The Virial Relation and Shape of Early-Type Galaxies

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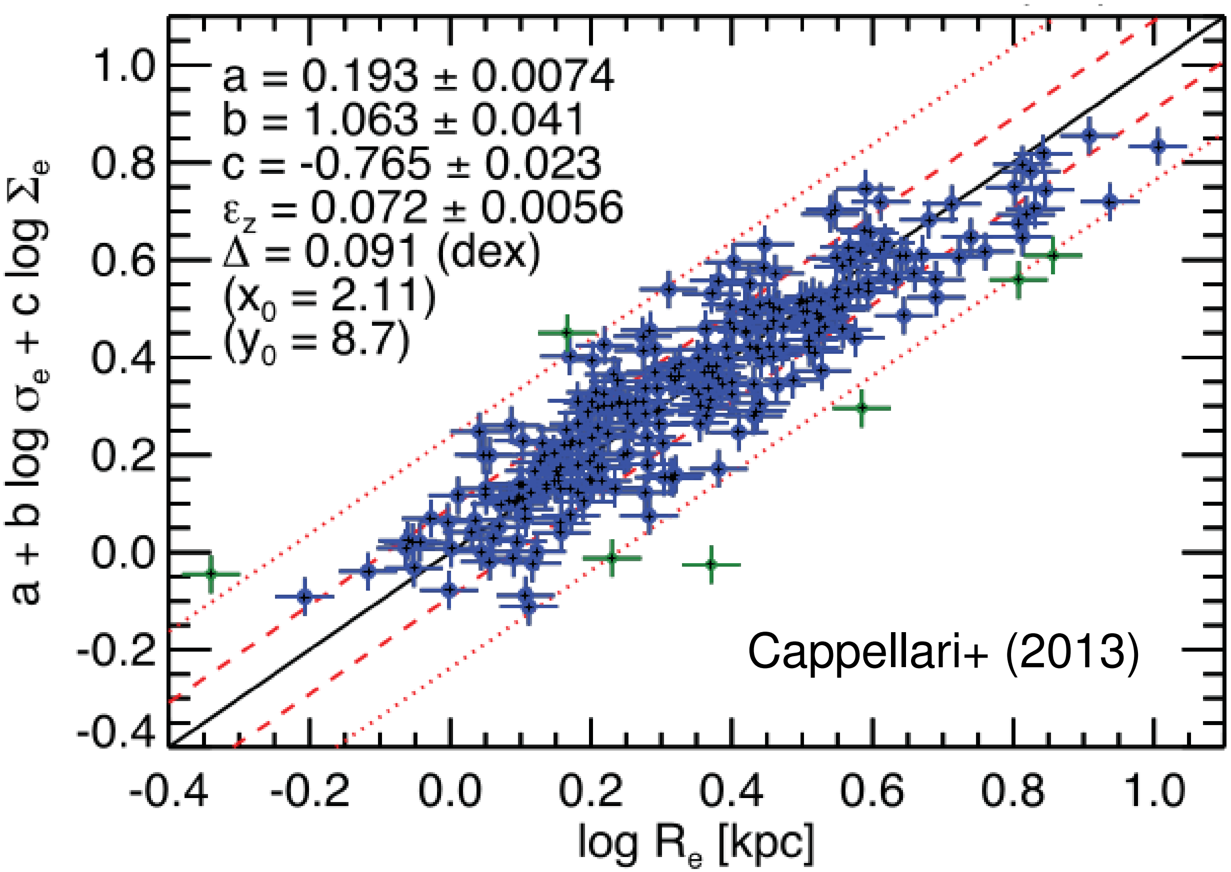
The fundamental plane



