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Cosmic evolution of the gas content of galaxies

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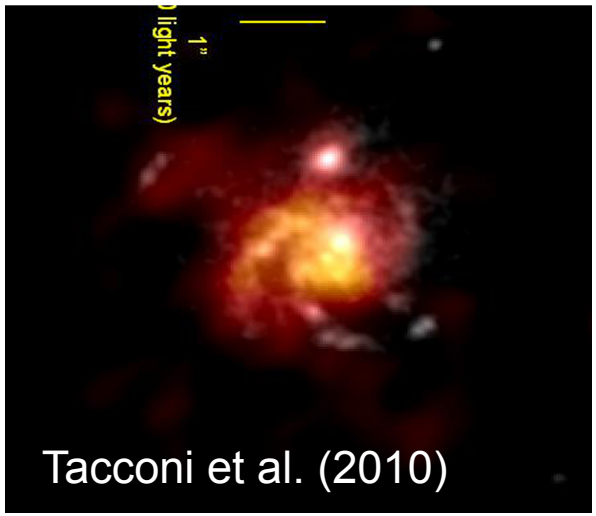
Powerful theoretical tool to predict galaxy evolution in CDM structures:

Semi-analytic models

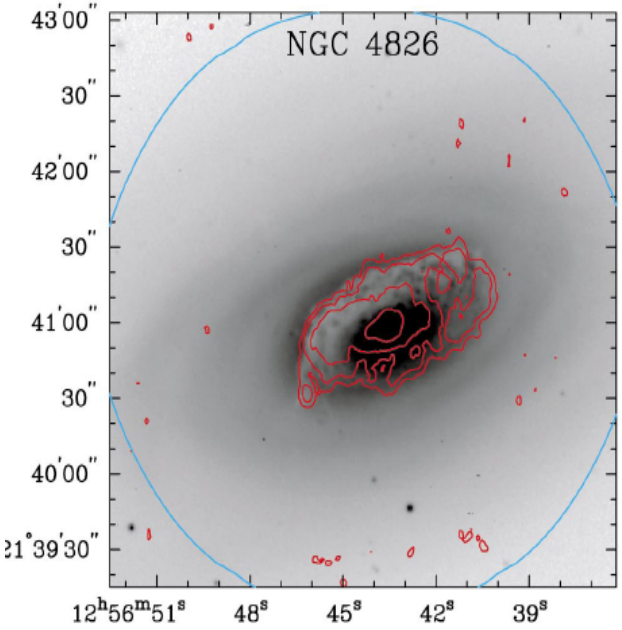
(i) All **relevant physics** that shapes galaxy formation and evolution.

(ii) ***Model gas content/star formation in a self-consistent scenario.***

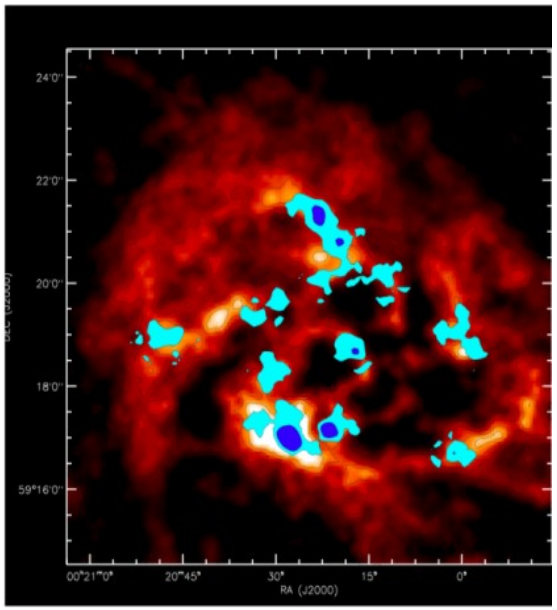
CO(3-2) and I-band



CO(1-0) and optical



BIMA-SONGS

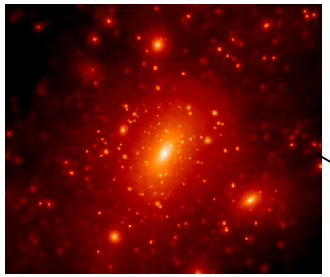


THINGS+CO

GALFORM: Cole et al. (2000), Baugh et al. (2005), Bower et al. (2006), Lagos et al. (2011)

The challenge of modelling galaxy formation
Cole et al. (2000)

