Outline

Studying statistical, mass limited samples of SF galaxies, can we gain insights on the relevance and nature of starburst systems ?

1. A bimodal Schmidt-Kennicutt law ?

2. What are starbursts ?

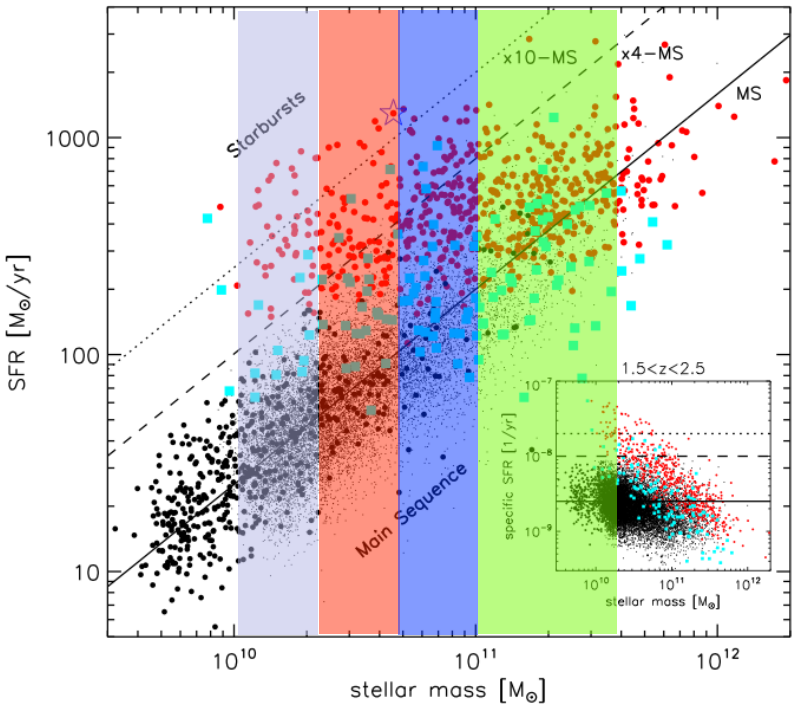
(nowadays defined as excess-sSFR sources/ MS outliers)

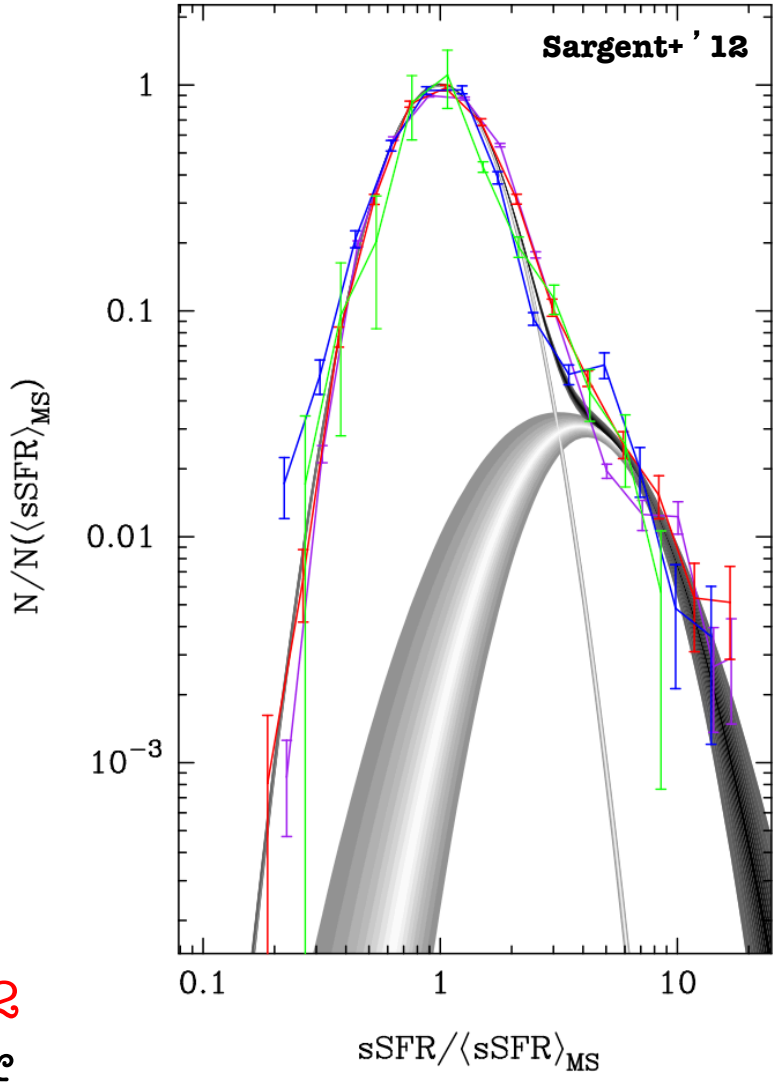
3. How much gas is consumed during a starburst ?

4. What is the impact of starbursts on:
   I. CO-luminosity function evolution at $0 < z < 2.5$
   II. The contribution of starbursts to H_2-mass function and the cosmic H_2-abundance

Counting starbursts: the 2-SFM decomposition...

Distribution of (*massive*) star-forming galaxies at 1.5 < z < 2.5 w.r.t (s)SFR & $M_\star$ (Rodighiero+ ' 11):





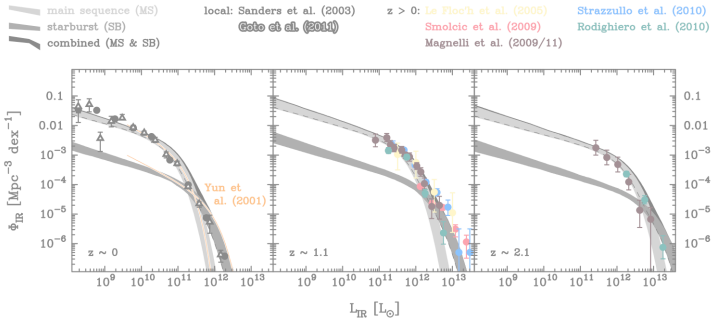
Mass-invariant decomposition into 2 log-normal distributions ('normal' & starbursting galaxies, resp.).

