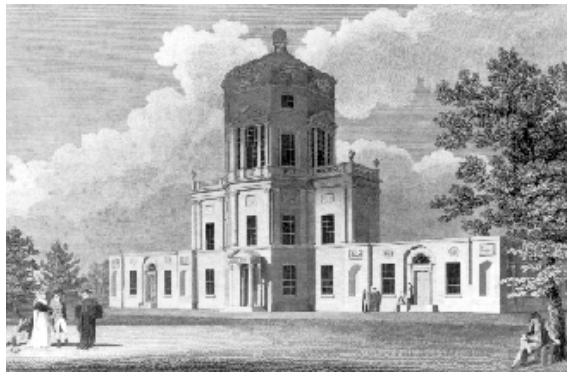
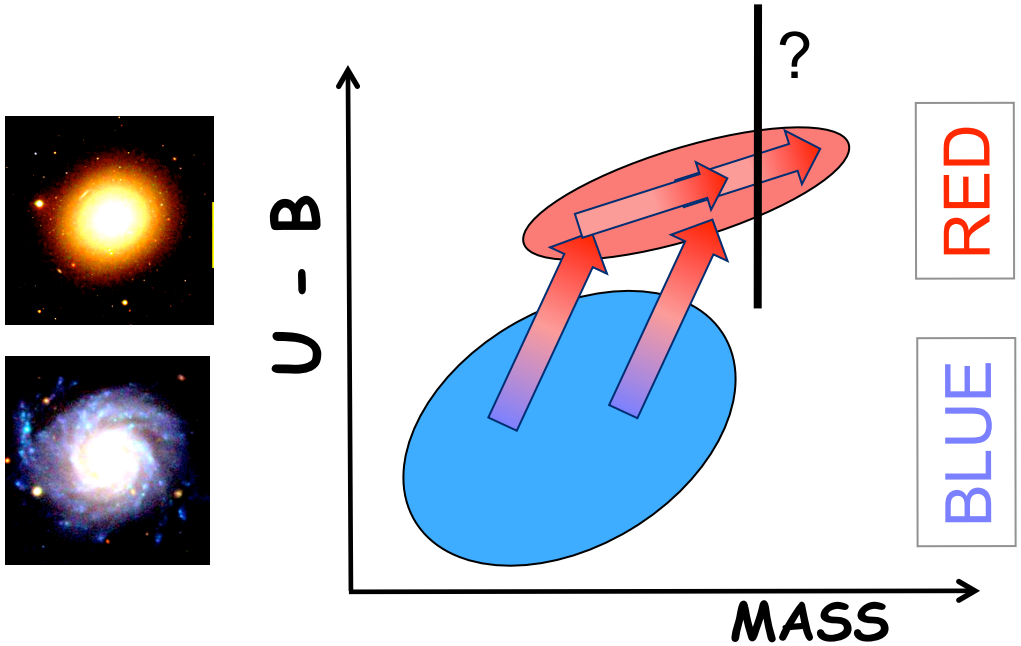
Dynamical properties of nearby early-type galaxies through Atlas^{3D} survey

Davor Krajnović



Moving galaxies to the red sequence



Faber et al. 2007

- Bimodal galaxy distribution
- From blue cloud to red sequence
  - Fading (same mass)
  - Gas rich mergers (mass increase)
    - major and (multiple) minor

} rotation

- Highest masses: mergers of red galaxies
  - Gas poor mergers

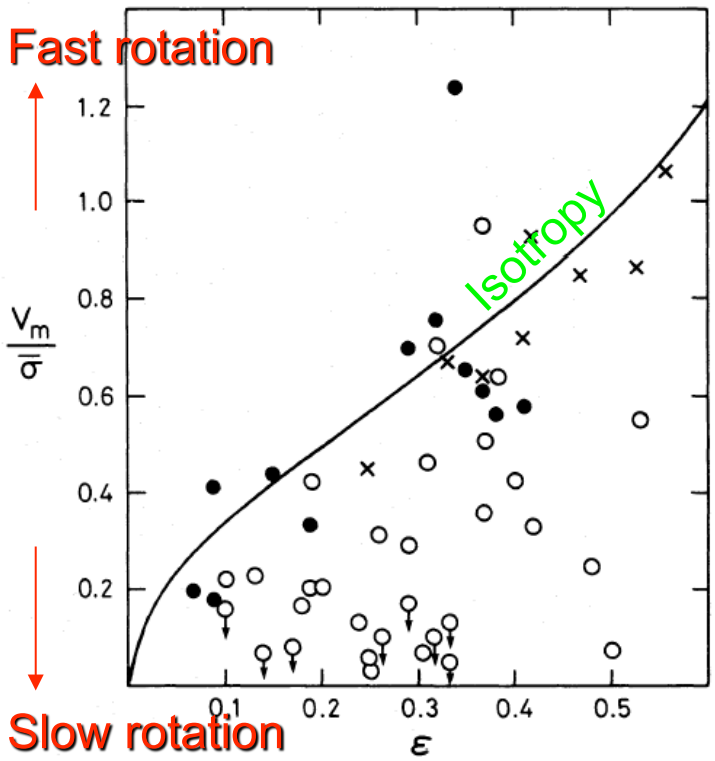
-> no ordered motion

- What is the relative importance of these processes?

