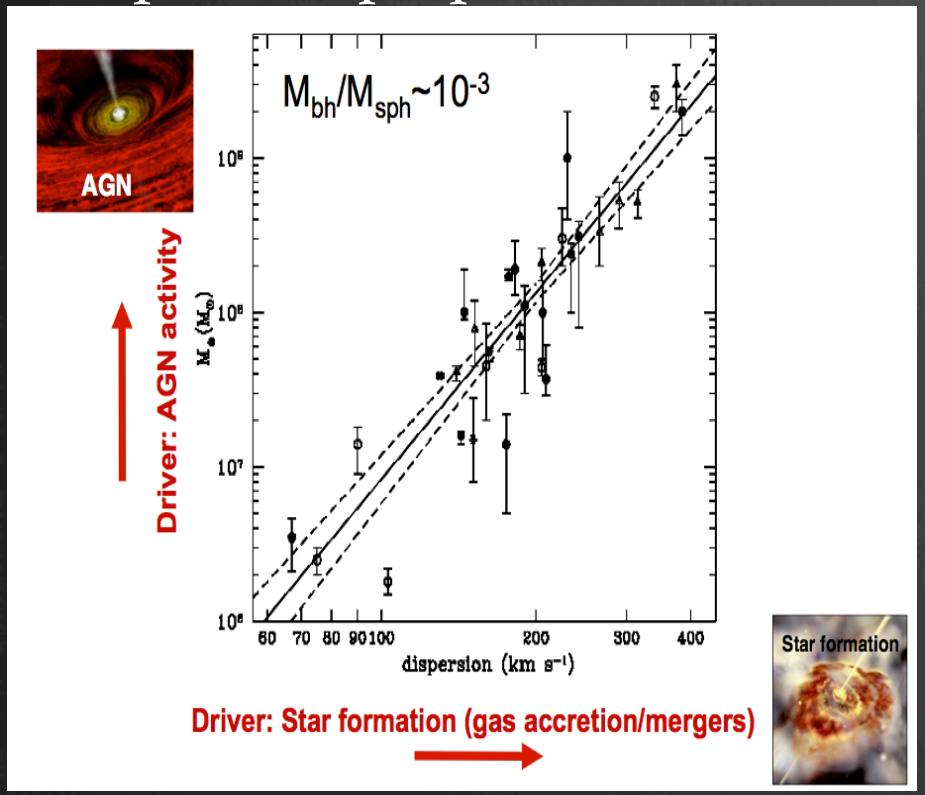
Constraining the SFRs of AGN host galaxies

Flora Stanley

Working with: Chris Harrison, Dave Alexander
Mark Swinbank, James Mullaney, Agnese Del Moro

Evidence of an AGN-SF connection: Observations

- Mass of nuclear SMBH – Spheroid properties



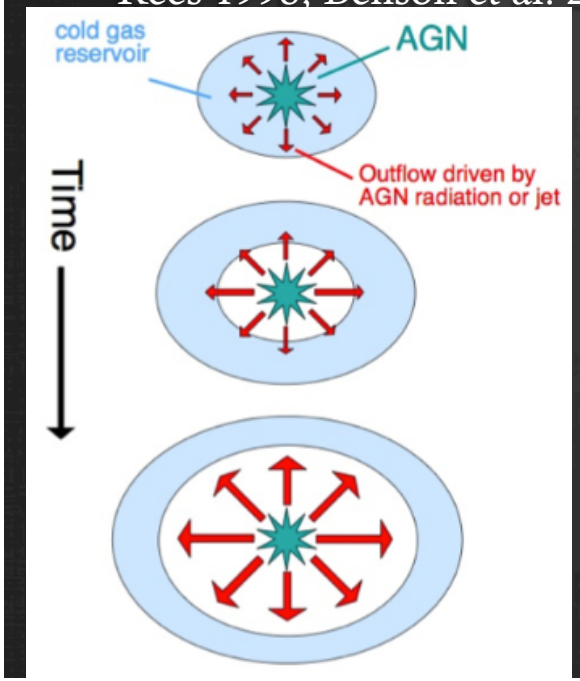
(Magorian et al 1998; Ferrarese & Merritt 2000; …)

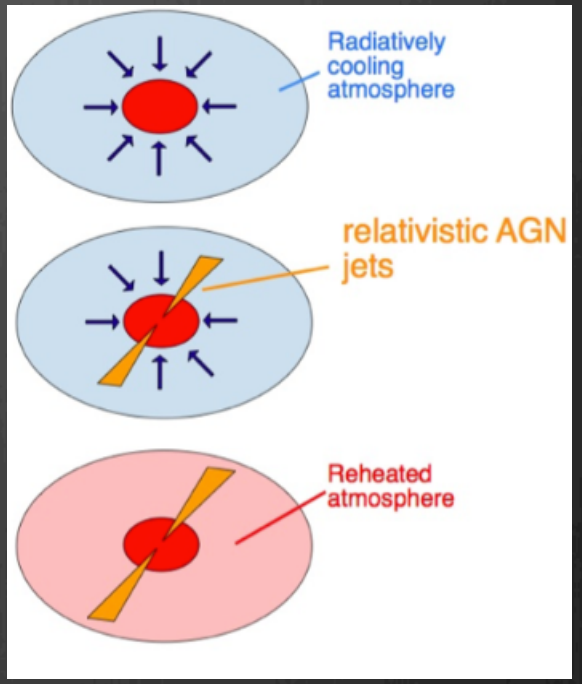
- AGN activity & SFR both peak at high redshifts
- Space density of luminous AGN and SFR (Chapman et al 2005; Merloni & Heinz 2008; …)
- **AGN predominantly live in star-forming galaxies** (Mullaney 12, Rosario;..)

