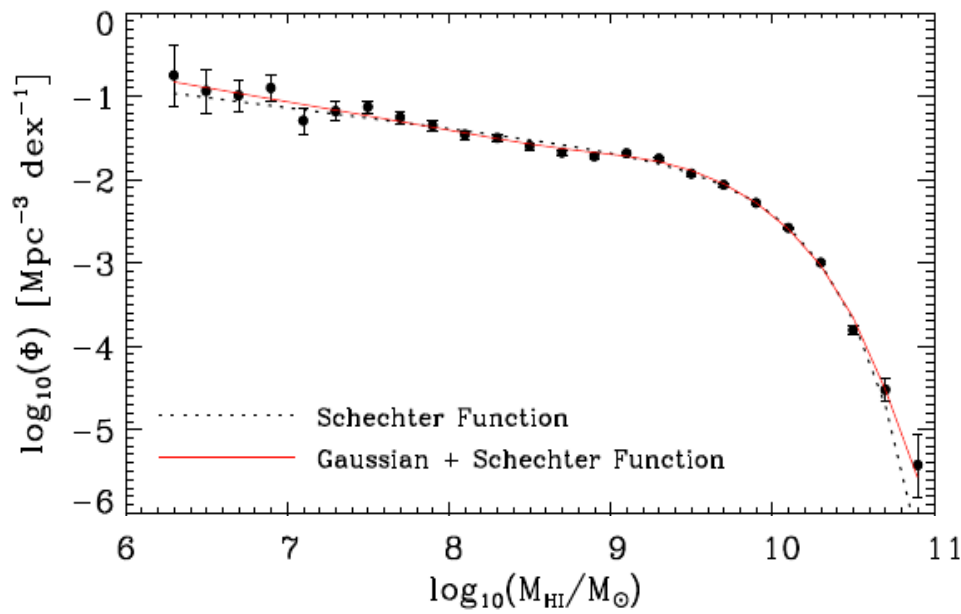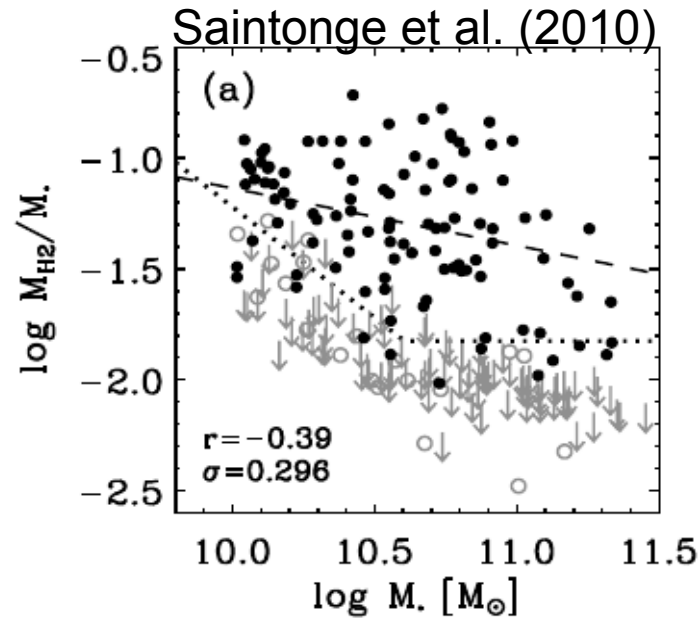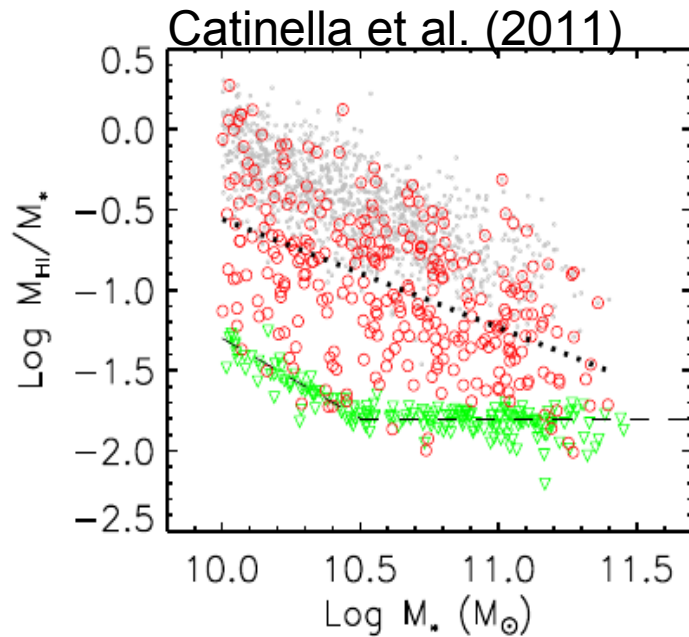# Gas in galaxies: the perspective of semi-analytic models

Claudia Lagos (ESO), Carlton Baugh (Durham), Cedric Lacey (Durham), Estelle Bayet (Oxford), Chris Power (West U), Andrew Benson (Carnegie), Hank Kim (Melbourne) , James Geach (McGill), Nikos Fanidakis (MPIA)
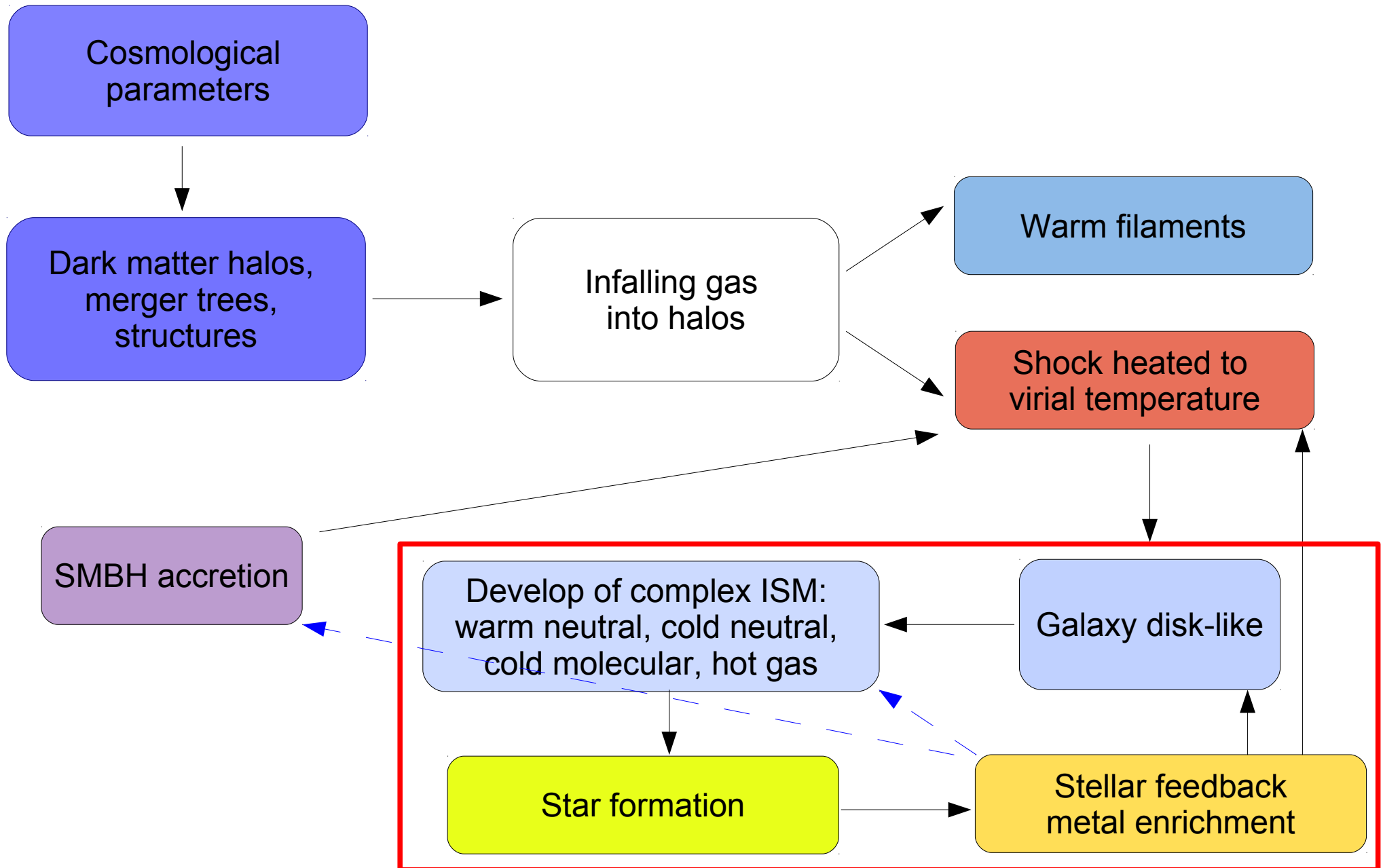
The neutral gas content of the Universe

Catinella et al. (2011)

Saintonge et al. (2010)

