Cosmic Backgrounds

by

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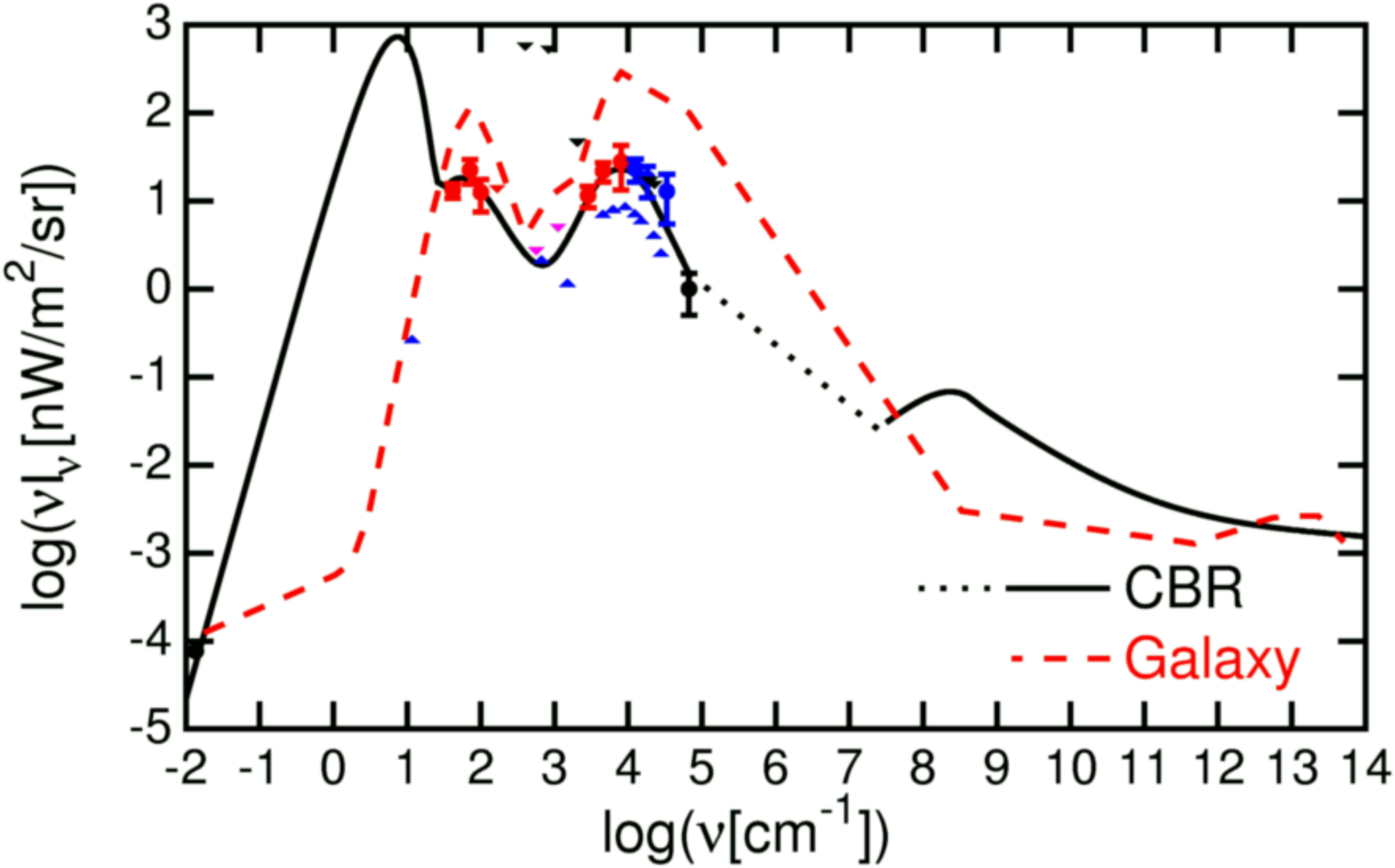
http://www.astro.ucla.edu/~wright/intro.html

See:

- http://www.astro.ucla.edu/~wright/cosmolog.htm
- http://www.astro.ucla.edu/~wright/DIRBE
- http://www.astro.ucla.edu/~wright/CIBR
- http://spitzer.caltech.edu
- http://wise.astro.ucla.edu

