The LEGA-C Spectroscopic Survey of z ~ 1 Galaxies

Gas Kinematics and Stellar Kinematics

Arjen van der Wel
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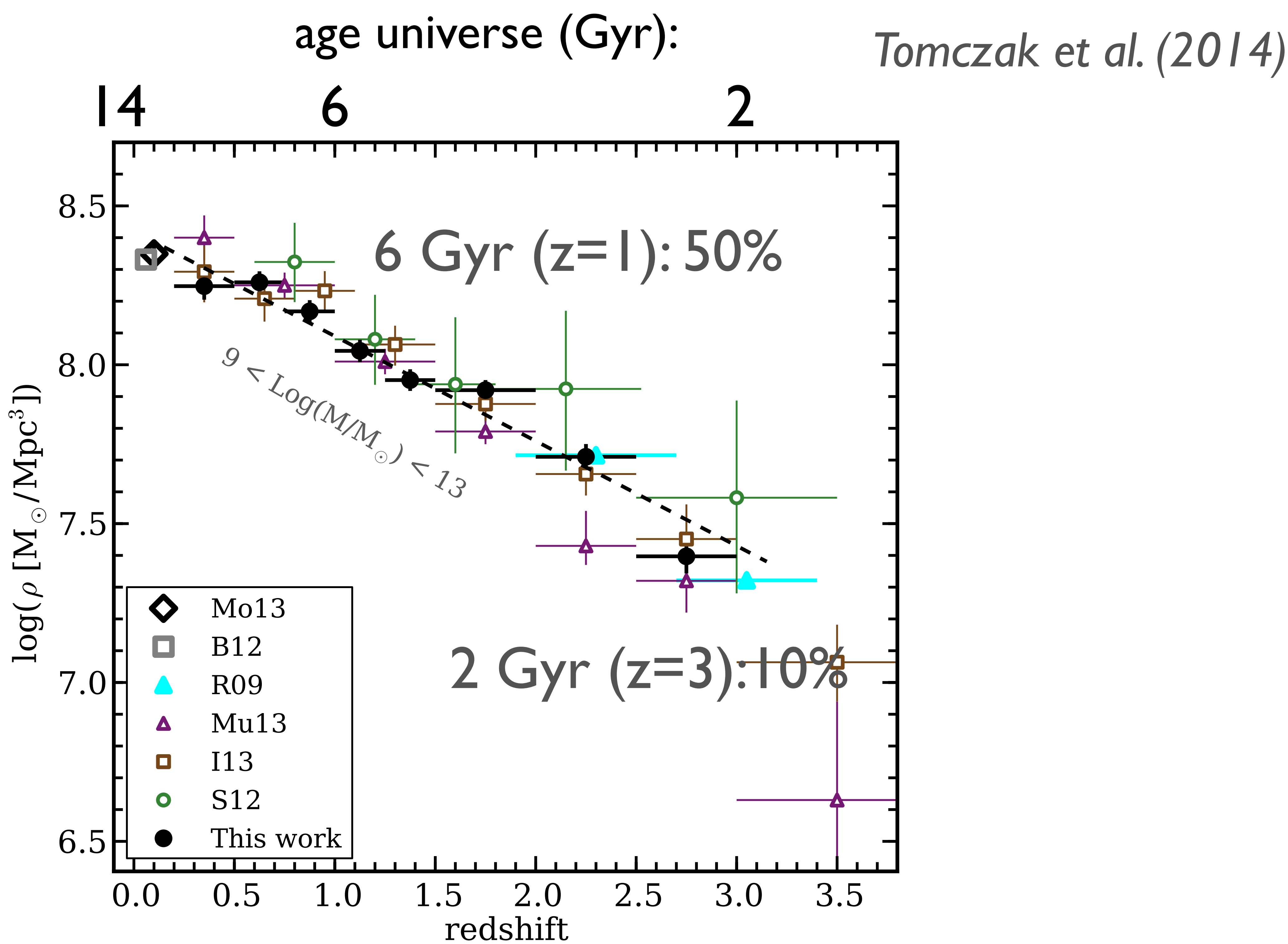
Outline

- Introduction & the LEGA-C survey
- Stellar populations at z~1
- Integrated gas vs. stellar dynamics
- Spatially resolved kinematics
- Dynamical modeling

Introduction

- 90% of stars formed between z=3 and z=0
- 50% of stars formed between z=1 and z=0

Introduction



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- 50% of stars formed between z=1 and z=0

- Most stars form in L* galaxies (5×10^{10} Msol) at all z<3
- SF-ing L* galaxies are disk-dominated at all z<3

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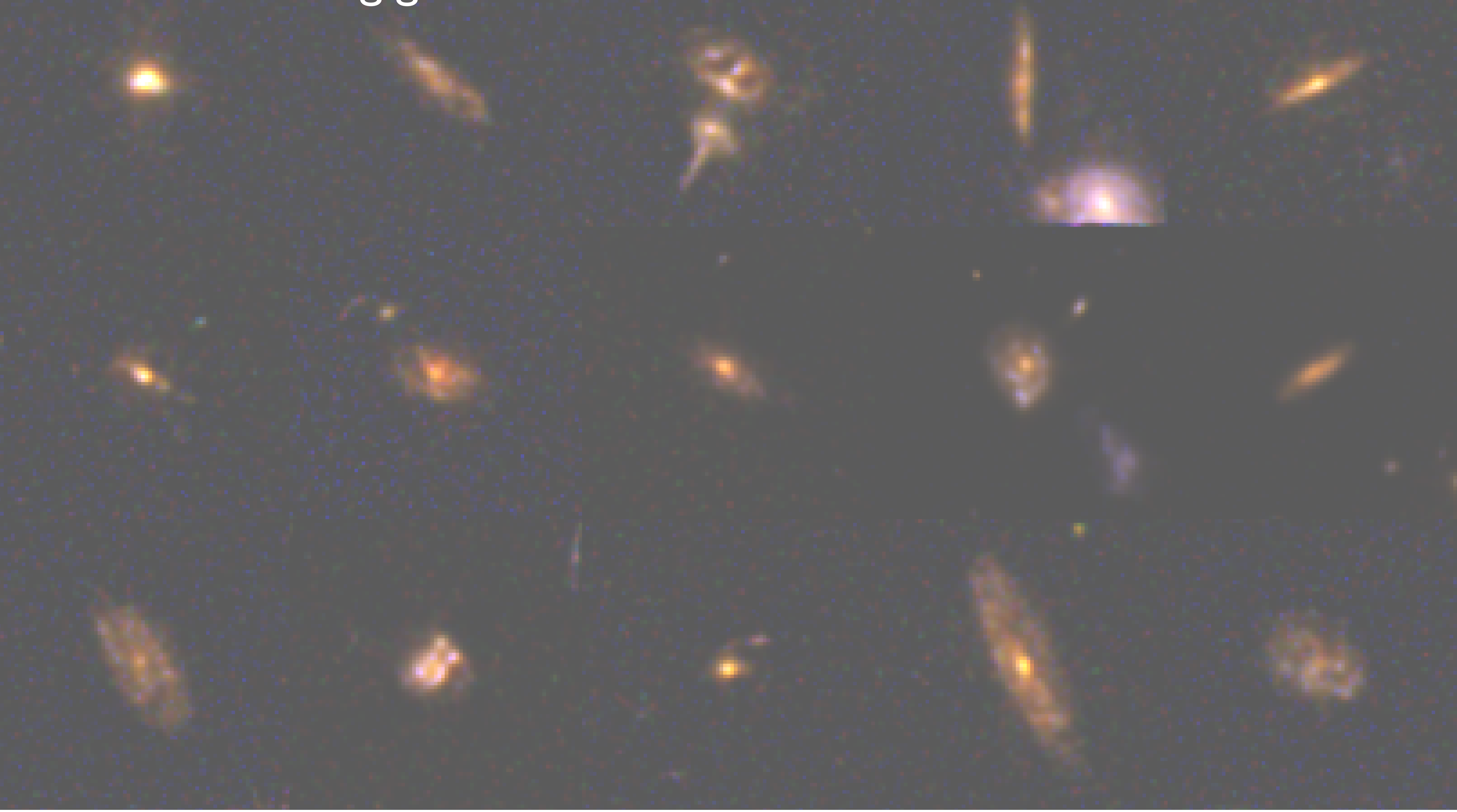
Redshift	Log(M^*)
$0.20 < z < 0.50$	10.59 ± 0.09
$0.50 < z < 0.75$	10.65 ± 0.23
$0.75 < z < 1.00$	10.56 ± 0.13
$1.00 < z < 1.25$	10.44 ± 0.11
$1.25 < z < 1.50$	10.69 ± 0.12
$1.50 < z < 2.00$	10.59 ± 0.10
$2.00 < z < 2.50$	10.58 ± 0.18
$2.50 < z < 3.00$	10.61 ± 0.22

Tomczak et al. (2014)

Introduction

z=1.5-2 L* SF-ing galaxies — CANDELS



Introduction

- 90% of stars formed between z=3 and z=0
- 50% of stars formed between z=1 and z=0

- Most stars form in L* galaxies (4×10^{10} Msol) at all z<3
- SF-ing L* galaxies are disk-dominated at all z<3

- Many stars end up in kinematically `hot’ systems

Introduction

- 90% of stars formed between z=3 and z=0
- 50%
- Mos z<3
- SF-i

The challenge is that we cannot connect
high-redshift progenitors to
low-redshift descendants

- Many stars end up in kinematically `hot' systems

LEGA-C: science drivers

- Star-formation histories of individual galaxies
- Growth of disk galaxies
- The path to passiveness (quenching)
- Maintaining passiveness
- Growth through merging

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Answers through high-quality spectroscopy of many distant galaxies:

— Stellar populations (star-formation histories)

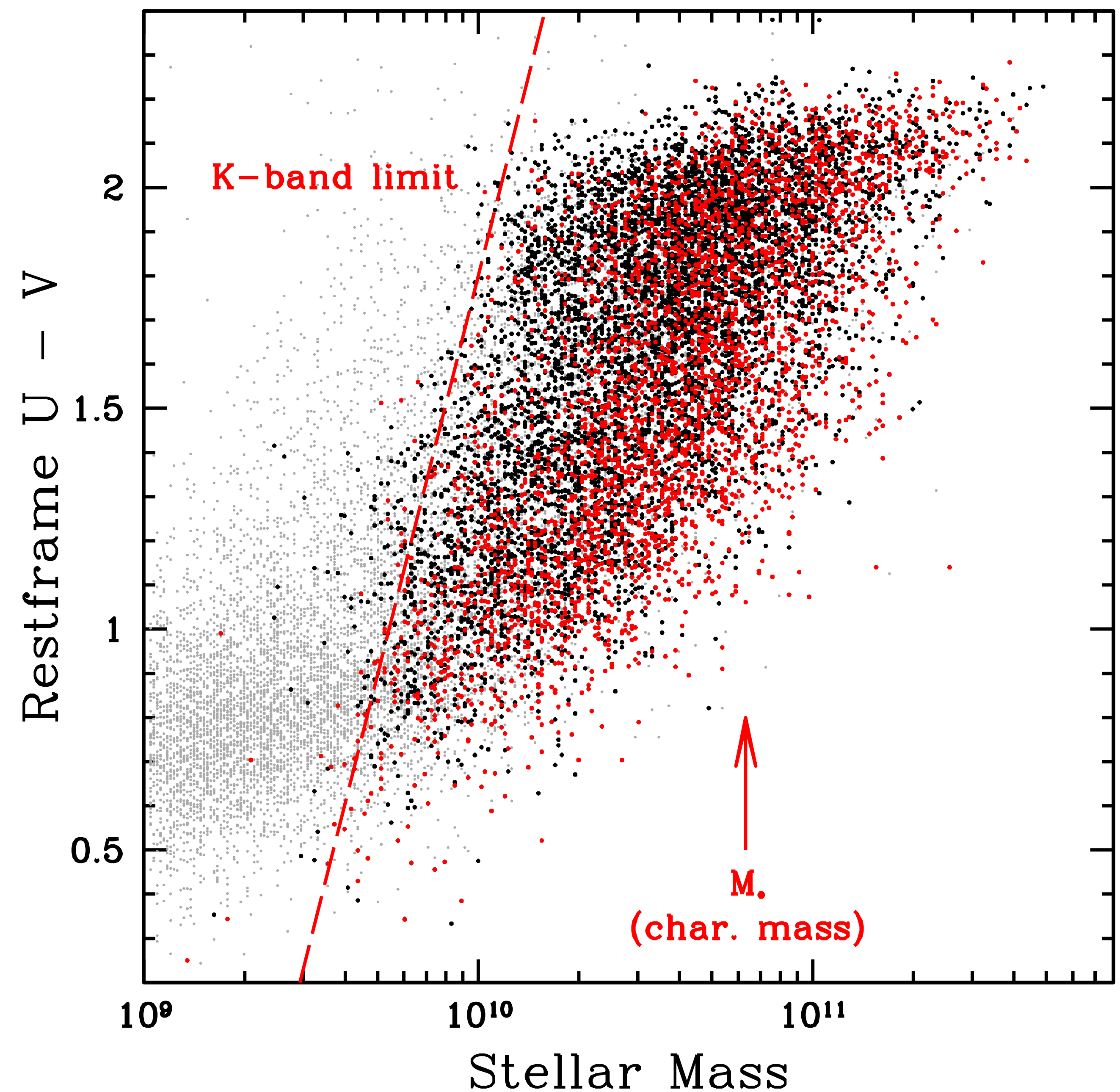
— Stellar dynamics

LEGA-C: a VLT/VIMOS Public Survey

Large **E**arly **G**alaxy **A**strophysics **C**ensus (*van der Wel et al. 2016*)

COSMOS/Ultra-VISTA field

- 128 night allocation
- December '14 - Spring '18
- R = 3000, λ = 6000 - 9000 Å
- >3000 galaxies at 0.6 < z < 1.0
- 20h integrations; typical S/N=20/Å
- DR1 in September 2016
- DR2 in September 2017



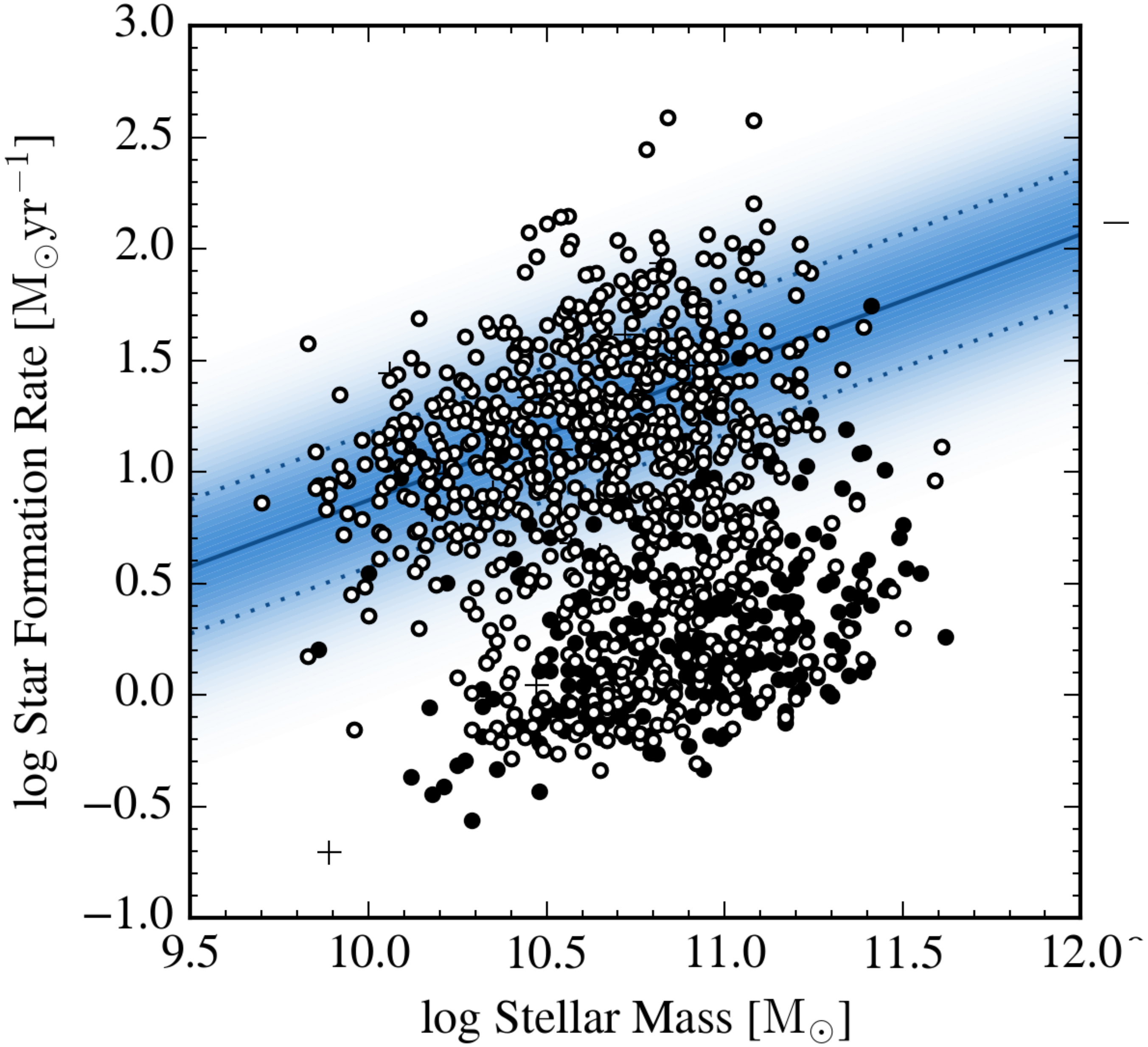
LEGA-C: a VLT/VIMOS Public Survey

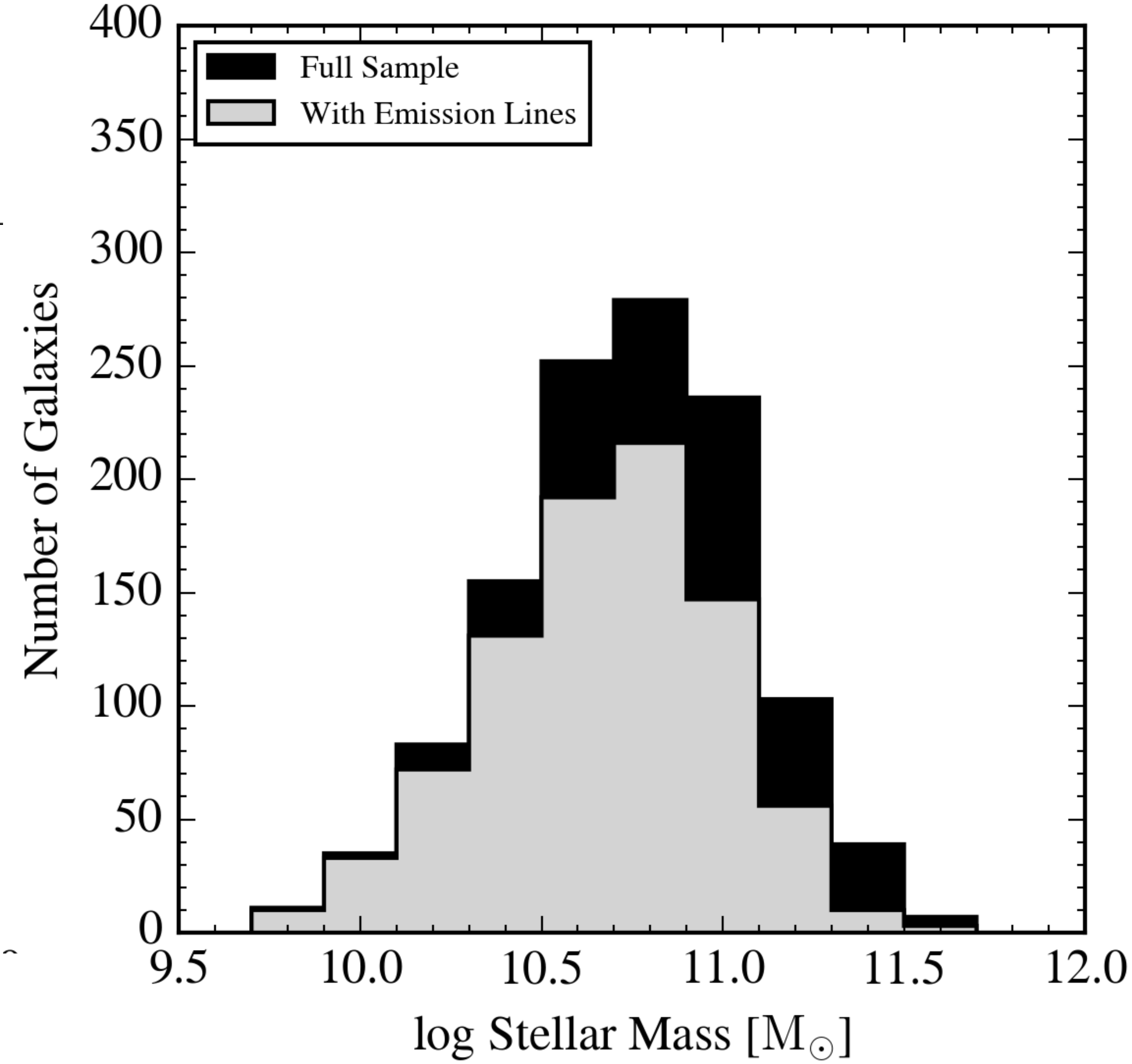
The LEGA-C group at MPIA:

Ivana Barisic
Priscilla Chauke
Josha van Houdt
Caroline Straatman
Arjen van der Wel (PI)
Po-Feng Wu

