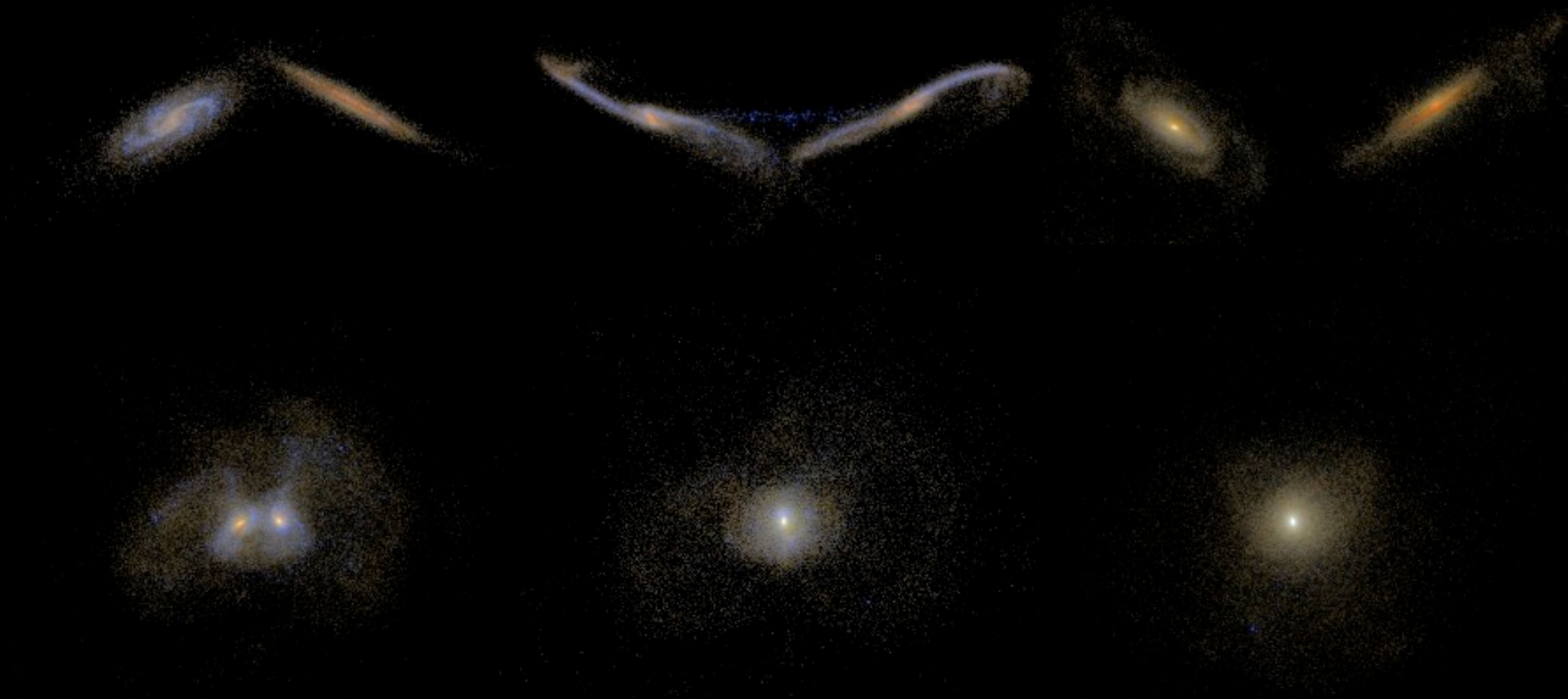
Do sub-mm galaxy number counts provide evidence for an evolving IMF?



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Collaborators

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- Phil Hopkins (Berkeley)
- T.J. Cox (Carnegie Observatories)

Sub-millimeter galaxies (SMGs)

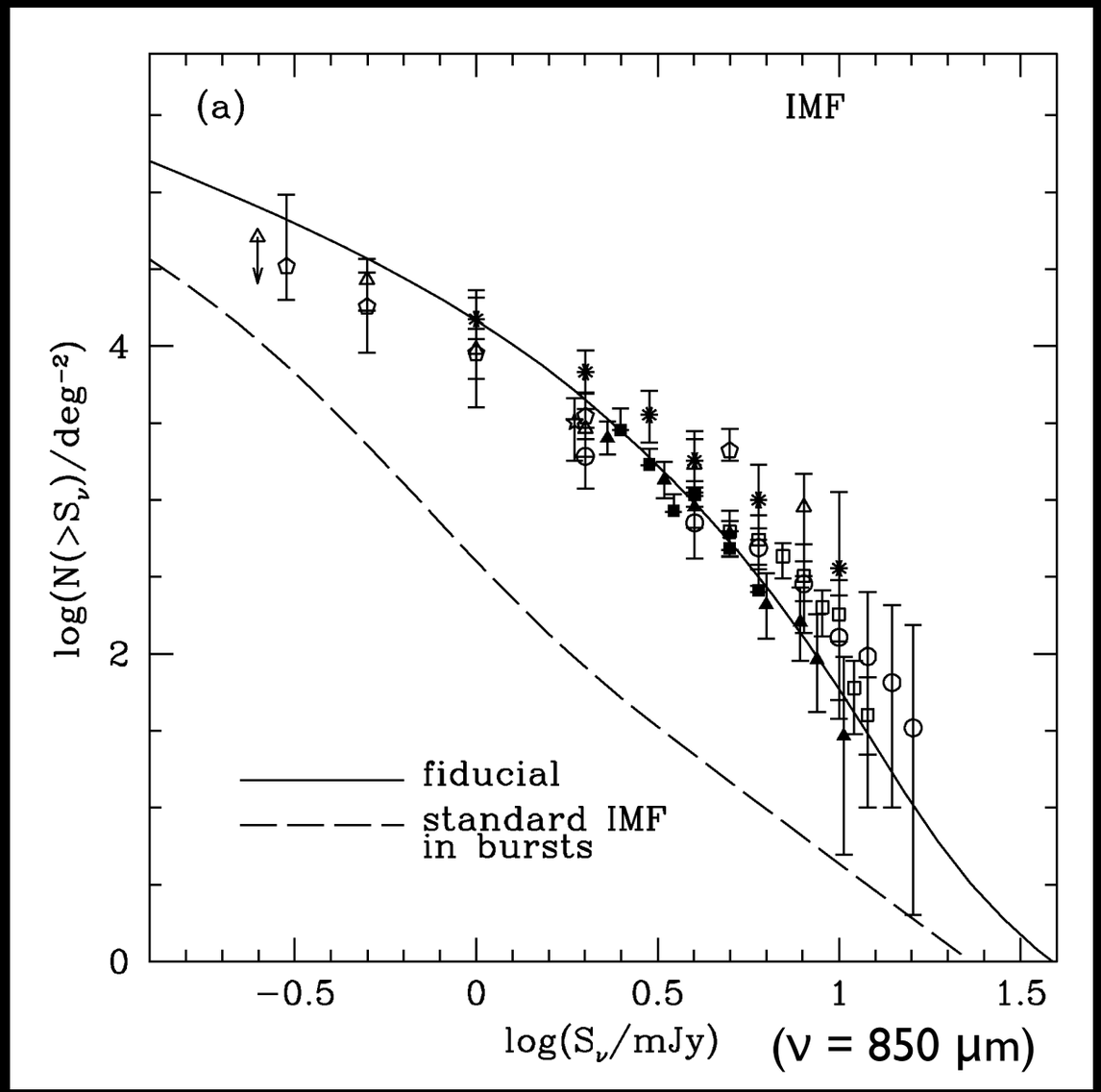
- Population of optically faint sources detected in sub-mm (fiducial cut S_{850} > ~5 mJy)
- 99% of L is emitted in IR
- Powered by SF rather than AGN
- L_{IR} ~ 10^{12} - few x 10^{13} L_{sun} ⇒ SFR ~ 100s-1000s M_{sun}/yr
- Median z ~ 2.2, σ ~ 1.2 ⇒ sub-mm traces ~ 200-400 μm emission (longward of peak)

