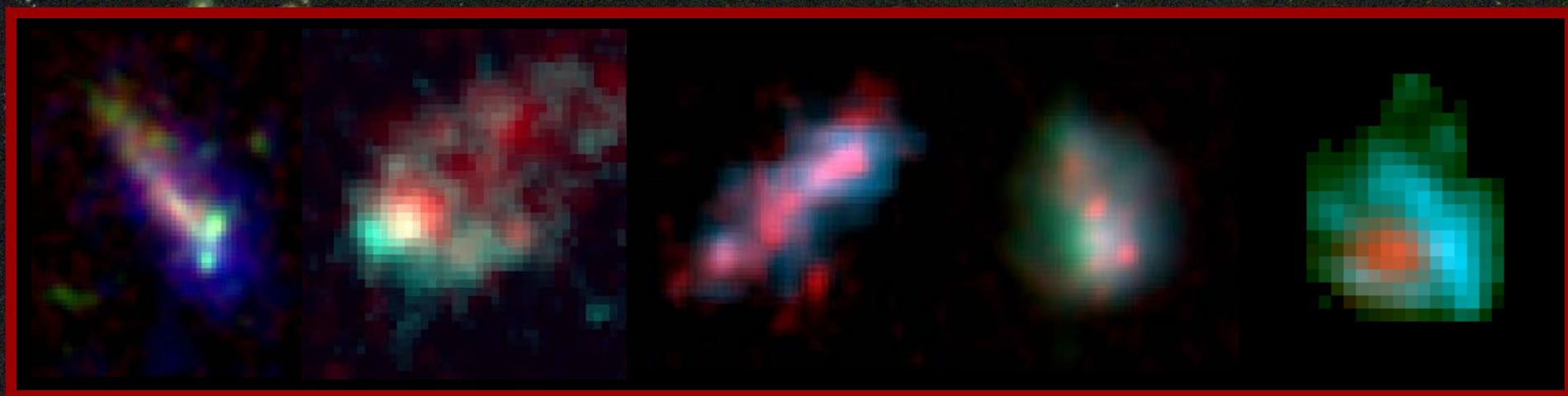


Star Formation in high z Galaxies: Insights from Resolved Observations of the Ionized and Molecular Gas



N.M. Förster Schreiber (MPE)

The Team and Collaborations

N.M. Förster Schreiber, L.J. Tacconi, R. Genzel, N. Bouché, G. Cresci,
R. Davies, K.L. Shapiro, P. Buschkamp, S. Genel, E.K.S. Hicks,
J. Gracia-Carpio, J. Kurk, D. Lutz, A. Sternberg, A. Burkert, T. Naab

MPE/Berkeley/UCSB/Tel Aviv/USM Munich

A. Renzini, S. Lilly, A. Cimatti, E. Daddi, C. Mancini, Y. Peng, D. Vergani,
G. Zamorani, L. Pozzetti, P. Oesch, M. Mignoli, & zCOSMOS, GMASS, Deep3a Teams

Padova/ETH Zürich/Bologna/CEA Saclay

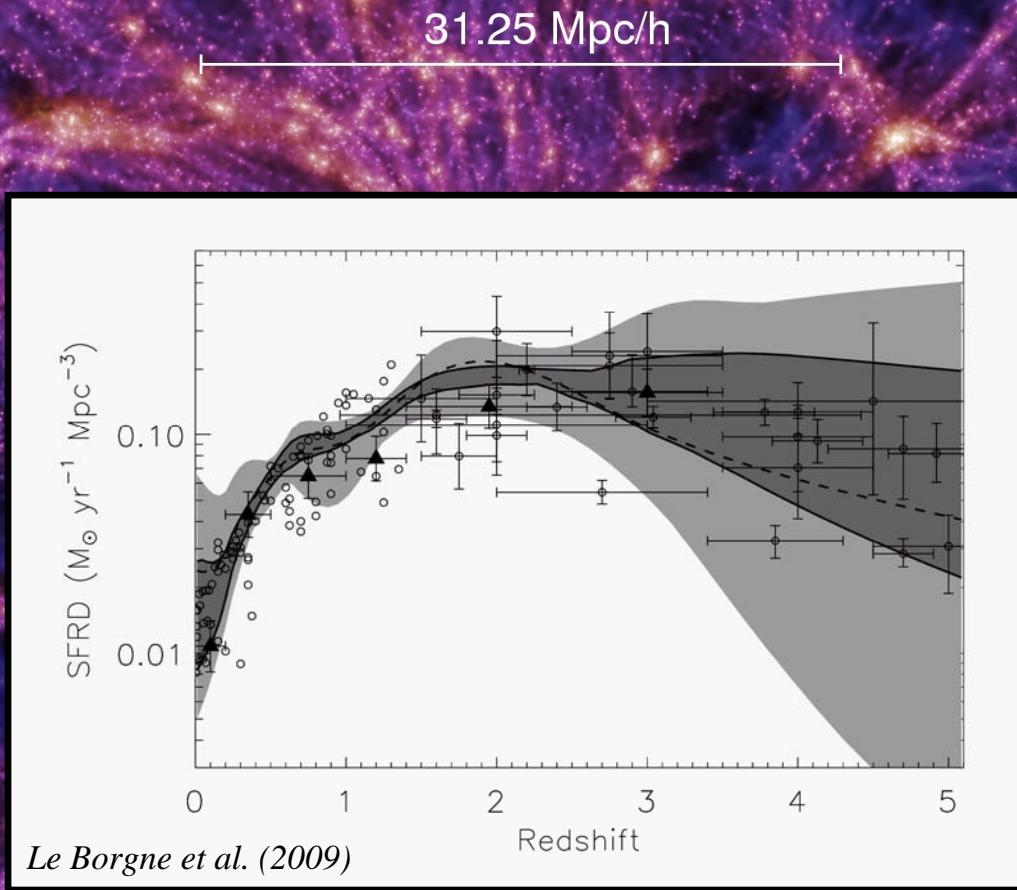
A.E. Shapley, D. K. Erb, C.C. Steidel

UCLA/UCSB/Caltech

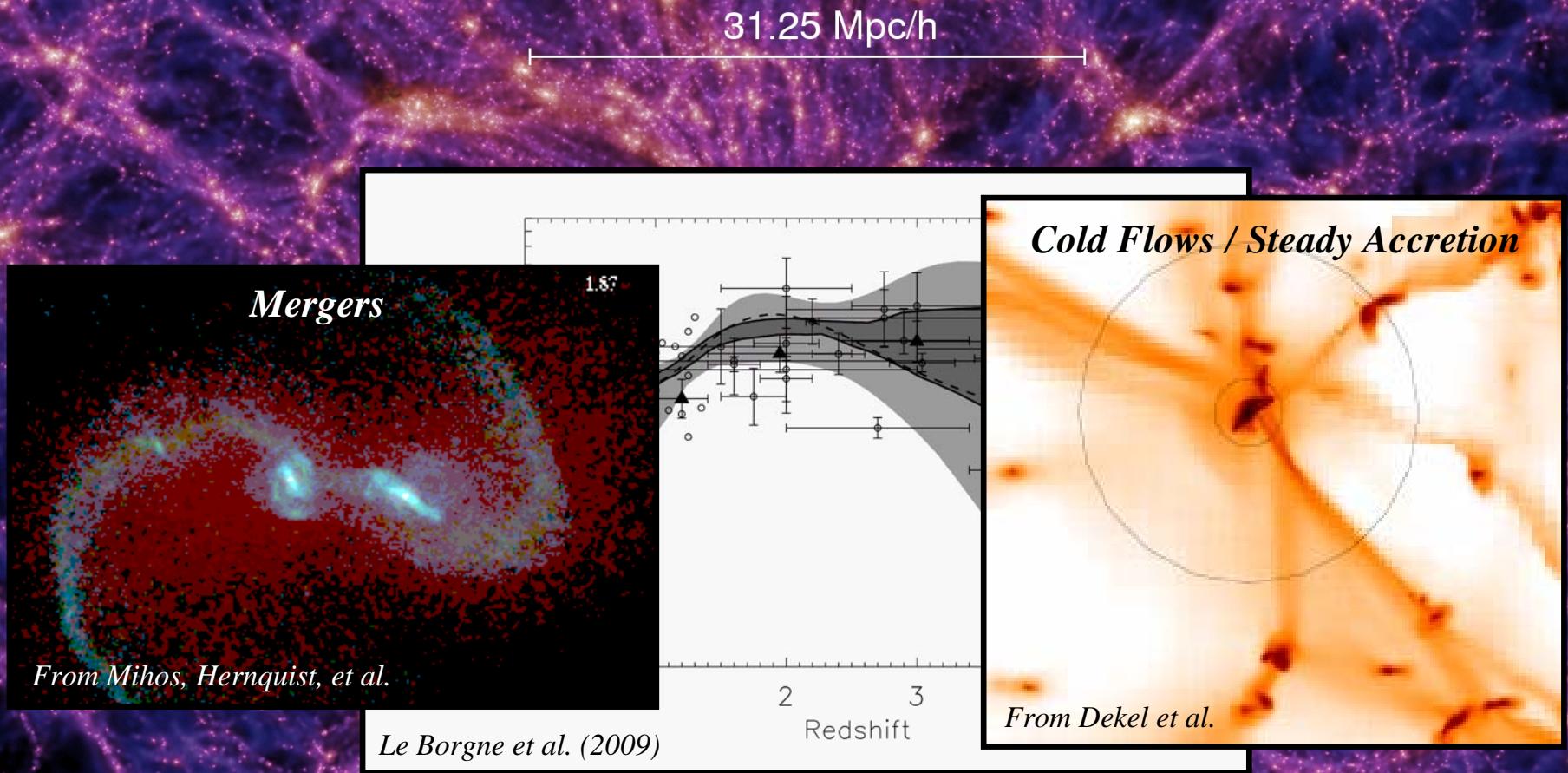
R. Neri, P. Cox, M.C. Cooper, A. Bolatto, F. Bournaud, F. Combes, J. Comerford,
M. Davis, S. García-Burillo, A. Omont, B. Weiner & AEGIS Team

