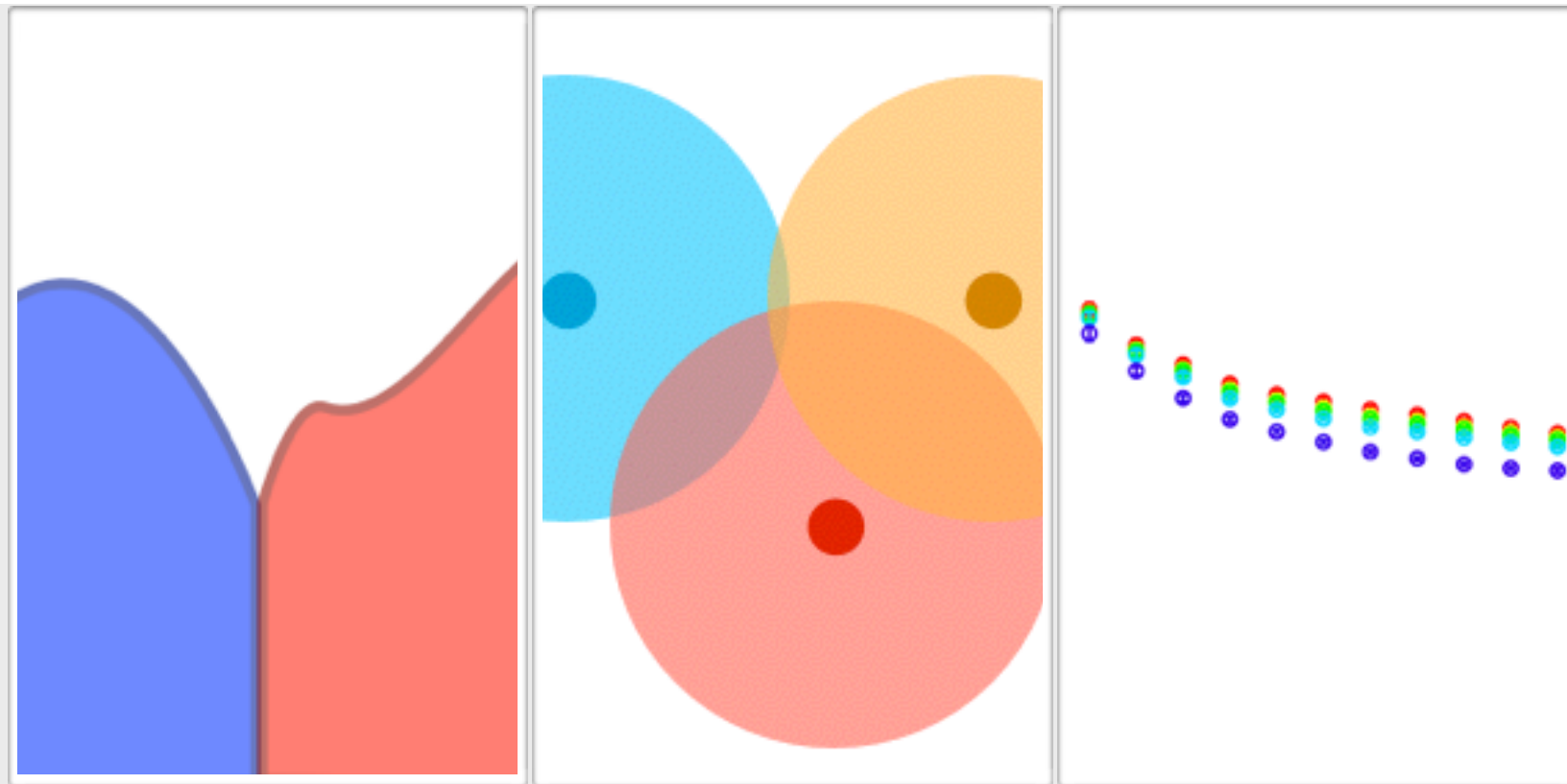




Occupy Dark Matter:
Uncovering the 99% of dusty galaxies
lying beneath the confusion noise floor

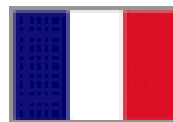
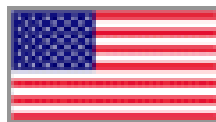
Marco Viero - Caltech

HerMES - Herschel Multi-tiered Extragalactic Survey

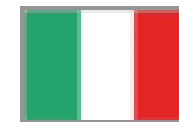
**To study the evolution of galaxies in the distant Universe
The biggest project on the Herschel Space Observatory
A European Space Agency mission**



Astronomy Technology Centre
California Institute of Technology
Cardiff University
CEA, Saclay
Cornell
ESAC
Godard Space Flight Centre



Imperial College, London
Infrared Processing Analysis Centre
Institut d'Astrophysique de Paris
Institut d'Astrophysique Spatiale
Institute Astrophysica Canarias
Jet Propulsion Lab.
Laboratory of Astrophysics of Marseilles



Mullard Space Science Laboratory
OAPd University of Padova
UC Irvine
University of British Columbia
University of Colorado
University of Hertfordshire
University of Sussex

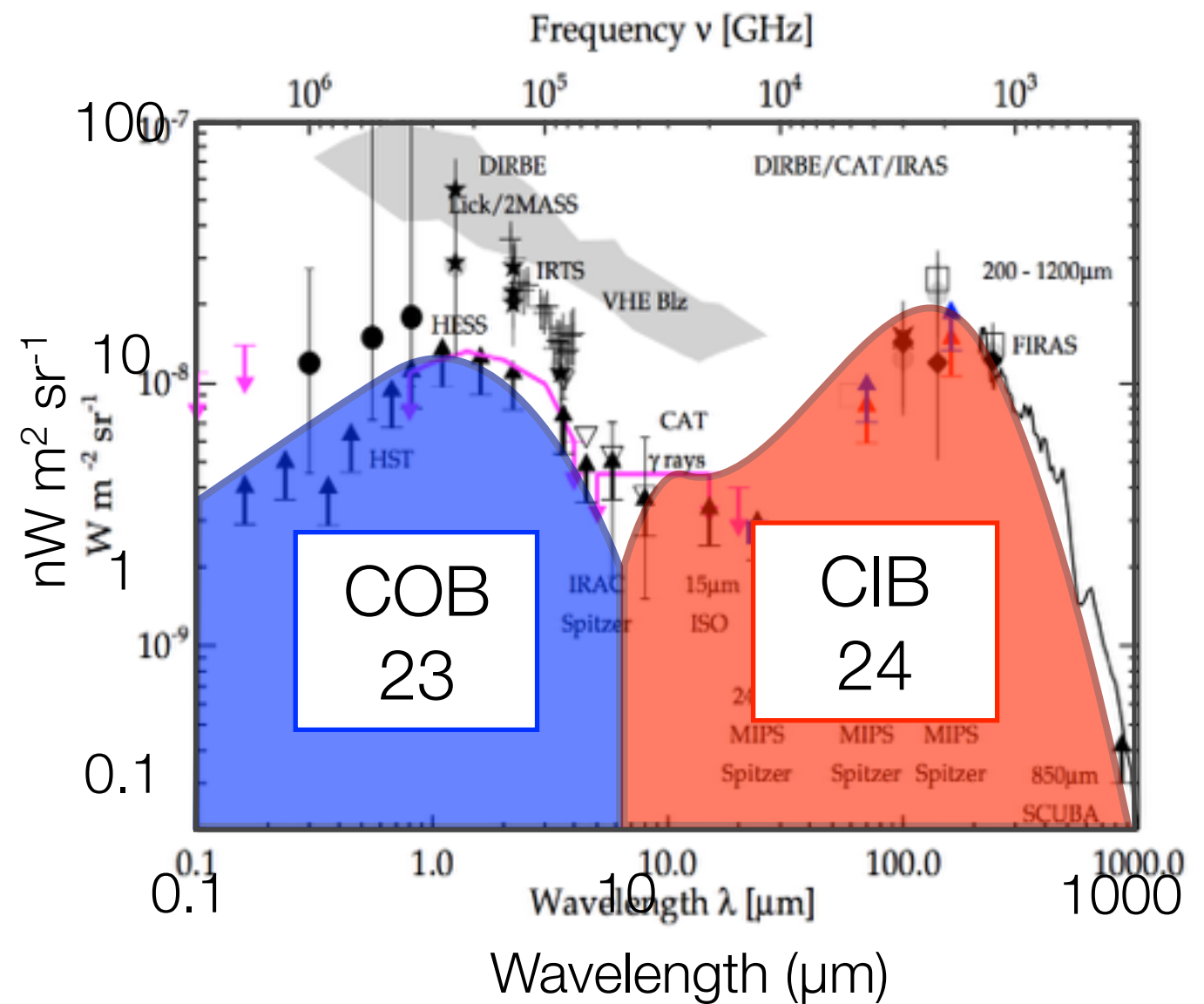


The Team

Bruno Altieri, Alex Amblard, Rick Arendt, Vinod Arumugam, Robbie Auld, Herve Aussel, Alexandre Beelen, Andrew Blain, Jamie Bock, Alessandro Boselli, Carrie Bridge, Drew Brisbin, Veronique Buat, Denis Burgarella, Nieves Castro-Rodriguez, Antonia Cava, Pierre Chanial, Ed Chapin, Michele Cirasuolo, Dave Clements, Alex Conley, Luca Conversi, Asantha Cooray, Emanuele Daddi, Gianfranco De Zotti, Darren Dowell, Jim Dunlop, Eli Dwek, Simon Dye, Steve Eales, David Elbaz, Erica Ellingson, Tim Ellsworth-Bowers, Duncan Farrah, Patrizia Ferrero, Mark Frost, Ken Ganga, Elodie Giovannoli, Jason Glenn, Eduardo Gonzalez-Solares, Matt Griffin, Mark Halpern, Martin Harwit, Evanthia Hatziminaoglou, George Helou, Jiasheng Huang, Ho Seong Hwang, Edo Ibar, Olivier Ilbert, Kate Isaak, Rob Ivison, Martin Kunz, Guilaine Lagache, Glenn Laurent, Louis Levenson, Carol Lonsdale, Nanyao Lu, Suzanne Madden, Bruno Maffei, Georgios Magdis, Gabriele Mainetti, Lucia Marchetti, Gaelen Marsden, Jason Marshall, Glenn Morrison, Angela Mortier, Hien Trong Nguyen, Brian O'Halloran, Seb Oliver, Alain Omont, Francois Orieux, Frazer Owen, Matthew Page, Biswajit Pandey, Maruillo Pannell, Pasquale Panuzzo, Andreas Papageorgiou, Harsit Patel, Chris Pearson, Ismael Perez Fournon, Michael Pohlen, Naseem Rangwala, Jason Rawlings, Gwen Raymond, Dimitra Rigopoulou, Laurie Riguccini, Guilia Rodighiero, Isaac Roseboom, Michael Rowan-Robinson, Miguel Sanchez Portal, Bernhard Schulz, Douglas Scott, Paolo Serra, Nick Seymour, David Shupe, Anthony Smith, Jason Stevens, Veronica Strazzu, Myrto Symeonidis, Markos Trichas, Katherine Tugwell, Mattia Vaccari, Elisabetta Valiante, Ivan Vatchanov, Joaquin Vieira, Marco Viero, Lingyu Wang, Don Wiebe, Kevin Xu, Michael Zemcov

Faculty & Researchers PostDocs PhD Students

Plus engineers, instrument
builders, software developers etc.

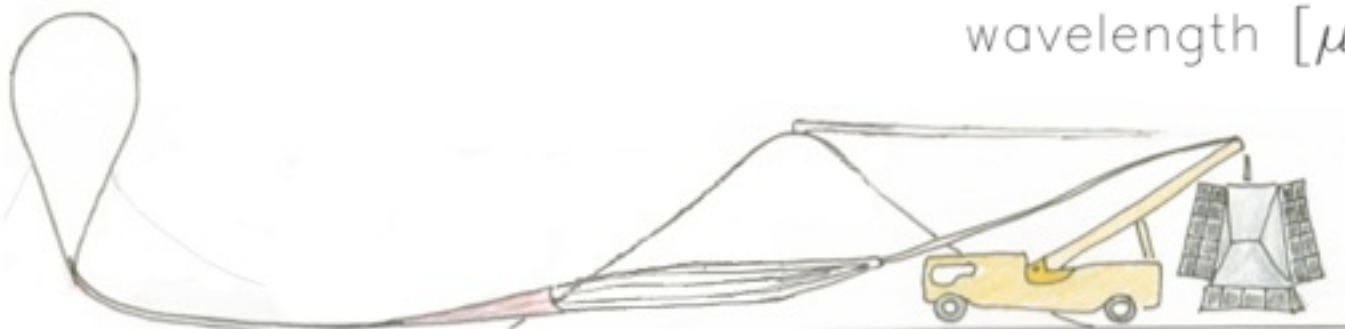
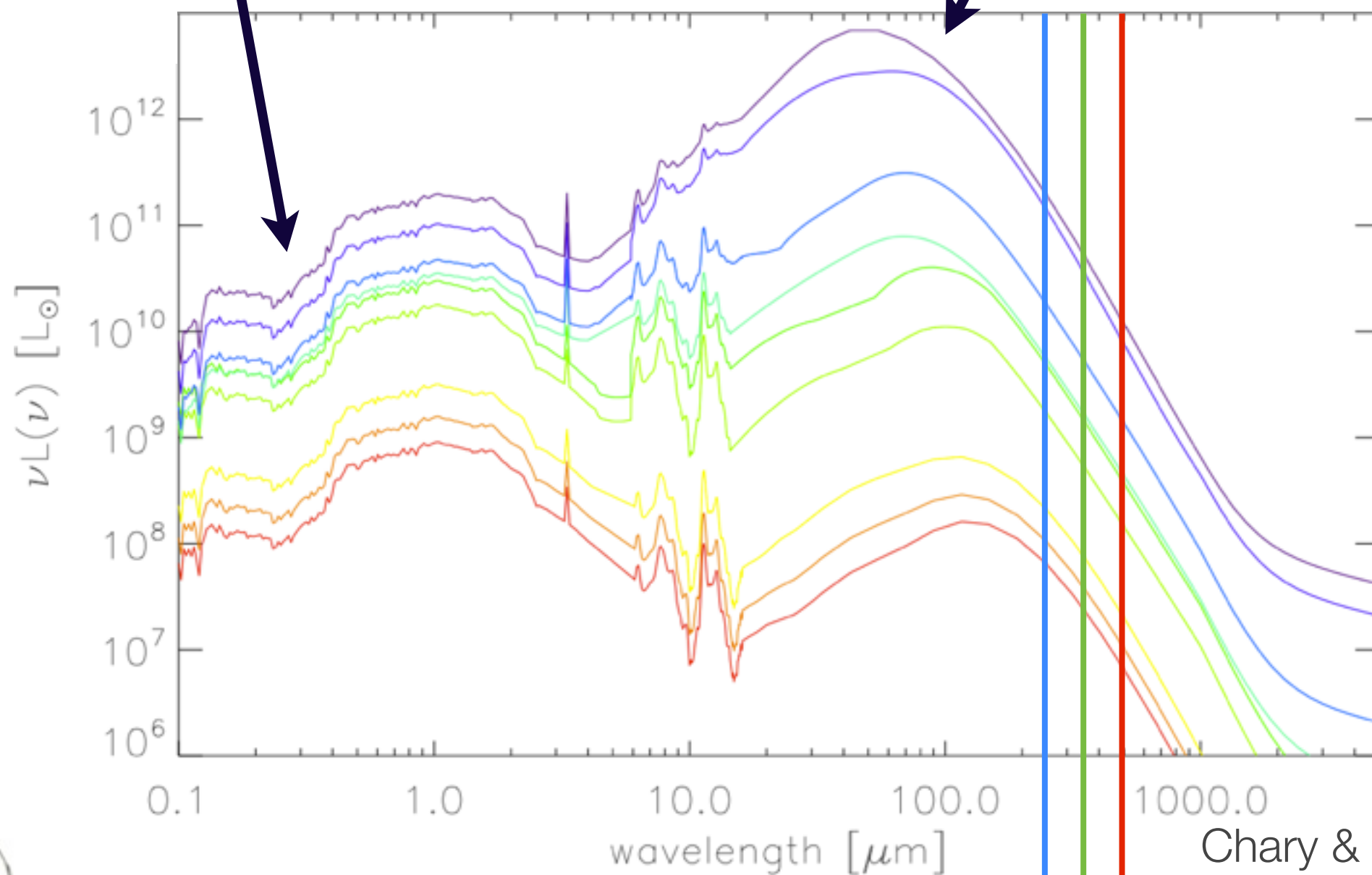


Dole et al (2006)

optical and infrared
backgrounds

Optical/UV Starlight absorbed by dust

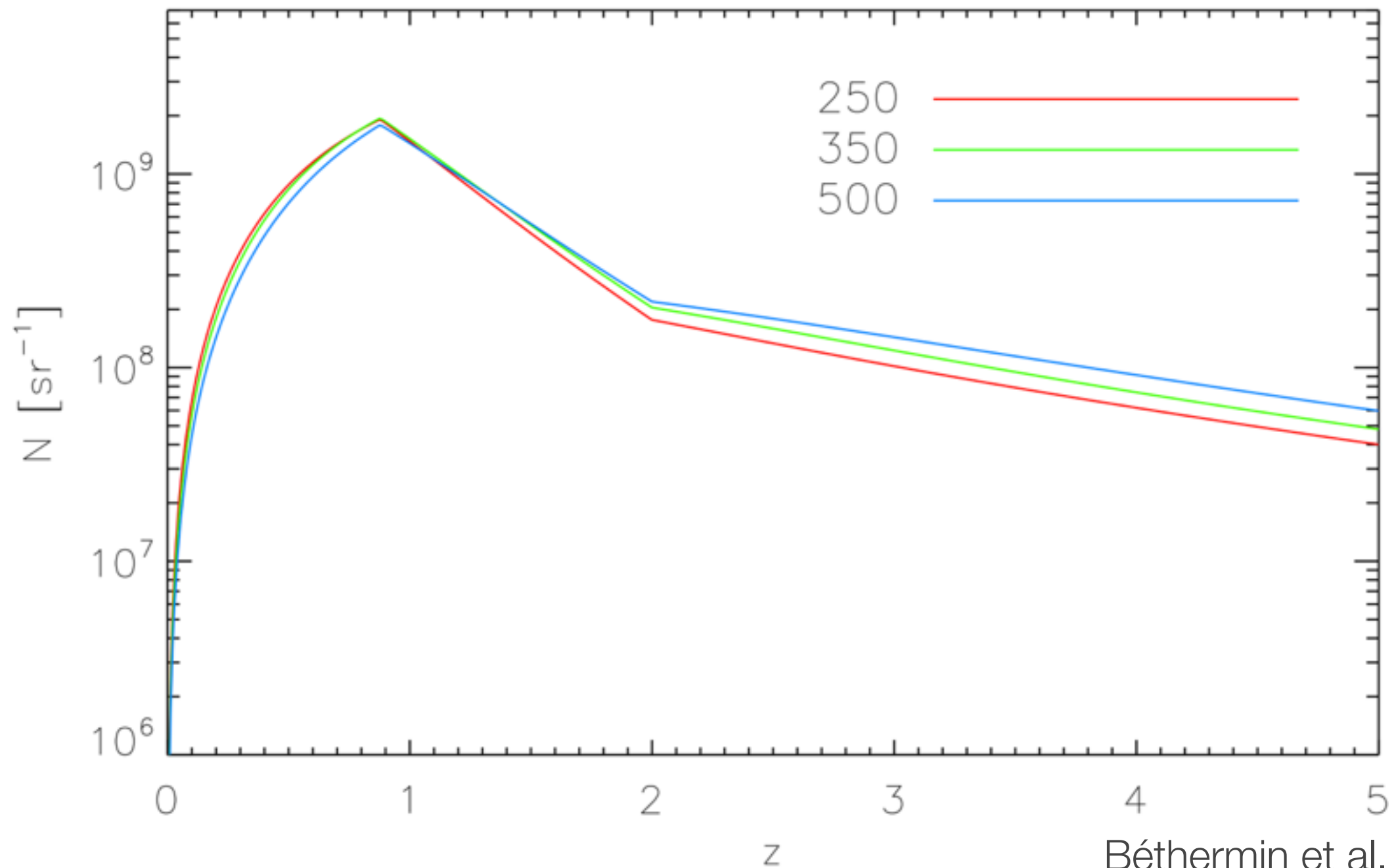
Dust re-emits in the FIR



250
350
500

UV/optical to IR relationship

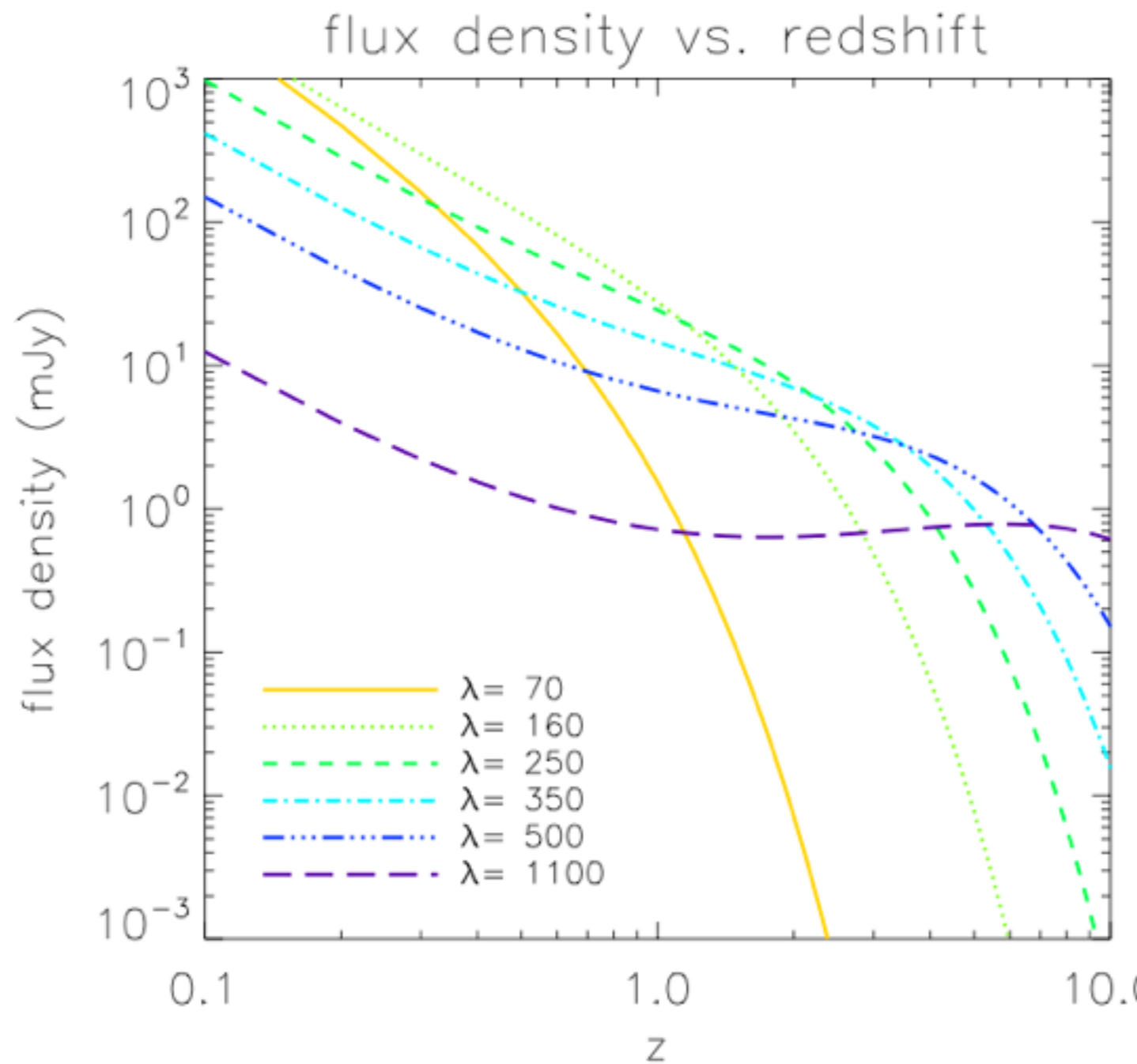
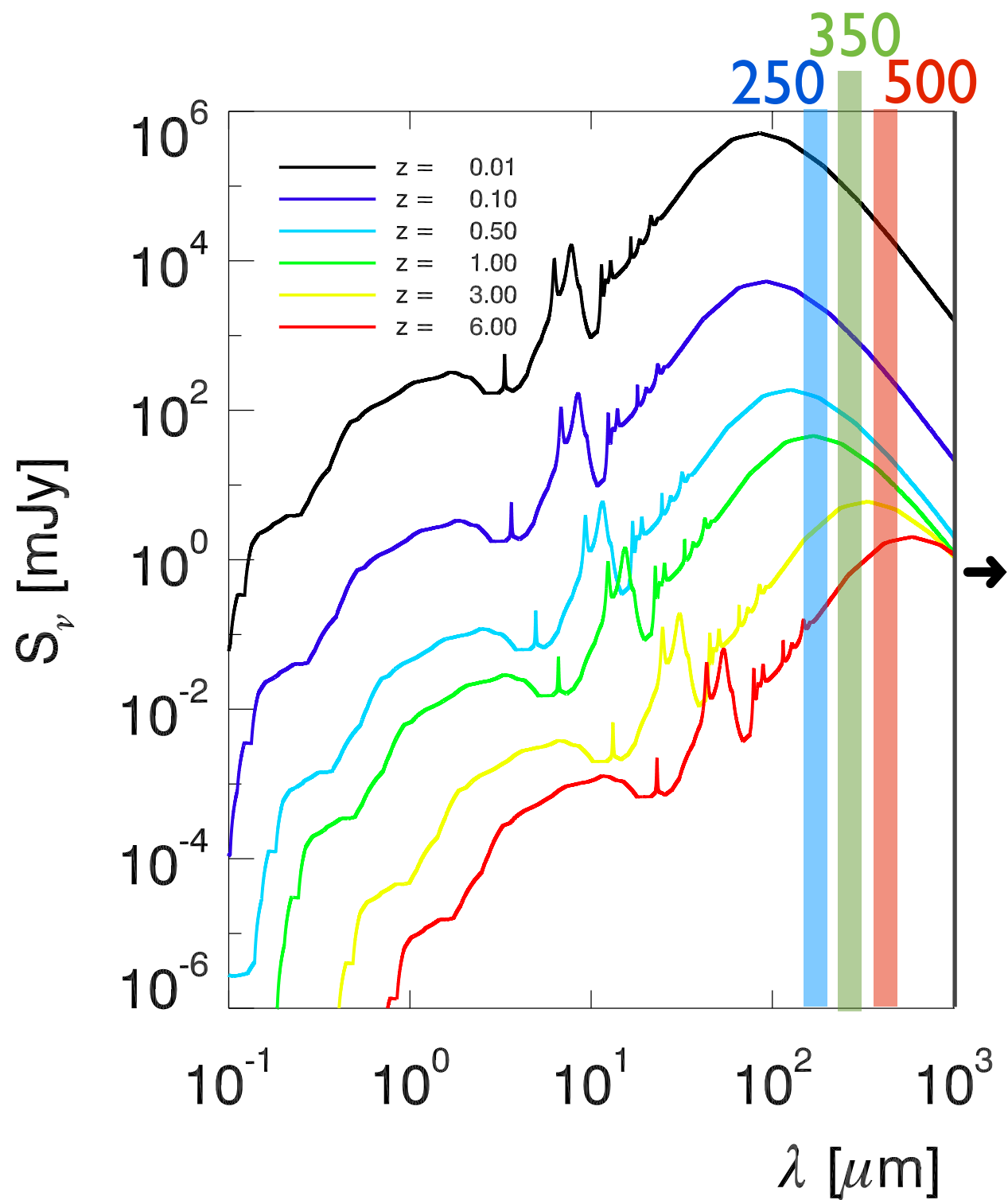
get this model @ <http://www.ias.u-psud.fr/irgalaxies/model.php#Counts>