$$\log R_{\rm e} = a + b \log \sigma + c \log \Sigma_{\rm e}$$

eff. radius

velocity dispersion

surface brightness

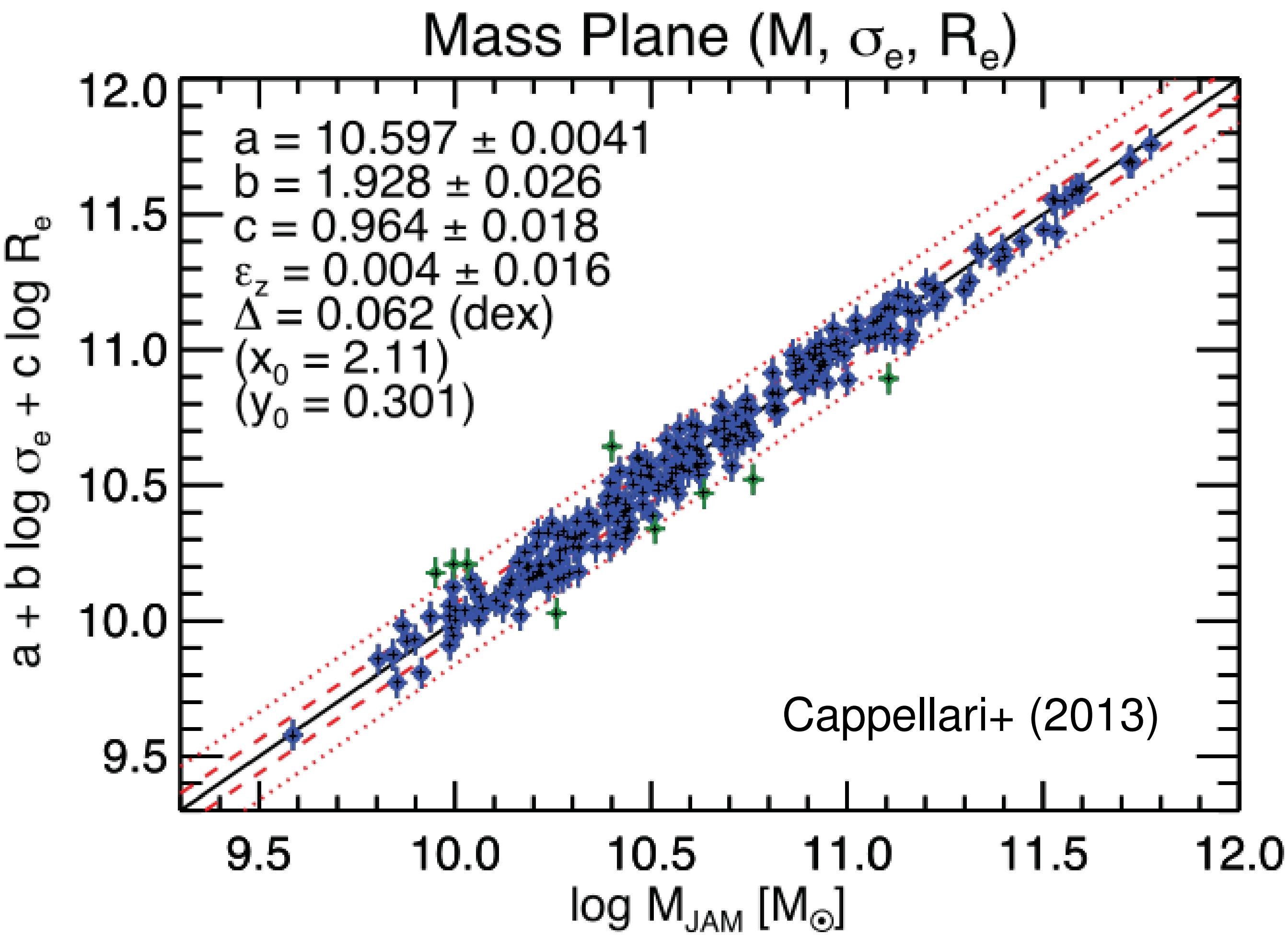
Expected: $b = 2$, $c = -1$

Observed: $b \approx 1$, $c \approx -0.8$

↳ Difference due to scaling of *M/L* with velocity dispersion

Dressler+ (1987); Djorgovski & Davis (1987); many others since then

The mass plane



Virial relation

$$M = k_e \frac{\sigma_*^2 R_e}{G}$$

$k_e \approx 4 \ldots 5$

Theory: $b = 2$, $c = 1$; observations agree? Or not?

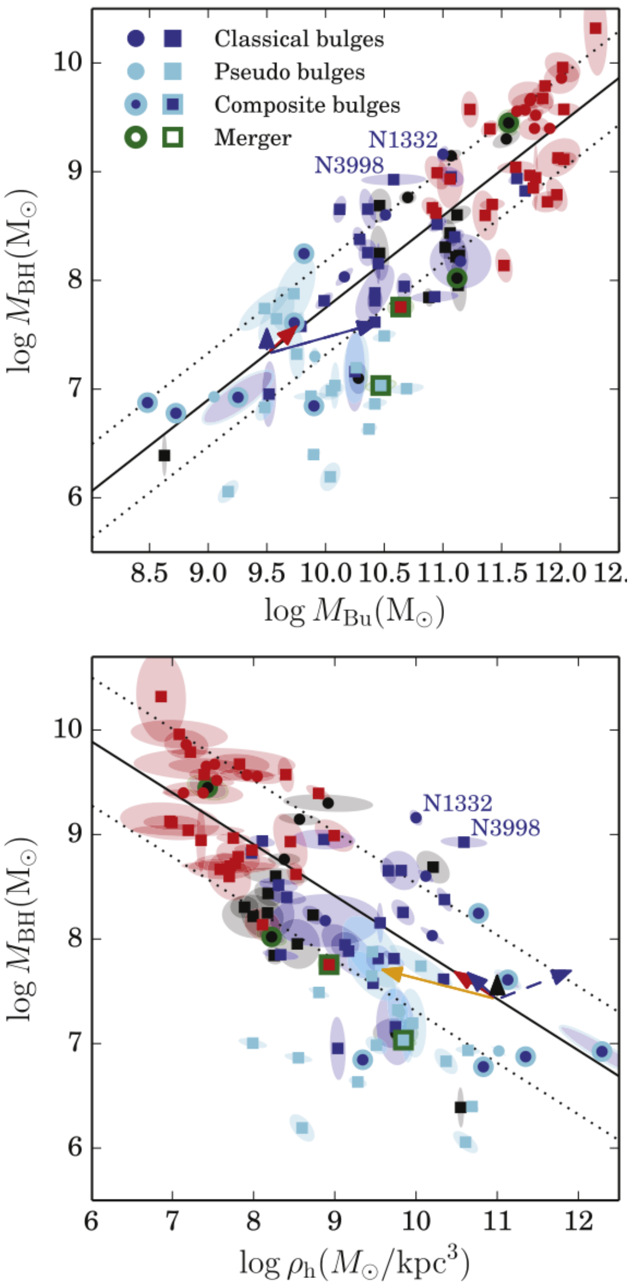
Bolton+ (2007); Hyde & Bernardi (2009); Cappellari+ (2013); Scott+ (2015)

