

Disentangling the high redshift Universe

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Collaborators.....

GALFORM: semi-analytic code

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GRASIL: spectrophotometric code

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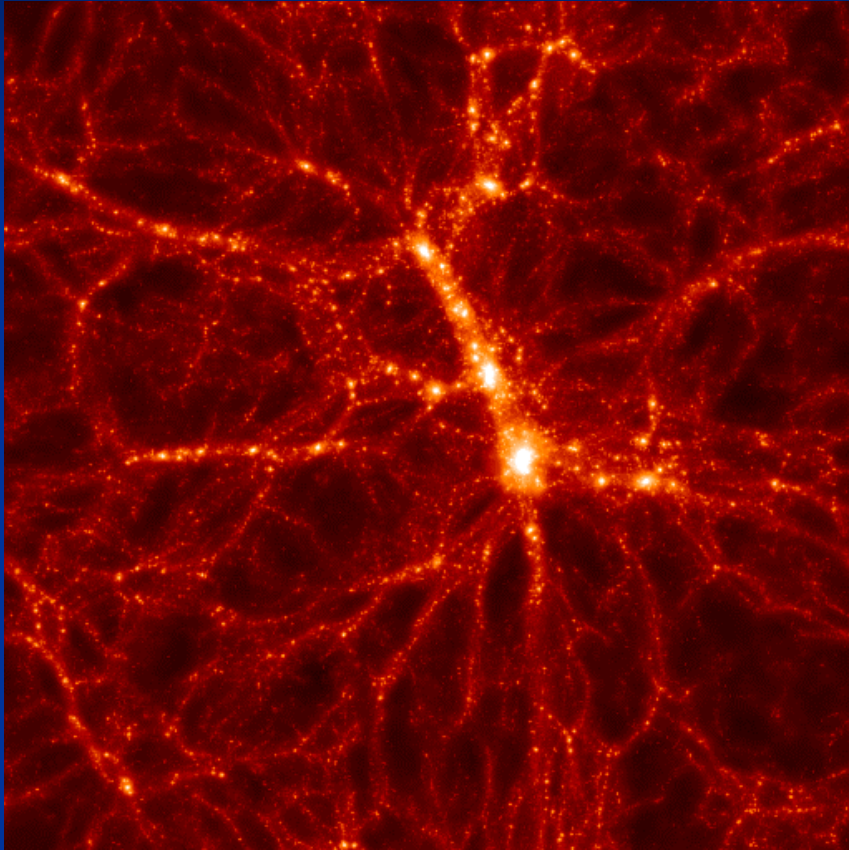
Gian-Luigi Granato

Laura Silva (Trieste)

Outline

- What is a semi-analytic galaxy formation model?
- A new model for the high-redshift Universe.

Where should the galaxies be?

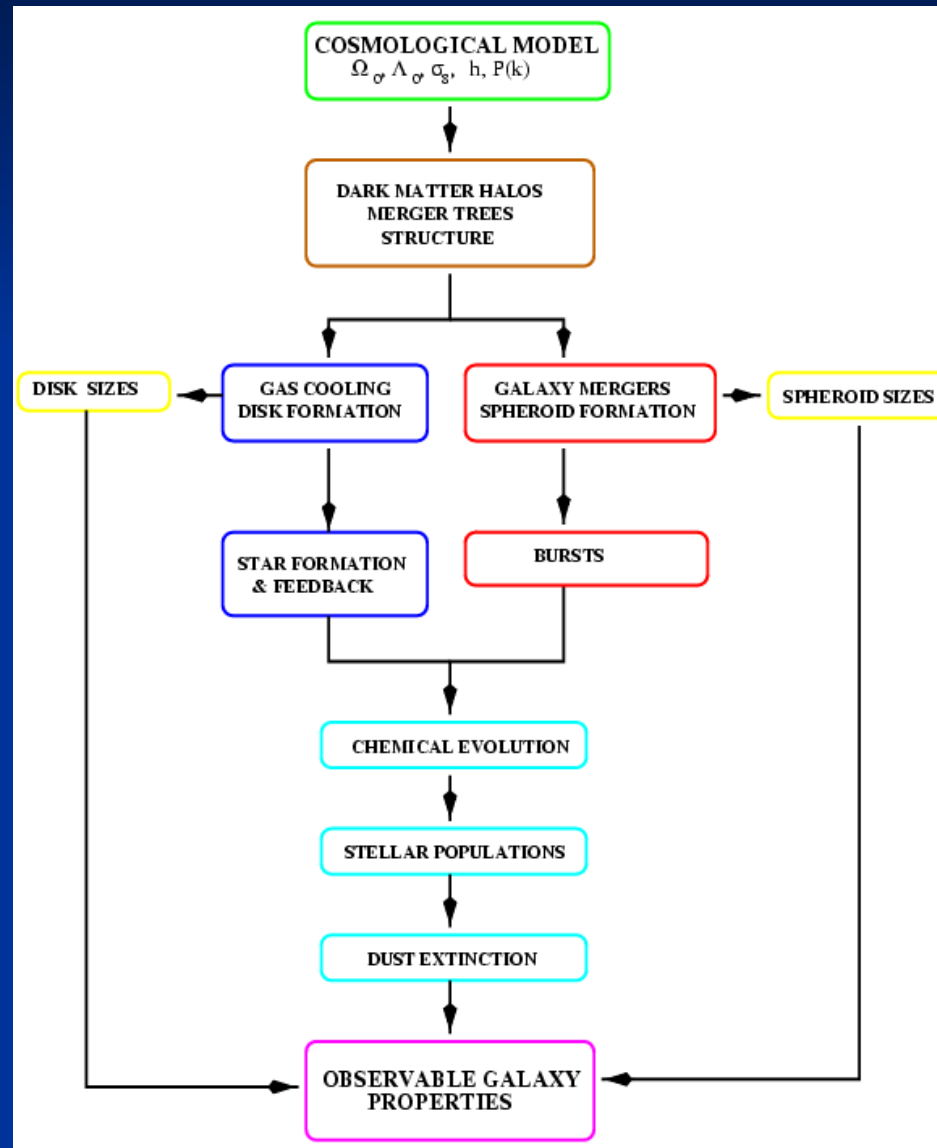


LCDM cosmological box (Virgo Cons.)



