What's the deal with submillimeter (submm) galaxies?

Papers:
Chakrabarti et al. 2008, An Evolutionary Model for Submm Galaxies

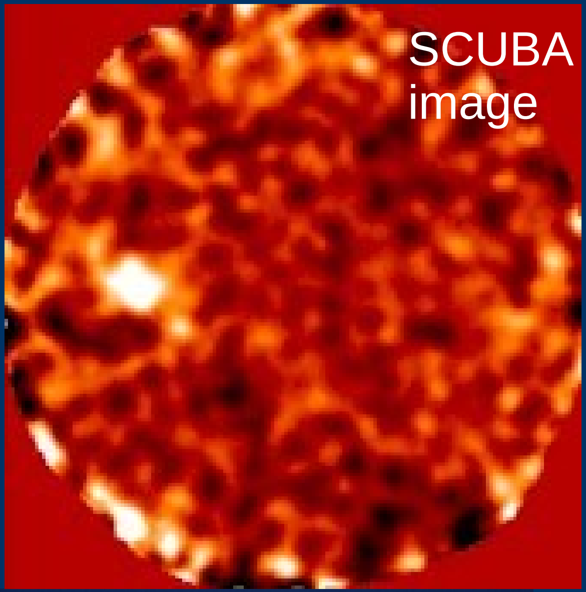
Swinbank et al. 2008, The properties of submm galaxies in hierarchical models

Schinnerer et al. 2008, Molecular gas in a submm galaxy at z=4.5: Evidence for a Major Merger at 1 Billion Years after the Big Bang

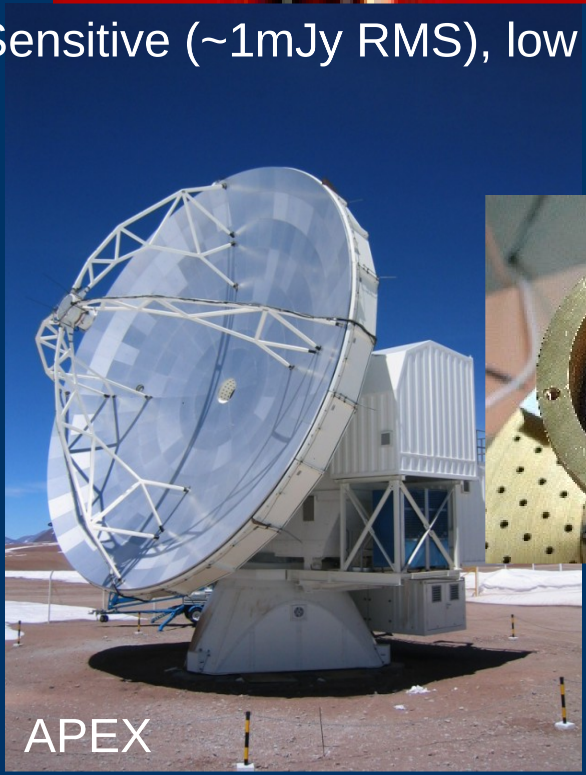
Coppin et al. 2009, A submm galaxy at z = 4.76 in the LABOCA survey of the Extended Chandra Deep Field-South

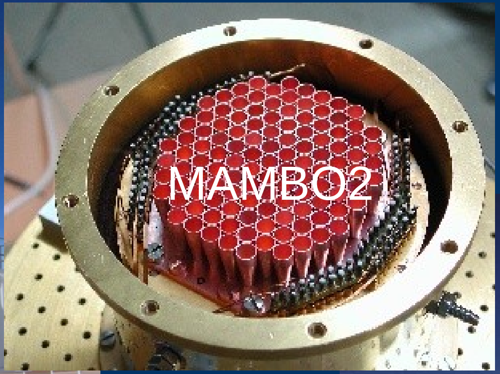
Presented by Robert Lindner

First generation of sensitive mm-wave continuum detector arrays look at the sky in 1997 (smail et al. 1997)