~10% SFRD contribution of starbursts

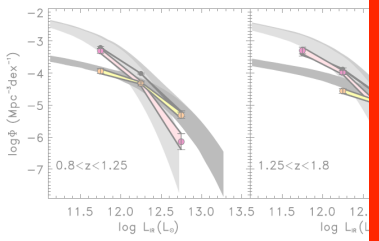
Bimodality of SF modes

Successes of the 2-SFM description

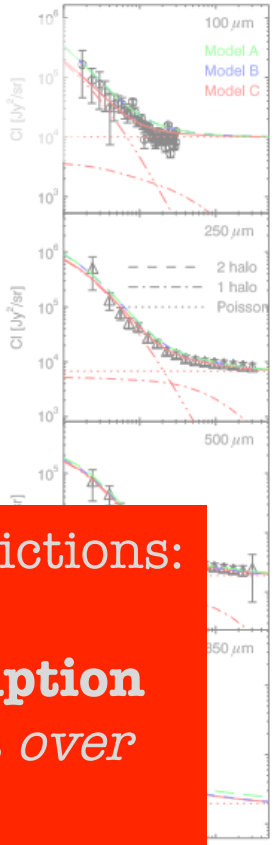
IR LFs: pre-*Herschel* (Sargent+ '12)...



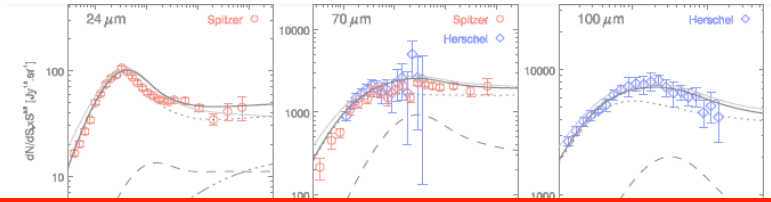
... & using *Herschel* (Gruppioni+ '13)



CIB cross power spectra (Béthermin+ '13):



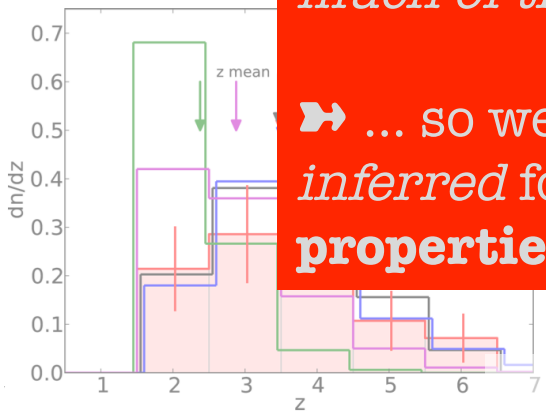
IR number counts (Béthermin+ '12):



Consistency of measurements & 2-SFM predictions:

➽ 2-SFM apparently provides a **valid description of dust-emission** from star-forming galaxies *over much of the history of the Universe*...

➽ ... so we might as well adopt it to see *what can be inferred* for the **less well known (molecular) gas properties**



redshift-distrib. of SPT sources (Weiß+ '13)

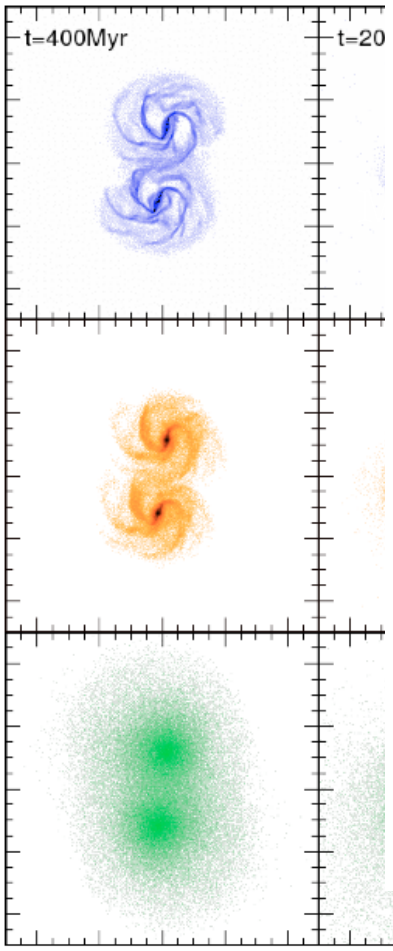
Merger simulations II

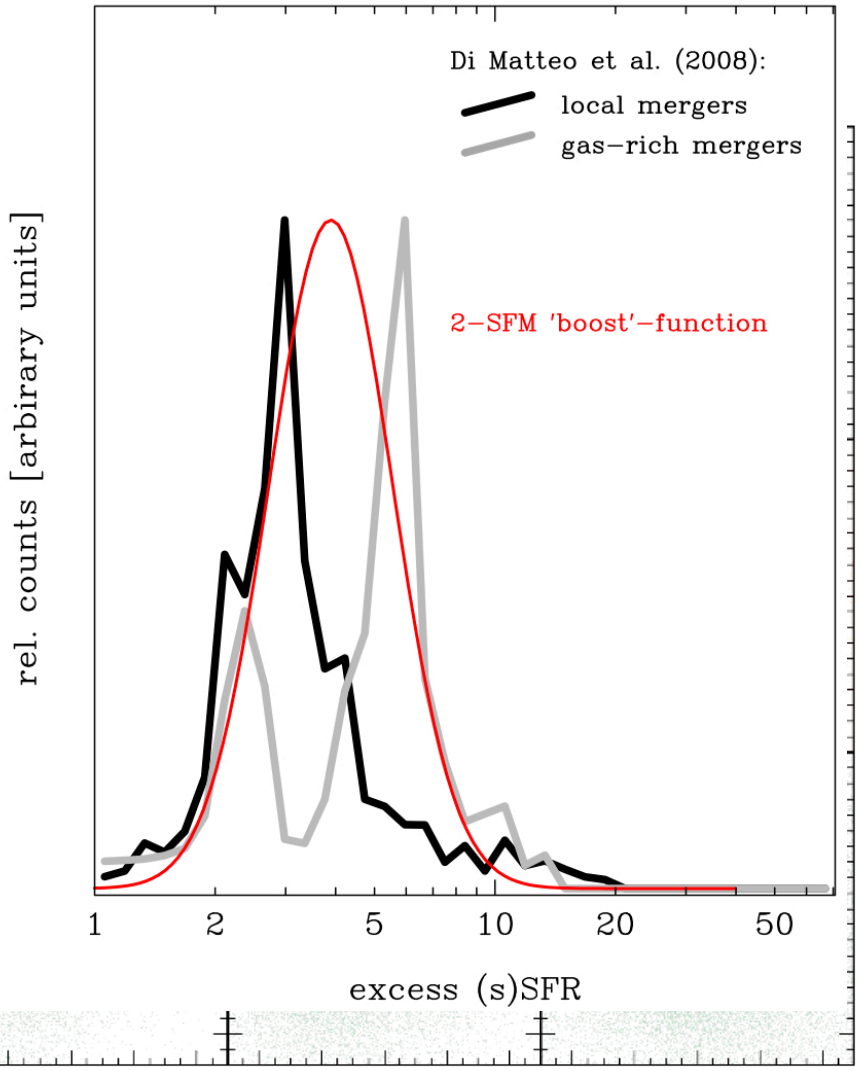
Di Matteo+ '07:
retrograde merger
of 2 Sbc galaxies
at z=0

