Dynamical masses from stellar and gas kinematics

The LEGA-C survey at z~1

(The Large Early Galaxy Astrophysics Census)

Foto credit: Iztok Bončina/ESO

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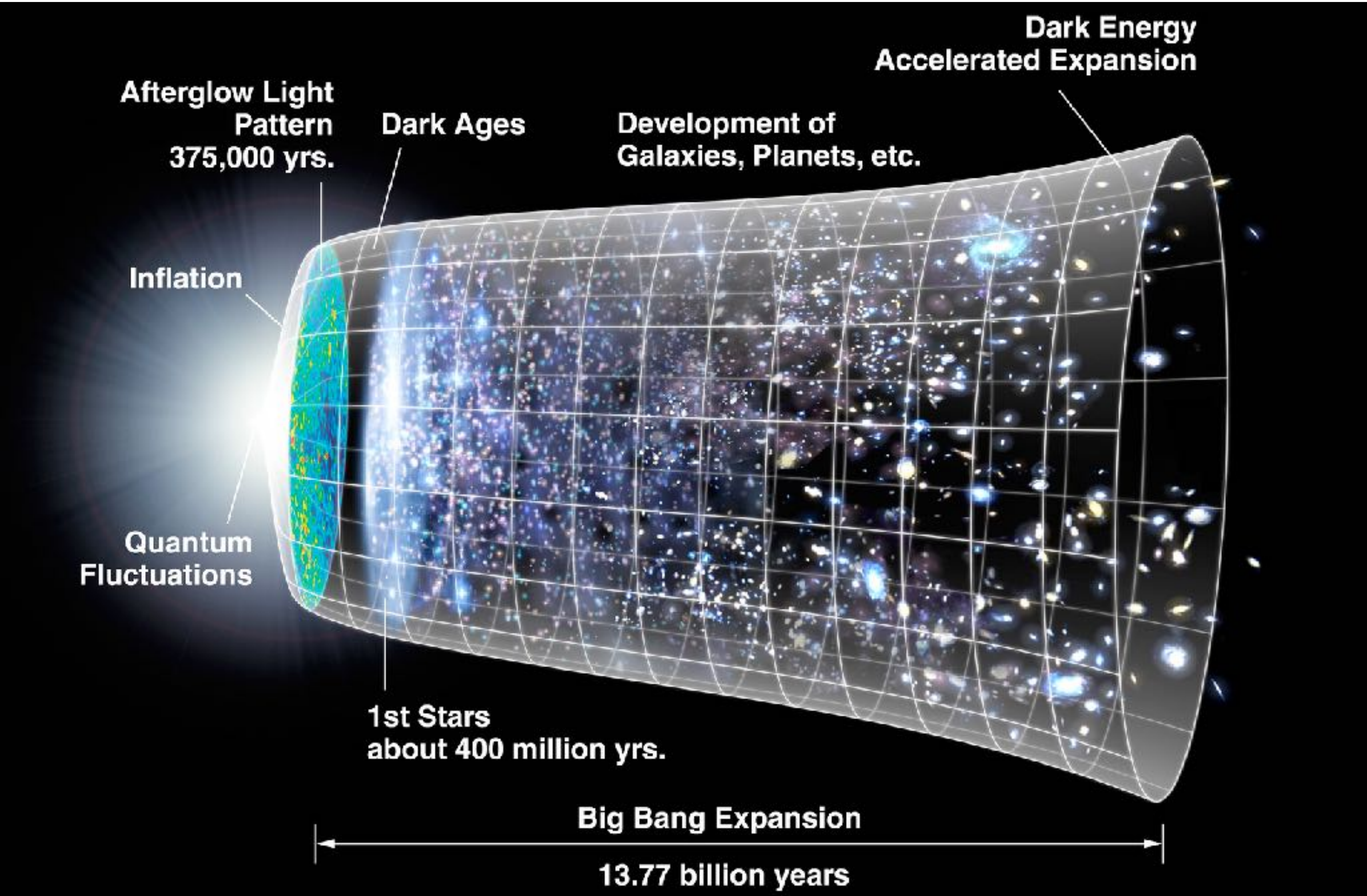
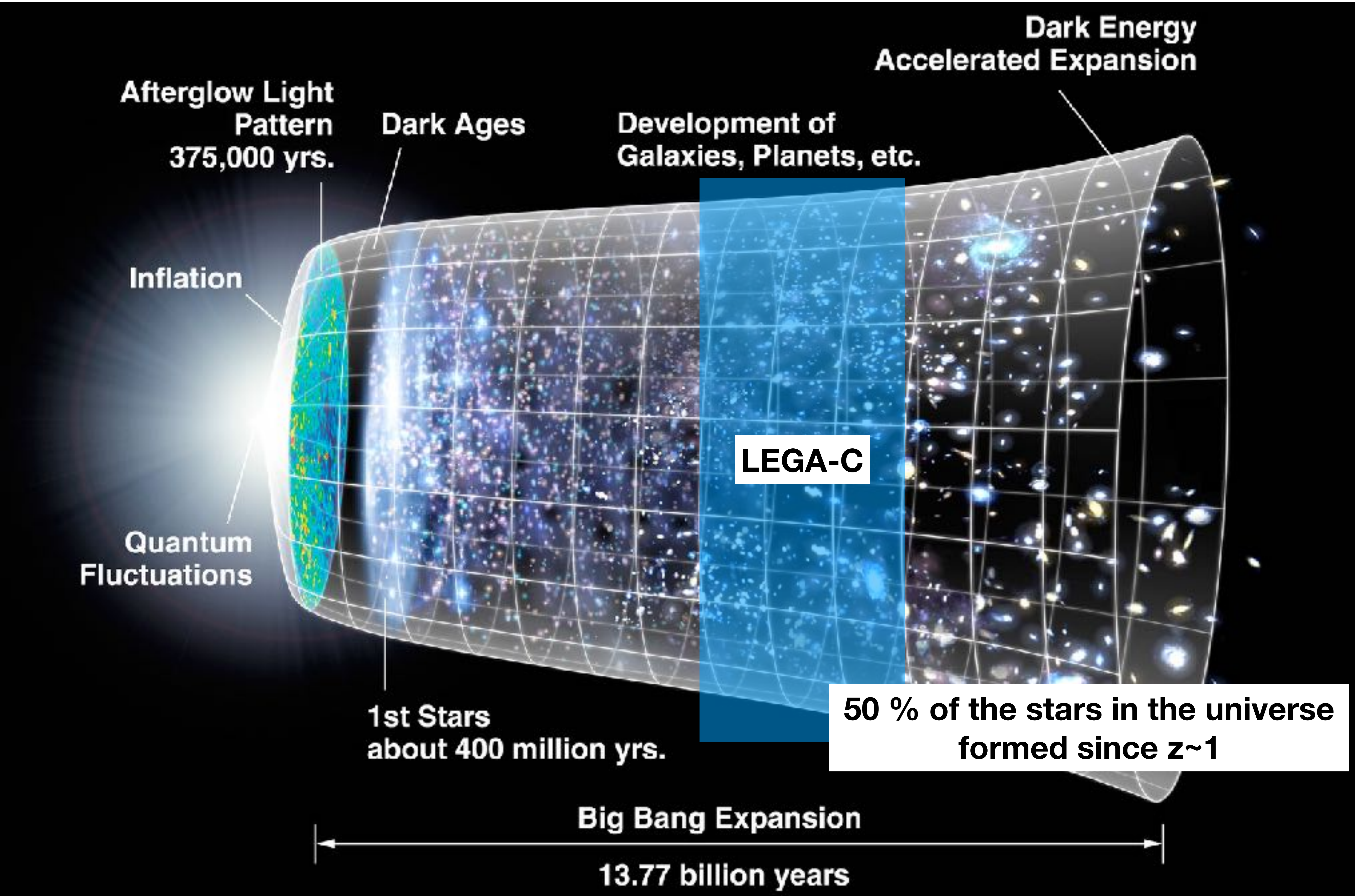
Ghent University, Belgium

20th Meeting of the FNRS Contact Group Astronomie & Astrophysique
June 14th, 2019


