Resolving the CIRB

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Image Credit: Ashby et al. (2009)

The Near IR EBL

…the **dominant source of error** in directly measuring the CIRB, the model-based subtraction of the **zodiacal light**, will not be significantly reduced with currently available data.

A **directly measured** map of the zodiacal light, which would have to be **observed from outside** the bulk of the IPD cloud, beyond about 3AU…

…could be a **camera on a probe to one of the outer planets**…

…observing the same fields at widely different solar elongations during a long-lived mission **as the craft orbits the Sun**, or by observing during the **cruise from 1 to 3 AU** as the dust density decreases …a space mission of this type will ultimately be required.

- Levenson, Wright & Johnson (2007)

NIR Measurements;
A Discrepancy?

DIRBE Minus 2MASS Foreground Subtraction Wright & Johnson (2001), Wright (2001)	*Spitzer*/IRAC Counts Fazio et al. (2004)
•10.1 ± 7.4 kJy/sr at 1.25 µm •17.6 ± 4.4 kJy/sr at 2.2 µm •16.1 ± 4 kJy/sr at 3.5 µm.	6.5 kJy/sr at 3.6 µm

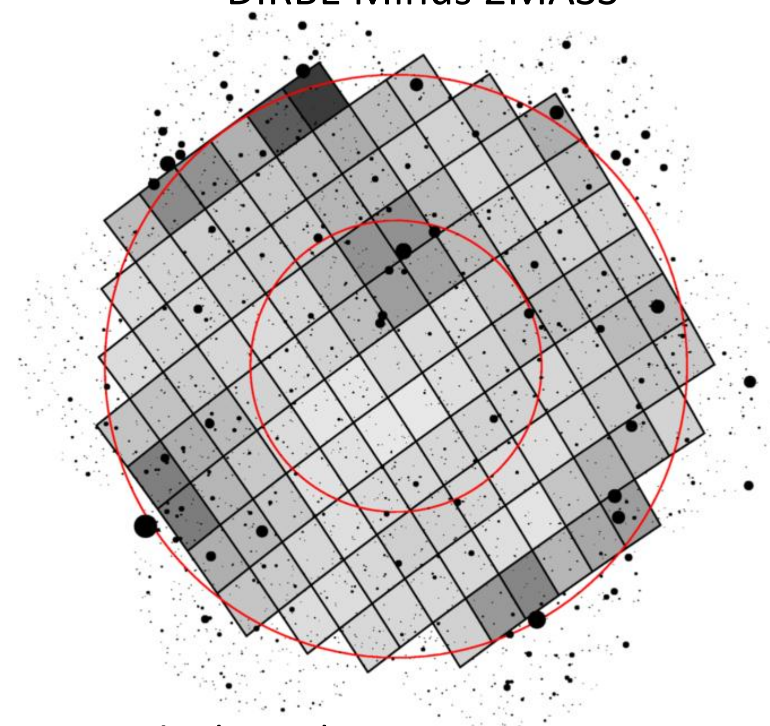
Foreground Subtraction from DIRBE Maps

Zodi Subtraction

Kelsall et al. (1998)

Wright (1998)

DIRBE Minus 2MASS



Wright (2001)

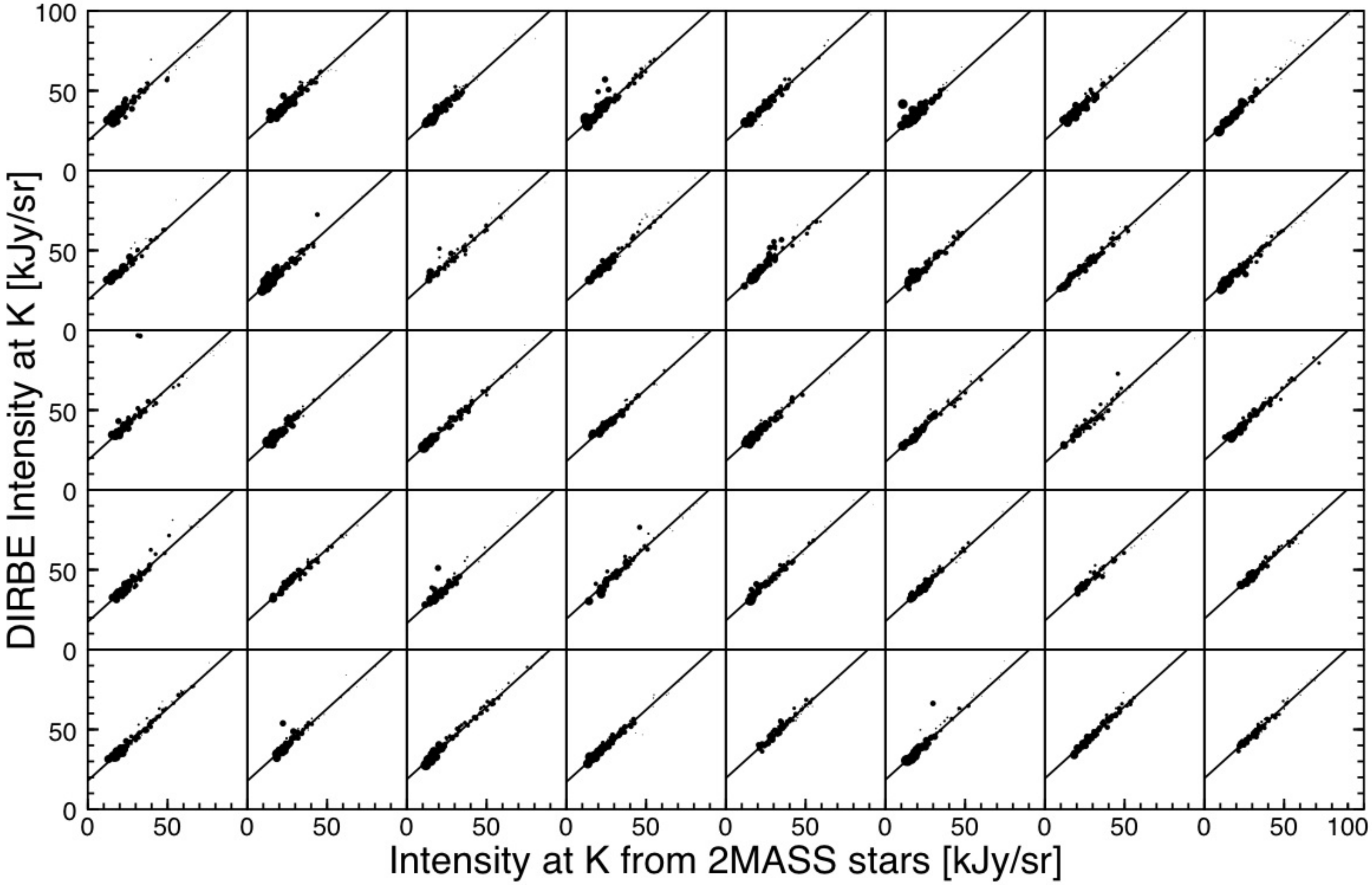
Wright & Johnson (2001)

