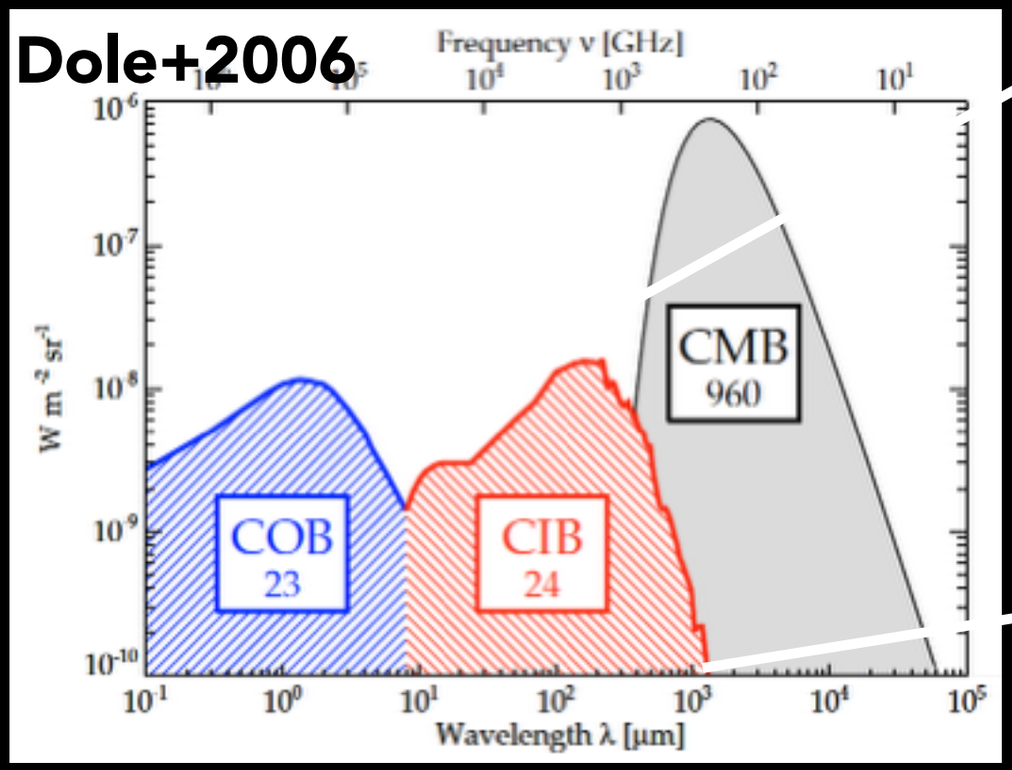
Resolving the Extragalactic Background into Normal Star Forming Galaxies with ALMA

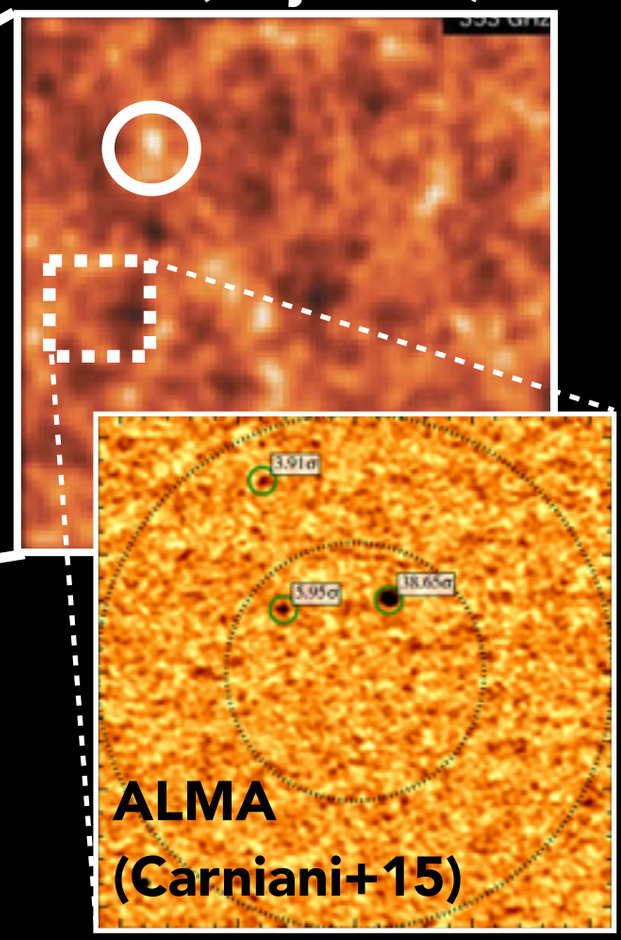
Seiji Fujimoto, Masami Ouchi, Yoshiaki Ono,
Masafumi Ishigaki, and Rieko Momose (University of Tokyo)

Extragalactic Background Light (EBL)

Dole+2006



Planck (Seljak+12)



Single-dish Sources

~1.0 – 10mJy

~10% (e.g., Scott+12)

ALMA Sources

~0.1 – 1.0 mJy

~60% (Hatsukade+13, Ono+14, Carniani+15)

EBL have not been fully resolved…

This work:

Largest dataset of multi-field deep ALMA

-> Resolve EBL

Sample Selection

DATA : ALMA Band 6 & 7

- Our quite deep 4 ALMA data

+

- ALL ALMA data so far archived (2011/12 - 2015/3)

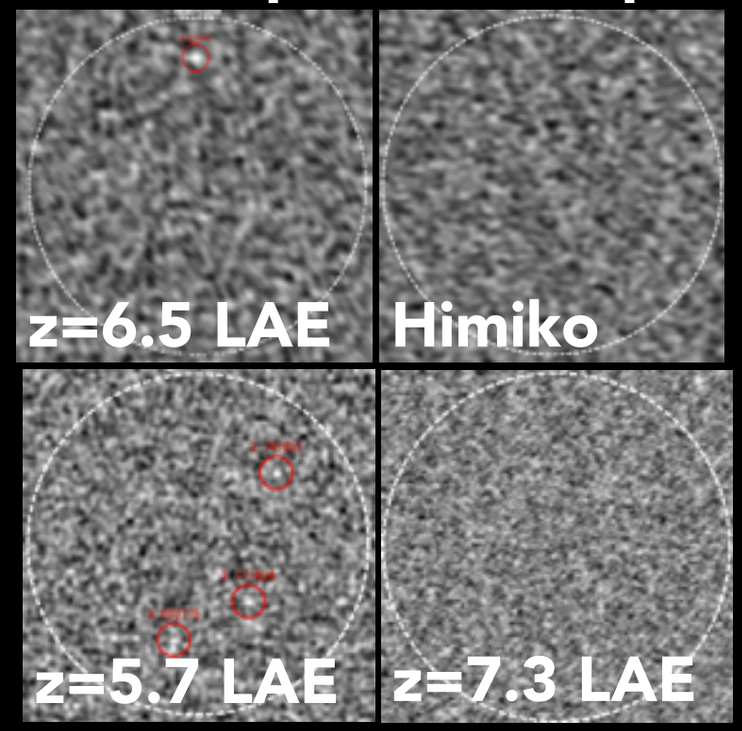
- Noise level < 0.1 mJy
- No too Bright/Extended Sources

Total : ~51 maps (~100 pointings)

