The Galaxy Evolution View of the Extragalactic Background Light

Alberto Domínguez
(University of California, Riverside)

Collaborators:
Joel Primack, Rachel Somerville, Rudy Gilmore, Francisco Prada

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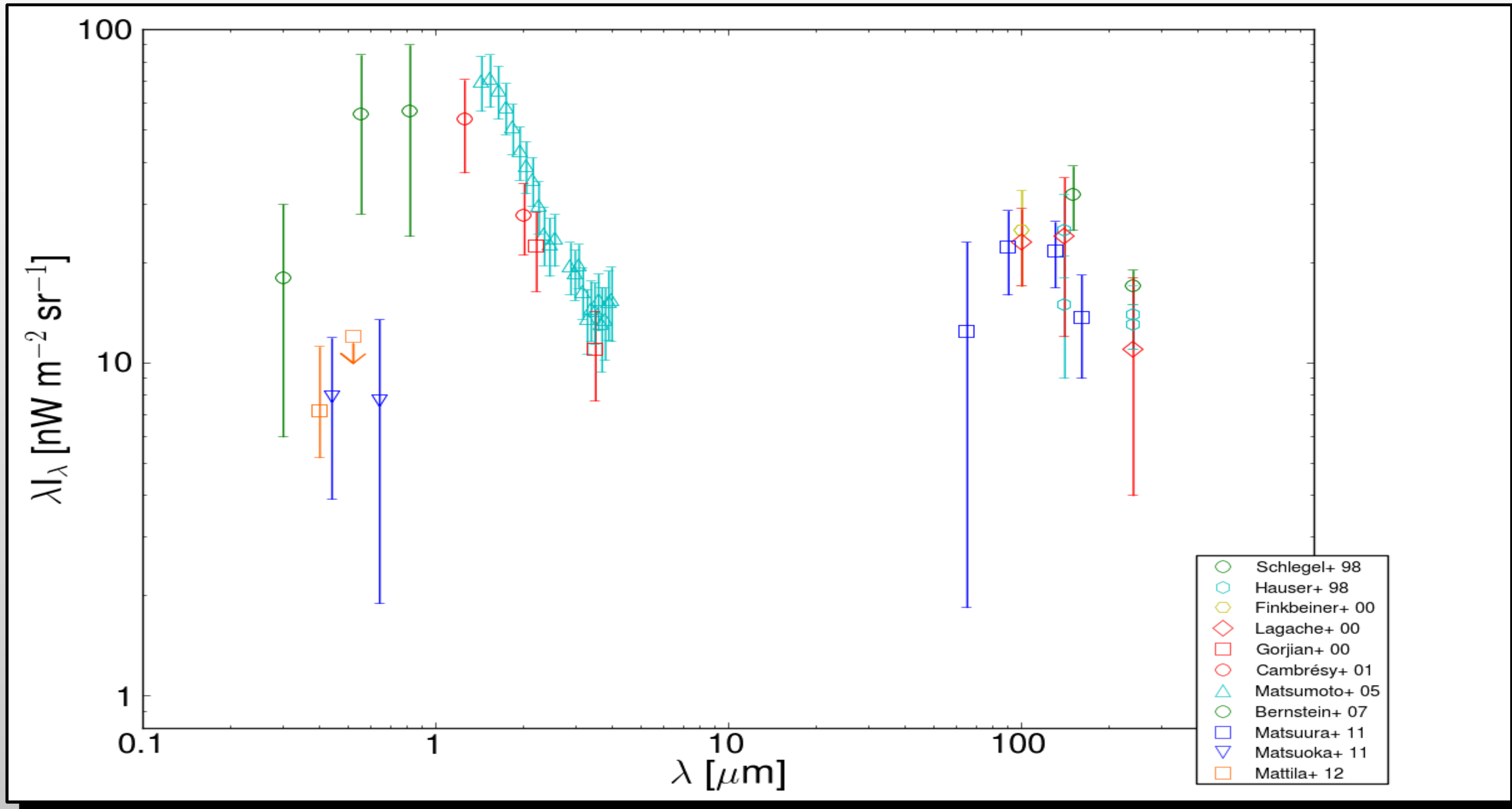
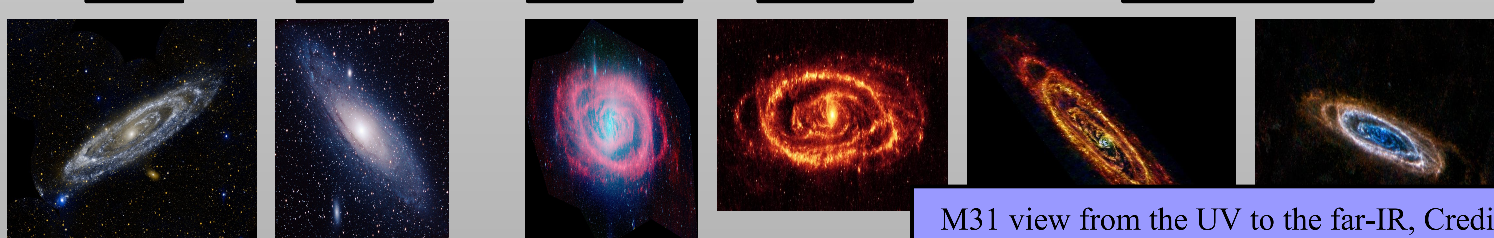
The local spectral energy distribution of the EBL

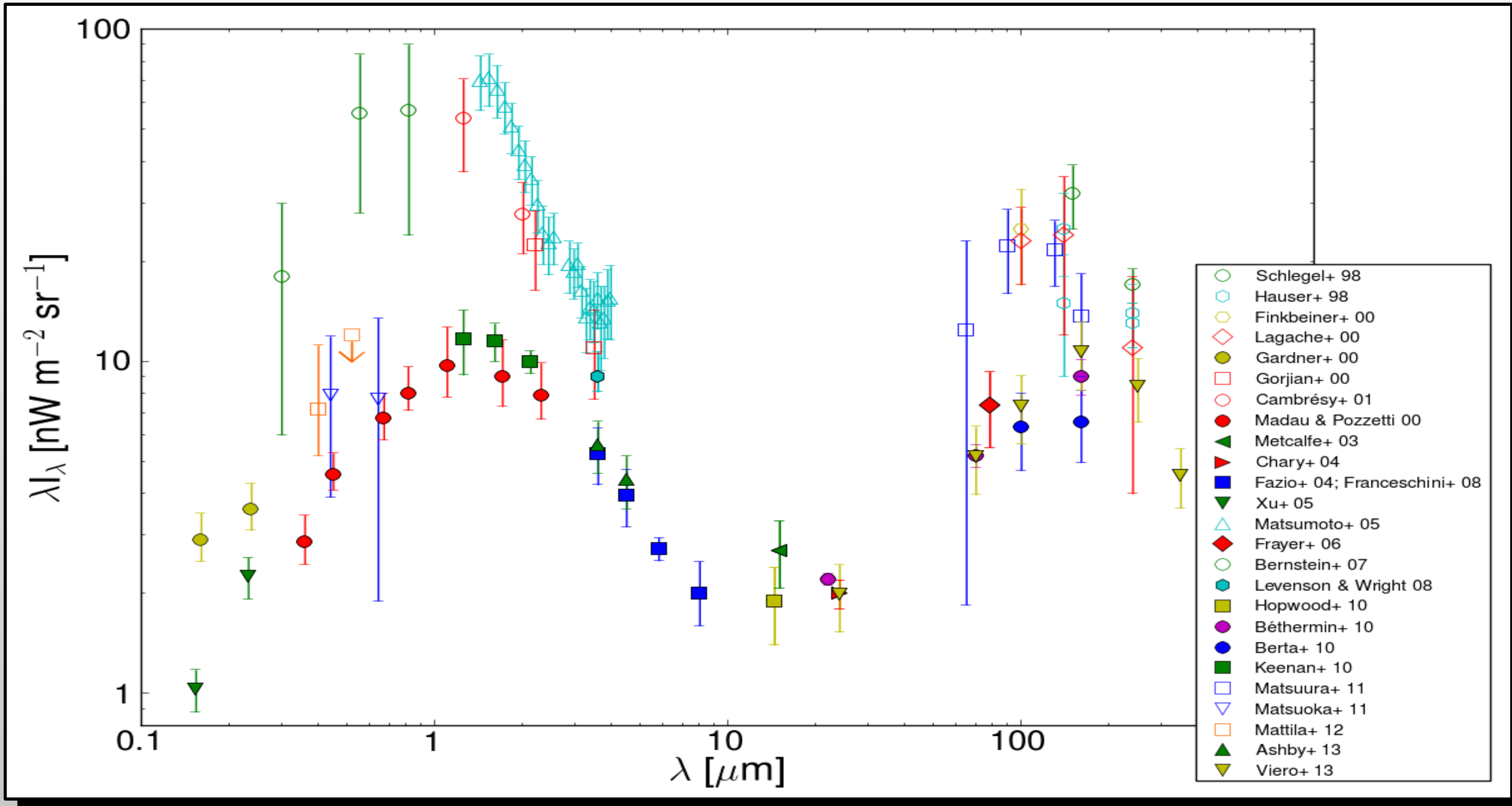


UV | optical | near-IR | mid-IR | far-IR



M31 view from the UV to the far-IR, Credit: NASA & ESA

The local spectral energy distribution of the EBL



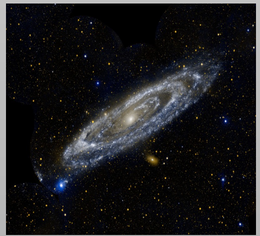
UV

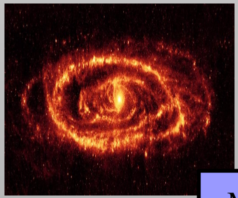
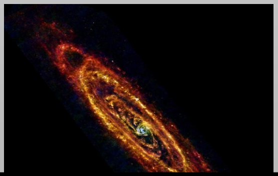
optical

near-IR

mid-IR

far-IR



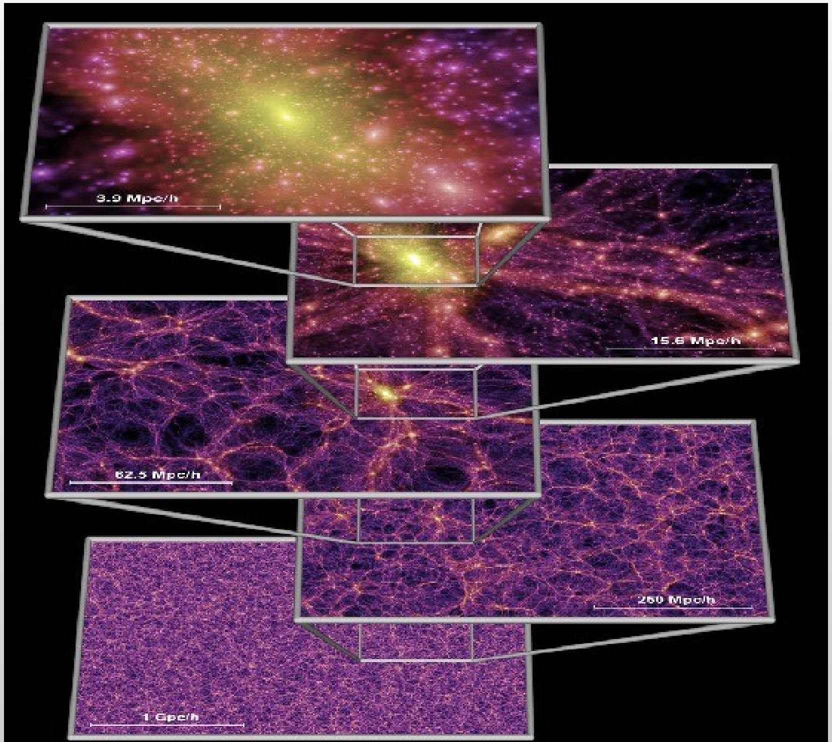





M31 view from the UV to the far-IR, Credit: NASA & ESA

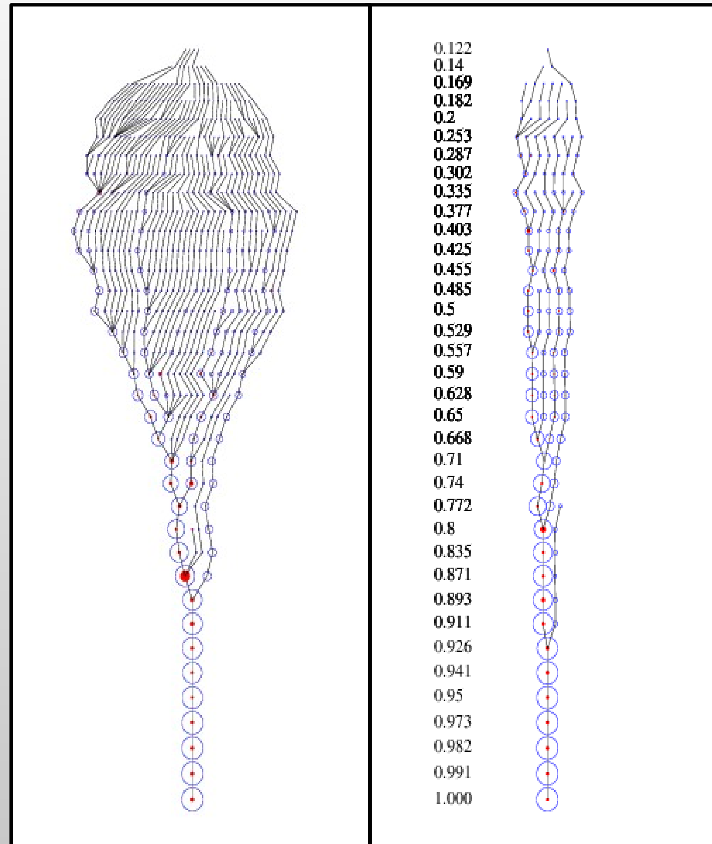
Methodologies for the EBL modeling

Type of modeling and refs.	Galaxy number evolution	Galaxy emission
Type i, Forward evolution (*Somerville+ 12; Gilmore+ 12*; Inoue+ 13)	**Semi-analytical models**.	**Modeled**. Stars: Bruzual & Charlot 03 (BC03); Dust Absorption: Charlot & Fall, 00; Dust Re-emission: Rieke+ 09.
Type ii, Backward evolution (Stecker+ 06; *Franceschini+ 08*)	**Observed** local-optical galaxy luminosity functions (starburst population) and near-IR galaxy luminosity functions up to z=1.4 (elliptical and spiral populations)	**Modeled**. Consider only a few galaxy types based on optical images.
Type iii, Inferred evolution (*Finke+ 10; Kneiske & Dole 10*)	**Parameterization** of the history of the star formation density of the universe. By construction, they do not include quiescent and AGN galaxies.	**Modeled**. Stars: Single bursts of solar metallicity from BC99 (Kneiske+)/BC03 (Finke+); Dust Absorption: General extinction law; Dust Re-emission: Modified black bodies.
Type iv, Observed evolution (*Domínguez+ 11*; Stecker+ 12; Helgason+ 12)	**Observed** near-IR galaxy luminosity functions up to z=4.	**Observed**. Multiwavelength photometry from the UV up to MIPS 24 for approximately 6,000 galaxies up to z=1. Consider 25 different galaxy types.