Levenson, Wright & Johnson (2007)

$$I_{DIRBE} = I_{ZODI} + I_{STAR} + I_{M} + I_{CIRB}$$

DIRBE Minus 2MASS

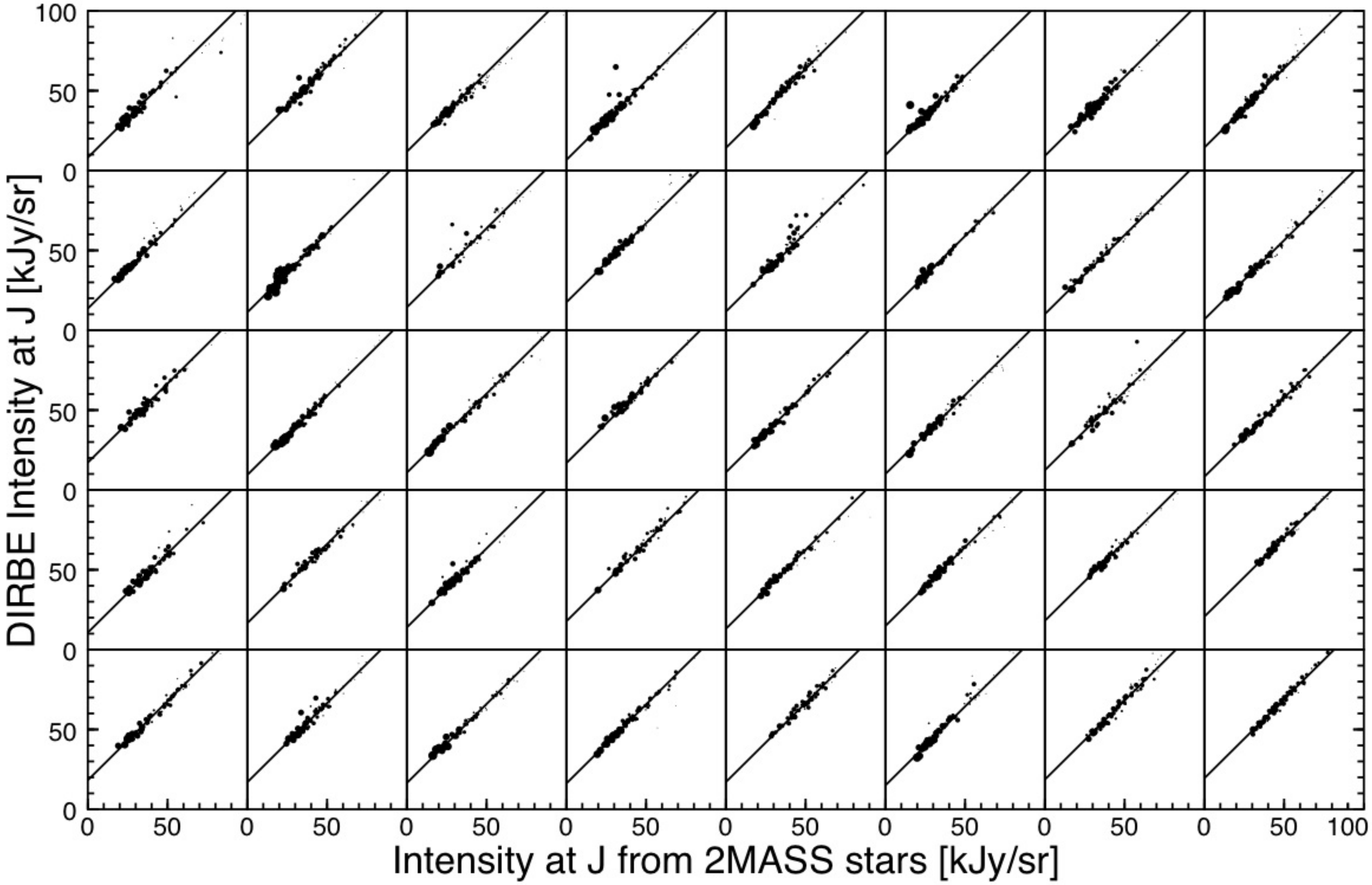
40 New Regions at 2.2 Microns



Levenson, Wright & Johnson (2007)

