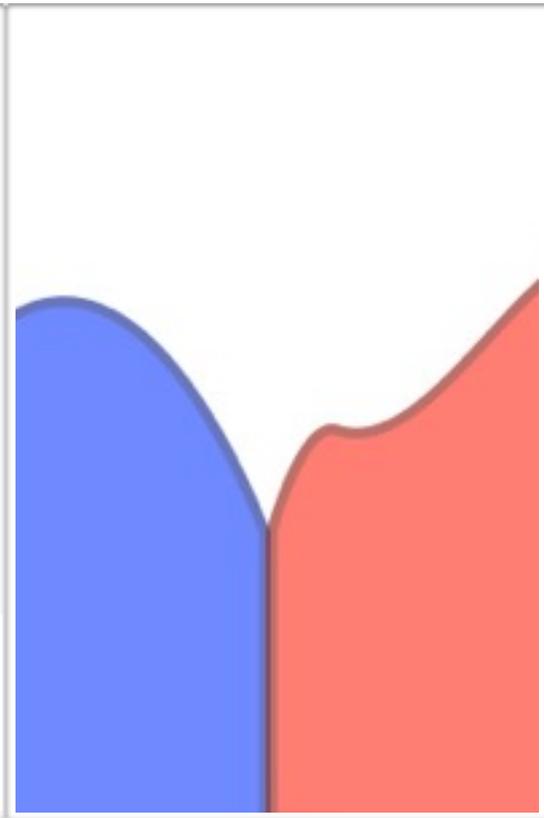
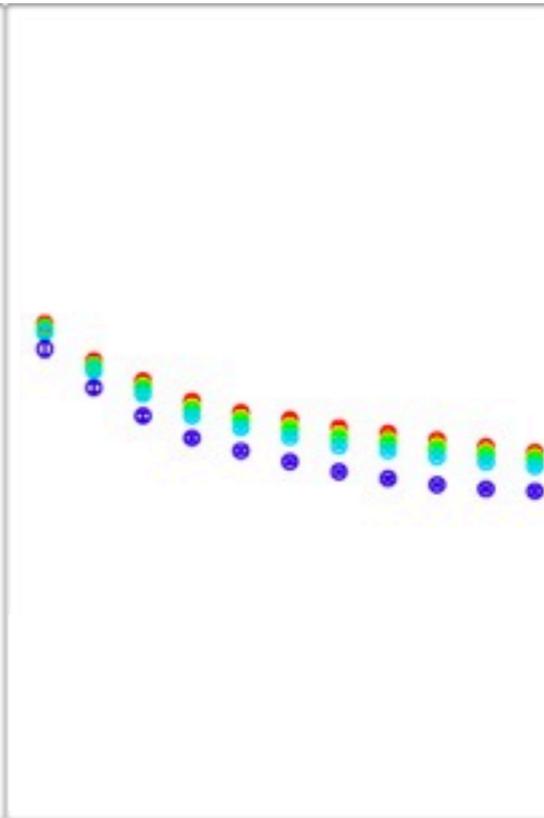
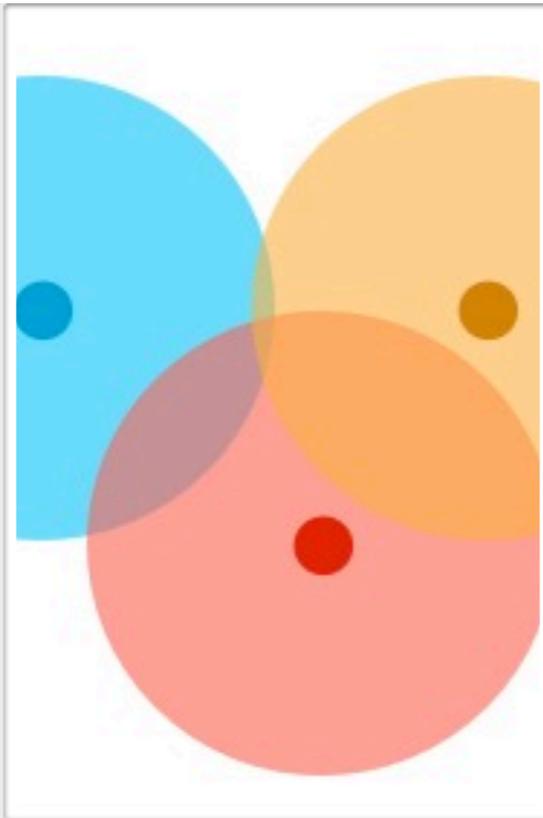
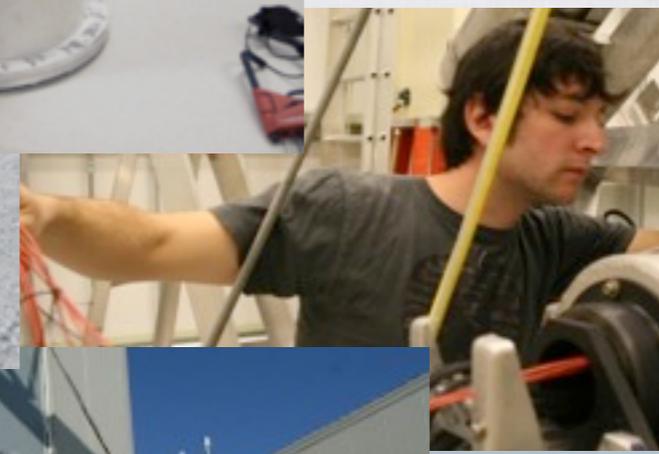
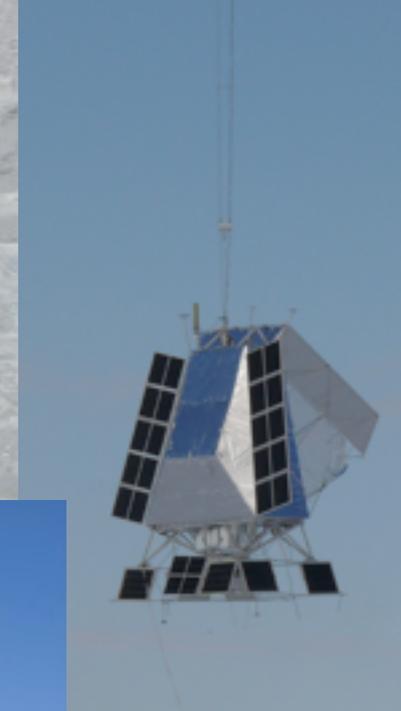


Occupy Dark Matter: Accessing the 99% of Dusty Star-forming Galaxies



Marco Viero - Caltech



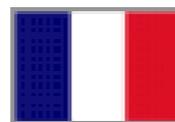
BLAST

HerMES - Herschel Multi-tiered Extragalactic Survey

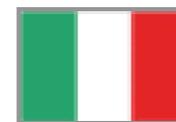
To study the evolution of galaxies in the distant Universe
The biggest project on the Herschel Space Observatory
A European Space Agency mission



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

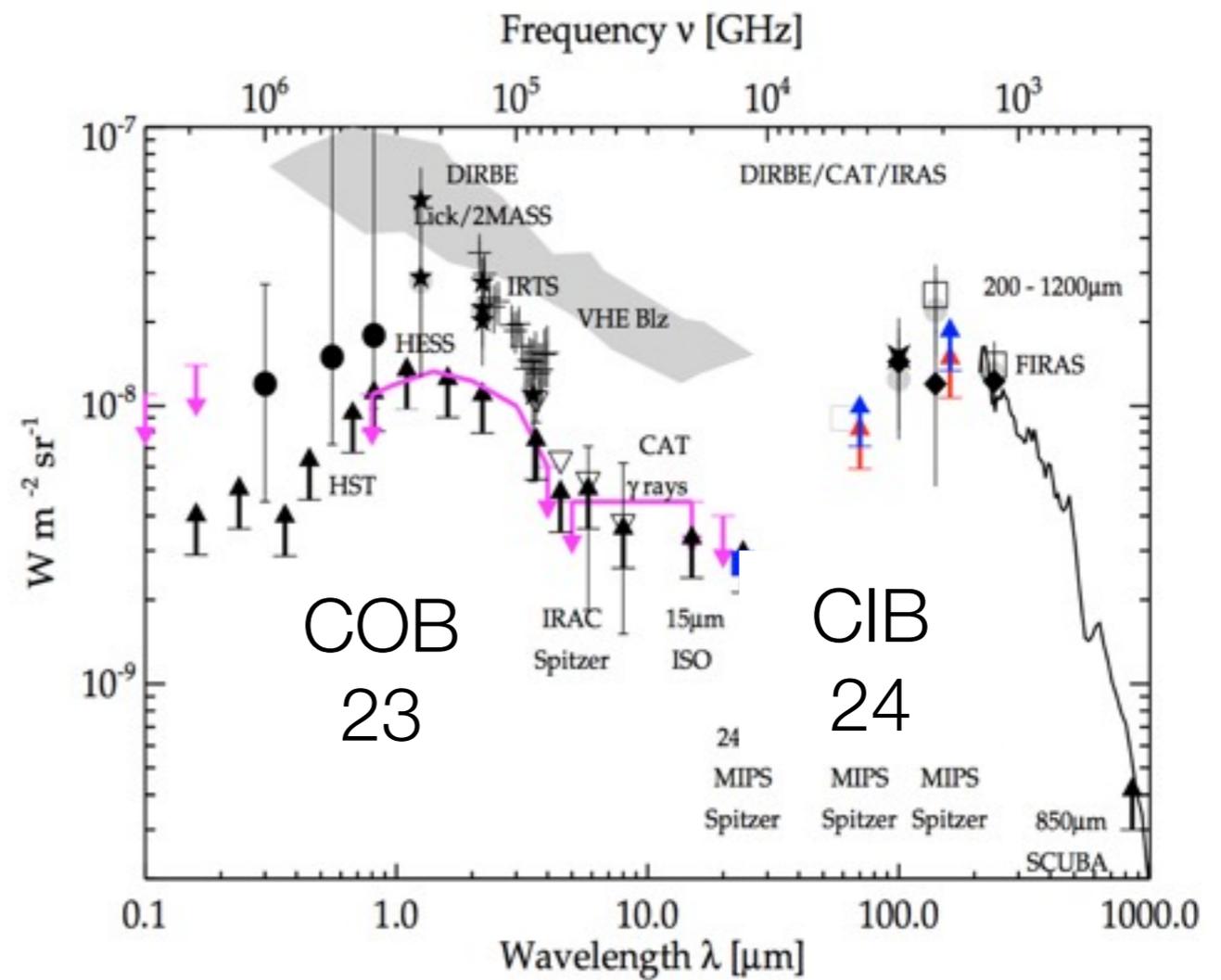
Bruno Altieri, Alex Amblard, Rick Arendt, **Vinod Arumugam**, Robbie Auld, Herve Aussel, Alexandre Beelen, Andrew Blain, Jamie Bock, Alessandro Boselli, **Carrie Bridge**, **Drew Brisbin**, Veronique Buat, Denis Burgarella, **Nieves Castro-Rodriguez**, Antonia Cava, Pierre Chaniel, Ed Chapin, Michele 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 Orioux, 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.

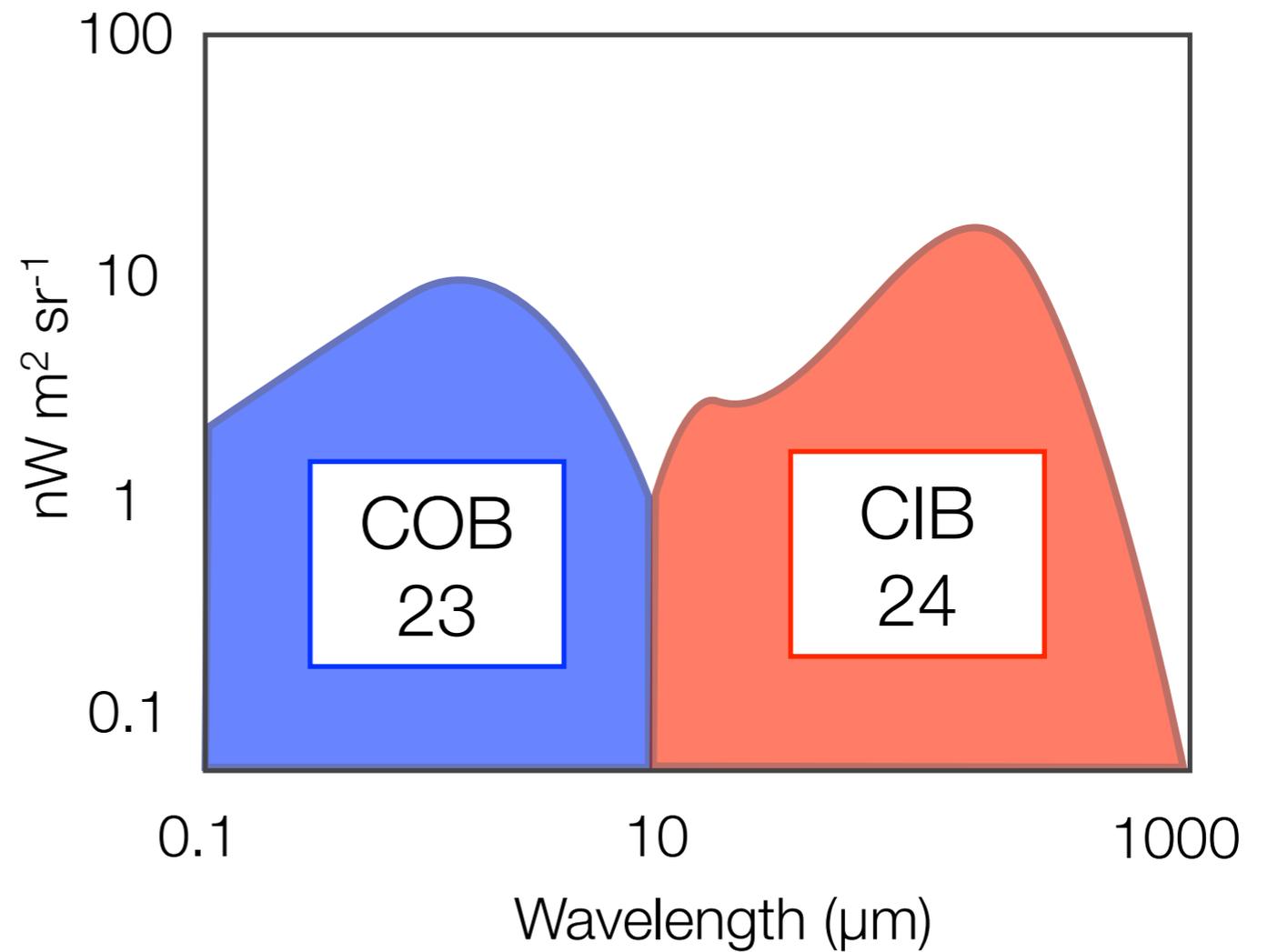
outline

- galaxy properties
- galaxy distribution
- herschel redshift survey

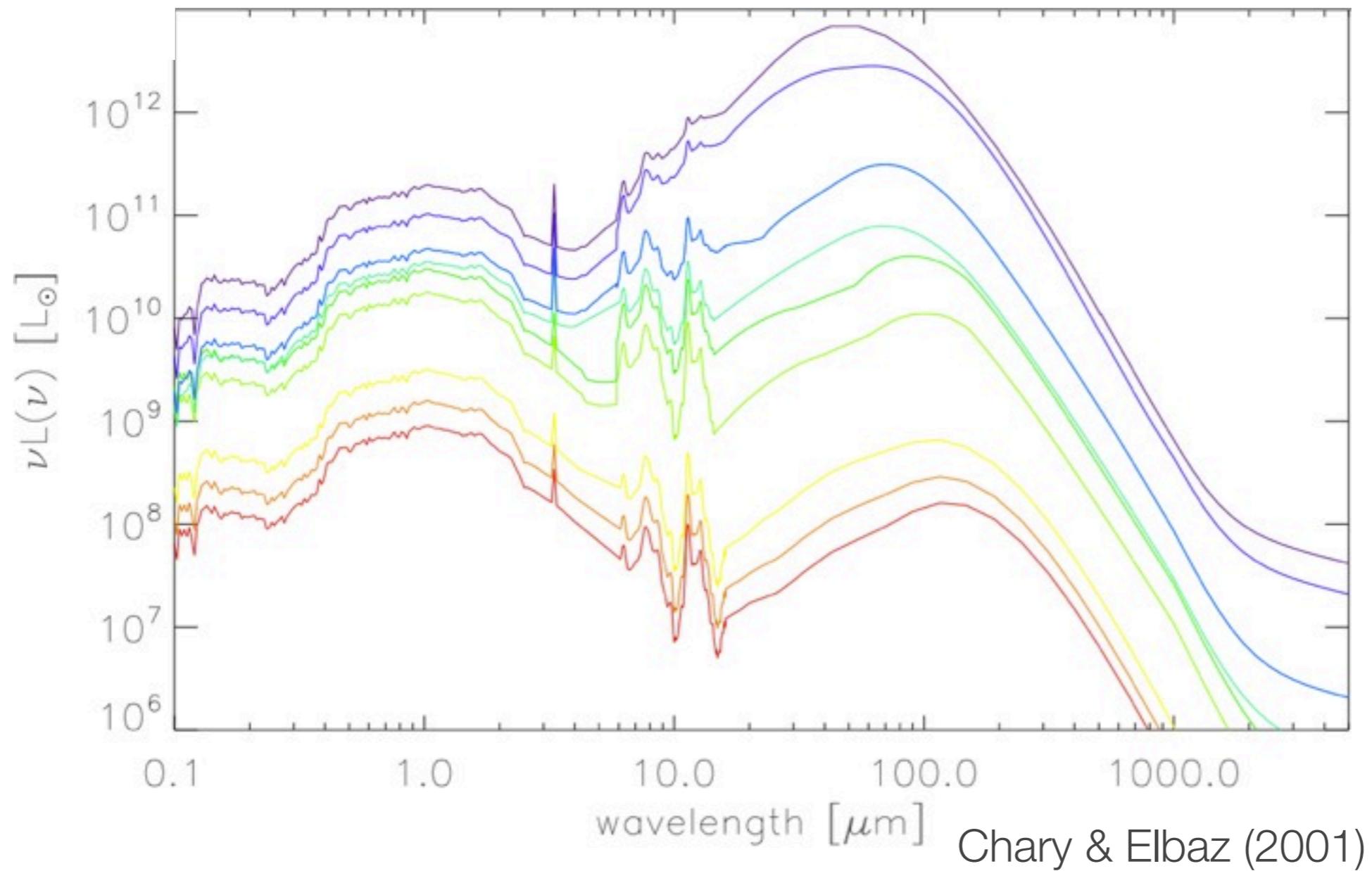


Dole et al (2006)

optical and infrared
backgrounds



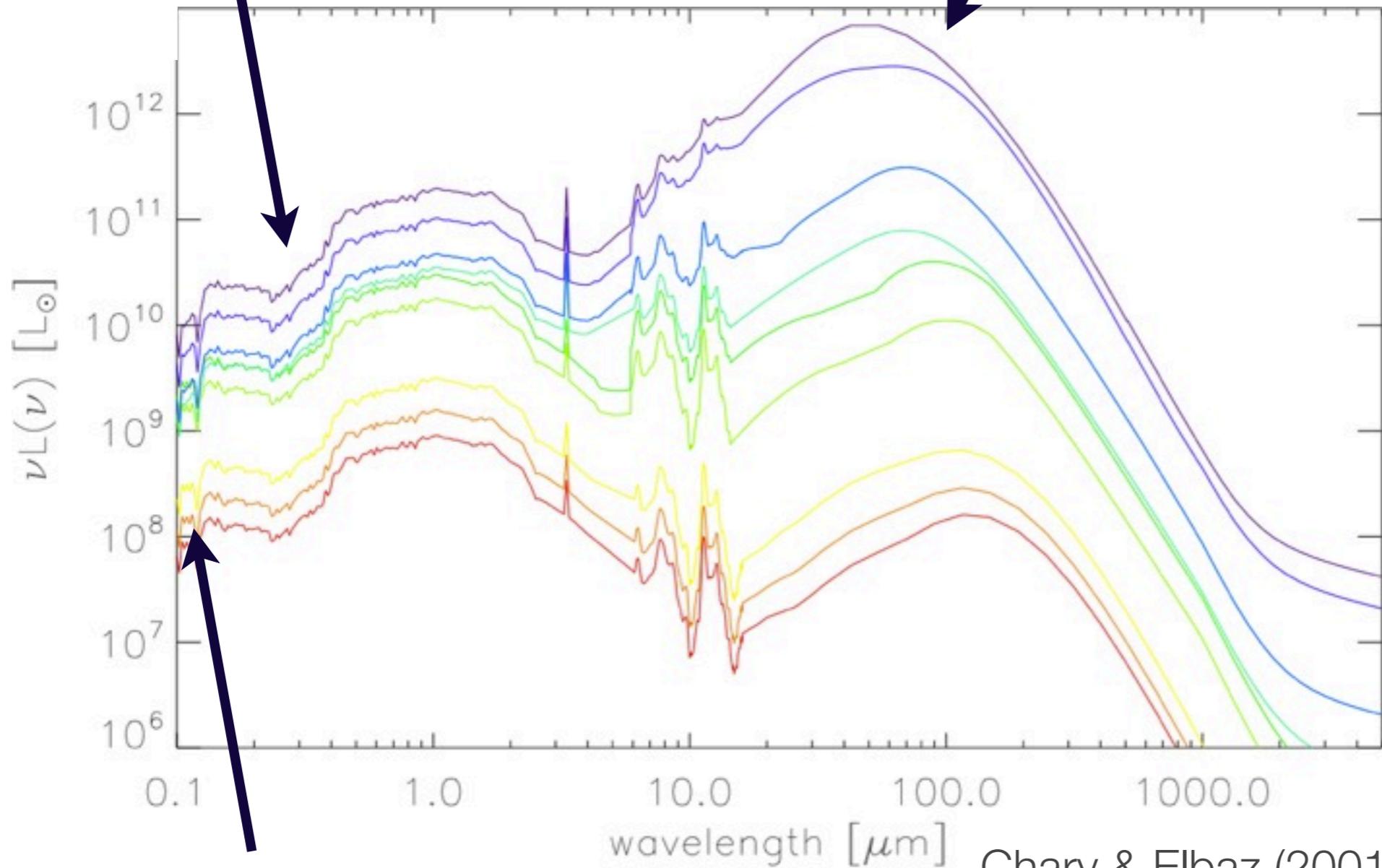
optical and infrared
backgrounds



CIB source: UV/optical light

Dust re-emits in the FIR

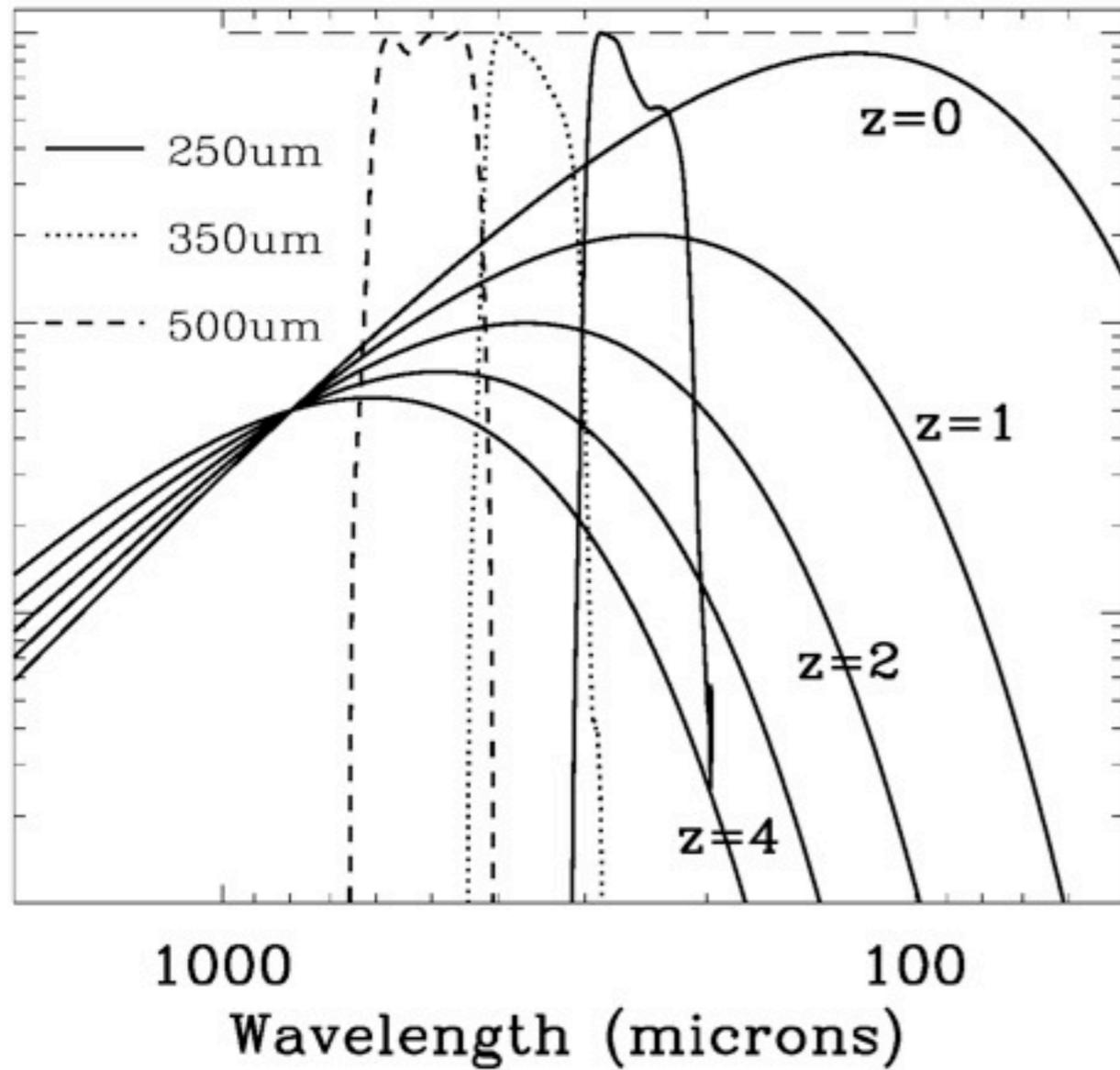
Optical/UV Starlight absorbed by dust



UV from young, hot stars

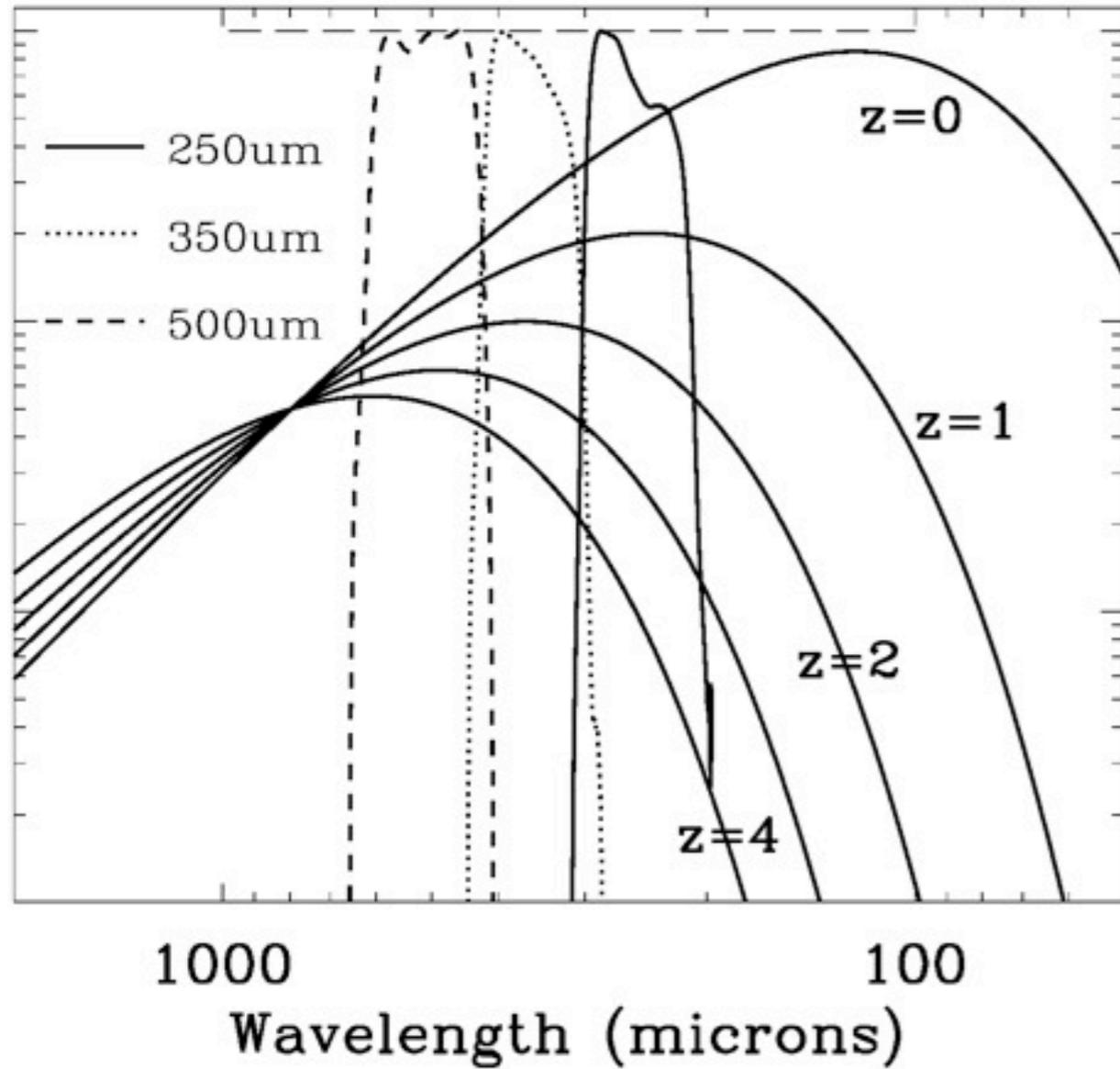
CIB source: UV/optical light

flux density vs. wavelength

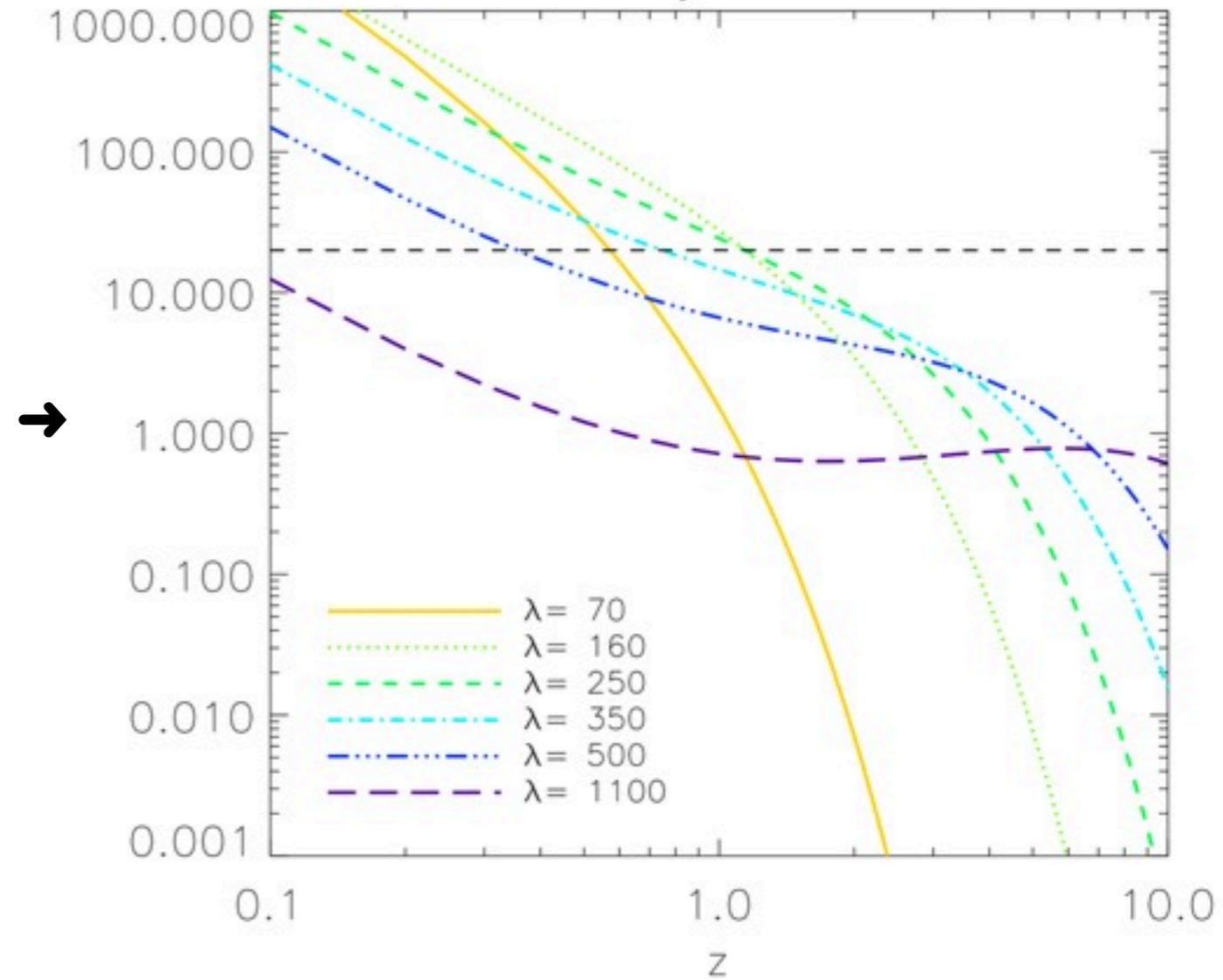


negative K -correction

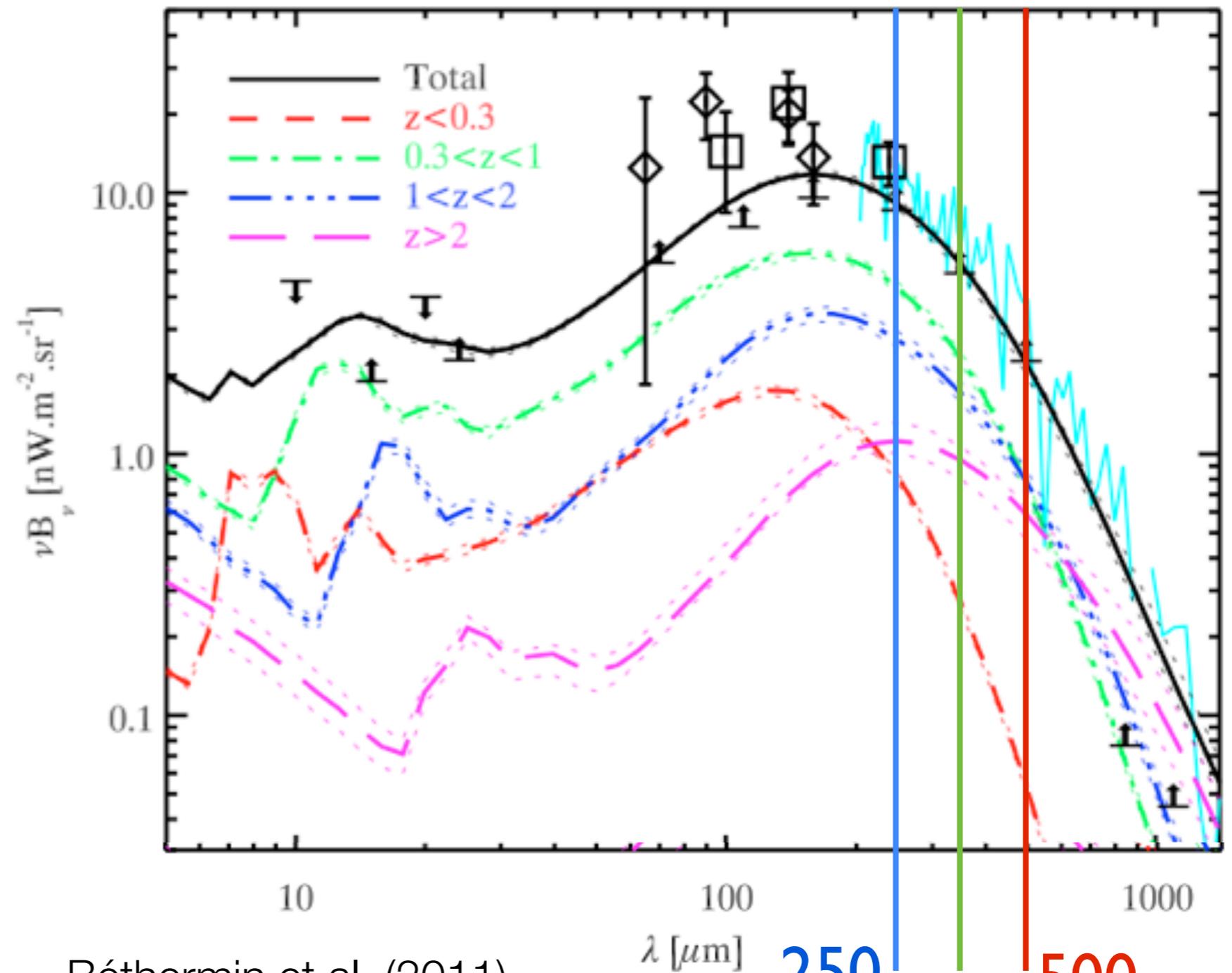
flux density vs. wavelength



flux density vs. redshift

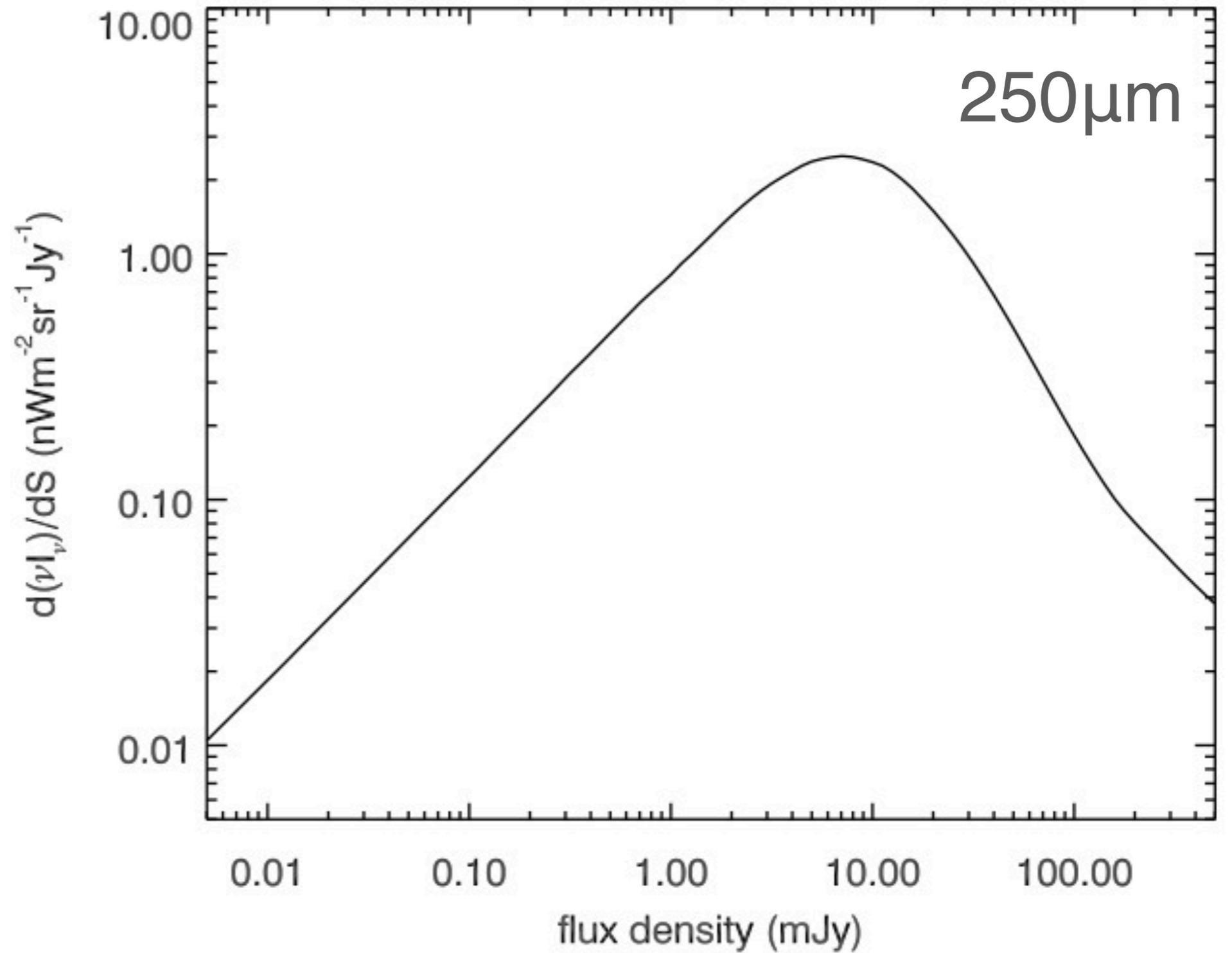


negative K -correction



Béthermin et al. (2011)
 arXiv:1010.1150

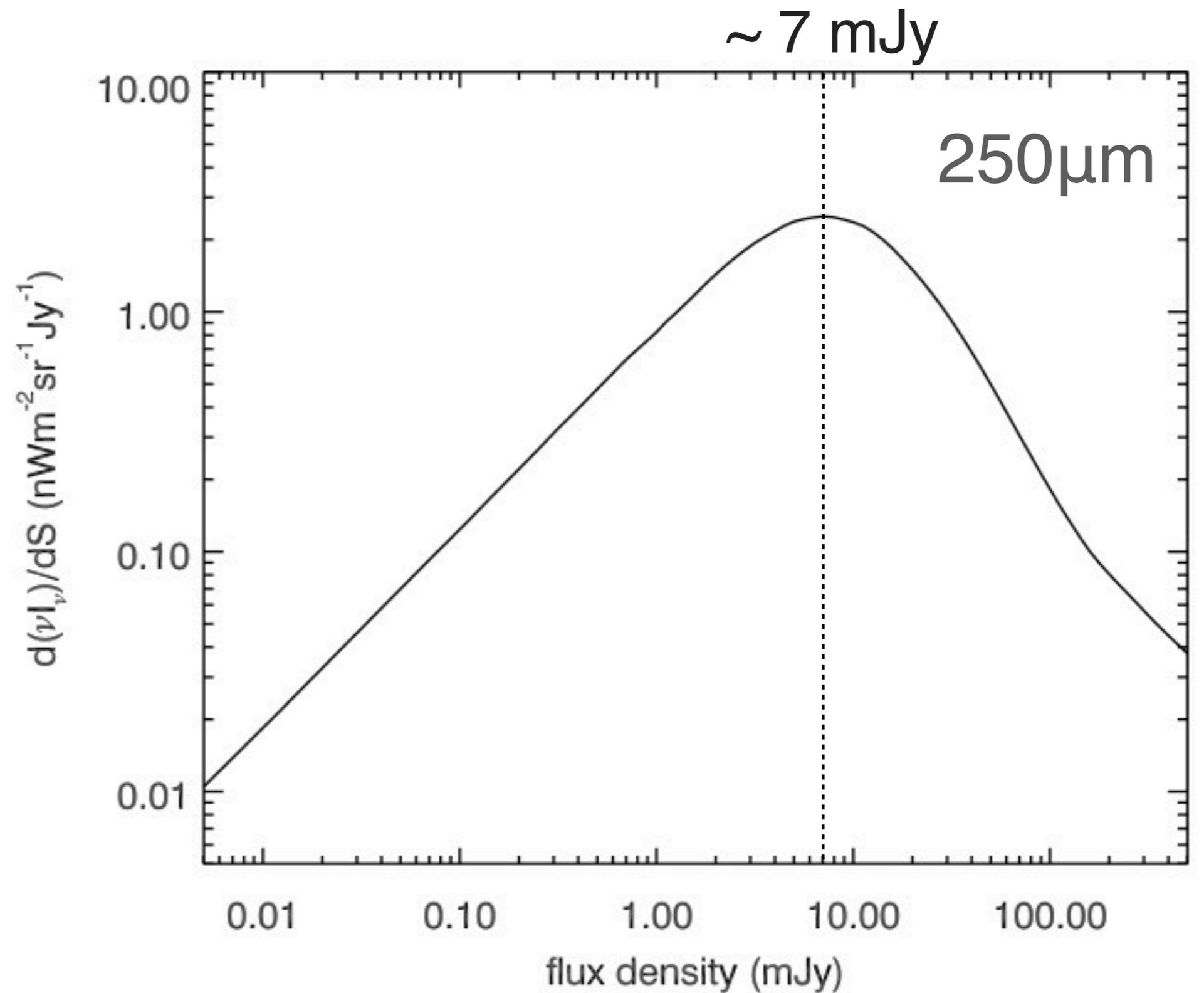
redshift distribution of CIB



Béthermin et al. (2011)
arXiv:1010.1150

differential CIB

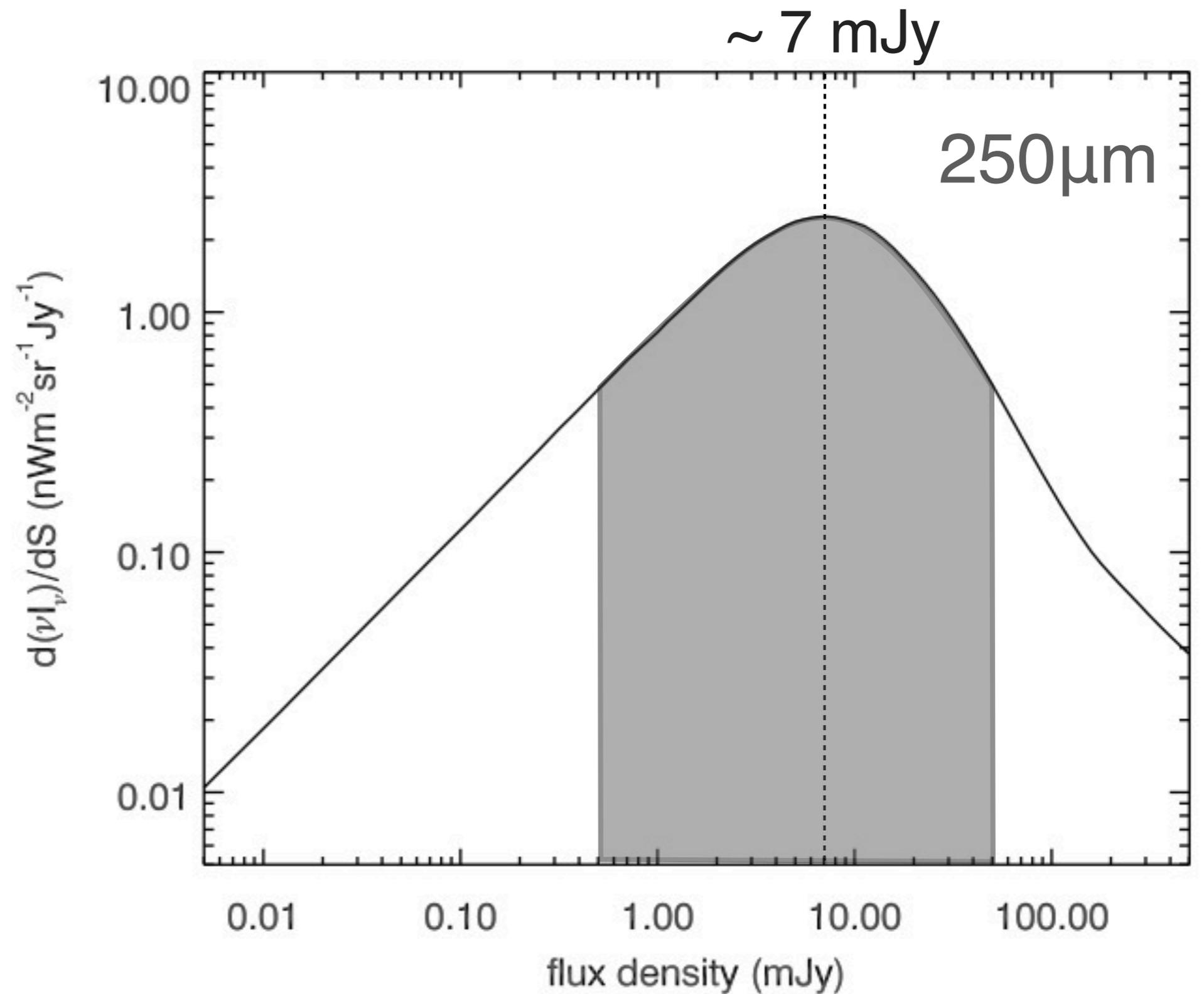
- Peak contribution to CIB from sources ~ 7 mJy



Béthermin et al. (2011)
arXiv:1010.1150

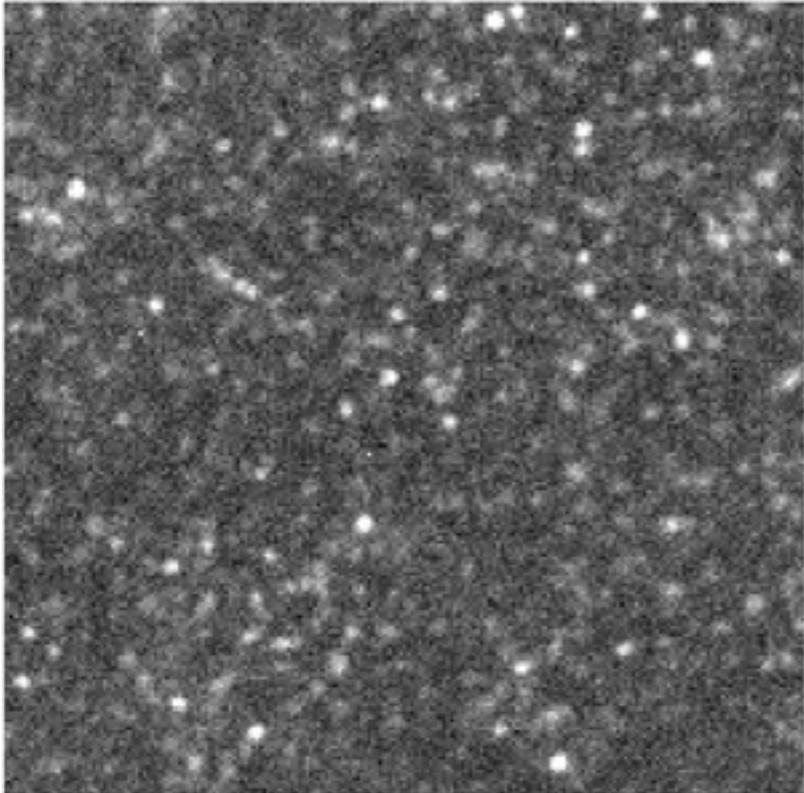
differential CIB

- Peak contribution to CIB from sources ~ 7 mJy
- $\sim 90\%$ from sources between 0.5 and 50 mJy