IRAM/UofA/UMD/CEA Saclay/Paris/Berkeley/OAN Madrid/IAP

Star Formation and Mass Assembly at Early Stages of Galaxy Evolution



Star Formation and Mass Assembly at Early Stages of Galaxy Evolution



Spatially-resolved Studies of $z \sim 1-3$ Star-forming Galaxies

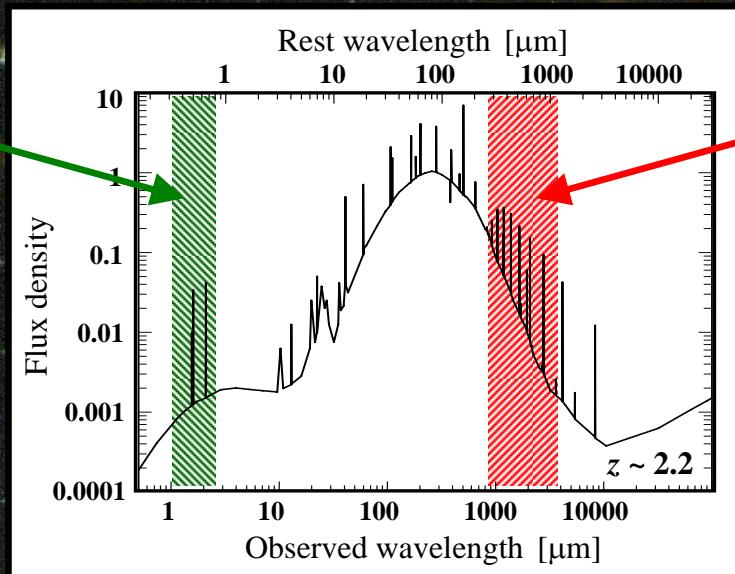
Star formation, dynamics, morphologies, physical properties



Rest-frame optical

Stellar & nebular components

Integral field spectroscopy
and imaging
in the near-IR



Rest-frame submm

Molecular gas & cold dust

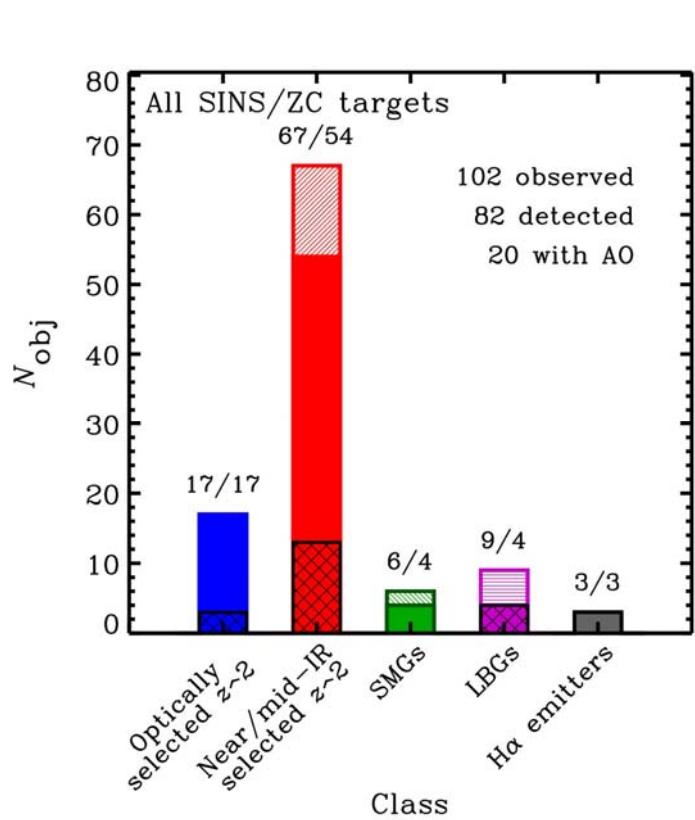
Interferometry mapping
in the mm

The SINS/ZC Survey

- Emission line survey of ~ 100 $z \sim 1 - 3$ galaxies ($H\alpha$, ...)

Near-IR

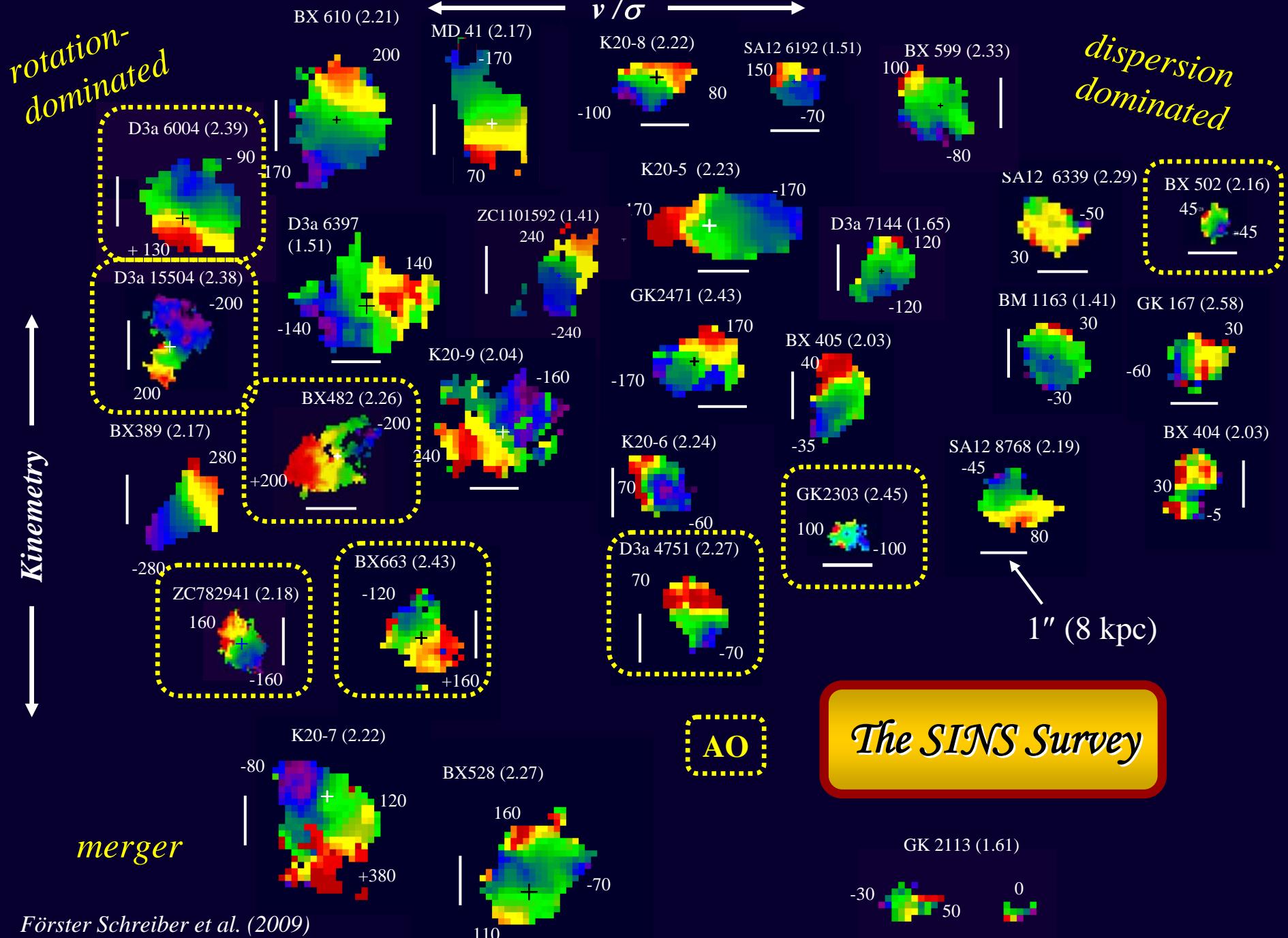
integral field spectroscopy
with SINFONI (AO/no-AO)
at the VLT