Evidence of an AGN - SF connection: Simulations

- **"Maintenance mode"**
  AGN preventing regulating cooling of hot gas to maintain low SFRs
  (e.g. Bower et all. 2006, Croton et al. 2006, …)

- **"Quasar mode"**
  AGN blowing the gas out of the galaxy(e.g Silk & Rees 1998, Benson et al. 2003,Di Matteo et al. 2005, …)





Schematics from Alexander & Hickox 2012

- Two of the possible outcomes

Quenching of Star Formation	Increase of Star Formation

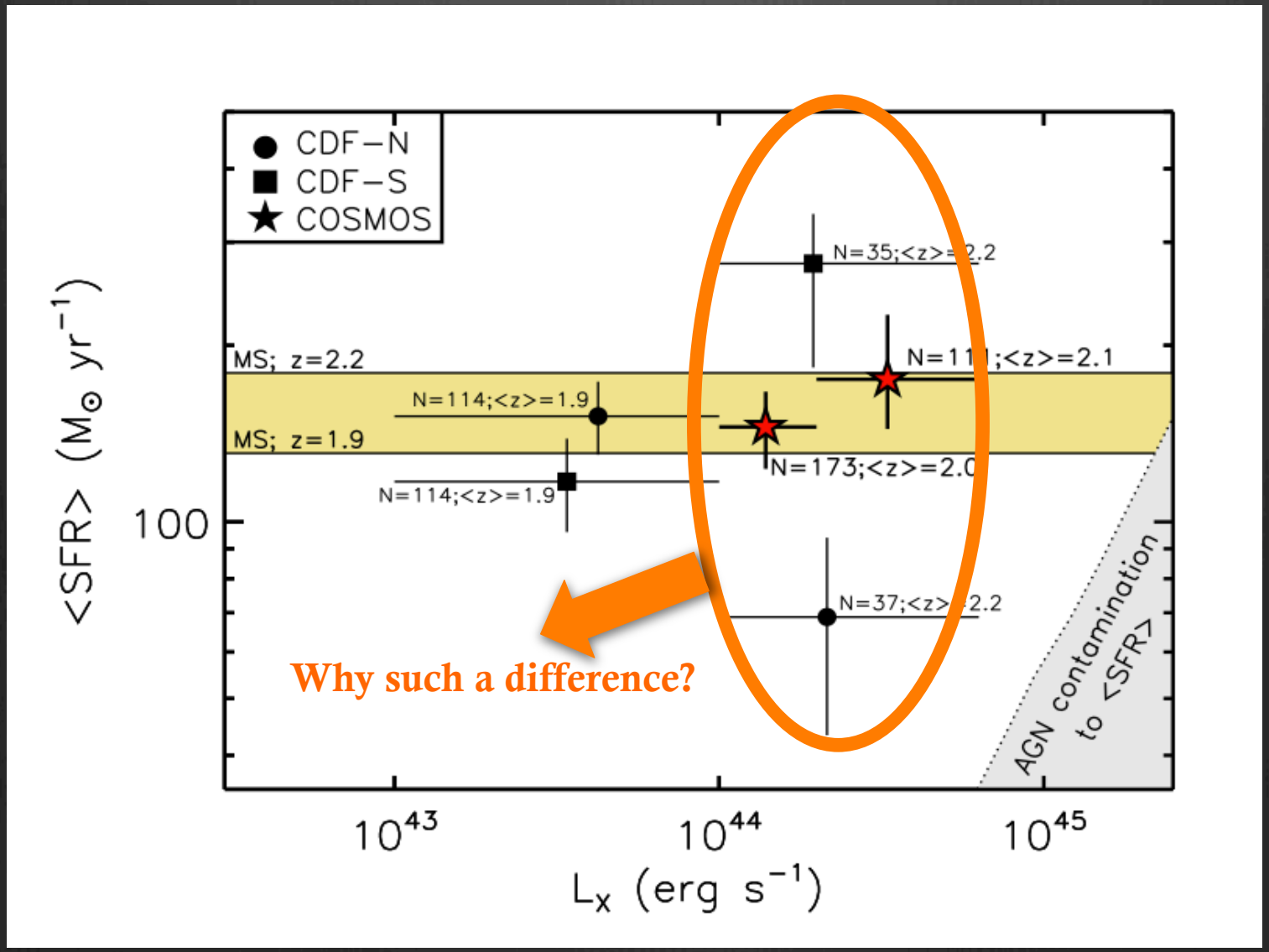
See *Harrison, C. M. 2013* for a brief review

Is SFR dependent on AGN luminosity?

<SFR> results based on Stacking of FIR data

- $L_x < 10^{44}$ erg/s (moderate luminosity AGN):
  - <SFR> consistent with normal SF galaxies (Noeske et al 2007; Elbaz et al 2007; Daddi et al 2007; Panella et al 2009)
  - Studies are in **agreement** (Mullaney et al 2010; Hatziminaoglou et al 2010; Lutz et al 2010; Santini et al 2012; Rovilos et al 2012; Rosario et al 2012; Page et al 2012; Harrison et al 2012b)
- $L_x > 10^{44}$ erg/s (luminous AGN) :
  - **Increase**: Lutz et al 2010; Rovilos et al 2012; Santini et al 2012
  - **Decrease:** Page et al 2012
  - **No change**: Harrison et al 2012b; Rosario et al 2012

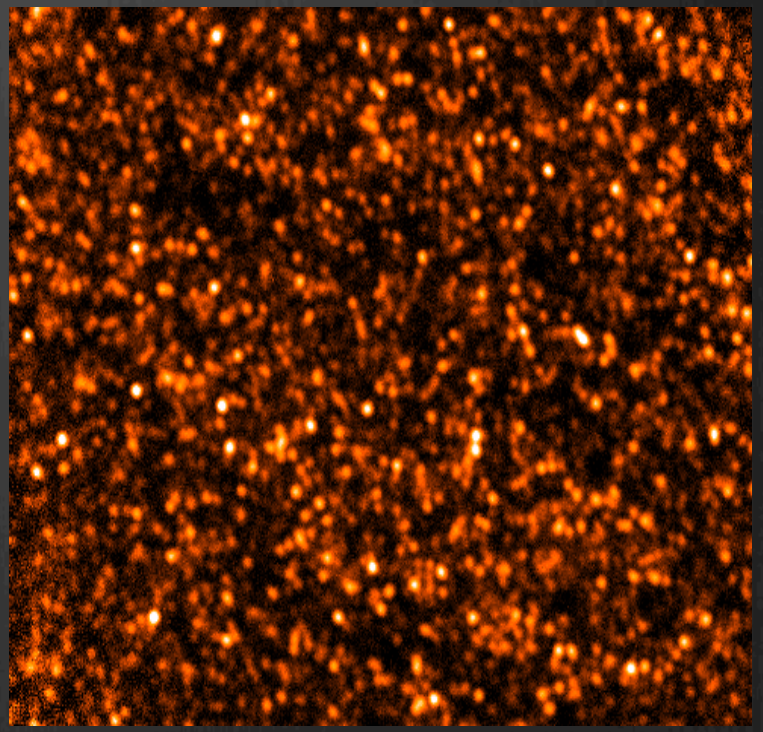
Is SFR dependent on AGN luminosity?