Béthermin et al. (2011)

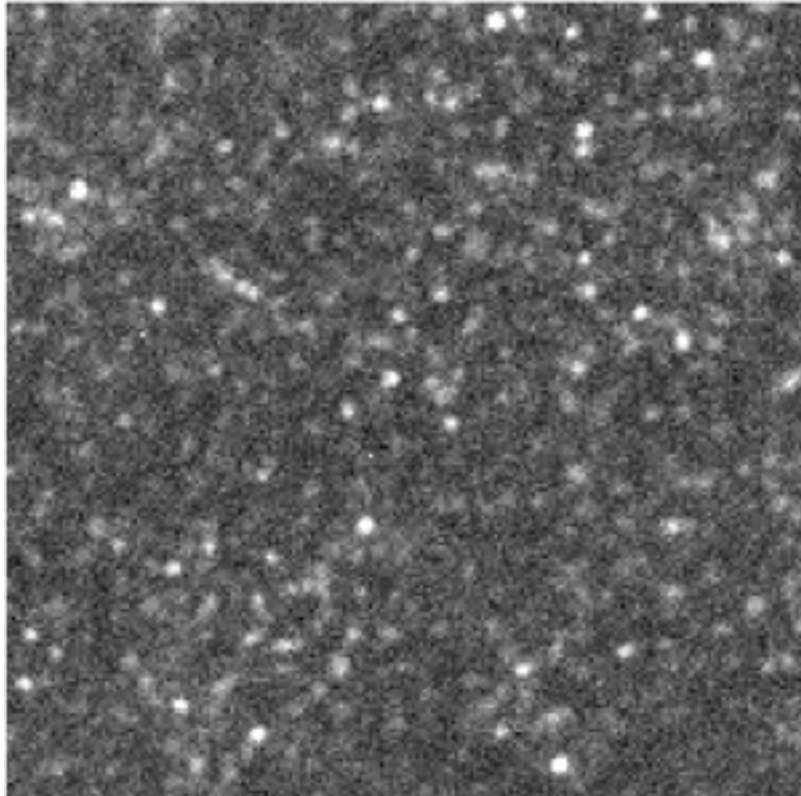
arXiv:1010.1150

z-distribution of DSFGs



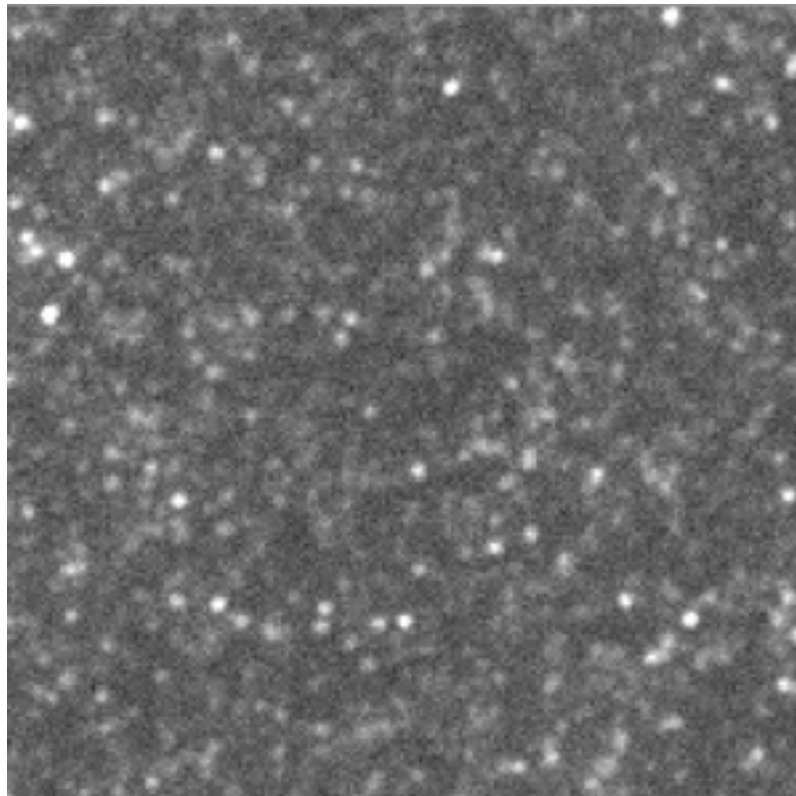
negative K -correction

2 repeats (fls)



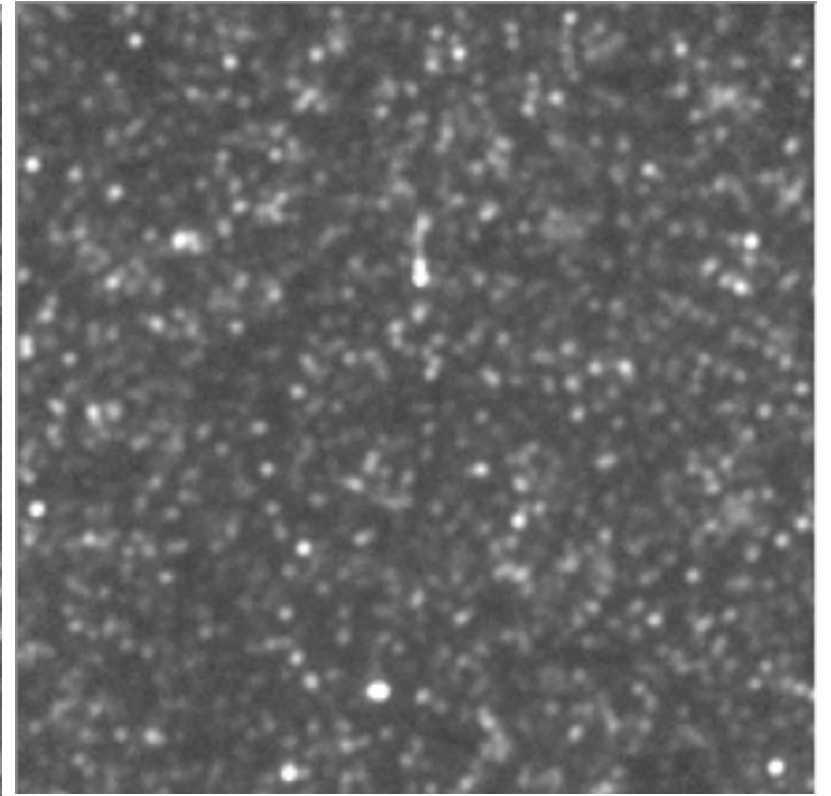
33.5 mJy (3σ)

7 repeats (uds)



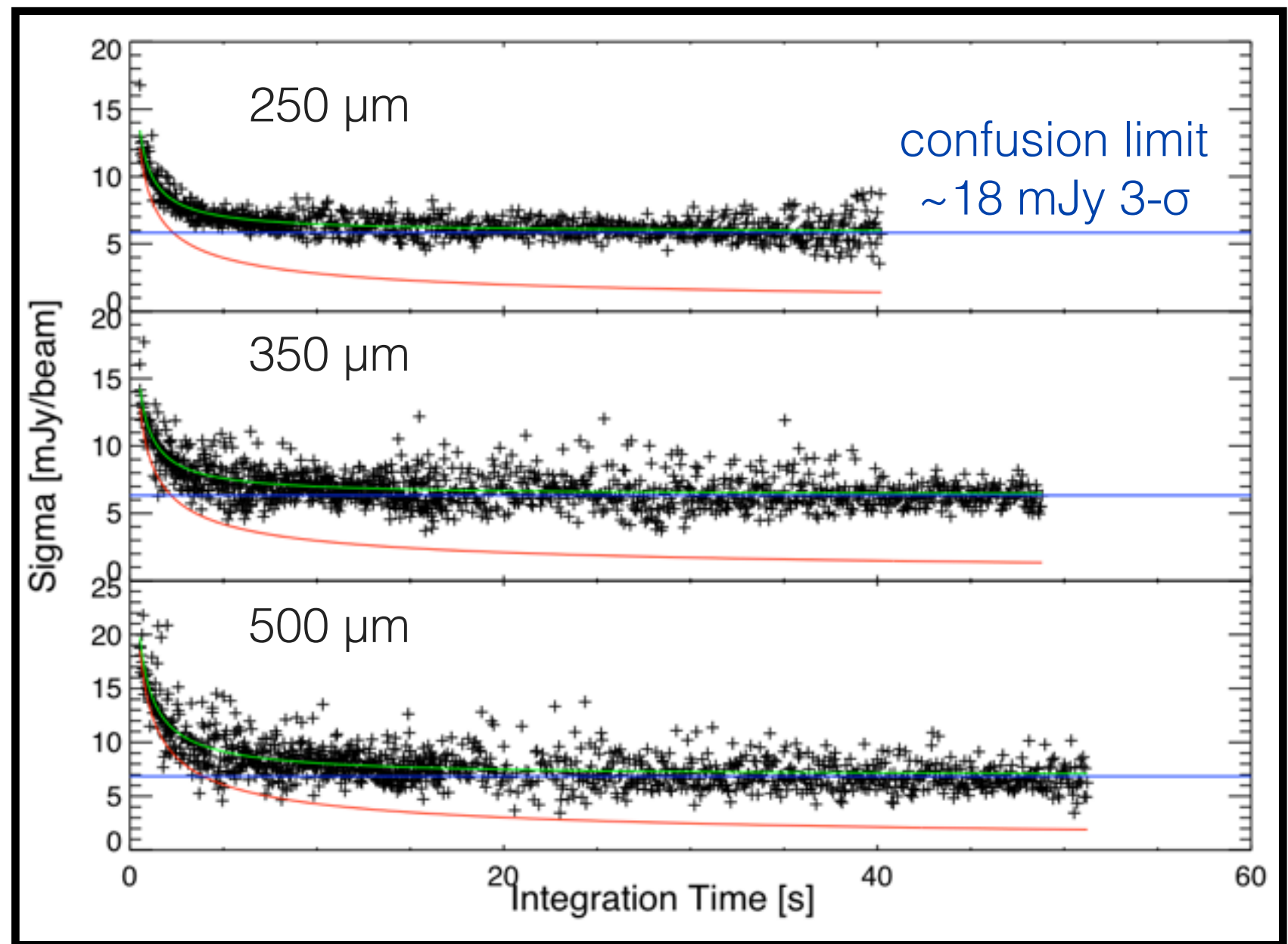
24.7 mJy (3σ)

76 repeats (goods-s)



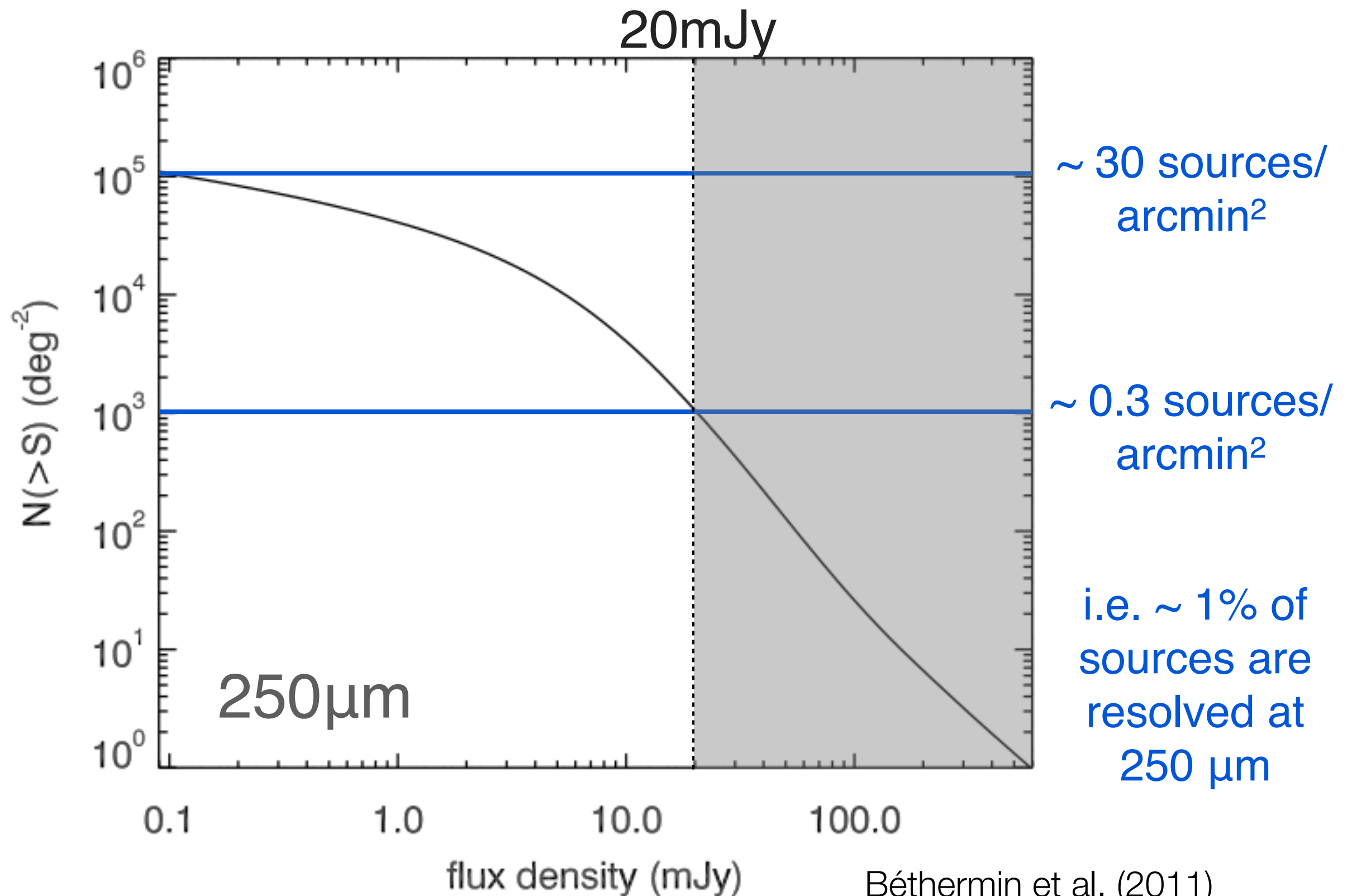
20.2 mJy (3σ)

source confusion



Nguyen et al. (2009)

source confusion



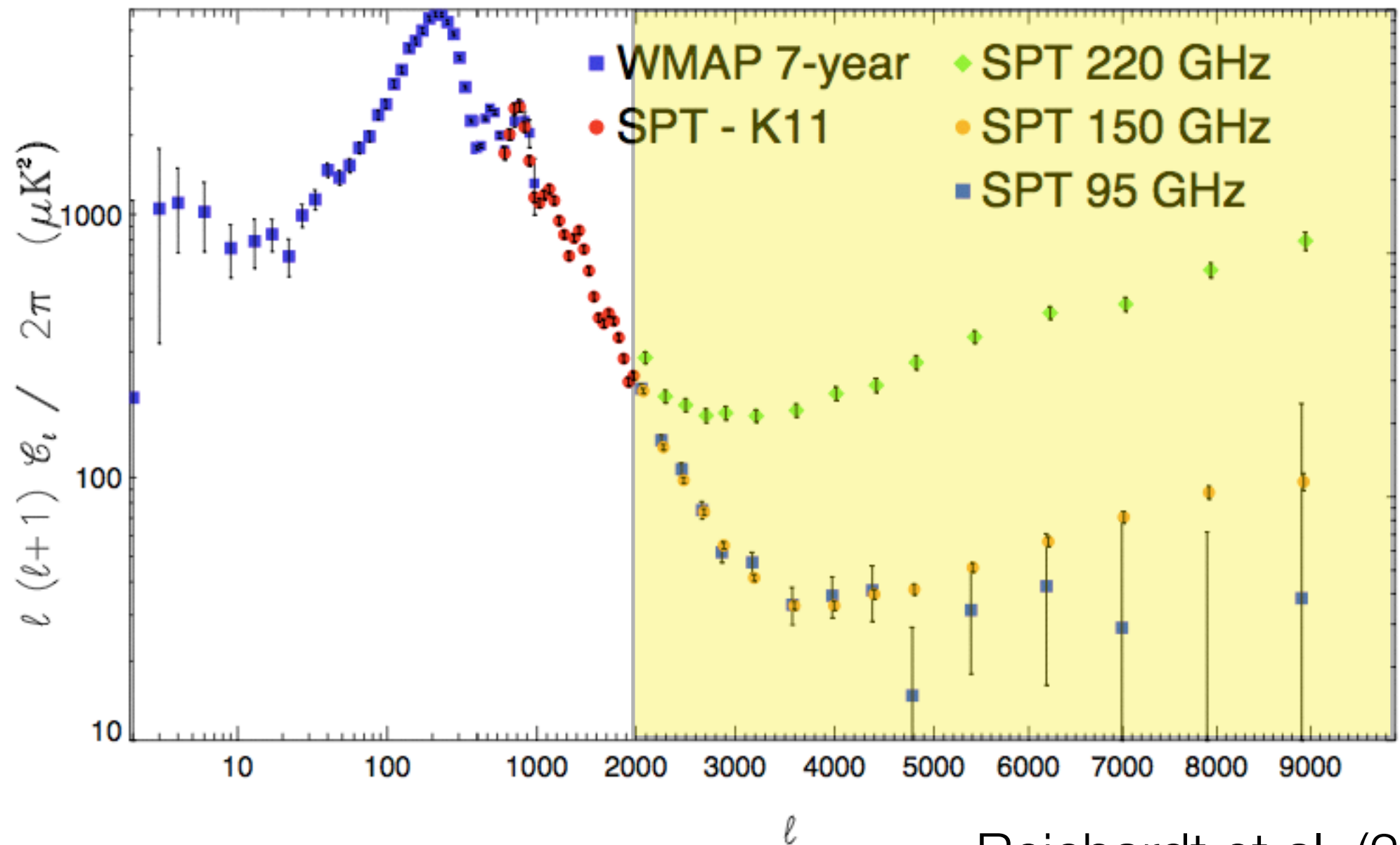
cumulative number counts

outline

- clustering of dusty galaxies
- contribution from optical galaxies to CIB
- HeRS

goals

- measure the clustering of dusty star-forming galaxies in order to:
 - measure the typical bias of star-forming regions
 - provide constraints for semi-analytic and phenomenological models
 - interpret with a model to obtain a halo occupation distribution of DSFGs

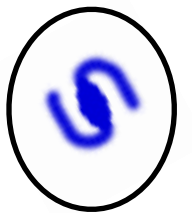
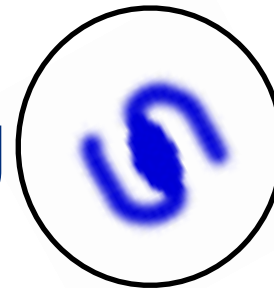
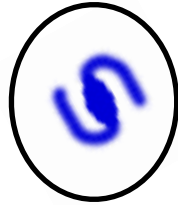


Reichardt et al. (2011)

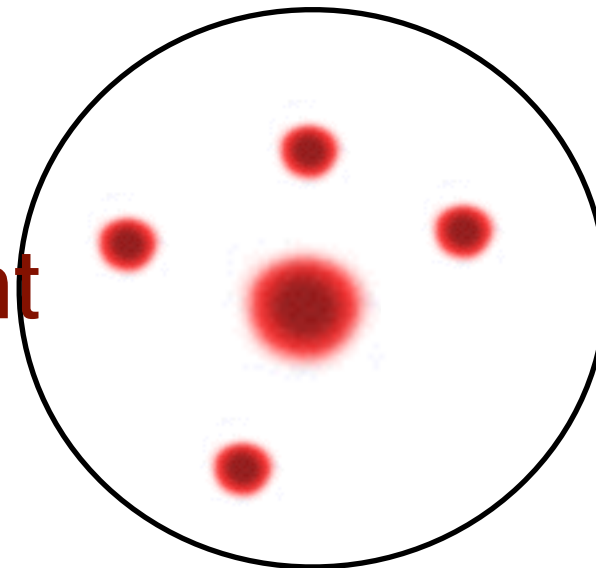
- $\ell > 2000$ dominated by secondary anisotropies

CIB part of CMB

Blue
Star-Forming
Galaxy



Red
Quiescent
Galaxy



$w(\theta)$ (arcsec)

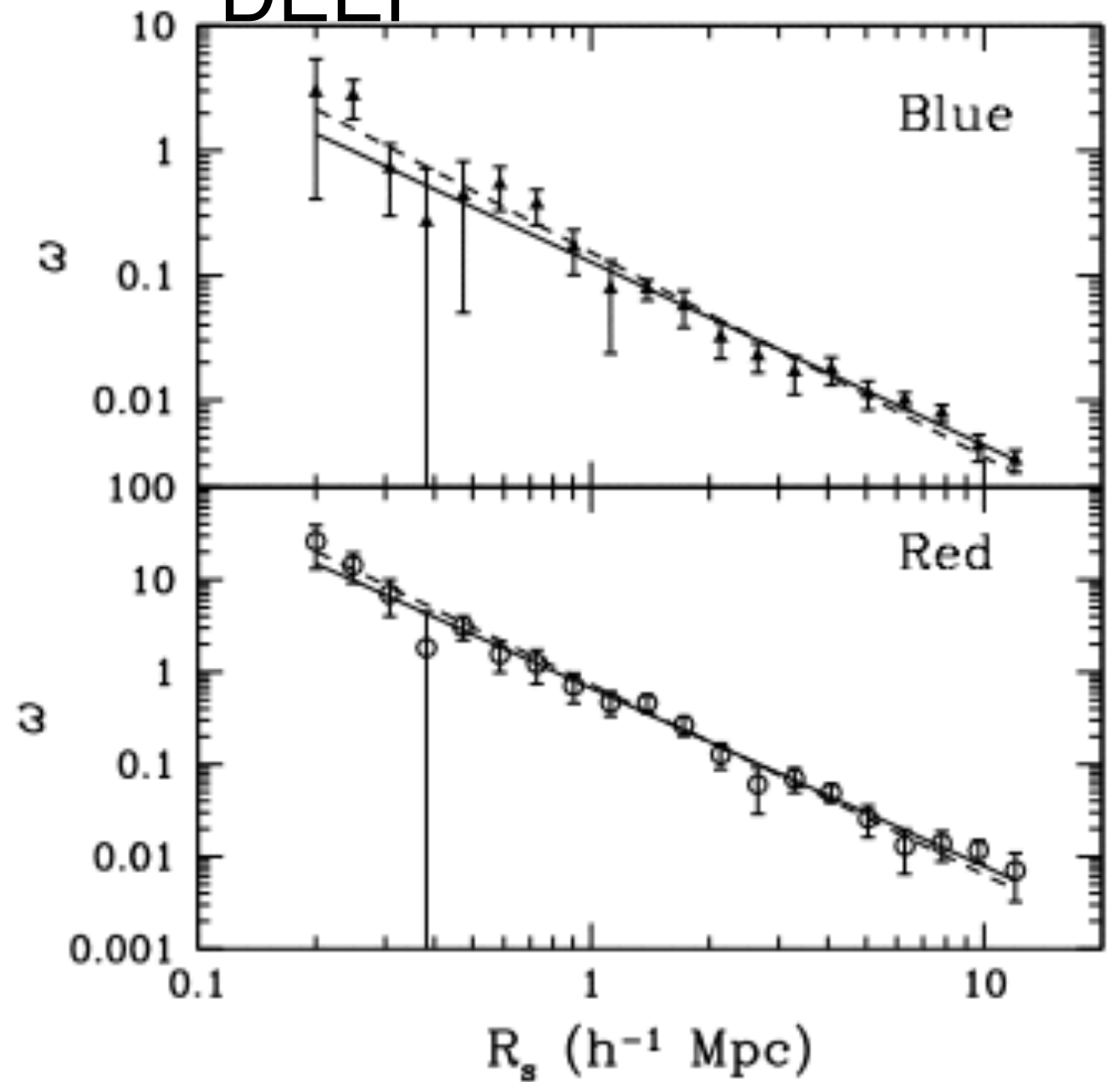
↑
stronger
clustering

— larger scales →

θ (arcsec)



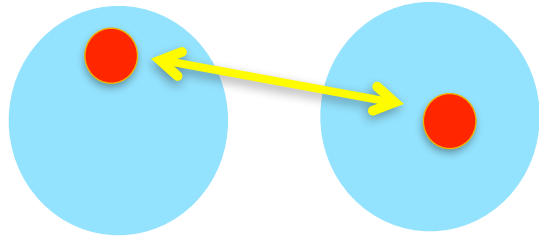
DEEP



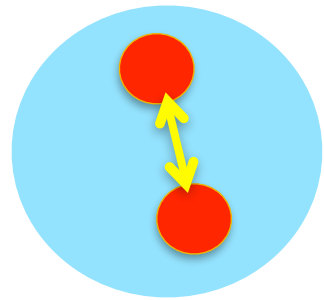
Coil et al.

