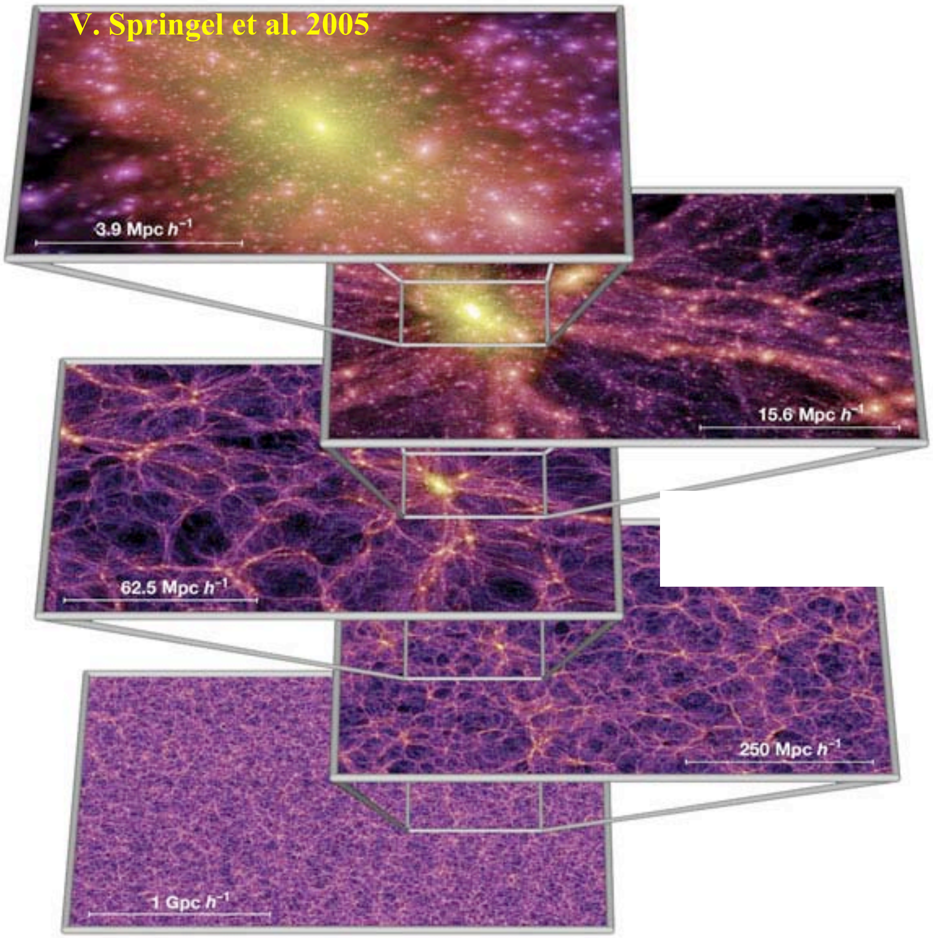
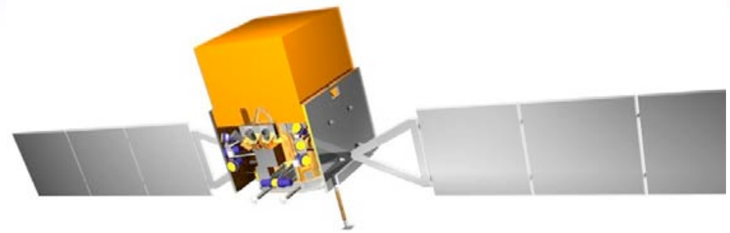


Extragalactic Background Light

Probed in the GLAST Era



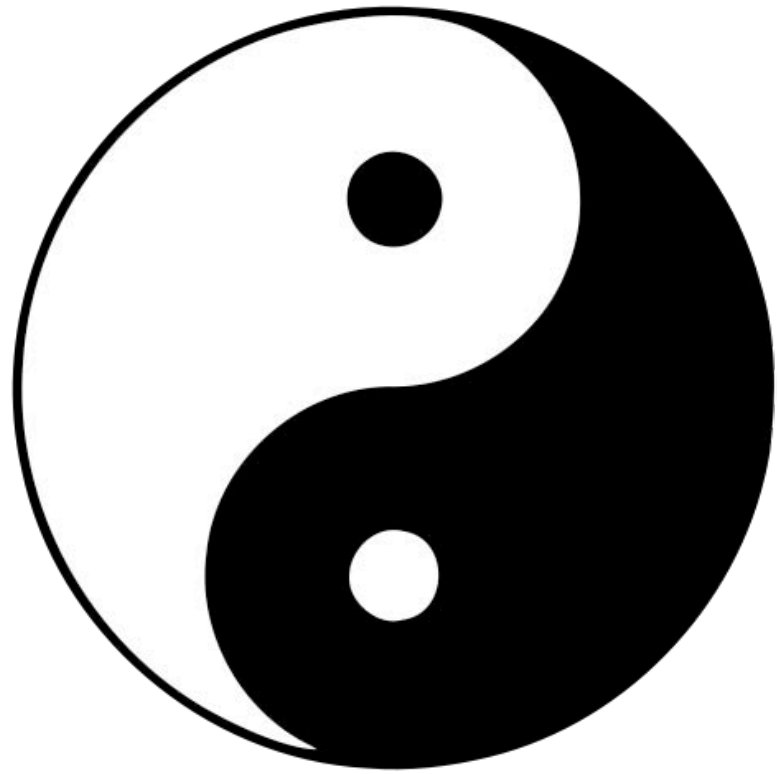
D. H. Hartmann
Clemson University

Thanks to many (re)sources:
APOD: antwrp.gsfc.nasa.gov/apod/
ADS: adswww.harvard.edu/
Tanja Kneiske, Karl Mannheim, Paolo Coppi, …

WIKIPEDIA
Di freyi Enzyklopedy

1st GLAST Symposium:
Stanford 2/2007

?