DIRBE Minus 2MASS

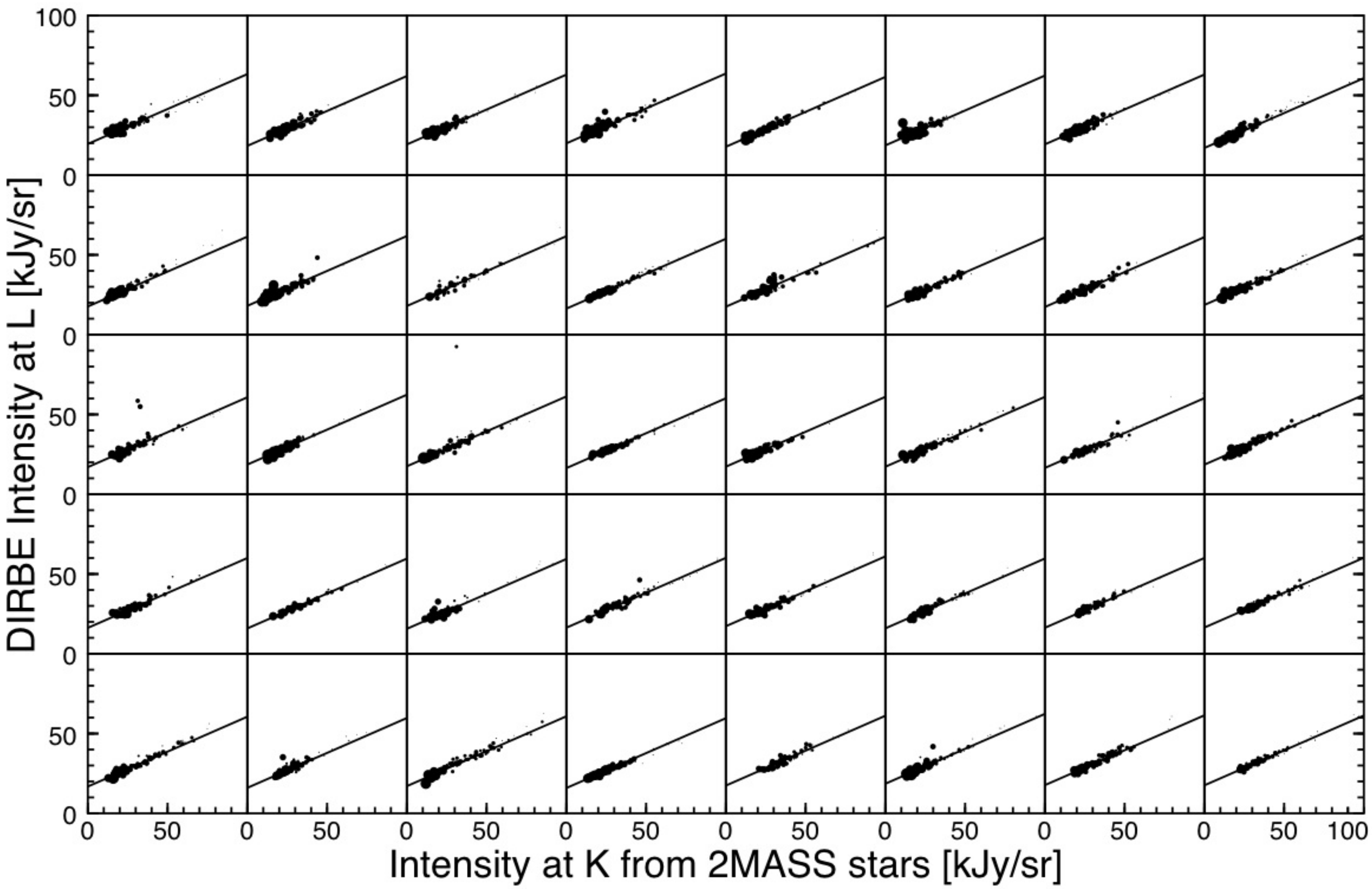
40 New Regions at 1.25 Microns



Levenson, Wright & Johnson (2007)

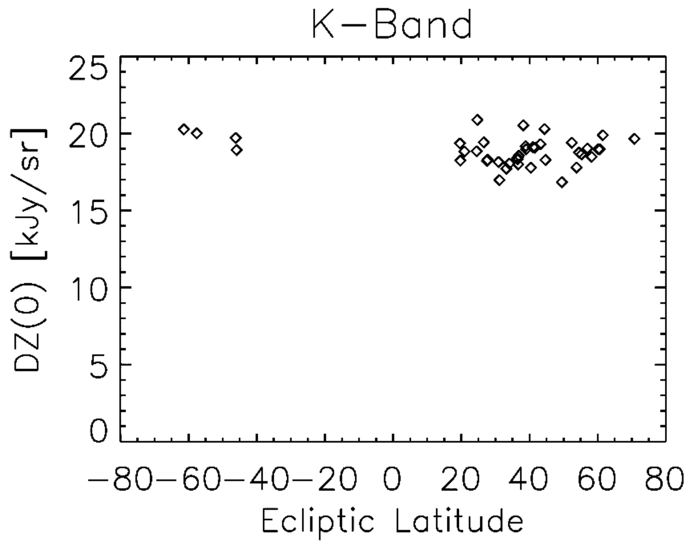
DIRBE Minus 2MASS

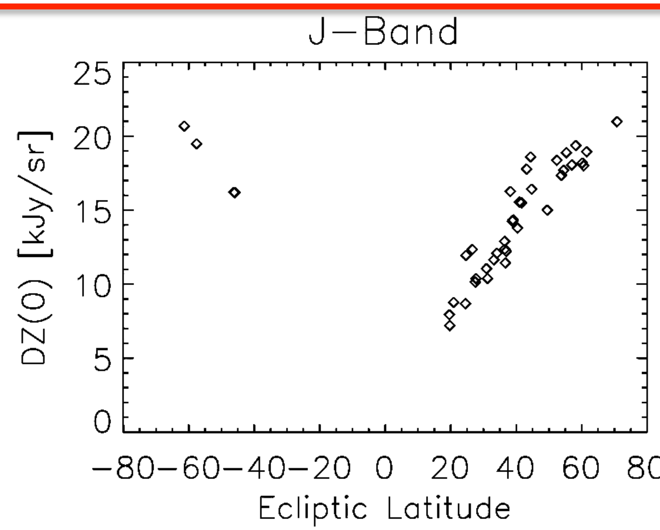
40 New Regions at 3.5 Microns



Levenson, Wright & Johnson (2007)

