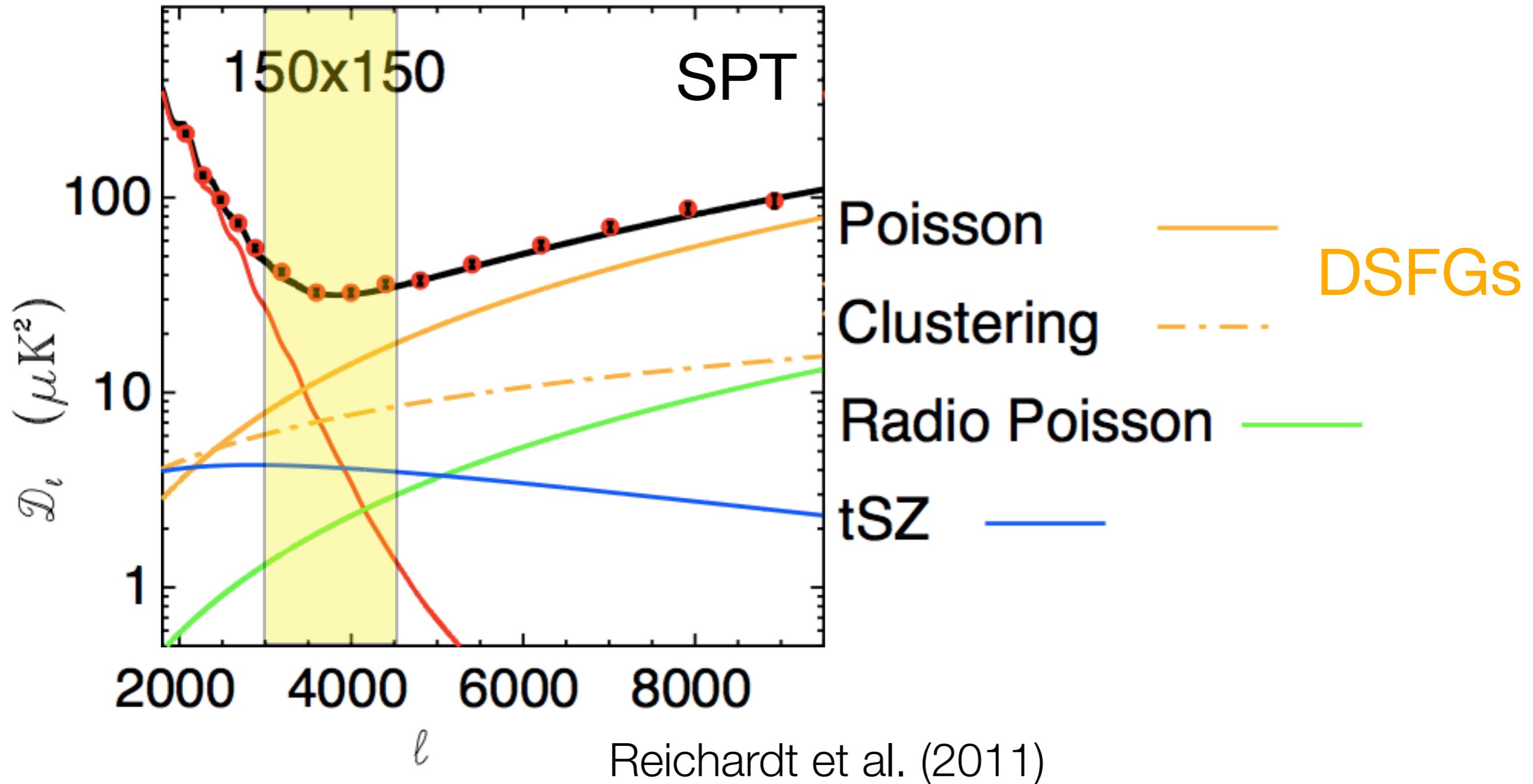
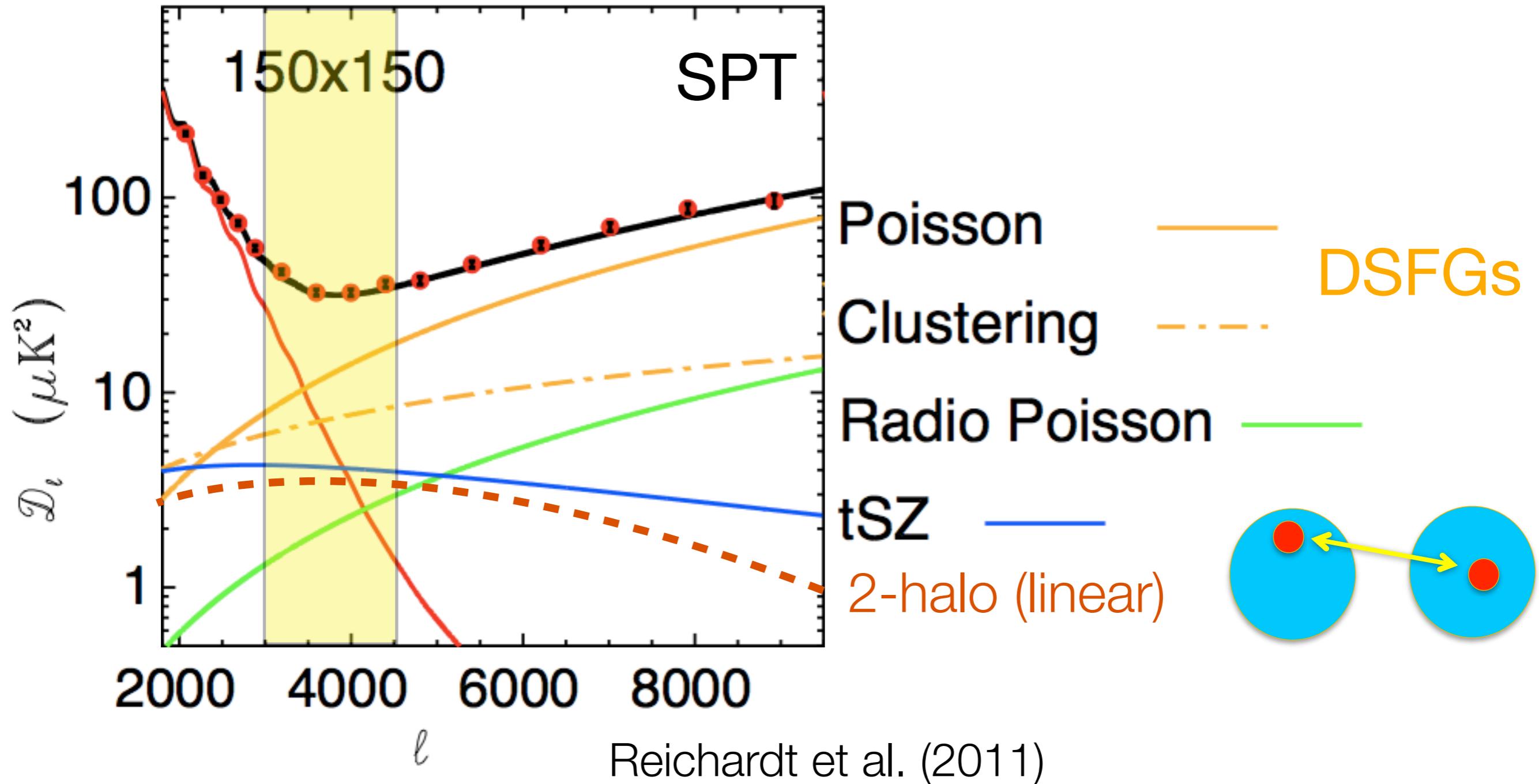


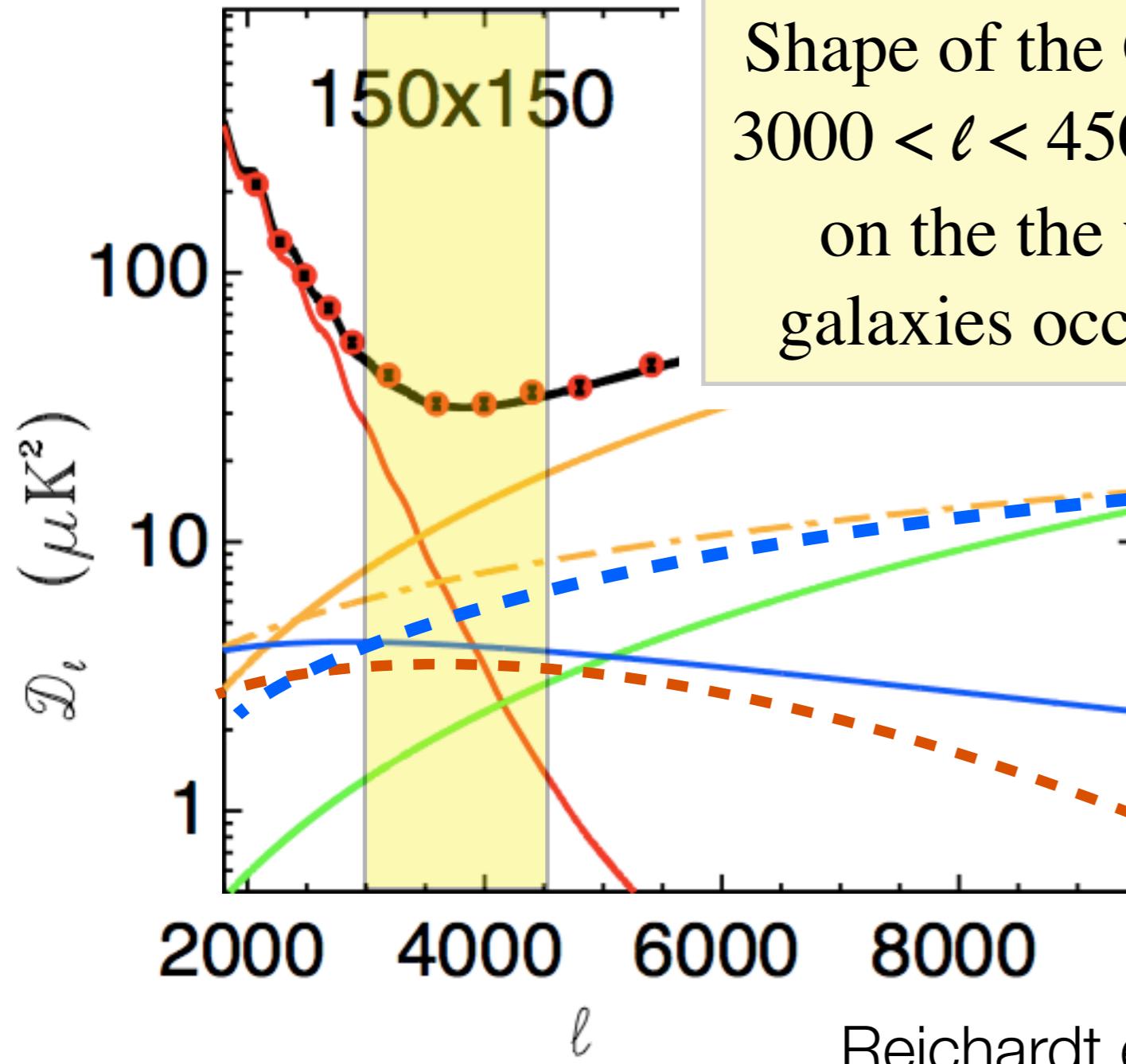
Occupy Dark Matter:
Uncovering the Properties of high- z Dusty Star-
Forming Galaxies with Statistical Techniques
Marco Viero - Caltech



Power Sources in CMB maps



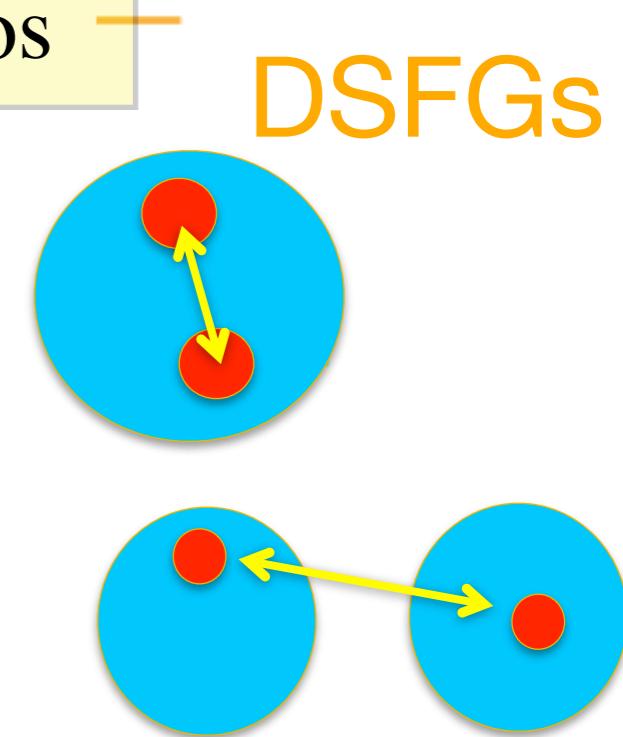
Power Sources in CMB maps



Shape of the Galaxy Spectrum at $3000 < \ell < 4500$ highly dependent on the way star-forming galaxies occupy massive halos

1-halo
(non-linear)

2-halo (linear)



Reichardt et al. (2011)

Power Sources in CMB maps

outline

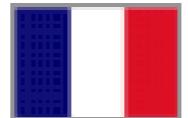
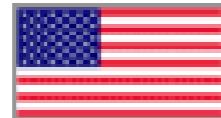
- measuring and modeling CIB Anisotropies (CIBA)
- properties of galaxies that make up the CIB w. stacking

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

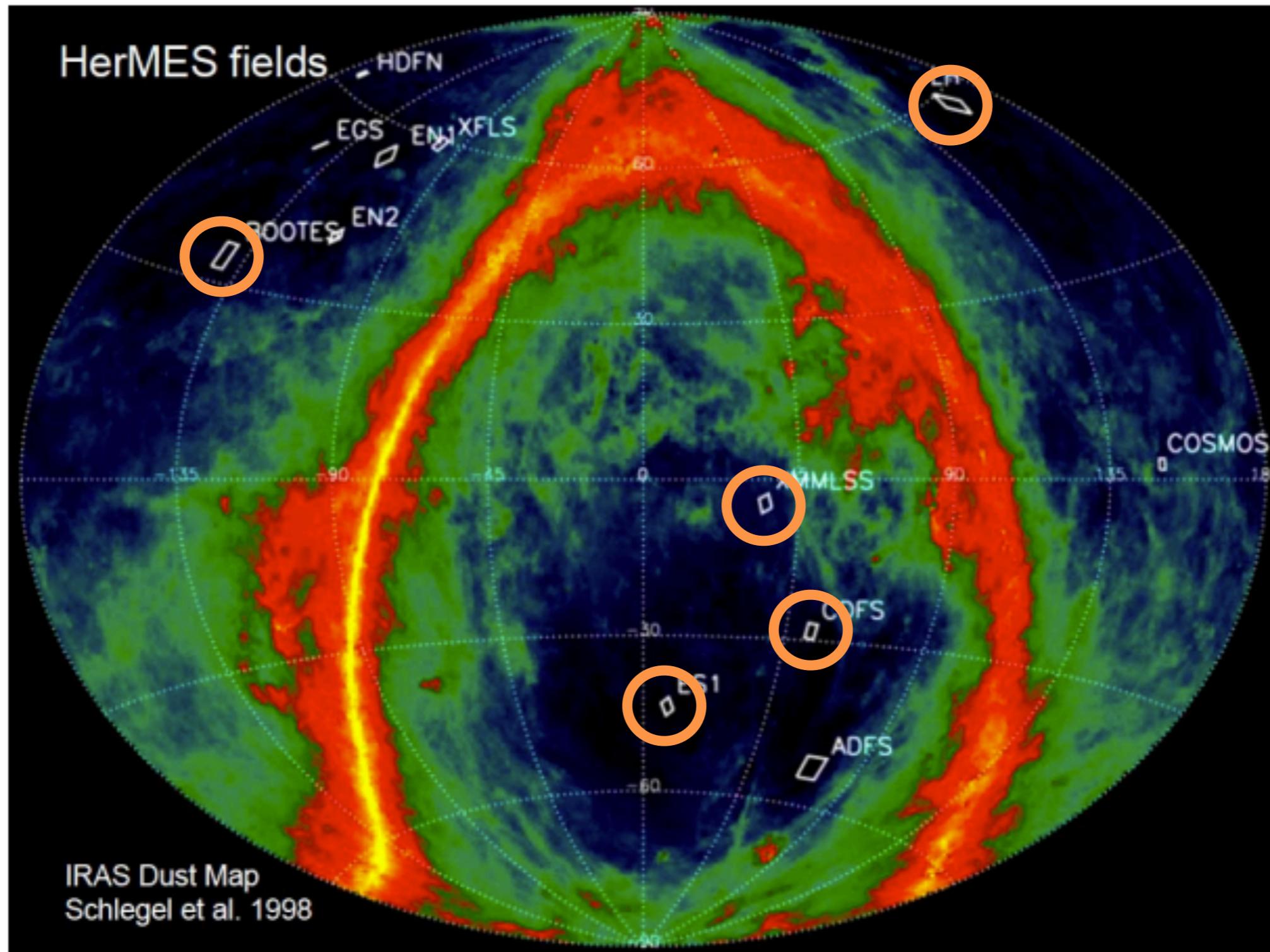


The Team

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, Giulia 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

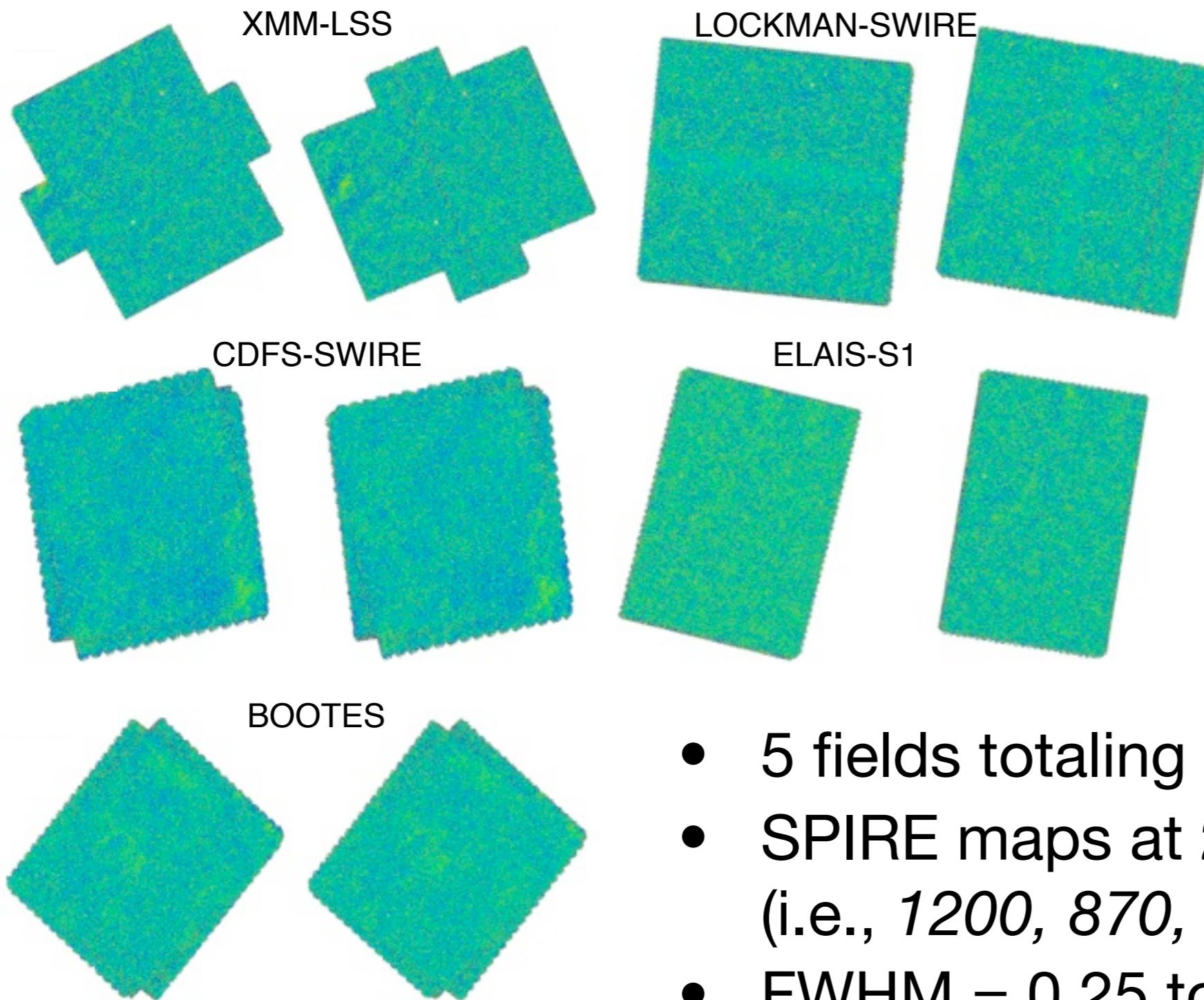
Faculty & Researchers PostDocs PhD Students

Plus engineers, instrument
builders, software developers etc.



HerMES Fields

CIB maps



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

- 5 fields totaling ~ 70 deg 2
 - SPIRE maps at **250, 350, and 500 μ m**
(i.e., 1200, 870, 600 GHz)
 - FWHM = 0.25 to 0.5 arcmin
 - Modes $>\sim 0.5$ deg filtered



SMAP Team

Alex Conley

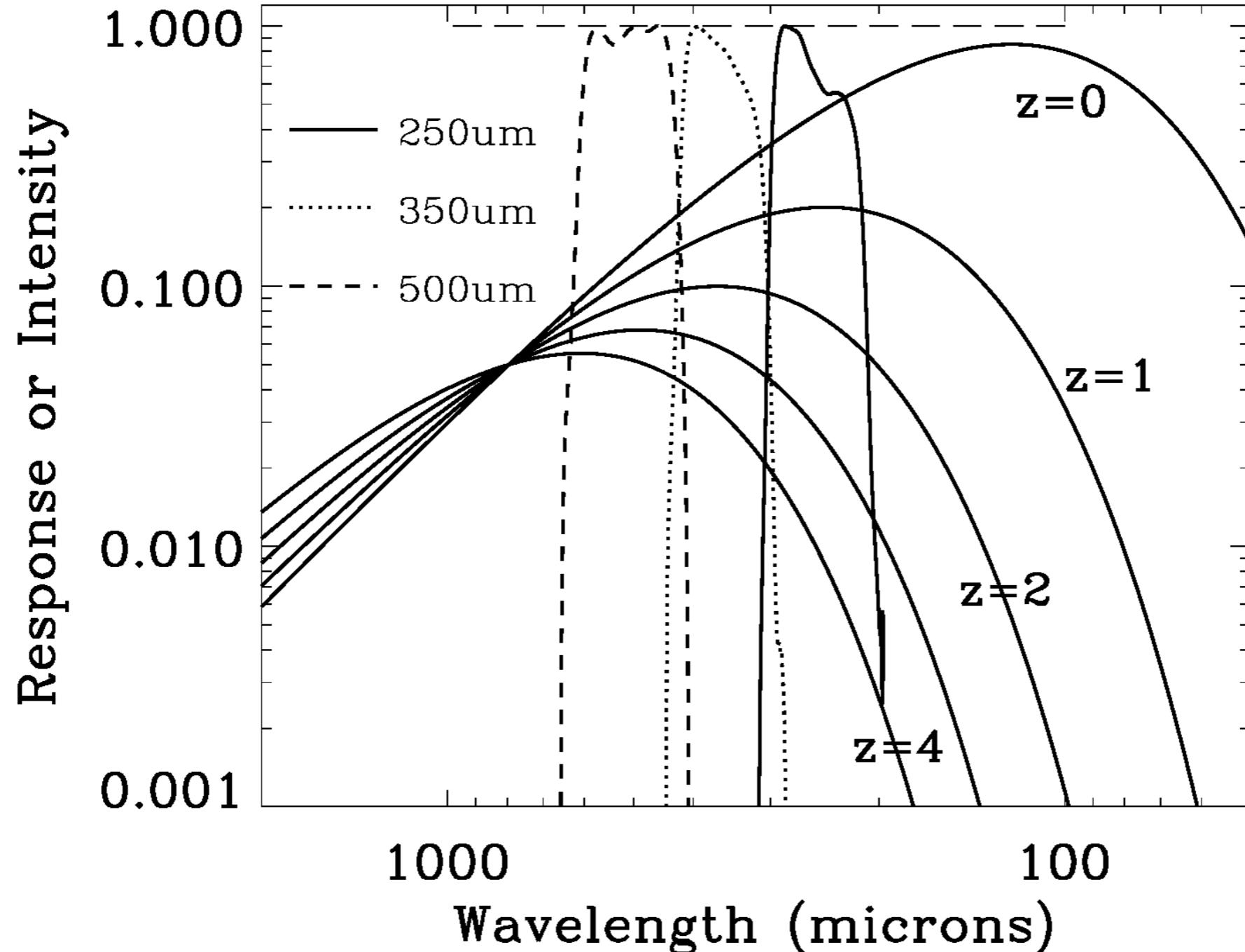
Louis Levenson

Gaelen Marsden

Bernhard Schulz

Marco Viero

Mike Zemcov

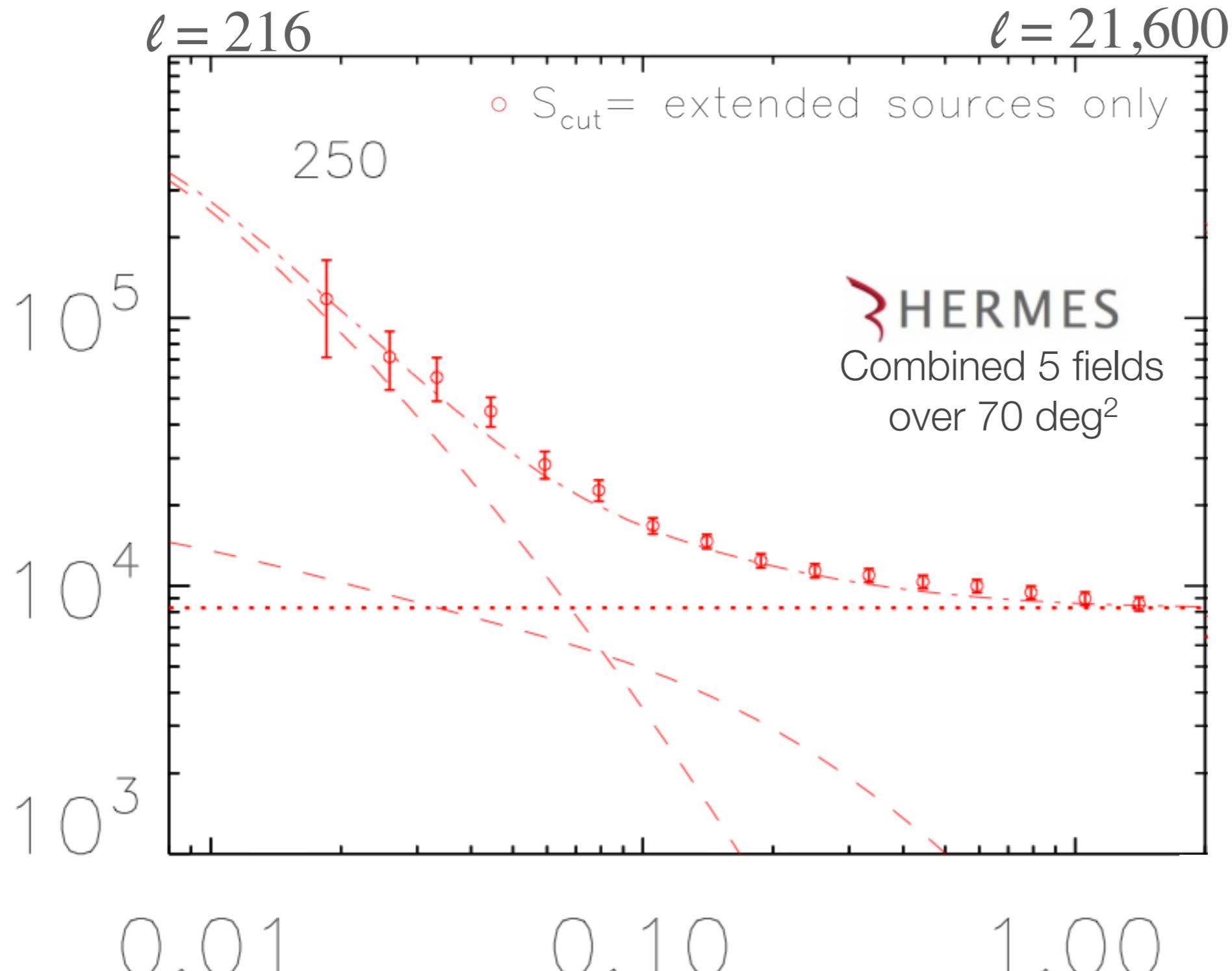


ERMES

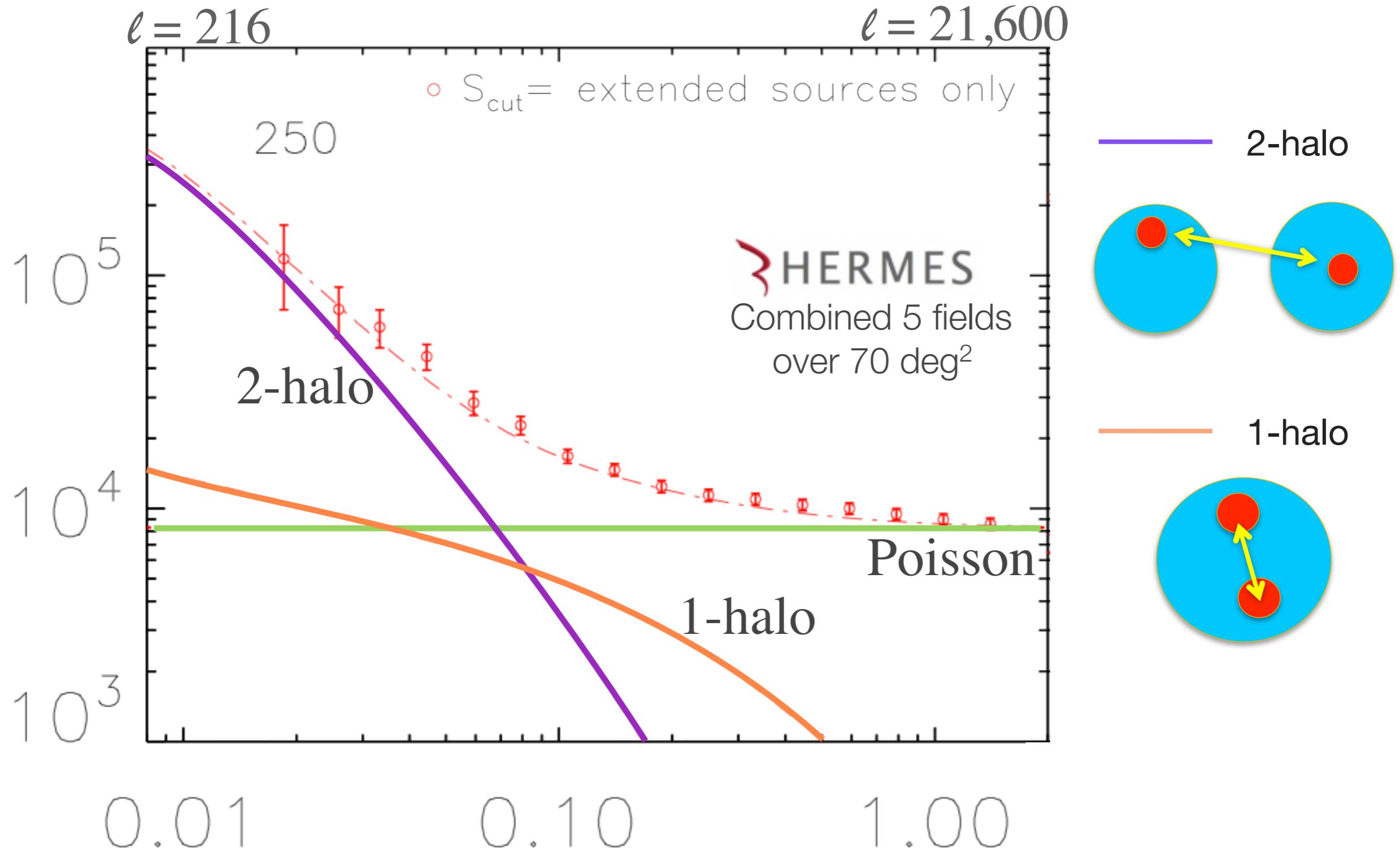
IAP Team
Ex Conley
Levenson
Ben Marsden
Hard Schulz
Marco Viero
Bo Zemcov

- SPIRE maps at **250, 350, and 500 μ m** (i.e., 1200, 870, 600 GHz)
- FWHM = 0.25 to 0.5 arcmin
- Modes $>\sim 0.5$ deg filtered

HerMES power spectra

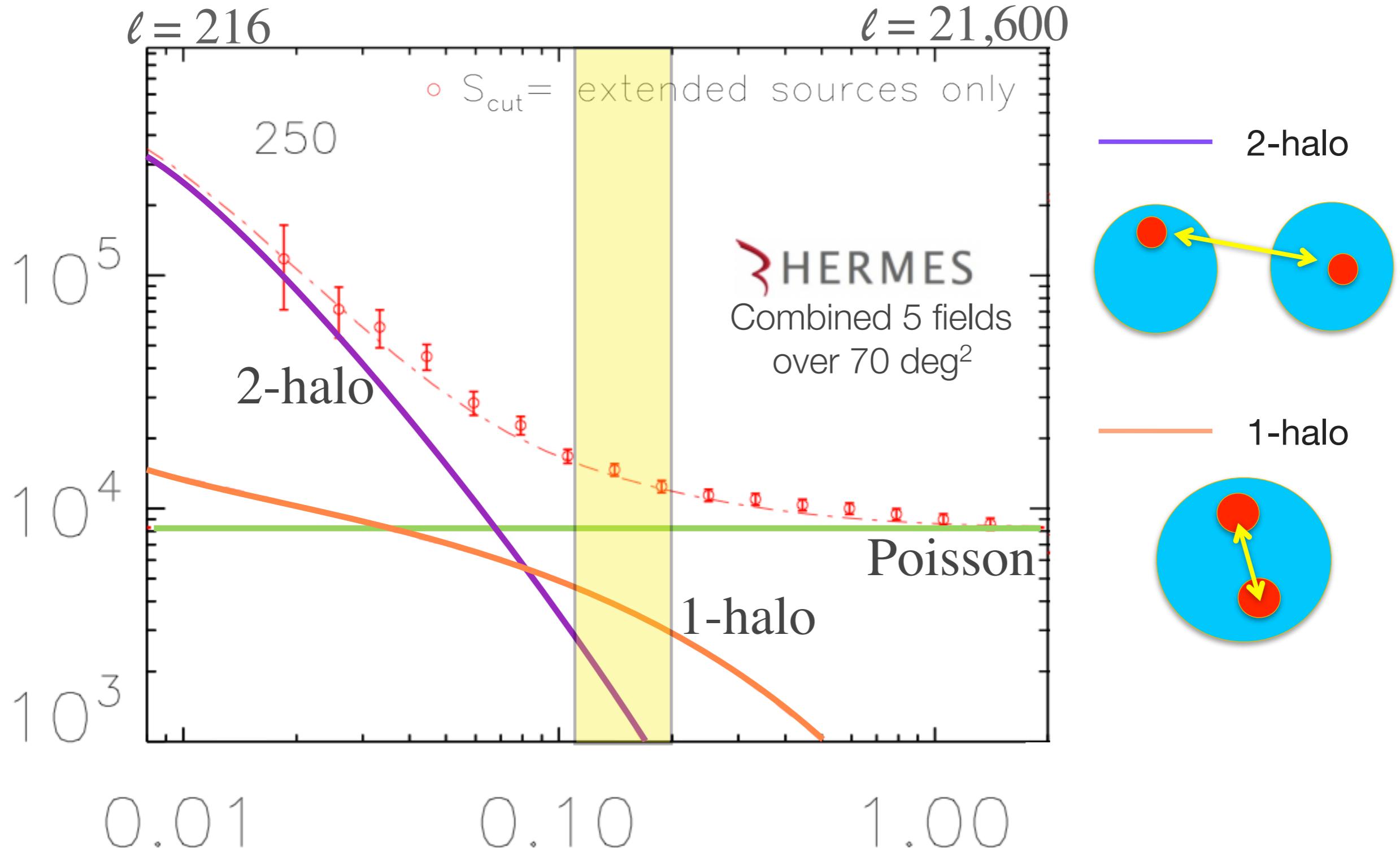


HerMES power spectra



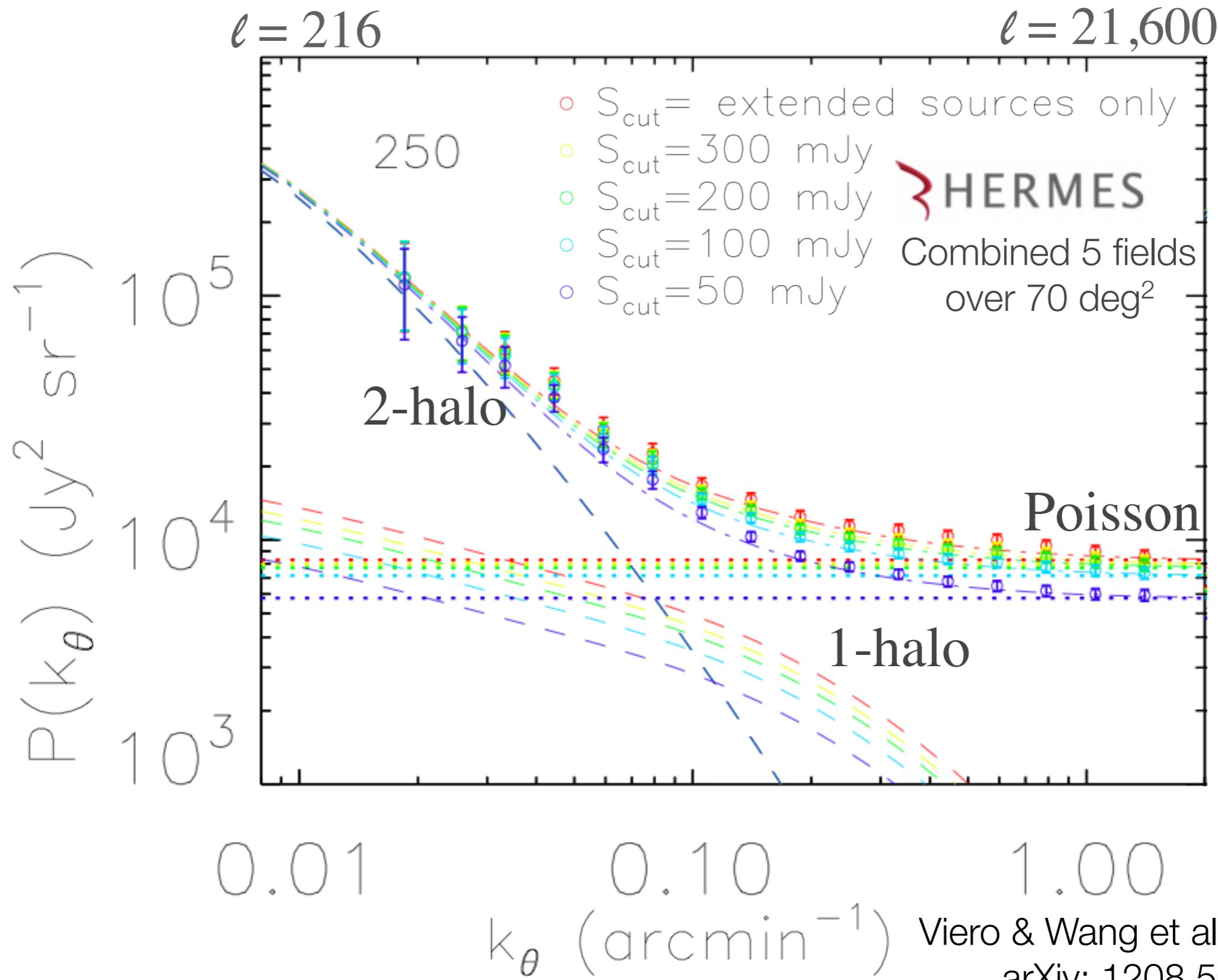
Viero & Wang et al. (2012b)
arXiv: 1208.5049

