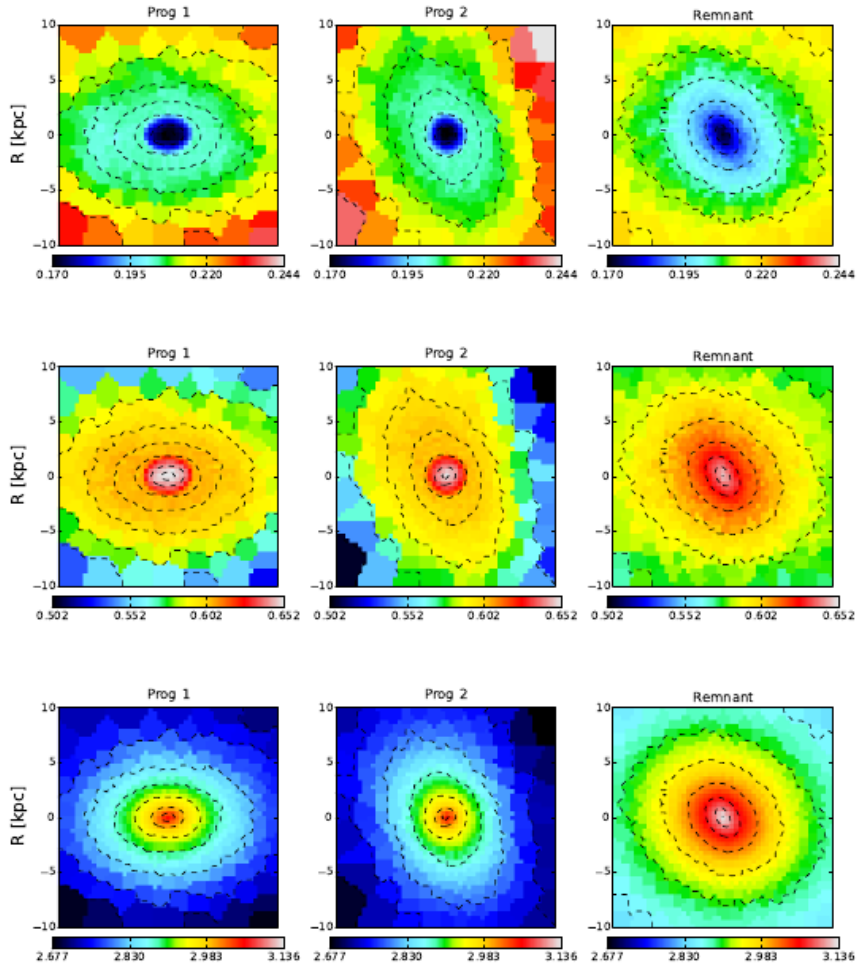


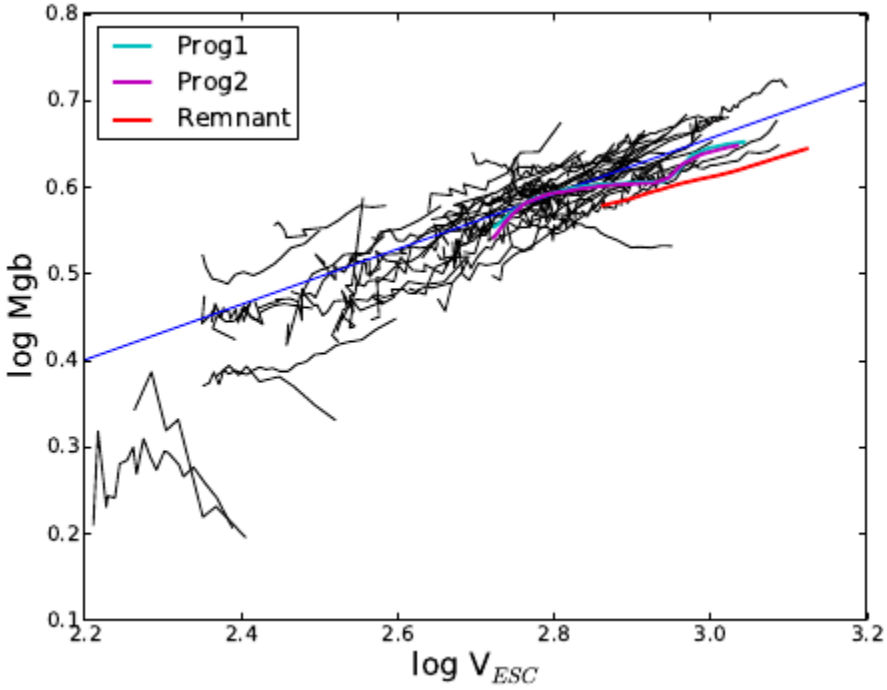
Abundance



Spectral Colouring of Simulations

