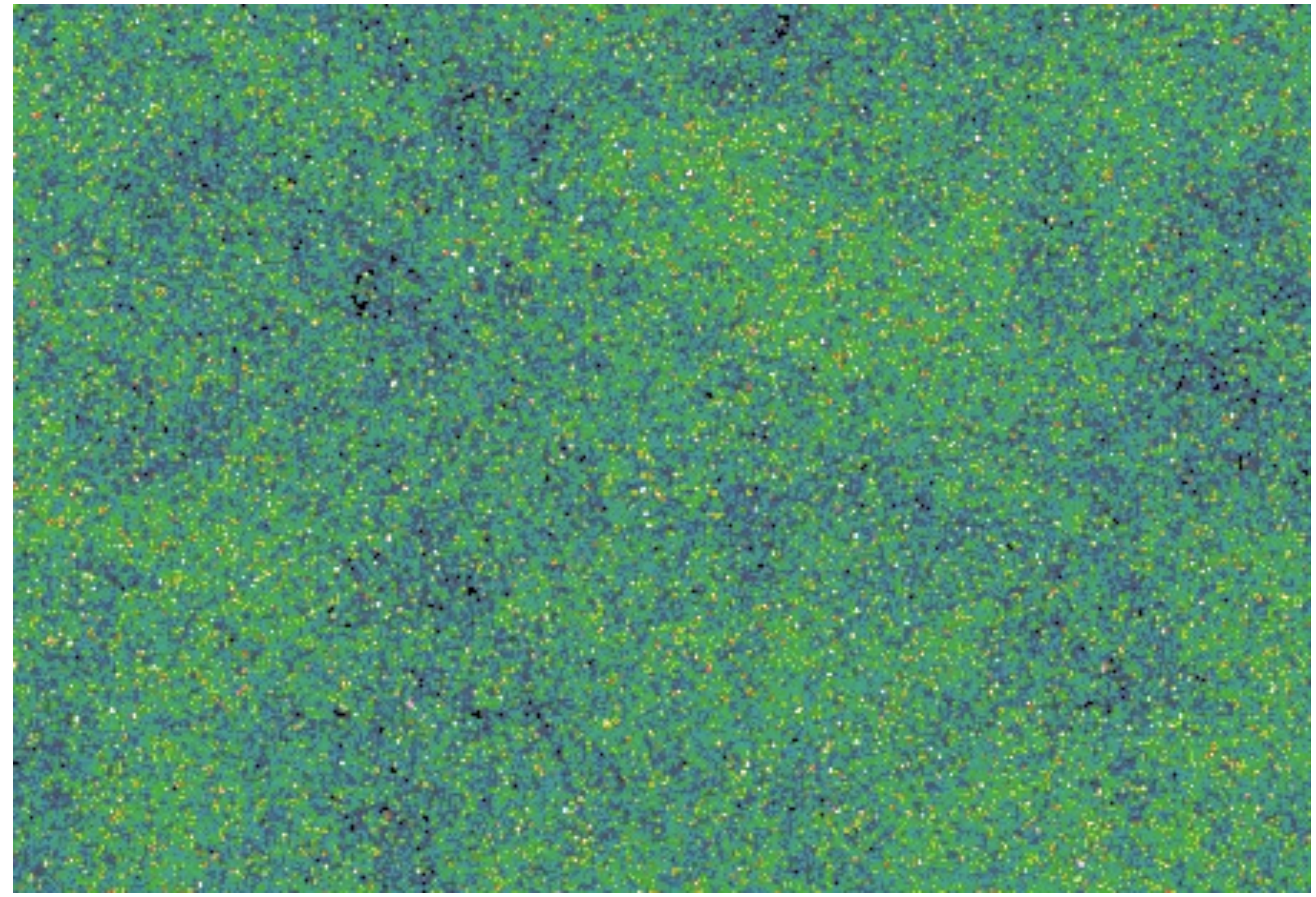


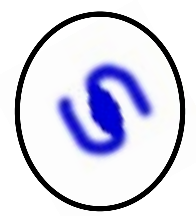
Implications of Galaxy Clustering to the CMB

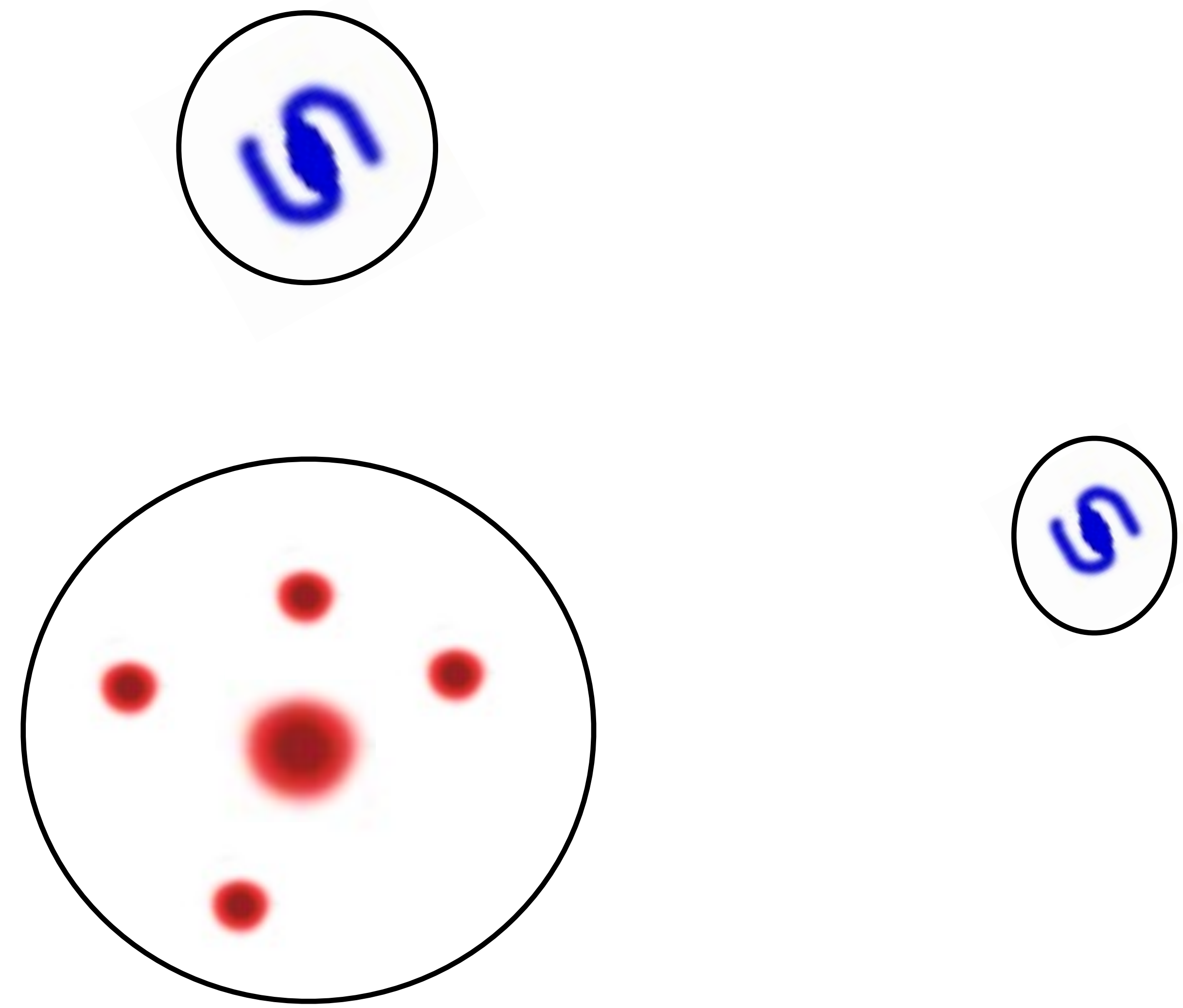
Marco Viero - Caltech

Blue
Star-Forming
Galaxy

Red
Quiescent
Galaxy

Brief History of Clustering

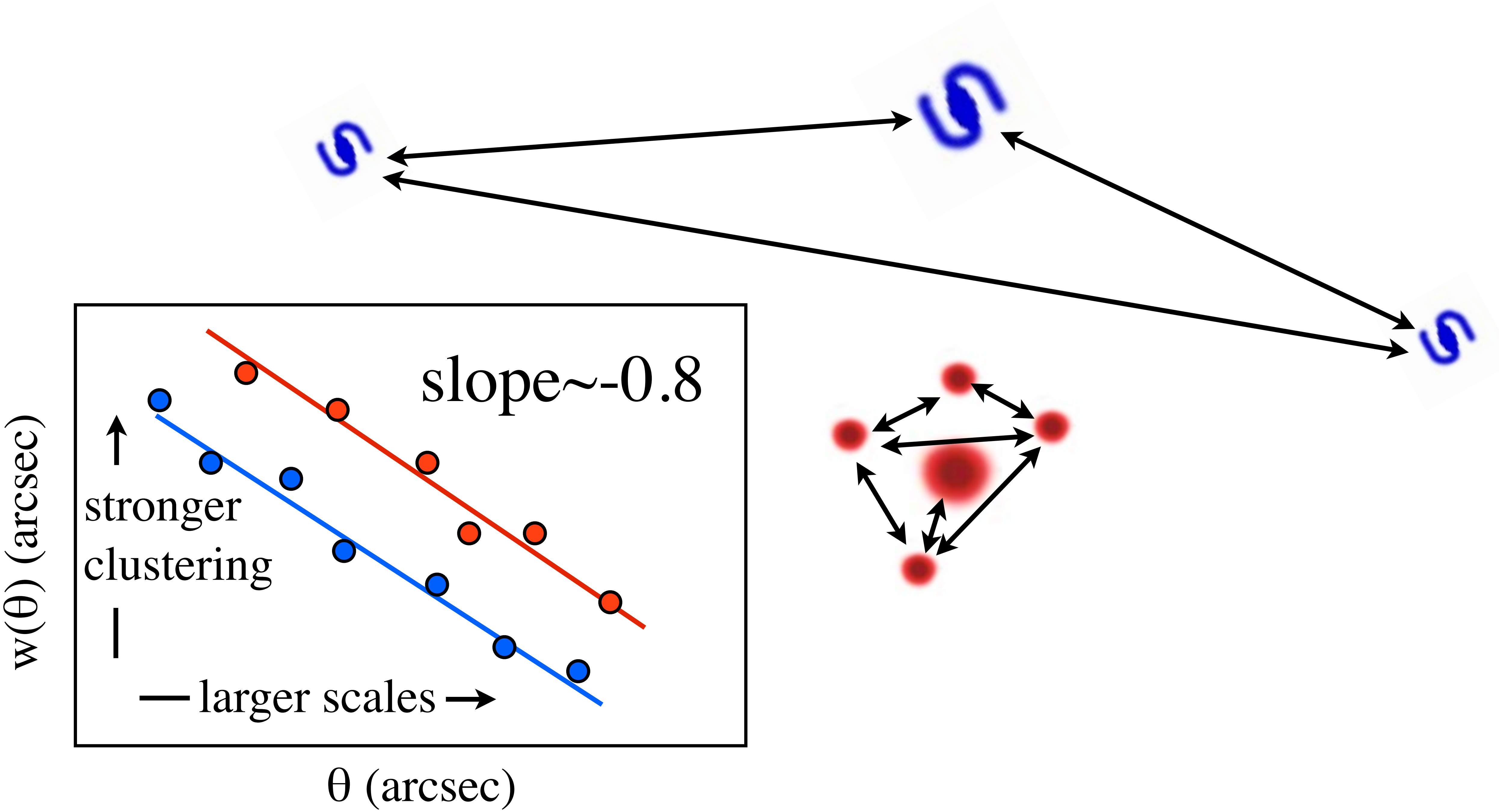




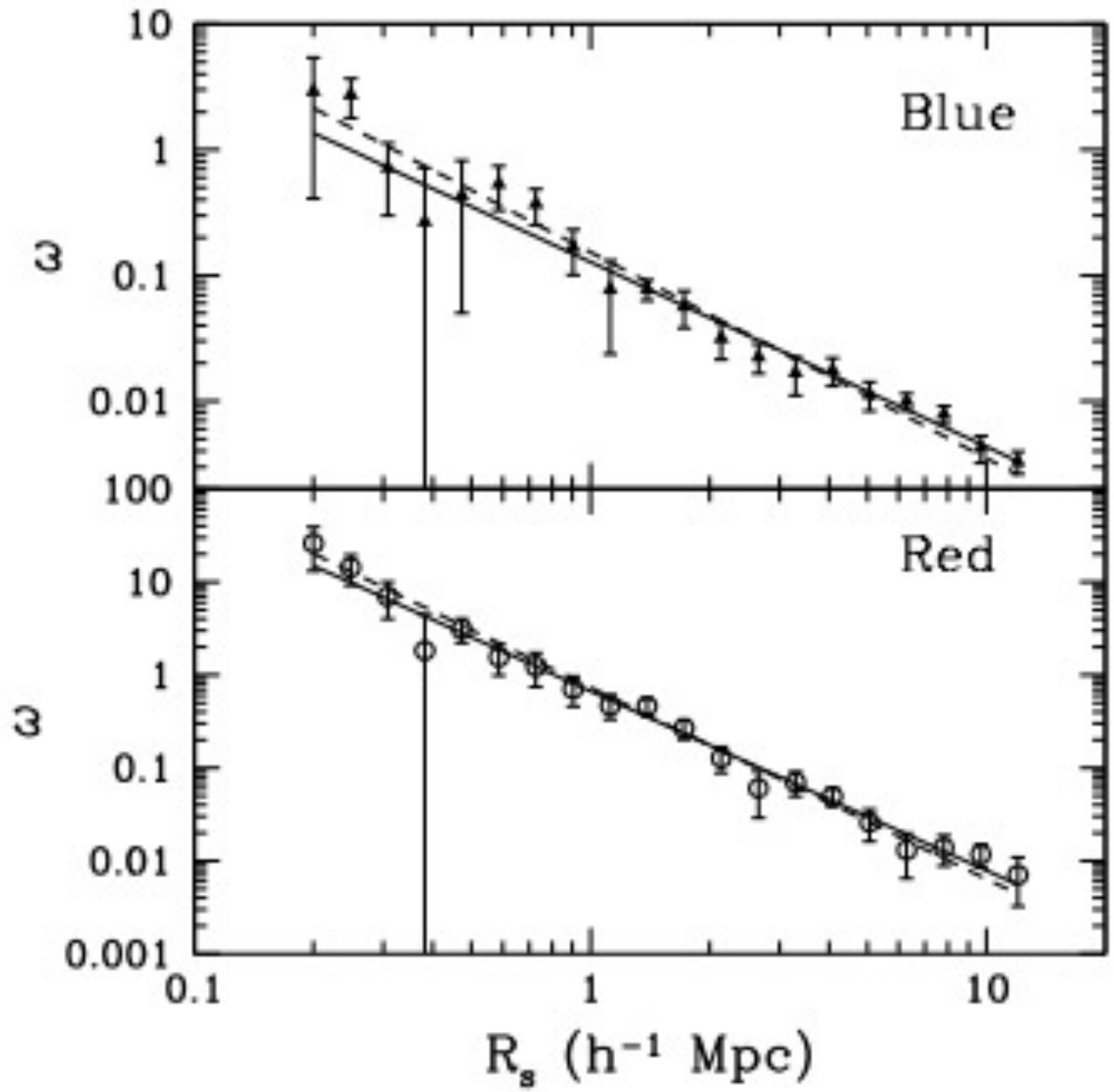
More Strongly Clustered:

- more luminous
- redder

Brief History of Clustering



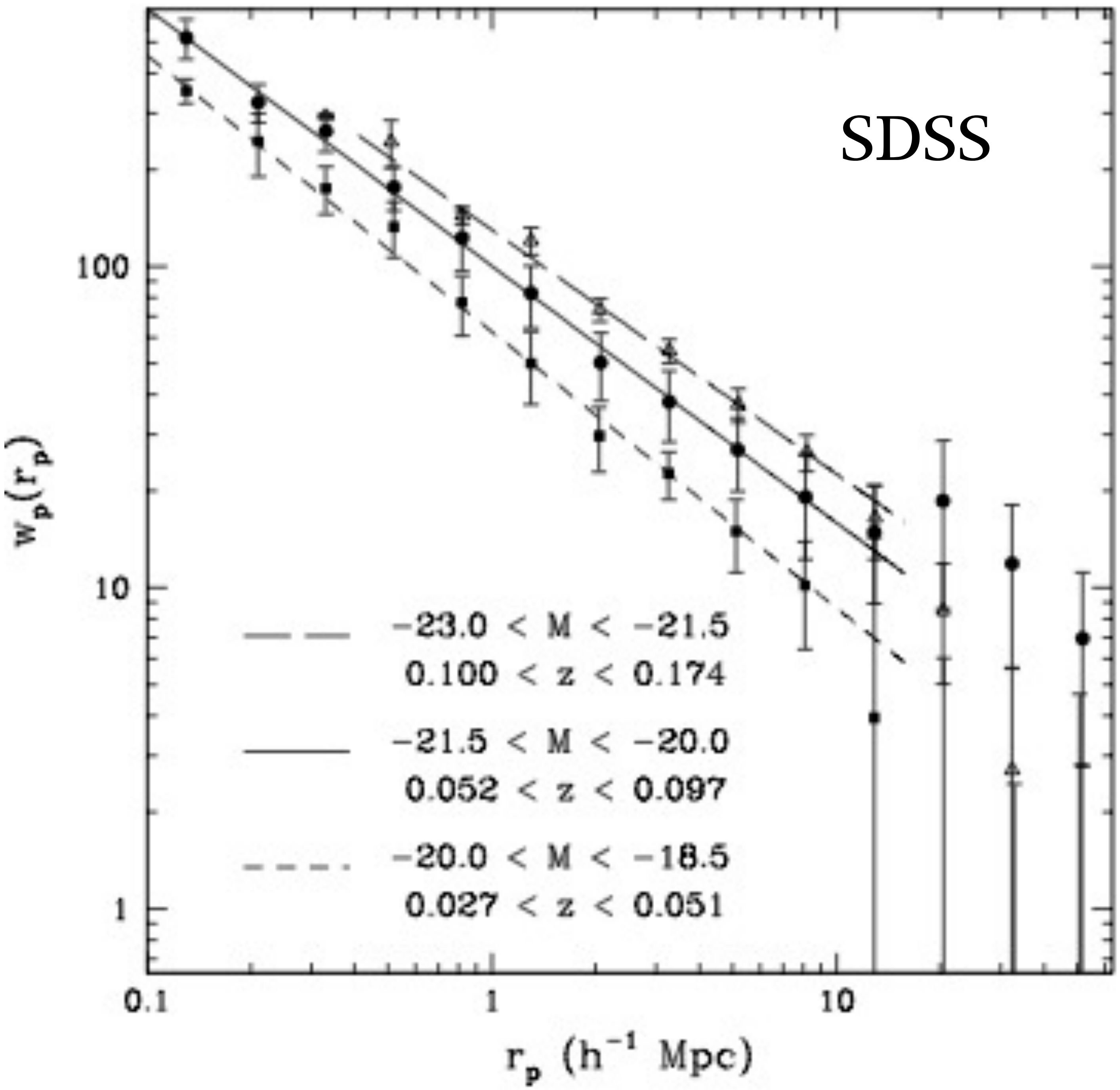
Brief History of Clustering



DEEP2

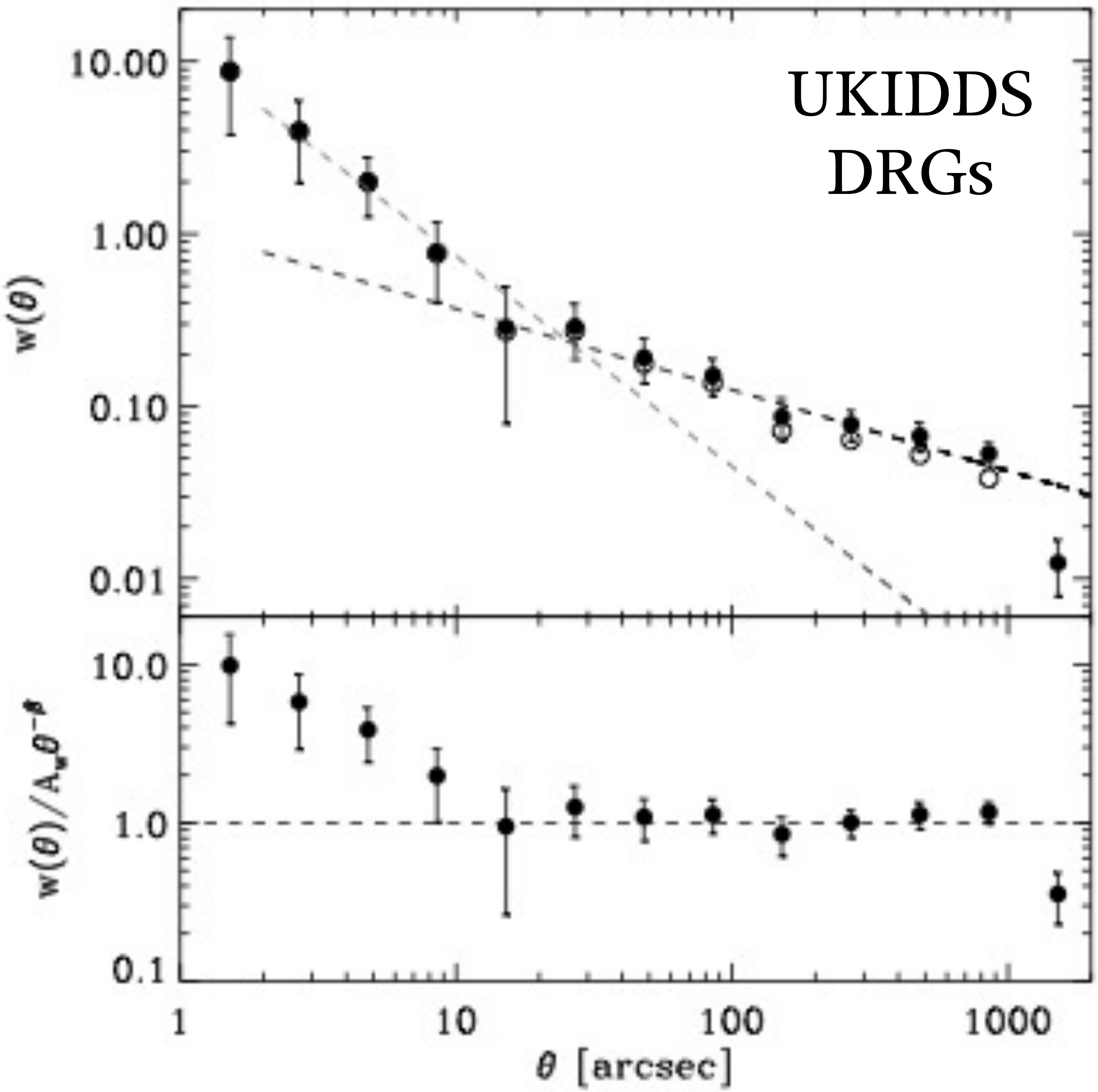
Coil (2008)

Brief History of Clustering



Zehavi (2003)

Brief History of Clustering



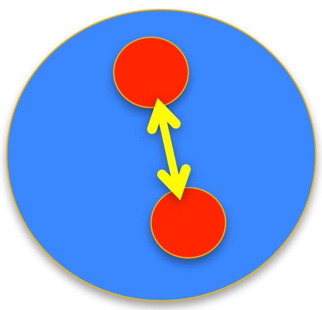
Quadri (2008)

Brief History of Clustering

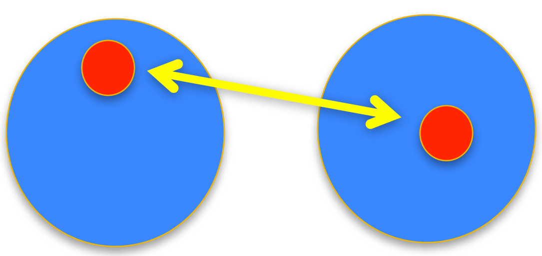
Halo Model

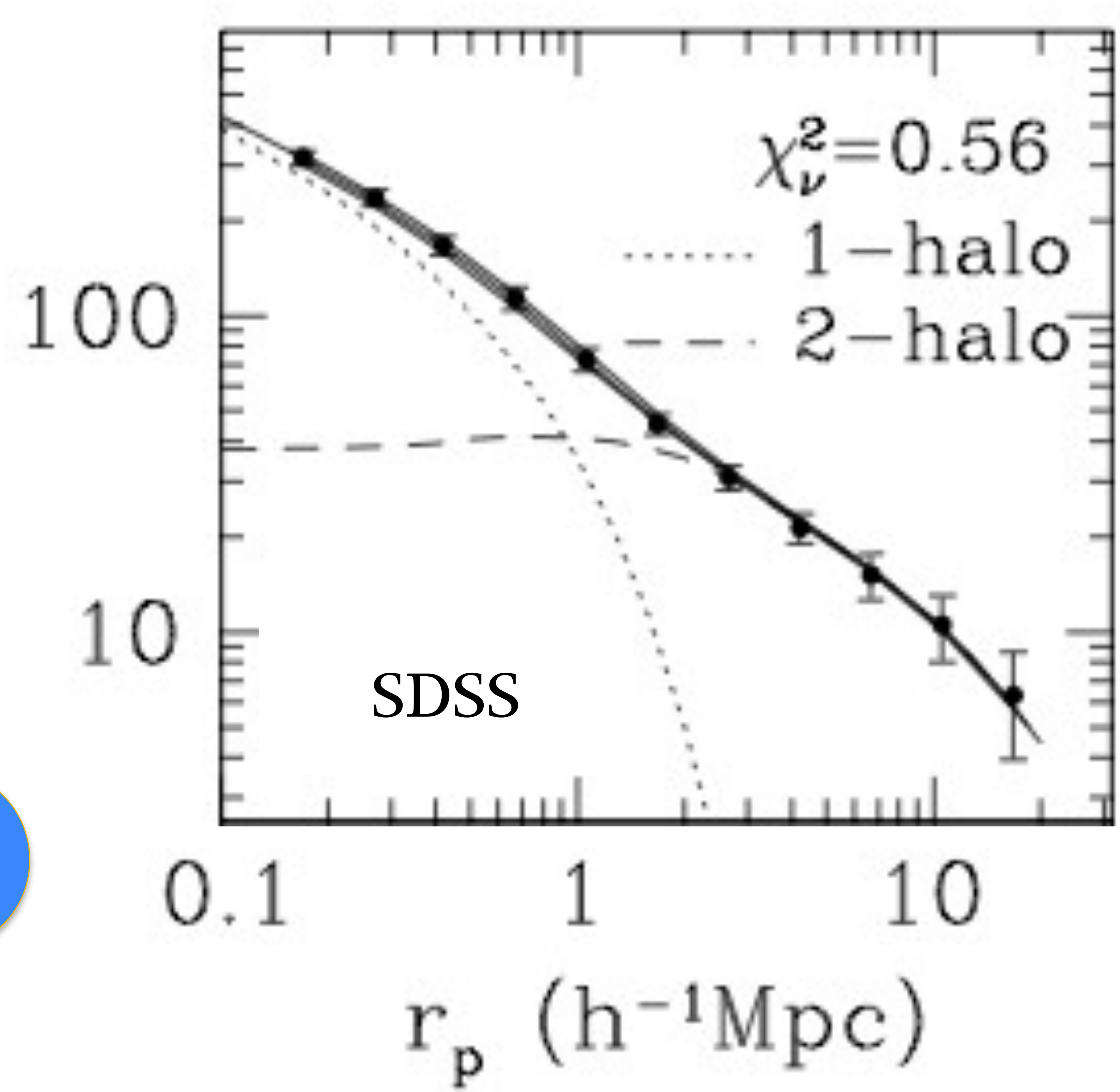
see e.g.,
Cooray & Sheth (2000),
Zehavi et al. (2005, 2008)

One-halo:



Two-halo:



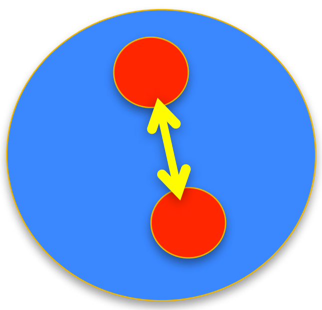


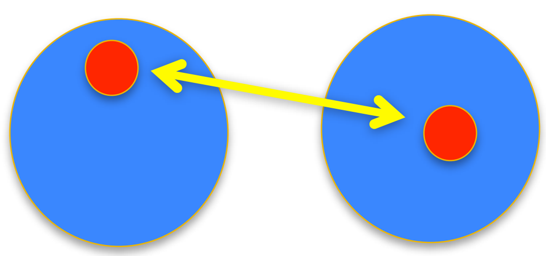
Zheng (2007)

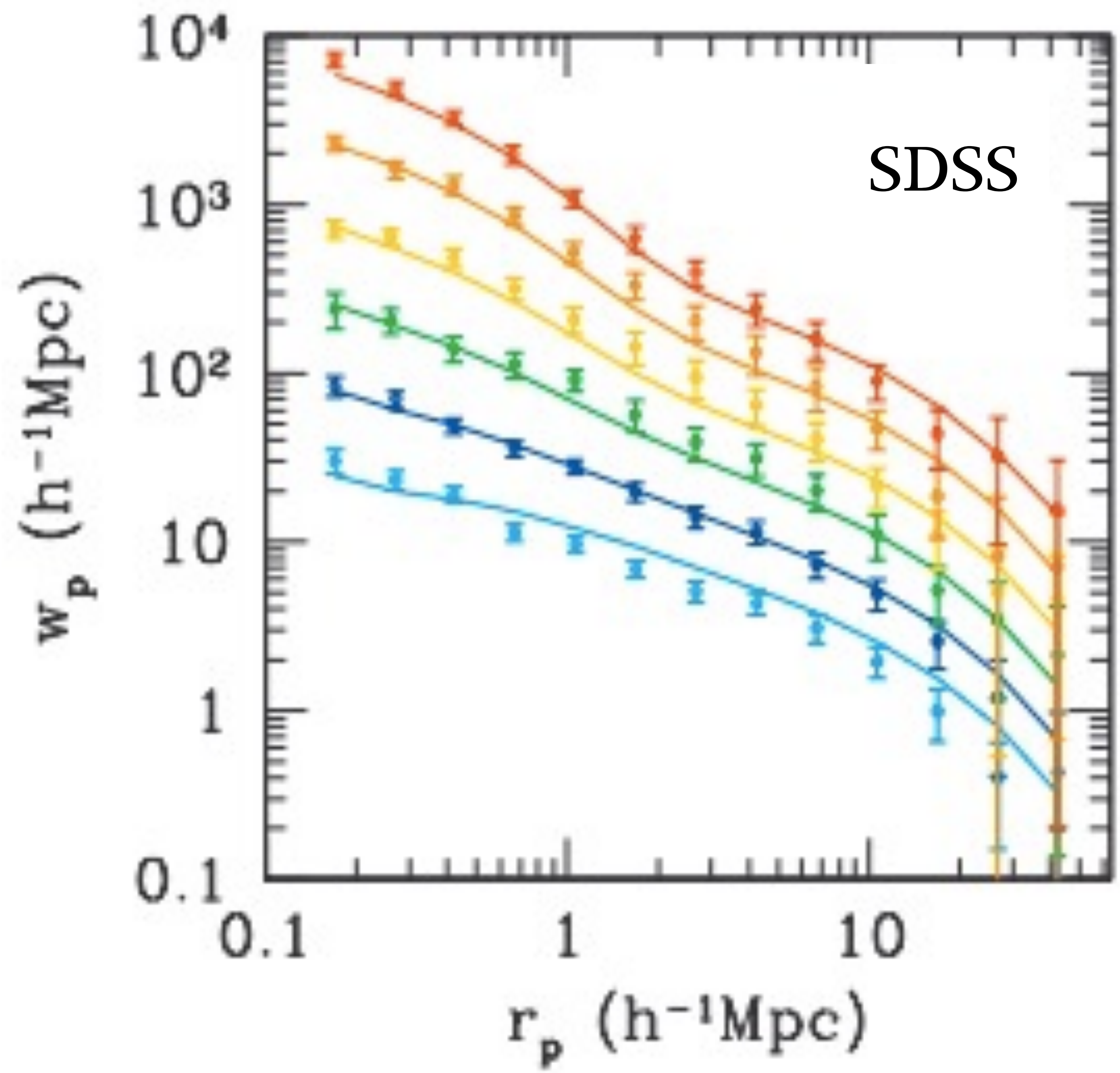
Brief History of Clustering

Halo Model

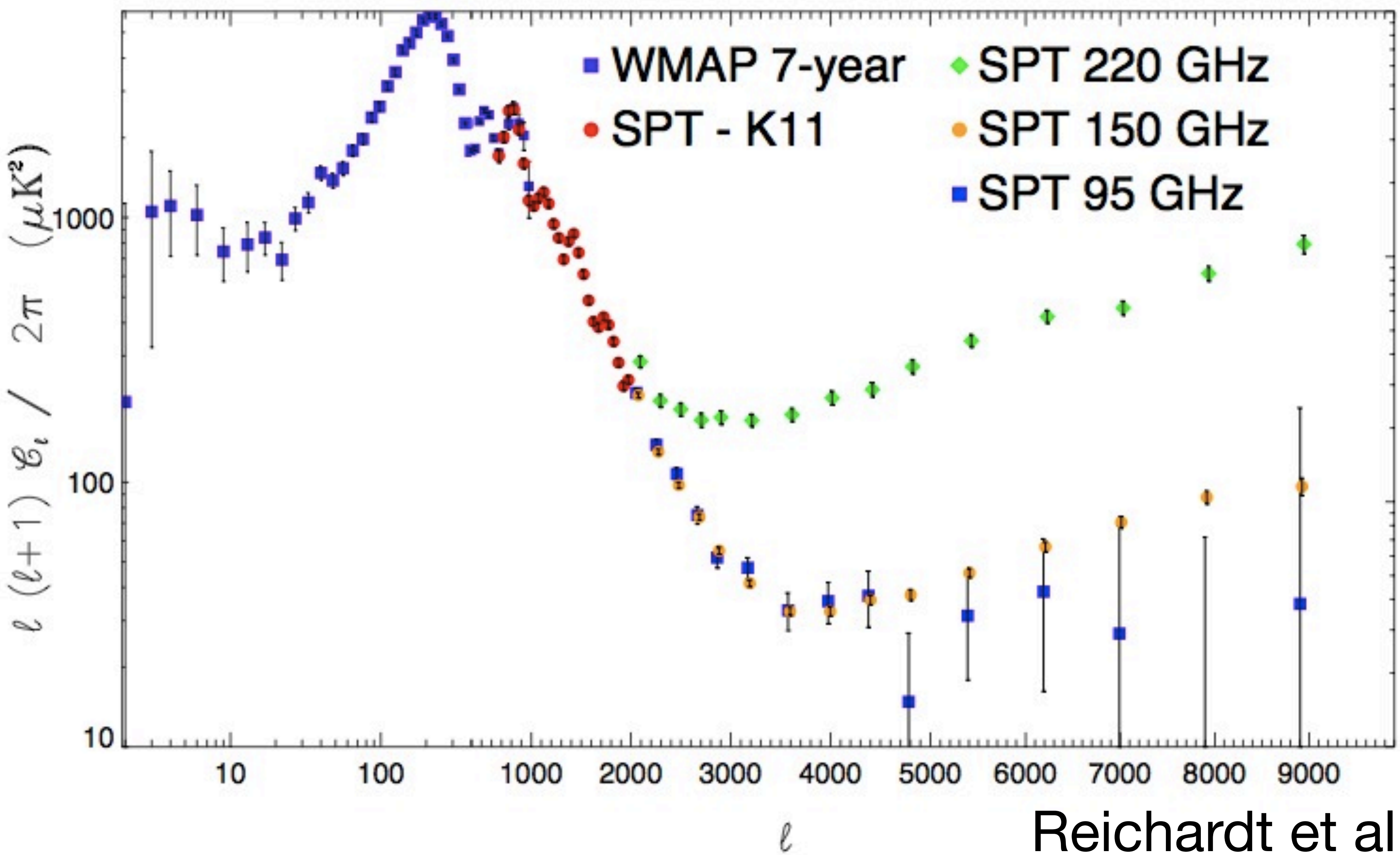
see e.g.,
Cooray & Sheth (2000),
Zehavi et al. (2005, 2008)

One-halo: 

Two-halo: 

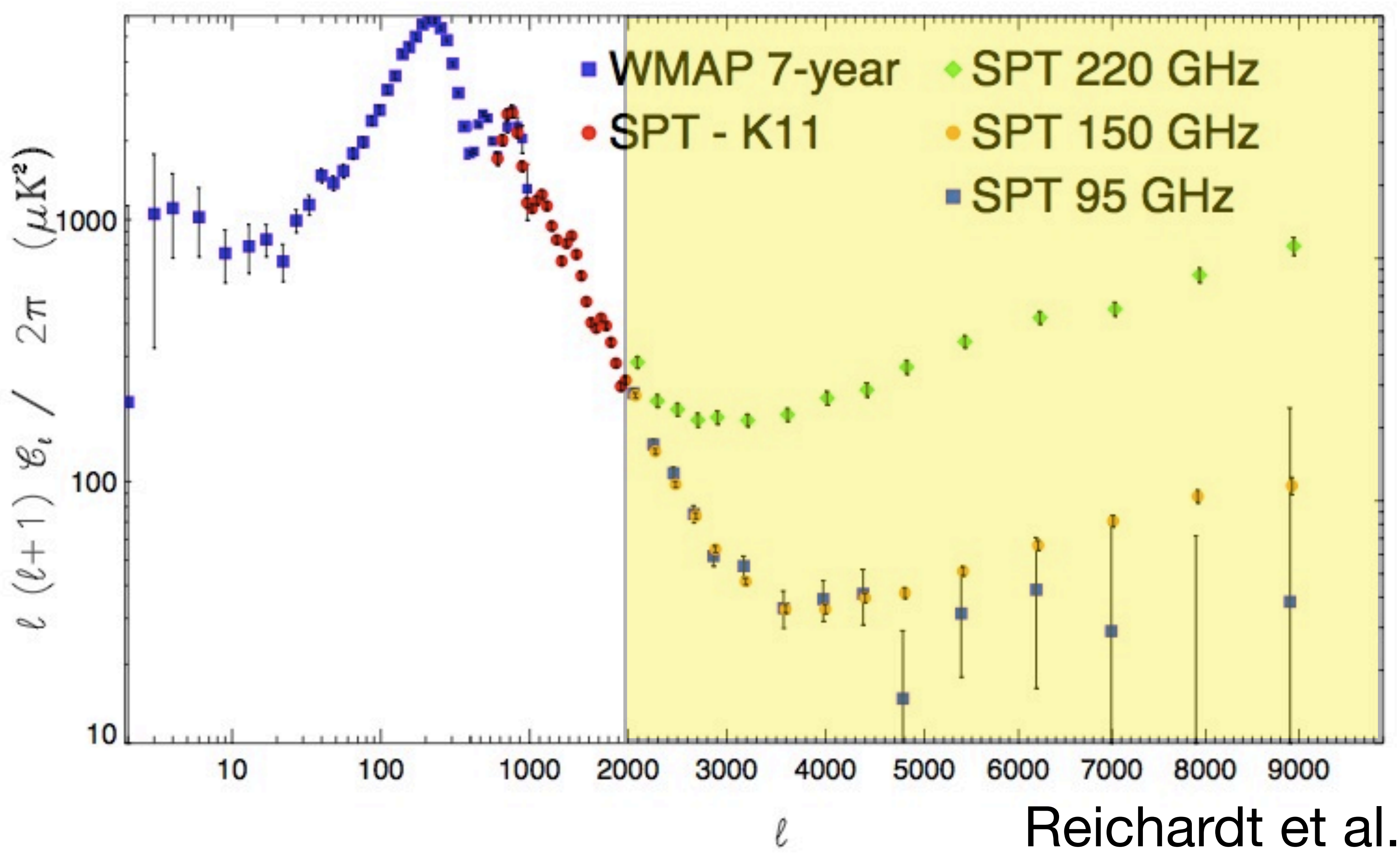


Zehavi (2011)



Reichardt et al. 2011

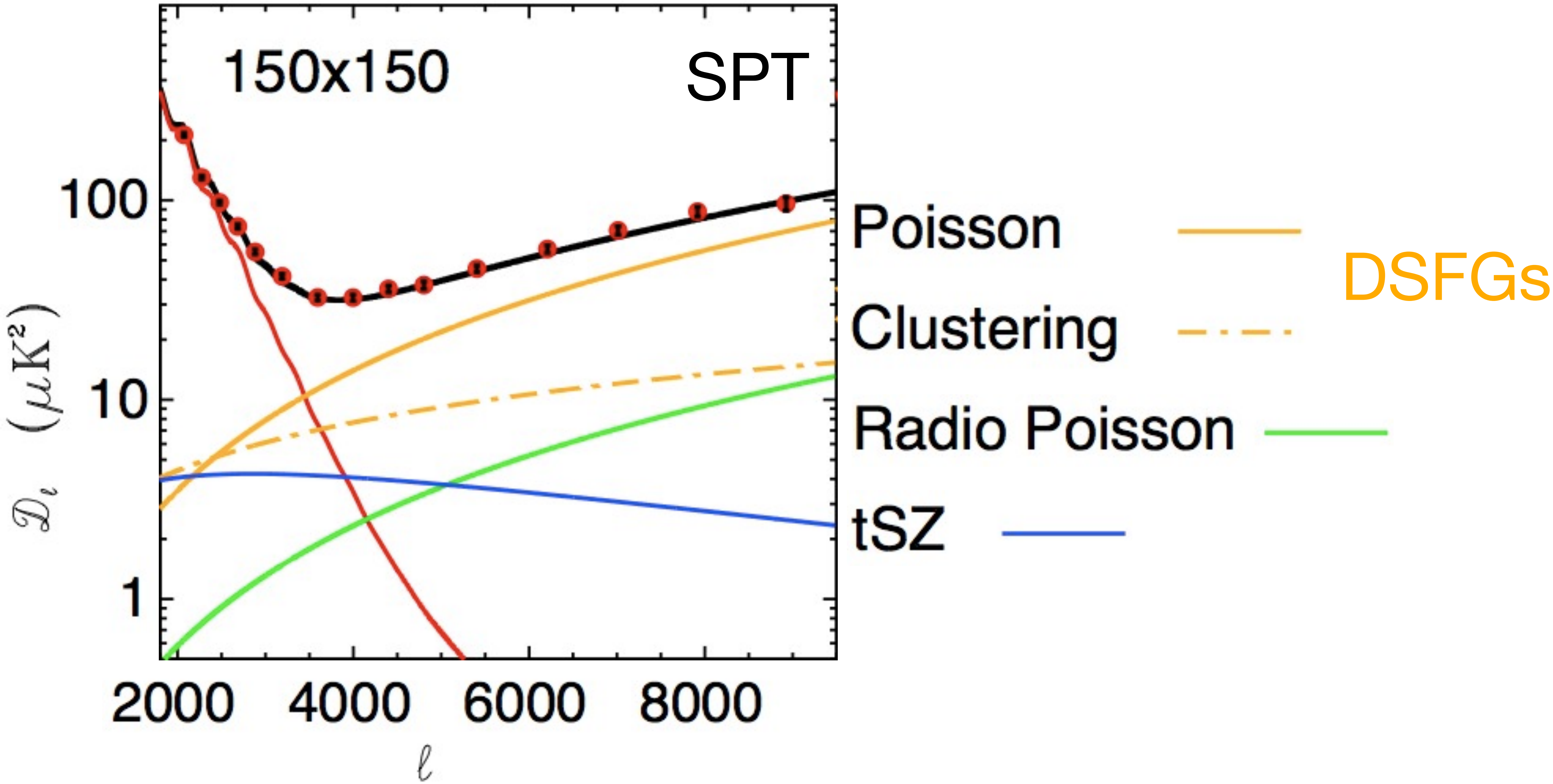
Motivation



Reichardt et al. 2011

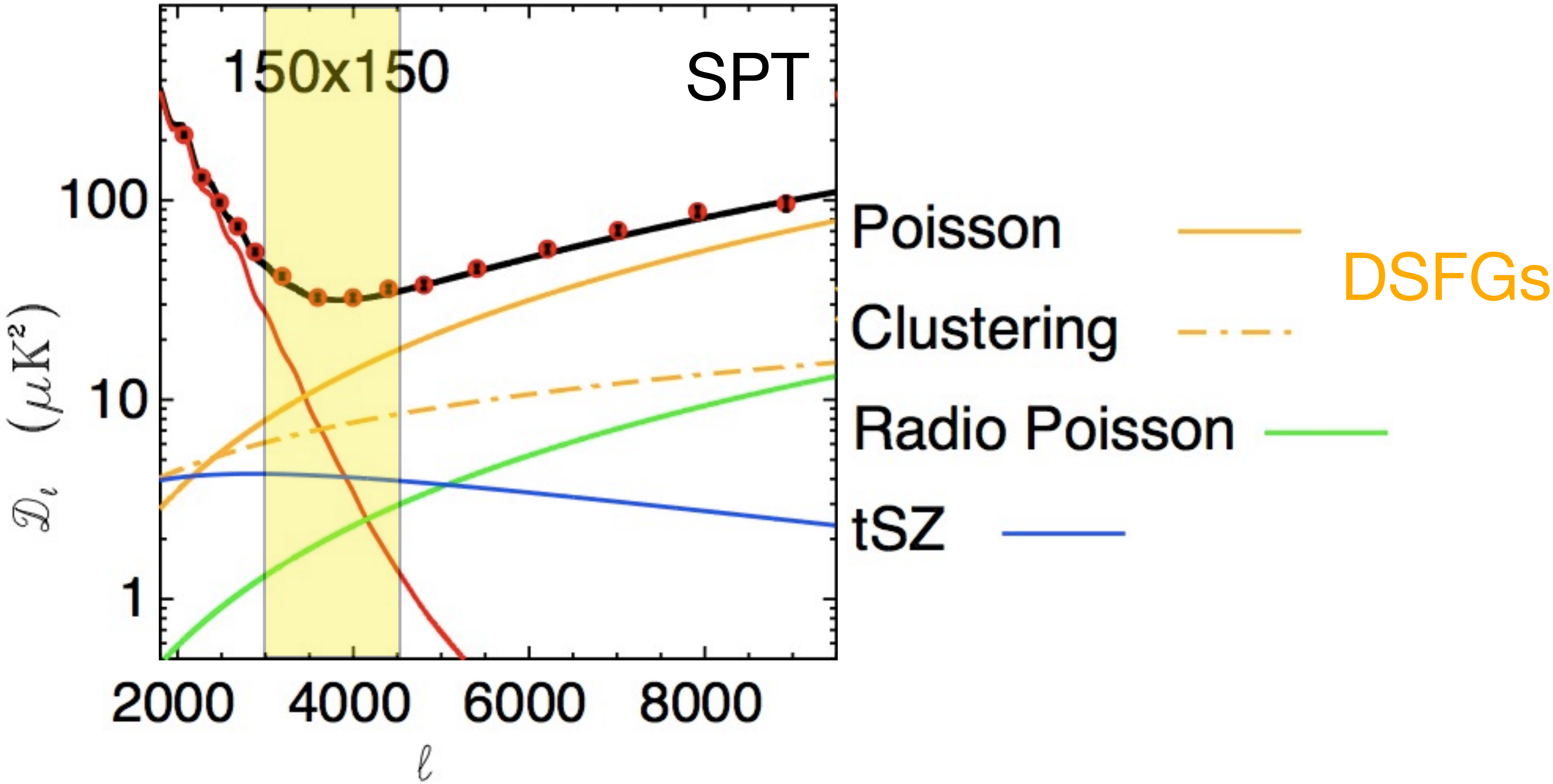
- $\ell > 2000$ dominated by secondary anisotropies

Motivation



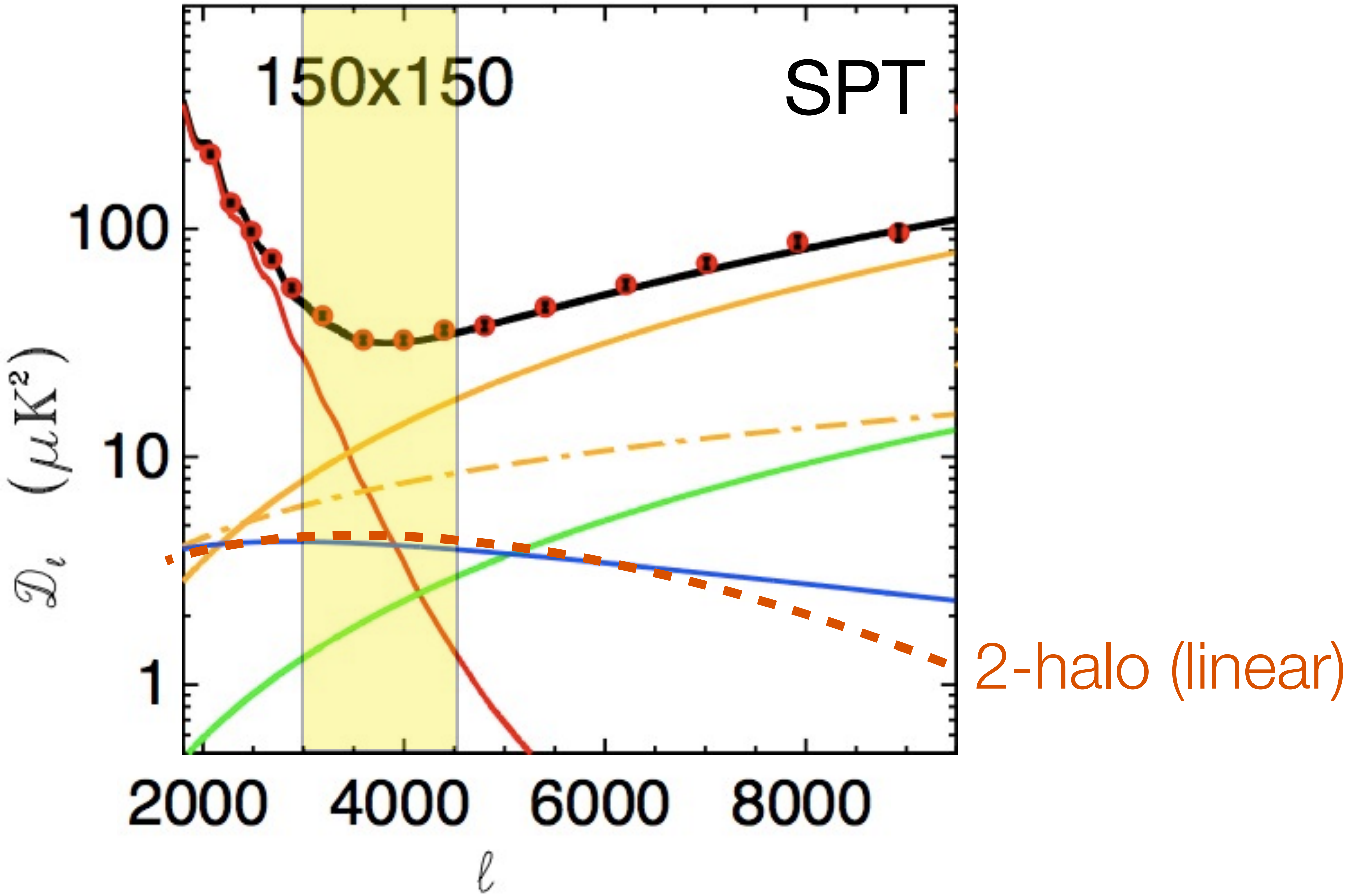
Reichardt et al. 2011

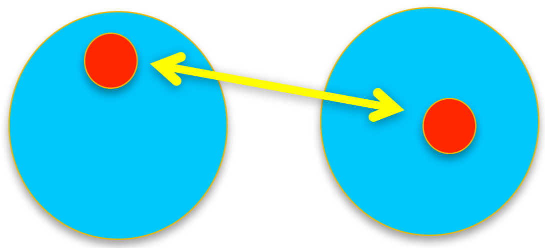
Motivation (i)



Reichardt et al. 2011

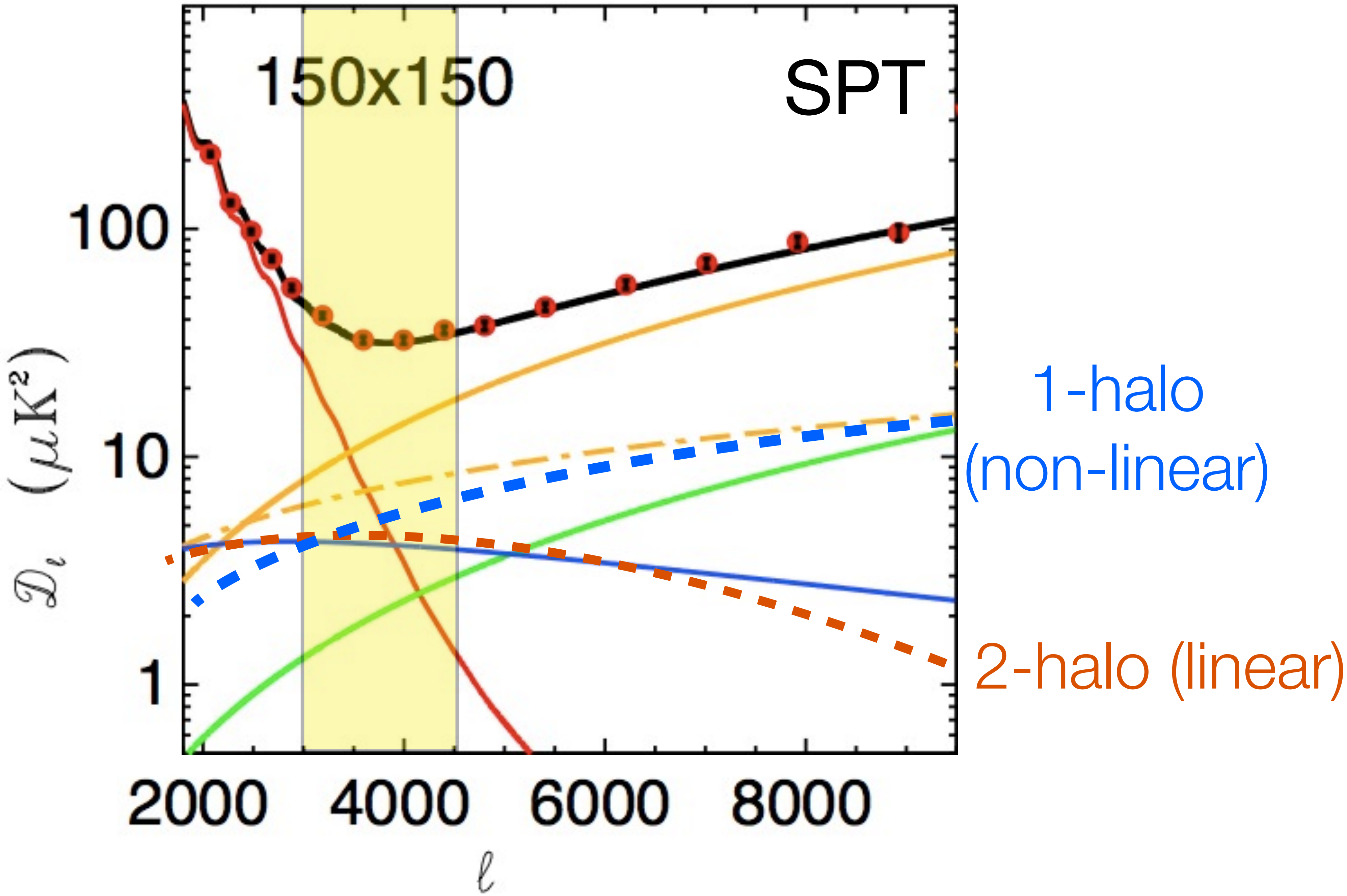
Motivation (i)

