ALMACAL

SURVEY THE UNIVERSE WITH ALMA CALIBRATION OBSERVATIONS

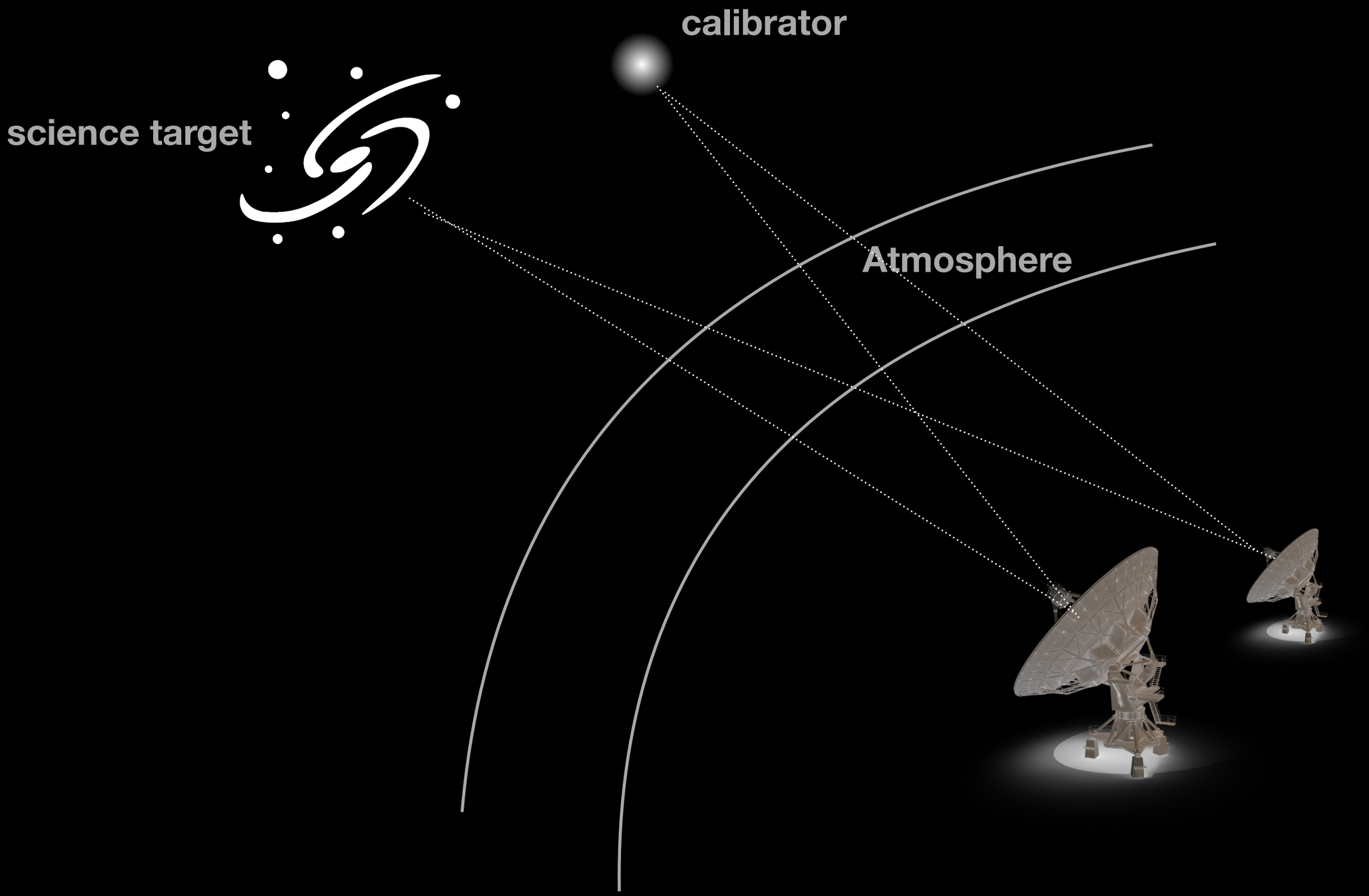
Multi-band ALMA survey for dusty star-forming galaxies

Jianhang Chen (陈建杭)

Collaborators: Rob Ivison, Martin Zwaan, Ian Smail, Anne Klitsch, Céline Péroux, Andrew Biggs, Roland Szakacs, Claudia Lagos, Gergö Popping

