

The Odd Meanderings of the IMF Across Cosmic Time

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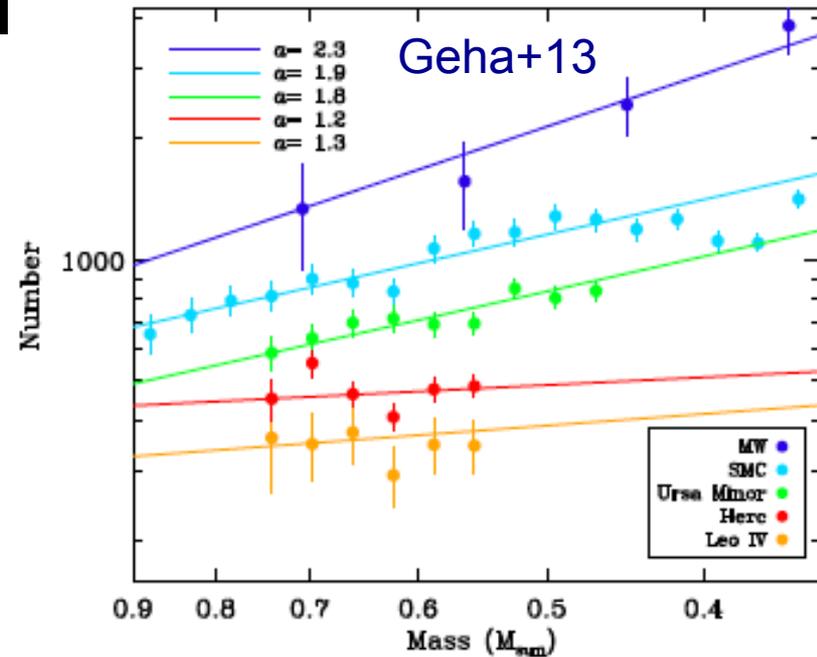
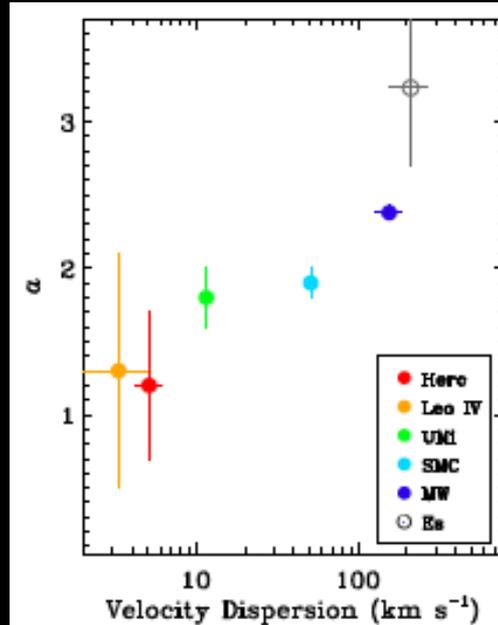
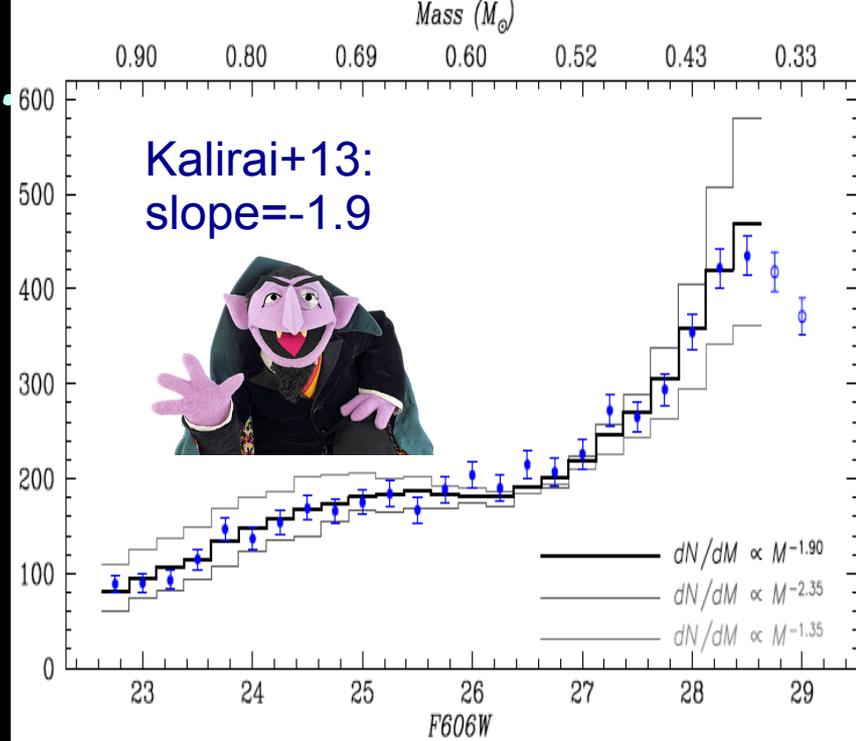


Thou Shalt
Not Vary
the IMF!



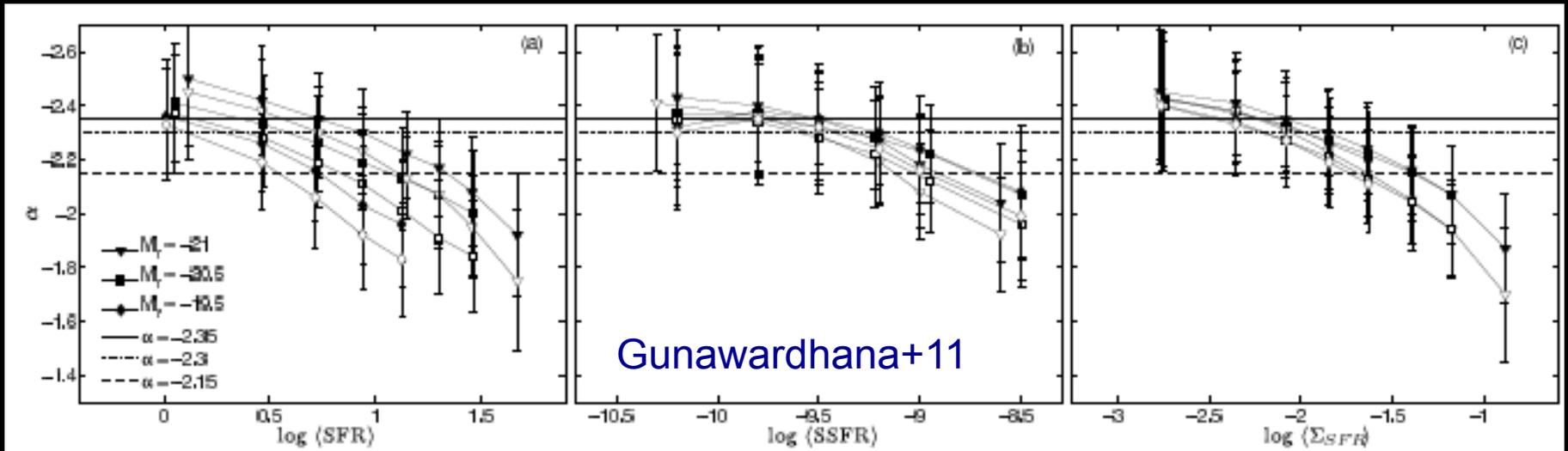
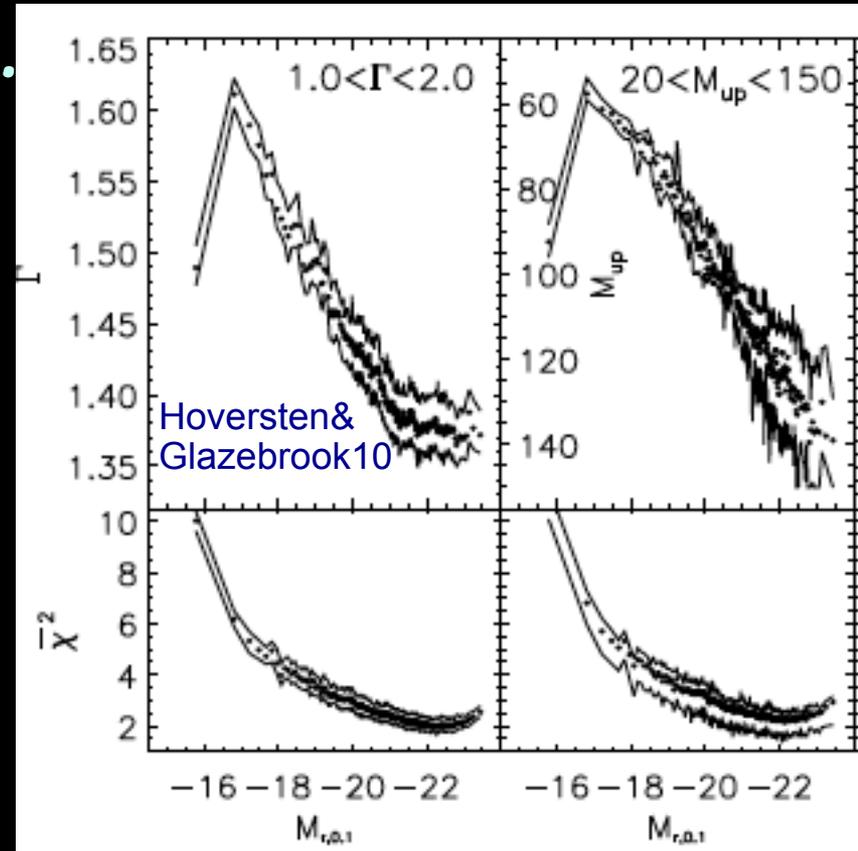
Maybe just a little... but how?

