Cosmology 2018

Tully & Fisher

Faber & Jackson

Kinematic Scaling Relations of CALIFA and MaNGA galaxies:

A Dynamical Mass Proxy for Galaxies Across the Hubble Sequence.

$\log \Upsilon_e = \log V^2 - \log I_e - \log r_e + \text{const.}$

$S_K^2 = K V_{rot}^2 + \sigma^2$

PhD. Candidate

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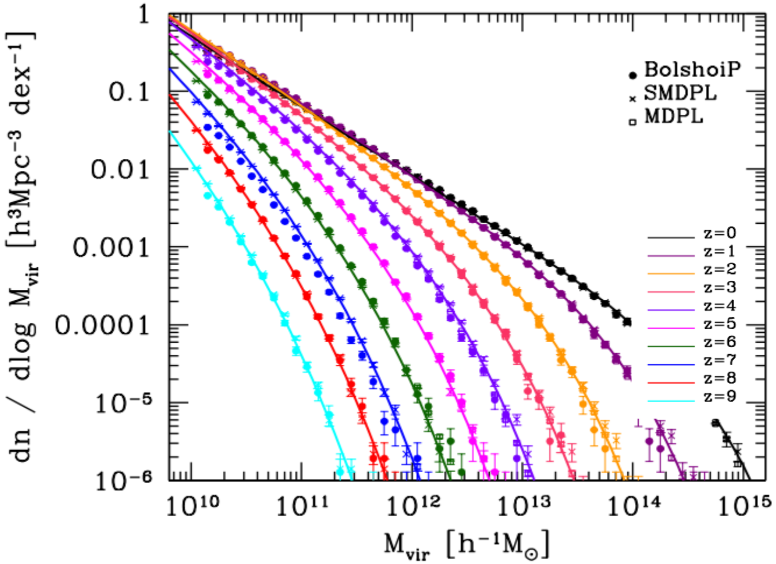
Dubrovnik, Croatia, October - 2018

SDSS

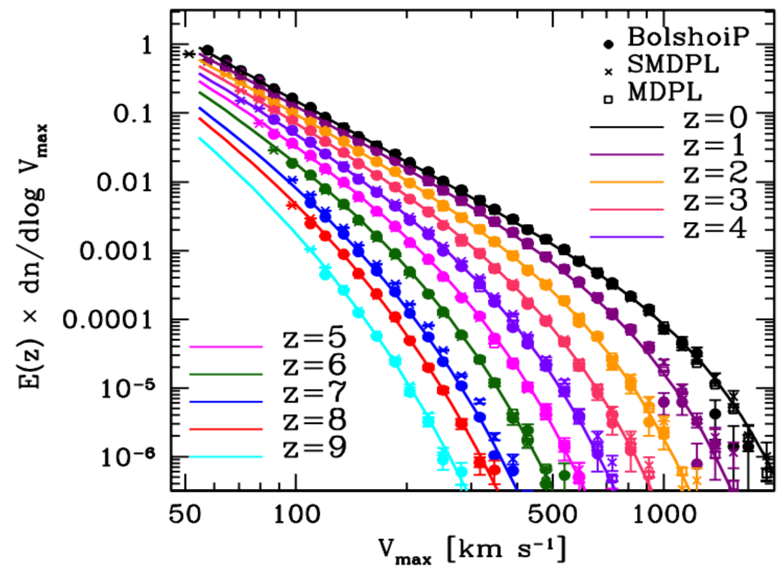
CALIFA Survey

Motivation: LCDM robust theoretical predictions; Galaxy-Halo Connection.

Halo mass function.



Circular velocity function.

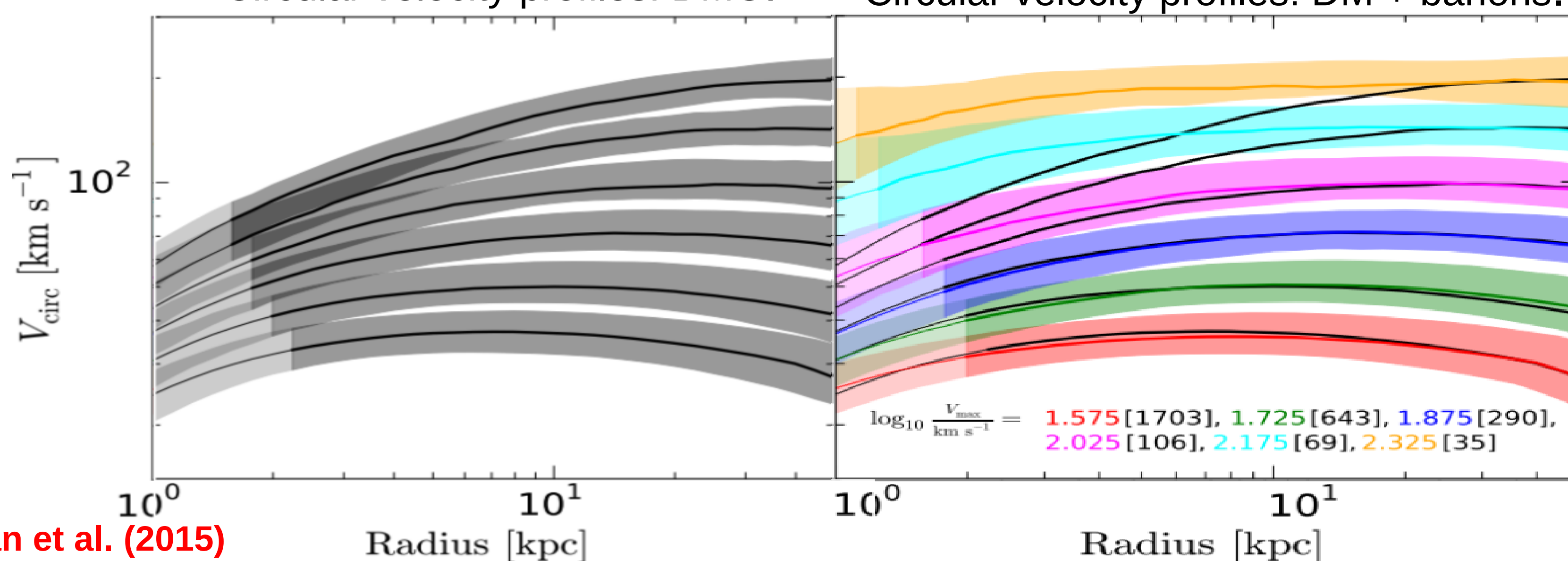


Integrated Kinematics.

Rodriguez-Puebla et al. (2016)

Circular velocity profiles: DMO.

Circular velocity profiles: DM + barions.



Resolved Kinematics.

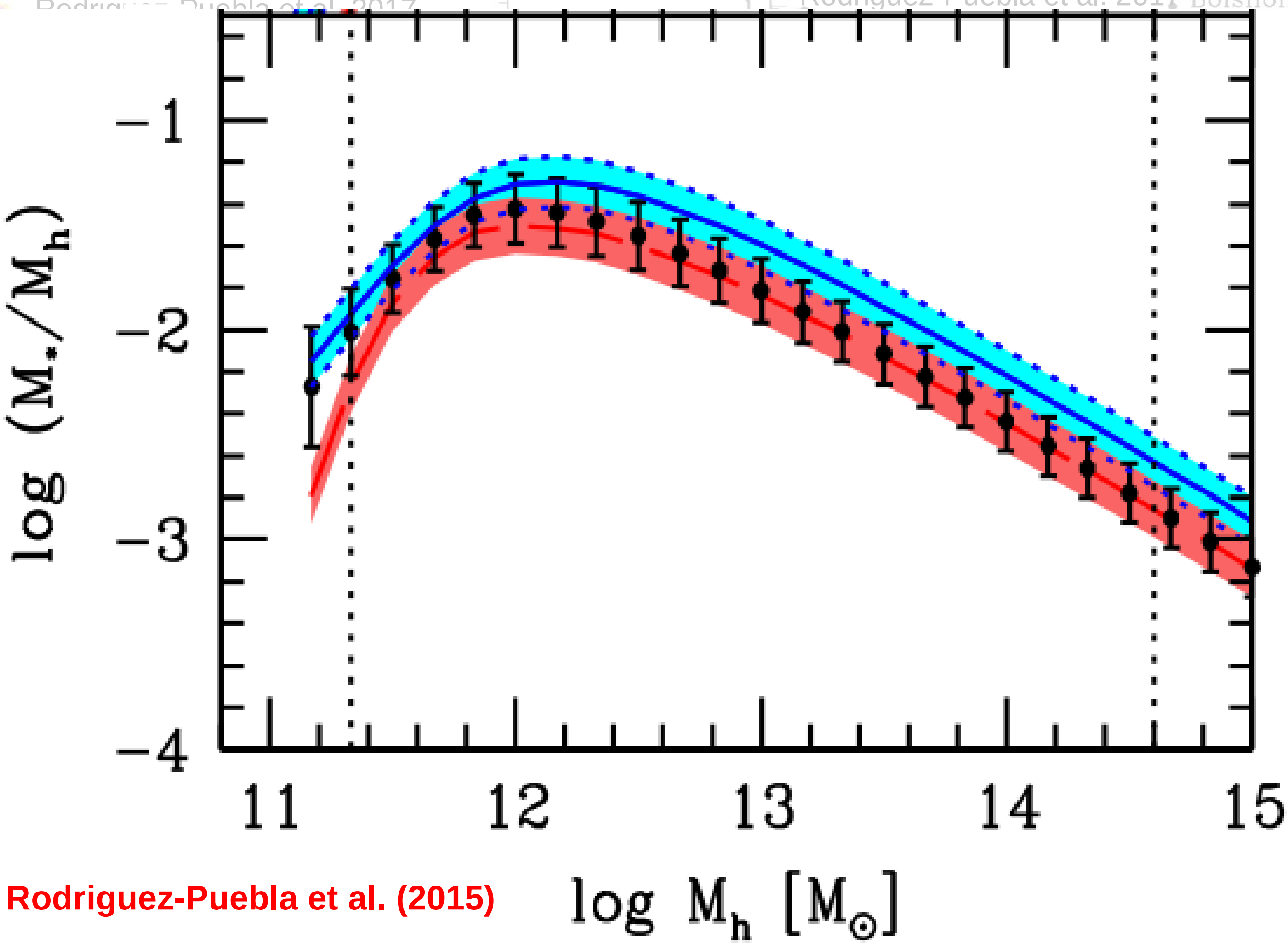
Oman et al. (2015)

Motivation: Statistical prediction; Galaxy-Halo Connection

Halo mass function.

Circular velocity function.

Ms – MH mass function.

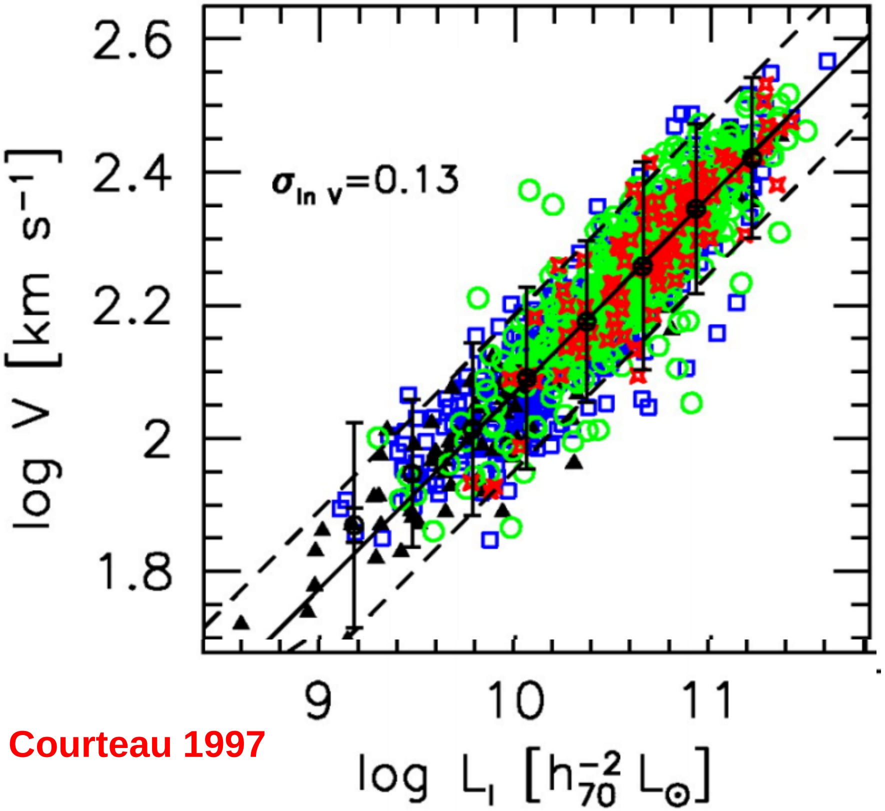


Rodriguez-Puebla et al. (2015)

Integrated Kinematics.

Resolved Kinematics.

Background: Tully-Fisher relation (Spiral galaxies)



Courteau 1997

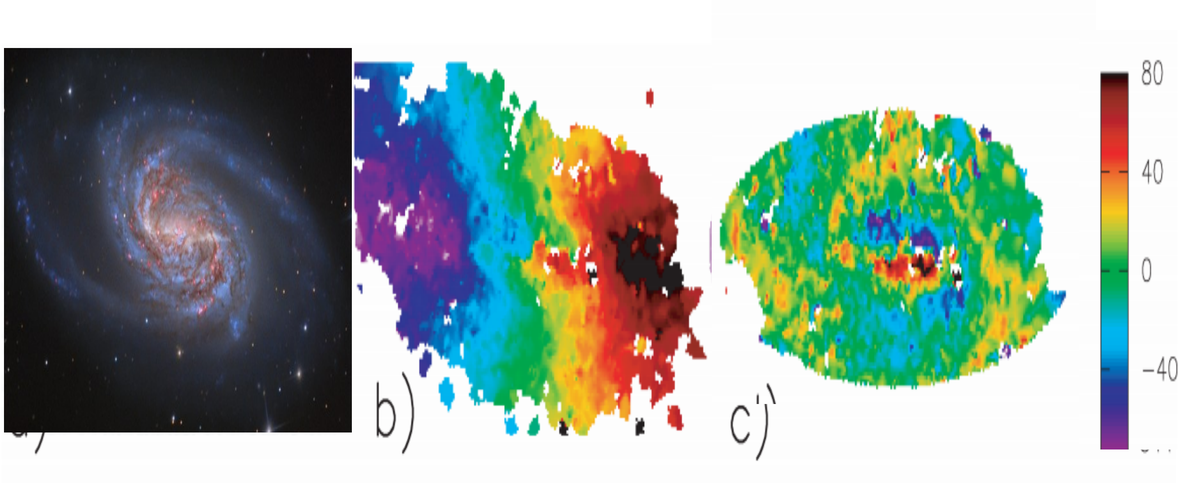
The *empirical* TF.

$$L \propto V^{\alpha}$$

Reported values of the log slope a range from 2.8 in the blue to 4.0 in the infrared.