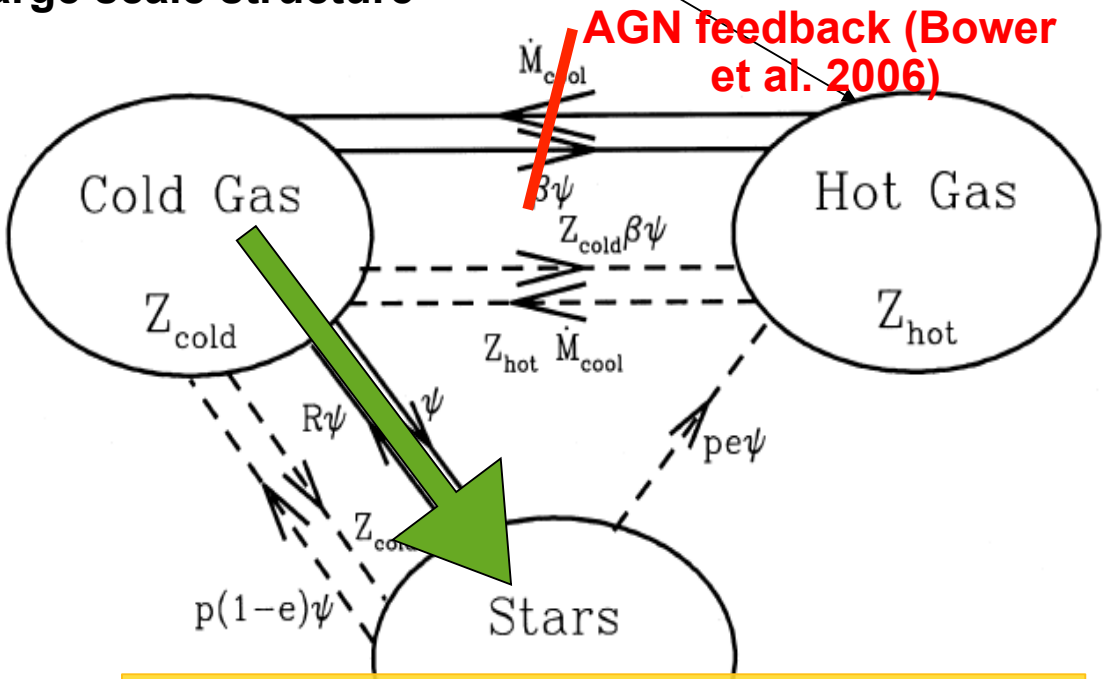
Cosmological model → $\Omega_0, \Lambda_0, \sigma_8,$ h, P(k)



DARK MATTER HALOS
Large scale structure

$$\psi = M_{\rm cold} / \tau_*$$ **??**

$$
\begin{aligned}
\dot{M}_\star &= (1-R)\psi \\
\dot{M}_{\rm cold} &= \dot{M}_{\rm cool} - (1-R+\beta)\psi \\
\dot{M}_{\rm hot} &= -\dot{M}_{\rm cool} + \beta\psi \\
\dot{M}^Z_\star &= (1-R) Z_{\rm cold}\psi \\
\dot{M}^Z_{\rm cold} &= \dot{M}_{\rm cool} Z_{\rm hot} \\
&+ (p - (1+\beta-R) Z_{\rm cold})\psi \\
\dot{M}^Z_{\rm hot} &= -\dot{M}_{\rm cool} Z_{\rm hot} + (p\,e + \beta Z_{\rm co}
\end{aligned}
$$