- Bottom heavy: ETGs
- Bottom light/top heavy?
 - SMC star counts
 - Ultra-faint dwarf counts
 - $H\alpha$ vs. UV
 - $H\alpha$ vs. color



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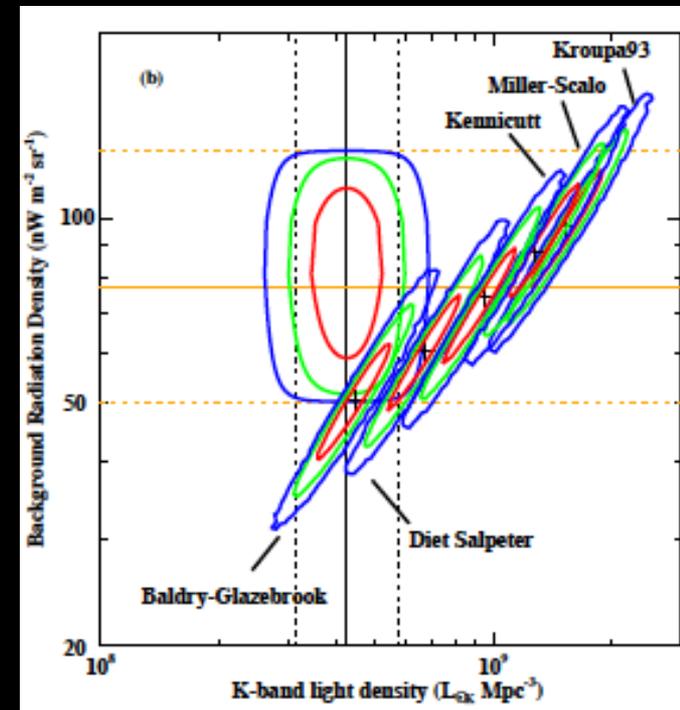
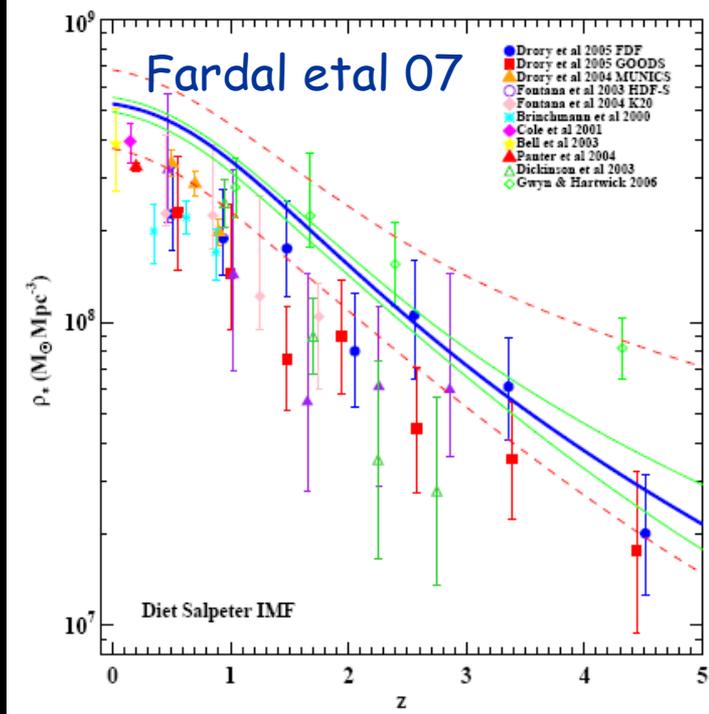


An IMF Test: SFR vs. dM_*/dt

- SFR vs. M^* \Rightarrow IMF shape
- $\int \text{SFR} dt \neq M_*(z=0)$ for Salpeter; need **slope ≈ -2.1** .

