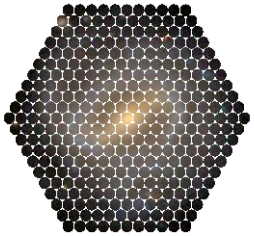


CALIFA Survey

university of groningen

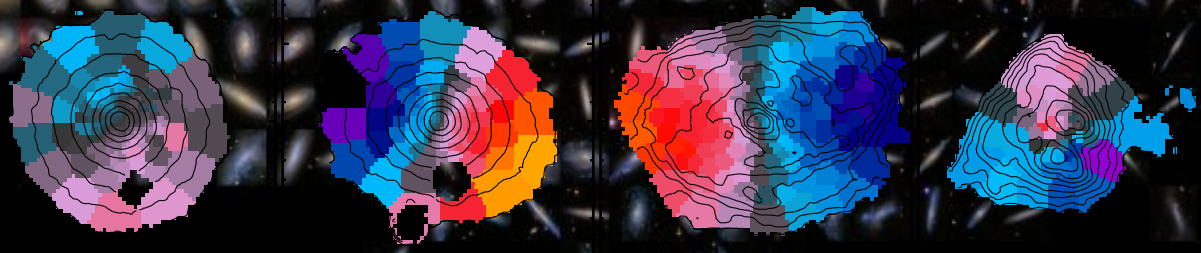
Max-Planck-Institut für Astronomie Heidelberg

Max Planck Institute for Astronomy Heidelberg

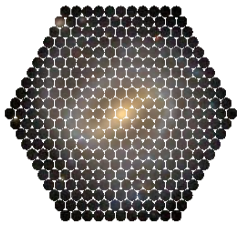
CALIFA
galaxy dynamics across the Hubble sequence

Mariya Lyubenova (Kapteyn) and Glenn van de Ven (MPIA)

and the CALIFA team

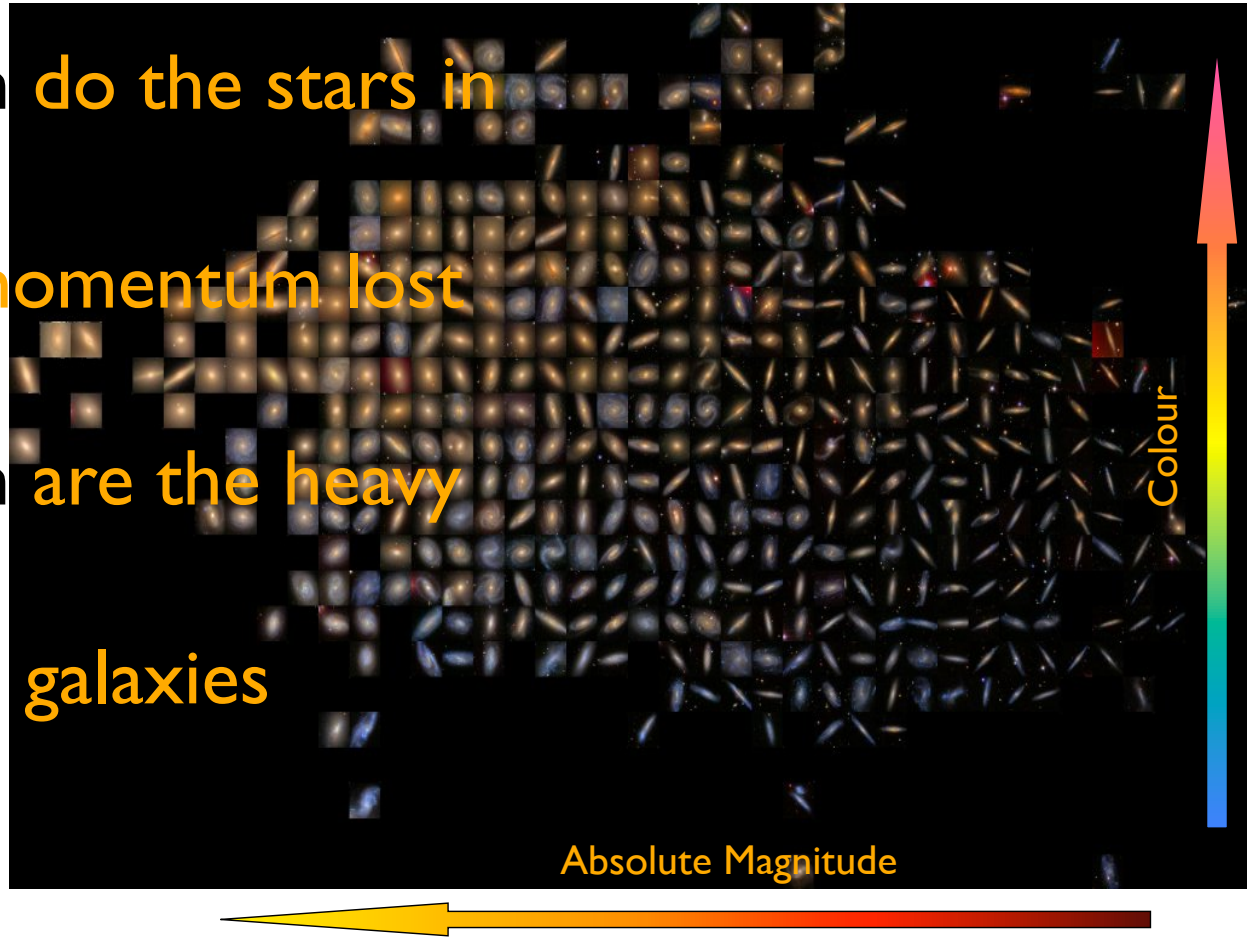


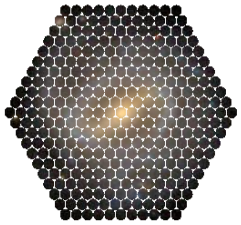
3D2014, Garching, 11 March 2014



Science Drivers

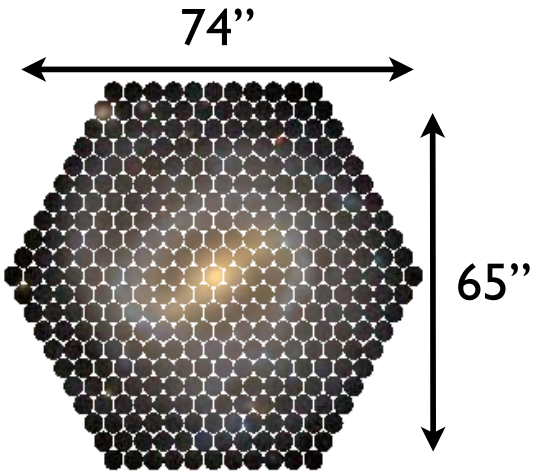
- Where and when do the stars in galaxies form?
- How is angular momentum lost and found?
- Where and when are the heavy elements made?
- How is the gas in galaxies processed?



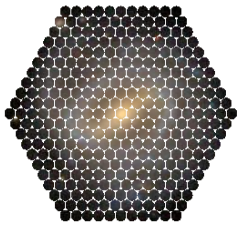


CALIFA Survey

Sample properties

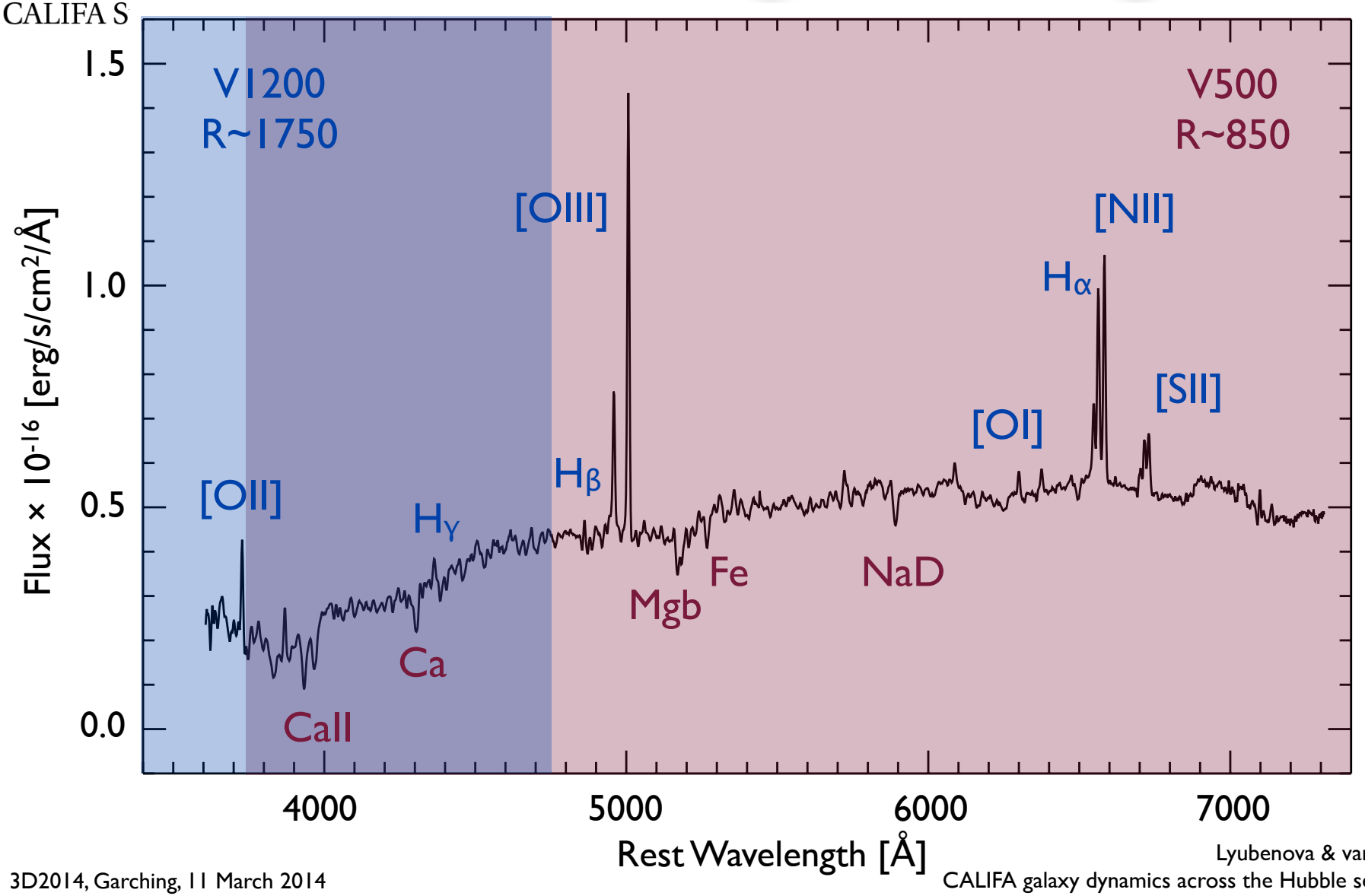


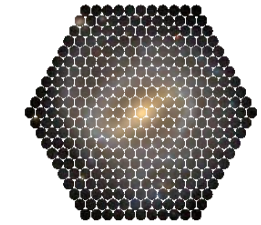
- PMAS/PPAK @ 3.5 Calar Alto
- 600 galaxies will be observed out of
- a mother sample of 937 galaxies
- selected from SDSS imaging
- 45” < D_{25} < 80” isophotal diameter at 25 mag/arcsec^2
- Redshift range: 0.005 < z < 0.03
- Final spatial resolution: 2” ≈ 0.5-1 kpc
- complete in Mass in the range 9.4<log(M)<11.4 $M_\odot$