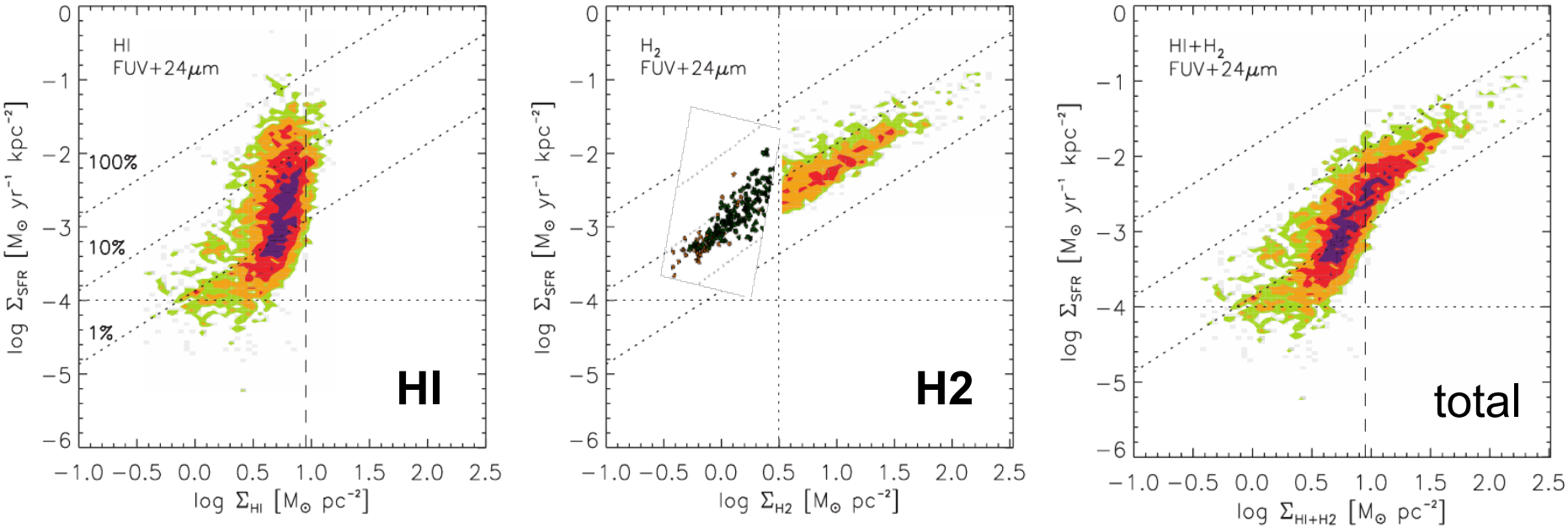


GOOD NEWS!
Better understanding of the SF law

Characterisation of the SF law in local galaxies

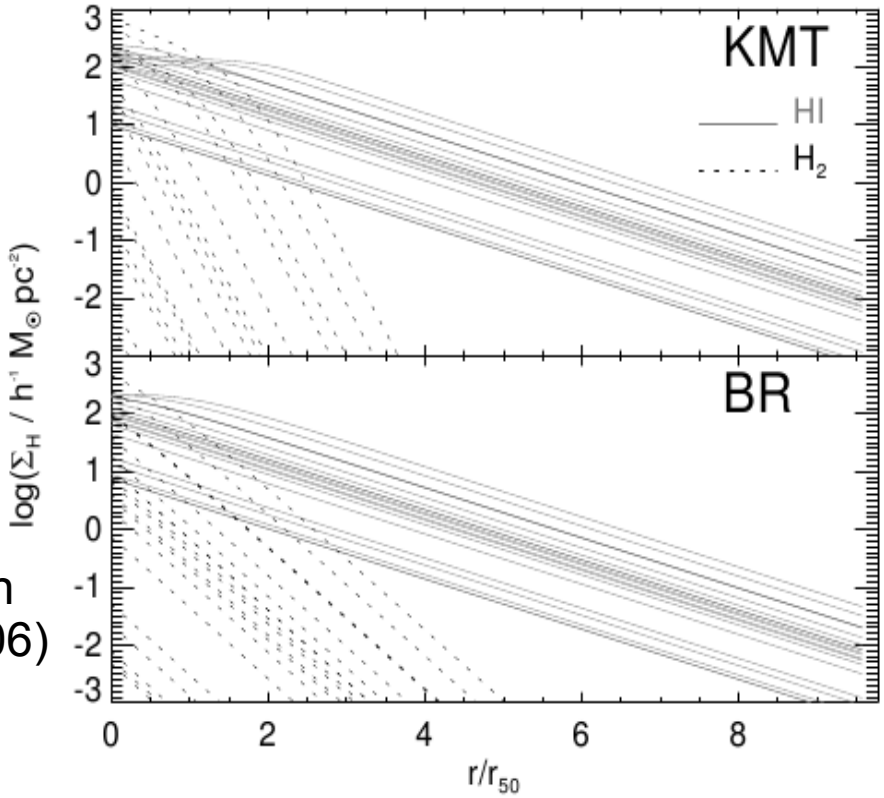
Bigiel et al. (2008): 18 late-type (THINGS, HERACLES, BIMA-SONGS, Spitzer, GALEX)

Kennicutt et al. (2007), Wyder et al. (2009), Roychowdhury et al. (2009), Onodera et al. (2010), Schruba et al. (2010, 2011), Bigiel et al. (2011), etc.



