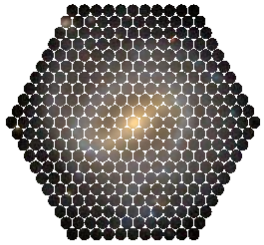


CALIFA Survey

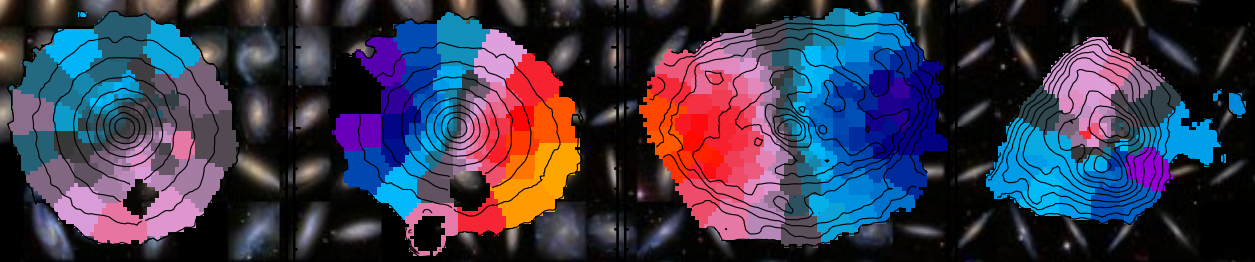
university of groningen

The interplay between baryons and dark matter in galaxies

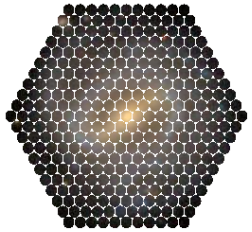
Mariya Lyubenova (Kapteyn)

G. van de Ven (MPIA), J. Falcón-Barroso (IAC)

and the CALIFA team



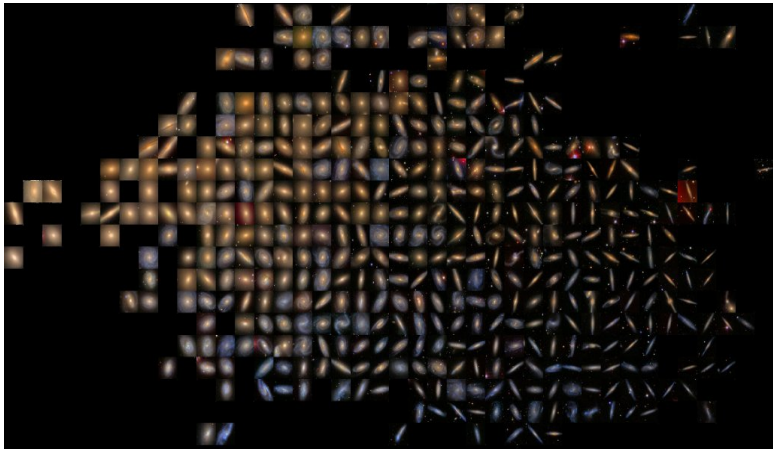
The Interplay between local and global processes, 11 April 2016, Cozumel

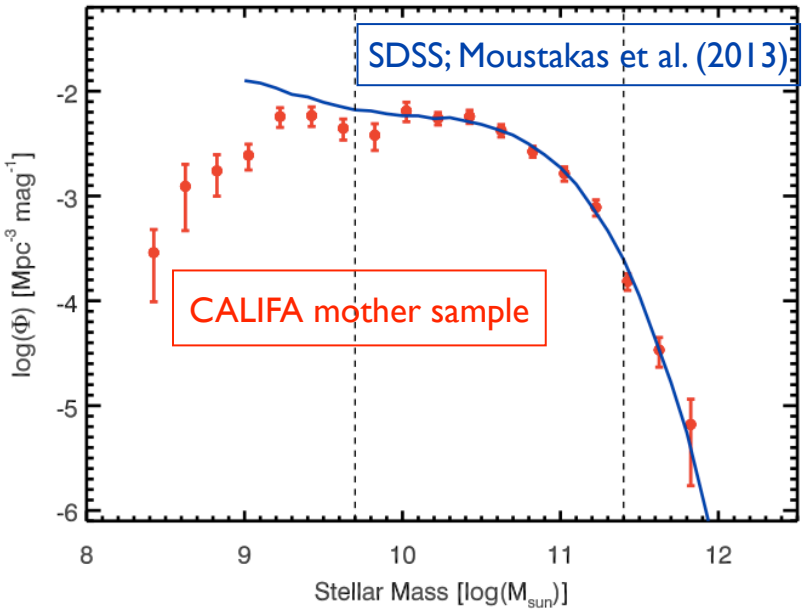


CALIFA Survey

Calar Alto Legacy Integral Field Area Survey

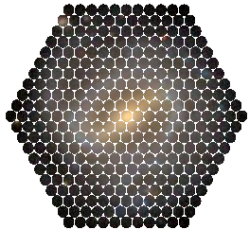
1. Morphologically unbiased
2. Representative in a broad mass range
3. Statistically well defined sample