No circular motions in spiral galaxies.
(e.g. Valenzuela et al. 2007; Randriamampandry et al. 2015; Holmes et al. 2015)

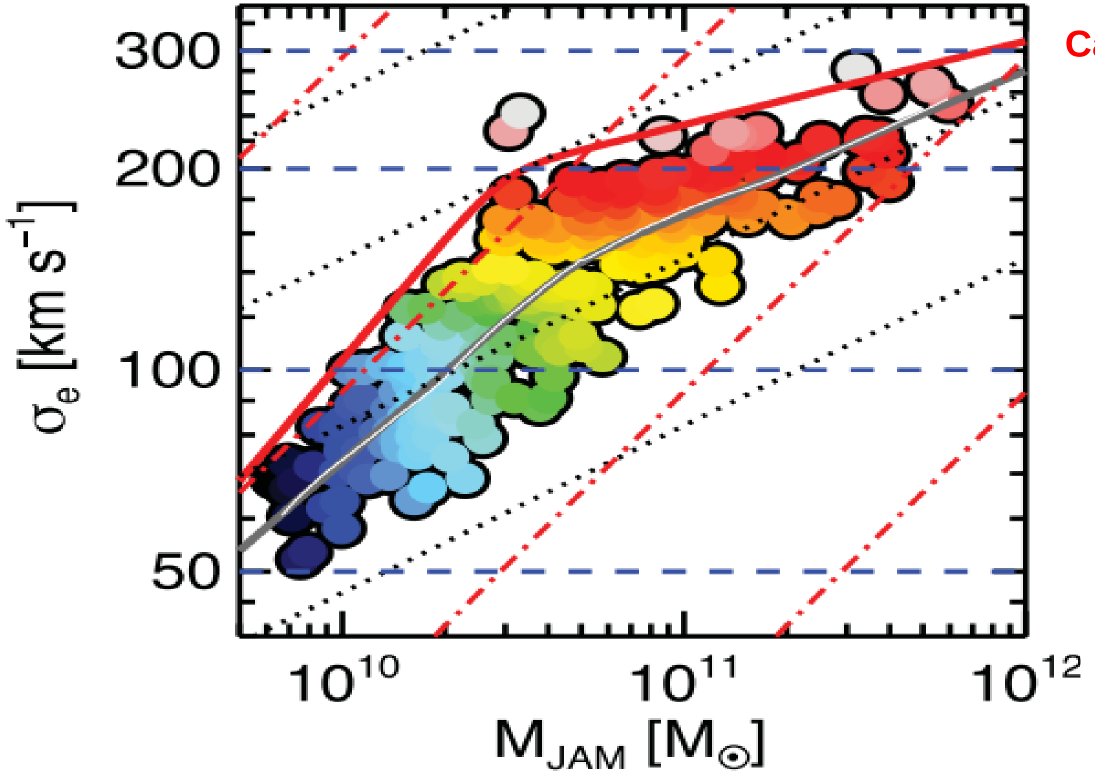
Non-circular motions on disc galaxies may contribute to miss a fraction of the gravitational potential.



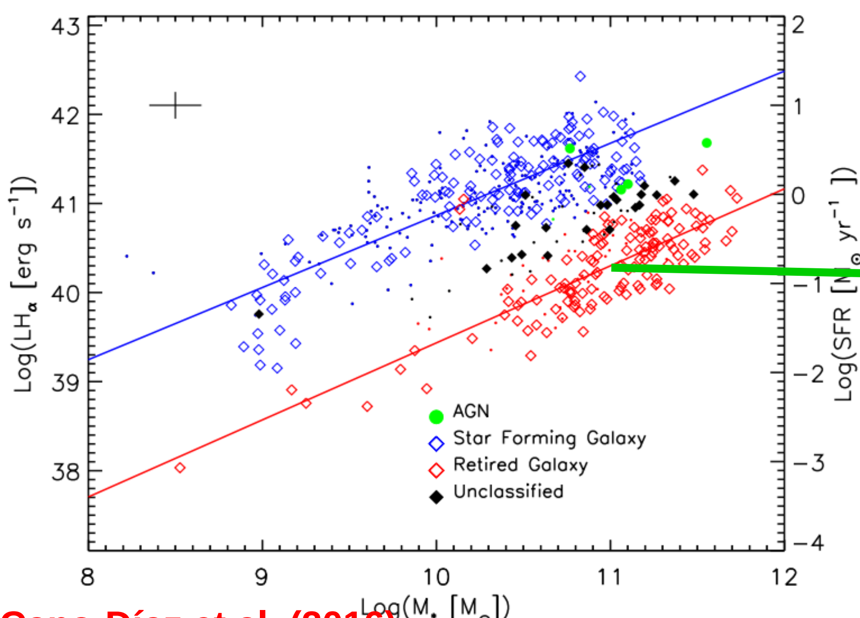
NGC2903

Sppekkens and Sellwood (2007)

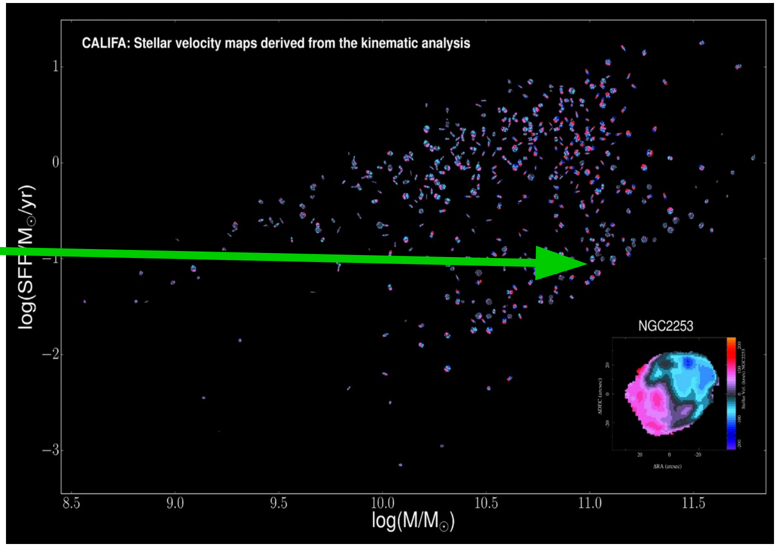
Background: Faber-Jackson relation (Elliptical galaxies)



Capellari et al., (2013)



Cano-Díaz et al. (2016)



Credit: Sebastián Sánchez

Rotation in elliptical galaxies.

Emsellem et al. (2007)
Cappellari et al. (2011)
Emsellem et al. (2011)
Rong et al. (2018)

Background: Generalized kinematic scaling relation

If spiral galaxies dominated by rotation shown no circular motions and ellipticals dominated by velocity dispersion shown rotation.

If galaxies are in equilibrium follow the tensor virial theorem

$$\frac{1}{2}\frac{d^2\mathcal{I}_{jk}}{dt^2} = 2\mathcal{T}_{jk} + \Pi_{jk} + \mathcal{W}_{jk}$$

We evaluate the components of ordered and disordered motions of the kinetic energy and the potential energy:

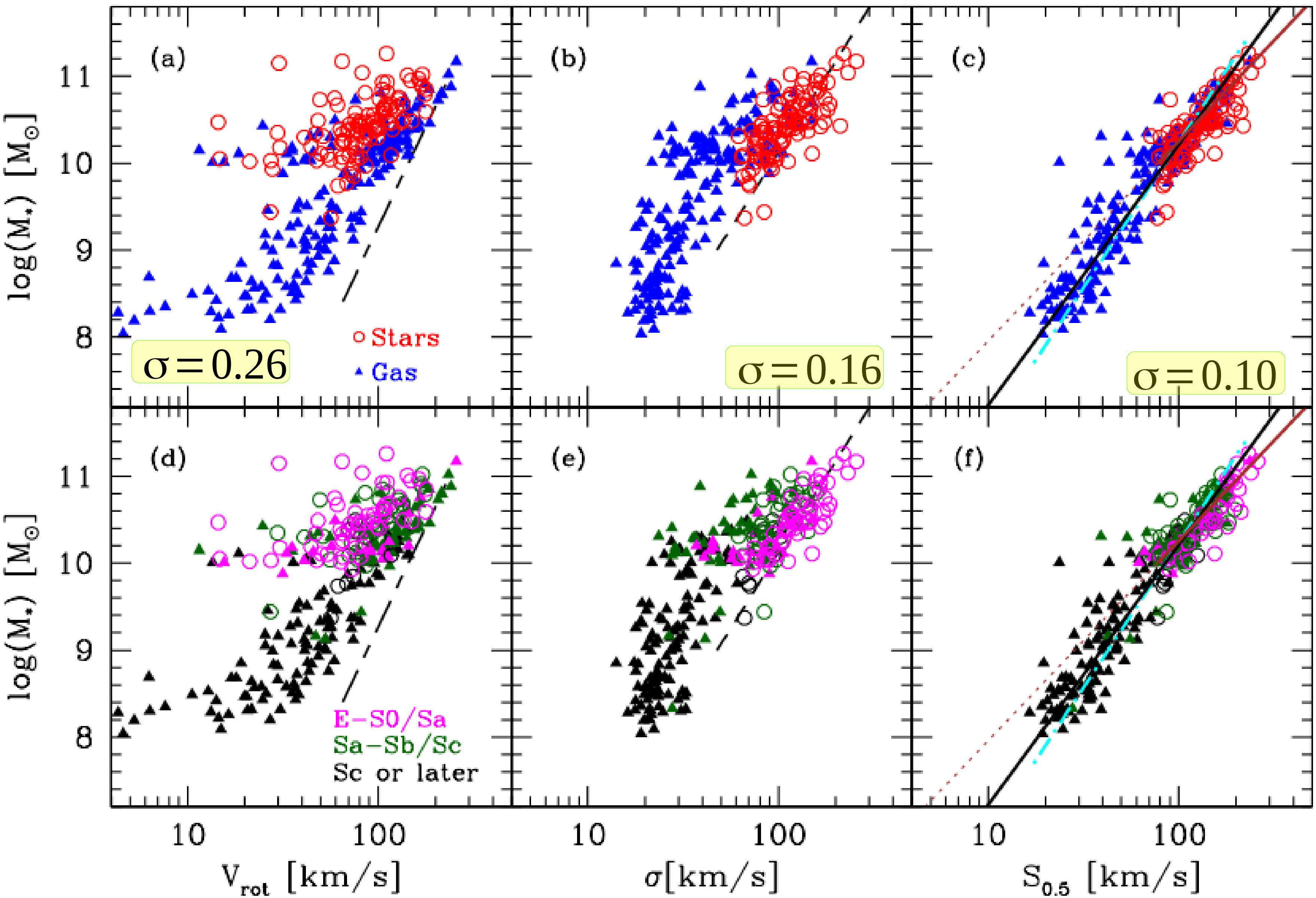
$$\underbrace{A_0 v_c^2 + A_1 \sigma^2}= B_0 \frac{GM}{r_r}$$

Winier et al., (2006)
Kassin et al., (2007)
Zaritsky et al., (2008)

$$S_K^2 = K v_c^2 + \sigma^2 \longrightarrow M_{dyn} = \eta \frac{r_r S_K^2}{G}$$

K and η are different for each galaxy and could be strong functions of the shape of the galaxy, projection effects, dynamical structure, dynamical state, etc.

Background: First study in the local universe **using integrated Kinematics within 1Re**.



Cortese et al. (2014); SAMI Survey

Open questions

Tully – Fisher and Faber – Jackson relation.

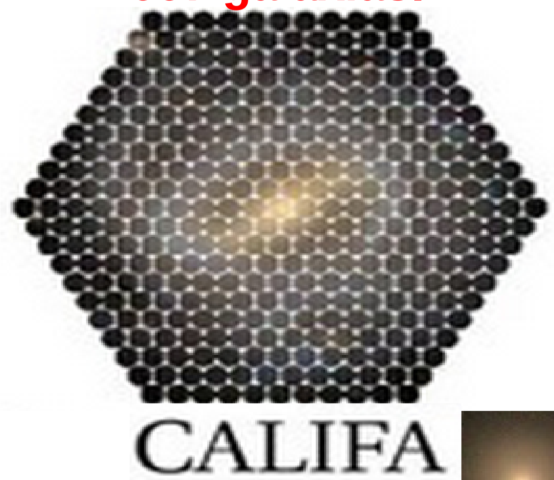
- Are true relationship between **total circular velocity** of dark matter halo and galaxy properties?
- No-circular motions on spirals, rotation on ellipticals, non equilibrium state modify the shape of scaling relations?.
- Bending at low and higher masses in the TFR?
- **Dependence on Dark Matter Nature, Feedback (SN, AGN)**

Ms – Sκ. Relation.

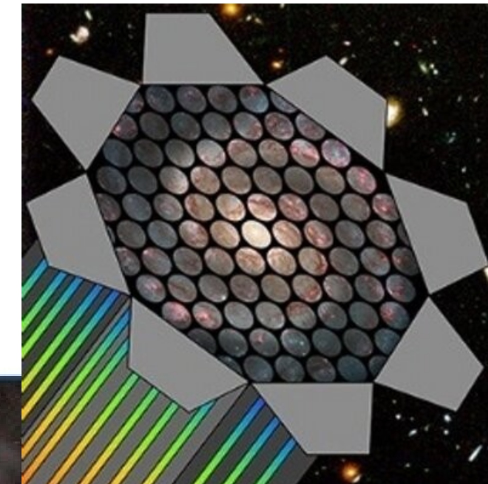
- Is the Sk parameter a true proxy of the gravitational potential?
- Relationship between the SK and TFR of FJR?
- Verify Ms-Mh relation
- **Dependence on Dark Matter Nature, Feedback (SN, AGN)**

Integral field spectroscopy.
Gas and stellar kinematics.