The ATLAS^{3D} sample

- 260 elliptical galaxies within 42 Mpc
- Volume-limited sample
- SAURON integral-field spectroscopy
- Masses and effective radii from modeling of surface brightness and velocity dispersion distributions in the sky plane
  Jeans Anisotropic Multi-Gaussian Expansion (JAM) algorithm
- High-quality results for 101 galaxies
- Formal uncertainties:
  0.041 dex for effective radii
  0.021 dex for average velocity dispersions
  0.049 dex for galaxy masses

Cappellari+ (2011), 30+ more ATLAS^{3D} papers since then

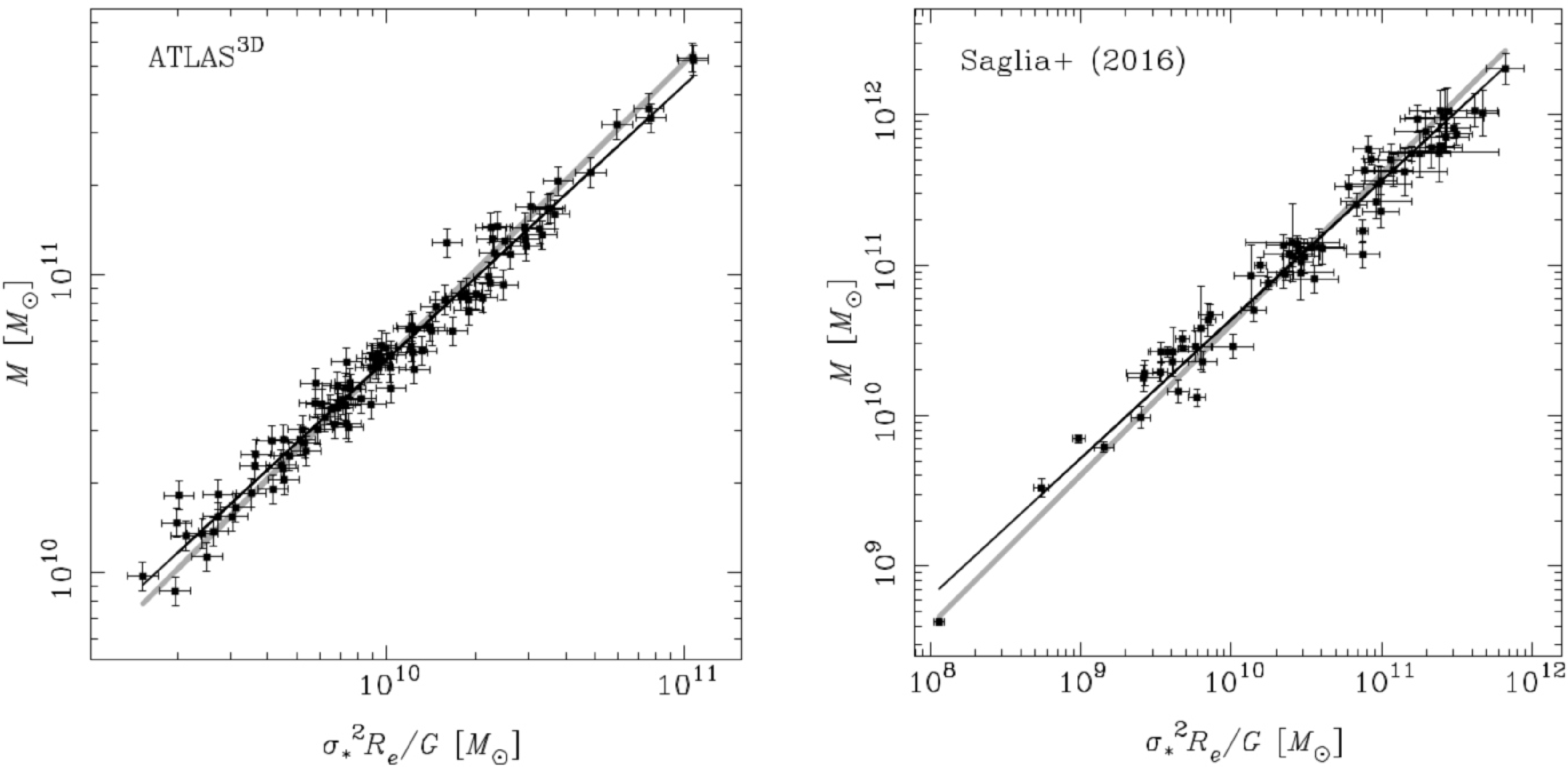
The Saglia+ (2016) sample



- 72 galaxies & bulges within 150 Mpc
- Aimed at black holes – galaxy relations, selected for large range in dispersion
- SINFONI integral-field spectroscopy, various archival data sets
- Masses and radii from photometry, various dynamical models
- Median formal uncertainties:
  0.096 dex for effective radii
  0.021 dex for average velocity dispersions
  0.083 dex for galaxy masses