Survey Area: ~7arcmin^2 (Largest Survey)

Noise level : 8.5 - 100 uJy

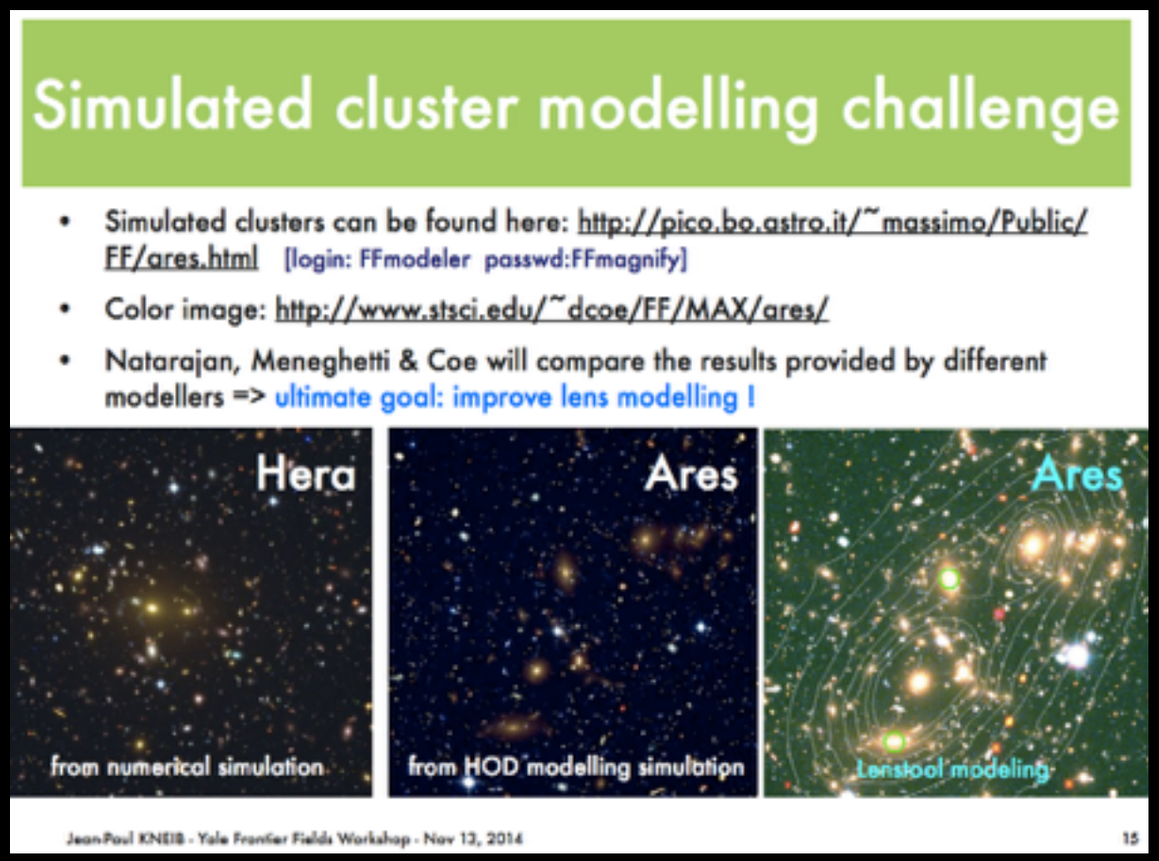
Our Deep ALMA Maps



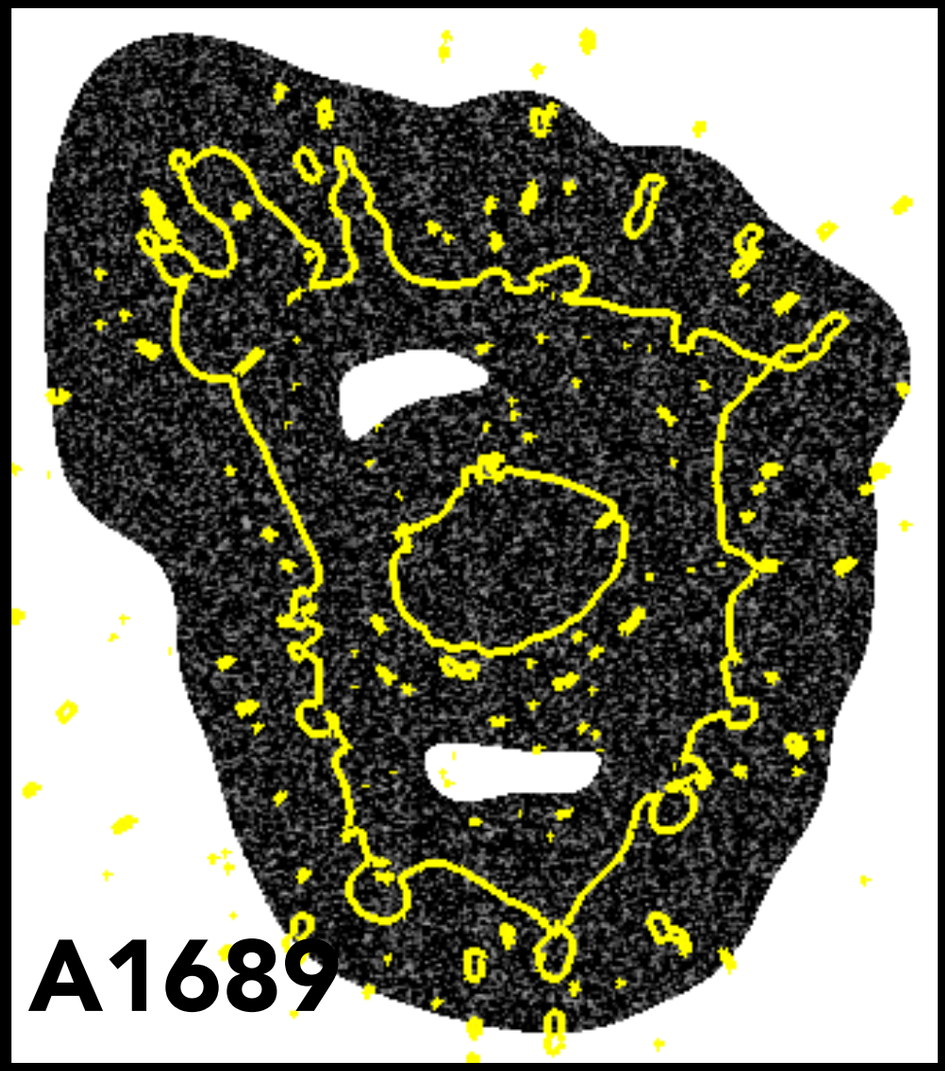
Cluster Data (1 map)

- Multiple image: Diego+14
- Optical Catalog: Diego+14, Coe+10
- Software: GLAFIC (Oguri 10)

(e.g., Ishigaki+15)



(Organized by D. Coe+)