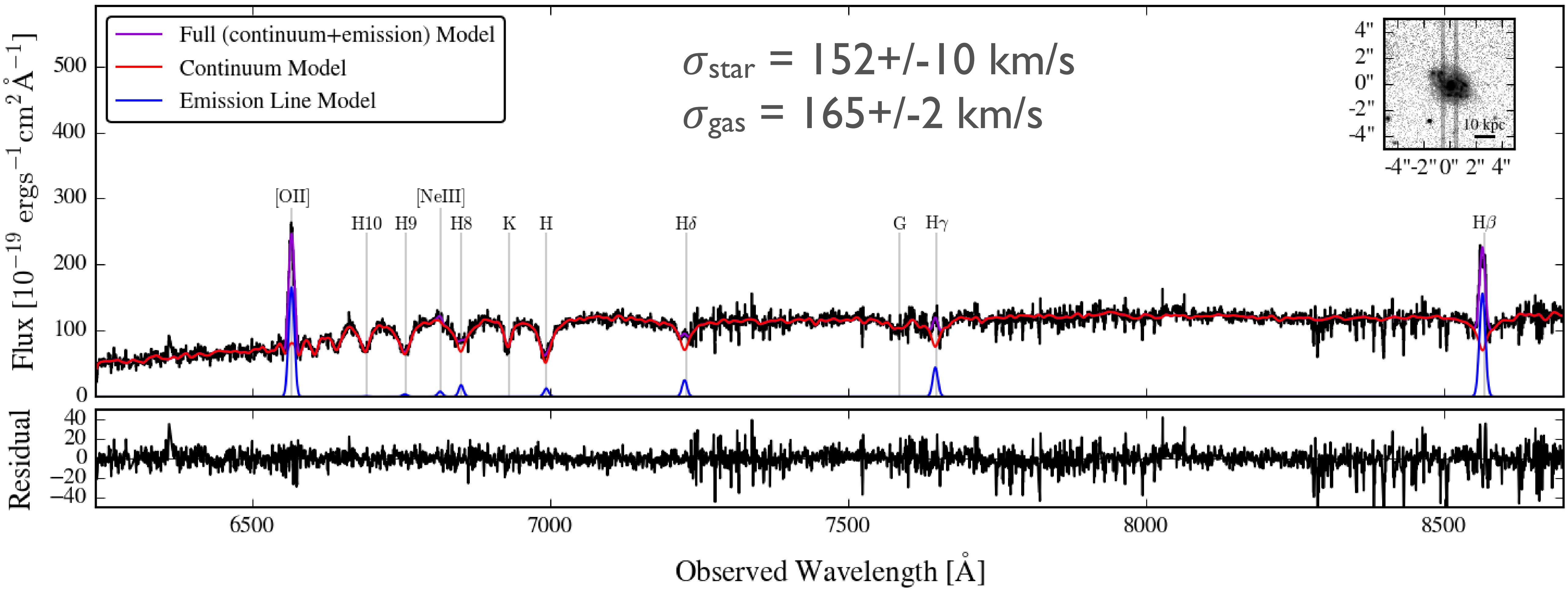
Eric Bell (Michigan)
Rachel Bezanson (Princeton)
Gabriel Brammer (STScI)
Joao Calhau (Lancaster)
Stephane Charlot (IA Paris)
Marijn Franx (Leiden)
Anna Gallazzi (Arcetri)
Ivo Labbe (Leiden)
Michael Maseda (Leiden)
Juan Carlos Munoz (ESO)
Adam Muzzin (York)
Kai Noeske (Heilbronn planetarium)
Camilla Pacifici (Goddard)
Hans-Walter Rix (MPIA)
David Sobral (Lancaster)
Jesse van de Sande (Sydney)
Ros Skelton (Capetown)
Justin Spilker (Arizona)
Pieter van Dokkum (Yale)
Vivienne Wild (St. Andrews)
Christian Wolf (ASU)

The current sample : 1550 galaxies





Spectral decomposition



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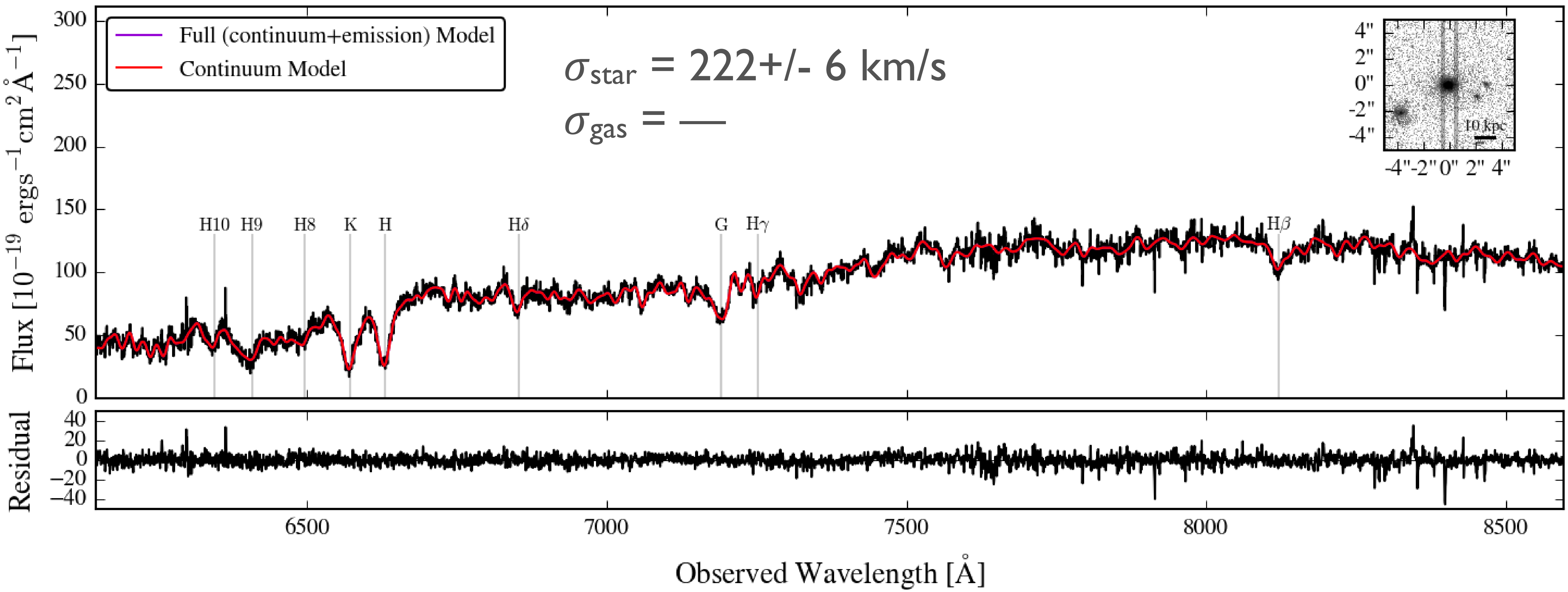

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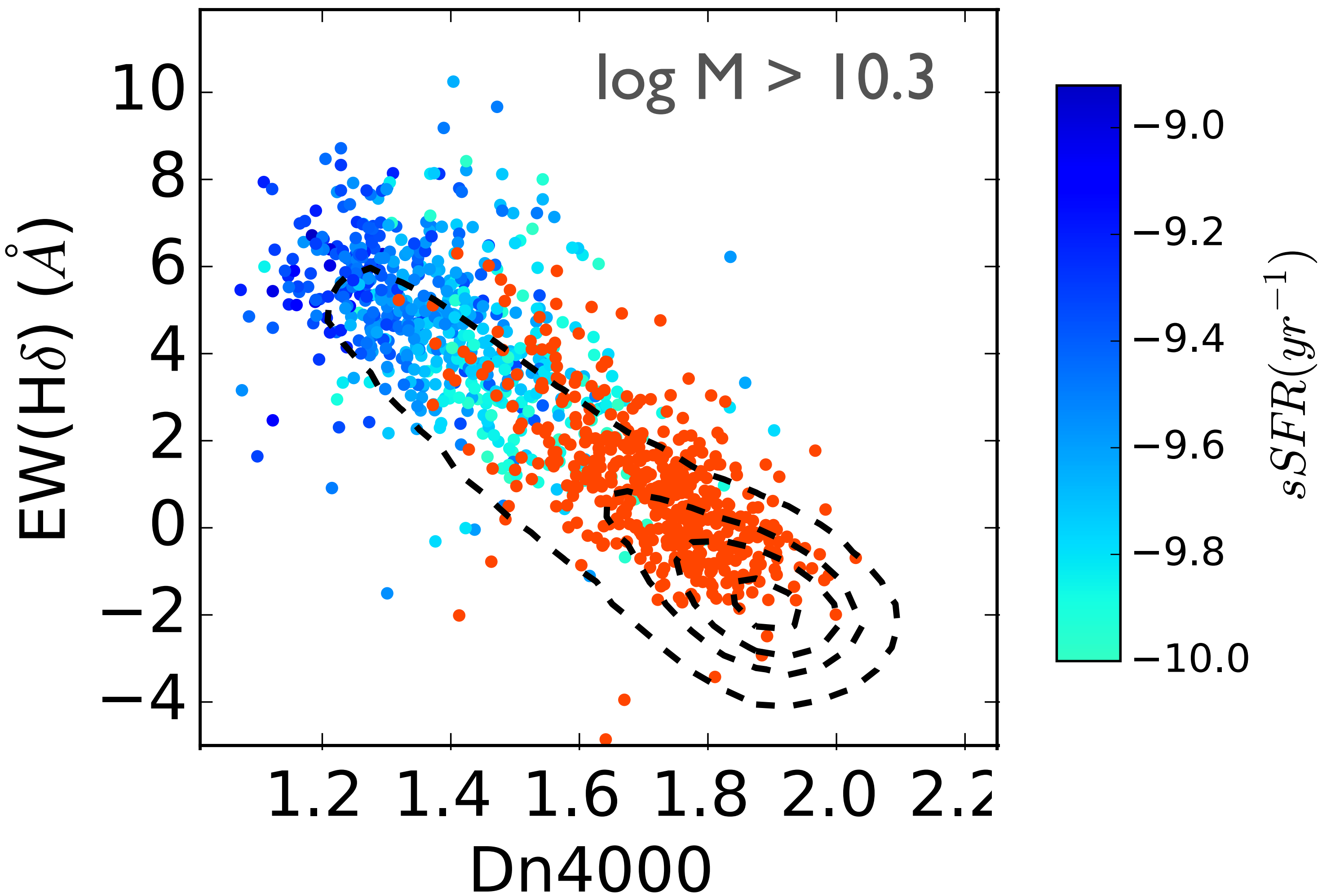
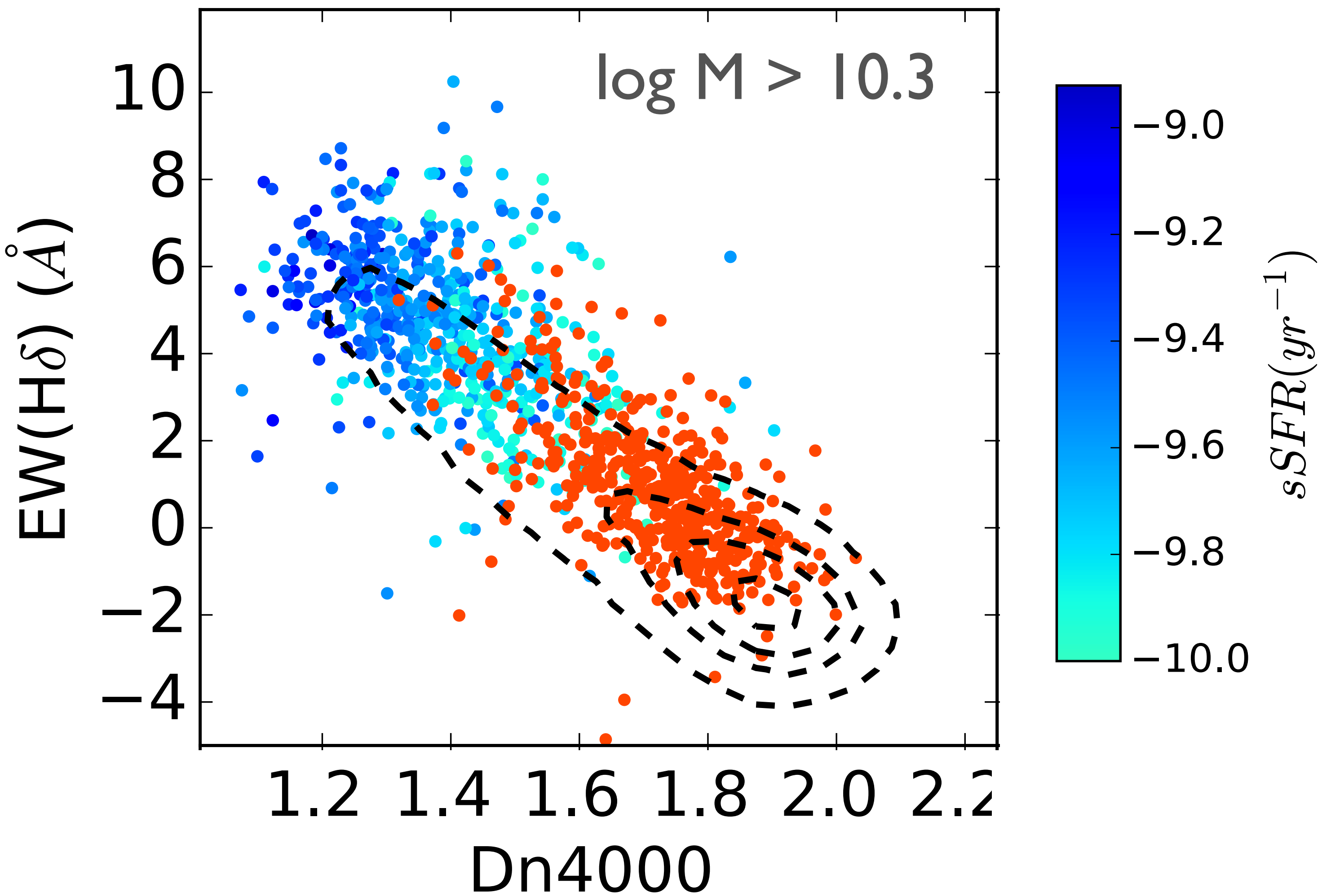
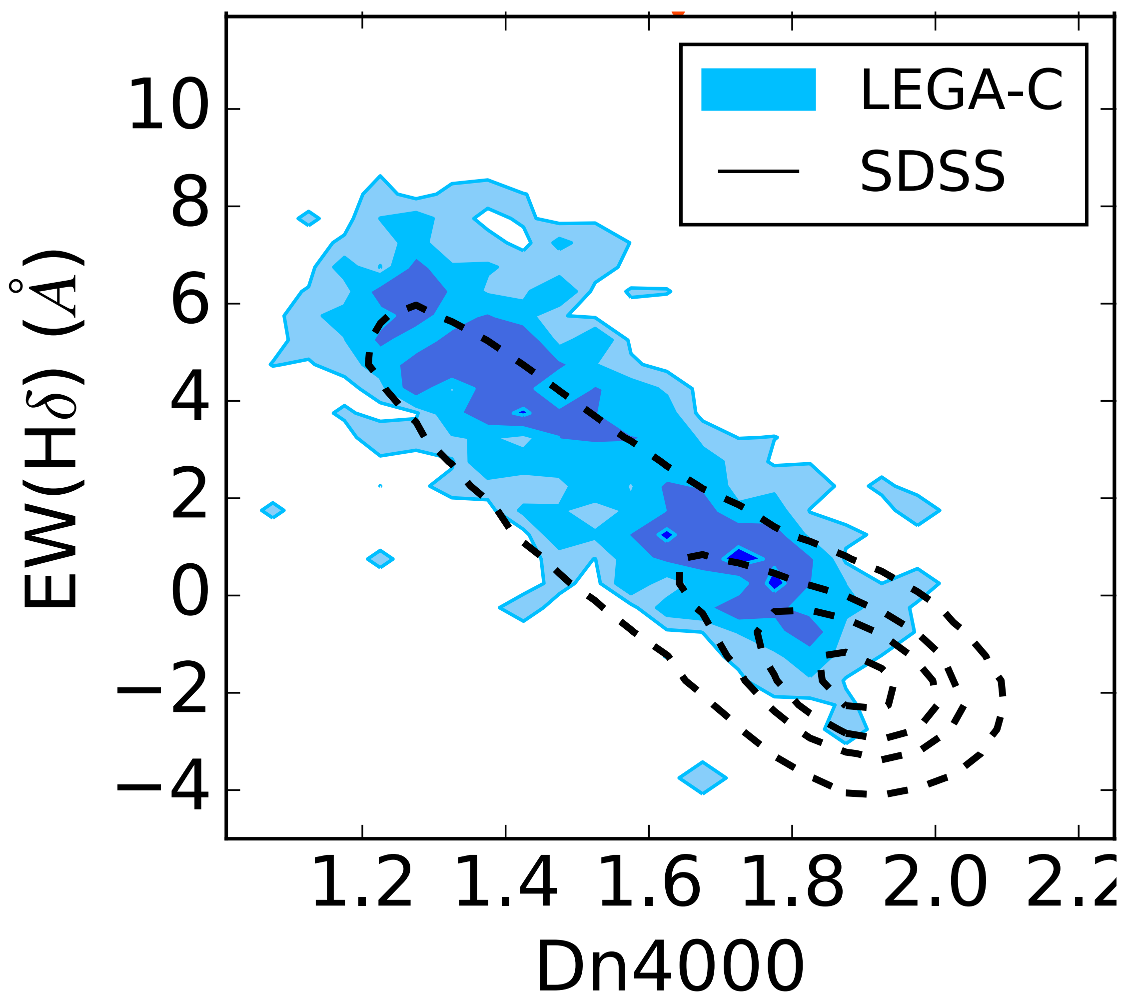
Stellar Populations



SDSS: Kauffmann+03
LEGA-C: Wu, van der Wel et al., in prep.

Stellar Populations





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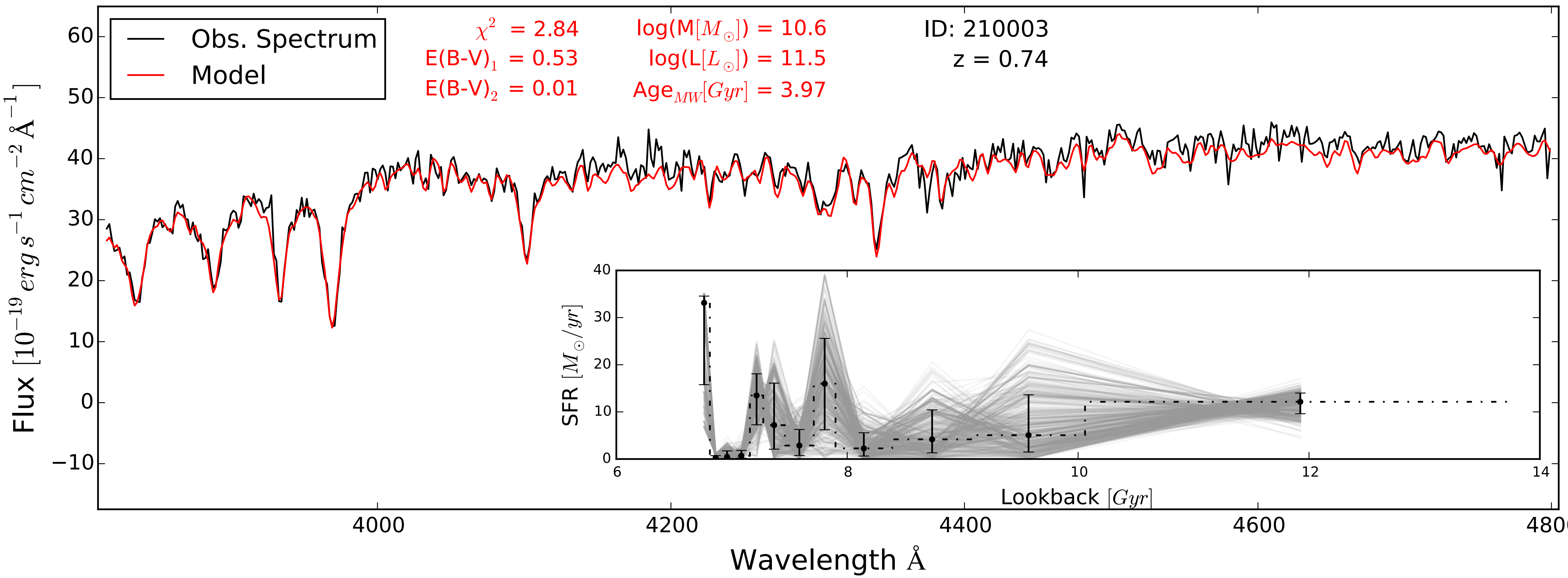
Stellar Populations

Measure SFHs of individual galaxies



Chauke, van der Wel et al., in prep.

