Modeling of the Extragalactic Background Light

Rudy Gilmore
SISSA

Santa Cruz Galaxies Conference
UCSC
August 10, 2011

Outline

Somerville et al. - ArXiv:1104.0669 (MNRAS submitted)
Gilmore et al. - ArXiv:1104.0671 (MNRAS submitted)

✓ Modeling the evolving extragalactic background light with semi-analytic methods

✓ The EBL and gamma-ray sources

✓ Comparison with other results and future work

Collaborators:

❖ Joel Primack - UCSC

❖ Rachel Somerville - STScI

❖ Alberto Domìnguez - UCSC and Inst Astro Andalusia

The Extra-Galactic Background Light (EBL)

Photon population created by structure formation (stars+AGN+others?)

Determining the EBL from observations is difficult:

★ Direct photometry measurements must contend with difficult foreground subtraction and calibration issues!

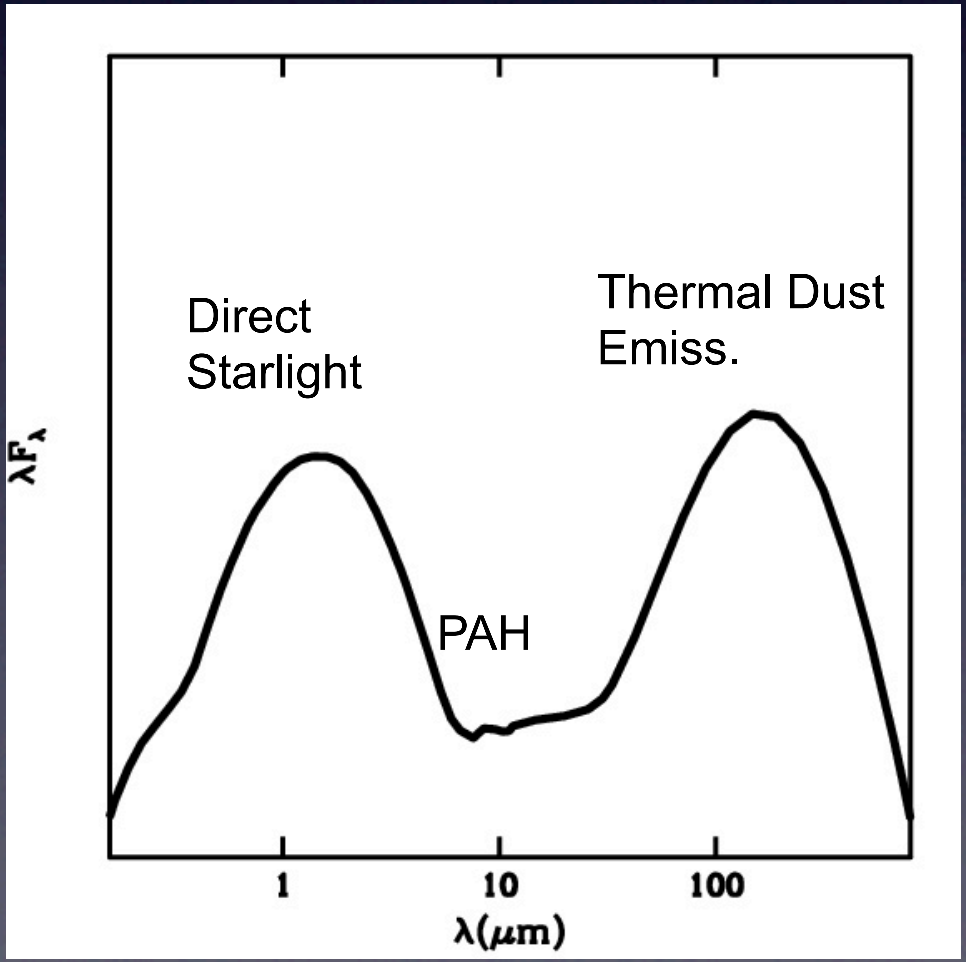
★ Number counts available at many wavelengths, but degree of convergence often controversial, also fringe issues, source confusion.

Fully understanding the creation and evolution of this photon population requires sophisticated modeling

Observationally-based models:
Kneiske et al. (2002; 2004); Finke et al. (2010); Younger & Hopkins (2011); Dominguez et al. (2011)

Backward evolution:
Stecker et al. (2006); Franceschini et al. (2008)

Forward evolution (semi-analytic) models:
Primack et al. (2005; 2008);
Gilmore et al. (2009), this work

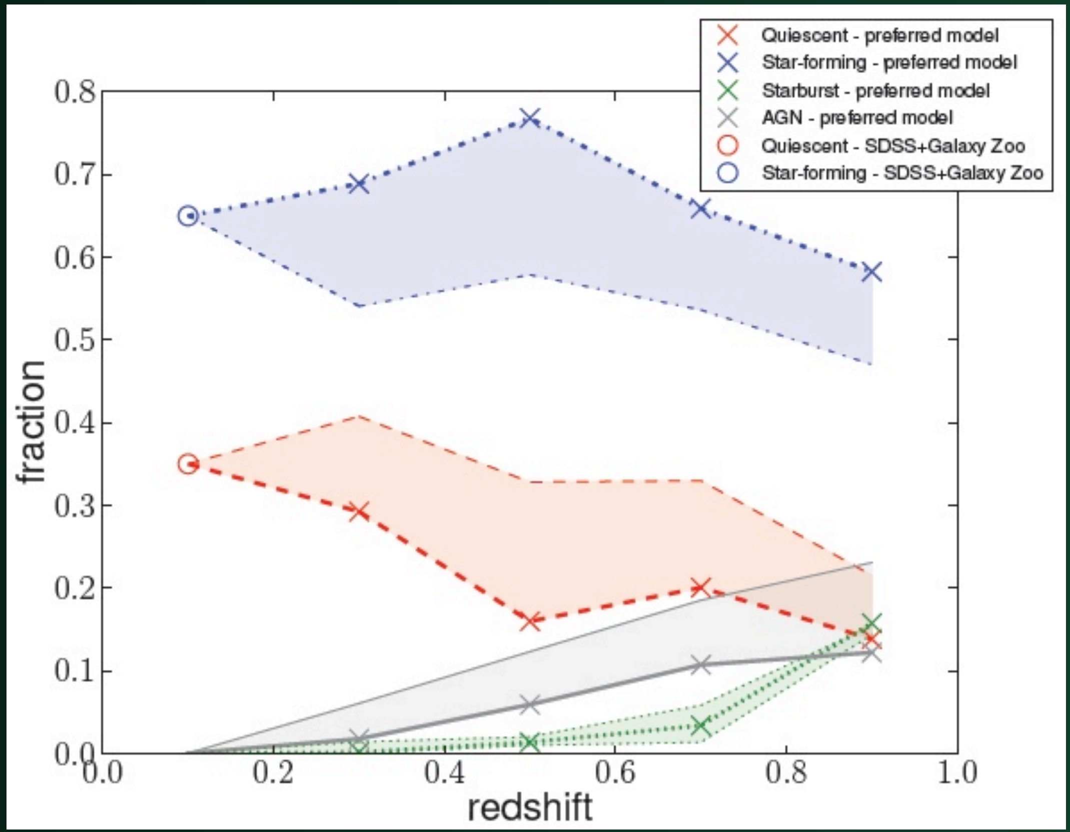


EBL from observations:

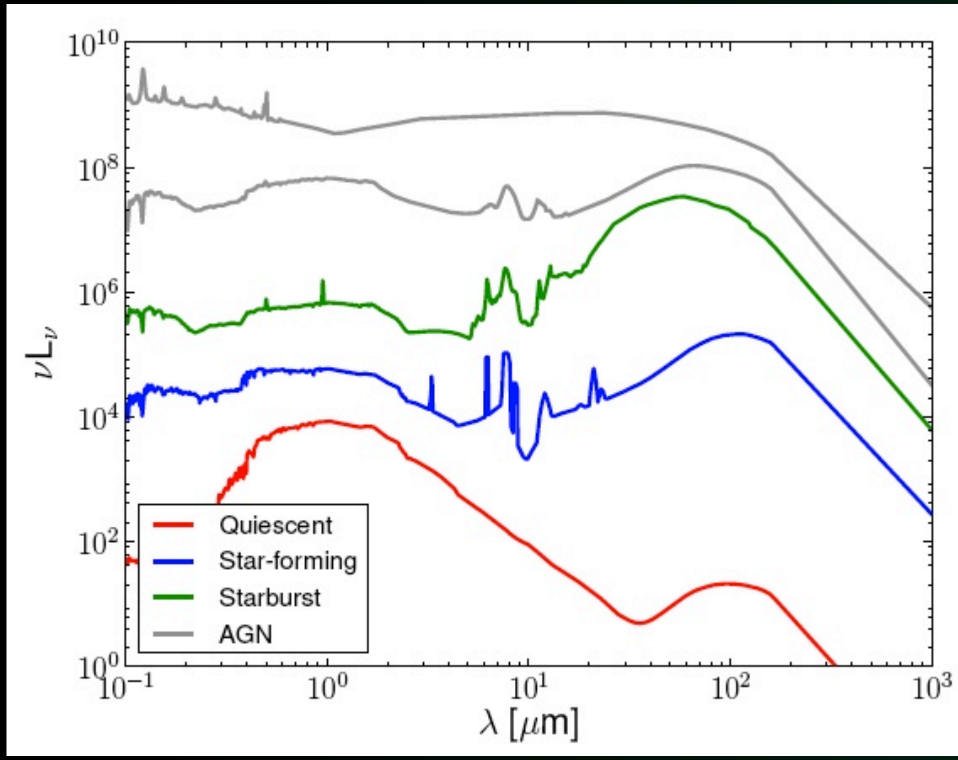
Dominguez et al., 2011
MNRAS 410, 2556 (ArXiv:1007.1459)

• Uses evolution galaxy number fraction across 25 spectral types seen in some 6000 AEGIS galaxies, with normalization to K-band luminosity functions (Cirasuolo 2010)

AGN and starburst-like spectral type fractions increase with redshift to z~1, while quiescent decrease.