e.g. Bournaud et al. 2007; Hopkins et al. 2008, 2009

Galaxy kinematics: V/σ diagram

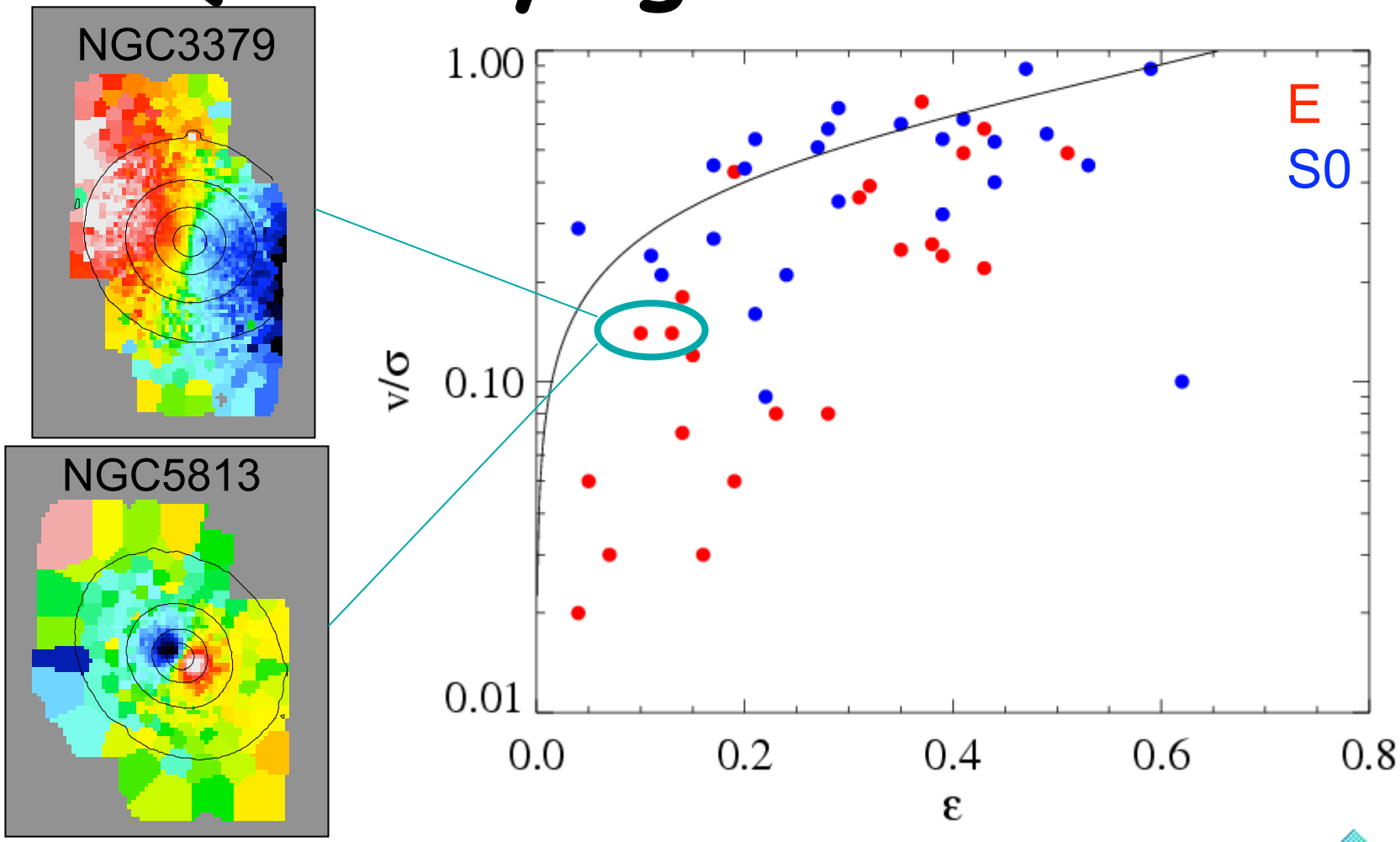
- Ellipticals once thought to be isotropic, flattened by rotation
  (e.g. Gott 1975)
- Giant ellipticals rotate slowly and are likely anisotropic and triaxial
  (Bertola & Capaccioli 1975; Illingworth 1977; Binney 1978)
- Small ellipticals/bulges rotate faster and appear isotropic
  (Kormendy & Illingworth 1982; Davies et al. 1983)
- Small E tend to have disky isophotes
  (Bender 1988, Bender et al. 1989)
- Do they actually contain disks?
  (Rix & White 1990; Kormendy & Bender 1996)



O = big ellipticals
● = small ellipticals

Davies et al. (1983)

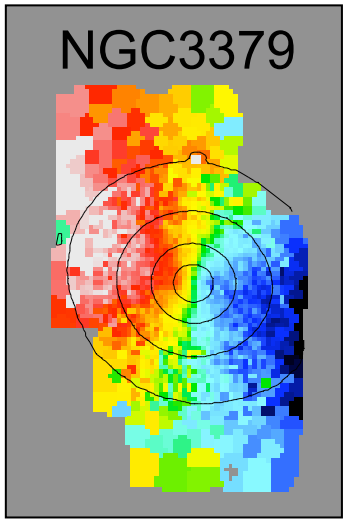
Quantifying Kinematics: V/σ

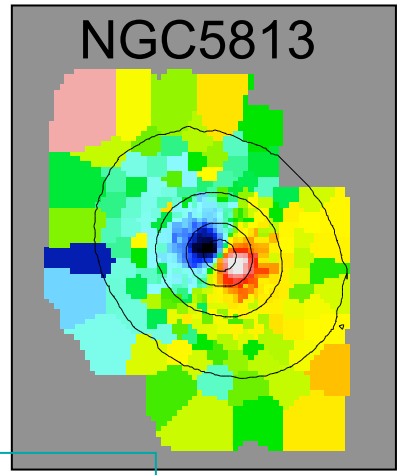


- V/σ quantifies rotation vs. random motion
- No clear relation with 'E/S0' or velocity maps

New Kinematic Quantifier: λ_R

- SAURON galaxies show either ordered rotation, or no rotation except for decoupled component





A measure of angular momentum

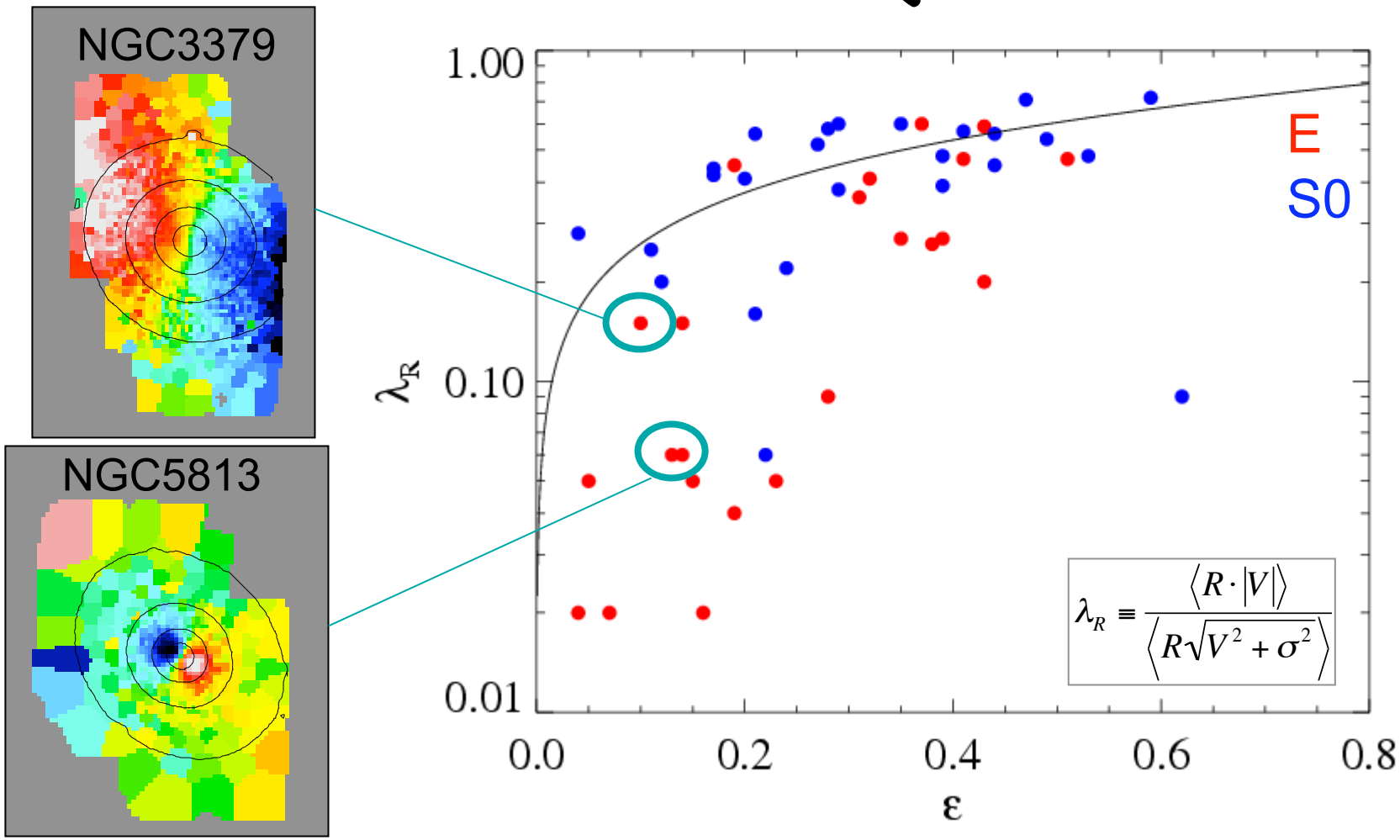
$$\lambda_R = \frac{\langle R \times |V| \rangle}{\langle R \times \sqrt{V^2 + \sigma^2} \rangle}$$