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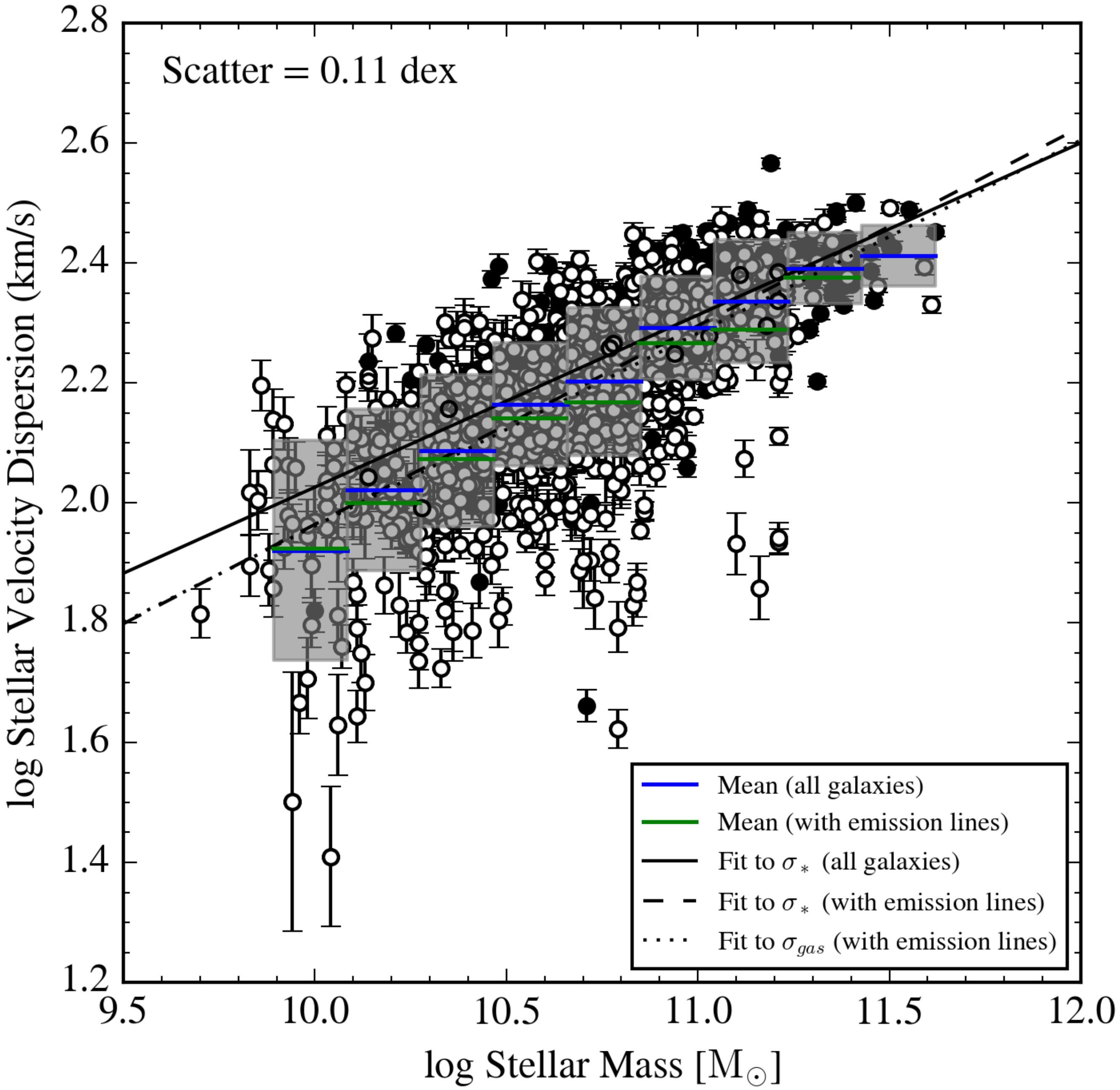
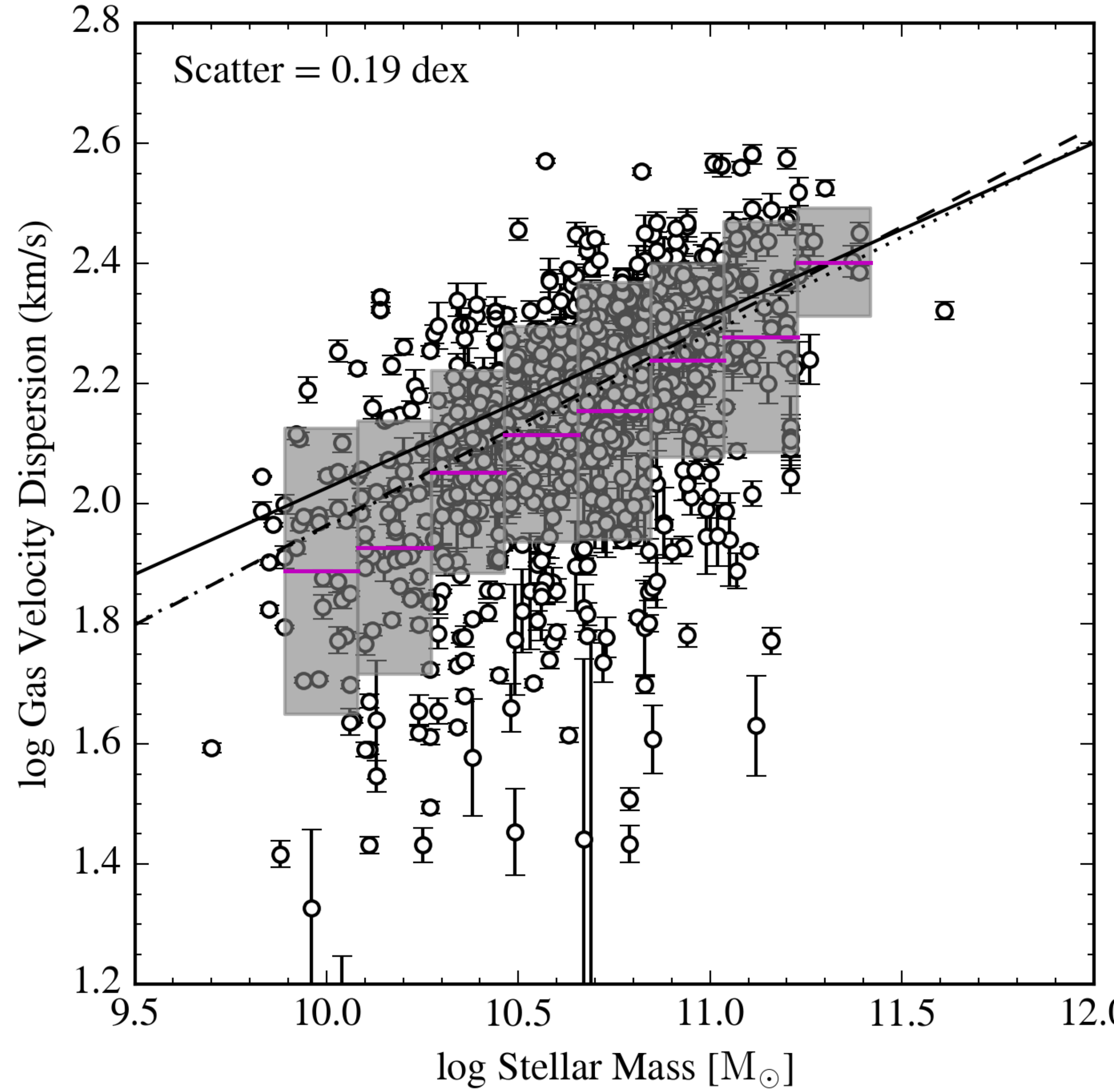
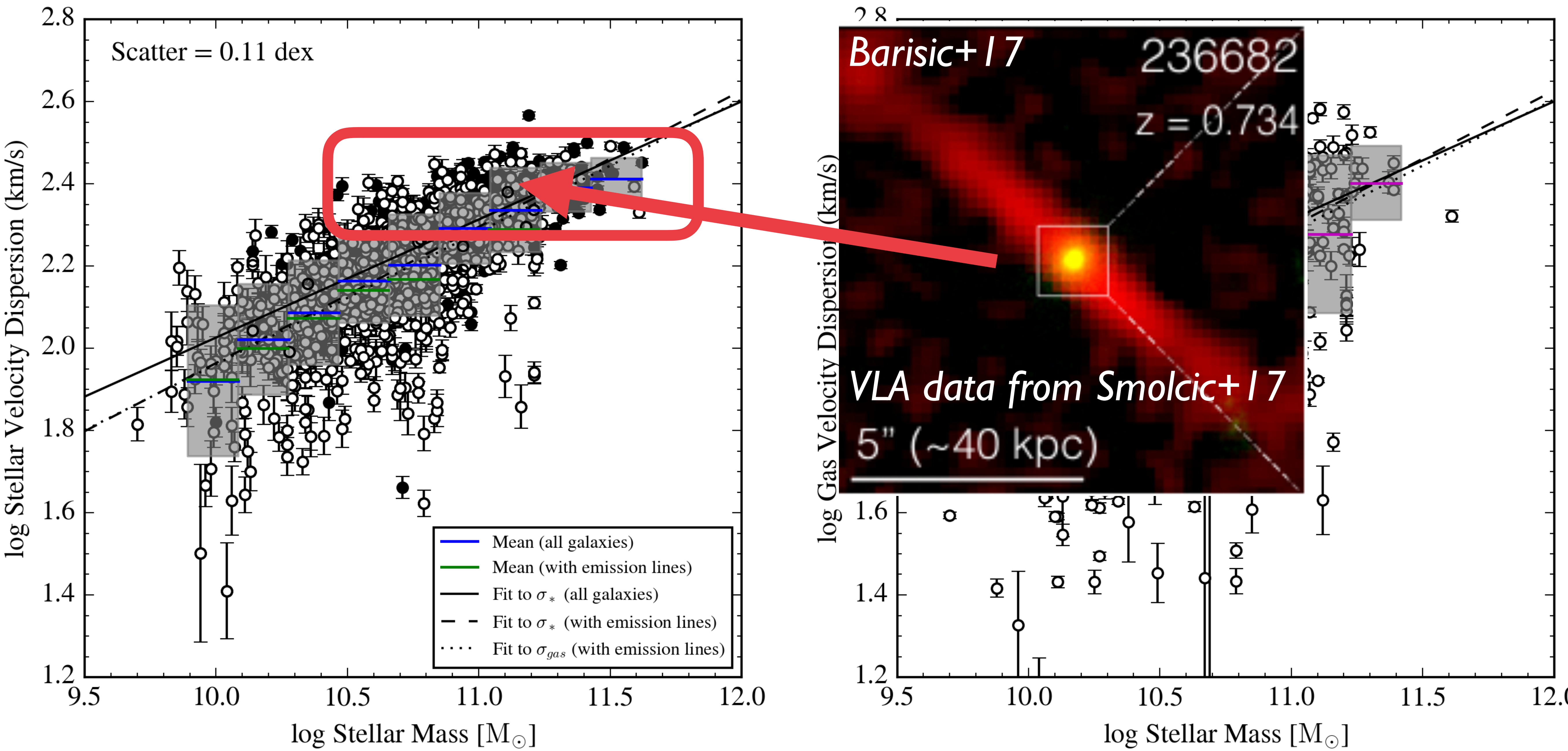
Faber-Jackson relations





Bezanson, van der Wel et al., in prep.

Faber-Jackson relations



Bezanson, van der Wel et al., in prep.

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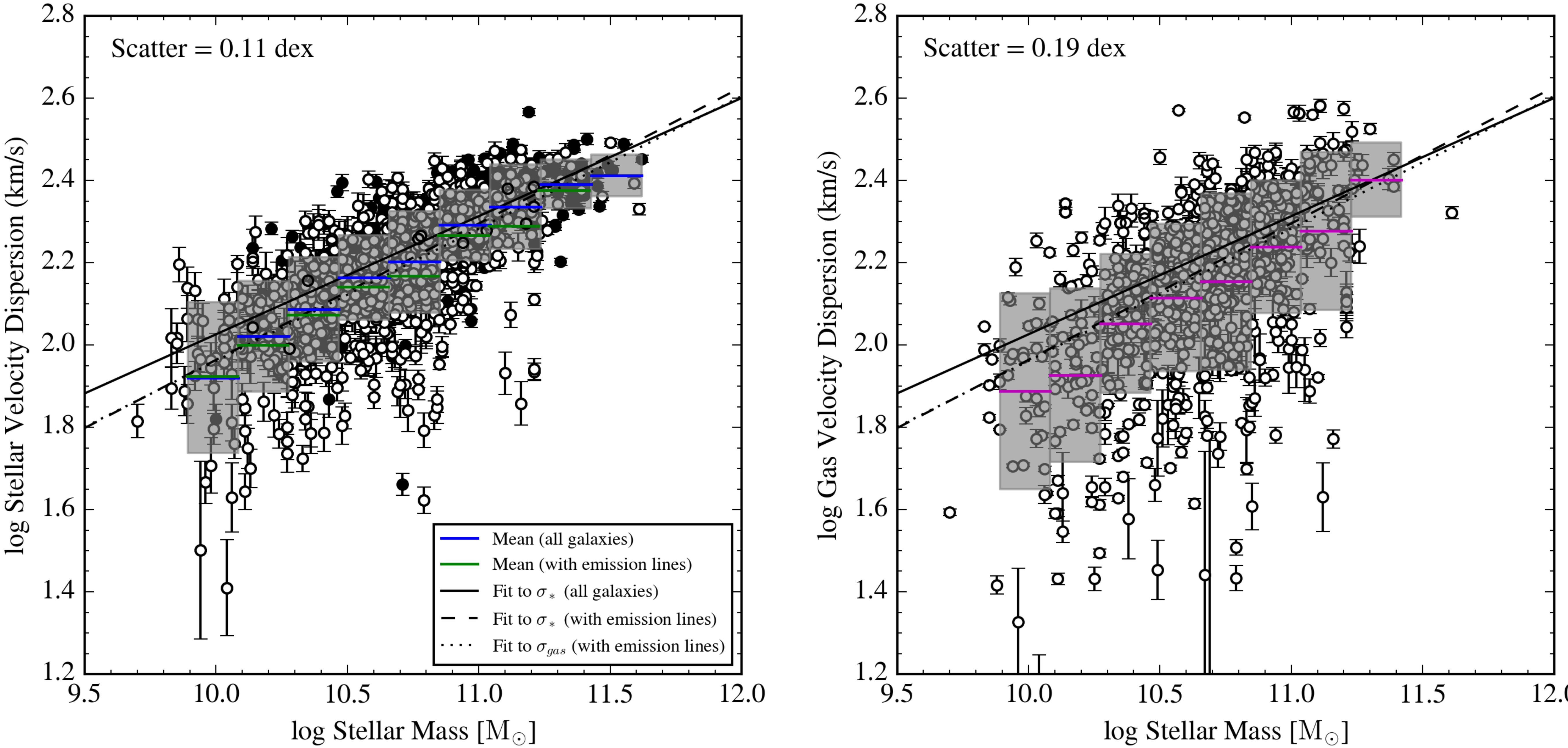
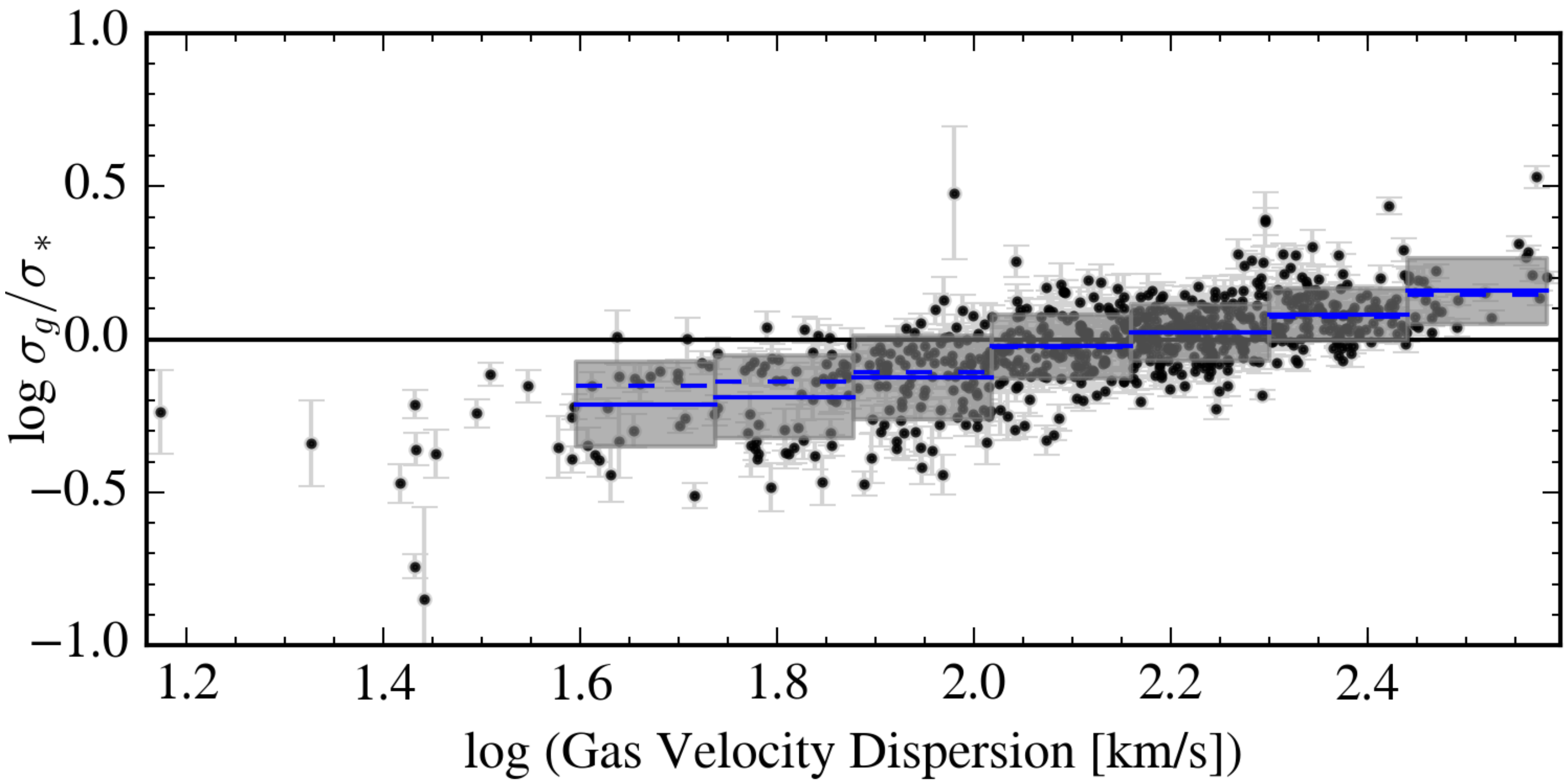


Bezanson, van der Wel et al., in prep.

Low gas dispersions are suspect



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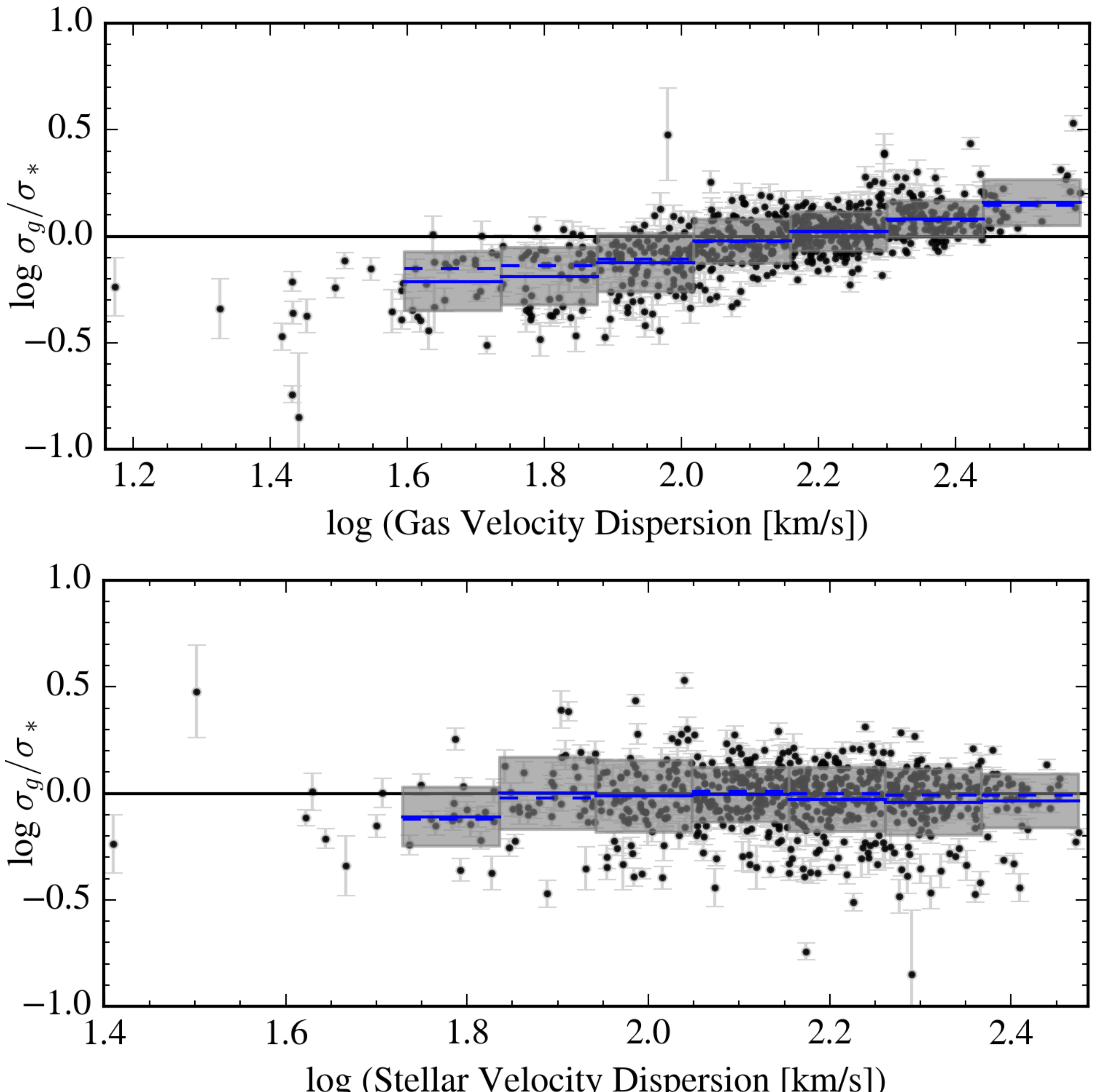

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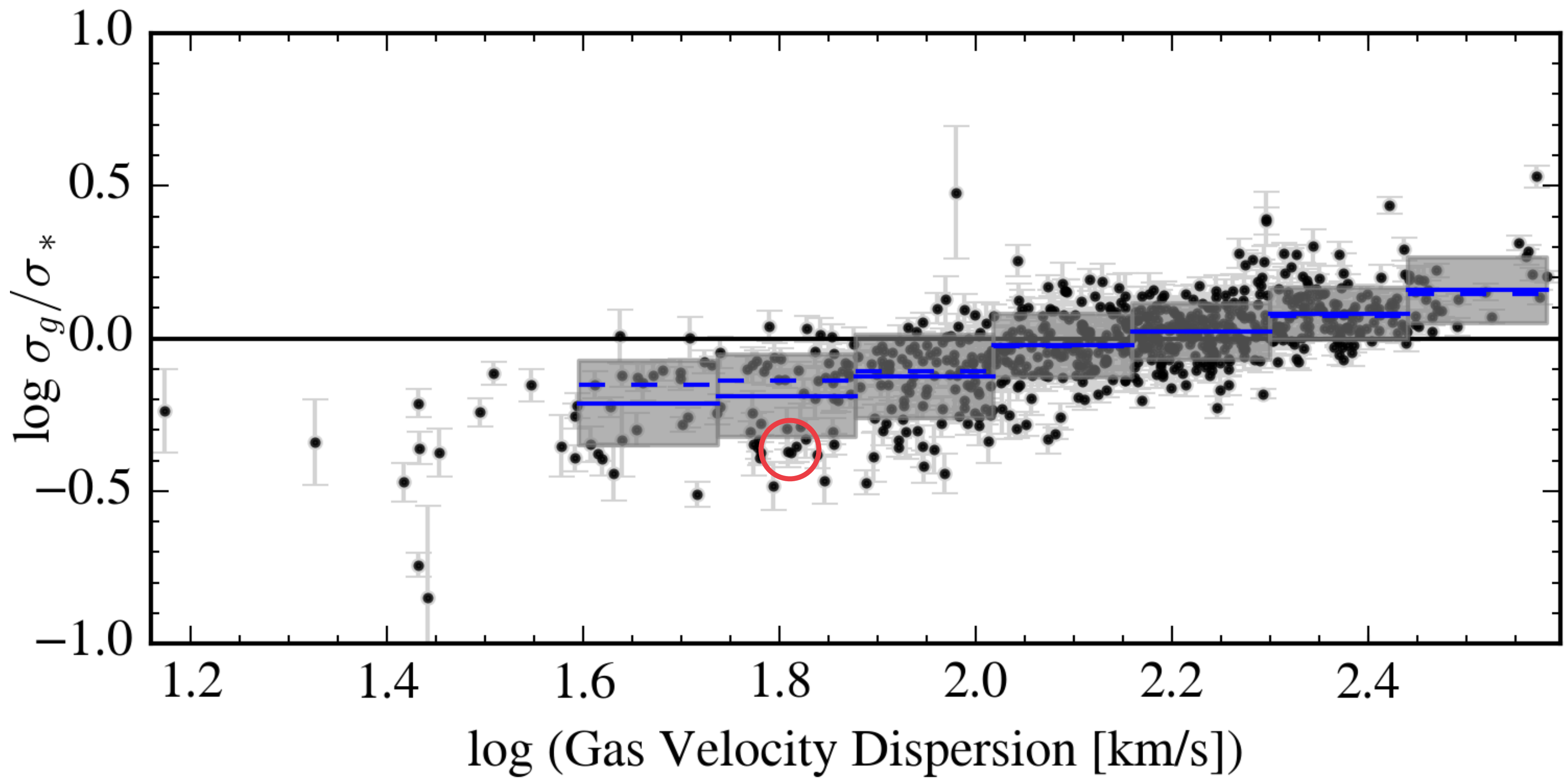