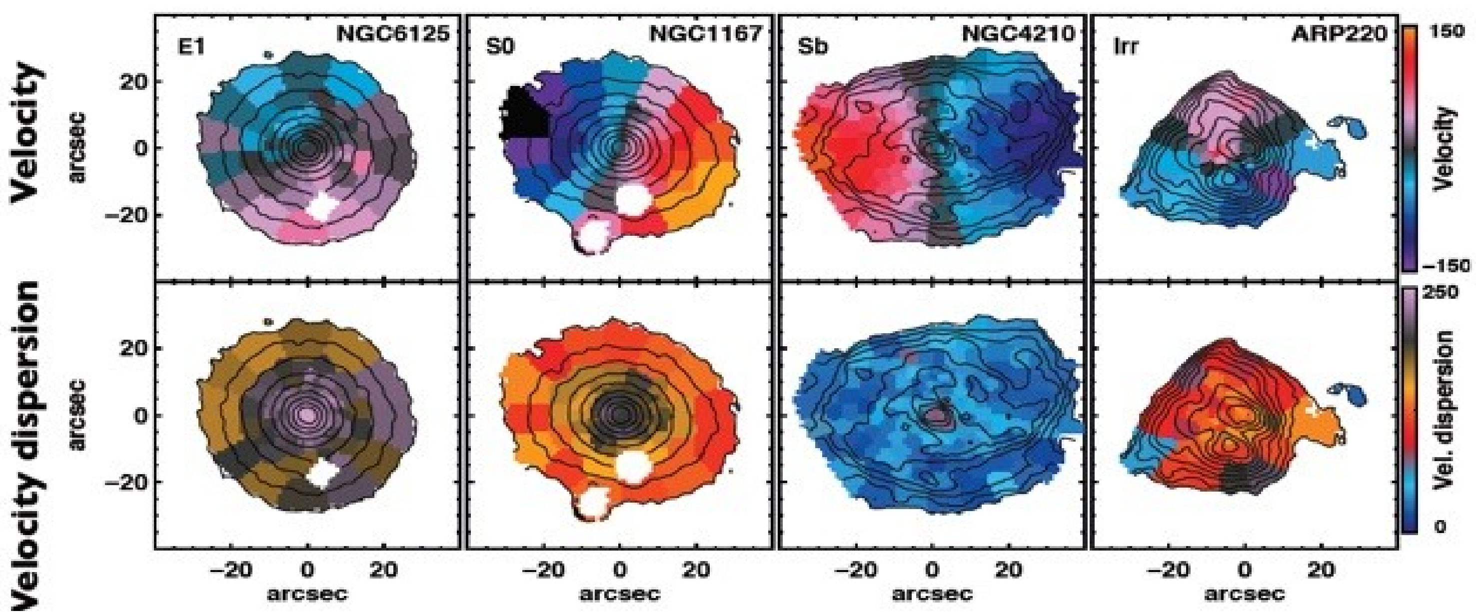
667 galaxias.



10,000 galaxias.



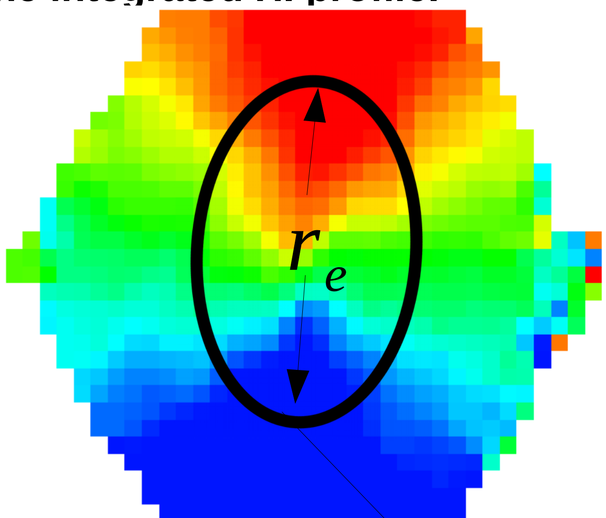
Early and late type galaxies

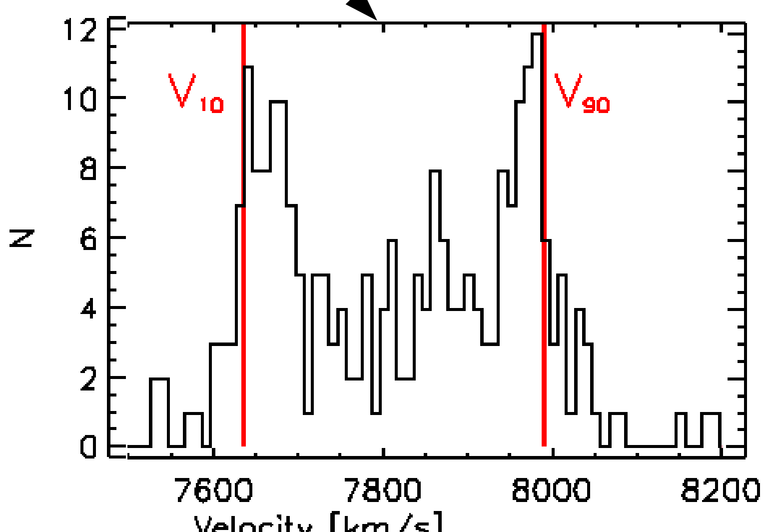


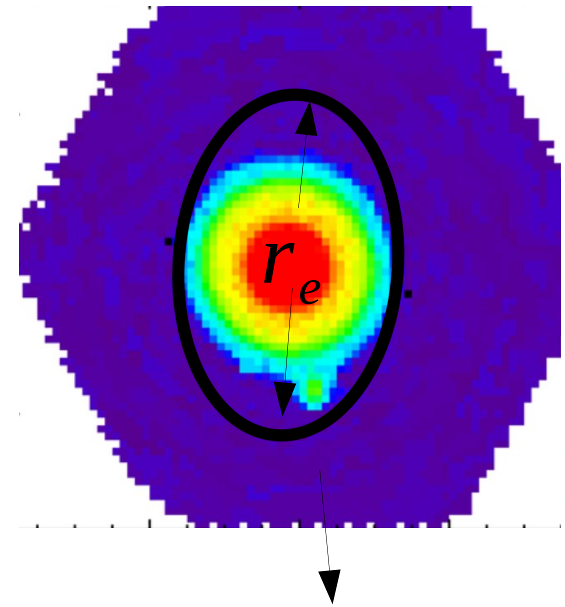
Data products from Pipe3D (Sanchez et al. 2016)

Methodology: Same as Cortese et al. (2014) at **1Re**
How was it done?

We built a line of sight histogram similar to the integrated HI profile.







$$\sigma = \langle \sigma \rangle$$

Widths of the "Profile" (**Catinella et al., 2005**)

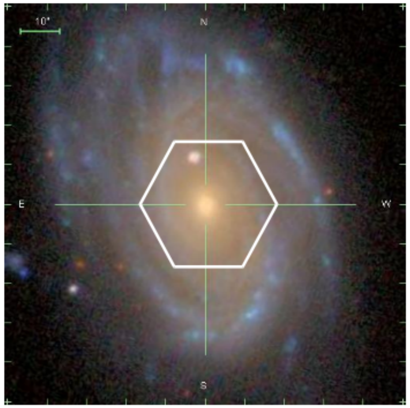
$$\mathbf{W_{80} = W_{90} - W_{10}}$$

$$V_{rot} = \frac{W}{2(1+z)sin(i)}$$

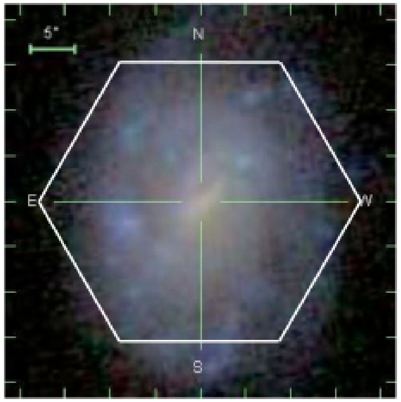
Methodology: Spatially resolved kinematics.

Studying systematics: Velfit tool (Spekkens & Selwood 2007.)

