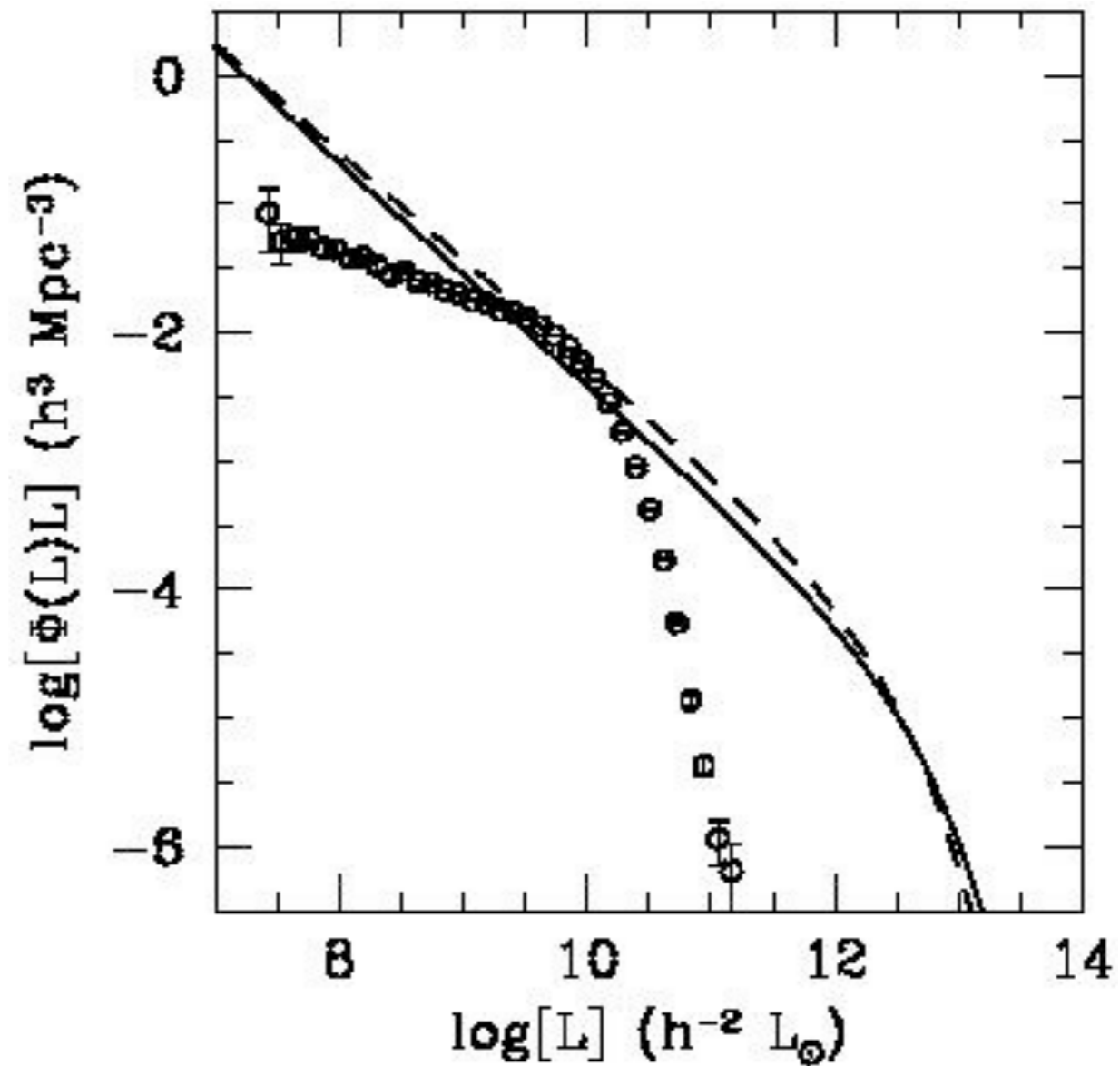


Star formation feedback in galaxy formation models

Yu Lu
(KIPAC/Stanford)

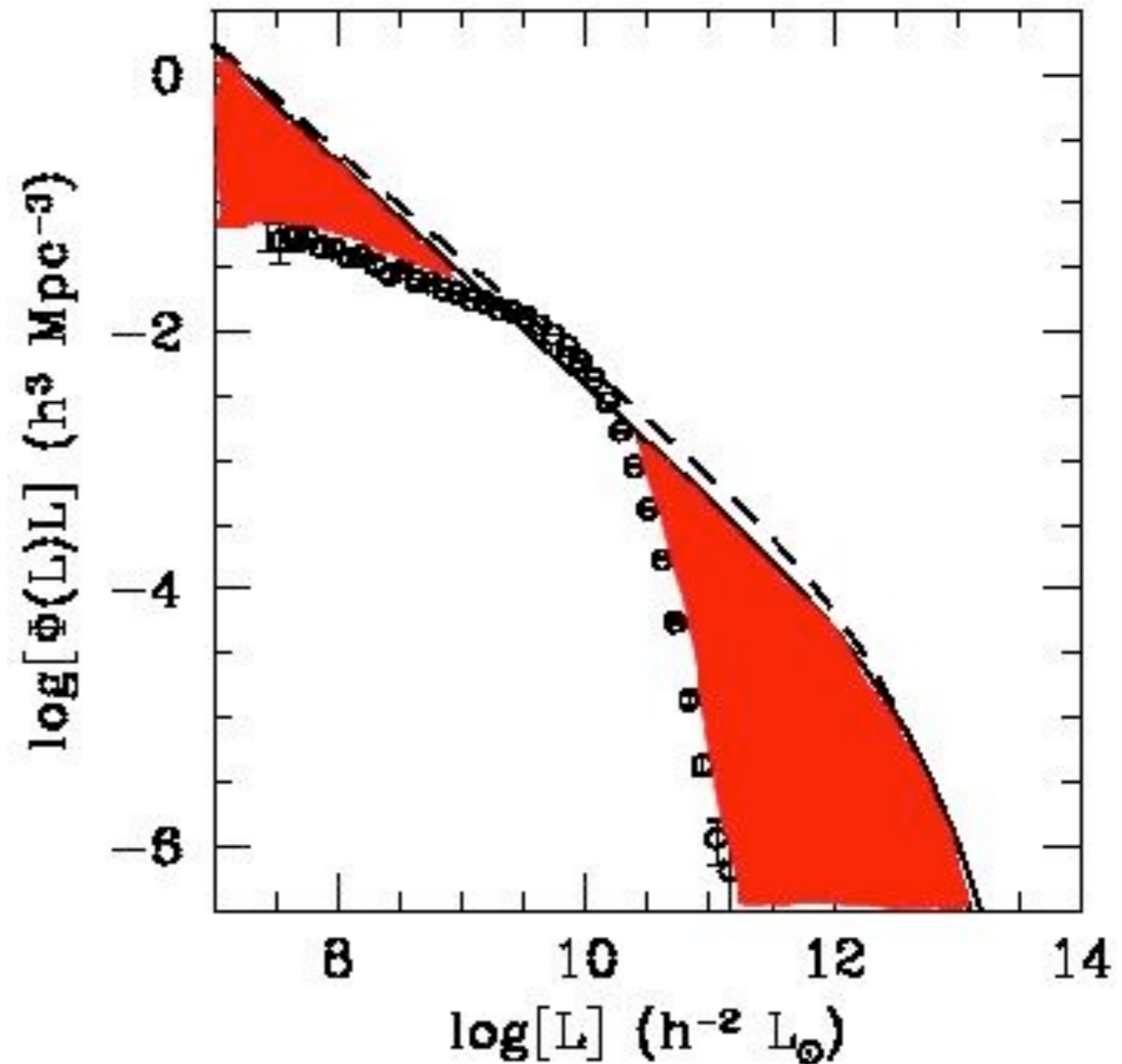
Overview

- Galaxies form in dark matter halos.
- CDM model predicts too many low-mass and high-mass halos.
- “Feedback” is needed to explain galaxy LFs.



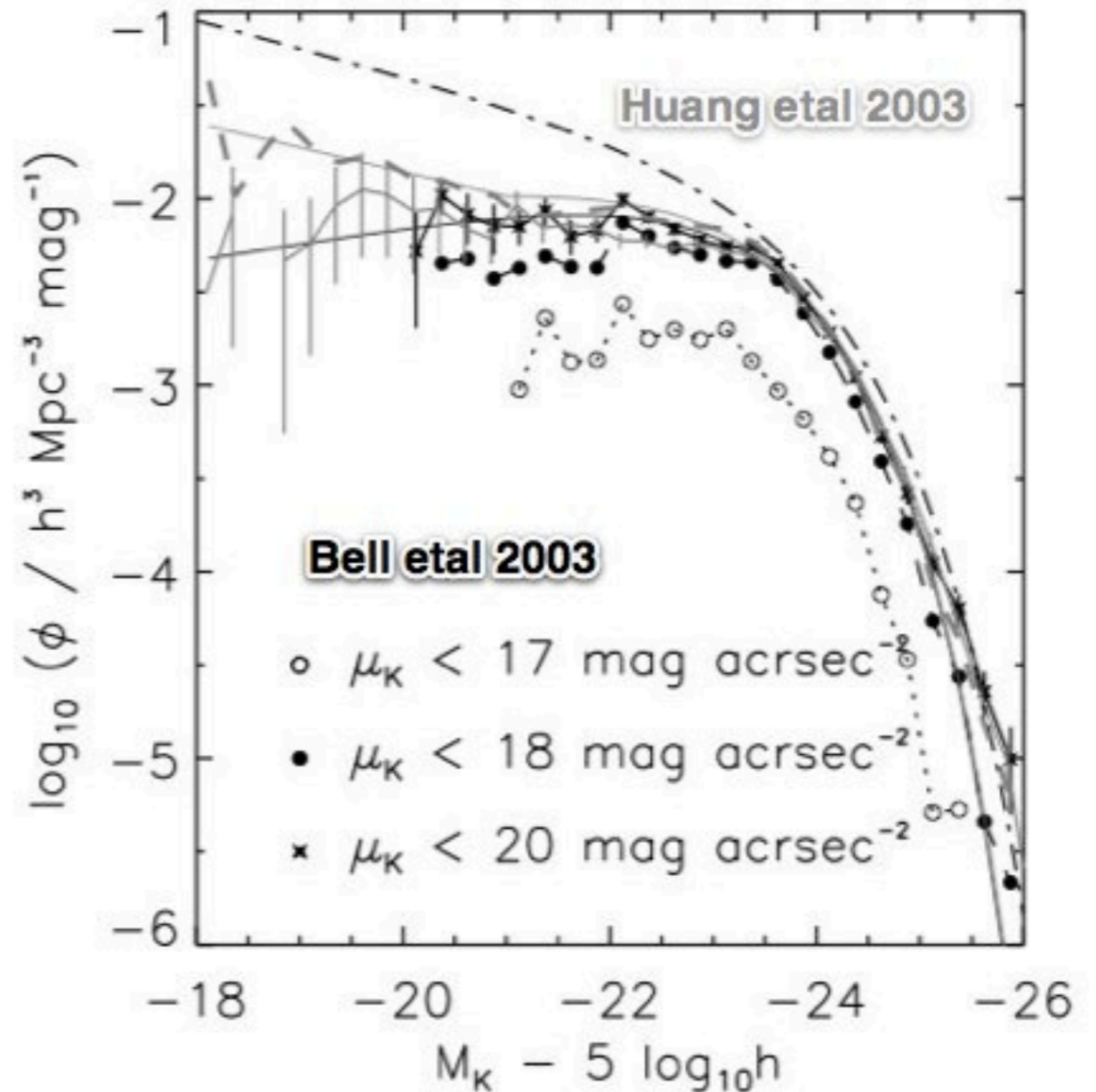
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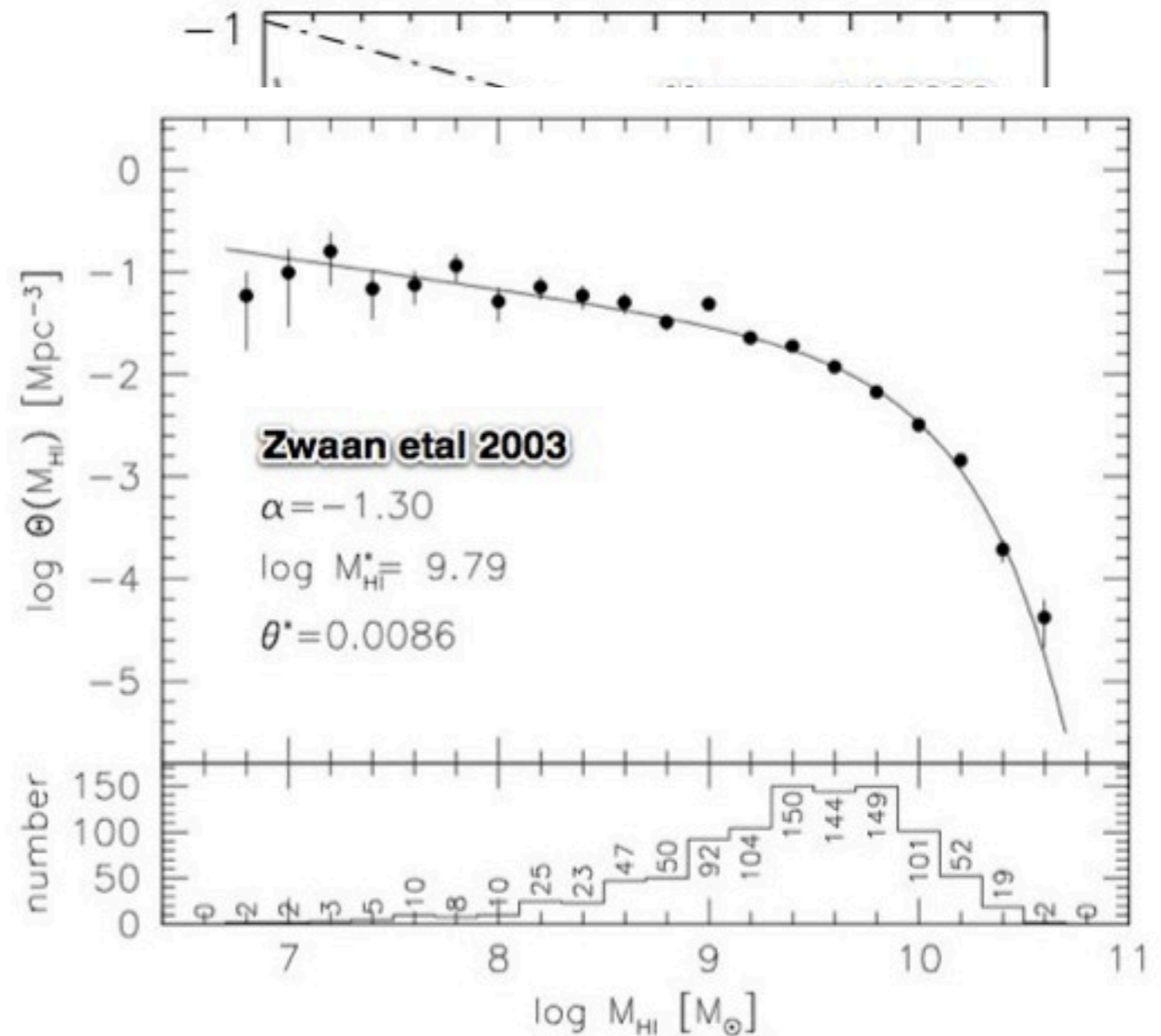
Overview

- For low mass halos, $t_{\text{cool}} < t_{\text{hubble}}$. Feedback is needed.
- In galaxy formation models (Semi-Analytic Models):
 - Baryons are accreted into a halo, $f_b * m_{\text{vir}}$;
 - Gas cools, forms stars, and generates outflows.
 - All the feedback processes are related to star formation (SN II, stellar wind, radiation pressure).
 - Stellar mass - source; cold gas mass - residual.
- Questions: 1). can this type of models explain LF and HIMF at $z=0$? 2). What can we learn something from those models?