- No correlation with HI
- Linear correlation with H_2
- Multiple regimes with total gas density

New SF laws: Splitting the interstellar medium- He, atomic and molecular Hydrogen



Lagos et al. (2011a, in press, arXiv:1011.5506)

$f_{\rm mol}(\Sigma_{\rm comp}, Z)$

Krumholz et al (2008, 2009)

FUV photo-dissociation +formation on dust grains

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

Wong & Blitz (2002), Blitz & Rosolowski (2006), Kennicutt et al. (2007), Leroy et al. (2008)

Incorporate observationally motivated, parameter free SF laws: ***model is modular: self-consistent implementation***

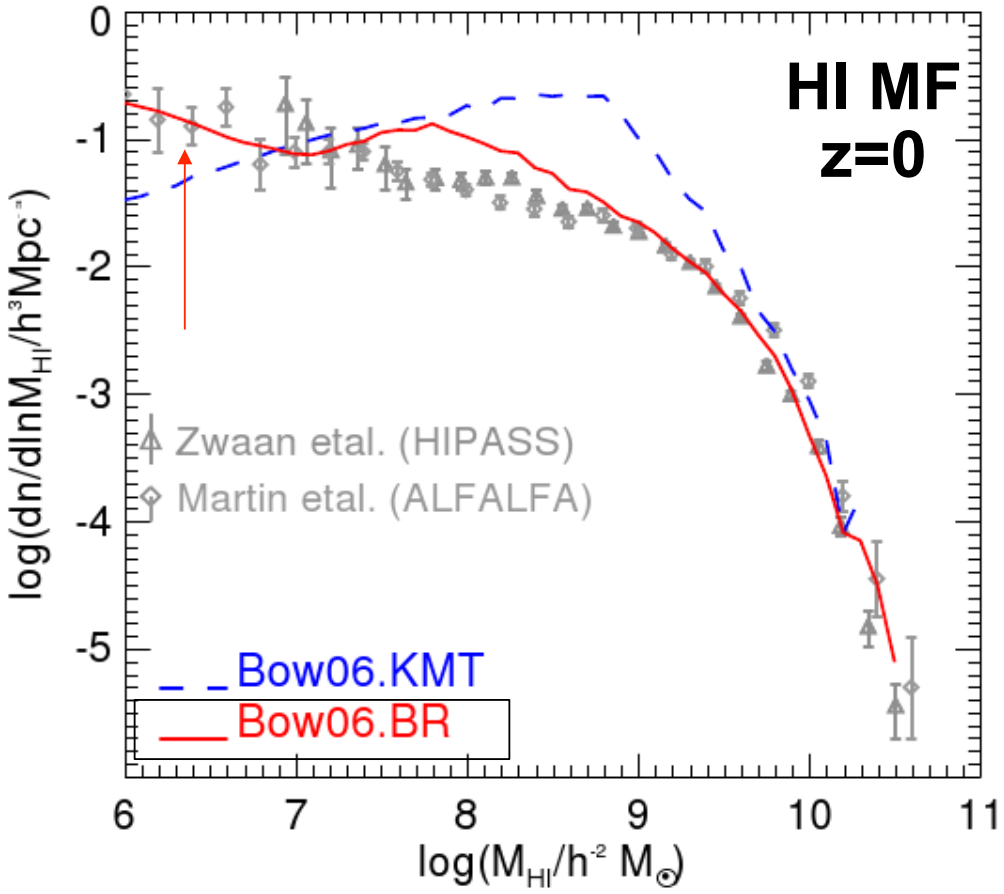
Can we predict the stellar and gas content of galaxies at the same time?

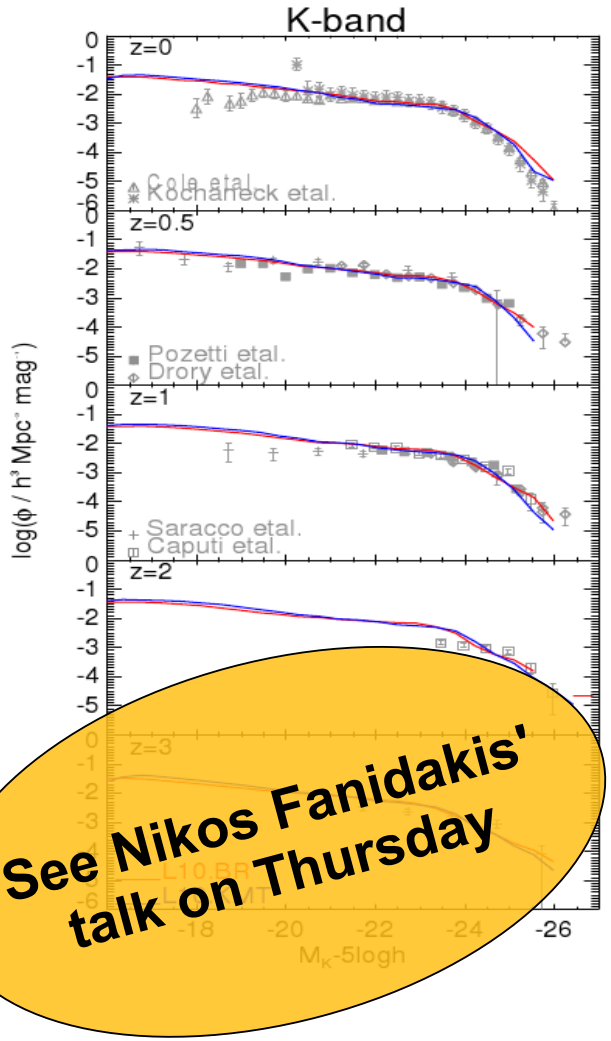
How does molecular and neutral hydrogen content relate to other galaxy properties?