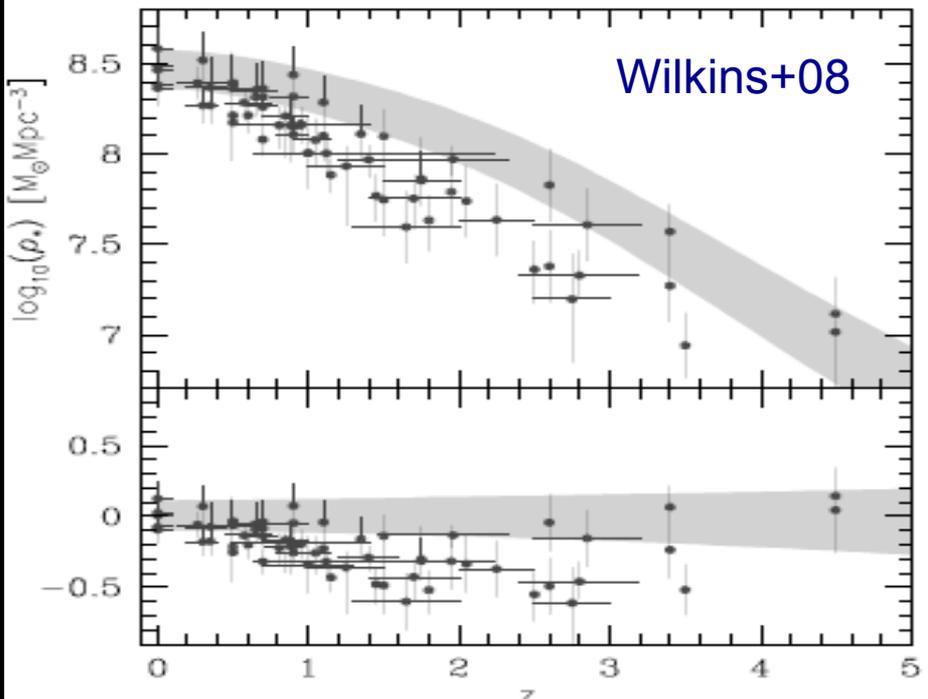
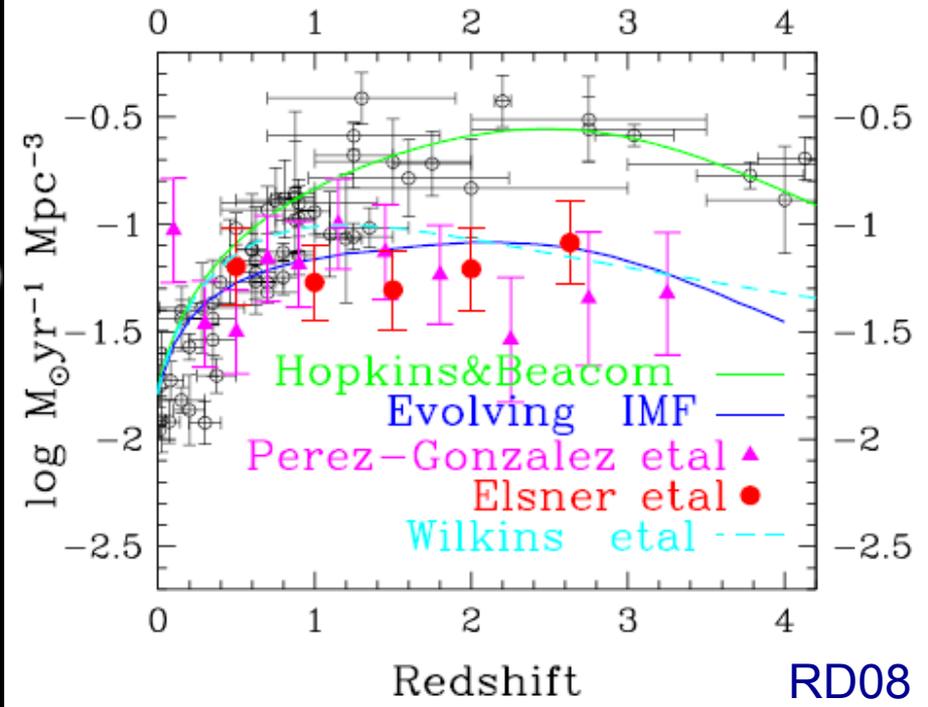
Madau, Pozzetti, Dickinson 98; Baldry & Glazebrook 03

- Fardal et al 07: + EBL \Rightarrow “Paunchy” IMF (heavy at $3M_\odot$)
- Harry's mystery: LBGs at $z=4$ can't evolve into LBGs at $z=3$, yet LF is remarkably similar.



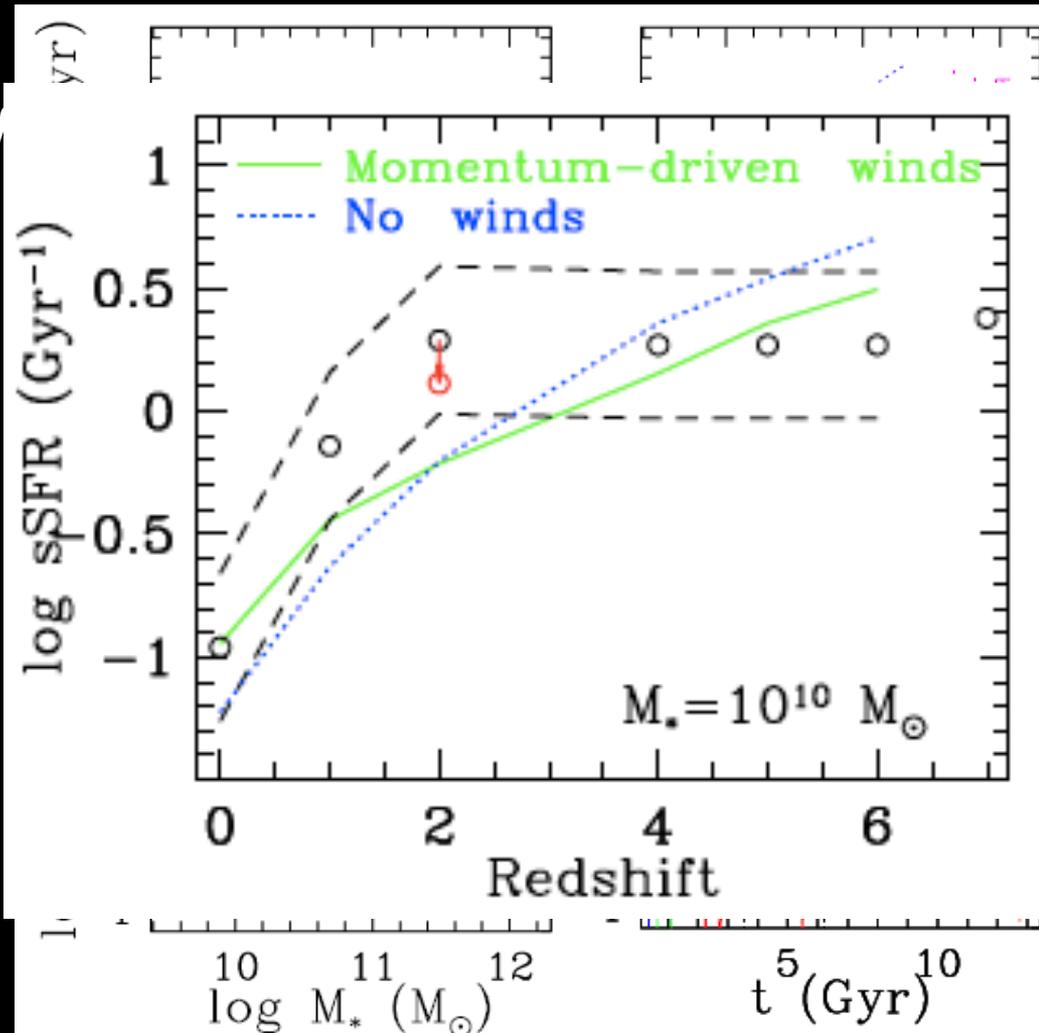
Discrepancy at $z > 1$?

- dM_*/dt vs SFR favor top-heavy IMF at $z > 1$?
- Steep GSMF? But then $\rho_*(z=2) > 0.5 \rho_*(z=0)$
- All about the extrapolations...



