Star Formation and Feedback in Simulations with Molecular Hydrogen

Charlotte Christensen
University of Arizona
Tom Quinn, Fabio Governato, Romeel Dave
Alyson Brooks, Sijing Shen, James Wadsley

Motivation

- How does the structure of the ISM affect gas loss from supernova feedback?
  - Compare three different ISM models – primordial cooling, metal-line cooling, metal-line cooling + H_2
- How are star formation, H_2 and supernova feedback related over cosmic time
  - Compare histories of dwarf and spiral galaxies simulated with H_2

Implementing Molecular Hydrogen

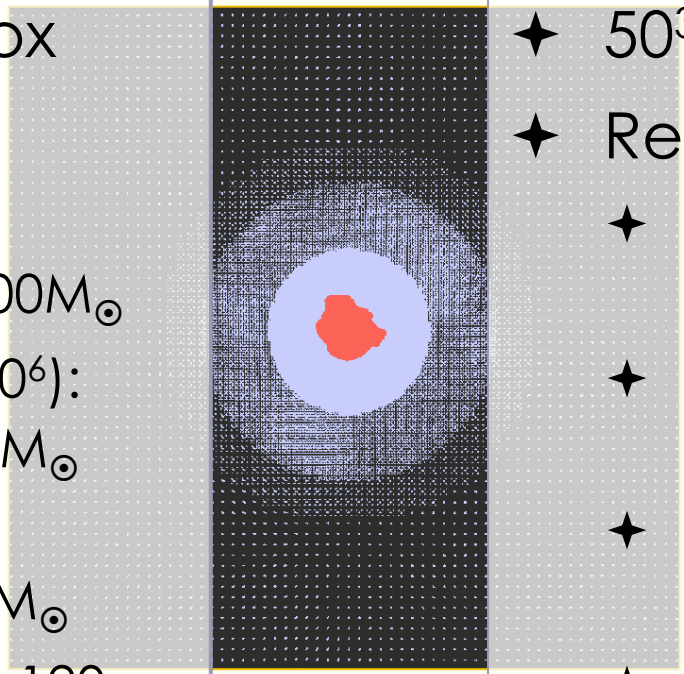
- GASOLINE (Wadsley+, 2003)
  - Metal line cooling (Shen+ 2010)
  - Star formation based on free-fall time
  - Supernovae feedback (blastwave) (Stinson+ 2006)
- Non-equilibrium H_2 abundances for particles
  - Integrated through simulation based on local formation and destruction rates (Gnedin et al., 2009)
  - Formation on dust grains
  - Lyman-Werner Radiation
  - Shielding of H_2 and HI
  - Other gas-phase physics: H_2 cooling, collisional dissociation, formation via H^-
  - H_2-based star formation

Implementing Molecular Hydrogen

- GASOLINE (Wadsley+, 2003)
  - Metal line cooling (Shen+ 2010)
  - Star formation based on free-fall time
  - Supernovae feedback (blastwave) (Stinson+ 2006)
- Non-equilibrium H_2 abundances for particles
  - Integrated through simulation based on local formation and destruction rates (Gnedin et al., 2009)
  - Formation on dust grains
  - Lyman-Werner Radiation
  - Shielding of H_2 and HI
  - Other gas-phase physics: H_2 cooling, collisional dissociation, formation via H^-
- H_2-based star formation