What is the form of these relations at high redshift?

We use GALFORM. Without changing any other model parameter (Lagos et al. 2011a, 2011b).

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



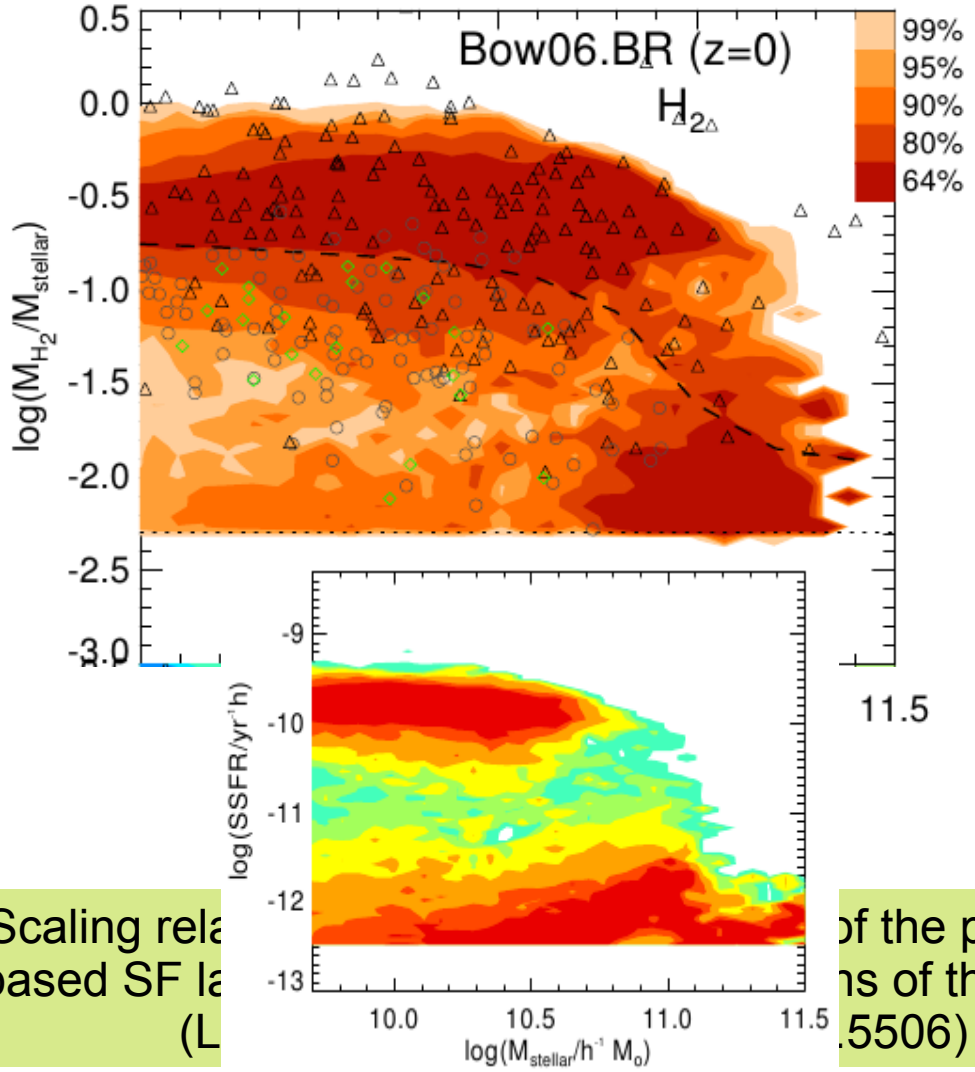


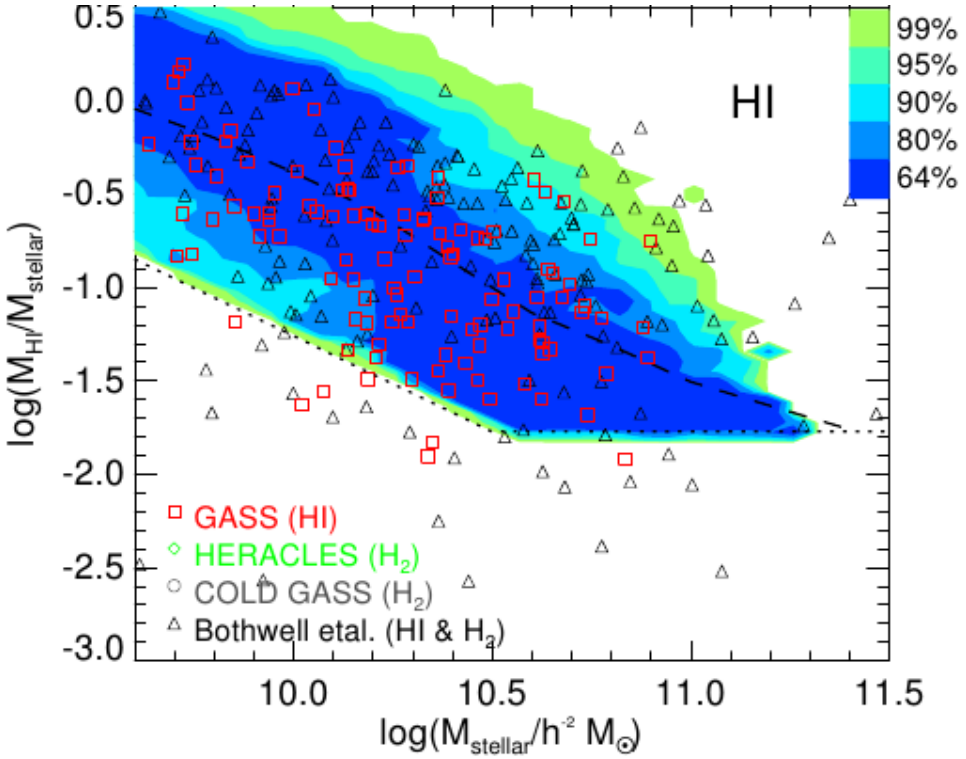