correlation function

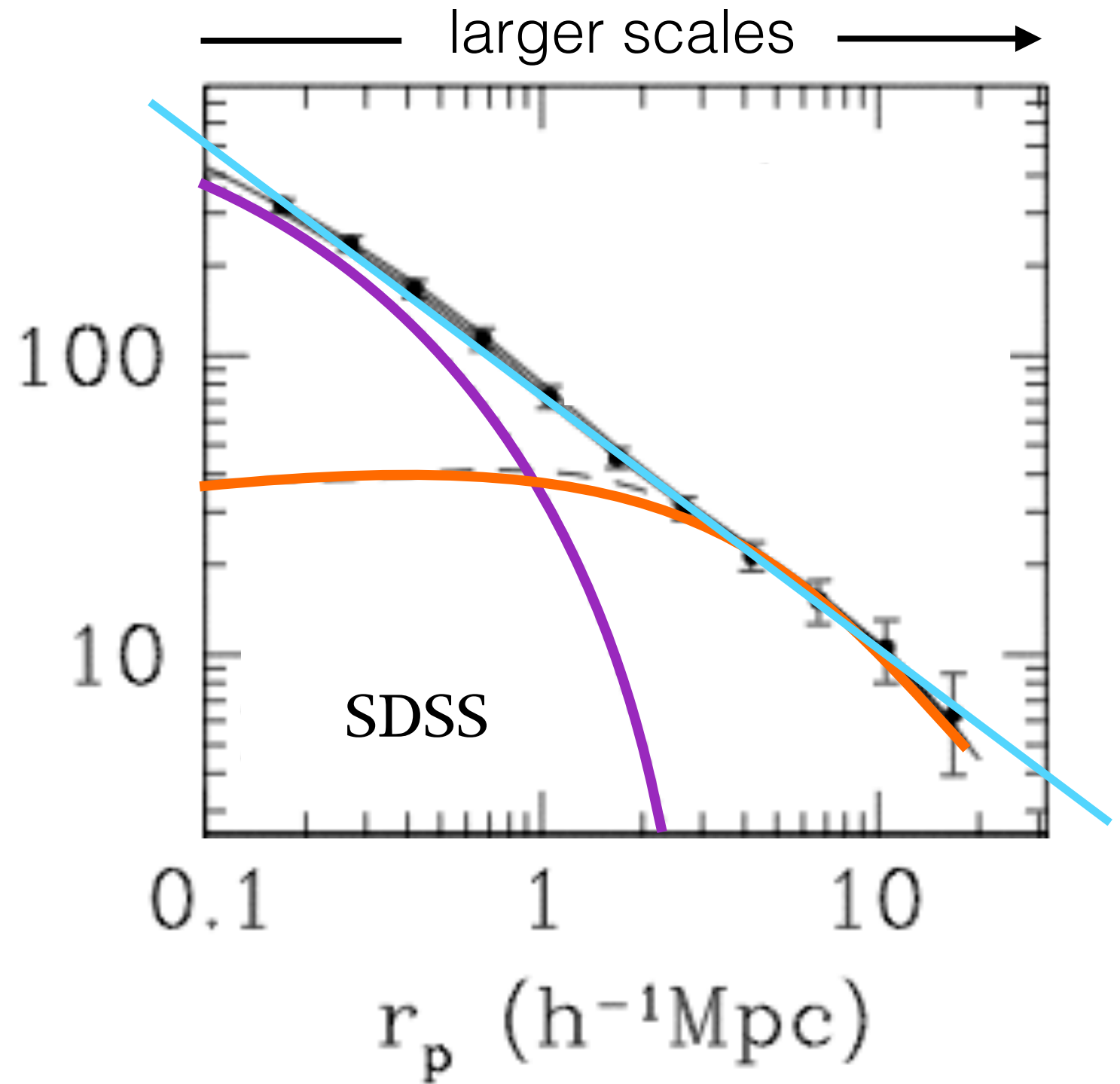
Two-halo: —



One-halo: —



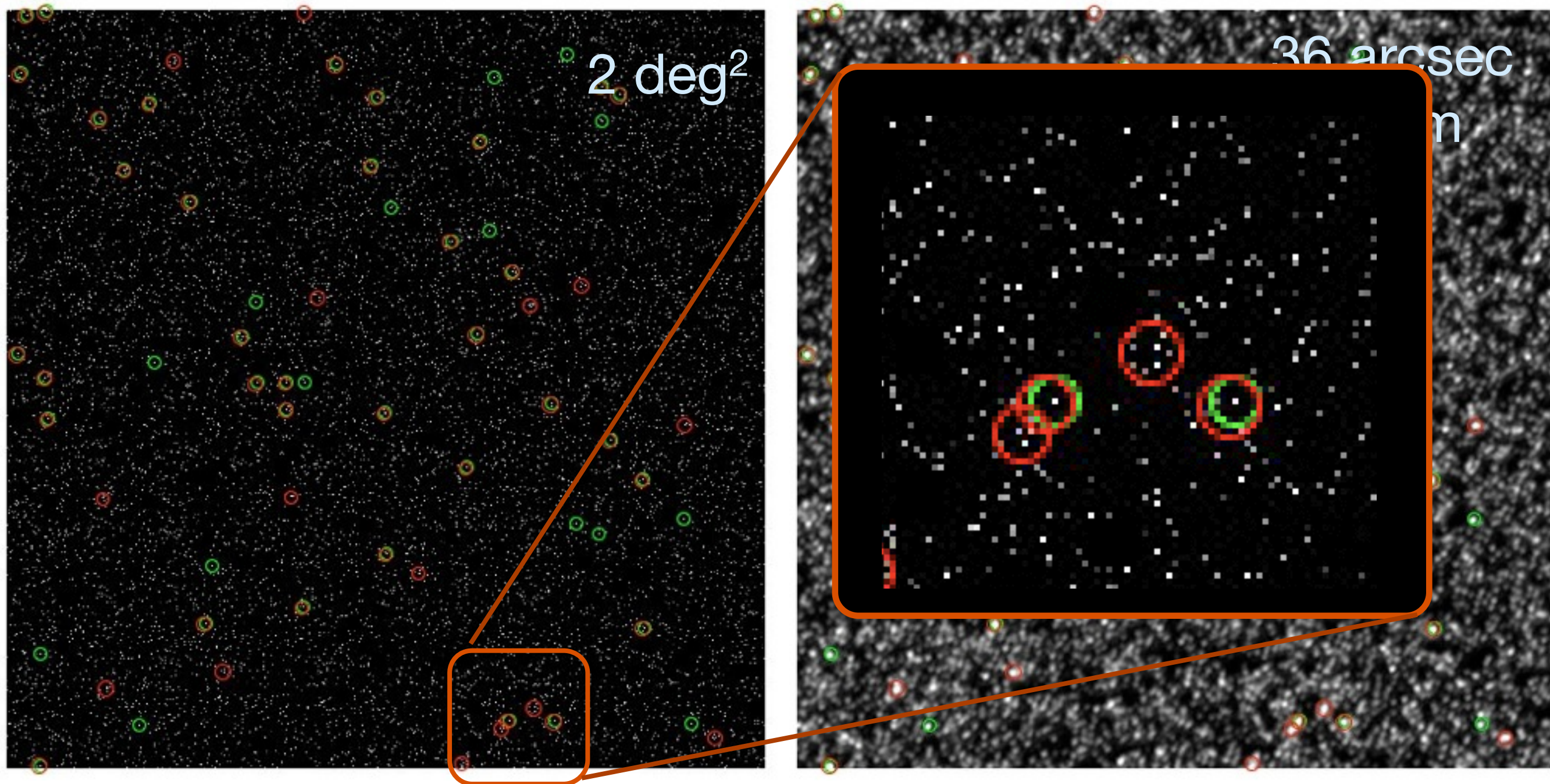
see e.g.,
Cooray & Sheth (2000),
Zehavi et al. (2005, 2008)



Zheng (2007)