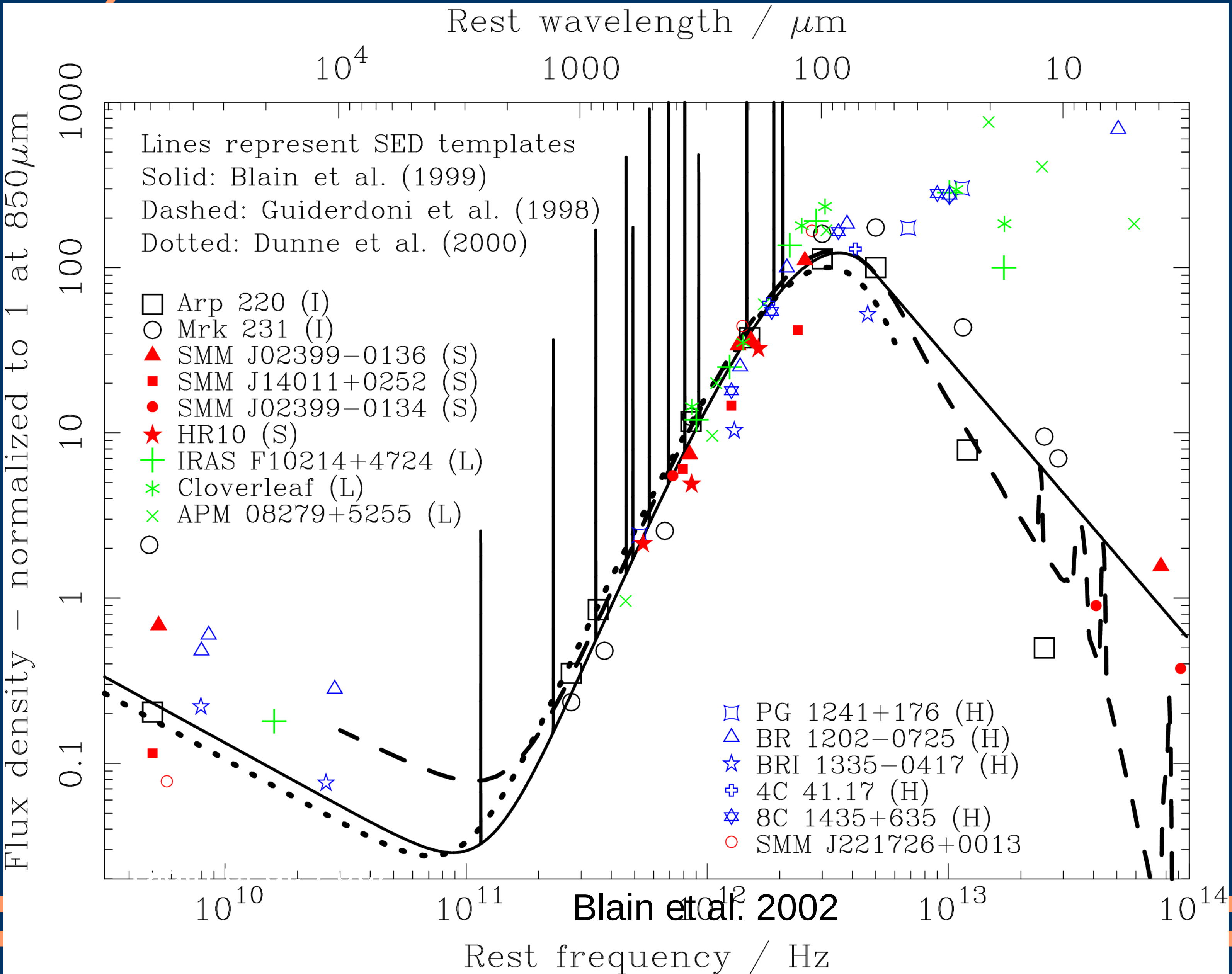


Sensitive (~1mJy RMS), low resolution



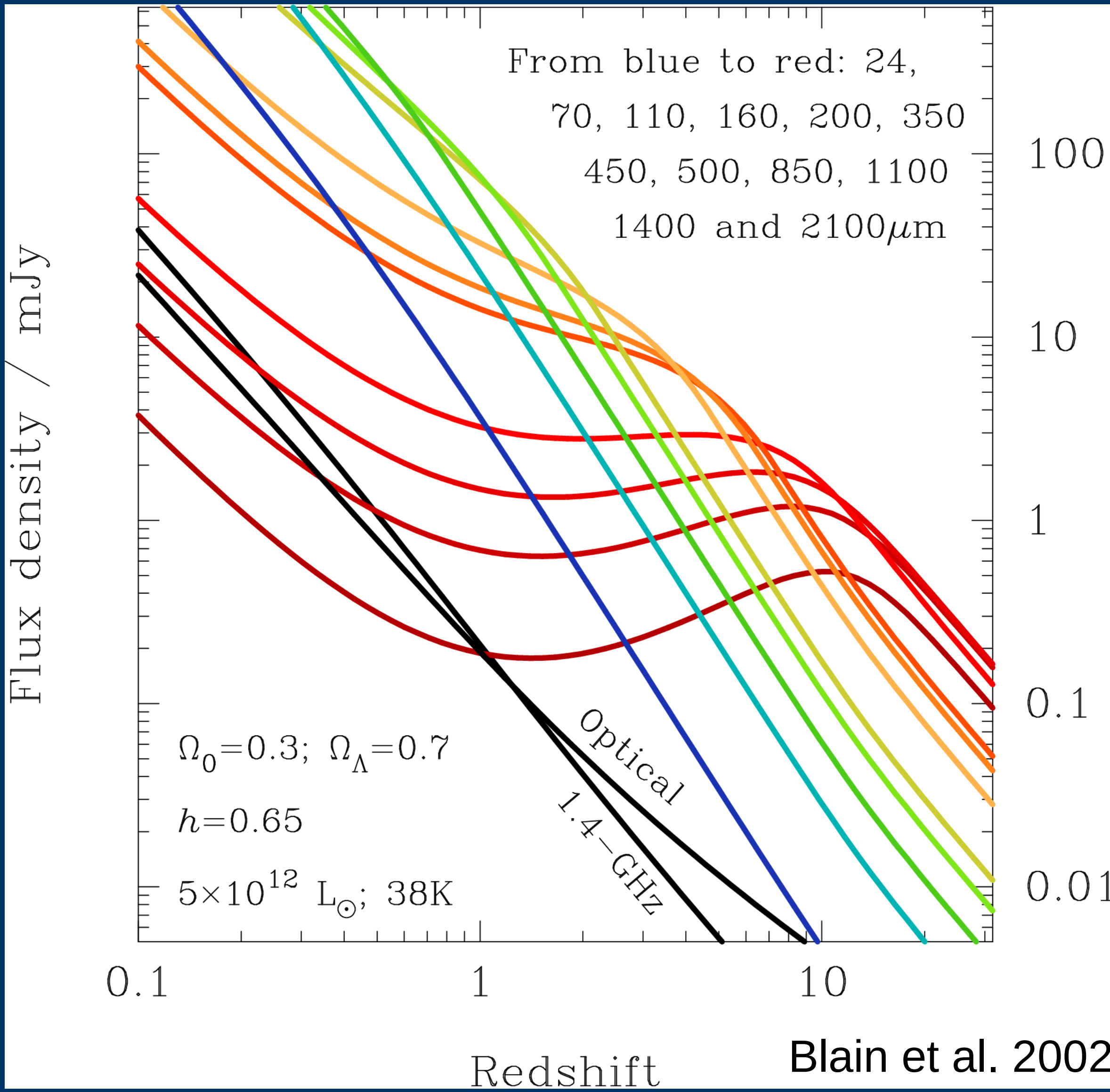


Submm Galaxies (SMGs):
At 1000-850µm their SEDs are probably dominated by thermal dust emission , like local luminous infrared galaxies (LIRGS)



Blain et al. 2002

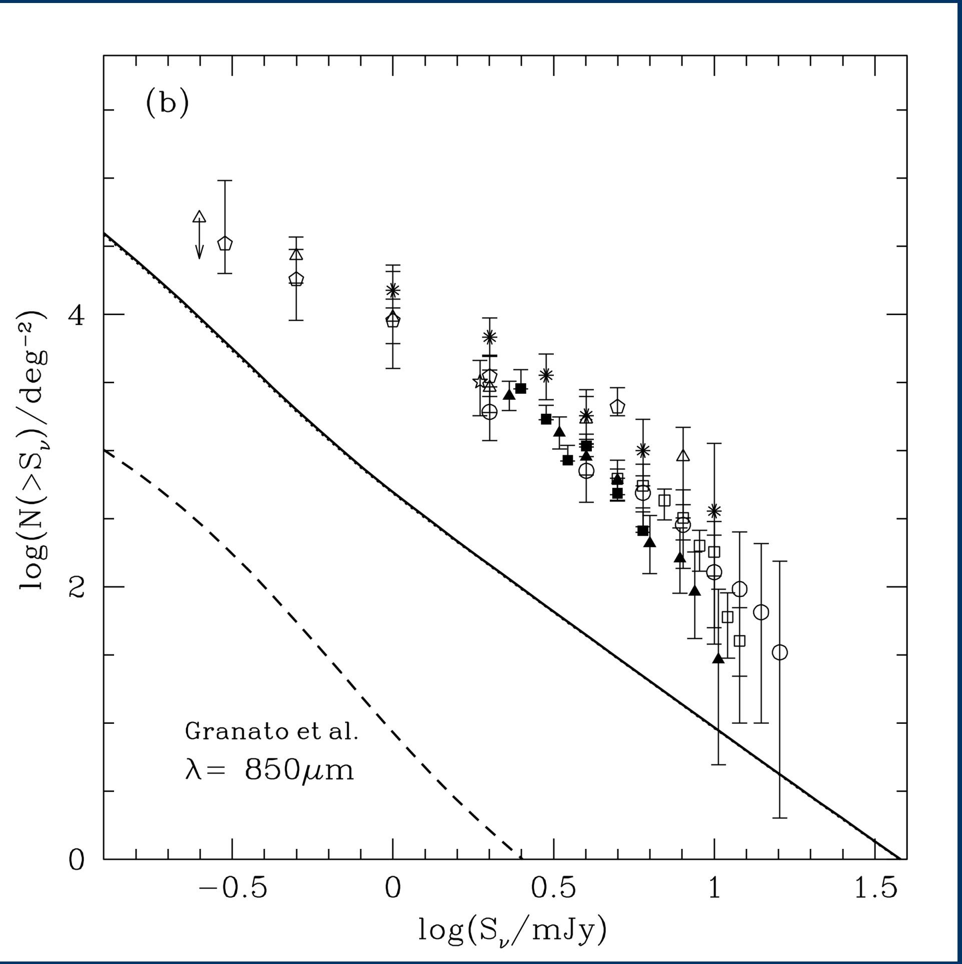
The K-correction in this region of the SED makes for interesting observations.



Blain et al. 2002

An epic battle between luminosity distance, and K-correction

The number counts disagreed with predictions based on non-evolving models of the local ULIRG population

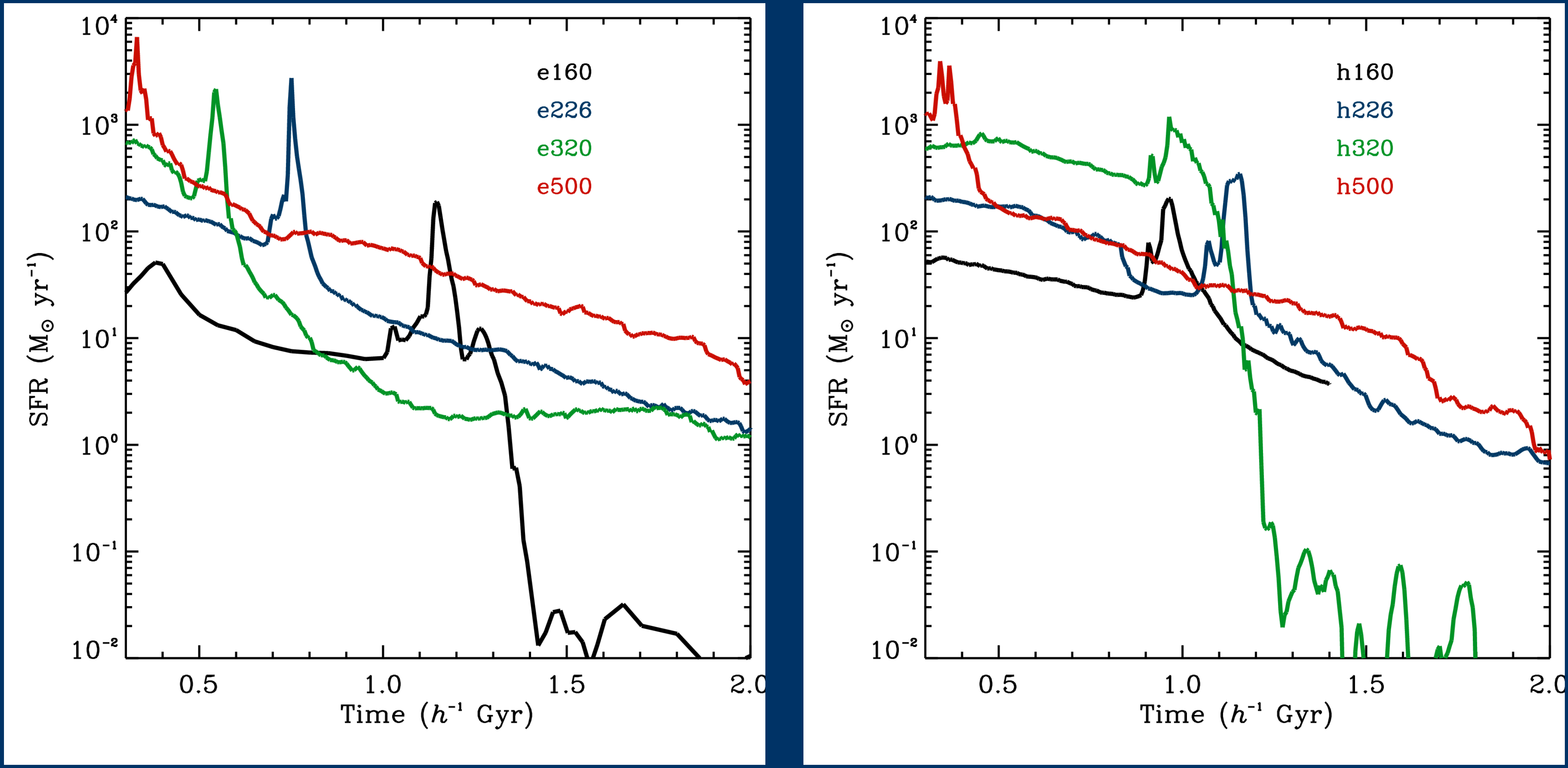


from Baugh et al. 2005

Chakrabarti et al.: 3D radiative transfer simulation of merging galaxies. One merger at a time