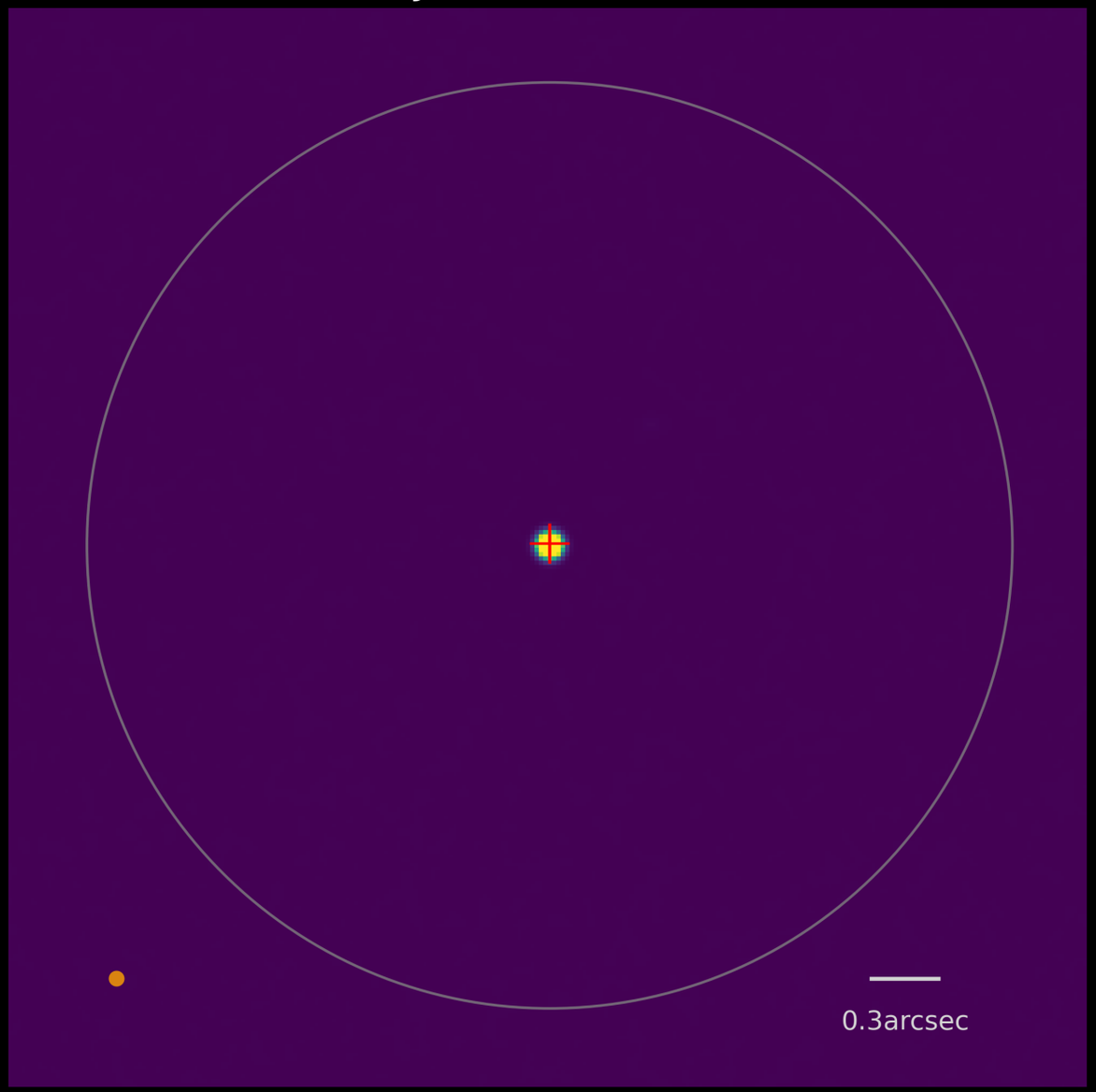
ALMACAL

Turning ALMA into a survey instrument

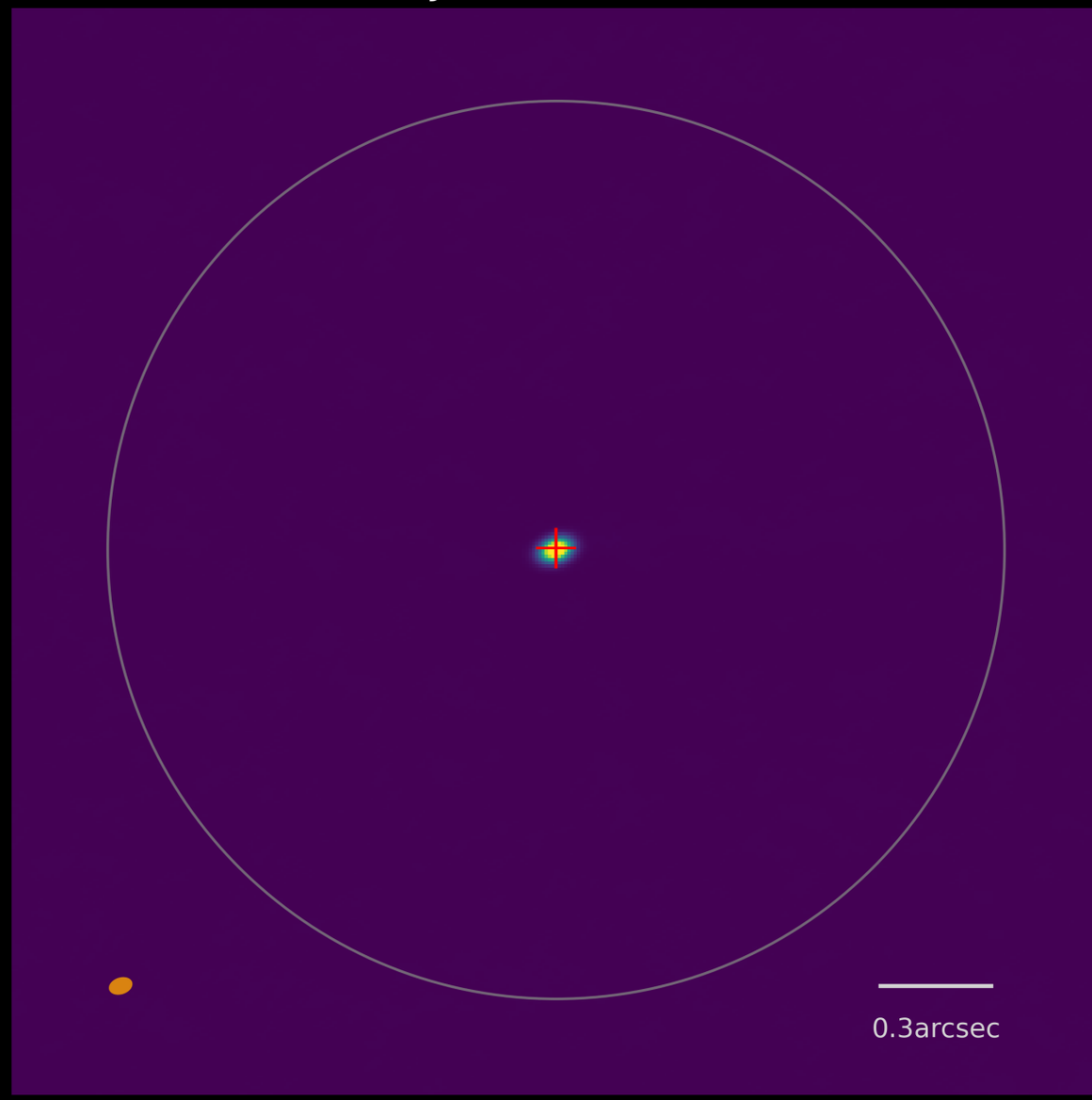


ALMACAL

J0108+0135

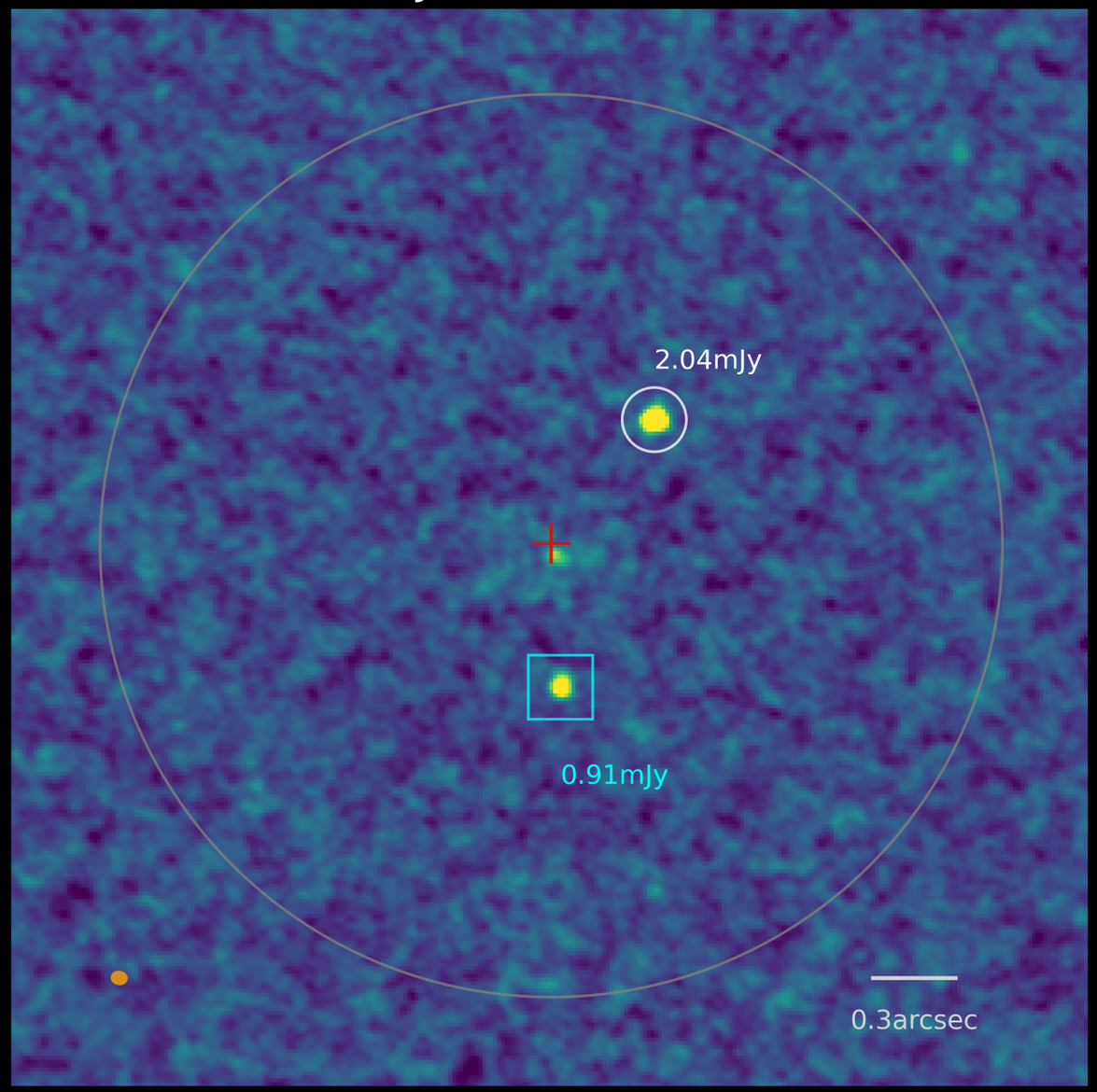


J0635-7516

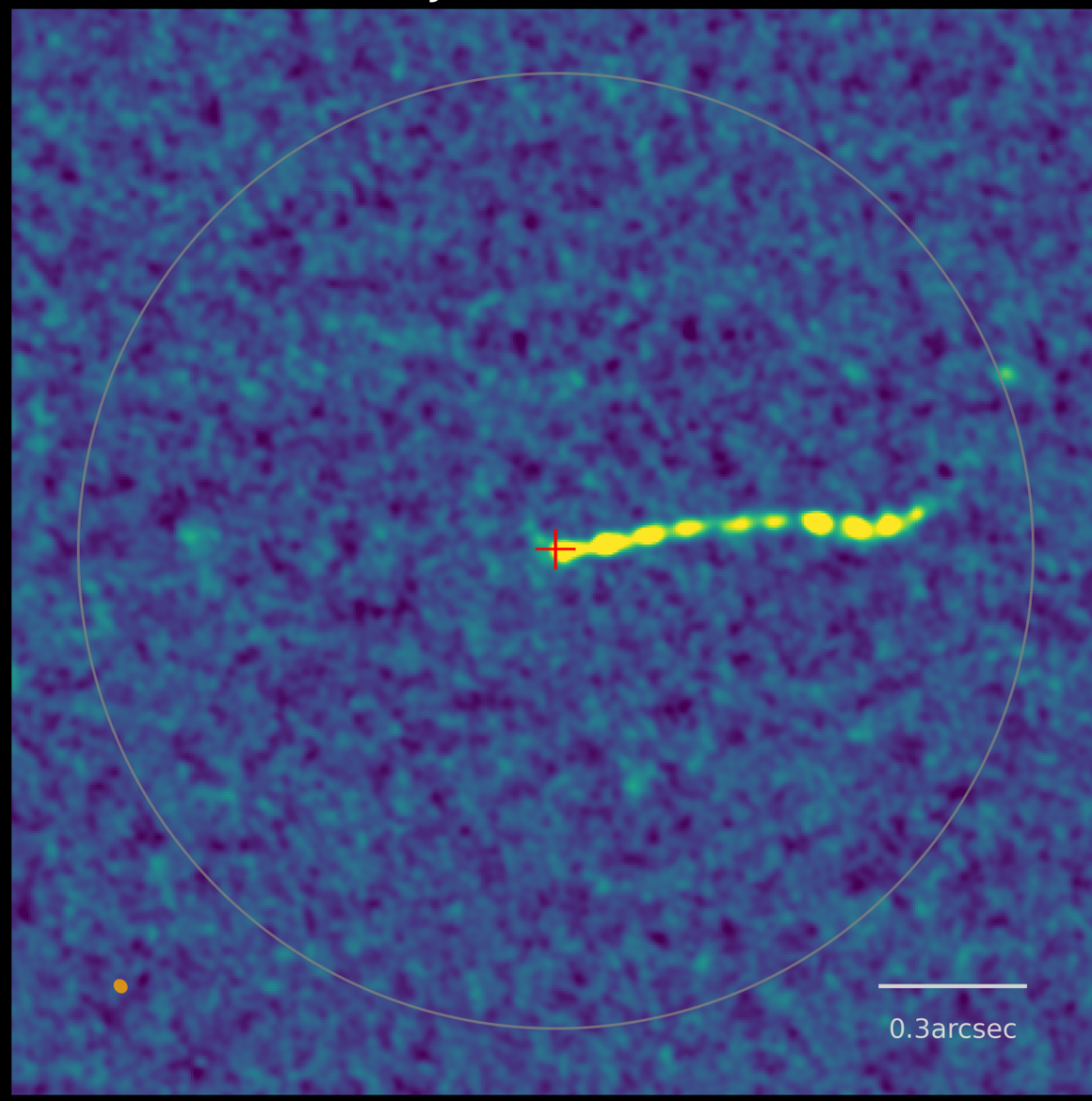


ALMACAL

J0108+0135



J0635-7516

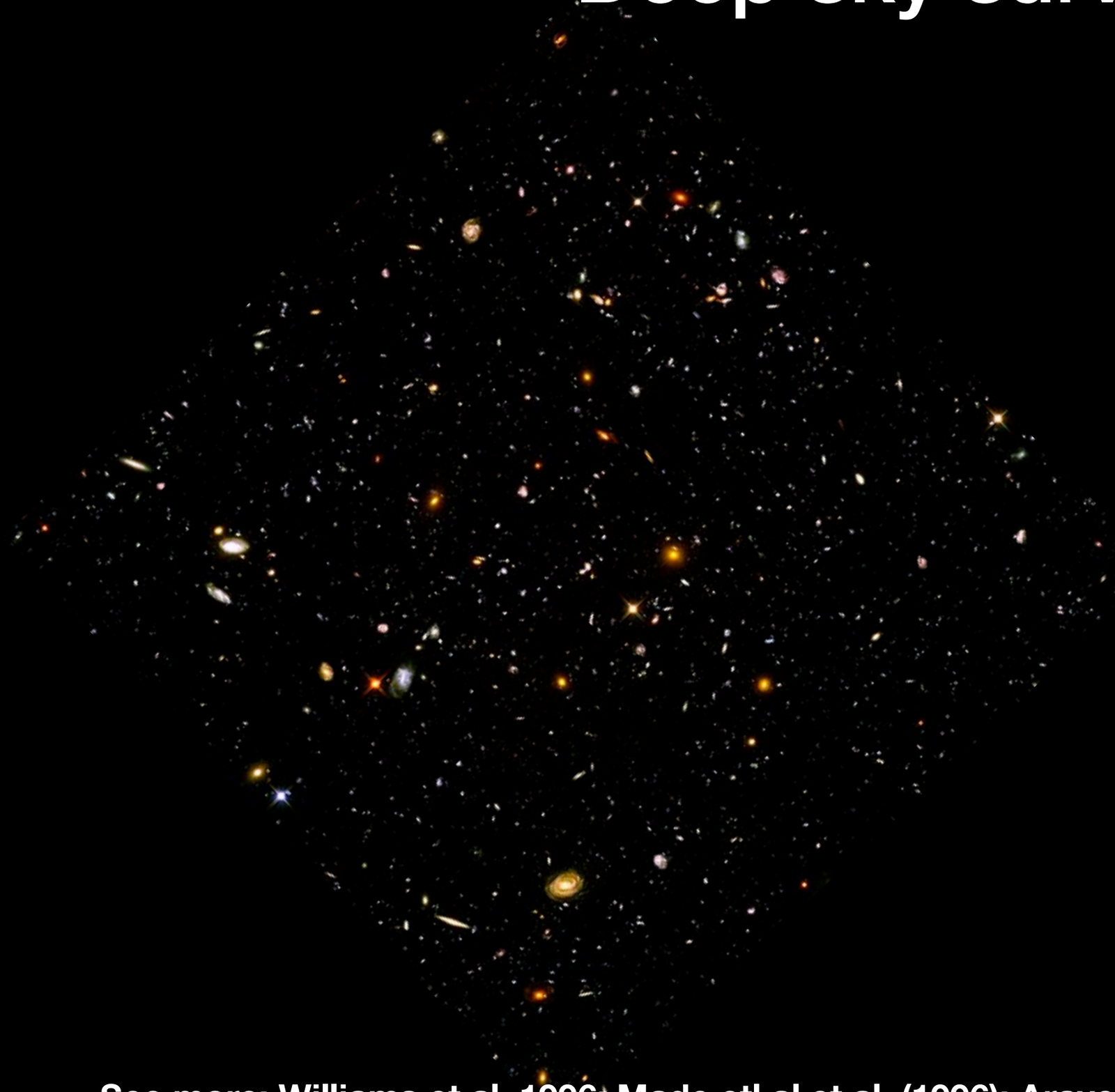


ALMACAL: statistics

Band	Number of fields	On-source time /hr	Number of detections	SMGs	Radio sources
3	668	250.58	44	3	11
4	269	53.08	31	16	8
5	76	20.80	13	9	4
6	670	344.71	170	108	21
7	407	275.17	104	81	10
8	114	52.67	16	15	0
9	37	20.89	2	2	0
10	5	0.46	0	0	0

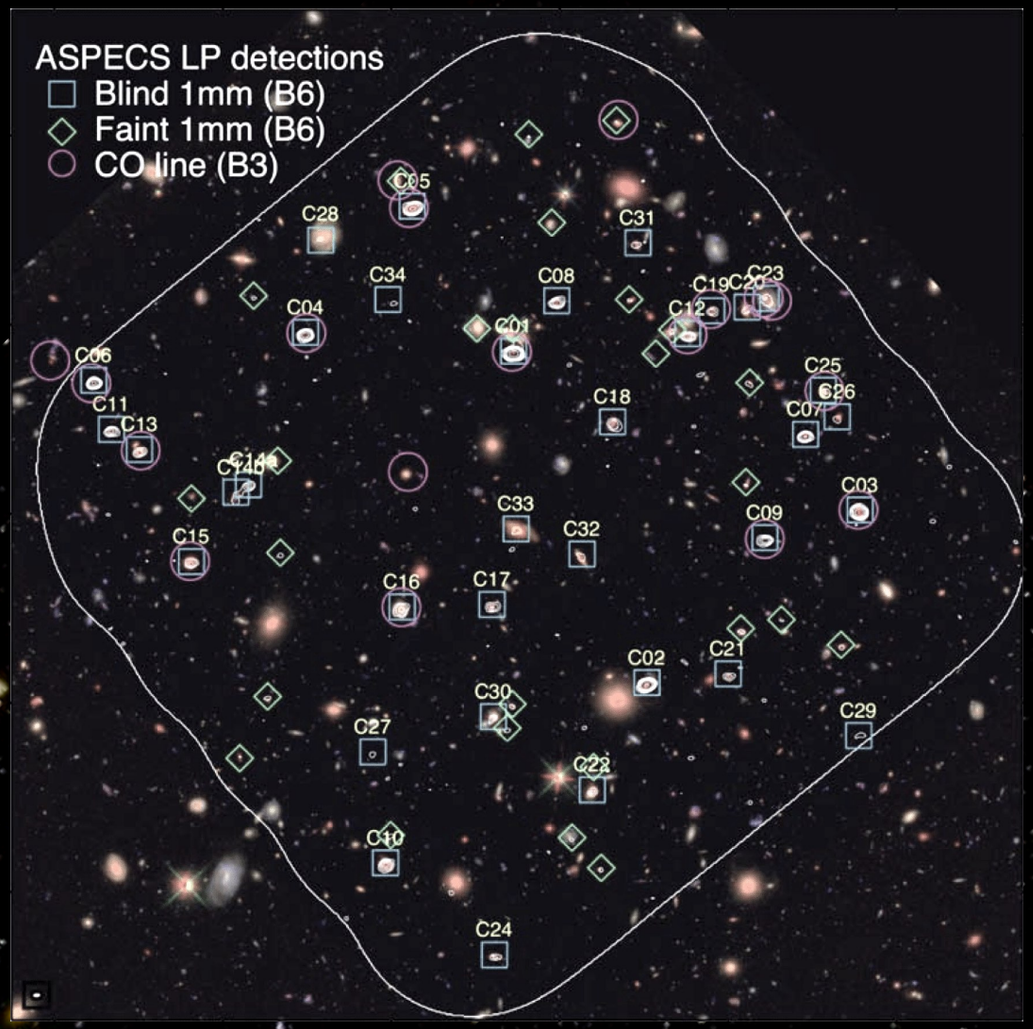
Chen et al. (arXiv: 2210.09329)

Deep sky survey



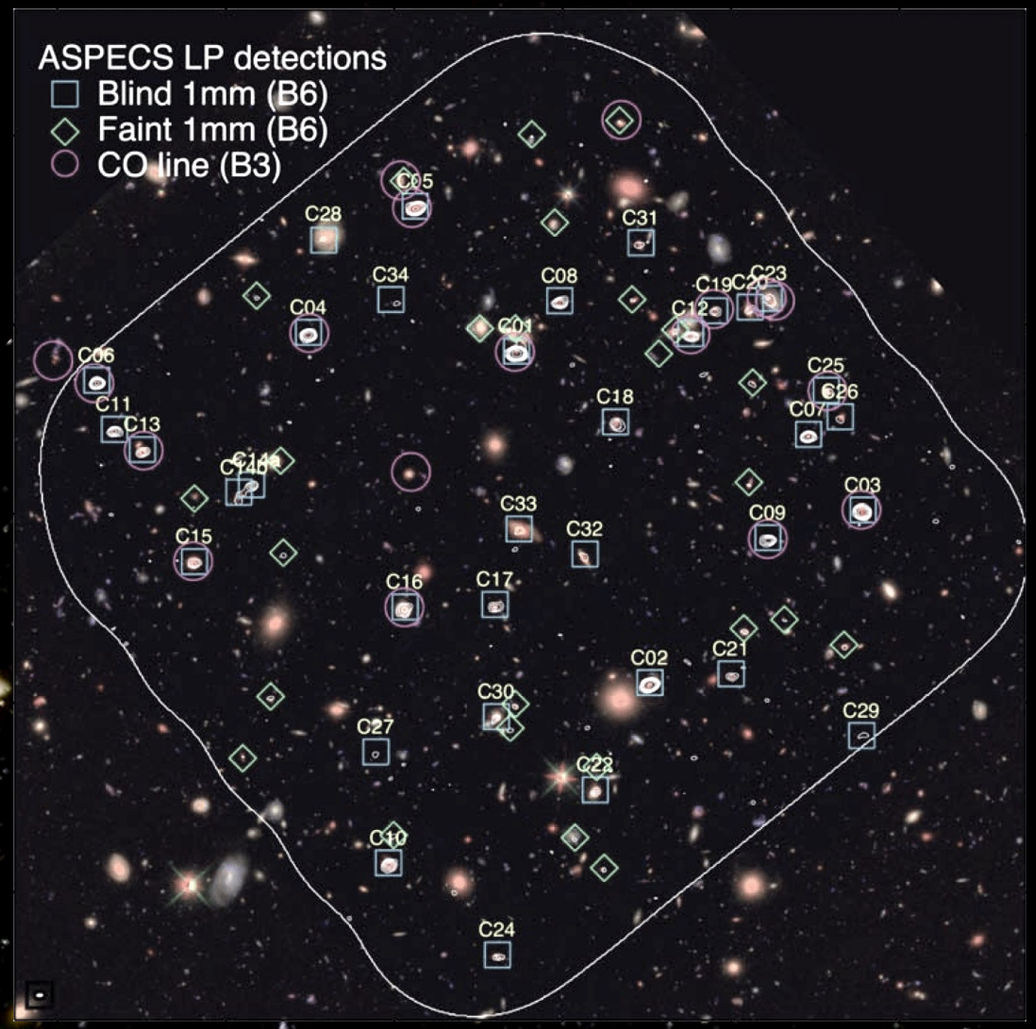
See more: Williams et al. 1996; Made etl al et al. (1996); Aravena et al. 2020; Walter et al. 2016,2020

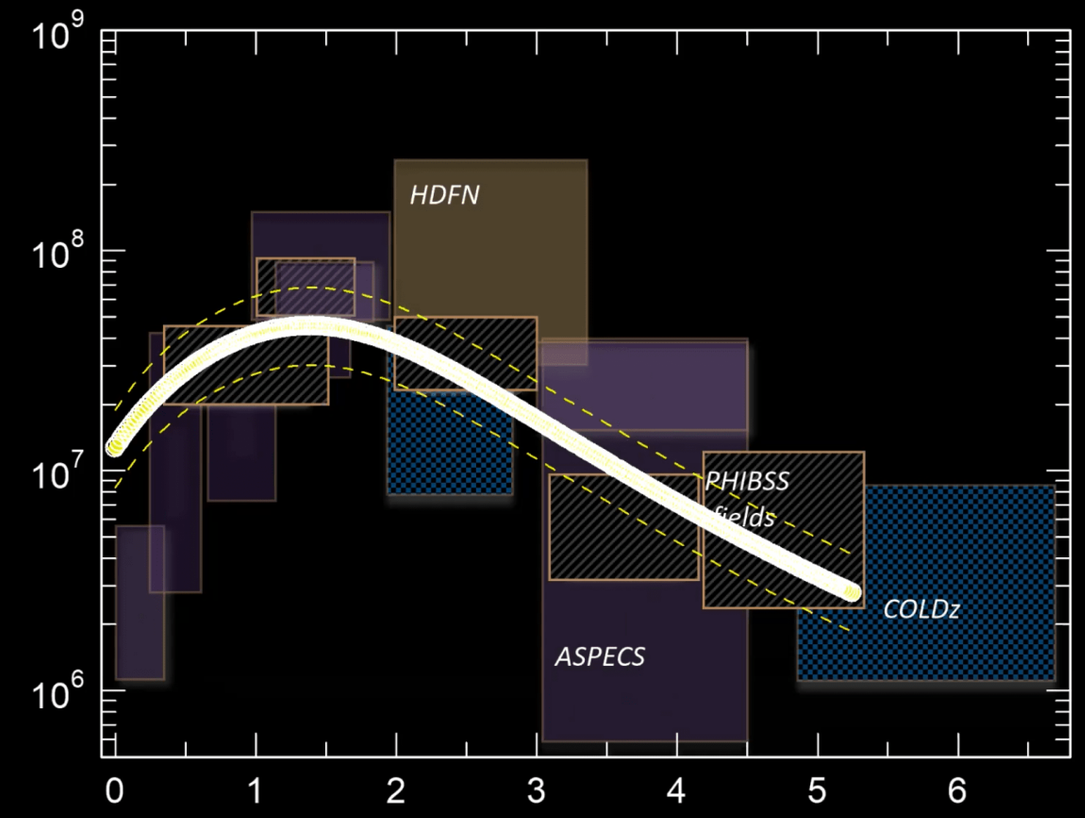
Deep sky survey



See more: Williams et al. 1996; Made etl al et al. (1996); Aravena et al. 2020; Walter et al. 2016,2020

Deep sky survey

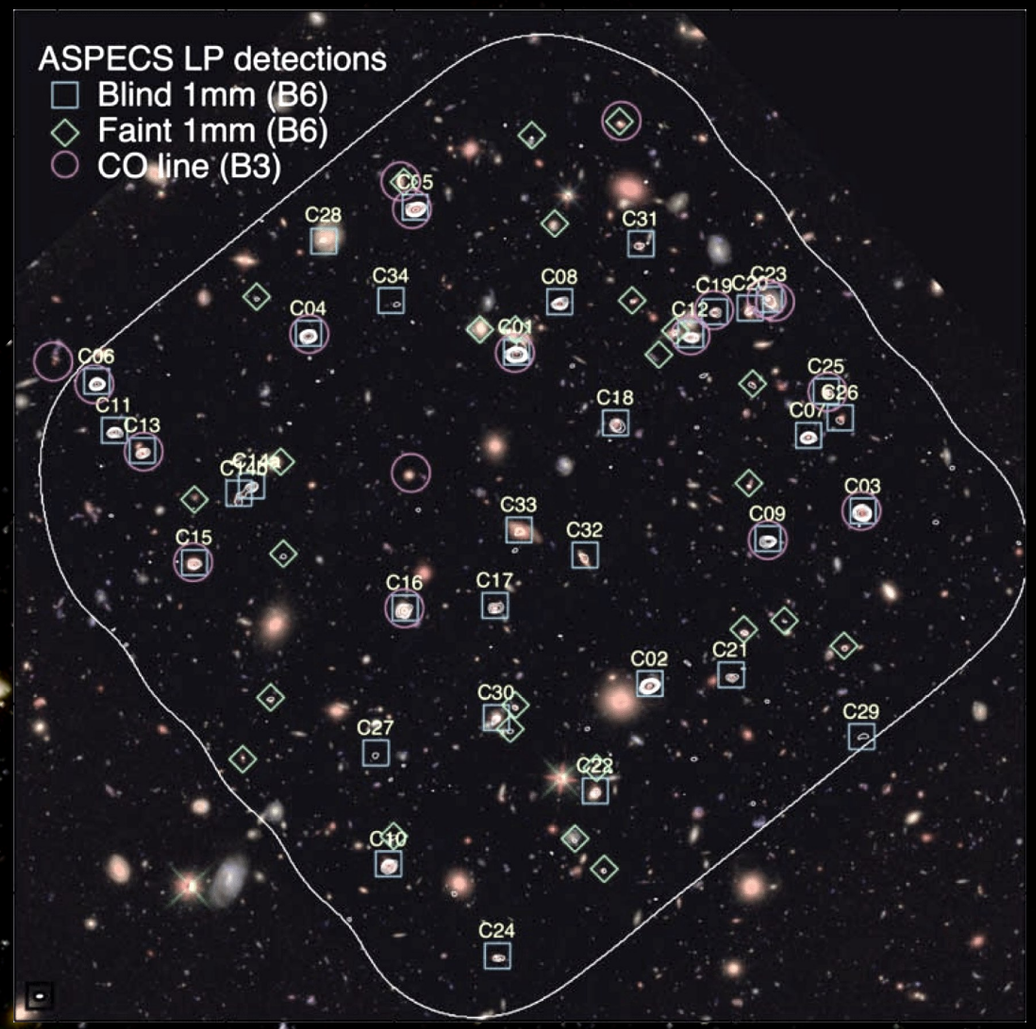


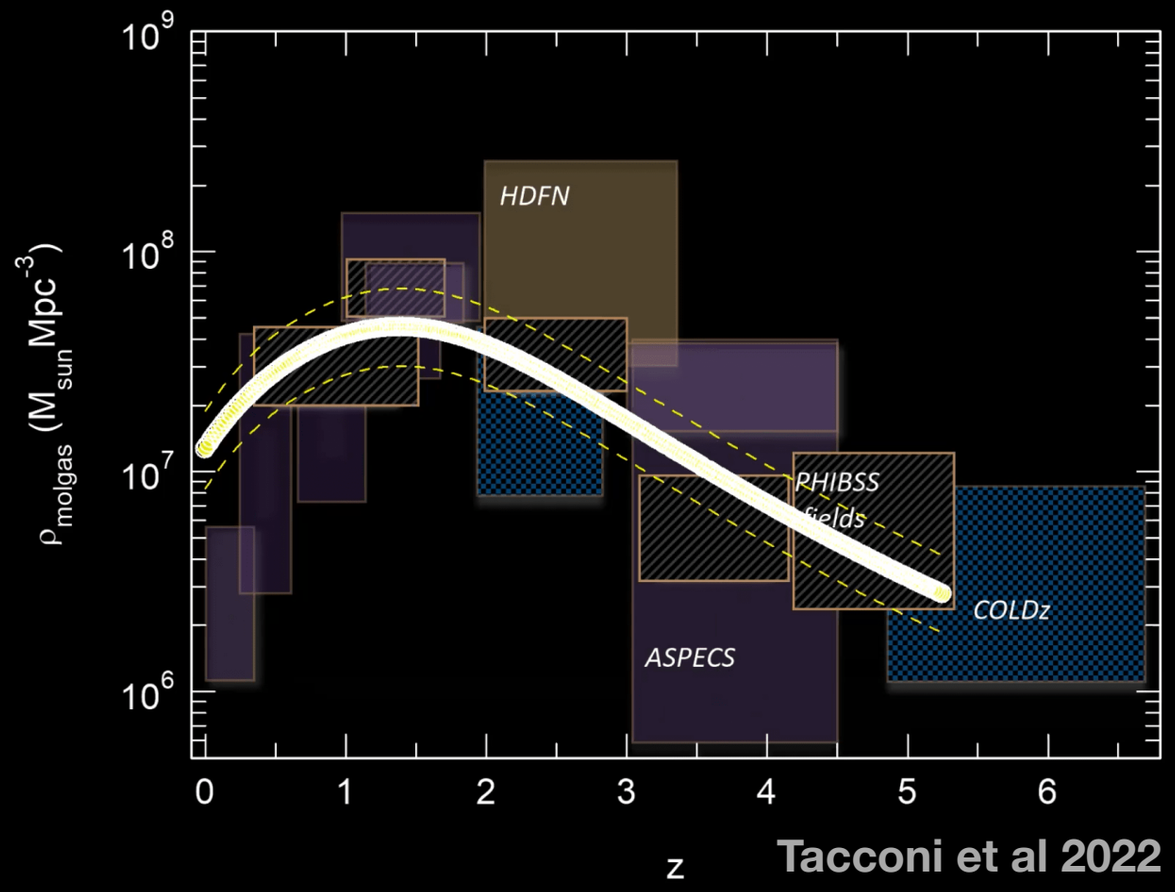


Tacconi et al 2022

See more: Williams et al. 1996; Made etl al et al. (1996); Aravena et al. 2020; Walter et al. 2016,2020

