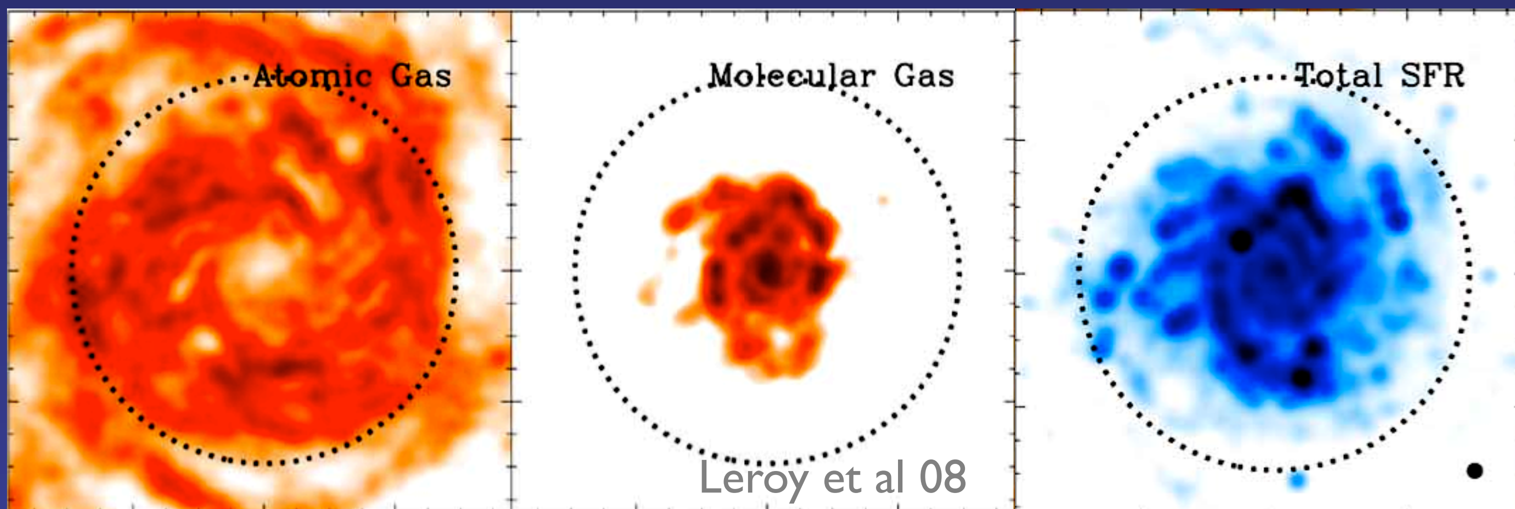
Molecular Hydrogen in Simulations of Dwarf Galaxies

Charlotte Christensen
University of Washington

Tom Quinn, Fabio Governato,
James Wadsley, Alyson Brooks, Adrienne Stilp

H_2 in Dwarf Galaxies

- Dwarfs are an extreme environment for SF



- SF traces H_2 *better than* HI and total H
  (for example, Bigiel et al 08)
- H_2 important coolant at 200 K < T < 3000 K
  (Glover & Abel 08, Gnedin et al 10)

H_2 in Dwarf Galaxies

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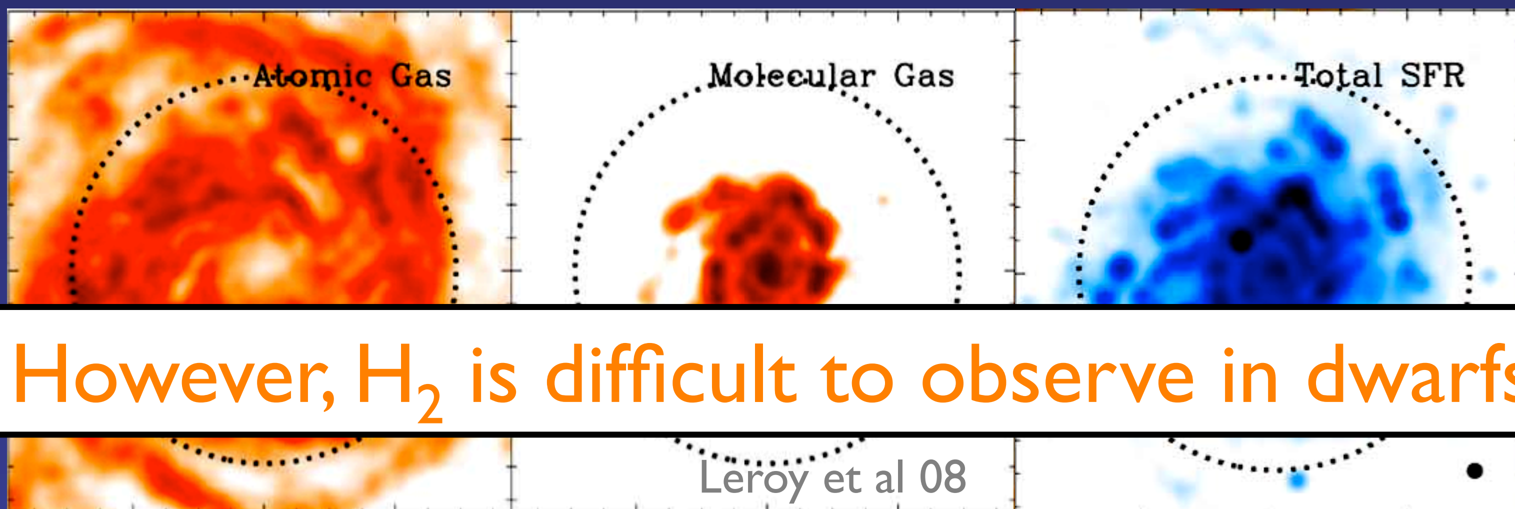