Very exciting times to be working in gas! (in and outside galaxies)
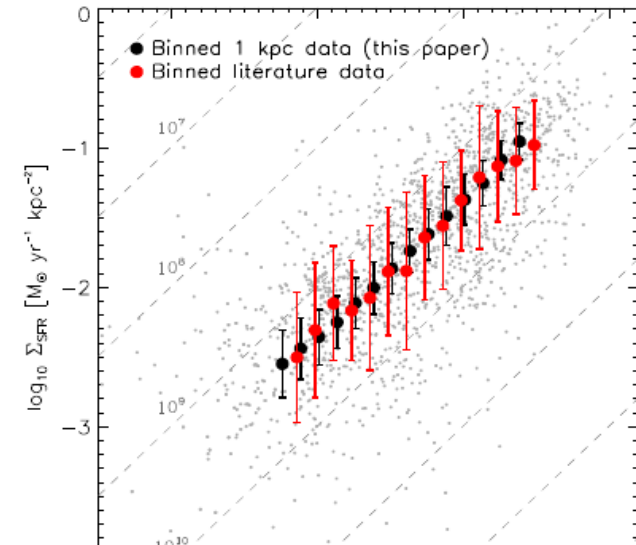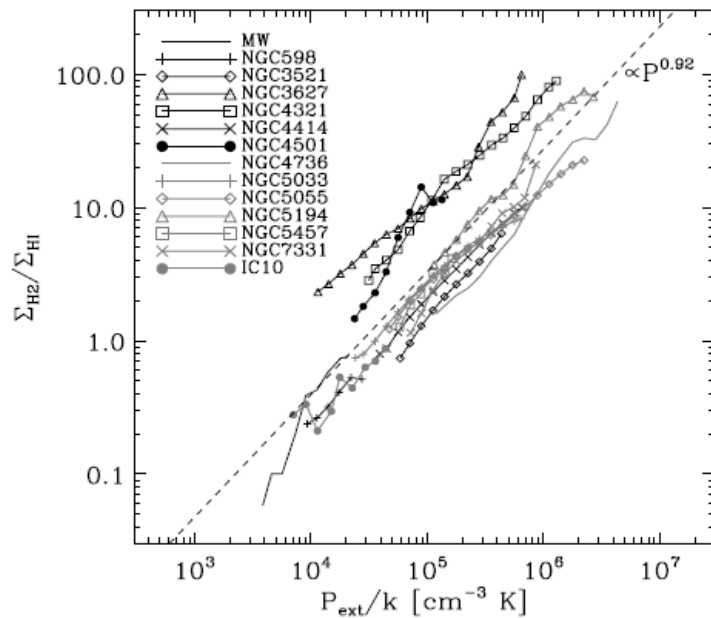- ASKAP, SKA, MeerKAT, ALMA, EVLA, JVLA, … (lots more)

Martin et al. (2010)
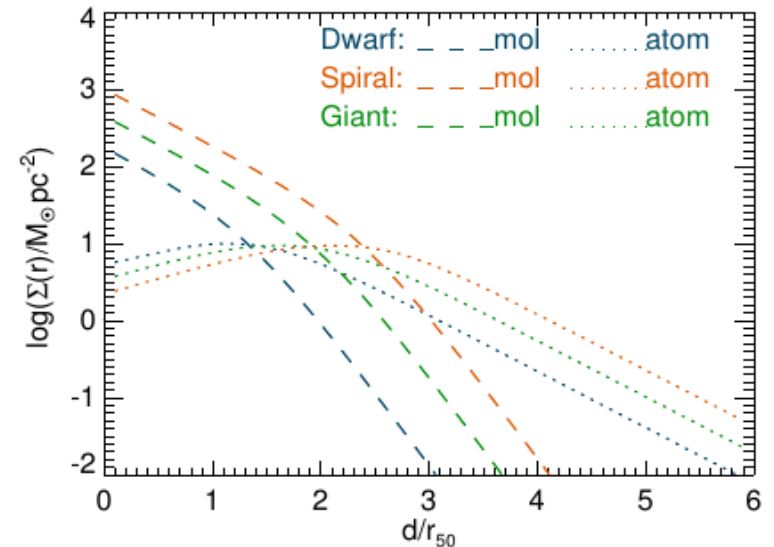
Galaxy formation step by step...

Pressure star formation law:
insight from local resolved studies

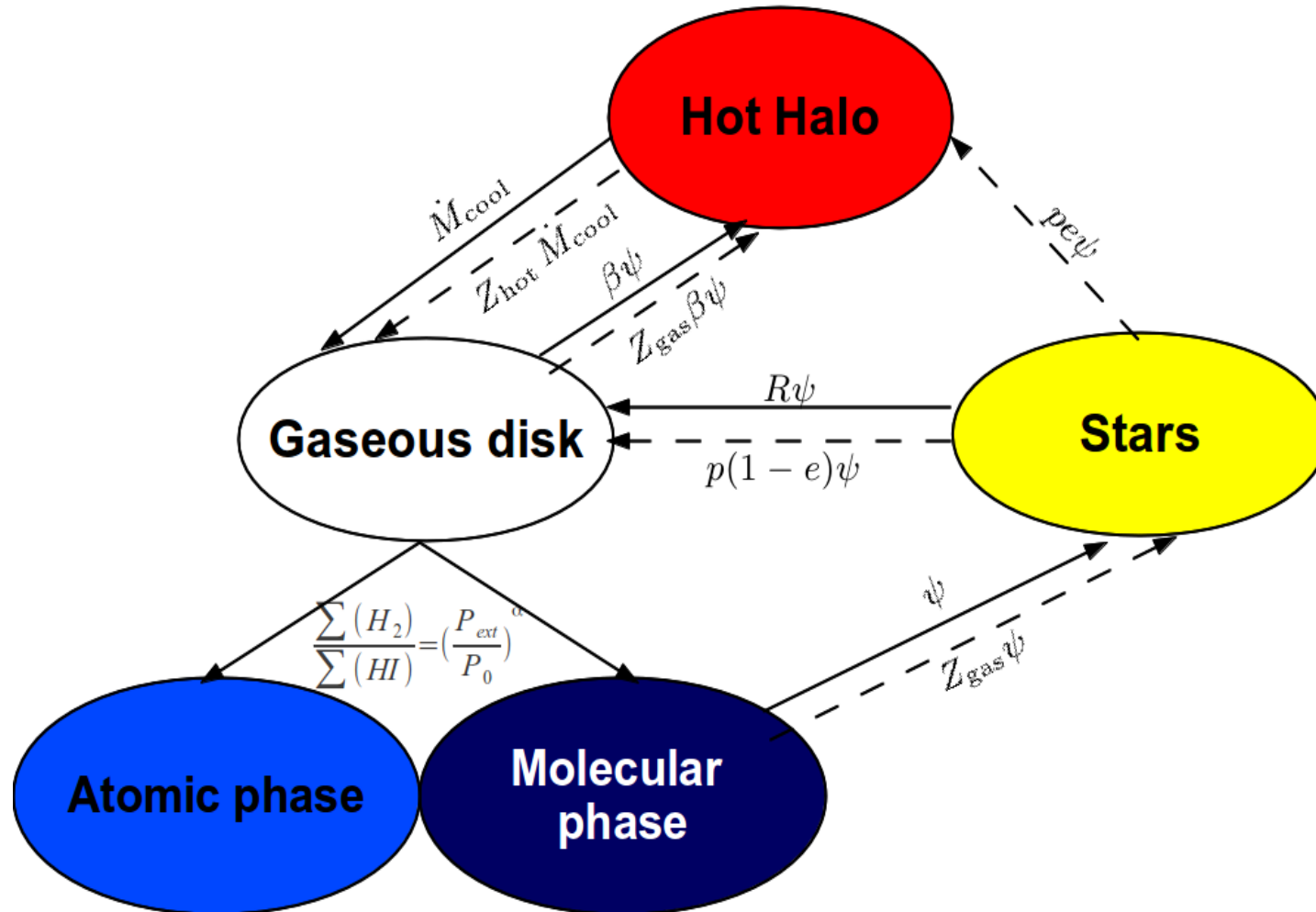Blitz & Rosolowsky (2006); Wong et al. (2002); Leroy et al. (2008); Bigiel et al. (2008,2010)