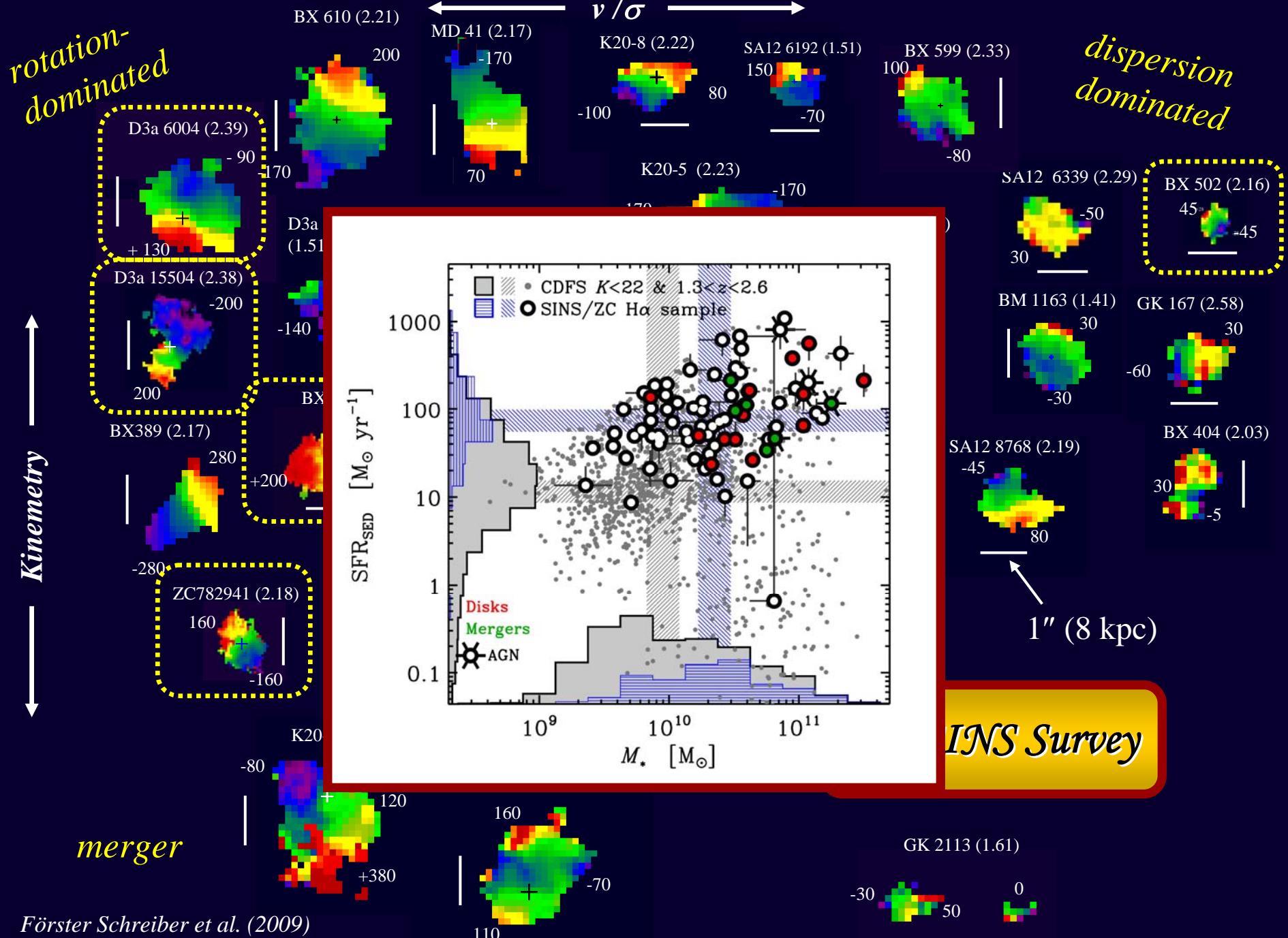


Complemented with
near-IR imaging
with HST/NICMOS-NIC2
and VLT/NACO+AO

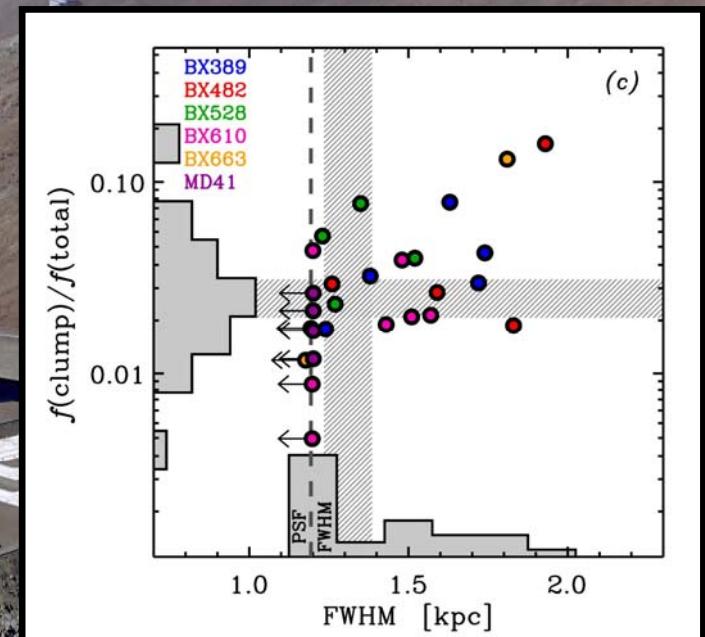
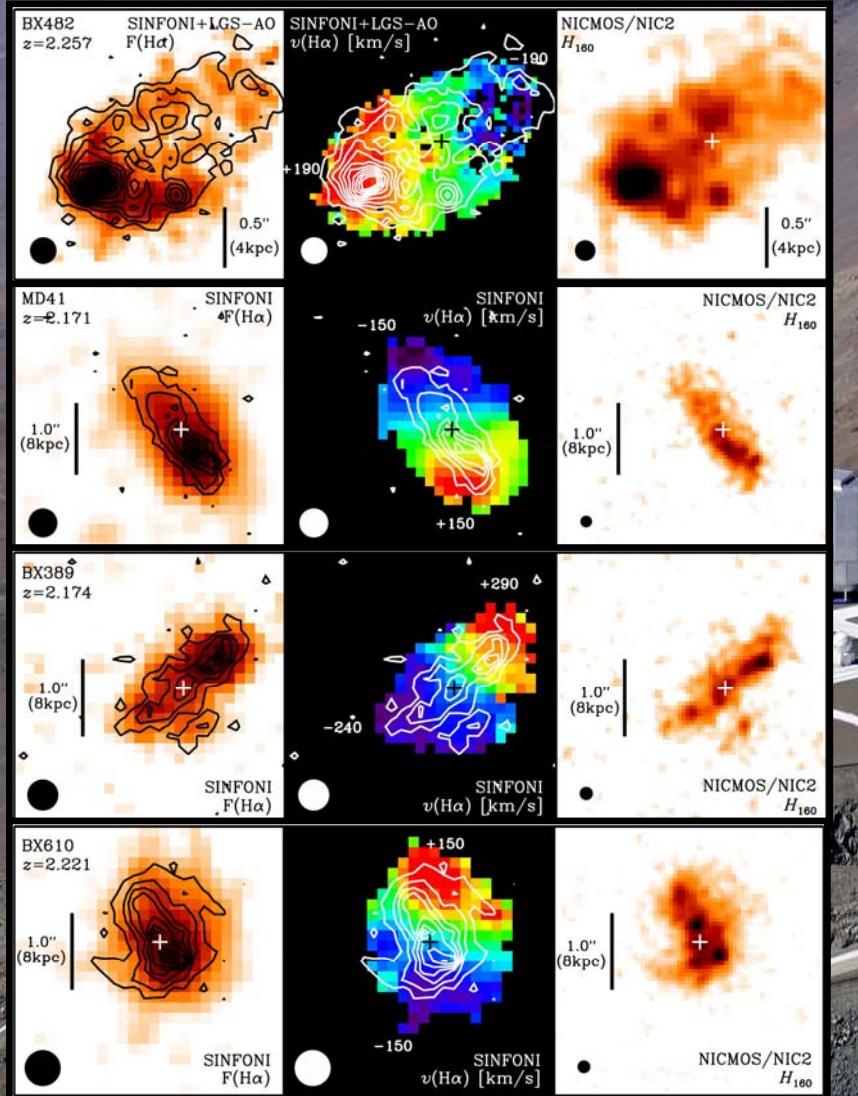
Förster Schreiber et al. 06/9; Genzel et al. 06/8; Bouché et al. 07; Shapiro et al. 08/09; Cresci et al. 09; Mancini et al. 10

Other IFU studies: e.g., Swinbank et al. 06/7; Nesvadba et al. 06-08; Wright et al. 07/9; Law et al. 07/9; Stark et al. 08; Bournaud et al. 08; van Starkenburg et al. 08; Épinat et al. 09; Mannucci et al. 09; Jones et al. 09; Lemoine-Busserolle et al. 10





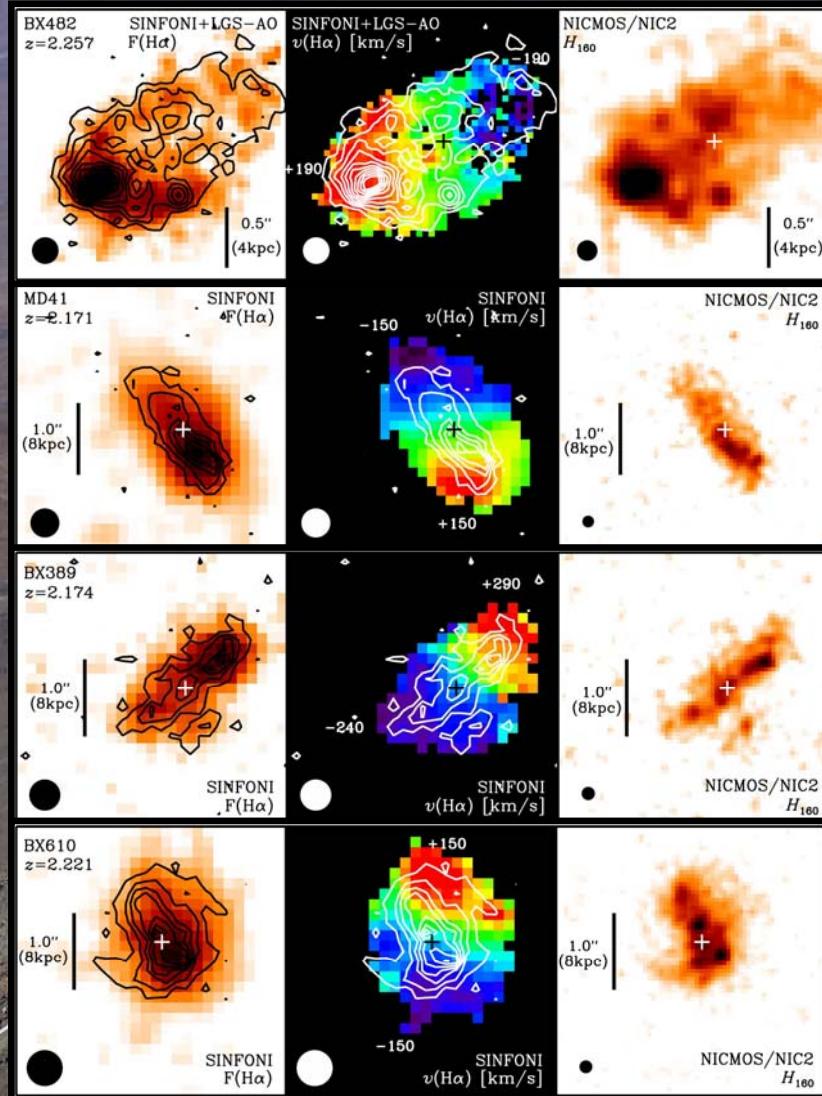
Clumps in High z Star-forming Galaxies



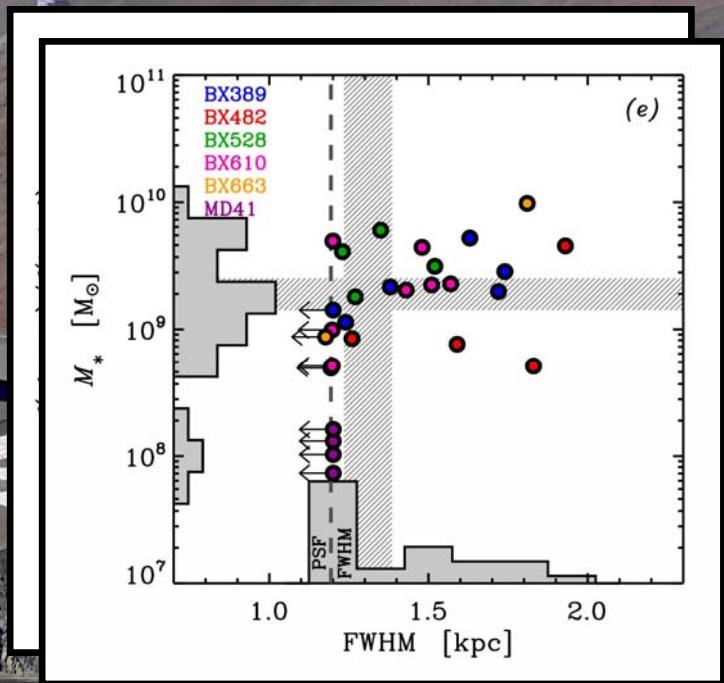
Förster Schreiber, Shapley, et al. (2010); Genzel et al. (2008)

Also, e.g., Cowie et al. 1995; van den Bergh et al. 1996;
Giavalisco et al. 1996; Conselice et al. 2004; Lutz et al. 2004;
Papovich et al. 2005; Elmegreen, Elmegreen, et al. 2004-2009

Clumps in High z Star-forming Galaxies



- For $Q \approx 1$:
- $L_J \propto (\sigma_0/v_c)R_d \sim 1 - 2 \text{ kpc}$
 - $M_{\text{cl}} \propto (L_{\text{cl}} v_c)^2/R_d \sim 10^{7.5} - 10^{9.5} M_{\odot}$