HerMES power spectra

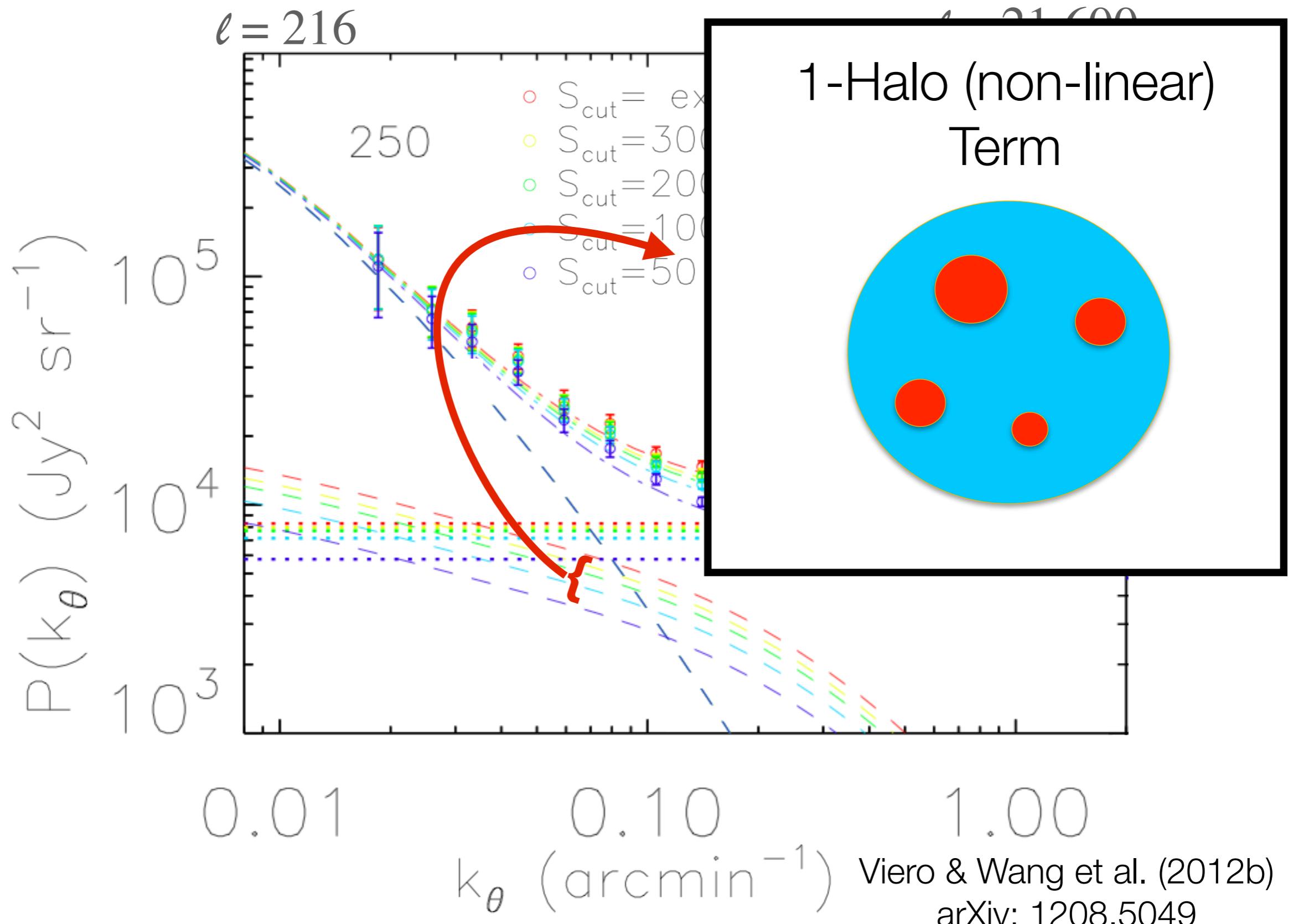


Viero & Wang et al. (2012b)
arXiv: 1208.5049

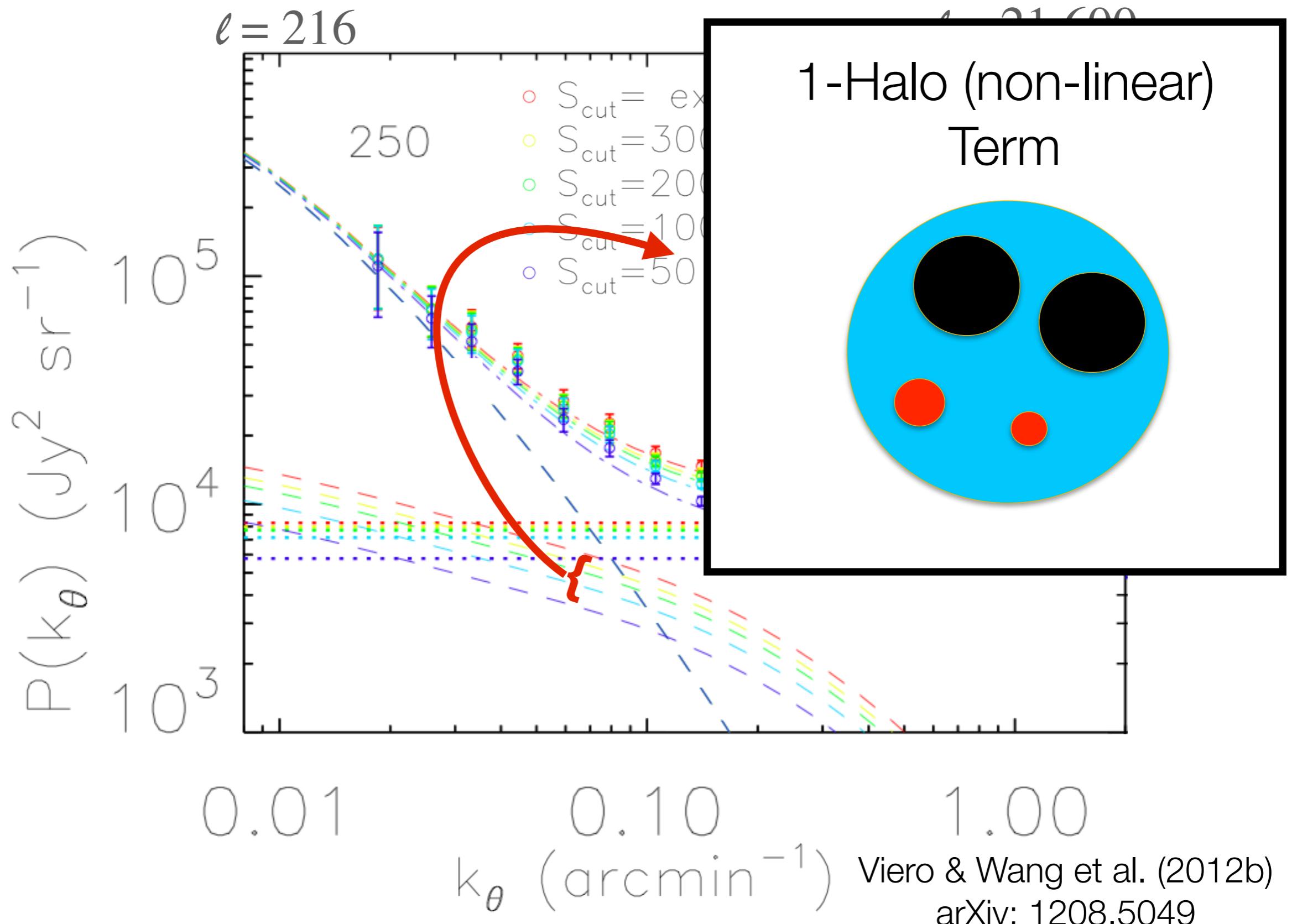
HerMES power spectra



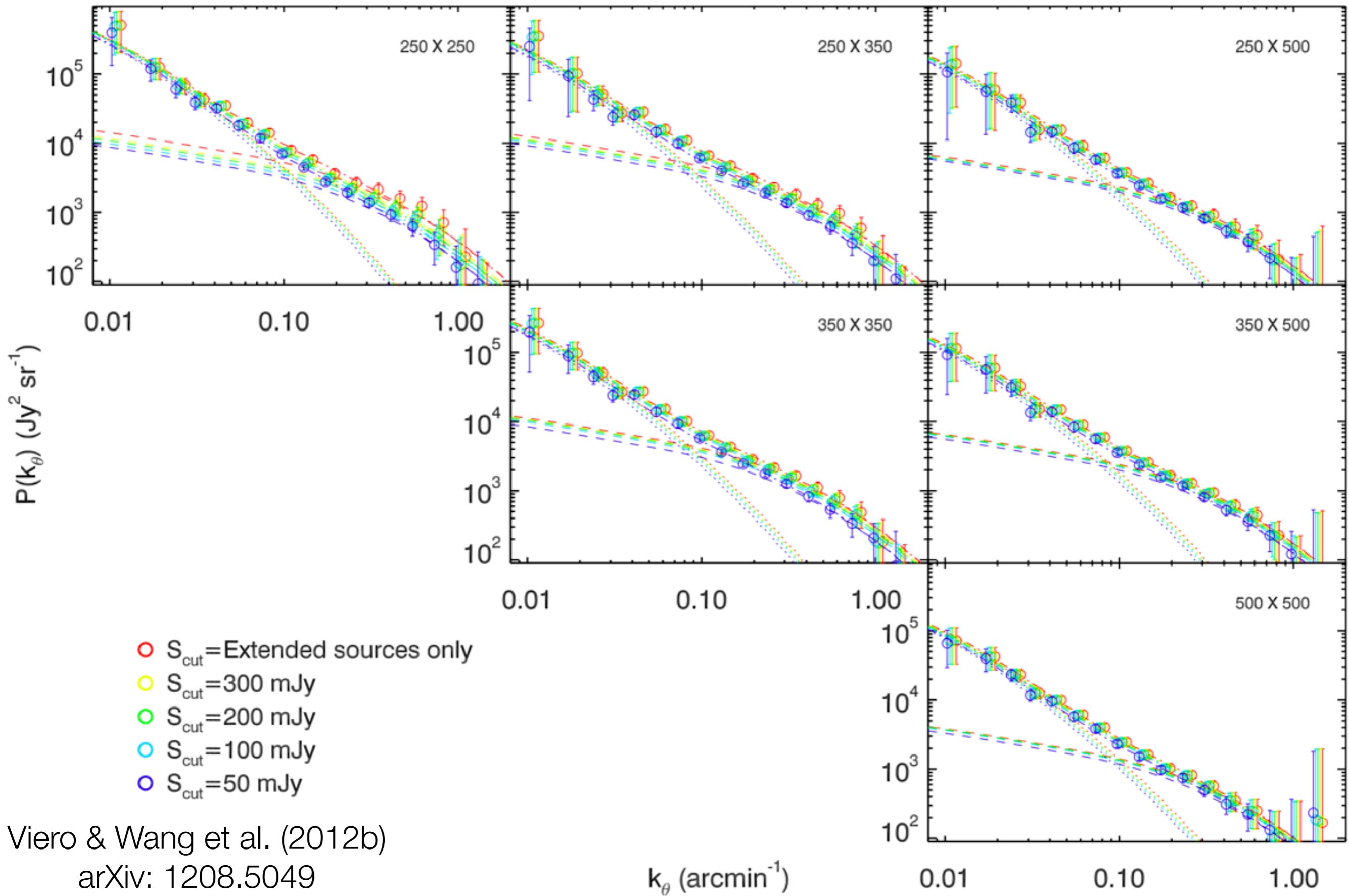
HerMES power spectra



HerMES power spectra



Poisson-Removed CIBA

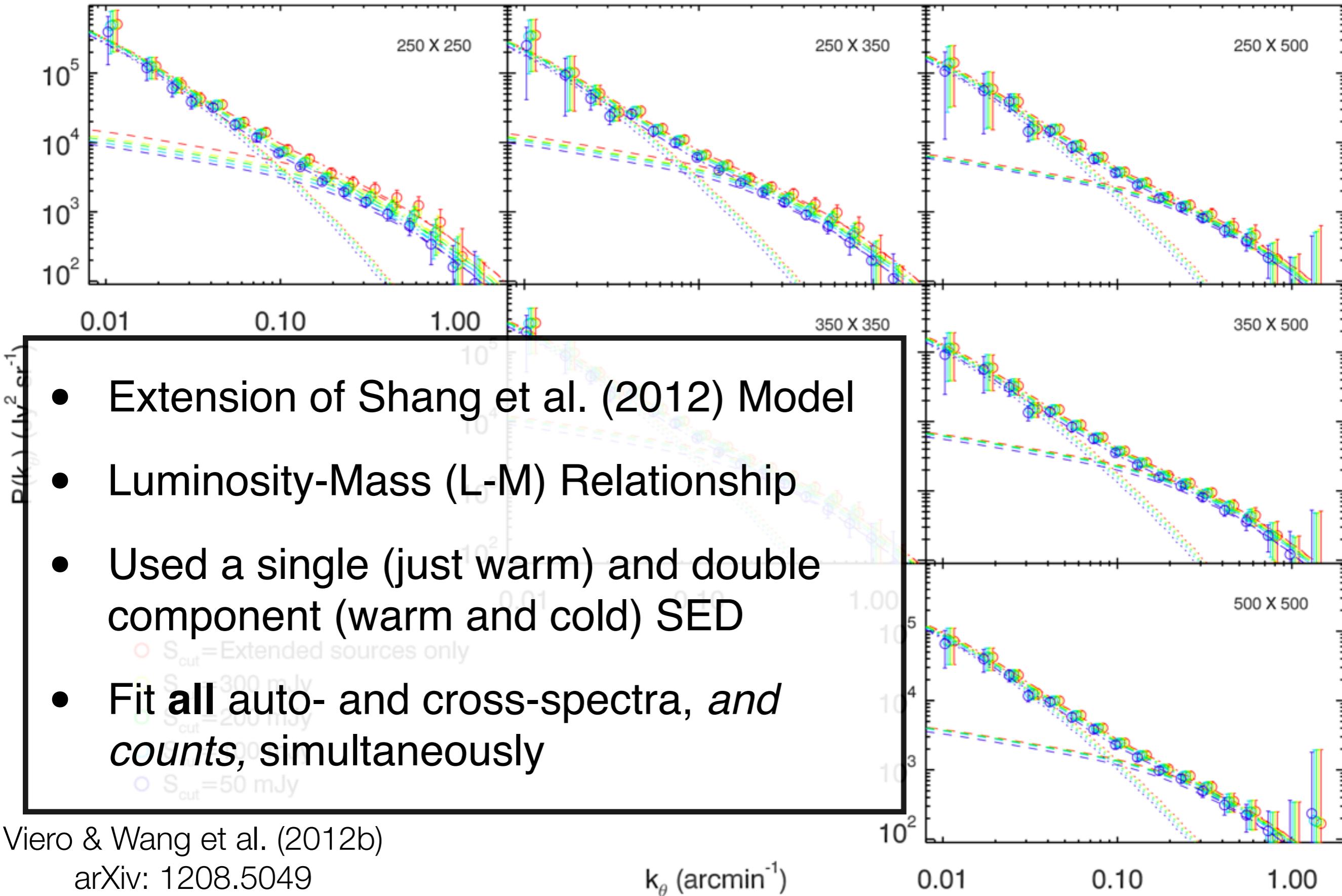


Viero & Wang et al. (2012b)

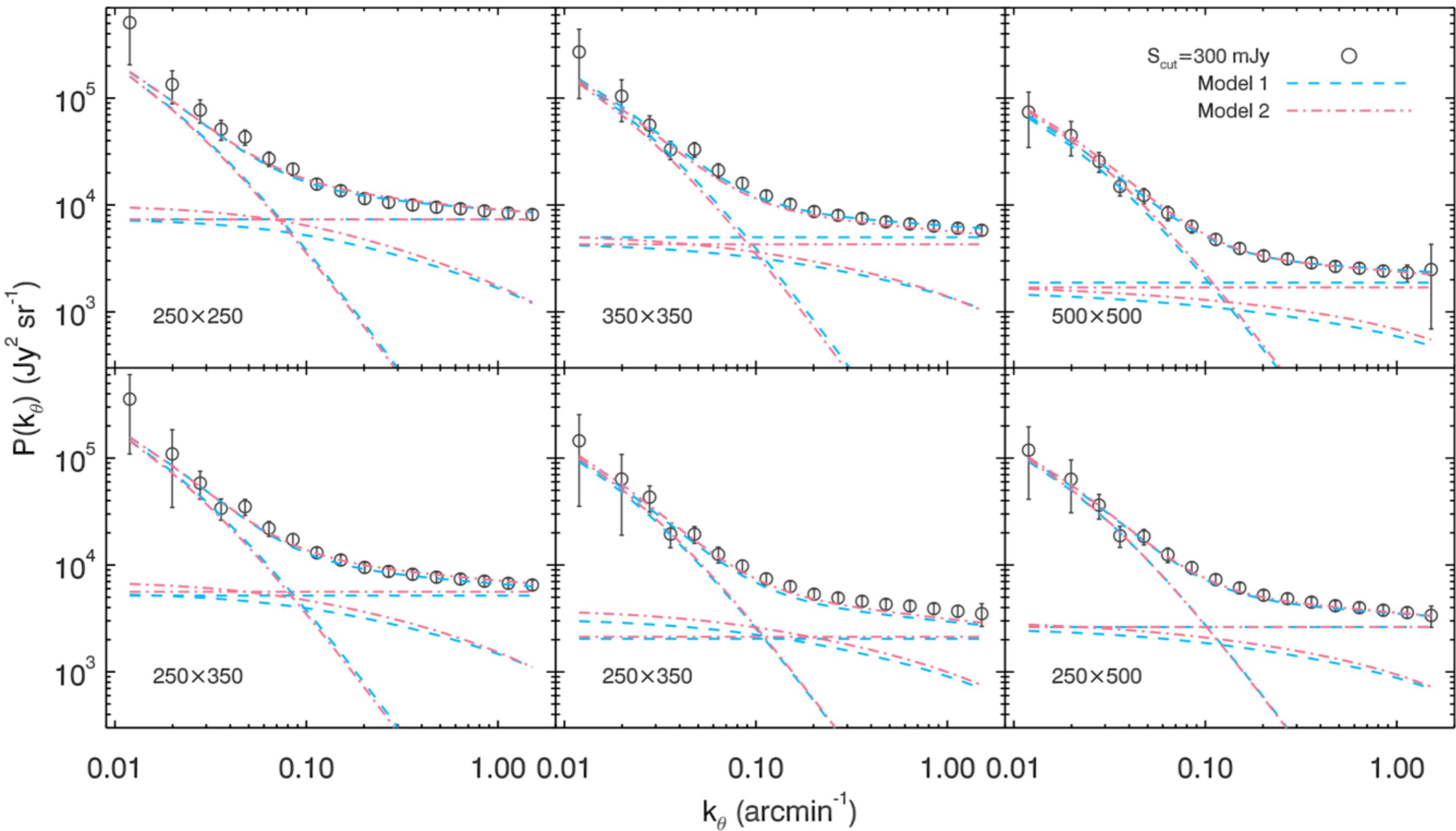
arXiv: 1208.5049

k_θ (arcmin^{-1})

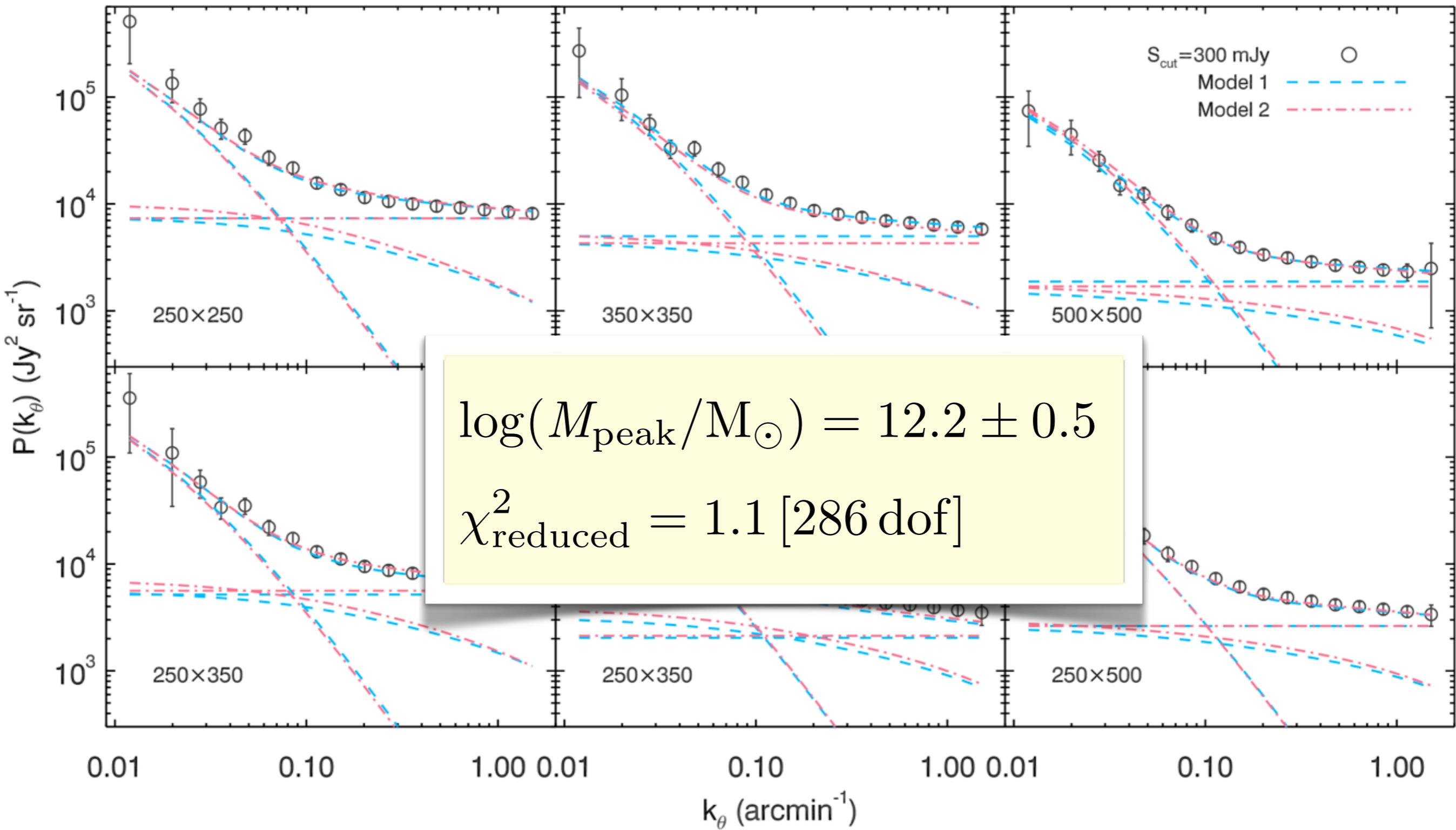
Poisson-Removed CIBA



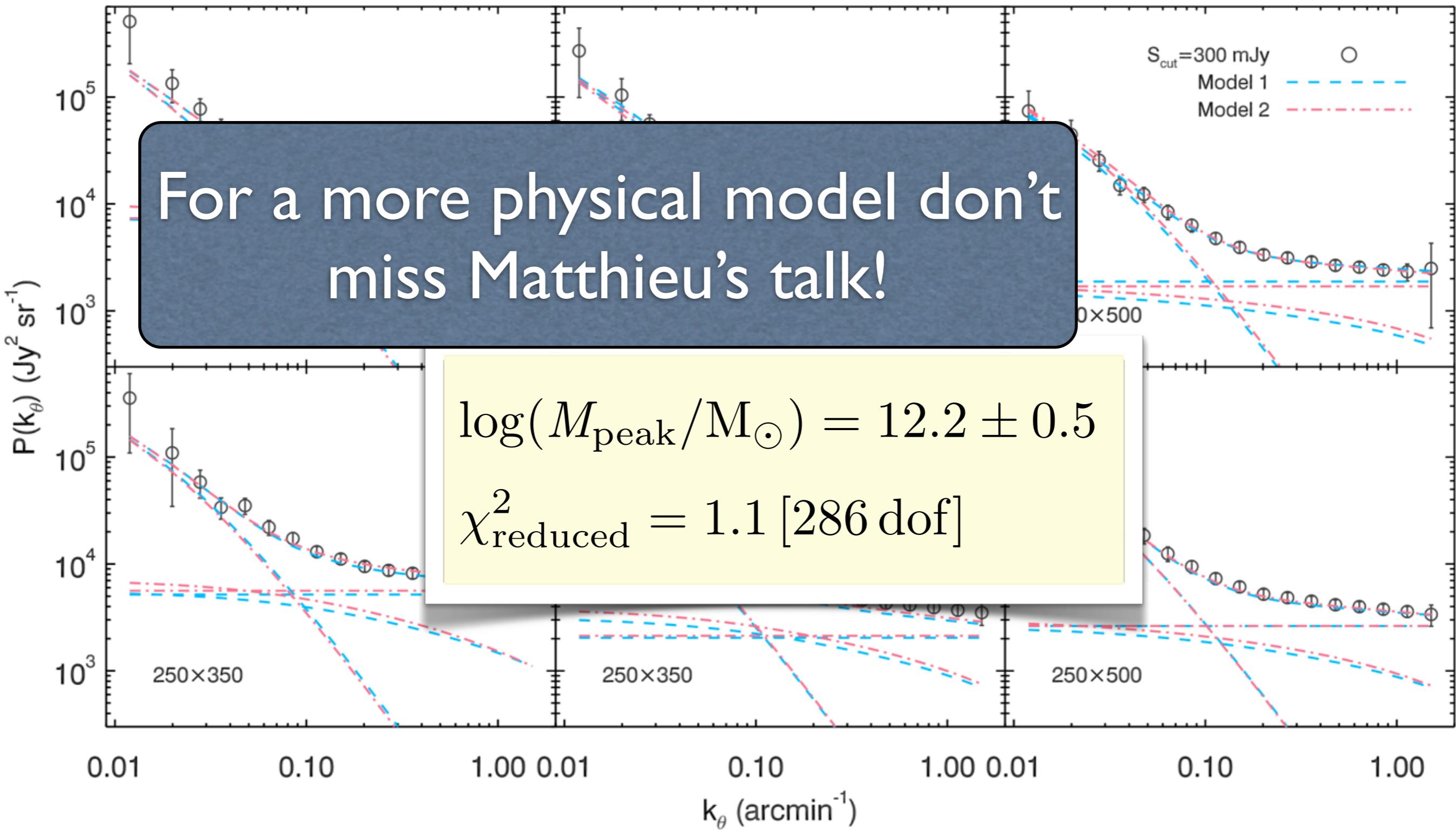
Best-Fit Halo Model



Best-Fit Halo Model



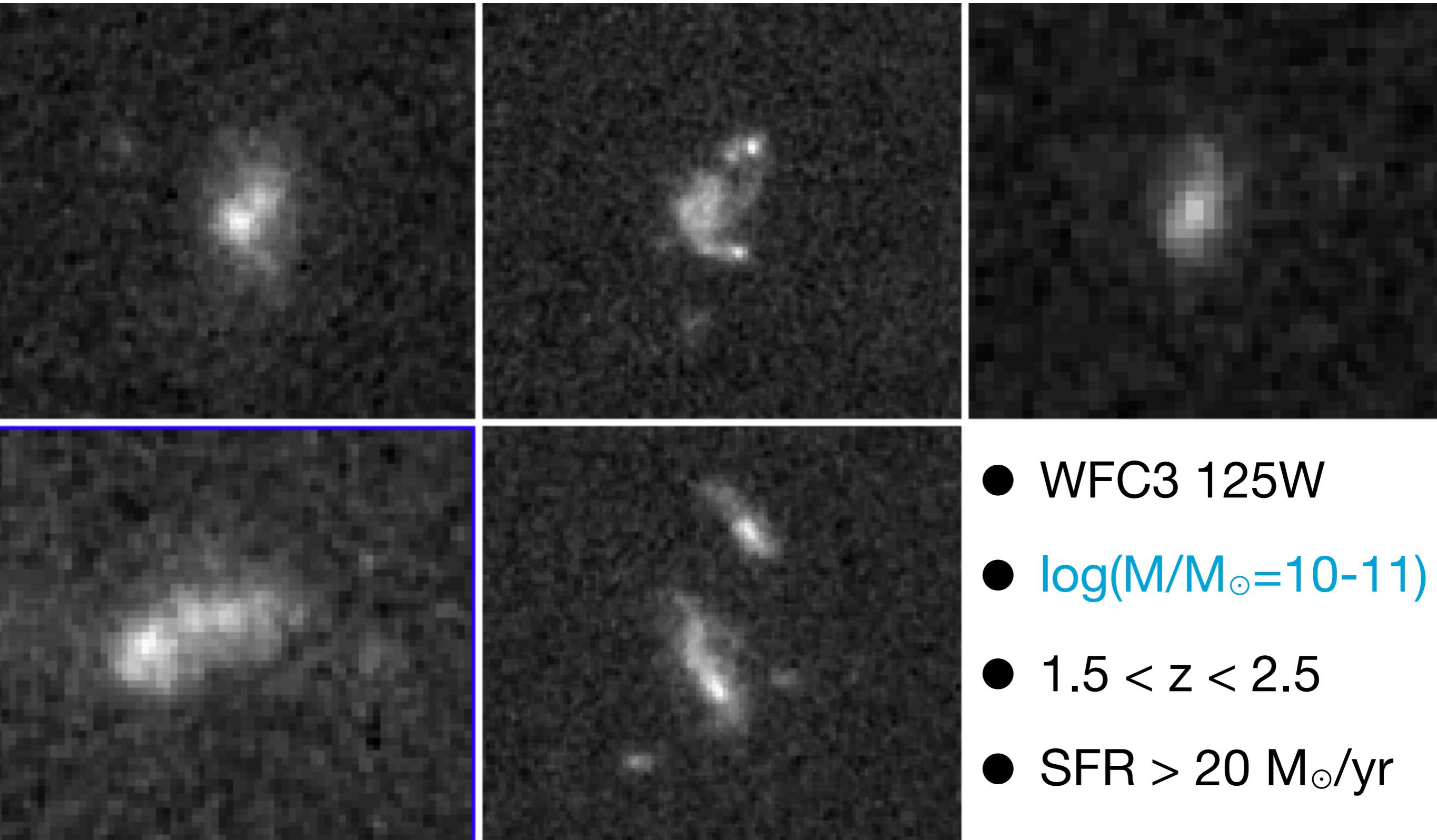
Best-Fit Halo Model

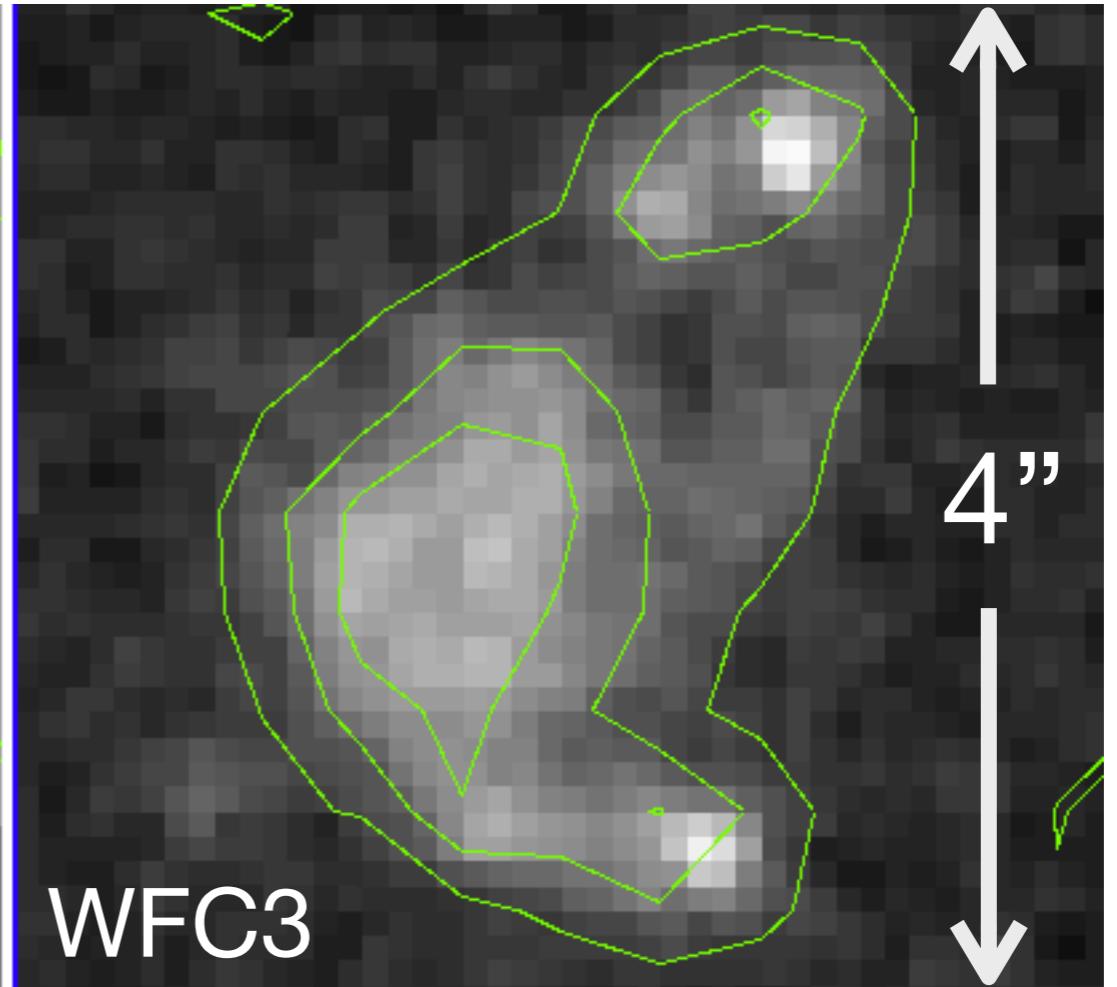
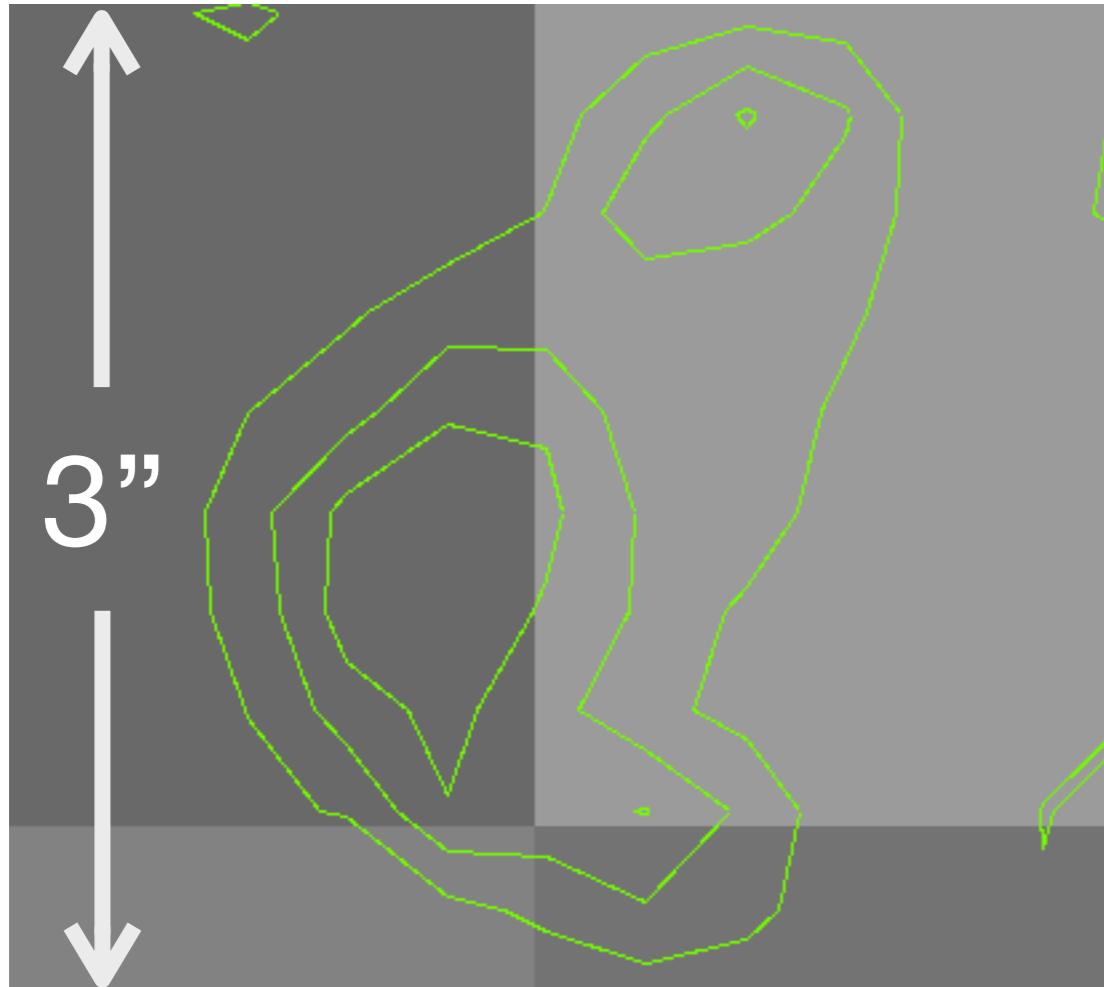