Bois+Martig et al., in prep





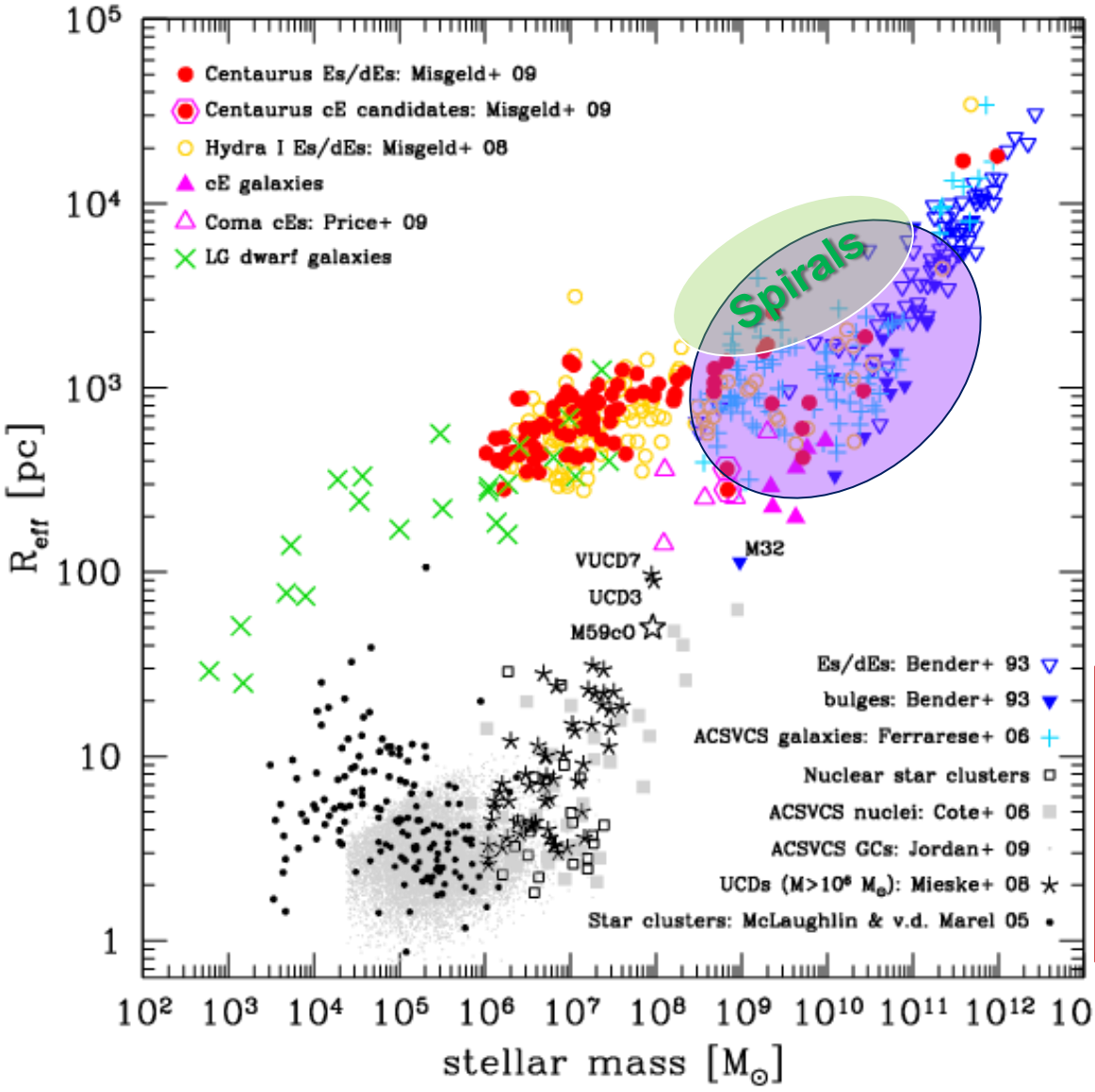
- Correlation between metal enrichment and depth of Φ