LCDM galactic halo Power et al 2003

The physics of galaxy formation



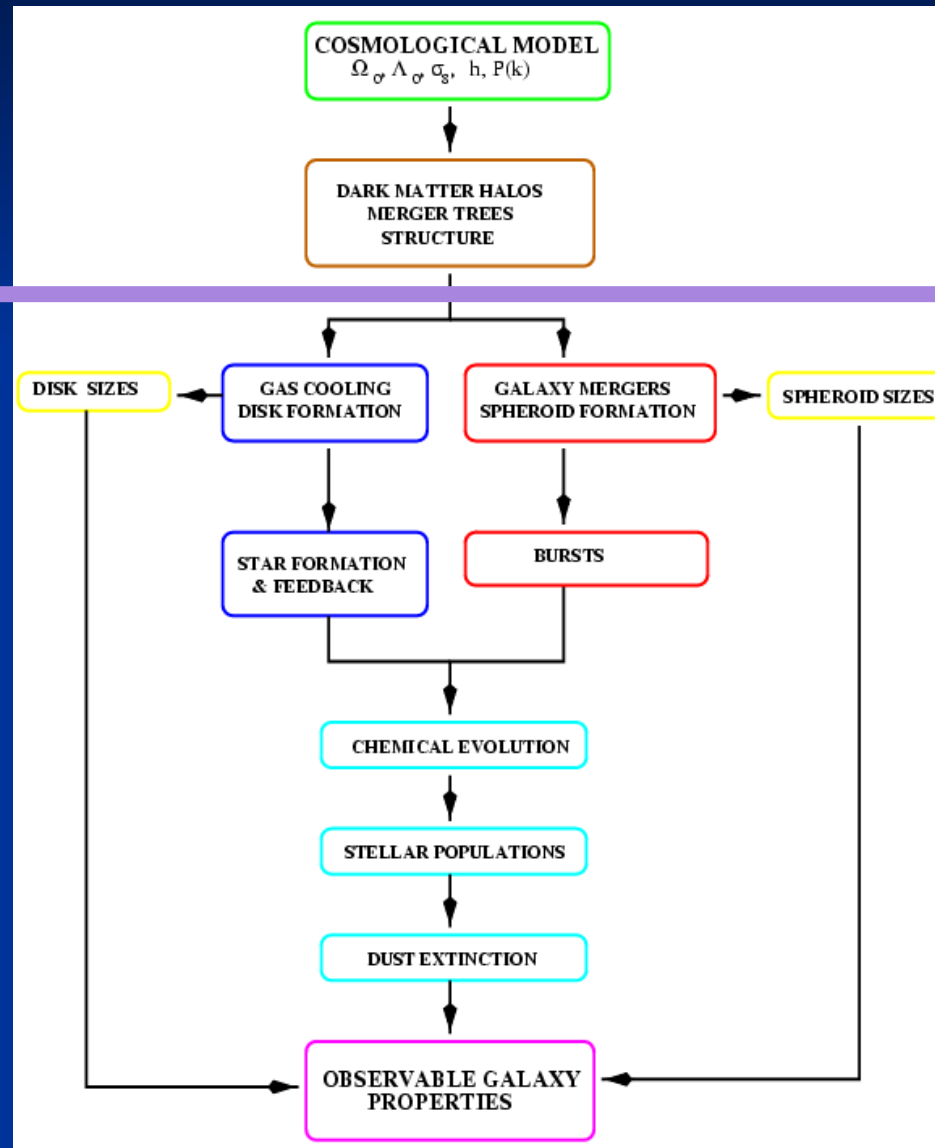
The physics of galaxy formation

easy

Dissipationless
Physics well
understood

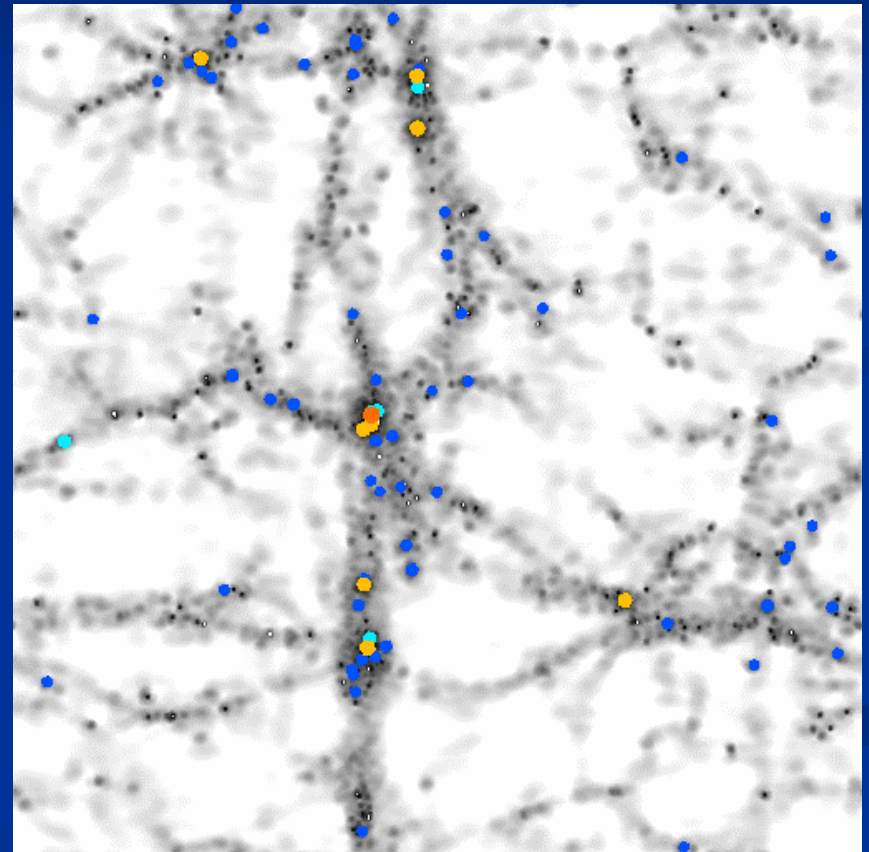
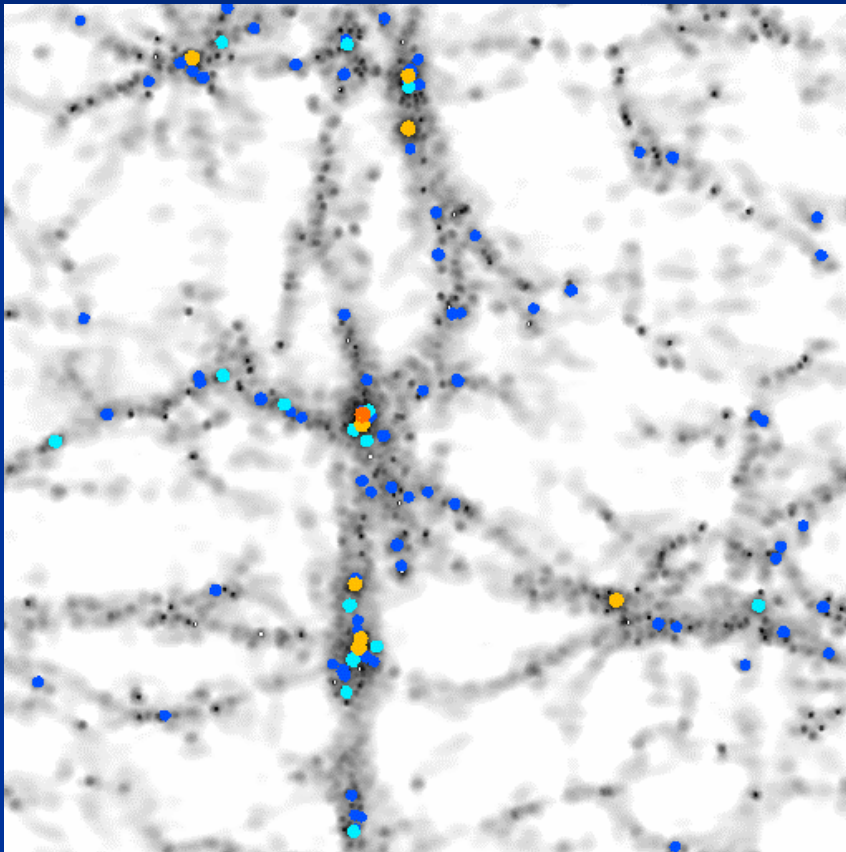
hard

Dissipative.
Physics poorly
understood.



Semi-analytics vs SPH

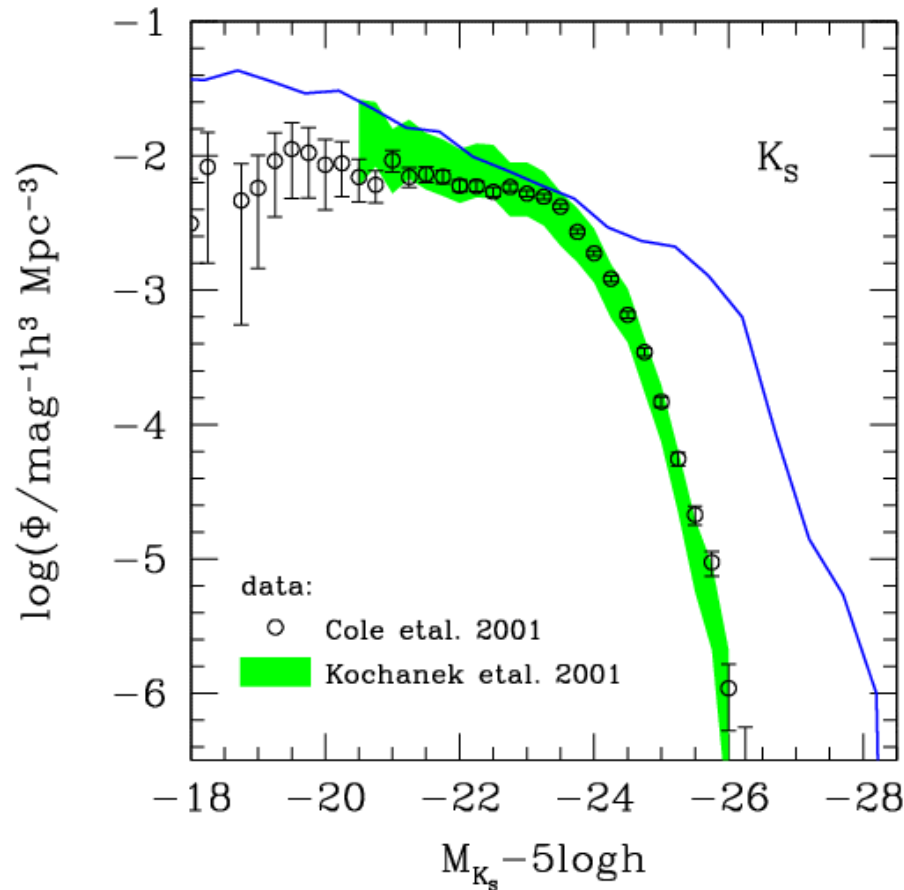
Comparison of cold gas masses
Gas cooling modelled in very different ways