Deep sky survey





deep, wide, sub-arcsec resolution survey
—> **expensive**

See more: Williams et al. 1996; Made etl al et al. (1996); Aravena et al. 2020; Walter et al. 2016,2020

Cosmic variance

$$\frac{\sigma}{\mu} = \sqrt{(\rho\Omega)^{-1} + A\Omega^{(1-\gamma)/2}}$$

Cosmic variance

$$\frac{\sigma}{\mu} = \sqrt{(\rho\Omega)^{-1} + A\Omega^{(1-\gamma)/2}}$$

Poisson Variance

Cosmic variance

$$\frac{\sigma}{\mu} = \sqrt{(\rho\Omega)^{-1} + A\Omega^{(1-\gamma)/2}}$$

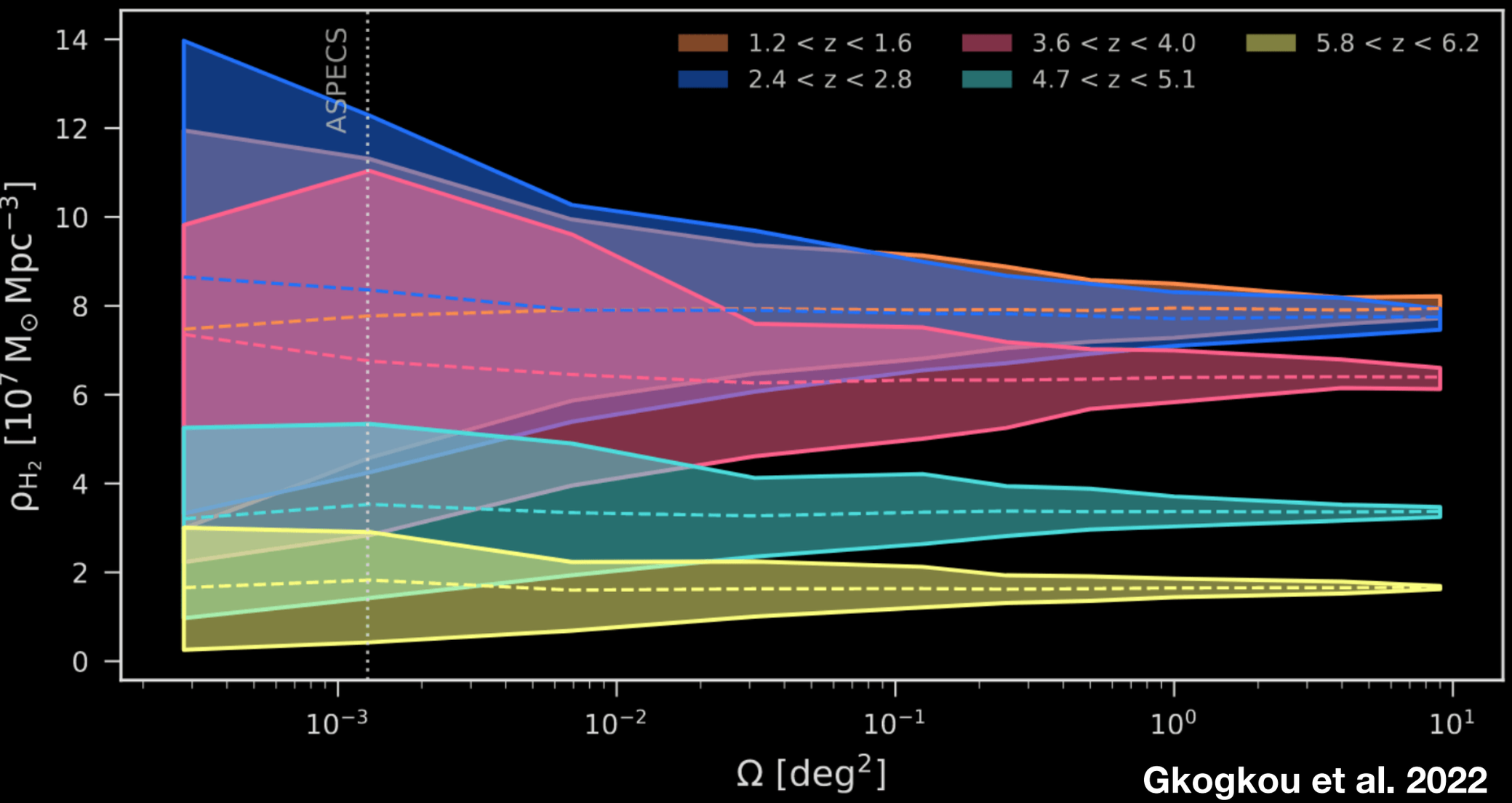
Poisson Variance

Clustering Effects

Cosmic variance

$$\frac{\sigma}{\mu} = \sqrt{(\rho\Omega)^{-1} + A\Omega^{(1-\gamma)/2}}$$

Poisson Variance **Clustering Effects**



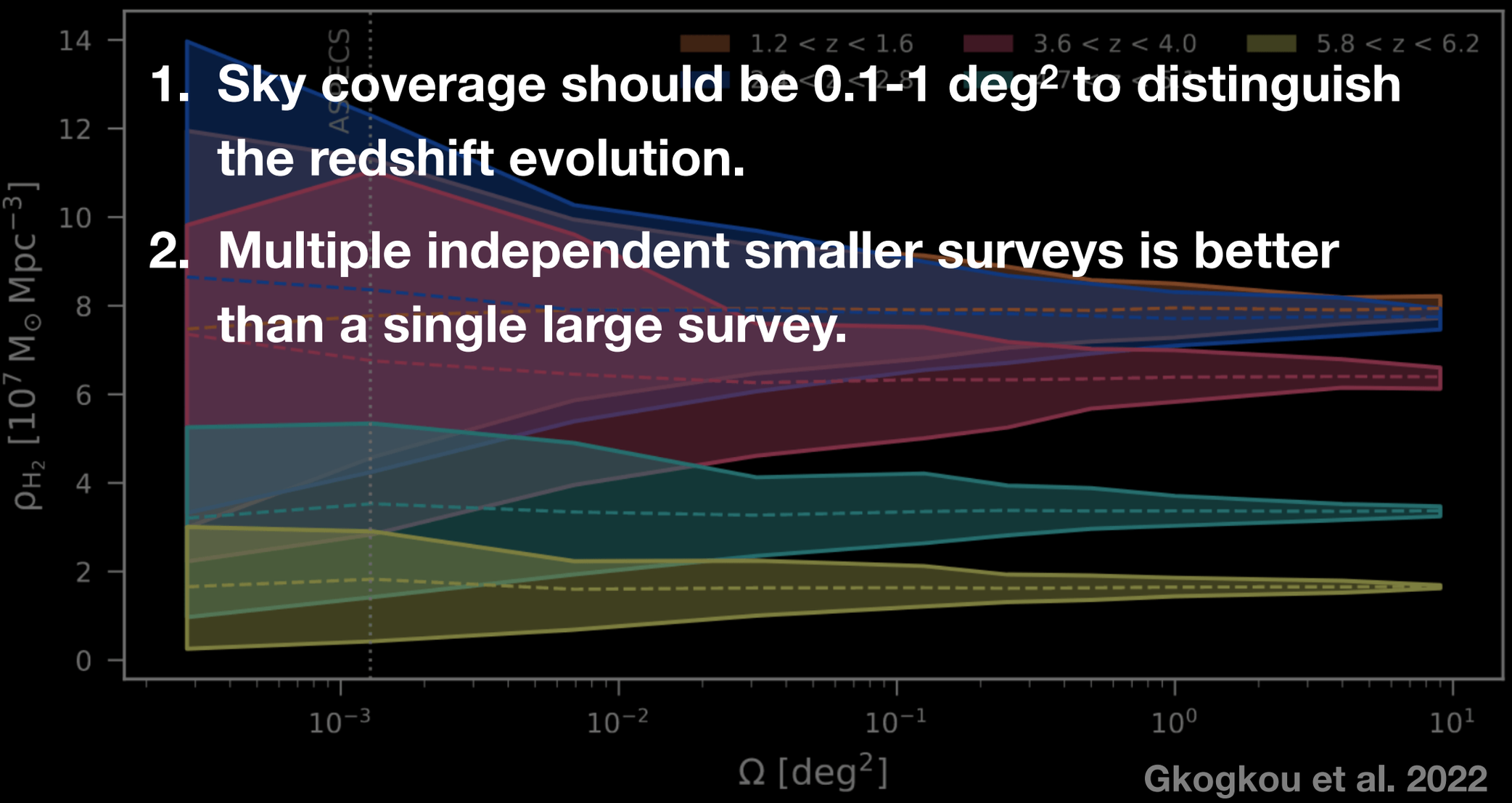
Gkogkou et al. 2022

Cosmic variance

$$\frac{\sigma}{\mu} = \sqrt{(\rho\Omega)^{-1} + A\Omega^{(1-\gamma)/2}}$$

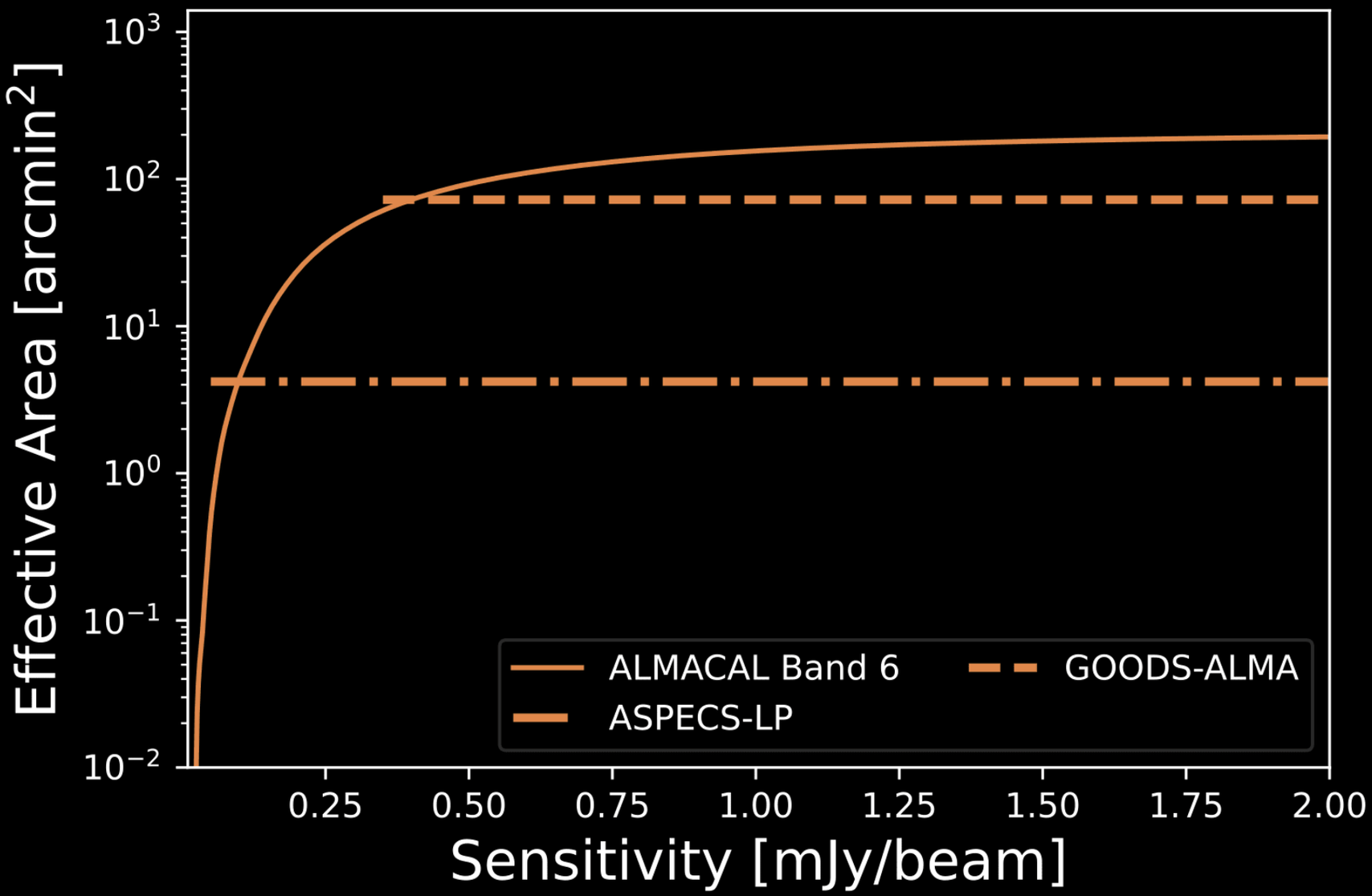
Poisson Variance **Clustering Effects**

1. **Sky coverage should be 0.1-1 deg² to distinguish the redshift evolution.**
2. **Multiple independent smaller surveys is better than a single large survey.**