gas

stars

dark matter



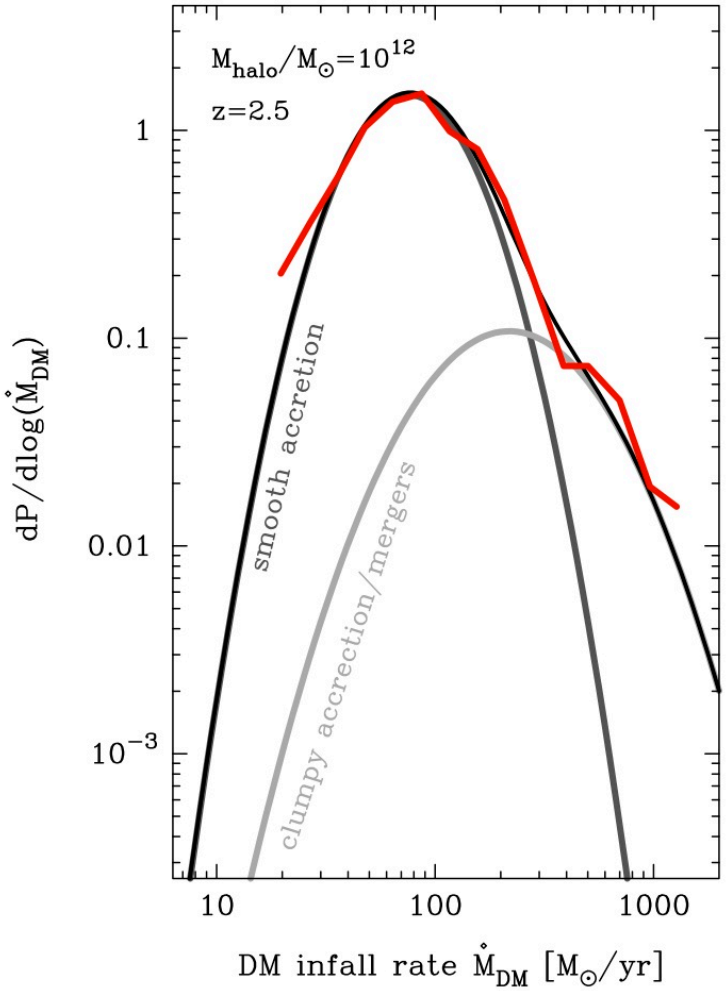


Cause(s) & effect: Interpreting the decomposition...

A snapshop at z ~ 2, prior to measuring (s)SFR distributions...

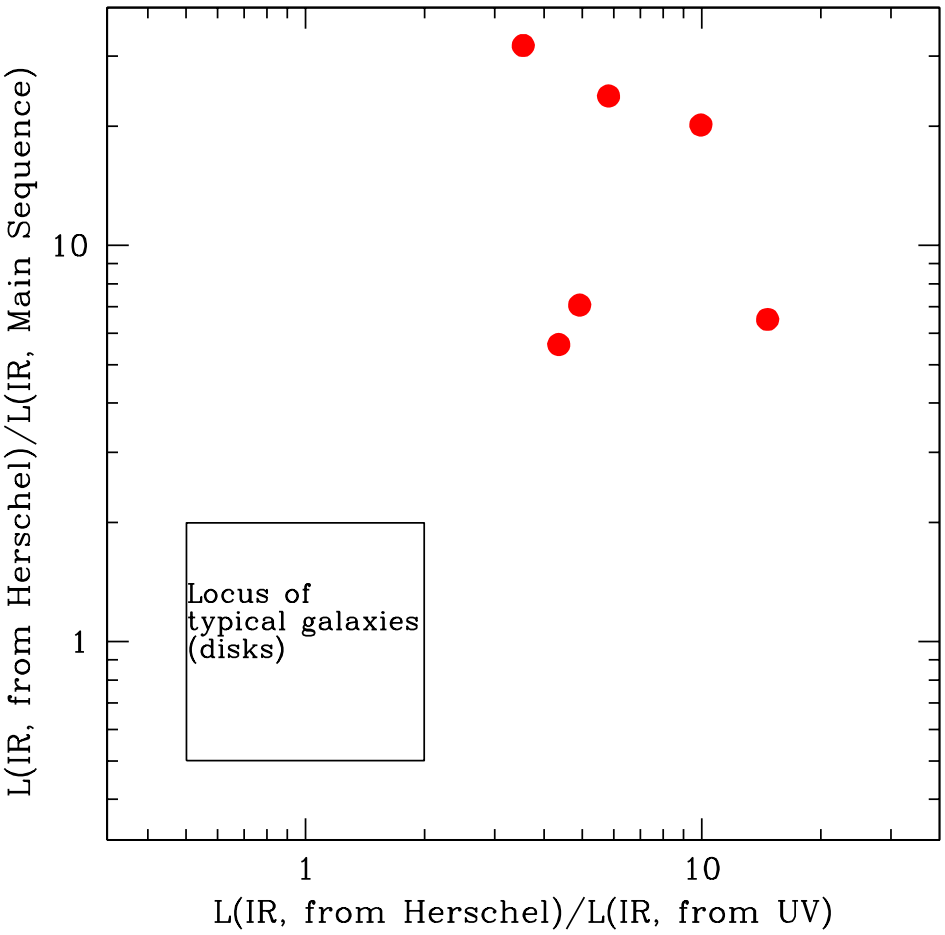
Dark matter accretion spectrum in cosmological simulations (Dekel+ '09; Goerdt+, in prep.):

- smooth accretion
  - ➳ ***main-sequence activity?***
- clumpy accretion with major mergers in high-$\dot{M}_{DM}$ tail
  - ➳ ***starbursts?***



MS outliers: are they mergers ?

