Integral-field view of early-type galaxies (ETGs)

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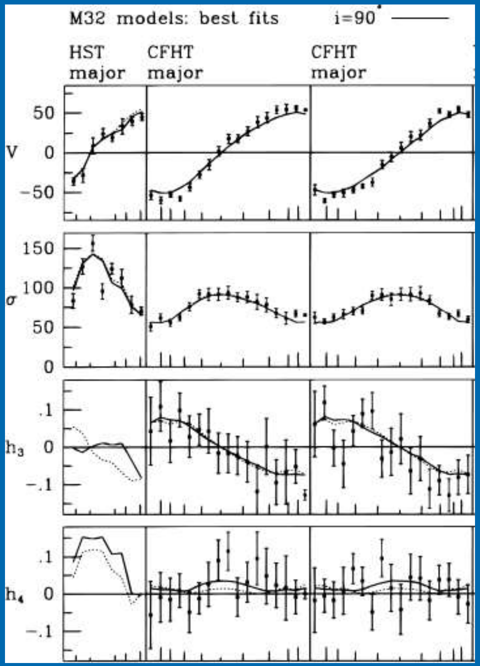
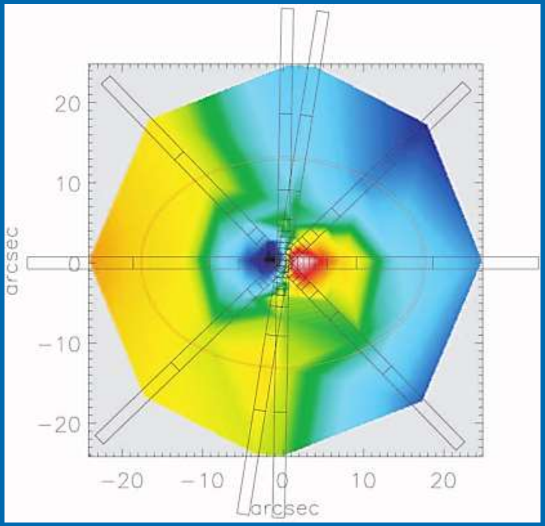
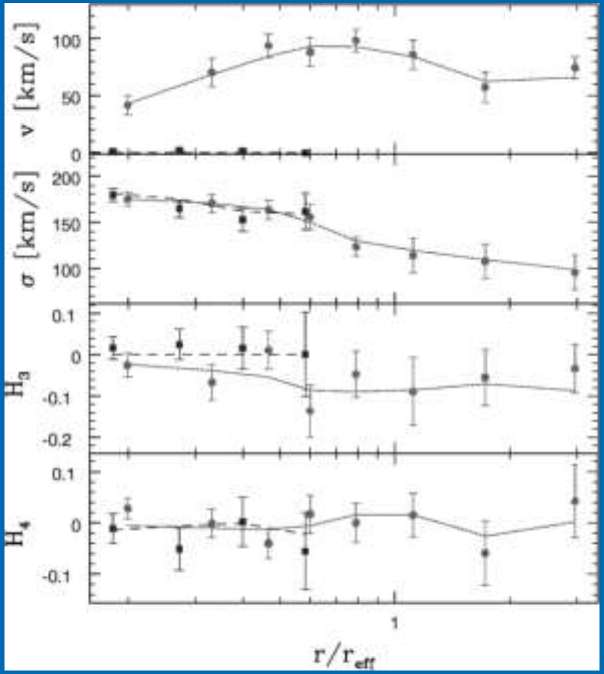
ETGs stellar kinematics in 2000



(van der Marel+98)



(Cappellari+02)



(Thomas+05)

- Most studies based on major-axis kinematics
- Multiple-PA was state-of-the-art

The power of integral-field data

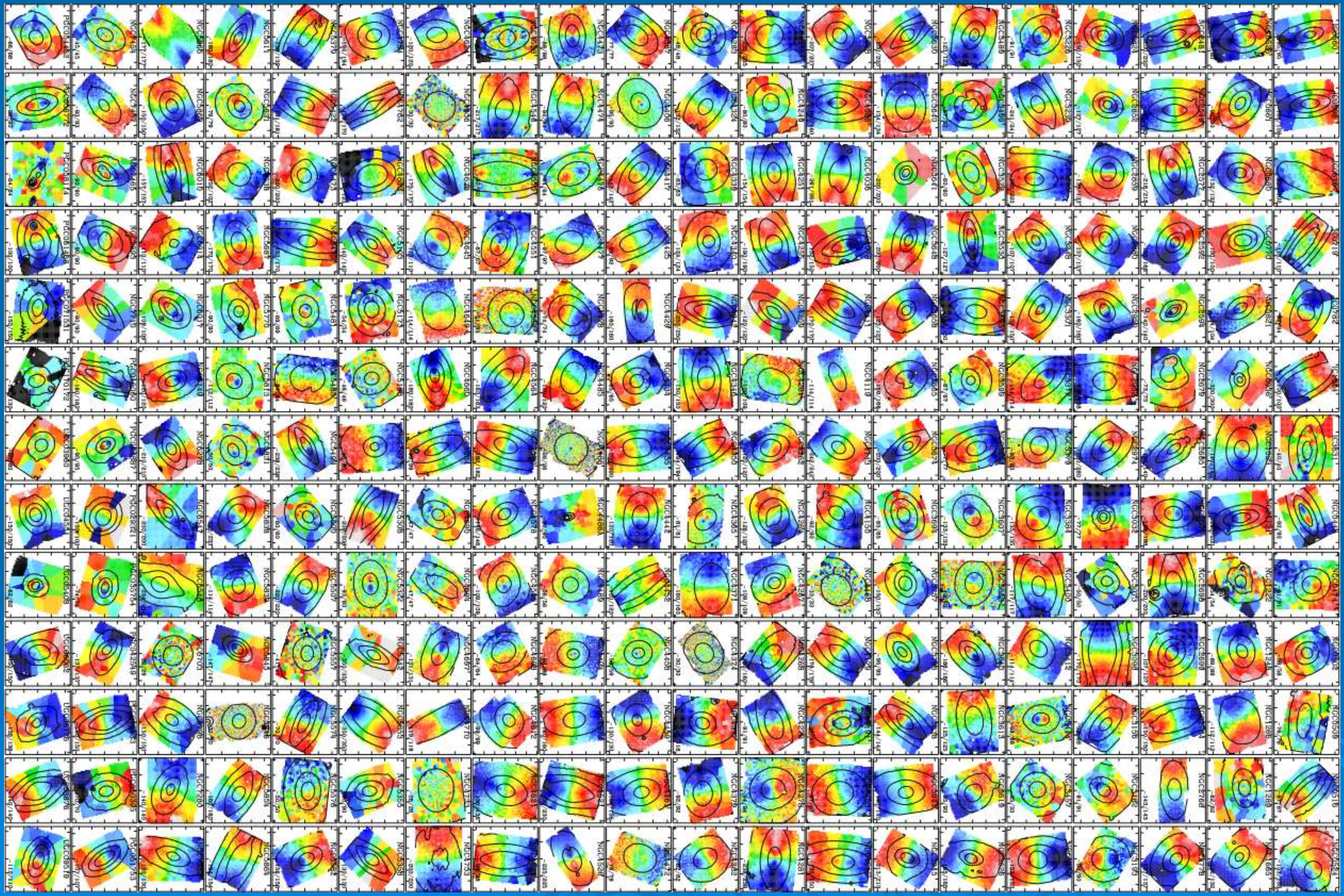
(Kinematic maps from Emsellem+04 and Krajnovic+11=P2)