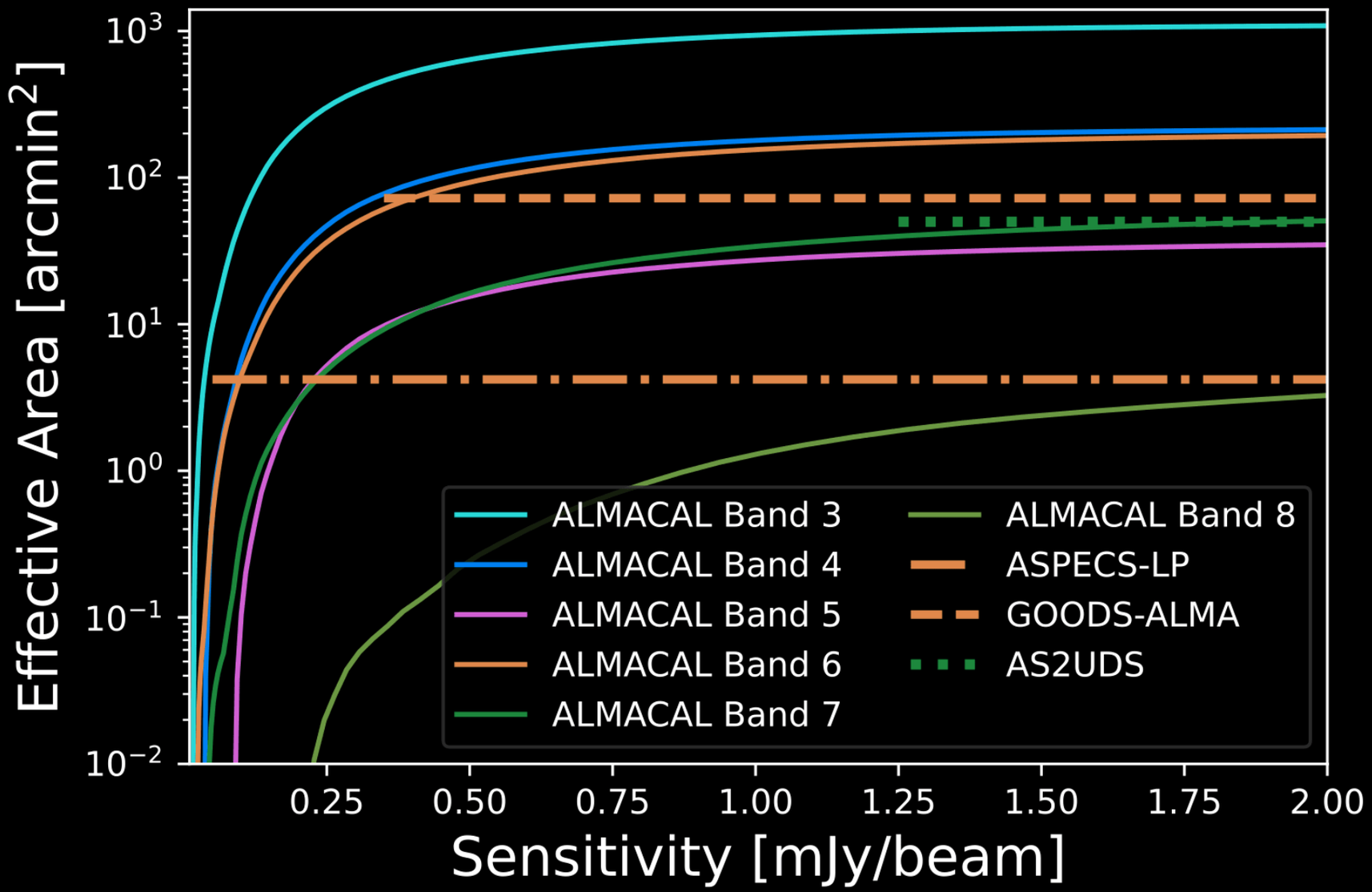
Gkogkou et al. 2022

ALMACAL: effective area



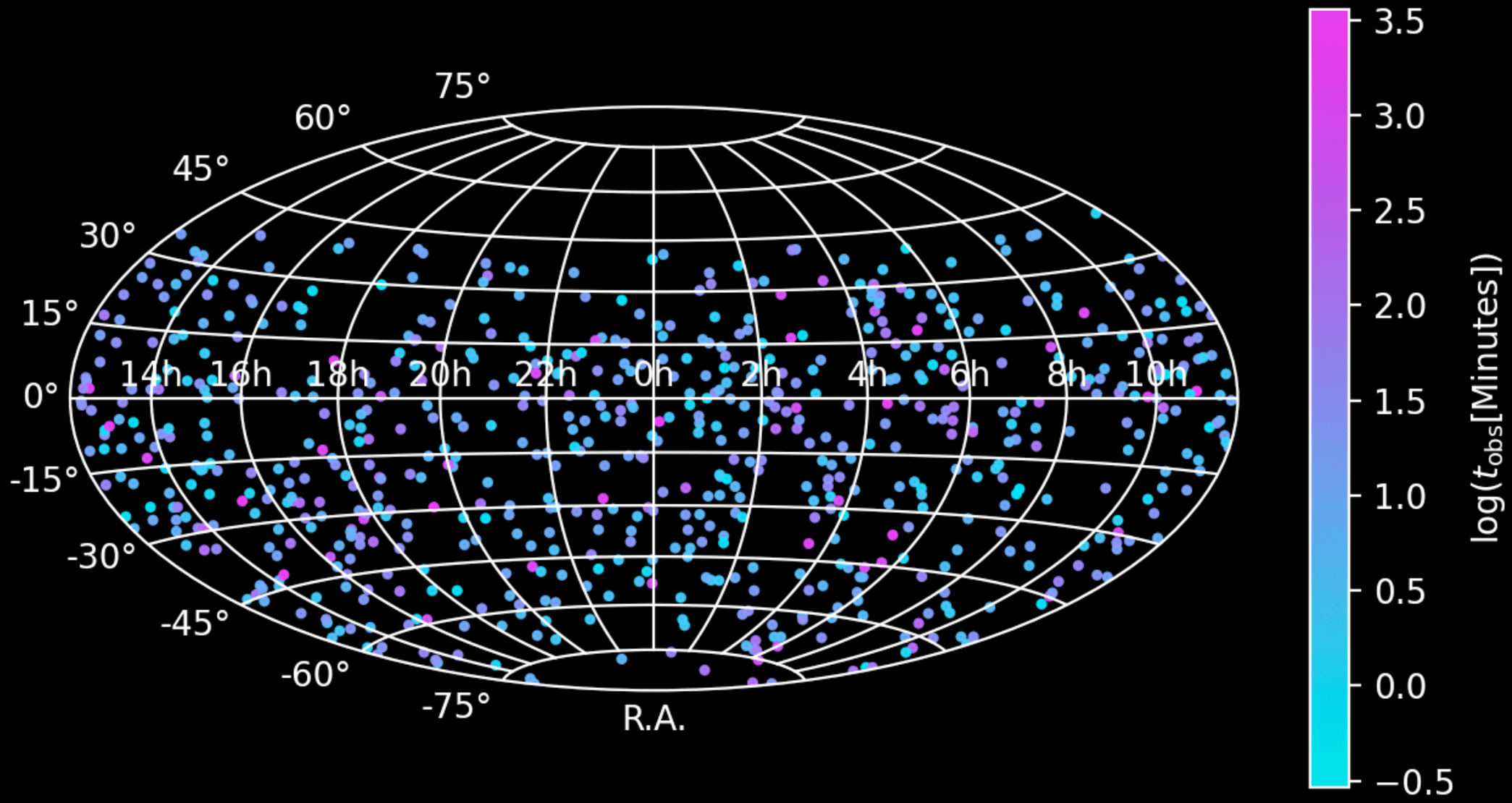
‘Free’ data from ALMACAL can already compete with ALMA dedicated large program

ALMACAL: effective area



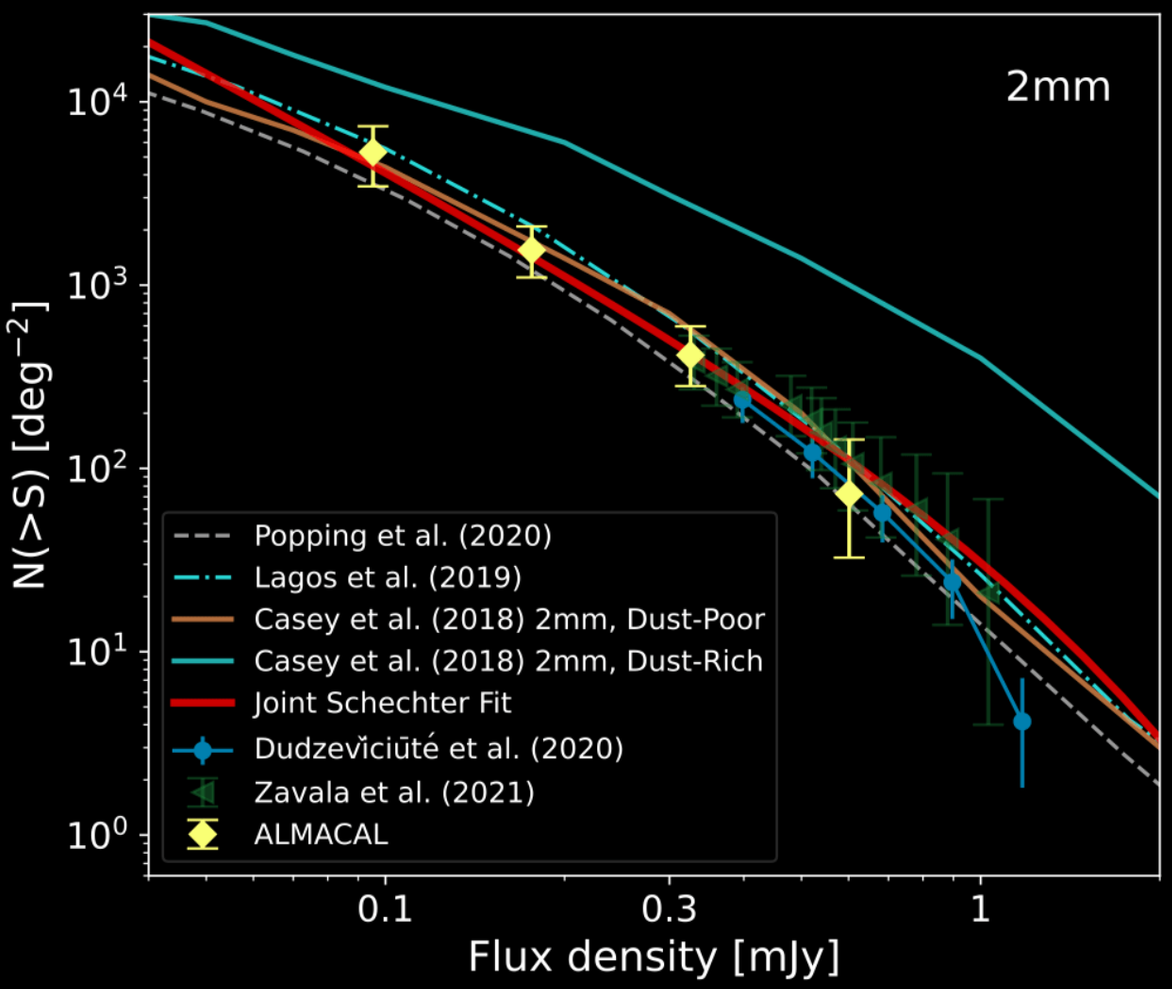
'Free' data from ALMACAL can already compete with ALMA dedicated large program

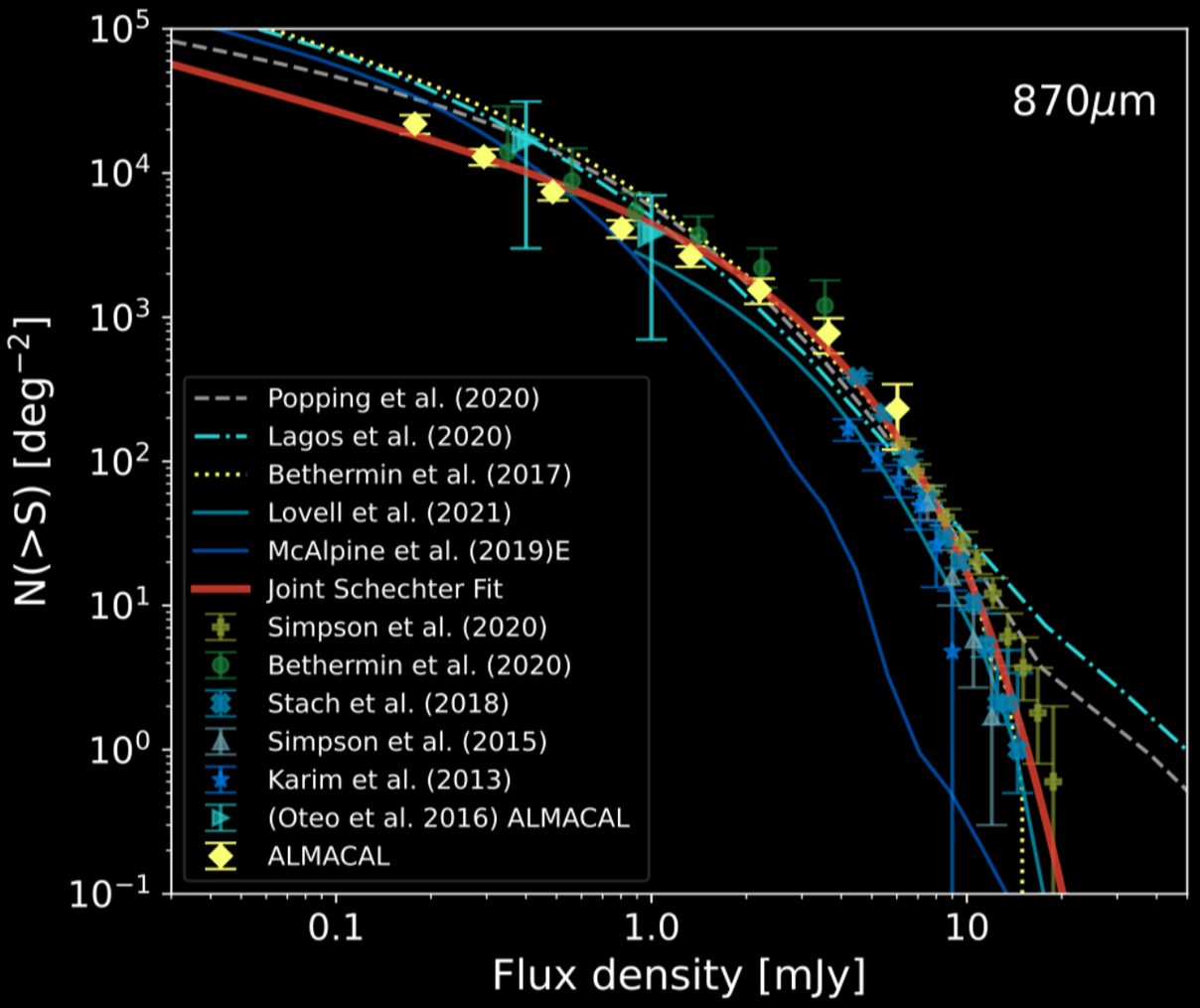
ALMACAL: pointings



~1000 pointings make ALMACAL free from cosmic variance

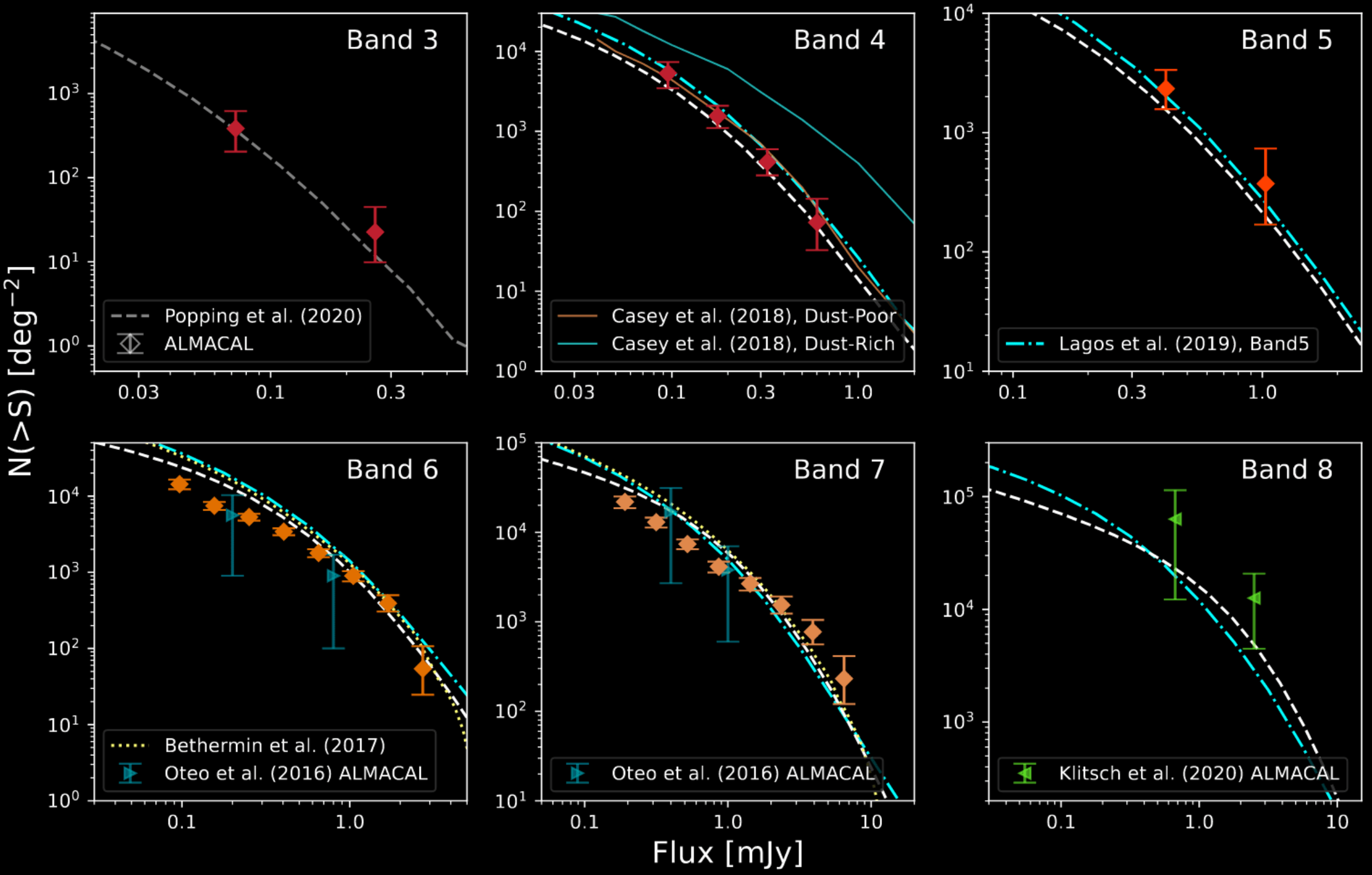
ALMACAL: Number counts





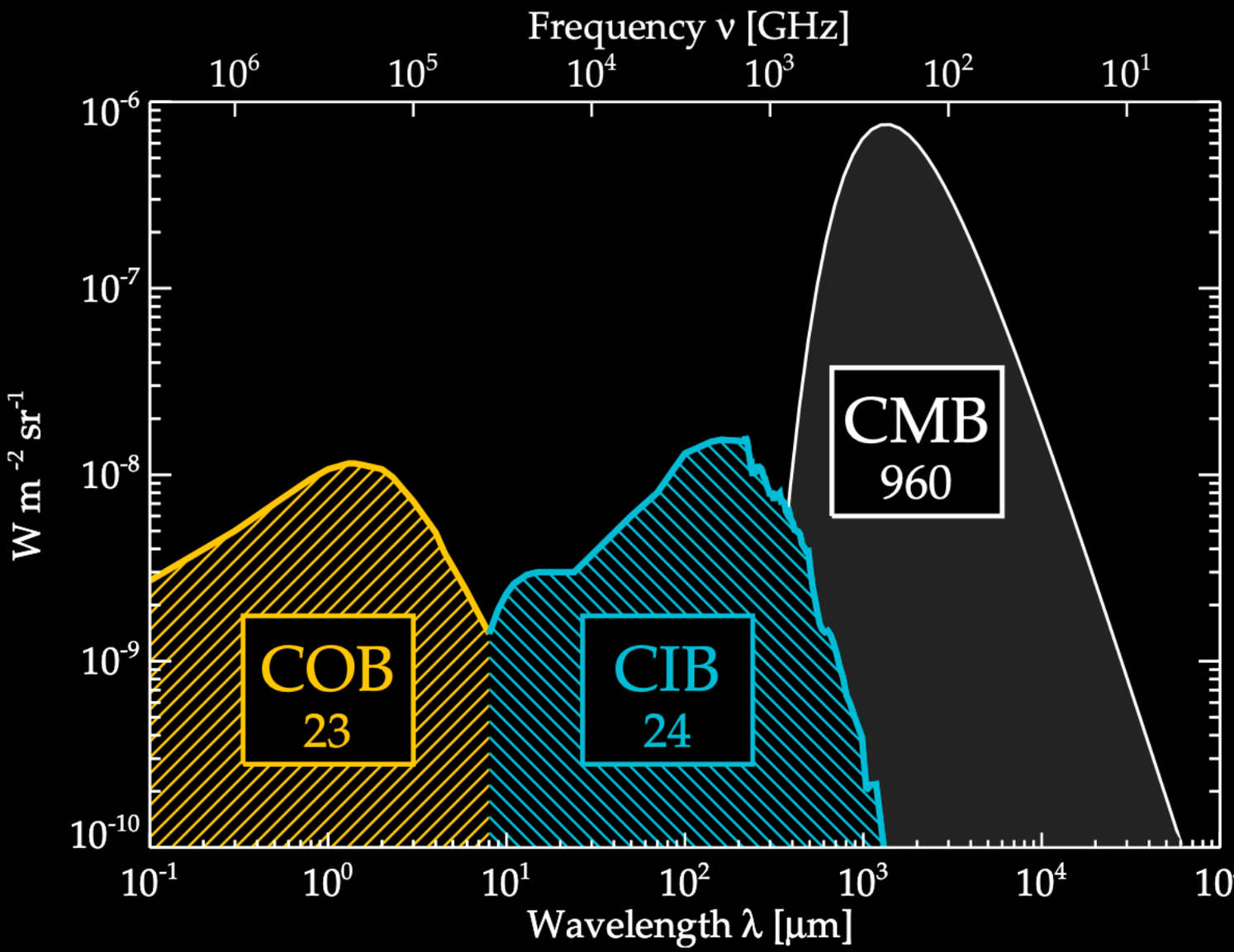
ALMACAL: the deepest survey available at 2mm and 870um

ALMACAL: Number counts



Multi-bands number counts are the testbeds for galaxy formation and evolution models.