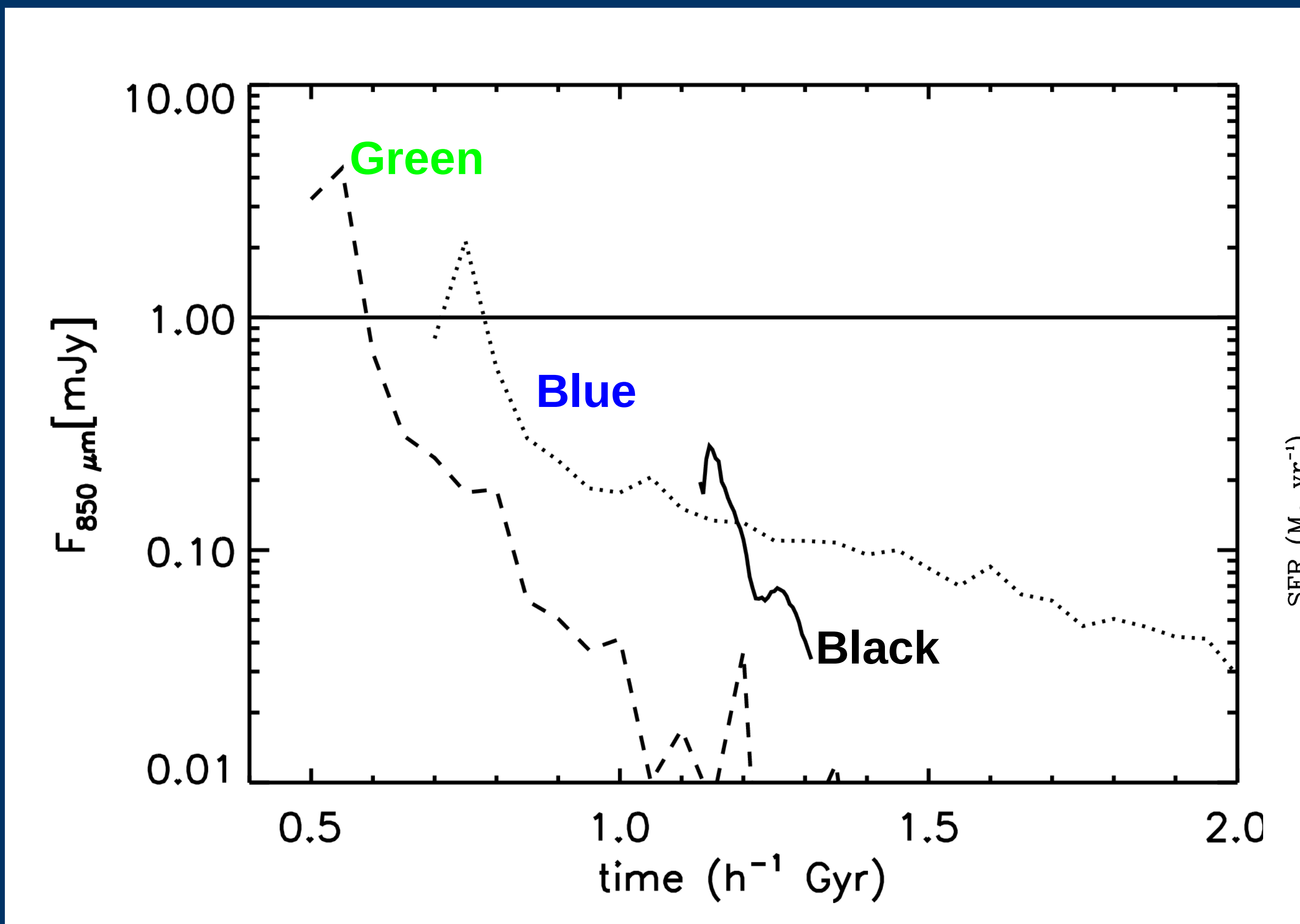
Great at predicting SED trends related to the dynamics of the mergers.

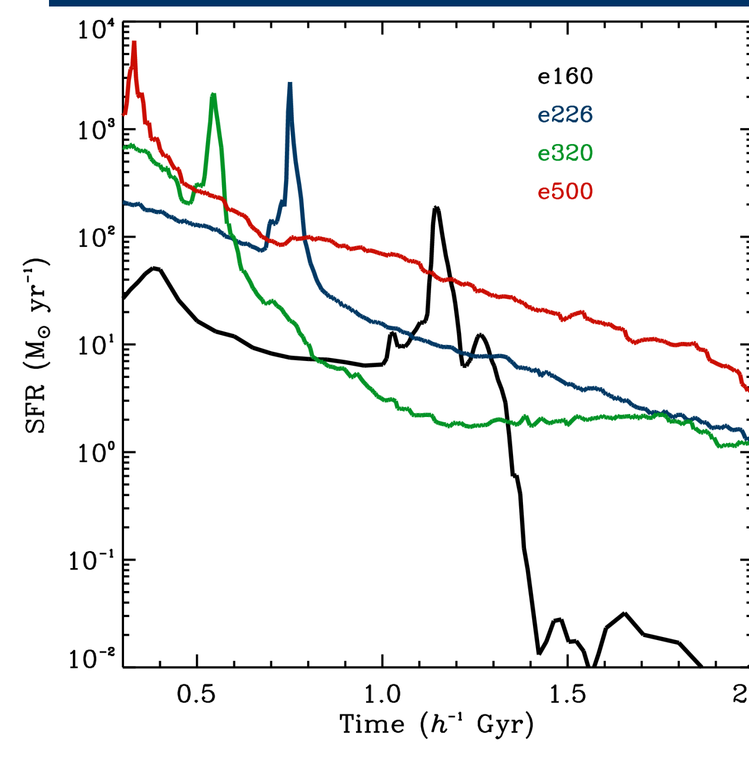
Live view of star-formation vs. time in the mergers



Chakrabarti et al.

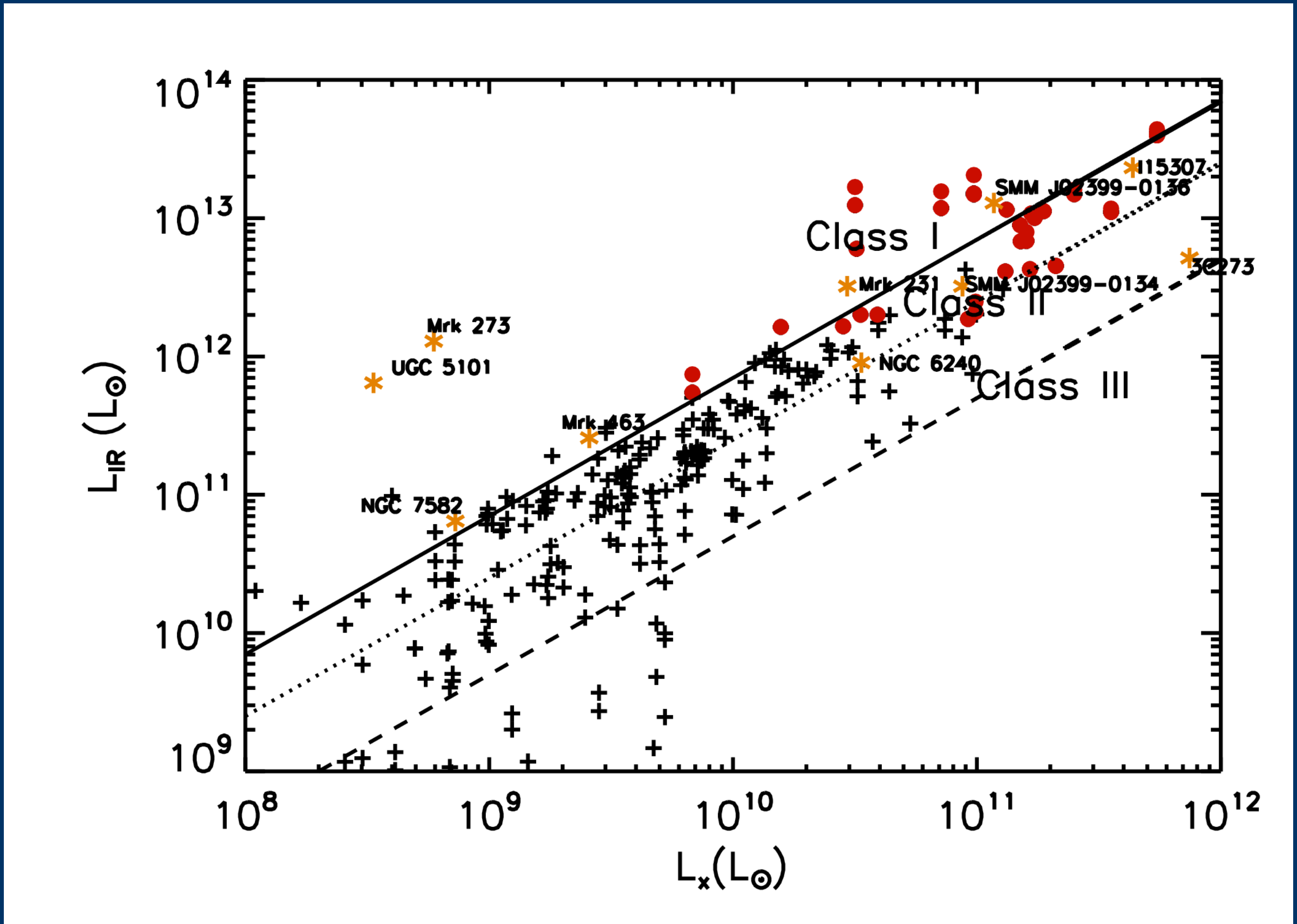
Simulation postdicts successfully that the 850 micron flux traces starformation.