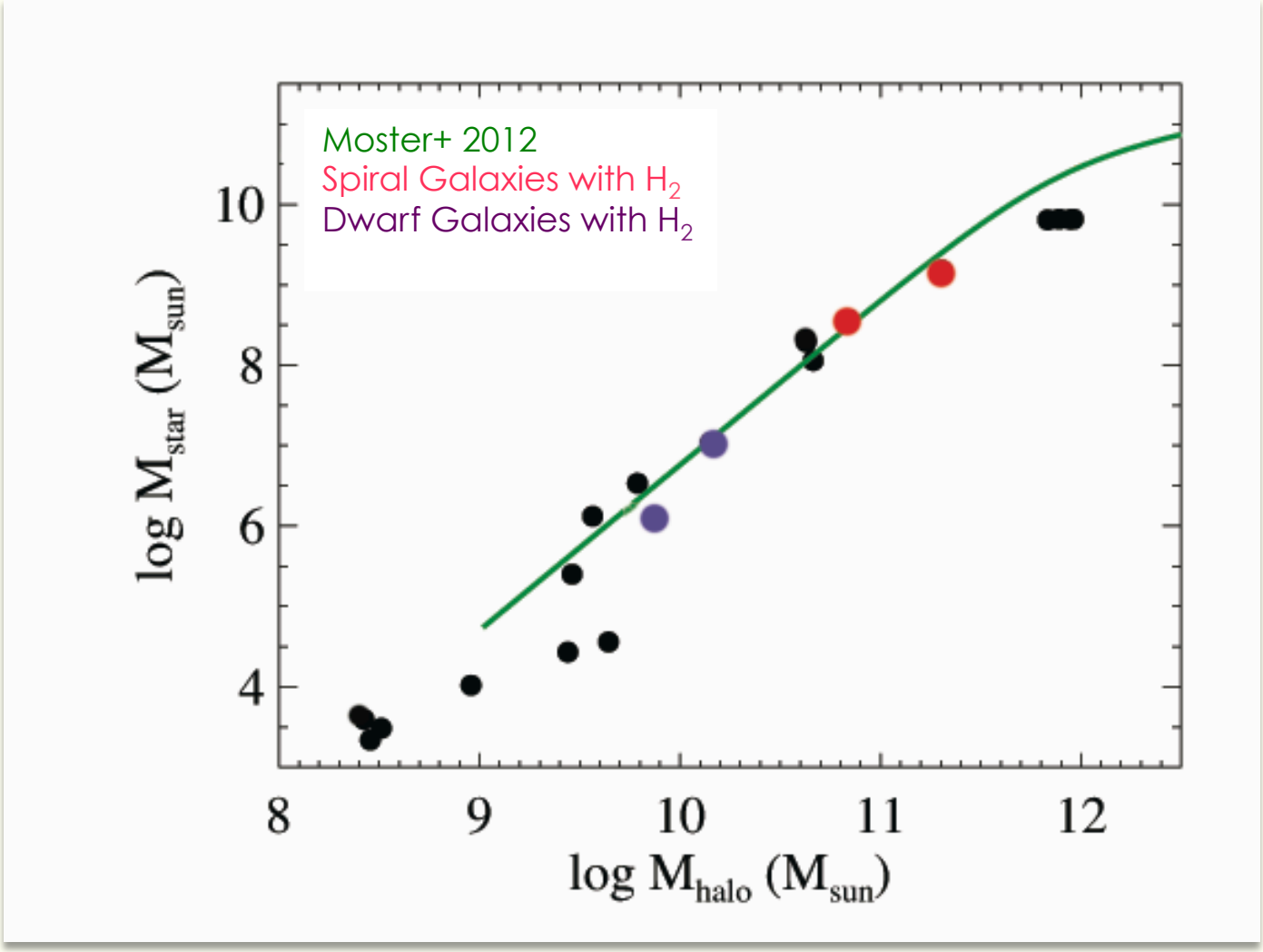
Initial Conditions

- 2 Dwarf Galaxies
- 25^3 Mpc^3 Box
- Resolution
  - DM (10^7): $m_p = 16{,}000 M_\odot$
  - Gas (6×10^6): $m_g = 3300 M_\odot$
  - Star: $m_s = 1000 M_\odot$
  - Softening: 120 pc
  - Smoothing: ~60 pc in disk



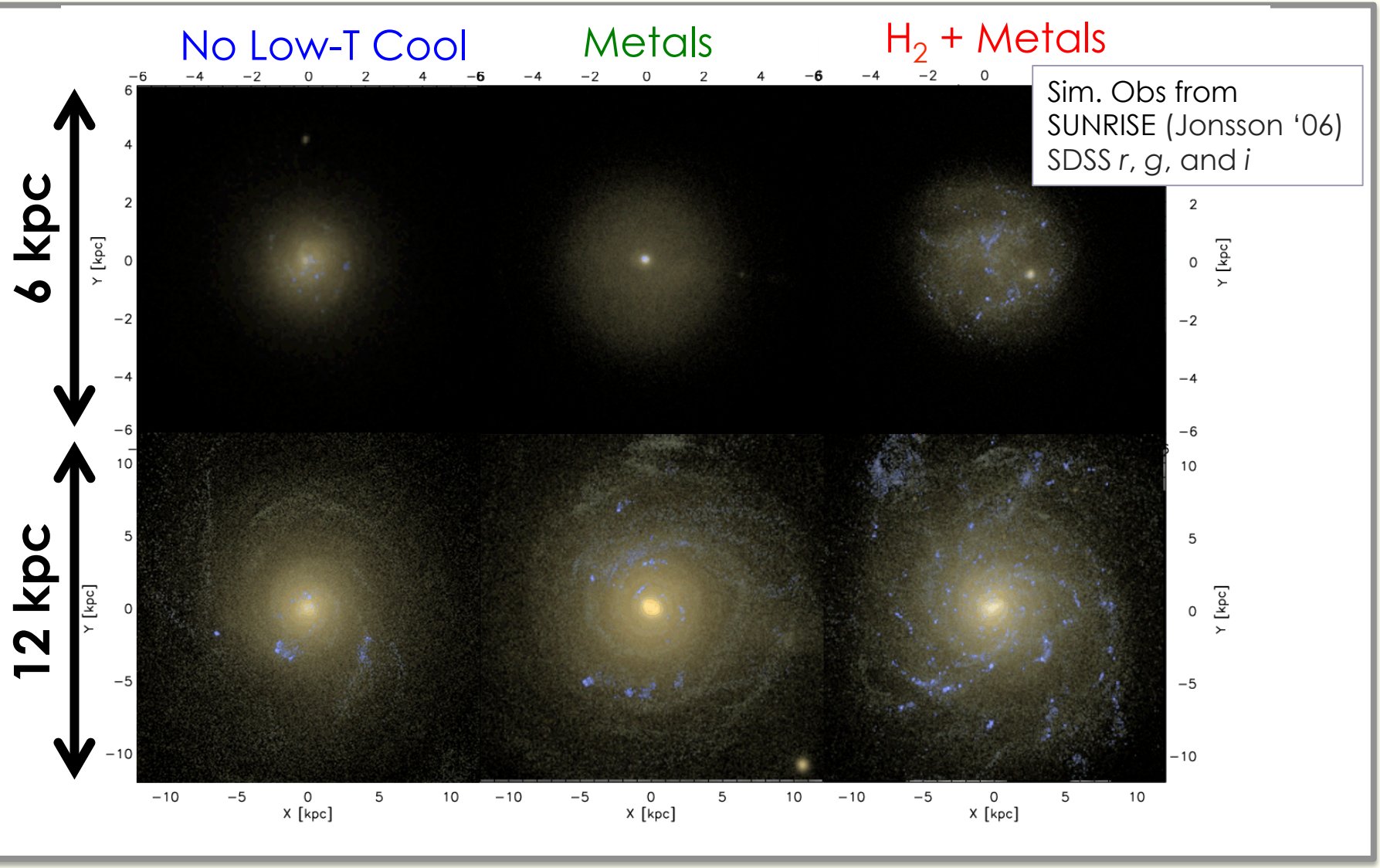
- 2 Spiral Galaxies
- 50^3 Mpc^3 Box
- Resolution
  - DM (10^7): $m_p = 128{,}000 M_\odot$
  - Gas (6×10^6): $m_g = 25{,}000 M_\odot$
  - Star: $m_s = 8000 M_\odot$
  - Softening: 230 pc
  - Smoothing: ~100 pc in disk