See Nikos Fanidakis' talk on Thursday

Predicted HI MF in good agreement!

Faint end is a fundamental success of the new SF law

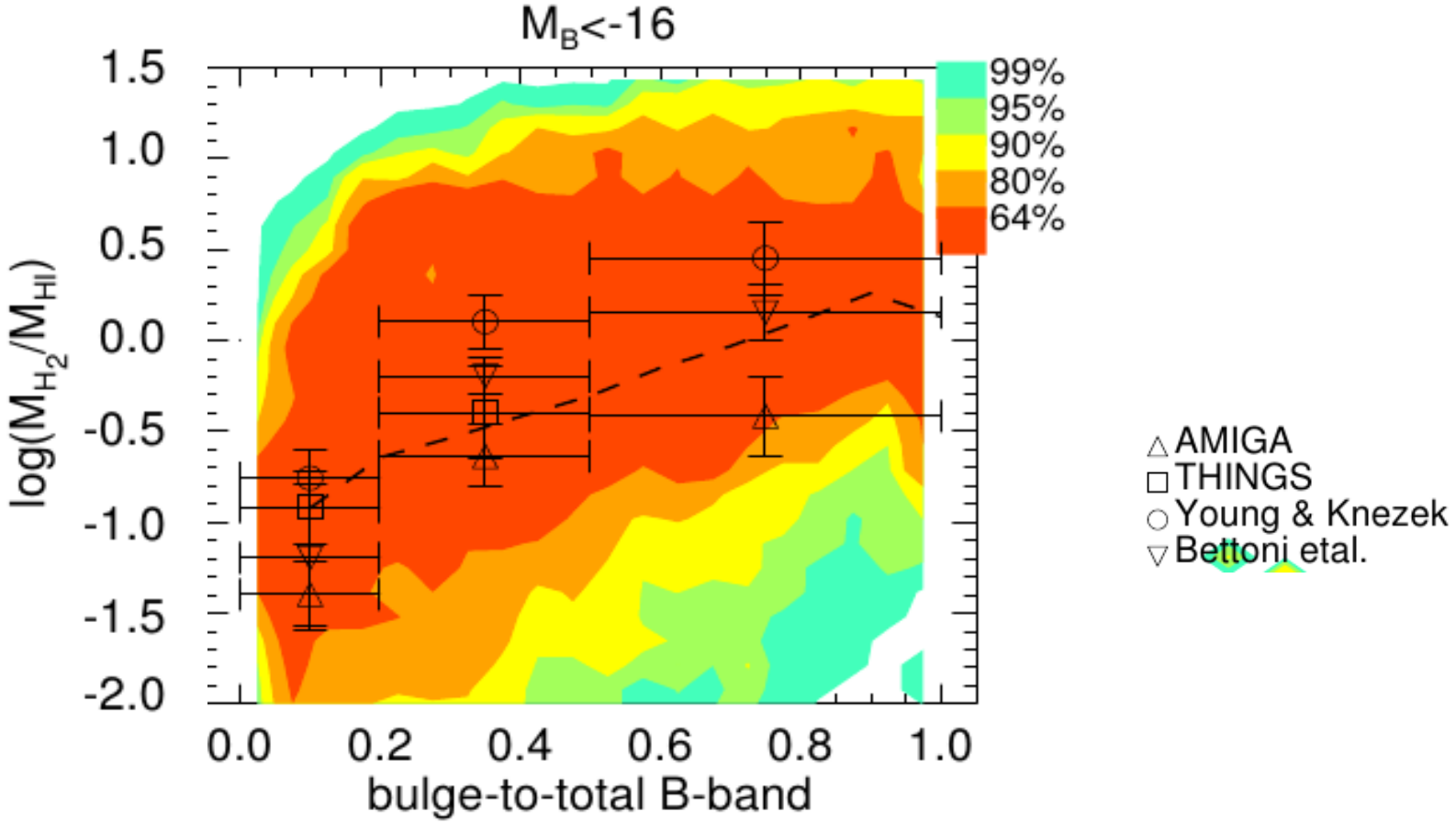
Scaling relations: stars/cold gas (Lagos et al. 2011b, arXiv: 1105.2294)