NGC3379 (E1) NGC5631 (S0) NGC4374 (E1)

- Genuine ellipticals → spheroids from all directions
- Lenticulars → look elliptical close to face-on
- Kinematics provide basis for new classification

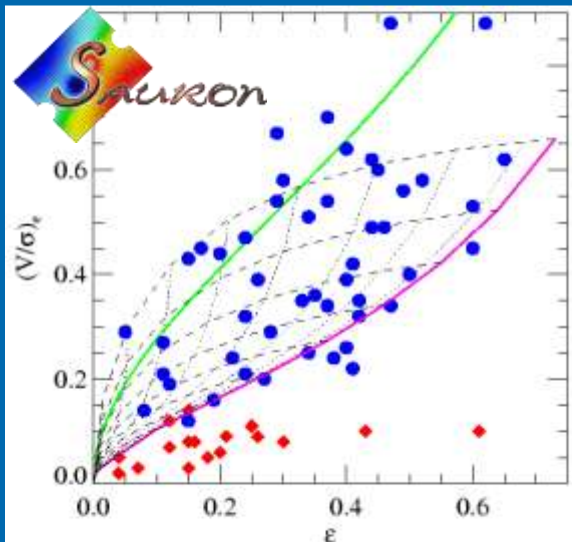
  (Emsellem+07; Cappellari+07; → updated in Emsellem+11=P3)

Stellar kinematics of 260 ETGs



(Krajnovic+11=P2)

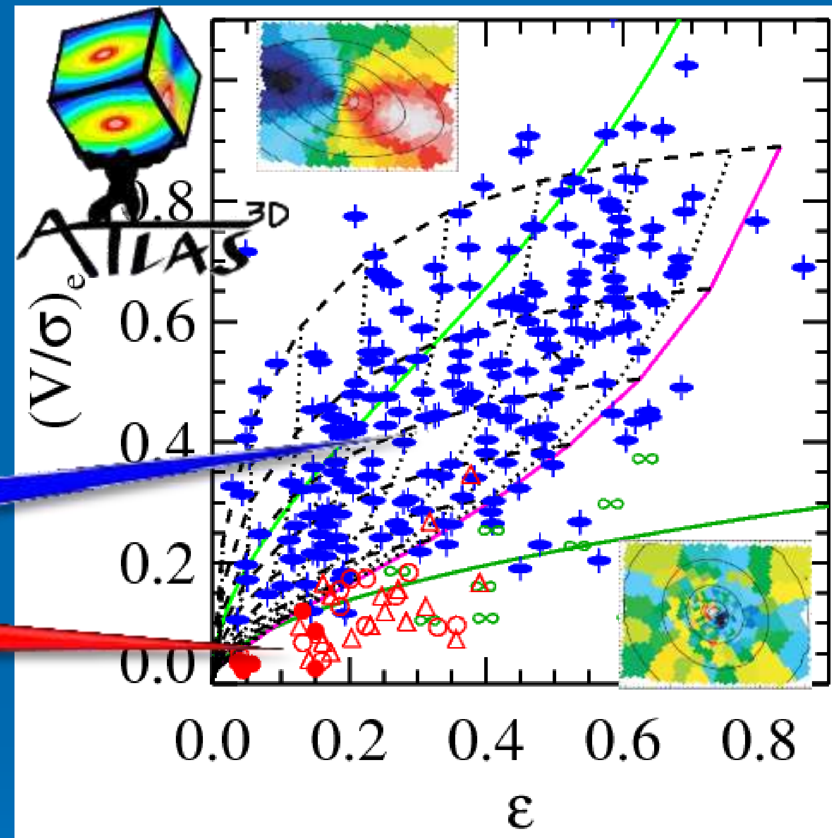
ETGs dominated by inclined disks



(Cappellari+07)