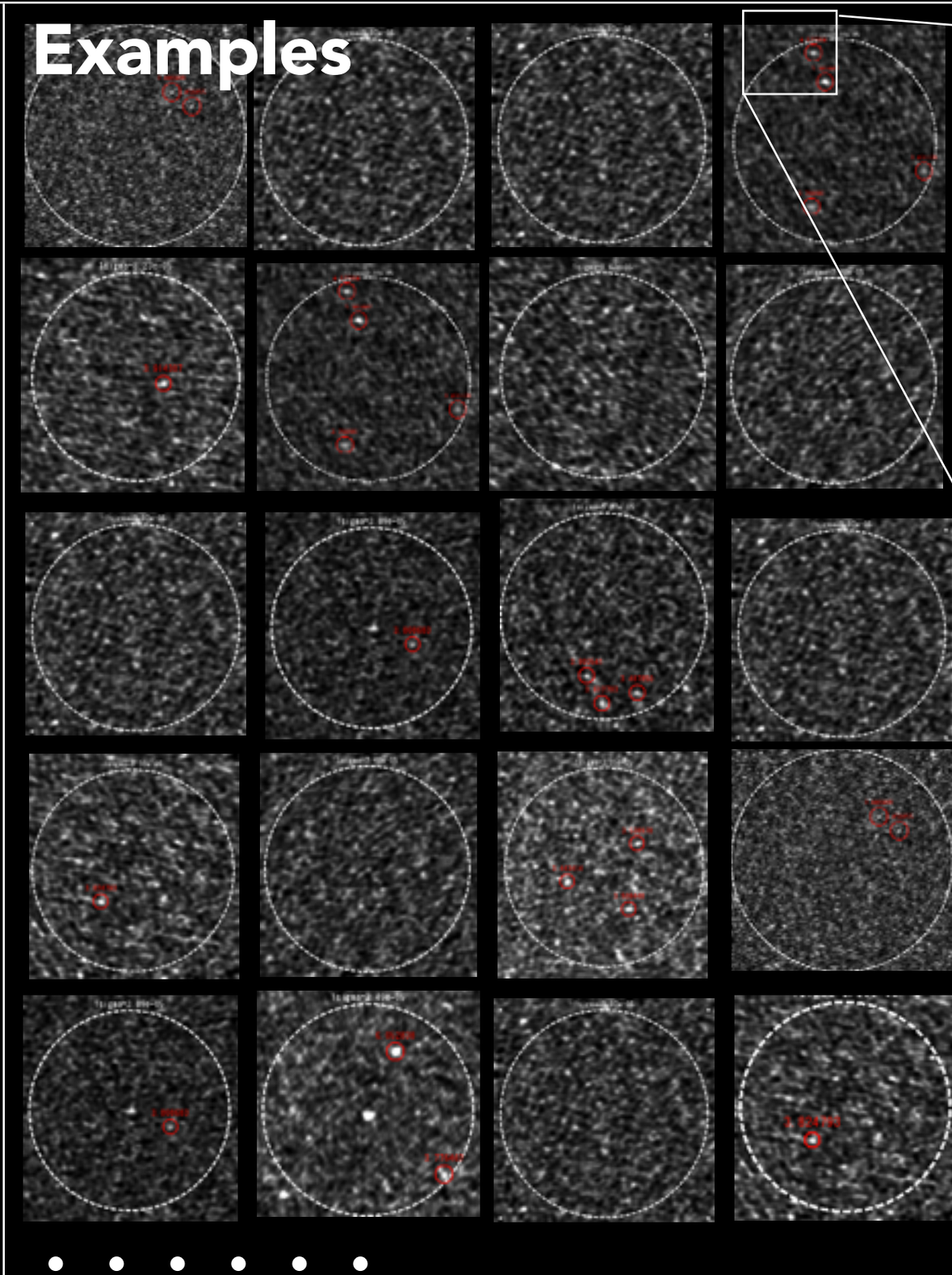


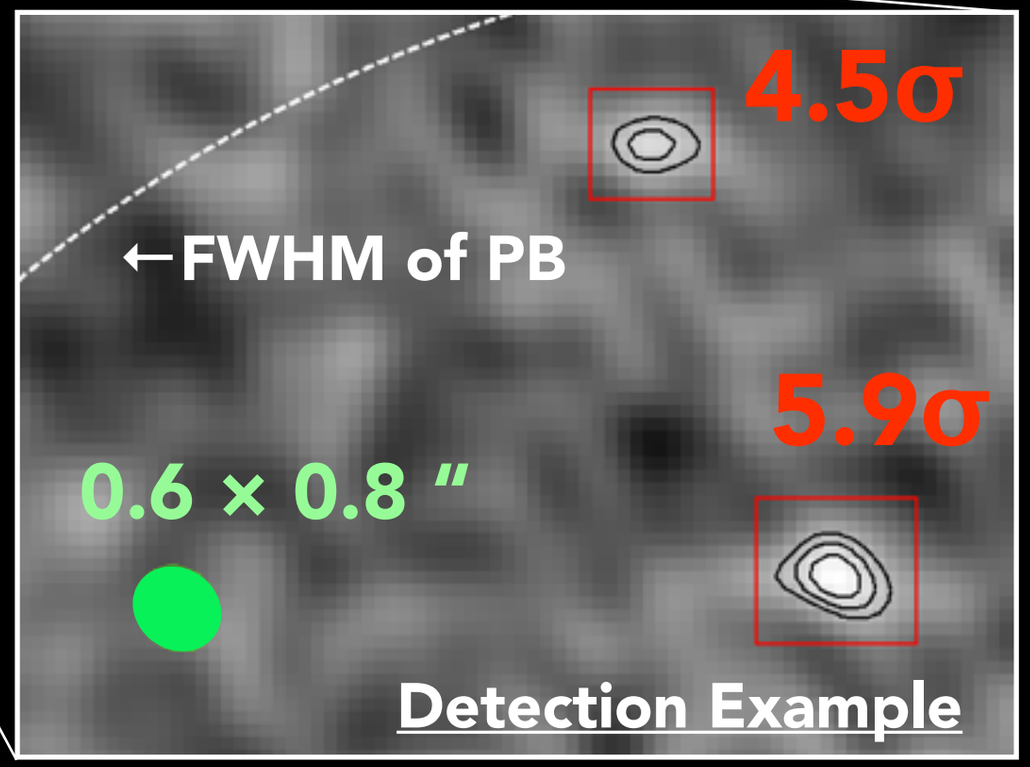
Critical Line

Mass model uncertainty is reported ~ 20-30%.

Field Data (50 maps)

