Kinematics of star-forming galaxies at z~1-2 with KMOS^{3D}

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MPE, Garching

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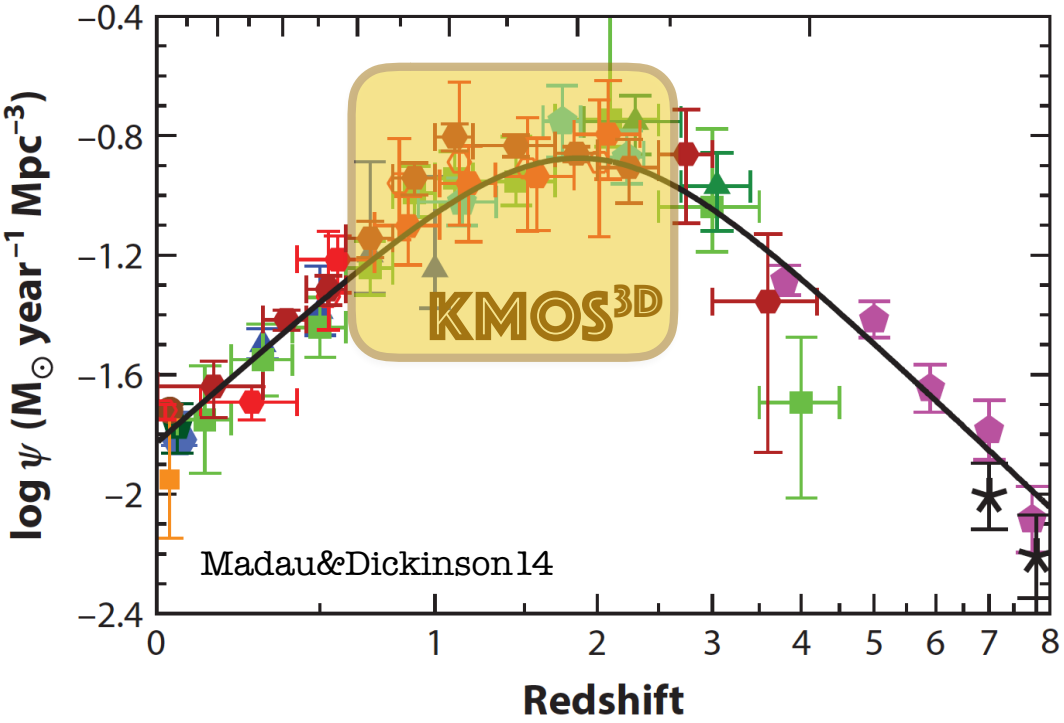
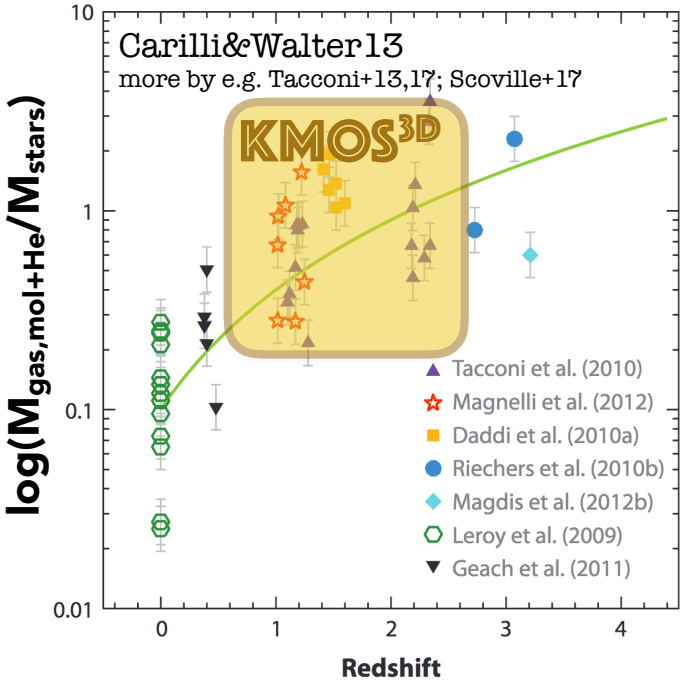
& the KMOS^{3D} team

KICC Workshop 2017

Star formation & disks across cosmic time

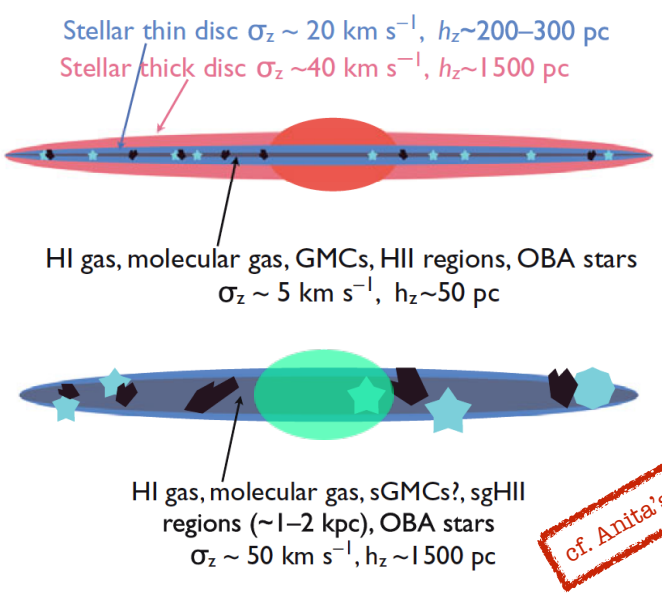


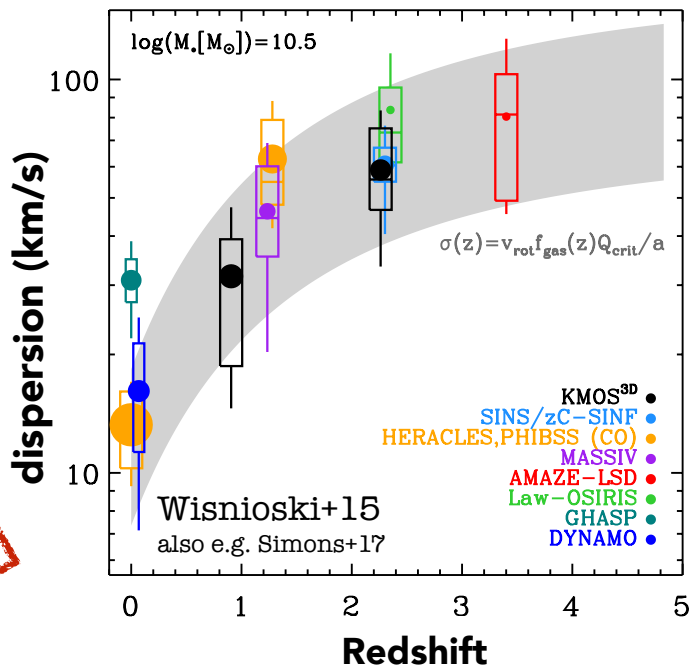


thin+thick, cool, stellar disks at z=0

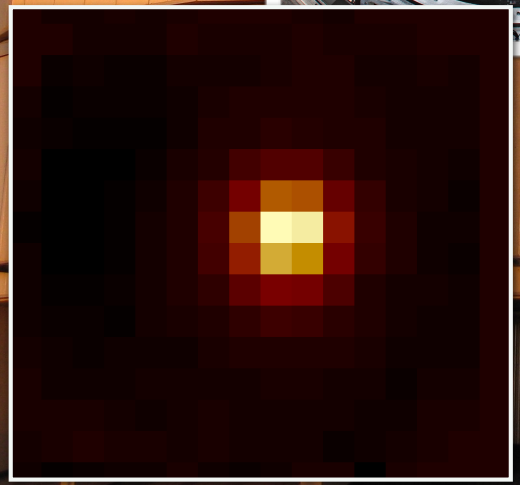
vs.