Sky-averaged
- Need IFU

Normalized by Mass

Emsellem et al. 2007

New Kinematic Quantifier: λ_R

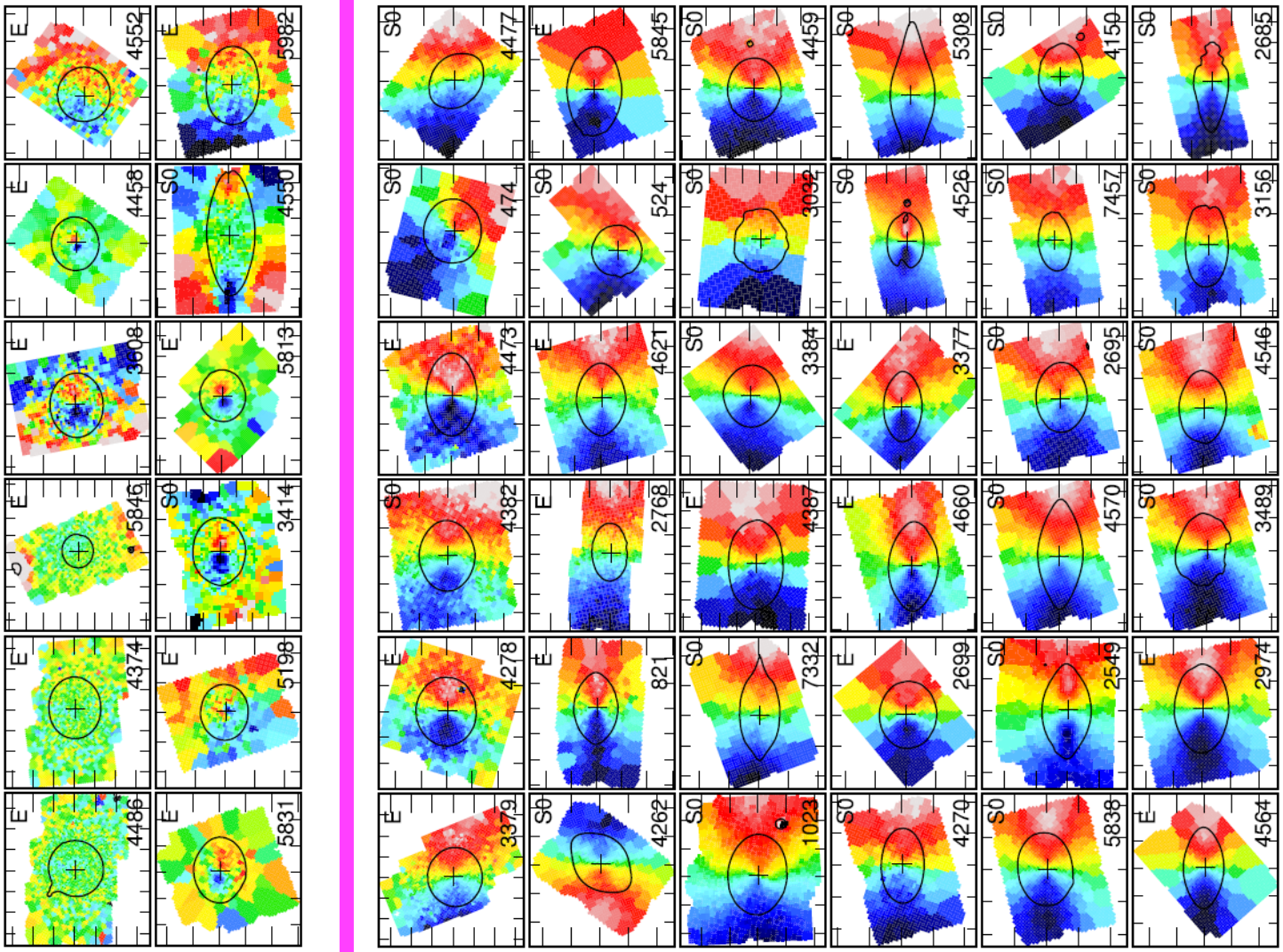


- Better separation of galaxies with different V maps

Emsellem et al. 2007

SAURON Sample: 48 E/S0

λ_R → Increasing angular momentum

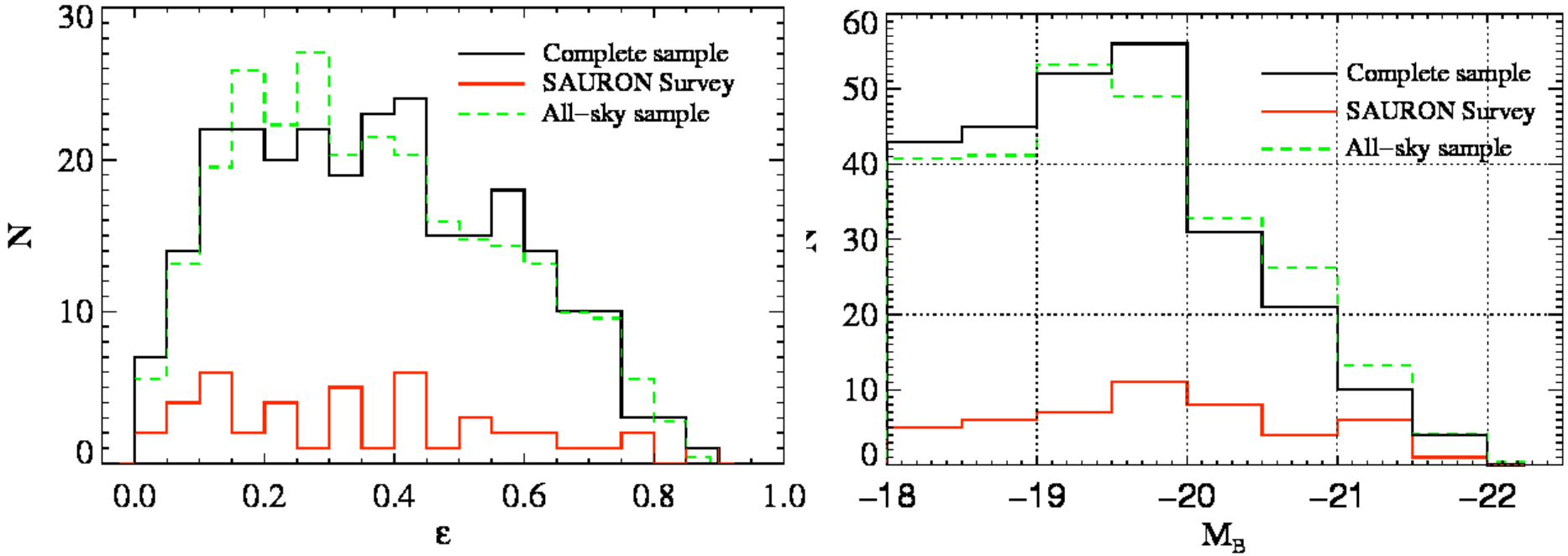