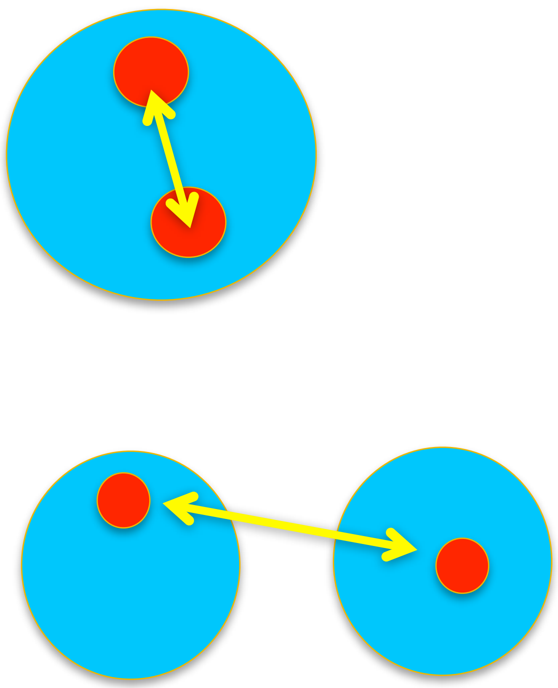




Reichardt et al. 2011

Motivation (i)

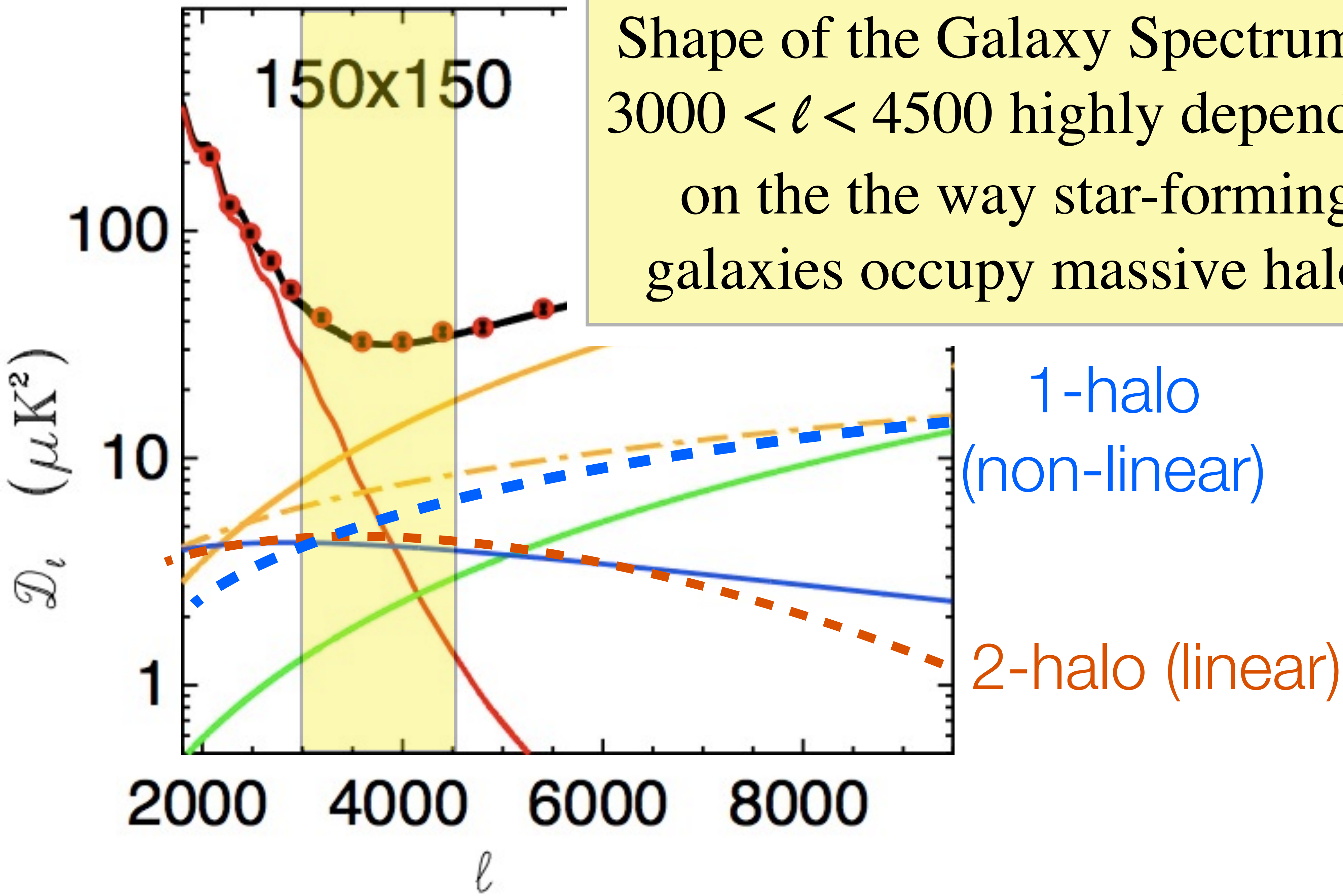


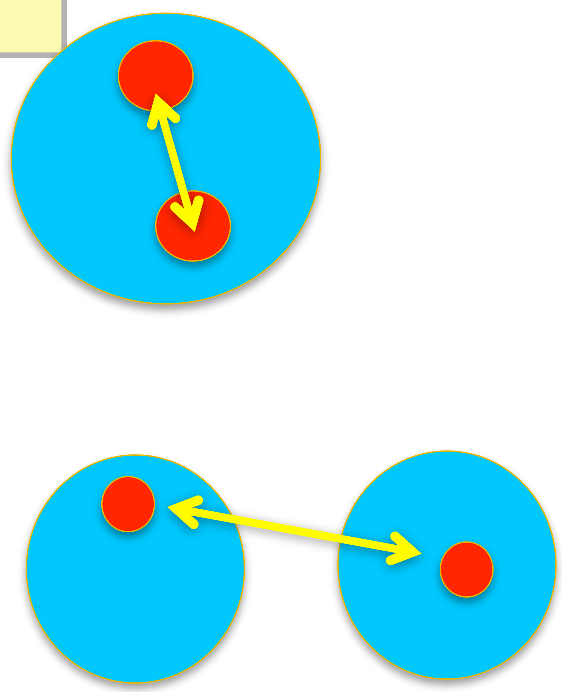


Reichardt et al. 2011

Motivation (i)

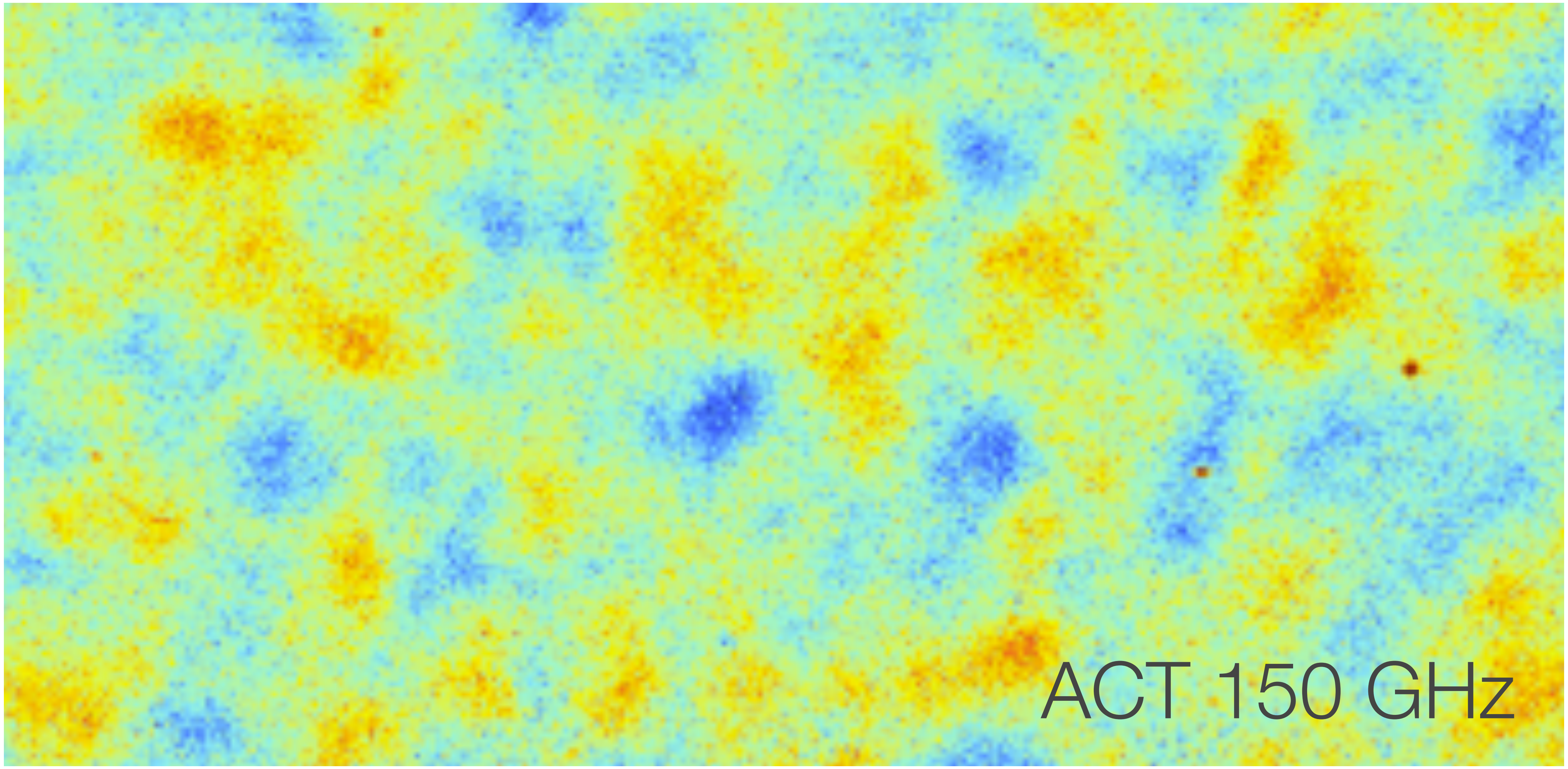
Shape of the Galaxy Spectrum at $3000 < \ell < 4500$ highly dependent on the the way star-forming galaxies occupy massive halos



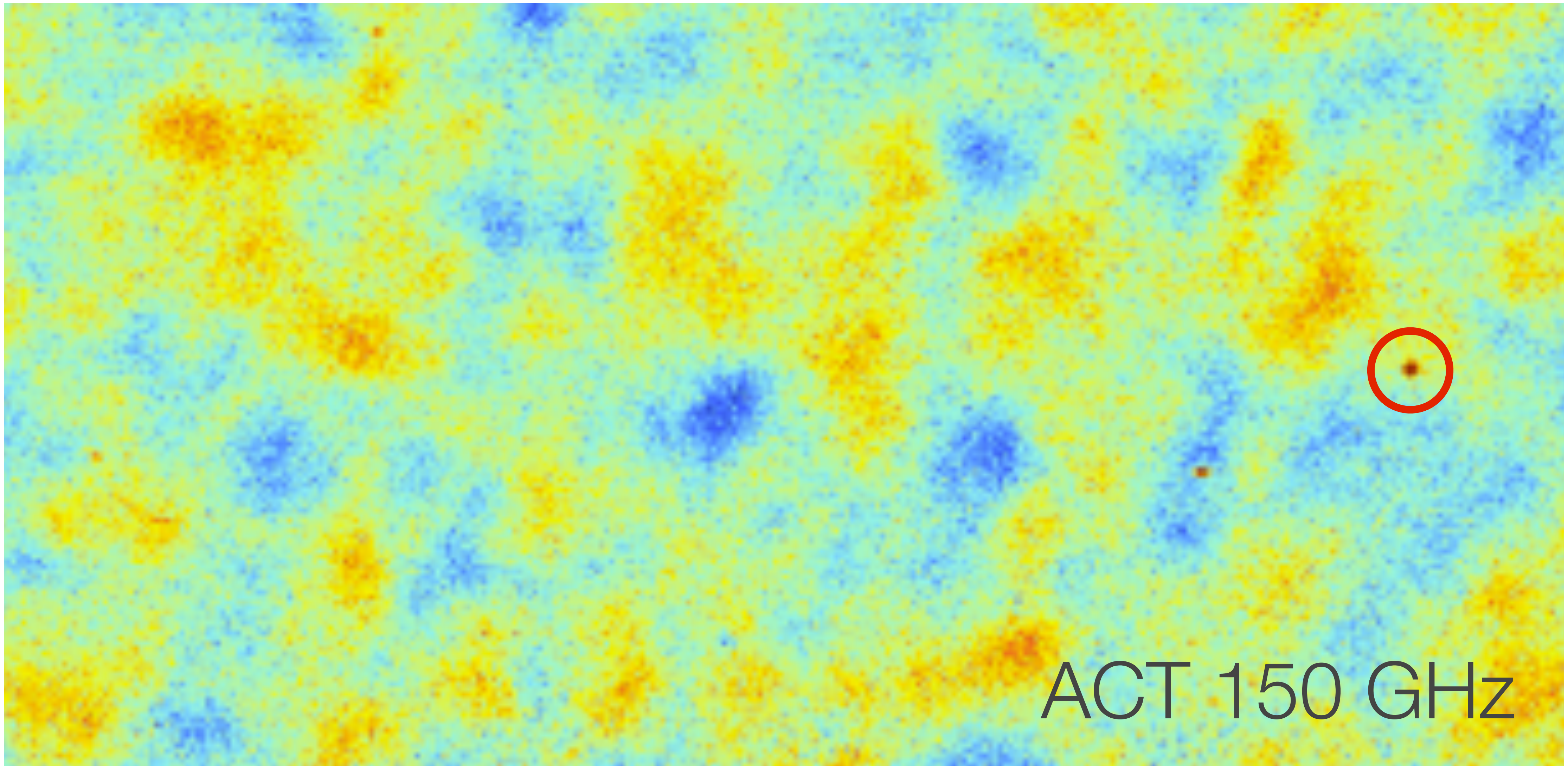


Reichardt et al. 2011

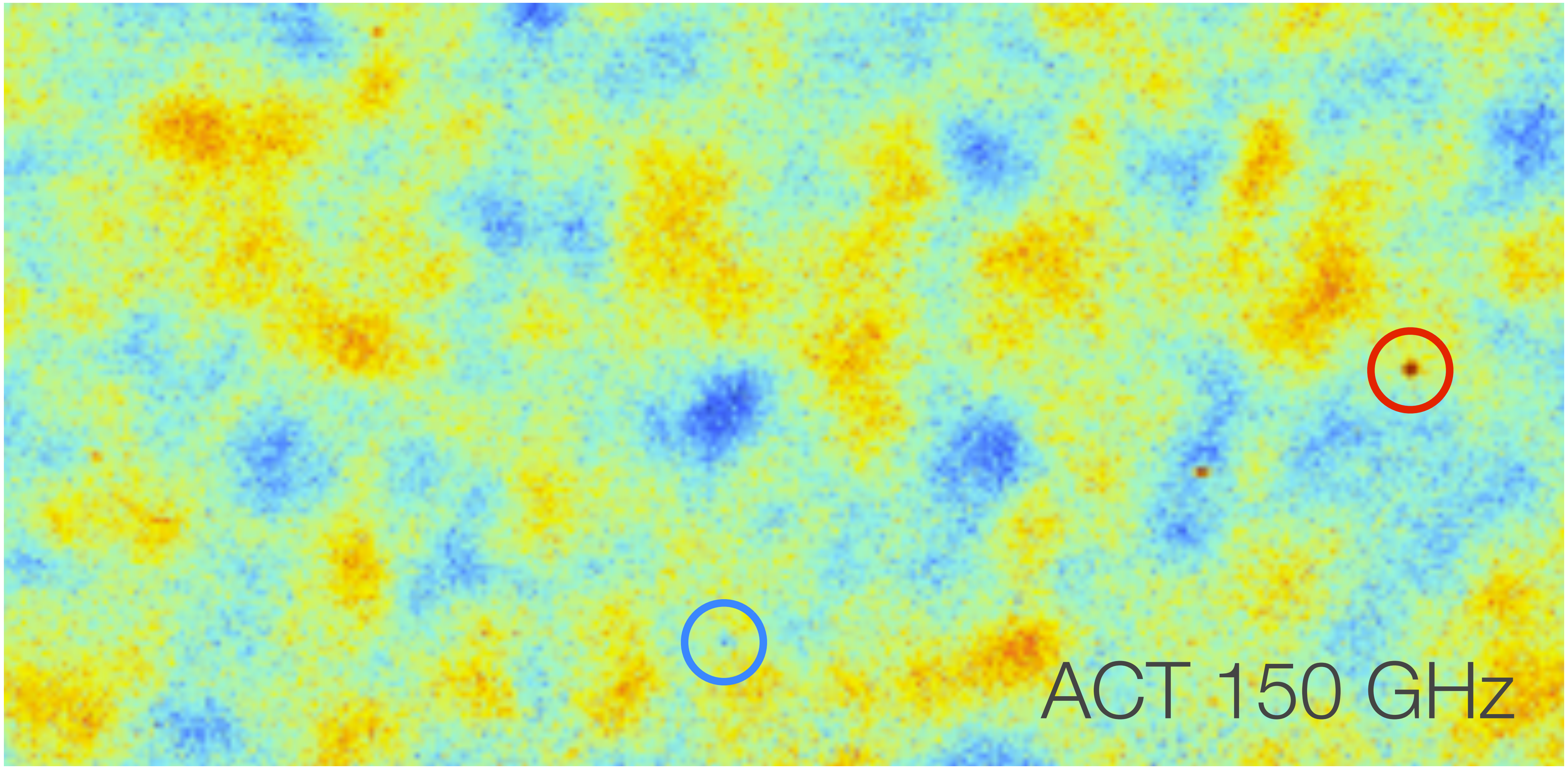
Motivation (i)



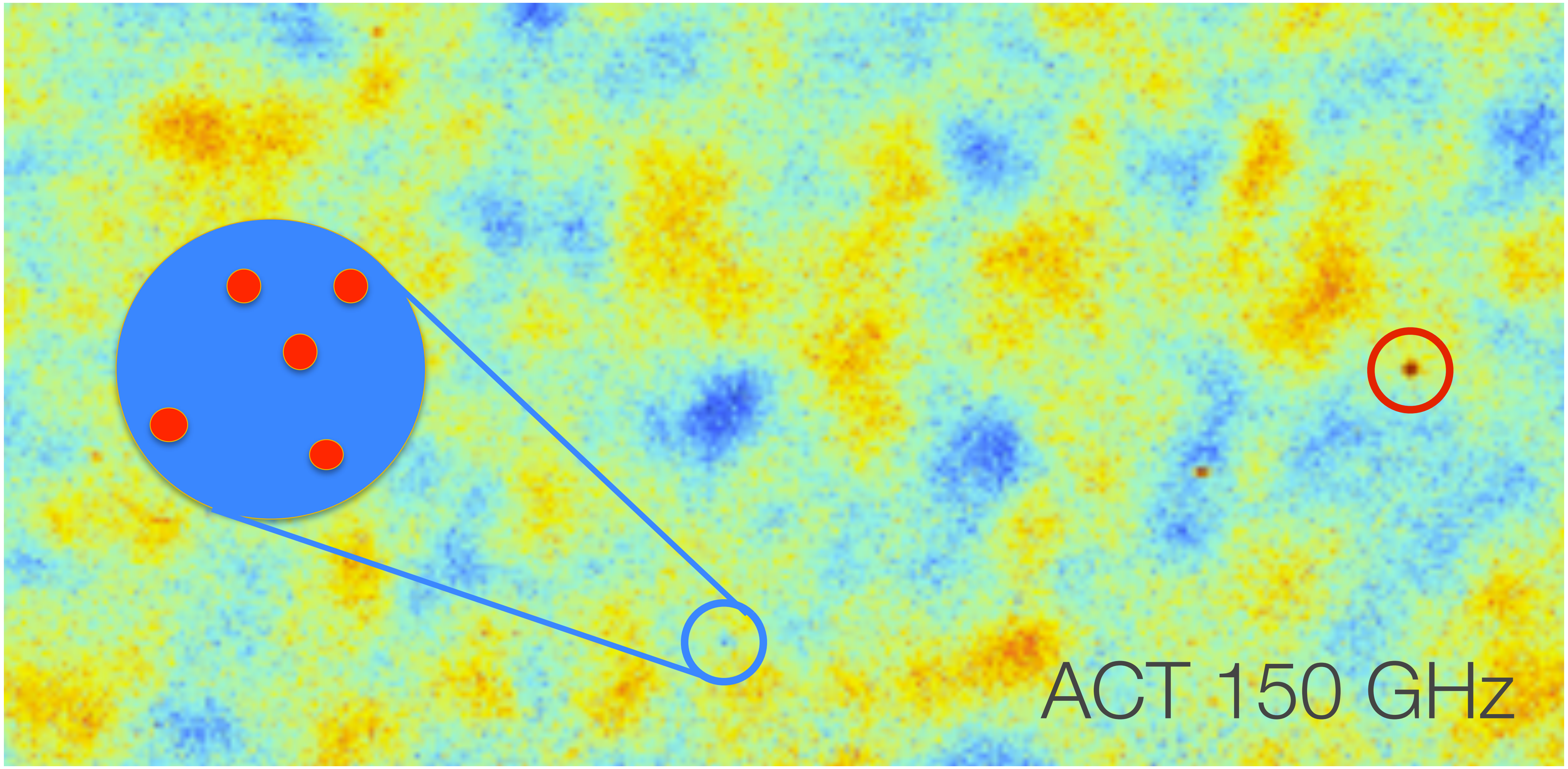
Motivation (ii)



Motivation (ii)

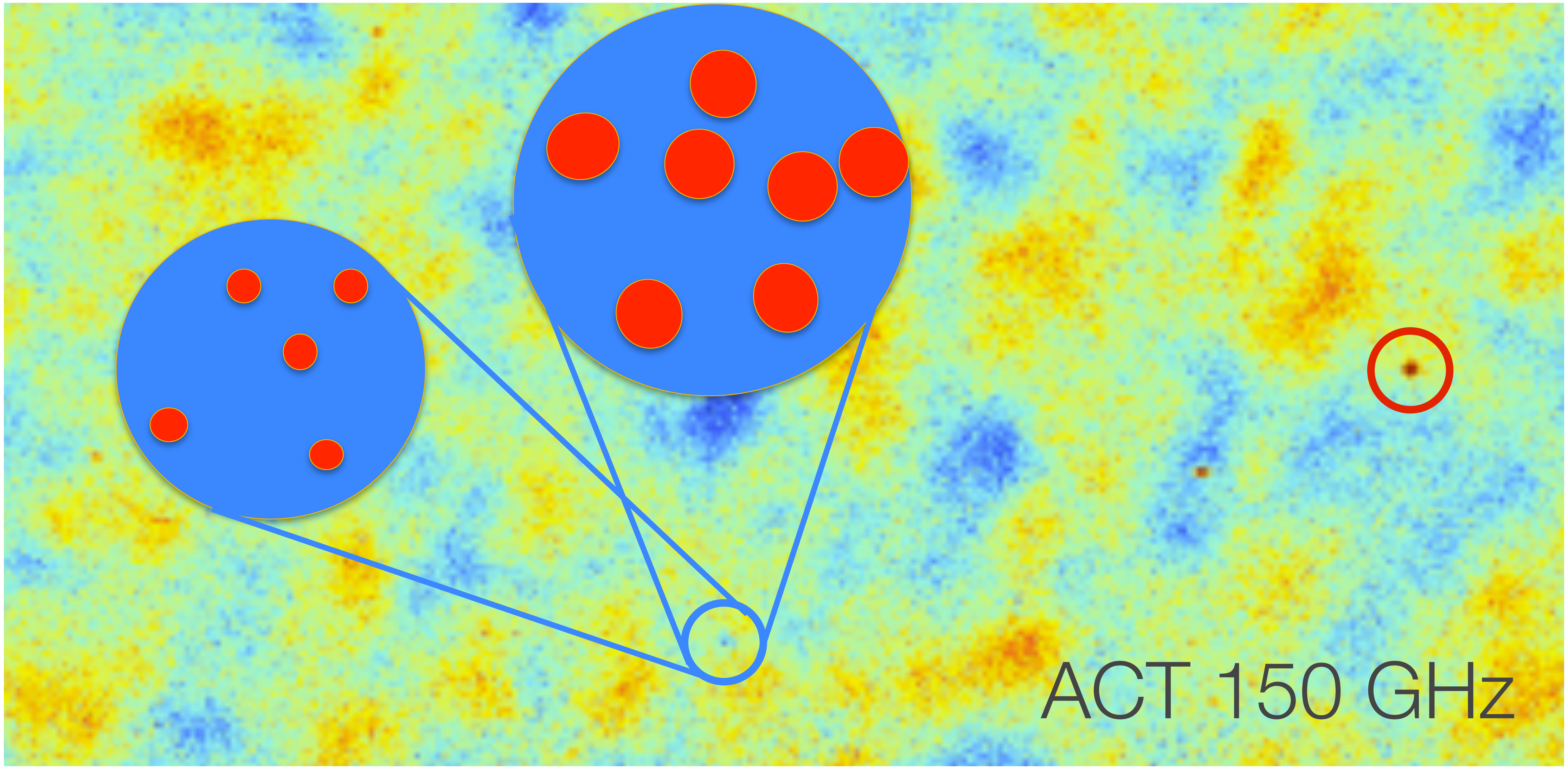


Motivation (ii)



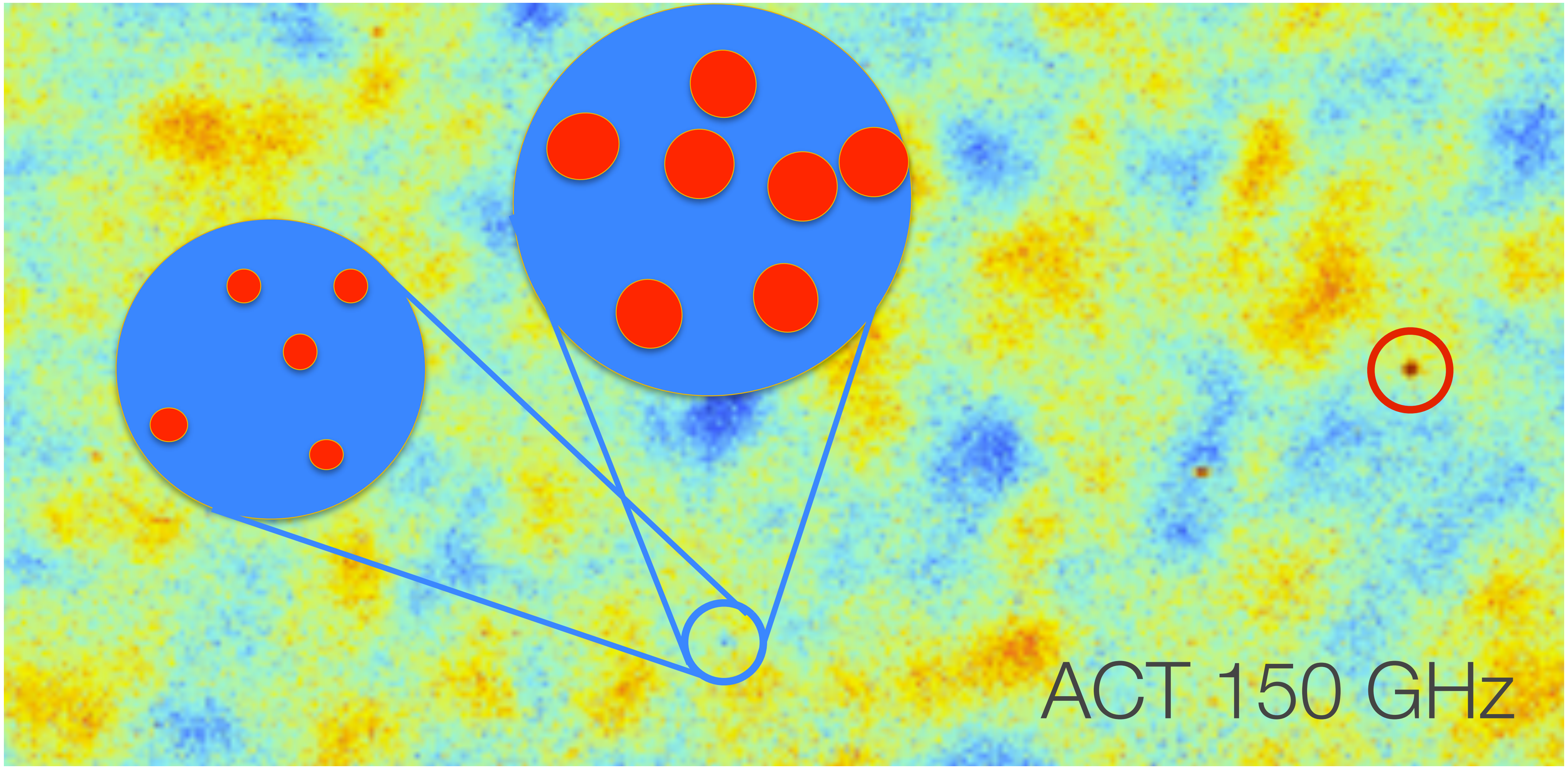
- Halo Occupation Distribution (HOD):
  - How many satellites per given halo mass?

Motivation (ii)



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

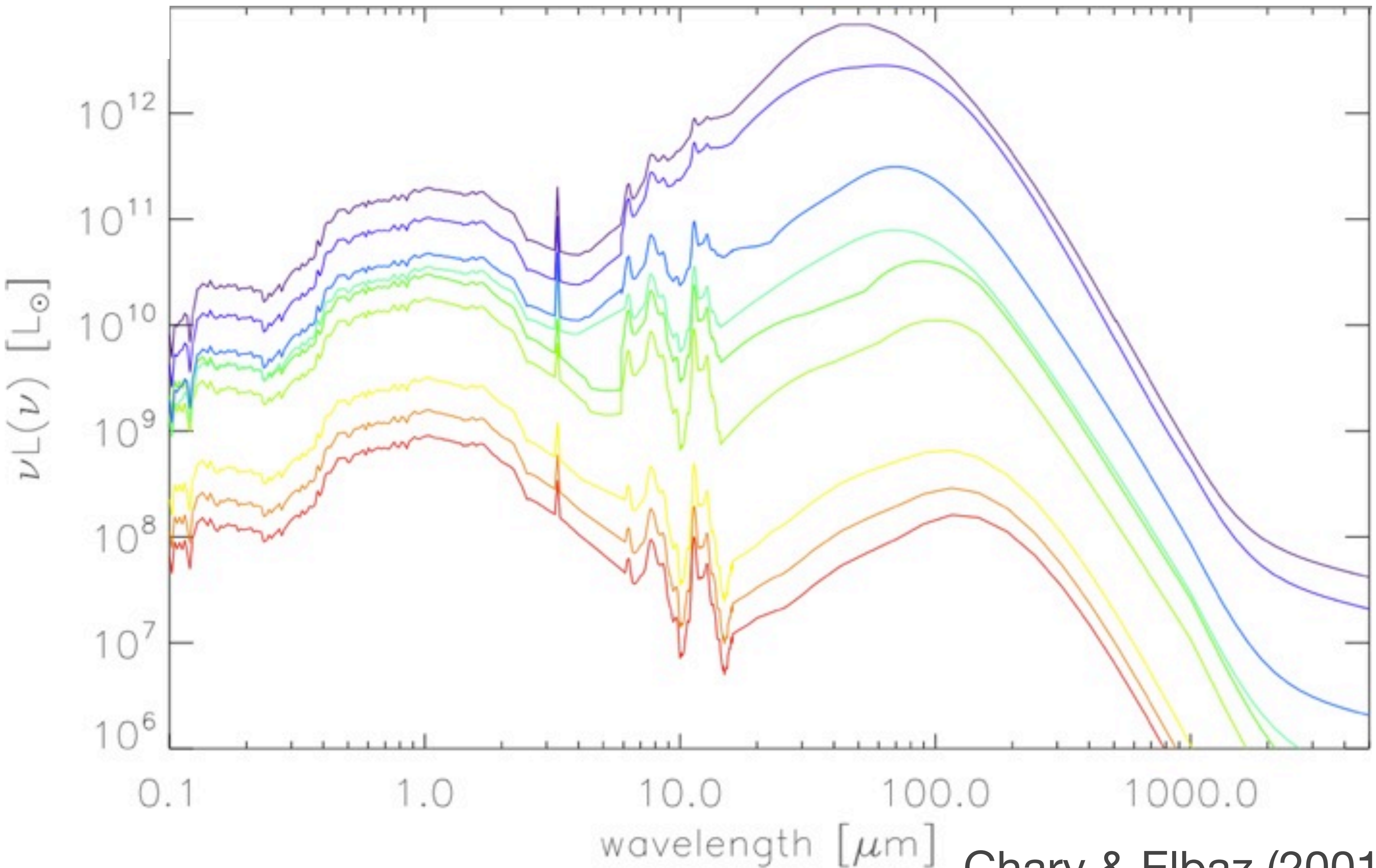
Motivation (ii)



- Halo Occupation Distribution (HOD):
  - How many satellites per given halo mass?
  - Luminosity-Mass relation?
- This is imprinted on the 1-halo term of the CIB power spectrum!

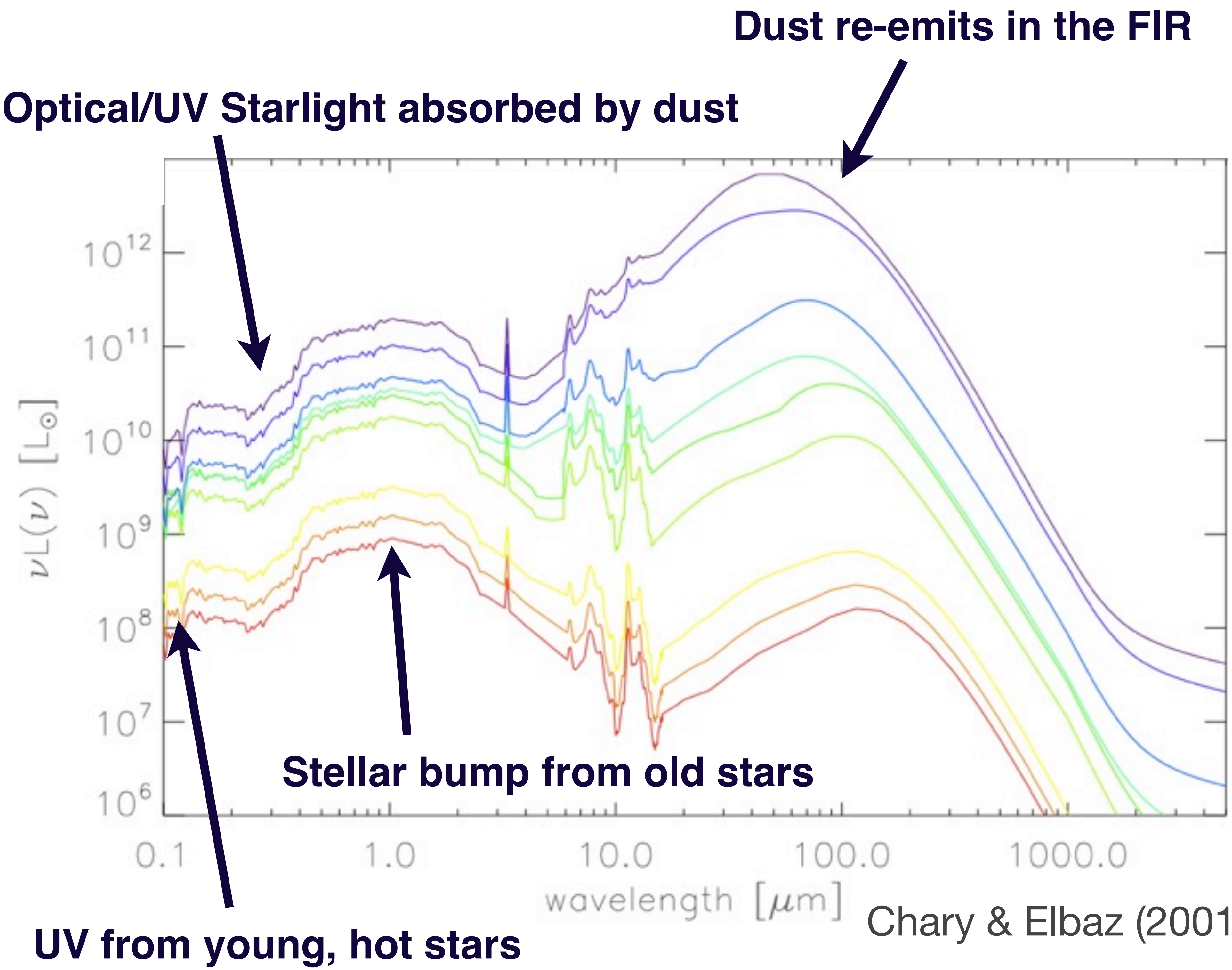
Motivation (ii)

Cosmic Submillimeter Background



Chary & Elbaz (2001)

Galaxy SEDs



Chary & Elbaz (2001)

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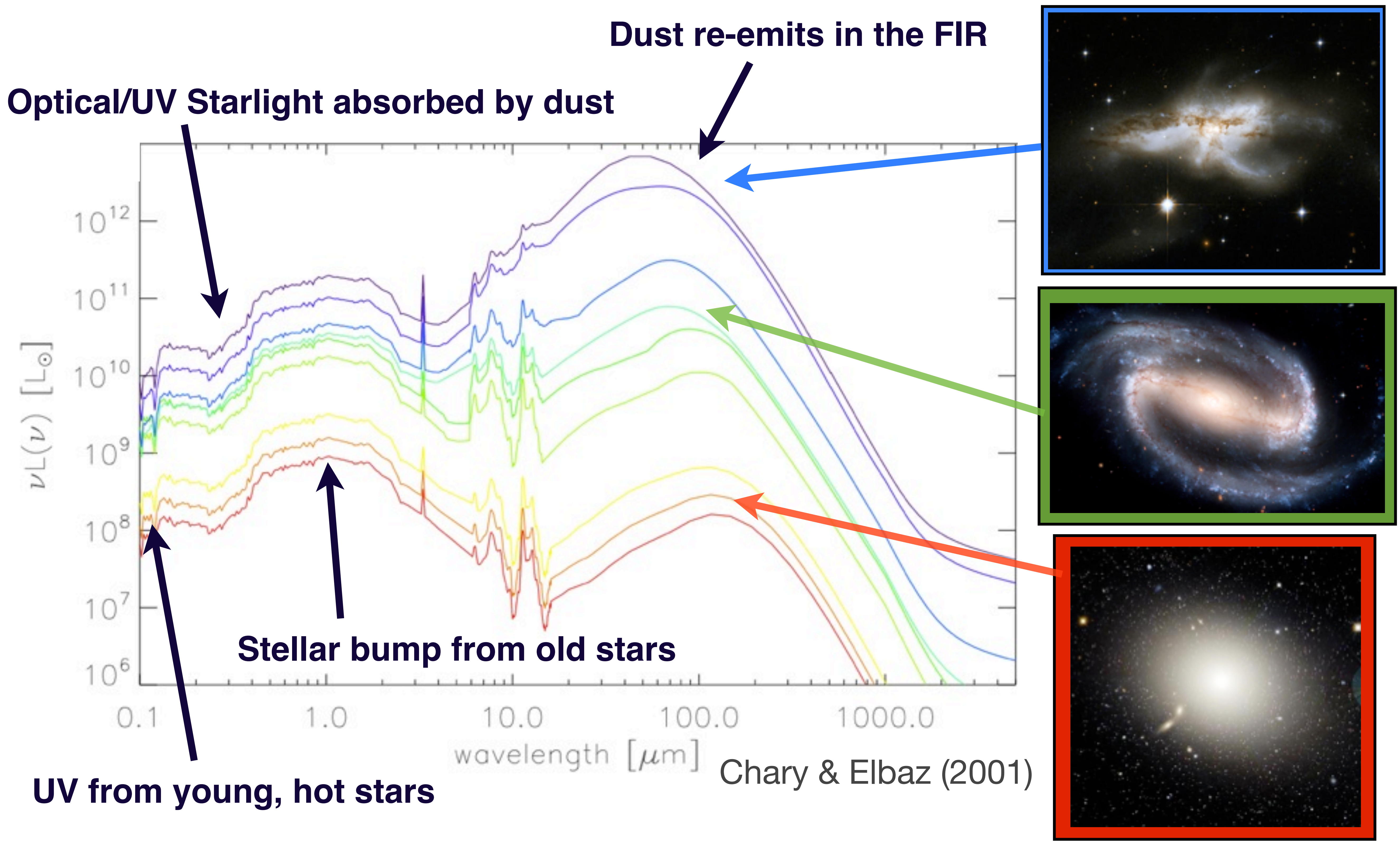
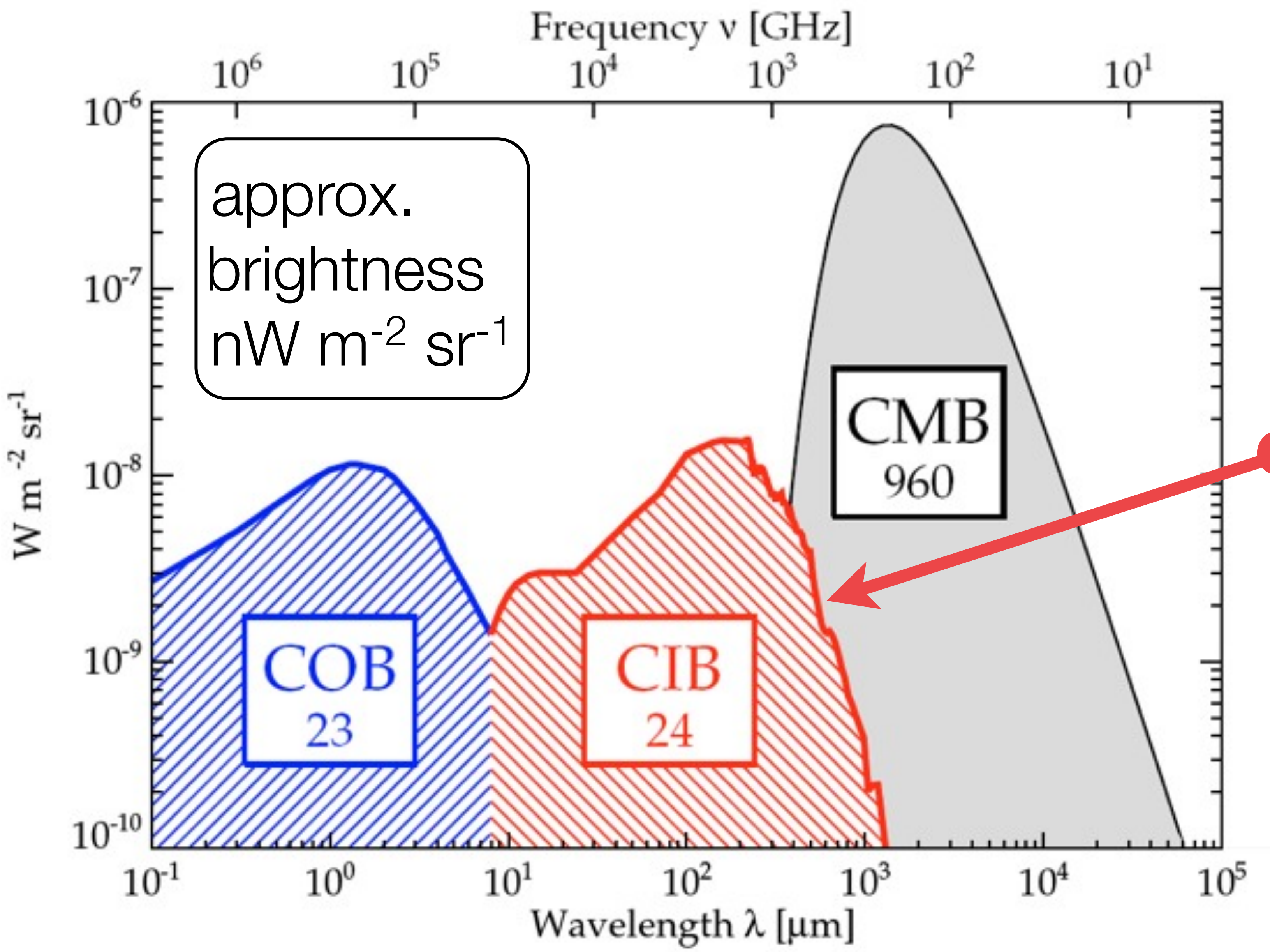


Chary & Elbaz (2001)

Galaxy SEDs

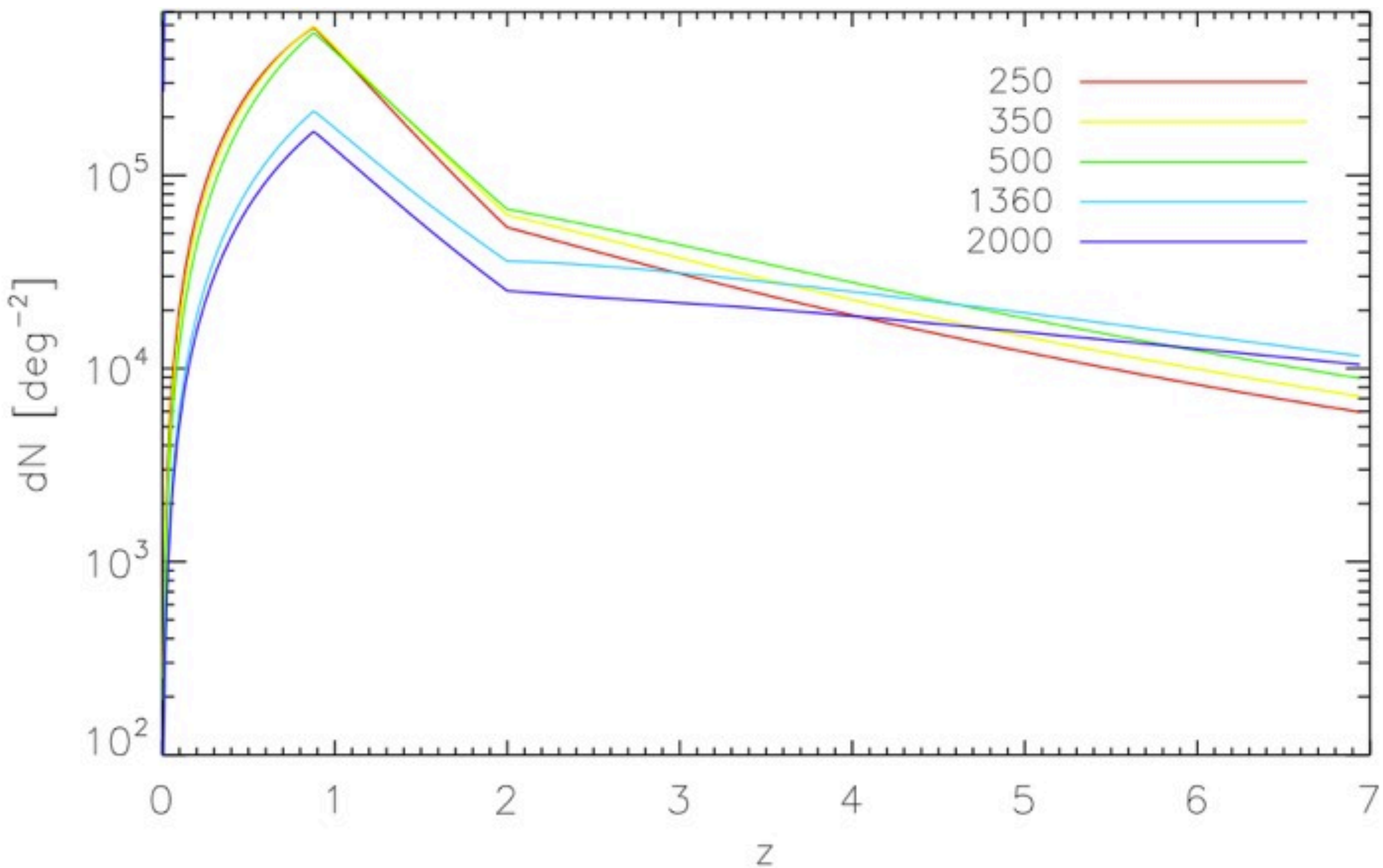


Half the light emitted by stars is absorbed and re-emitted in the IR

Dole et al. (2006)