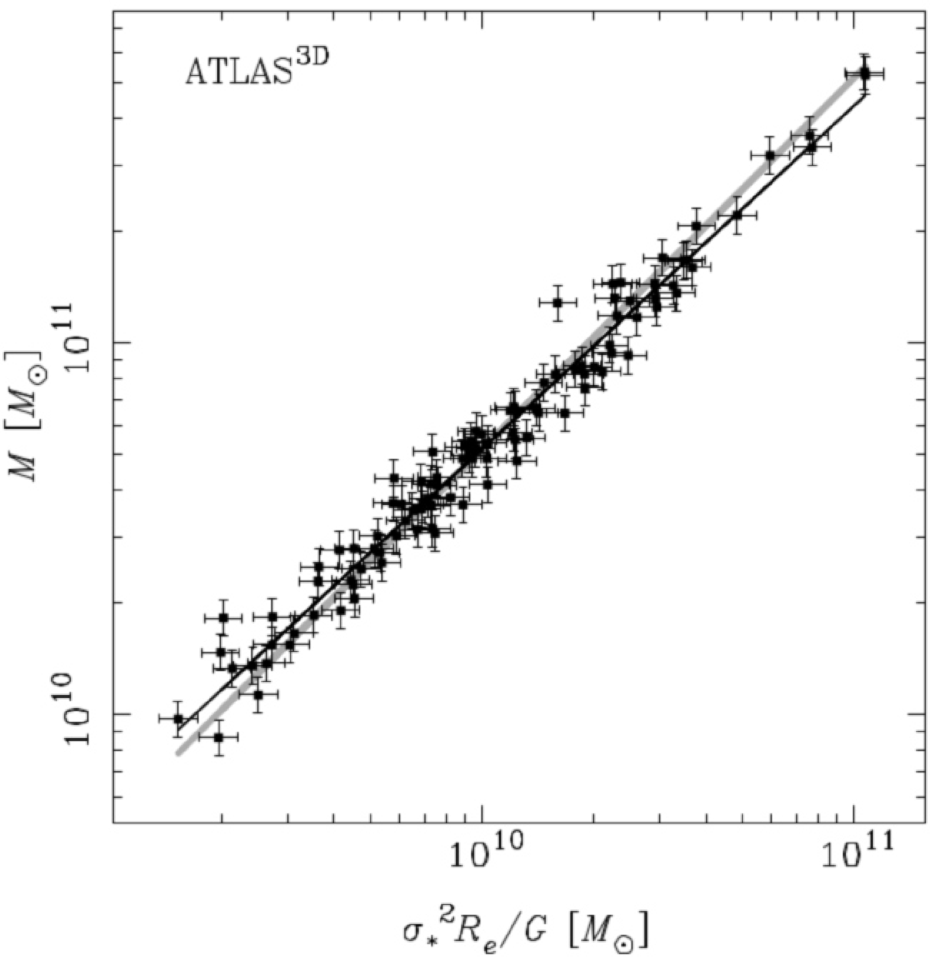
Saglia+ (2016), obviously

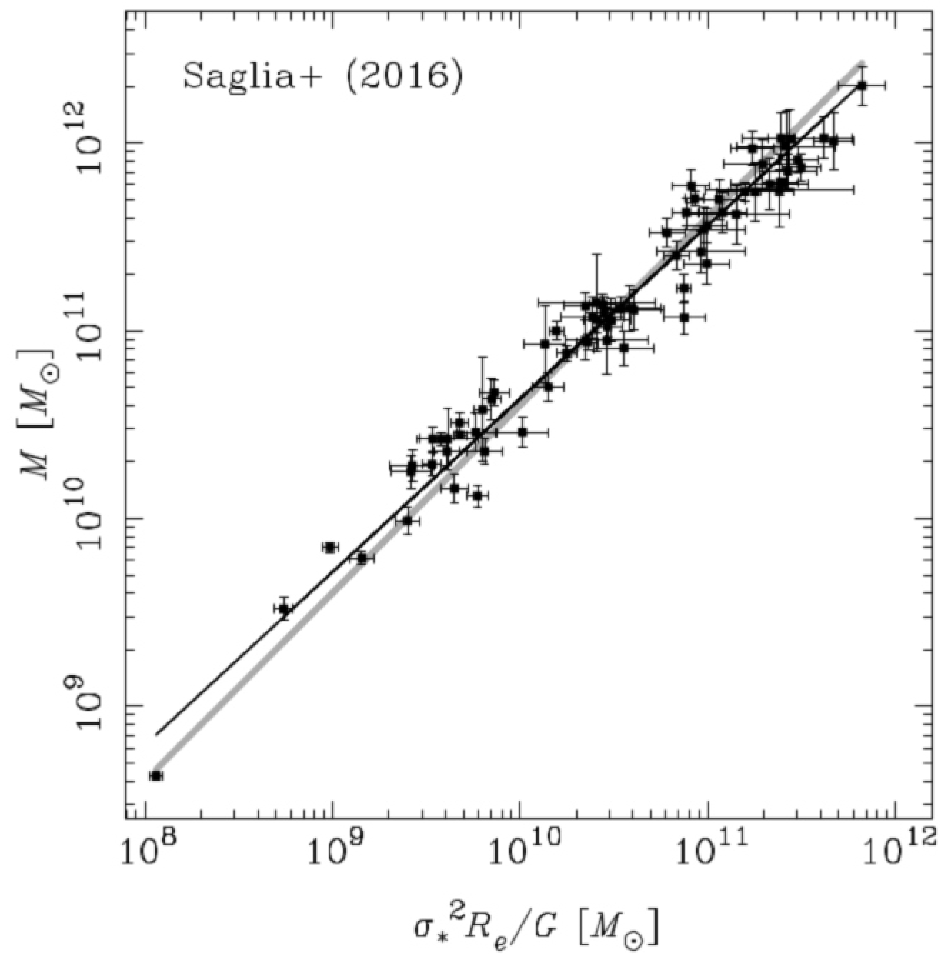
The virial relation with R_e



$$\log\left(\frac{M}{10^{11}M_\odot}\right) = x\log\left(\frac{\sigma_*^2 R_e/G}{10^{10.5}M_\odot}\right) + y$$