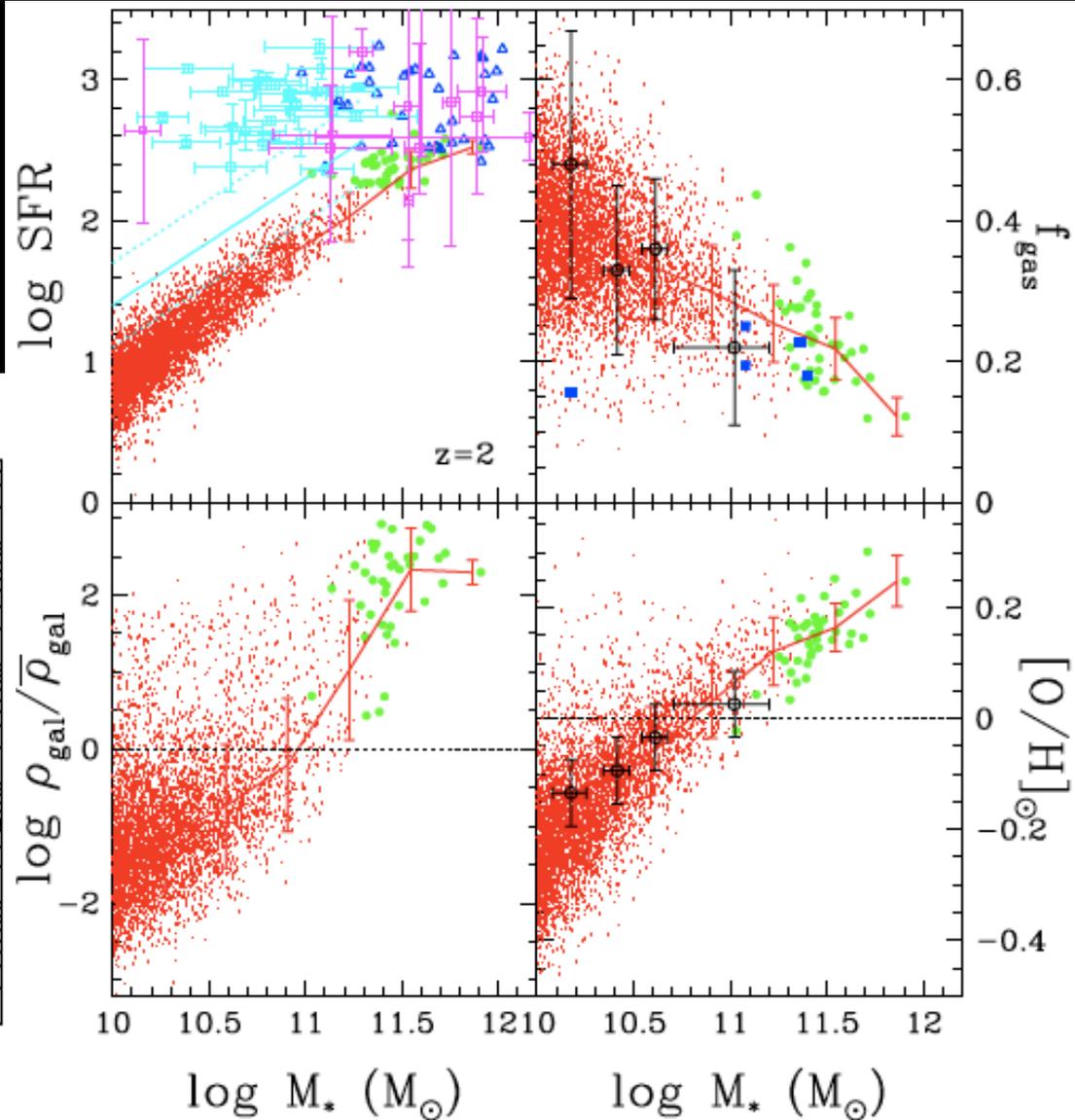
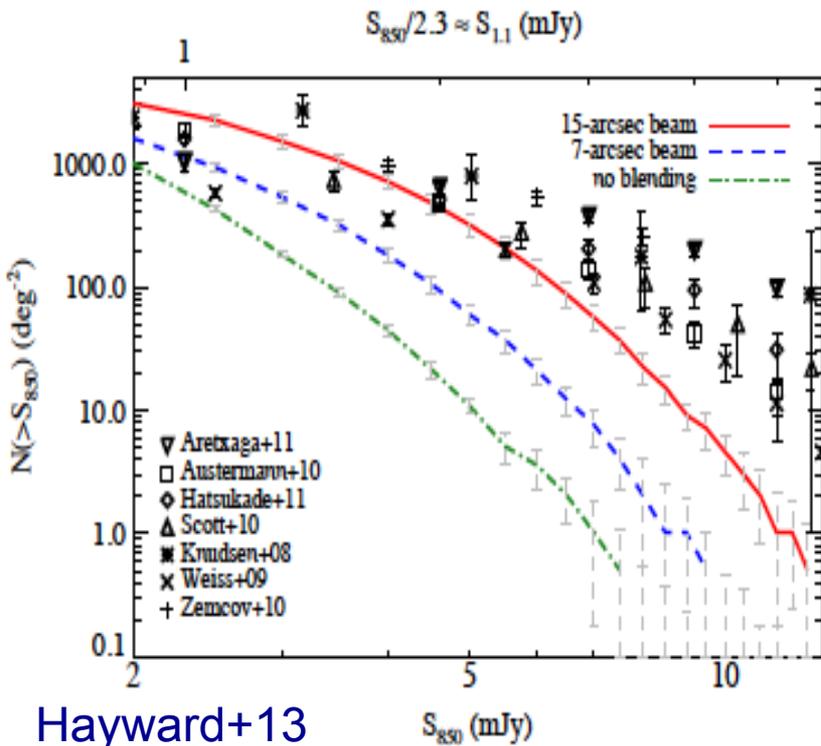
M*-SFR vs. Models

- Red, magenta: SPH
- Green: Millenium SAM
- Blue: Data ($\sigma=0.3$)
- Slope \sim unity? ✓
- Scatter small? ✓
- Evolves independent of M_* ? ✓
- Evolves at observed rate? ✗
- Hard to fix with feedback/SF recipe.



Sub-mm Galaxies

- SMGs would like a top-heavy IMF?

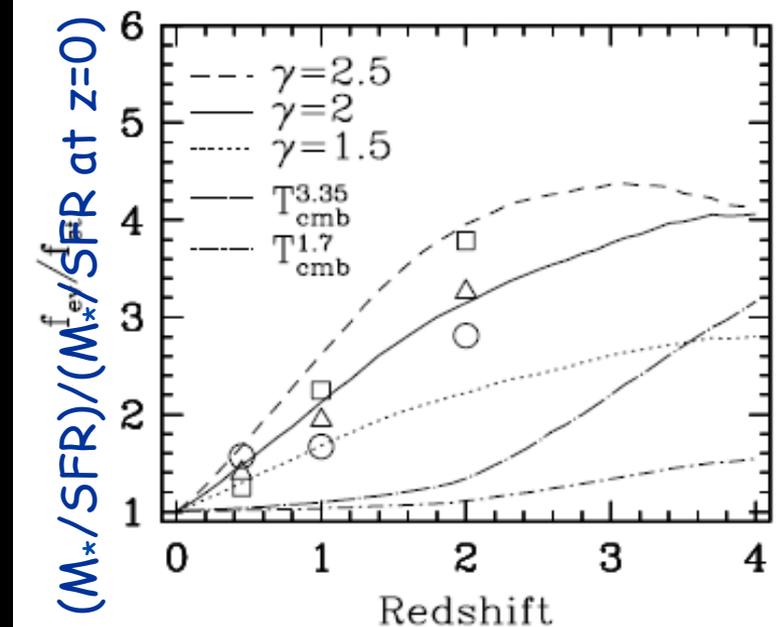
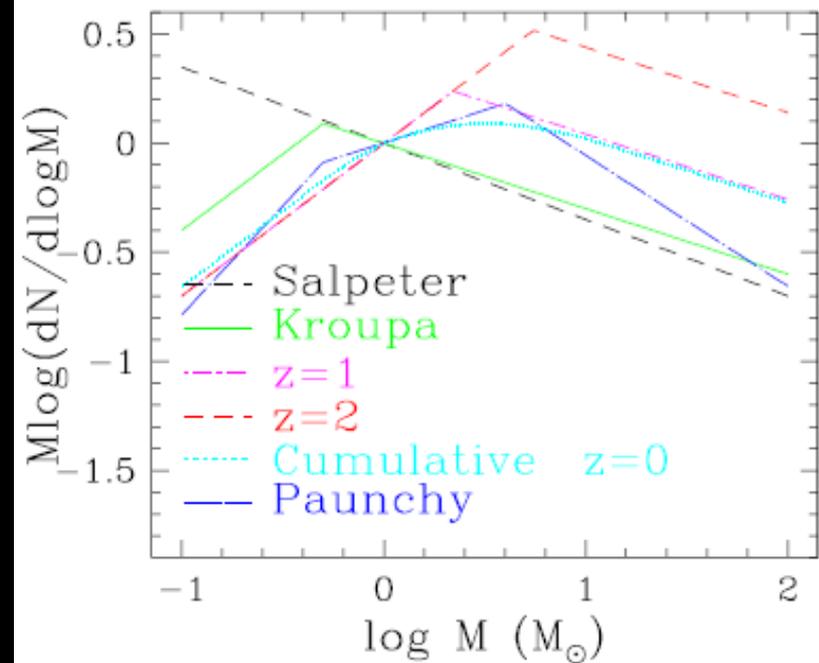