From binary mergers to cosmological context

- Can fit spectra (and colours) well
  - Constraint on stellar M/L
  - But “a posteriori” treatment

- What we need now :
  - Understand pAGB, etc
  - Non solar abundances
  - Tools to better constrain the SFH

Intermediate mass ETGs



Misgeld & Hilker 2011

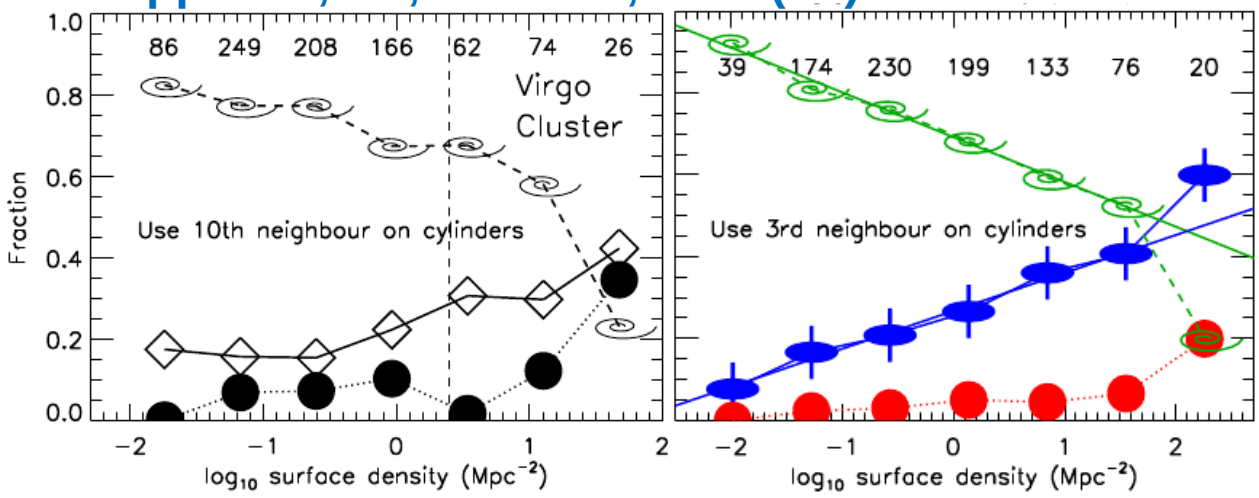
- Zoology
  - Star clusters vs galaxies
  - Small vs Big

Stellar component:

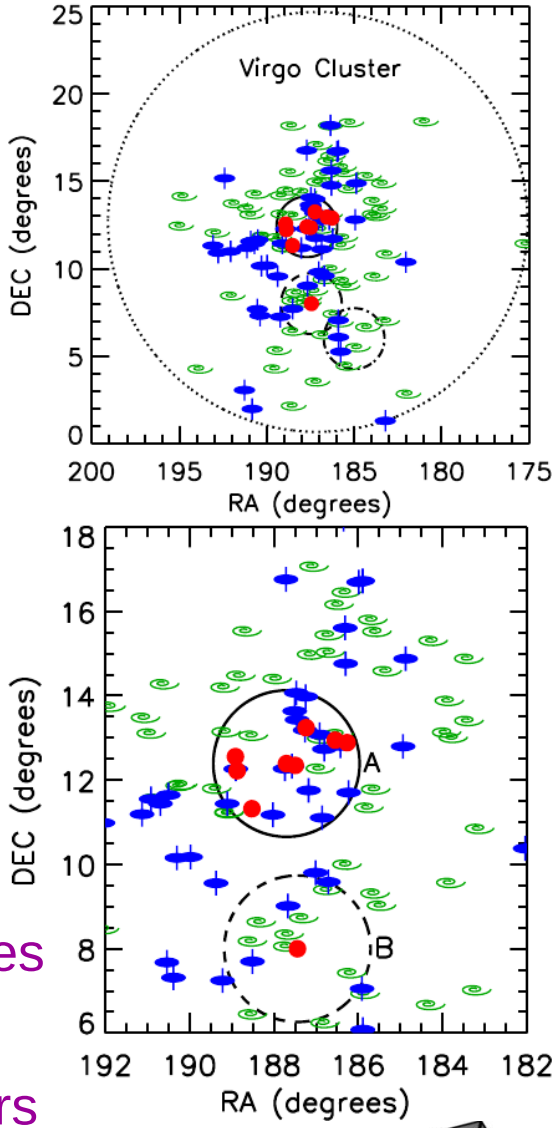
- Formation vs Assembly

Morphology-Density relation

Cappellari, EE, DK et al., 2011 (P7)



FR SR

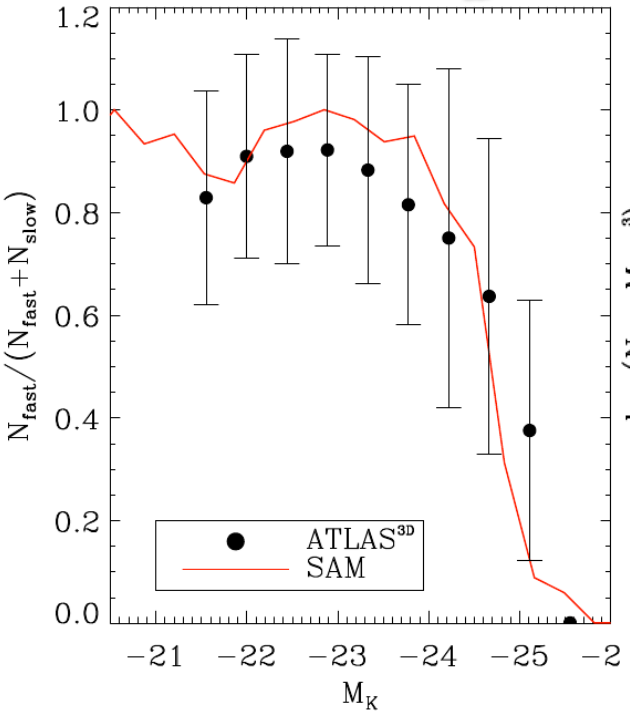


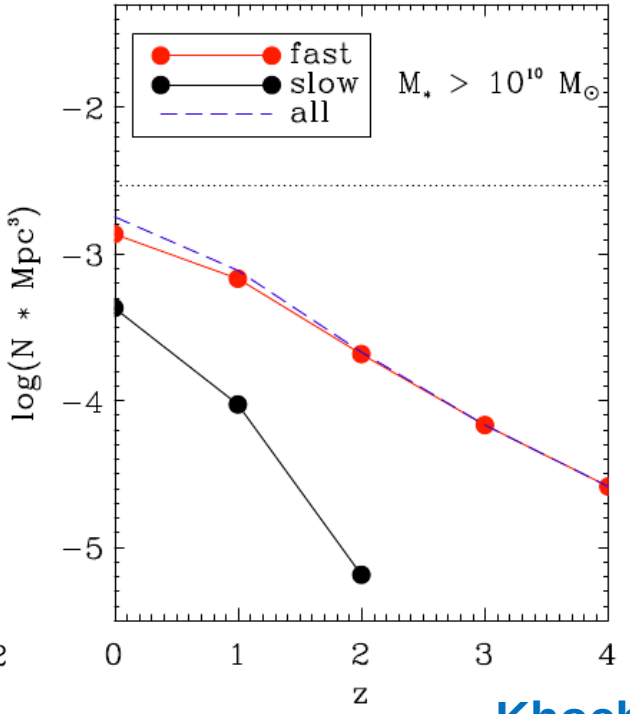
Only 1/3 of systems classified as E's are SR