A flat IMF?

- Baugh+05 models: GALFORM (Cole +00) SAM + GRASIL (Silva+98)
- Under-predicts by 20-60x when using Kennicutt IMF
- Modified SAM matches; key change is use of flat IMF in bursts (more L & M_d/M_{sun} formed):

$$dN/d\ln m = \text{const},$$

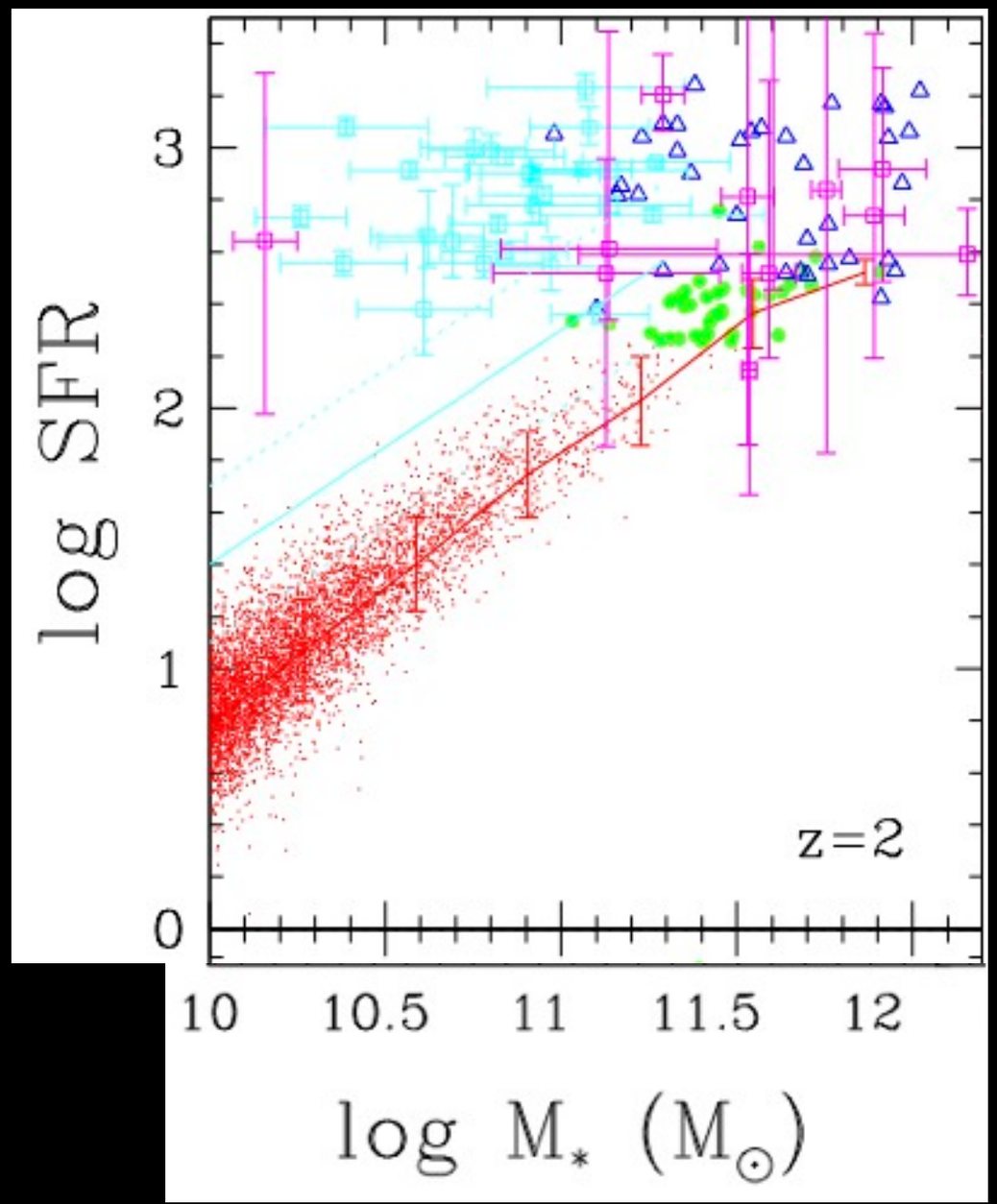
$$0.15 < m < 125 M_\odot$$



Baugh+05

Or "bottom-light"?