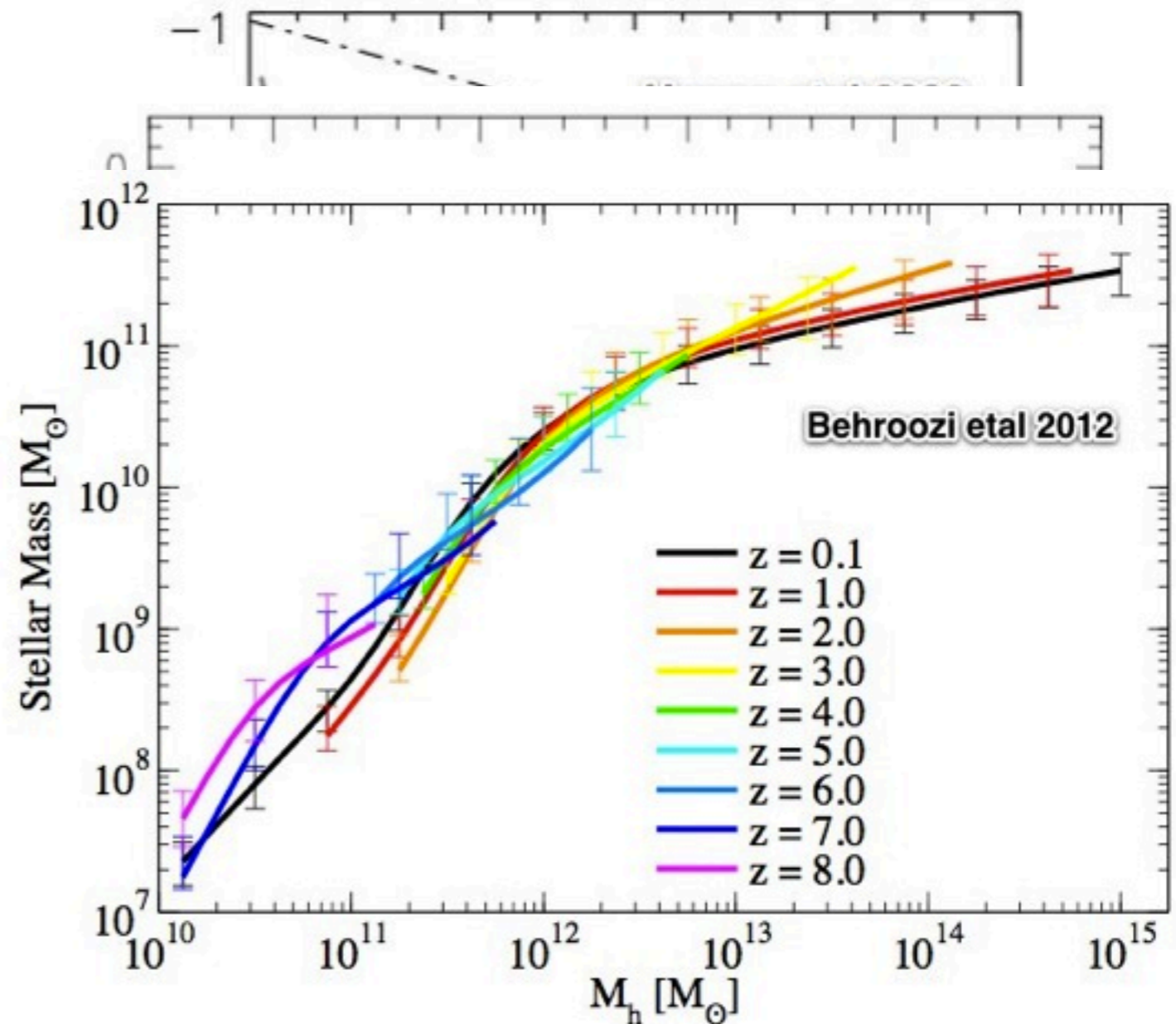
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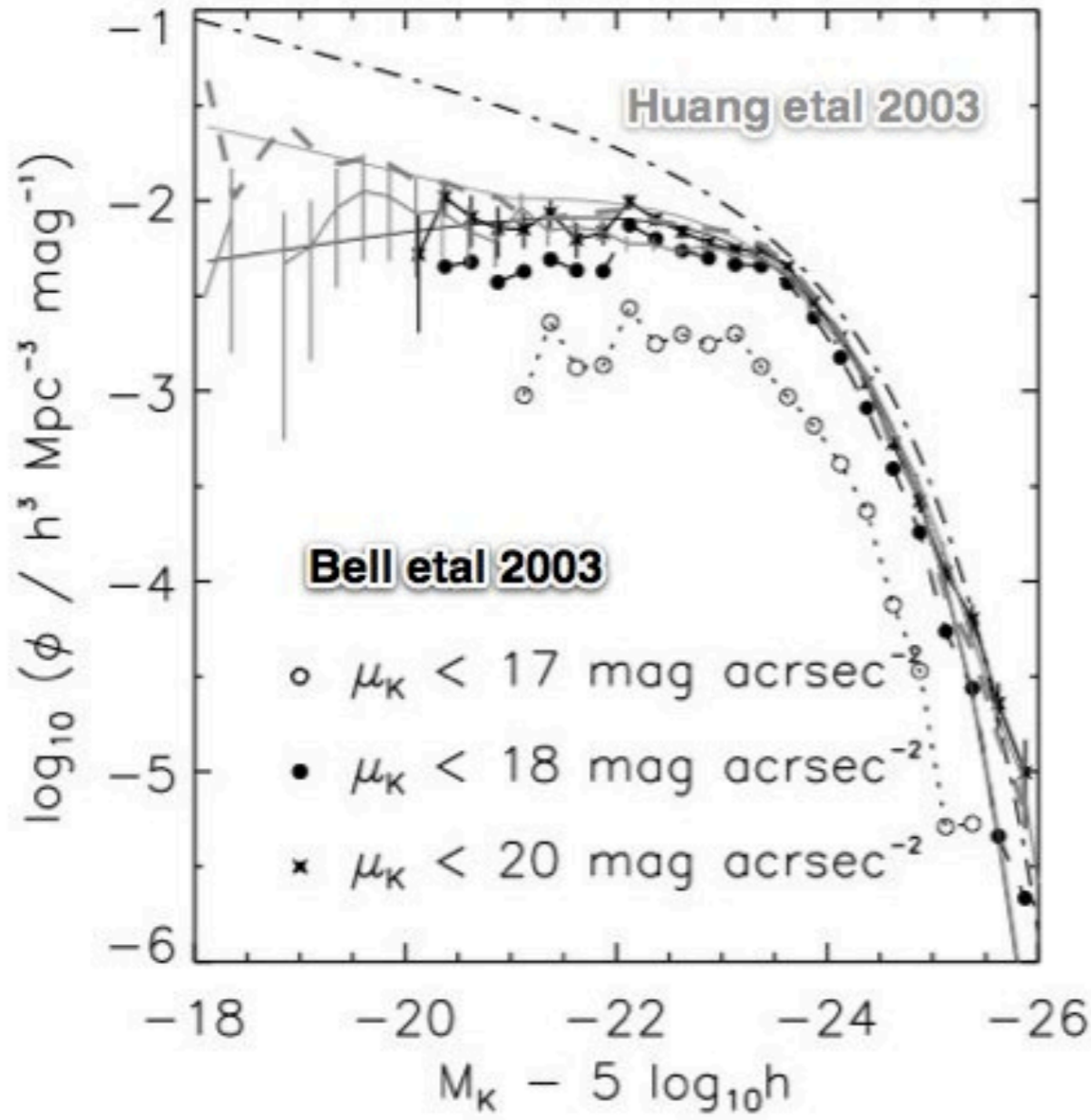


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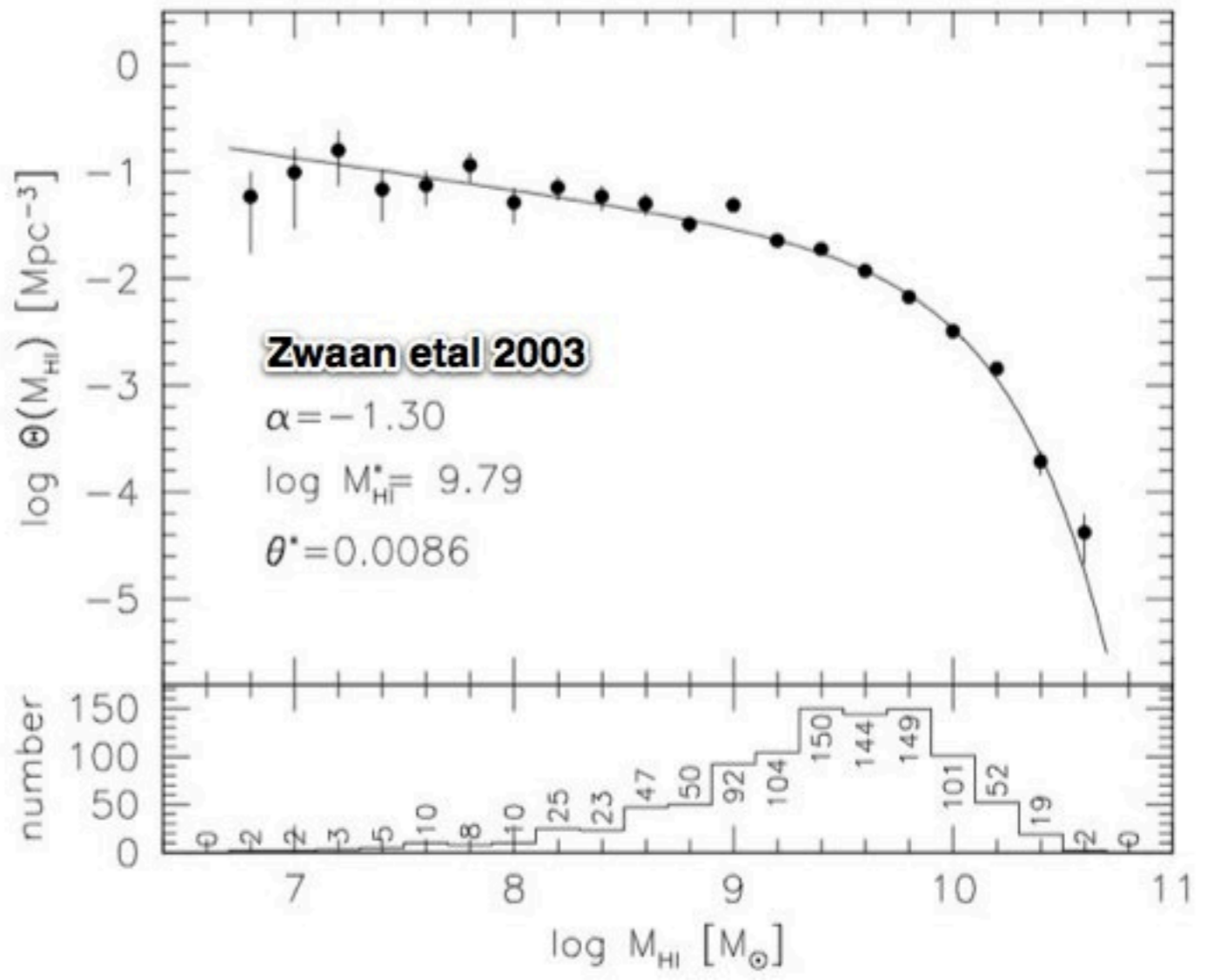
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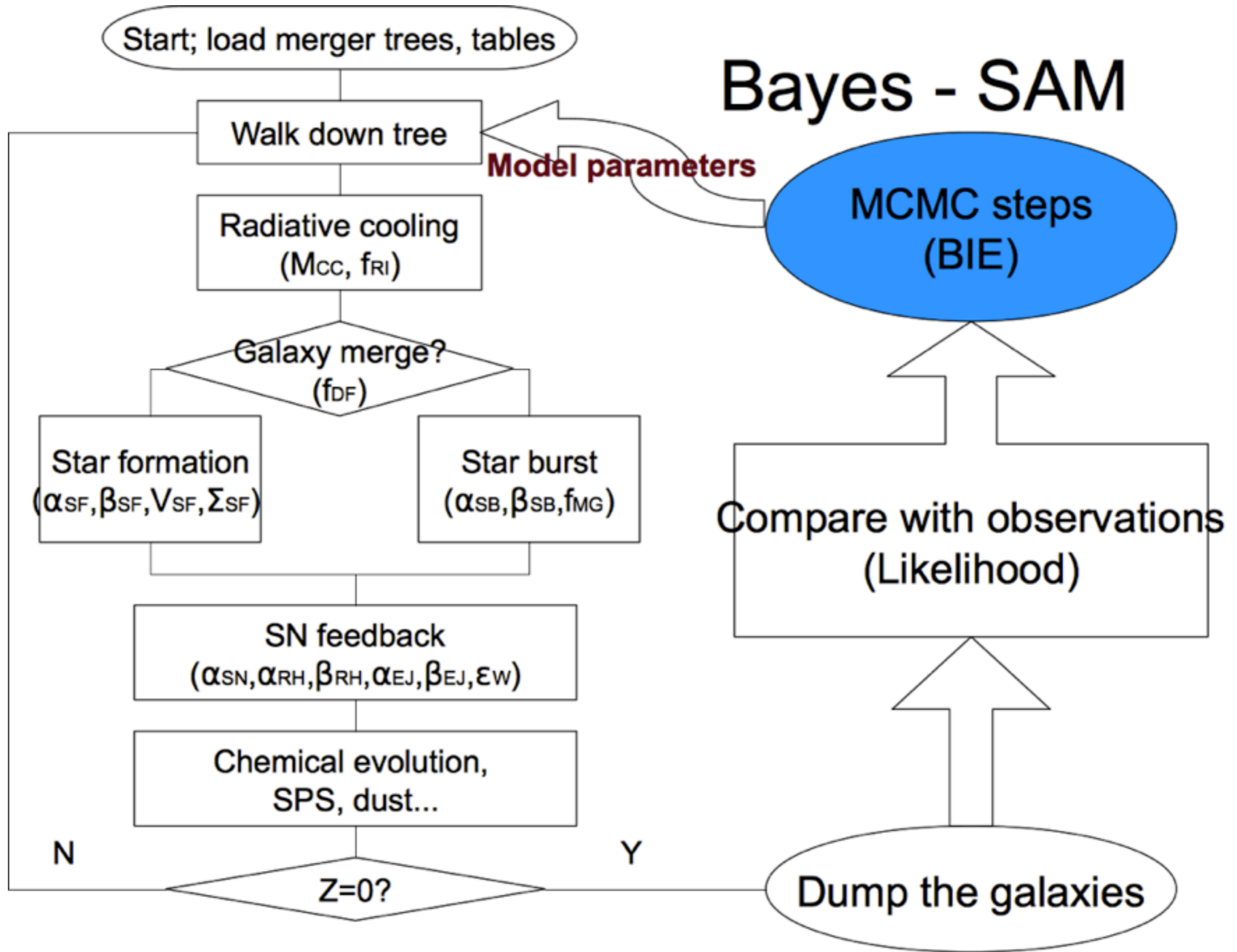
K-band LF