Harrison, C. M. 2013

Limitations of previous work

- High confusion levels of FIR images
- Assumption that all flux observed is due to Star Formation
- Fitting SEDs to a single wavelength band
- Upper limits are often ignored



CDF-N at 250um

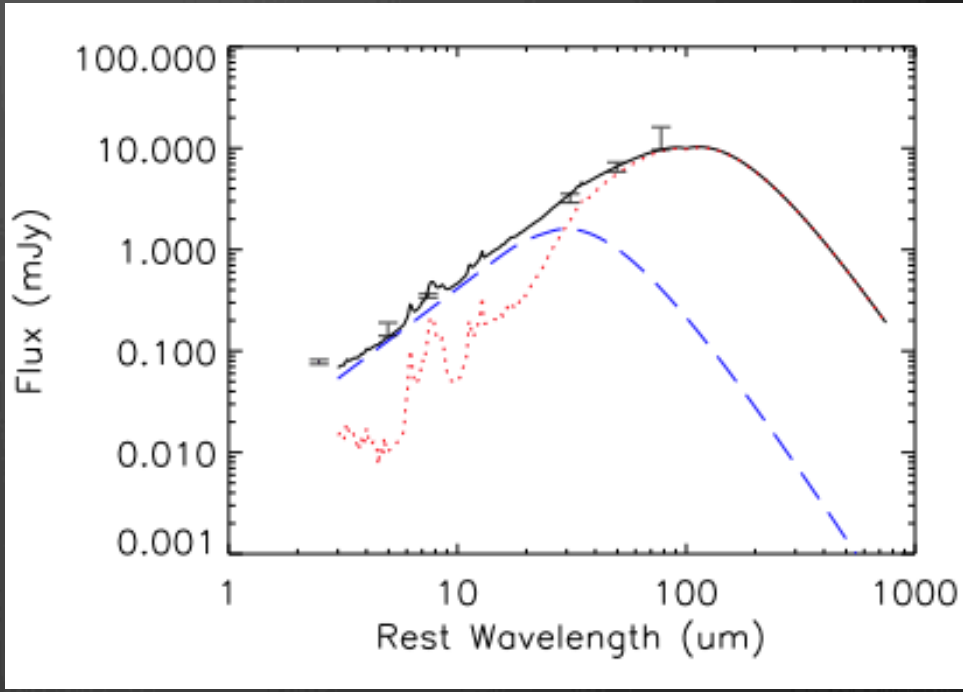
Our aim in this research

Constraining the SFR distribution of X-ray AGN

- Fields: GOODS-N, GOODS-S, COSMOS (covered by PACS)
- X-ray detected AGN ($L_X > 10^{42}$ erg/s)
  (Alexander et al, 2003; Xue et al, 2011;)
- Redshift range: 0.5 – 3 → Today I'll be **concentrating on z = 1 – 3**
- Multi-wavelength (from 8um to 500um) → SED-fitting
- Advantages:
  - Use of deconvolved catalogues of PACS and SPIRE
  - Use of SED decomposition to best determine the SFR value

Decomposing the FIR

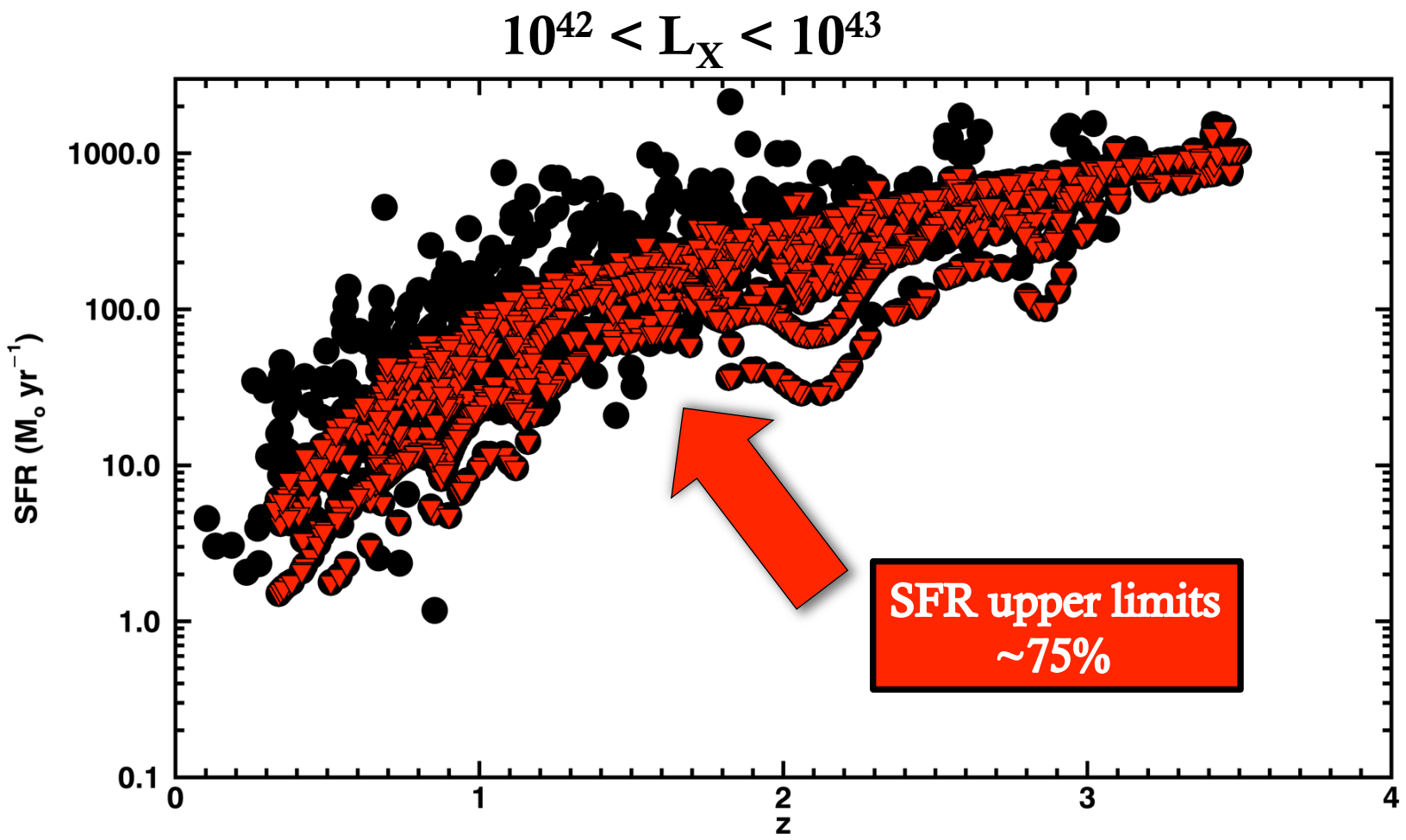
- Mullaney et al, 2011 templates:
  - 5 x Empirical host galaxy
  - 1 x Power law
- Fitting to IR data in two ways:
  - Only a host galaxy component
  - Host galaxy + AGN power law
- Estimation of SFR upper limits for sources with not enough information to constrain the fit