- Davé+10 map SMGs to most star-forming galaxies in a cosmological simulation
- Sim objects consistent w/ many observed properties, but SFR ~3x < inferred SFR
- SMGs' high L_{IR} confirmed by Herschel (Magnelli+10)
- Bottom-light IMF could explain (more L/M_{sun} formed → lower SFR)



Davé+10

Our model for number counts

1. High-resolution N-body/SPH simulations of mergers/disks + 3-D polychromatic RT → sub-mm duty cycles
2. Merger rates from "semi-empirical" model
3. Combine to get number counts:

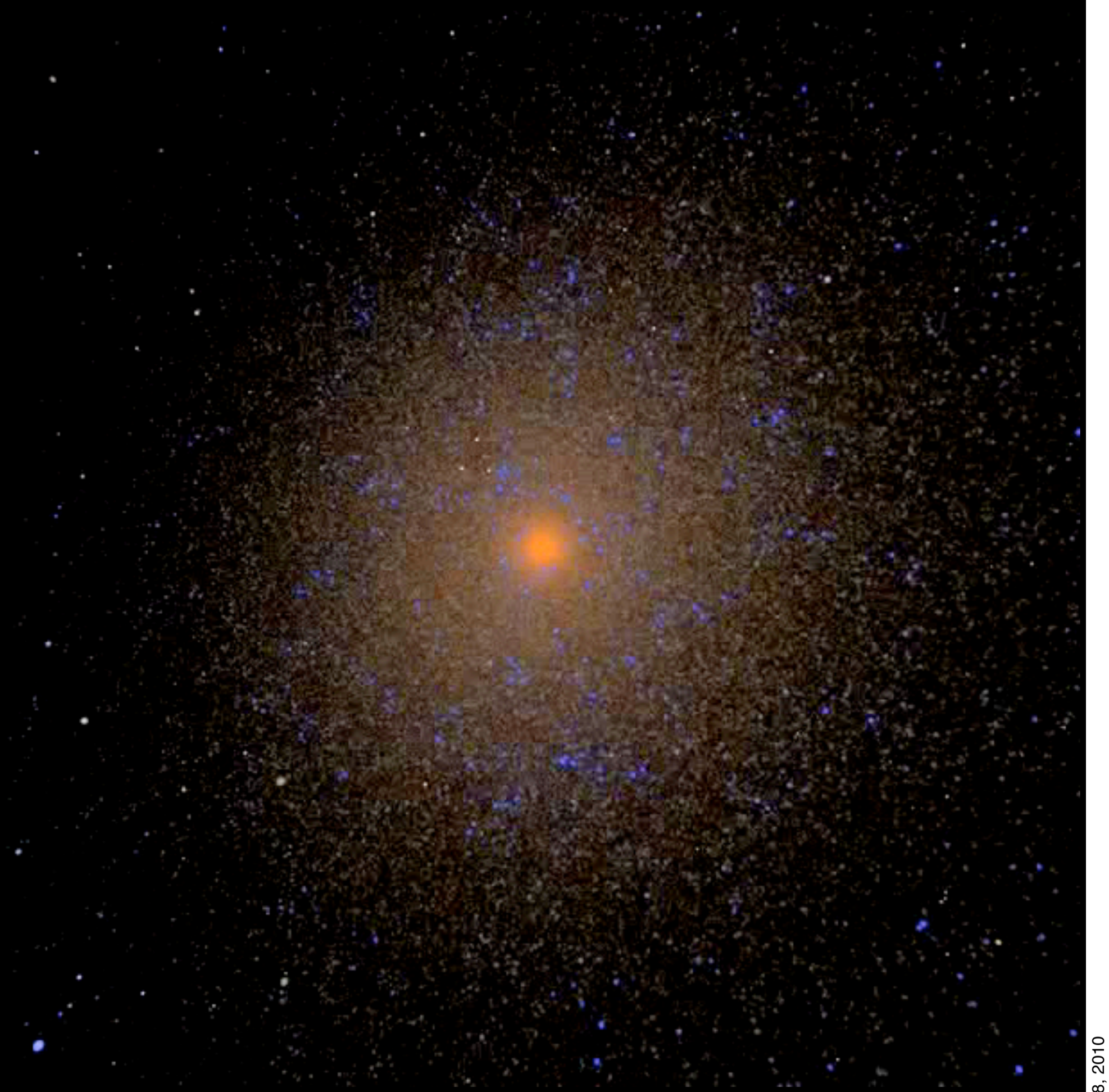
$$\frac{dN(>S_\lambda)}{d\Omega} = \int \frac{dN}{dV\,dt d\log M_b d\mu df_g}(M_b,\mu,f_g,z)\tau(>S_\lambda,M_b,\mu,f_g,z)\frac{dV}{d\Omega dz}(z) d\log M_b d\mu df_g dz$$

Our philosophy: Use as many observational constraints as possible and systematically test importance of poorly constrained aspects of model - test IMF null hypothesis