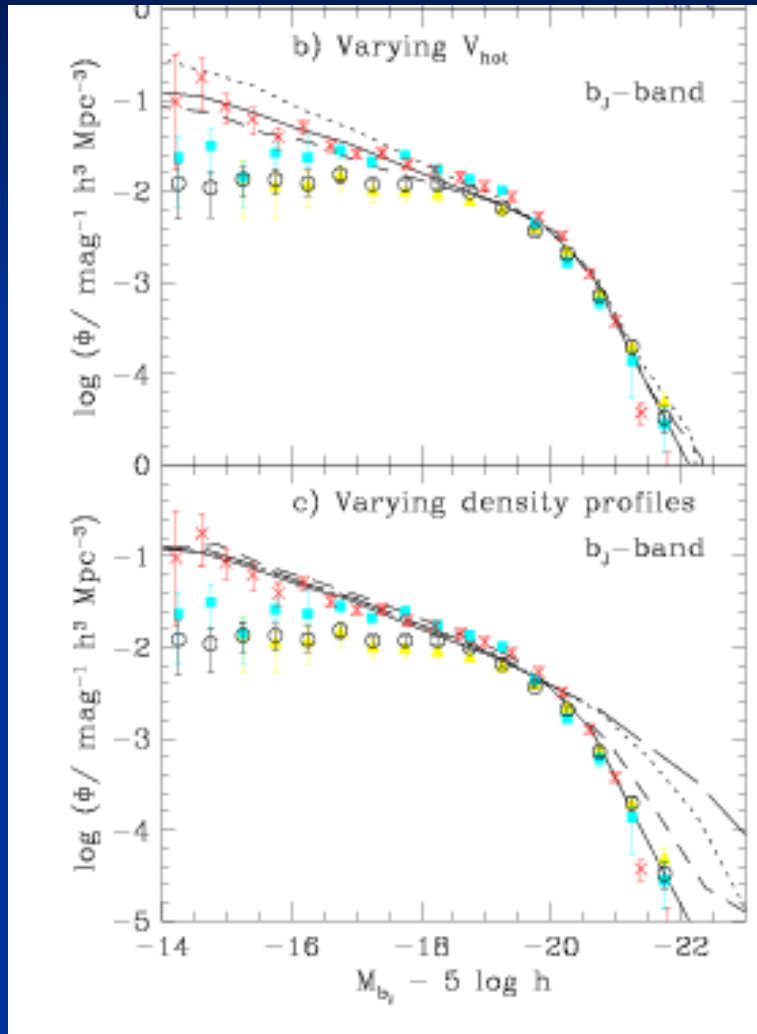
Helly et al. 2002
Yoshida et al. 2002

Semi-analytic models are fast

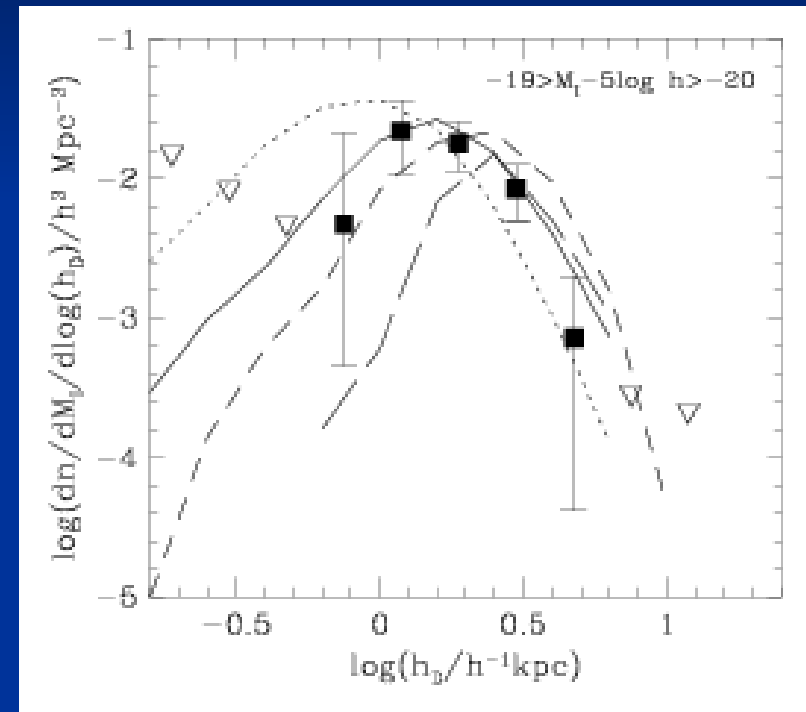
Rapid exploration of parameter space
e.g. strength of superwind



The models are not a black box!



b_J field luminosity function

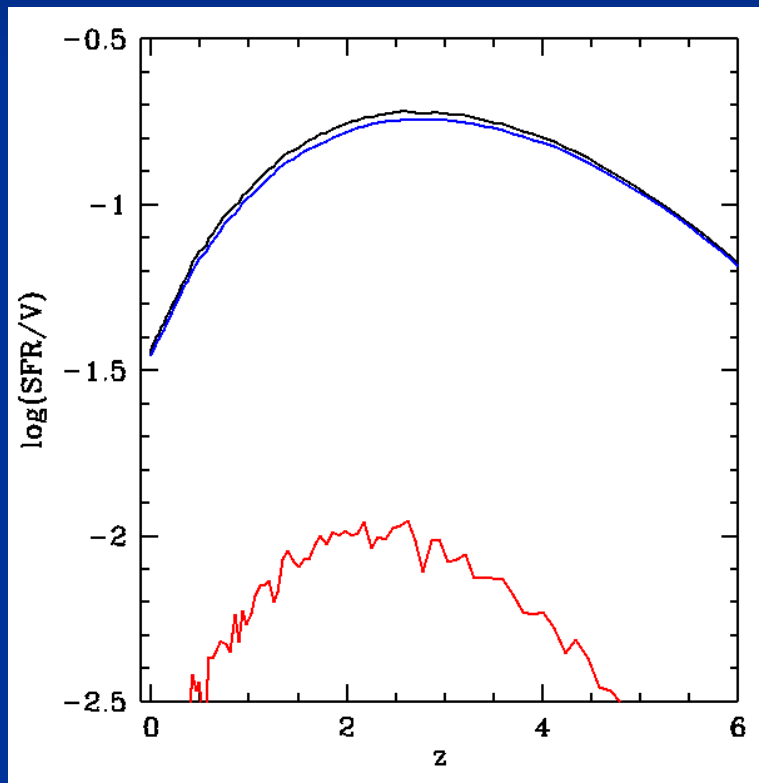


Disk scale length distribution

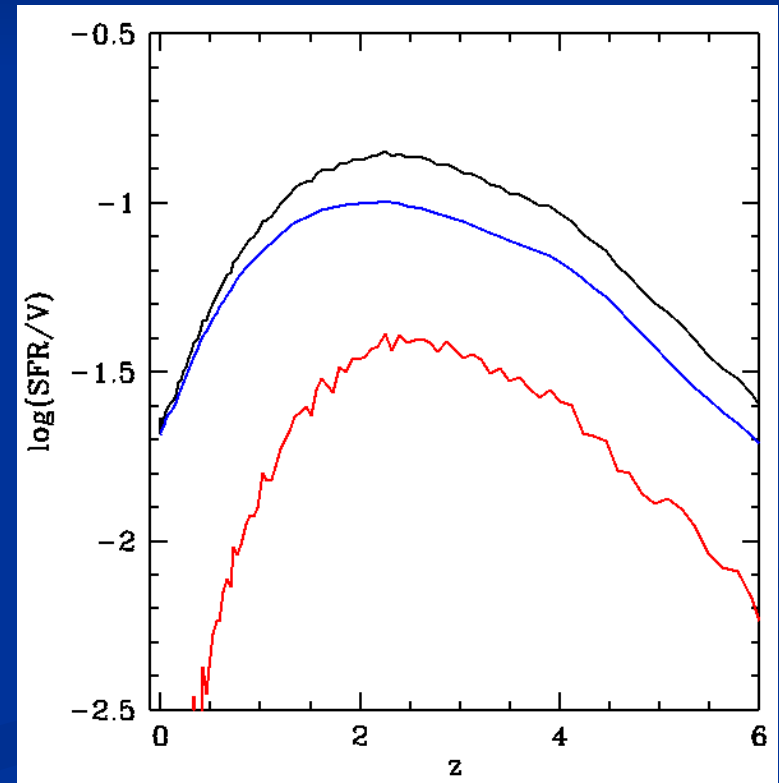
Semi-analytic models are flexible

Modular code: different prescriptions can be tried
e.g. How should the star formation timescale vary with redshift?