However, H_2 is difficult to observe in dwarfs

- SF traces H_2 *better than* HI and total H
  (for example, Bigiel et al 08)
- H_2 important coolant at 200 K < T < 5000 K
  (Glover & Abel 08, Gnedin et al 10)

Simulations of H_2 In Galaxies

- Until recently, most simulations of galaxies did not include H_2
- New Simulations with GMCs/H_2
  (Gnedin et al 09, 10a, 10b, Papadopoulos & Pelupessy10, Pelupessy et al 06, Pelupessy & Papadopoulos 09, Robertson & Kravtsov 08)
  - Link H_2, metallicity and Kennicutt-Schmidt Law

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  - Link H_2, metallicity and Kennicutt-Schmidt Law

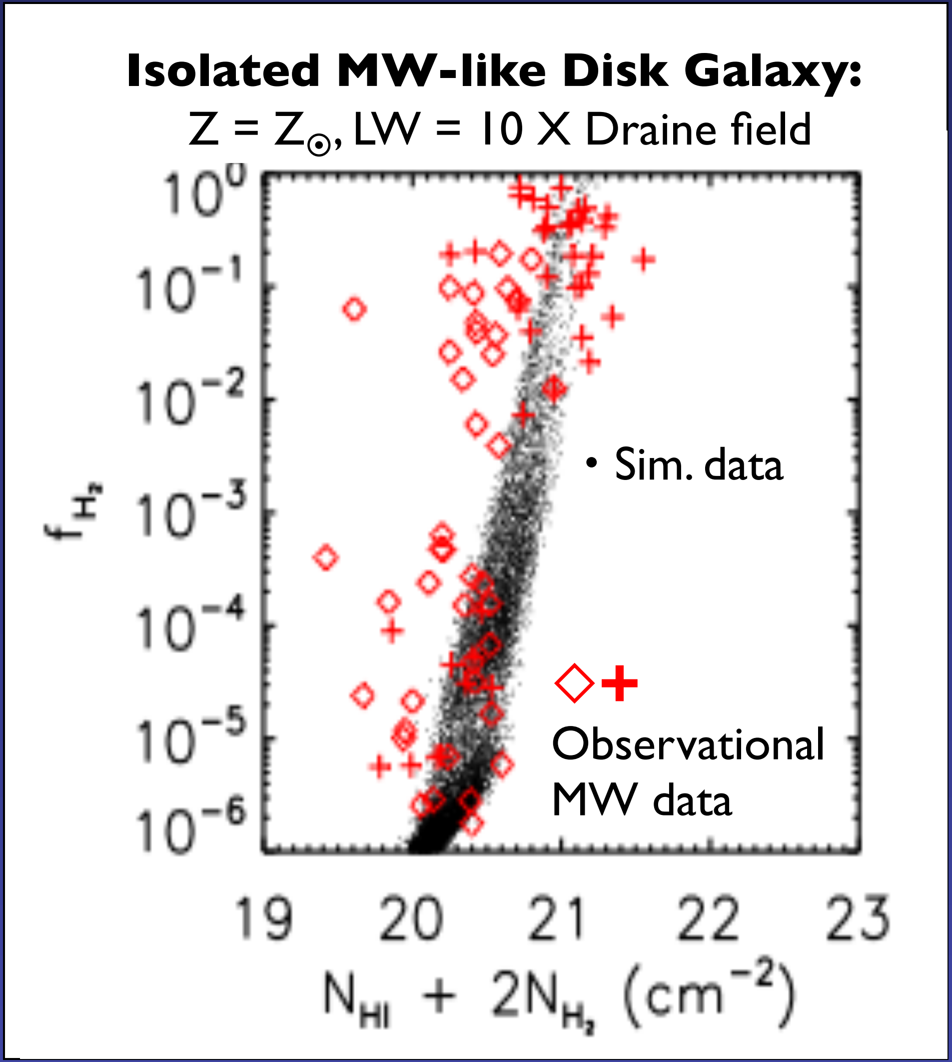
- H_2 in cosmological sims. to z=0

The Code

- Gasoline (Wadsley et al 04), an SPH code with
  - Cosmic UV background radiation
  - H & He ionization
  - Metal cooling
  - Metal diffusion
  - Star formation
  - Supernovae feedback
- Which reproduces
  - Damped Lyman-α systems (Pontzen et al 08, 10)
  - Mass-metallicity relation (Brooks et al 07)
  - Broken exponential disks in spirals (Roskar et al 08)
  - HI holes
  - Tully-Fisher relation (Governato et al 07)
  - Realistic dwarfs (Governato et al 10)