IMF evolution?

- Need less M^* formed per unit high-mass SF
- “Evolving Kroupa” IMF:
 $dN/d\log M \propto M^{-0.3}$ for $M < M_{\text{char}}$
 $dN/d\log M \propto M^{-1.3}$ for $M > M_{\text{char}}$.

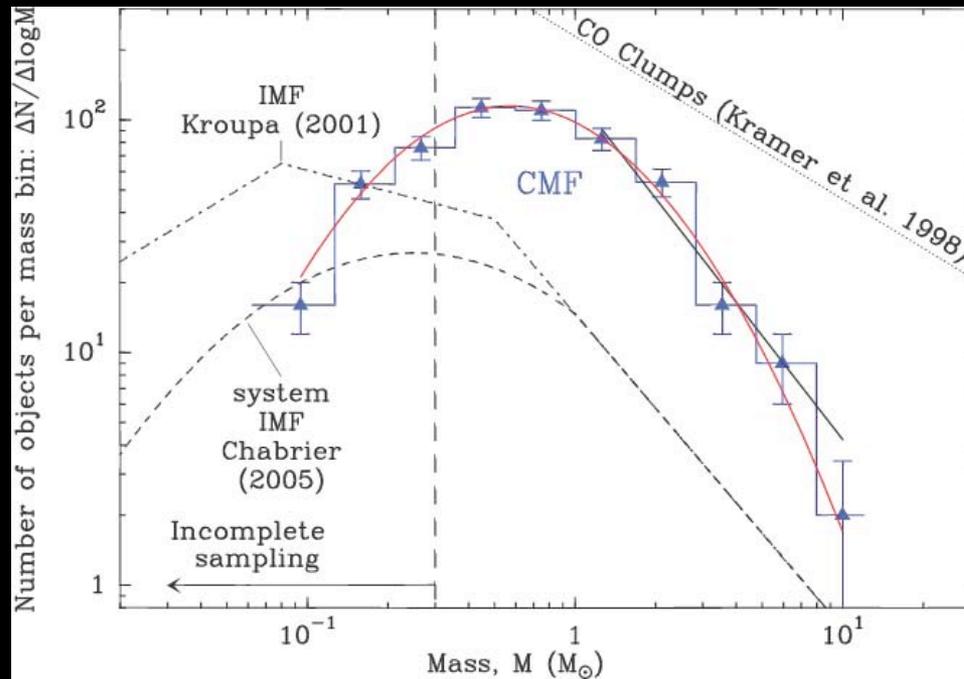
$$M_{\text{char}} = 0.5(1+z)^2 M_{\odot}$$

BUT... *only from $0 < z < 2$*
 At higher z , reverts back!



What might cause the IMF to vary?

- Larson's conjecture: IMF M_{char} ($\sim 0.5 M_{\odot}$ today) \Leftrightarrow thermal Jeans mass in GMC cores ($T_{\text{min}} \sim 8\text{K}$).
- Or it's a sampling/ M_{max} issue (e.g. IGIMF).
- At *high-z*: More SF, higher Σ_{SFR} , lower Z , more shocks, higher $T_{\text{CMB}} \rightarrow$ **top-heavy/bottom-light**



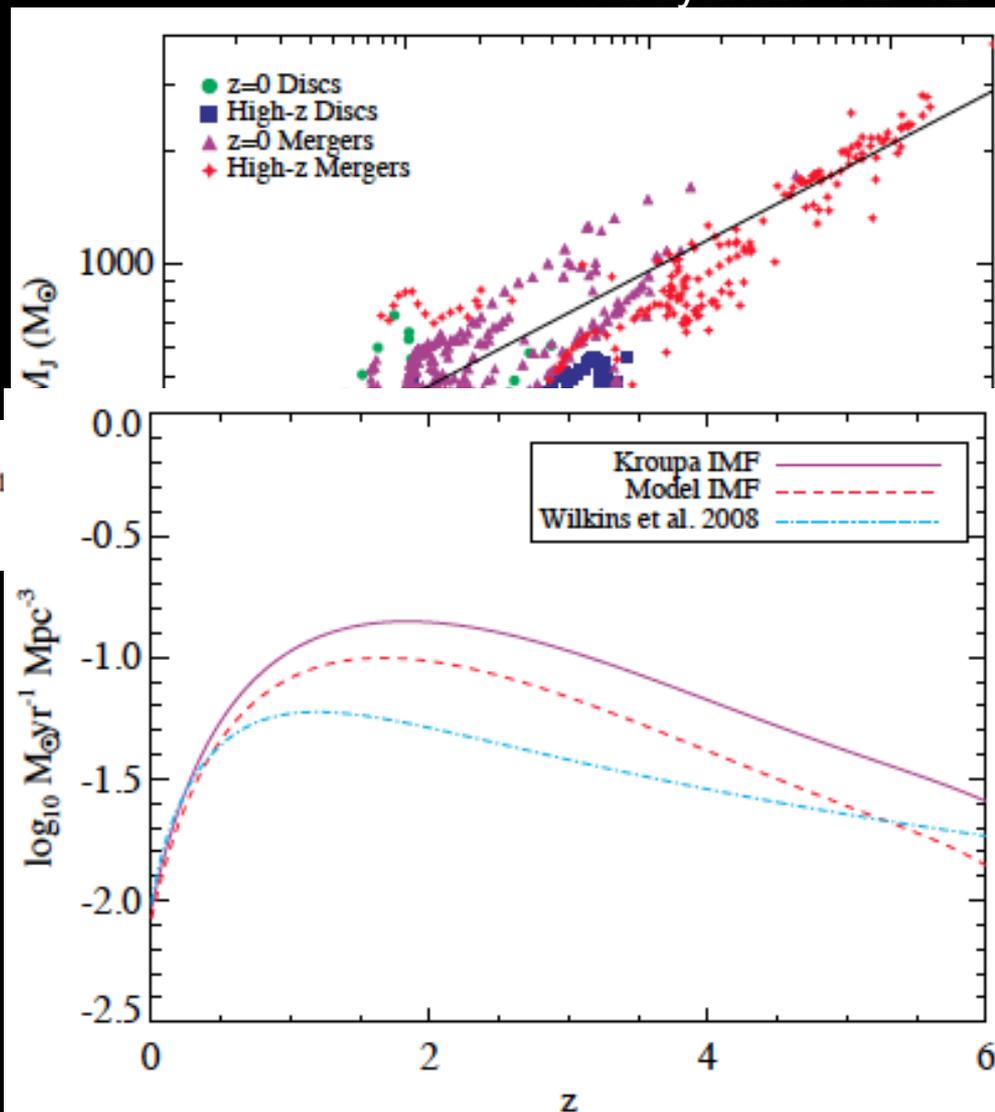
Physical IMF variation using Larson's Conjecture