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years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50 % of the stars in the universe
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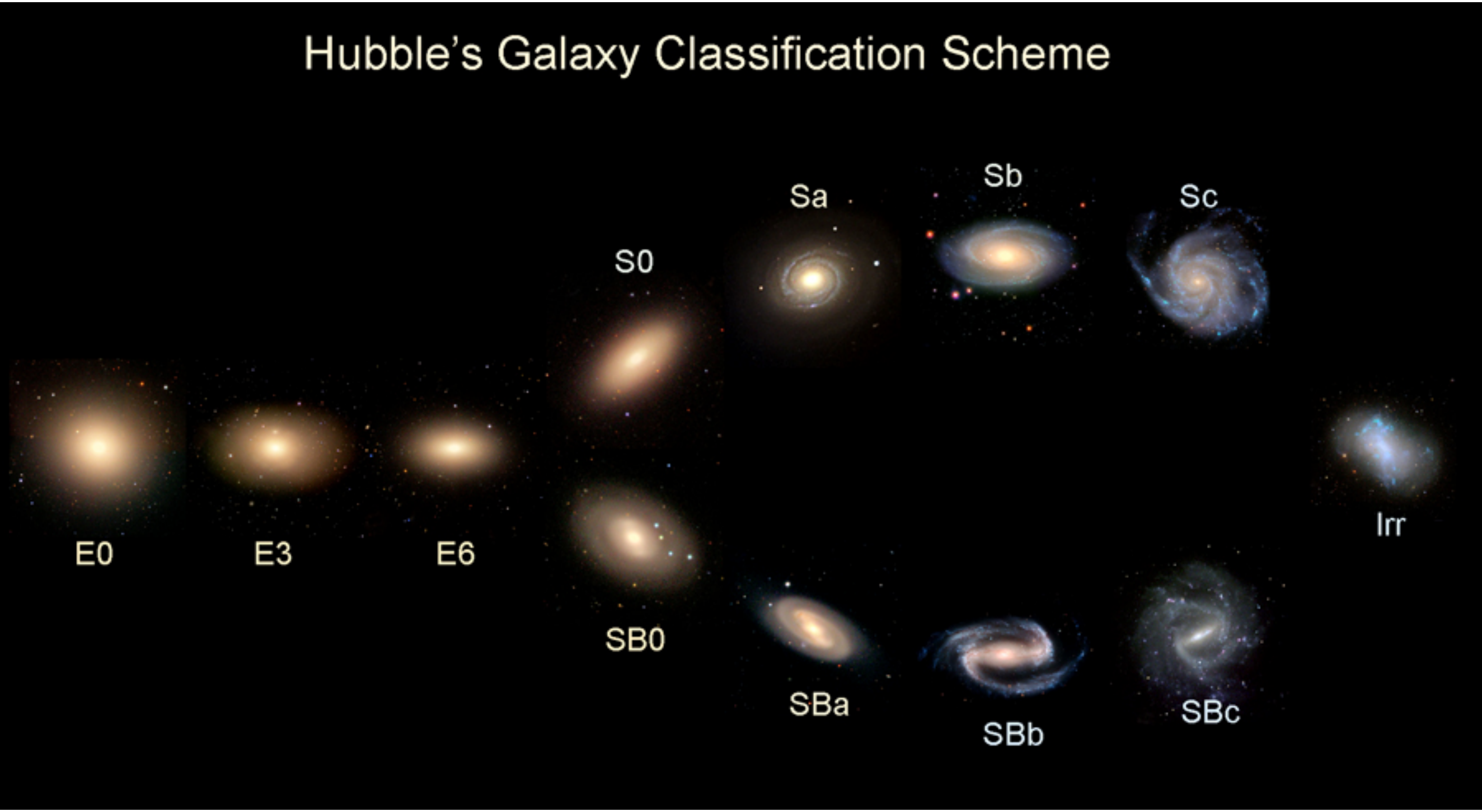
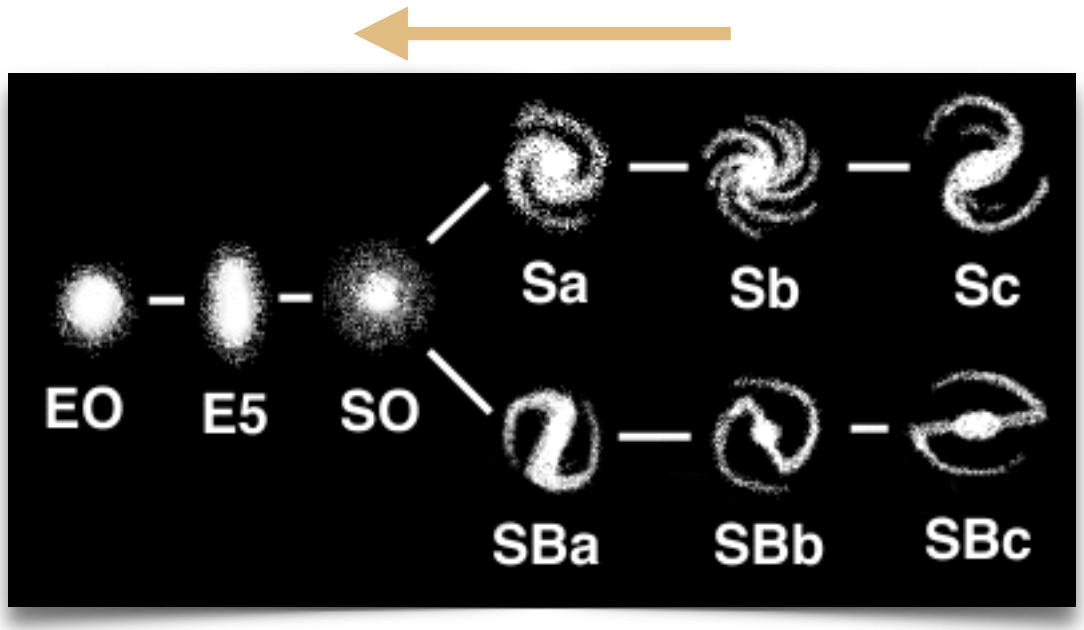


Galaxies at z~1 had different stellar populations and dynamics

50 % of the stars in the universe formed since z~1

Stellar dynamics & stellar populations at large look-back time



50 % of the stars in the universe formed since z~1

Galaxies at z~1 had different stellar populations and dynamics

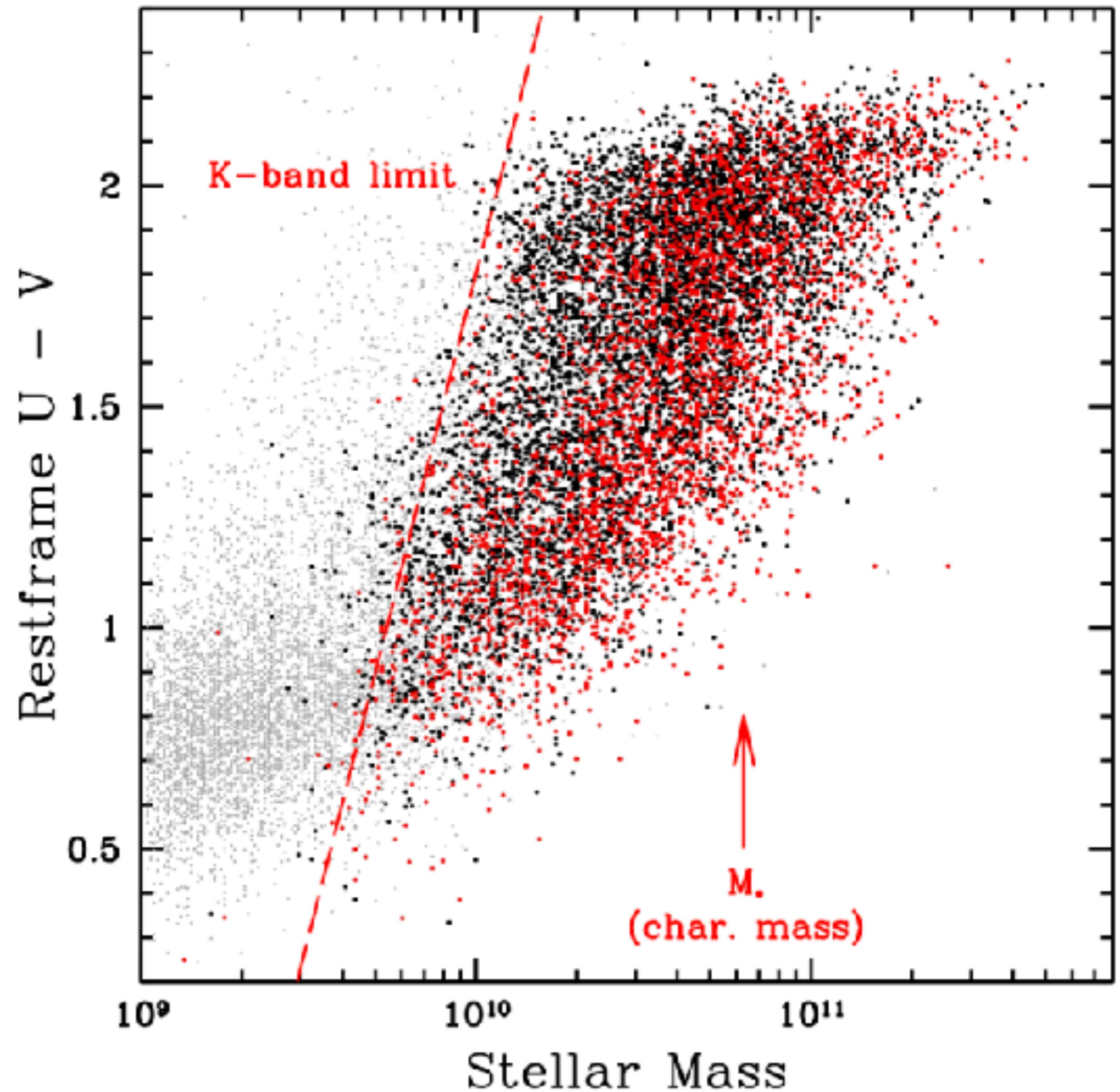
- **128 night** allocation on VLT
- observations: **2014-18**
- **>3000** galaxies at **0.6 < z < 1.0**
- **1.7 sq. deg.** in COSMOS/UltraVISTA
- **20h** integrations; **S/N=20/Å** at **R~4500**
- **DR2** (Straatman+**2018**)

van der Wel+16, Barisic+17, Wu+18ab, Chauke+18, Spilker+18, Bezanson+18ab, Straatman+18 erc