The virial relation with R_e



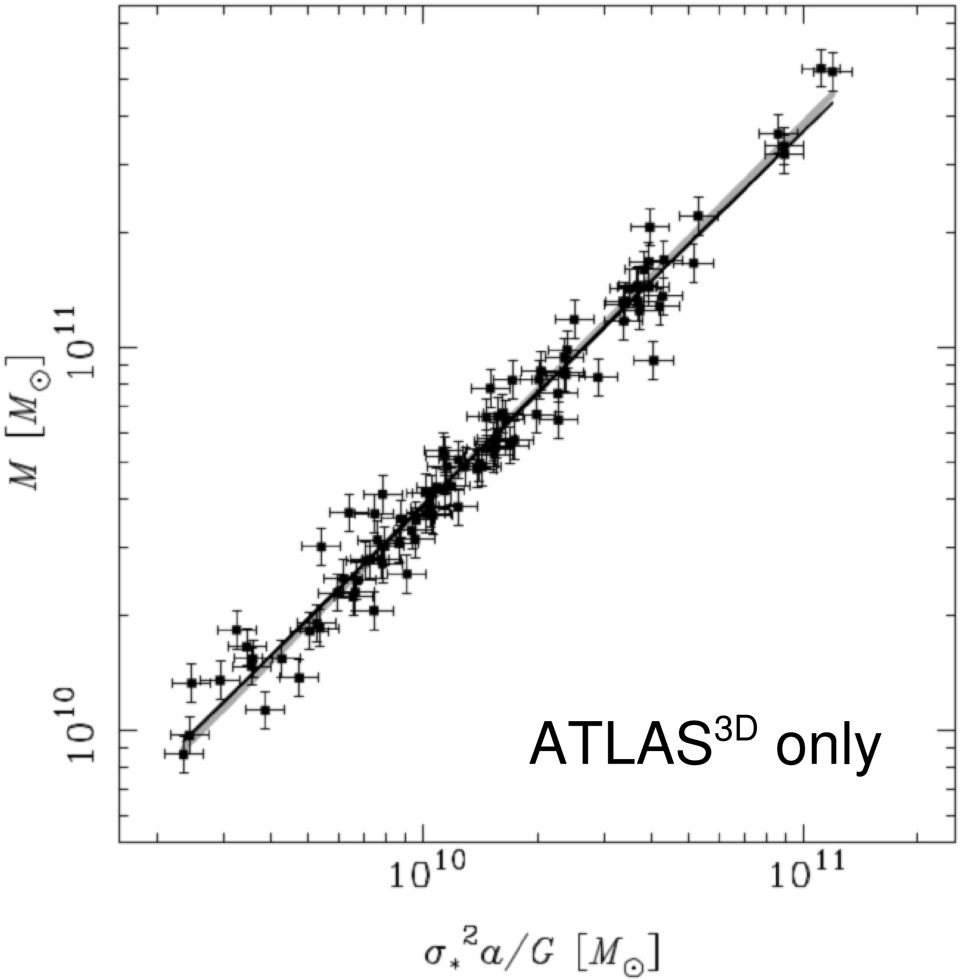


$x = 0.924 \pm 0.016$

$x = 0.923 \pm 0.018$

↪ Virial relation of ETGs is tilted

The virial relation with semimajor axis *a*



$$\log\left(\frac{M}{10^{11}M_\odot}\right) = x' \log\left(\frac{\sigma_*^2 a/G}{10^{10.5}M_\odot}\right) + y'$$