CIRB vs Ecliptic Latitude





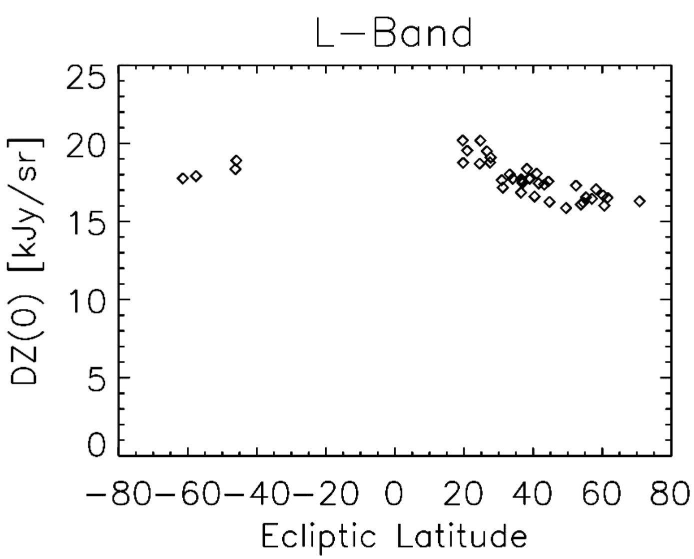
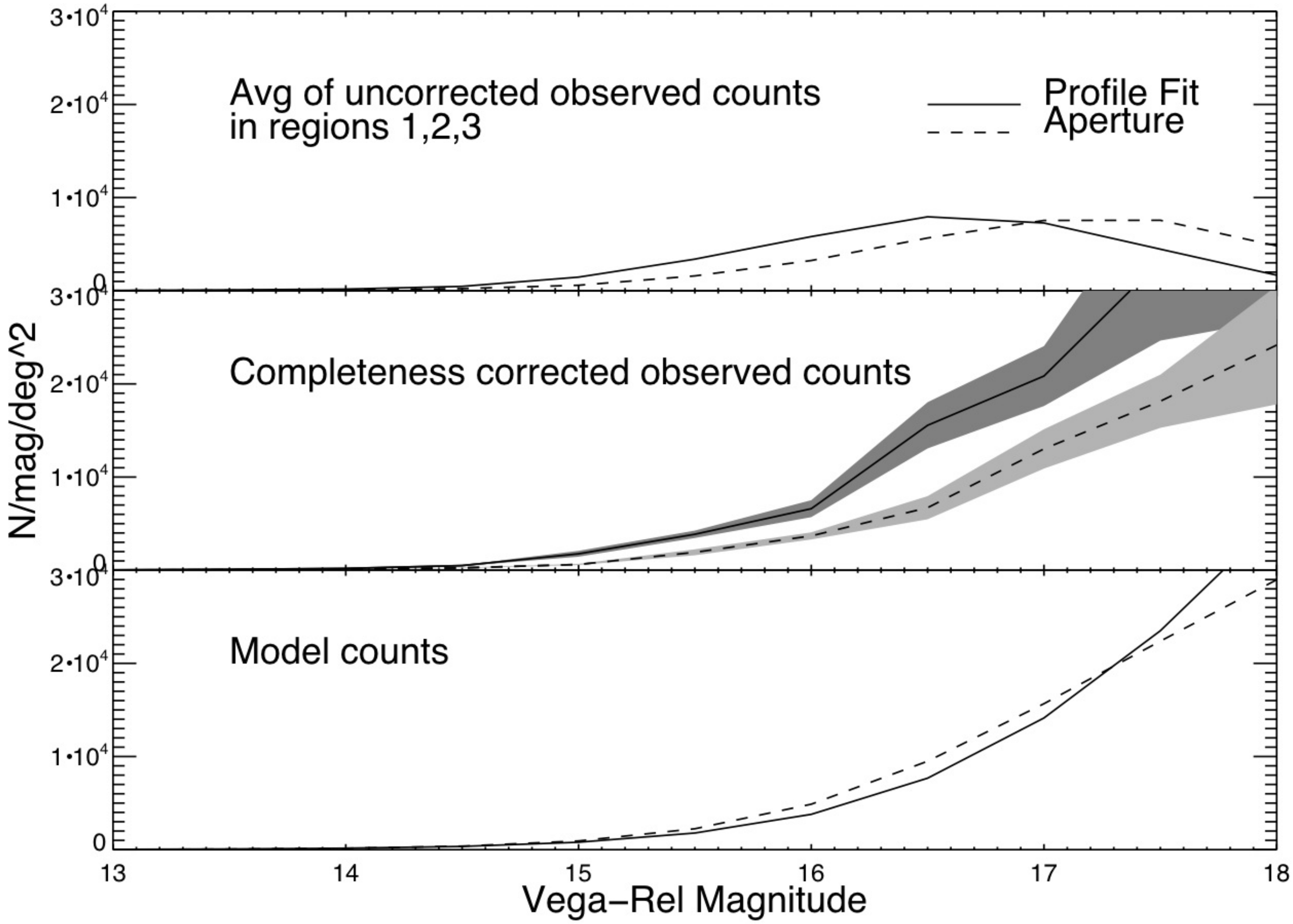


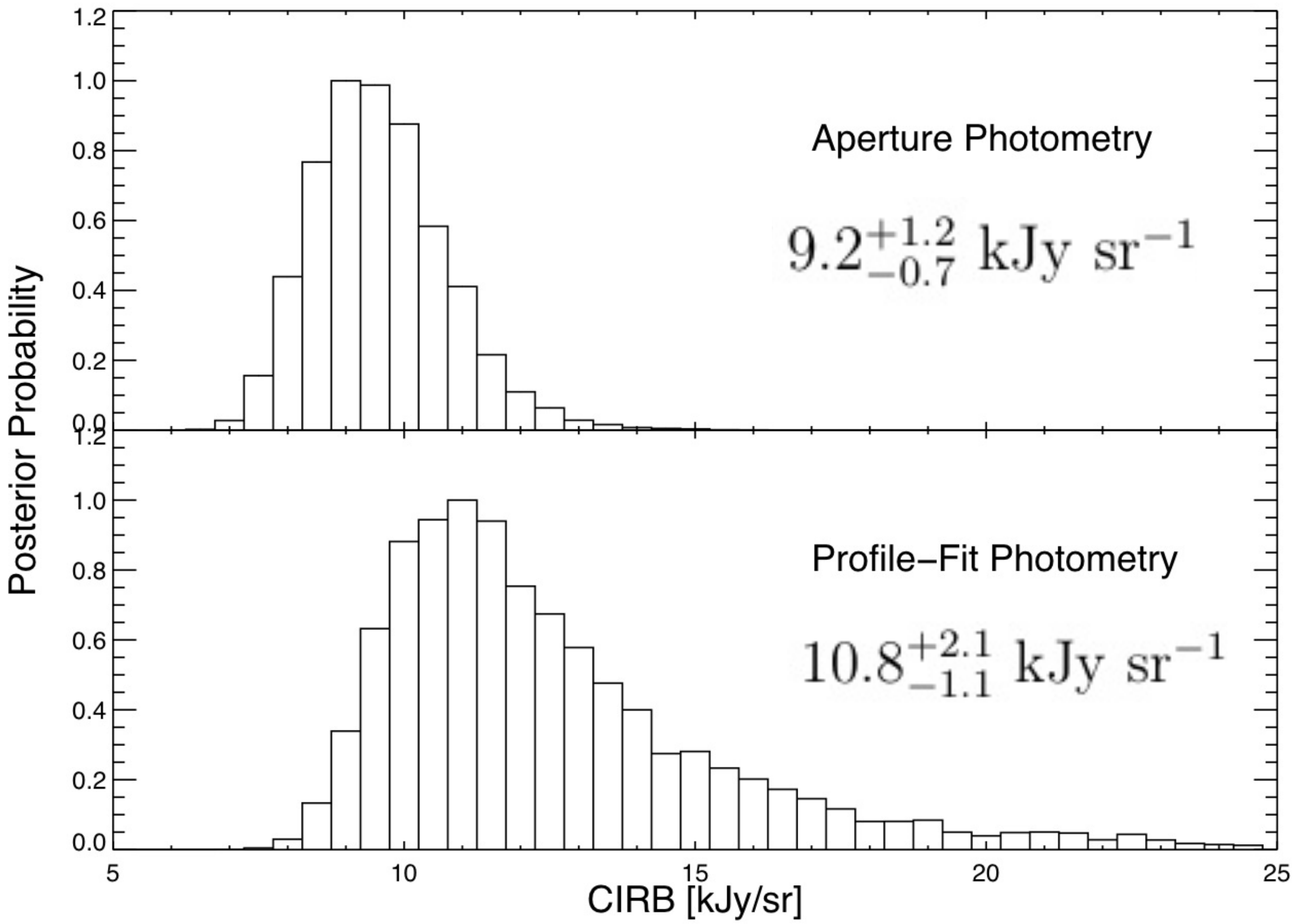
Table 5. Error Budget for the CIRB [kJy/sr]