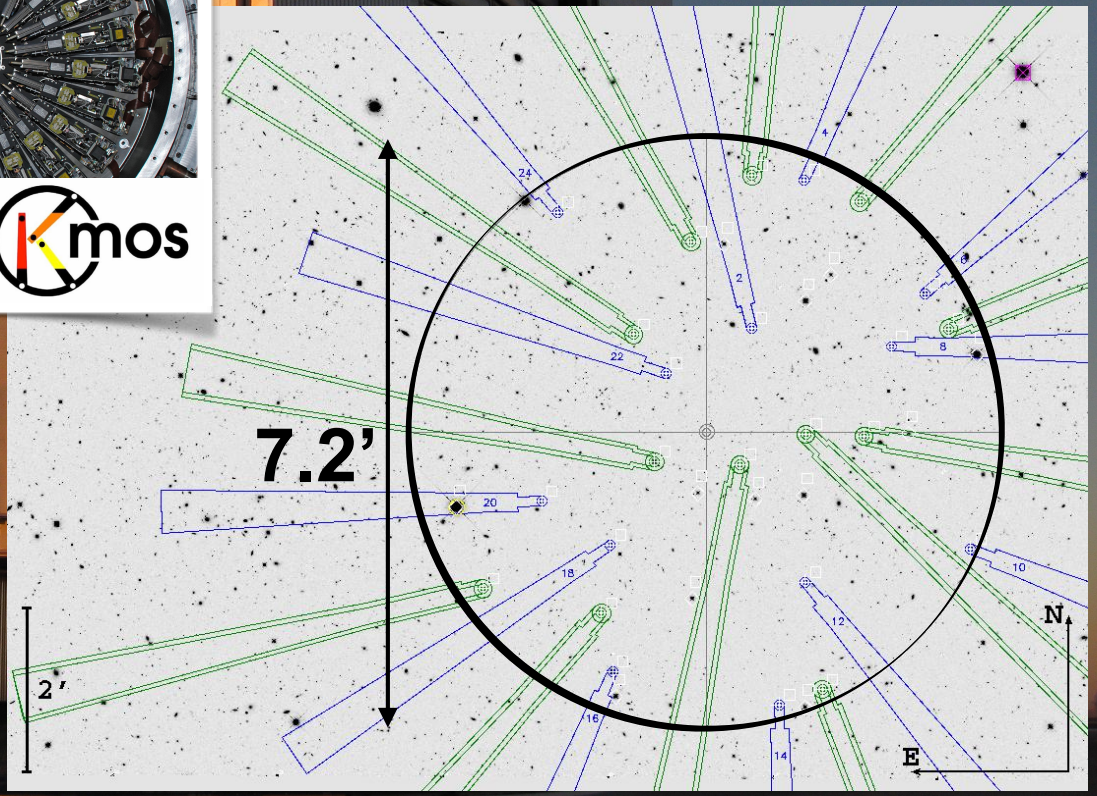
thick, hot, gas-rich disks at z=2



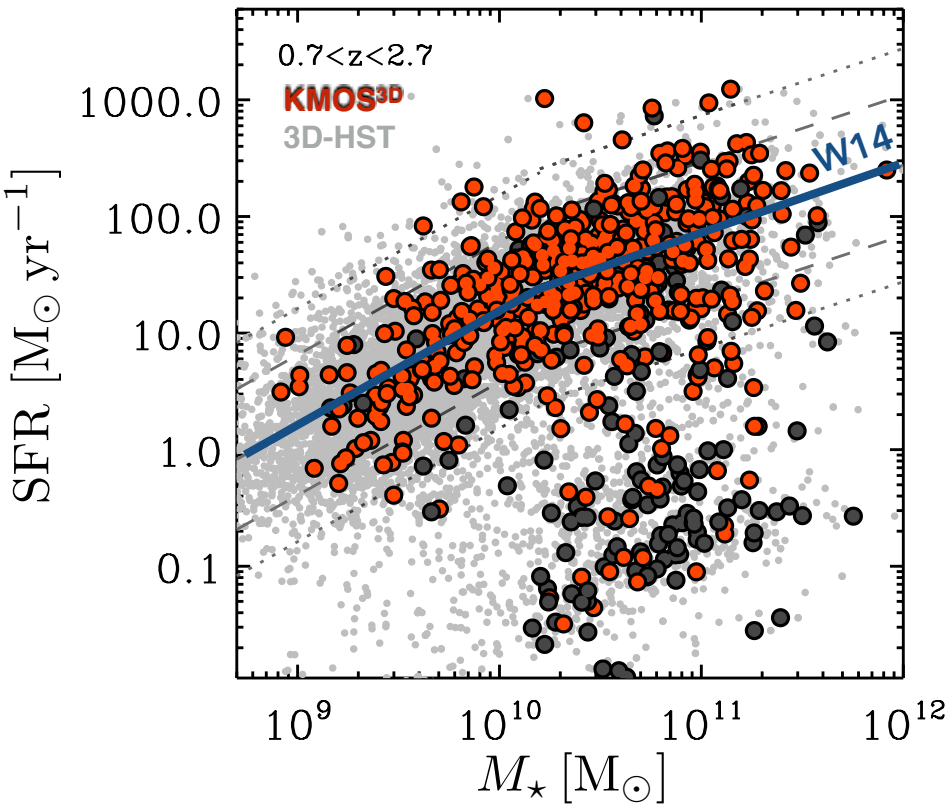


KMOS - the K-band Multi Object Spectrograph at ESO/VLT in Chile





The KMOS^{3D} survey



The KMOS^{3D} Survey

3D-*HST* & CANDELS targets with spec-z or grism-z

see Iva's talk

⇩

Hα emission in *YJ/H/K* filters of KMOS@VLT — 0.6<z<2.7

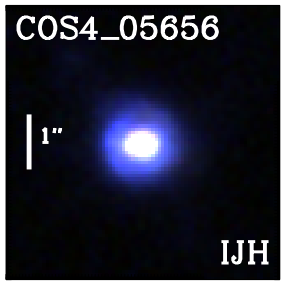
⇩

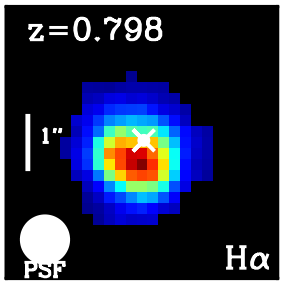
magnitude cut *Ks* < 23

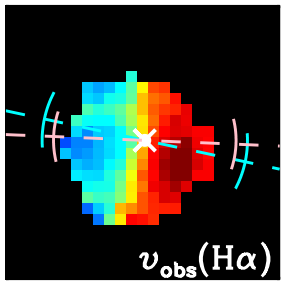
⇩

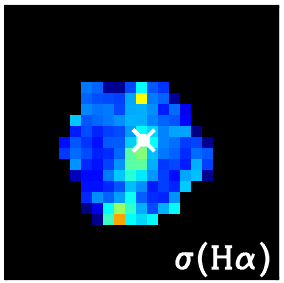
OH night skyline avoidance

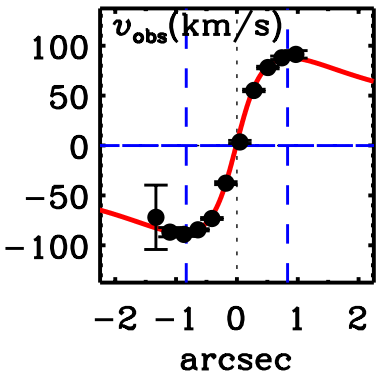
PIs: Natascha Förster Schreiber & Dave Wilman