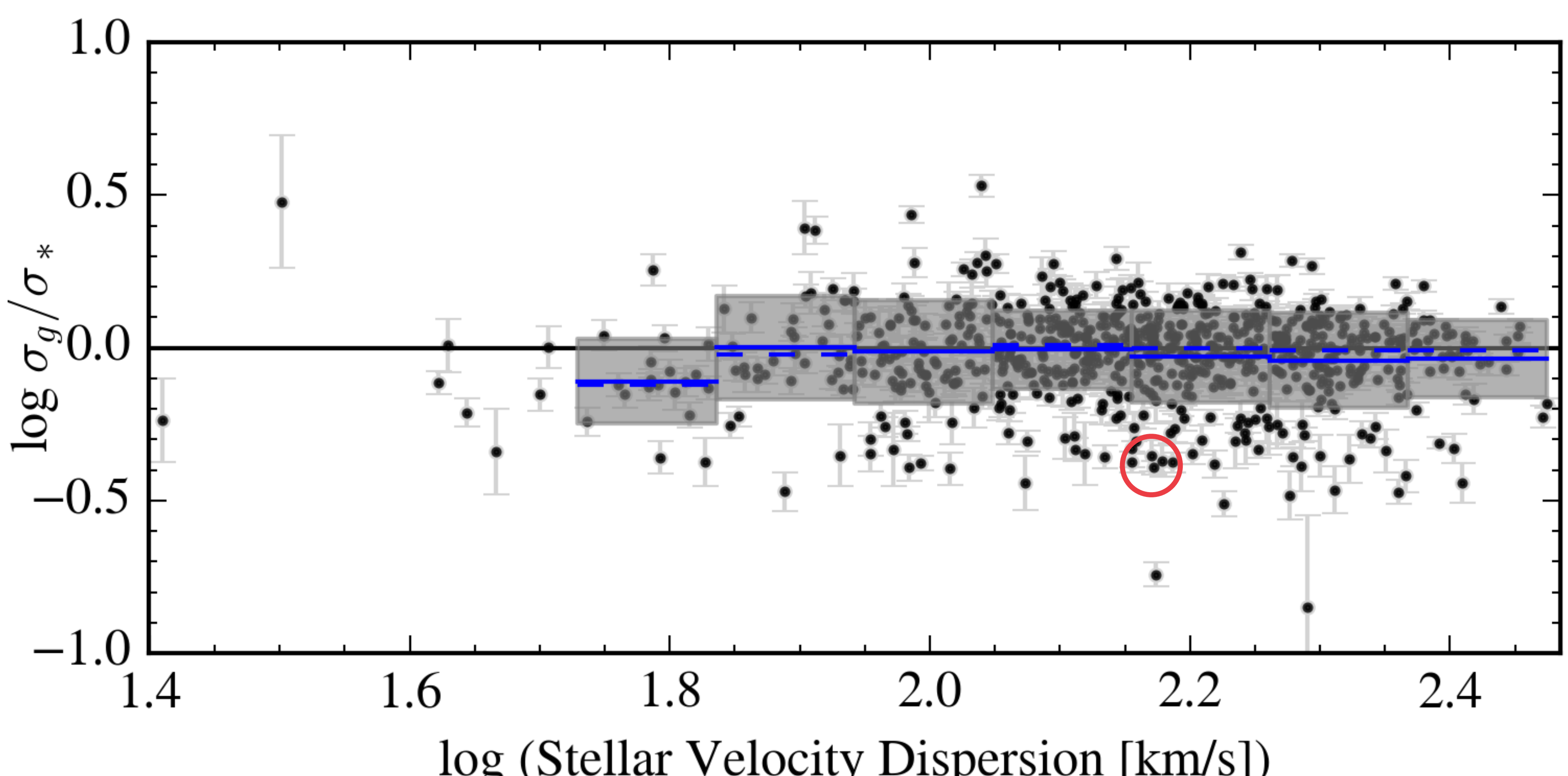

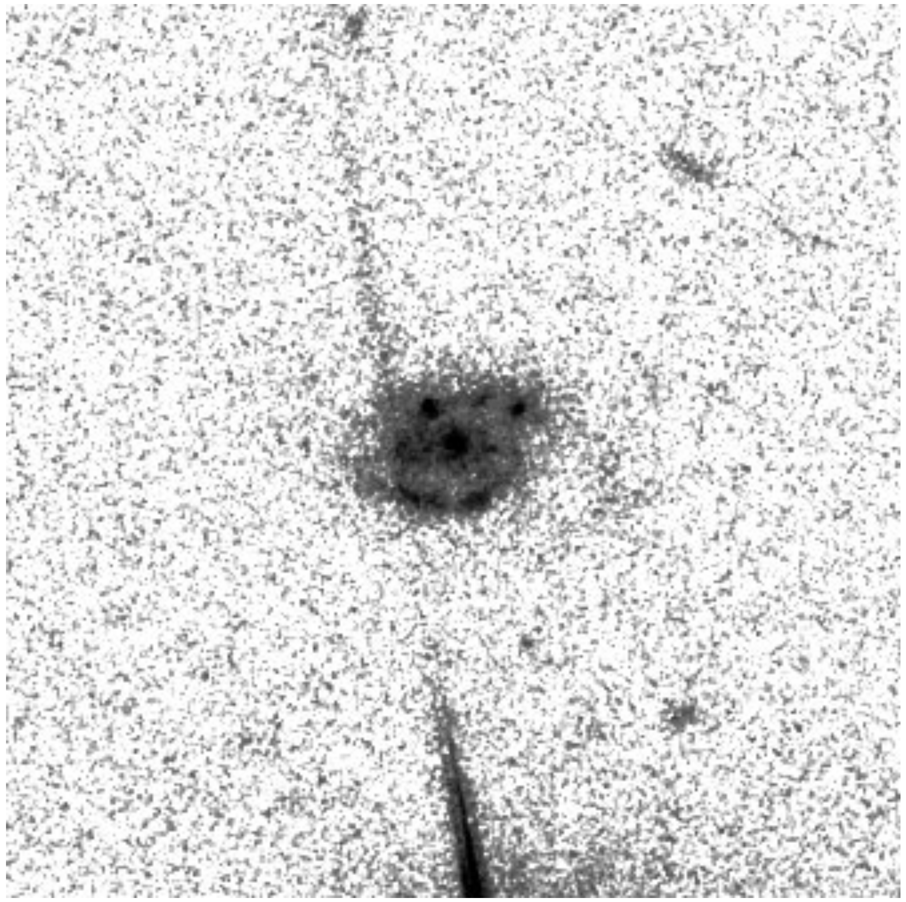

Bezanson, van der Wel et al., in prep.

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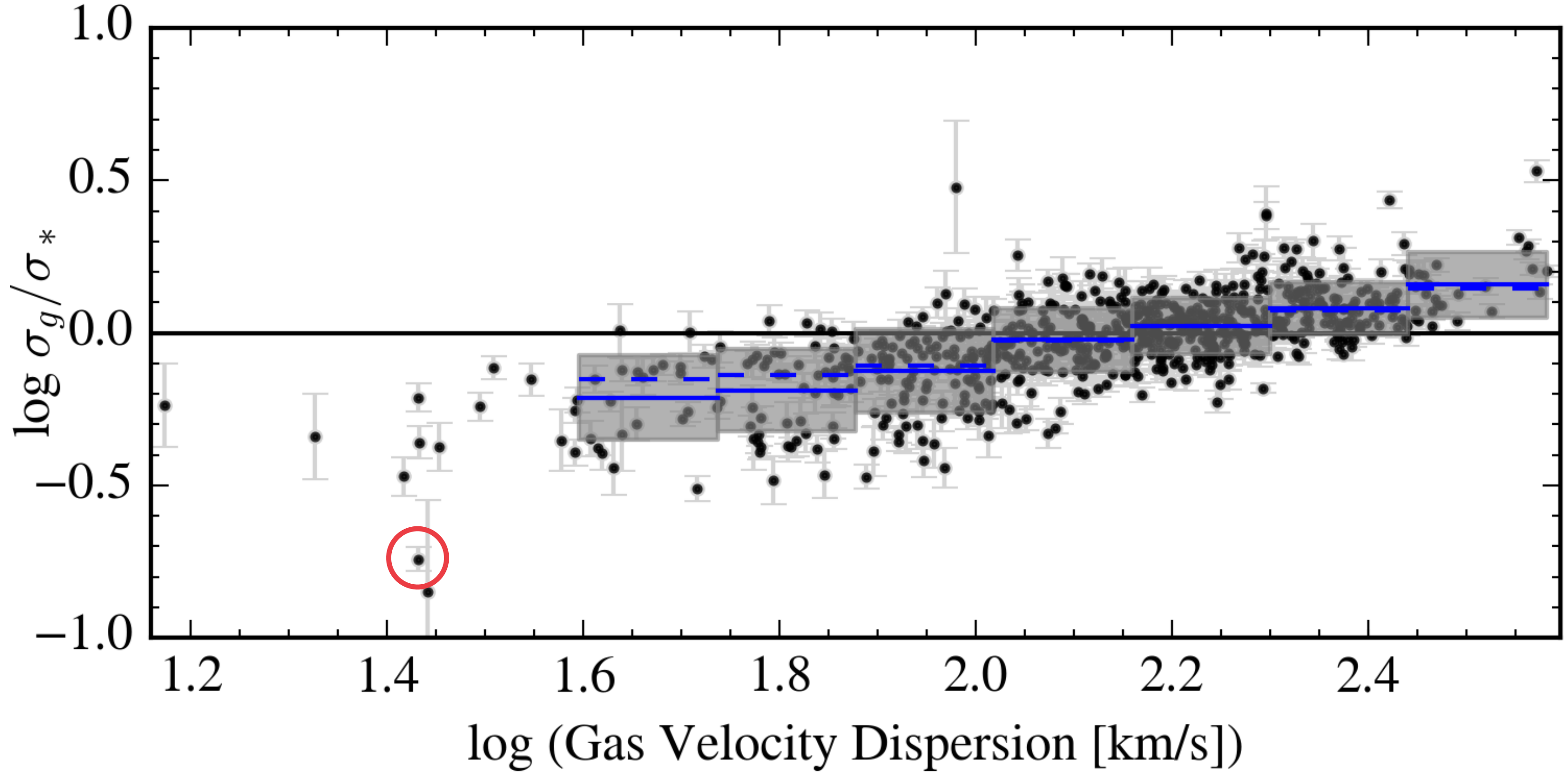

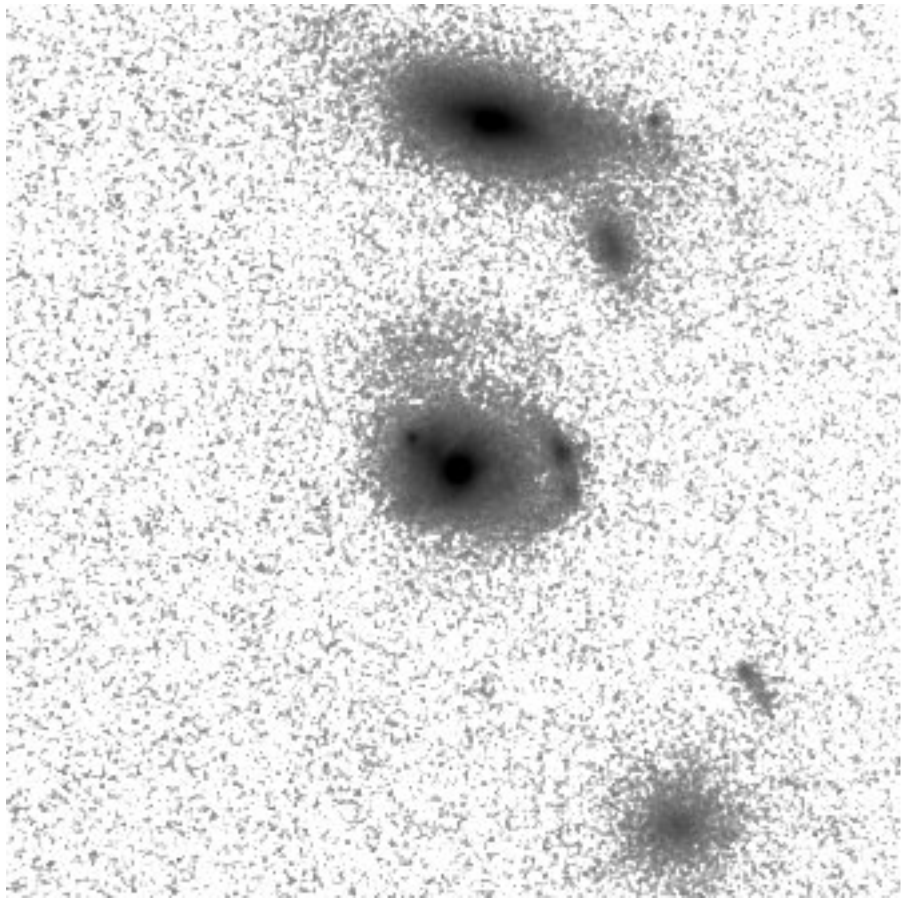

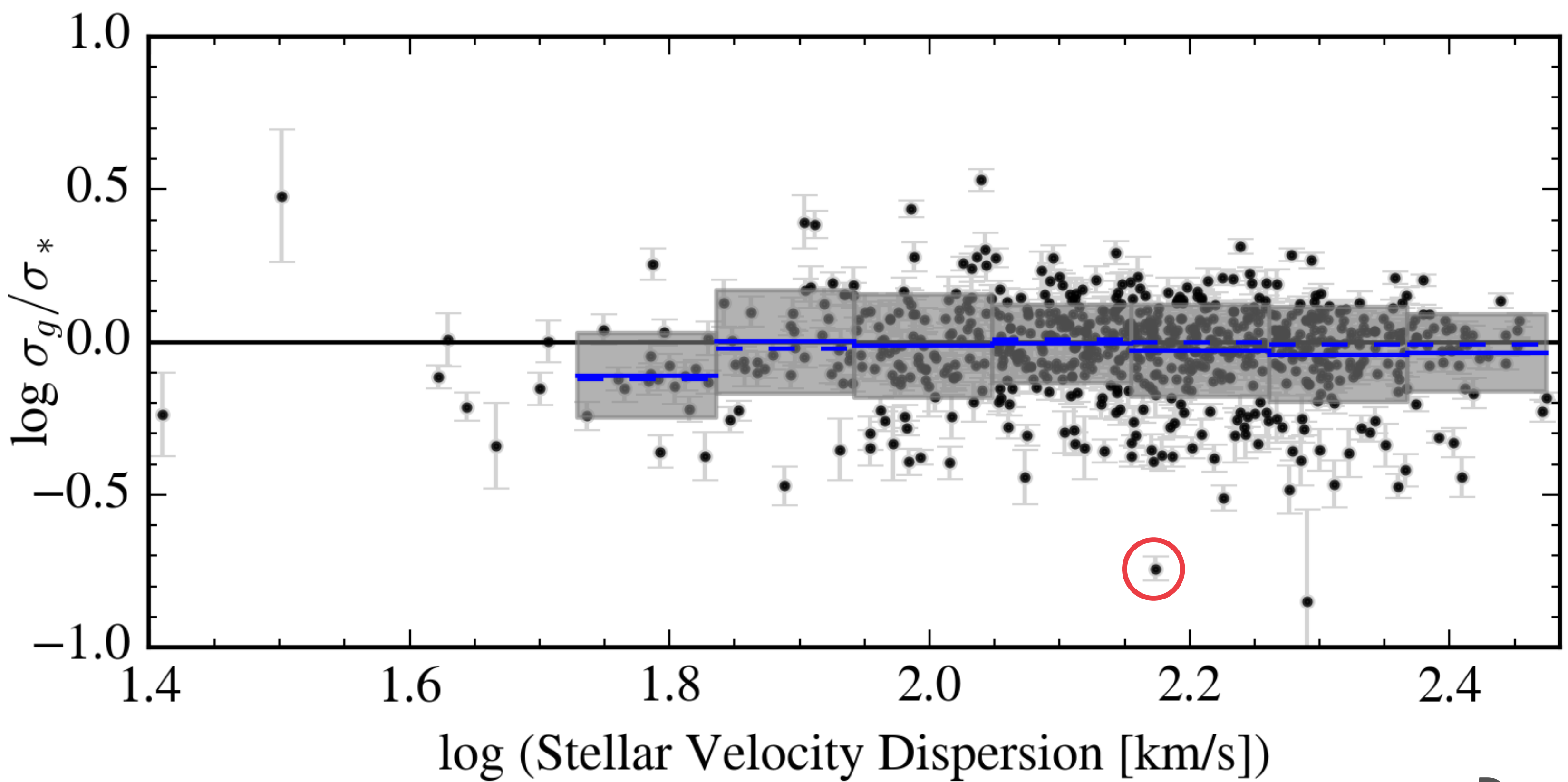

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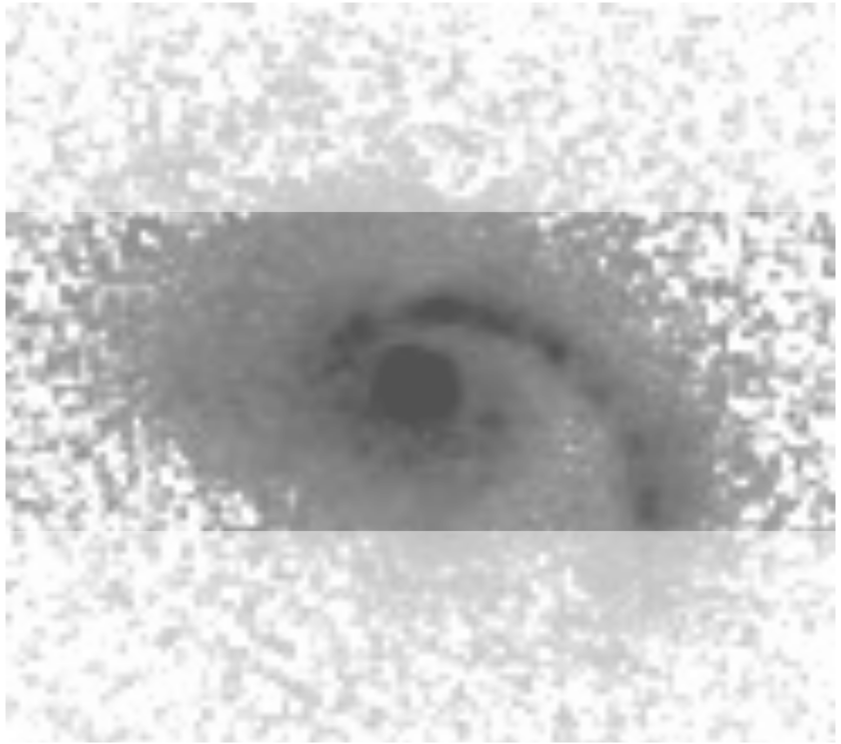
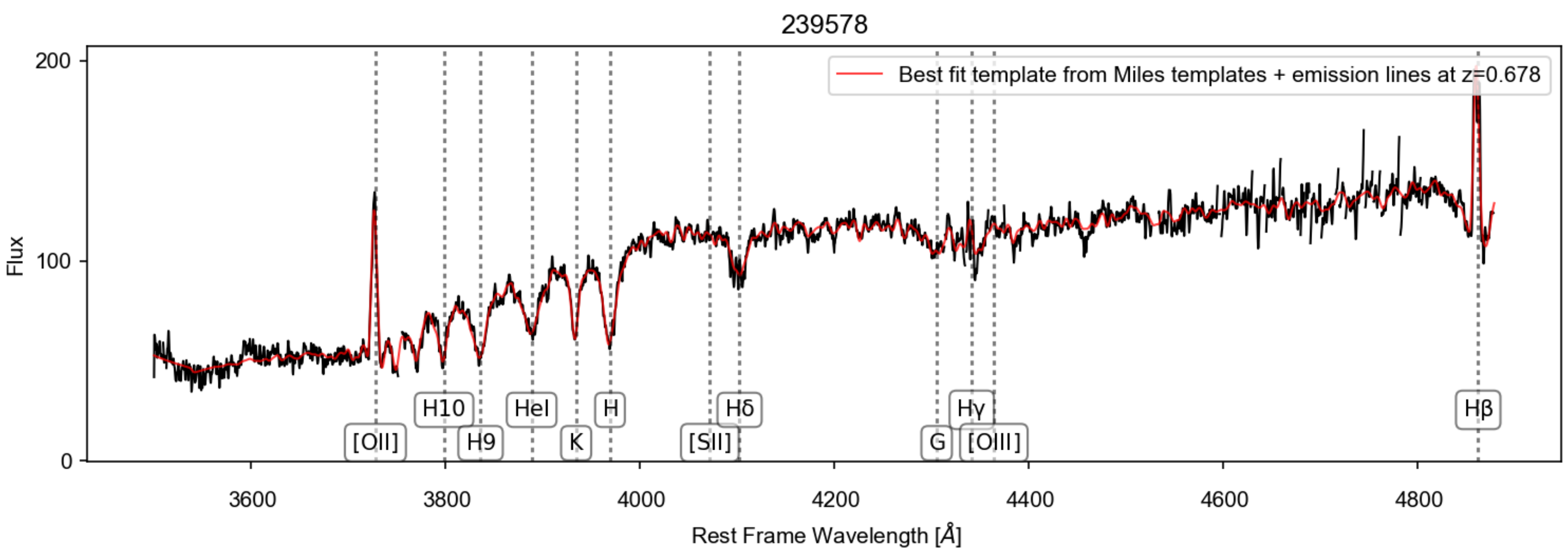
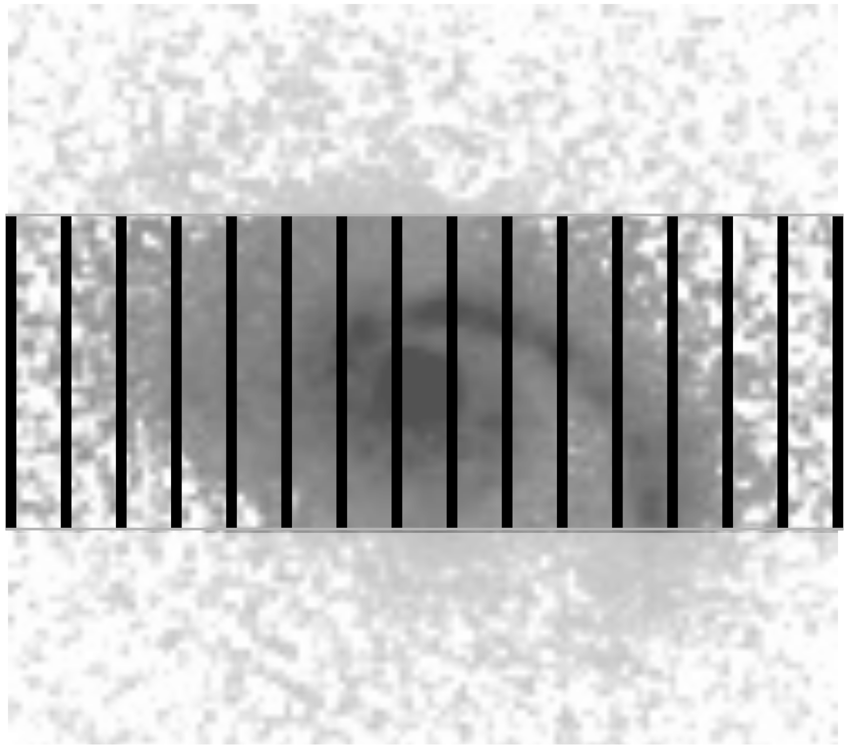
Spatially Resolved Kinematics