halo model

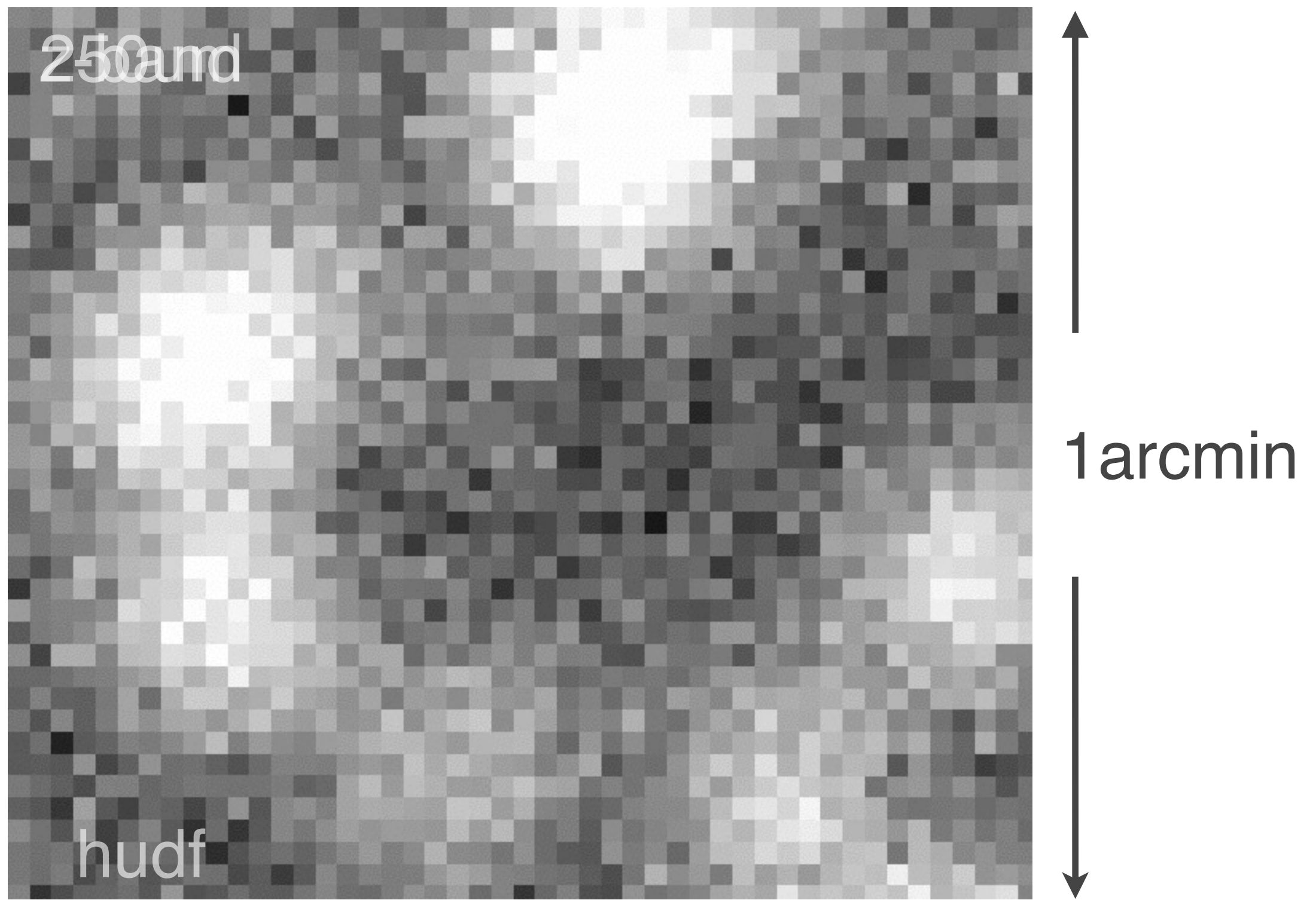
source confusion



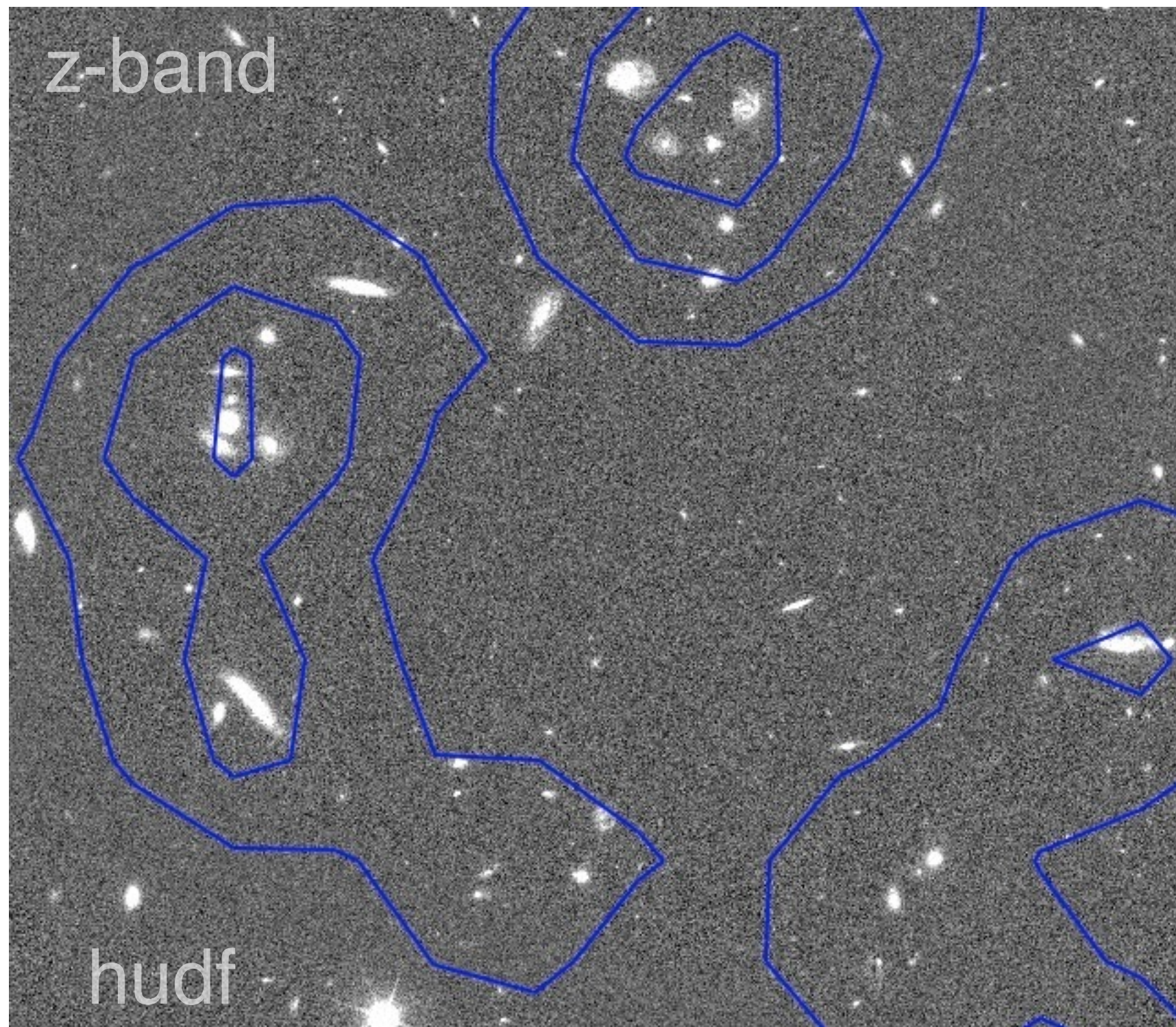
50 brightest
placed

70% of the
brightest
recovered

50 brightest
recovered



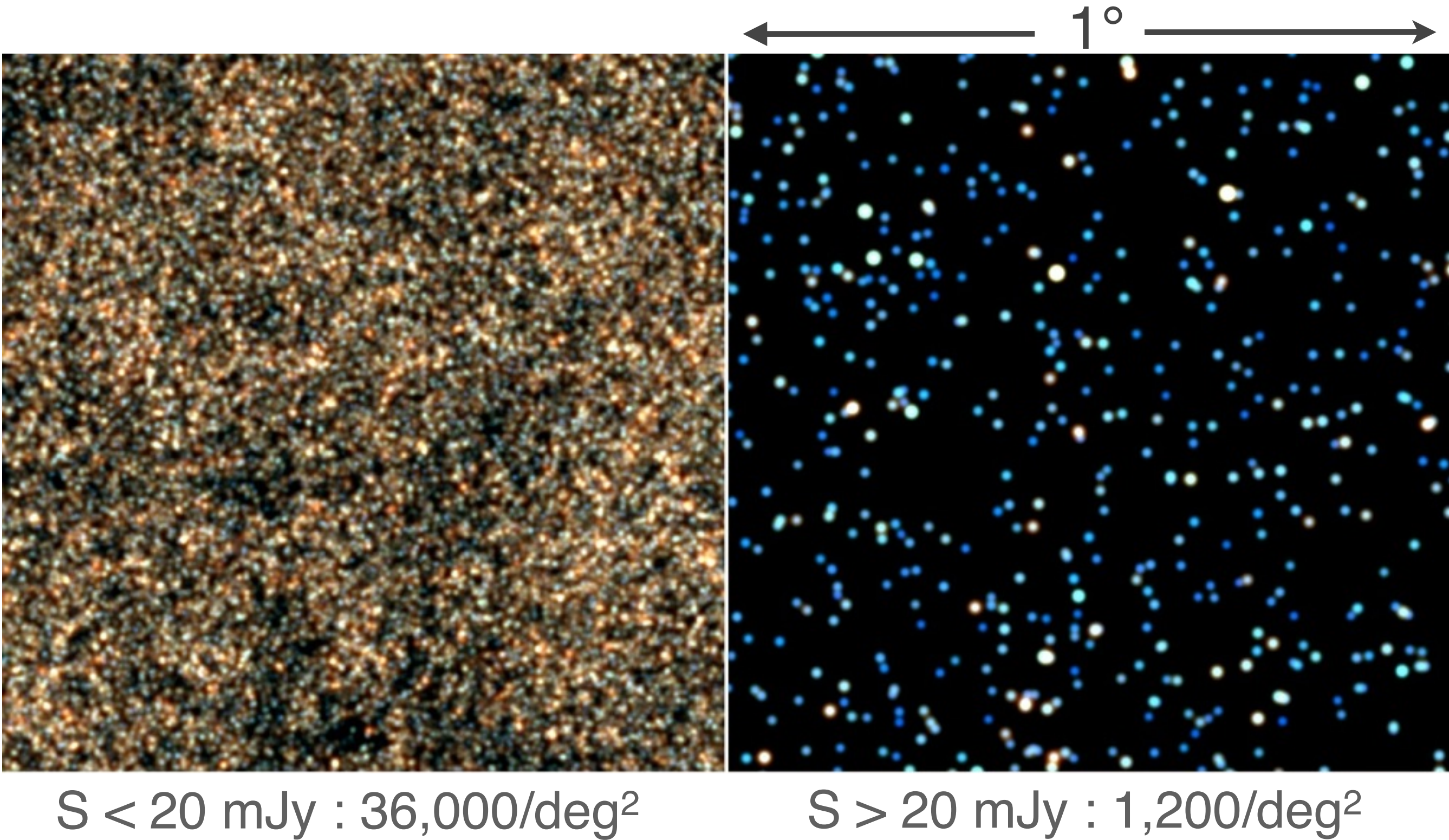
source confusion



1 arcmin

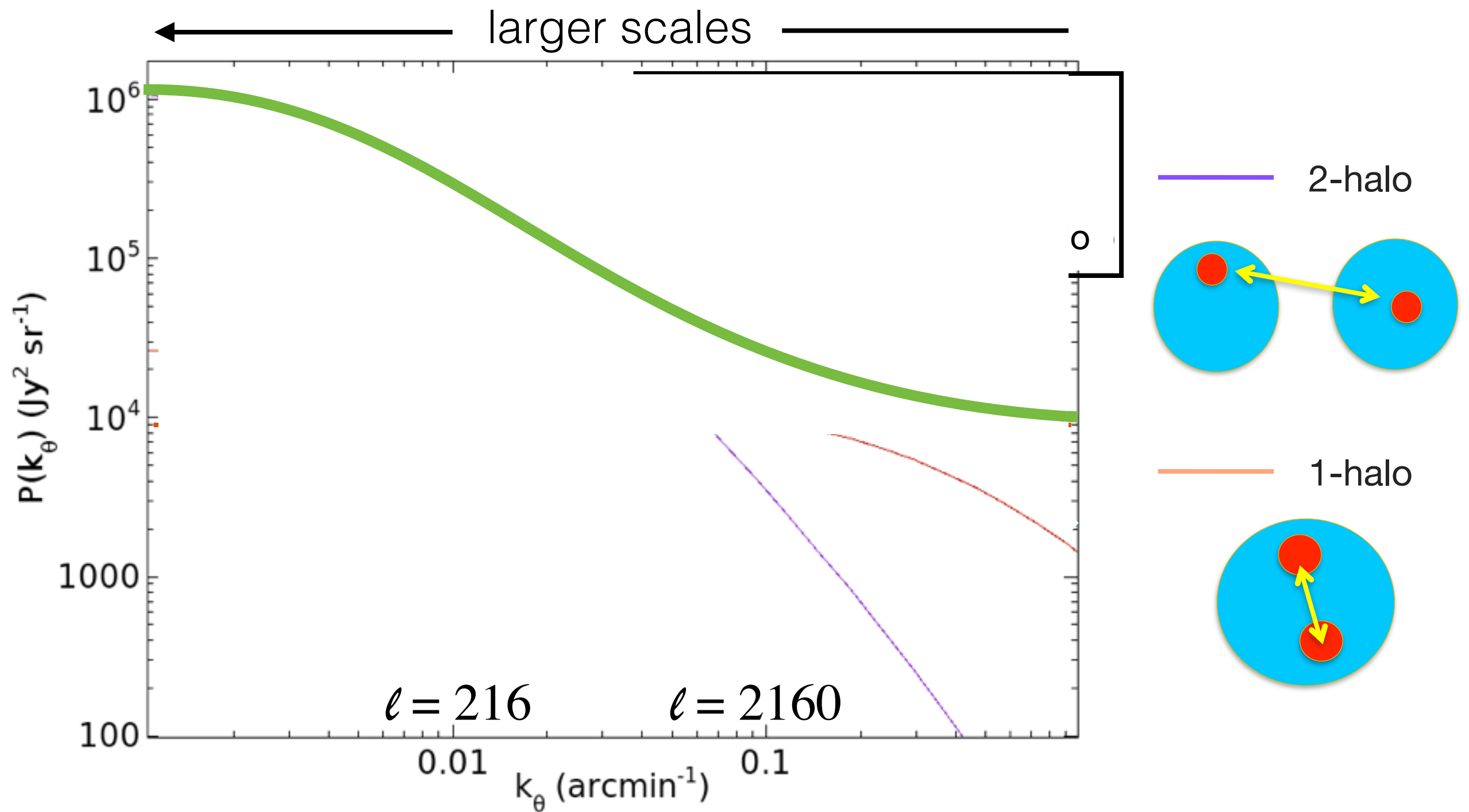


source confusion



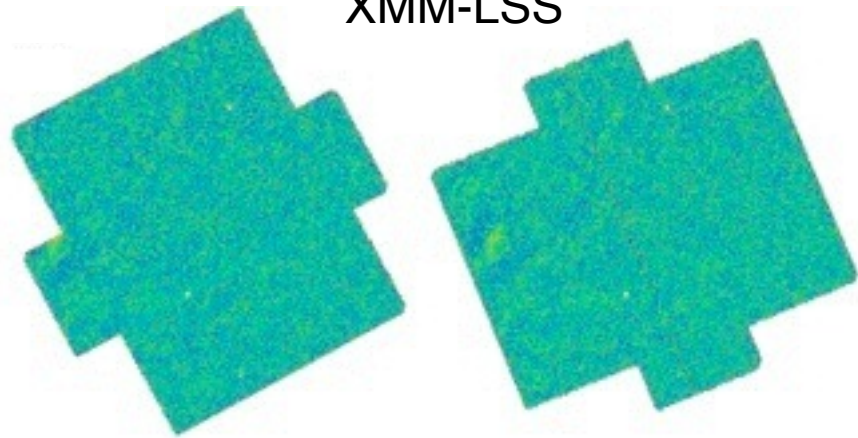
unresolved/resolved CIB

CIBA power spectra

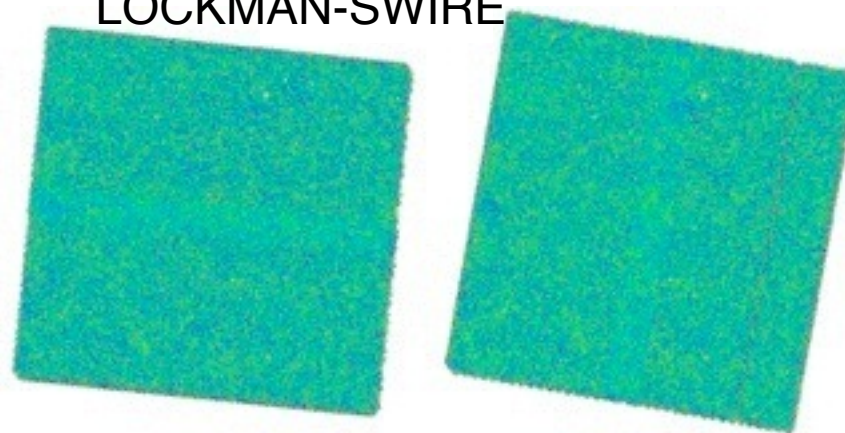


data

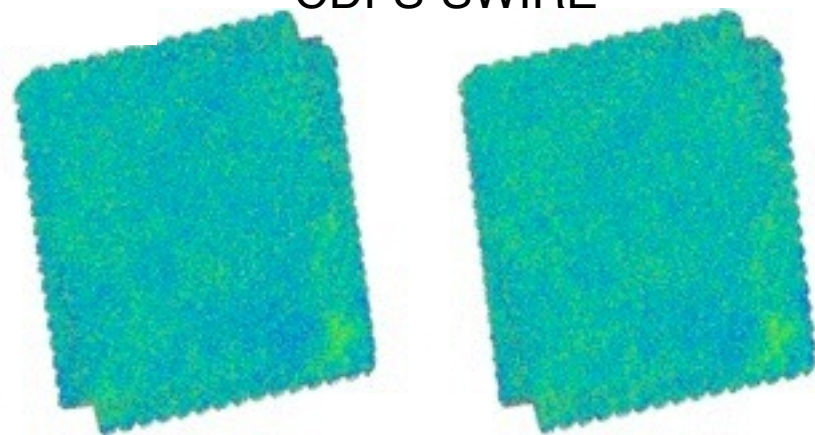
XMM-LSS



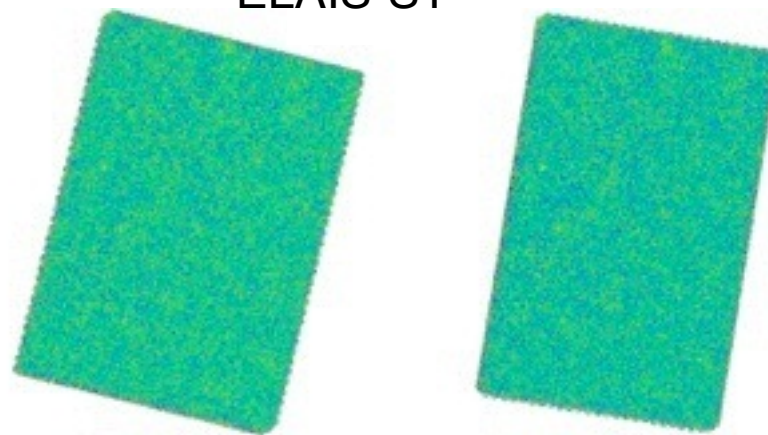
LOCKMAN-SWIRE



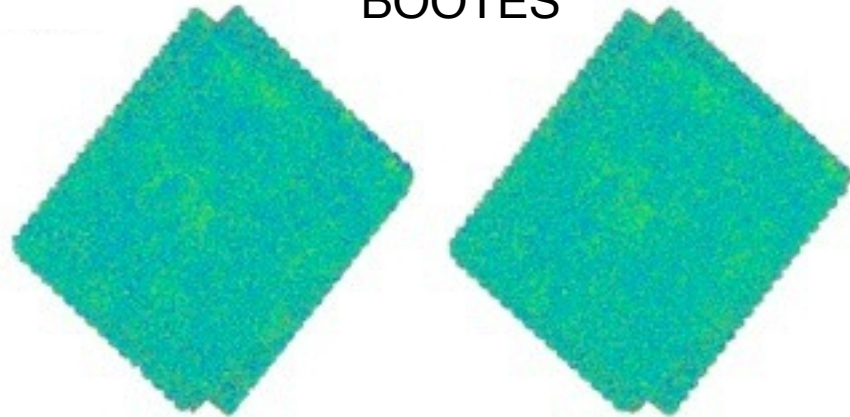
CDFS-SWIRE



ELAIS-S1



BOOTES



SMAP Team

Alex Conley

Louis Levenson

Gaelen Marsden

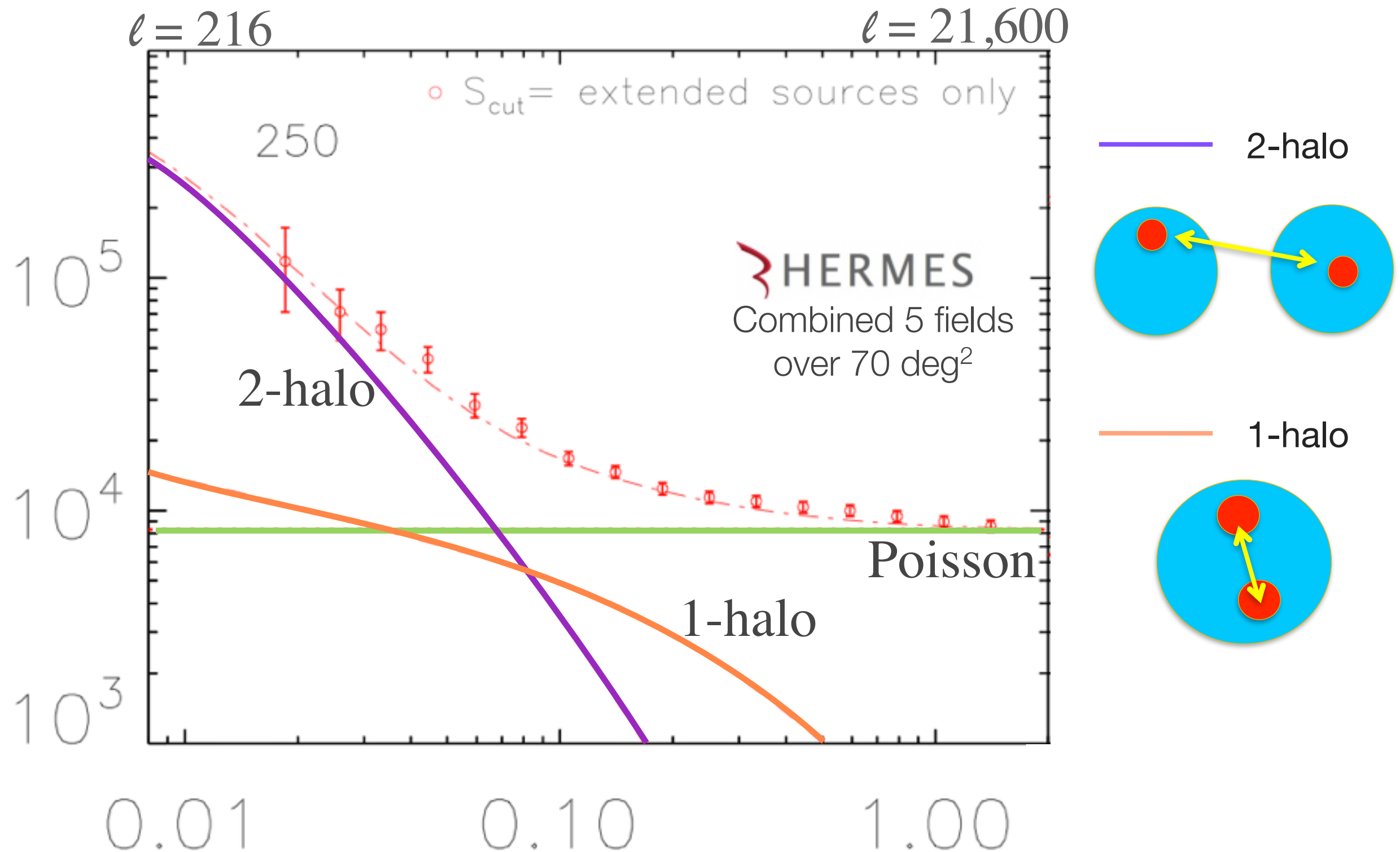
Bernhard Schulz

Marco Viero

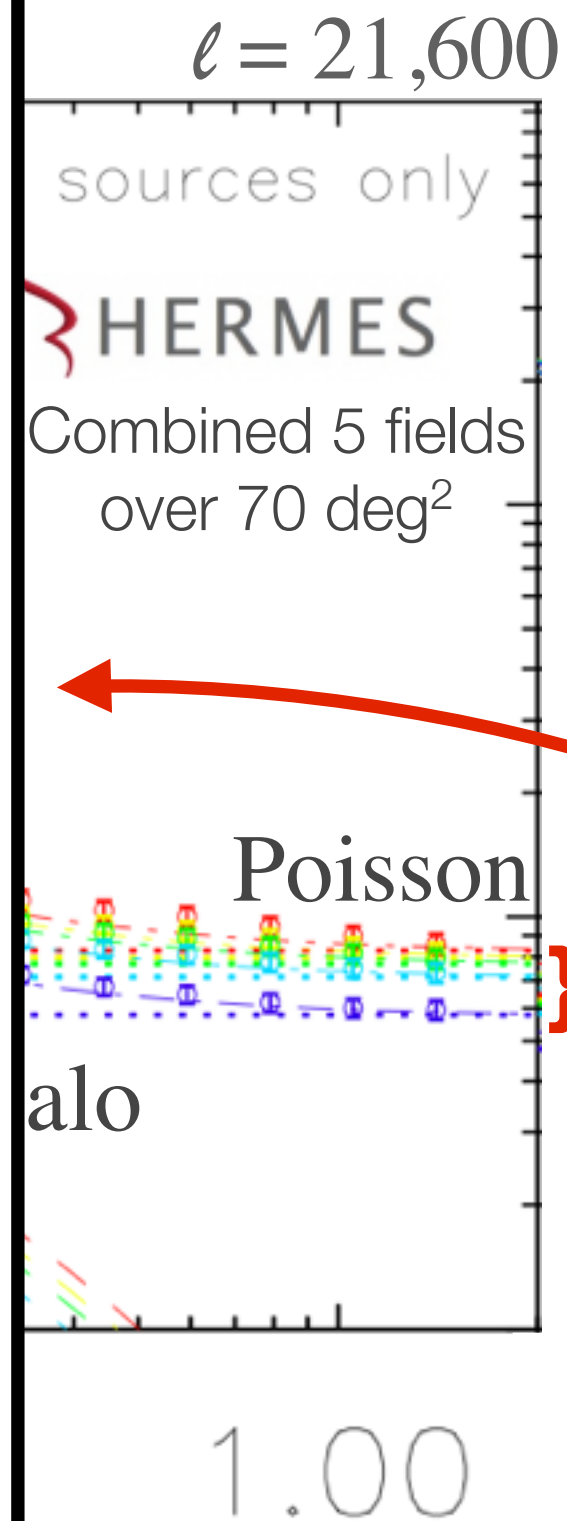
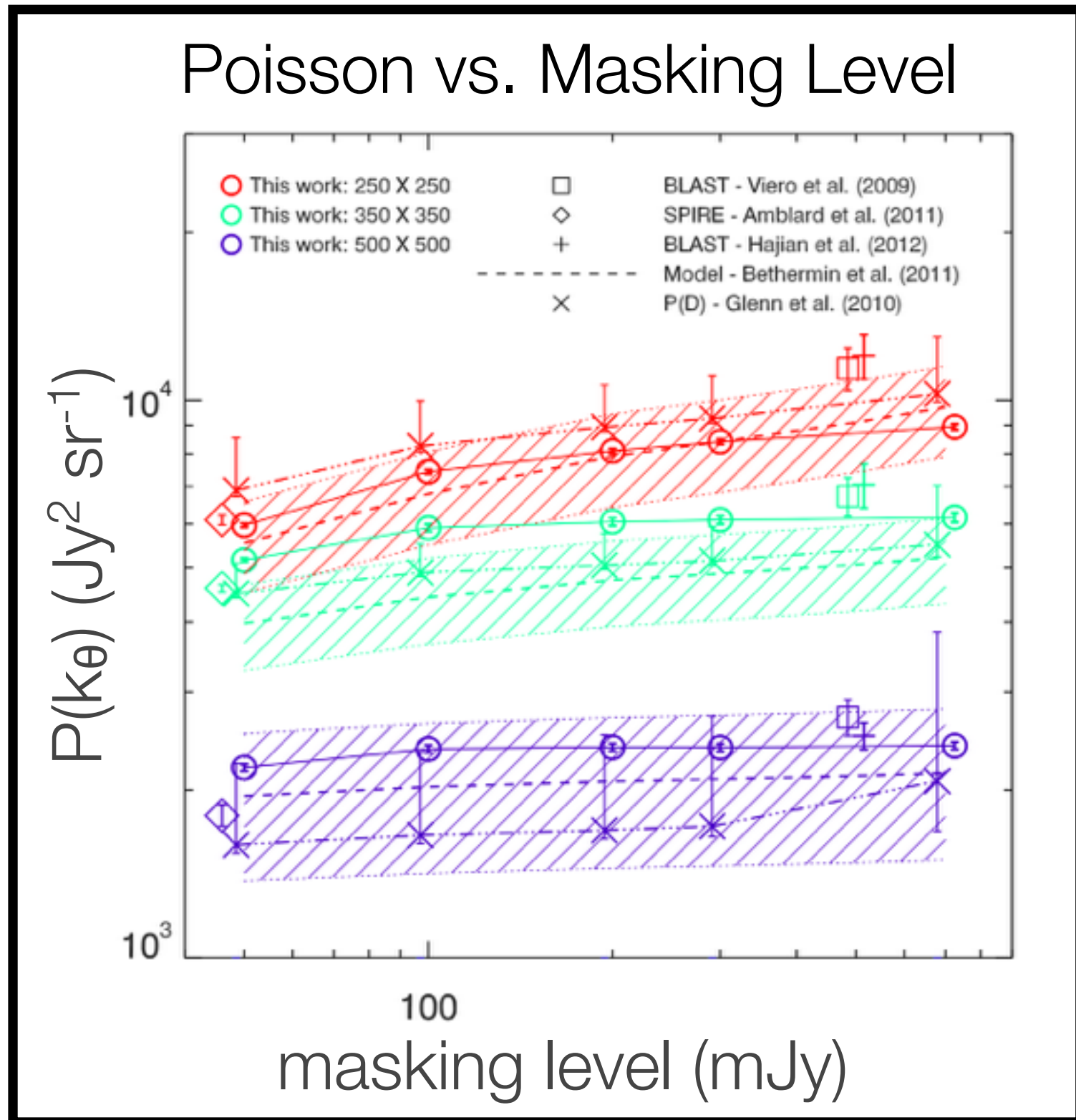
Mike Zemcov

- SPIRE maps at 250, 350, and 500 μm
- Maps made with HerMES SMAP pipeline
- 5 fields totaling $\sim 70 \text{ deg}^2$
- Modes $> \sim 0.5 \text{ deg}$ filtered
- Sources $> 50, 100, 200, 300 \text{ mJy}$ masked