Wide window on the CBR

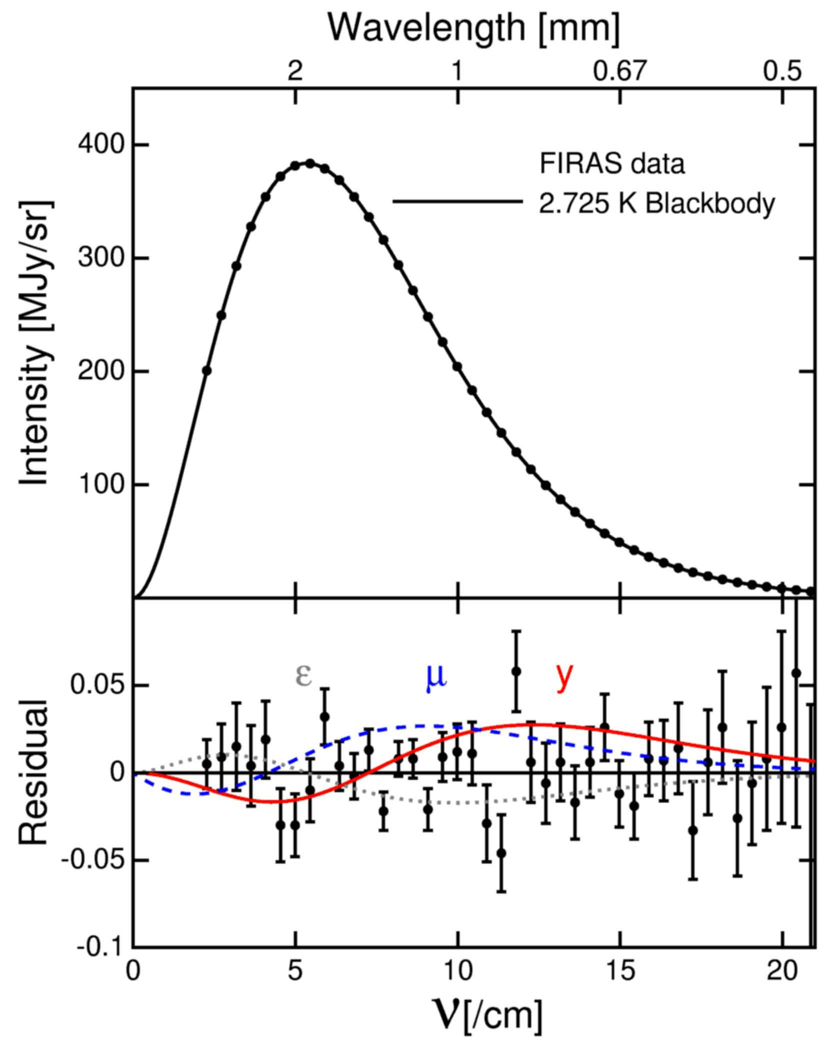


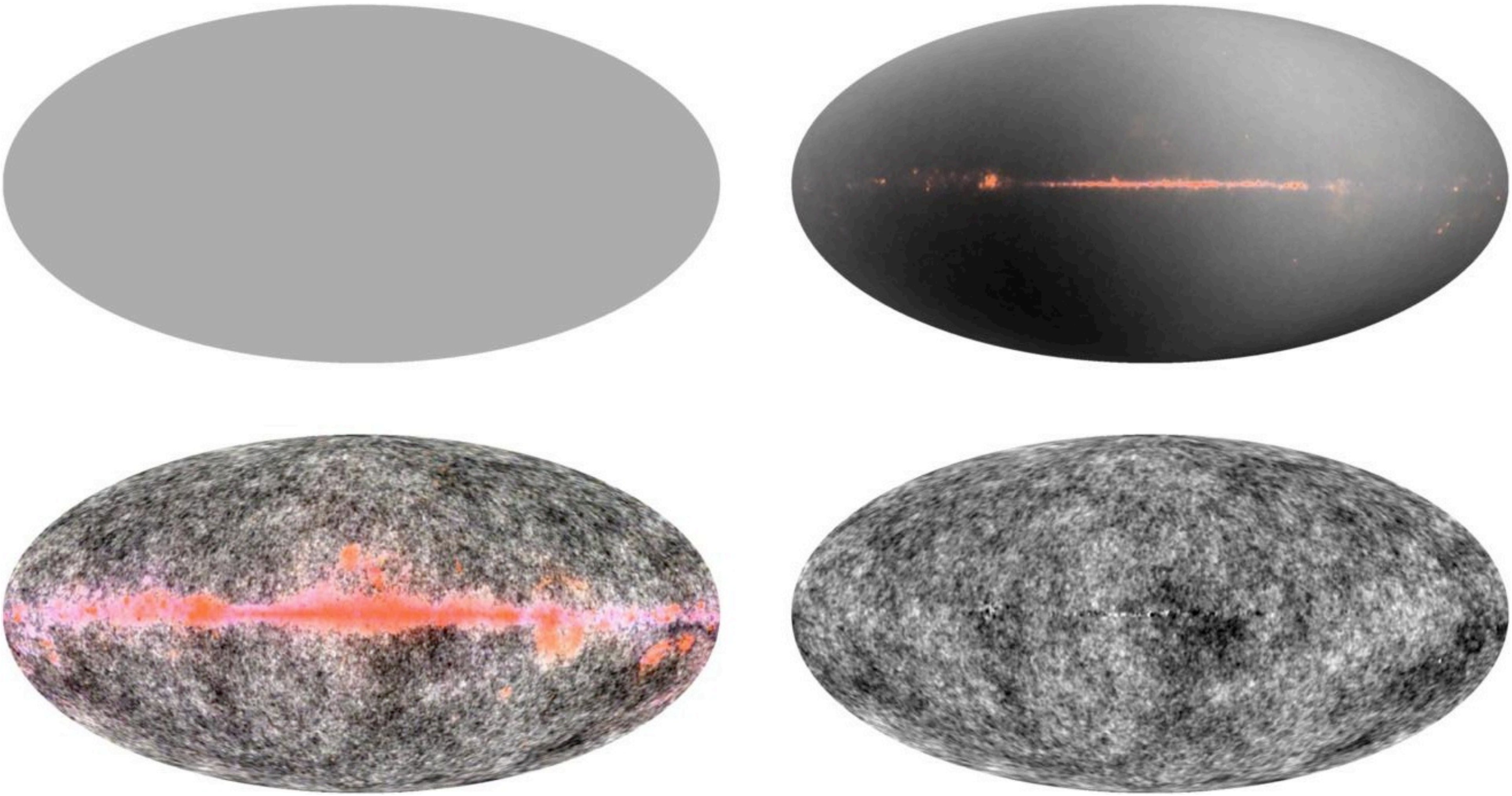
Backgrounds

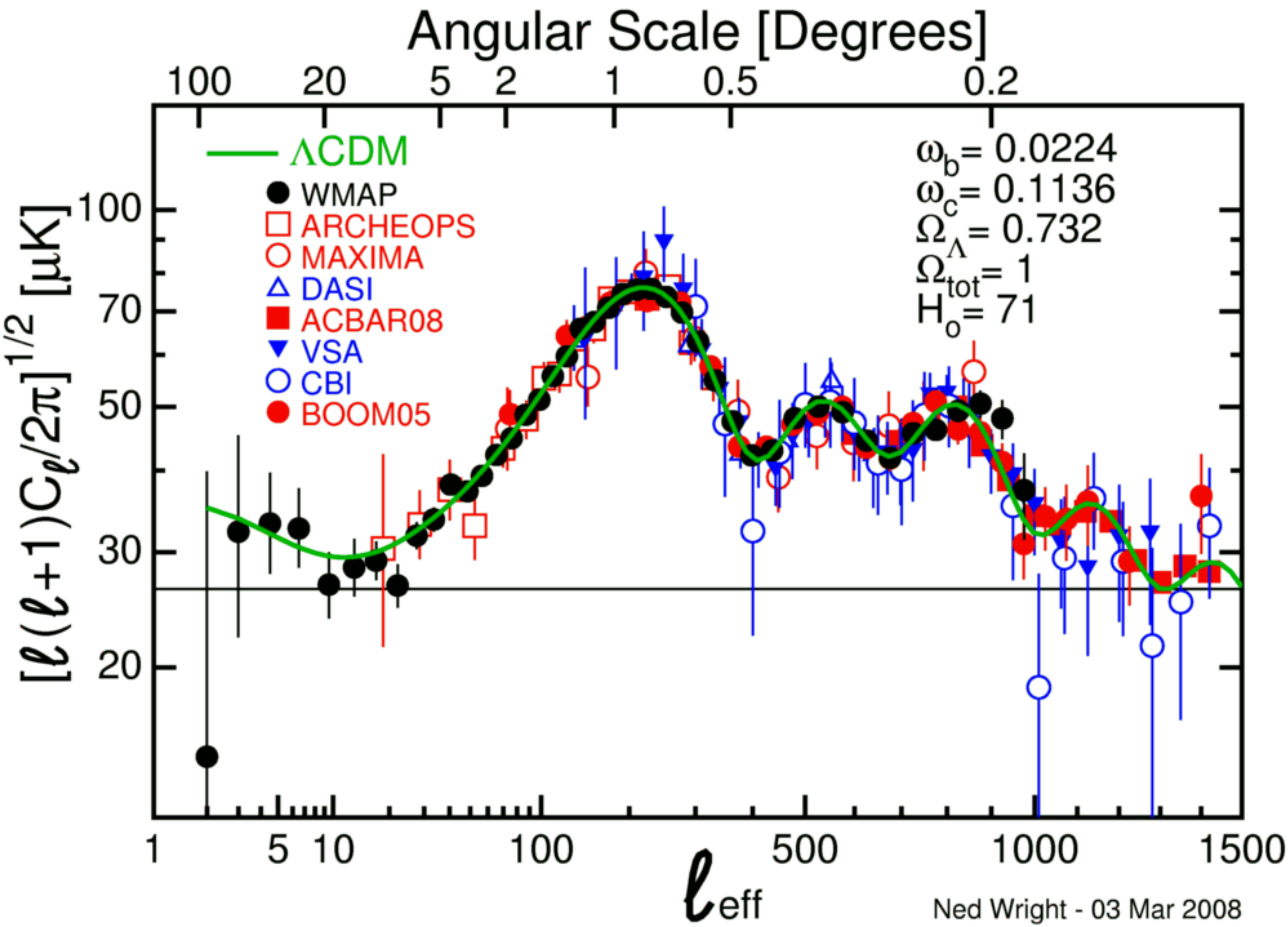
- Microwave – the CMB is 10,000 times brighter than the galactic foreground & the spectrum is very close to a blackbody: Primordial
- Far Infrared – the FIRB is 10 times fainter than the galaxy with a spectrum similar to the galaxy: Galaxies and Quasars
- Near IR and Optical – also 10 times fainter than galaxy: Galaxies and Quasars
- X-ray – the XRB is 10 times brighter than the galaxy: Quasars

FIRAS Final Spectrum

- SZ Effect ∝ $y = N_e \sigma_T k T_e / m_e c^2 < 15\times10^{-6}$
- Bose-Einstein $\mu < 9\times10^{-5}$
- Energy from hot electrons into CMB < 60 parts per million







Angular Scale [Degrees]
100
20
5
2
1
0.5
0.2
ΛCDM
WMAP
ARCHEOPS
MAXIMA
DASI
ACBAR08
VSA
CBI
BOOM05
ω_b= 0.0224
ω_c= 0.1136
Ω_Λ= 0.732
Ω_{tot}= 1
H_o= 71
$[\ell(\ell+1)C_\ell/2\pi]^{1/2}$ [μK]
100
70
50
30
20
1
5
10
100
500
1000
1500
ℓ_{eff}
Ned Wright - 03 Mar 2008

parameter	Planck15 CMB	Planck15 CMB+BAO+SNe
ρ_b [yg/m^3]	0.4181 ± 0.0043	0.4189 ± 0.0026
ρ_c [yg/m^3]	2.228 ± 0.038	2.232 ± 0.019
u_{DE} [eV/cc]	3352 ± 125	3349 ± 67
$\mathrm{H}_\circ$ [km/s/Mpc]	67.80 ± 0.9	67.74 ± 0.46
$t_\circ$ [Gyr]	13.799 ± 0.038	13.799 ± 0.021

extension	Value
oCDM	$\Omega = 0.9992 \pm 0.002$
νCDM	$\Sigma m_\nu < 0.19$ eV
	$N_{eff} = 3.04 \pm 0.17$
tensors	$r < 0.11$
wCDM	$w = -1.019 \pm 0.078$
	$d\ln(u_{DE})/dt = (0.057 \pm 0.233)\mathrm{H}_\circ$

Consider a mirrored box, where the mirrors move with the galaxies in the Hubble flow, and define the *comoving luminosity density*:

$$\ell(t) = \frac{\sum_{\text{in box}} L_{gal}(t)}{V_{box}(t_\circ)}$$

For a static, unchanging Universe the energy density in the box now is

$$u(t_\circ) = \frac{4\pi J}{c} = \int_{-\infty}^{t_\circ} \ell(t_\circ) dt \rightarrow \infty \qquad \text{[Olber's Paradox]}$$

In an expanding Universe with scale factor $a(t)$, and $1 + z = a(t_\circ)/a(t)$, then:

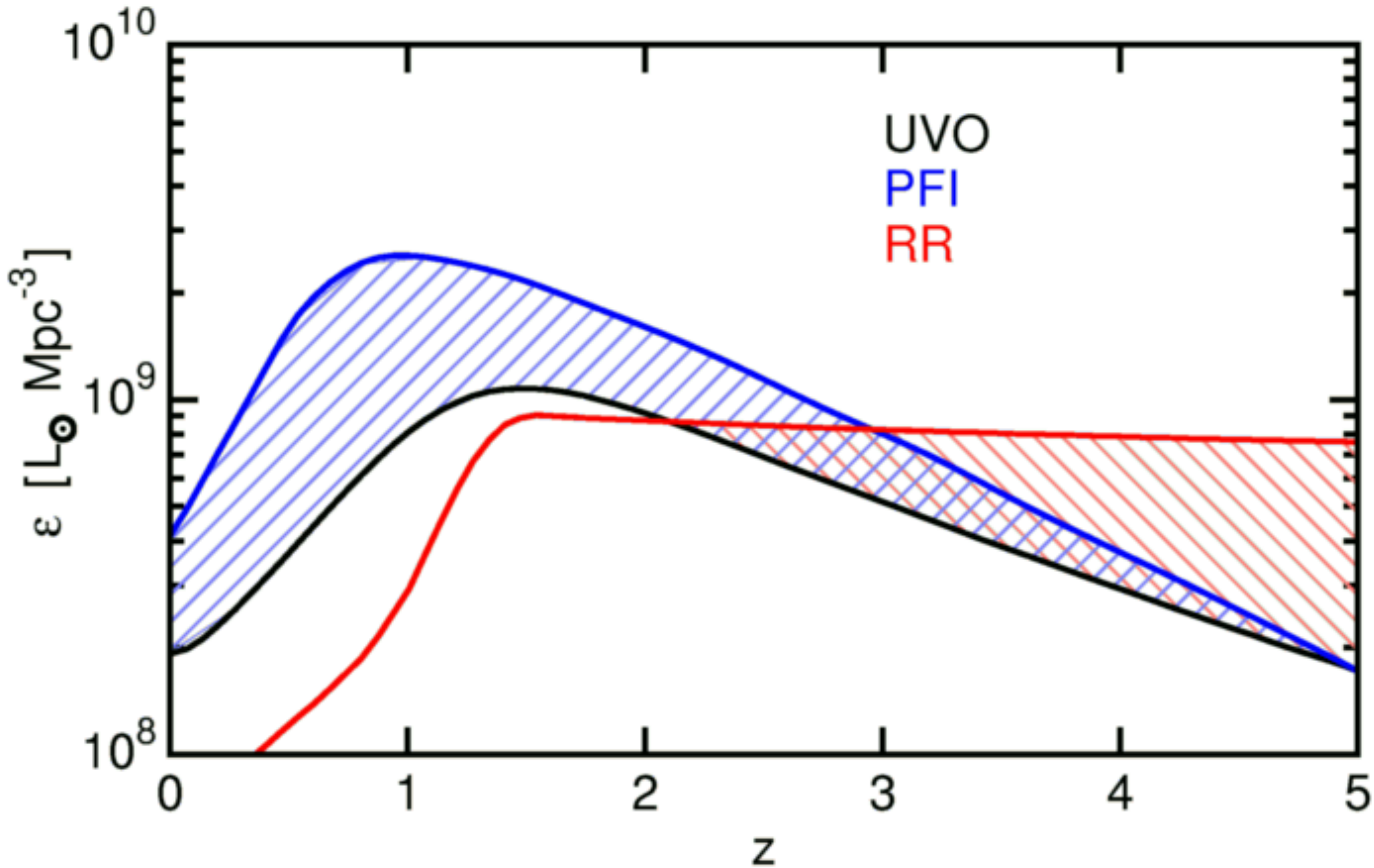
$$u(t_\circ) = \frac{4\pi J}{c} = \int_{0}^{t_\circ} \frac{\ell(t)}{1+z} dt$$

The total energy produced, $\int \ell(t)dt$, is more than the CIRB energy density because it does not have the $(1+z)$ factor in the denominator. For the baryon density given by Big Bang Nucleosynthesis, $\Omega_B h^2 = 0.02$, if 1% of the baryons are converted from hydrogen to helium releasing 0.7% of their mass into energy, then

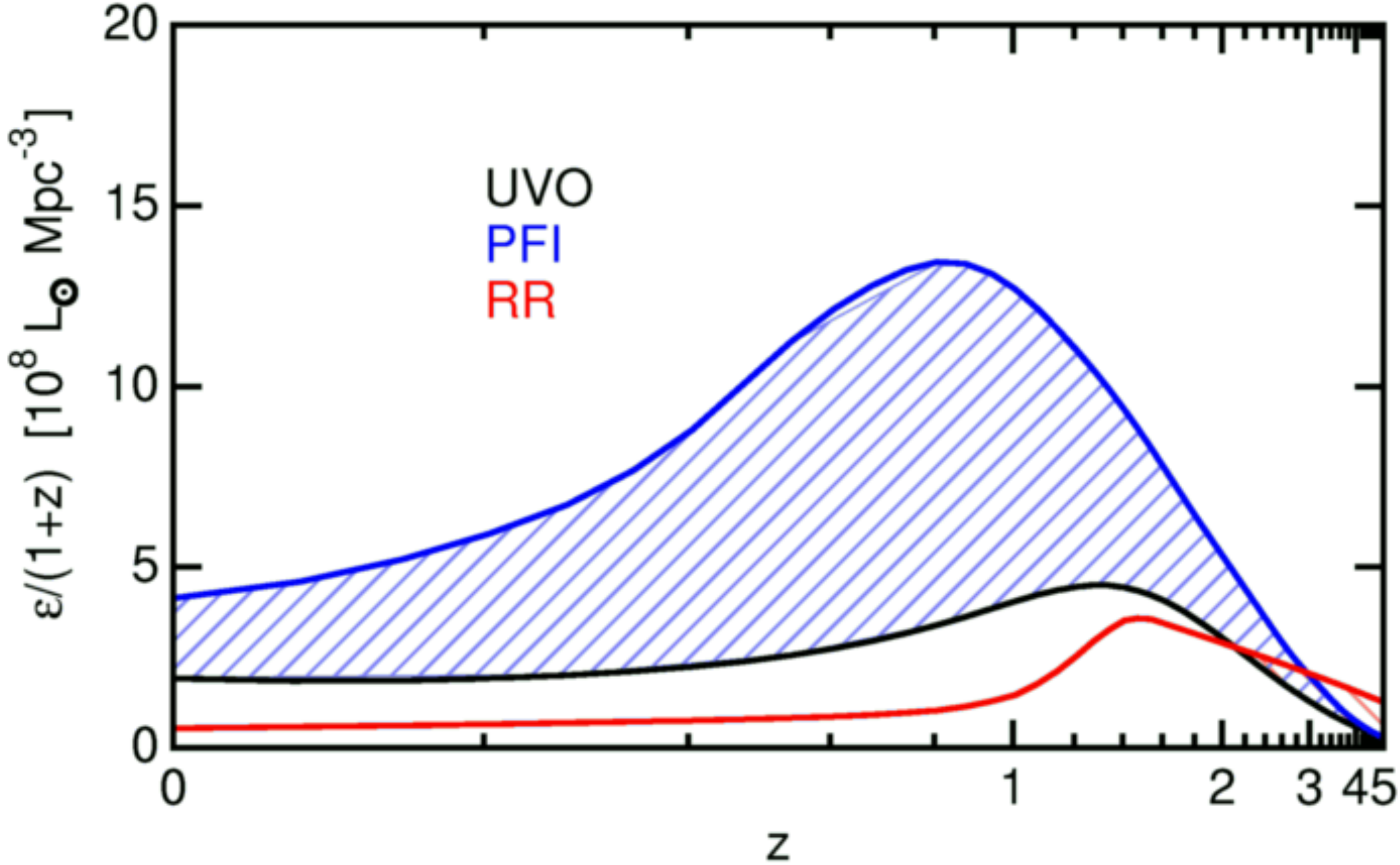
$$\int \ell(t)dt = 0.02 \times 0.01 \times 0.007 \times 10539.4 \frac{\text{eV}}{\text{cm}^3} = \frac{1}{68} \frac{\text{eV}}{\text{cm}^3}$$