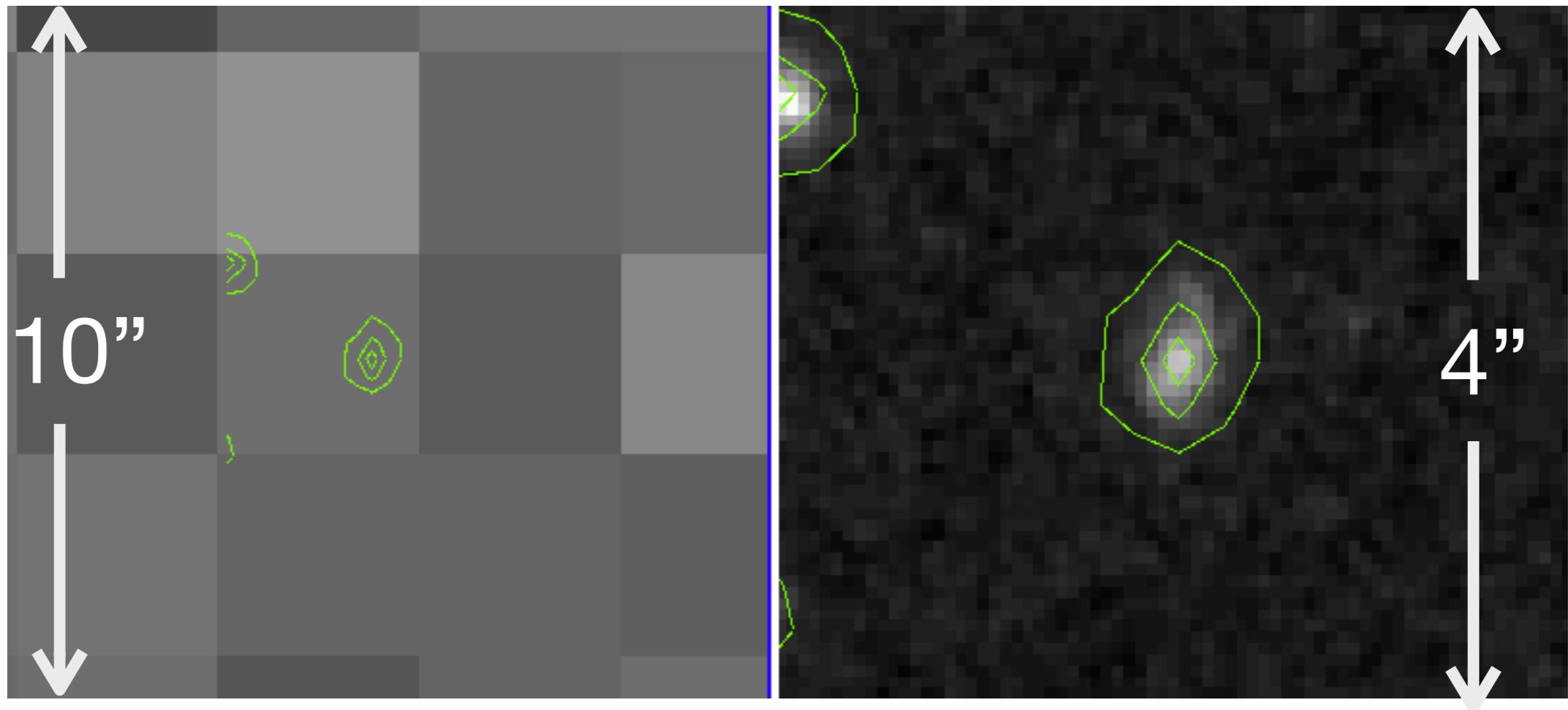
outline

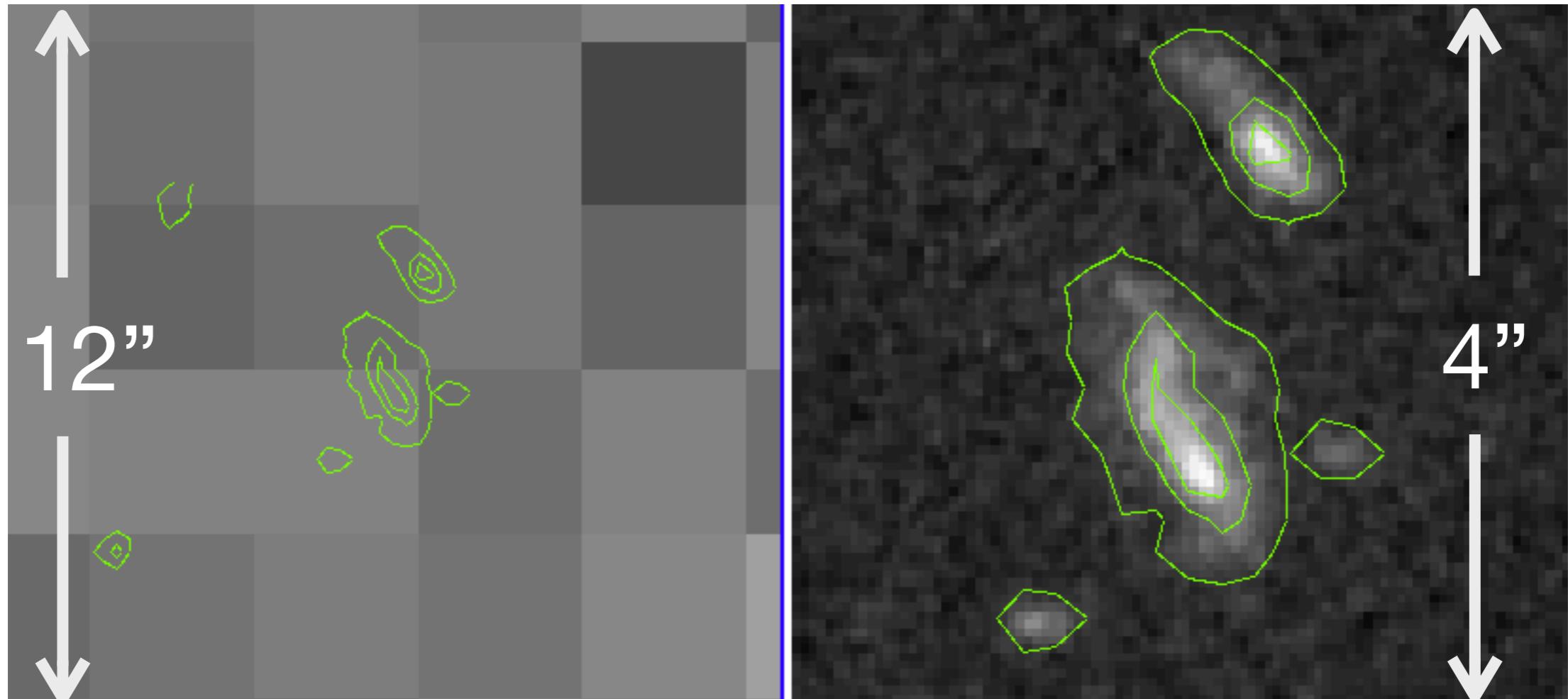
- measuring and modeling CIB Anisotropies (CIBA)
- properties of galaxies that make up the CIB w. stacking

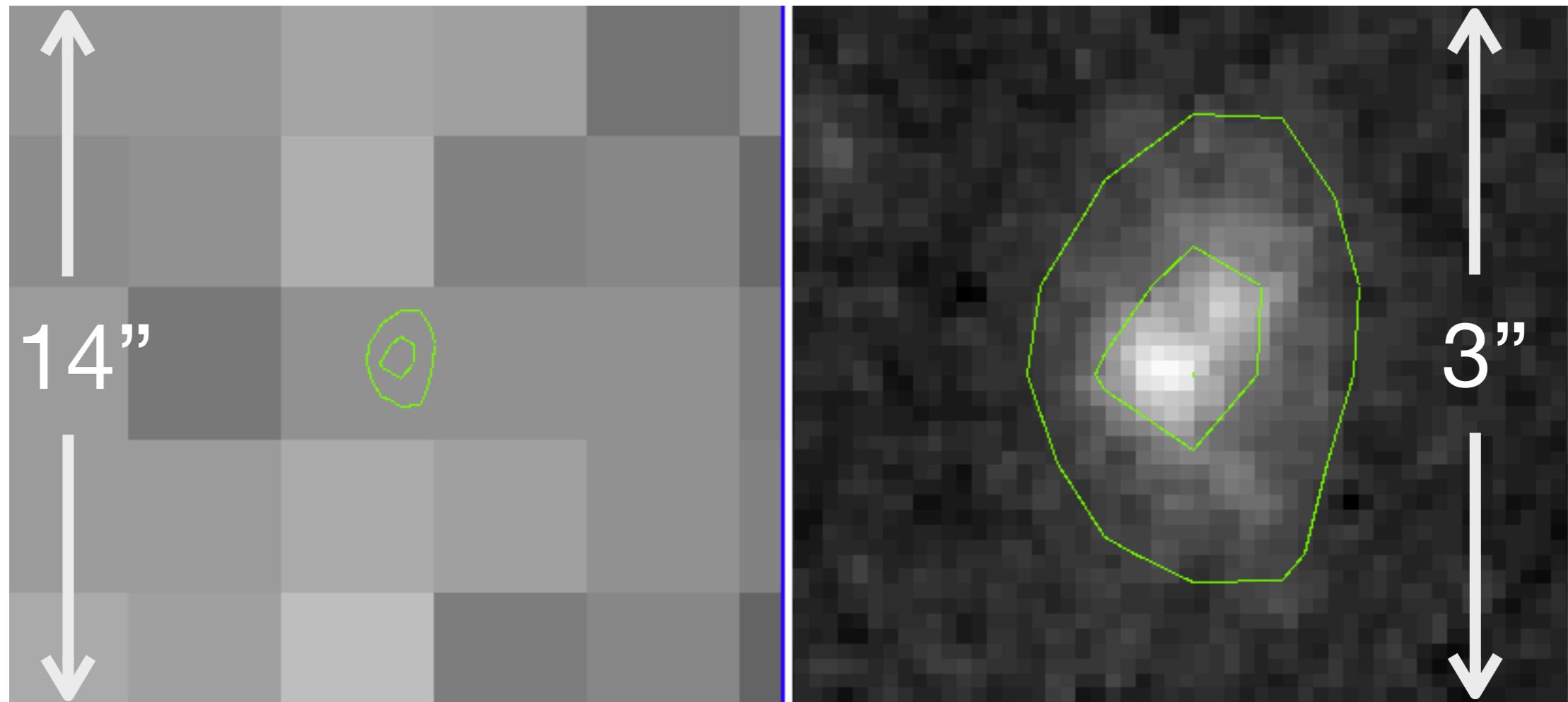
What is the contribution to the CIB from typical galaxies like these?

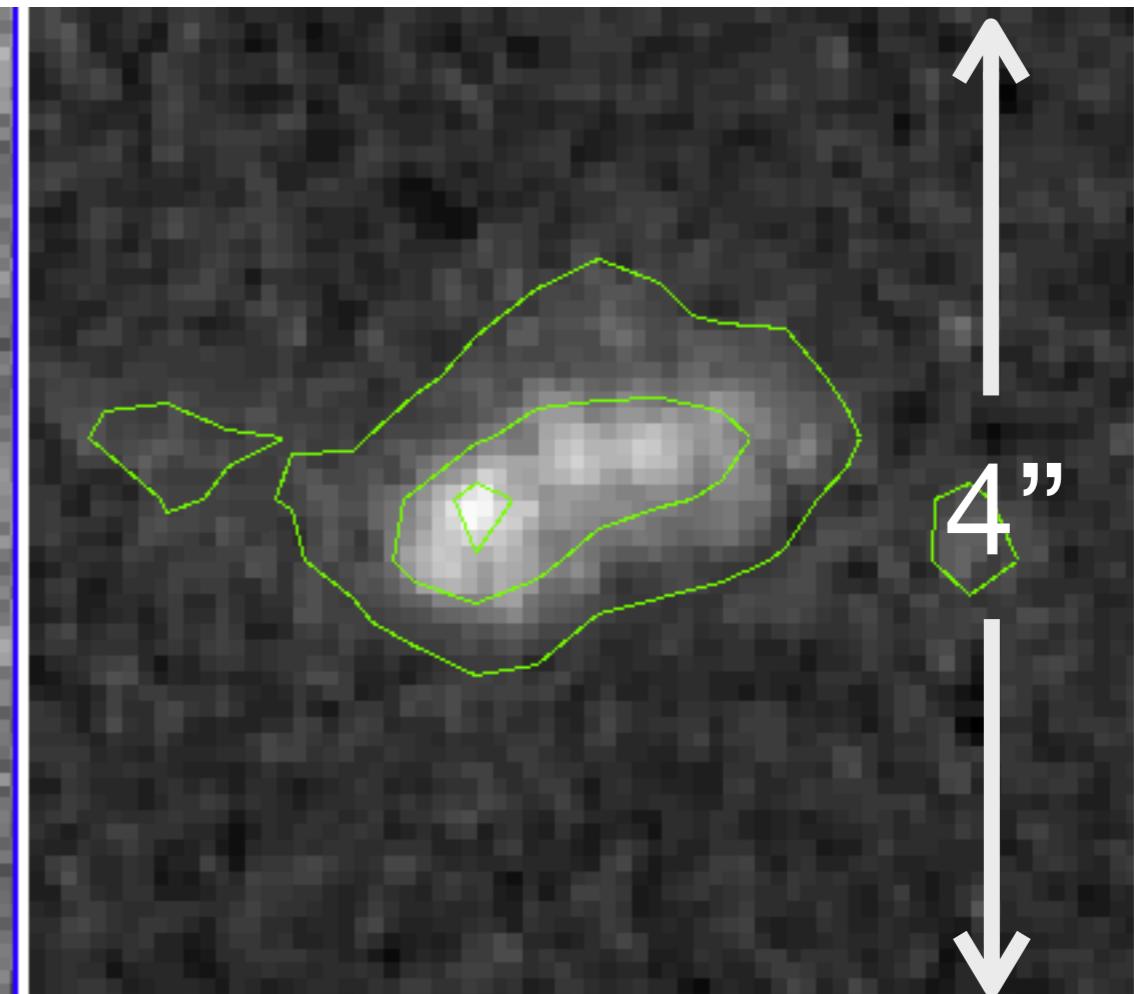
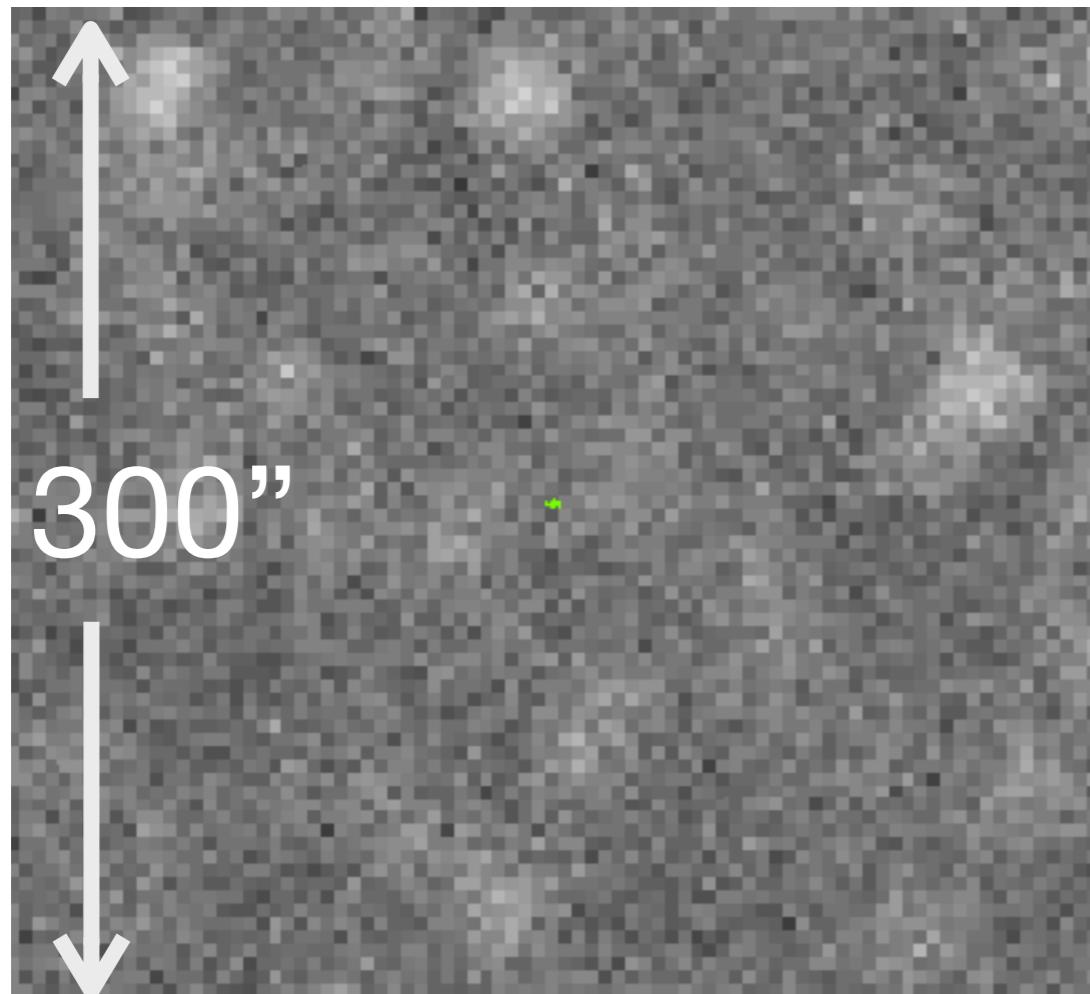