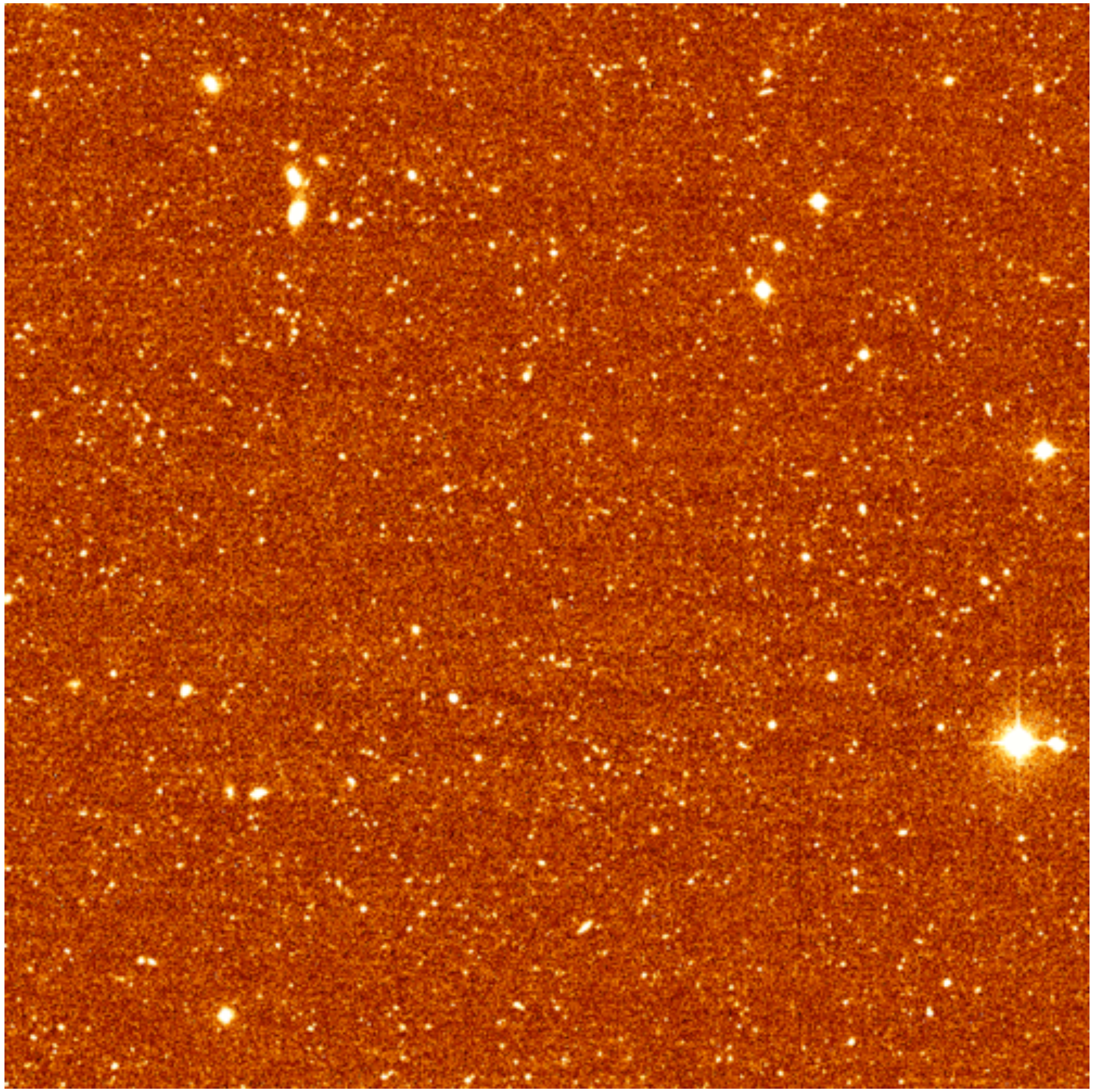
Extragalactic Background

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



Béthermin et al. (2011)
arXiv:1010.1150

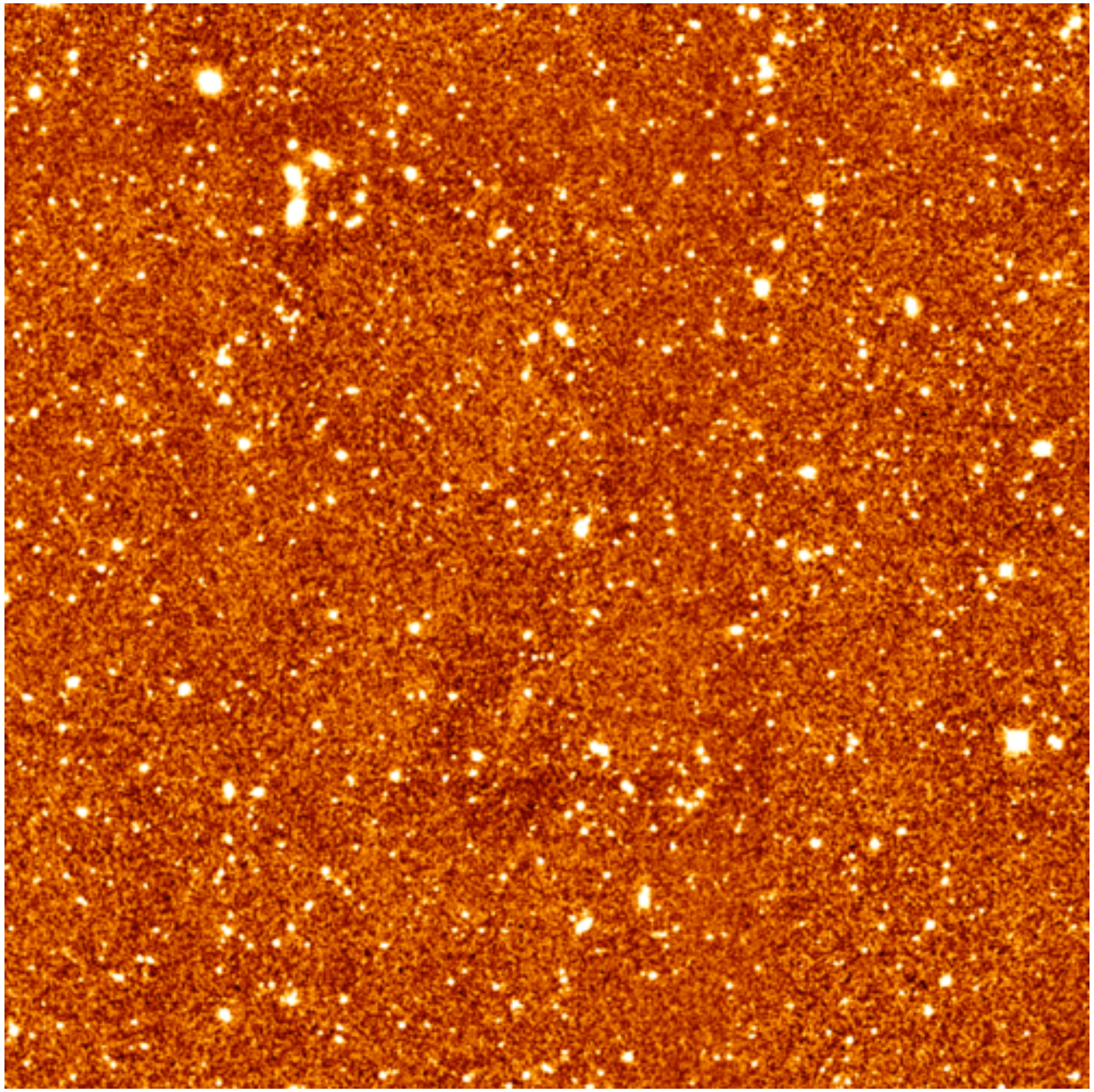
Redshift Distribution of Sources



10 ‘

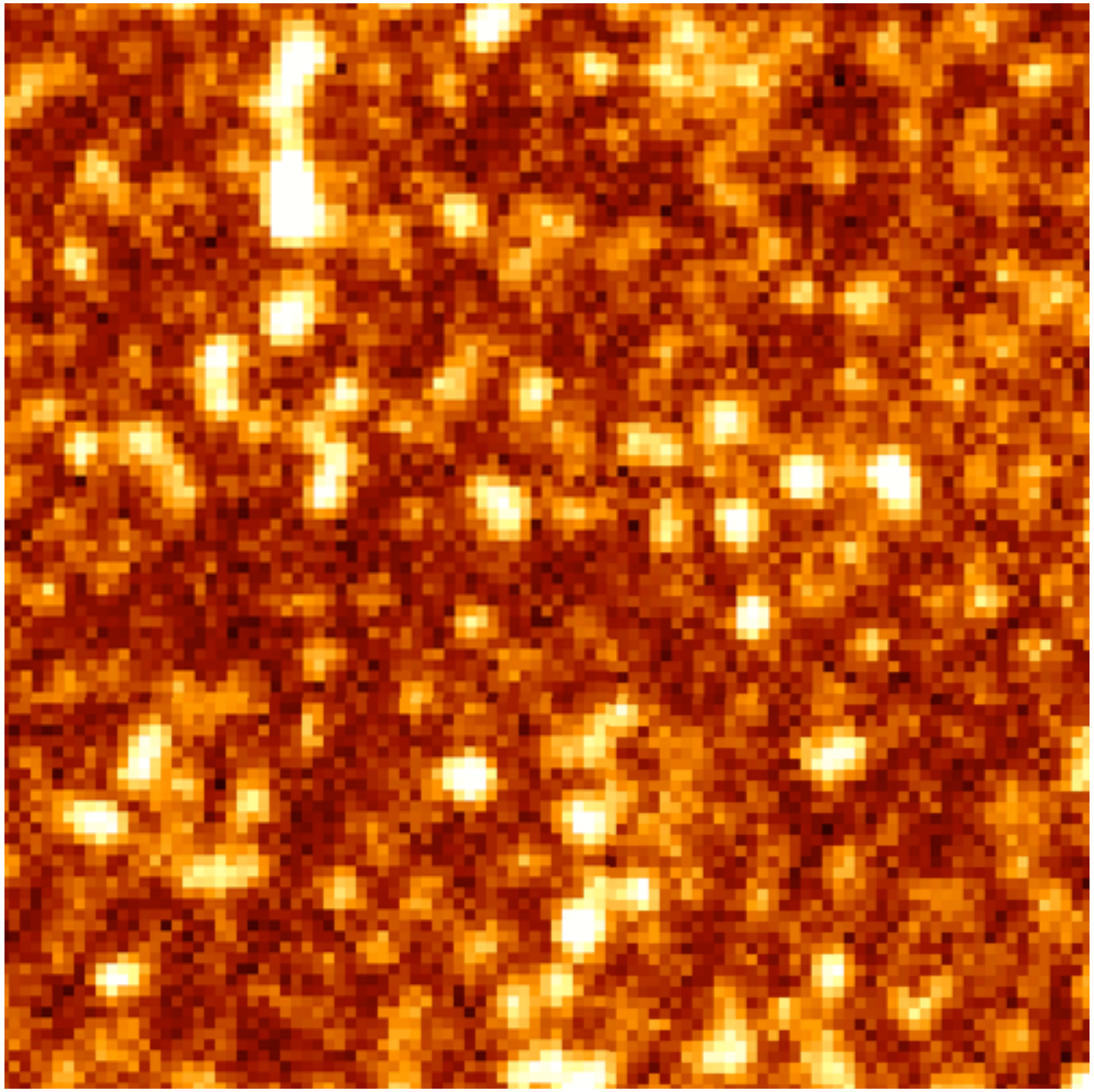
U-band : MUSYC

Confusion



10 ‘ K-band : MUSYC

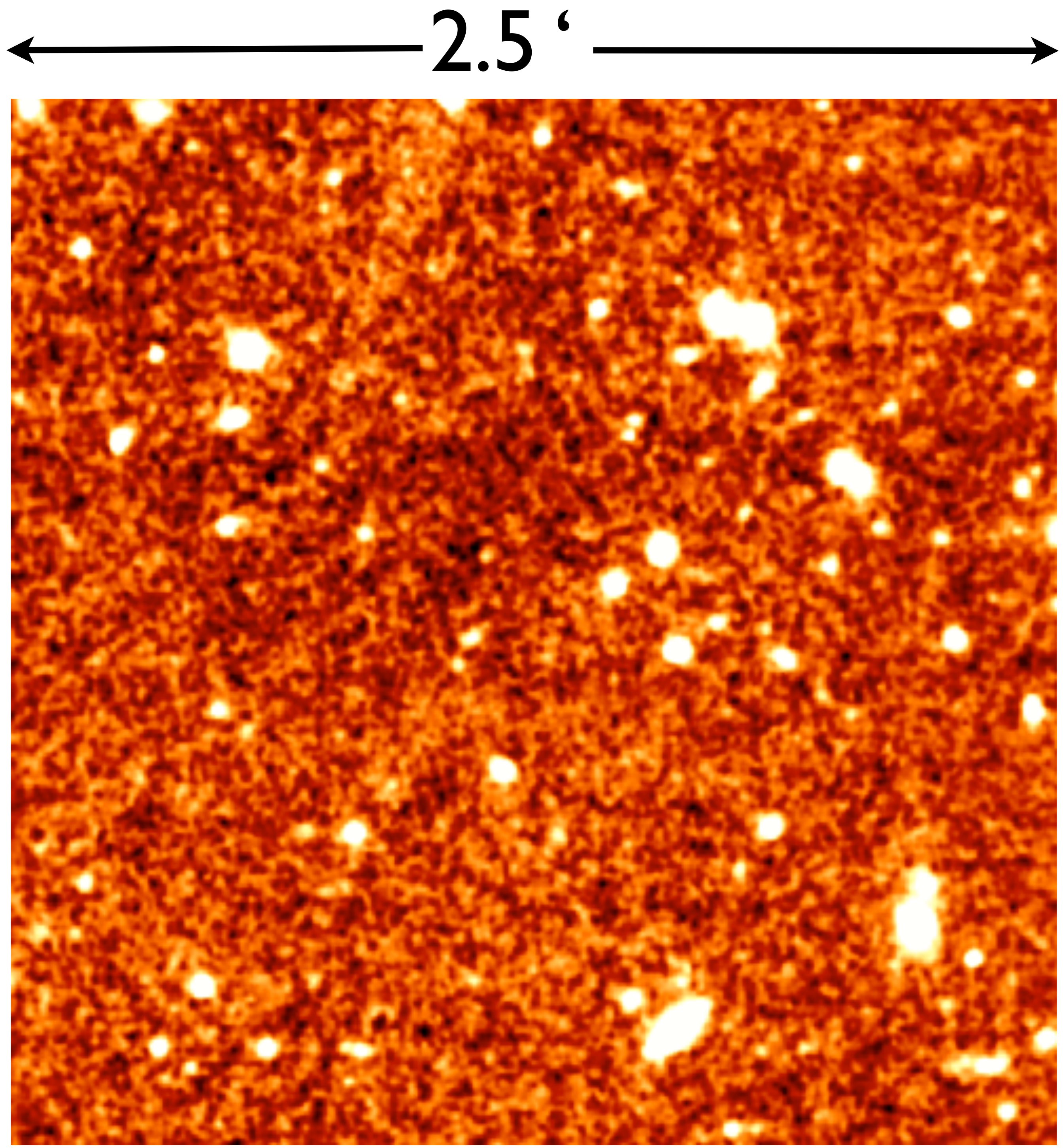
Confusion



SPIRE

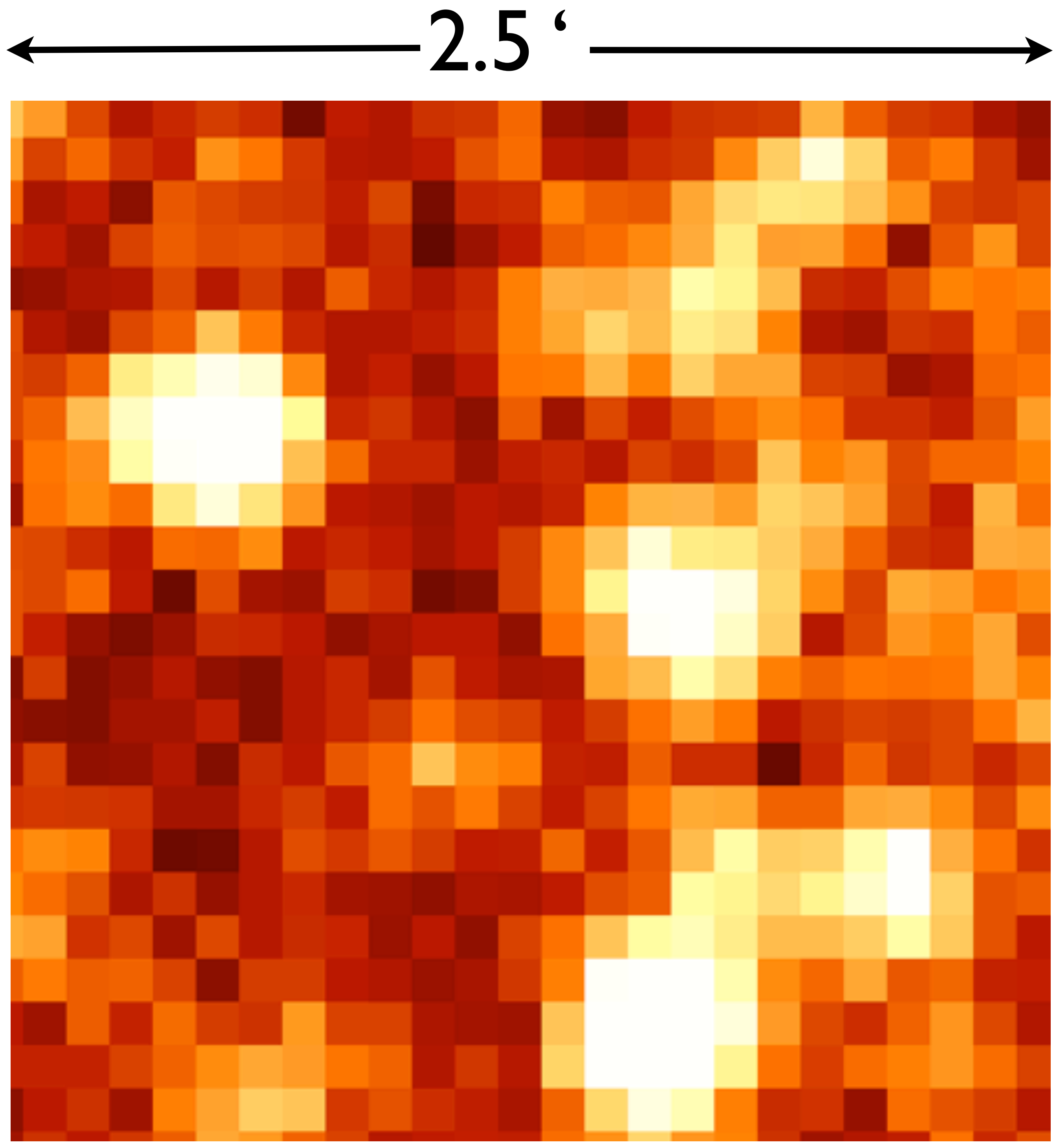
~18, 25, 36” FWHM
@ 250, 350, 500 µm

Confusion



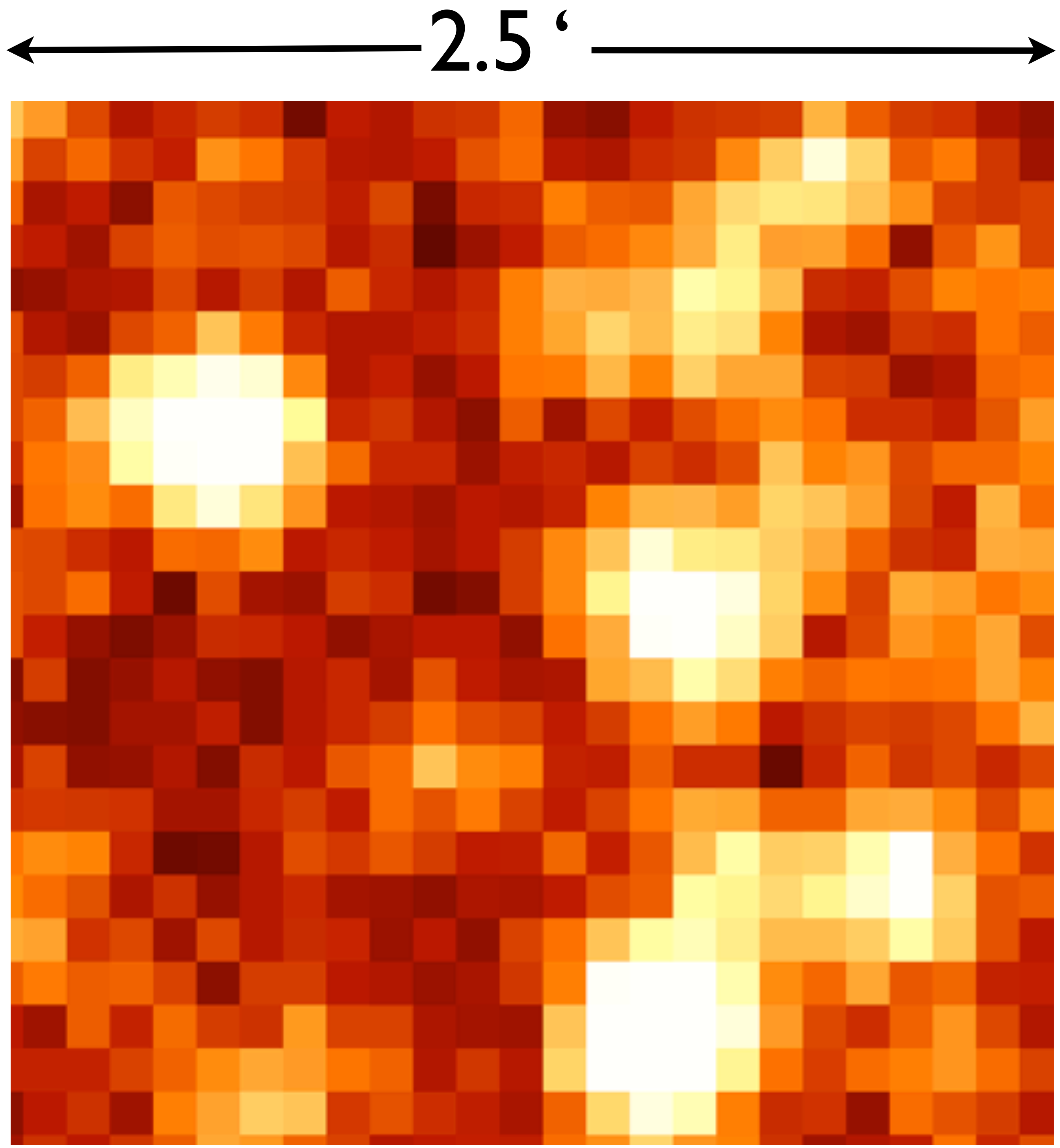
K-band

Confusion



SPIRE 250 μm

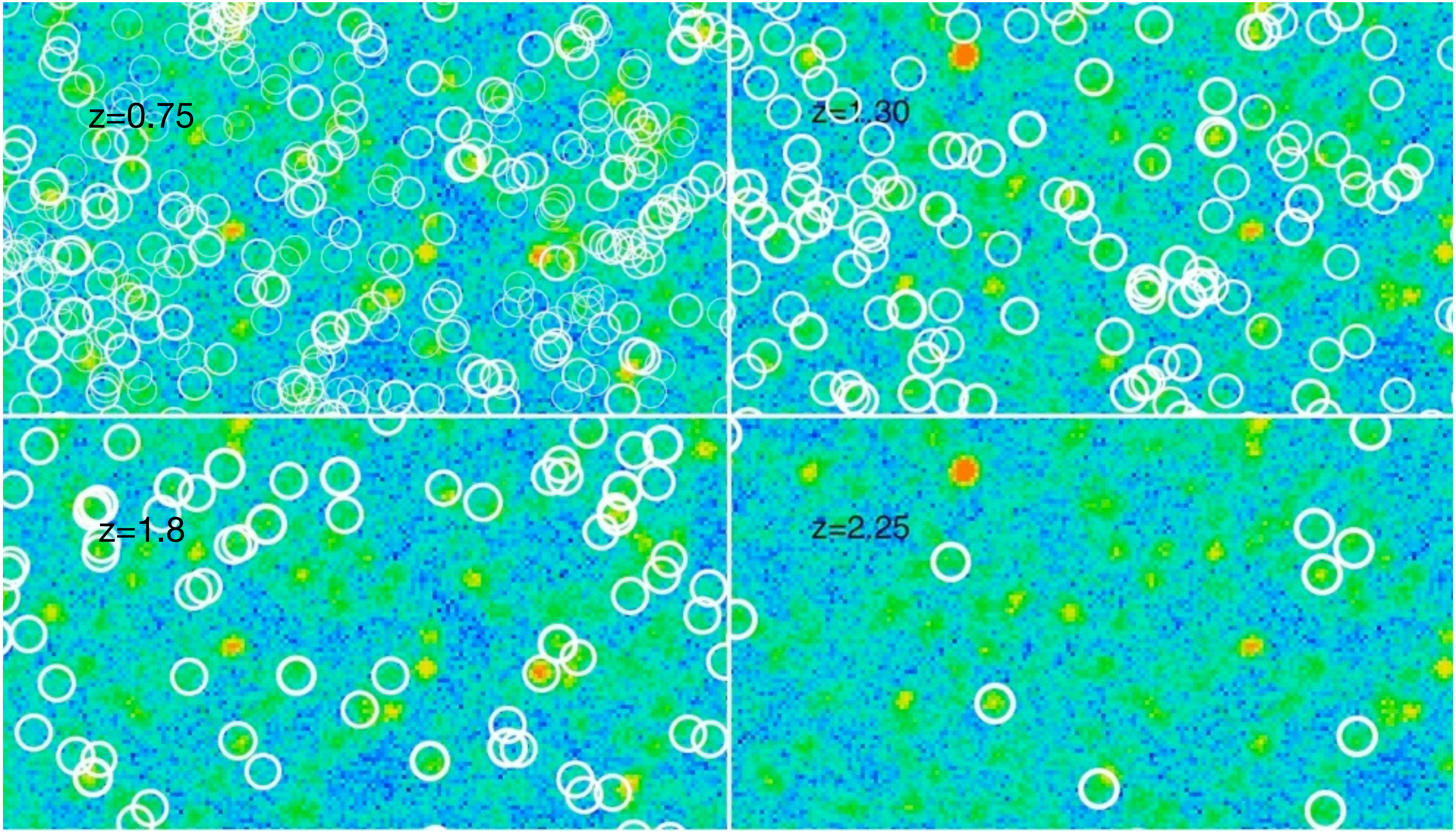
Confusion



SPIRE 250 μm

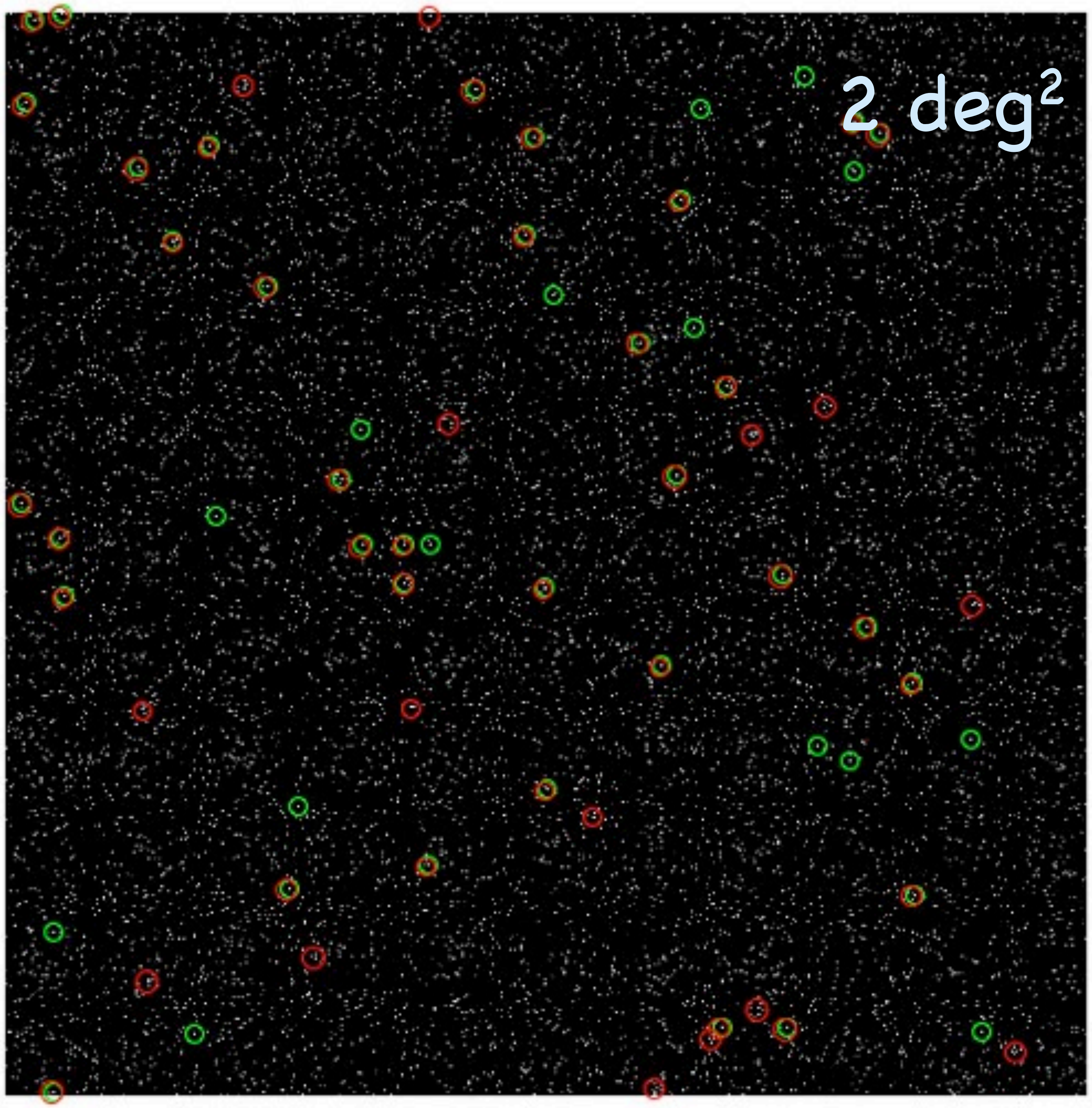
S>20mJy
(at best 15% of all flux, i.e., 0.5% of all sources) is resolved

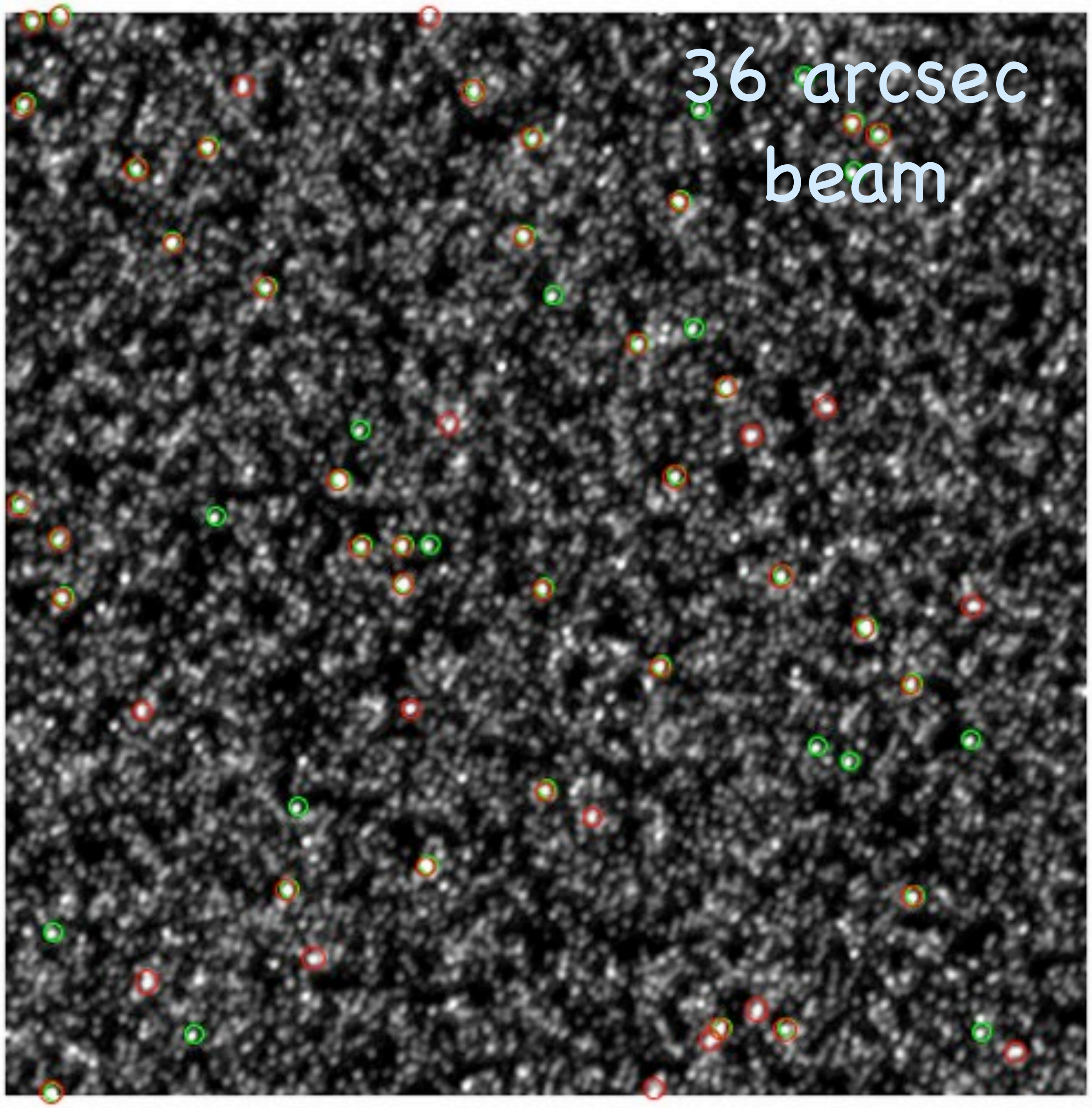
Confusion



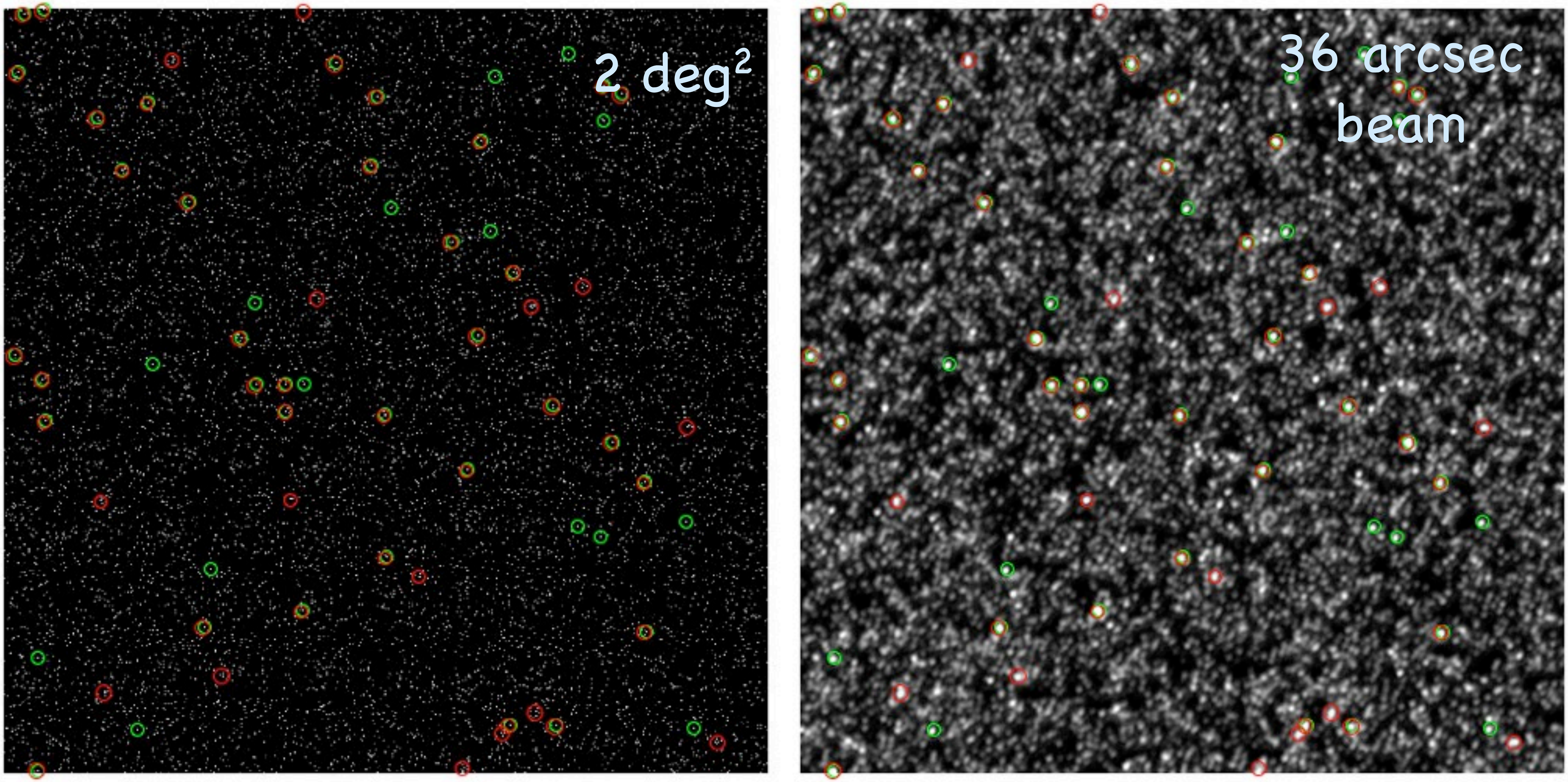
Confusion

Confusion





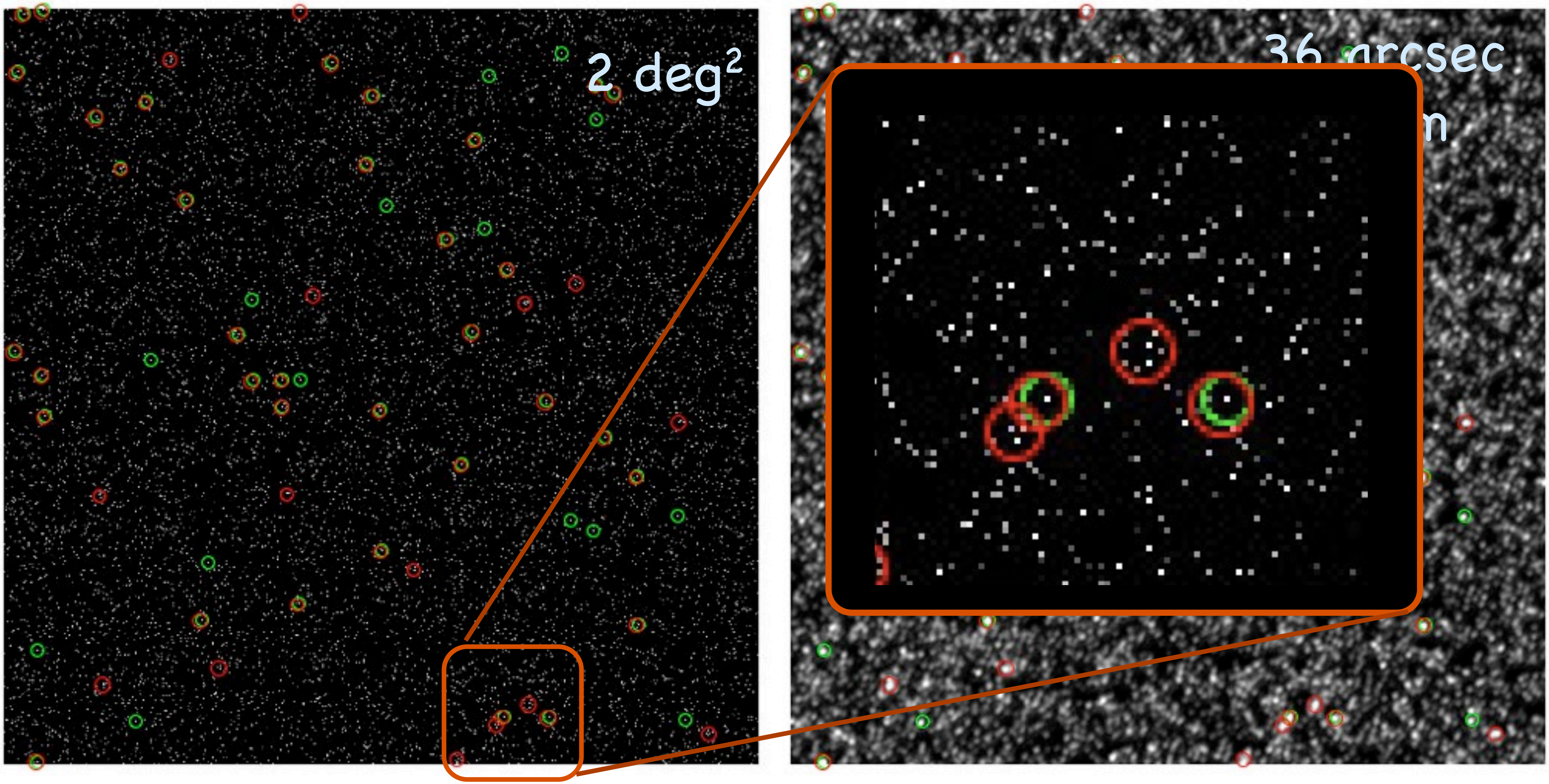
Confusion



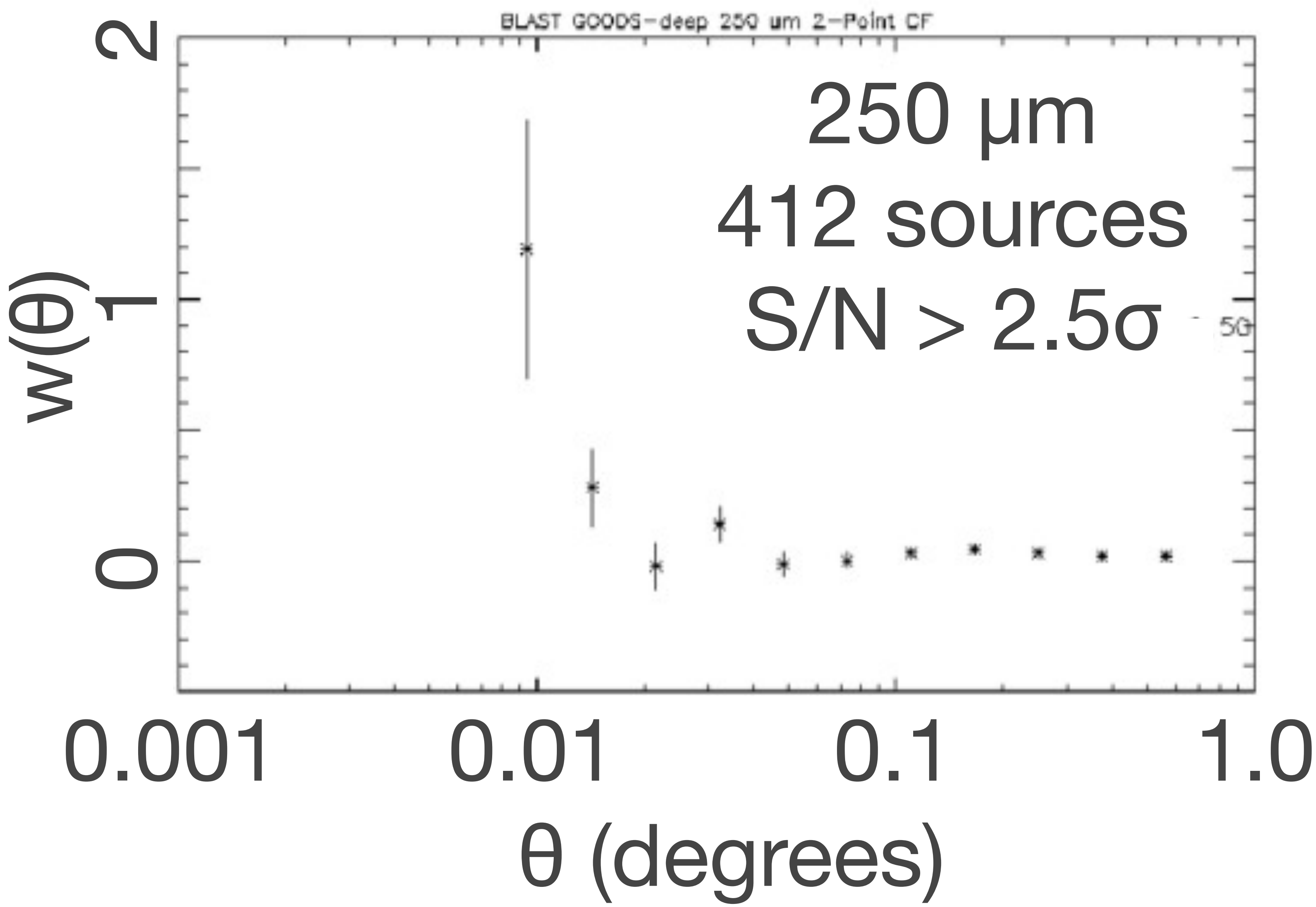
50 brightest (top 0.5%)