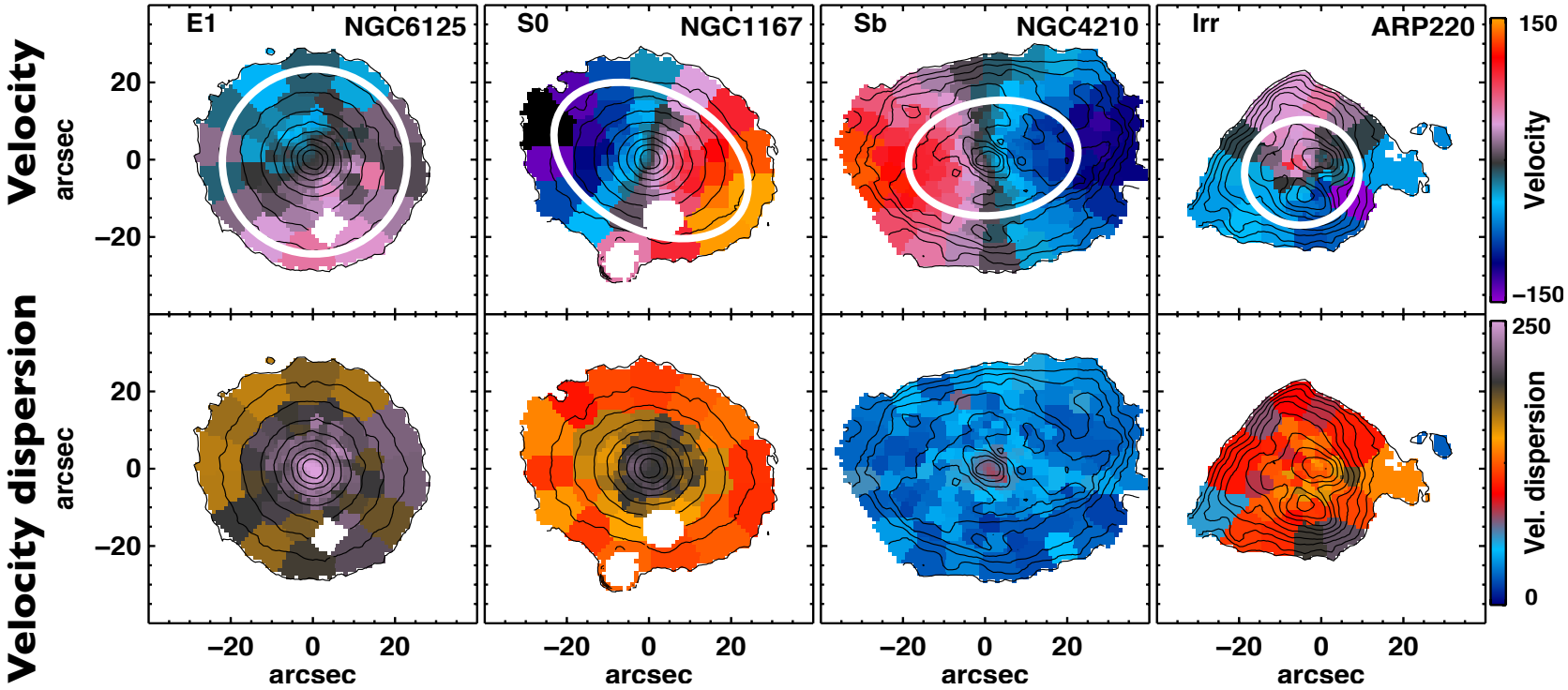
Walcher et al., 2014

yubenova
yons and
dark matter in galaxies



CALIFA Survey

CALIFA Stellar Kinematics

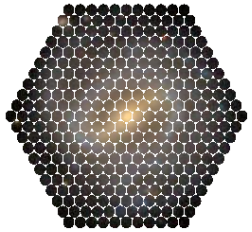


Slow Rotator
low V, high σ

Bulge+Disk
high V, high σ

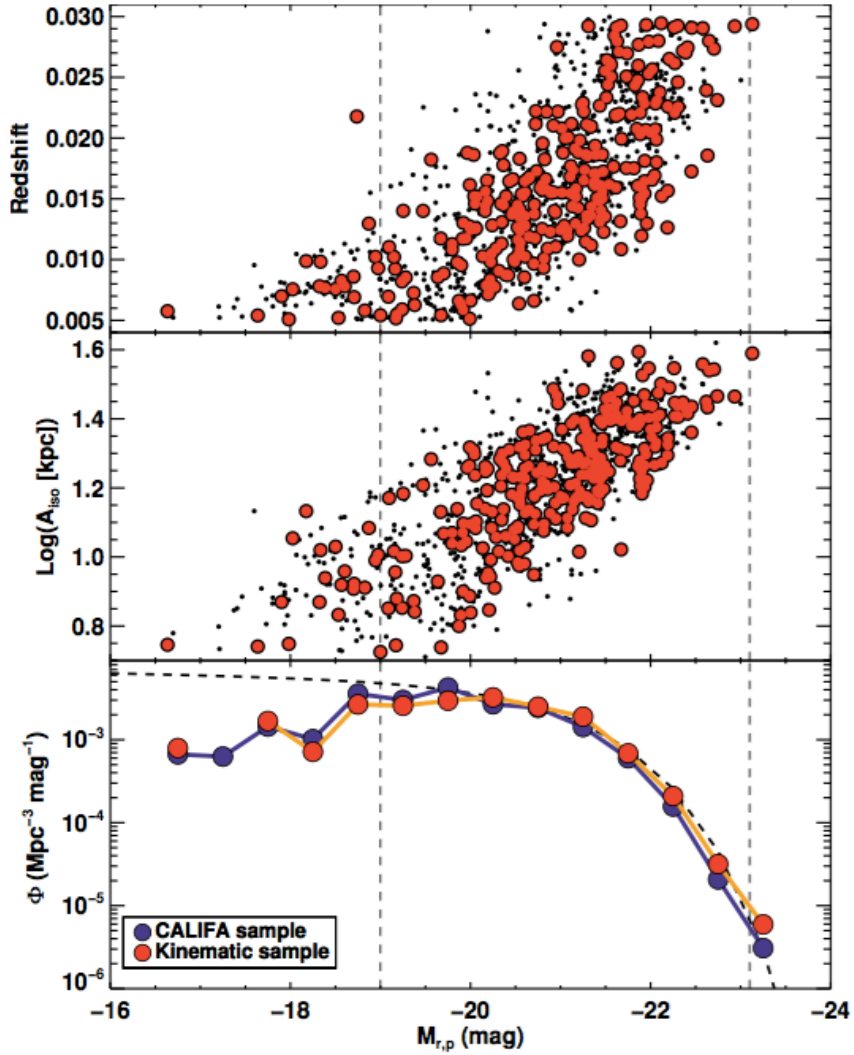
Pure Disk
high V, low σ

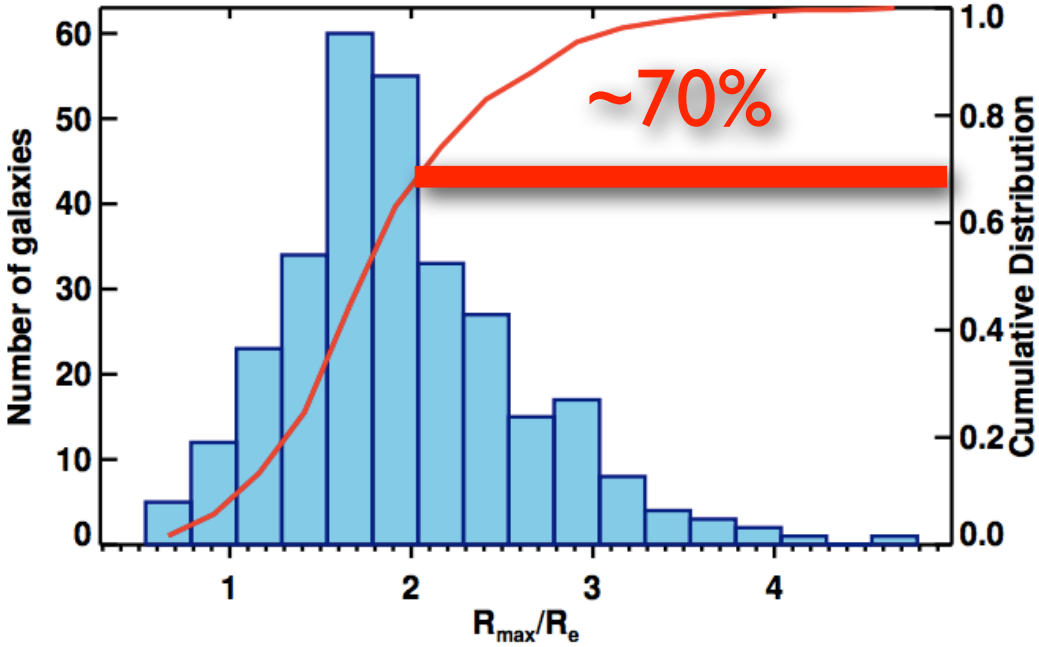
Interacting



CALIFA Survey

300 galaxies with excellent stellar kinematics



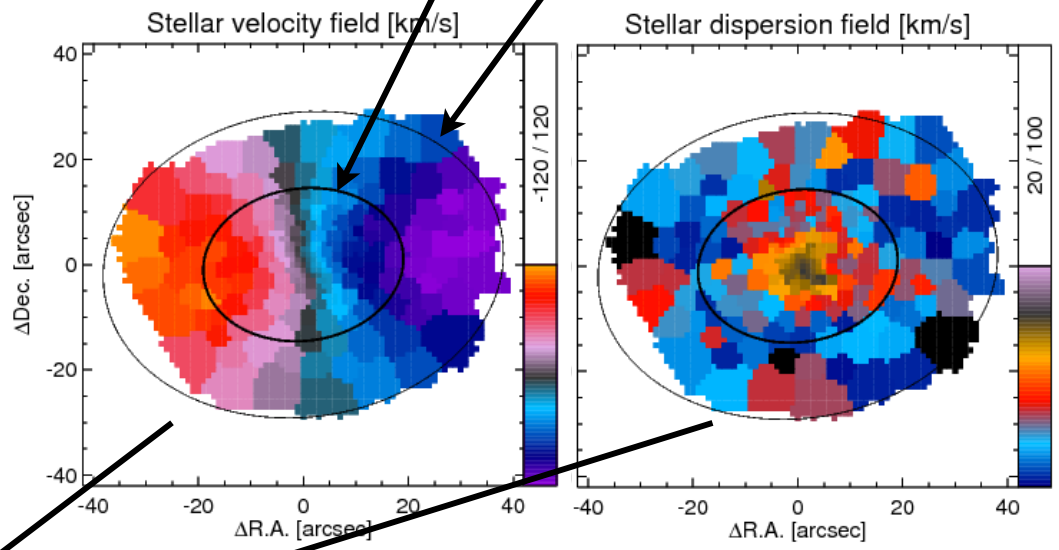


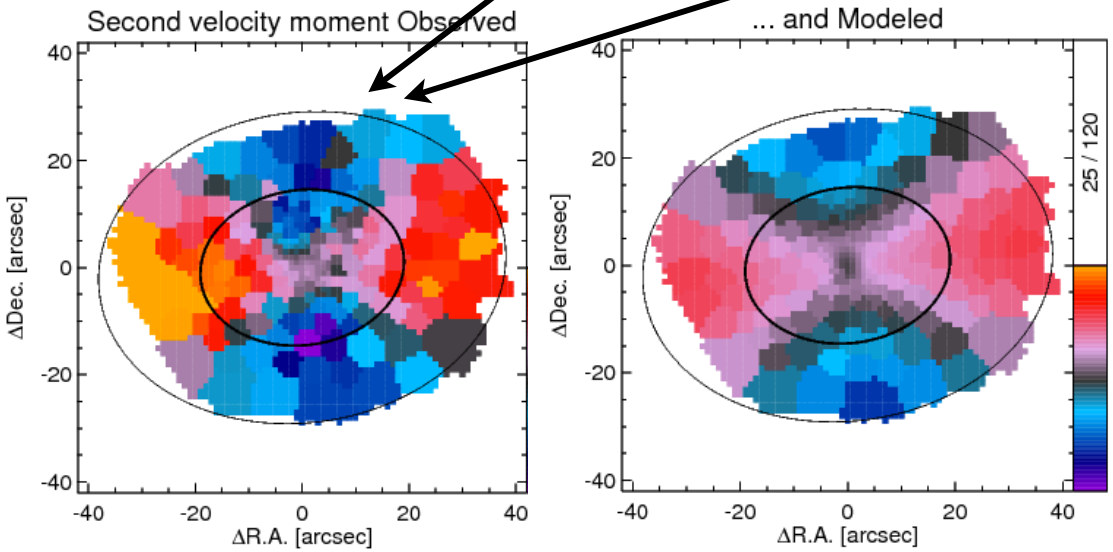
Falcón-Barroso, Lyubenova, van de Ven et al.,
A&A submitted

Dynamical modeling

CALIFA Survey NGC4210

1 and 2 R_{eff}



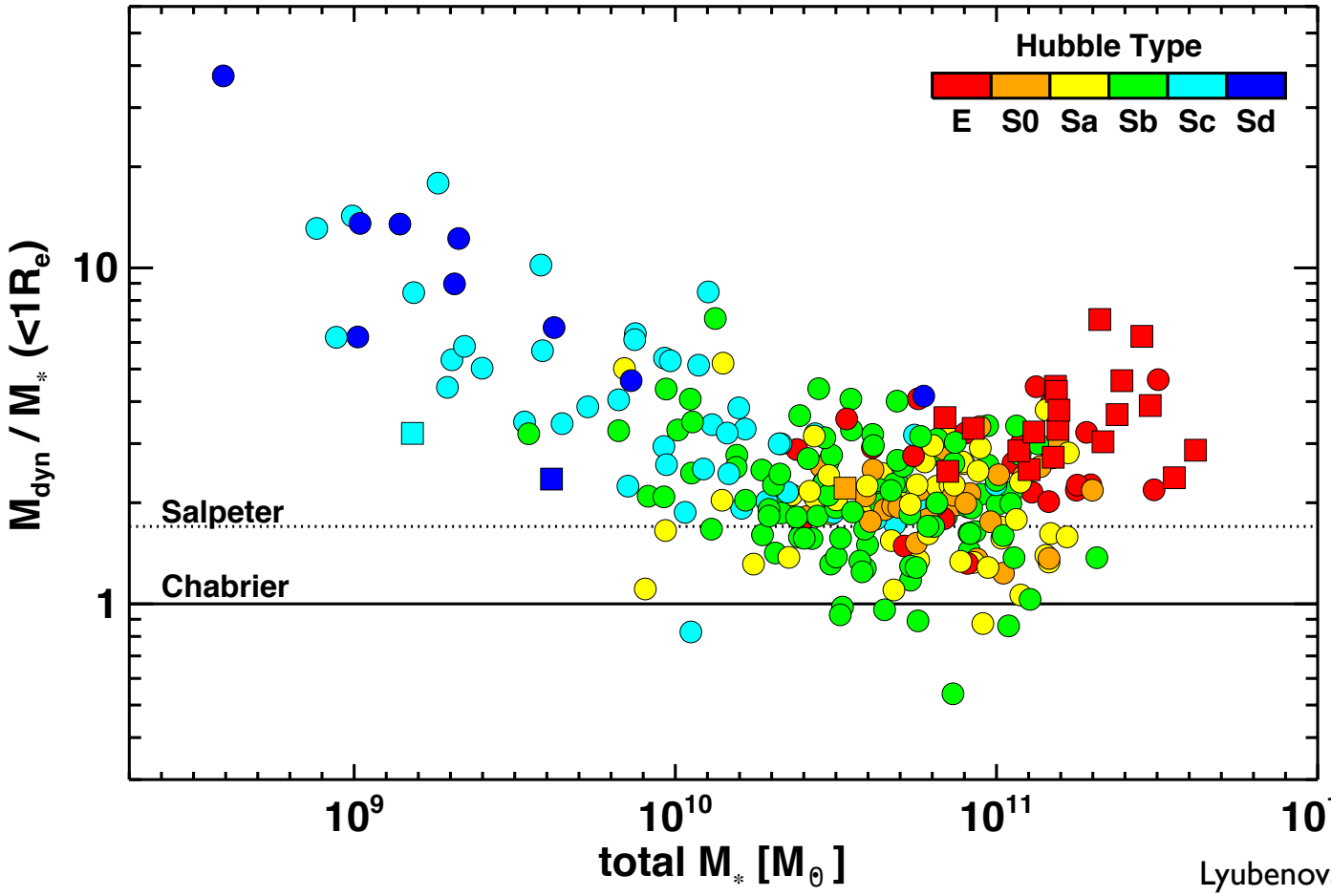


- Jeans equations (Lyubenova et al.)
- Schwarzschild orbit superposition (Zhu et al.)
- Distribution functions (Posti et al.)