where the half-light ellipse obeys

$$R_e = \sqrt{ab}$$

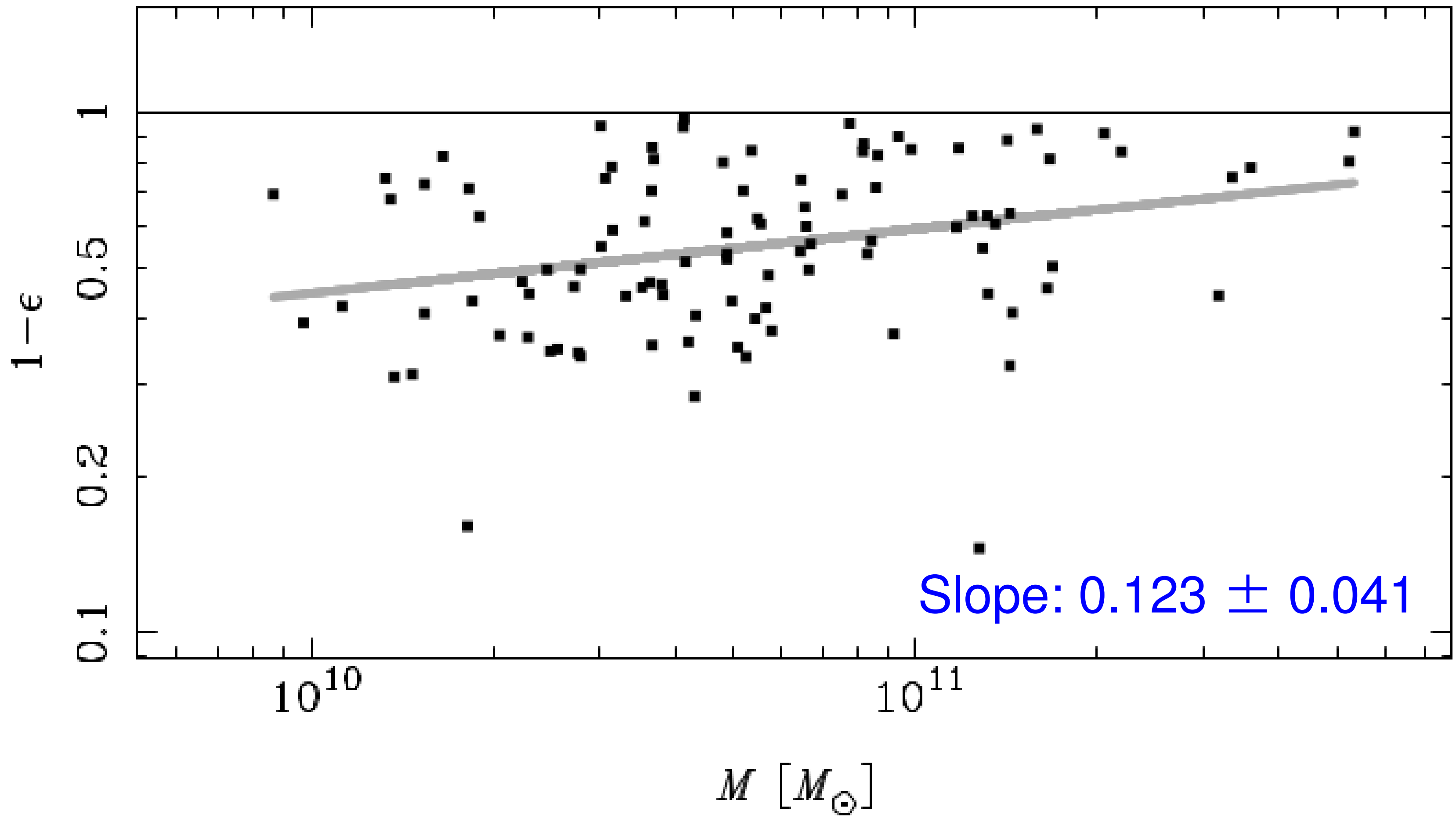
$$R_e = a\sqrt{1-\epsilon}$$

gives a new slope

$$x' = 0.976 \pm 0.018 \equiv 1$$

↳ **Semimajor axis, not effective radius, is the true scale radius of ETGs**