Chakrabarti et al.

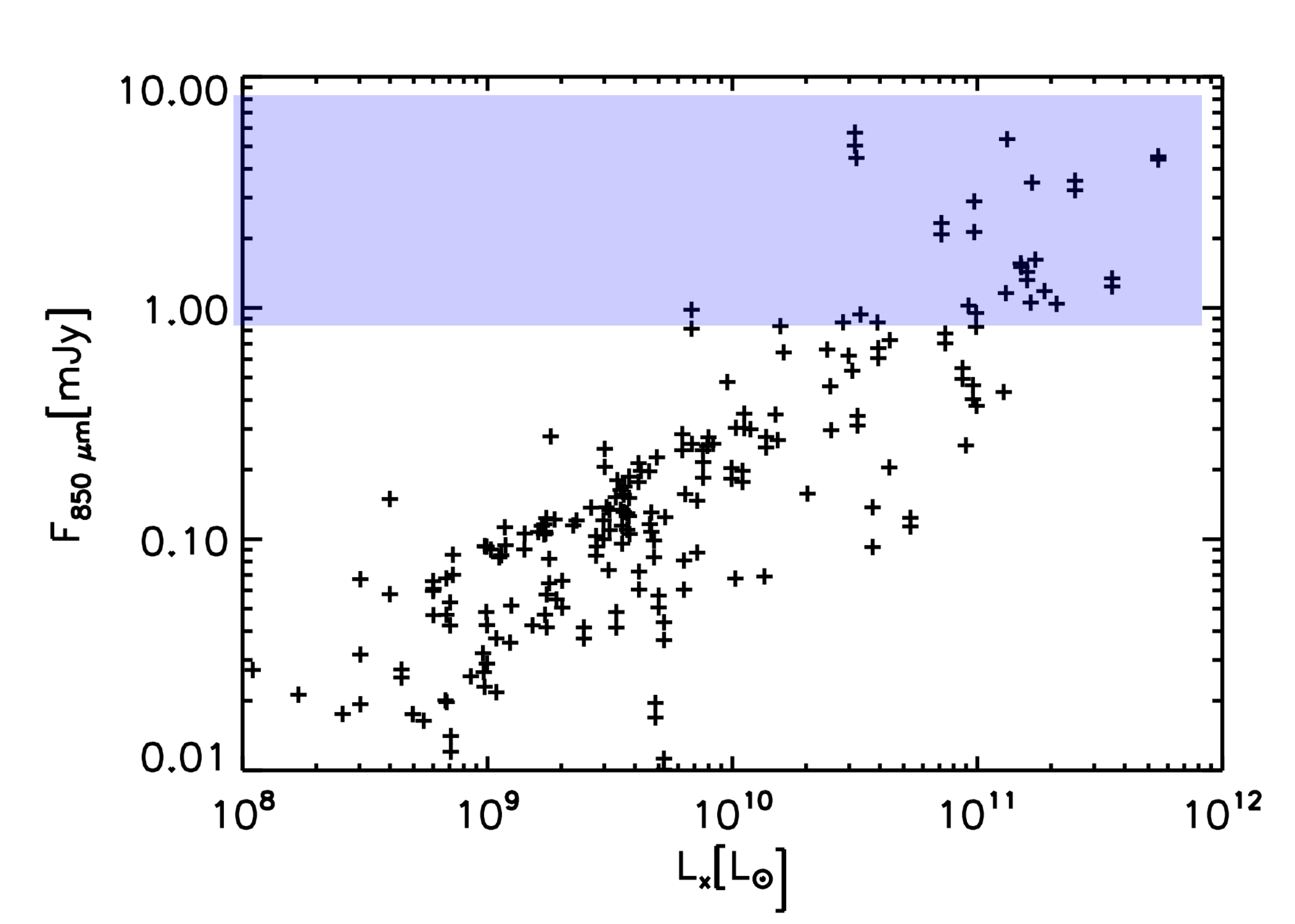
The Main (only) Prediction



Chakrabarti et al.

Correlation between IR (70 and 24 micron), Hard X-rays

But what about the 850 micron flux?

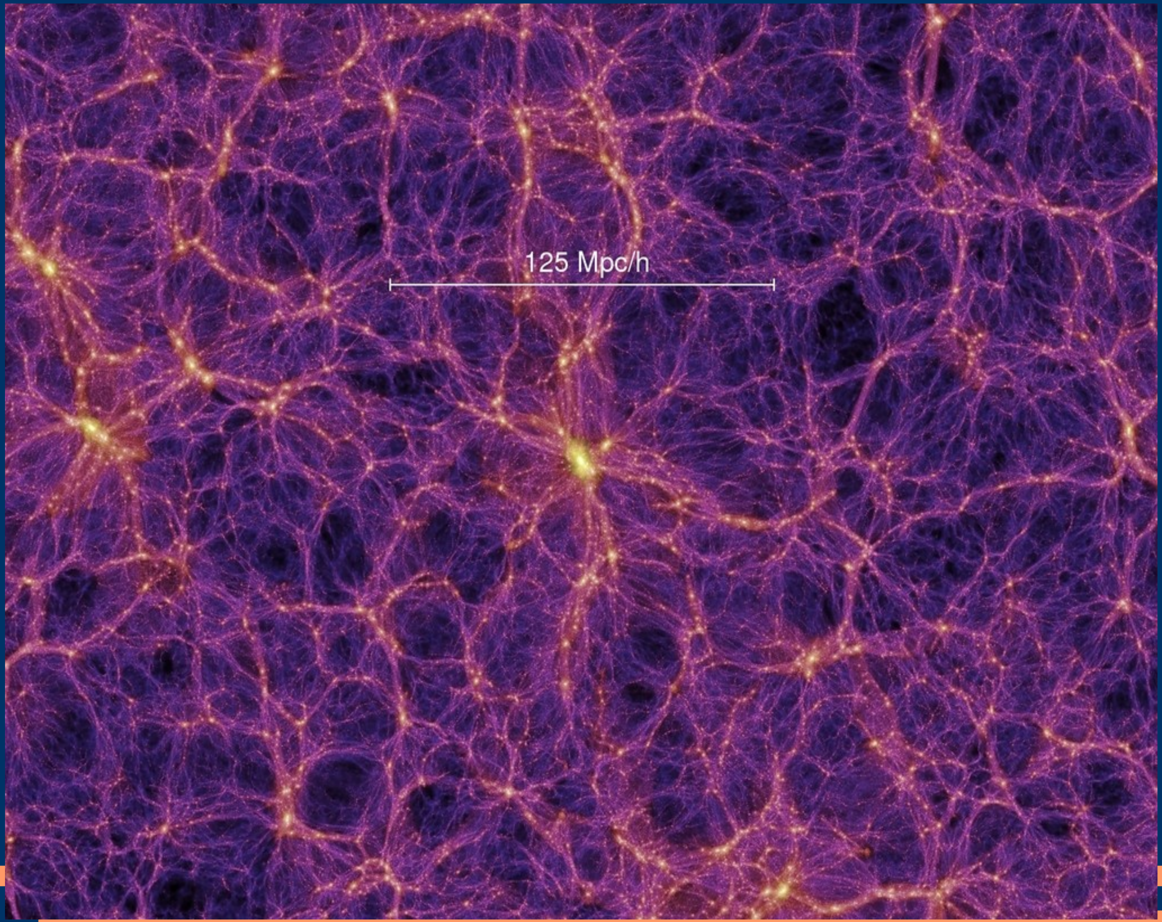


Chakrabarti et al.