50 brightest recovered

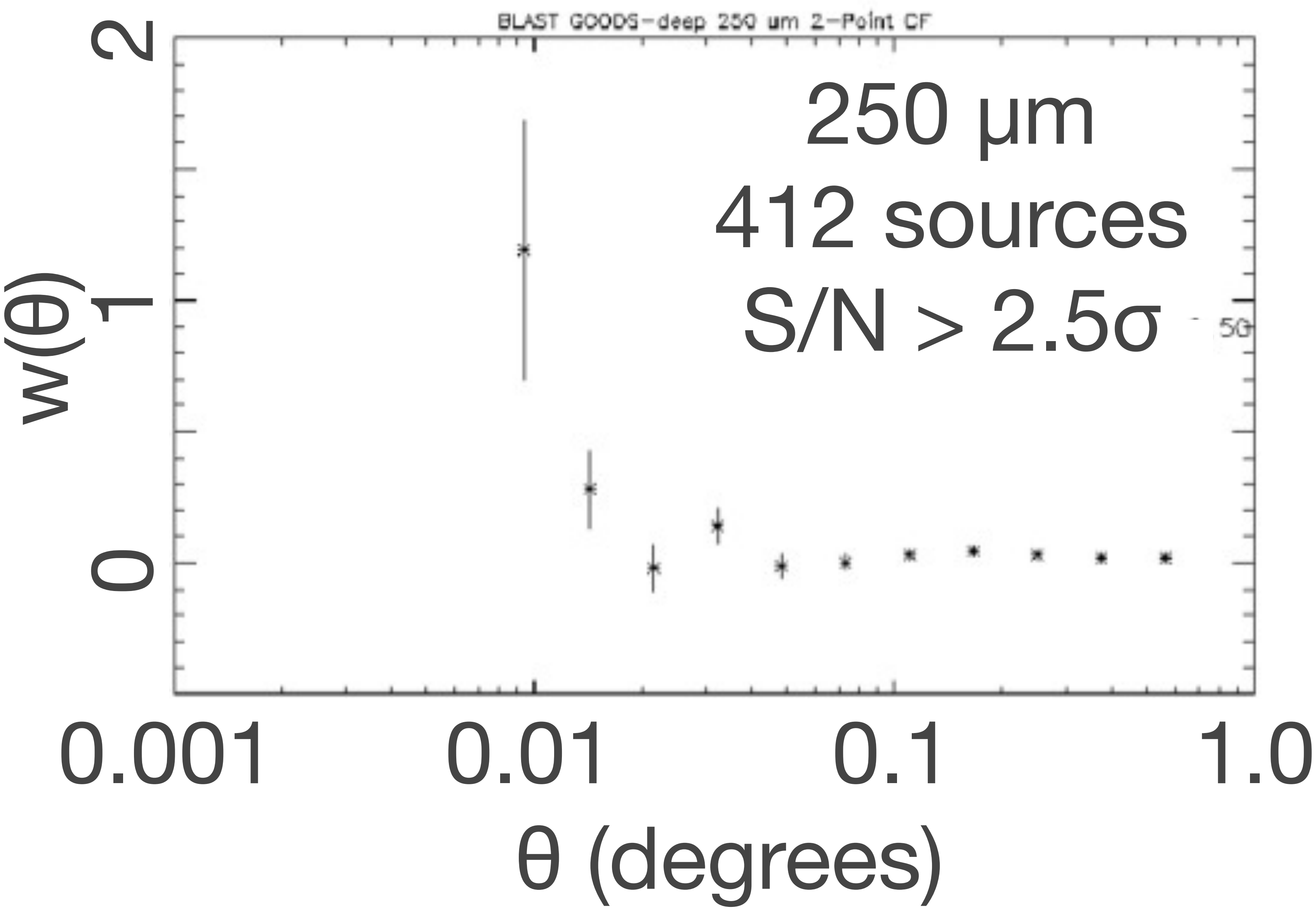
Confusion



70% of top
0.5%
recovered

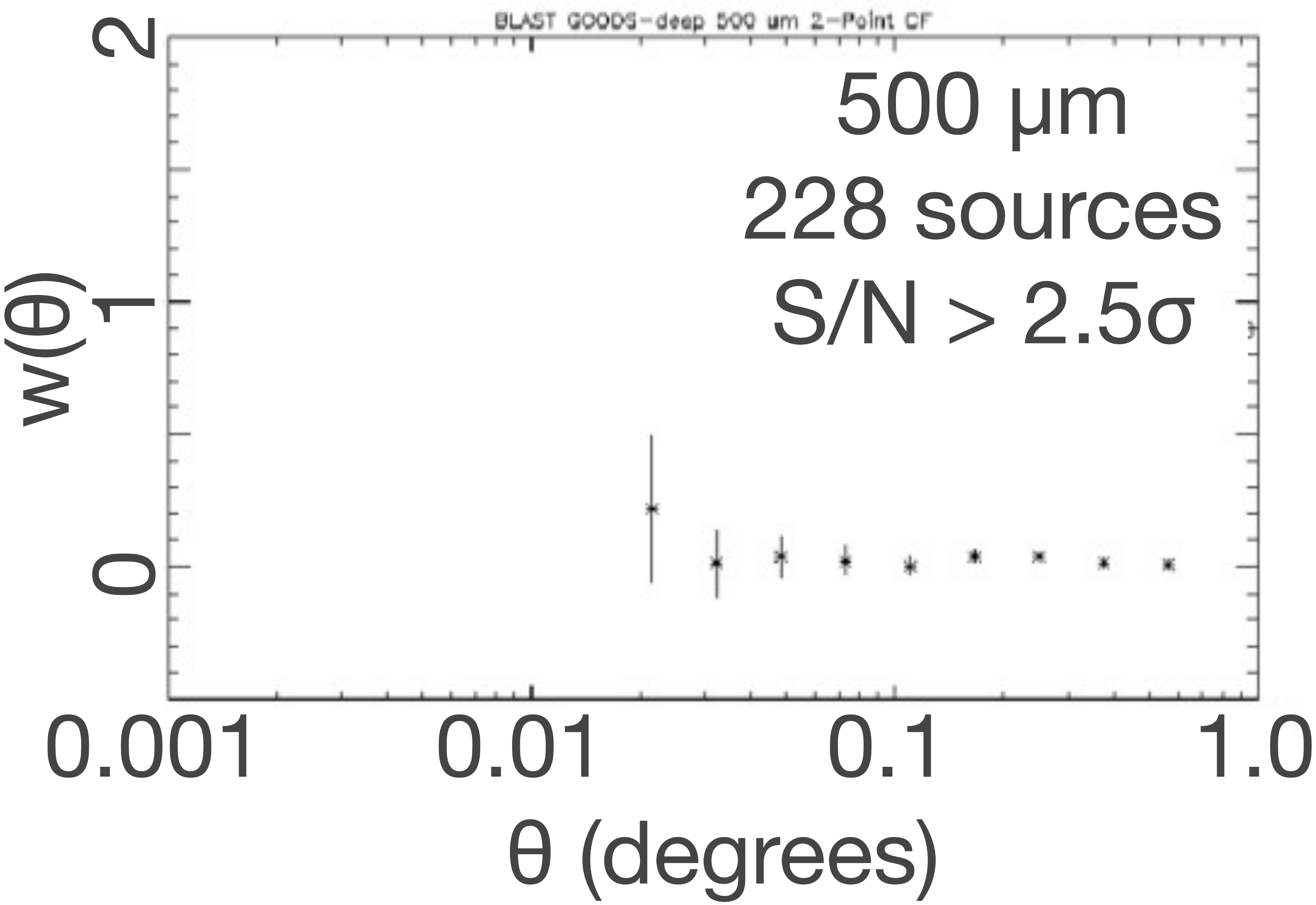


Resolved Source Clustering



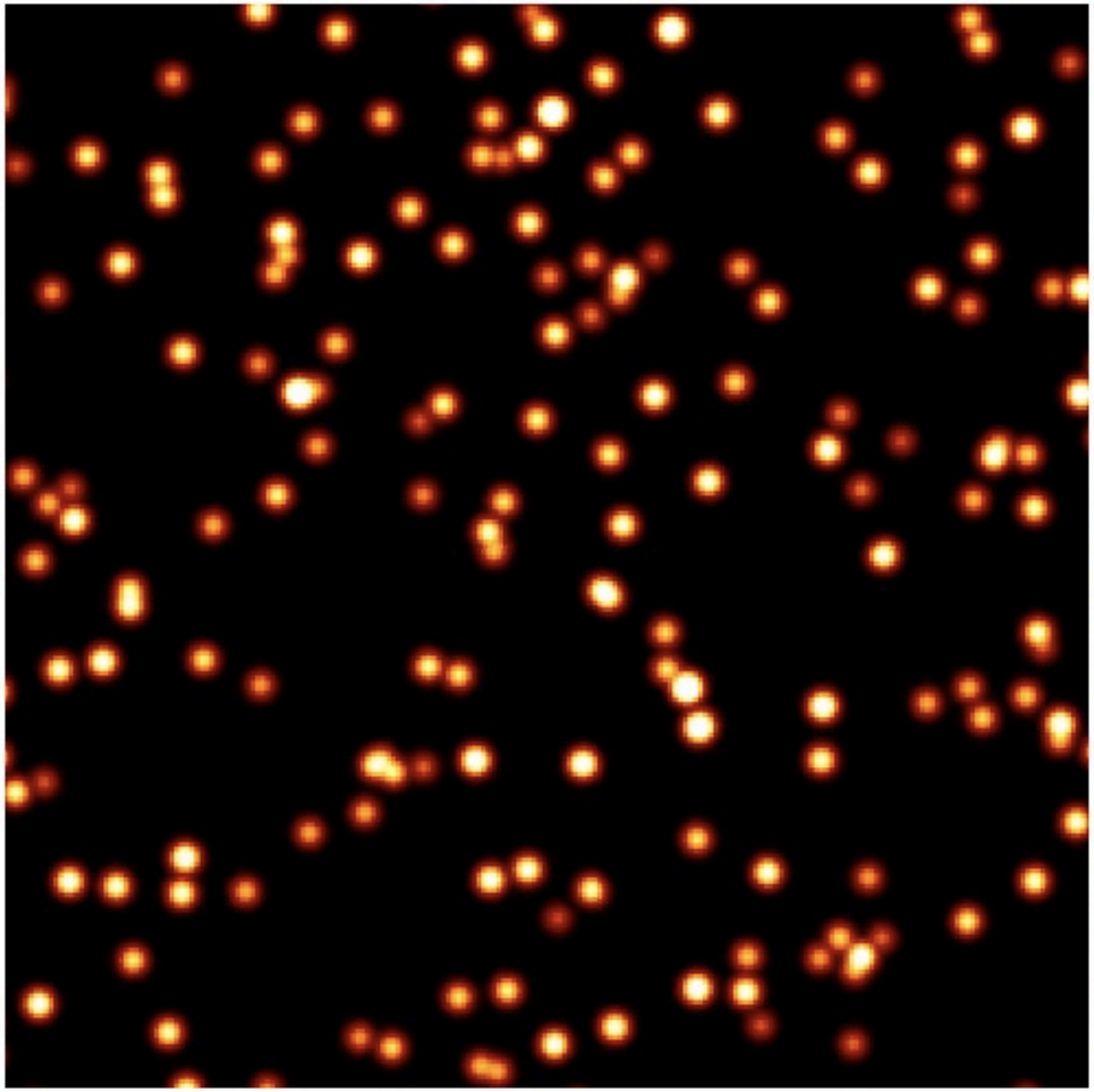
- Marginal Signal at 250 um

Resolved Source Clustering

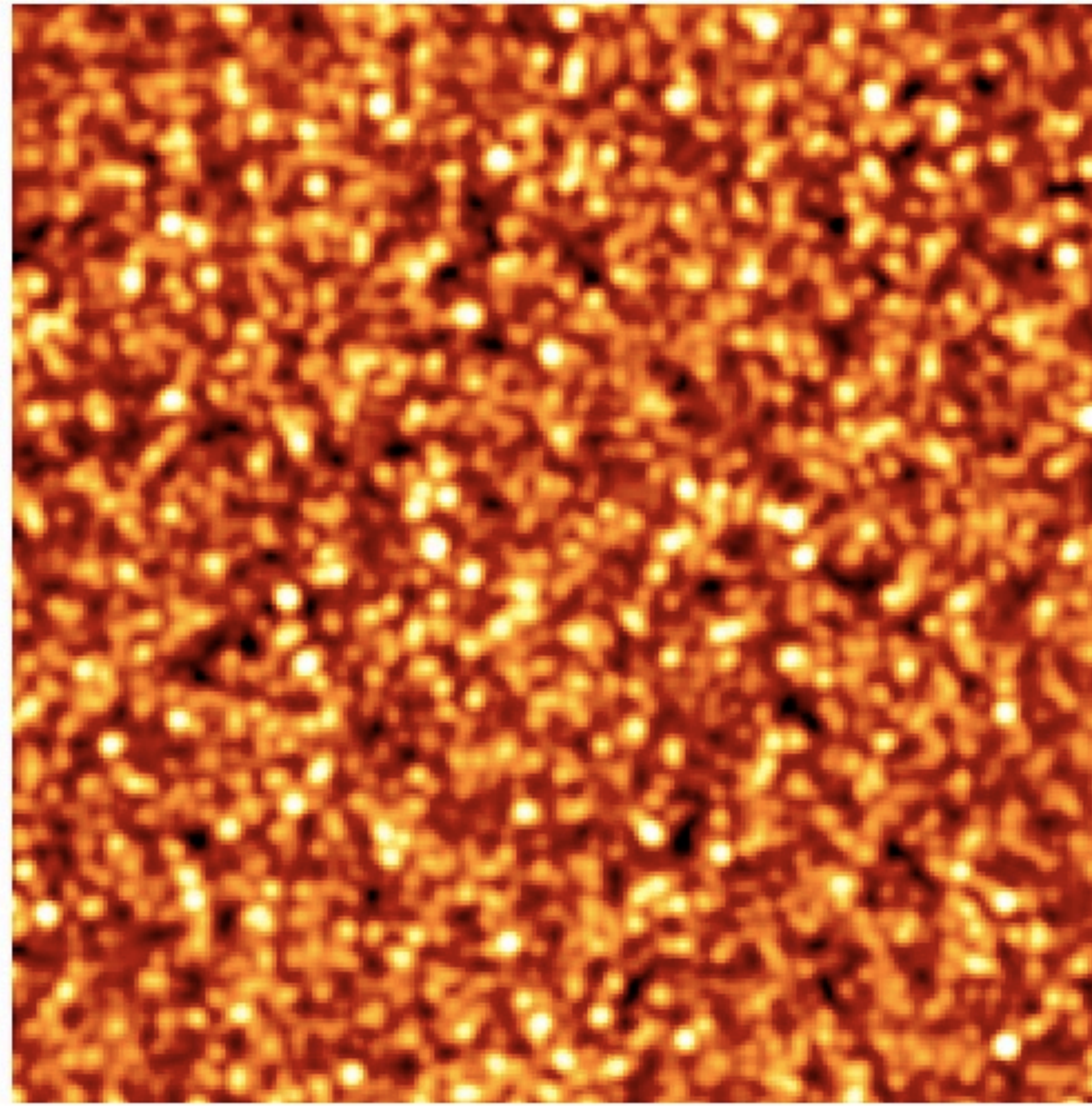


- Marginal Signal at 250 um
- Consistent with zero at 500 um

Resolved Source Clustering

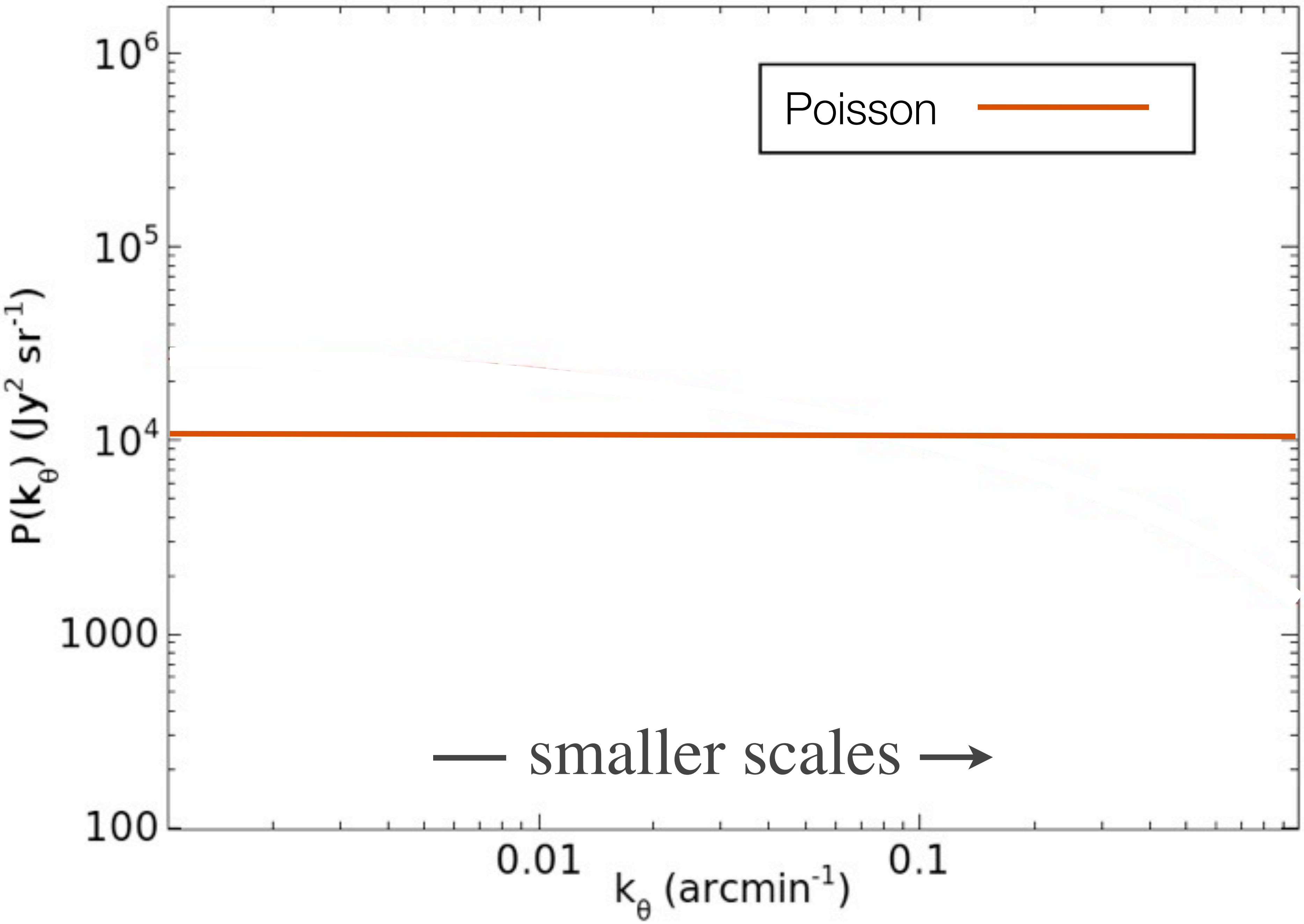


S > 20 mJy : 1,200/deg^2

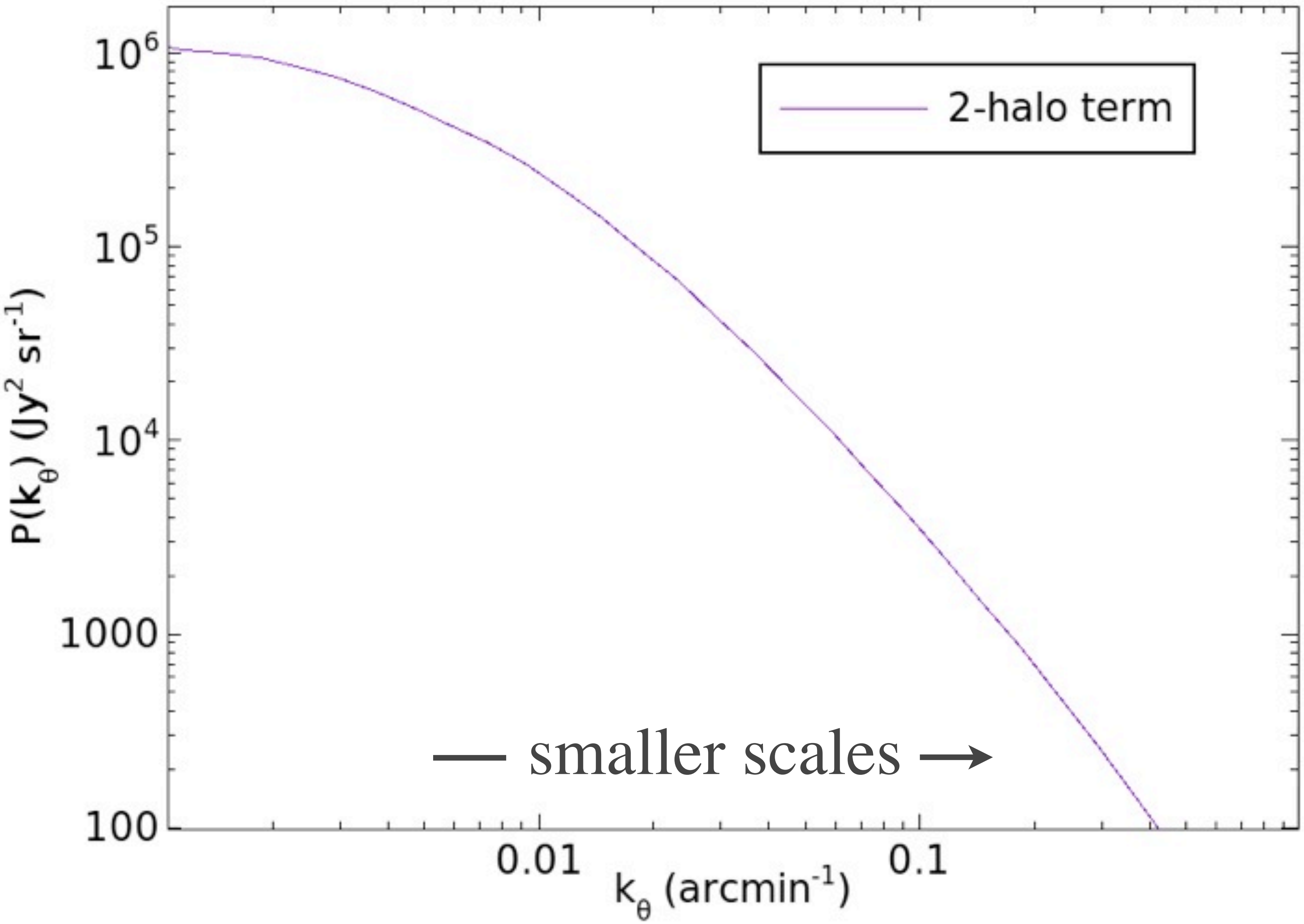


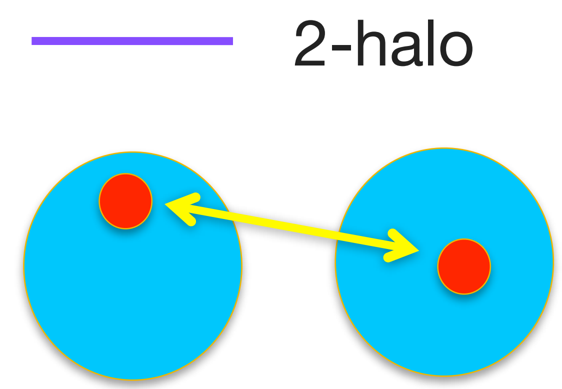
S < 20 mJy : 480,000/deg^2

Confusion

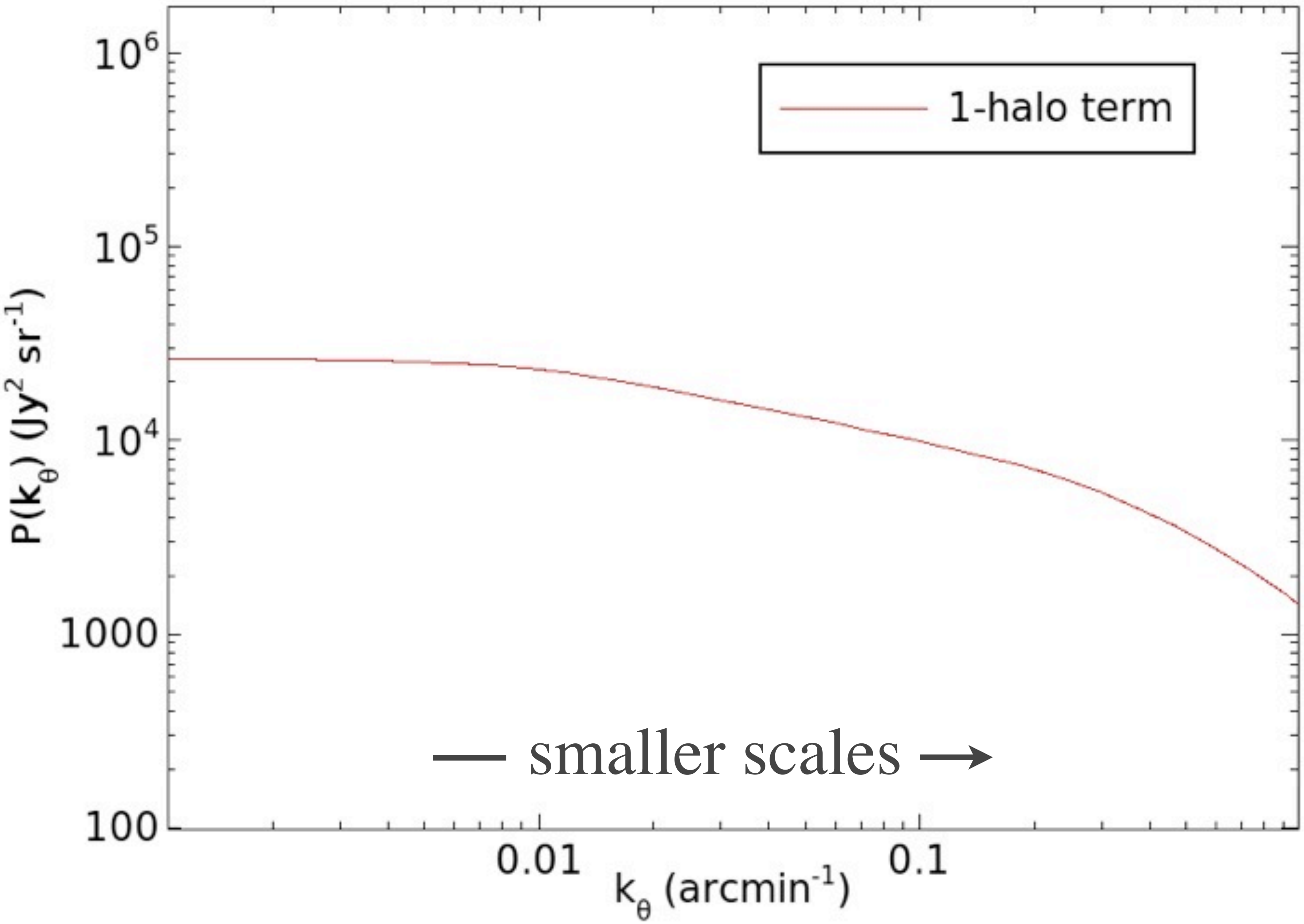


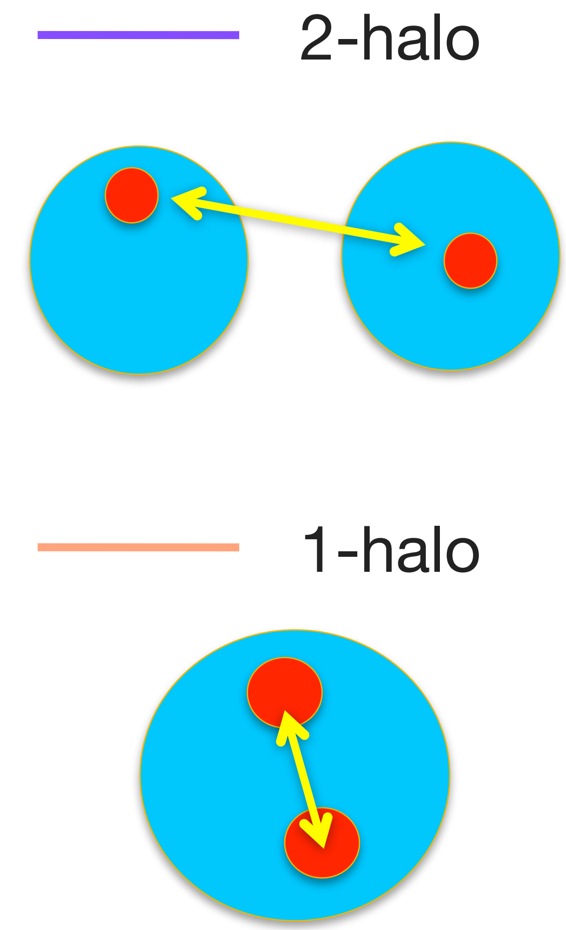
Power Spectrum



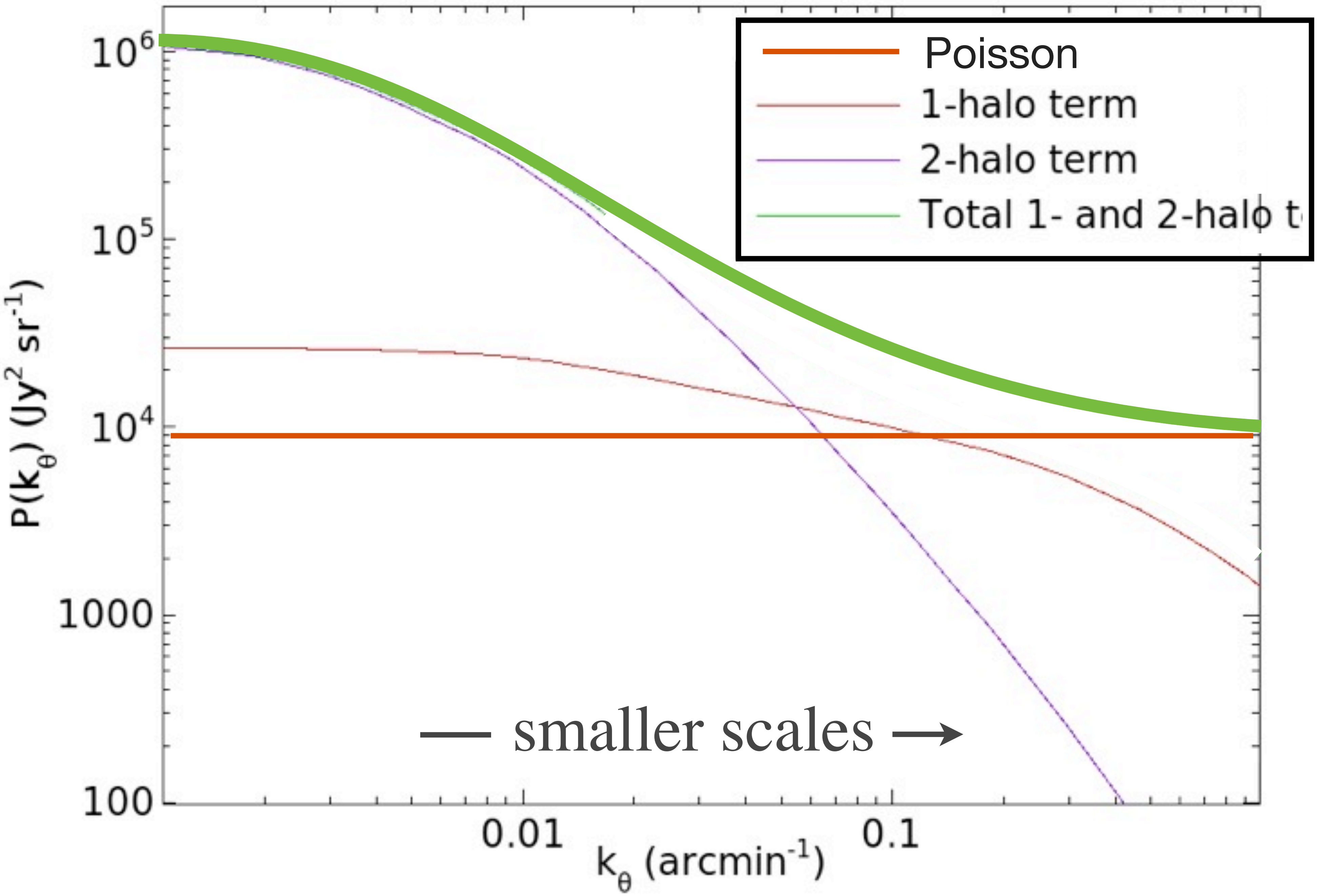


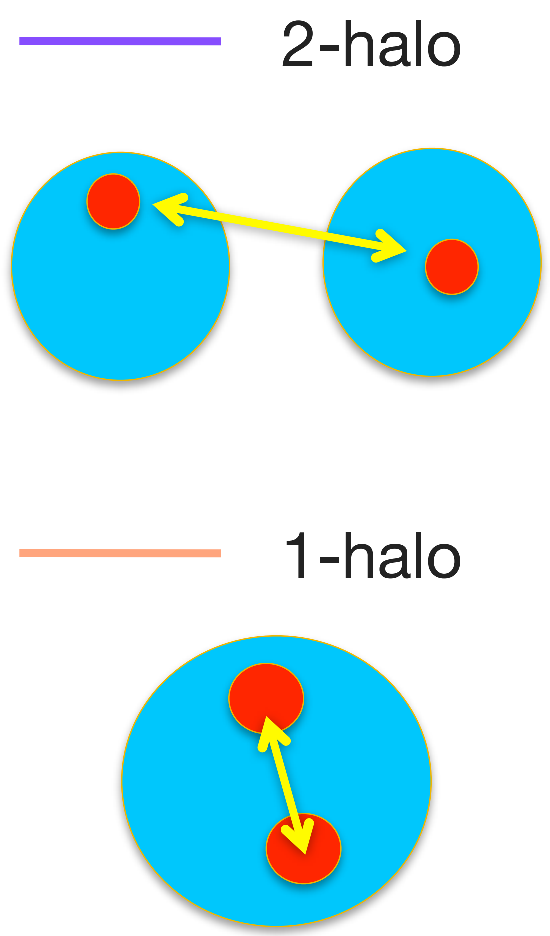
Power Spectrum



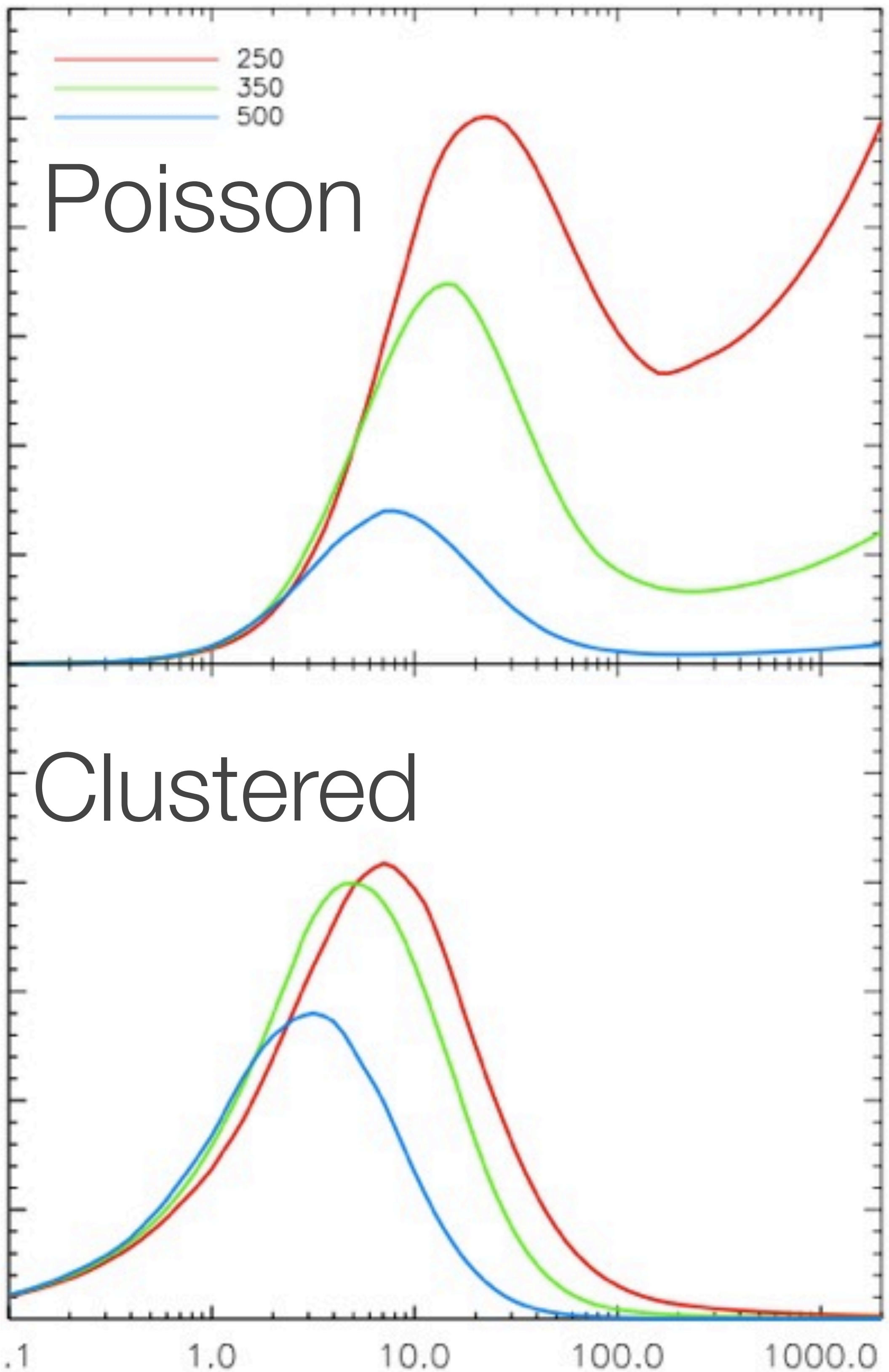


Power Spectrum



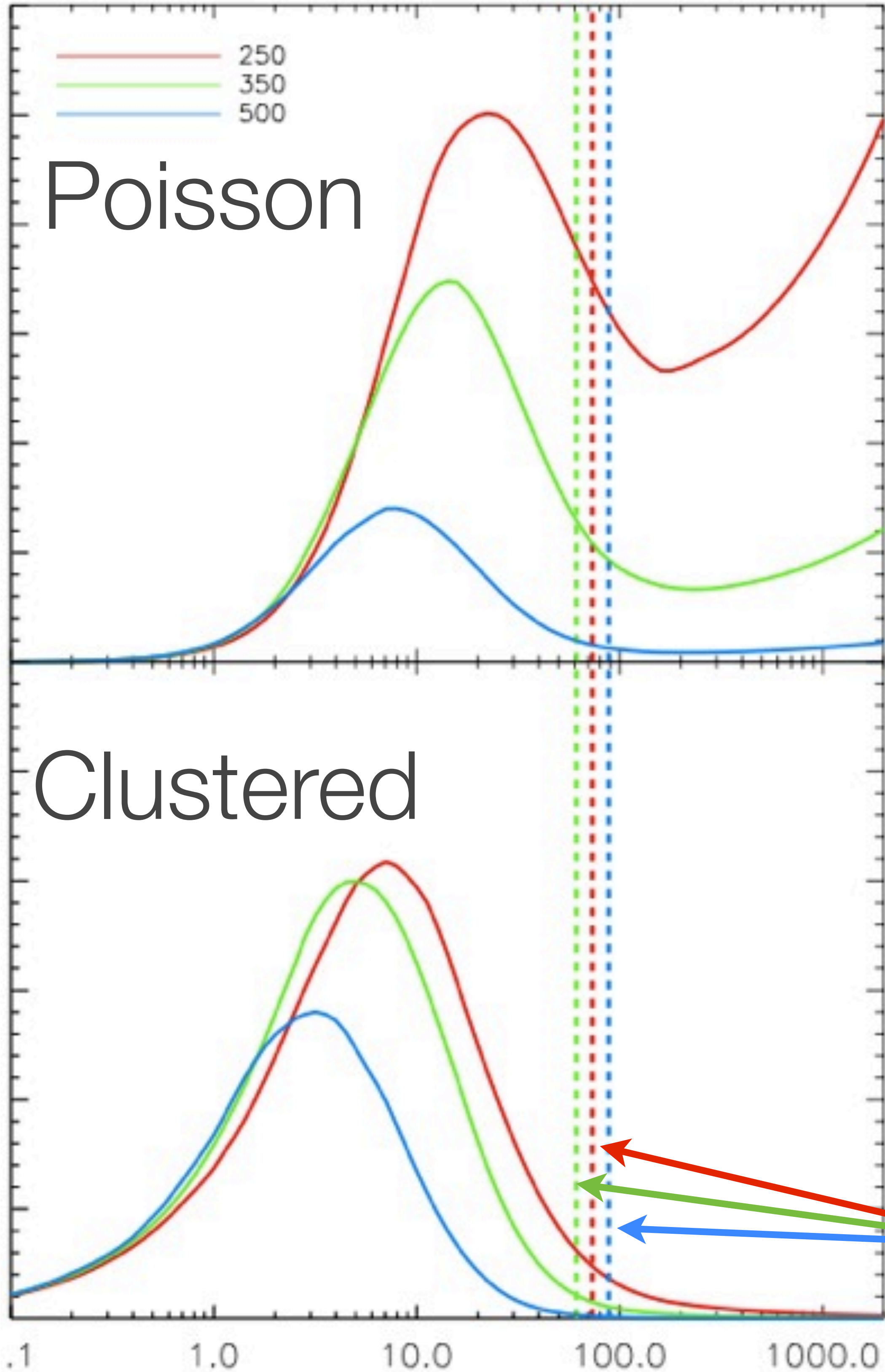


Power Spectrum



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

Contribution to Power

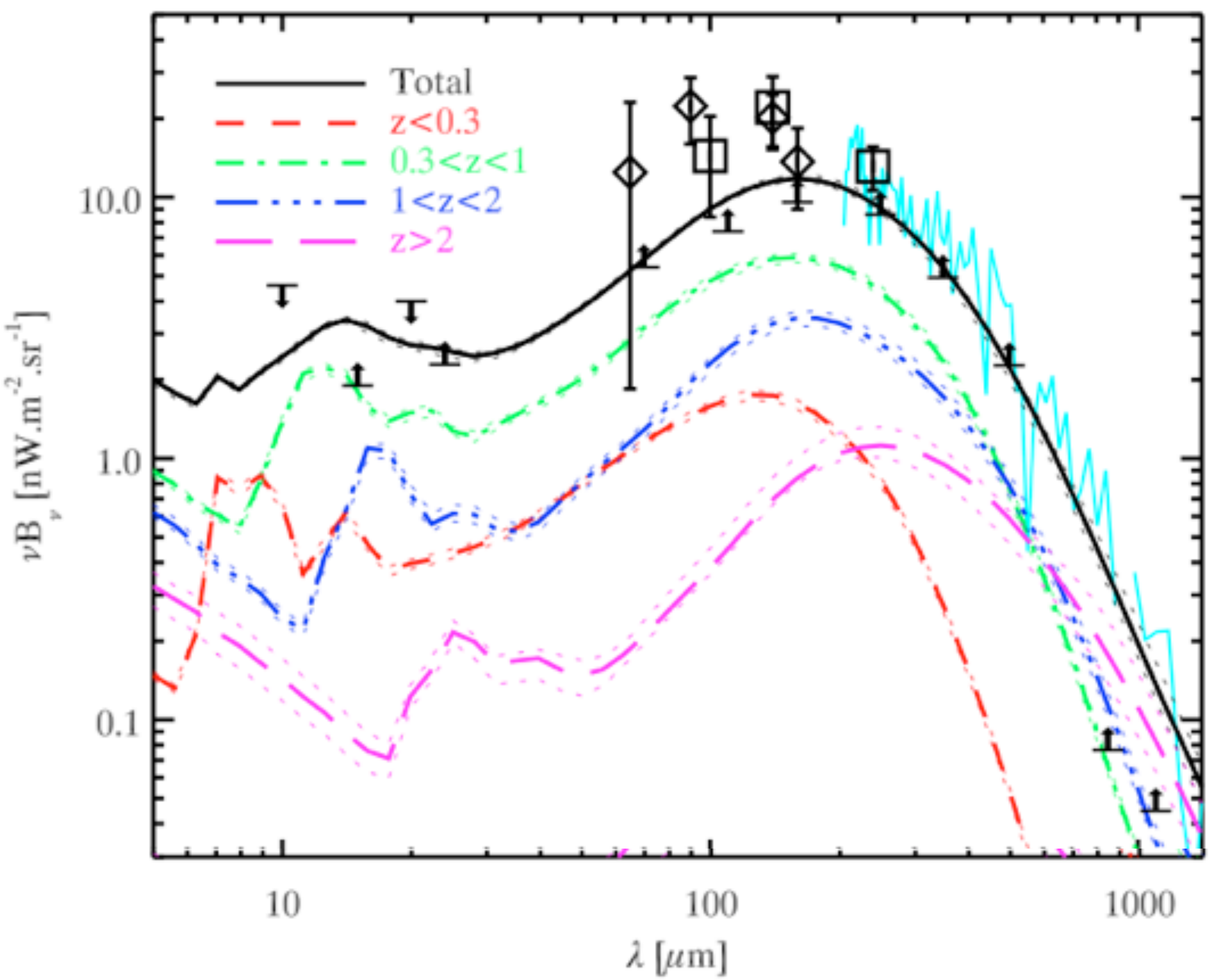


- Bulk of CIB power from ~10 mJy sources
- Masking has much less impact at longer λ

Vertical lines are 5-σ confusion noise limits

Contribution to Power

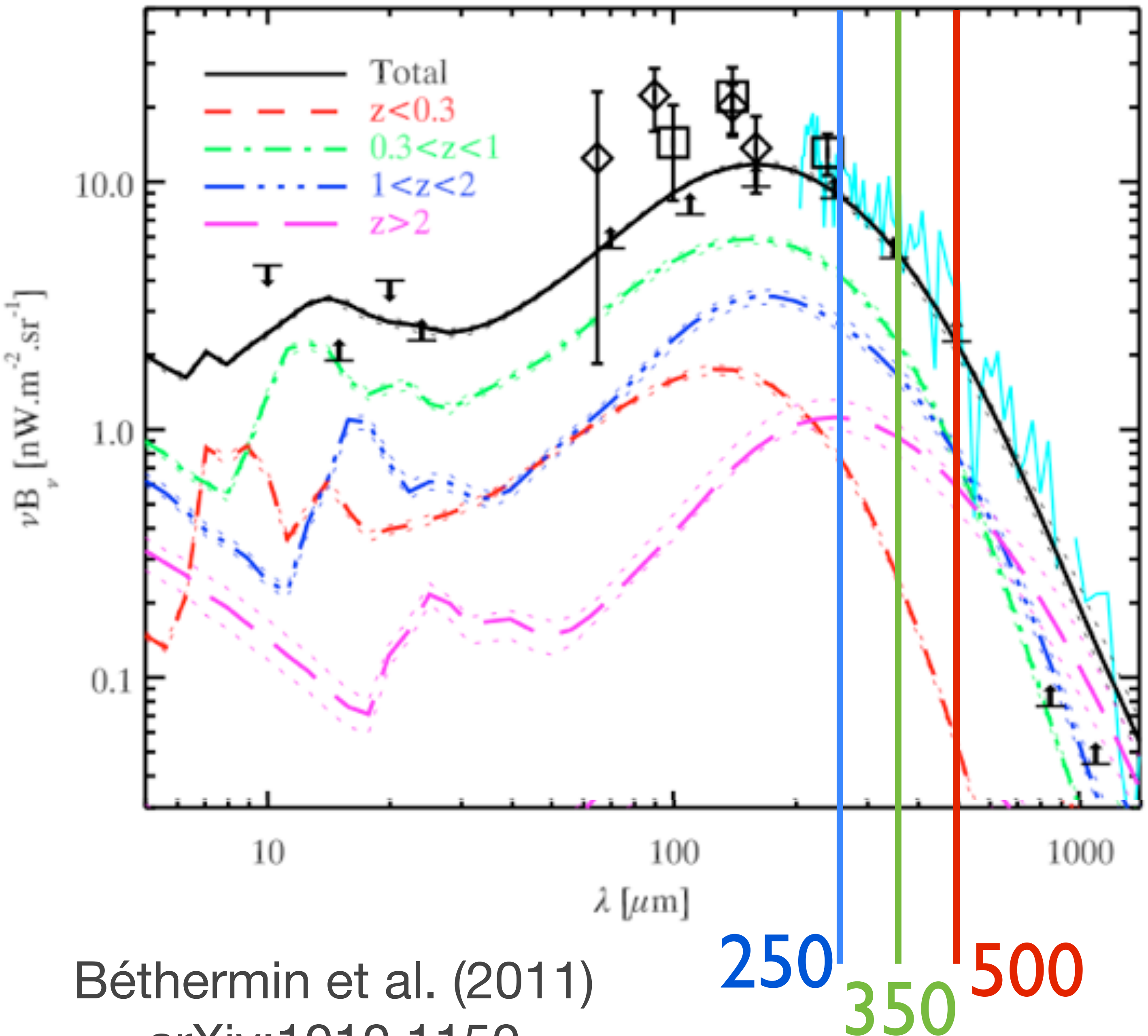
CIB in redshift slices



Béthermin et al. (2011)
arXiv:1010.1150

Redshift Distribution of CIB

CIB in redshift slices



Béthermin et al. (2011)
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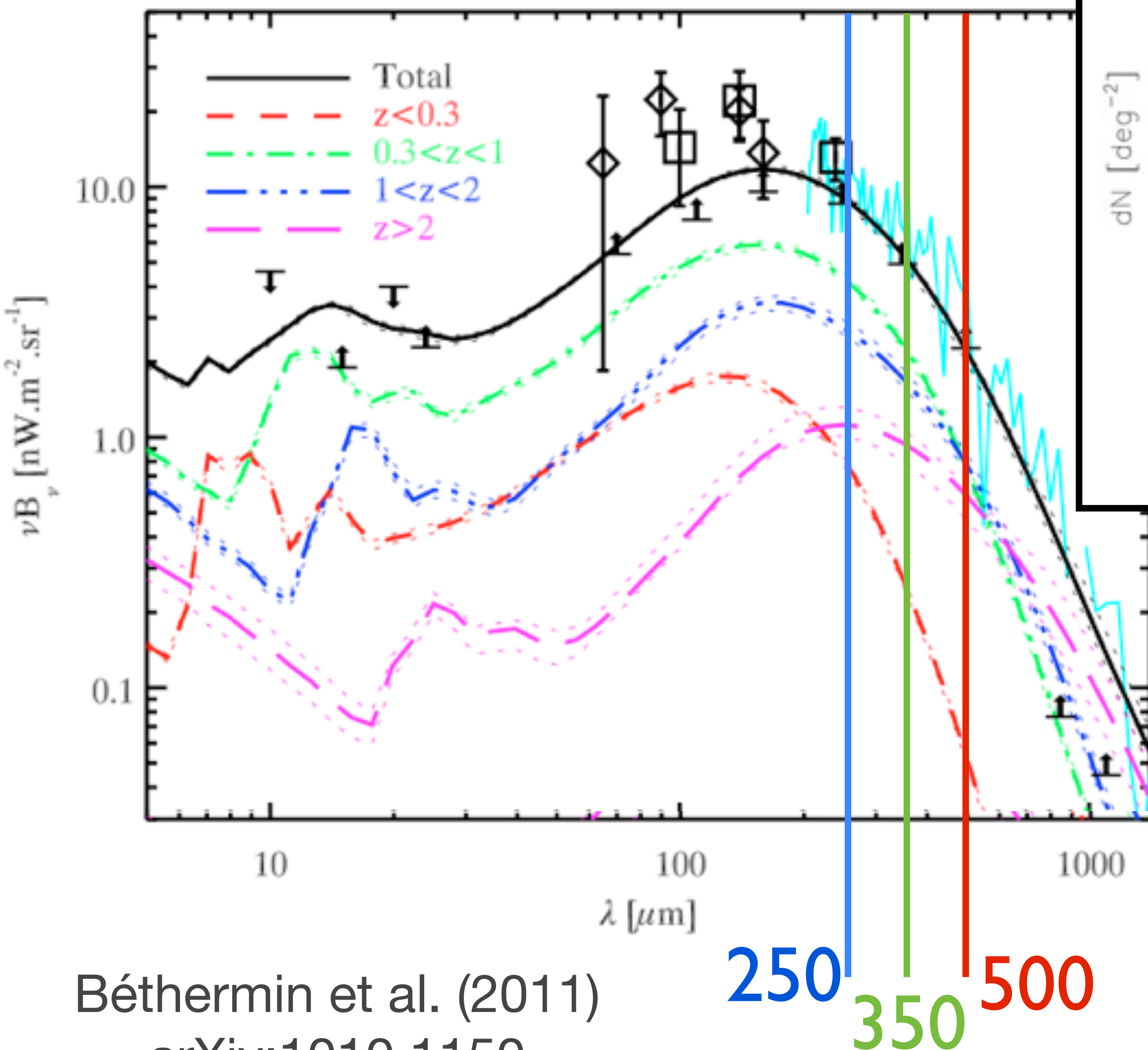
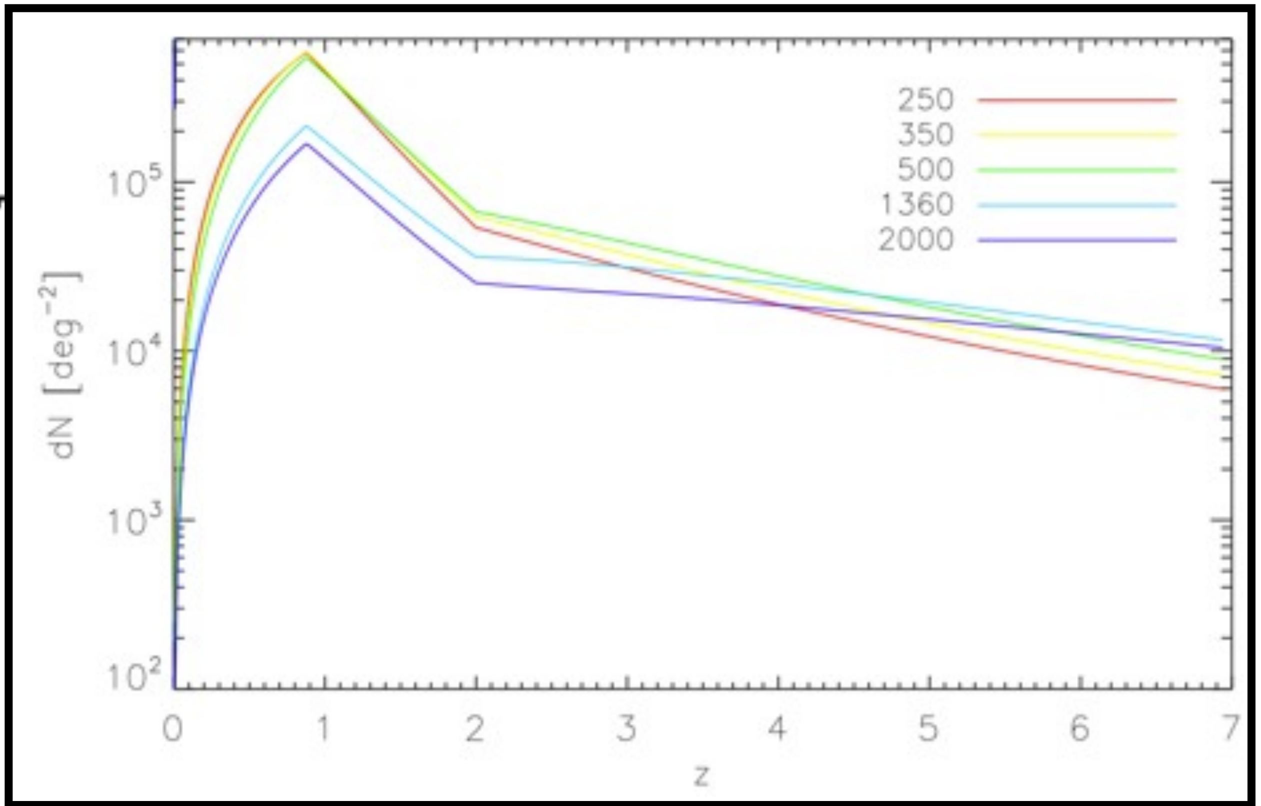
Infrared Background
at submm wavelengths
probes z ~ 0.3 to 2