RED: bursts BLUE: quiescent BLACK: total



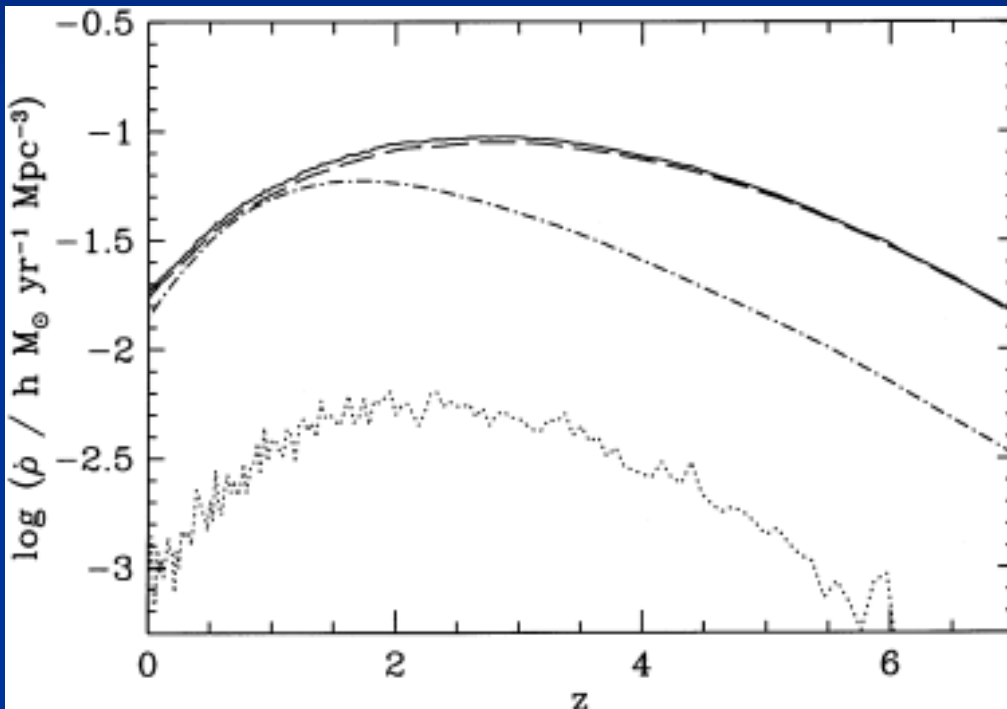
Star formation timescale \sim dynamical time



Star formation timescale \sim constant

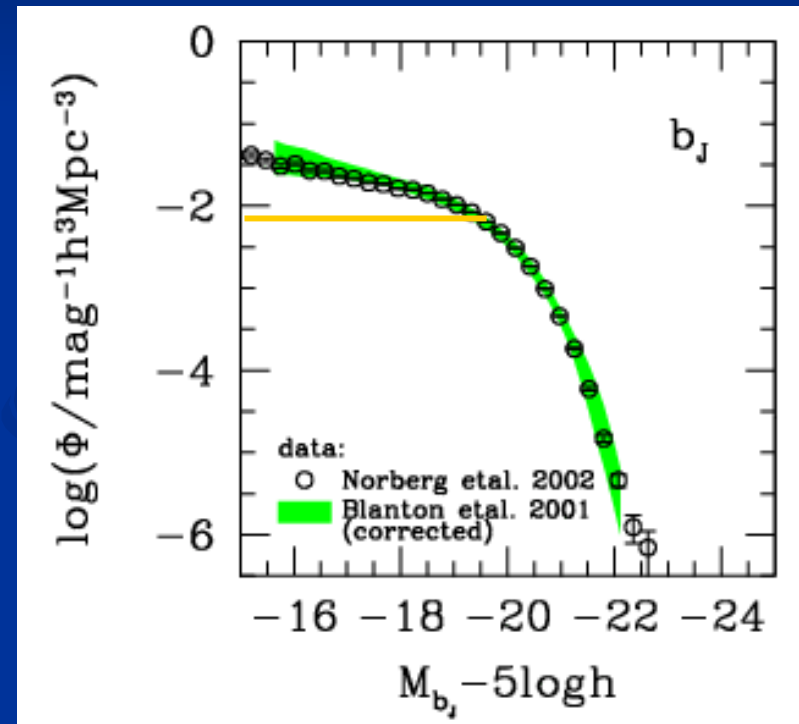
Does it tell us anything at all?

What are the generic predictions?



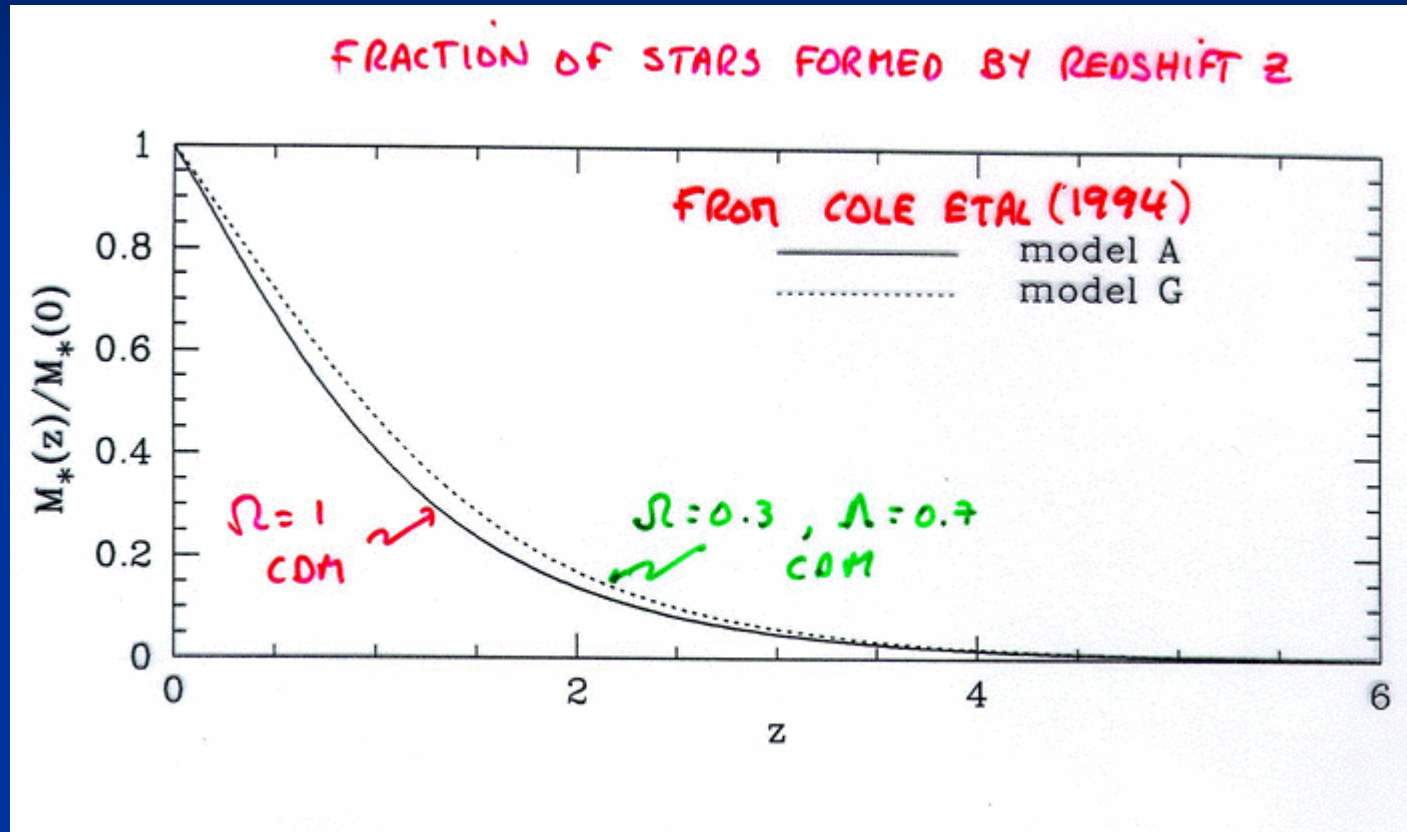
Global star formation history

Cole et al. (1994)