GADGET simulations

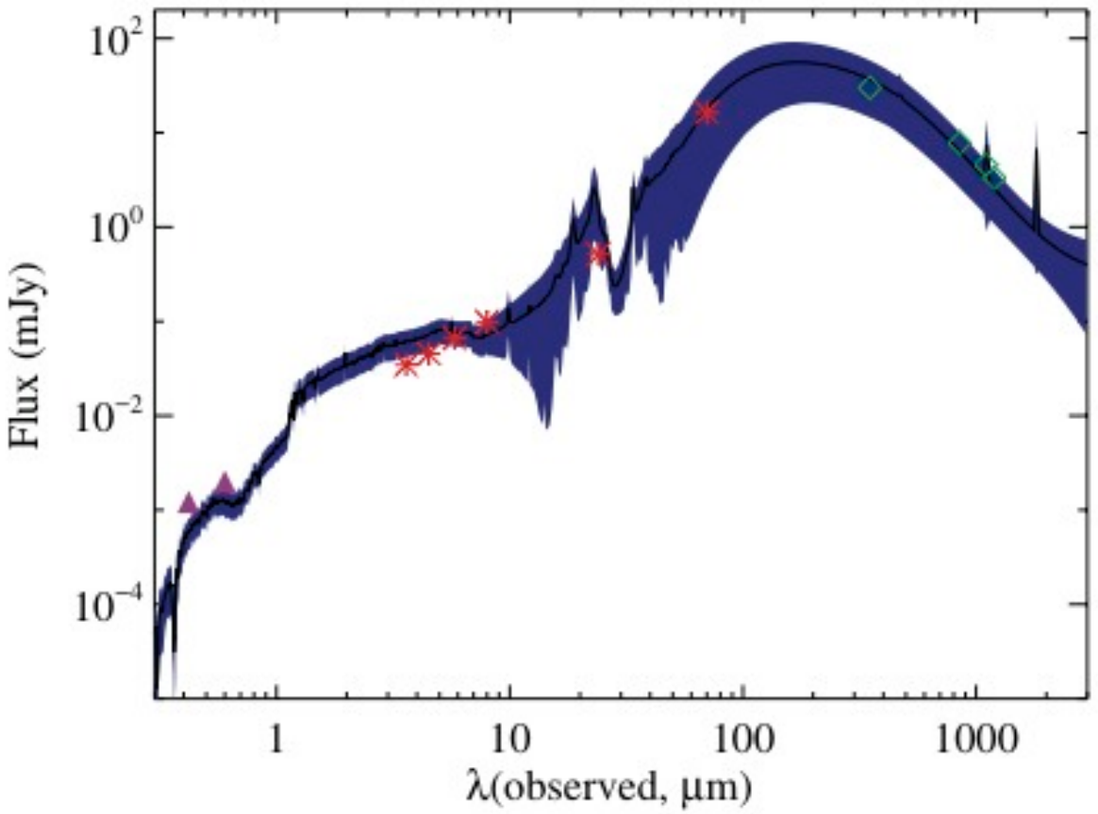
- Large suite of major & minor mergers, isolated disks; non-cosmological
- GADGET-2 N-body/SPH (Springel 05)
- Schmidt-Kennicutt SF recipe
- Two-phase ISM of Springel & Hernquist (03)
- Radiative heating & cooling (Katz+96)
- BH growth & feedback (Springel+05)