Component	1.25 μm	2.2 μm	3.5 μm
Scatter	0.51	0.14	0.20
Faint Source	1.17	0.85	0.42
Galaxies	0.05	0.10	0.05
Calibration	1.77	2.24	0.60
Zodiacal	5.87	3.79	3.25
Quadrature Sum	6.26	4.49	3.34

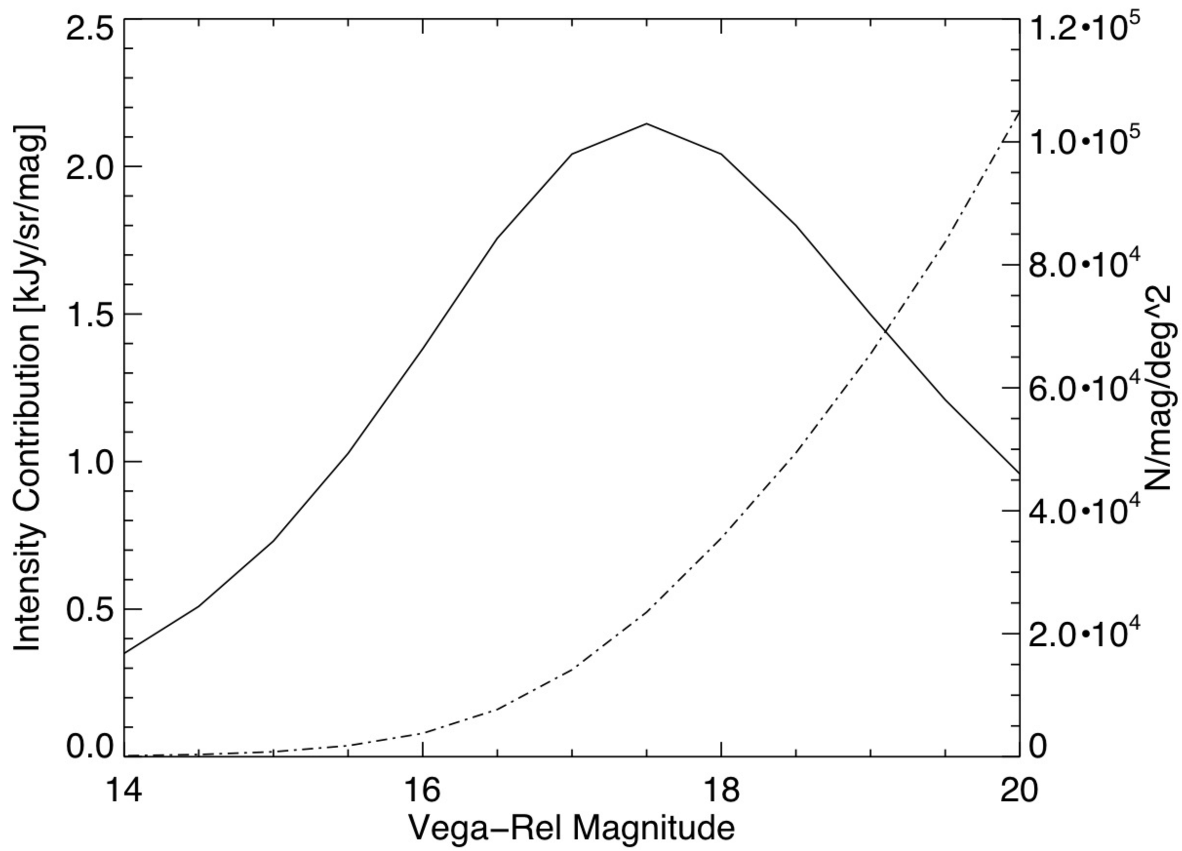
Spitzer Counts



MCMC Results



Resolving the *galactic contribution*



• JWST NIRCAM should reach M_vega > 25 and resolve the galactic contribution to the CIRB in small fields.
• This does *not* necessarily mean JWST will resolve the CIRB!