Fast

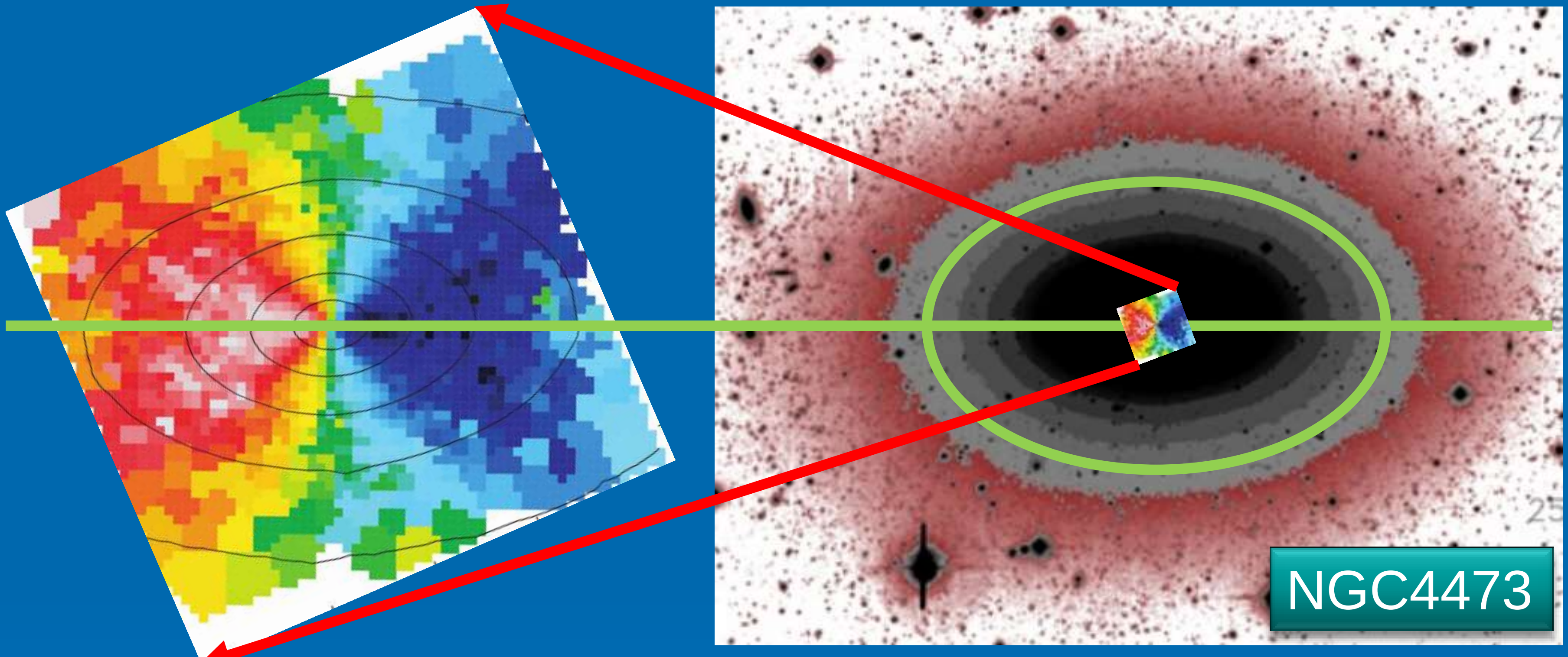
Slow



(Emsellem+11=P3)

- ATLAS^{3D} volume-limited sample (Cappellari+11=P1)
- 90% are fast rotators (Emsellem+11=P3)
- Consistent with randomly oriented galaxies with disks

Measuring kinematical misalignment

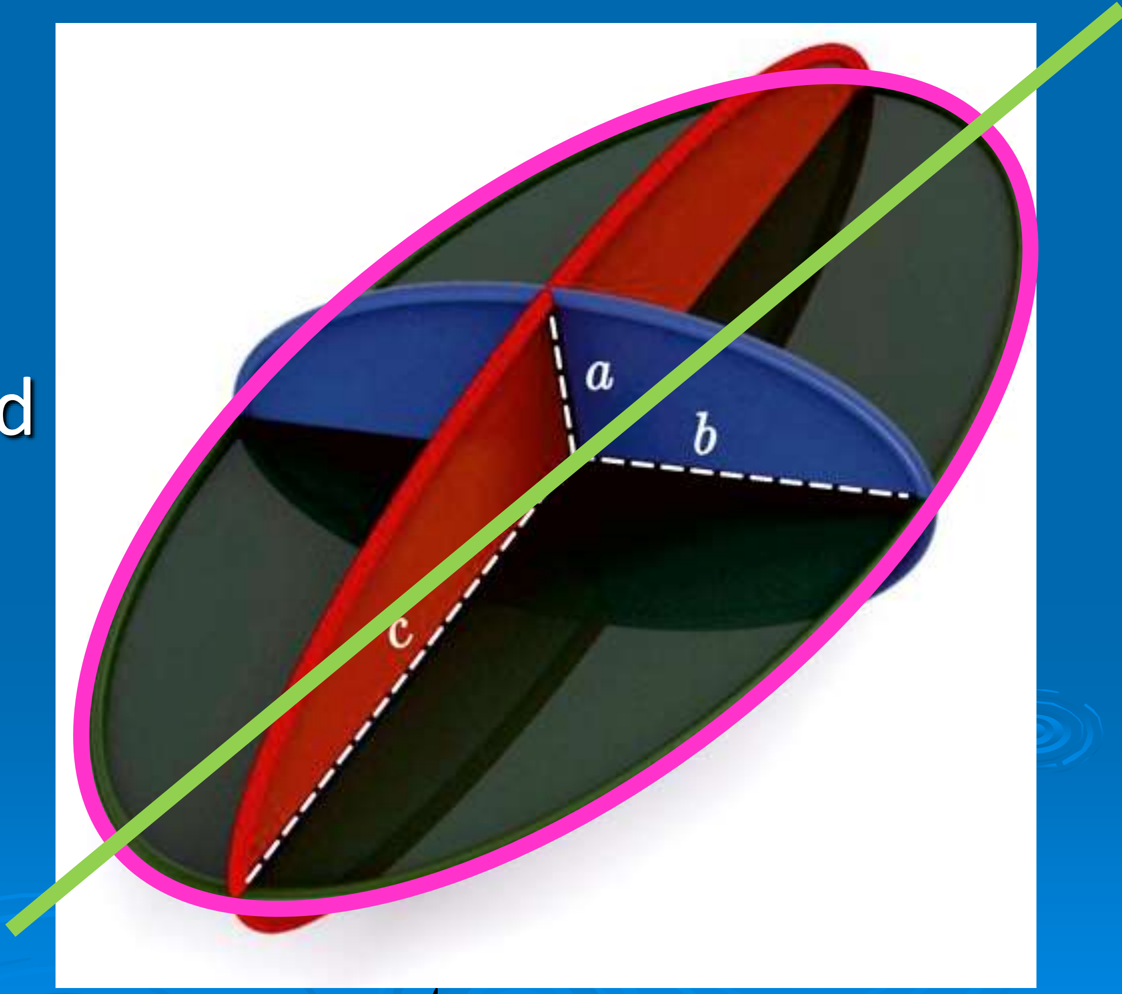


SAURON stellar velocity MegaCAM image (Duc+)