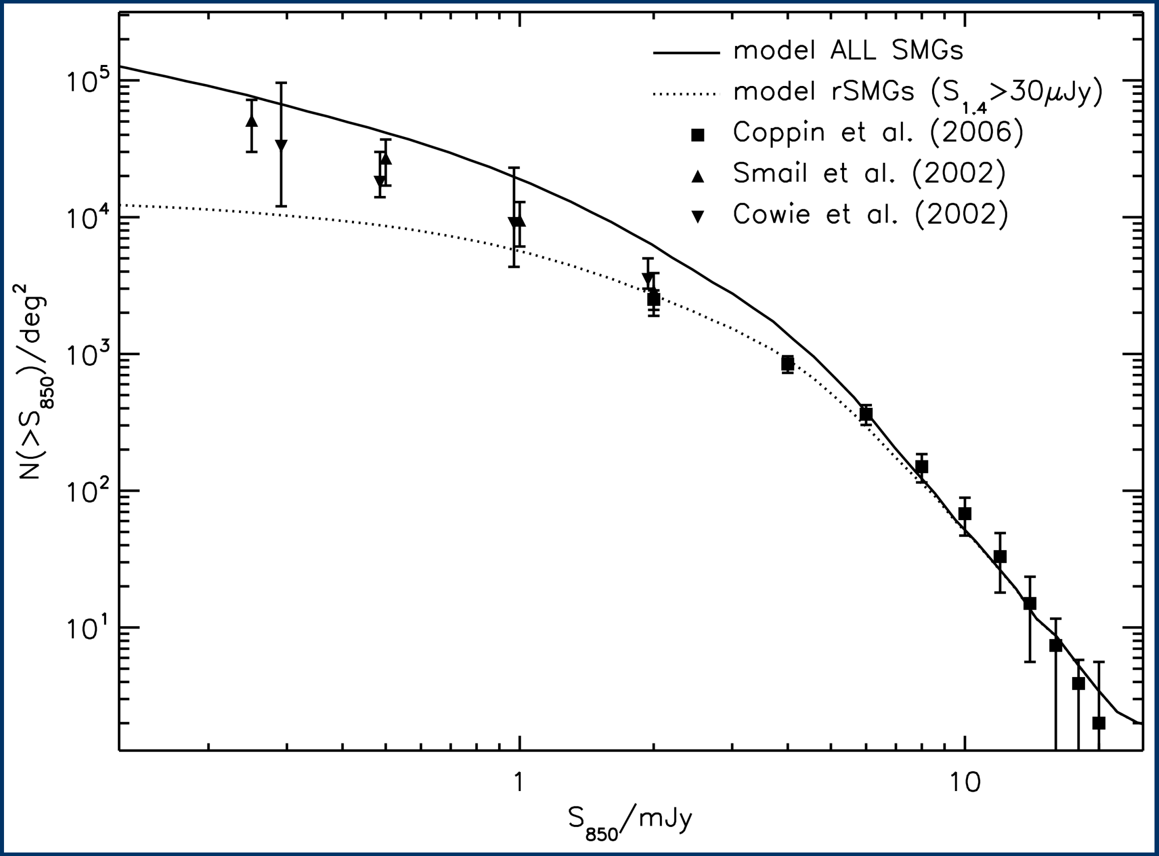
Not so much

Swinbank et al.: Hierarchical evolution simulation with physics mixed in

Ideal to test the large scale number counts, not so great for detailed merger physics



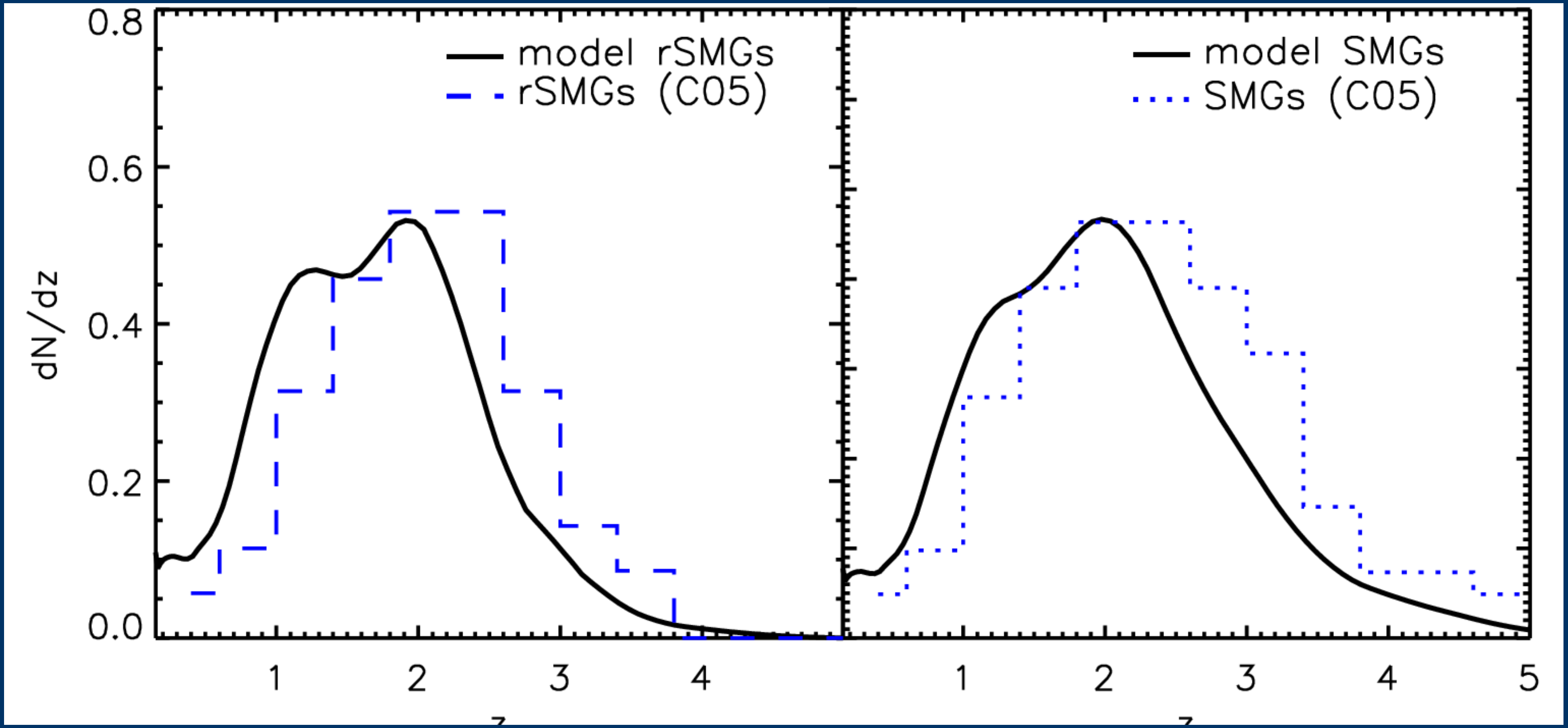
As a hierarchical simulation, number counts are the most powerful pre postdiction



Swinbank et al.

Postdiction of Redshift distribution of submm selected galaxies

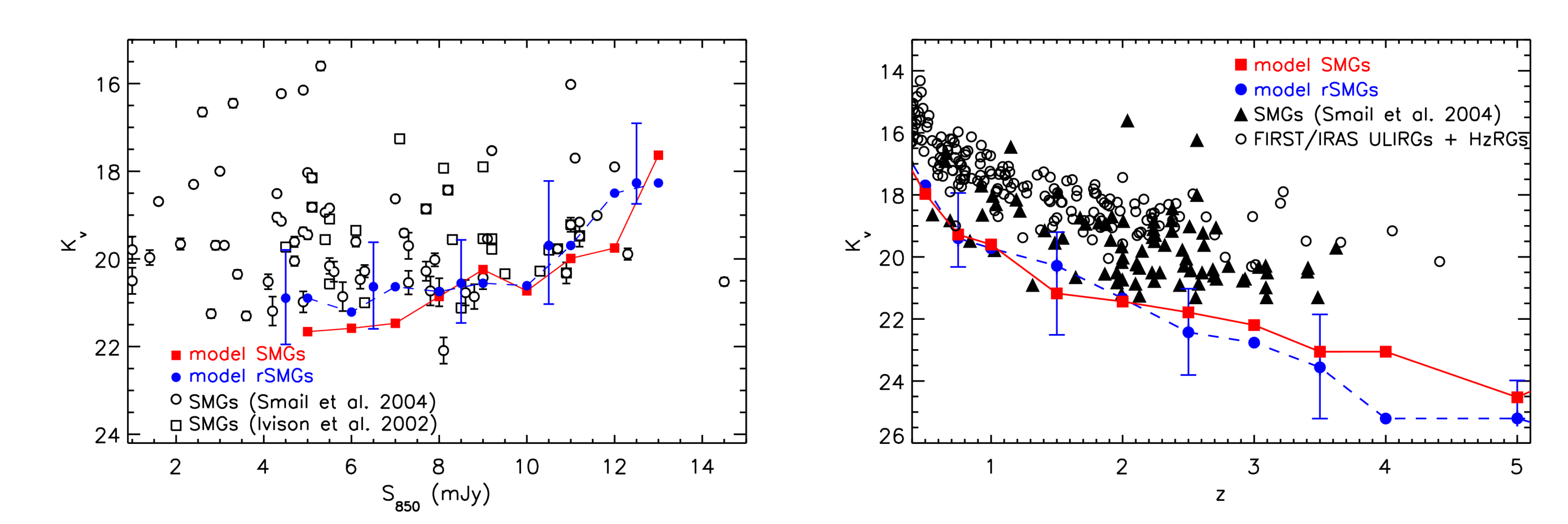
Swinbank et al.