Type i: Forward evolution



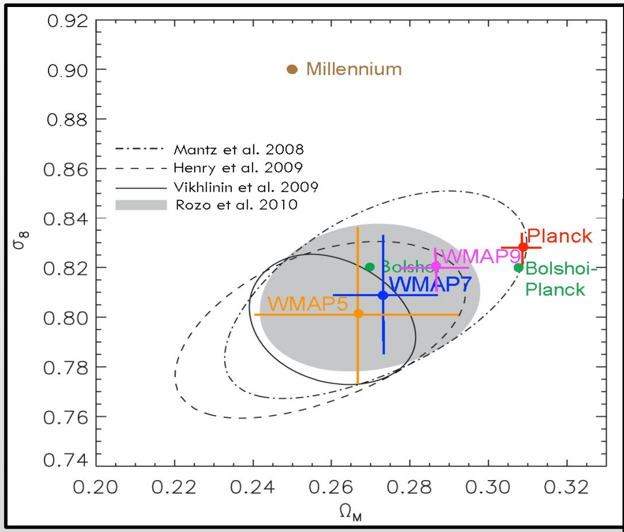
Cosmic web at different distance scales, Springel+ 05



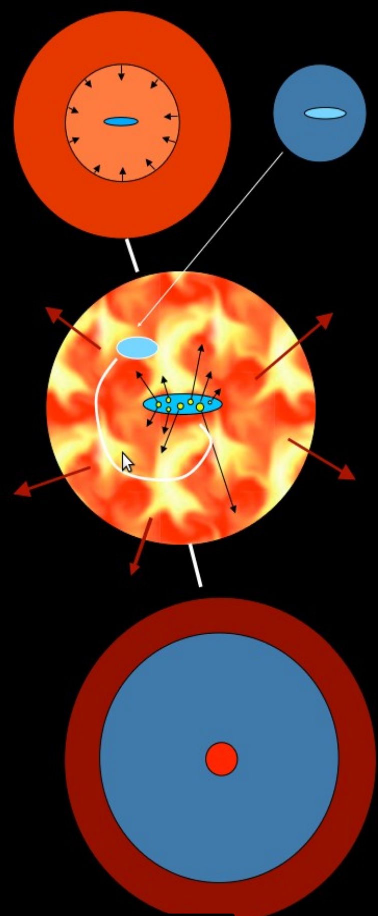
Examples of Λ Cold Dark Matter merger trees from Wechsler+ 02

Our SAMs are based on Monte Carlo realizations of dark matter halo mergers histories calculated using the modified and extended Press-Schechter methods.

Type i: Forward evolution



Galaxy Formation in ΛCDM

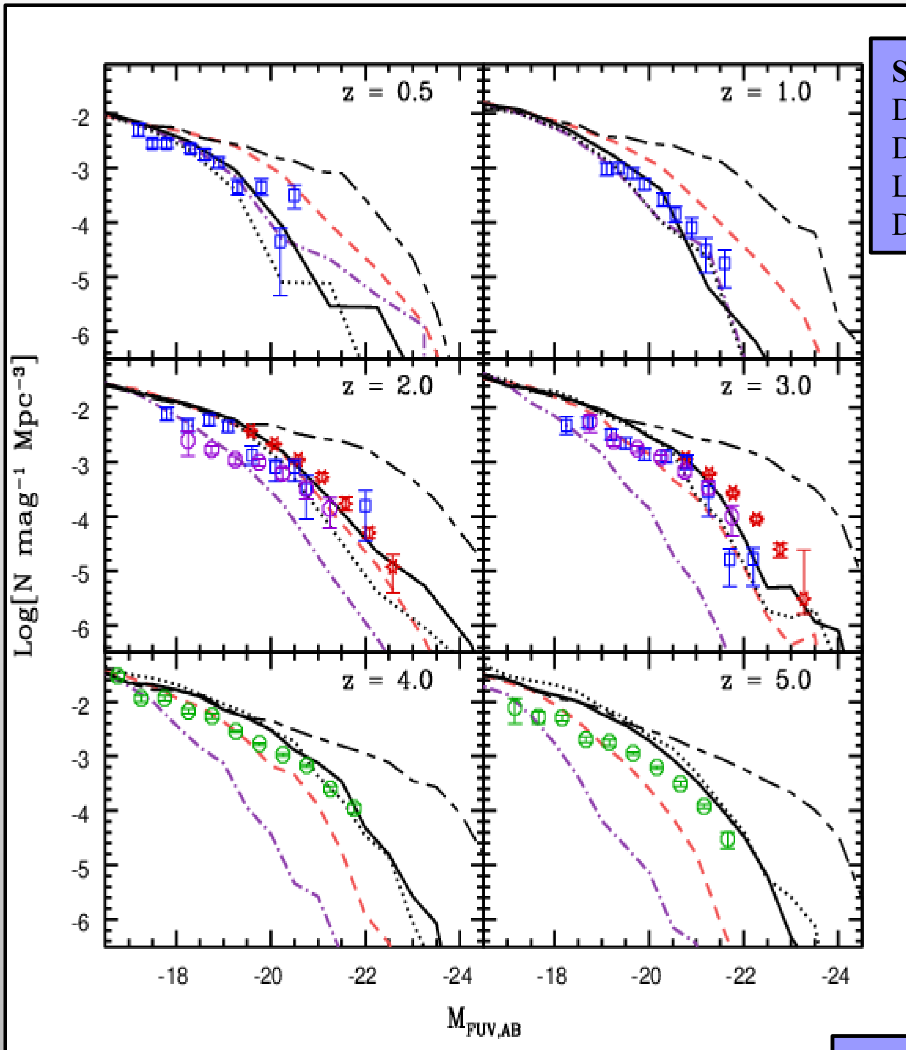


- gas is collisionally heated when perturbations 'turn around' and collapse to form gravitationally bound structures
- gas in halos cools via atomic line transitions (depends on density, temperature, and metallicity)
- cooled gas collapses to form a rotationally supported disk
- cold gas forms stars, with efficiency a function of gas density (e.g. Schmidt-Kennicutt Law)
- massive stars and SNae reheat (and in small halos expel) cold gas and some metals
- galaxy mergers trigger bursts of star formation; 'major' mergers transform disks into spheroids and fuel AGN
- AGN feedback cuts off star formation

White & Frenk 91; Kauffmann+93; Cole+94; Somerville & Primack 99; Cole+00; Somerville, Primack, & Faber 01; Croton et al. 2006; Somerville +08; Fanidakis+09; Guo+2011; Somerville, Gilmore, Primack, & Domínguez 12 (discussed here)

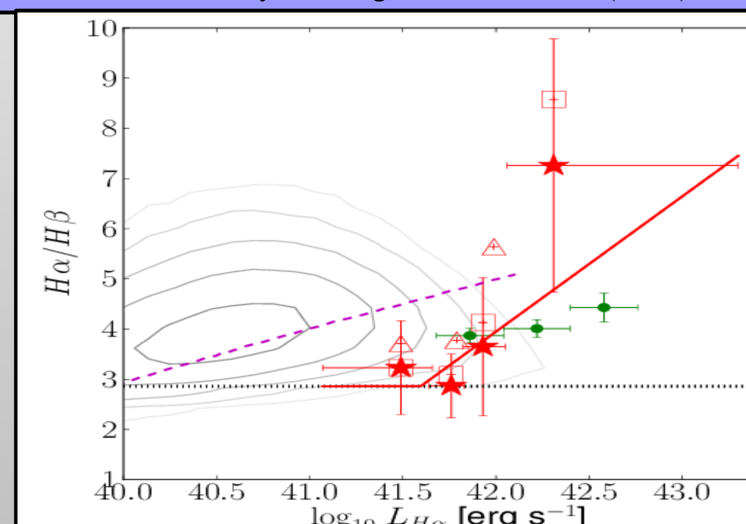
by Joel Primack

Type i: Forward evolution



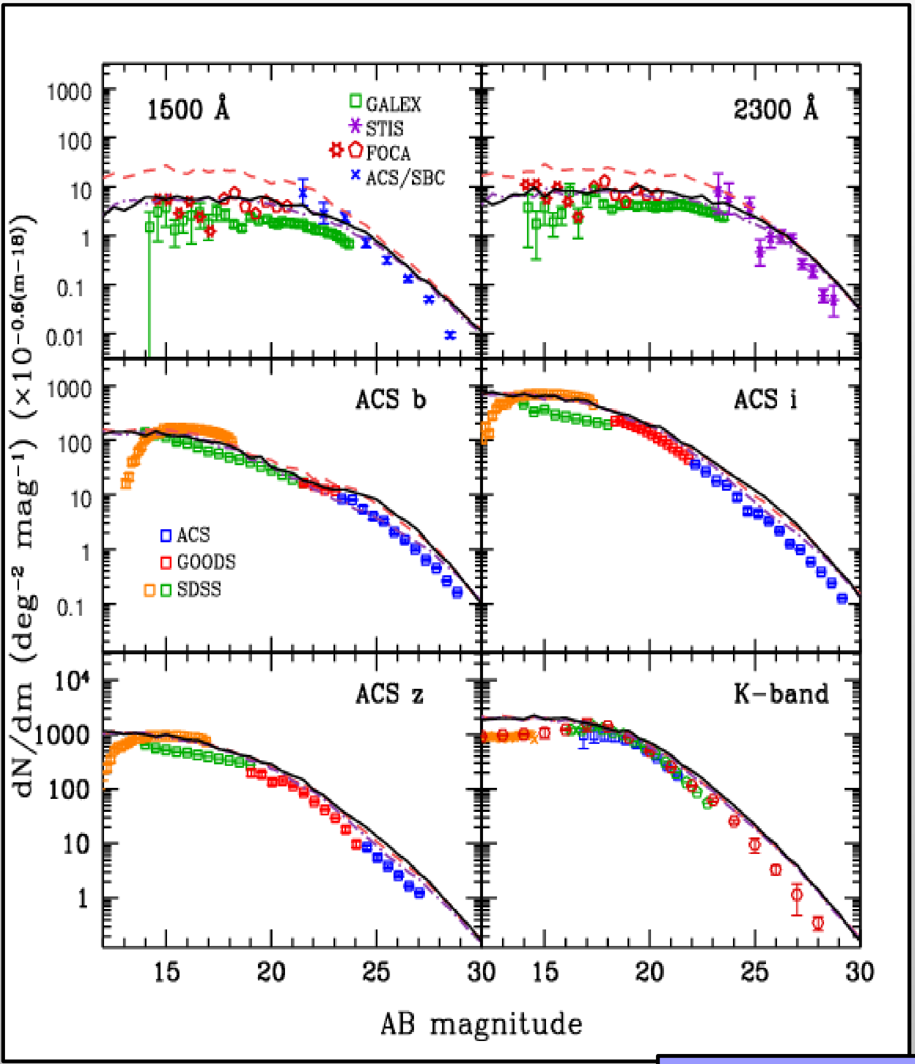
Solid-black, Fiducial: WMAP5+Charlot & Fall, evolving dust
Dash-dotted purple: WMAP5+Charlot & Fall, fixed dust
Dashed-red: WMAP5+Calzetti
Long-dashed-black: WMAP5+no dust
Dotted-black: Concordance cosmology