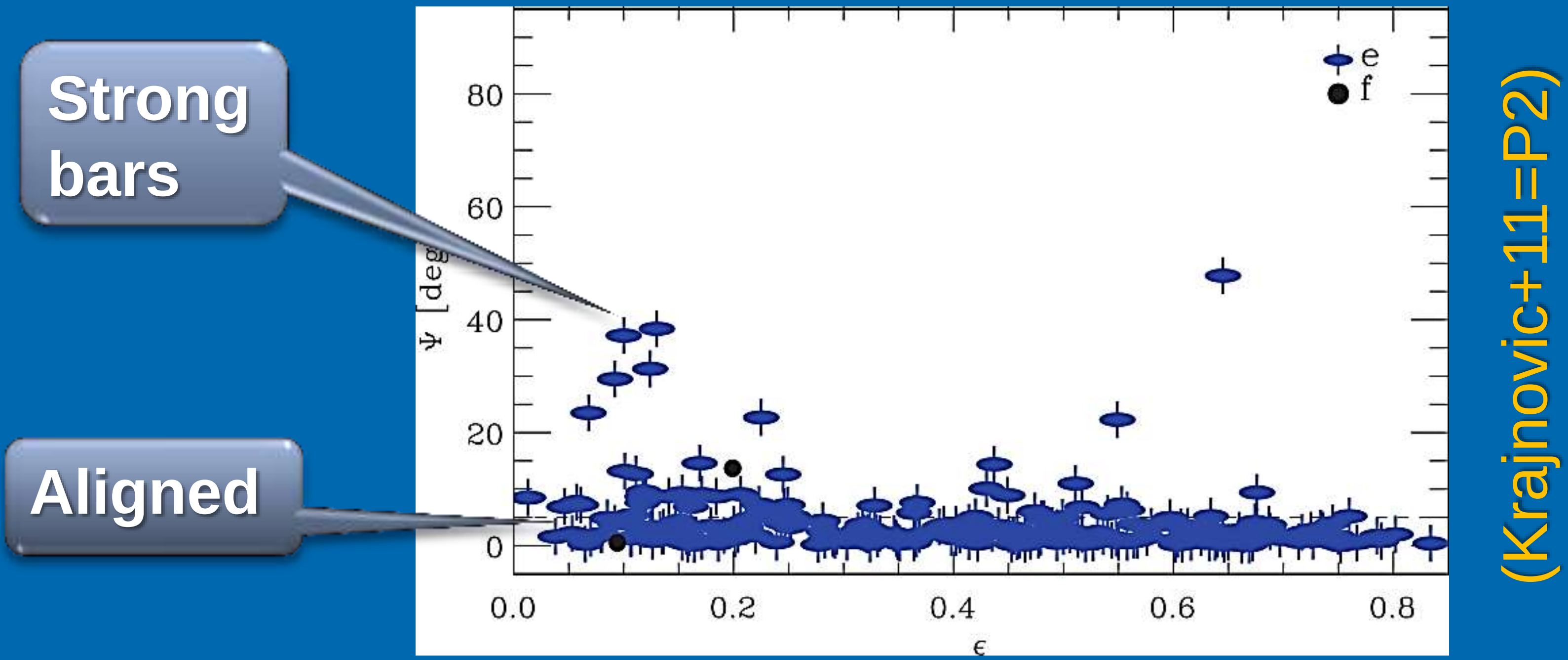
- $\mathrm{PA_{kin}}(1R_e) \approx \mathrm{PA_{phot}}(3R_e)$ (Krajnovic+11=P2)
- Kinematics aligned with outer stellar halo
- Stellar halos consistent with axisymmetry

Triaxial kinematic misalignment

- In triaxial stellar halos
- Little relation between projected and intrinsic axes
- Misalignment <u>widespread</u>

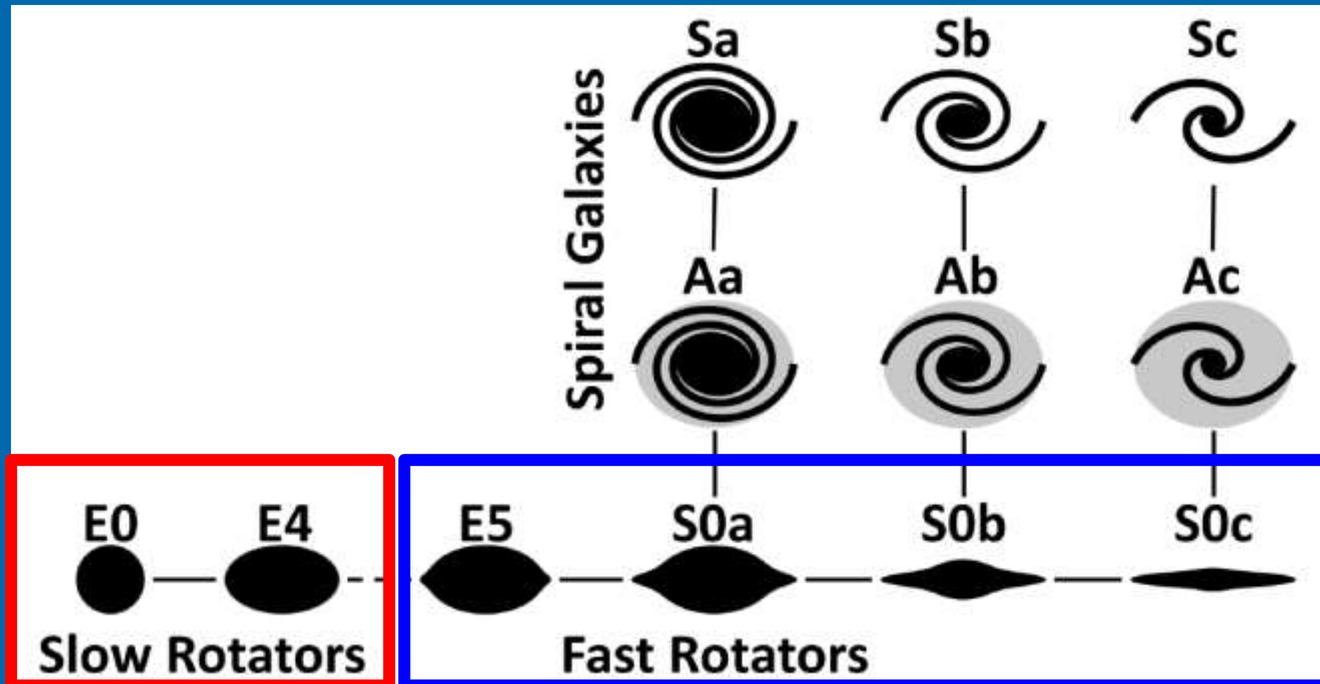


Fast rotators are axisymmetric



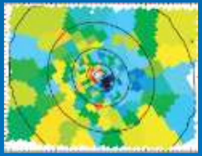
- 90% of all fast rotators aligned within ≈ 5°
- Only exceptions are bars and interactions
- Non-axisymmetric shape strongly excluded
- Out to the stellar halo $\sim 3R_e$

What are fast/slow rotators?