HI MF



Bayes - SAM



Star formation feedback model

- causes outflow from ISM:

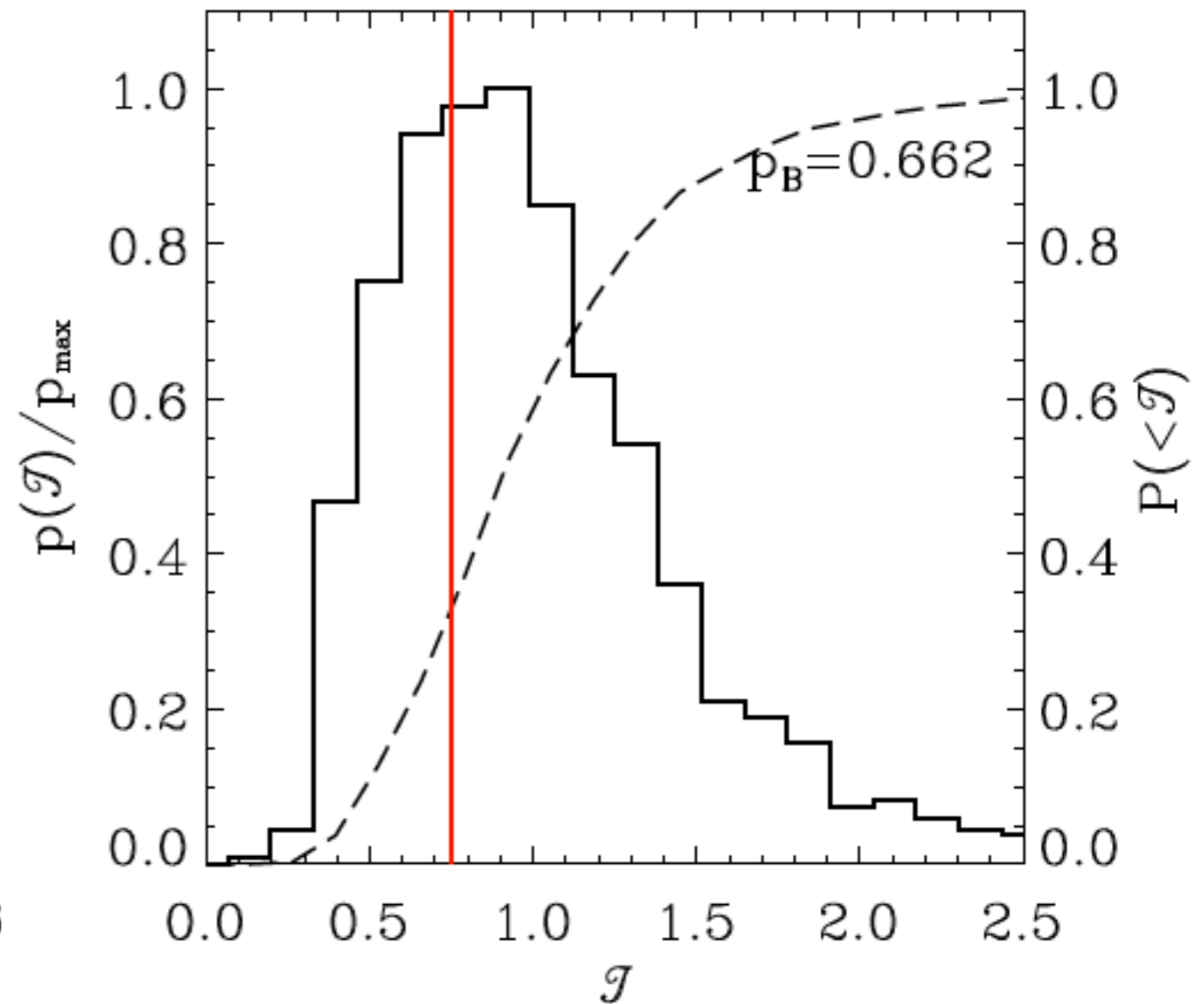
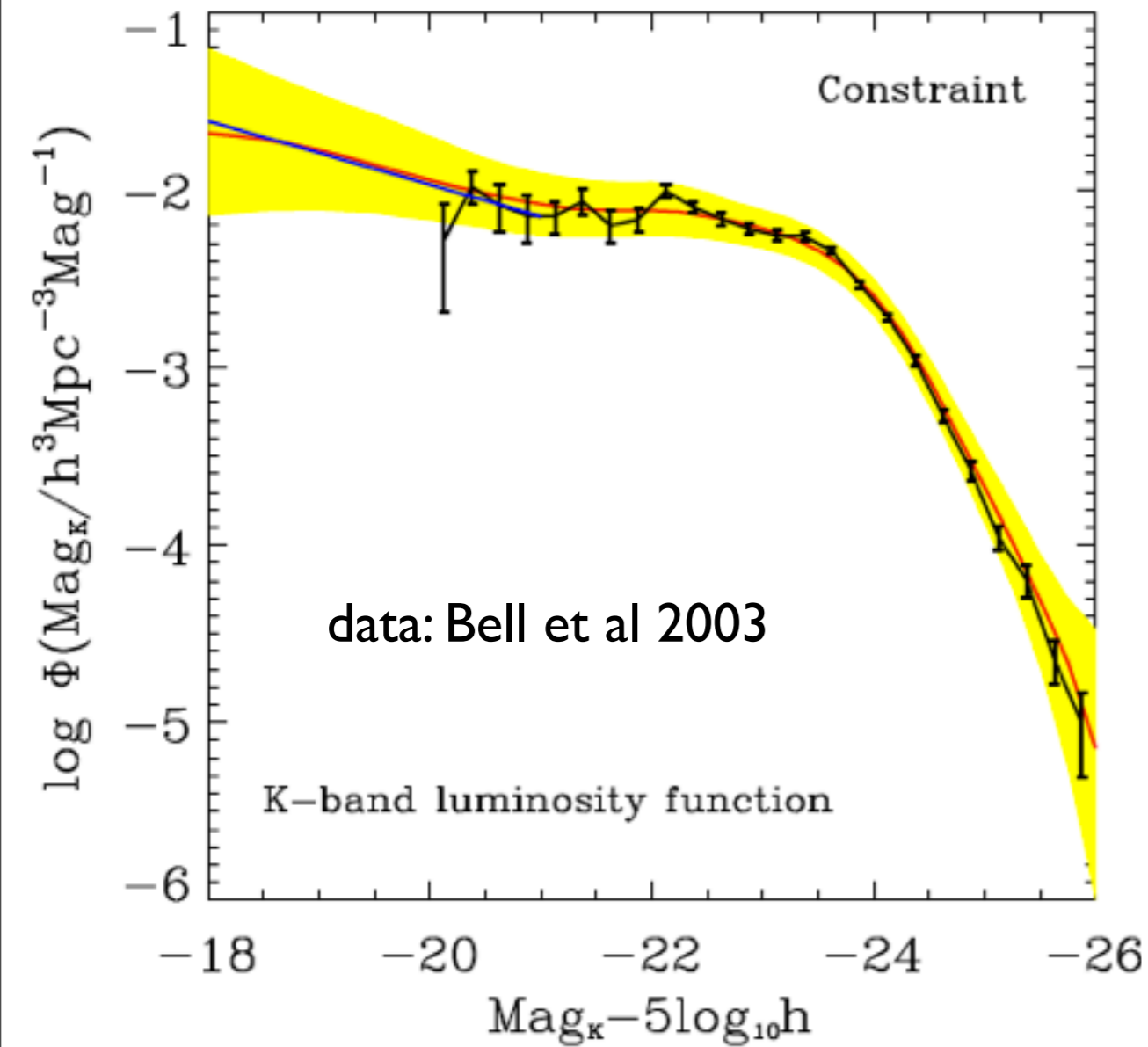
$$\dot{M}_{\text{out}} = \alpha_{\text{RH}} \left(\frac{V_0}{V_c} \right)^{\beta_{\text{RH}}} \dot{M}_{\text{sf}}$$

- ejects a fraction of the outflow out of halo:

$$f_{\text{ej}} = \left[1 + \left(\frac{V_c}{V_{\text{EJ}}} \right)^{\beta_{\text{EJ}}} \right]^{-1}$$

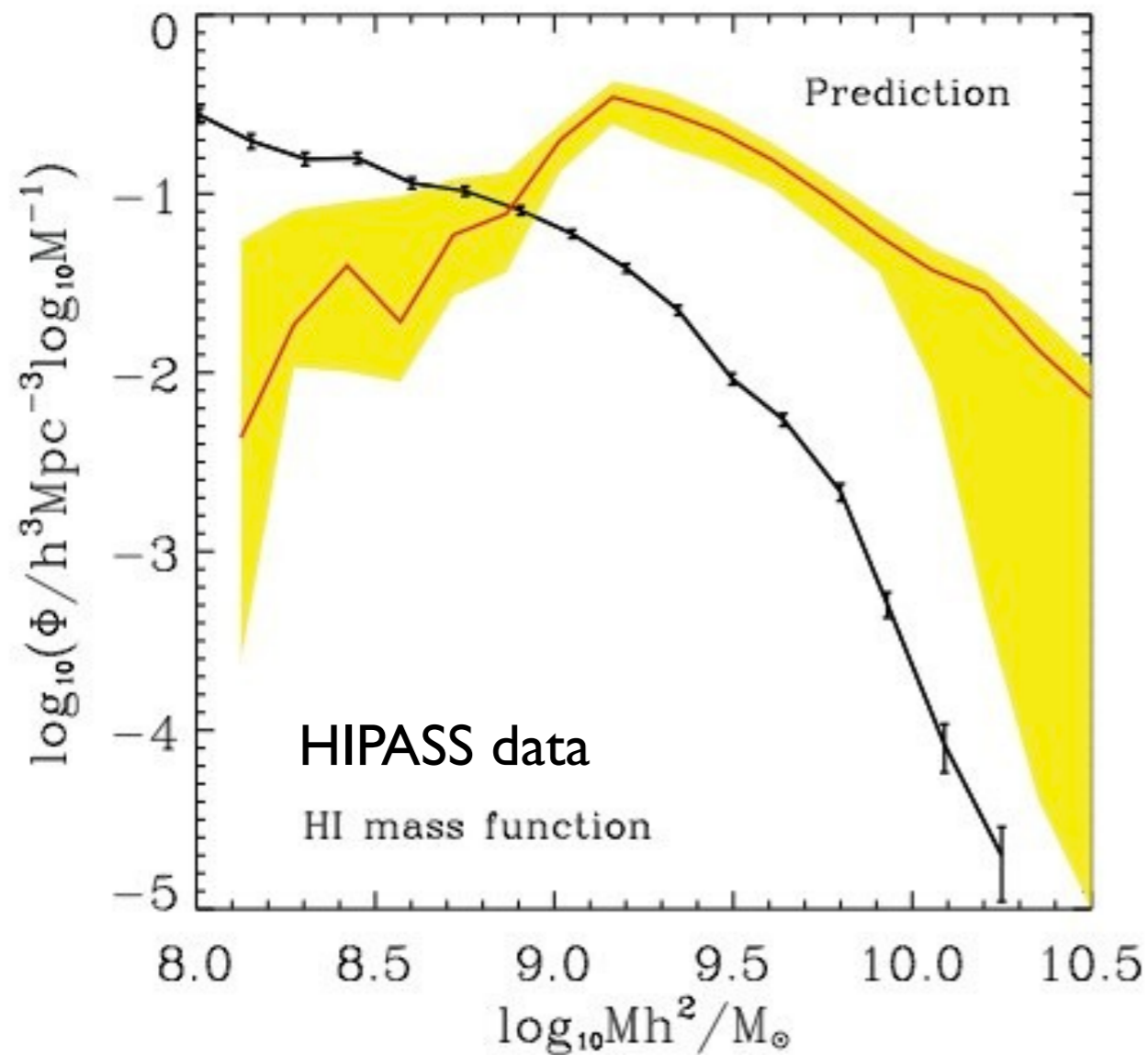
- retaining/ejecting

retaining model:

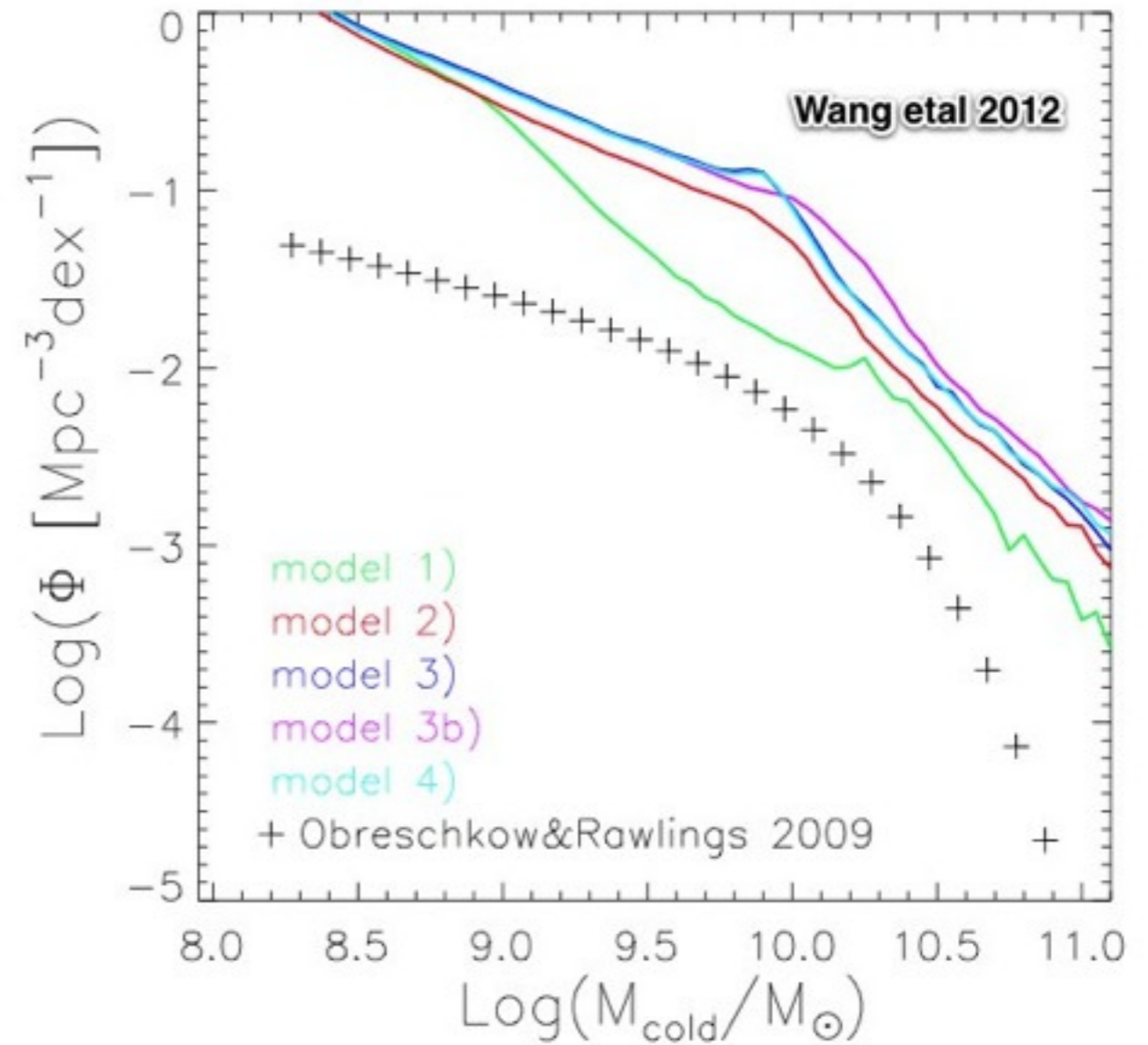


Lu et al 2012

retaining model: prediction



Lu et al 2012



Star formation feedback model

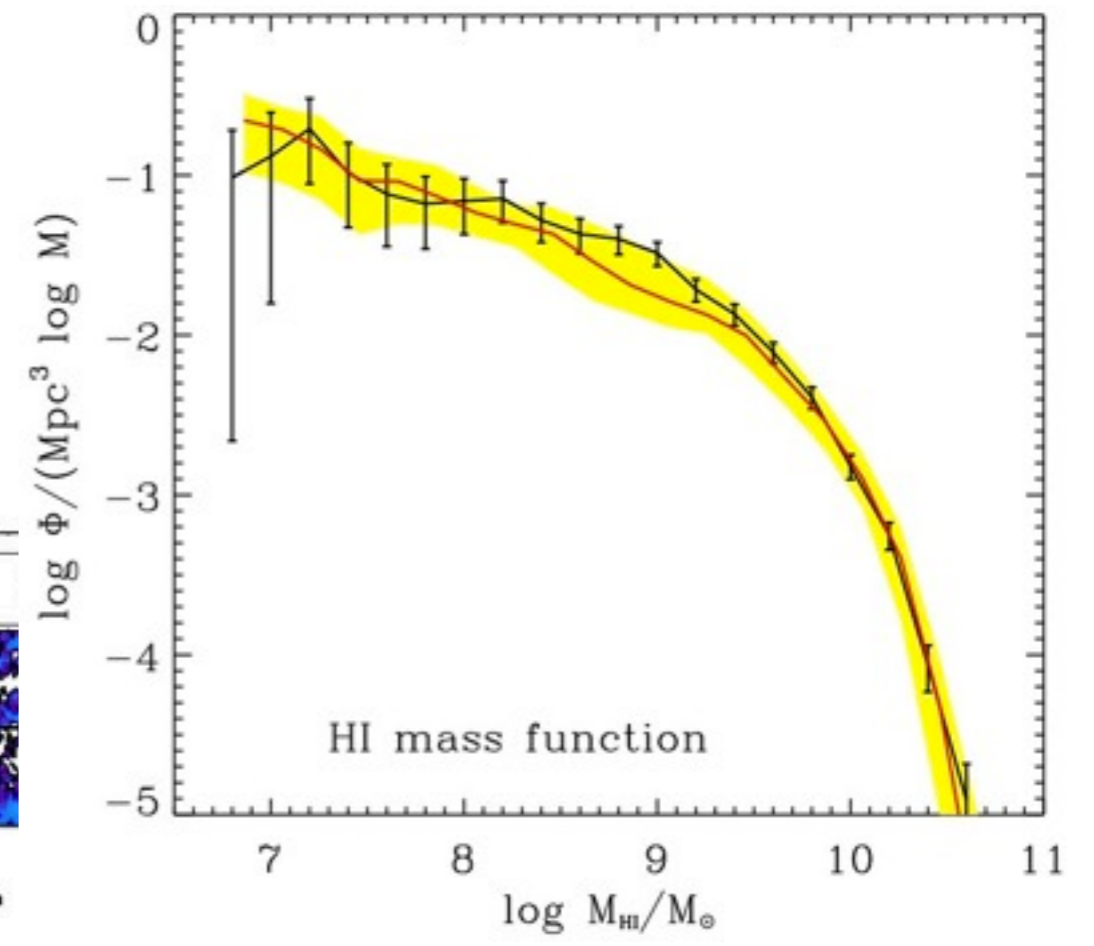
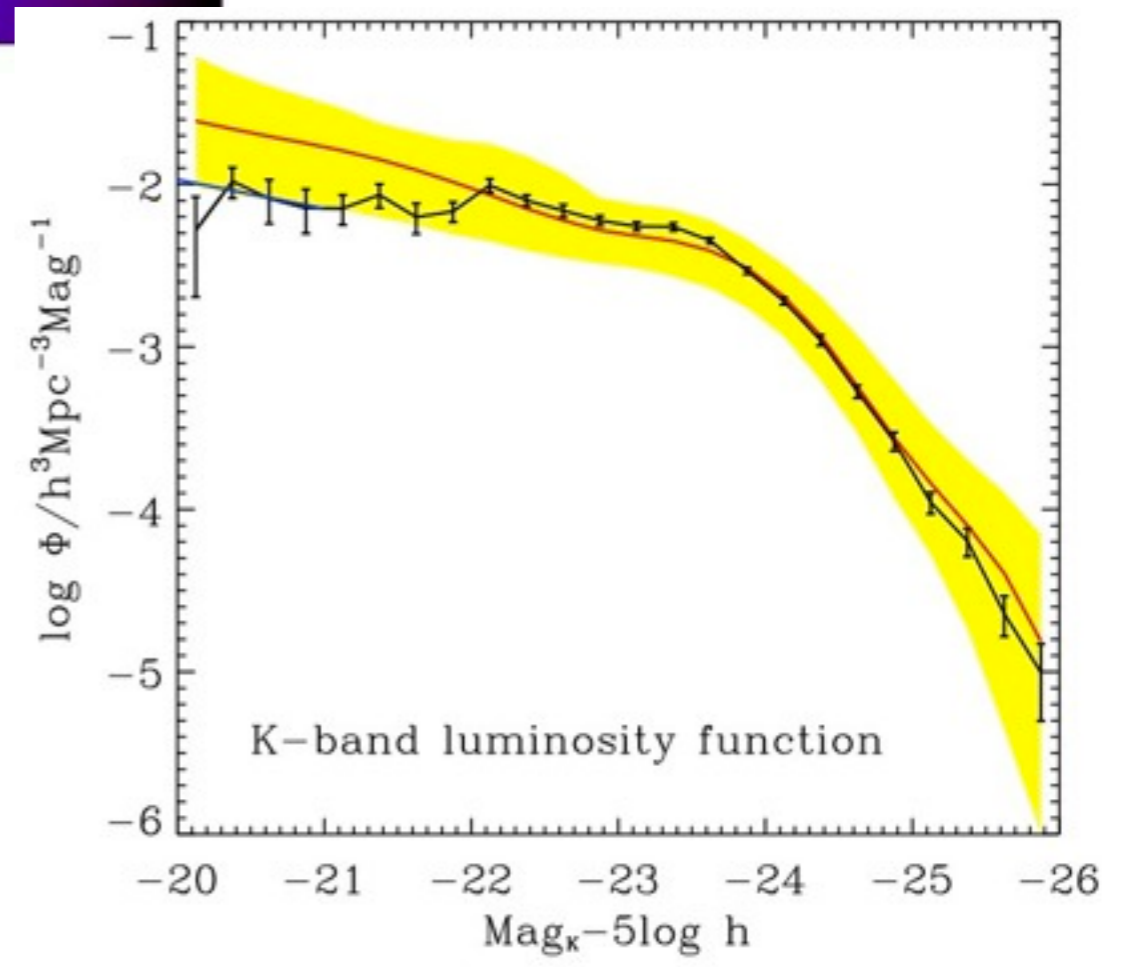
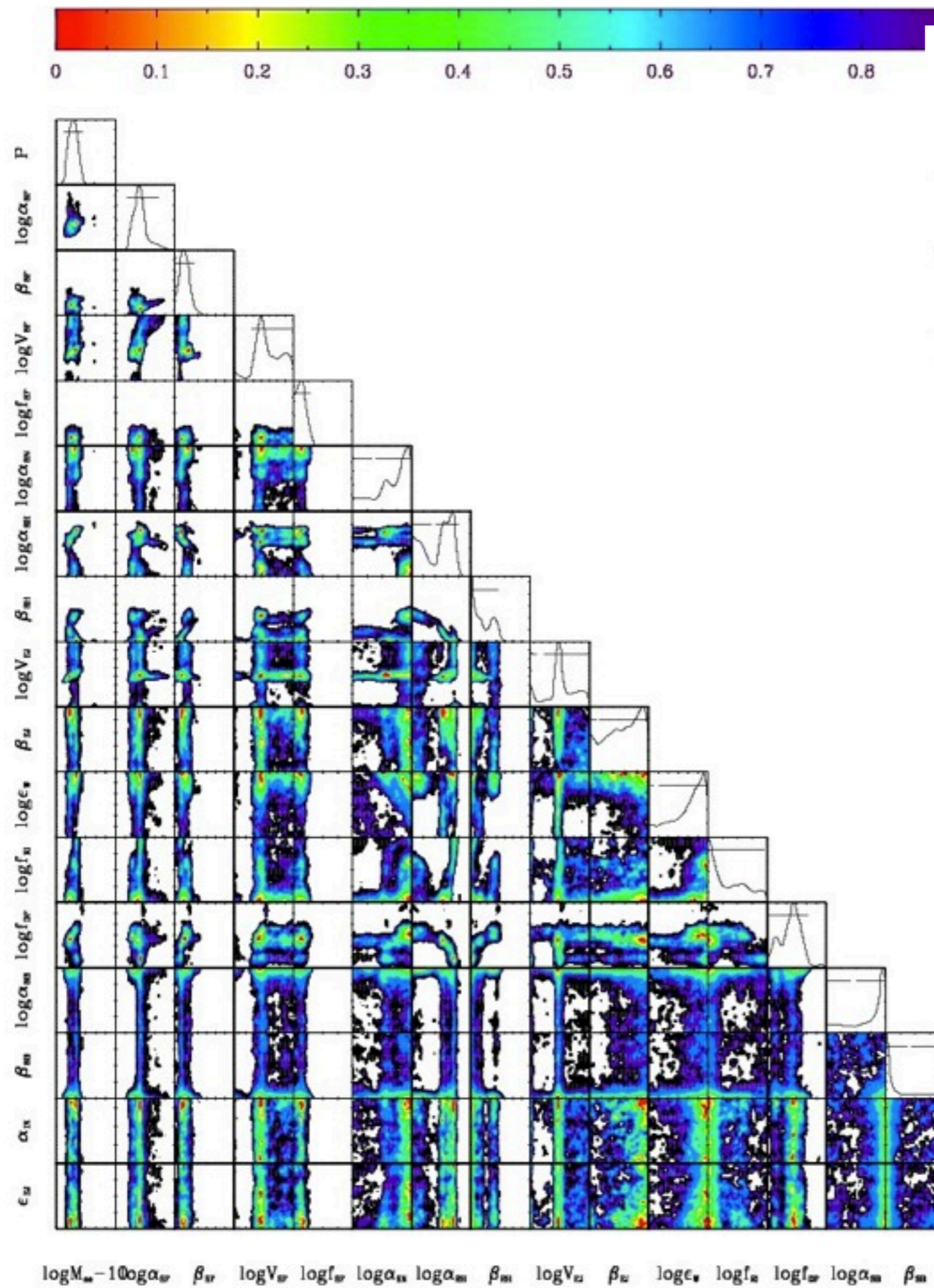
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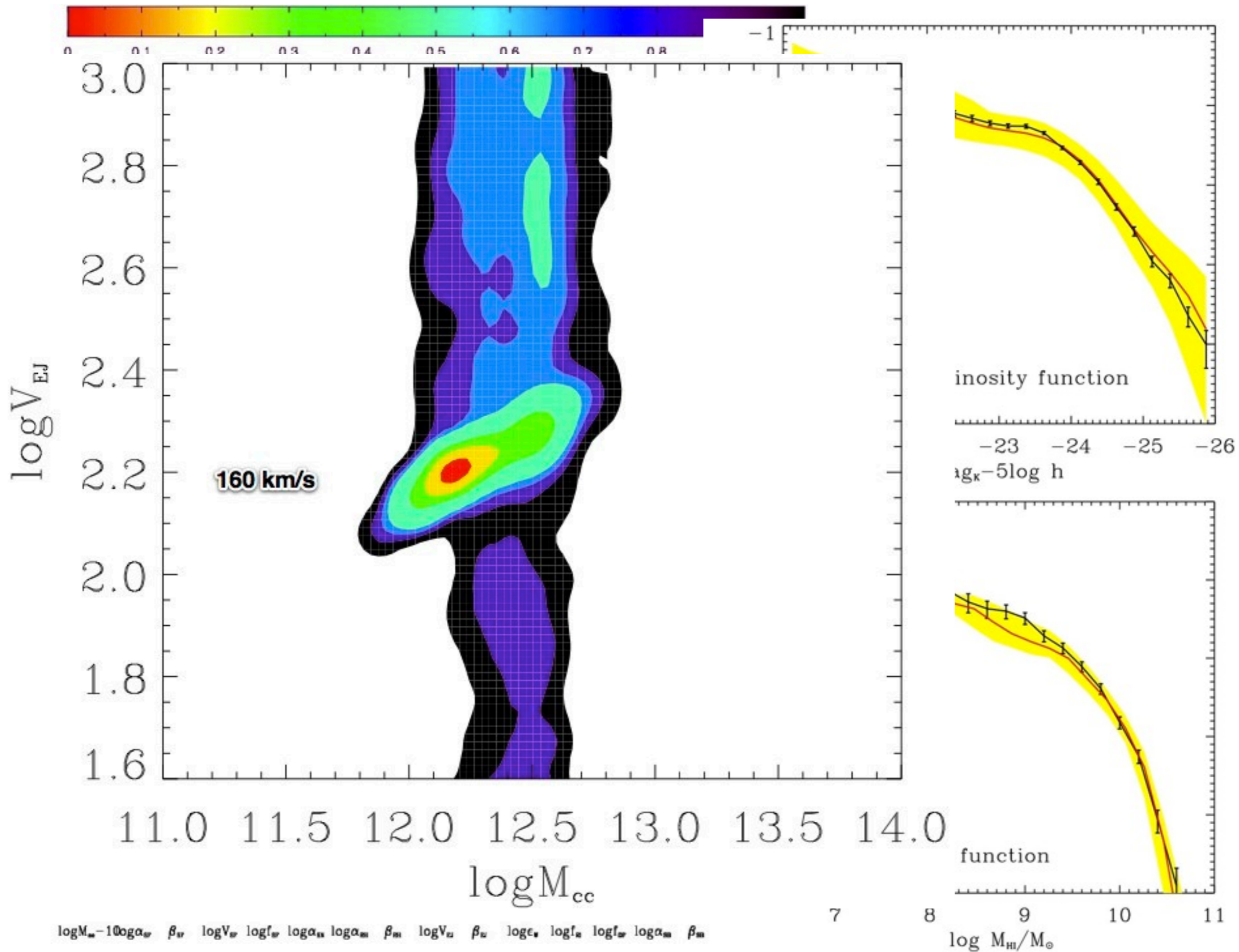
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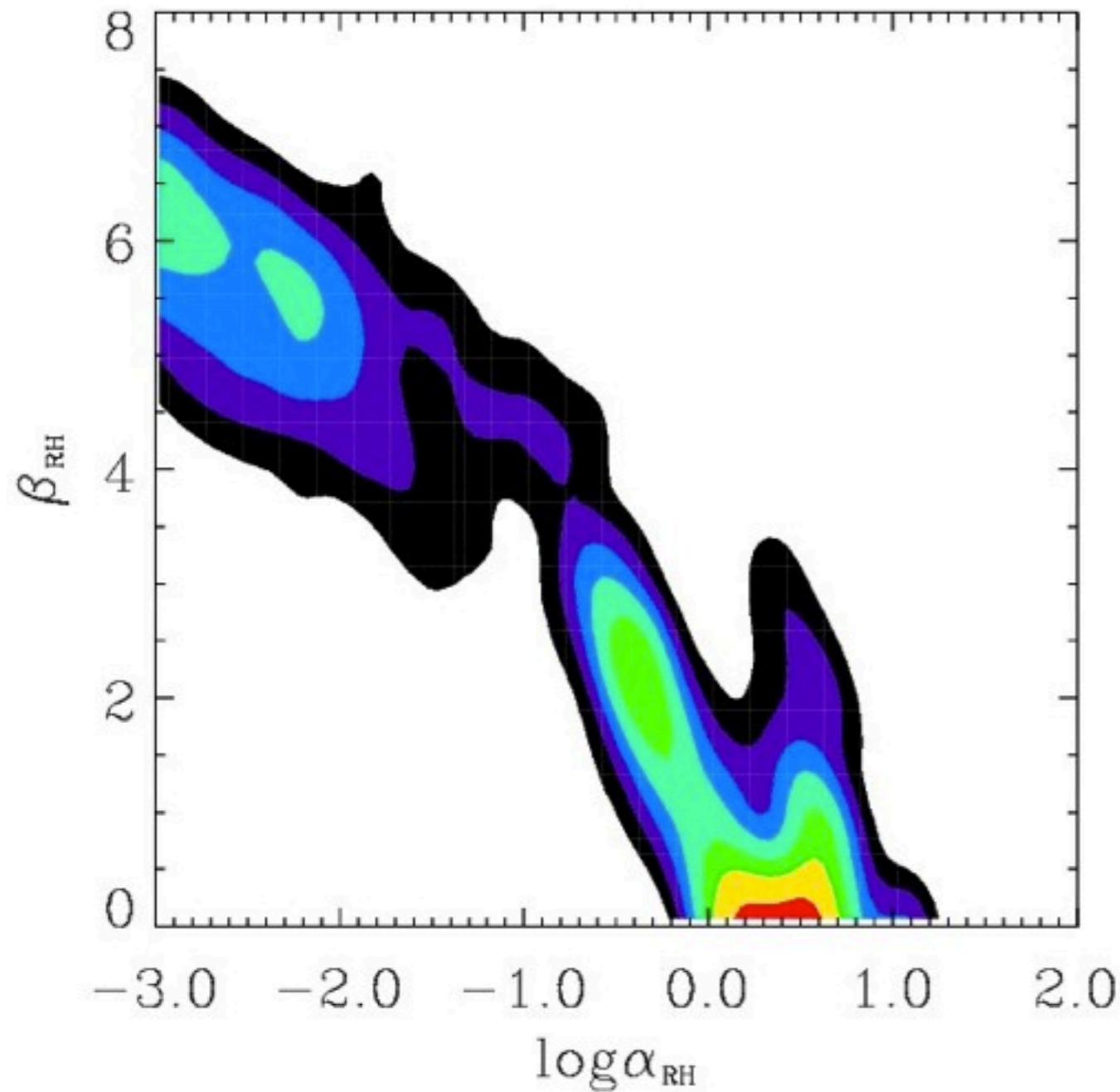
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- retaining/ejecting