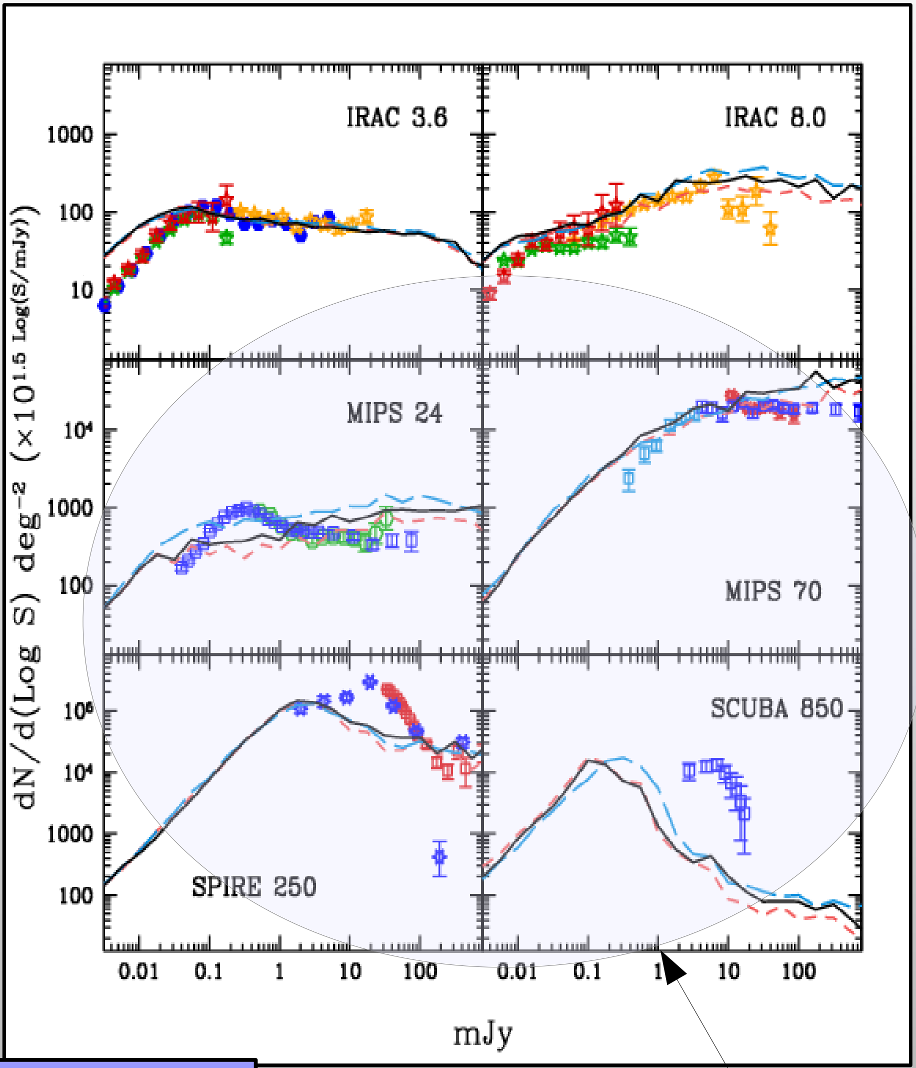
Evolving dust extinction over redshift compatible with spectroscopic Balmer decrement measurements using HST/WFC3 by Domínguez, Siana, et al. (2013)



UV luminosity functions by Somerville+ 12

Type i: Forward evolution

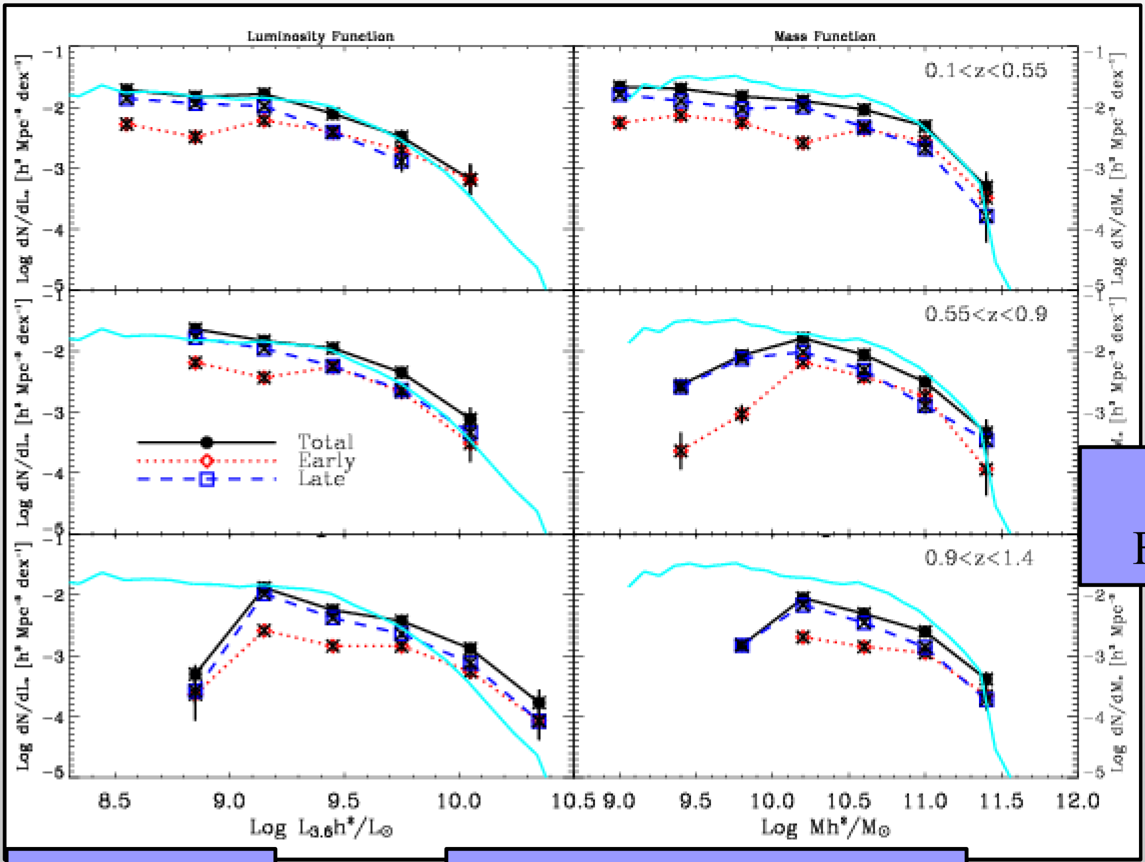




Number counts by Somerville+ 12

Disagreements in the far-IR

Type ii: Backward evolution

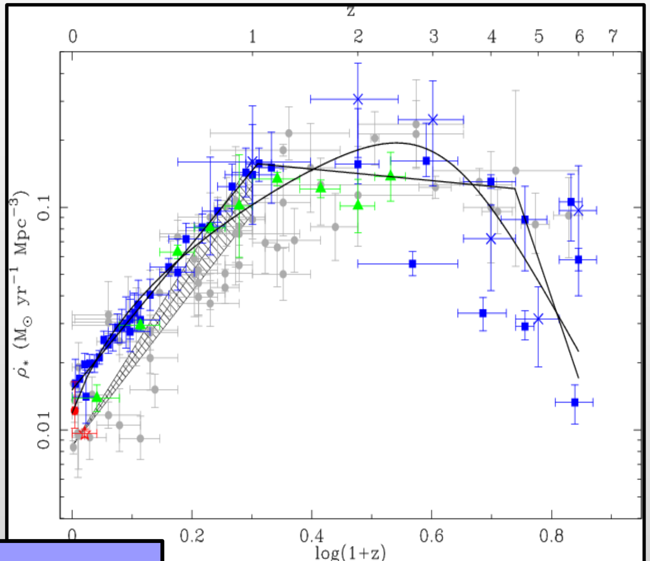


Franceschini+ 06

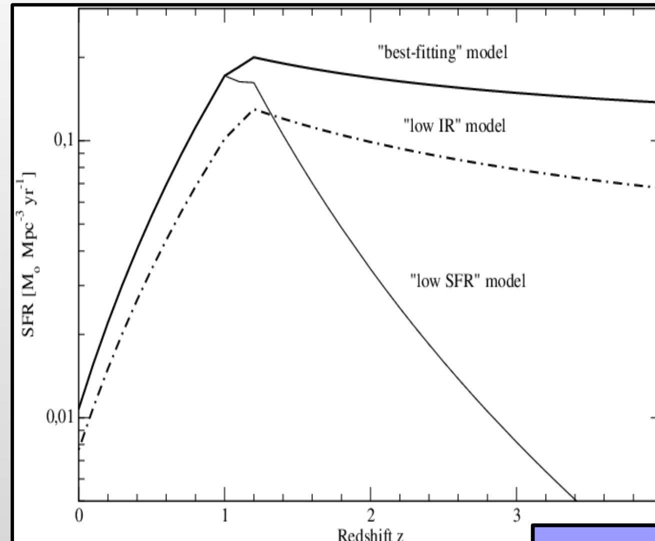
Near-IR luminosity and stellar mass functions observed up to z~1.4

See Alberto Franceschini's talk

Type iii: Inferred evolution

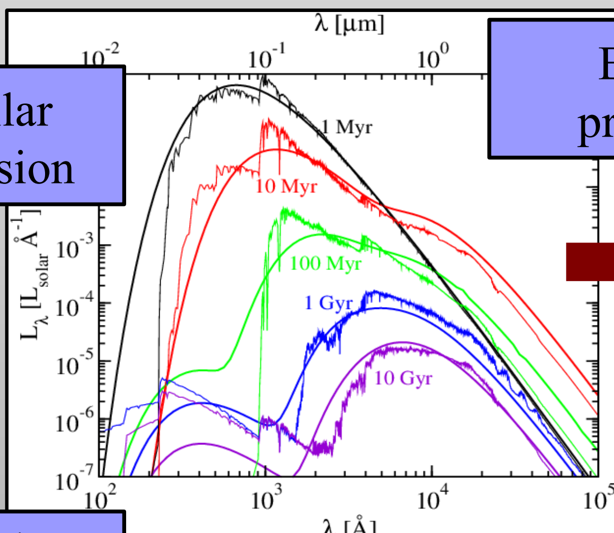


Hopkins & Beacom 06



Kneiske+ 04

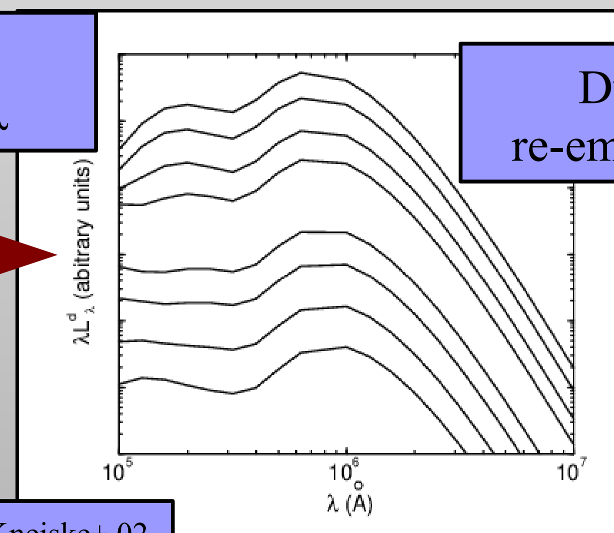
Stellar emission



Finke+ 10

Extinction law proportional to λ

Dust re-emission



Kneiske+ 02

Type iv: Observed evolution

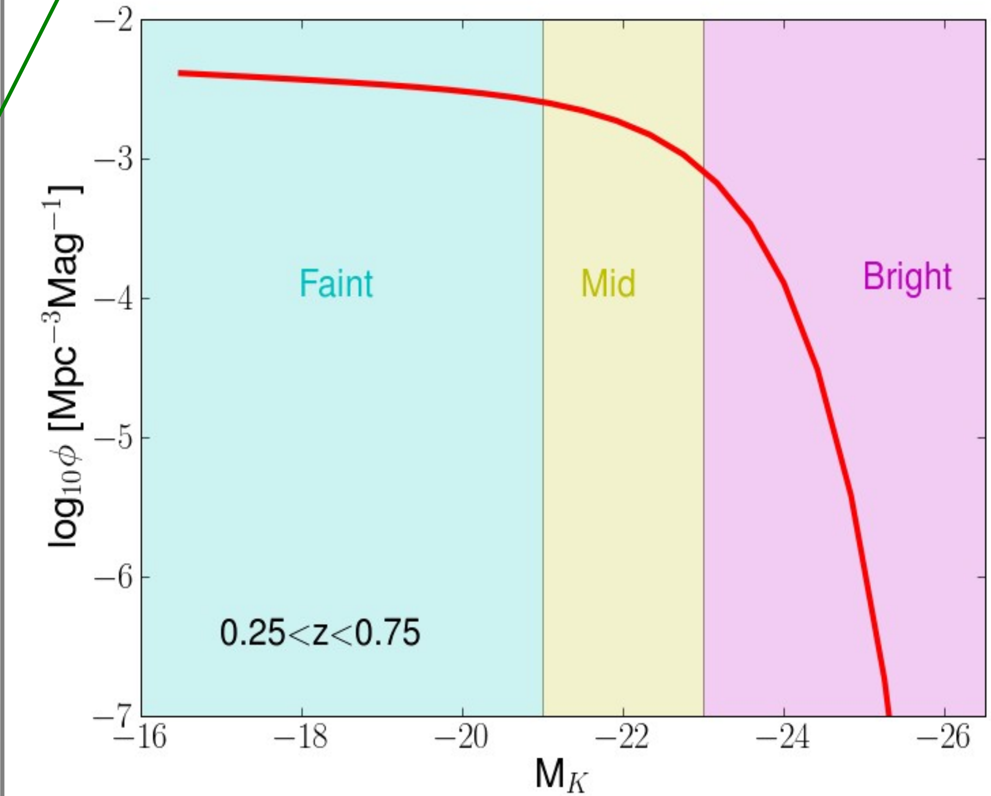
$$j_K(z) = -\int_{M_i}^{M_f} \Phi(M_K, z) L_K \, dM_K$$