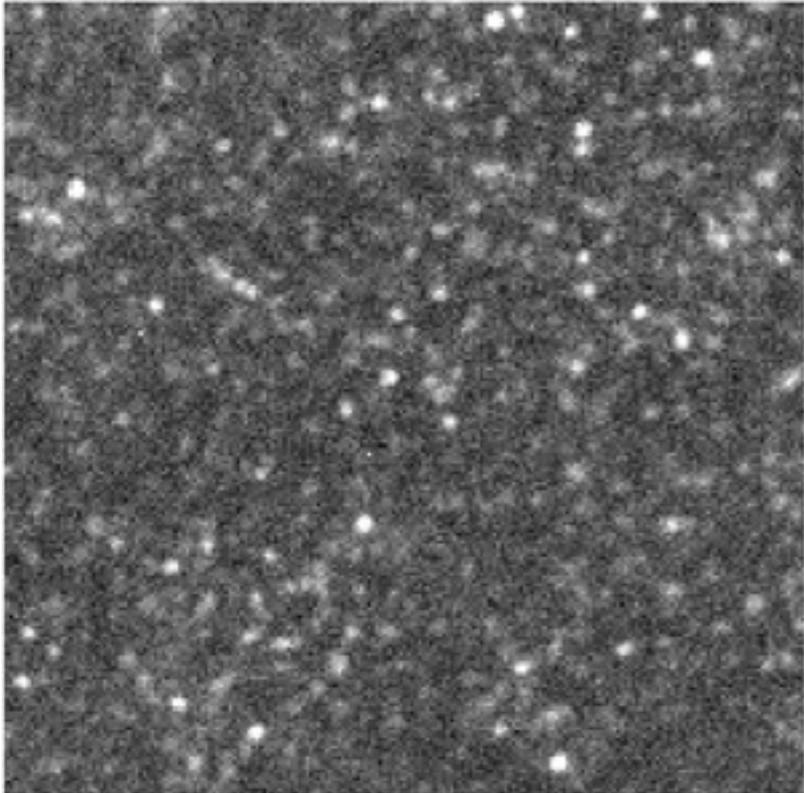
Béthermin et al. (2011)
arXiv:1010.1150

differential CIB



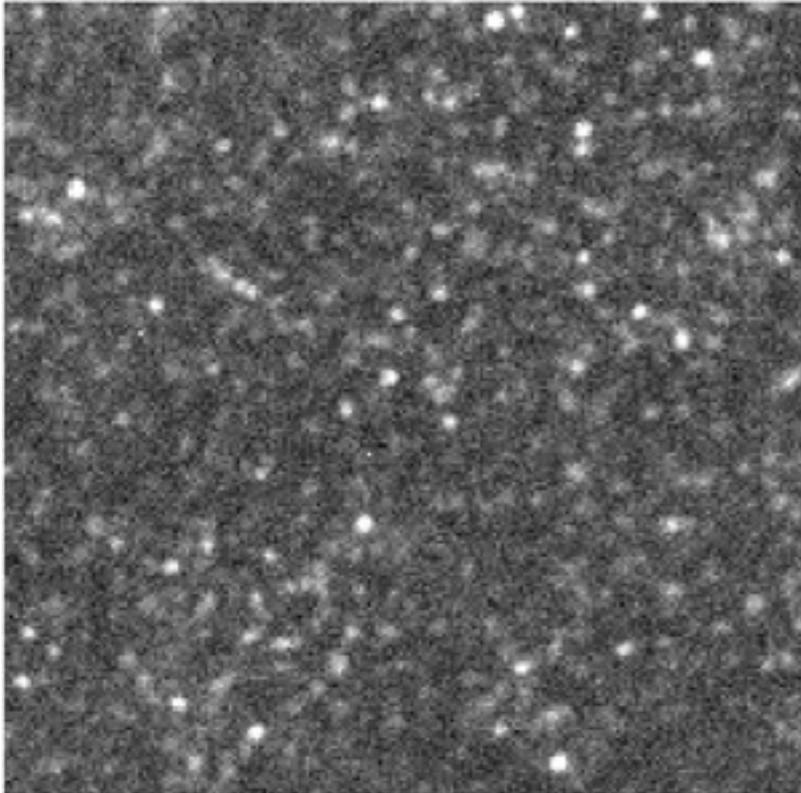
2 repeats (fls)

source confusion

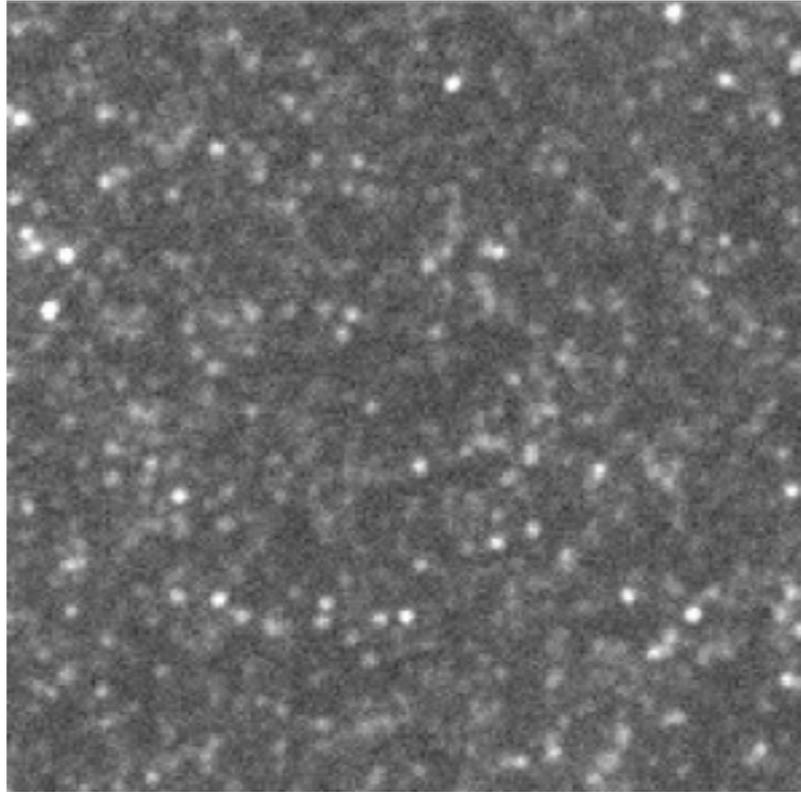


2 repeats (fls)
33.5 mJy (3σ)

source confusion

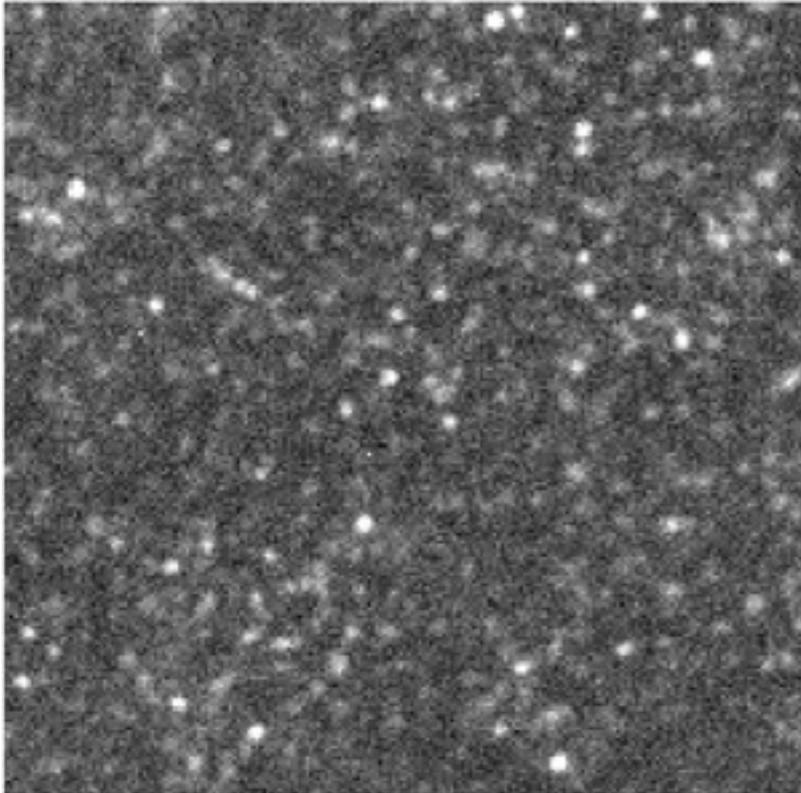


2 repeats (fls)
33.5 mJy (3σ)

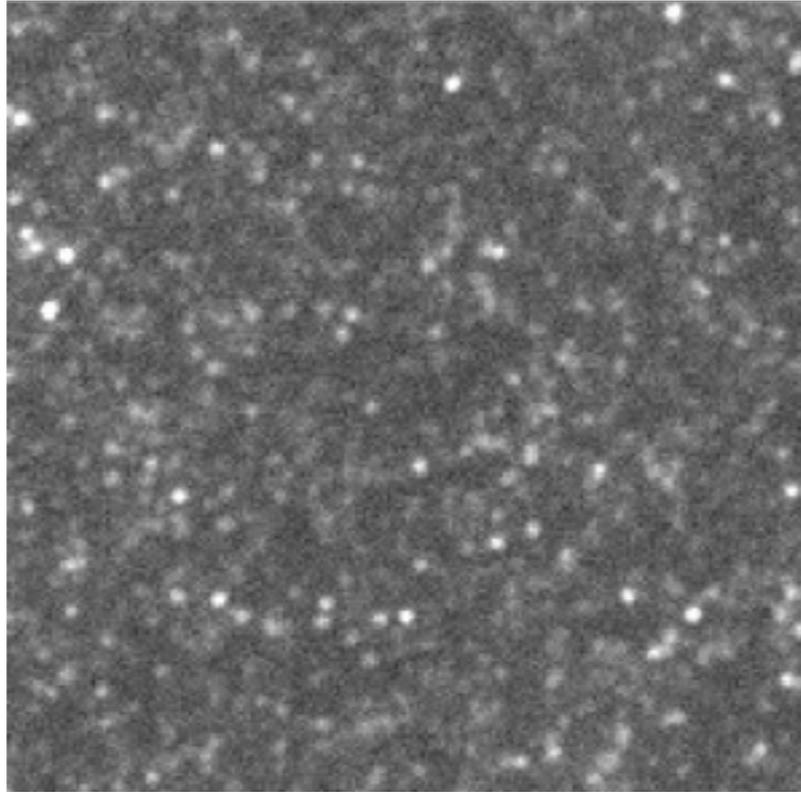


7 repeats (uds)

source confusion

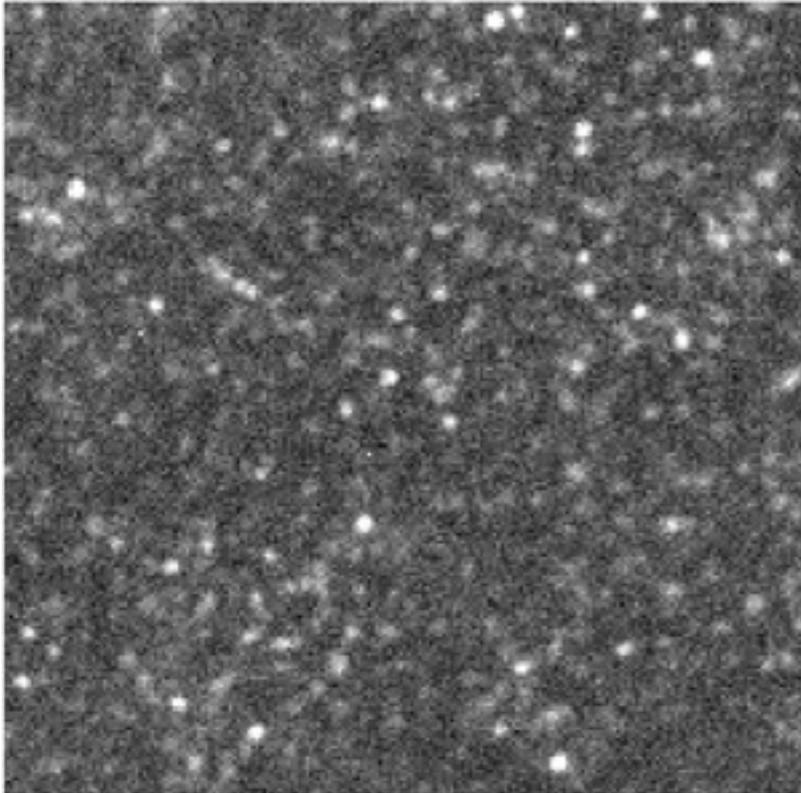


2 repeats (fls)
33.5 mJy (3σ)

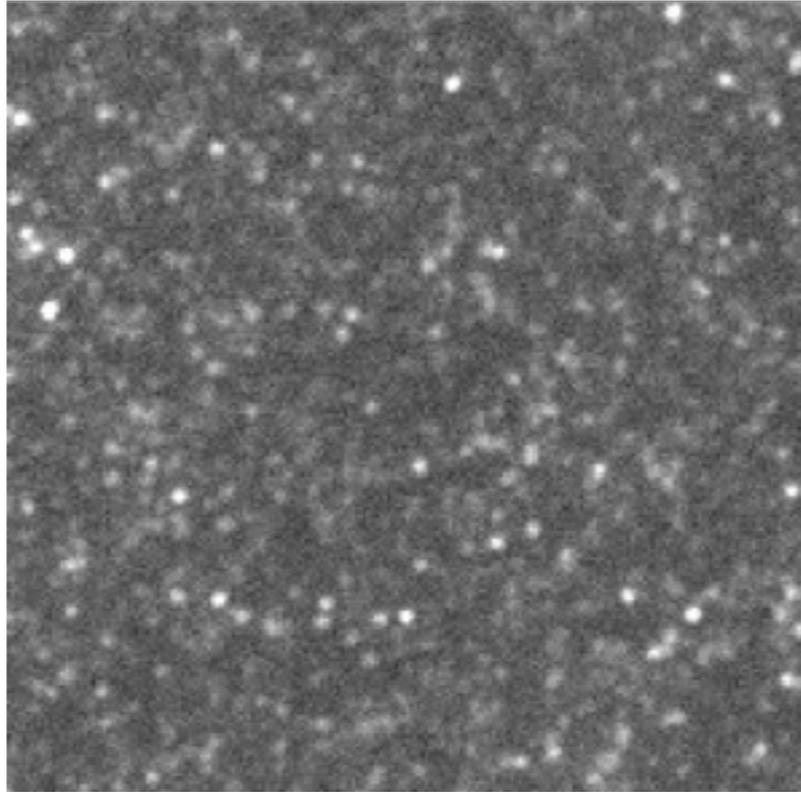


7 repeats (uds)
24.7 mJy (3σ)

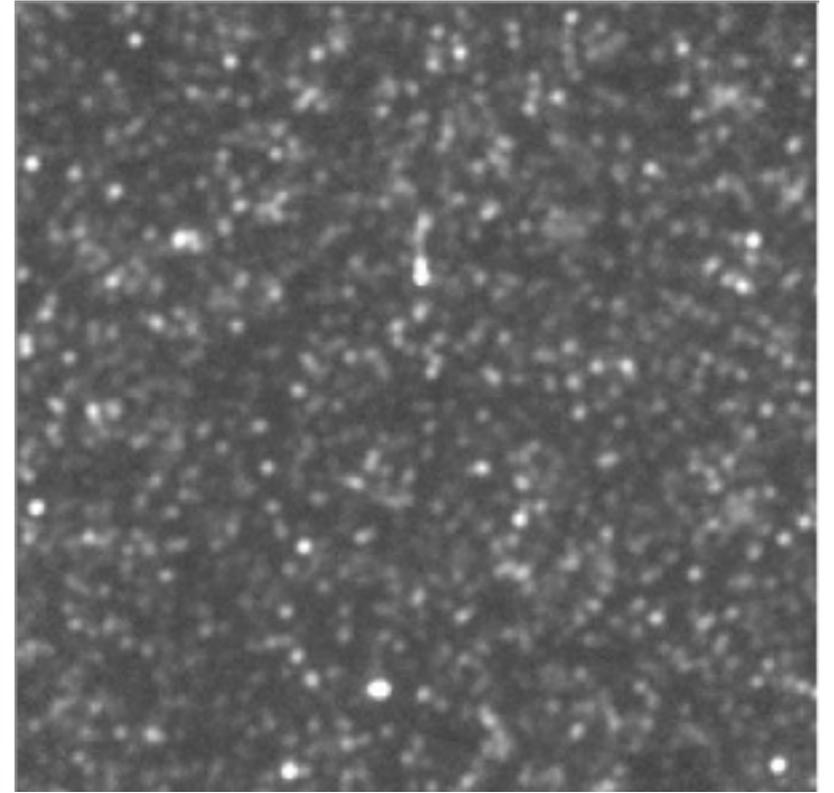
source confusion



2 repeats (fls)
33.5 mJy (3σ)

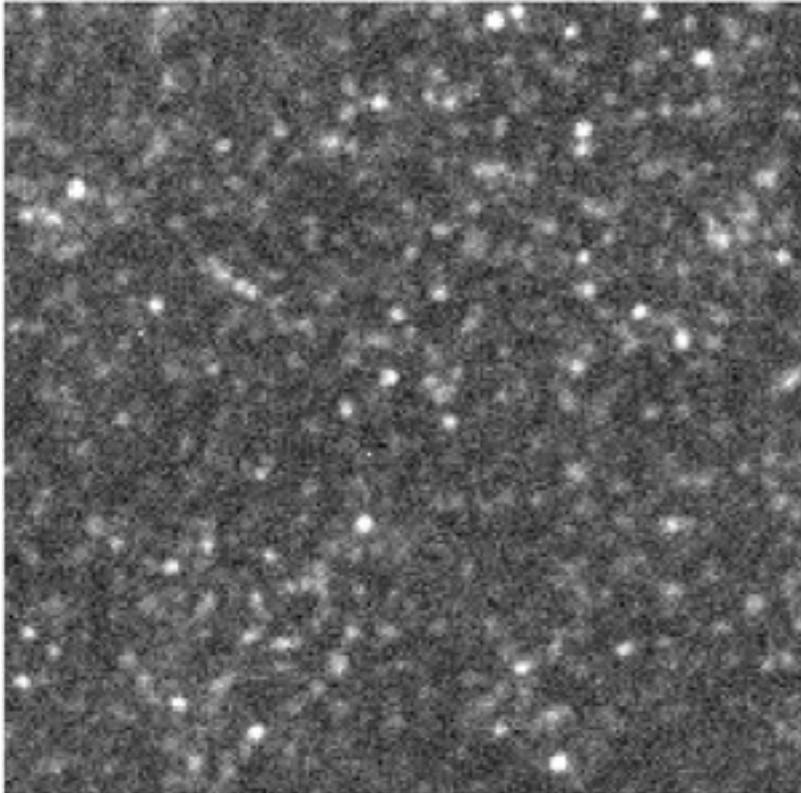


7 repeats (uds)
24.7 mJy (3σ)

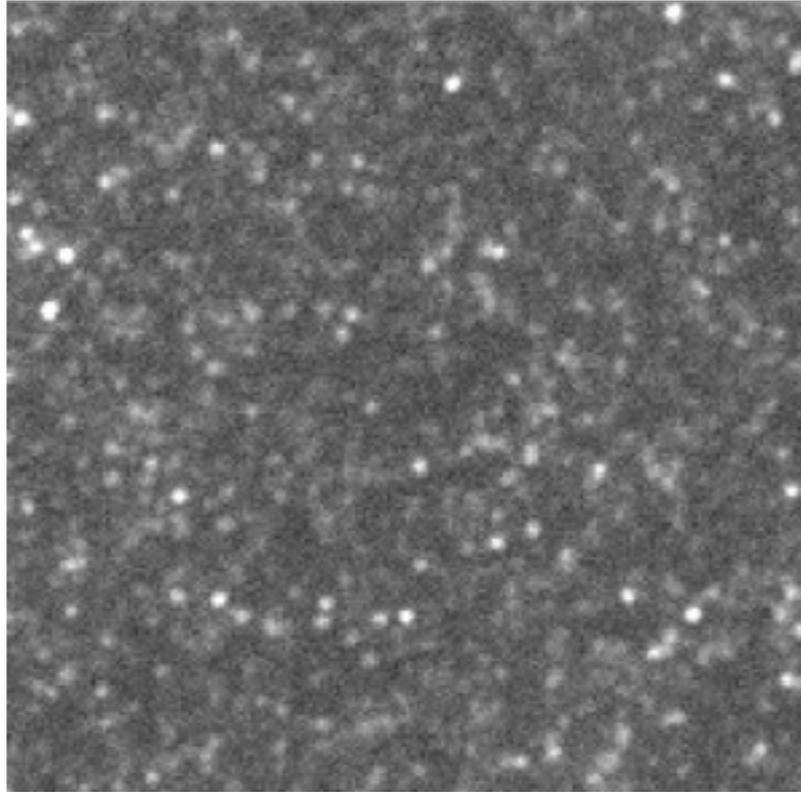


76 repeats (goods-s)

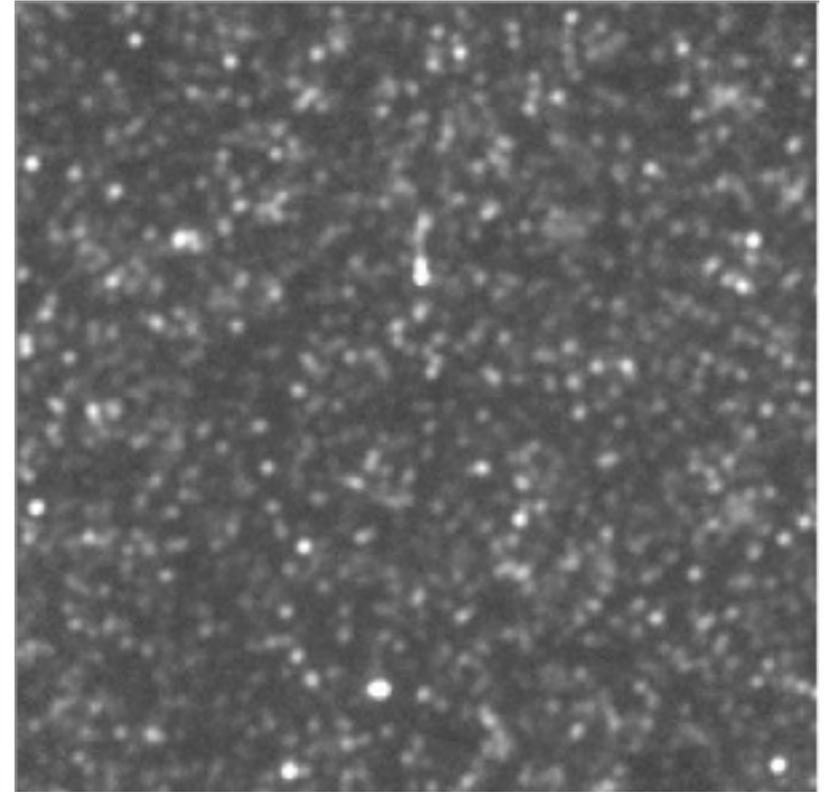
source confusion



2 repeats (fls)
33.5 mJy (3σ)

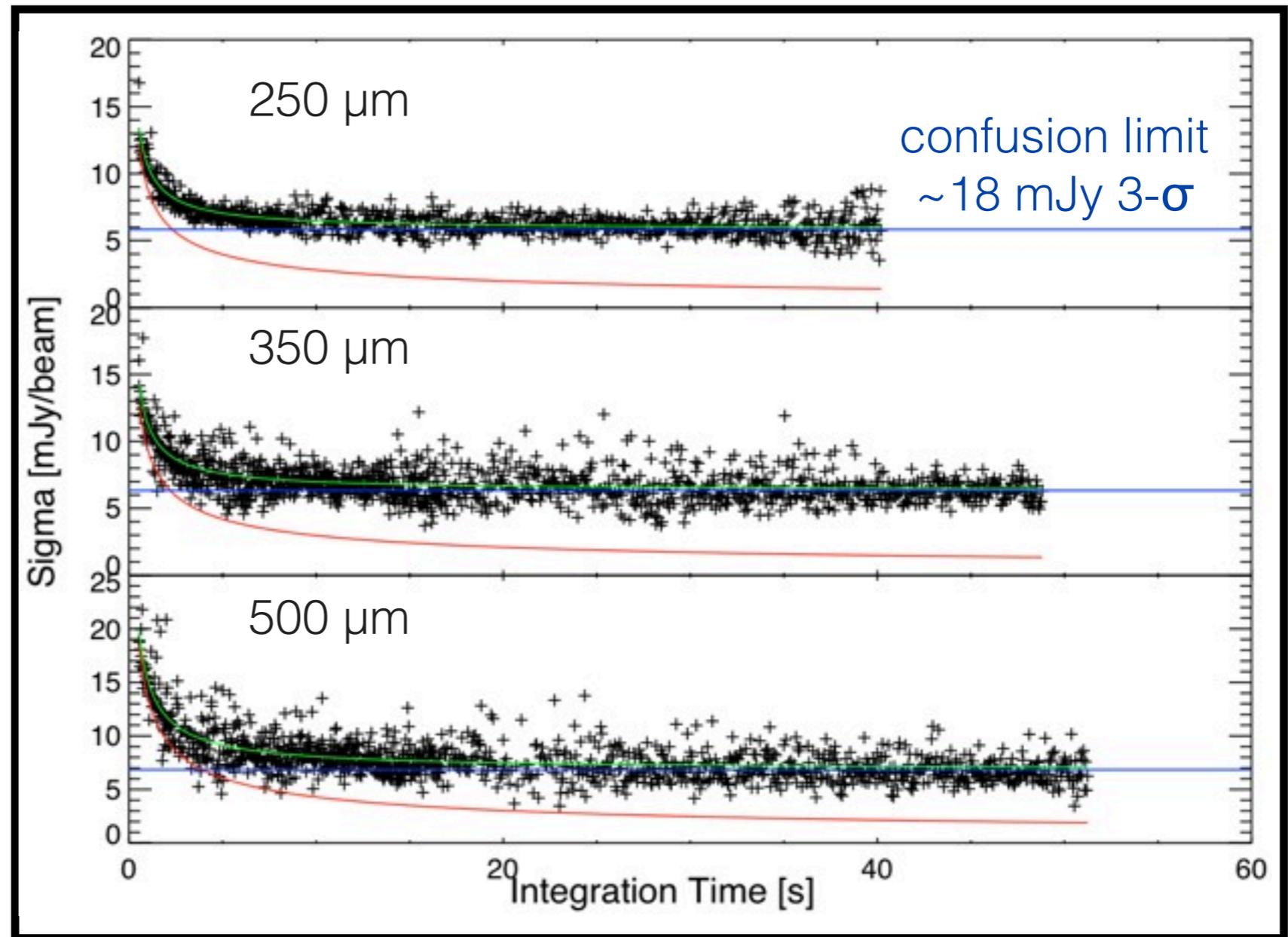


7 repeats (uds)
24.7 mJy (3σ)



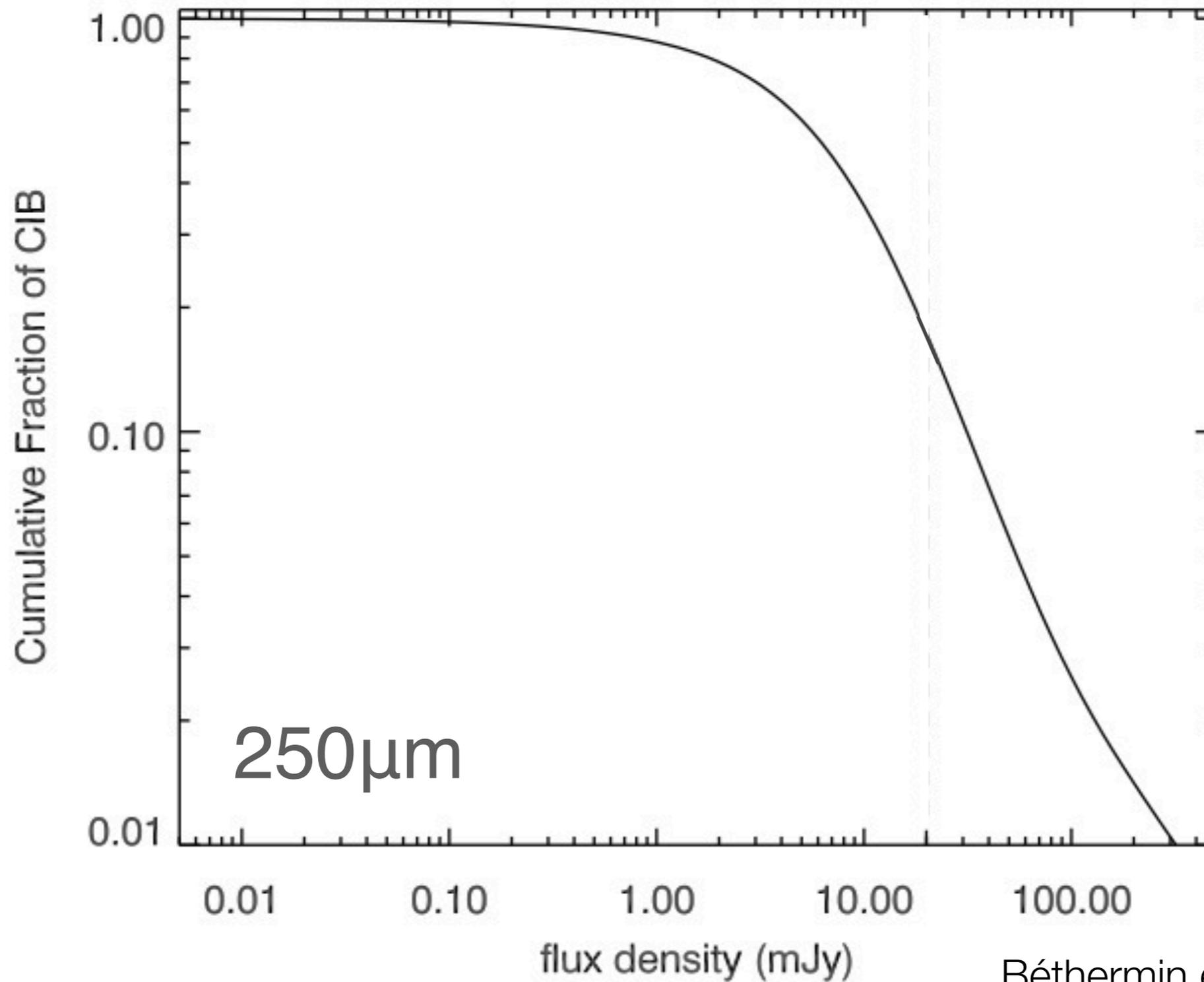
76 repeats (goods-s)
20.2 mJy (3σ)

source confusion



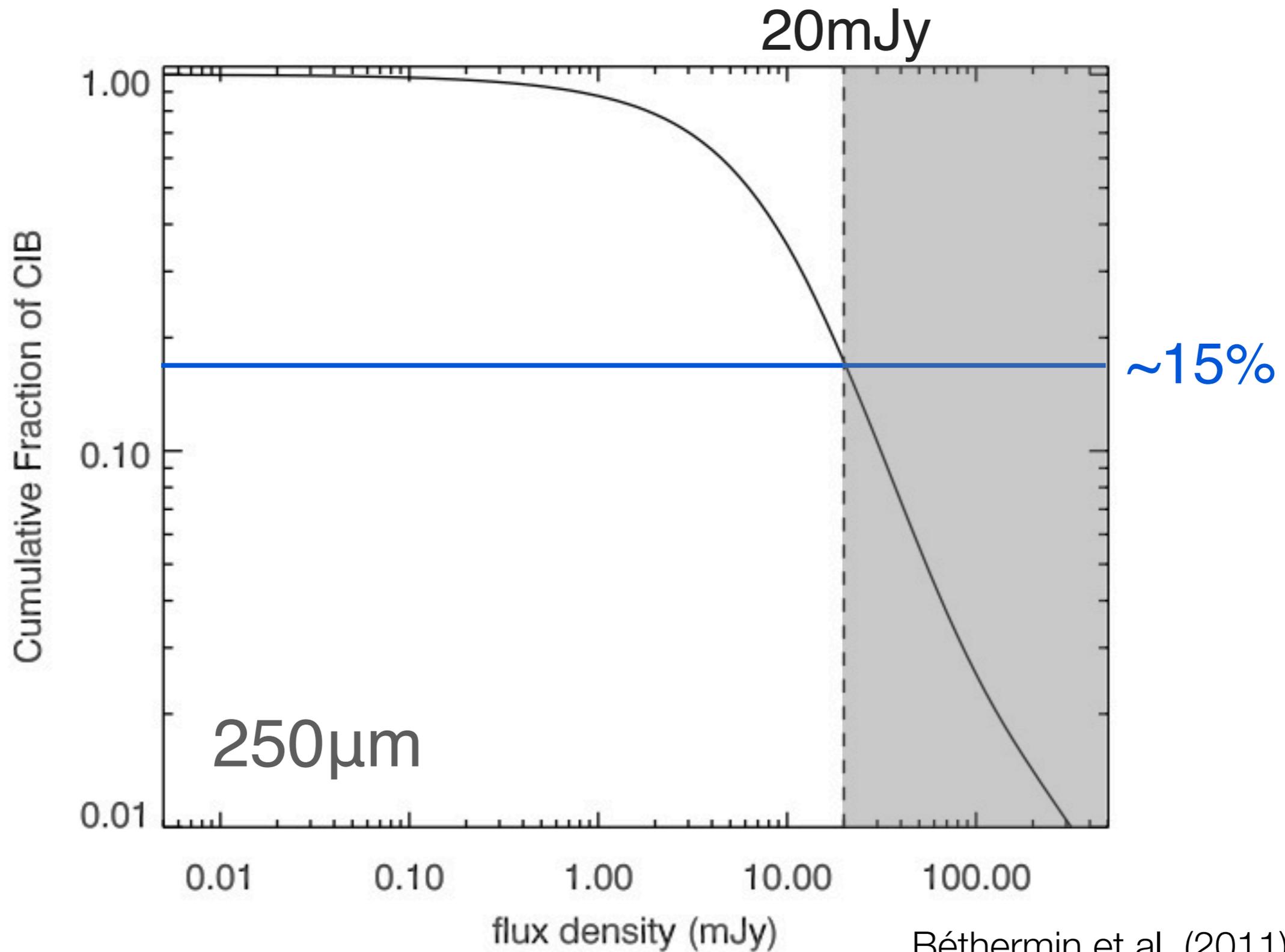
Nguyen et al. (2009)

source confusion



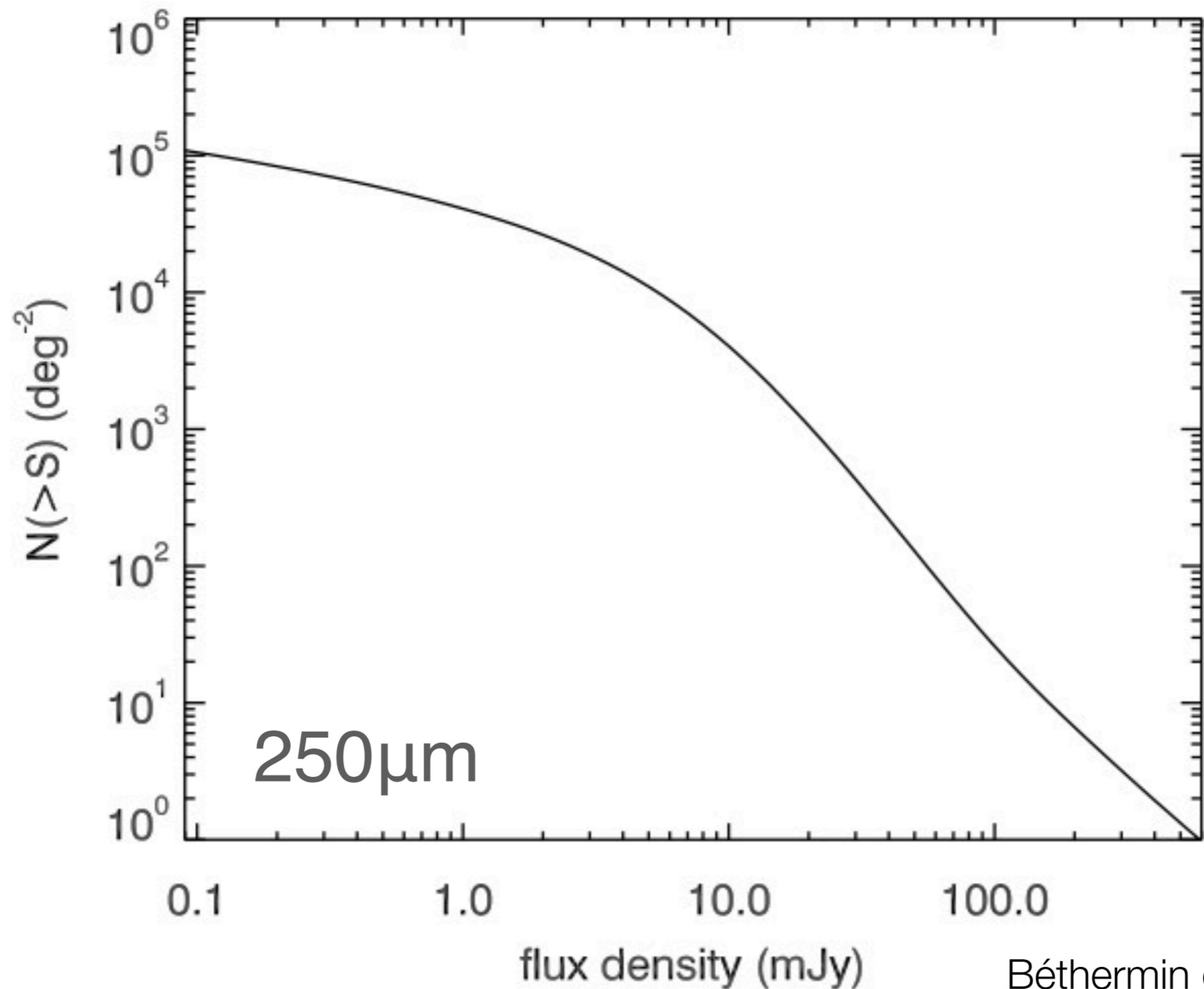
Béthermin et al. (2011)
arXiv:1010.1150

cumulative CIB



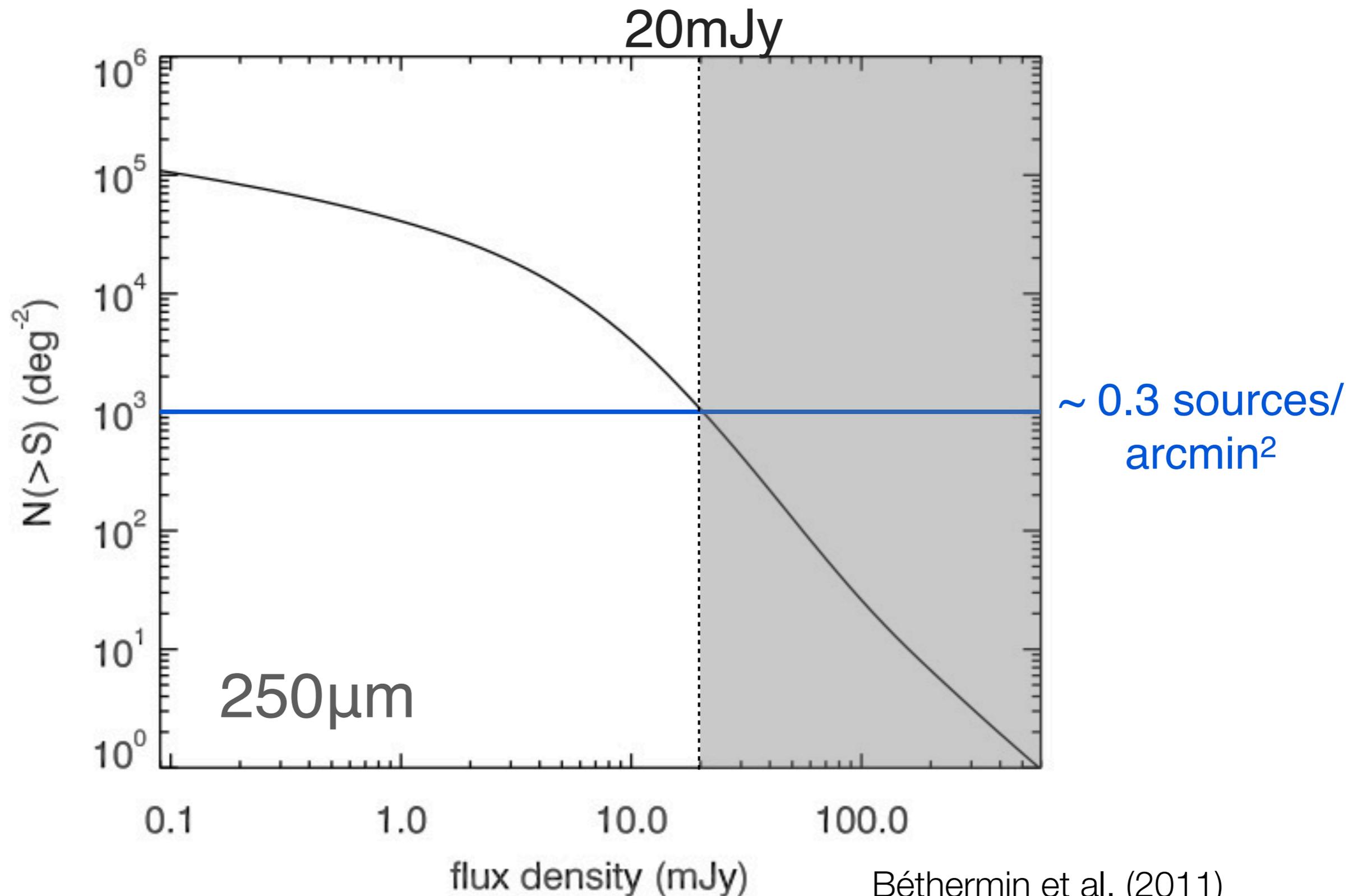
Béthermin et al. (2011)
arXiv:1010.1150

cumulative CIB



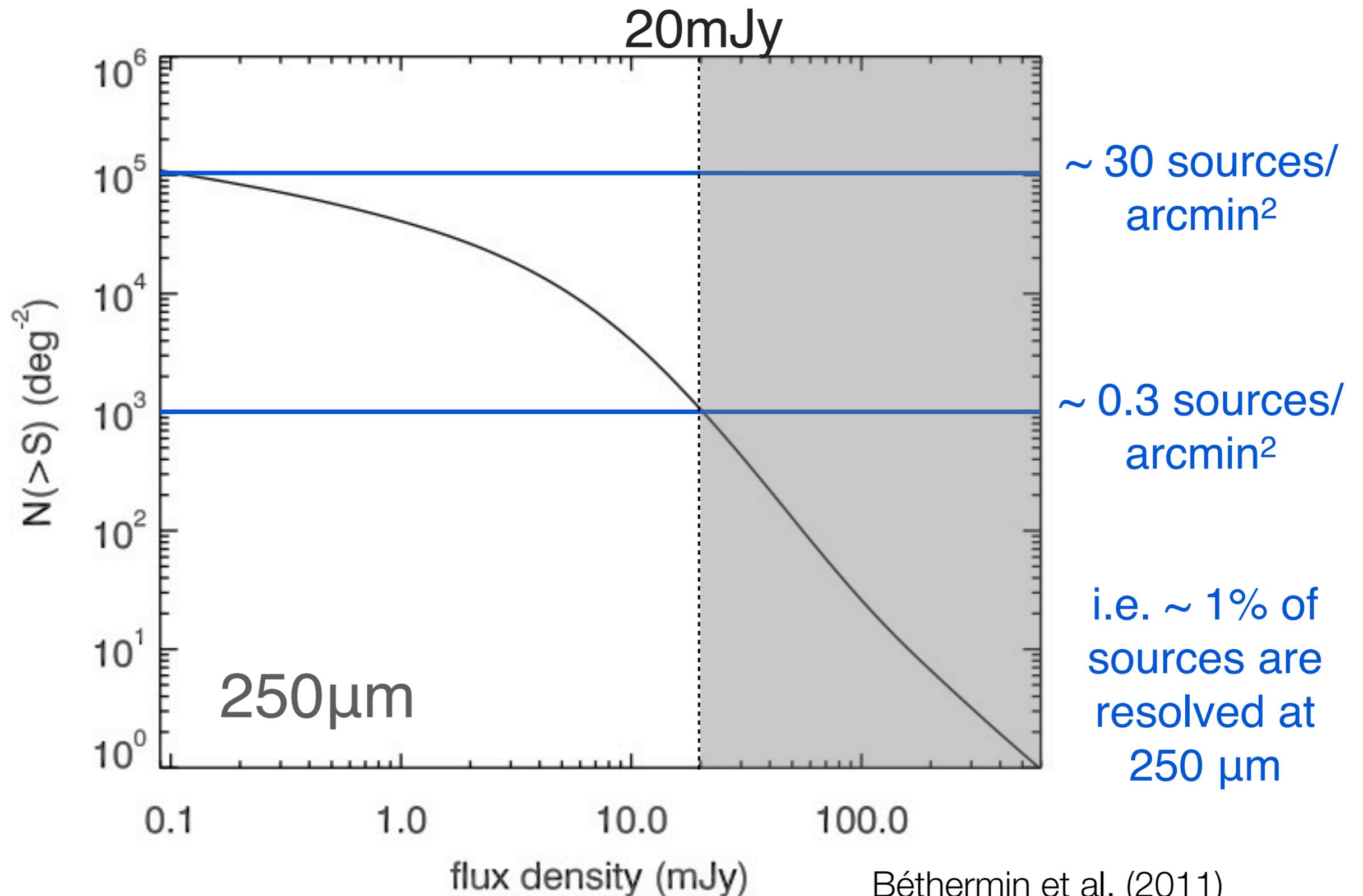
Béthermin et al. (2011)
arXiv:1010.1150

cumulative number counts



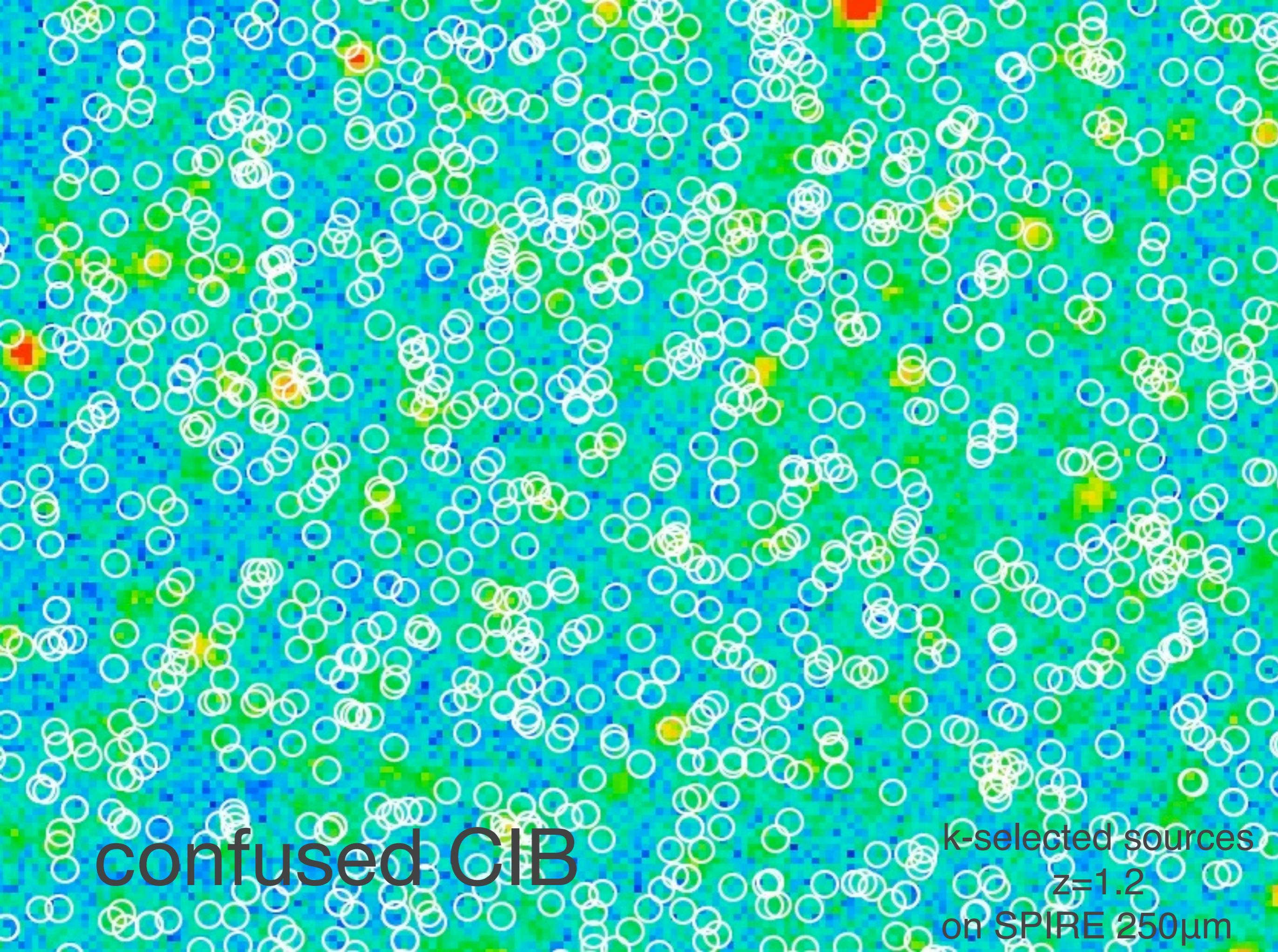
Béthermin et al. (2011)
arXiv:1010.1150

cumulative number counts



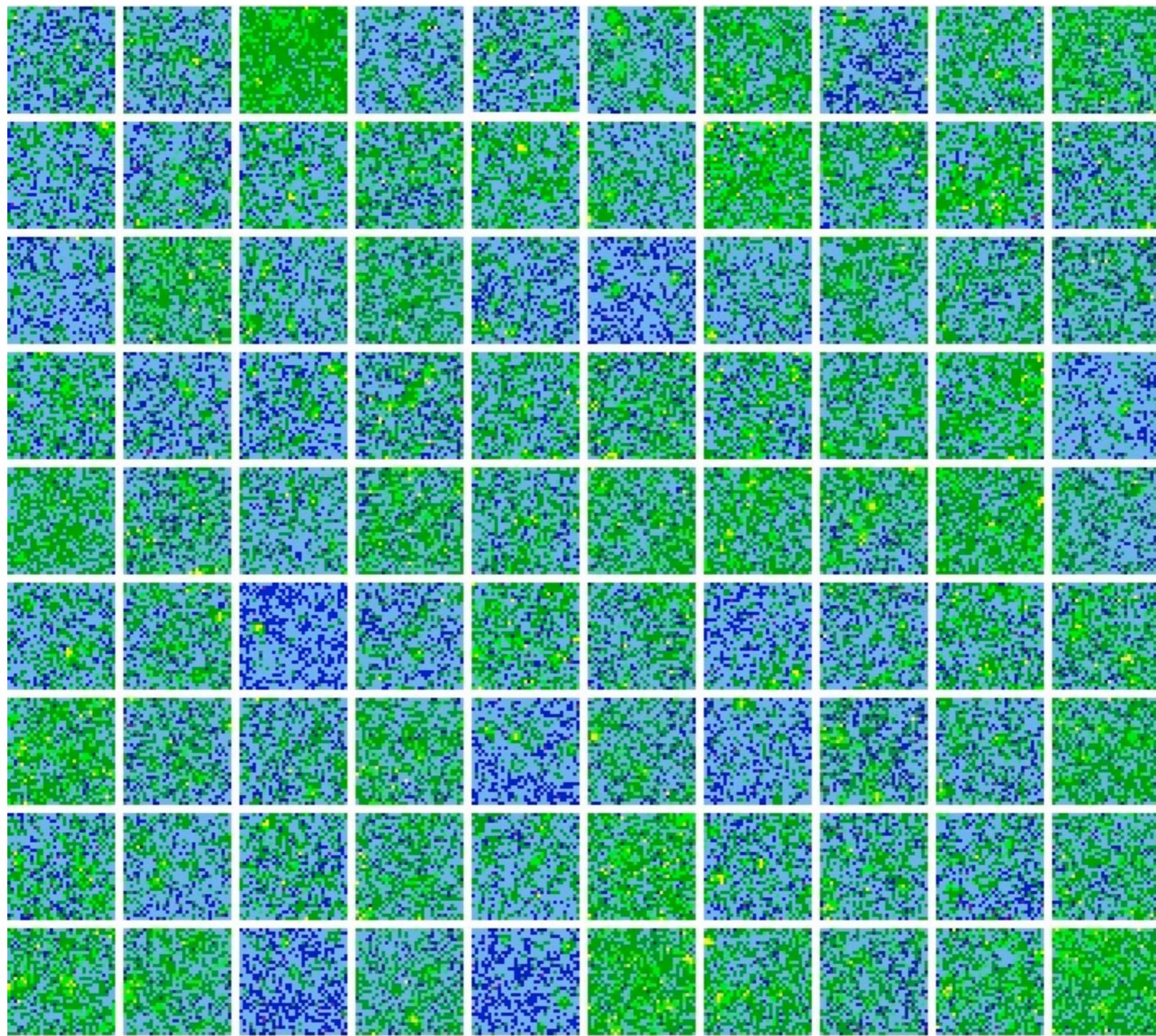
Béthermin et al. (2011)
arXiv:1010.1150

cumulative number counts

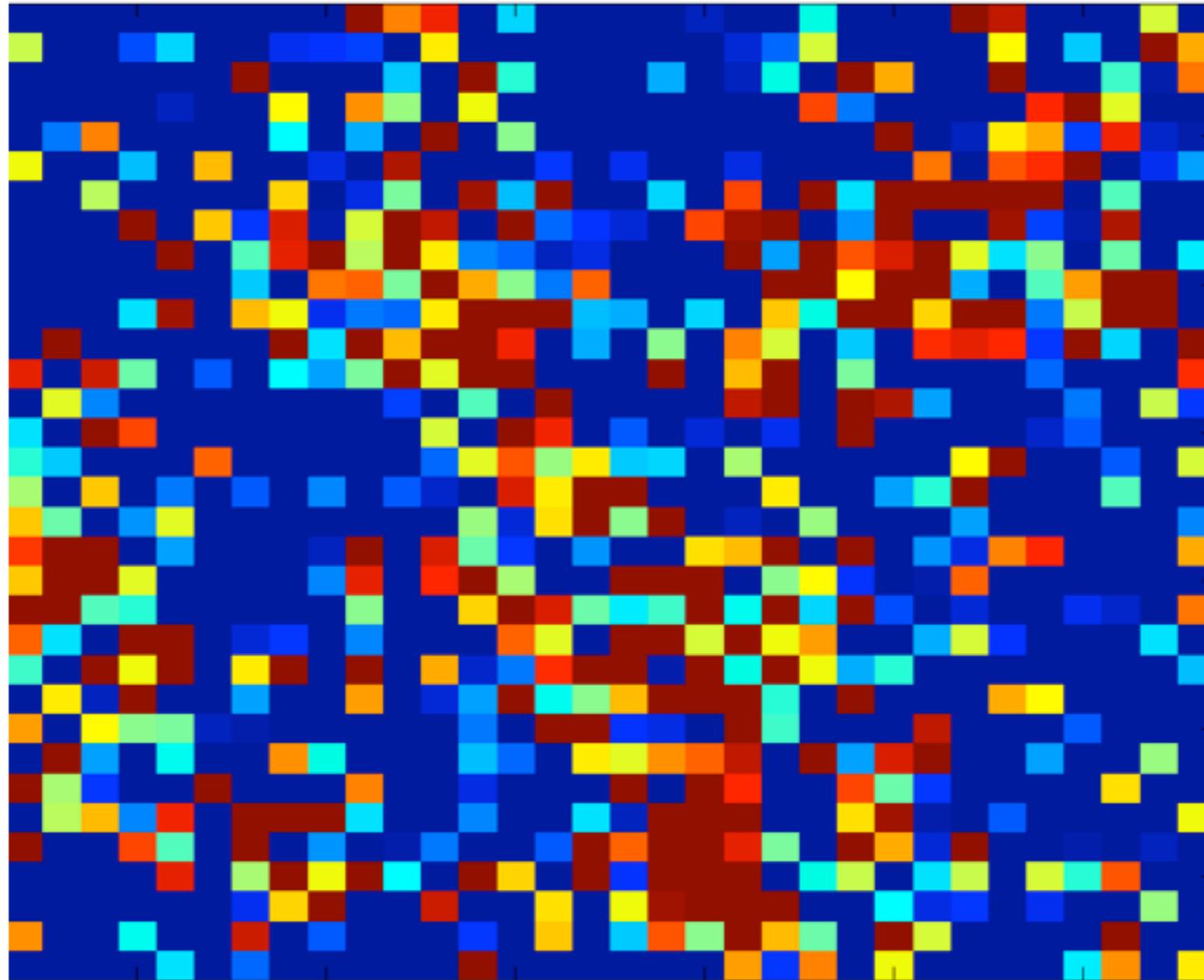


confused CIB

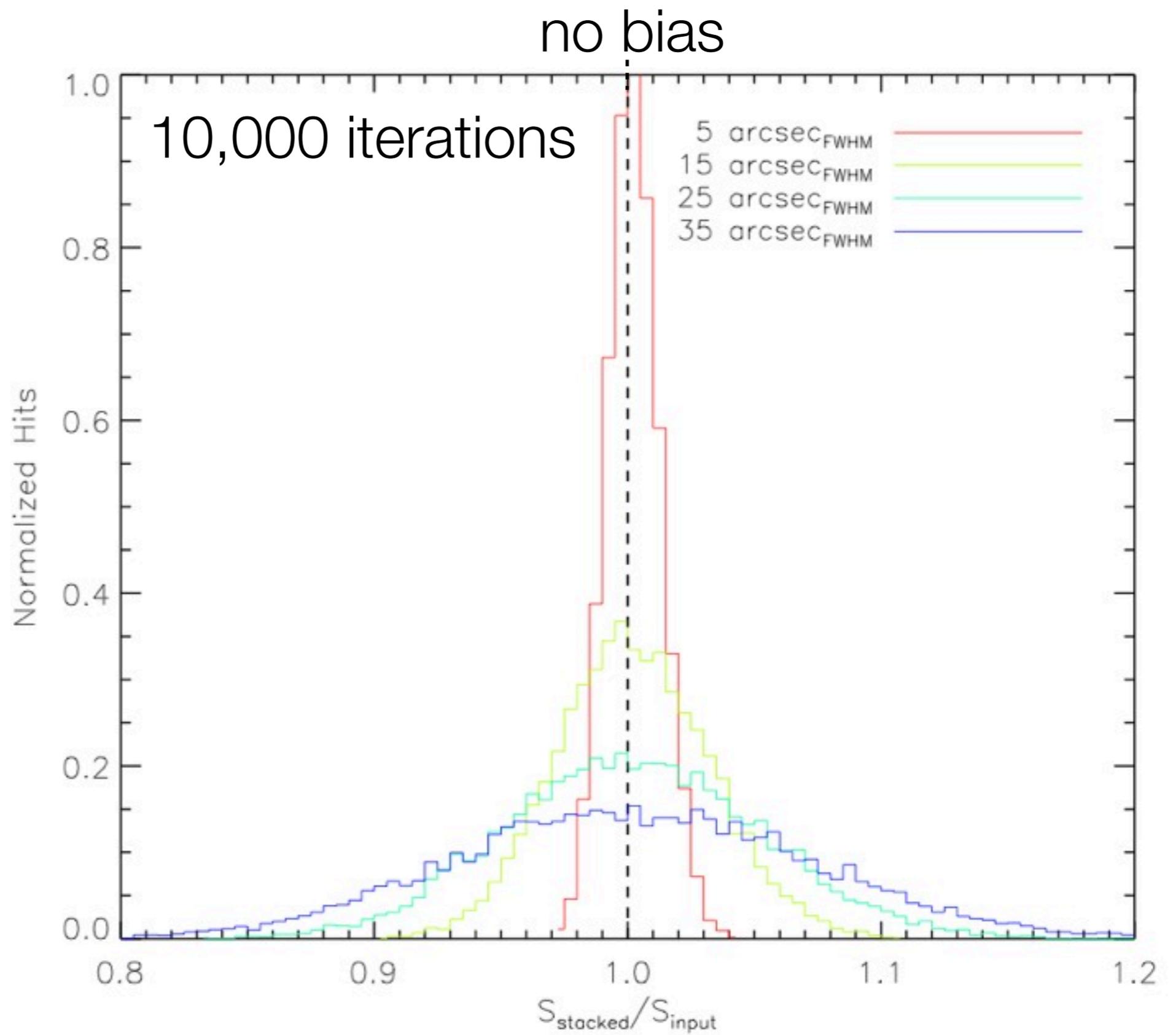
k-selected sources
 $z=1.2$
on SPIRE $250\mu\text{m}$