→ $M_{tot}(<R)$

CALIFA Survey

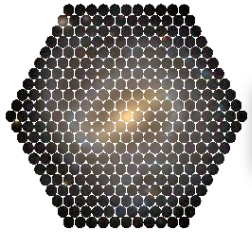
The interplay between baryons and DM



Stellar masses via full spectrum fitting

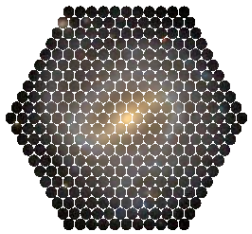
(Gonzales-Delgado et al. 2014)

Lyubenova, van de Ven, Falcón-Barroso et al., *in prep.*



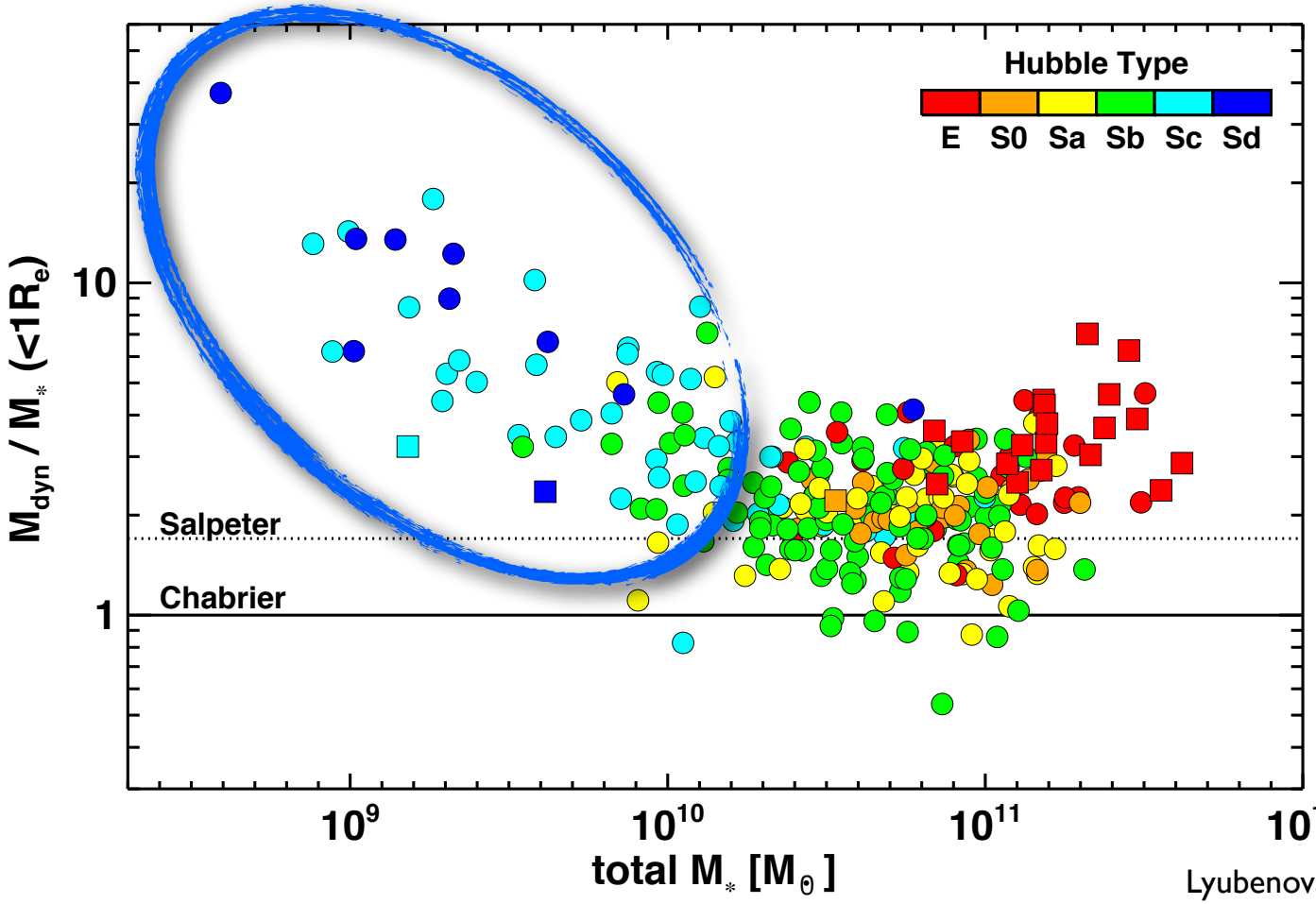
CALIFA Survey

Low mass **Late** Type Galaxies



CALIFA Survey

High Dark matter fractions?



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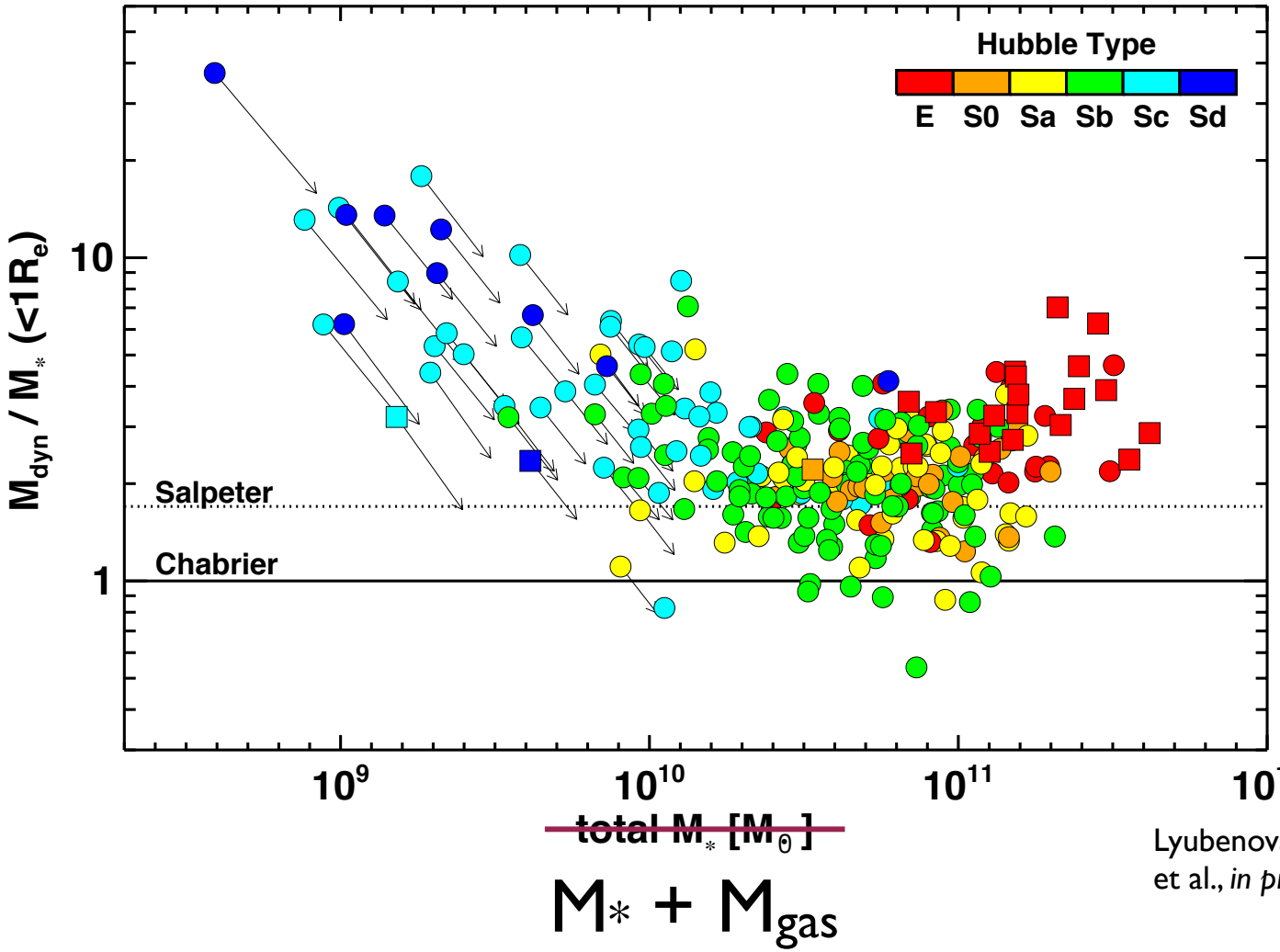
CALIFA Survey

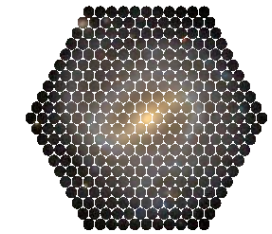
High Dark matter fractions?



Stellar masses via full spectrum fitting
(Gonzales-Delgado et al. 2014)

Gas masses via Papastergis et al. 2012

Lyubenova, van de Ven, Falcón-Barroso et al., *in prep.*



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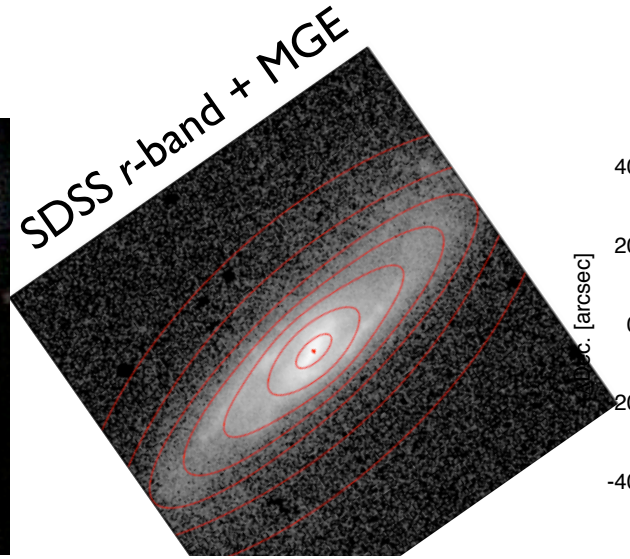
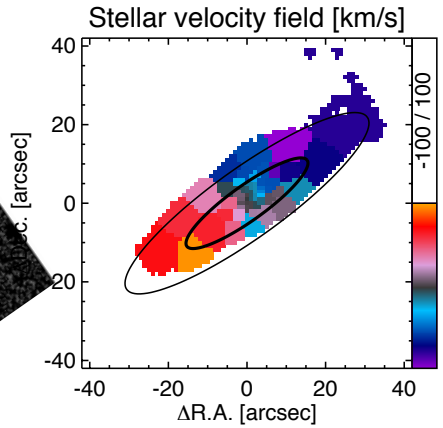
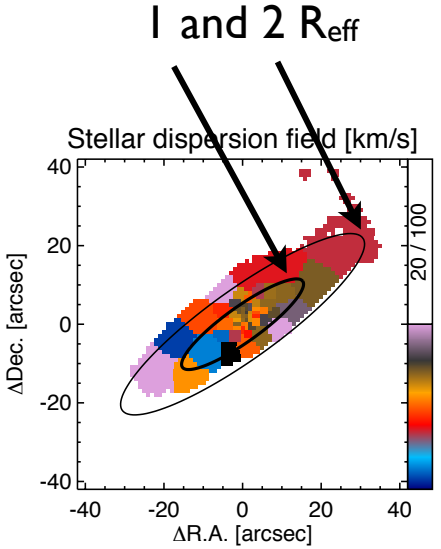
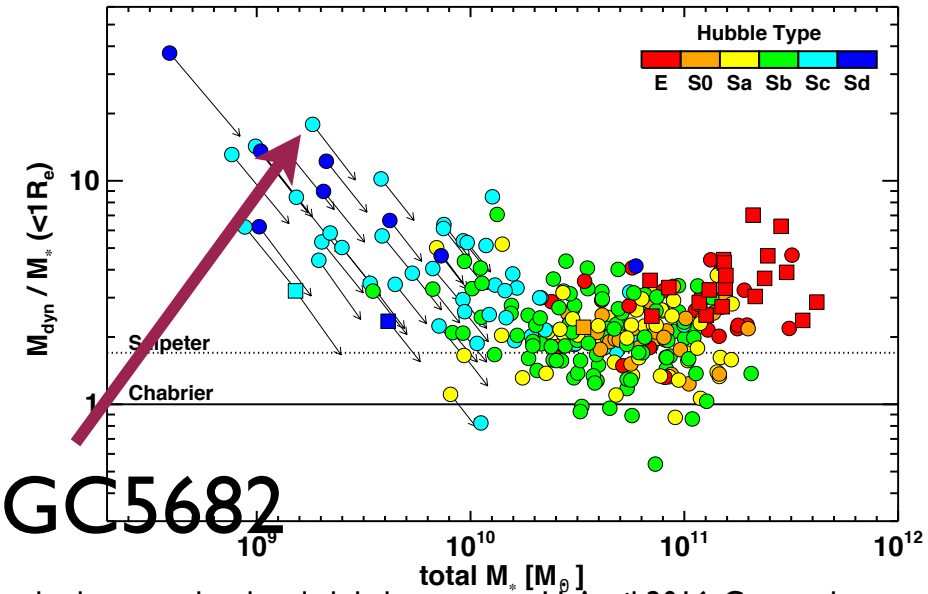
The "outliers"