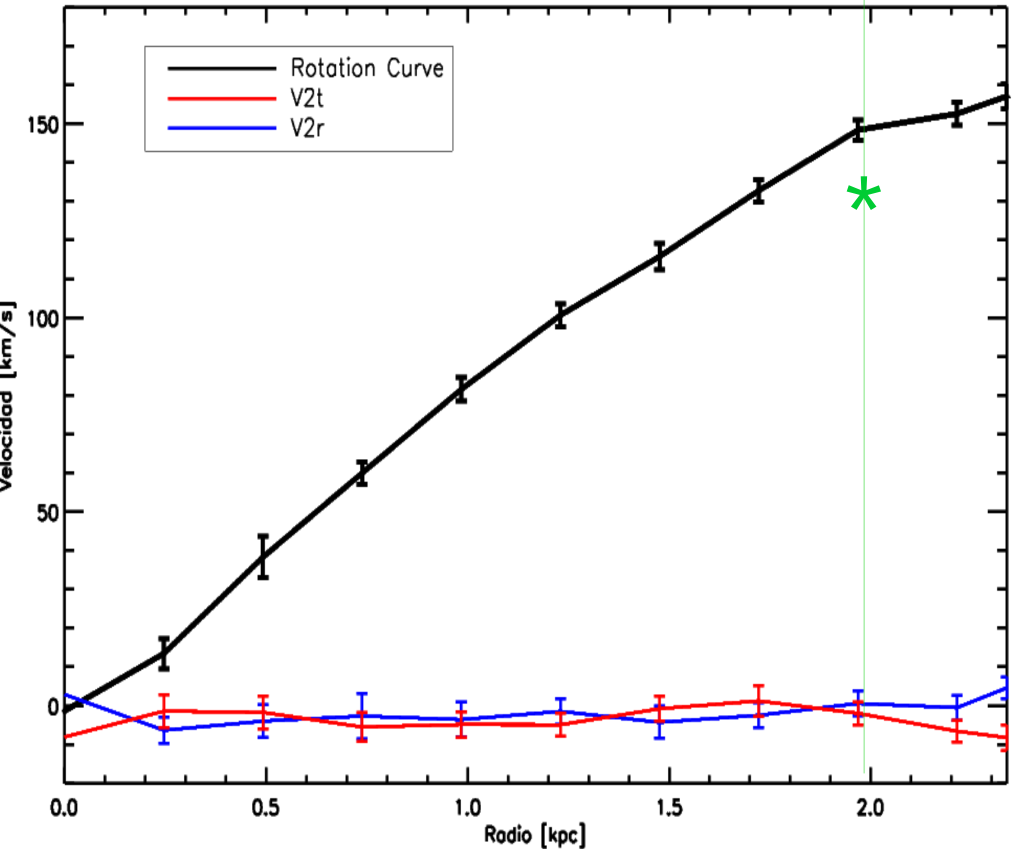
NGC 2906



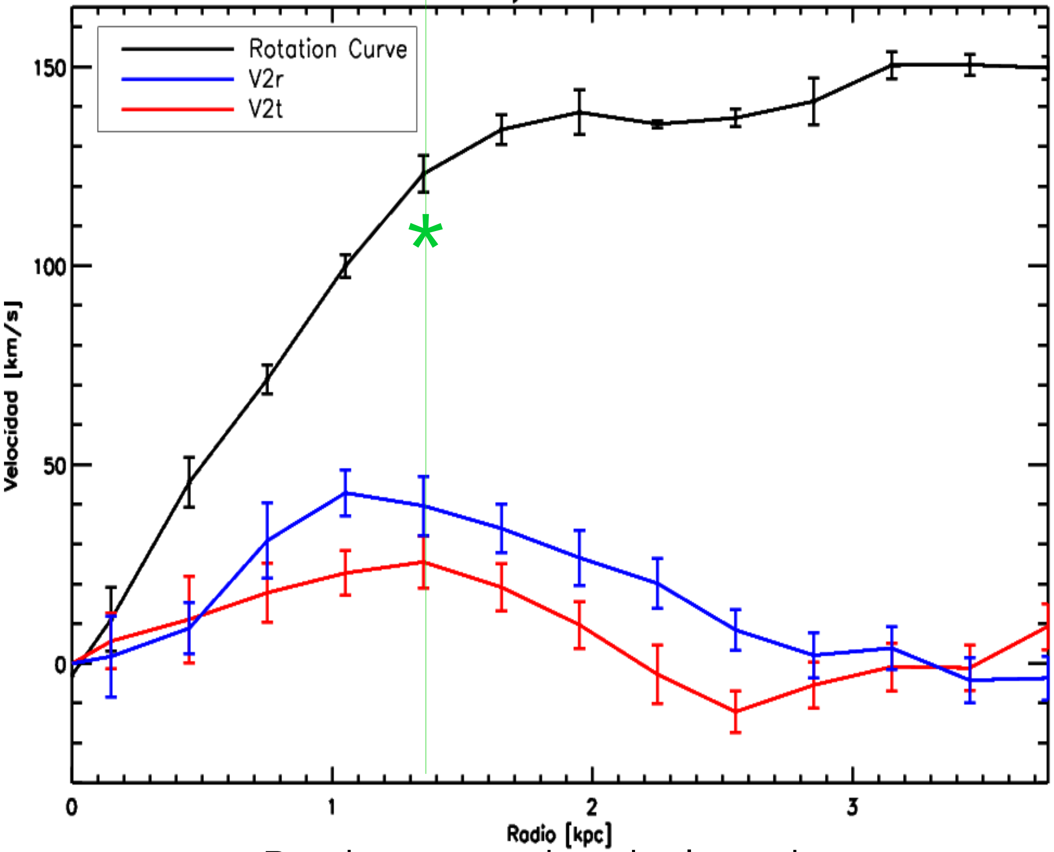
KUG 1354+143



Vrot by integrated kinematics

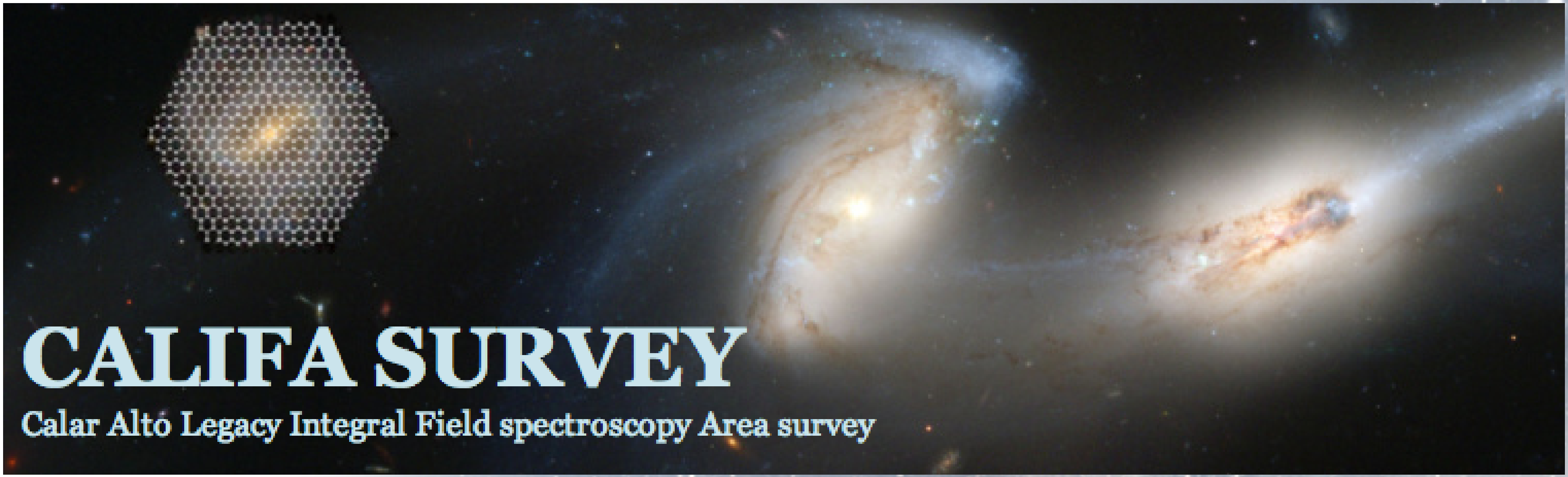


Rotation curve and no-circular motions



Rotation curve and no-circular motions

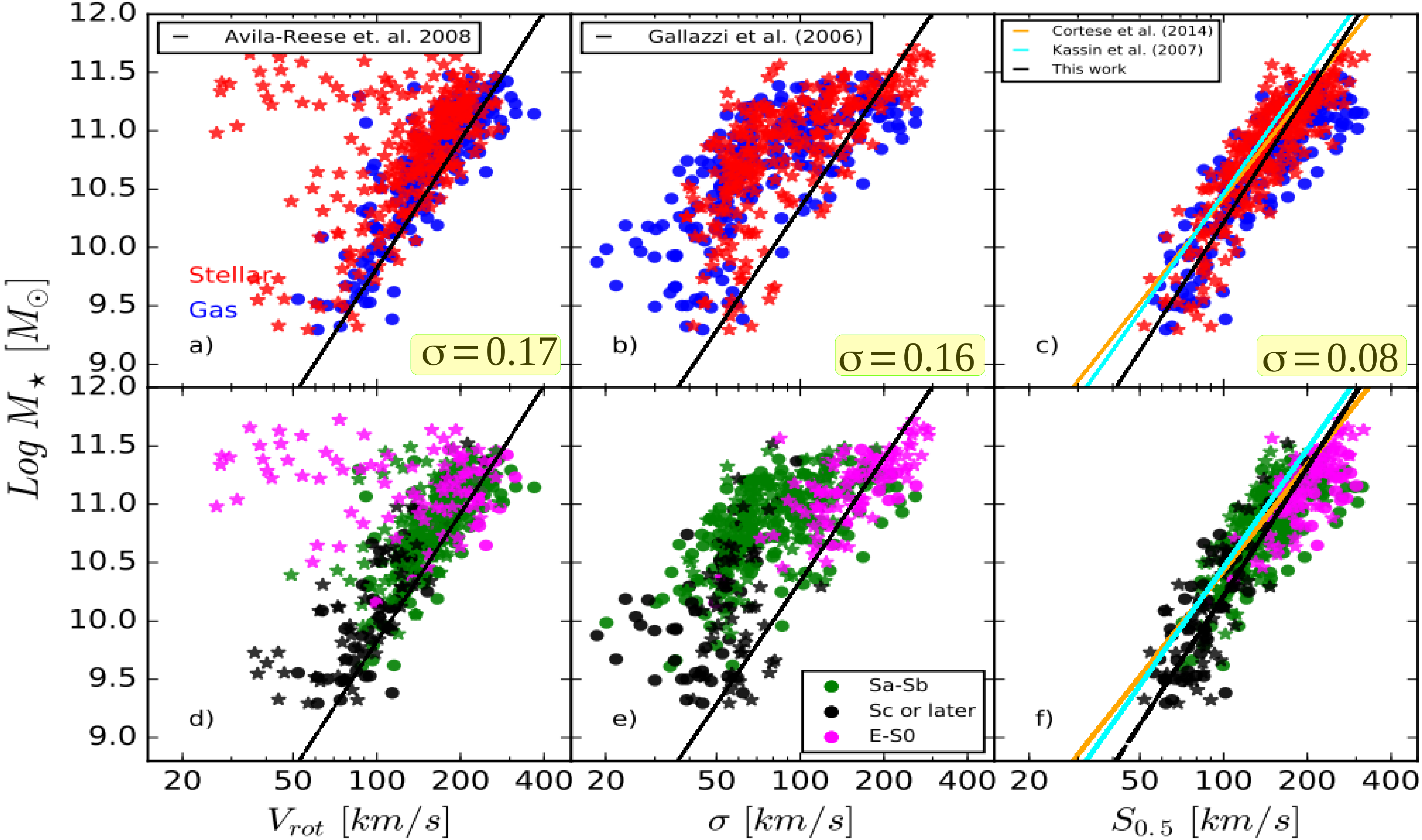
Results using



Results: Integrated kinematics within 1Re

Interacting, mergers and perturbed galaxies are discarded.

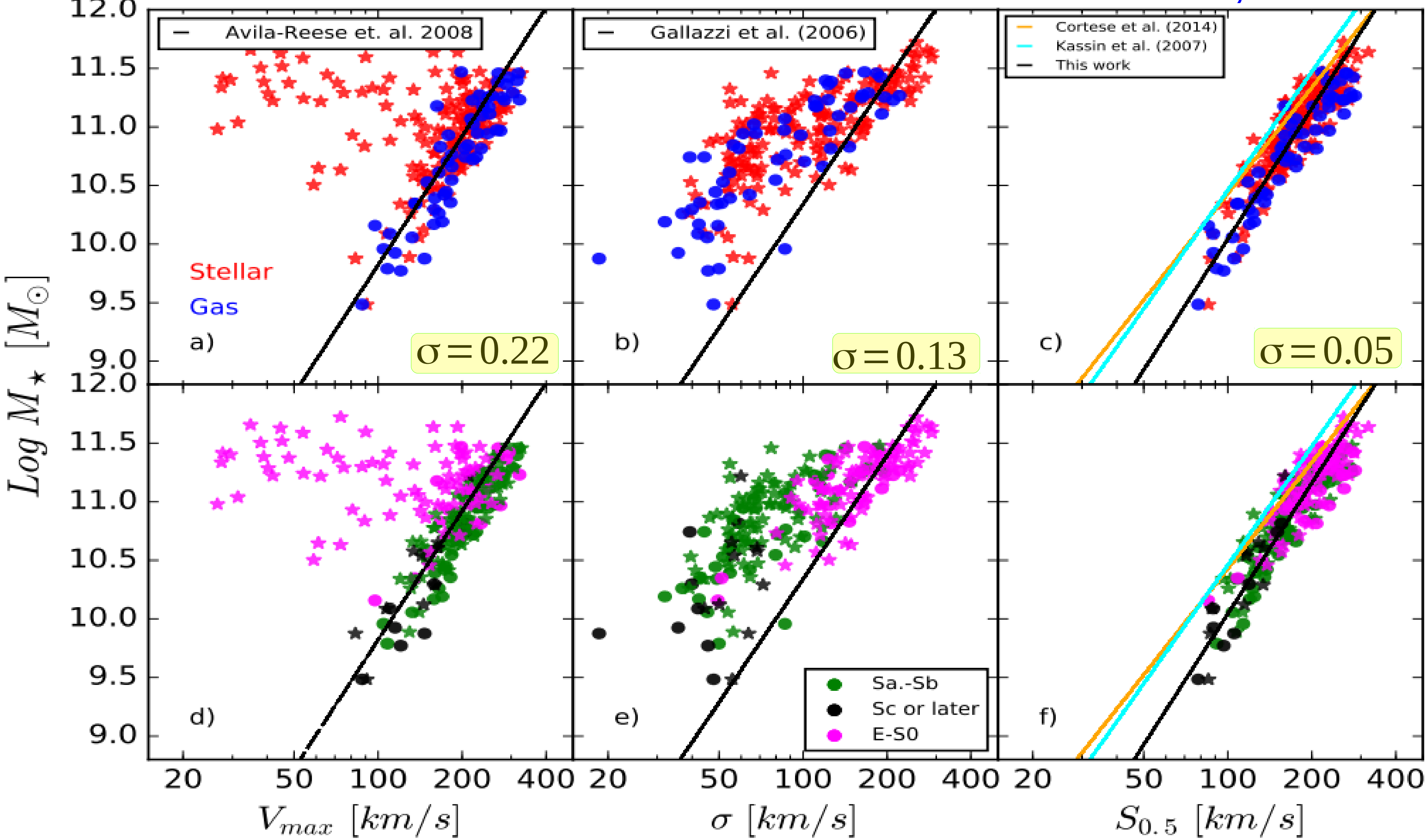
Aquino-Ortíz et al. (2018)
MNRAS 479, 2133-2146



Results: Spatially resolved kinematics.

Interacting, mergers and perturbed galaxies are discarded.

Aquino-Ortíz et al. (2018)
MNRAS 479, 2133-2146



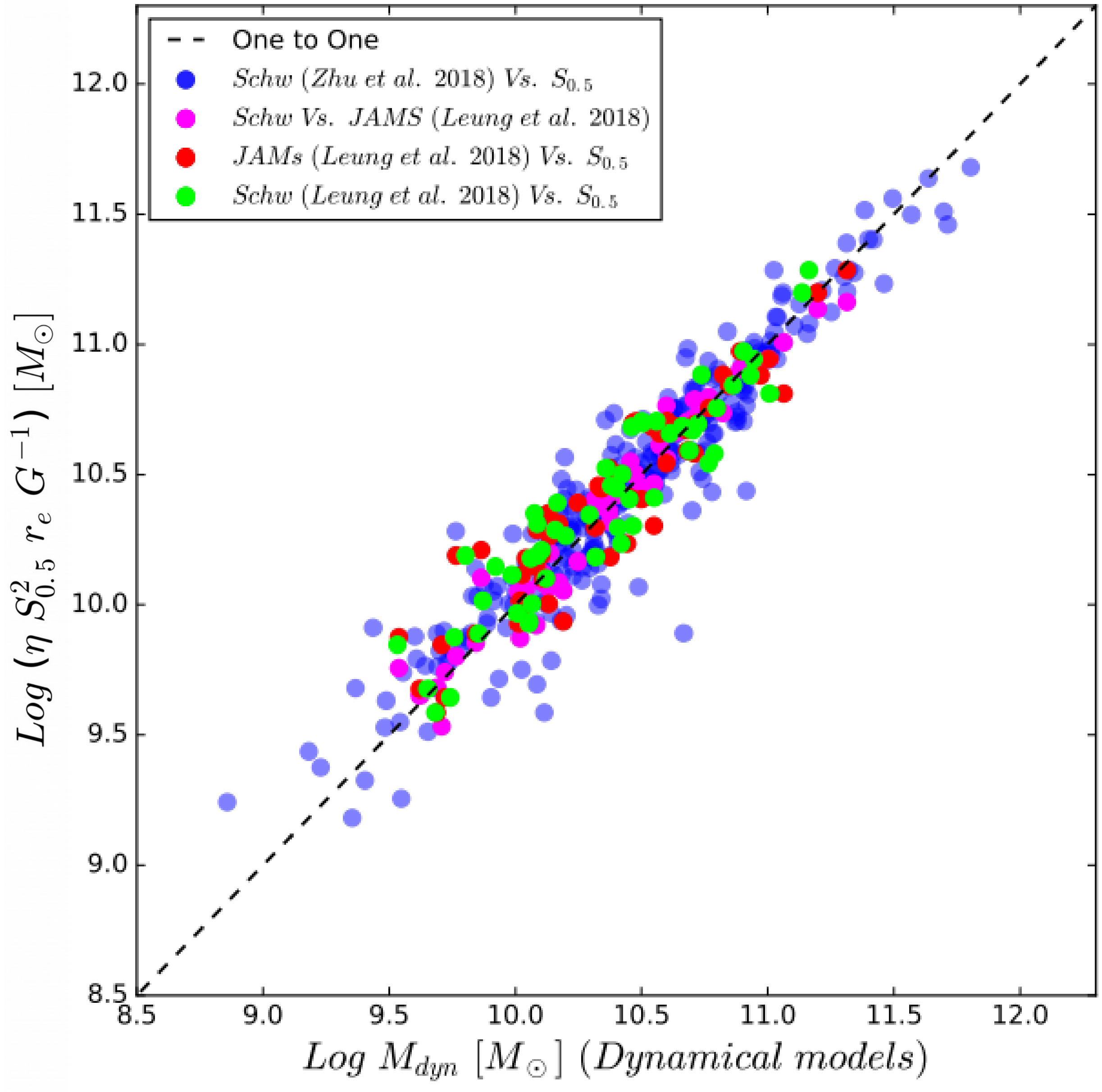
Results: A dynamical mass proxy.

Aquino-Ortíz et al. (2018)
MNRAS 479, 2133-2146

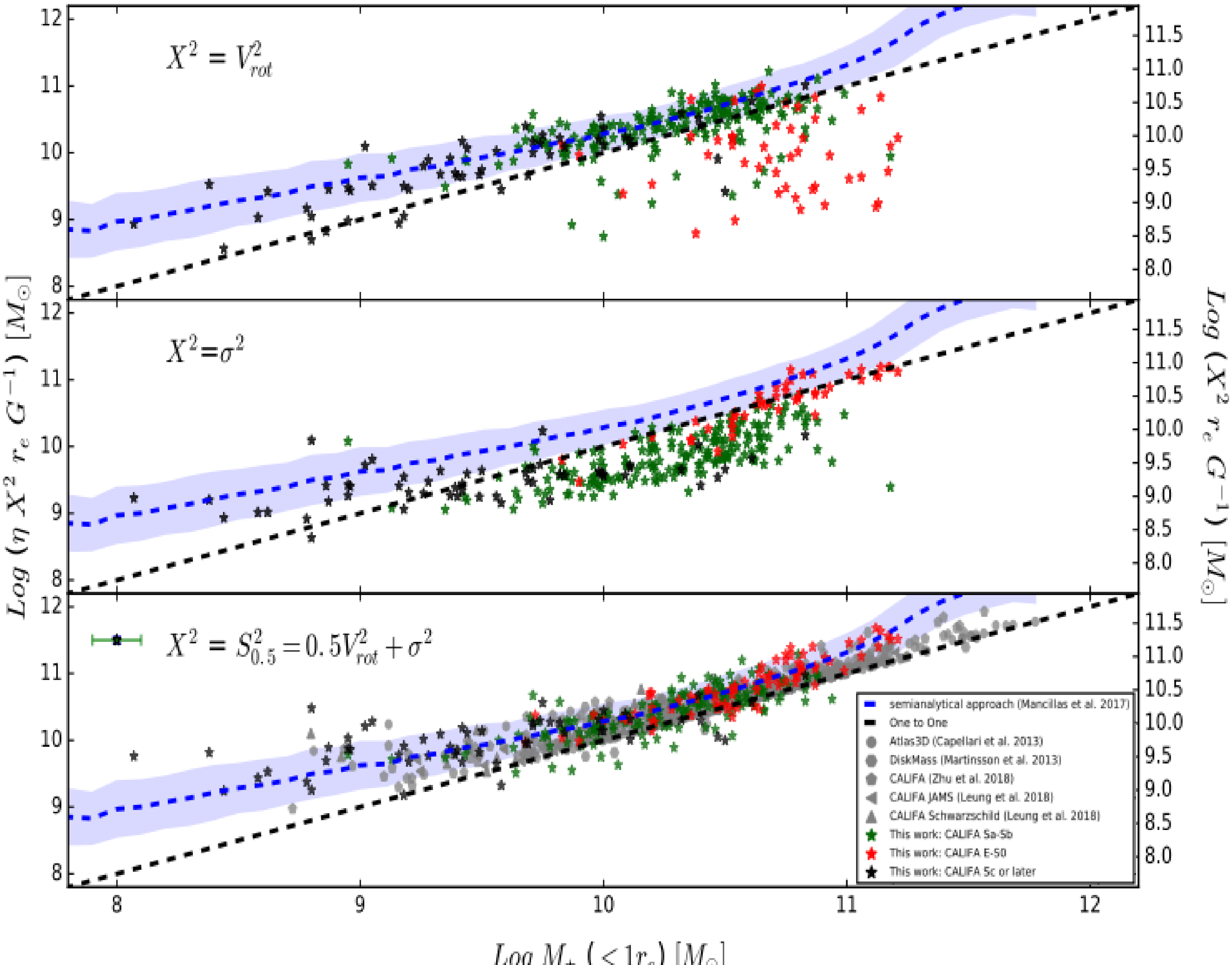
$$M_{dyn} = \eta \frac{r_e S_{0.5}^2}{G}$$

We calibrated the equation using Schwarzschild and JAMs dynamical models from **Leung et al., (2018)** and **Zhu et al. (2018)**.