Galaxies on z = 0, M_{star}–M_{halo} Relation

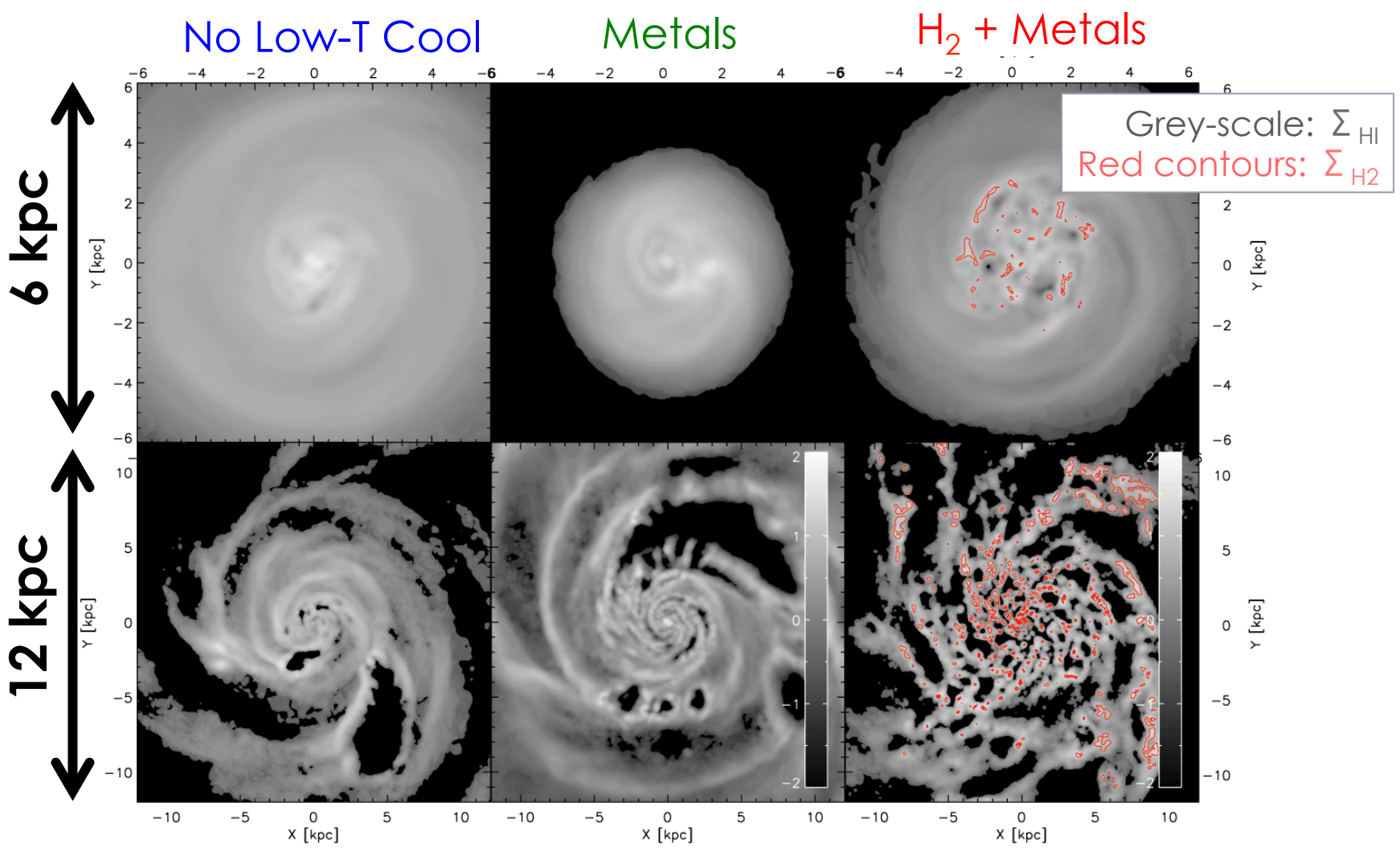


Munshi et al, *in prep*

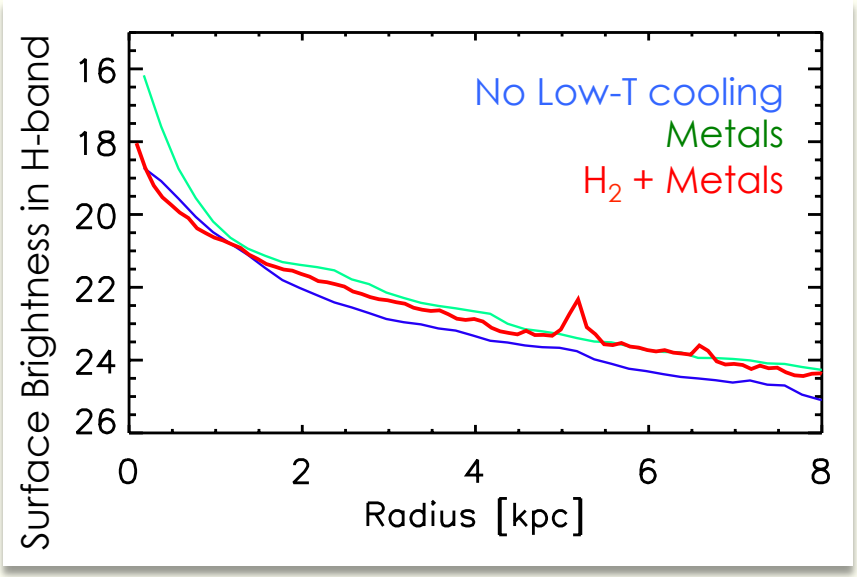
Simulated Observations

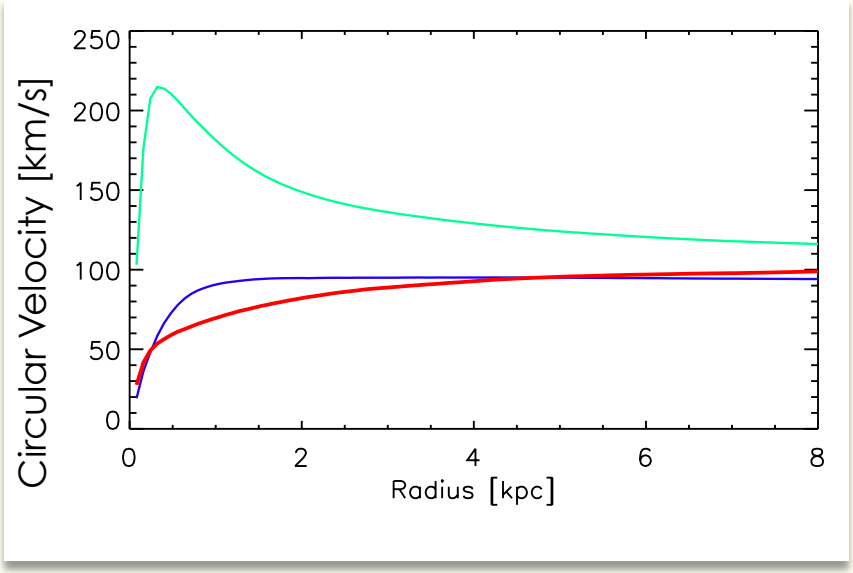


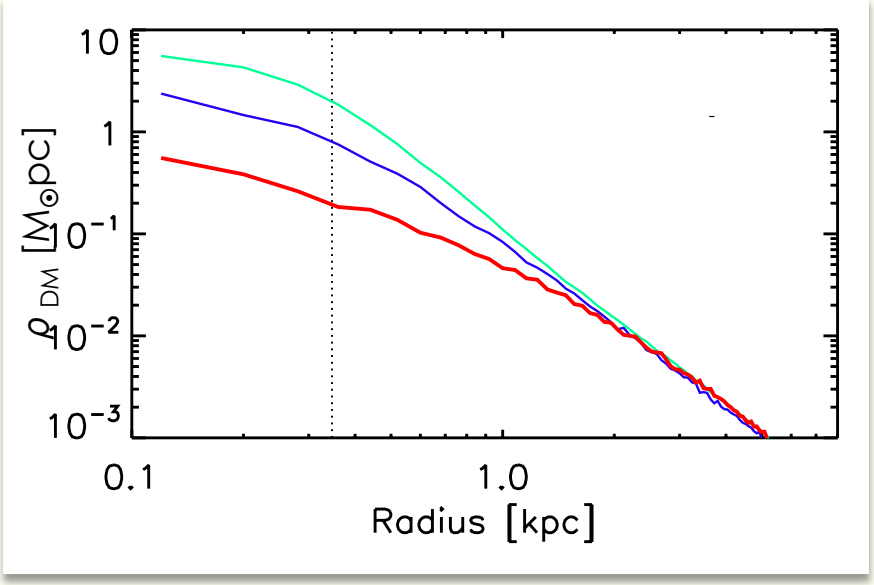
ISM Models


No Low-T Cool
Metals
H_2 + Metals
Grey-scale: Σ_{HI}
Red contours: Σ_{H2}
6 kpc
12 kpc
X [kpc]
Y [kpc]