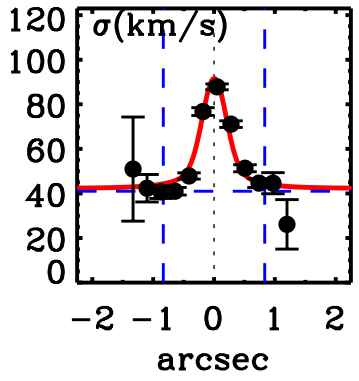






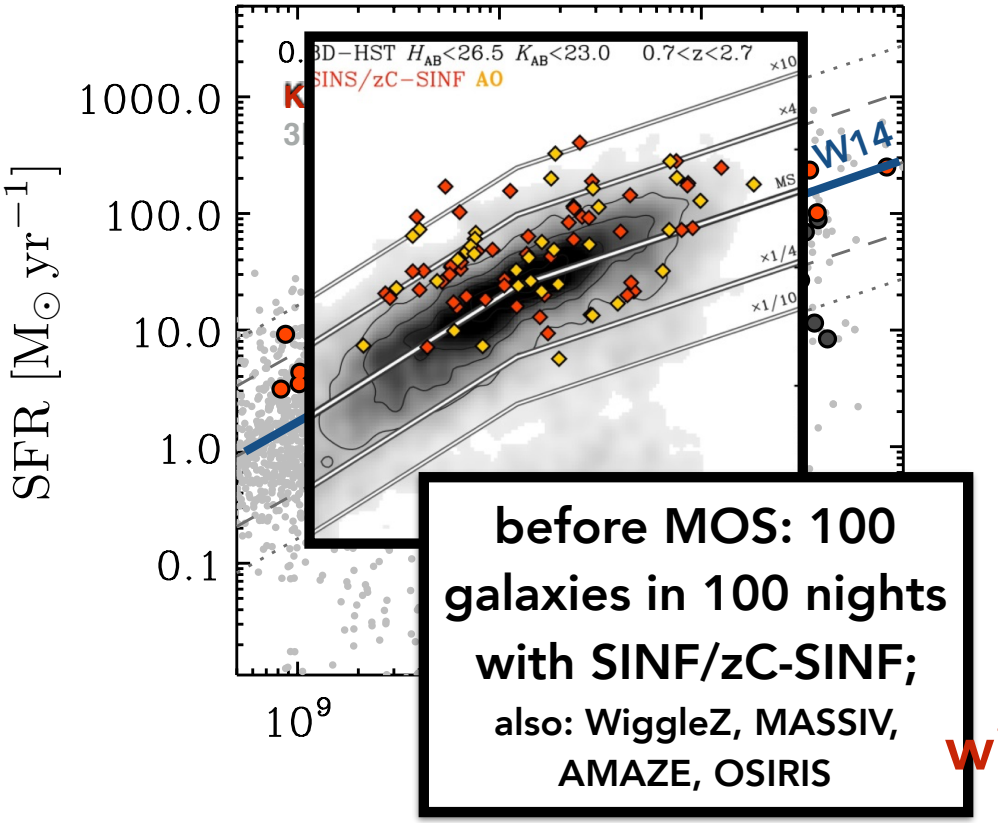






Emily Wisnioski + 2015, ApJ 799, 209

The KMOS^{3D} survey



before MOS: 100 galaxies in 100 nights with SINF/zC-SINF;
also: WiggleZ, MASSIV, AMAZE, OSIRIS

so far: **656** SFGs at *0.6 < z < 2.7*

Hα+[NII]+[SII]

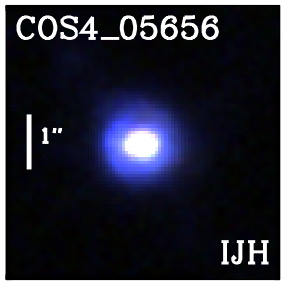
integration times minimum 4-10 h

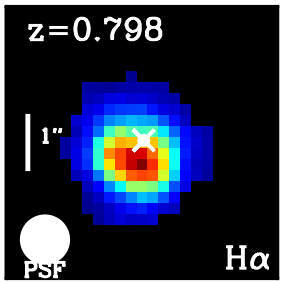
➔ high S/N, spatially resolved data

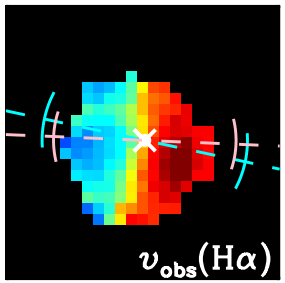
- ✦ 80% detected in Hα
- ✦ resolved: 80% turbulent disks

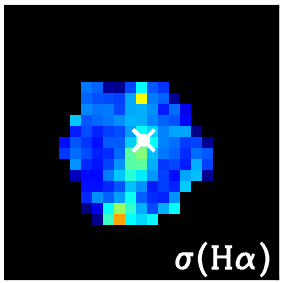
with MOS: 600+ galaxies in 75 nights!

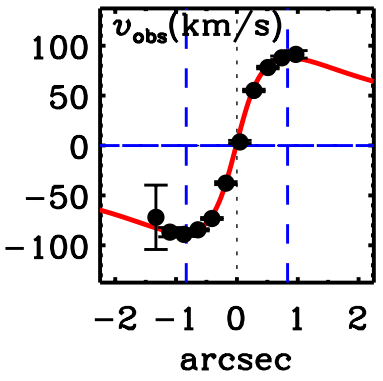
also: KROSS, MOSDEF, KDS, VANDELS, VUDS, LEGA-C, ...