$c/[4\pi]$ times this energy density is 56 $\text{nW/m}^2\text{/sr}$.

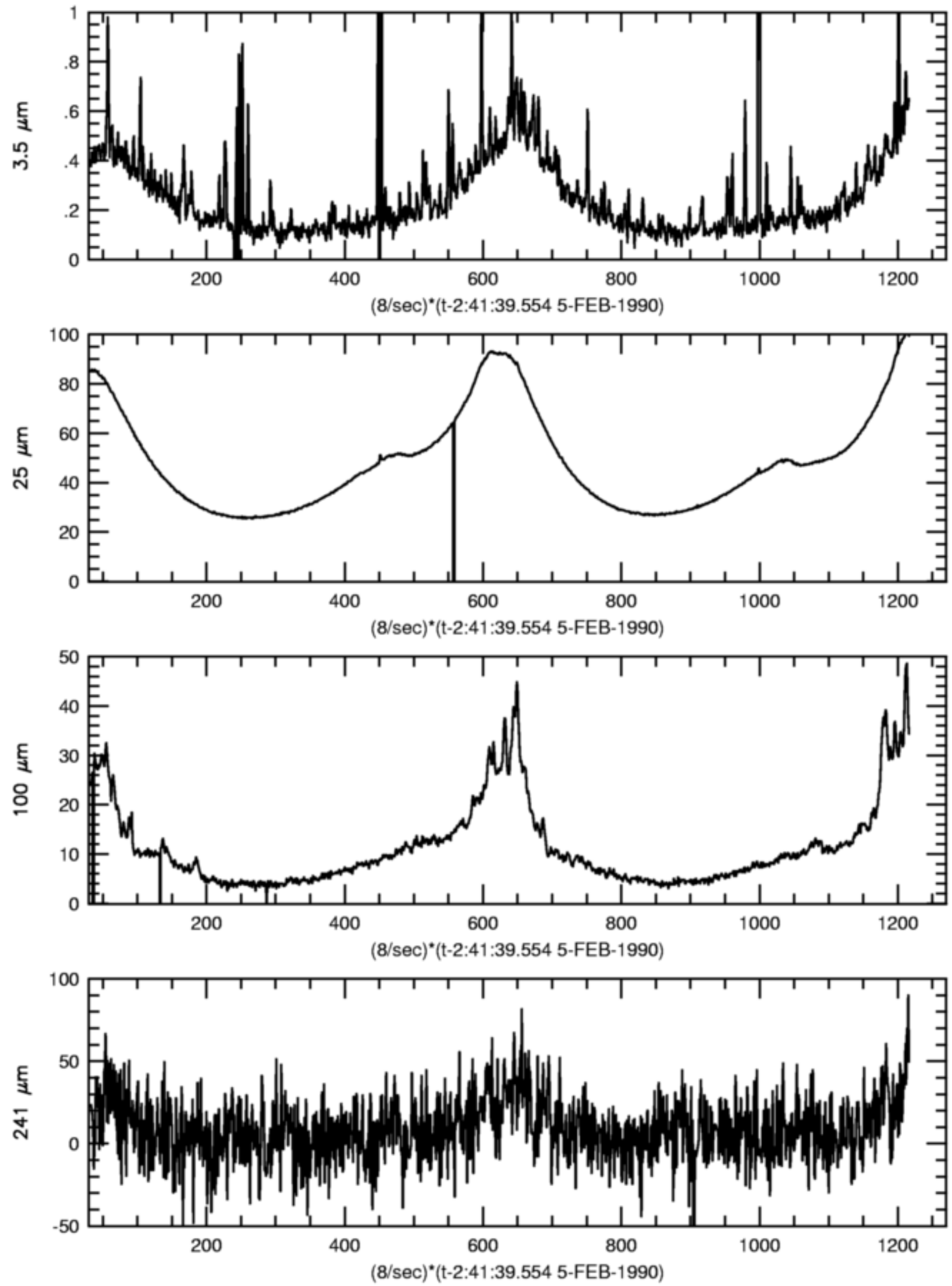
Luminosity density vs. redshift



L/(1+z) vs. time

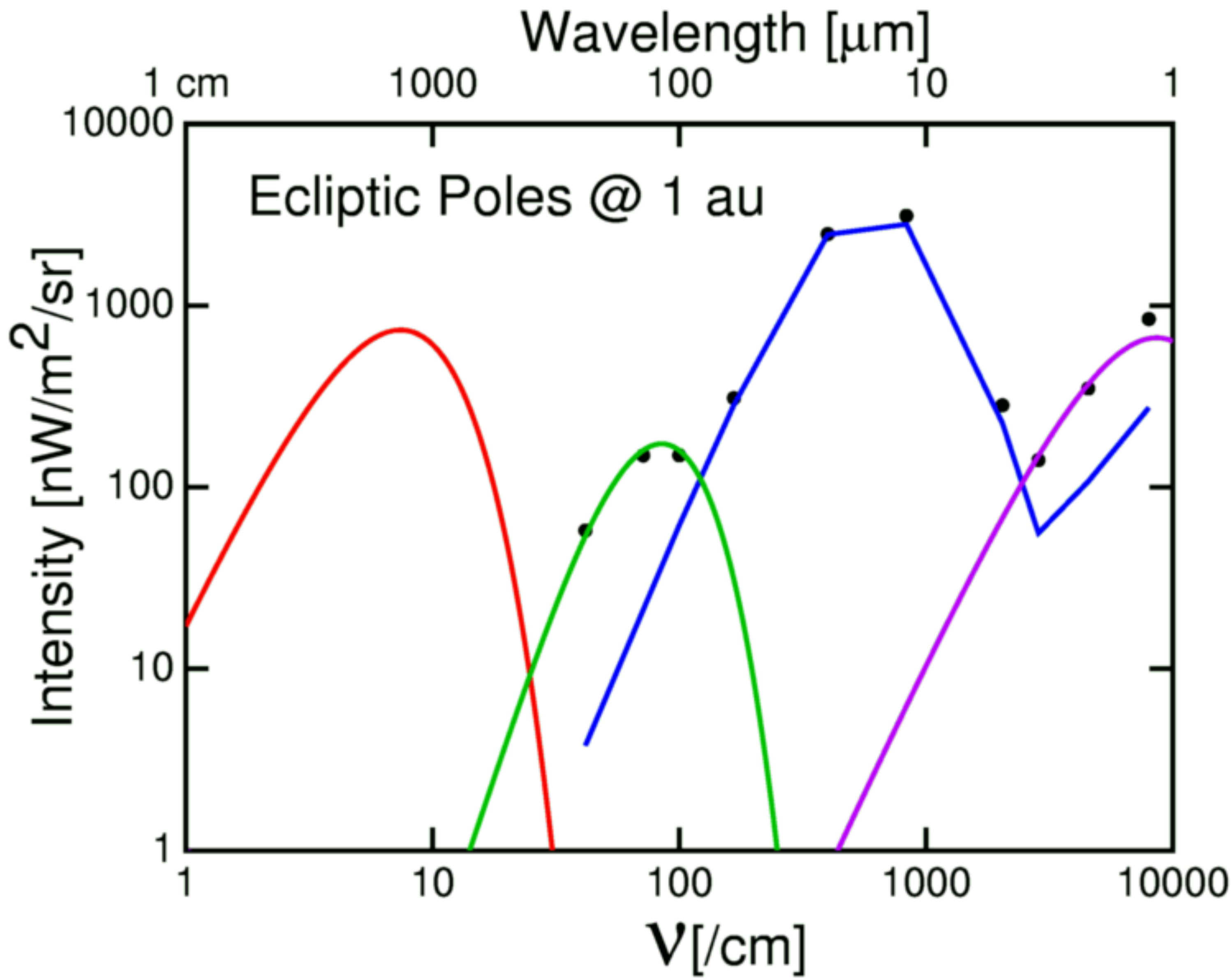


DIRBE Beam Size

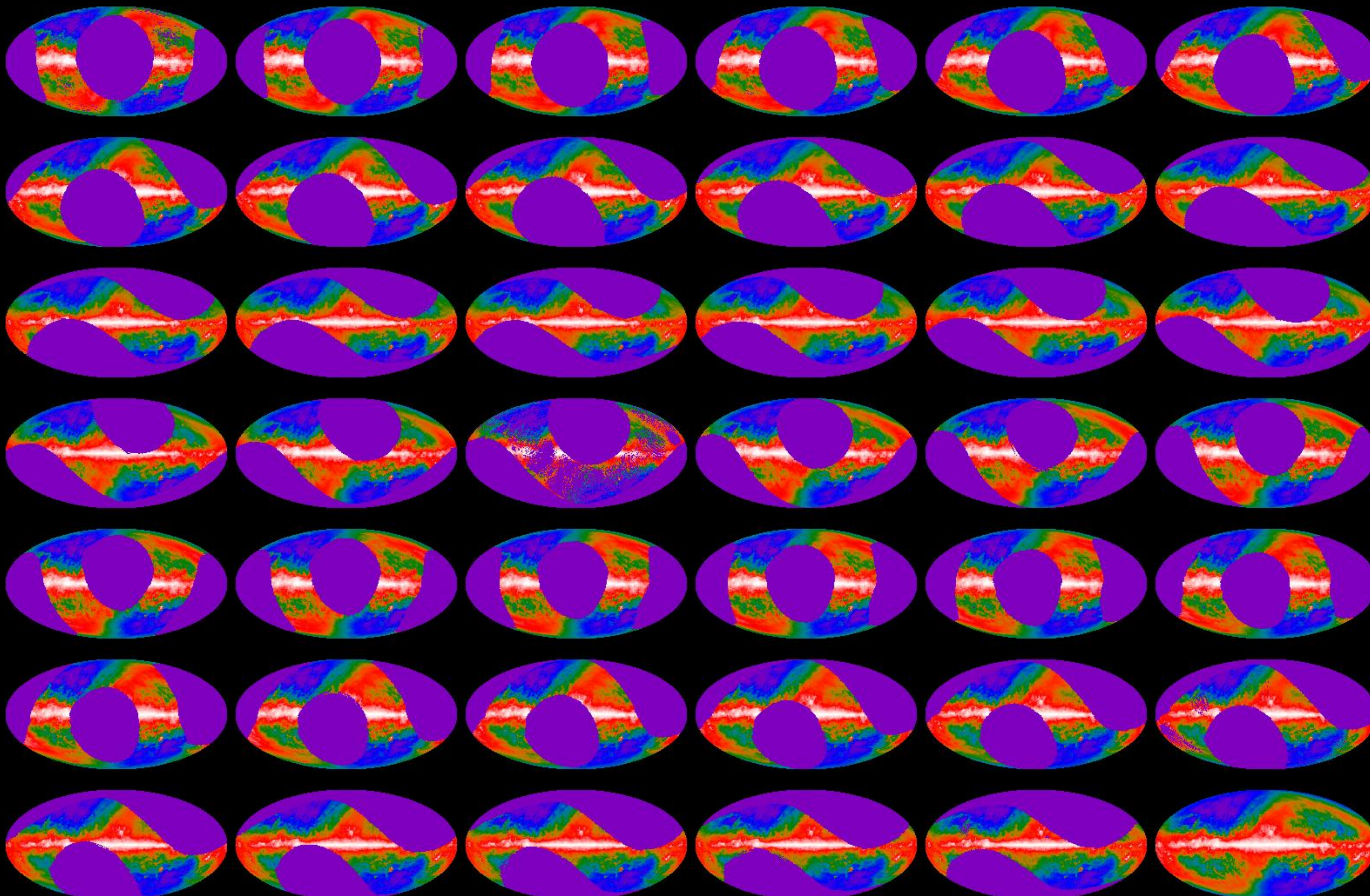


3.5 μm
(8/sec)*(t-2:41:39.554 5-FEB-1990)
25 μm
(8/sec)*(t-2:41:39.554 5-FEB-1990)
100 μm
(8/sec)*(t-2:41:39.554 5-FEB-1990)
241 μm
(8/sec)*(t-2:41:39.554 5-FEB-1990)

Bump Chart: Where is the CIRB?