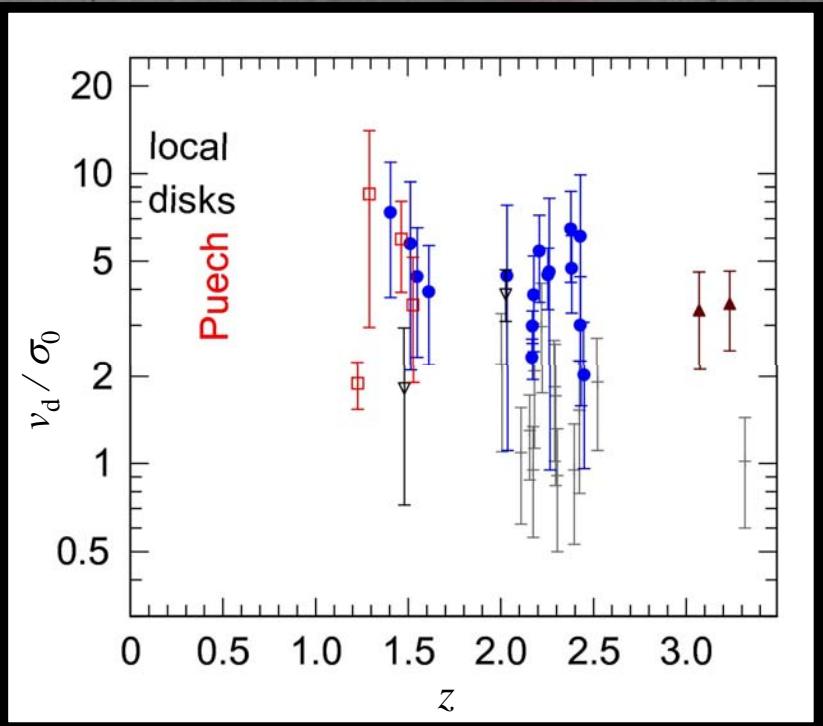
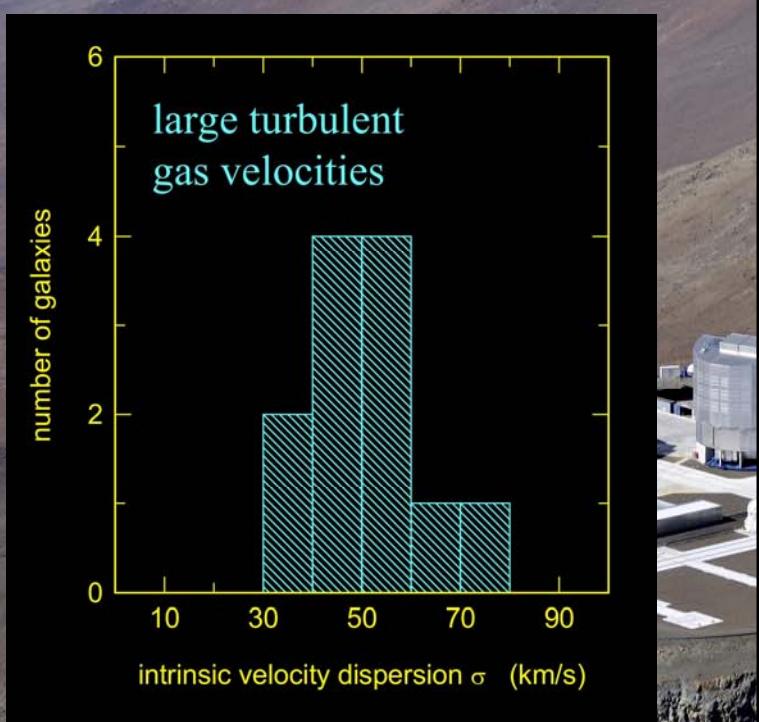


Förster Schreiber, Shapley, et al. (2010); Genzel et al. (2008)

Also, e.g., Cowie et al. 1995; van den Bergh et al. 1996;
Giavalisco et al. 1996; Conselice et al. 2004; Lutz et al. 2004;
Papovich et al. 2005; Elmegreen, Elmegreen, et al. 2004-2009

Large Velocity Dispersion in High-z Disks

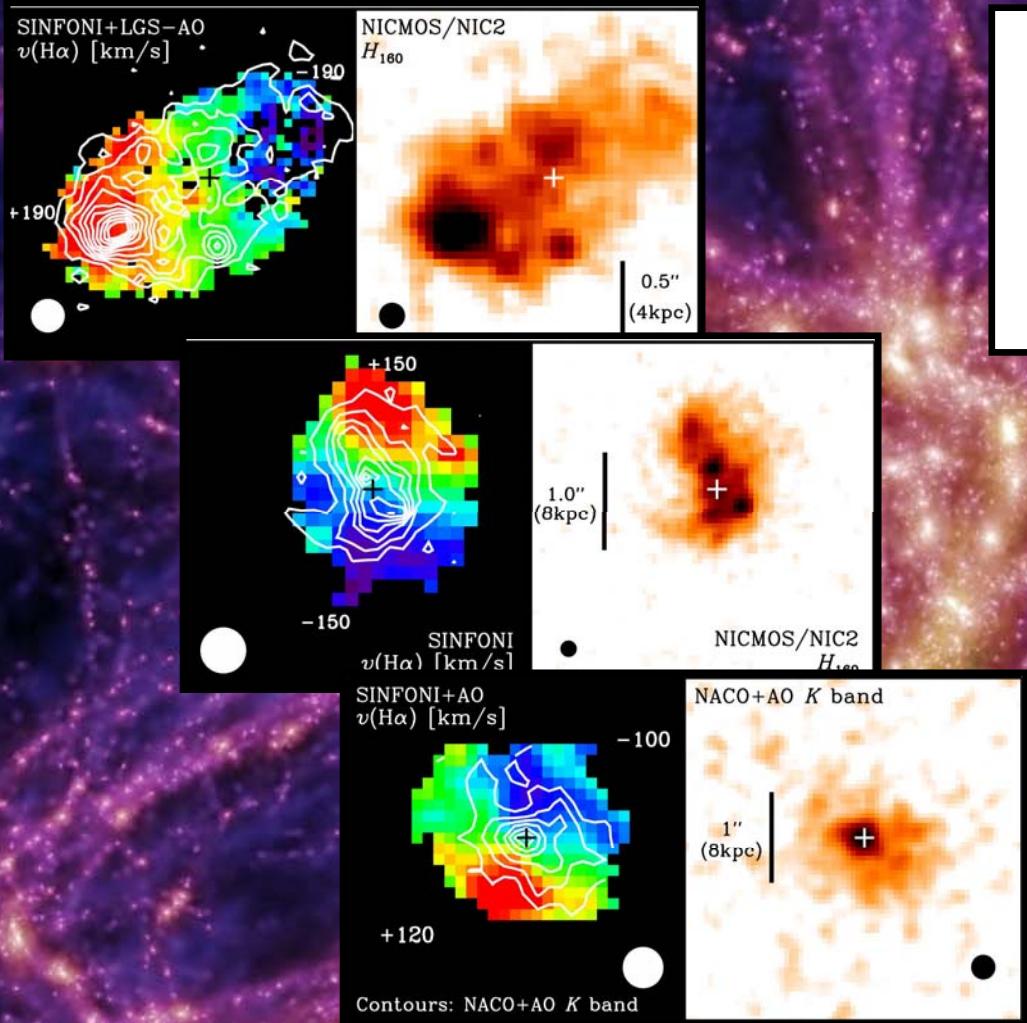
- For disks with $Q \approx 1$, $v_c/\sigma_0 \propto 1/f_{\text{gas}}$



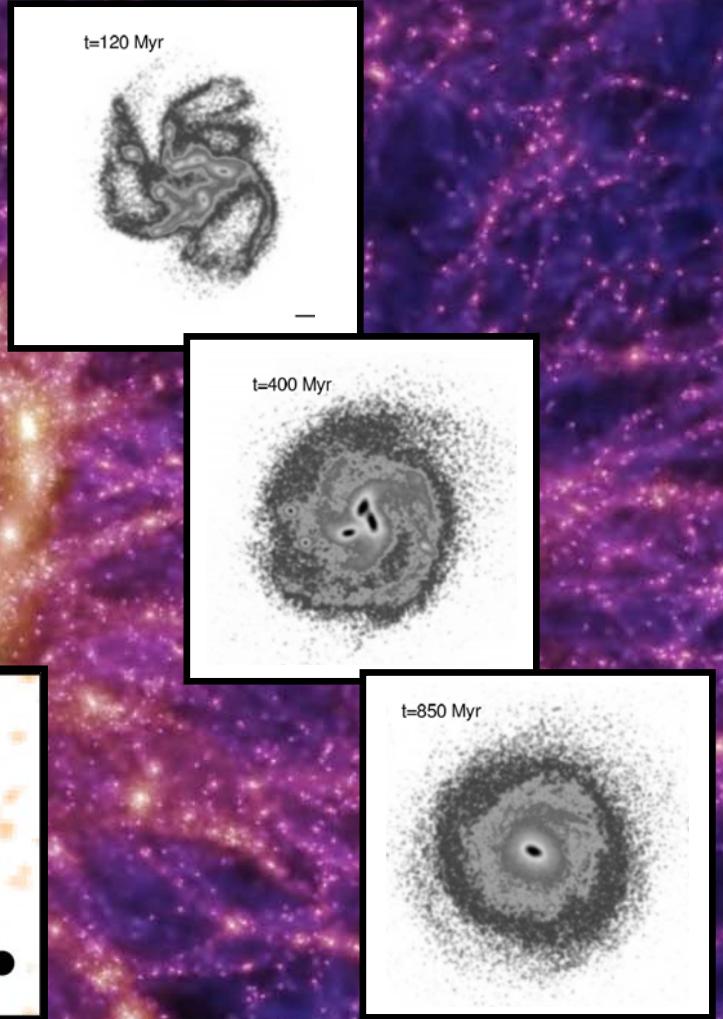
*Förster Schreiber et al. (2006, 2009); Cresci et al. (2009); Genzel et al. (2006, 2008);
Also: Nesvadba et al. (2006); Puech et al. (2006); Stark et al. (2008); Law et al. (2007, 2009); Wright et al. (2007, 2009);
Epinat et al. (2009); Dib et al. (2006); Jones et al. (2009); Khochfar & Silk (2009); Burkert et al. (2009)*