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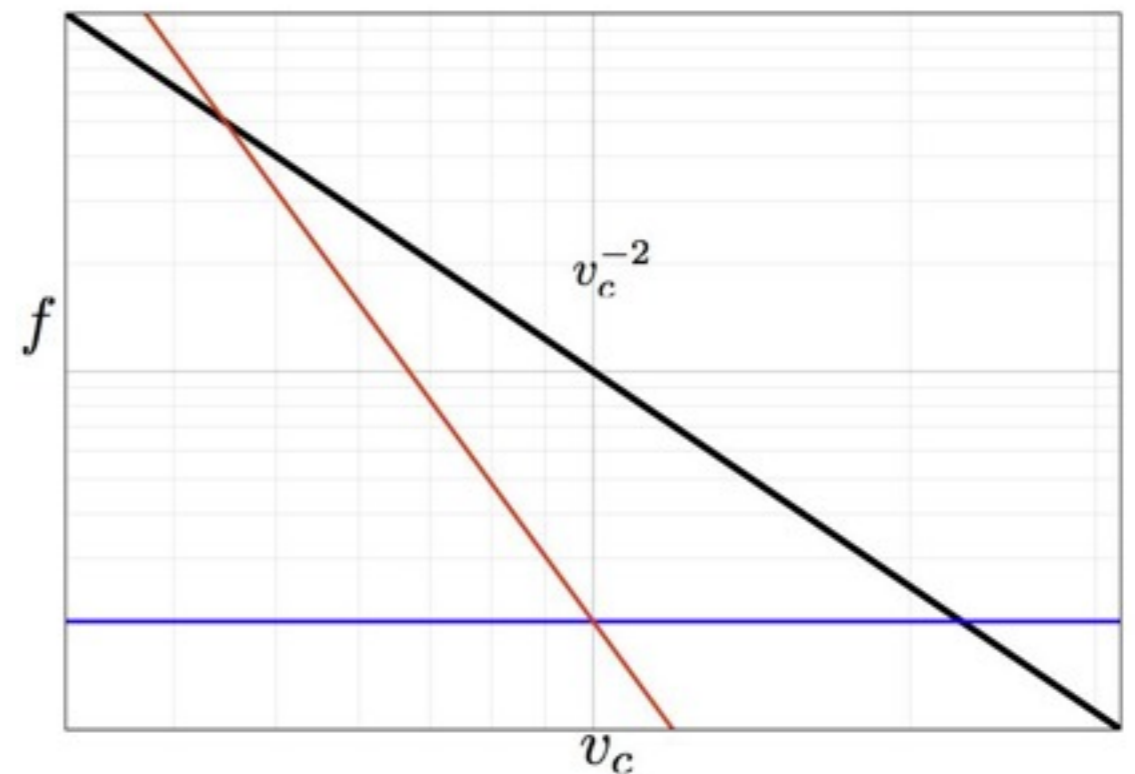
$$\Delta E_{out} = \begin{cases} \frac{1}{2} \Delta M_{out} V_{esc}^2 & \text{ejection;} \\ \frac{5}{4} \Delta M_{out} V_c^2 & \text{reheating.} \end{cases}$$

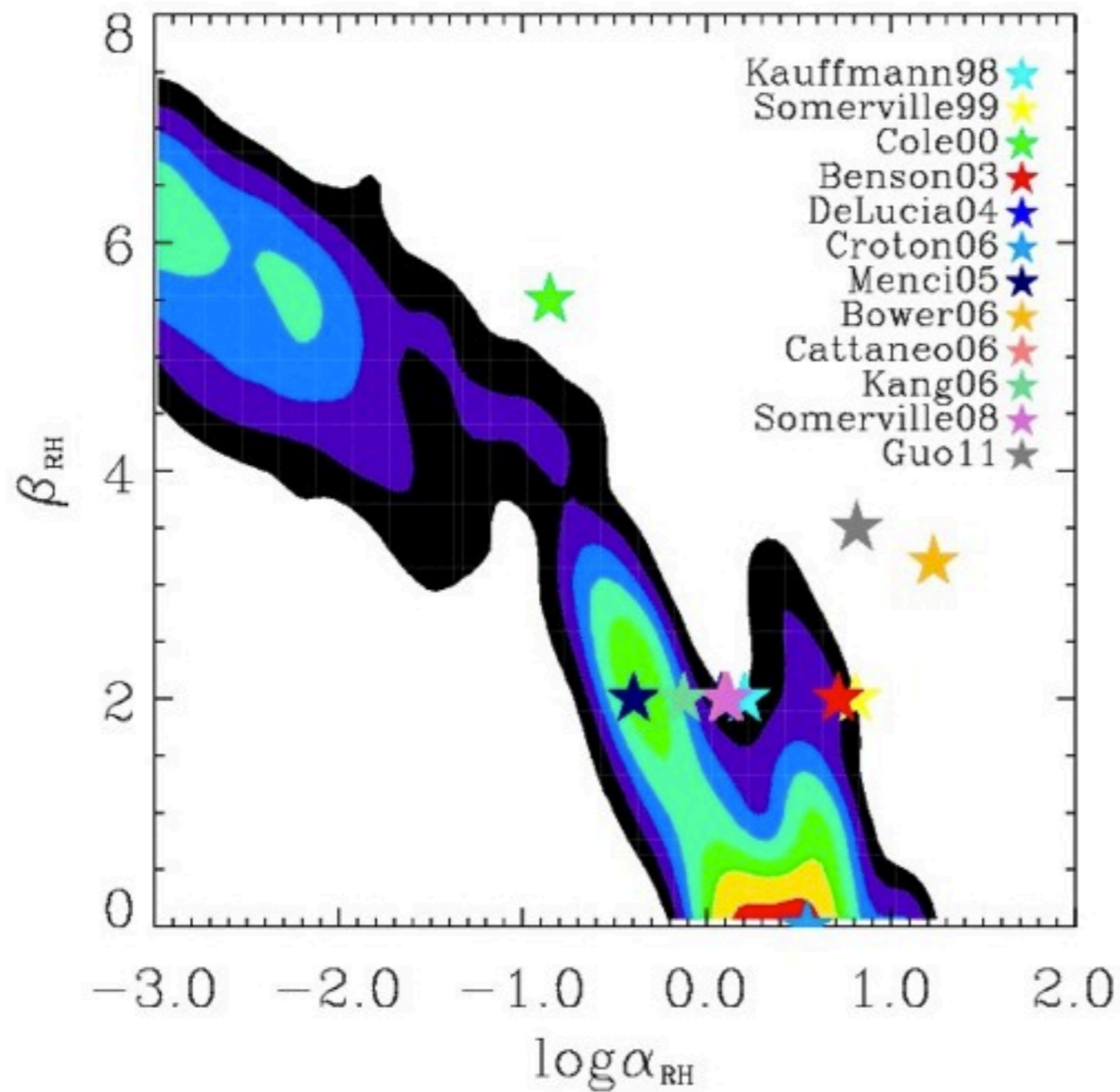
$$\Delta E_{fb} = \epsilon_{FB} \eta_{SN} E_{SN} \Delta M_*,$$