HGOODS objects with sSFR x4 excess and measured zspec



→ Optically thick sources

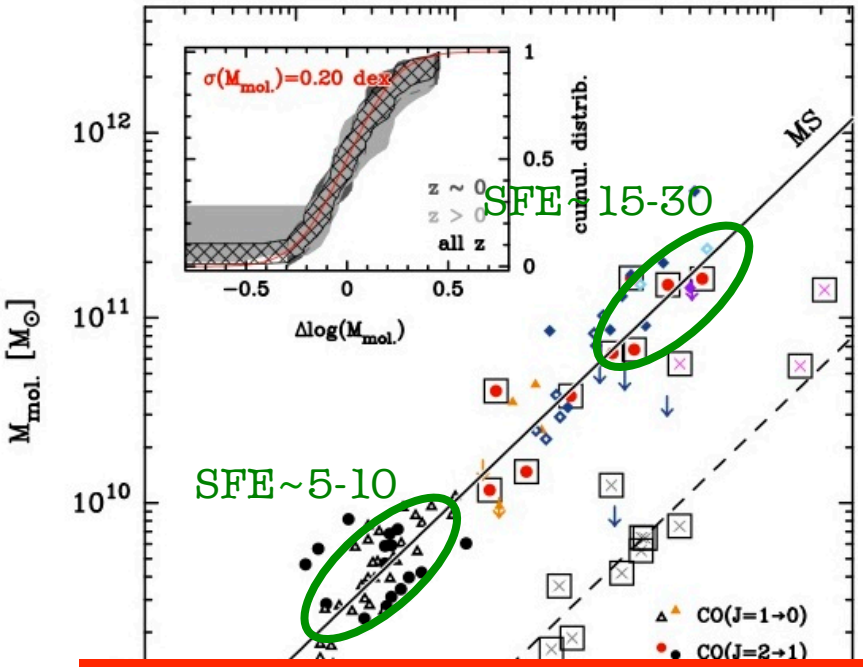
For all cases the UV SFR fails (optically thick)

UV underestimate similar to excess sSFR

Most likely they are indeed 'Dense' mergers

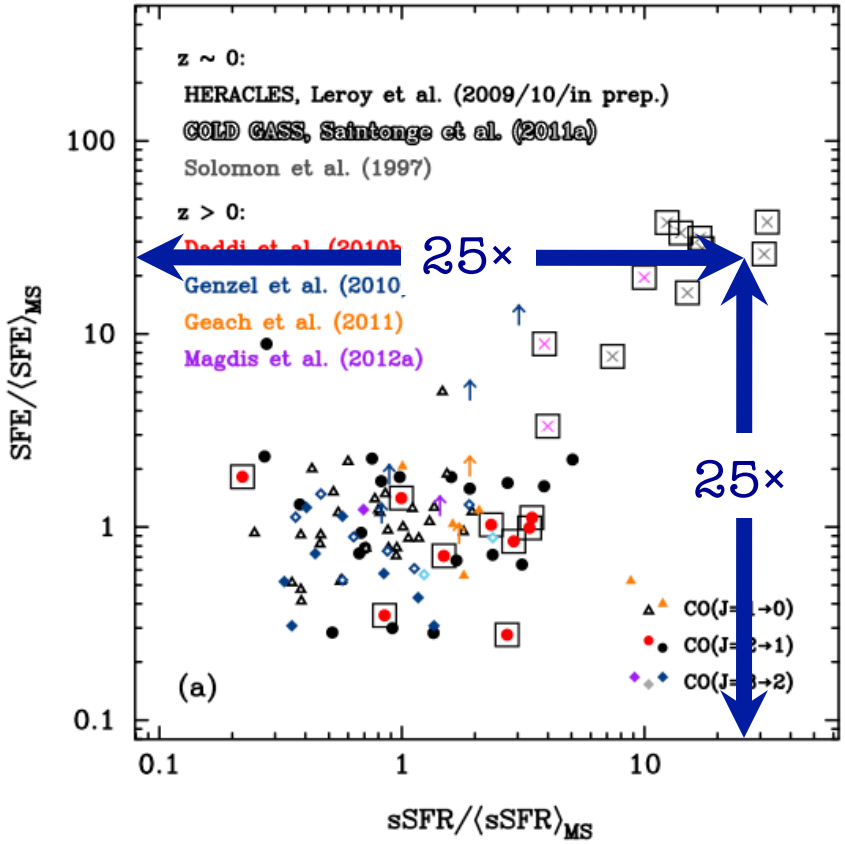
2 Star formation modes: Schmidt-Kennicutt plane I

Integrated Schmidt-Kennicutt law for main seq. galaxies - tight and sub-linear:



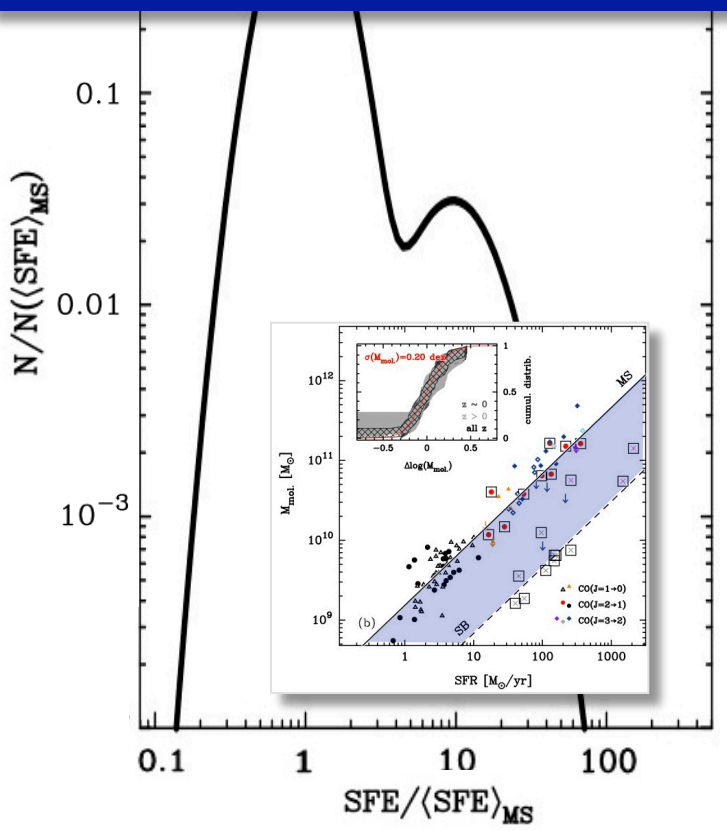
The apparent bimodality in the S-K plane remains in place also when measured (see Magdis+ '12), rather than canonical X_{CO} values are used!