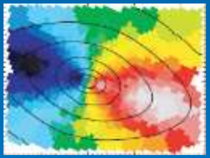
(Cappellari+11b=P7)

Slow rotators



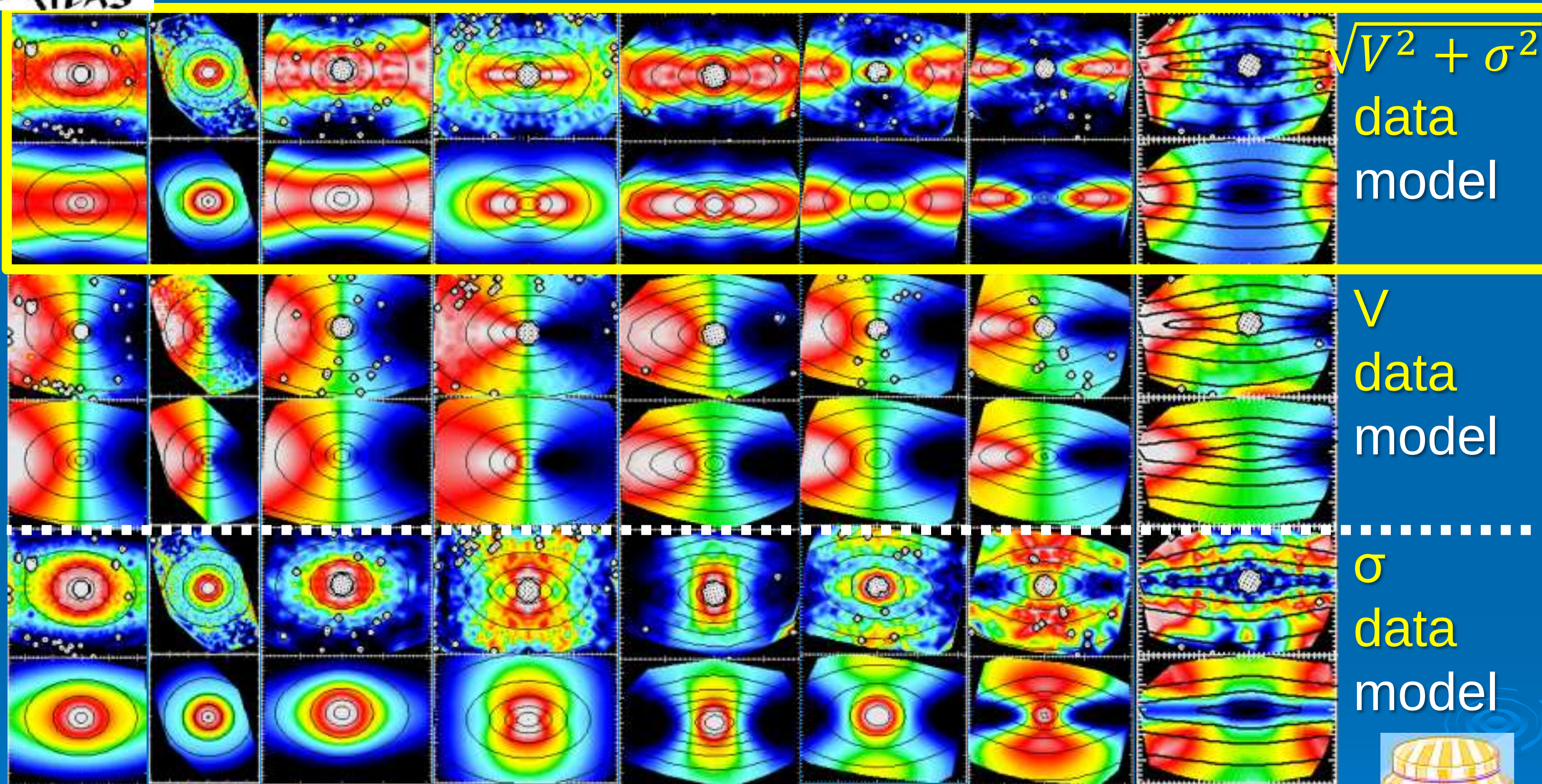
- Weakly triaxial
- NO disks
- Elliptical isophotes <u>from any direction</u>

Fast rotators



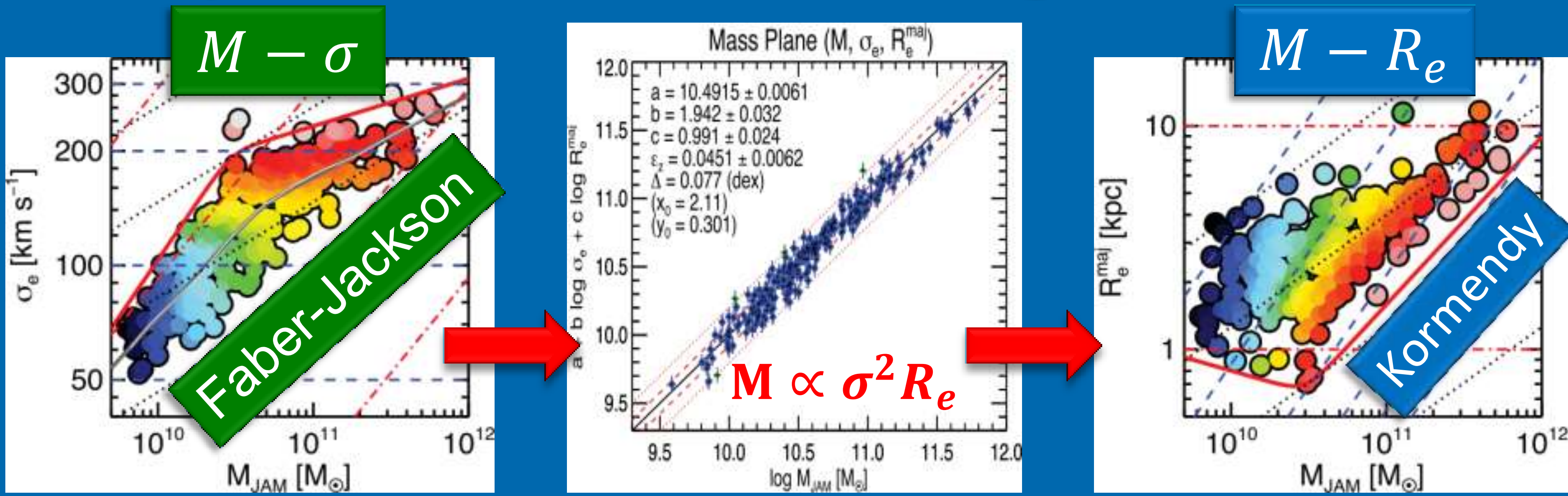
- Axisymmetric
- With stellar disks
- Classified disky-E or S0 <u>when seen edge-on</u>

Accurate galaxy M/L



- Kinematics shape well 'predicted' by JAM (i, σ_z/σ_R)
- Parameters recovered from simulations (Lablanche+12=P12)
- JAM → tool to measure dynamical quantities