Luminosity density

$[\mathrm{erg\ s^{-1} Mpc^{-3} Hz^{-1}}]$

Galaxy luminosity function

Luminosity in K-band



Type iv: Observed evolution

$$j_i(\lambda, z) = j_i^{faint} + j_i^{mid} + j_i^{bright} =$$

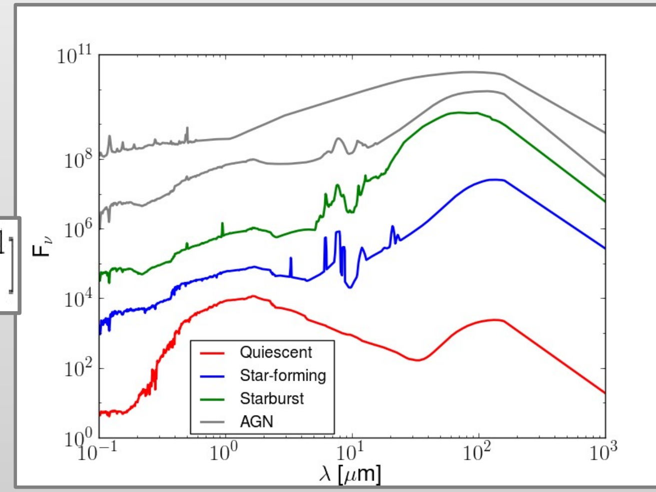
$$= \int_{M_2=-21.0}^{M_1=-16.6} \Phi(M_K^z, z) f_i T_i(M_K^z, \lambda)(1+z) dM_K^z +$$

$$+ \int_{M_3=-23.0}^{M_2=-21.0} \Phi(M_K^z, z) m_i T_i(M_K^z, \lambda)(1+z) dM_K^z +$$

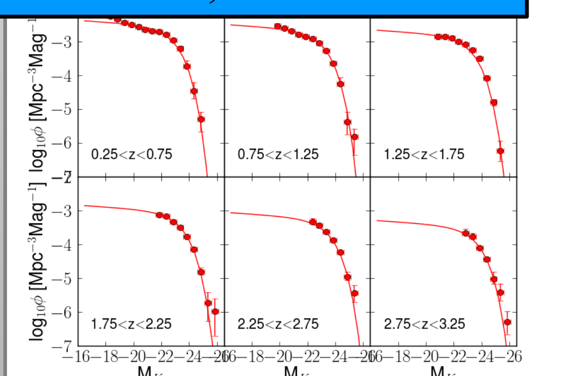
$$+ \int_{M_4=-25.0}^{M_3=-23.0} \Phi(M_K^z, z) b_i T_i(M_K^z, \lambda)(1+z) dM_K^z$$

Galaxy Spectral Energy Distributions (SEDs)
SWIRE template library, Polletta+ 07

$[\mathrm{erg\ s^{-1} Mpc^{-3} Hz^{-1}}]$



Galaxy luminosity function
rest-frame K-band, Cirasuolo+ 10



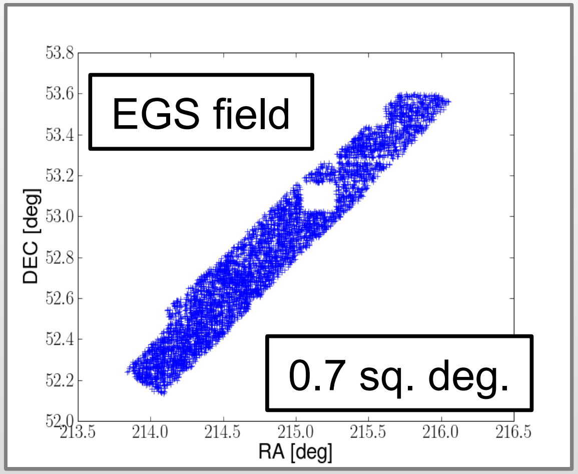
Galaxy SED-type fractions, this work

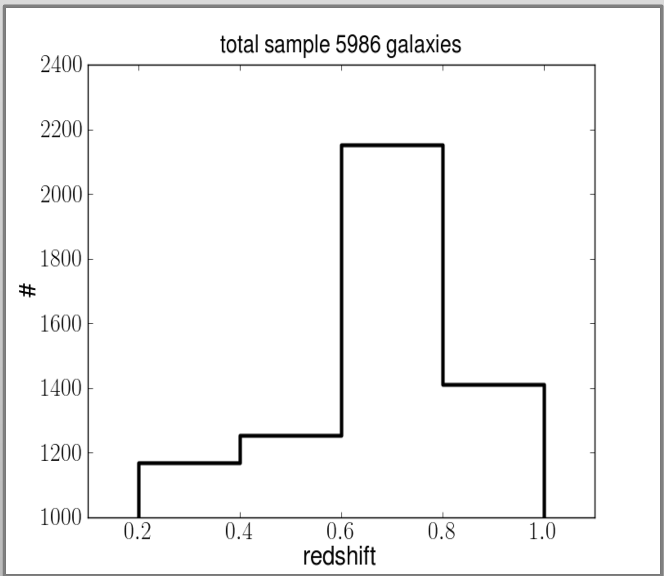
$$\lambda I_\lambda(\lambda, z) = \frac{c^2}{4\pi\lambda} \int_z^{z_{max}} j_{total}[\lambda(1+z)/(1+z'), z'] \left| \frac{dt}{dz'} \right| dz'$$

SED of the EBL

$[\mathrm{nW\ m^{-2} sr^{-1}}]$

Galaxy sample



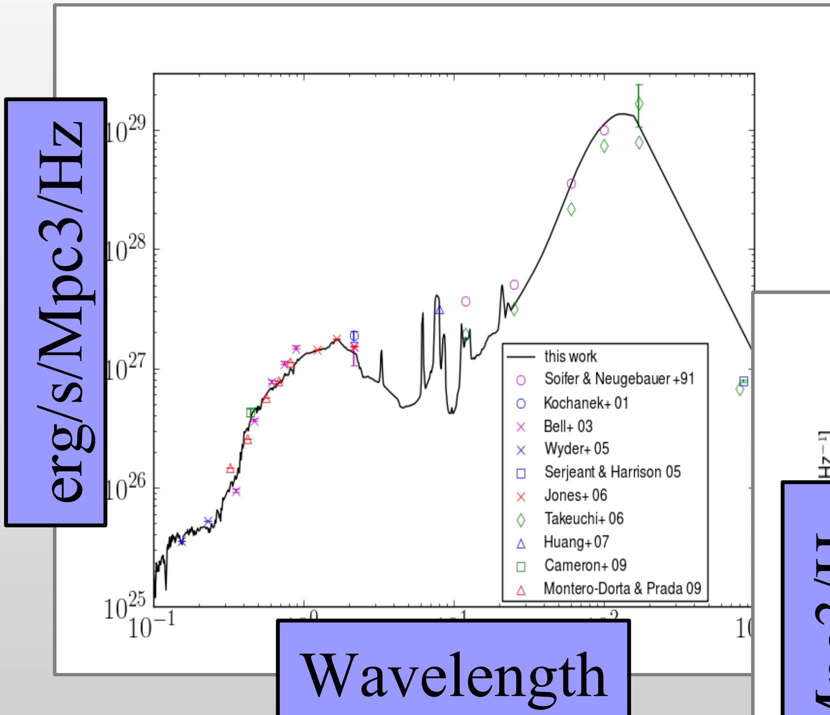


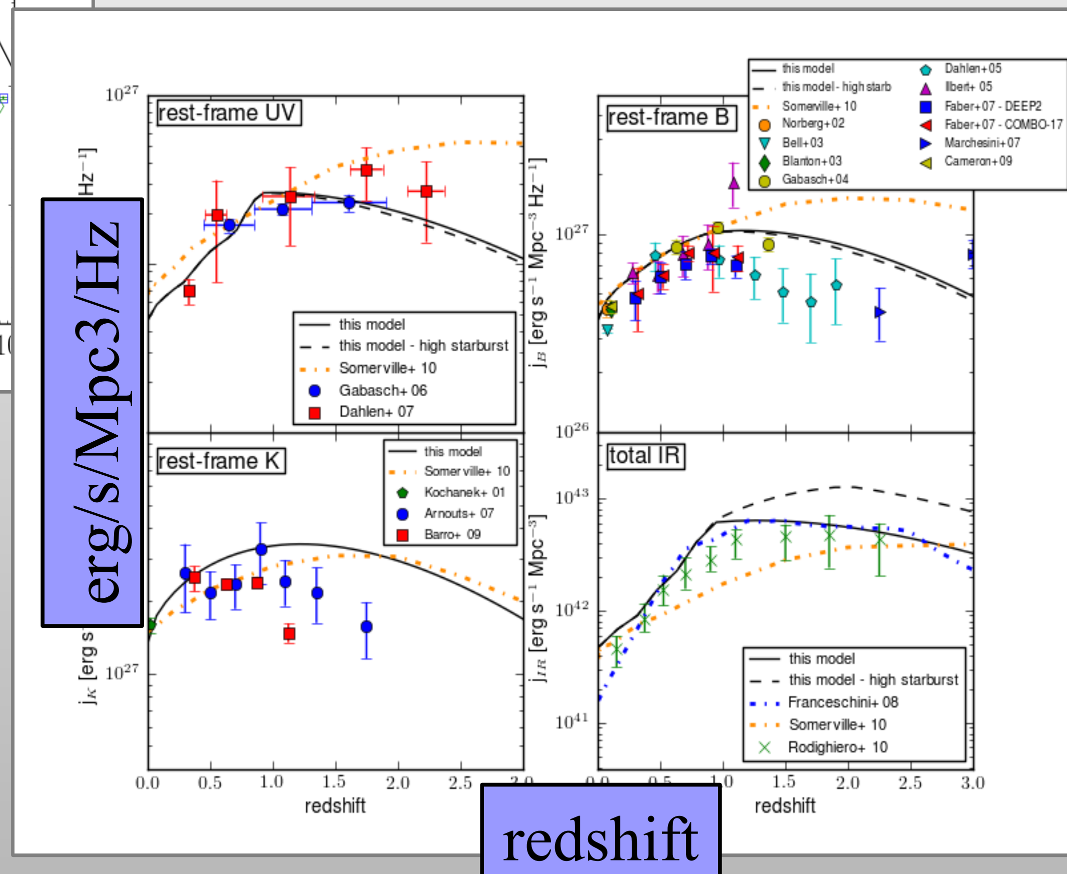
Band	λ_{eff} [μm]	Observatory	Req.	UL [μJy]
FUV	0.1539	GALEX	ext	-
NUV	0.2316	GALEX	ext	-
B	0.4389	CFHT12K	det	-
R	0.6601	CFHT12K	det	-
I	0.8133	CFHT12K	det	-
K_S	2.14	WIRC	det	-
IRAC 1	3.6	IRAC	det	-
IRAC 2	4.5	IRAC	obs	1.2
IRAC 3	5.8	IRAC	obs	6.3
IRAC 4	8.0	IRAC	obs	6.9
MIPS 24	23.7	MIPS	obs	30

Total: 5986 galaxies

DEEP2 spectroscopic redshift: 4376 galaxies
Photometric redshift with mean error less than 0.1: 1610 galaxies