5 sample templates:

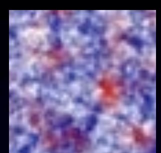


• AEGIS multiwavelength data covers several optical and NIR bands, IR (IRAC and MIPS), and UV (GALEX)

• High redshift (z > 1): 2 assumptions about evolution of SED types were considered

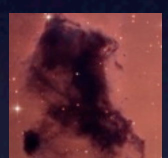
EBL from our semi-analytic model

- Treats co-evolution of AGN, black holes, and galaxies in ΛCDM framework
- Based on model of Somerville et al. (2008), including:

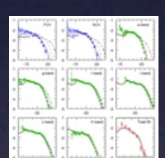


• Galaxy formation based on hierarchical buildup of cold dark matter halos.

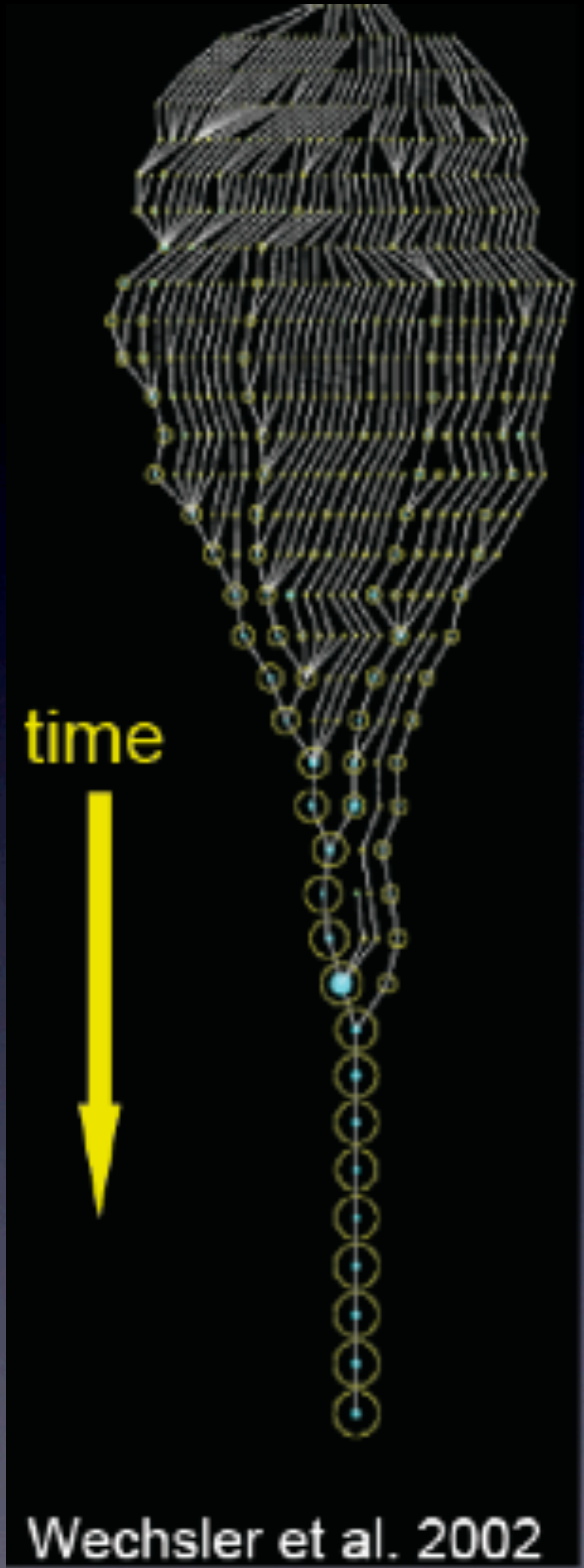
• Star formation in quiescent and burst (merger-triggered) modes, with regulation by AGN feedback. Stellar emission spectrum from Bruzual & Charlot (2003).



• Optical and UV starlight absorbed using (modified) dust model of Charlot & Fall (2000), IR re-emission based on Spitzer templates



• Model parameters set by well-determined local observables and results from simulations of galaxy mergers



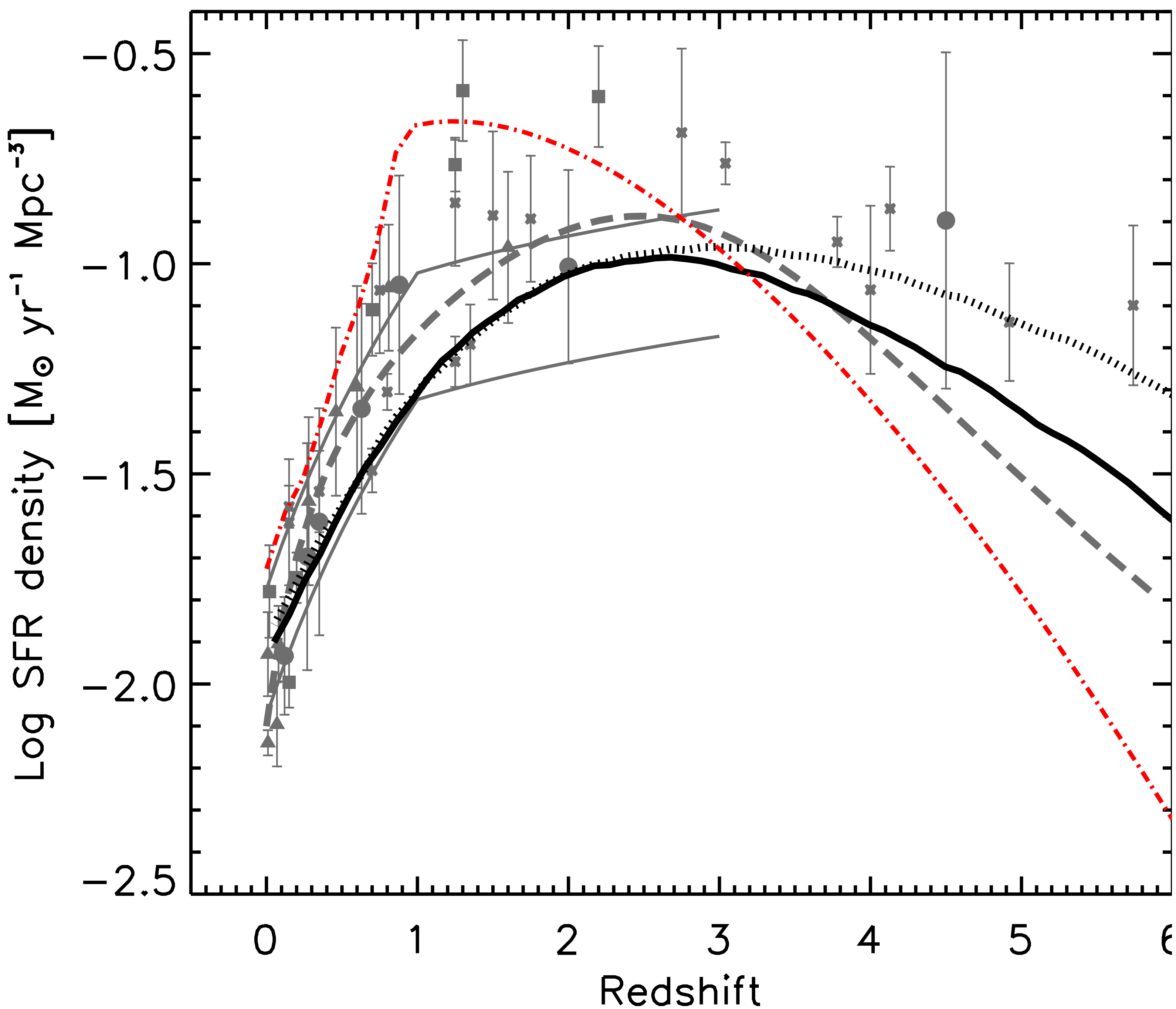
Our recent work:

➡ "CLCDM" model based on concordance (WMAP1) cosmology (Primack, Gilmore, Somerville 2008)

- Gilmore et al. 2009: Focused on high-z UV evolution, included QSO component, comparison with IGM data

➡ This work based on new WMAP5/7 model with updated cosmological parameters

Star formation rate density across cosmic time



WMAP1 Model (Primack et al. 2008)