Redshift Distribution of CIB

CIB in redshift slices

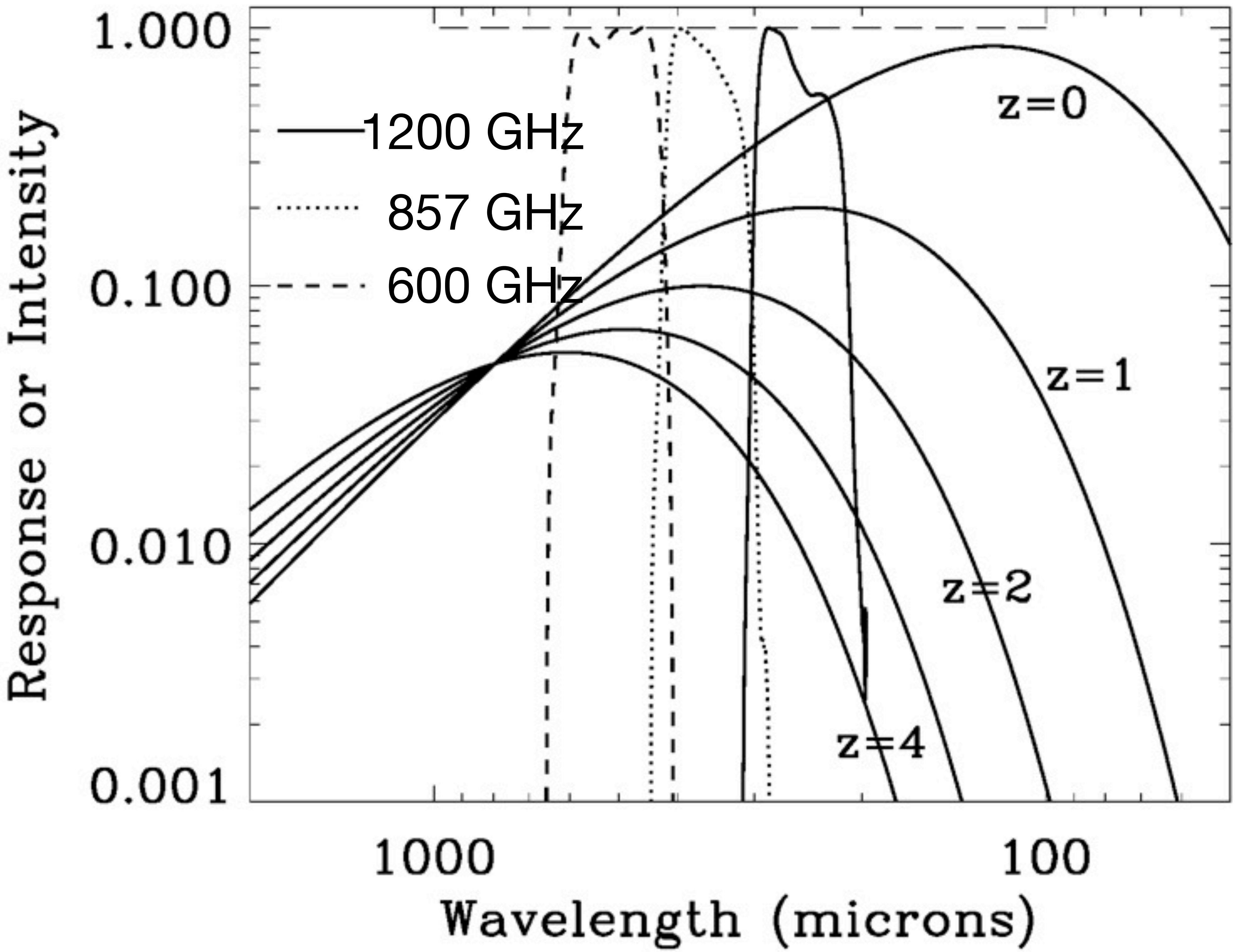




Infrared Background at submm wavelengths probes z ~ 0.3 to 2

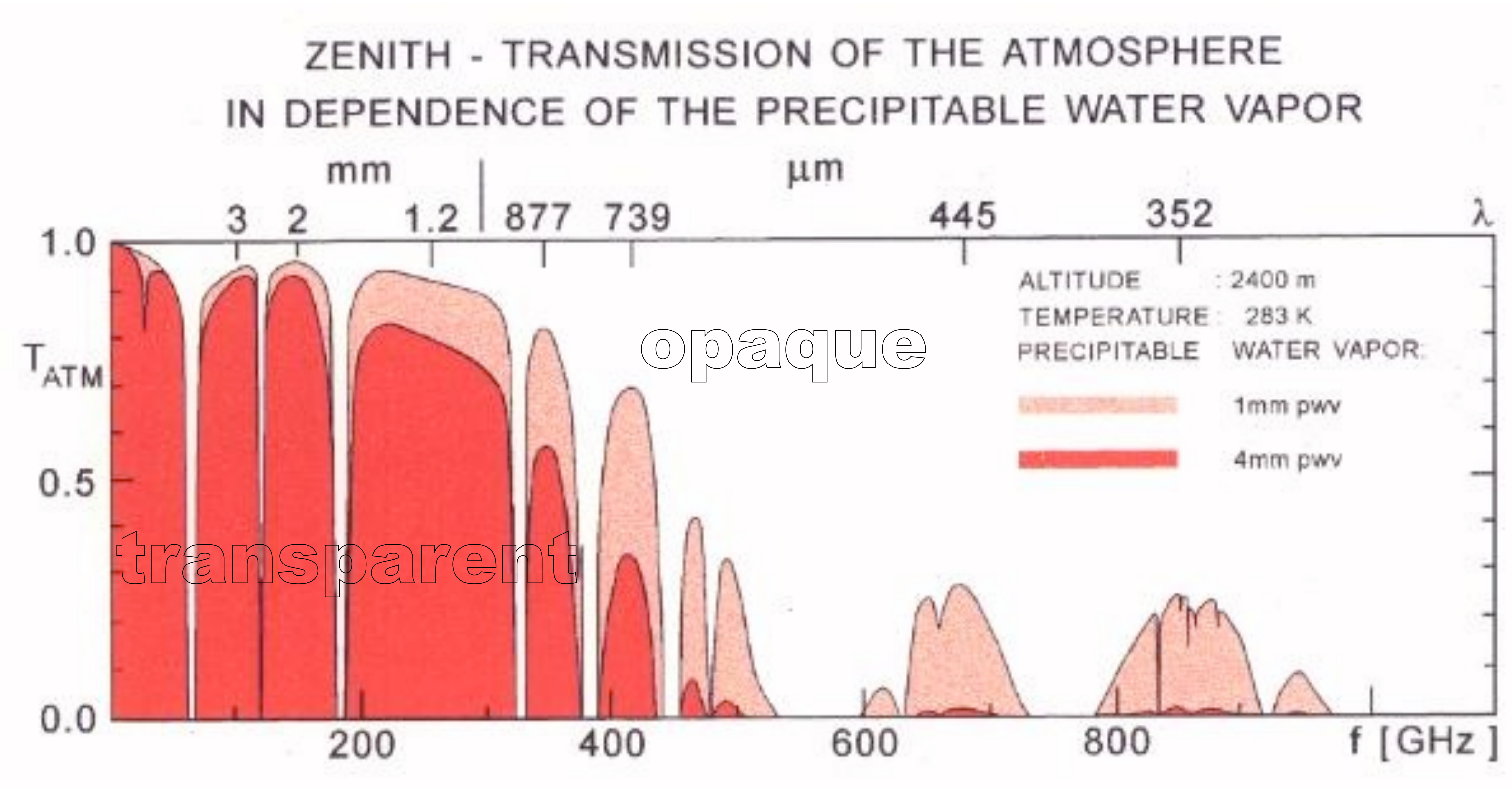
Béthermin et al. (2011) arXiv:1010.1150

Redshift Distribution of CIB

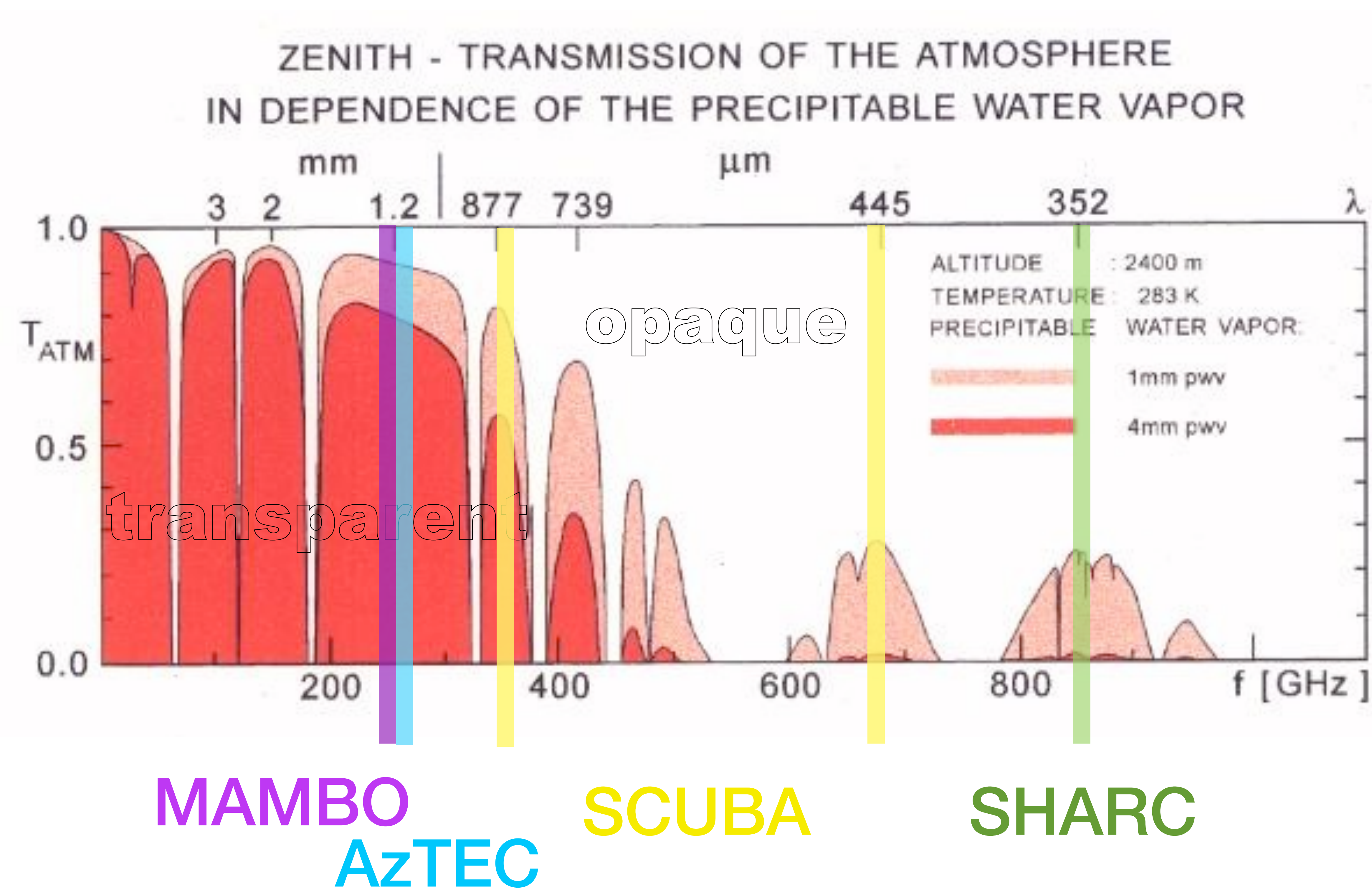


redshifted dust SED (T~35) peaks at λ~200-800μm

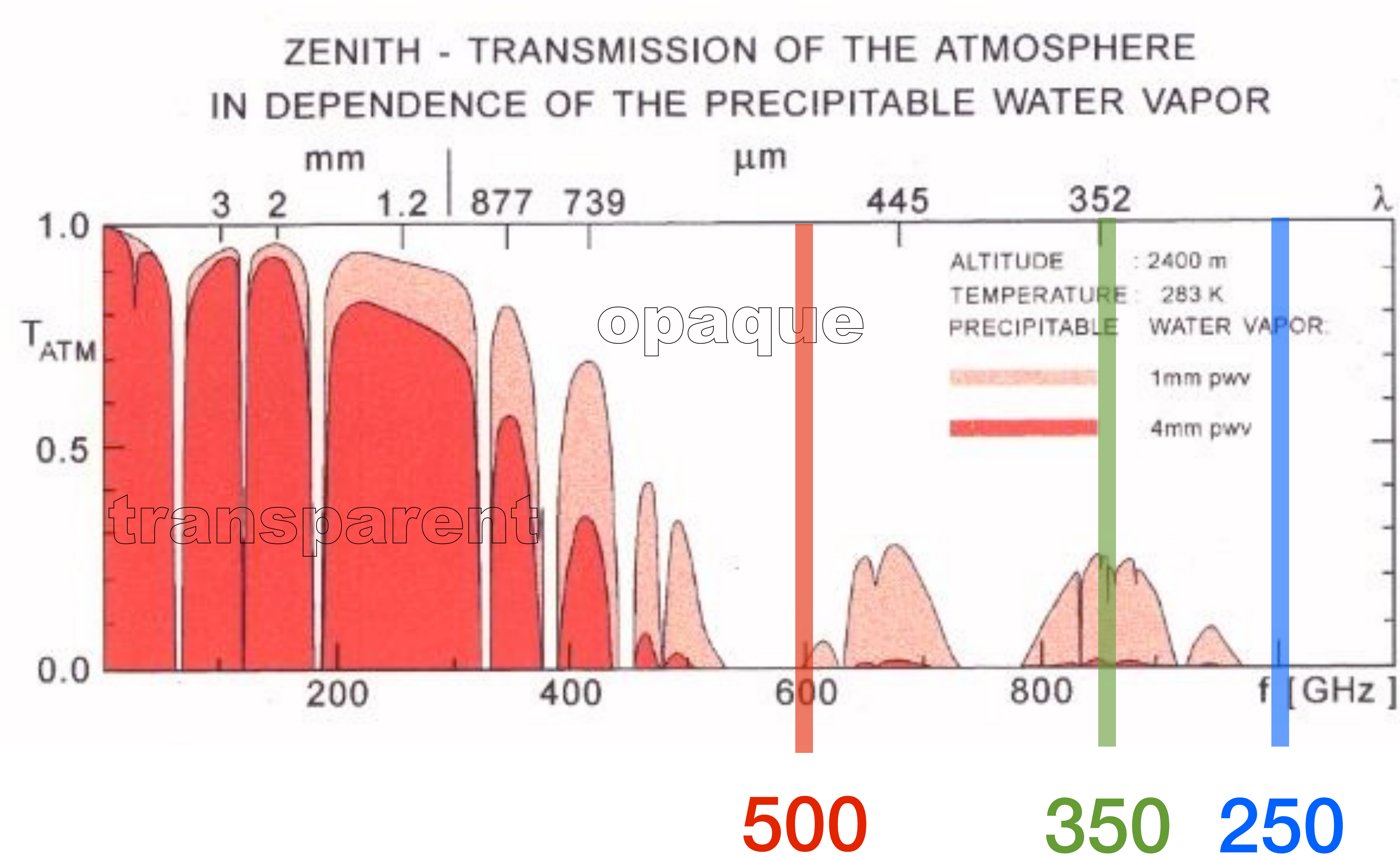
Submillimeter light



Submm Visibility

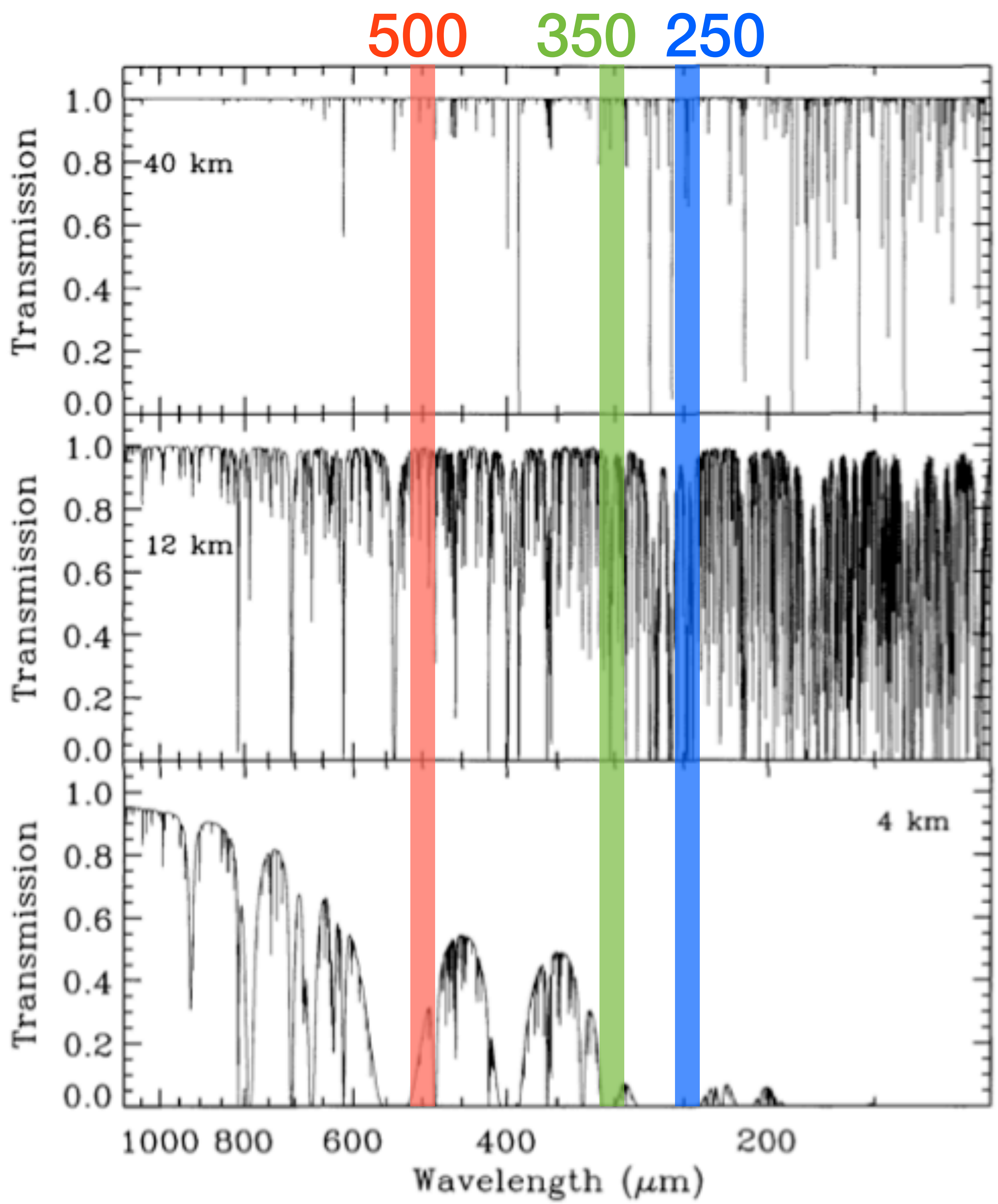


Submm Visibility

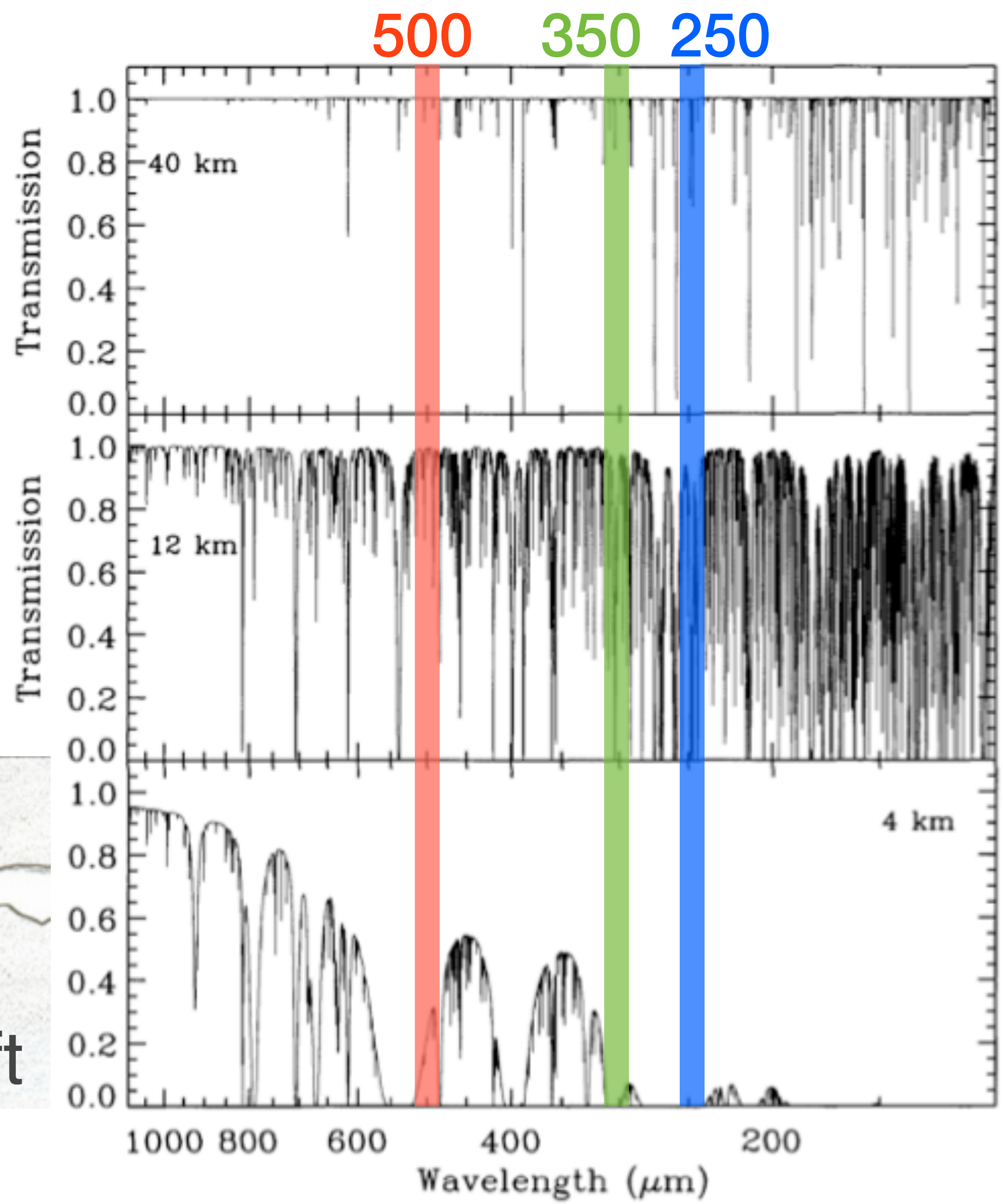


Submm Visibility

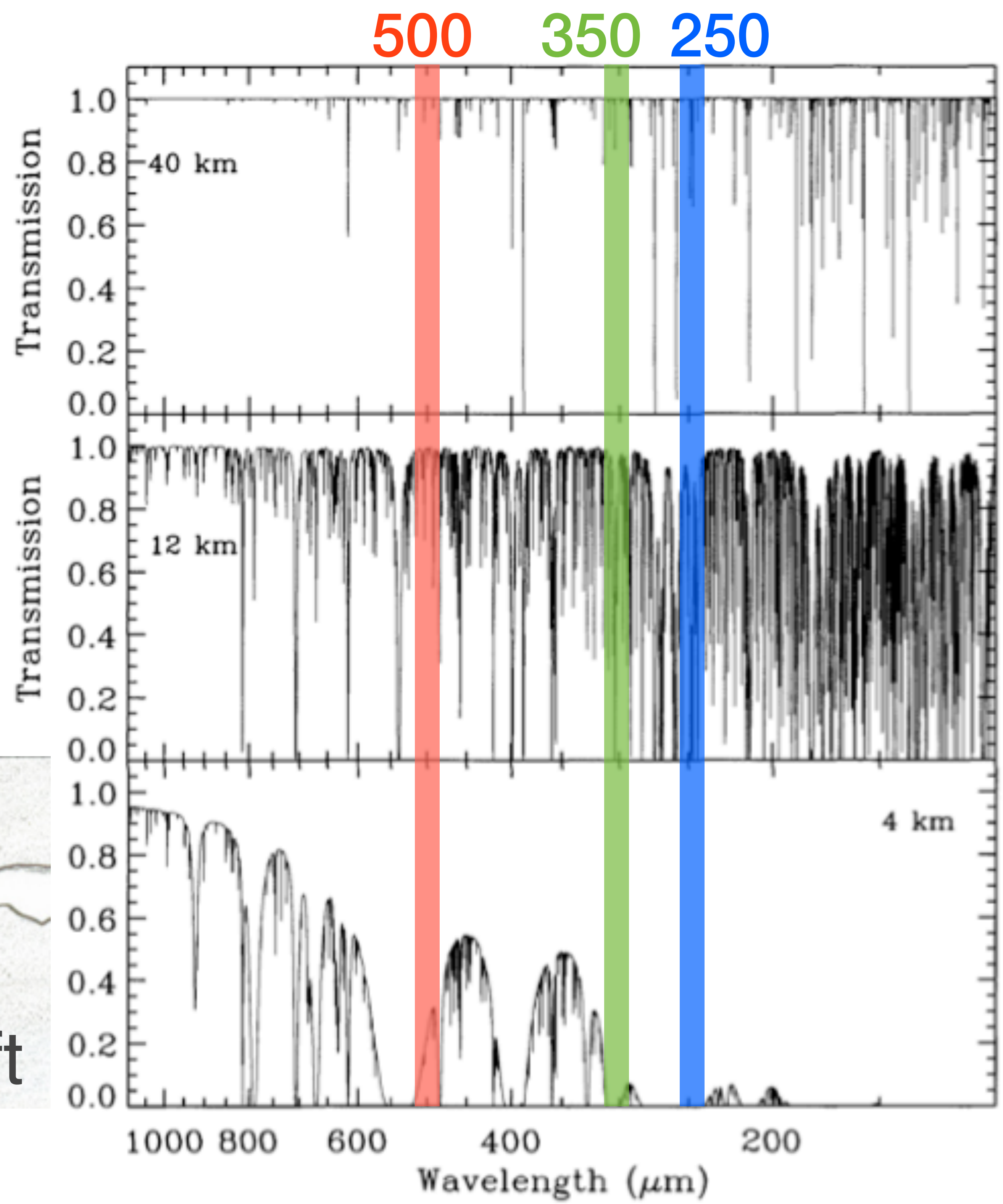
Submm Visibility



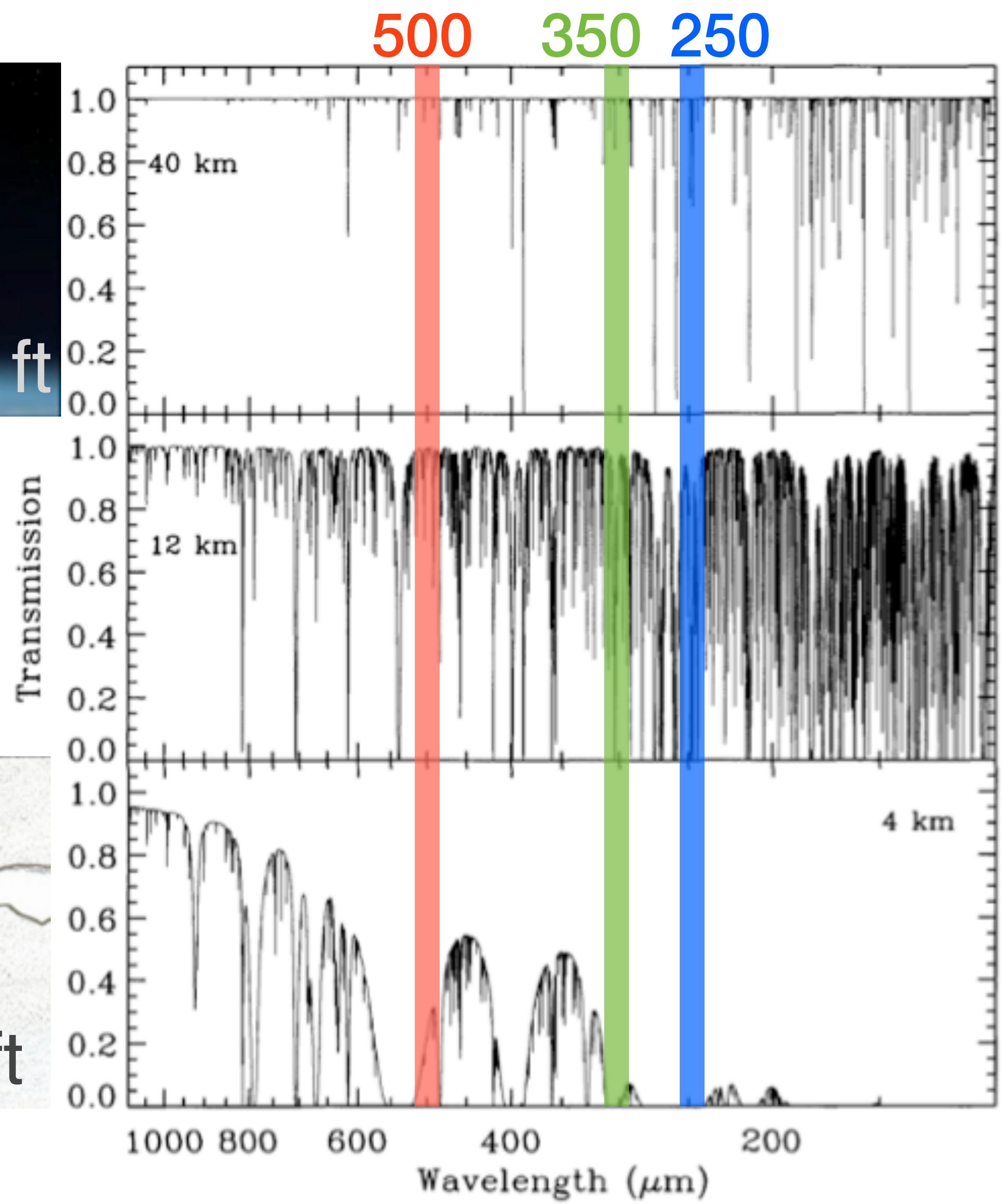
Submm Visibility

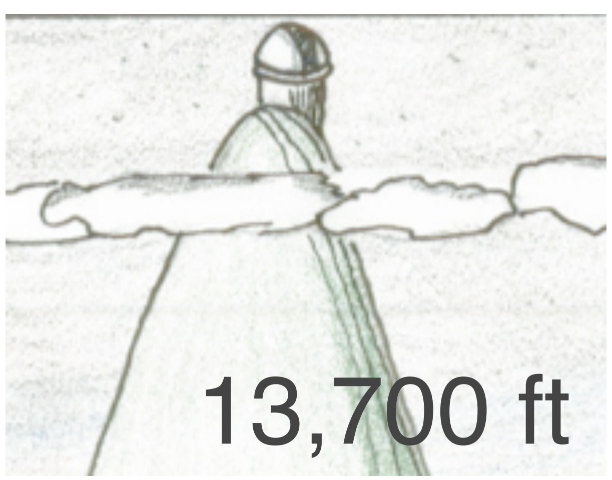


Submm Visibility

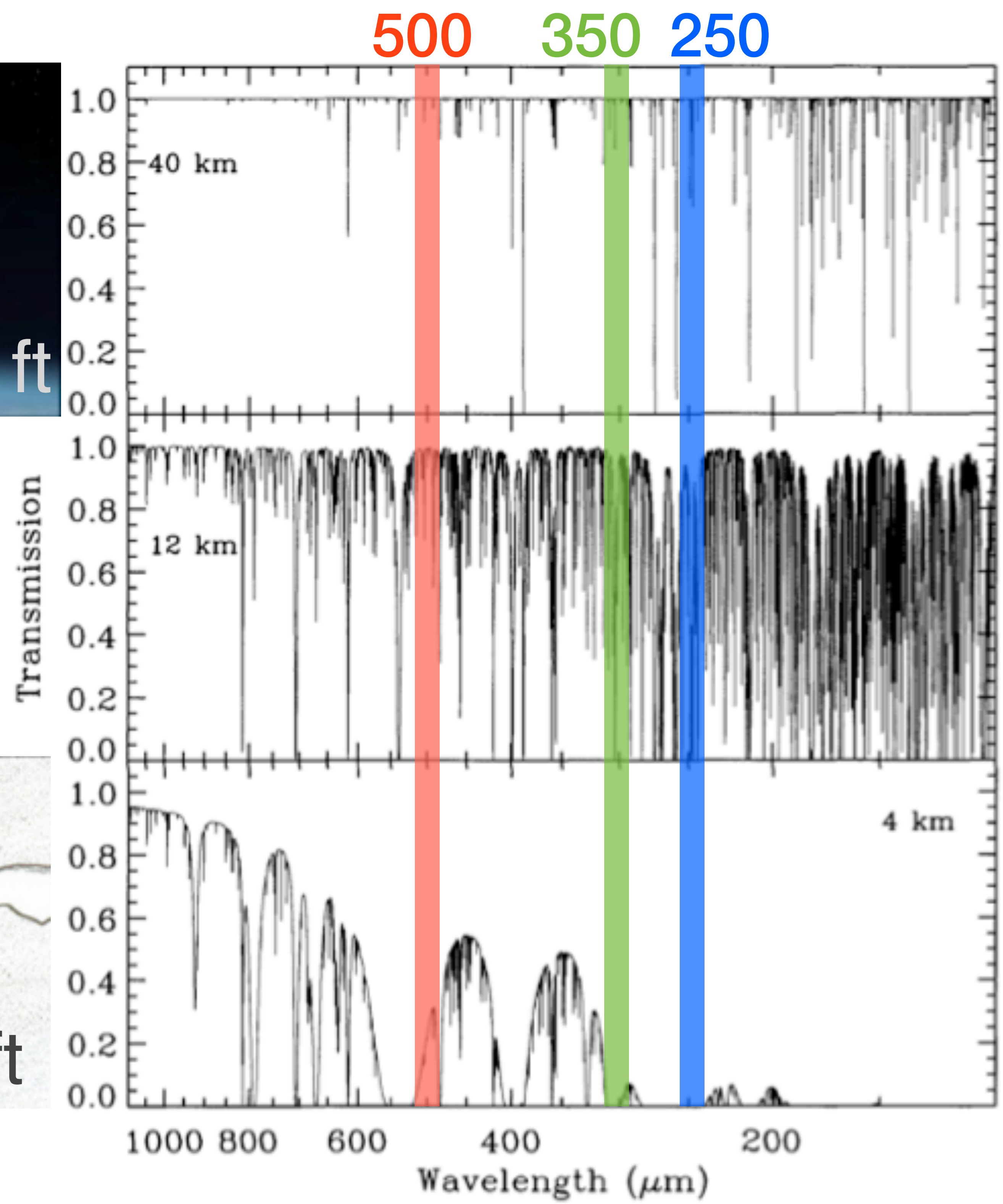


Submm Visibility



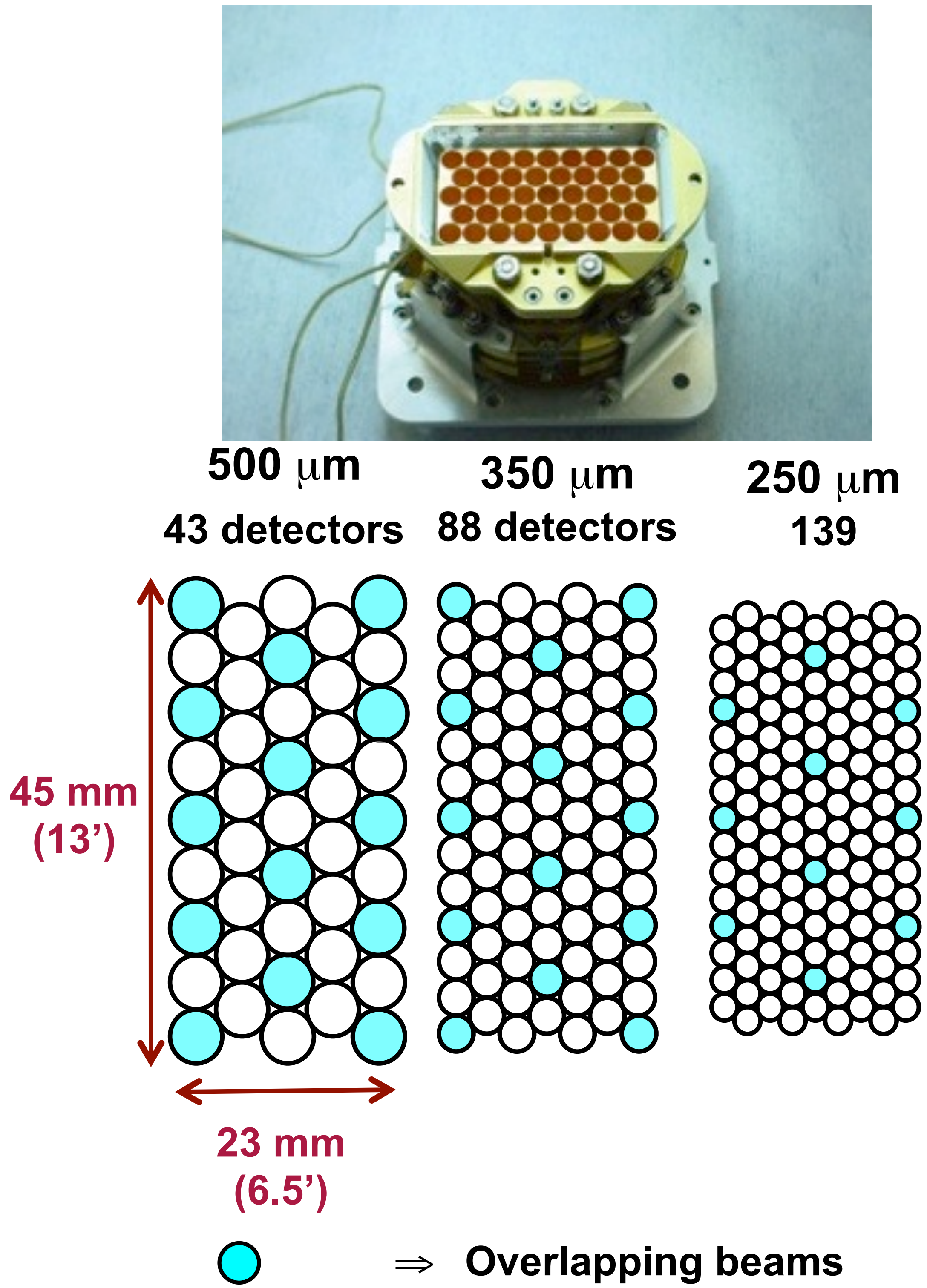


Submm Visibility

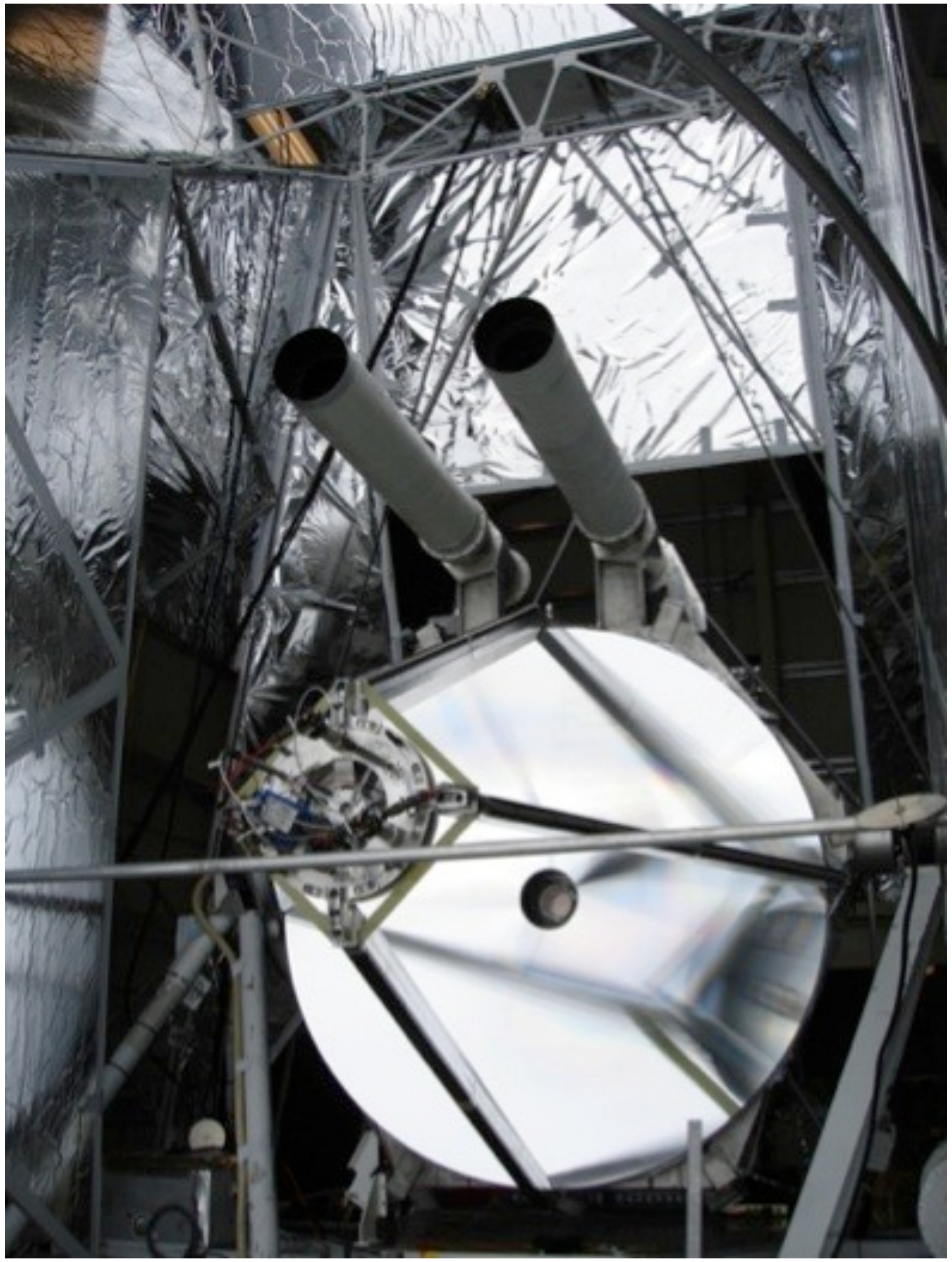


BLAST

SPIRE-like
spider-web bolometer
detector arrays...



BLAST



SPIRE-like
spider-web bolometer
detector arrays...

... but a 1.8 m primary
resulting in beams:
36” - 250 μm
45” - 350 μm
60” - 500 μm
i.e., twice the size of SPIRE’s
beams

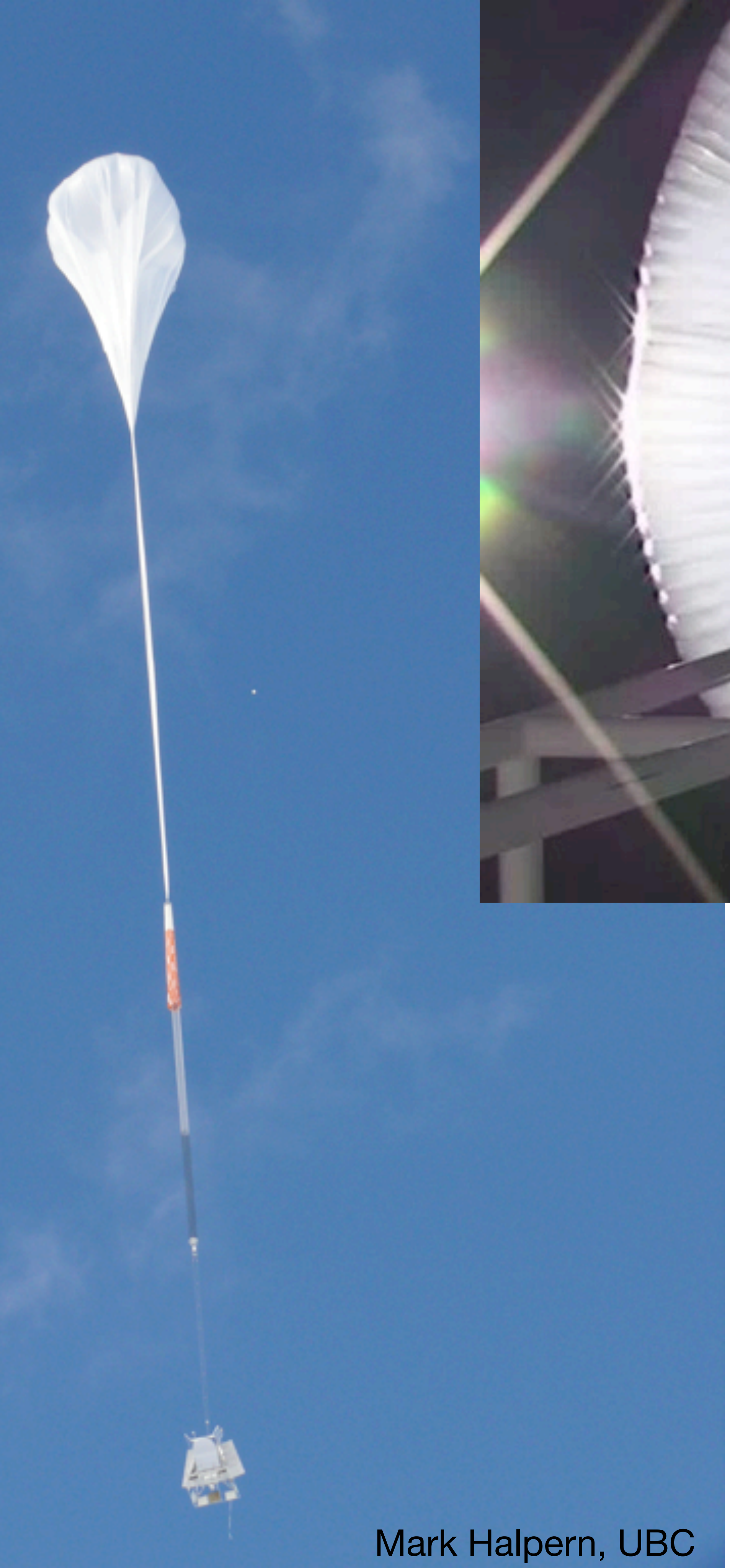
BLAST

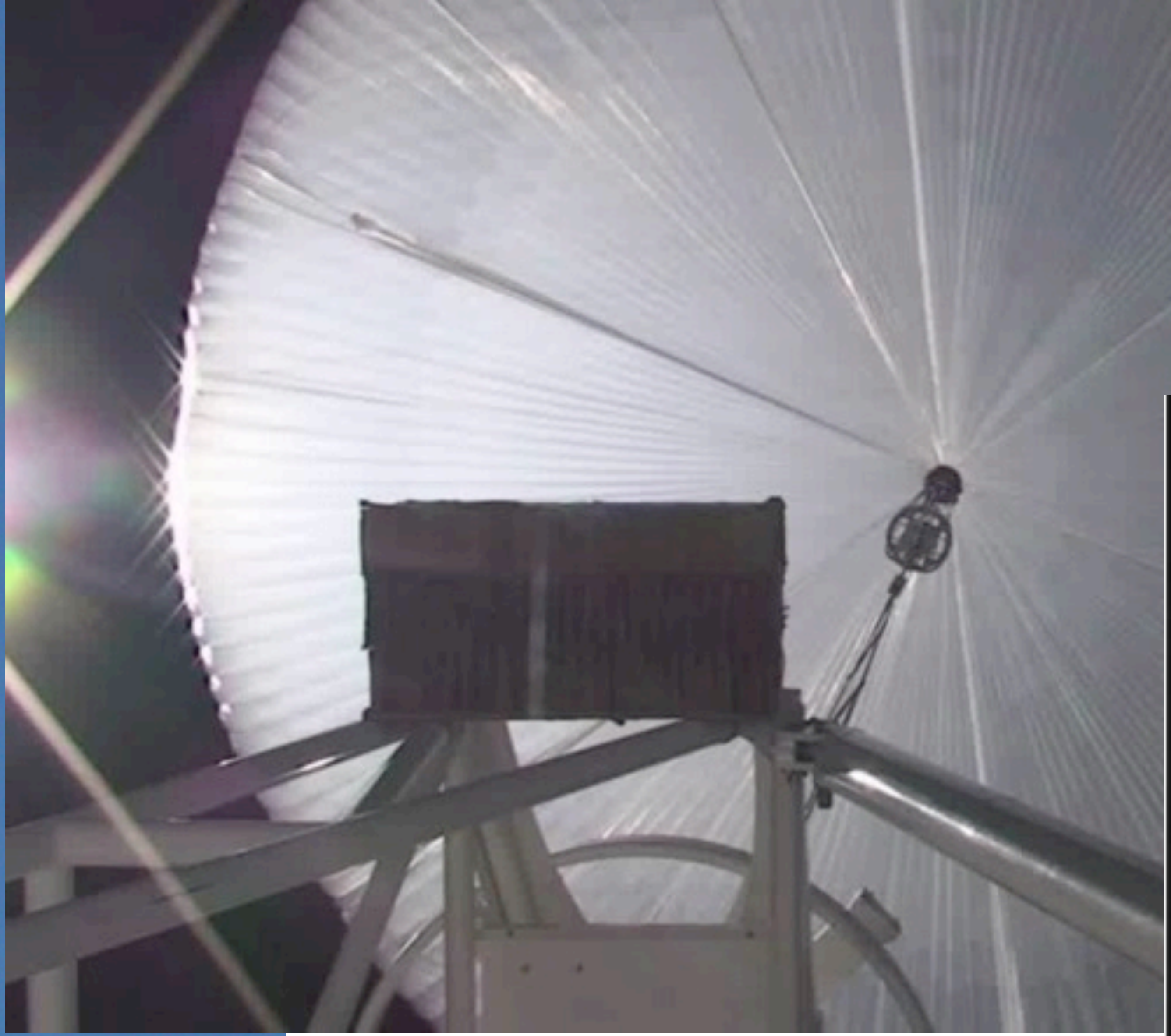

A-333-S
ICECUBE
SURF2DOM

bye bye BLAST!

Mark Halpern, UBC

Don Wiebe, UBC





Perfect Flight!

BLAST payload hanging from balloon
float altitude of 120,000 ft.

Perfect Landing!

BLAST

Perfect Landing?

BLAST

looking for this...

BLAST

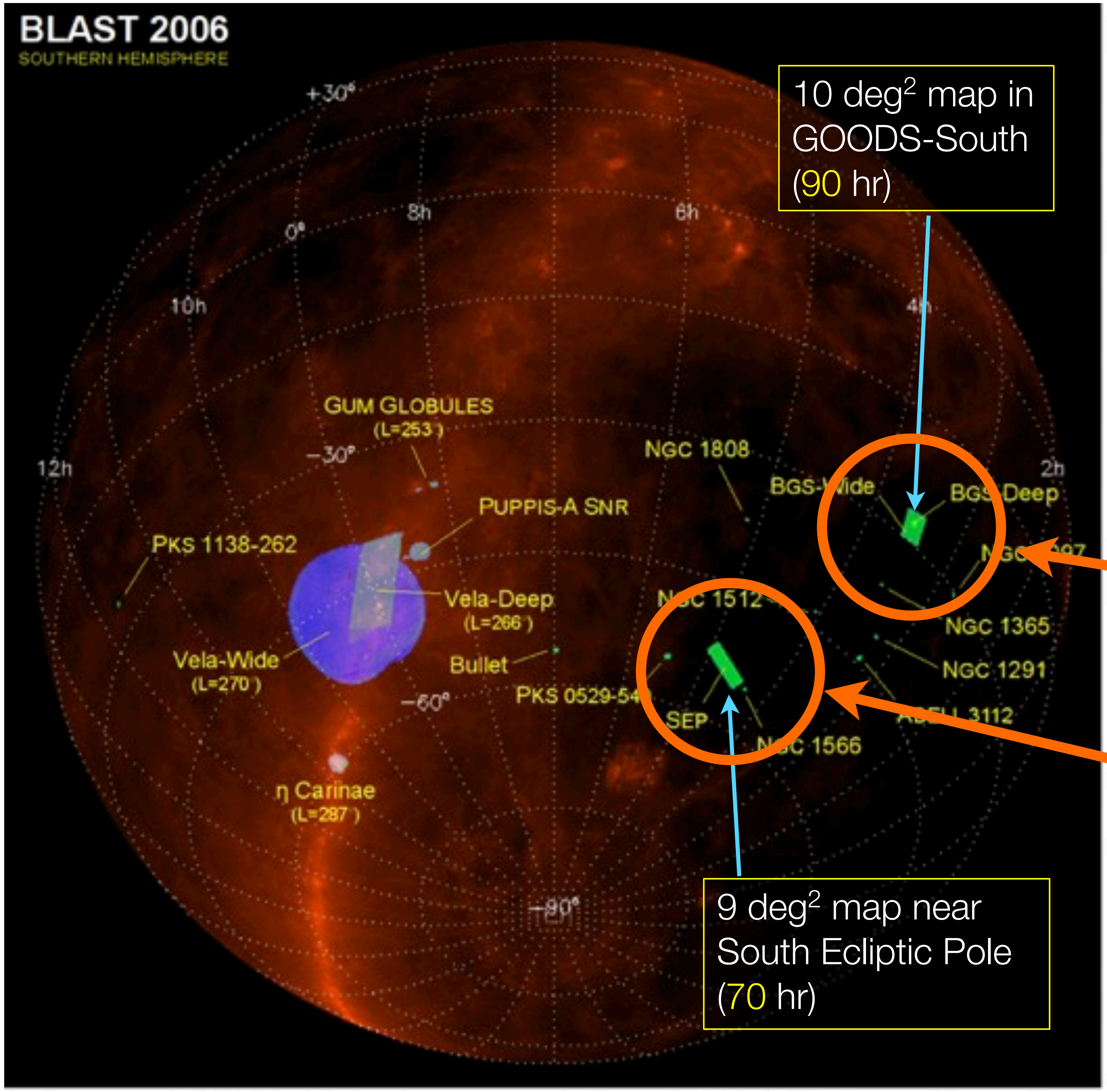
BLAST

BLAST

BLAST

see it all in
“BLAST!”
the movie

BLAST



~180/260 hours (70%) spent observing extragalactic fields

GOODS-south

SEP

Fields

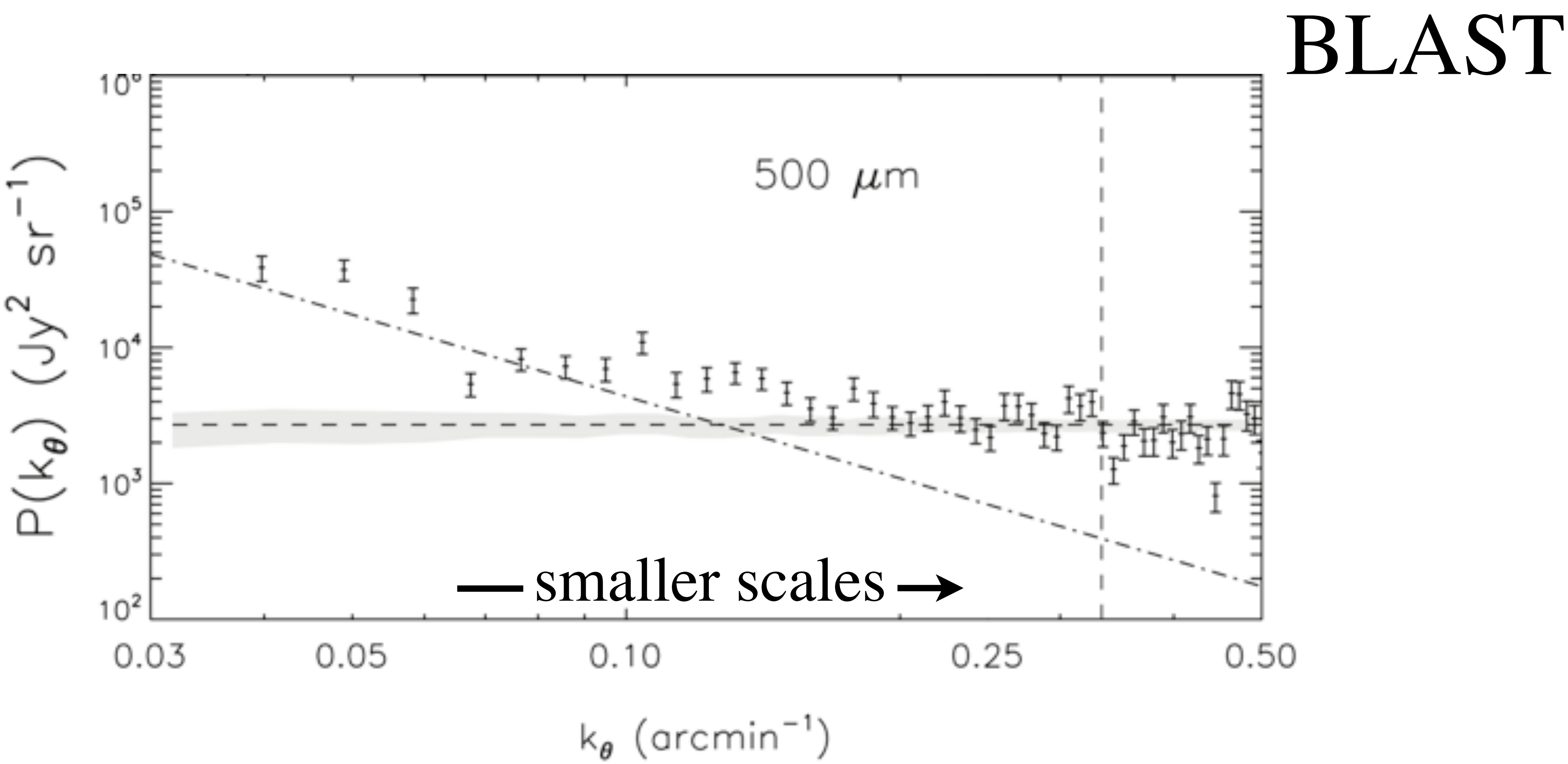
BLAST

— smaller scales →

Viero et al. (2009)

arXiv: 0904.1200

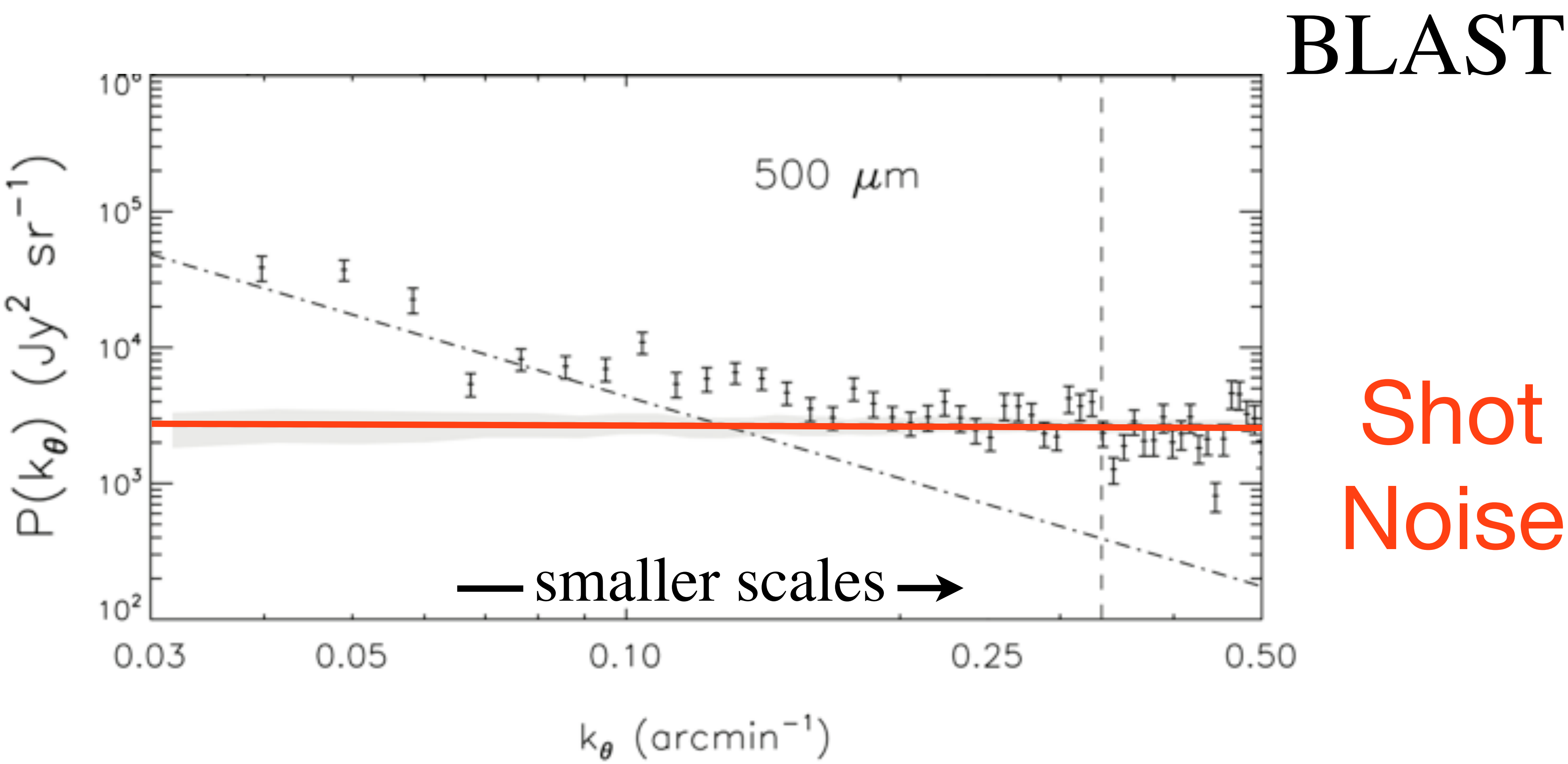
Power Spectrum



Viero et al. (2009)

arXiv: 0904.1200

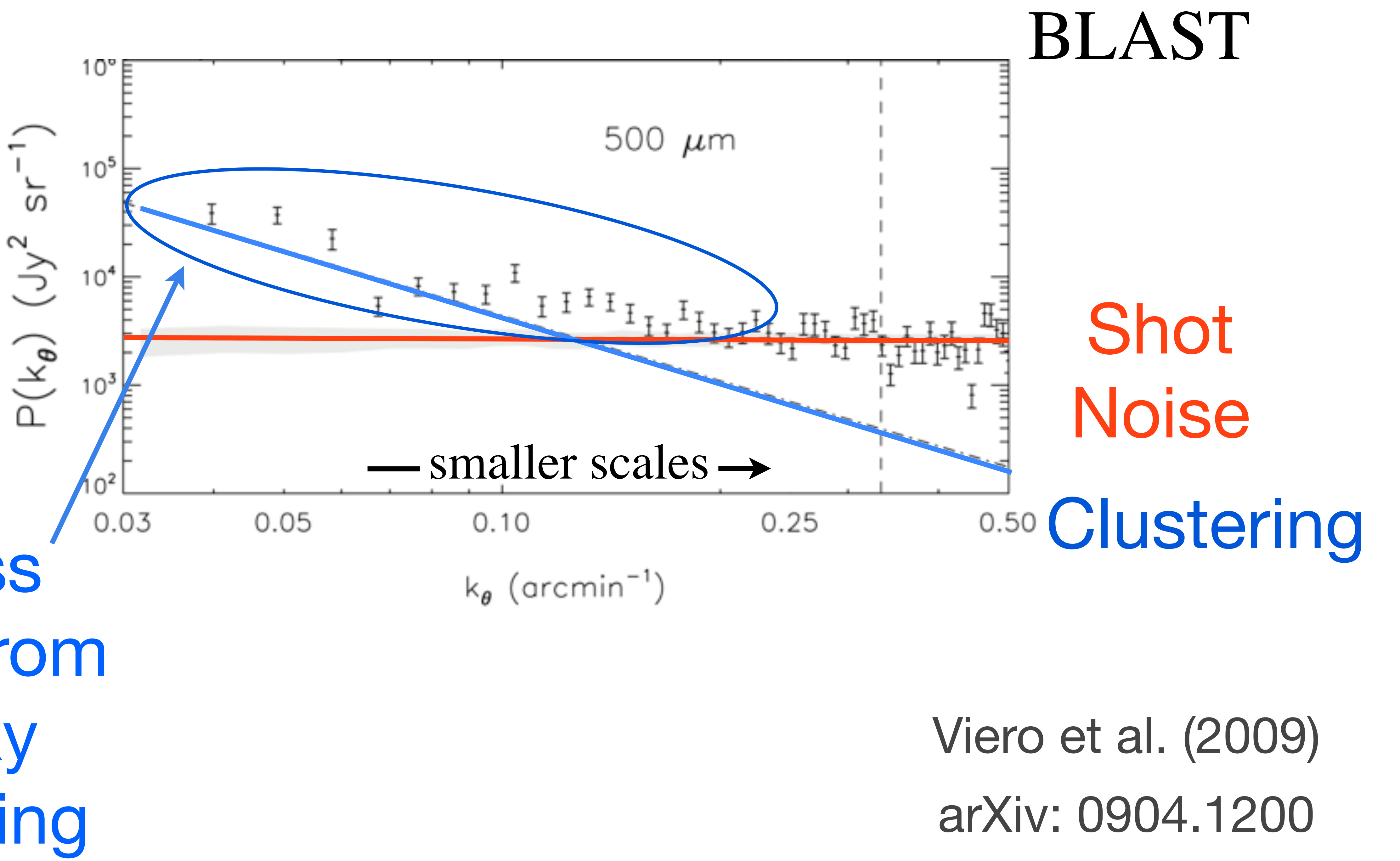
Power Spectrum



Viero et al. (2009)

arXiv: 0904.1200

Power Spectrum

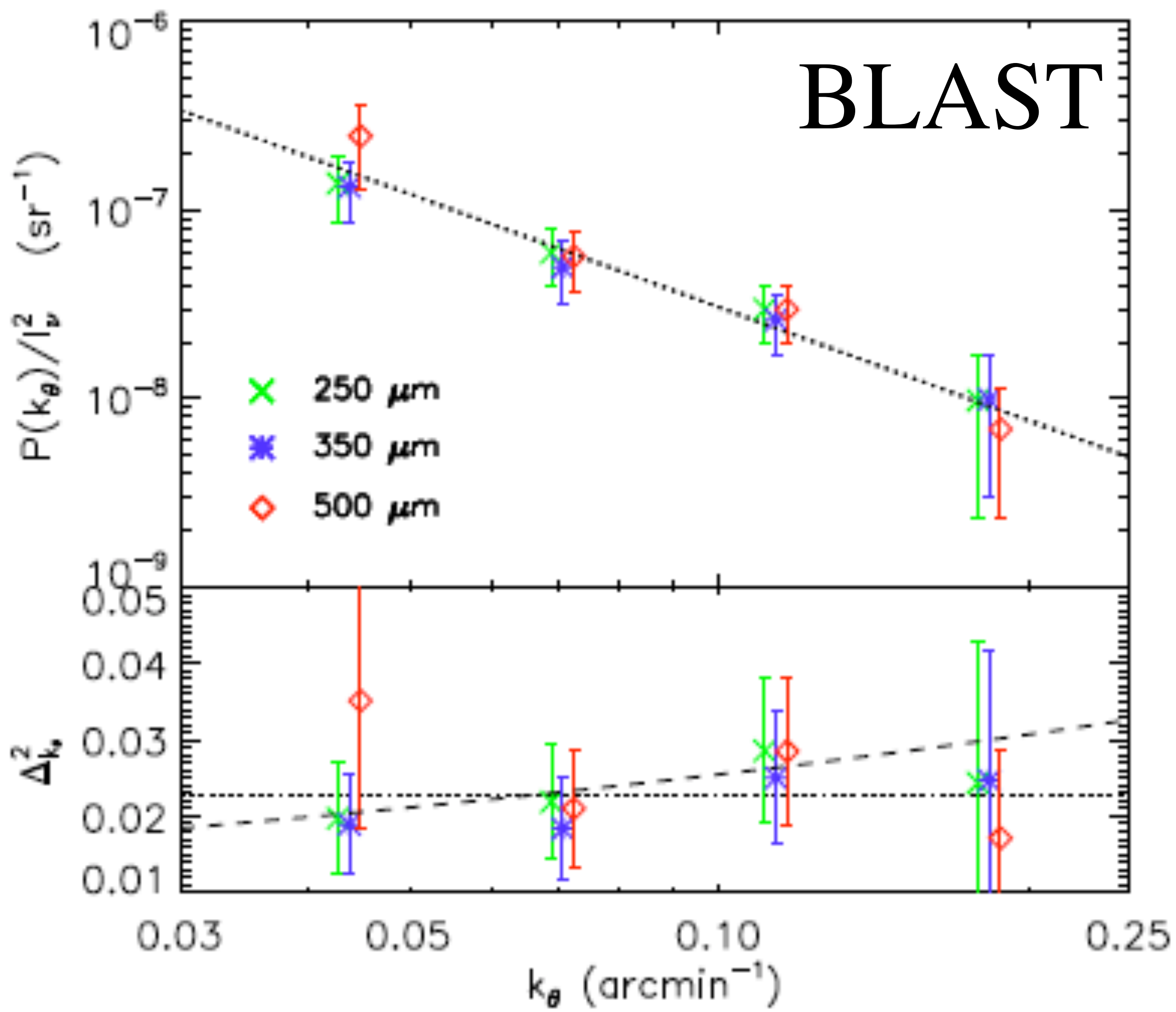


Viero et al. (2009)

arXiv: 0904.1200

Power Spectrum

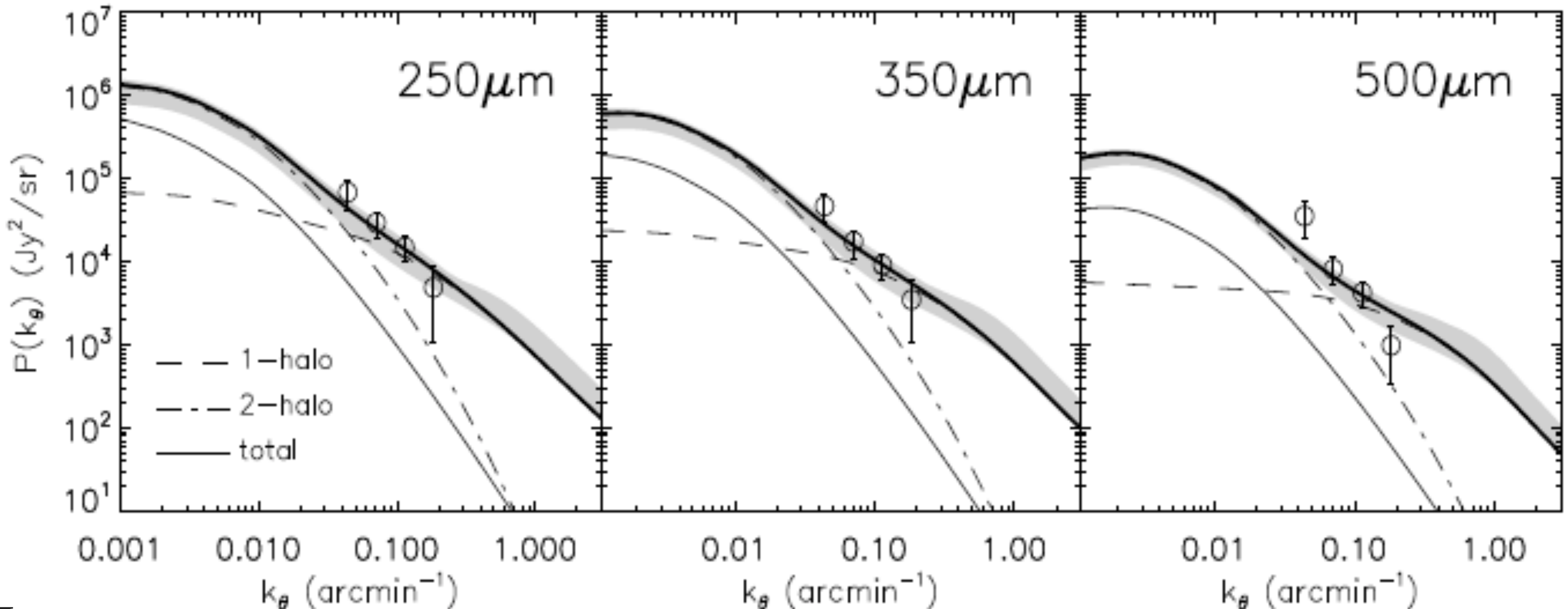
Clustering Signal After Removal of Shot Noise:
well-fit
by power-law