thumbnail stacking



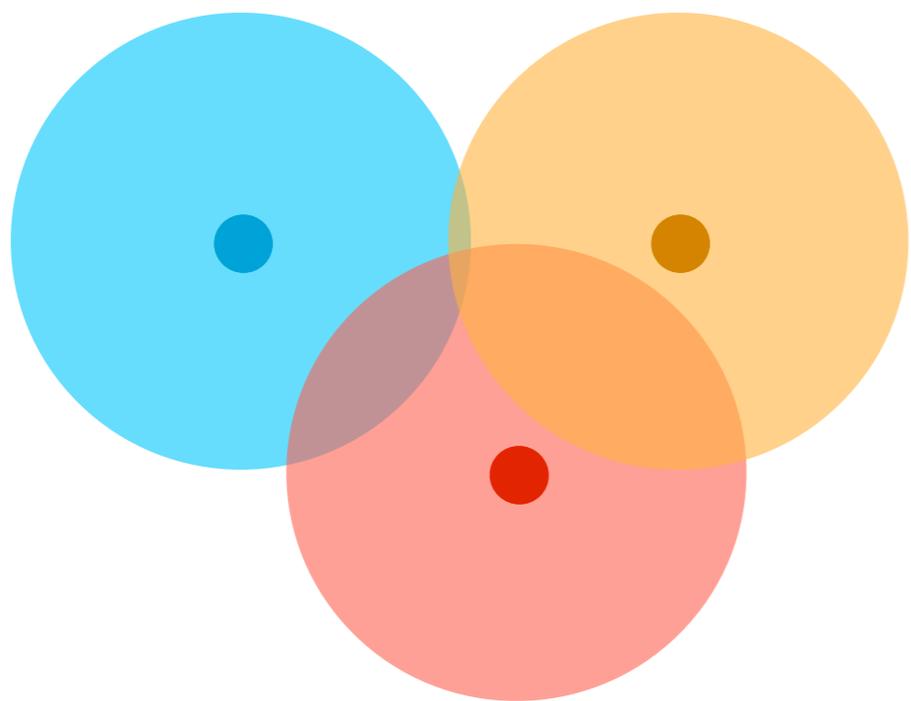
thumbnail stacking



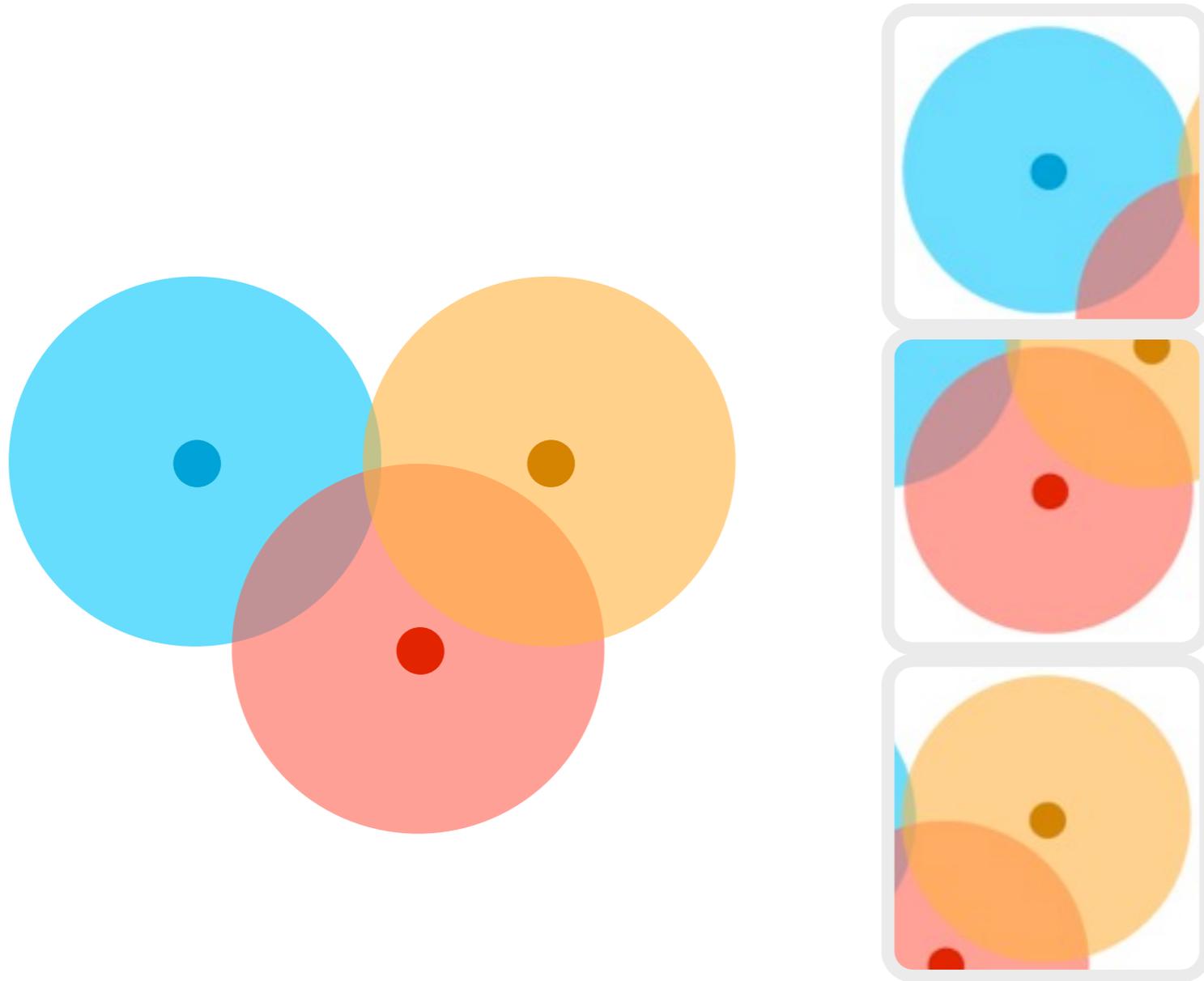
uncorrelated source simulation



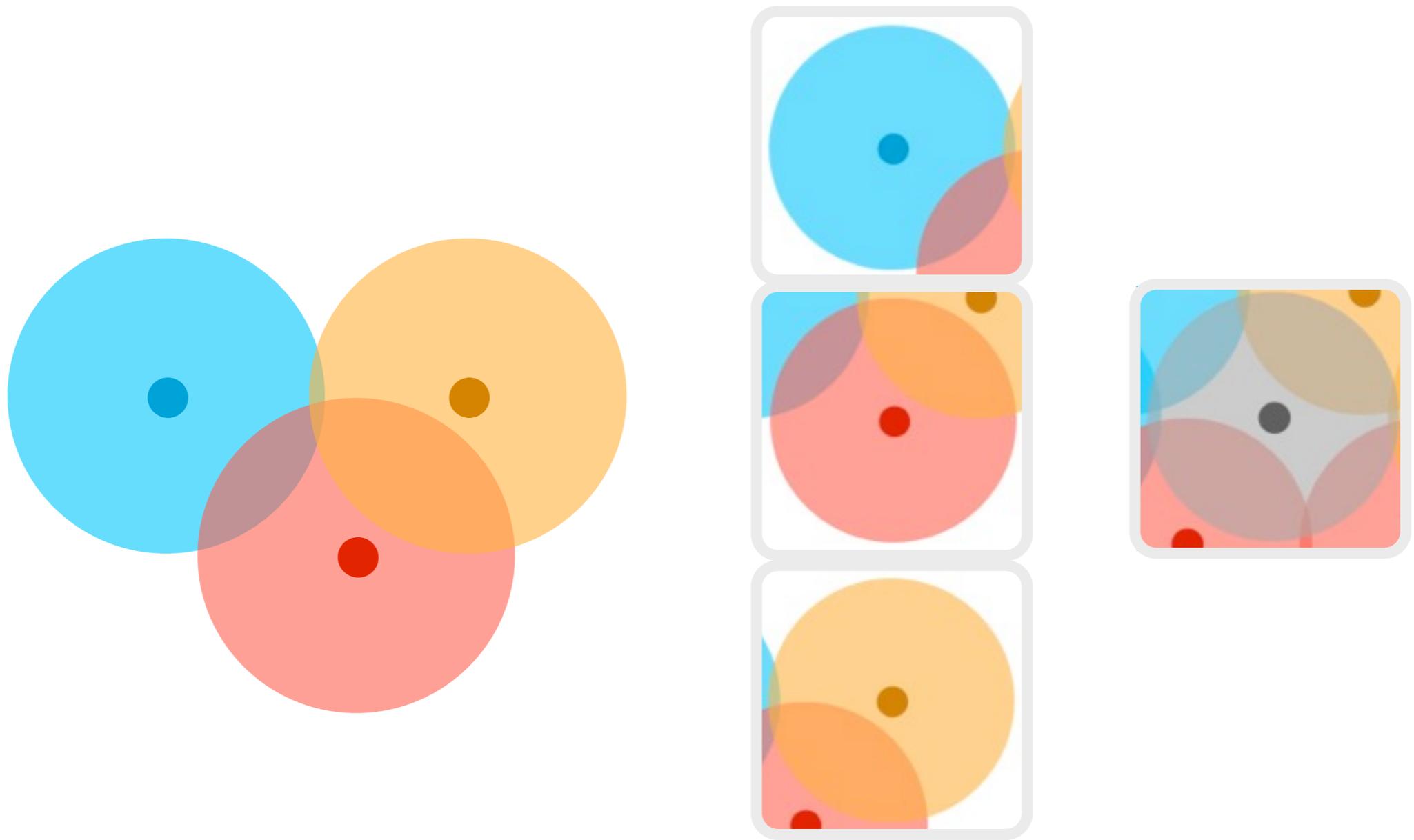
clustering induced bias



clustering induced bias



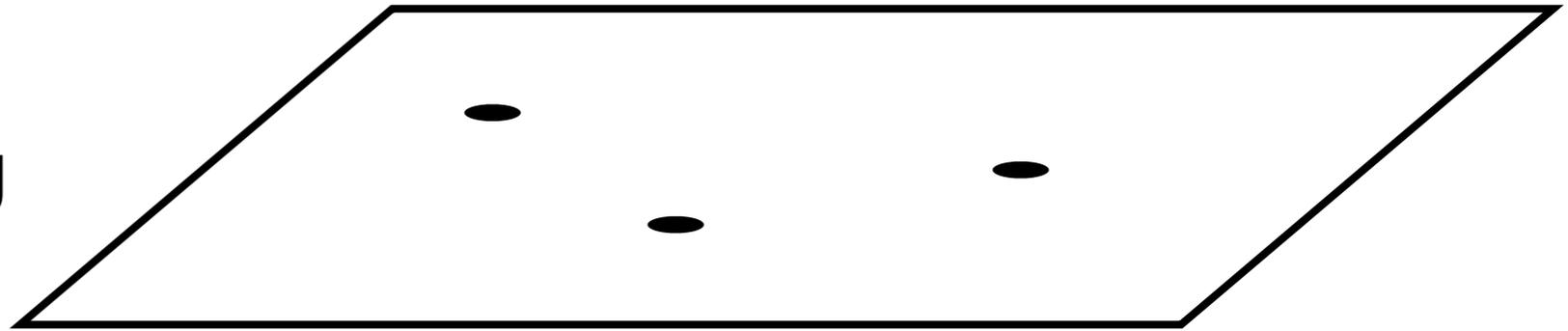
clustering induced bias



clustering induced bias

simultaneous stacking

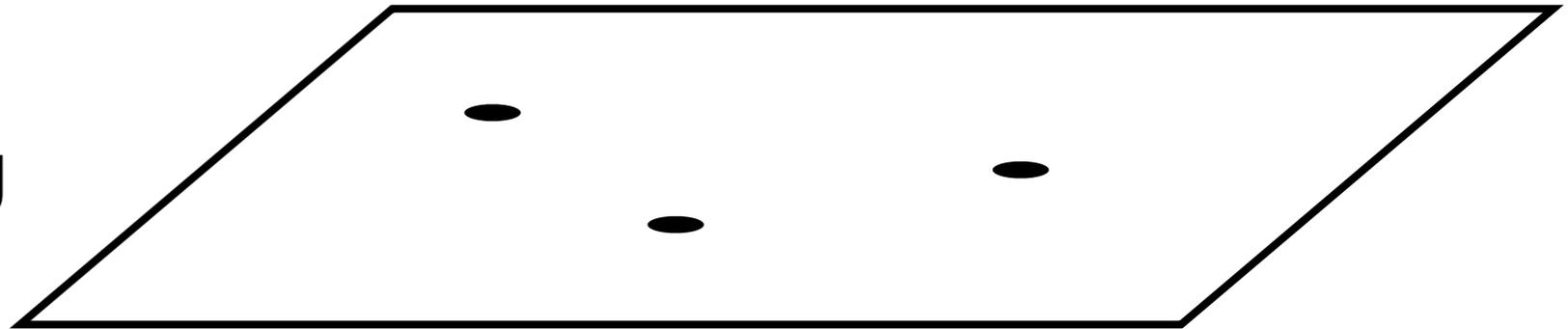
make hits map from catalog



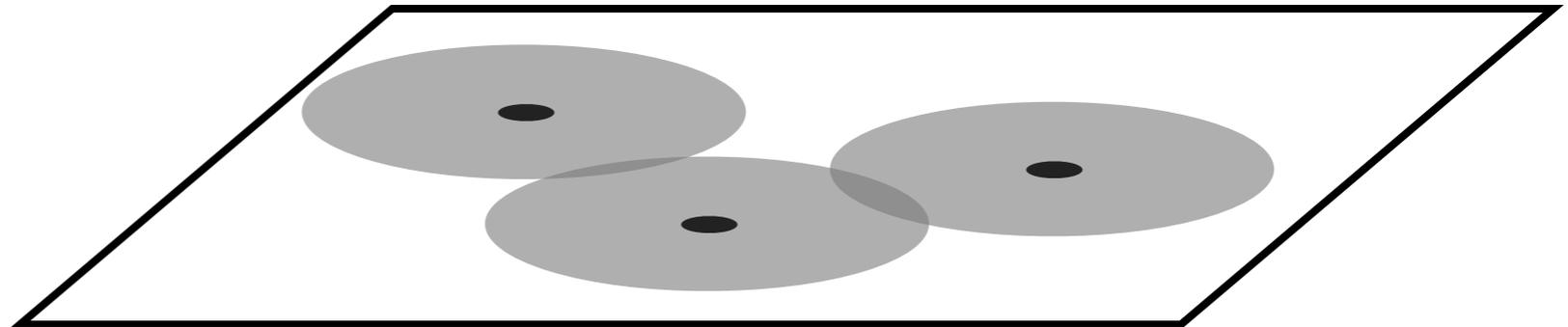
Formalism developed w/
Lorenzo Moncelsi (Caltech) &
Isaac Roseboom (ROE)

simultaneous stacking

make hits map from catalog



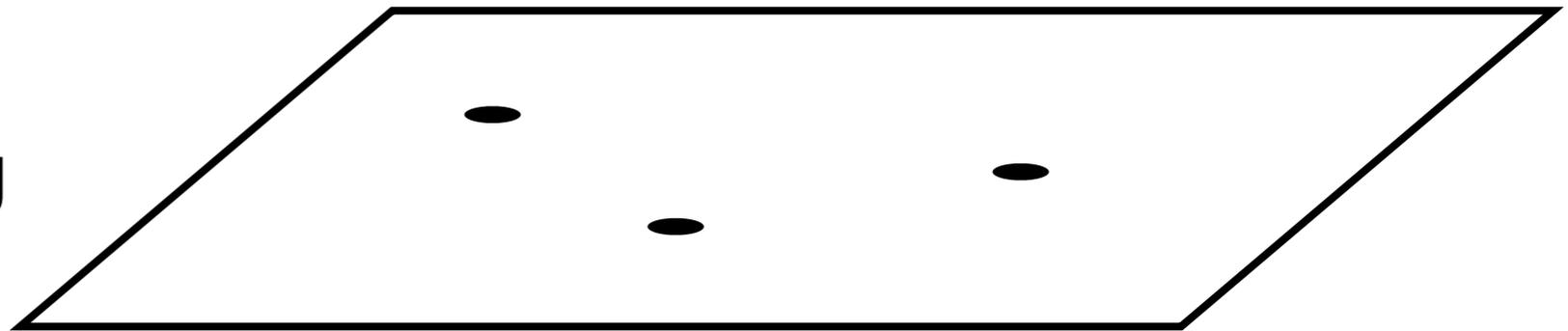
convolve with map p.s.f.



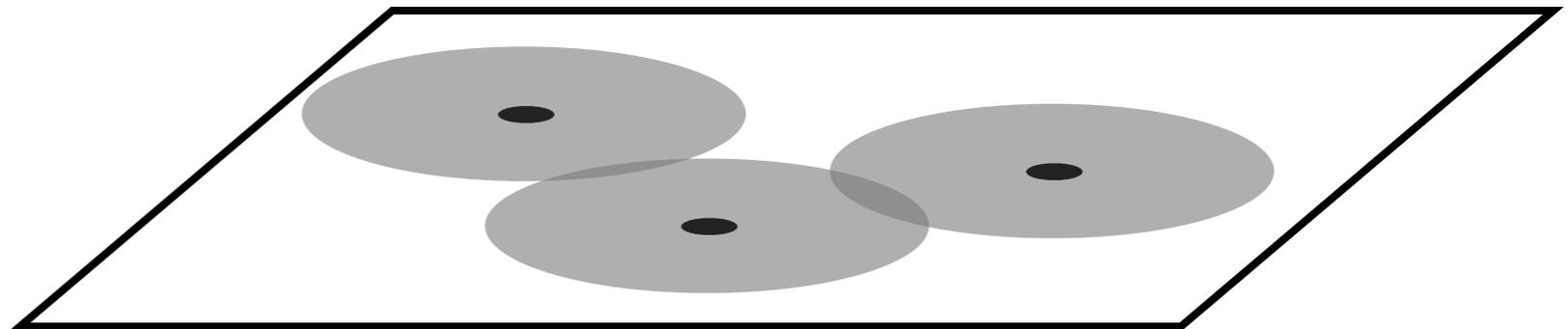
Formalism developed w/
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simultaneous stacking

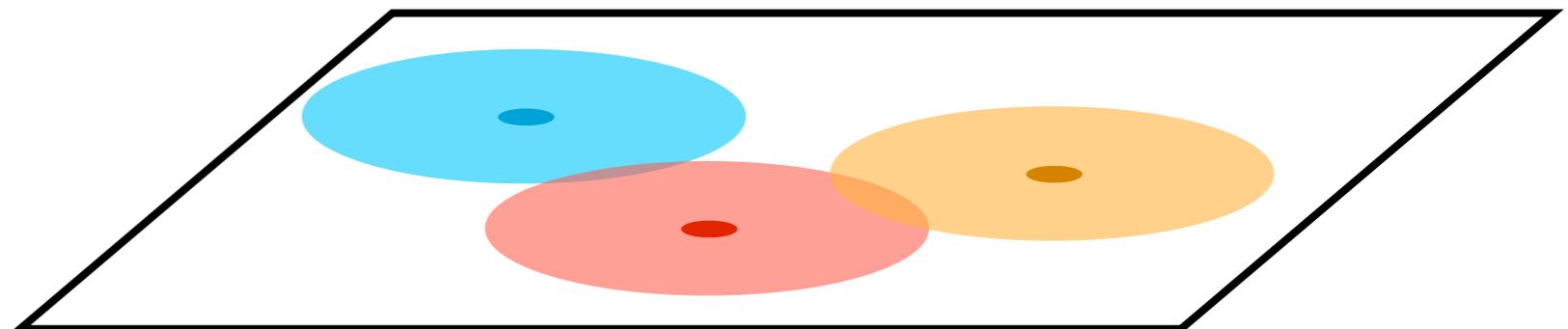
make hits map from catalog



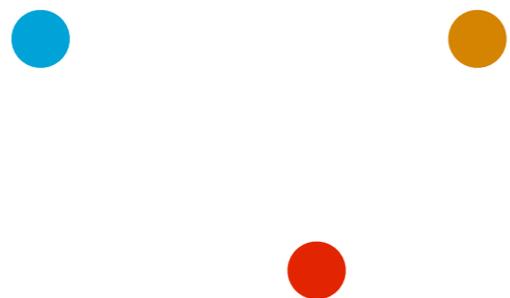
convolve with map p.s.f.



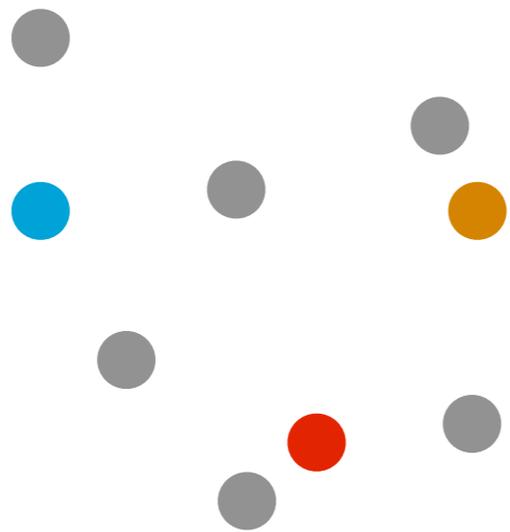
regress to find stacked flux



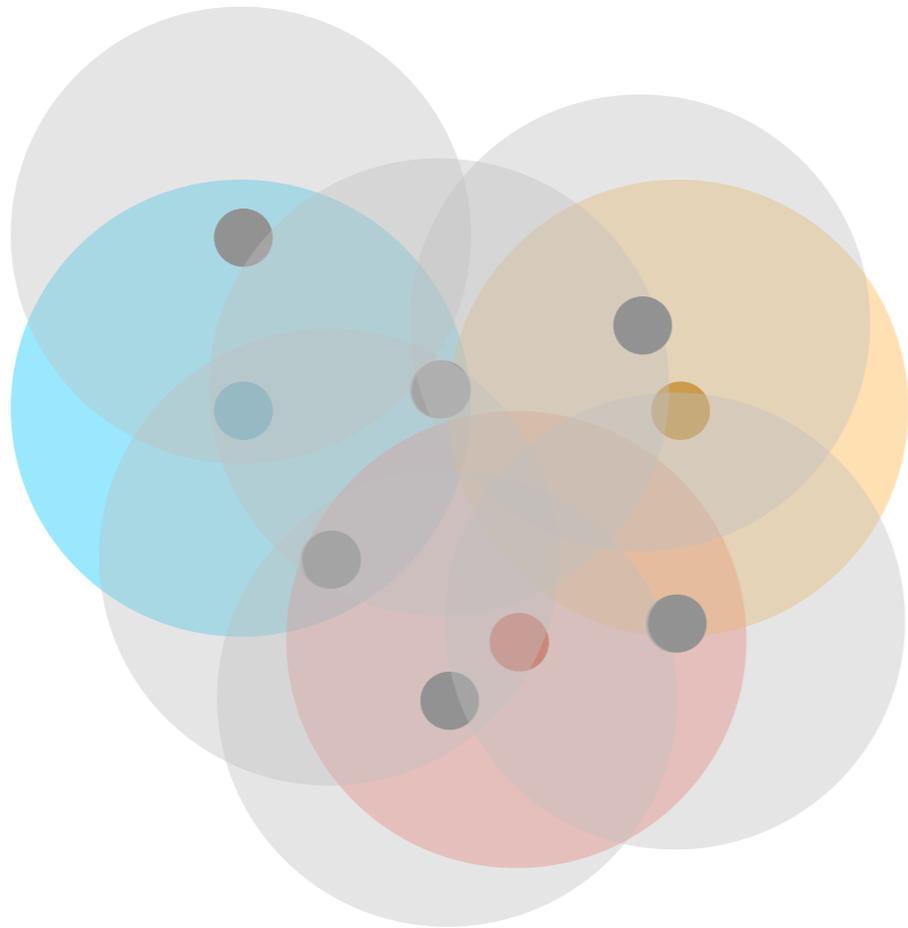
Formalism developed w/
Lorenzo Moncelsi (Caltech) &
Isaac Roseboom (ROE)



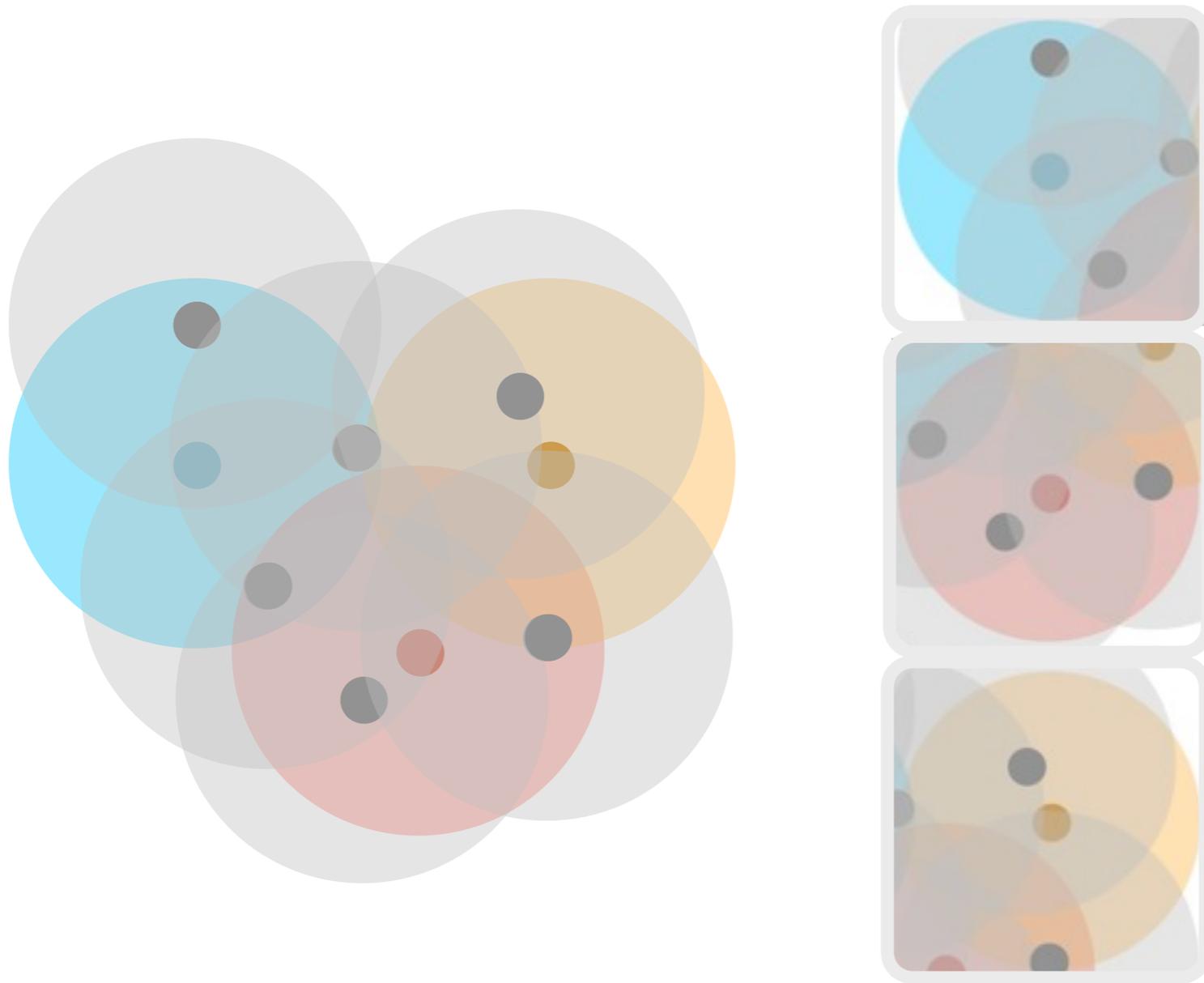
non-target induced bias



non-target induced bias

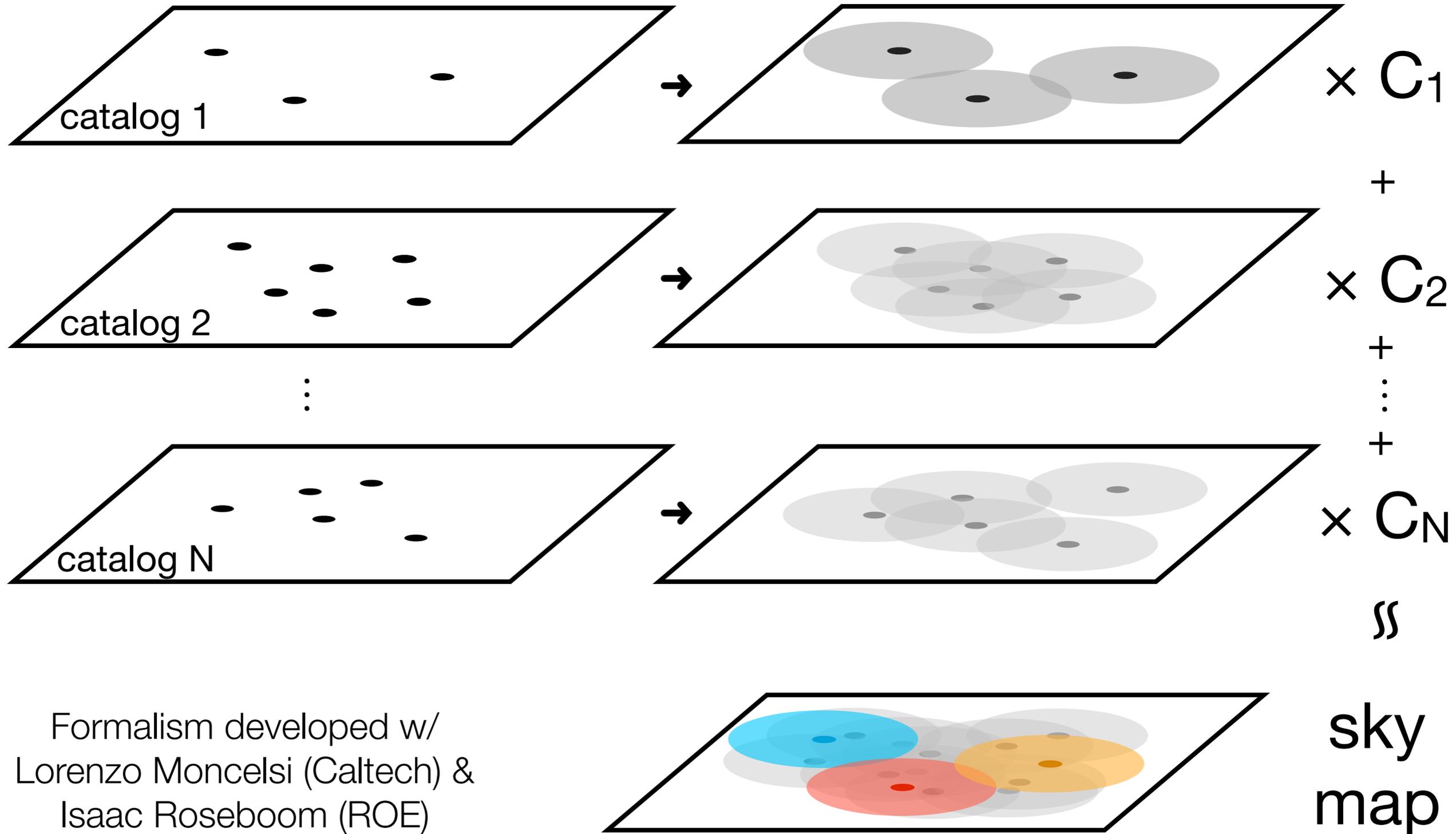


non-target induced bias



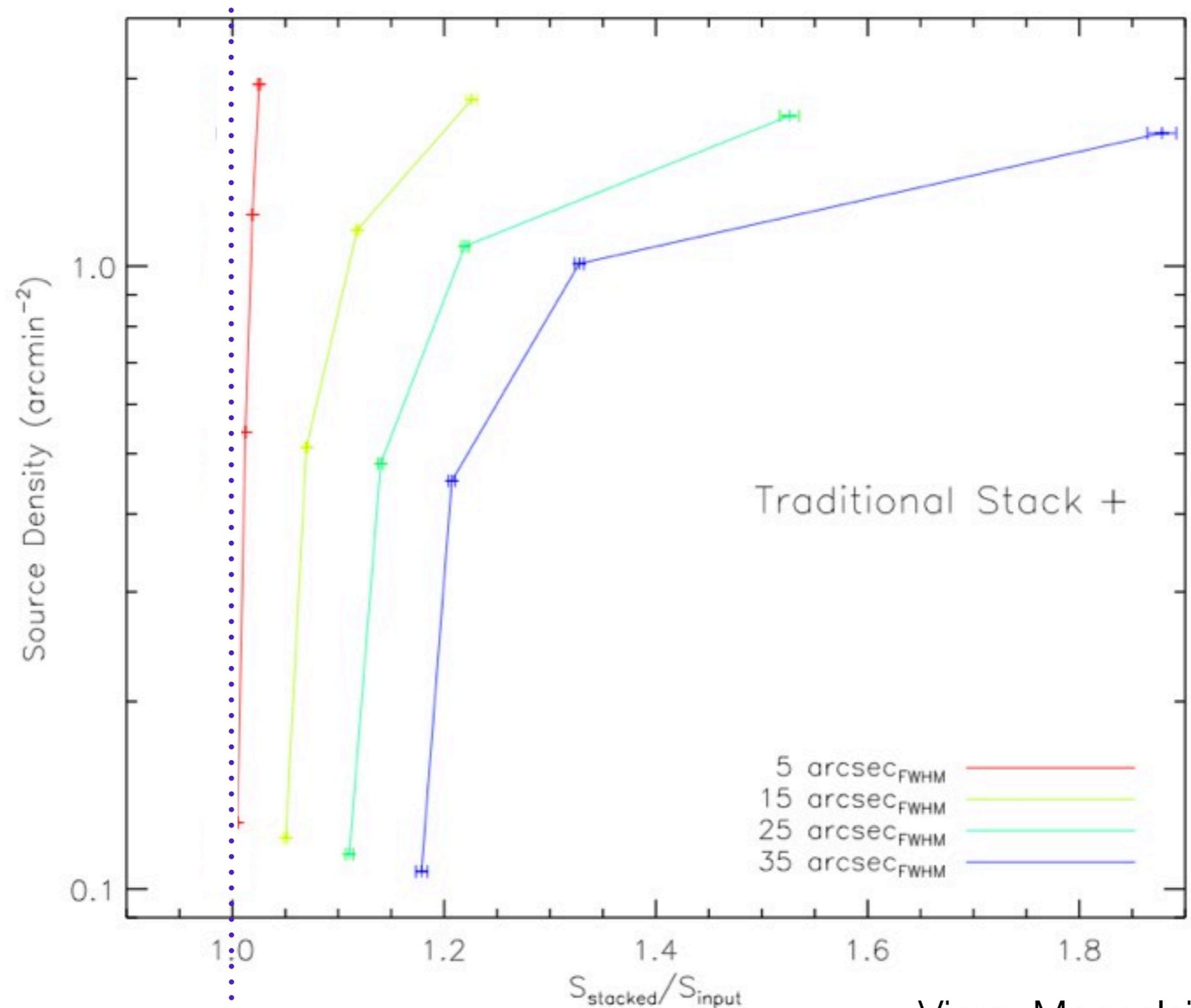
non-target induced bias

simultaneous stacking



Formalism developed w/
Lorenzo Moncelsi (Caltech) &
Isaac Roseboom (ROE)

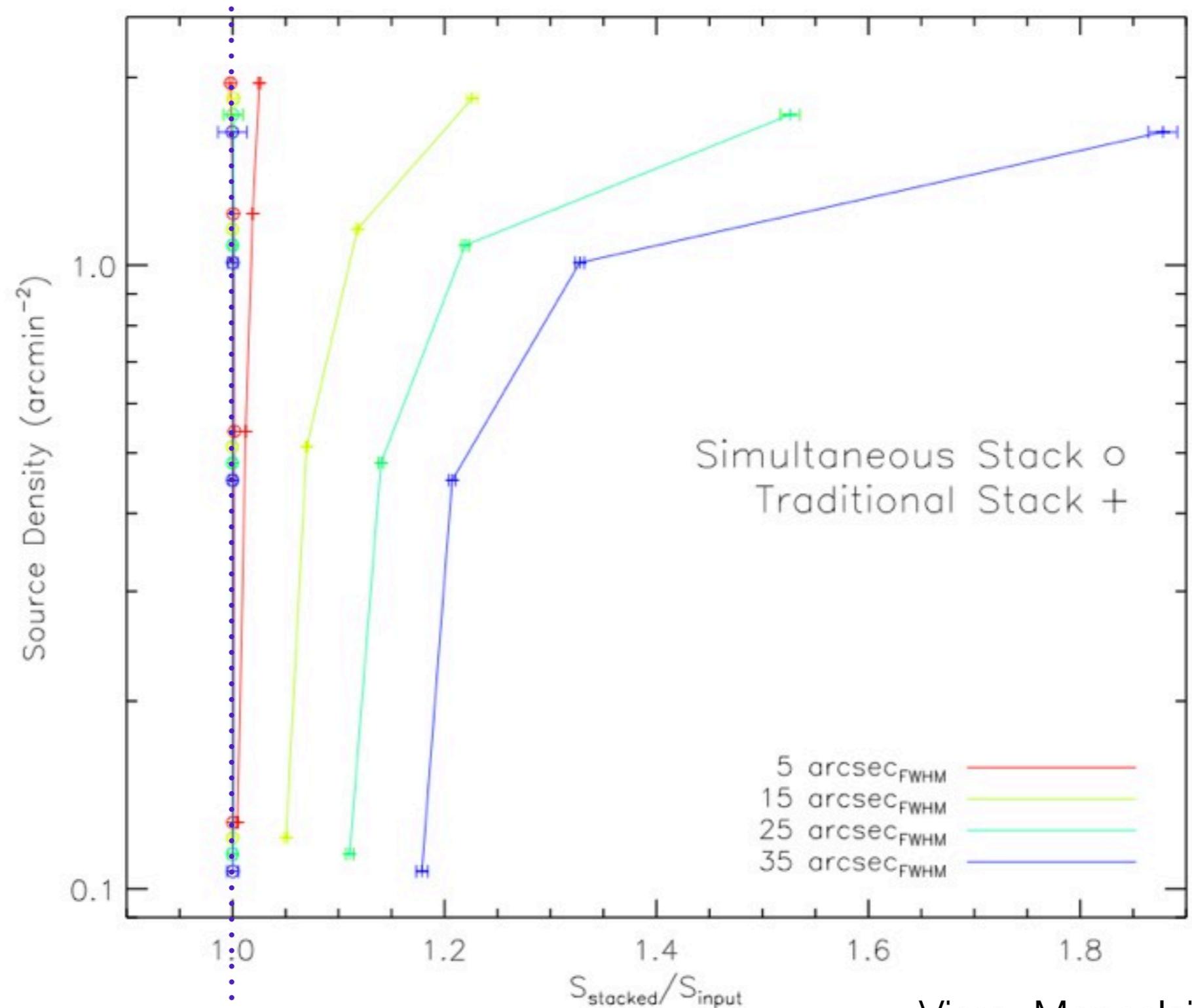
simultaneous stacking sim



unbiased

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

simultaneous stacking sim



unbiased

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

data

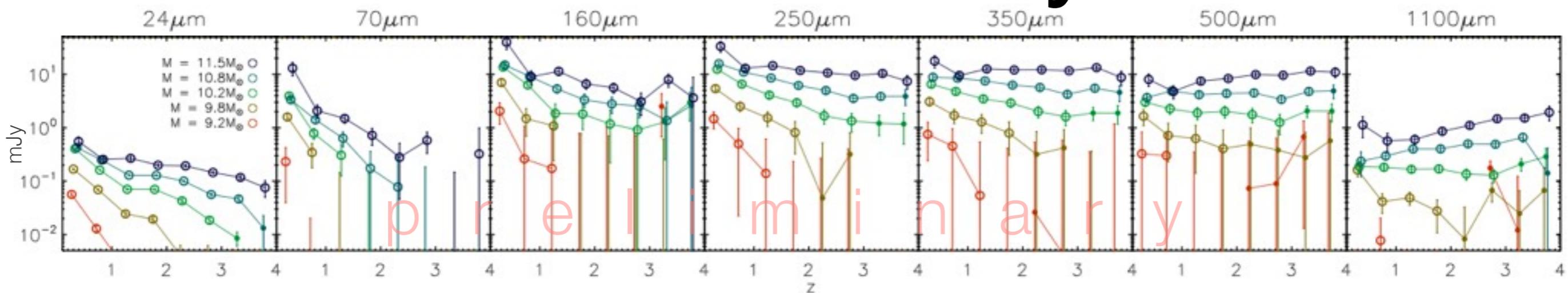
catalogs

- UKIDSS/UDS [2/3 deg²]
 - uBVRizJHK + IRAC ch1234
 - Williams & Quadri (in prep.)
- redshifts - EAZY (Brammer 2008)
- masses - FAST (Kriek 2009)
- K-band magnitude cut 24 AB
- #sources
 - divide into mass and redshift bins

maps

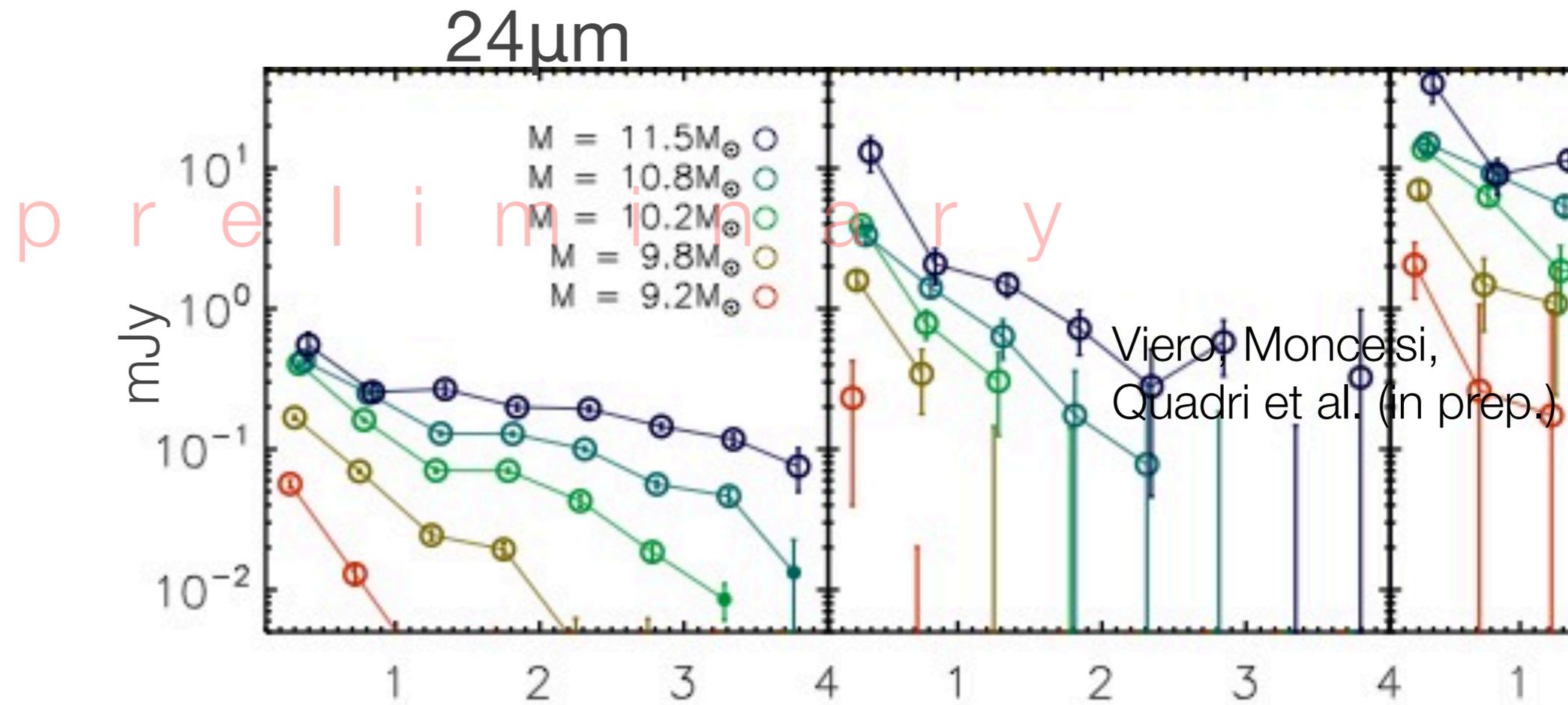
- Spitzer/MIPS
 - 24, 70, 160um
 - X, X, X" FWHM
- Herschel/SPIRE
 - 250, 350, 500um
 - 18.1, 25.4, 36.6" FWHM
- ASTE/AzTEC
 - 1100um
 - 30" FWHM

stacked flux density



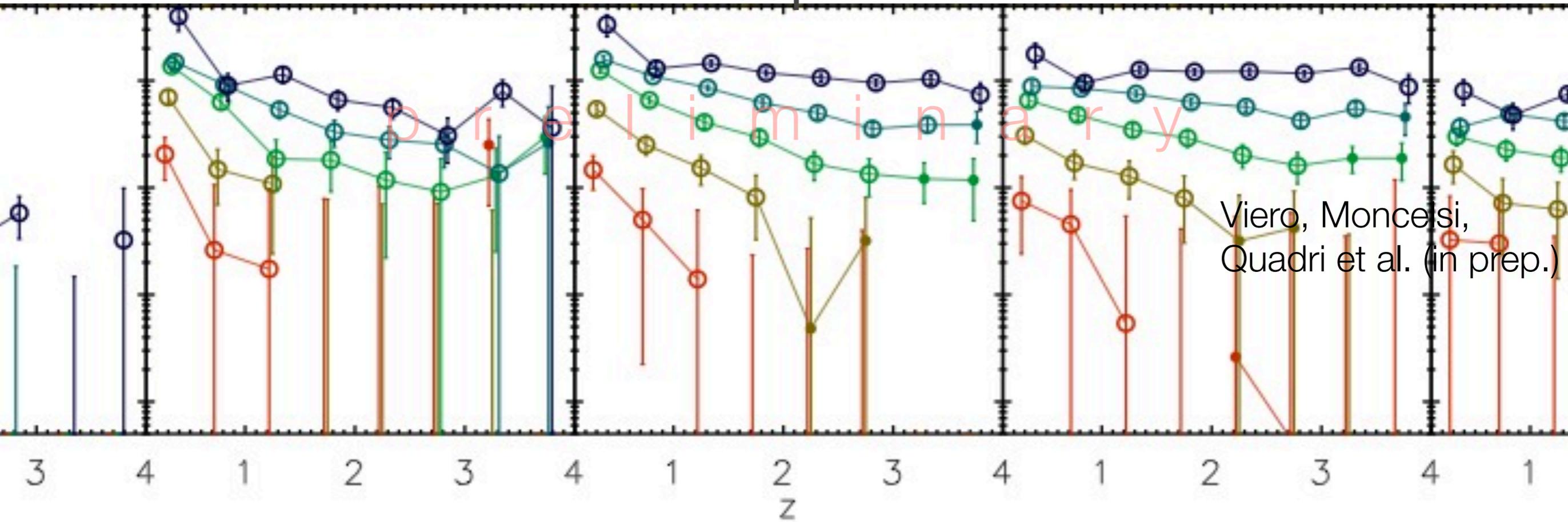
Viero, Monceli,
Quadri et al. (in prep.)