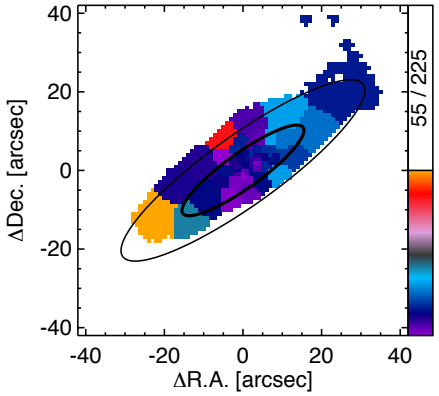


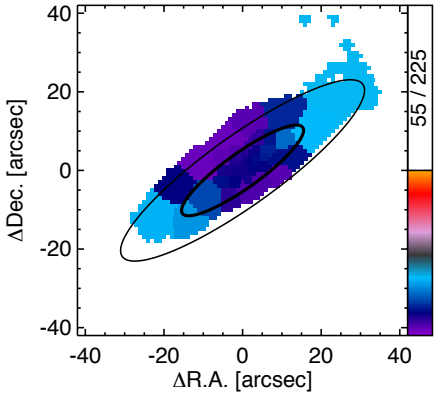


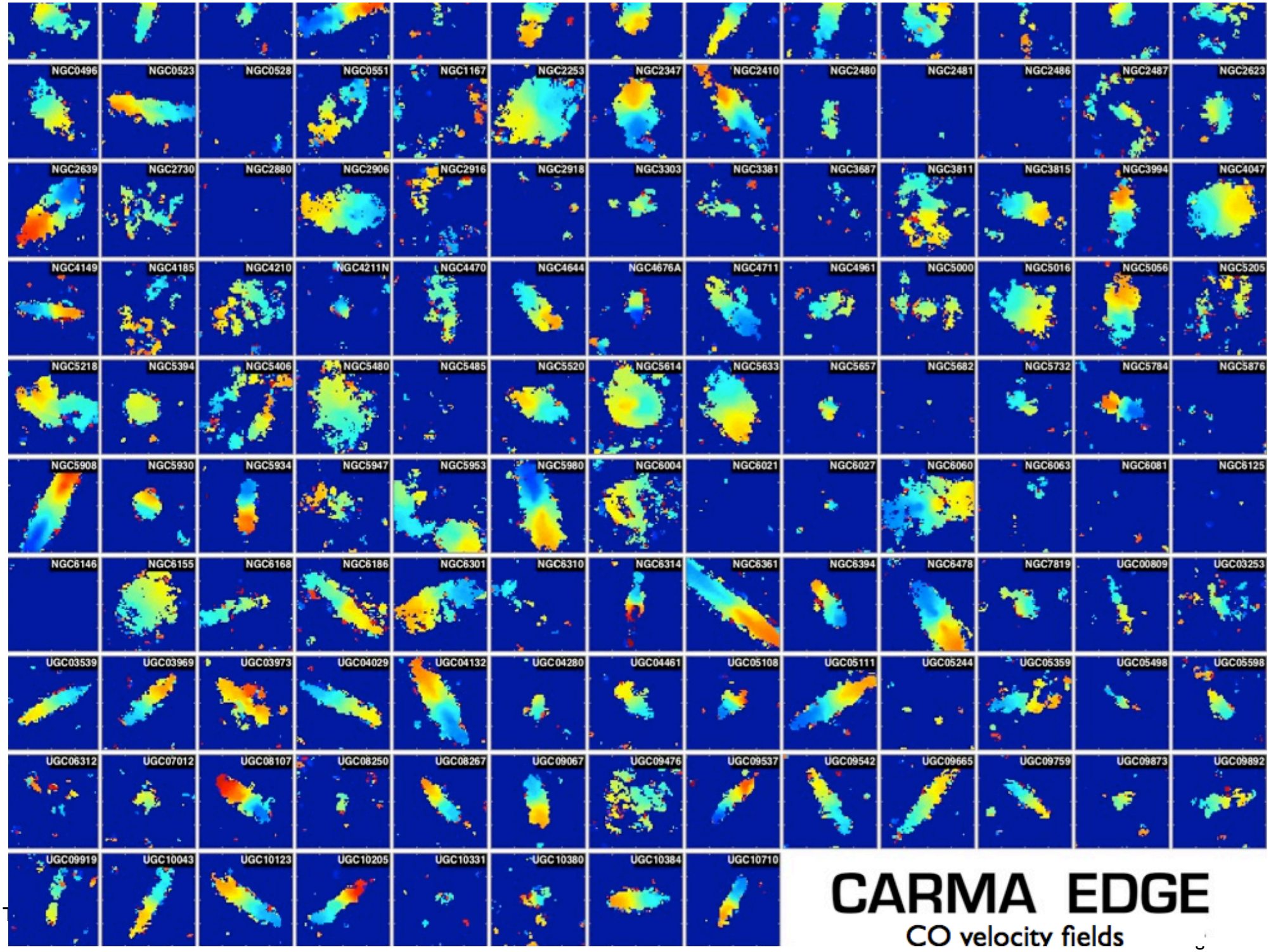




NGC5682



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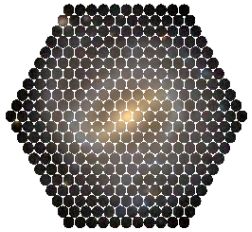
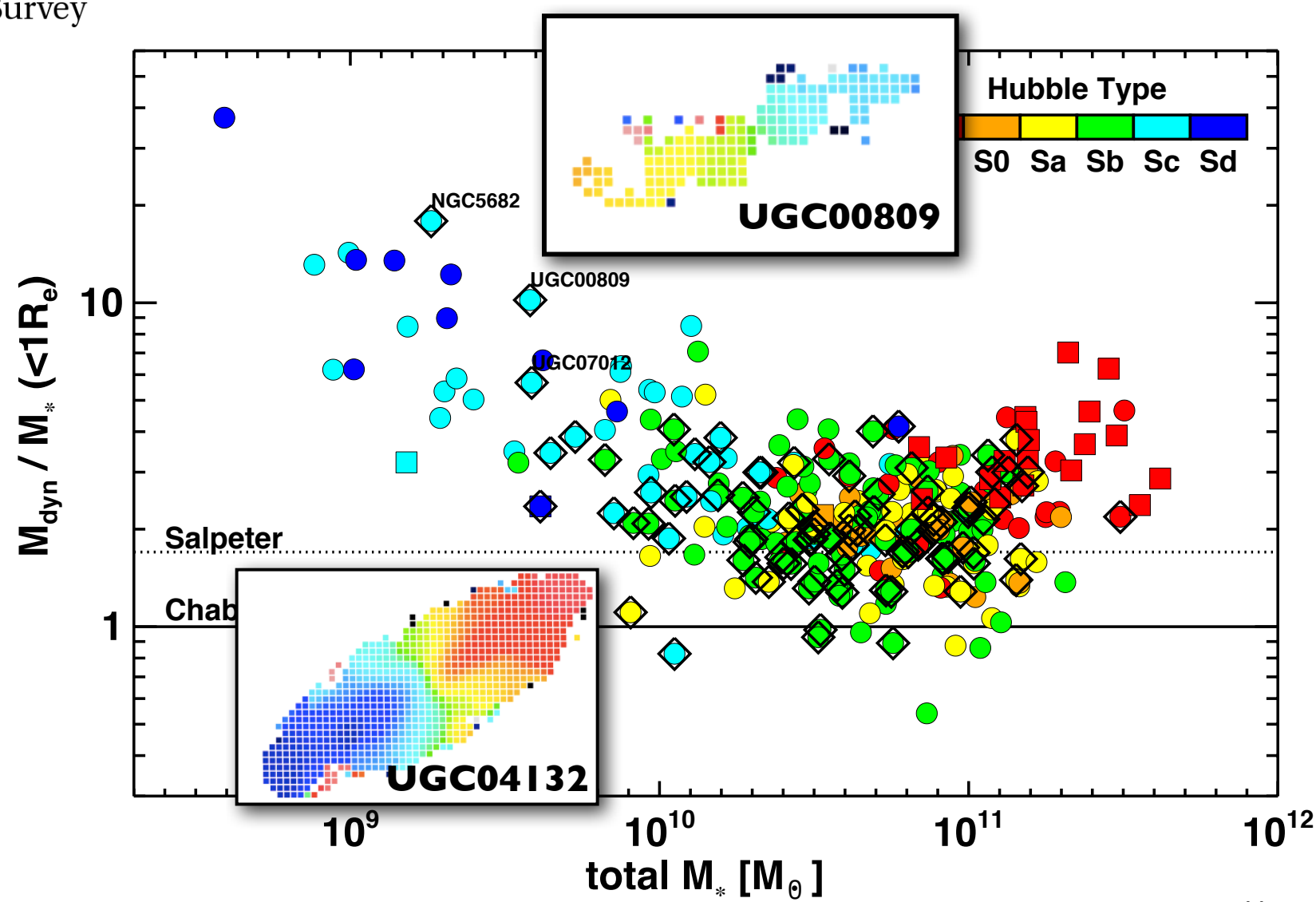
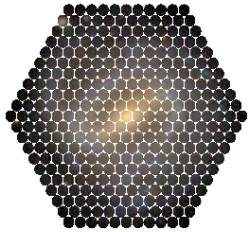
CARMA EDGE
CO velocity fields