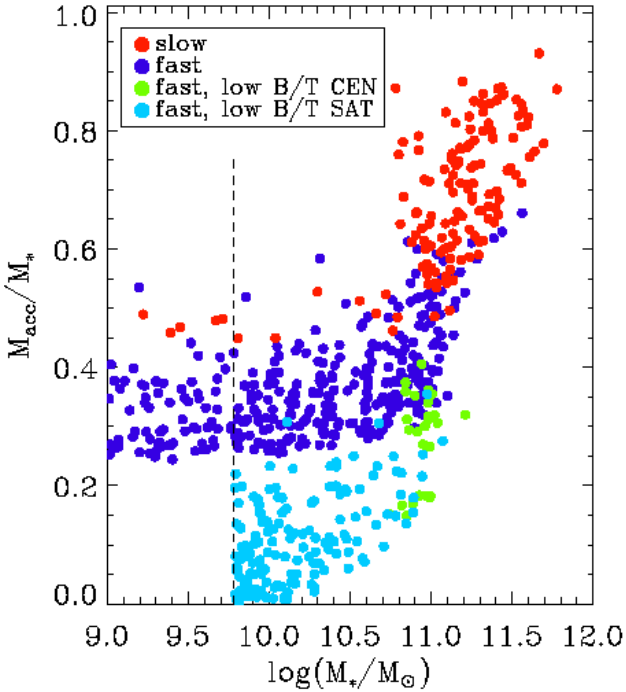
~4% of the parent sample are Slow Rotators

- **Slow rotators** : efficient formation only at high densities
- Monotonic trends from low to high densities
- Excludes cluster processes for the onset of fast rotators
- Processes at the small-groups scale in low density environments

Probing Growth processes via SAM







Khochfar, EE, PS, et al. 2011 (P8)