DIRBE 100 µm Weekly Maps



NO ZODI Principles

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

- Weak No Zodi: No restriction on I_c
- Strong No Zodi: $I_c(\lambda, l, b)$ independent of (l, b) for $|b| > 20^\circ$ and $\lambda = 25\ \mu$m.
- Very Strong No Zodi: $I_c(\lambda, l, b) = 0$ for $|b| > 20^\circ$ and $\lambda = 25\ \mu$m.

Comparison of Zodi Models

Table 1: Intensities in the Lockman Hole

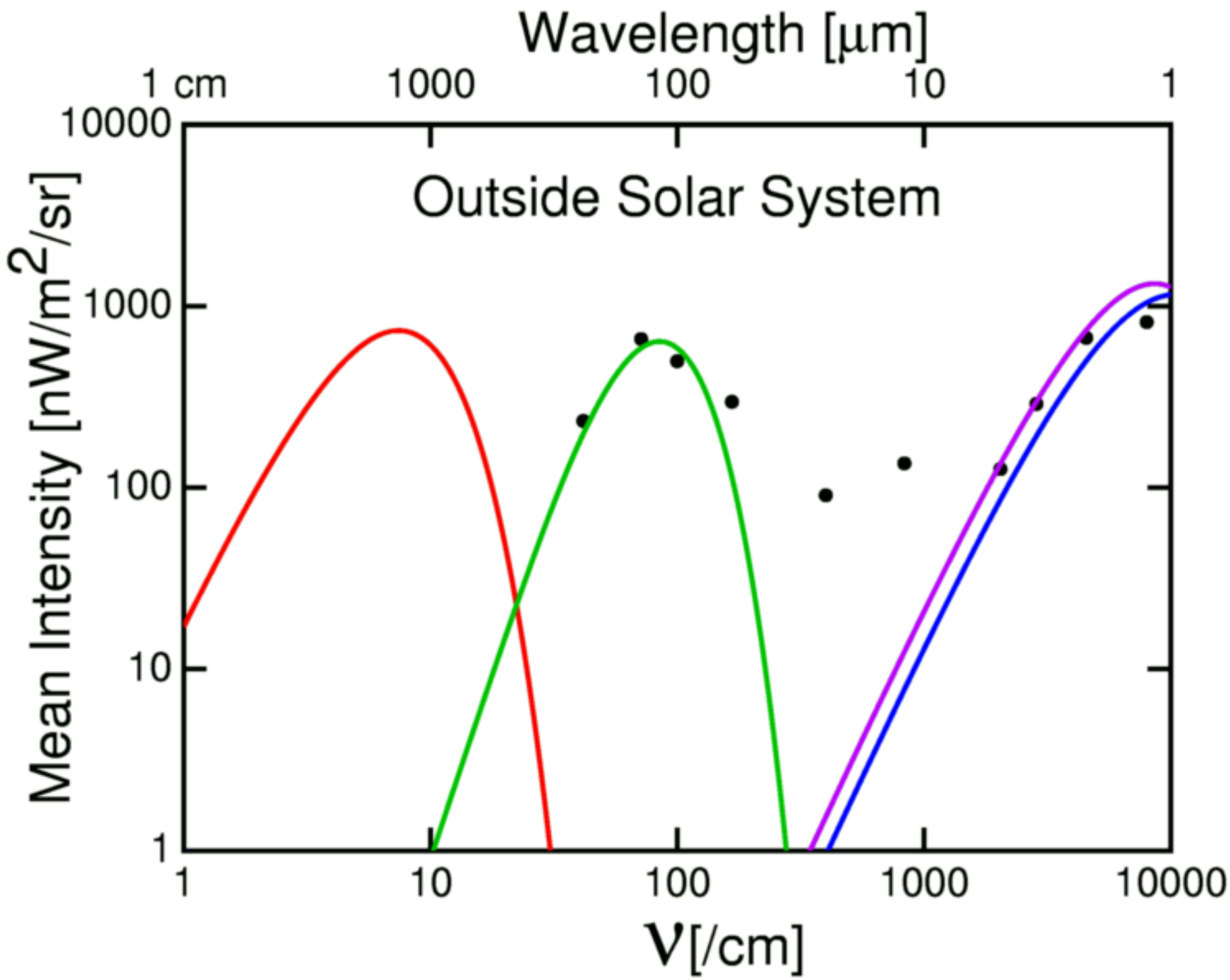
Intensity in MJy/sr in the Lockman Hole

λ [μm]	GOOD1	GOOD2	GOOD3	FIZZ1	FIZZ2	FIZZ3	FIZZ3P	REALITY
1.25	0.1364	0.1407	0.1501	0.1696	0.1694	0.1806	0.1797	0.2228
2.2	0.0942	0.0971	0.1037	0.1171	0.1170	0.1247	0.1240	0.1492
3.5	0.0770	0.0788	0.0856	0.0897	0.0913	0.0976	0.0974	0.1149
5	0.4287	0.4491	0.4699	0.4993	0.4954	0.5097	0.5088	0.5389
12	13.4690	14.1695	14.7320	16.5817	16.2459	16.8580	16.8374	16.5239
25	24.6018	27.2783	30.4484	29.2170	28.4249	30.2288	30.2234	30.0306
60	6.8324	7.2153	7.4800	8.3259	8.0314	8.6145	8.6166	8.7382
100	2.4155	2.5468	2.6346	3.0647	2.9380	3.1912	3.1932	4.1884
140	1.1585	1.2219	1.3091	1.4817	1.4246	1.5838	1.5848	2.4480
240	0.3571	0.3769	0.4028	0.4622	0.4414	0.4923	0.4927	0.9459

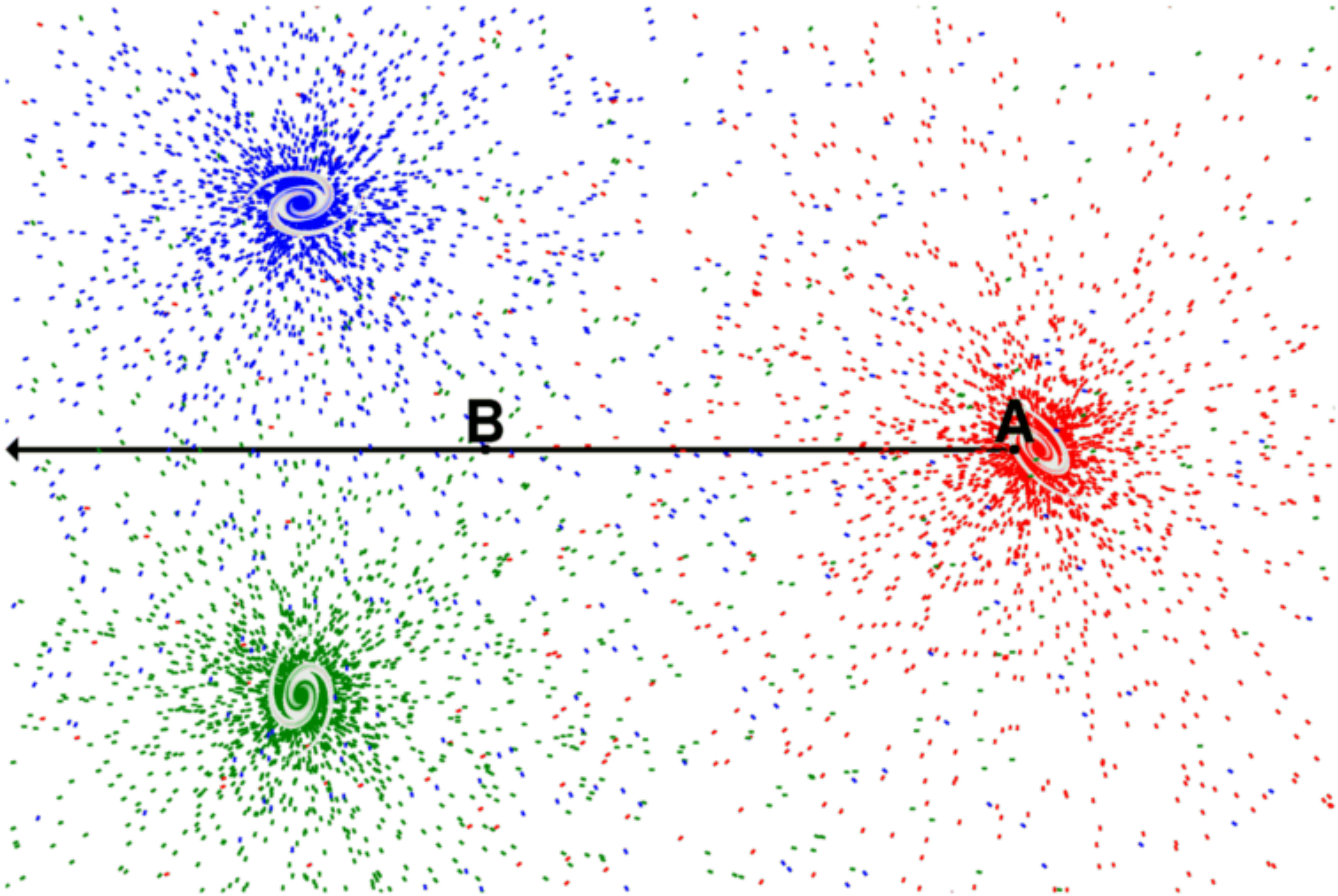
0.0897 0.0913 0.0976

Biggest uncertainty is from the zodi models: change of 8 out of 90 kJy/sr at 3.5 μm for different no-zodi principles.