There seems to be a systematic offset, but they claim that it is cosmic variance of the observations.

Cosmic variance, maybe, but not likely when there are other confirmed systematic errors unexplained

K-Band luminosity of hierarchical model is under-predicted.

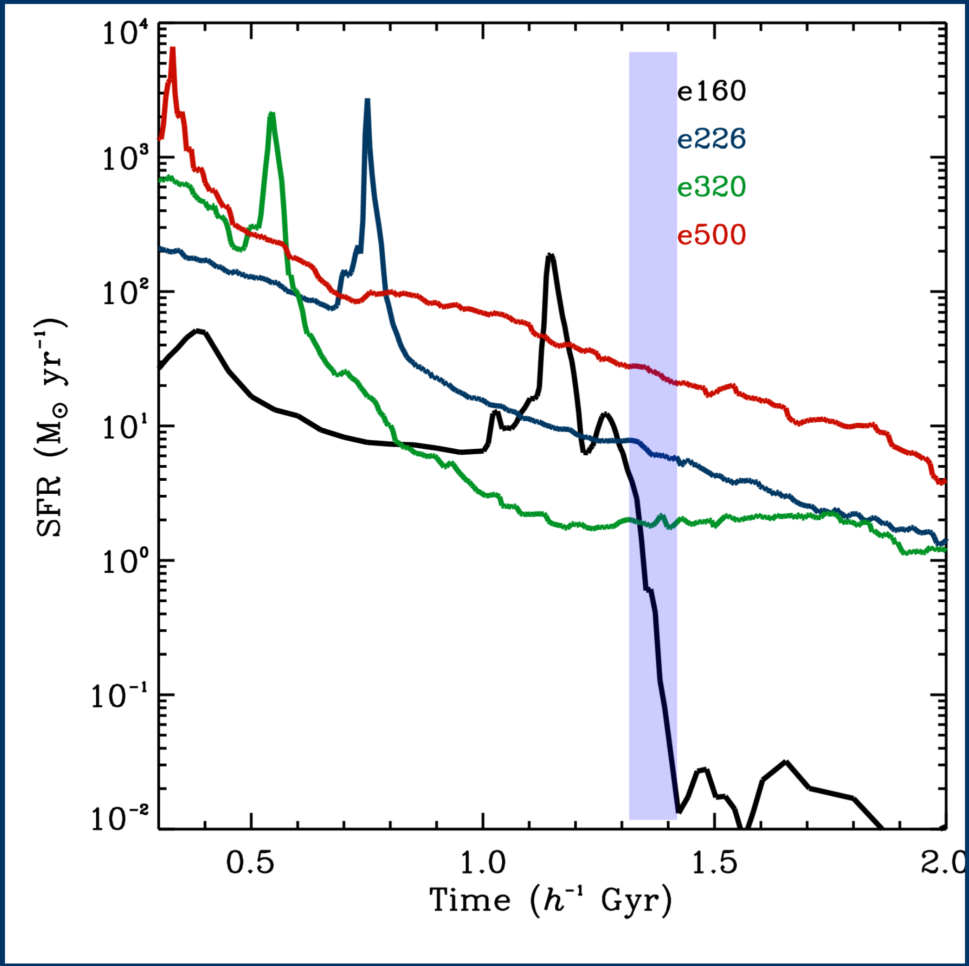


Swinbank et al.

Is there a systematically-wrong assumption being made? maybe.

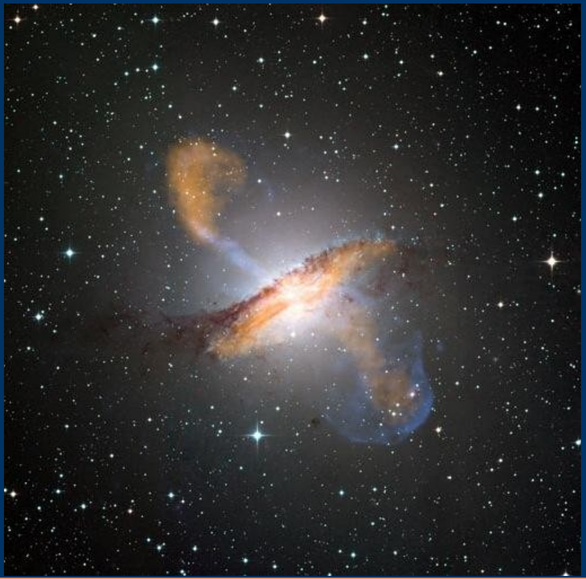
SFR timescale assumption by Swinbank et al. (that the SFR changes slowly over 100Myr) does not respect predictions by Chakrabarti et al.

Chakrabarti et al.



Do submm galaxy examples fit in with the simulations?

Schinnerer et al. 2008 and Coppin et al. 2008 have some data-rich examples. I find that the quoted measurement with the most uncertainty in the SFR with has to do with the initial mass function.



The Initial Mass Function (IMF)

The “Salpeter” IMF is measured in local clusters. It is a power law with exponent ~-1.3.

There is evidence that the form of the IMF changes in other environments.

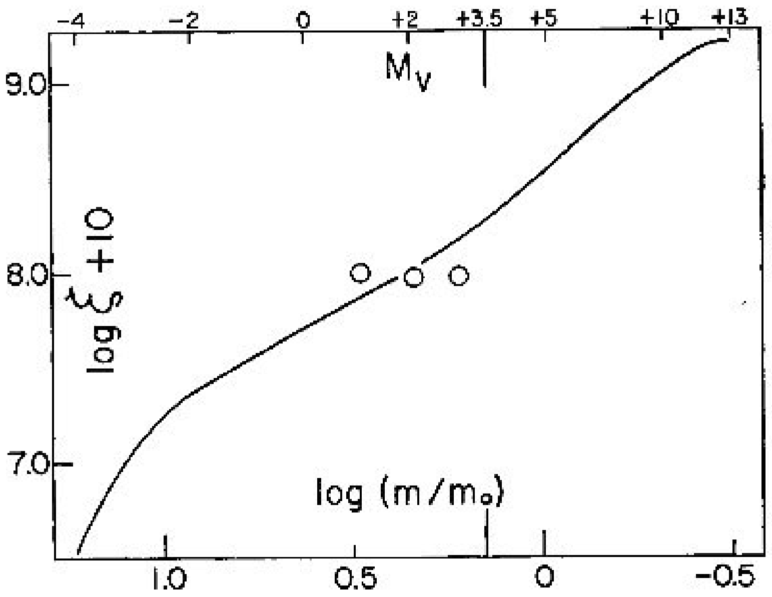
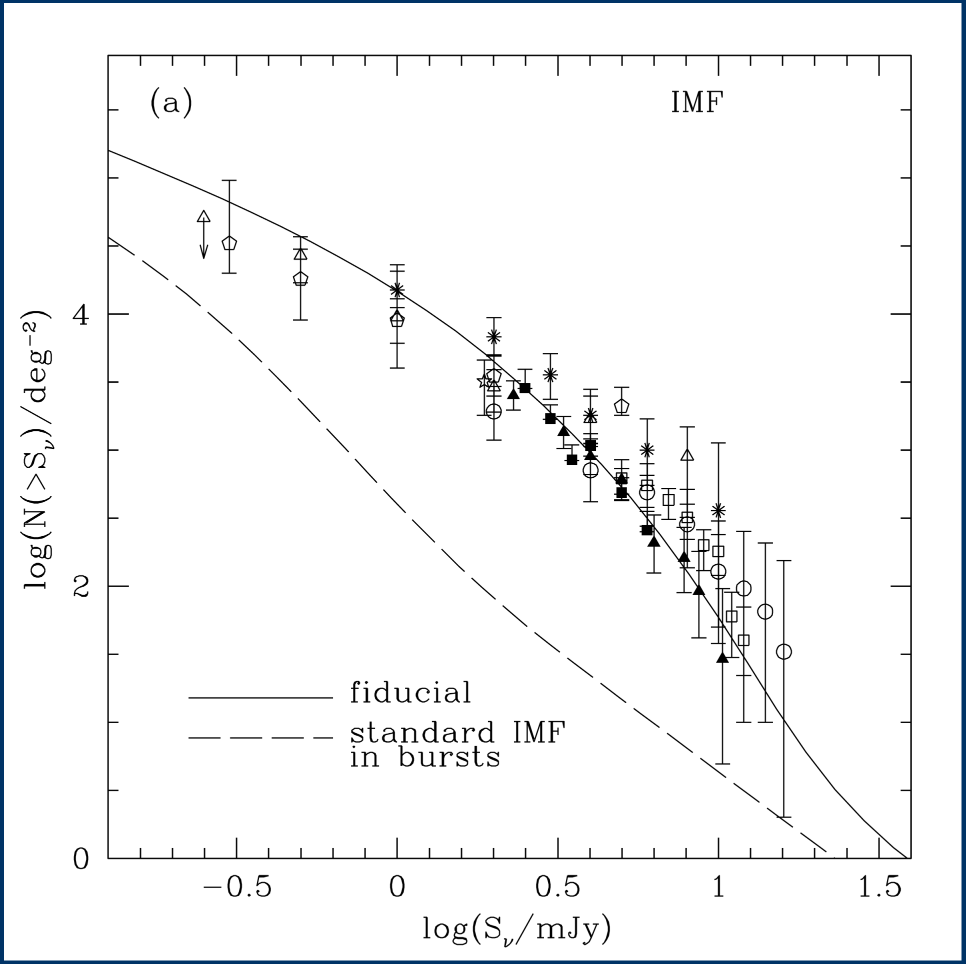


FIG. 2.—The logarithm of the “original mass function,” ξ, plotted against the mass, 𝔐, in solar units.