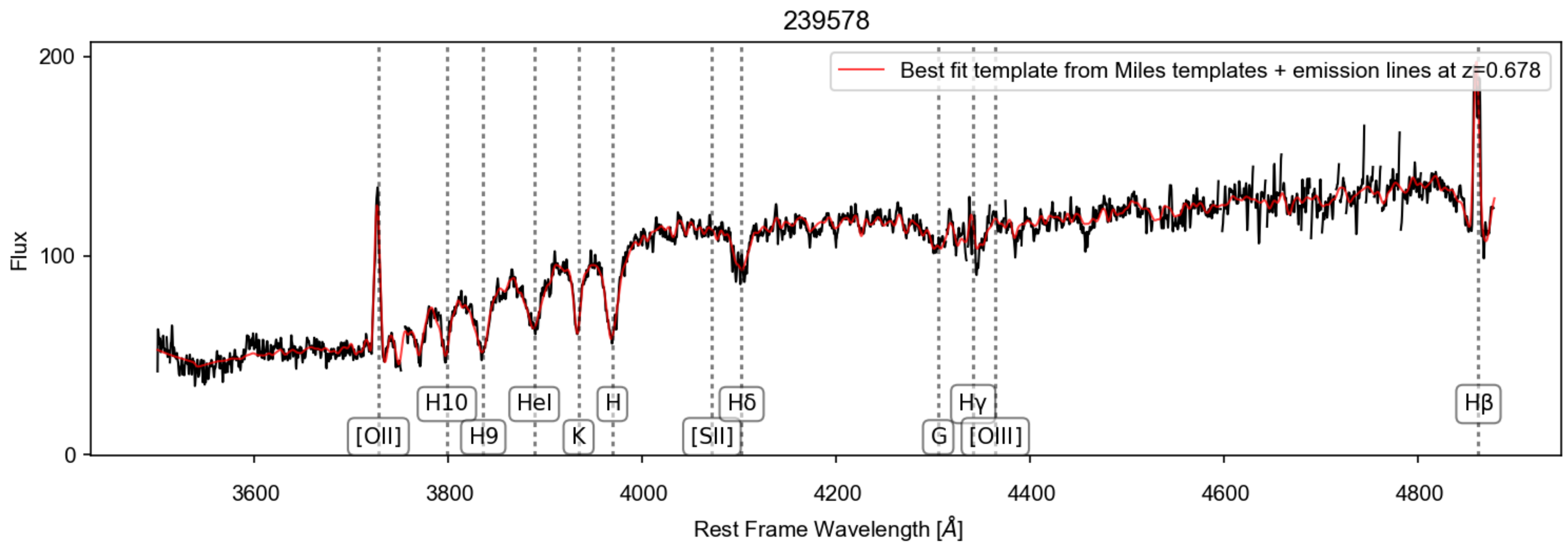




z = 0.68
Mstar = 4 x 10^{10} Msol
SFR = 28 Msol/yr

Spatially Resolved Kinematics





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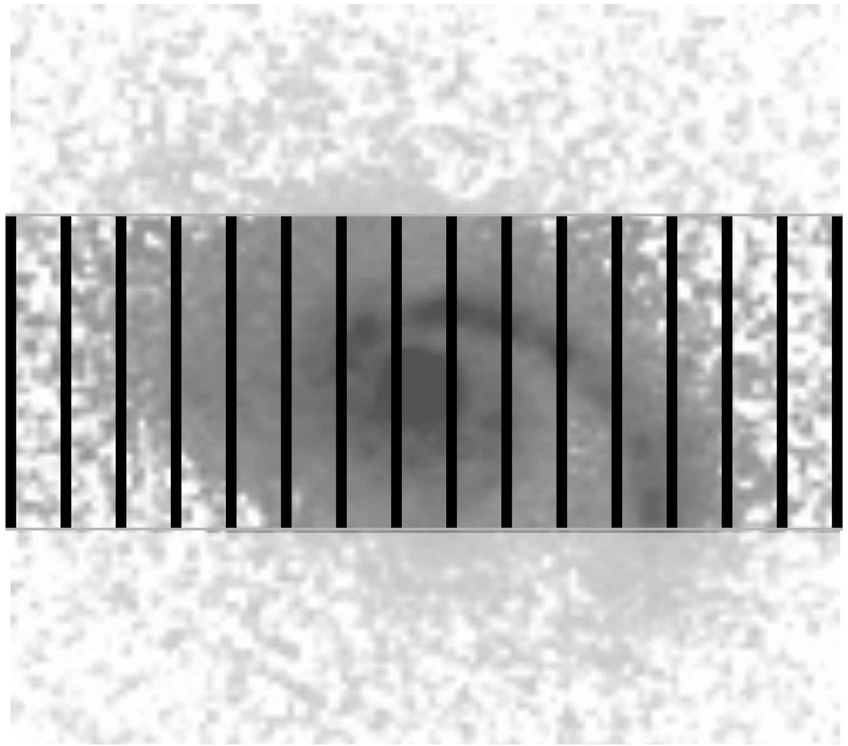

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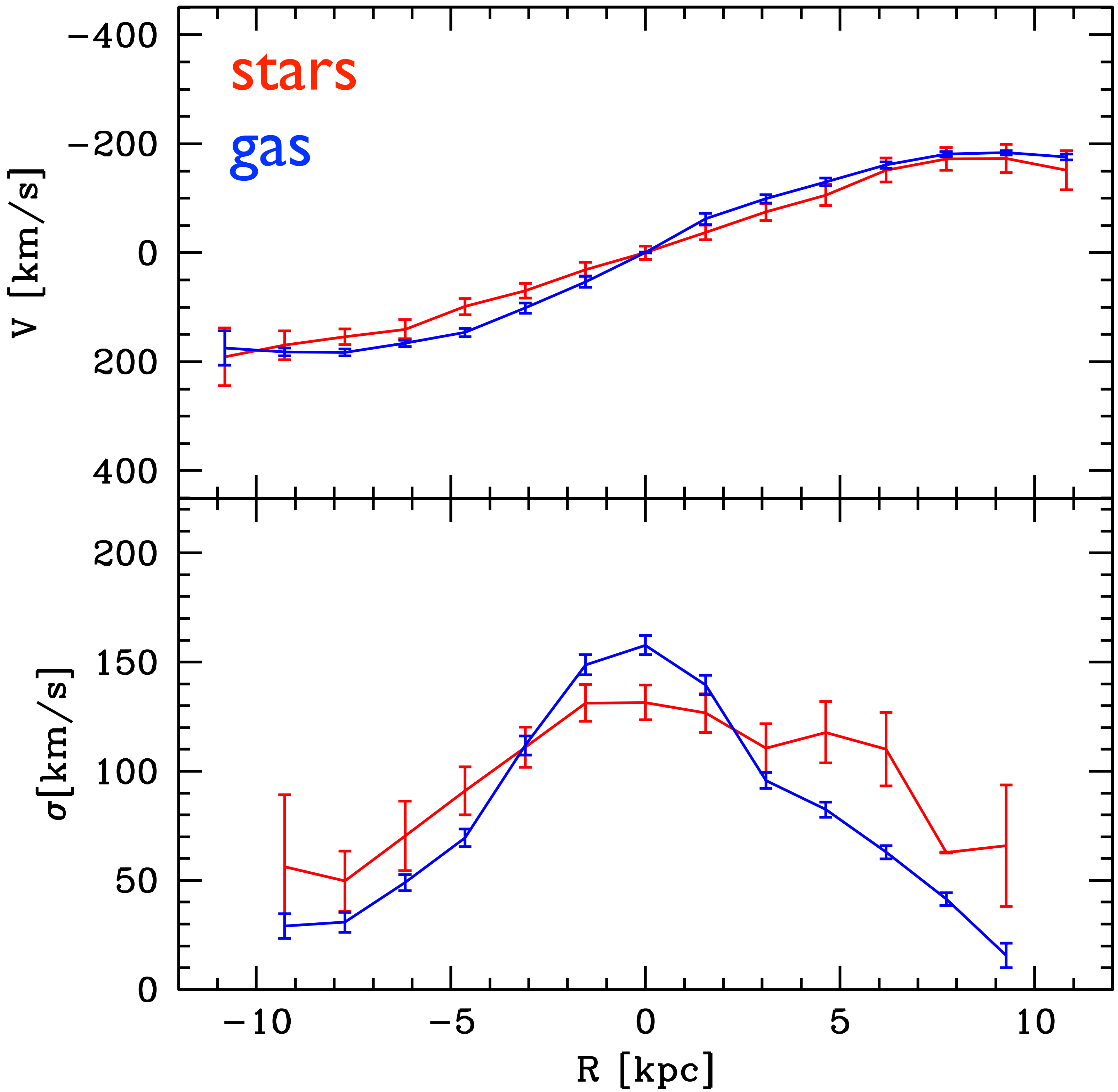

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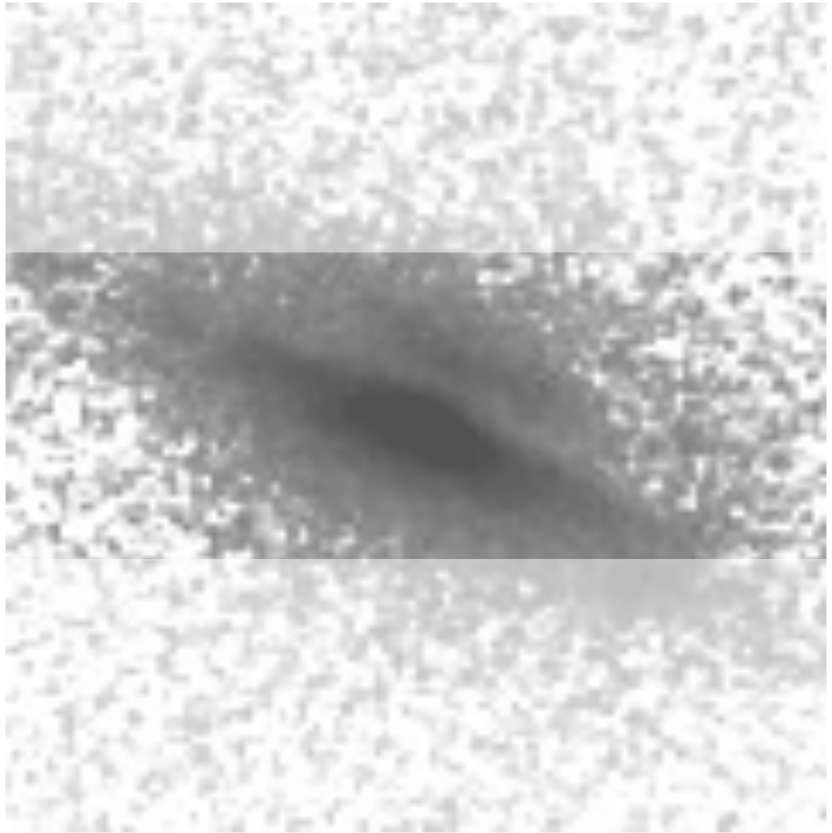
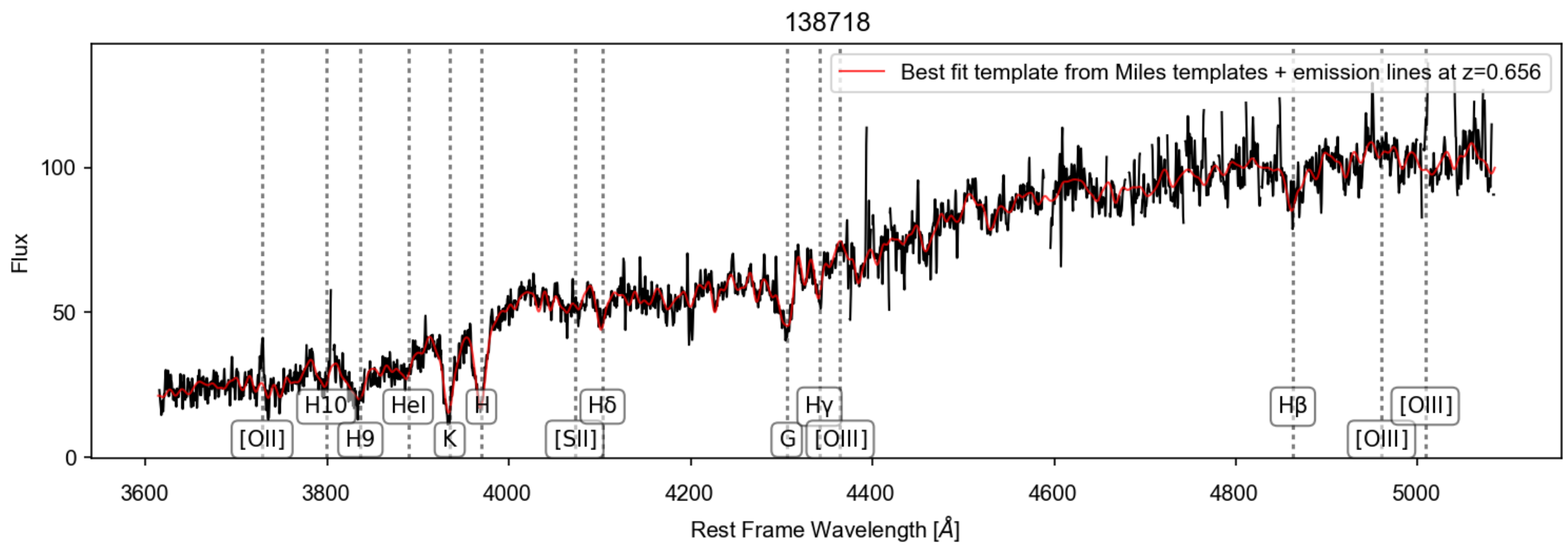
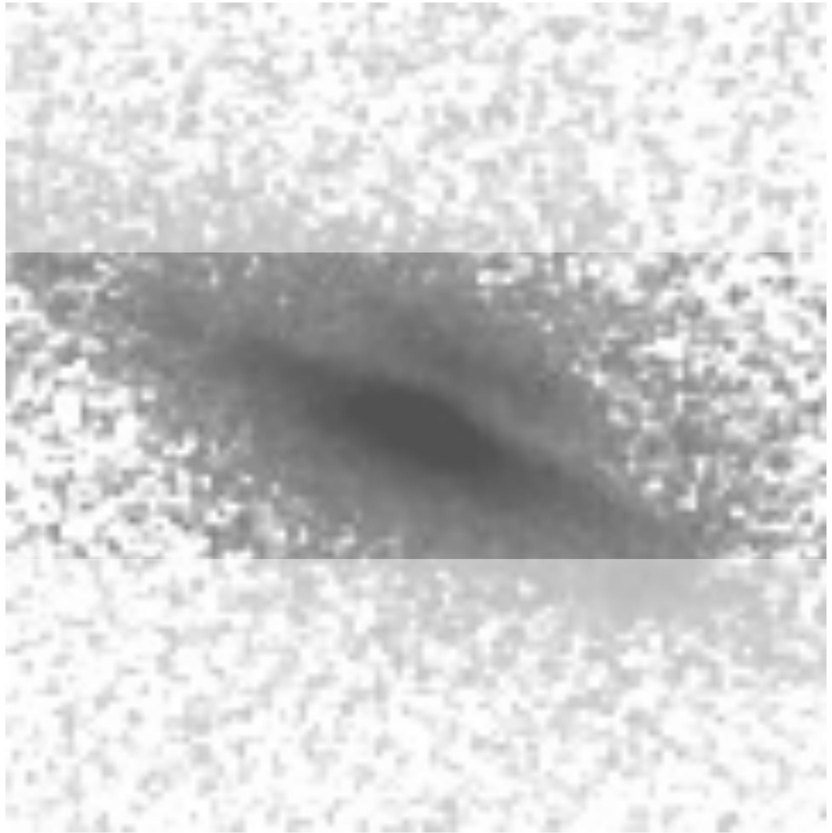




z = 0.66
Mstar = 1.3×10^{11} Msol
SFR = 6 Msol/yr

Spatially Resolved Kinematics



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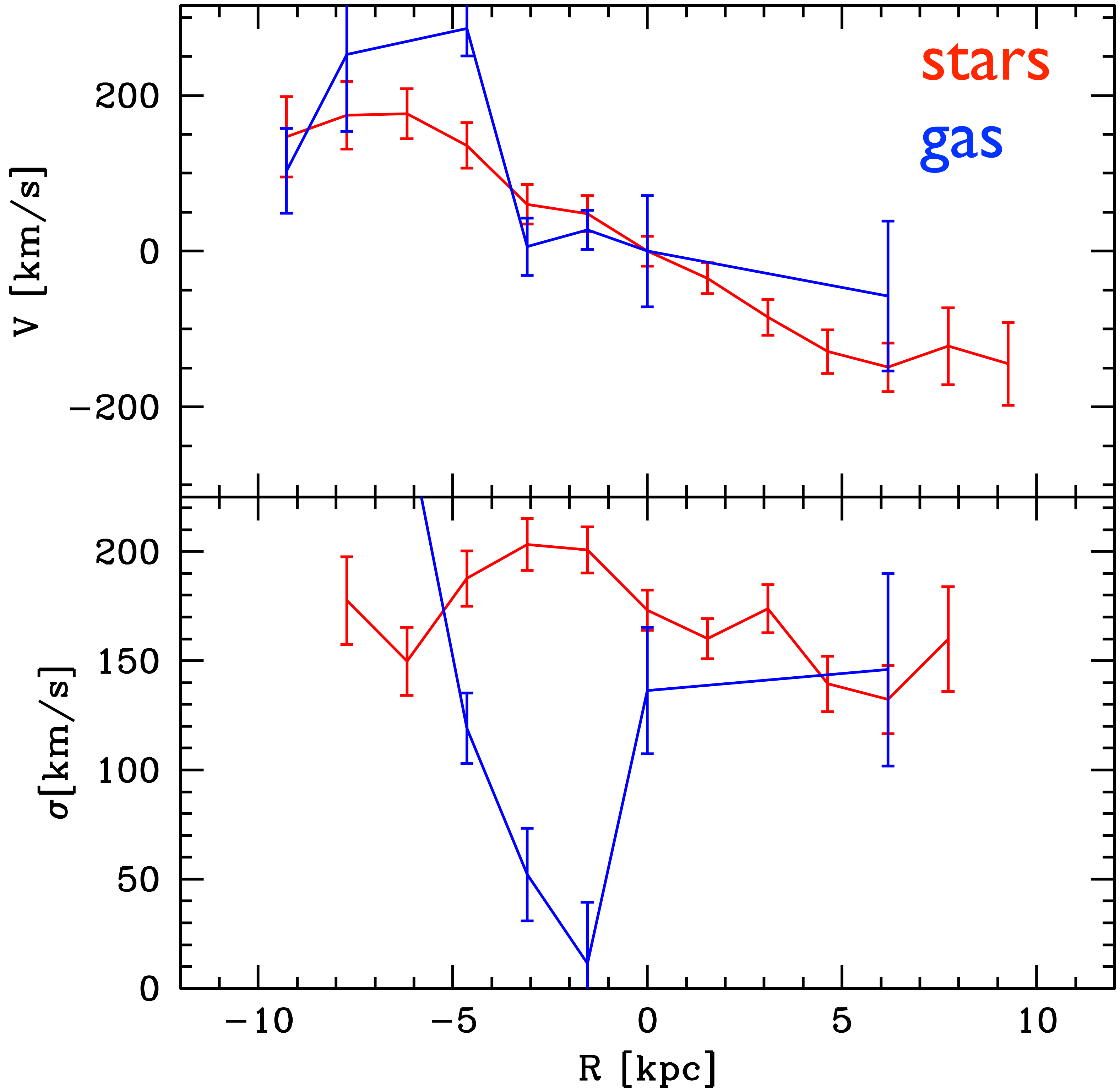

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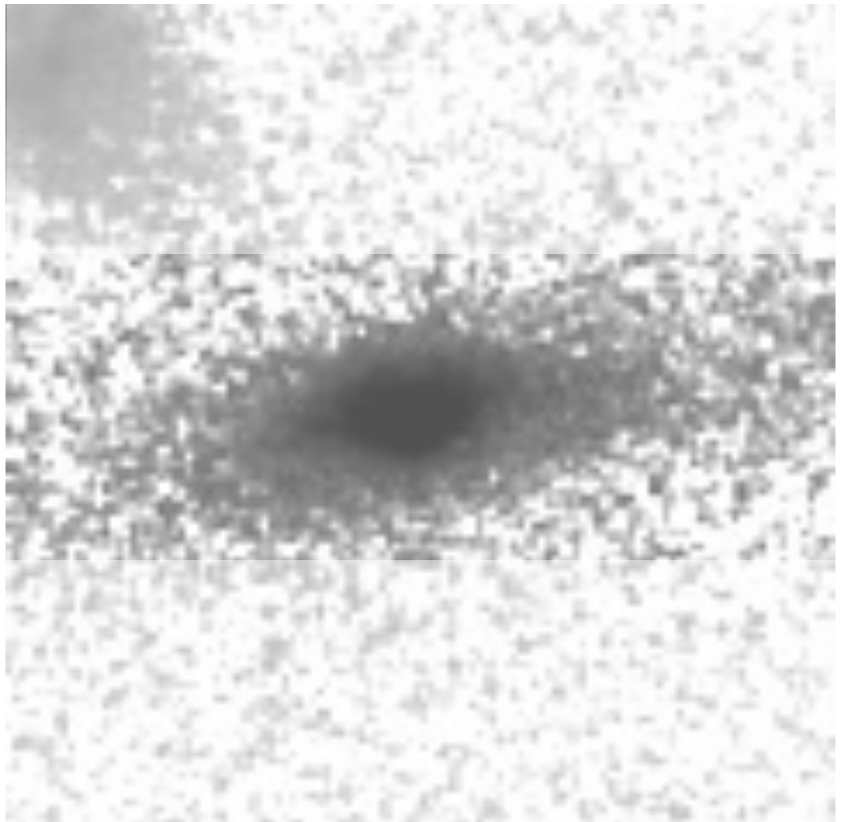
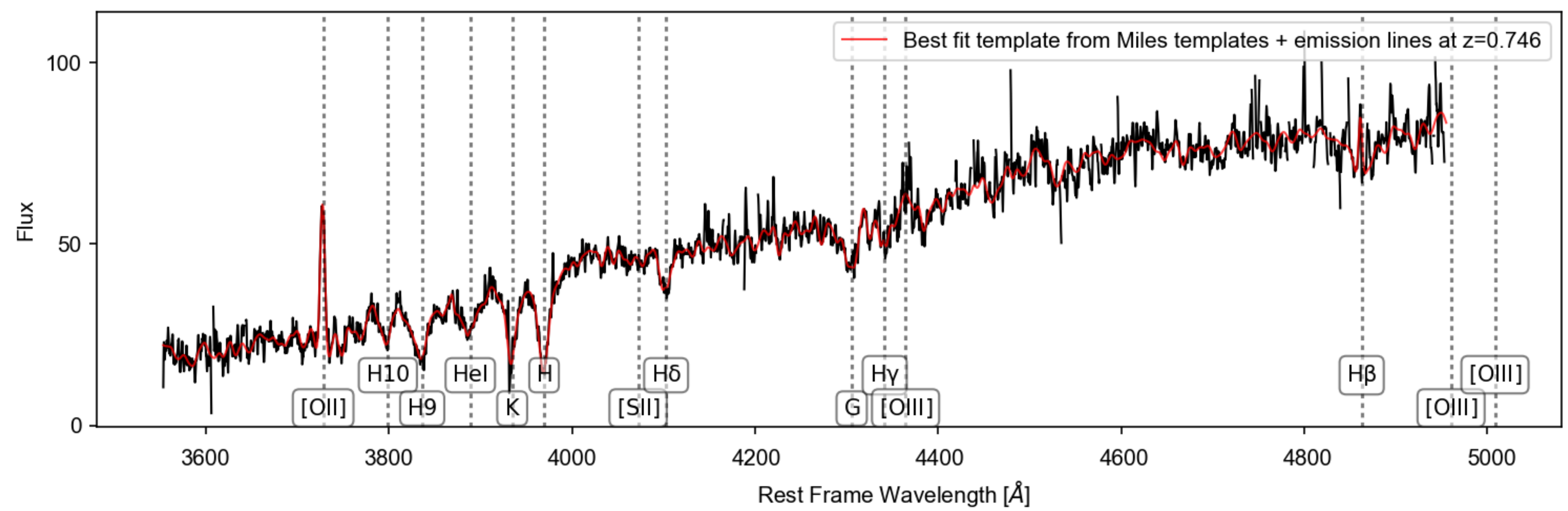
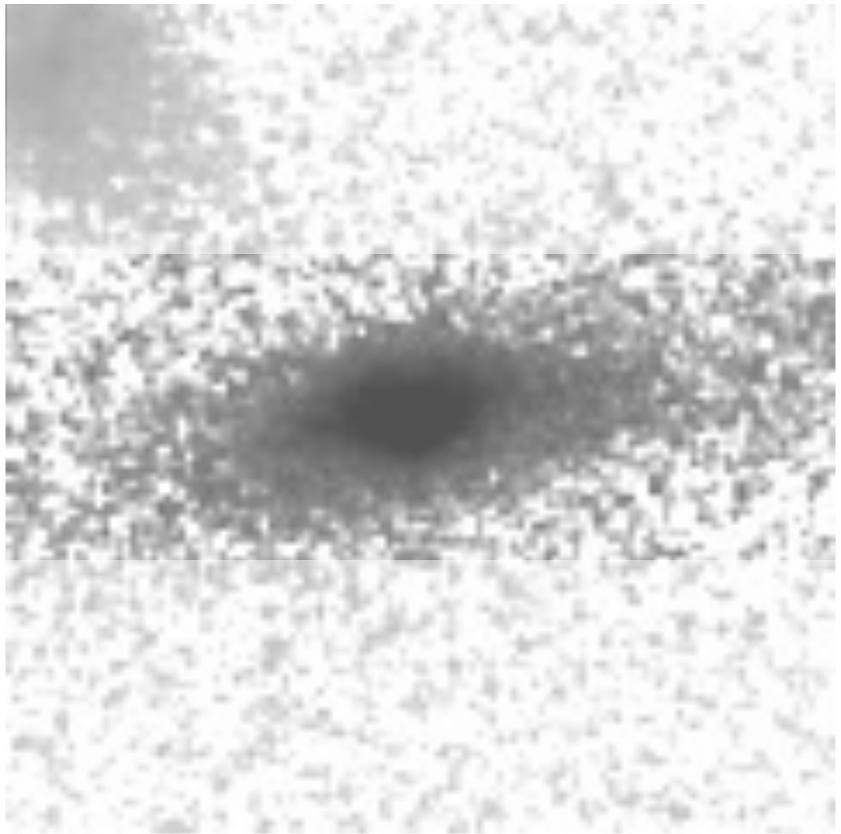