- Statistical testing → best fitting solution

Technique analysed in more detail in Del Moro et al (2013)

Resulting SFRs



Kaplan-Meier Product Estimator

- Kaplan & Meier (1958) :
  - **<u>Allows the inclusion of limits in the statistical analysis</u>**
  - Maximum-likelihood-type estimator of the distribution $\{x_1, x_2, x_3, \ldots, x_n\}$ (including limits)

$$S[x_j] = \prod_{i=1}^{j-1} \left(1 - \frac{1}{n+1}\right)^{\delta_i}$$

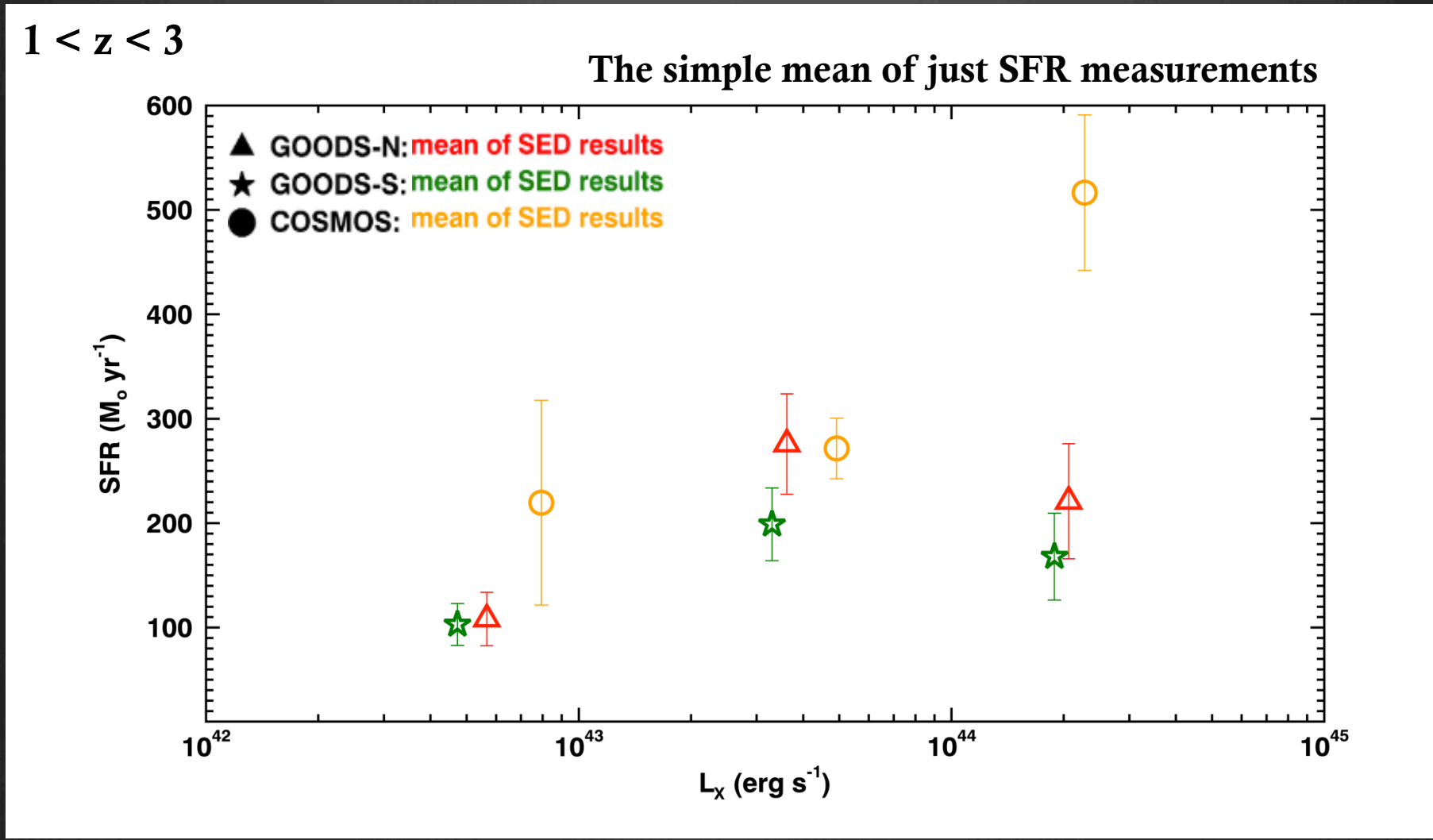
Estimated distribution
"Survival function"