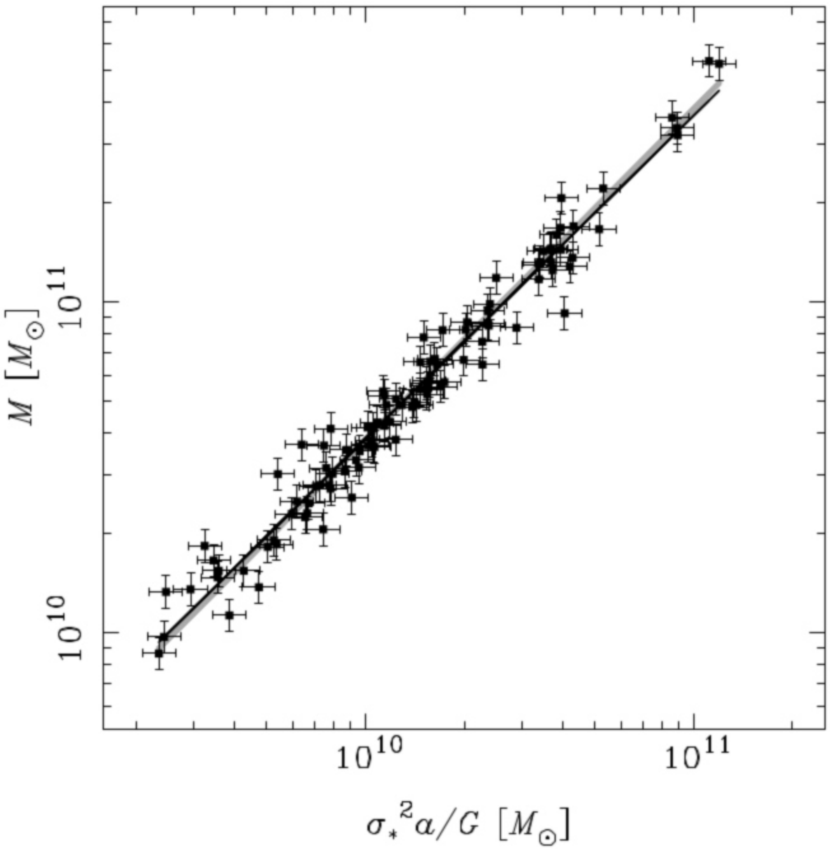
Ellipticity scales with mass

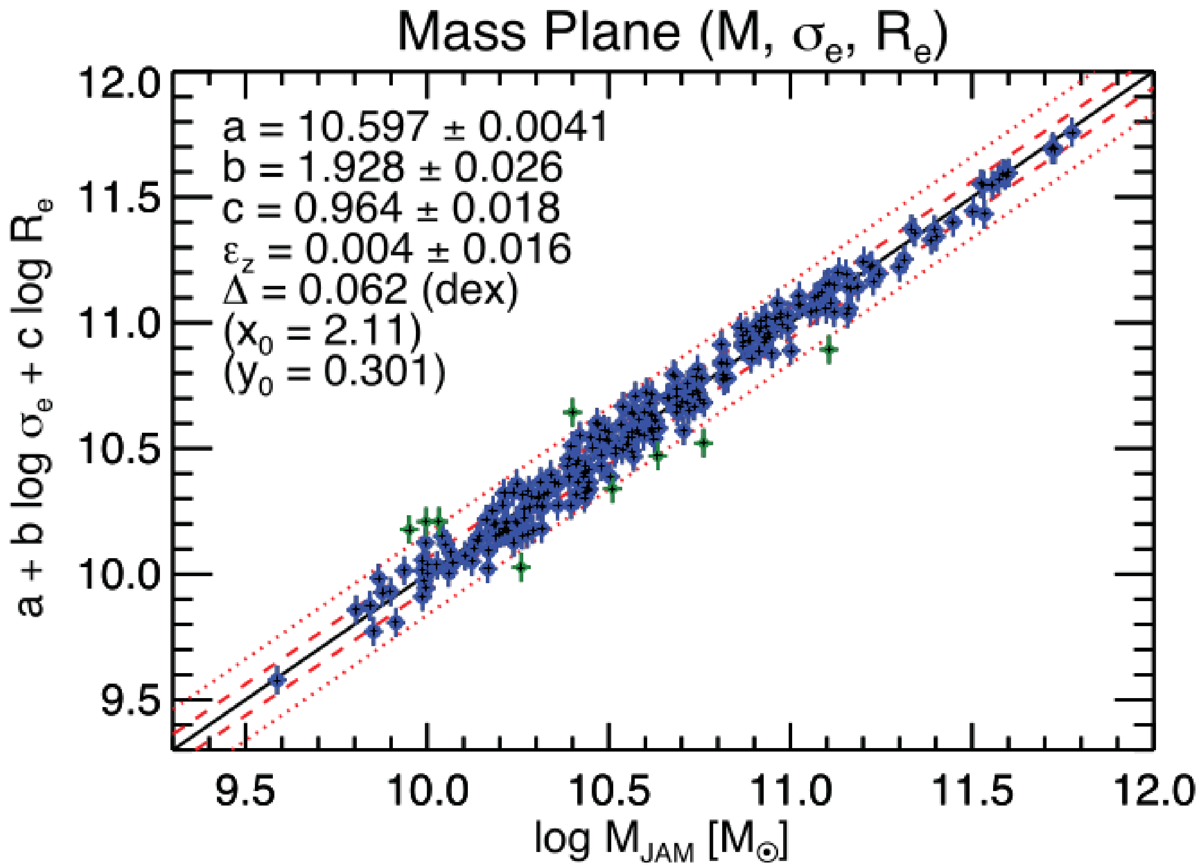


↪ **Lack of very elliptical high-mass galaxies explains mass plane tilt**

cf. van der Wel+ (2009)

There is no mass "plane"