HerMES power spectra

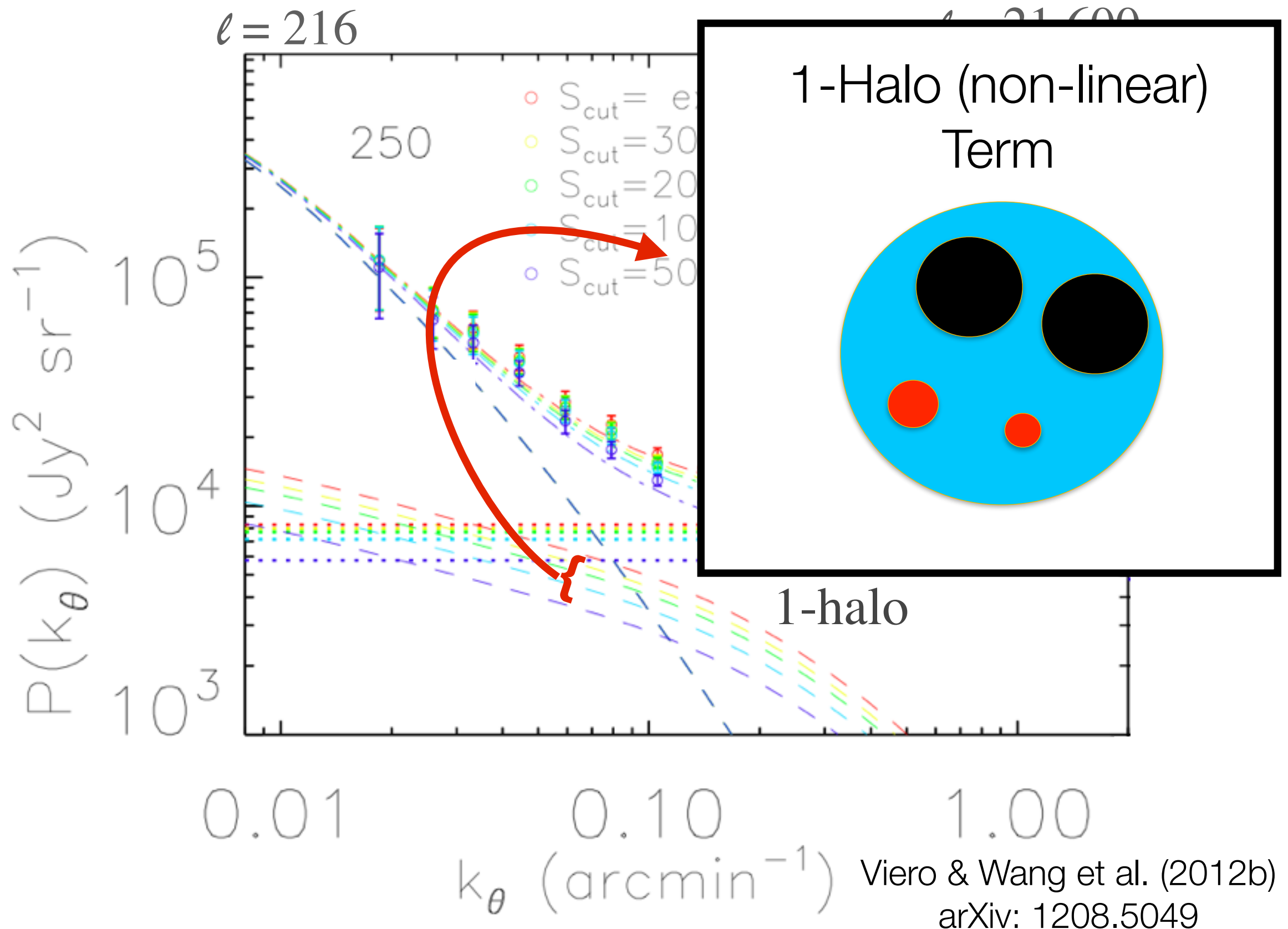


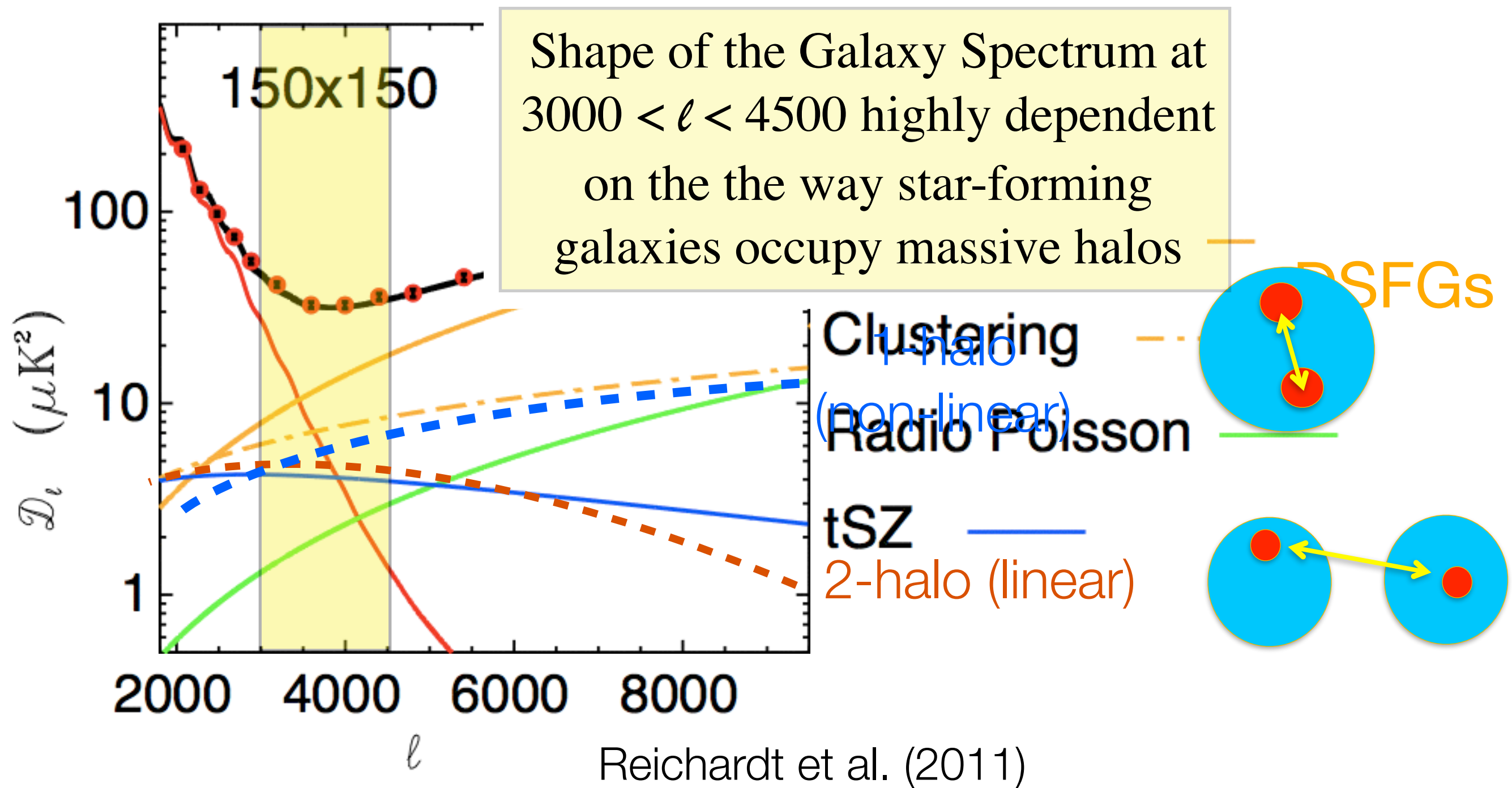
HerMES power spectra



Viero & Wang et al. (2012b)
arXiv: 1208.5049

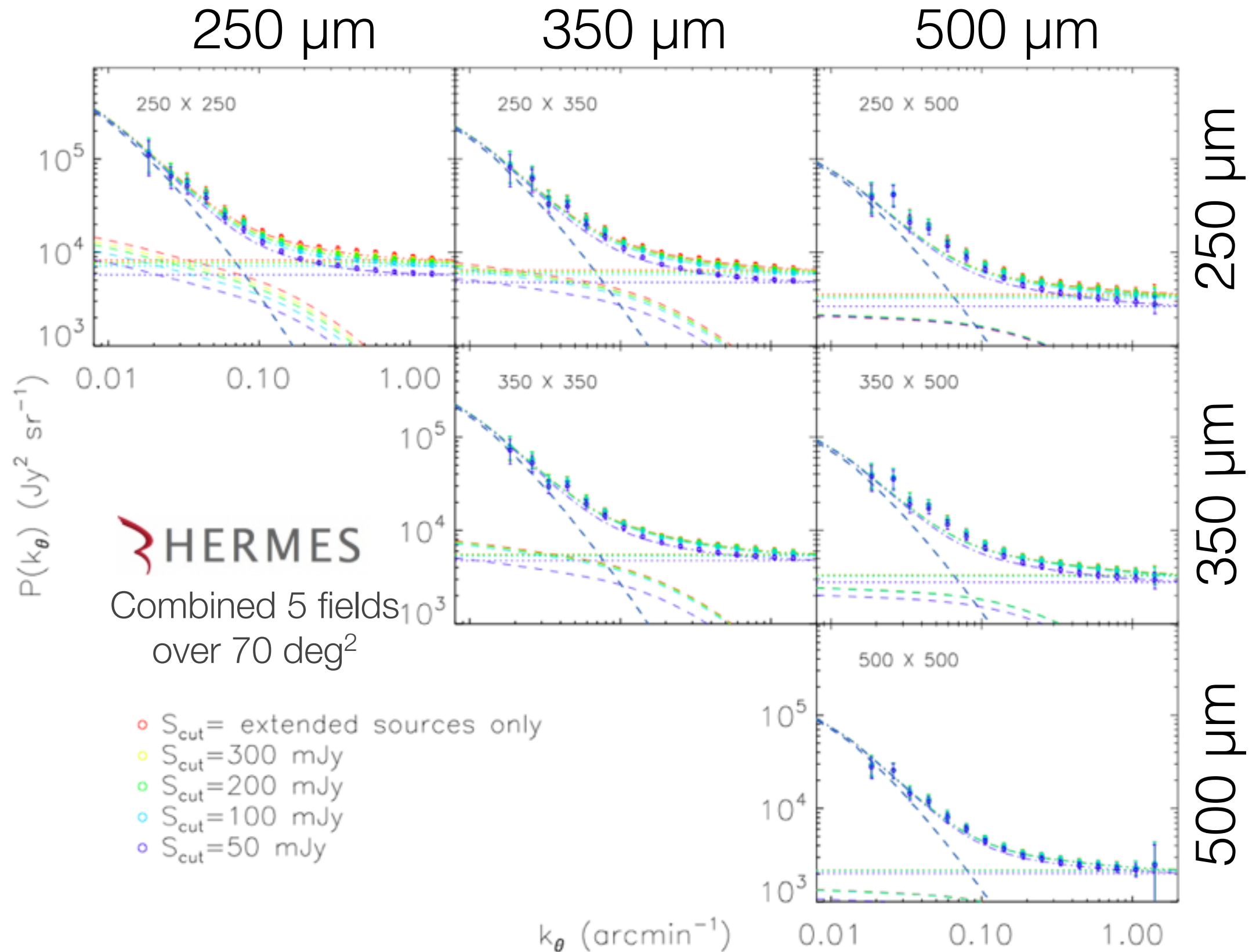
HerMES power spectra



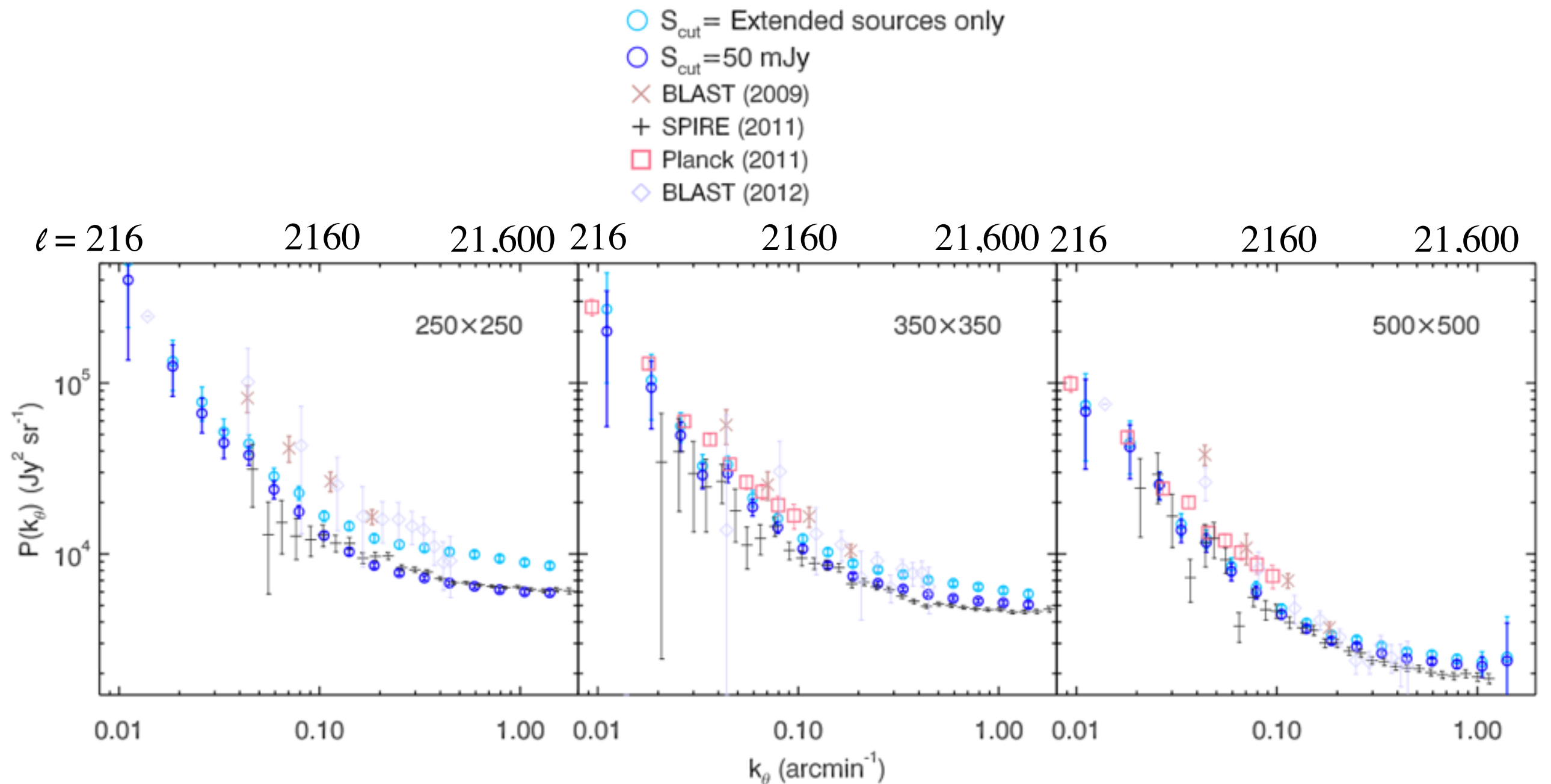


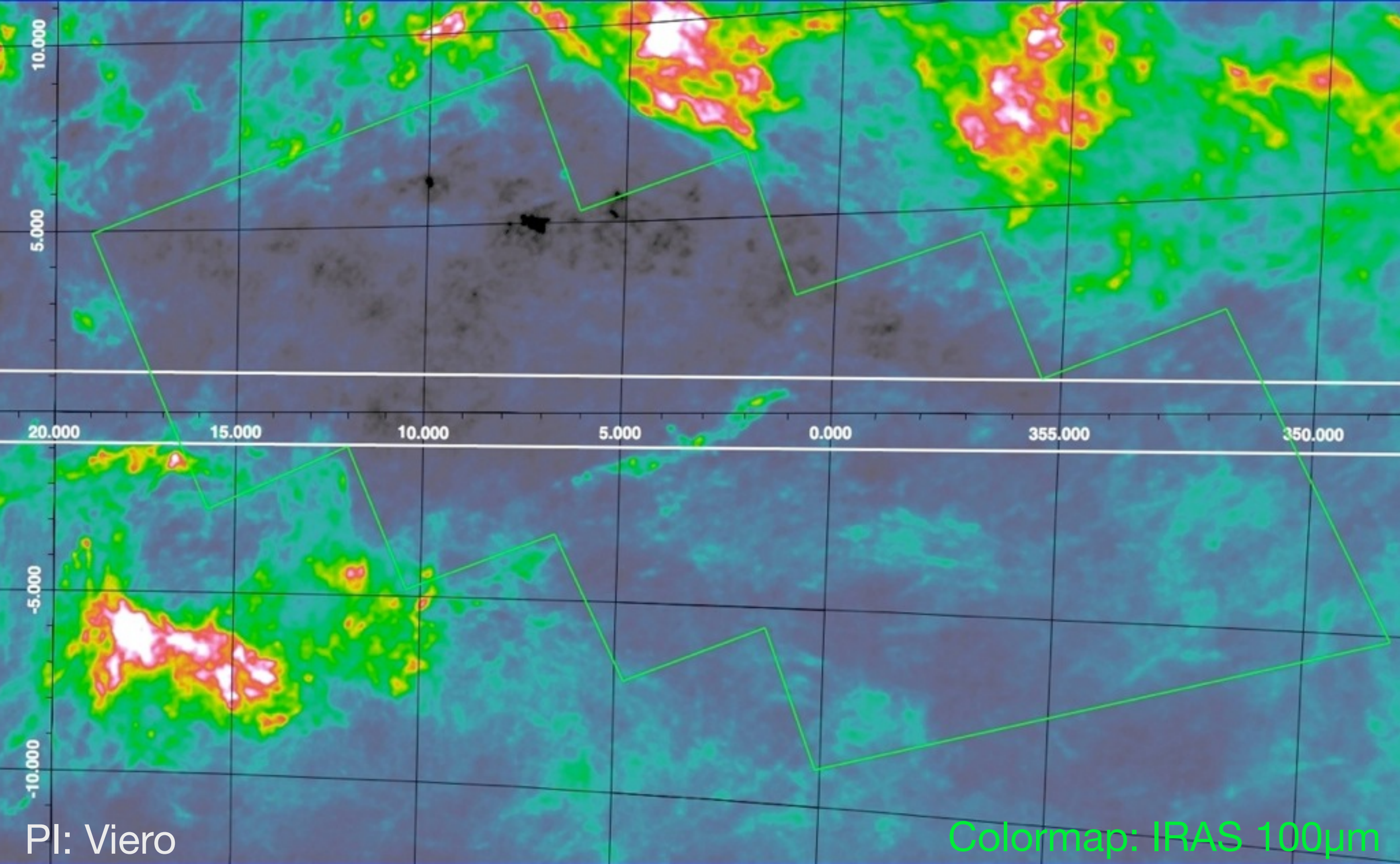
sources of CMB power

HerMES power spectra

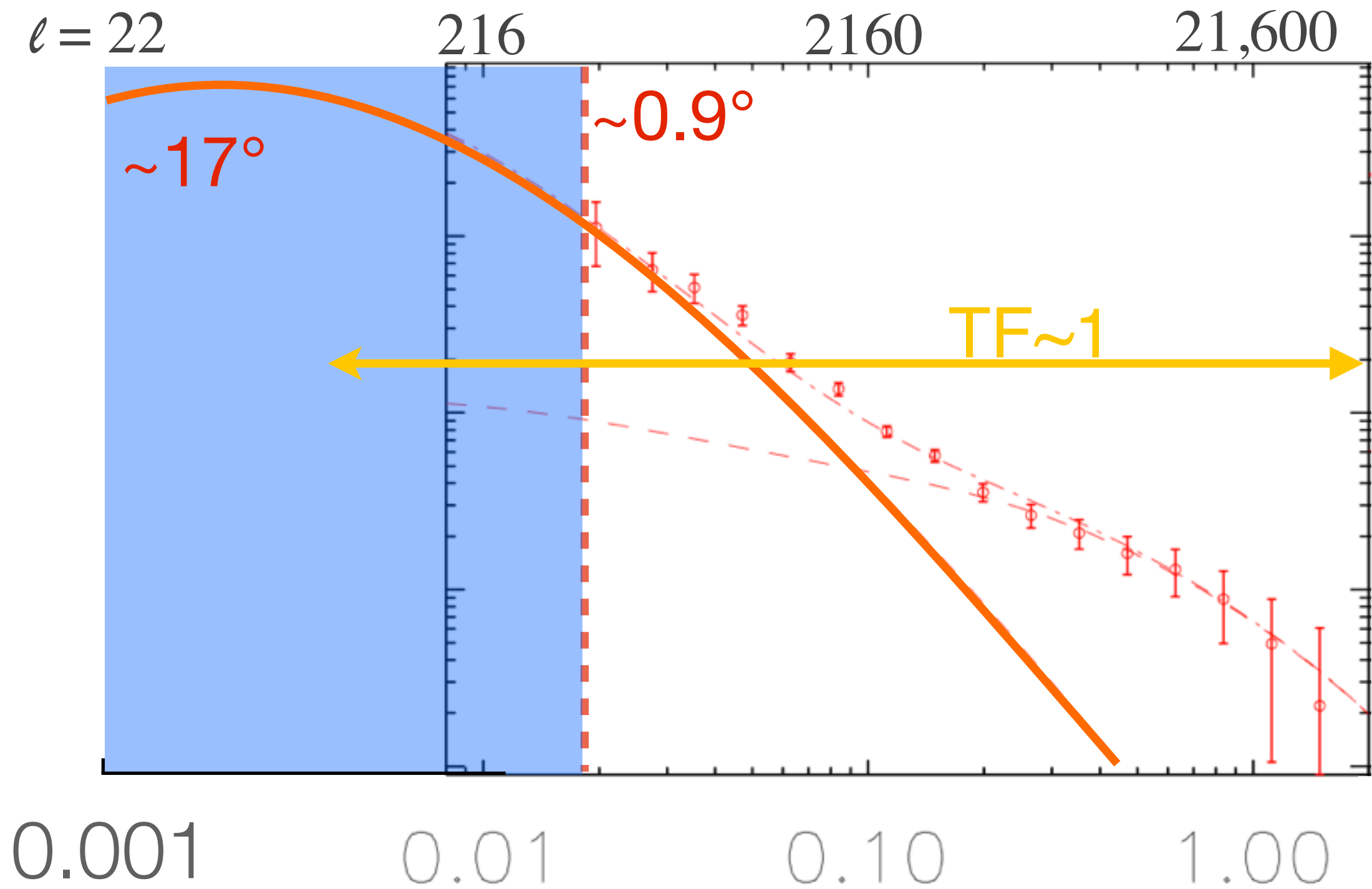


HerMES power spectra



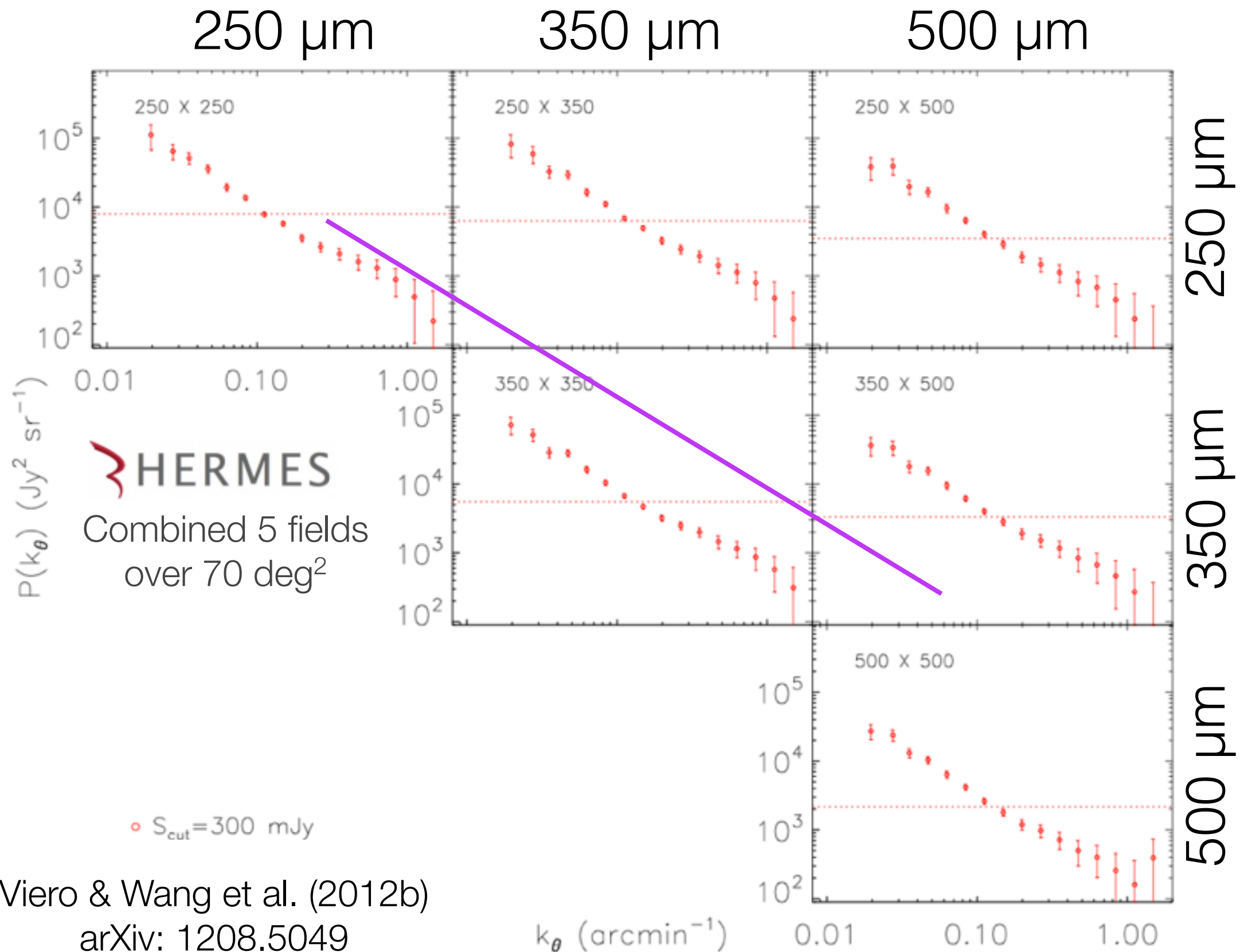


HerMES Large-Mode Survey (HeLMS)



HeLMS

CIBA power spectra



Viero & Wang et al. (2012b)
arXiv: 1208.5049

halo model

Requirements

- Fit all spectra simultaneously
- Fits counts (and Poisson level) as well
- Few parameters as possible

Ingredients (extension of Shang et al. 2012)

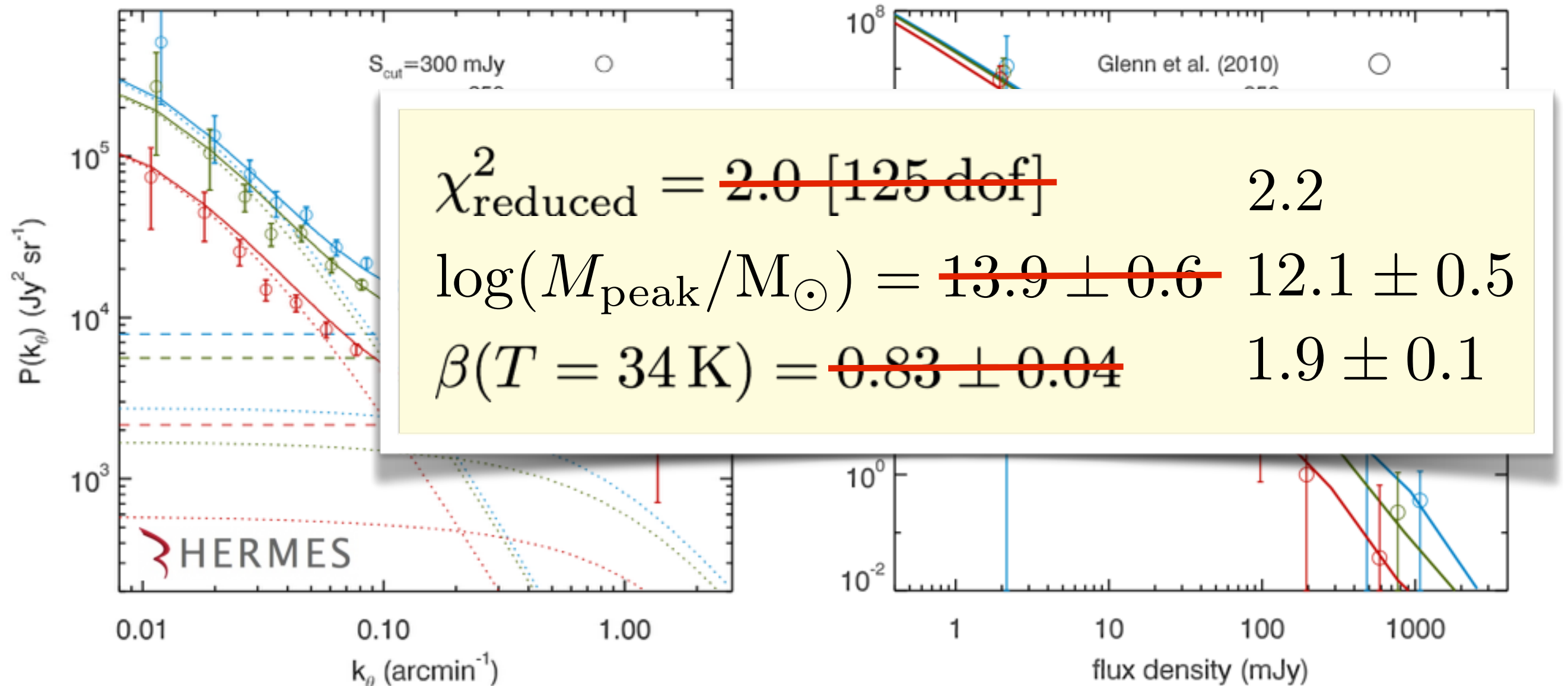
- Luminosity-Mass (L-M) relationship
- single SED template
- 7 parameters (5 free):

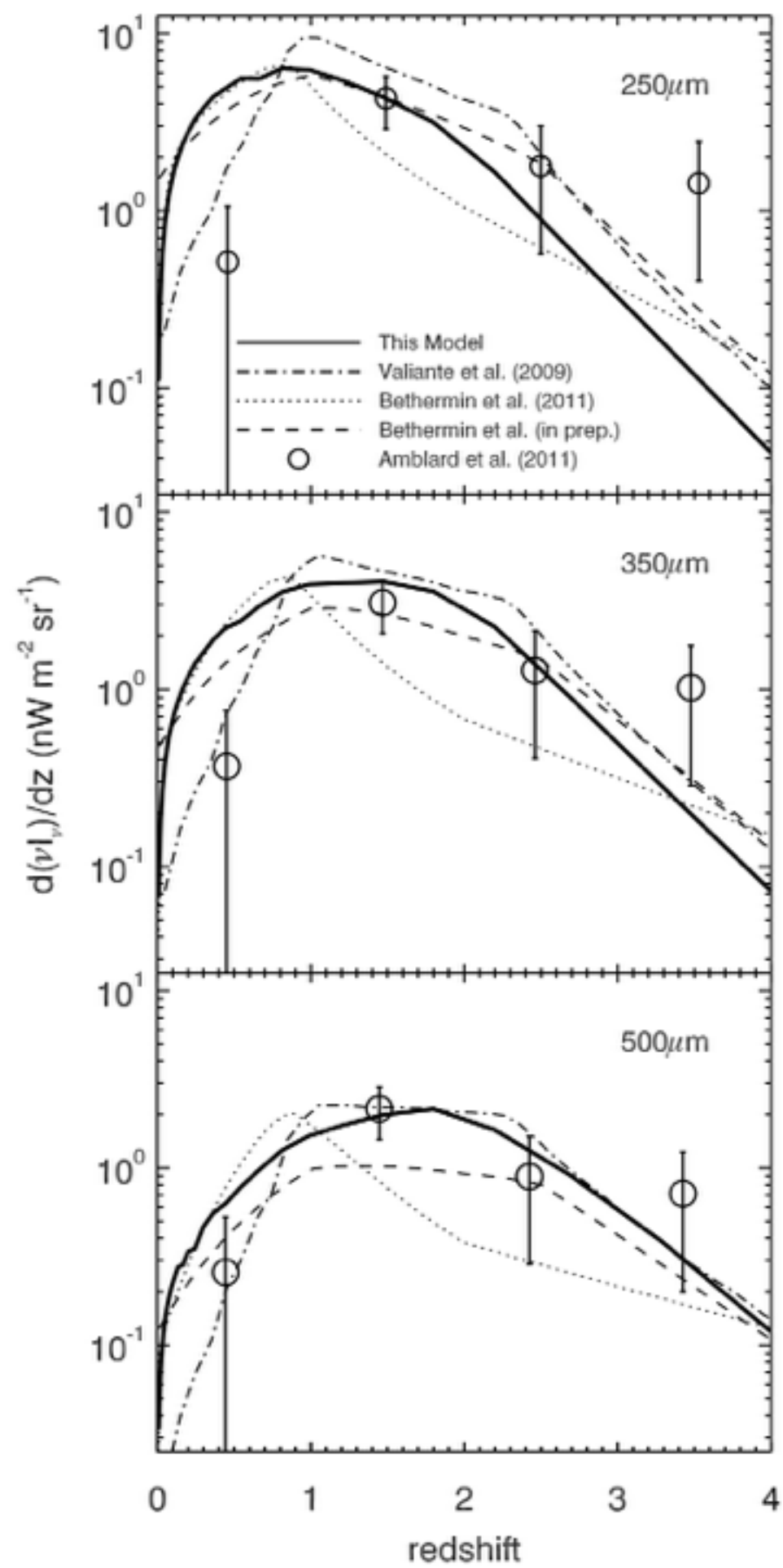
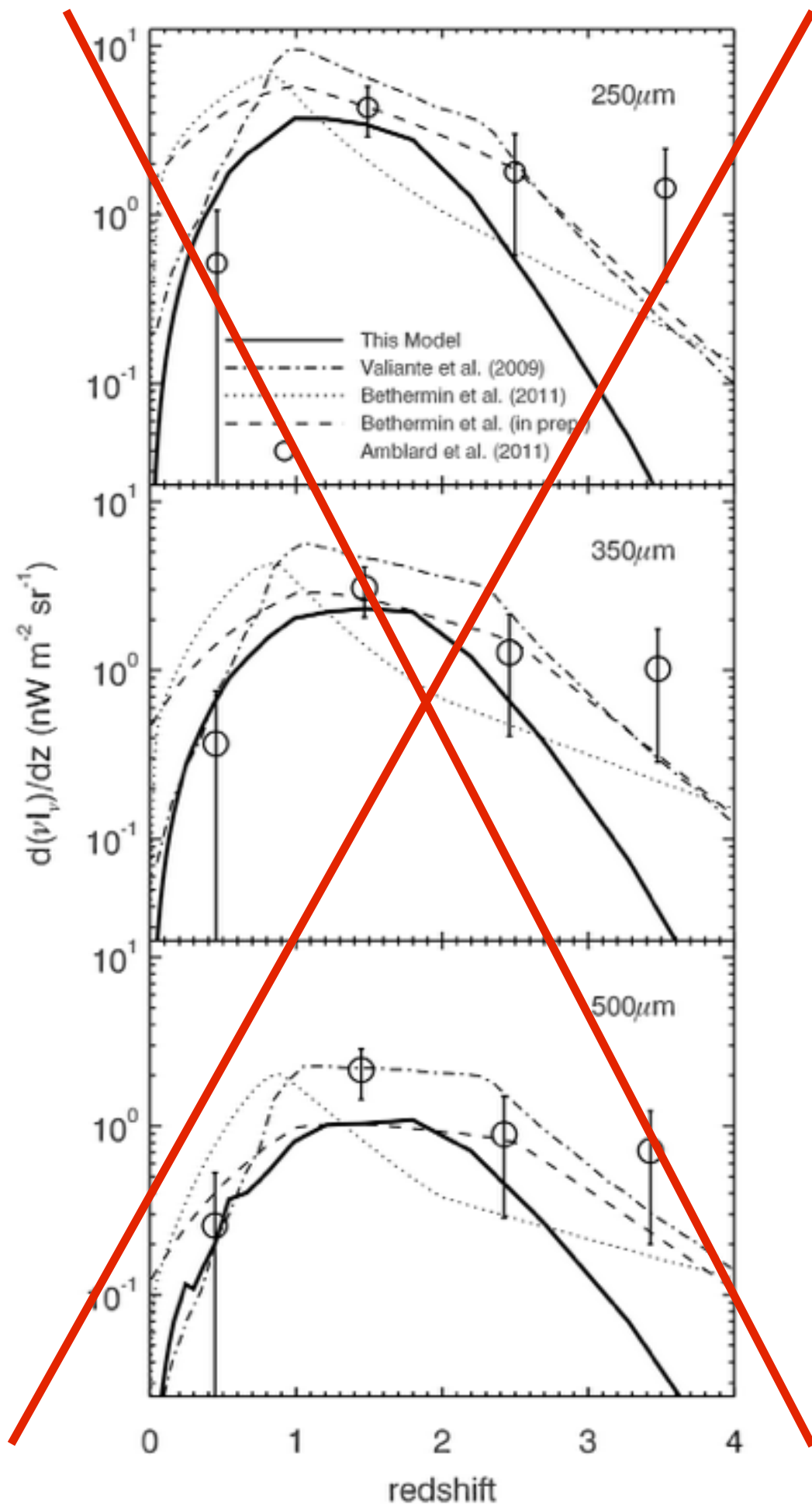
$$\cancel{X}, \beta, M_{\min}, M_{\text{peak}}, \sigma_{L/m}^2, L_0, \cancel{\eta}$$