Cosmic SED

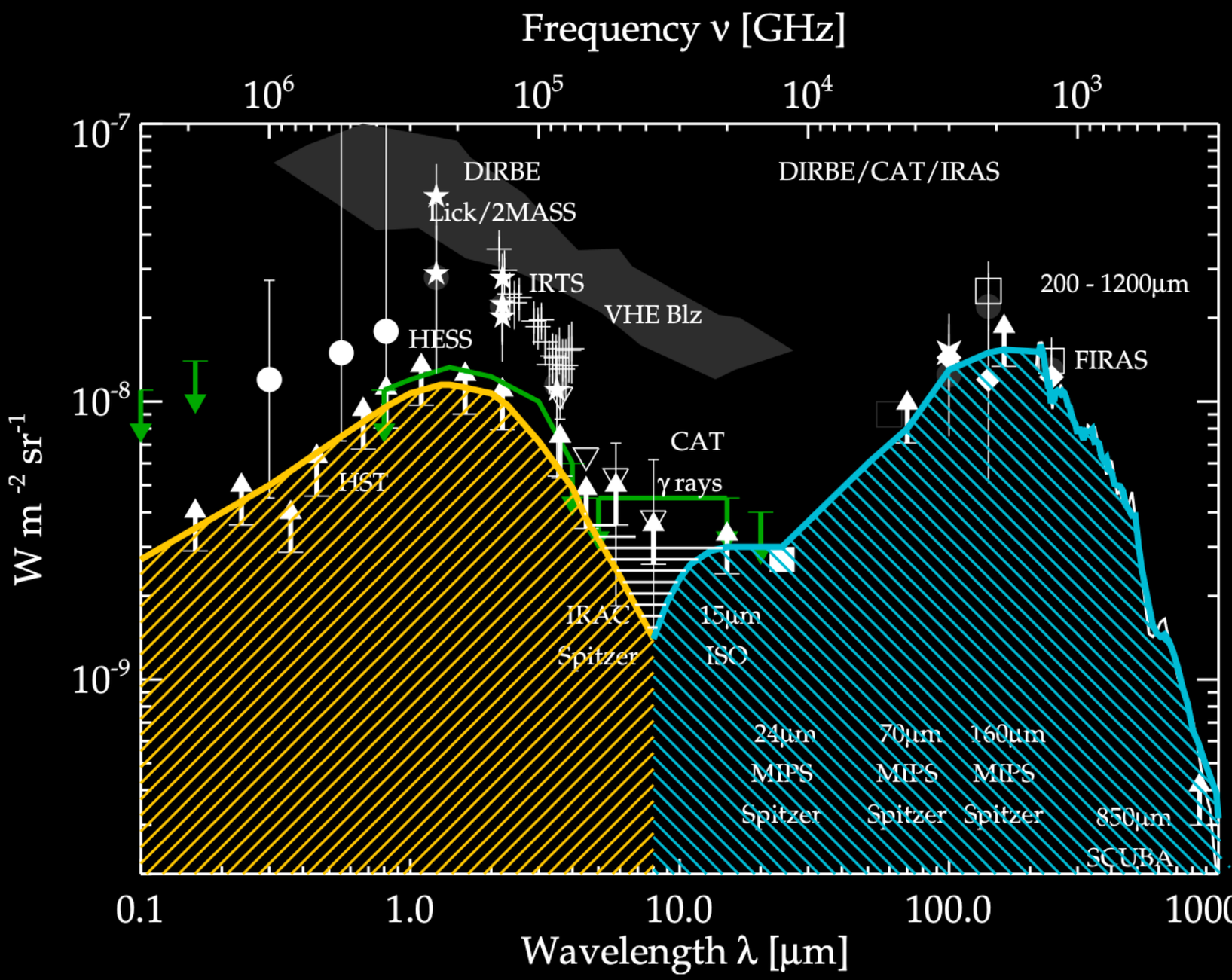


COB:
cosmic optical background
CIB:
cosmic infrared background
CMB:
cosmic microwave background

Cole et al. (2006)

see also: Lagache et al. (2005), Berta et al. (2011), Bethermin et al. (2012)

Cosmic SED

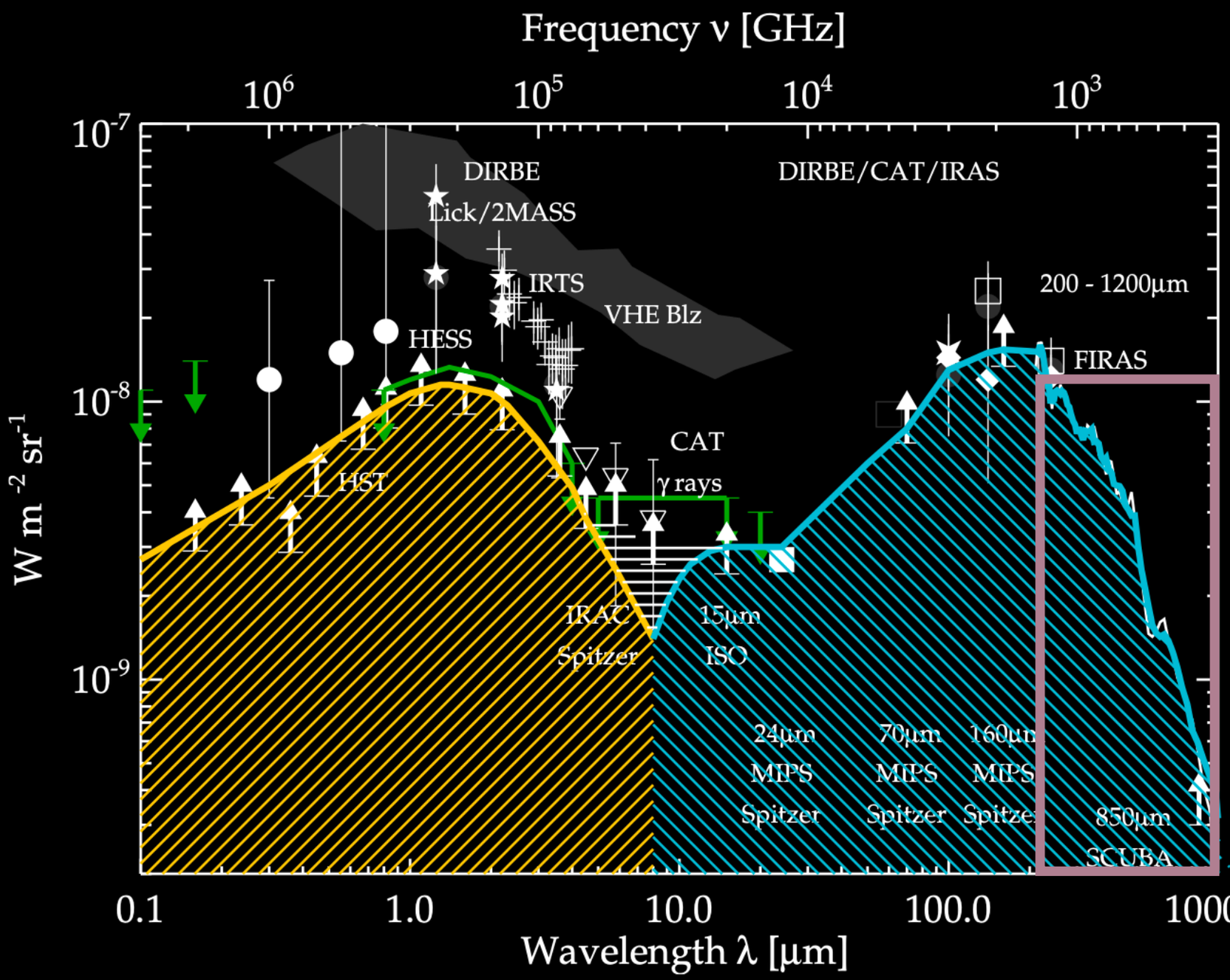


COB:
cosmic optical background
CIB:
cosmic infrared background
CMB:
cosmic microwave background

Cole et al. (2006)

see also: Lagache et al. (2005), Berta et al. (2011), Bethermin et al. (2012)

Cosmic SED

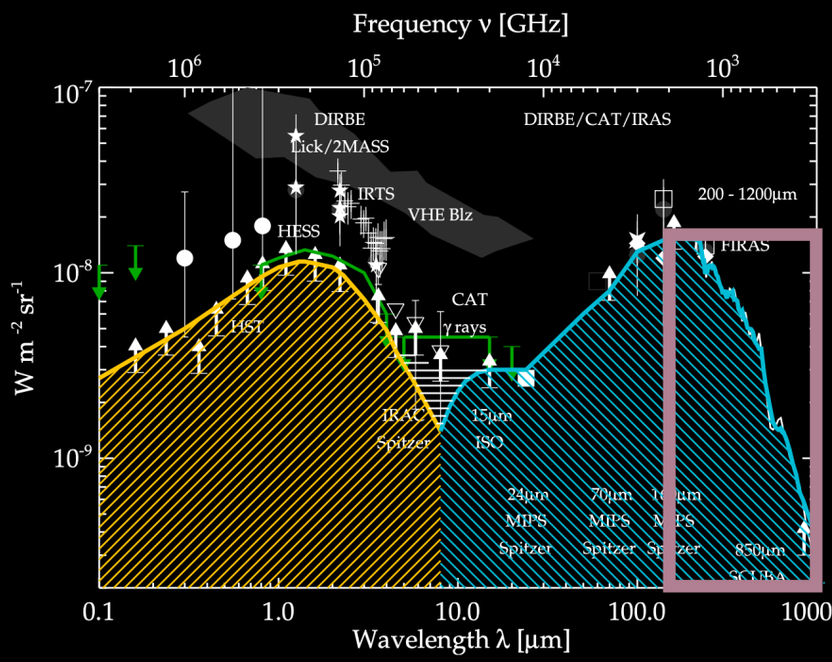


Cole et al. (2006)

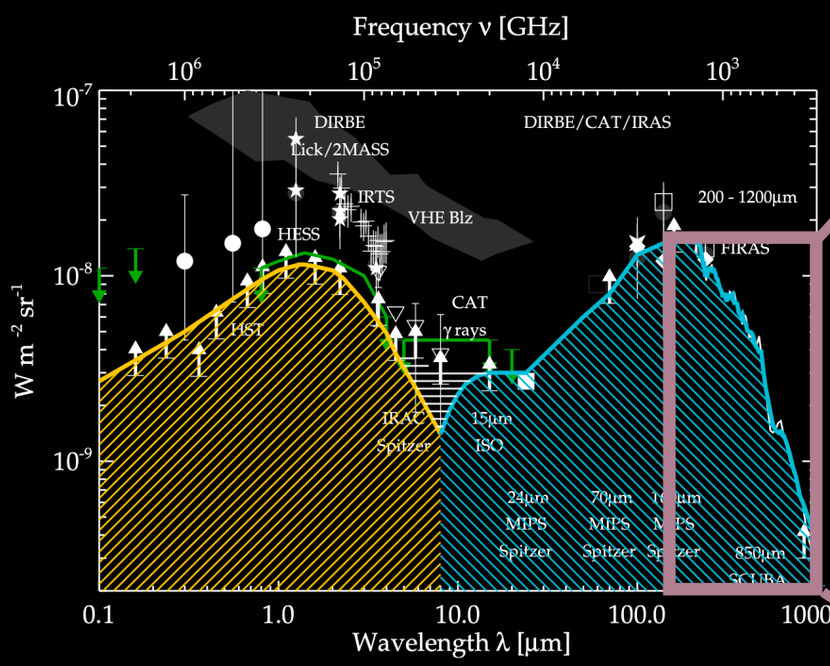
COB:
cosmic optical background
CIB:
cosmic infrared background
CMB:
cosmic microwave background

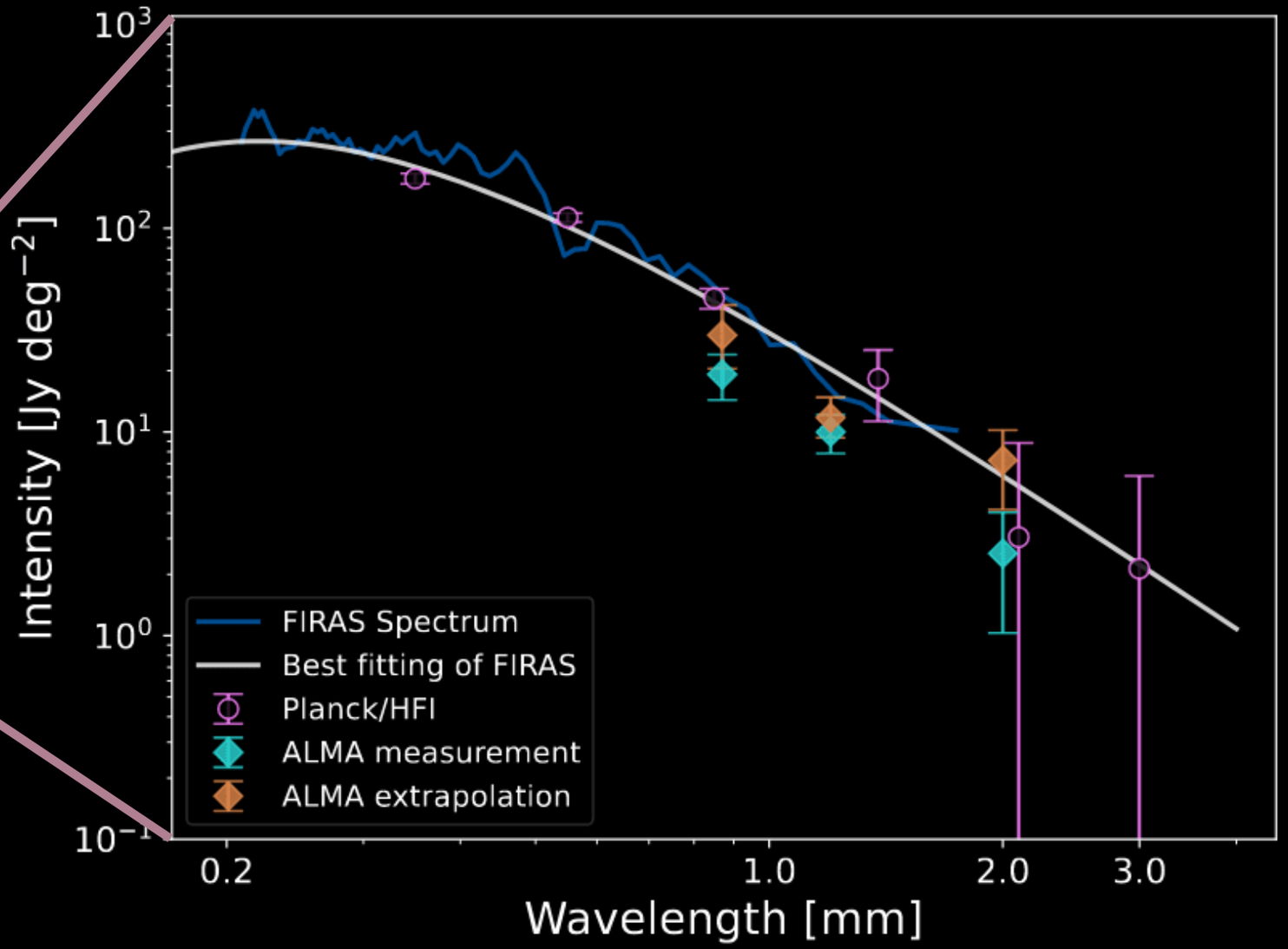
see also: Lagache et al. (2005), Berta et al. (2011), Bethermin et al. (2012)