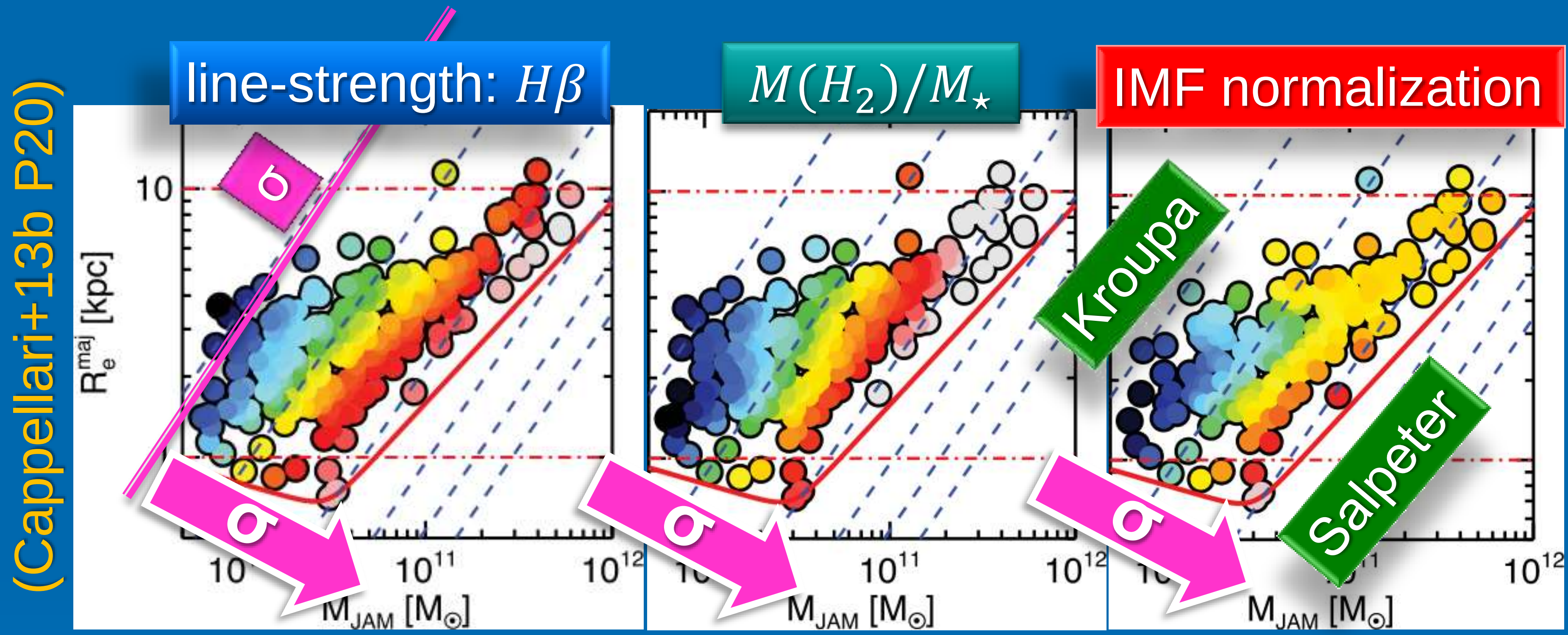
Dynamical-mass scaling relations



(Cappellari+13b=P20) (Cappellari+13a=P15)

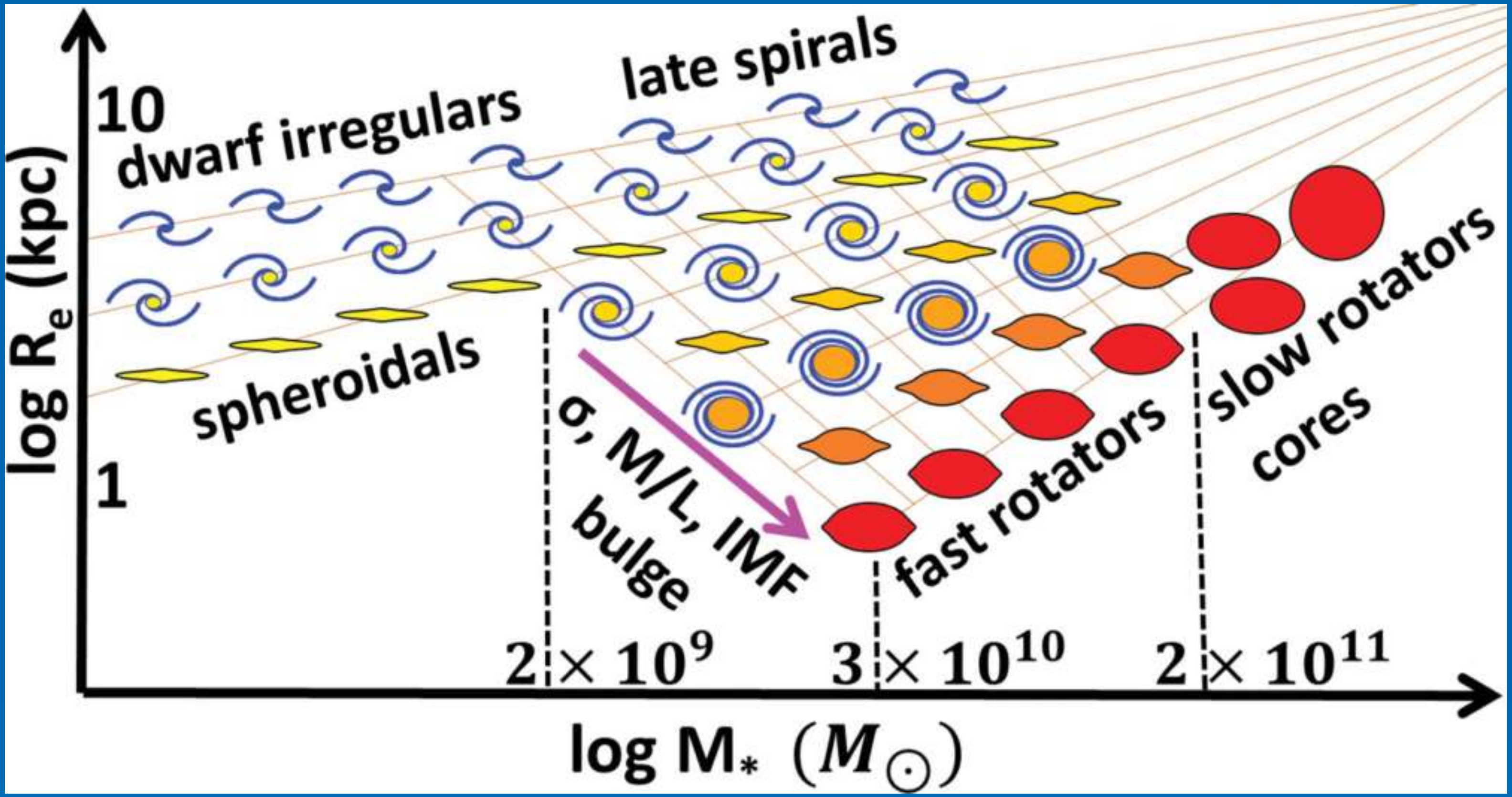
- Replace L→M in Faber-Jackson and Kormendy rel.
- Both projection provide the same information
- Linked by virial equation $M \propto \sigma^2 R_e$
  (see Cappellari+06; Bolton+08; Auger+10)
- But details of measuring σ, R_e are critical!