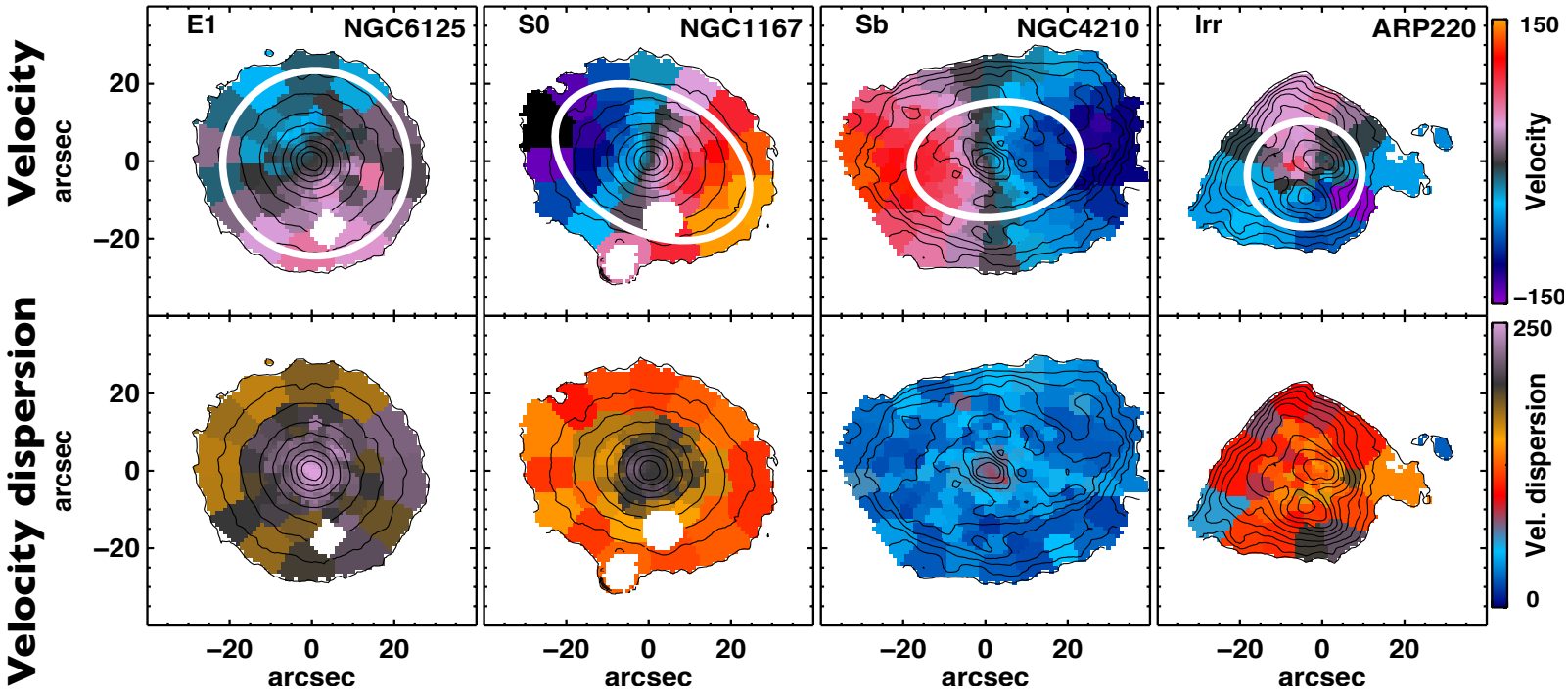
CALIFA S

Wavelength coverage





Stellar Kinematics

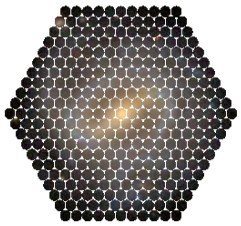


Slow Rotator
low V, high σ

Bulge+Disk
high V, high σ

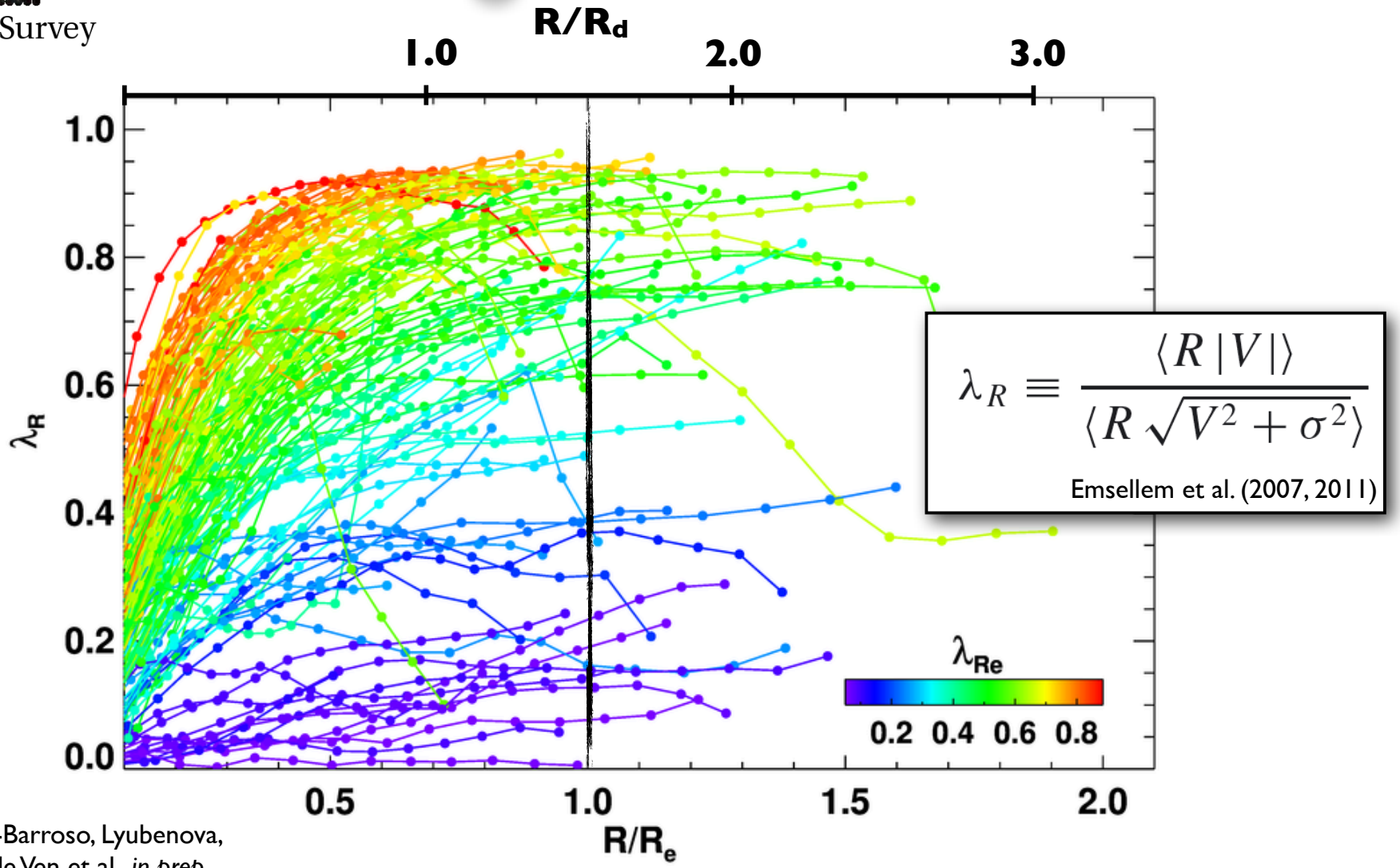
Pure Disk
high V, low σ

Interacting



CALIFA Survey

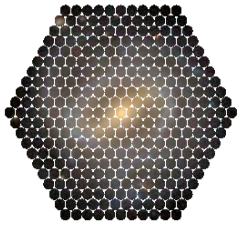
Angular momentum



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

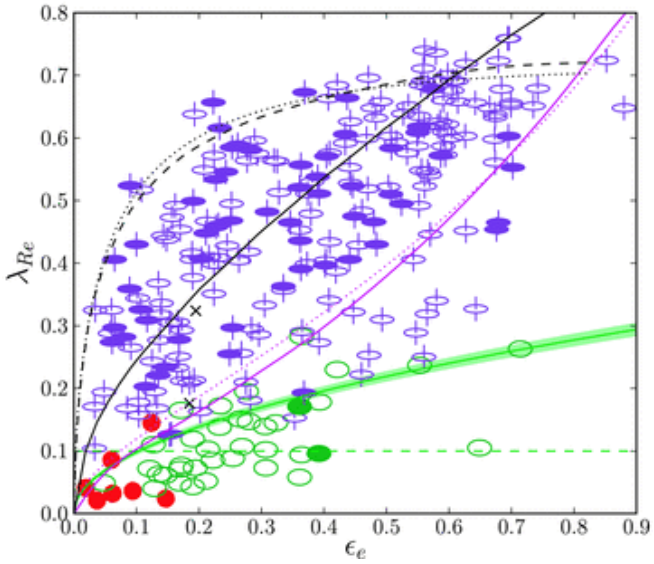
Emsellem et al. (2007, 2011)

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



CALIFA Survey

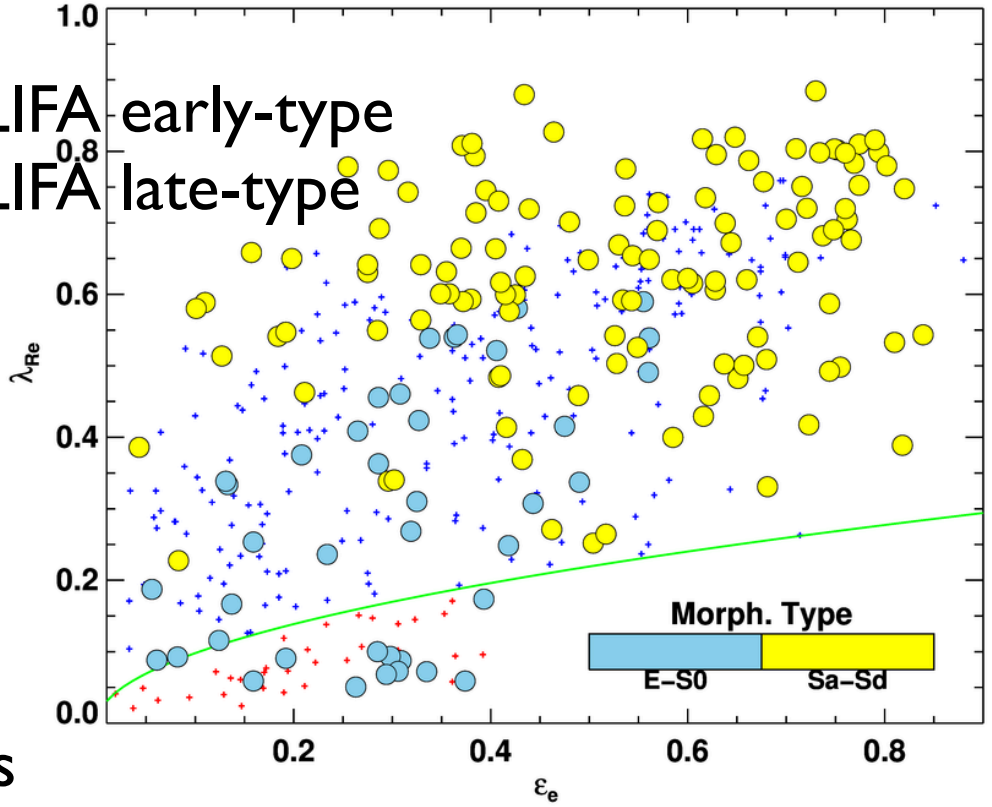
CALIFA angular momentum



Emsellem et al. (2007, 2011)

CALIFA early-type

CALIFA late-type



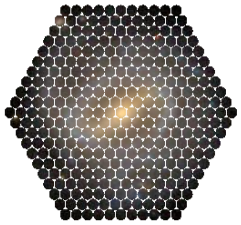
Falcón-Barroso, Lyubenova, van de Ven et al., *in prep.*

Atlas^{3D} **E/S0**

\+ slow rotators

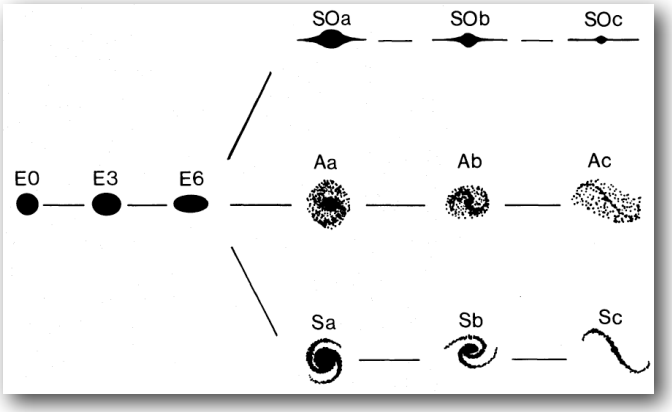
\+ fast rotators

Observed CALIFA galaxies expand the Atlas^{3D} sample

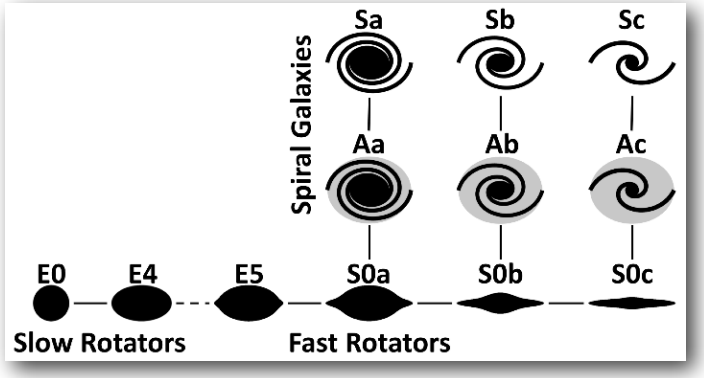


CALIFA Survey

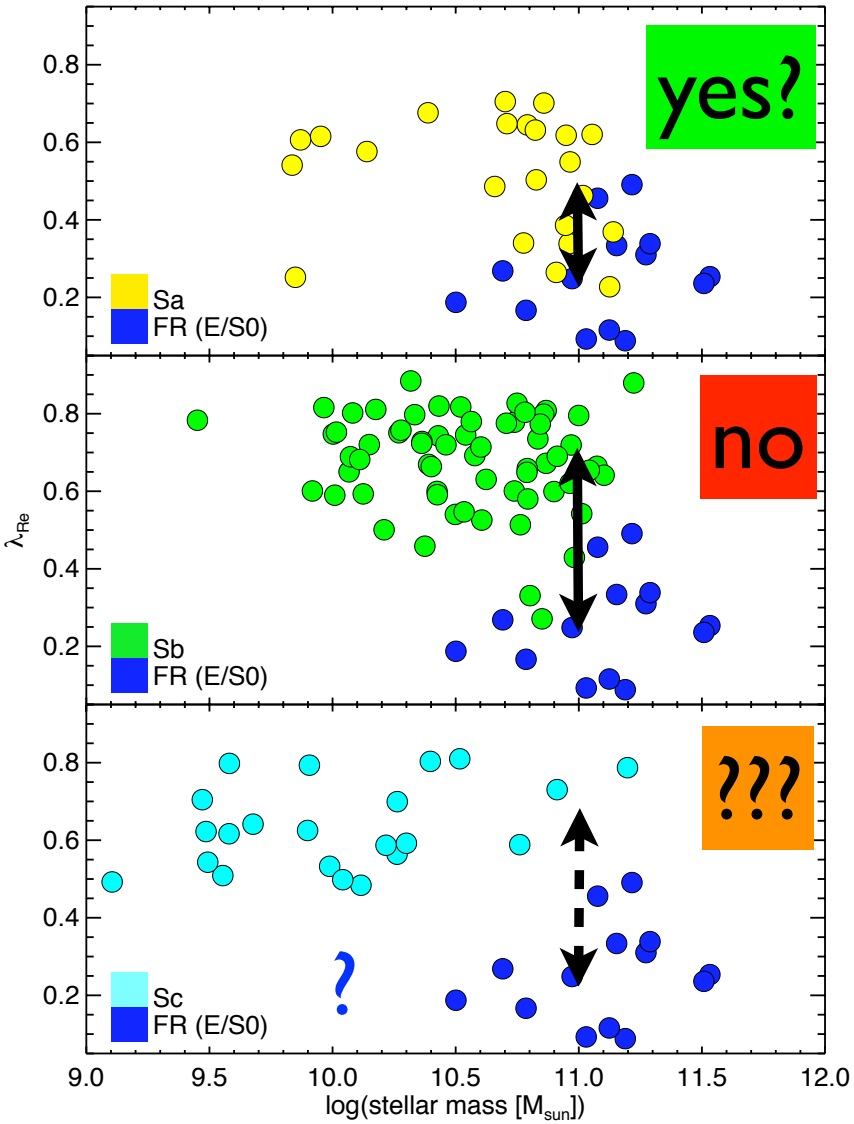
Are Lenticulars faded Spirals?