P. Jonsson, G. Novack

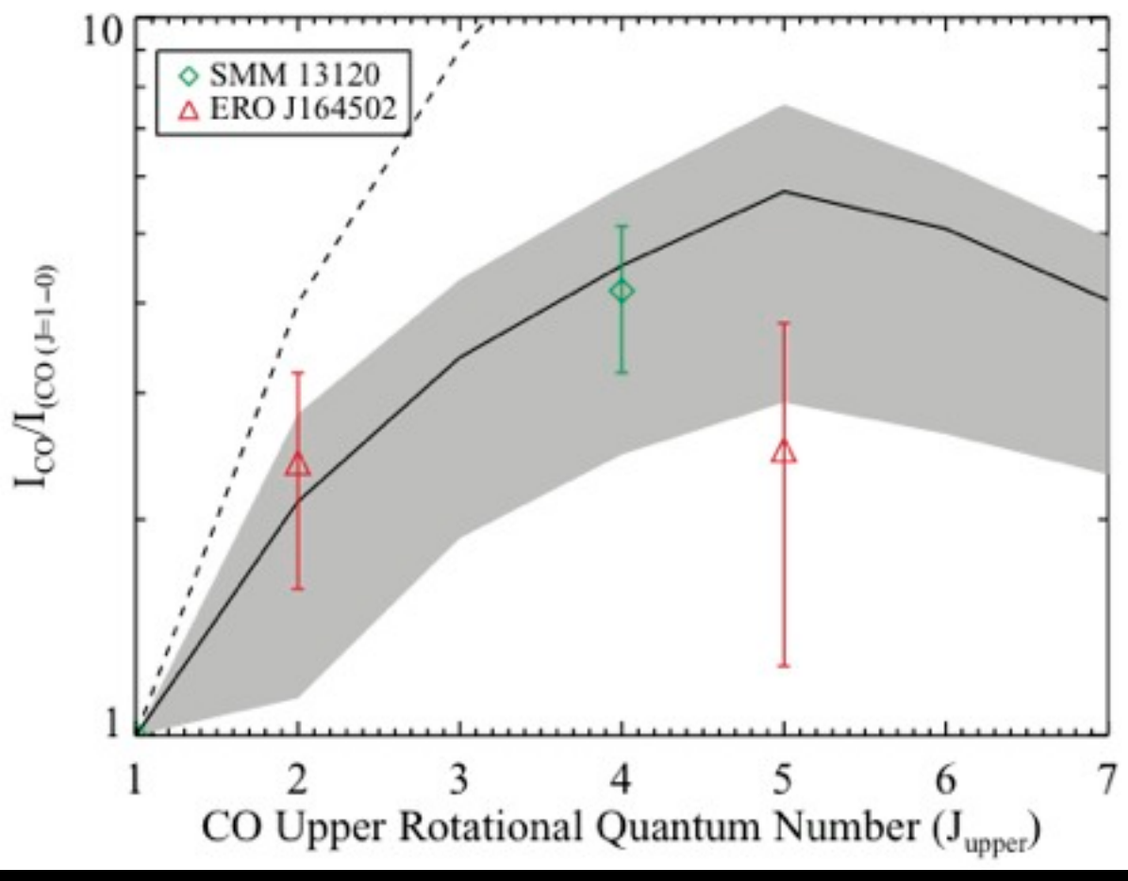


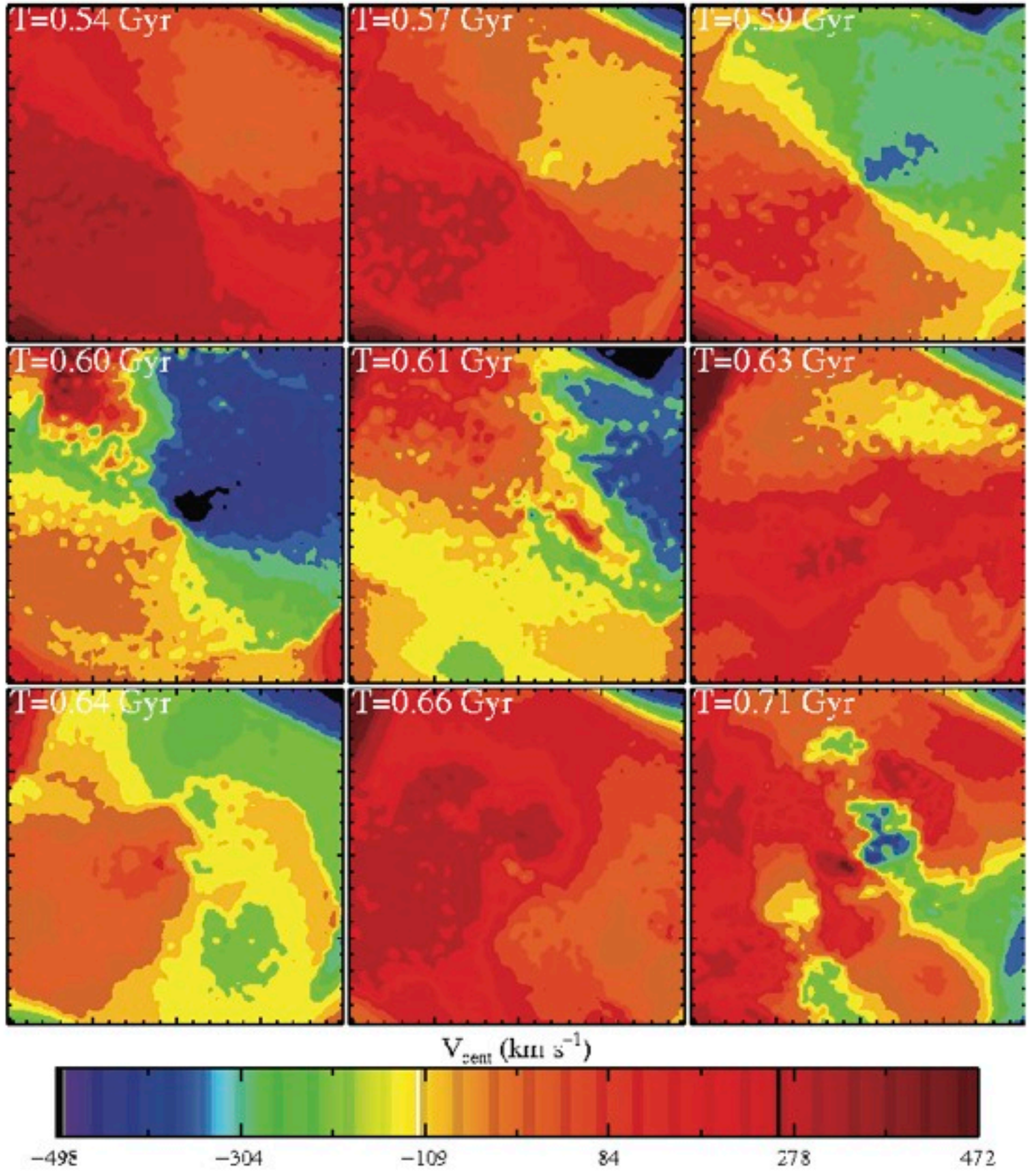
Sunrise details

- Stellar SEDs from *Starburst99* (Leitherer+99)
- AGN template of Hopkins+07
- Kroupa IMF; don't vary in order to test null hypothesis
- WD01 + DL07 MW dust model, dust-to-metals = 0.4 (vary this, also use dust-to-gas)
- Initialize disks w/ Z_{gas} = 0.015 (but vary) so that SMG phase has metallicity consistent w/ observations (~solar - super-solar); consistent also with mass-metallicity relation for progenitors
- All parameter choices are "normal" - nothing exotic