"Slow-rotator" | λ_R=0.1 "Fast-rotator"

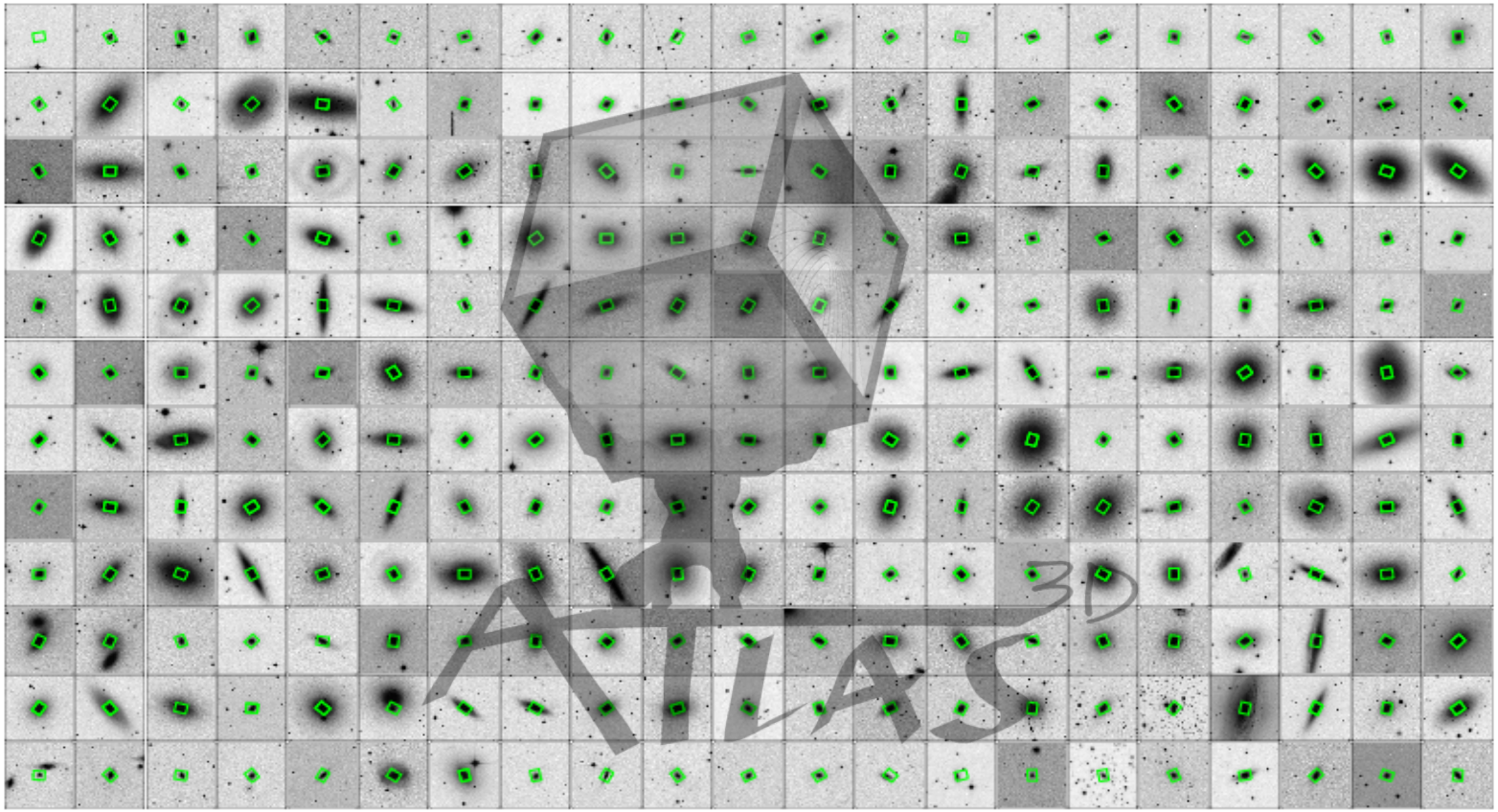
Emsellem et al. 2007

Next Step : Complete Survey

- SAURON sample was selected to be representative, not complete
- Based on E/S0 classification (not useful)
- Makes statistical comparisons with models impossible