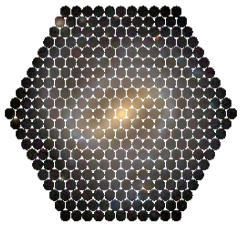
van den Bergh (1976)



Cappellari et al. (2011)



Lyubenova & van de Ven
CALIFA galaxy dynamics across the Hubble sequence



CALIFA Survey

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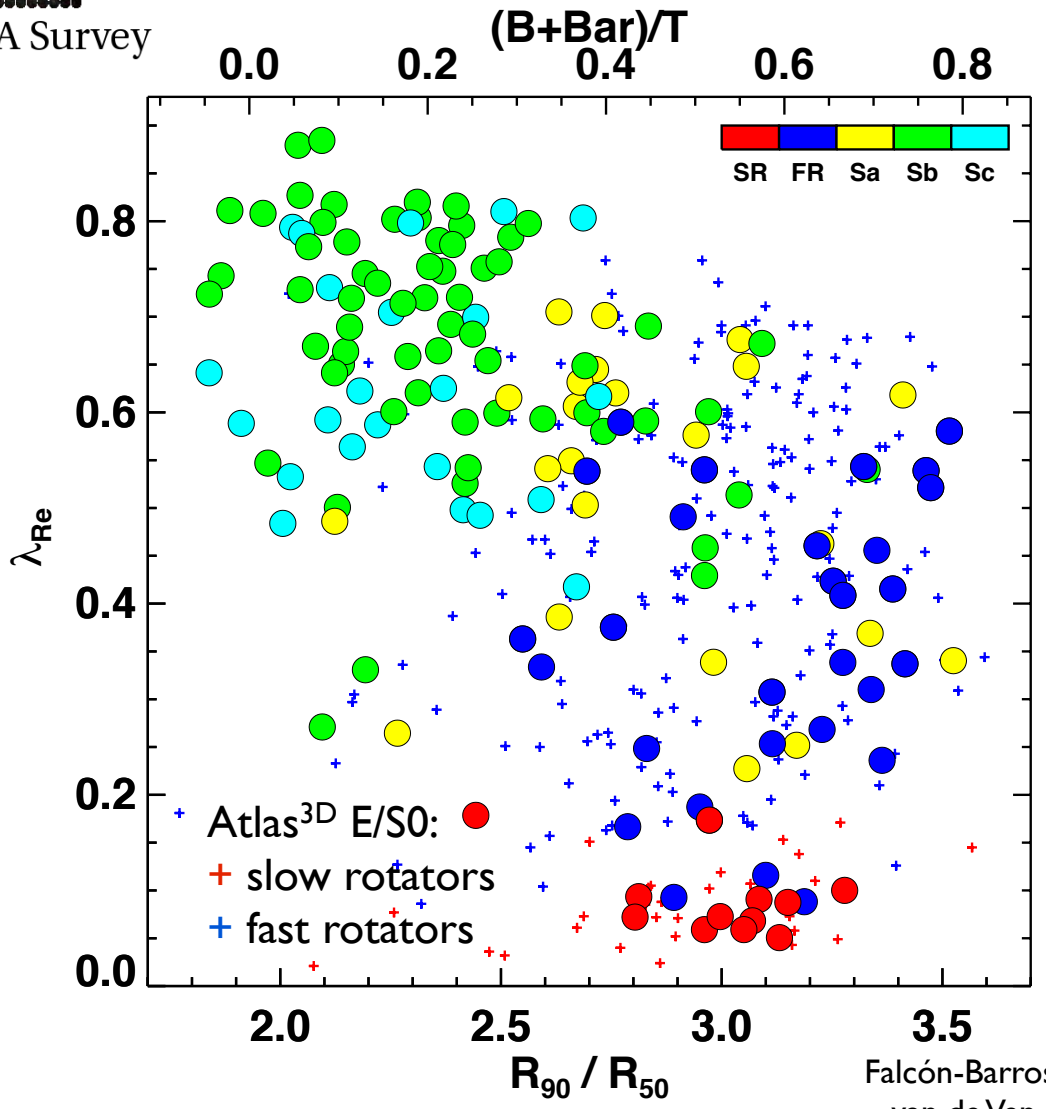
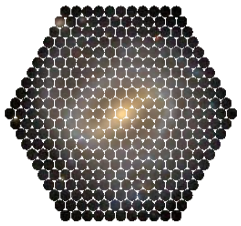


Falcón-Barroso, Lyubenova, van de Ven et al., *in prep.*

Not fading alone!

- Mergers: major/minor? wet/dry?
- Environment: harassment? stripping?
- Internal: feedback? fading?
- Secular evolution?



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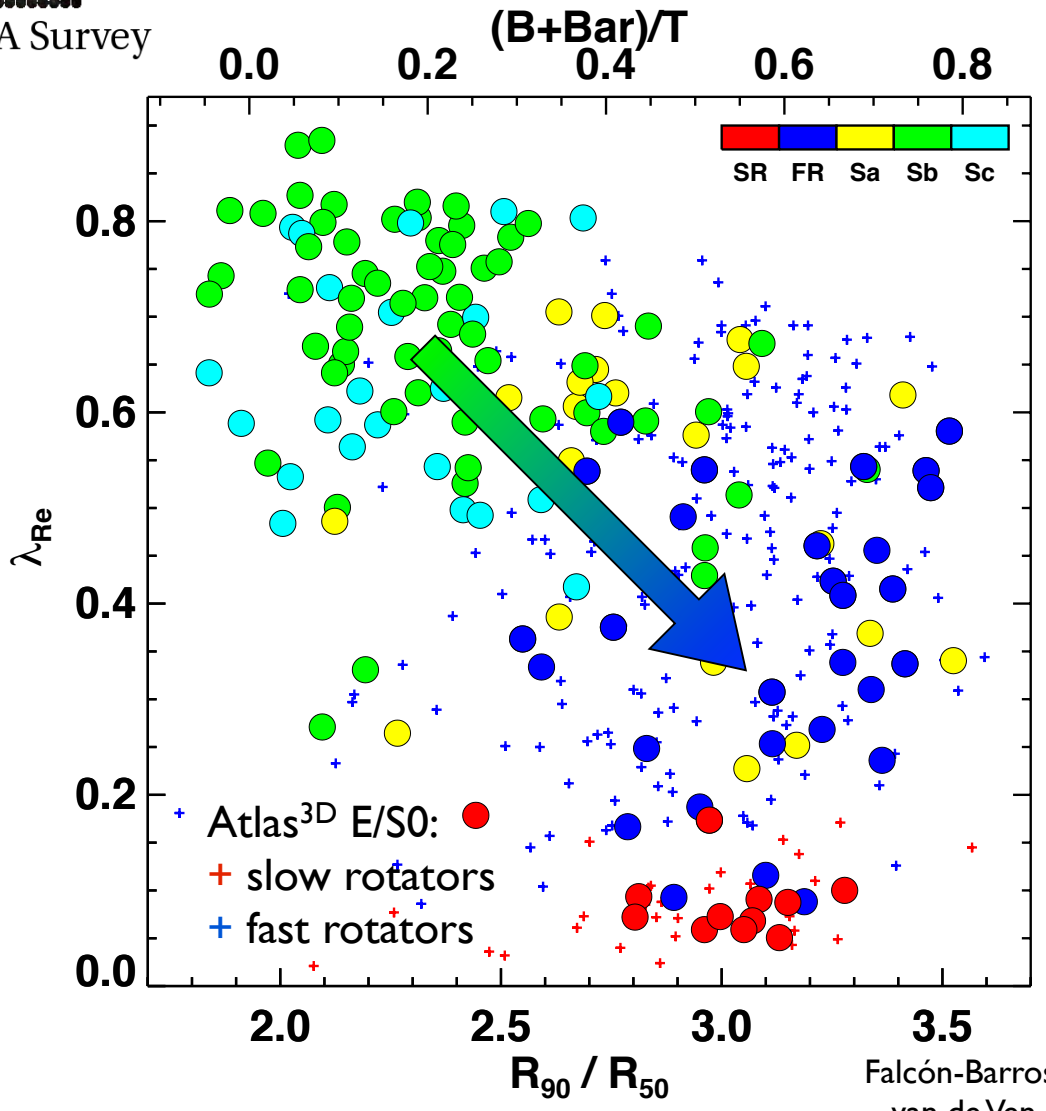

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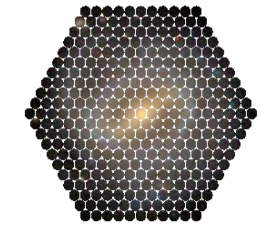
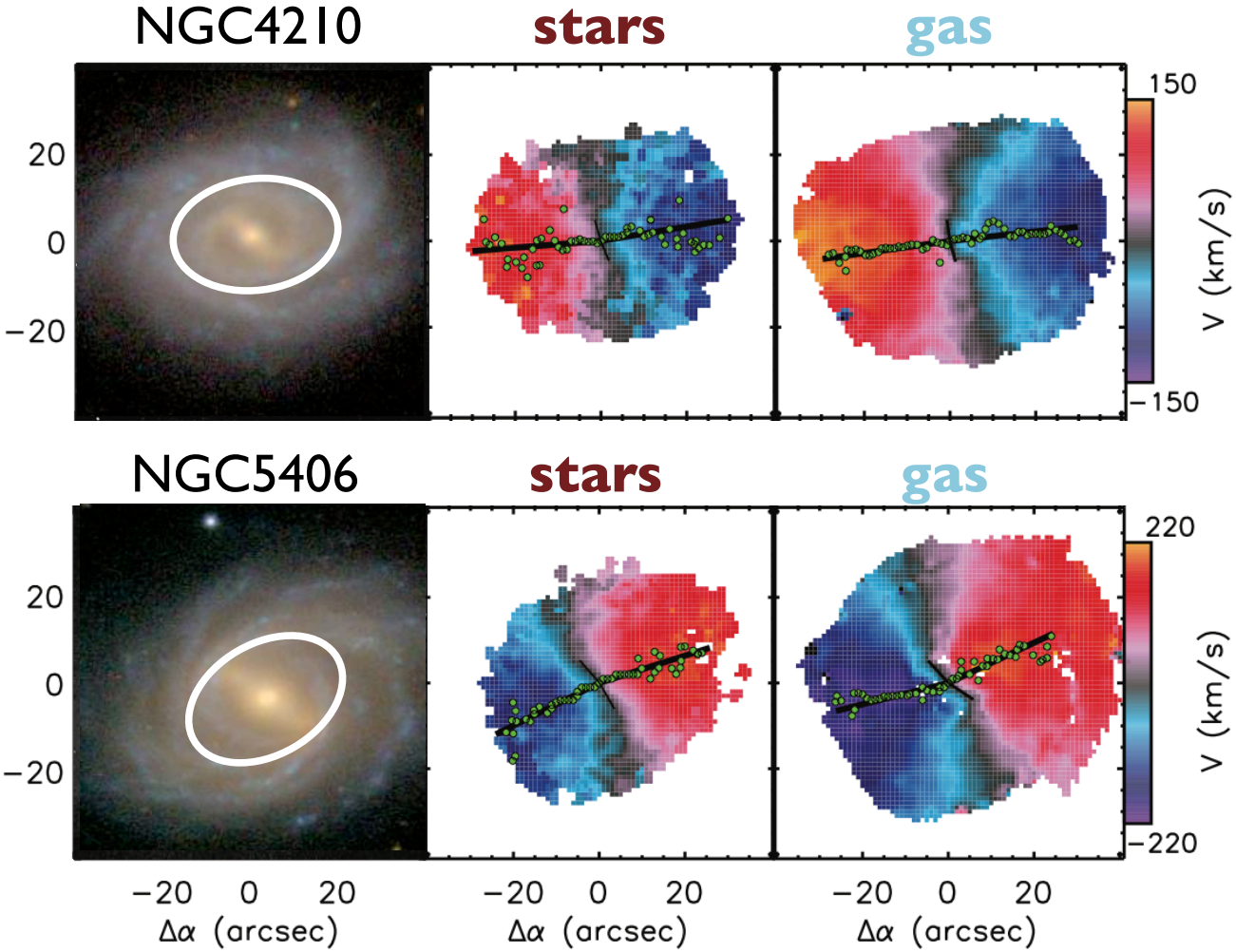
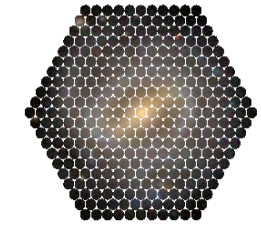


CALIFA Survey

Kinematic alignment of non-interacting galaxies



Barrera-Ballesteros et al.,
A&A submitted



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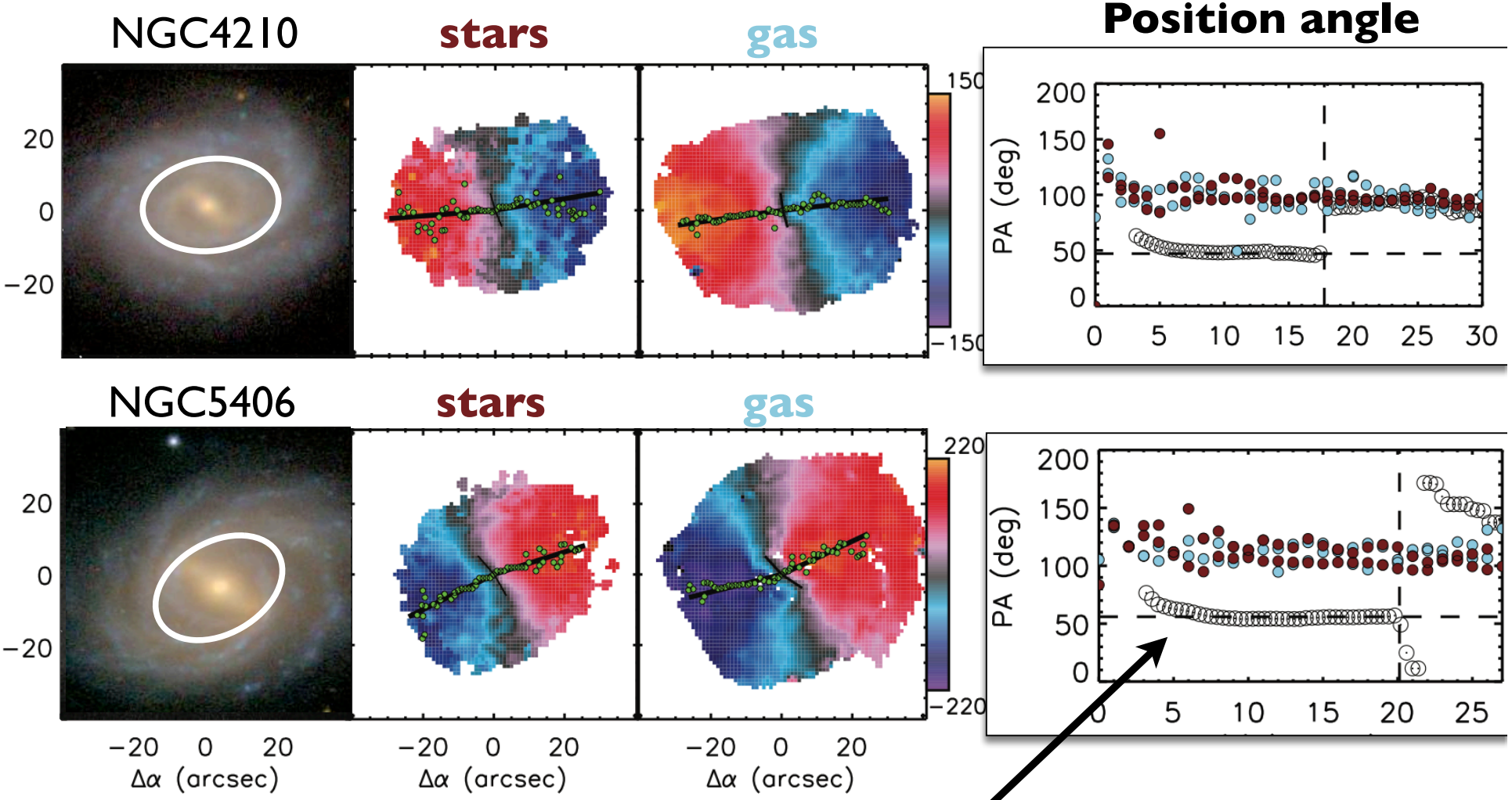