Examples





* Original Target Sources Removed

Total Sources : 85

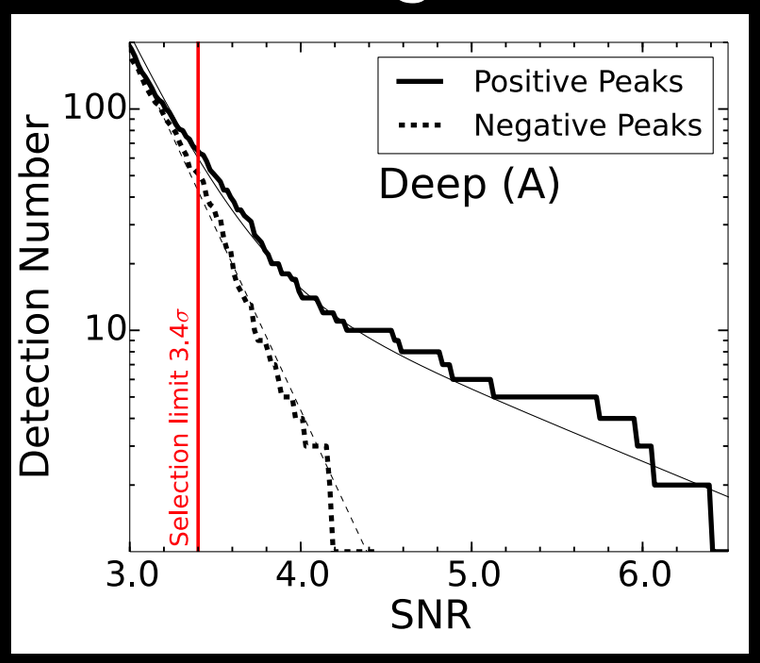
Data Analysis

Resolve EBL -> Derive Number Counts

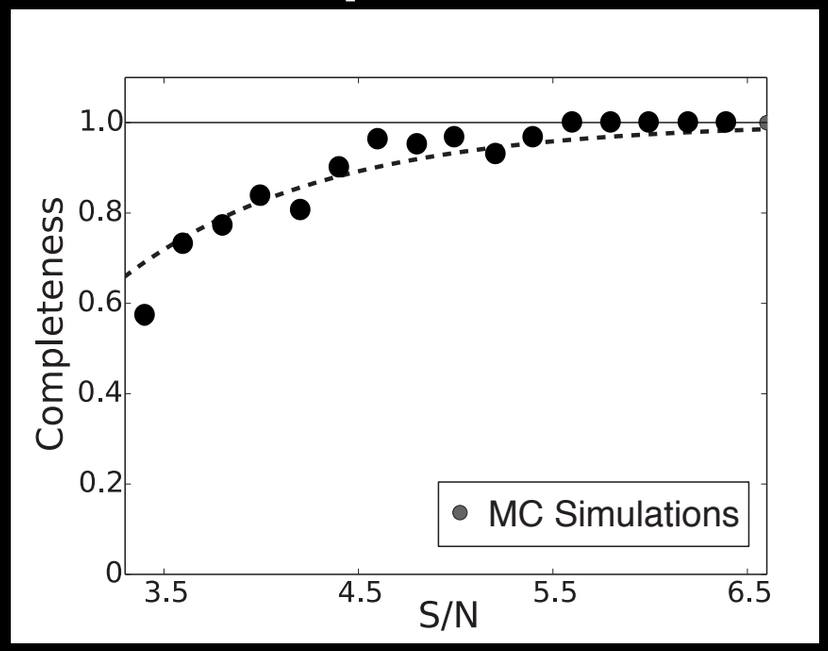
$$N_{eff} = \frac{1 - R_S(S/N)}{C(S/N)}$$

Rs (S/N): Spurious Source Rate
C (S/N): Completeness

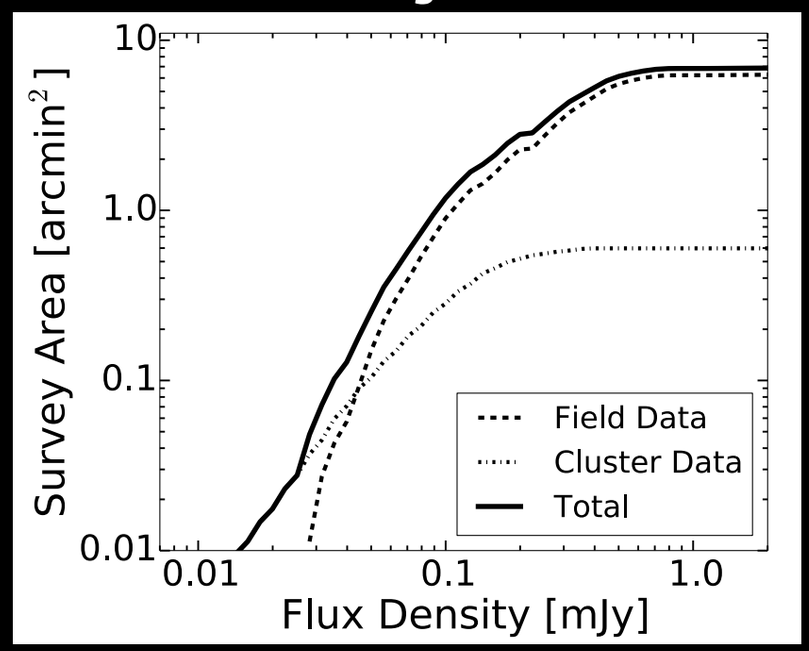
Positive & Negative Peaks



Completeness



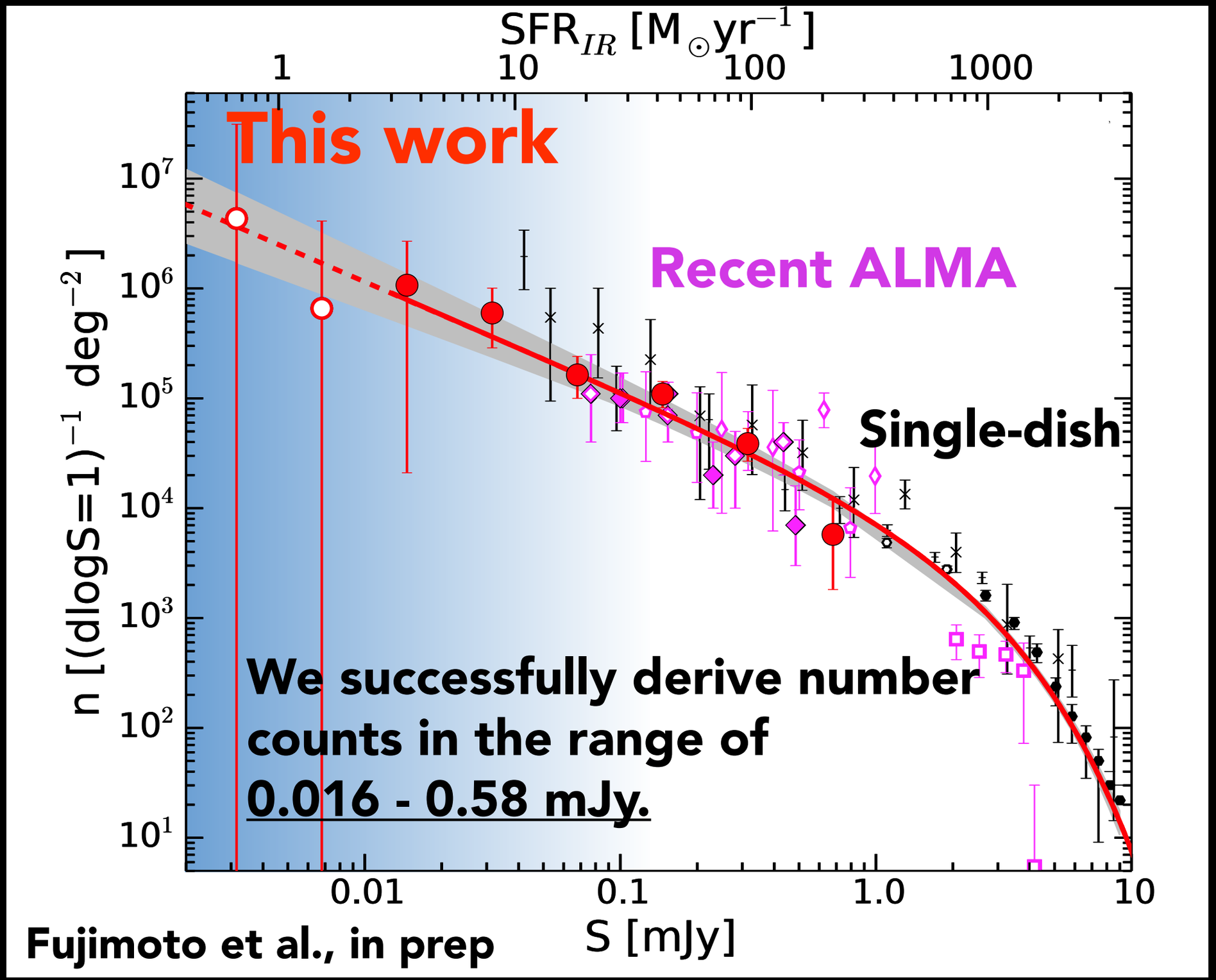
Survey Area



(e.g., Hatsukade+13, Ono+14, Carniani+15)