H-band Profile, Rotation Curve, Central Density

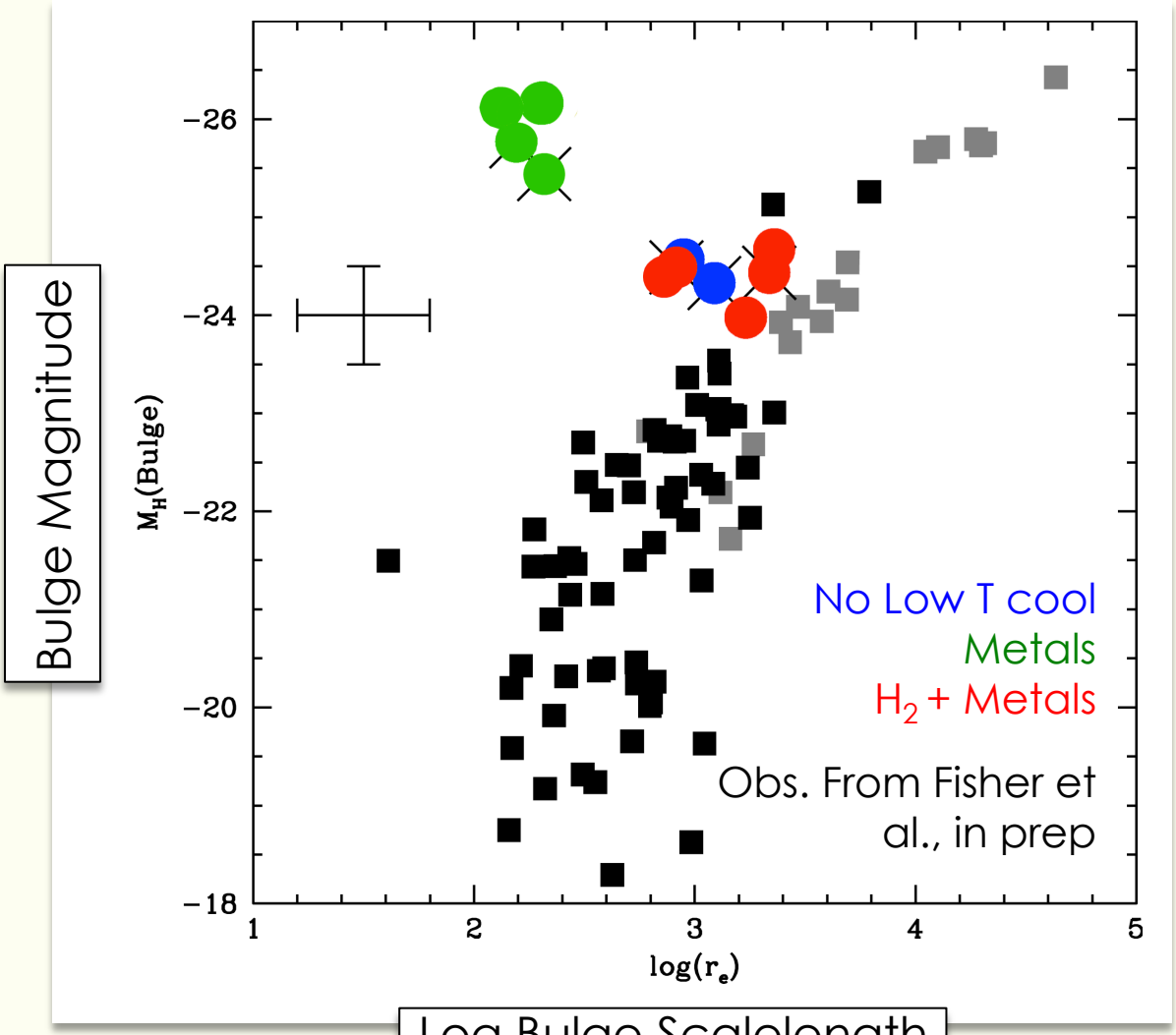






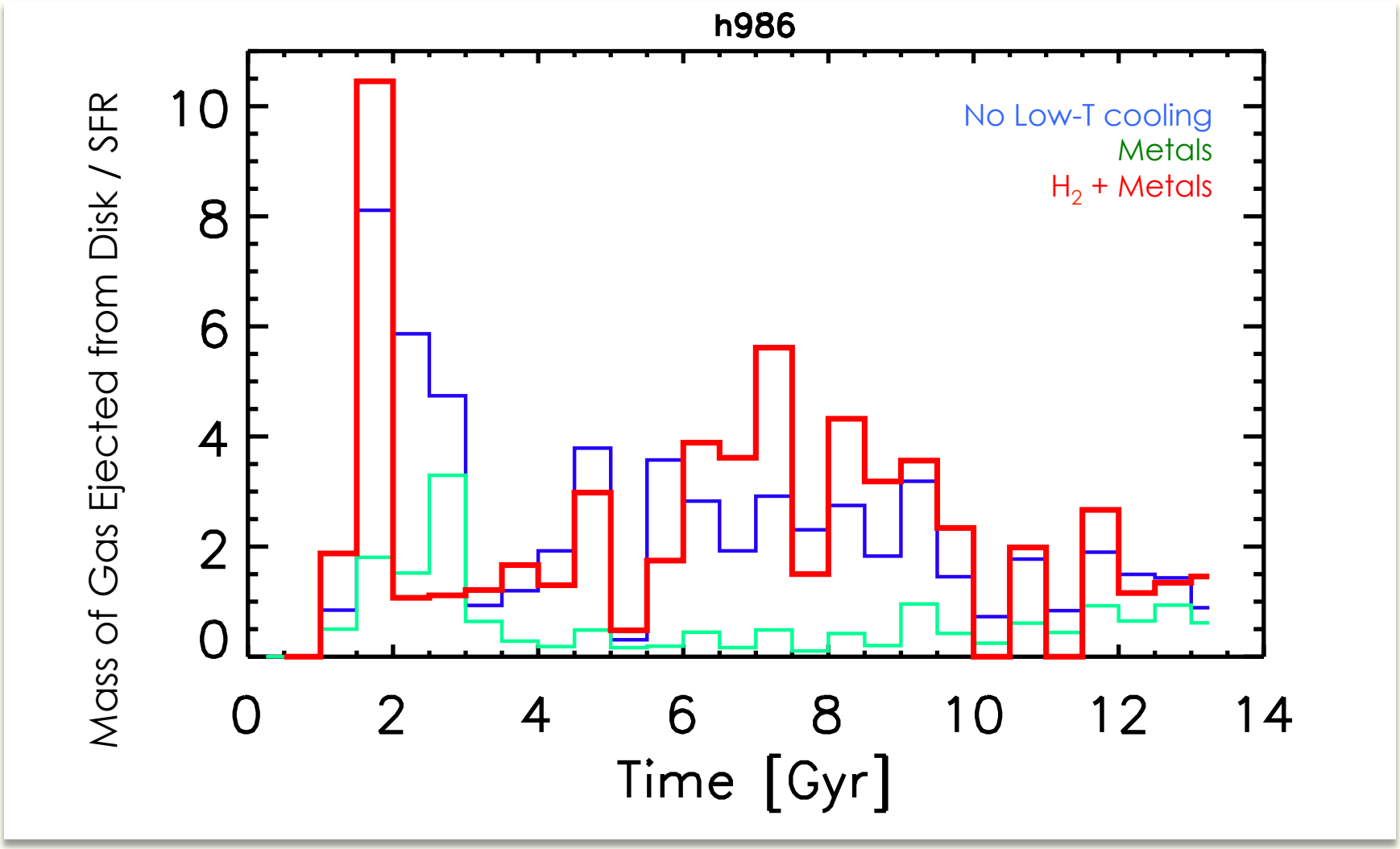
Christensen et al, *in prep*

Comparing to Observed Bulges



Christensen et al, *in prep*

Mass Loading

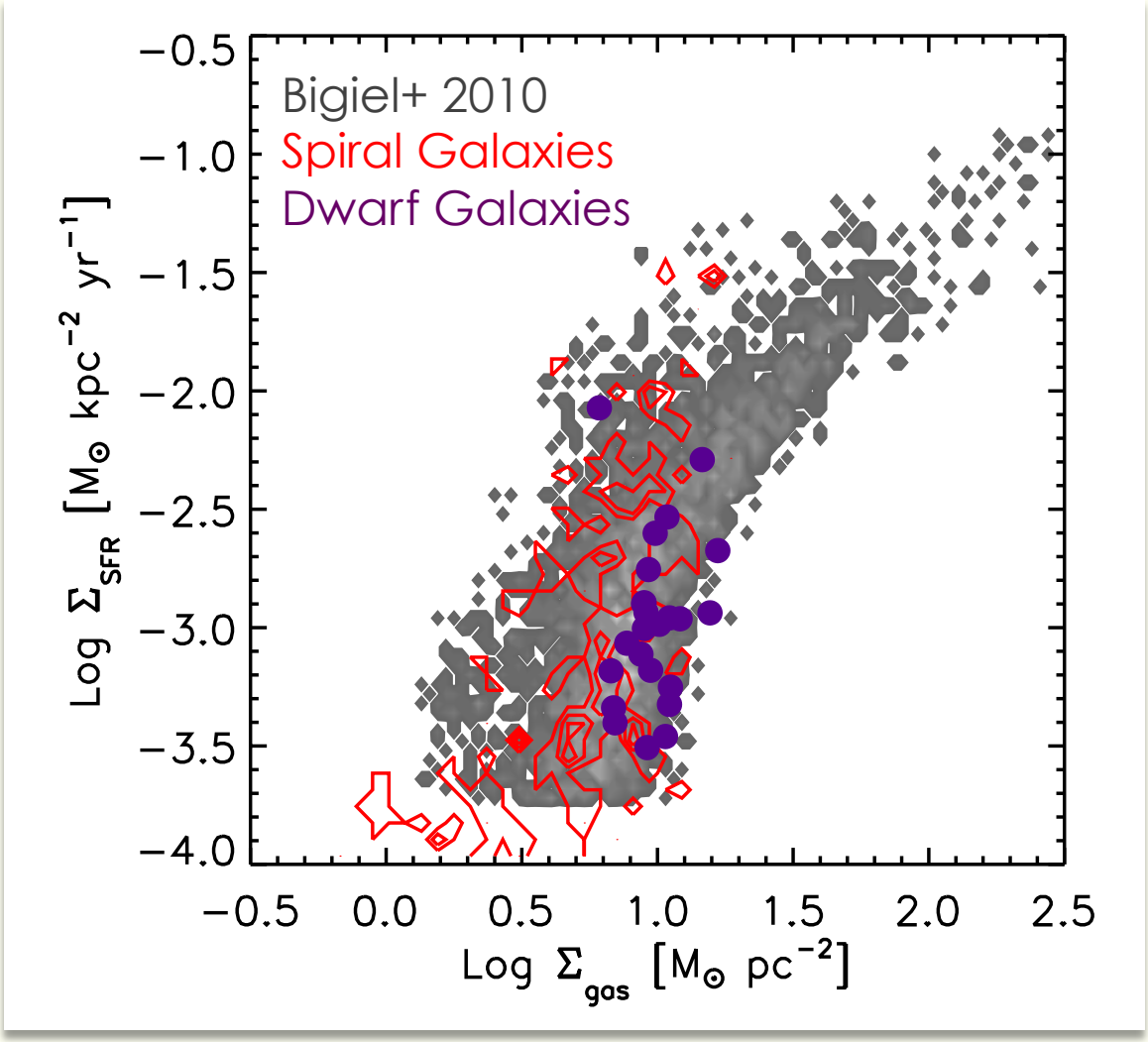