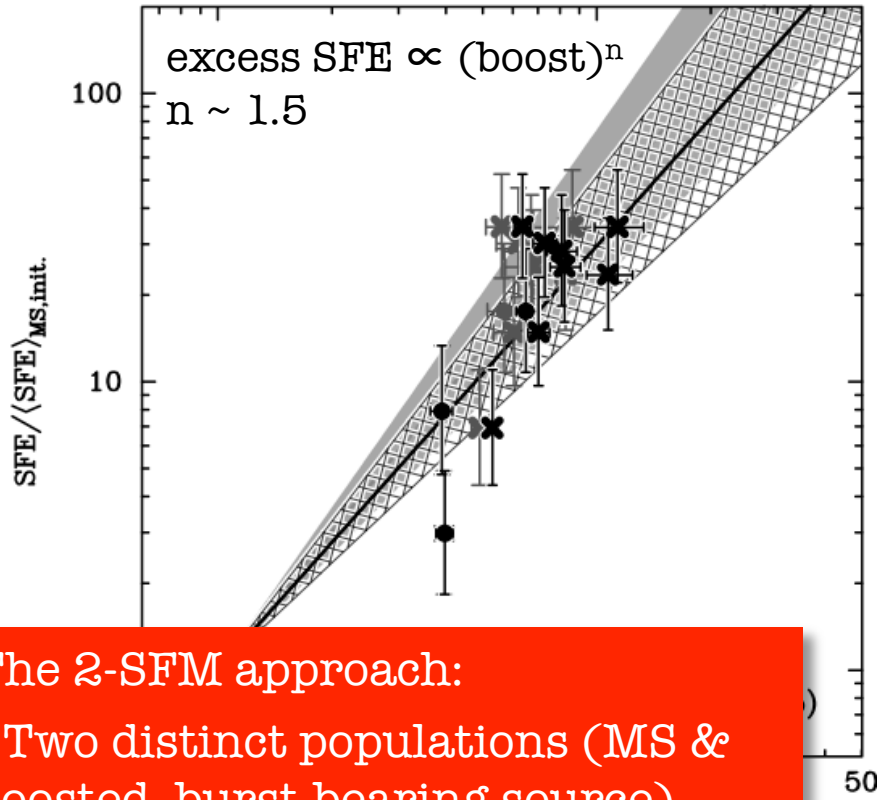
SFE = SFR/$M(H_2)$ Sargent+ (2013a)



2 Star formation modes: Schmidt-Kennicutt plane II

Within the 2-SFM framework, a dichotomy in the S-K plane naturally arises due to the non-linear relation between SFE & SFR in starbursts.





The 2-SFM approach:

- Two distinct populations (MS & boosted, burst-bearing source)
- A continuum of physical properties (e.g. SFE, X_{CO}) for starbursts, *depending on magnitude of boost*

No "discrete" bimodality!

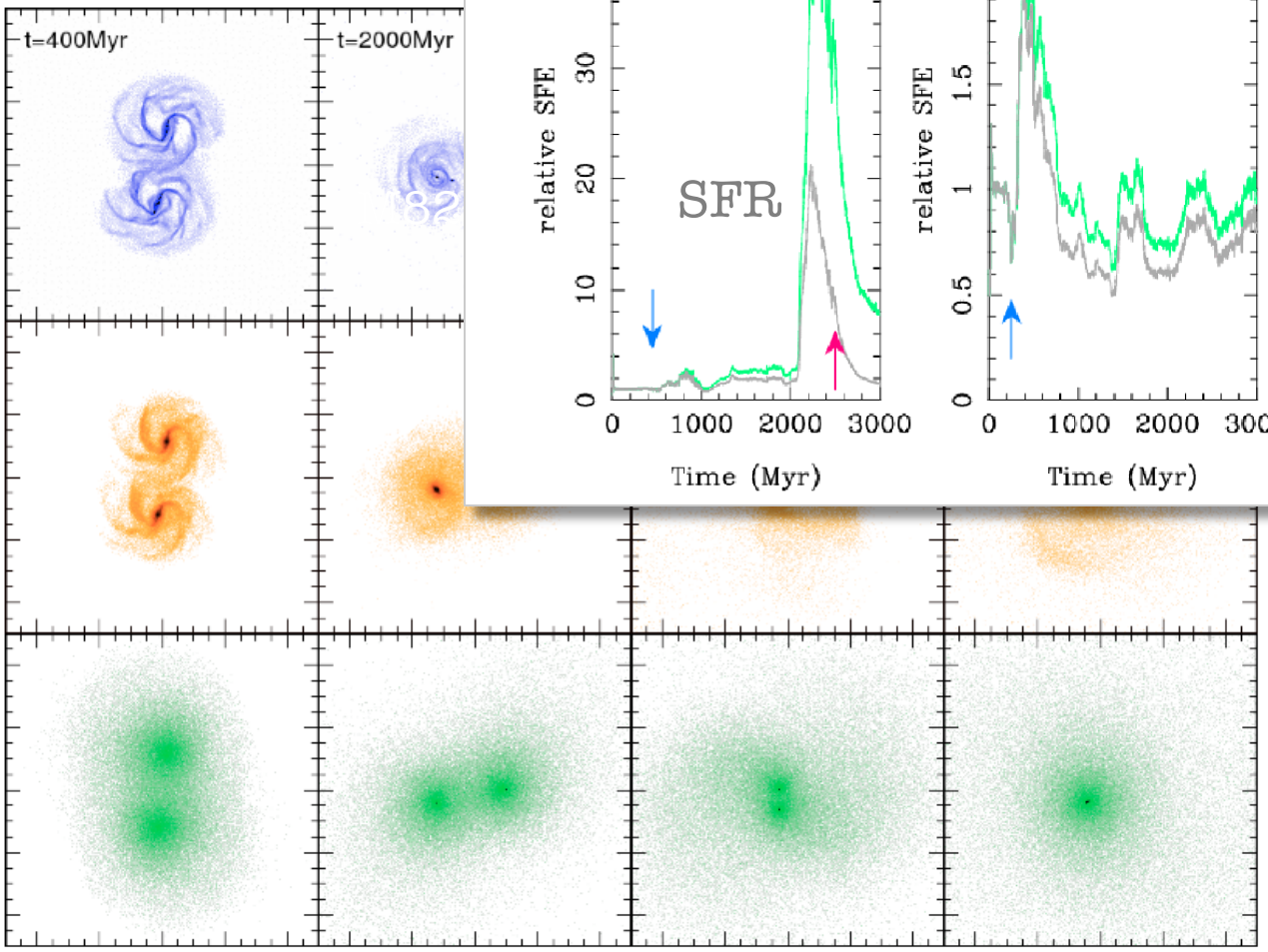
Merger simulations I

Di Matteo+ ’07:
retrograde merger
of 2 Sbc galaxies
at z=0

gas ➳

stars ➳

dark matter ➳



SFR & SFE response in a
di Matteo+ ’07 merger... & ... a fly-by:

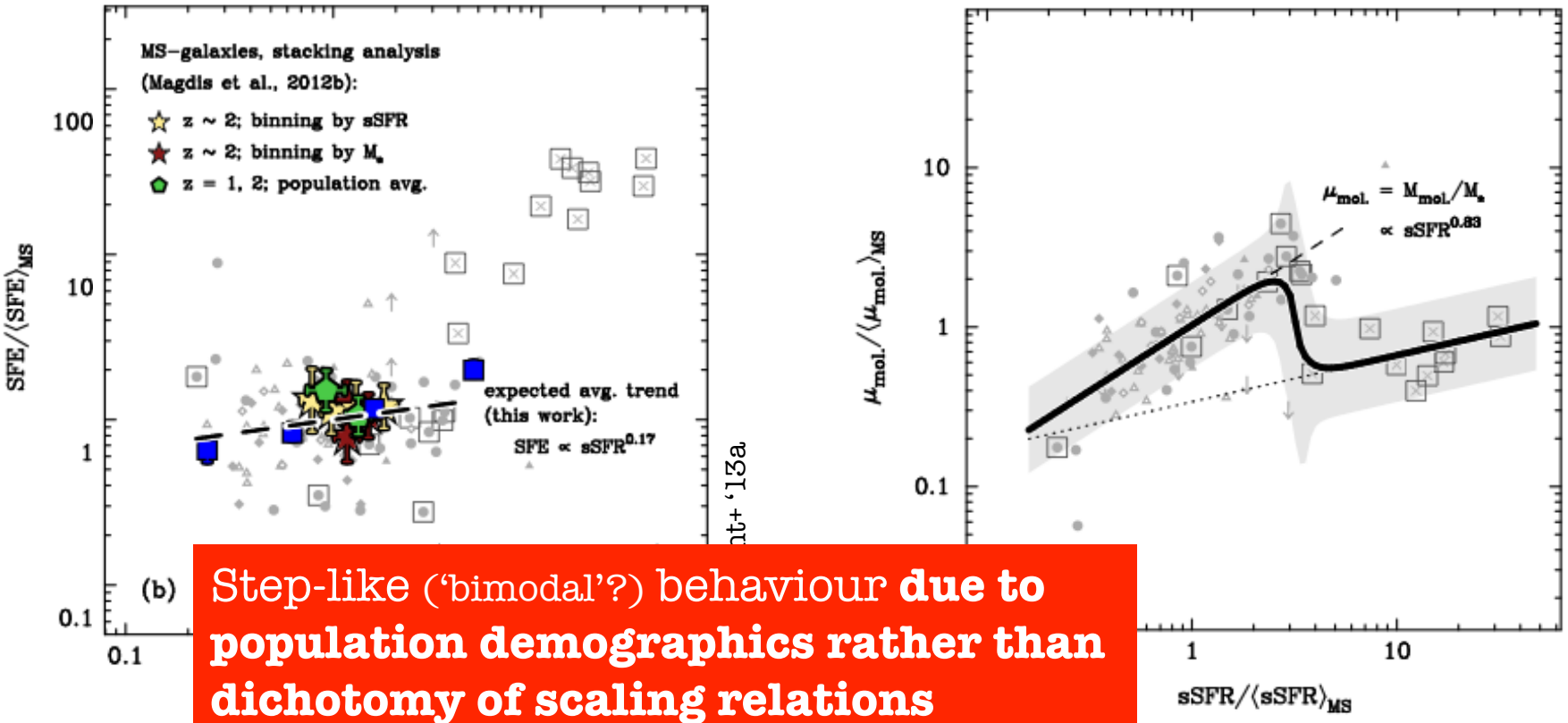
Analytical description of SFE- & f_{gas}-variations

→ redshift-invariant (for $M_*/M_\odot > 10^{10}$) due to re-normalization

SFE vs. sSFR-offset from main seq.

f_{gas} vs. sSFR-offset from main seq.

($\mu = M(H_2)/M_*$)

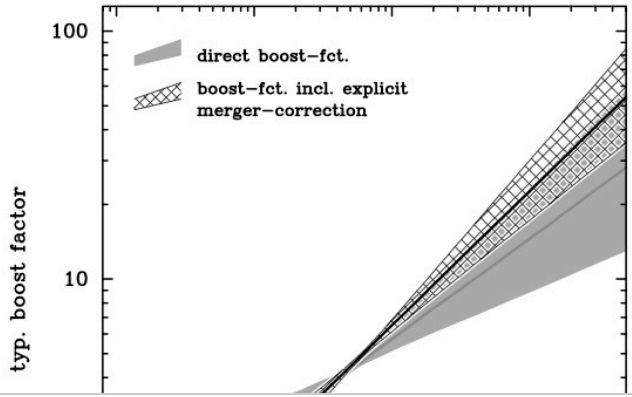


Step-like ('bimodal'?) behaviour **due to population demographics rather than dichotomy of scaling relations**

At step: predict *enhanced dispersion* due to population mix

The former life of starbursts

Statistical link to past:
sSFR-excess vs. (s)SFR-boost relation



Toy model: SFR proceeds on much shorter time scales than gas can be accreted:

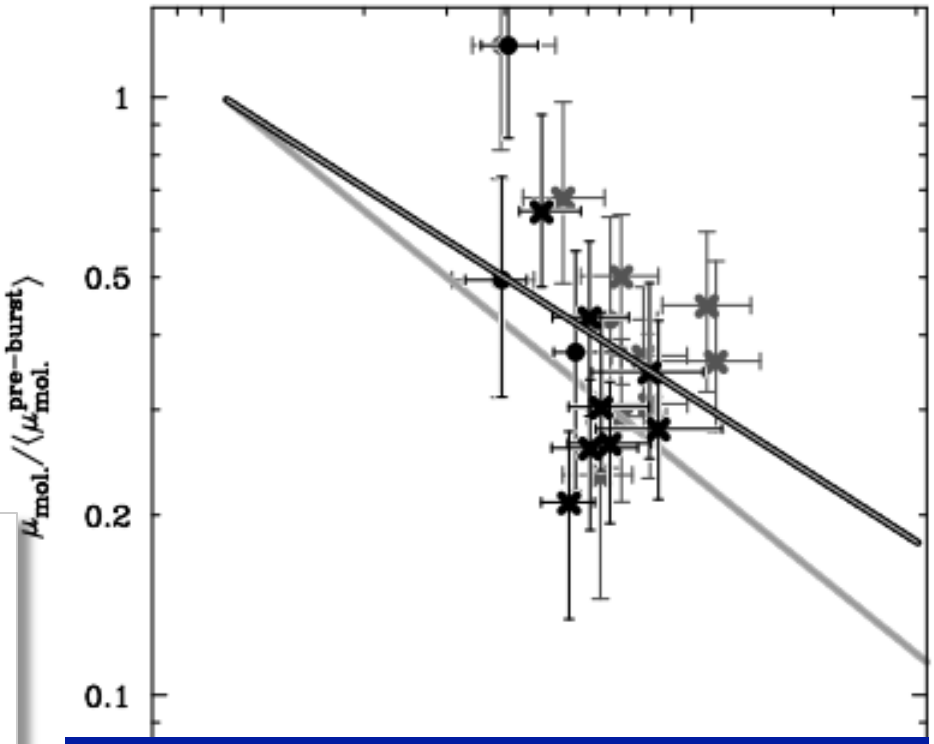
$M_{\star} \rightarrow M_{\star,\,pre\text{-}burst} + SFR \times t^{merger}$

$M_{gas} \rightarrow M_{gas,\,pre\text{-}burst} - SFR \times t^{merger}$

$$\frac{f_{mol.}}{f_{mol.}^{pre-burst}} = \left(1 + (boost)^{\gamma_{SFE}} \frac{t_{1/2}^{merger}}{\tau^{pre-burst}}\right)^{-1}$$