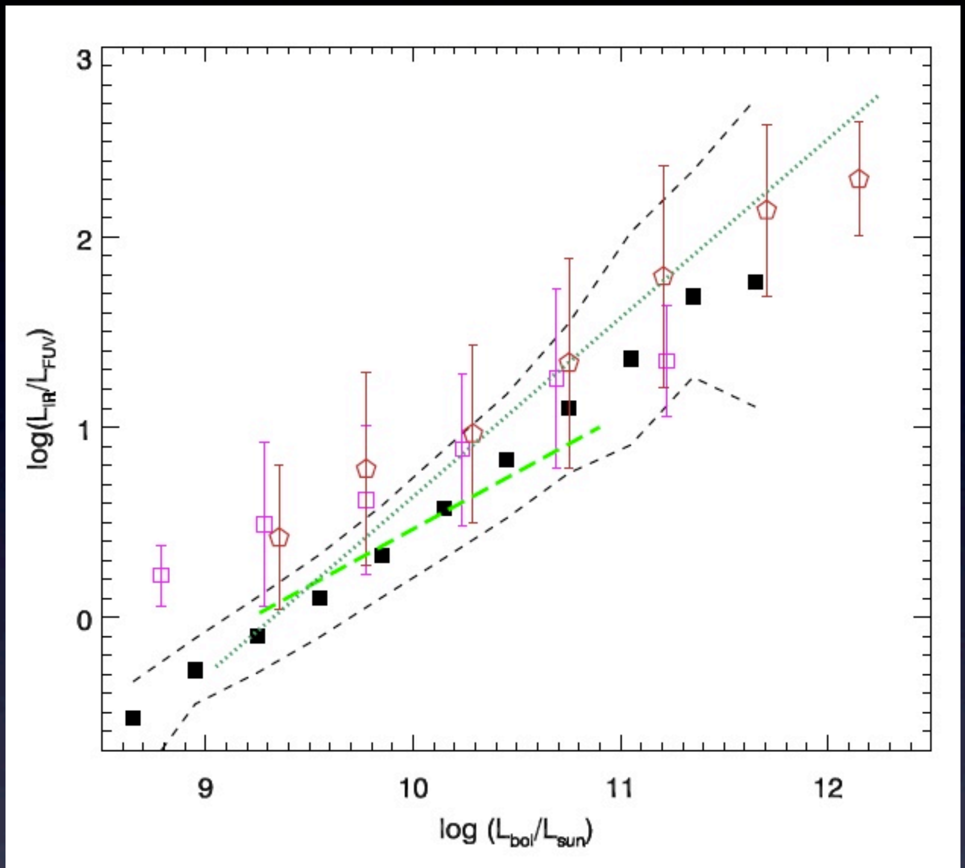
WMAP5 (this work)

Hopkins & Beacom 2006 best fit

Dominguez et al. (2011)
(inferred from UV and IR light)

Dust Absorption of Starlight

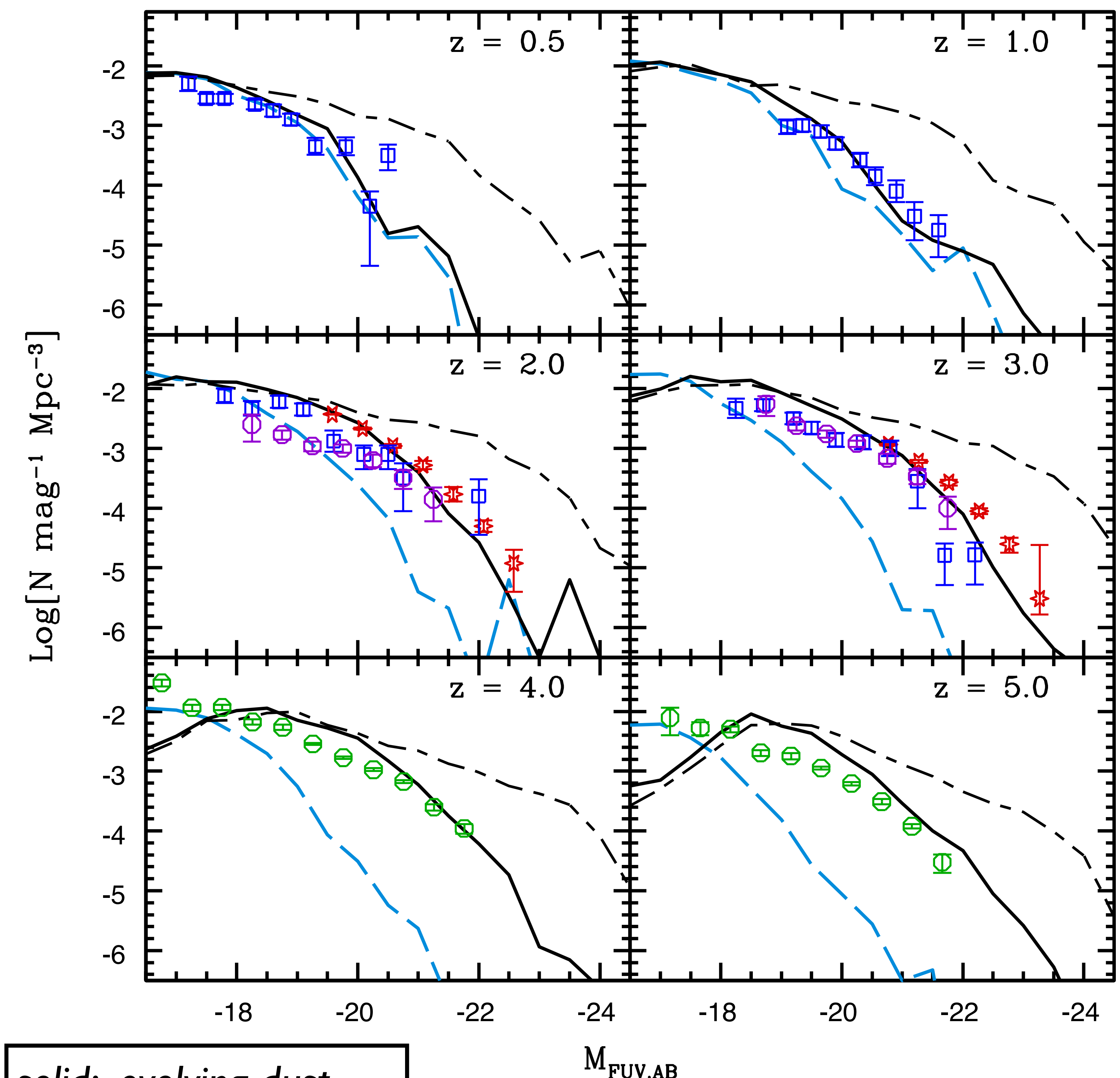
• Our results use dust absorption model of Charlot & Fall 2000.



• Our fiducial model includes an additional `evolving dust' factor to correct UV (right) luminosity functions.

• Currently looking at effect of increased resolution of small haloes (strongest effect in high-z UV output)