Narayanan, CCH+10

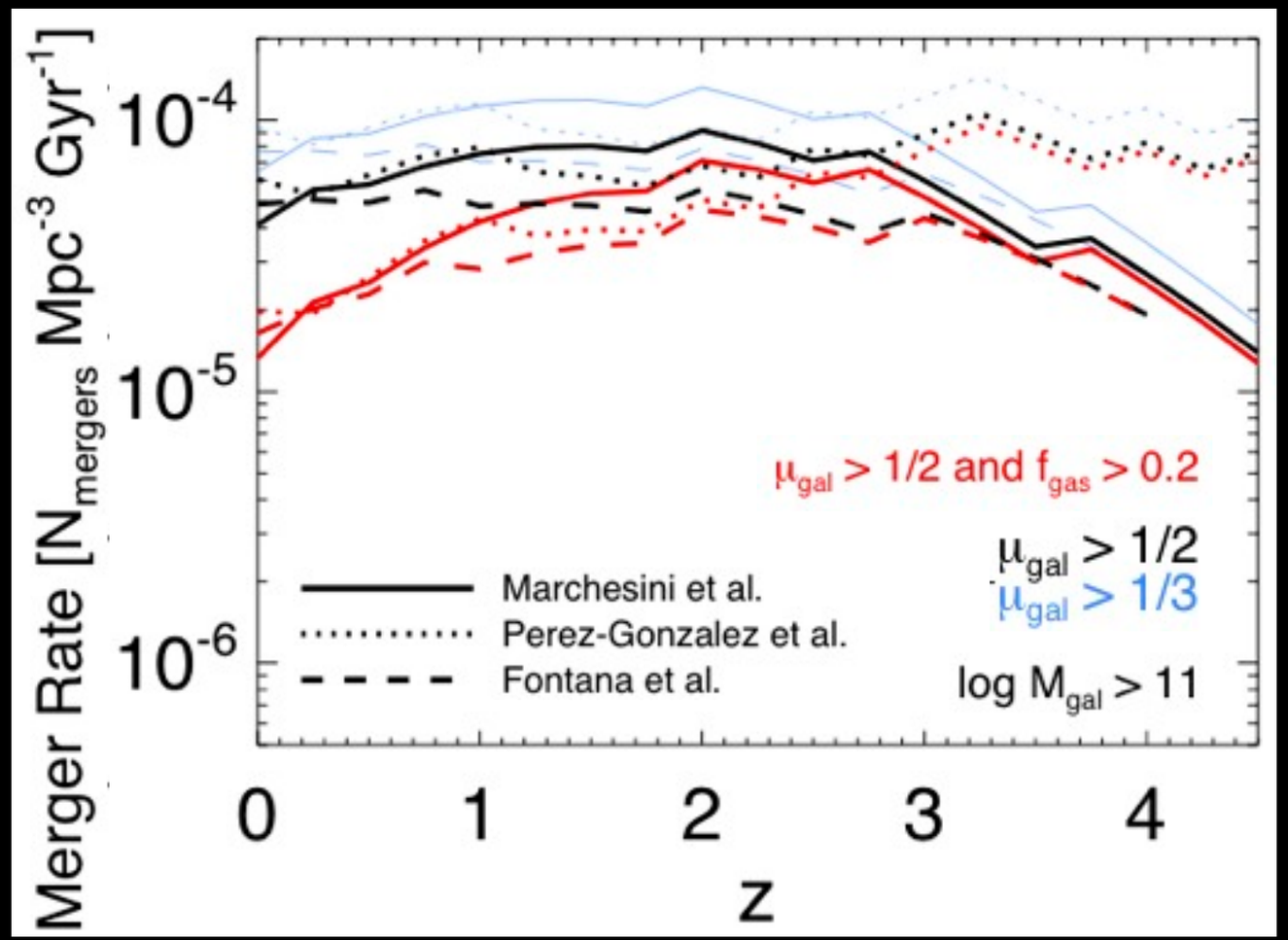




Narayanan, Cox, CCH+10

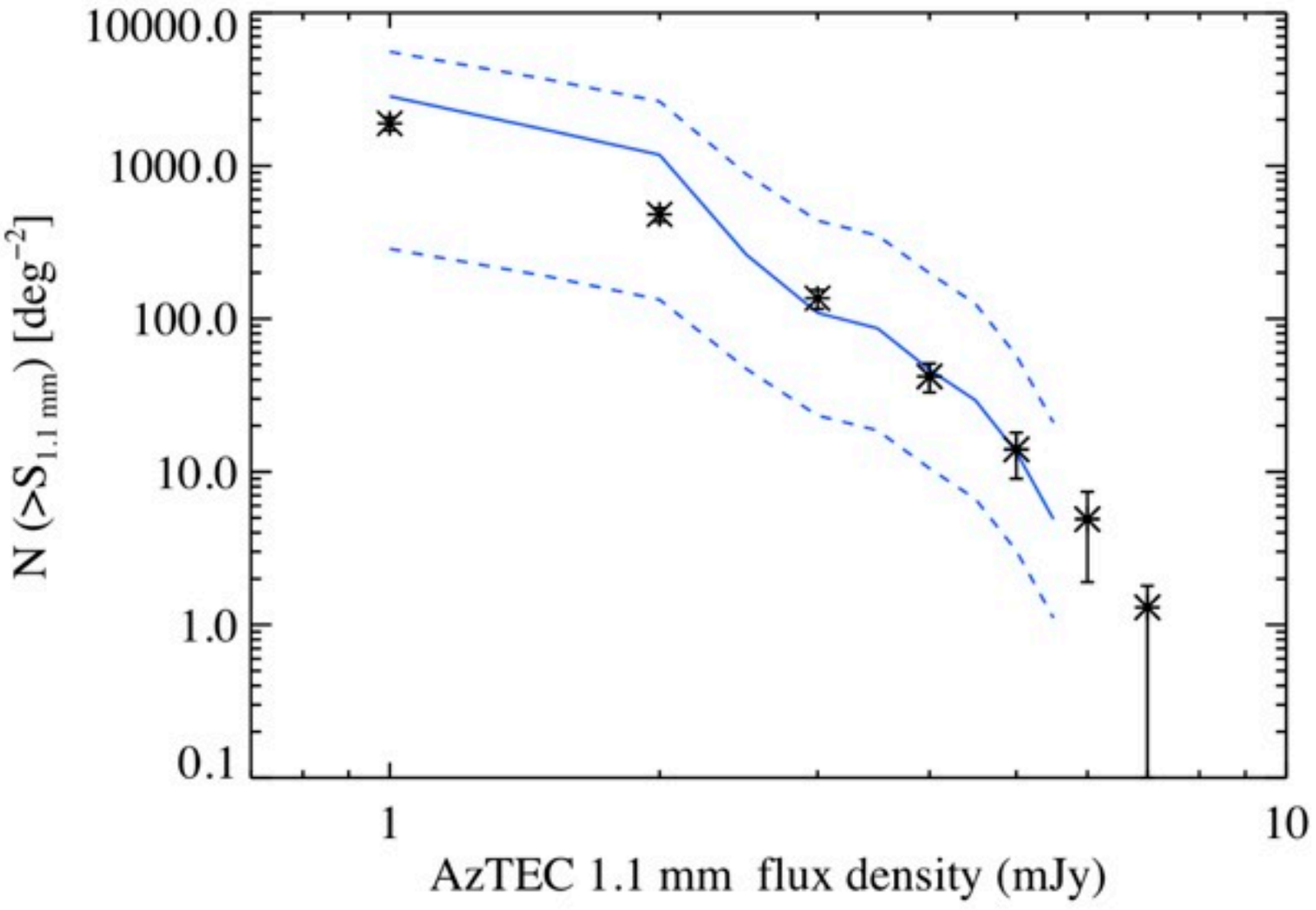
Calculating merger rates

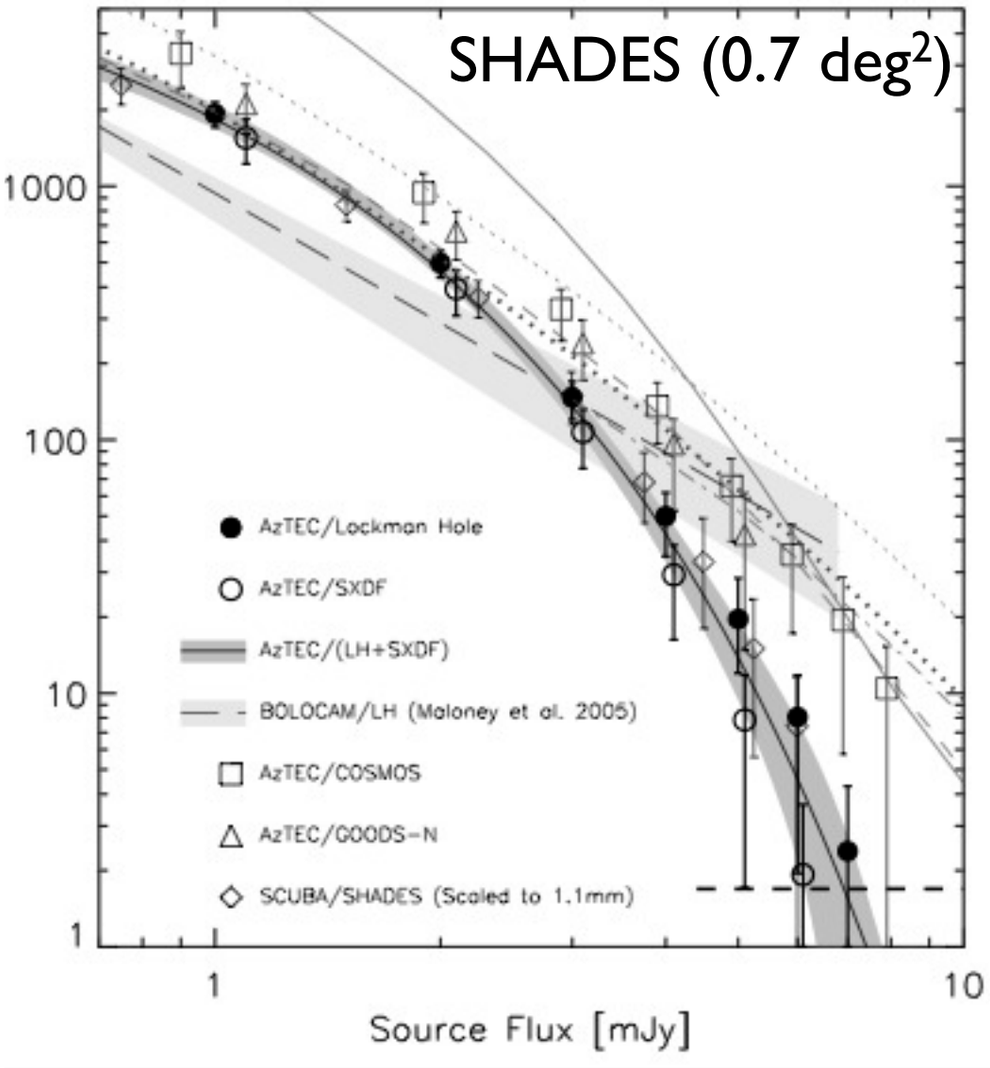
1. Start w/ stellar MF (Marchesini+09)
2. Assign f_g from observations
3. Assign galaxies to halos using HOD (Conroy & Wechsler 09)
4. Halo merger rates from N-body (Fakhouri & Ma 08)
5. Use $t_{\text{dyn friction}}$ to link halo-halo to galaxy-galaxy mergers



Hopkins+10

Predicted number counts (mergers only)