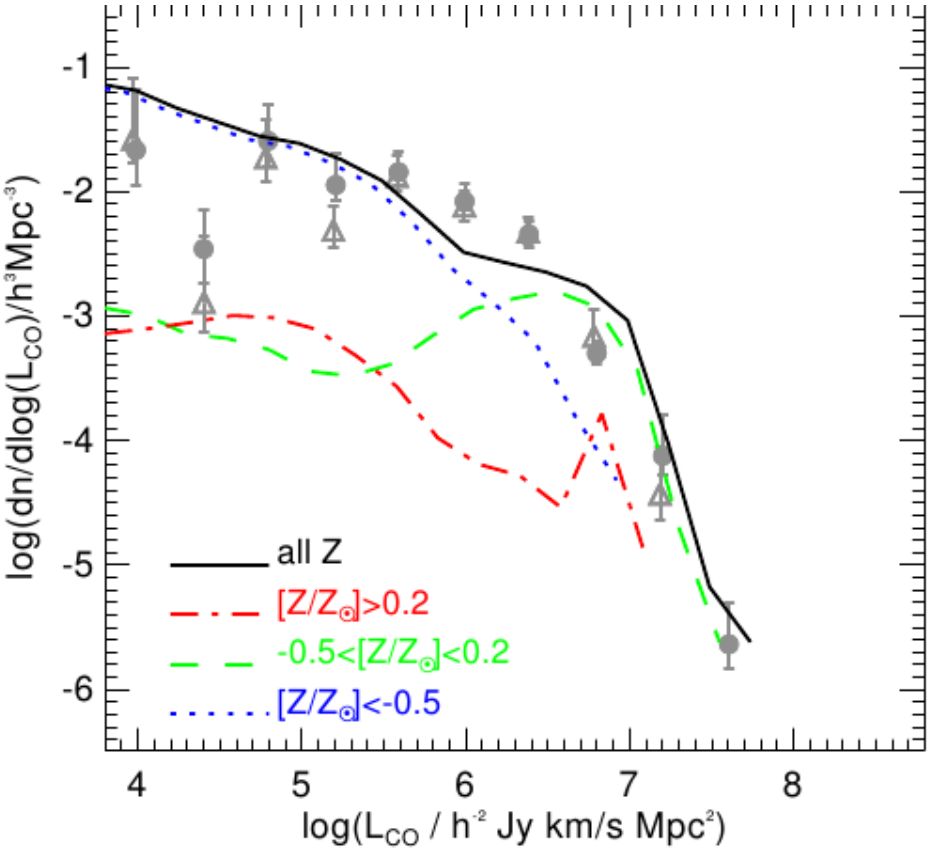
Scaling rela of the pressure-based SF la ns of the model (L .5506)

Scaling relations: morphology (Lagos et al. 2011b; arXiv: 1105.2294)



Stellar content contributes more to gas pressure in early-type galaxies.