H_2 Implementation

- H_2 abundances per particle
  - Integrated through simulation
  - Non-equilibrium
  - Based on local formation and destruction rates



(FUSE, Gillmon et al. 06 & Wolfire et al. 08)

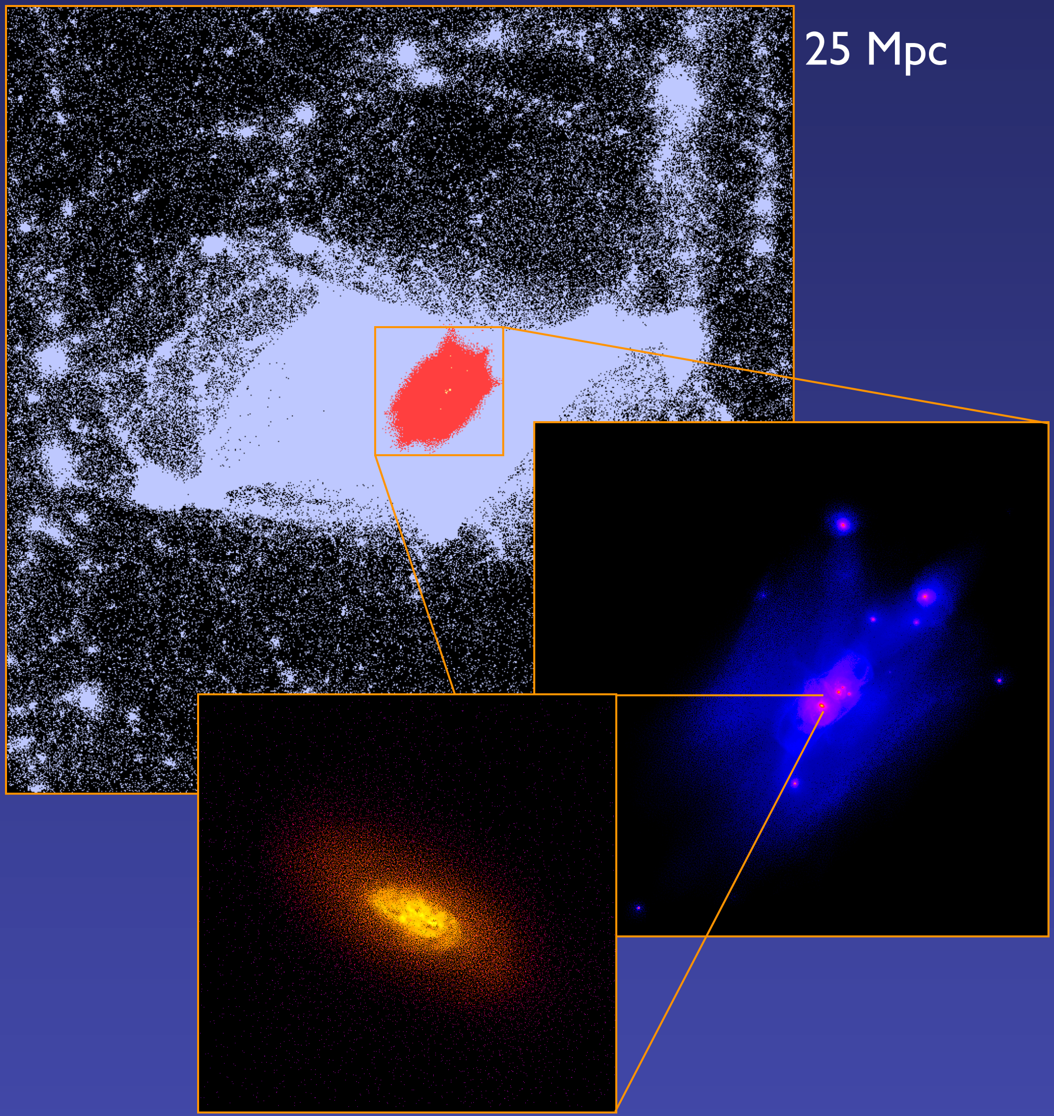
Formation and Destruction

- Forms on dust (metals) (Wolfire et al 08)
  - Metallicity
  - Density
  - Gas clumpyness (McKee & Ostriker et al 07)

- Destroyed by LW radiation
  - Flux from local young stars
- Self-shielding and shielding by dust (Draine & Bertoldi 96)
  - Column length/density (Pavlovski et al 02)
  - Metallicity

A Dwarf Galaxy Simulated 4 Ways

- ΛCDM cosmology
- Zoomed-in initial conditions
- Final Galaxy:
  - $M_{vir} = 4 \times 10^{10}\, M_{\odot}$
  - $V_{200} = 58$ km/s
- Resolution
  - $M_{gp} \approx 4 \times 10^{4}\, M_{\odot}$
  - $h \geq 30$pc in disk