z = 0.75
Mstar = 9 x 10^{10} Msol
SFR = 6 Msol/yr

Spatially Resolved Kinematics



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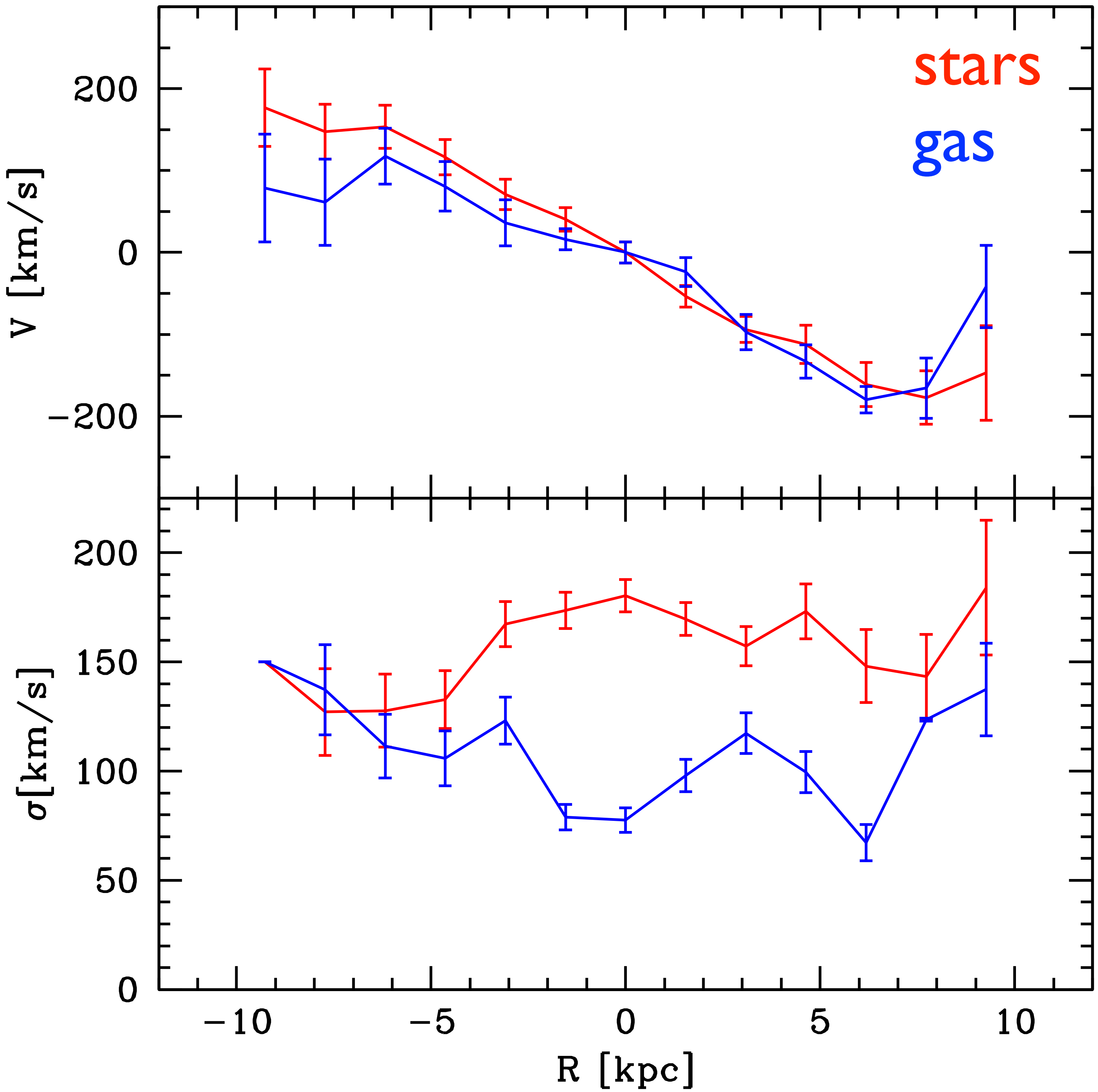


Spatially Resolved Kinematics

What do we do with it?

— Tully-Fisher relation of emission lines galaxies

see next talk by Caroline Straatman

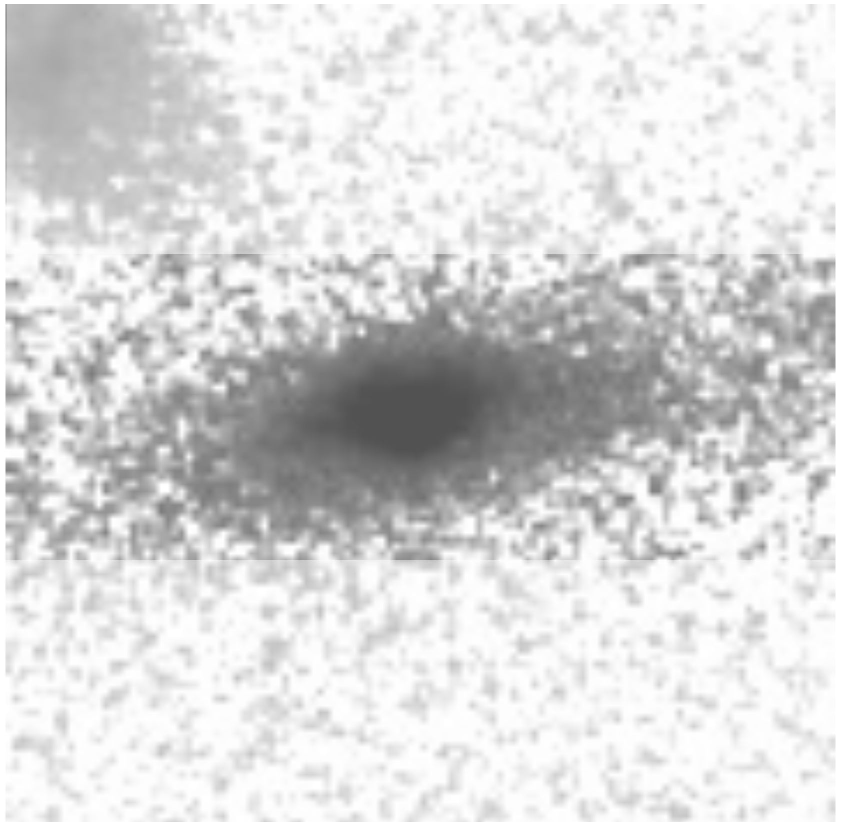
— Stellar rotation

Bezanson, van der Wel et al., subm.

— Dynamical modeling

van Houdt, van der Wel et al., in prep.

V_5 / σ_0



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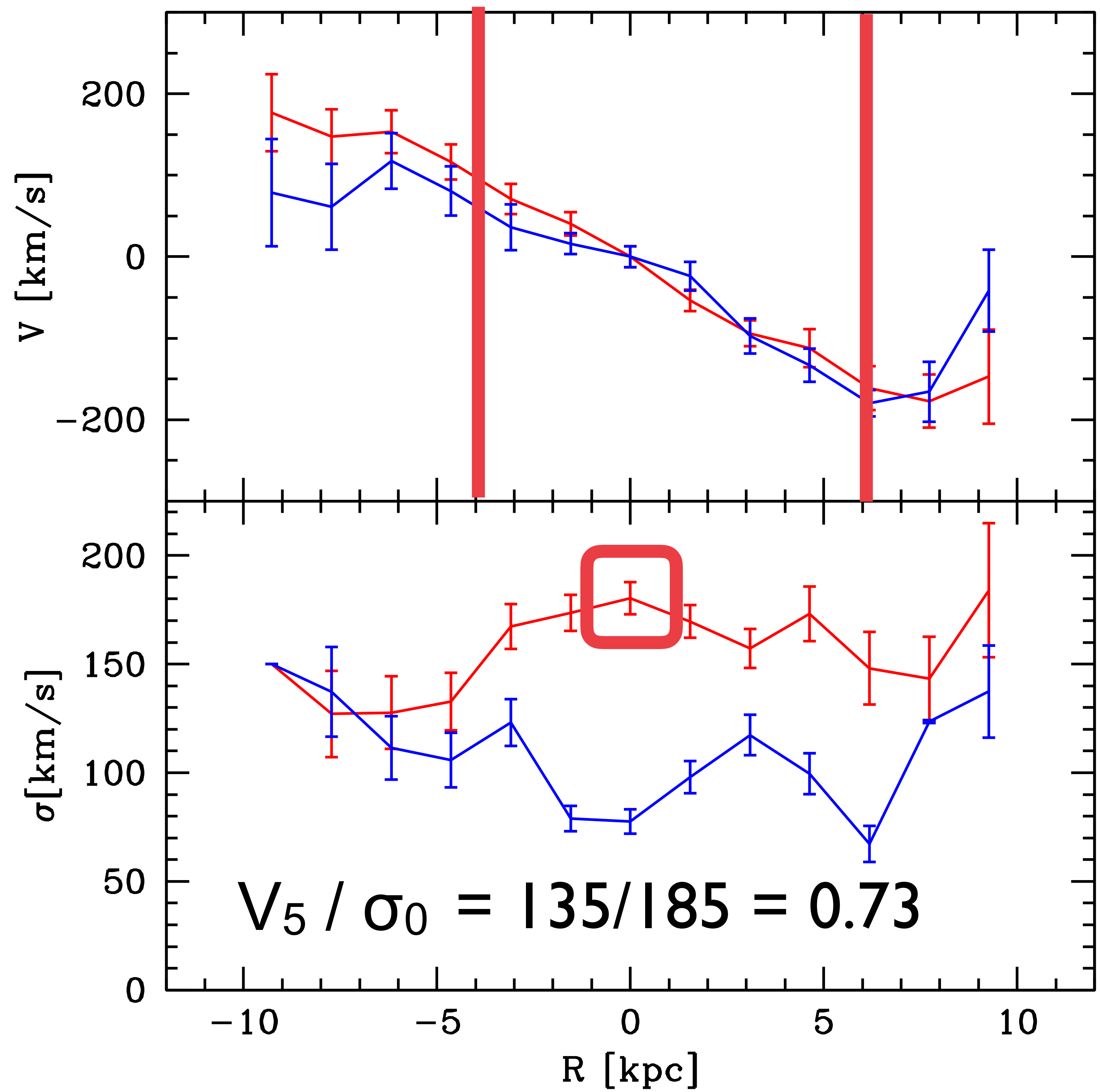
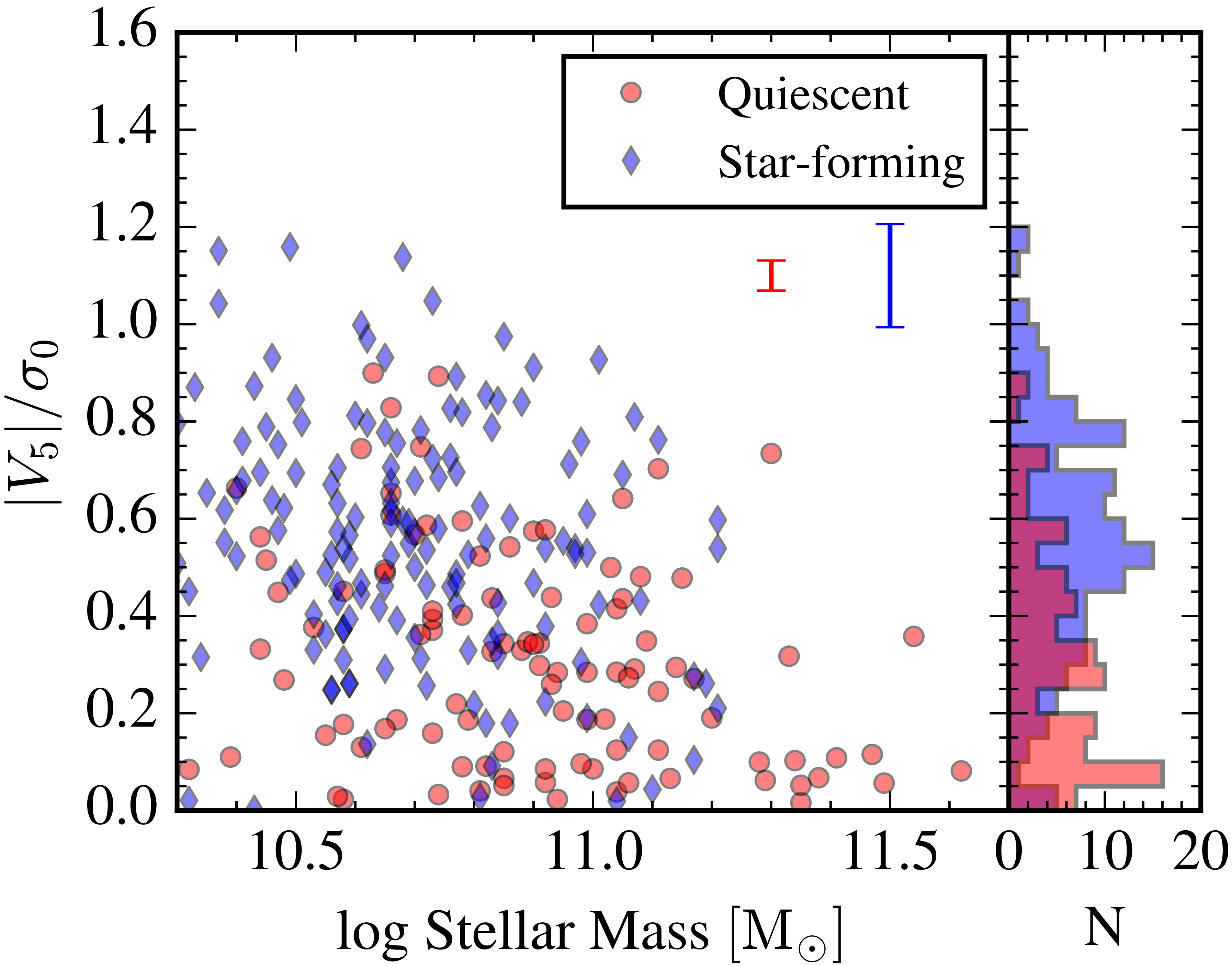
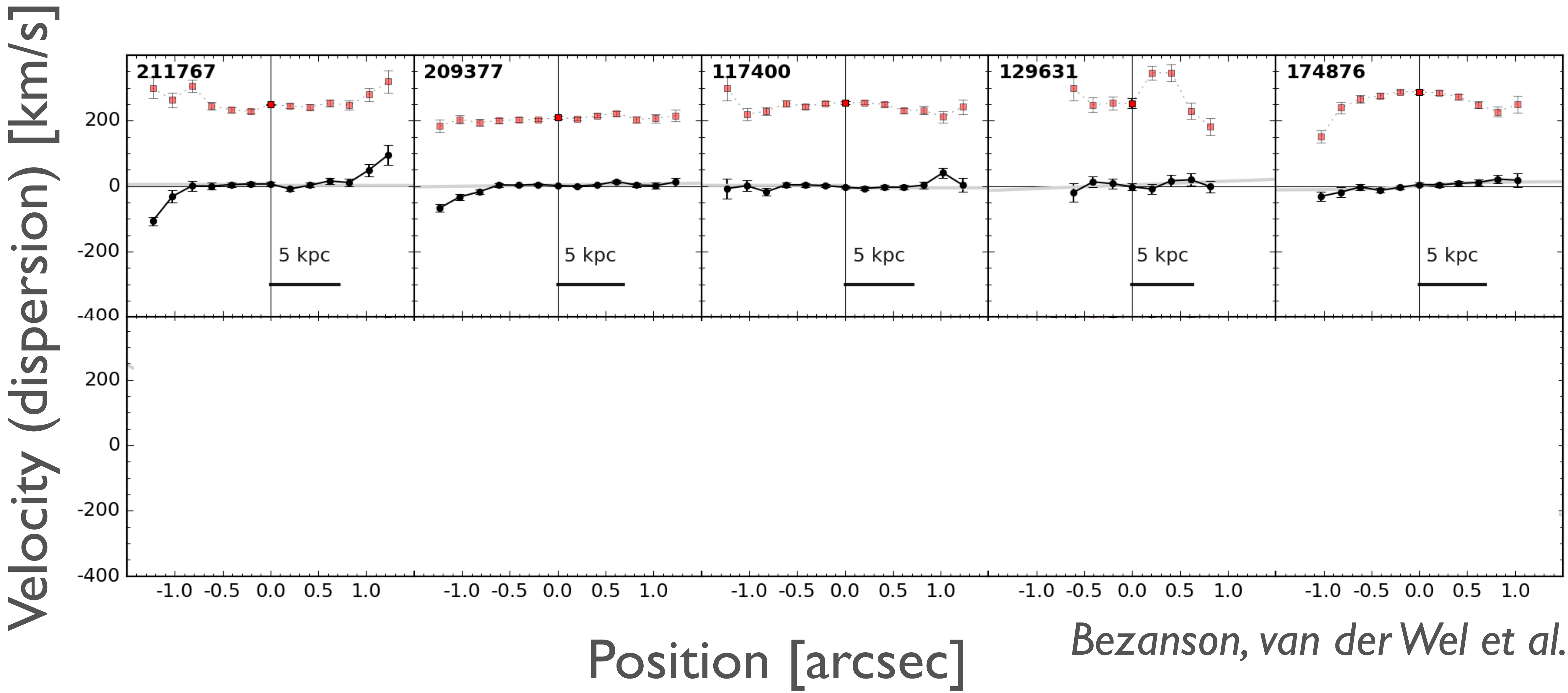


Stellar rotation distribution



Bezanson, van der Wel et al.