Far-UV evolving luminosity functions

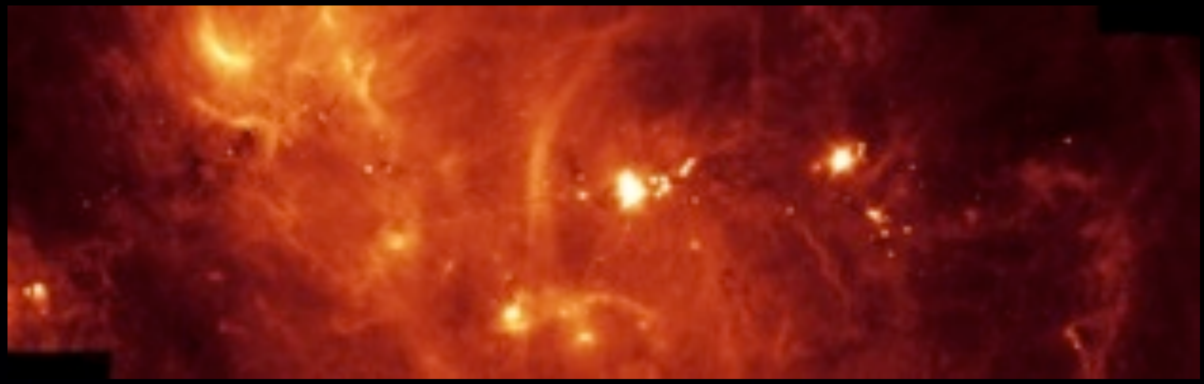


solid: evolving dust

dashed: no dust

blue dashed: fixed dust

Re-emission by Dust

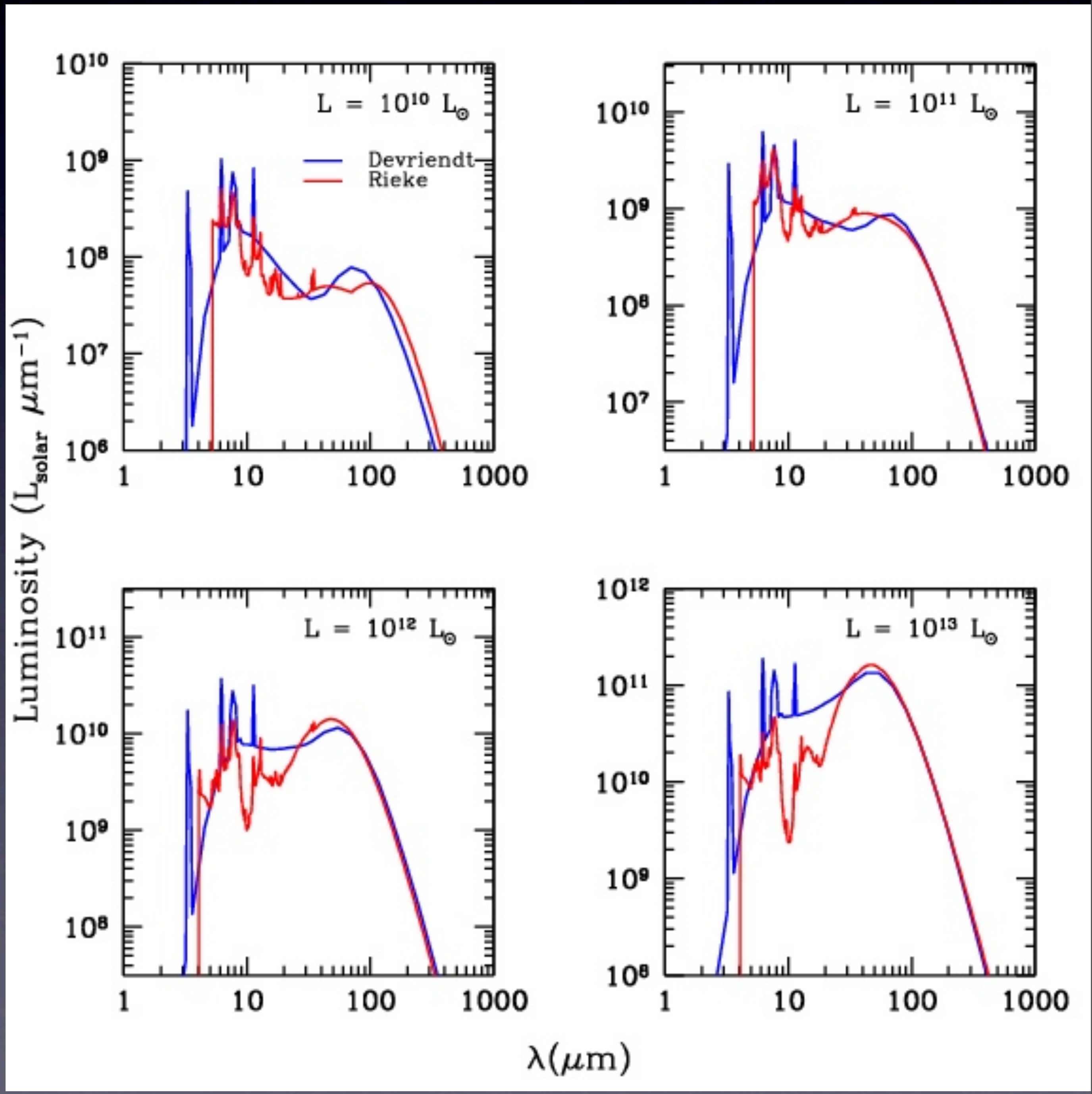


- Starlight absorbed by dust is re-emitted in the IR
  (energy in = energy out)

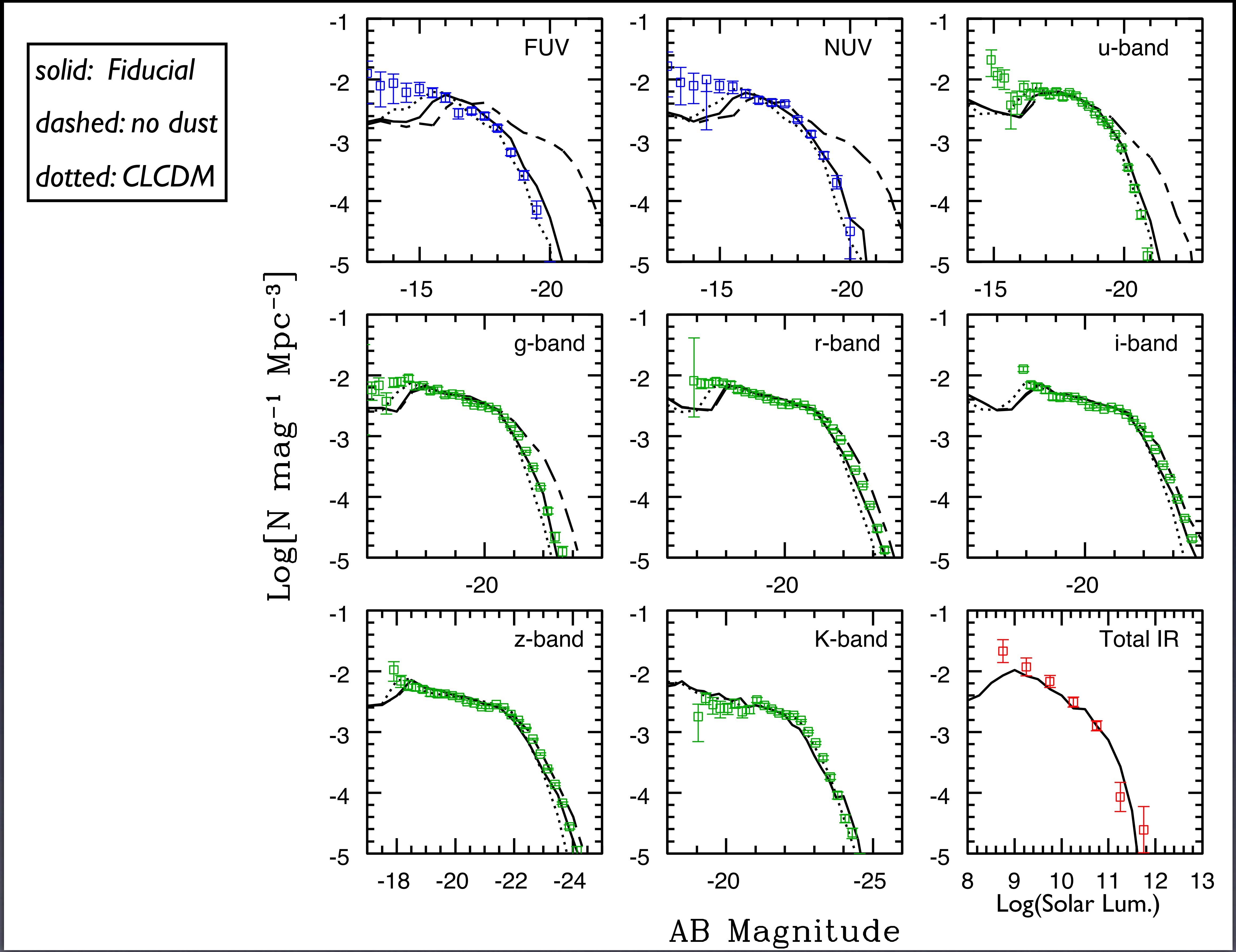
- Our older models have used templates from Devriendt & Guiderdoni (1999), based on IRAS

- Our new WMAP5 model uses templates of Rieke et al. (2009), based on Spitzer data.

- Rieke templates predict lower emissivity from 10 to 50 microns, esp for bright galaxies.