Barrera-Ballesteros et al.,
A&A submitted

Lyubenova & van de Ven
CALIFA galaxy dynamics across the Hubble sequence

CALIFA Survey

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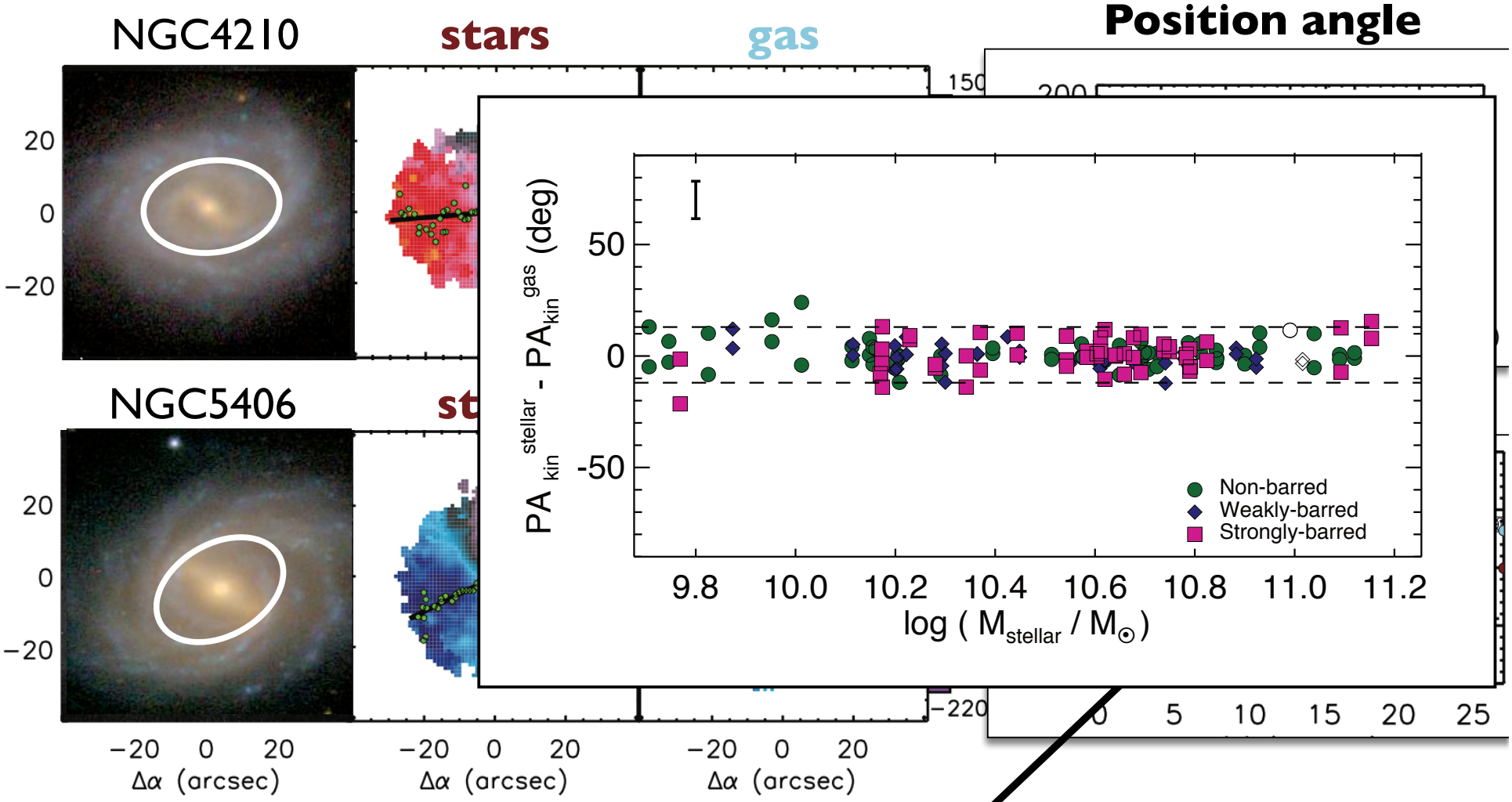
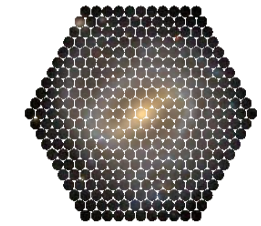
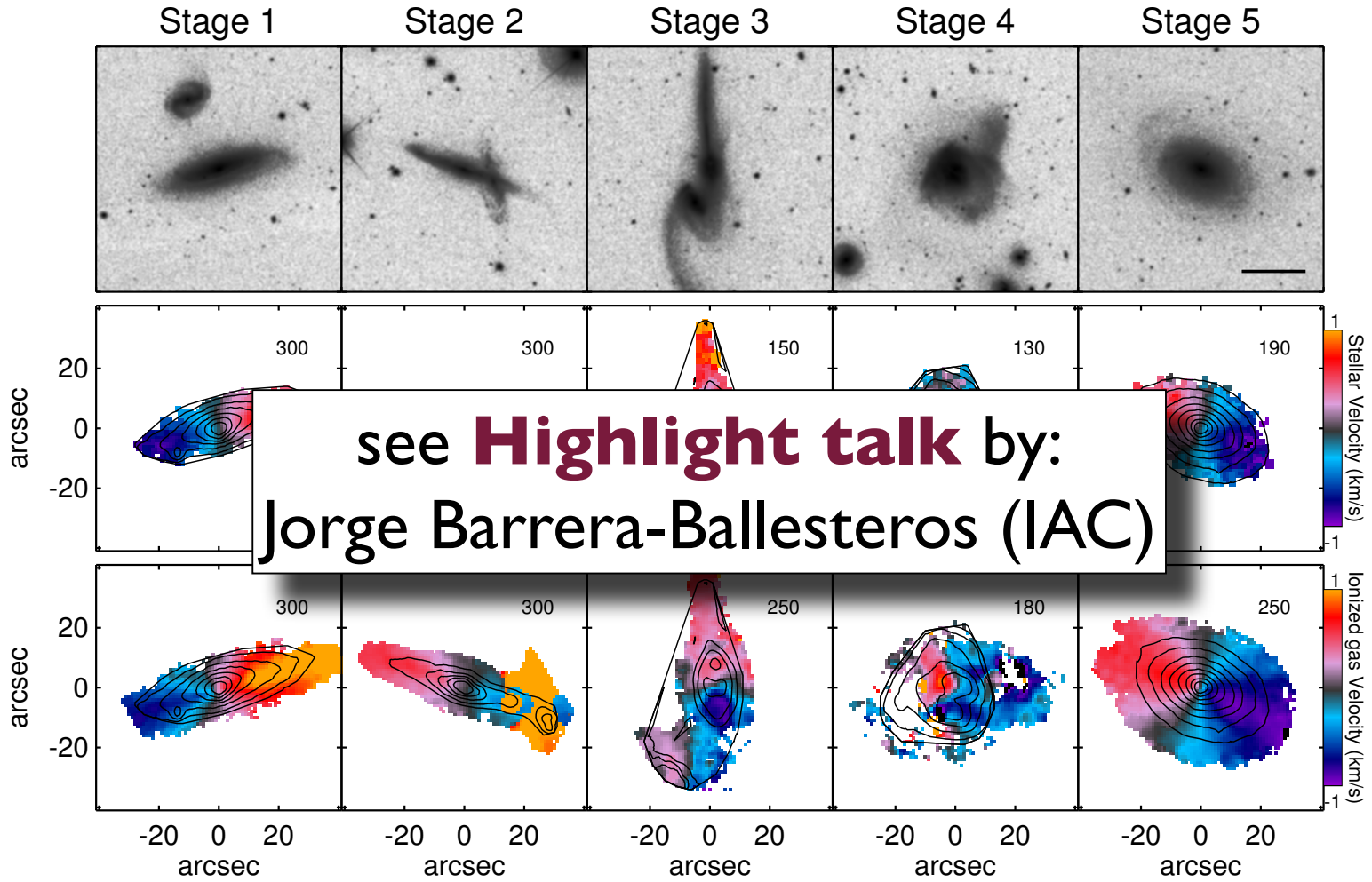


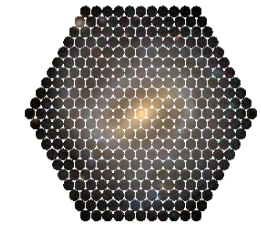
Barrera-Ballesteros et al., *A&A submitted*



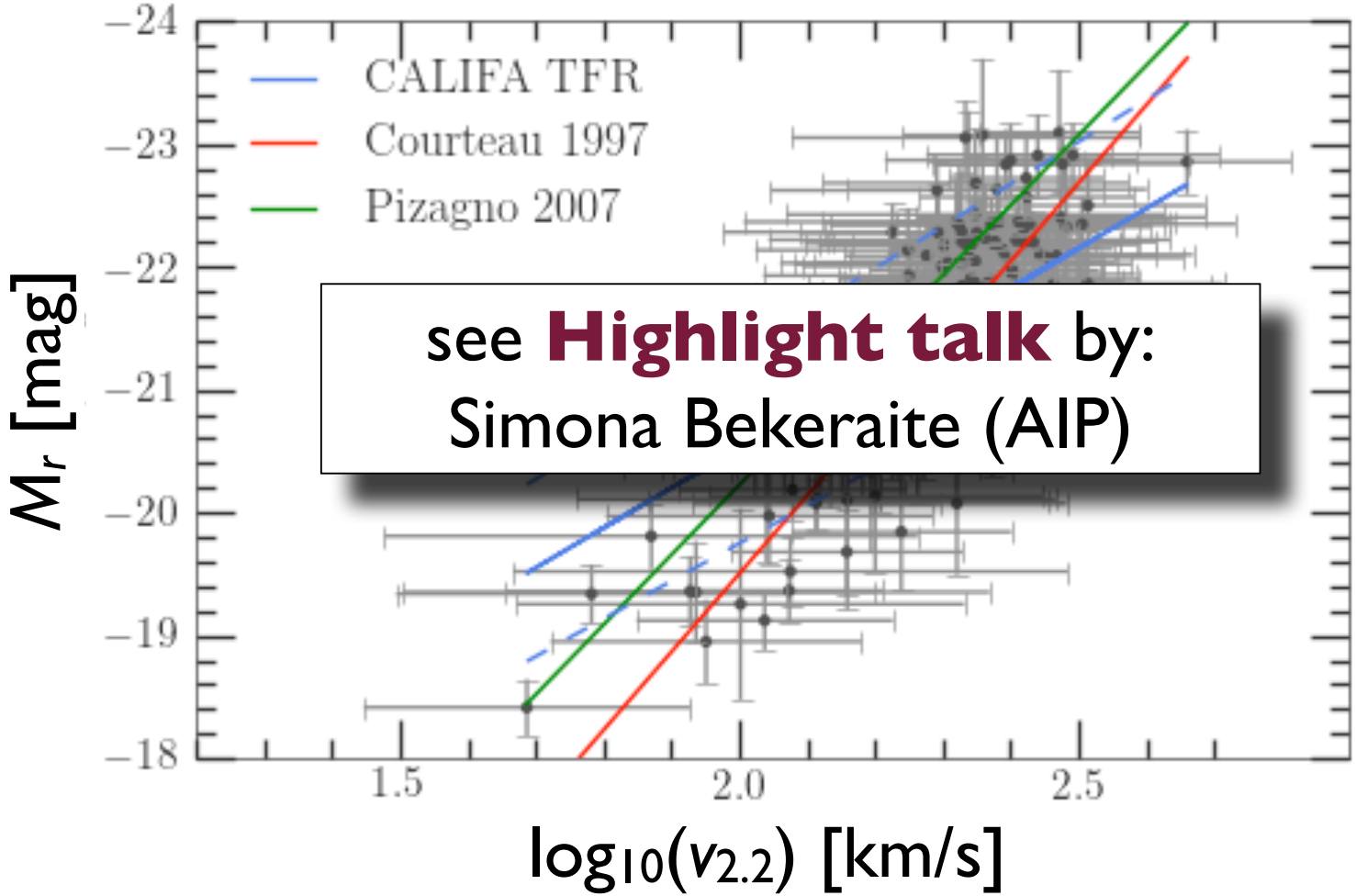
Kinematics of major mergers



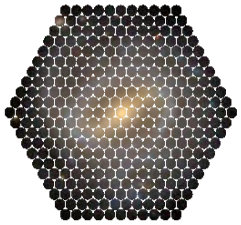
see **Highlight talk** by:
Jorge Barrera-Ballesteros (IAC)



Unbiased Tully-Fisher relation

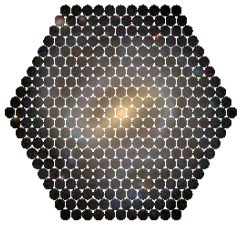


see **Highlight talk** by:
Simona Bekeraite (AIP)



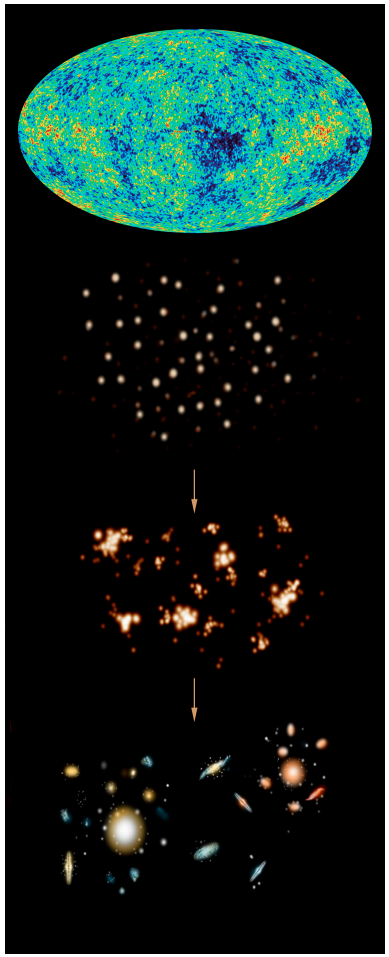
CALIFA Survey

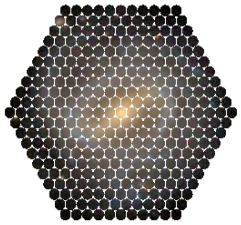
Dynamical modelling of early- and late-type galaxies in CALIFA



Mass distribution across the Hubble sequence

- ΛCDM model: flat universe + dark energy + cold dark matter
- successful on large scales, but tests inconclusive on scales of galaxies
- need dark matter, but observe light:
  - 'adding' baryons to dark-matter-only simulations via empirical prescription
  - 'subtracting' baryons from total mass distribution inferred through luminous tracers of the gravitational potential