Star light – nucleosynthesis -

black hole – accretion -

Heinrich Wilhelm Matthäus Olbers (1757-1840)

From Wikipedia, the free encyclopedia

The **Extragalactic Background Light** (EBL) is the faint diffuse light of the night sky, consisting of the combined flux of all extragalactic sources. Its main significance for astronomers is that it contains information regarding the history and formation of other galaxies, and also the large scale structure of the universe.

EBL = fossil record of the cosmic history of light

Indirect: source counts → lower limits

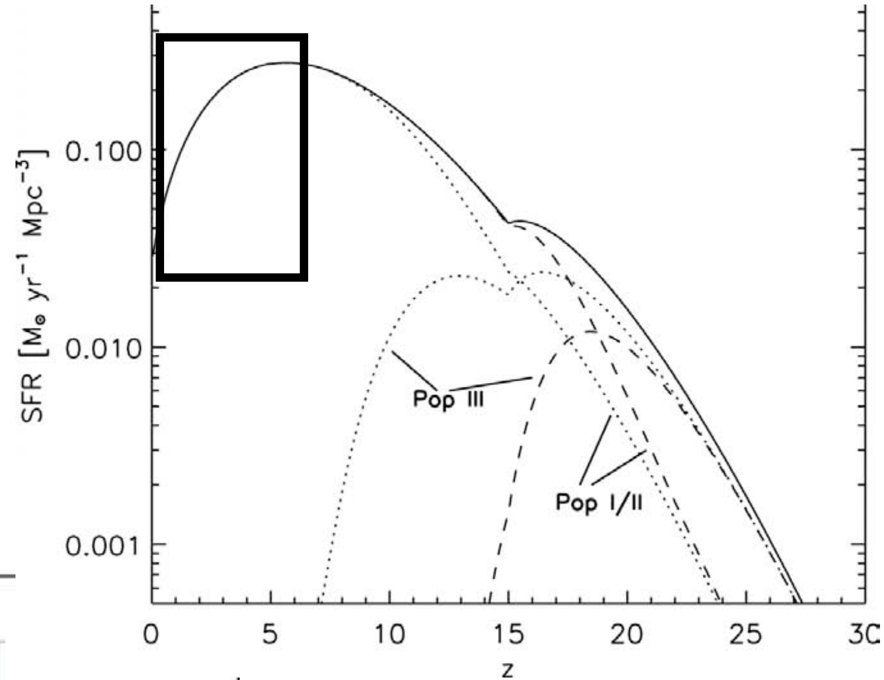
Direct: (absolute photometry) → $F^{EBL} = F^{tot} - F^{corr}$

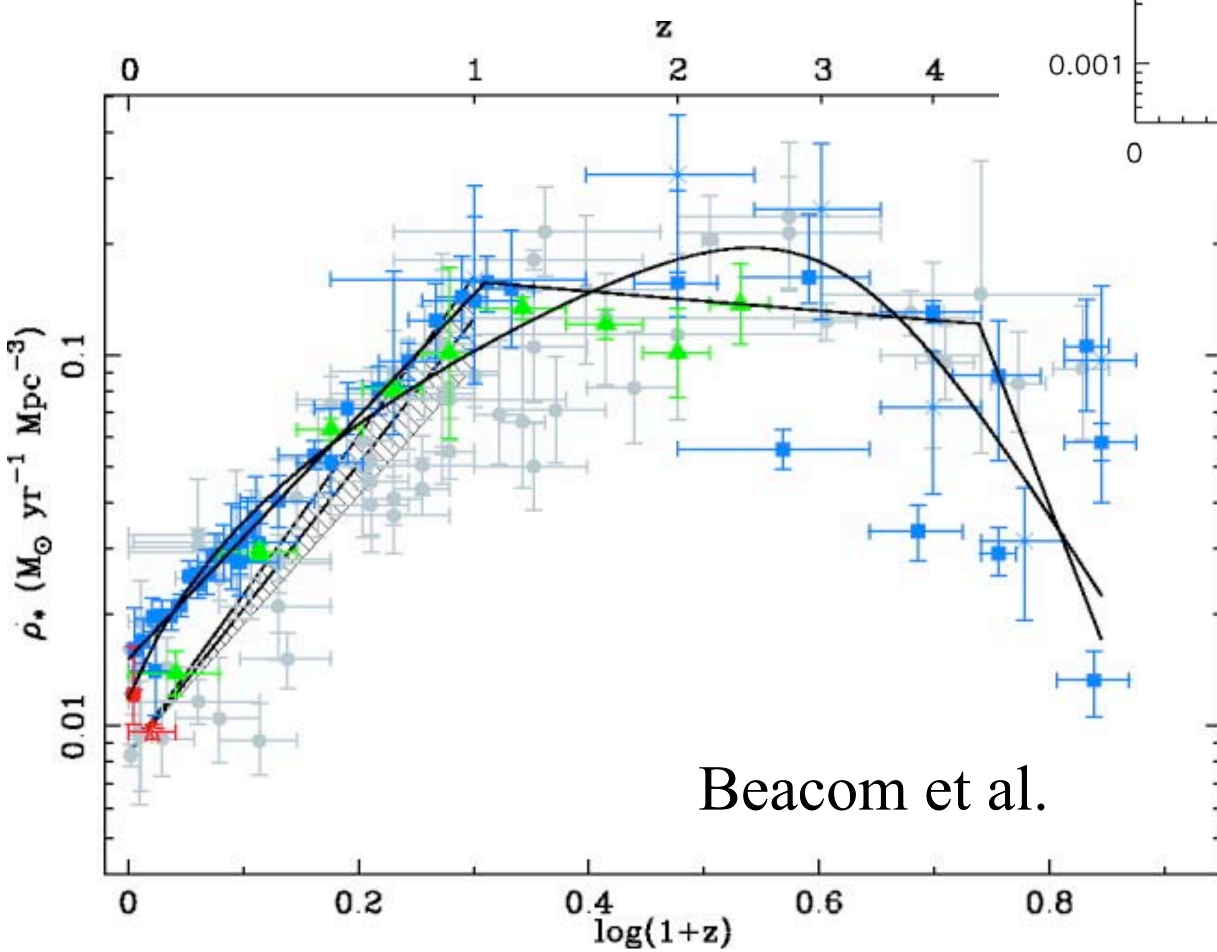

Jimmy Westlake (APOD061226)
Gegenschein


Zodiacal Light


Discrete stars
Diffuse Galactic Light
(model)