Star-Formation Law

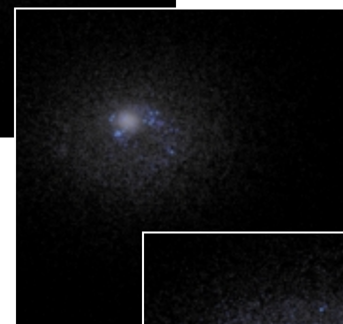
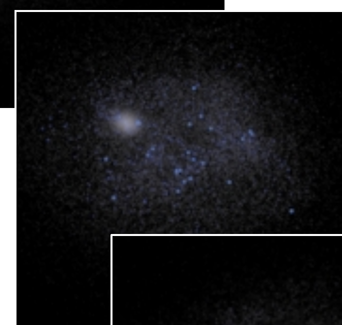
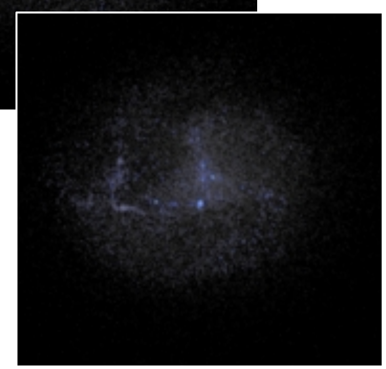
- Probabilistic, based on local gas properties

- Formation time: $t_{dyn} \propto \rho^{-1/2}$
- Efficiency: c*
- Threshold density allowed: ρ_{min}

(Stinson et al 06)

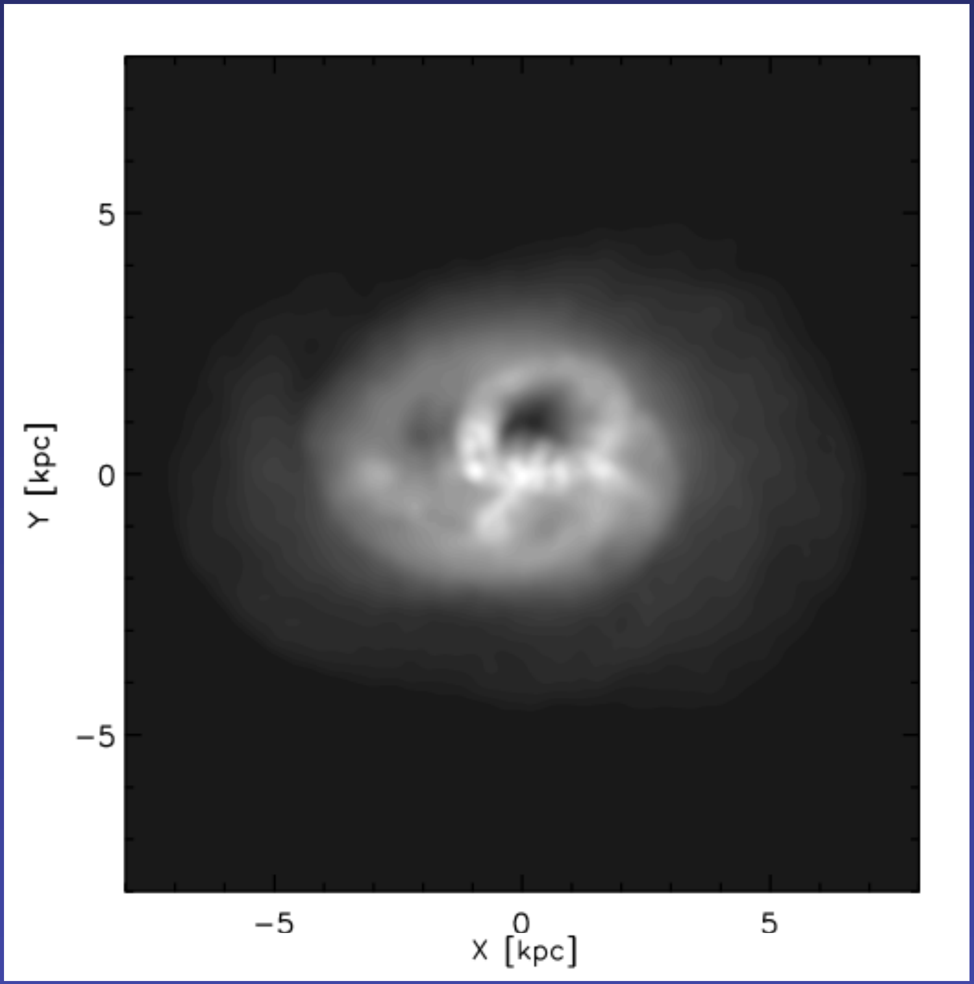
Comparing Four Simulations

- No H_2, Standard SF
  - $c^* = 0.1$, $\rho_{min} = 10$ amu/cc
- H_2, Standard SF
  - $c^* = 0.1$, $\rho_{min} = 10$ amu/cc
- H_2, H_2 based SF
  - $c^* = H_2/(HI + H_2)\ 0.1$, $\rho_{min} = 0.1$ amu/cc
- H_2, High-H_2 based SF
  - $c^* = H_2/(HI + H_2)\ 0.1$, $\rho_{min} = 0.1$ amu/cc,
  - $H_2/(HI + H_2) \geq 0.1$