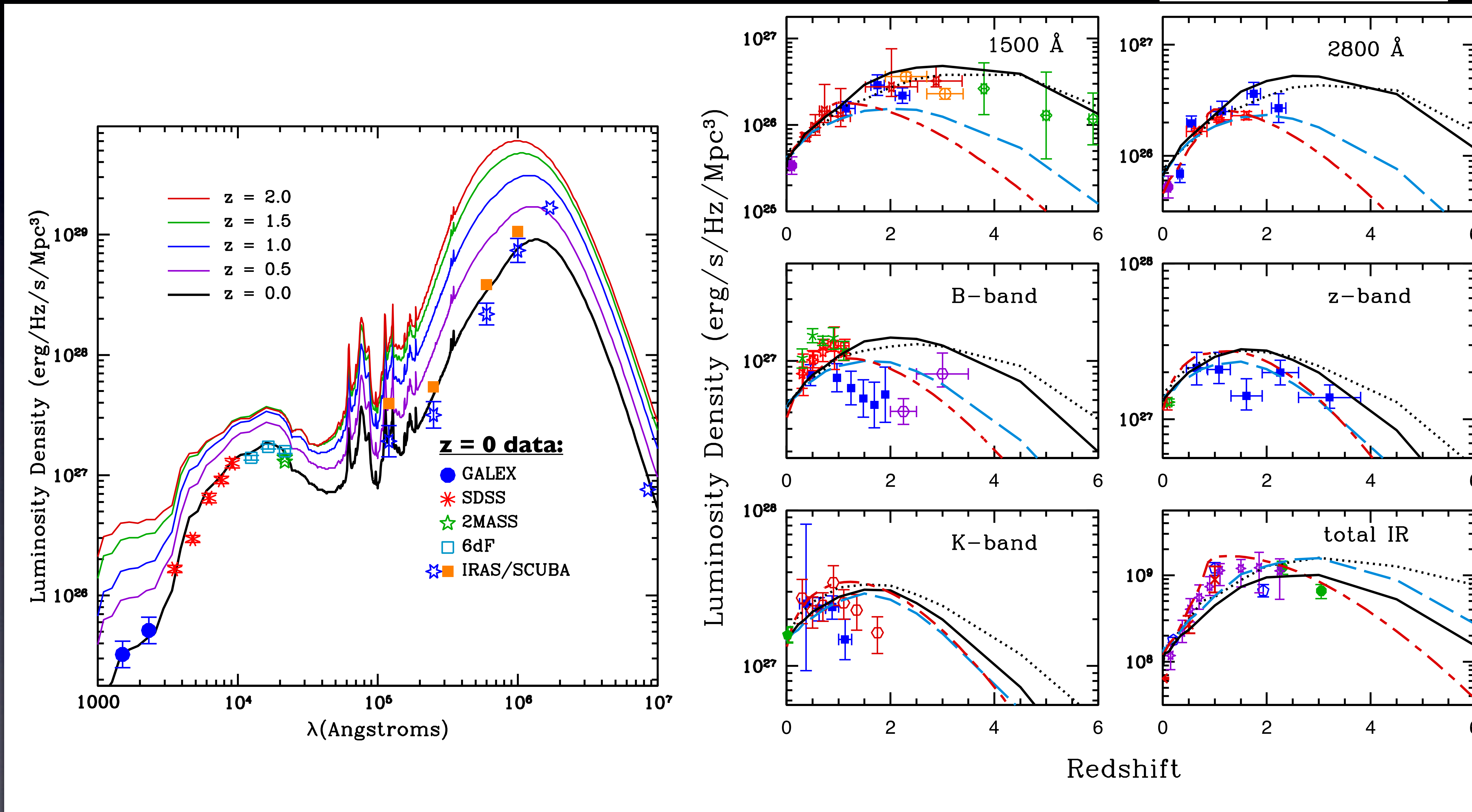


Local Luminosity Functions



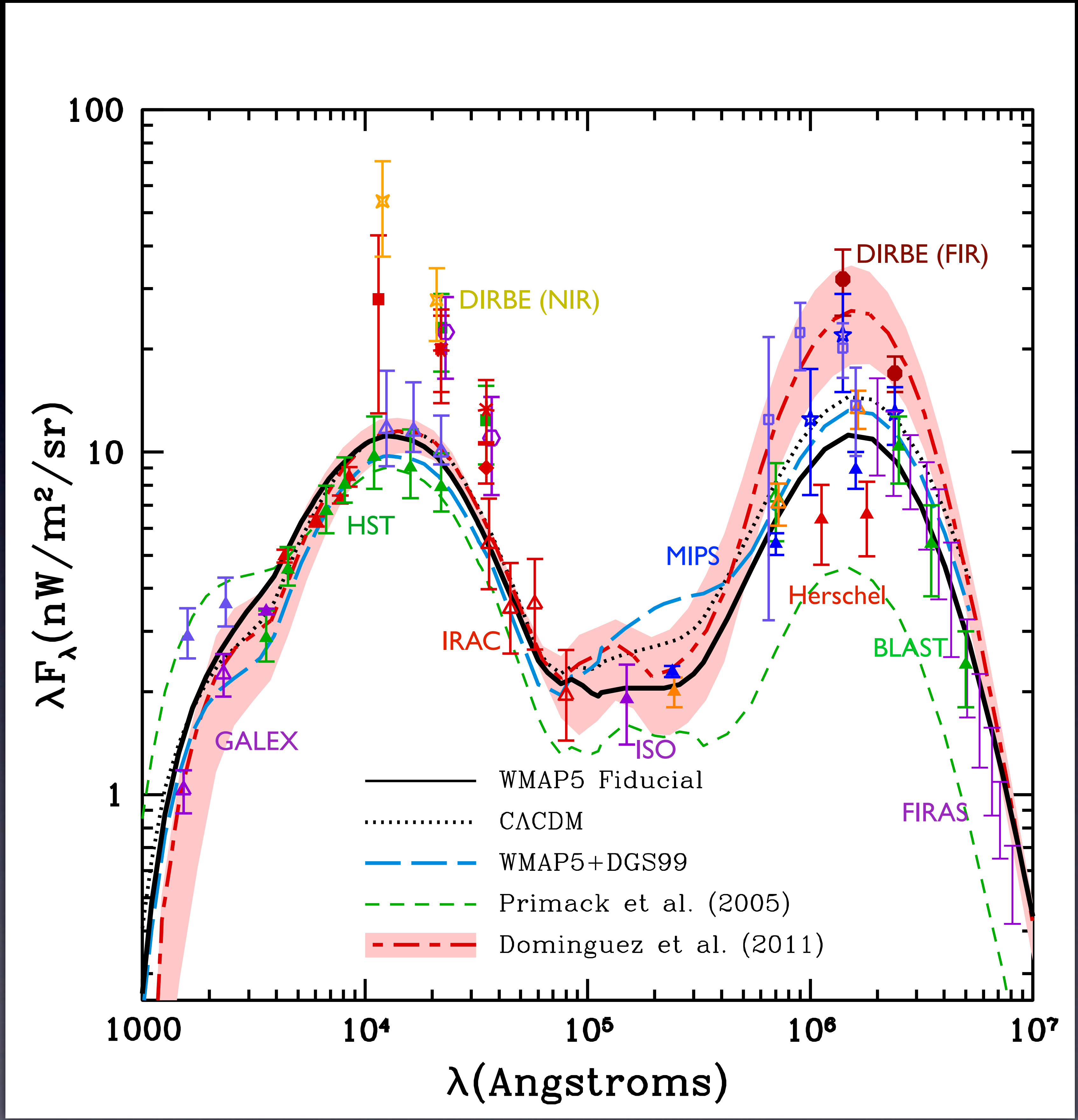
Predicted luminosity density

Fiducial
Fixed-dust
Dominguez et al. (2011)



The Local Background Flux

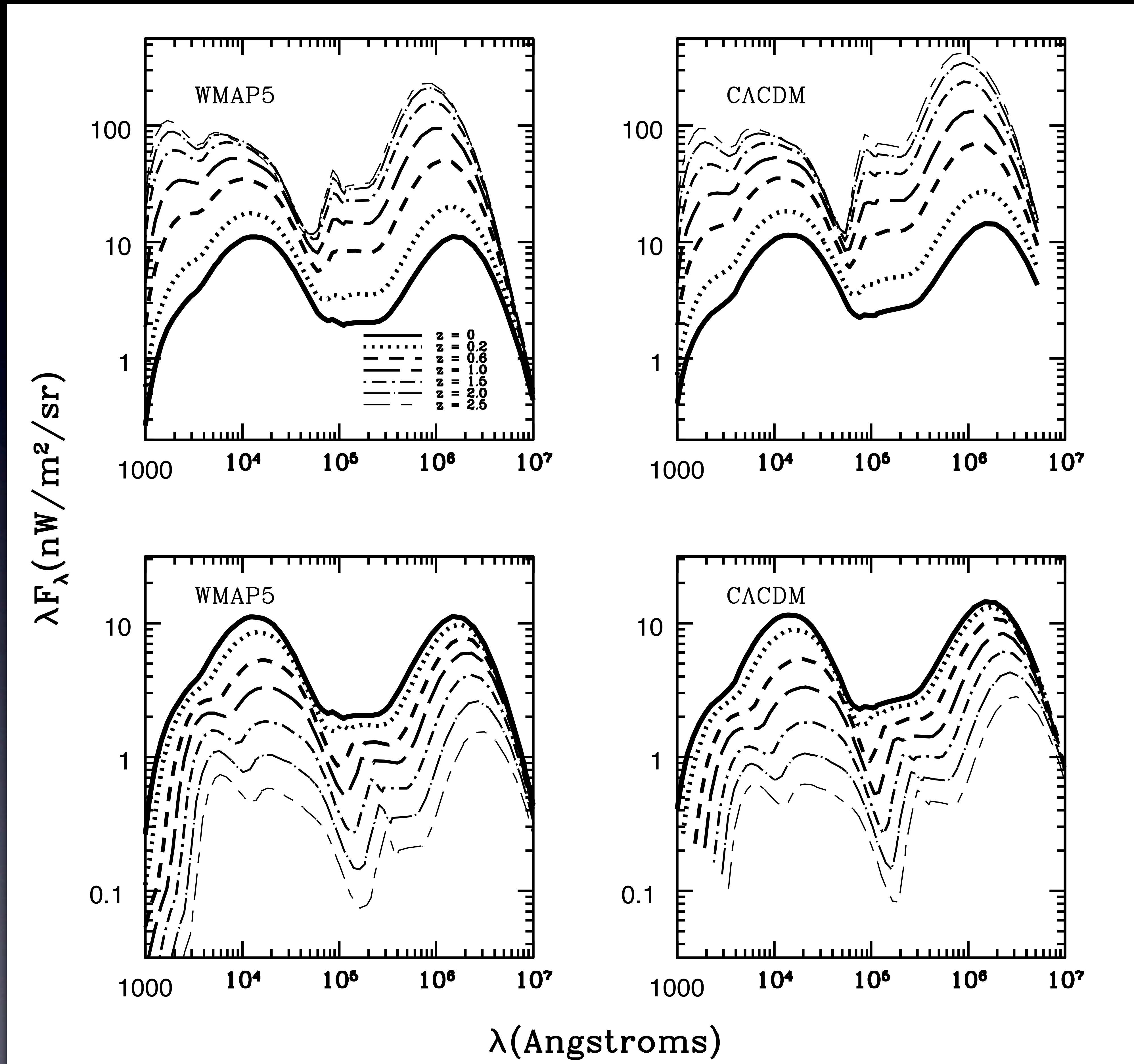
- We predict a flux near the level set by number counts at most wavelengths.
- Below diffuse near-IR background claims of DIRBE/IRTS
- Large uncertainty remains in far-IR; conflicting results between methods



EBL Buildup

Rest Frame:

Observed Frame:



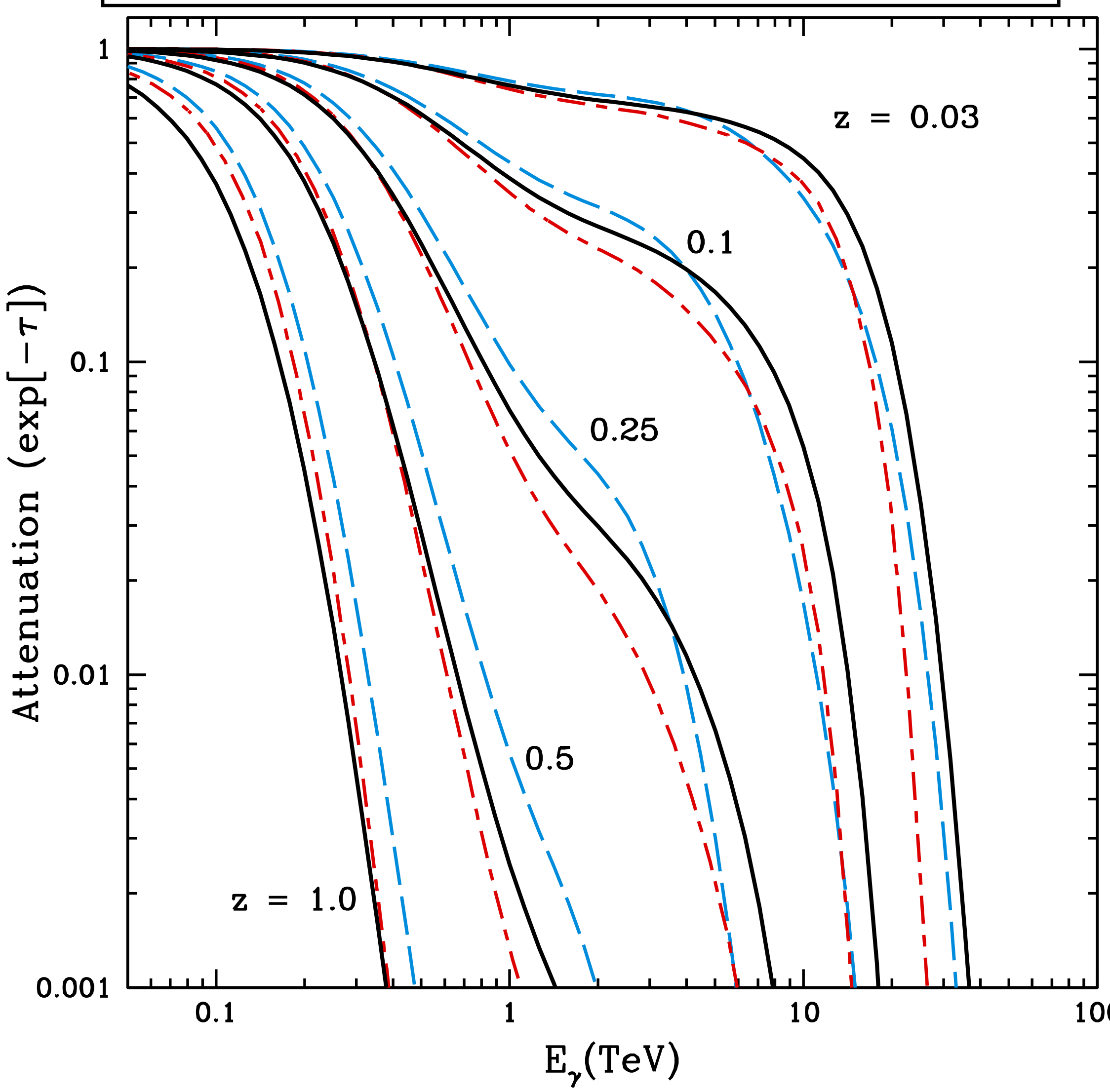
Absorption of Gamma Rays by EBL

- Gamma-ray attenuation via e^+e^- pair production provides a link between galaxy history and high energy astrophysics.

- This leads to softening and cutoff in gamma ray spectra of distant extragalactic sources (blazars and GRBs), as well as gamma ray horizon.

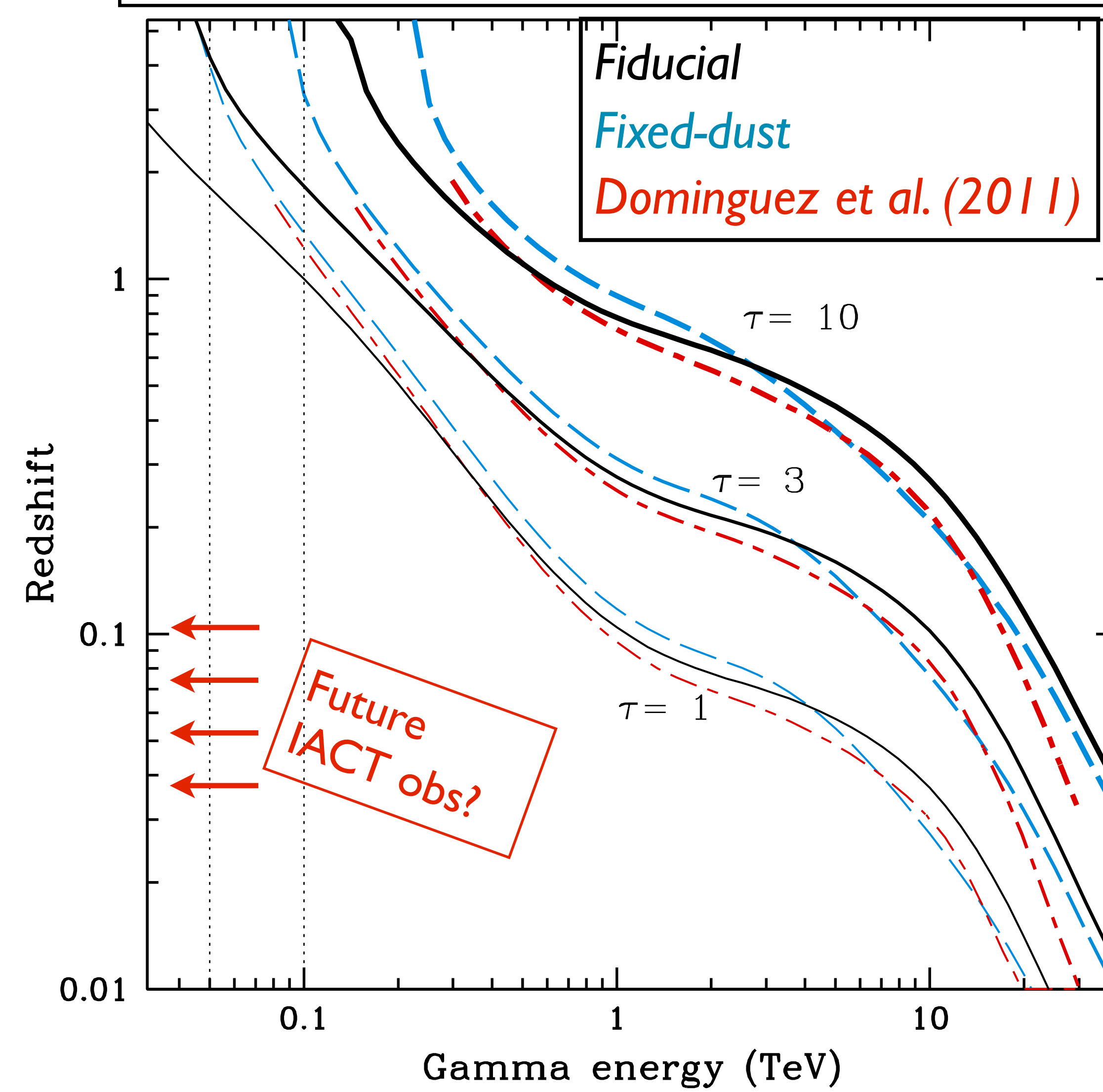
Gamma-ray attenuation

Gamma-ray optical depth vs energy at several redshifts



Cosmological "Attenuation Edge"