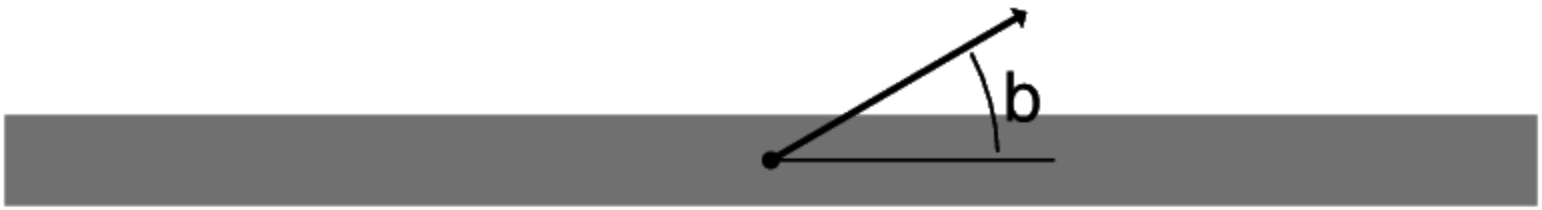
Still no CIRB Bump:



We want νJ_ν at B but sit at A

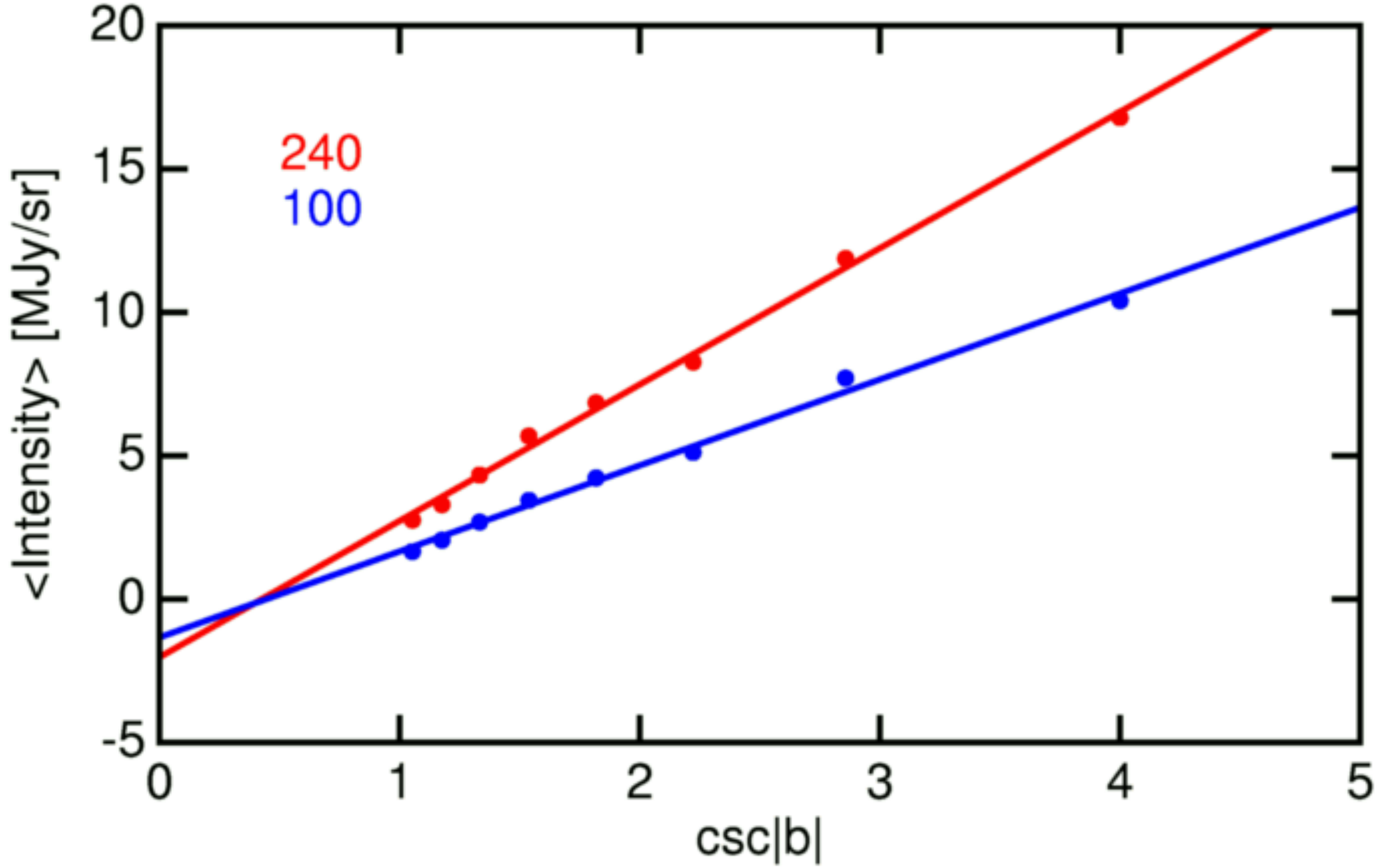


Extrapolation to NO Galaxy?

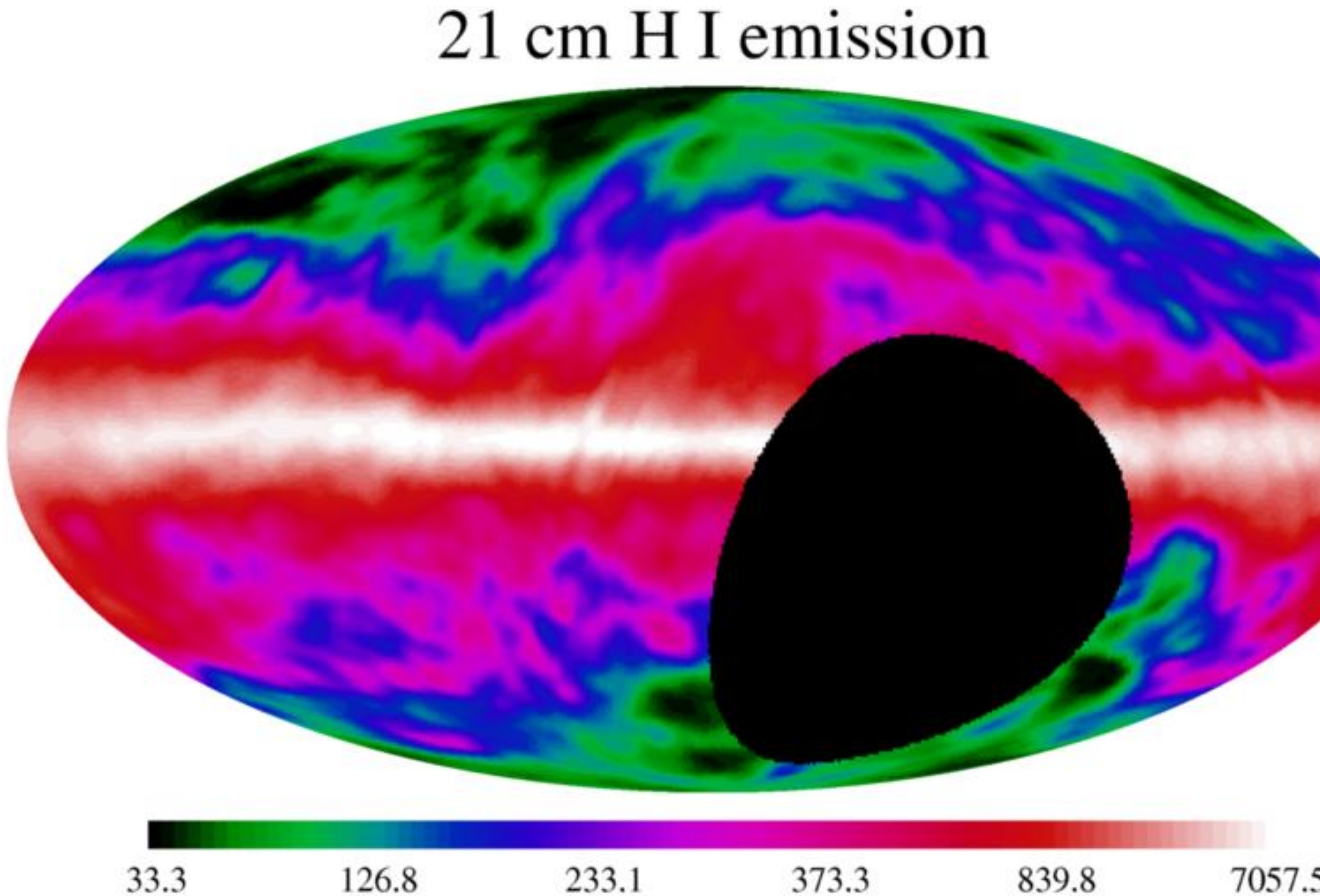


- Galaxy is a *very* thin disk
- Average column density $\propto \csc |b|$

Extrapolation to csc|b|=0 in Far IR



Atomic Hydrogen Map



DIRBE Team IRB Results

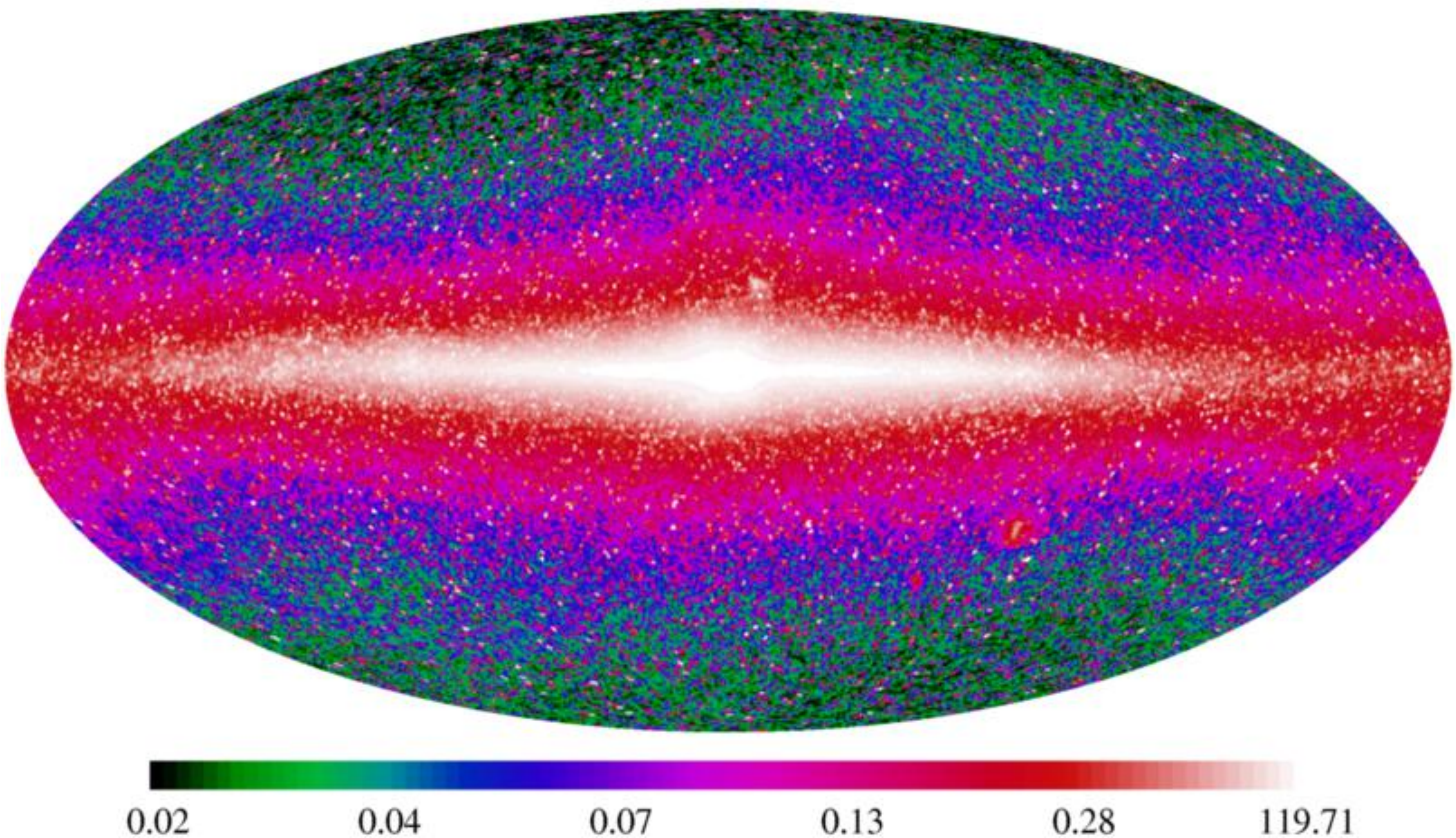
Hauser, . . . , Wright (1998, ApJ, 508, 25)