Stellar rotation in massive, passive galaxies



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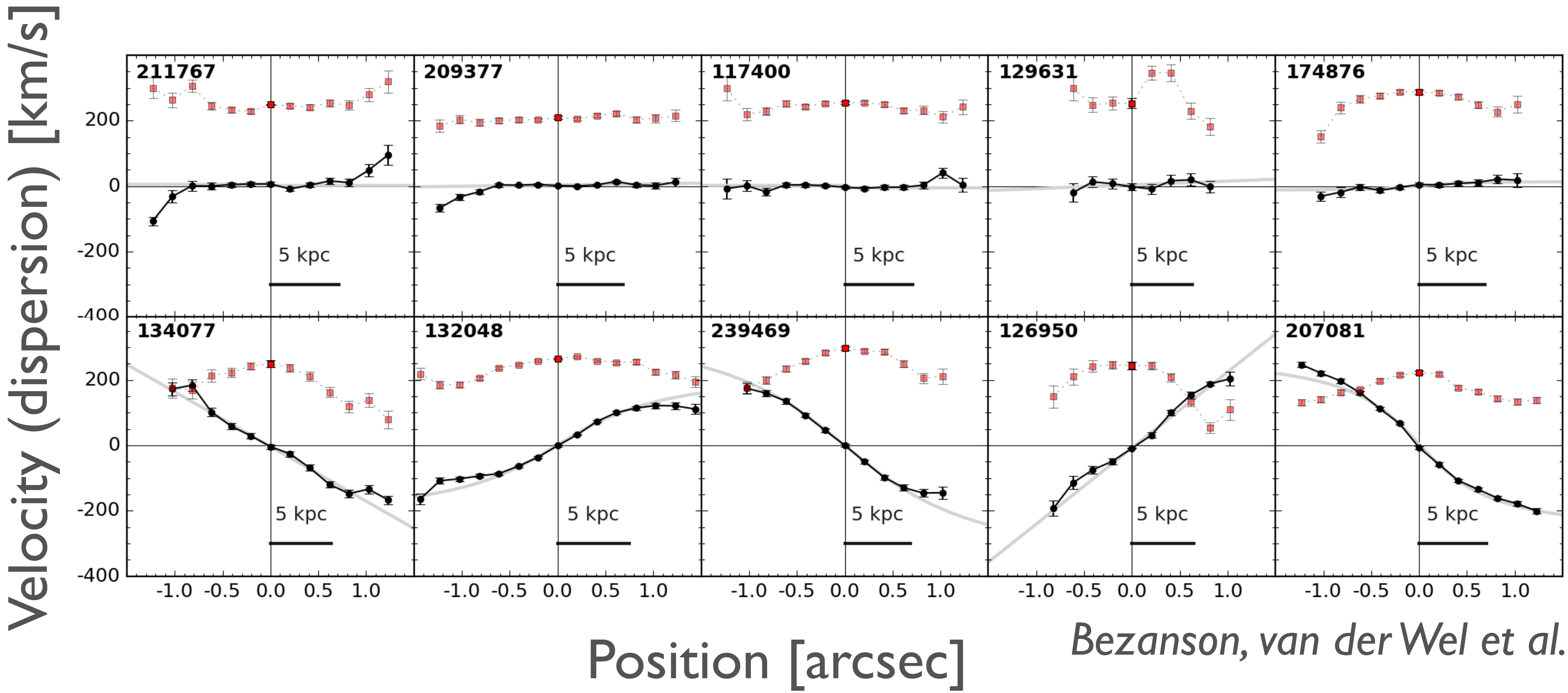

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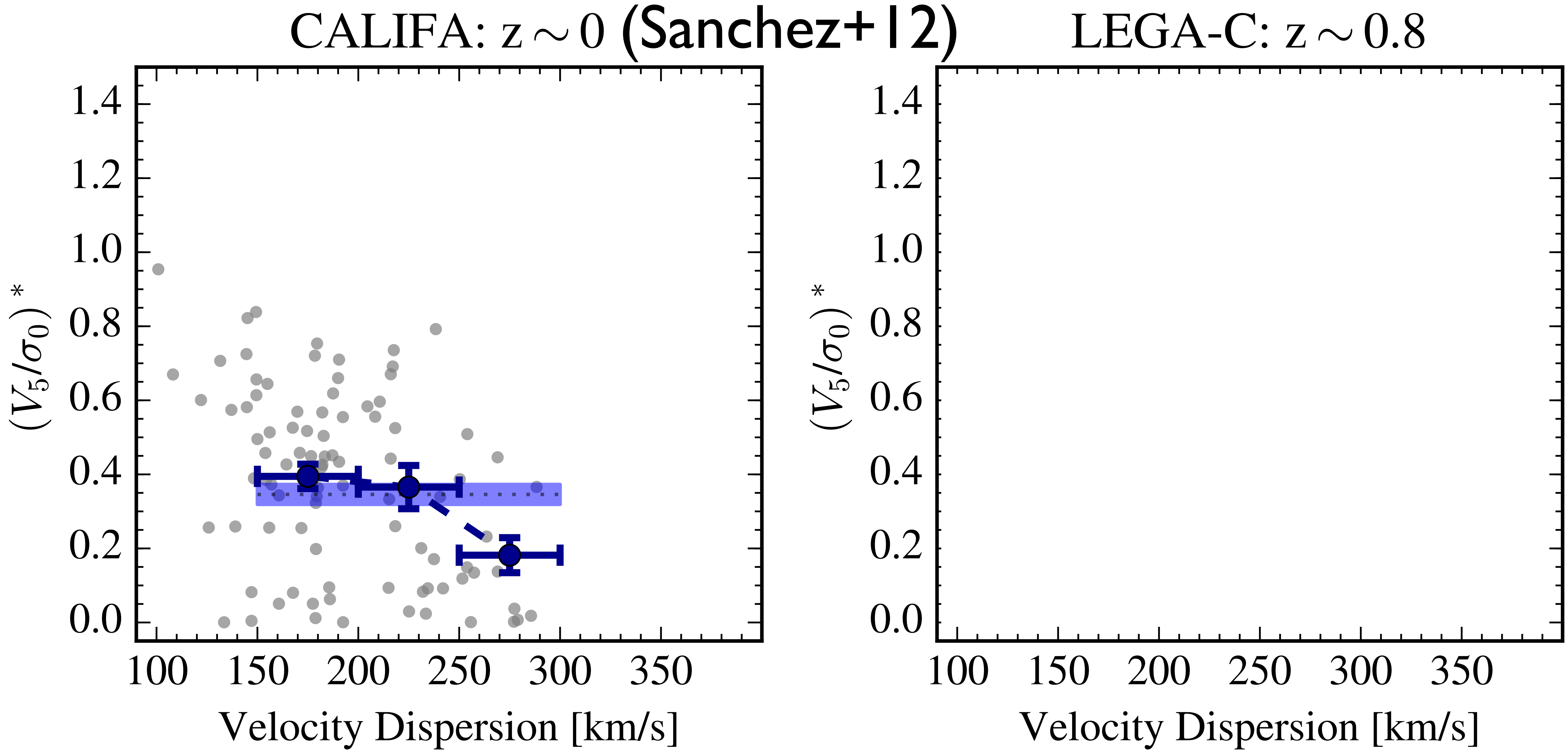
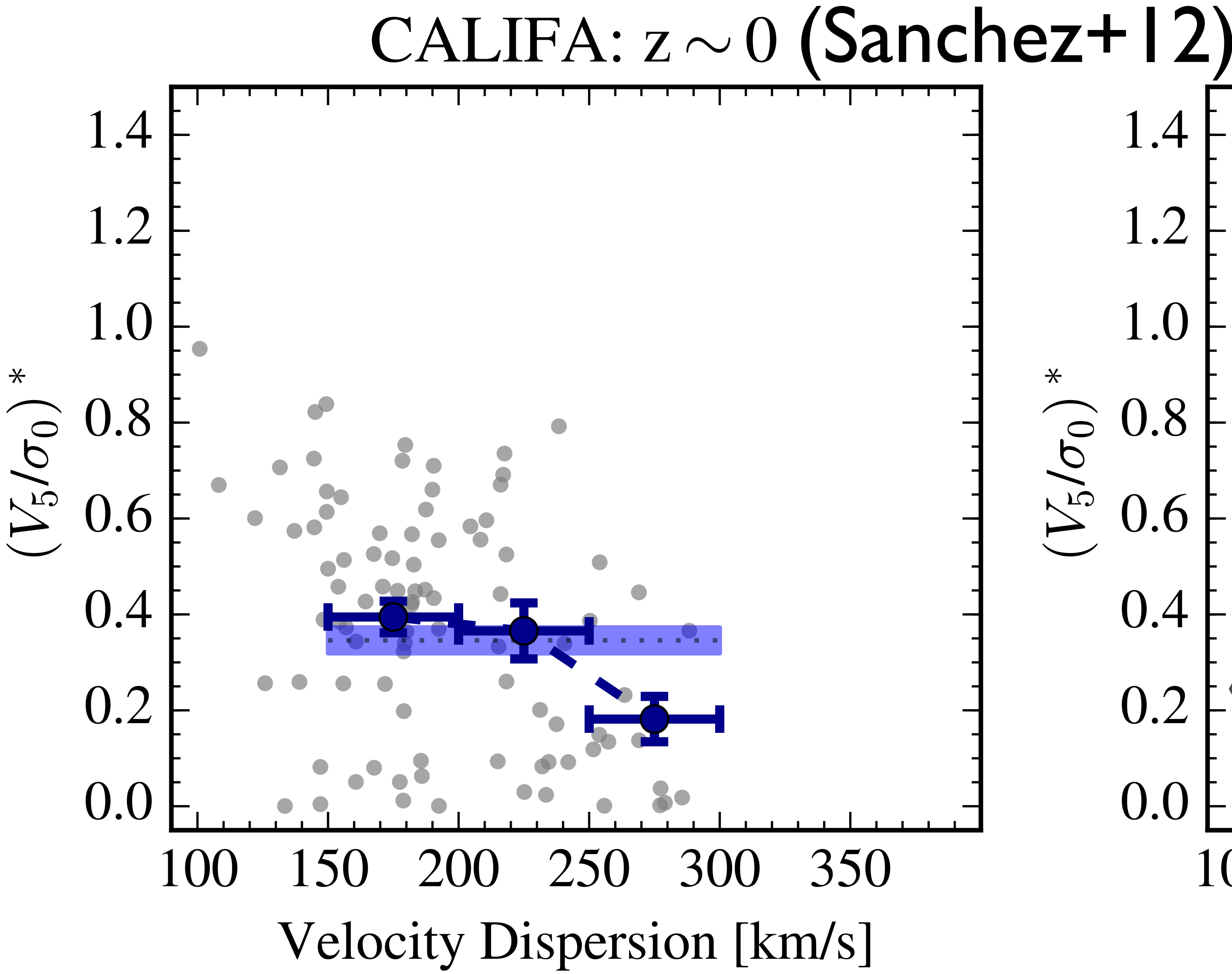
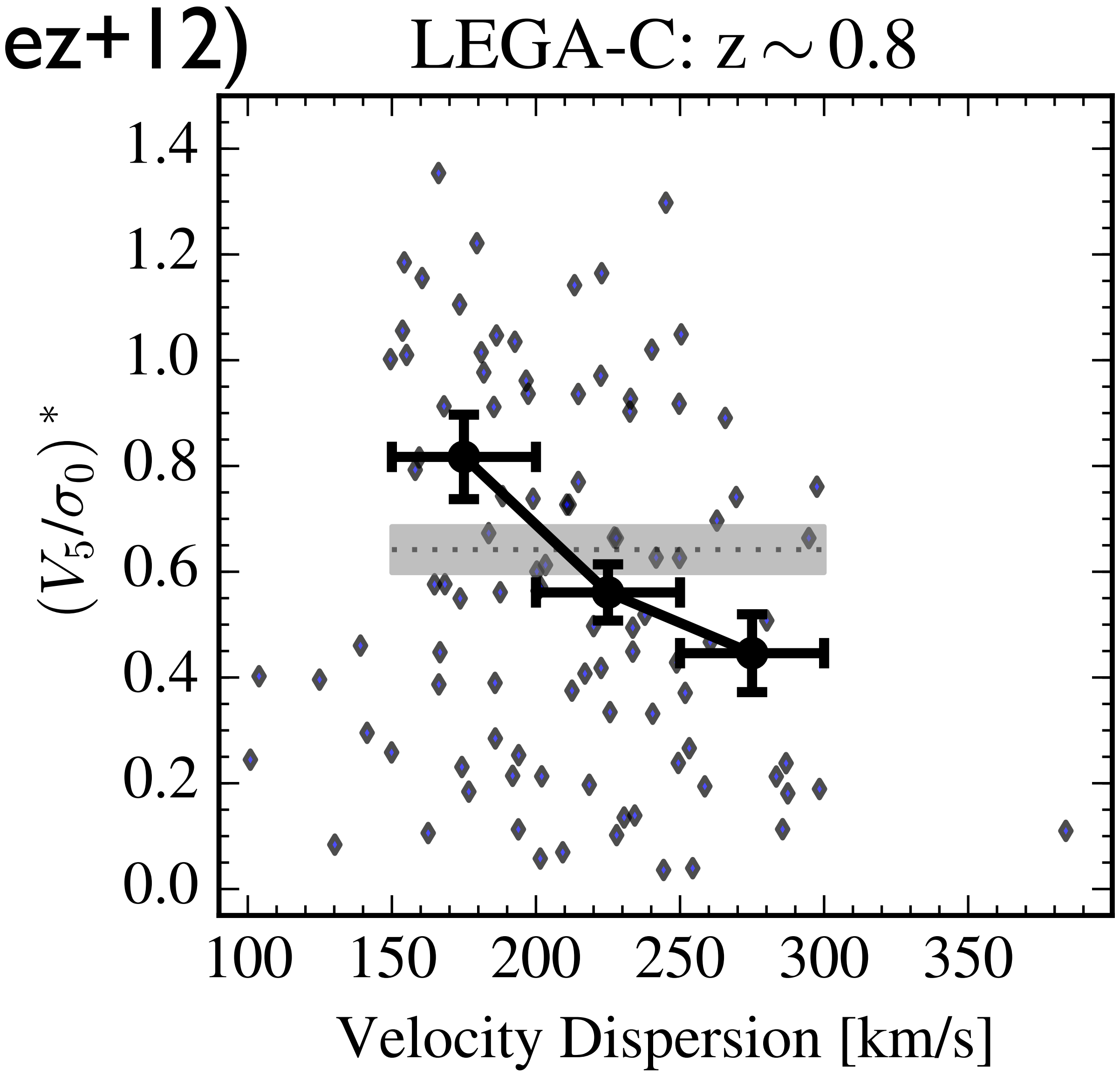


Previous work: 25 z~1 ellipticals (van der Wel+08)
2 z~2 lensed galaxies (Newman+15; Toft+17)

Stellar rotation in passive galaxies





The decrease in rotational support implies significant merging activity

Previous work: 25 z~1 ellipticals (van der Wel+08)
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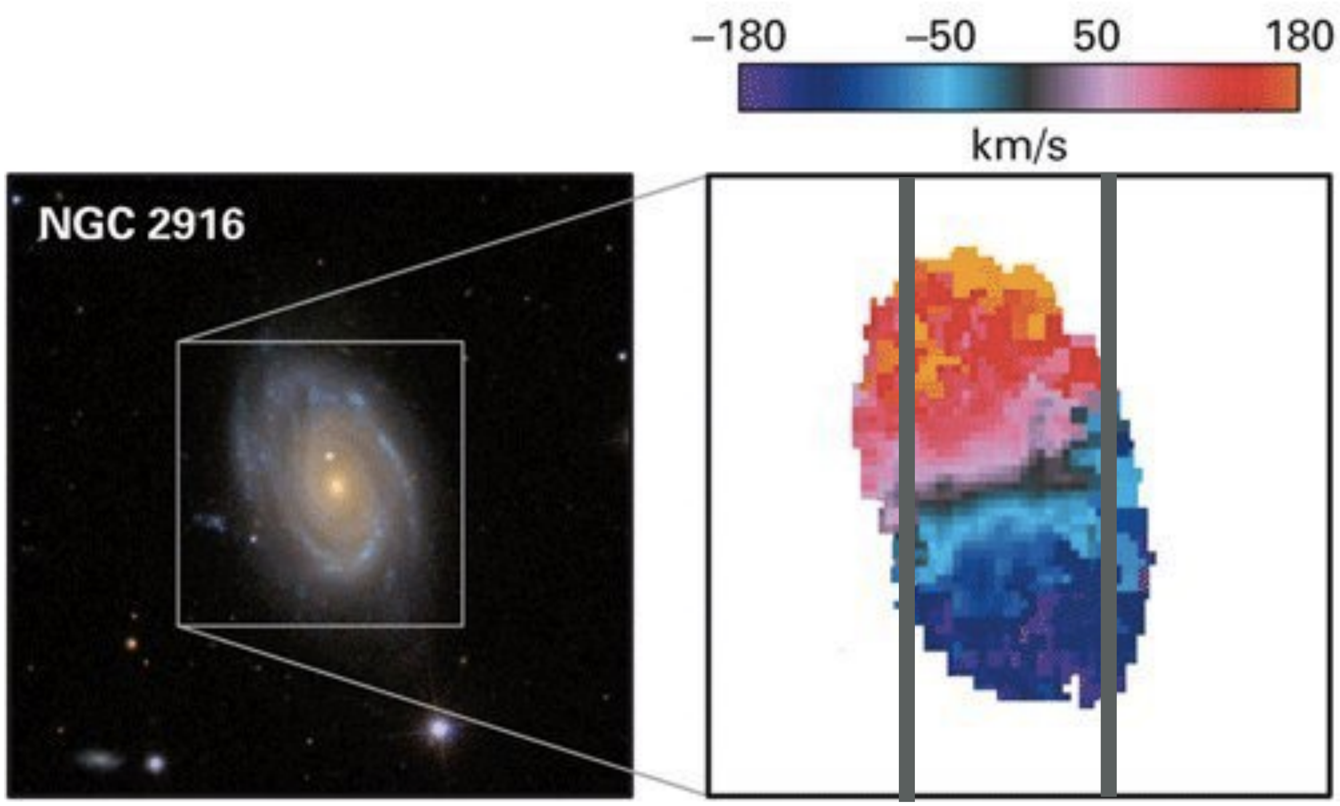
Stellar rotation in passive galaxies

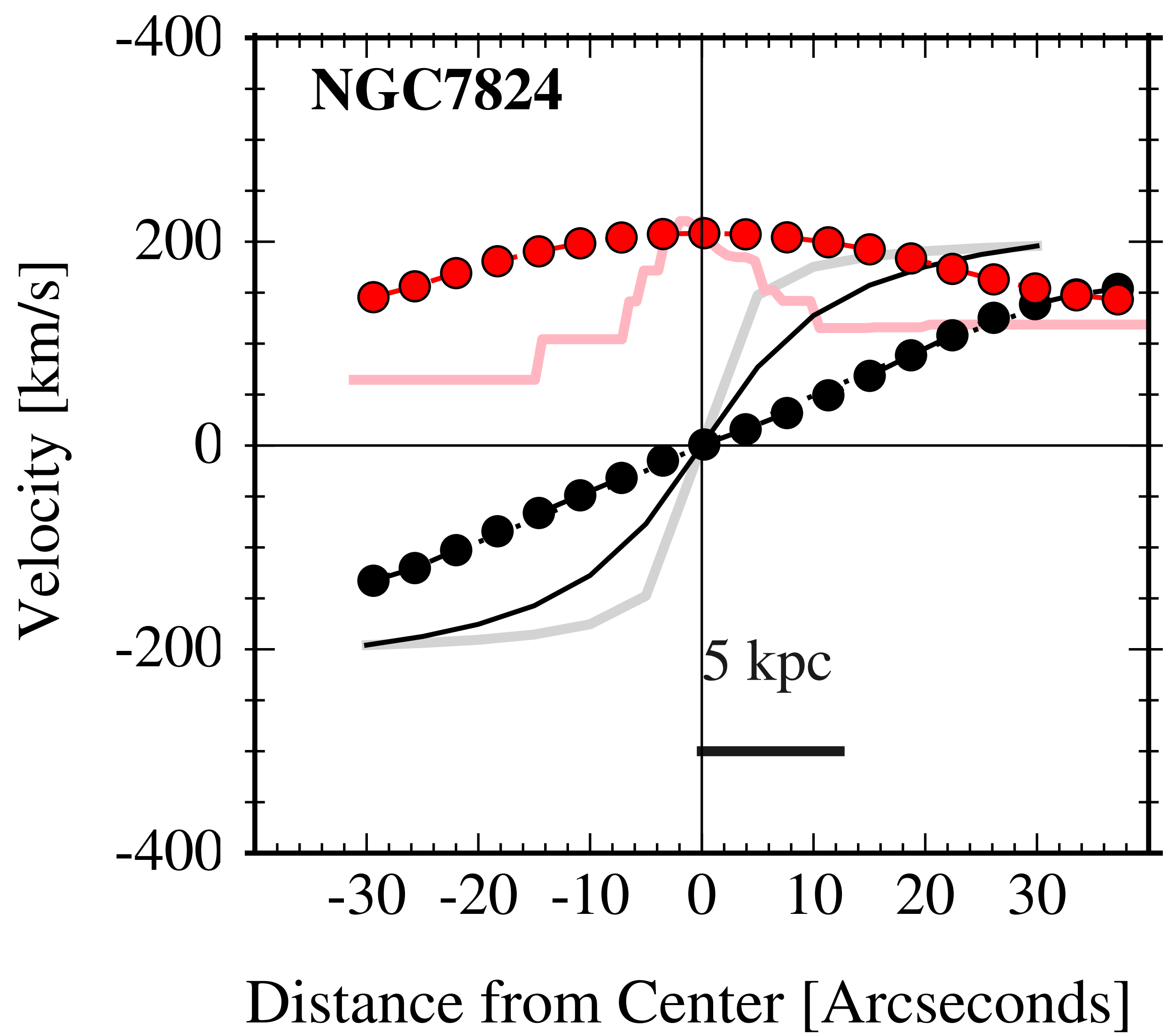
How we (mis-)treated the CALIFA data…



Recall Alfred Tiley's talk

Stellar rotation in passive galaxies

How we (mis-)treated the CALIFA data…



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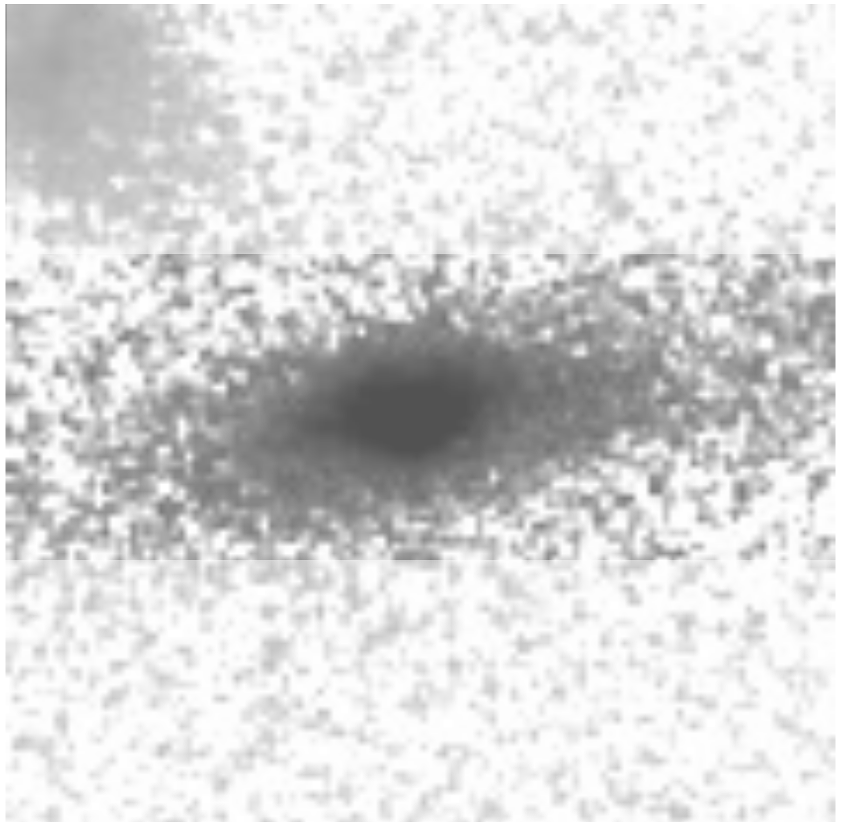
Dynamical modeling