LEGA-C

A spectroscopic galaxy survey with VLT/VIMOS

Stellar dynamics & stellar populations at large look-back time

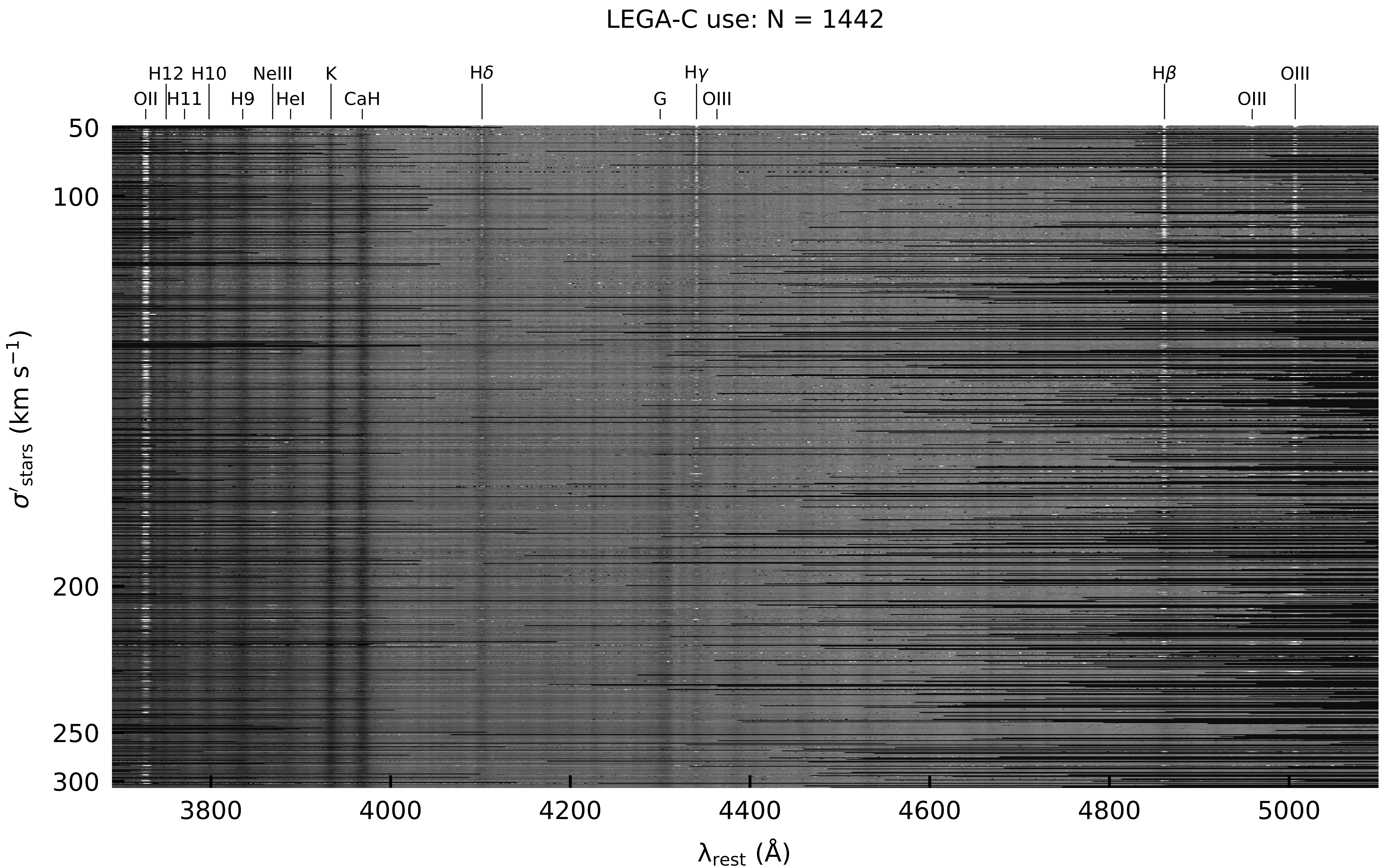


- **128 night** alloc… …S/UltraVISTA
- observations: 2… …20/Å at R~4500
- >3000 galaxies …)

van der Wel+16, Barisic+17, Wu+18ab, Chauke+18, Spilker+18, Bezanson+18ab, Straatman+18

LEGA-C: a wealth of spectral features at 0.6 < z < 1.0

High S/N continuum: stellar populations and stellar dynamics at large look back time



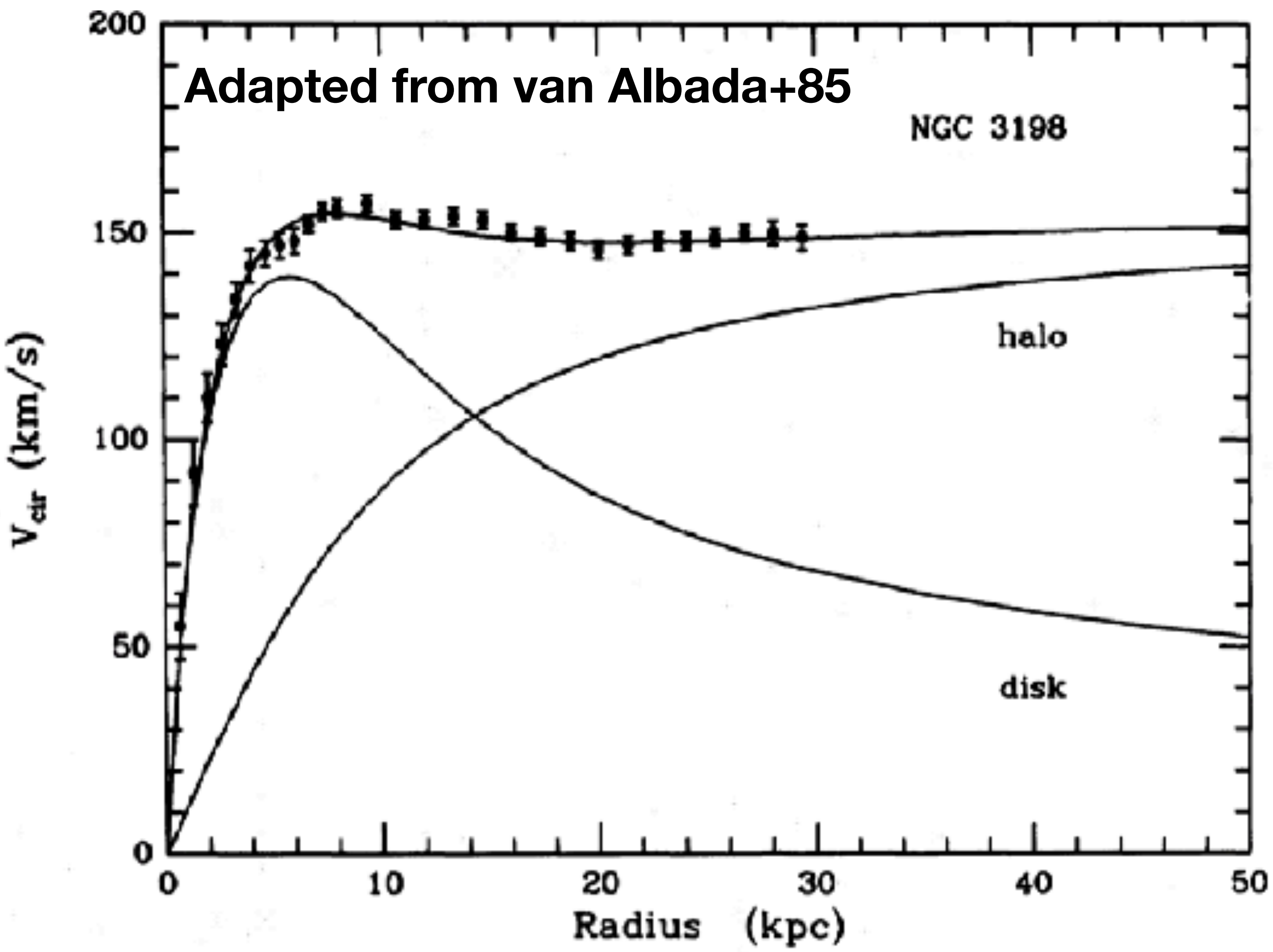
Fundamental property of galaxies: gravitational potential well (or dynamical mass)

Measured indirectly from dynamics of stars and gas

Rotation (v) and intrinsic dispersion (σ) → kinetic energy → dynamical mass

Equilibrium assumption: kinetic energy = potential, gravitational energy

HI 21 cm line



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Stars on collisionless orbits are reliable tracer