Star Formation in the Early Universe:
e.g., Bromm & Loeb 2006, ApJ 642, 382





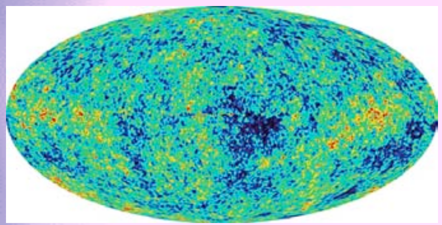
Beacom et al.

quasars: $z_{max} \sim 6.4$

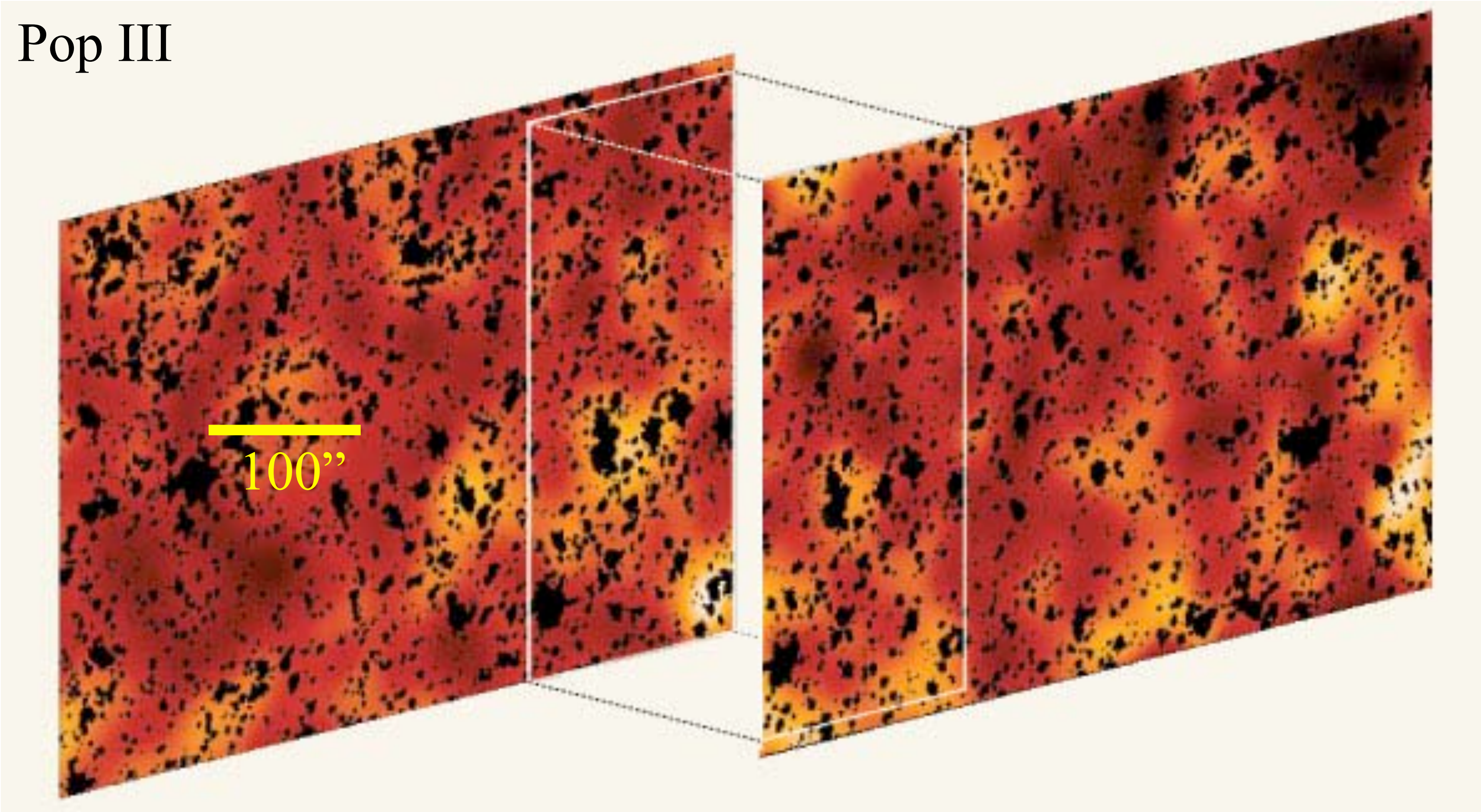
galaxies: $z_{max} = 7.0$

GRBs: $z_{max} = 6.3$

WMAP3: Π÷T → $z_{reion} > 11$



Pop III stars: $z \sim 20$ → EBL



Kashlinsky et al. 2007, ApJ, astro-ph/0612(445&447)
GOODS – Spitzer/IRAC 3.6 μm , 4.5 μm

1-10% fluctuations (1-10 arcmin scale), emitted at 1 Gyr (z=10)

Corresponding to ~ 1 Mpc (@z=10) pre-collapse DM halos

HST: **Bernstein** et al 2003 (Airglow)