Reproducing the Resolved Kennicutt-Schmidt Law at z=0

- HI
  - Mock THINGS (Walter et al 08) observation



Reproducing the Resolved Kennicutt-Schmidt Law at z=0

- HI
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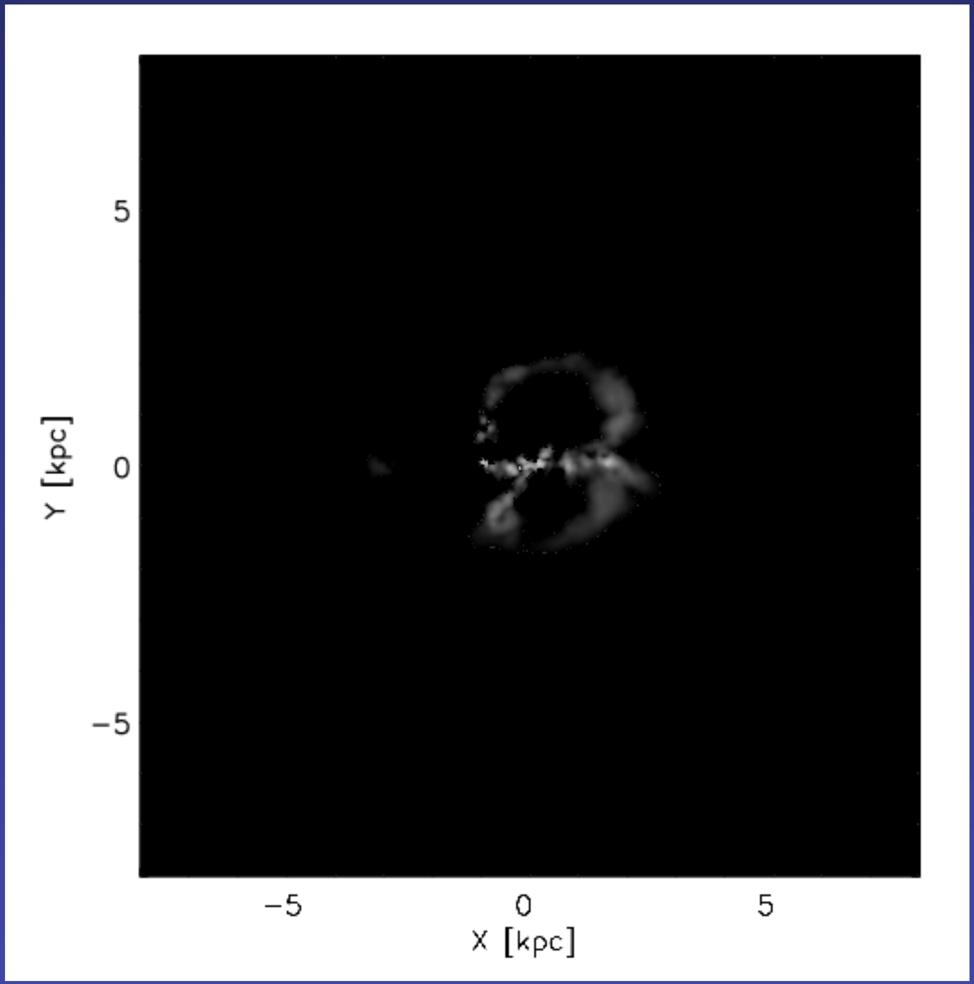
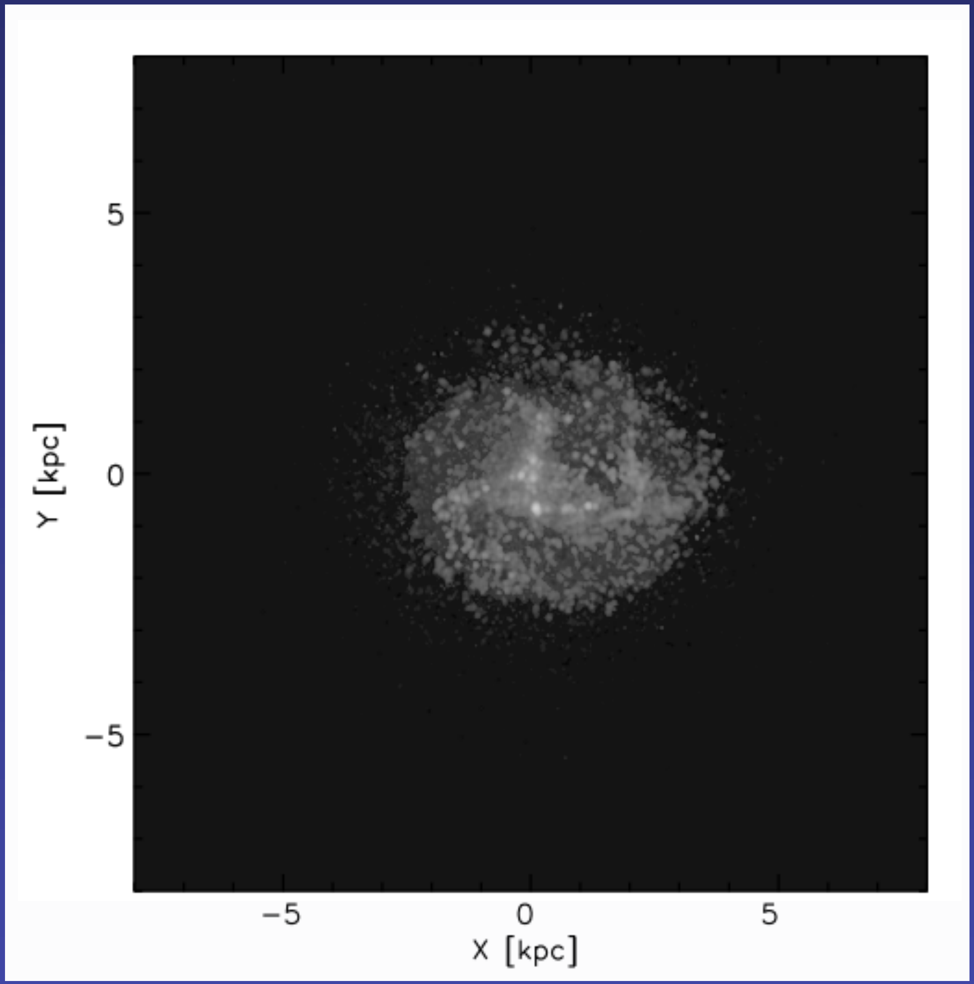
- H_2