$$\mu = \int_0^{\infty} S[x]\,dx = \sum_{j=1}^{n} S[x_j][x_j - x_{j-1}]$$

Mean of the estimated distribution

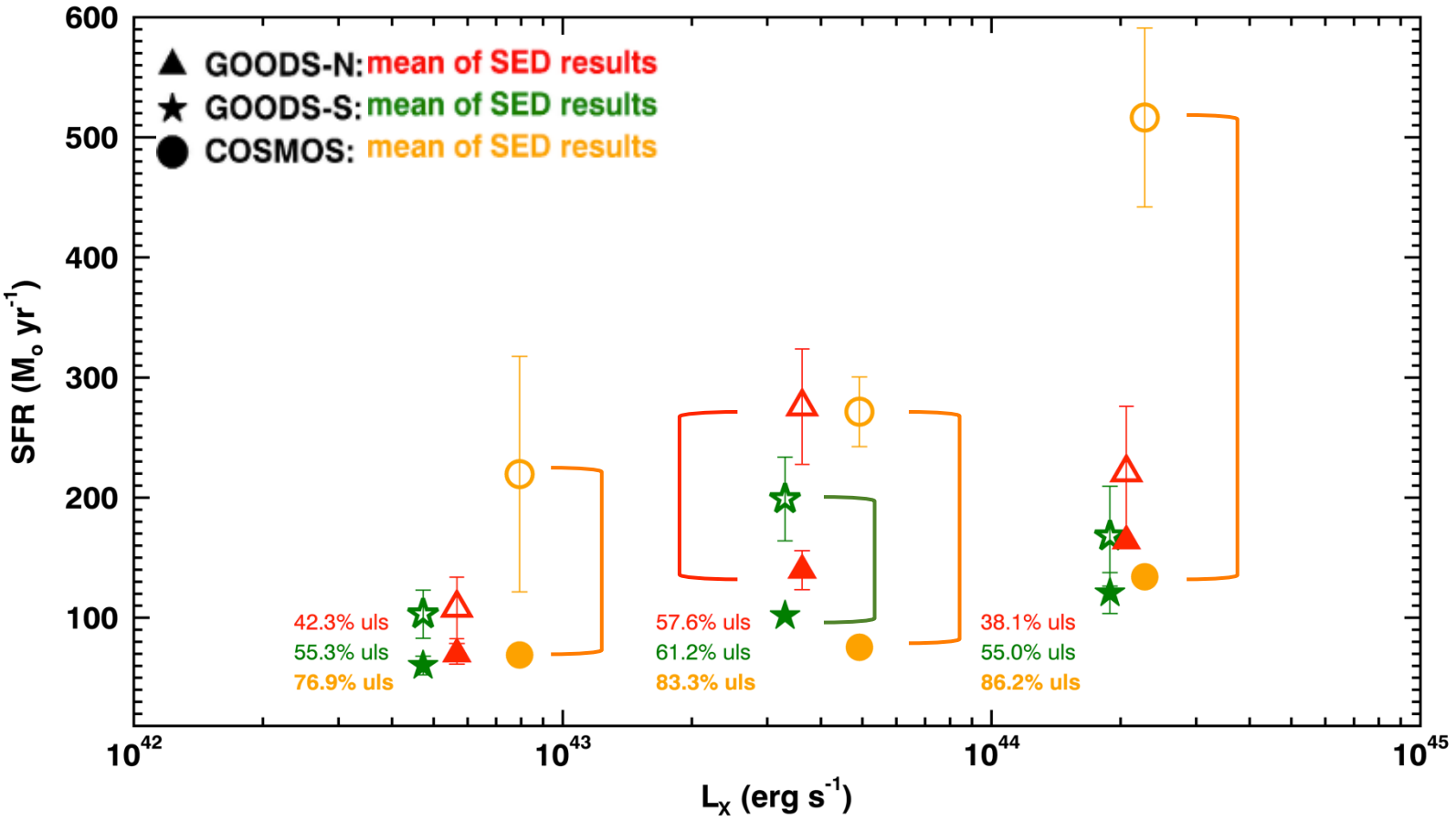
Detailed analysis in Feigelson et al, 1985