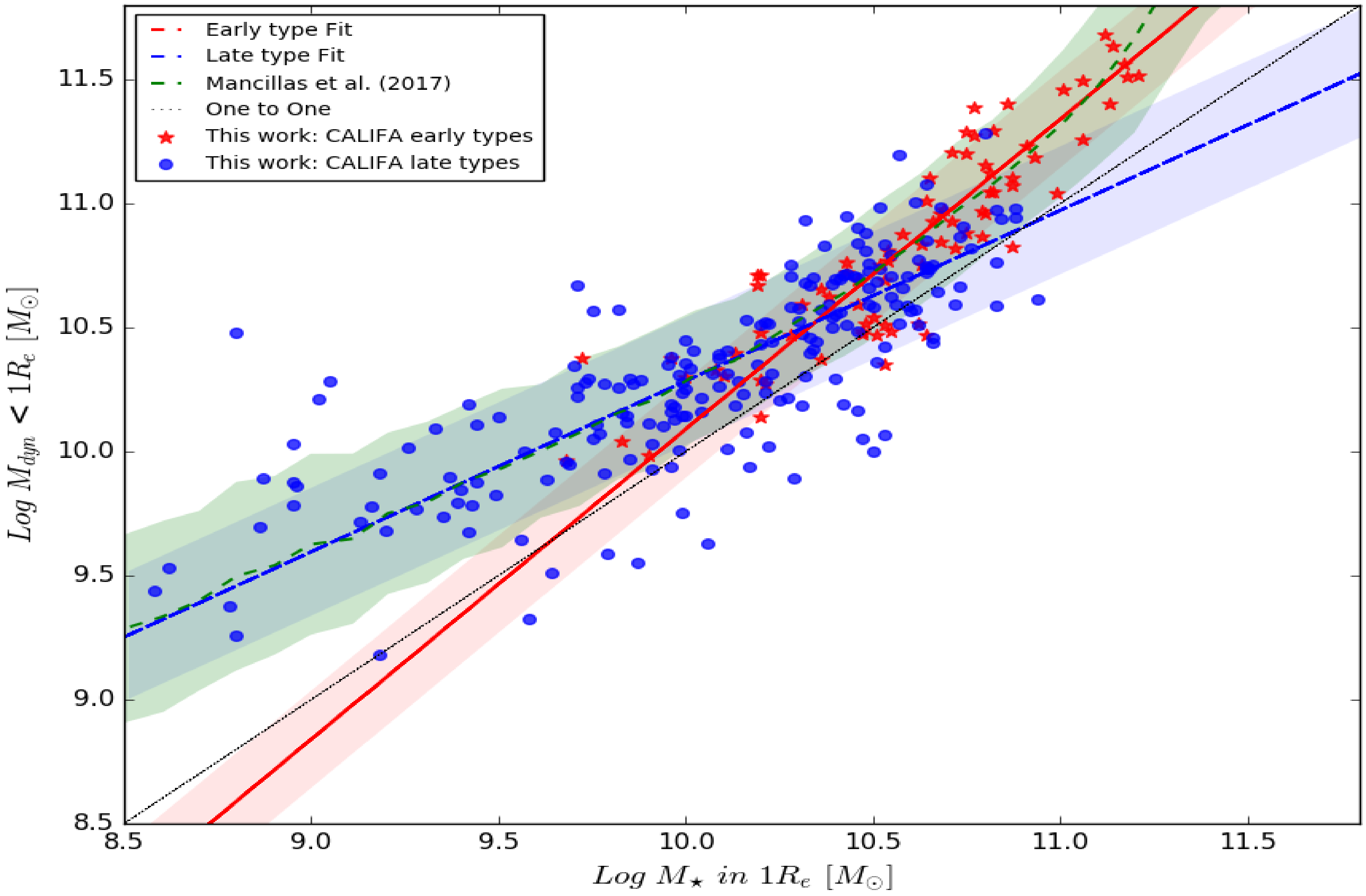
We recover the dynamical mass with $\eta = 1.8$ with a scatter of 0.15dex.



Results with CALIFA galaxies. Our proxy is almost as good as detailed dynamical models



Results: Towards constraining the M_S-M_H relation: Sensitive to baryon-dark matter interaction.



Aquino-Ortíz et al. In prep.

Published paper (Aquino-Ortíz et al., 2018).
A simple tool to estimate dynamical masses in huge surveys

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

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Kinematic scaling relations of CALIFA galaxies: A dynamical mass proxy for galaxies across the Hubble sequence

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ABSTRACT

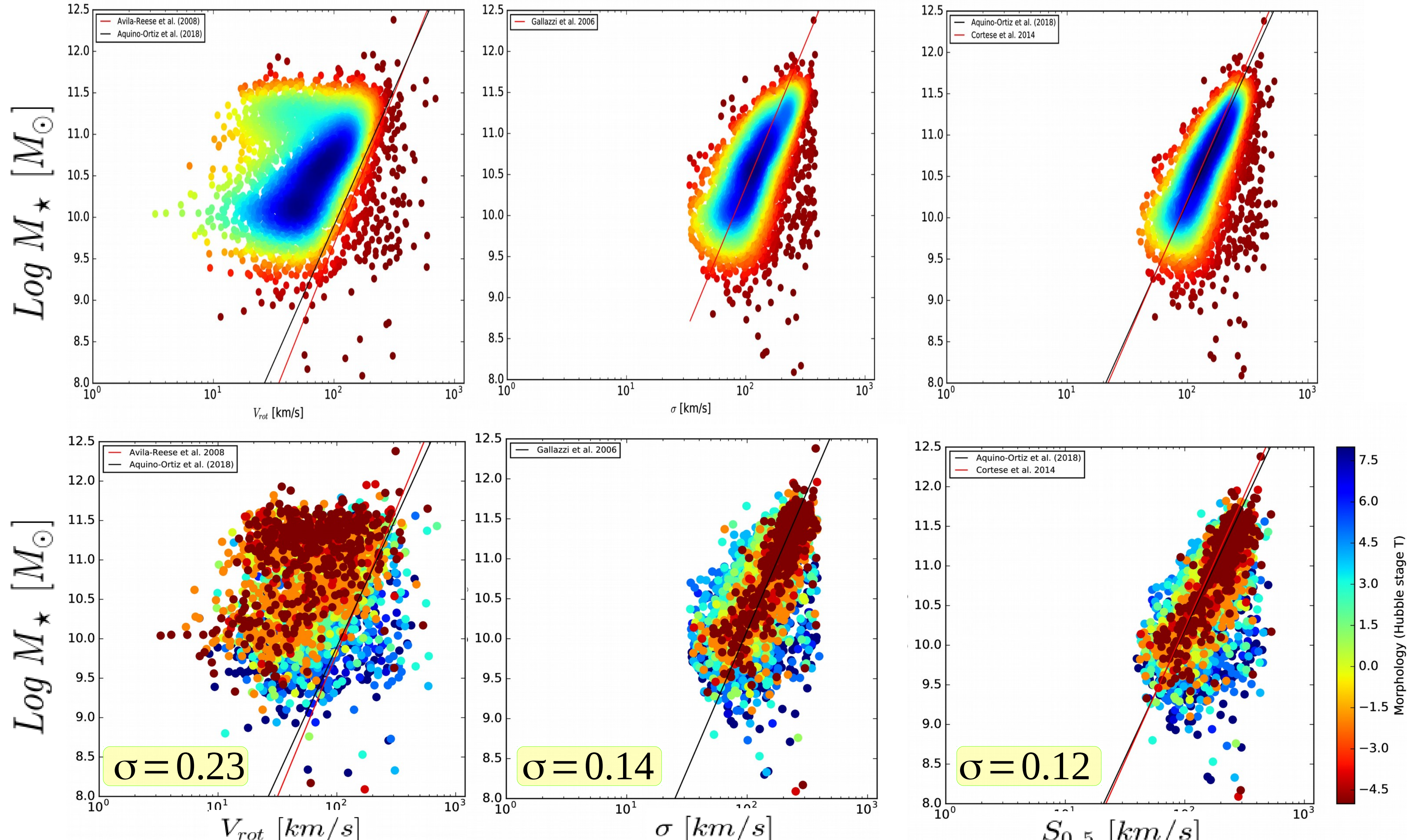
We used ionized gas and stellar kinematics for 667 spatially resolved galaxies publicly available from the Calar Alto Legacy Integral Field Area survey (CALIFA) third Data Release with the aim of studying kinematic scaling relations as the Tully & Fisher (TF) relation using rotation velocity, V_{rot}, the Faber & Jackson (FJ) relation using velocity dispersion, σ, and also a combination of V_{rot} and σ through the S_K parameter defined as $S_K^2 = KV_{rot}^2 + \sigma^2$ with constant K. Late-type and early-type galaxies reproduce the TF and FJ relations. Some early-type galaxies also follow the TF relation and some late-type galaxies the FJ relation, but always with larger scatter. On the contrary, when we use the S_K parameter, all galaxies, regardless of the morphological type, lie on the same scaling relation, showing a tight correlation with the total stellar mass, $M_\star$. Indeed, we find that the scatter in this relation is smaller or equal to that of the TF and FJ relations. We explore different values of the K parameter without significant differences (slope and scatter) in our final results with respect to the case $K = 0.5$ besides a small change in the zero-point. We calibrate the kinematic S_K^2 dynamical mass proxy in order to make it consistent with sophisticated published dynamical models within 0.15 dex. We show that the S_K proxy is able to reproduce the relation between the dynamical mass and the stellar mass in the inner regions of galaxies. Our result may be useful in order to produce fast estimations of the central dynamical mass in galaxies and to study correlations in large galaxy surveys.

Results using MANGA survey.
~ 4,000 galaxies

Results: Kinematic scaling relations
Including merger, interacting, inclined galaxies.

Stellar kinematics: 3950 galaxies

Aquino-Ortíz et al. In prep.

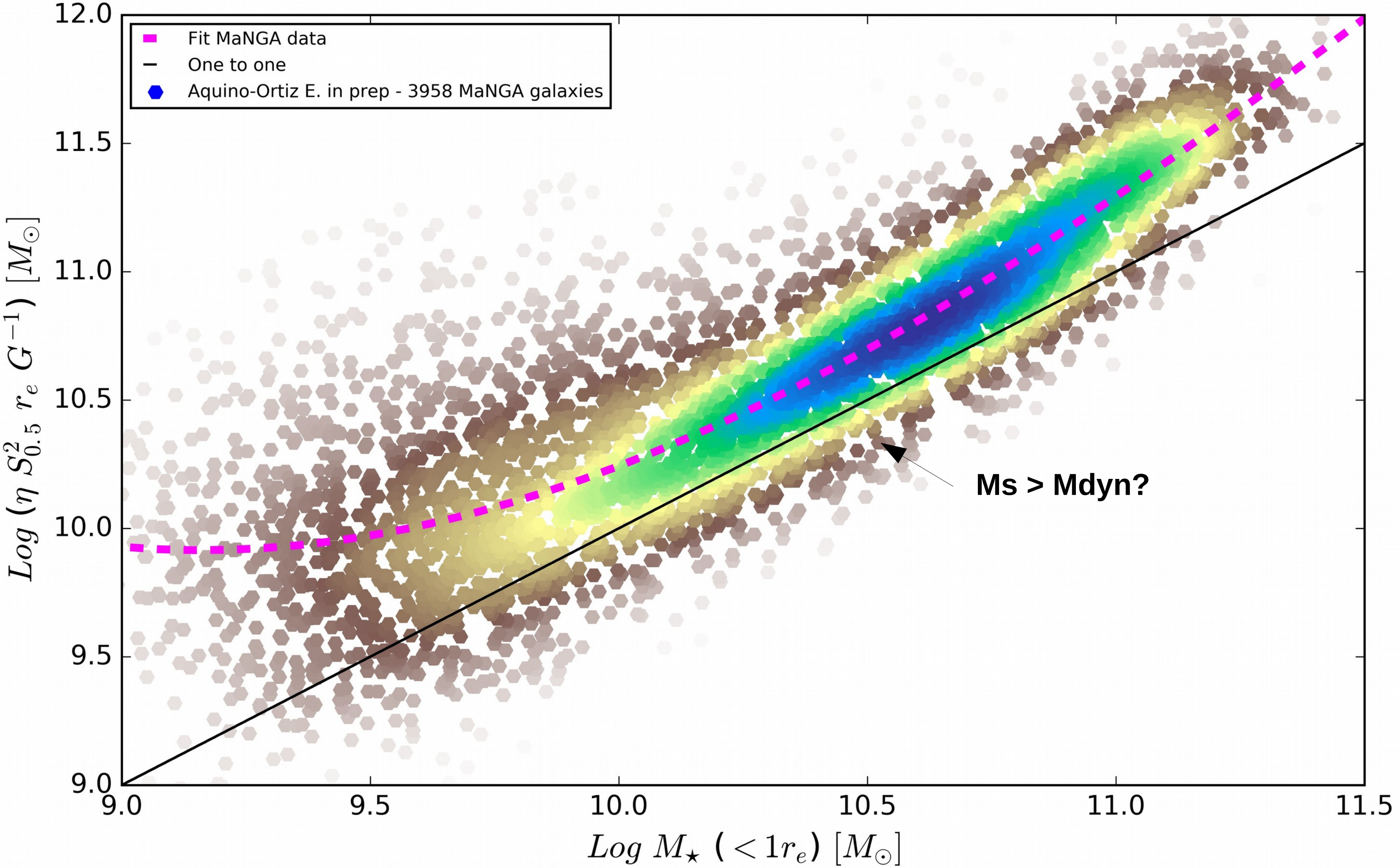


Results: Dynamic to stellar mass relation

Towards constraining the Ms-MH relation.

$$M_{dyn} = \eta \frac{r_e S_{0.5}^2}{G}$$

Aquino-Ortíz et al. In prep.