*** All flux densities (1.1-1.3 mm) are scaled to 1.2 mm**

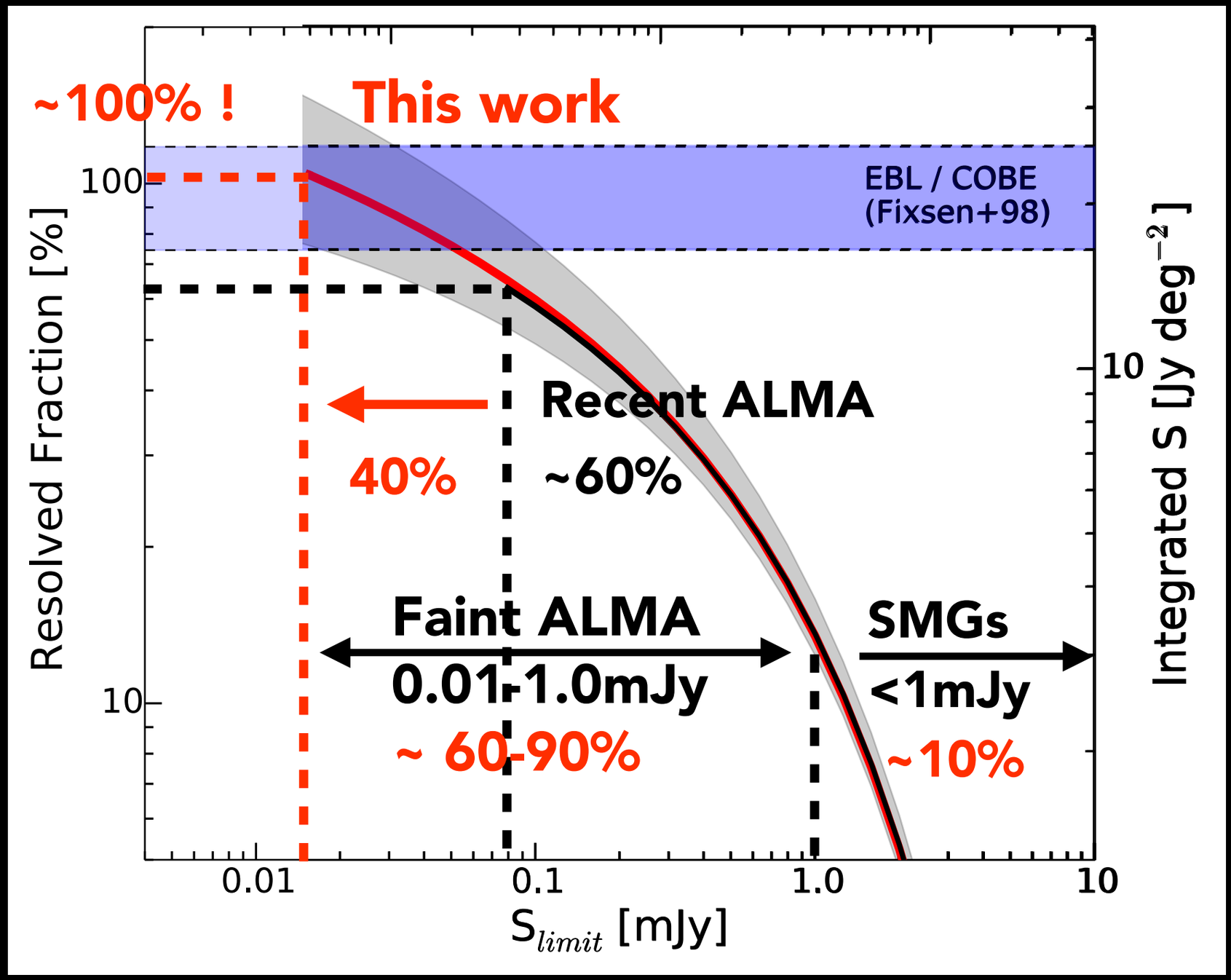
Number Counts at 1.2 mm



Fujimoto et al., in prep

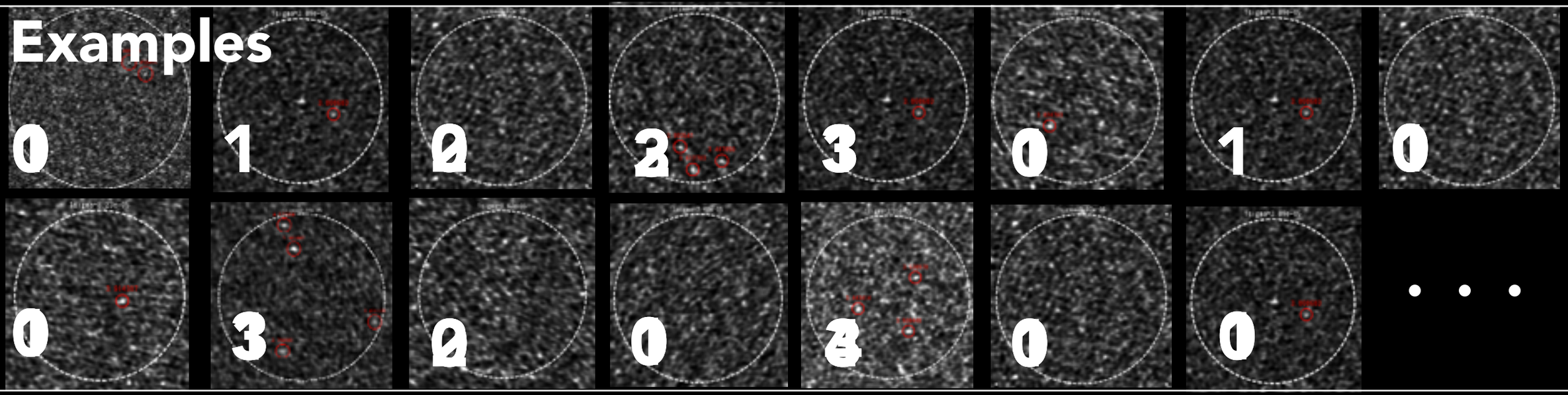
Resolve the EBL

- **Almost fully (102±30%) resolve the EBL**
- **< 0.01 mJy sources might be negligible**



What are the faint ALMA sources ?