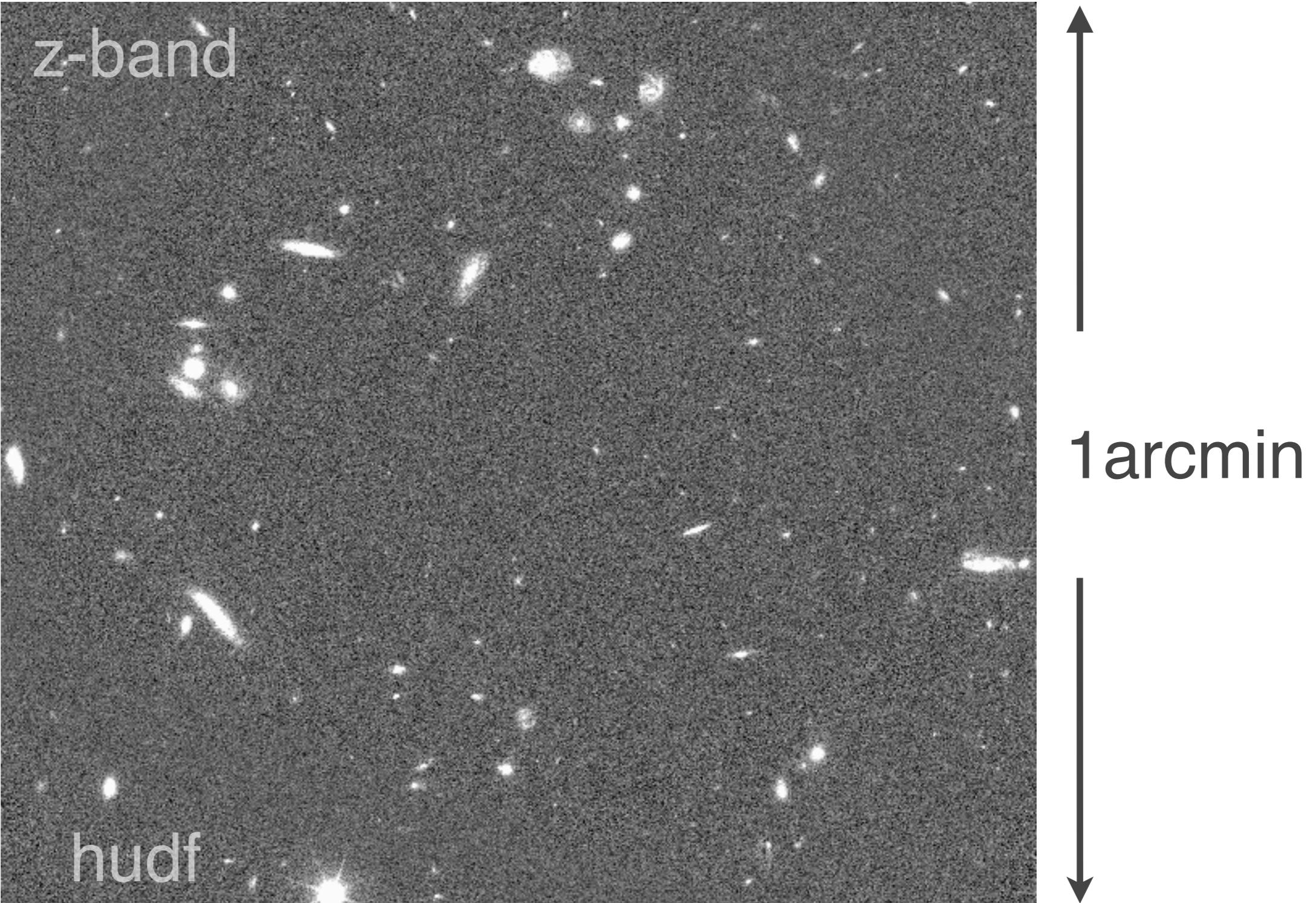




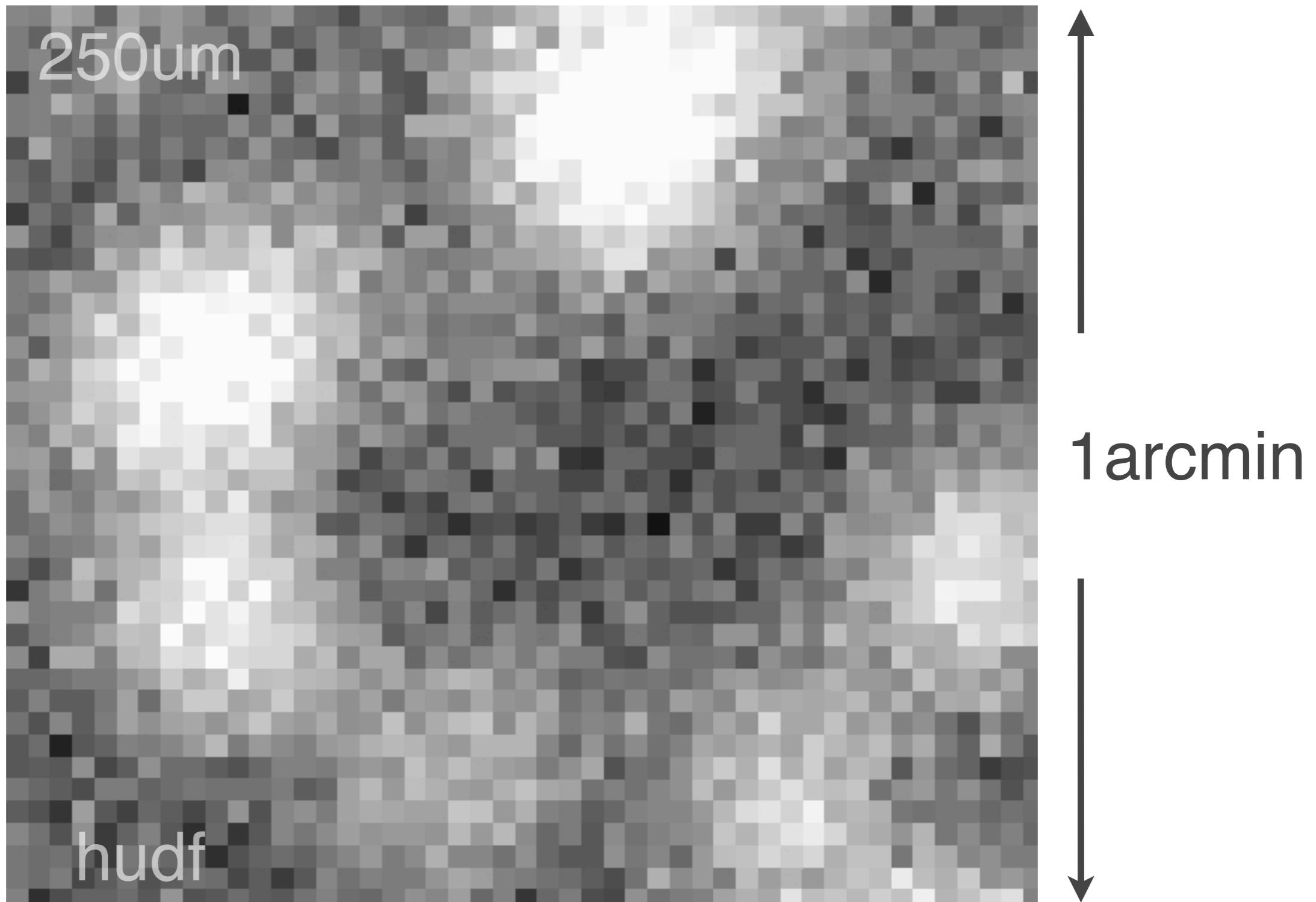




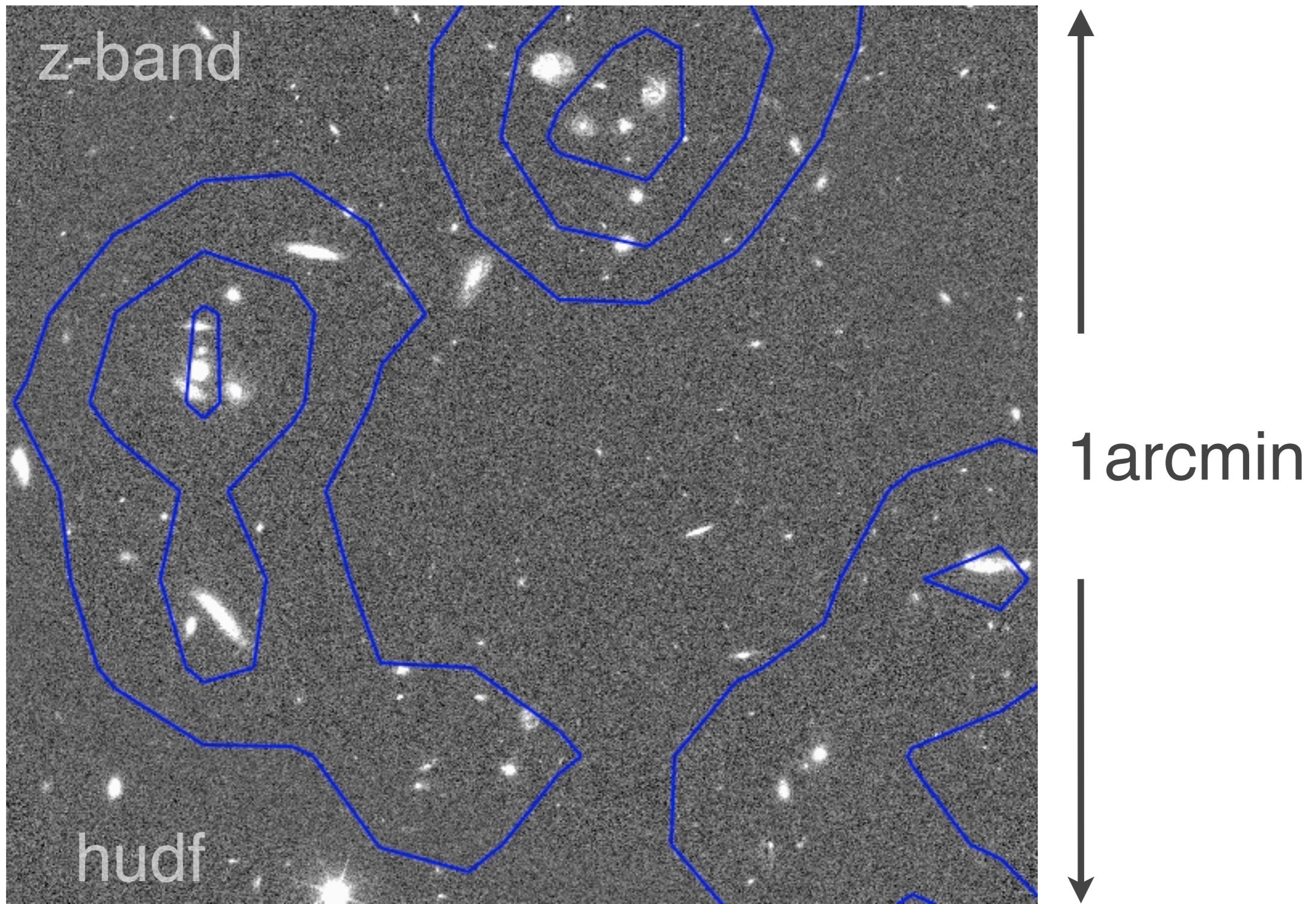




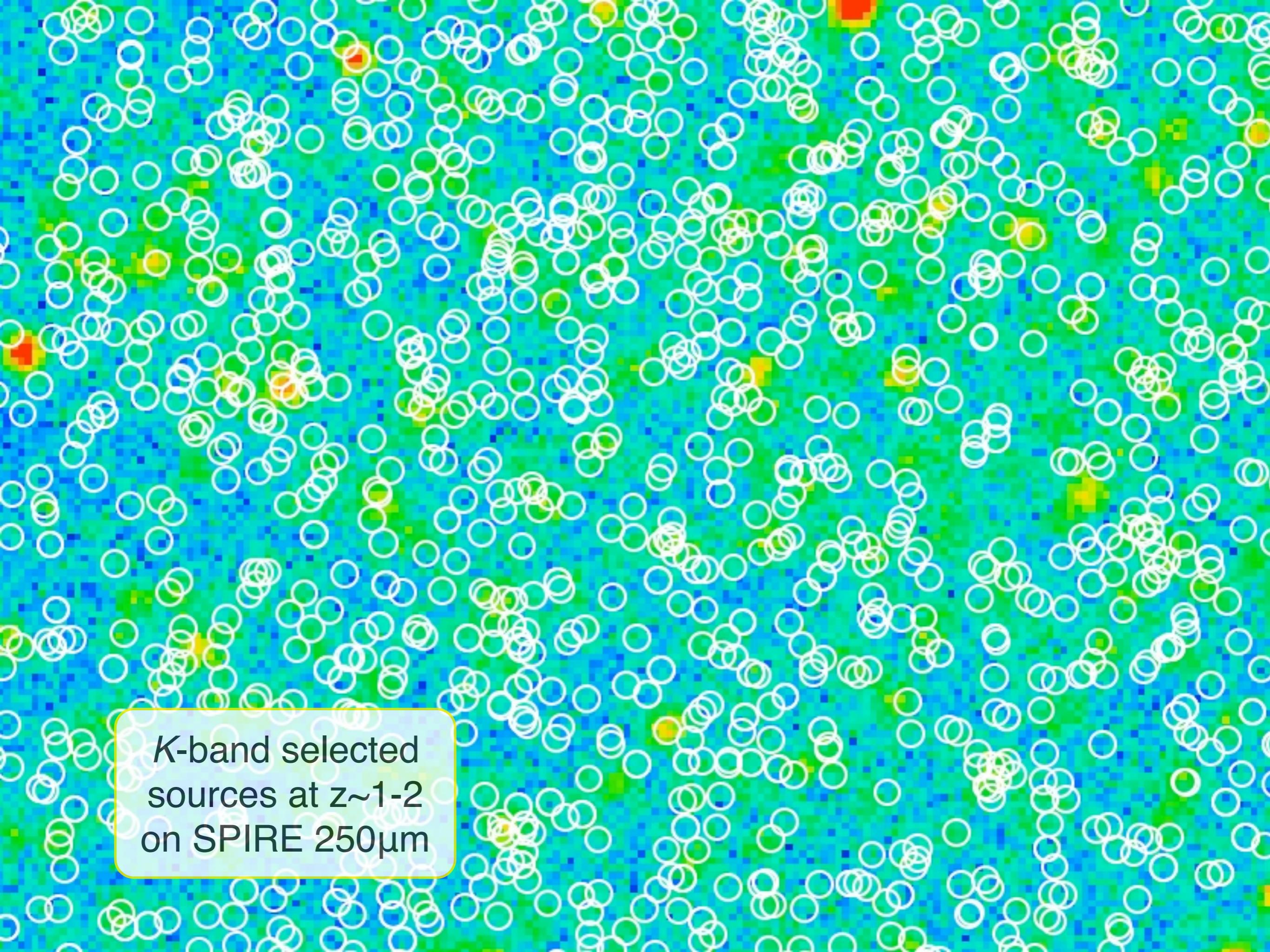
source confusion



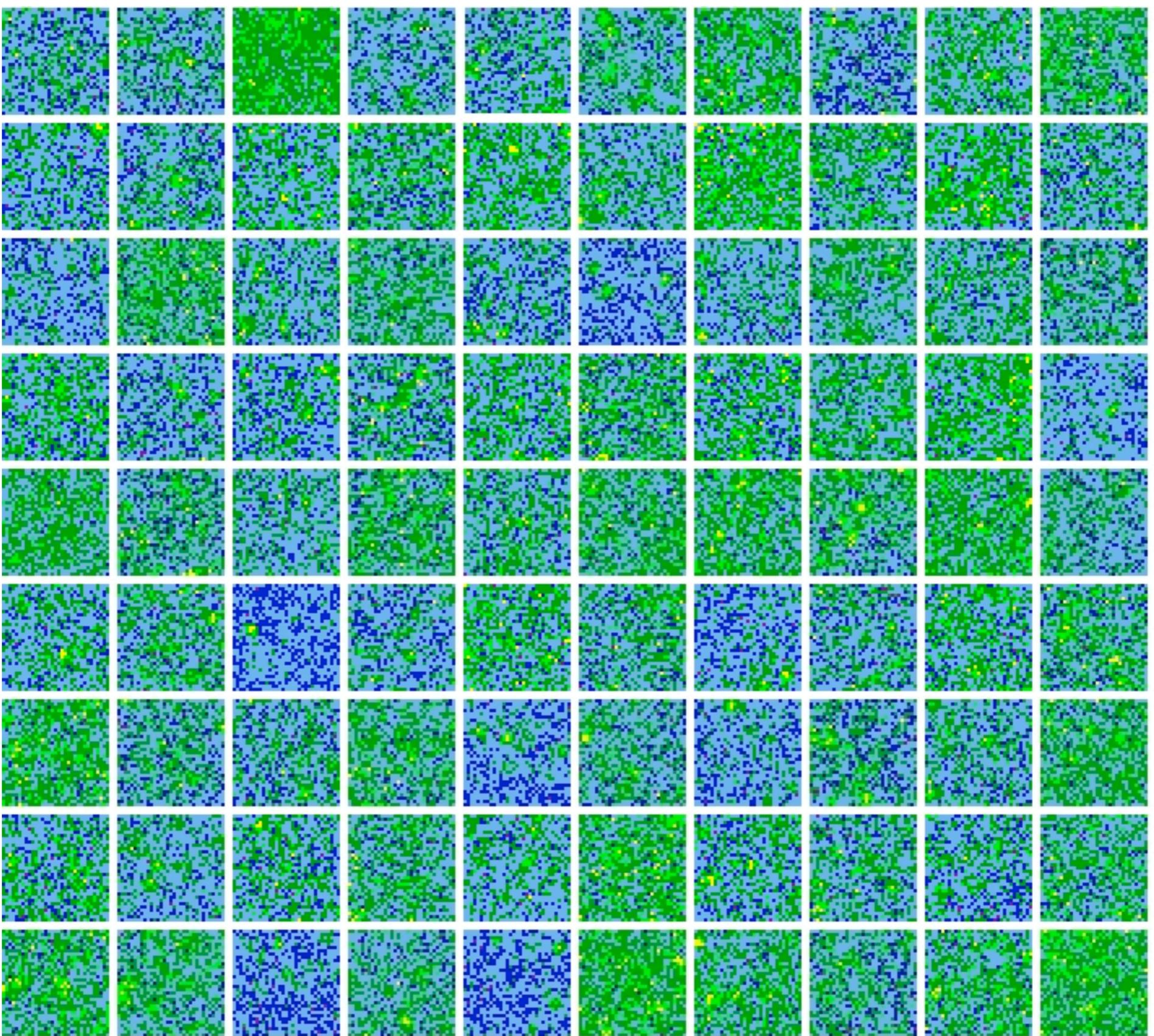
source confusion



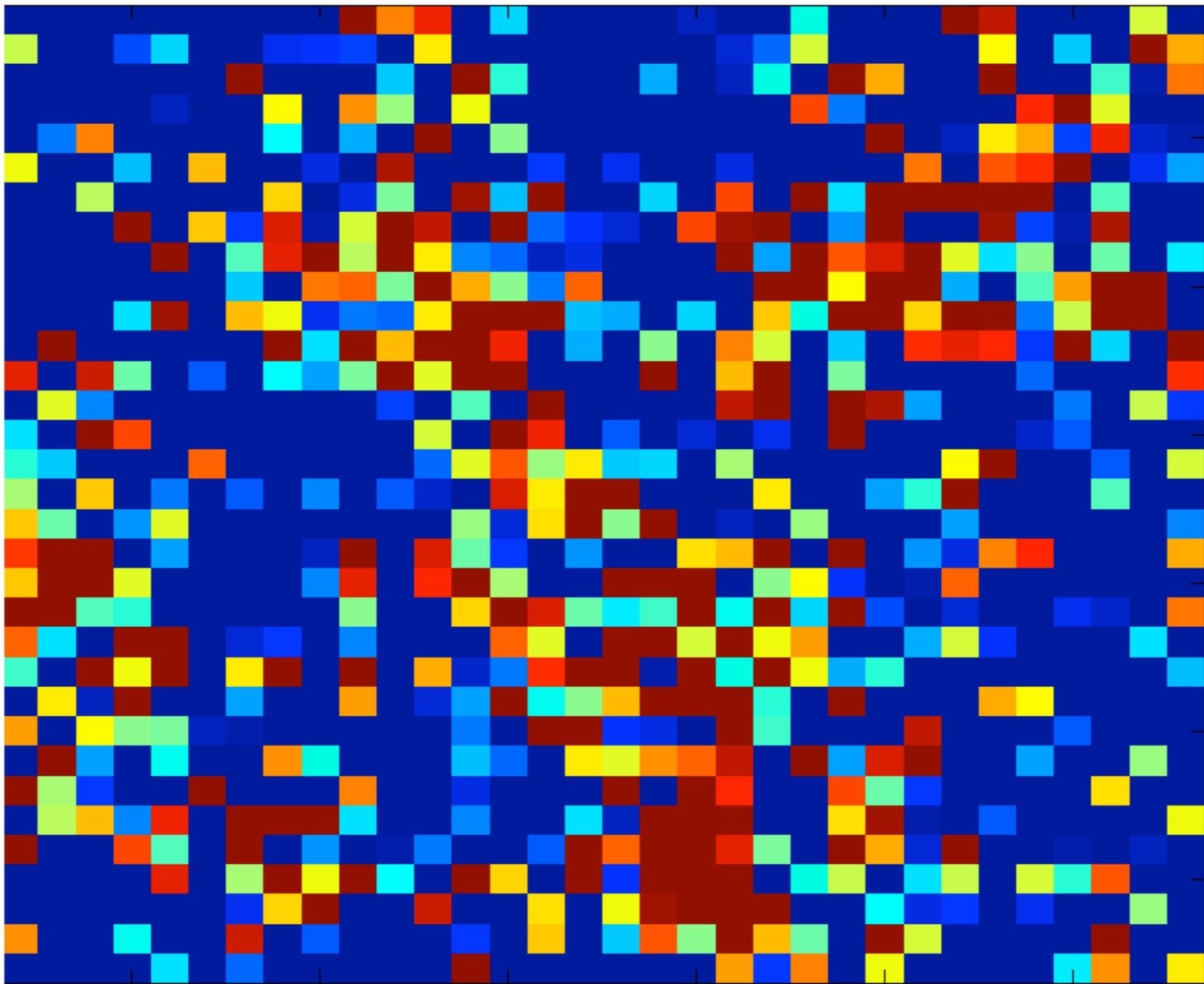
source confusion



K-band selected
sources at $z \sim 1-2$
on SPIRE 250 μ m

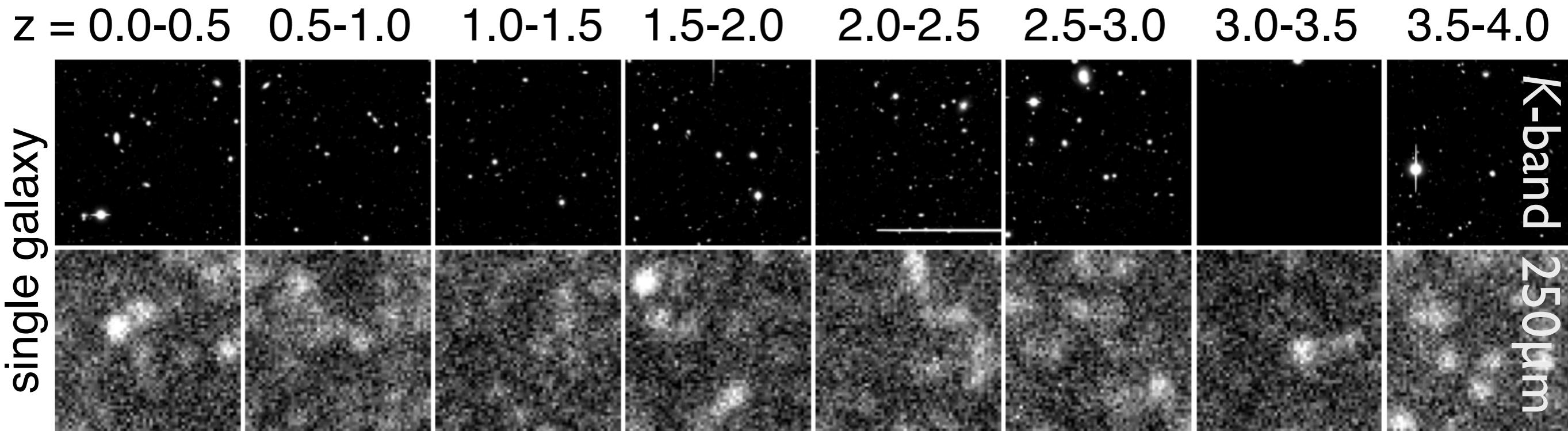


thumbnail stacking



Phil Korngut (Caltech)

thumbnail stacking

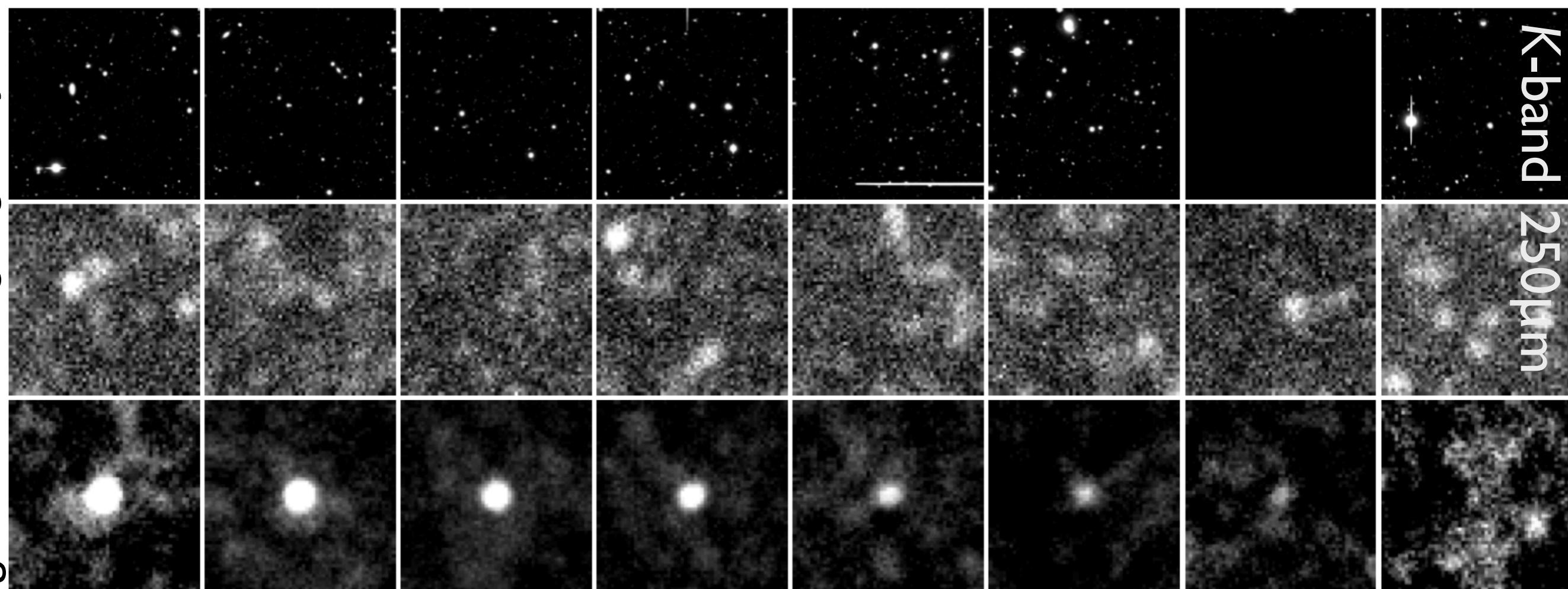


stacking is magic

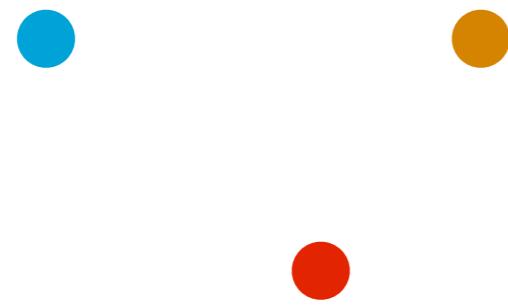
$z = 0.0\text{-}0.5 \quad 0.5\text{-}1.0 \quad 1.0\text{-}1.5 \quad 1.5\text{-}2.0 \quad 2.0\text{-}2.5 \quad 2.5\text{-}3.0 \quad 3.0\text{-}3.5 \quad 3.5\text{-}4.0$

$N_{\text{gal}} \geq 100$ single galaxy

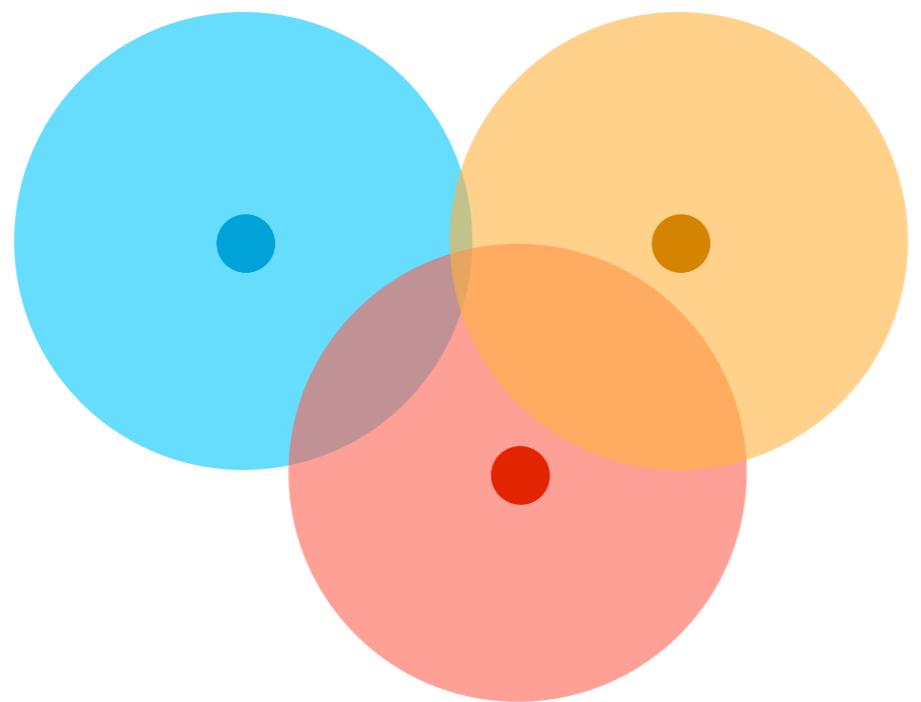
K-band
250 μ m



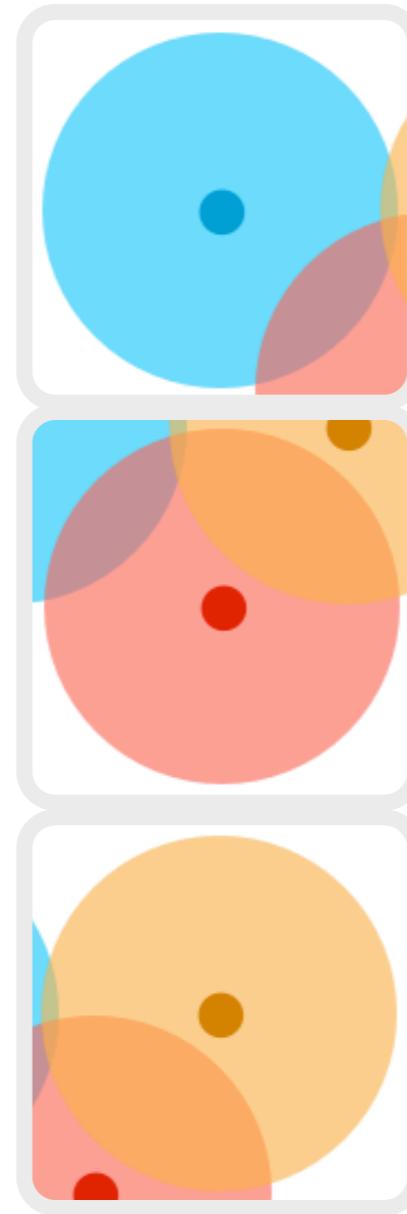
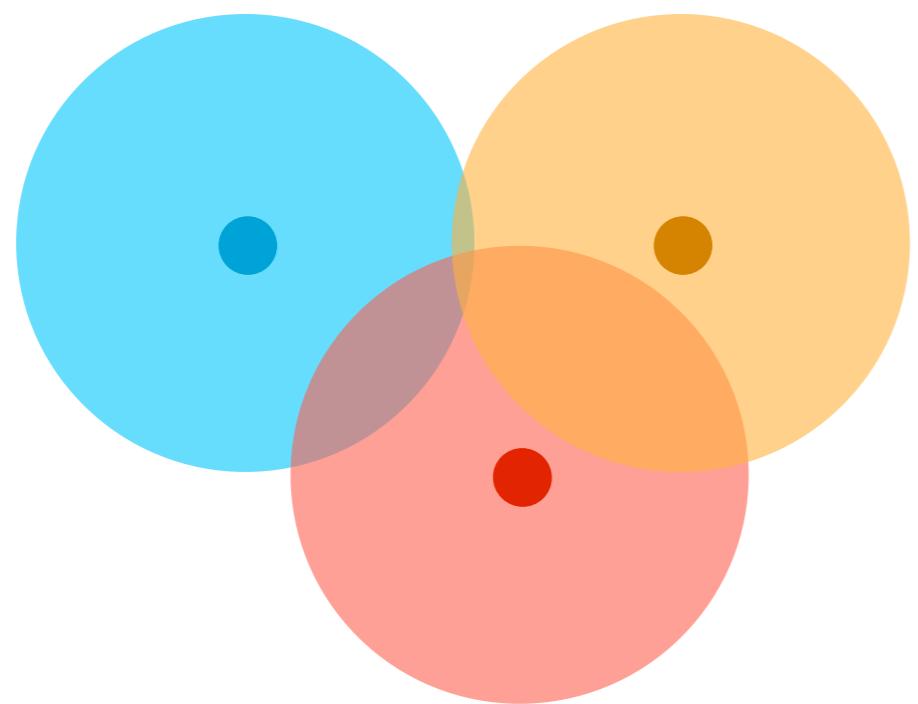
stacking is magic



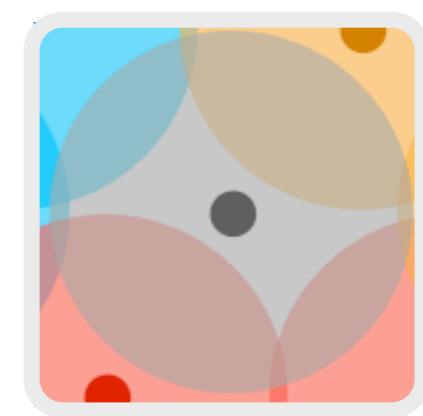
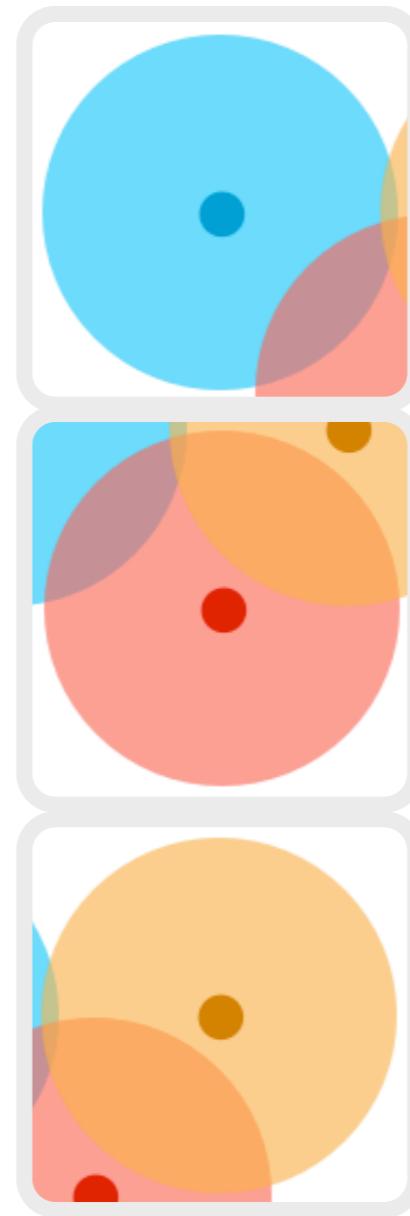
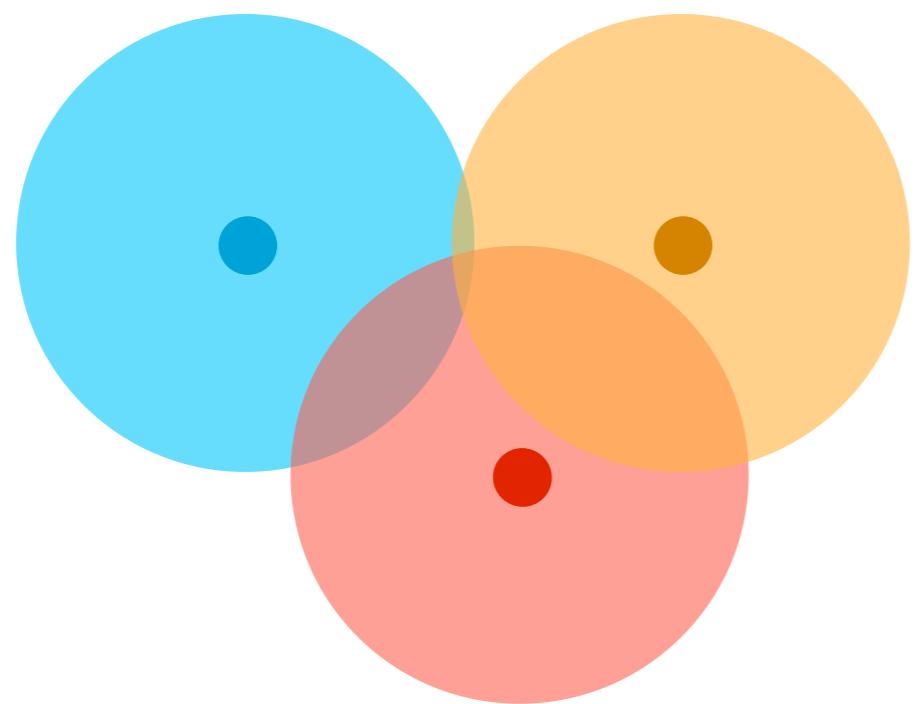
clustering induced bias



clustering induced bias

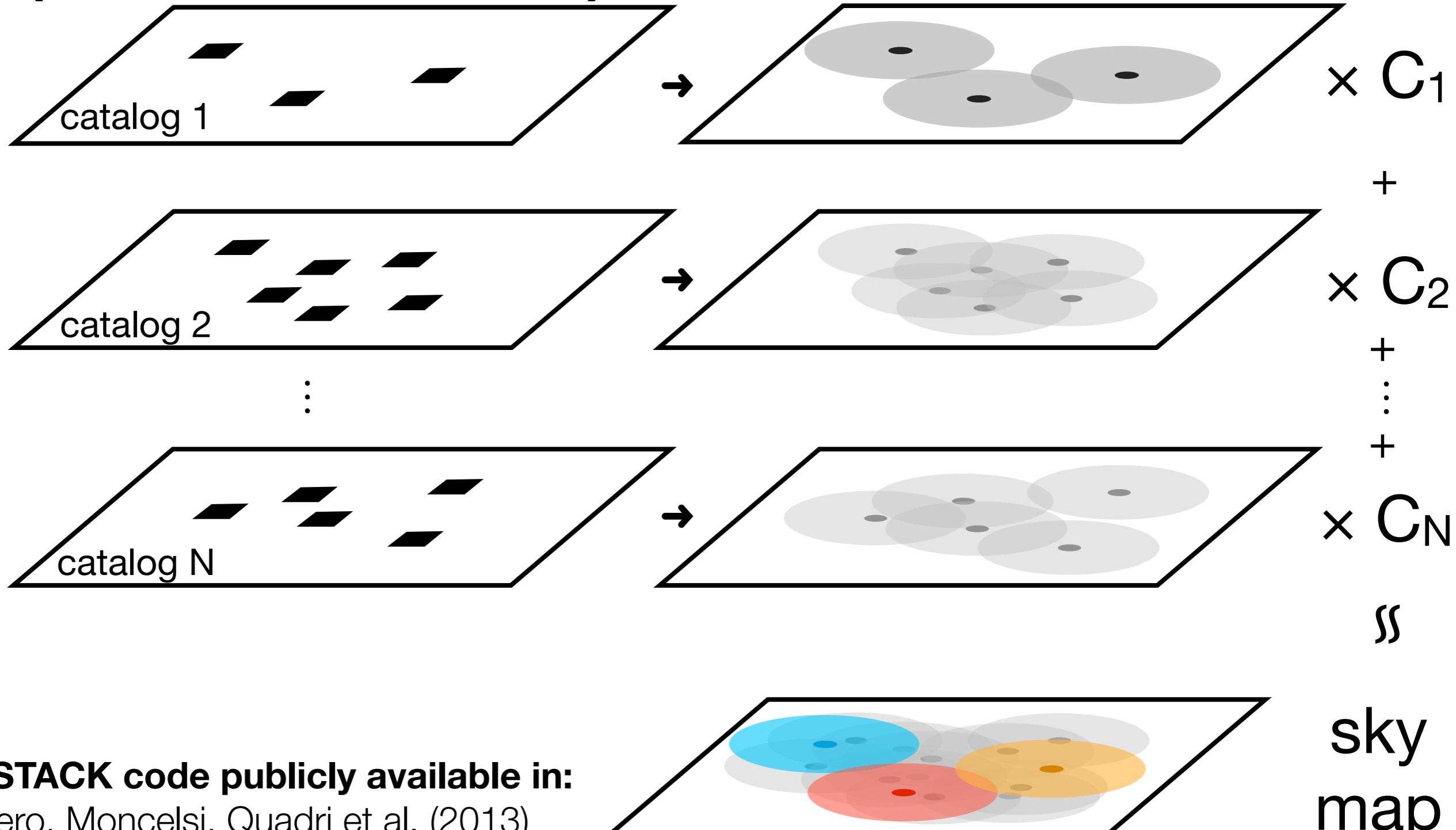


clustering induced bias



clustering induced bias

simultaneous stacking (SIMSTACK)

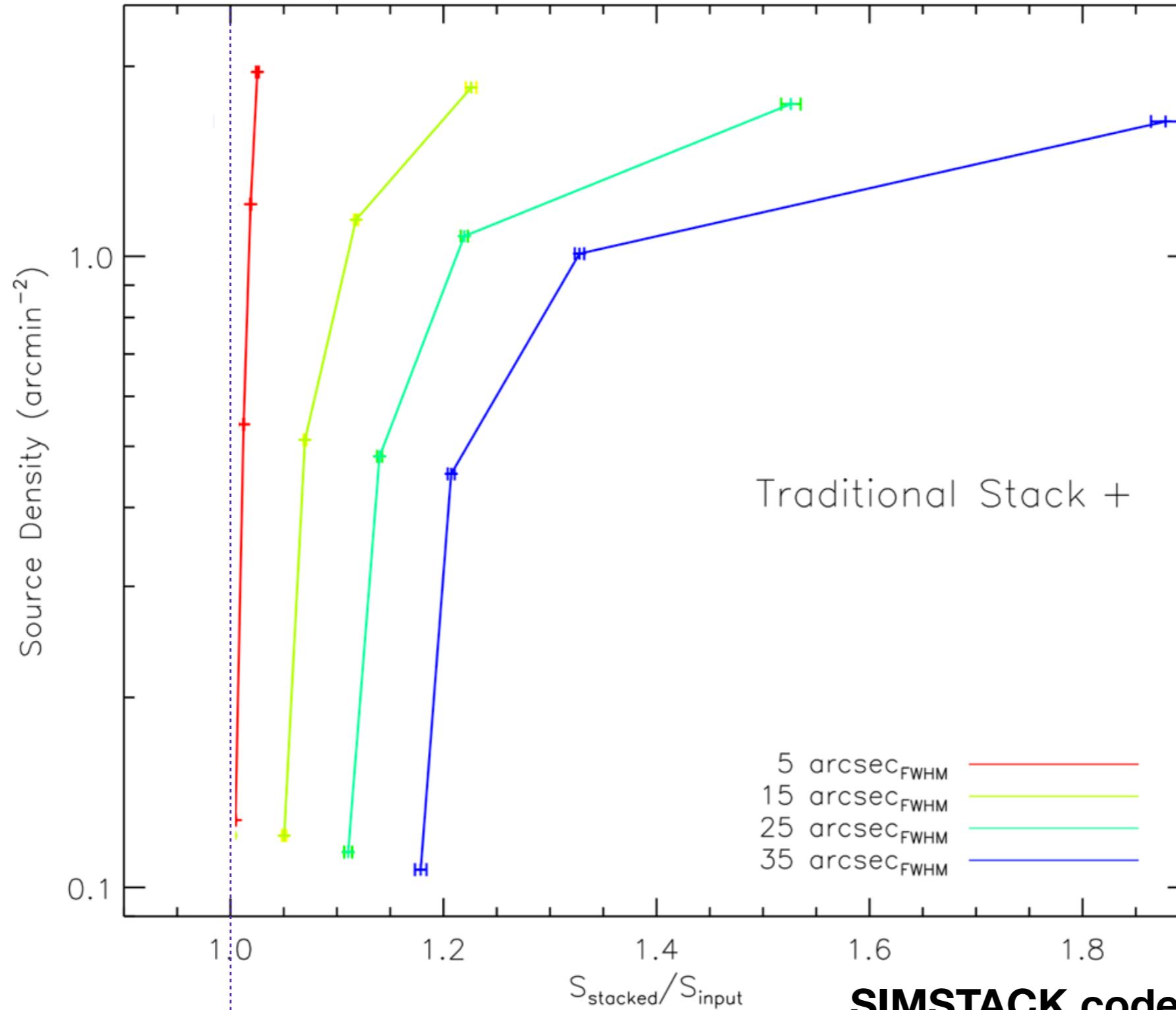


SIMSTACK code publicly available in:

Viero, Moncelsi, Quadri et al. (2013)

arXiv:1304.0446

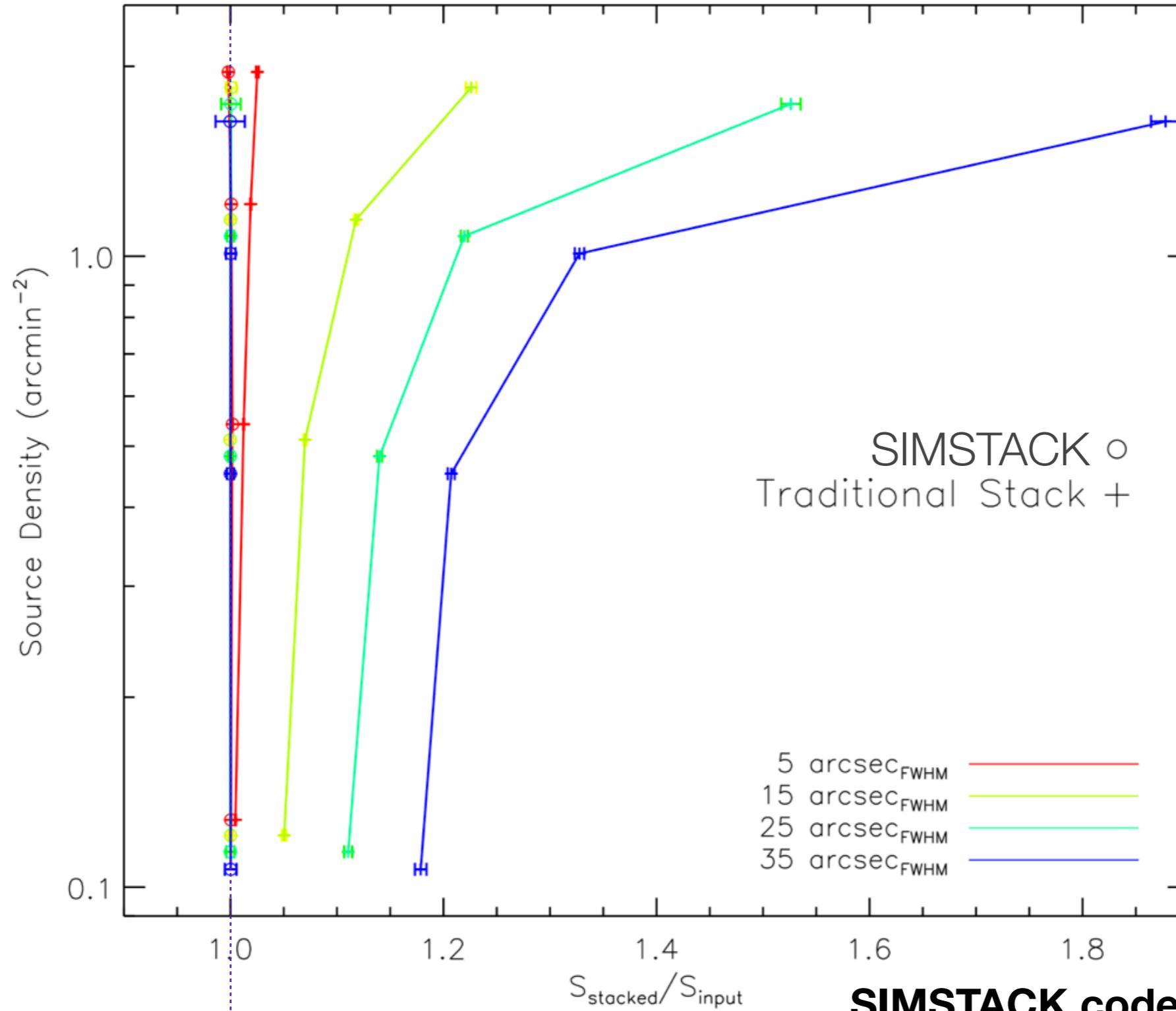
SIMSTACK simulation



unbiased

SIMSTACK code publicly available in:
Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446

SIMSTACK simulation



unbiased

SIMSTACK code publicly available in:
Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446

UDS data

catalogs (Williams & Quadri, in prep.)