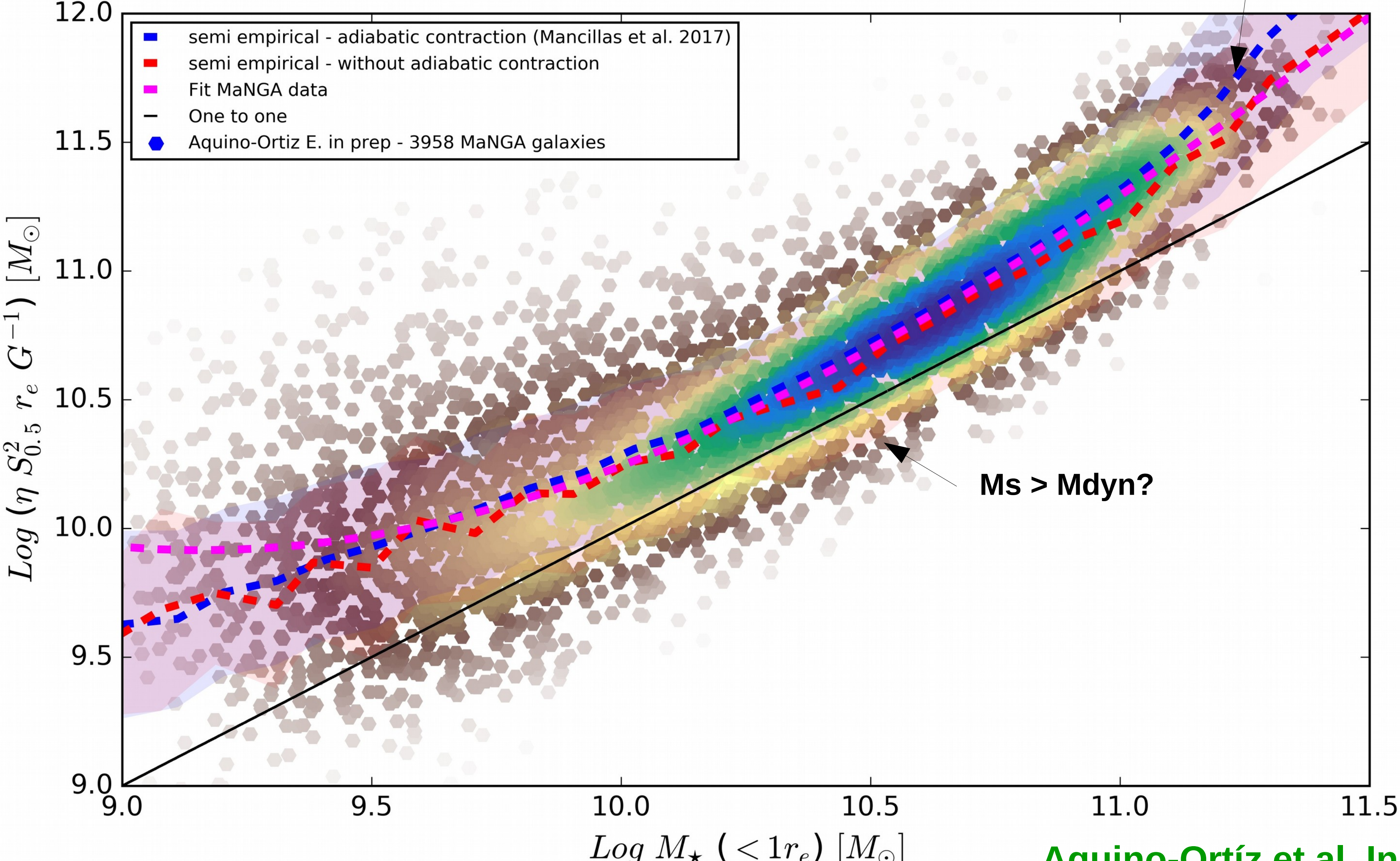


Results: Dynamic to stellar mass relation

Towards constraining the Ms-MH relation.

Adiabatic contraction:
Barions - dark matter interaction.
* Feedback (SN, AGN)
* Dark Matter Compressibility
* Model of Gravity

$$M_{dyn} = \eta \frac{r_e S_{0.5}^2}{G}$$



Aquino-Ortíz et al. In prep.

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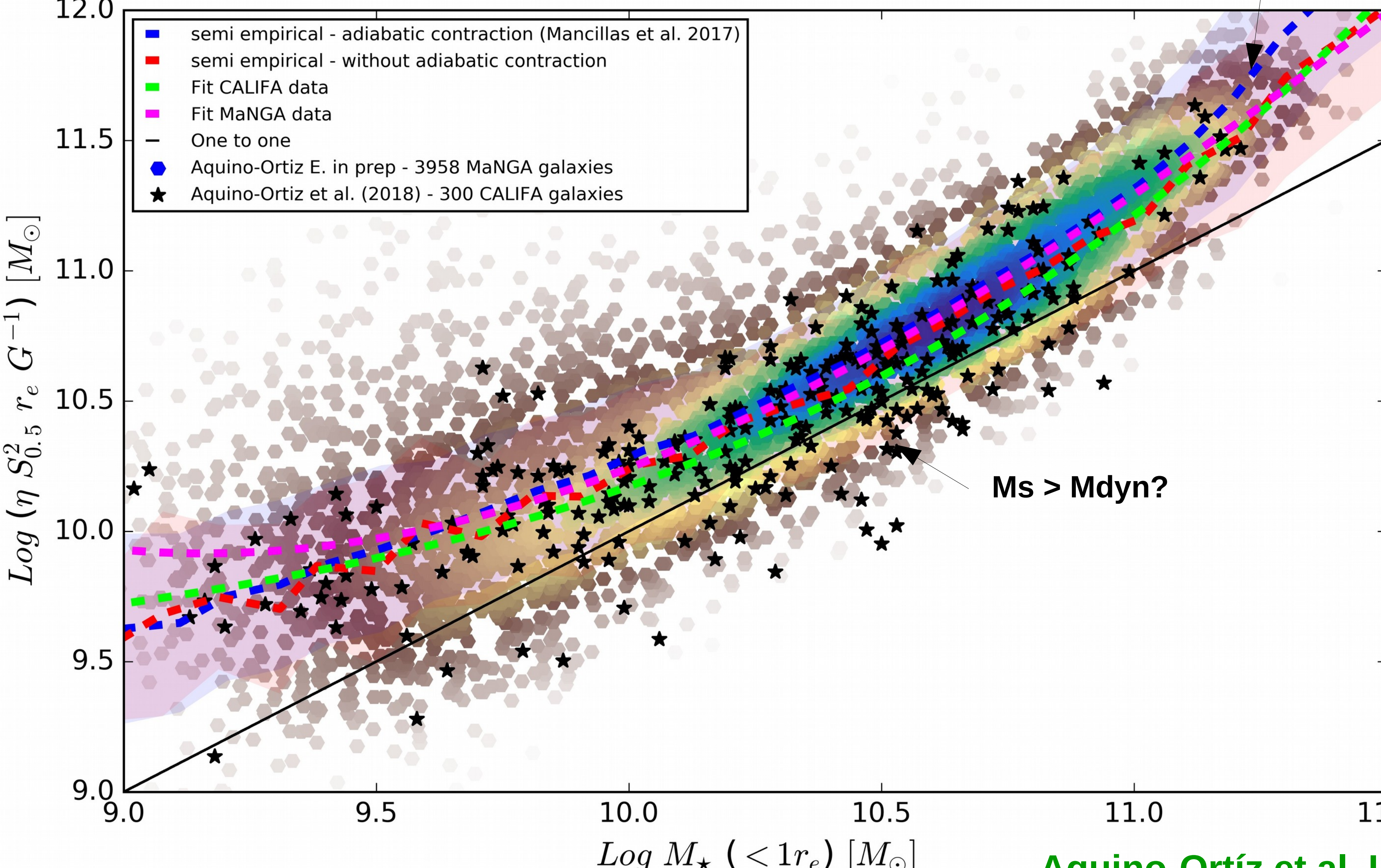


Aquino-Ortíz et al. In prep.

Conclusions.

- A **detailed kinematic analysis is required** to avoid biases due to aperture effects, projection effects or non-circular motions.

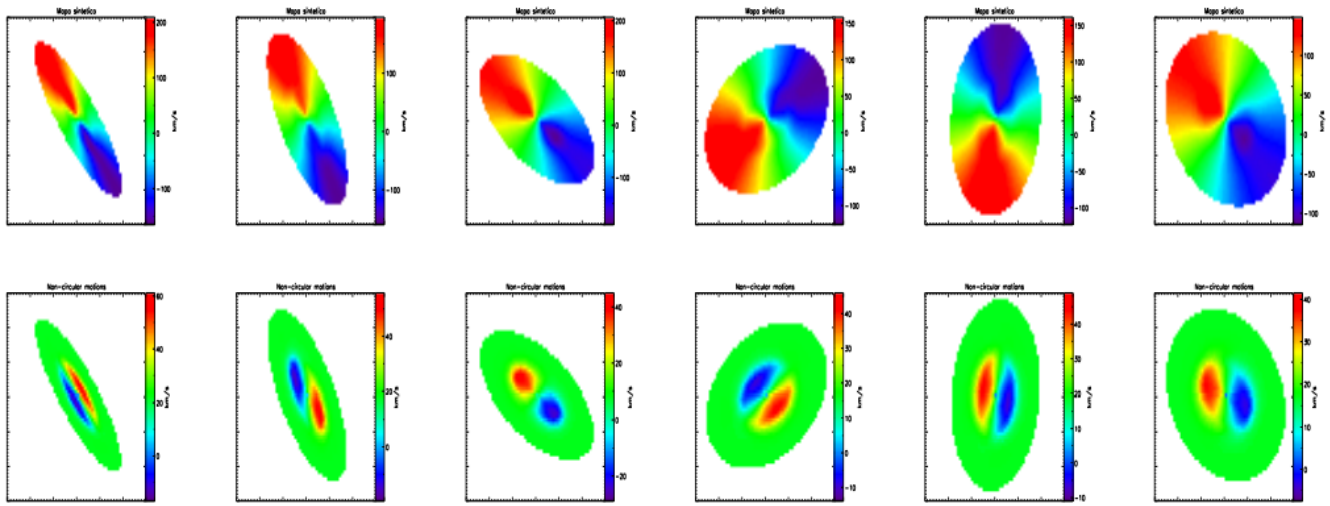
- We confirm that the **Ms-Sκ scaling relation is tighter than the TF and FJ relations** for all type galaxies.

- The remarkable reduction in the scatter of the Ms-Sκ relation shows that **the internal kinematics of galaxies is more complex: early type galaxies show rotation** and **late type galaxies show no circular motion.**

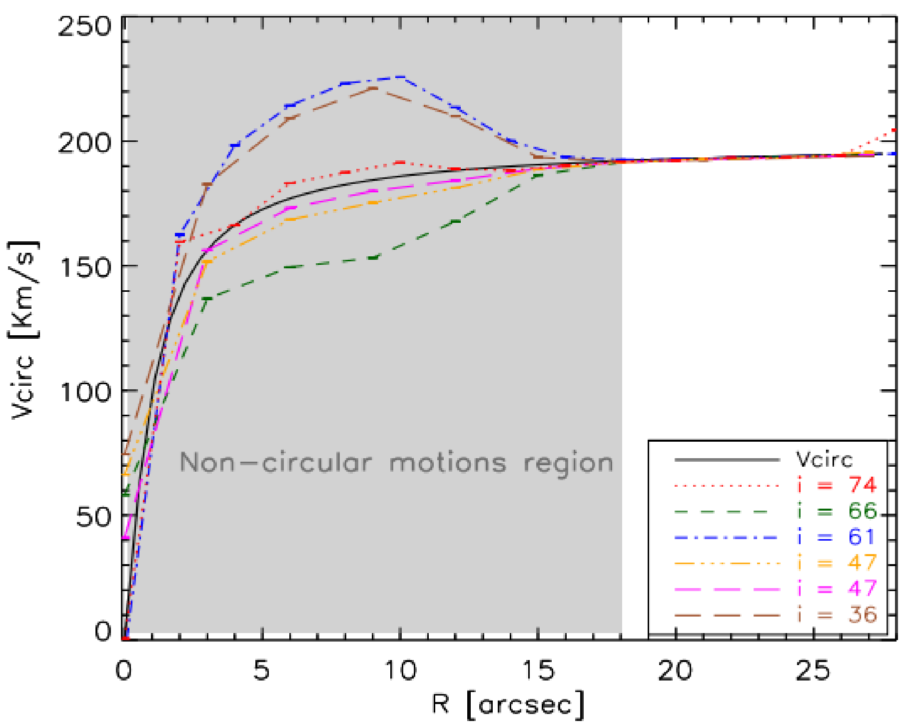
- The **Sκ parameter is a simple and competitive procedure to estimate the dynamical mass in galaxies**, easier to do in huge surveys (e.g. MaNGA) that detailed analysis (e.g. dynamical models), but with lower precision.