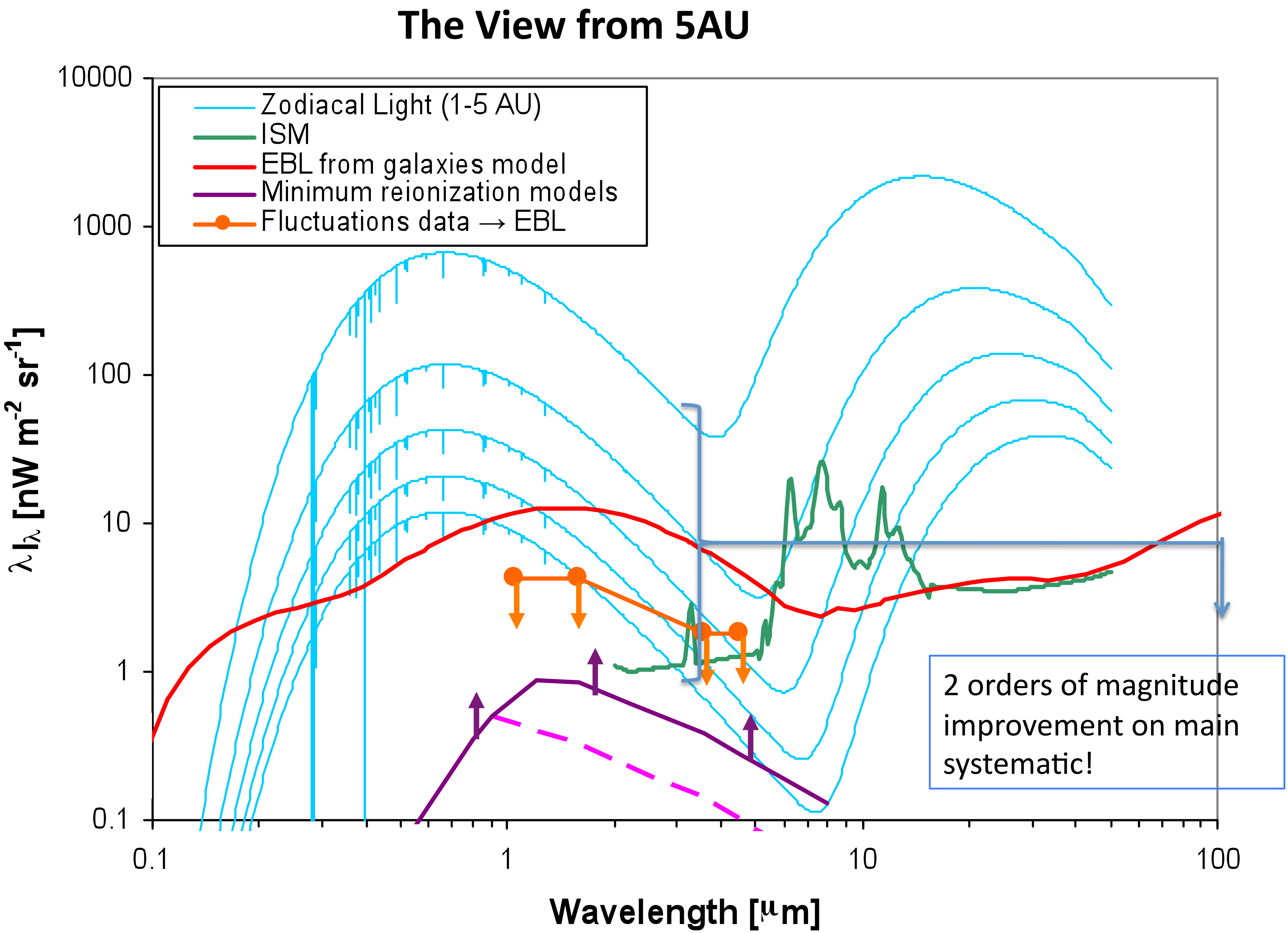
Current Status

- DIRBE Minus 2MASS in 53 Regions:
  - K: 14.7 ± 4.5 kJy/sr
  - L: 15.6 ± 3.3 kJy/sr
  - J: 8.9 ± 6.3 kJy/sr

- MCMC simulation of Profile Fit Galaxy Counts:
  - L: $10.8^{+2.1}_{-1.1}$ /sr
  - Weakly constrains CIRB on bright end

<u>Cosmic Infrared Background ExpeRiment (CIBER, Jamie Bock PI)</u>

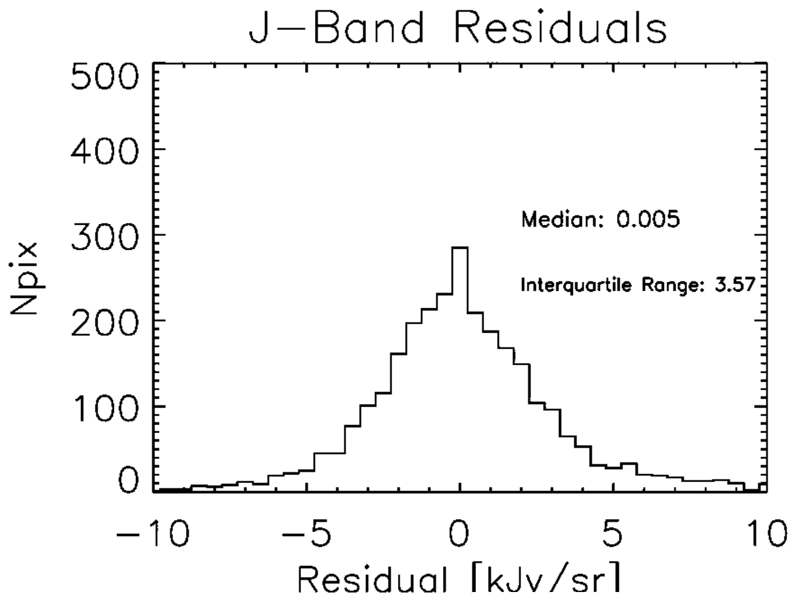
- Engineering Flight Completed (Feb 2009)
- 2nd Flight Scheduled (June 2010)
- Narrow Band Fraunhofer Line Spectrometer (CaII)
- Low Resolution Spectrometer
- I & H Band Wide Field Images for Fluctuations
- Will nail down absolute zodi intensity in a few regions of sky from 1AU
- See Zemcov poster in this workshop.

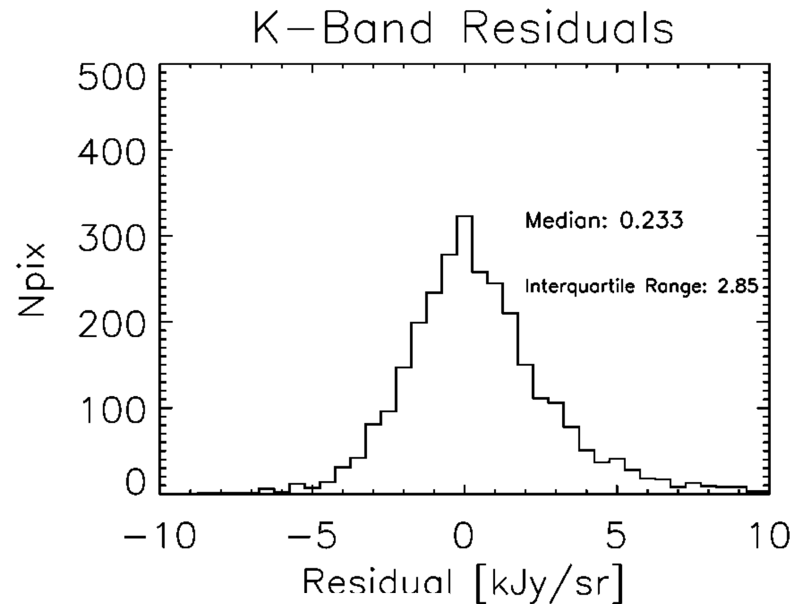

The View from 5AU
Zodiacal Light (1-5 AU)
ISM
EBL from galaxies model
Minimum reionization models
Fluctuations data → EBL
2 orders of magnitude improvement on main systematic!
10000
1000
100
10
1
0.1
0.1
1
10
100
λIλ [nW m^-2 sr^-1]
Wavelength [μm]