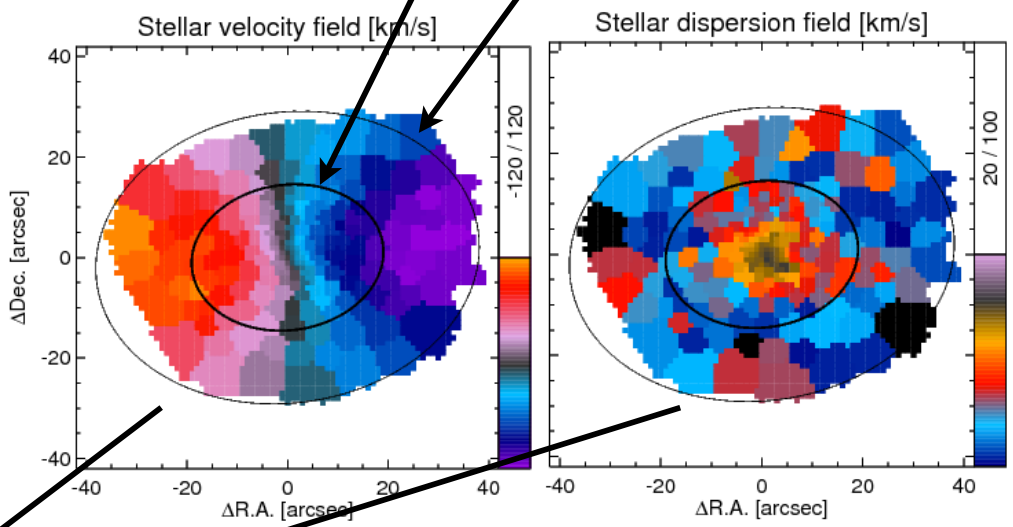


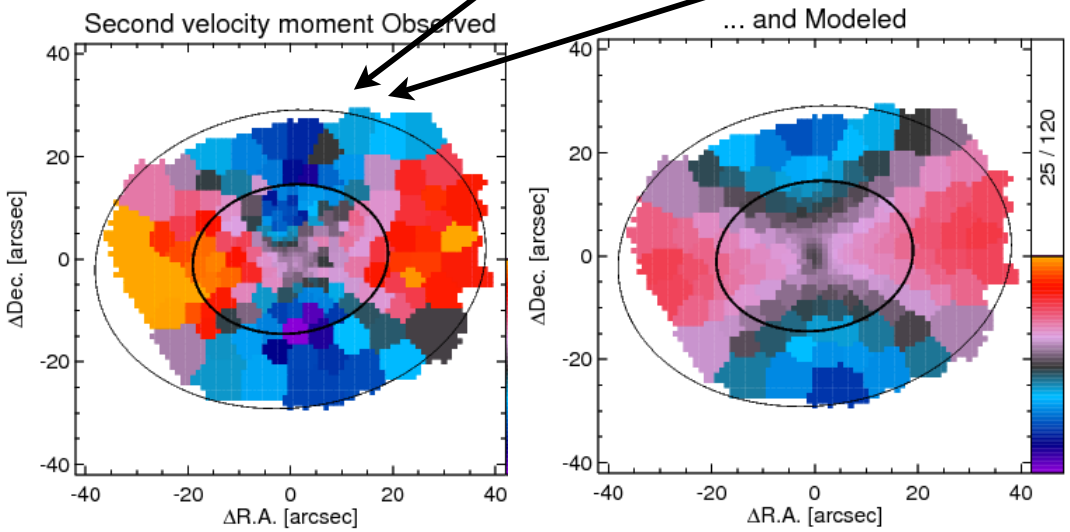
CALIFA Survey

Total mass distribution

NGC4210

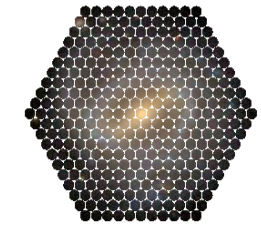
1 and 2 R_{eff}



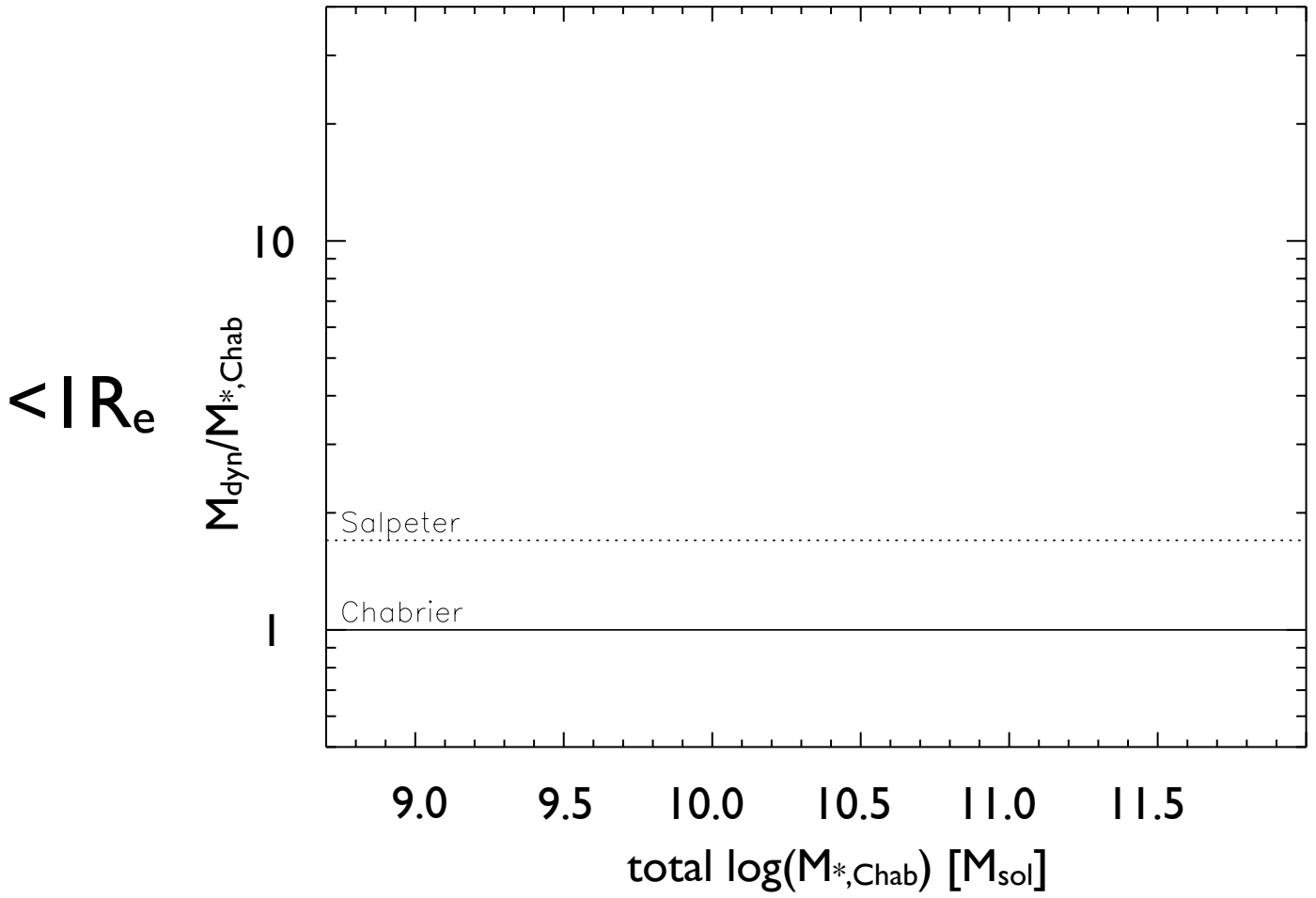


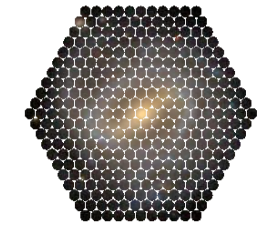
Jeans & Schwarzschild dynamical models → $M_{tot}(<R)$

Lyubenova, van de Ven et al., *in prep.*



Dark matter fractions





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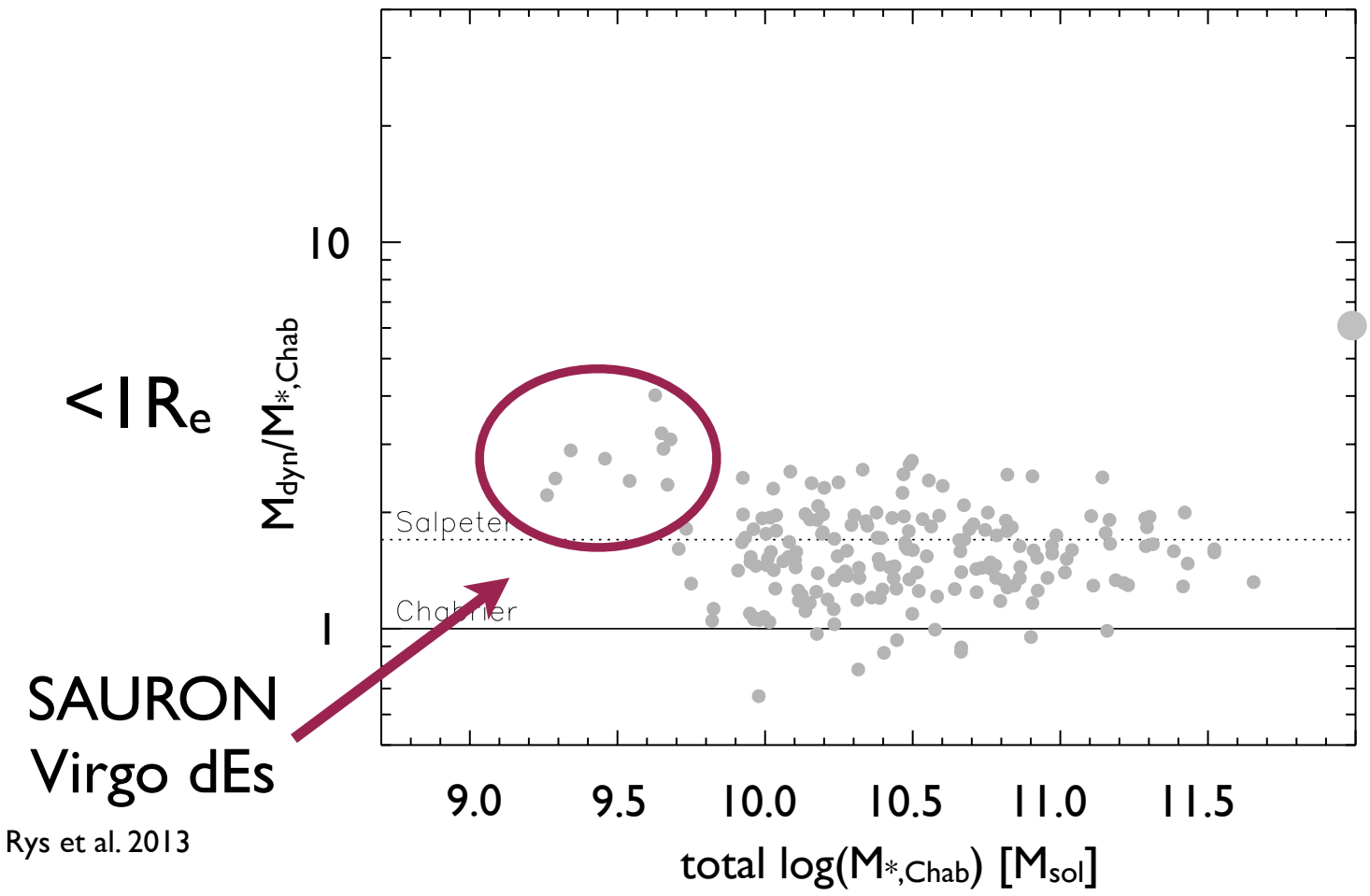


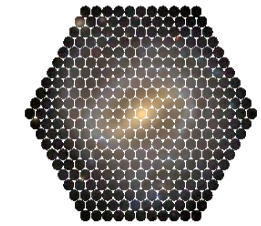
<1 R_e

SAURON
Virgo dEs

Rys et al. 2013

Atlas^{3D}/
SAURON
E/S0 only

Cappellari et al. 2011, 2012



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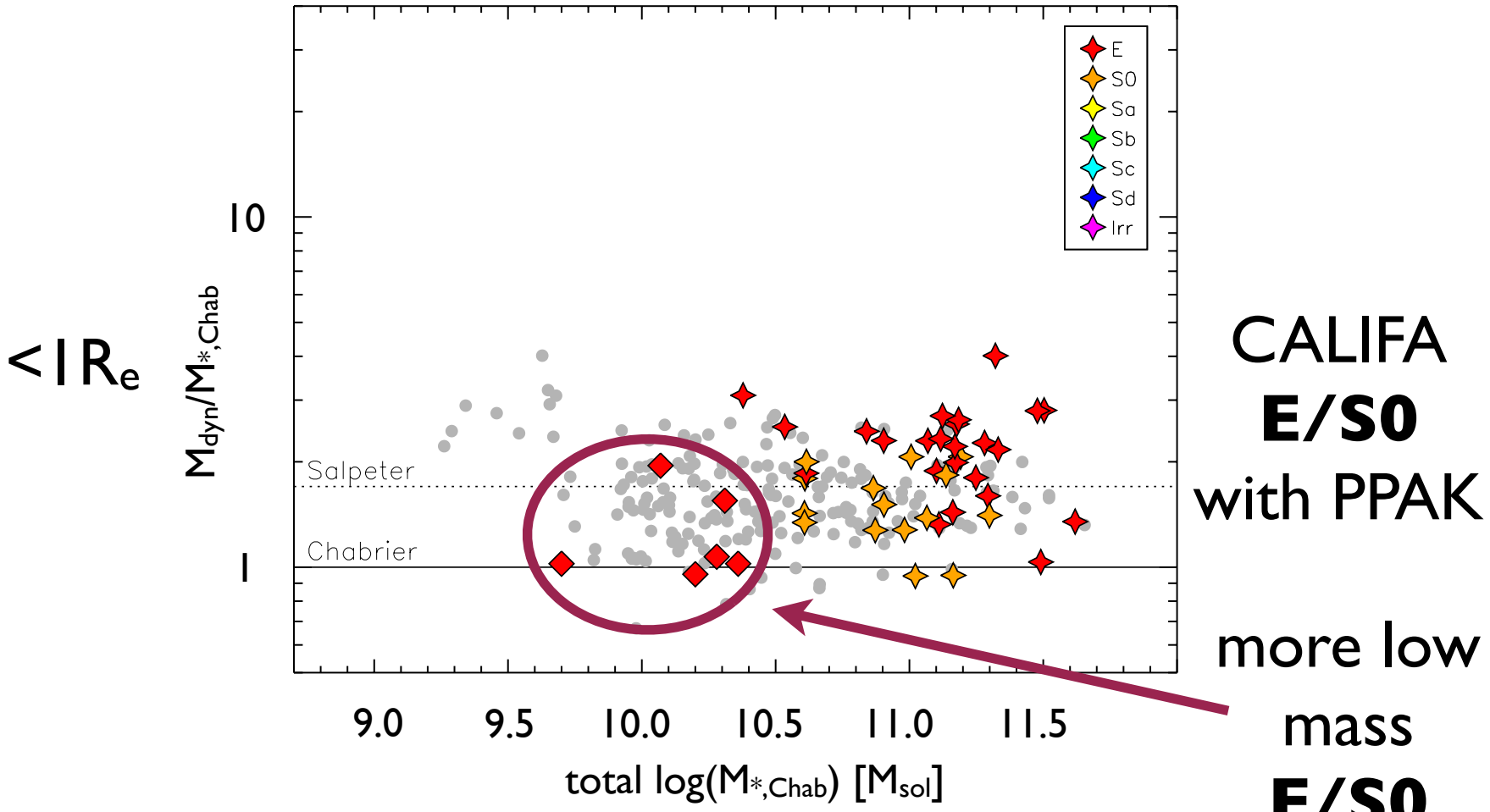
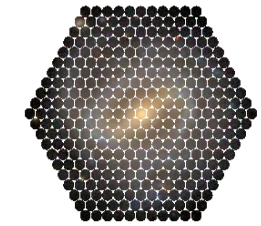