Christensen et al, *in prep*

Why the different profiles?

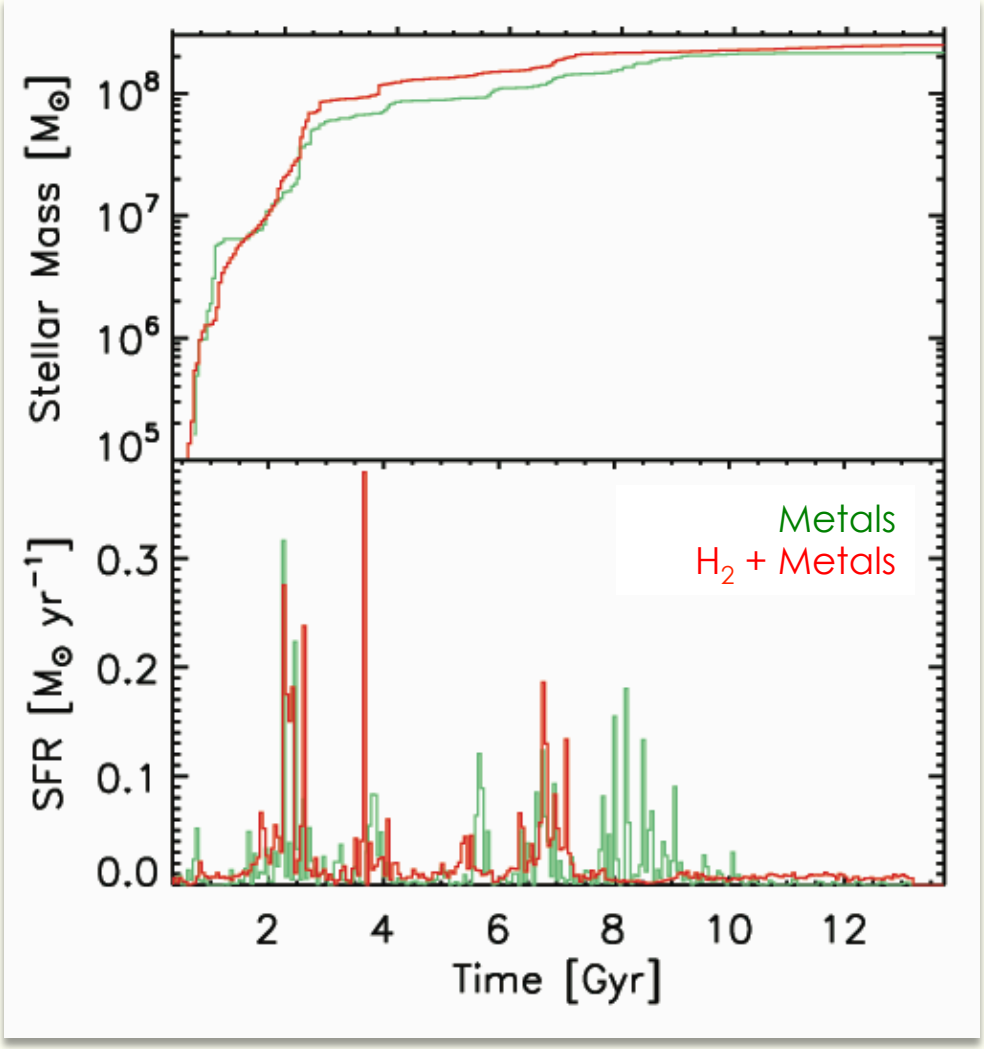
- Changing amounts of gas loss
- Two competing phenomena:
  - Cooling reduces gas loss
  - Clumpiness increases effectiveness of feedback
- The No Low-T Cool ISM model produces more efficient feedback by *having a high minimum temperature and less efficient cooling in the halo*
- The Metals ISM model has a somewhat clumpy ISM but less gas is lost because of *the extra cooling*
- The H_2+ Metals model produces more efficient feedback because *shielding produces a clumpier ISM*