Absolute surface photometry WFPC2

Zodiacal Light: **ZL**

Discrete stars (AB ~ 27.5)

DGL: Scattered *-light off MW dust

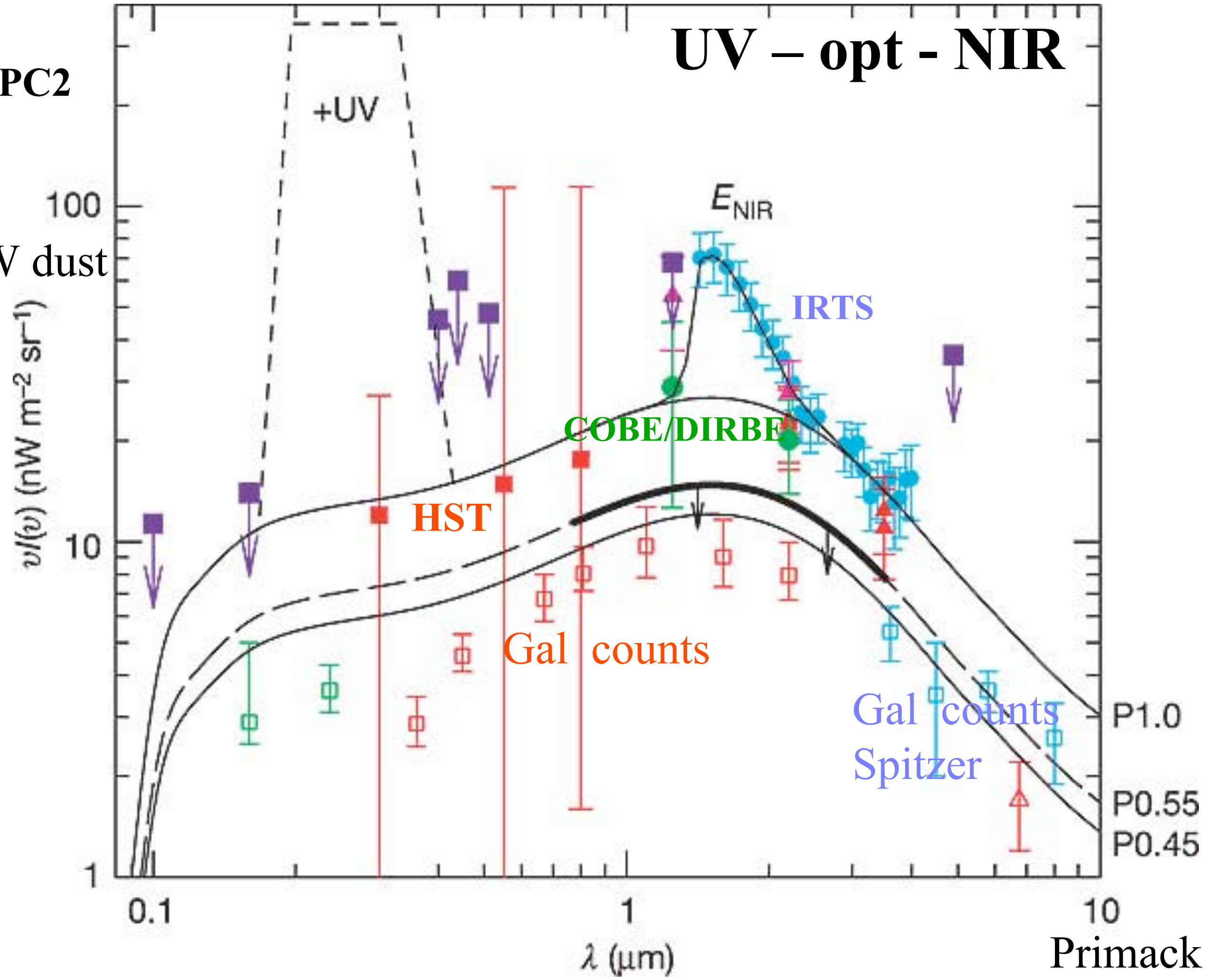
ISM line emission

Mattila 2003 ZL-correction

EBL ~ 1% of total

~ 33% Ω_b processed in stars

F. Aharonian et a. 2006, Nature 440, 1018 (April 20)

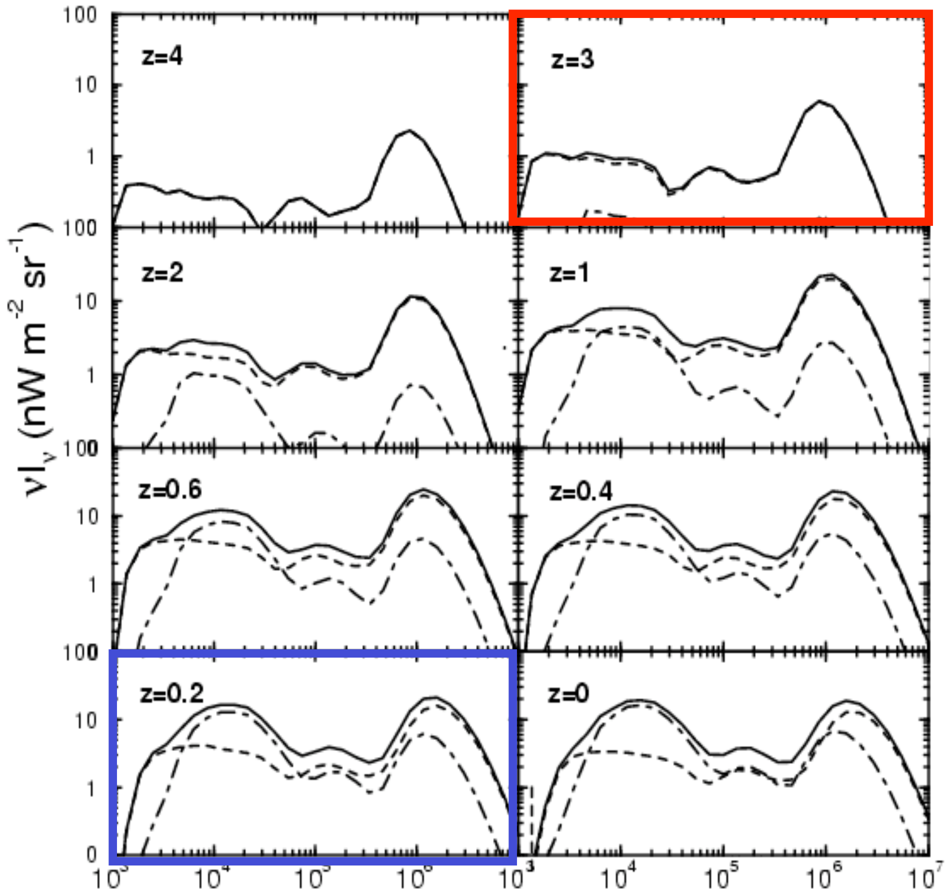


Primack