$$\Delta E_{fb} \geq \Delta E_{out}.$$

$$\eta_{SN, \text{Salp}} = 0.006 M_{\odot}^{-1};$$

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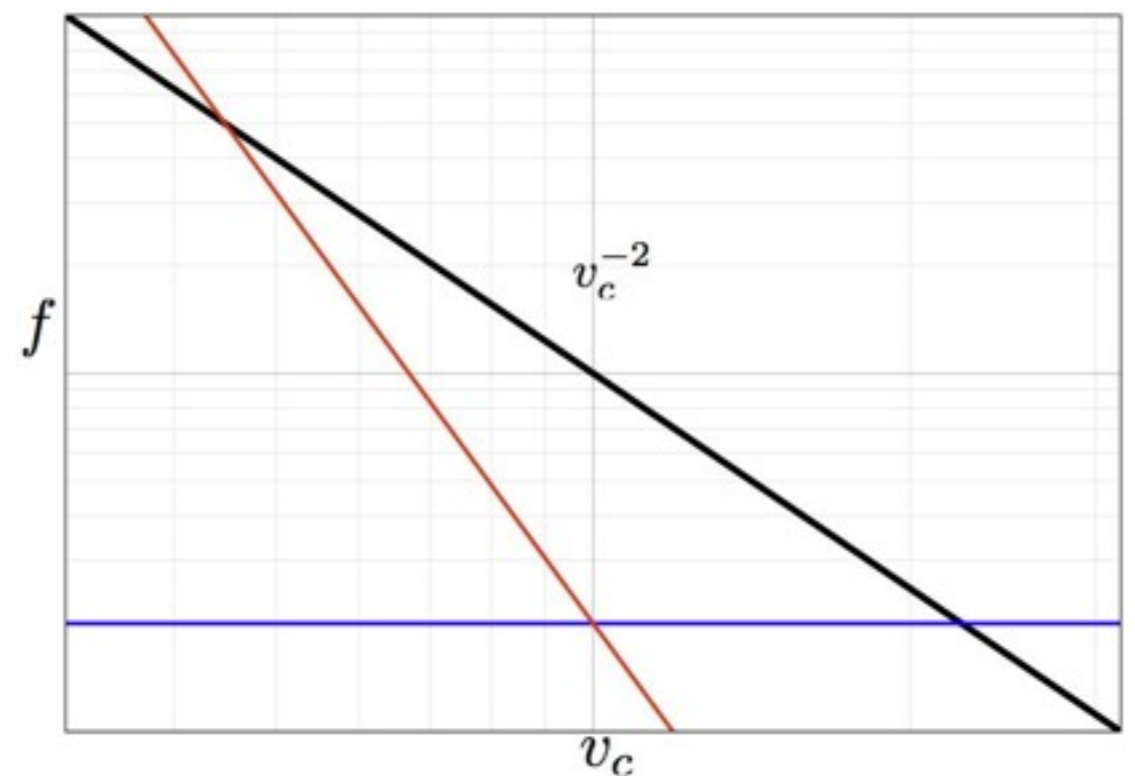
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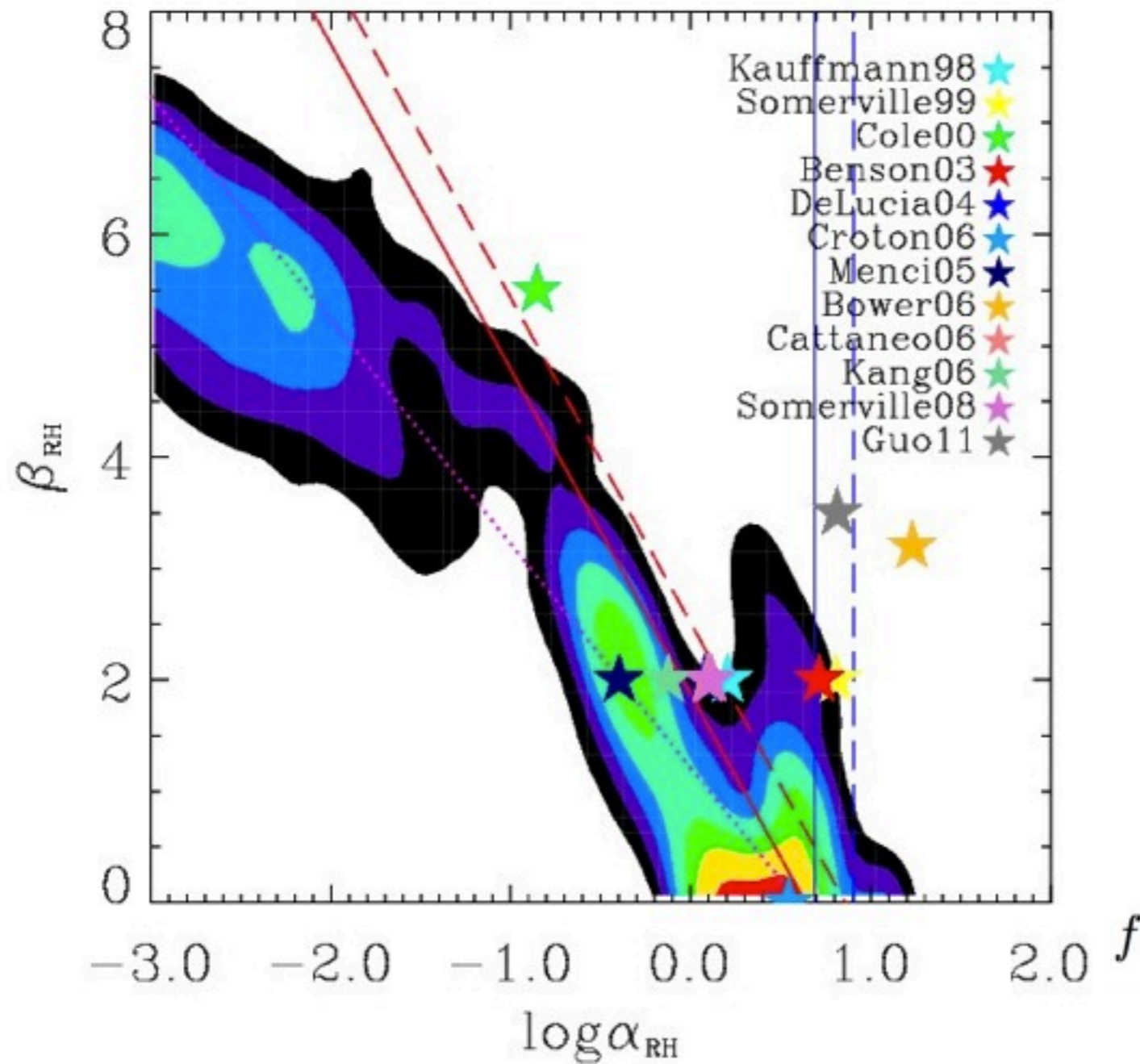
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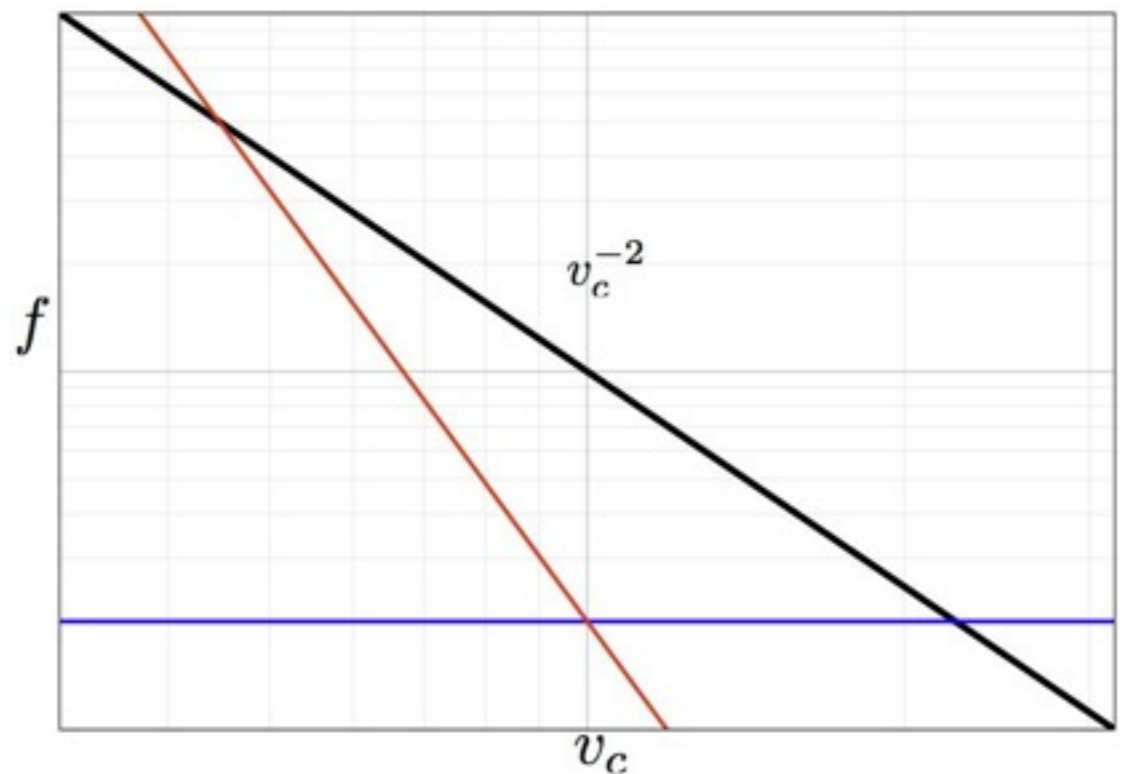
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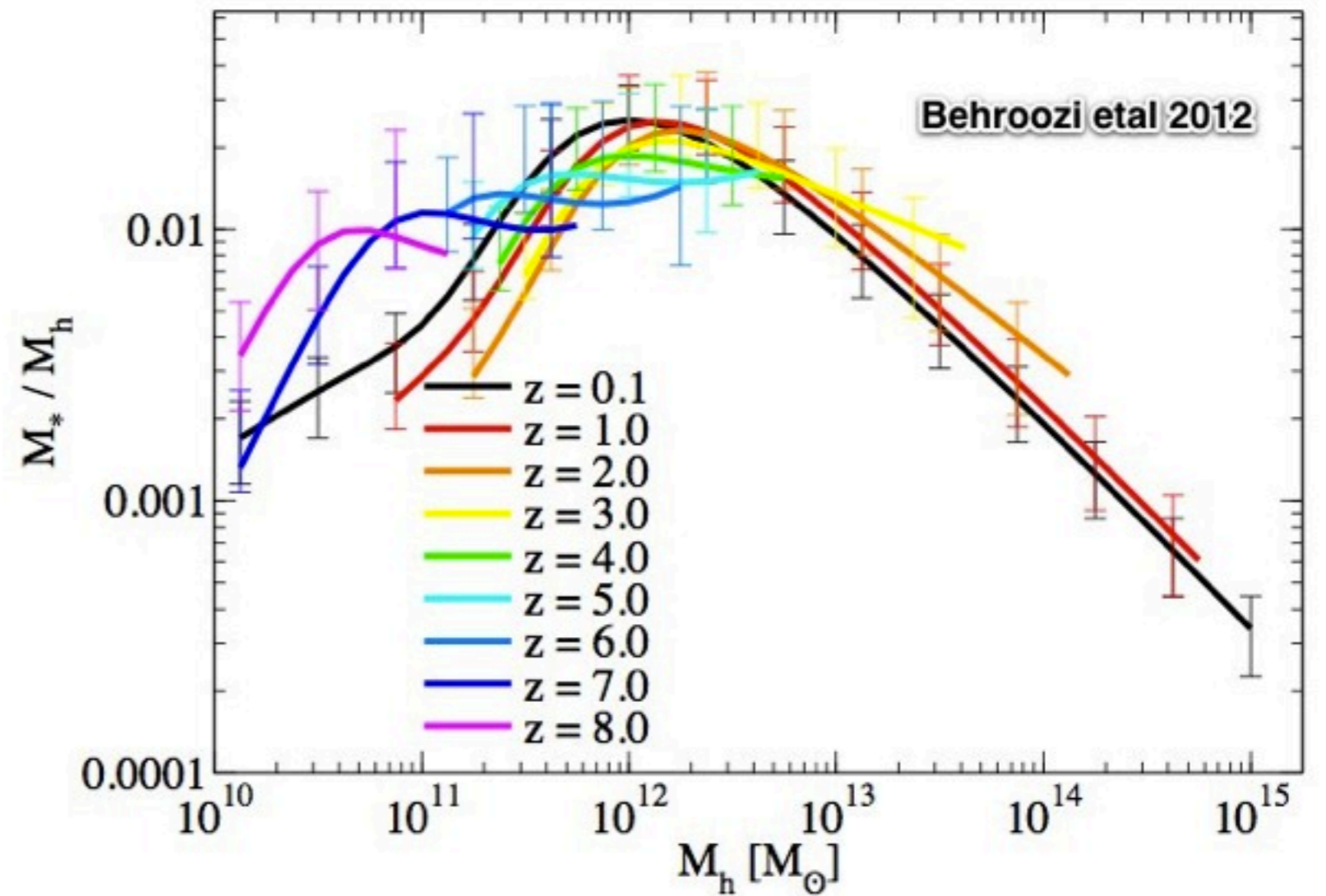


$$M_h = 10^{11} M_\odot$$

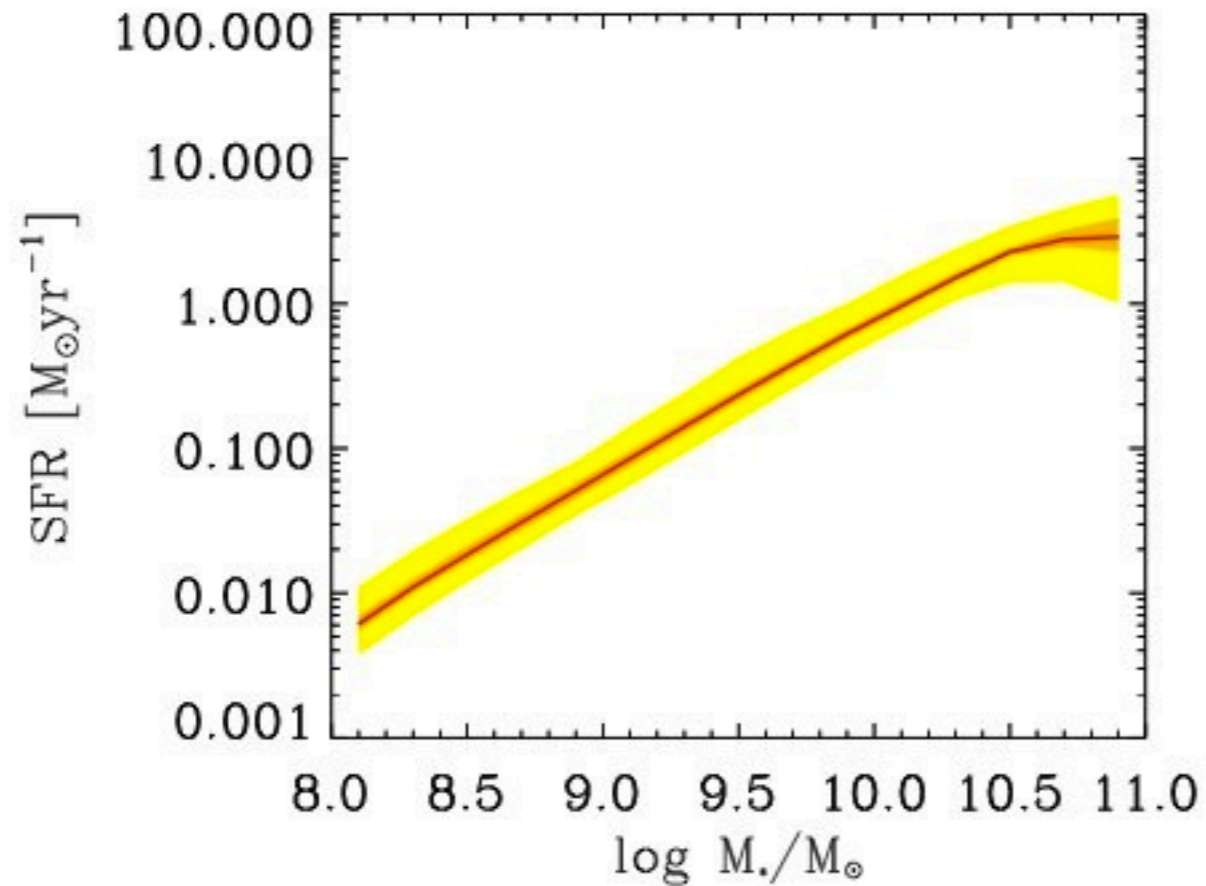
$$M_* \approx 0.004 M_h$$

$$M_{\text{cold}} \approx 10 M_*$$

$$\frac{M_{\text{outflow}}}{M_{\text{SF}}} \approx \frac{0.17 - 0.004 \times 10 - 0.004}{0.004 \times 2} \approx 16$$