ALMACAL: Cosmic infrared background

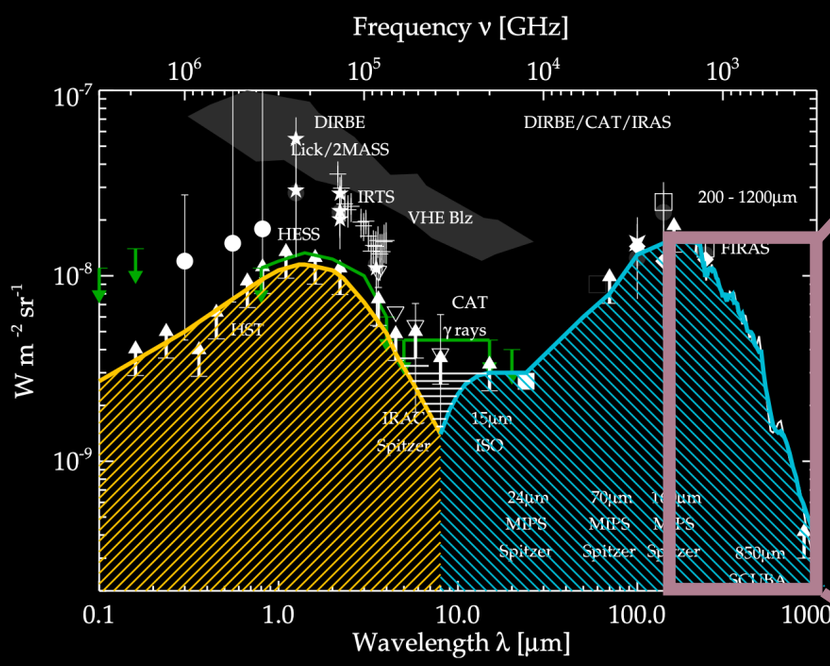


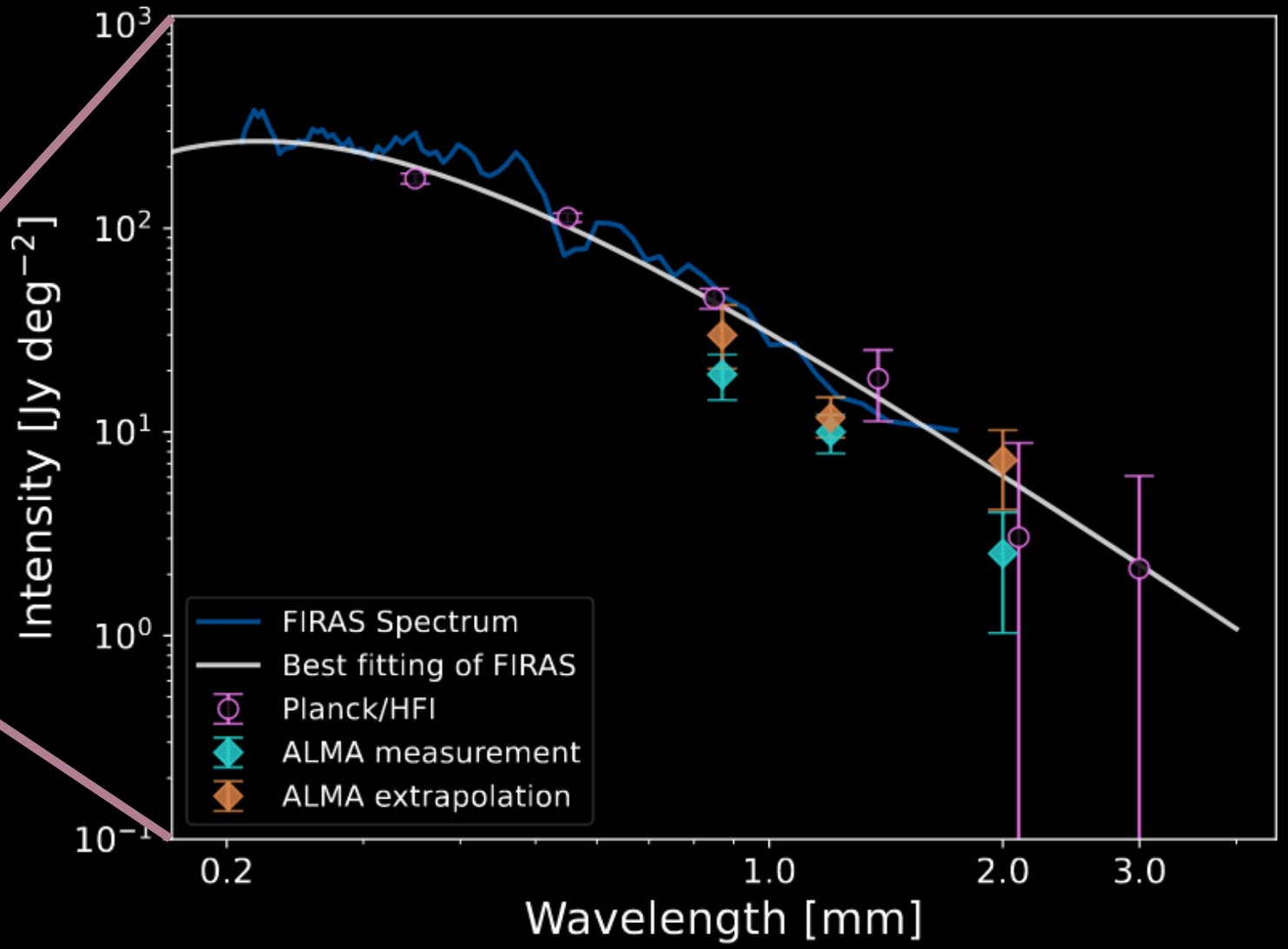
ALMACAL: Cosmic infrared background





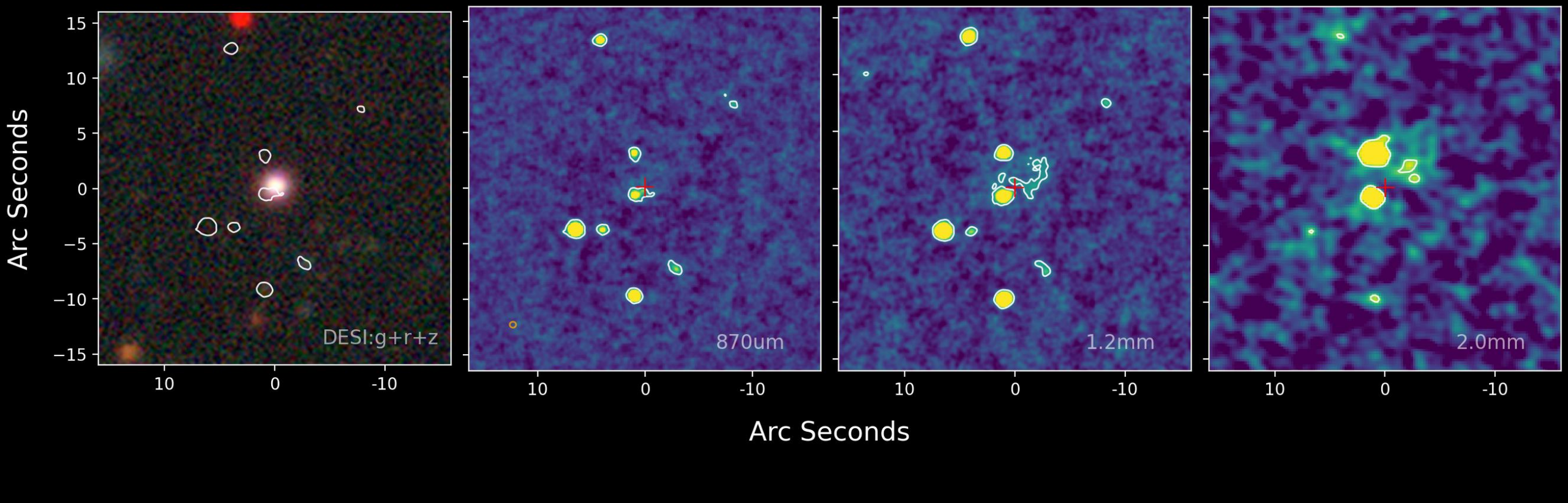
ALMACAL: Cosmic infrared background



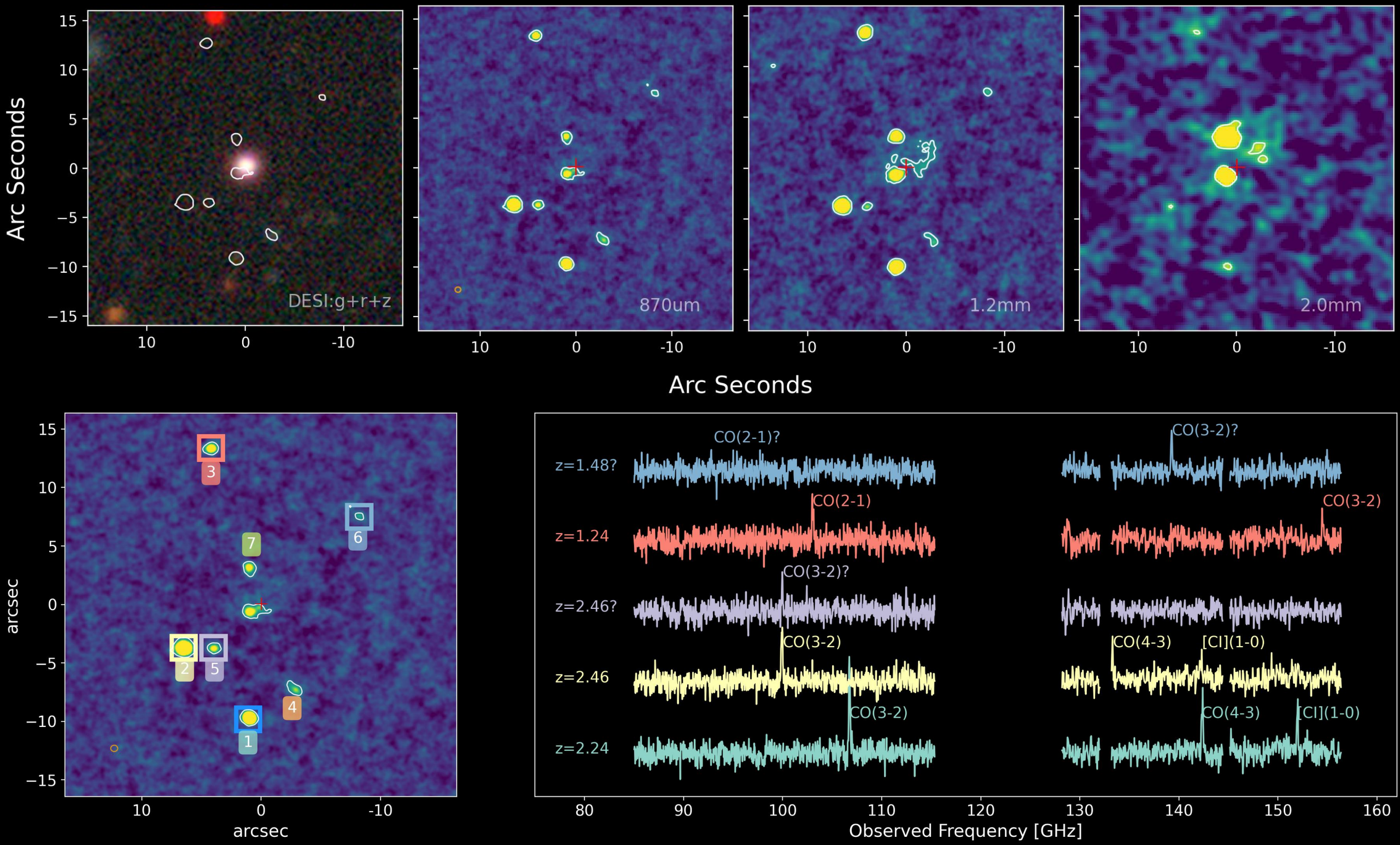


Dusty, star-forming galaxies are the dominant contributor of cosmic infrared background in the (sub-)millimetre range.

Cosmic variance



Cosmic variance



Science with ALMACAL

- Calibrators
  - ⋆ Blazer **light curve**, **jets** and **SED** (e.g. Bonato+2018)
  - ⋆ ISM, CGM and IGM **absorptions** (e.g. Klitsch+2019)
- Extended fields
  - ⋆ Searching for **line emitters** (e.g. Klitsch+2020, Hamanowicz+2022)
  - ⋆ Detailed **morphology** (e.g. Oteo+2017)
- and more …

In summary

1. ALMACAL is a promising alternative for future **multi-band, sub-arcsec, deep** untargeted survey.

2. Multi-band number counts is a powerful testbed for galaxy formation and evolution models.

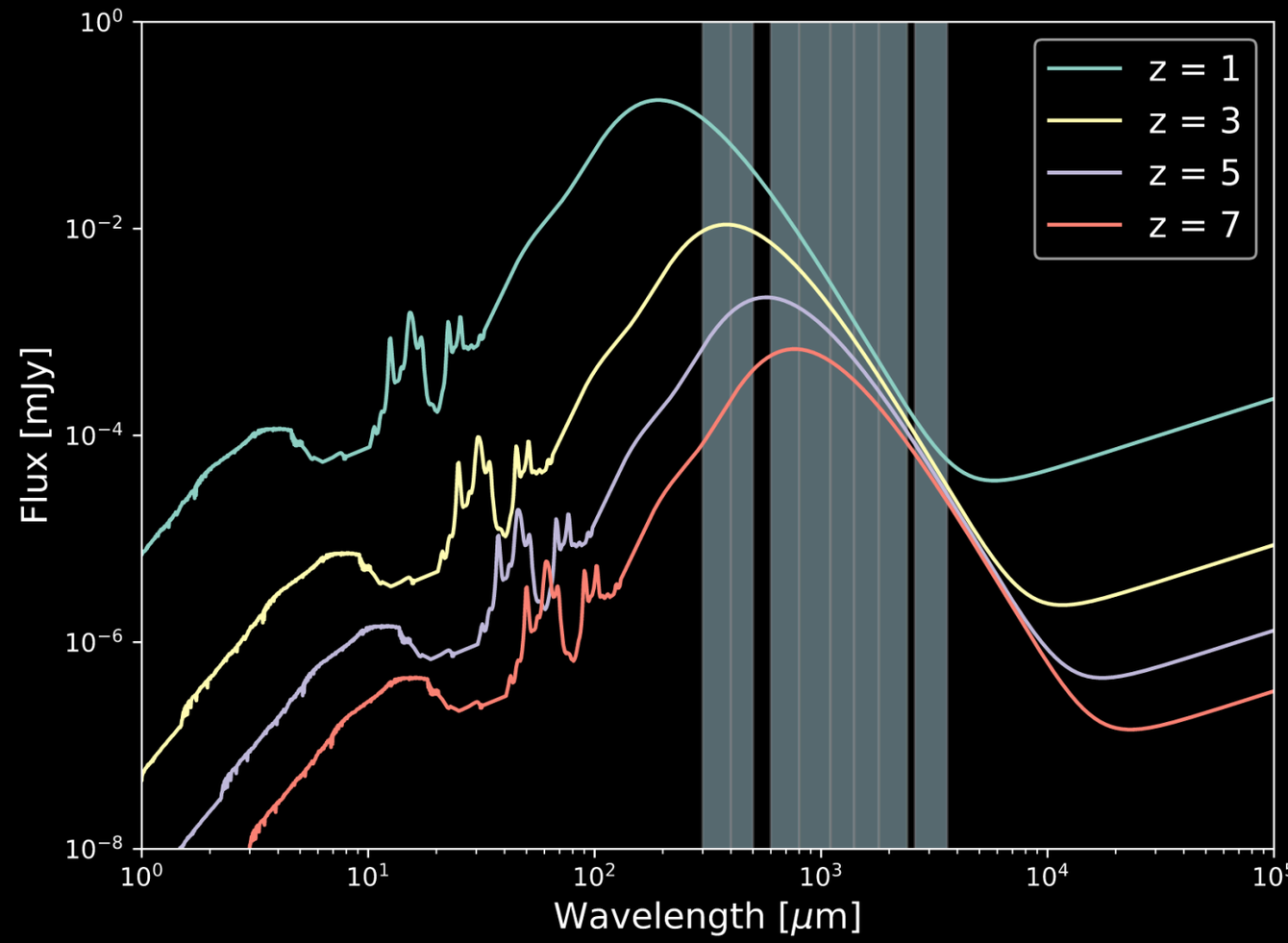
3. Distant, dusty star-forming galaxies dominate the cosmic infrared background.