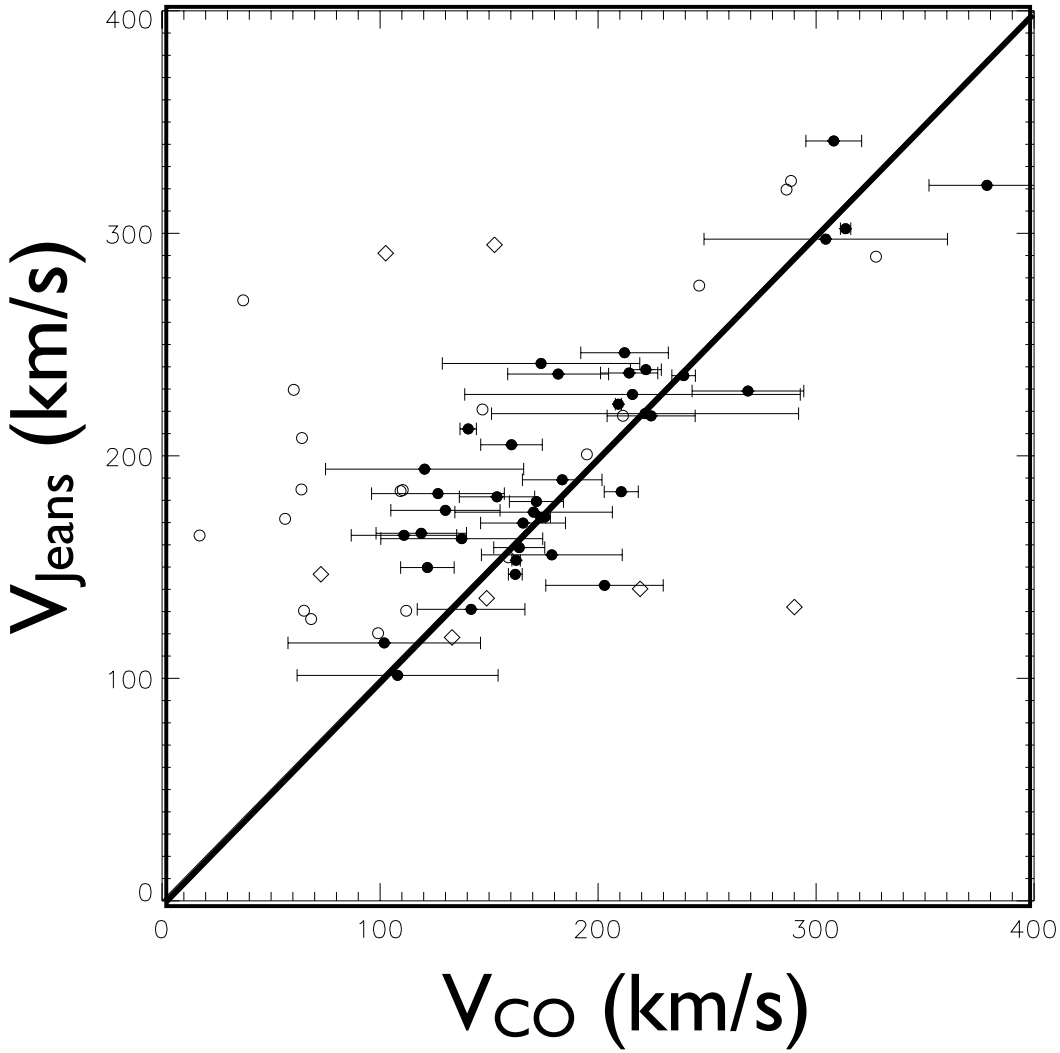
CARMA EDGE Survey



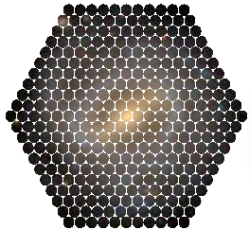


CARMA EDGE Survey

Vcirc at 1 R_{eff}

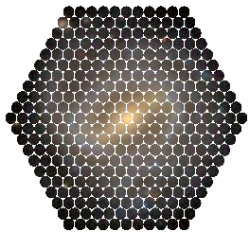


Leung et al., *in prep.*



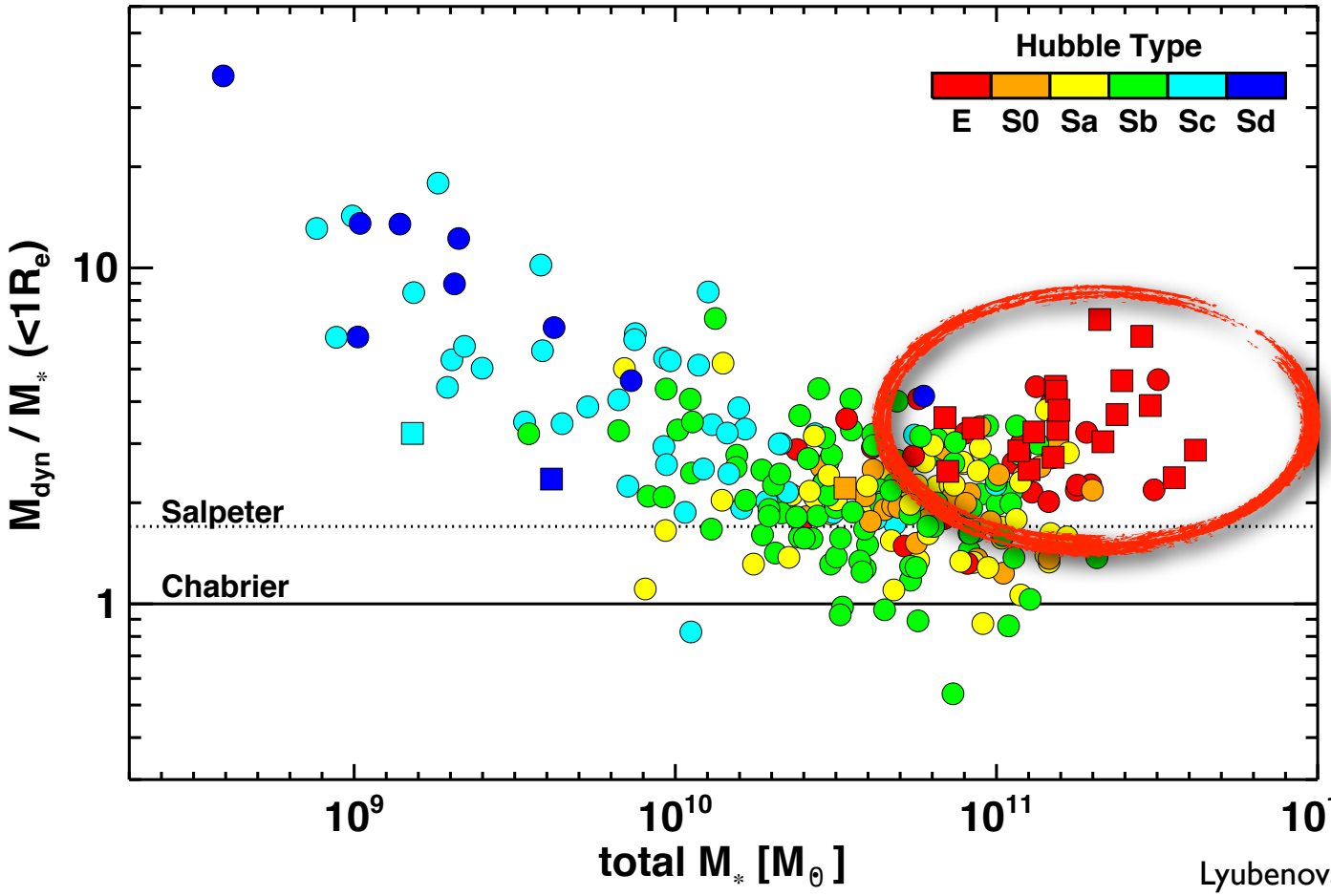
CALIFA Survey

High mass **Early** Type Galaxies



CALIFA Survey

Varying Initial Mass Function?



Stellar masses via full spectrum fitting

(Gonzales-Delgado et al. 2014)

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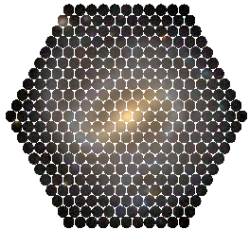
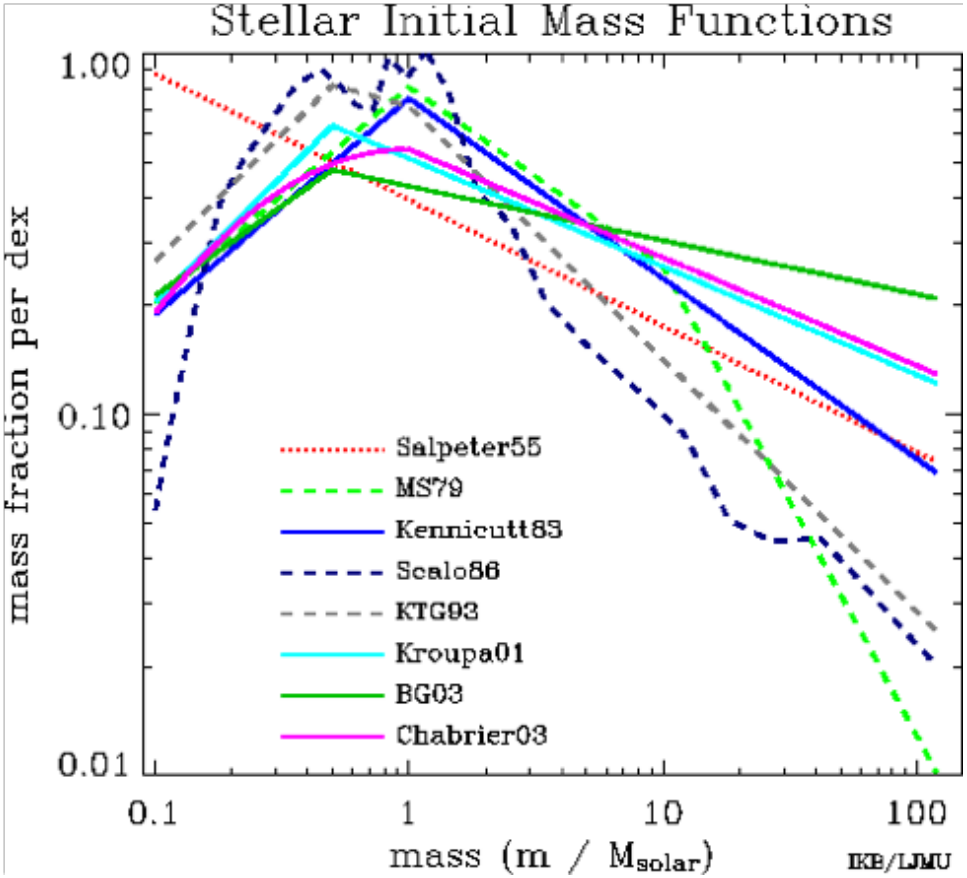


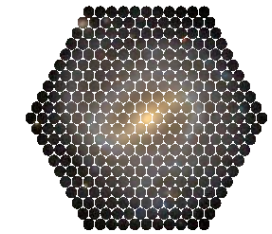
CALIFA Survey

Varying Initial Mass Function?