ATLAS^{3D}

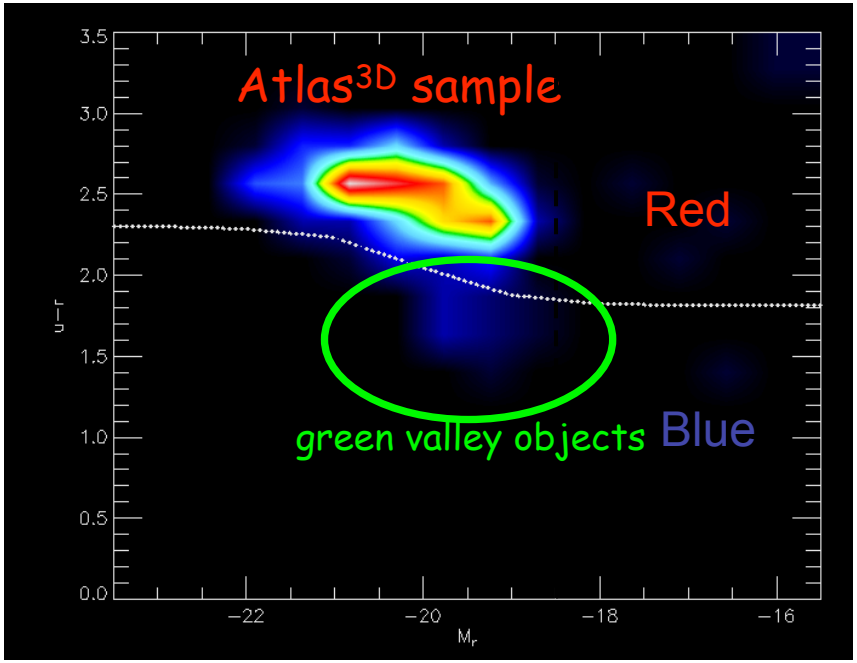


Observe a complete volume-limited sample of ETGs

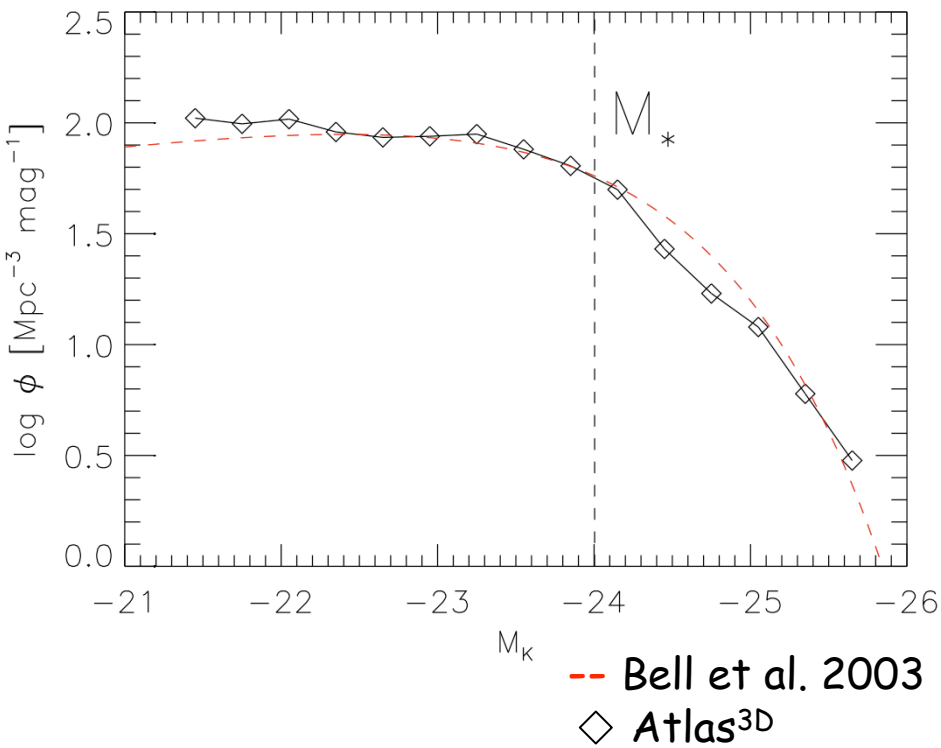
- $M_K < -21.5$ $D < 41$ Mpc
- $|\delta - 29| < 35°$
- $|b| > 15°$

ATLAS^{3D} Sample Selection

Galaxies on the red sequence



Luminosity function



Parent sample: 900 nearby galaxies
Morphological selection: spirals vs. early-types (DSS/SDSS)
No colour cut
263 galaxies

Cappellari et al., 2009, in prep.

The ATLAS3D Team

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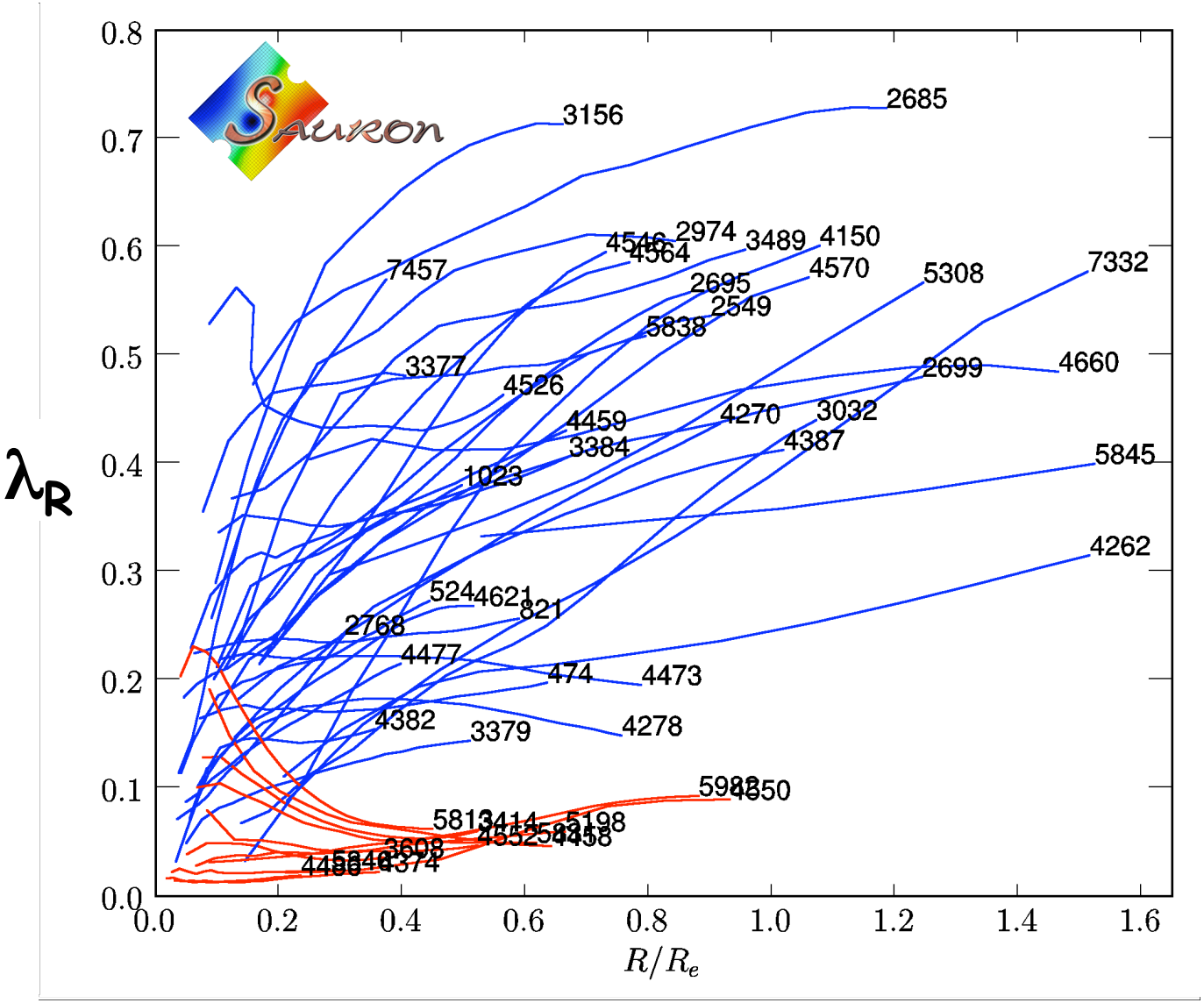
(28 researchers in 16 institutes)