λ [μm]	νI_ν [nW m^{-2} sr^{-1}]	I_ν [MJy sr^{-1}]
1.25	$< 75.$	< 0.031
2.2	$< 39.$	< 0.029
3.5	$< 23.$	< 0.027
4.9	$< 41.$	< 0.067
12.	$< 468.$	< 1.87
25.	$< 504.$	< 4.2
60.	$< 75.$	< 1.5
100.	$< 38.$	< 1.27
140.	25.0 ± 6.9	1.17 ± 0.32
240.	13.6 ± 2.5	1.09 ± 0.2

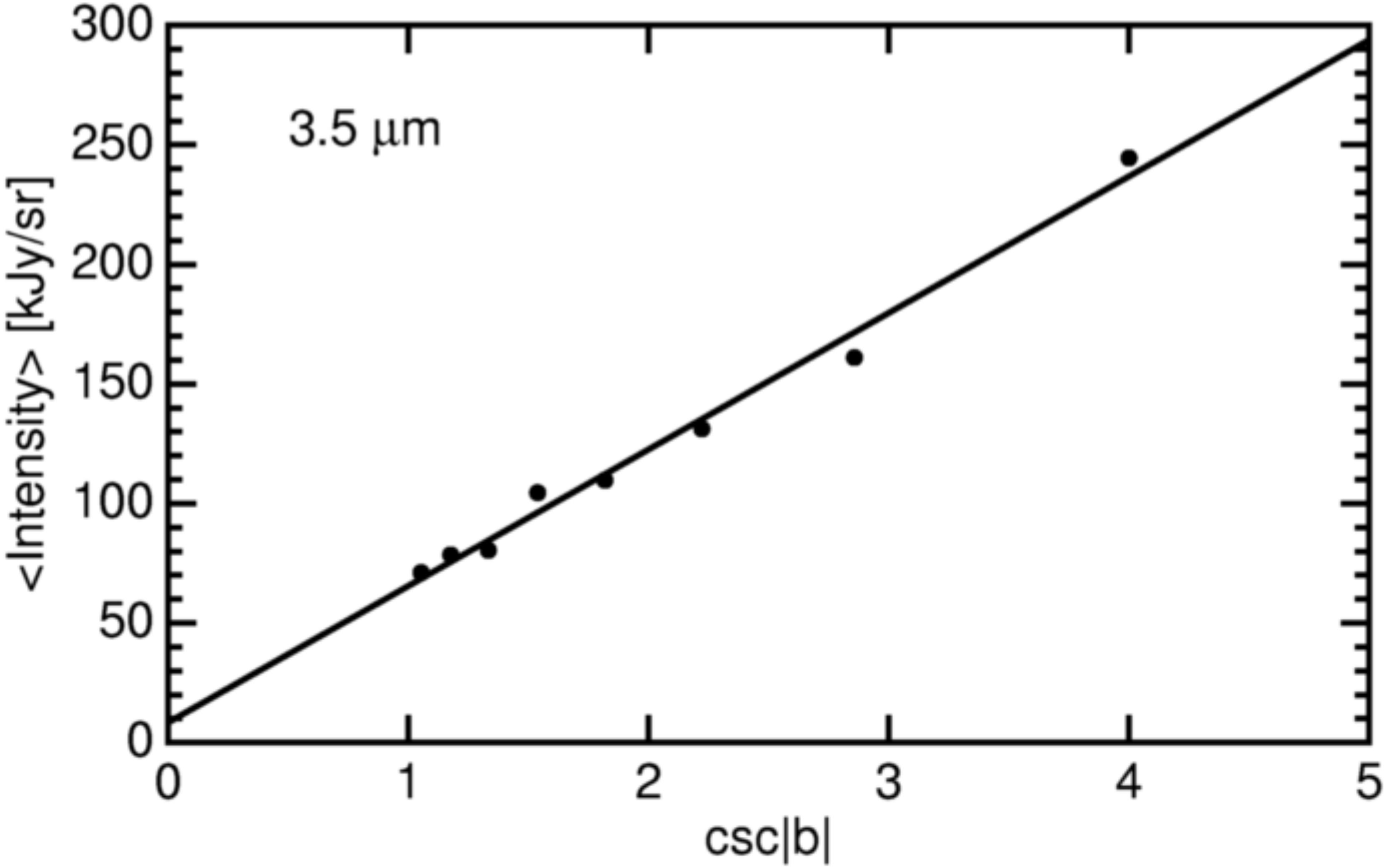
$$I_\nu \approx (1.3 \pm 0.4) \times 10^{-5} (\tilde{\nu}/100)^{0.64 \pm 0.12} B_\nu (18.5 \pm 1.2 \text{ K})$$