Viero et al. (2009)
arXiv: 0904.1200

Power Spectrum

halo model: Mattia Negrello



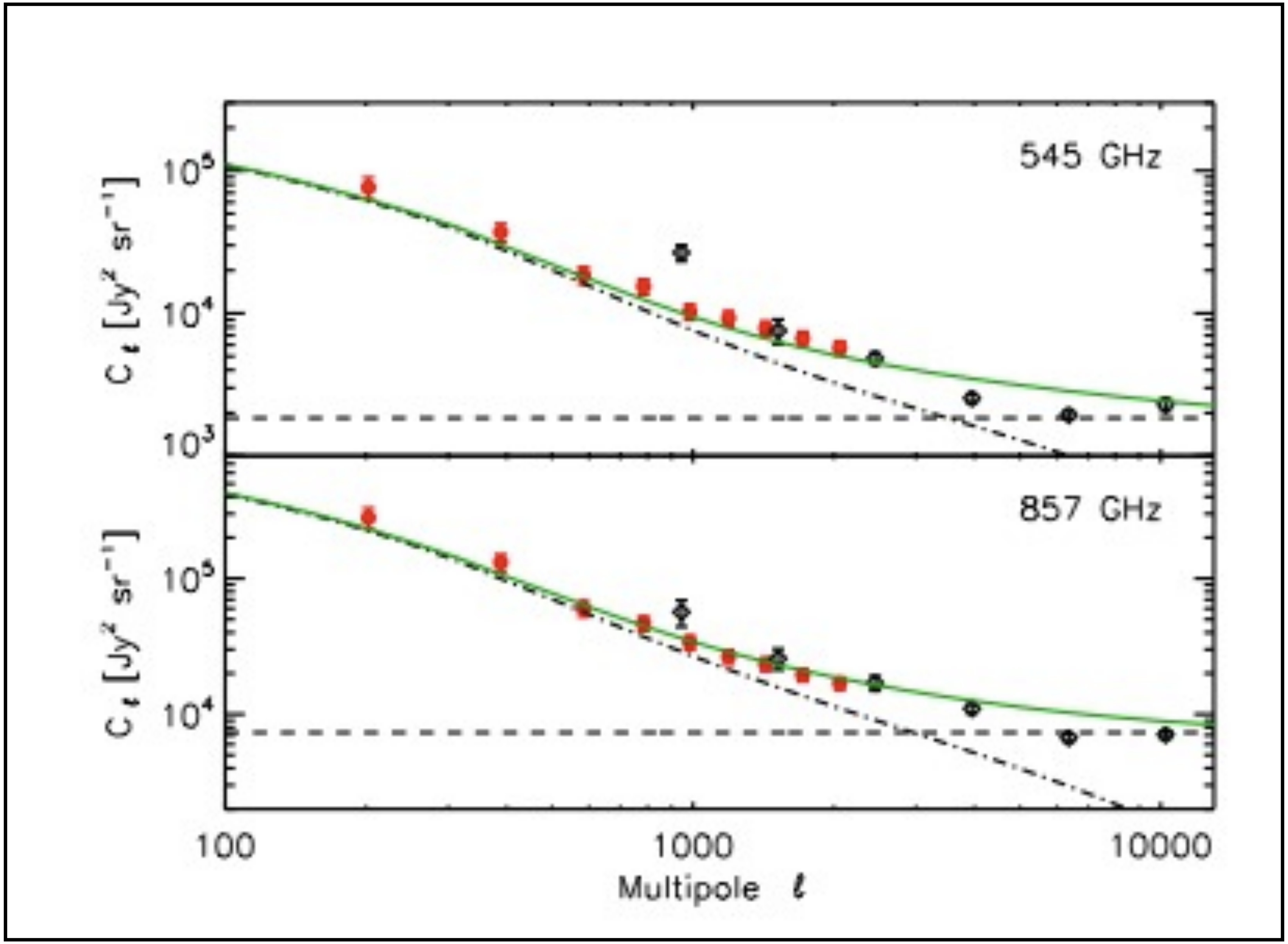
At z ~ 2

- $M_{eff} \approx 6 x 10^{12} M_{sun}$
- $M_{min} \approx 3 x 10^{11} M_{sun}$
- $b_{eff} \approx 2.4$

Viero et al. (2009)

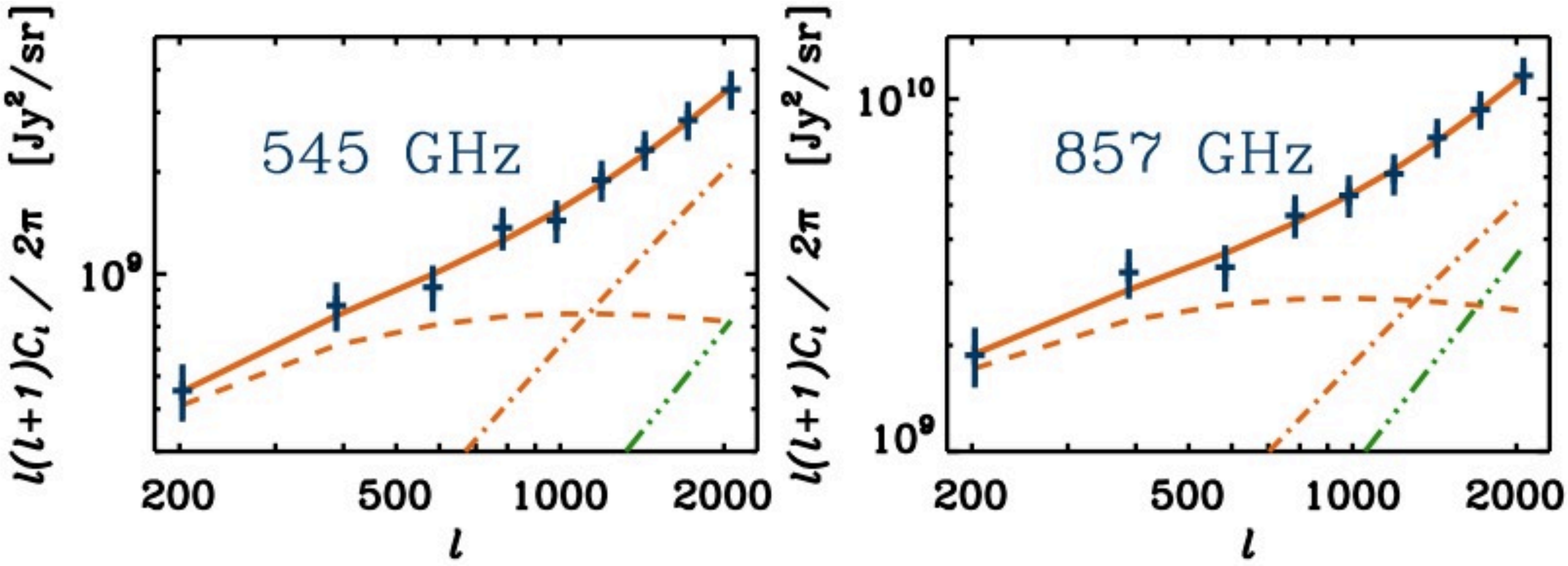
arXiv: 0904.1200

Power Spectrum



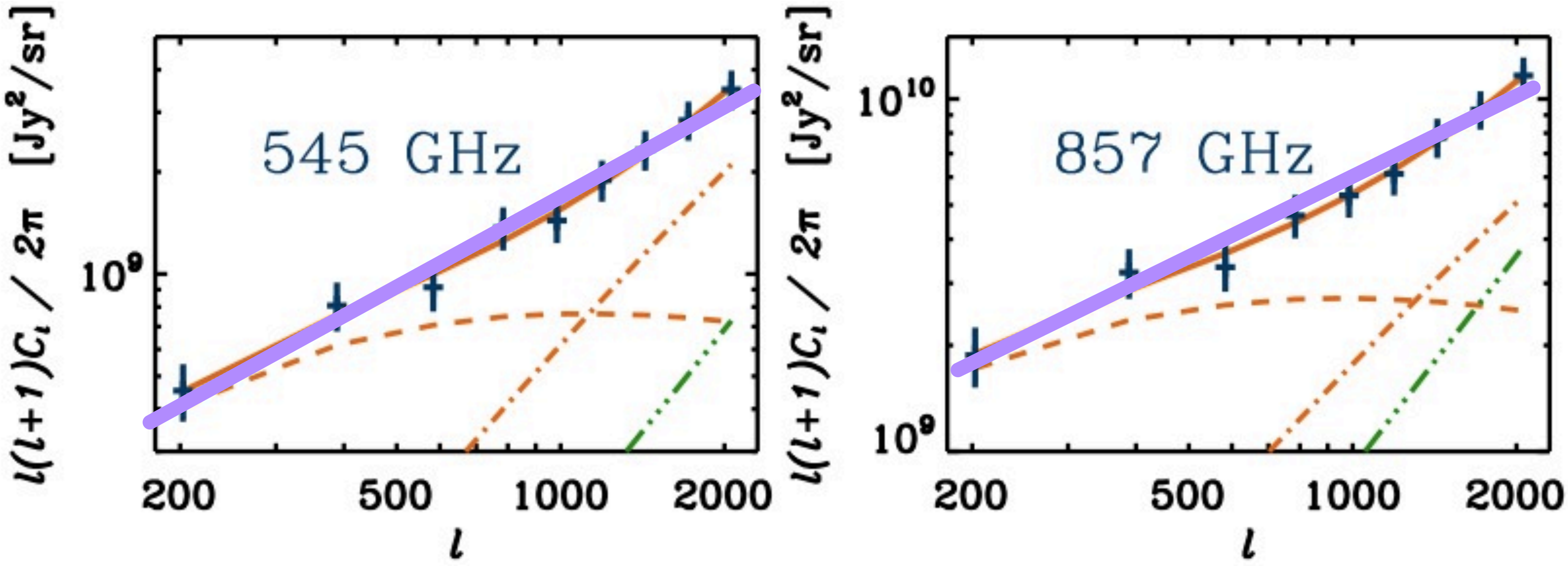
Planck Collaboration et al. (2011): arXiv: 1101.2028

Planck Power Spectrum



Planck Collaboration et al. (2011): arXiv: 1101.2028

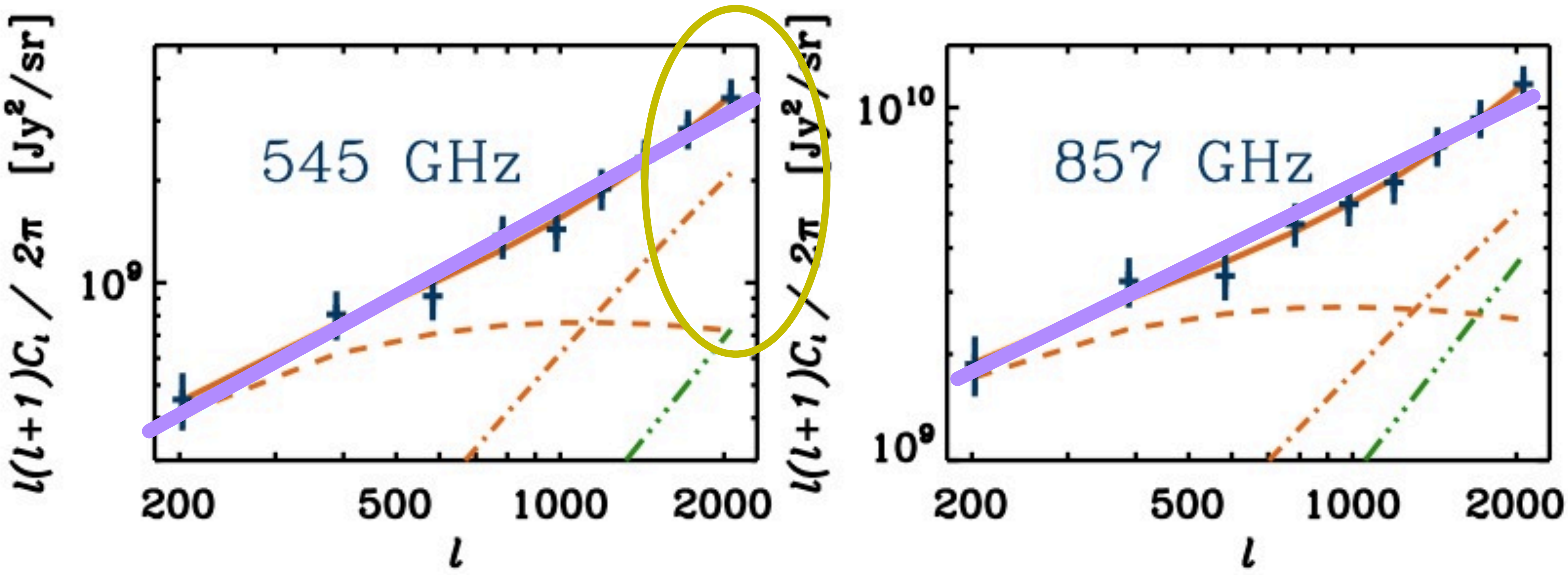
Planck Power Spectrum



- Fit just as well to power-law

Planck Collaboration et al. (2011): arXiv: 1101.2028

Planck Power Spectrum

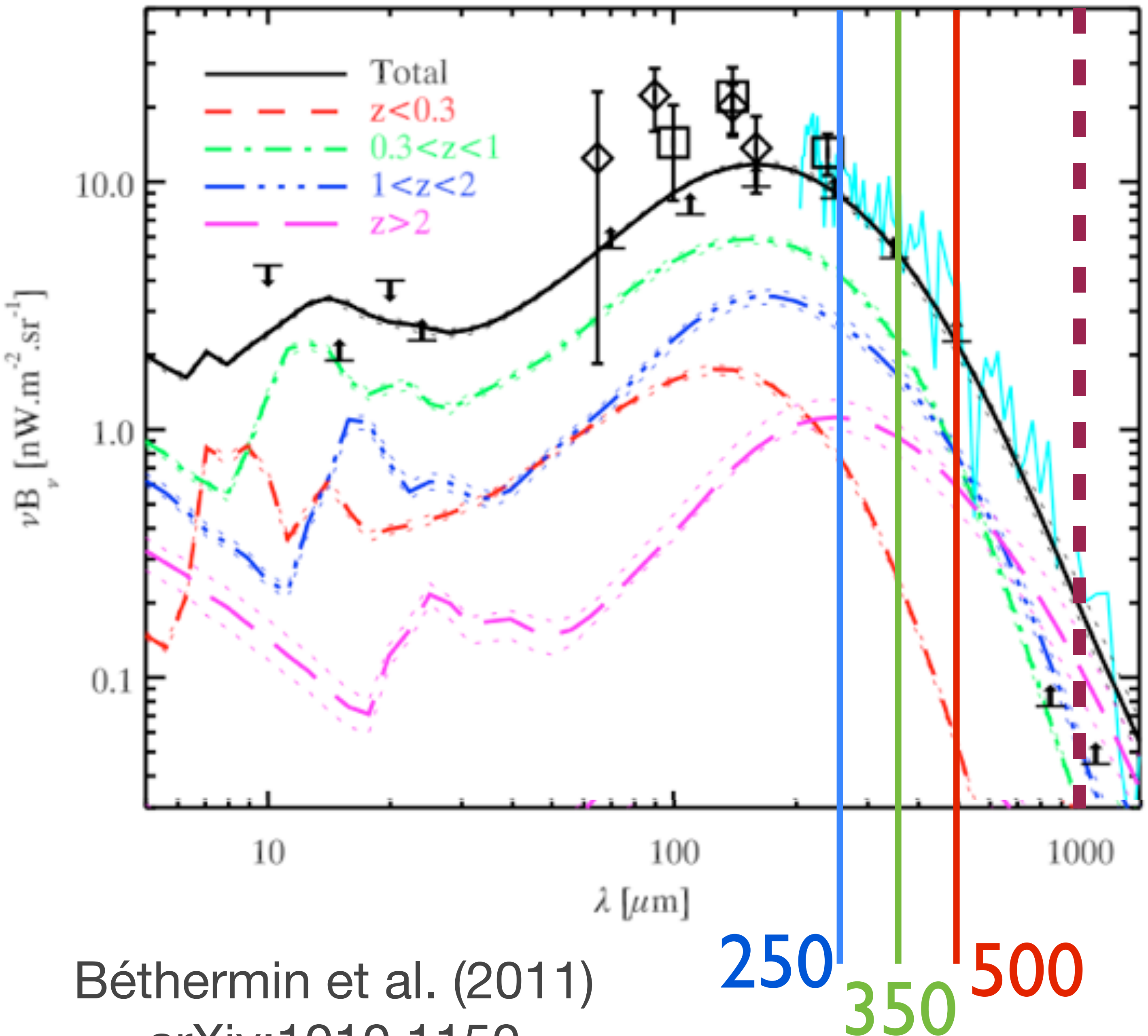


- Fit just as well to power-law
- Poisson unconstrained (thus model-dependent)

Planck Collaboration et al. (2011): arXiv: 1101.2028

Planck Power Spectrum

CIB in redshift slices

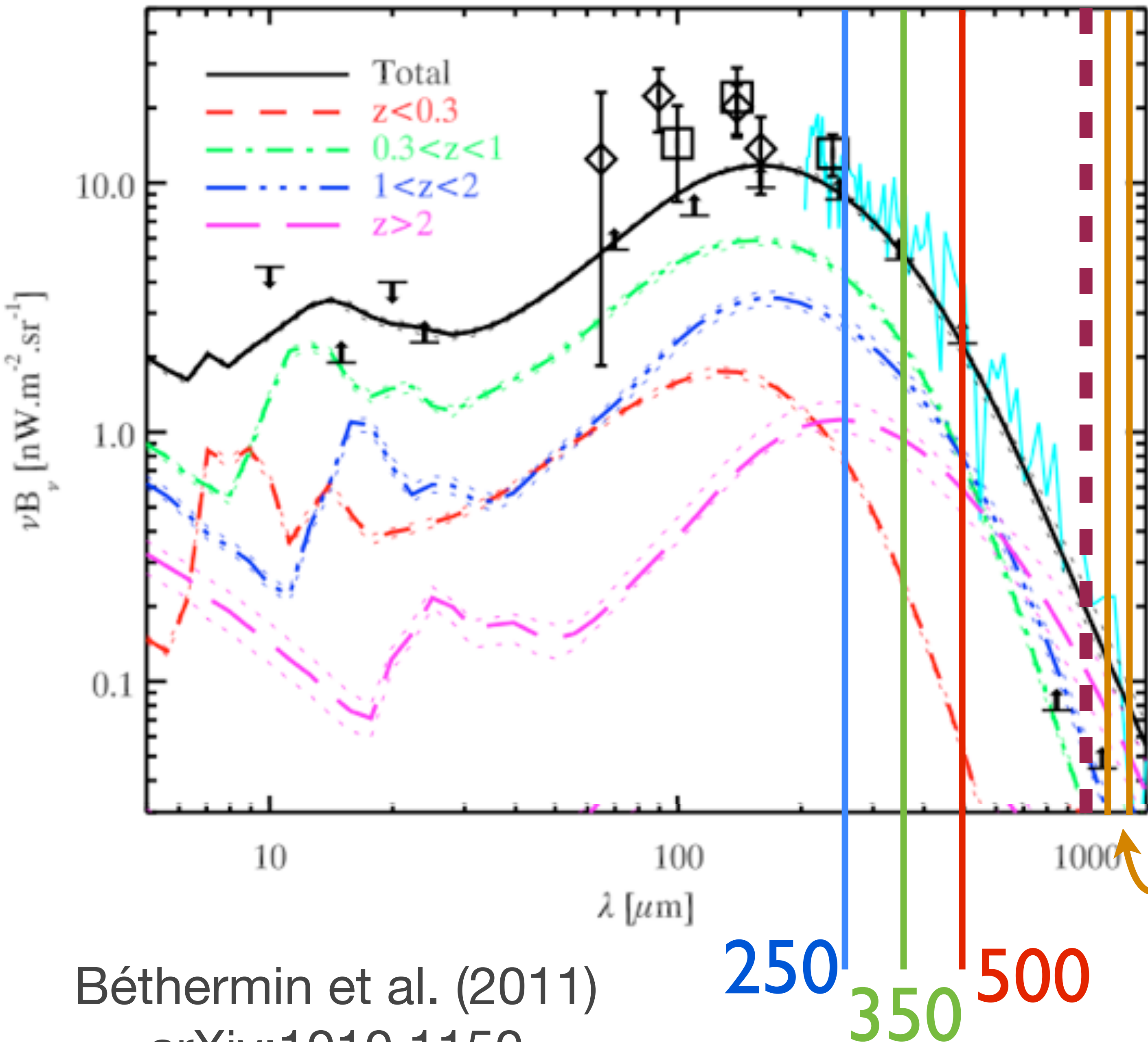


Béthermin et al. (2011)
arXiv:1010.1150

Infrared Background
at λ > 1 mm
dominated by
high-redshift sources

Probing High-z

CIB in redshift slices



Béthermin et al. (2011)
arXiv:1010.1150

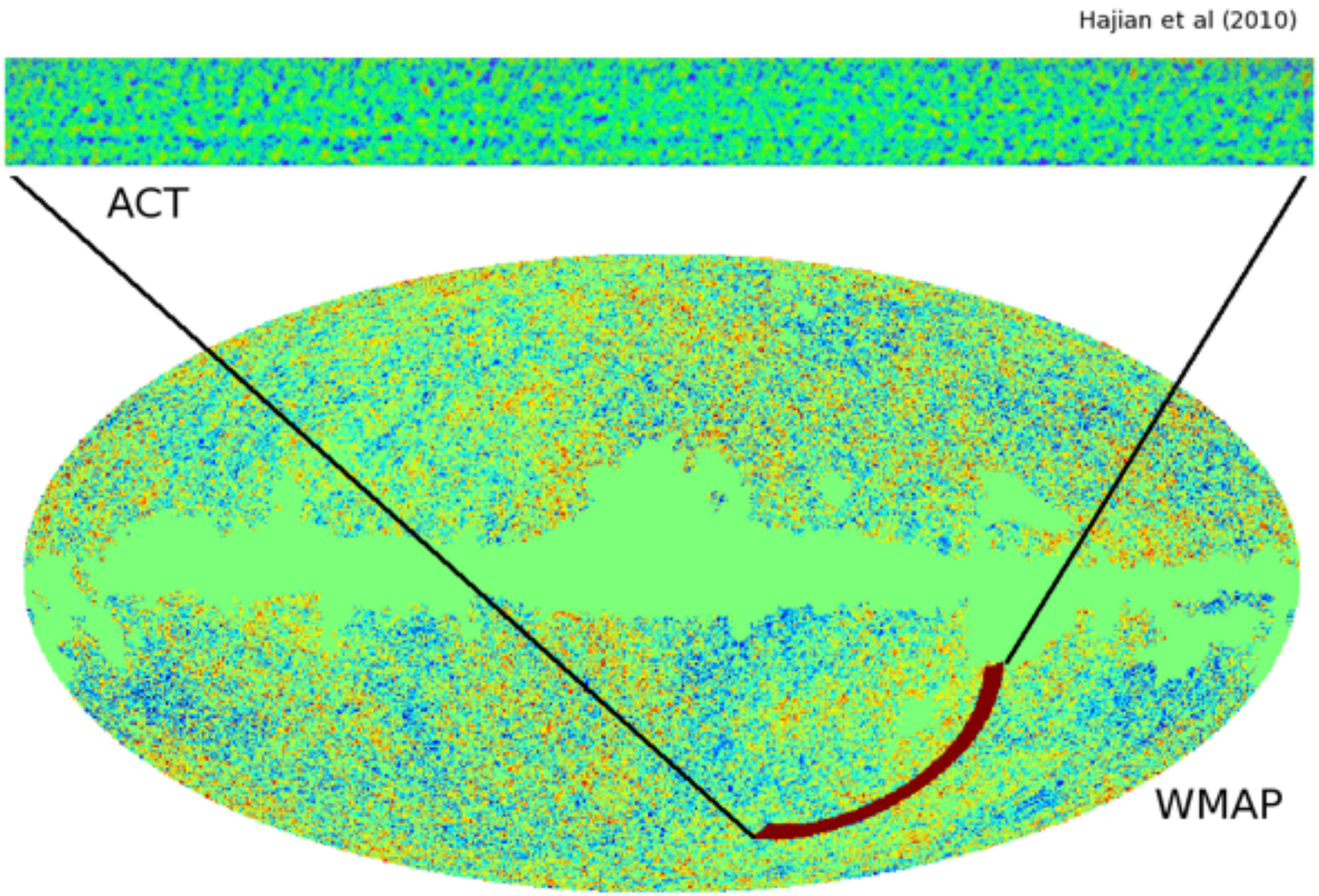
Infrared Background
at λ > 1 mm
dominated by
high-redshift sources

1.4 mm (220 GHz)
2 mm (148 GHz)

CMB

Probing High-z

ACT Southern Field



- 300 deg^2
- 1' resolution
- 3 bands

  148 GHz (~2.0 mm)

  218 GHz (~1.4 mm)

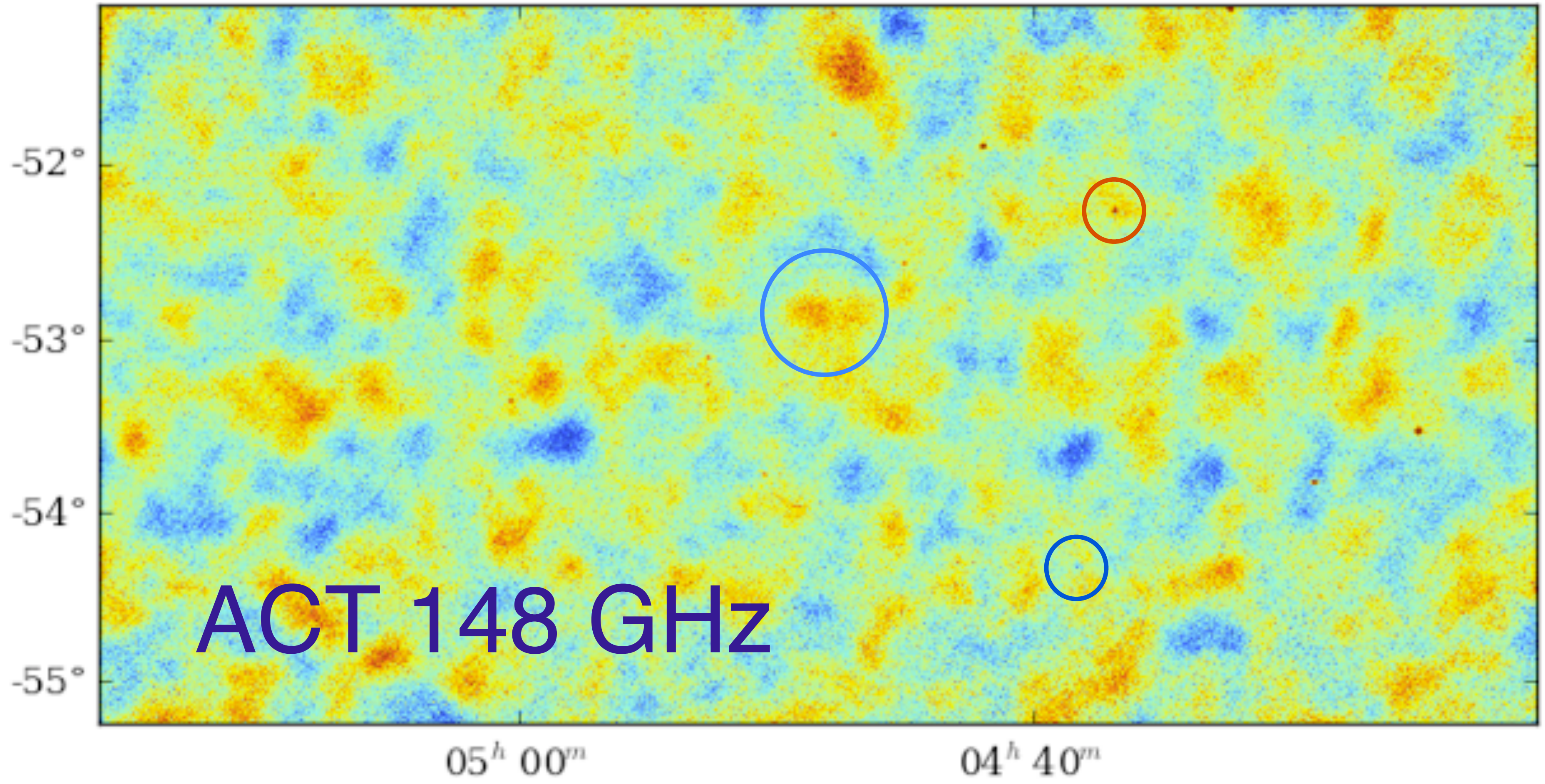
  277 GHz (~1.1 mm)

CMB

Resolved Radio Galaxies

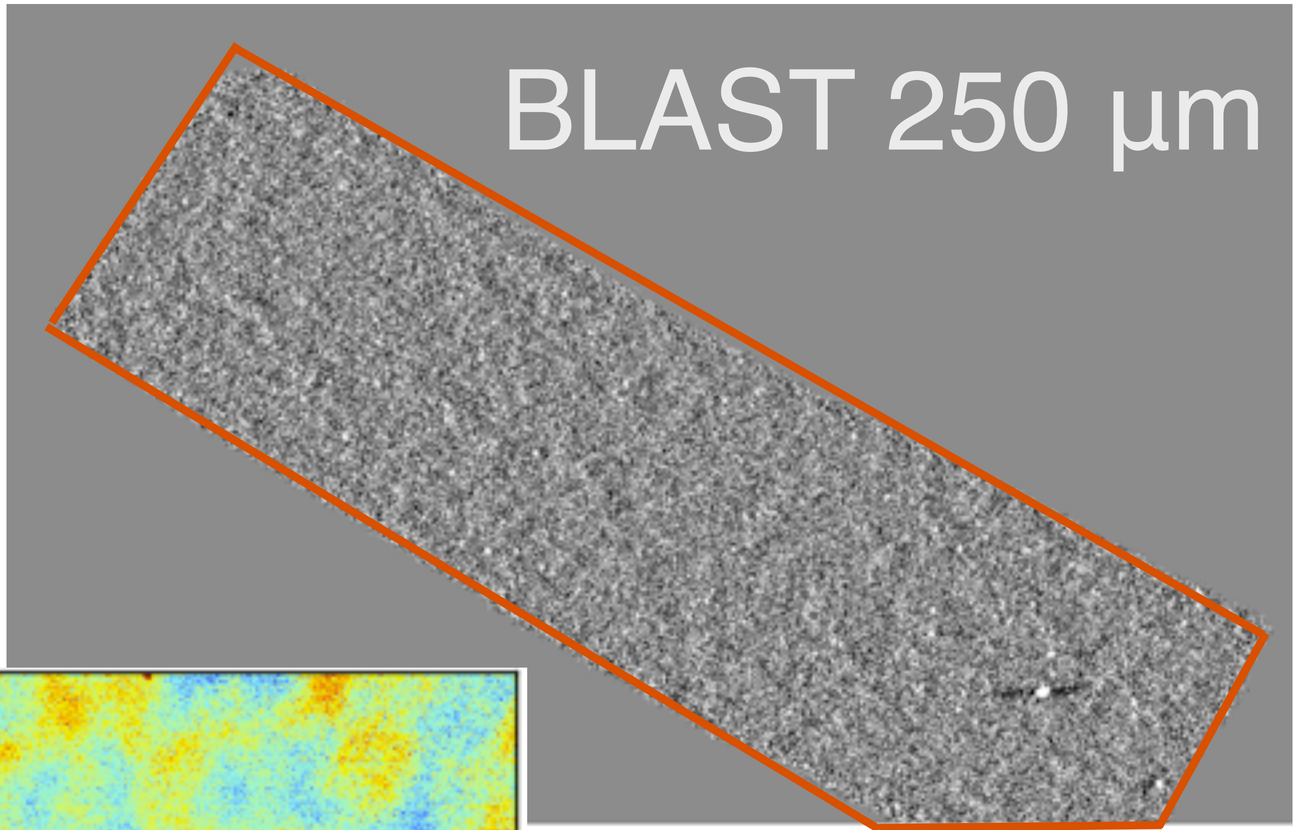
SZ Clusters

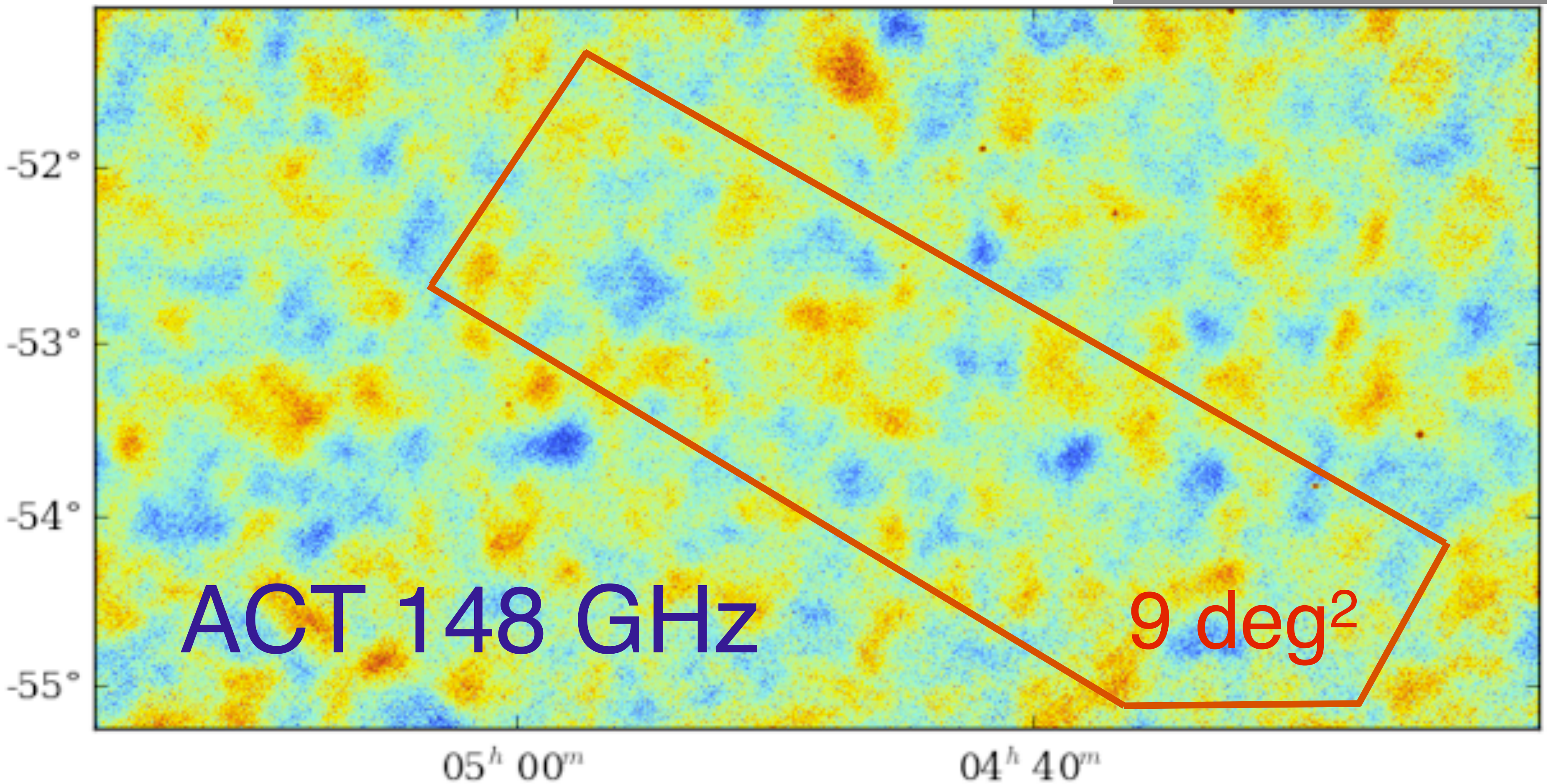
Unresolved CIB



Separating the CMB sky

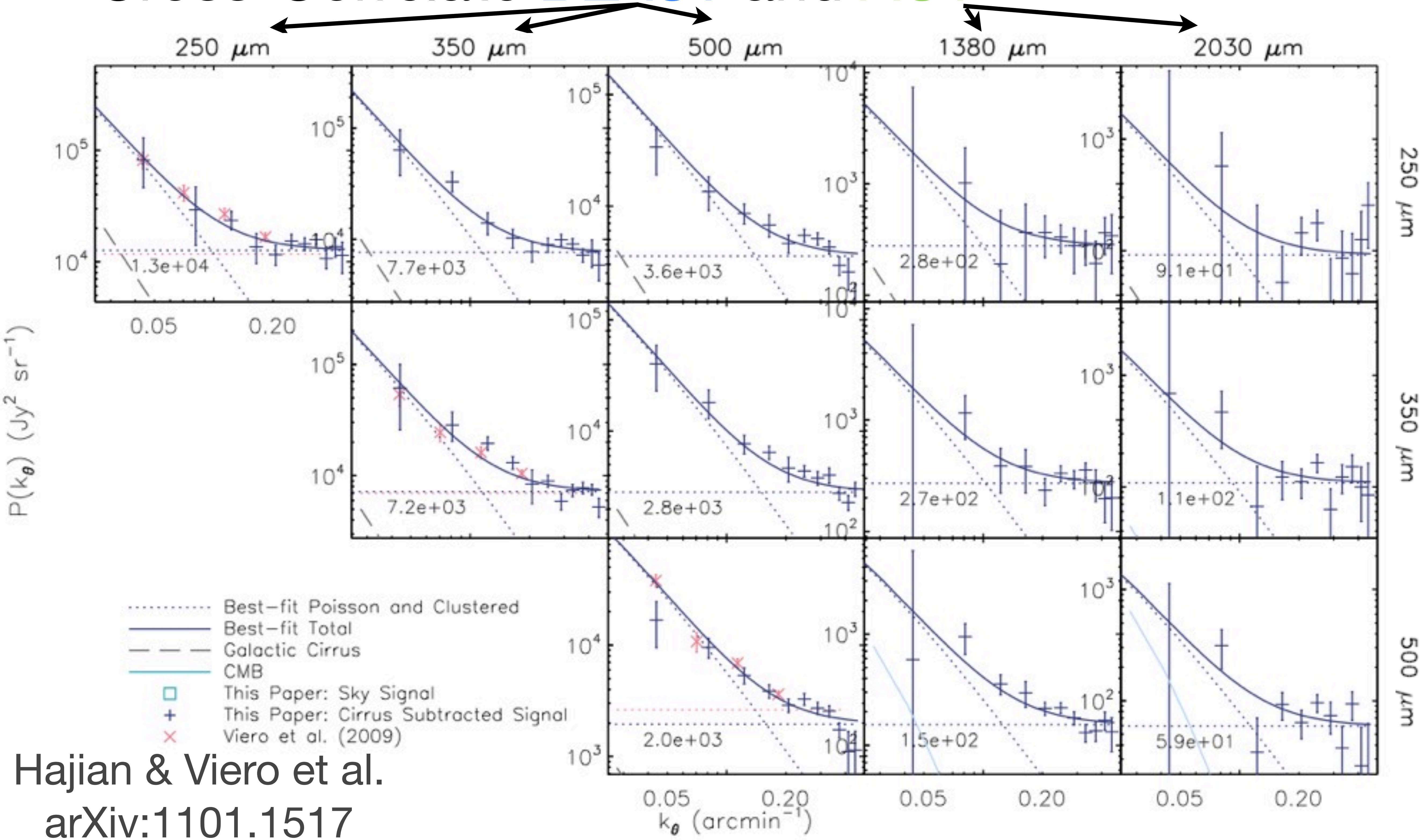
Cross-Correlations Isolate Dusty Galaxies from the Rest





CIBxCMB

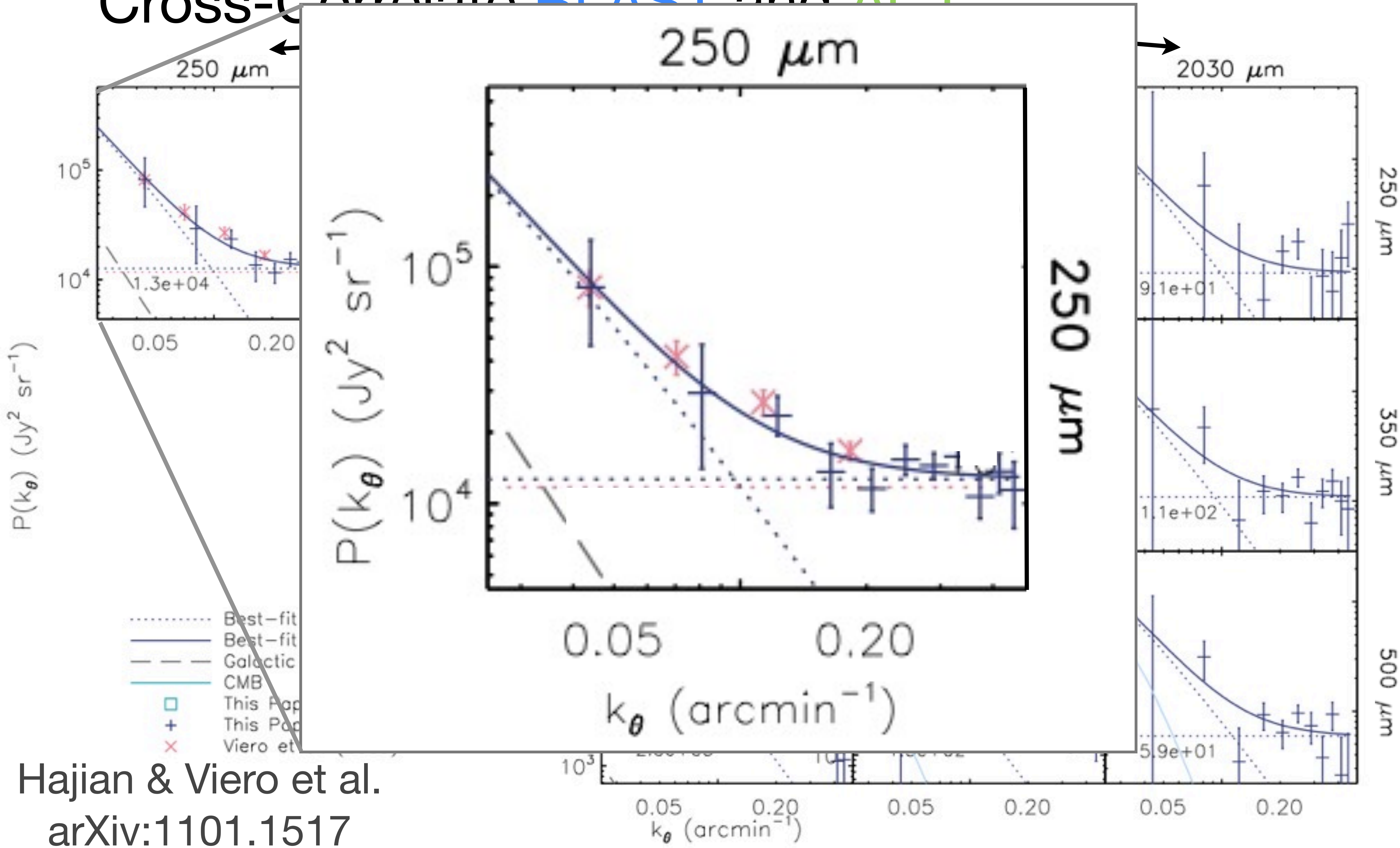
Cross-Correlate BLAST and ACT



Hajian & Viero et al.
arXiv:1101.1517

CIBxCMB

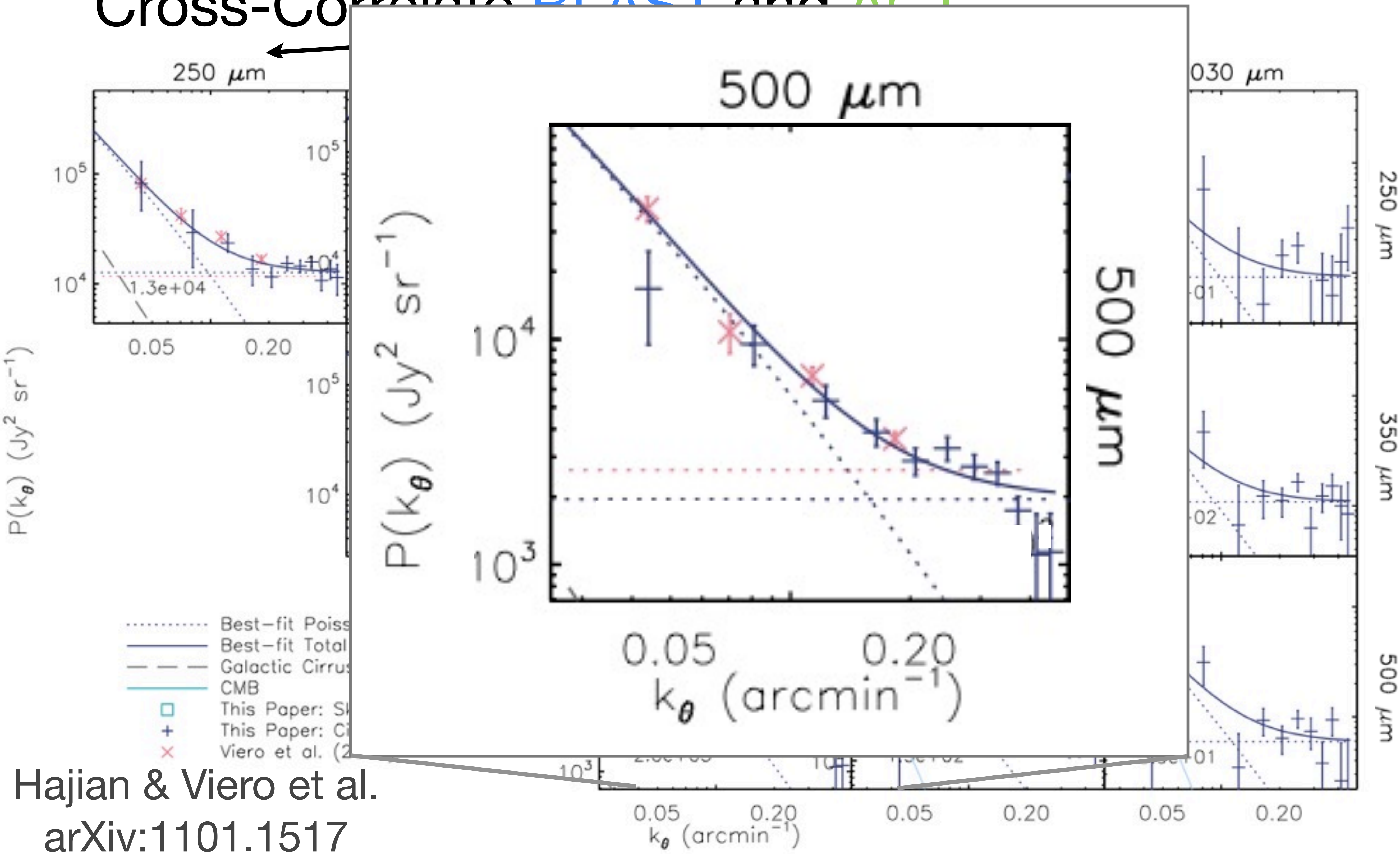
Cross-Correlate BLAST and ACT



Hajian & Viero et al.
arXiv:1101.1517

CIBxCMB

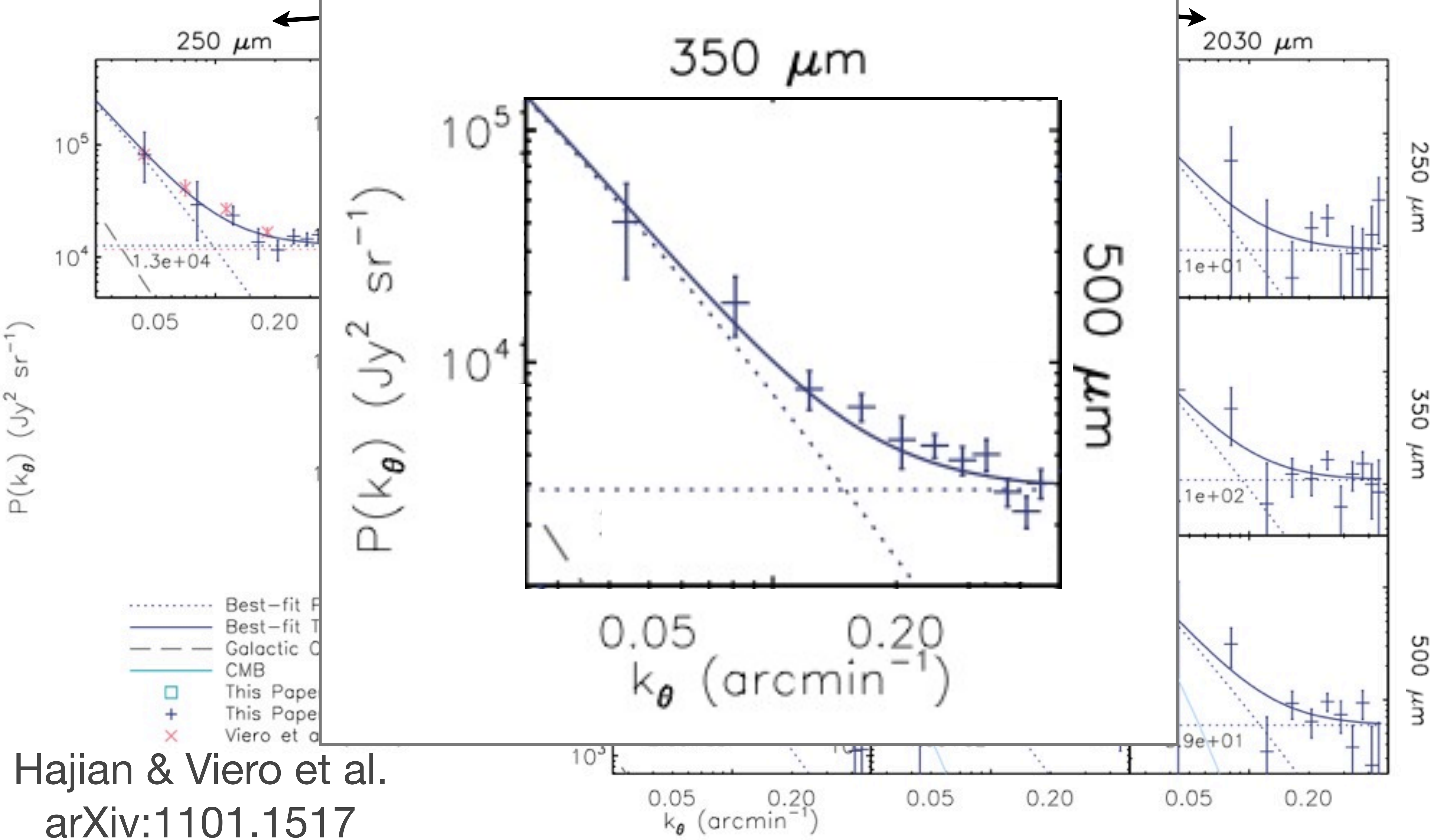
Cross-Correlate BLAST and ACT



Hajian & Viero et al.
arXiv:1101.1517

CIBxCMB

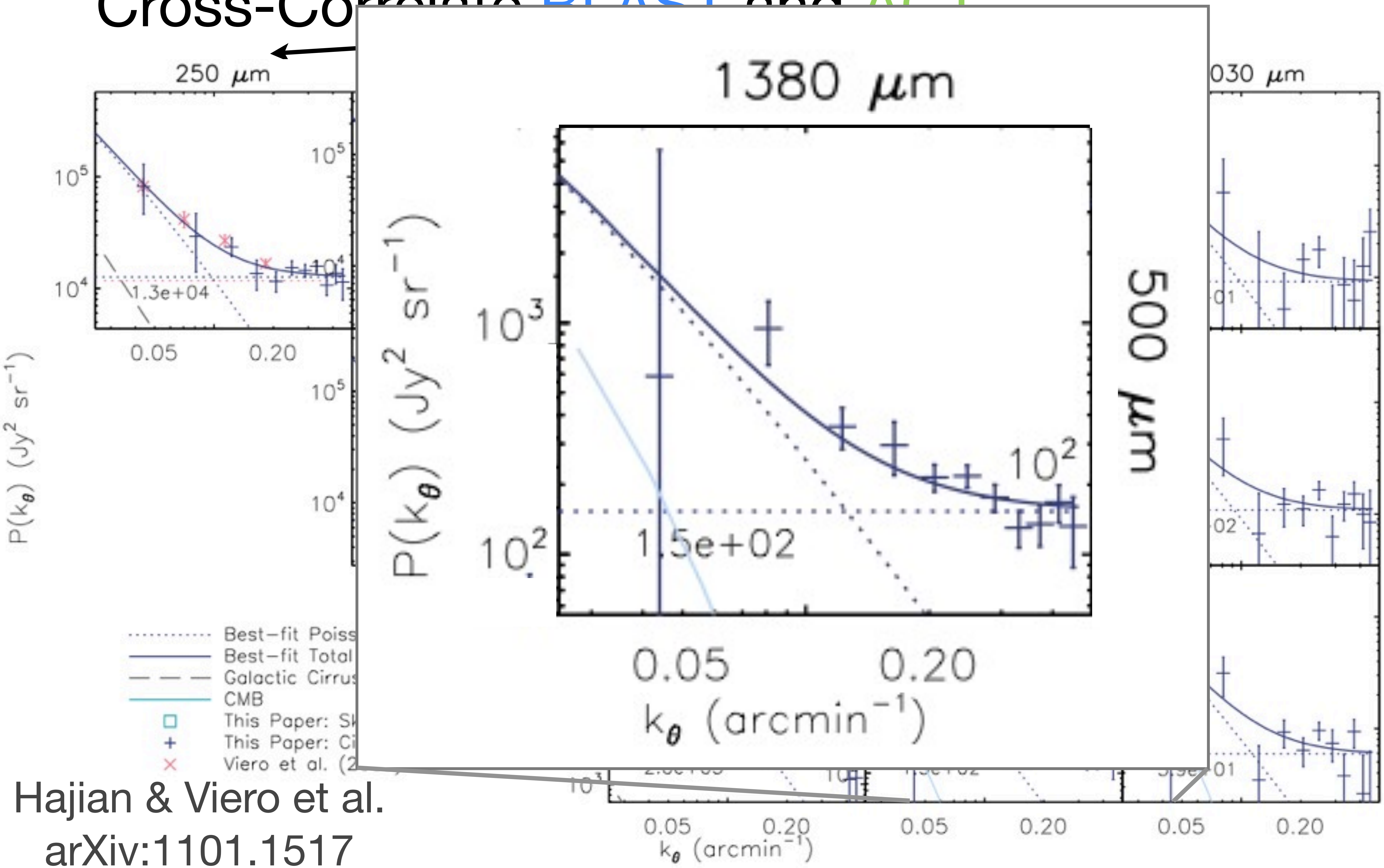
Cross-Correlate BLAST and ACT



Hajian & Viero et al.
arXiv:1101.1517

CIBxCMB

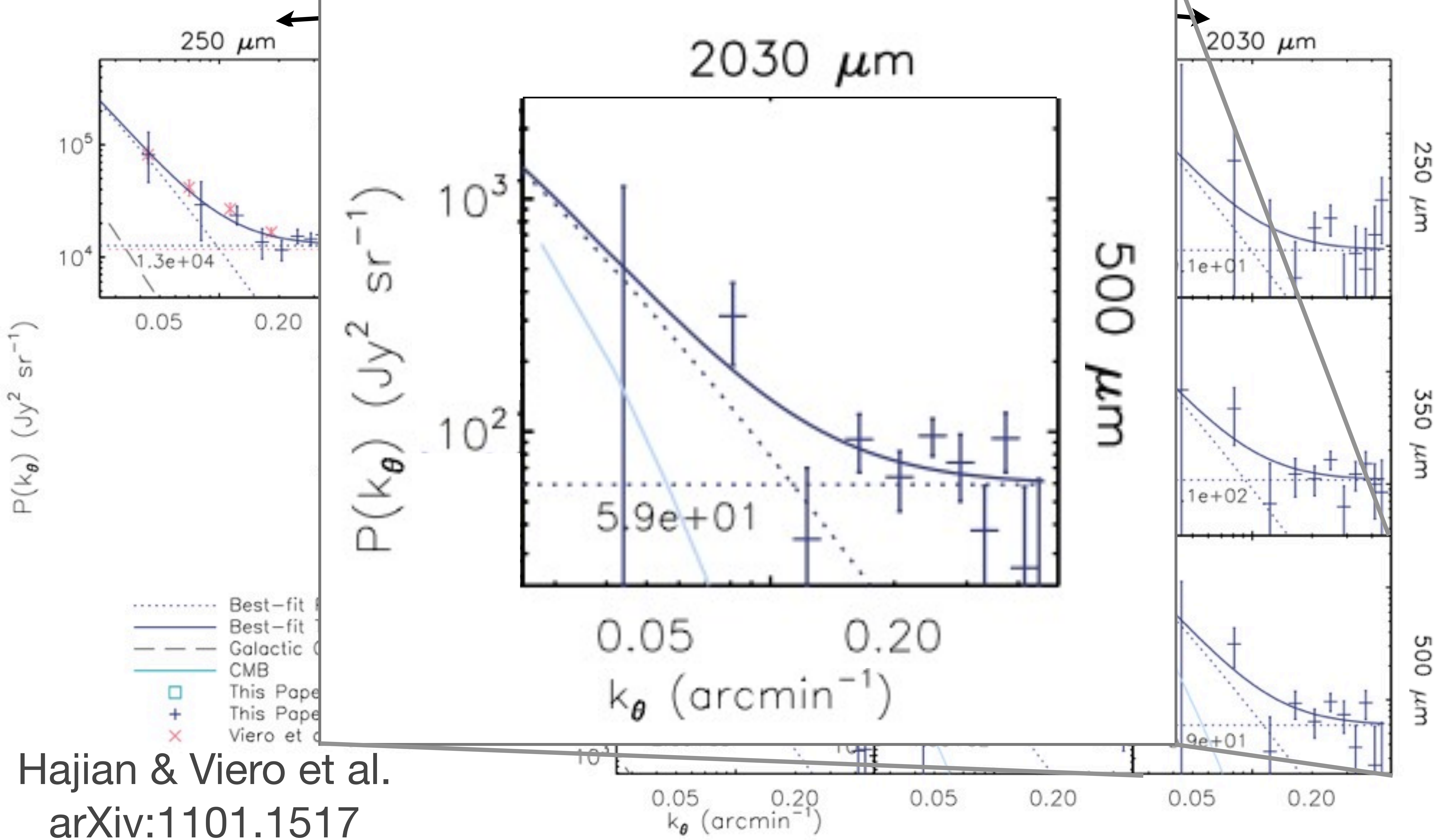
Cross-Correlate BLAST and ACT



Hajian & Viero et al.
arXiv:1101.1517

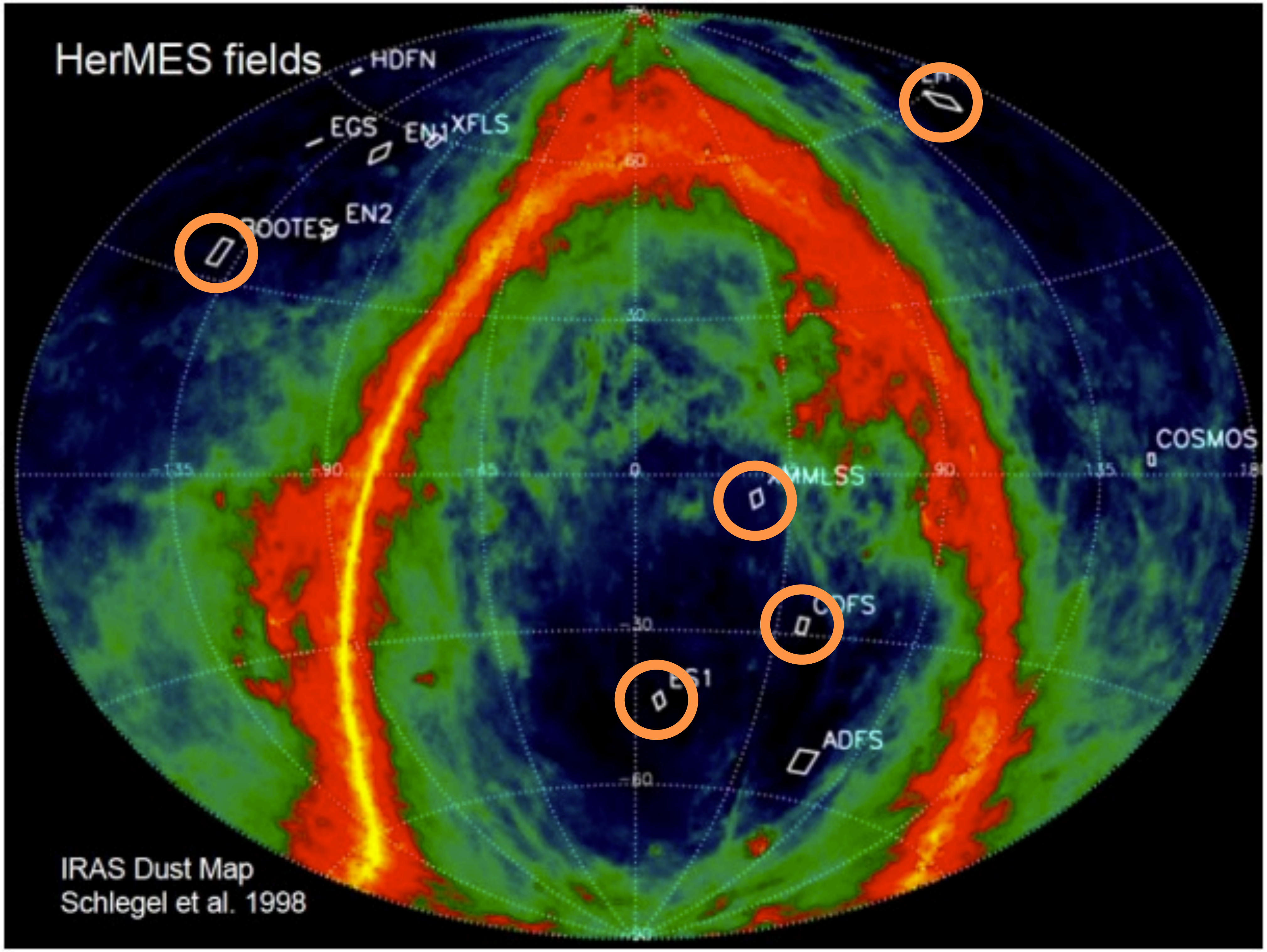
CIBxCMB

Cross-Correlate BLAST and ACT



Hajian & Viero et al.
arXiv:1101.1517

CIBxCMB


HerMES fields
HDFN
EGS
EN1
XFLS
BOOTES
EN2
COSMOS
XMMLSS
CDFS
ES1
ADFS
IRAS Dust Map
Schlegel et al. 1998