Contours of constant tau in redshift and observed energy



Our models with gamma-ray upper limits

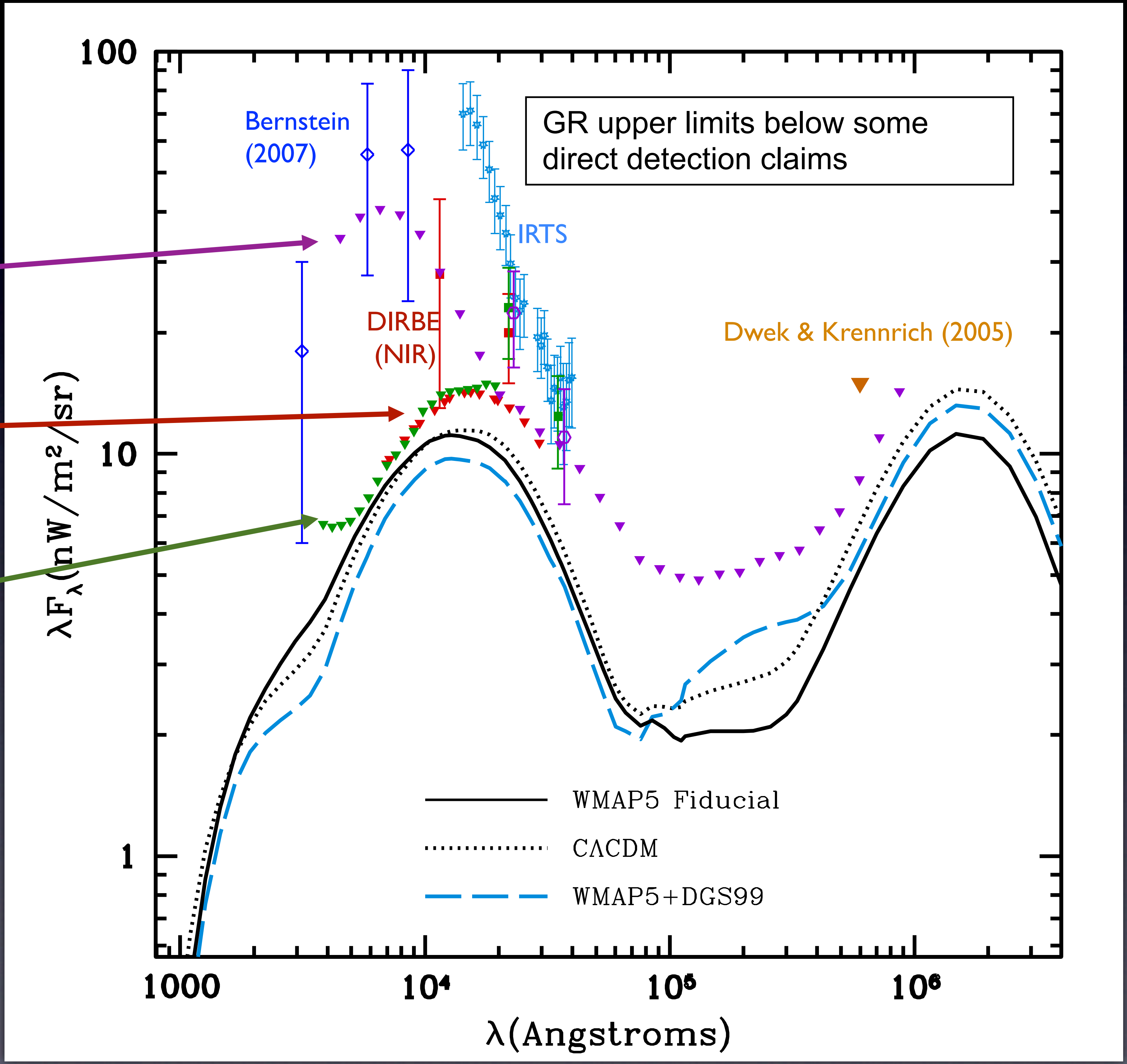
Our models are within new low bounds set by blazar observation

(Γ ≤ -1.5 criterion)

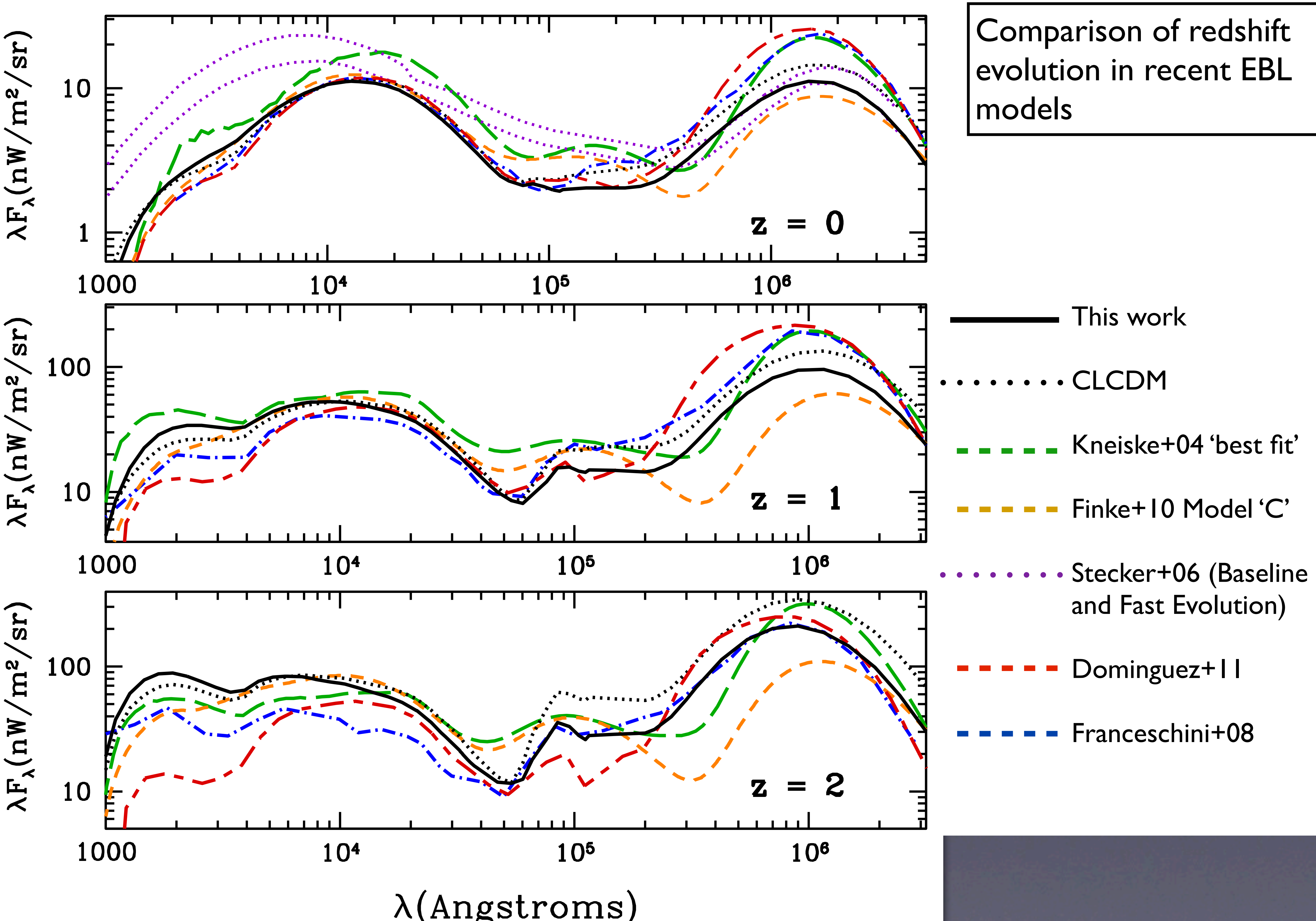
(Mazin & Raue 2007)
limits from 14 gamma-ray blazars

H 2356-309 and 1ES 1101-232 (z=0.165 and 0.186) (Aharonian 2006)

3C279 (z=0.536) (Albert 2008)



Comparison of redshift evolution in recent EBL models



Conclusions

✦ Using semi-analytic techniques, we have created an updated model of background light from the UV to far-IR

✦ We match well with measured number counts, luminosity functions, and luminosity density

✦ General convergence between results from our SAM and very different modeling techniques (Franceschini 2008, Finke 2009, Dominguez 2011) out to z~1...

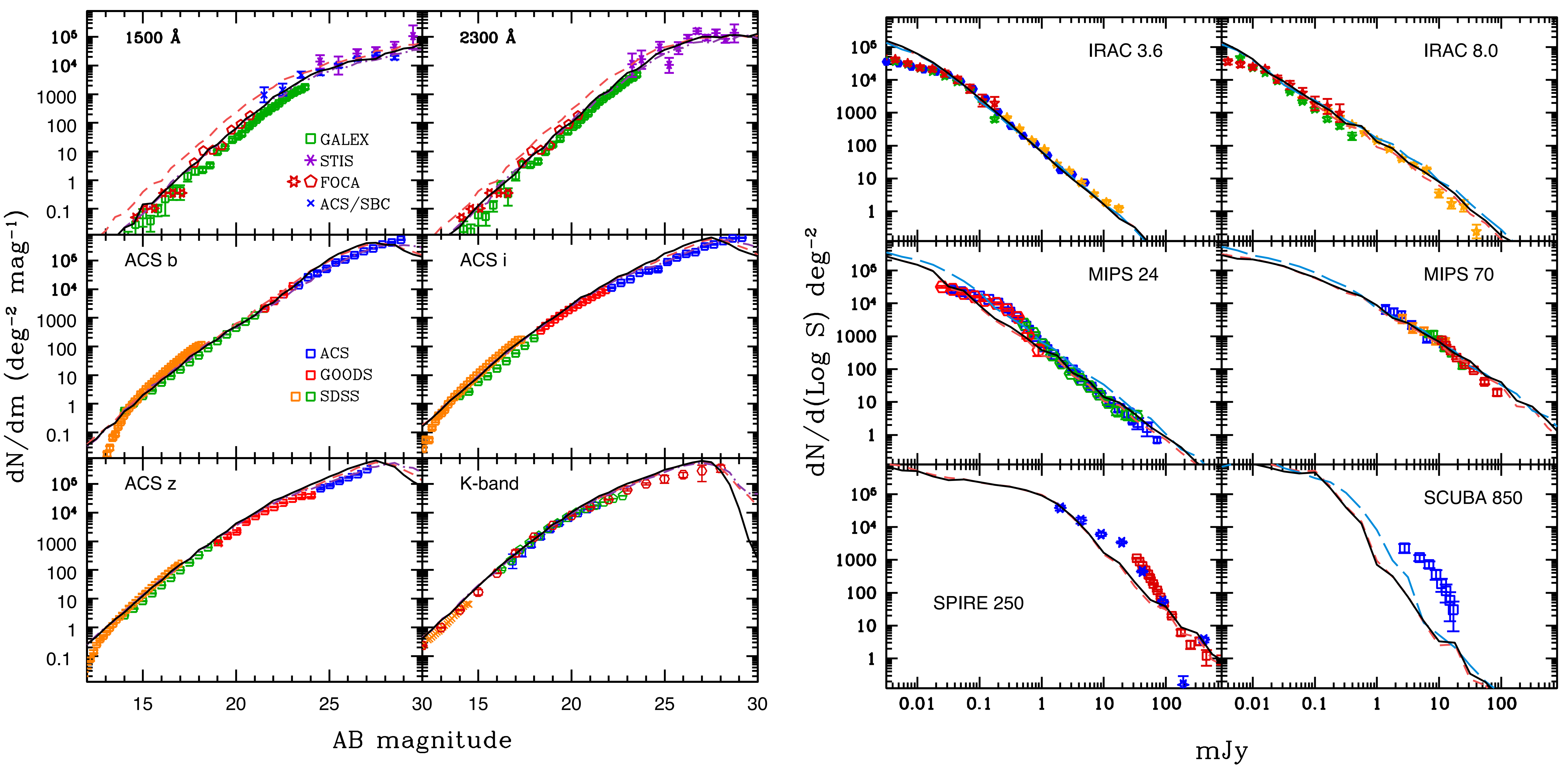
✦ ...However, large uncertainties remain in high-z evolution of UV flux, and overall normalization of IR peak.