In massive galaxies stars dominate central potential well

high continuum S/N needed

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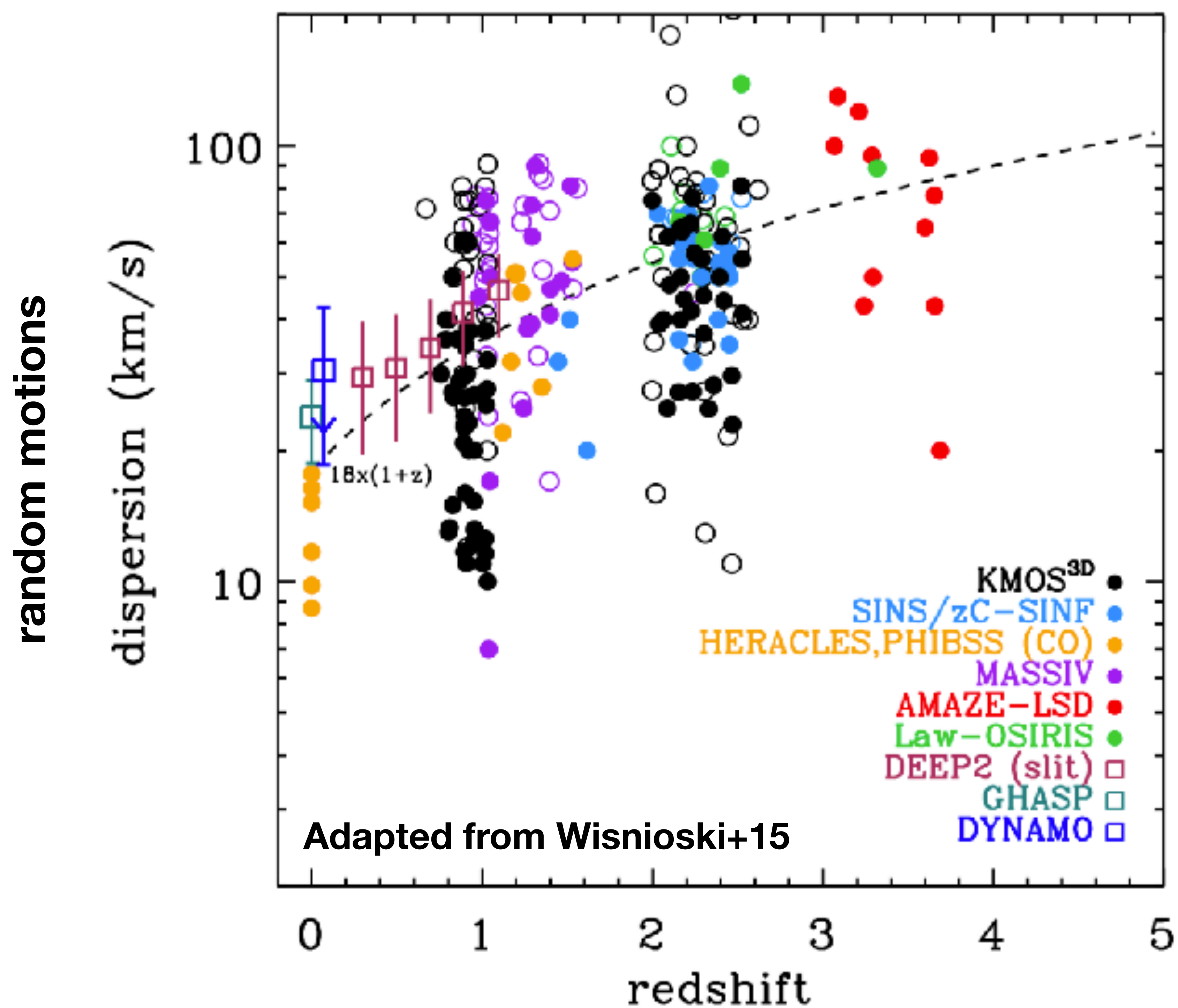
Stars	Gas
Stars on collisionless orbits are reliable tracer	Gas dynamics may also trace disk instabilities / disturbances due to accretion, mergers, feedback…
In massive galaxies stars dominate central potential well	Gas is not collisionless
high continuum S/N needed	Bright emission lines useful for high redshift observations

Evidence for increased amount of random motions / pressure support in high redshift star-forming galaxies



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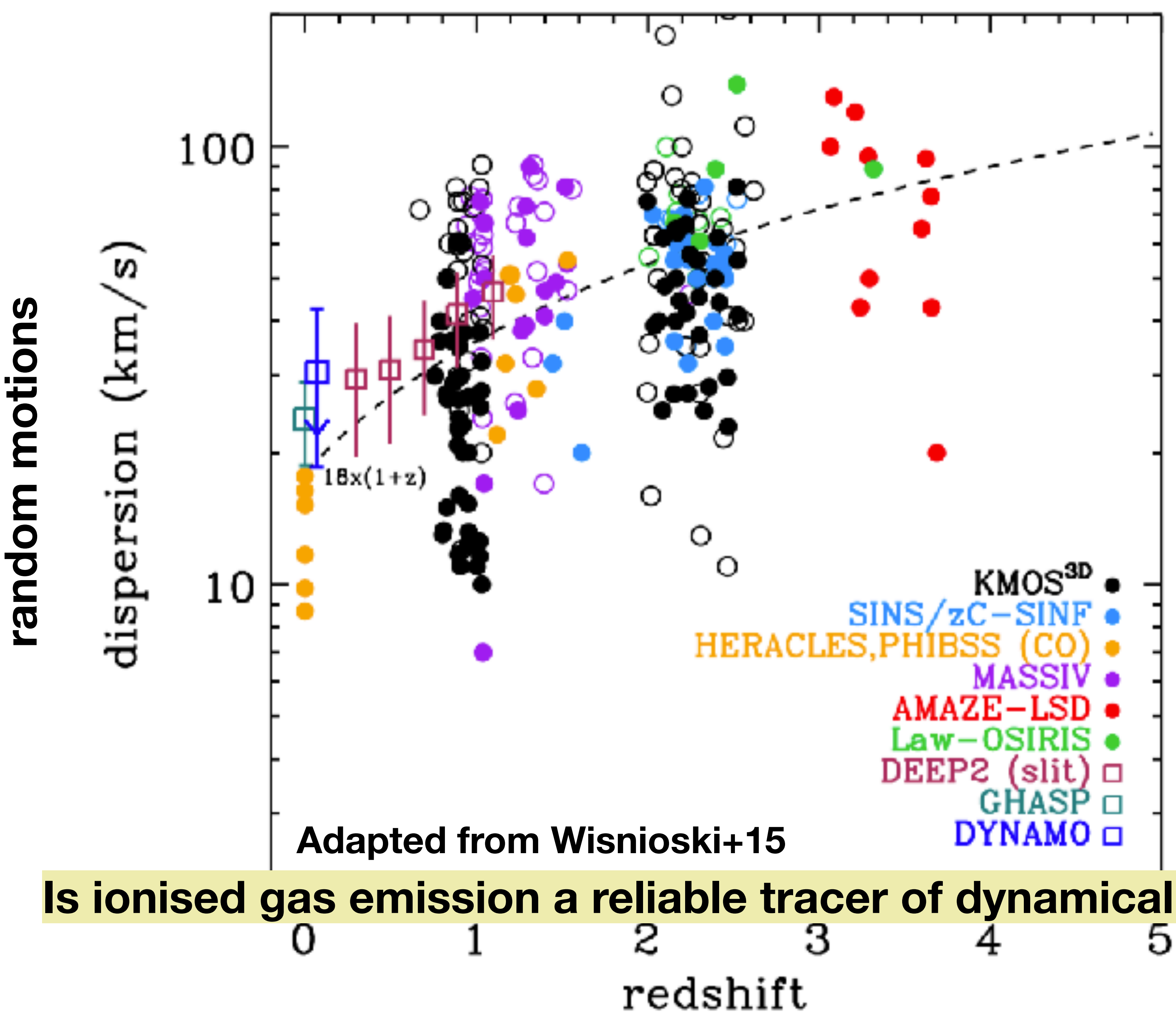
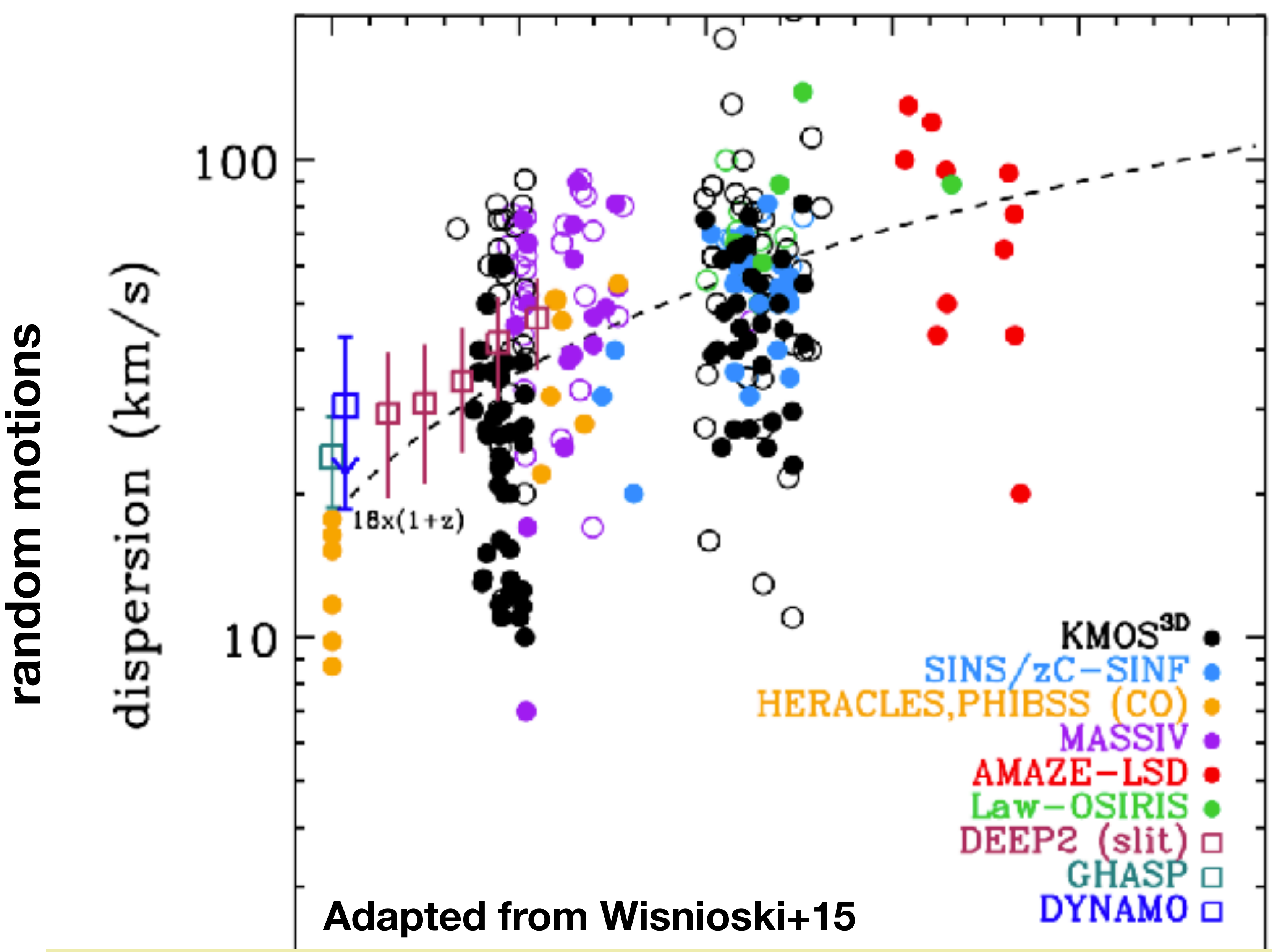


Is ionised gas emission a reliable tracer of dynamical mass?