Growing in size and mass: SF versus Assembly

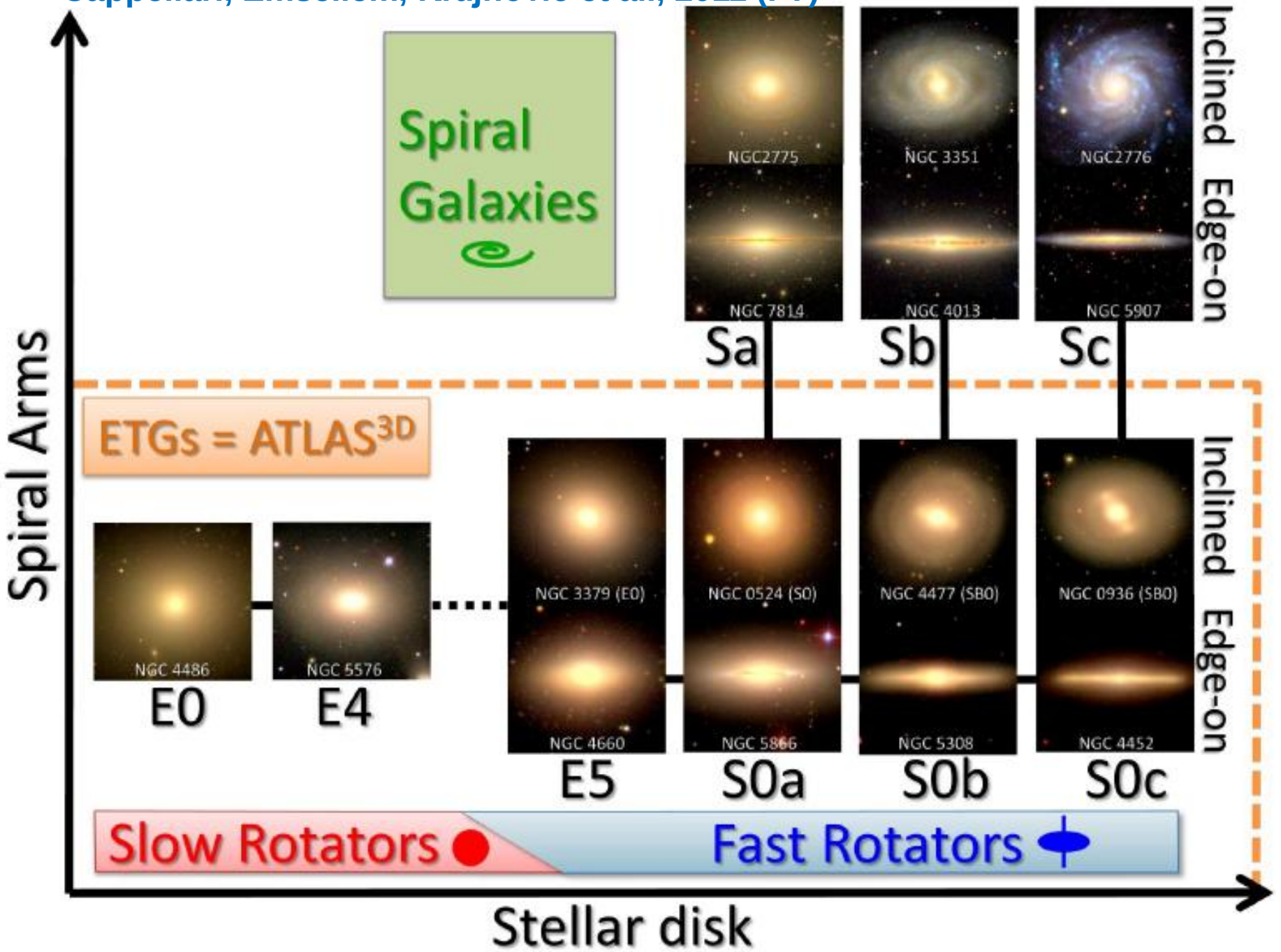
- *Slow rotators*
  - **Accrete more material (50-90%), more major mergers (~3), KDCs**
  - **Very few at z> 2: progenitors should have been fast**
  - **Complete shut-down of gas cooling**
- *Fast rotators:*
  - **2/3 have large B/T, 1/3 have low B/T (e.g., stripped in clusters)**