$<1R_e$

CALIFA **E/S0** with PPAK

more low mass **E/S0**



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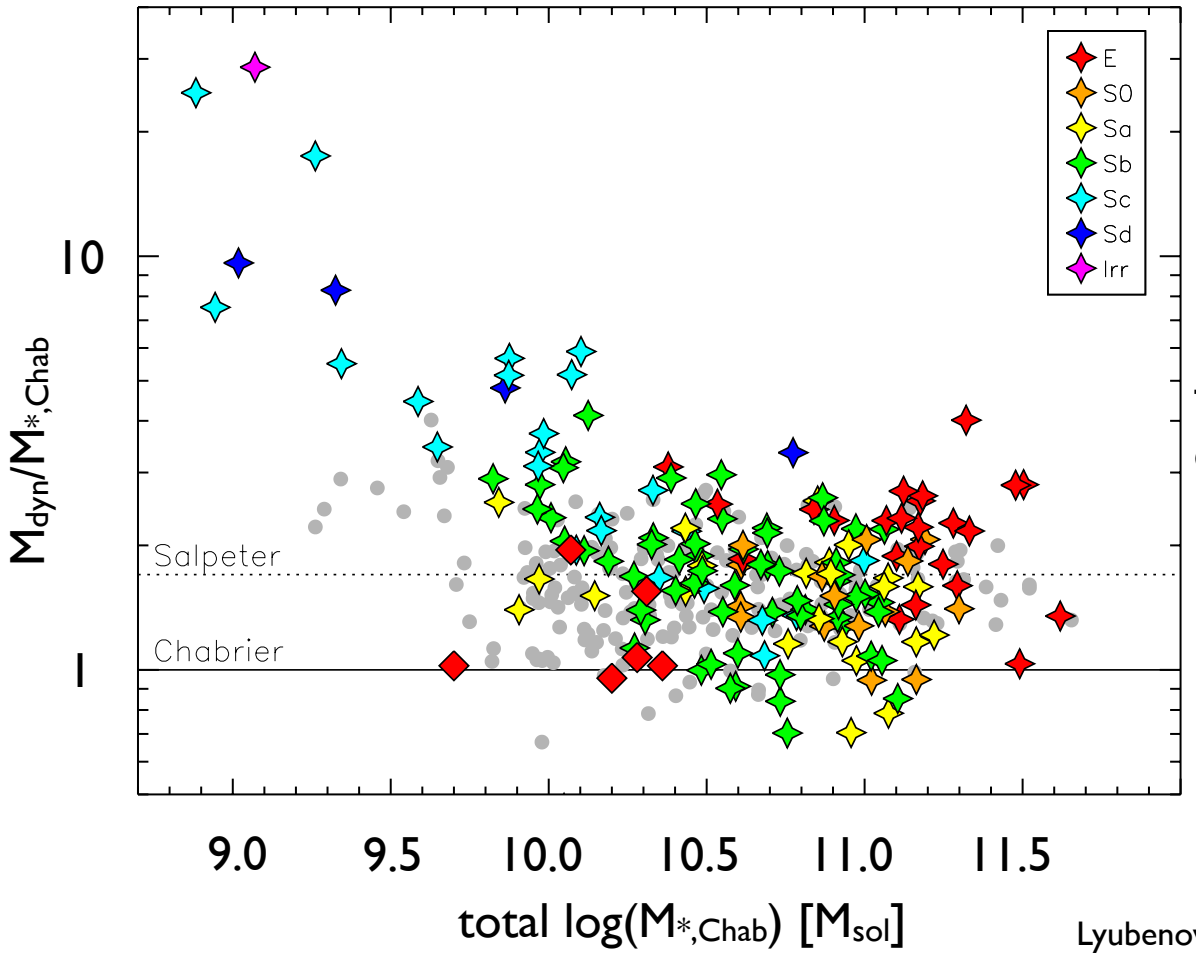
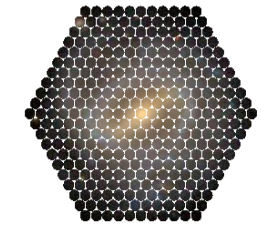


< 1 R_e

✦ Stellar masses from full spectrum fitting

Gonzales-Delgado et al. 2014

Lyubenova, van de Ven et al., *in prep.*



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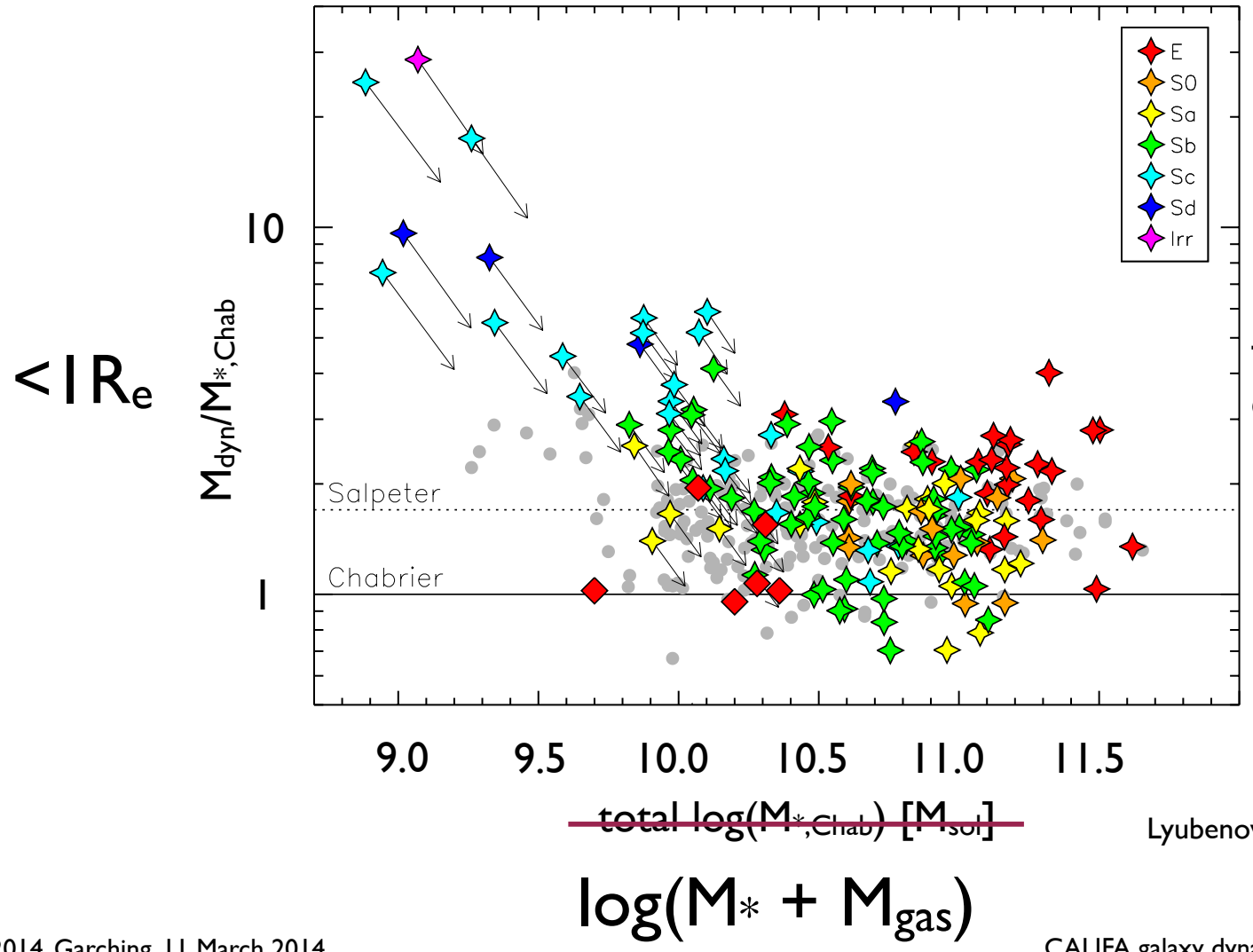
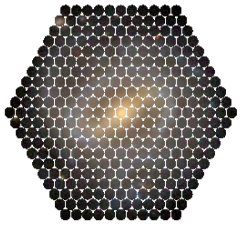


< 1 R_e

✦ Stellar masses from full spectrum fitting
Gonzales-Delgado et al. 2014

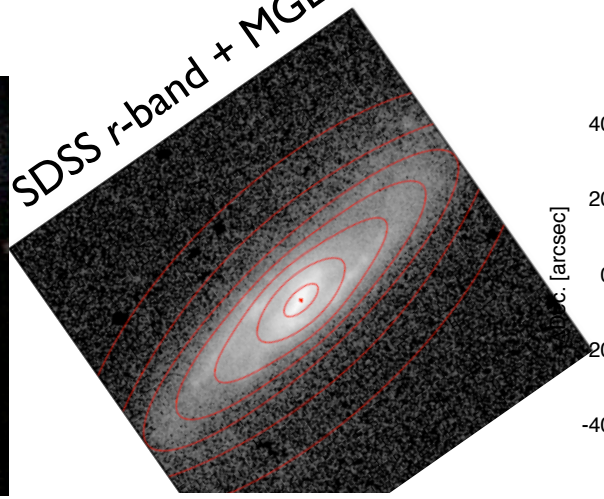
✦ Gas masses via Papastergis et al. 2012

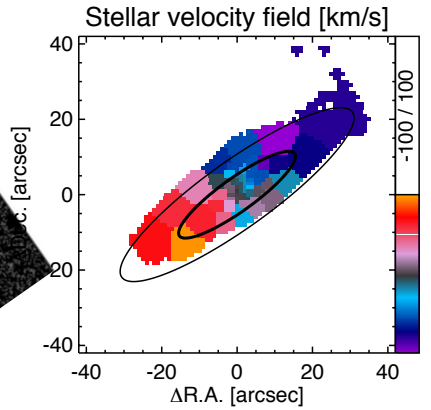
Lyubenova, van de Ven et al., *in prep.*

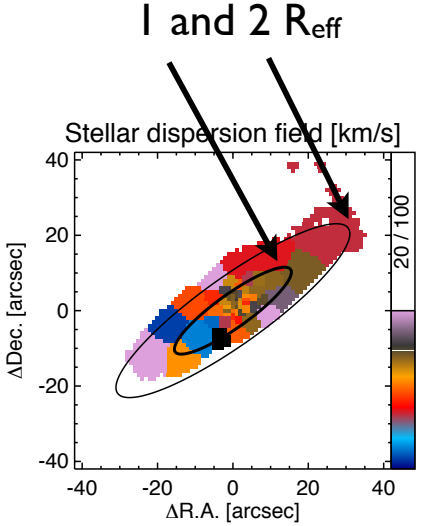


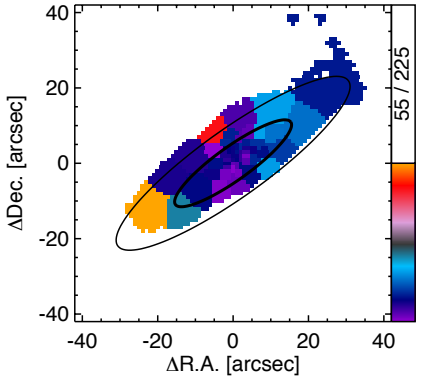
CALIFA Survey

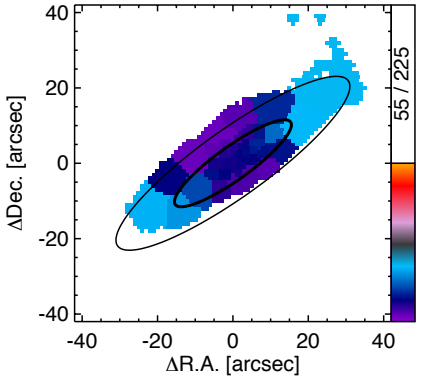
The "outliers"