1. Statistical Approach: Cluster Analysis



Field-to-Field Scatter - Poisson error = Galaxy Bias

Counts-in-Cells

$$b_g^2 \approx \frac{\sigma_N^2 - \bar{N}}{\bar{N}^2 \sigma_V^2(z)}$$

(e.g., Robertson+10)

b_g: galaxy bias σ_V: matter variance

σ_N: dispersion of source counts

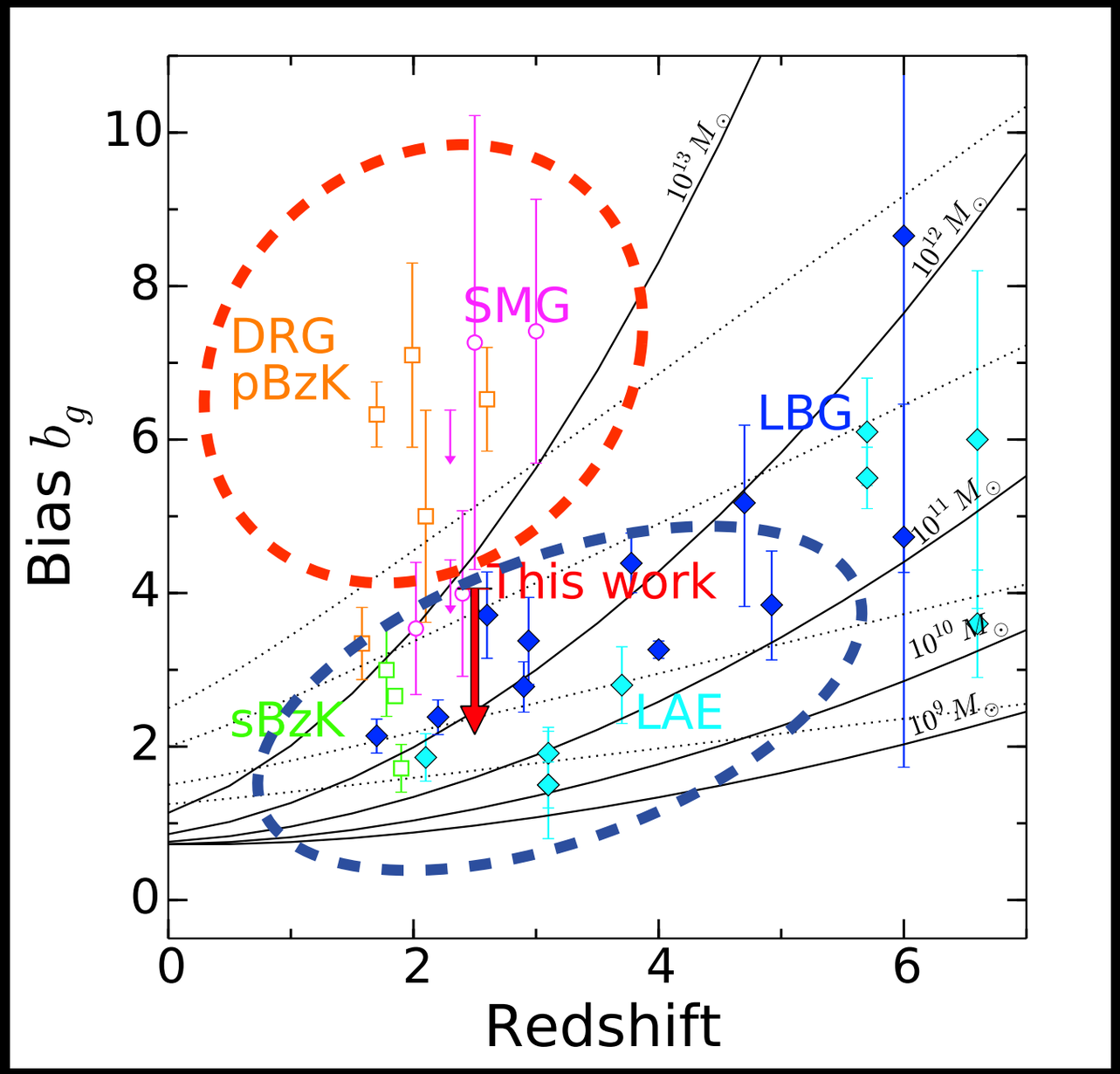
N: mean source counts

Faint ALMA Sources

$b_g < 4.1$

(ΛCDM->) $M_{DH} < 8 \times 10^{12}\ M_{sun}$

1. Statistical Approach: Cluster Analysis

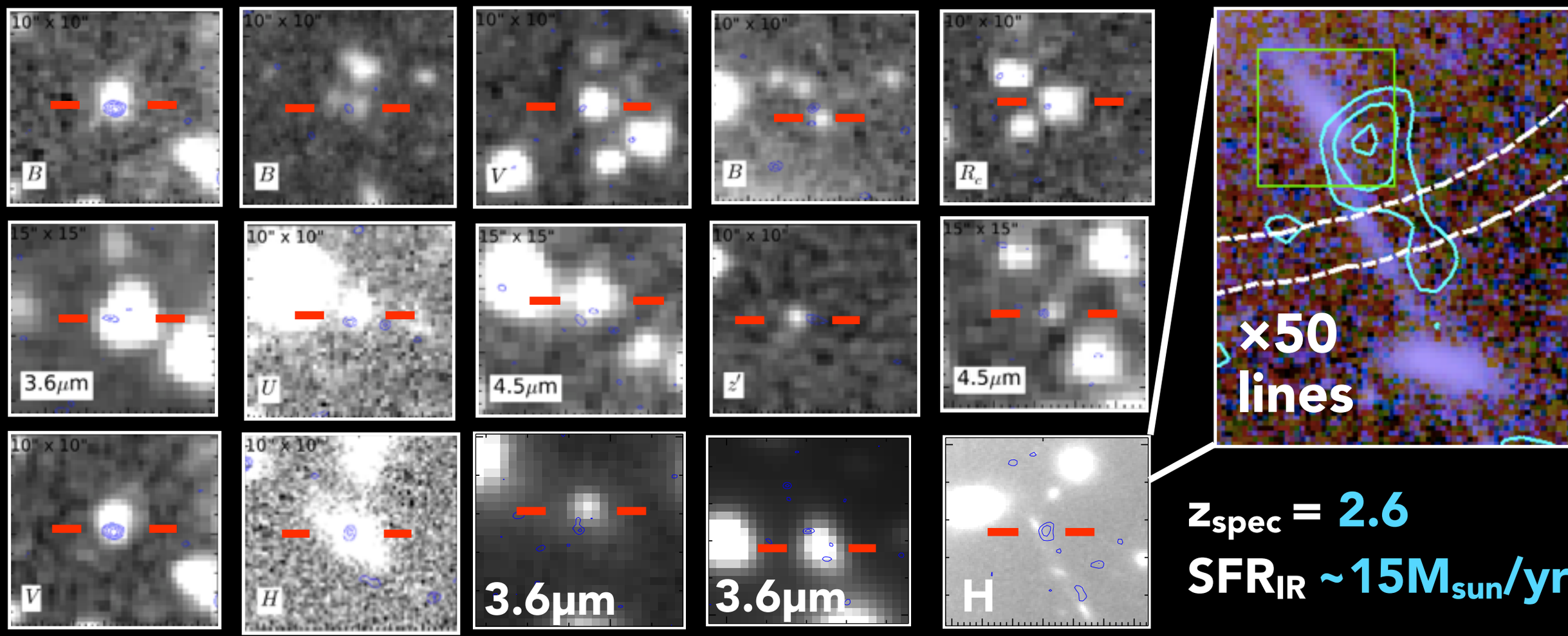


- Faint ALMA Sources
  $b_g < 4.1$
- SMGs / DRGs / pBzK
  $b_g \sim 5 - 7$
- sBzK / LBGs / LAEs
  $b_g \sim 2 - 3$

Faint ALMA Sources = sBzK, LBGs, LAEs?