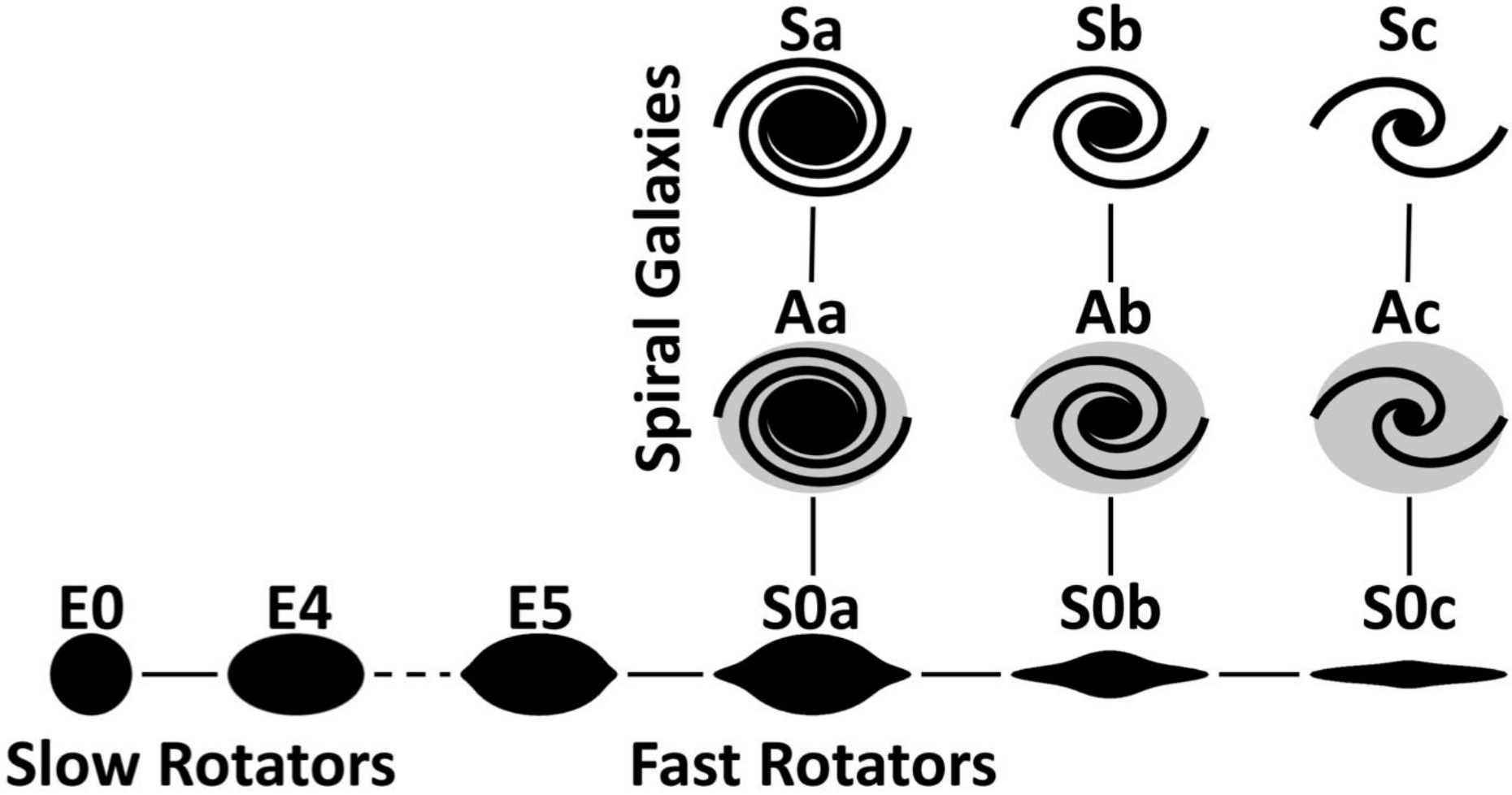
Probing galaxy formation/evolution with SAM

- Global picture is ok
  - Need to check predictions at high redshift (Olivier's talk)
  - Can we observe the progenitors without any bias?

- What we need now :
  - How to classify galaxies properly at high z ?
    - ➔ there is hope!
  - Get good predictions from SAM for colours, **sizes**
  - Link with metal enrichment, gradients

Cappellari, Emsellem, Krajnović et al., 2011 (P7)





Cappellari, Emsellem, Krajnović et al., 2011 (P7)

A few Results

- ***E/S0 separation should be abandoned***:
  - results based on this separation ➔ consider with scepticism

- **Continuity from spirals** to fastest rotators
  - ***> 86% of ETGs are disk-like***
  - ***➔ Only 4% (9% in mass) of local galaxies are "ellipticals"***

- **Environment & local (groups) effects are important**
  - Slow rotators in cores of clusters/groups
  - Mass dependent growth process: SF vs Assembly

Perspectives

- **Compromise between spatial/mass resolution**
- **Implement the main physics ingredients**

  - Things should improve continuously
    - but **need to be able to handle the data** then ➔ specific questions
  - Need to understand the role of each process properly
    - Timescales : a few Gyr at least
  - Stellar populations including non-solar abundances
    - IMF, stellar enrichment, etc

PyMGE

A Python tool for ICs of isolated galaxies

- **Hypothesis: oblate - axisymmetric**
  - All components described by (local) 6D Gaussians
    - Can include Gas, Dark Matter and Stars
    - **Any geometry** for the dispersion tensor
- (non-optimised) code ➔ 20' for ~5 Million particles
- Largest IC so far: 300 Million particles (Milky Way like)
  - Thin disc, Thick disk, bulge, spheroid, dark matter halo, gas disc (Besançon Model) ➔ 1.5 day on 5 CPUs