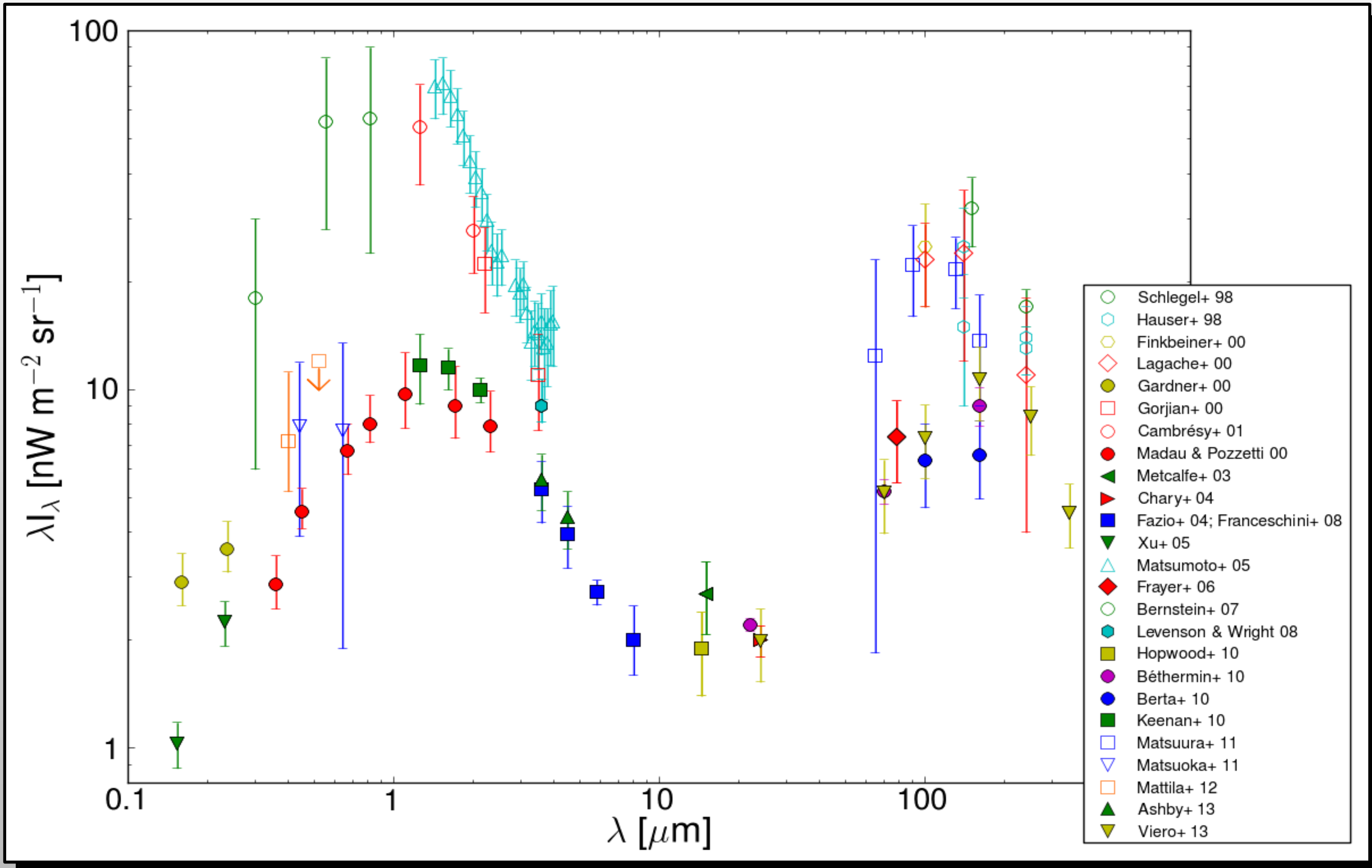
Luminosity densities



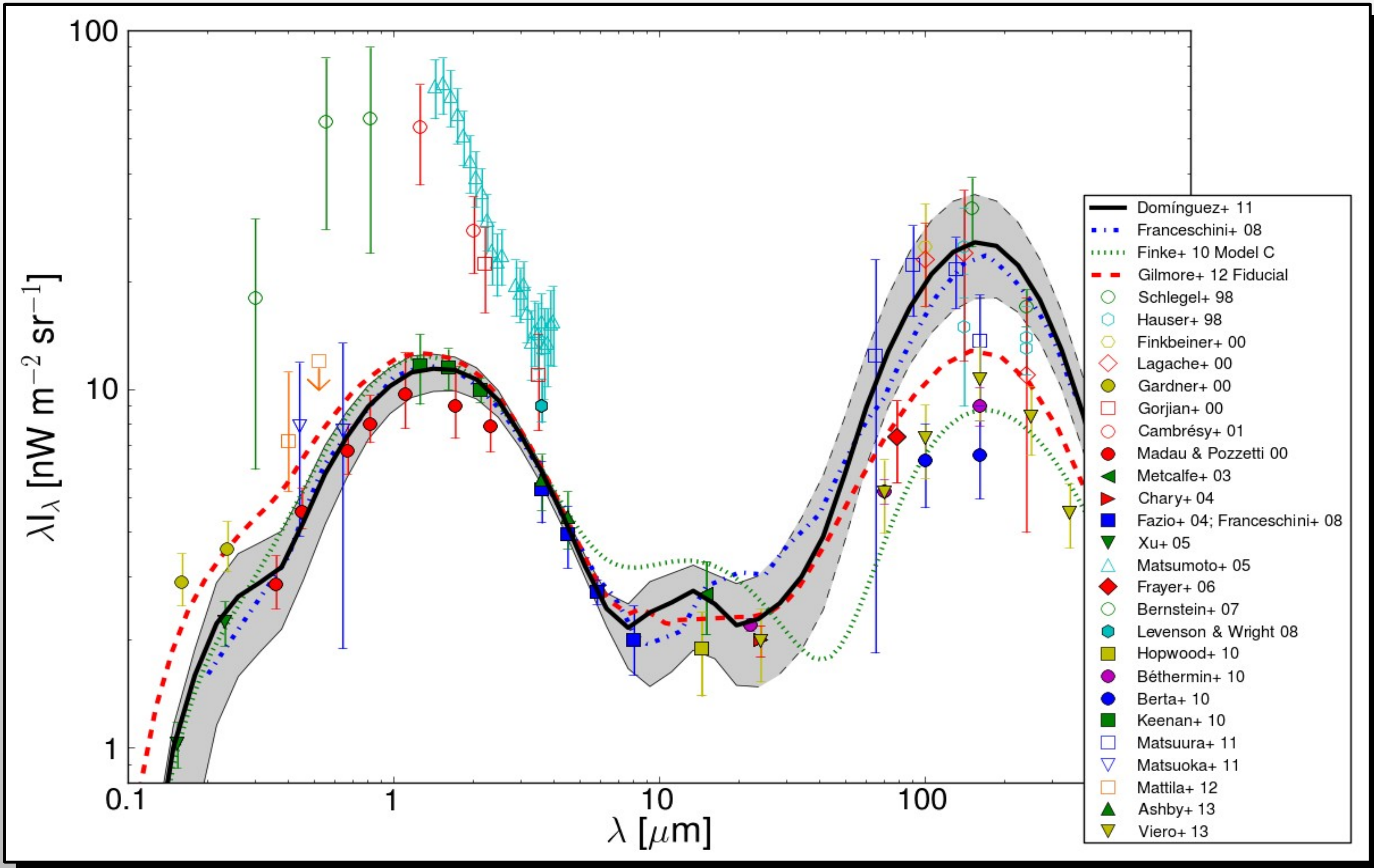


Domínguez+ 11

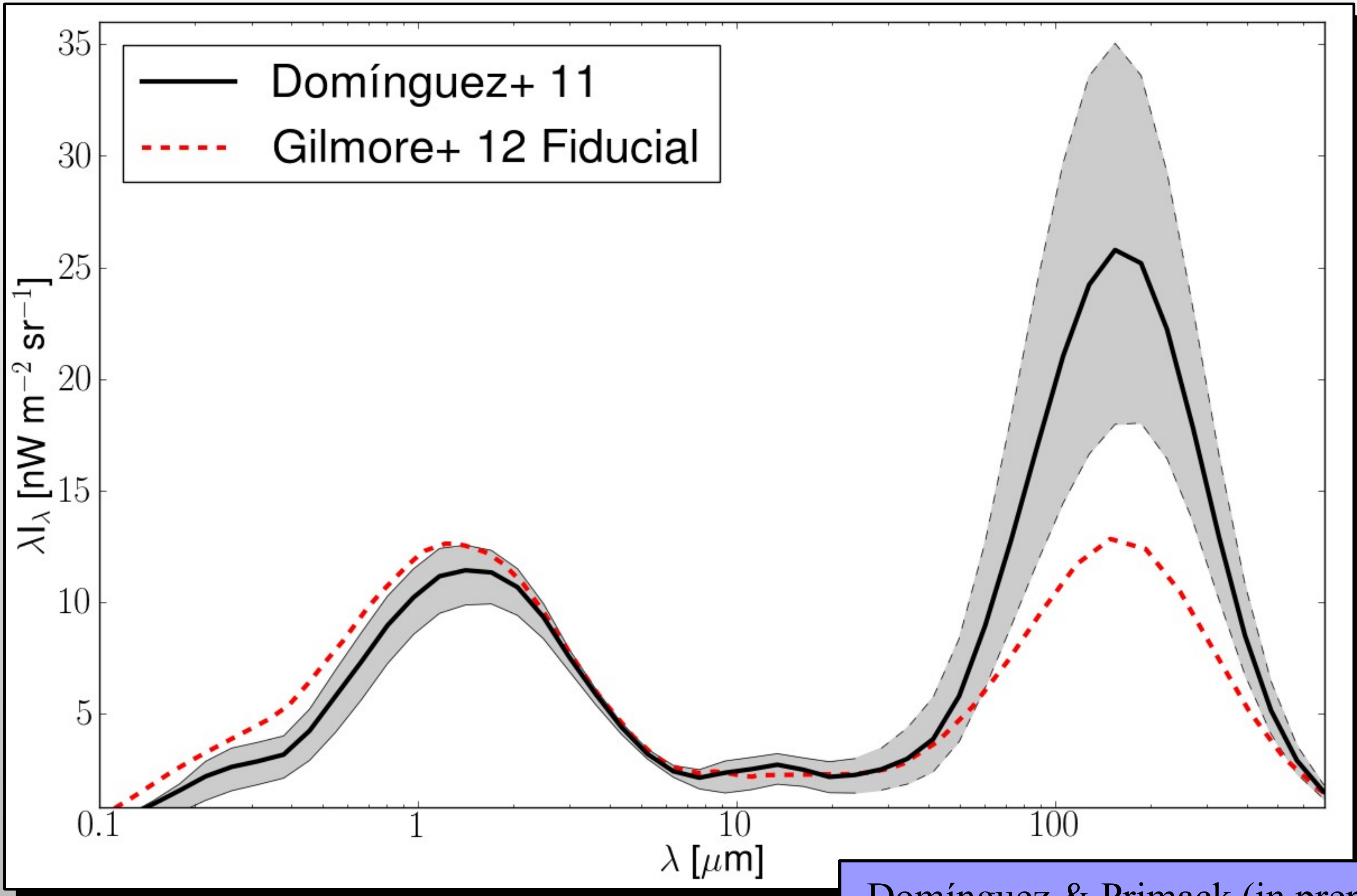
Local EBL: Data and Models



Local EBL: Data and Models

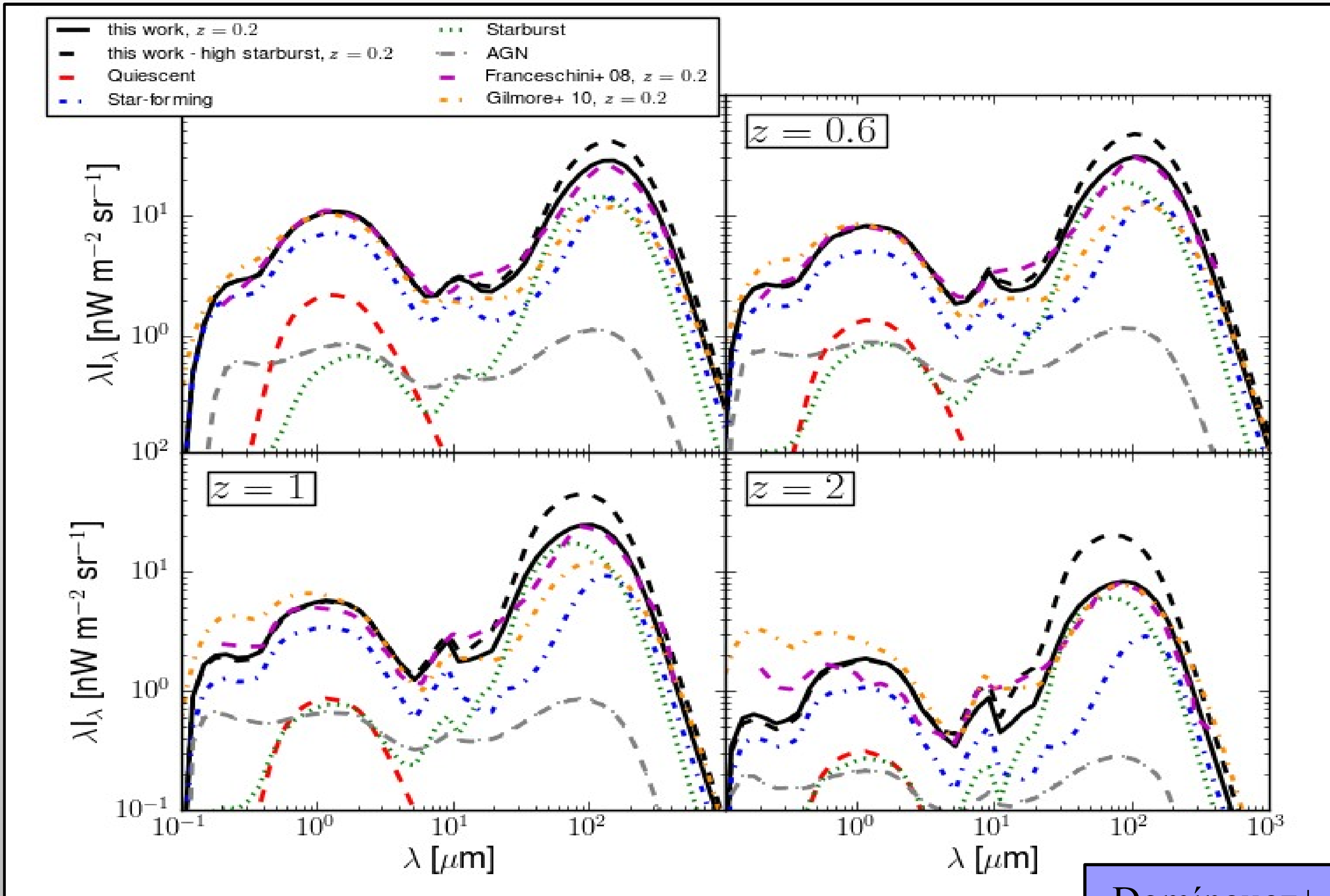


Current uncertanties in the far-IR



Domínguez & Primack (in prep.)