$$\frac{\Sigma(H_2)}{\Sigma(HI)} = \left(\frac{P_{ext}}{P_0}\right)^{\alpha}$$

$$P_{ext} \approx \frac{\pi}{2} G \Sigma_{gas} \left[\Sigma_{gas} + \left(\frac{\sigma_g}{\sigma_\star}\right) \Sigma_\star\right]$$
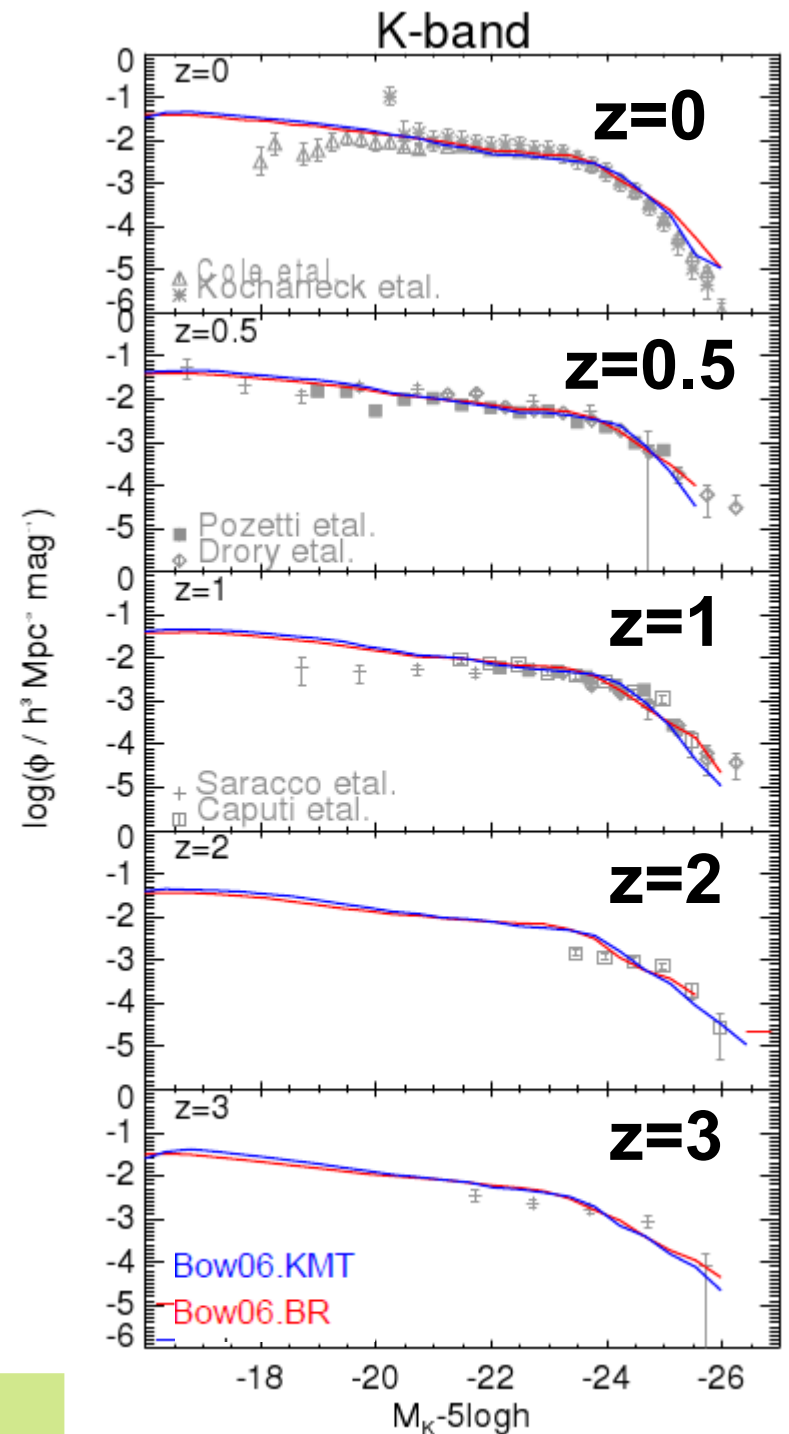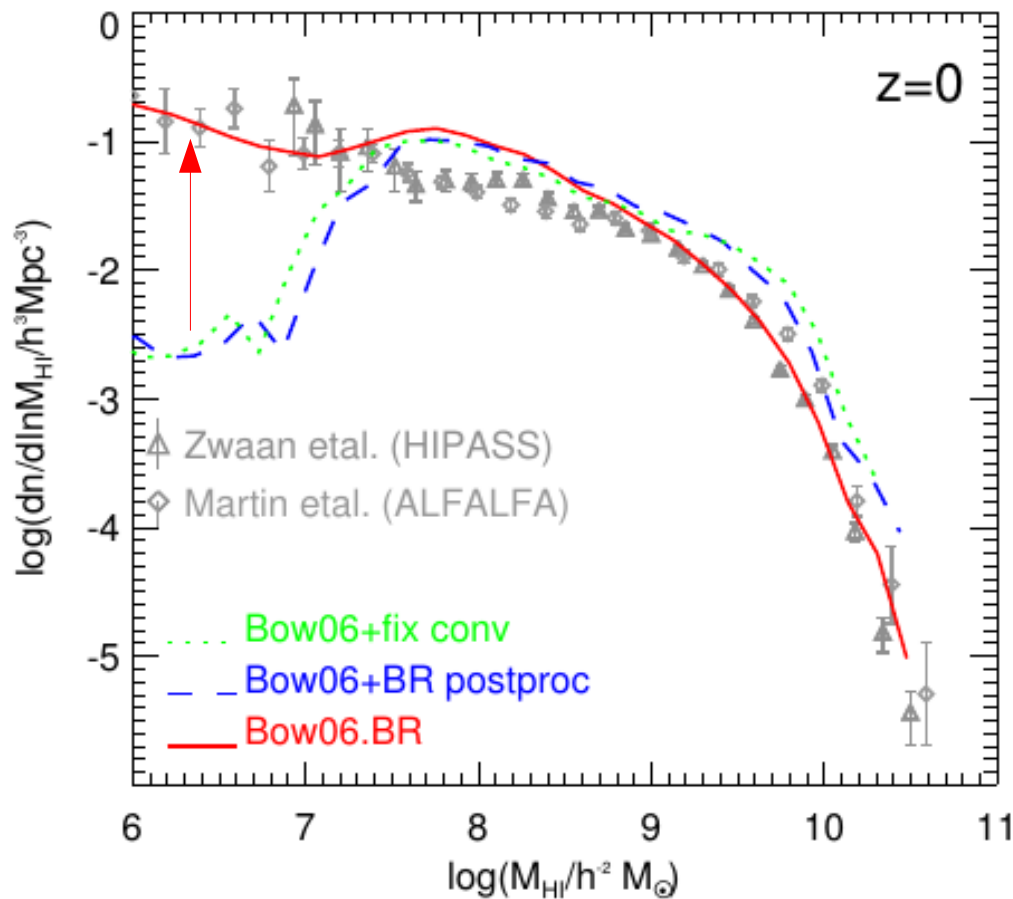
The galaxy formation paradigm
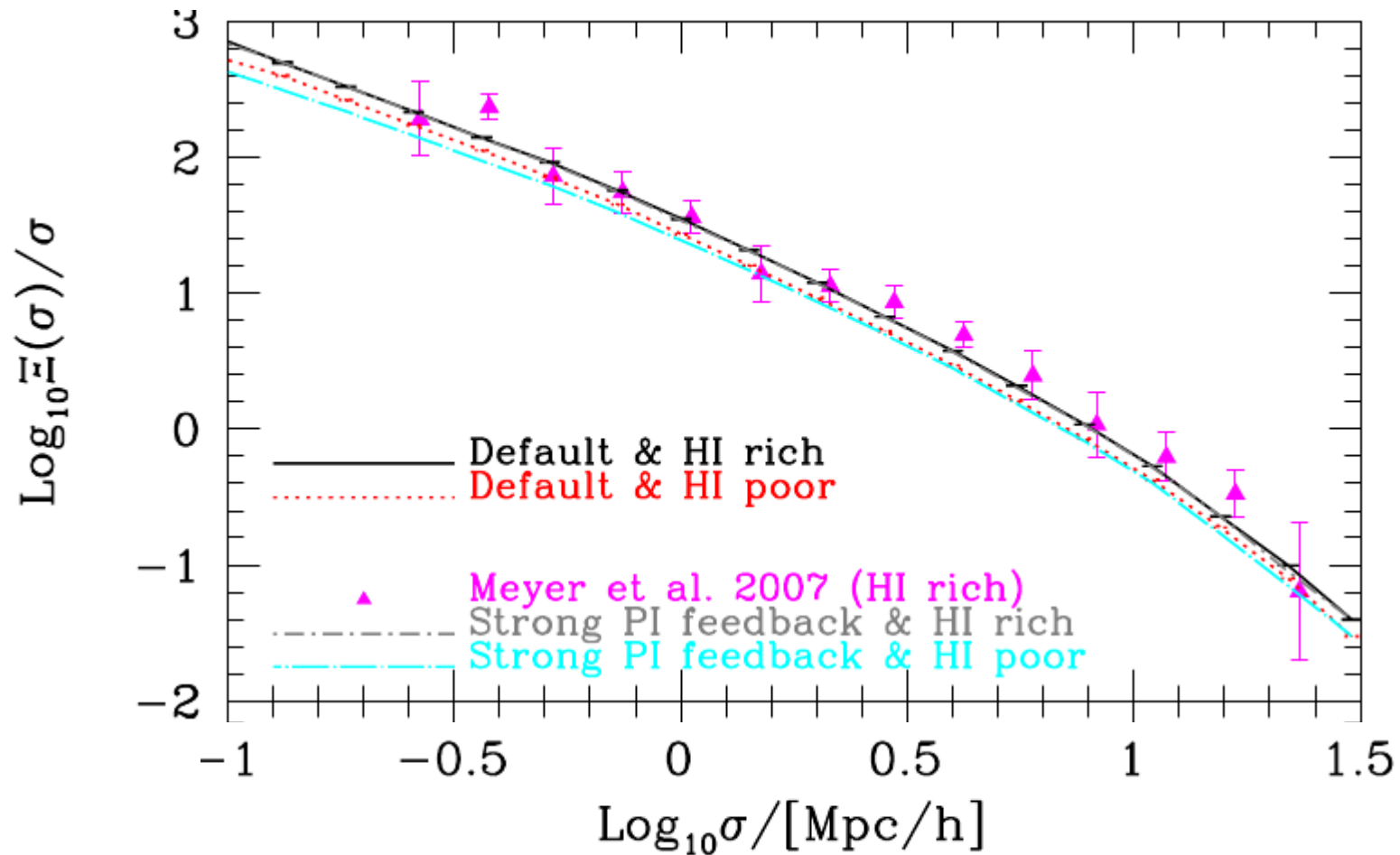## Cole et al. (2000), Lagos et al. (2011a)

The predicted LF and HI mass functions
(Lagos et al. 2011a, 2011b)

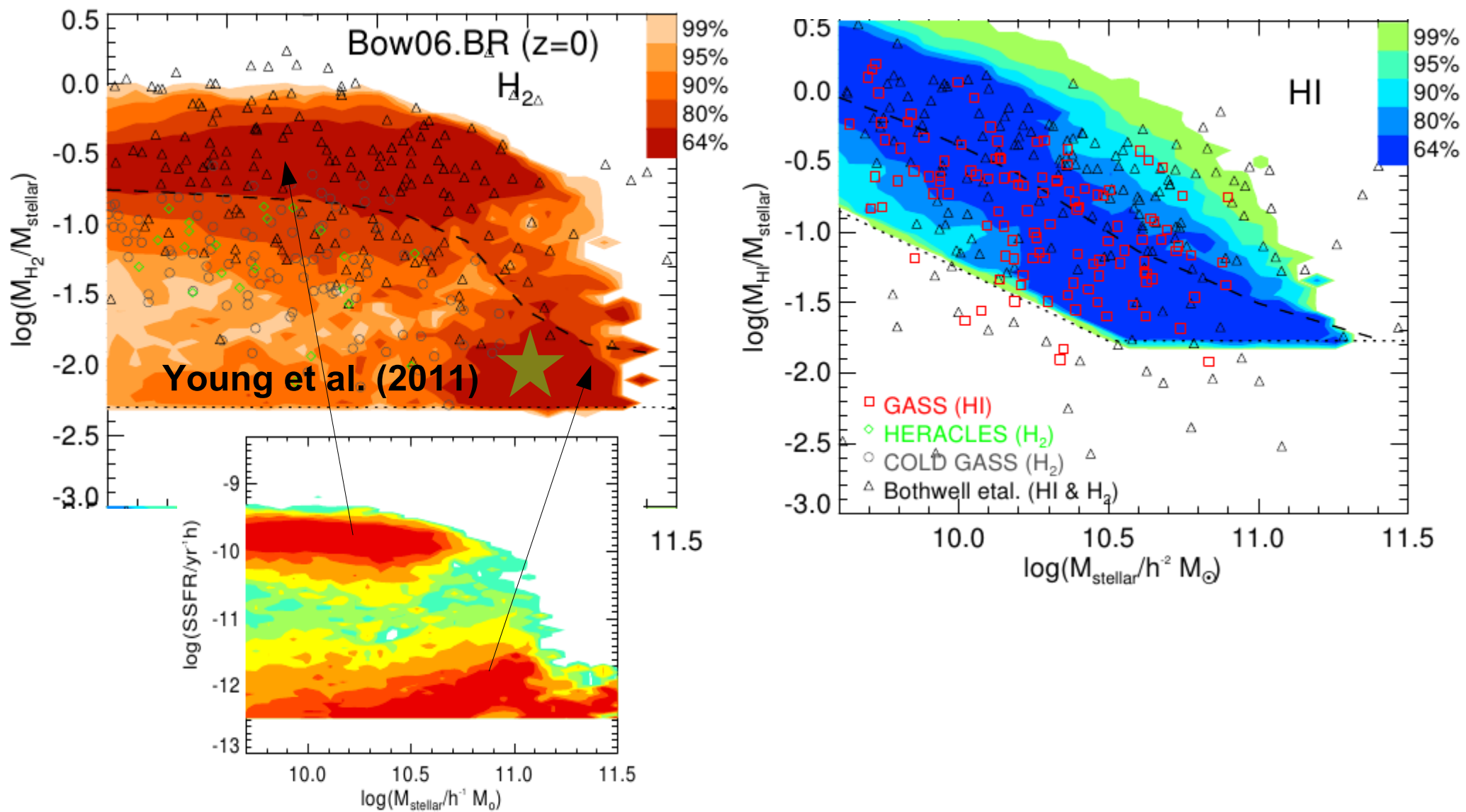**Results from non-linear relation between depletion timescale and gas content**