Reproducing the Resolved Kennicutt-Schmidt Law at z=0

- HI
  - Mock THINGS (Walter et al 08) observation
- H_2
- SFR
  - Mock FUV and 24μm observations

Sunrise, Jonsson 06



Reproducing the Resolved Kennicutt-Schmidt Law at z=0

Bigiel et al 08

- HI
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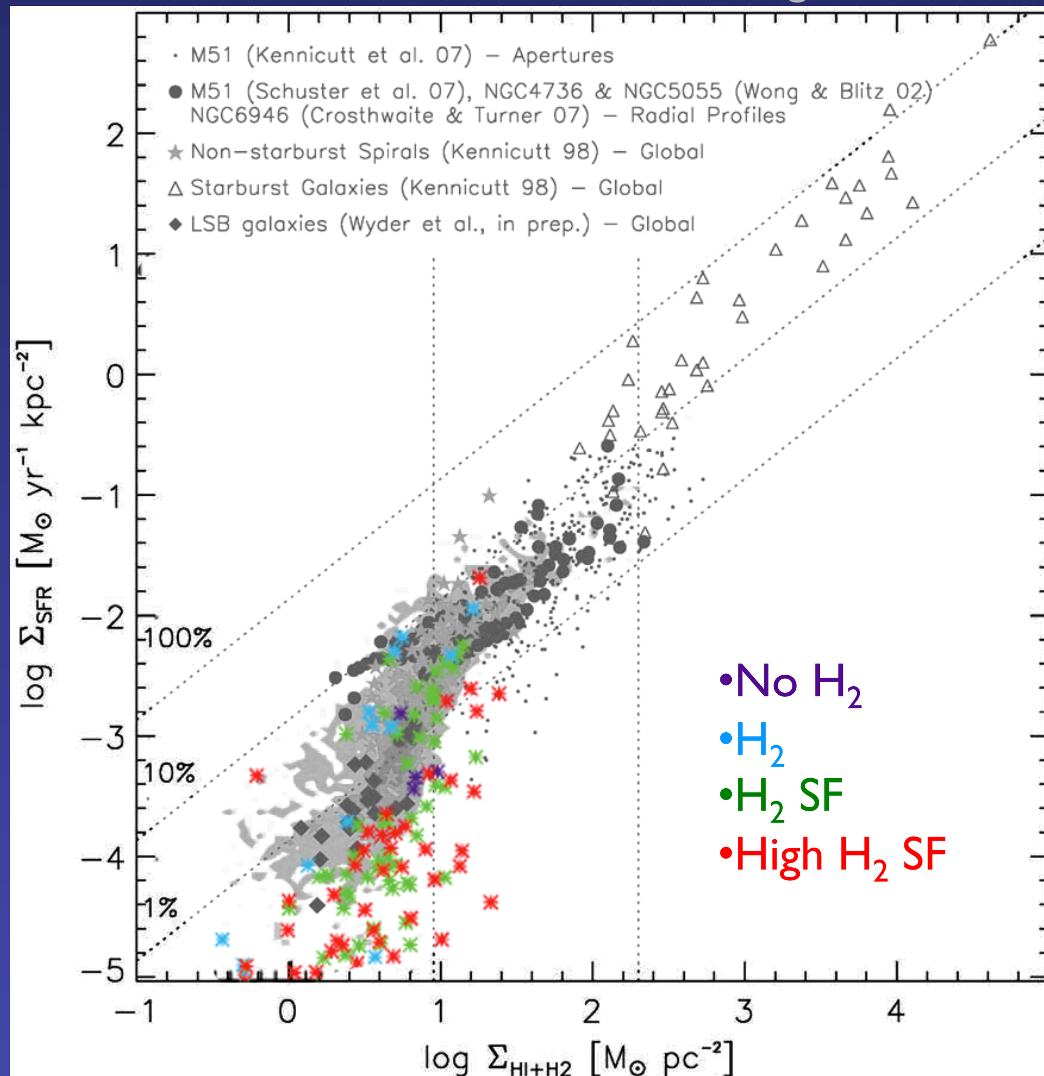
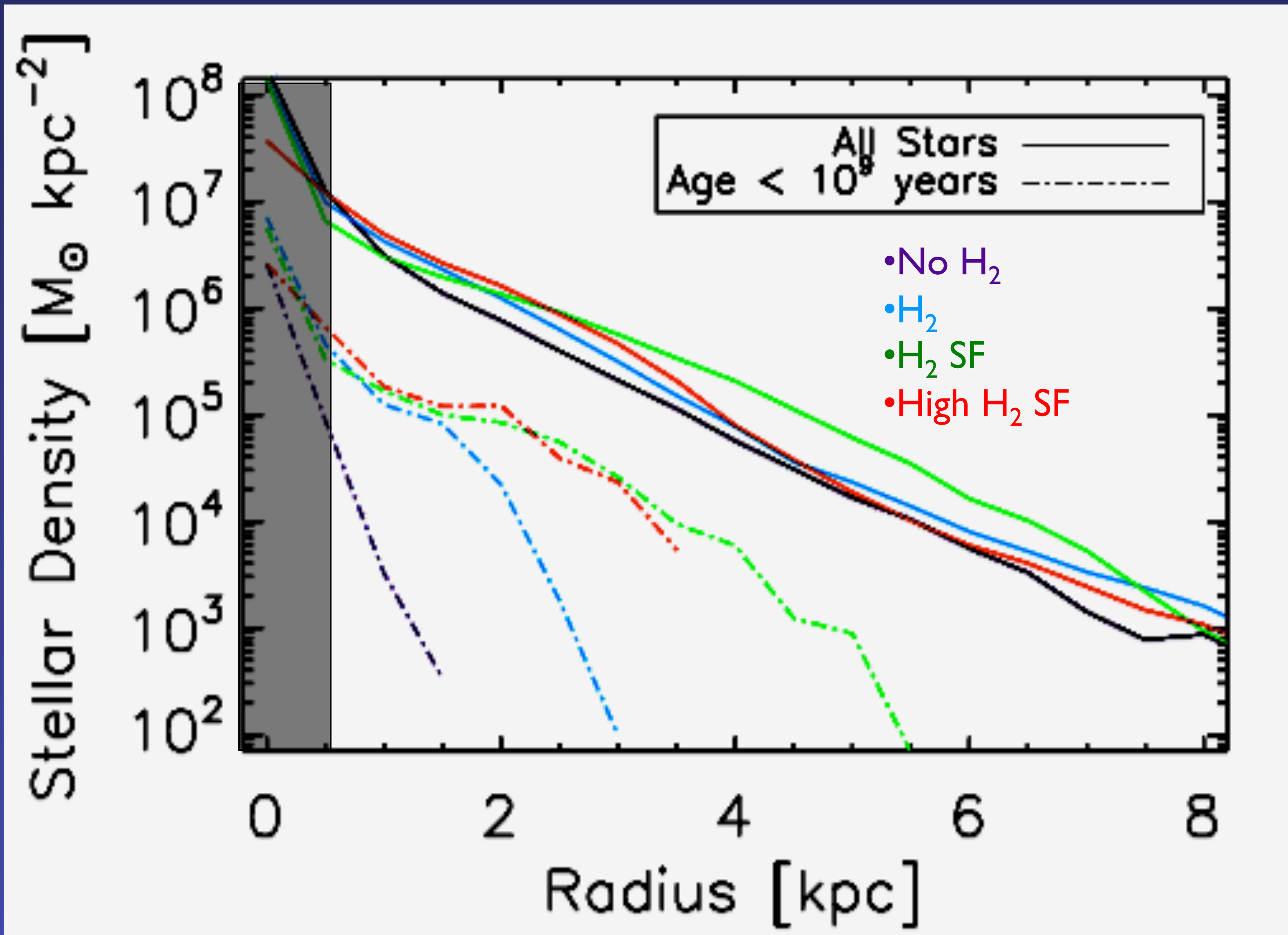
- H_2
- SFR
  - Mock FUV and 24μm observations