Collaborations are warmly welcomed…

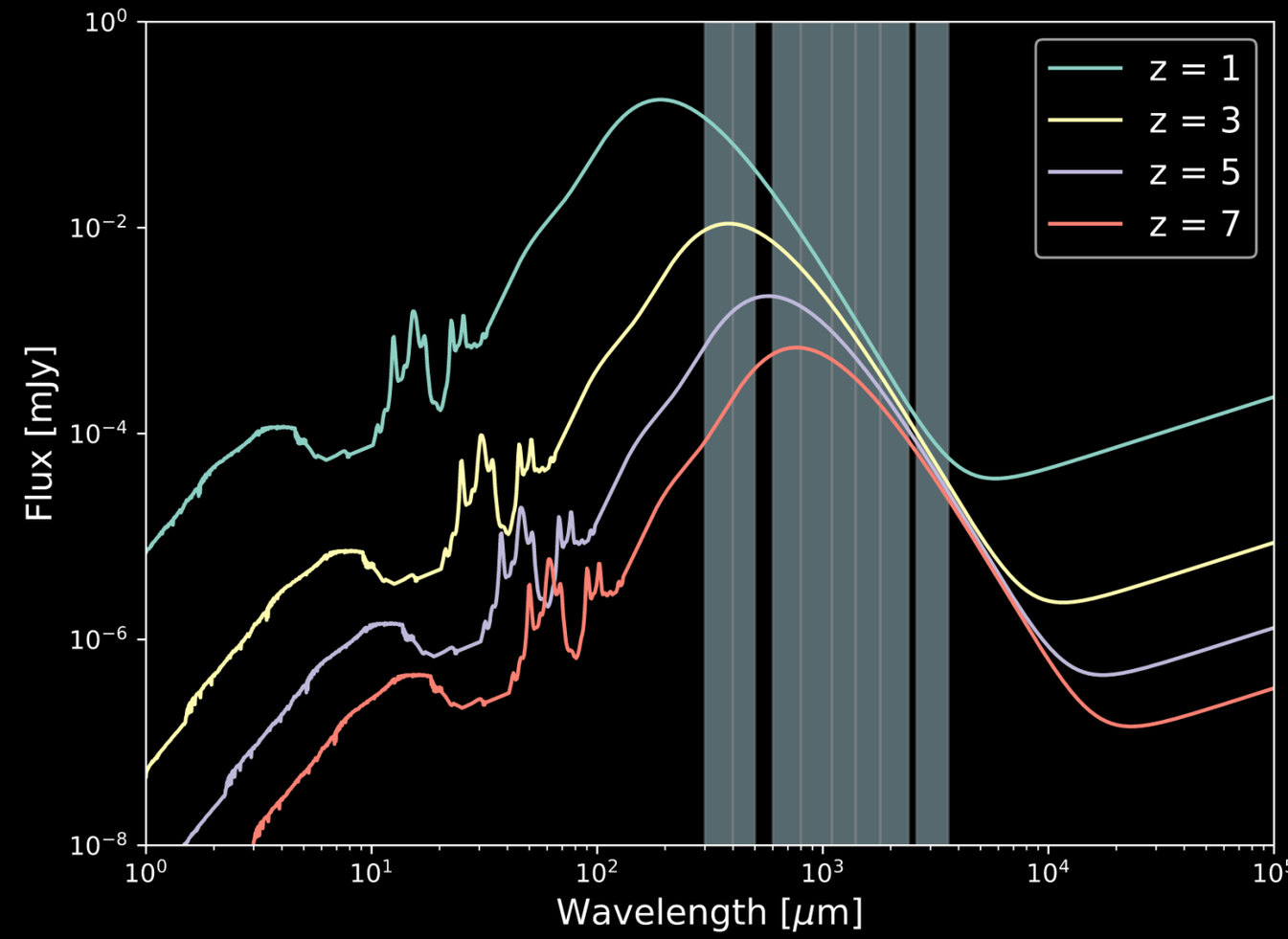
almacal@eso.org

https://almacal.wordpress.com

Why (sub-)millimetre

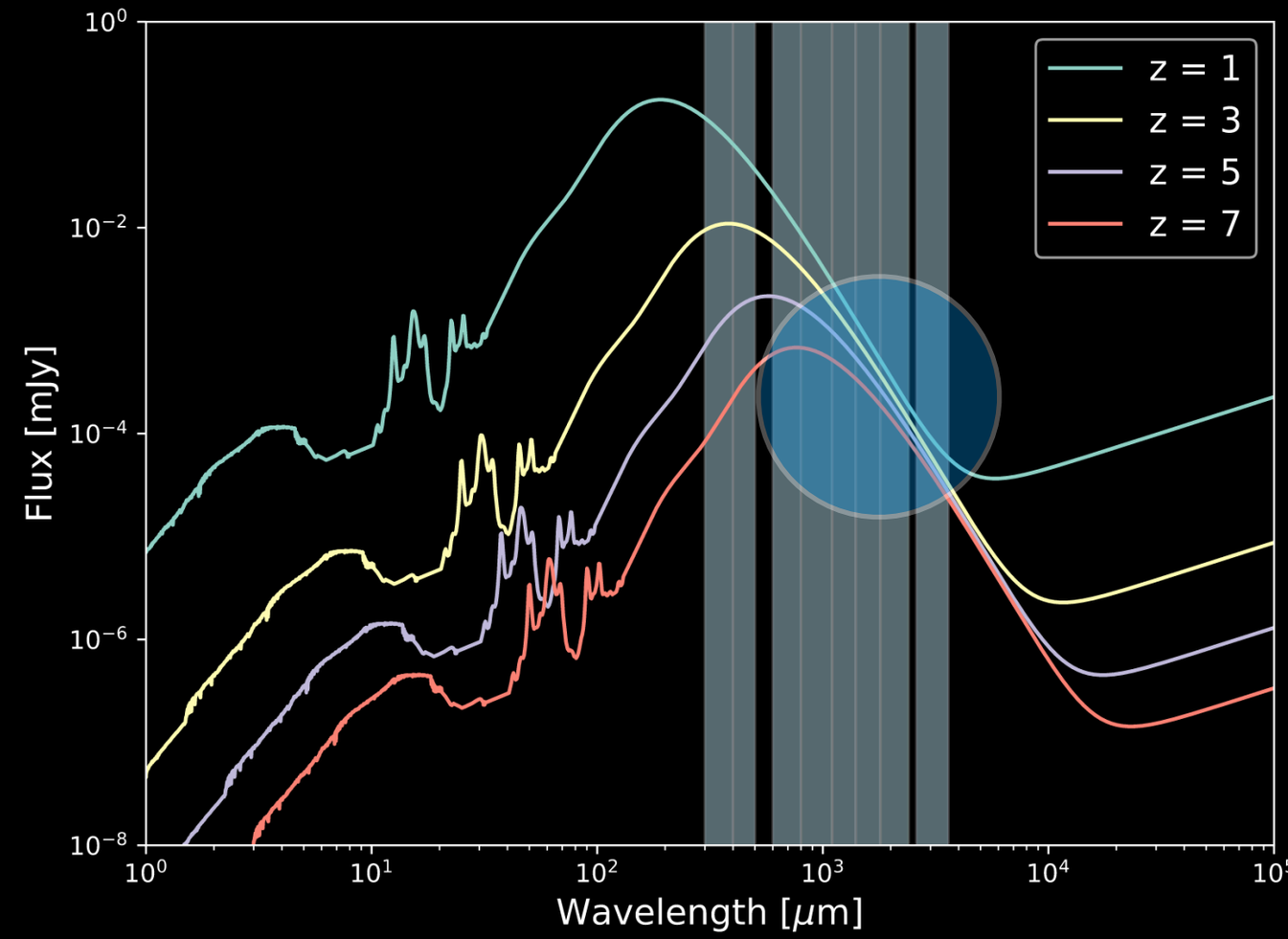


Why (sub-)millimetre



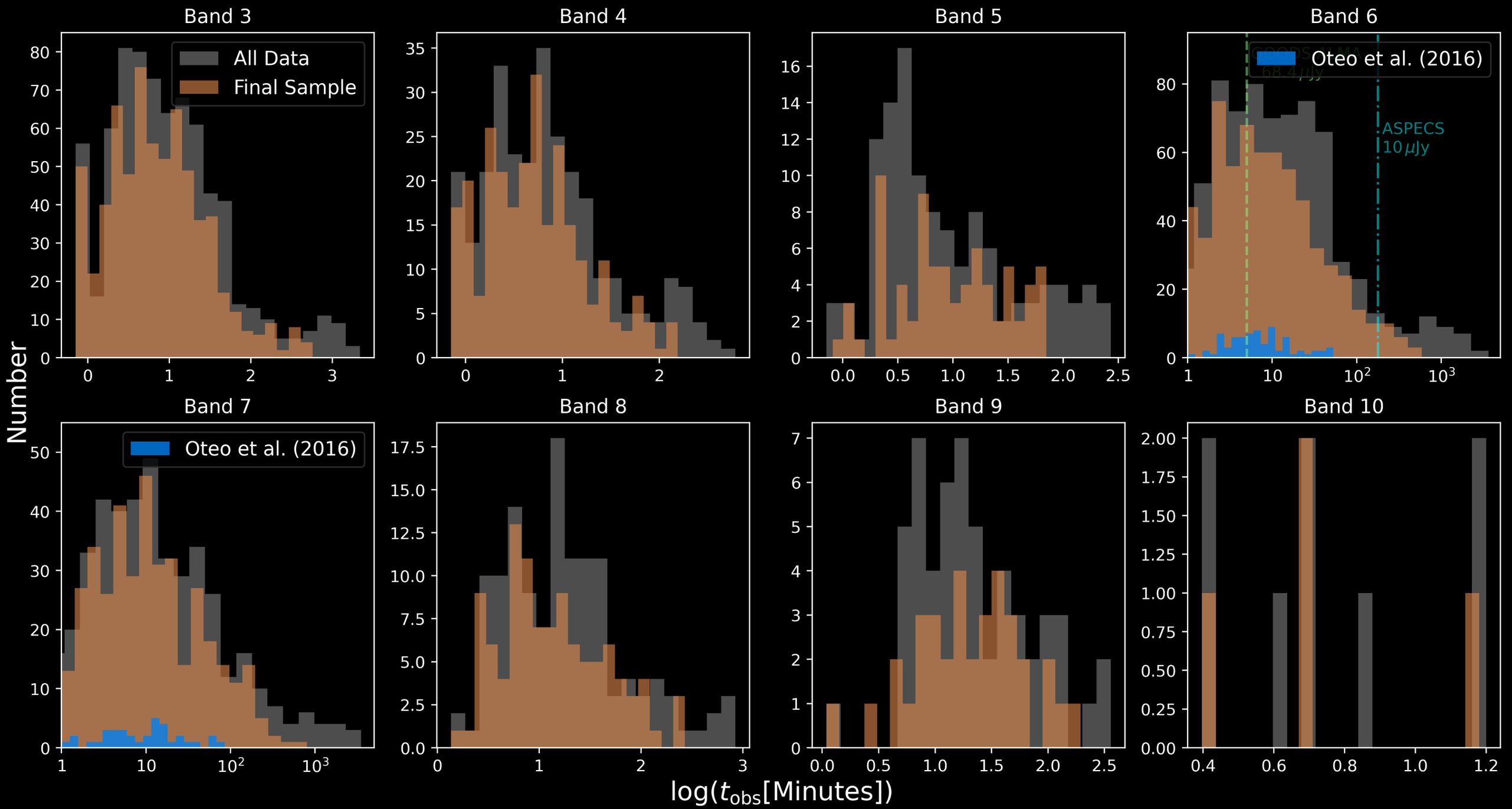
Negative K-correction make submm/mm sensitive the to high-z DSFGs