Popul., molec. gas & IMF follow σ



- ATLAS^{3D} (Cappellari+11=P1) complete ETGs sample with (i) photometry (ii) population, (iii) IFU kinematics, (iv) CO and (v) HI gas
- Population (Age, Z, α), molecular gas fraction and IMF trace σ

Properties driven by bulge fraction

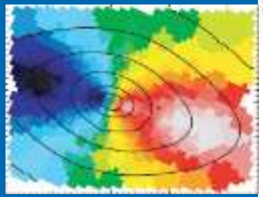


(Cappellari+13b=P20)

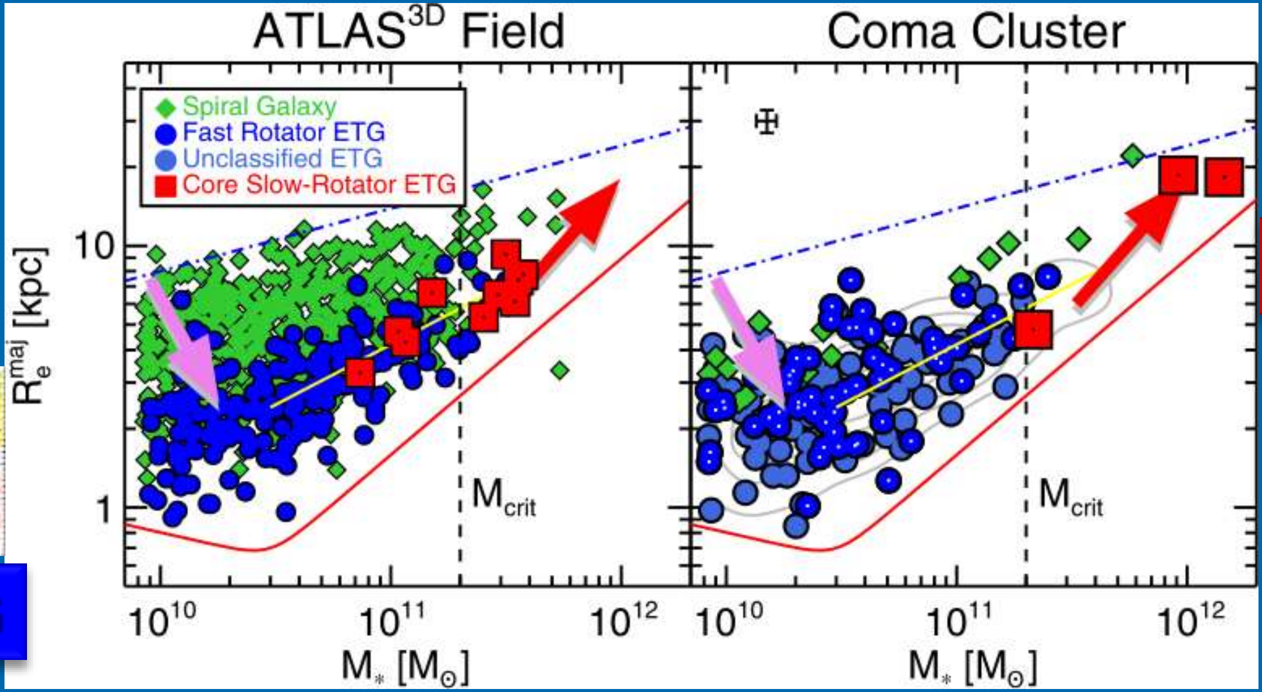
- Bulge linked to quenching for $M_* \lesssim 2 \times \ 10^{11} M_\odot$
  (also Cappellari-11; Bell+12; Saintonge+12; Cheung+12; Fang+13)
- Three characteristic galaxy stellar masses
  (cfr. Faber+97; Kauffmann+03; van der Wel+09; Bernardi+11; Geha+12)

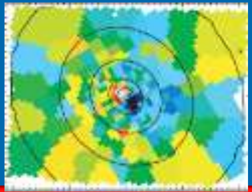
From outside-in to inside-out evolution

spiral



fast ETG





slow ETG

Coma dark halo:
$M \approx 1.4 \times 10^{15}\ M_\odot$
(Lokas+Mamon03)

$\Delta \log \Sigma_3 \sim 3$
increase in number density

(Cappellari-13 ApJL) (Coma IFU kinematics: Houghton+13)