stacked flux density



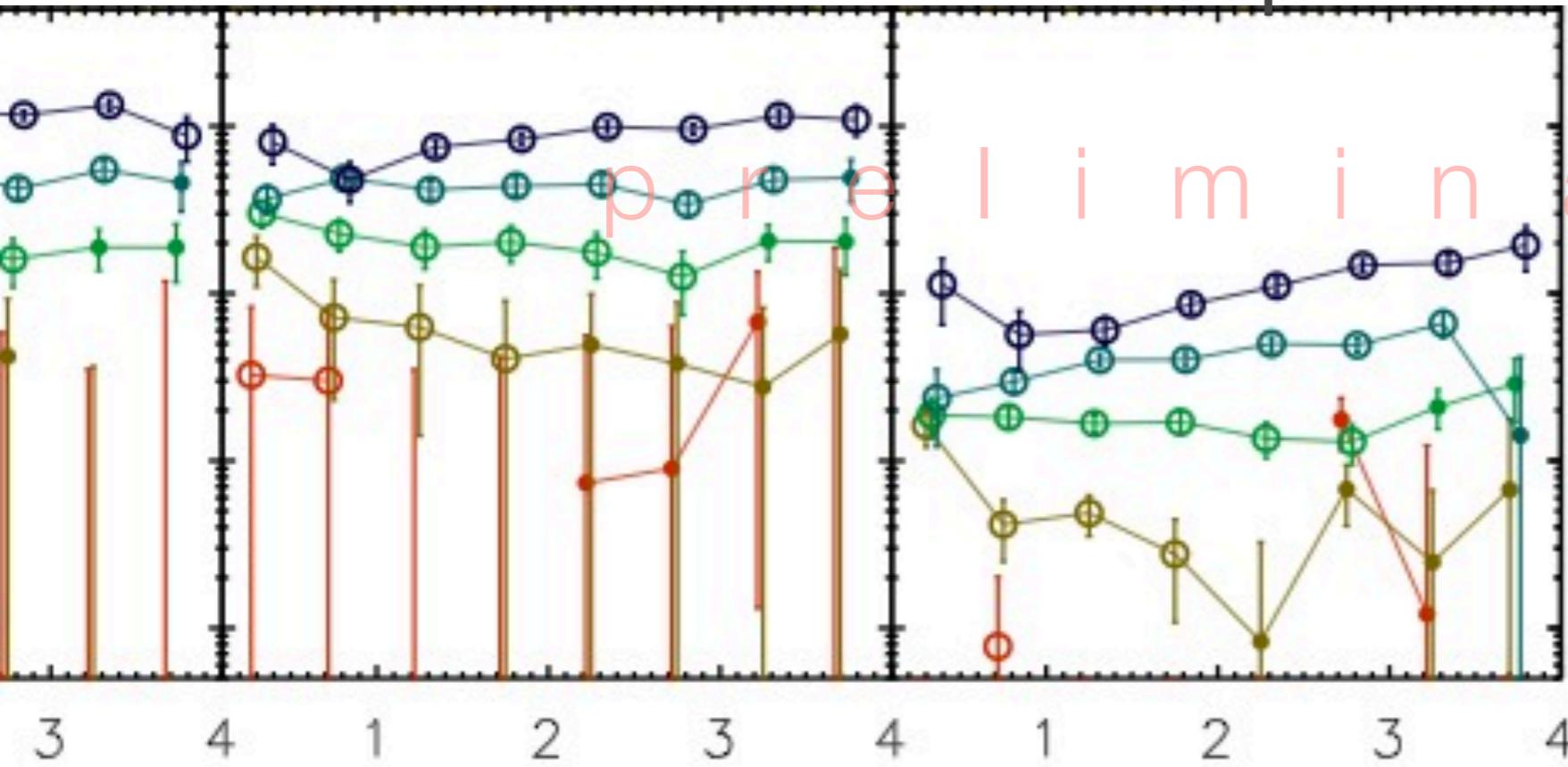
stacked flux density

250 μ m



stacked flux density

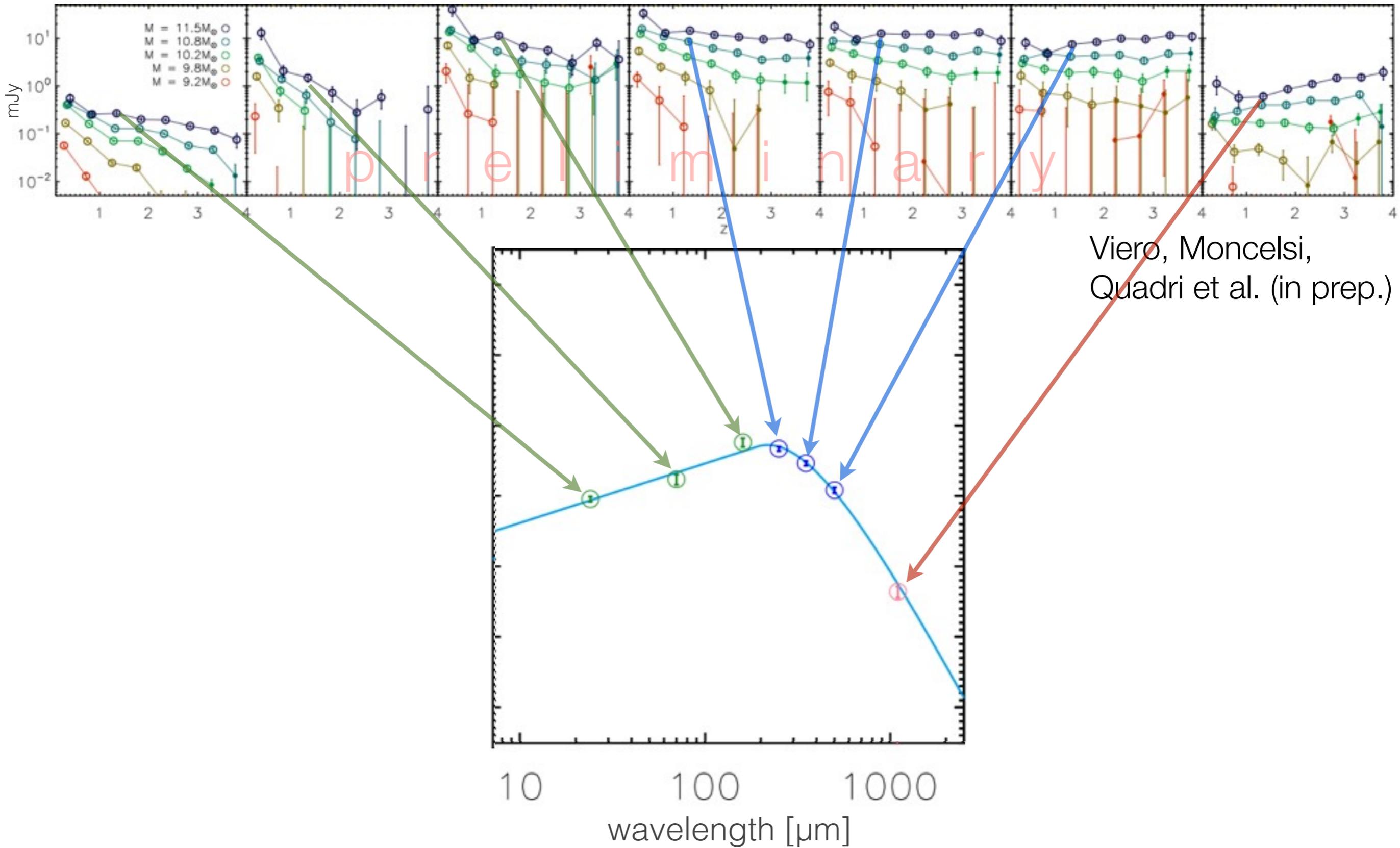
1100 μm



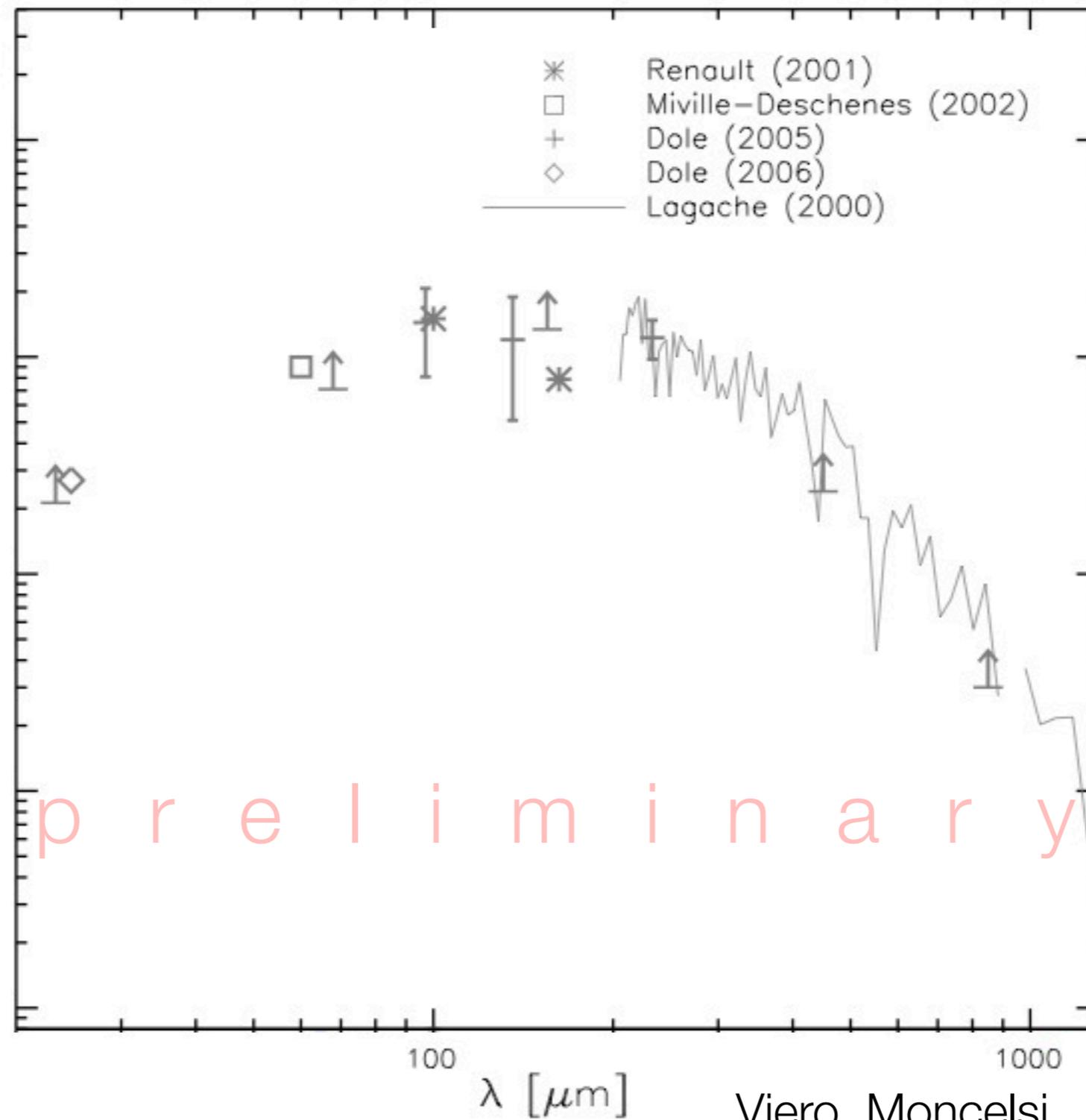
preliminary

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

stacked flux density



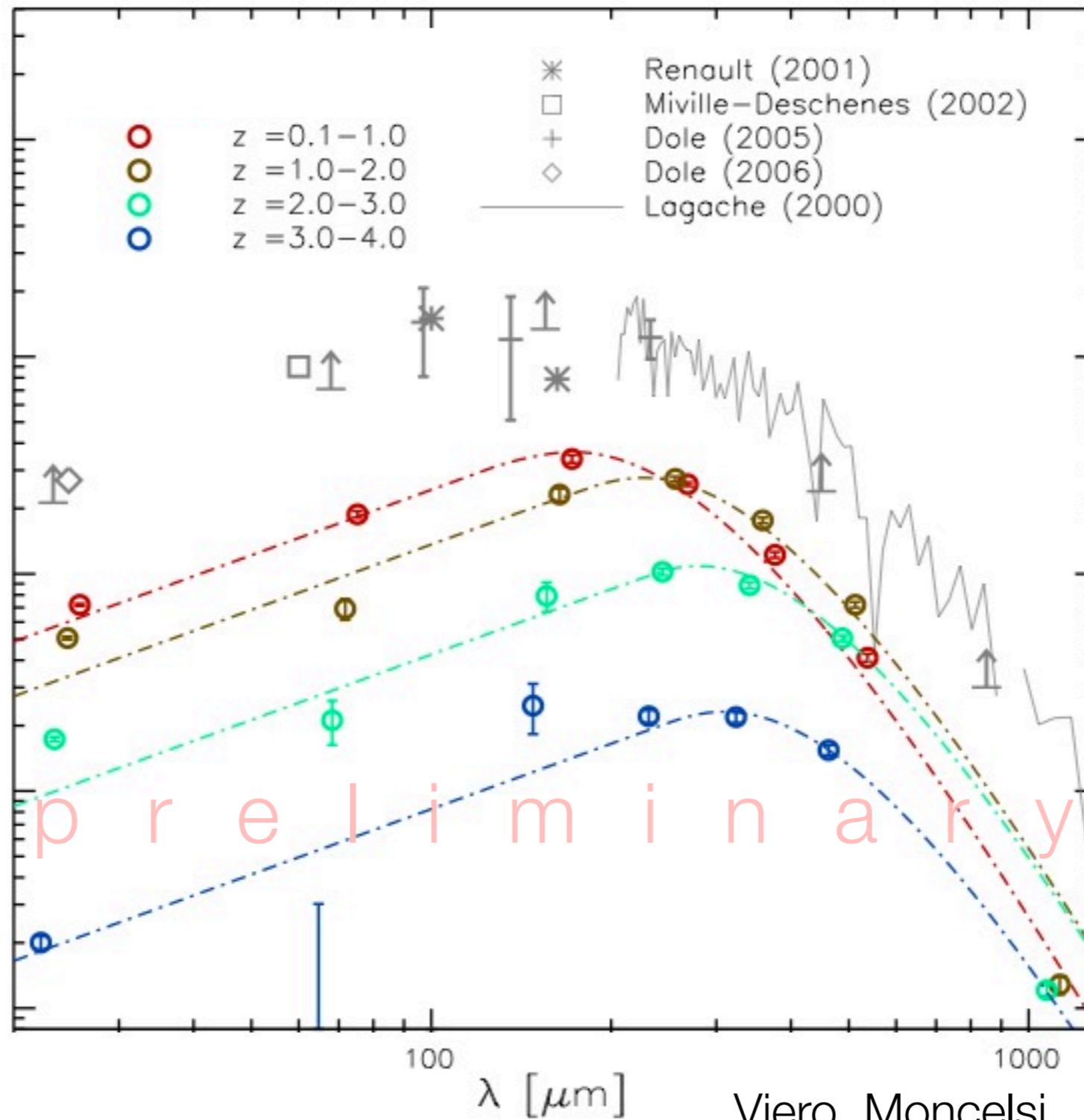
stacked CIB



p r e l i m i n a r y

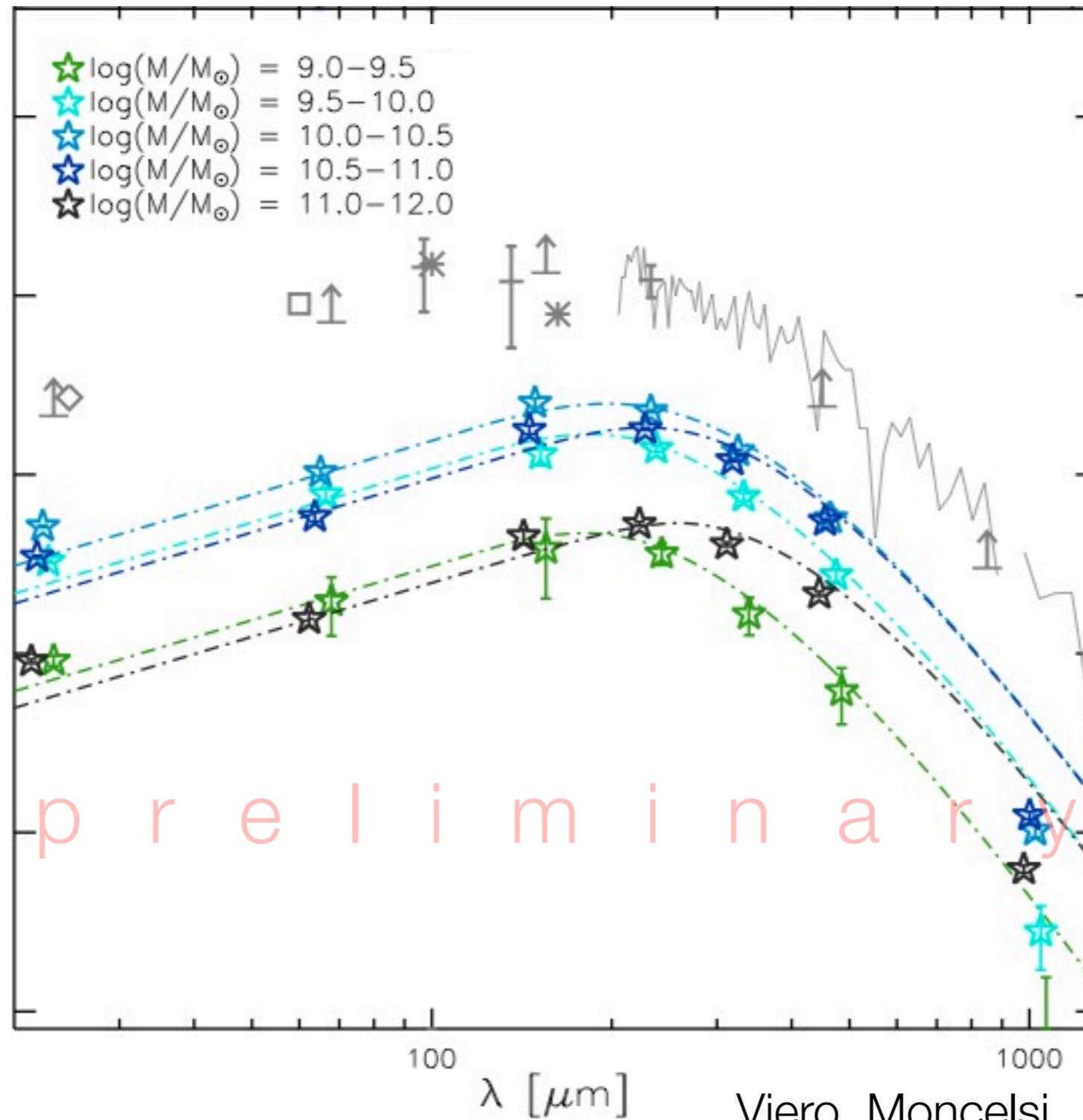
Viero, Moncelsi,
Quadri et al. (in prep.)

stacked CIB

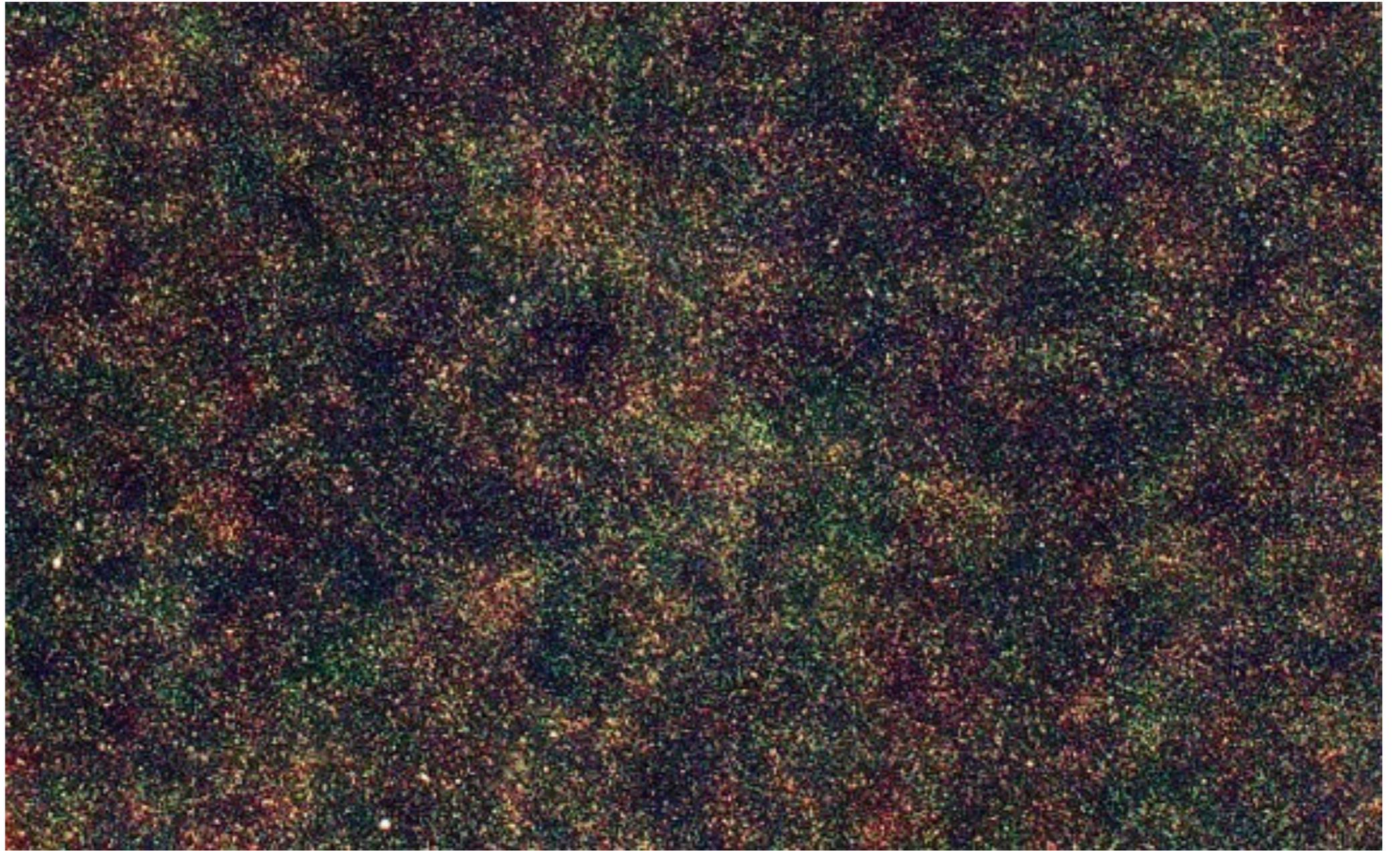


Viero, Moncelsi,
Quadri et al. (in prep.)

stacked CIB



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



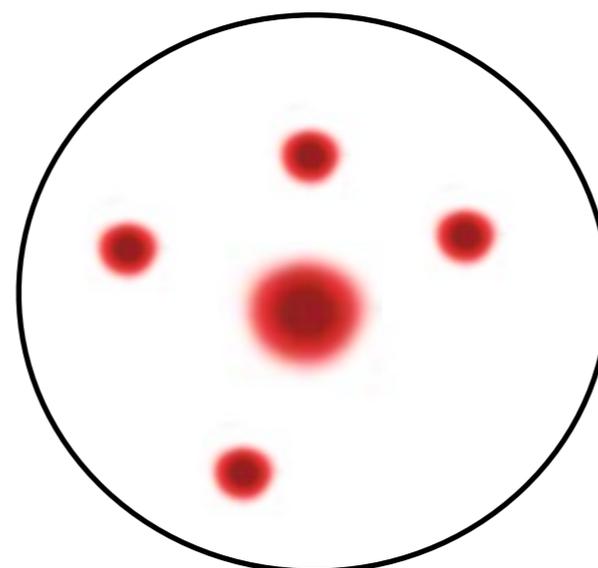
dusty galaxy distribution

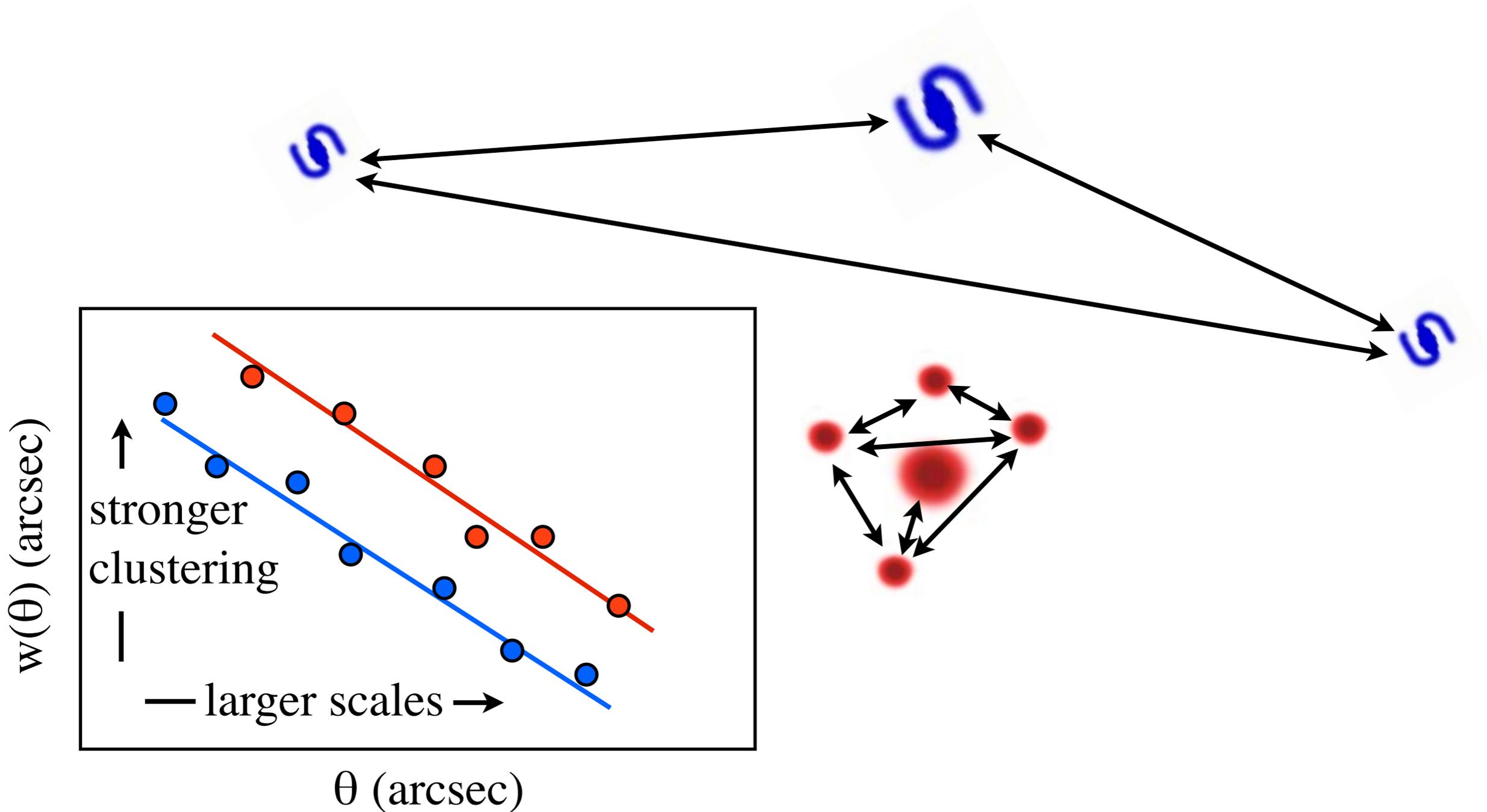
Blue
Star-Forming
Galaxy



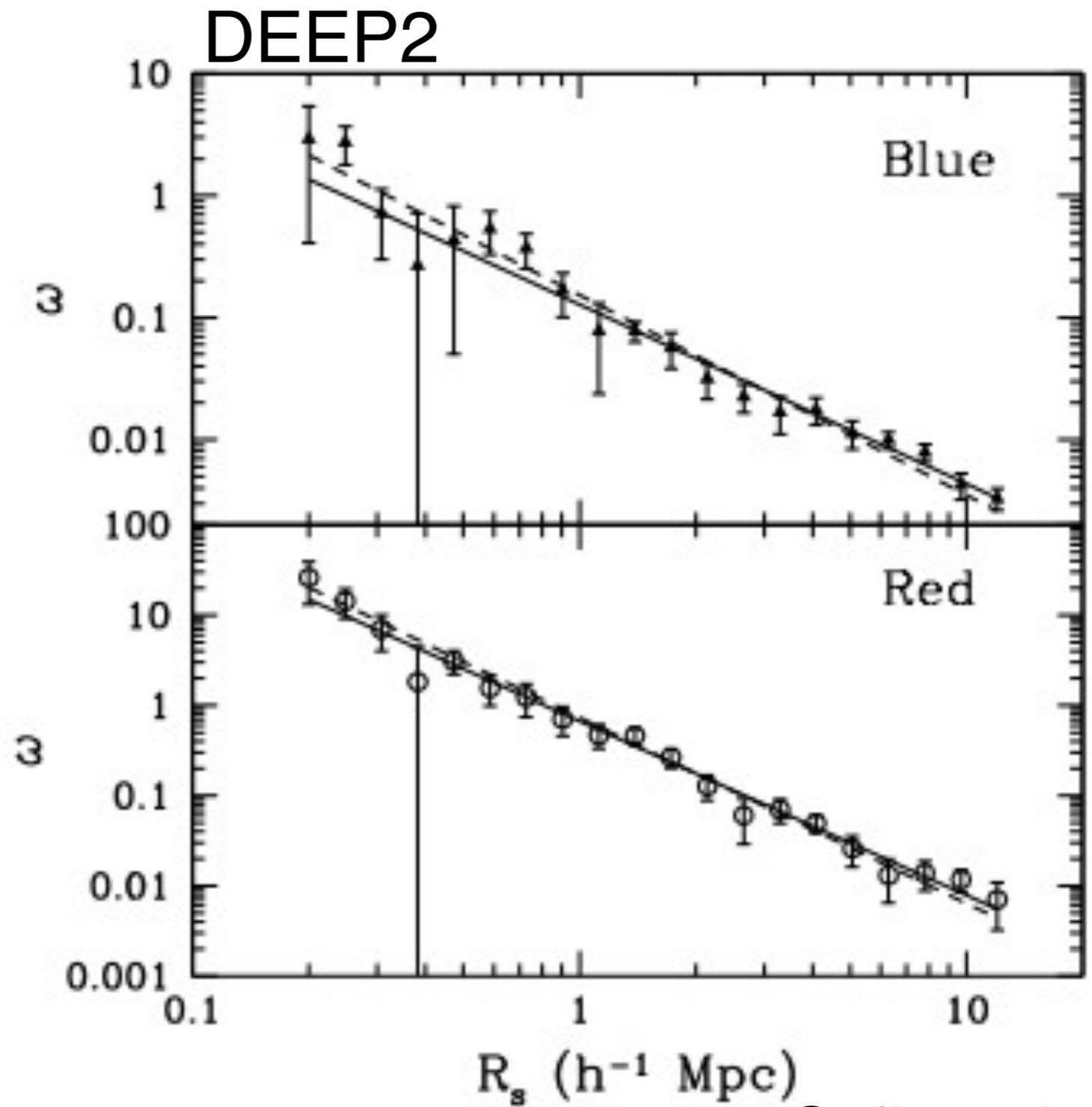
Red
Quiescent
Galaxy







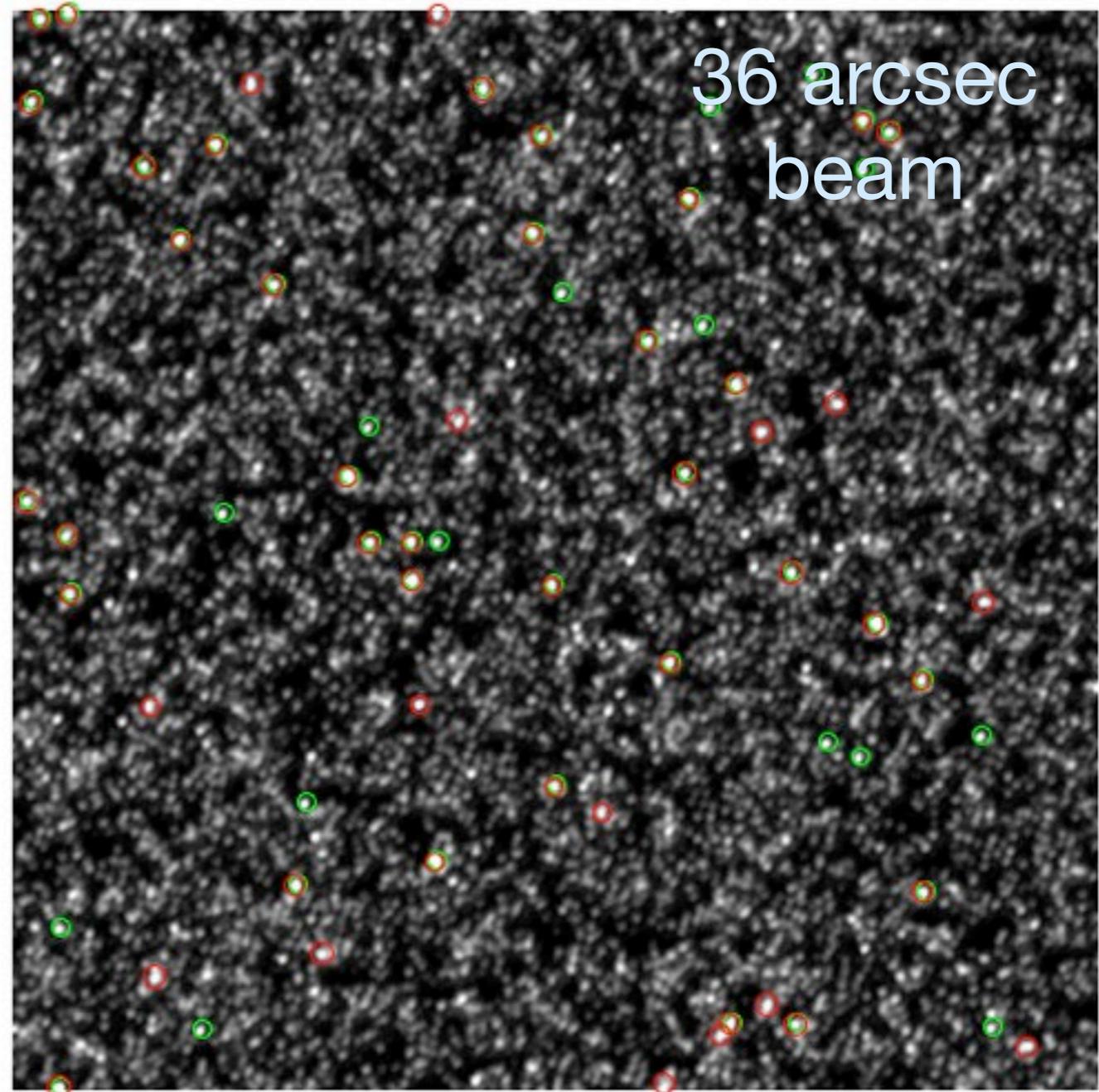
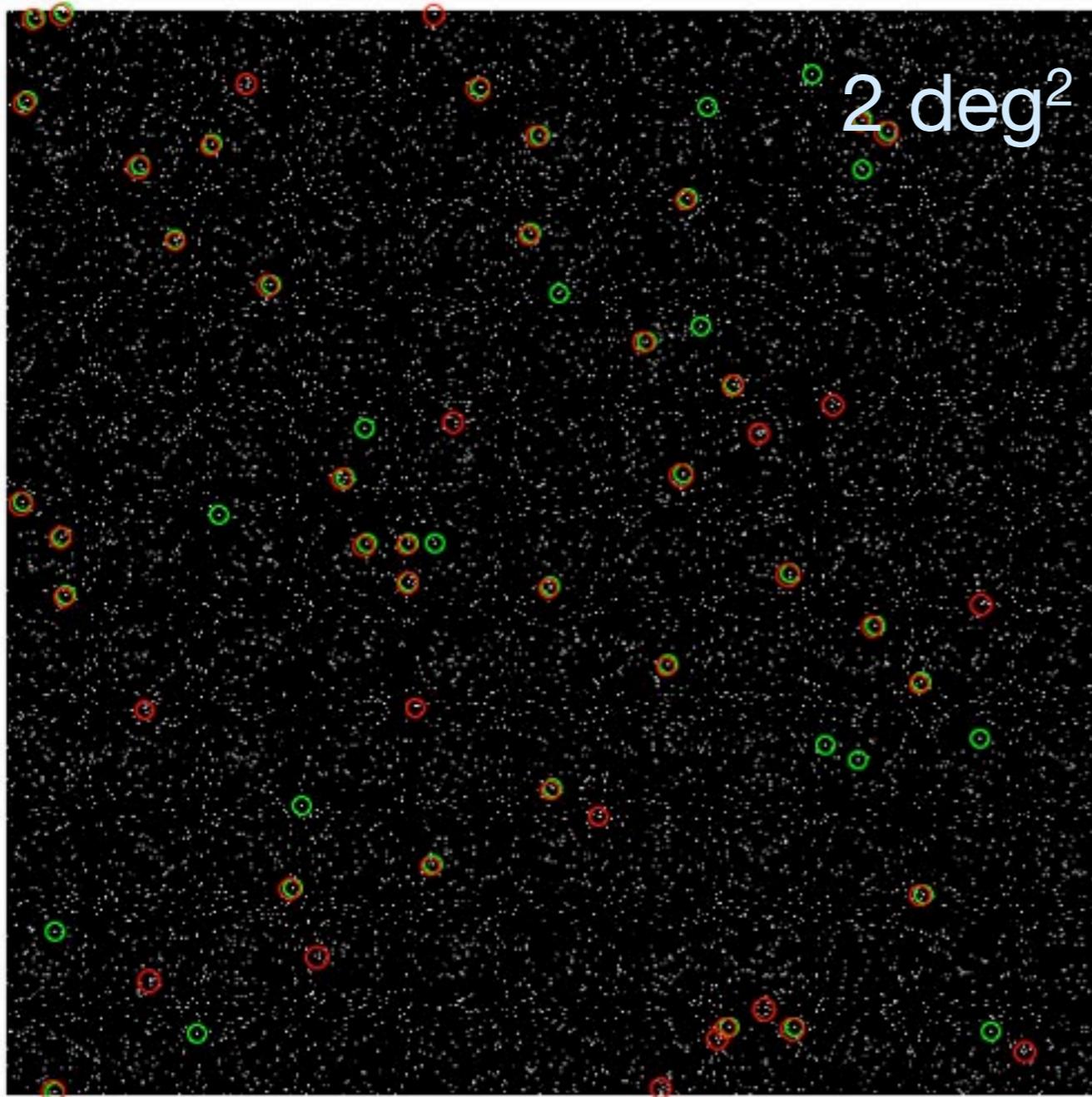
correlation function



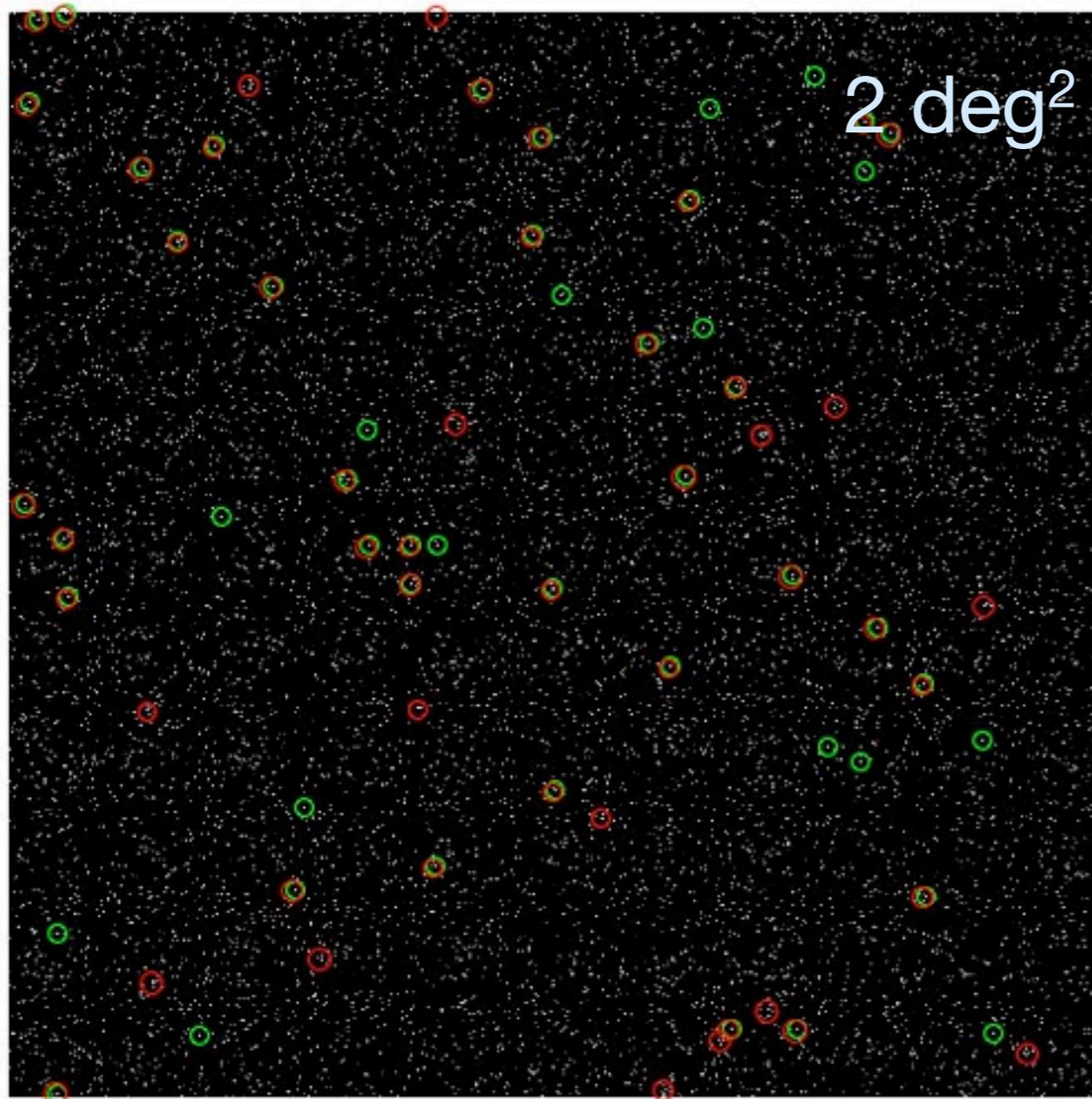
Coil et al. (2008)

correlation function

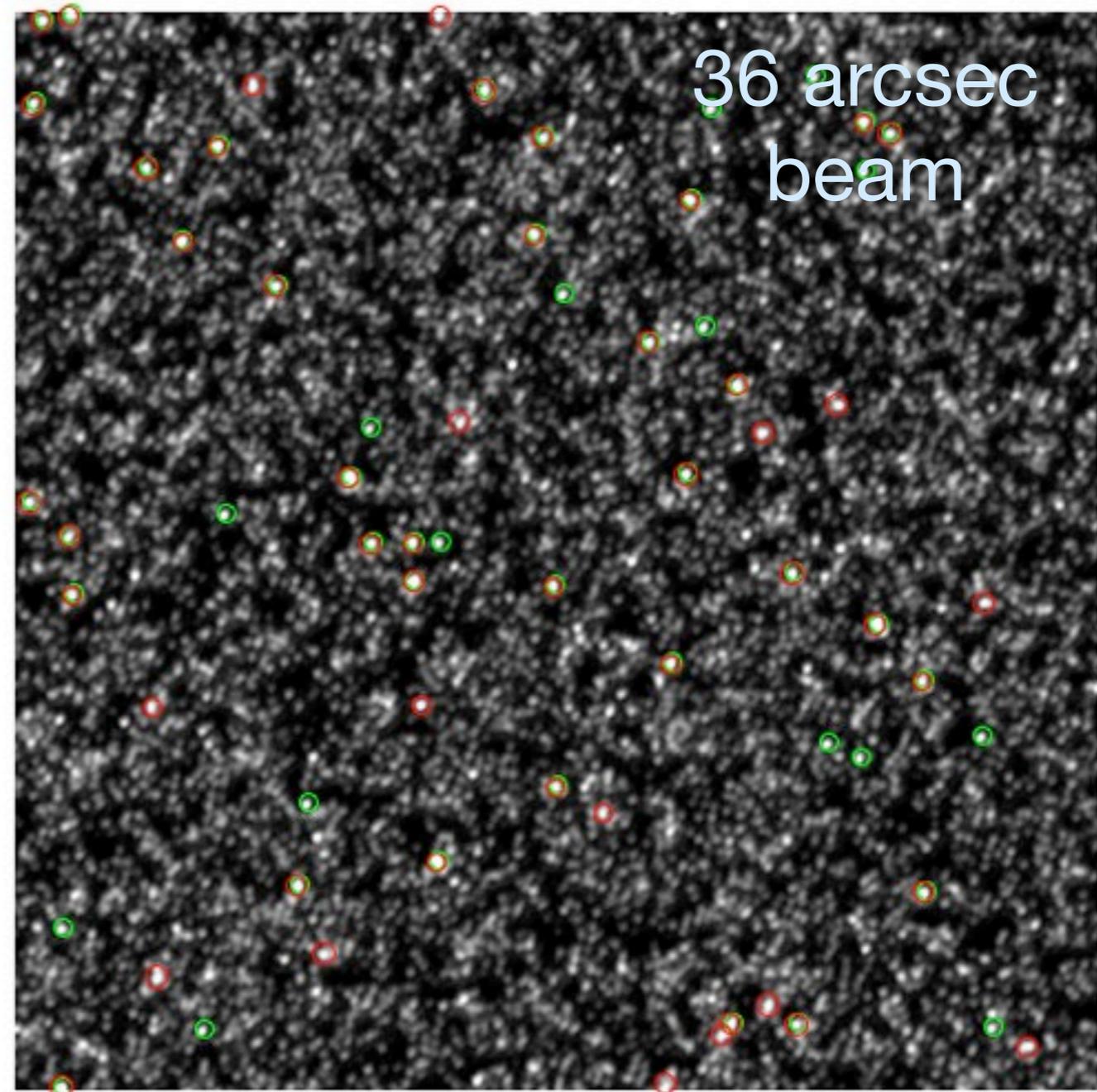
source confusion



source confusion

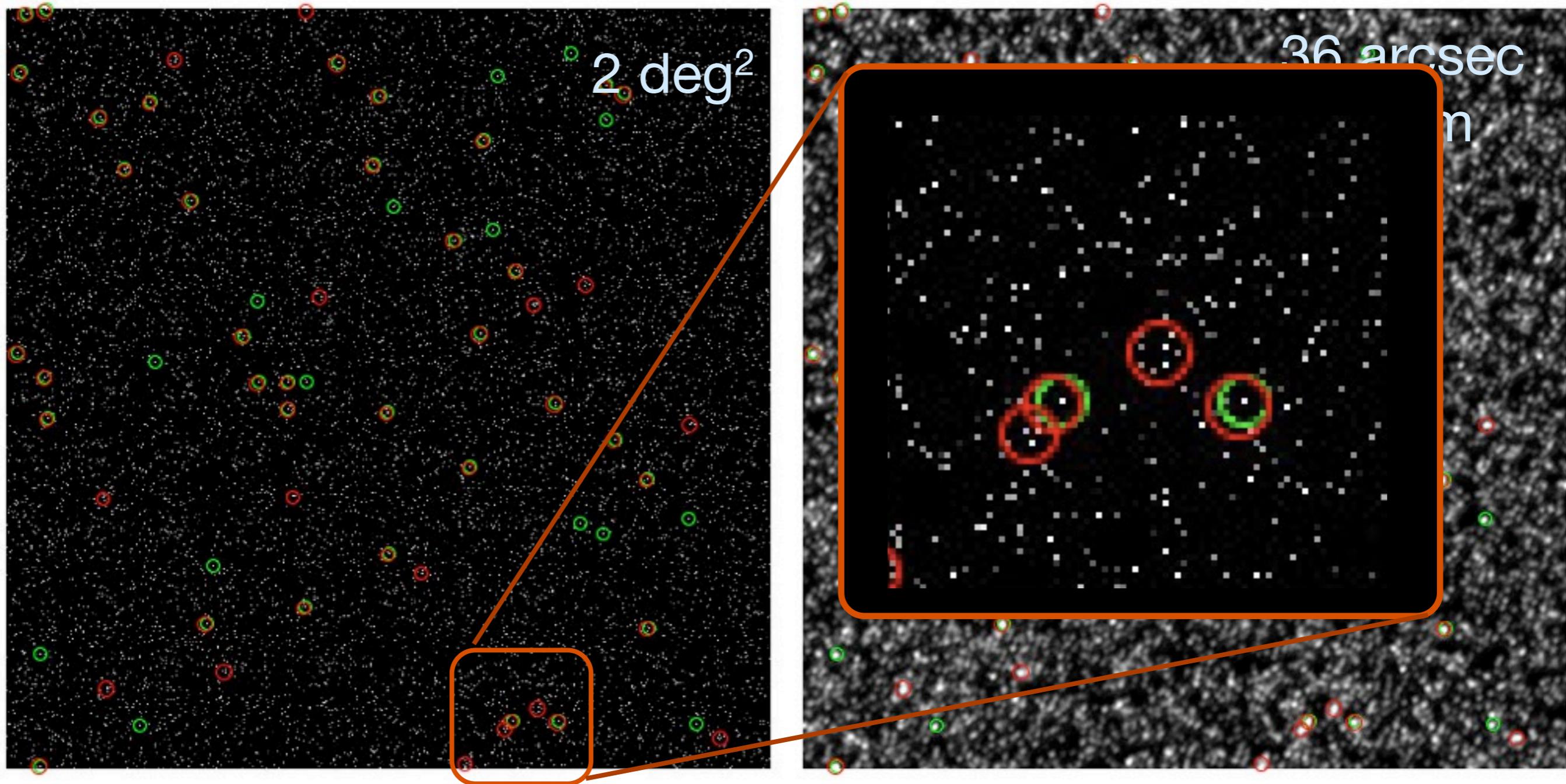


50 brightest
(top 0.5%)