The H2 mass function
(Lagos et al. 2011b, arXiv:1105.2294)



Xco=3.5 (non-starbursts)
Xco=0.8 (starbursts)

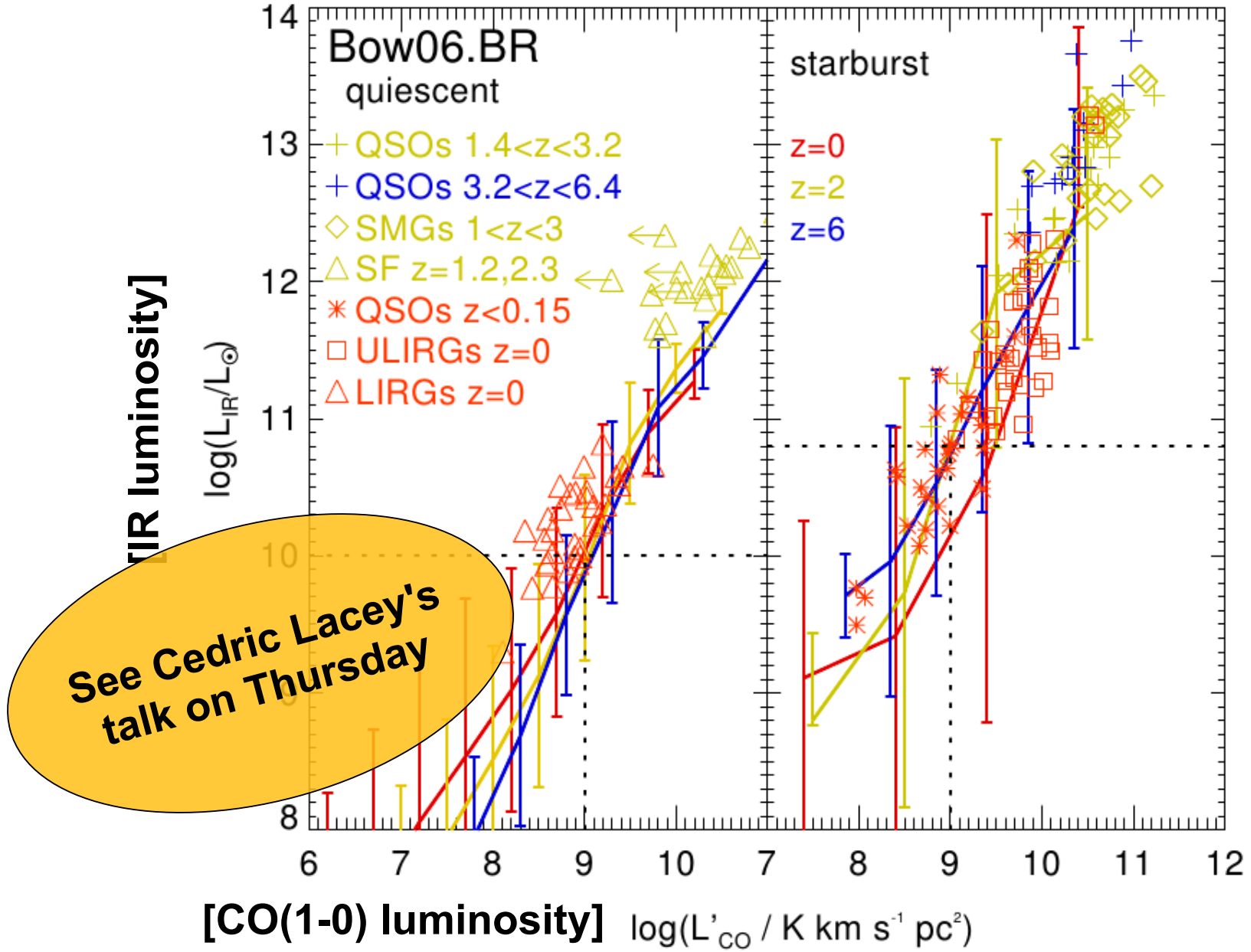
L_{CO} Keres etal. (2003) B-band (z=0)

L_{CO} Keres etal. (2003) 60μm (z=0)

CAVEAT: constant H2-CO conversion factor
(fundamental uncertainty)

CO - IR luminosity relation

(Lagos et al. 2011b, arXiv:1105.2294)



See Cedric Lacey's talk on Thursday

Conclusions

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

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

- The SF law has a small impact on the total SFR density and b_J/K LF, but large on the gas content.

- HI, CO LF, HI clustering at z=0 well matched by the predictions of the BR SF law.

- Scaling relations at z=0: Fundamental prediction of pressure-based law and GALFORM.

- IR-CO luminosity relation: 2 regime of star formation.

- Molecular gas fraction evolution: ***Strong evolution with z due to higher pressure driven by size evolution*** (Jim Geach's talk)***.***