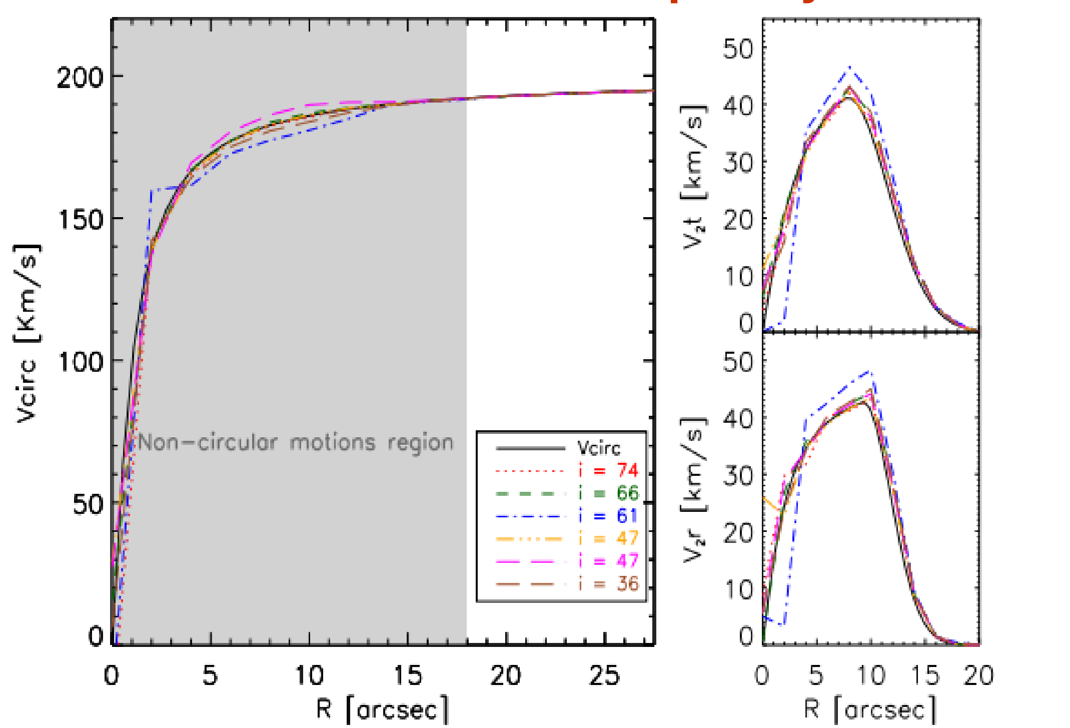
- Our preliminary results test both: the adiabatic contraction models of dark halos (SN and AGN feedback) and the compressibility of dark matter. **The results suggest that there is no adiabatic contraction or the dark matter is not so compressible (WDM, Axion/Fuzzy dark matter, self-interacting dark matter).**

Testing biases in the kinematic modeling.

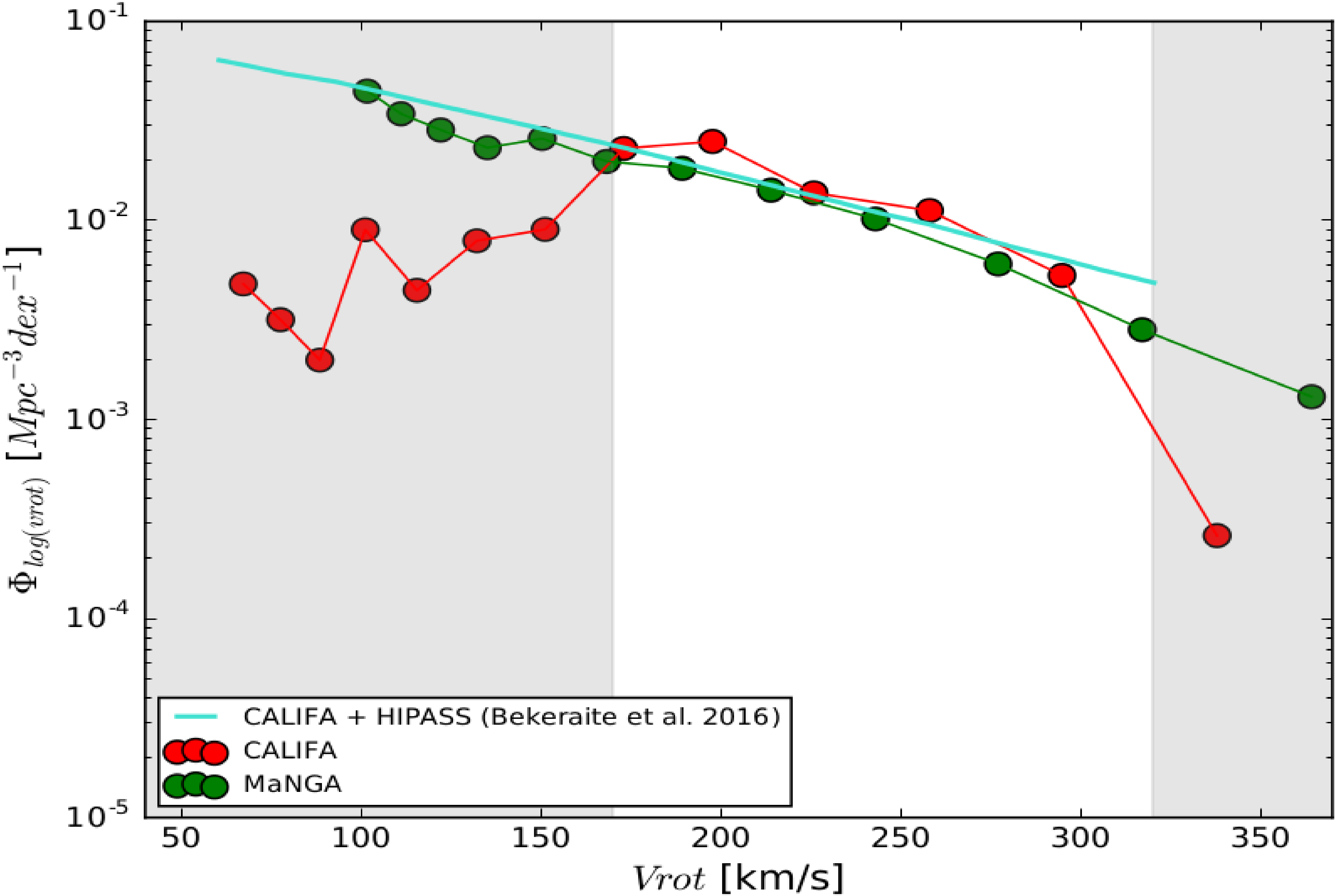


Randriamampandry et al. 2015



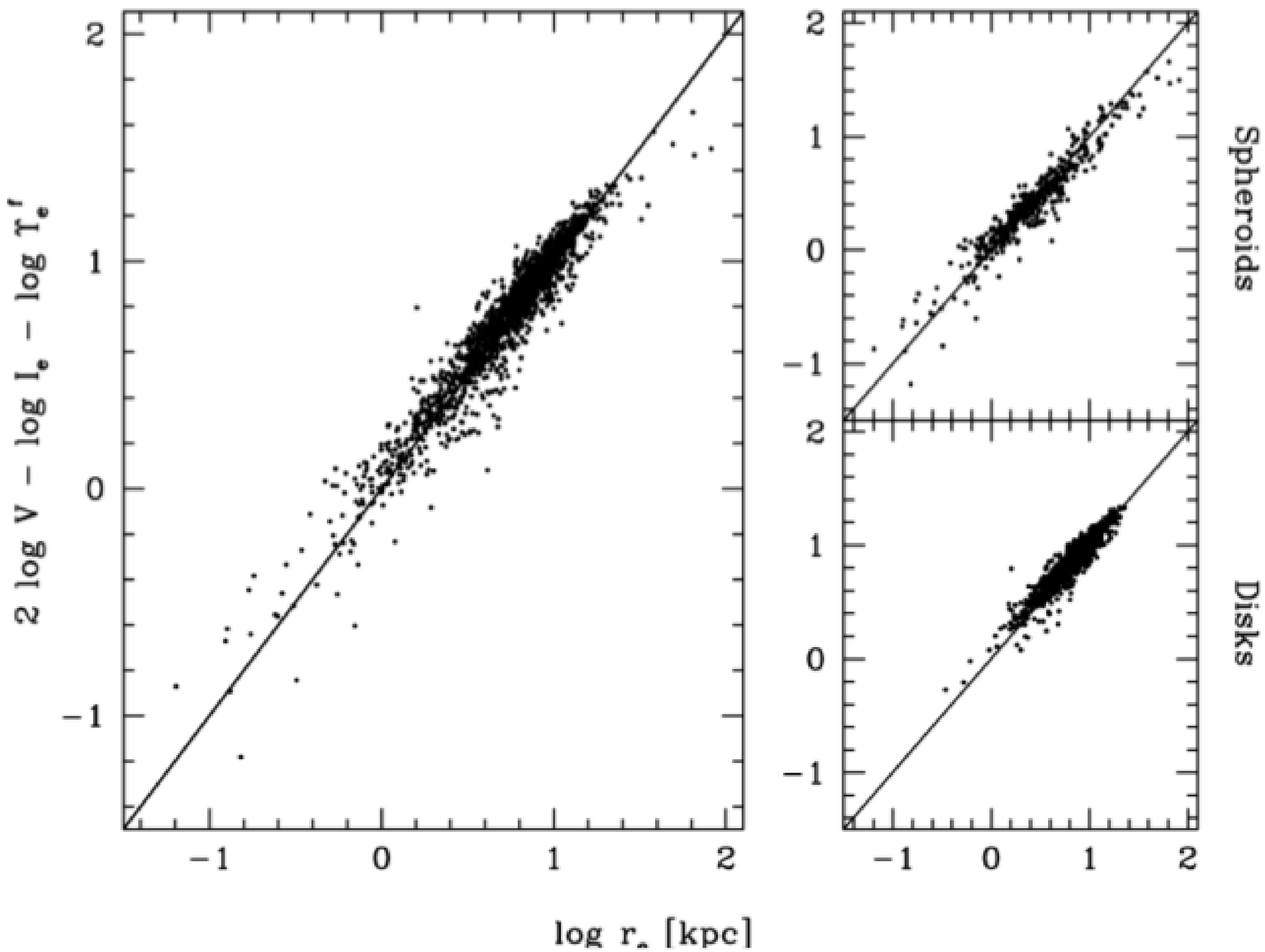


Result: Circular velocity function in prep.



A general (virial) scaling relation. (Zaritsky et al 2008.)

$$M_{dyn} = \eta \frac{r_r S_{0.5}^2}{G} \Rightarrow \log \Upsilon_e = \log V^2 - \log I_e - \log r_e + \text{const.}$$

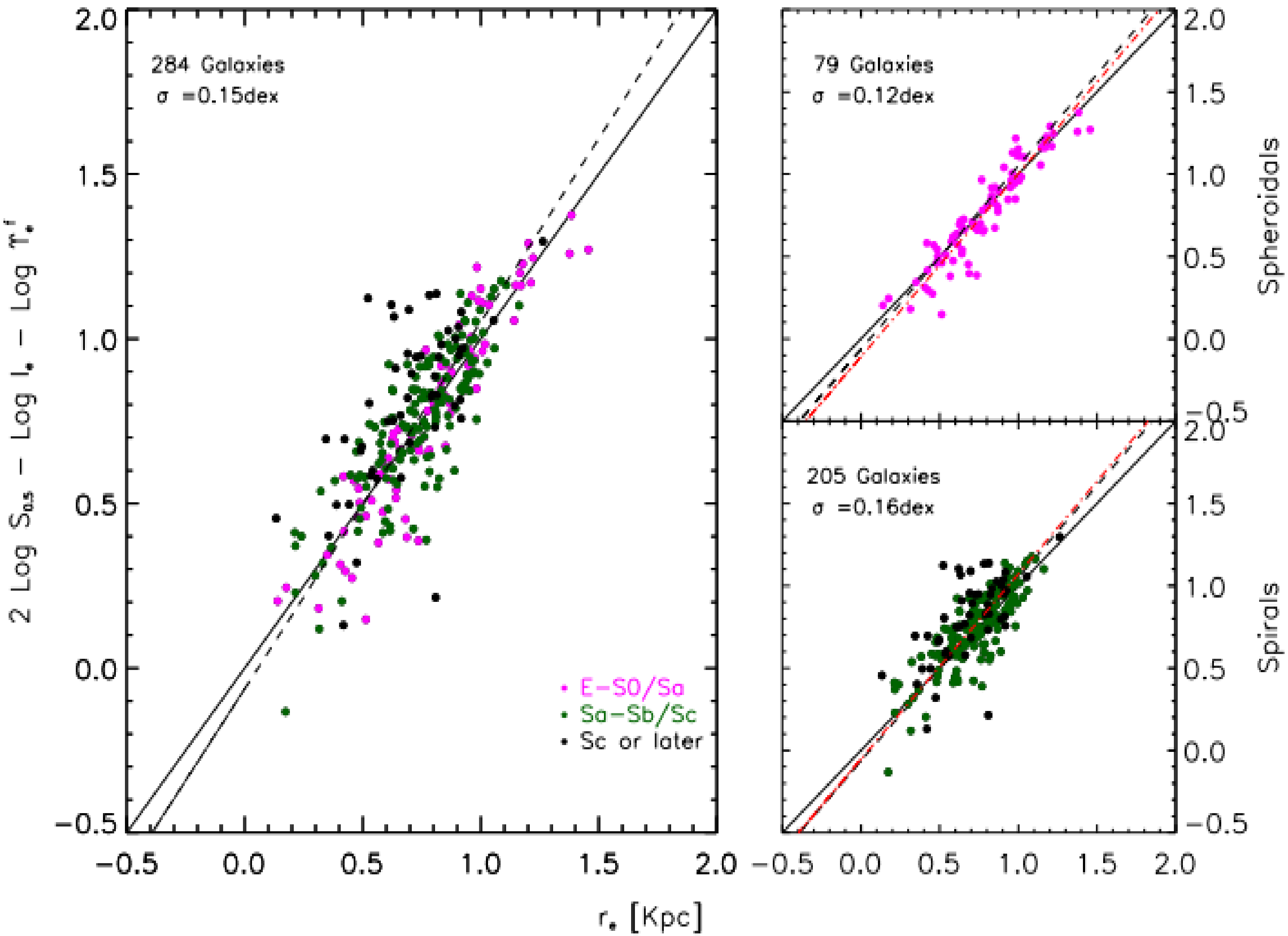


Scatter ~ 0.05

- Orbital structure
- Nuclear activity
- Lost mass history
- Environment
- Accretion mass.
- Shape of galaxies.

Preliminary results.
A general (virial) scaling relation. (Zaritsky et al 2008.)