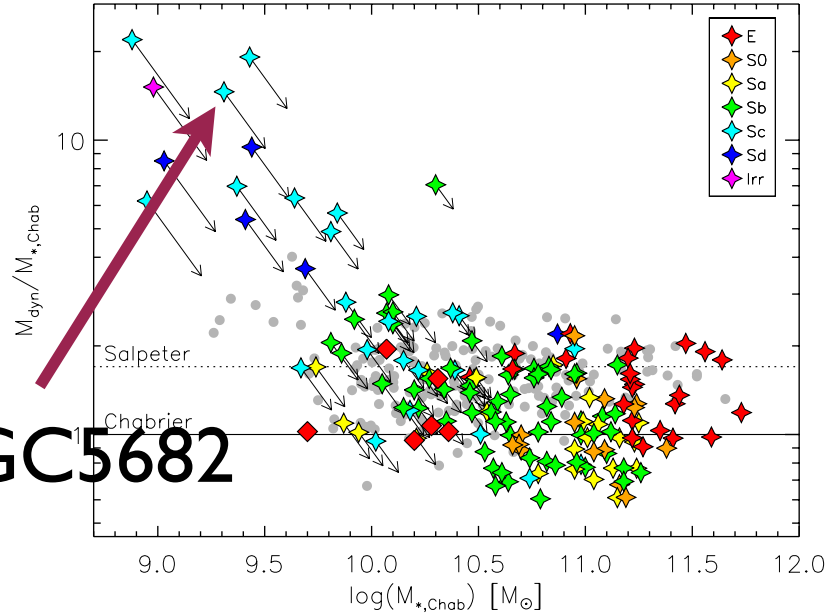




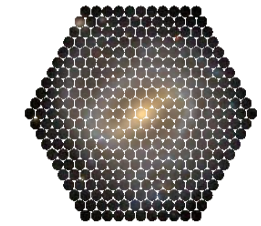








NGC5682



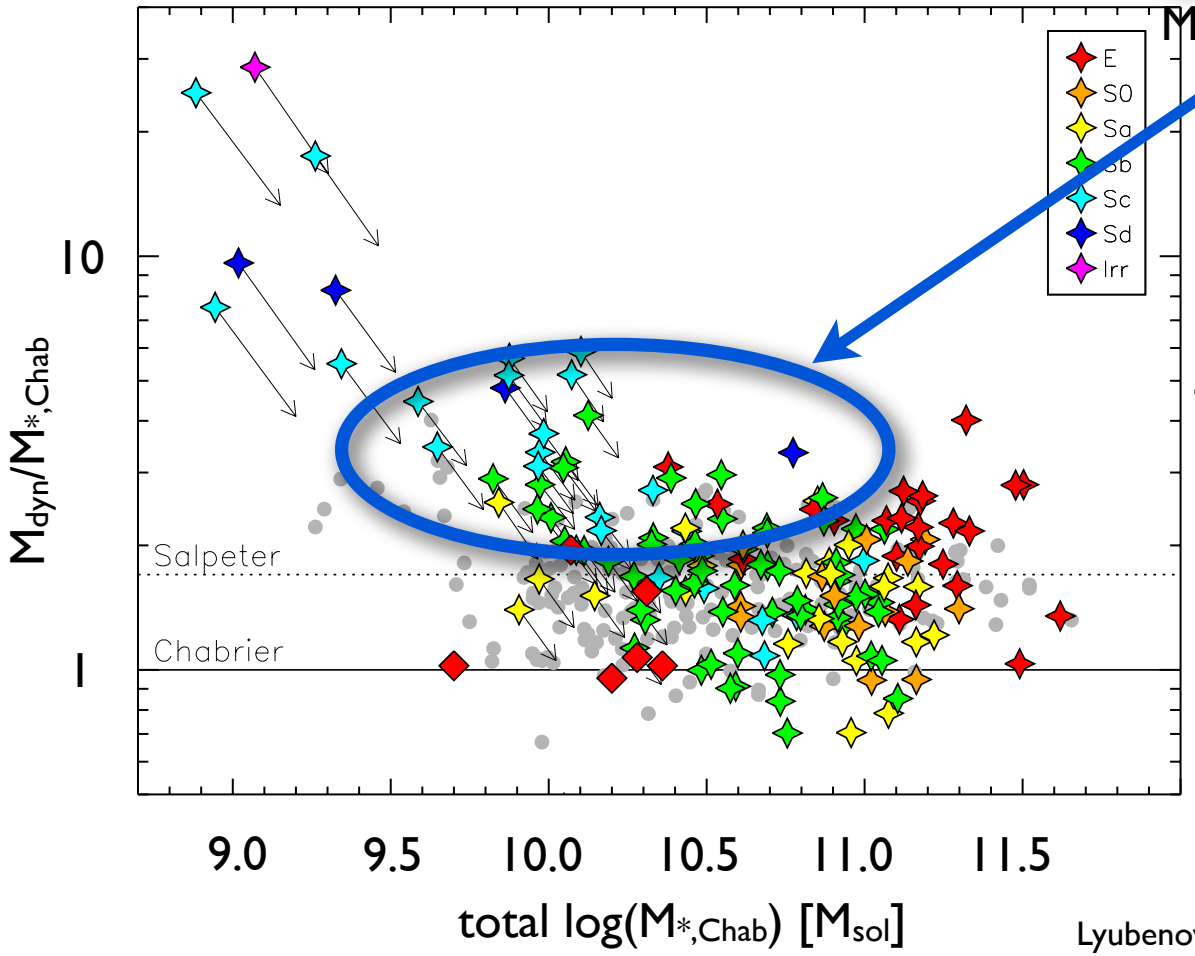
Dark matter fractions

DMS

Martinsson et al. 2013

M_{dyn}/M_{bar}

<1 R_e

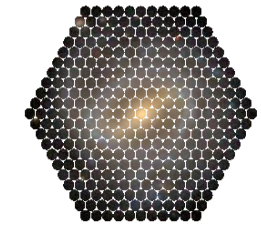


✦ Stellar masses from full spectrum fitting

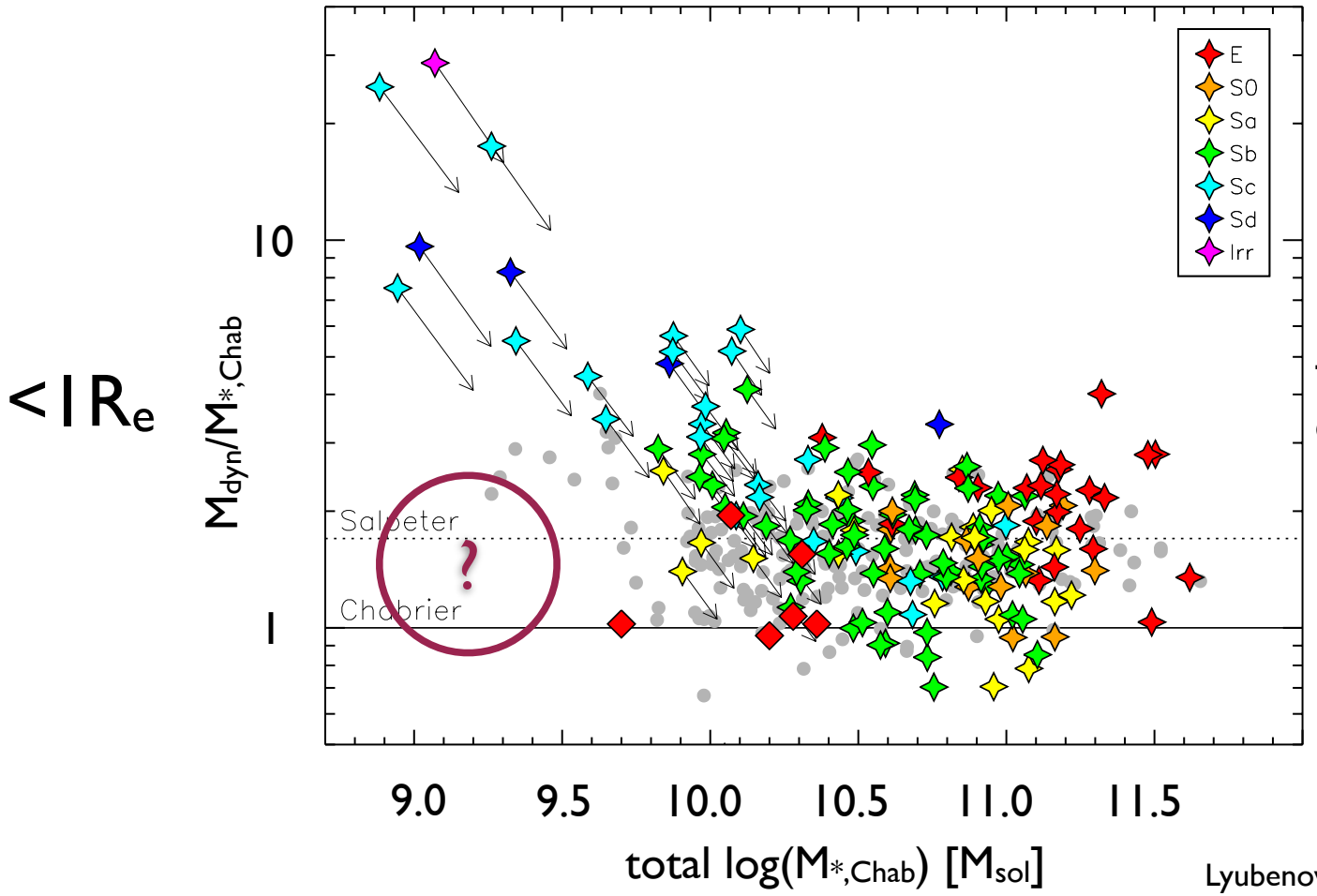
Gonzales-Delgado et al. 2014

✦ Gas masses via Papastergis et al. 2012

Lyubenova, van de Ven et al., *in prep.*



Dark matter fractions



<1 R_e

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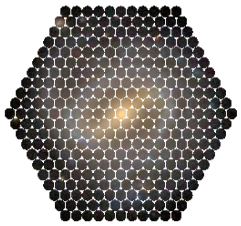


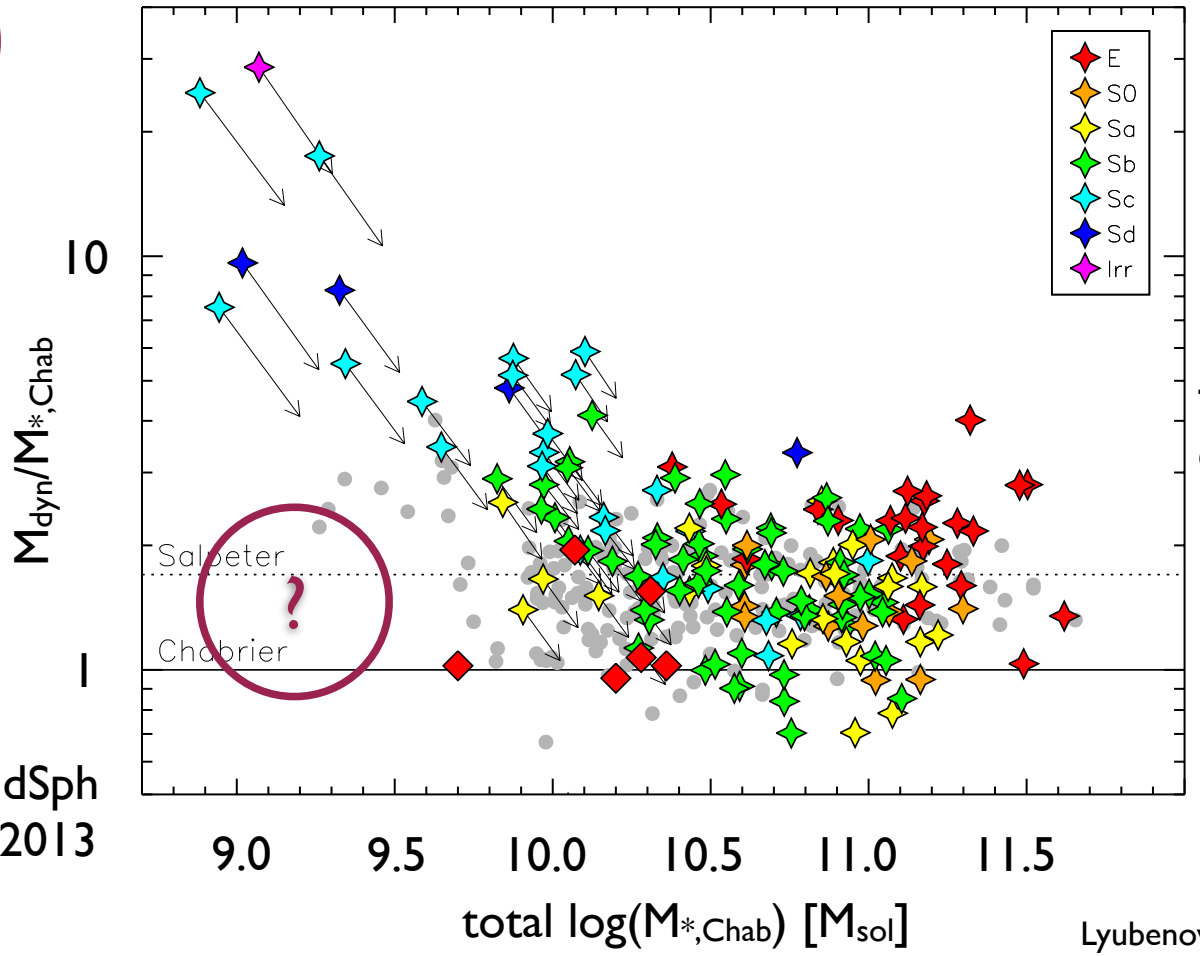
CALIFA Survey

Dark matter fractions

dSph

<1 R_e

Local Group dSph
Collins et al. 2013



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Gonzales-Delgado et al. 2014

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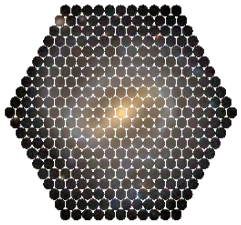
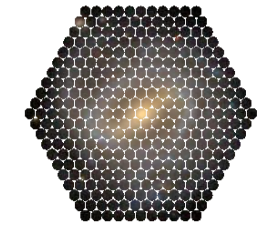
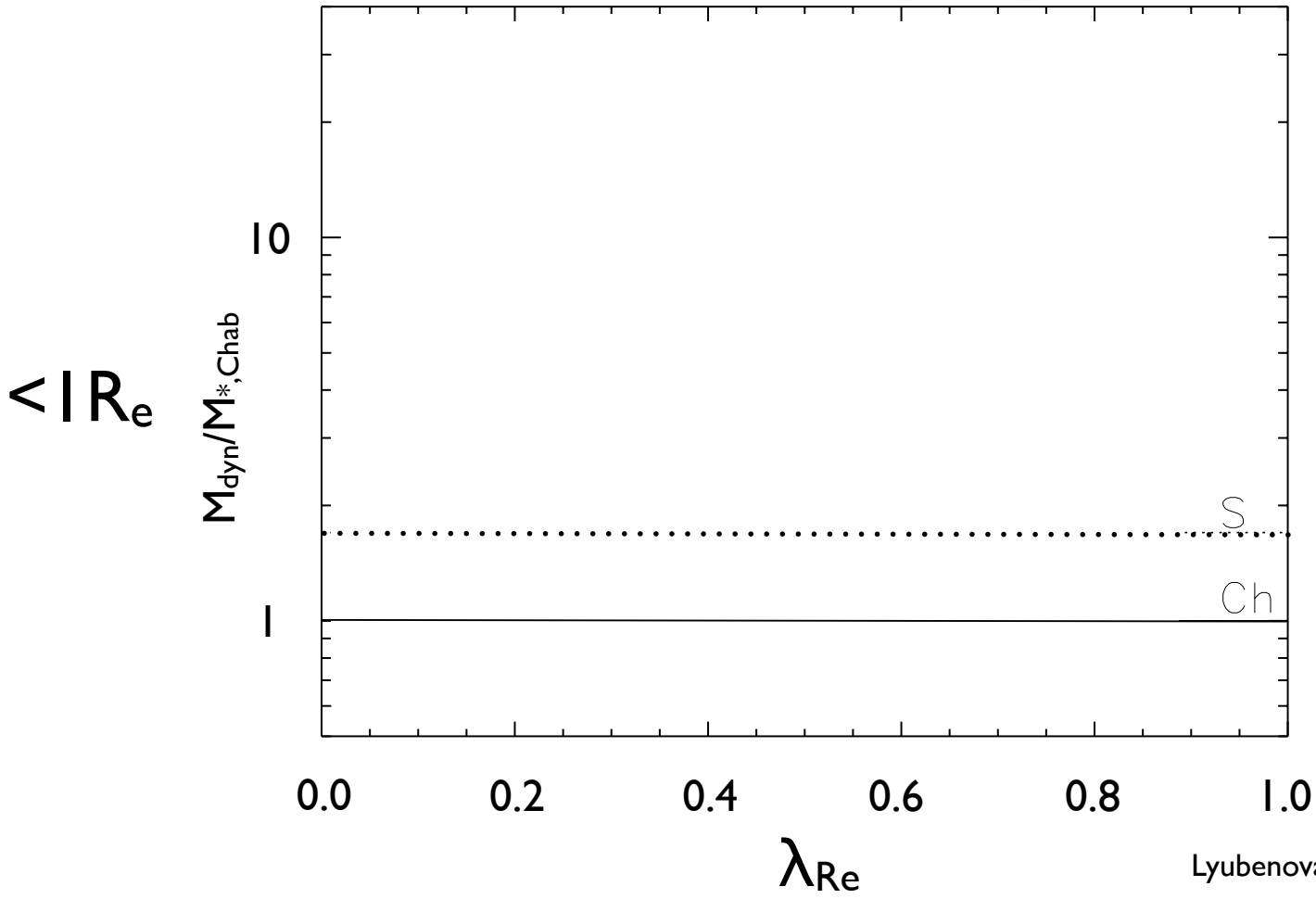


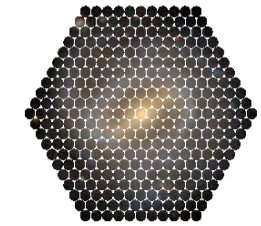
Kinematics + Dynamics + Stellar populations