~0.6, i.e. $\mu/\mu^{pre\text{-}burst} \sim 0.4$

Sargent+ '13a

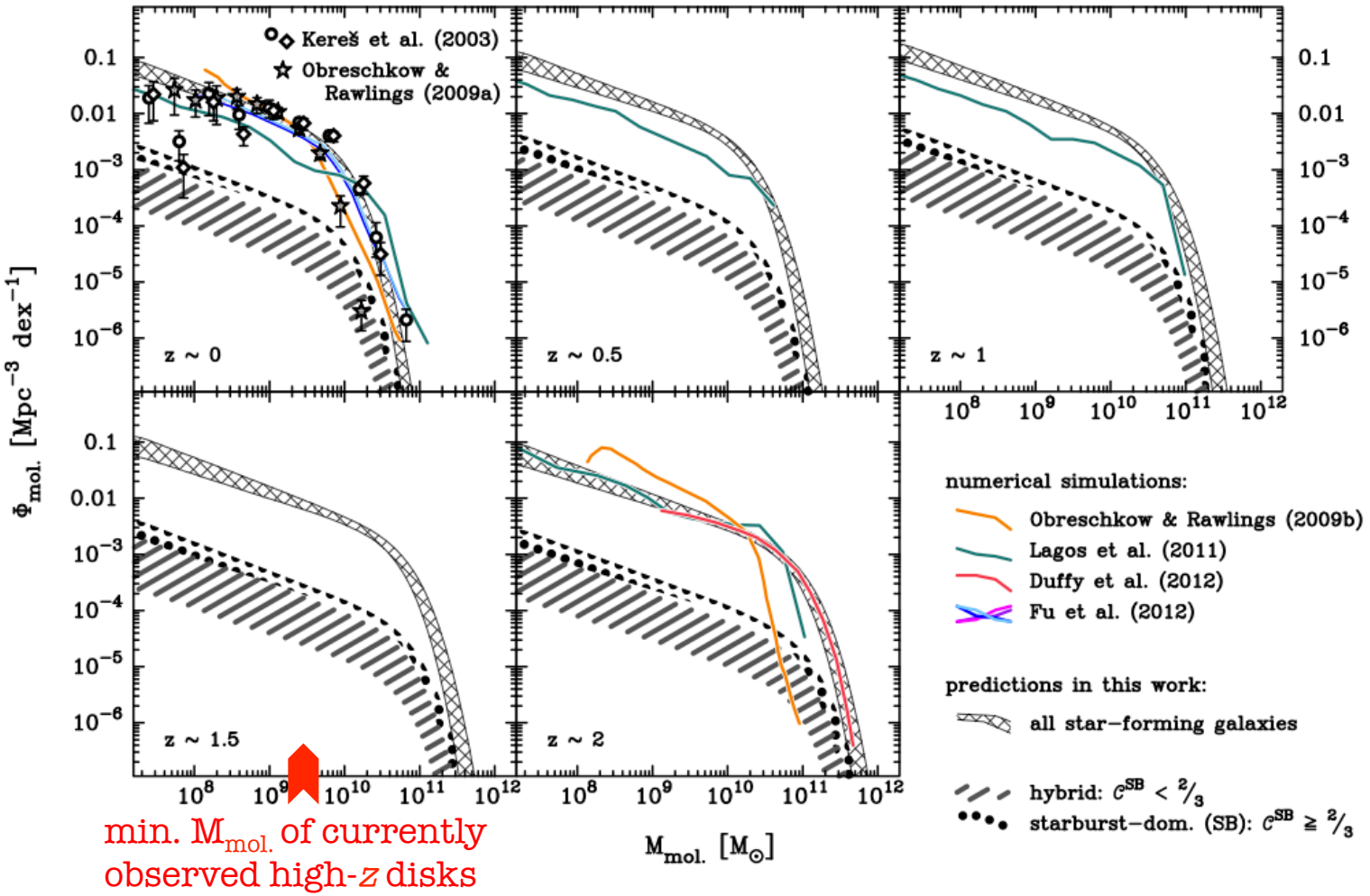


The gas fractions in sSFR-excess srcs. (starbursts) are in agreement with those expected based on merger simulations with standard IMF

The molecular gas mass function ($z < 2.5$)

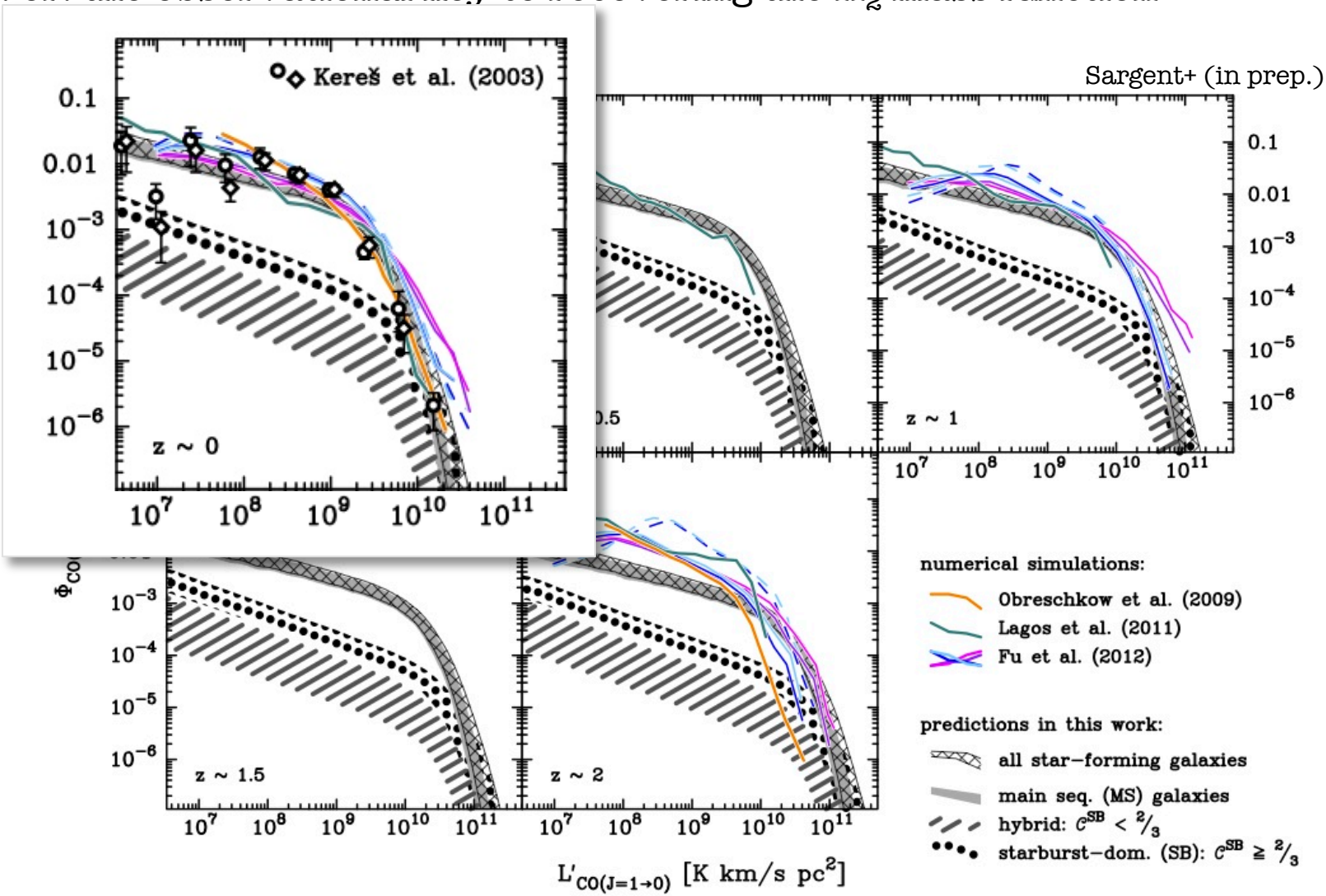
Indirect measurements! (Currently we only have ~40 high-z (public) mol. gas mass measurements in main-seq. galaxies)