Luminosity function data

The build-up of stellar mass in hierarchical models



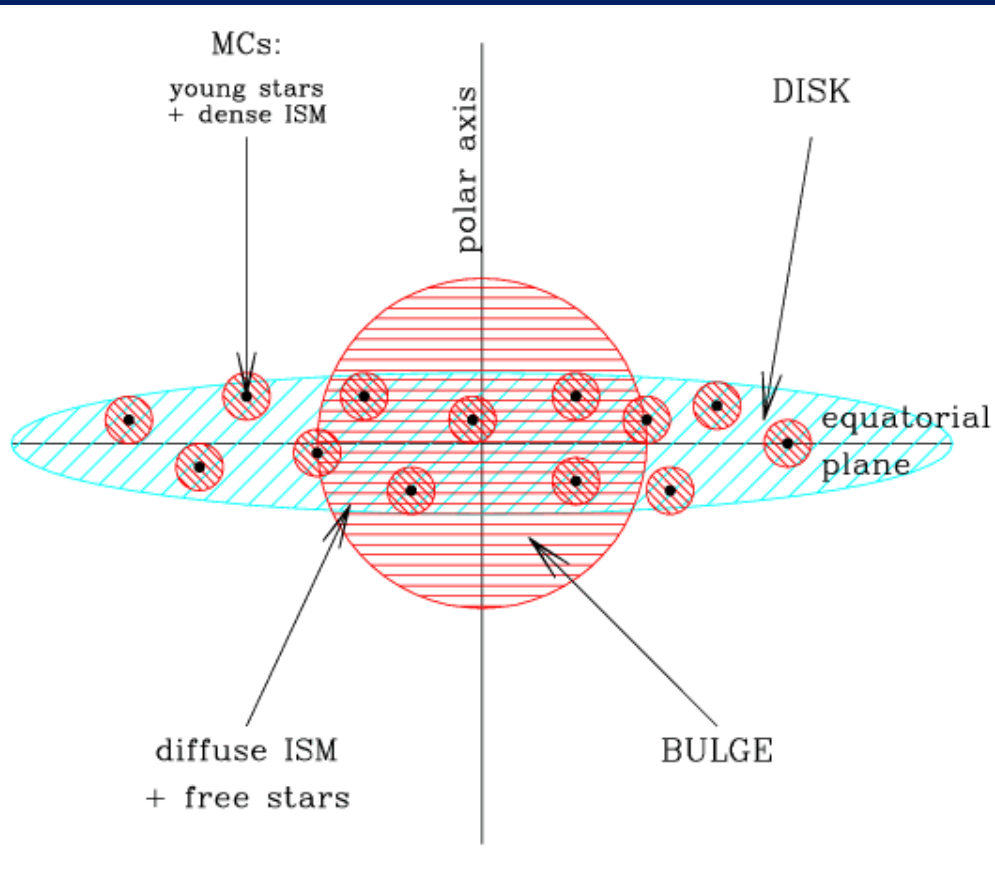
Franx: 10-15% of stellar mass at $z=3$; 50% form $z < 1.5$ Abraham: ?

A new model for the high redshift universe

Combine *GALFORM* semi-analytic code with *GRASIL* spectro-photometric code.

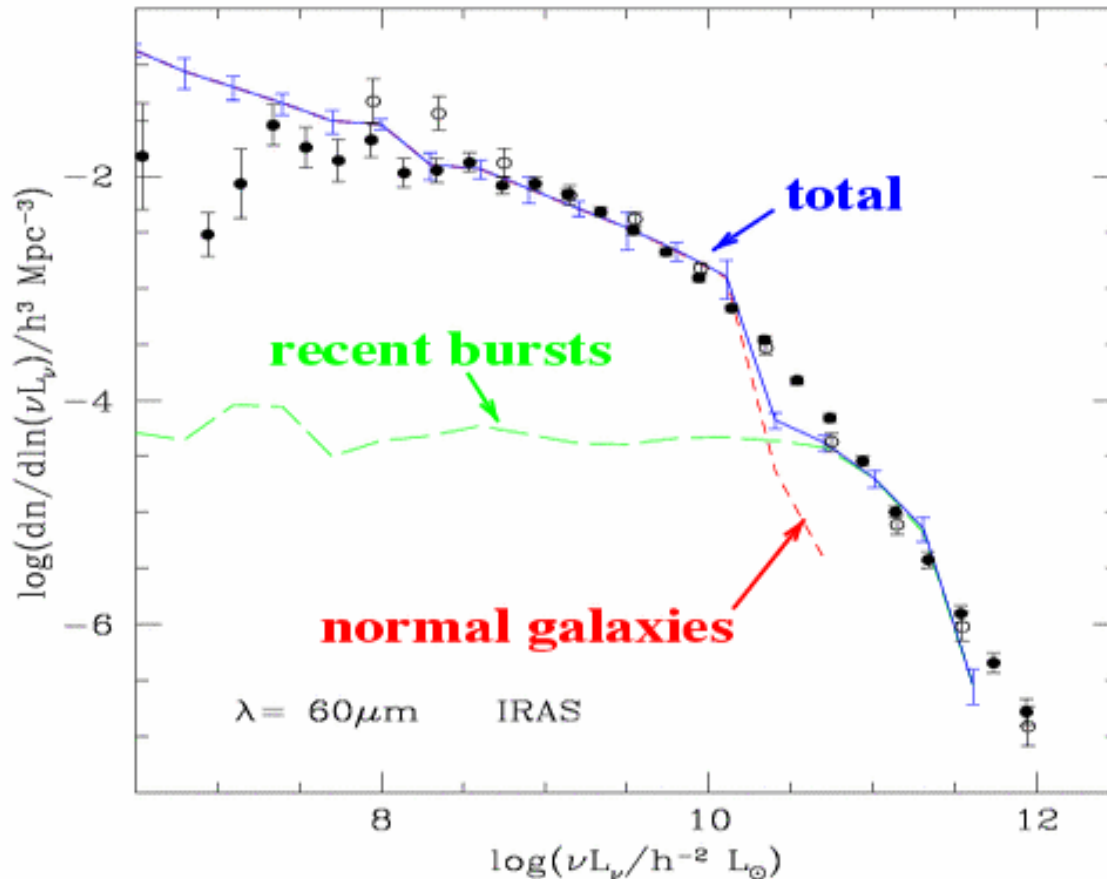
This is important for a self-consistent calculation of the dust *ABSORPTION* at short wavelengths and for the *EMISSION* of this energy by the dust at long wavelengths.

GRASIL: spectro-photometric code



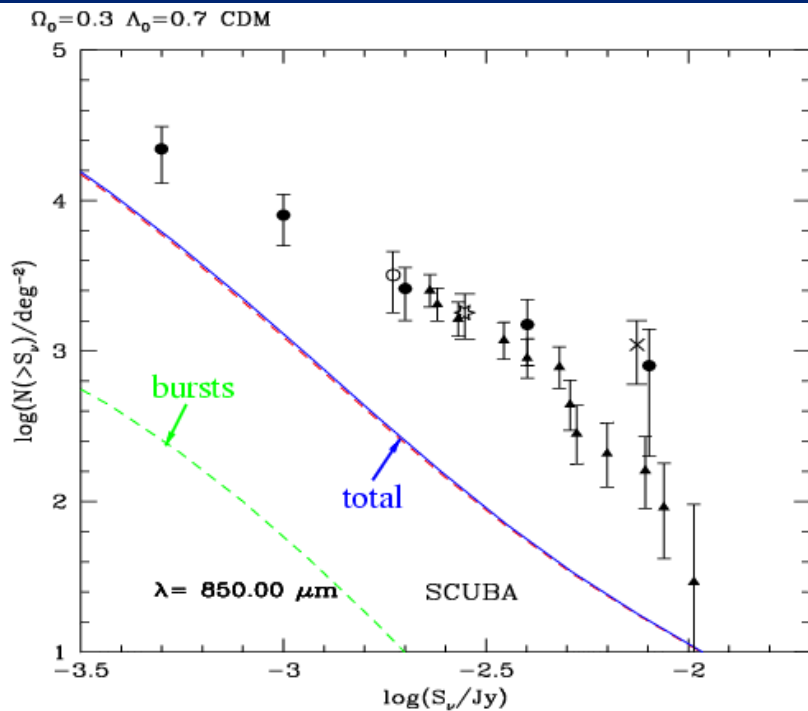
- Dust in 2 components: diffuse and clouds
- Radiative transfer to compute dust temperature at every point
- Optical depth: depends on chemical evolution model and calculation of galaxy scale-lengths

GALFORM + GRASIL



obs data: Saunders et al. (1990), Soifer & Neugebauer (1991)

The high- z Universe with Cole et al. 2000



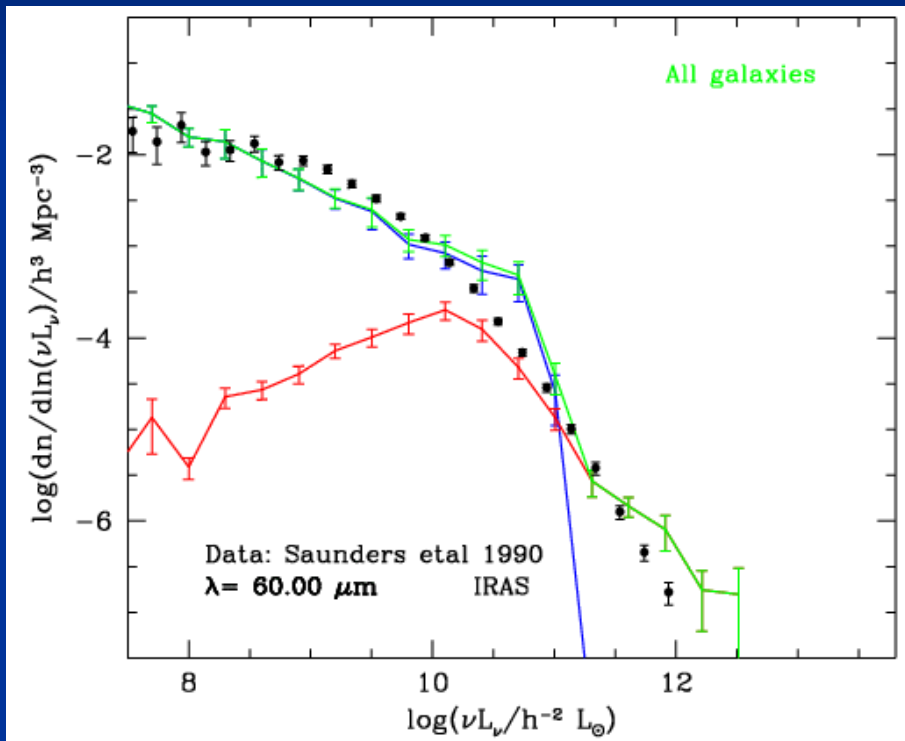
Observational data: Blain et al 1998, Hughes et al 1998,
Holland et al 1998, Eales et al 1998, Barger et al 1999