Narayanan+RD 12

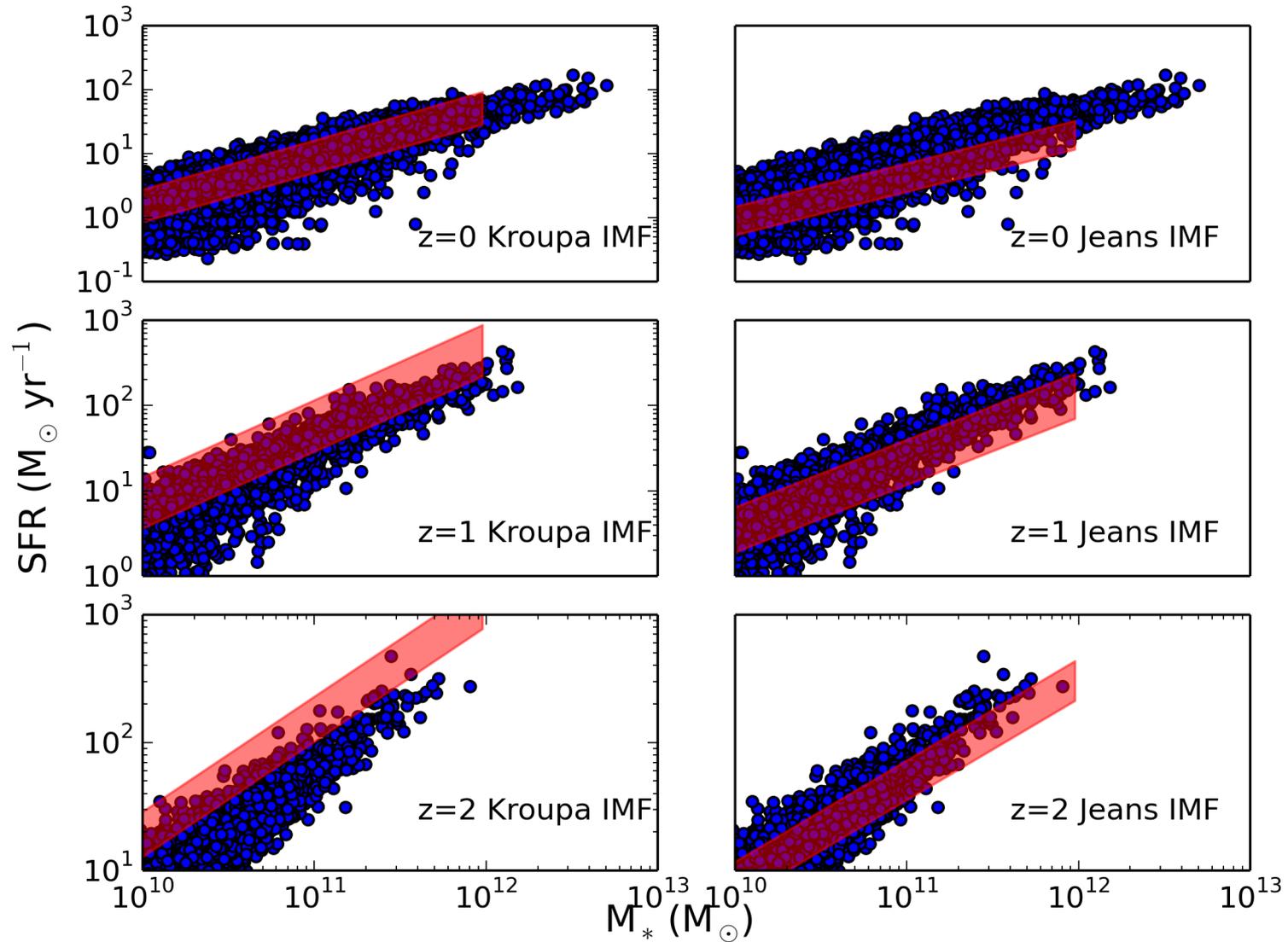
- Isolated merger simulations:
(T, ρ) \rightarrow M_J vs. SFR

$$\text{SFR} = \left[\frac{L_{\text{bol}}}{10^{10} L_{\odot}} \right]^{0.88} M_{\odot} \text{yr}^{-1}, \quad \text{for SFR} \gtrsim 3 M_{\odot} \text{yr}^{-1}$$