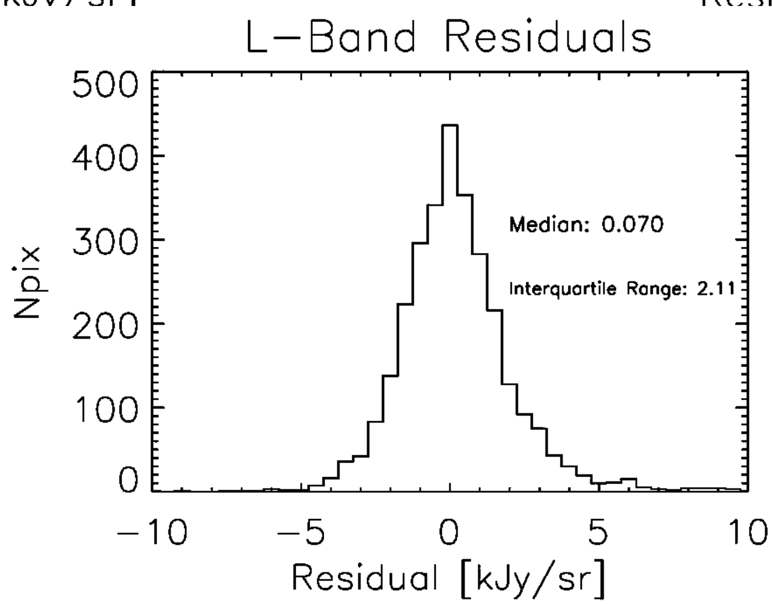
Conclusions

- Zodi-prevents precision measurement of the total CIRB.
- Galaxy counting is only ever a lower limit on the CIRB.
- CIBER will not map the shape of the IPD cloud.
- Transition from foregrounds that are 1,000% to foregrounds that are < 10-25% of the signal we are looking for!

Residuals


J–Band Residuals
Median: 0.005
Interquartile Range: 3.57
Npix
Residual [kJy/sr]


K–Band Residuals
Median: 0.233
Interquartile Range: 2.85
Npix
Residual [kJy/sr]


L–Band Residuals
Median: 0.070
Interquartile Range: 2.11
Npix
Residual [kJy/sr]

CIRB Corrections

Table 4. CIRB Corrections [kJy sr^{-1}]

Photometry	$\sum n(m) f(m)$	$\sum (n(m)/comp(m)) f(m)$	$\sum n_{model}(m) f(m)$
Profile Fit	9.3	12.9	$10.8^{+2.1}_{-1.1}$
Aperture	5.3	7.1	$9.2^{+1.2}_{-0.7}$

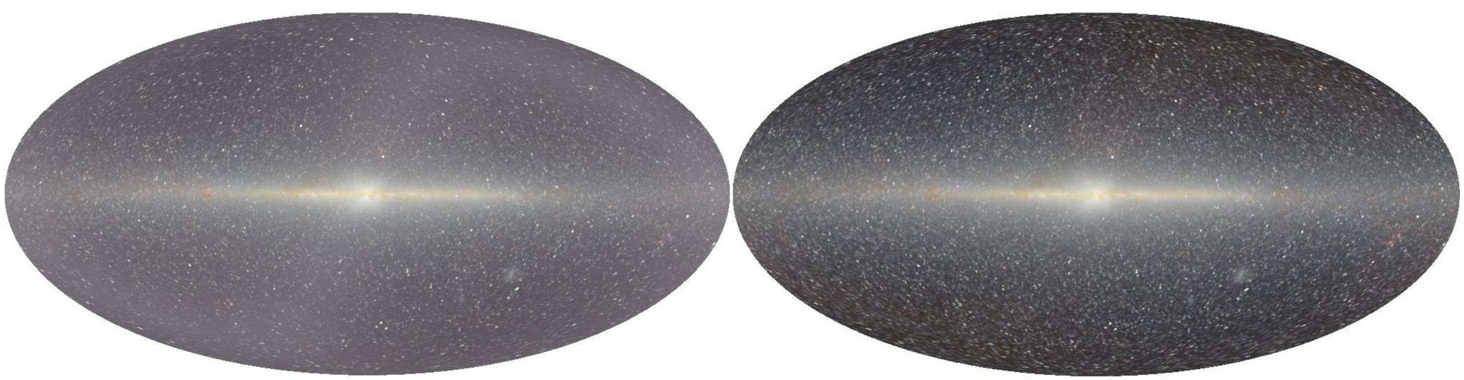
Note. — The non-Gaussian nature of the flux errors, seen in Figures 8 and 15, makes a determination of the errors in the first two numerical columns difficult, necessitating the modeling procedure that gives the above 1σ confidence limits on the modeled CIRB.

Zodiacal Light Model

$$I_{obs}(\lambda, l, b, t) = Z(\lambda, l, b, t; P) + I_c(\lambda, l, b)$$

$$\begin{aligned} Z(\lambda, l, b, t; P) &= \sigma_\lambda \int (\rho_c[\mathbf{r}(\mathrm{s})] + \rho_\mathrm{r}[\mathbf{r}(\mathrm{s})] + (\mathrm{p}_{12\mathrm{S}})\, \rho_\mathrm{b}[\mathbf{r}(\mathrm{s})])\, \Phi(\mu)\, \mathrm{D}_\lambda(\mathrm{T}_\odot)\, \mathrm{R}^{-2}\, \mathrm{ds} \\ &\quad + \kappa_\lambda \int (\rho_c[\mathbf{r}(\mathrm{s})] + \rho_\mathrm{r}[\mathbf{r}(\mathrm{s})] + (\mathrm{p}_{12\mathrm{T}})\, \rho_\mathrm{b}[\mathbf{r}(\mathrm{s})])\, \mathrm{D}_\lambda(\mathrm{T}(\mathrm{R}))\, \mathrm{ds}\,. \end{aligned}$$

Kelsall et al. (1998), Wright (1998)