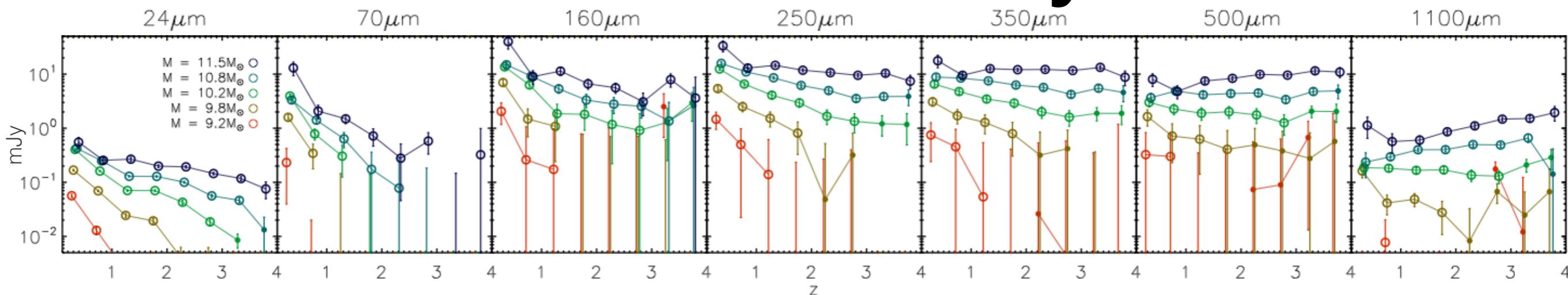
- UKIDSS/UDS [2/3 deg²]
 - uBVRizJHK + IRAC ch1234
 - K-band magnitude cut 24 AB
 - 54,000 sources in ~0.63 deg²
- redshifts - EAZY (Brammer 2008)
- masses - FAST (Kriek 2009)

maps (HerMES; Oliver et al. 2012)

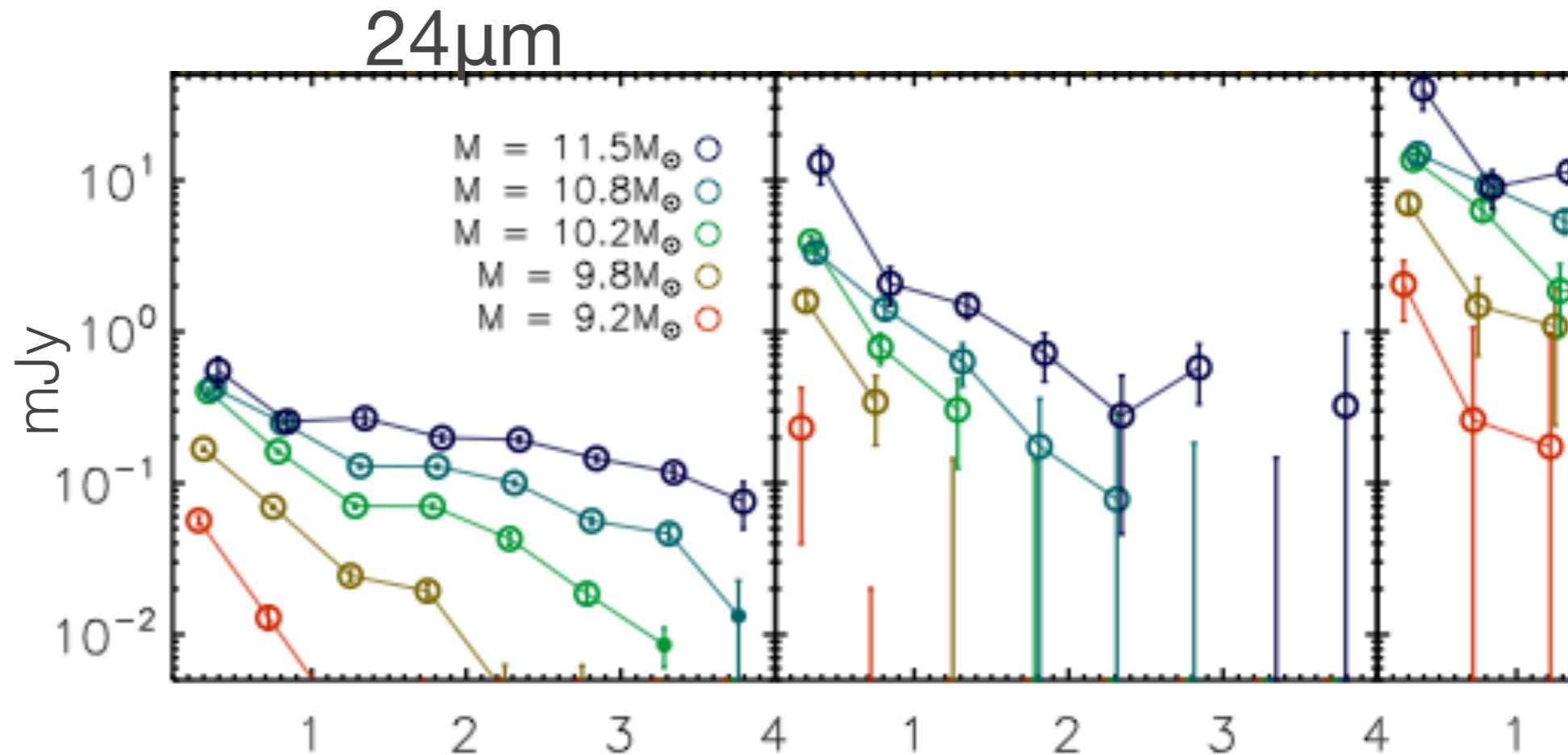
- *Spitzer*/MIPS
 - 24, 70, 160um
- *Herschel*/SPIRE
 - 250, 350, 500um
- ASTE/AzTEC
 - 1100um

Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446

stacked flux density

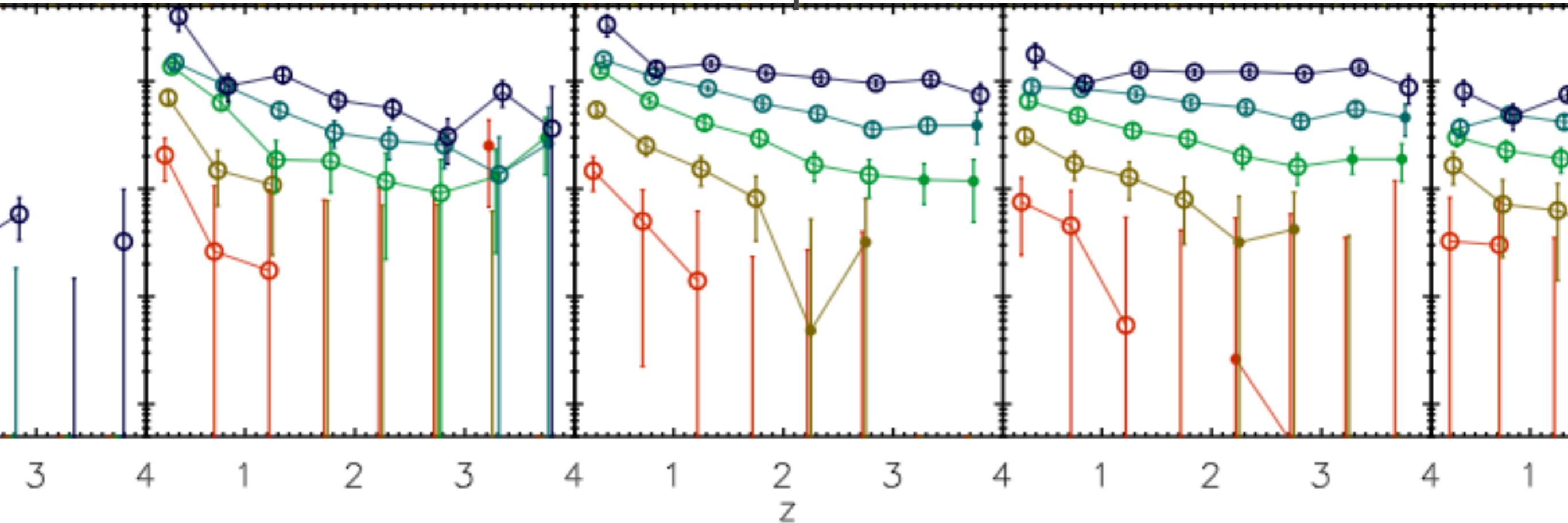


stacked flux density



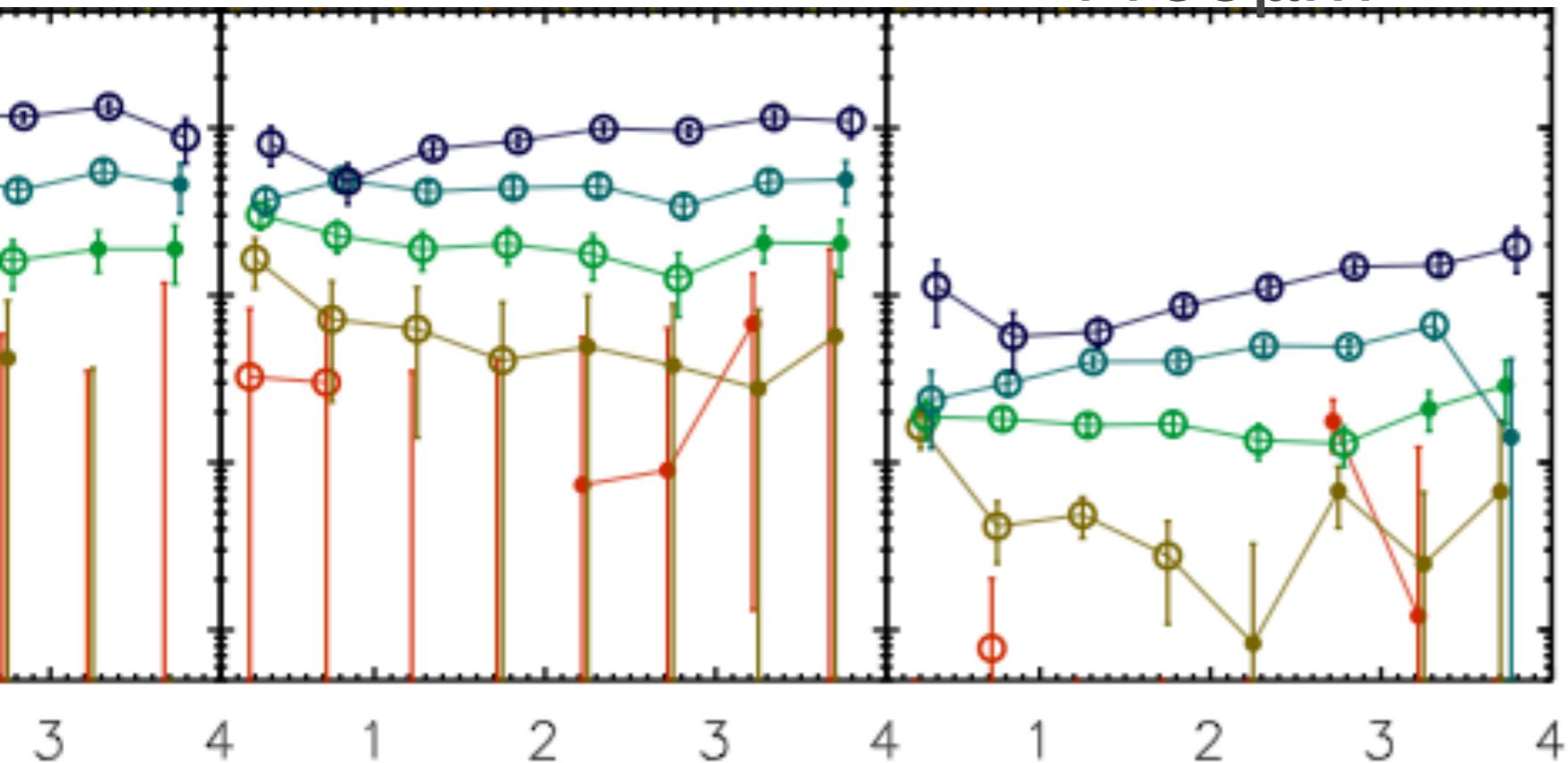
stacked flux density

250 μ m

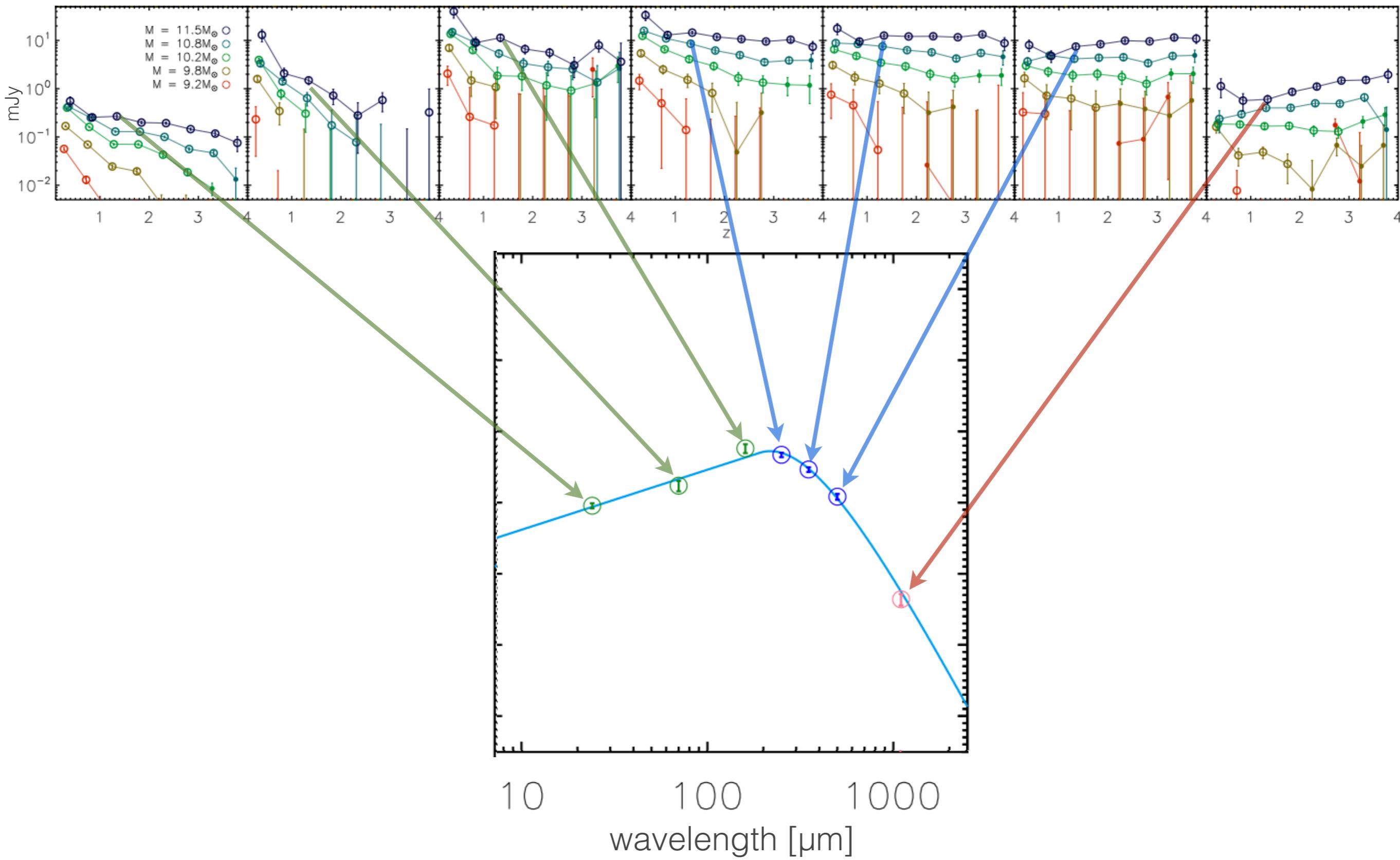


stacked flux density

1100μm



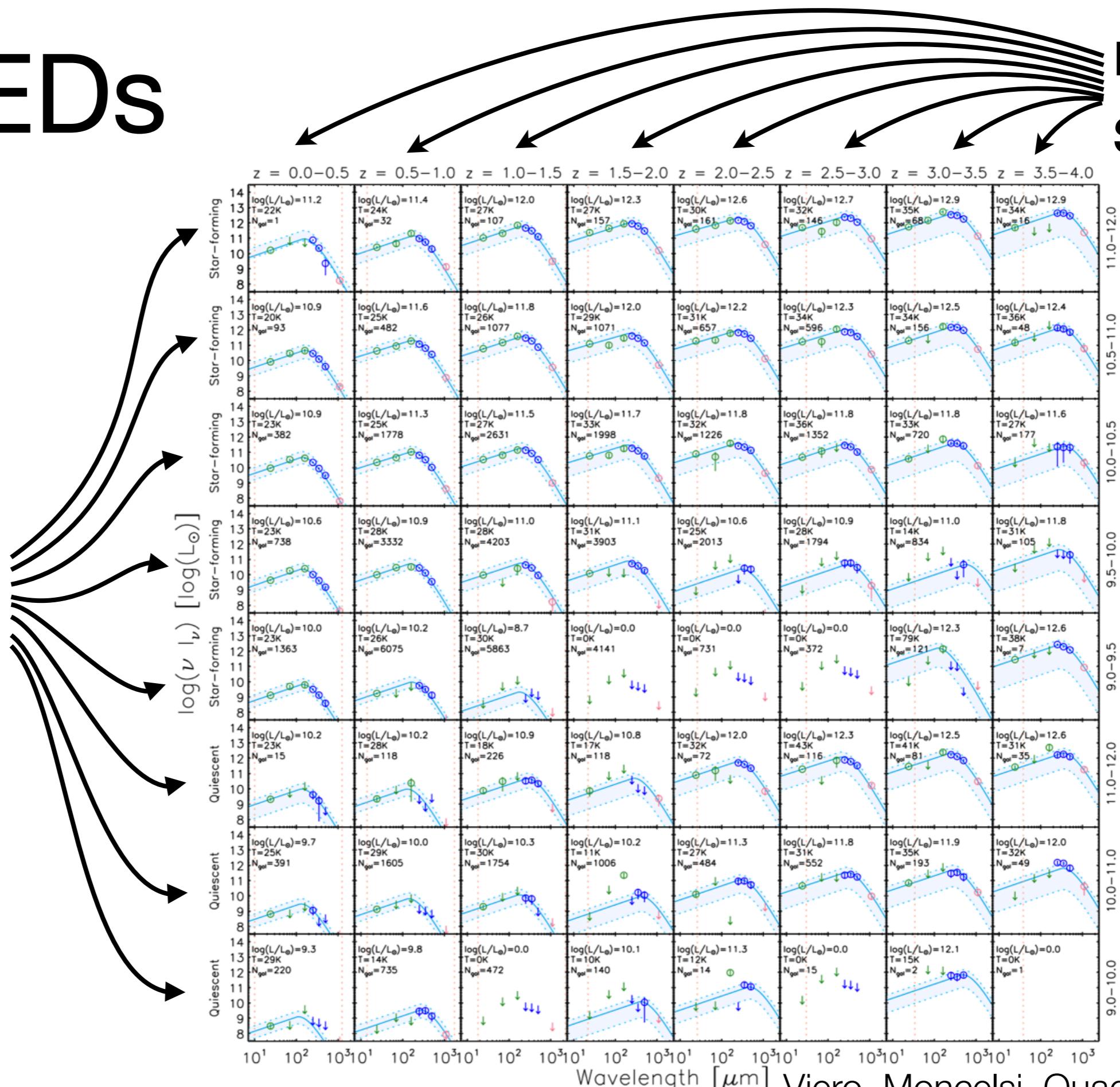
stacked flux density



SEDS

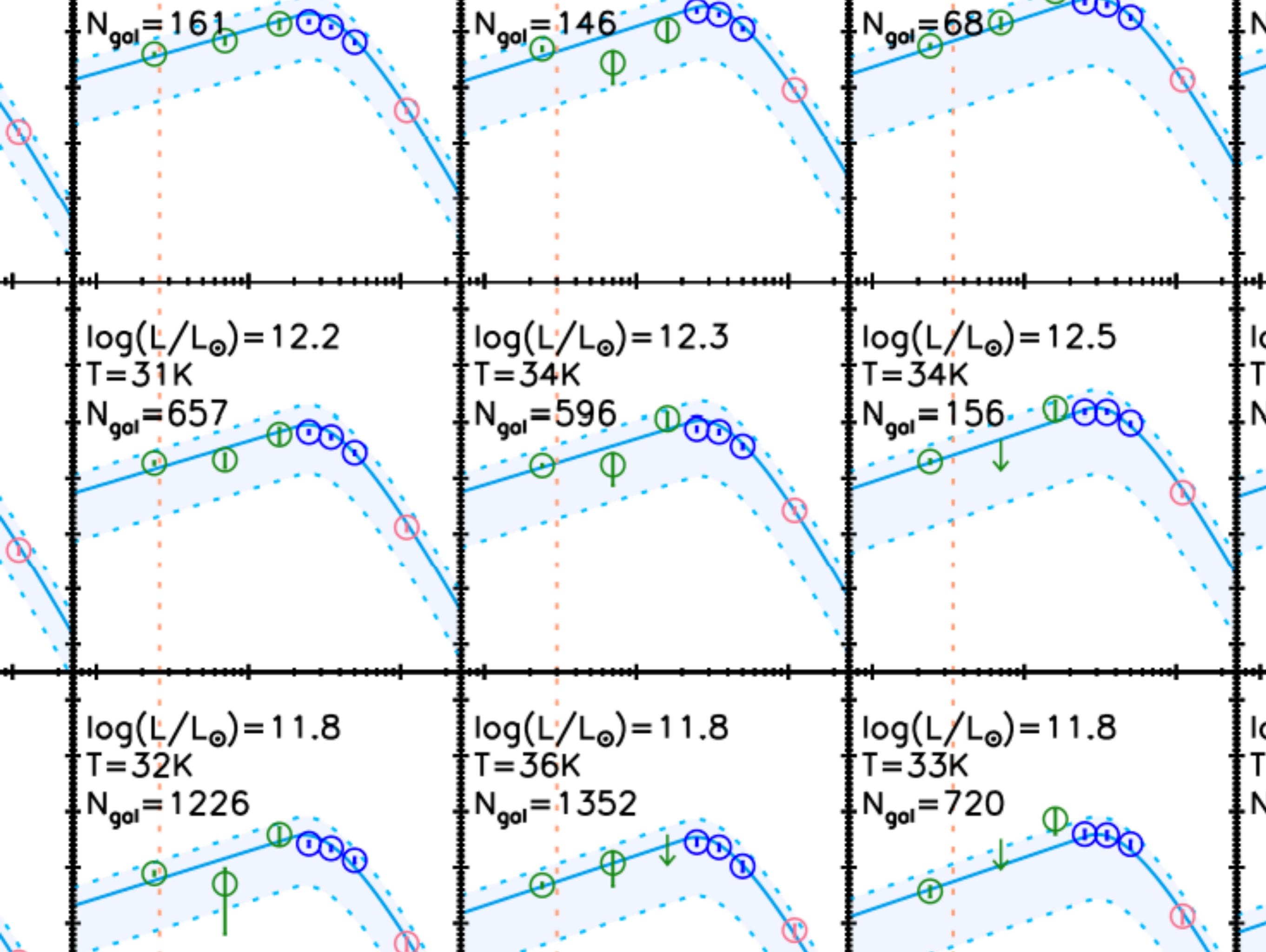
redshift
slices

mass
slices

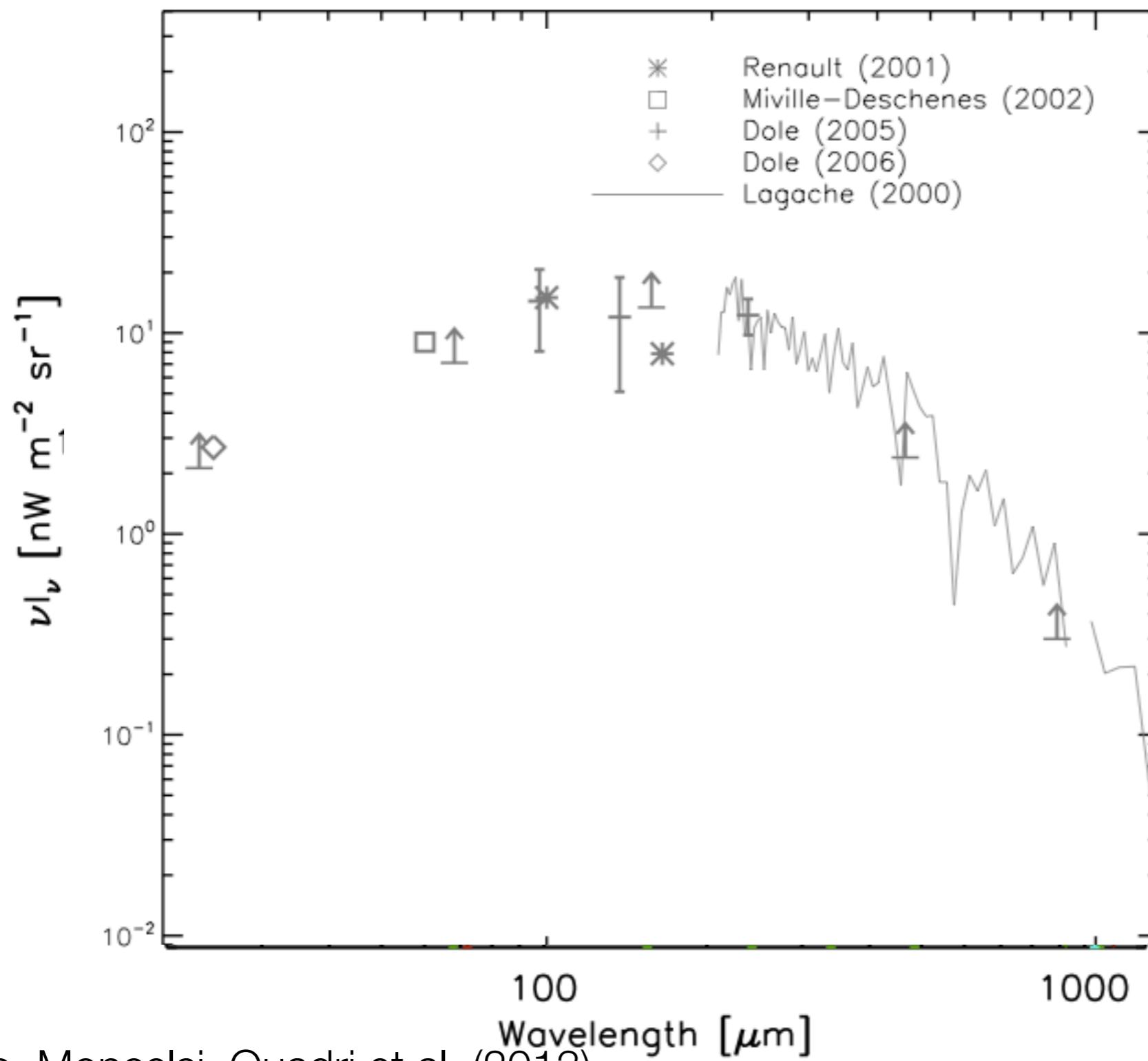


Viero, Moncelsi, Quadri et al. (2013)

arXiv:1304.0446



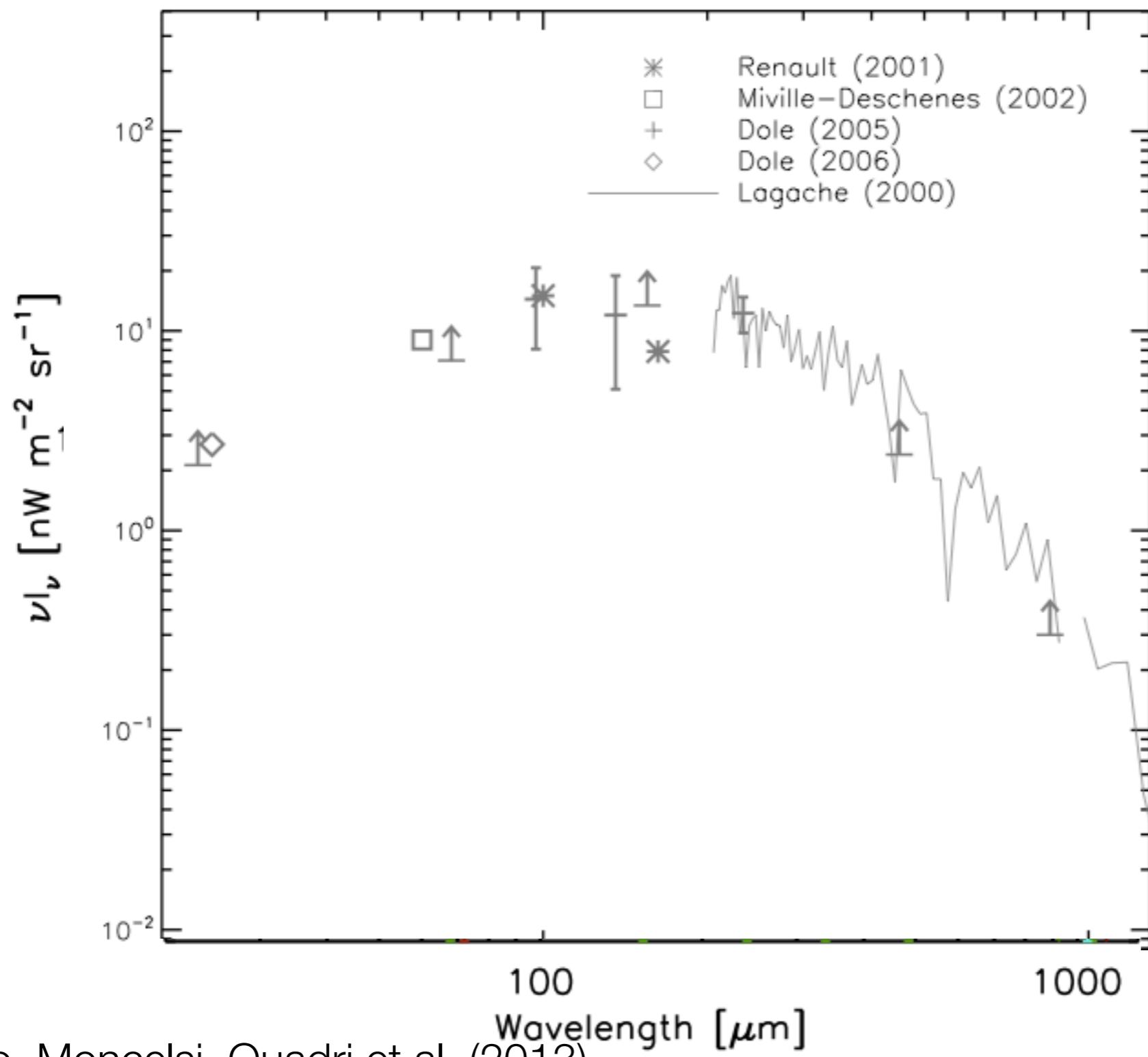
stacked CIB



Viero, Moncelsi, Quadri et al. (2013)

arXiv:1304.0446

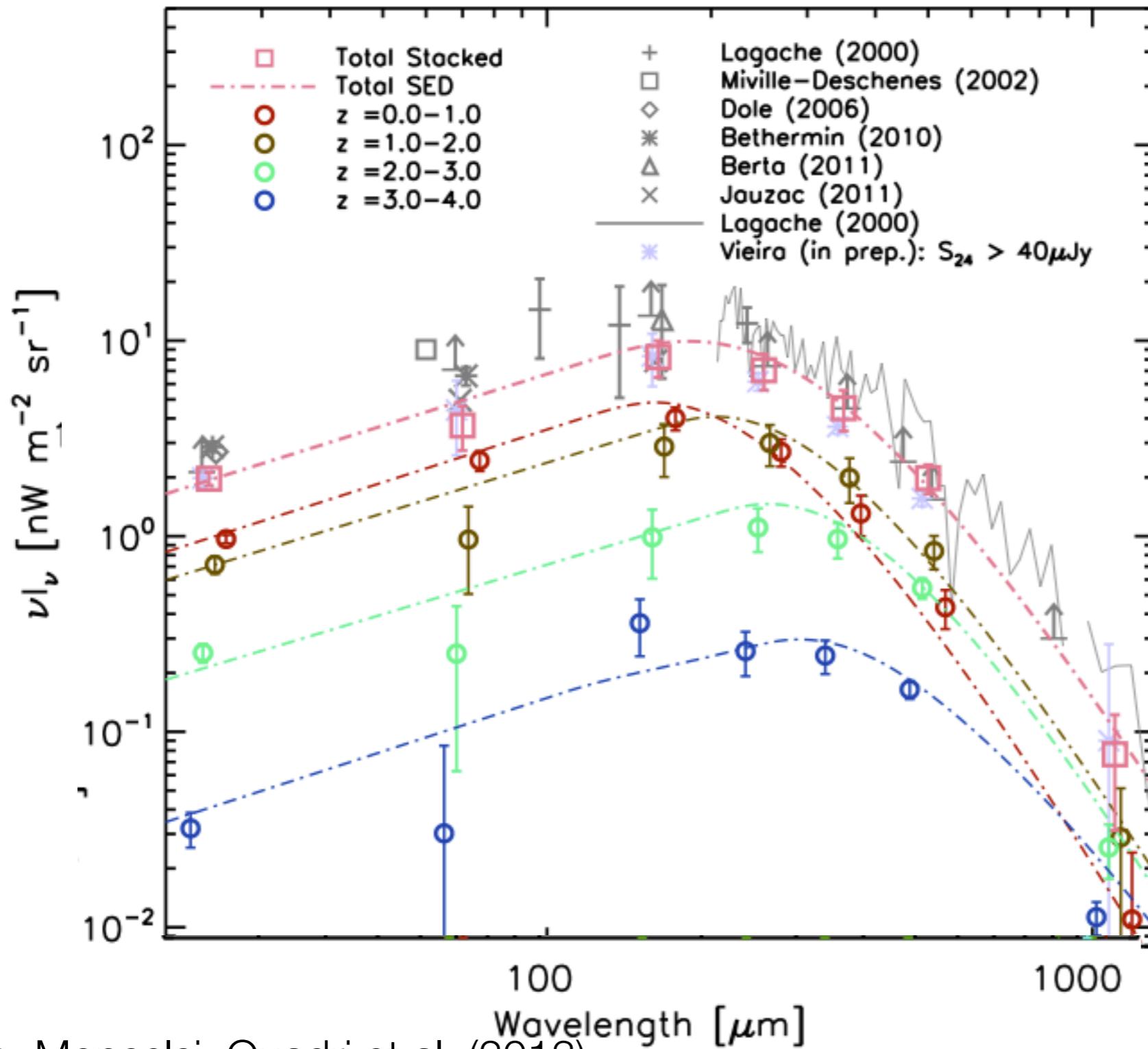
stacked CIB



Viero, Moncelsi, Quadri et al. (2013)

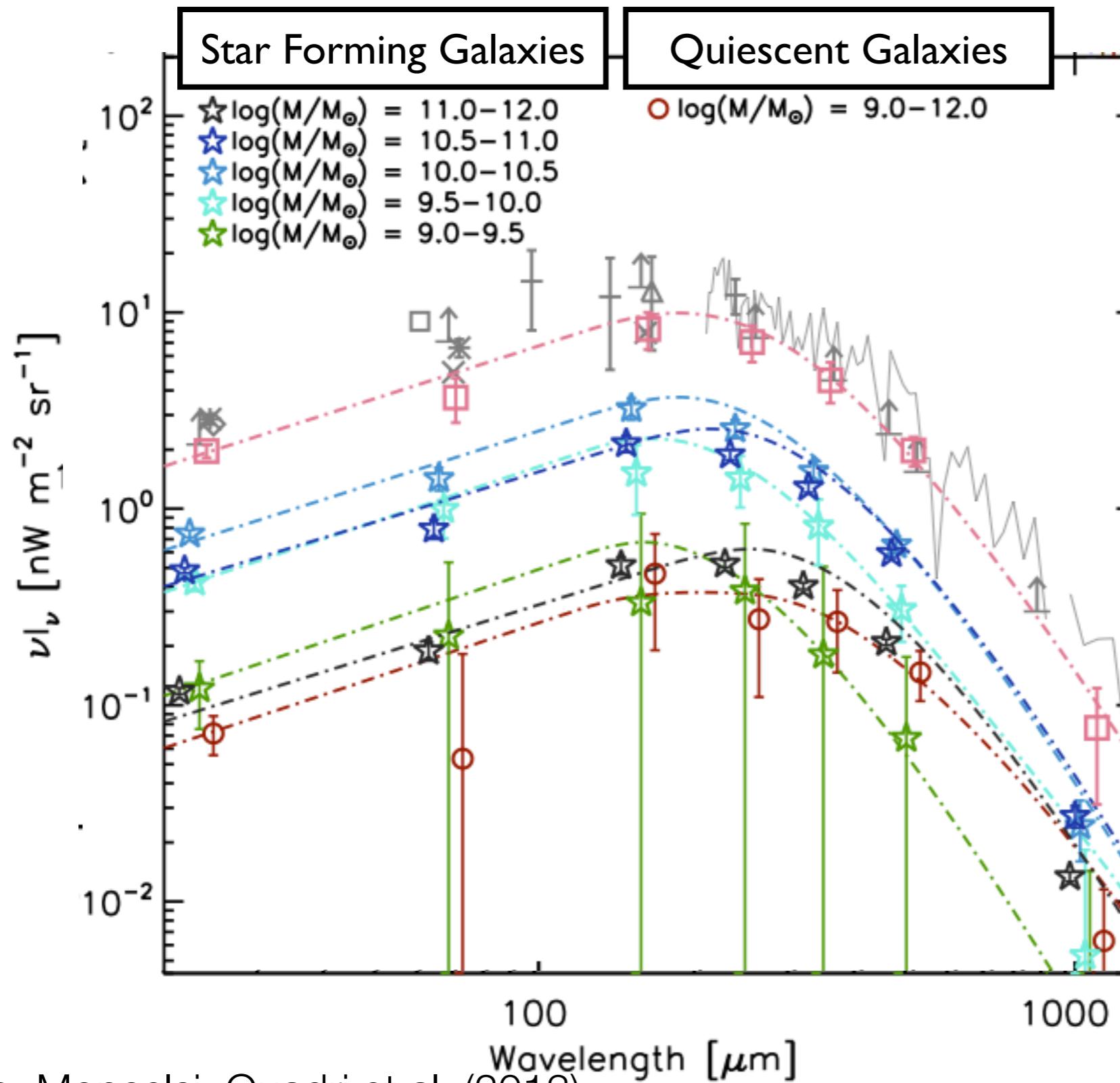
arXiv:1304.0446

stacked CIB



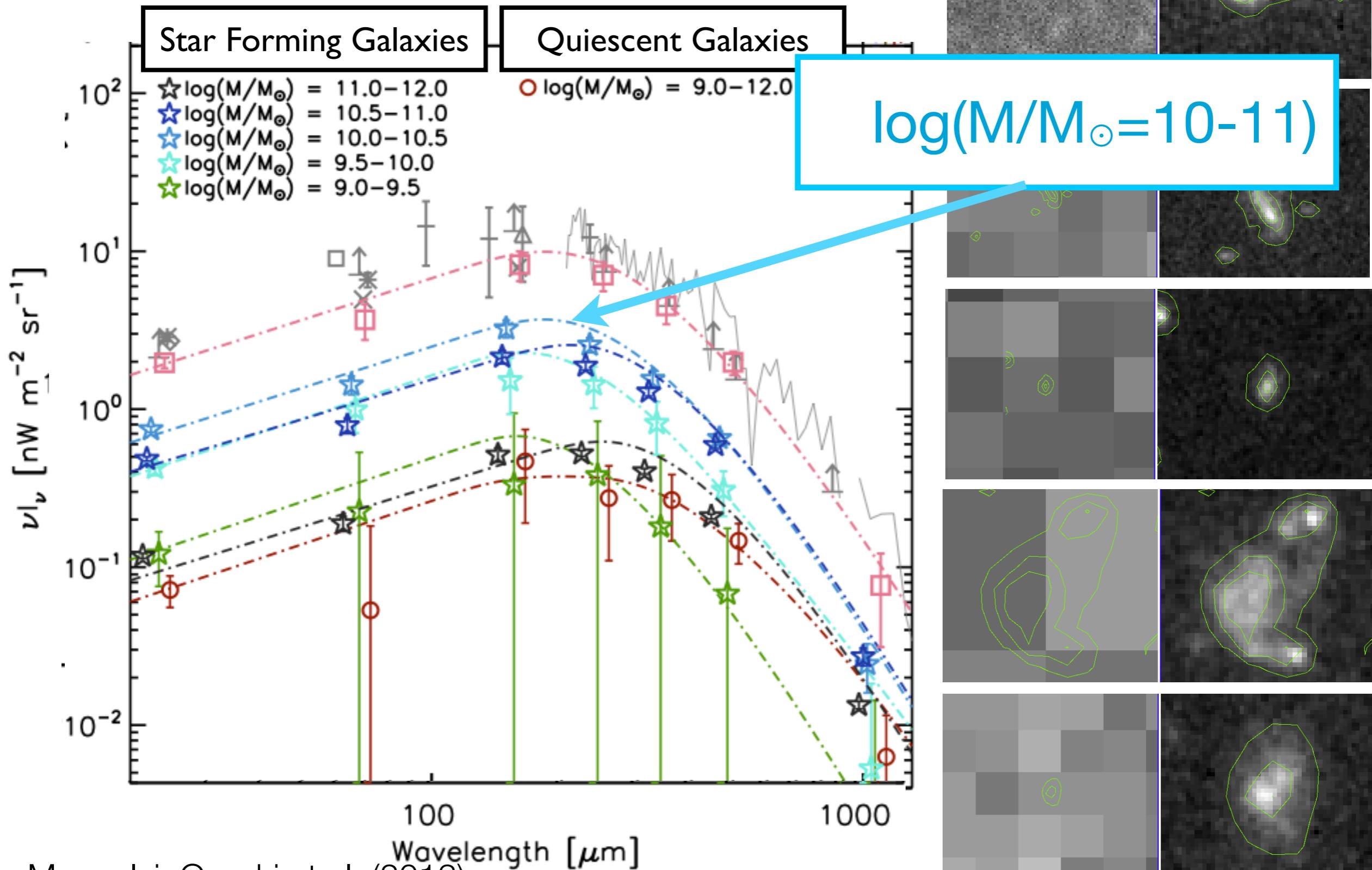
~80% at SPIRE
wavelengths

stacked CIB



~80% at SPIRE
wavelengths

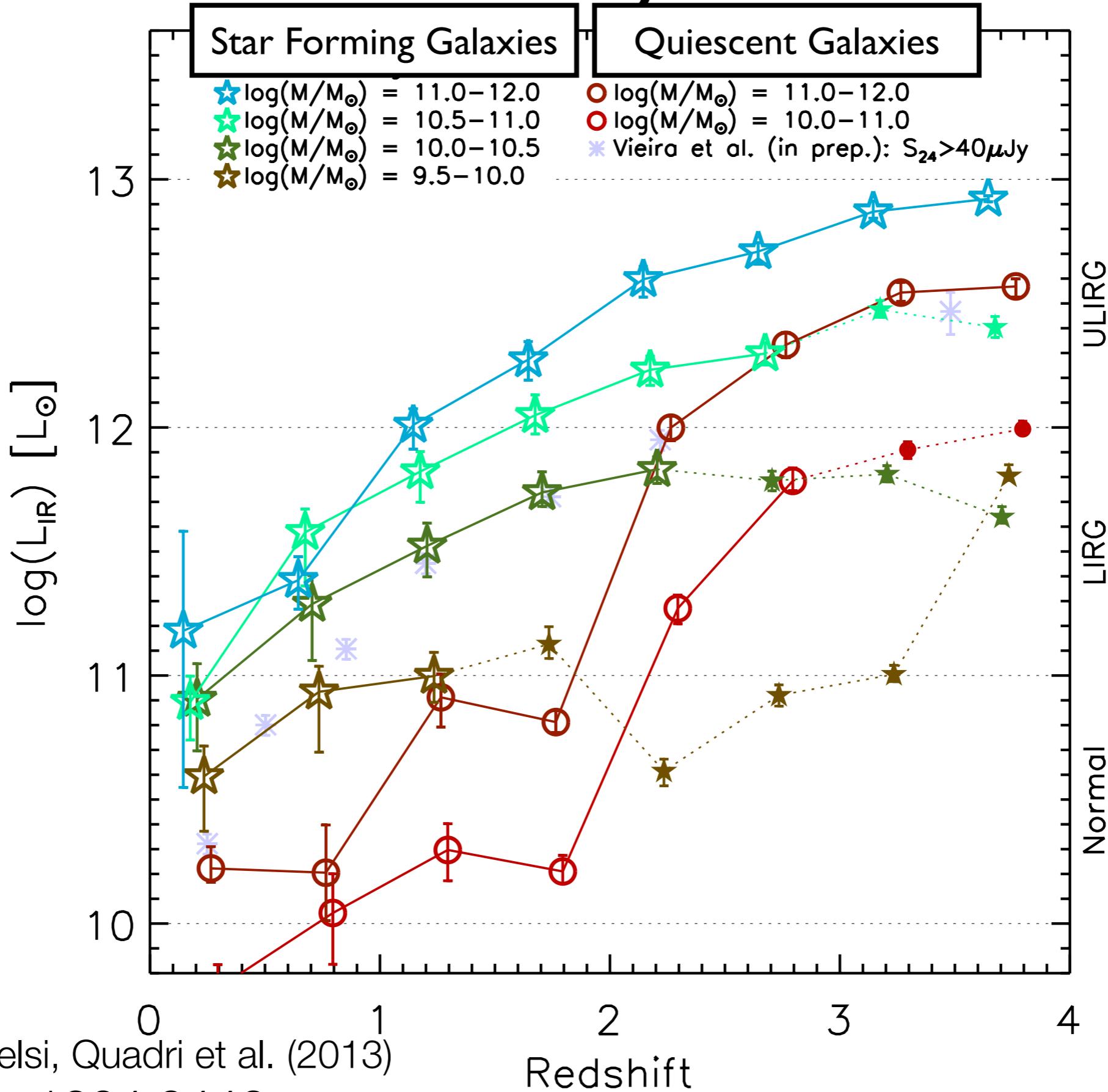
stacked CIB



Viero, Moncelsi, Quadri et al. (2013)