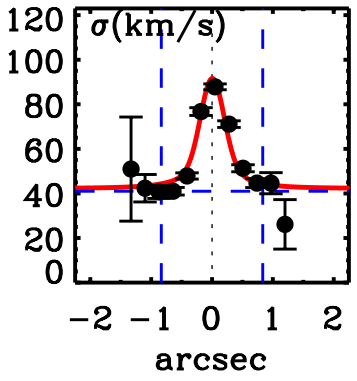






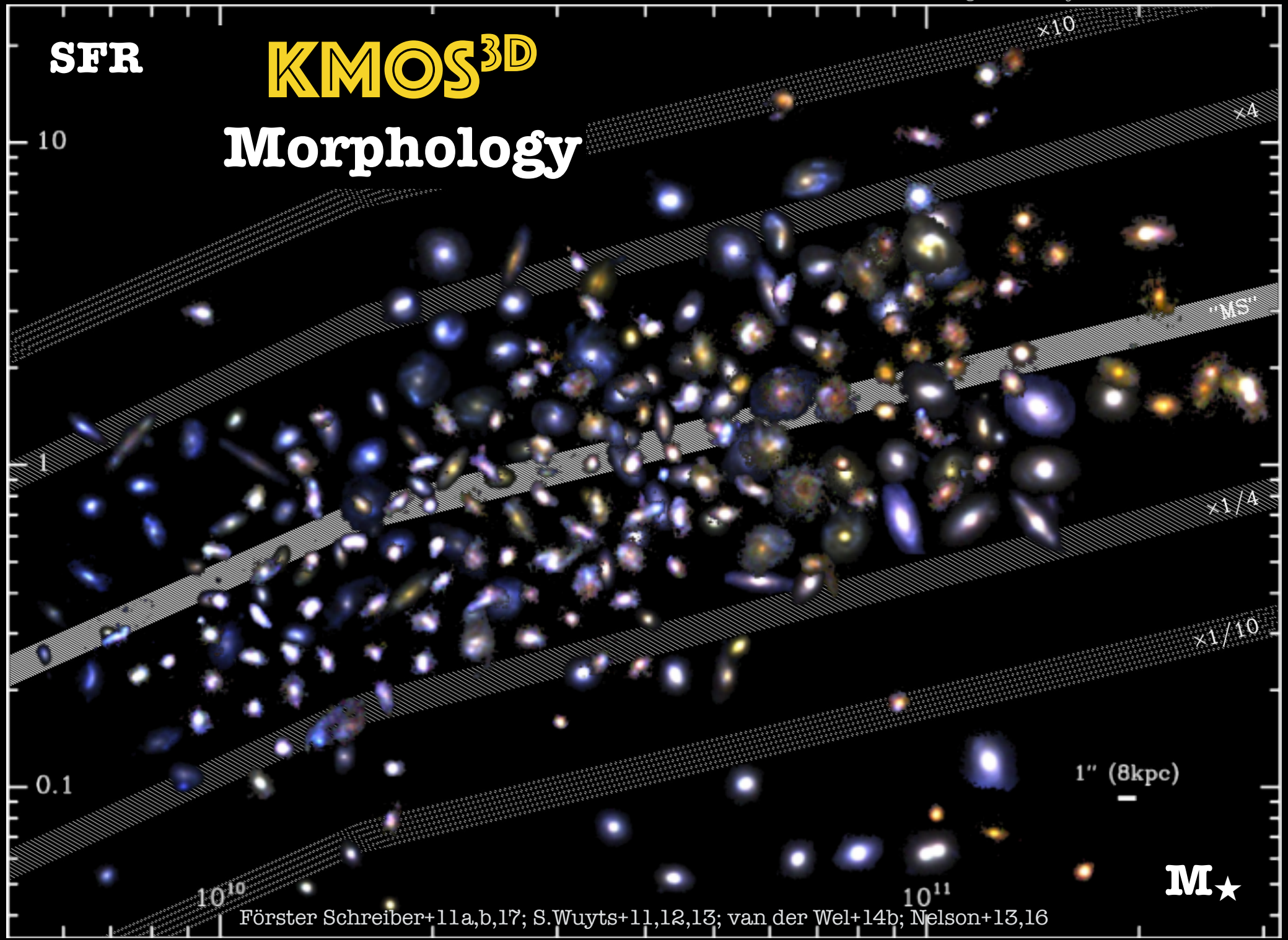






Emily Wisnioski + 2015, ApJ 799, 209

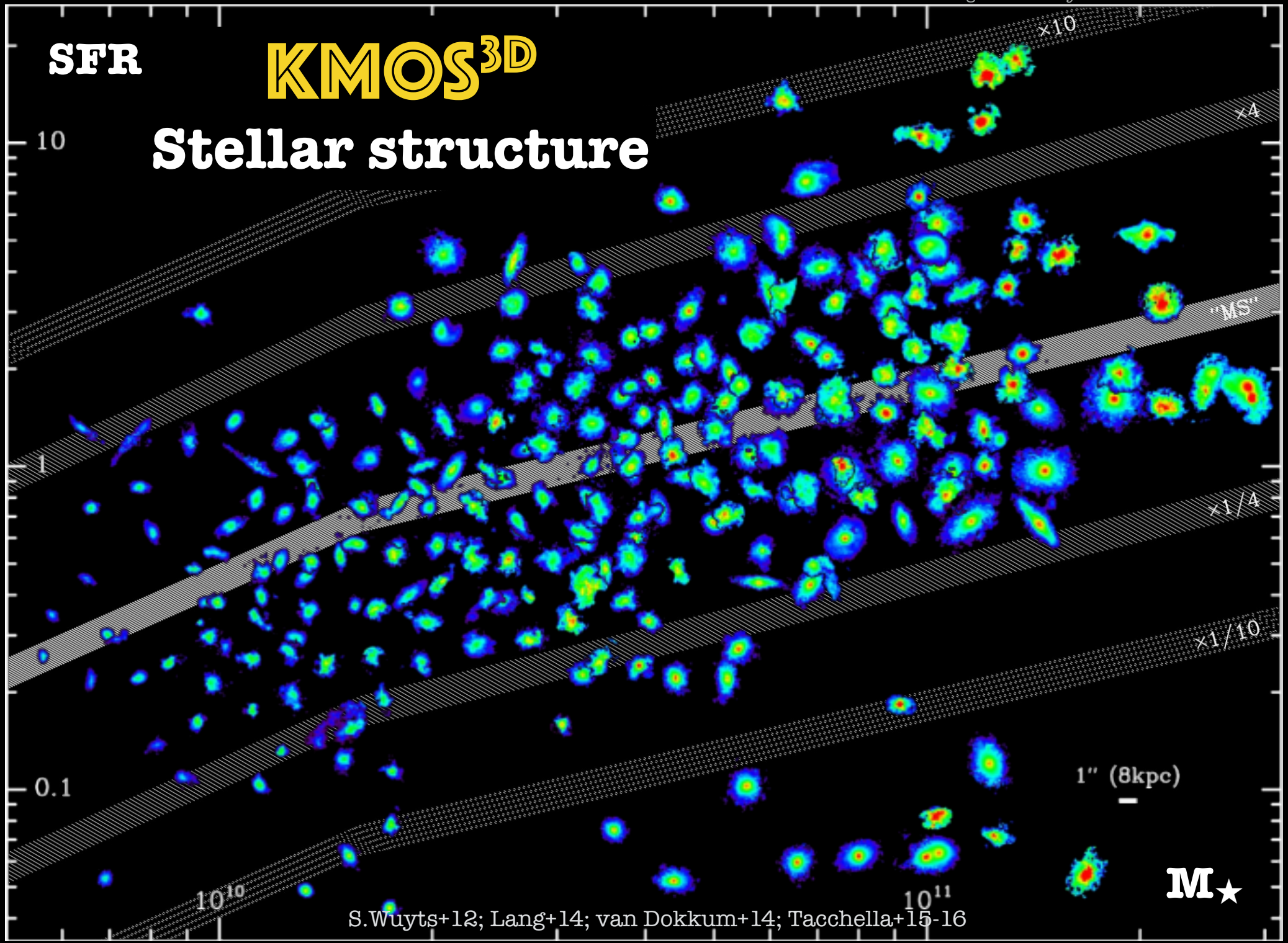
Figure courtesy of N.M.Förster Schreiber



Förster Schreiber+11a,b,17; S.Wuyts+11,12,13; van der Wel+14b; Nelson+13,16

also Labbé+03;Lotz+06,08,10; Elmegreen+04-09;Kriek+09;Guo+12,15;Szomoru+13;Tacchella+15a,b;Tadaki+14a;Cibinel+15

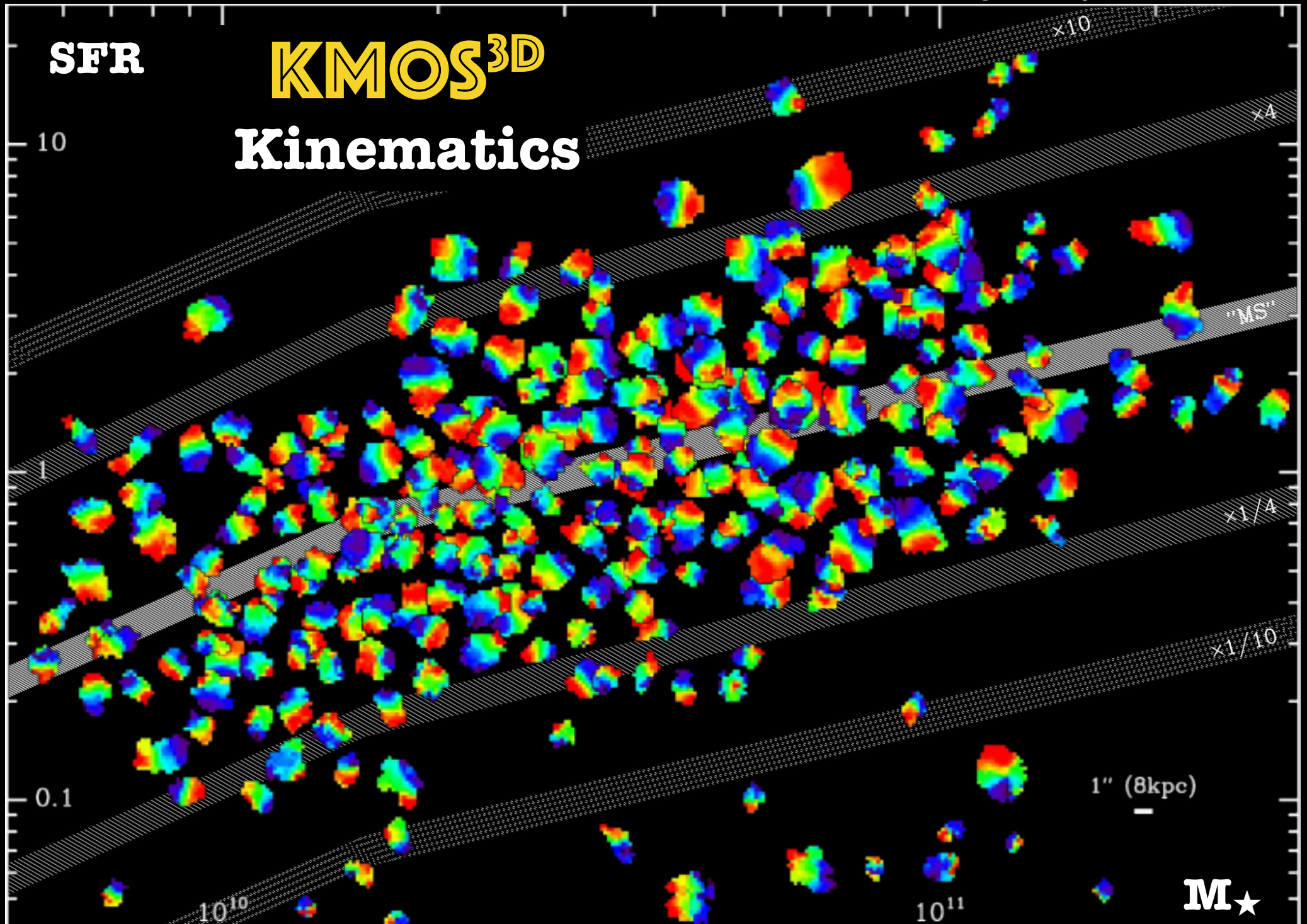
Figure courtesy of N.M.Förster Schreiber



S.Wuyts+12; Lang+14; van Dokkum+14; Tacchella+15-16

e.g. Kauffmann+03,06;Schiminovich+07;Bell+08,12;Cheung+12;Bruce+12,14;Fang+13;Bluck+14 ; Hunter+98;Martig+09,13;Saintonge+12;Crocker+12