2. Individual-basis Approach: Optical Counterparts

- Optical counterparts in SXDS, A1689 with rich multi-wavelength data
- 25 sources in these fields effectively (N_{det} - N_{spu})
- 15/25 Sources (~60%) have optical counterparts

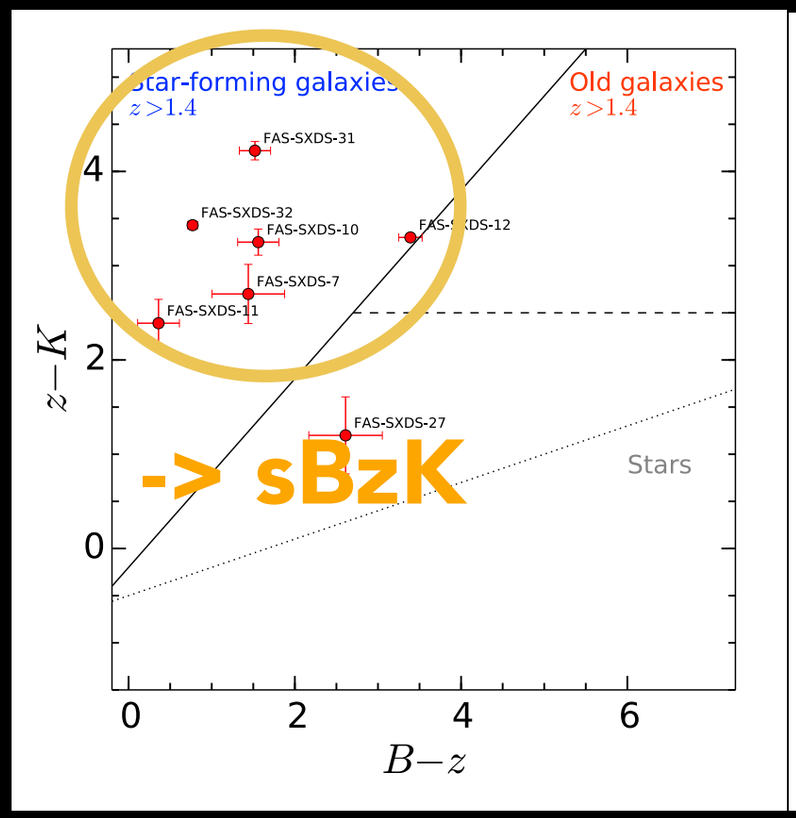


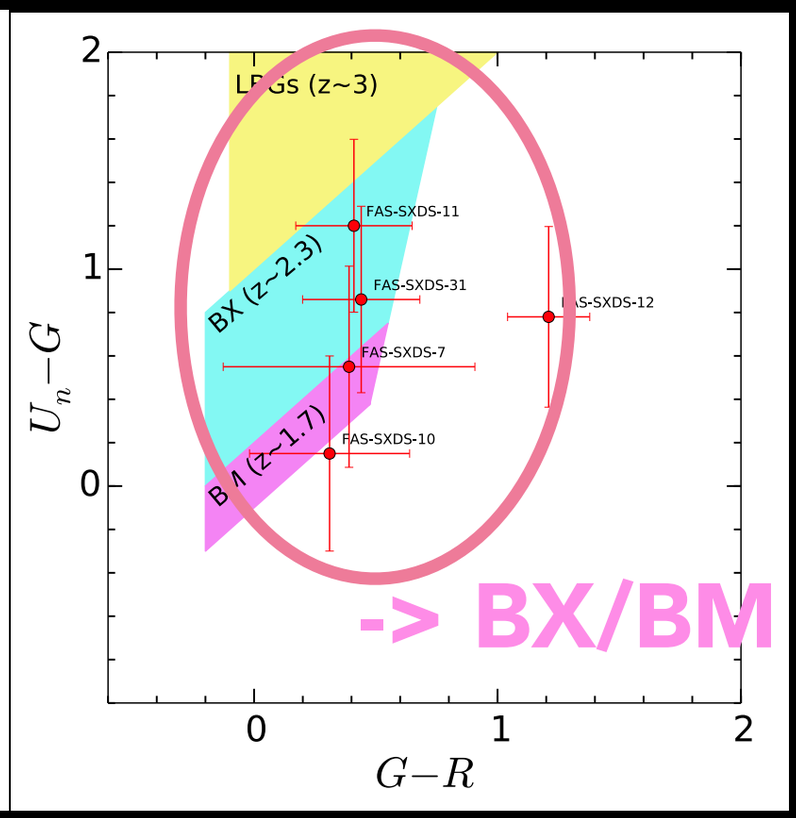
z_{spec} = 2.6

SFR_{IR} ~15M_{sun}/yr

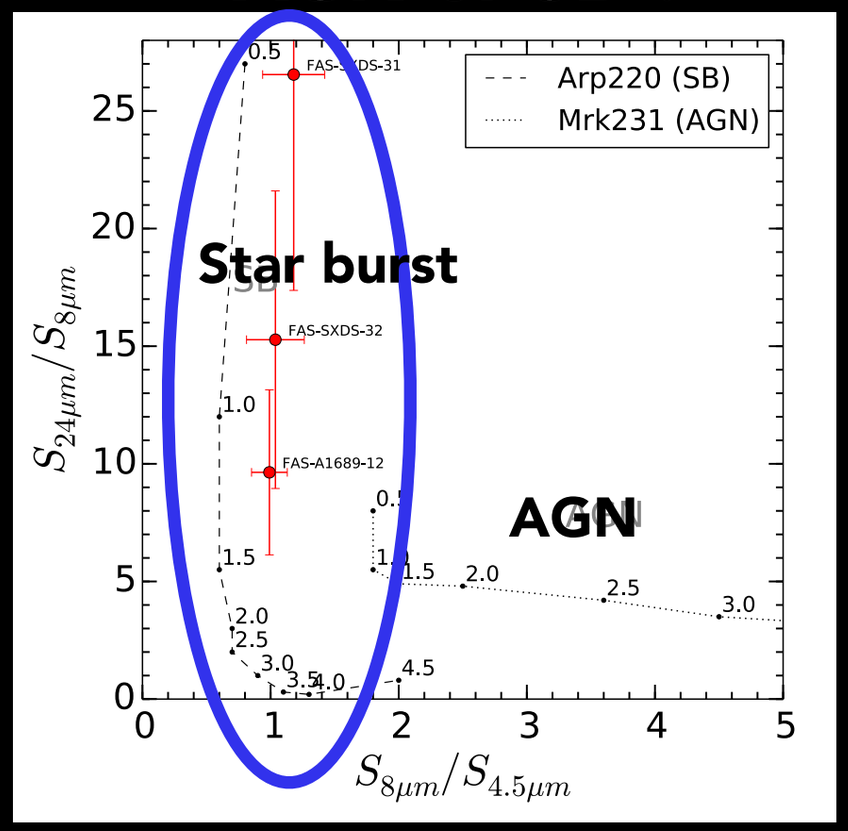
Photometric Properties

Bzk & LBG Selection





AGN or SB ?