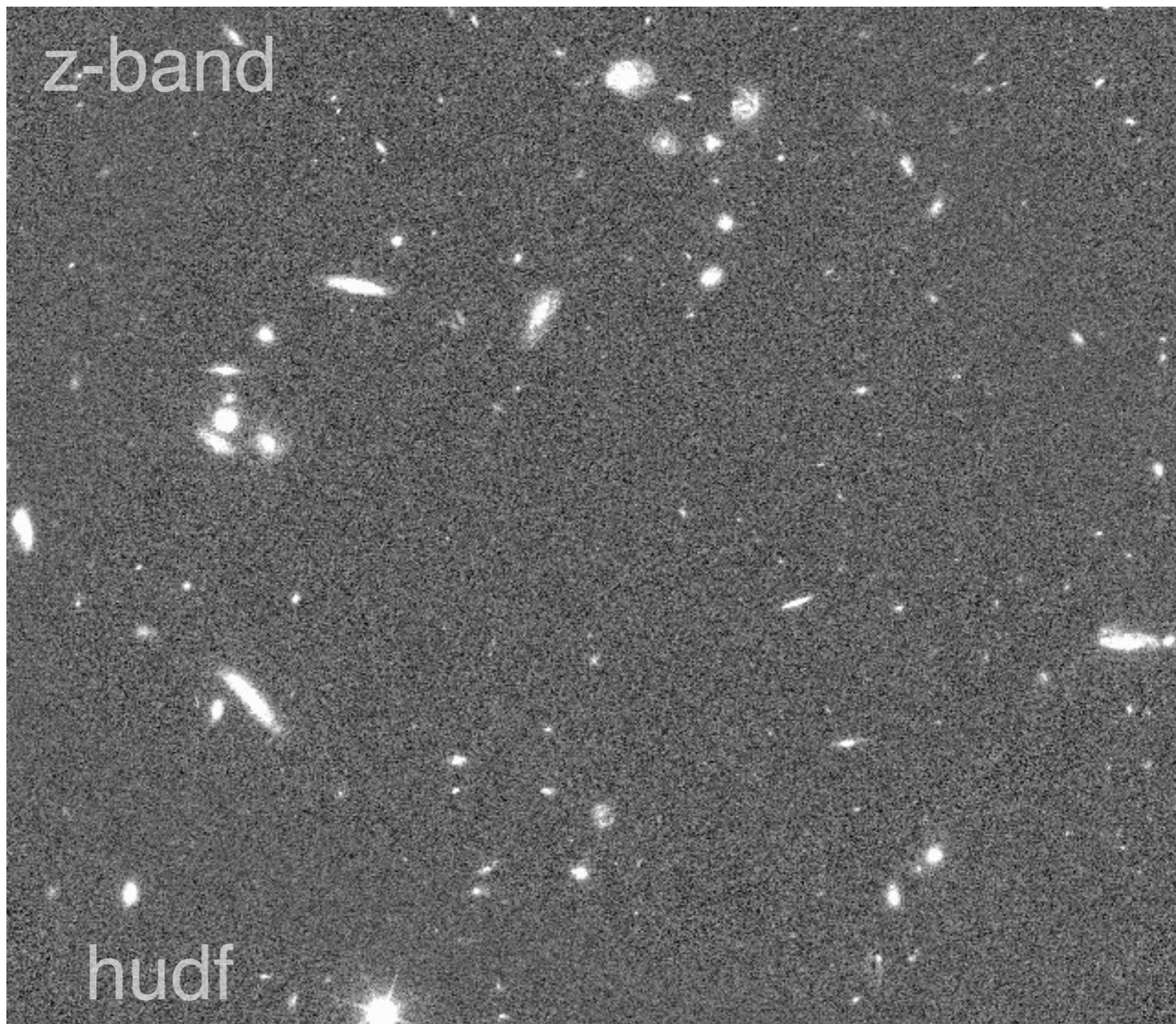


50 brightest
recovered

source confusion

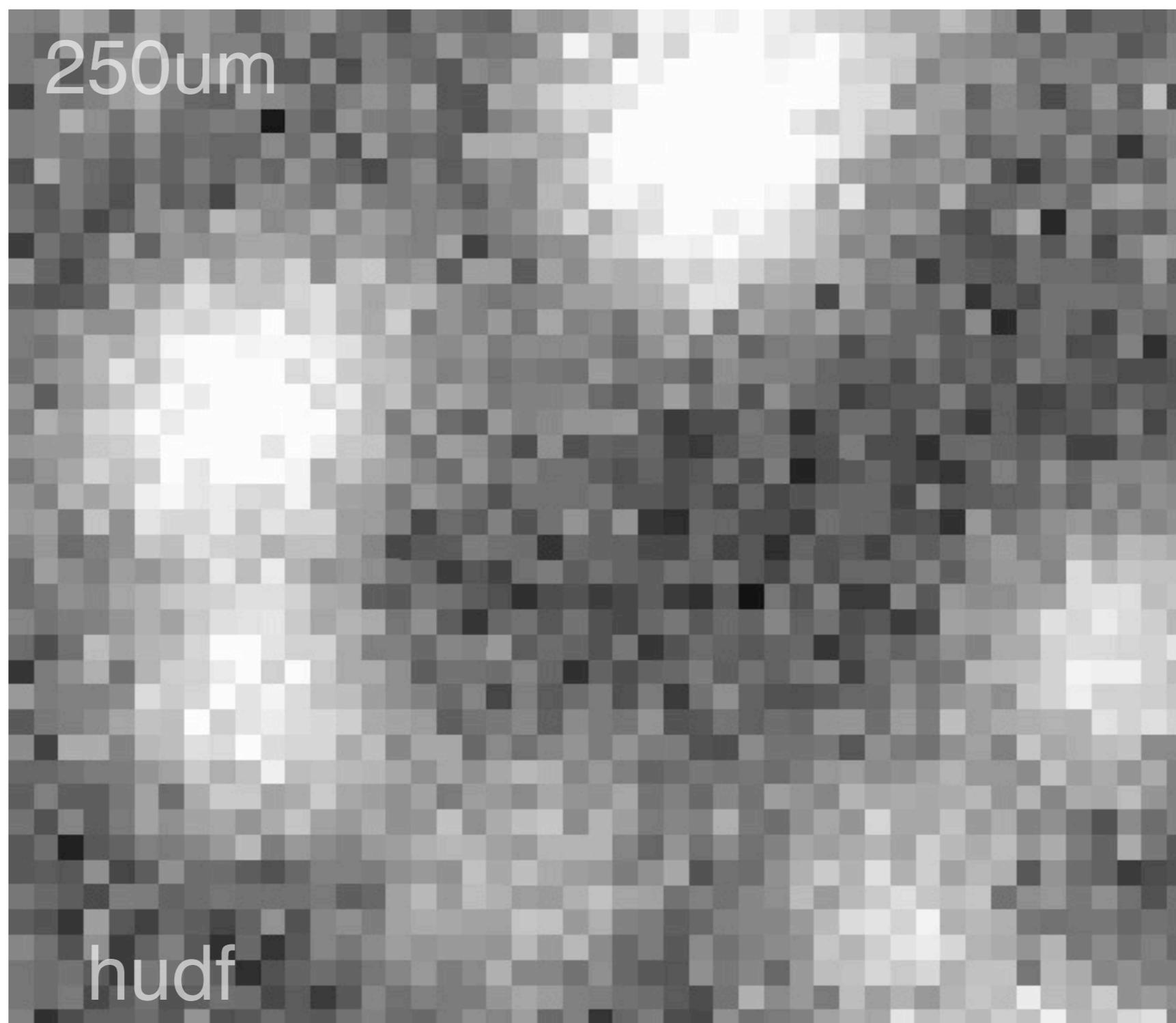


70% of top
0.5%
recovered



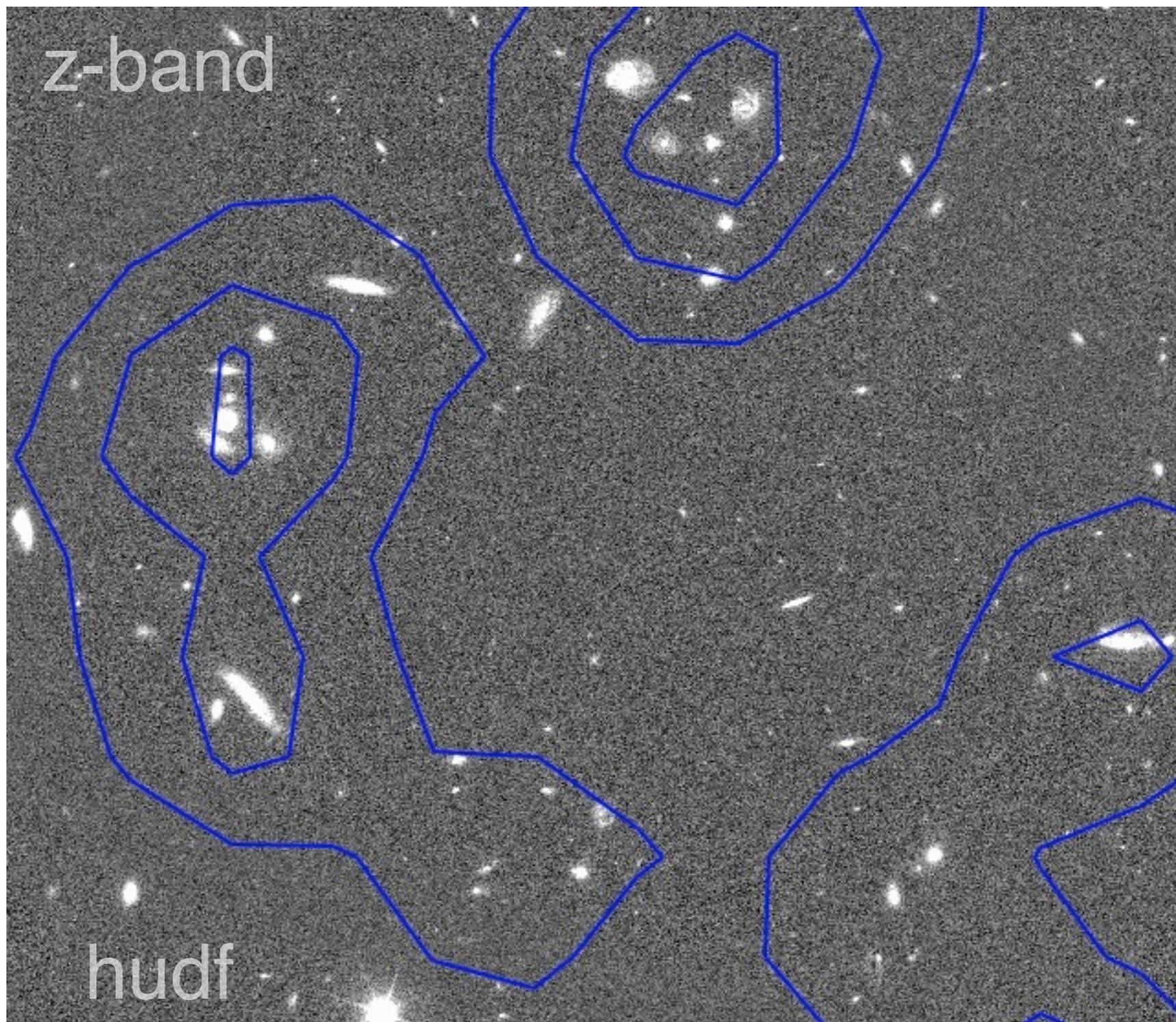
1 arcmin

source confusion



1 arcmin

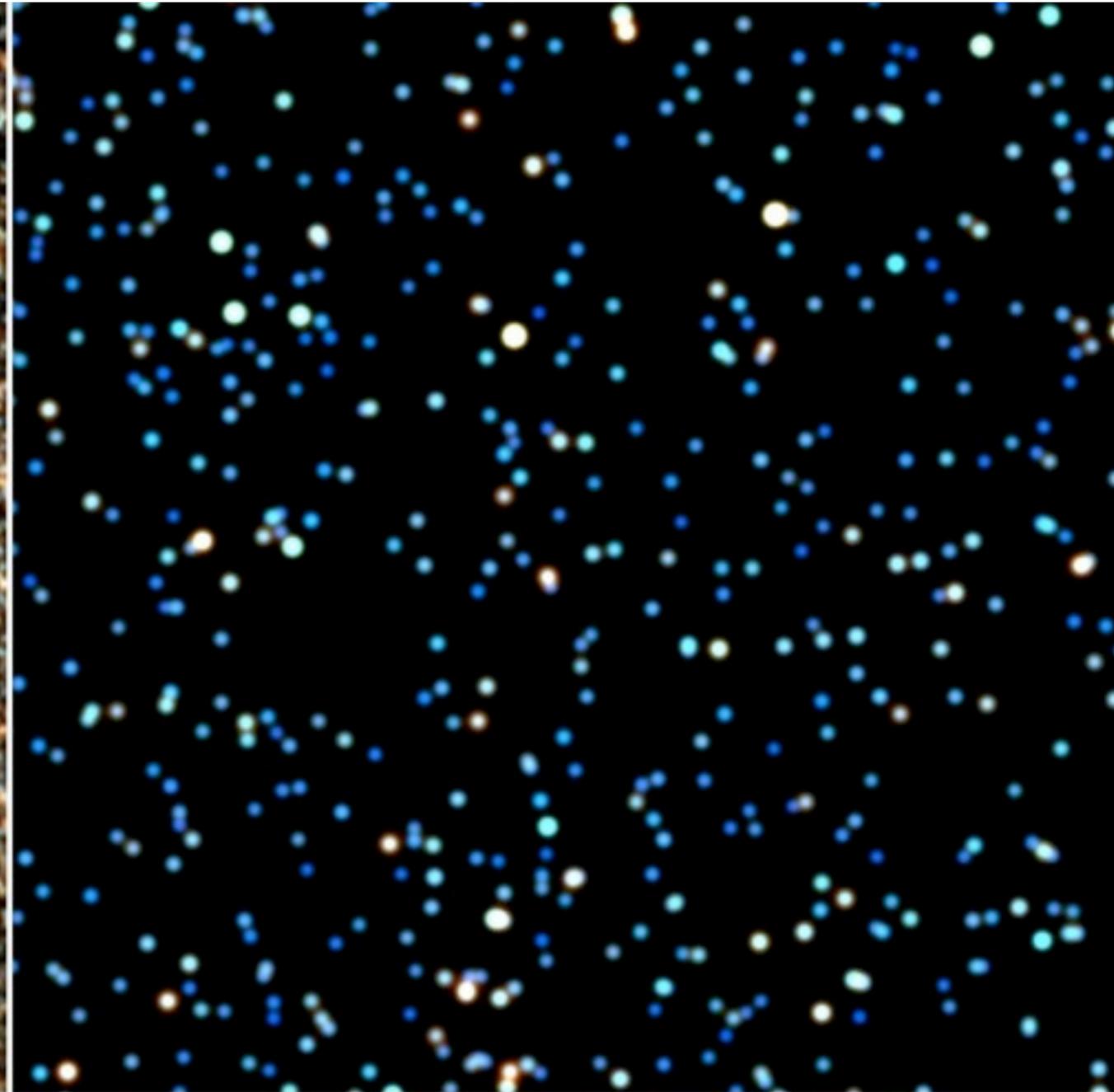
source confusion



1 arcmin

source confusion

← 1° →

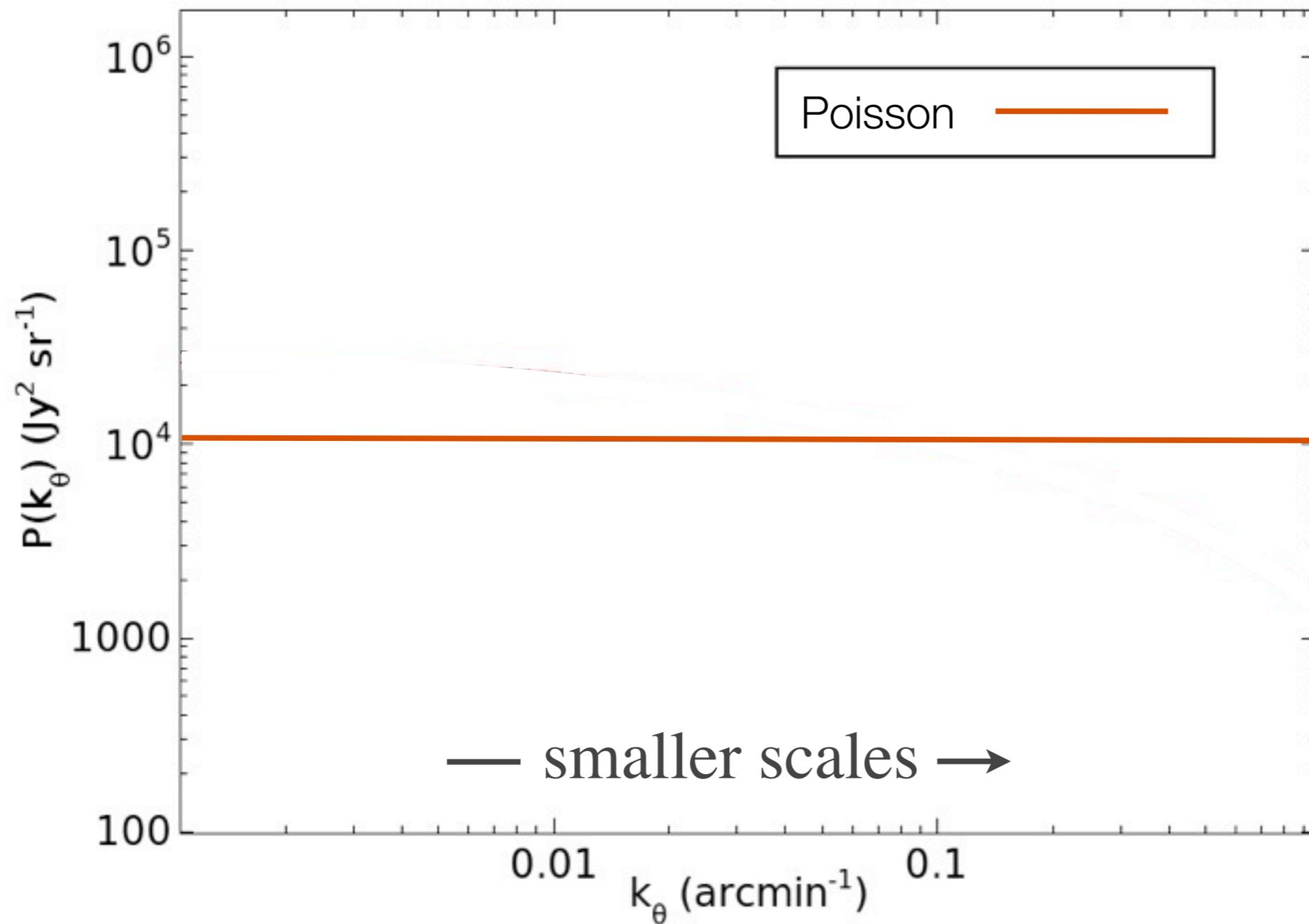


$S < 20$ mJy : 480,000/deg²

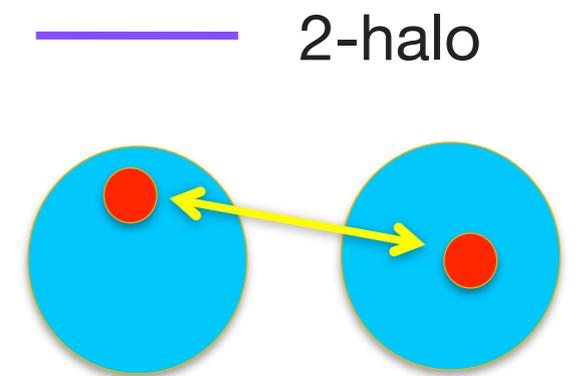
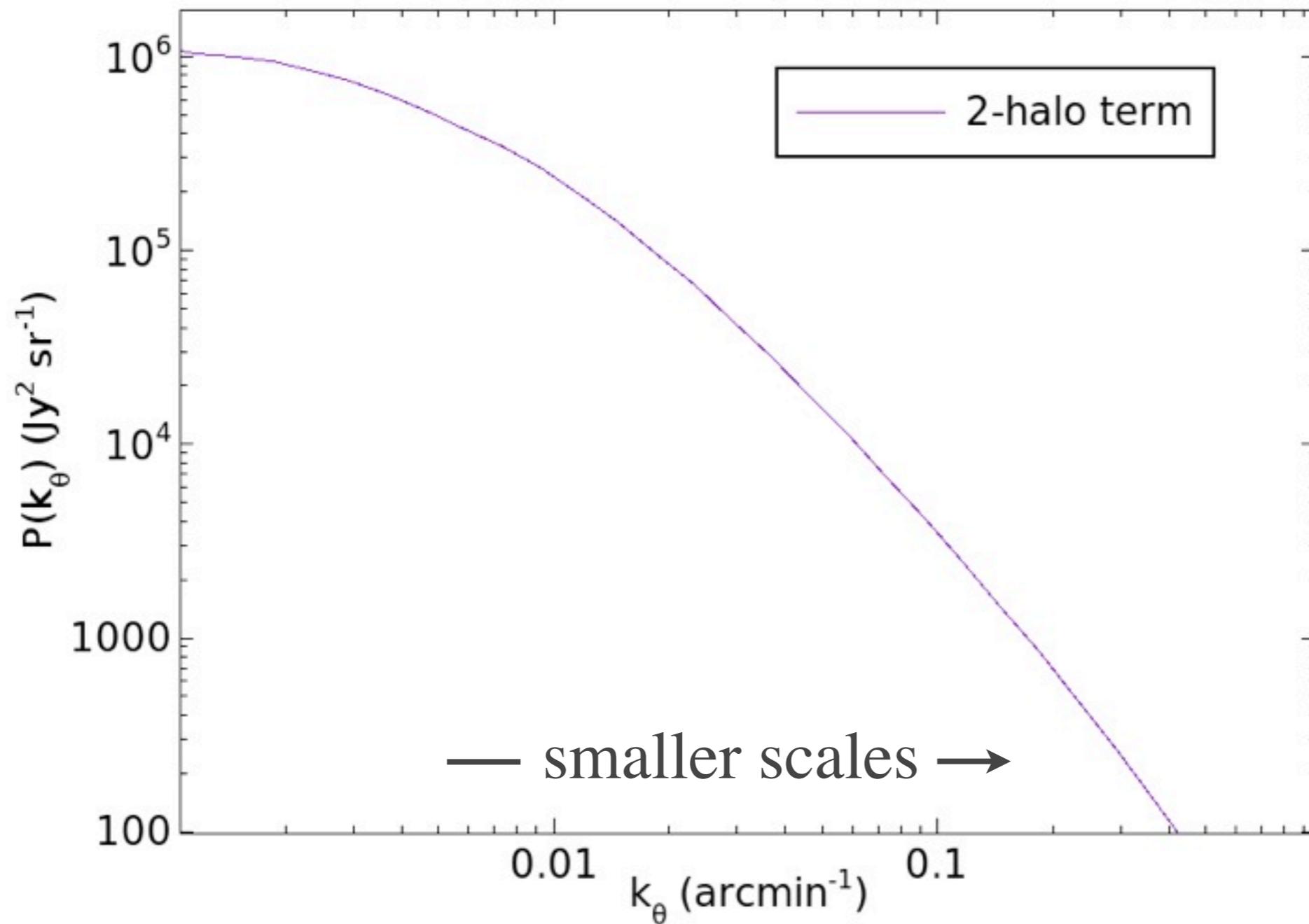
$S > 20$ mJy : 1,200/deg²

unresolved/resolved CIB

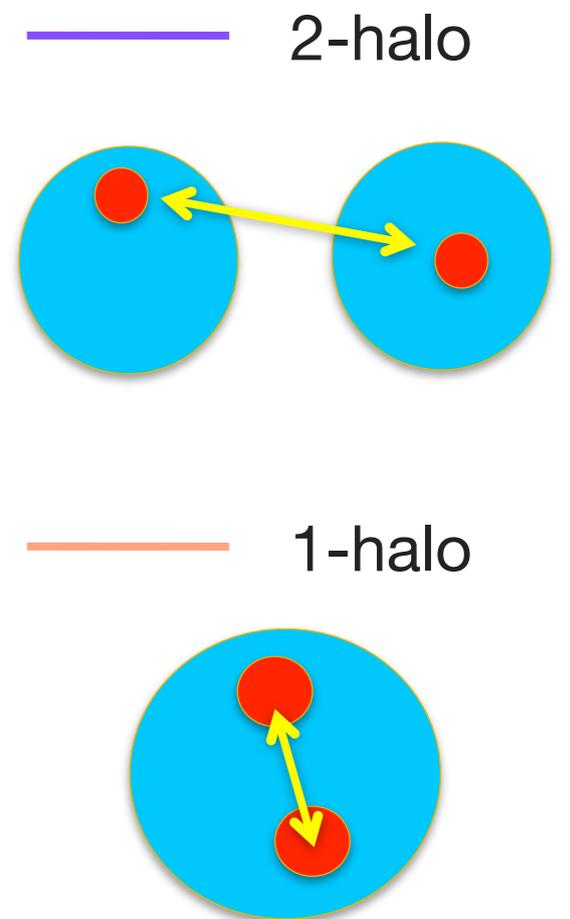
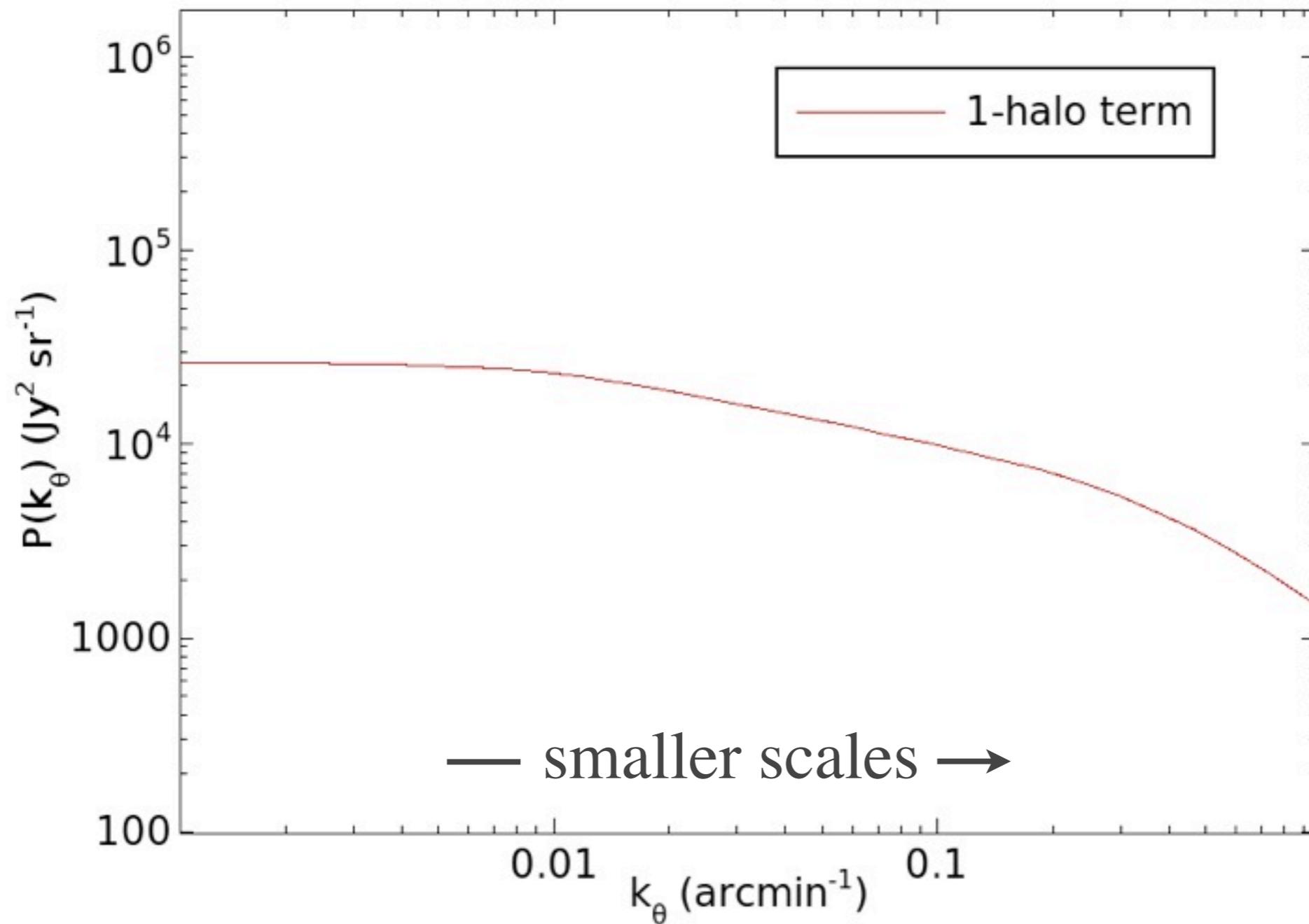
CIBA power spectra



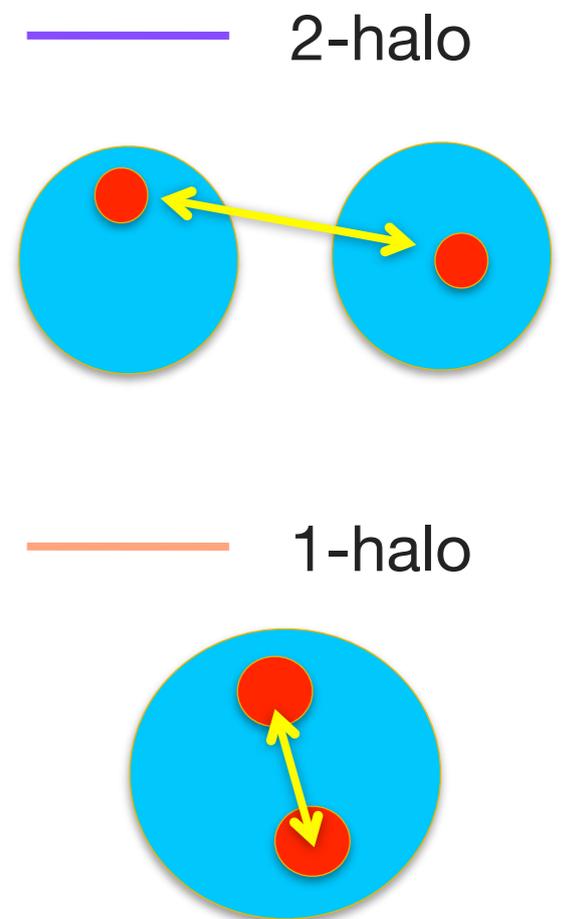
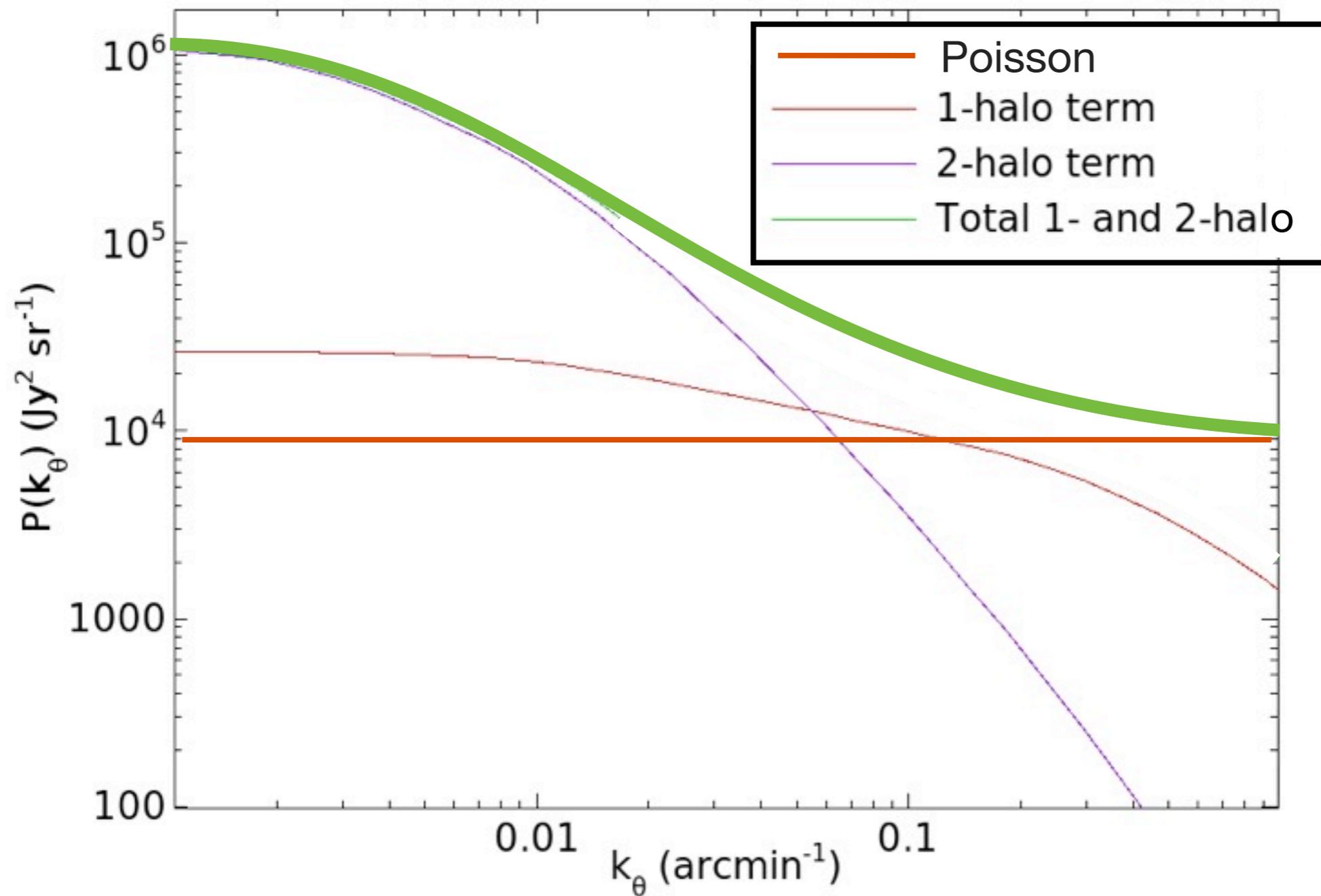
CIBA power spectra



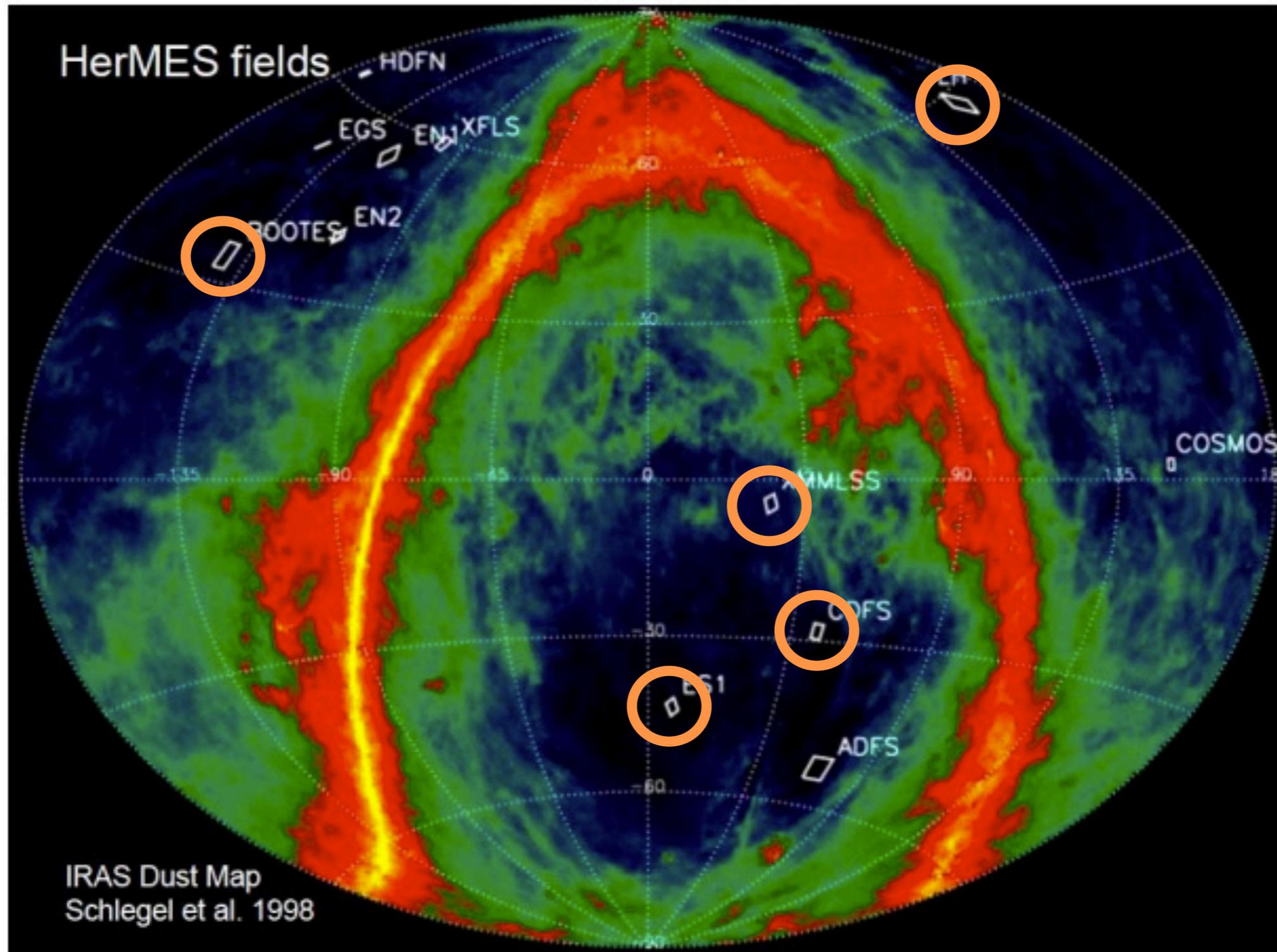
CIBA power spectra



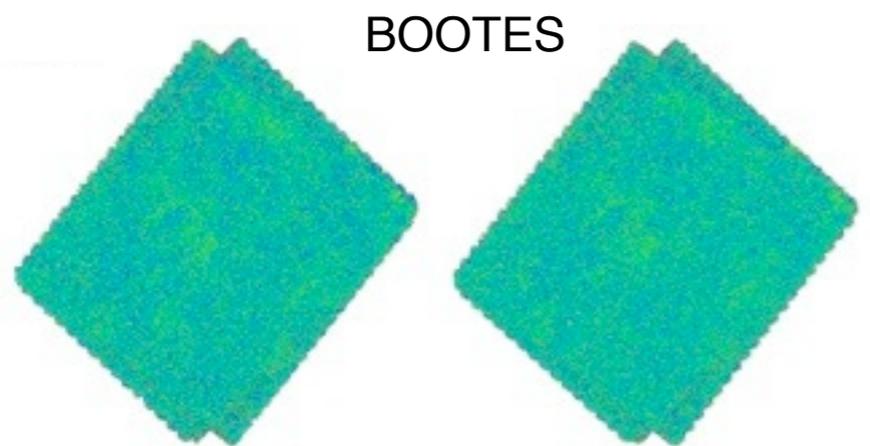
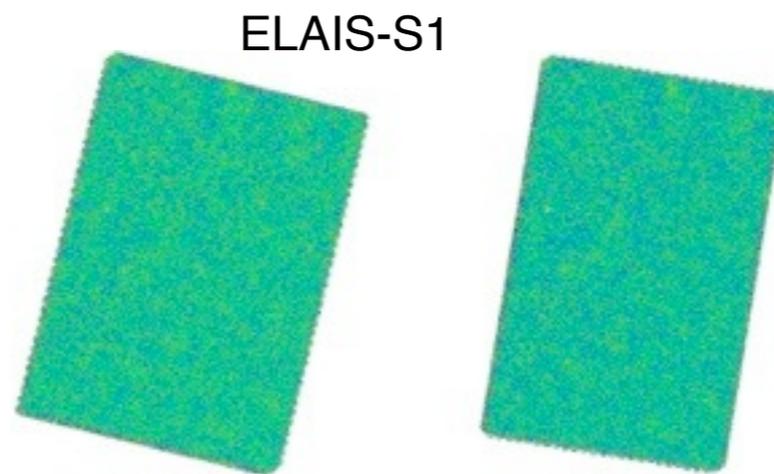
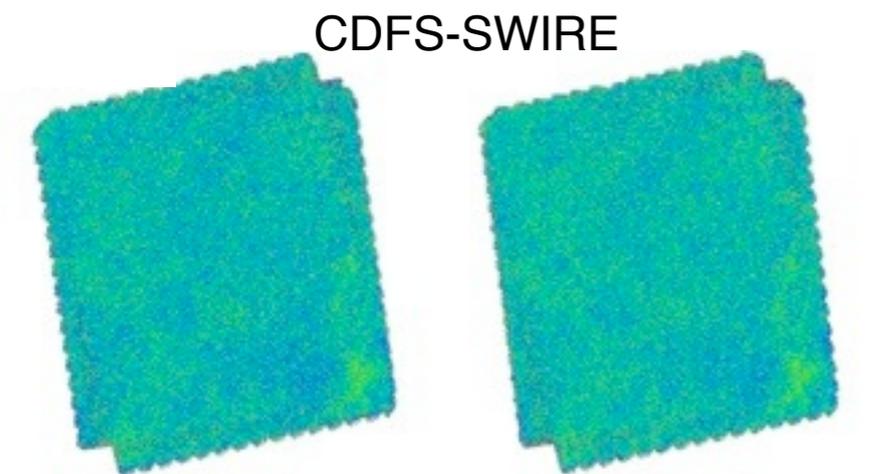
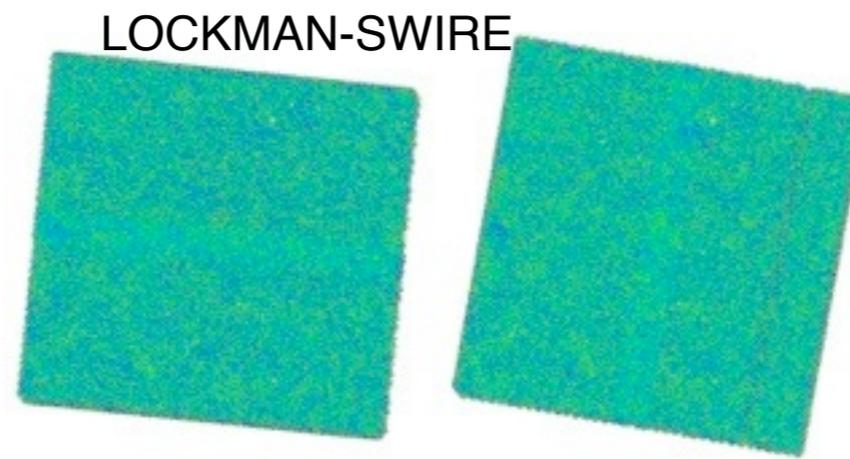
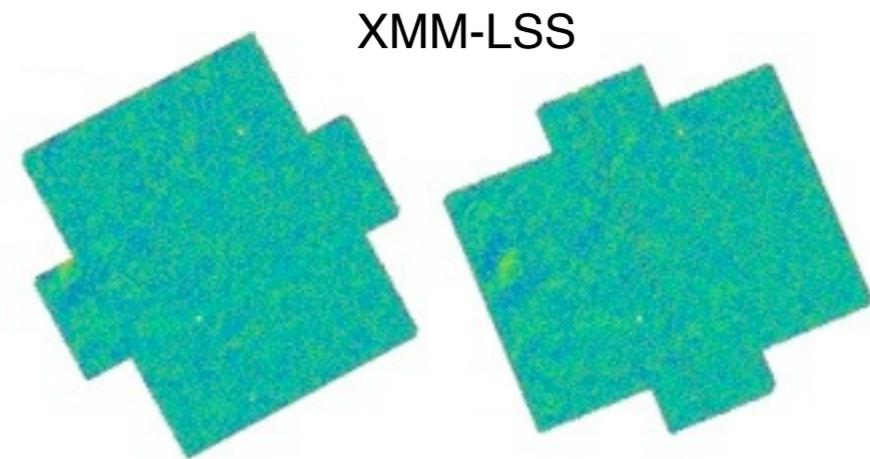
CIBA power spectra



HERMES



data



SMAP Team

Alex Conley

Louis Levenson

Gaelen Marsden

Bernhard Schulz

Marco Viero

Mike Zemcov

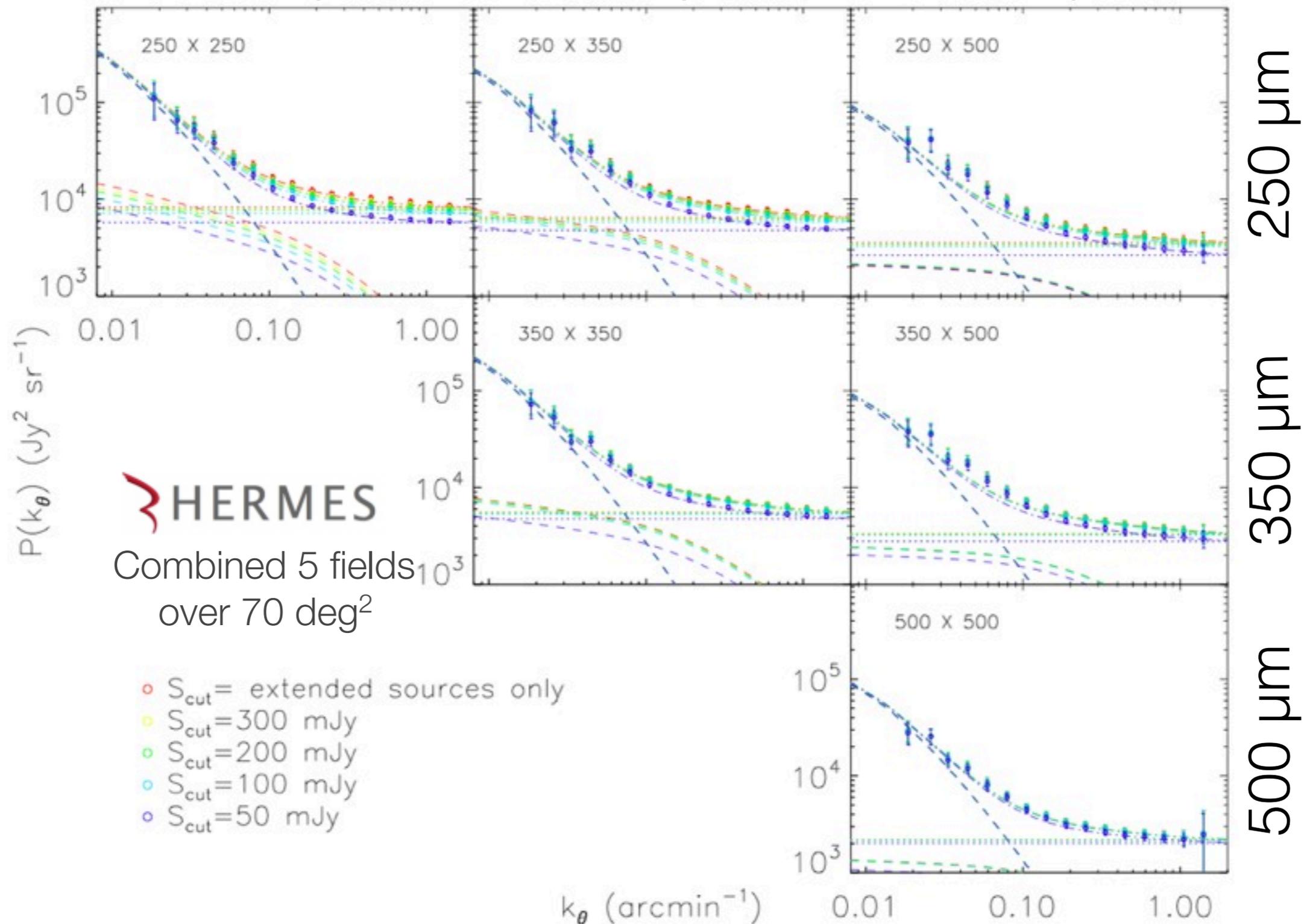
- SPIRE maps at 250, 350, and 500 μm
- Maps made with HerMES SMAP pipeline
- 5 fields totaling $\sim 70 \text{ deg}^2$
- Modes $> \sim 0.5 \text{ deg}$ filtered
- Sources $> 50, 100, 200, 300 \text{ mJy}$ masked