Why (sub-)millimetre

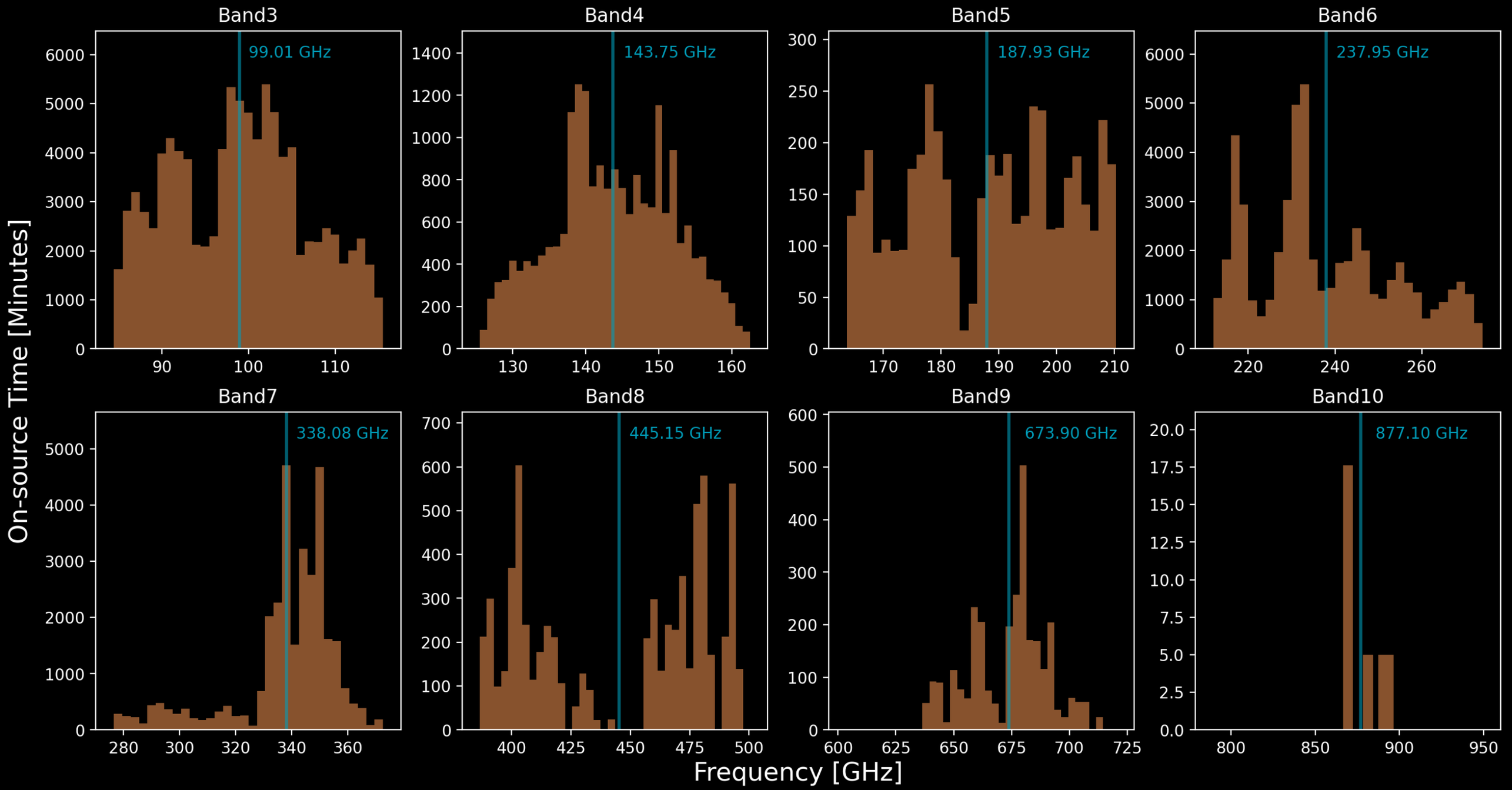


Negative K-correction make submm/mm sensitive the to high-z DSFGs

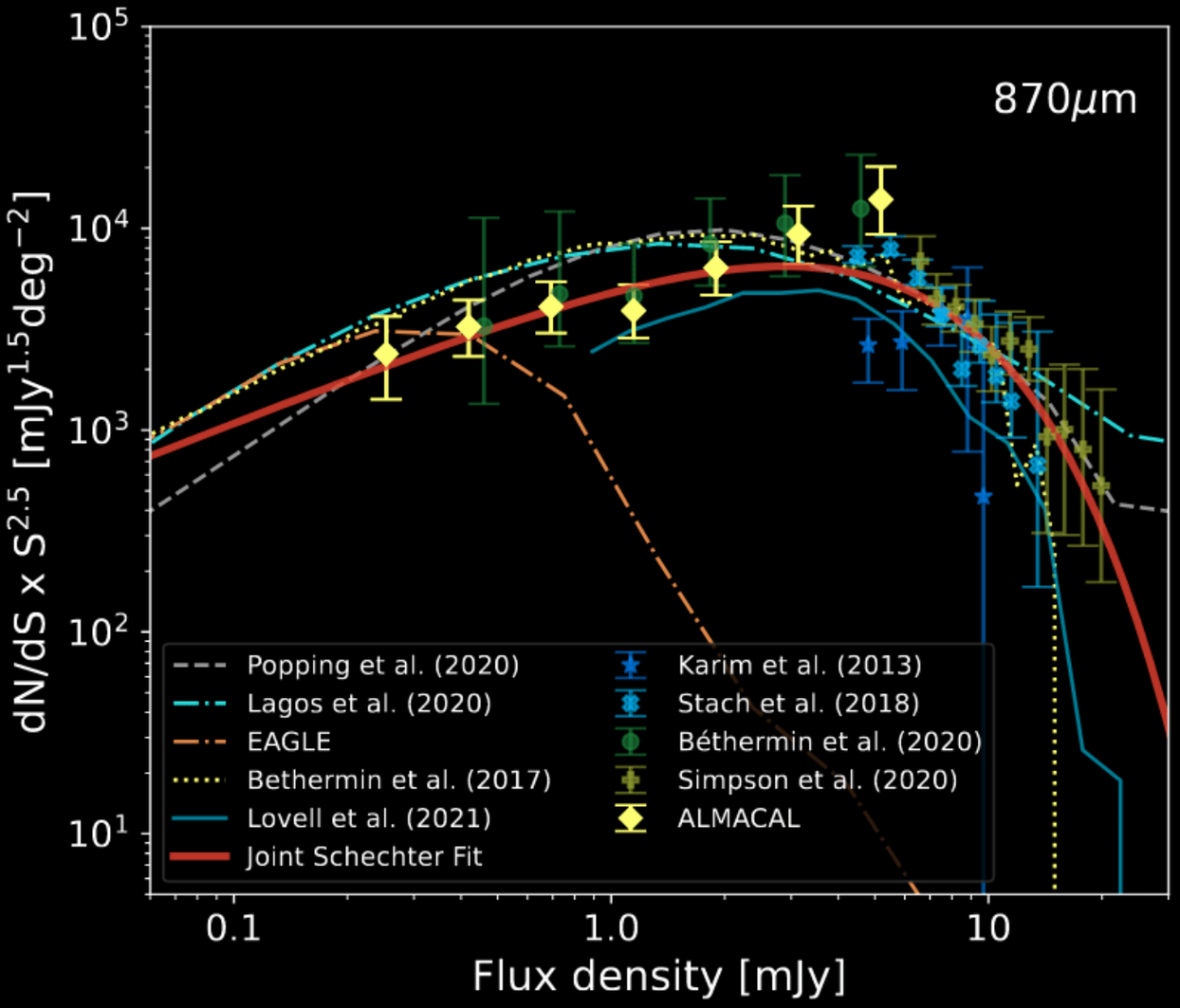
Appendix: observations statistics

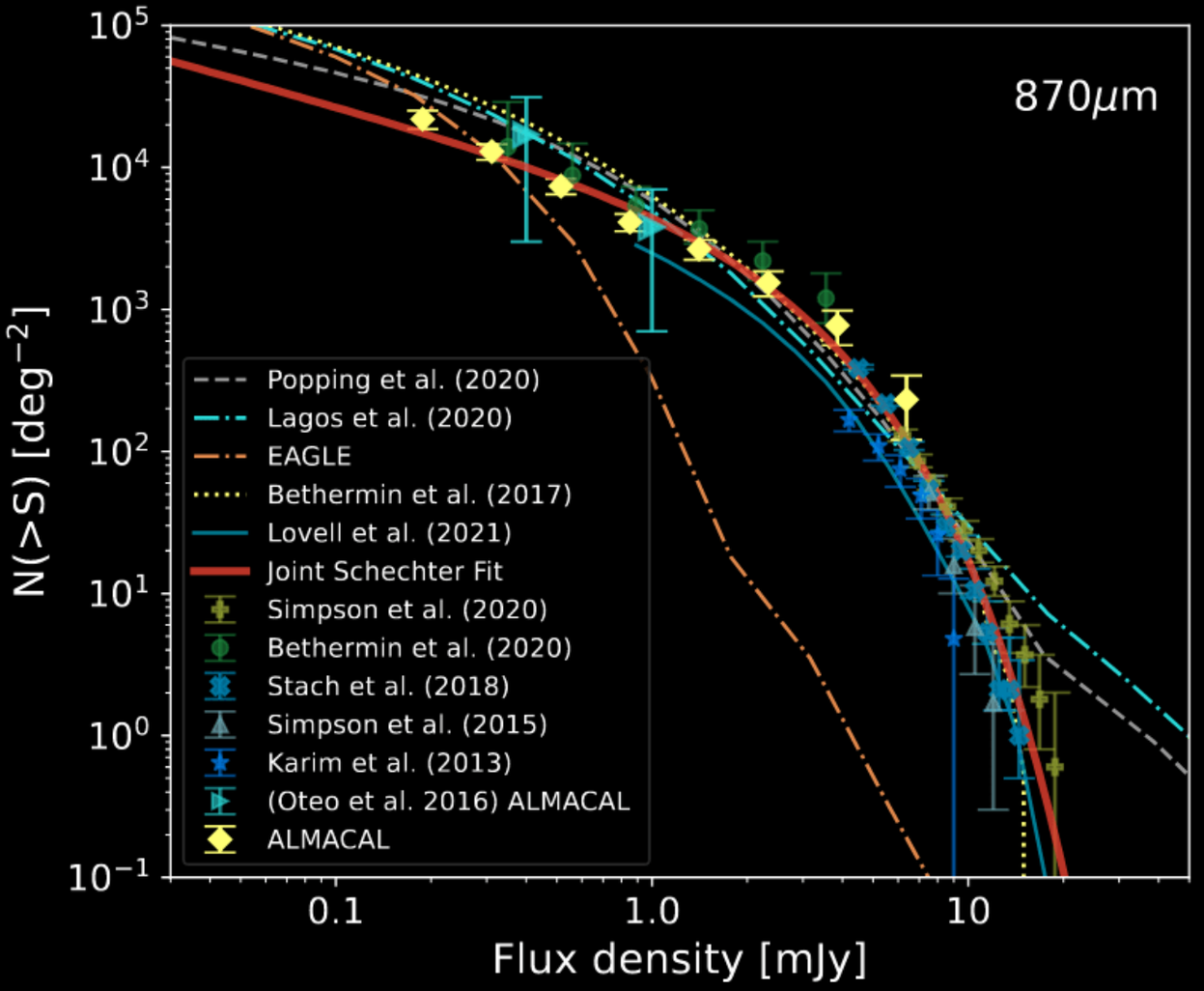


Appendix: spectral distribution



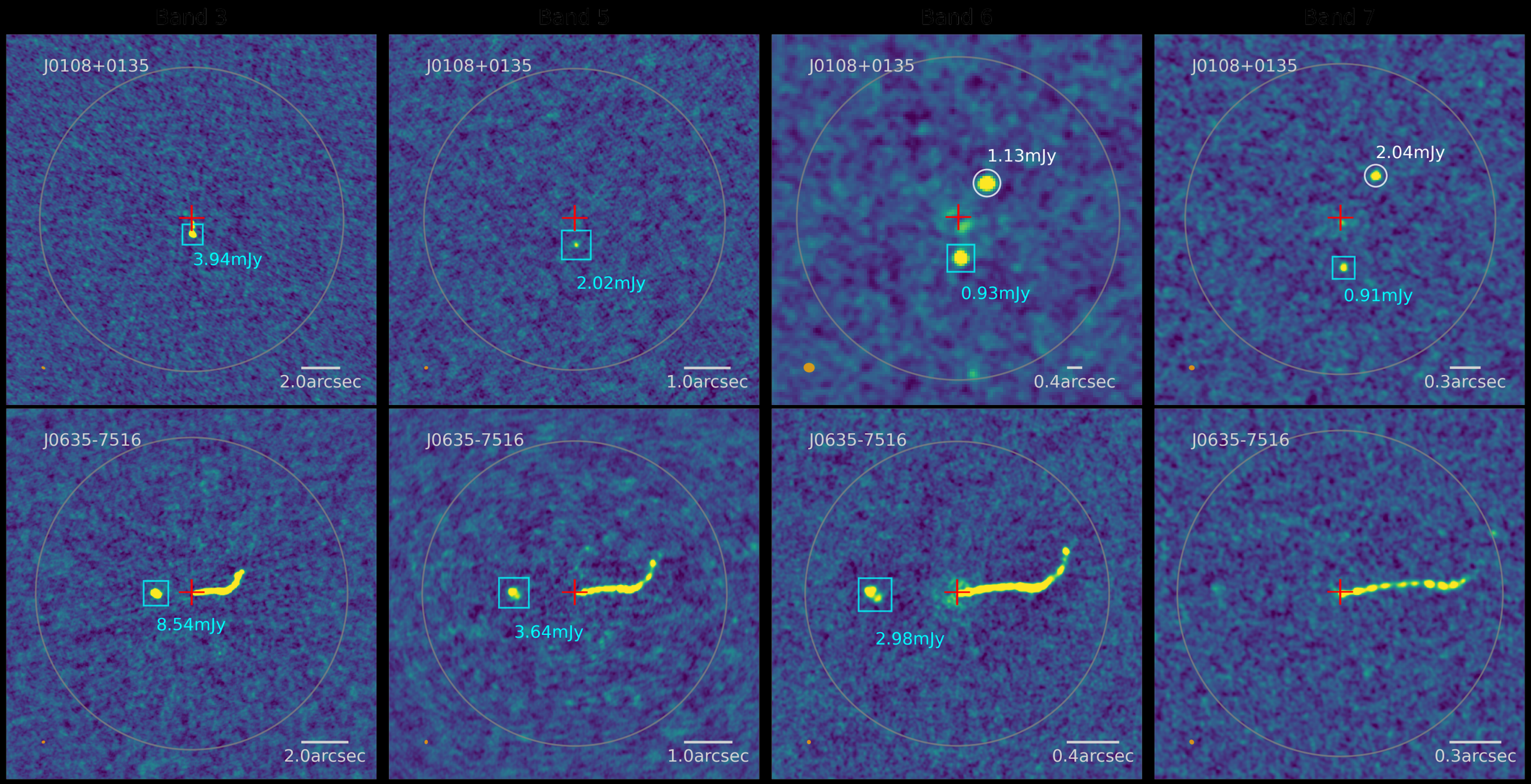
ALMACAL: Number counts

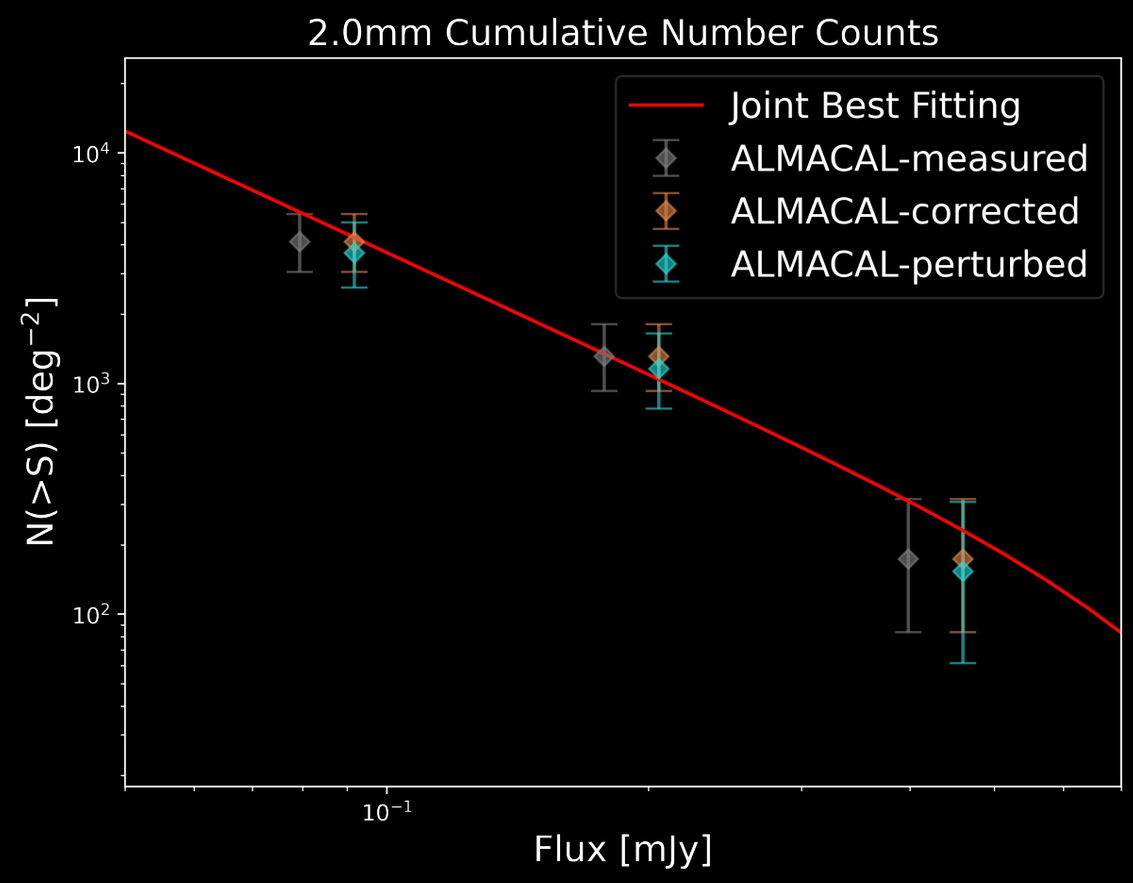


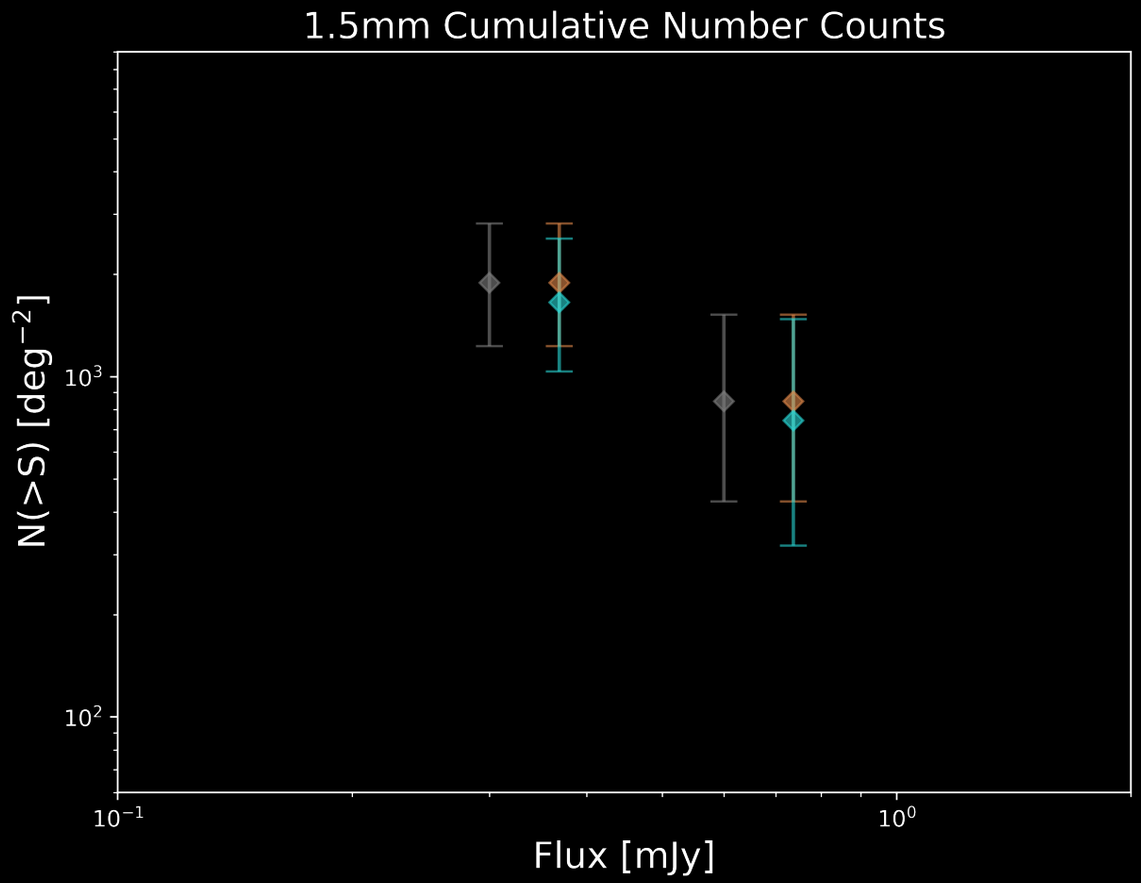


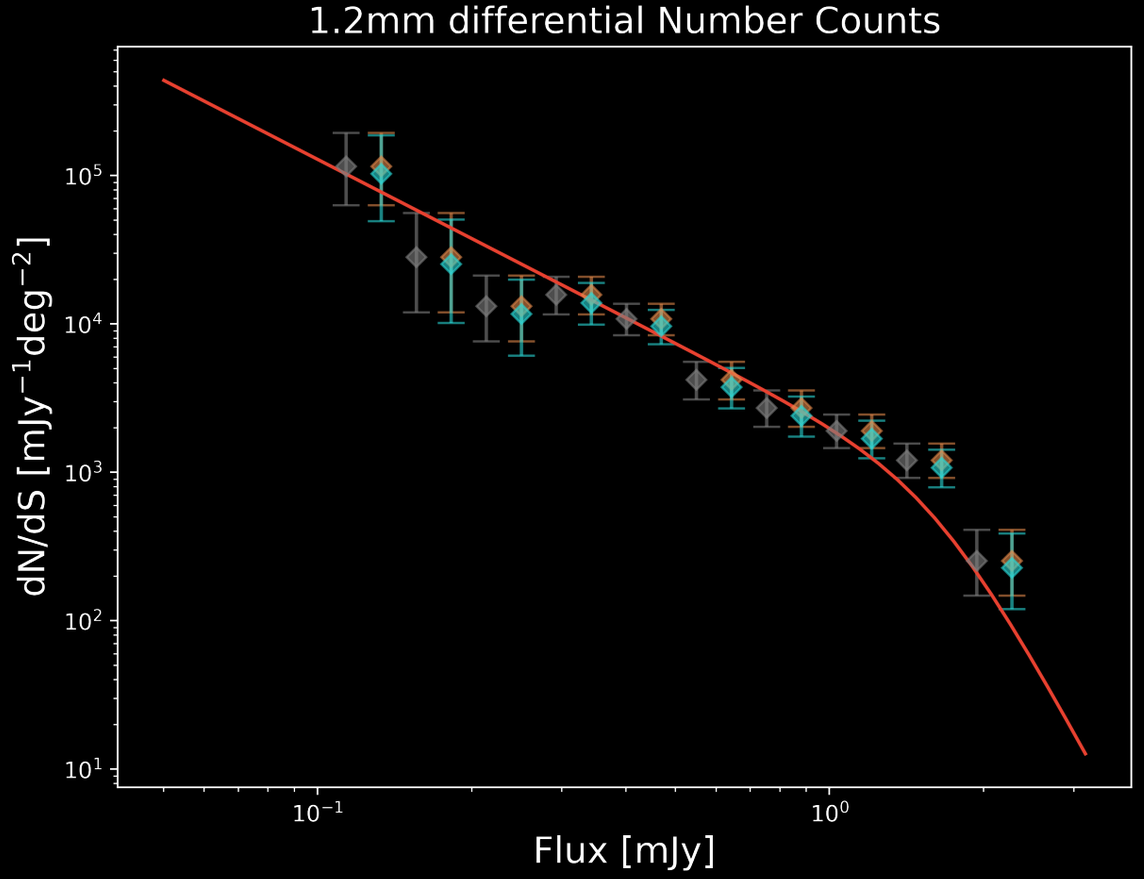
Deepest DSFGs number counts in multiple ALMA bands

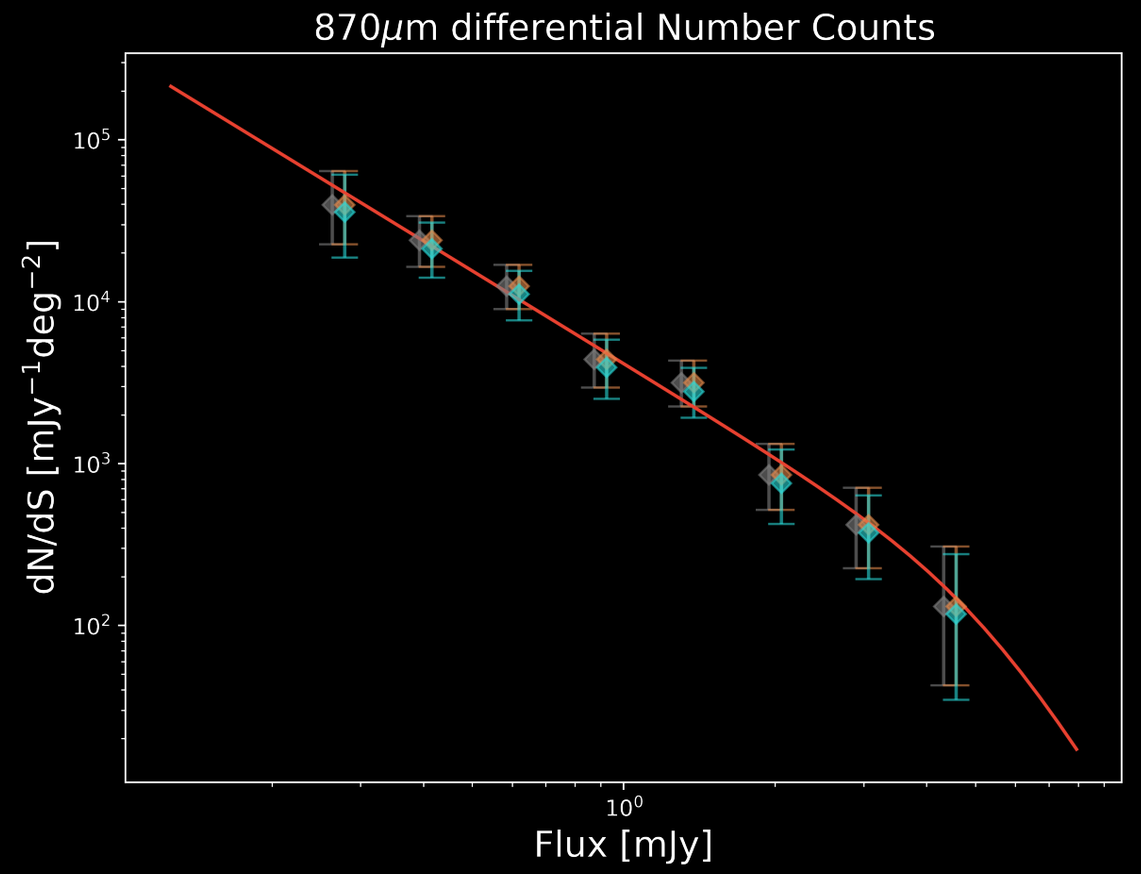
Appendix: source classification



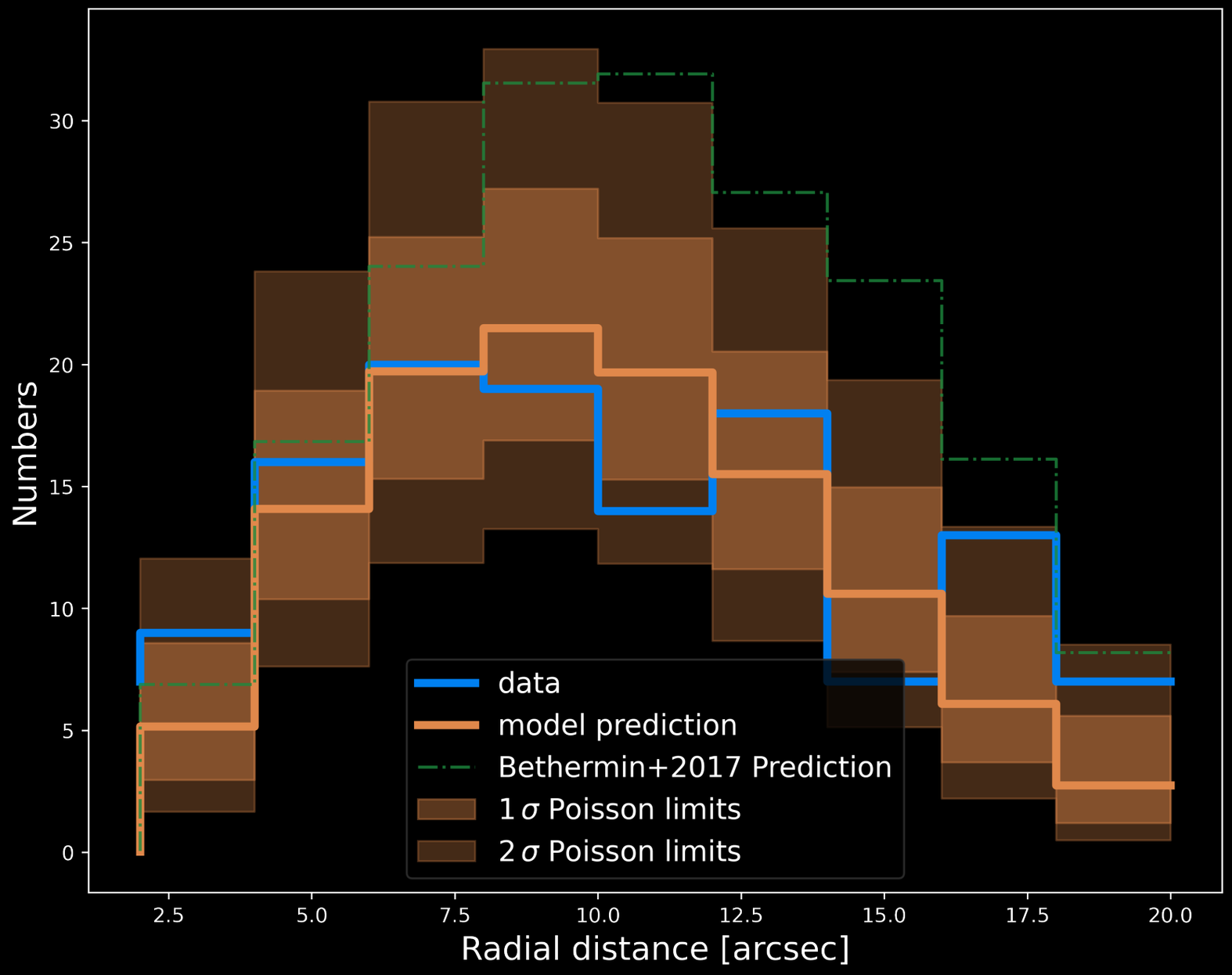

2.0mm Cumulative Number Counts
Joint Best Fitting
ALMACAL-measured
ALMACAL-corrected
ALMACAL-perturbed
N(>S) [deg^{-2}]
Flux [mJy]


1.5mm Cumulative Number Counts
N(>S) [deg^{-2}]
Flux [mJy]


1.2mm differential Number Counts
dN/dS [mJy^{-1}deg^{-2}]
Flux [mJy]


870μm differential Number Counts
dN/dS [mJy^{-1}deg^{-2}]
Flux [mJy]

Appendix: selection bias



Appendix: projected over-densities