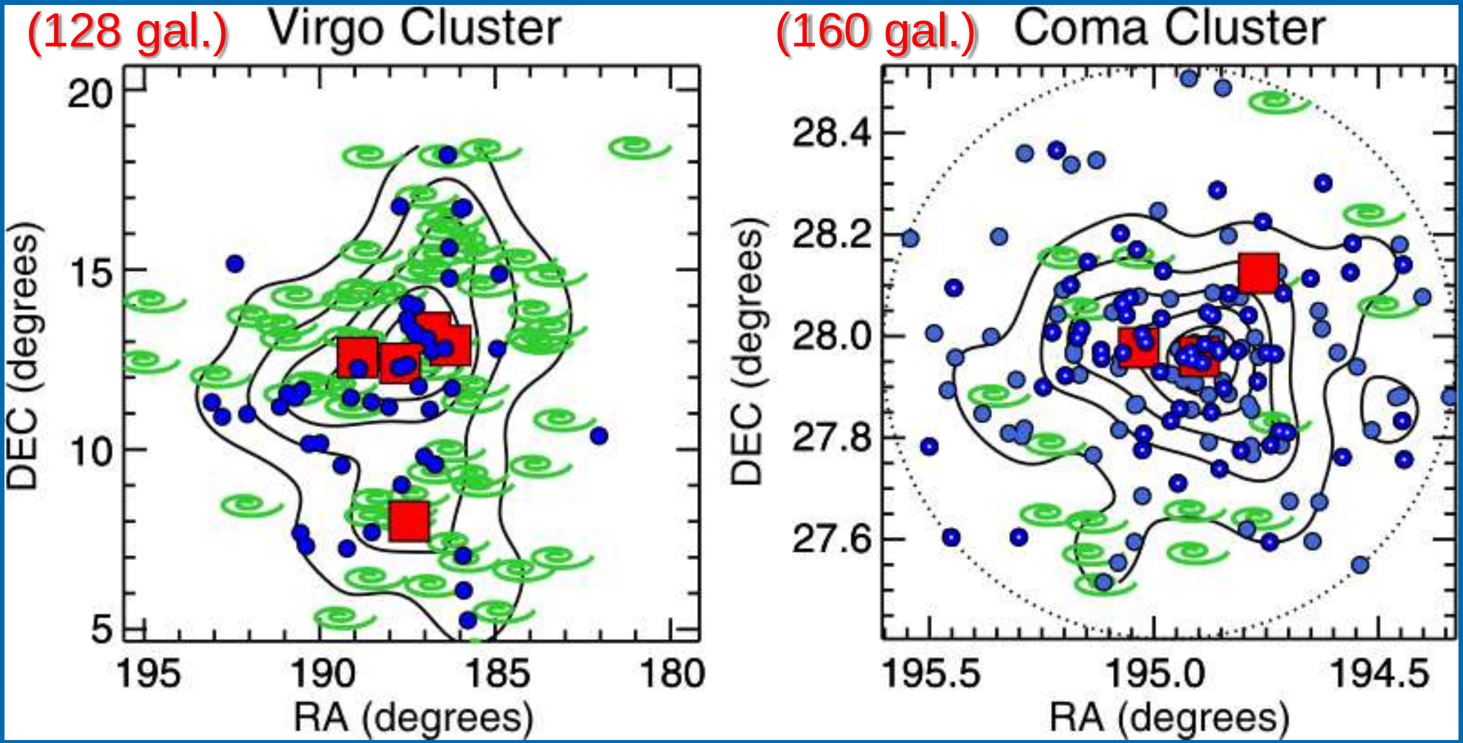
Spirals → Fast rotators

- NO mass change
- Environment quenching
- Bulge quenching
- outside-in evolution

Core slow rotators →

- Mass growth $M \propto R_e$
- Halo quenching
- Inside-out evolution

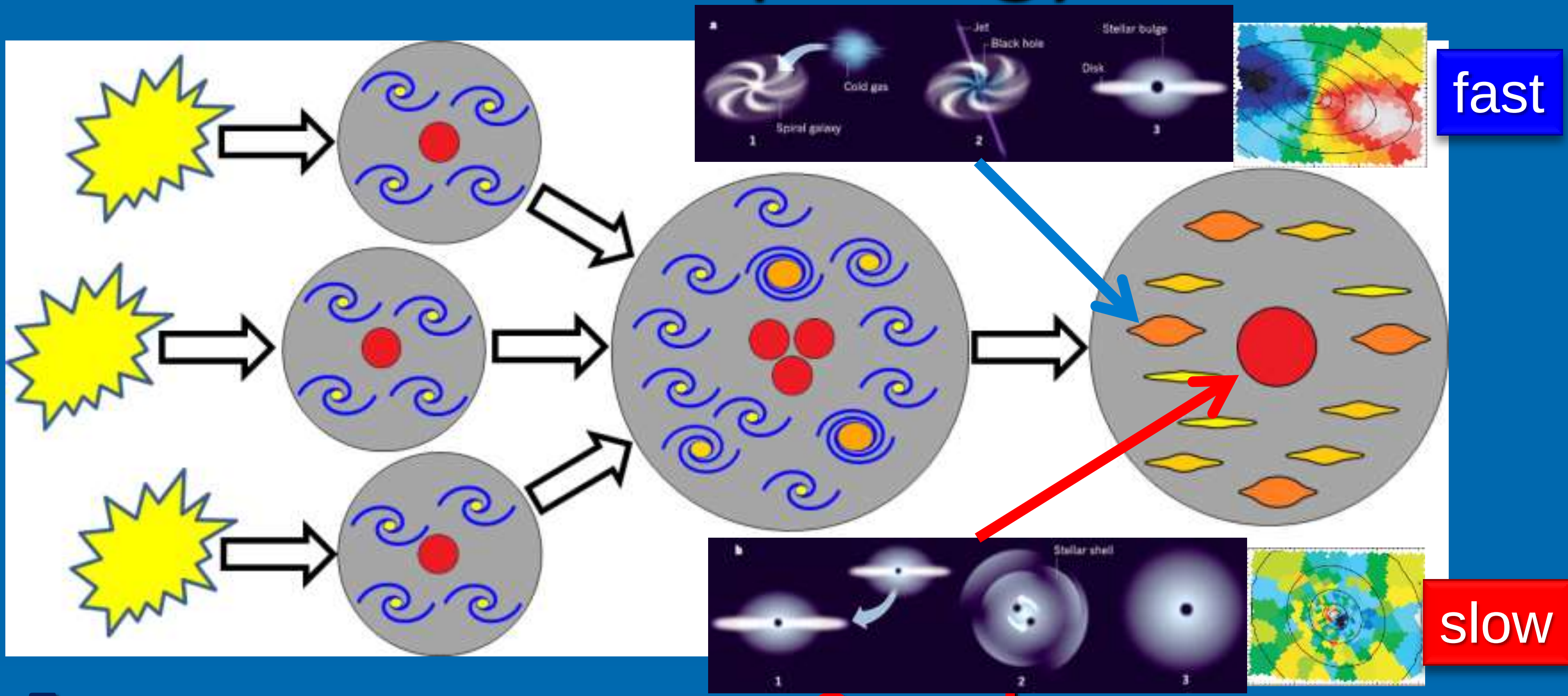
Core slow rotators in cluster centres



(Cappellari-13 ApJL)

- Strong decrease of spirals in Coma
- Strong increase of fast rotators
- But less core slow rotators in Coma

Hierarchical morphology evolution



Fast rotators

- Generally satellites
- Quenched by environment
- Bulge grows with quenching

(also De Lucia+12; Wilman+Erwin-12)

Core slow rotators

- Generally near halo centre
- Sink by dynamical friction
- ISM → No cold accretion
- Mass grows by dry mergers