- Empirical SFR(z):
“retrofit” with new IMF, get new SFRD



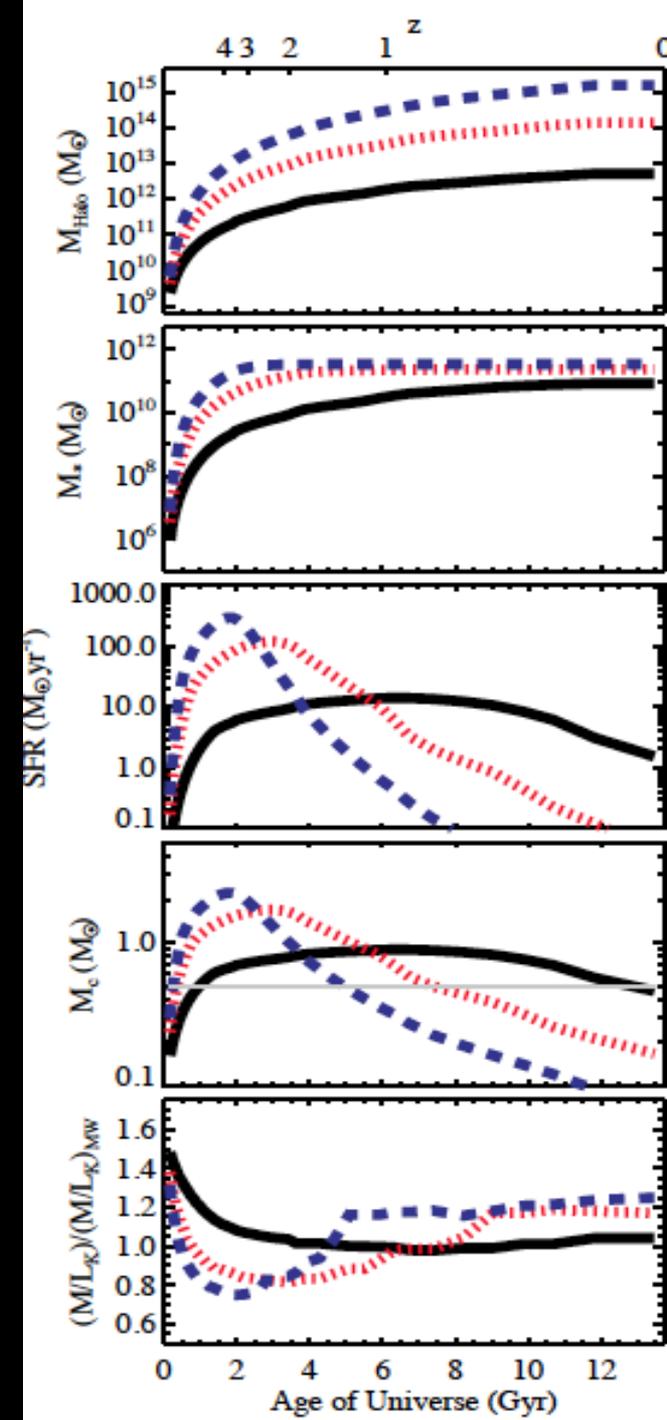
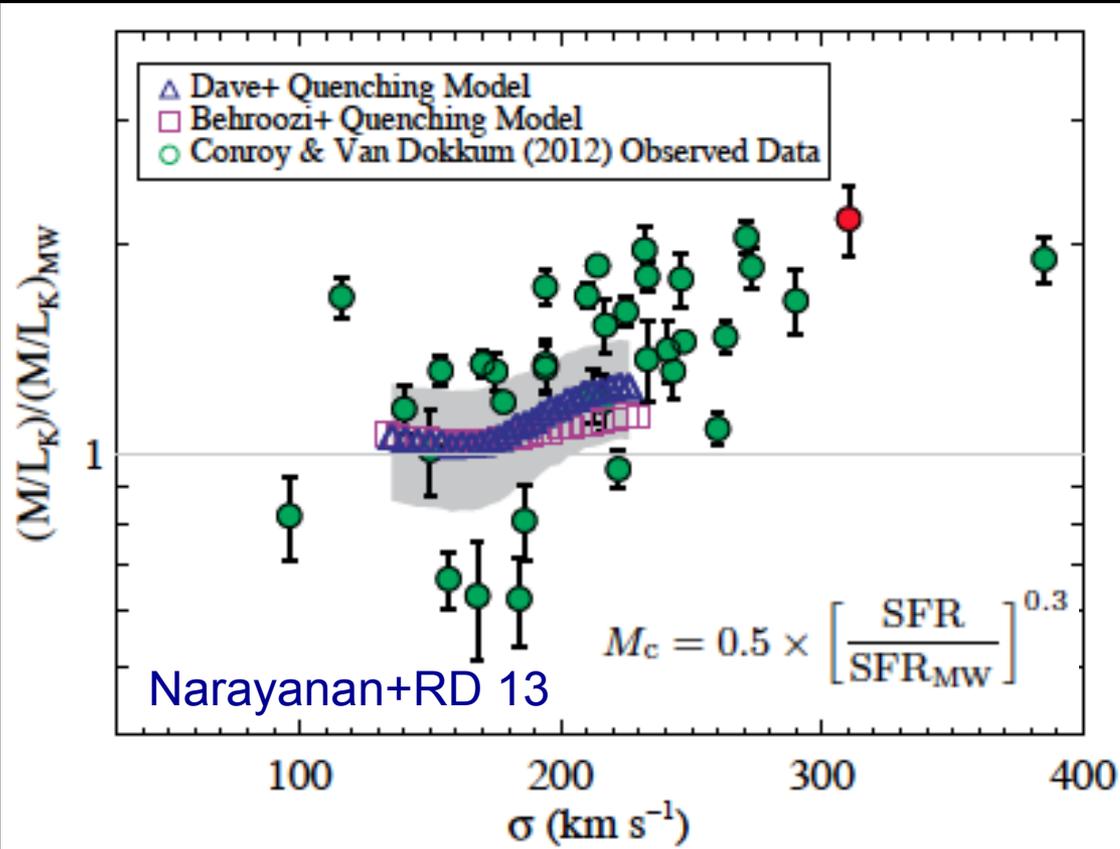
SFR- M_* with Jeans mass IMF





Wait, isn't the IMF bottom-heavy??

- $\text{SFR}(M_h, z)$ from equilibrium model $\rightarrow M/L_K(z)$

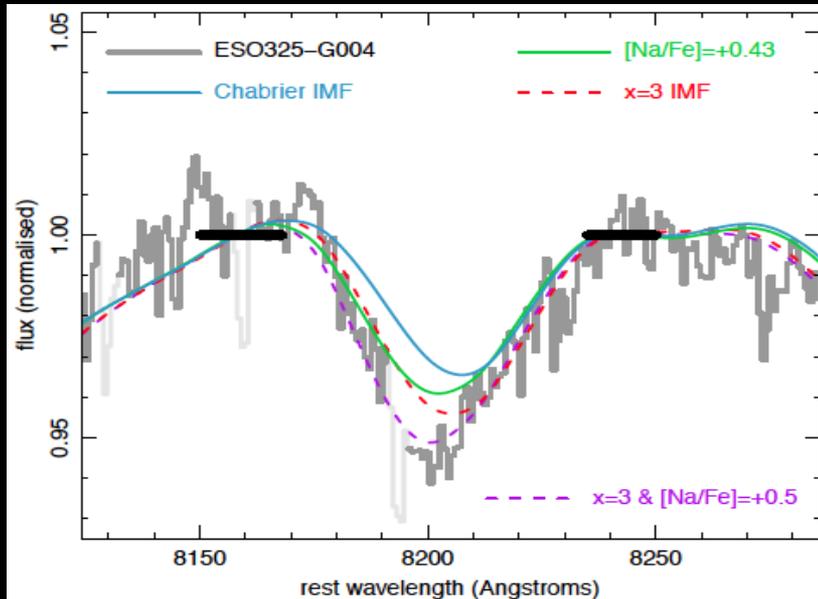
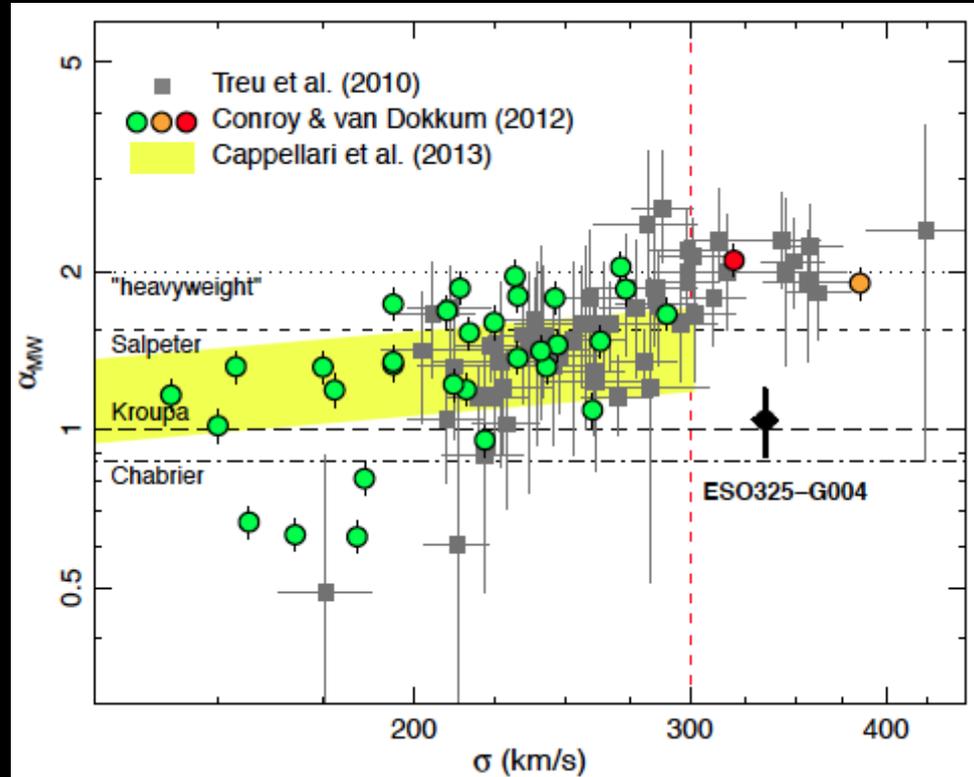


How can the IMF be both top-heavy *and* bottom-heavy?