LEGA-C:
stellar AND gas kinematics at high redshift

Evidence for increased amount of random motions / pressure support in high redshift star-forming galaxies



Is ionised gas emission a reliable tracer of dynamical mass?

If yes: useful for future (emission line) observations! e.g., JWST?

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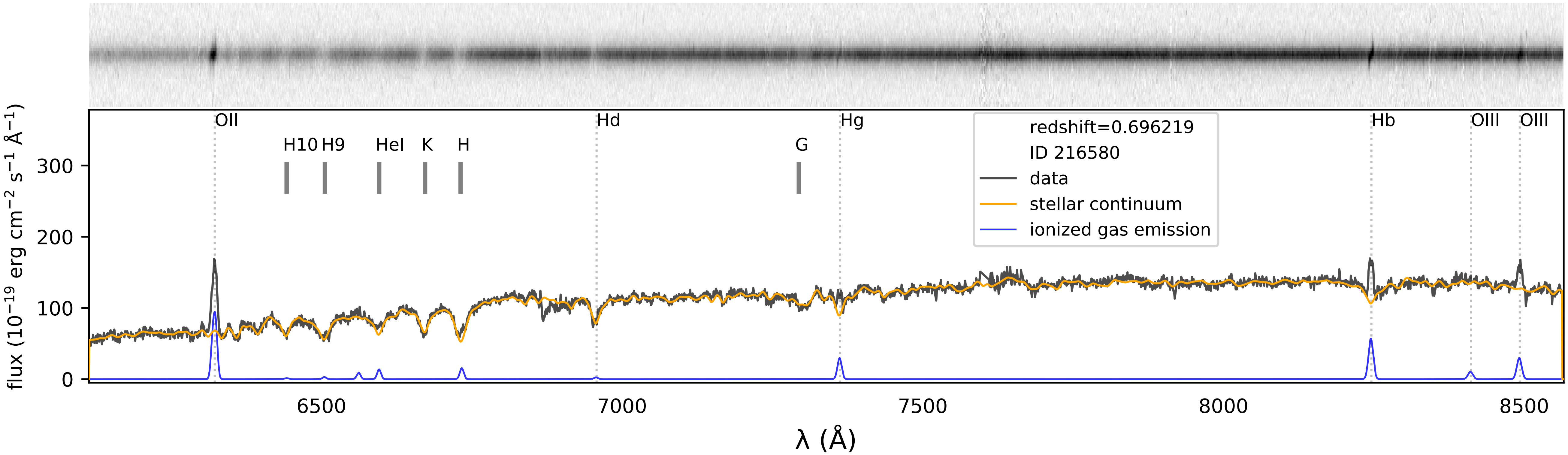

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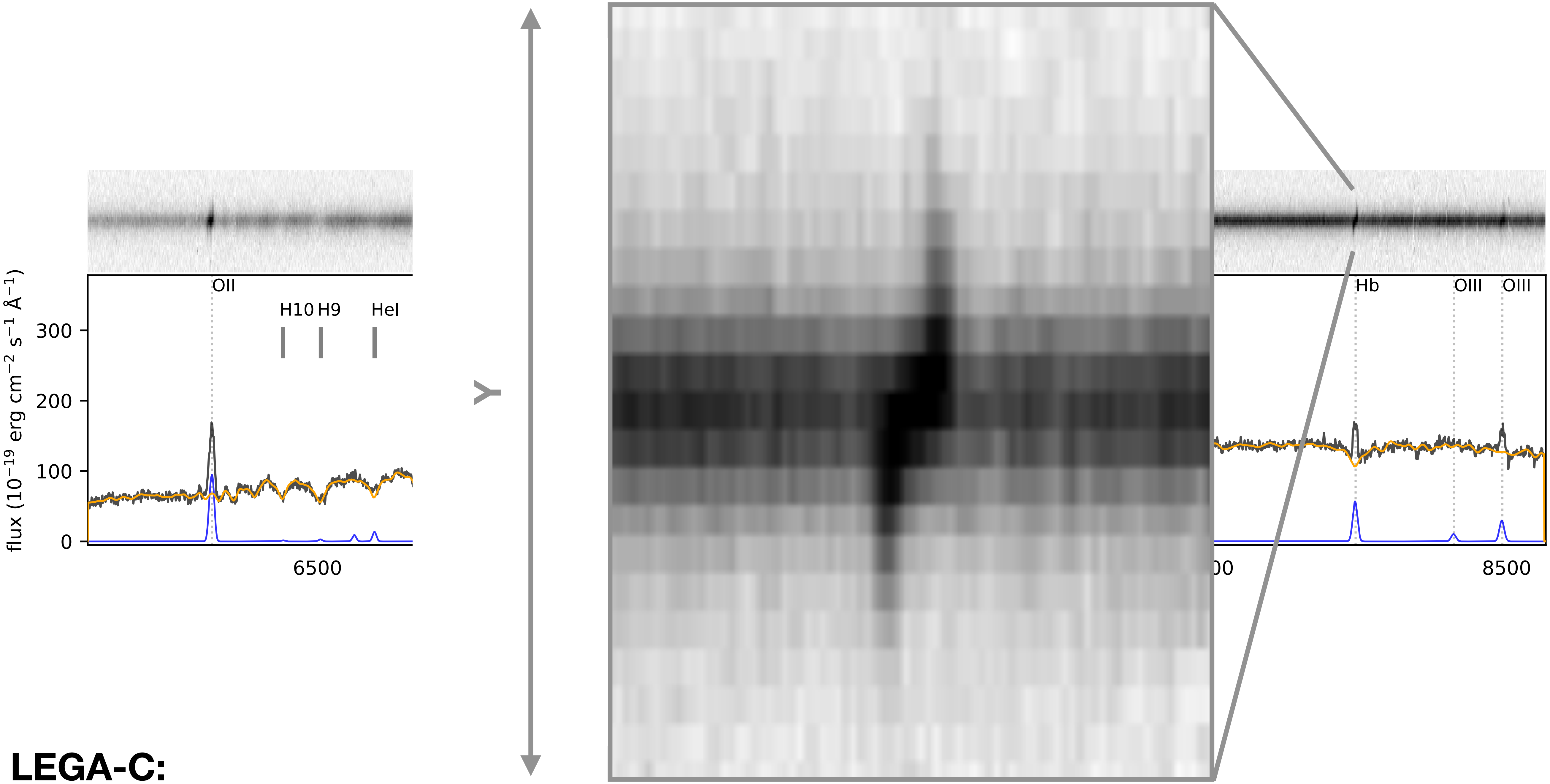

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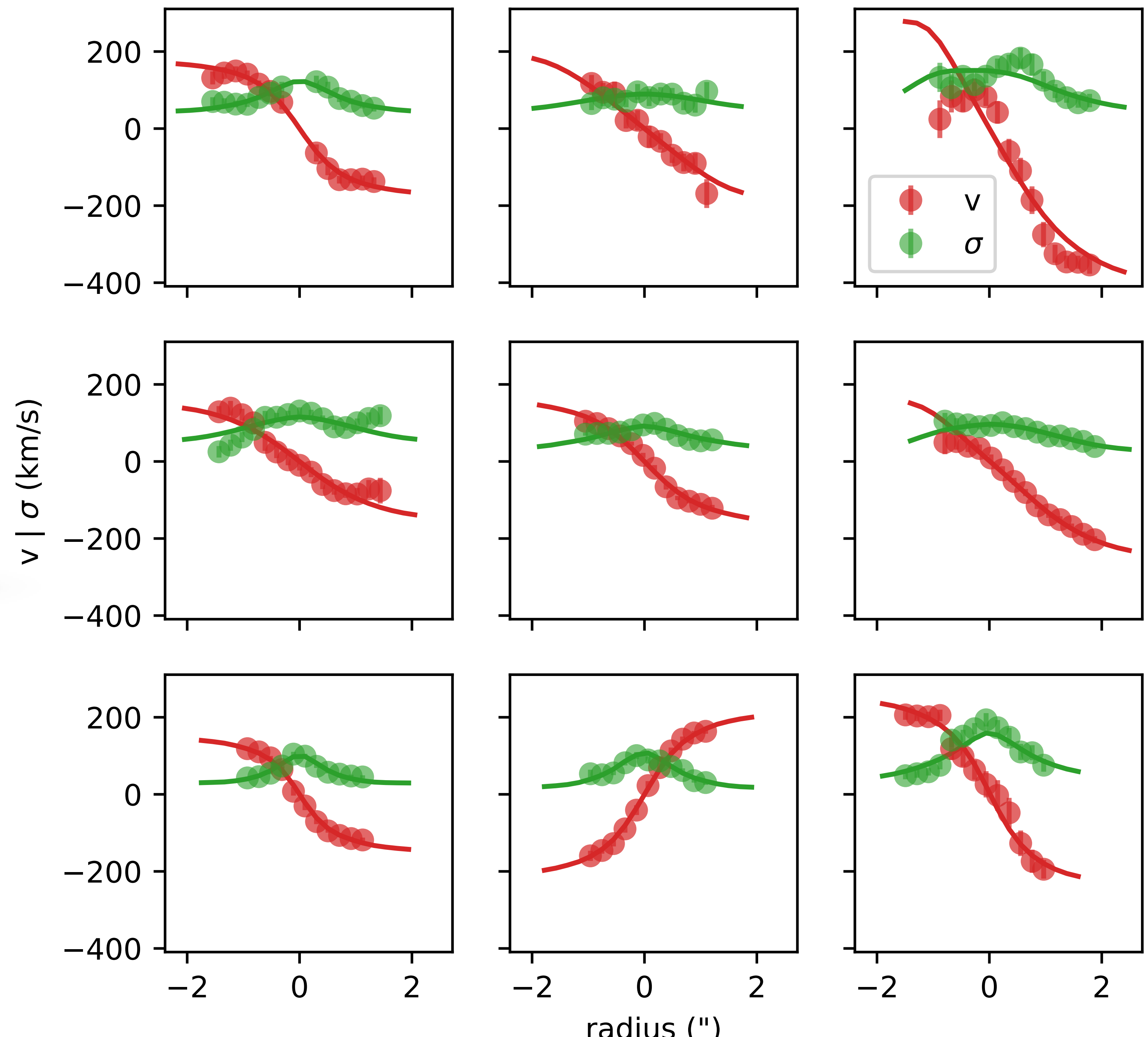
Rotation (v) and intrinsic dispersion (σ) → circular velocity → dynamical mass