CIBA power spectra

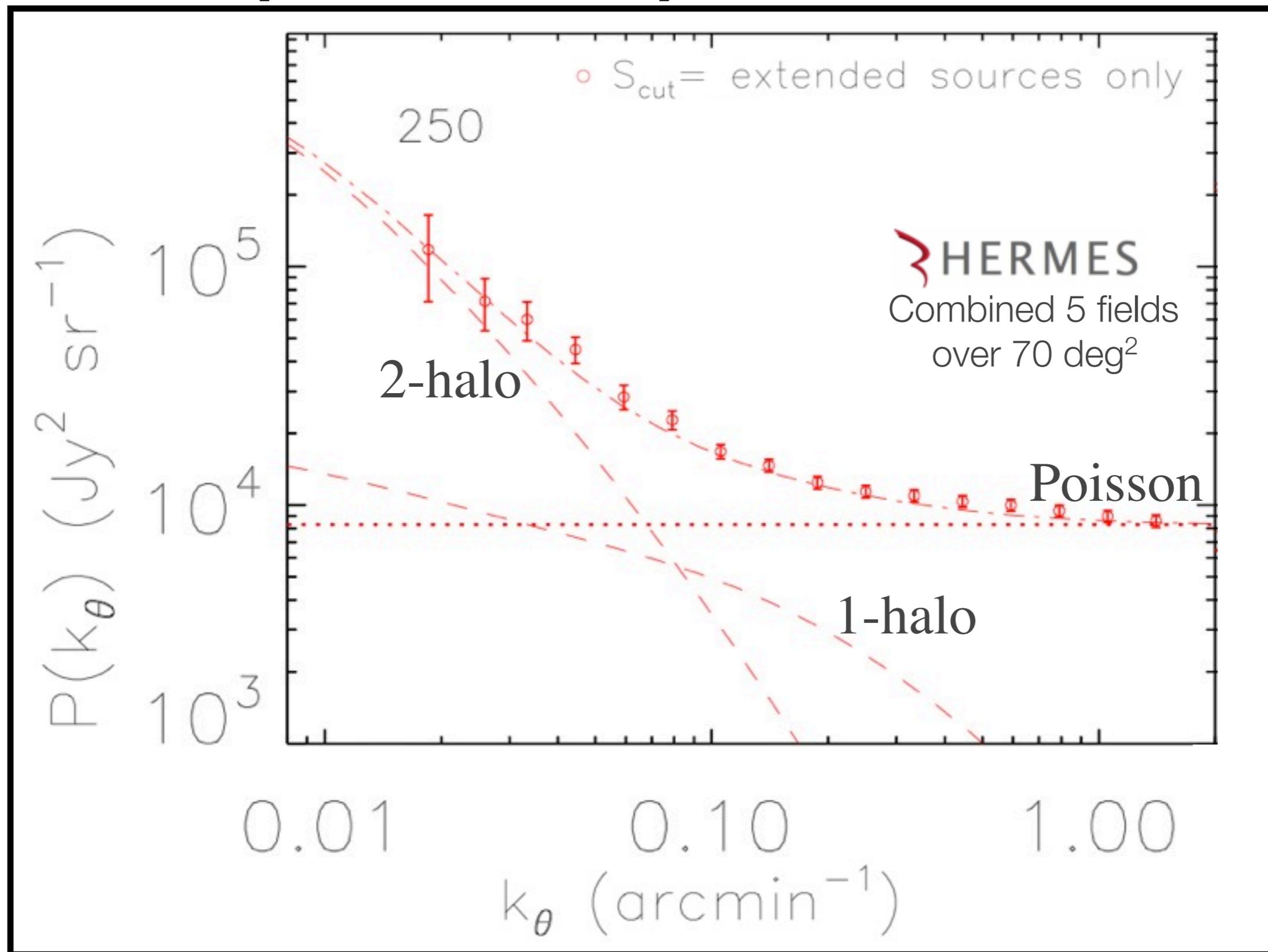
250 μm

350 μm

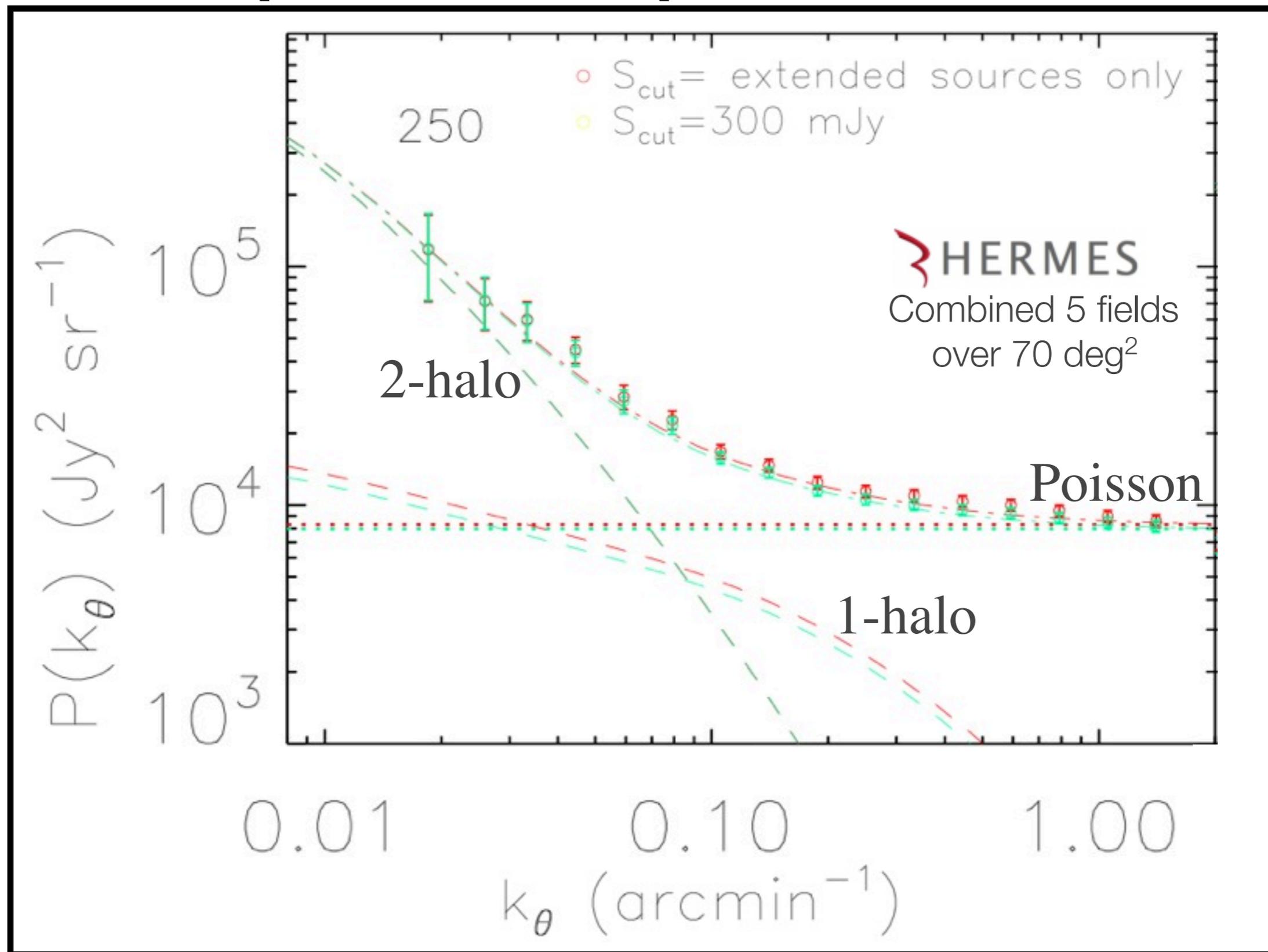
500 μm



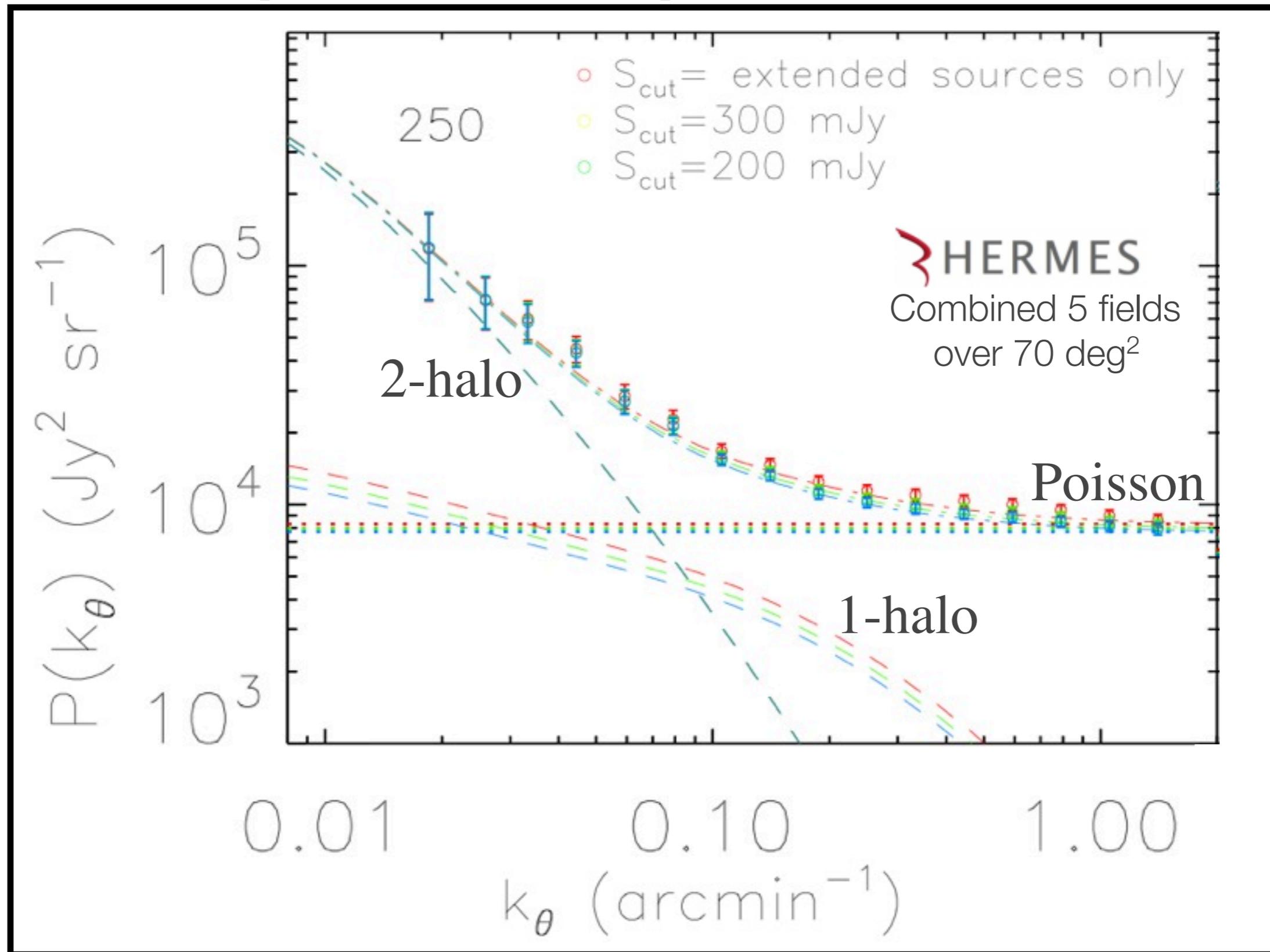
CIBA power spectra



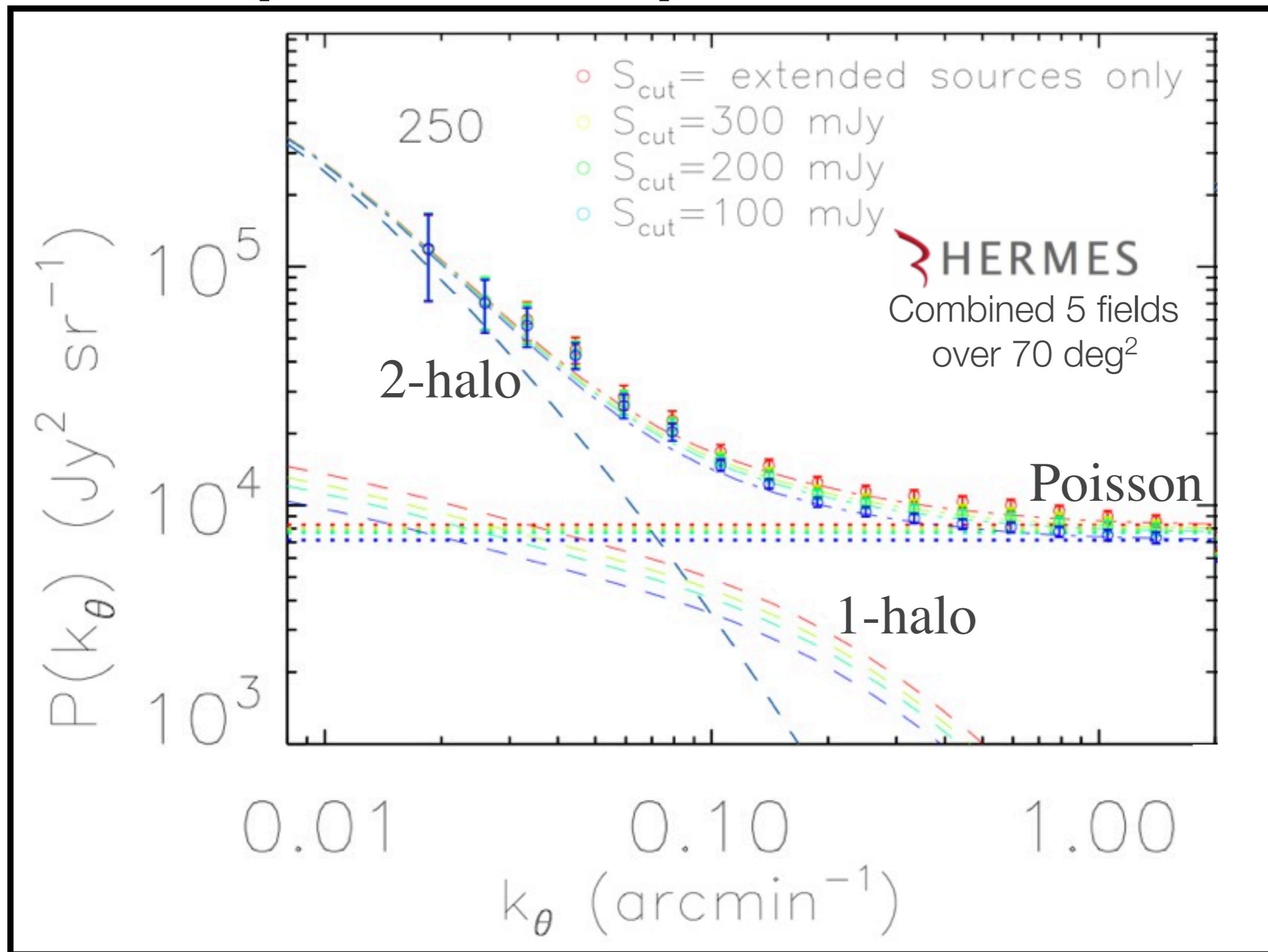
CIBA power spectra



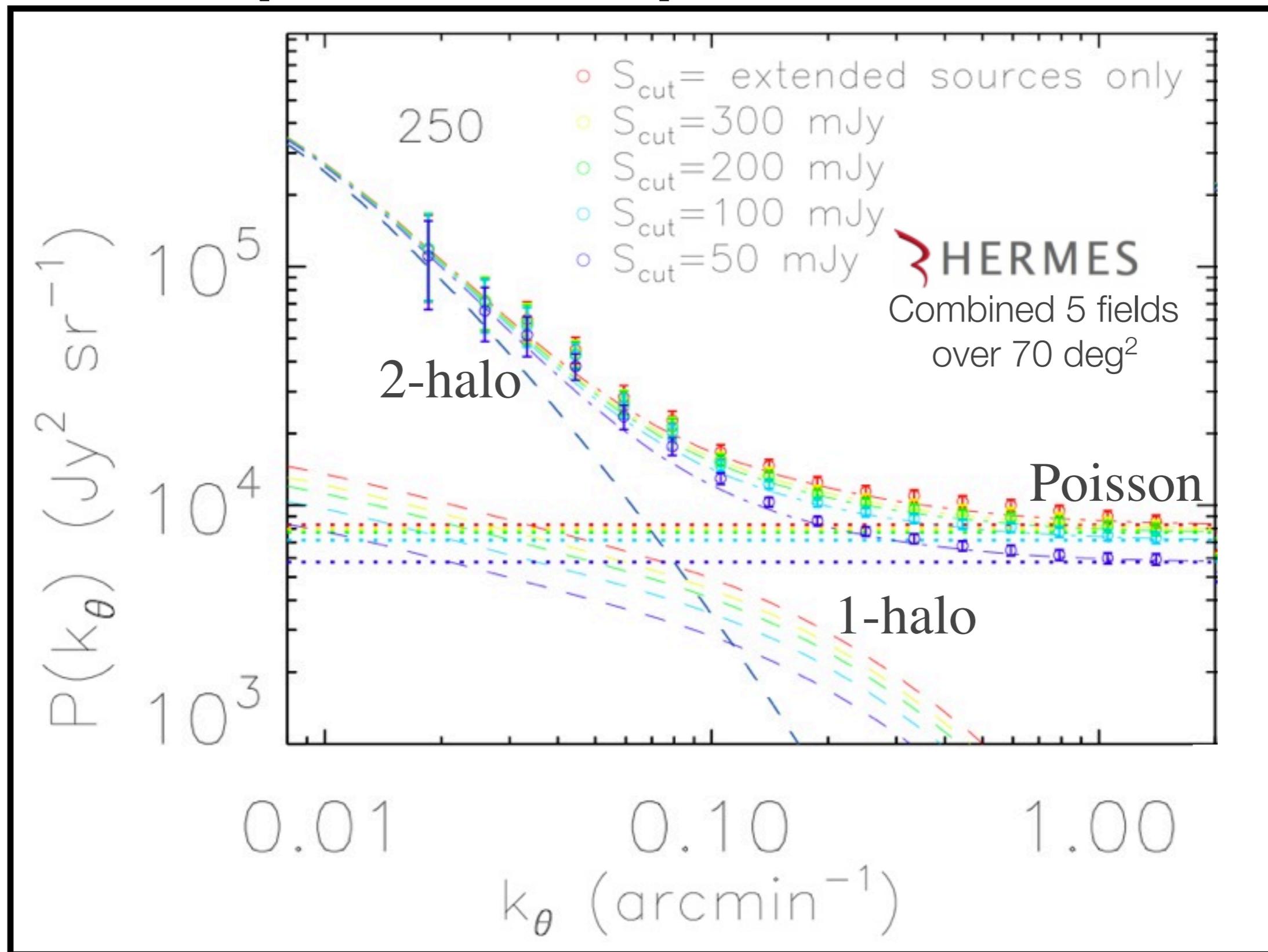
CIBA power spectra



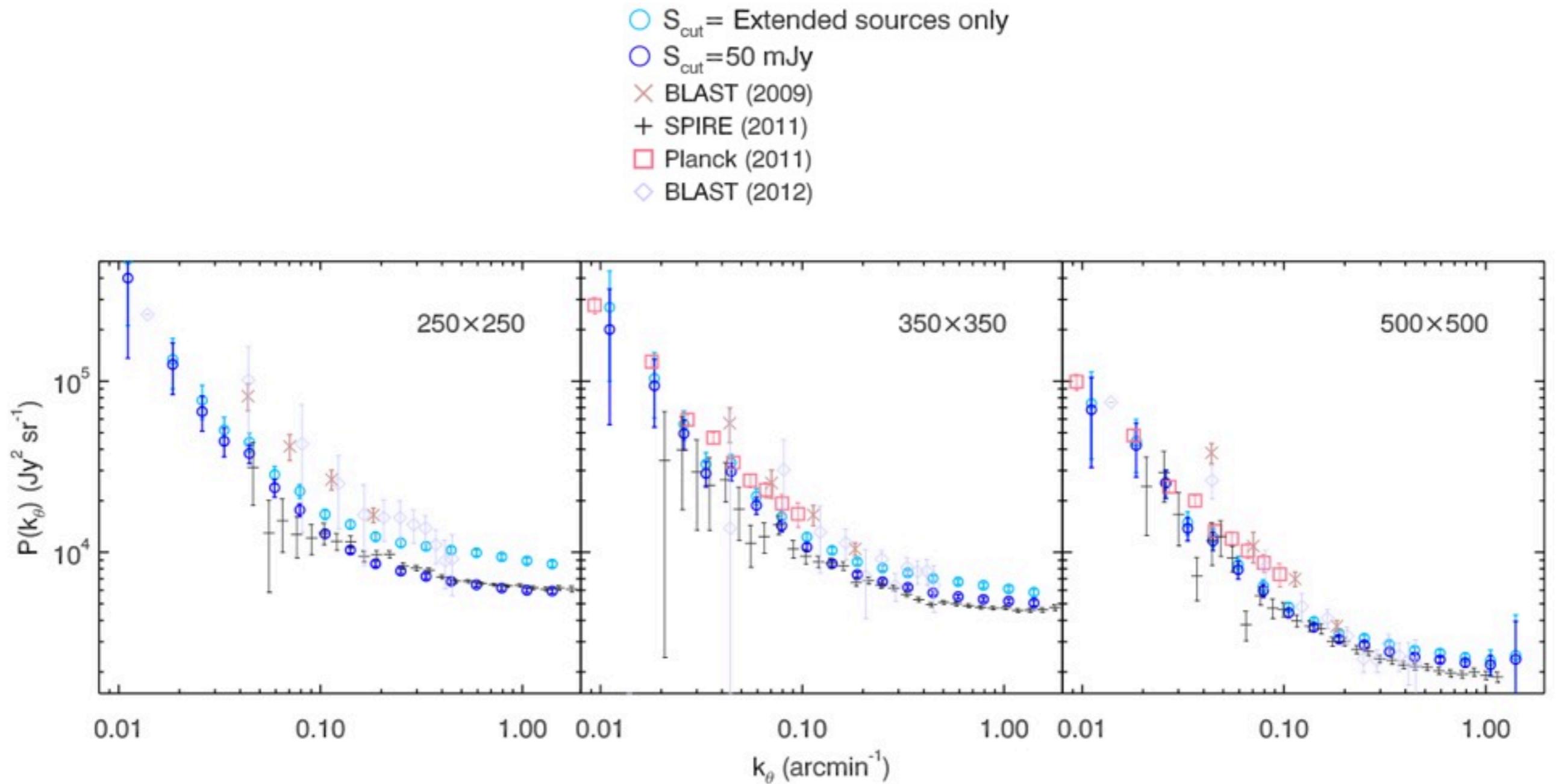
CIBA power spectra



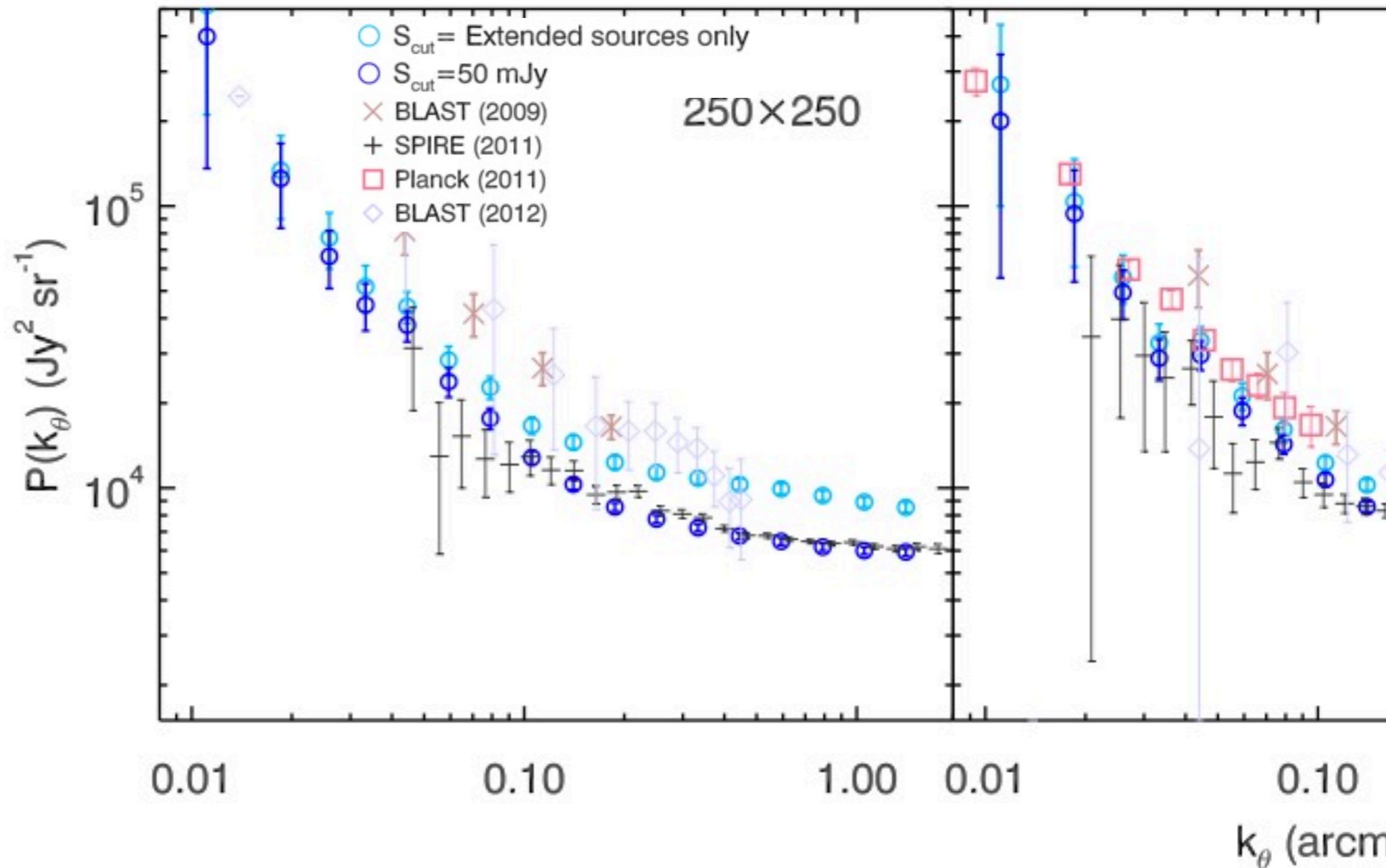
CIBA power spectra



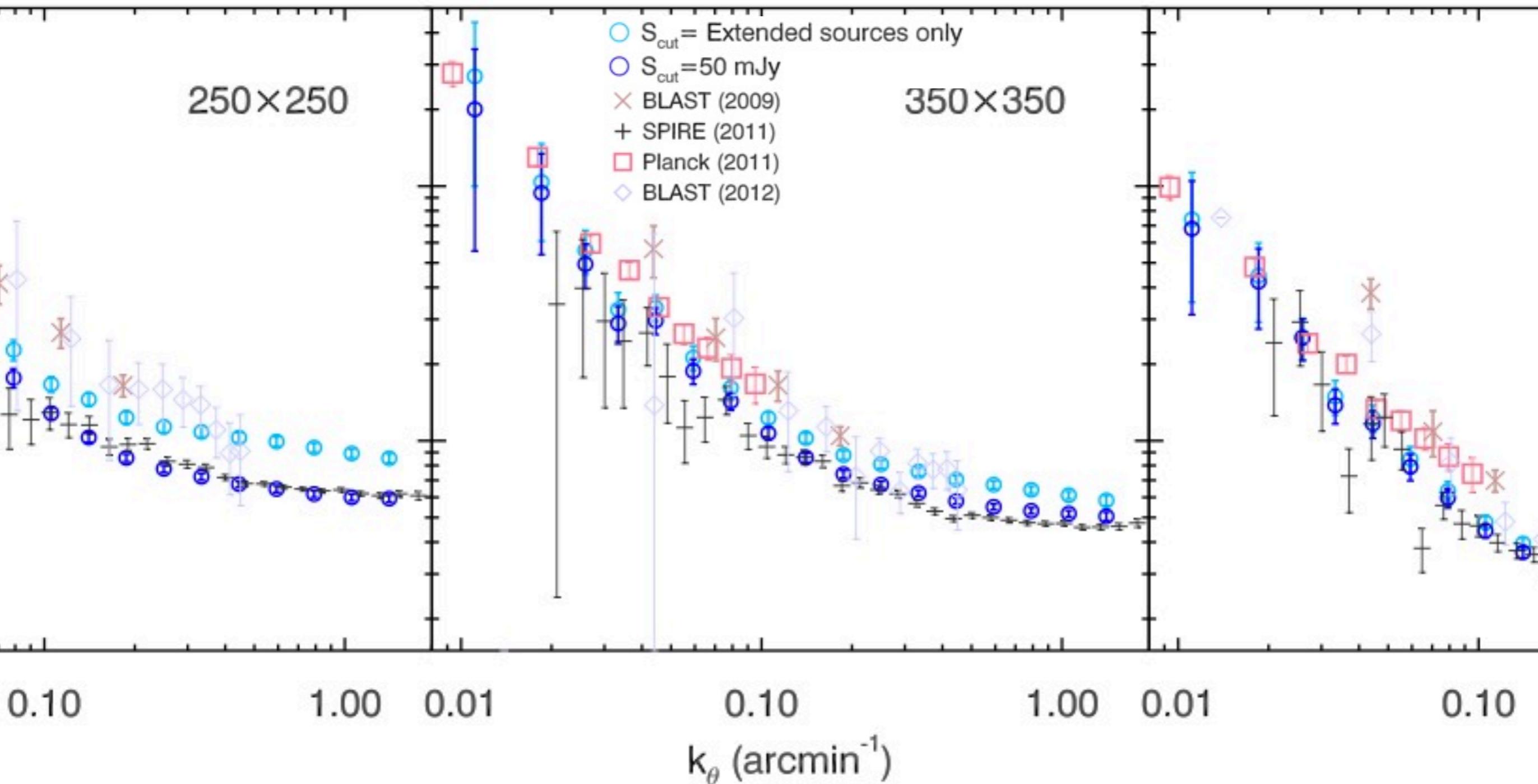
CIBA power spectra



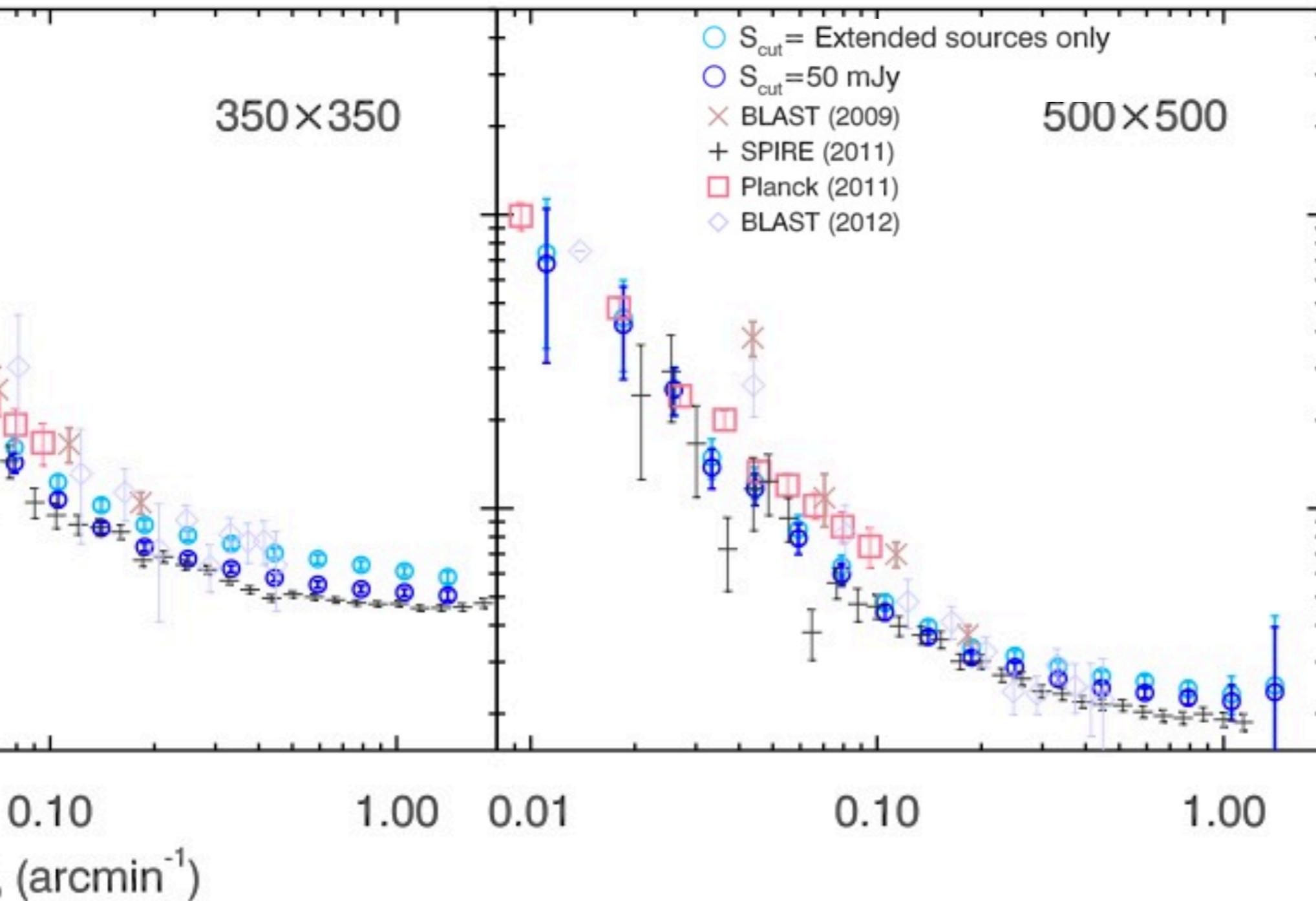
CIBA power spectra



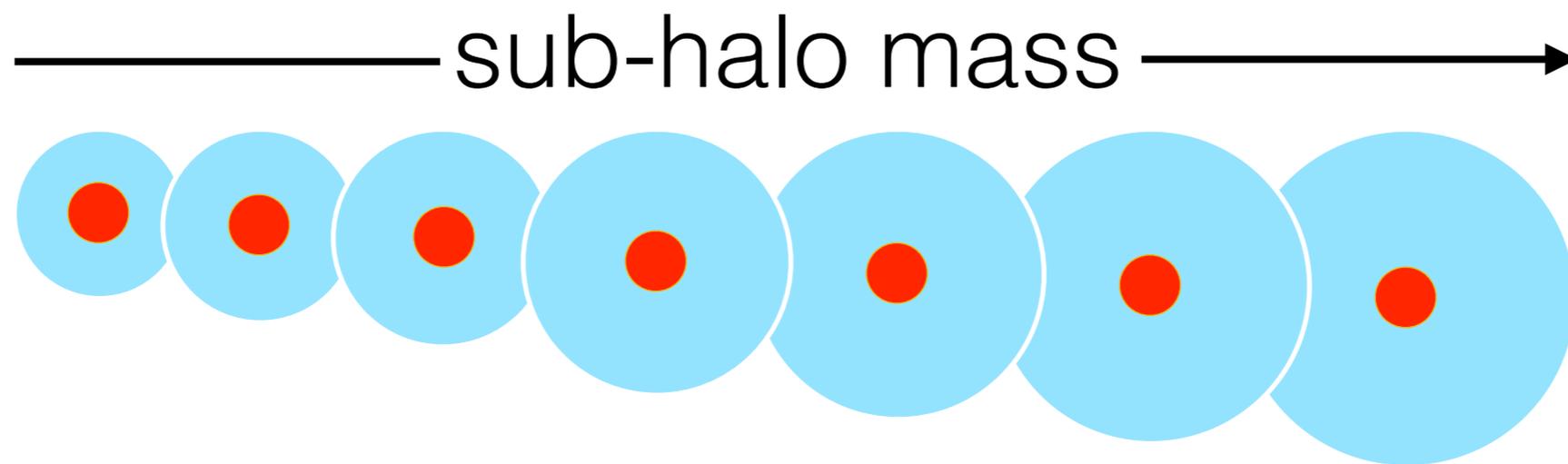
CIBA power spectra



CIBA power spectra



standard halo model



halo occupation number:

$$(M/M_{\text{sat}})^{\alpha}$$

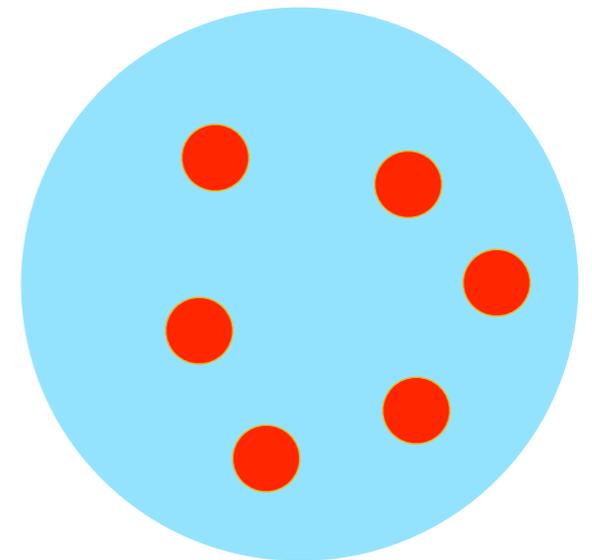
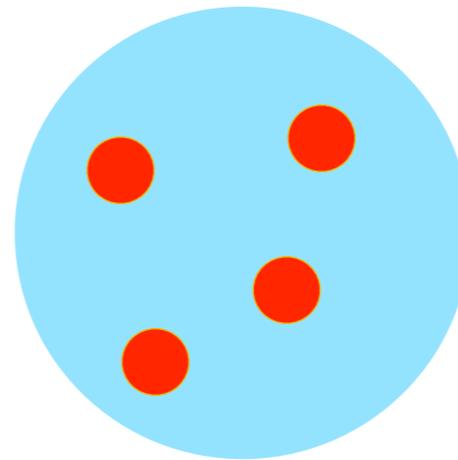
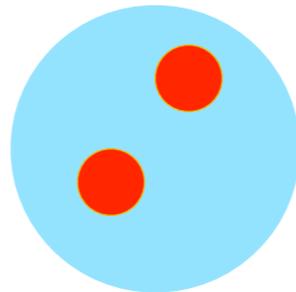
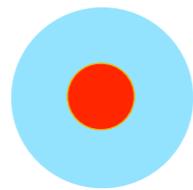
M_{sat}

$2M_{\text{sat}}$

$4M_{\text{sat}}$

$6M_{\text{sat}}$

N-body
simulations
 $\alpha \sim 1$



halo occupation number:

$$(M/M_{\text{sat}})^{\alpha}$$

M_{sat}

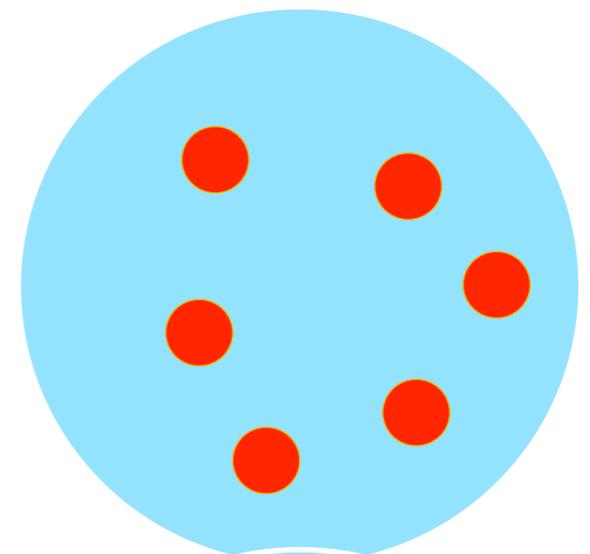
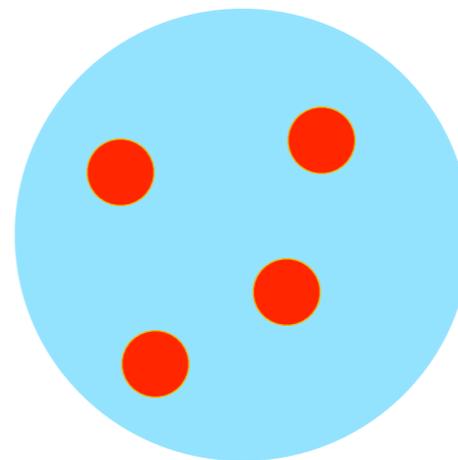
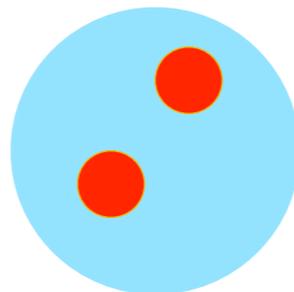
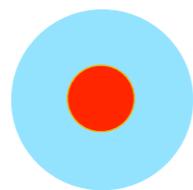
$2M_{\text{sat}}$

$4M_{\text{sat}}$

$6M_{\text{sat}}$

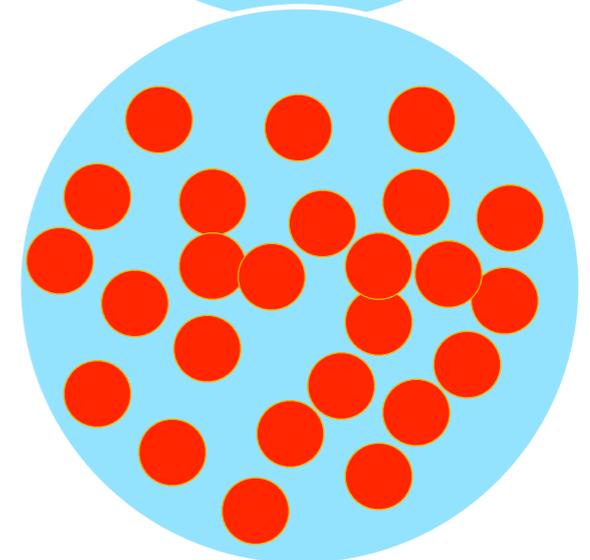
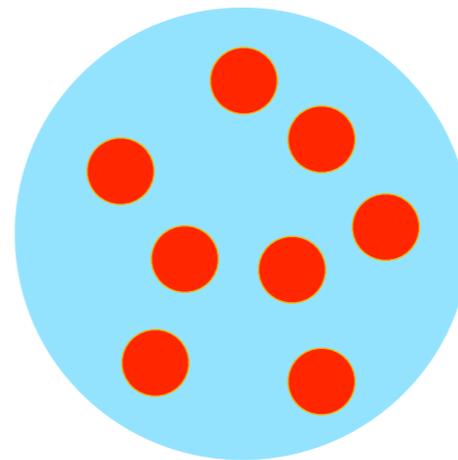
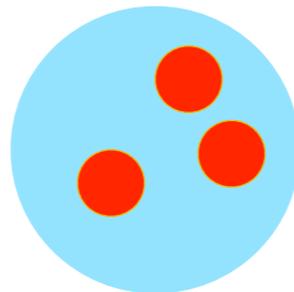
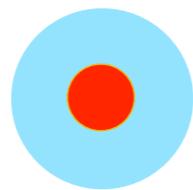
N-body
simulations

$\alpha \sim 1$

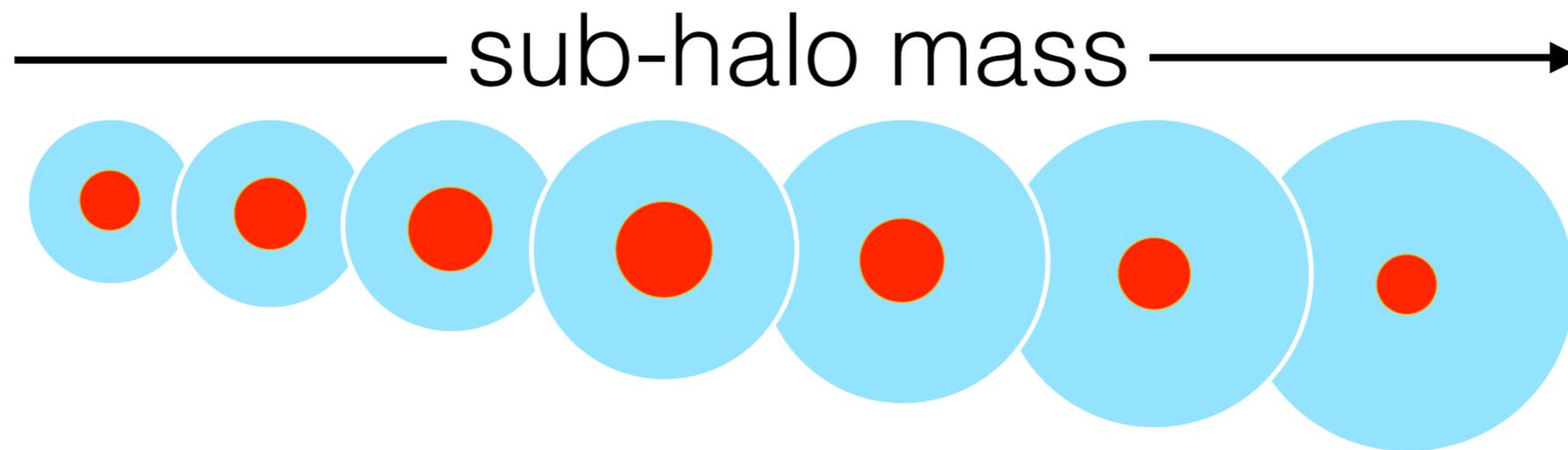


Standard
Halo model

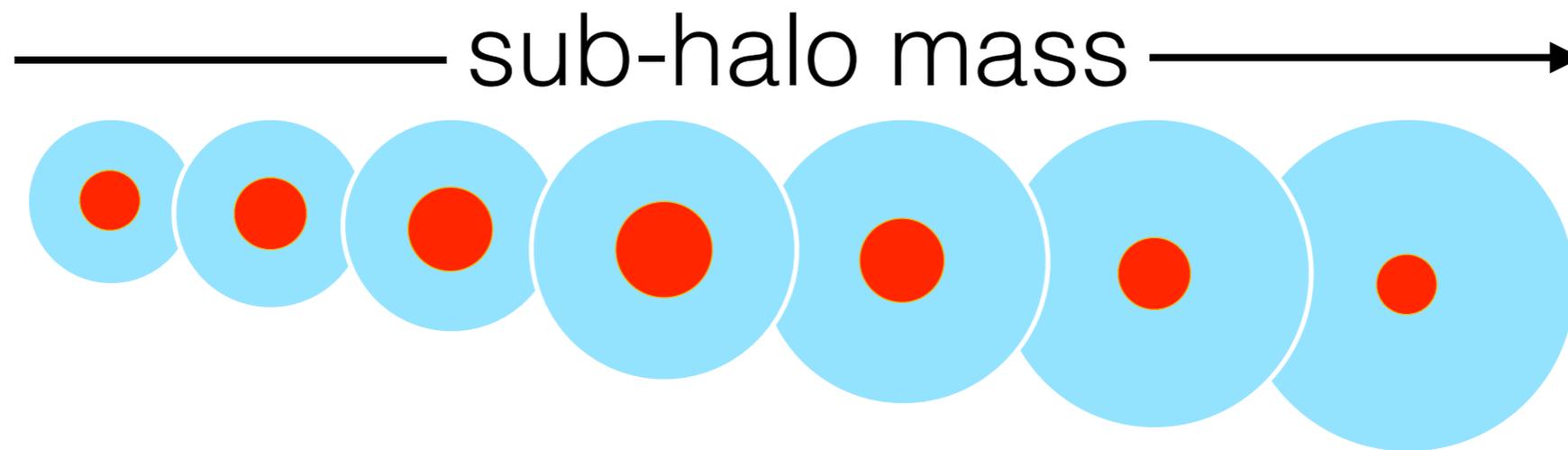
$\alpha \sim 1.8$



luminosity-mass (L-M) relation

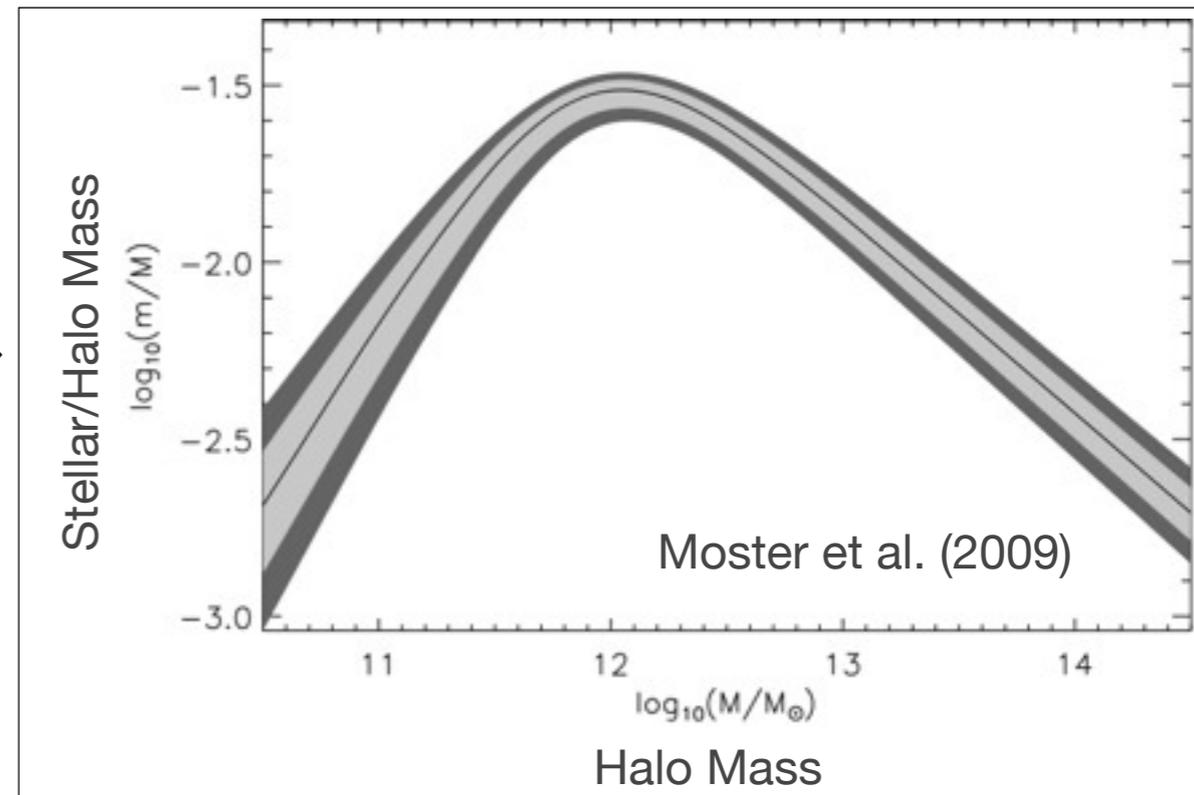


luminosity-mass (L-M) relation

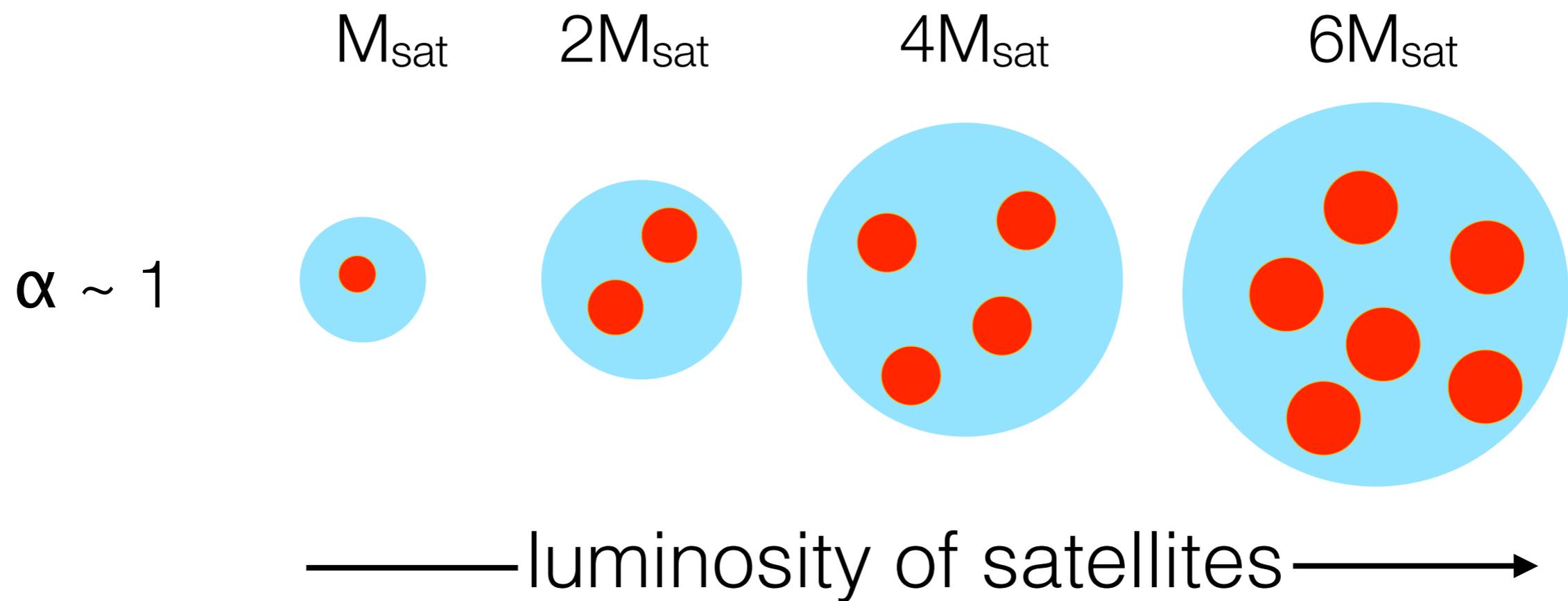


log-normal distribution:

$$\Sigma(m) = m \frac{1}{\sqrt{2\pi\sigma_{L/m}^2}} \exp \left[-\frac{(\log_{10} m - \log_{10} m_{\text{eff}})^2}{2\sigma_{L/m}^2} \right]$$



L-M relation model

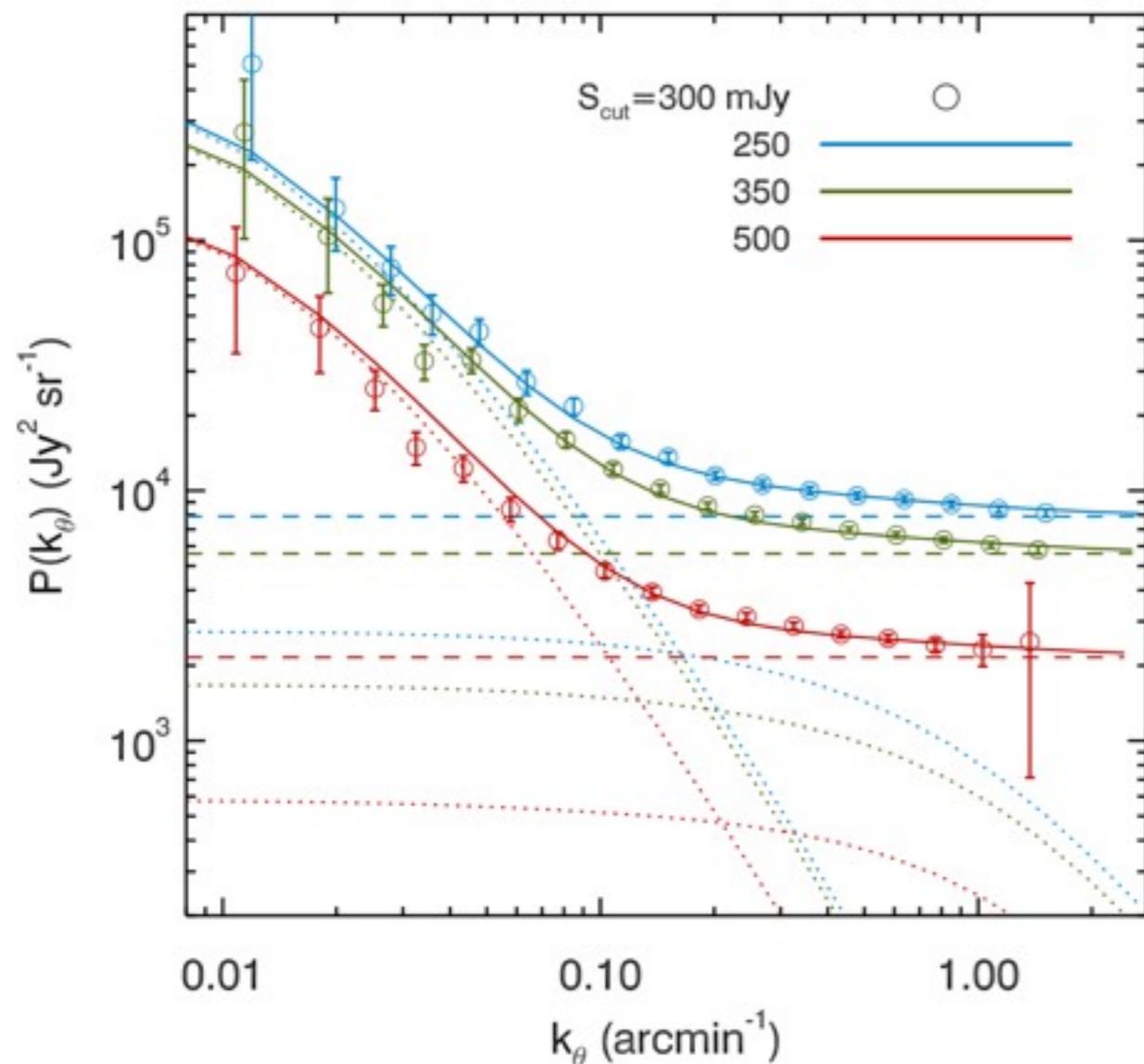


complex yet still simple

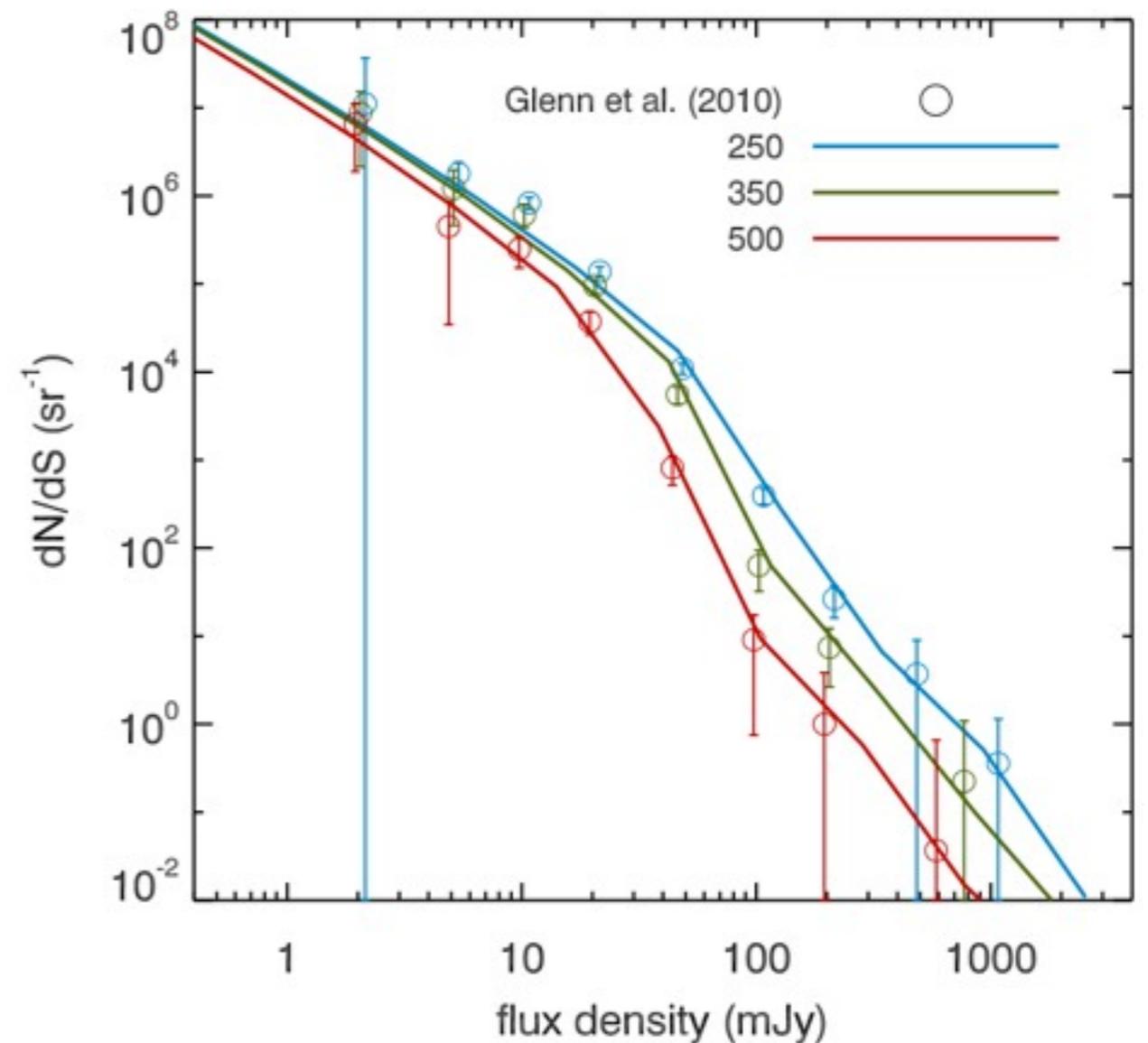
ref.	type	fit to:	# free [fixed] parameters	parameters
Viero (2012)	L-M	250+350+ 500+counts	5 [2]	$T, \beta, M_{\min}, M_{\text{peak}}, \sigma_{L/m}^2, L_0, \eta$
Shang (2012)	L-M	350,550	3 [4]	$T, \beta, M_{\min}, M_{\text{peak}}, \sigma_{L/m}^2, L_0, s_z$
Planck (2011)	standard	350,550, 850,1380	2 [2]	$M_{\min}, M_{\text{sat}}, \sigma_{\log M}, \alpha$
Amblard (2011)	standard	250,350,500	8 [0]	$M_{\min}, M_{\text{sat}}, \alpha, P(k)_{\text{shot}}, 4 \times dS/dz$
Viero (2009)	standard	250,350,500	2 [0]	M_{\min}, α