Figure courtesy of N.M.Förster Schreiber

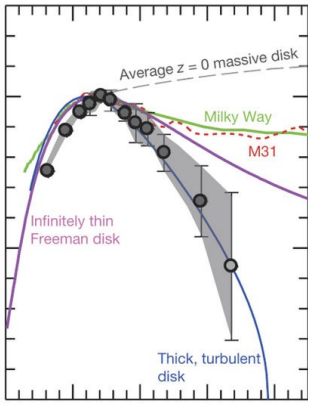


Wisnioski+15;Genzel+06,08,11;Förster Schreiber+06,09,17;Shapiro+08;Mendel+17; and Stott+14,16;Tiley+16;Harrison+17; Simons+16;Contini+16
& Kassin+07,12;Law+09,12;Epinat+09-12;Jones+10;Green+10;Wisnioski+11,12;Yuan+11,12;Vergani+12;Sobral+13;Livermore+15;Leethochawalit+15

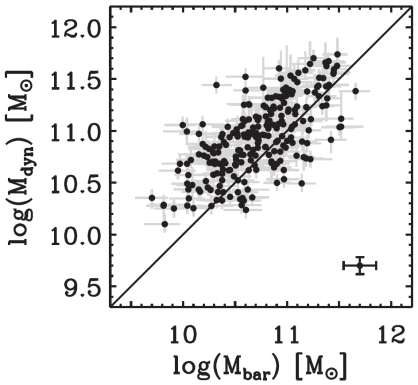
Recent KMOS^{3D} results

Rejuvenation
Belli+2017

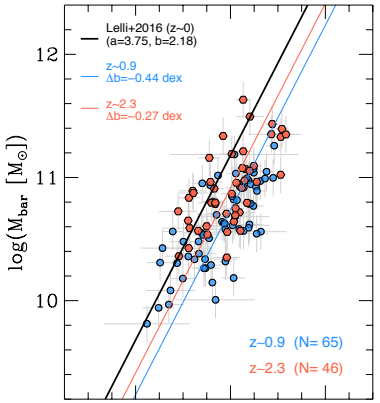
Outer rot curve
Lang+2017, Genzel+2017



Mass budget
S.Wuyts+2016

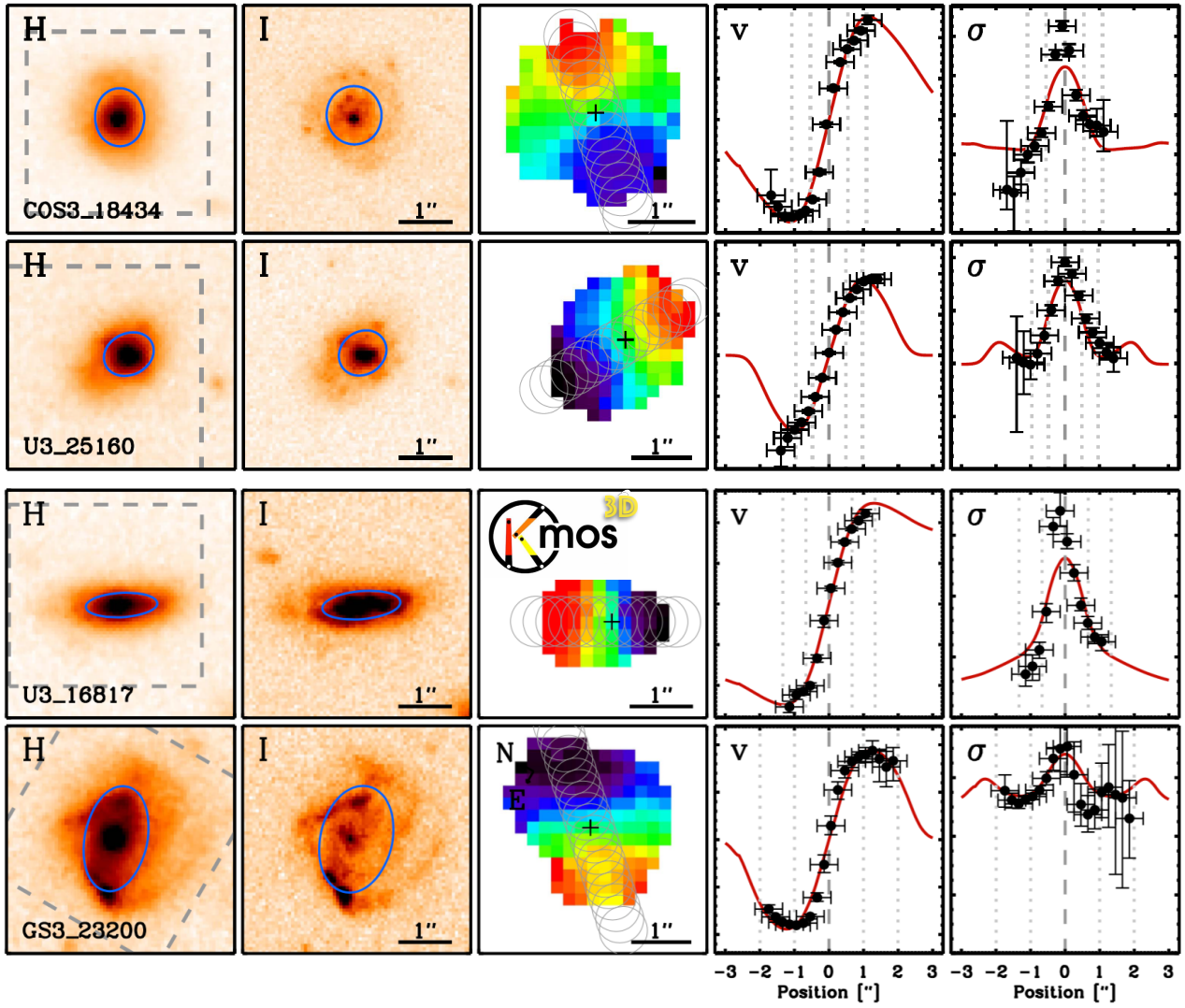


Tully-Fisher
Übler+2017



also: Genzel+2014b, E.Wuyts+2016, Burkert+2016, Tadaki+2017

Dynamical modelling of early star-forming disks



S.Wuyts+2016

The KMOS^{3D} Survey

3D-*HST* & CANDELS targets with spec-z or grism-z

⇩

Hα emission in *YJ/H/K* filters of KMOS@VLT — 0.6<z<2.7

⇩

magnitude cut *Ks* < 23

⇩

OH night skyline avoidance

first 3 years of data:

536 galaxies observed

↳ **407** Hα detected

↳ **316** resolved

⬇

selection for S.Wuyts+2016

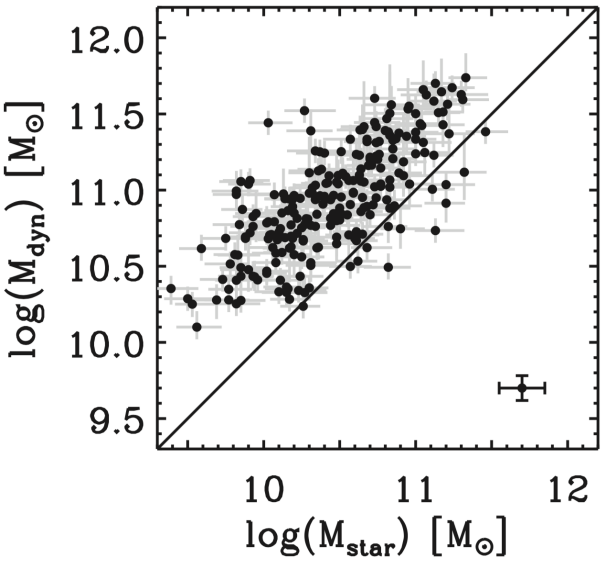
- velocity gradient along a single axis
- $|PA_{morph} - PA_{kin}| < 40°$
- $S/N \gtrsim 5$