Resolved Kennicutt-Schmidt Relation



Christensen et al, *in prep*

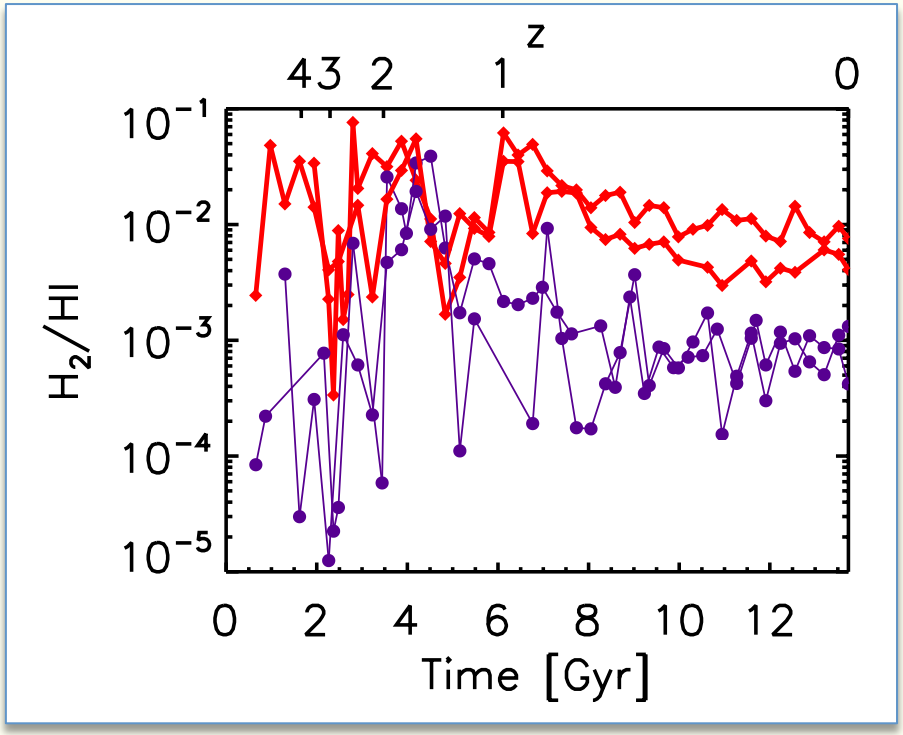
SFH of Dwarf Galaxy w/ and w/o H_2



Christensen et al, 2012

Molecular Hydrogen

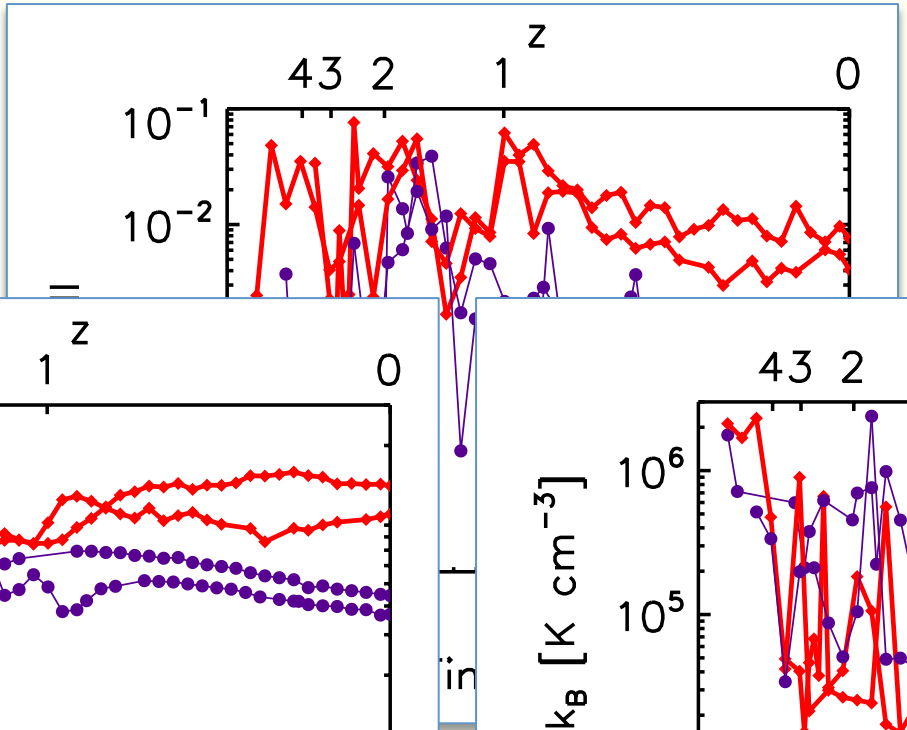
Spiral Galaxies
Dwarf Galaxies

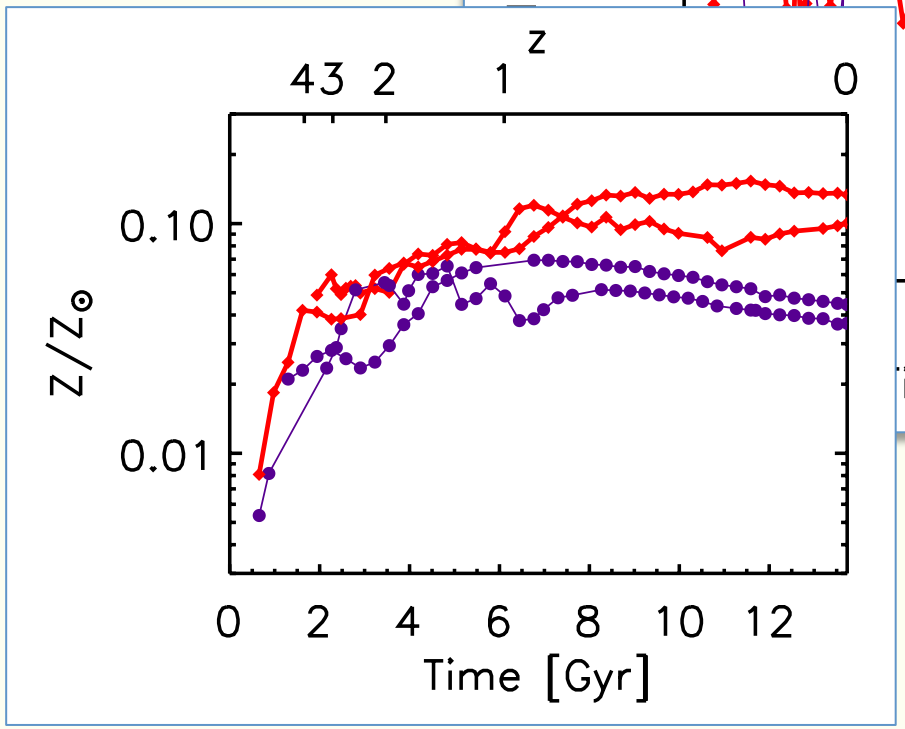


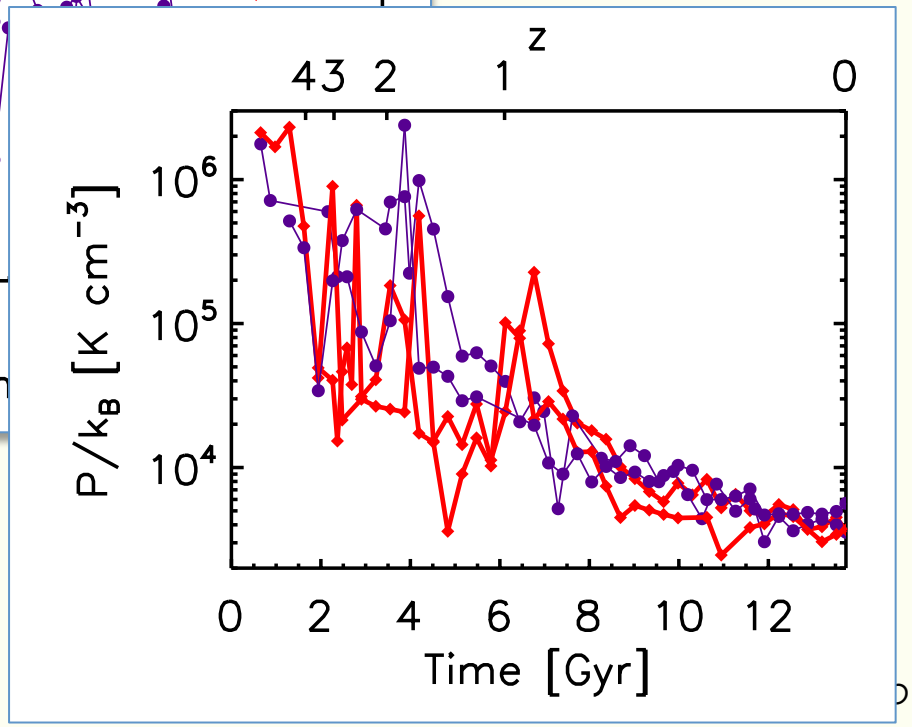
Christensen et al, *in prep*

Molecular Hydrogen