Bulge Formation in Gas-rich High z Disks

In-situ Observations



Numerical Simulations

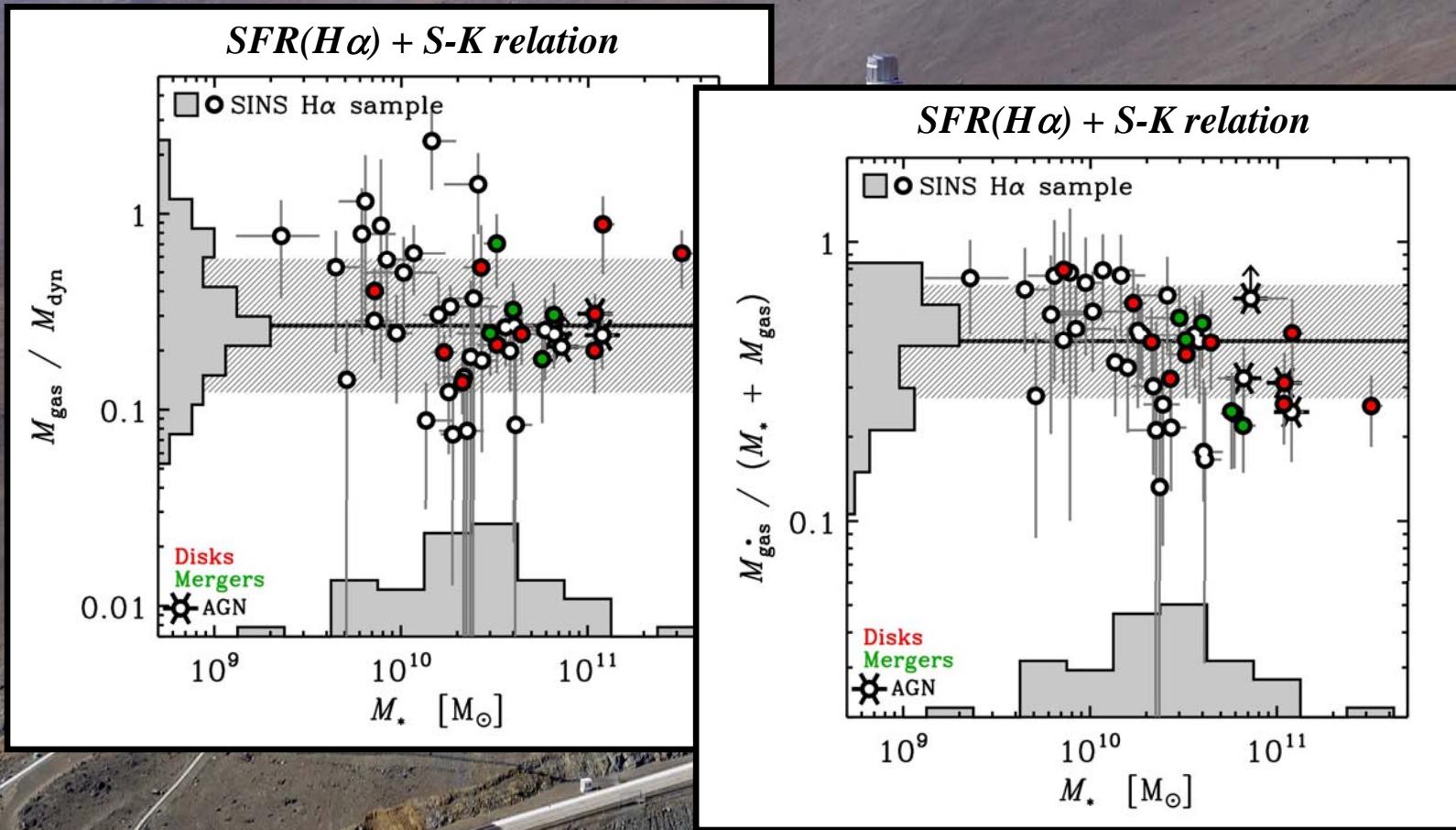


Genzel et al. (2008); Förster Schreiber et al. (2010)

Also, e.g., Noguchi 99; Immeli et al. 04; Governato et al. 06/07; Dekel et al. 2007-2009; Carollo et al. 07; Burkert et al. 09

Bournaud et al. (2007-2009)

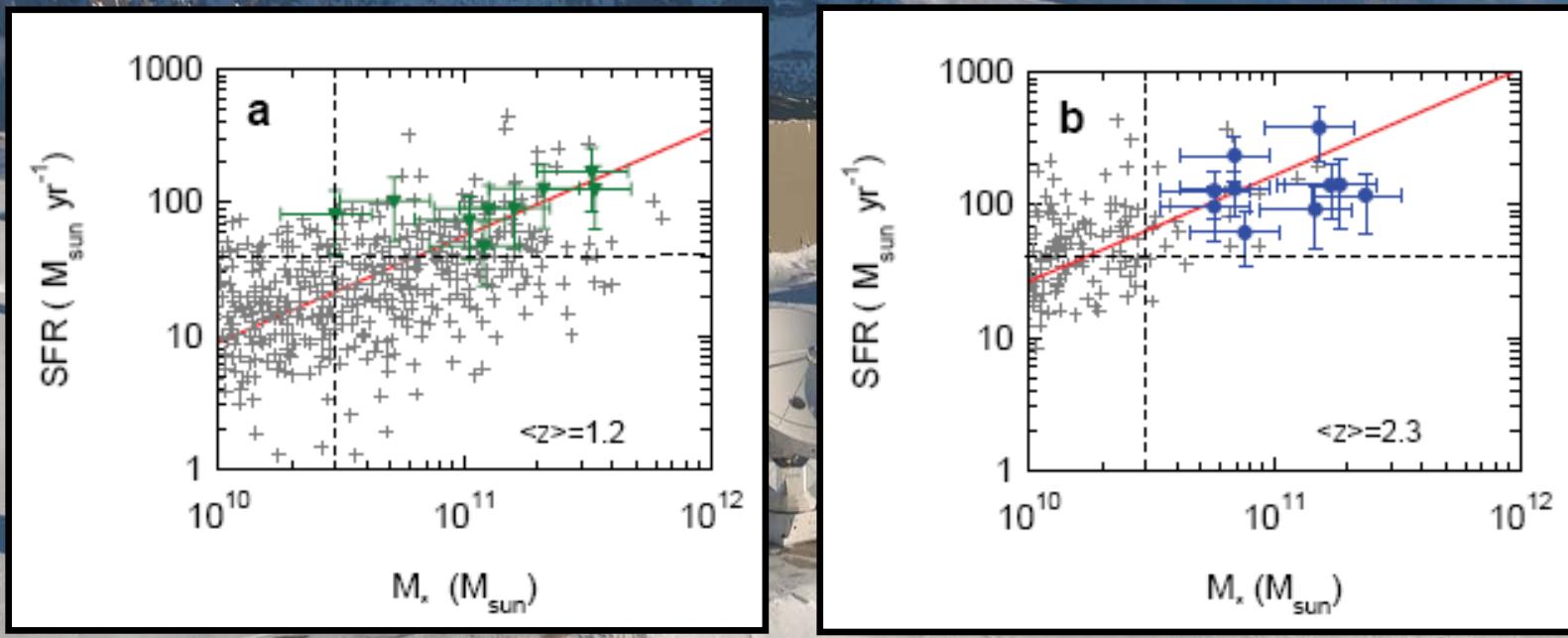
High Gas Fractions in High-z Star-forming Galaxies?



Förster Schreiber et al. (2009); Cresci et al. (2009)
Cf. also Erb et al. (2006b)

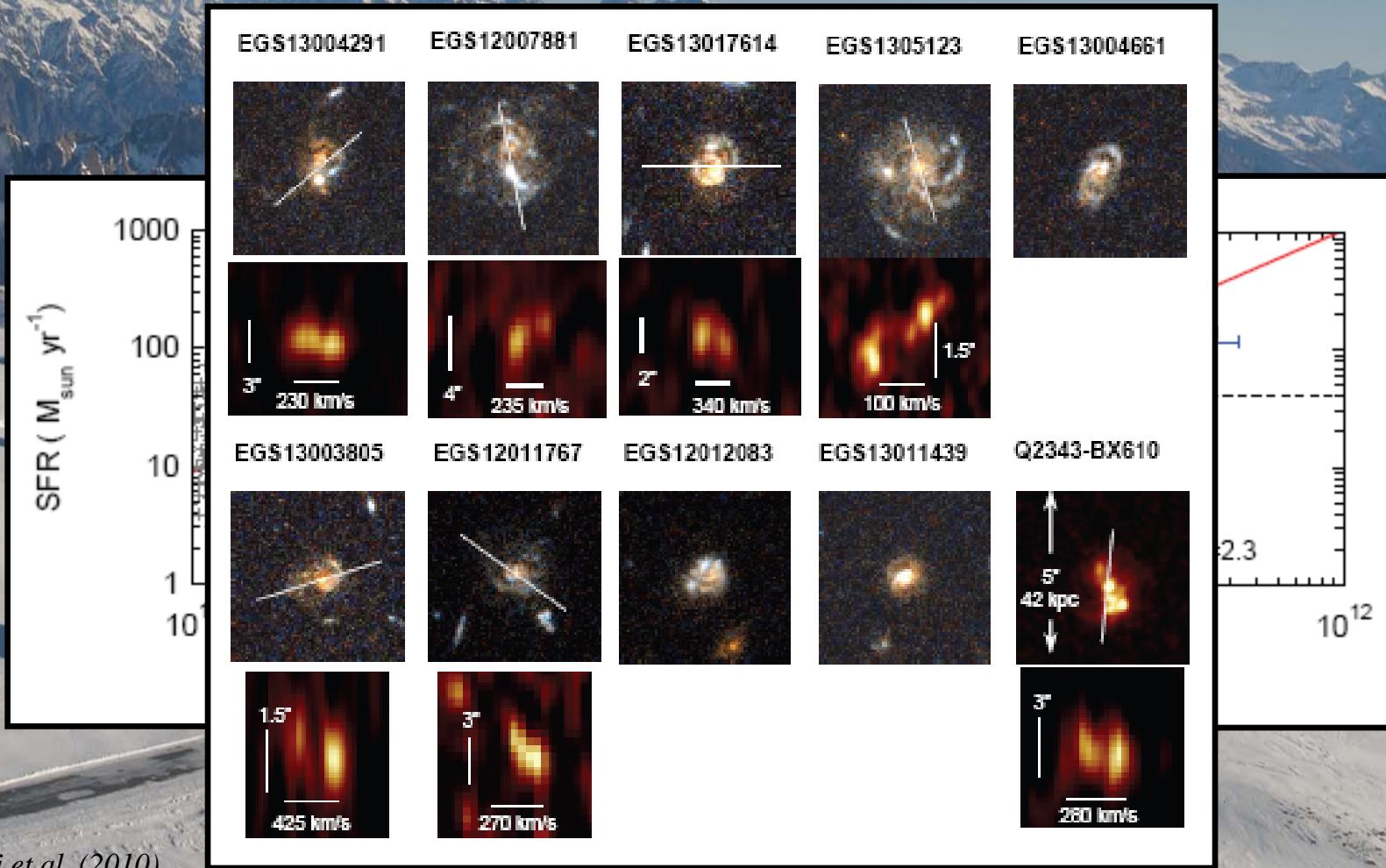
Mapping Molecular Gas in High z “Main Sequence” Star-forming Galaxies