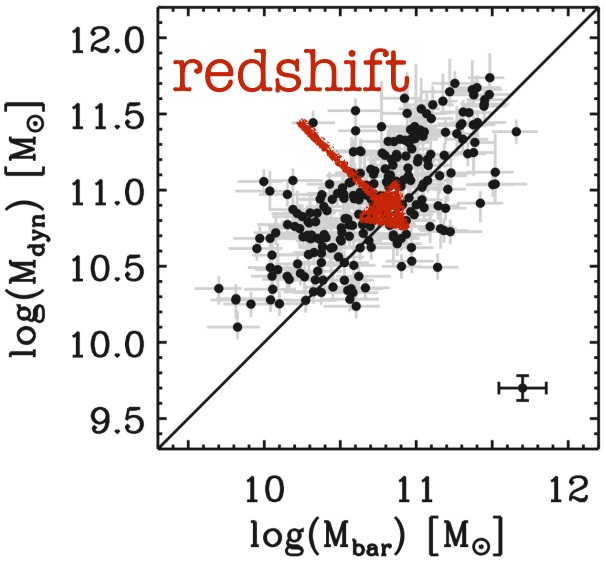
↳ **240** modelled galaxies

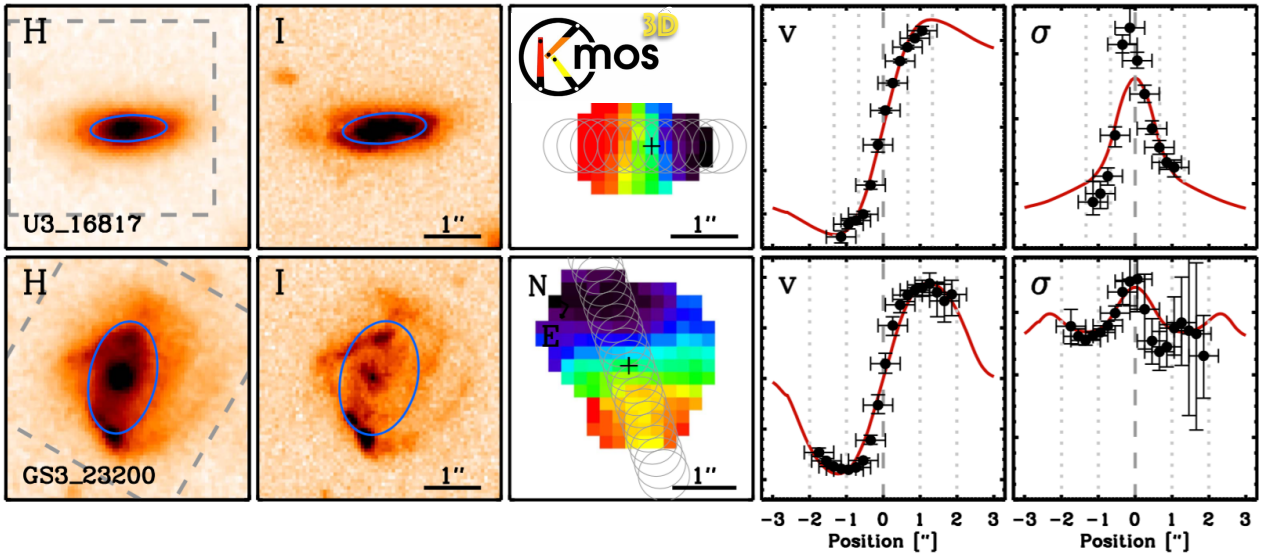
$$v_{\rm rot}^2(r) = v_{\rm circ}^2(r) - 2\sigma_0^2 \frac{r}{r_d}$$

Burkert+10,16; see also
$S_{0.5}$ by Weiner+06; Kassin+07,12; …

The mass budget in early star-forming disks







The KMOS^{3D} Survey

3D-*HST* & CANDELS targets with spec-z or grism-z

high-z SFGs are baryon-dominated with $f_{bar}(R_e)$ reaching 90% at $z>2$

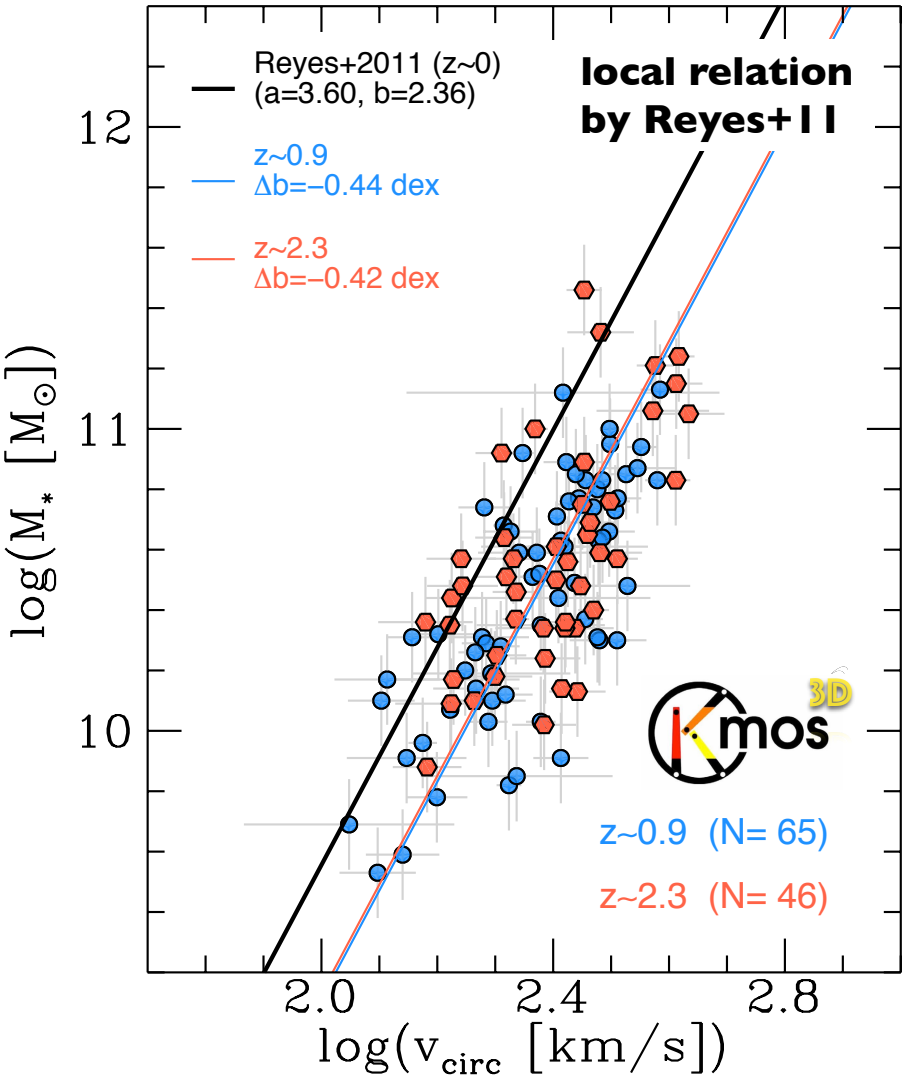
selection for S.Wuyts+2016

- velocity gradient along a single axis
- $|PA_{morph} - PA_{kin}| < 40°$
- $S/N \gtrsim 5$

↳ **240** modelled galaxies

S.Wuyts+2016 see also Förster Schreiber+09; Alcorn+16; Price+16; Burkert+16; Stott+16; Contini+16

The Tully-Fisher relation at z~0.9 and z~2.3



The Wuyts + 2016 sample

- velocity gradient along a single axis
- $|\,PA_{morph} - PA_{kin}\,| < 40°$
- $S/N \gtrsim 5$

↳ **240** modelled galaxies

selection for the TFR study

- RC turnover reached on one side
- 1D dispersion peak coincides with steepest velocity gradient
- $v_{rot,max}/\sigma_0 > \sqrt{4.4}$
- no close neighbours

↳ **135** Tully-Fisher galaxies

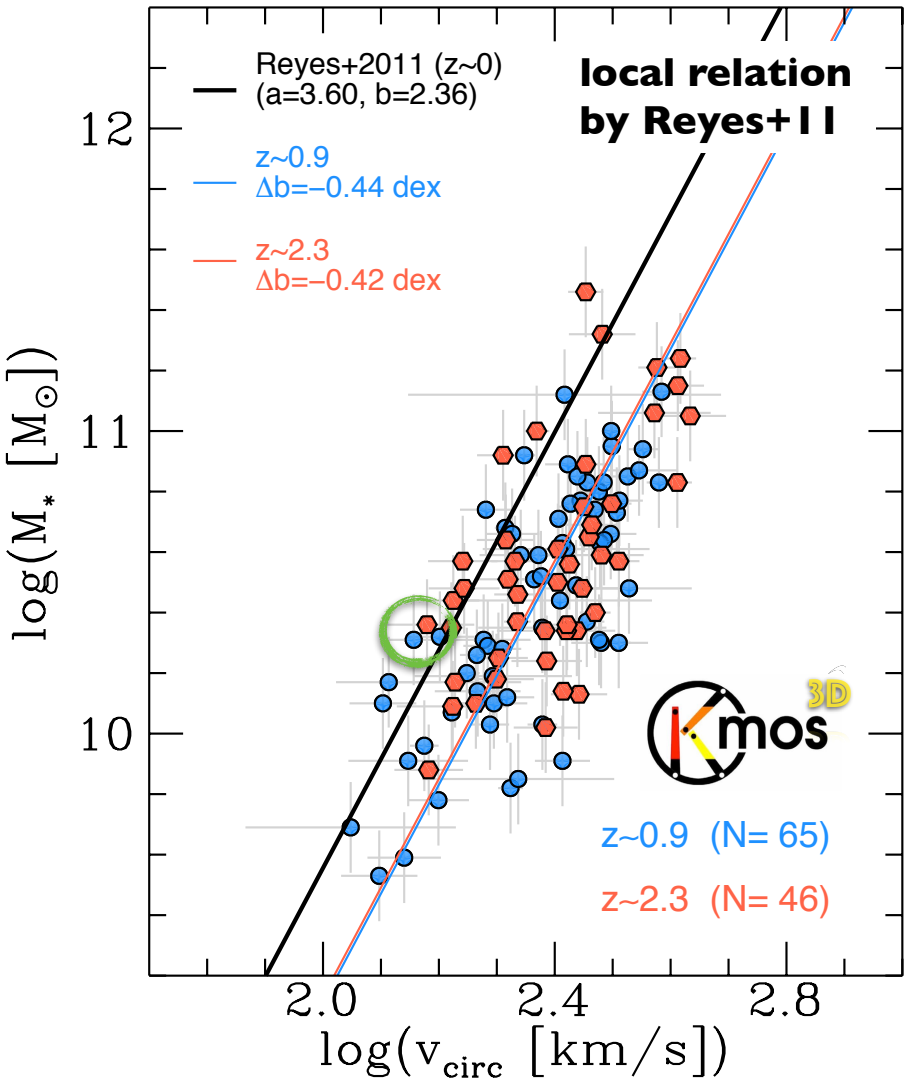
$$v_{\rm circ} = \sqrt{v_{\rm rot}^2 + 2\sigma_0^2 \frac{r}{r_d}}$$