<SFR> - L_X :
The importance of including upper limits



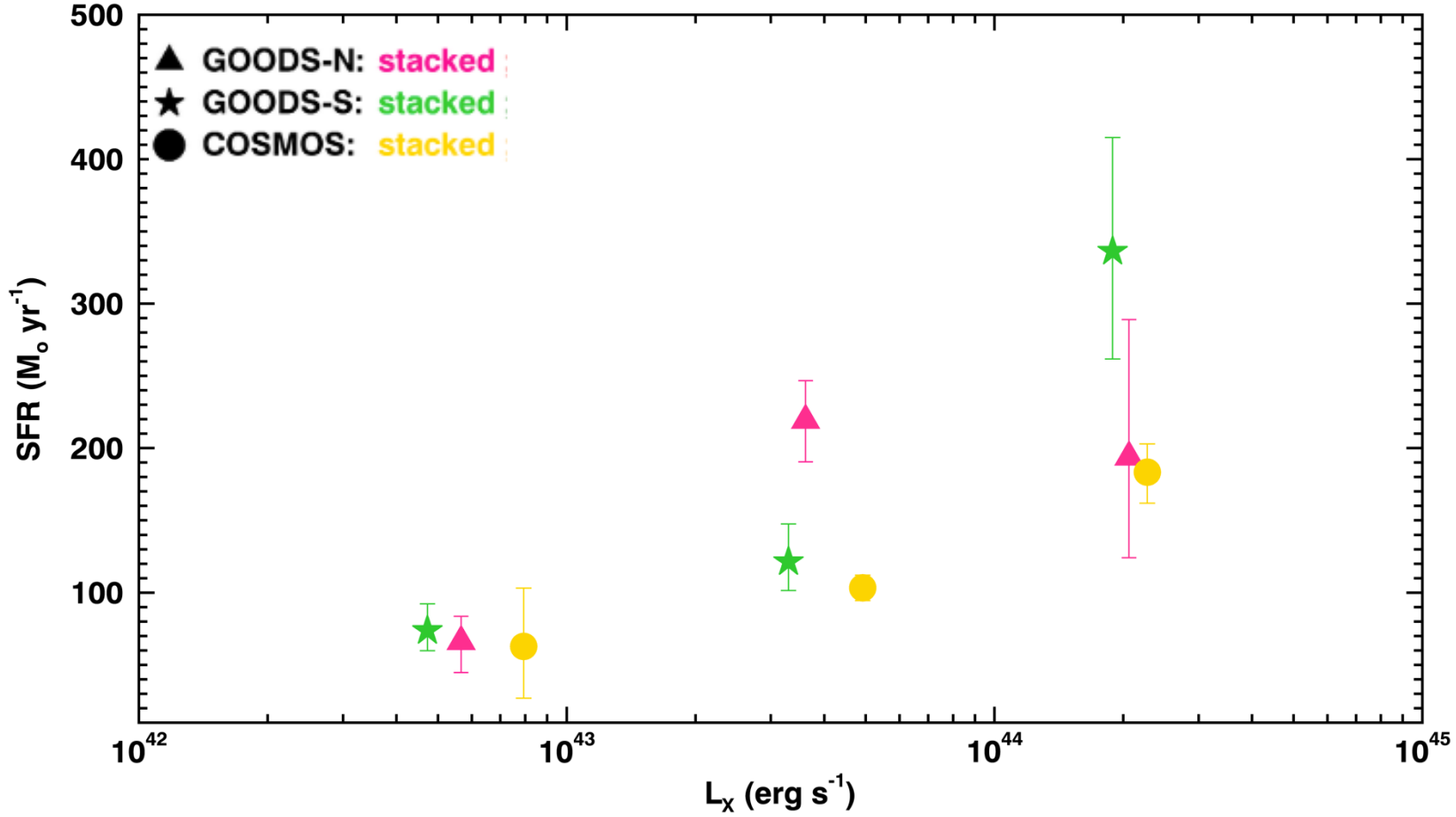
<SFR> - L_X :
The importance of including upper limits

$1 < z < 3$



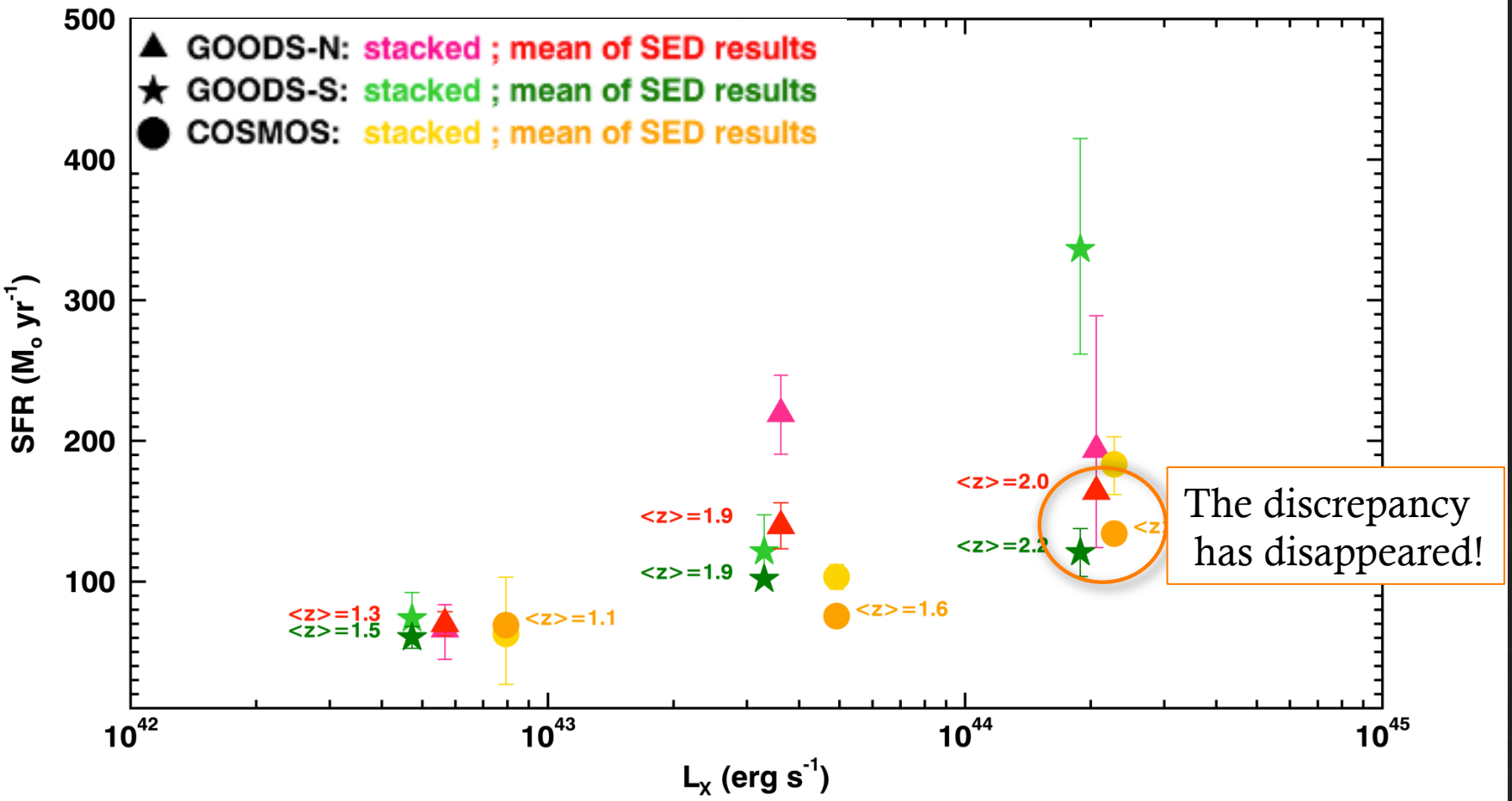
Comparing to results from stacking @ 250um