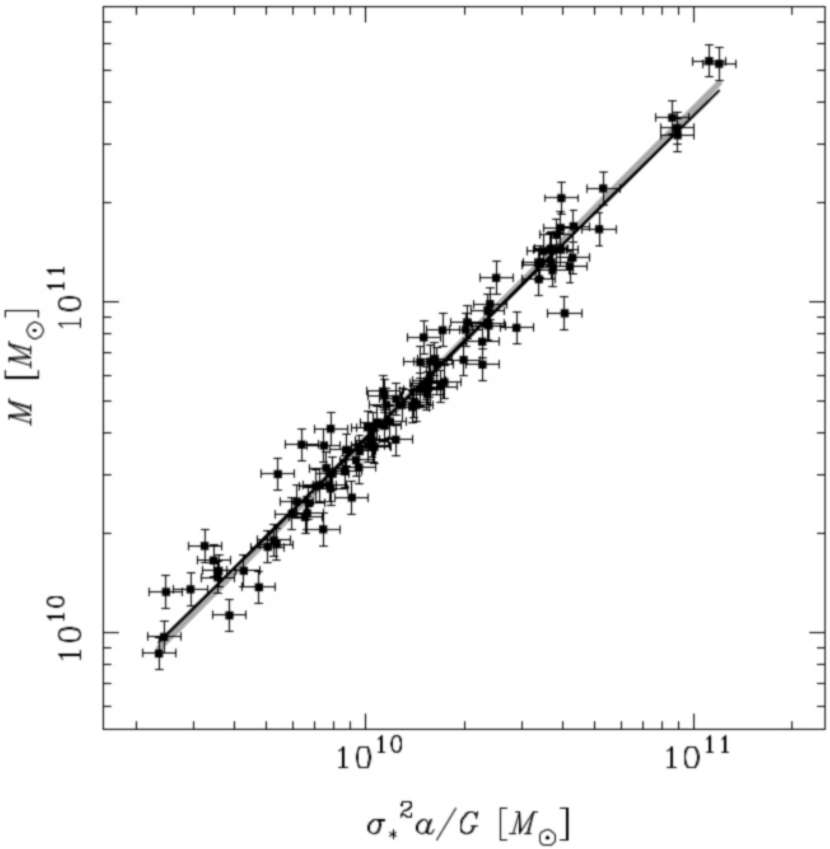


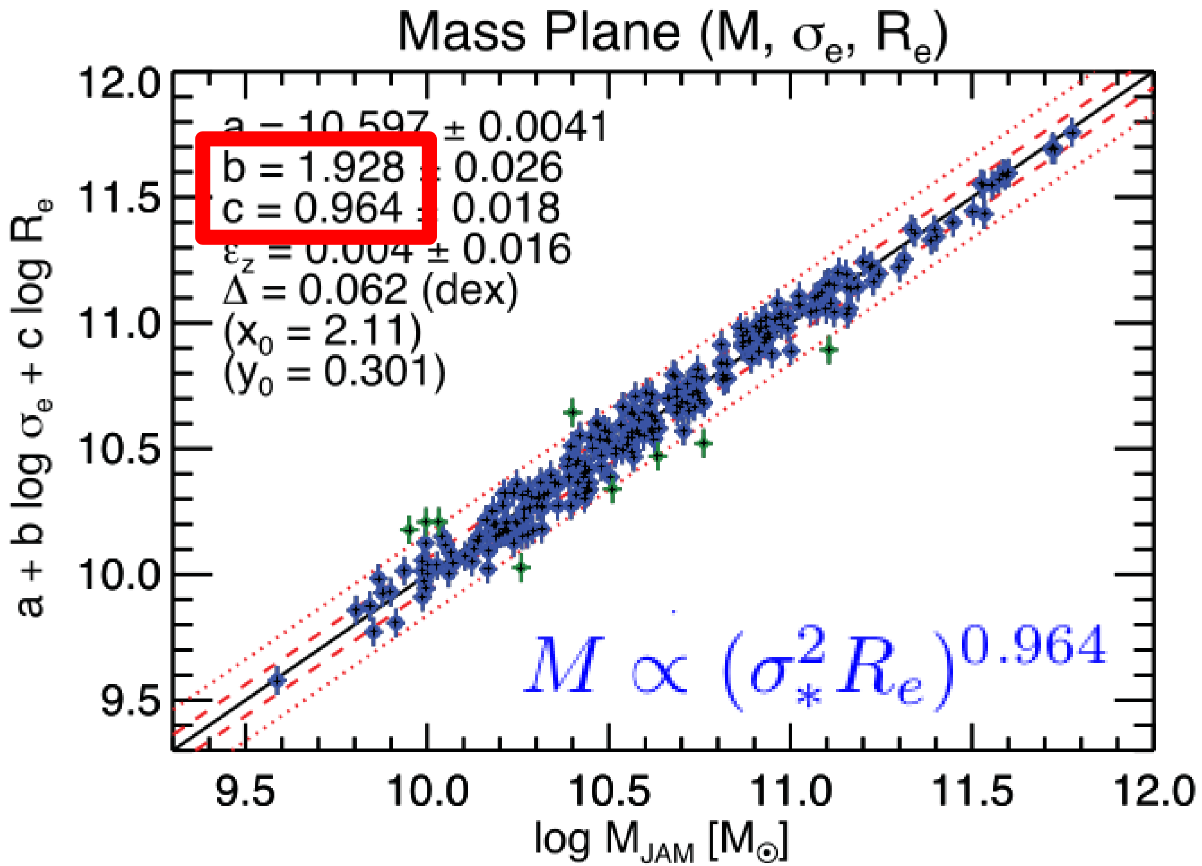
Best-fit virial relations agree with zero intrinsic scatter

↳ 2-parameter virial relation is sufficient (Occam's razor)

↳ 3-parameter mass plane has too many parameters

There is no mass "plane"





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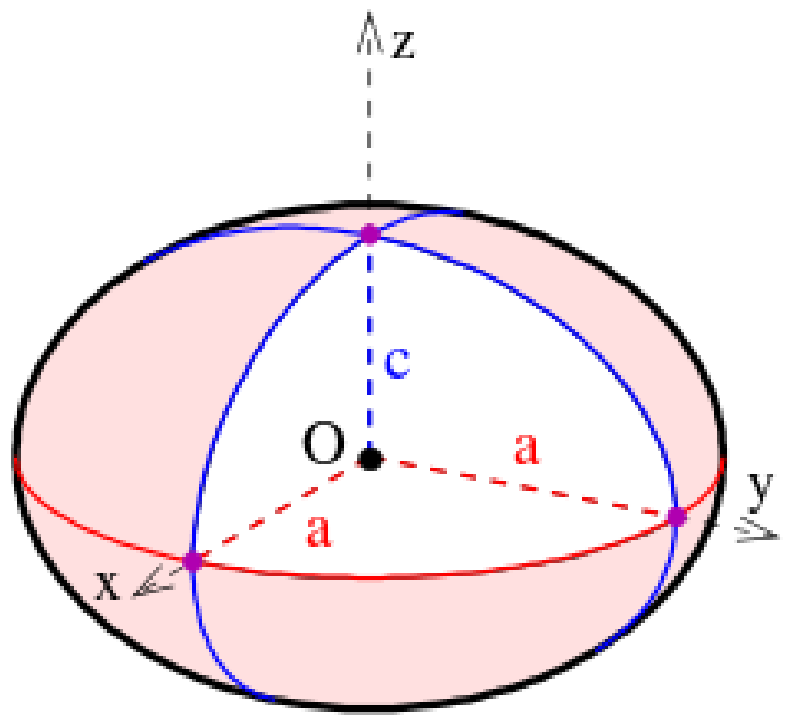
Local ETGs are axisymmetric and oblate



↪ **If not, *a* were not a characteristic radius**

↪ **Agrees with dynamical modeling (Weijmans+ 2014)**

Summary

- 72 & 101 ETGs from 2 recent surveys: ATLAS^{3D}, Saglia+ (2016)
- Using the virial relation with R_e shows a significant tilt
- Tilt disappears when using the semimajor axis *a* as scale radius
- Tilt is caused by a lack of very elliptical high-mass galaxies
- Virial relation fully determines ETG dynamics, no mass "plane"
- *a* is scale radius ➔ local ETGs are (mostly) axisymmetric and oblate

Trippe (2016), JKAS, in press – arXiv:1609.07188