Multi-λ Approach

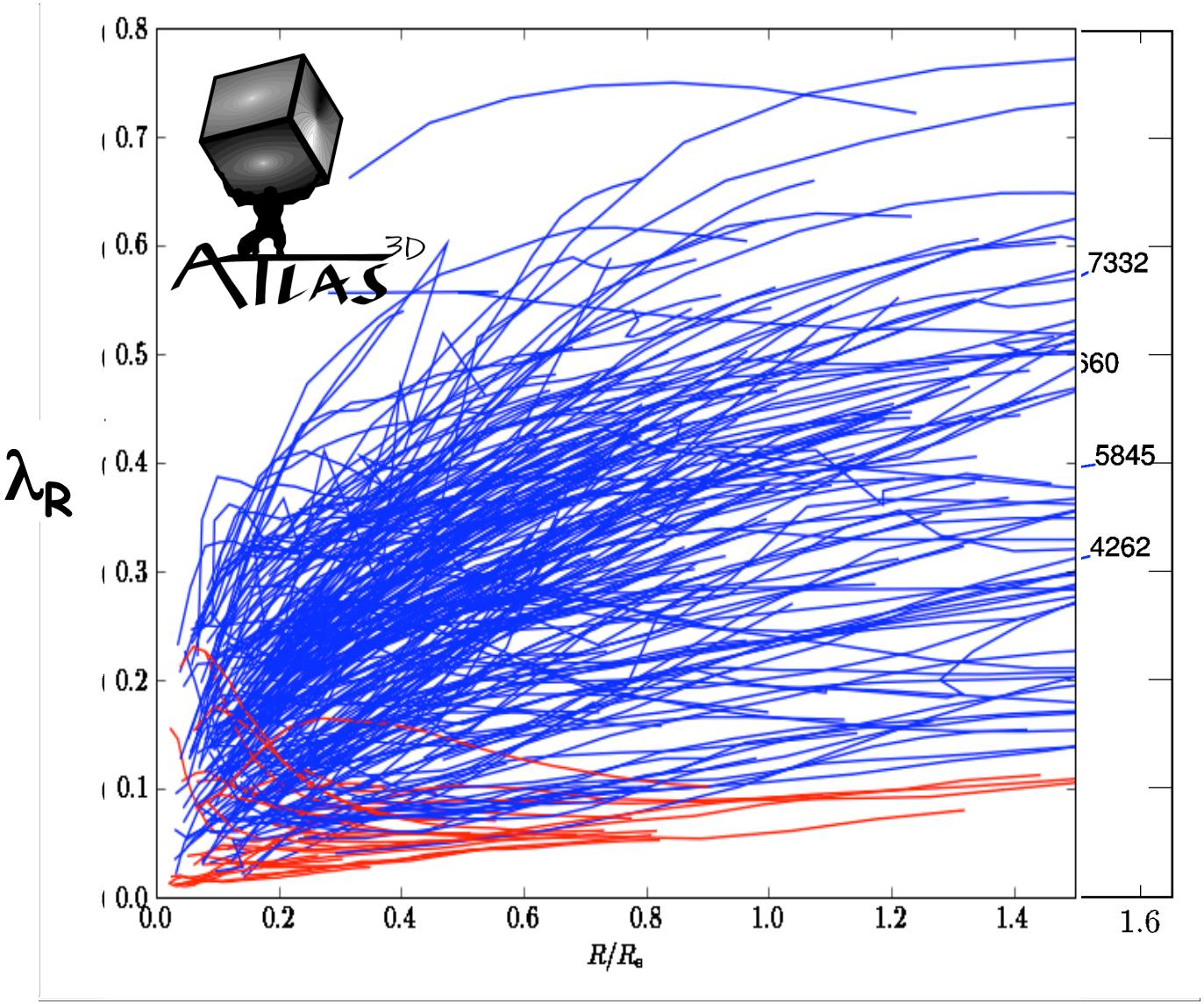
- *SAURON (IFU)* Large Program on WHT
- *HI survey* ~150 northern galaxies with WSRT (excl. Virgo)
- *Single-dish CO* survey of full sample (IRAM 30m)
- *CO interferometry* of detections with CARMA
- *Photometry* multi-bands (INT, 2MASS)
- *Archival* data (SDSS, Chandra, XMM, GALEX, HST, Spitzer)
- *Theory* SAM, cosmological and generic numerical simulations

λ_R radial profiles



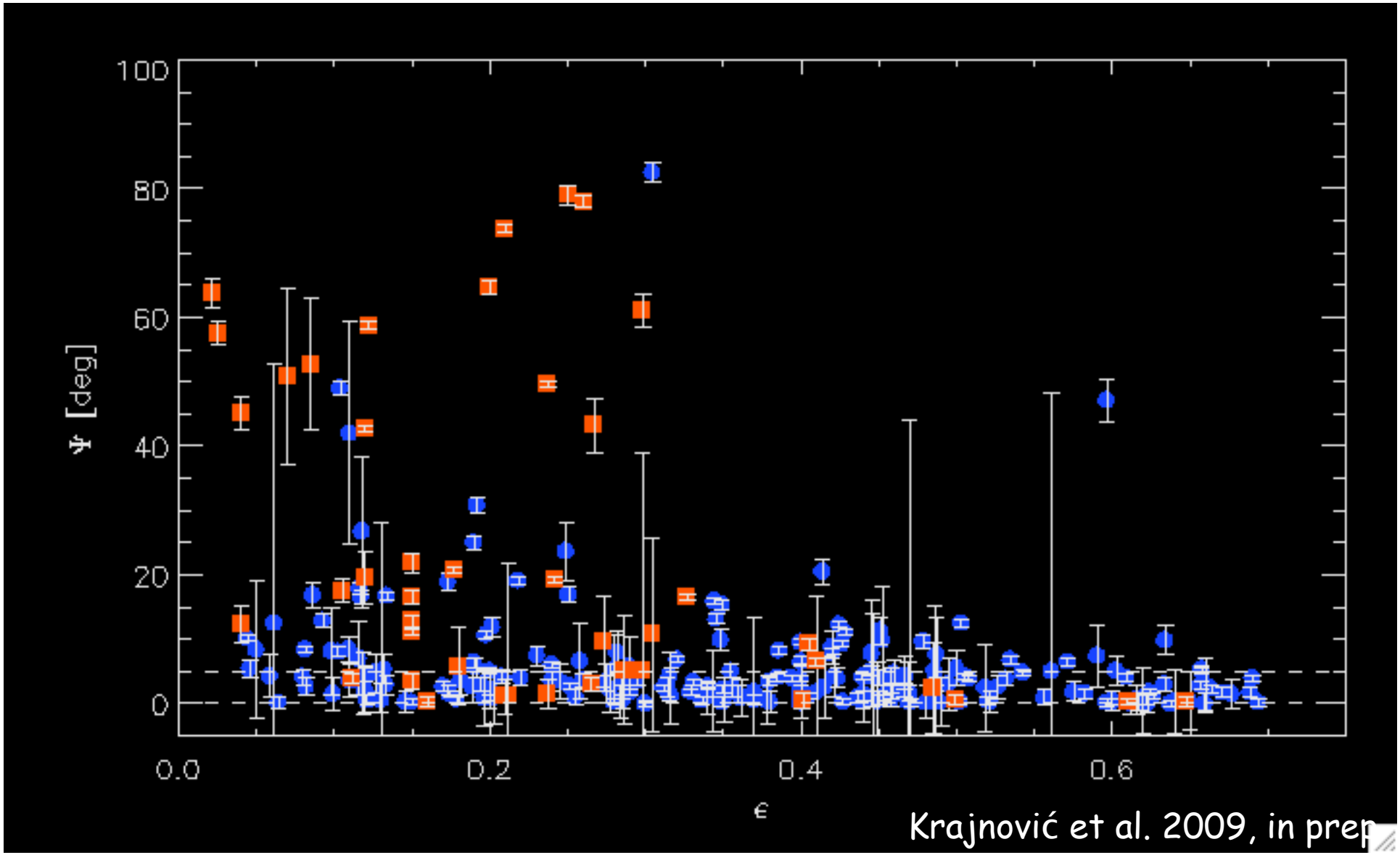
λ_R radial profiles

90% of ETG are disk dominated fast rotators



Emsellem et al., 2009, in prep.