L-M model fits

Power spectra

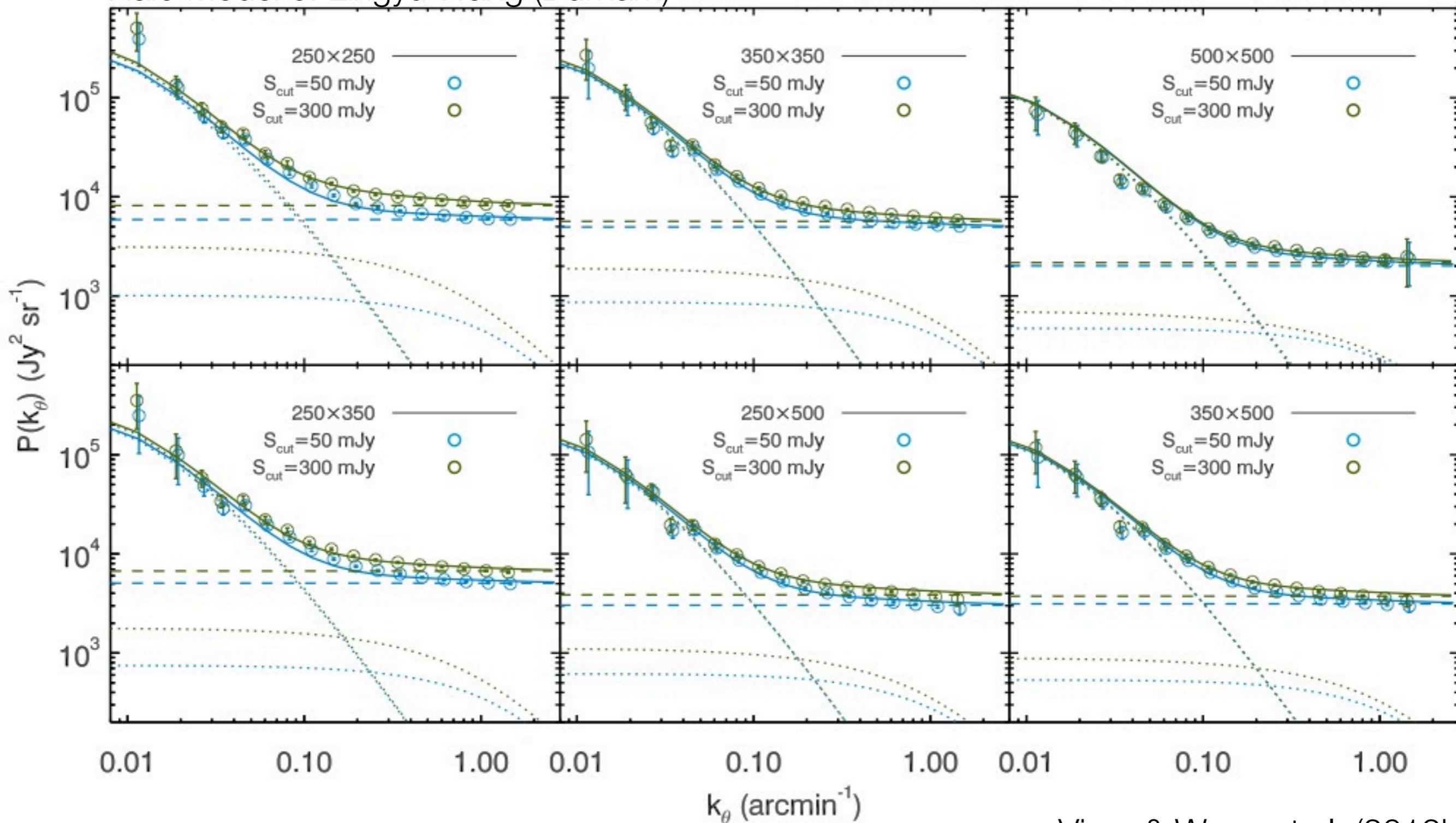


Number counts



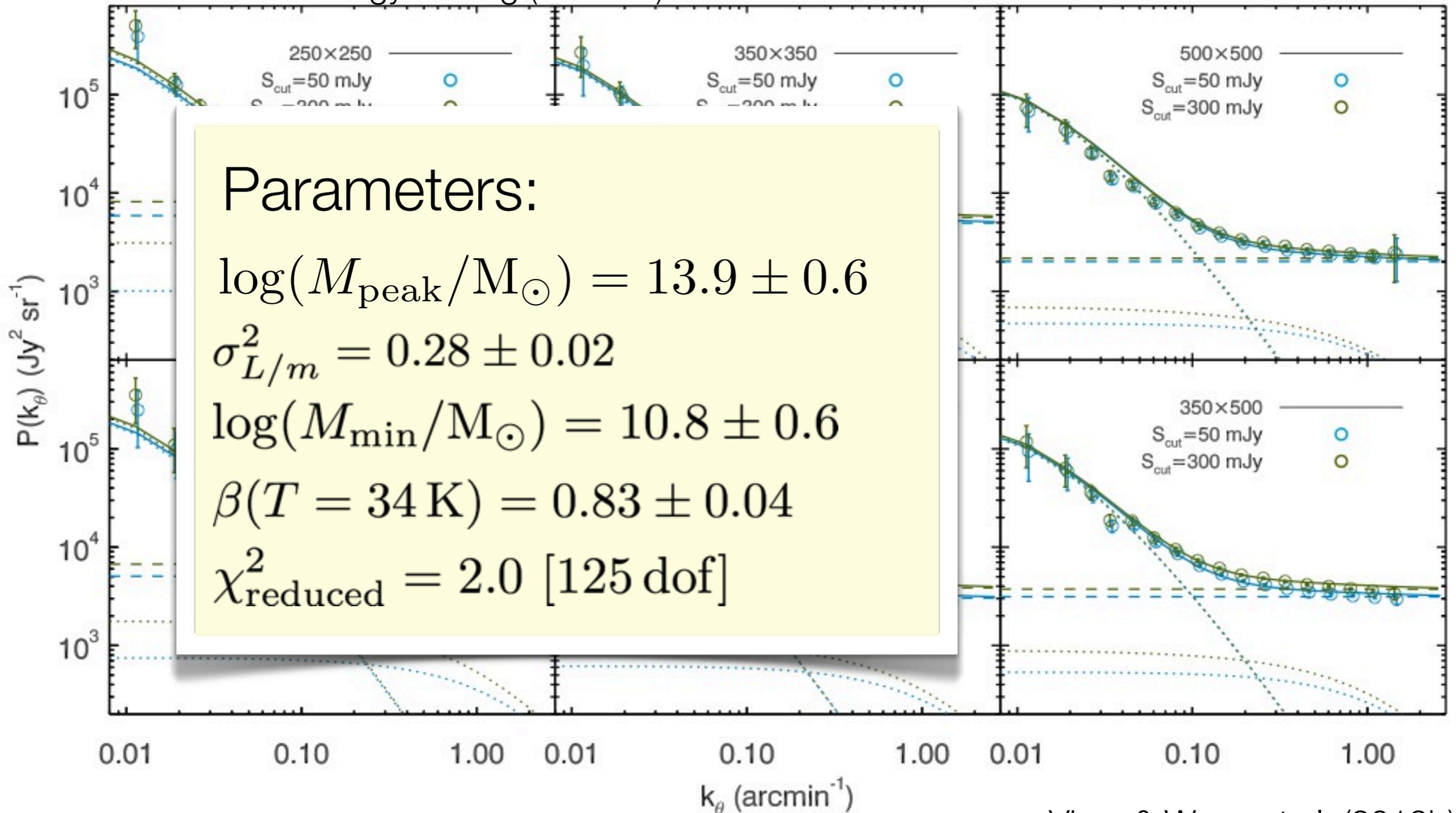
best-fit halo model

Halo Model of Lingyu Wang (Durham)



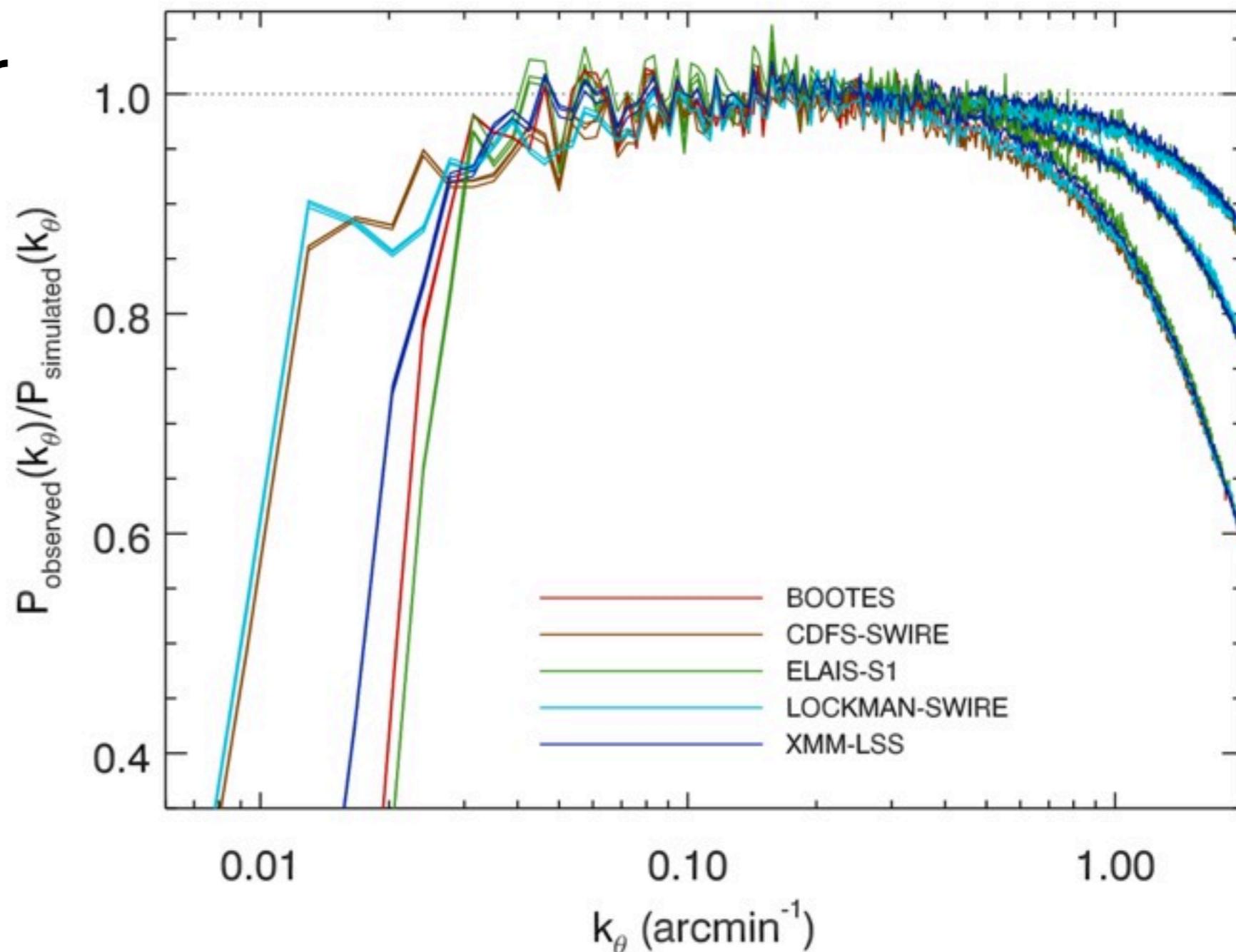
best-fit halo model

Halo Model of Lingyu Wang (Durham)

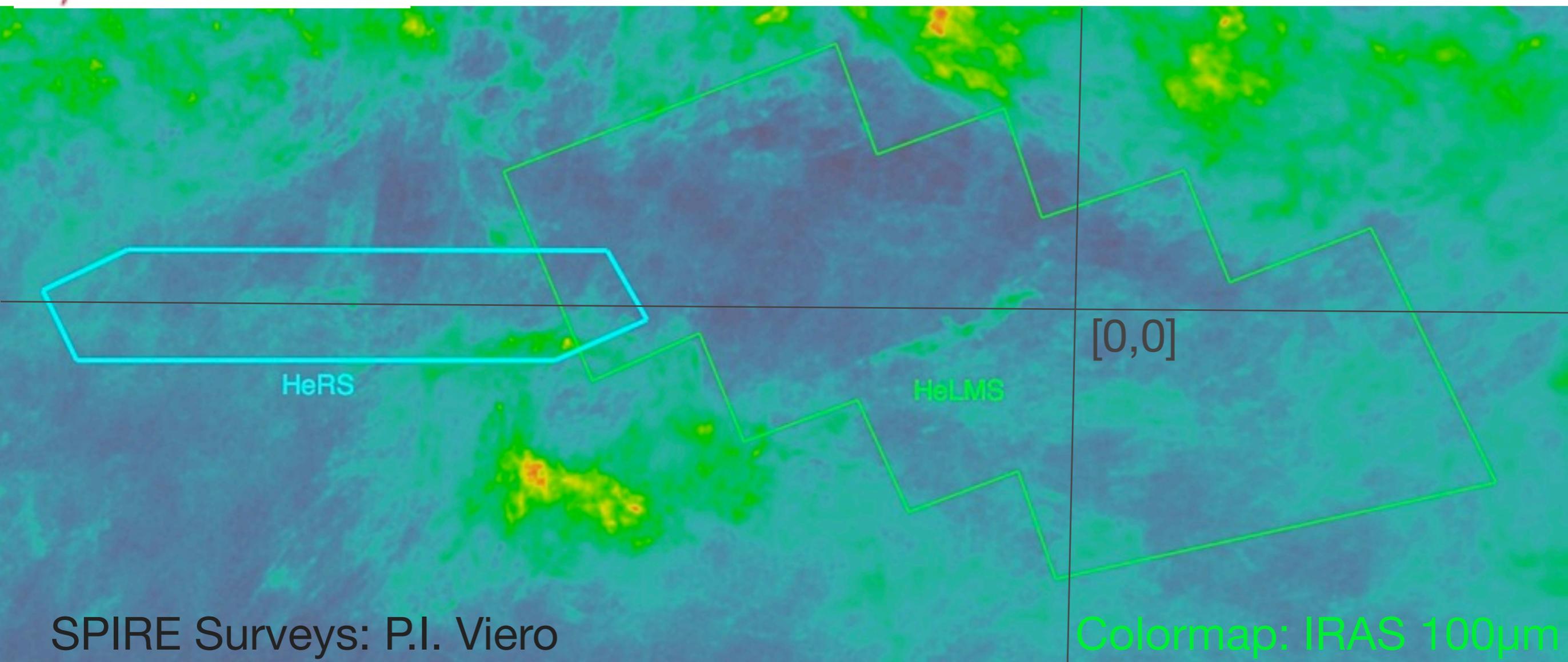


Recover larger modes with

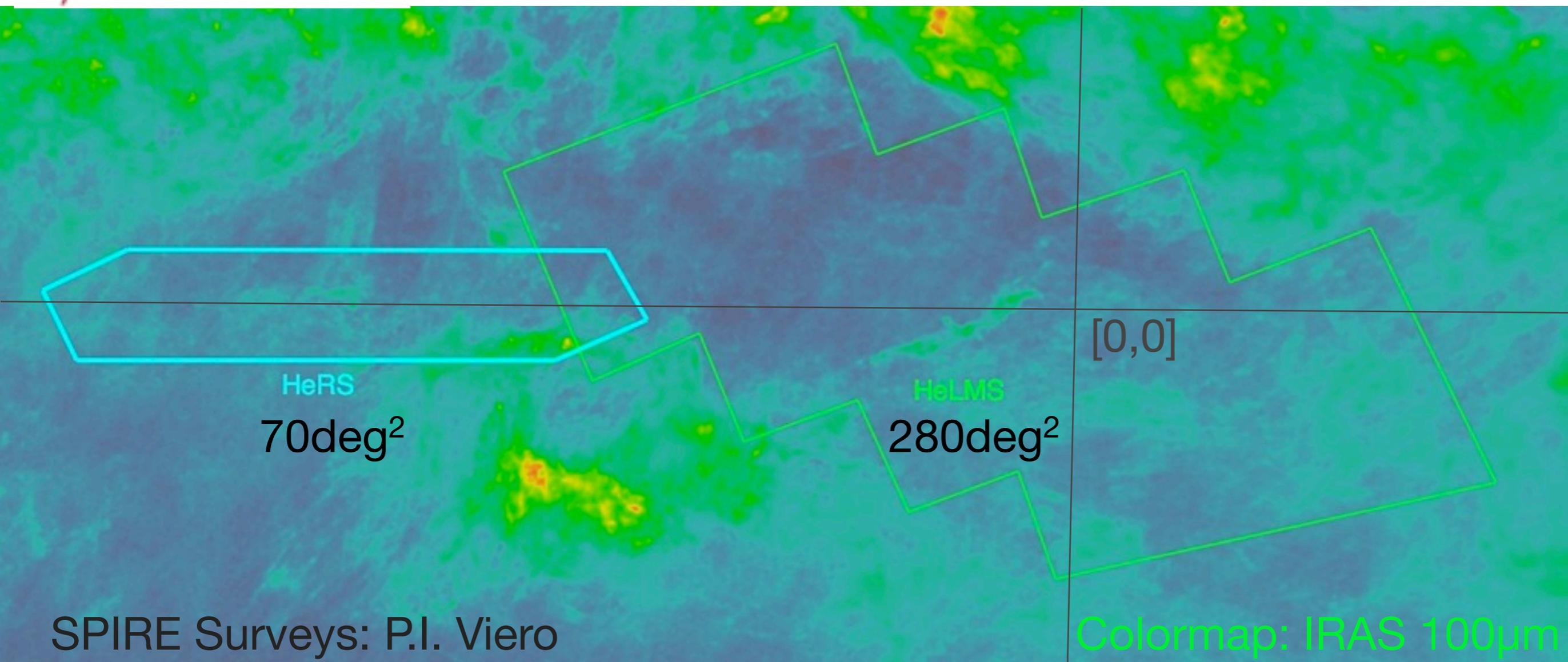
- faster scans
- longer scans
- larger maps



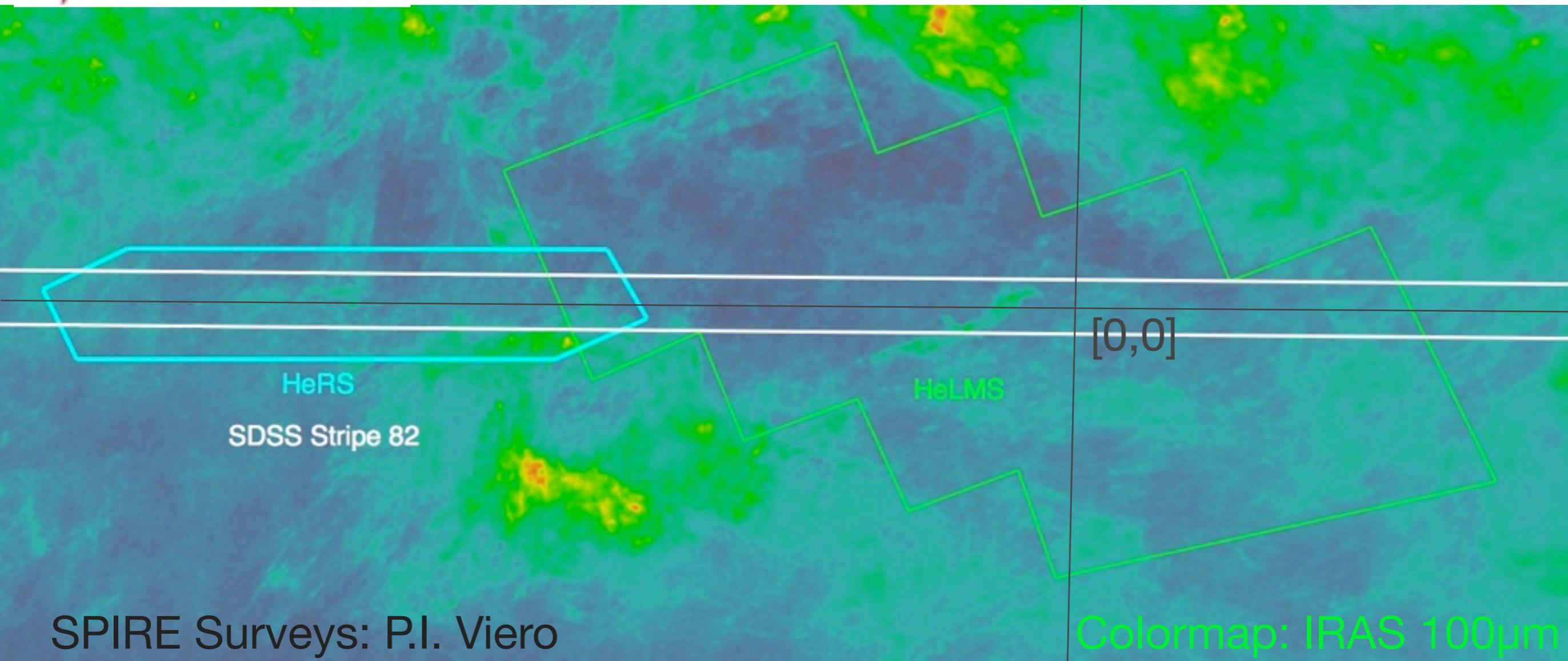
HeLMS/HeRS



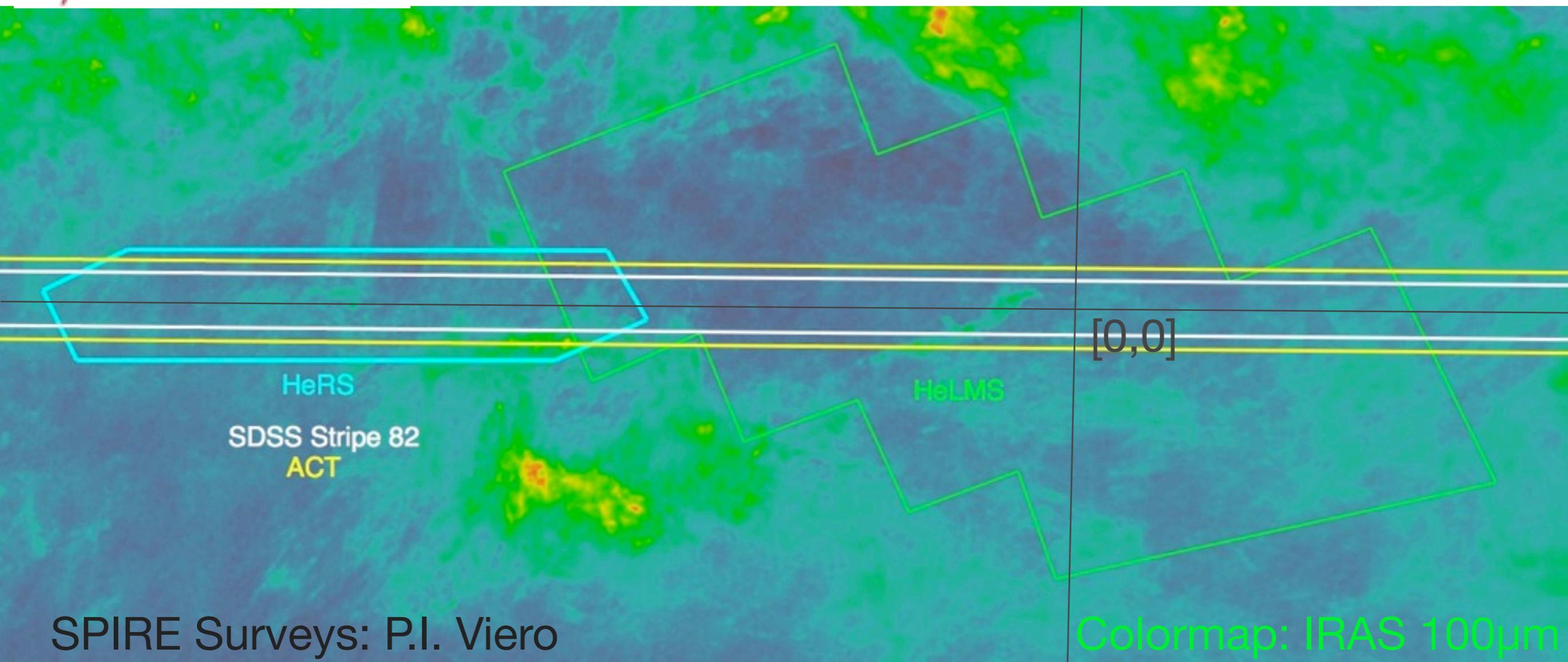
HeLMS/HeRS



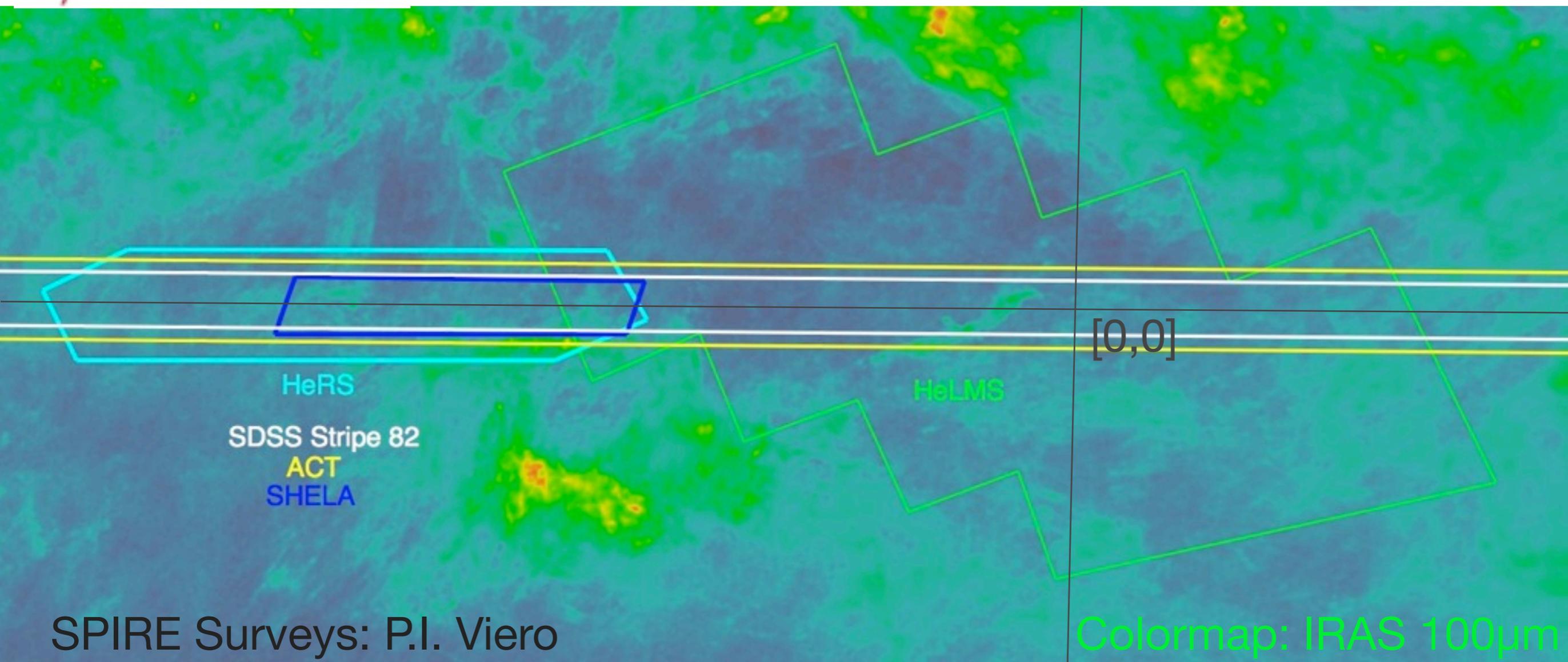
HeLMS/HeRS



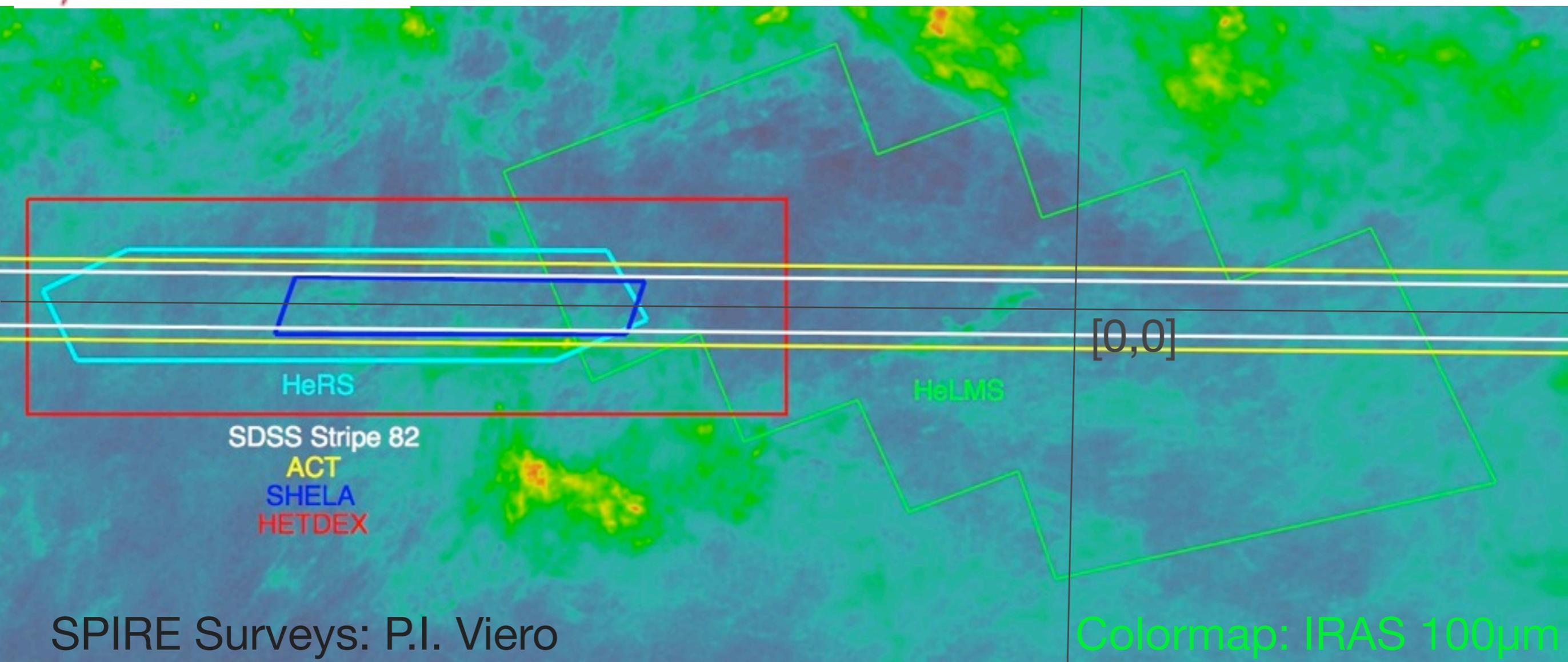
HeLMS/HeRS



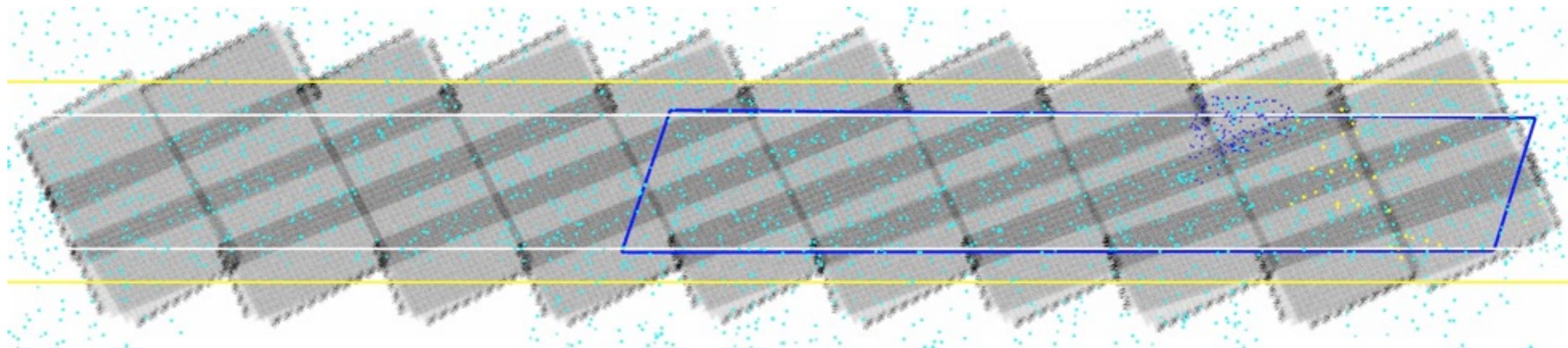
HeLMS/HeRS



HeLMS/HeRS

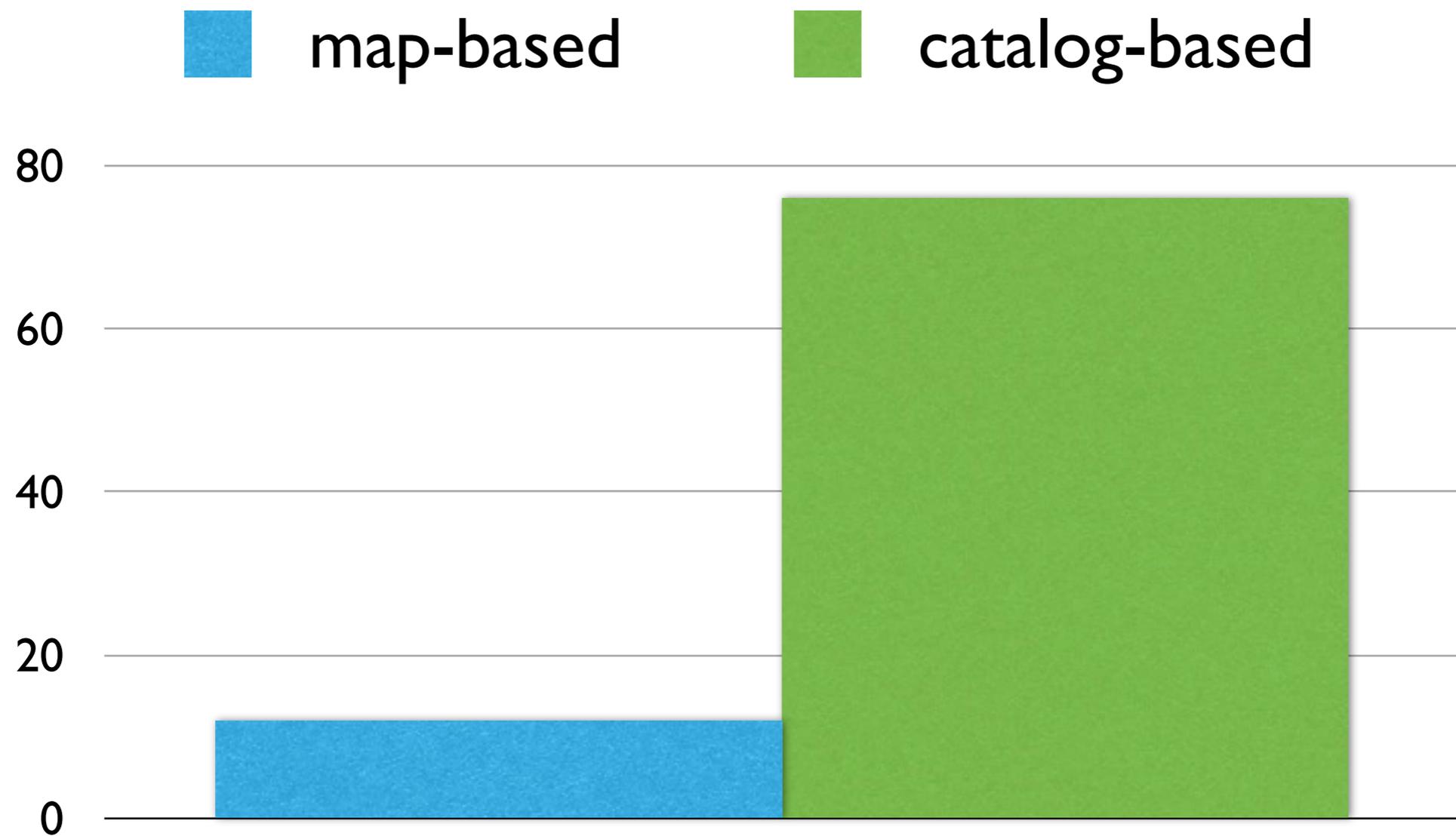


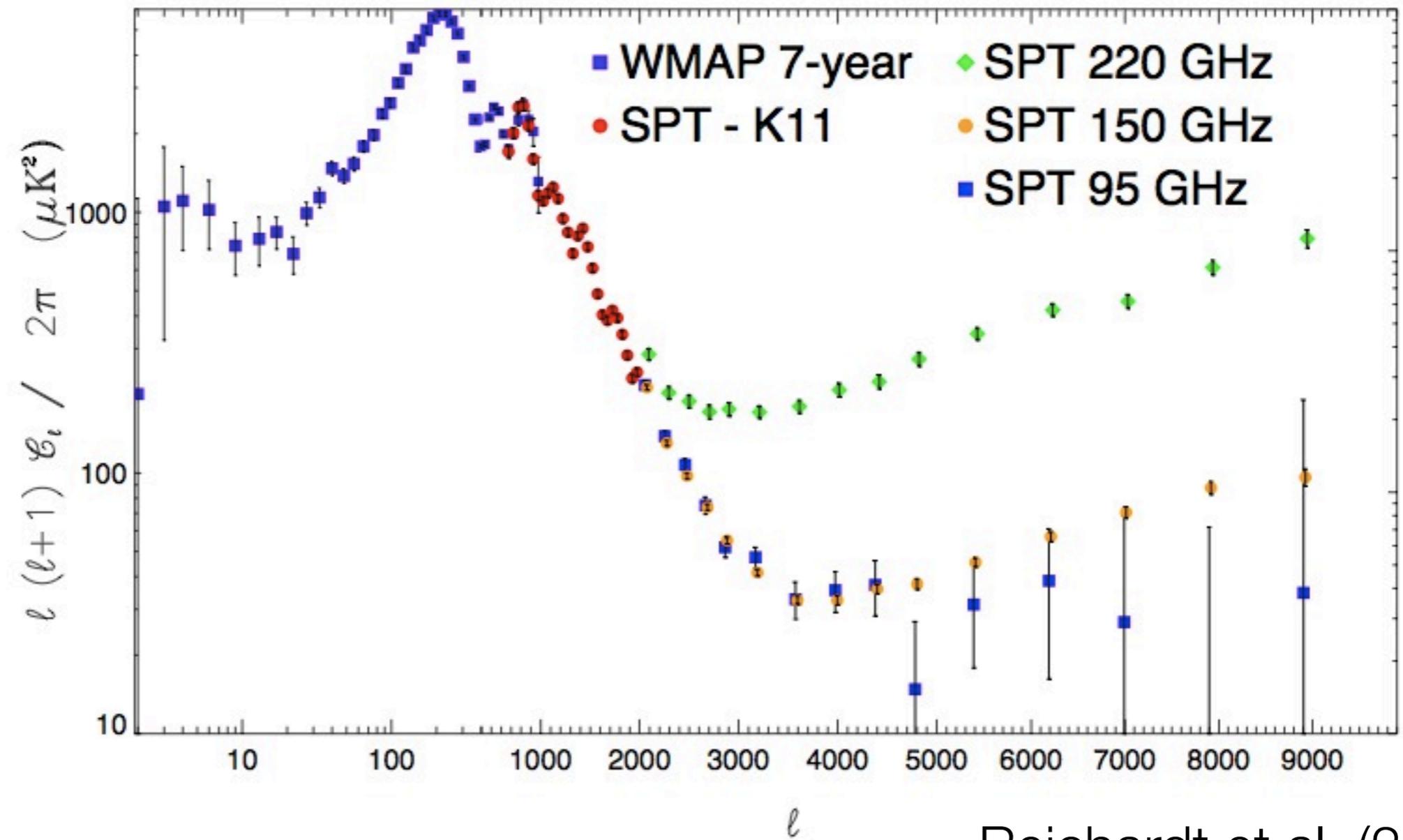
HeLMS/HeRS



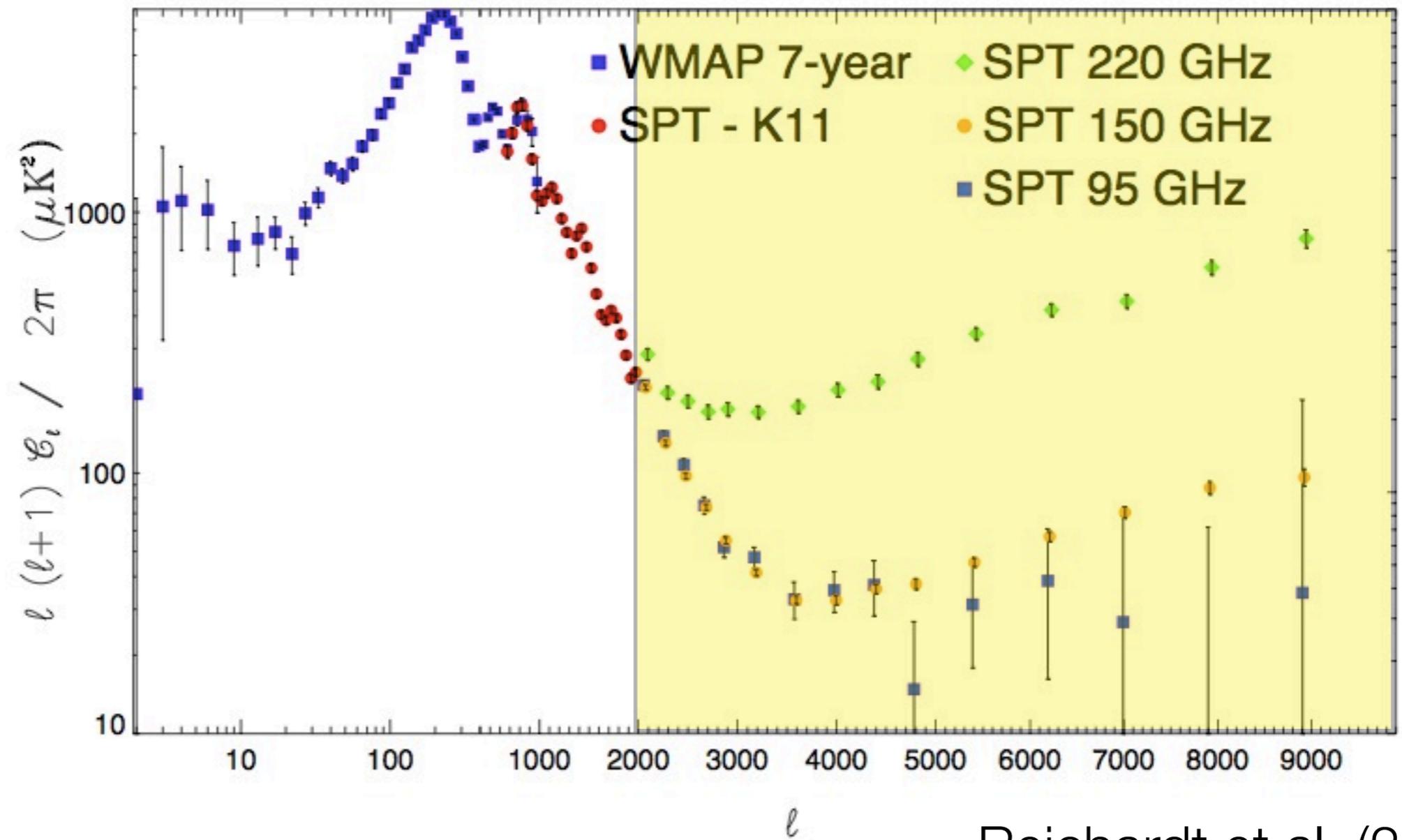
present ideas for collaborations...

ADS



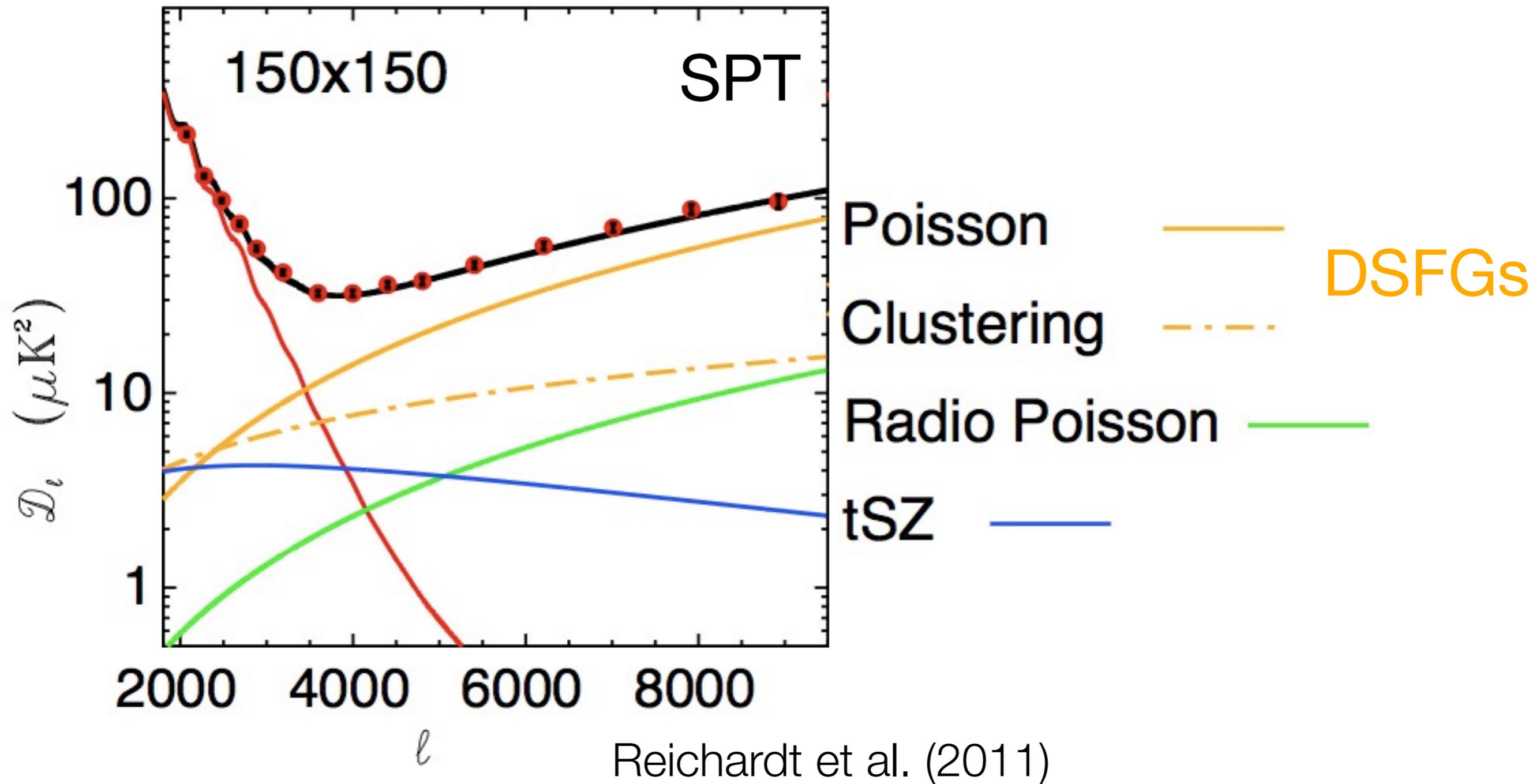


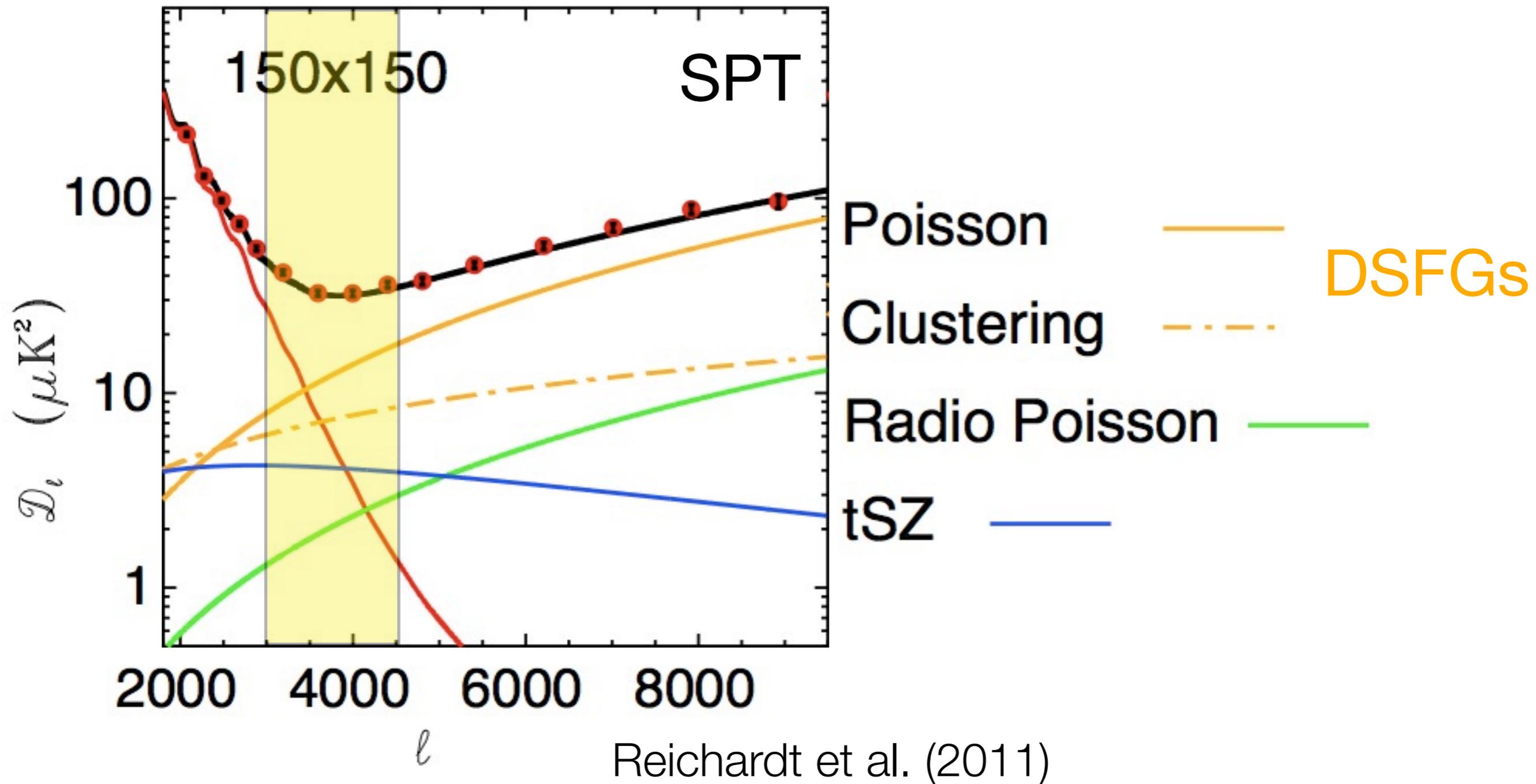
Reichardt et al. (2011)