Local Universe: Clustering of HI sources
(Kim et al., 2013)

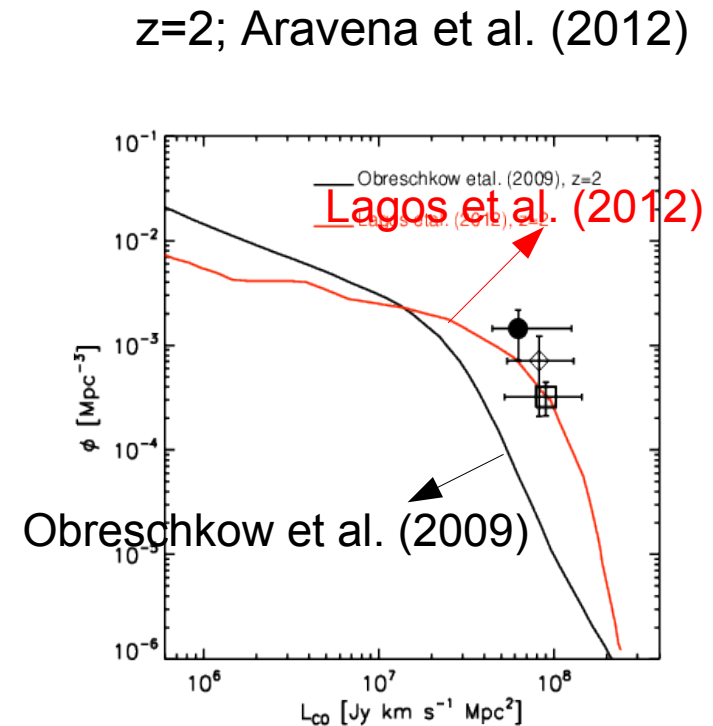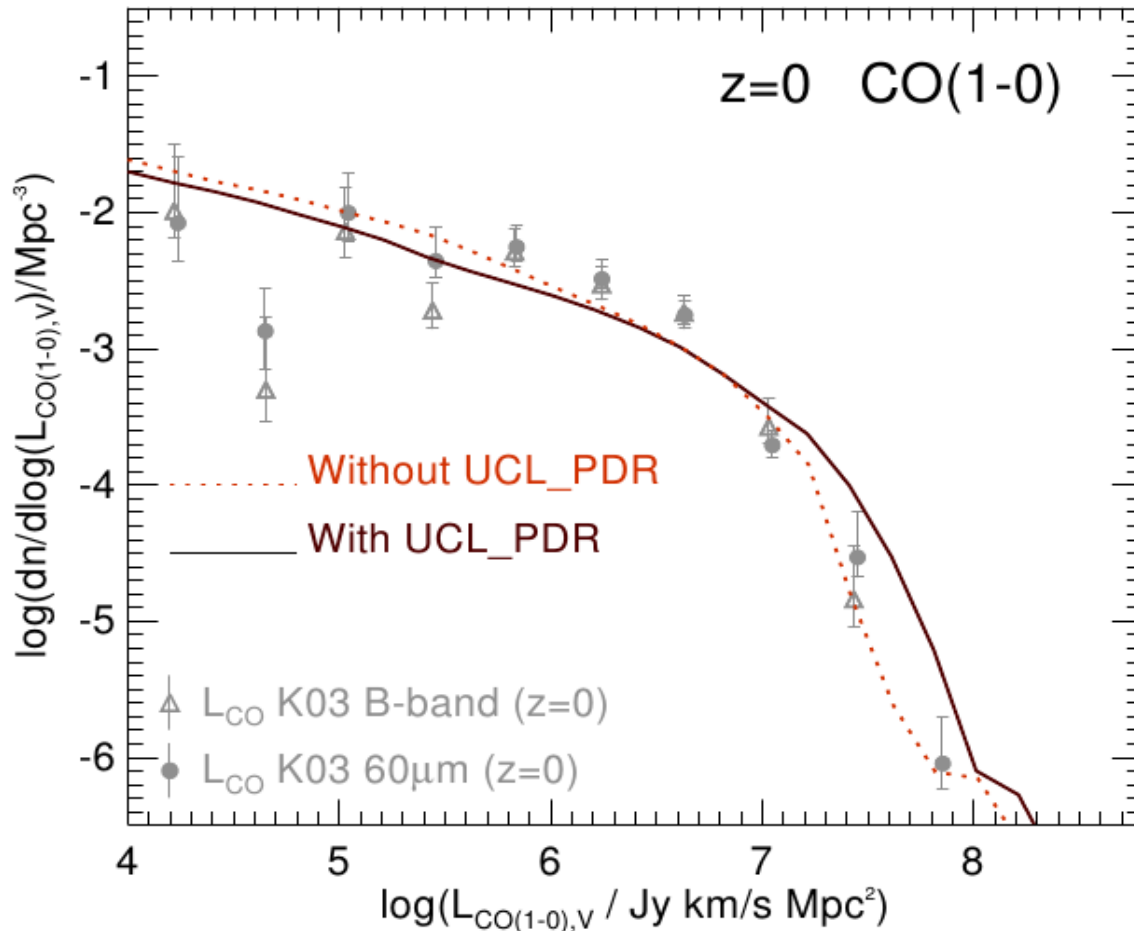**Model predictions: parameters have not been modified**

Scaling relations: stars/cold gas
(Lagos et al. 2011b)

→ Compared against volume limited samples of Catinella et al., Saintonge et al.

The predicted local CO(1-0) luminosity function

Using Lagos, Bayet et al. (2012), which combined GALFORM with a radiative transfer, photon dominated region code.
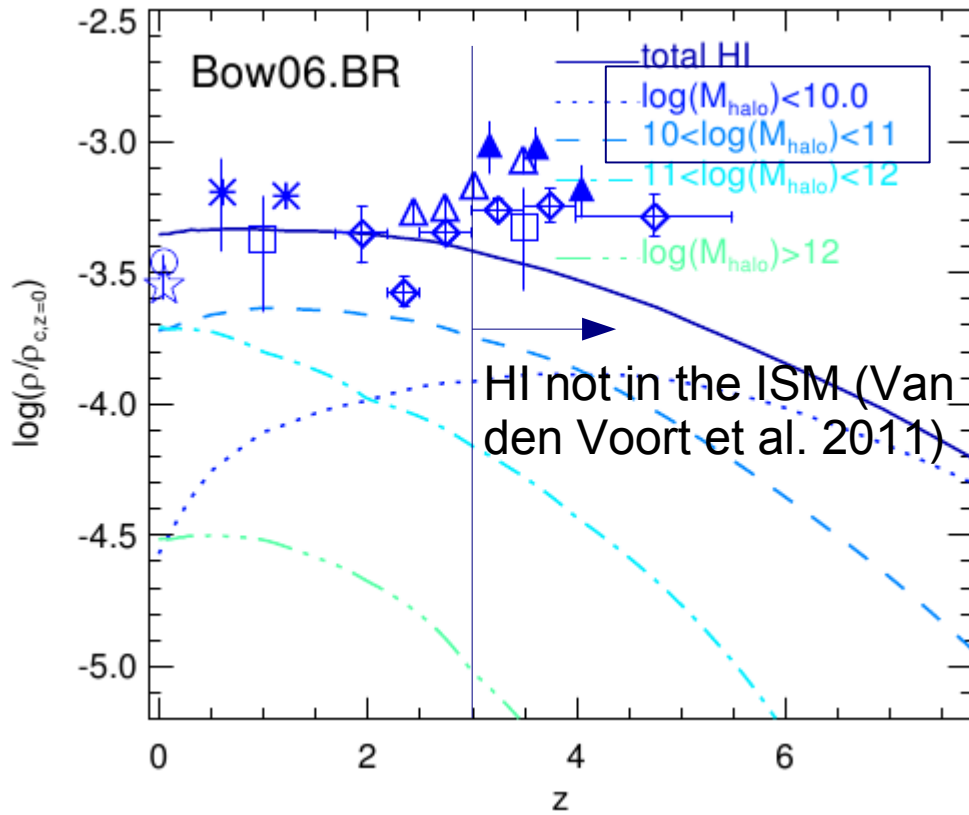

CO(1-0) → H2 conversion does make a difference, although not huge given that most of galaxies with the luminosities in the range observed have "normal" properties (see also Fu et al. 2012).