HERMES

HERMES

The Team

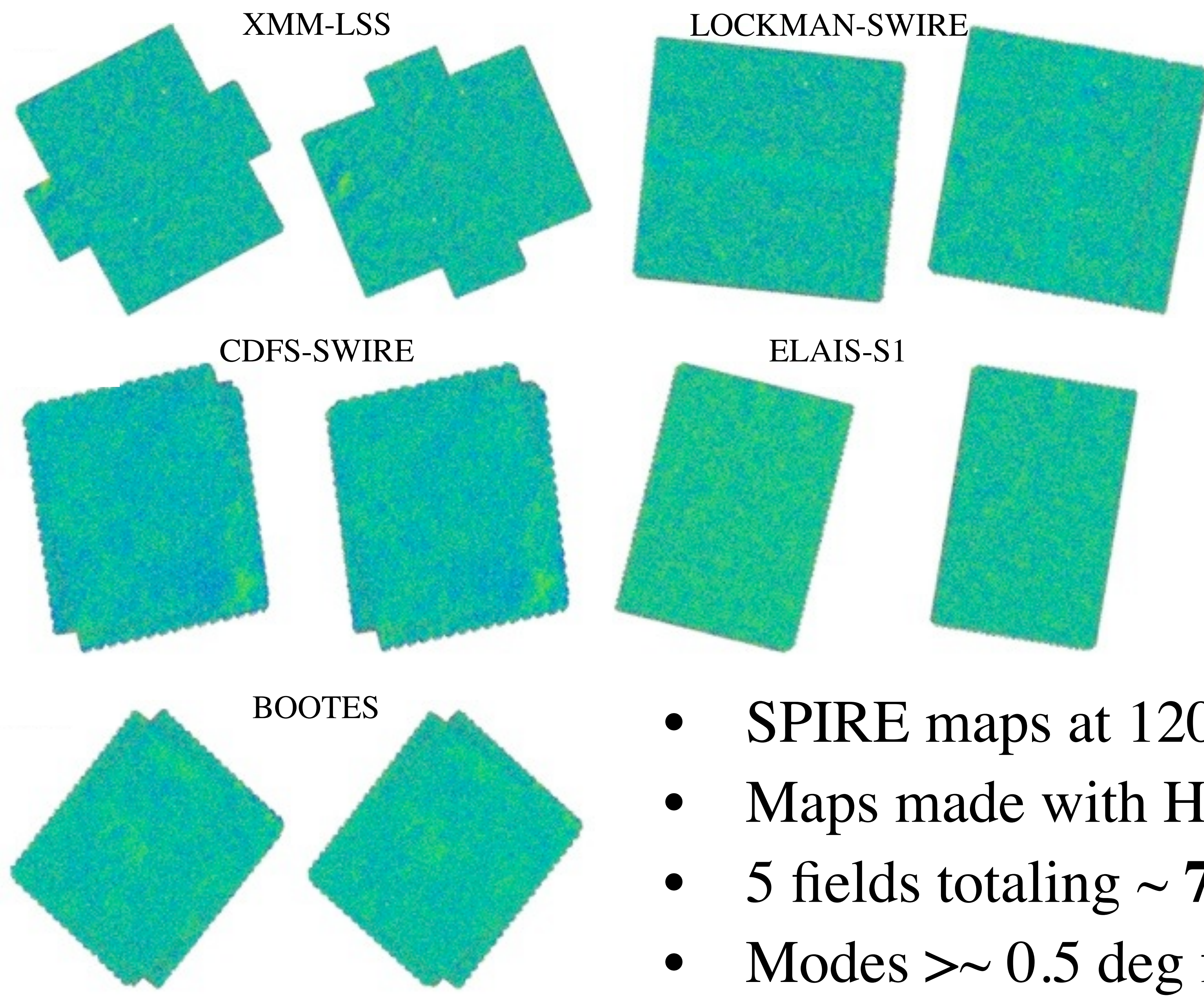
Bruno Altieri, Alex Amblard, Rick Arendt, Vinod Arumugam, Robbie Auld, Herve Aussel, Alexandre Beelen, Andrew Blain, Jamie Bock, Alessandro Boselli, Carrie Bridge, Drew Brisbin, Veronique Buat, Denis Burgarella, Nieves Castro-Rodriguez, Antonia Cava, Pierre Chanial, Ed Chapin, Michele Cirasuolo, Dave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

Data

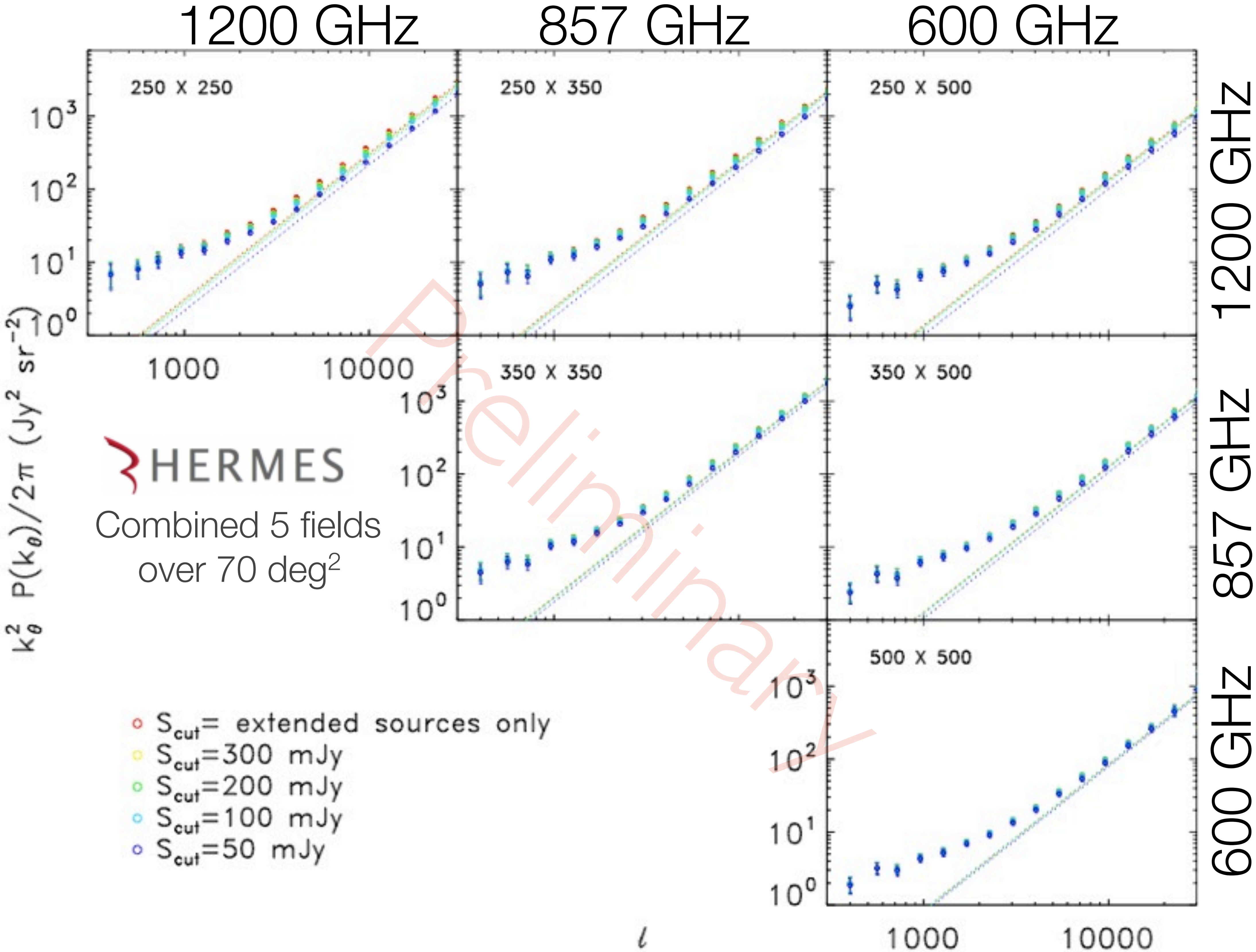
Data



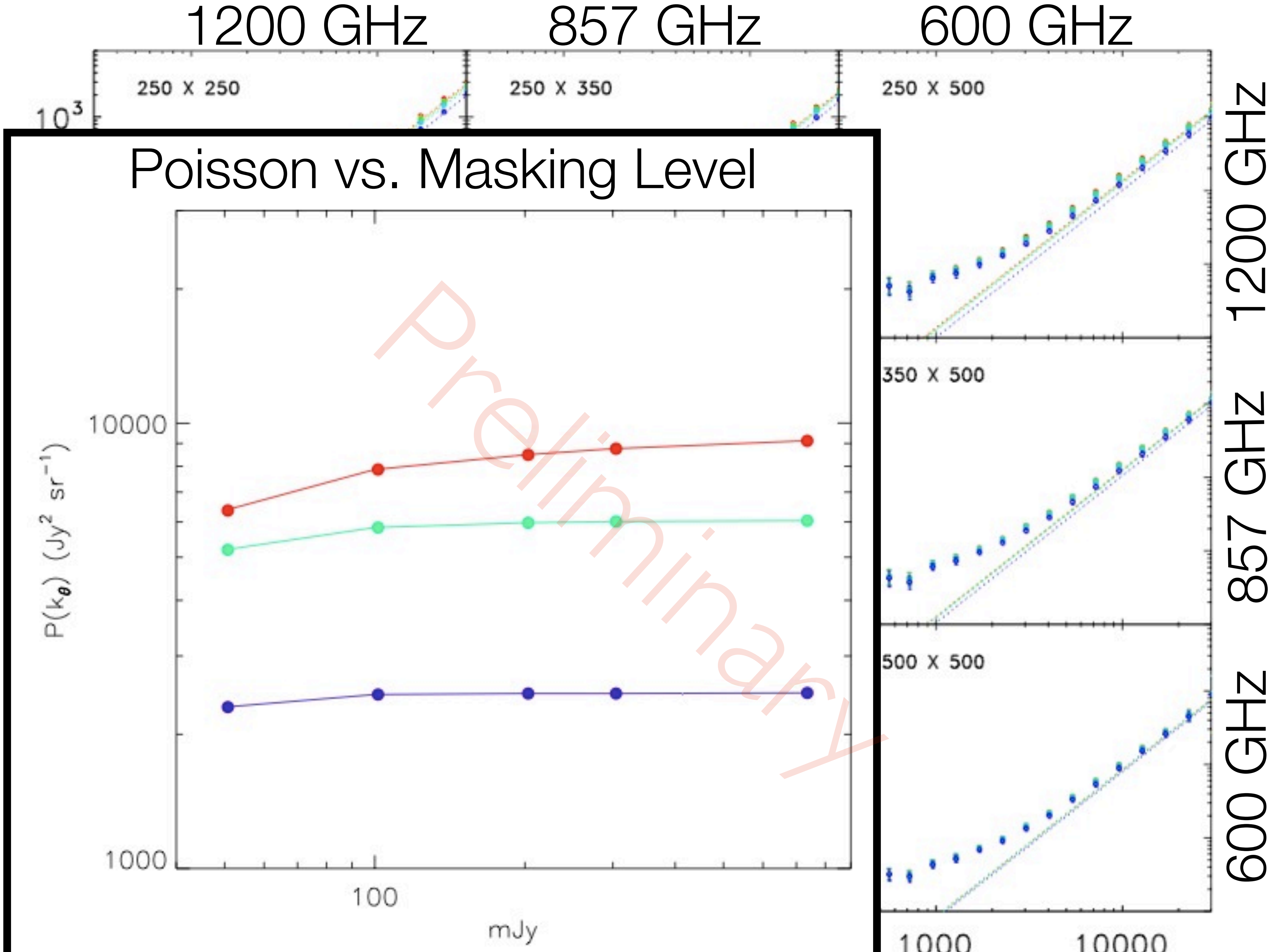
HERMES

SMAP Team
Alex Conley
Louis Levenson
Gaelen Marsden
Marco Viero
Mike Zemcov

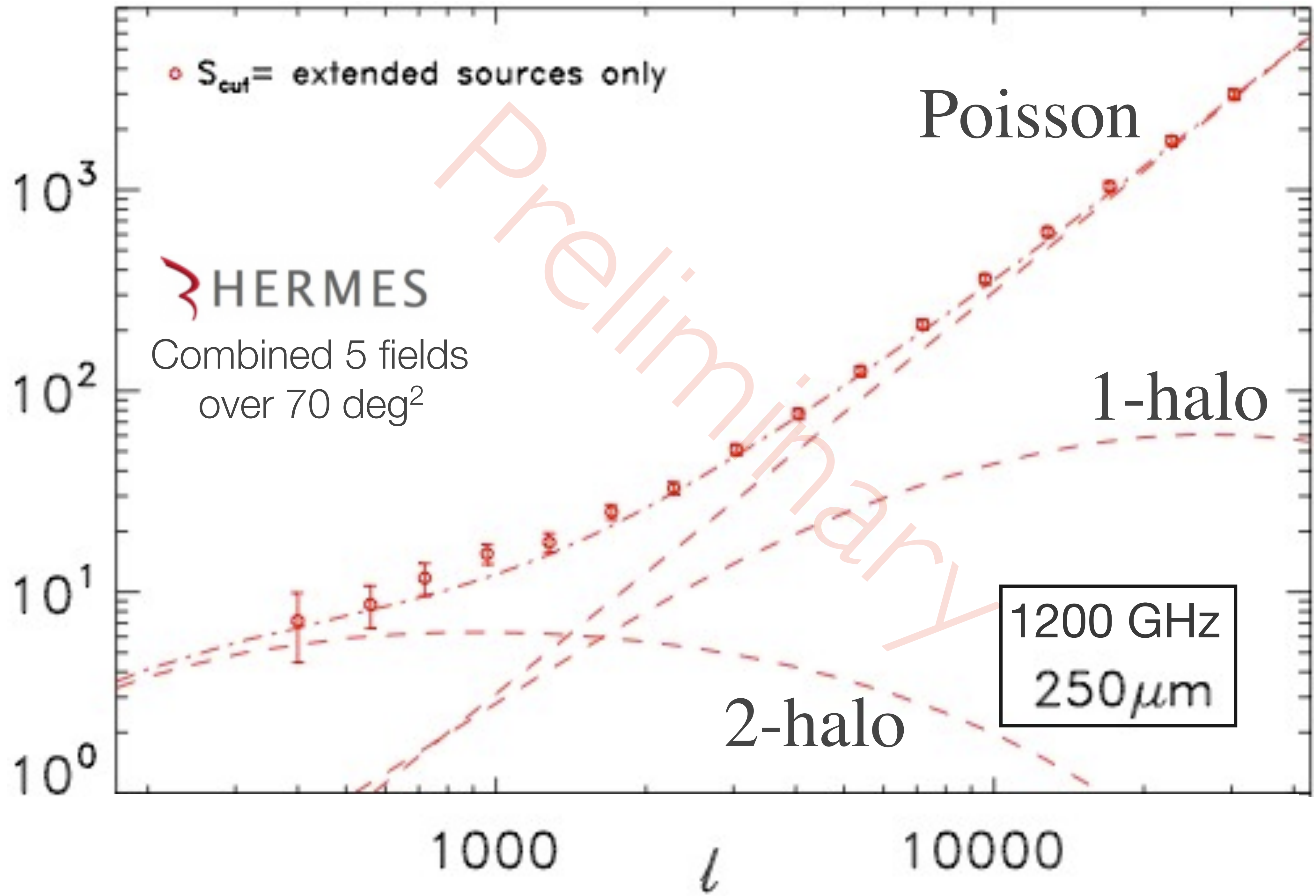
- SPIRE maps at 1200, 857, and 600 GHz
- Maps made with HeRMES SMAP pipeline
- 5 fields totaling ~ **70** deg^2
- Modes >~ 0.5 deg filtered
- Sources > 50, 100, 200, 300 mJy masked