$F_\lambda \sim 10^{-8}$ ergs/cm^2 s sr Å

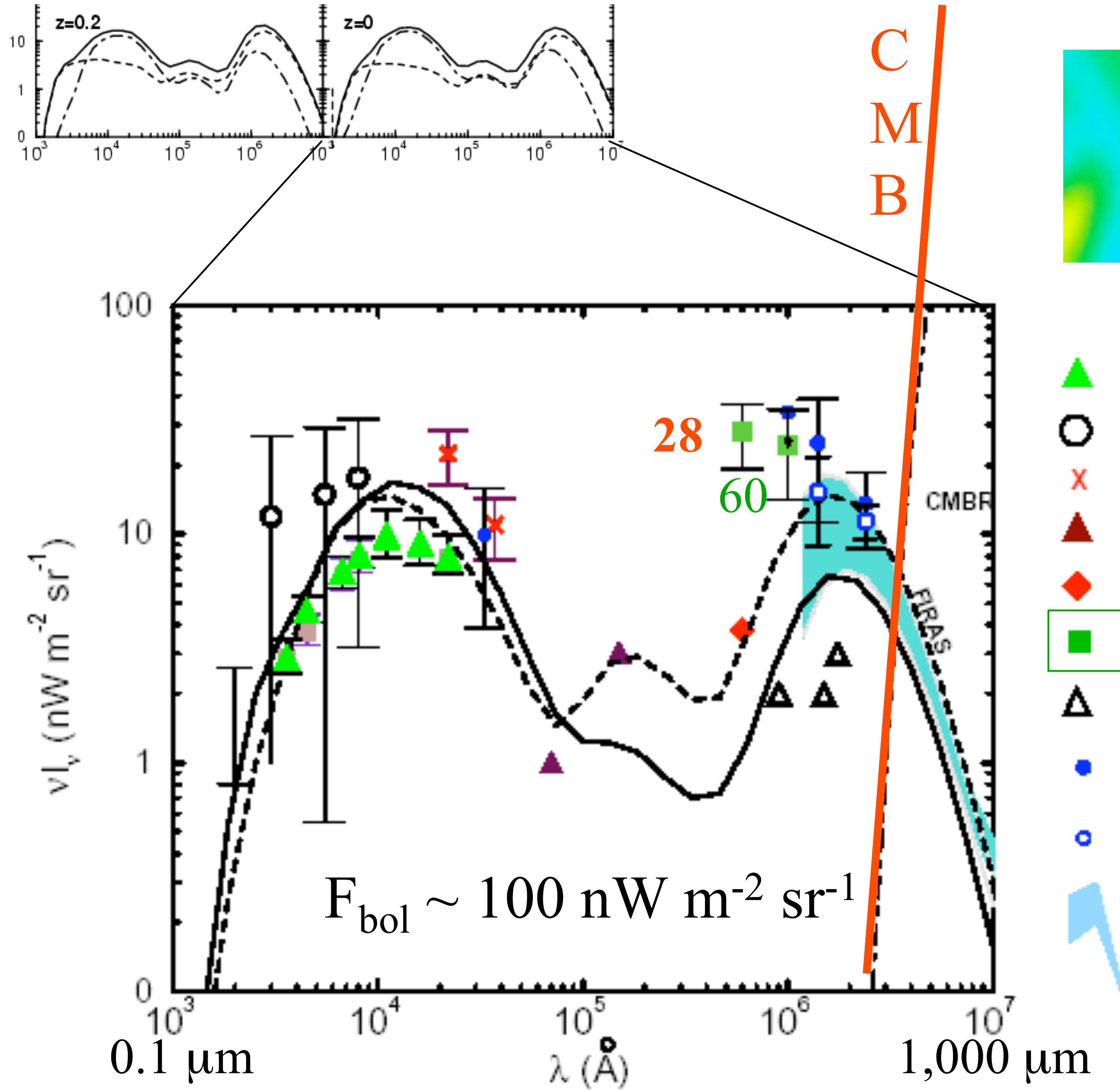
Reprocessing of light

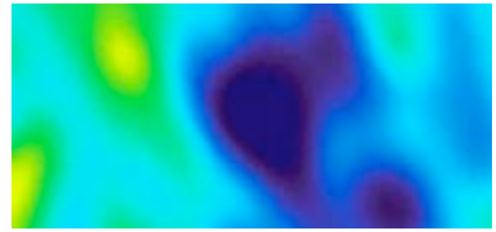
The metagalactic UVOIR background



Kneiske, Mannheim, Hartmann. 2000 A&A 386, 1

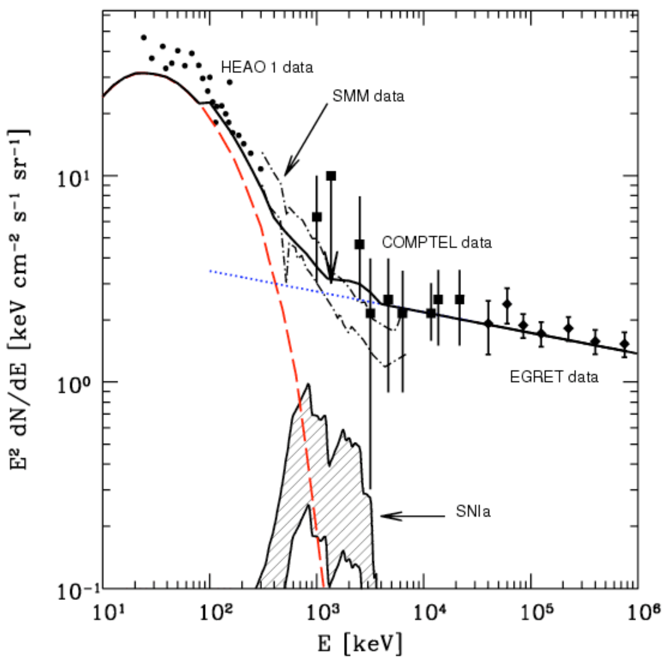
Tinsley 1977, … Madau, Primack, Fall, Pei, Dwek, Krennrich, Malkan, Stecker, Scully, ……