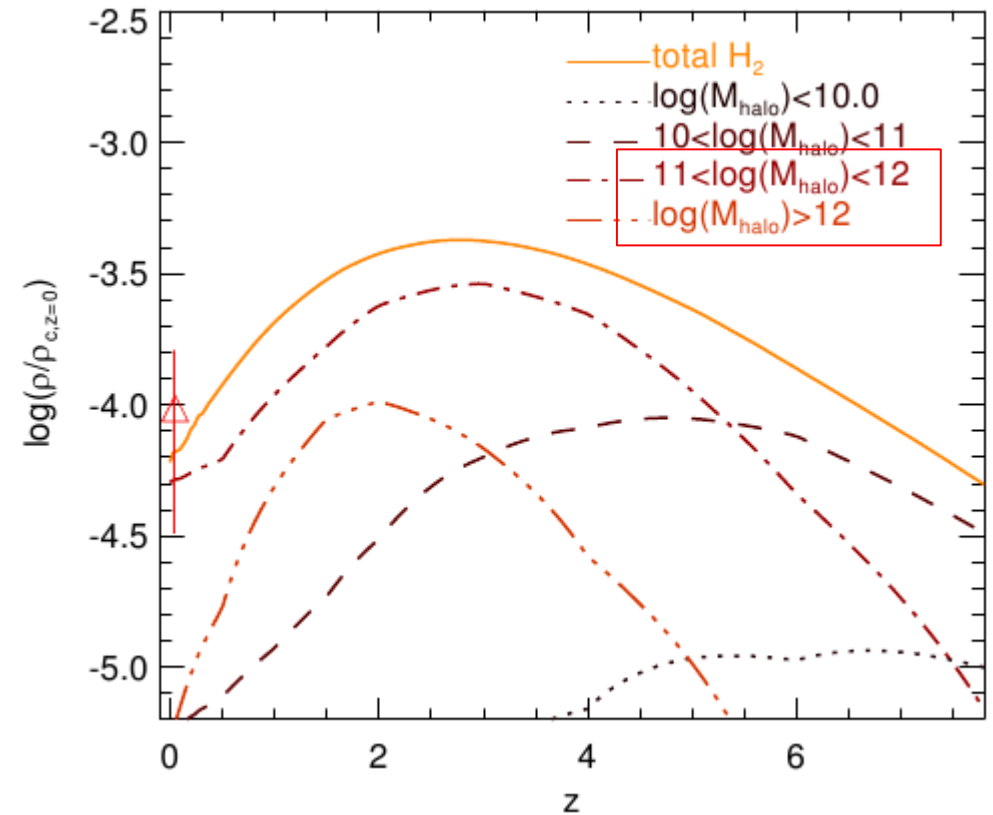# The predicted HI mass content of galaxies
(Lagos et al. 2011b)
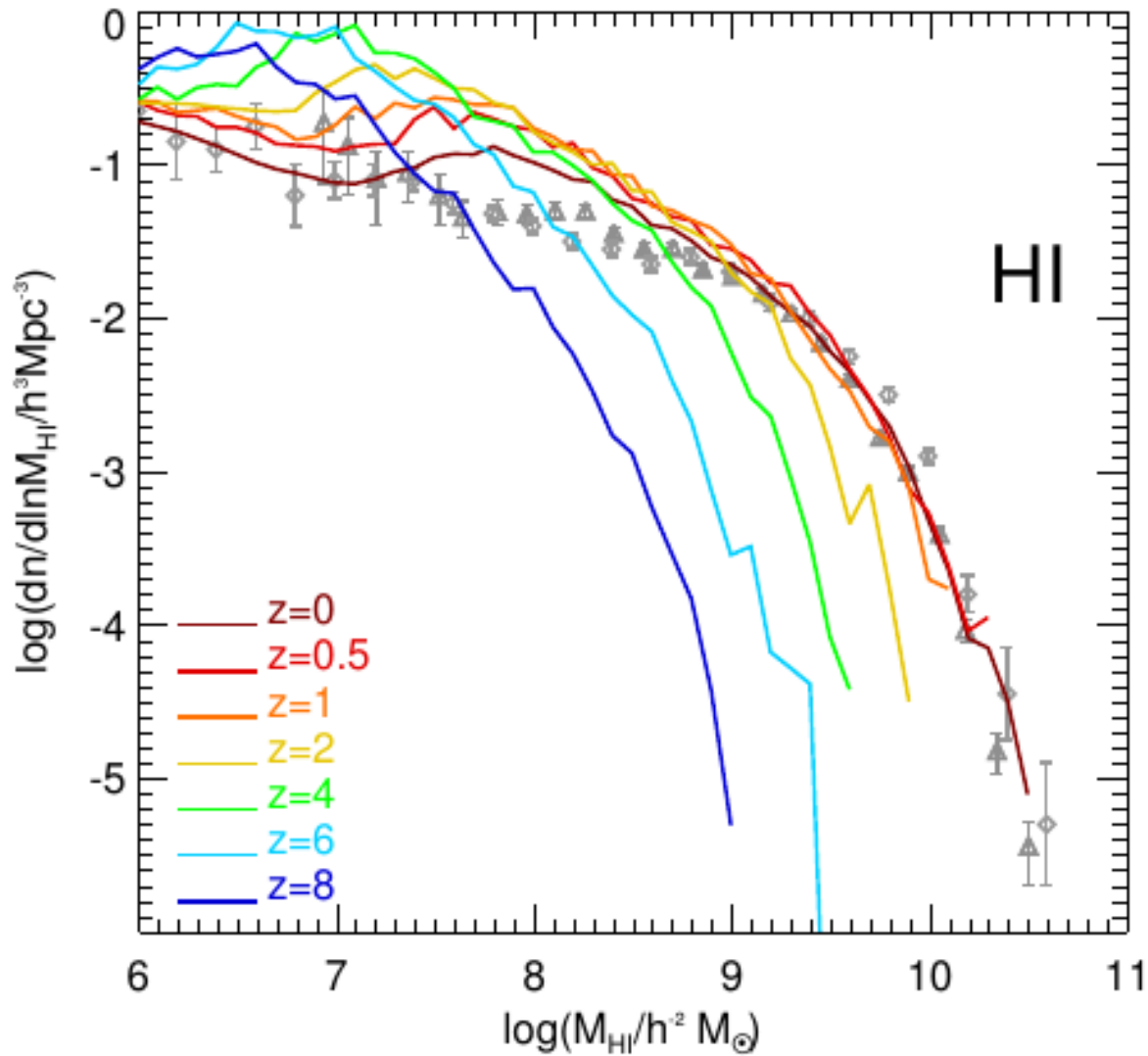
Atomic and molecular H cosmic evolution
(Lagos et al., 2011b)

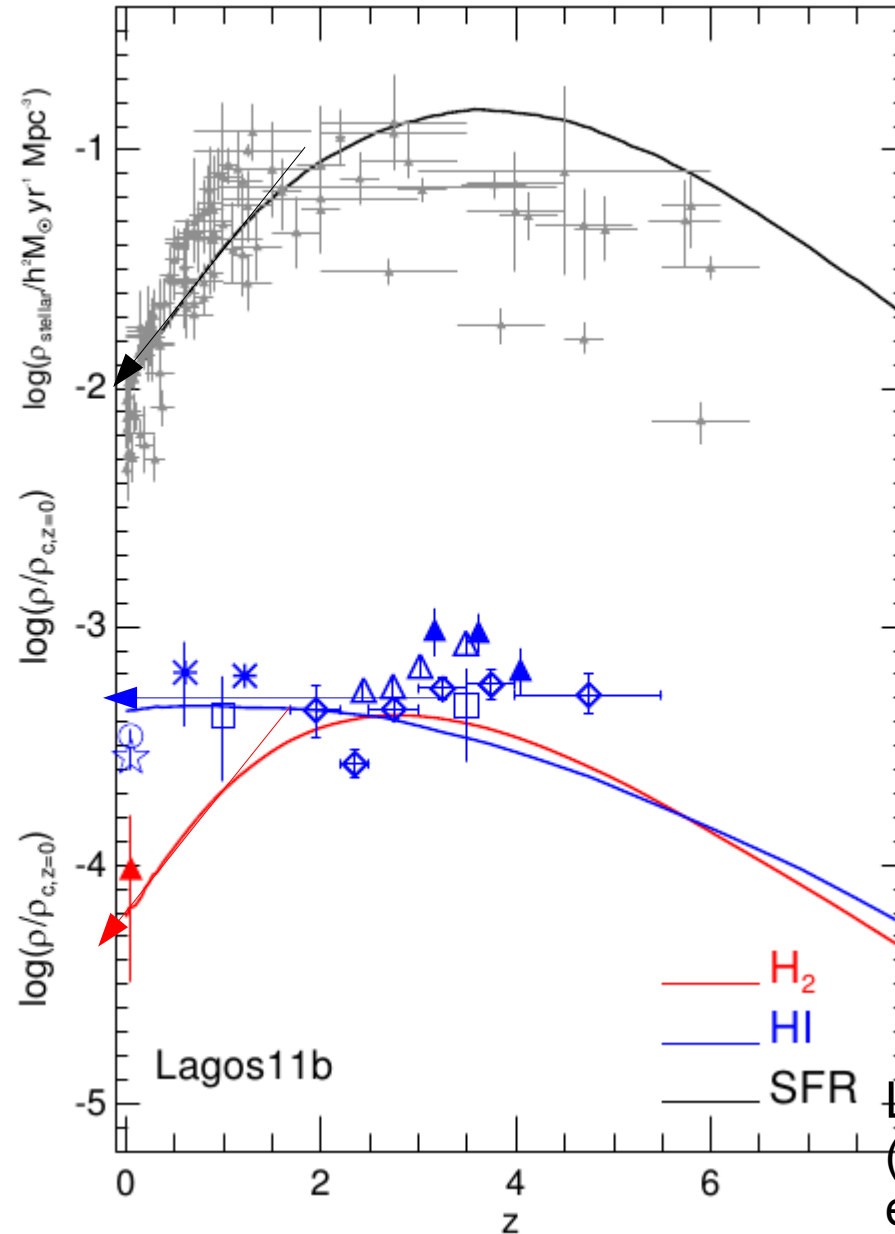# The SFR decline: a consequence of gas density decline