Salpeter 1955

The IMF makes a big difference for starbursts



With a top-heavy IMF, you can fit the counts of local infrared galaxies AND distant submm galaxies (Baugh et al. 2005).

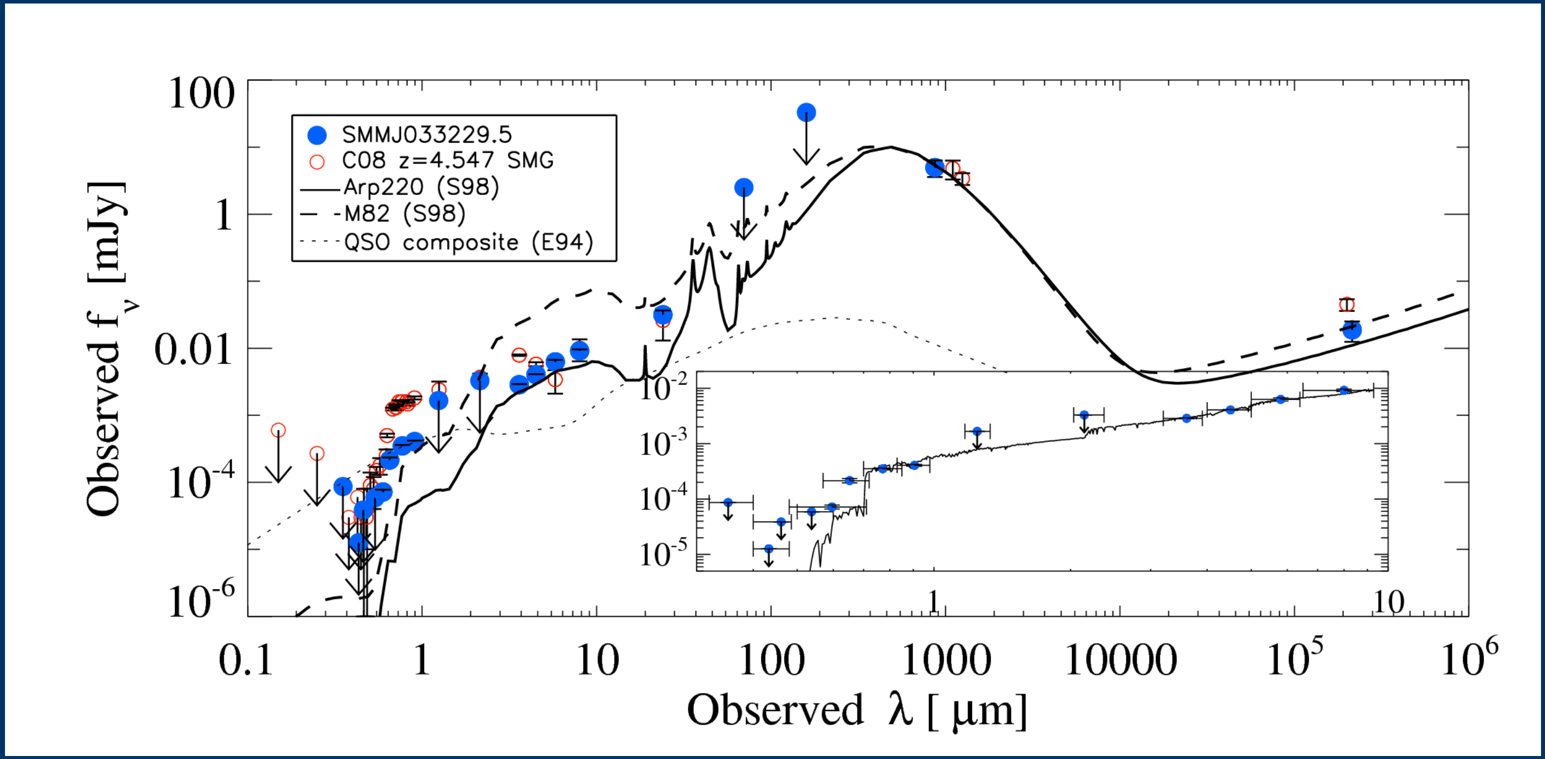
From Coppin et al:

Galaxy J033229 at z = 4.7

IR Luminosity = $1x10^{12}$ $L_\odot$

$3x10^{10}$ $M_\odot$ Gas Mass

SFR >1000 $M_\odot$/year



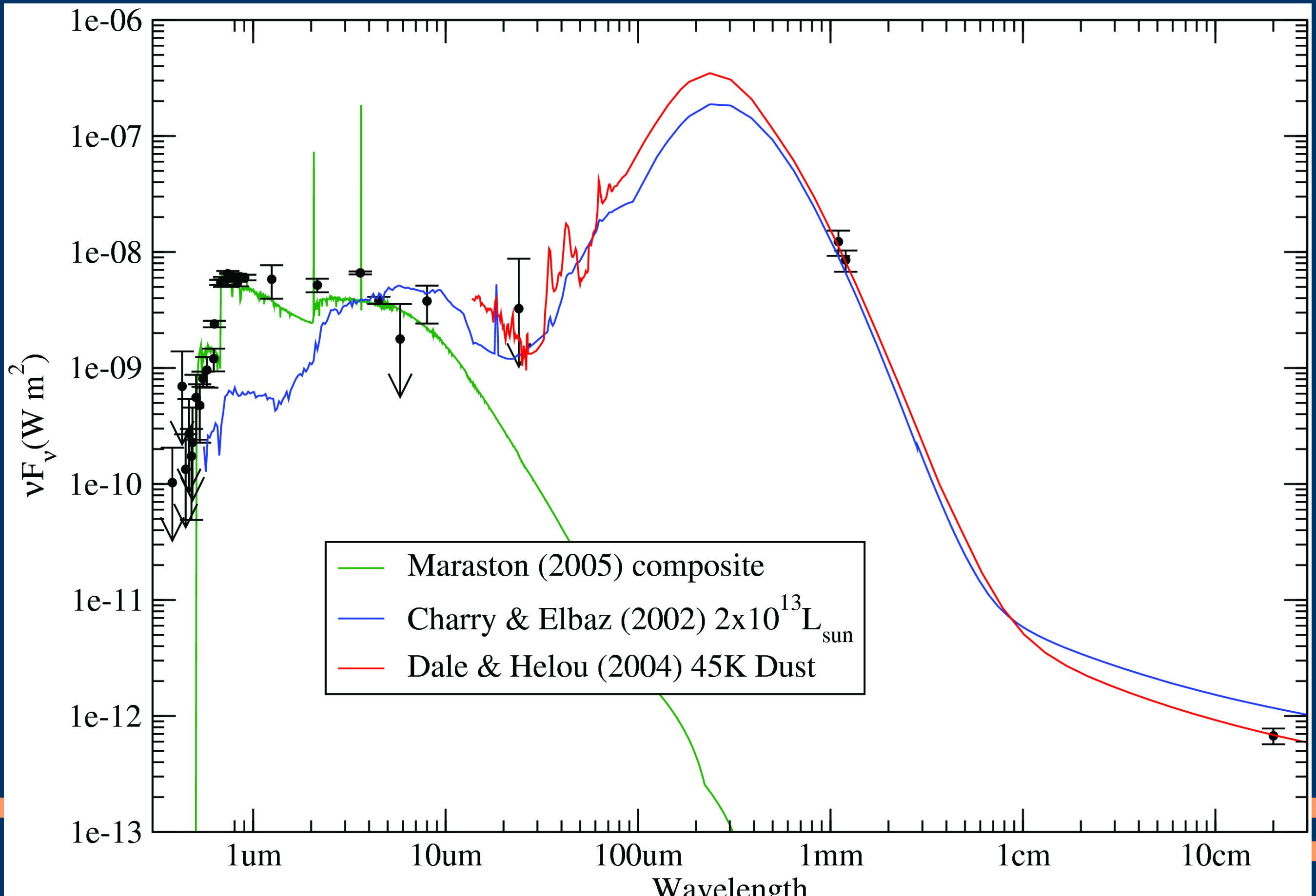
From Schinnerer et al:

Galaxy J100054+023436 at z=4.55

Luminosity= 1×10^{13} $L_\odot$

2×10^{10} Molecular gas mass

1.1×10^{11} Dynamical Mass, SFR >1000 $M_\odot$/year



Salpeter IMF is usually used to calculate the quoted SFRs in distant galaxies

Z=4.5 Submillimeter Galaxy, Schinnerer et al. 2008

we derive a SFR of $\sim$ 1000 $M_\odot\,yr^{-1}$ for LESS J033229.4, following Kennicutt (1998) who assumes a burst lifetime of $\sim$ 100 Myr and a Salpeter (1955) initial mass function (IMF). Next, we estimate a dust mass of $M_d \sim 5 \times 10^8\,M_\odot$

Z=4.7 Submillimeter Galaxy, Coppin et al. 2008

high redshifts.