arXiv:1304.0446

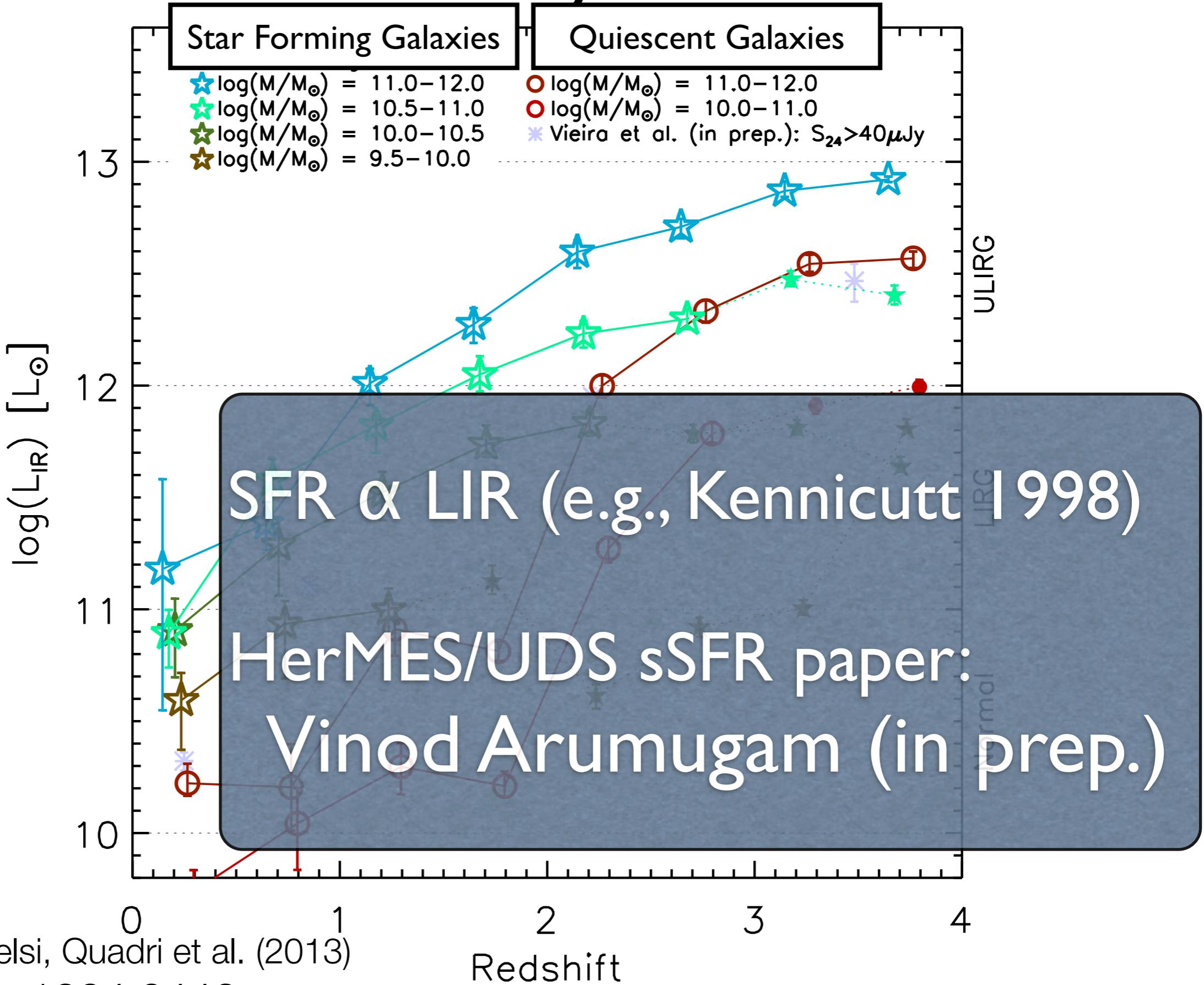
Infrared Luminosity



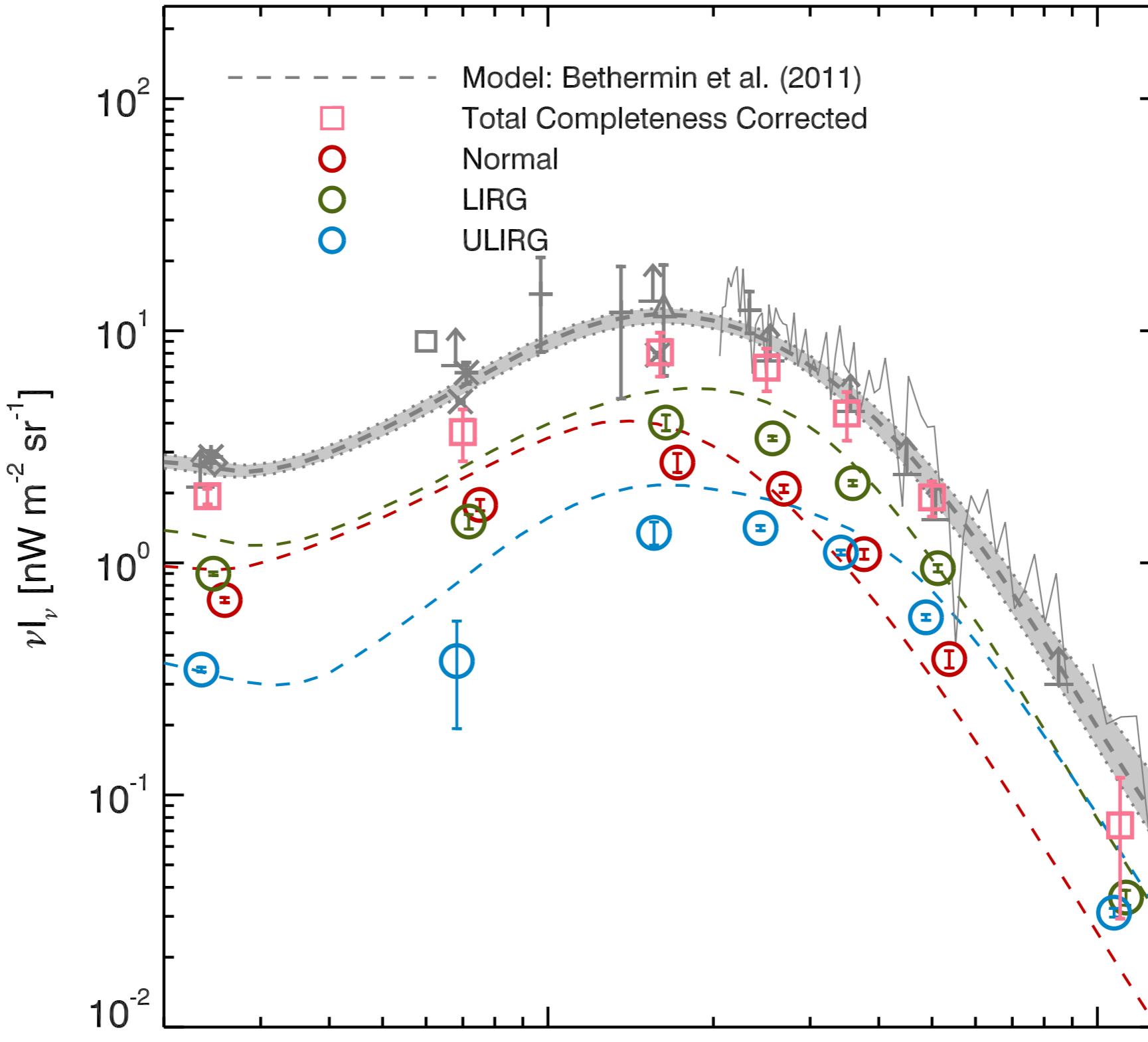
Viero, Moncelsi, Quadri et al. (2013)

arXiv:1304.0446

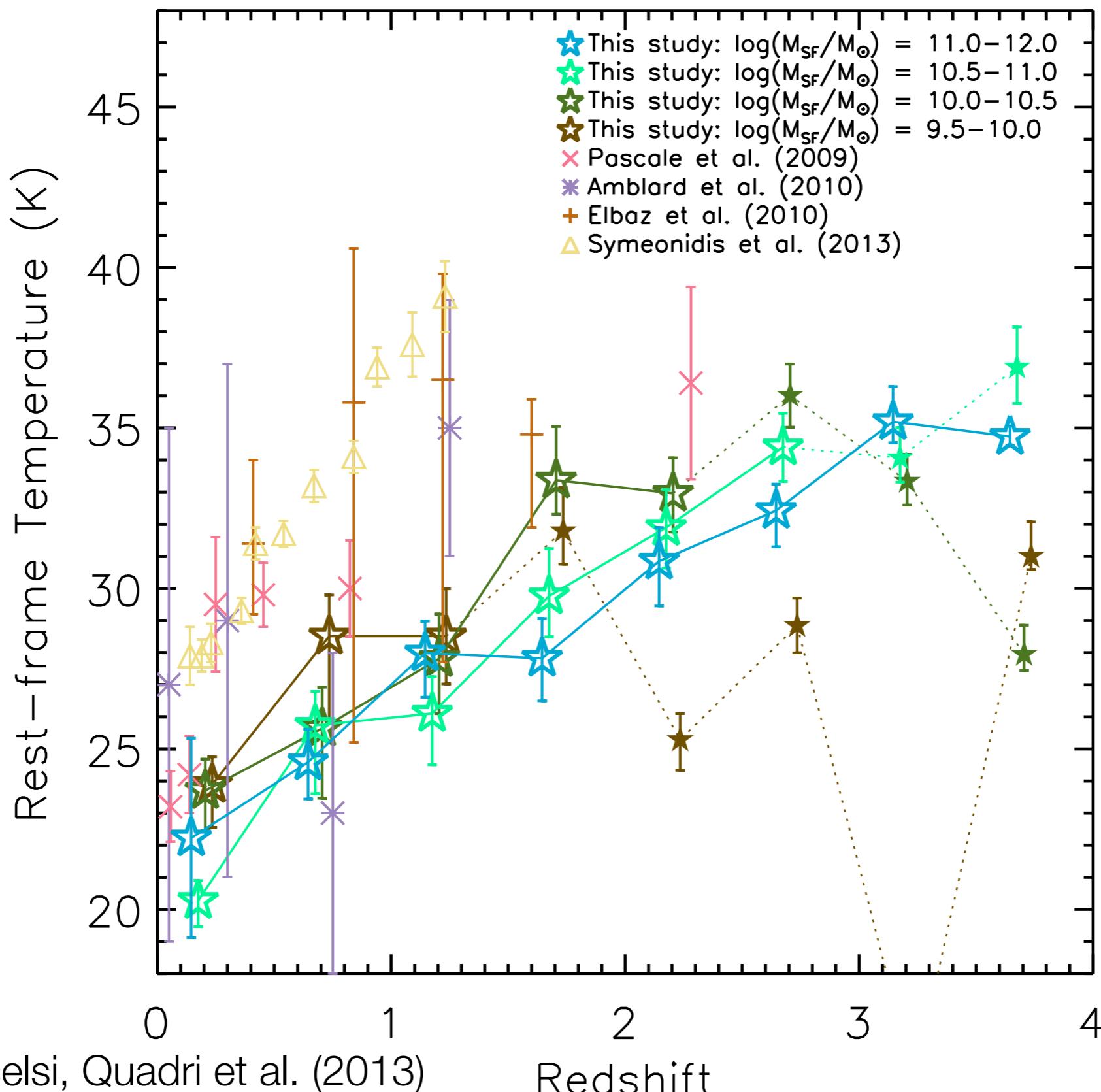
Infrared Luminosity



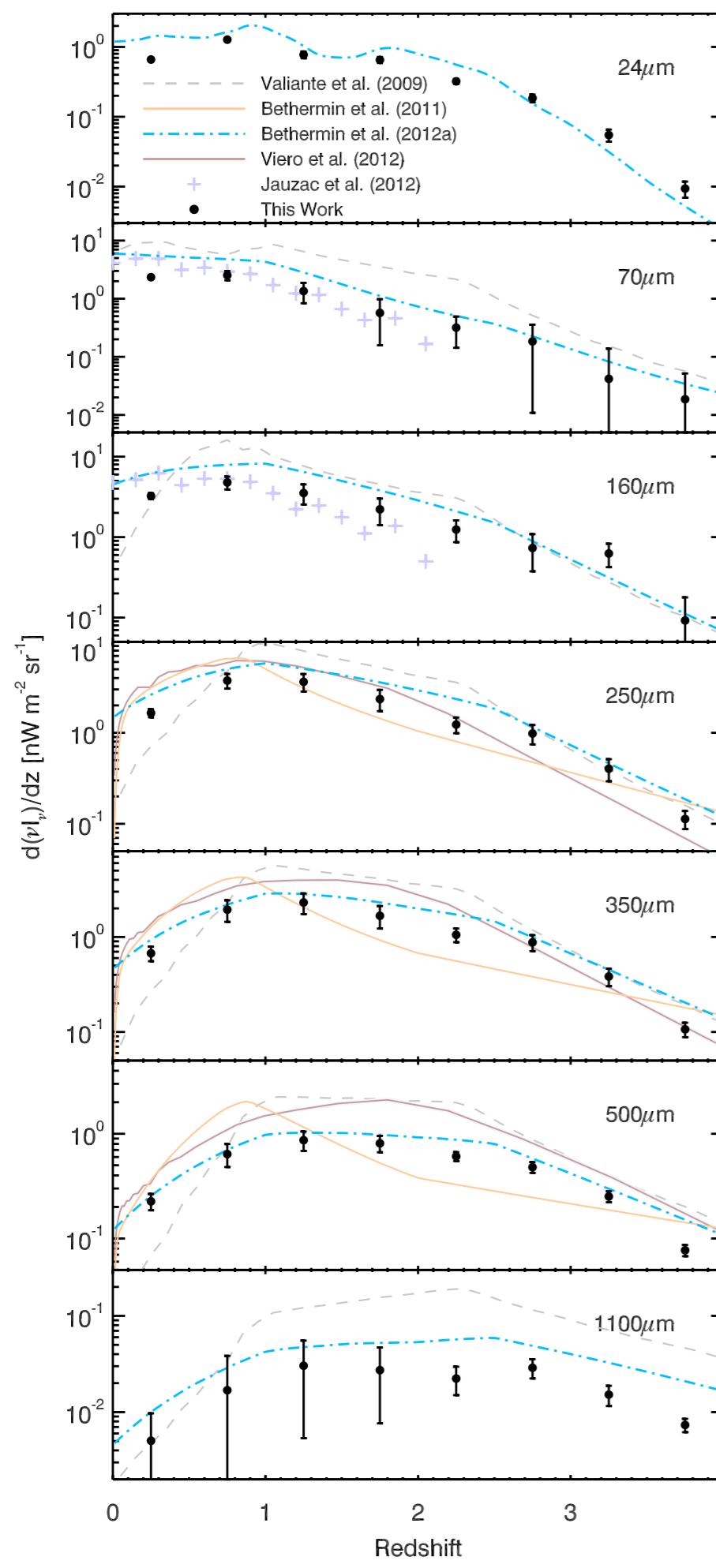
CIB by Luminosity Class



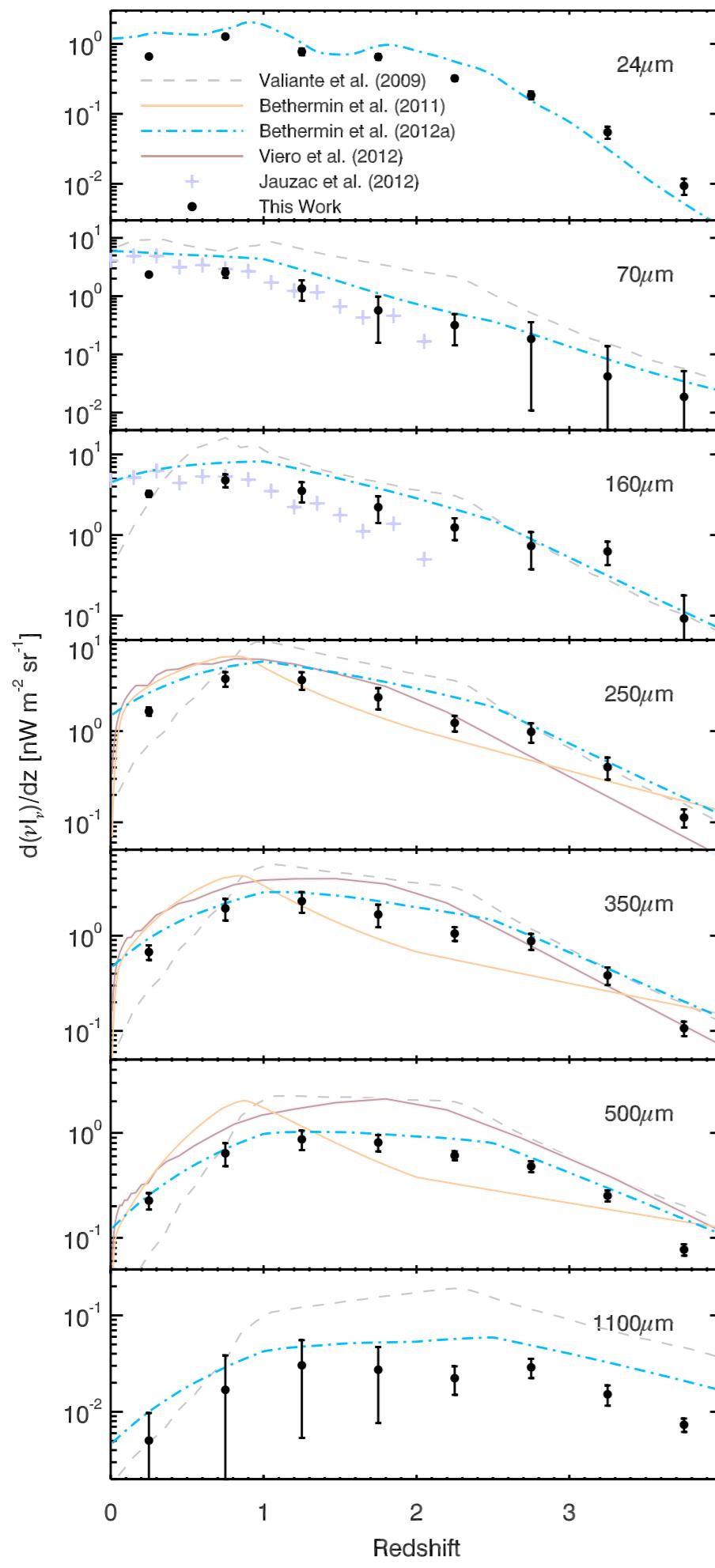
SED Temperature



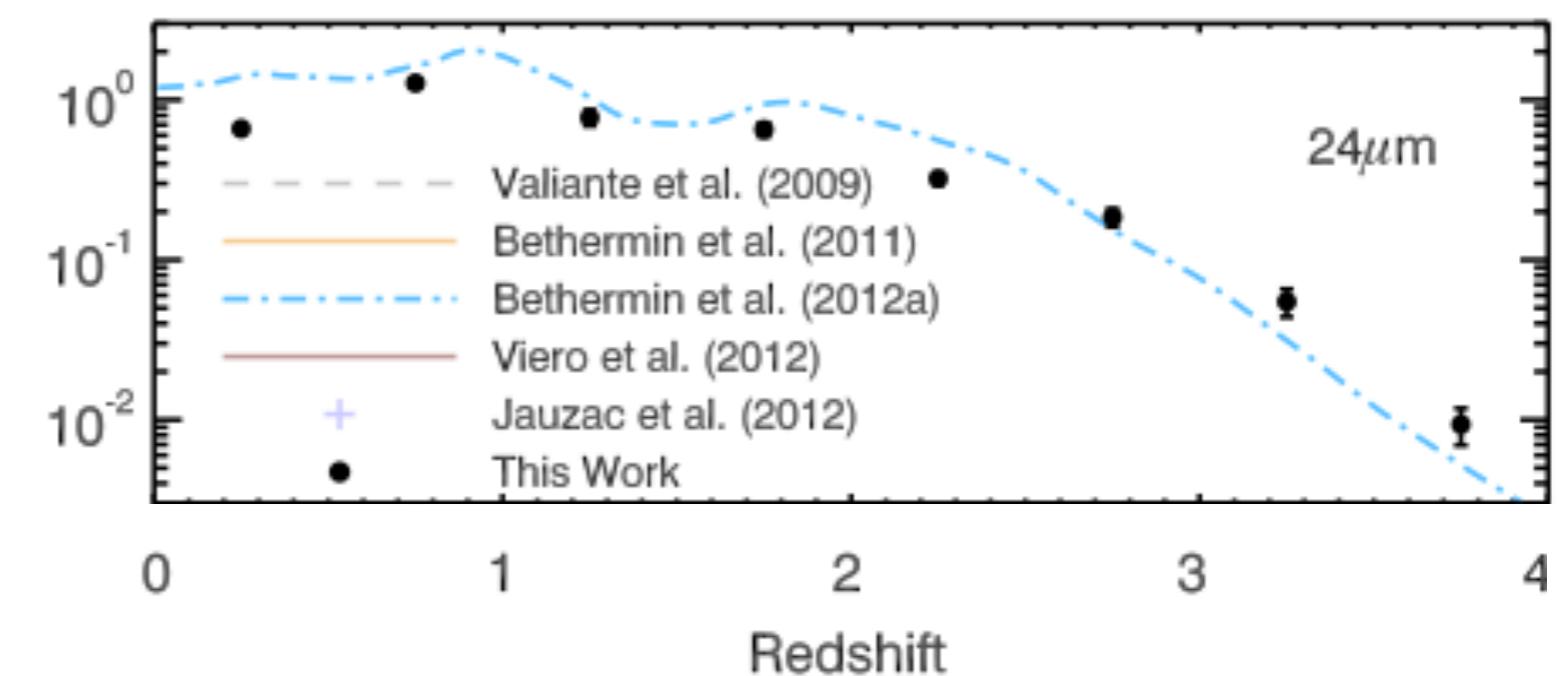
Redshift Distribution of CIB



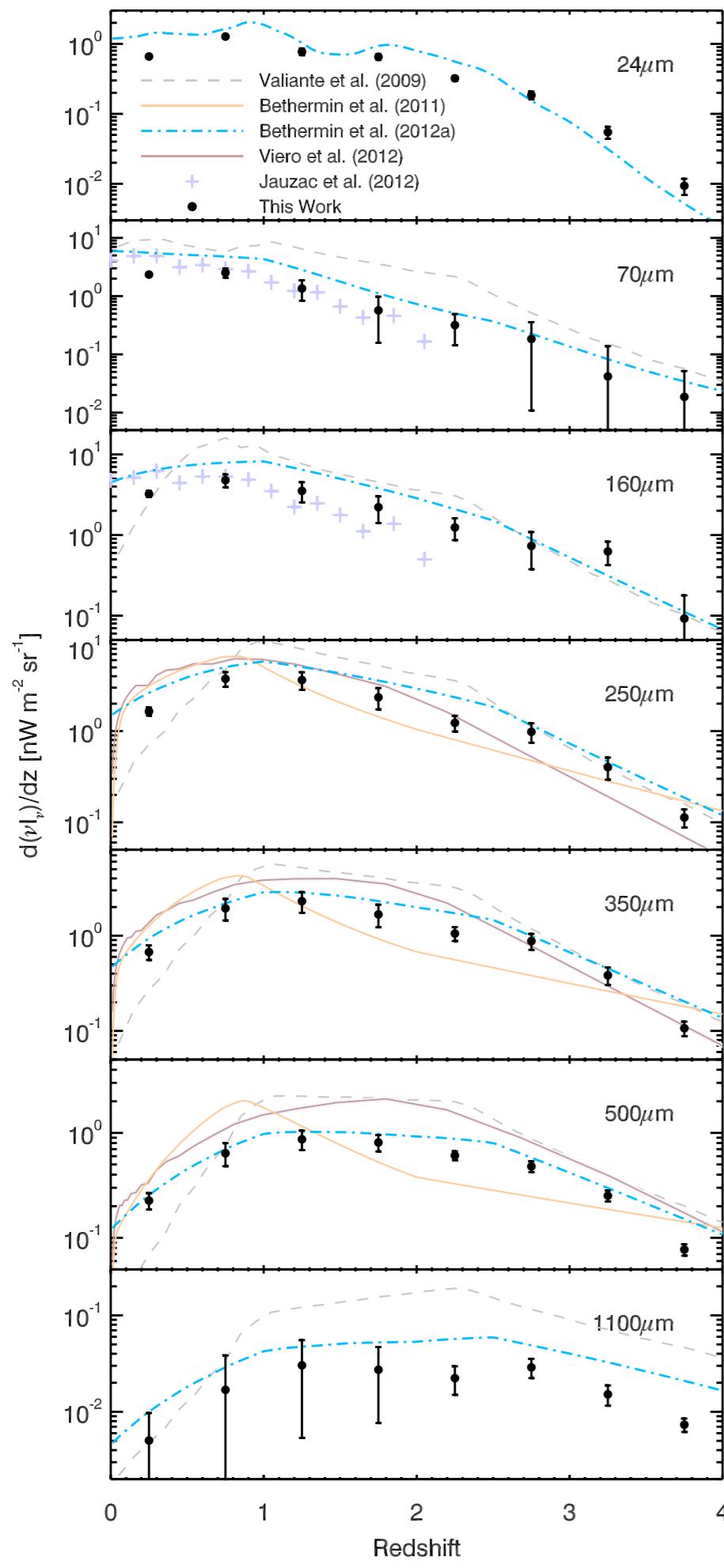
Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446



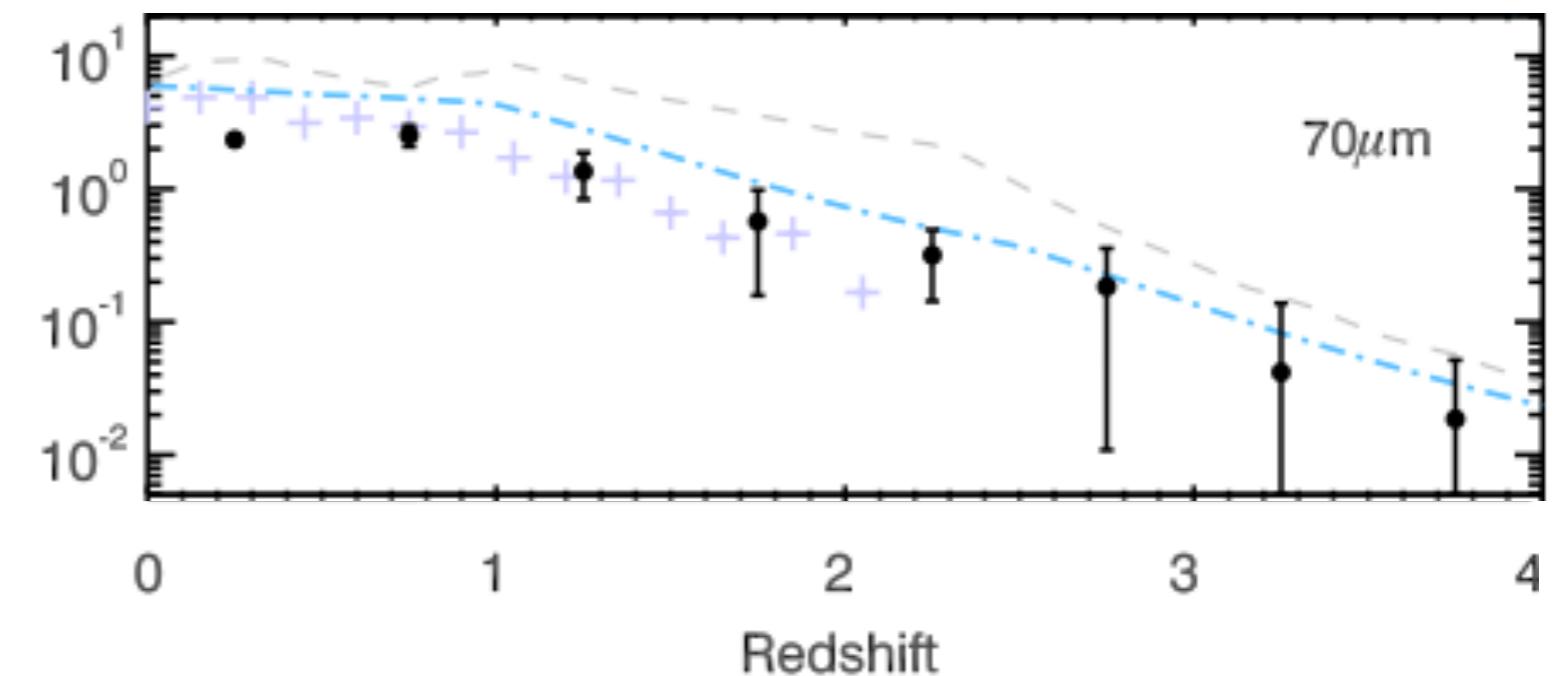
Redshift Distribution of CIB



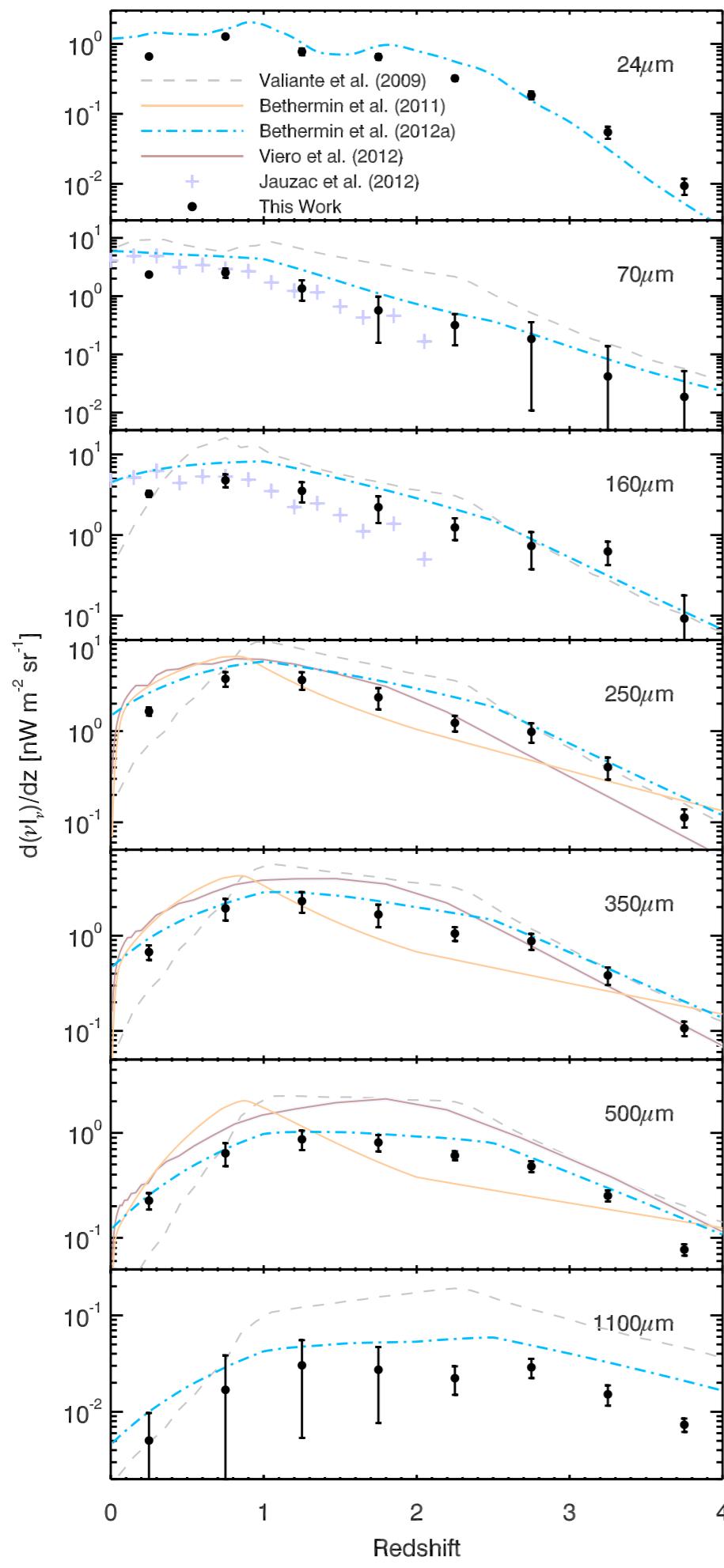
Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446