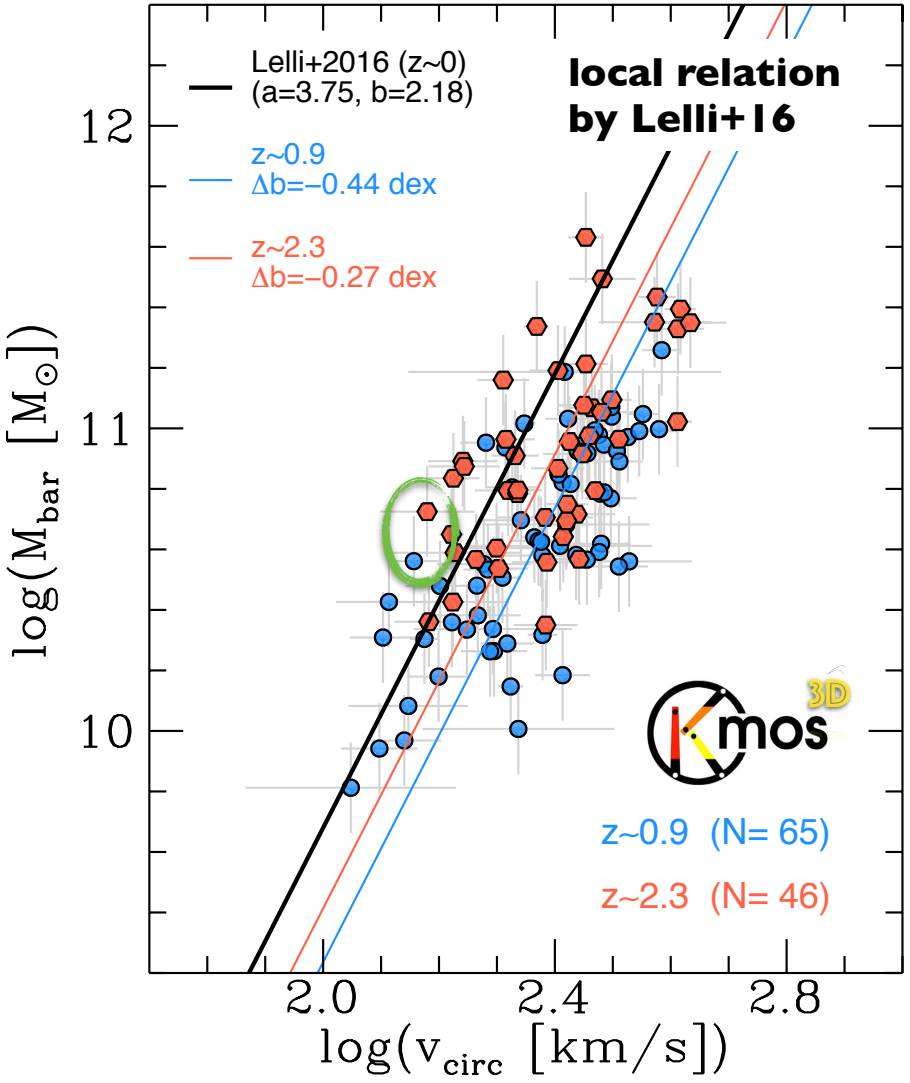
Burkert+10,16;
S.Wuyts+16;
$S_{0.5}$ by Weiner+06;
Kassin+07,12; …

Übler+2017

see also Conselice+05; Flores+06; **Kassin+07**; Puech+08,10; Epinat+09; Cresci+09; Gnerucchi +11; Miller+11,12,13; Swinbank+12; Vergani+12; Contini+16; Price+16; Simons+16; **Tiley+16**; Di Teodoro+16; Molina+17; Pelliccia+17; **Straatman+17**; Harrison+17; **Turner+17**