halo model fits

Power spectra

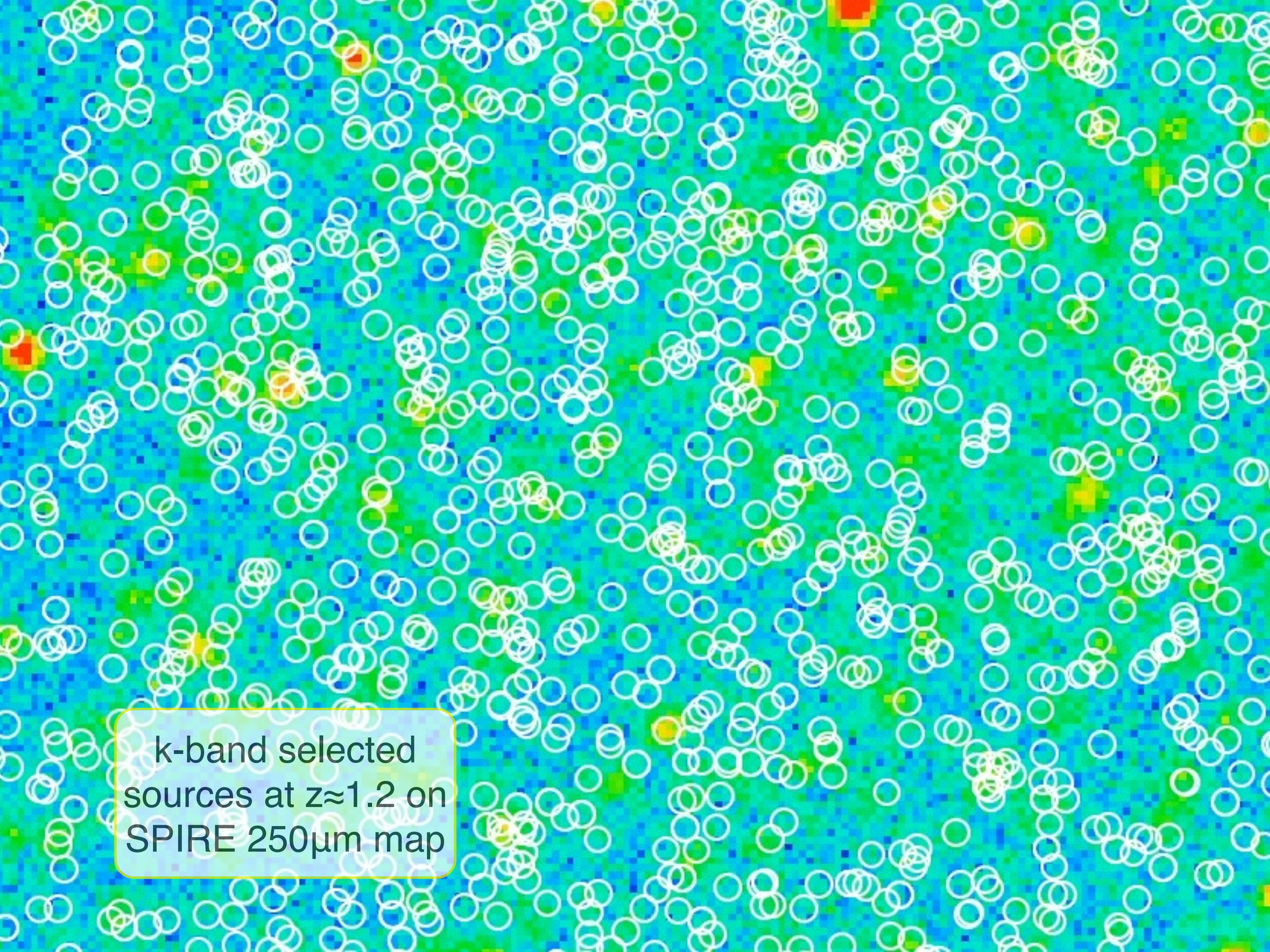
Number counts



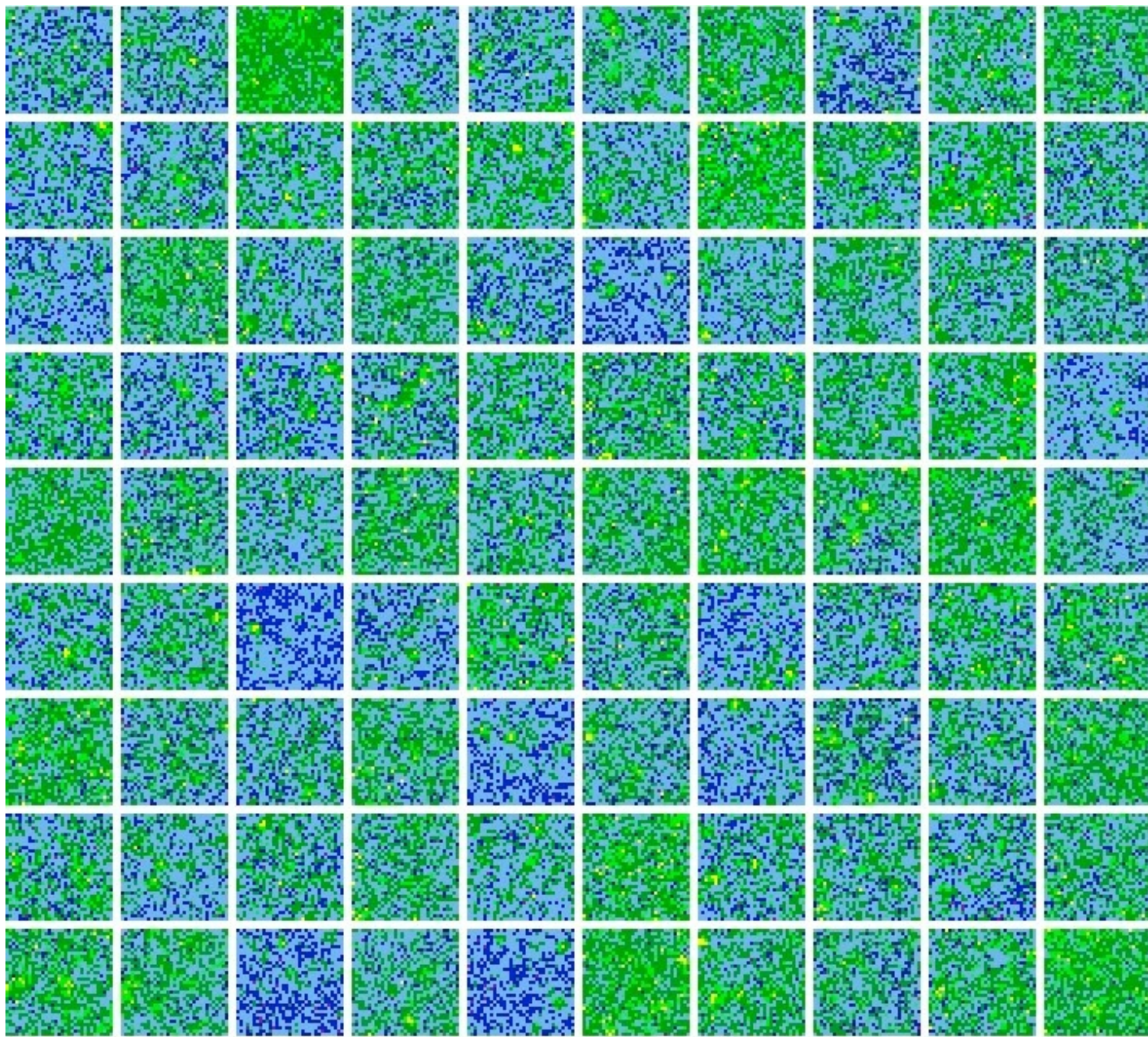


outline

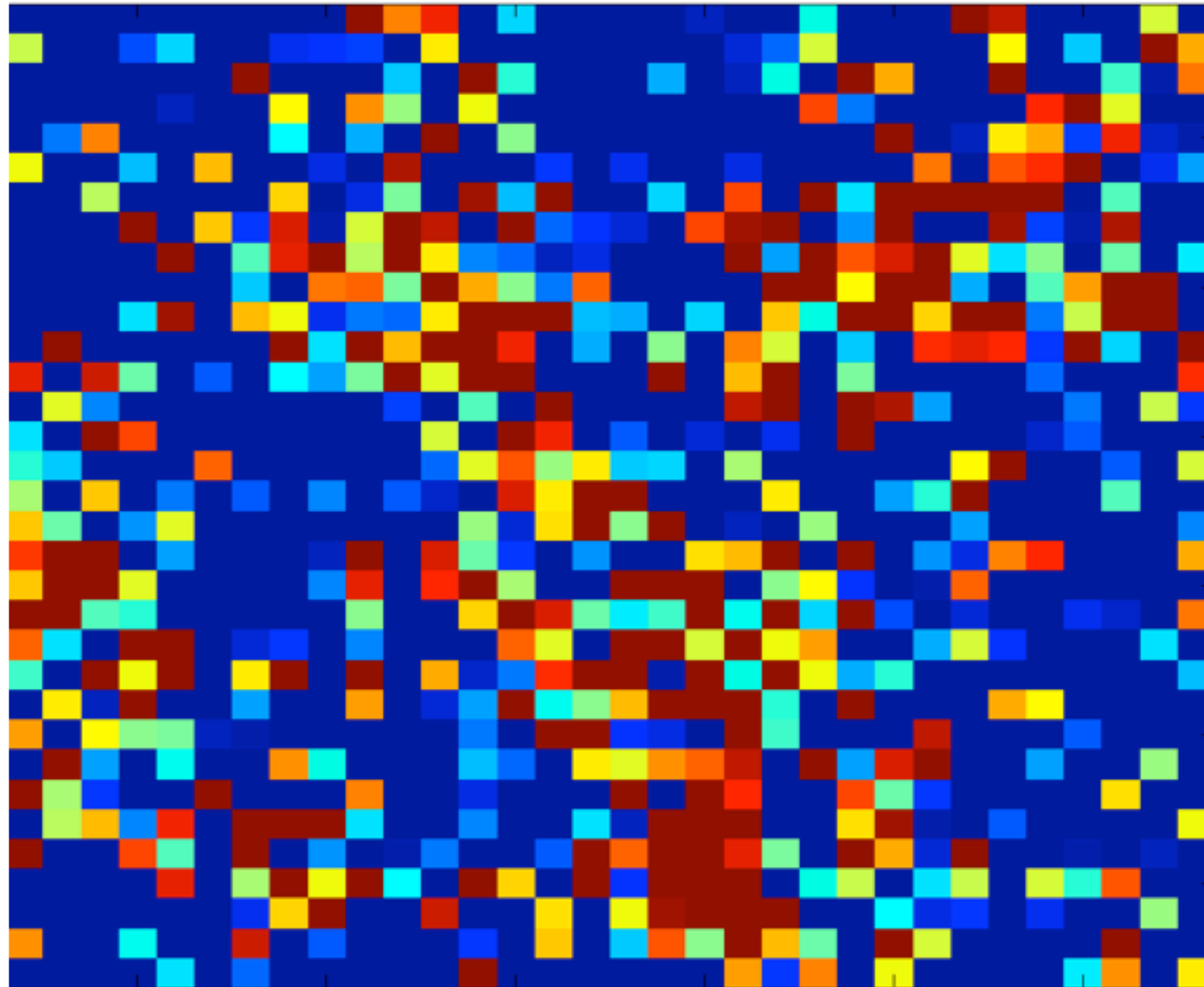
- clustering of dusty galaxies
- contribution from optical galaxies to CIB
- HeRS



k-band selected
sources at $z \approx 1.2$ on
SPIRE 250 μm map

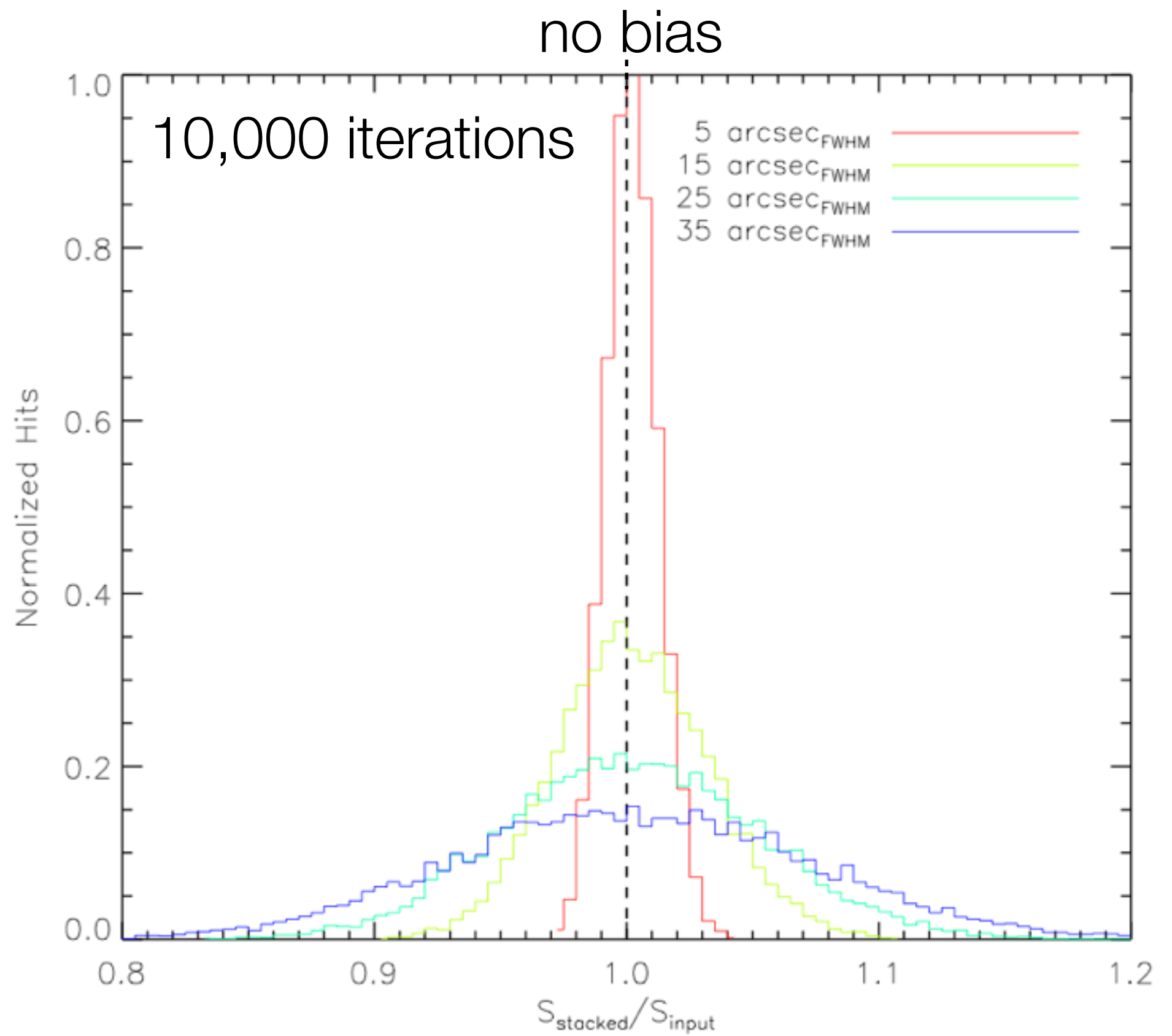


thumbnail stacking

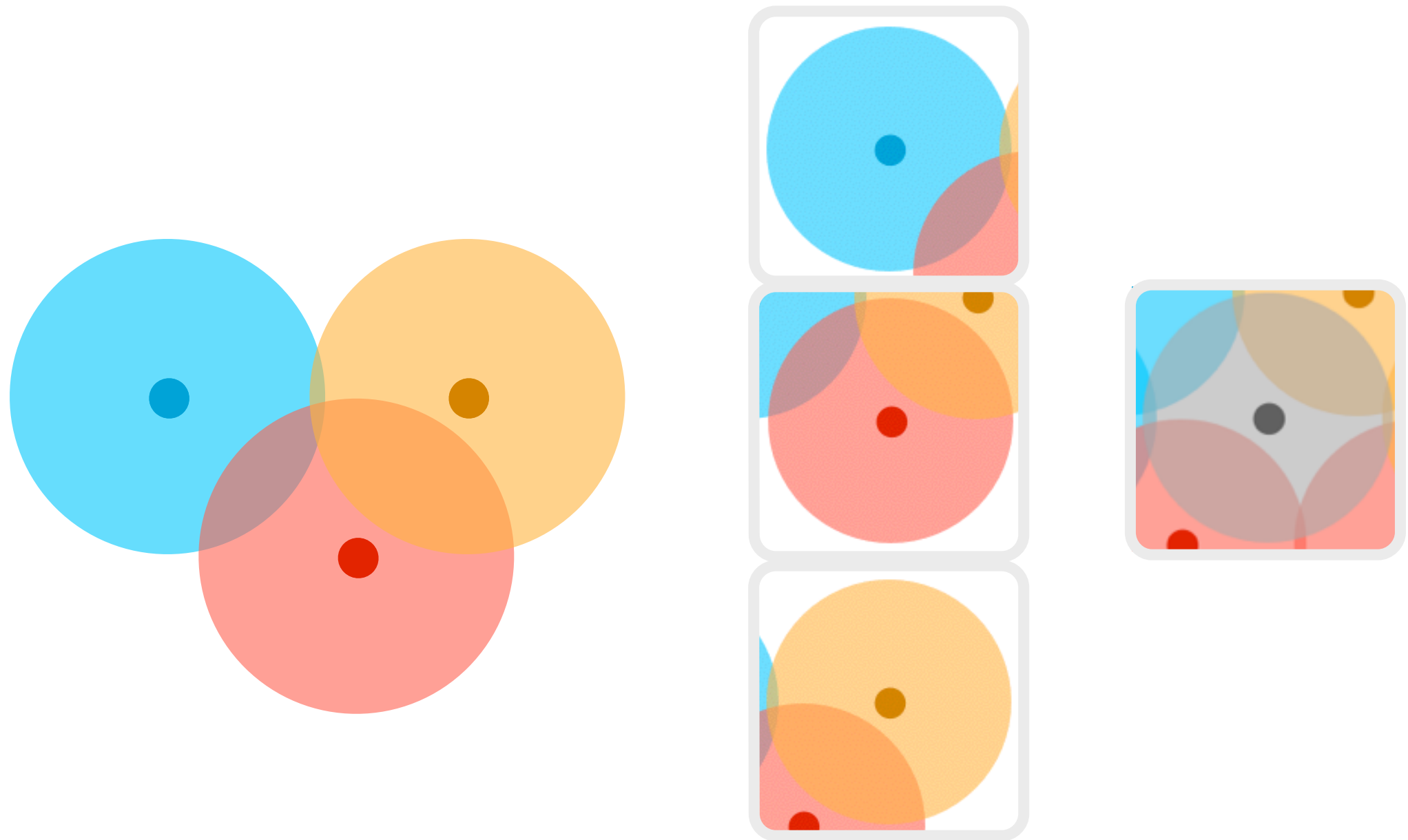


Phil Korngut (Caltech)

thumbnail stacking



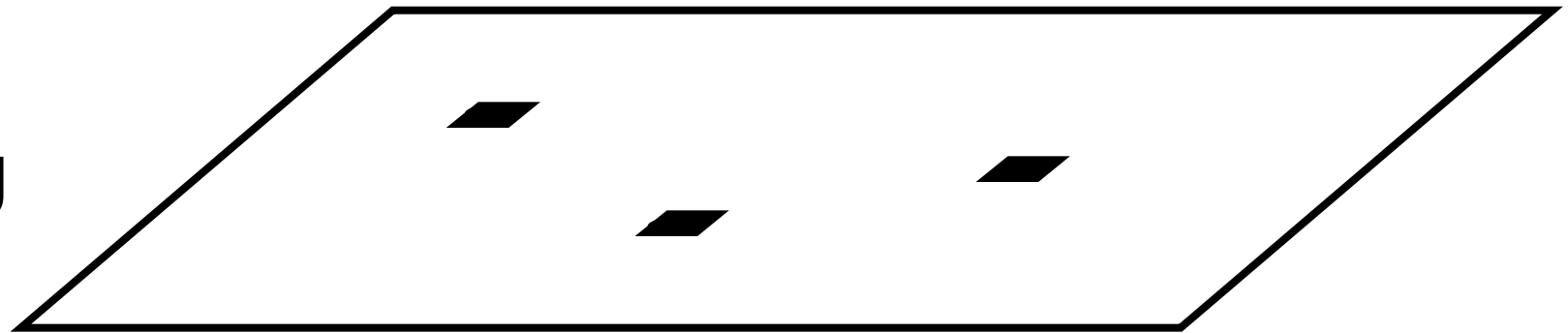
uncorrelated source simulation



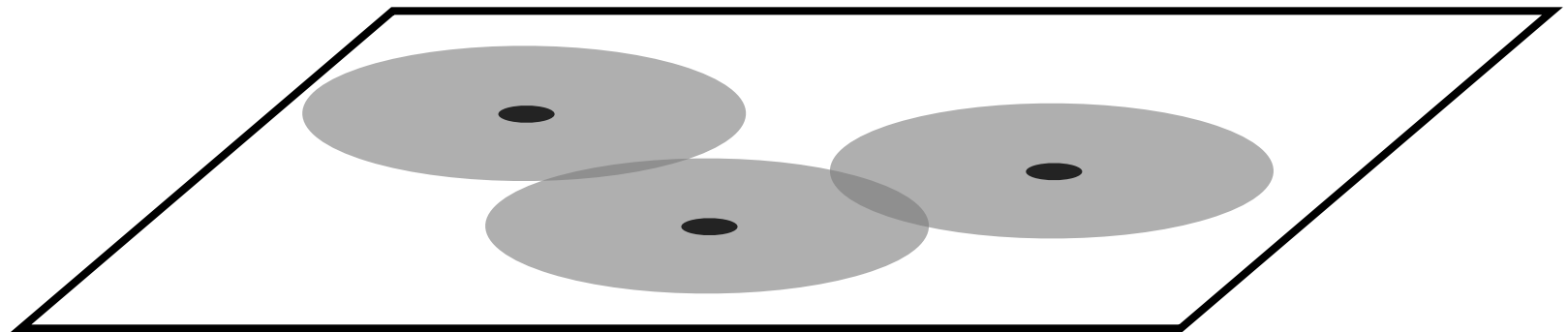
clustering induced bias

simultaneous stacking

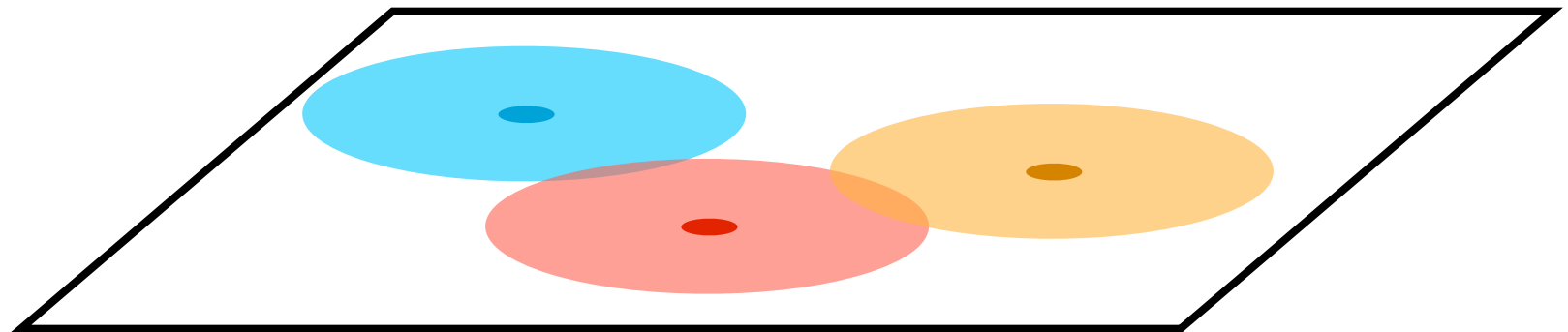
make hits map from catalog



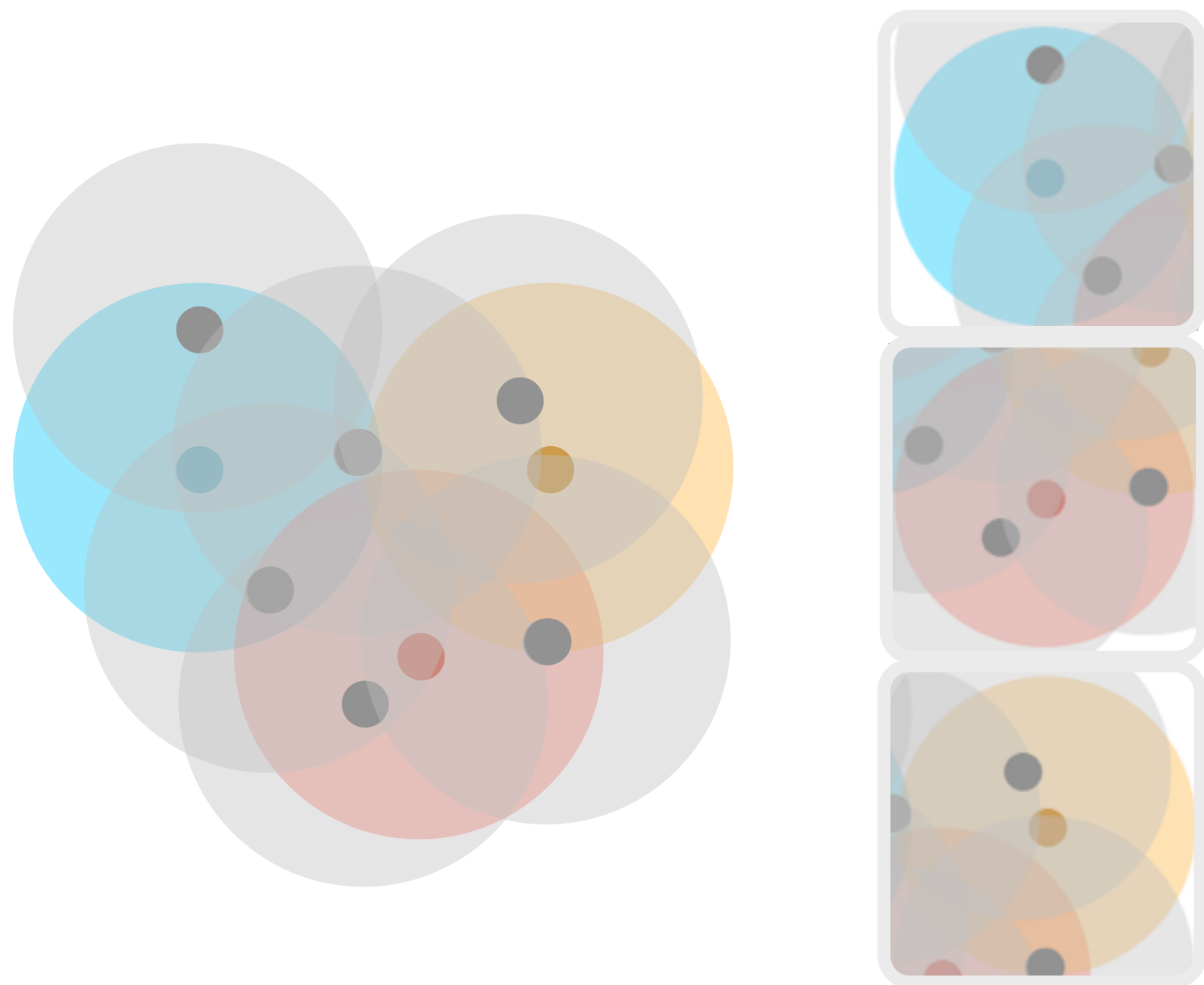
convolve with map p.s.f.



regress to find stacked flux

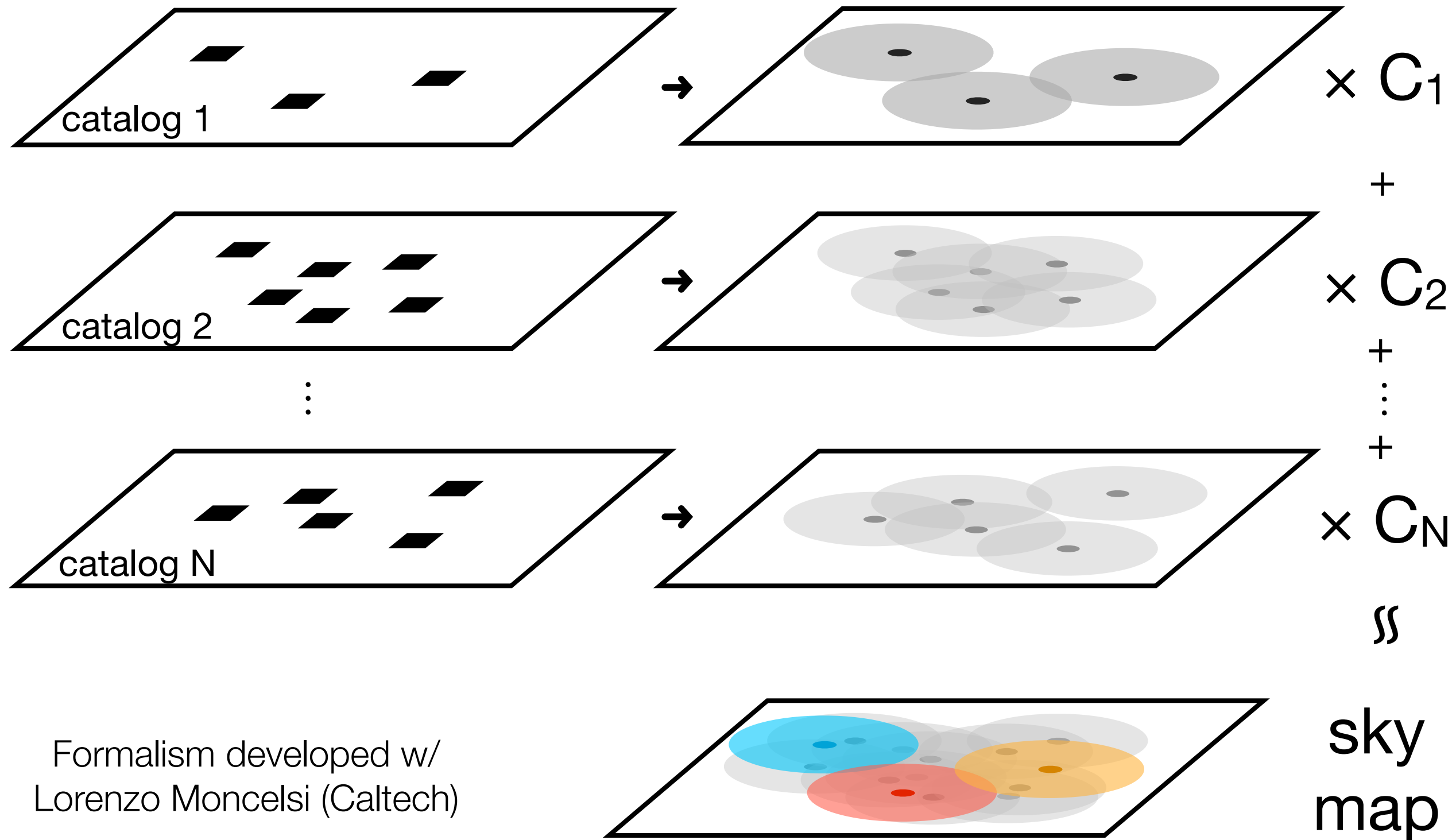


Formalism developed w/ Lorenzo Moncelsi (Caltech);
also see Kurczynski & Gawiser (2010), Roseboom et al. (2010)