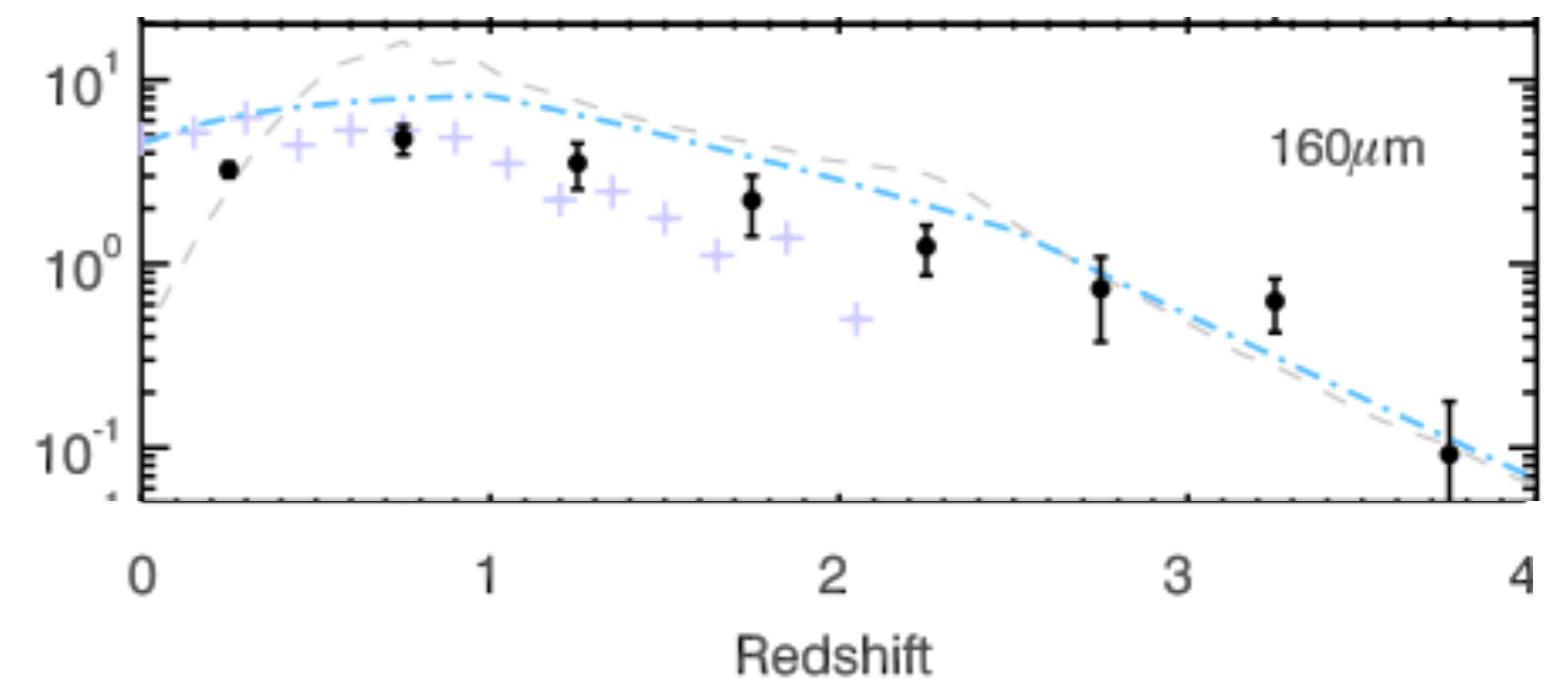
Redshift Distribution of CIB



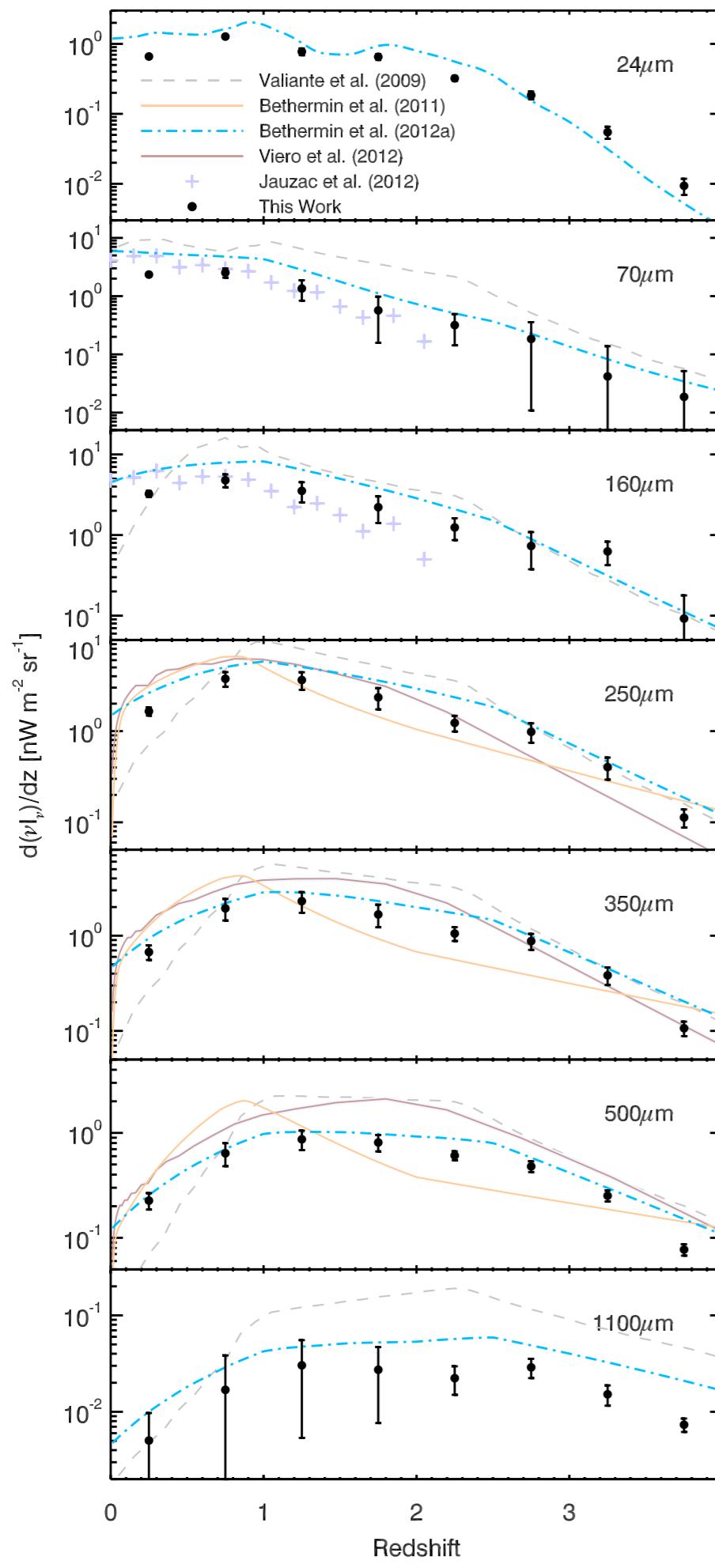
Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446



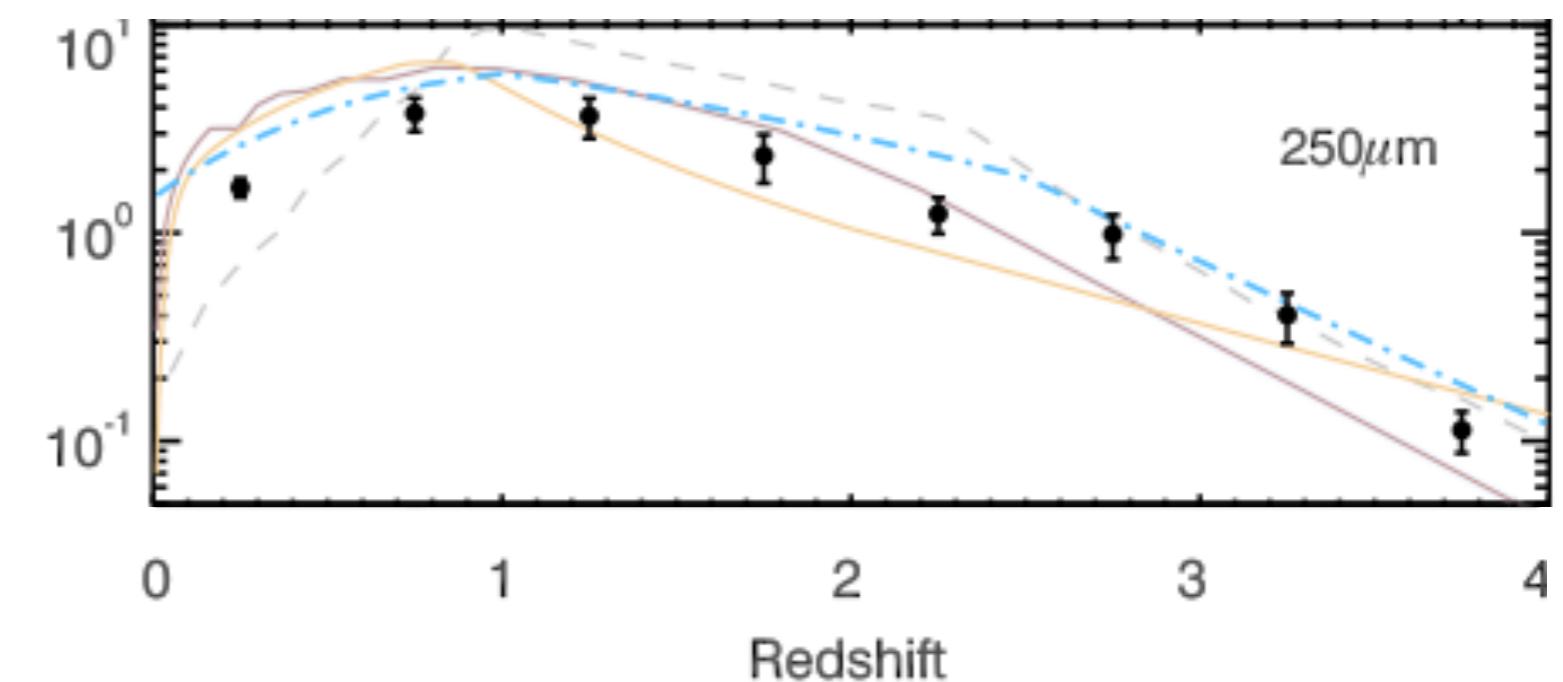
Redshift Distribution of CIB



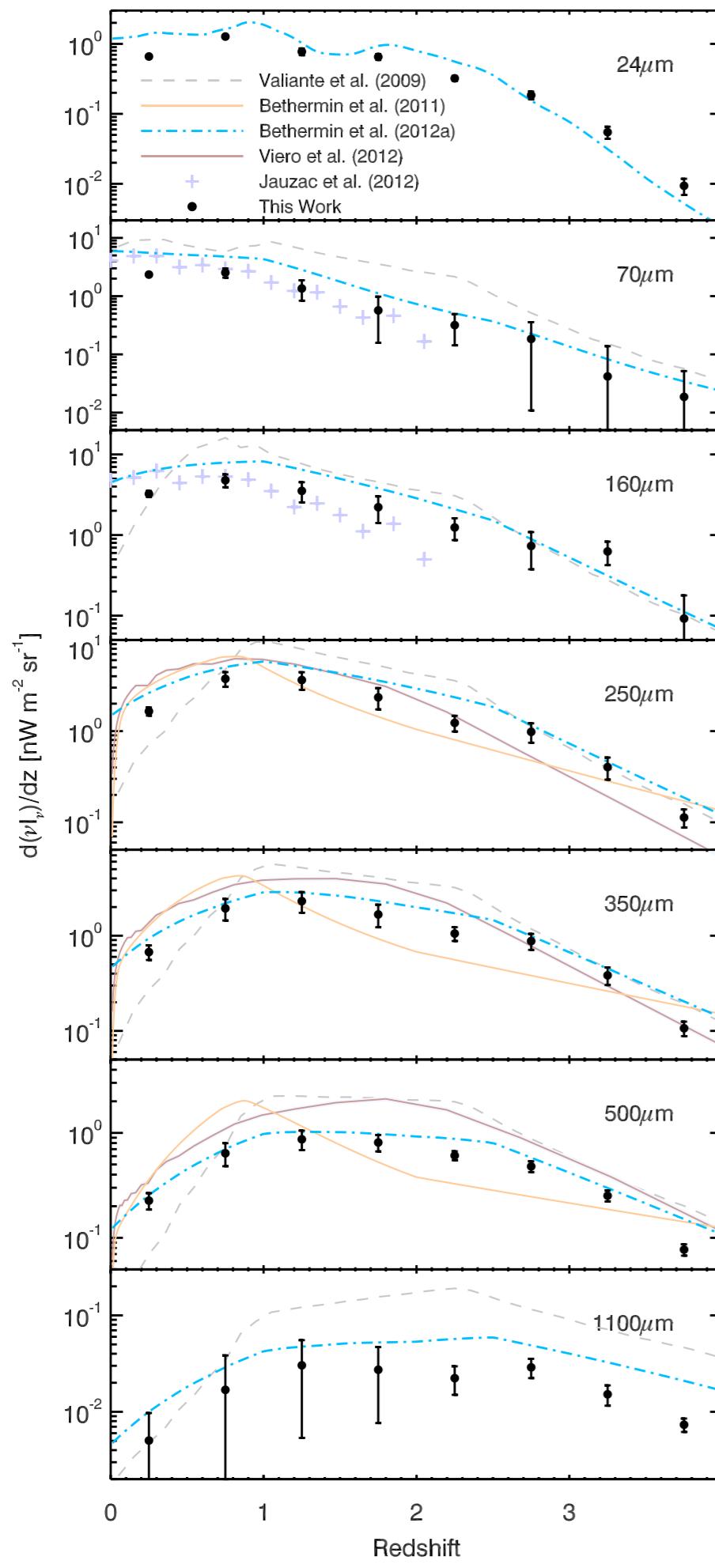
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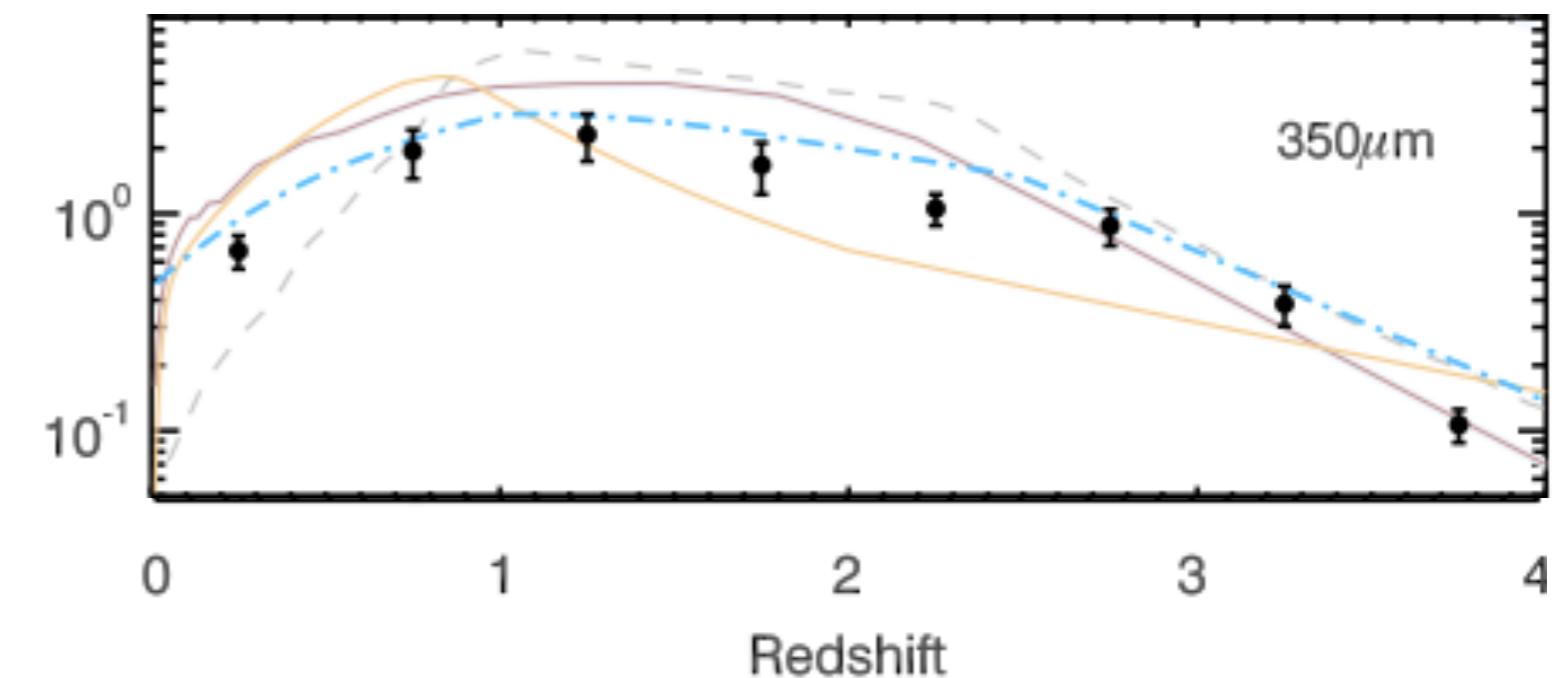
Redshift Distribution of CIB



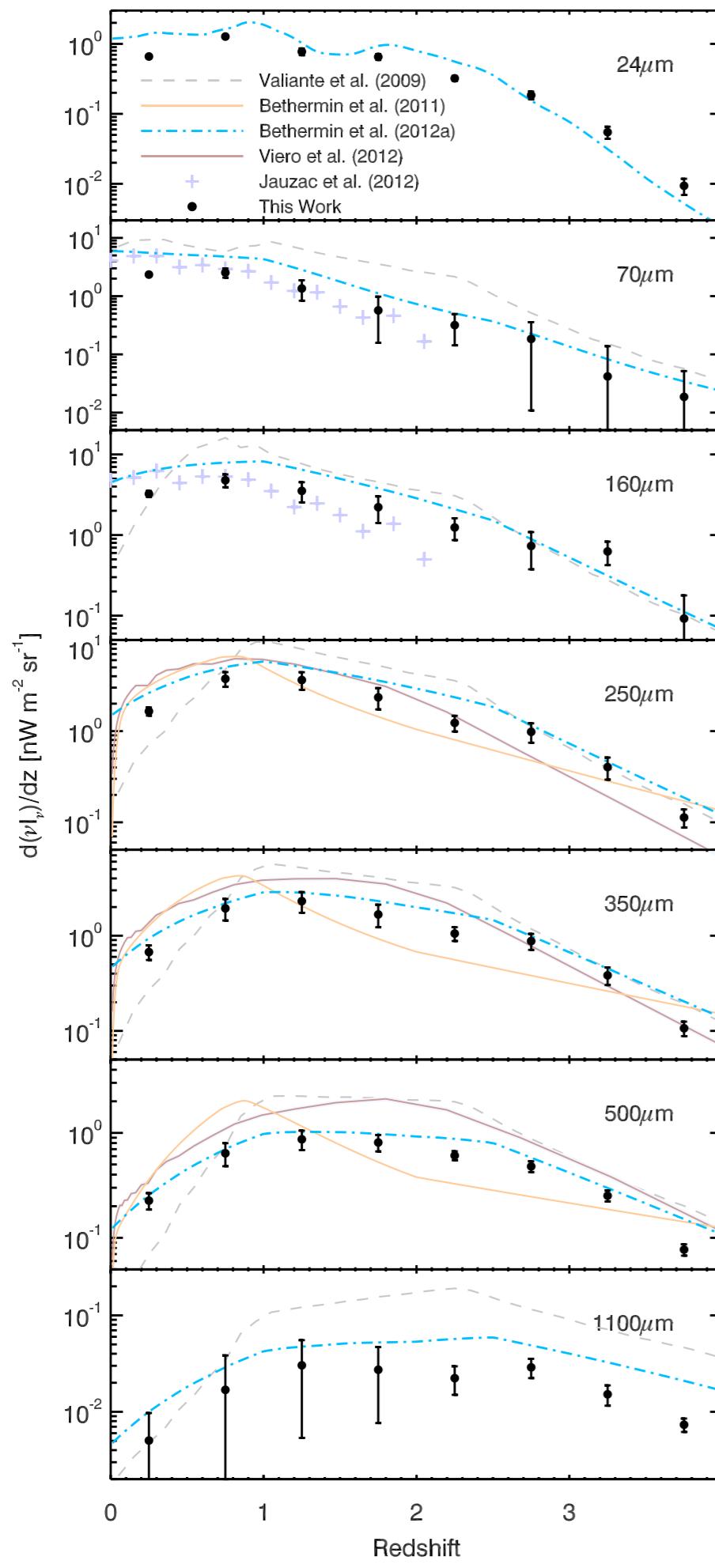
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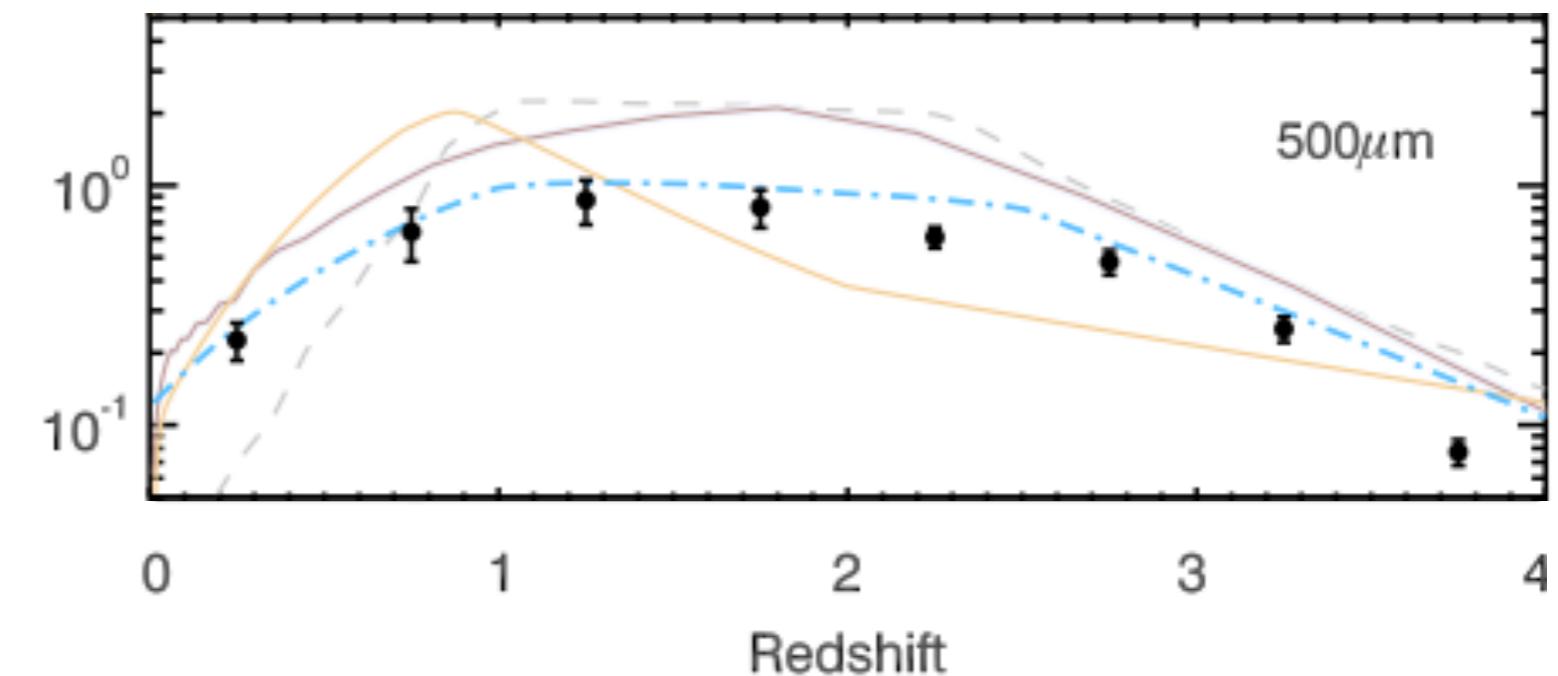
Redshift Distribution of CIB



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arXiv:1304.0446



Redshift Distribution of CIB



Viero, Moncelsi, Quadri et al. (2013)
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conclusion

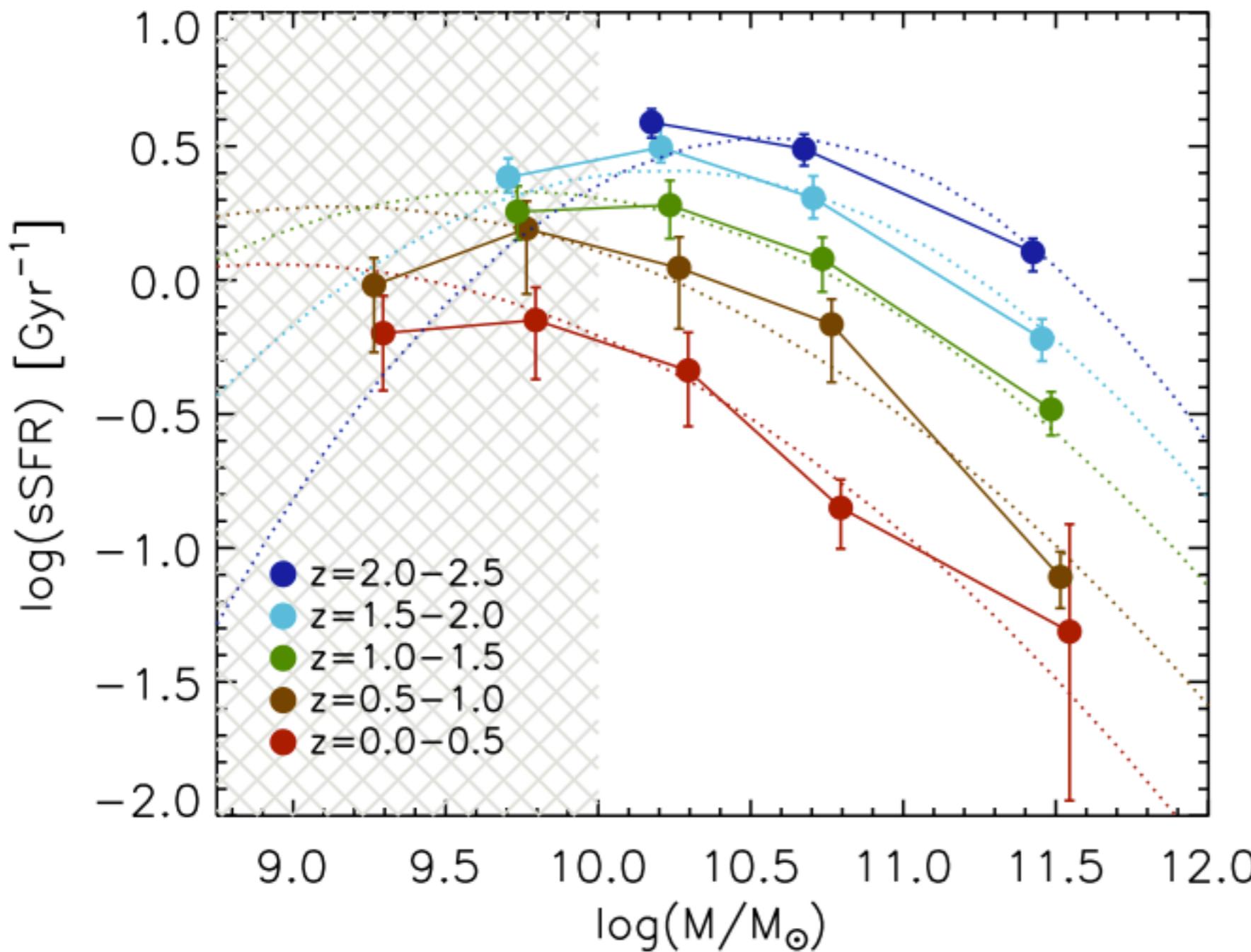
- ~99% of sources lie beneath the confusion noise floor
- Peak **Halo** Mass of efficient SF
 - $\log(M_{\text{halo}}/\text{M}_{\odot}) = 12.2 \pm 0.5$
- Peak **Stellar** Mass of SF
 - $\log(M_{\text{star}}/\text{M}_{\odot}) = 10-11$

SIMSTACK code publicly available in:

Viero, Moncelsi, Quadri et al. (2013)

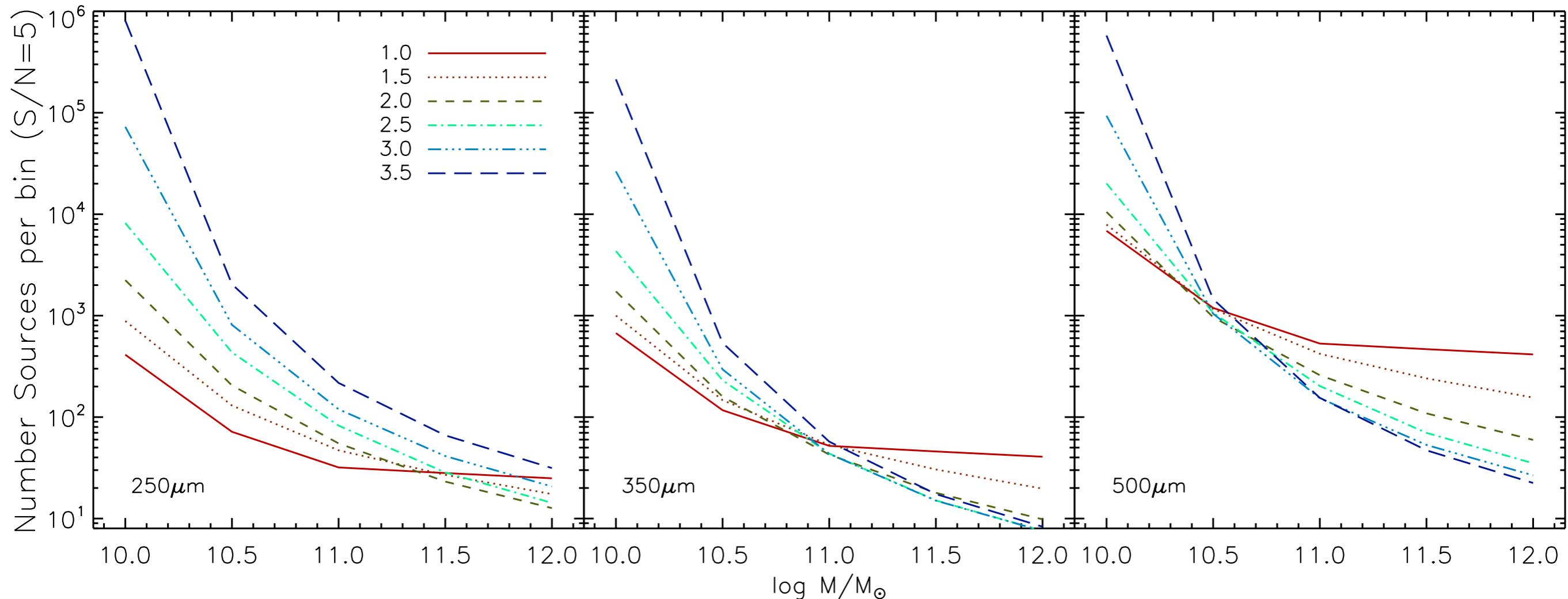
arXiv:1304.0446

Reaching our Limits

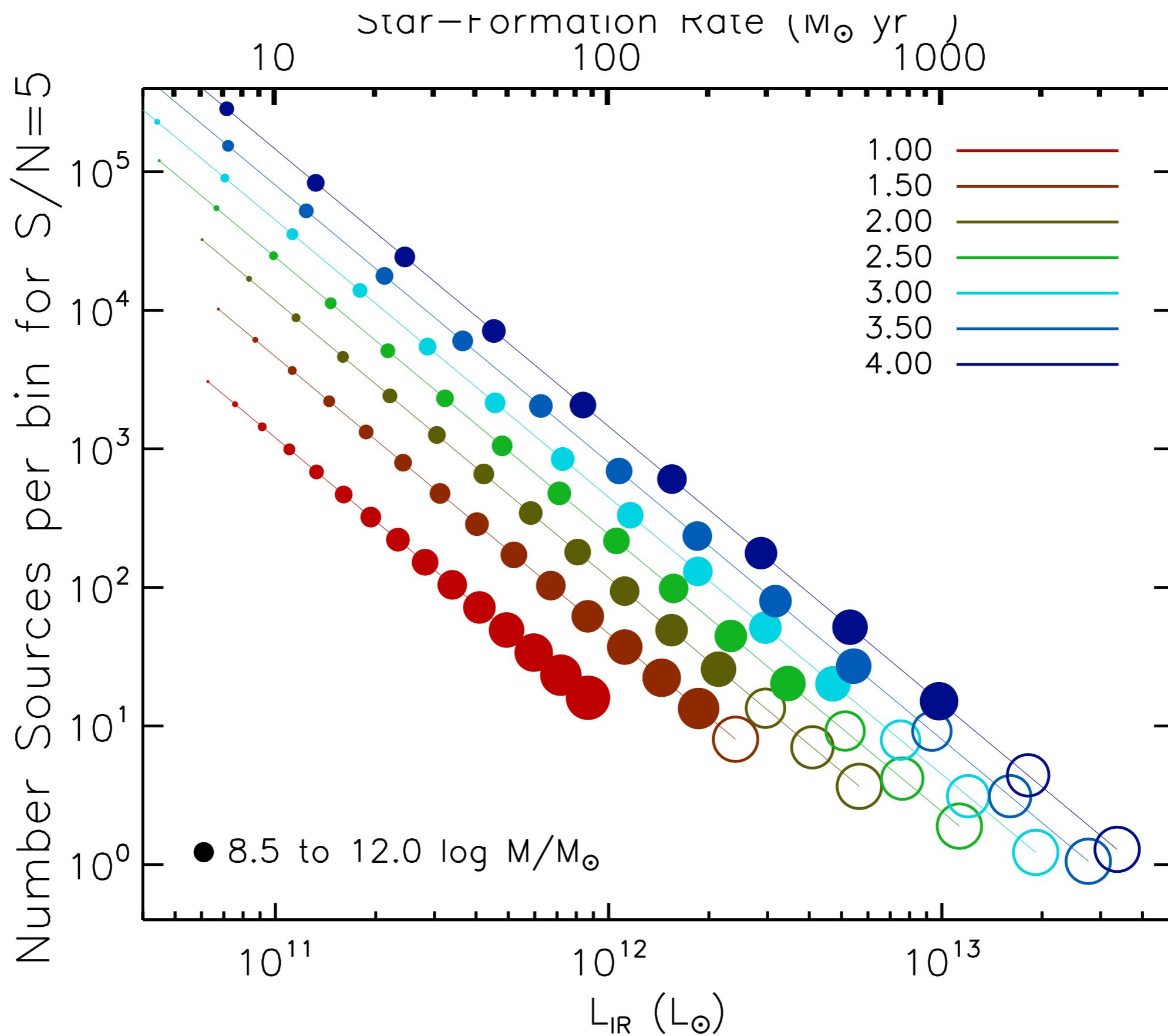


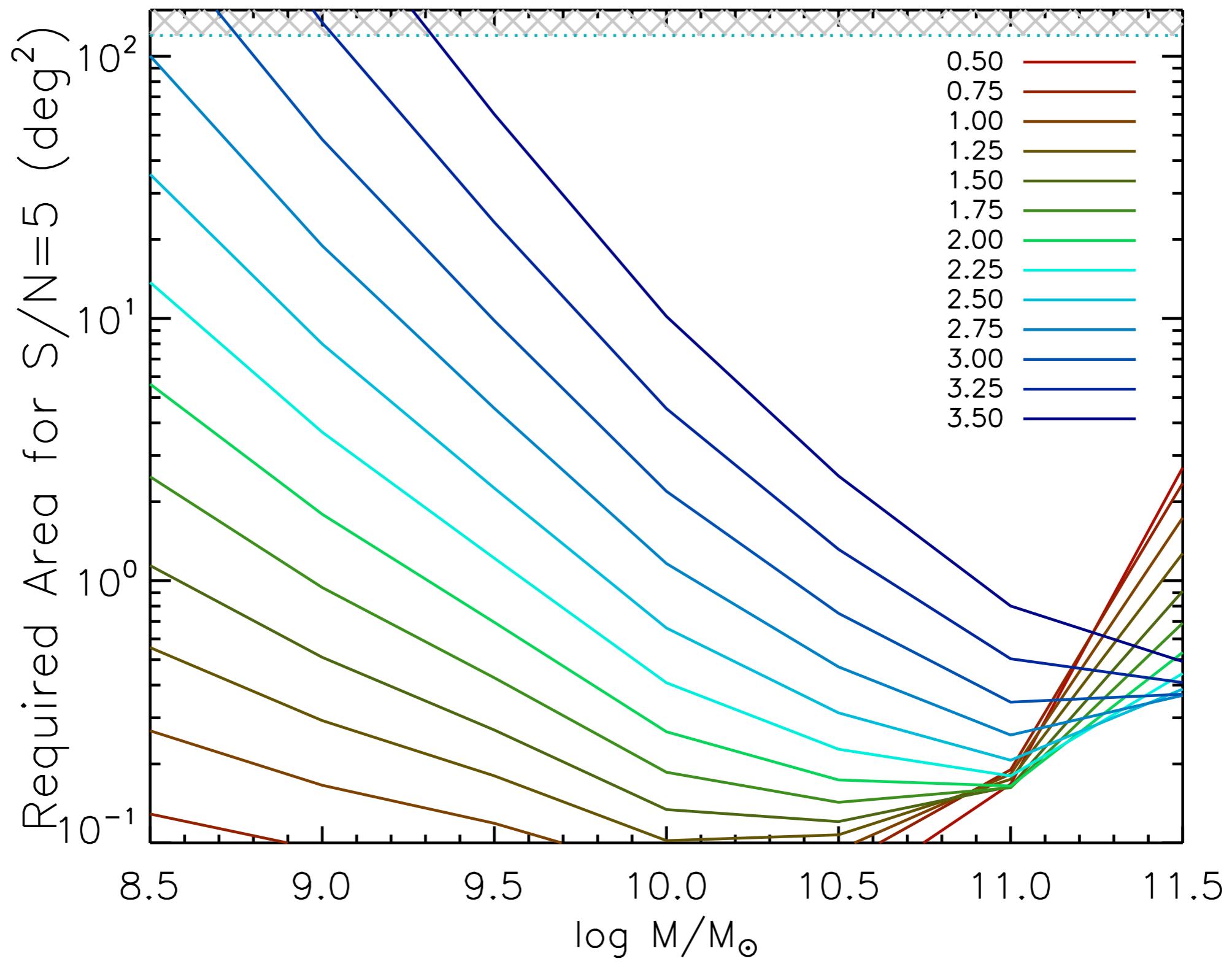
- Can Measure sSFRs well to:
 - $0 < z < 2.5$
 - $\log(M/M_\odot \gtrsim 10)$
- **How can we reach higher-z and lower mass?**