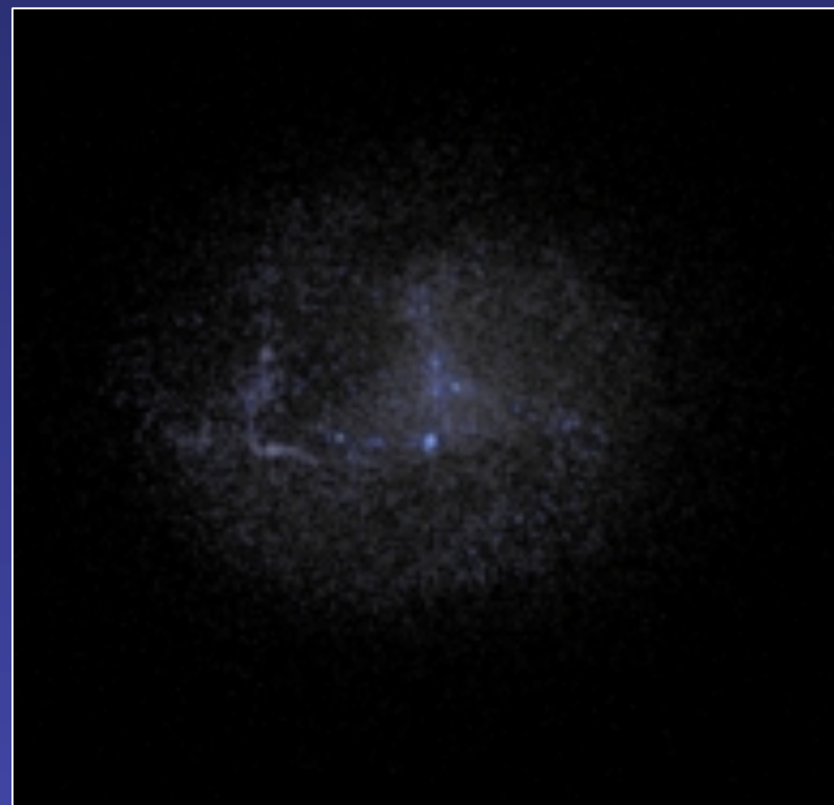
Stellar Profiles



Stellar Profiles

No H_2

High H_2 SF



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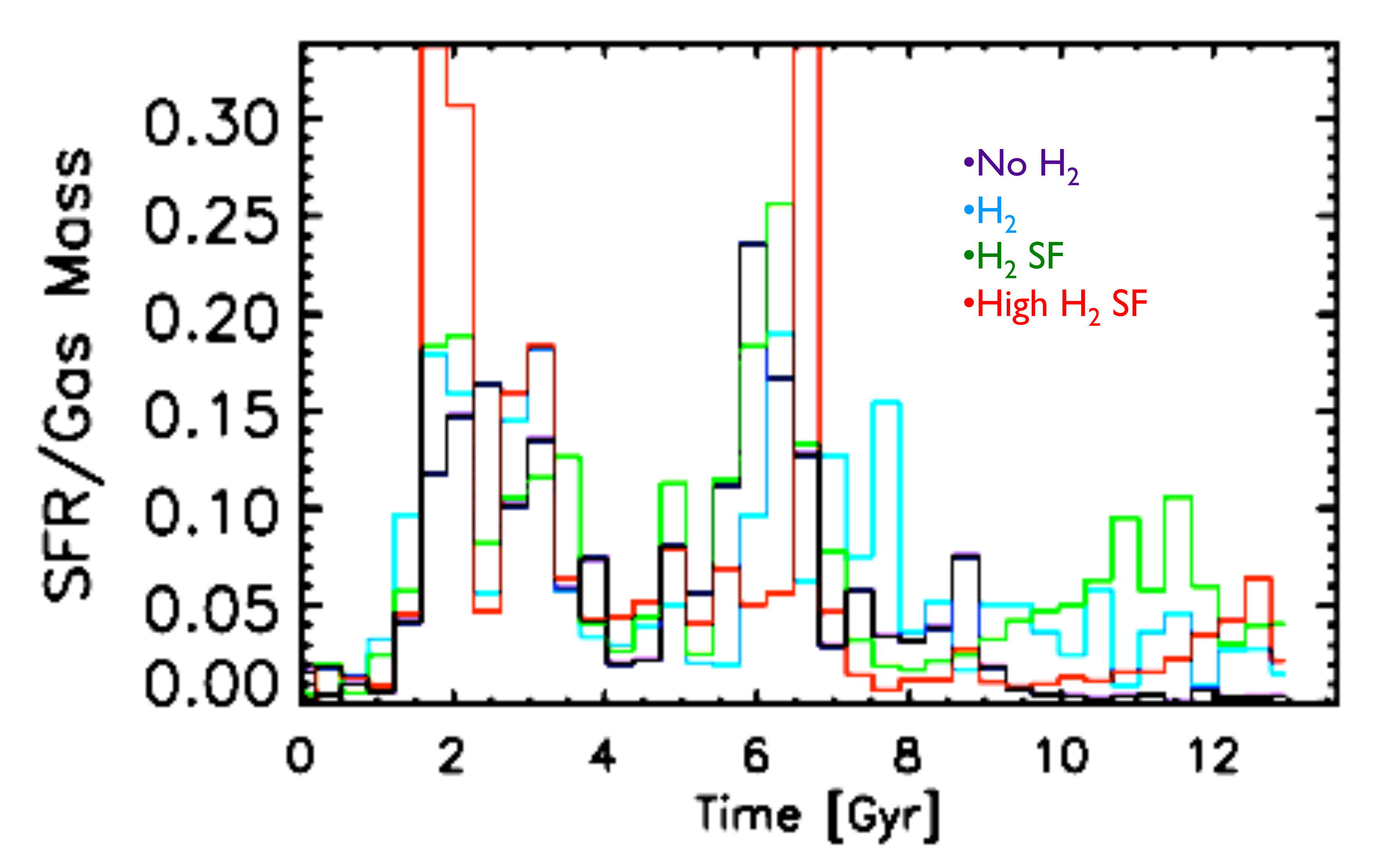
Star-Formation Histories



Conclusions

- More accurate modeling of physics
- Resolved Kennicutt- Schmidt Law similar in all simulations
- H_2 extends young stellar disks
- H_2 extends SFH

Future Work

- Star formation maps at high redshift
- Wider range of galaxy masses at similar or higher resolution
  - Scaling relations
- Increasing mass resolution
  - Mock CO observations
- Comparisons to ALMA