- Top-heavy phase leaves extra mass in remnants. Also, late-time SF in ETG's has low SFR, hence bottom-heavy.
- Consistent with dynamical IMF constraints
- Not consistent with stellar pop constraints
- Cannot get x2+ increase in M/L – this remains an challenging constraint if true.

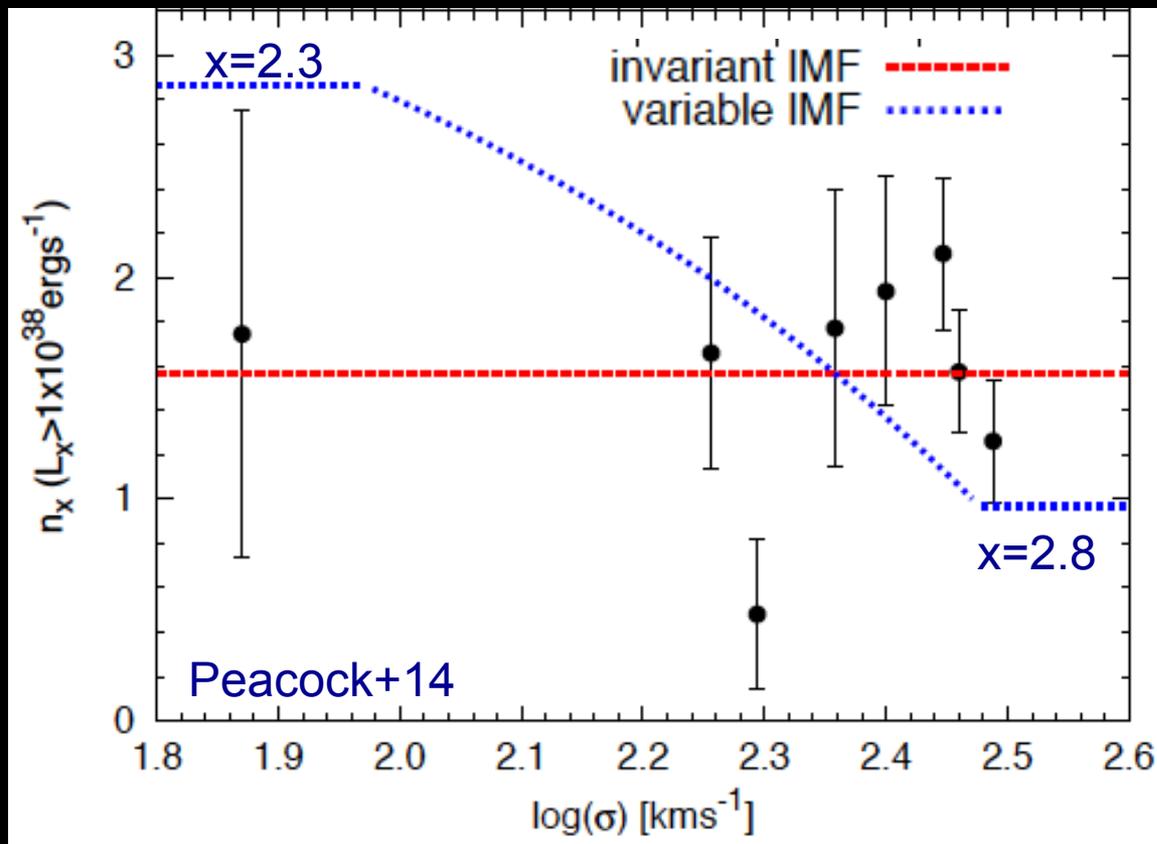
AO Dynamics vs Stellar Pops

- AO data suggests larger DM fractions, less bottom-heavy.
- Smith & Lucey (2013): Chabrier, despite strong Na absorption



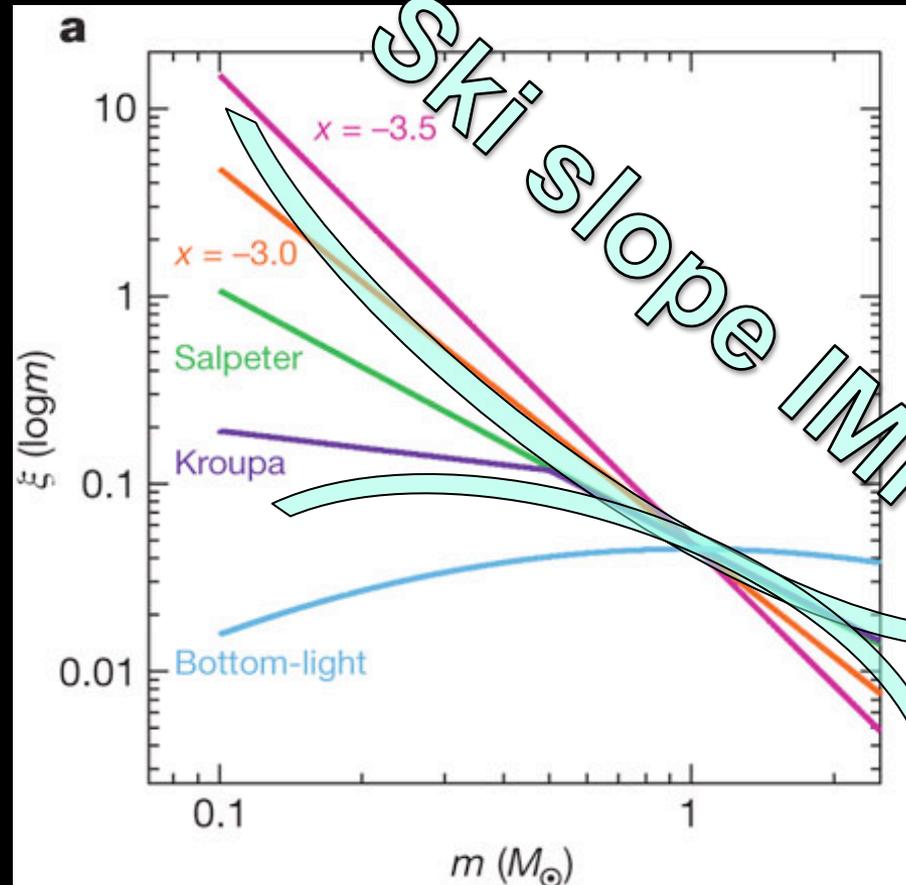
Is it turtles all the way up?

- XRBs: High-mass power law ($>\sim 2M_{\odot}$) cannot be more bottom-heavy with σ .



Can't we all just get along?

- “Flex” the IMF:
 - Early high-(Σ)SFR make lots of high-M and low-M stars, less $\sim 1M_{\odot}$.
 - Today, SFGs’ IMF flexes to peak at $\sim 0.5M_{\odot}$, reduced at high and low M.
 - Dwarfs are bottom-light, also don’t form massive stars



The features you want, at a price you can afford*

- Rapid SF in top-heavy phase.
- Enough $\sim 0.3M$ stars to get Wing-Ford ok.
- Get $H\alpha$ /UV stuff in rapid SFGs.
- Get shallower IMF in small low-SF galaxies, but also fewer high-M stars.
- Dynamics less bottom-heavy.
- Gets enough XRBs from top-heavy phase
- Helps reconcile SFR- M_* stuff.
- Strongly lowers SMG SFRs.

* sacred cow not included

Concluding Questions

- Can we all agree that the IMF isn't invariant over all space & time?
- Can we move past single power-law IMFs?
- What is the best way forward to measure the (high-M) IMF in star-forming systems?
- What are the best/most robust indirect constraints on the IMF?
- Do any models of the IMF produce something like a flex/ski-slope IMF?