- *CO survey of ~30 z ~ 1 – 2.5 Galaxies with IRAM/PdBI*

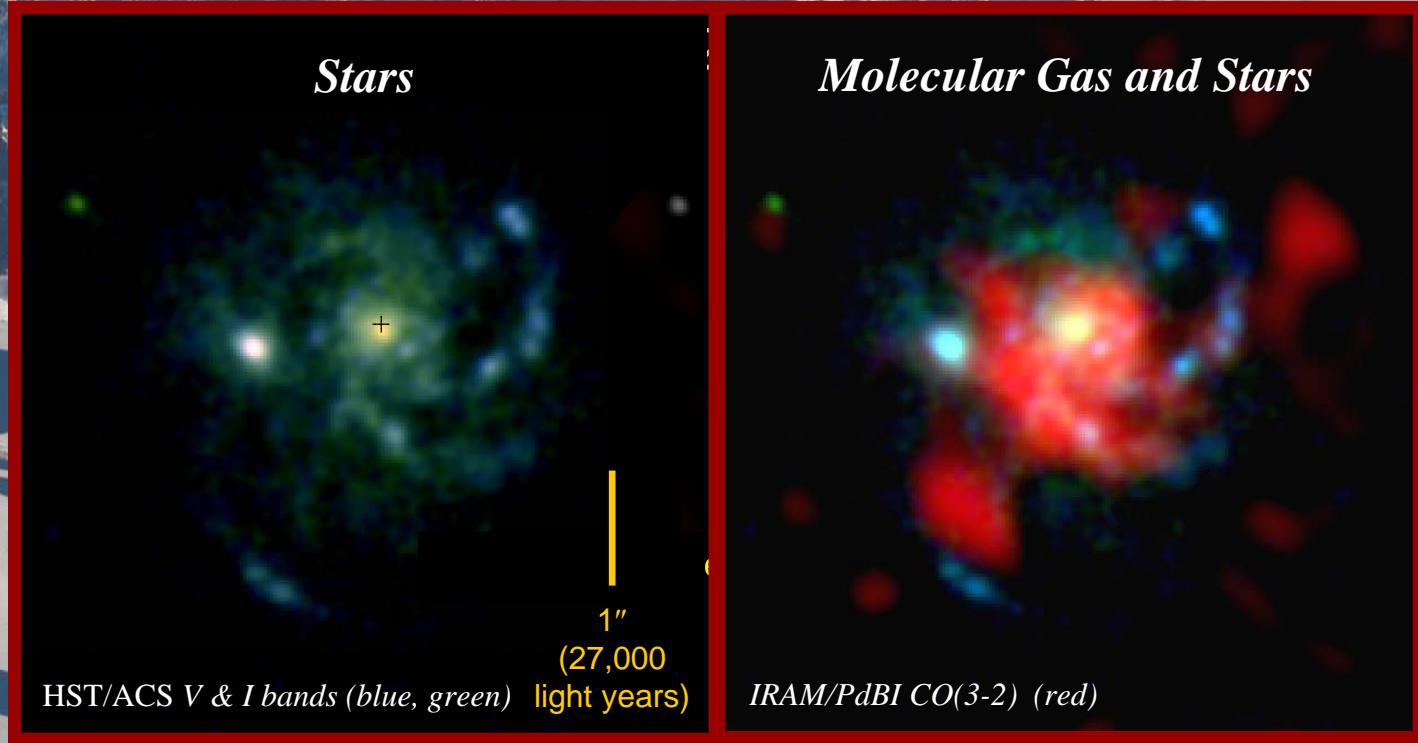


Mapping Molecular Gas in High z “Main Sequence” Star-forming Galaxies

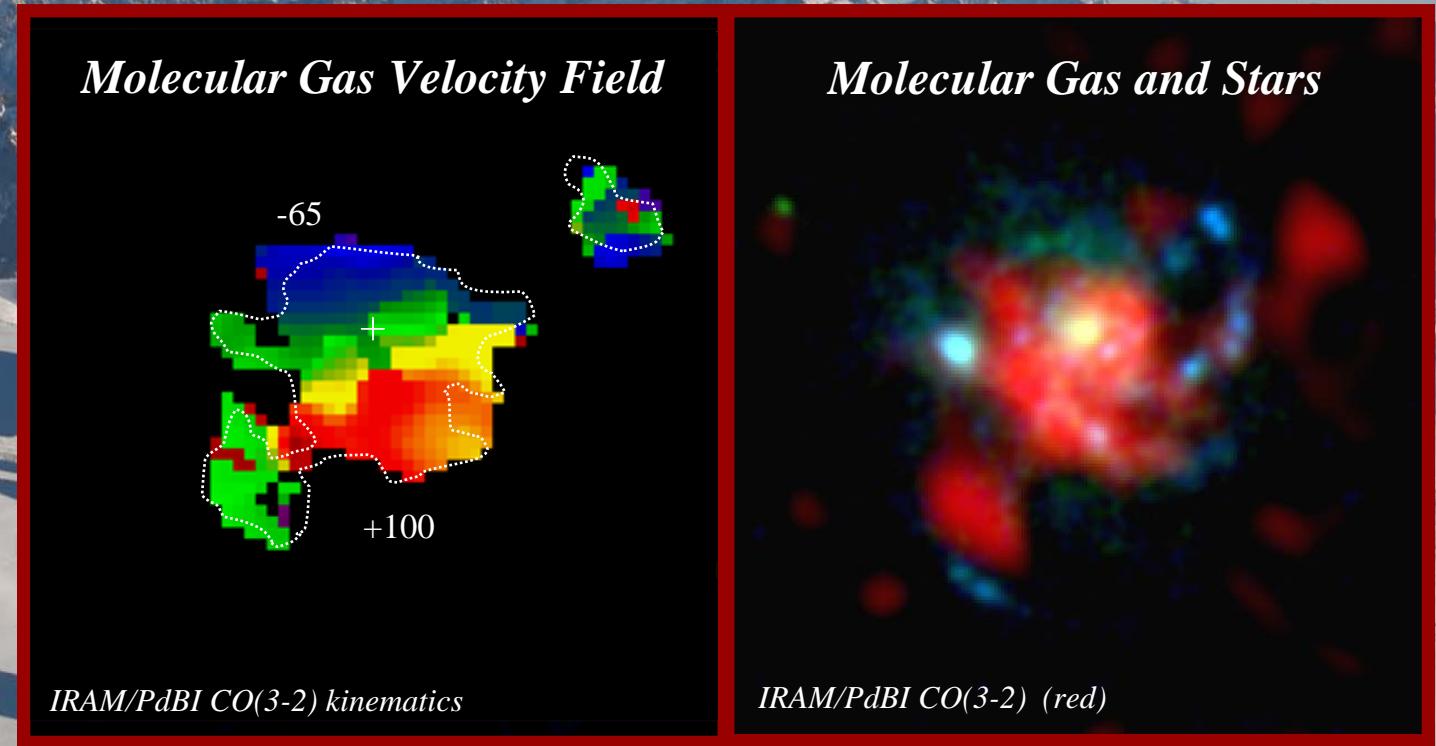
- CO survey of ~30 $z \sim 1 - 2.5$ Galaxies with IRAM/PdBI



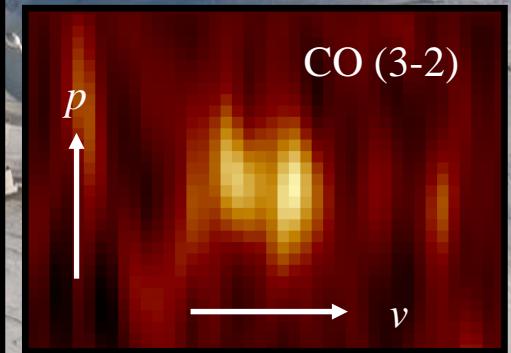
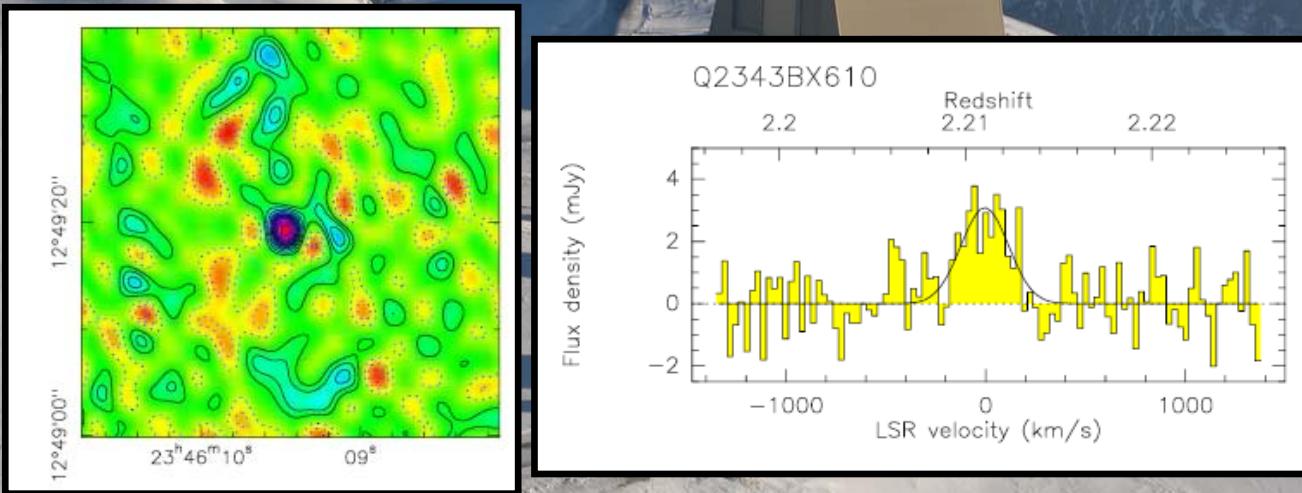
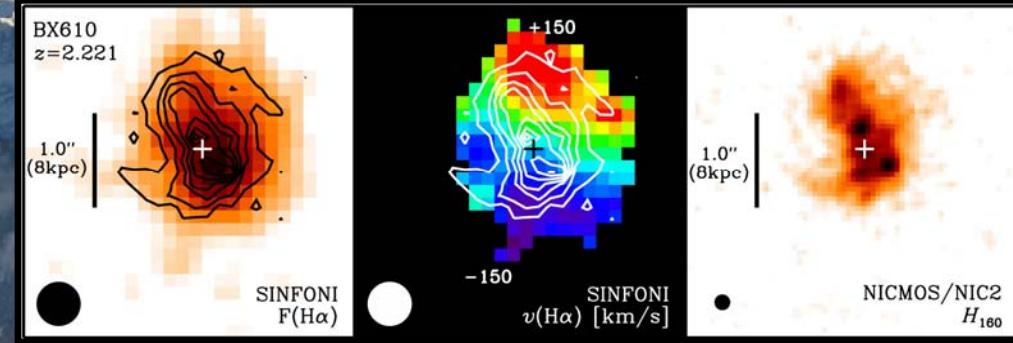
Mapping Molecular Gas in High z “Main Sequence” Star-forming Galaxies