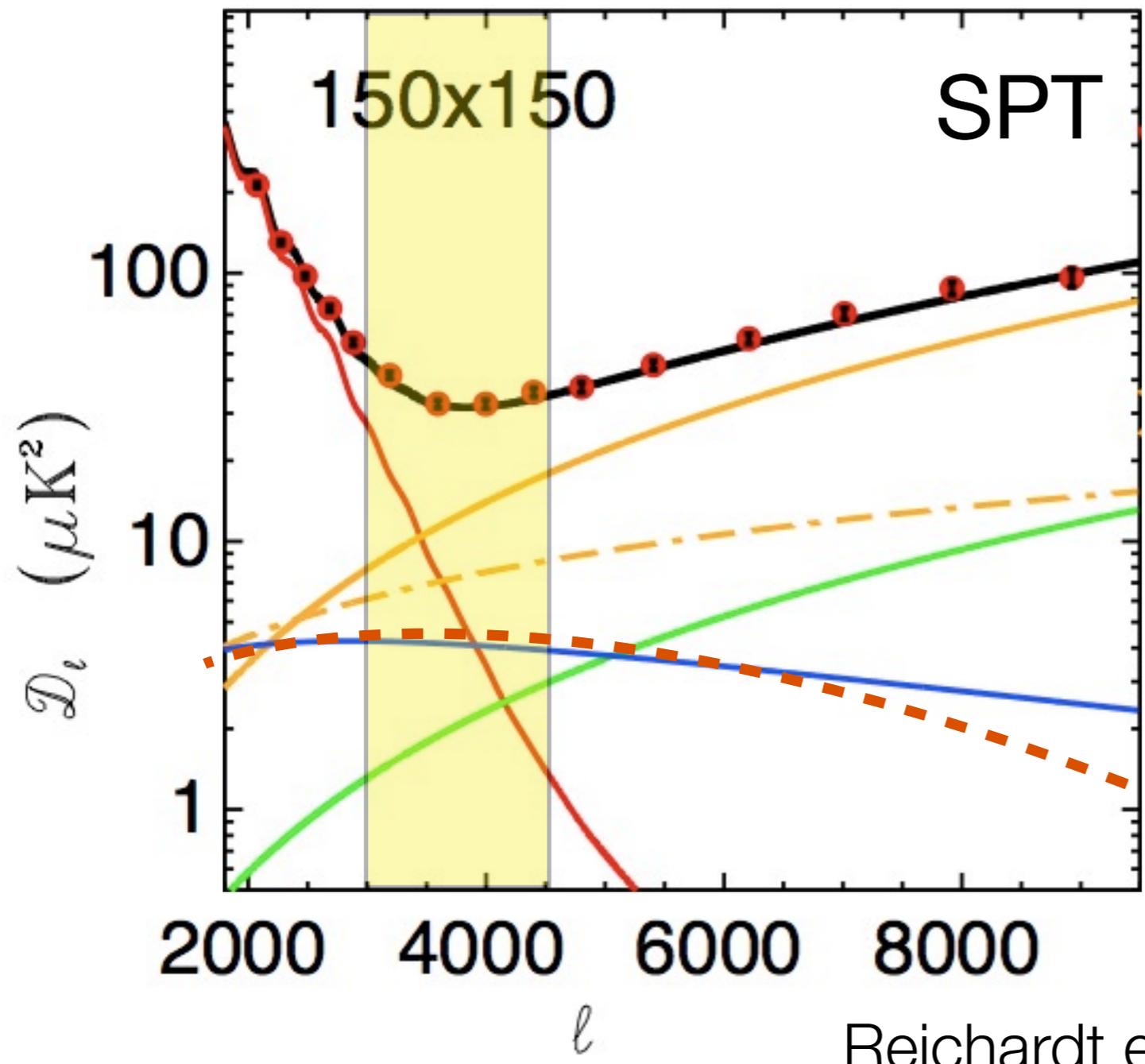


Reichardt et al. (2011)

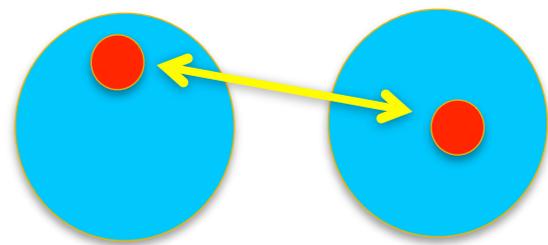
- $\ell > 2000$ dominated by secondary anisotropies

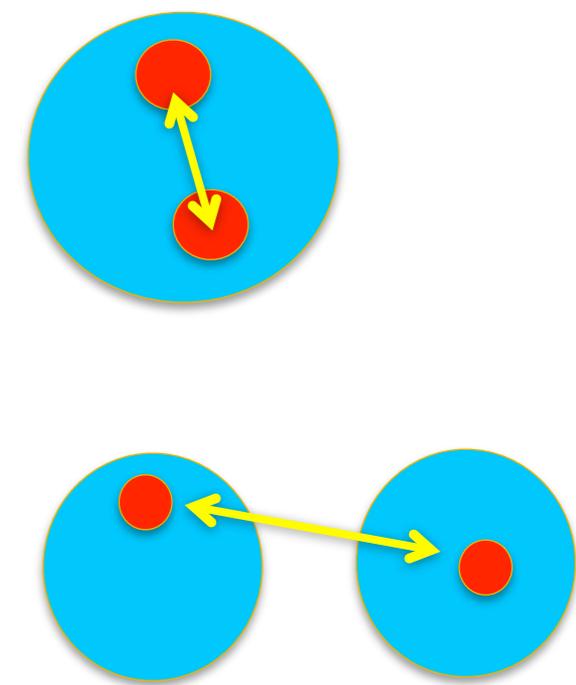
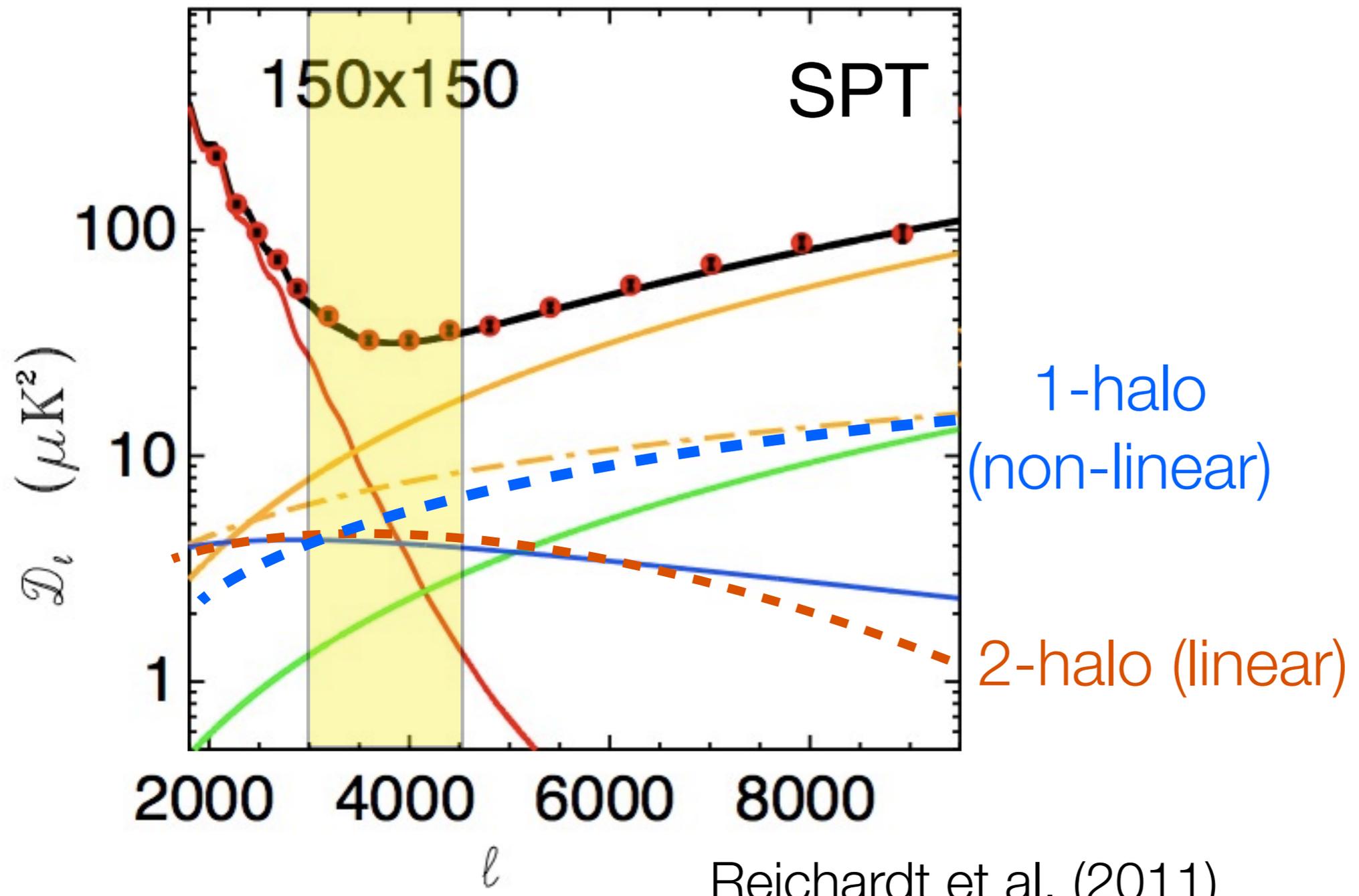


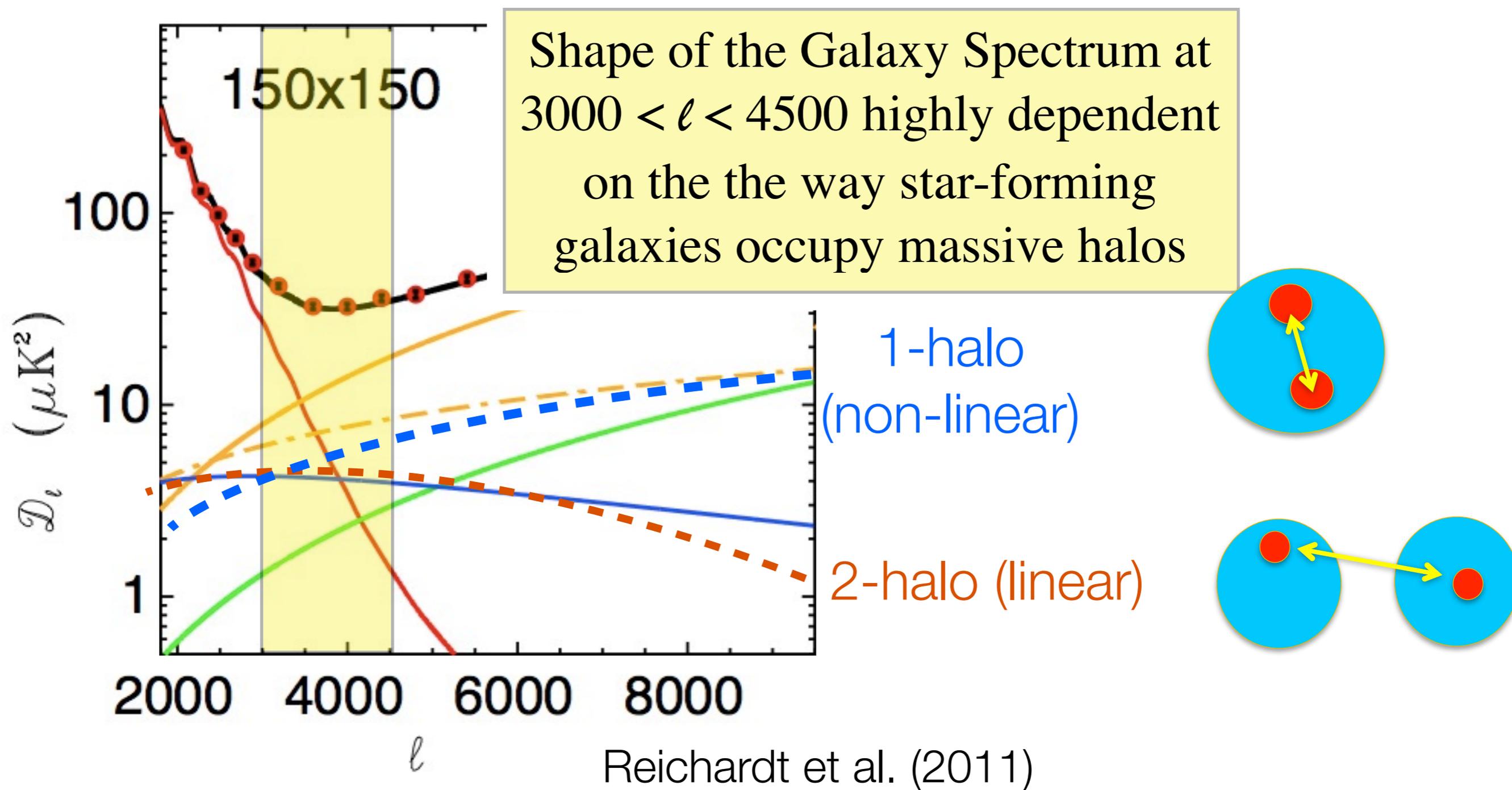


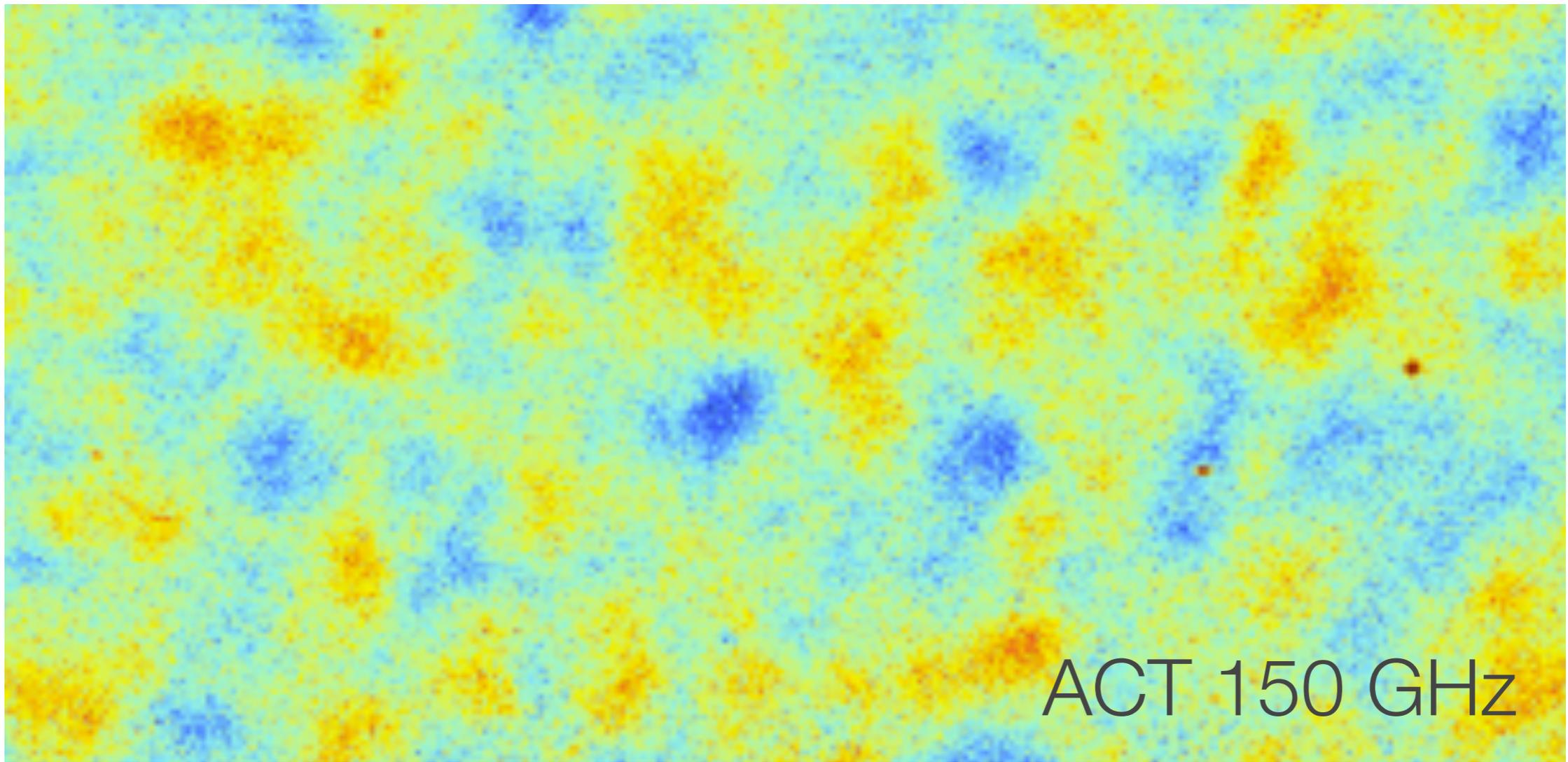


2-halo (linear)

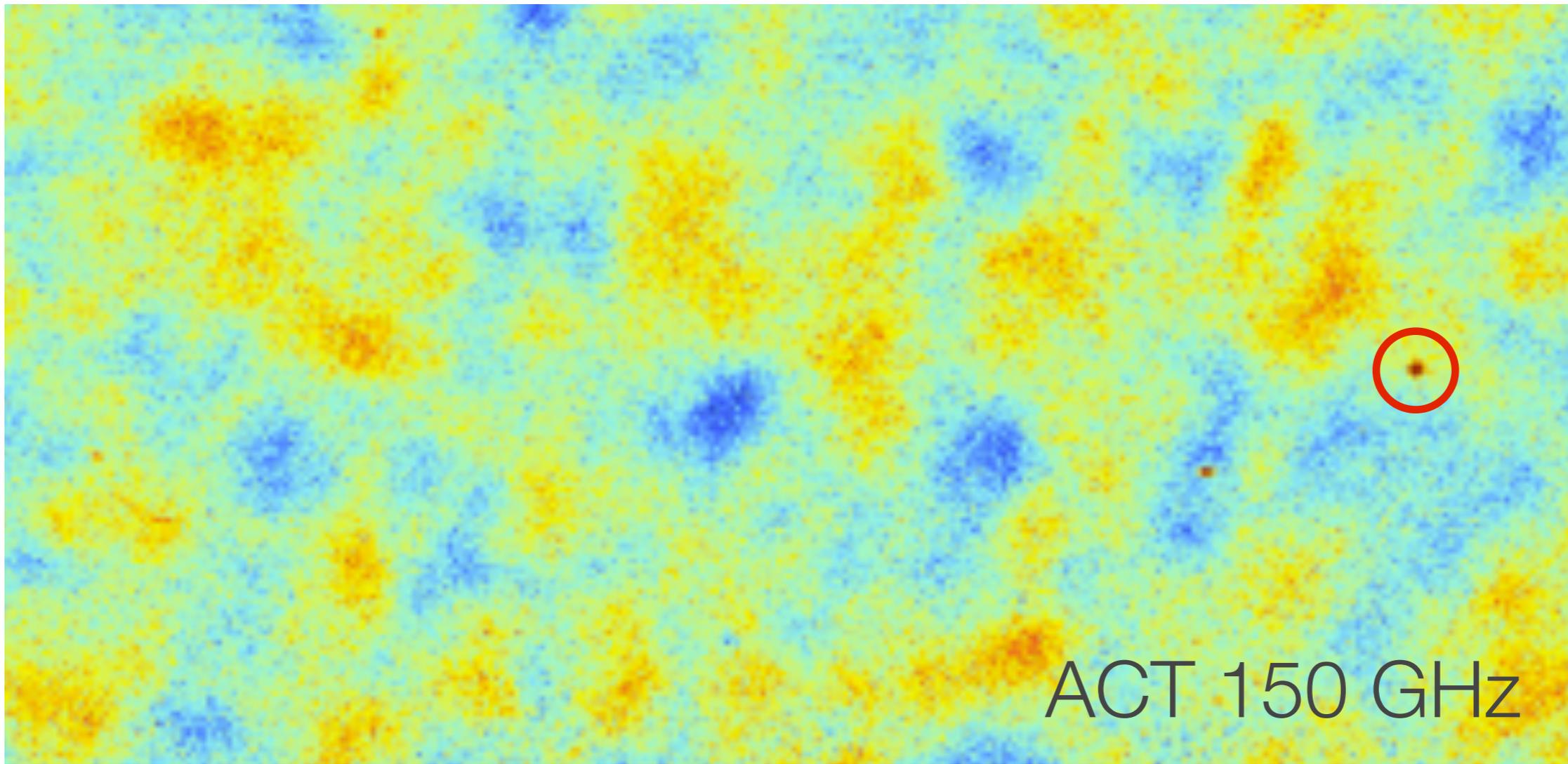


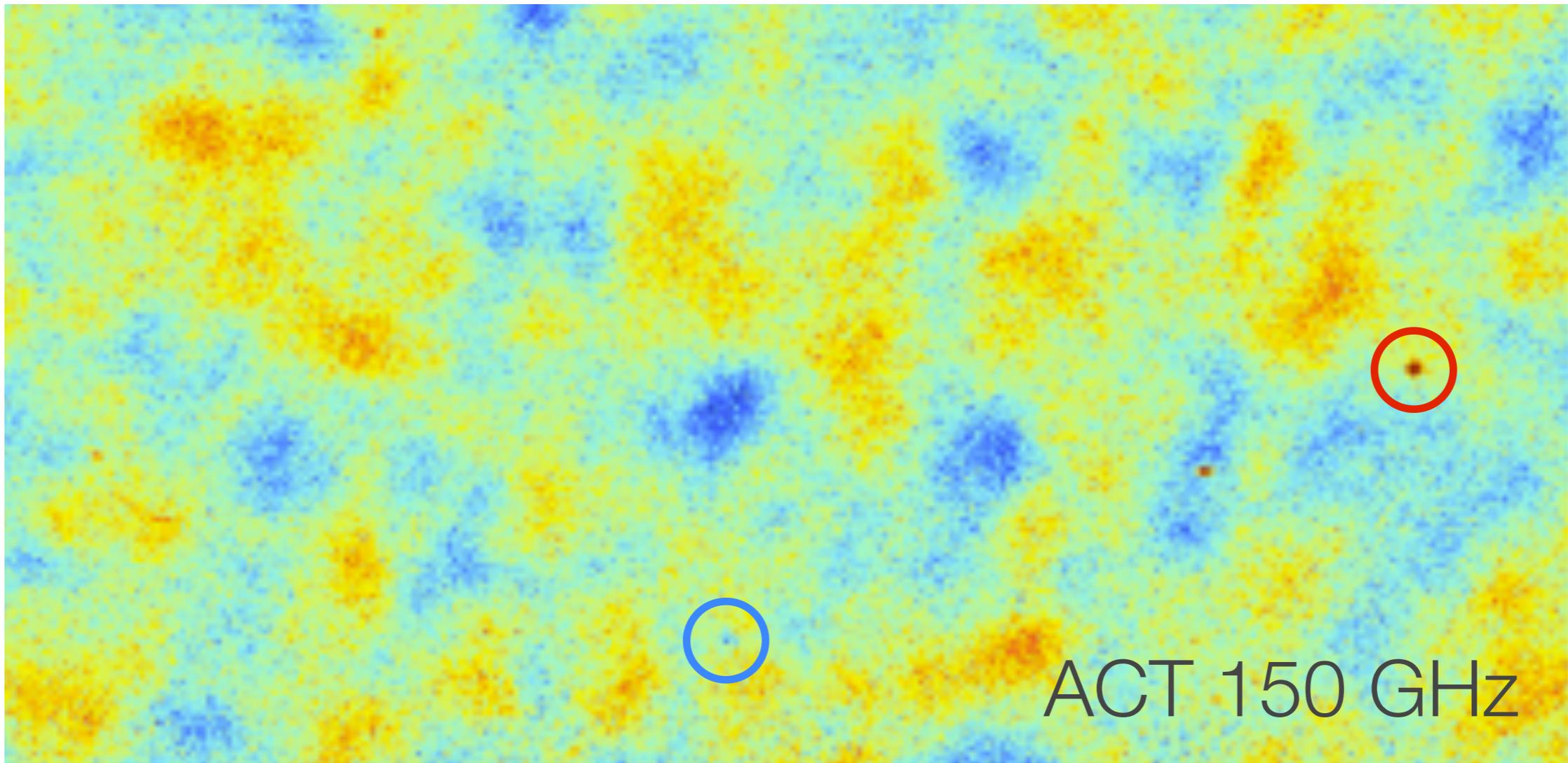


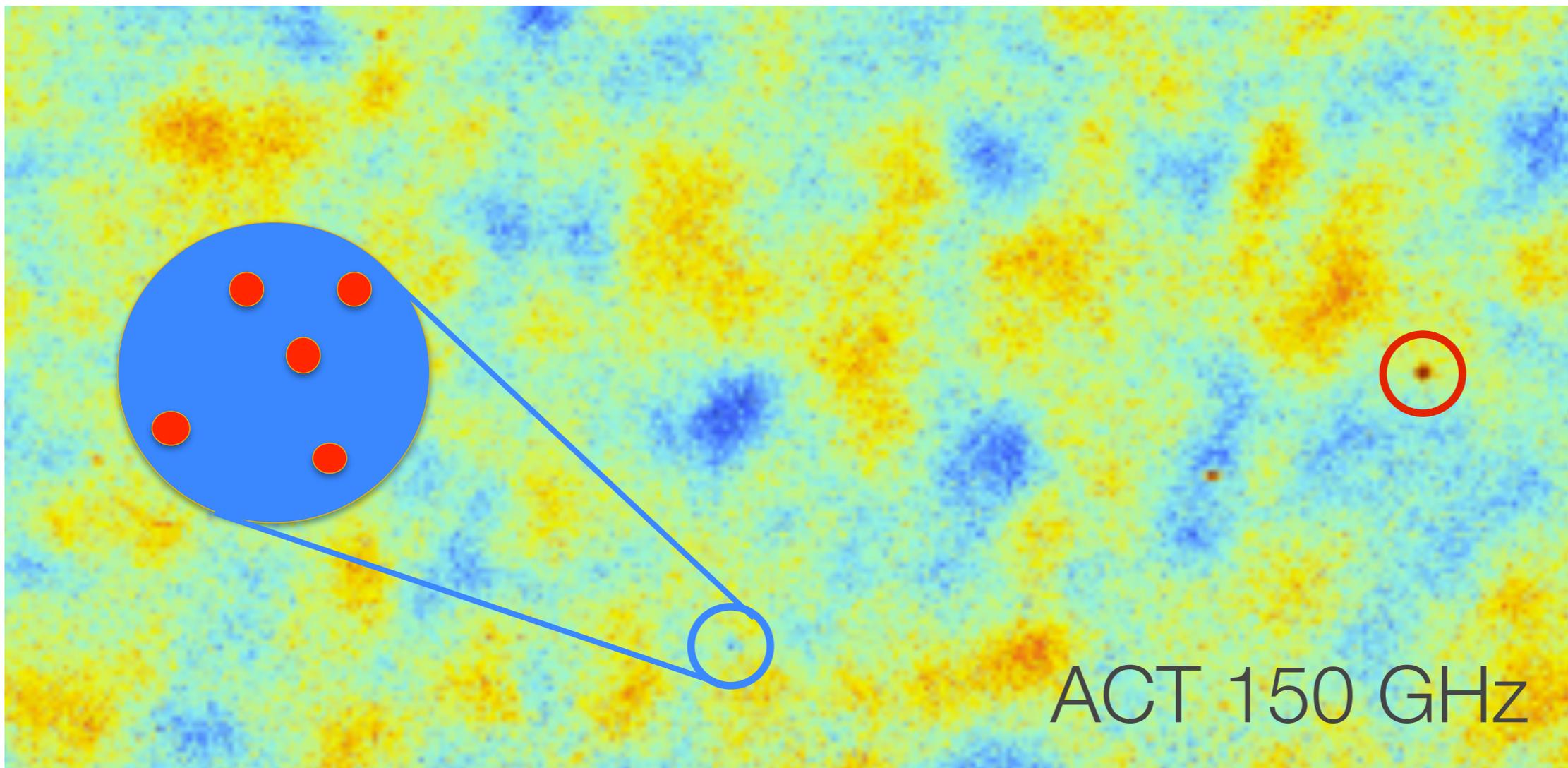


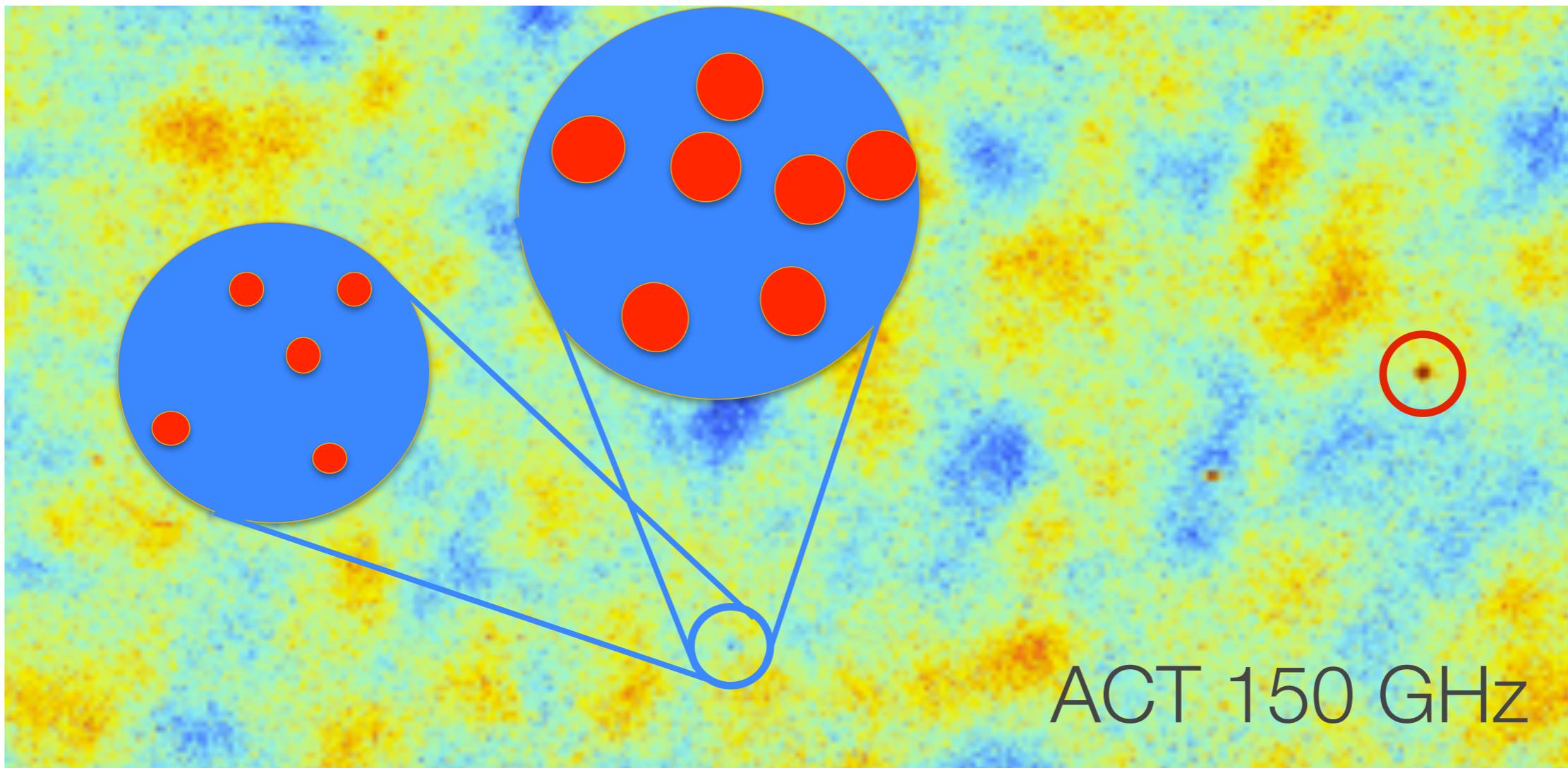


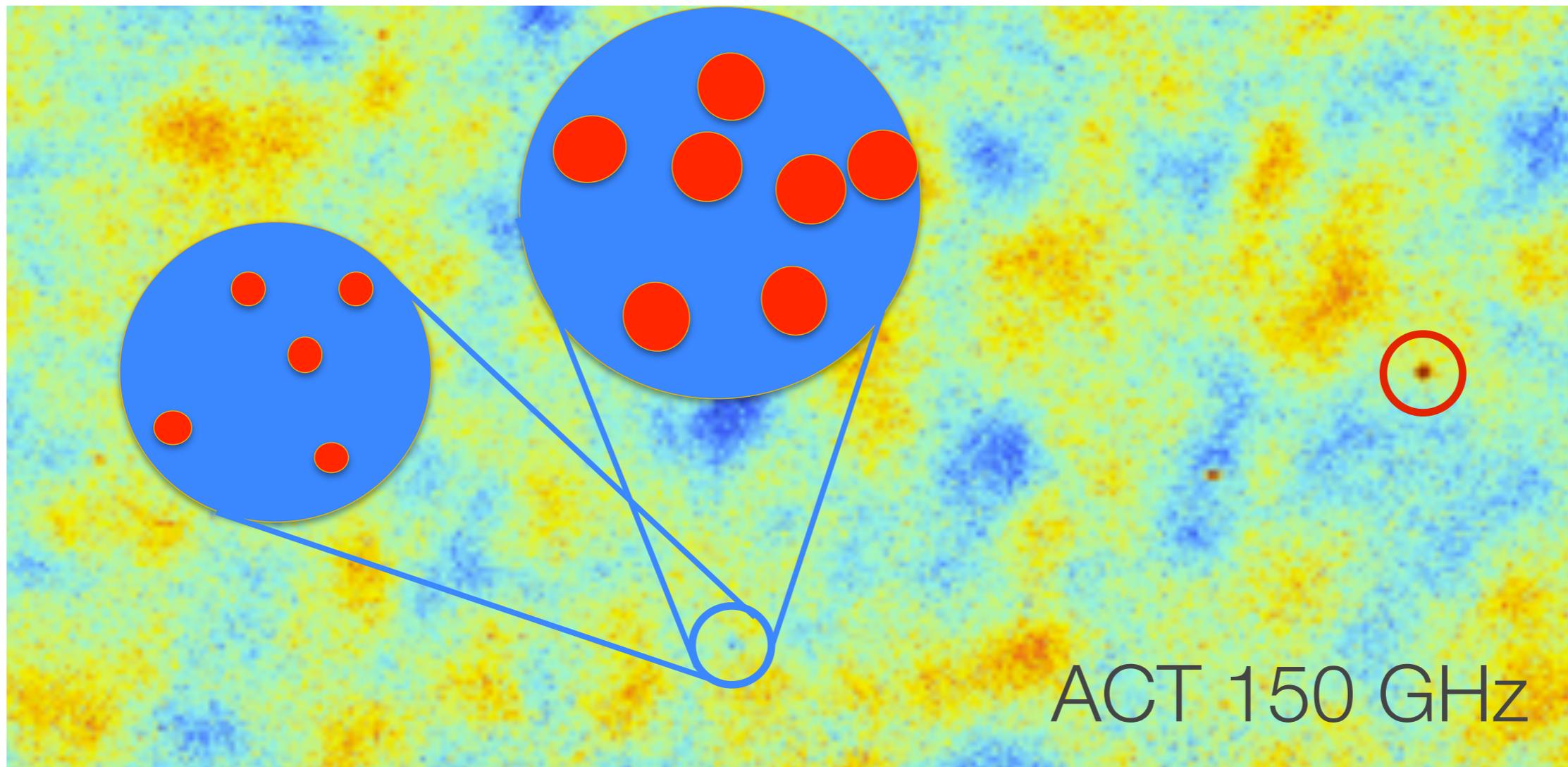
ACT 150 GHz



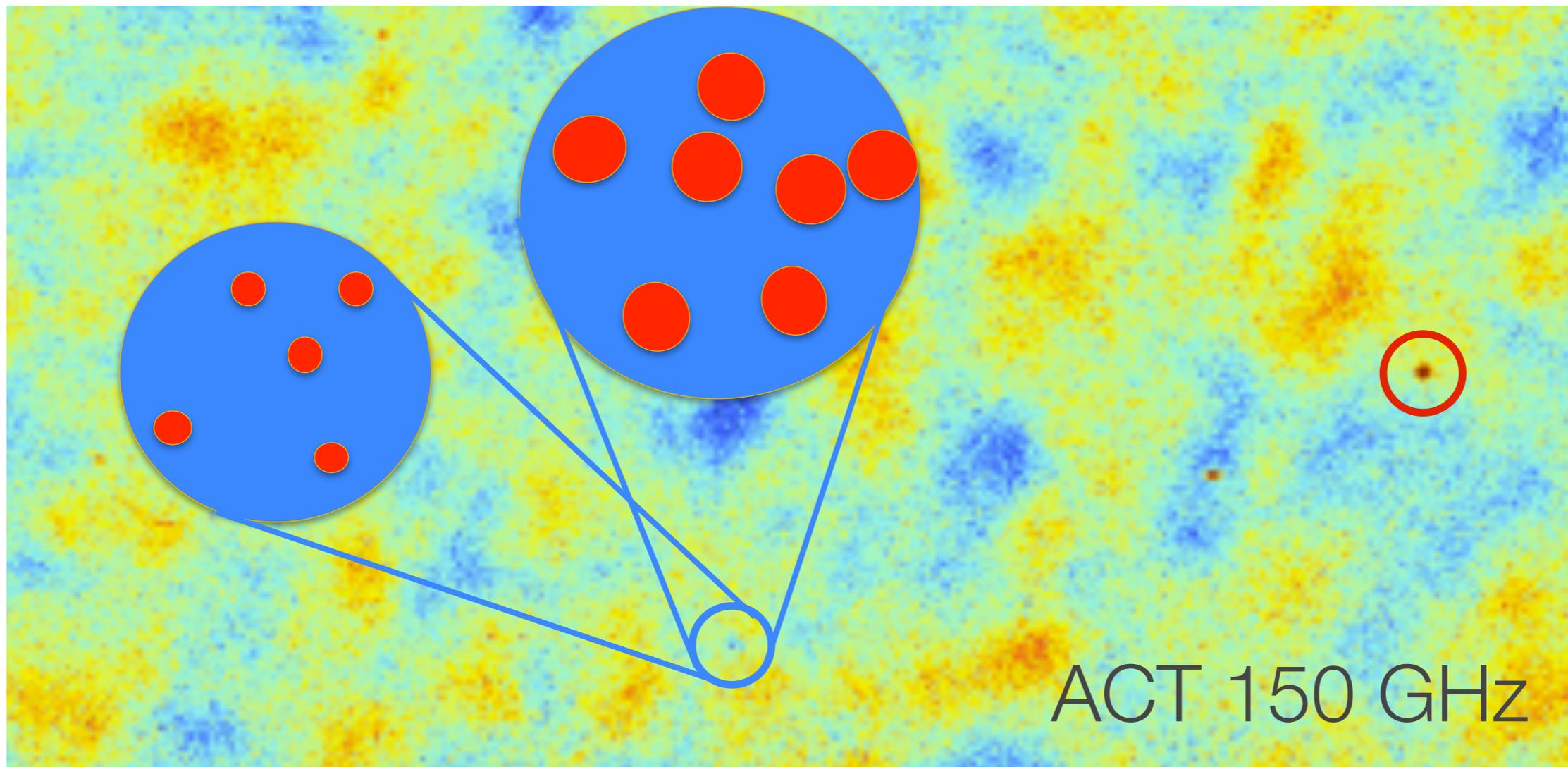




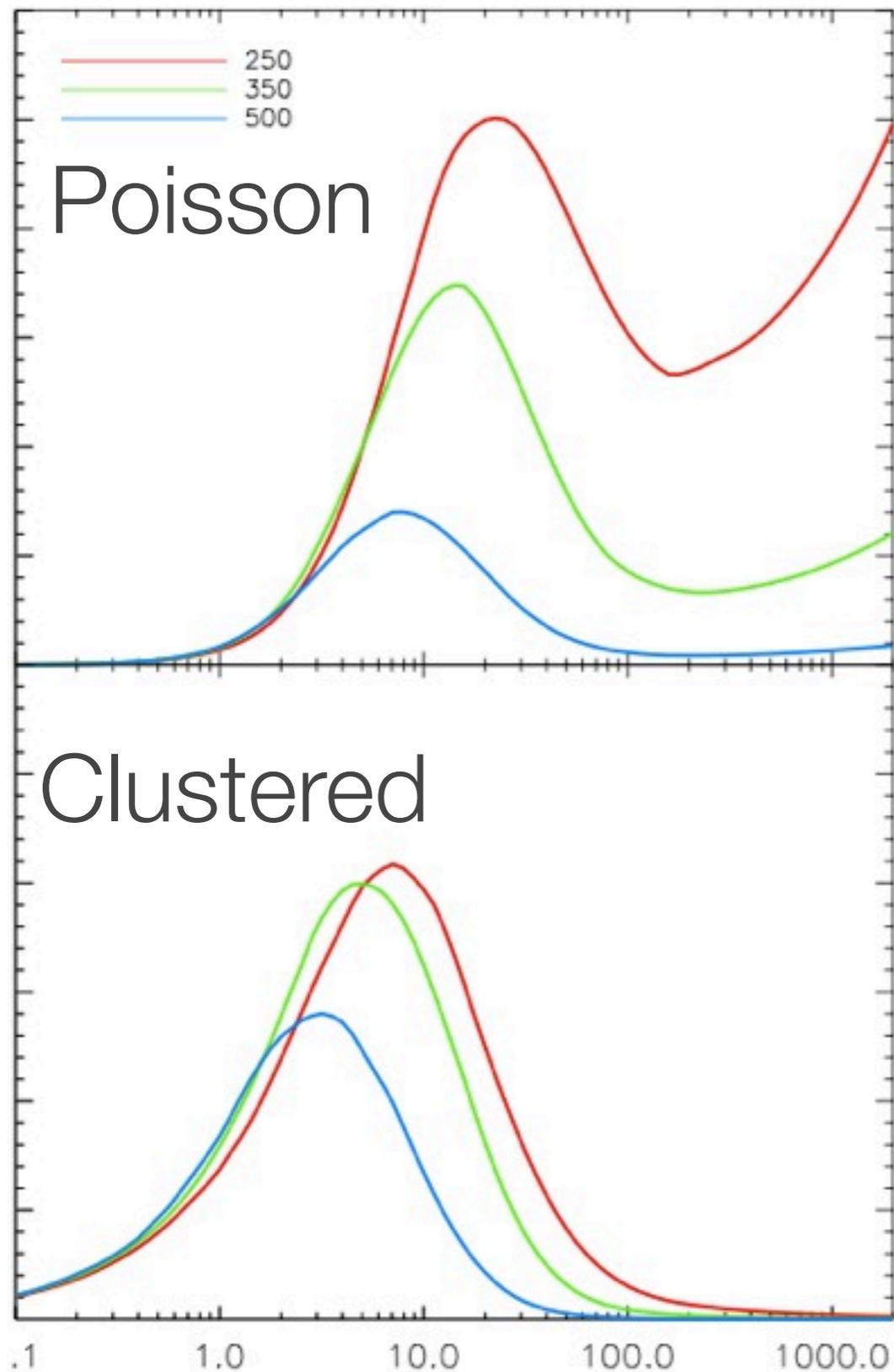




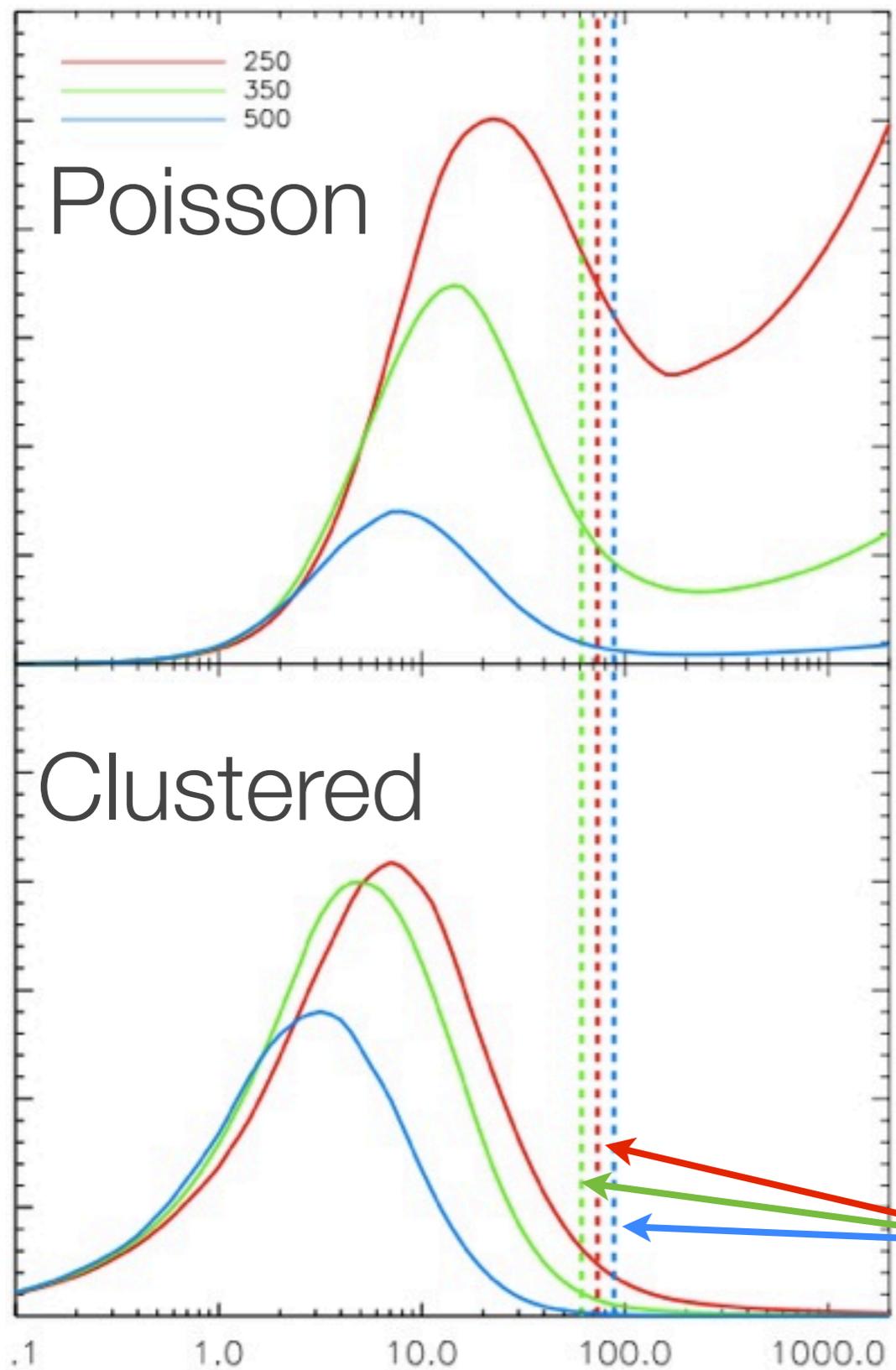
- Halo Occupation Distribution (HOD):
 - How many satellites per given halo mass?
 - Luminosity-Mass relation?



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 - How many satellites per given halo mass?
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- This is imprinted on the 1-halo term of the CIB power spectrum!



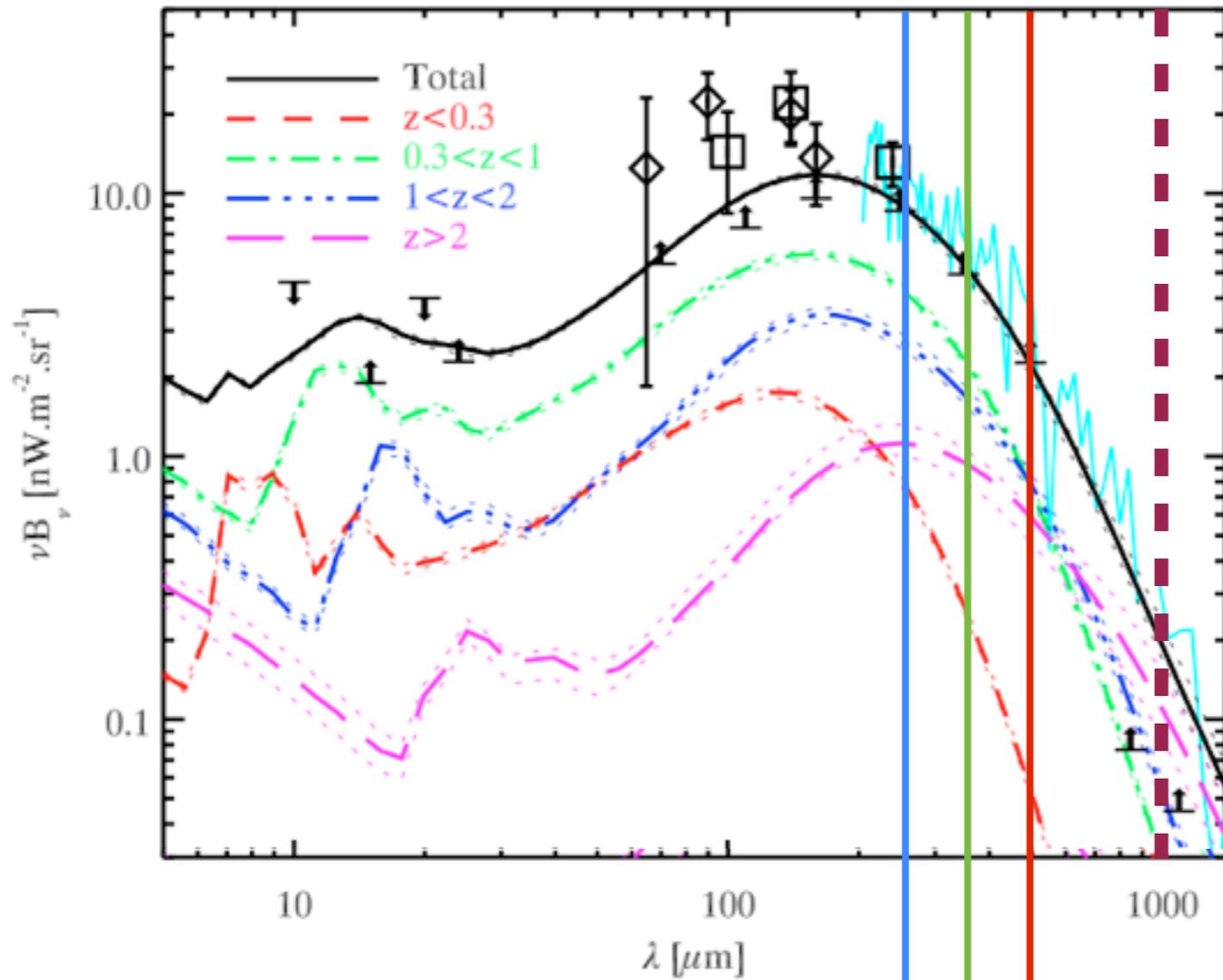
- Bulk of CIB power from ~ 10 mJy sources
- Masking has much less impact at longer λ



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Vertical lines are 5- σ confusion noise limits

CIB in redshift slices

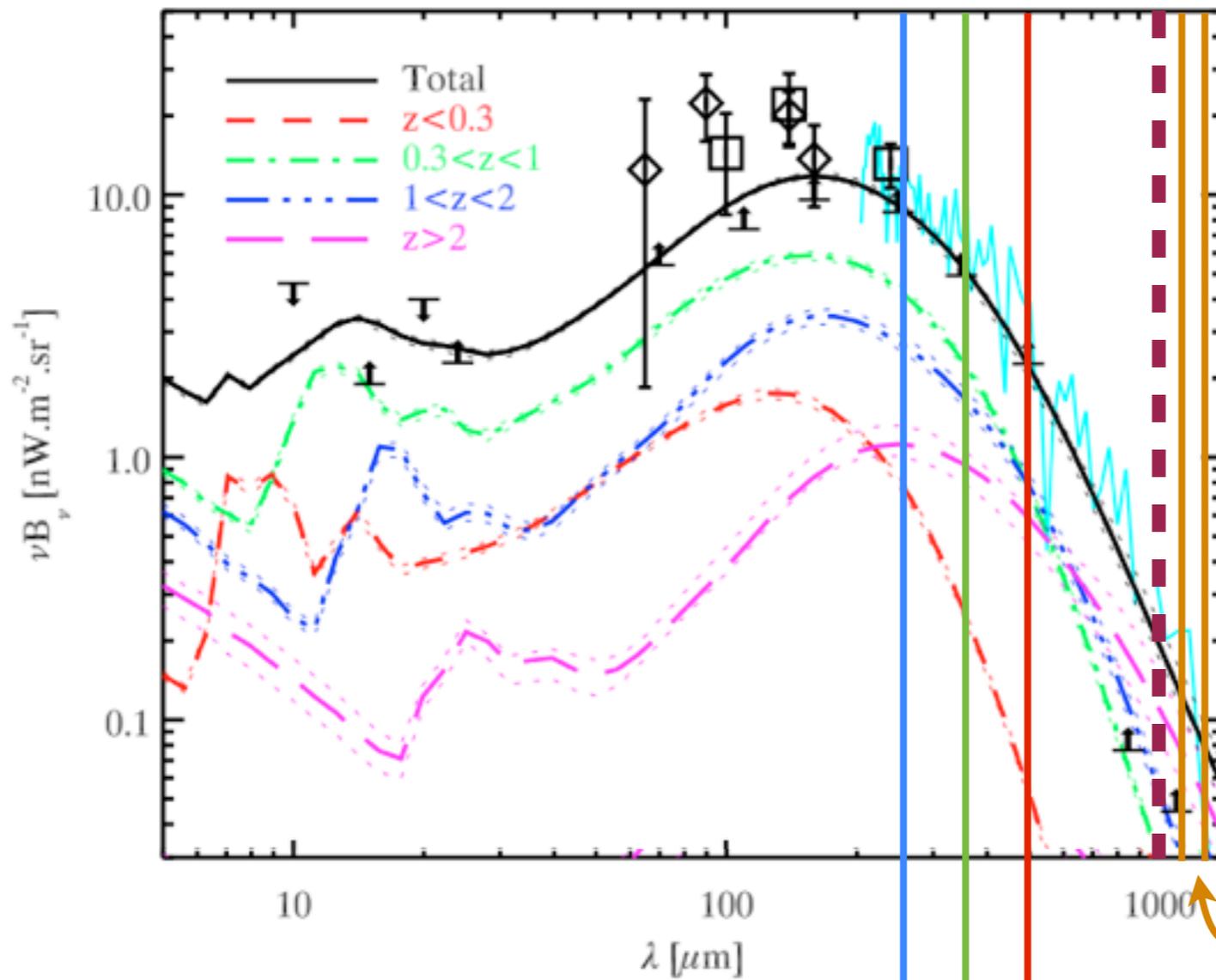


Infrared Background
at $\lambda > 1$ mm
dominated by
high-redshift sources

Béthermin et al. (2011)
arXiv:1010.1150

250
350
500

CIB in redshift slices



Infrared Background
at $\lambda > 1$ mm
dominated by
high-redshift sources

1.4 mm (220 GHz)

2 mm (148 GHz)

CMB

Béthermin et al. (2011)
arXiv:1010.1150

250
350
500