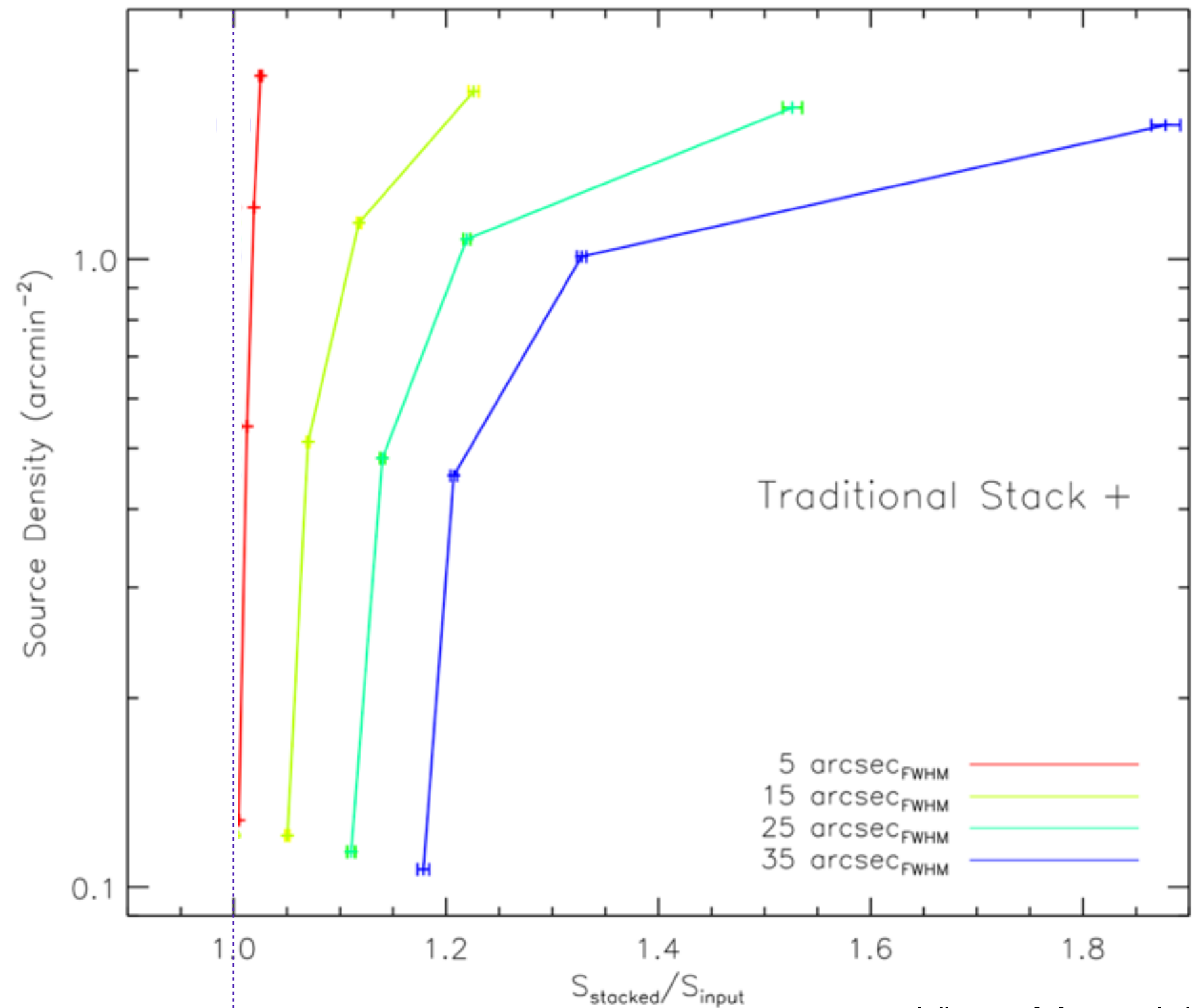


non-target induced bias

simultaneous stacking



simultaneous stacking sim



unbiased

Viero, Monceli,
Quadri et al. (in prep.)

goals

- determine contribution to the CIB from galaxies identified in the optical/NIR, as a function of galaxy:
 - redshift
 - stellar mass
 - luminosity
 - ??

data

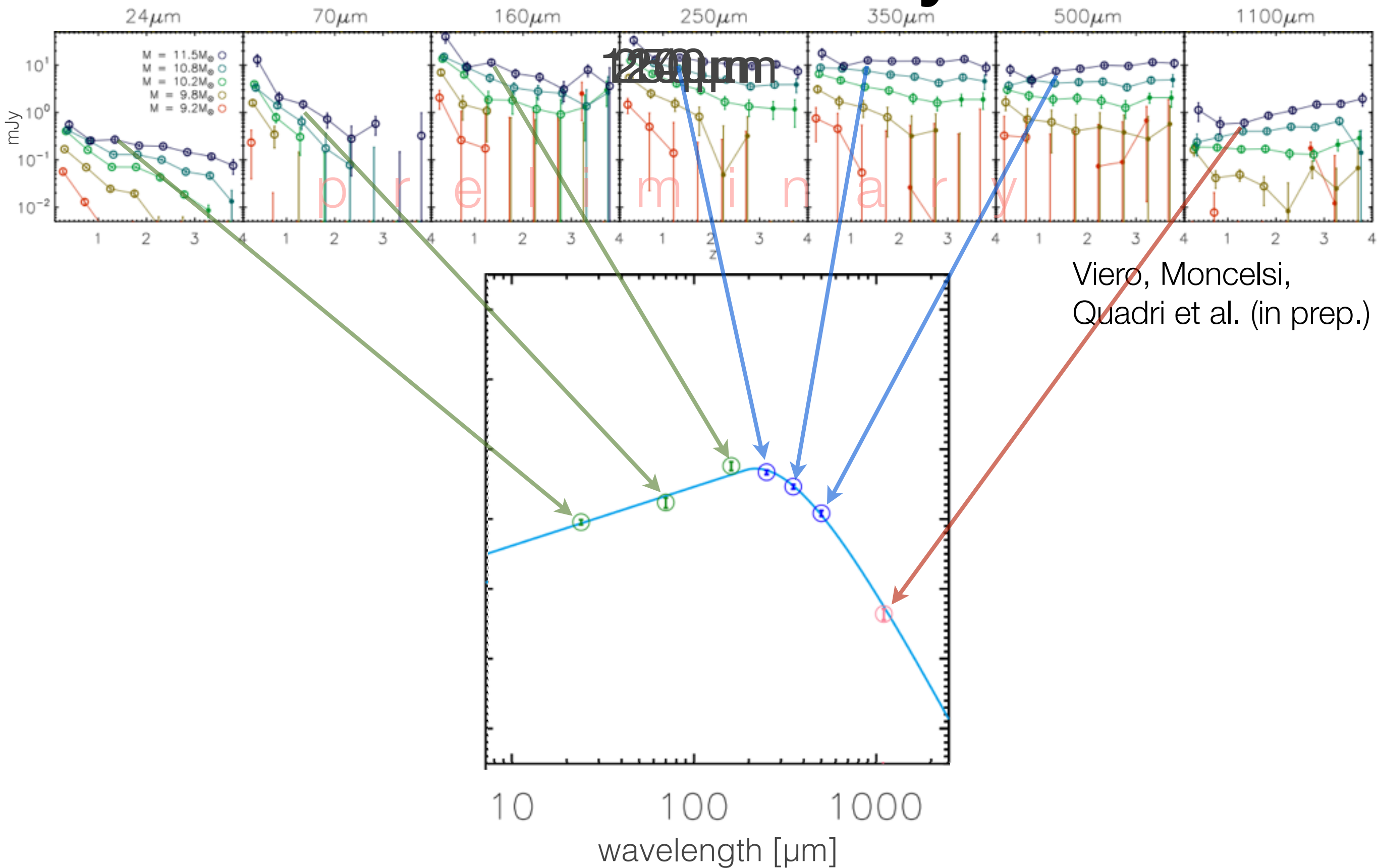
catalogs (Williams & Quadri, in prep.)

- UKIDSS/UDS [2/3 deg²]
 - uBVRizJHK + IRAC ch1234
 - K-band magnitude cut 24 AB
 - 54,000 sources in ~0.63 deg²
- redshifts - EAZY (Brammer 2008)
- masses - FAST (Kriek 2009)

maps (HerMES; Oliver et al. 2012)

- *Spitzer*/MIPS
 - 24, 70, 160um
- *Herschel*/SPIRE
 - 250, 350, 500um
- ASTE/AzTEC
 - 1100um

stacked flux density

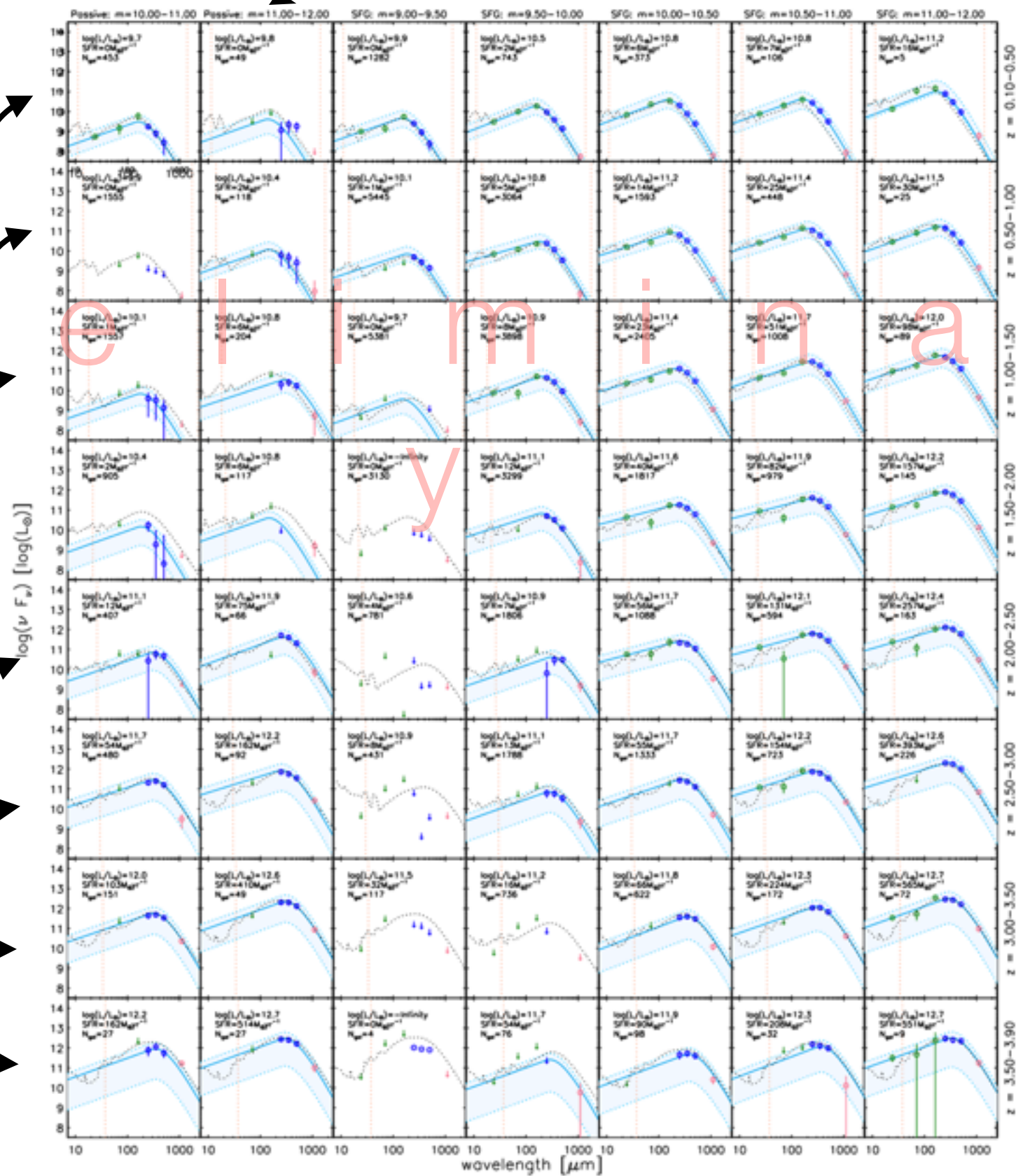


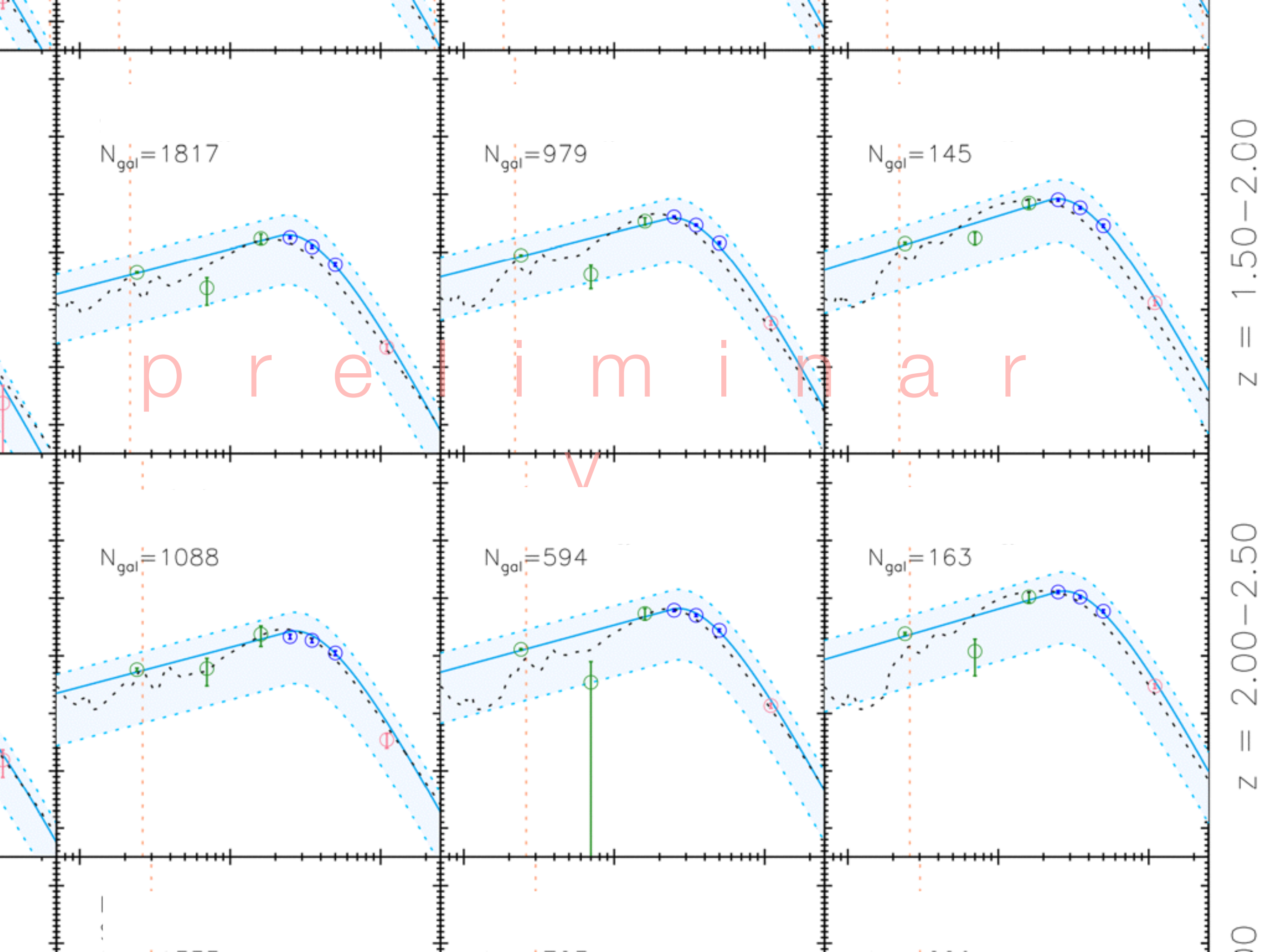
SEDs

mass
slices

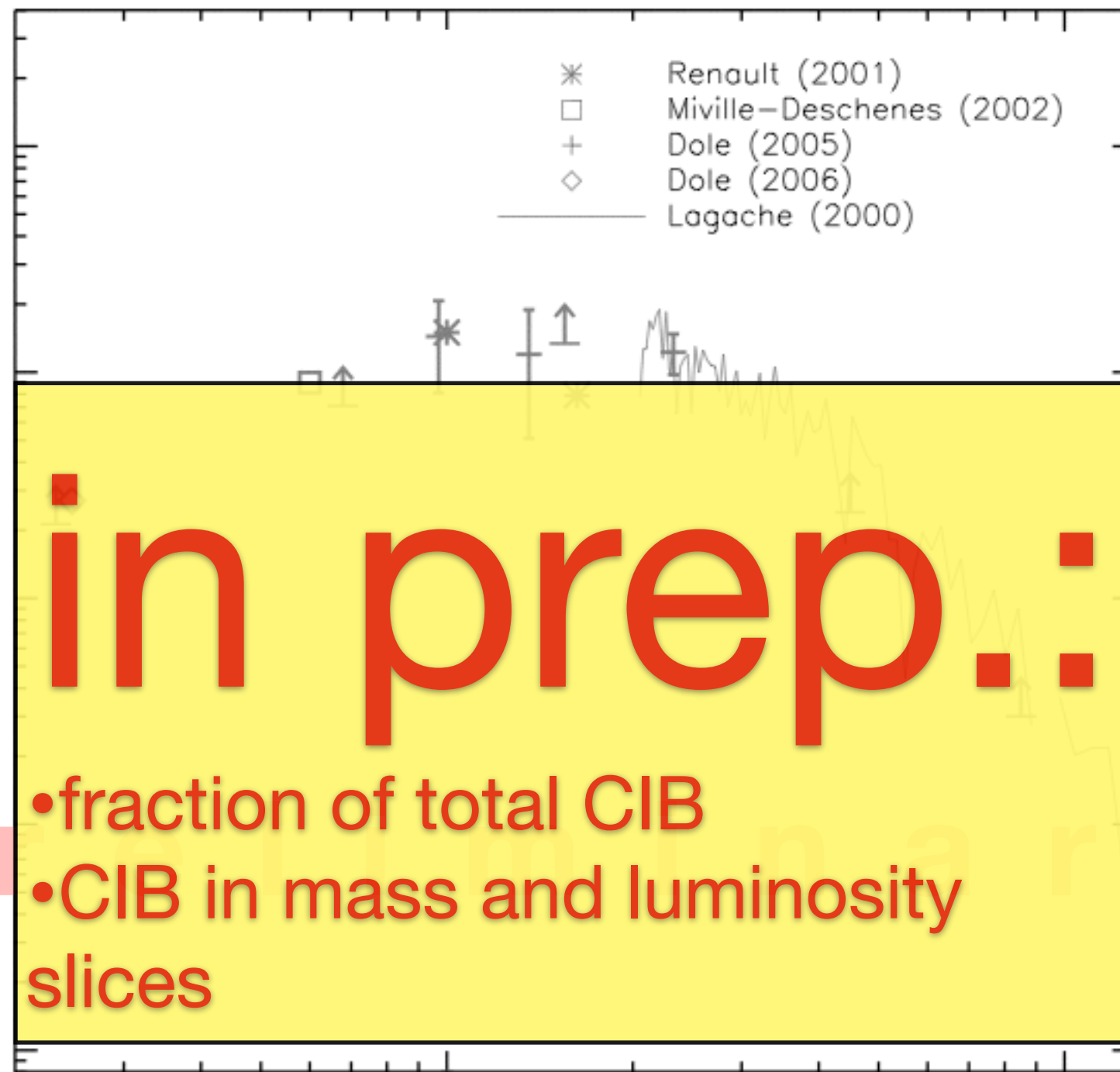
redshift
slices

peimr





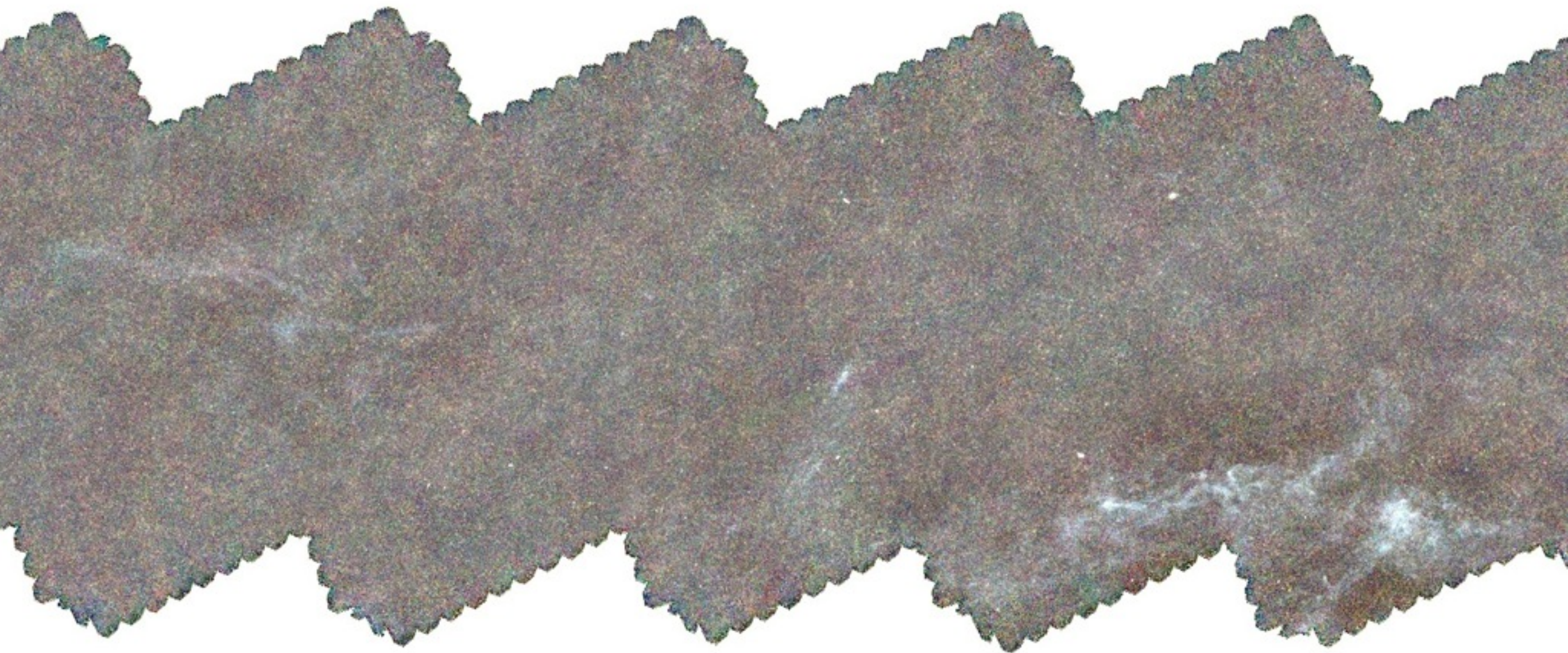
stacked ClB



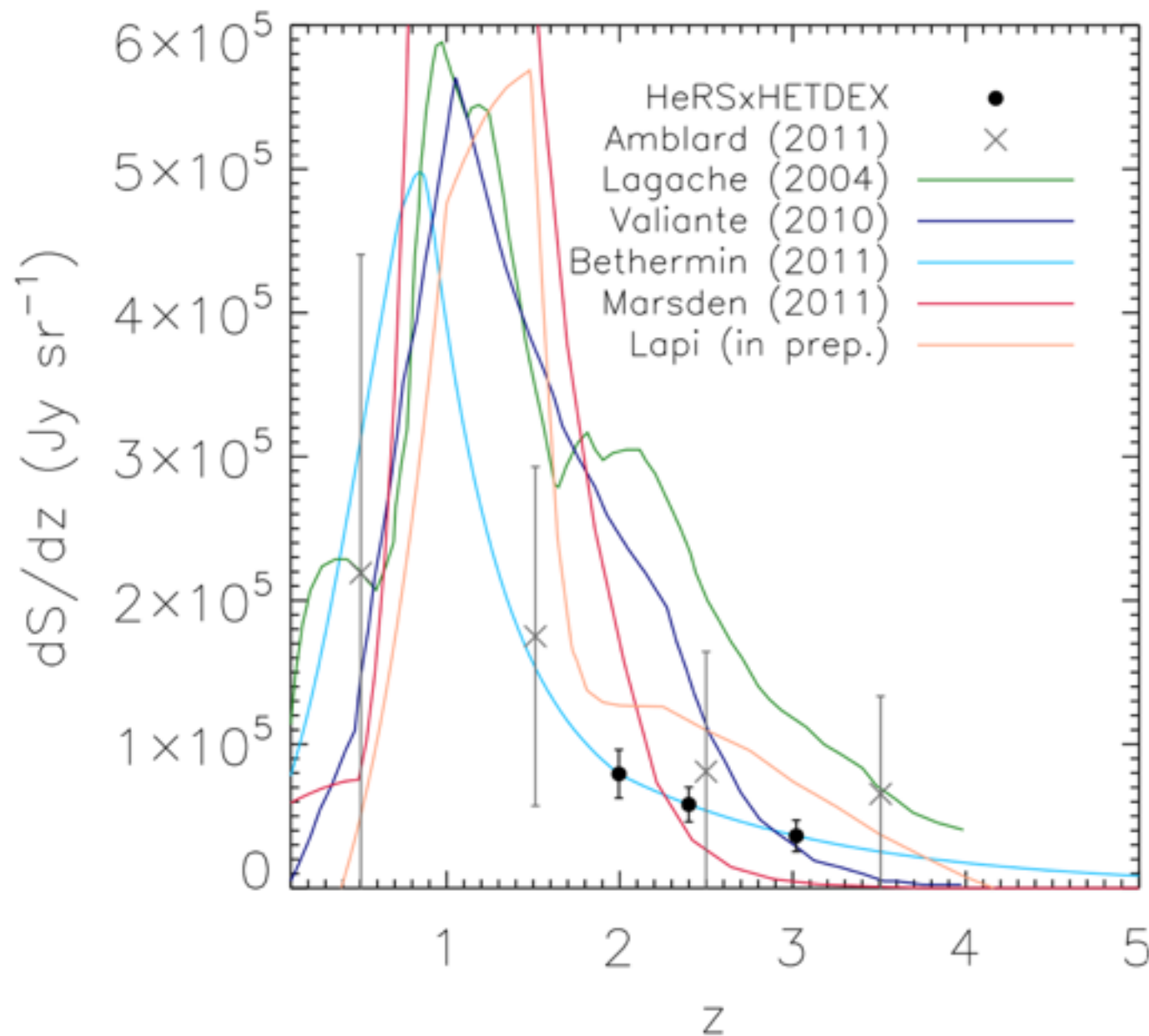
Viero, Monceli,
Quadri et al. (in prep.)