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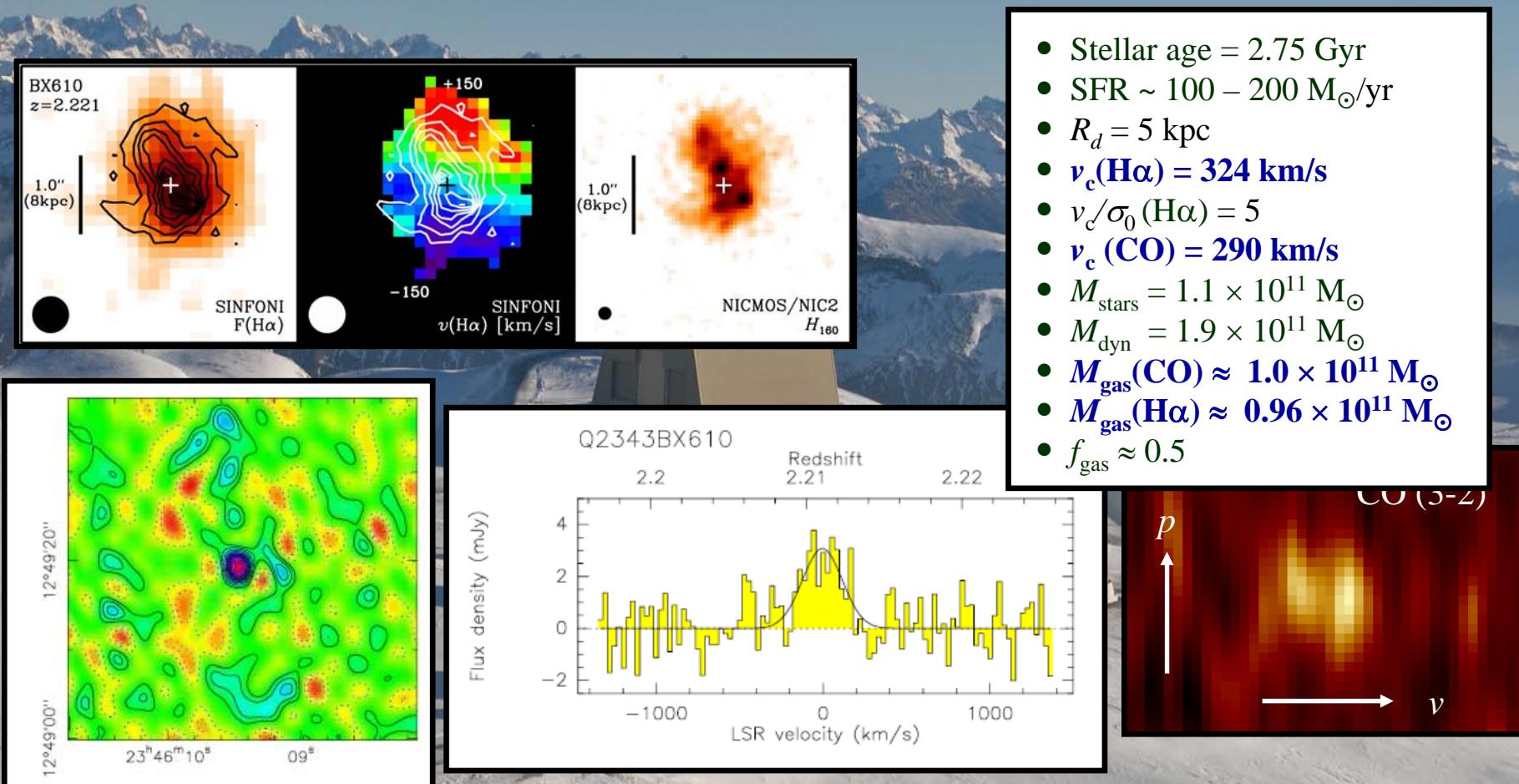
Mapping Molecular Gas in High z “Main Sequence” Star-forming Galaxies



Tacconi et al. (2010)

SINS: Förster Schreiber et al. 2006, 2009; Genzel et al. 2006, 2008; Bouché et al. 2007, Shapiro et al. 2008, Cresci et al. 2009

Mapping Molecular Gas in High z “Main Sequence” Star-forming Galaxies

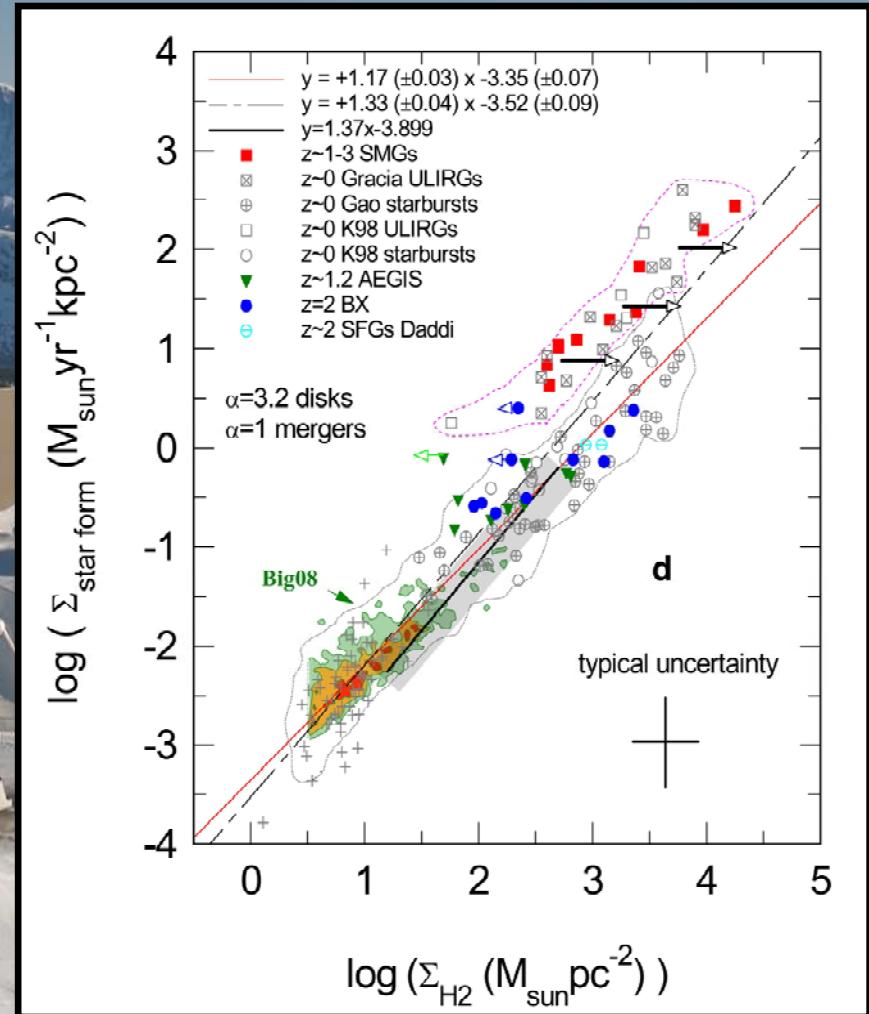
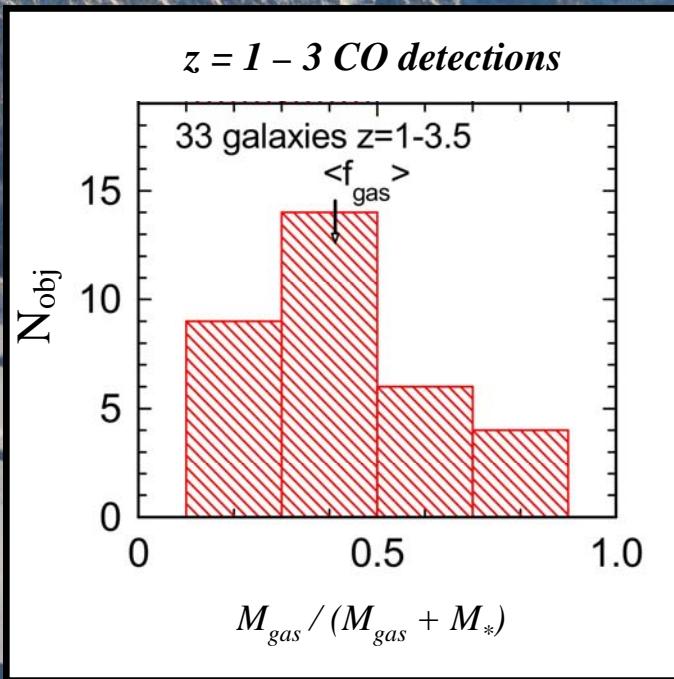


Tacconi et al. (2010)

SINS: Förster Schreiber et al. 2006,2009; Genzel et al. 2006,2008; Bouché et al. 2007, Shapiro et al. 2008, Cresci et al. 2009

High z Galaxies are very Gas-rich

- Gas mass fractions $\sim 40\%$ from CO measurements
- A universal Schmidt-Kennicutt law