- model predicts **correct** total background at $850\mu\text{m}$
- also predicts background dominated by sources at $z \approx 1 - 3$ – **consistent with observations**
- but predicted source counts too low c.f. SCUBA obs
⇒ sources individually too faint

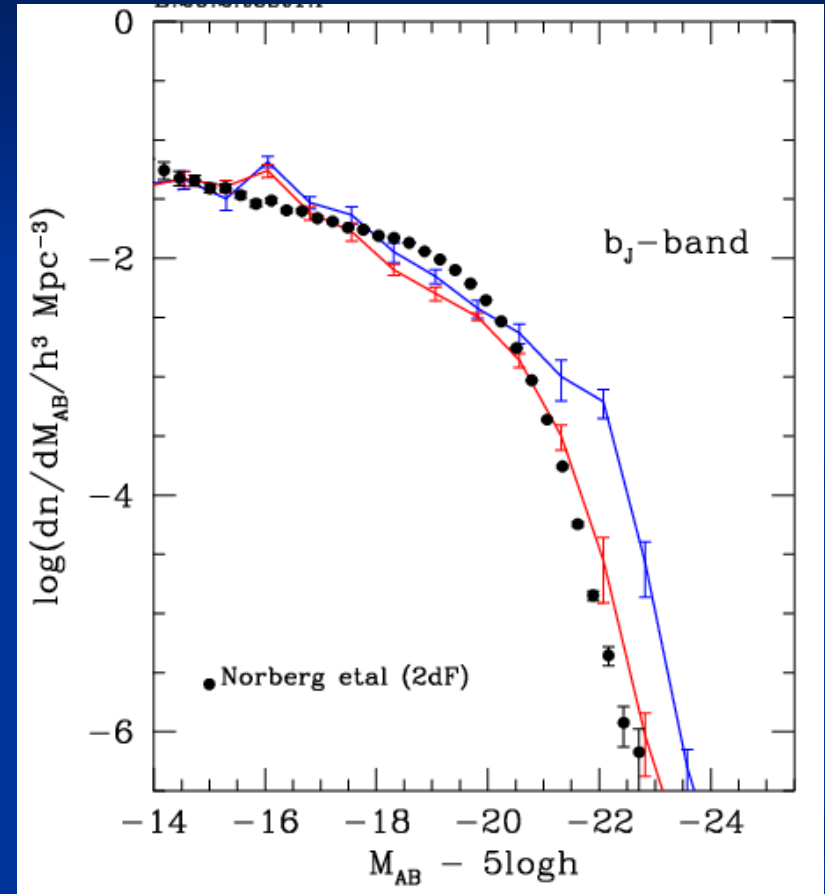
What is in the new model?

- Increased baryon fraction, in agreement with WMAP and current nucleosynthesis constraints.
- As a consequence, need to suppress star formation in big haloes as well as small haloes → Superwinds? Suppression of cooling by thermal conduction? See Benson et al. 2003.
- Star formation timescale is constant. High redshift mergers are between gas rich disks (e.g. QSO model of Kauffmann & Haehnelt 2000).
- Top-heavy IMF in bursts of star formation. Need to make bursts more luminous, without making dust too hot.

First: is $z=0$ still okay?