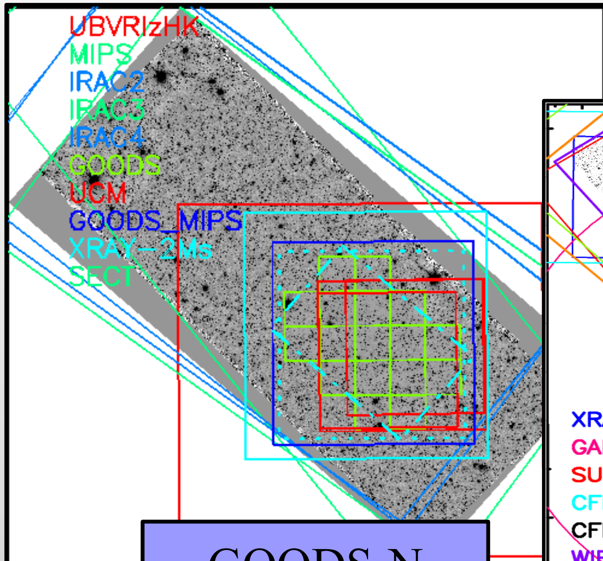
EBL evolution with redshift



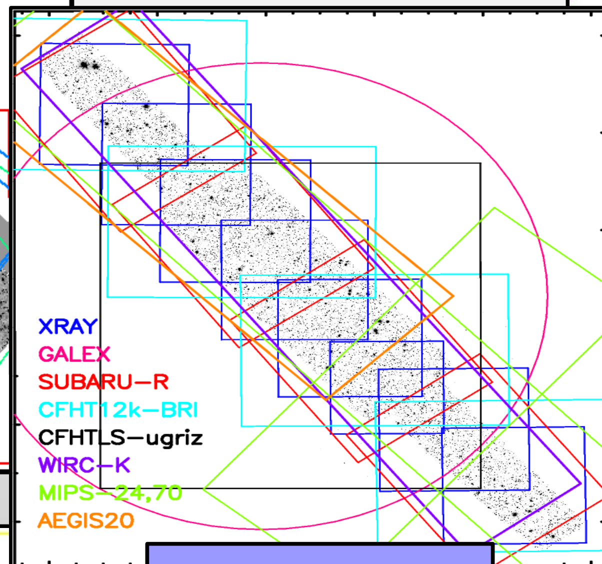
Domínguez+ 11

Improving the EBL modeling with galaxy surveys

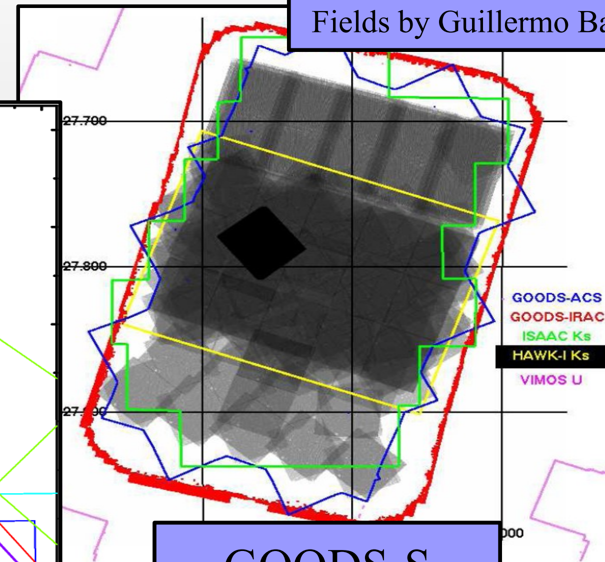
Fields by Guillermo Barro



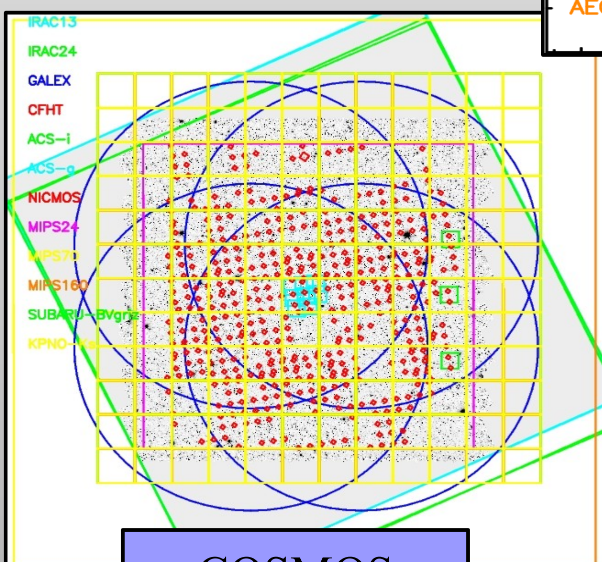
GOODS-N



EGS

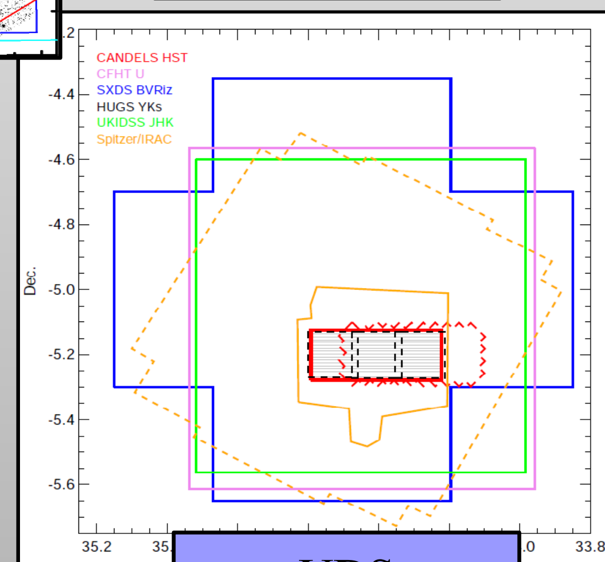


GOODS-S



COSMOS

Credit: ESA / AOES



UDS

Summary

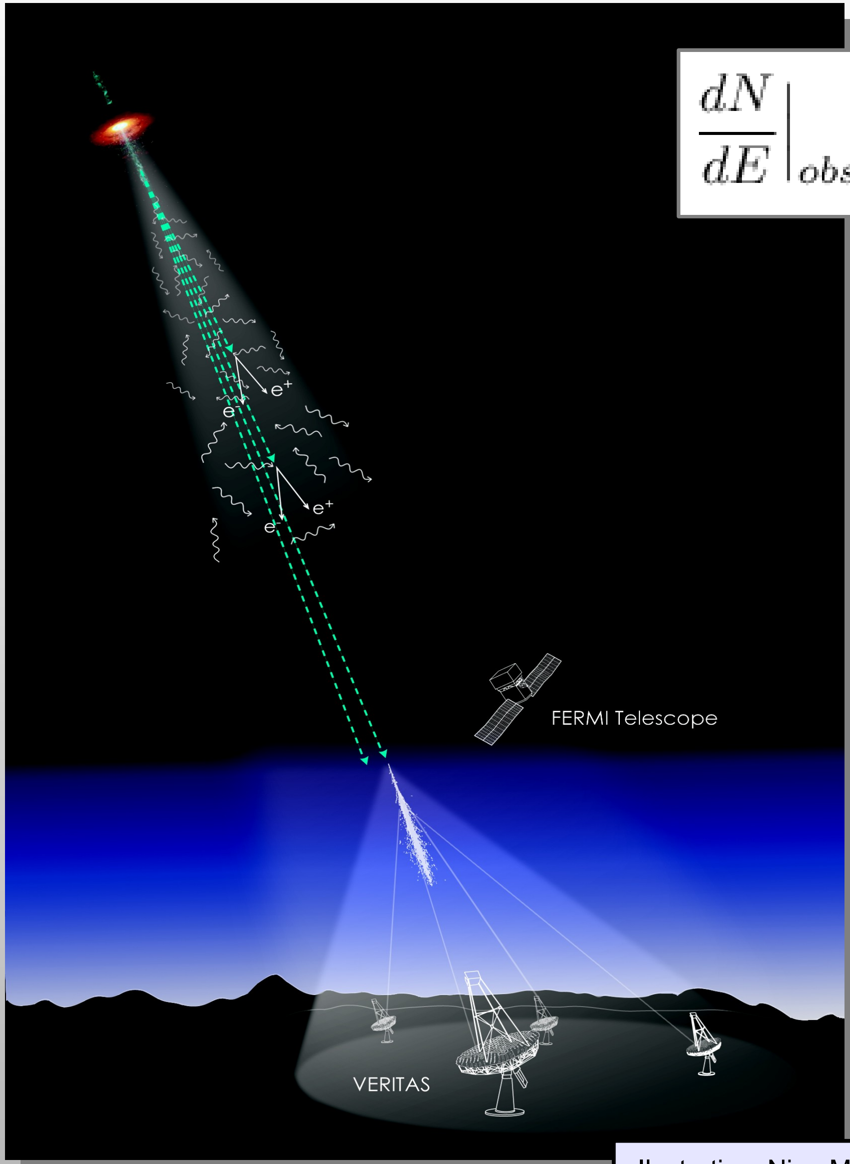
1.- Direct detection, galaxy count data, and independent EBL modeling methodologies agree within a factor of around two, at least, in the optical and near-IR.

2.- Uncertainties are large in the far-IR, which is a fundamental area of research for the coming years.

3.- There are also uncertainties on the EBL evolution at higher redshift, $z > 1$, especially in the UV and far-IR.

4.- New results from infrared astronomy soon and stay tuned..
gamma-ray astronomy is helping in the EBL understanding!

Improving the EBL modeling with gamma-rays

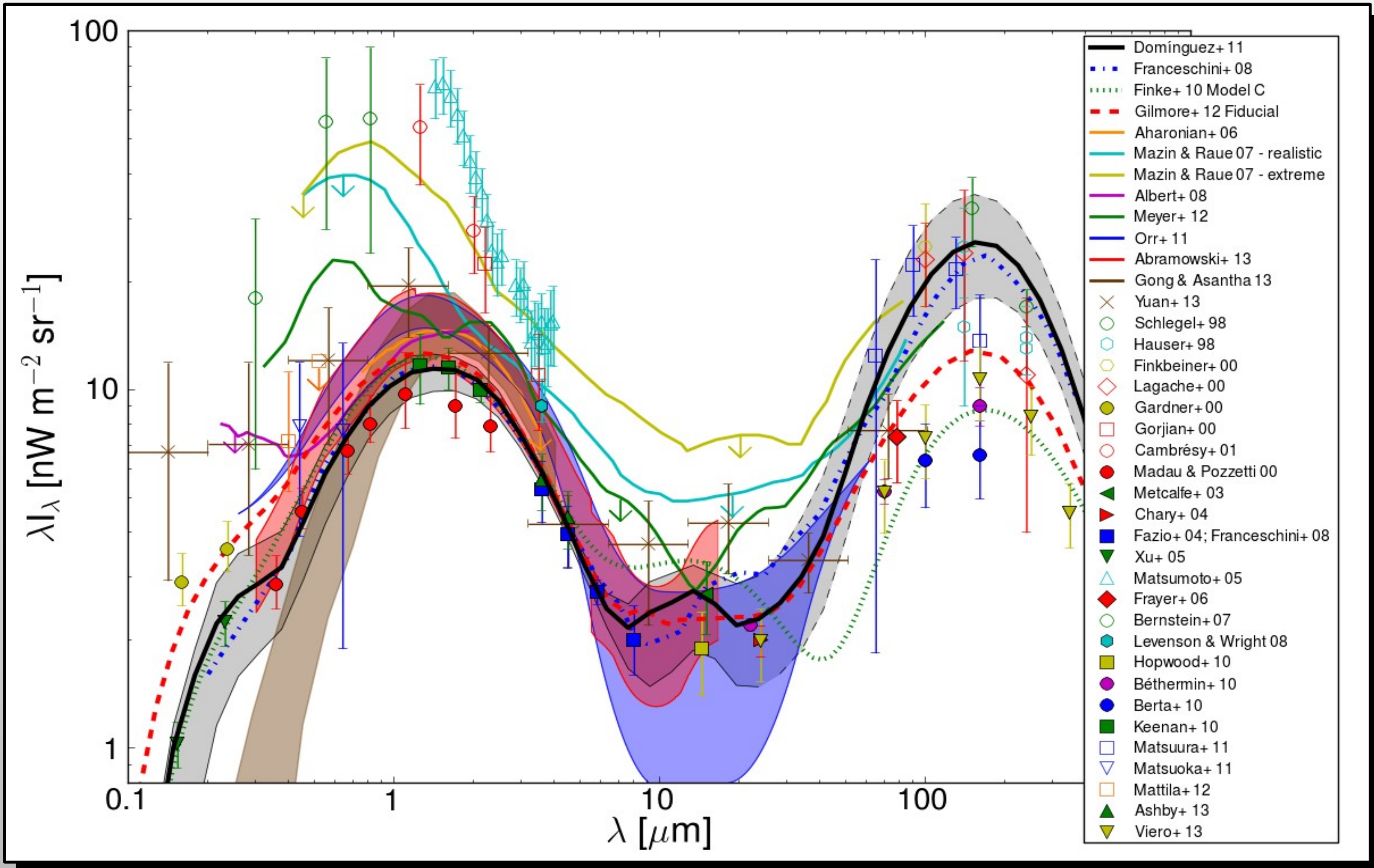


$$\left.\frac{dN}{dE}\right|_{obs} = \left.\frac{dN}{dE}\right|_{int} \exp\left[-\tau(E,z)\right]$$