Fixsen *et al.*, 1998, ApJ, 508, 123

Zodi Subtracted 3.5 Microns

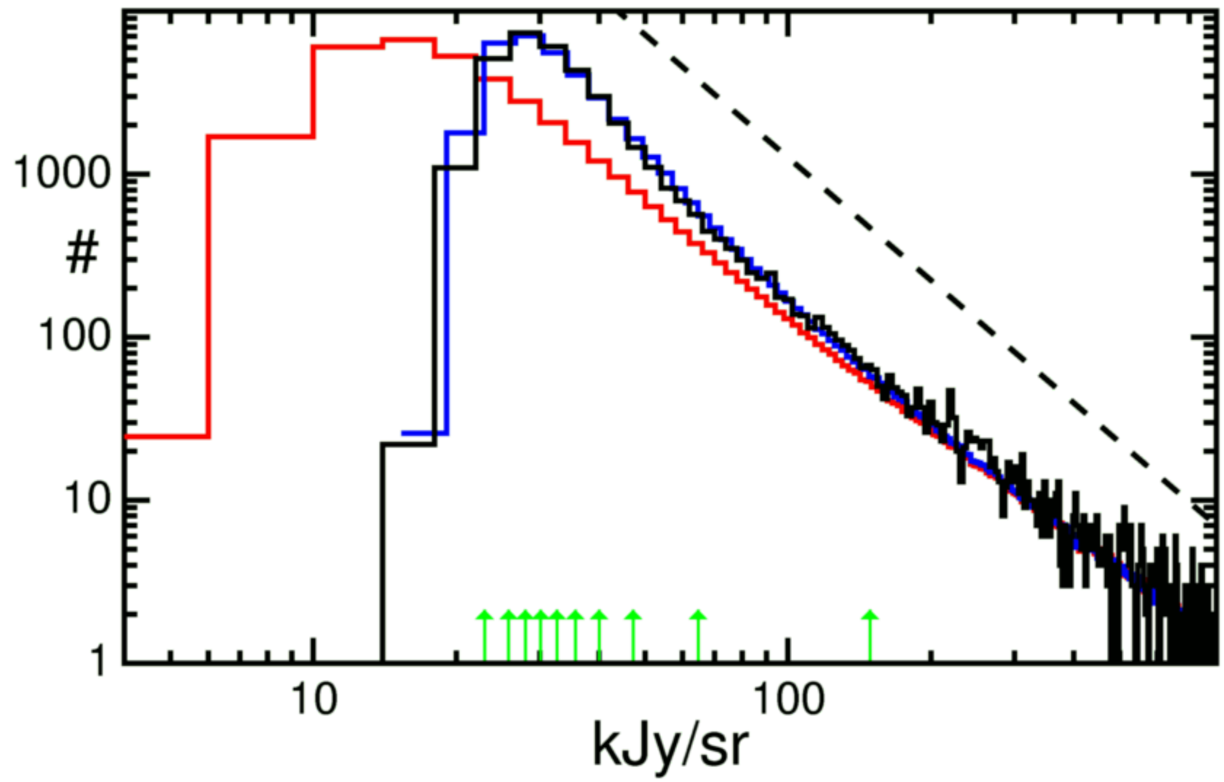


Extrapolation to csc|b|=0 at 3.5 μm

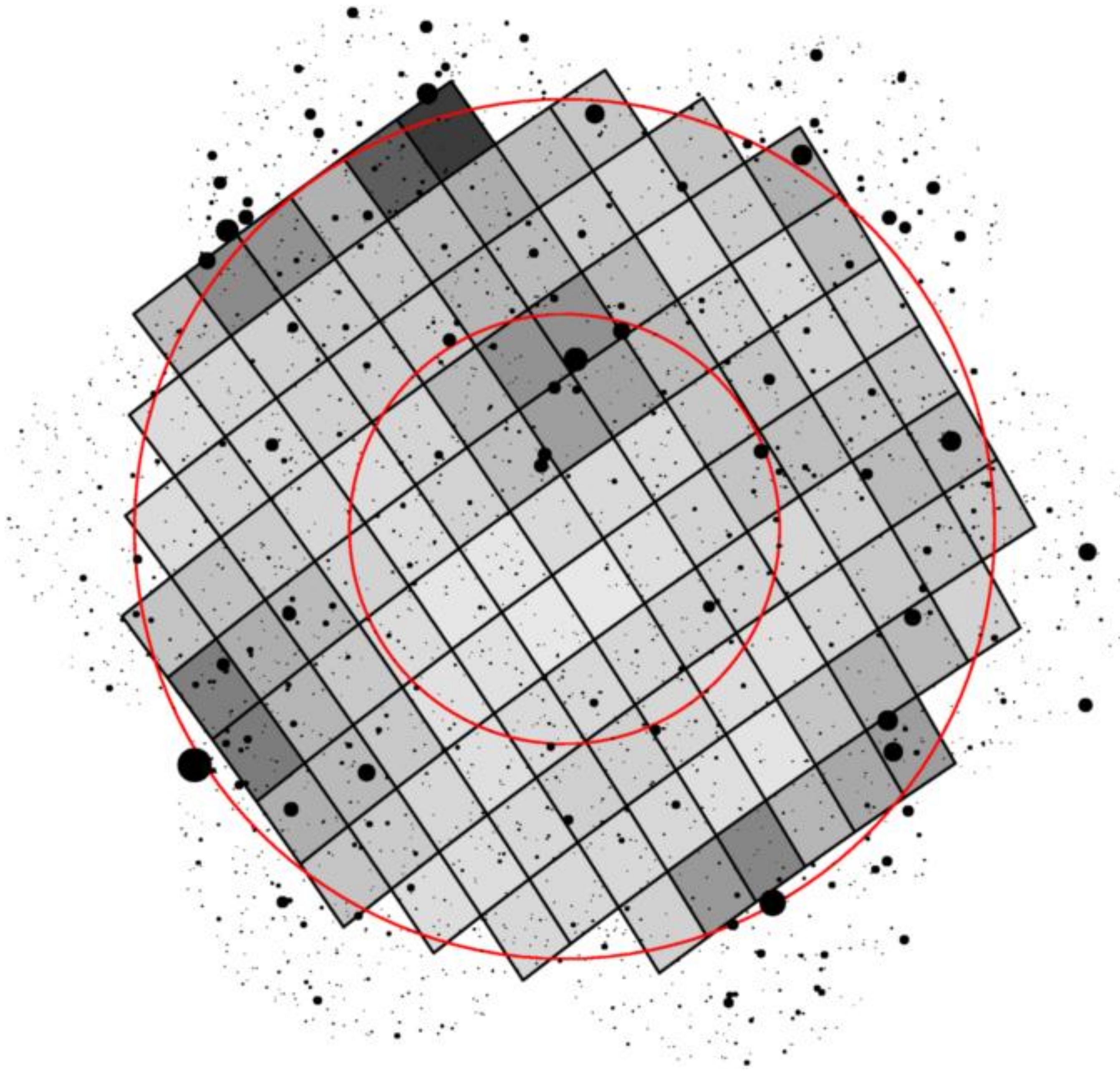


Wright & Reese, 2000

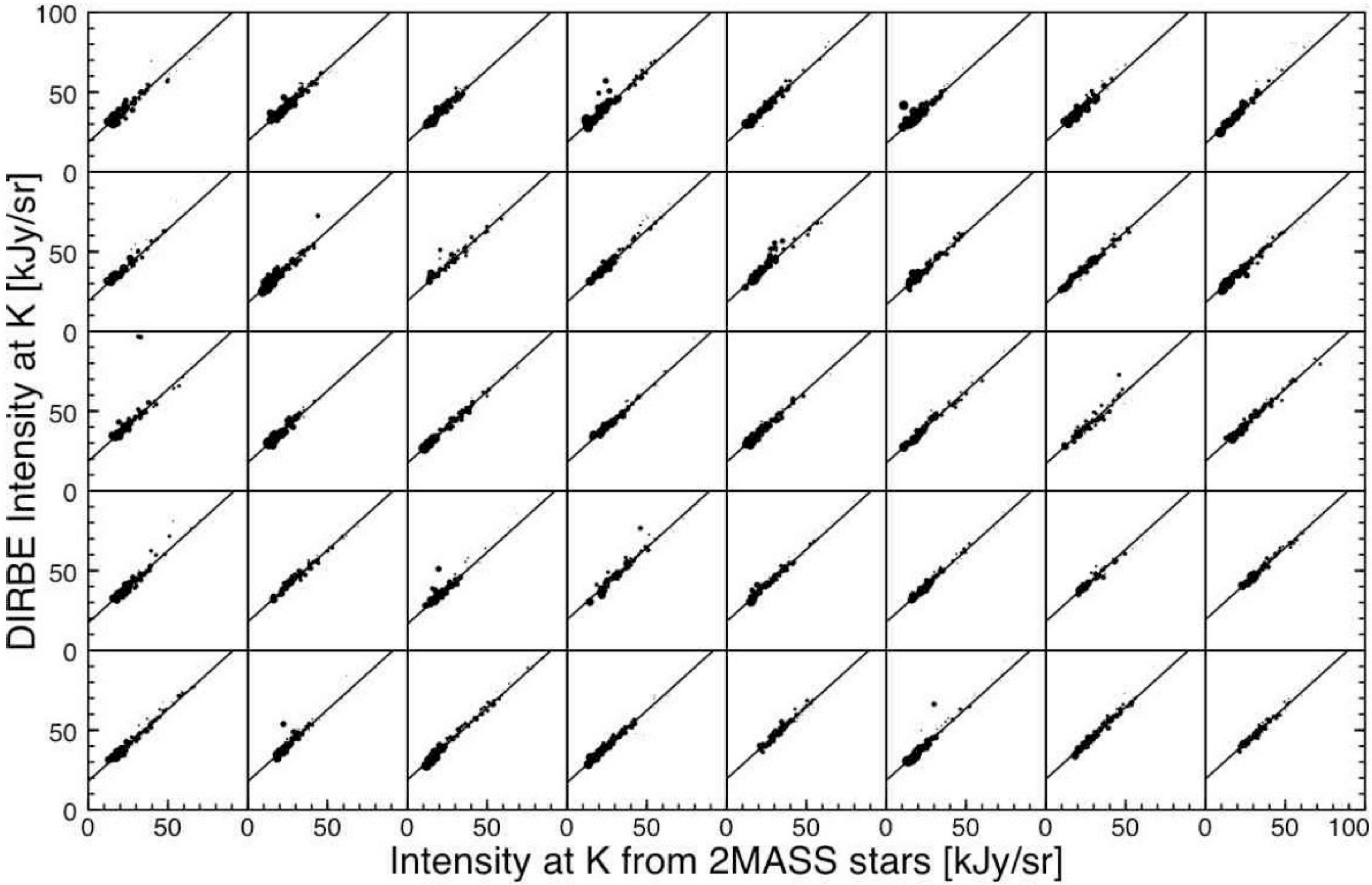
- Generated many fake star fields, |b| > 64°
- Properly allocated fluxes to DIRBE pixels
- Resulting model histogram
- Histogram shifted by 14.4 kJy/sr
- Actual zodi-subtracted DIRBE data
- Dashed: Euclidean



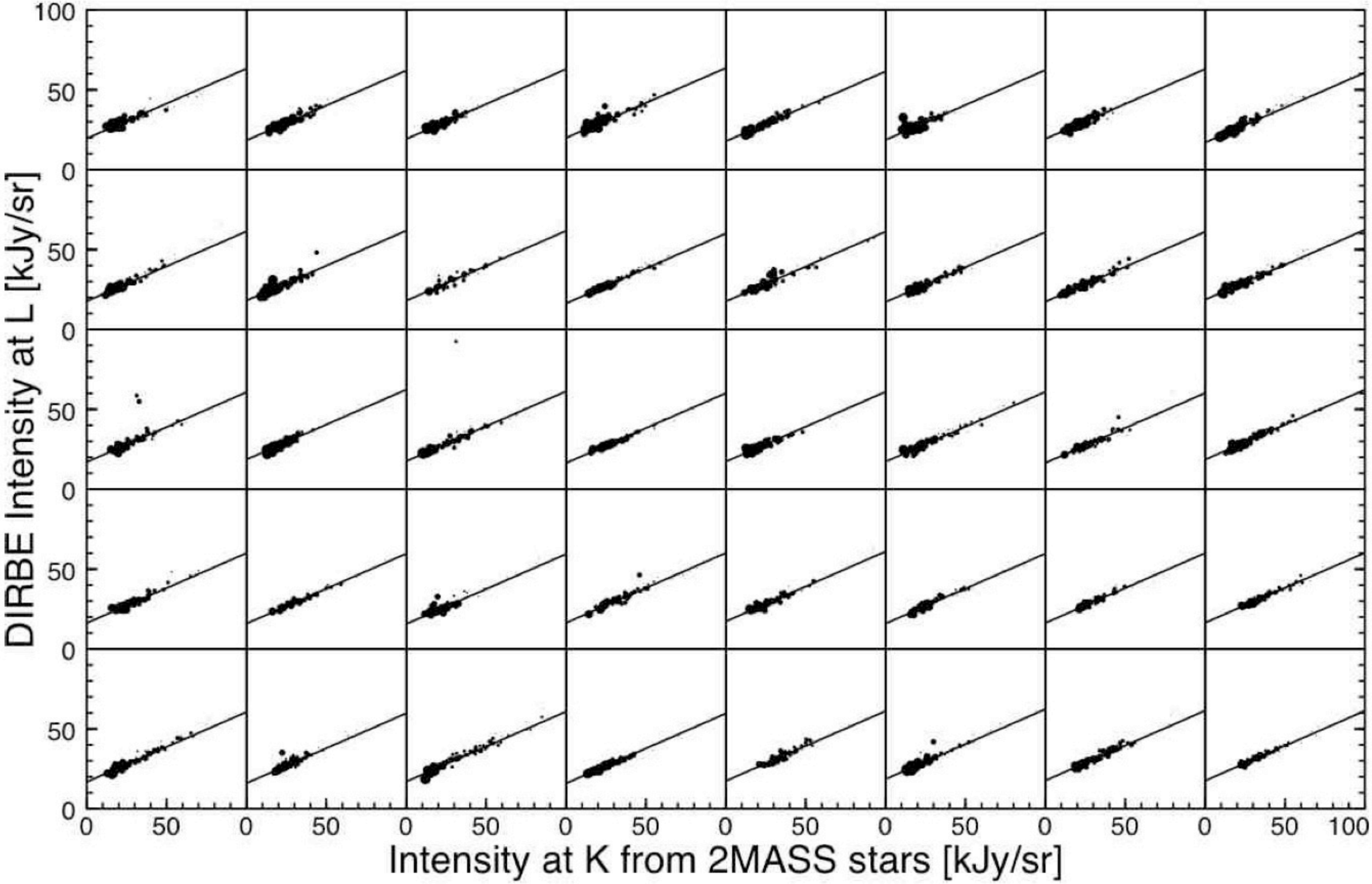
CIBR = 23.1±5.9 kJy/sr at 2.2 μm
14.4±3.7 kJy/sr at 3.5 μm