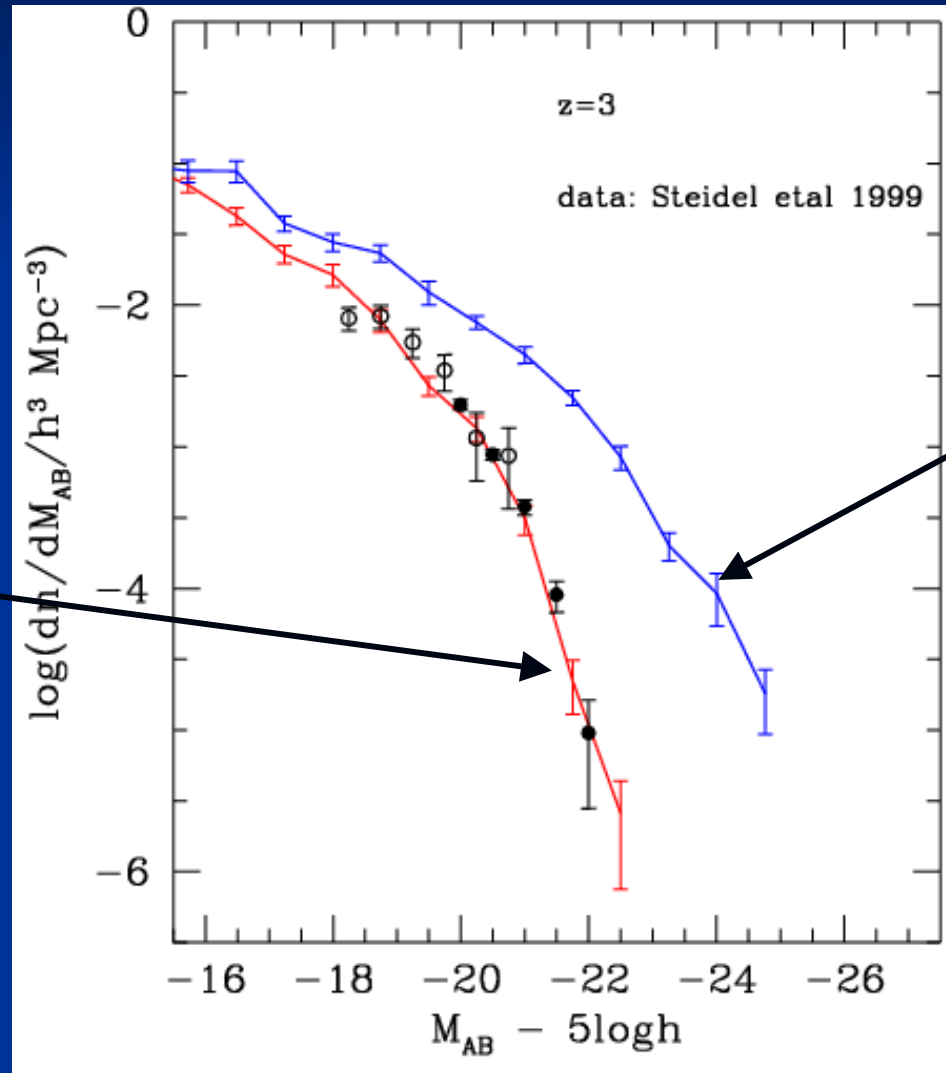


60 micron luminosity function



bJ field galaxy luminosity function

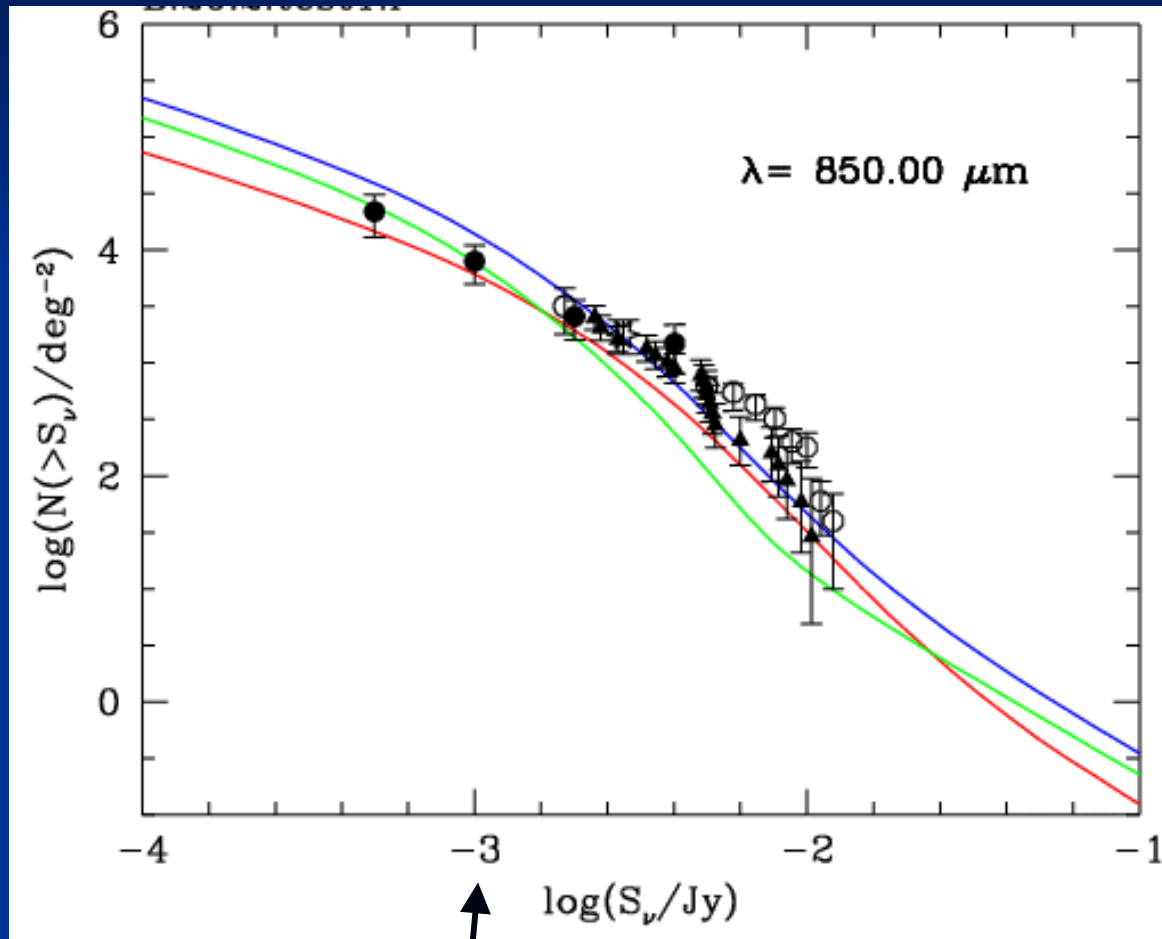
The luminosity function of Lyman break galaxies



With extinction

Without extinction

Cumulative 850 micron counts



Total: blue

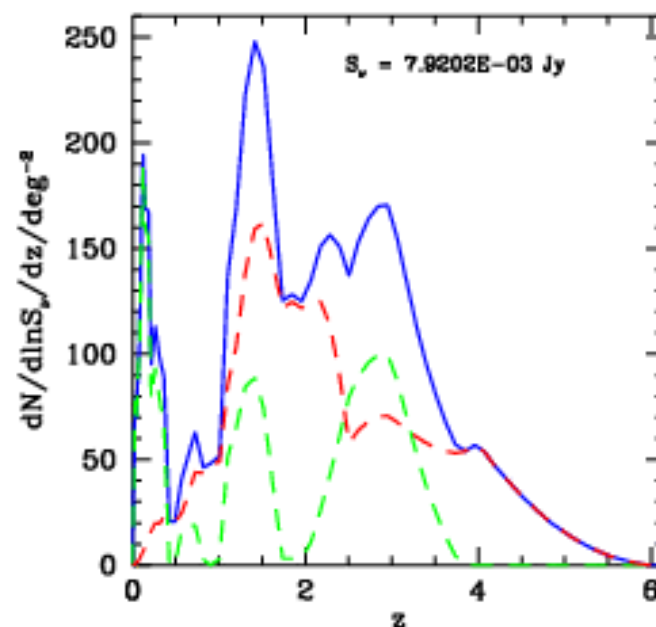
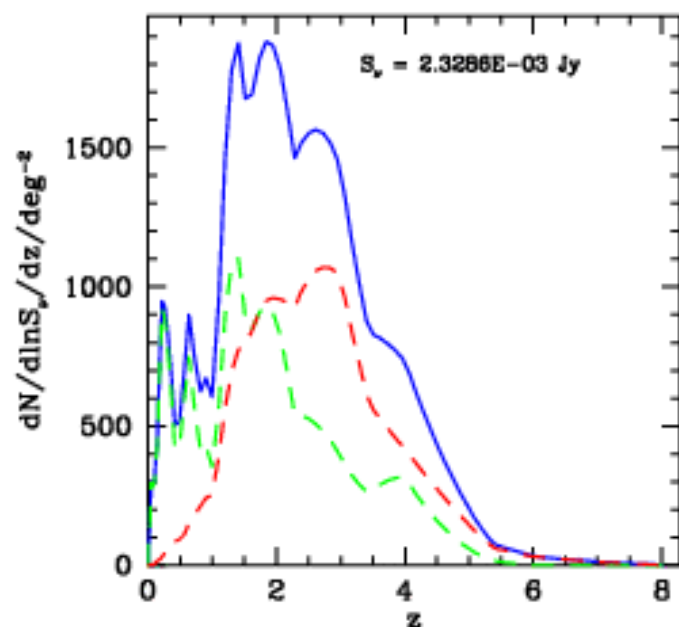
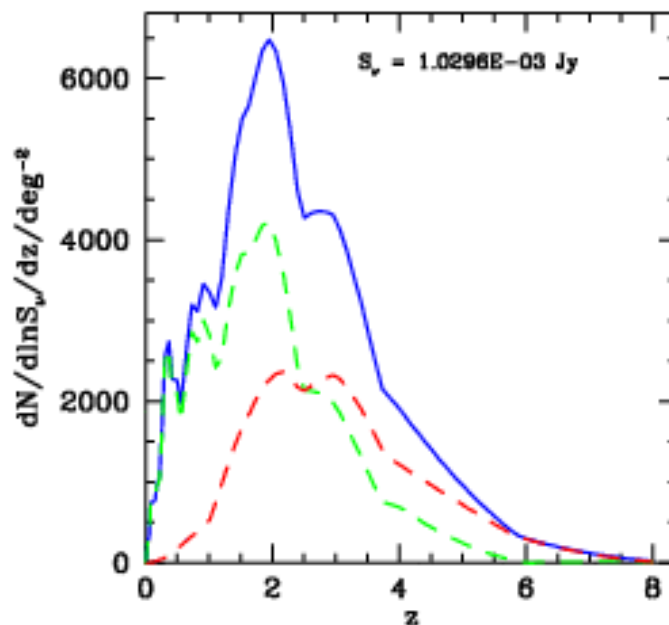
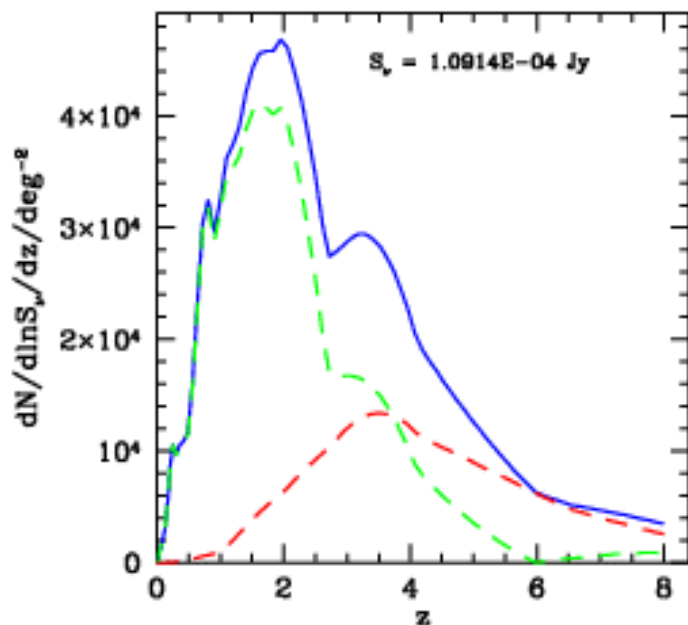
Recent bursts:
red