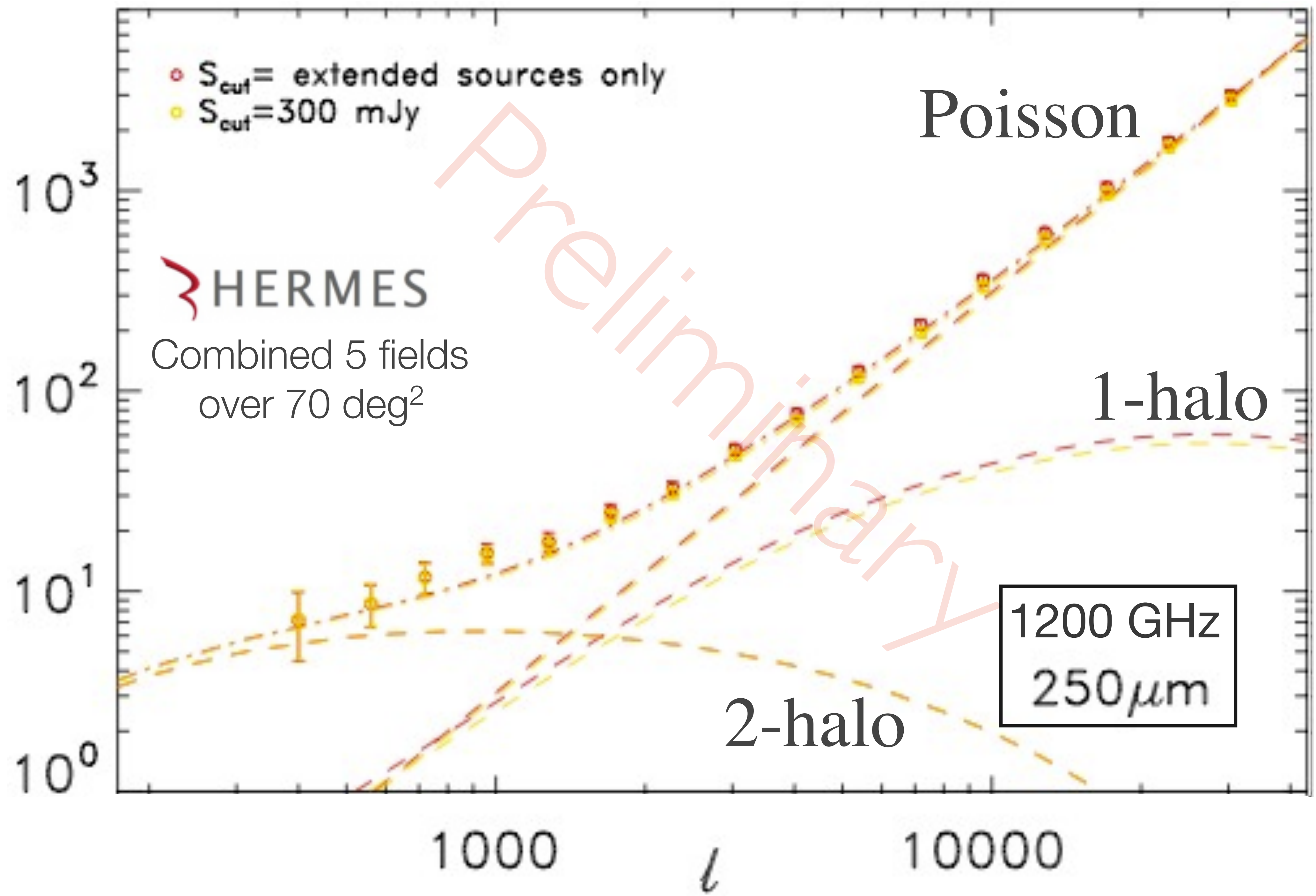
CIB Power Spectra



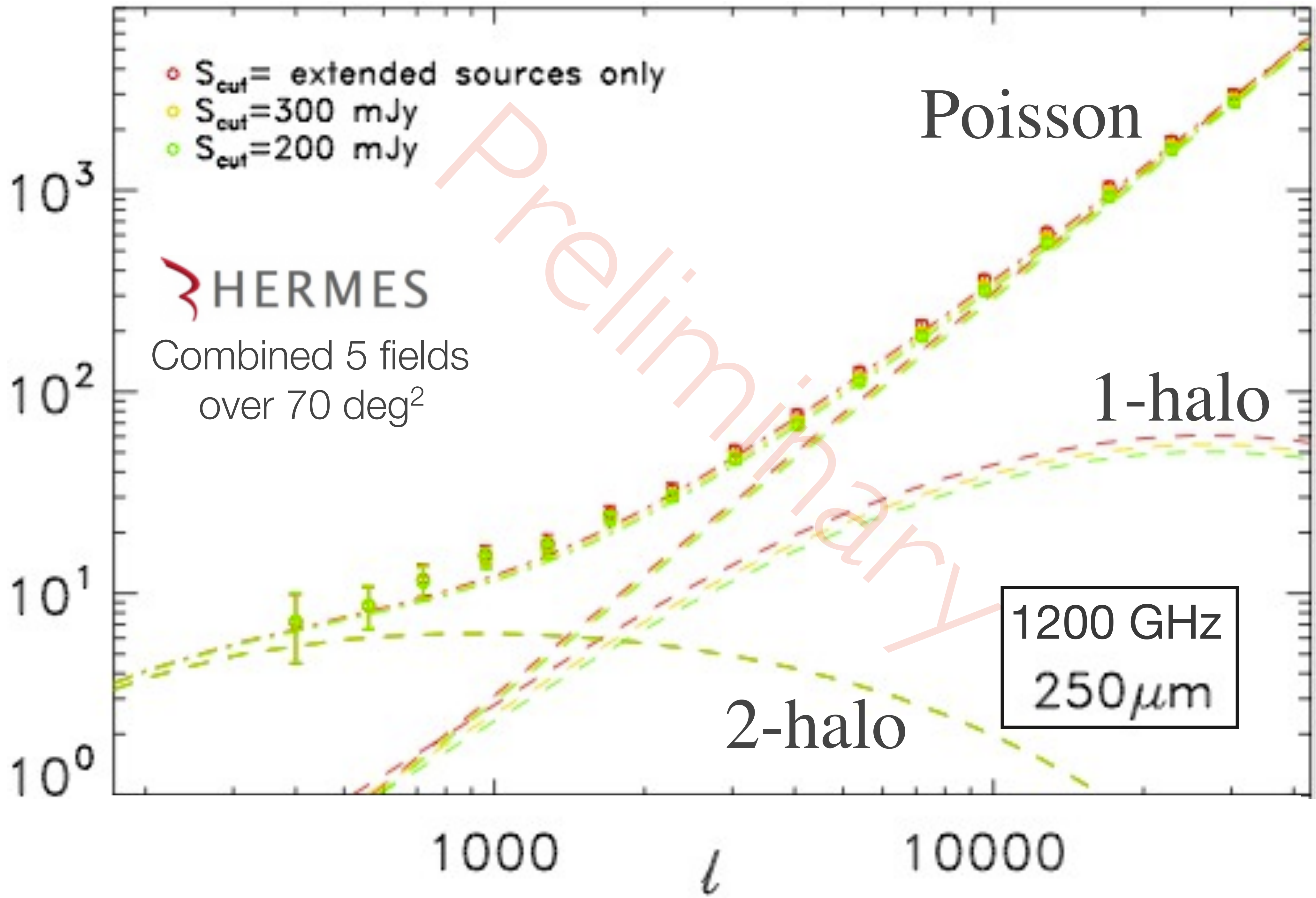
CIB Power Spectra



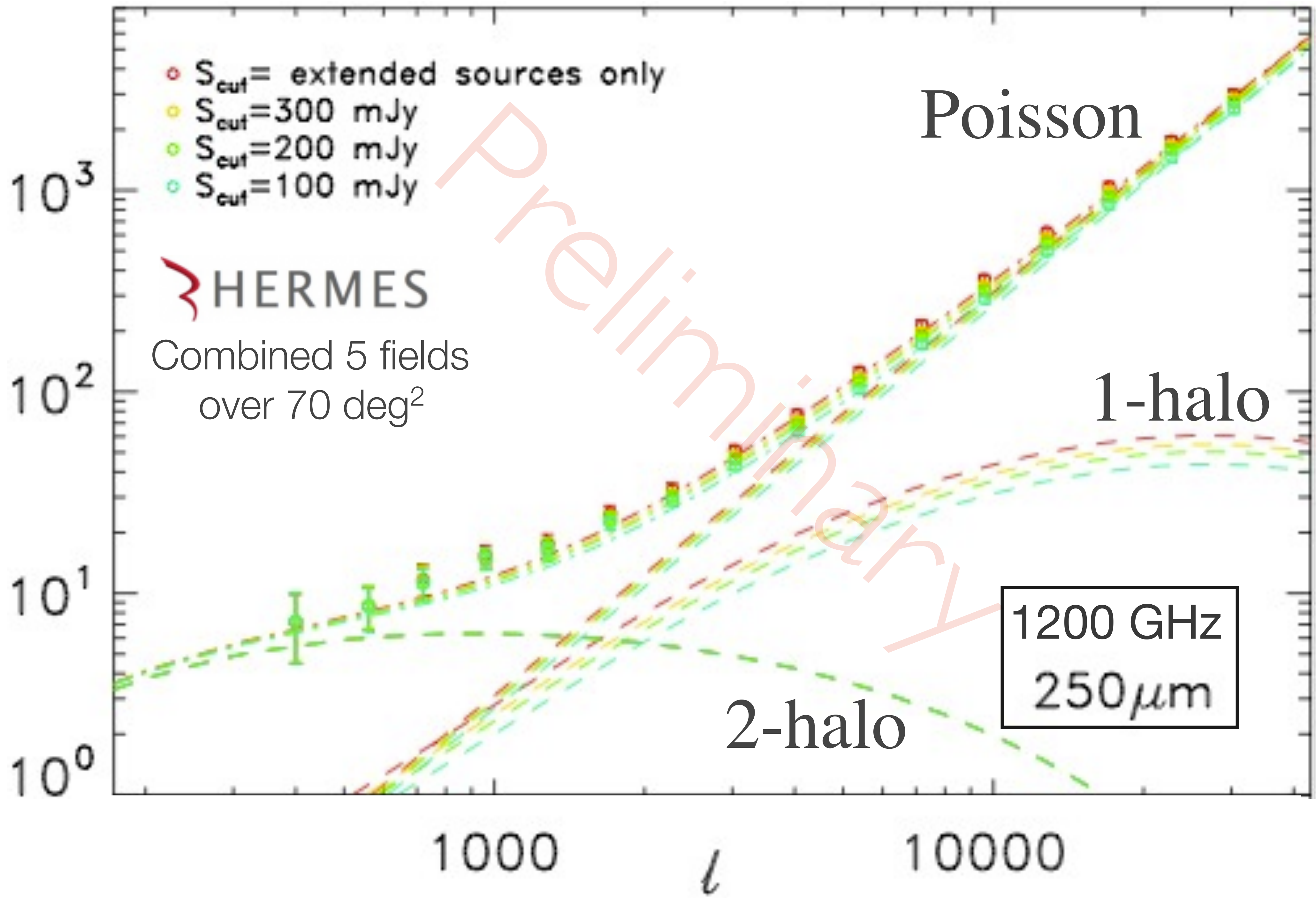
1-halo power vs. Masking



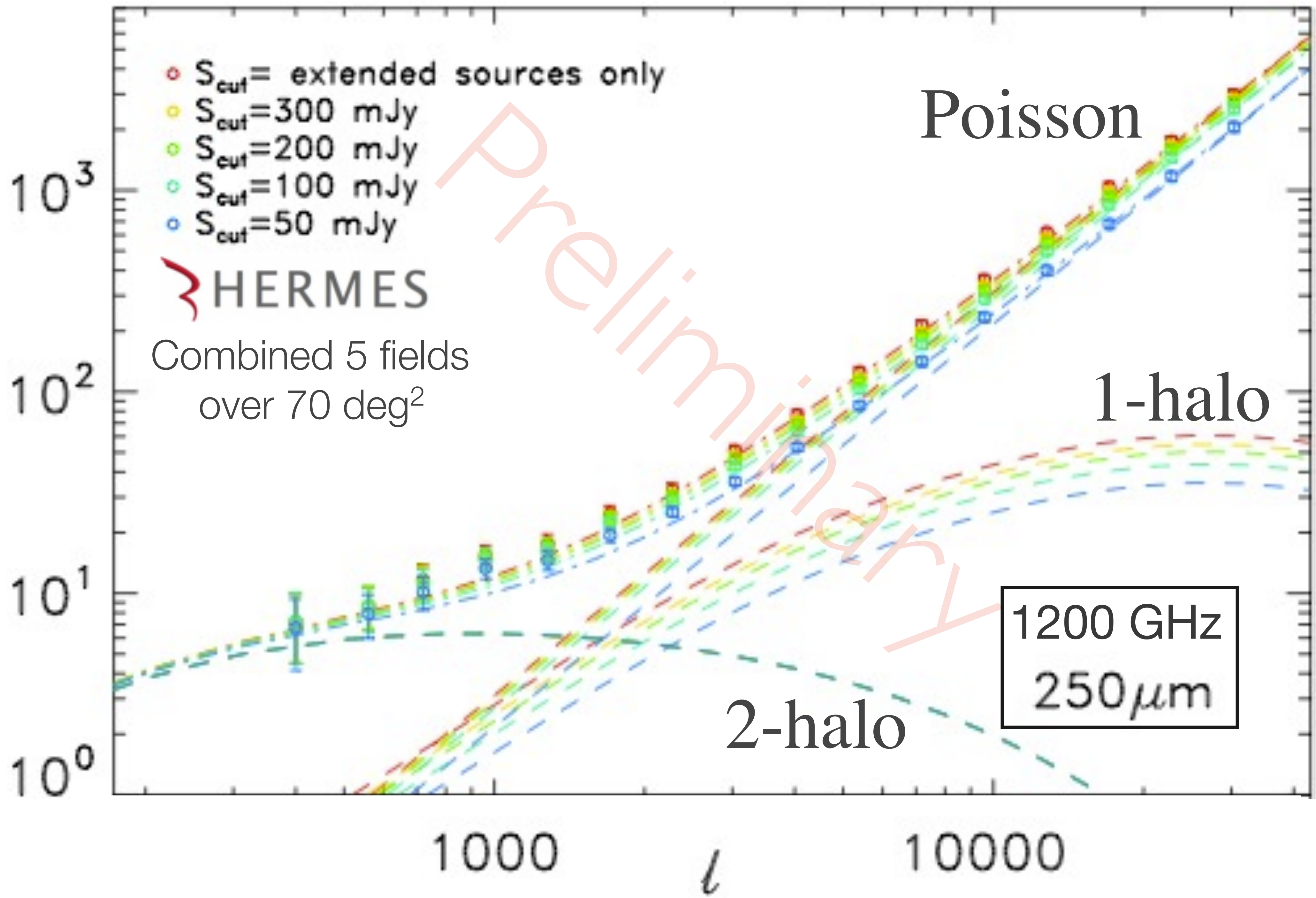
1-halo power vs. Masking



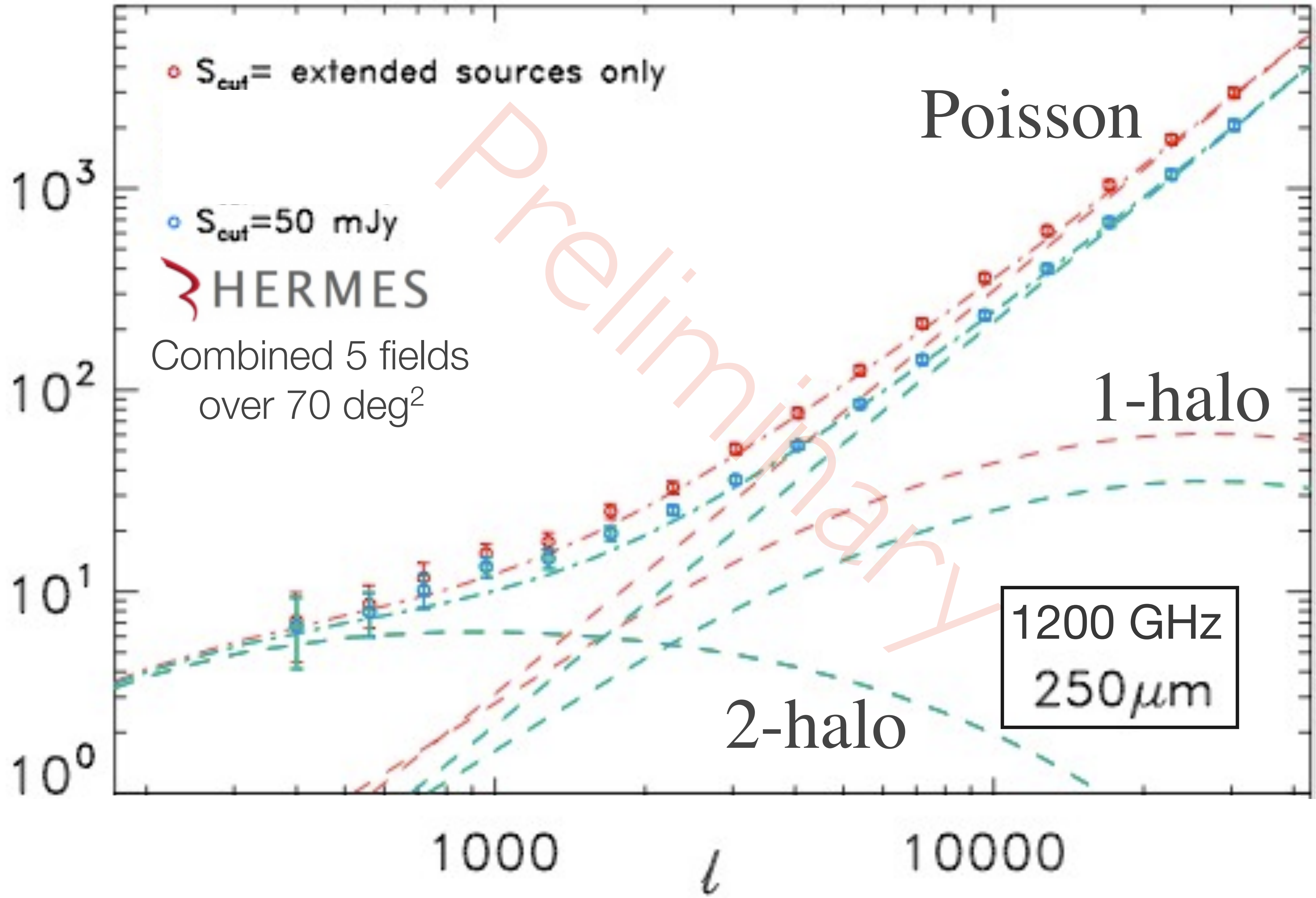
1-halo power vs. Masking



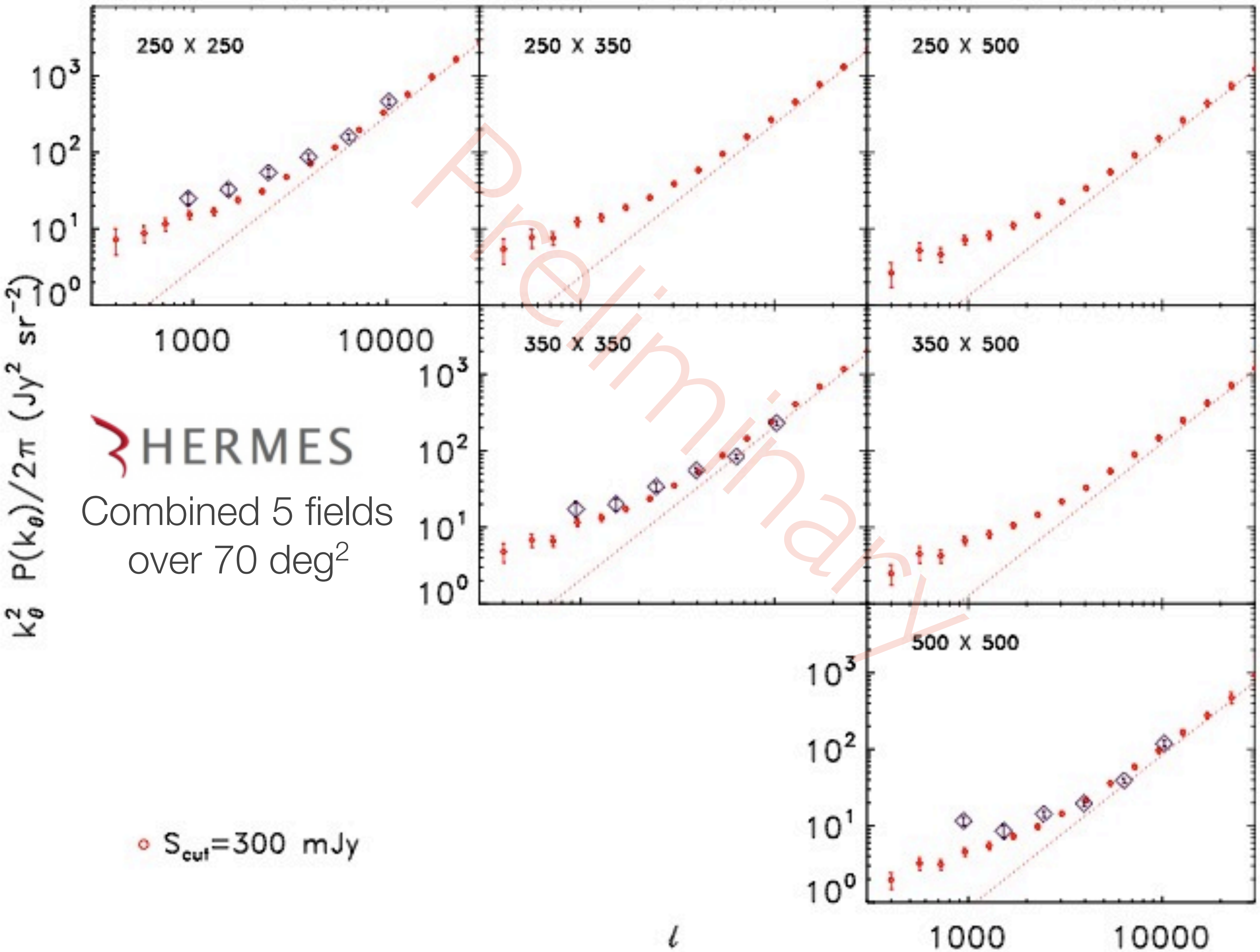
1-halo power vs. Masking



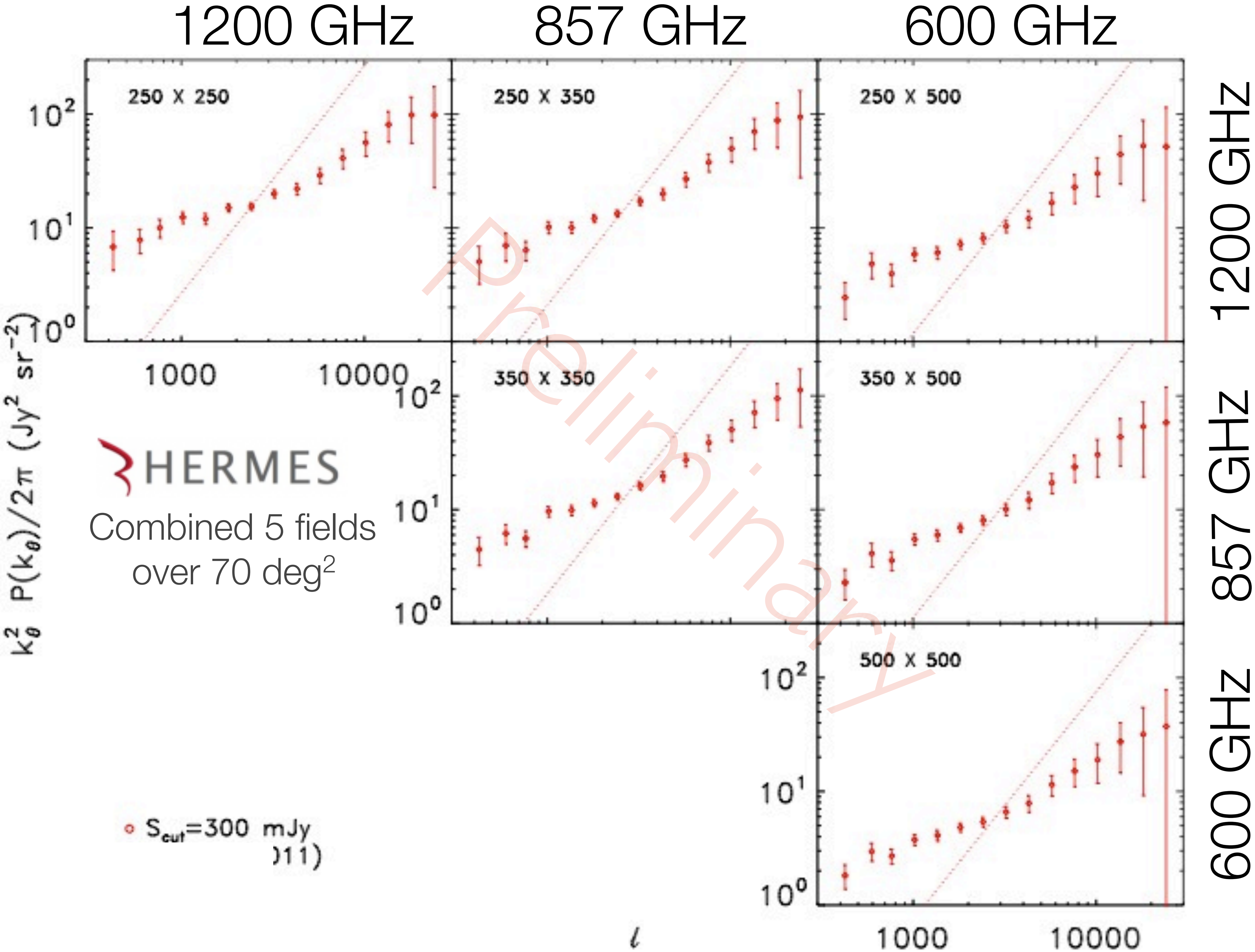
1-halo power vs. Masking



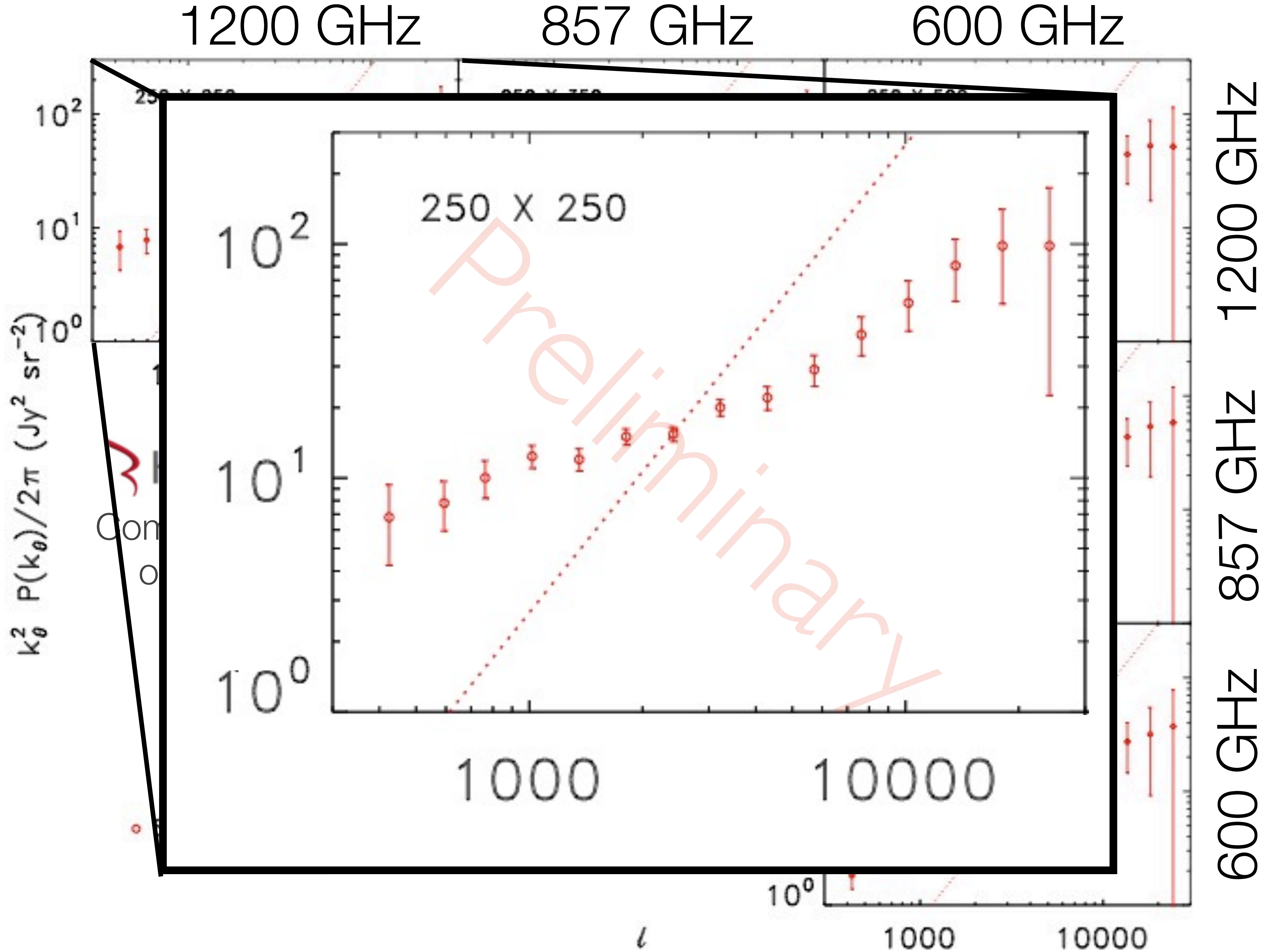
1-halo power vs. Masking



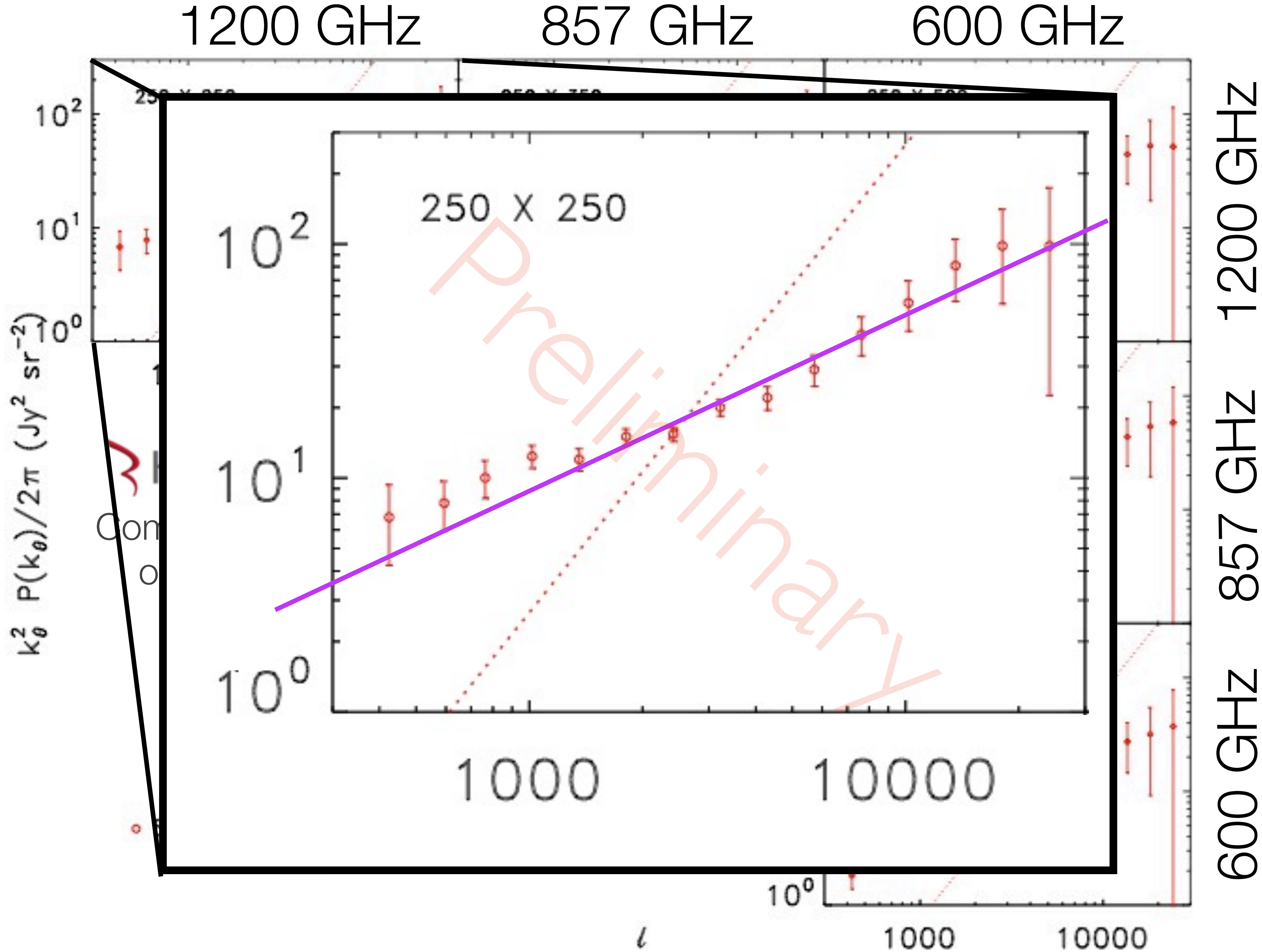
CIB Power Spectra



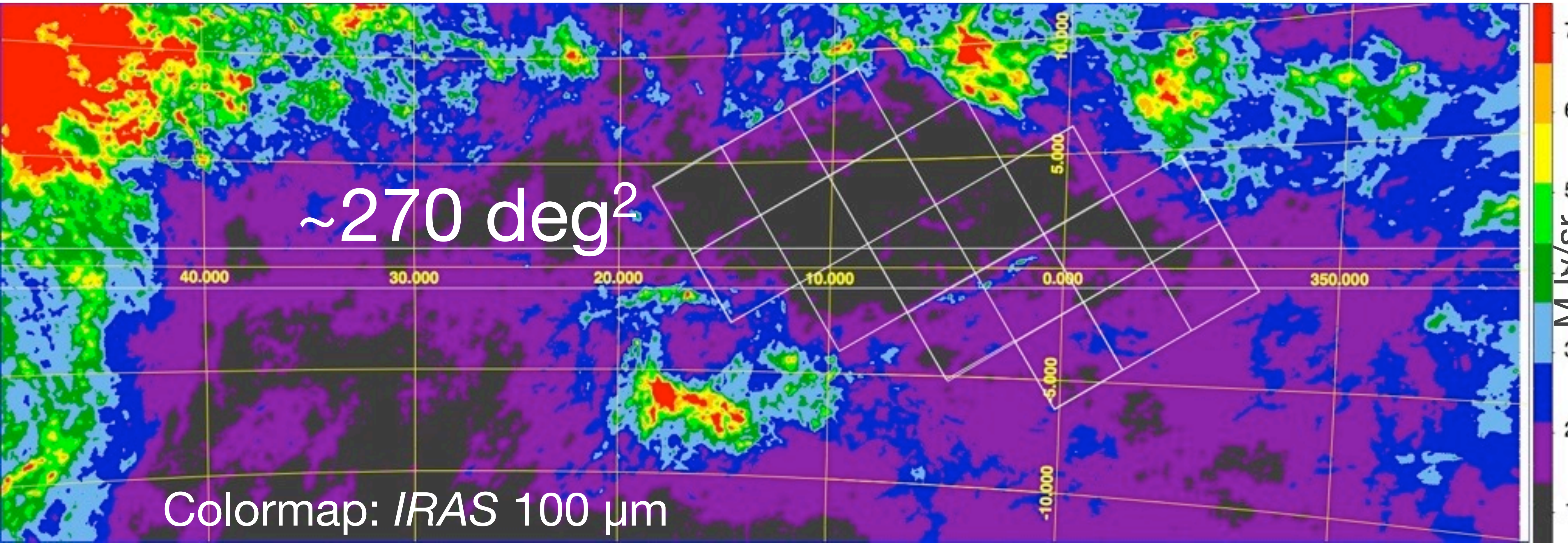
Clustering Spectra



Clustering Spectra



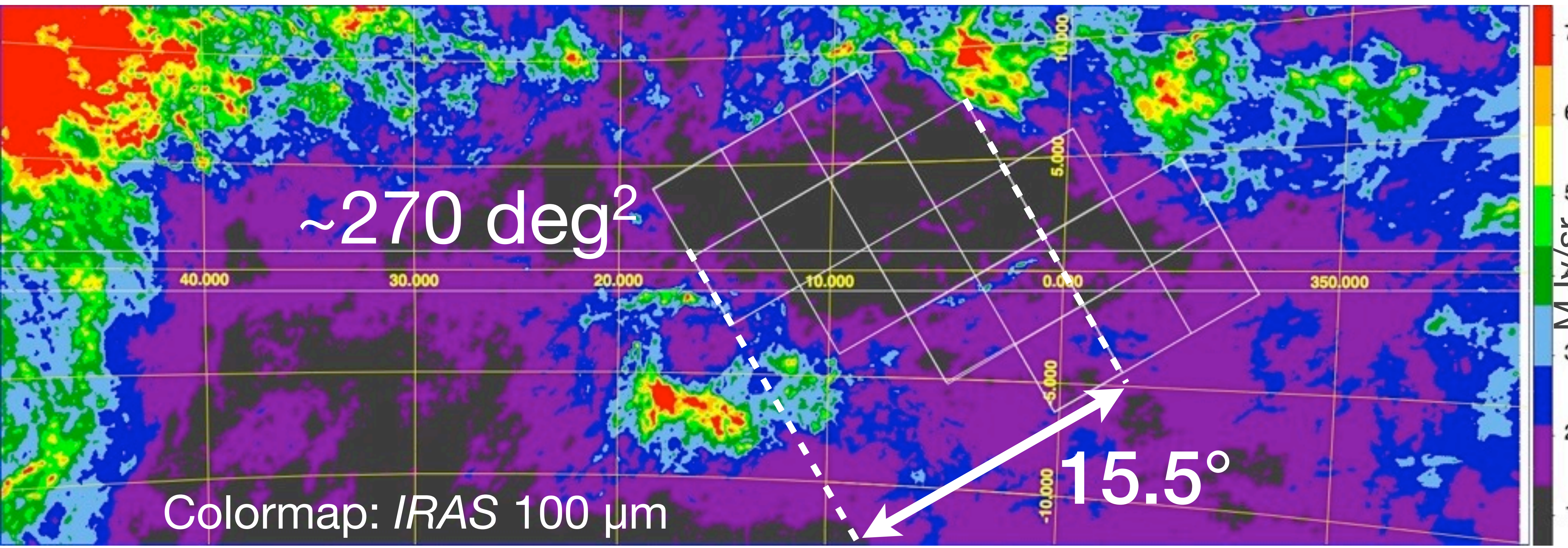
Clustering Spectra



PI: Viero

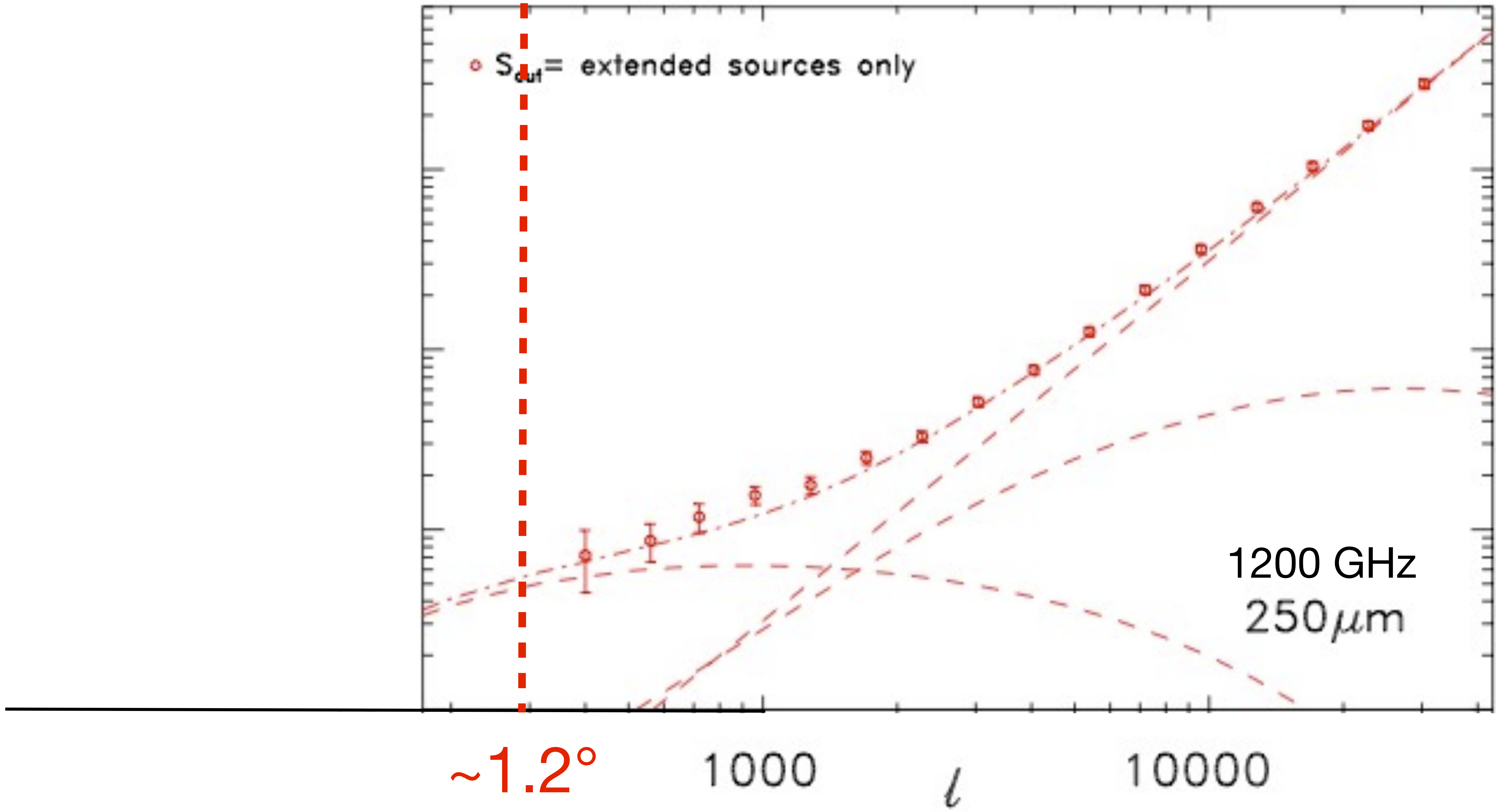
HerMES Large-Mode Survey (HeLMS)

HERMES

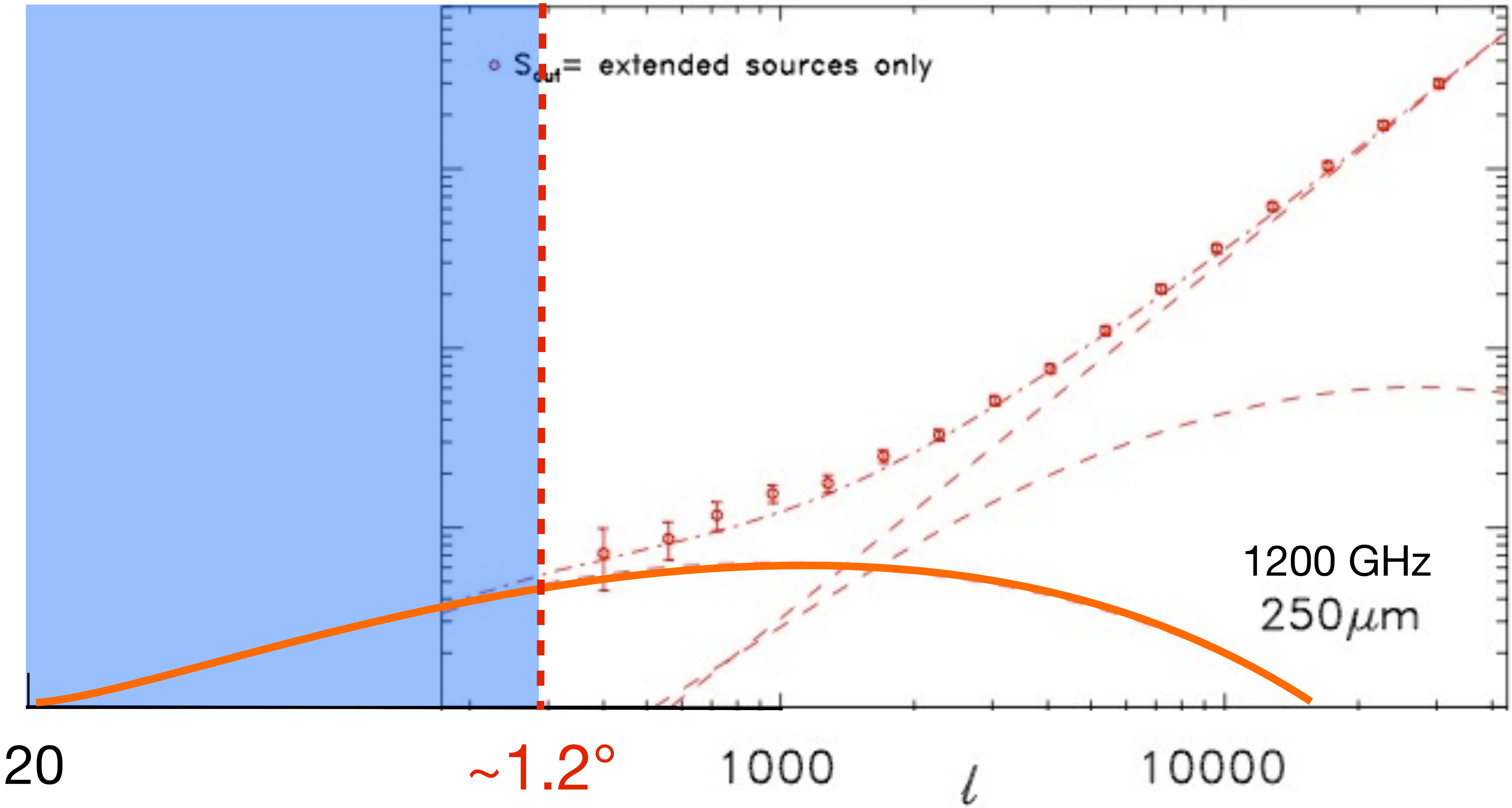


PI: Viero

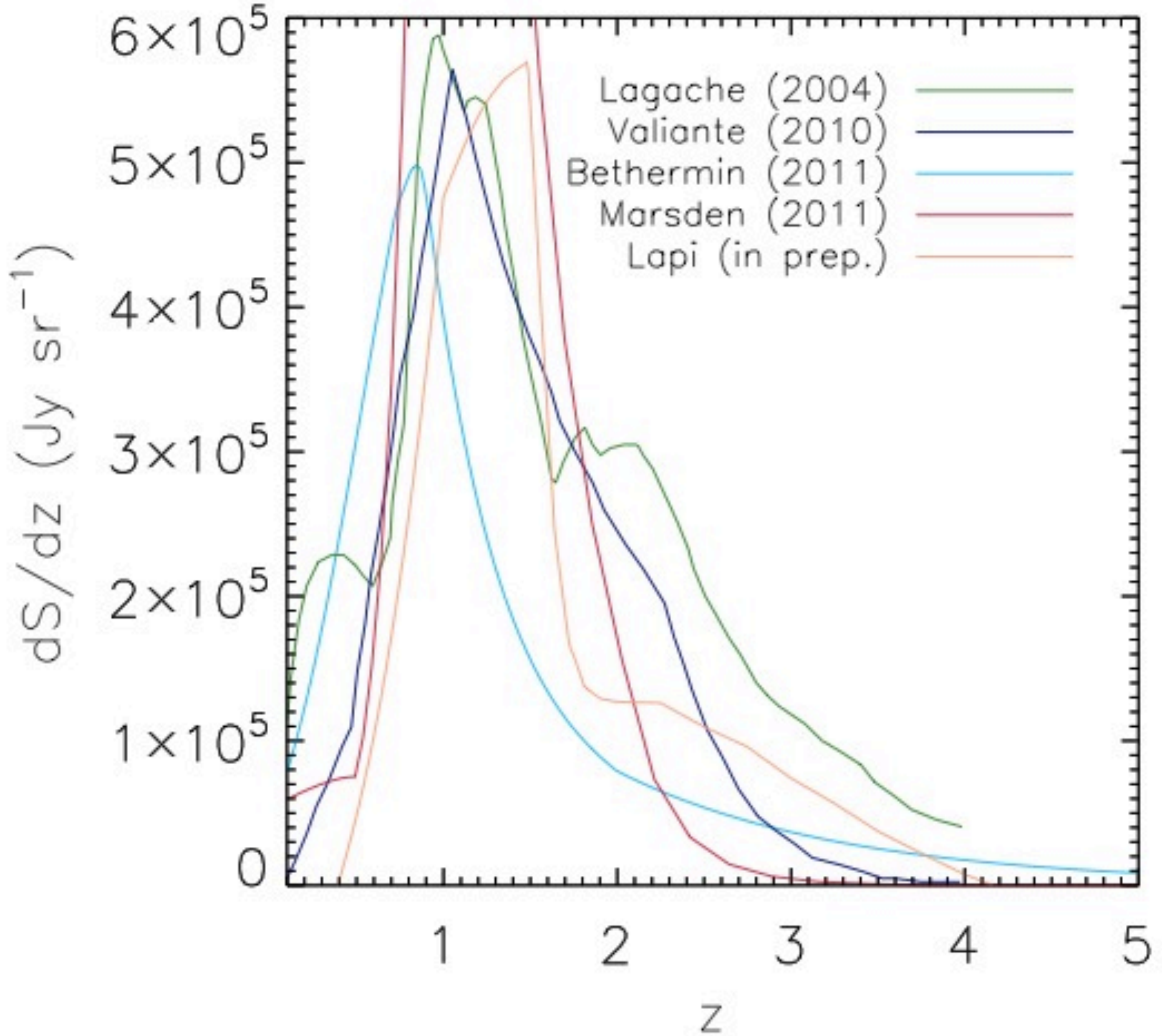
HerMES Large-Mode Survey (HeLMS)



HeLMS

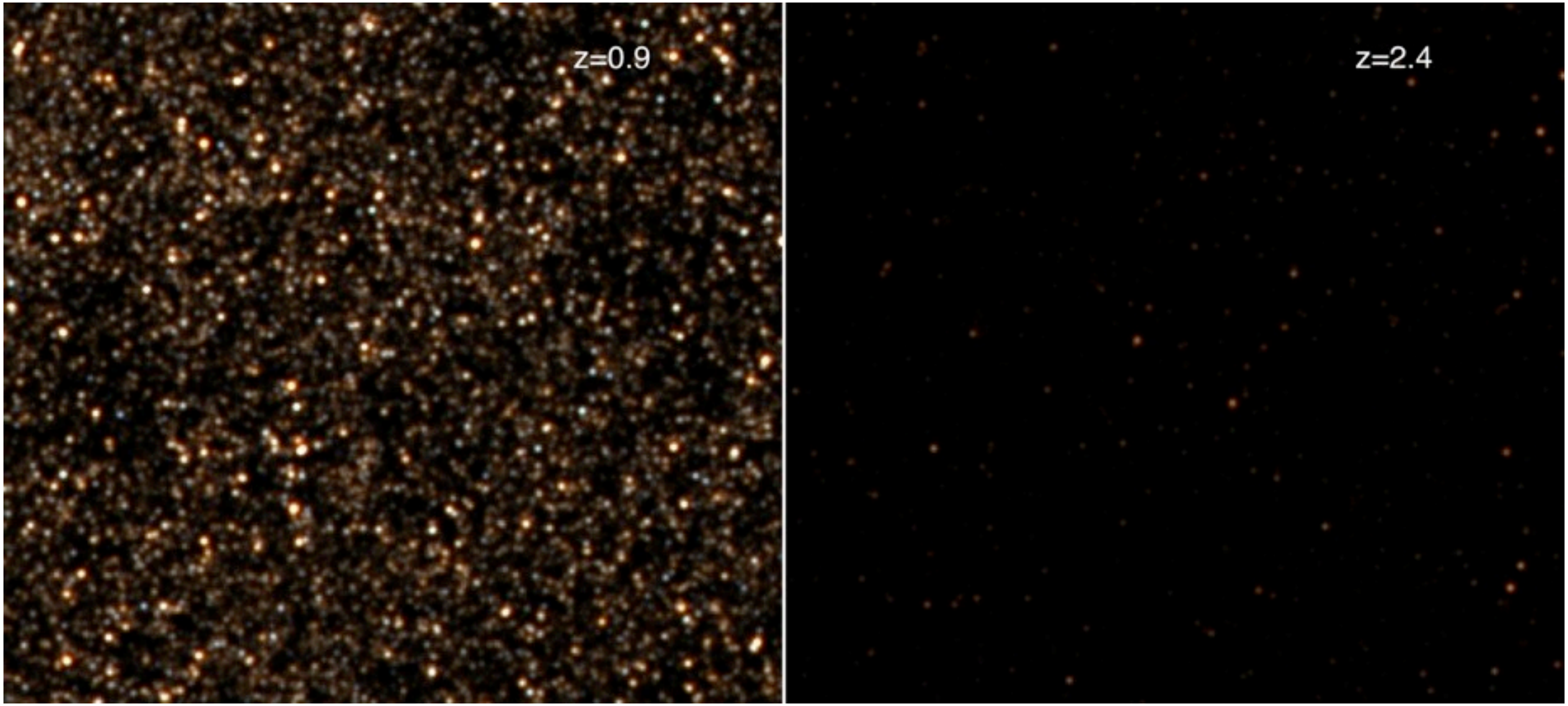


HeLMS

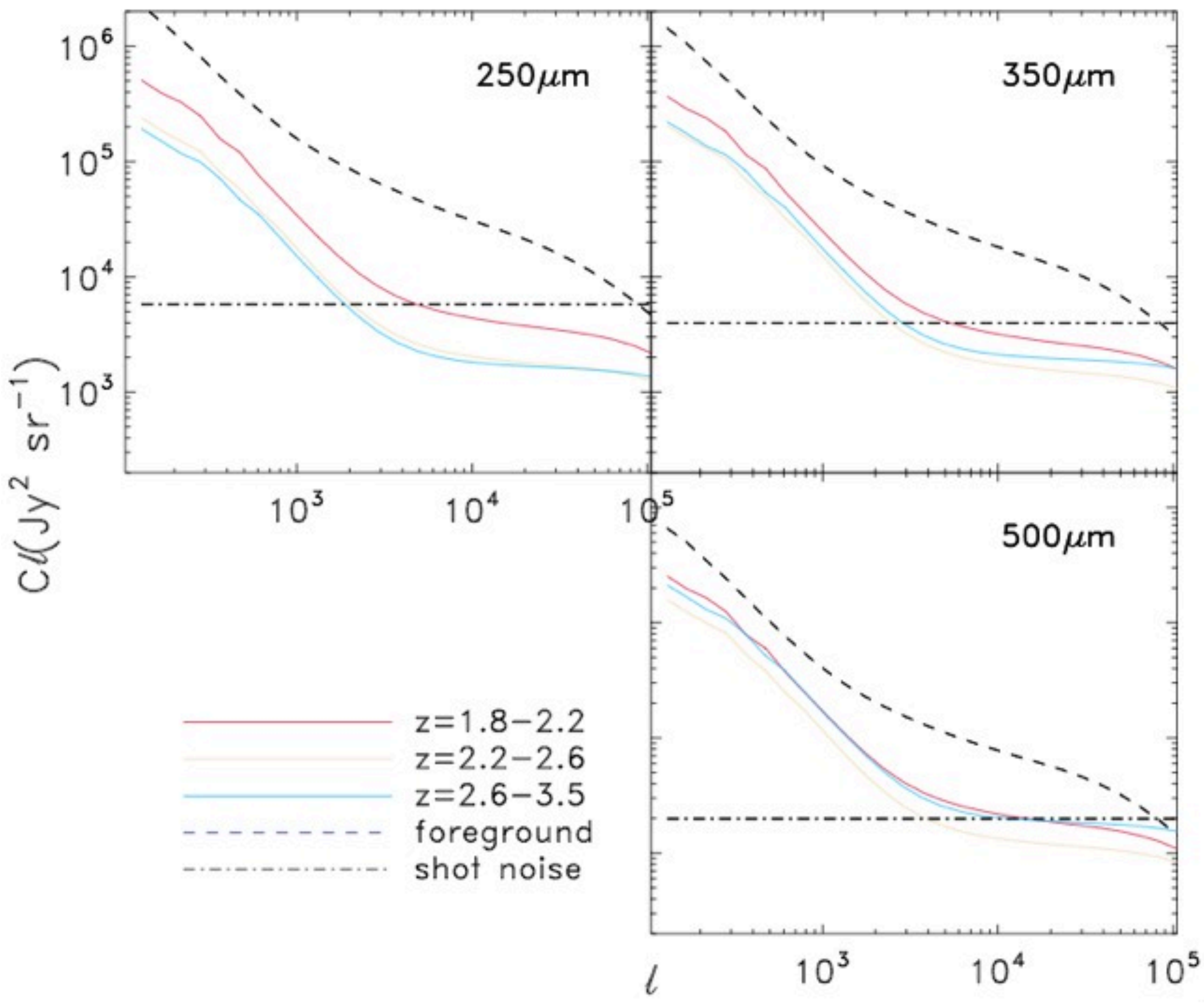


- dS/dz the redshift distribution of background light
- Models do not agree on dS/dz for z > 1

Redshift distribution of CIB

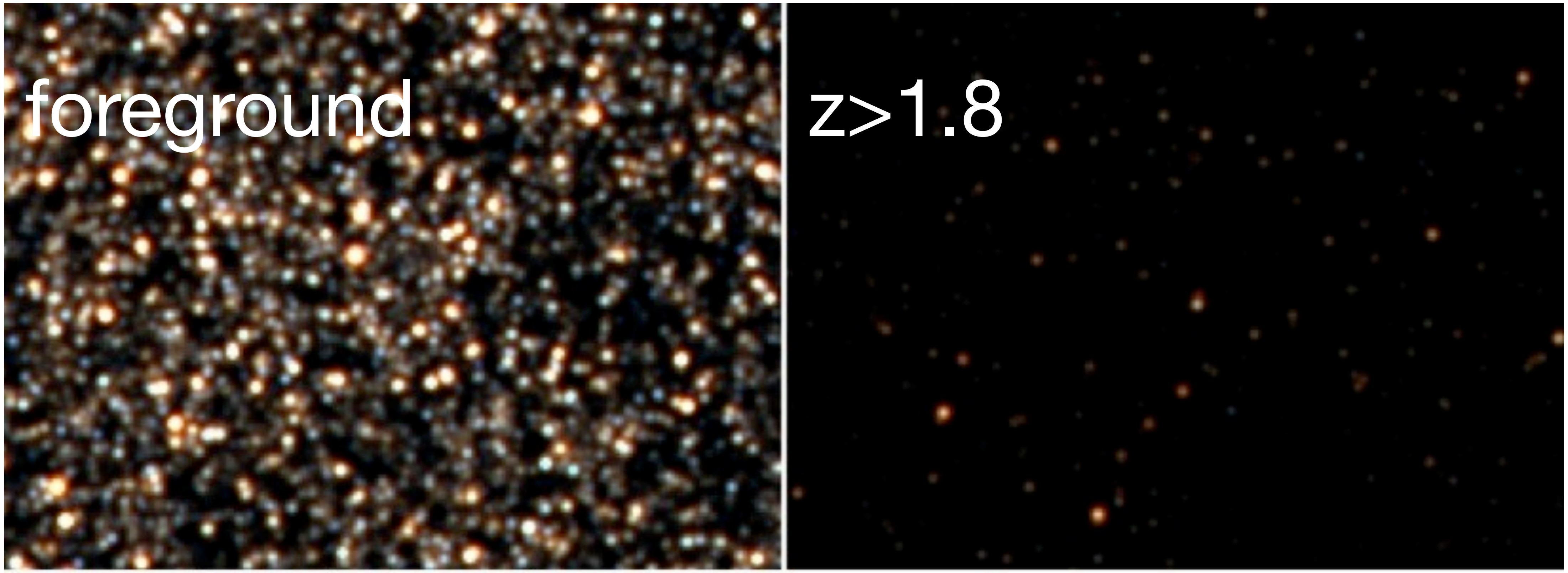


CIB as foreground



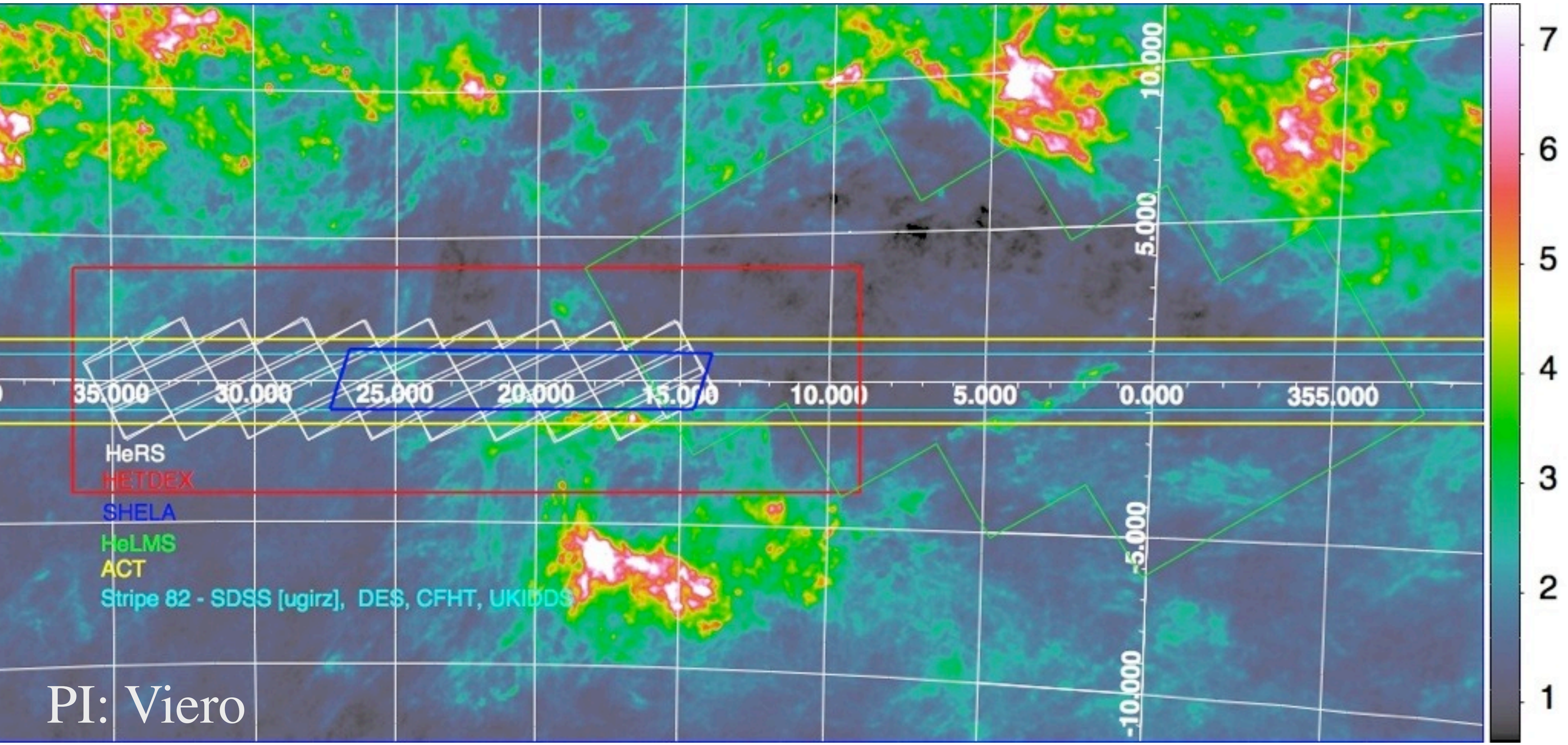
- z > 2 population sub-dominant contribution to total power

Foreground Spectra



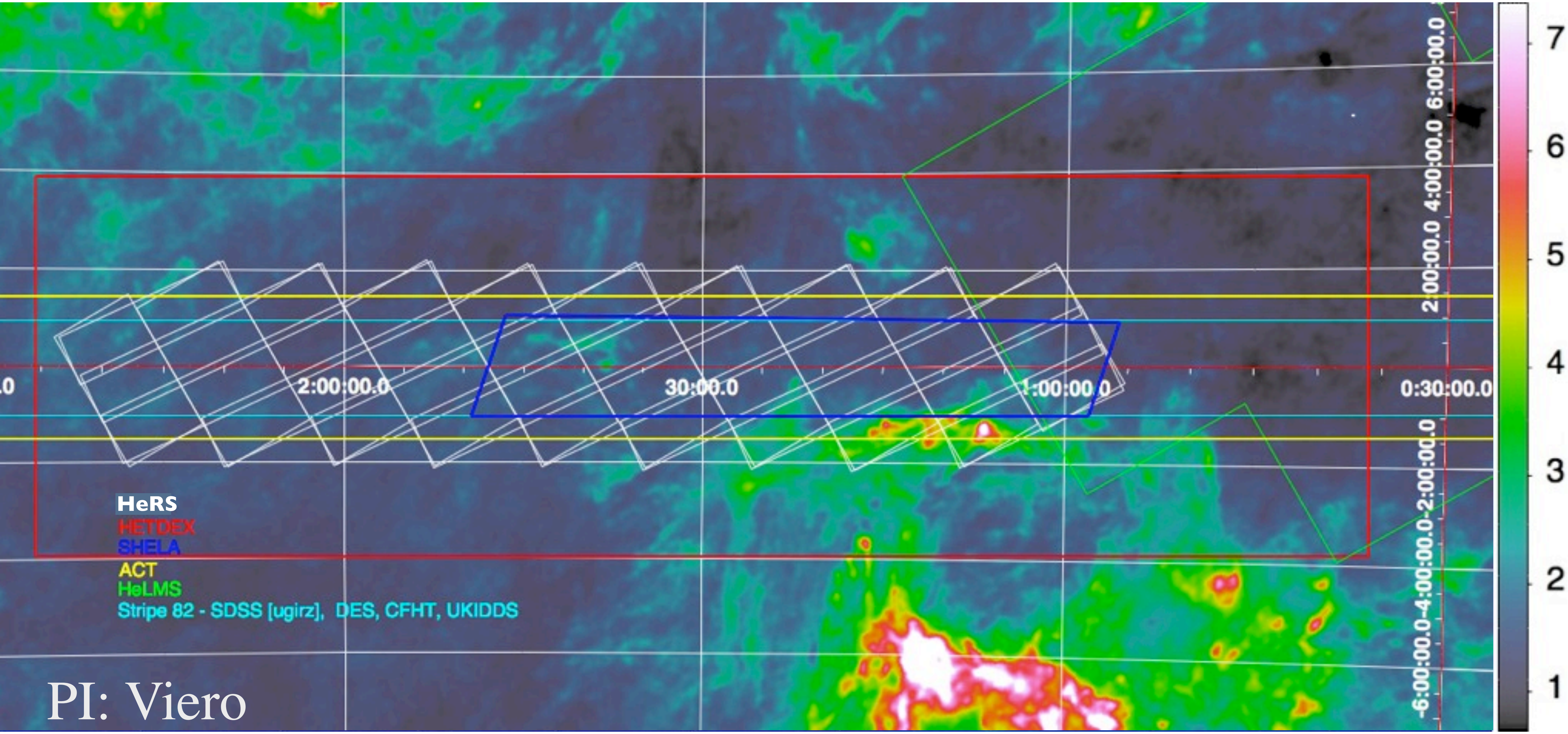
- HETDEX LAEs from $1.8 < z < 3.5$
- Biased tracer of the dark matter, bias known to 1-2%

Herschel Redshift Survey (HeRS)



100 μm map (Galactic cirrus)

Herschel Redshift Survey (HeRS)



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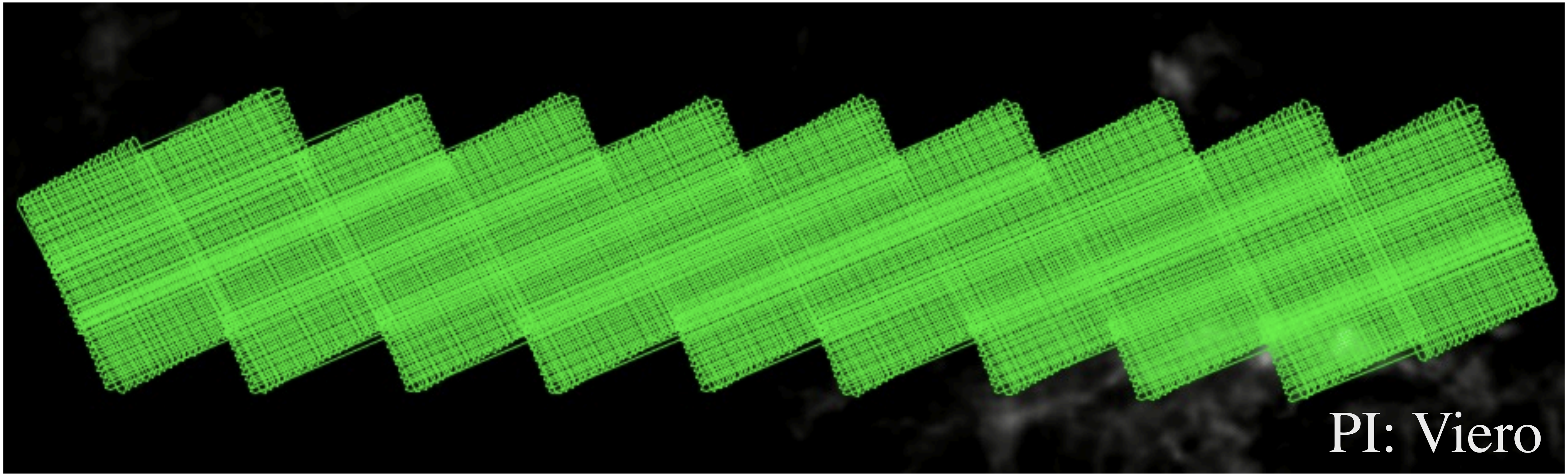
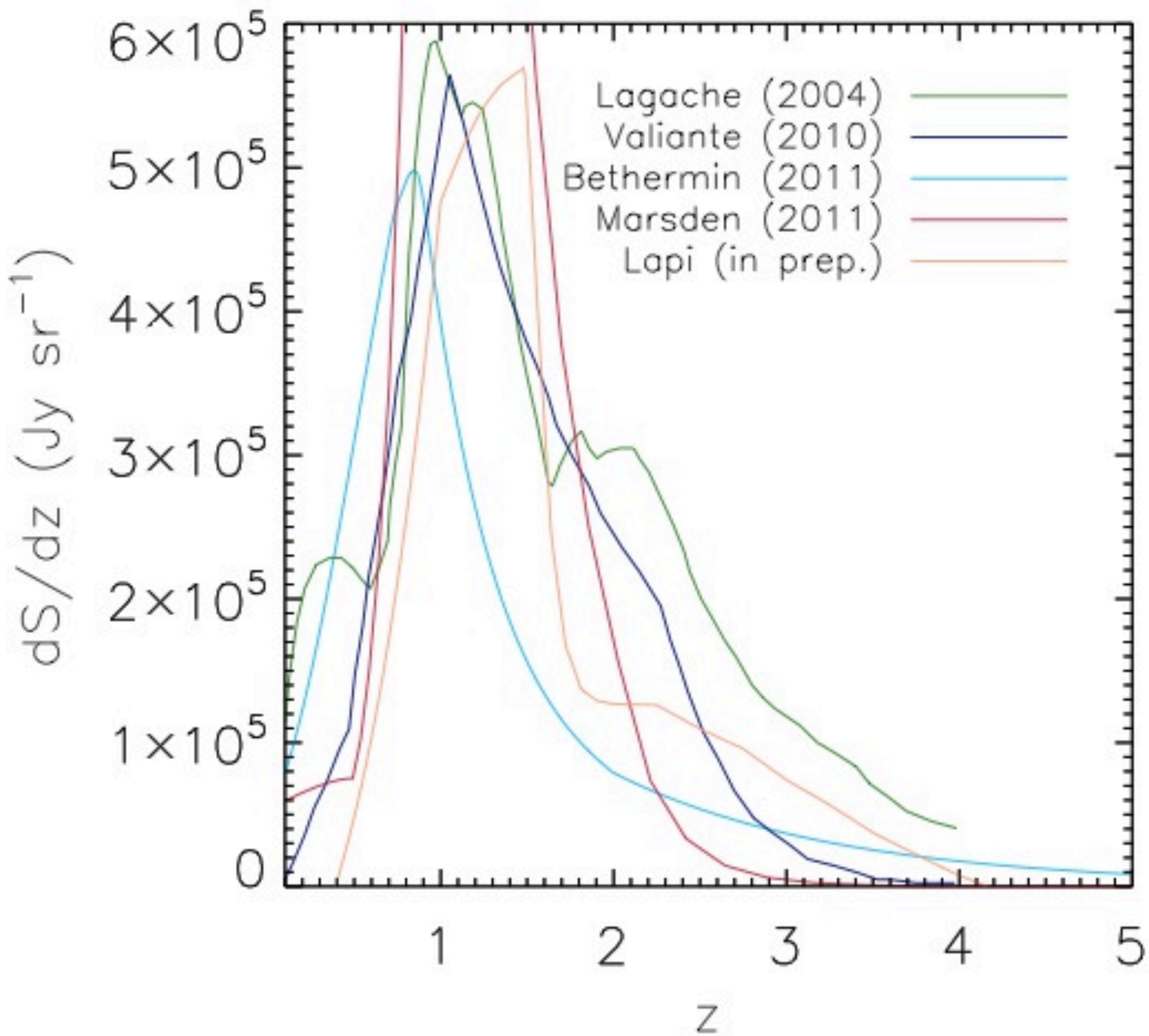


- 250, 350, 500 μm with SPIRE
- 35 hours for 70 deg^2 (Priority 1)
- Fast (60"/s) scans with 90° cross-linking

HeRS AORs



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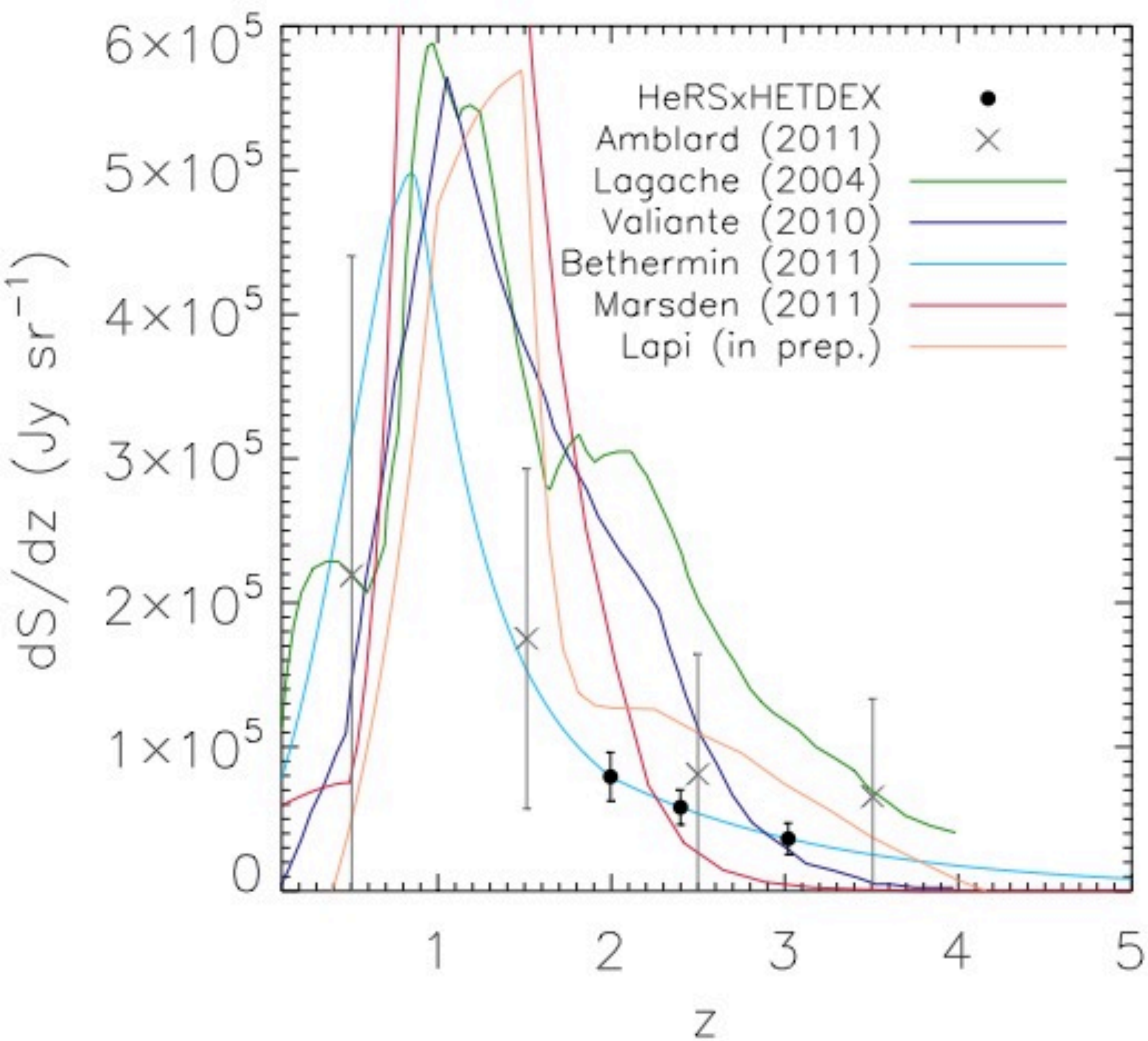

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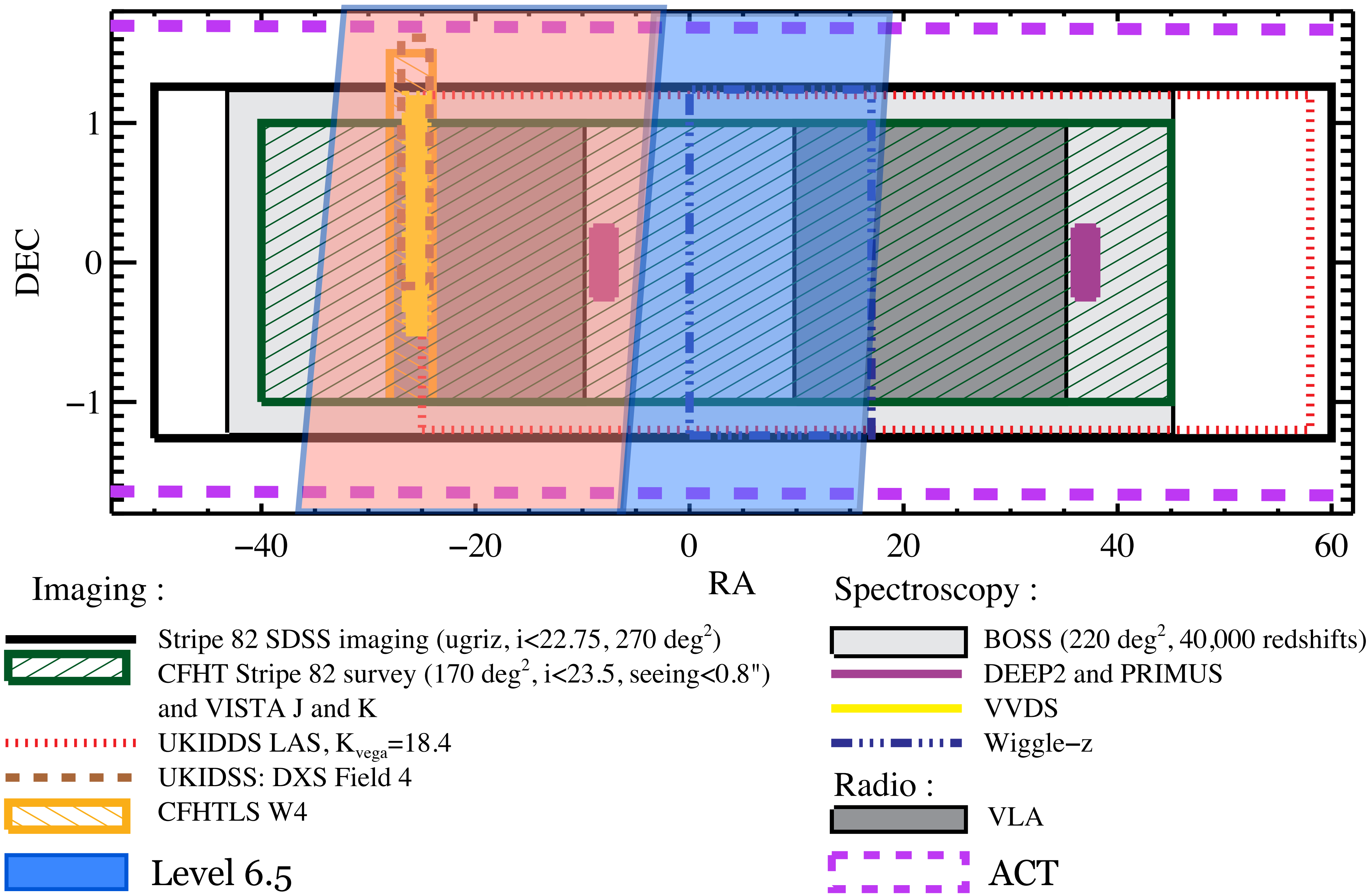

Today

- SDSS optical
- ACT (150 deg^2)
- CFHT
- UKIDDS
- VLA
- Wiggle-z
- BOSS

Tomorrow

- ALMA
- ACTpol
- Spitzer Warm
- HETDEX
- Visible from most sites

HeLMS/HeRS ancillary data

conclusions

- Measure clustering in the Power Spectrum because at best only 15% of flux is “resolved”

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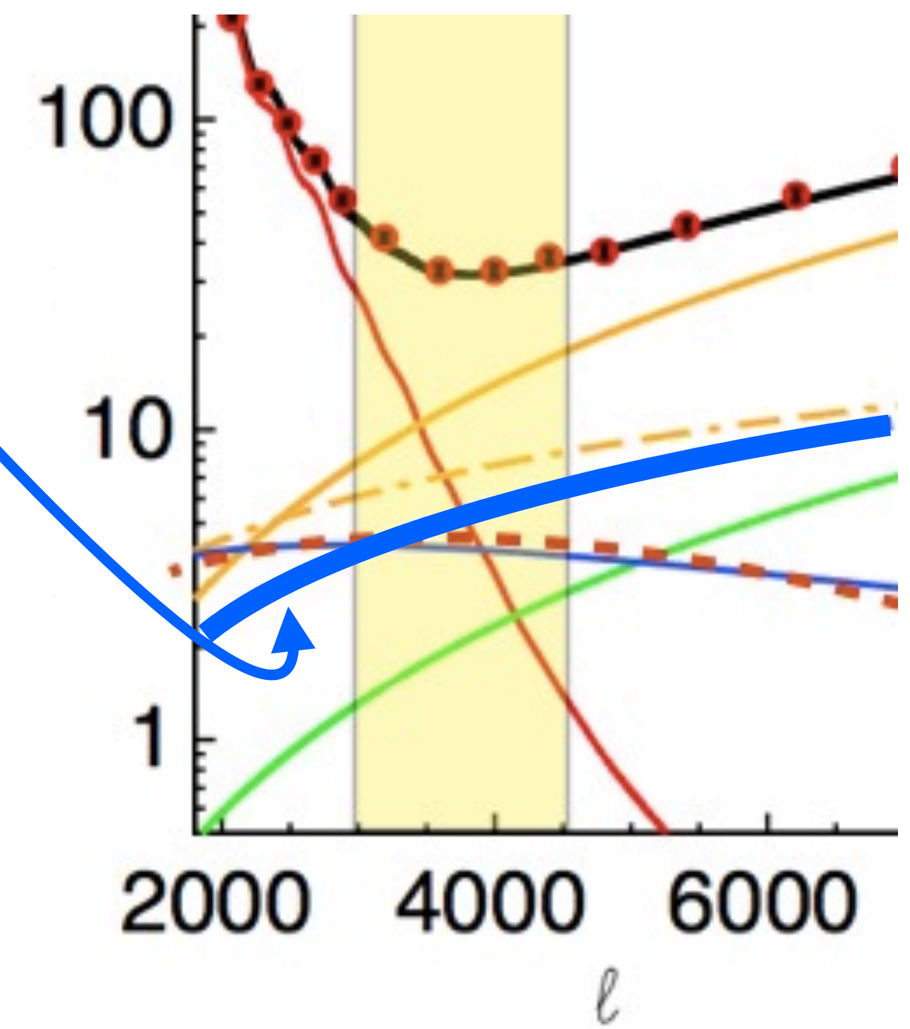
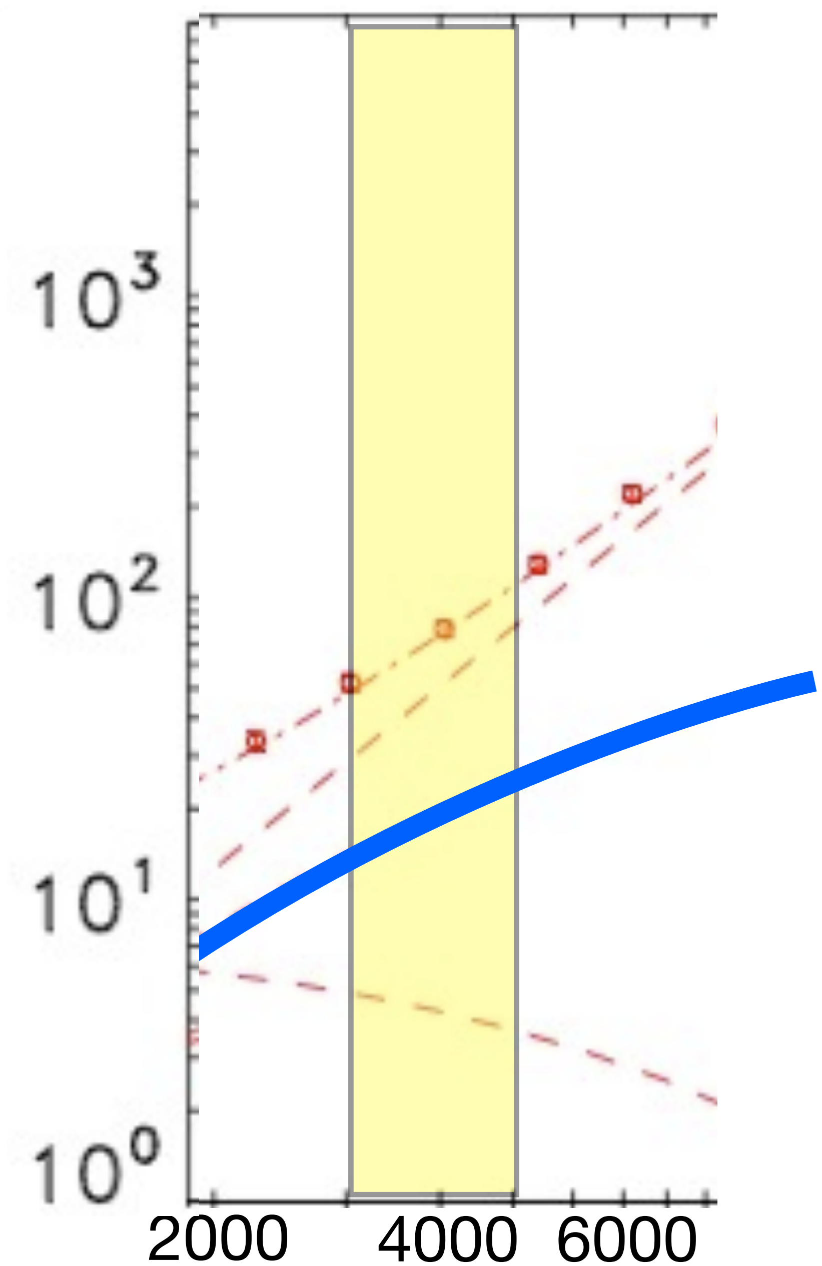
- Strength of 1-halo clustering term a strong function of the masking level



conclusions

- Measure clustering in the Power Spectrum because at best only 15% of flux is "resolved"
- Strength of 1-halo clustering term a strong function of the masking level
- Fitting an HOD to the CIB spectra should provide insight on how DSFGs occupy dark matter halos



conclusions