See Daniel Mazin's talk

Ilustration: Nina McCurdy & Joel Primack

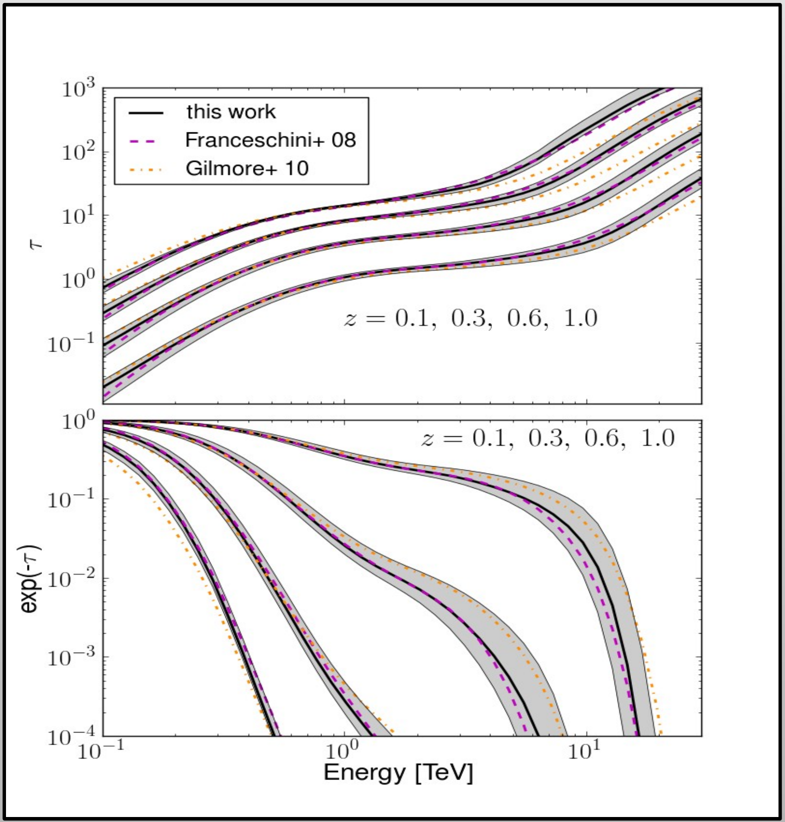
Local EBL: Data, Models, and gamma-ray measurements



The Cosmic γ-ray Horizon

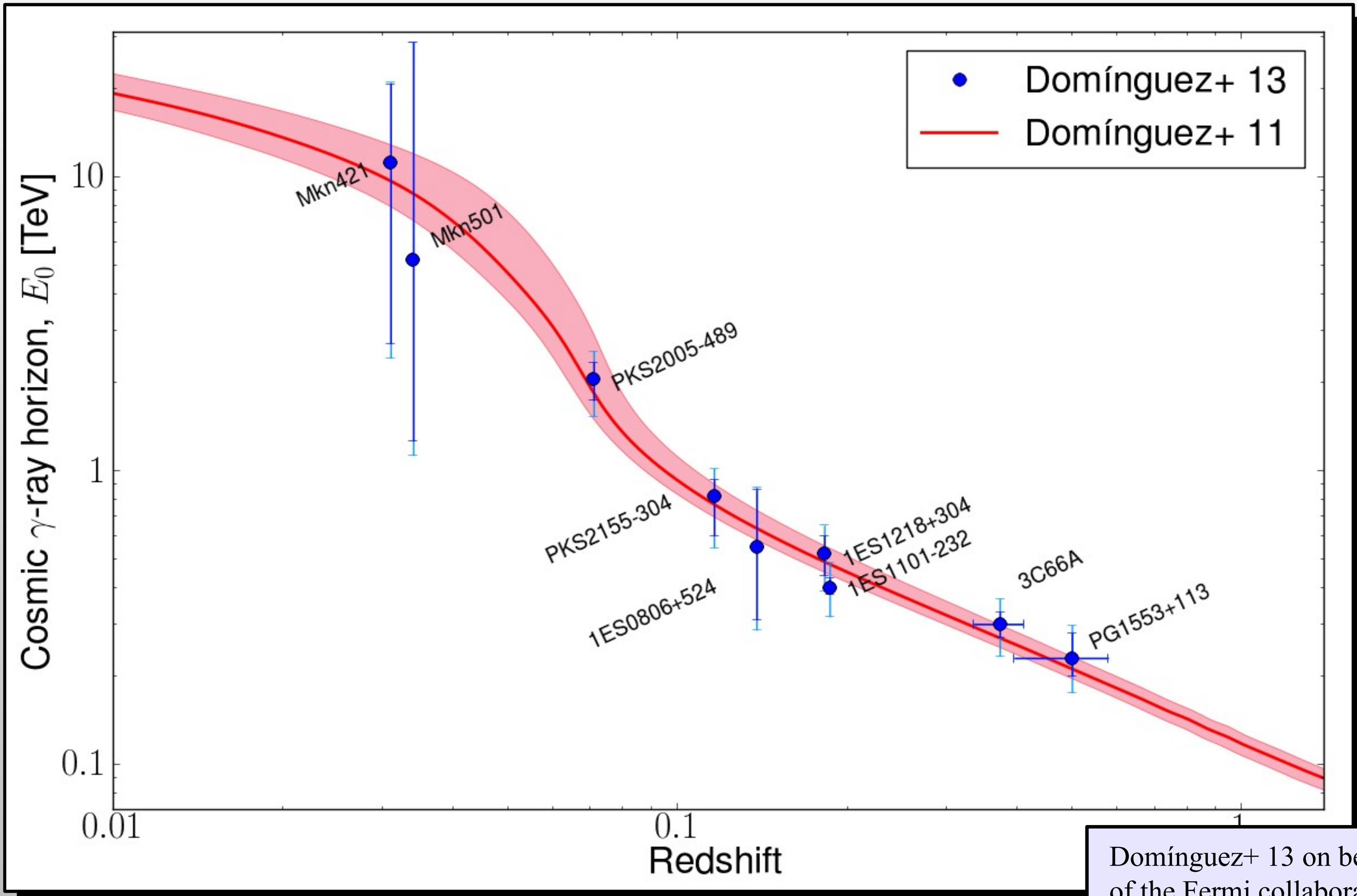
$$\left.\frac{dN}{dE}\right|_{obs} = \left.\frac{dN}{dE}\right|_{int} \exp\left[-\tau(E,z)\right]$$

The cosmic gamma-ray horizon (CGRH) is by definition the energy E0 as a function of redshift at which the optical depth due to EBL is unity.



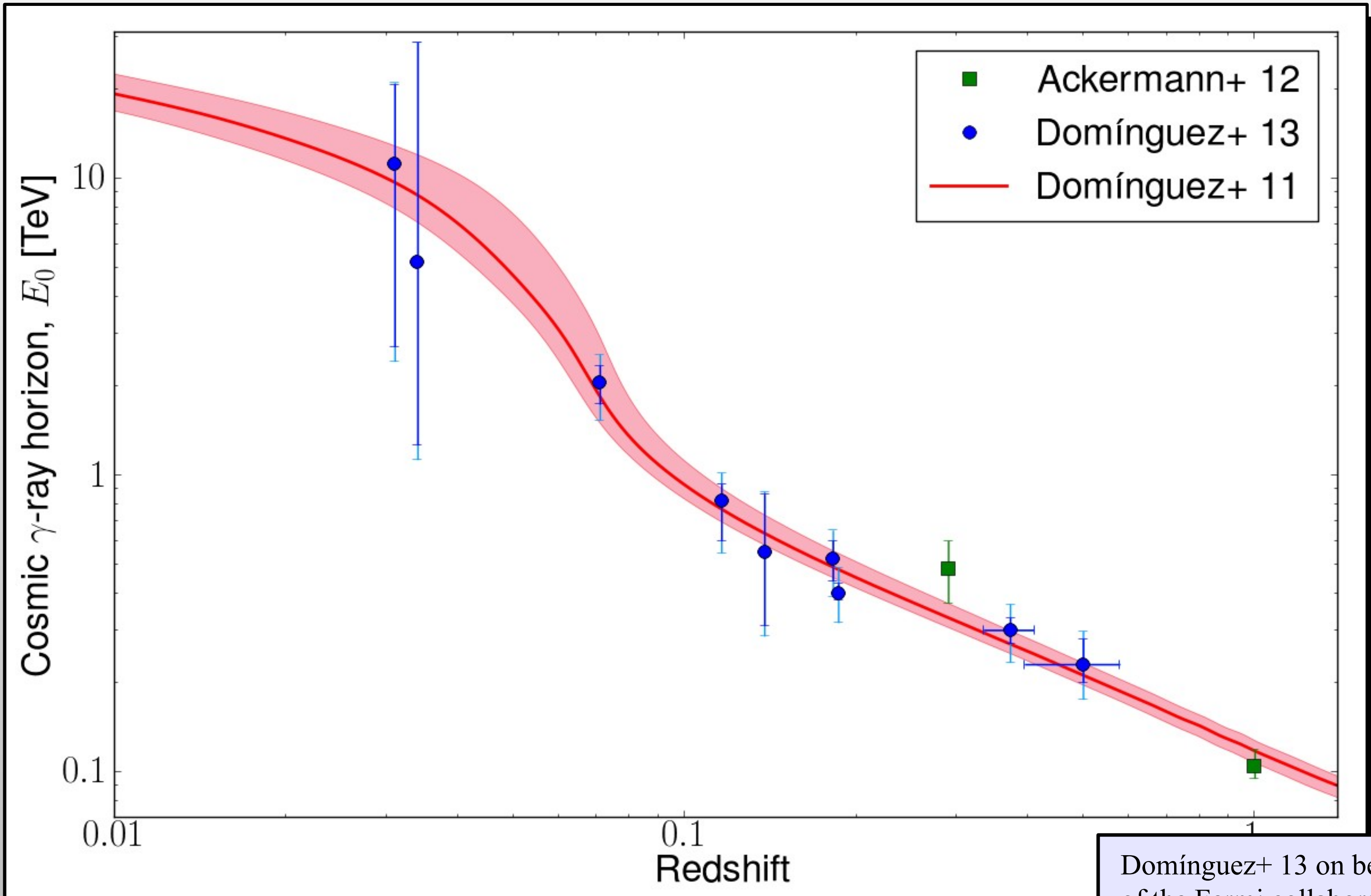
The measurement of the CGRH is a primary scientific goal of the Fermi Gamma-Ray Telescope (Hartmann 07; Stecker 07; Kashlinsky & Band 07)