outline

- clustering of dusty galaxies
- contribution from optical galaxies to CIB
- HeRS

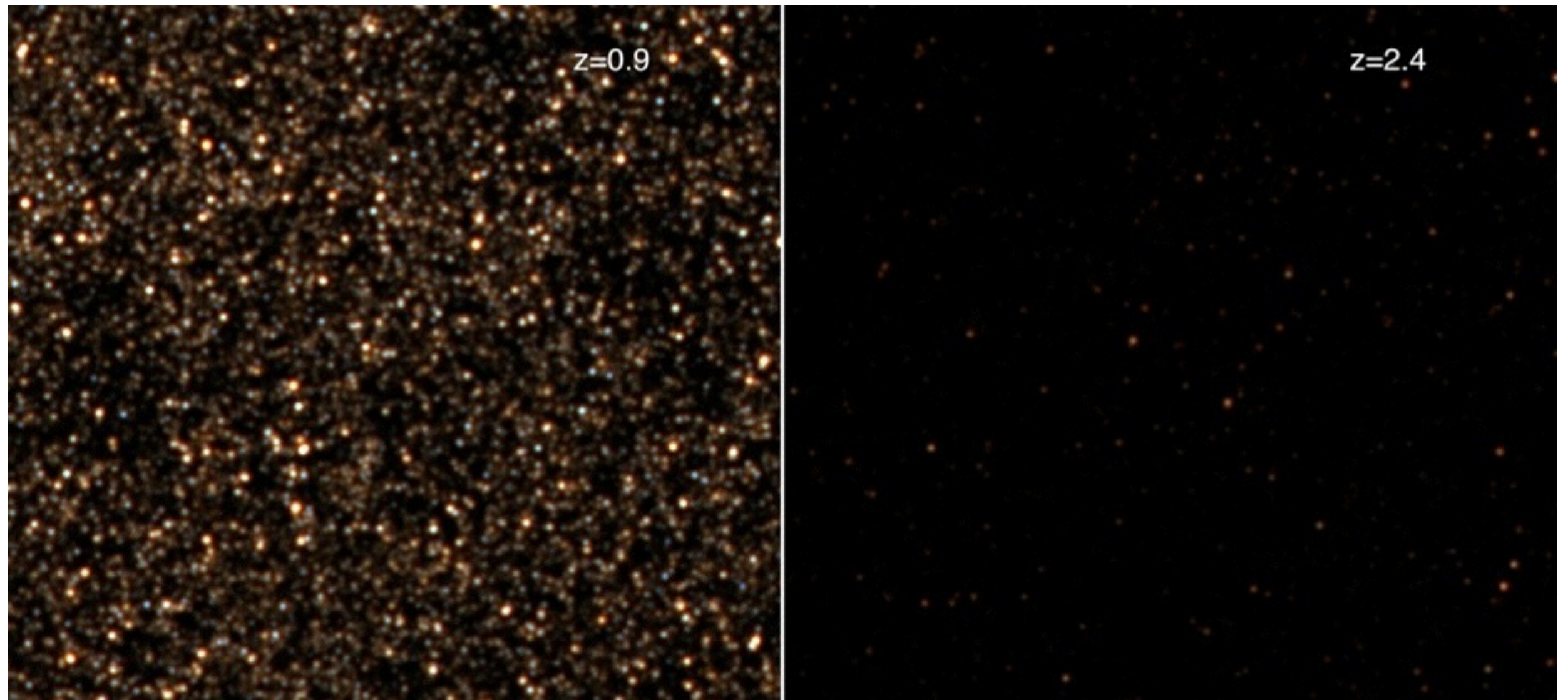


Herschel Redshift Survey (HeRS)



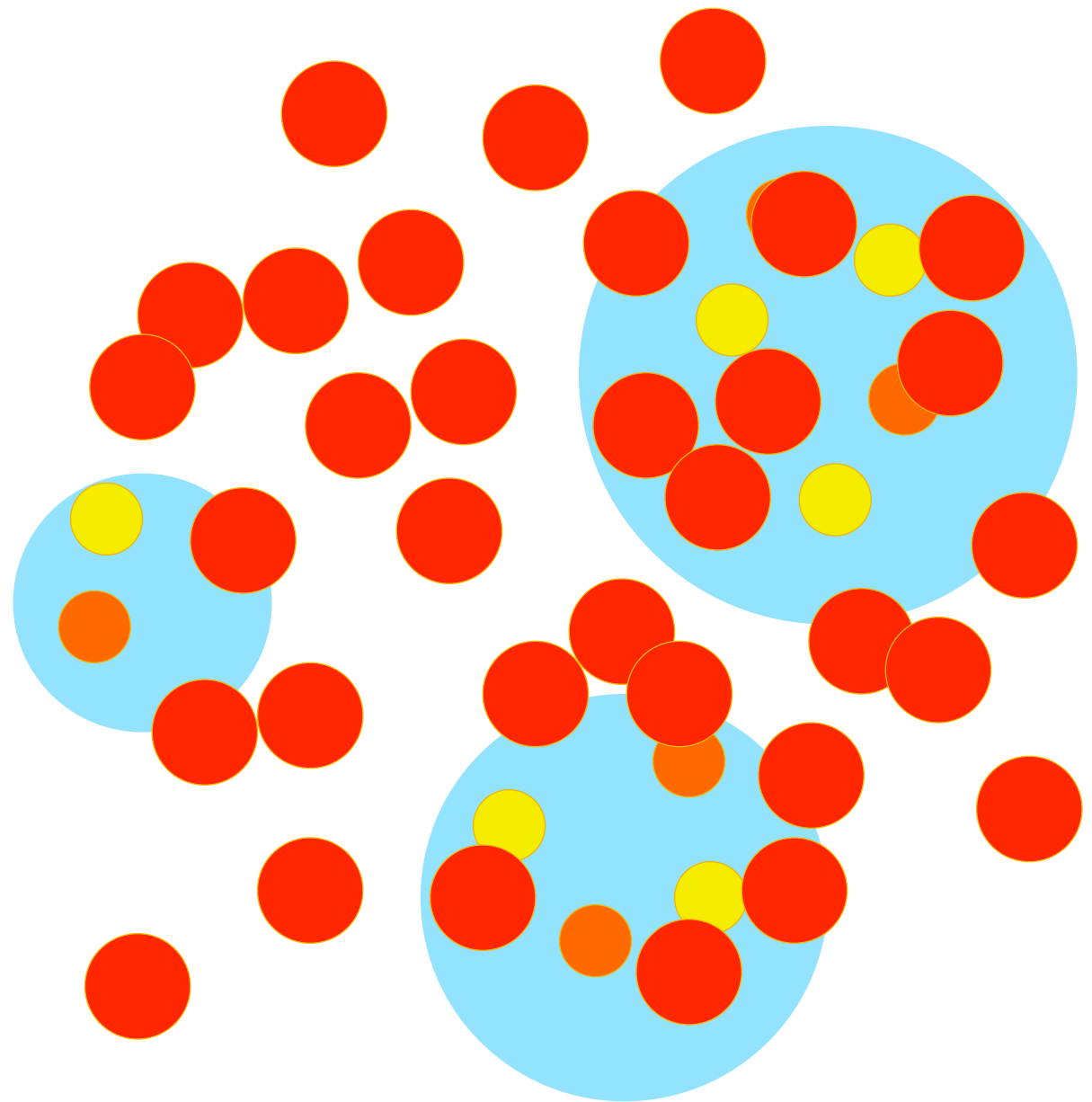
- dS/dz : redshift distribution of background light
- Models do not agree on dS/dz for $z > 1$
- Aim to constrain dS/dz from $2 > z > 3$ to 5σ

redshift distribution of CIB

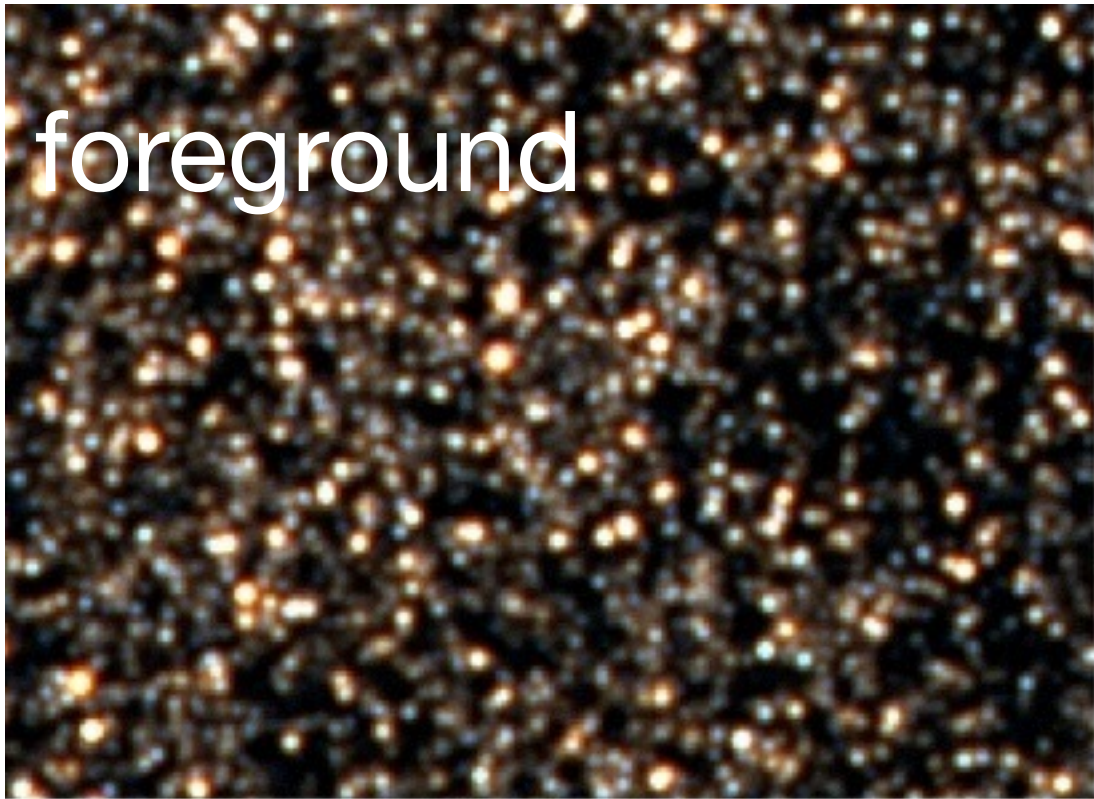


CIB as foreground

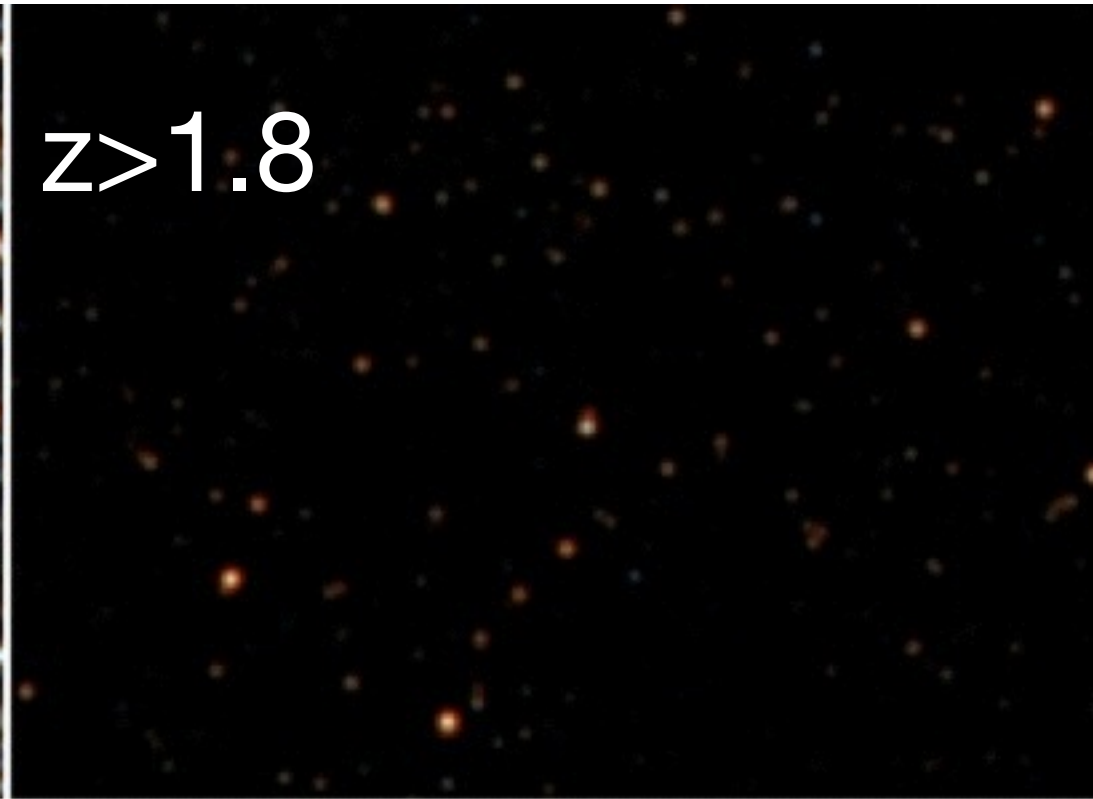
- Want DSFGs at $z > 1$
- high- z DSFGs dominated by foreground noise
- cross-correlate DSFGs with *tracers* of the same dark matter



cross-correlation with tracer



foreground



$z > 1.8$

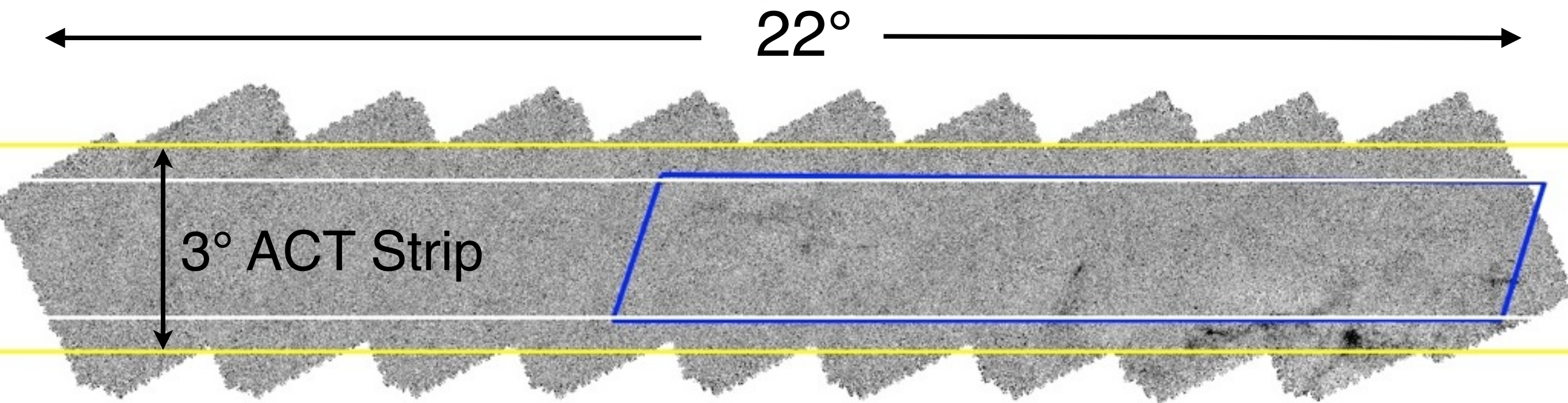


LAEs

- HETDEX LAEs from $1.8 < z < 3.5$
- Biased tracer of the dark matter, bias known to 1-2%

Herschel Redshift Survey (HeRS)

HeRS is here!

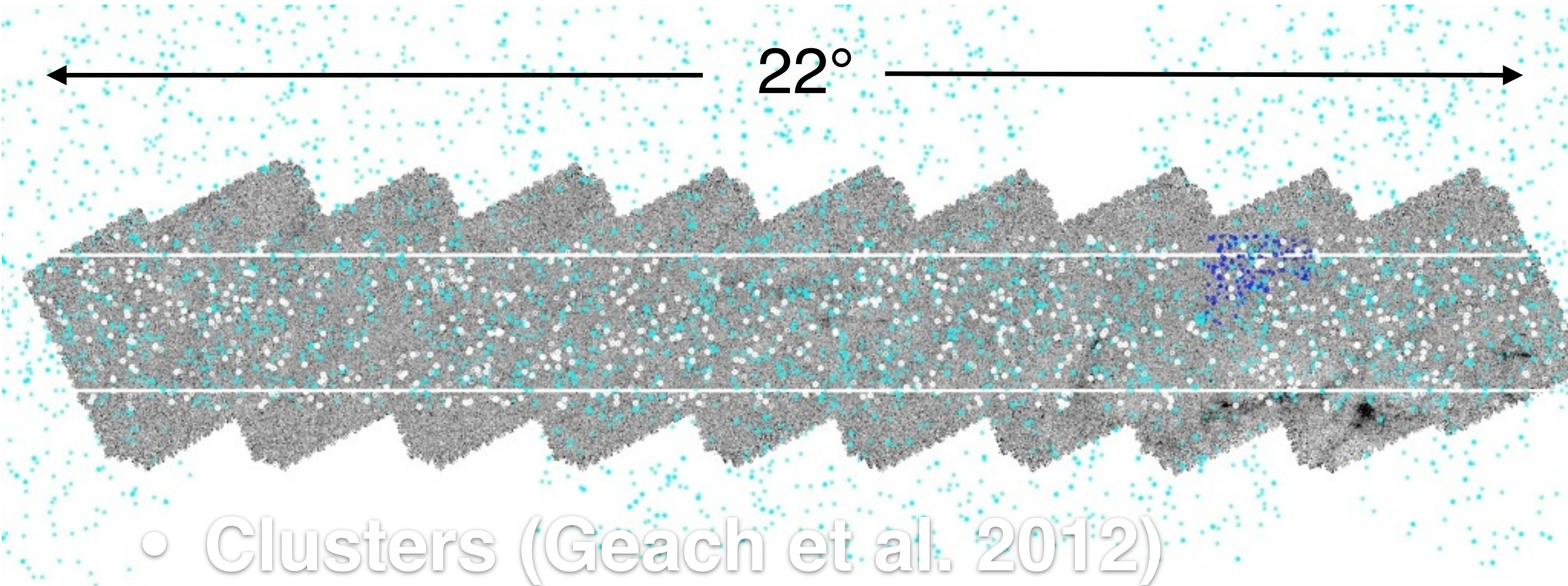


- ACT
- SHELA
- HETDEX

Collaborations welcome! More info at:

http://www.astro.caltech.edu/~viero/viero_homepage/hers.html

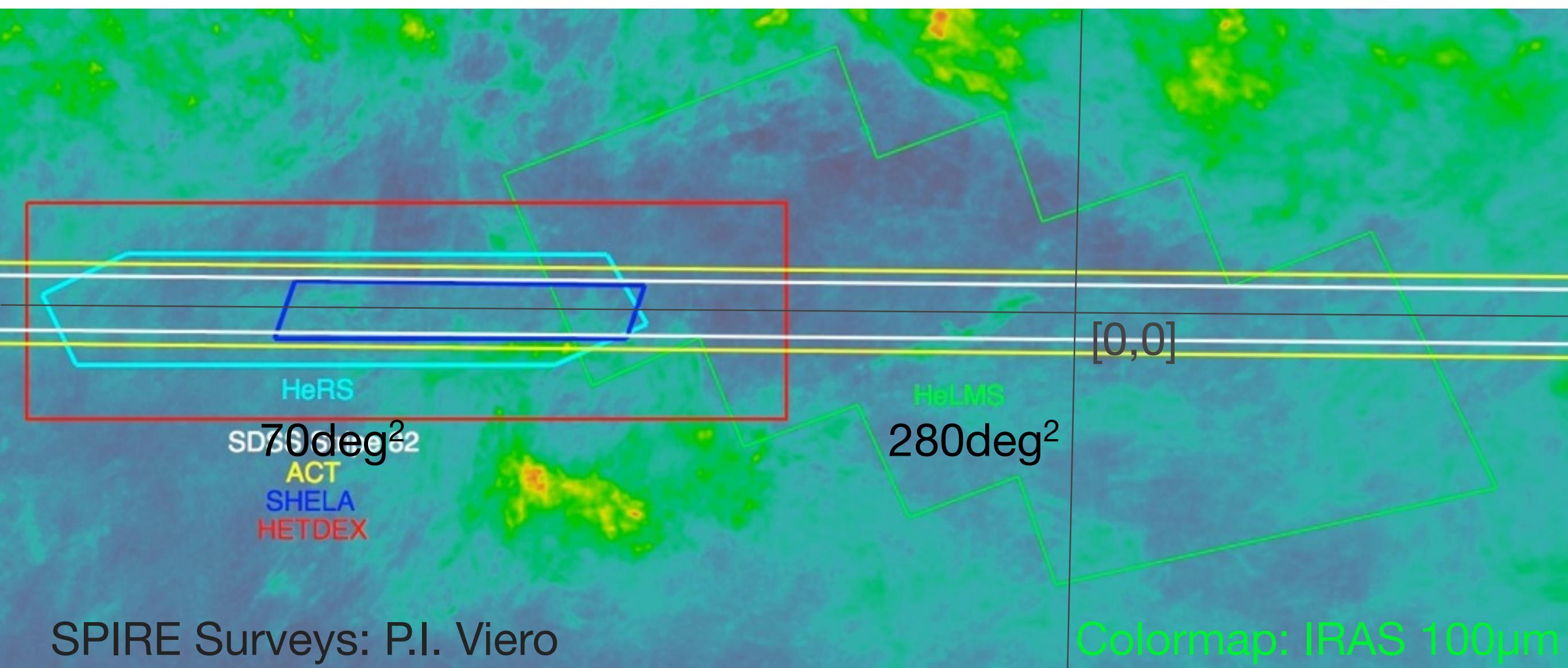
HeRS is here!



- Clusters (Geach et al. 2012)
- BOSS quasars
- Wigglez

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HeLMS/HeRS

HeRS projects underway:

- z-distribution of brightest resolved sources
- characterizing scattered starlight in the ISM
- dust content in optically identified clusters
- cross-correlations with dark matter mass tracers including:
 - quasars
 - clusters (optical, x-ray, SZ)
 - lyman-alpha forest
 - maxBCGs
 - lensed CMB kappa maps (w/ ACT)
- SED evolution of quasars
- sSFR of IRAC galaxies as function of stellar mass
- cluster mass diagnostic: comparing optical, SZ and x-ray mass estimates
- stacking satellites in mass and radius bins to measure star-formation dependence on environment and consequences for SZ decrement
- developing clump finding technique to identify Galactic cirrus clouds
- modeling (halo model and abundance matching) the CIB based on stacked SED templates
- follow-up of lensed SMGs
- determining SFRs of SN hosts as a function of SN type
- more ideas/collaborators (including students!) welcome

conclusion (call to action!)

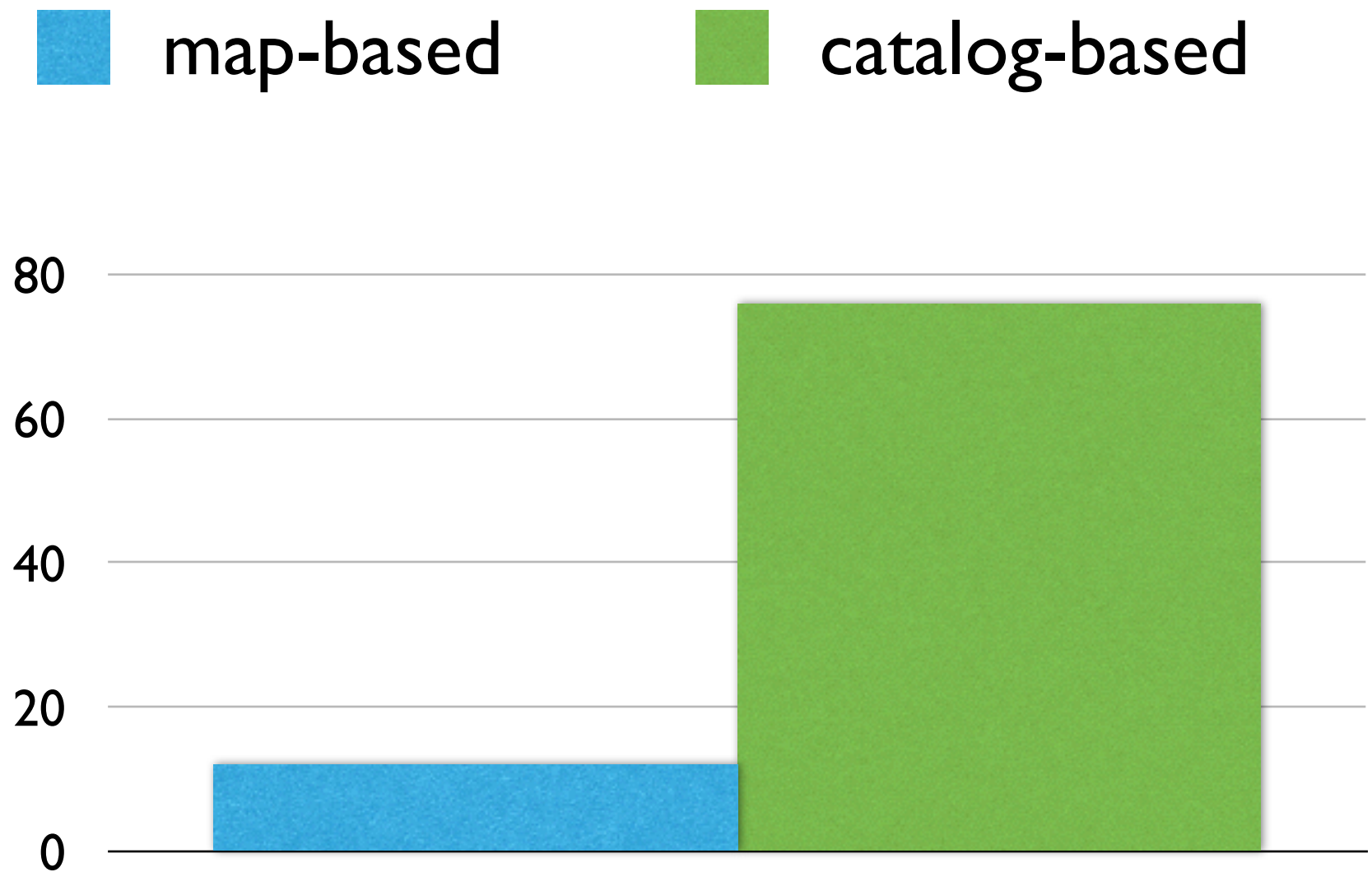
ADS

Catalog-Based

- ~1% of sources:
~86% of papers

Map-Based

- ~99% of sources:
~14% of papers



conclusion

- ~99% of sources lie beneath the confusion noise floor
- map based techniques such as stacking and CIBA spectra probe the faint sources which dominate the background
- leveraging high quality ancillary data will help deconstruct the CIB in redshift intervals