DIRBE vs. 2MASS Fits at K = 2.2 μm

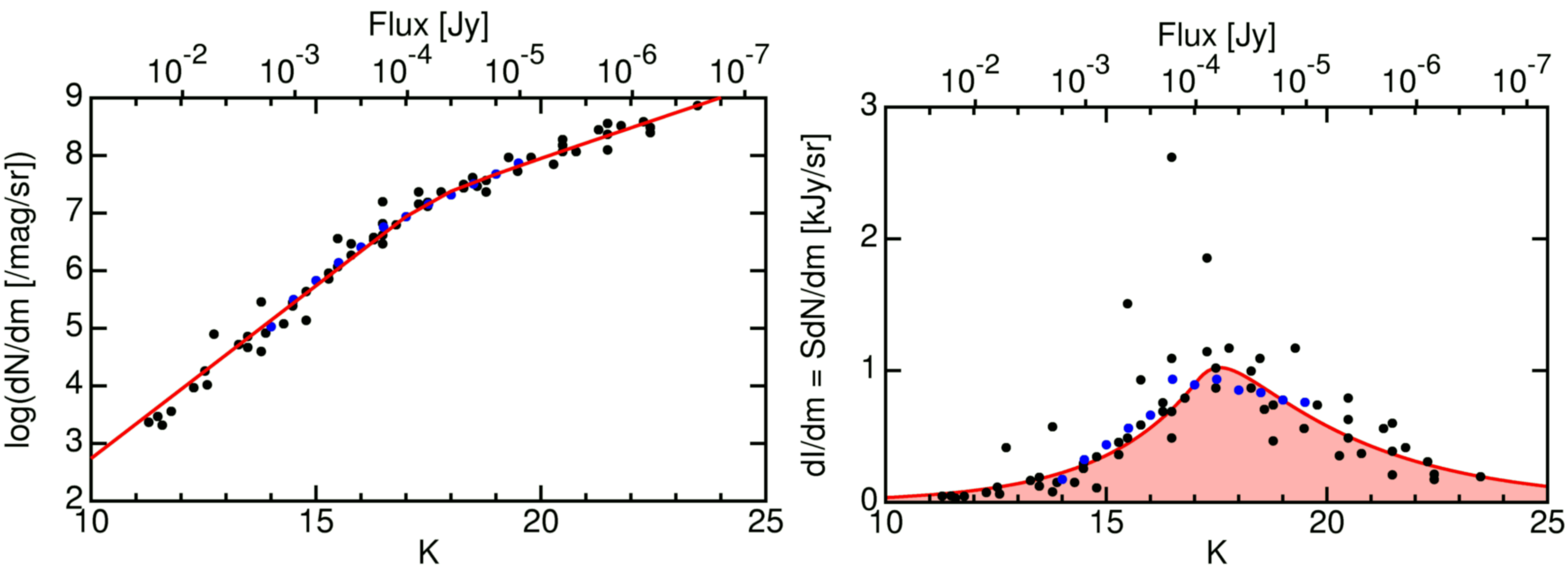


DIRBE at L = 3.5 μm vs 2MASS at K



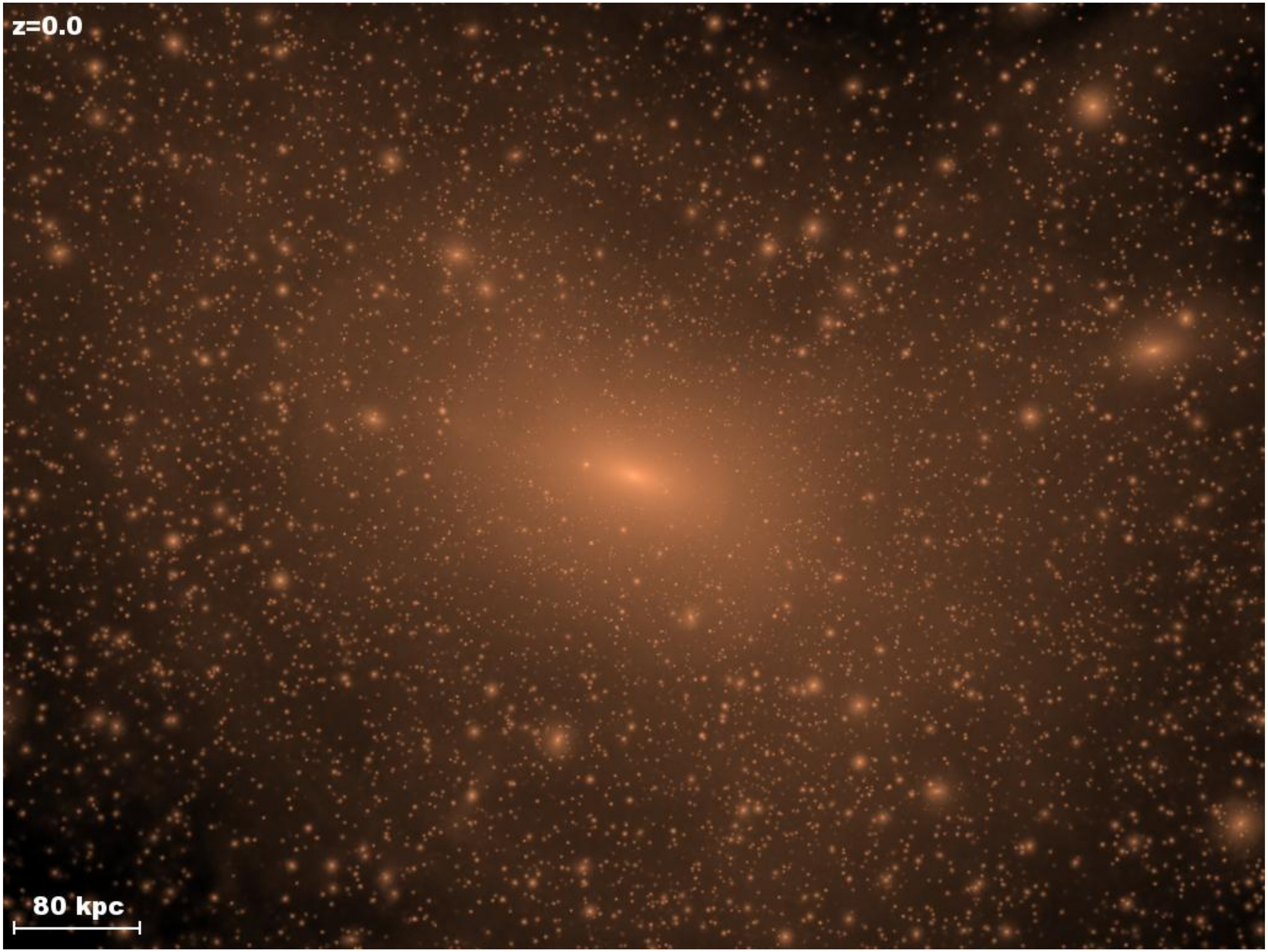
We don’t need arc-sec resolution to subtract galactic stars. DIRBE was almost good enough.

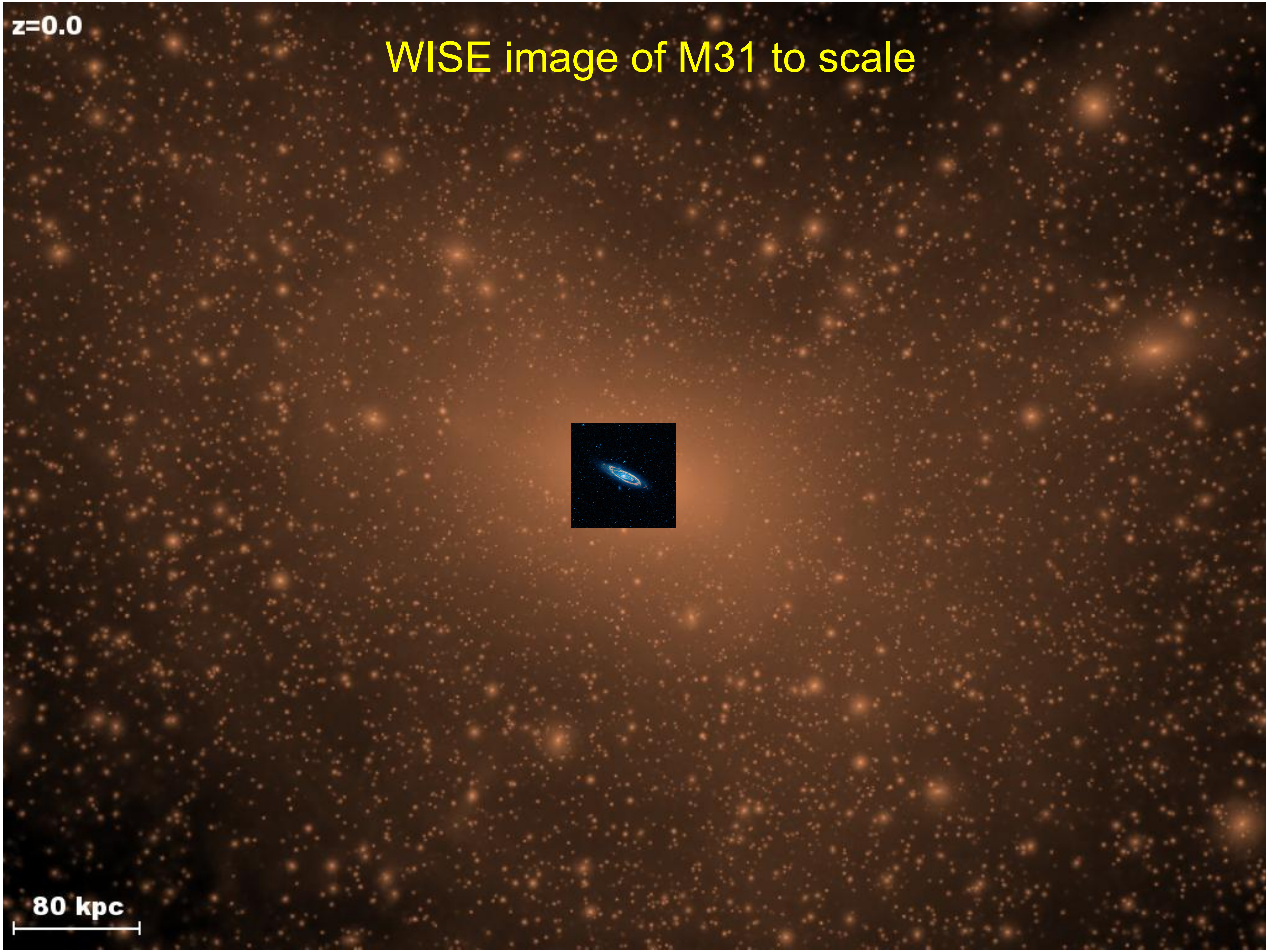
2.2 μm Galaxy Counts



- K counts from Figure 1 of Madau & Pozzetti, MNRAS, 312, L9-L15 (2000)
- CADIS counts from Huang etal astro-ph/0101269
- Integral under fit gives 6.3 kJy/sr or 8.6 nW/m^2/sr

M31-sized halo from Via Lactea




z=0.0
WISE image of M31 to scale
80 kpc

There is no blank sky between galaxies

FIRAS Far IR Background

- Any proposed FIR background must be compatible with the limits on the CMB distortion.
- This means the FIRB is either small or similar to the galactic spectrum.
- The FIRAS fit to the $N_H = 0$ intercept of the high frequency channel, [astro-ph/9803021]

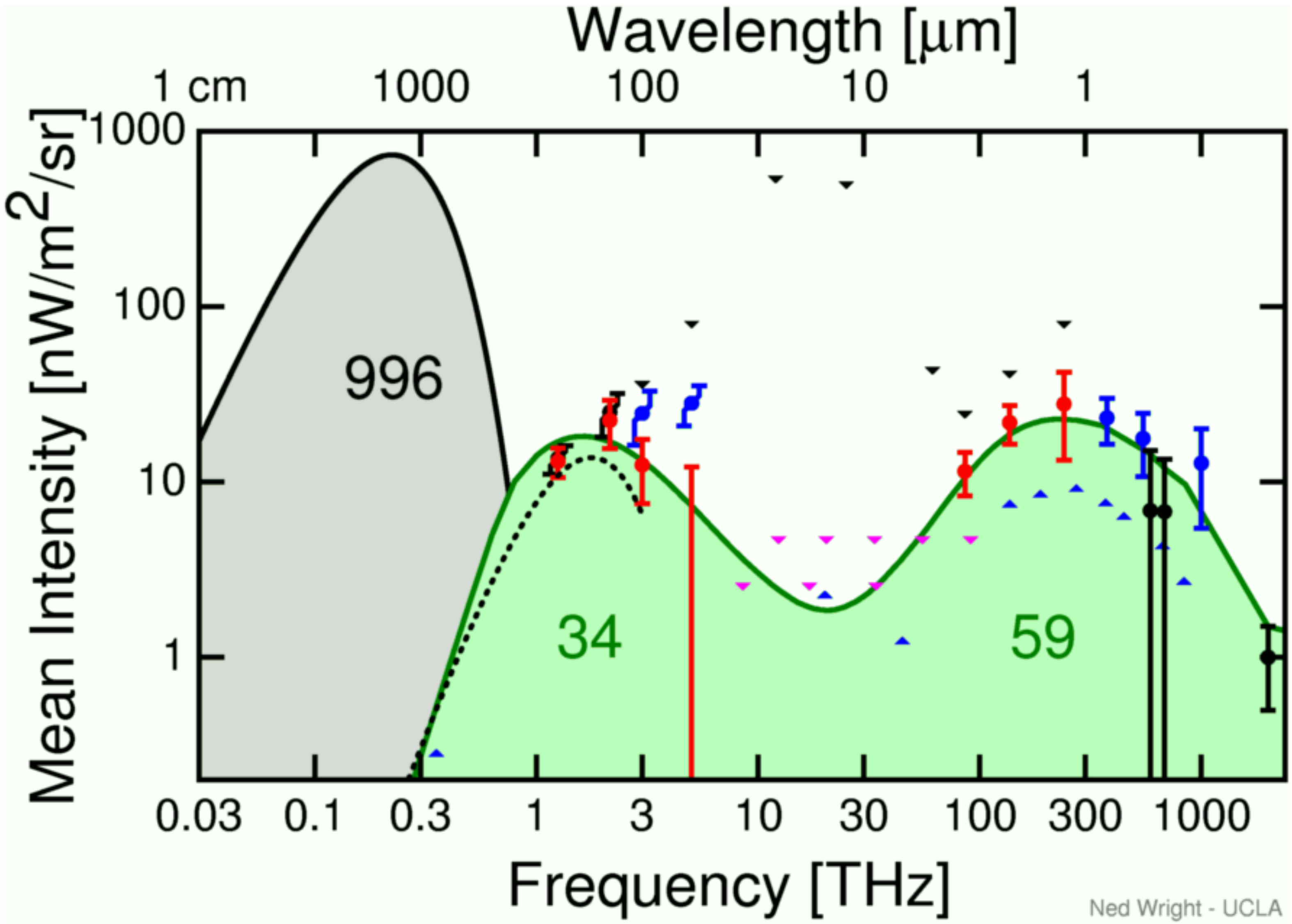
$$I_\nu = 1.3\times10^{-5}(\nu/100)^{0.64}B_\nu(18.5\ \mathrm{K}),$$

fails with $\Delta\chi^2 = 22.6$ ($4.75\ \sigma$)

No simple limit at 850 μm

- FIRAS fit fails with $\Delta\chi^2$ = 22.6 but
  I_{850} = 143 kJy/sr
- Lagache *et al*. fit [astro-ph/9901059] is marginal with $\Delta\chi^2$ = 5.8 but
  I_{850} = 115 kJy/sr
- A modified scaled Primack model on the next slide is fine with $\Delta\chi^2$ = 2.2 but
  I_{850} = 195 kJy/sr

Cosmic Optical & IR Background



Conclusions

- The CIRB has been detected in both the far IR and the near IR windows through the interplanetary dust, but measurements between 5-60 μm are impossible from 1 AU
- Bolometric OIR background is about 10^2 nW/m^2/sr or 10% of CMB
- Ratio of optical plus near IR to the far IR is about 2:1
- Biggest uncertainty is the zodiacal light, DESIRE, LZM or ZEBRA would help.