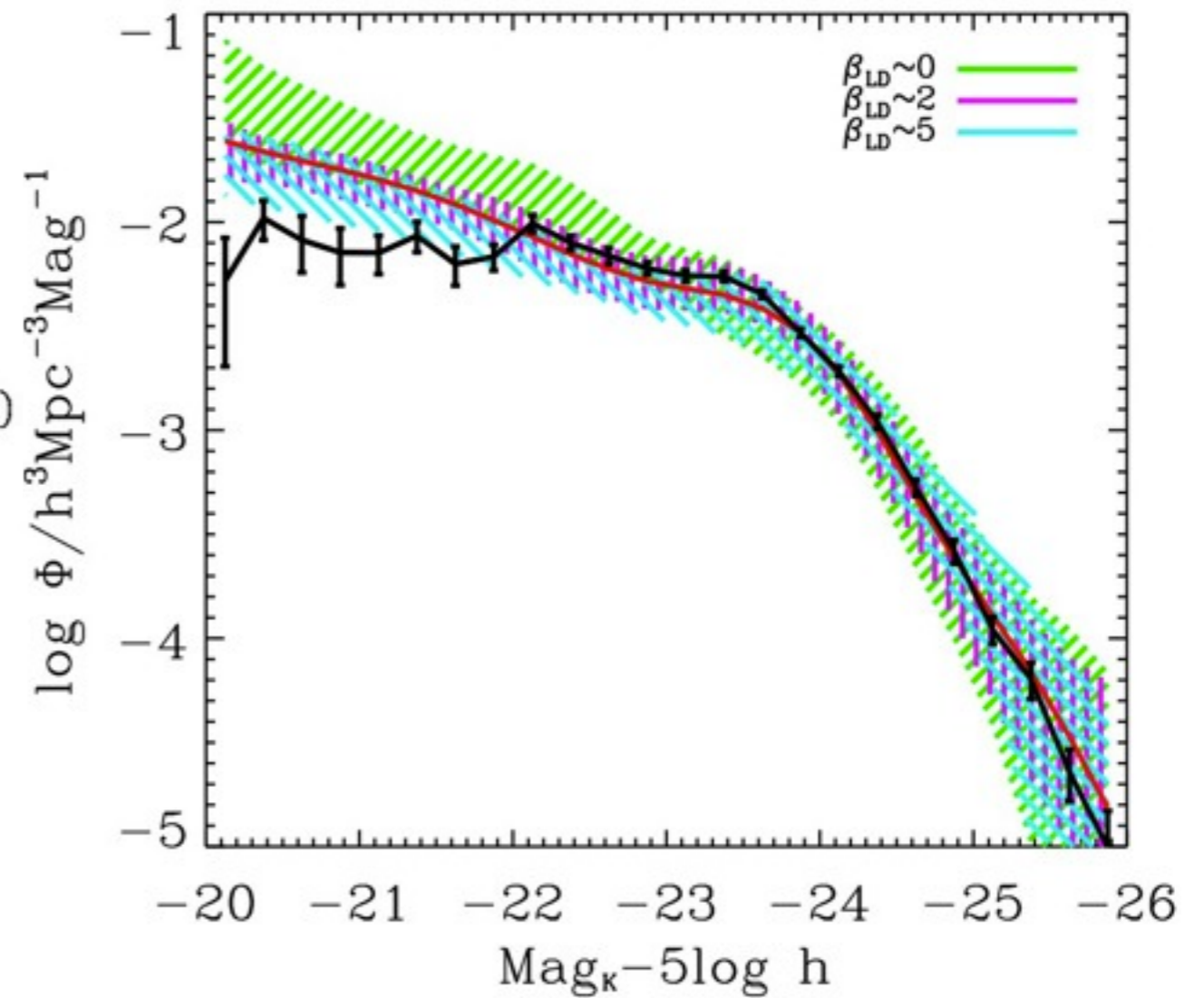
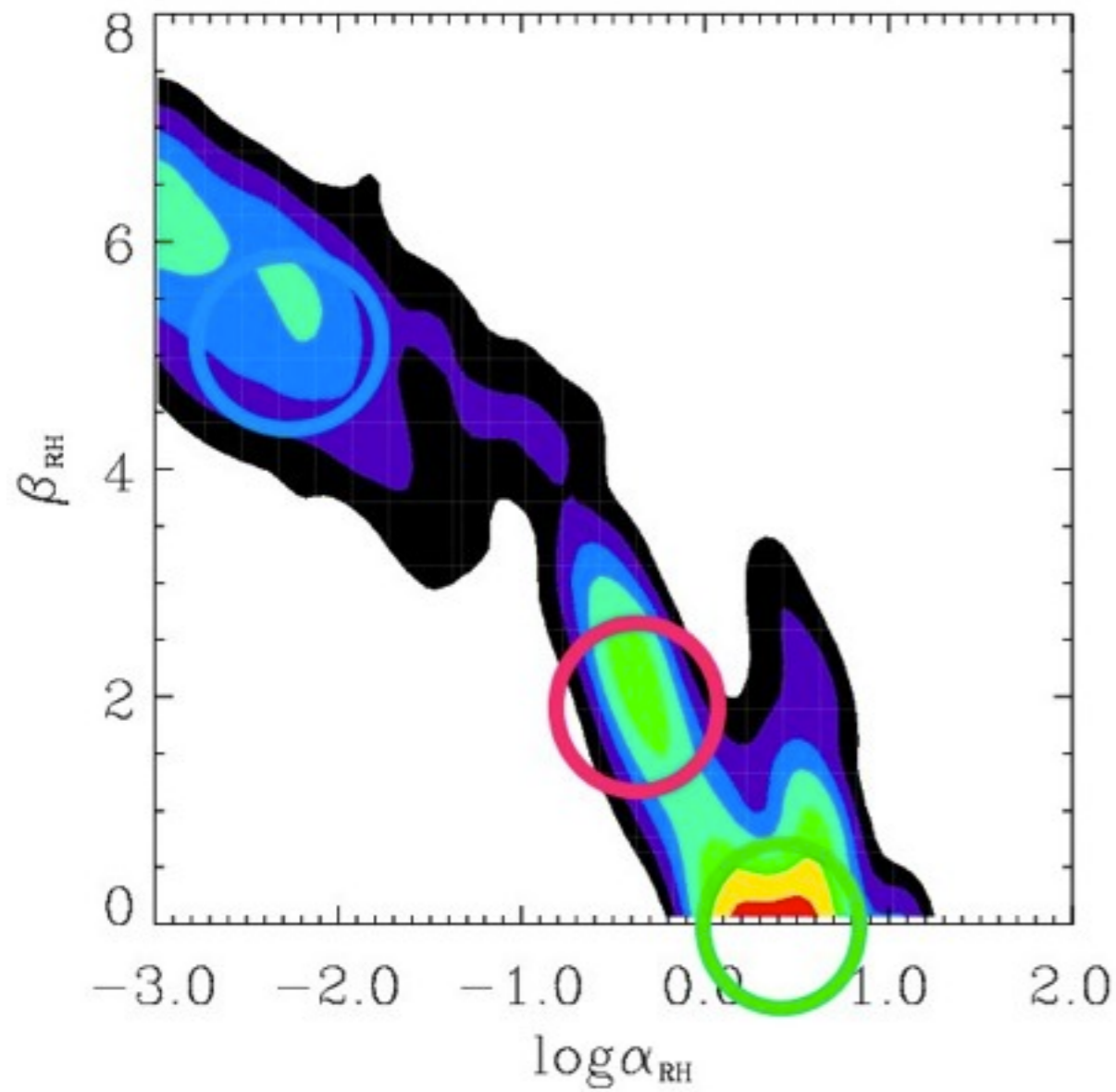


Star formation rate and outflow rate



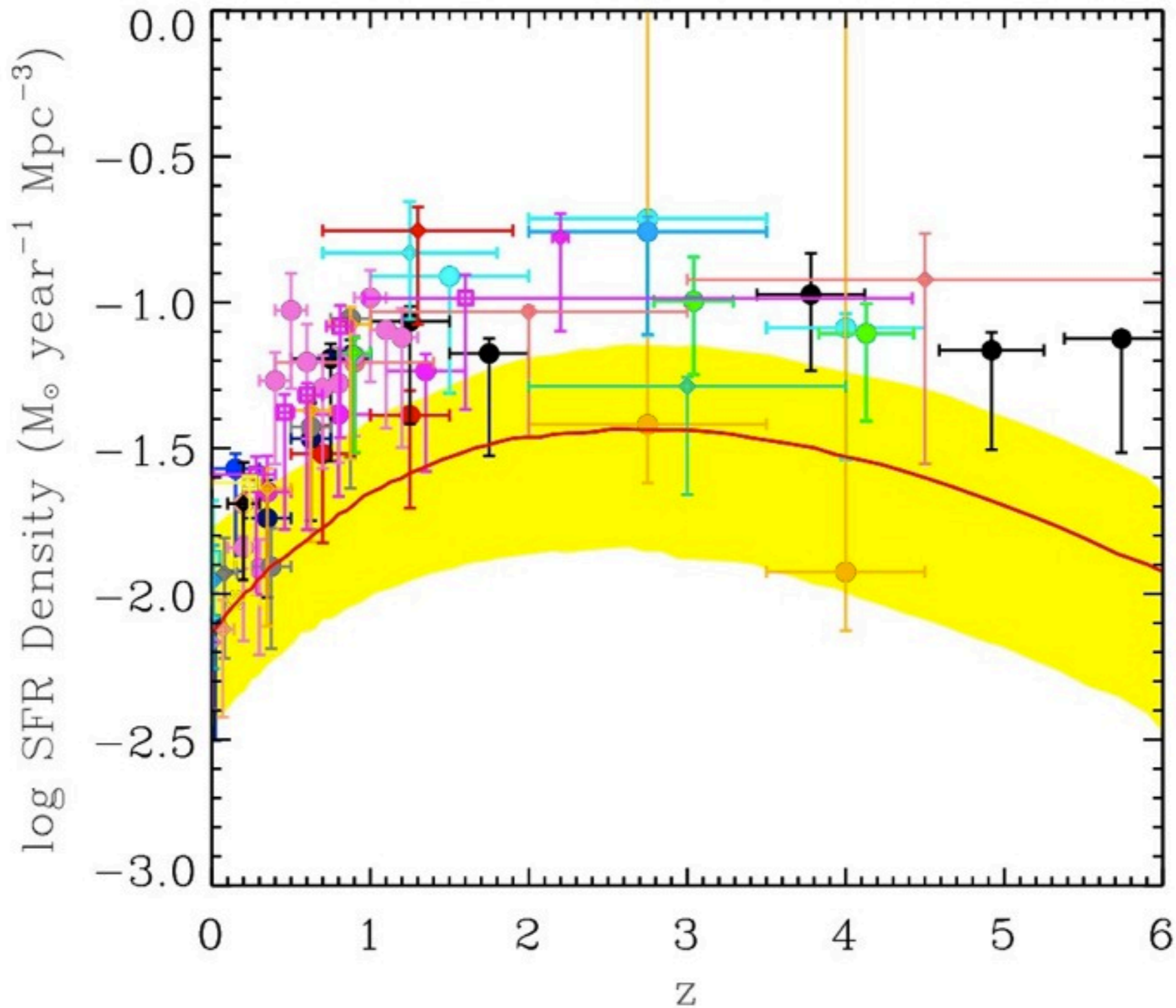
- observations show (Martin et al 2006):
 - $\text{OFR} \sim \text{SFR}$
 - The outflow rates in the cold component of the wind are of the order of 10% of the star formation rate.