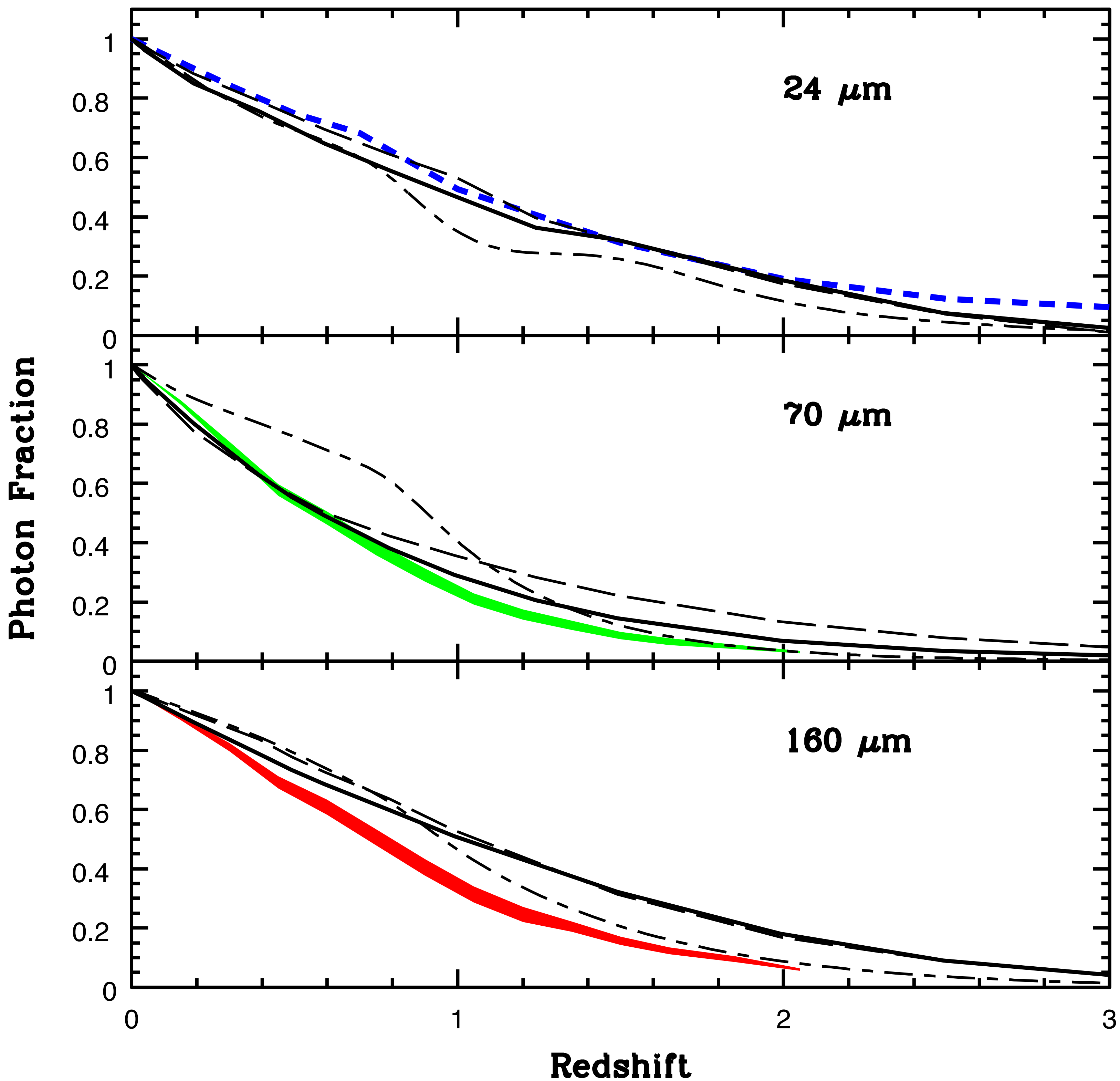
✦ Our model is near the level of resolved light (number counts) over wide range of wavelengths.

✦ Agreement with limits from gamma-ray experiments.

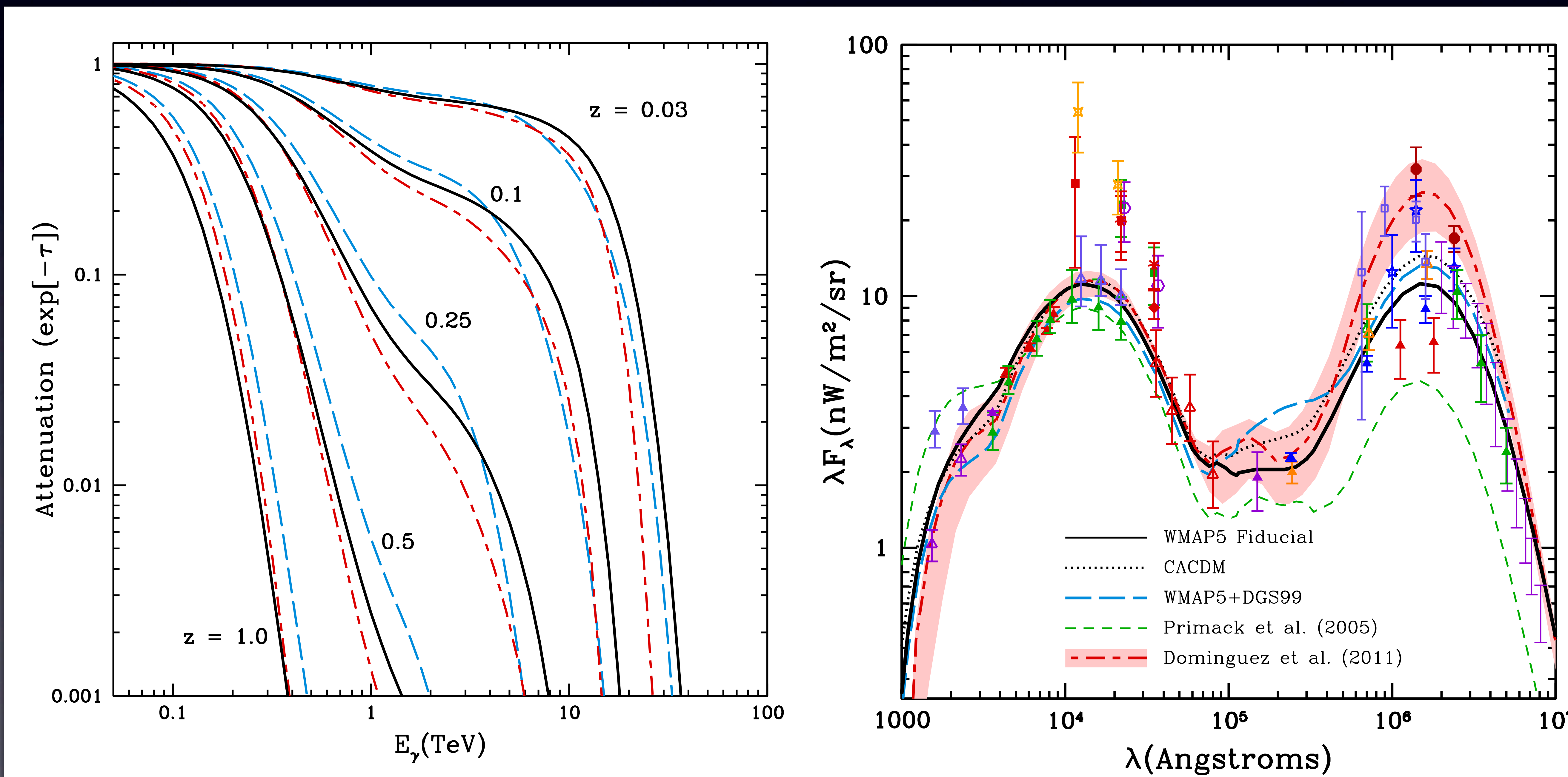
✦ Low levels of background are good news for Fermi and next-gen ground-based instruments. EBL does not significantly impede observations below 100 GeV at $z < 1$

Galaxy number counts





Data:
Lefloch (2009) (24 micron)
Jauzac (2011) (70 and 160)



Attenuation (exp[−τ])
1
0.1
0.01
0.001
0.1
1
10
100
E_γ(TeV)
z = 0.03
0.1
0.25
0.5
z = 1.0
λF_λ(nW/m²/sr)
100
10
1
1000
10⁴
10⁵
10⁶
10⁷
λ(Angstroms)
WMAP5 Fiducial
CΛCDM
WMAP5+DGS99
Primack et al. (2005)
Dominguez et al. (2011)