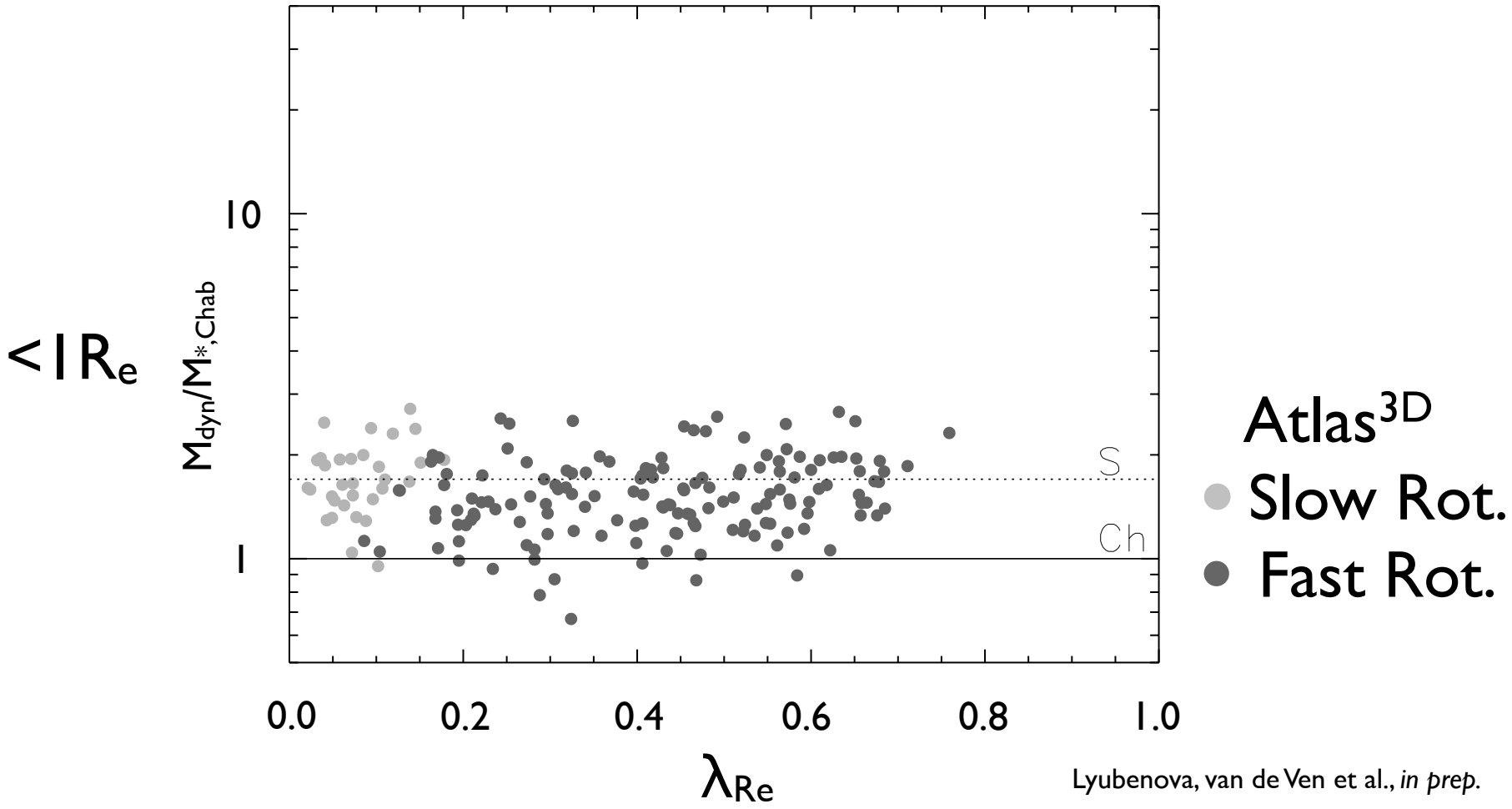
Kinematics + Dynamics + Stellar populations



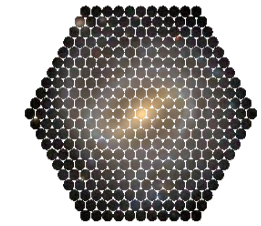
Lyubenova, van de Ven et al., *in prep.*



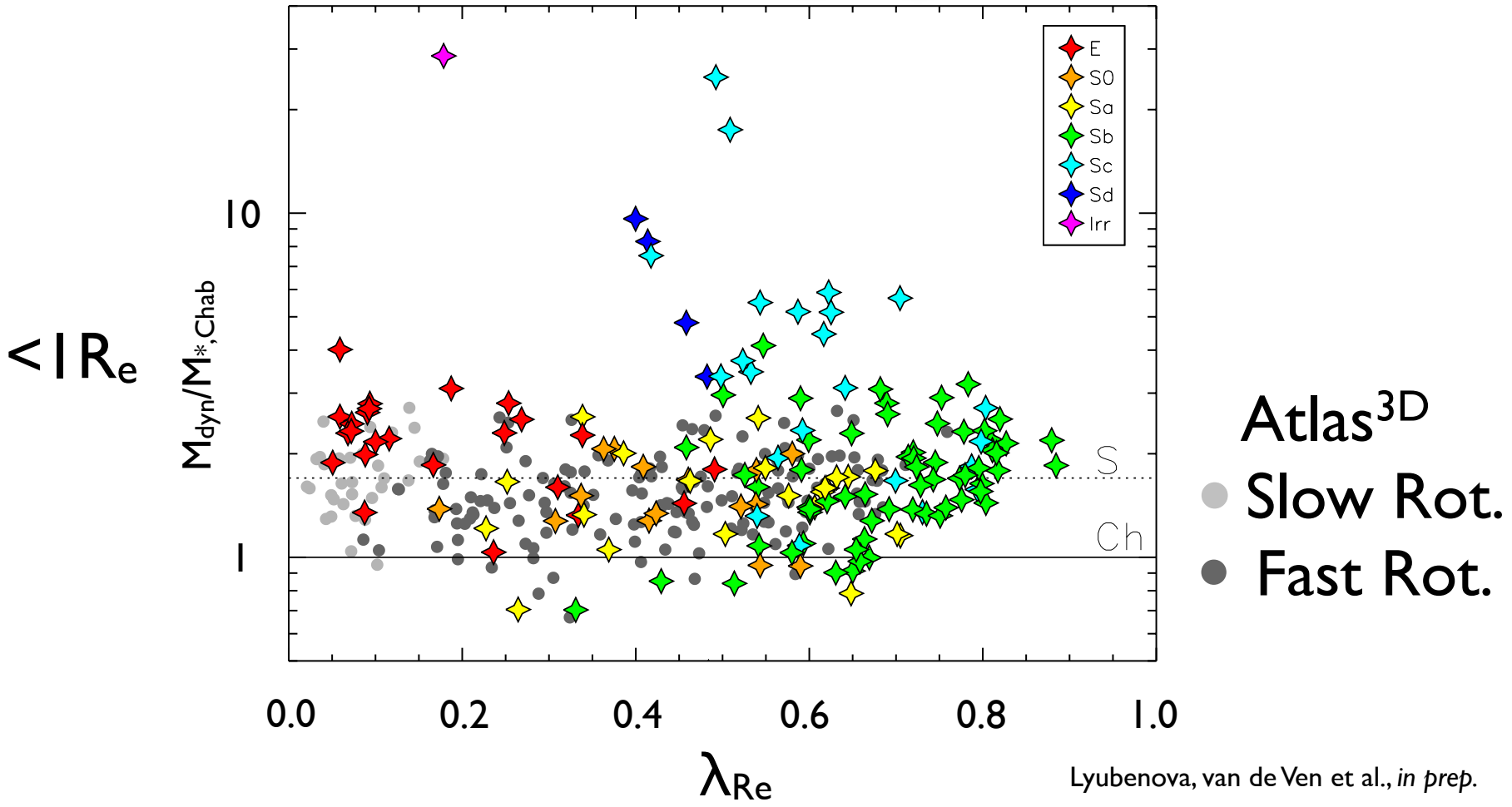
Kinematics + Dynamics + Stellar populations



Lyubenova, van de Ven et al., *in prep.*



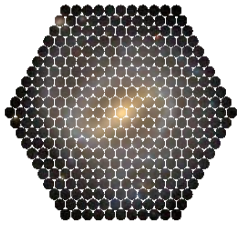
Kinematics + Dynamics + Stellar populations



$<1R_e$

Atlas^{3D}
- Slow Rot.
- Fast Rot.

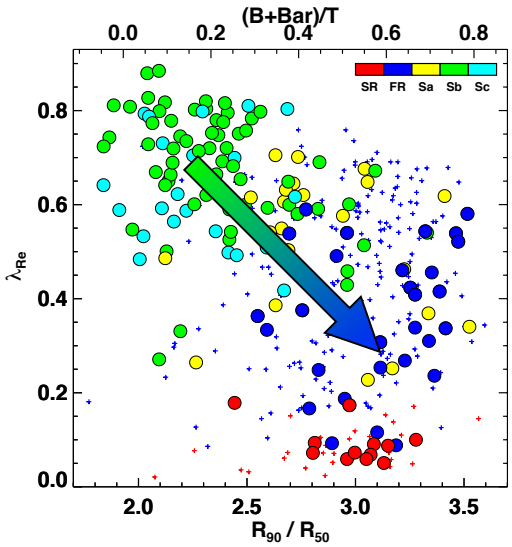
Lyubenova, van de Ven et al., *in prep.*

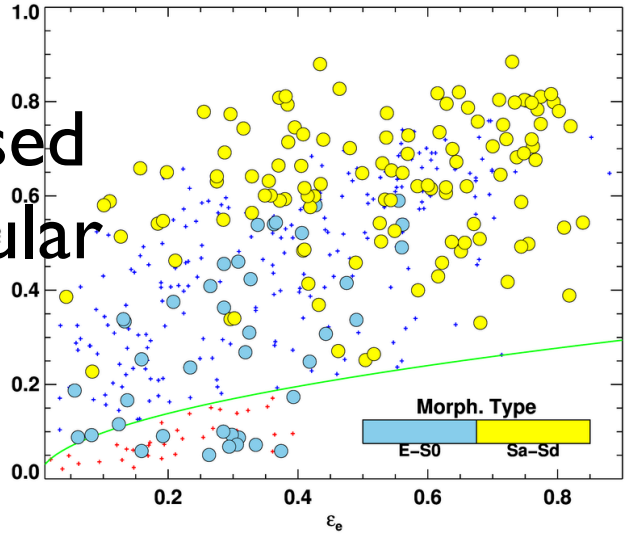


CALIFA Survey

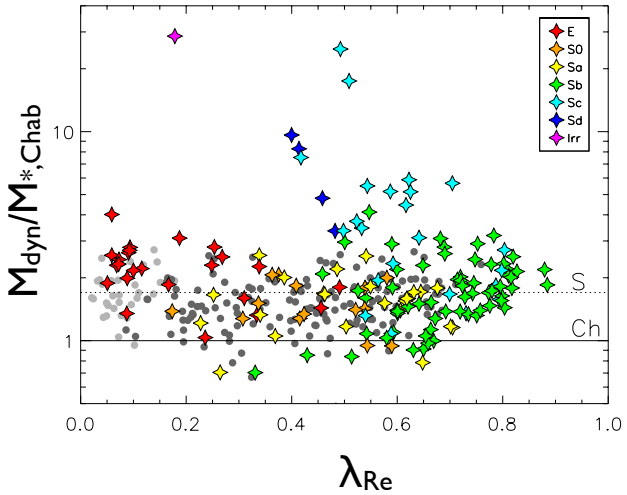
Conclusions

- **CALIFA** provides a morphologically unbiased view of the stellar angular momentum in galaxies



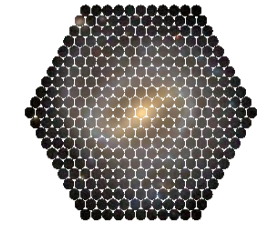


- Lenticulars are not only faded spirals



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

Lyubenova & van de Ven
CALIFA galaxy dynamics across the Hubble sequence

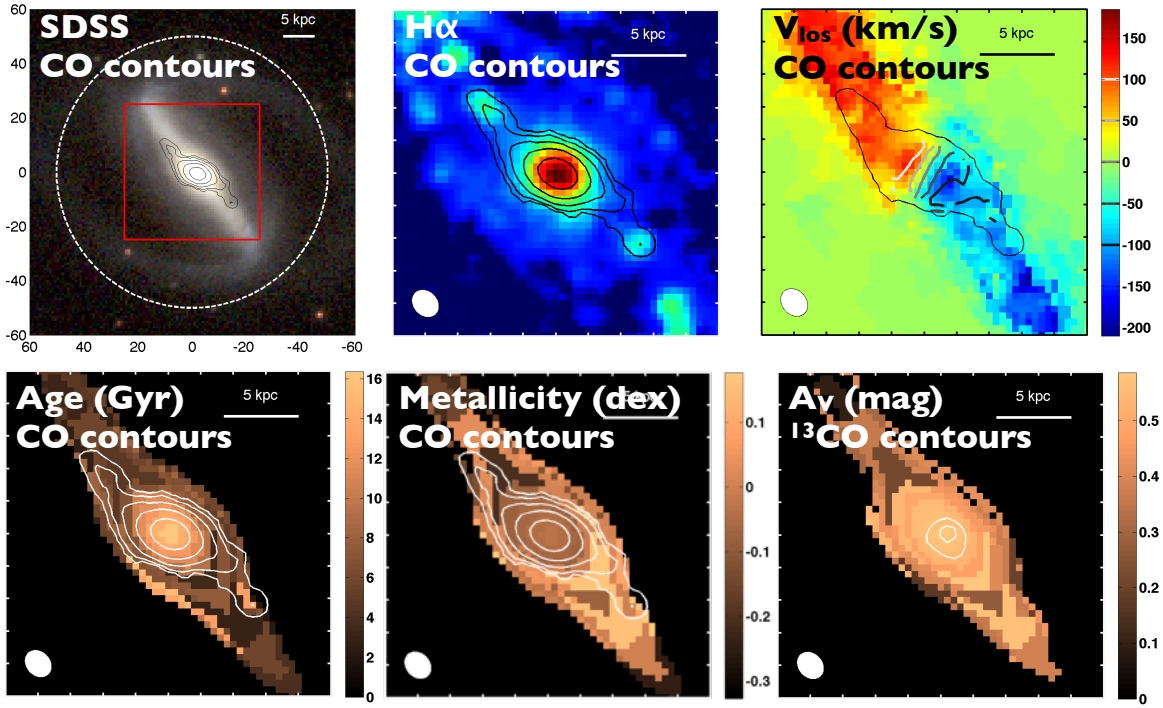


CALIFA Survey

on the EDGE with CARMA

Extragalacitc **D**atabase for **G**alaxy **E**volution

- Key Science:
  - A complete view of how H_2 forms stars
  - Resolved H_2 and the growth of galaxy structures
  - Explore the physics of the molecular ISM



PIs: Alberto Bolato (UMD) and Tony Wong (Illinois)
team: L. Blitz, H. Dannerbauer, Ph. Hopkins, A. Kravtsov, A. Leroy, E. Ostriker, E. Rosolowsky, K. Sandstrom, G. van de Ven, J. Vieira, S. Vogel, F. Walter