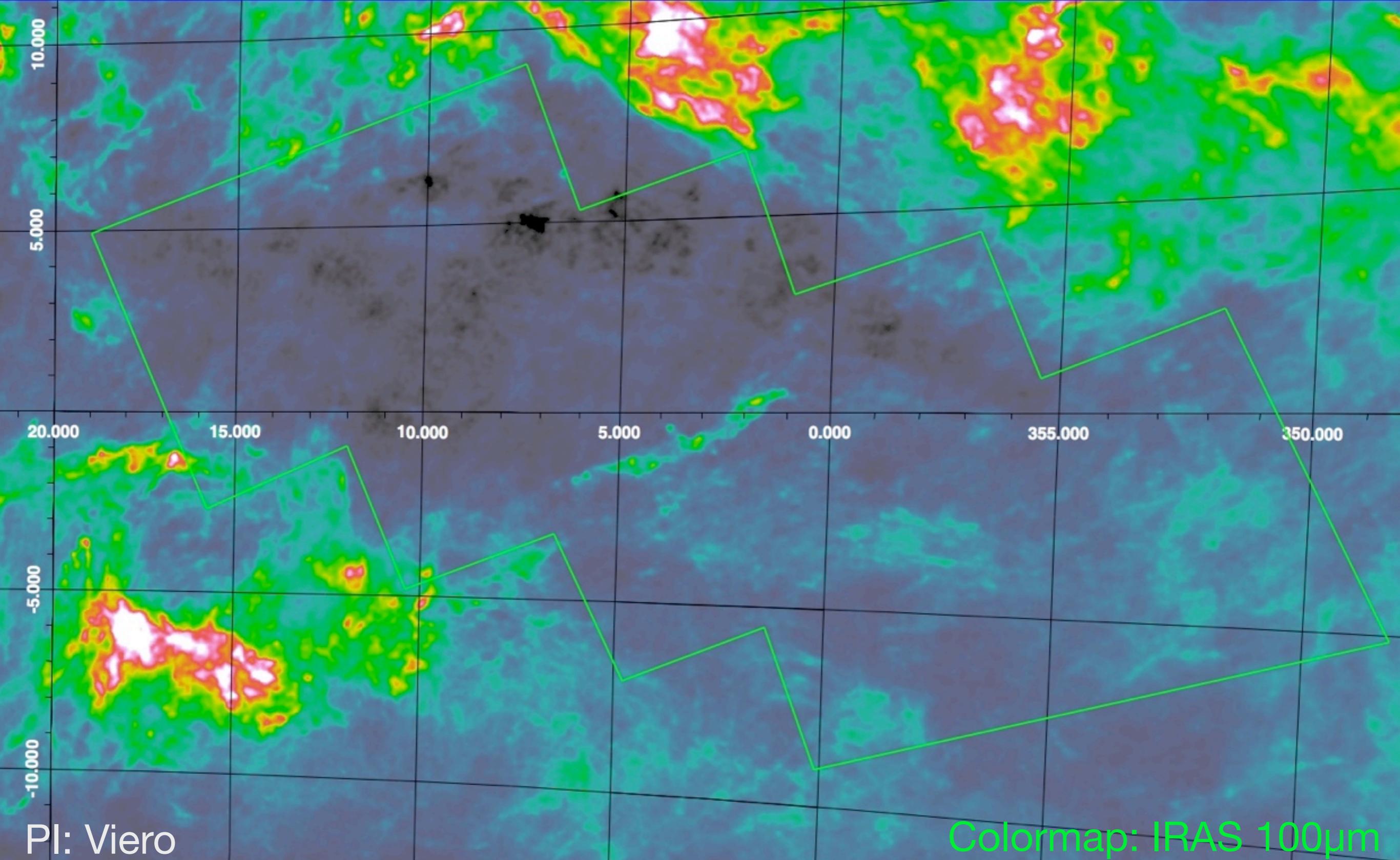
By going big!



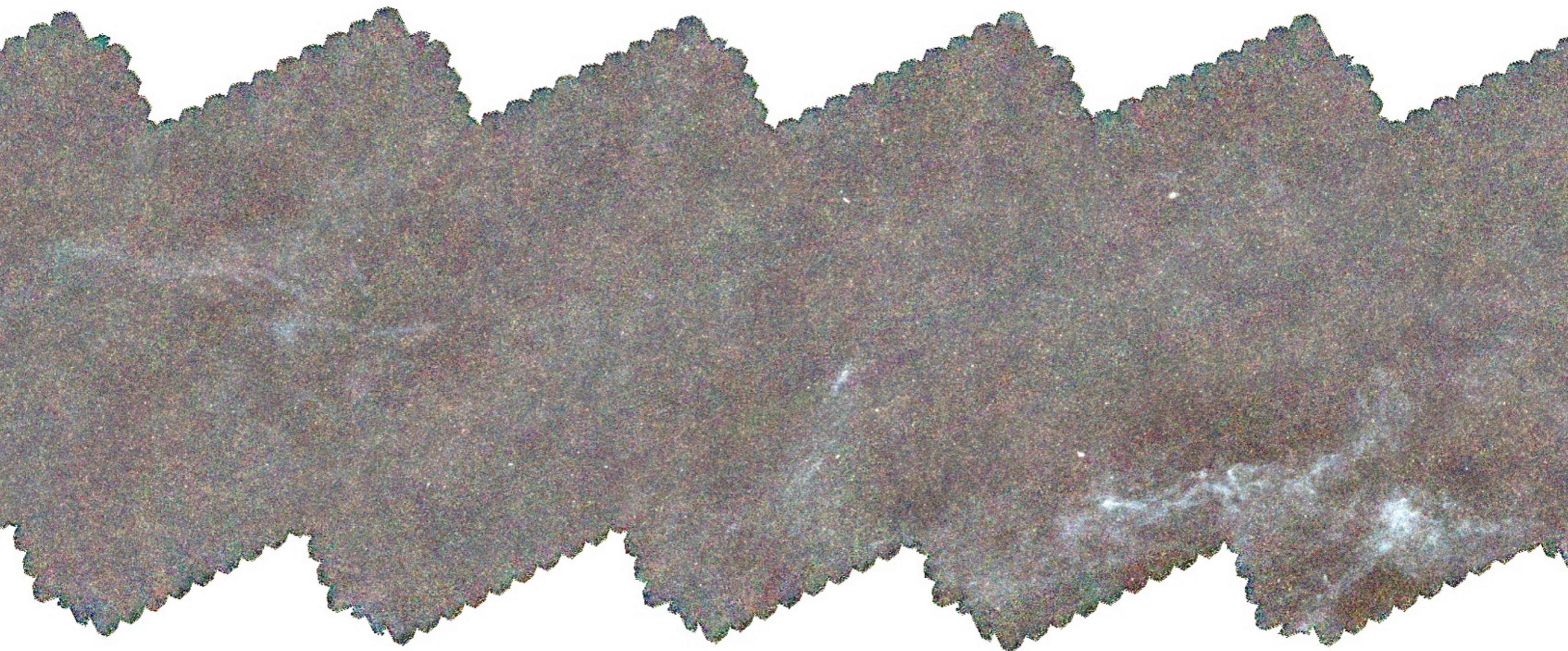
- Estimated using:
 - Mass Function (Muzzin et al. 2013: arXiv:1303.4409)
 - Polynomial Fits to My Stacked Fluxes



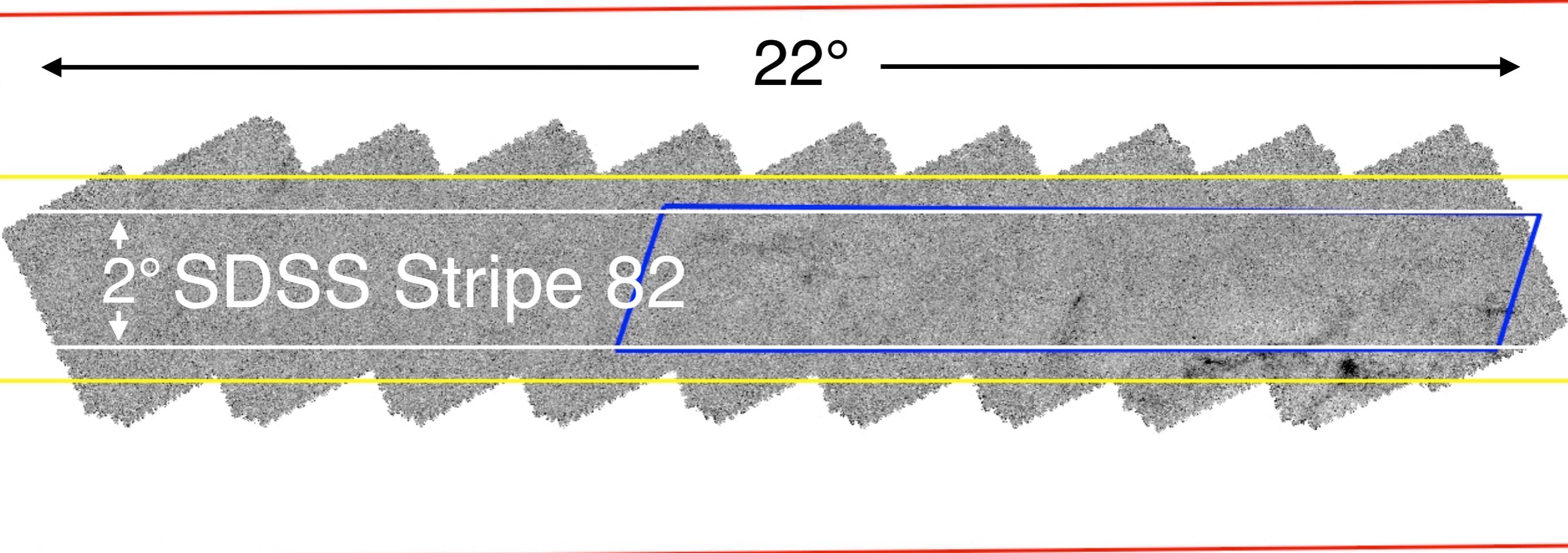




HerMES Large-Mode Survey (HeLMS)

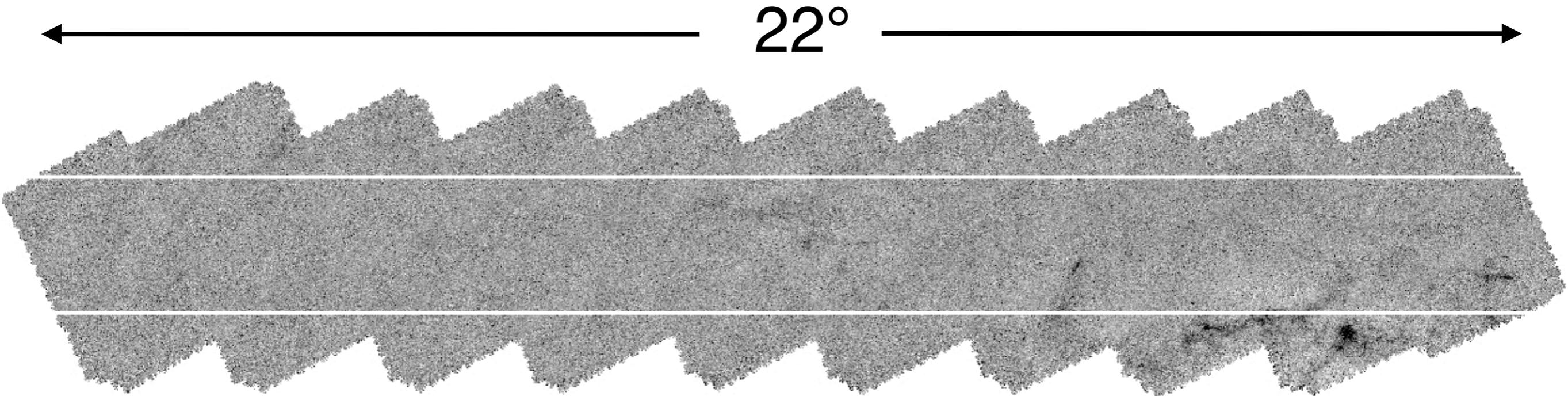


Herschel Redshift Survey (HeRS)

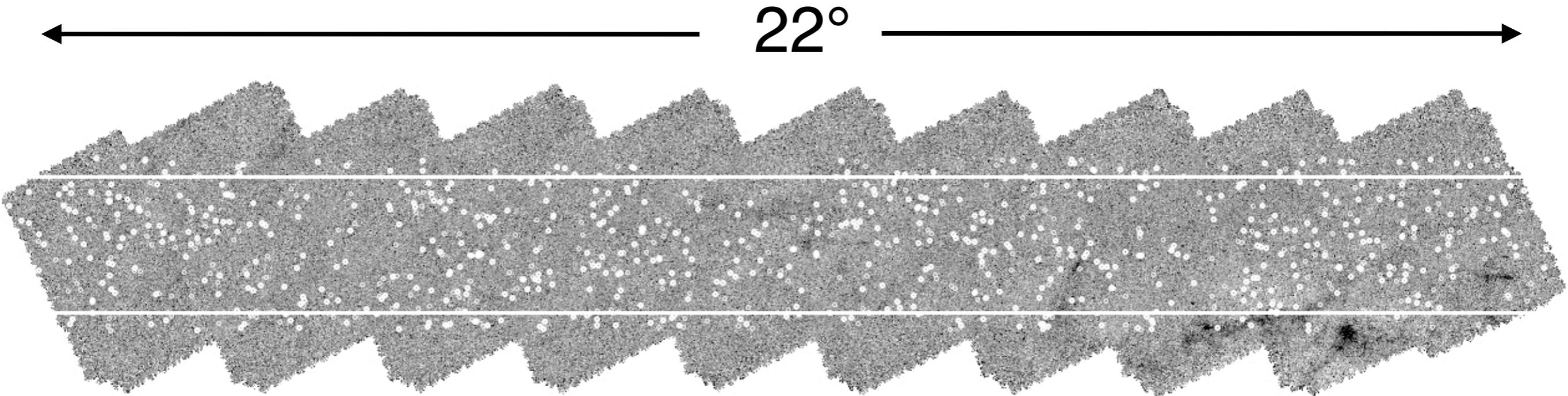


HeRS

- ACT
- SHELIA
- HETDEX

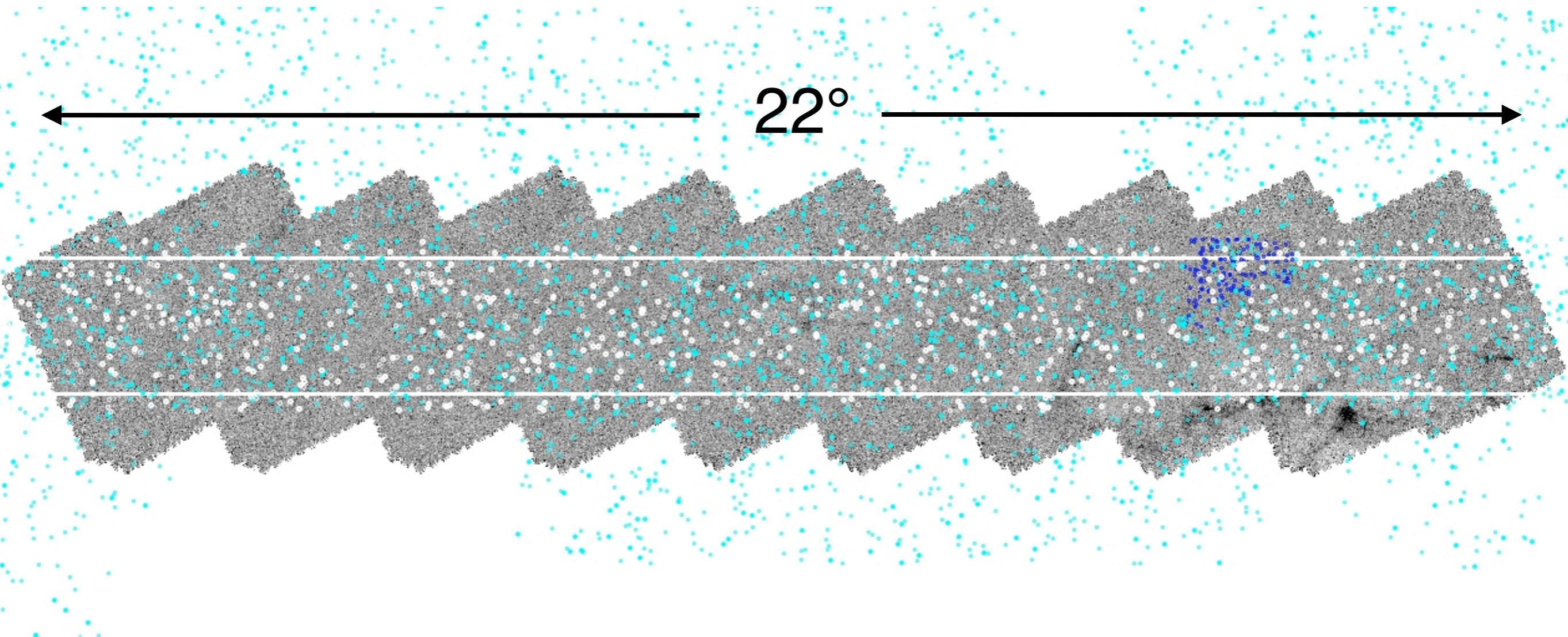


HeRS



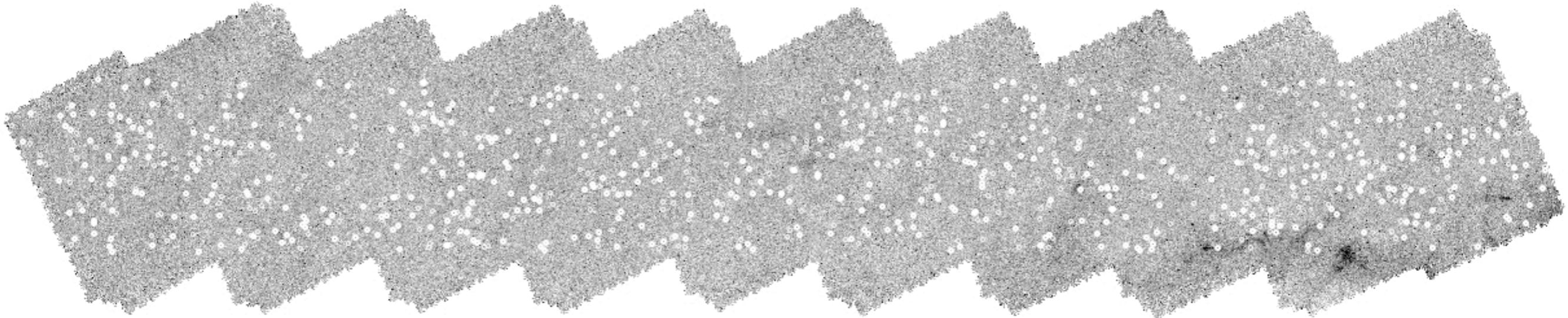
- Clusters (Geach et al. 2012)

HeRS



HeRS

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

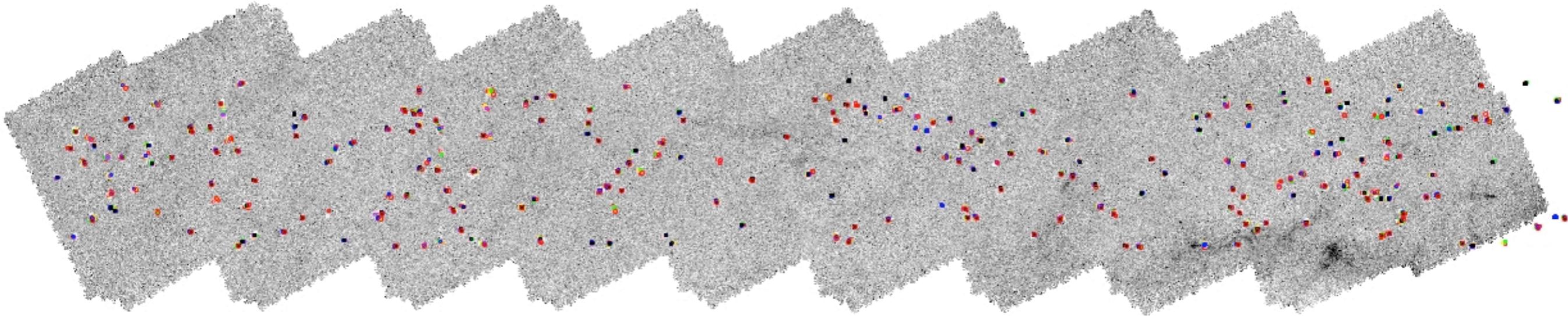


- Clusters (Geach et al. 2012)

HeRS

More info at:

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

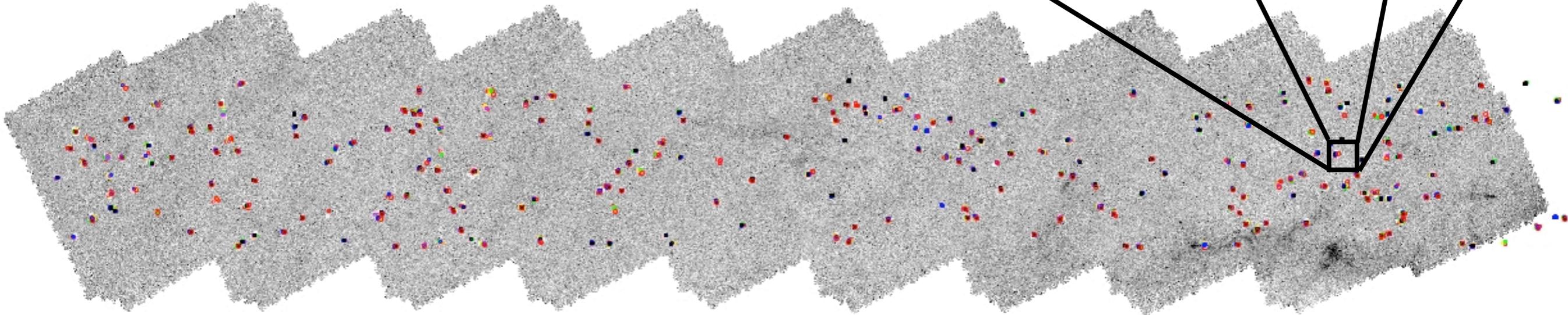


- Cluster Members

HeRS

More info at:

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

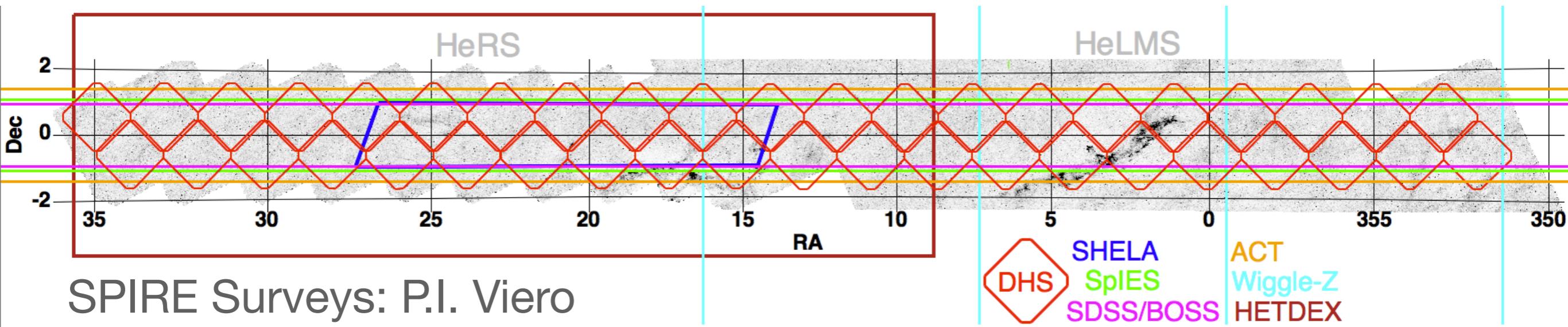


- Cluster Members

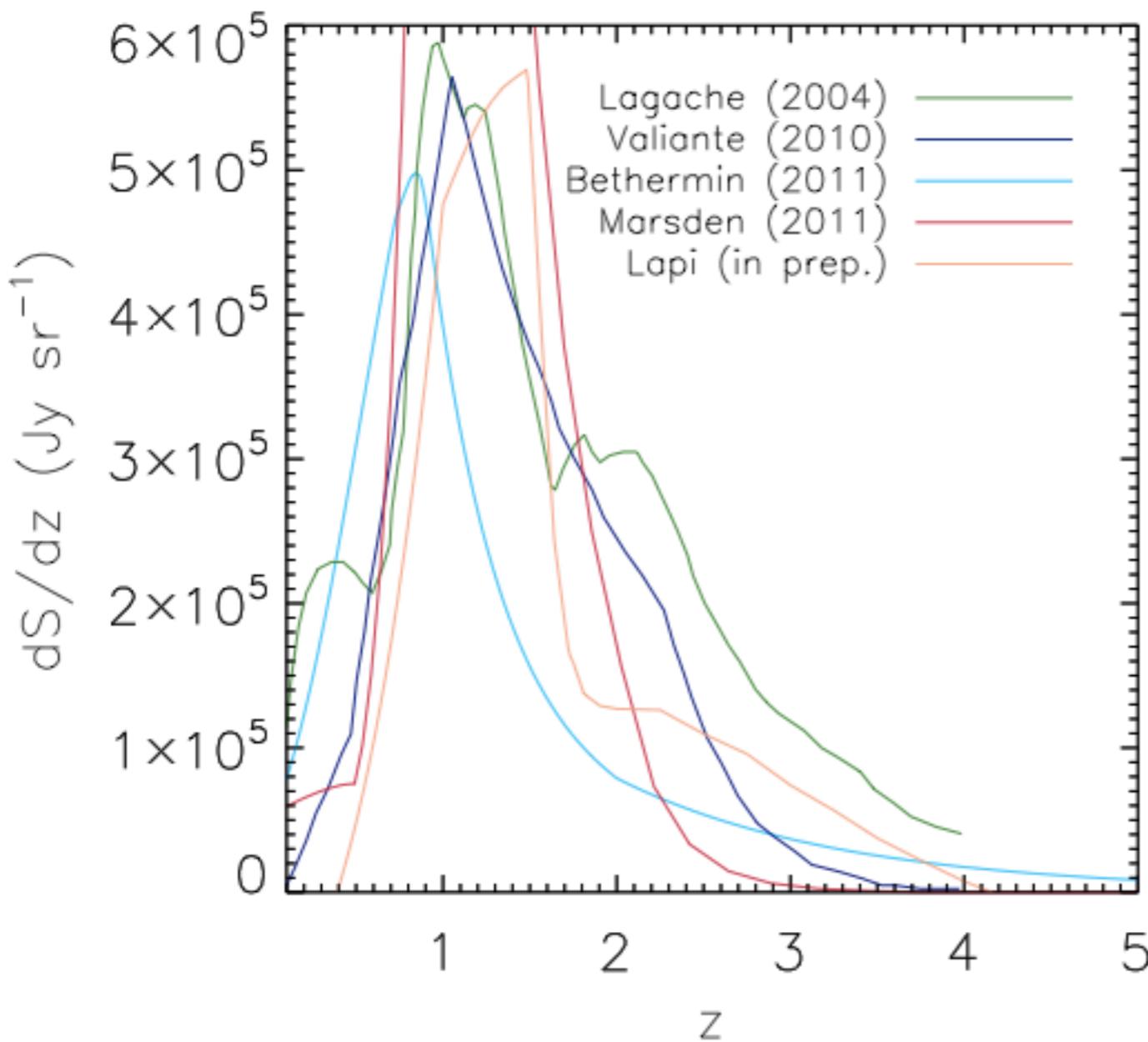
HeRS

More info at:

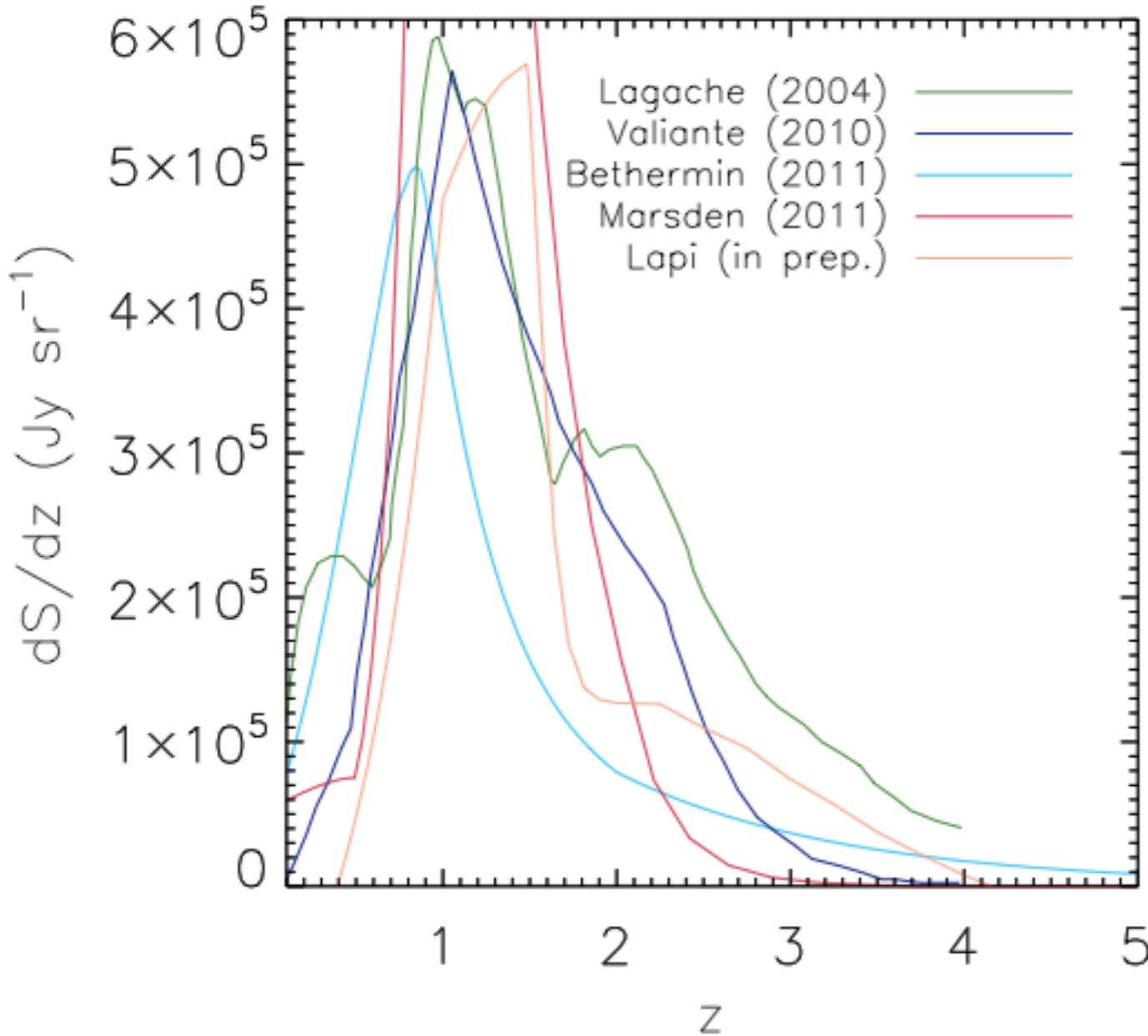
http://www.astro.caltech.edu/~viero/viero_homepage/hers.html



HeLMS/HeRS

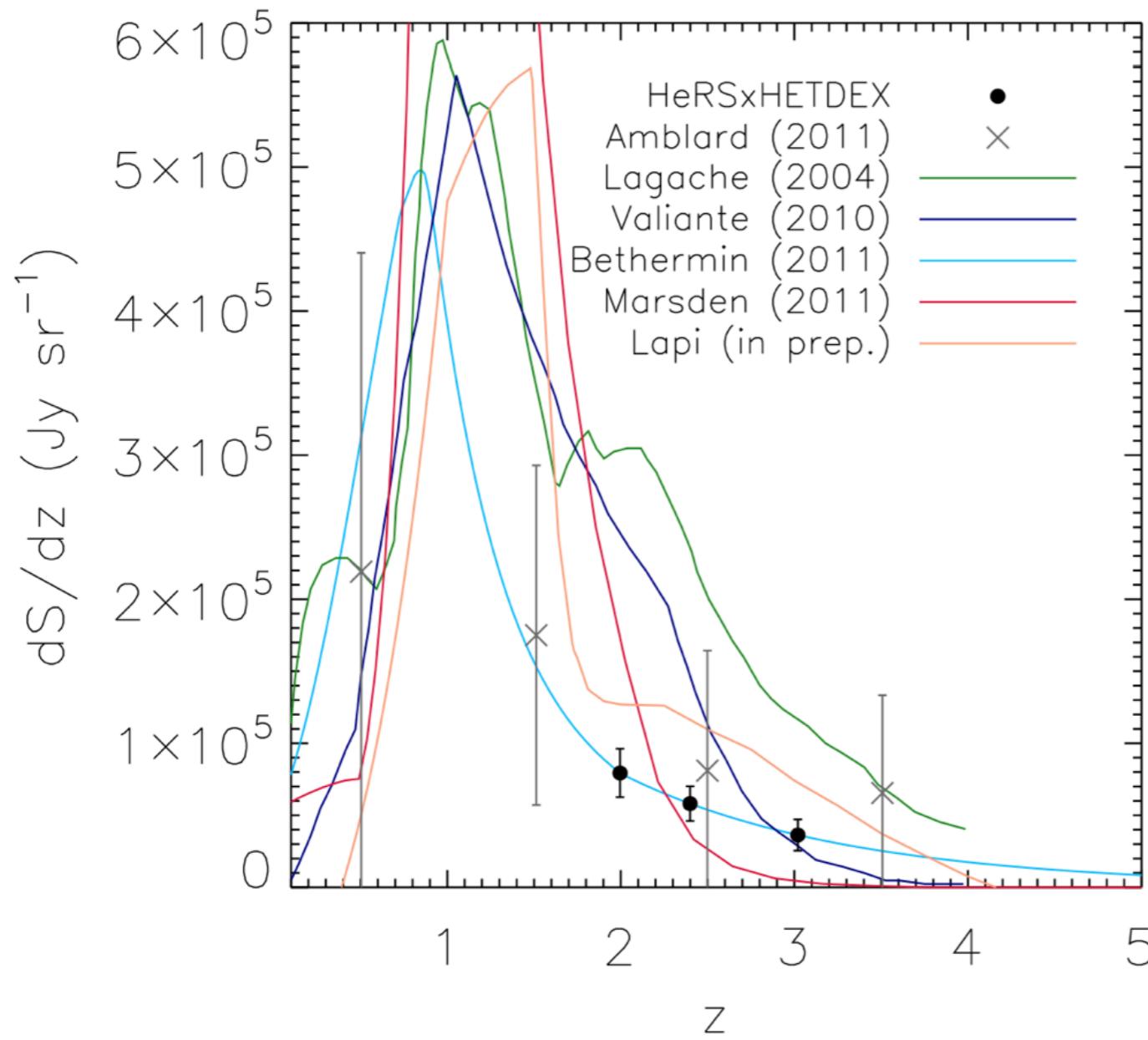


redshift distribution of CIB



- dS/dz : redshift distribution of background light
- Models do not agree on dS/dz for $z > 1$

redshift distribution of CIB



- 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