The faint-end slope

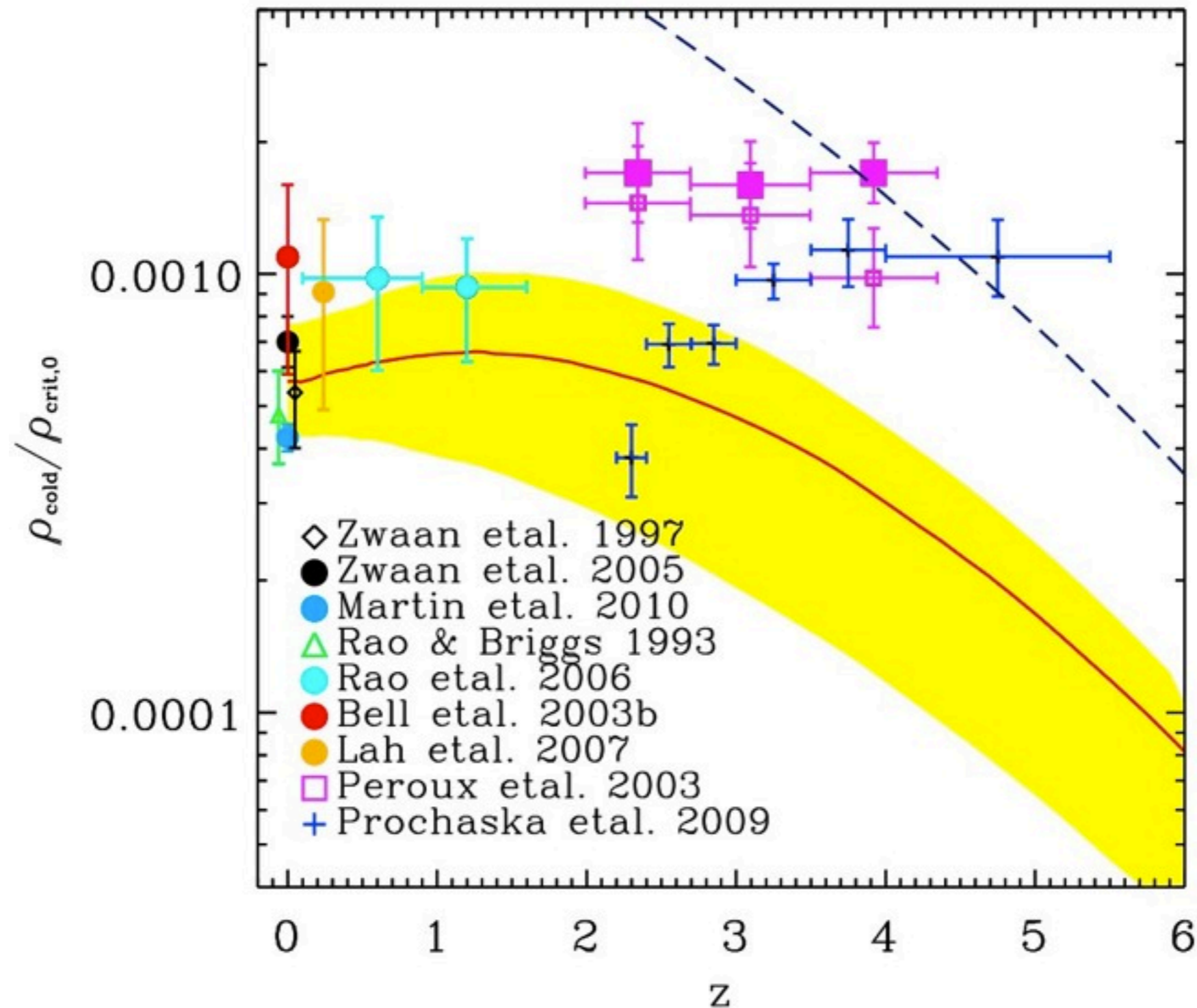


- also see Puchwein & Springel
arXiv:1205.2694

Cosmic SFR density

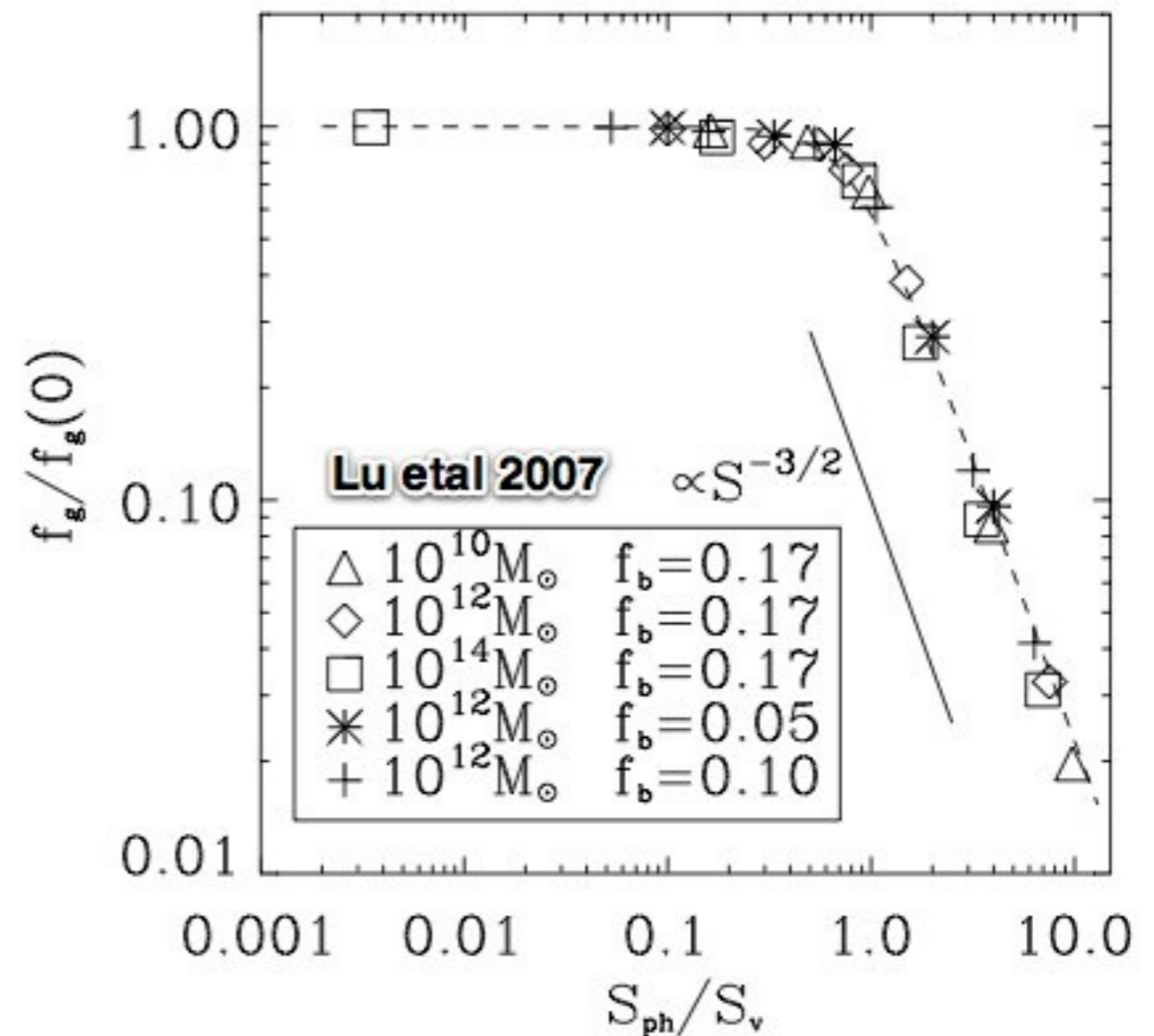


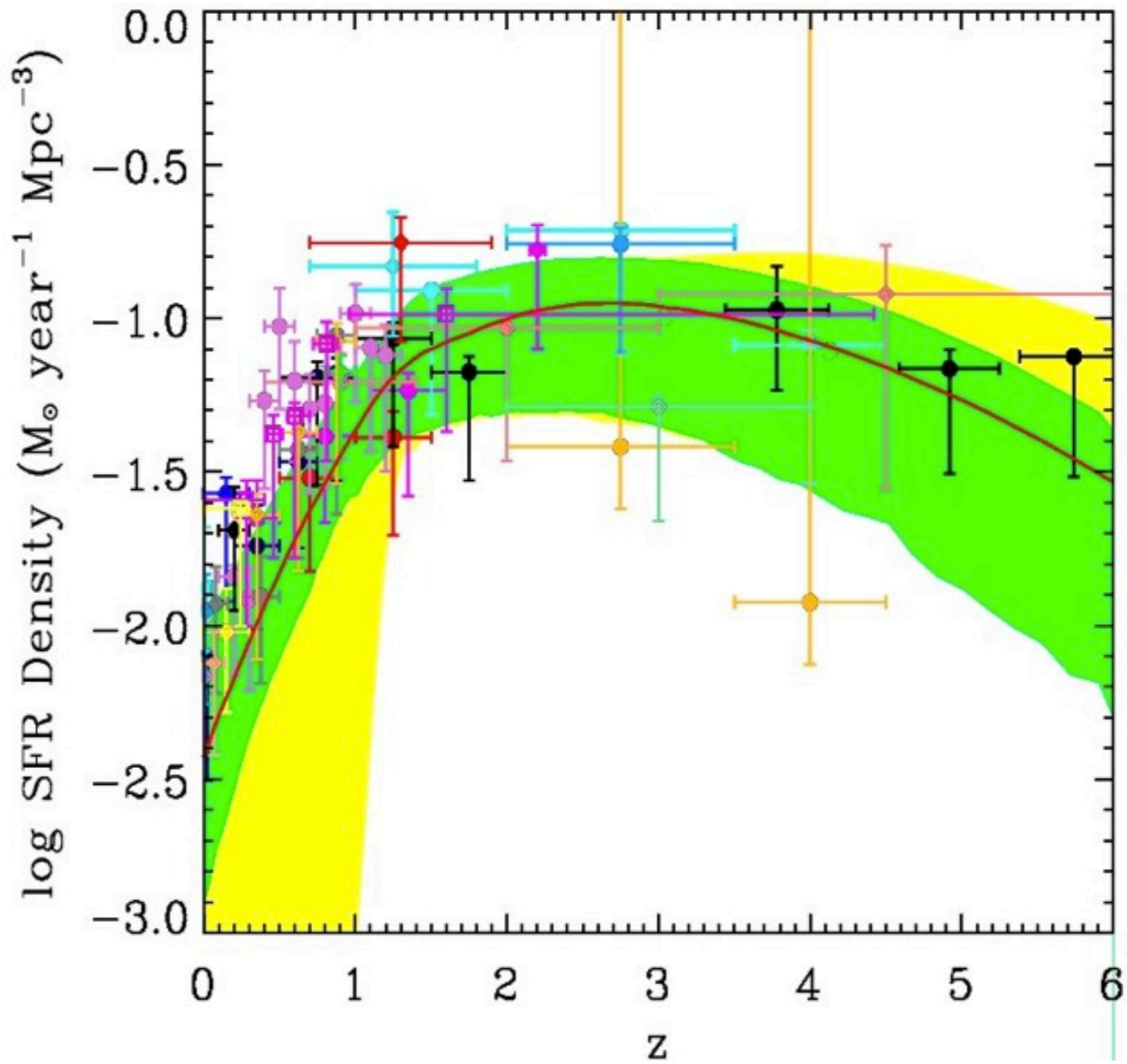
Cosmic cold gas mass density

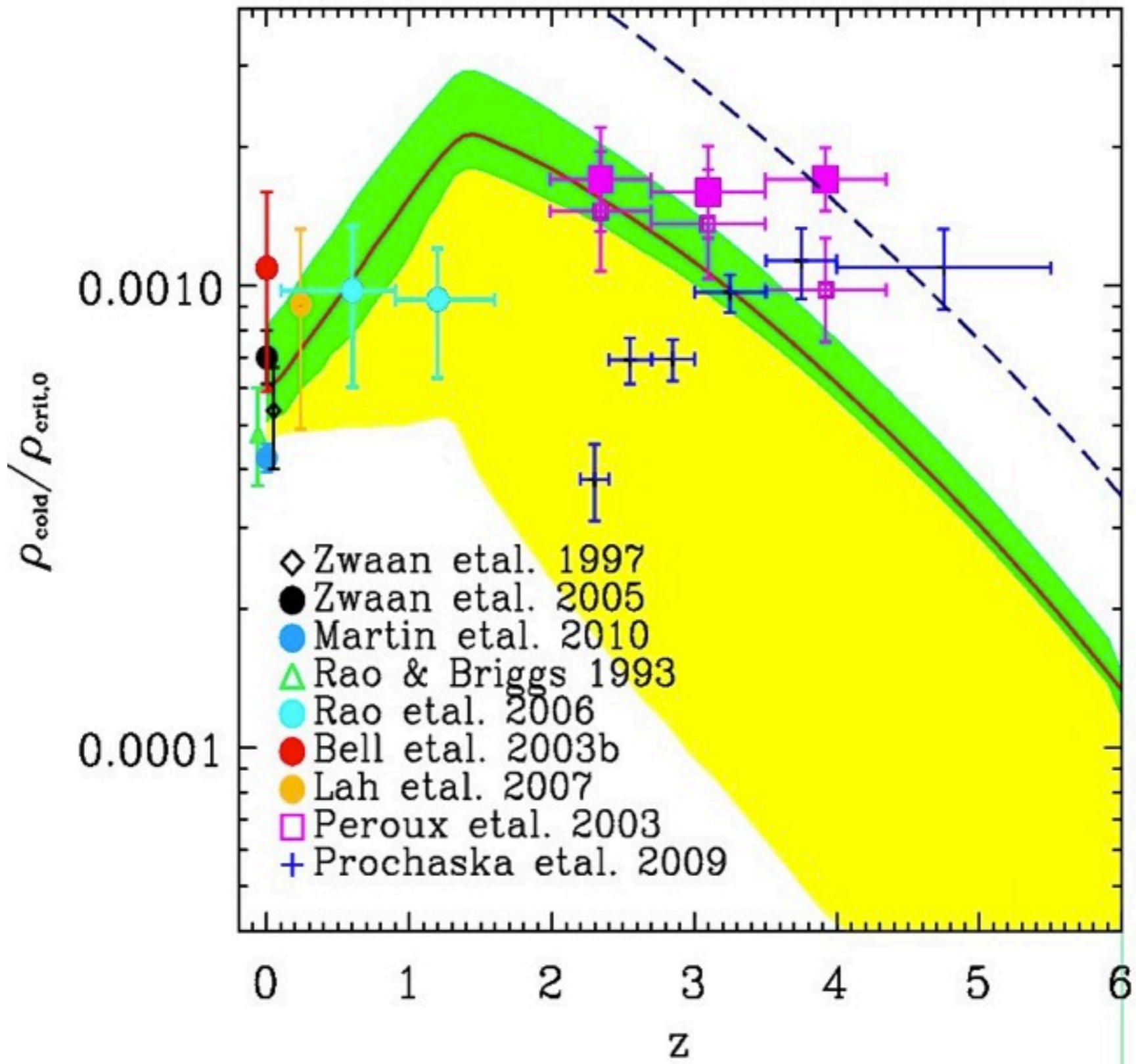


preheating scenario

- IGM is heated to a higher entropy before collapsing into a DM halo.
- physical processes: previrialization shocks (Mo et al 2005), early AGNs and starburst (Scannapieco et al 2009), TeV blazar heating (Broderick et al 2011), turbulence in filaments (Zhu 2011).







Conclusions

- To explain the LF and HI MF, strong feedback is needed. If halos accrete baryons with the universal baryon fraction, SN energy has to be efficiently used to drive super galactic winds. Radiation pressure provides more energy.
- The high mass loading factor of outflow required by present-day low-mass galaxies predicts mass outflow rates that are too high.
- How the loading factor scales with V_c can be constrained by the faint-end slope of LFs and cold gas mass functions. $2 < \beta < 5$ seems to be consistent with the data.
- Galaxy formation at high redshifts is also suppressed in the strong outflow model. The predictions for high- z are inconsistent with existing data.
- The physics of quenching star formation in low-mass halos needs to be understood.