Fitting n=1 disk models to <u>gas</u> rotation curves

Straatman, in preparation
see also Price+16



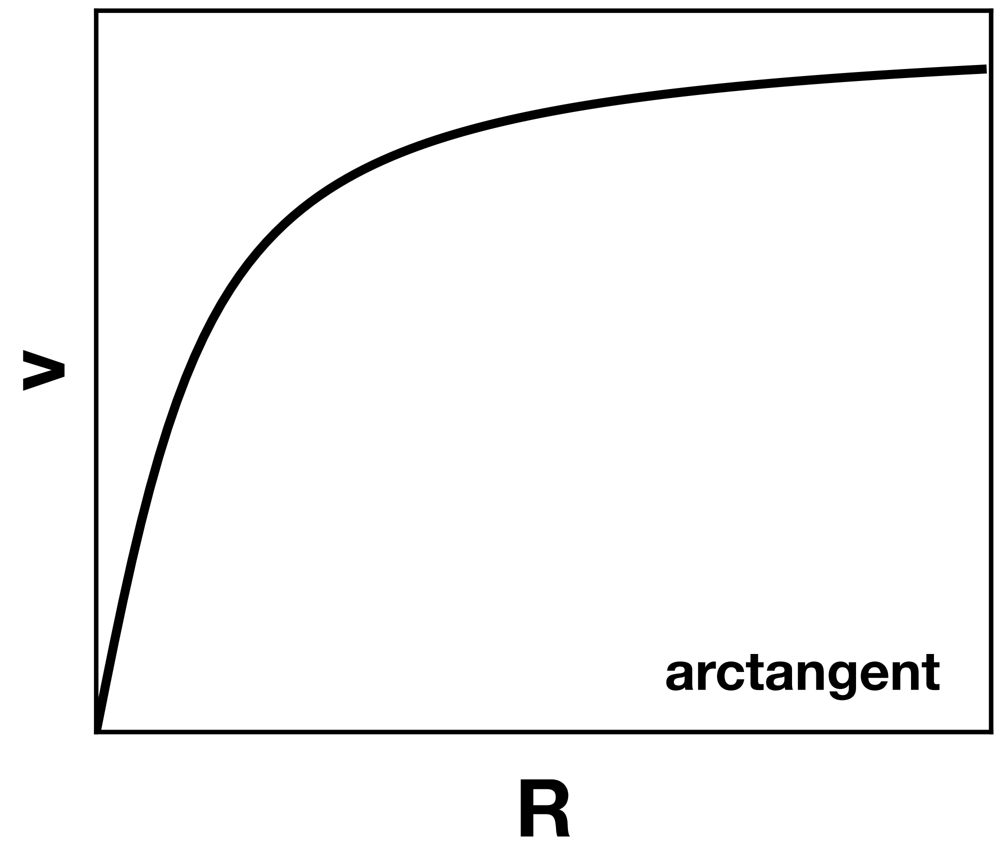
LEGA-C:
stellar AND gas kinematics at high redshift

Fundamental property of galaxies: gravitational potential well (or dynamical mass)

Measured indirectly from dynamics of stars and gas

2. Rotation (v) and intrinsic dispersion (σ) → circular velocity → dynamical mass

Physical properties are parameterised



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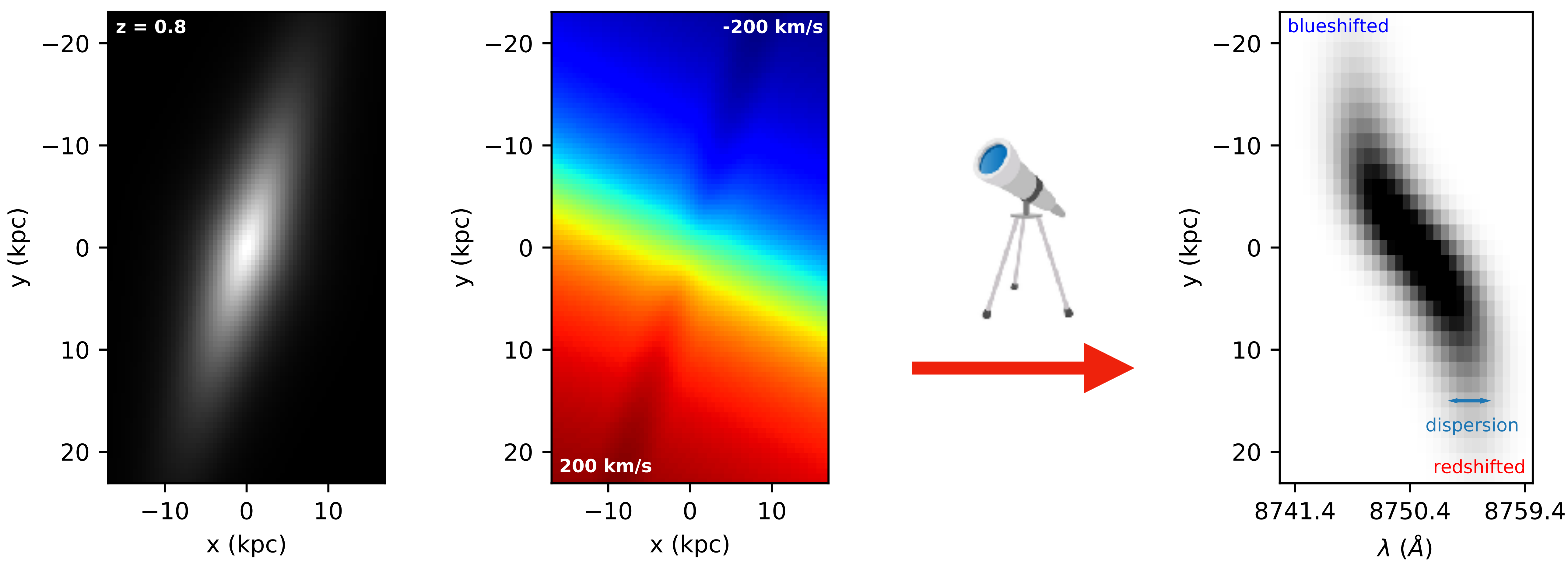
Fitting n=1 disk models to gas rotation curves

Model the gas disk in 3D and simulate light path through VIMOS instrument



LEGA-C first statistical & representative sample at large lookback time (0.6 < z < 1.0)