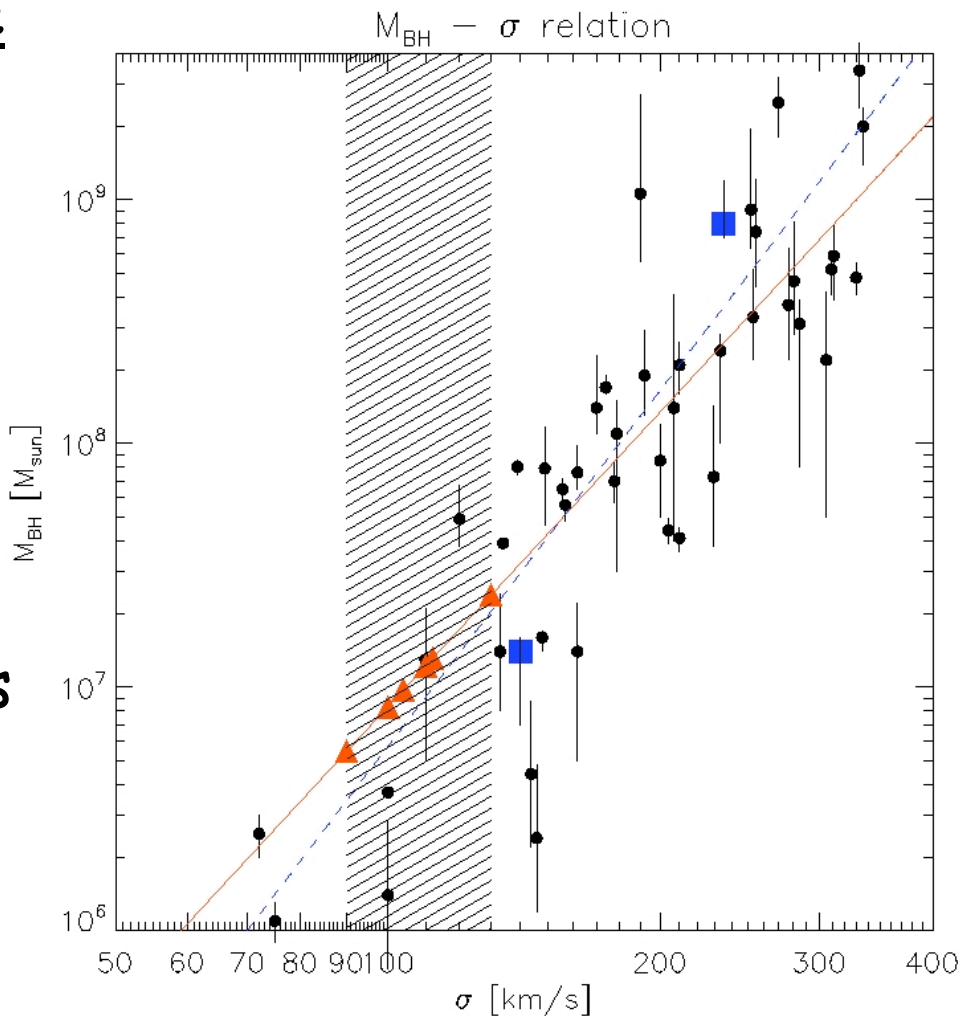
Kinematic misalignment



Krajnović et al. 2009, in prep

Atlas^{3D} BH project

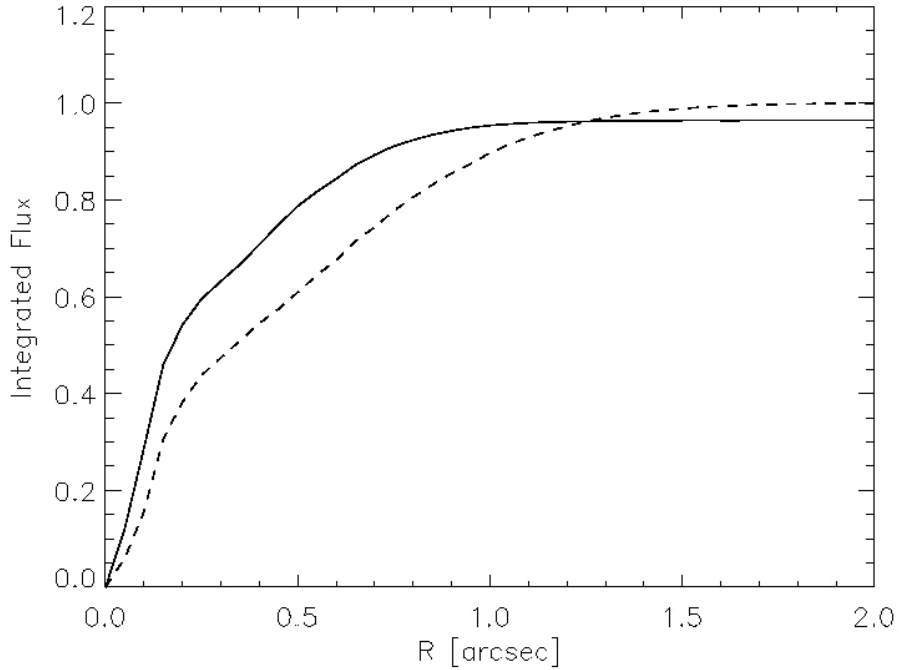
- Goal: derive a <u>representative</u> M_{BH} - σ_e relation for early-type galaxies!
- Atals^{3D}: a volume limited sample
  - all nearby early-type galaxies
- Target under-populated regions of M_{BH} - σ_e relation
  - σ_e < 130 km/s
- Large scale IFU observations in hand!!
- High resolution campaign:
  - Gemini + NIFS
  - LGS AO in 'open loop' mode



Gebhardt et al. (2000) & Merritt& Ferrarese (2000), Graham et al. (2008)