The Cosmic γ-ray Horizon: Results



Domínguez+ 13 on behalf of the Fermi collaboration

The Cosmic γ-ray Horizon: Results



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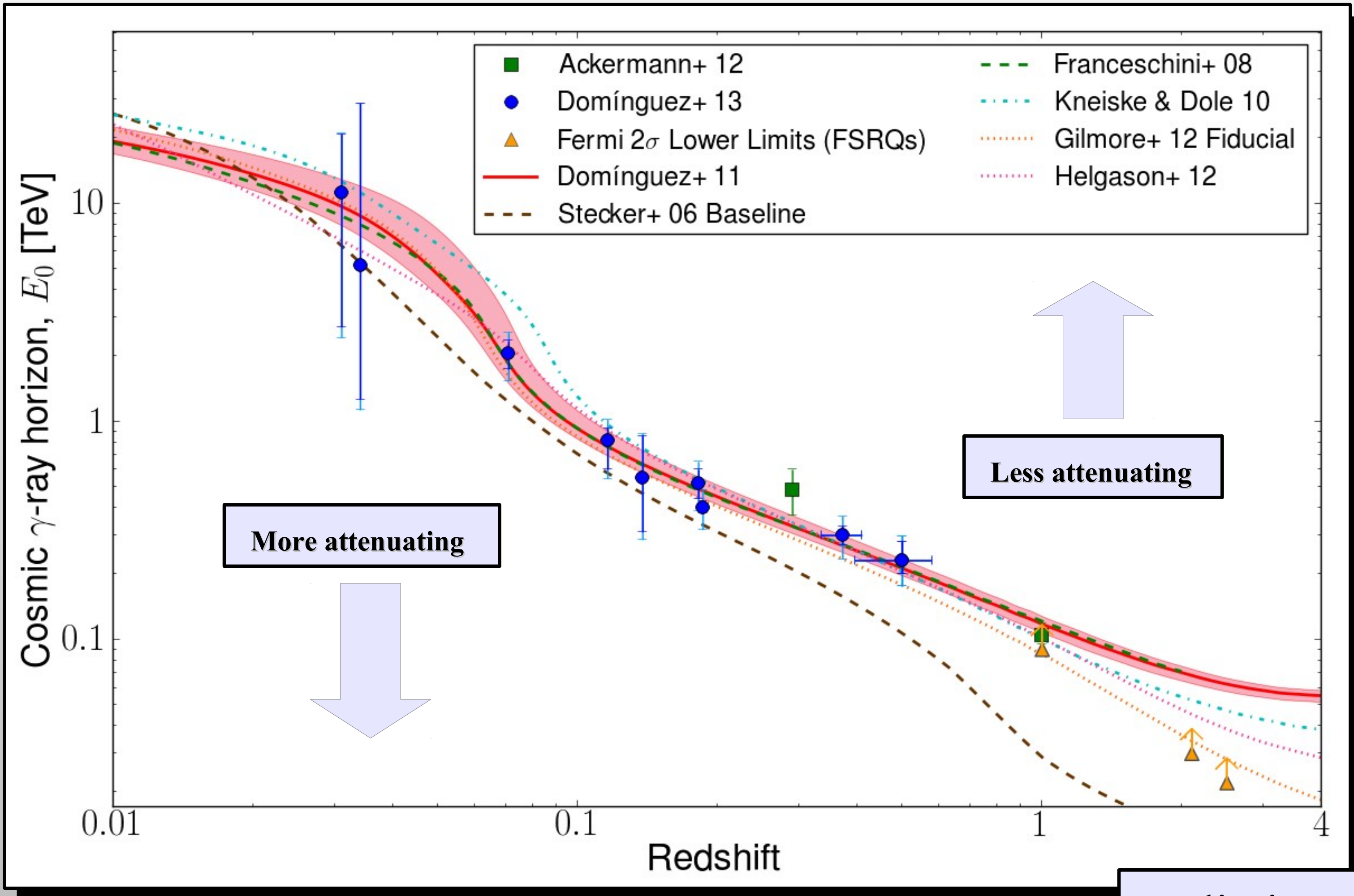
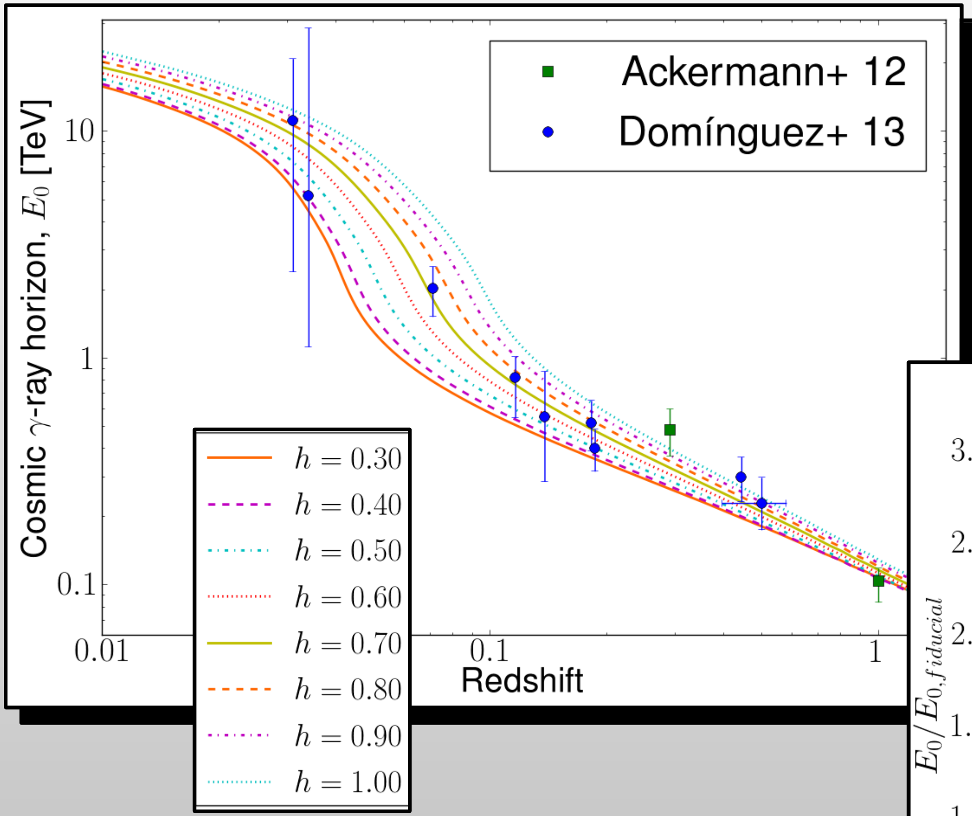
The Cosmic γ-ray Horizon: Results

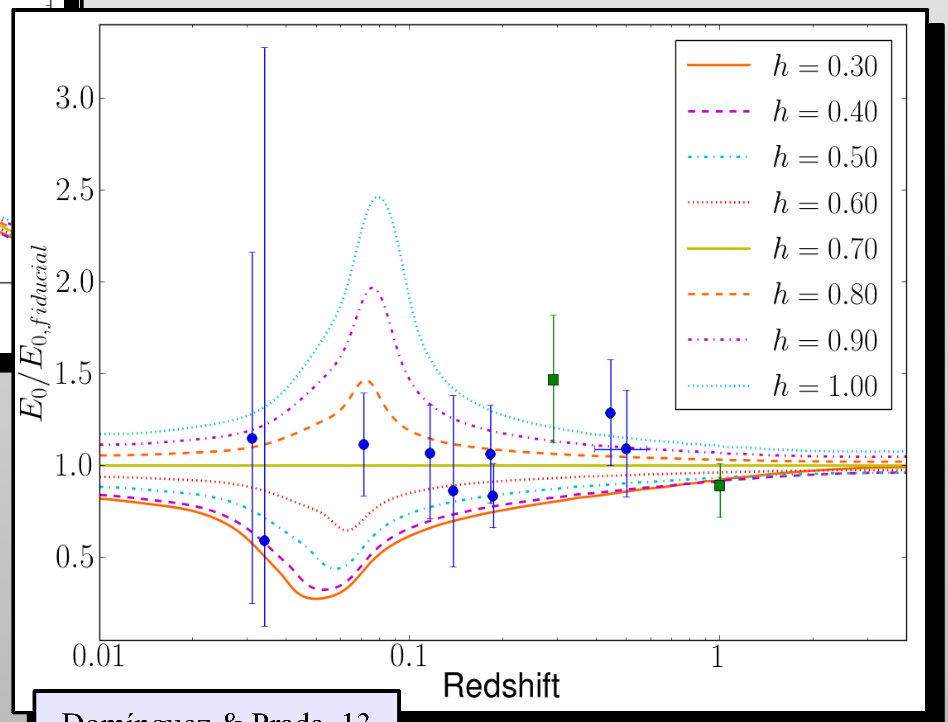


Preliminary

The Hubble constant from gamma-rays



See Oscar Blanch's talk

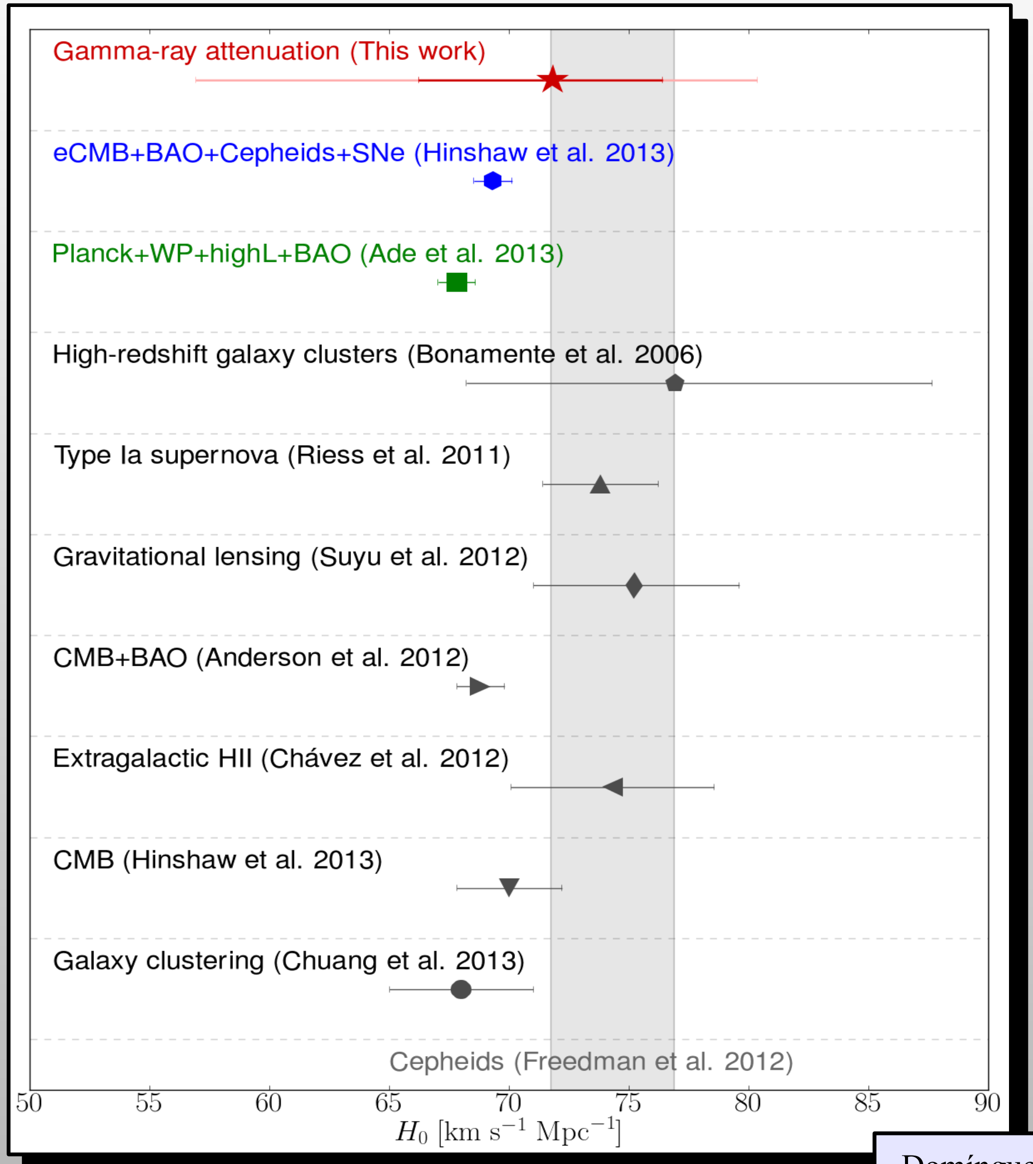


Domínguez & Prada, 13

$$H_0 = 71.8\,^{+4.6}_{-5.6}\,^{+7.2}_{-13.8}\ \text{km/s/Mpc}$$

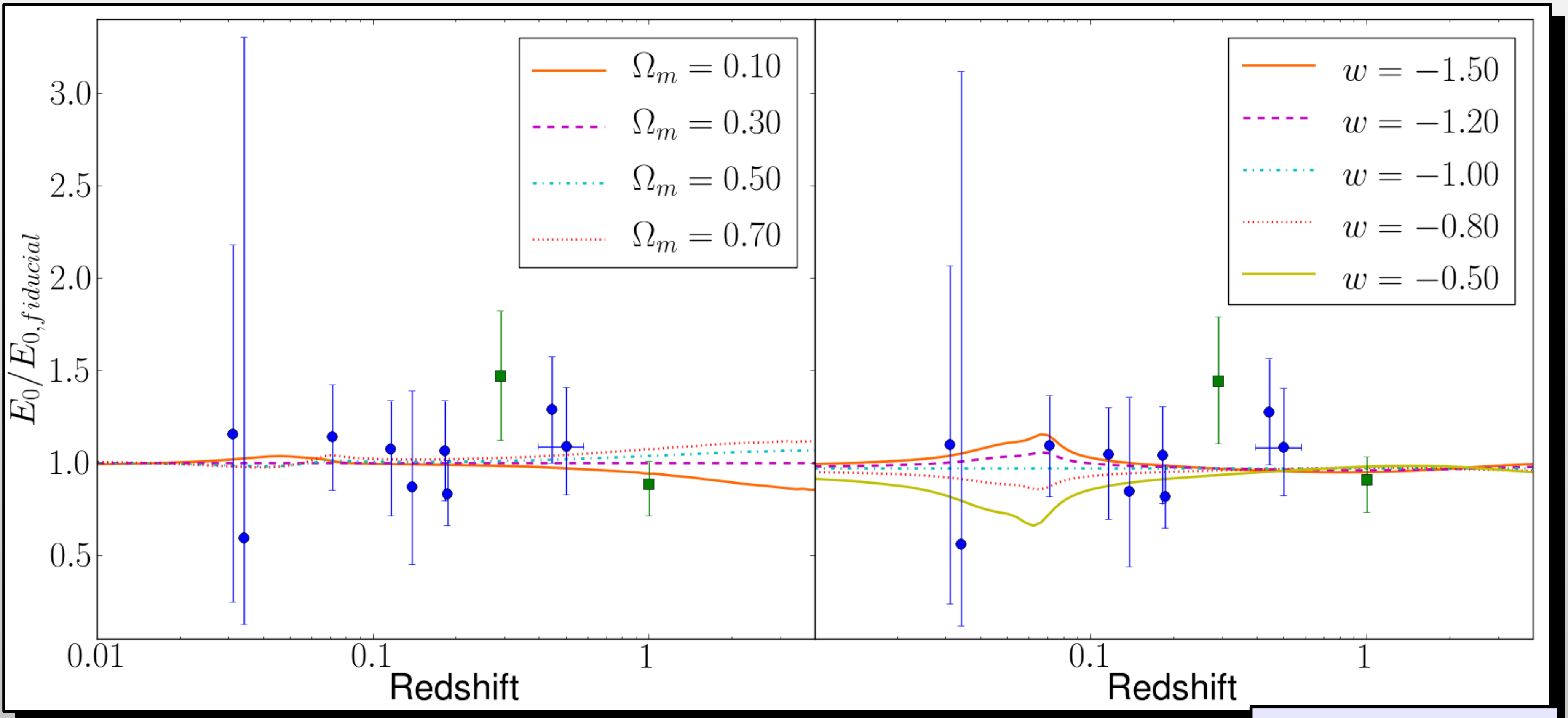
Statistical uncertainties **Systematic uncertainties**

The Hubble Constant from Different Methodologies



Domínguez & Prada, 13

Cosmological Parameters: Ω_m and w



Domínguez & Prada, 13