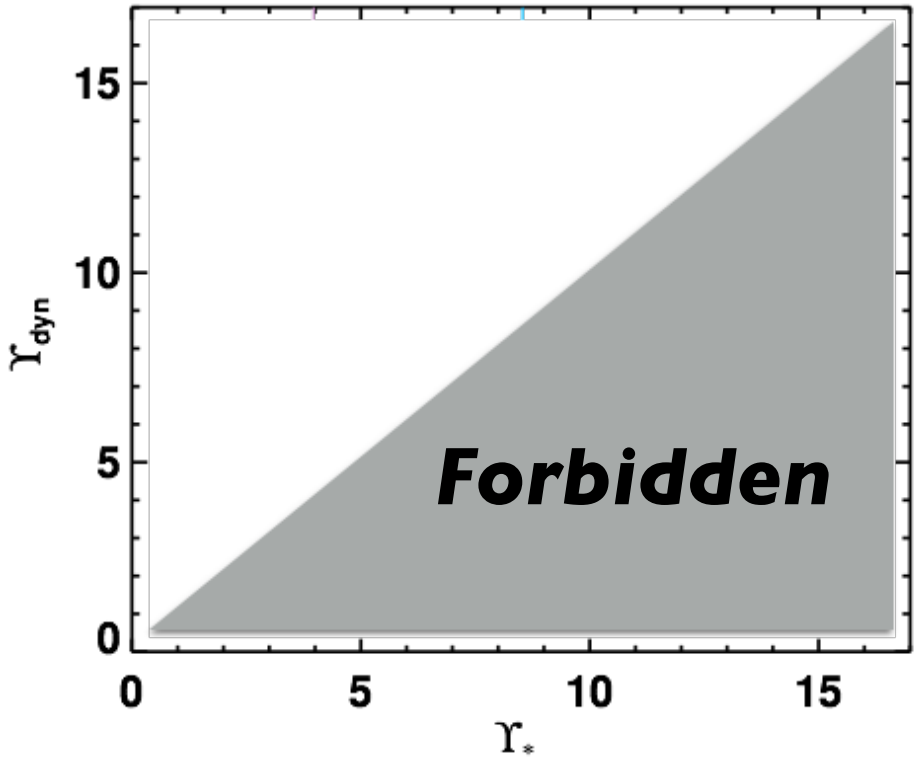
What does vary?

- the low mass slope
- the high mass slope
- the pivot point
- low mass cut off
- etc...



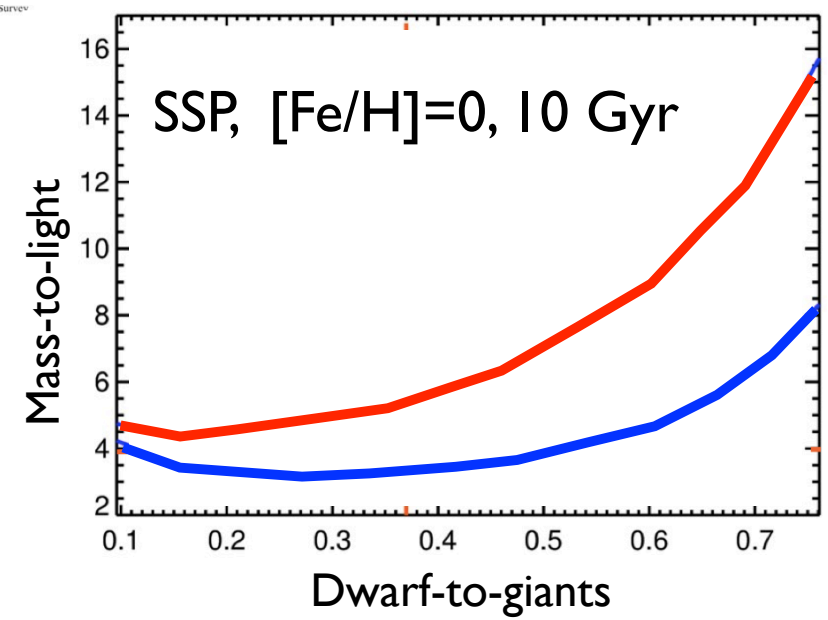


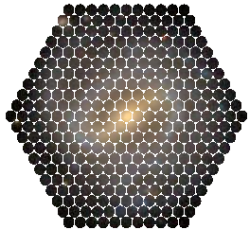
Dynamical constraints of the IMF shape



Υ_* **cannot** be larger than Υ_{dyn}

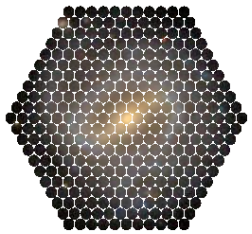
$\Upsilon = M/L_r$





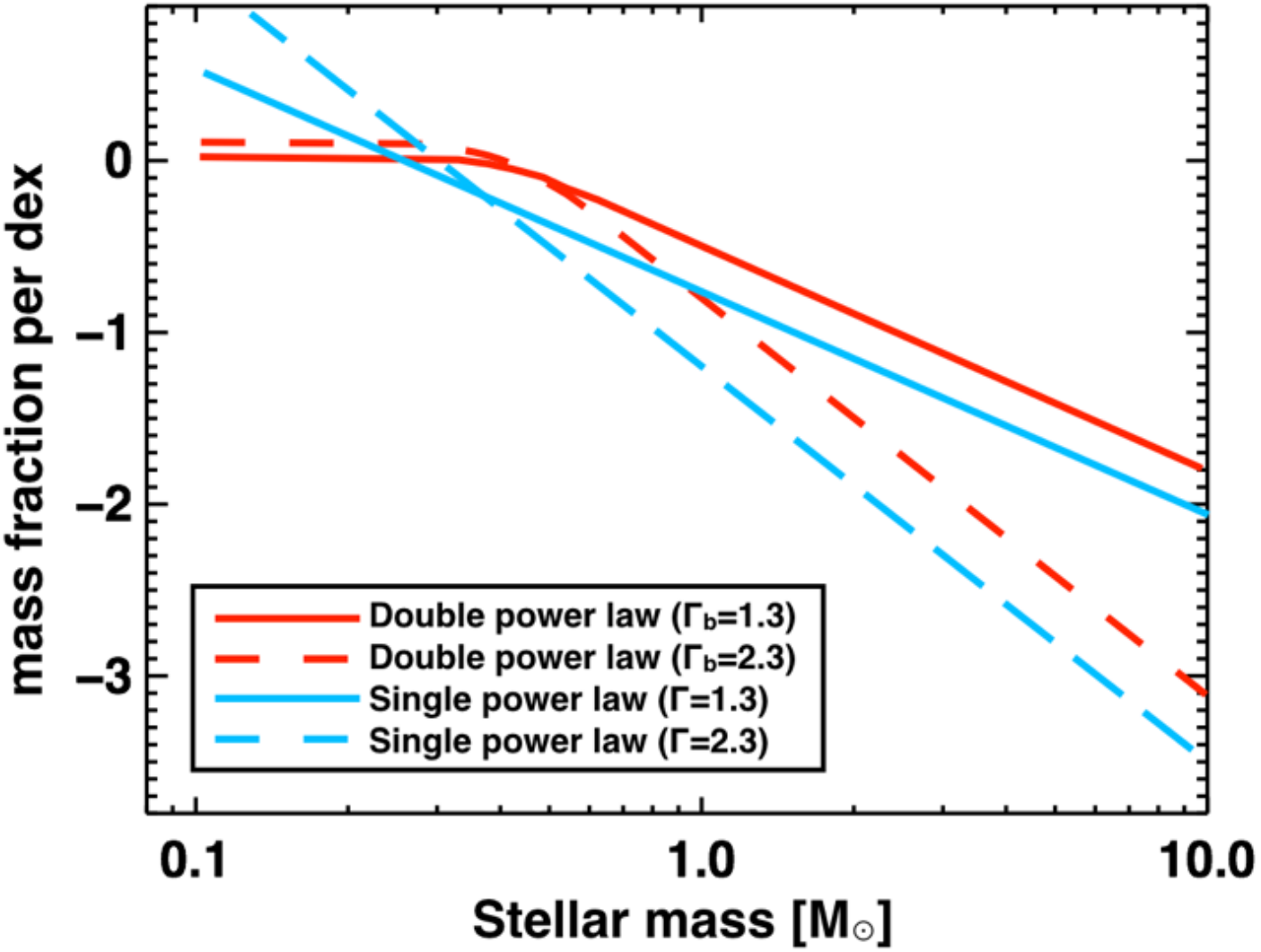
Stellar population analysis

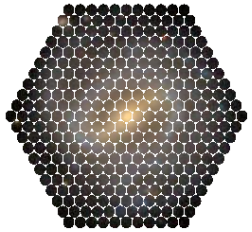
- 27 early-type galaxies with high quality IFU data
- Total stellar mass ~$10^{12}\,M_{\odot}$
- Stellar population parameters from $H_{\beta 0}$, [MgFe]′, and $TiO_{2CALIFA}$ (Martin-Navarro et al. 2015)
- MIUSCAT models (Vazdekis et al. 2010)