$1 < z < 3$



Comparing to results from stacking @ 250um

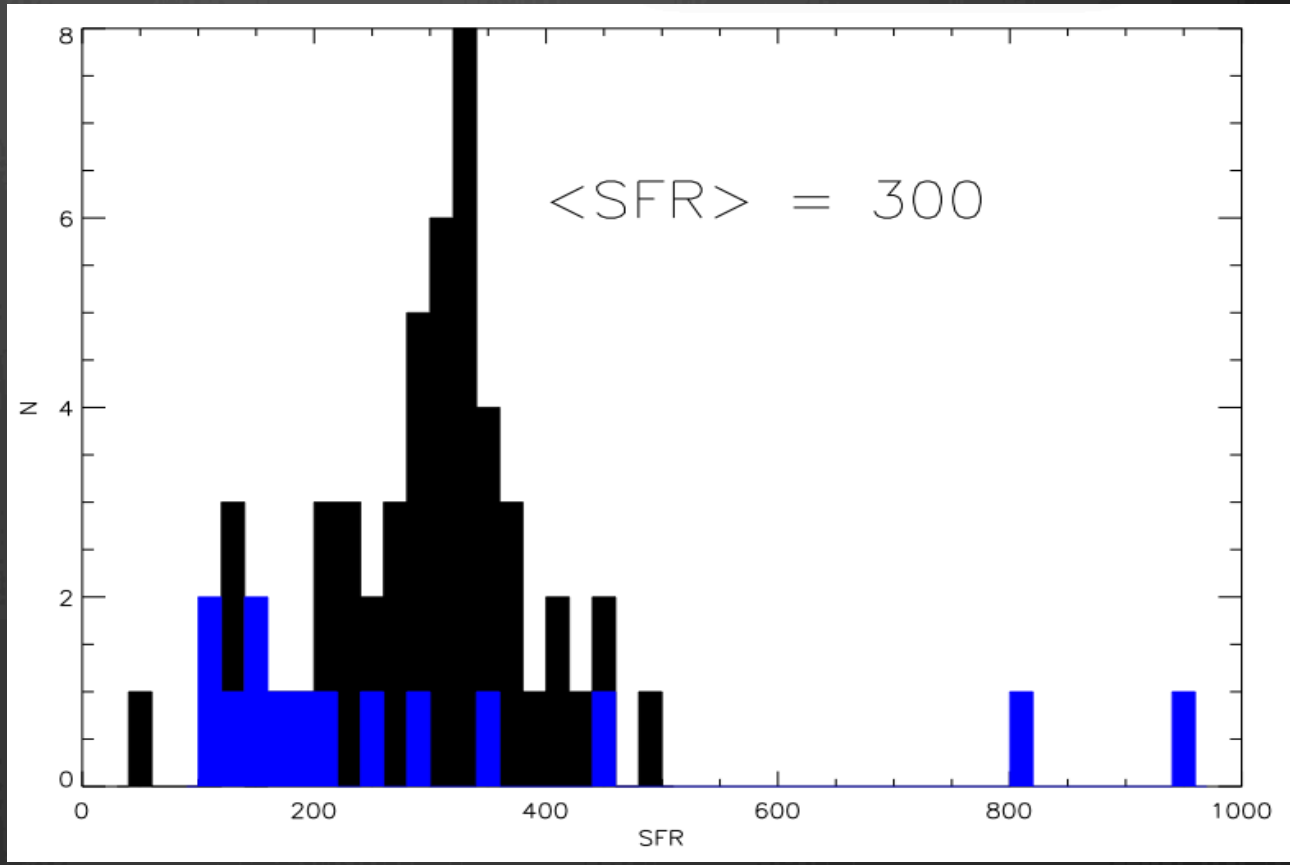
1 < z < 3



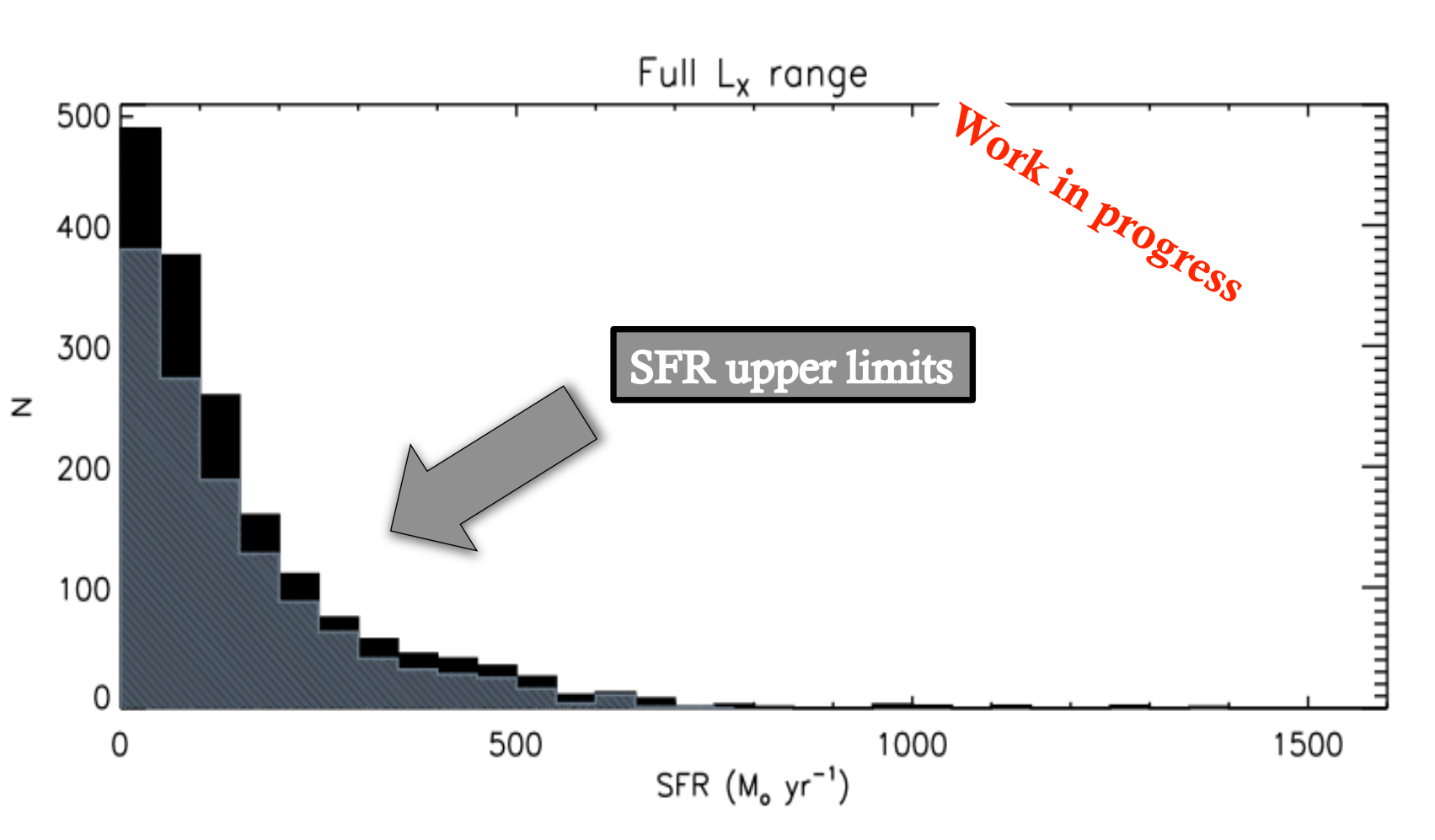
The discrepancy has disappeared!