Kneiske et al. 2000 A&A 386, 1

The γ-ray Background

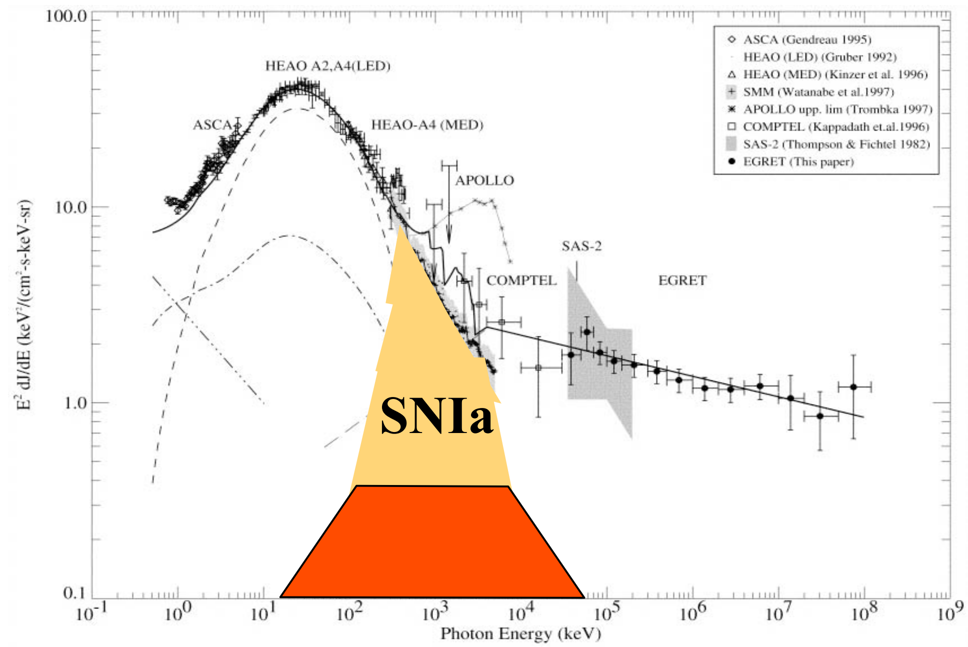


Strigari, Beacom,Walker, Zhang

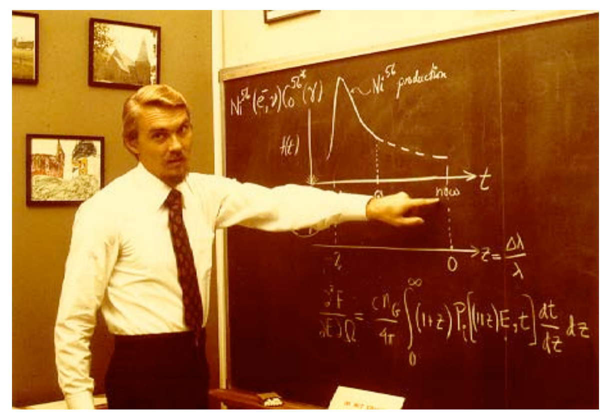
2004, JCAP 0504, 017

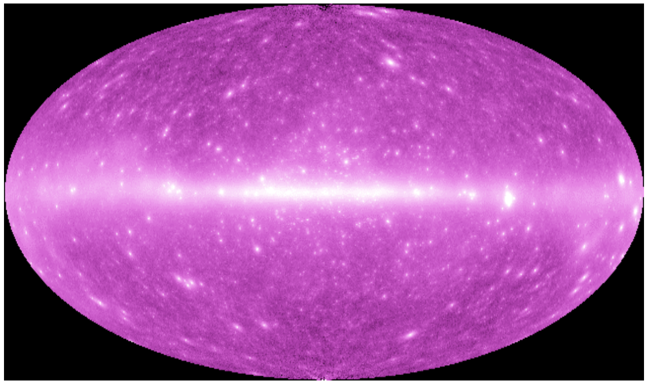
Missing sources

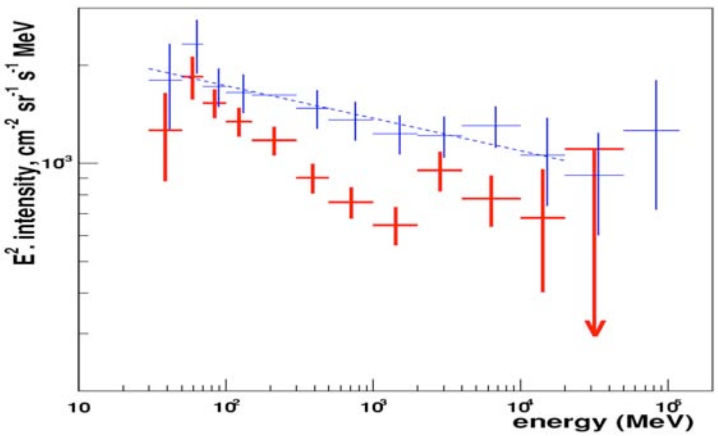
CGB (^{56}Co): Clayton & Silk 1969, ApJ 148, L43



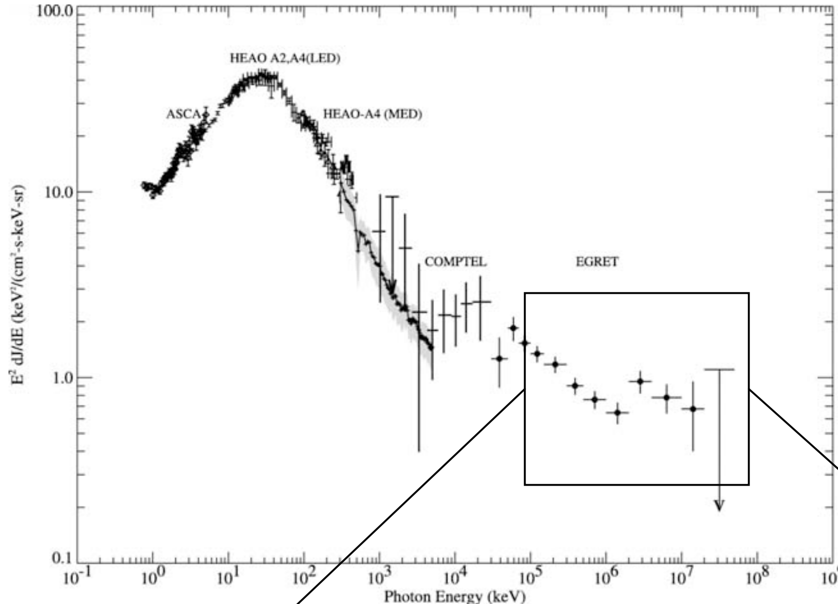
Watanabe, Hartmann, Leising, The 1999, ApJ 516, 285