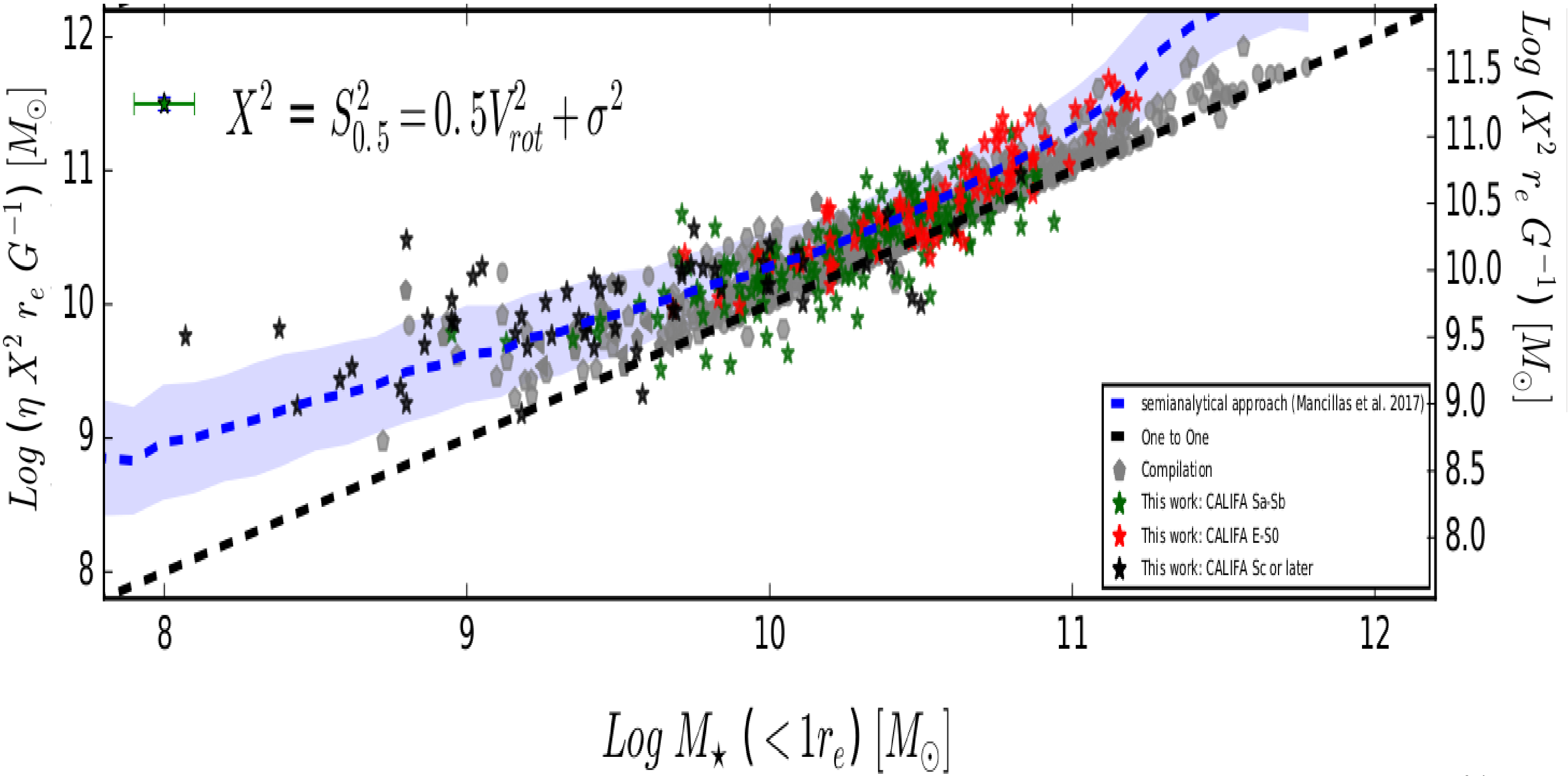
$$M_{dyn} = \eta \frac{r_r S_{0.5}^2}{G} \Rightarrow \log \Upsilon_e = \log V^2 - \log I_e - \log r_e + \text{const.}$$



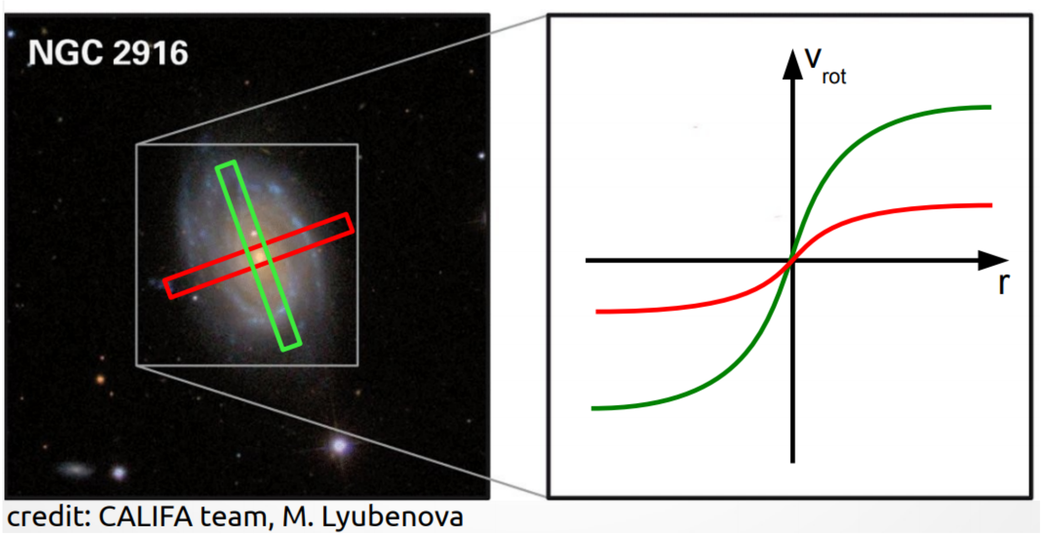
- Orbital structure
- Nuclear activity
- Lost mass history
- Environment
- Accretion mass.
- Shape of galaxies

Results: Our proxy is almost as good as detailed dynamical models.

Aquino-Ortíz et al. (2018) MNRAS 479, 2133-2146

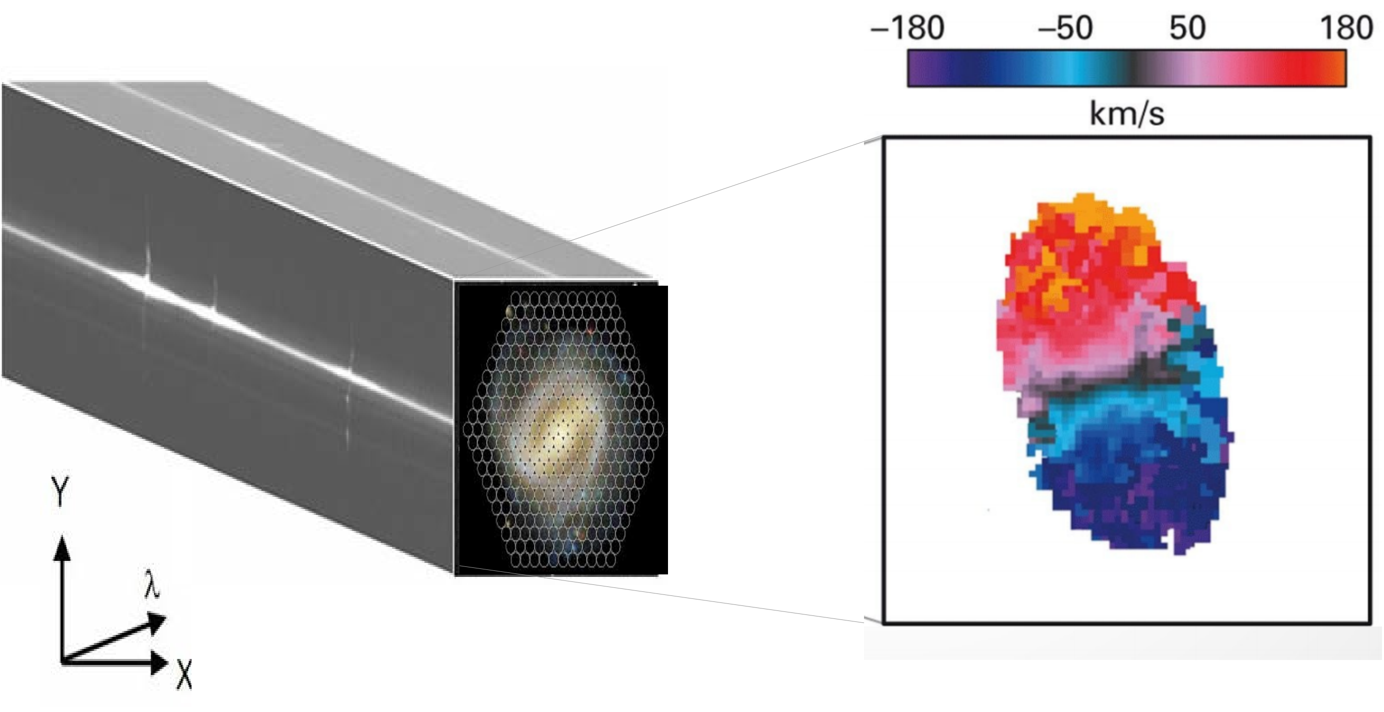


Data: Integral field spectroscopy.



Long slit spectroscopy.

* Geometrical assumptions.



Integral field spectroscopy.

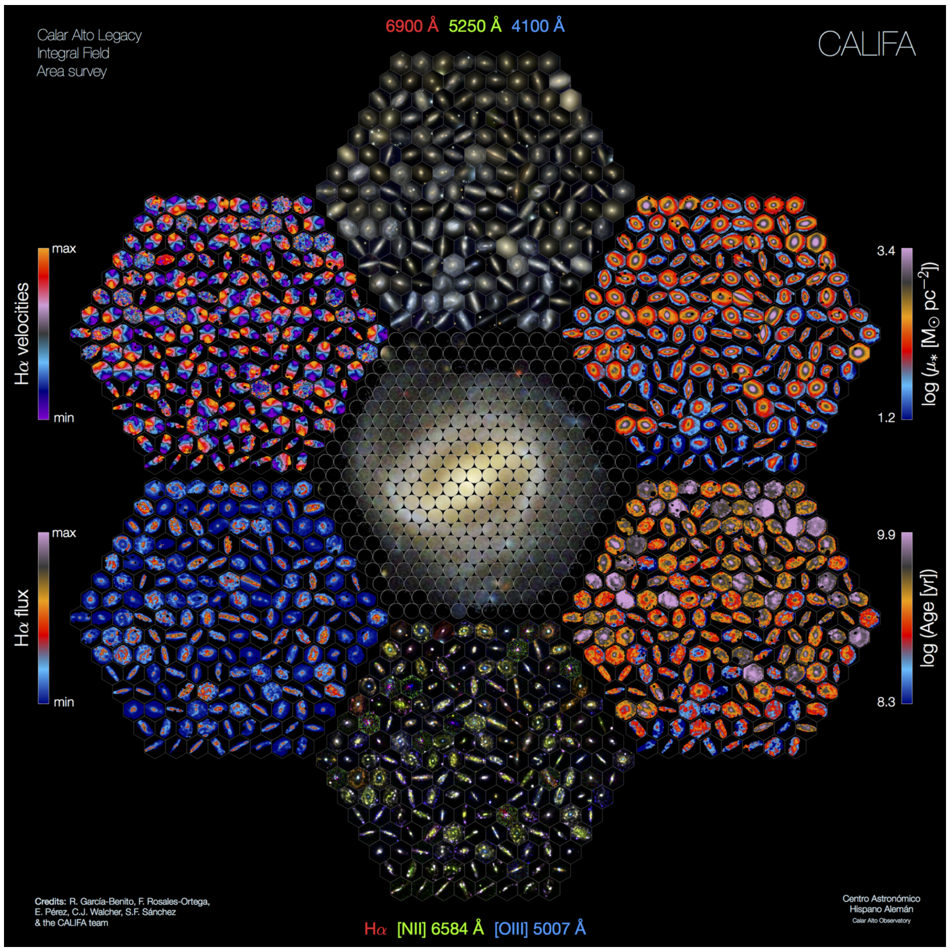
* Output: data cube
  - 2 spatial dimensions.
  - 1 spectroscopic dimension.

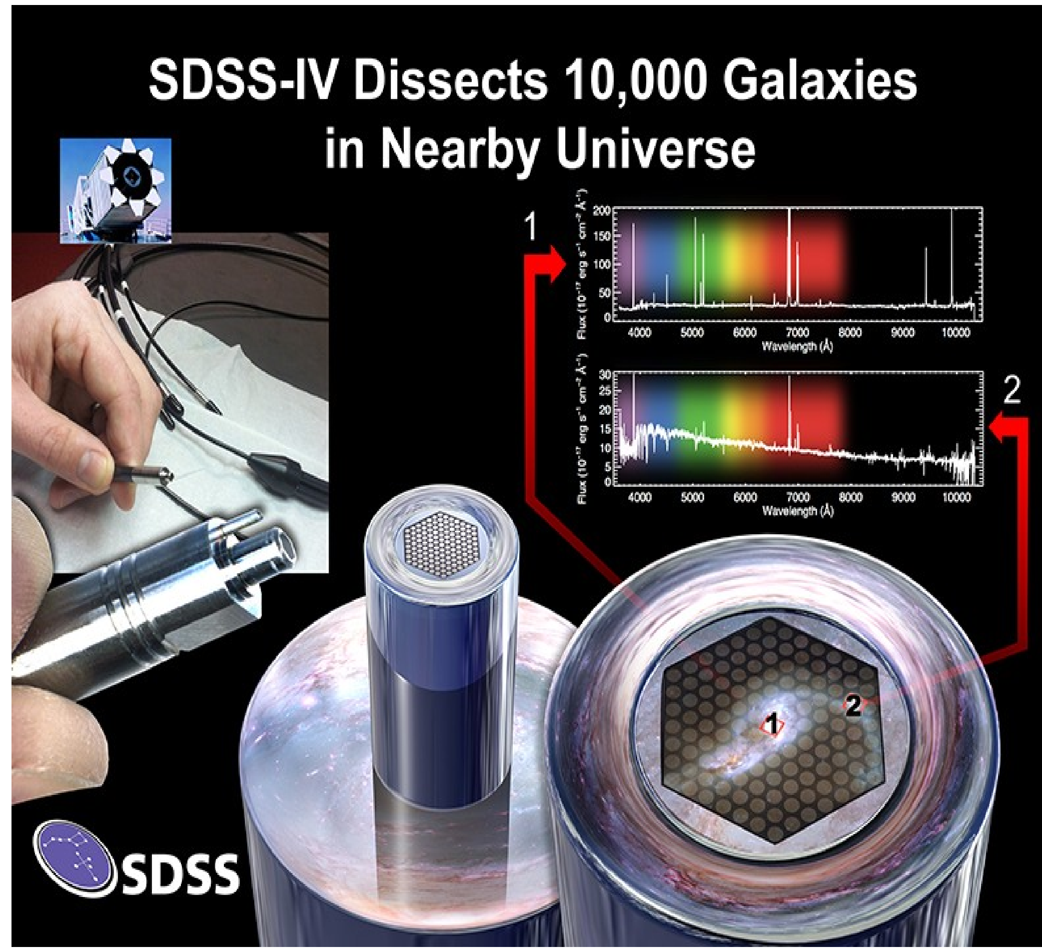
* Properties spatially resolved.
  -2D kinematic maps.

Data: Integral field spectroscopy.

CALIFA: 882 galaxies.

MaNGA: ~ 4,000 galaxies in this work.





Data products from Pipe3D **(Sanchez et al. 2016)**