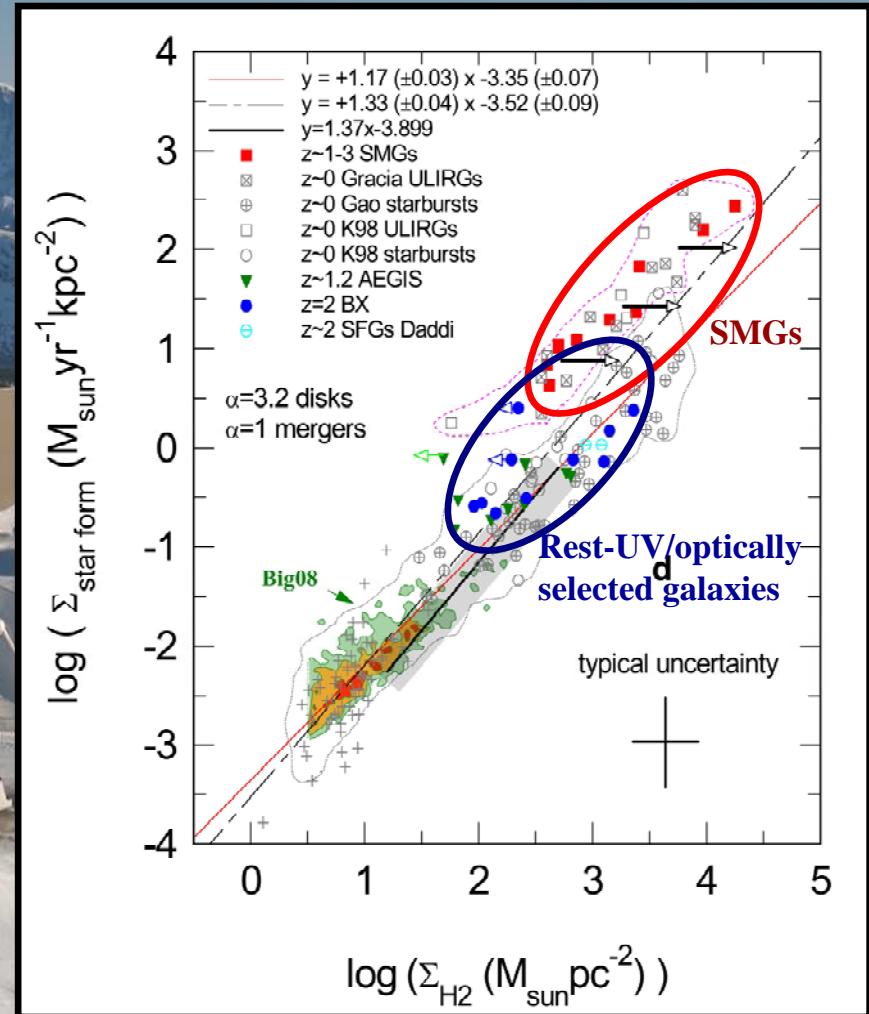
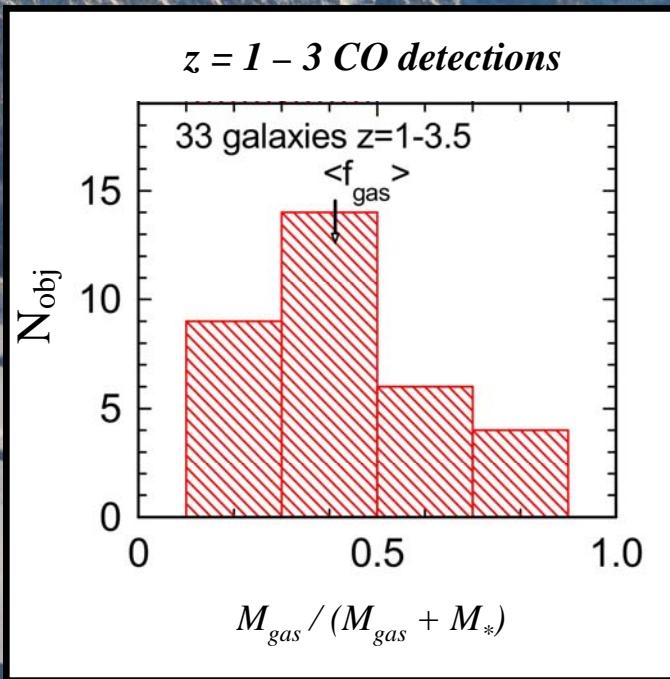


Tacconi et al. (2010)

Also: Baker et al. (2004); Coppin et al. (2007); Daddi, Dannerbauer, et al. (2007, 2008, 2009)

High z Galaxies are very Gas-rich

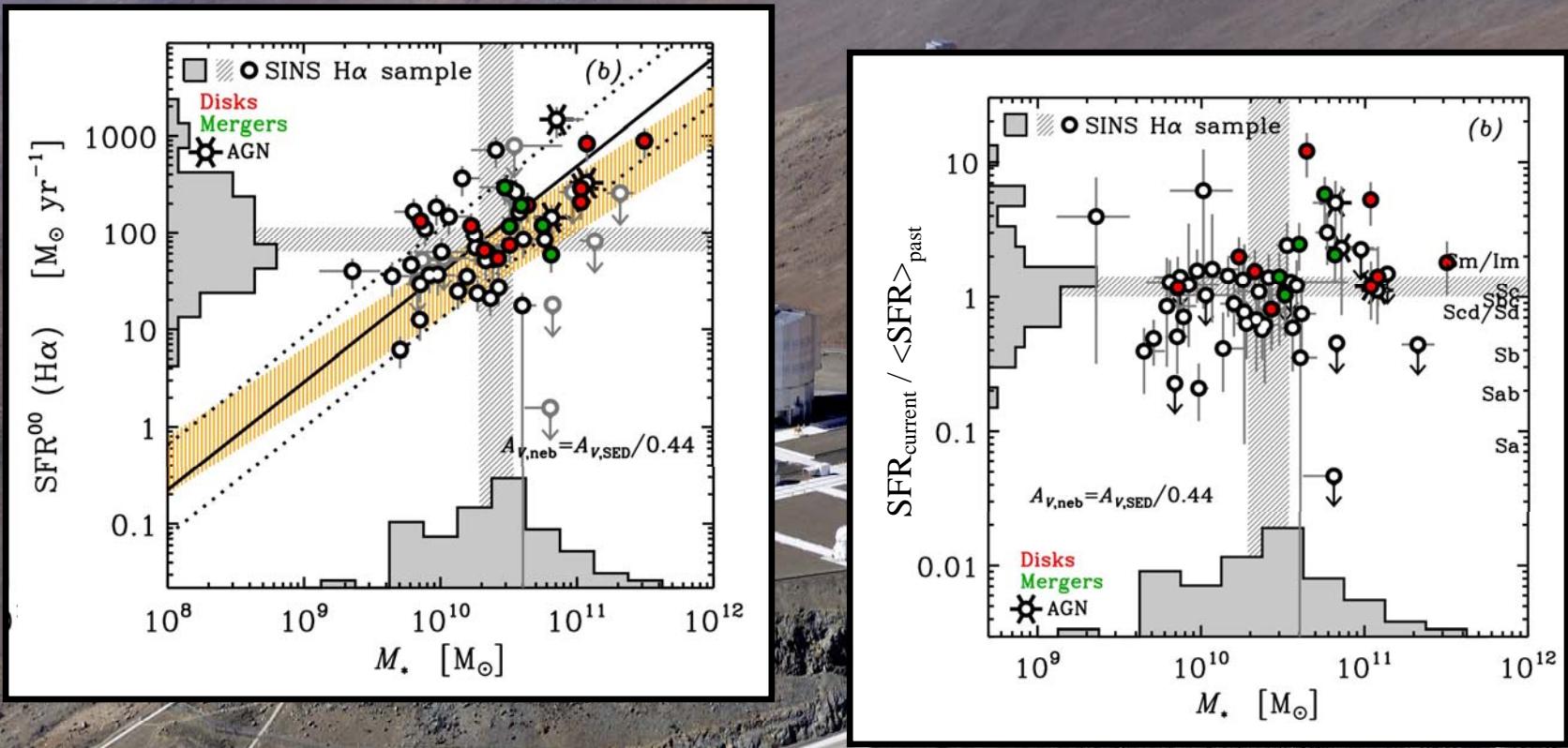
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Tacconi et al. (2010)

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Star Formation Activity

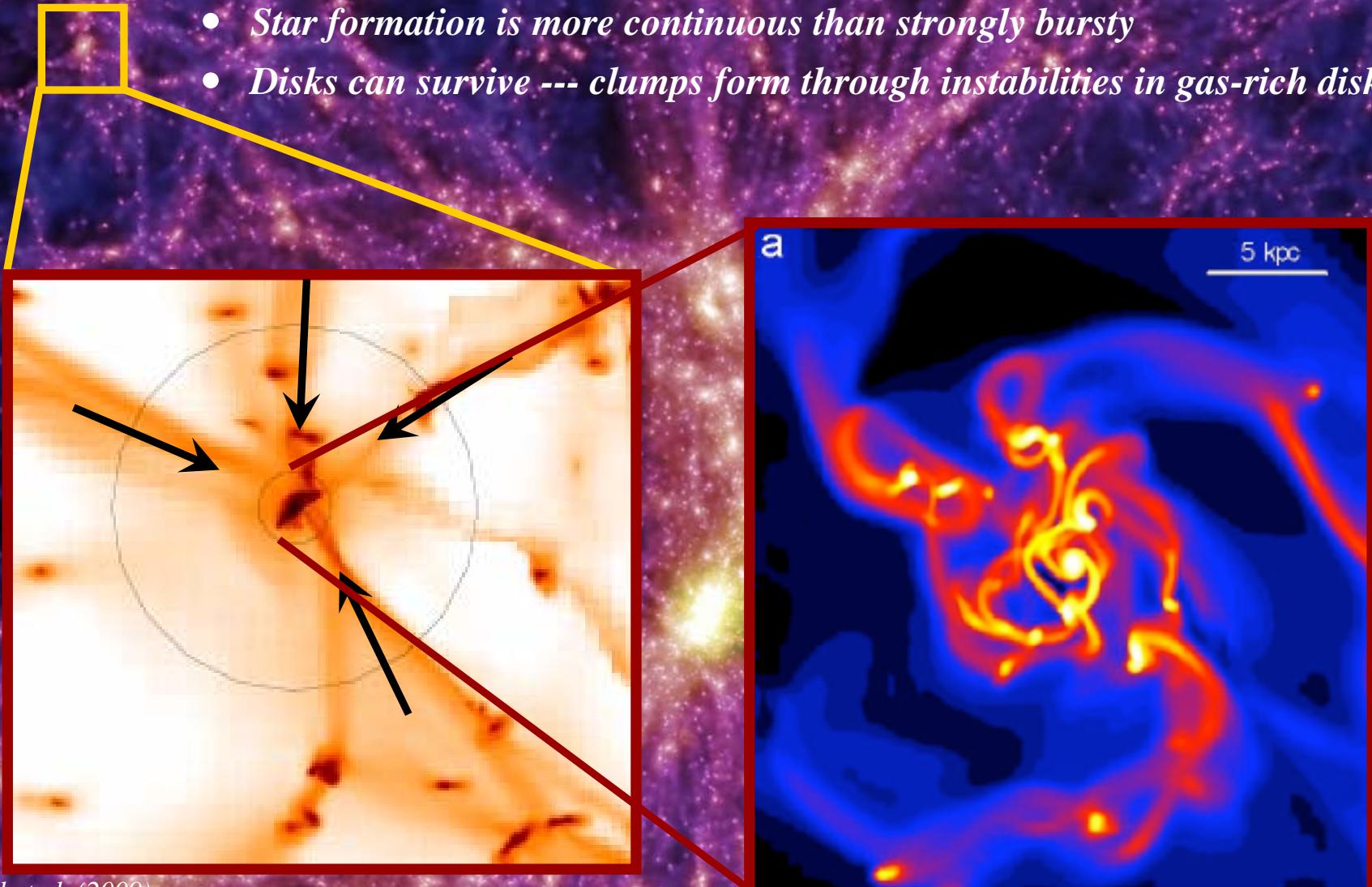


Förster Schreiber et al. (2009); Bouché et al. (2010)

See also, e.g., Daddi et al. (2007); Noeske et al. (2007); Elbaz et al. (2007); Davé (2008); Genzel et al. (2008); Kennicutt et al. (1994); Davé (2008); Chen et al. (2009); Damen et al. (2009)

Steady Accretion and Internal Evolution

- “Cold flowsstreams” regime of smooth gas accretion and minor mergers
- Star formation is more continuous than strongly bursty
- Disks can survive --- clumps form through instabilities in gas-rich disks



Star Formation at High Redshift

- Prime tracers ($H\alpha$, CO) can now be resolved in 3D at $z \sim 1 - 3$
- Smooth & continuous accretion modes are important in driving star formation activity / mass assembly at high z
- Schmidt-Kennicutt law appears to hold at $z \sim 1 - 3$