We assume a $H_o = 70$, $\Omega_v = 0.7$, $\Omega_m = 0.3$ cosmology and a star formation rate integrated across a Salpeter (1955) IMF from 0.1-100$M_\odot$ throughout this paper.

2. DATA

Calculations of Star Formation Rate (SFR) are dependent of the IMF.

Flat IMF:

$$SFR_{0.15-125M_\odot} = 1.01 \times 10^{-44} L_{bol}(erg\, s^{-1})$$

Salpeter IMF:

$$SFR_{0.1-100M_\odot} = 4.5 \times 10^{-44} L_{bol}(erg\, s^{-1})$$

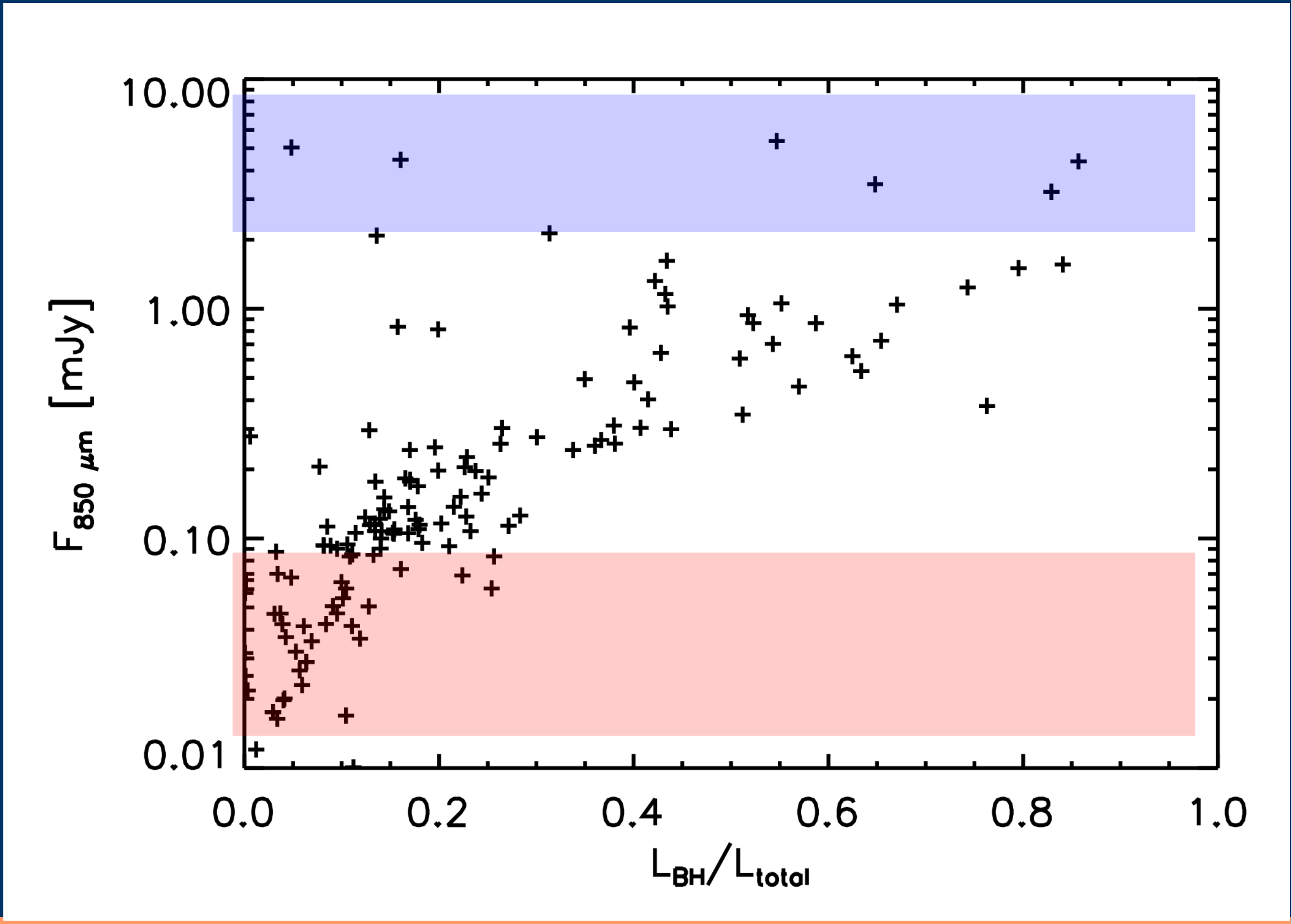
So, the observations consistently quote 4 times more star formation than the simulations by using the Salpeter IMF, the IMF which the simulations ruled out.

Typical model SMG: $L_{8-1000\mu m} = 2.0 \pm 1.5 \times 10^{12} L_\odot$ From Swinbank et al. 2008

The difference is 77 verses 300 solar masses per year.

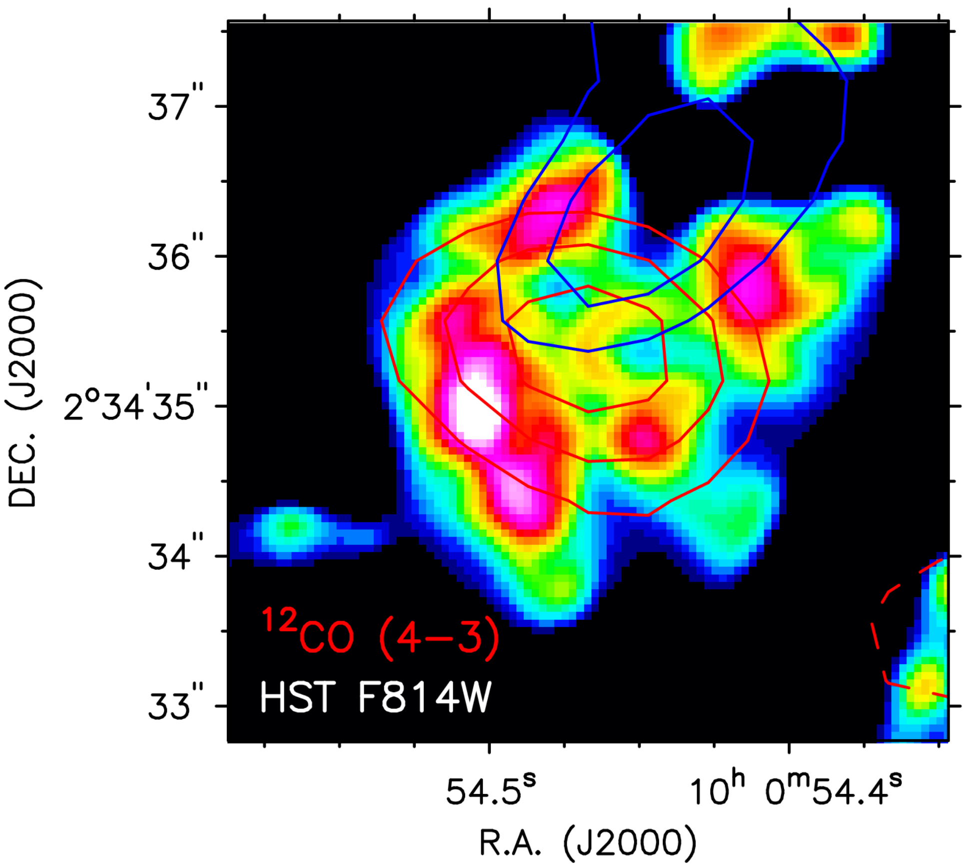
AGN are usually assumed to contribute a little because >80% of SMGs have no X-rays detections. However, this simulation Chakrabarti et al. show that the AGN can still be a key player in the bolometric power (heating).

Current detection limit for blank field surveys shown in blue.



Finally, technological limitations of the submm wave-band limit

Schinnerer et al.'s dynamical mass calculation and major merger argument is dependent on the distance between the 2σ and 3σ centroids.



So, there is a significant amount of play in the quoted values.

To wrap this up:

Based on the simulation's “predictions” vs the observation's “facts”, it looks like on the whole the submm galaxy population can be explained inside a hierarchical galaxy formation model.

Personally, I think it is not surprising that “everything” doesn't work out (like k-band luminosity, IMF, redshift distribution, ect..) because the models simulate either one or the other of large or small scale physics.