1mJy

Redshift Distributions

Total: blue

Recent bursts: red



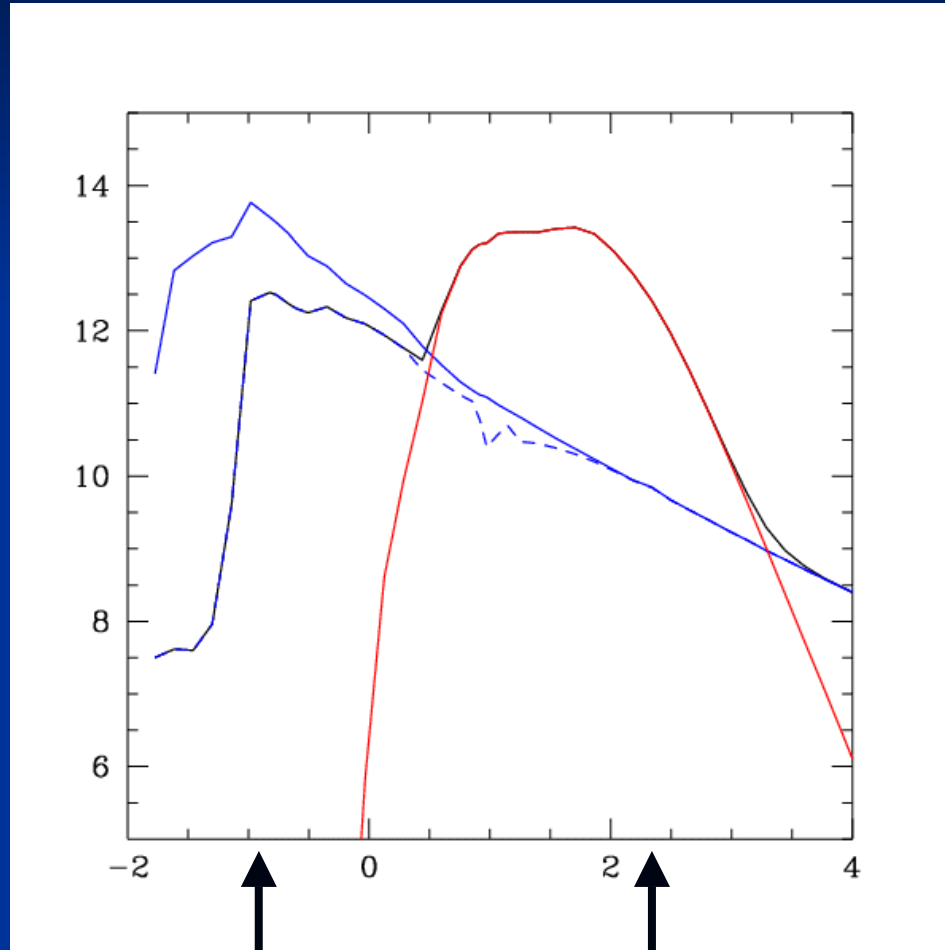
Panels show different fluxes:

- 0.1 mJy
- 1 mJy
- 2 mJy
- 8 mJy

The Lyman-break/SCUBA connection

Burst at $z=3$

Rest frame SED



Red: dust emission

Light blue: starlight without extinction

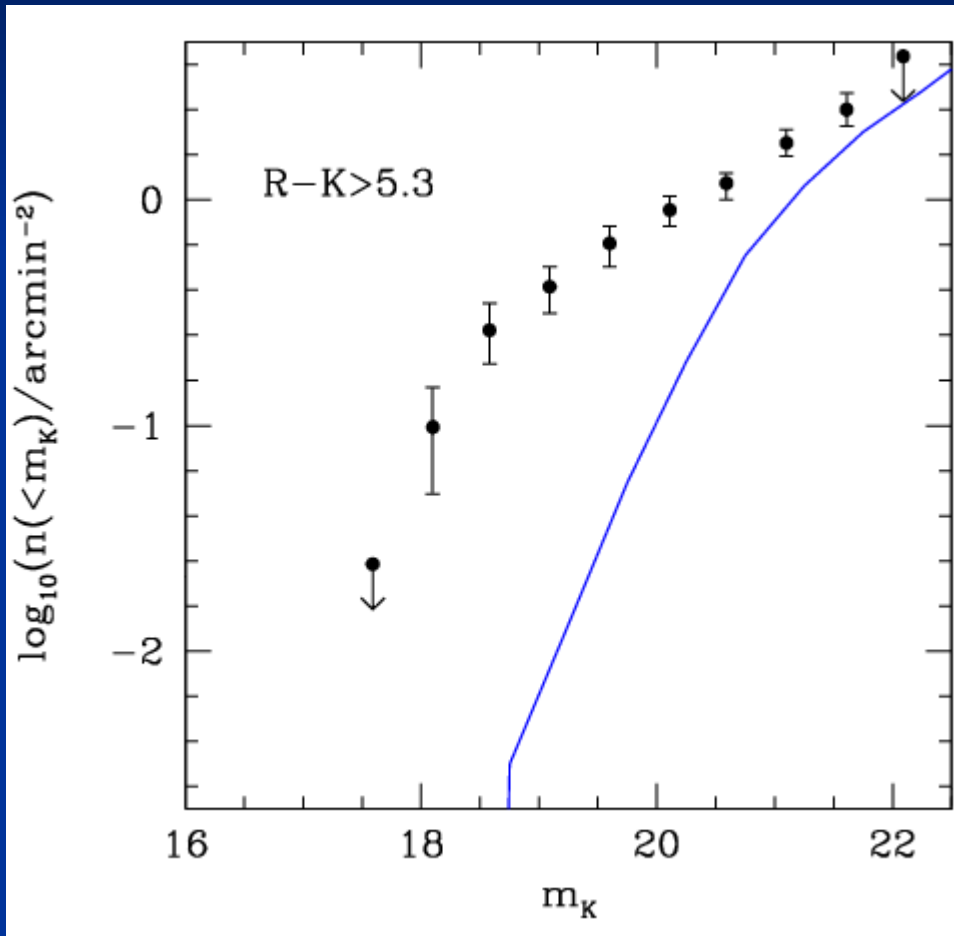
black: total

R

850 micron

Observer frame

What about EROs?

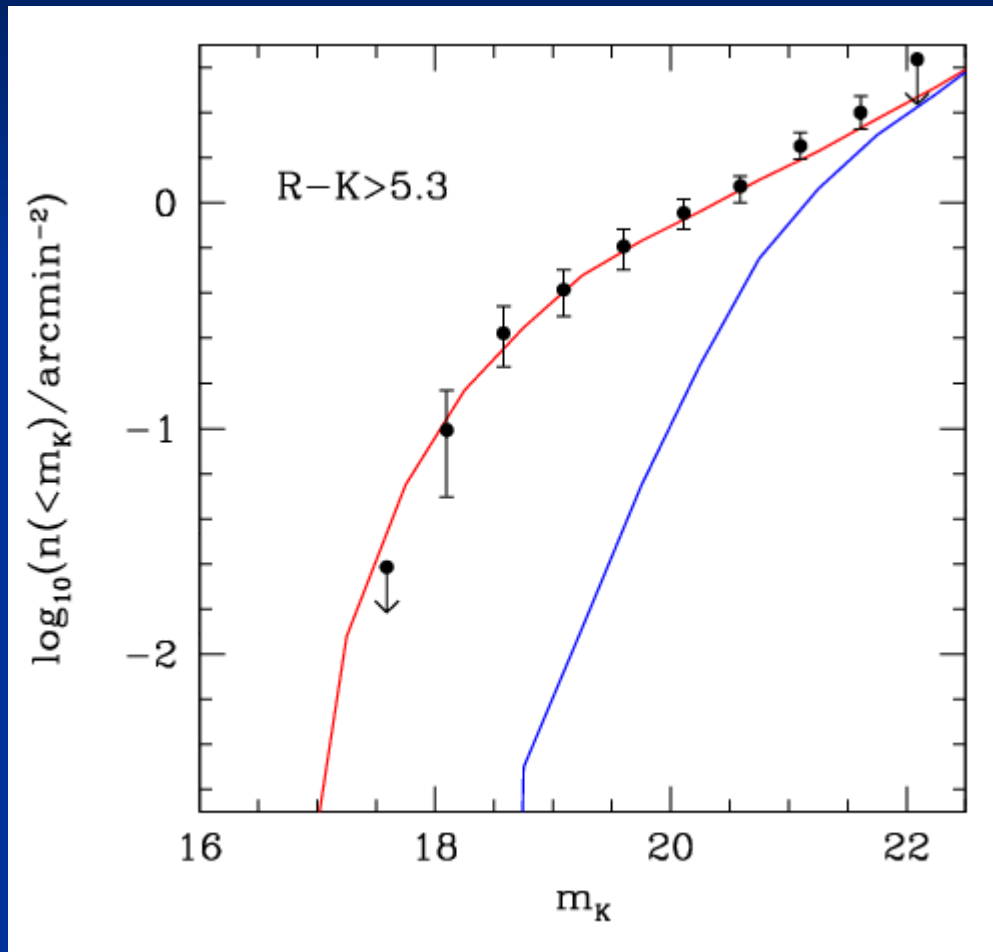


Surface density of EROs.

Data: Smith et al. 2000

Model: Cole et al. 2000
fiducial model

Surface density of EROs



DATA: Smith et al. 2000

MODELS:

red: new high-z model

blue: Cole et al. 2000

Summary

- Semi-analytic models are:
fast, flexible, powerful and useful!
- The general properties of the high- z Universe can be reproduced.
- SCUBA counts are the hardest: seem to require changing the IMF in bursts.
- The SCUBA/Lyman-break phenomena correspond to different stages in bursts.