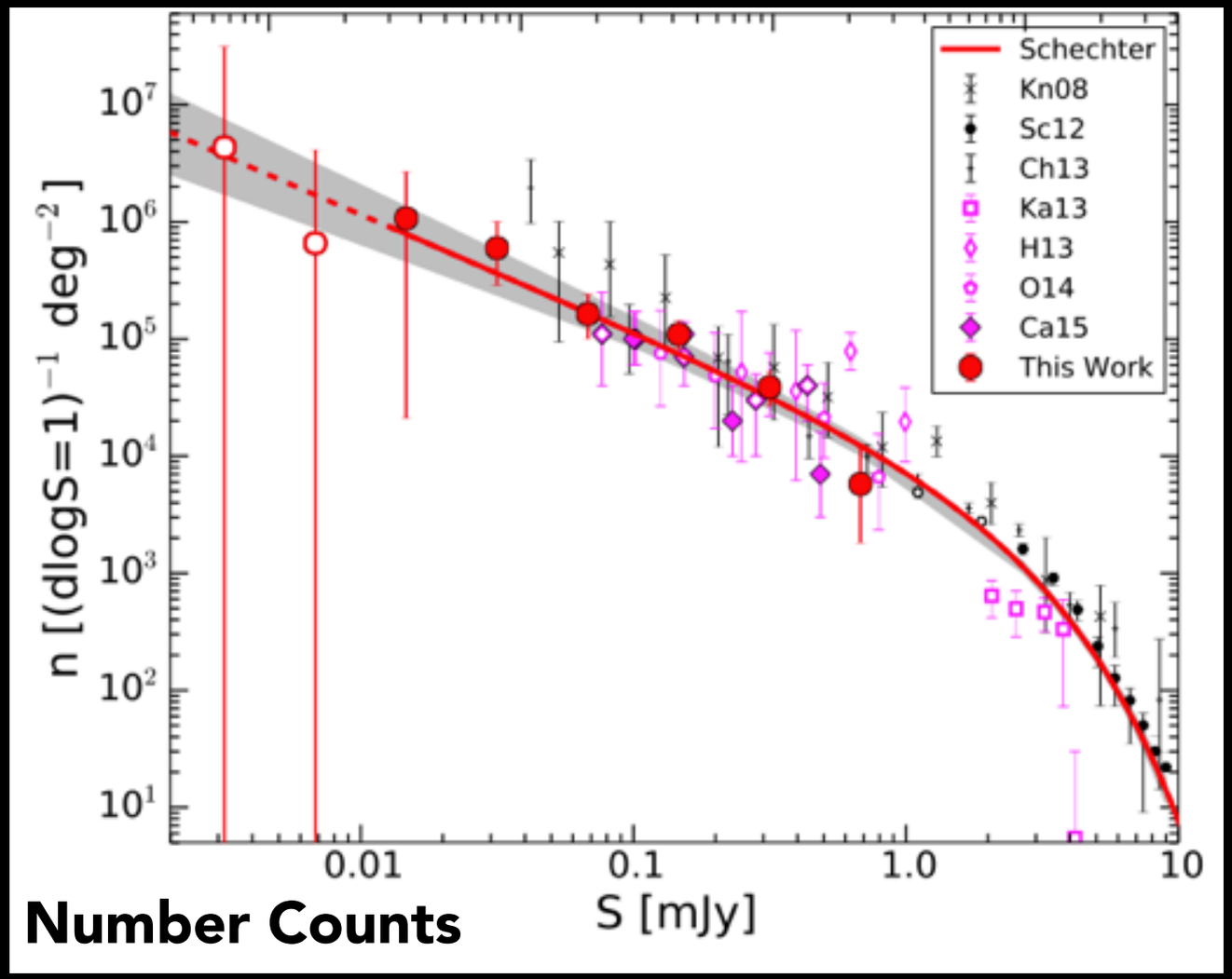


Faint ALMA Sources = sBzK / LBG(BX/BM)

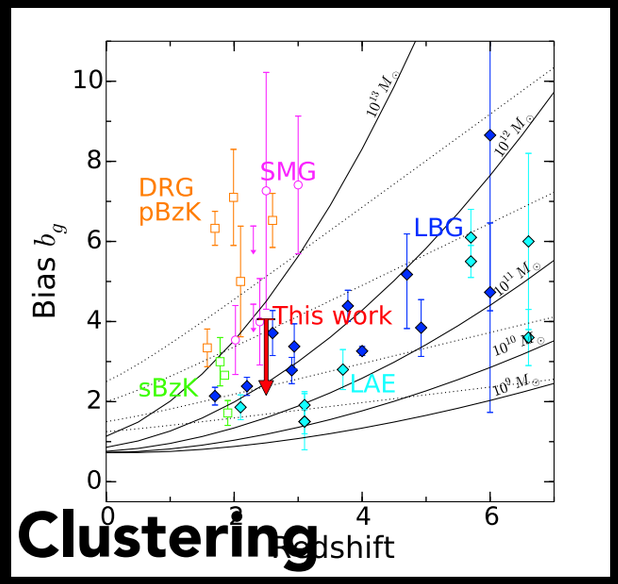
- Clustering (Statistical)
- Opt. Counterparts (Individual)

Faint ALMA Sources
↓
Optically Selected SFGs

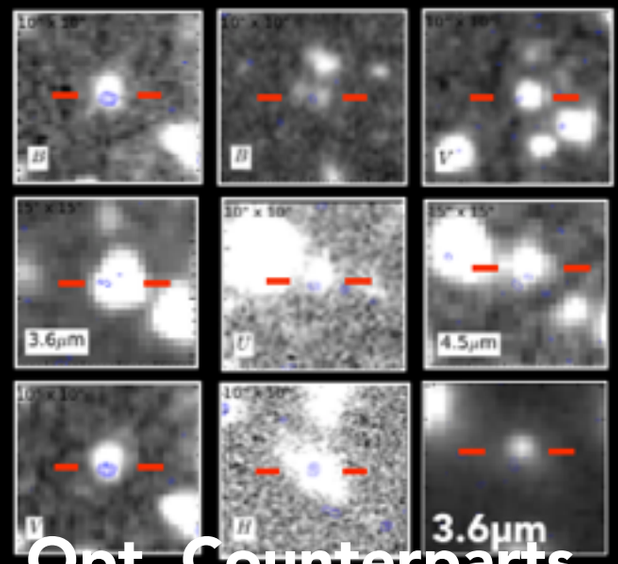
Summary



Number Counts



Clustering



Opt. Counterparts

- **Largest** ALMA Dataset (85 sources: down to 0.01 mJy)
- Number Counts -> Resolve ~ 100% of EBL

What are Faint ALMA Sources ?

- -> Opt. Selected SFGs (Clustering & Opt. Counterparts)

This research was supported(, in part,) by a grant from
the Hayakawa Satio Fund awarded by the Astronomical Society of Japan.