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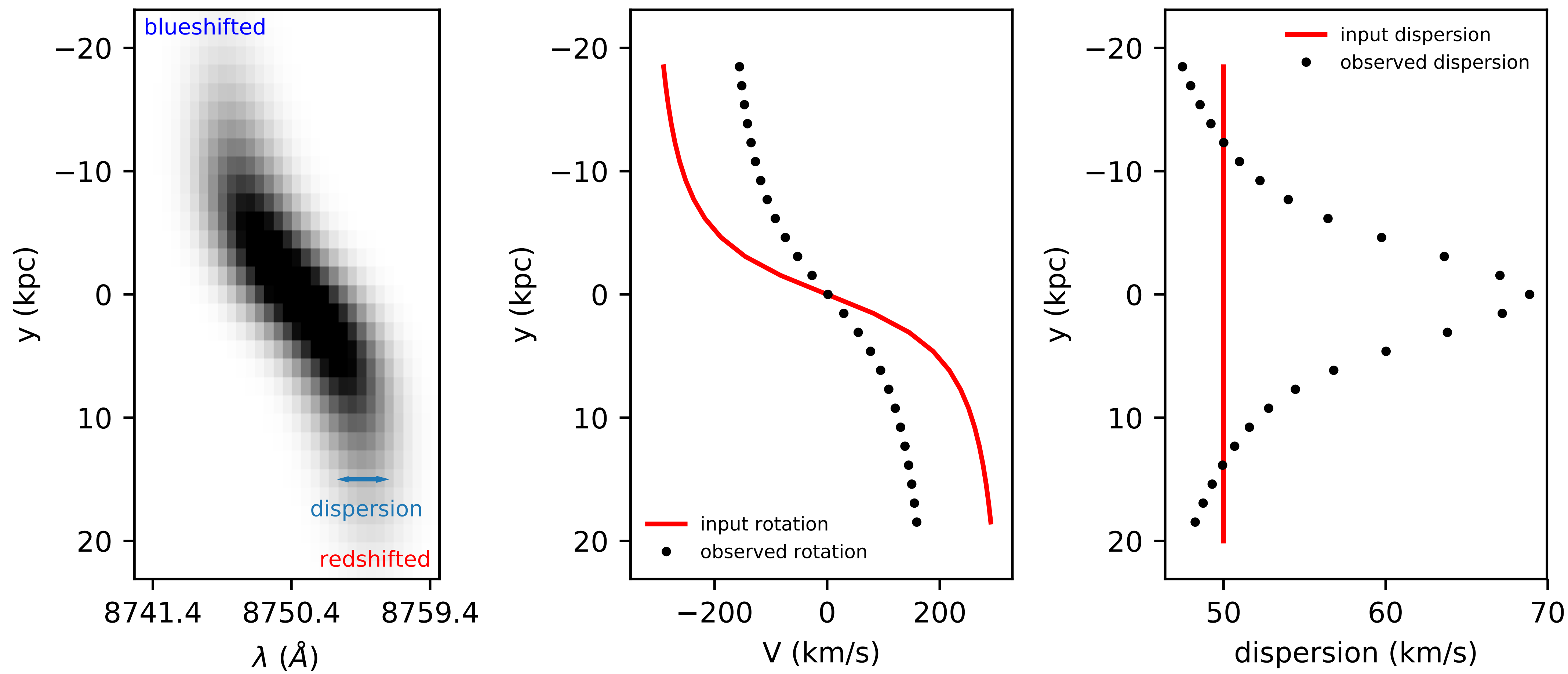

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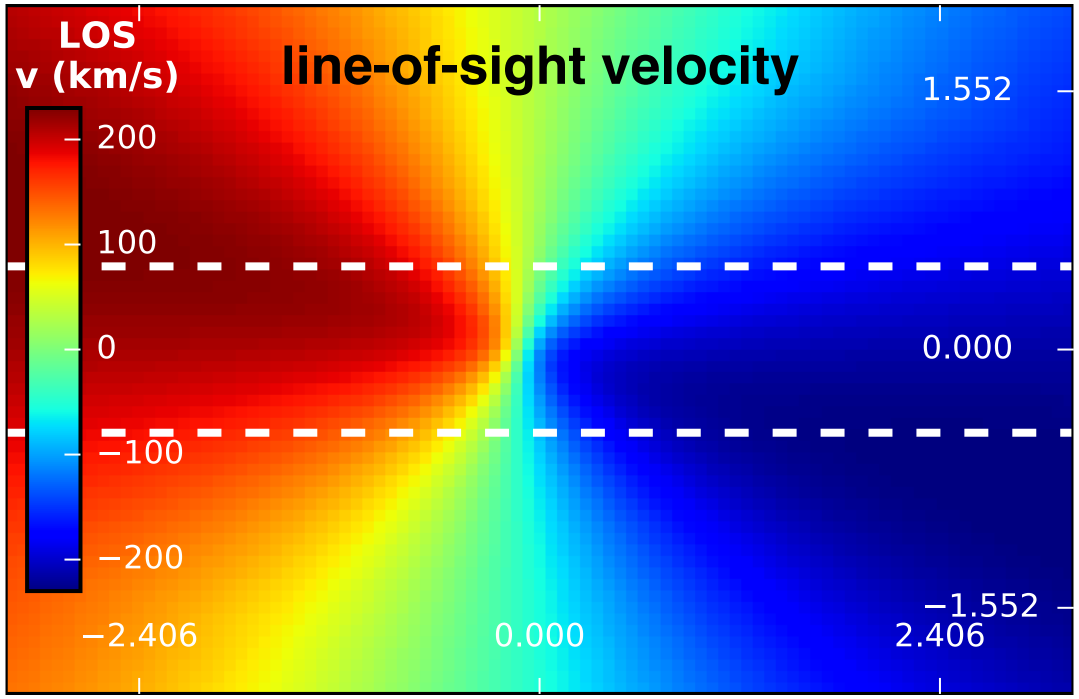
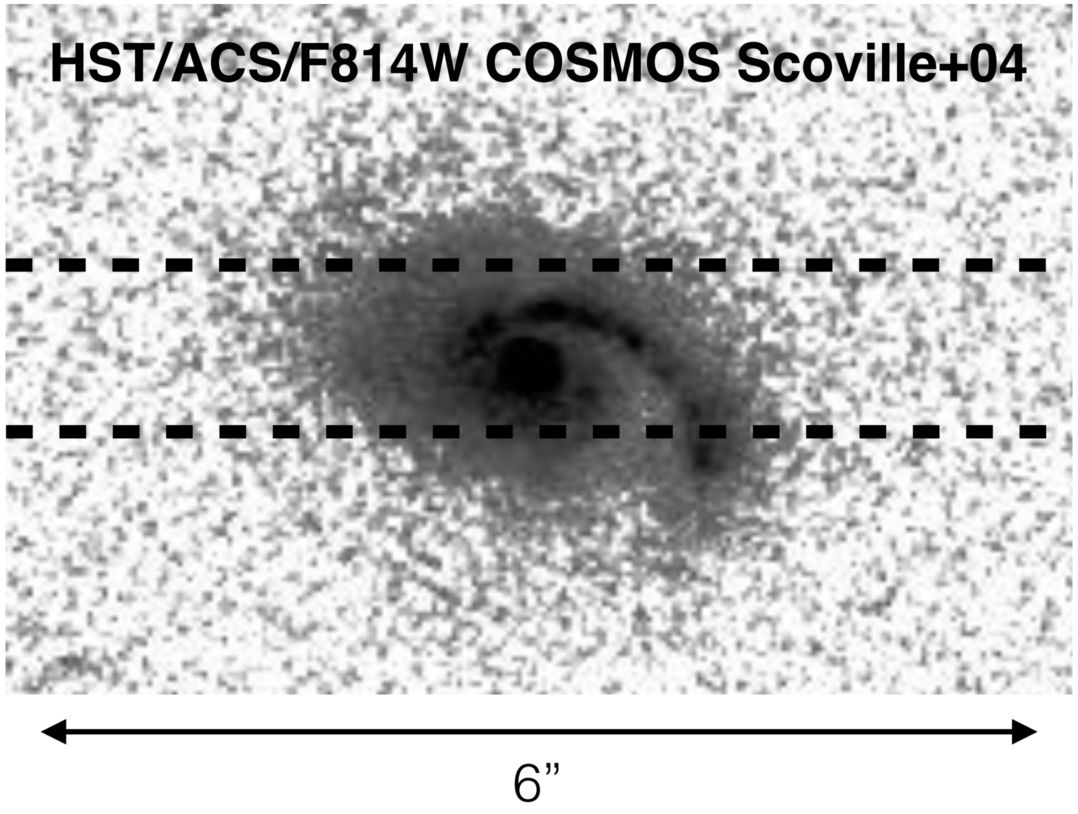
The win of a 3D model is to account for the mixing of light from lower velocity regions.