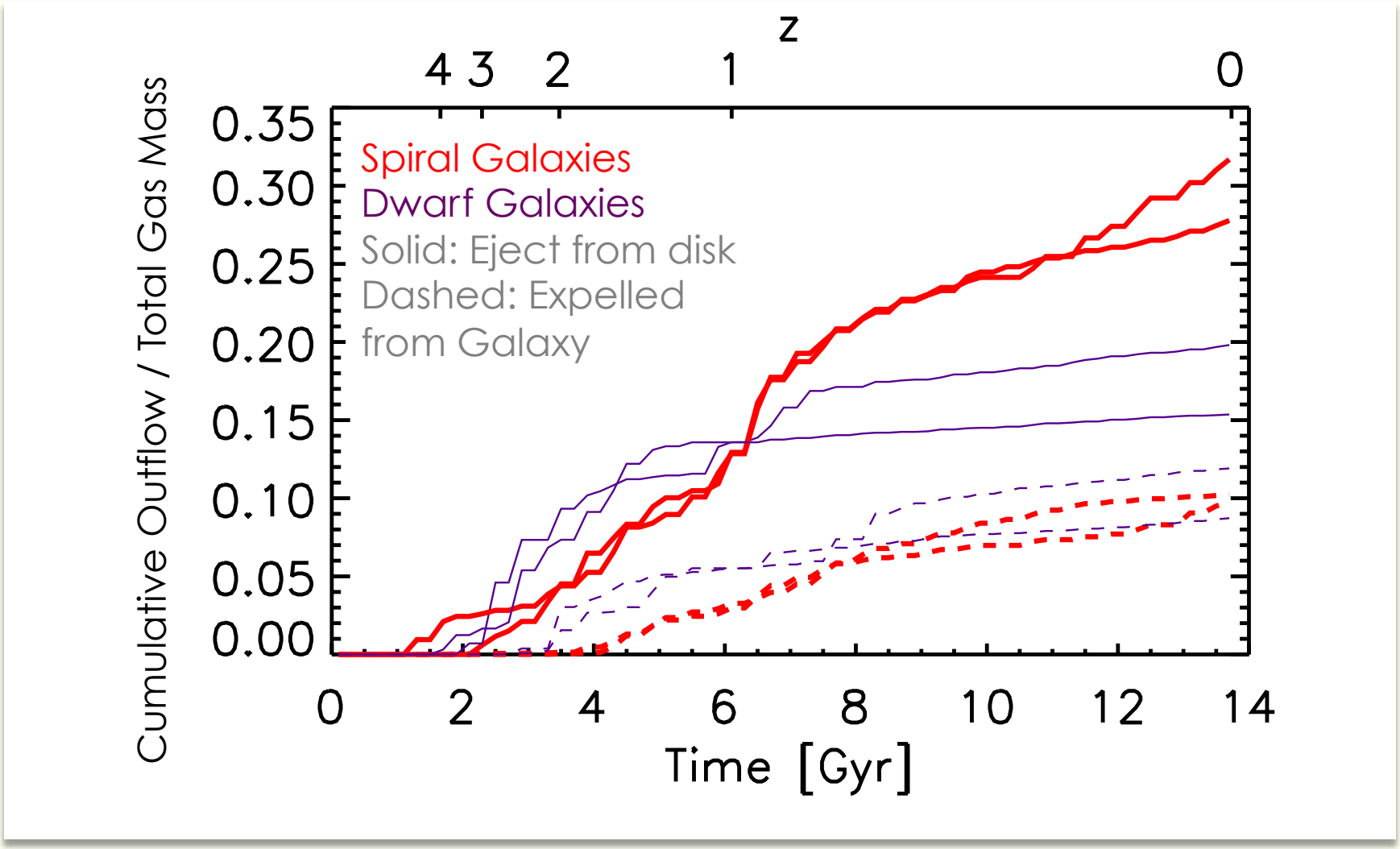
Spiral Galaxies
Dwarf Galaxies







Mass Loss



Christensen et al, *in prep*

Summary

- Simulated low-mass spiral and dwarf galaxies with: primordial cooling, metal-line cooling, and with H_2
- Changing the ISM can dramatically change the effectiveness of feedback and the structure of the galaxy
- When considering H_2-based SF in low-metallicity environments, must consider surface density