Sargent+ '13b

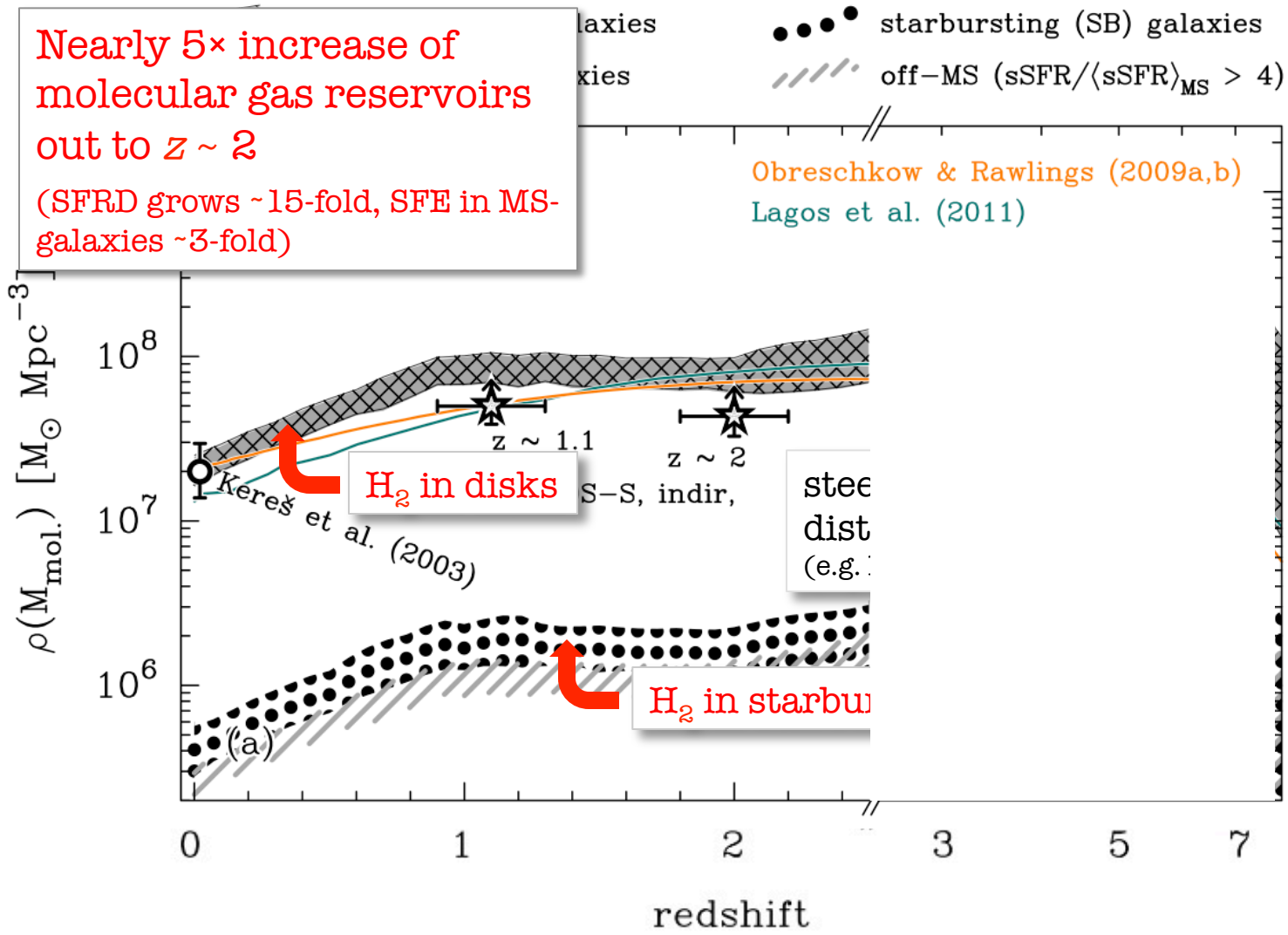


The CO(J=1-0) luminosity function

... or: the observational key to recovering the H_2 mass function



Cosmic evolution of H_2-reservoirs



Issues and worries ?

Are we getting right stellar masses for SBs ?

Is the LIR enhancement in SBs just due to top-heavy IMF ?

Both arguments basically could lead to conclude that SBs are normal because they are special – so contradictory in my view

If you apply both, could conclude they actually have very low sSFR respect to normal disks!

But certainly there is space for uncertainty!

Summary

- The simple & self-consistent statistical approach of the 2-SFM framework is capable of describing the evolution of fundamental properties of the star forming galaxy population by splitting the latter into main sequence and starburst galaxies.

- The contribution of interaction-induced starburst activity to the SFRD and to the H2-mass budget of the universe is small.
  - Secular star formation fuelled by smooth accretion dominates the build-up of stellar mass in galaxies during the last 10 Gyr
  - $\Omega(H_2)$ was approx. 5× larger than nowadays at $1 < z < 2.5$

- While the 2-SFM framework provides a simple description, it does away with the oversimplifying and unphysical assumption of a discrete bimodality of SF modes.
  - Bimodality (e.g. in the Schmidt-Kennicutt plane) arises naturally due to the changing population mix between main-sequence galaxies and starbursts.

- By normalizing physical properties to those representative of average, (supp.: *secularly evolving*...) main-seq. galaxy molecular gas properties can be described in a simple, redshift- and mass-independent way