Decline of molecular mass: SIZE evolution + lower neutral gas-to-total mass ratios
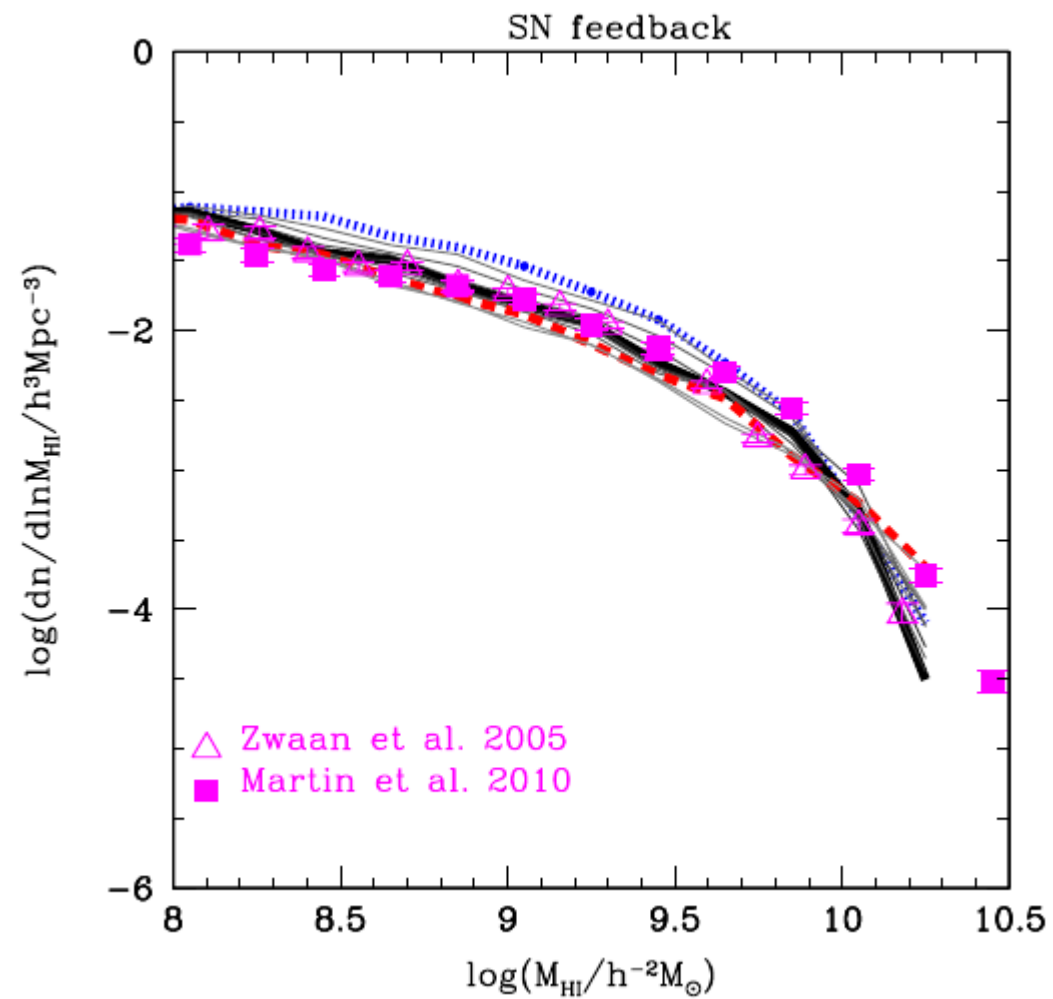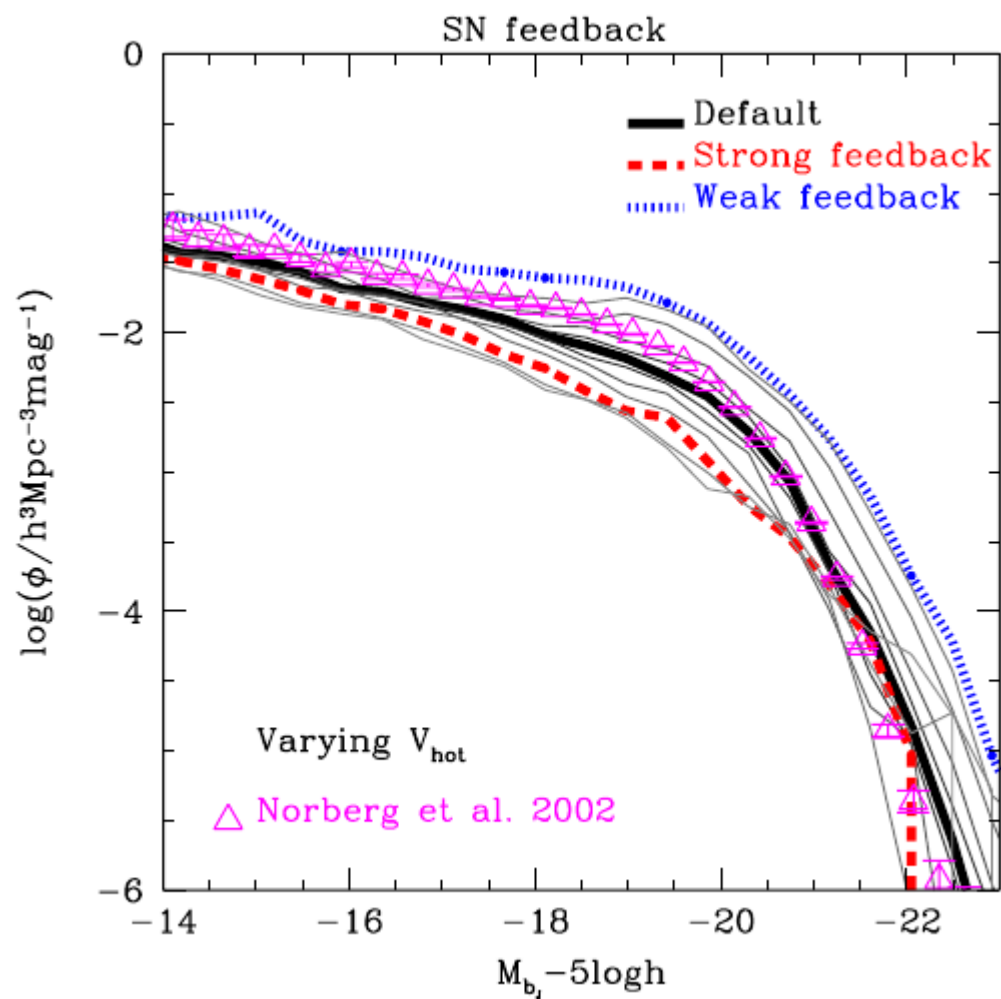

Zwann etal. 2005 (HI)
Martin etal. 2010 (HI)
Peroux etal. 2003 (DLA)
Rao etal. 2006 (DLA)
Guimaraes etal. 2009 (DLA)
Prochaska etal. 2005 (DLA)
Noterdaeme etal. 2009 (DLA)
Keres etal. 2003 (CO(1-0))

Lagos et al. (2011b) (see also Obreschkow et al. 2009; Fu et al. 2012)