CALIFA Survey

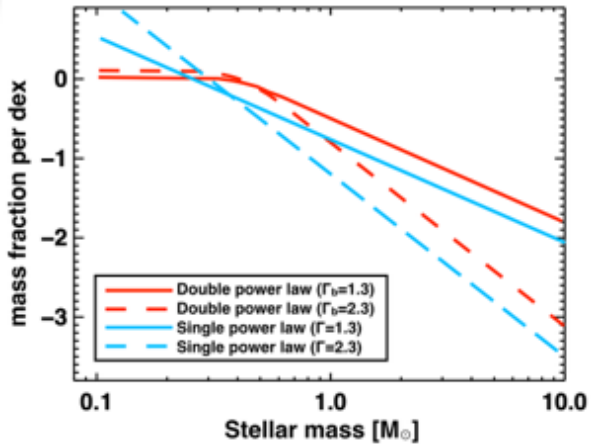
Two IMF shapes



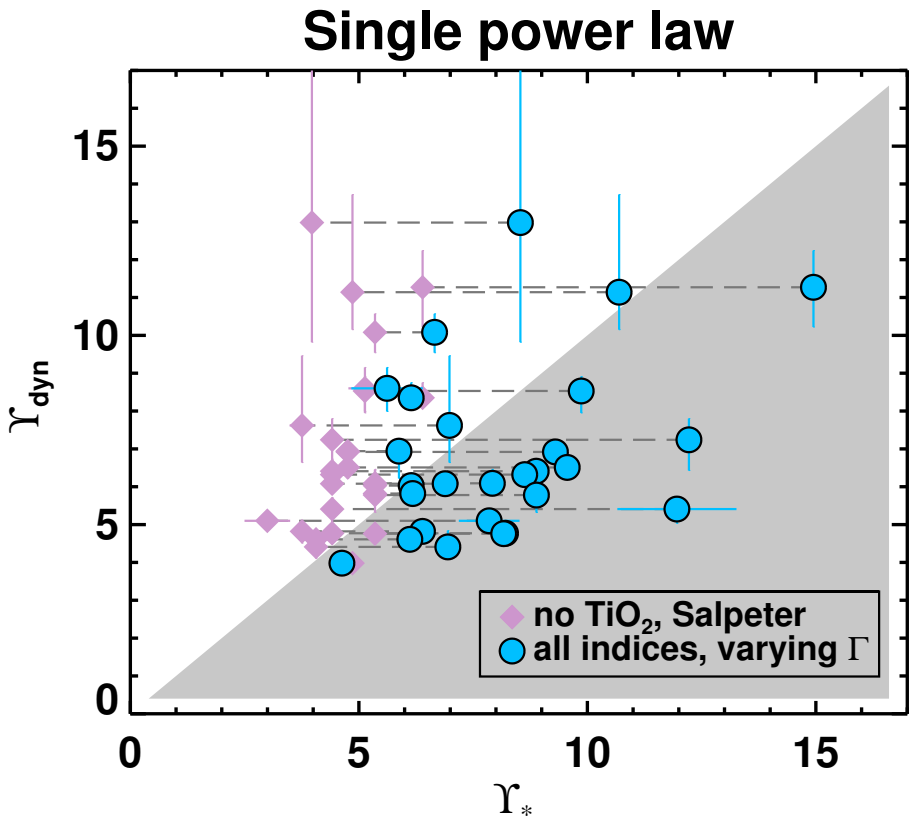


CALIFA Survey

Dynamical constraints of the IMF shape

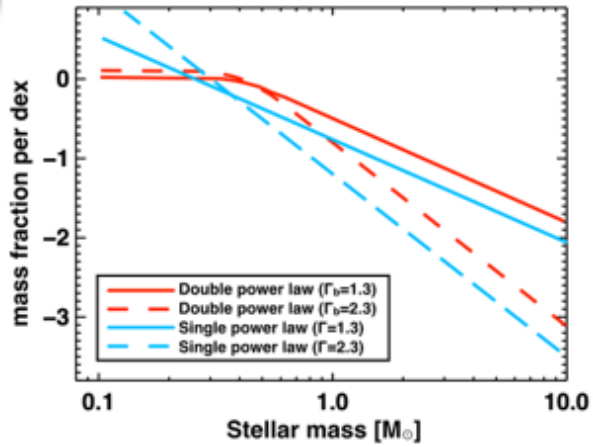


Lyubenova et al., *MNRAS submitted*



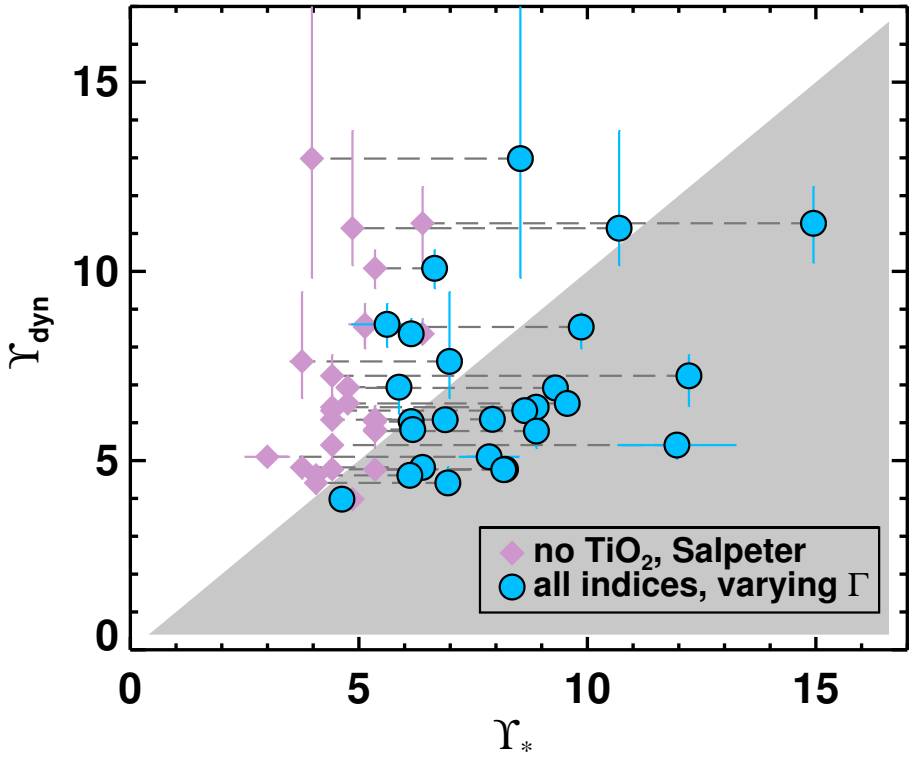
CALIFA Survey

Dynamical constraints of the IMF shape

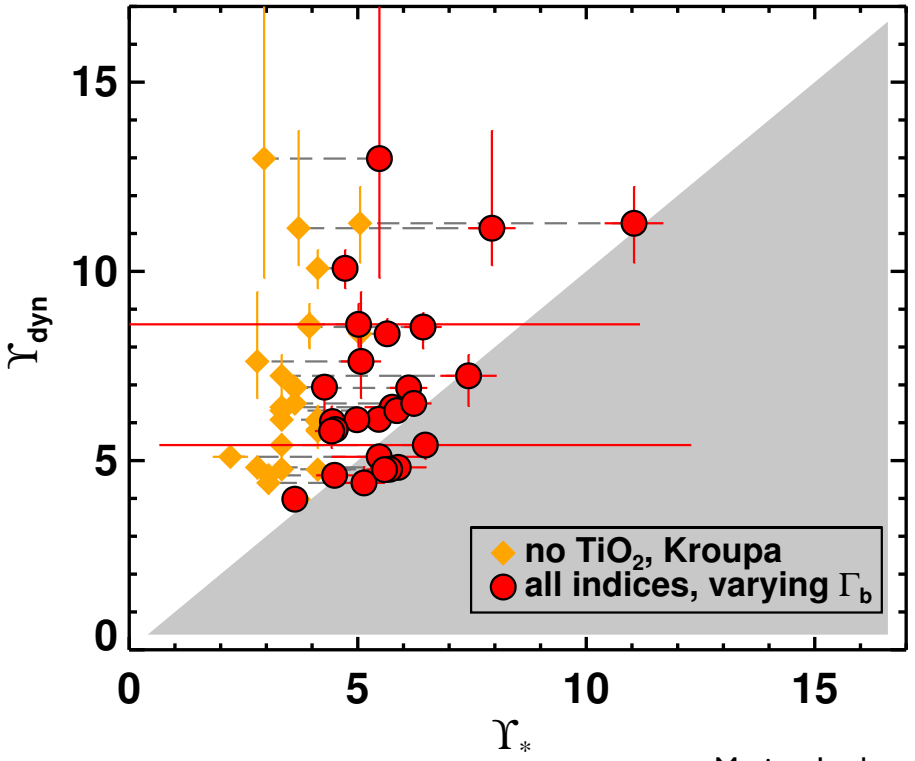


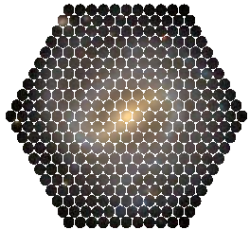
Lyubenova et al., *MNRAS submitted*

Single power law



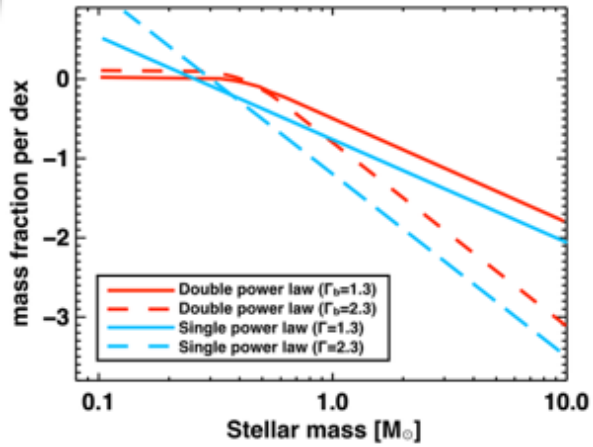
Double power law



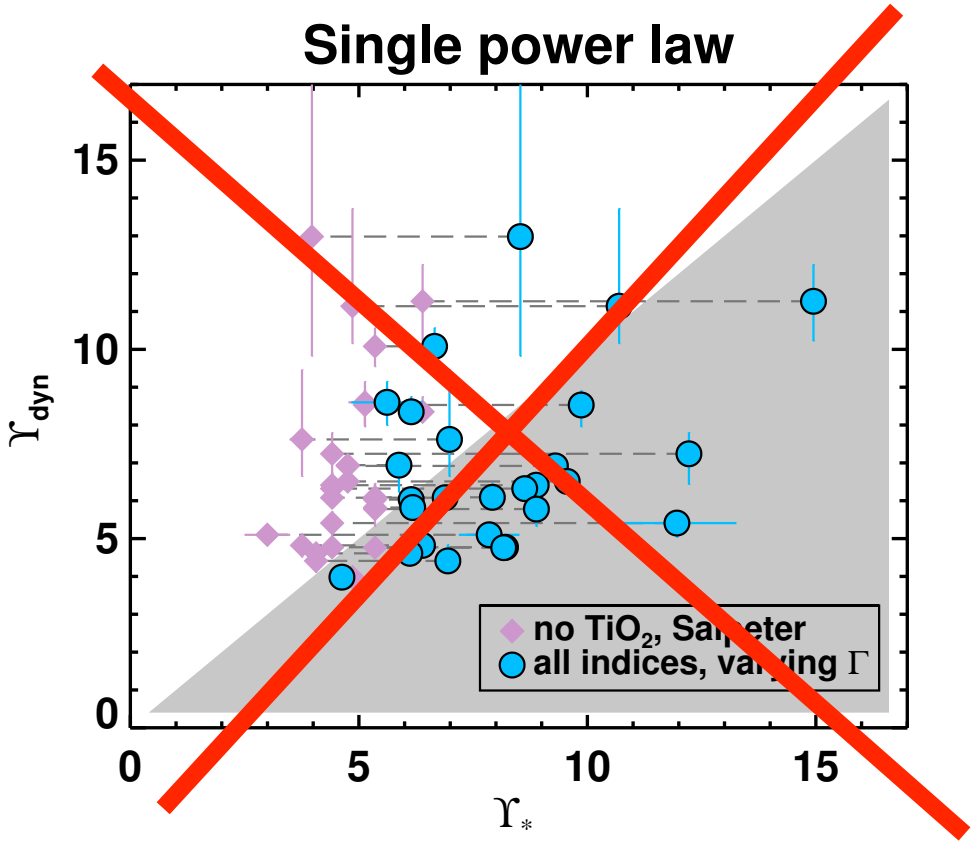


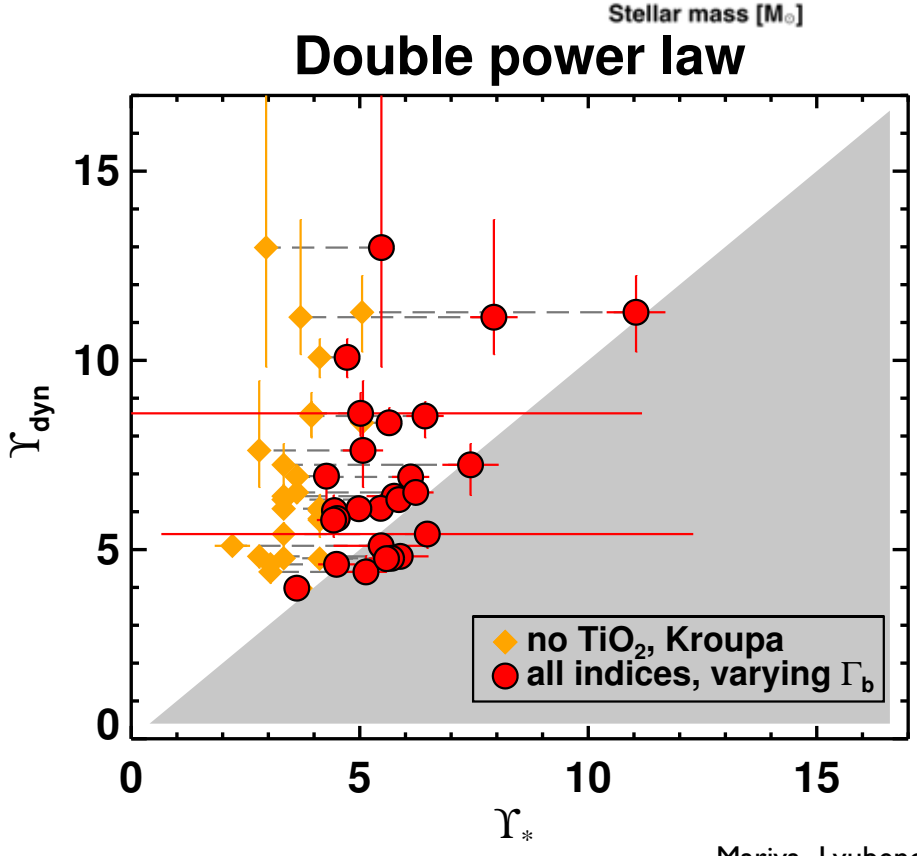
CALIFA Survey

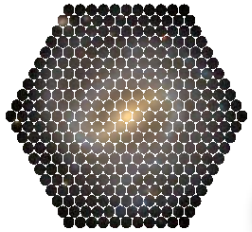
Dynamical constraints of the IMF shape



Lyubenova et al., *MNRAS submitted*

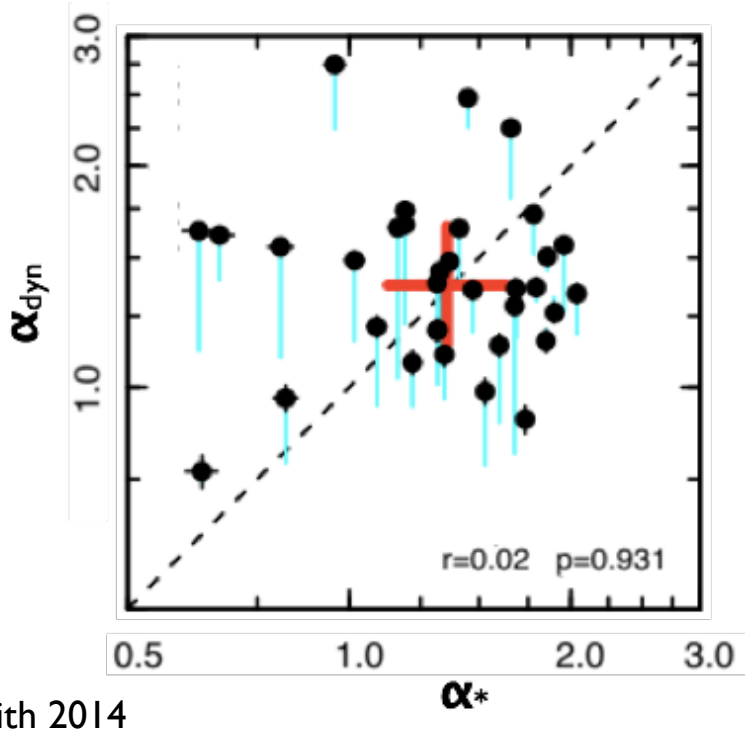






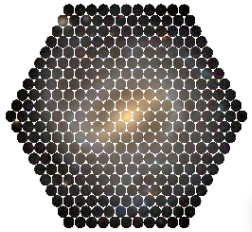
CALIFA Survey