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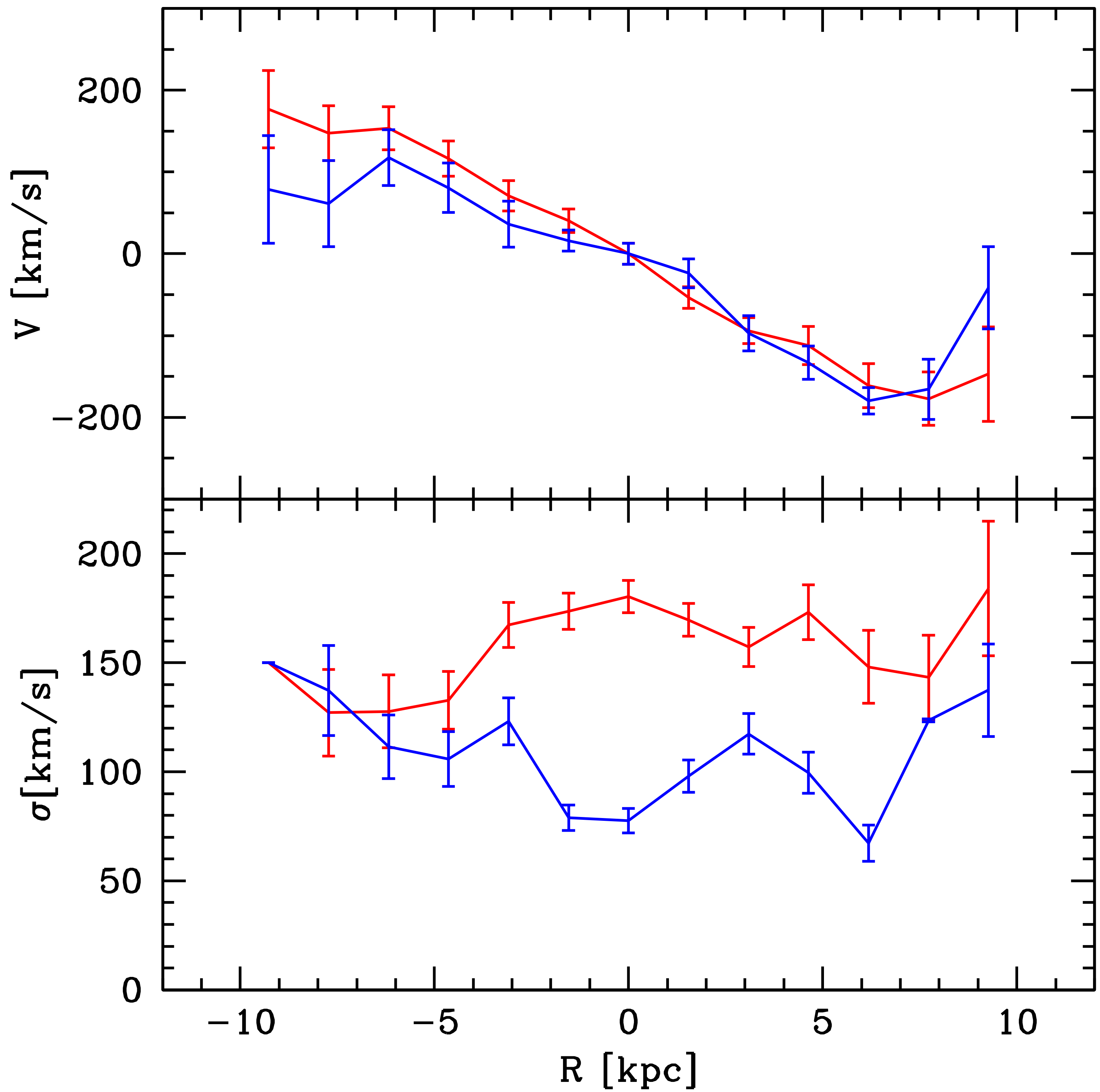
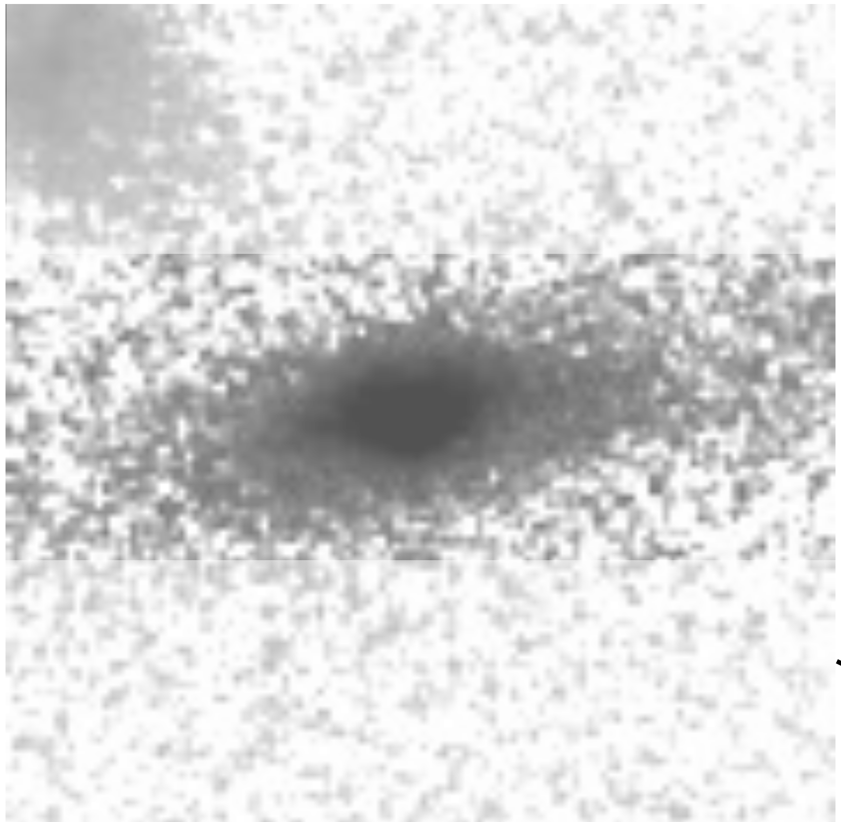


Dynamical modeling



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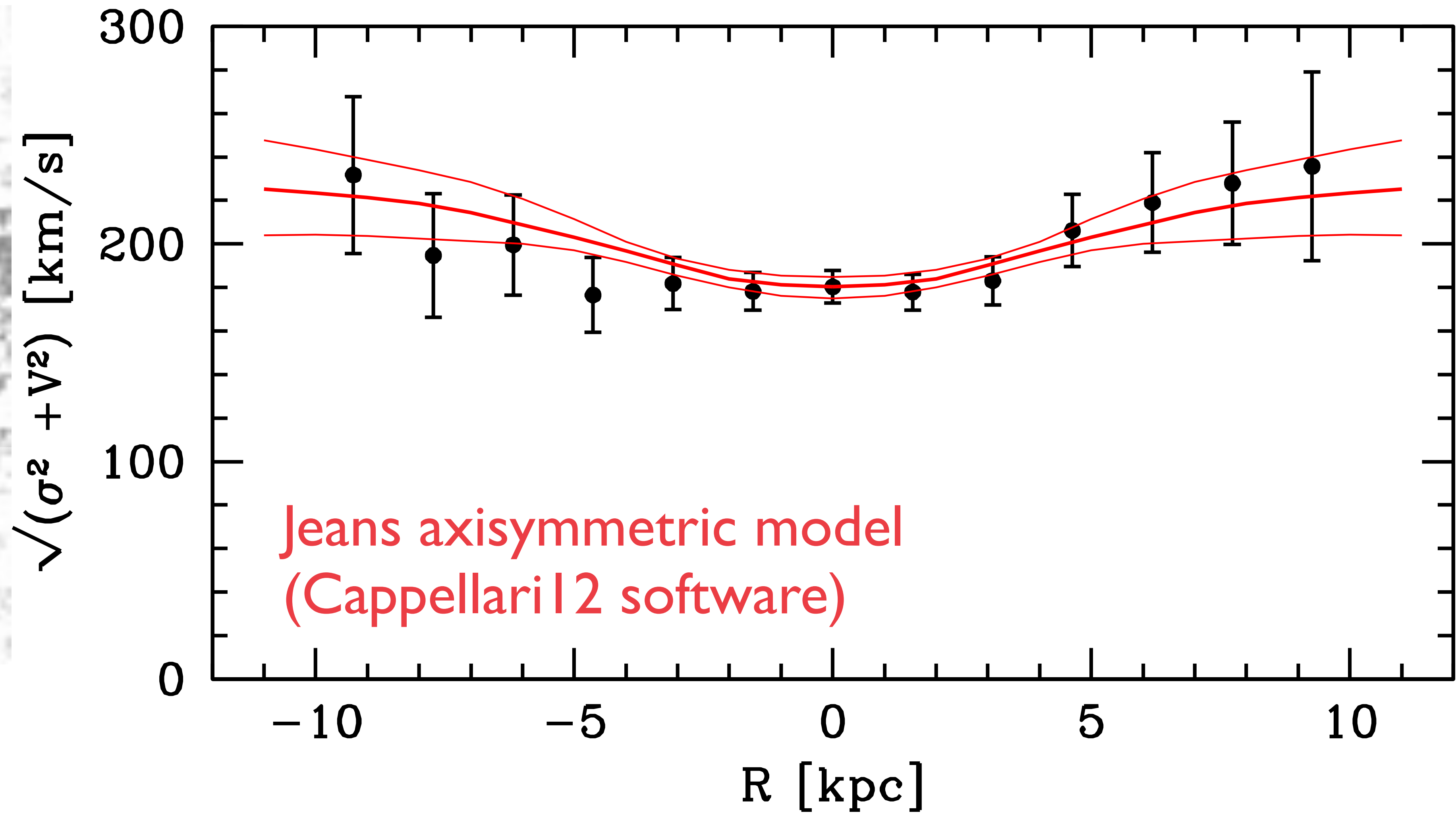


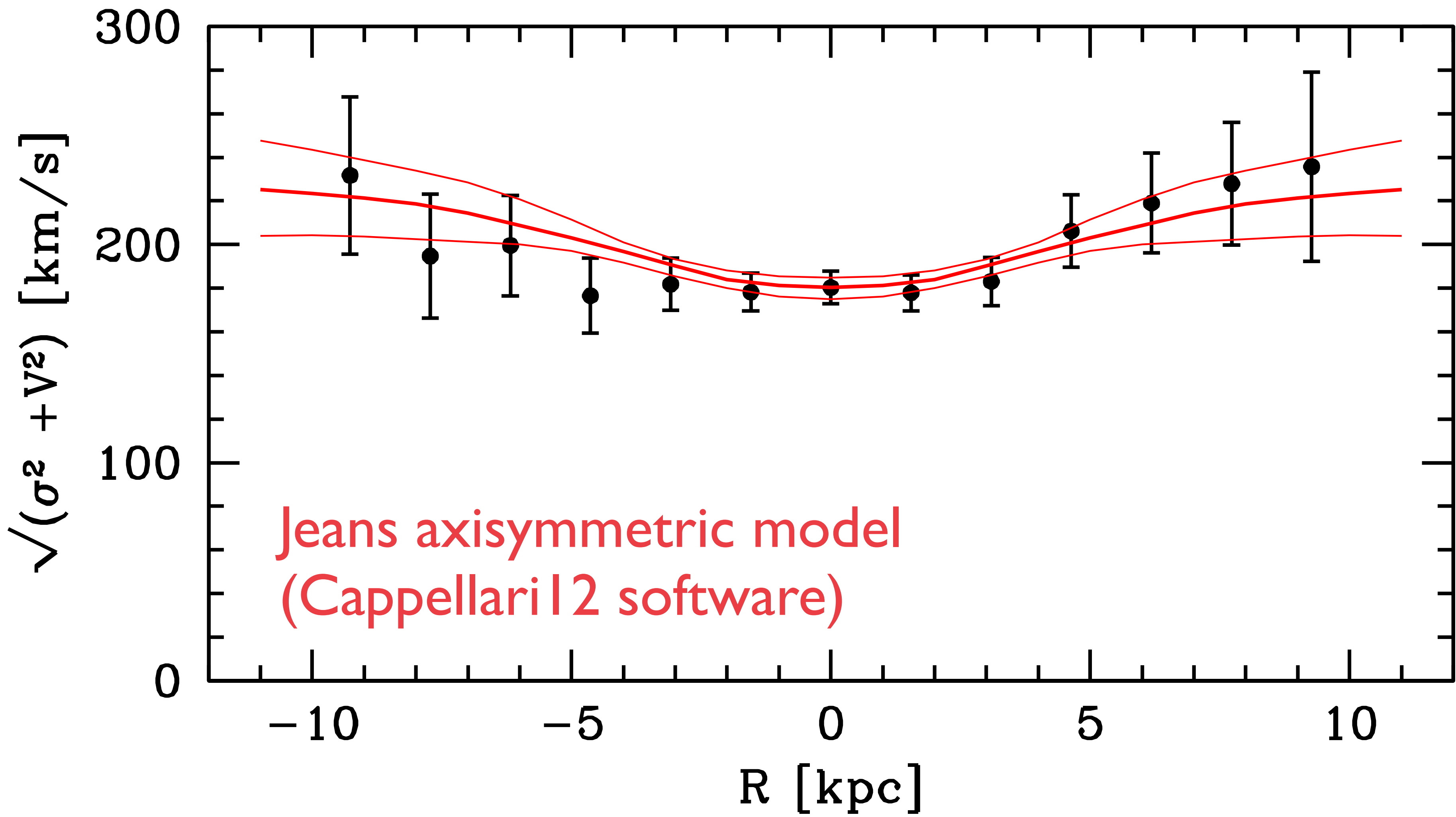
Dynamical modeling

Free parameters:

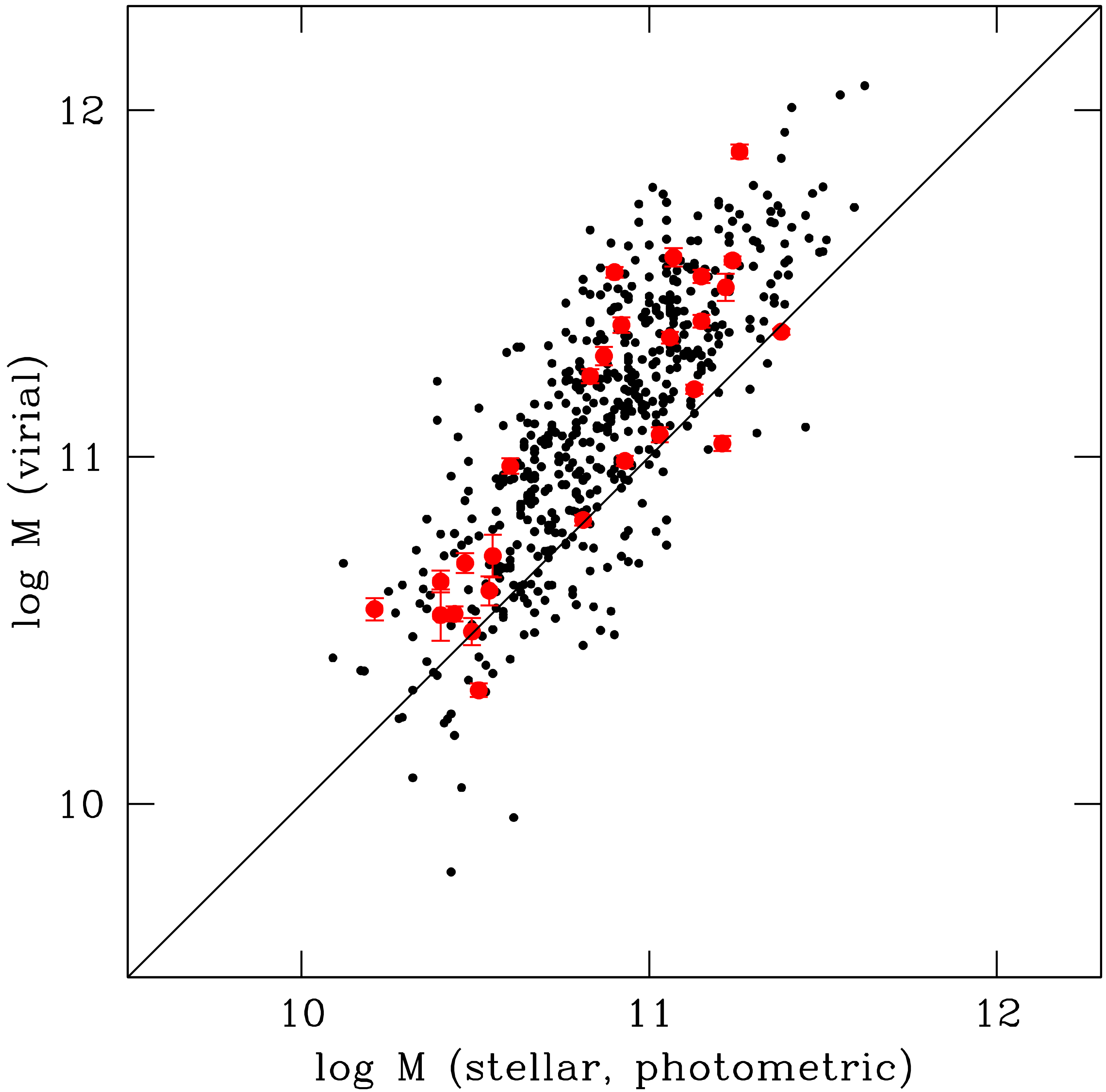
- MGE stellar mass
- NFW dark matter
- Inclination
- Anisotropy

$M = 2.7 \times 10^{11}$ Msol

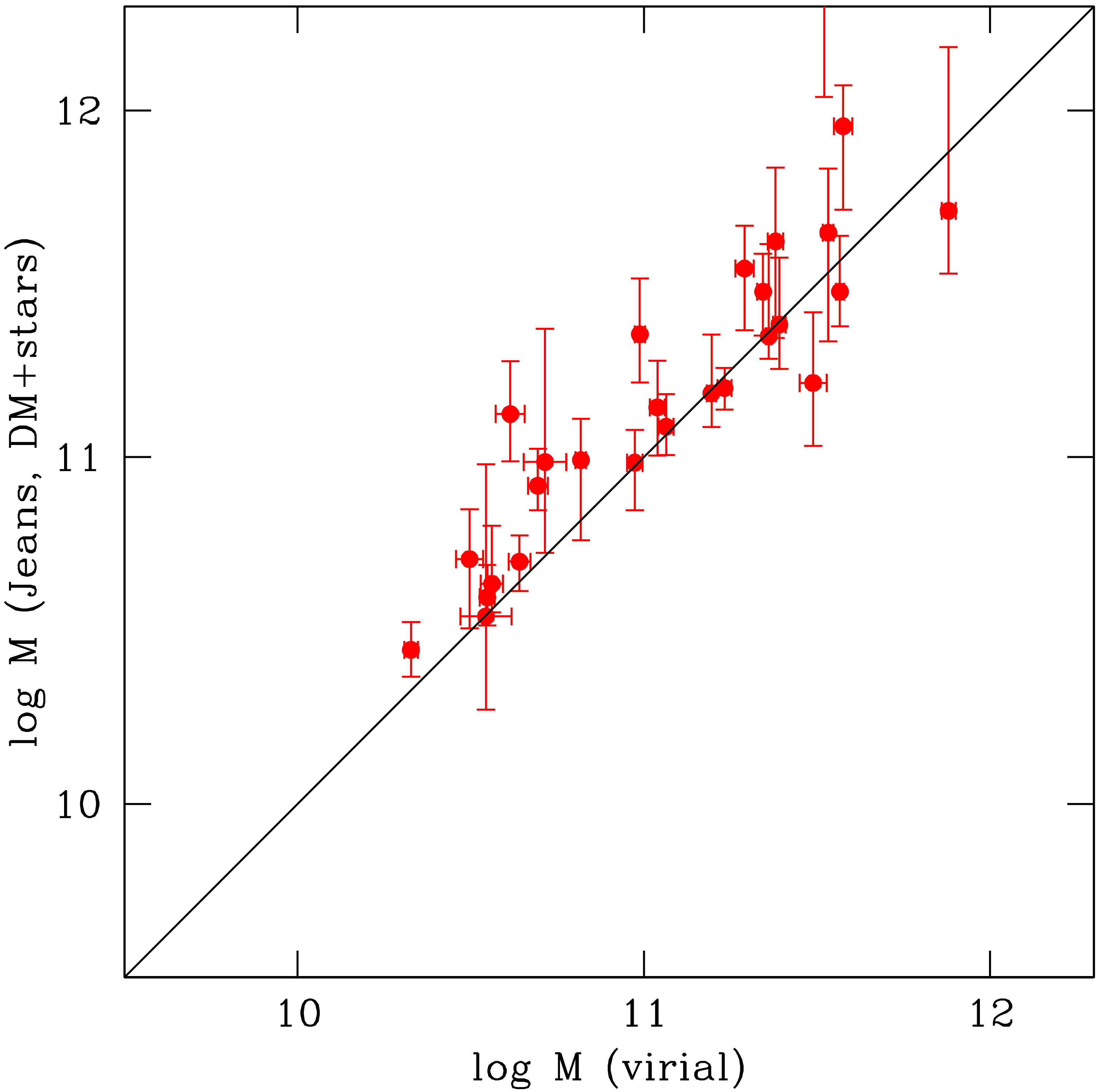
$(V_5 / \sigma_0)_{intr} = 1.3$



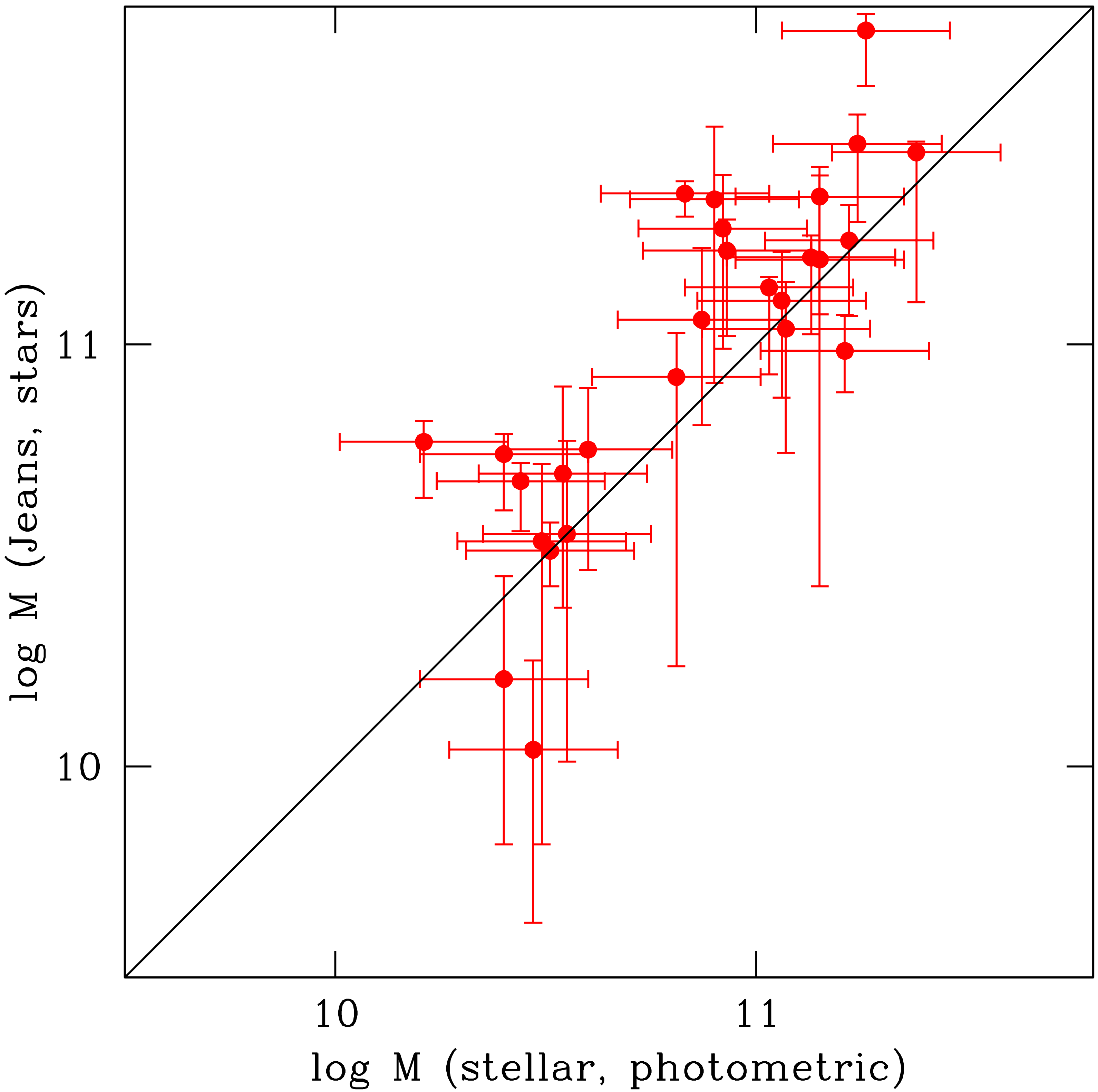
Virial mass — k(n) $R_{eff}\,\sigma^2/G$ — vs. stellar mass



Jeans mass vs. virial mass



Jeans mass (stellar component) vs. stellar mass



Takeaway points

- LEGA-C aims at characterizing the ages/kinematics of stars in z~1 galaxies
- Integrated gas velocity dispersions are not always a proxy for galaxy mass
- Passive galaxies at z~1 rotate faster than their present-day descendants
- We are beginning to dissect the radial distribution of stellar and dark matter