HI constraints on baryonic physics
Kim et al. (2013)
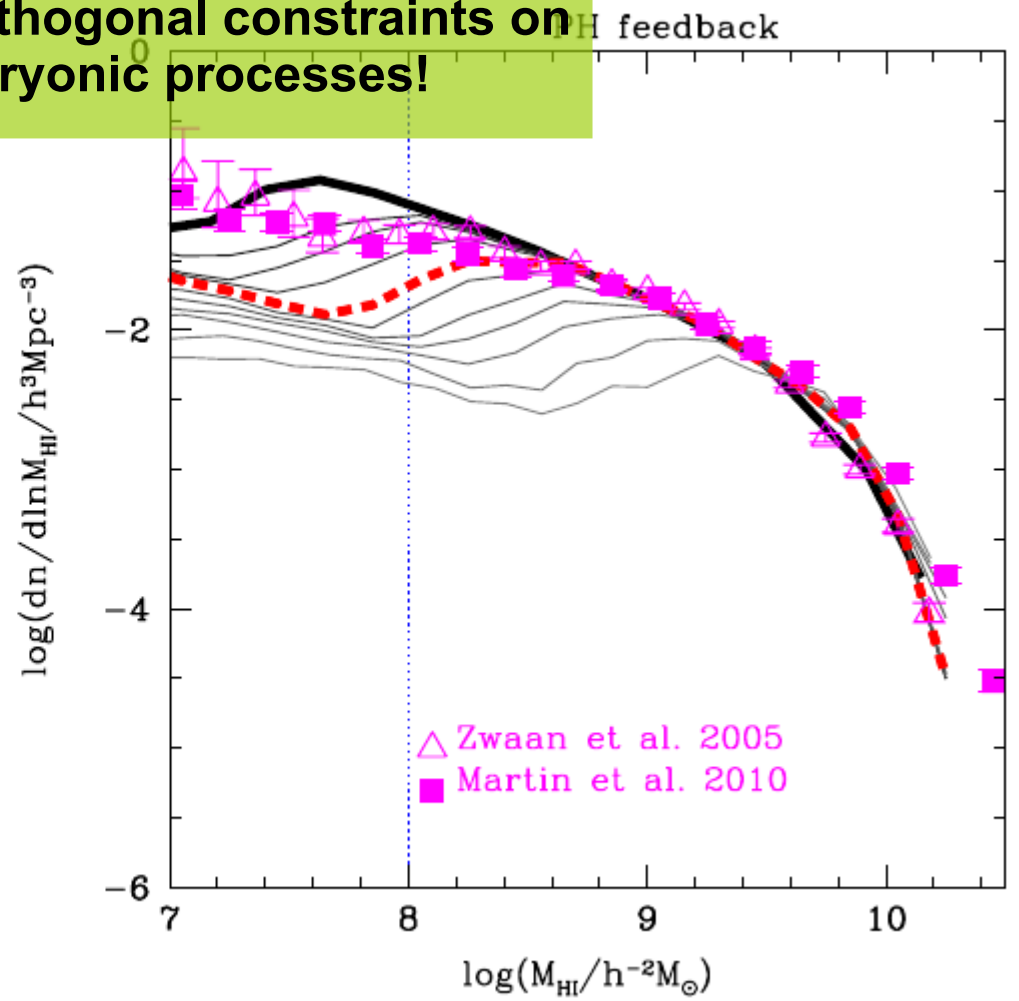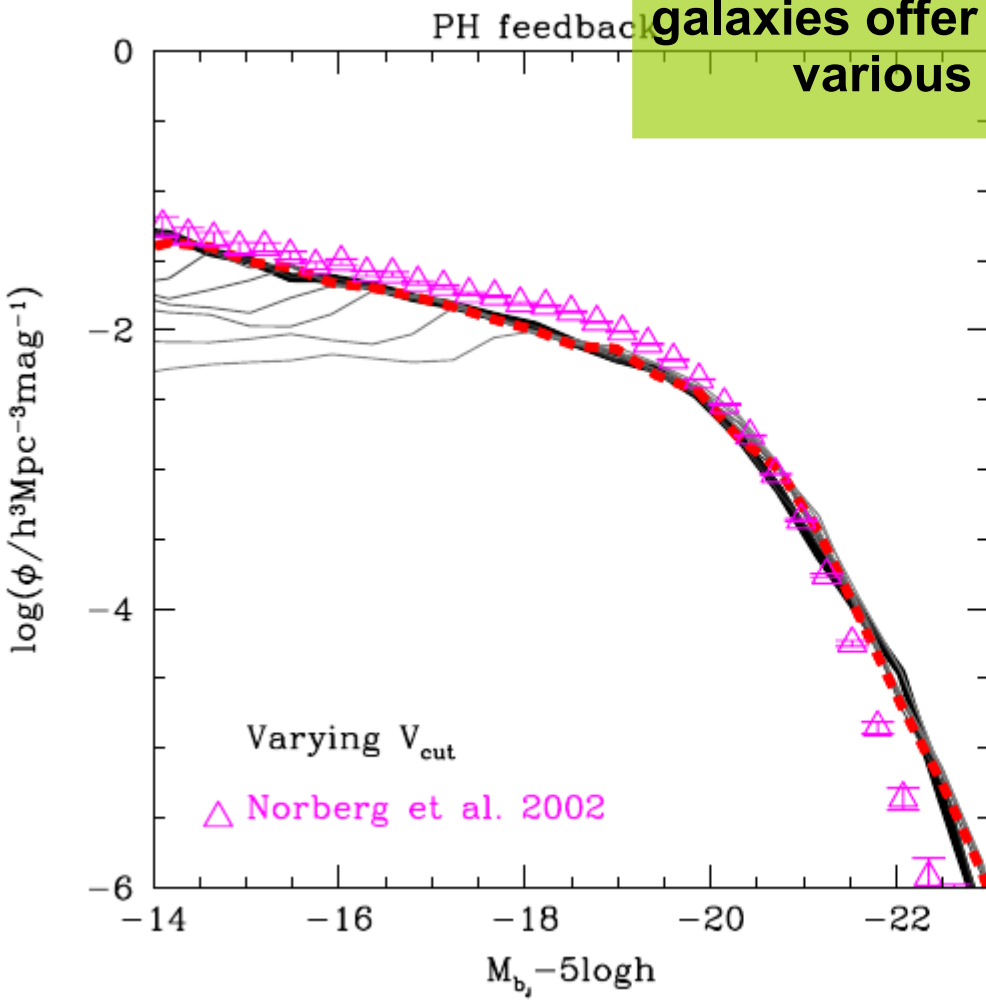
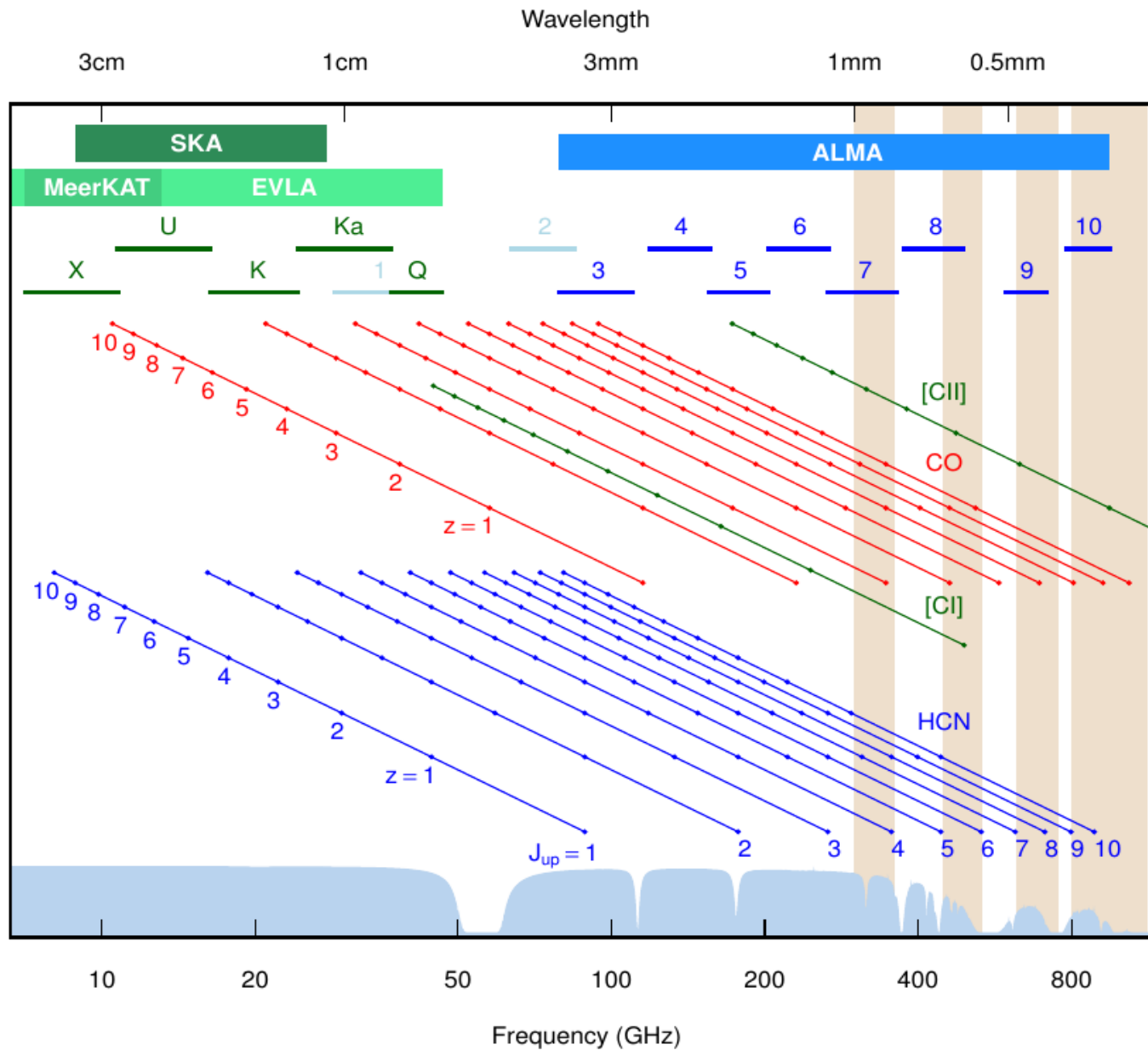# HI constraints on baryonic physics
Kim et al. (2013)

Molecular emission lines in radio telescopes

Using Lagos, Bayet et al. (2012), which combined GALFORM with a radiative transfer, photon dominated region code.
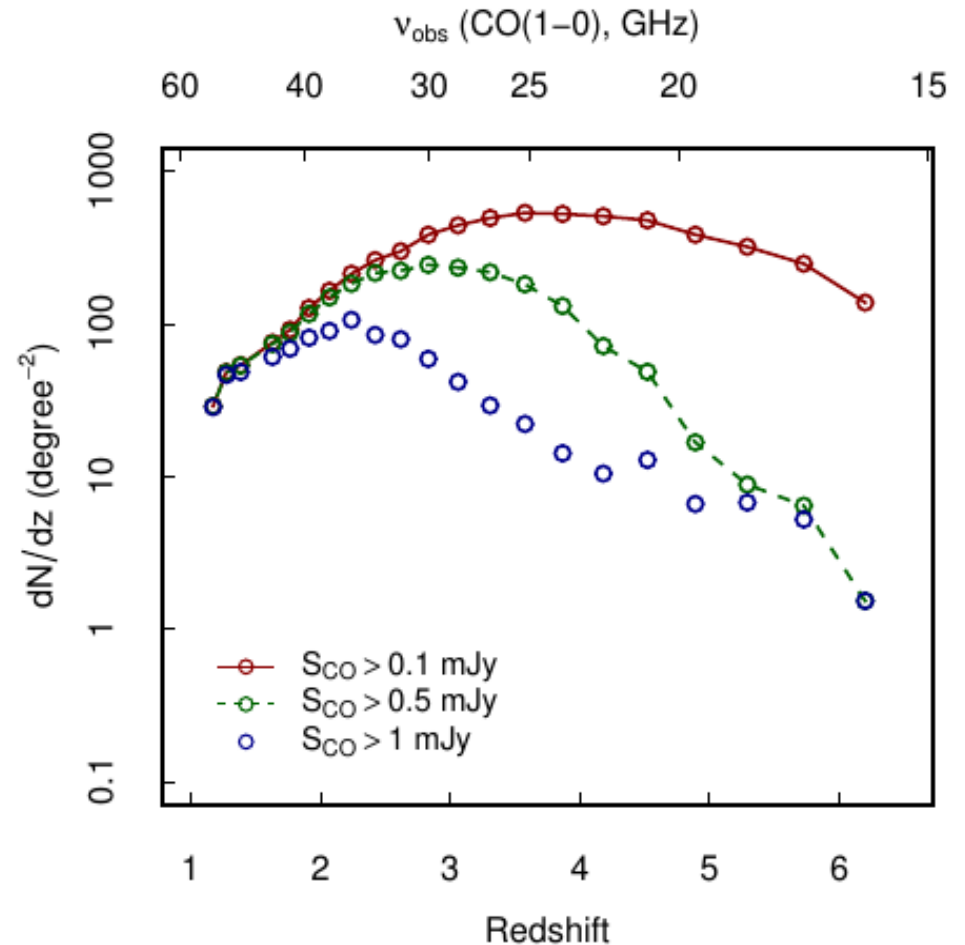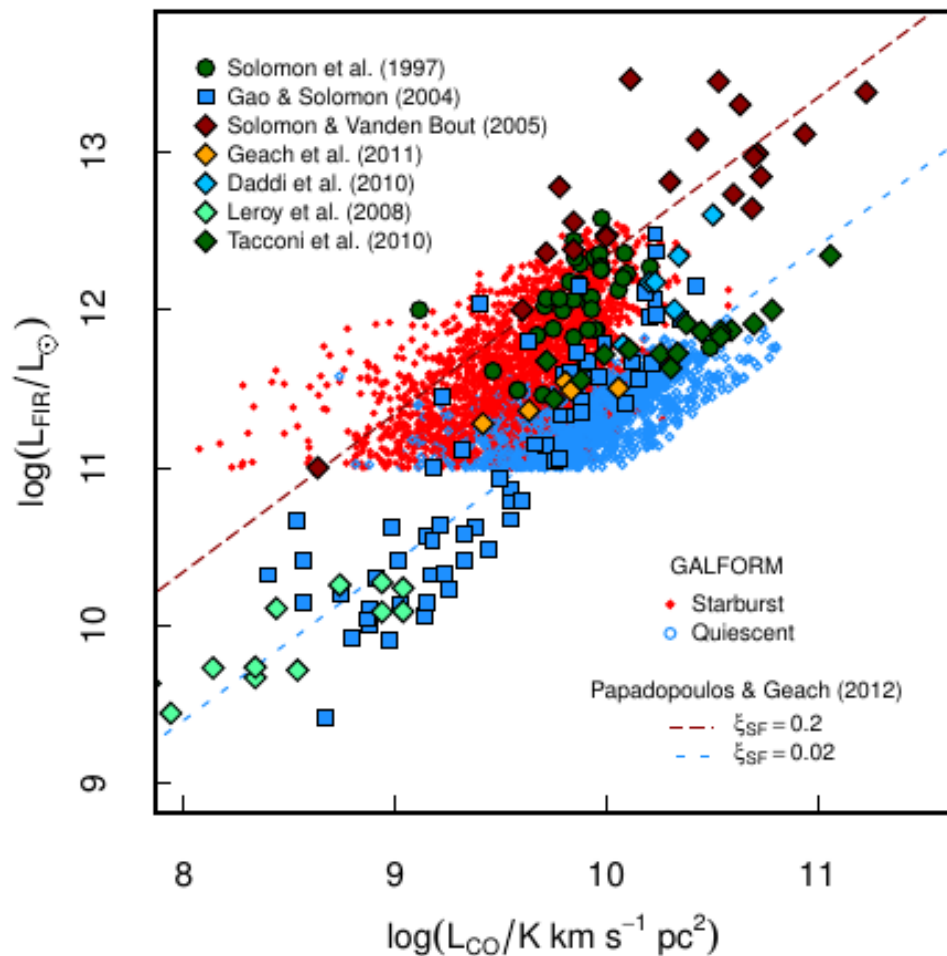
Conclusions