inclination, position angle & size from I-band data

Fitting n=1 disk models to gas rotation curves

Straatman, in preparation
see also Price+16





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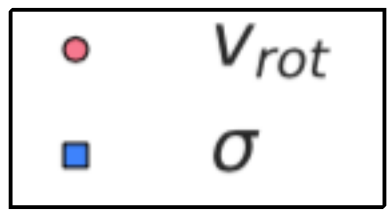
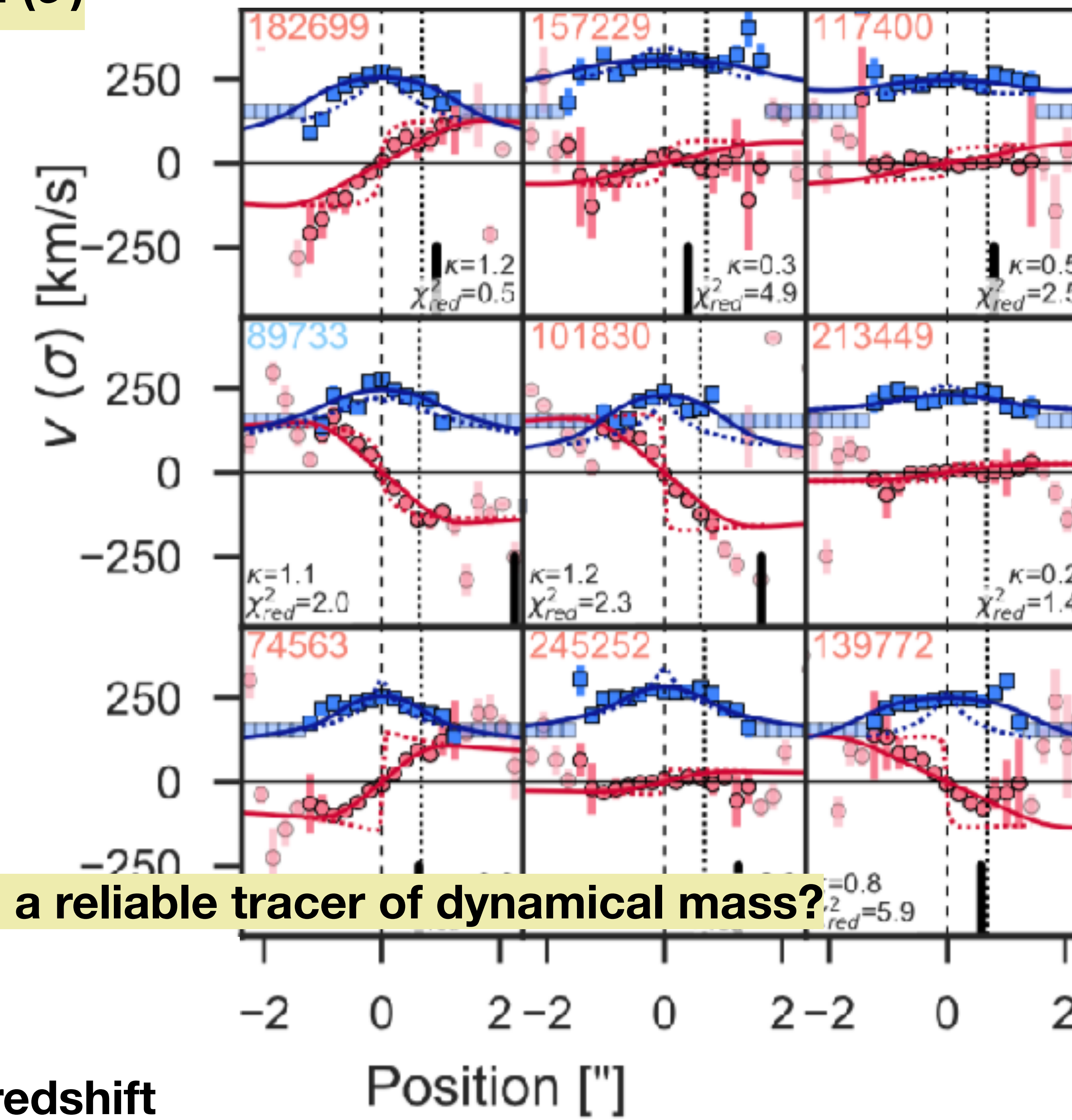


Fitting asymmetric Jeans models to <u>stellar</u> rotation curves

van Houdt, in preparation
see also Cappellari08,
Bezanson+18a



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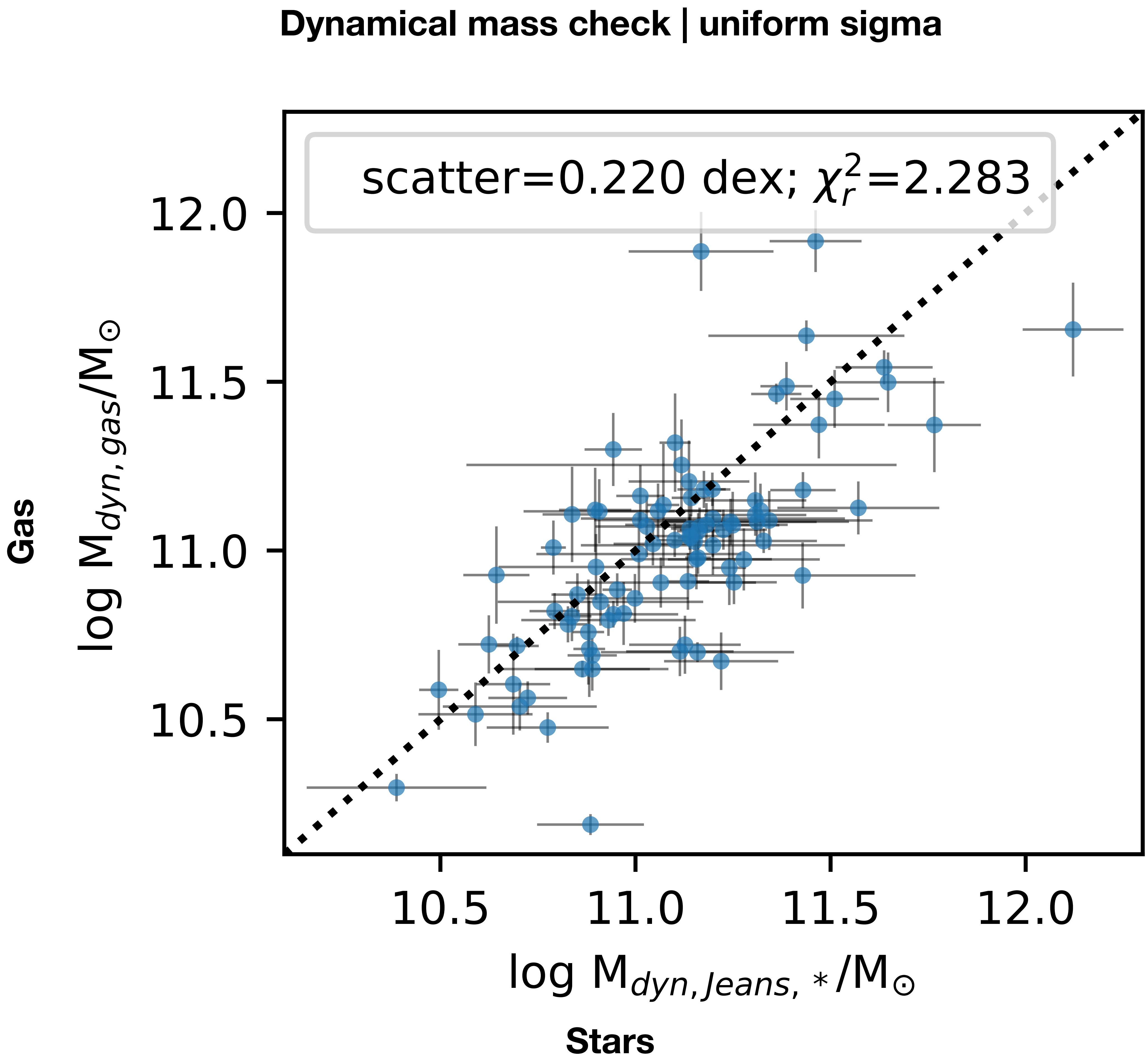
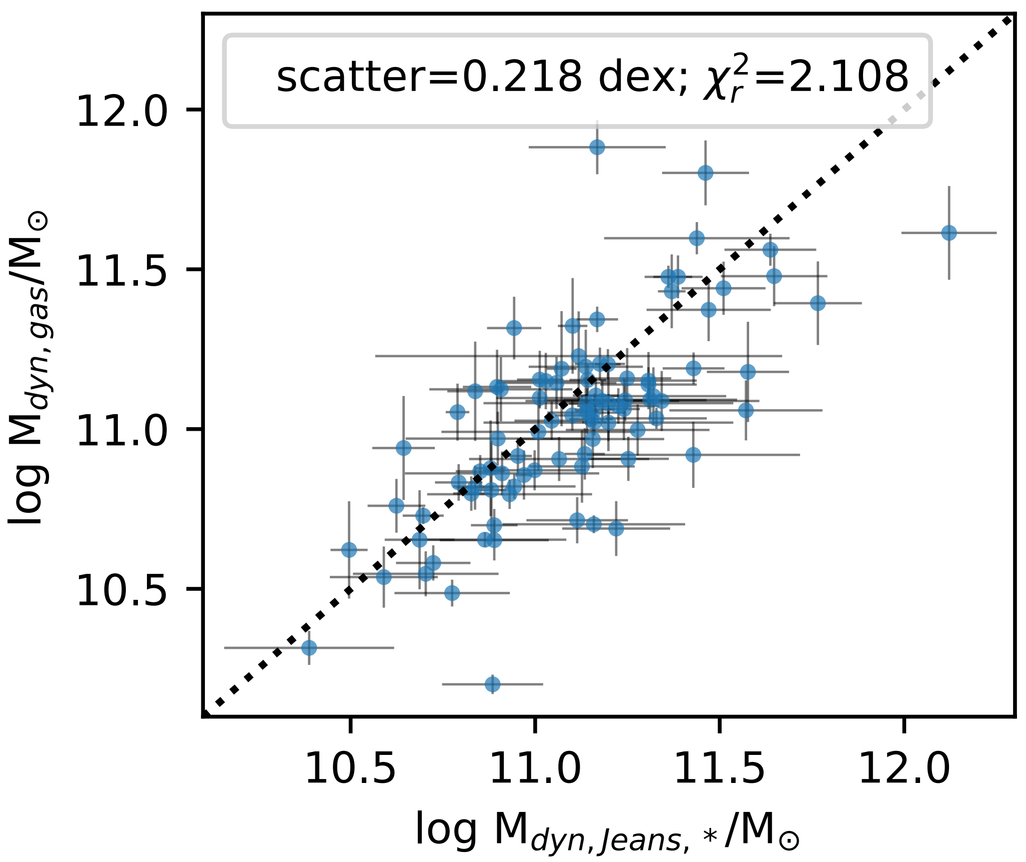

Dynamical mass check | uniform sigma
scatter=0.220 dex; χ_r^2=2.283
12.0
11.5
11.0
10.5
log $M_{dyn,gas}/M_\odot$
Gas
10.5
11.0
11.5
12.0
log $M_{dyn,Jeans,*}/M_\odot$
Stars

Conclusions

- **To first order, gas dynamics traces gravitational potential energy.**



- **Gas dynamics can be used to derive dynamical masses, but with ~0.22 dex uncertainty for individual galaxies.**