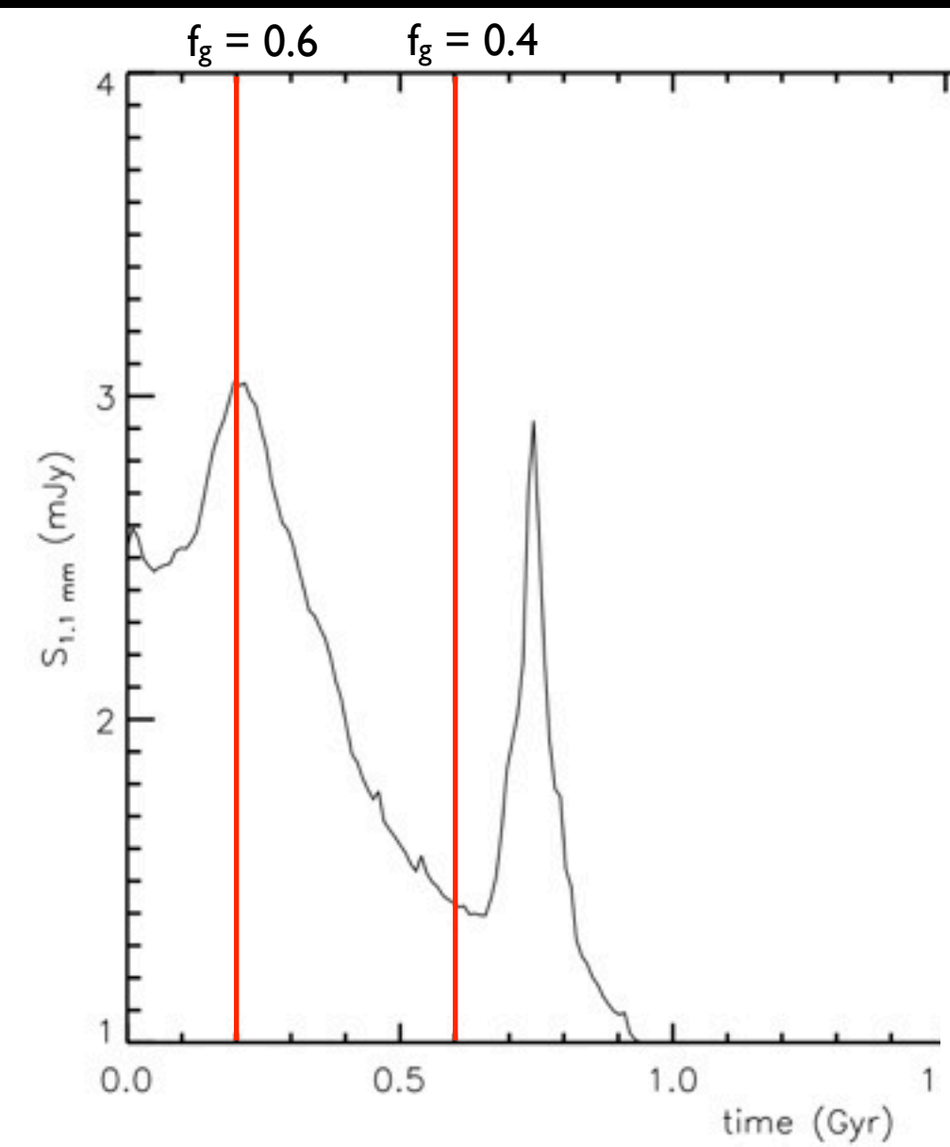


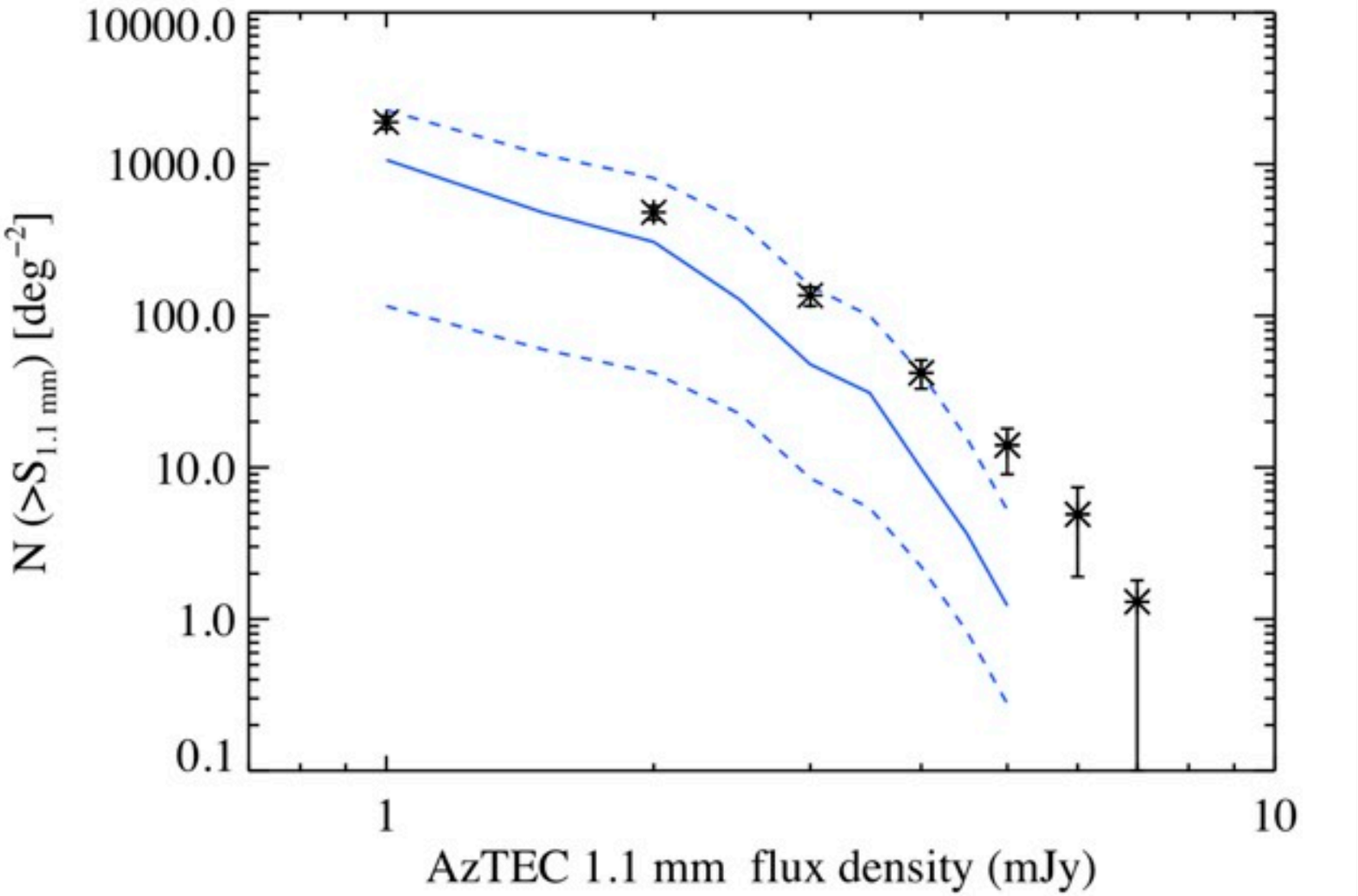


Austermann+10

Note: 1.1 mm cts; $S_{850} \sim 2\text{-}3 \times S_{1.1}$

Merger-induced burst counts





Summary

- Semi-empirical merger rates + high-res SPH sims + 3-D RT w/ full dust T calculation to predict SMG number counts
- Mergers create SMGs via 2 effects: 1. Sum of the flux of the two massive gas-rich progenitors. 2. Increase in luminosity owing to merger-induced burst (but mitigated by increase in dust T owing to rapid gas consumption)
- It is possible to match SMG number counts w/ standard IMF
- Approach still limited (lack of cosmological gas accretion, treatment of dust enrichment, ICs...); optimal approach is combining cosmological sims w/ RT; computationally even more expensive, so as intermediate step we'll add cosmologically motivated inflows to our idealized sims