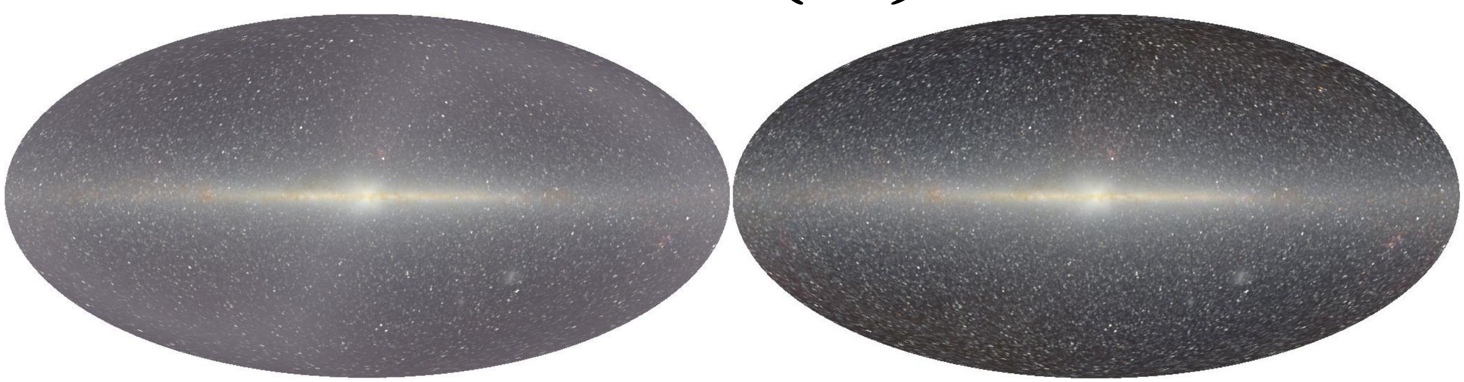


Foreground Subtraction from DIRBE Maps

$$I_{obs}(\lambda, l, b, t) = Z(\lambda, l, b, t; P) + I_c(\lambda, l, b)$$

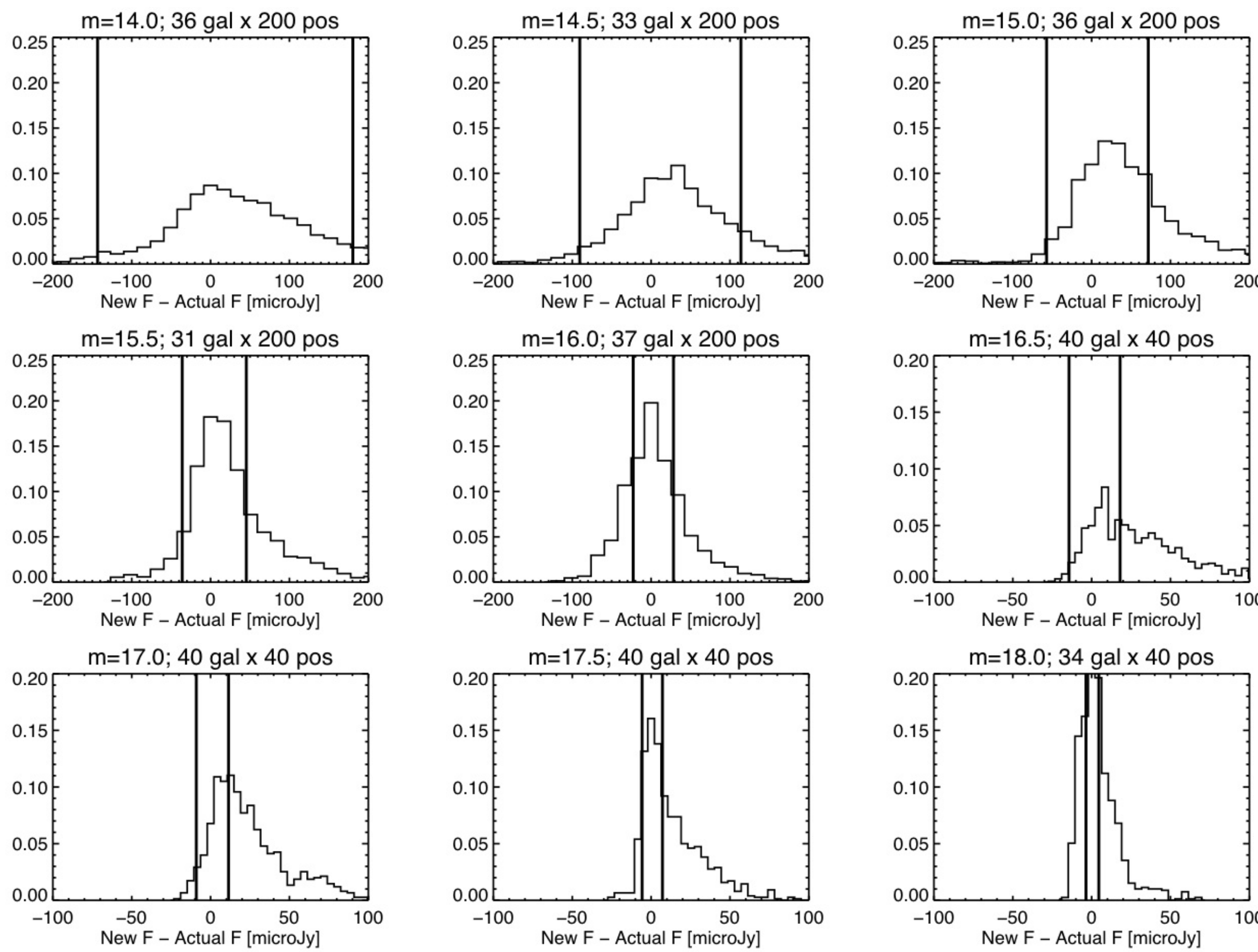
Kelsall et al. (1998), Wright (1998)

$$I_c(\lambda, l_i, b_i) = B(\lambda, l_i, b_i) + F(\lambda, l_r, b_r) + CIRB(\lambda)$$



Galaxy Counts: Flux Uncertainty

- Poisson Error
- Cosmic Variance
- Completeness
- Flux Uncertainty



DIRBE Minus 2MASS: Results

Levenson, Wright & Johnson (2007) ApJ, 666, 34-44

We find a consistent residual intensity in the 40 regions of:

- J: 8.9 ± 6.3 kJy/sr

- K: 14.7 ± 4.5 kJy/sr

- L: 15.6 ± 3.3 kJy/sr

These values are consistent with previous determinations of the NIR CIRB via direct detection.