Stellar Populations and Dynamics give consistent results about the IMF variation



Smith 2014

- $\alpha = \Upsilon/\Upsilon_{ref}$ - mismatch parameter
- Υ_{ref} = M/L of stellar population with that age, chemistry, and a given IMF



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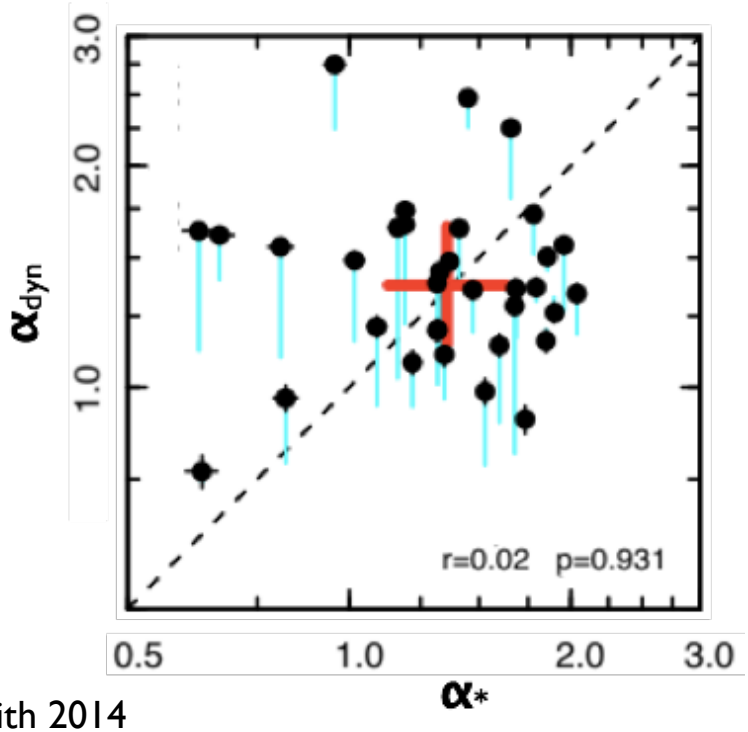
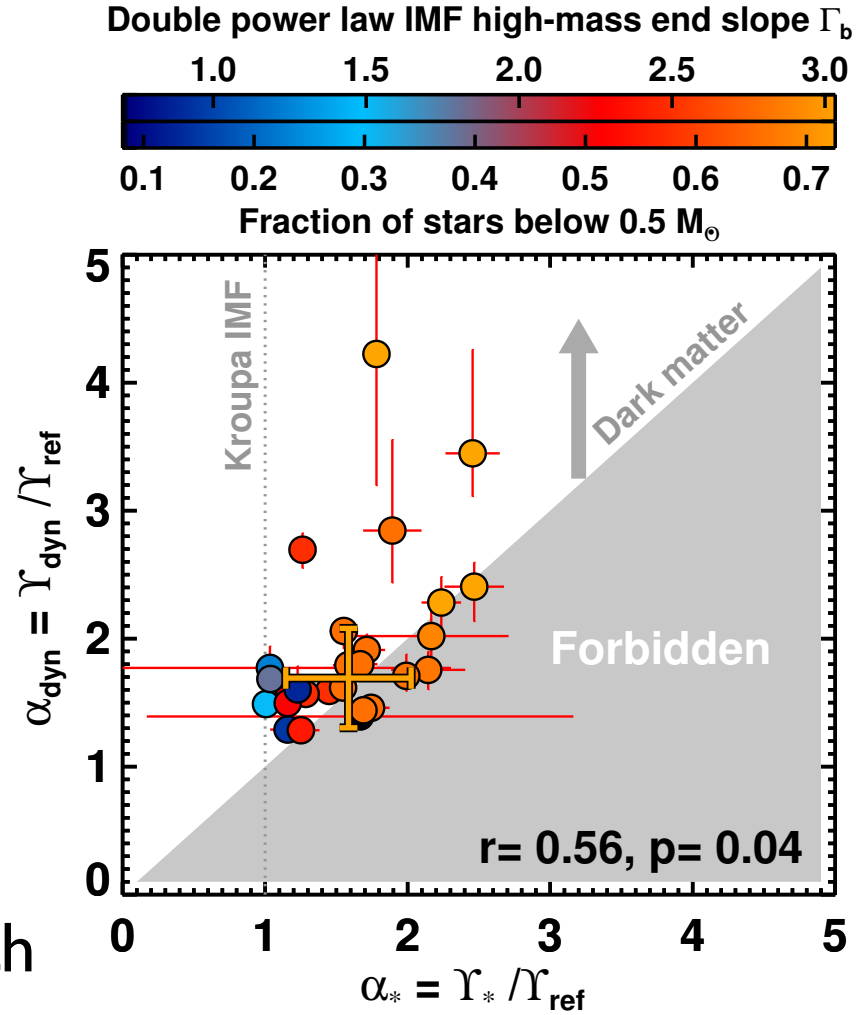


Smith 2014



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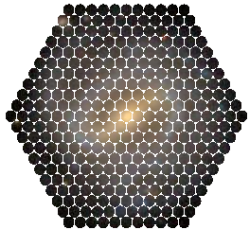
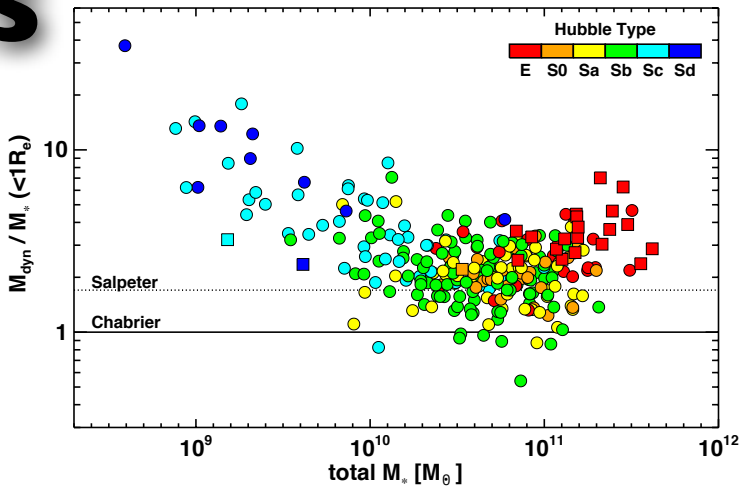
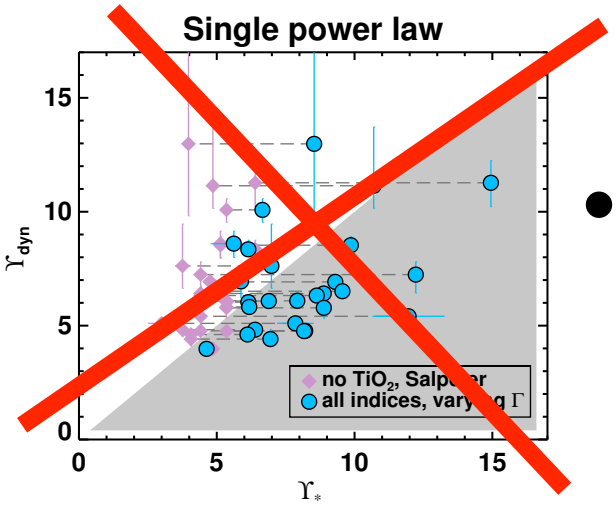


CALIFA Survey

Conclusions

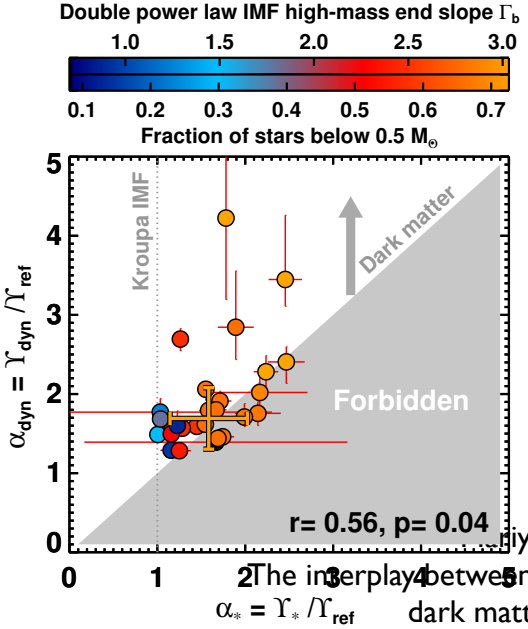
- **CALIFA** provides a statistical view of the interplay between baryons and dark matter of galaxies





- Single power-law IMF shape ruled out

- Low mass spirals are heavily dark matter dominated inside 1 R_{eff}



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