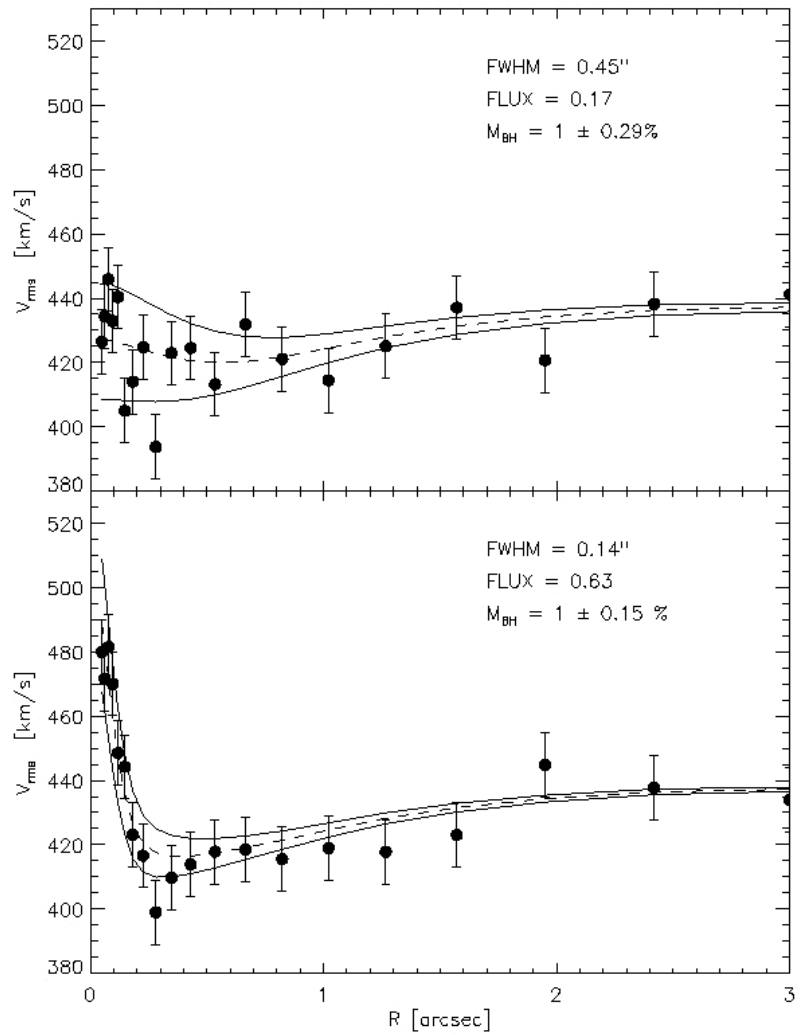
Influence of PSF

- LGS correction
  - NGC524: fwhm = 0.23″
  - NGC2549: fwhm = 0.17″
- Integrated flux
  - ~40% within 0.2″
- What is the dependence of M_{bh} accuracy on PSF?
  - Test with a spherical model galaxy
  - 2 different M_{bh} (and sphere (influence)
  - 100 different PSFs



Influence of PSF

- PSF:
  - narrow (change) and broad (fix) component
- Flux:
  - F(narrow) + F(broad) =1
- For each PSF determine the M_{bh} and values at 3σ uncertainties
- R_{sph} = 0.3″: 30 - 60%
- R_{sph} = 0.15″: 50 – 100%



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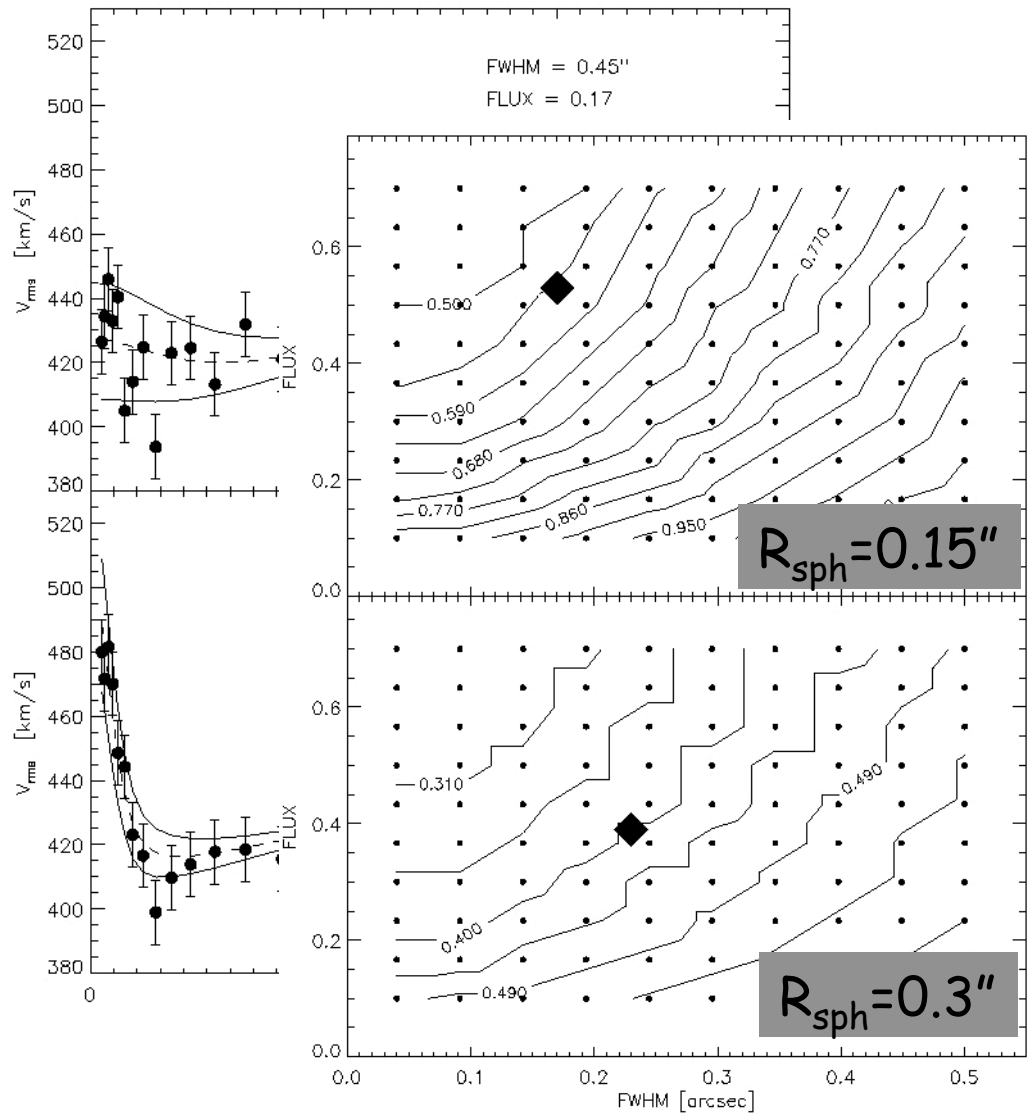

Summary

- Atlas3D – multi-wavelength survey
  - Stellar kinematics
  - Stellar populations and chemistry
  - ISM: molecular, atomic & ionised gas
  - Comparison with numerical simulations
- Atlas3D – BH project
  - Target unpopulated regions in M_{BH} - σ_e relations
  - Importance of hi-res and large-scale IFUs
  - LGS AO can decrease the uncertainty on M_{BH}
  - Need high SN IFU data