The $M_\star$ and M_{bar} Tully-Fisher relations at z~0.9 and z~2.3



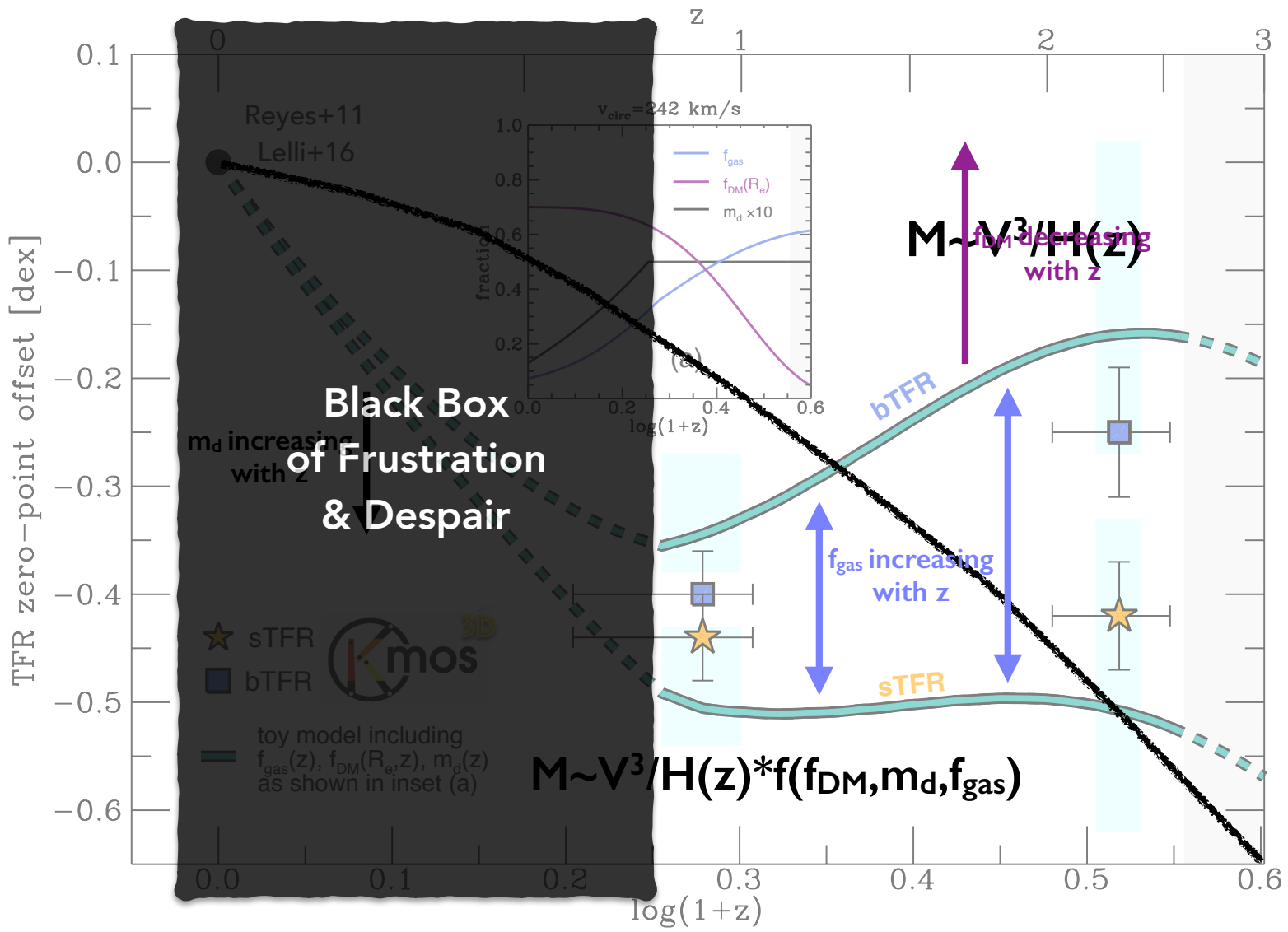


Übler+2017

$M_{gas}(z,\Delta MS,M_\star,R_e)$ from Tacconi+17

Evolution of the Tully-Fisher relation: a toy model

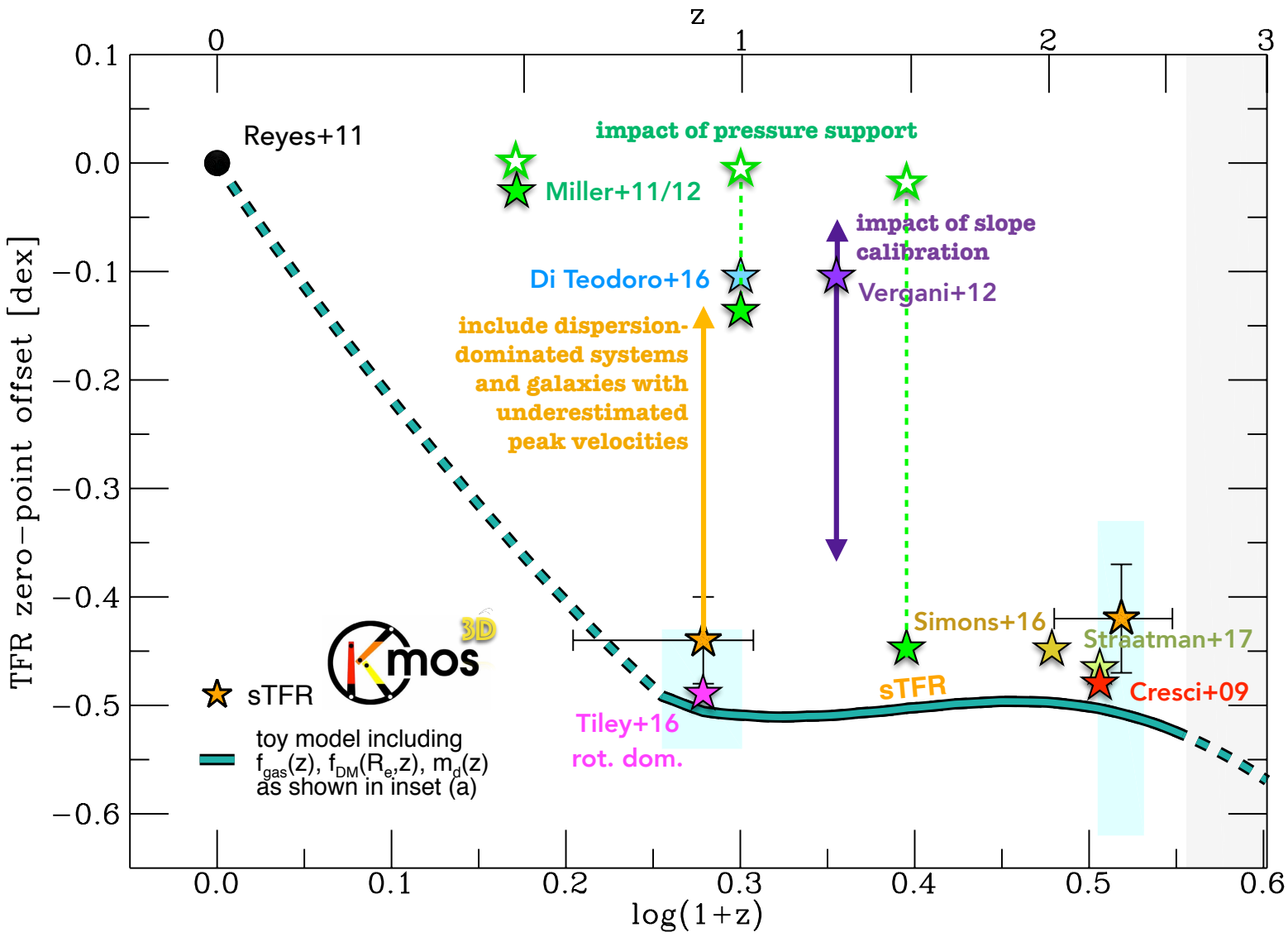
using v_{circ} !



gas fractions: Saintonge+11; Tacconi+17;
DM fractions (R_e): Martinsson+13a,b; Courteau+15; S.Wuyts+16;
disk mass fractions: Moster+13; Burkert+16

Übler+2017

But why the differences? – candidates:



measurement of masses, IMF

dynamical model & velocity measure
(v_{flat}, $v_{2.2}$, $v_{3.2}$, v_{80}, v_{max})

choice of slope

v_{rot} *vs.* accounting for σ

sample selection

statistics

slit *vs.* IFU

also: Conselice+05; Flores+06; Kassin+07; Puech+08,10; Epinat+09; Gnerucchi+11; Swinbank+12; Price+16; Contini+16; Pelliccia+17; Molina+17; Harrison+17; Turner+17
and baryonic TFR: Puech+10; Vergani+12; Price+16

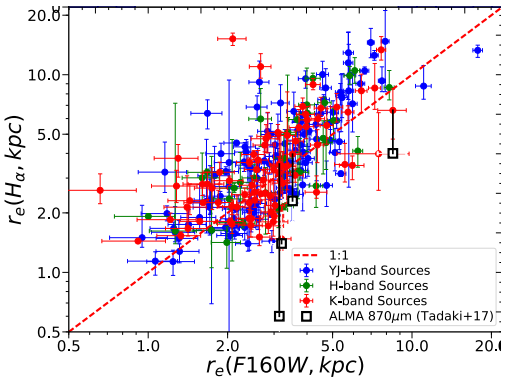
Übler+2017

see Bradford+16 for a detailed investigation for the local bTFR

KMOS^{3D} projects in the works

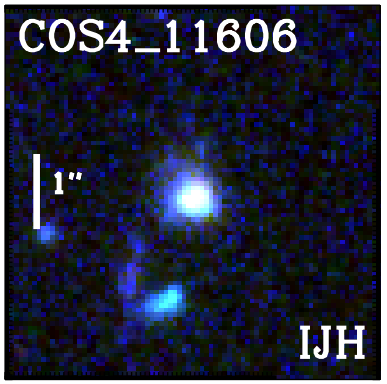
Hα sizes

Wilman+



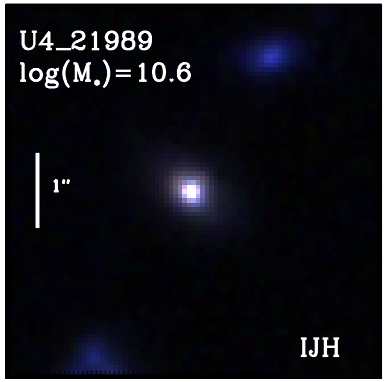
Pairs + mergers

Mendel+



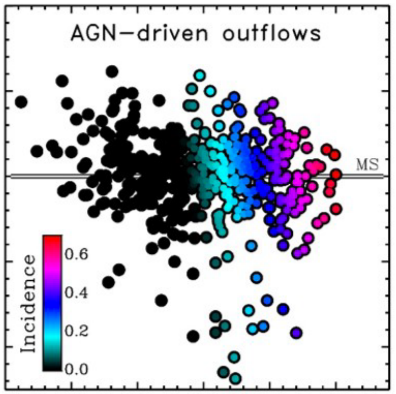
Compact SFGs

Wisnioski+



Outflows

Förster Schreiber+



Summary

- The **KMOS^{3D}** survey probes kinematics of SFGs at $0.7<z<2.7$ through ionized gas emission
  — and excitation, metallicity, outflows, ...

- With increasing redshift disks are more gas-rich, turbulent, and their kinematics increasingly dominated by baryons.

- The TFR evolves non-monotonically with redshift due to a non-trivial interplay of evolving mass fractions and $H(z)$
  — but caution should be exercised when comparing independent studies.