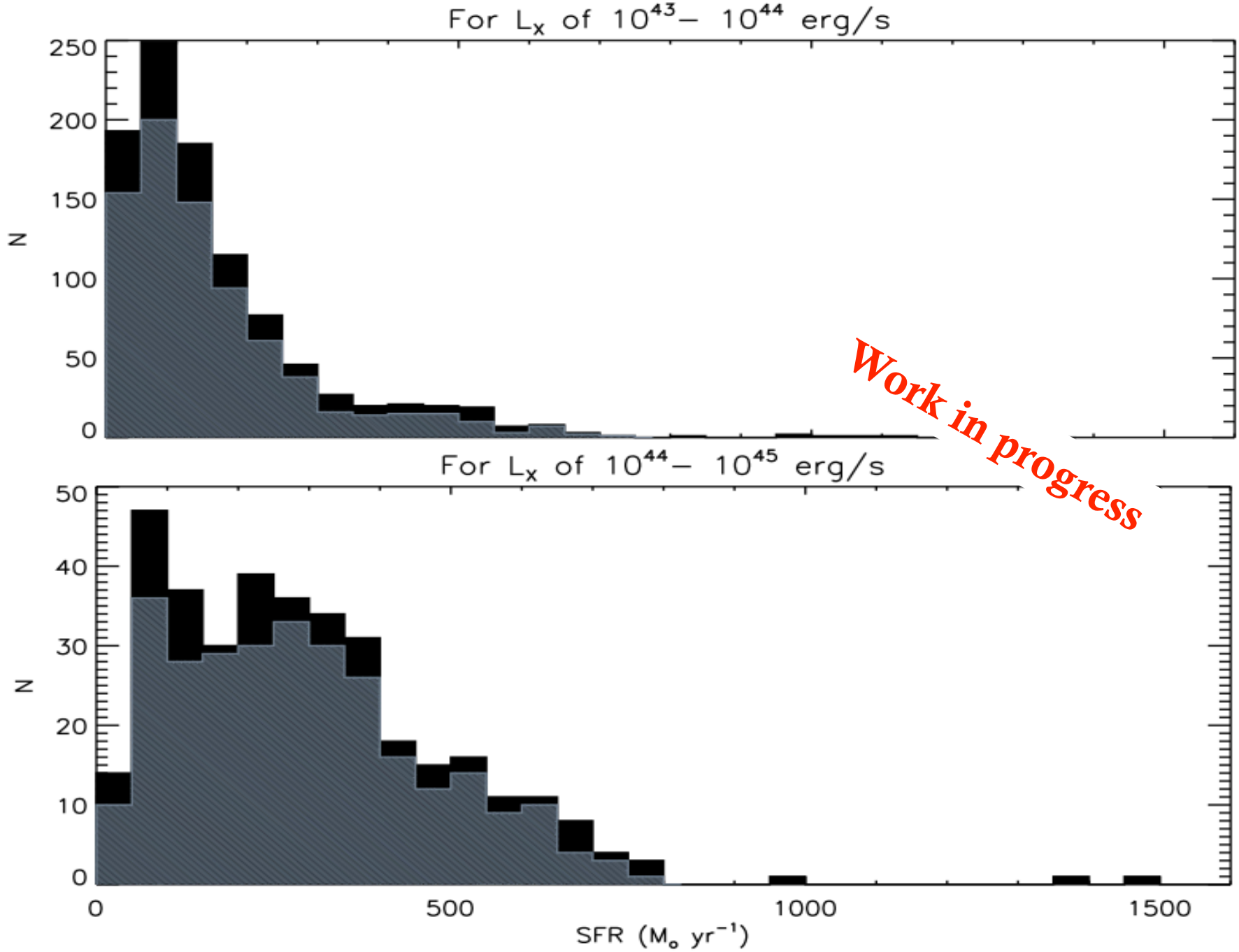
Hidden Information

- The mean value can give a good overview of the general population but will hide the extreme/ interesting cases



SFR distribution




For L_x of 10^{43}– 10^{44} erg/s
N
250
200
150
100
50
0
Work in progress
For L_x of 10^{44}– 10^{45} erg/s
N
50
40
30
20
10
0
0
500
1000
1500
SFR (M_o yr^{-1})

Summary

- Decomposing the FIR SED to the AGN and Host components is essential.
- Ignoring the upper limits in the analysis will bias the results.
- When using the Kaplan-Meier estimator to calculate the <SFR> the difference of the 3 fields at high Lx disappears, and all three fields are consistent with each other.

Up Next

- Detailed analysis of the distribution to uncover any hidden information
- Comparison of: - our distributions to models
  - the different Lx bins