Lagos et al. (2011a,b), Lagos et al. (2012a,b), Geach et al. (2011, 2013 in prep.), Kim et al. (2013)

- **SAM: Powerful tool to study the connection SF/H2/HI. Self-consistent use of parameter free SF laws.**

- **GALFORM.** Model has been tested against HI and H2 mass functions, HI clustering, HI/H2/Optical properties scaling relations.
    → natural result of the relation between H2/HI and pressure.
    → Soon HI/H2/CO luminosities information will be publicly available in Millennium database.
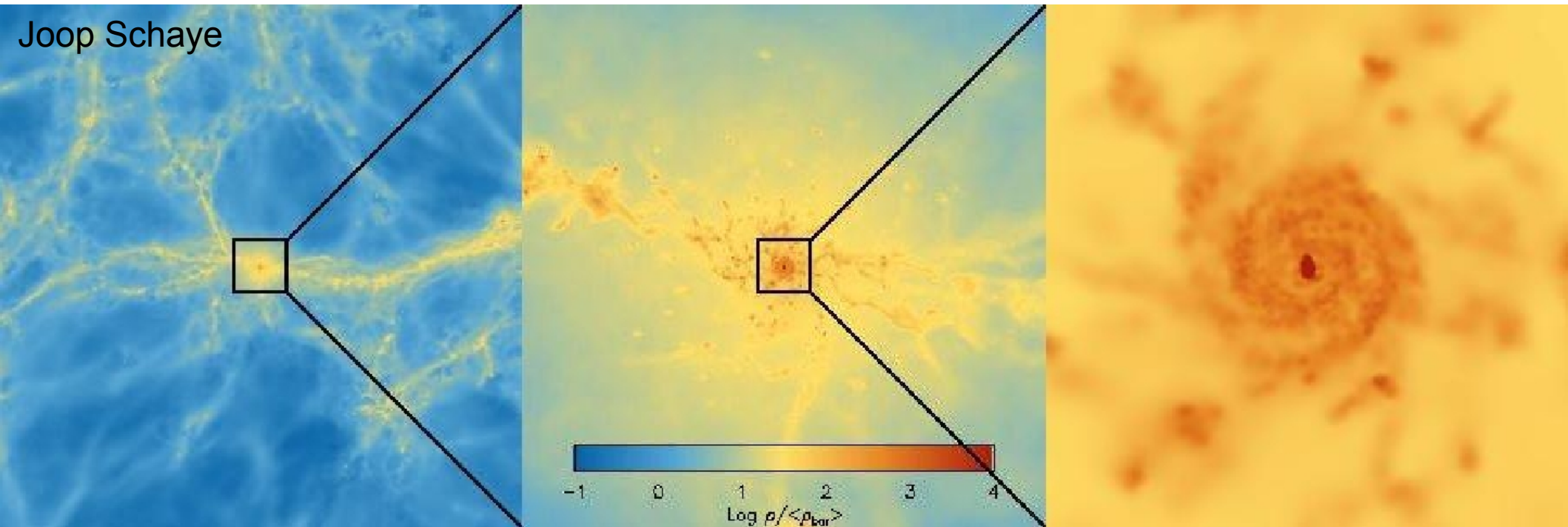
- HI density: consistent with galaxies dominating its content up to z~2.

- HI mass tends to be in low-mass halos in contrast to the H2 mass, which is primarily locked up in intermediate halo masses.

- Explore the power of radio telescopes in detecting high-z molecular emission lines.

# Why is it important to follow galaxy formation in a cosmological scenario?

Joop Schaye

- Cosmology → gives you an unbiased gas inflow and merger history
  → unbiased star formation history/chemical enrichment

"The right physics" should lead us to obtaining the "right" galaxy population.

→ star formation (triggering)
→ feedback (outflows, quenching)
→ multi-phase ISM
→ AGN accretion and jets/mechanical feedback

The universality of the molecular depletion timescale

Leroy et al. (2013)
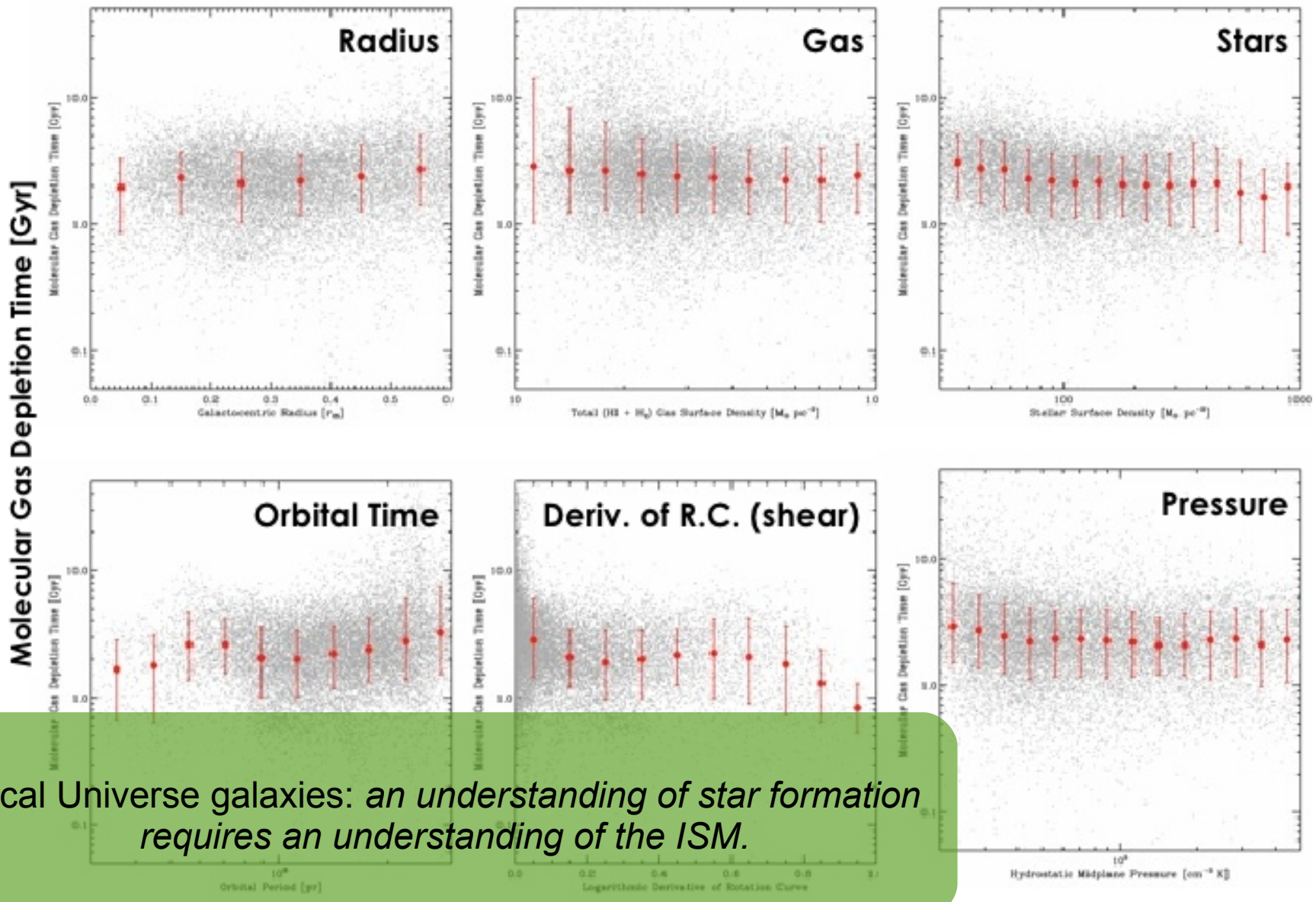
Local Universe galaxies: *an understanding of star formation requires an understanding of the ISM.*