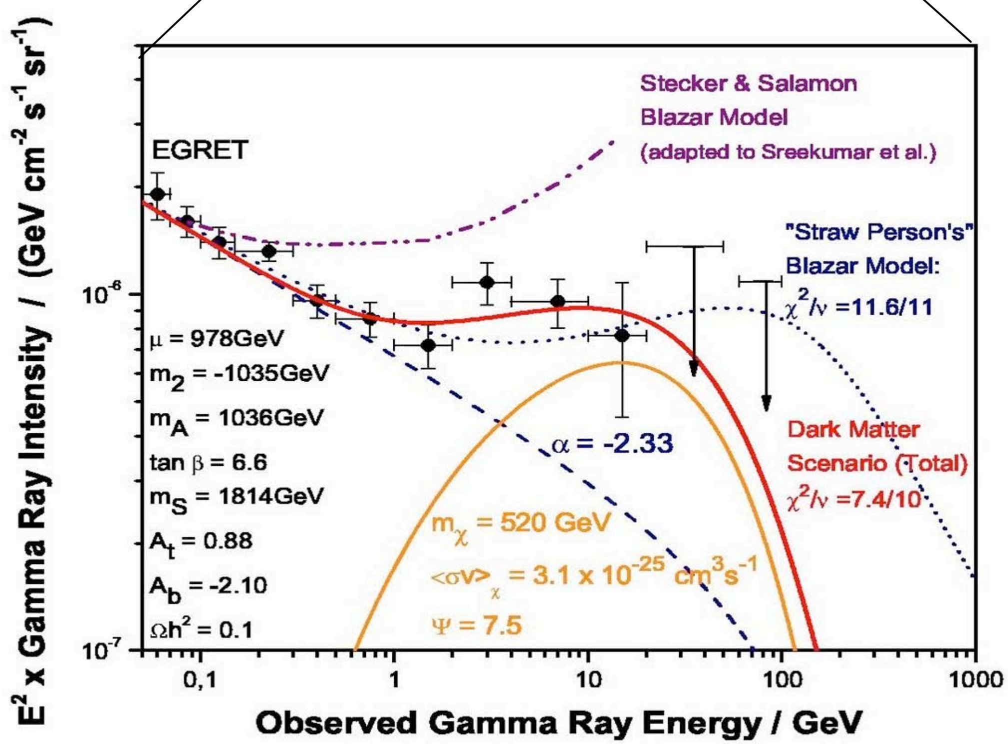






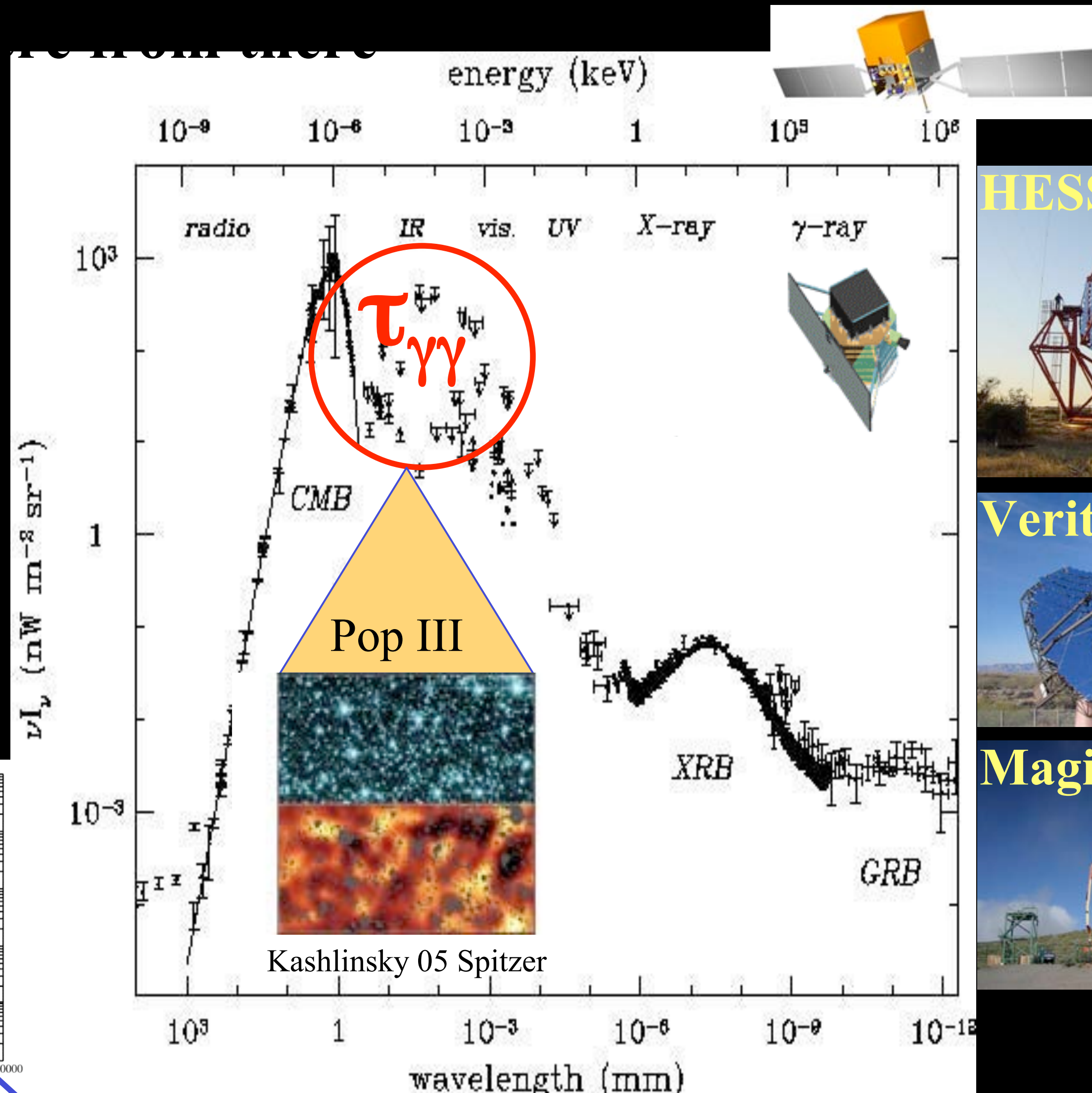
Strong, Moskalenko, Reimer, 2004 ApJ 613, 956

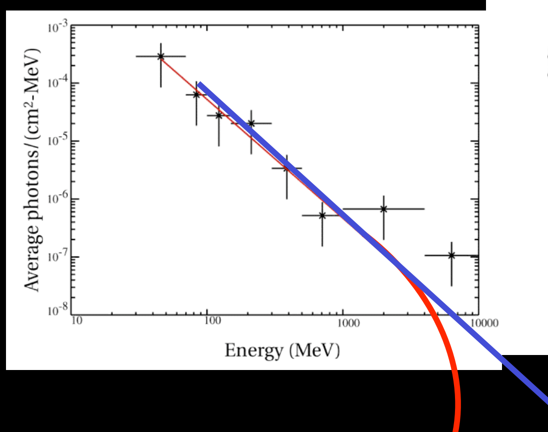




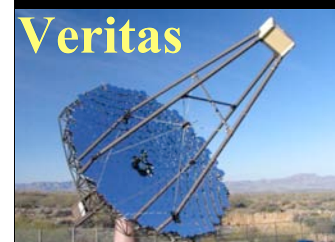
Elsässer & Mannheim 2005 PRL 94, 171302:

Neutralino Annihilation m_χ = 520 GeV


energy (keV)
10^-9 10^-6 10^-3 1 10^3 10^6
radio IR vis. UV X-ray γ-ray
10^3
1
10^-3
CMB
τγγ
Pop III
Kashlinsky 05 Spitzer
XRB
GRB
νIν (nW m^-2 sr^-1)
10^3 1 10^-3 10^-6 10^-9 10^-12
wavelength (mm)


Average photons/(cm2-MeV)
Energy (MeV)


HESS


Veritas


Magic

The optical depth of the universe

Nishikov 1962: $\tau_{\gamma\gamma}$

Gould & Schreder 1966

Jelly 1966

Stecker ; Fazio 1969/70

Stecker et al. 1992

COBE – IR bkgrd 1997

Hauser & Dwek 2001 Review

McMinn & Primack 1996
Franceachini 1998
Malkan & Stecker 1998, 2001
Kneiske et al. 2002, 2004

Dwek & Krennrich 2005

…..

$$\sigma_{\gamma\gamma}(E_\gamma,\ \epsilon,\ \mu) = \frac{3\sigma_T}{16}(1-\beta^2) \times \left[2\beta(\beta^2-2) + (3-\beta^4)\ln\left(\frac{1+\beta}{1-\beta}\right)\right]$$

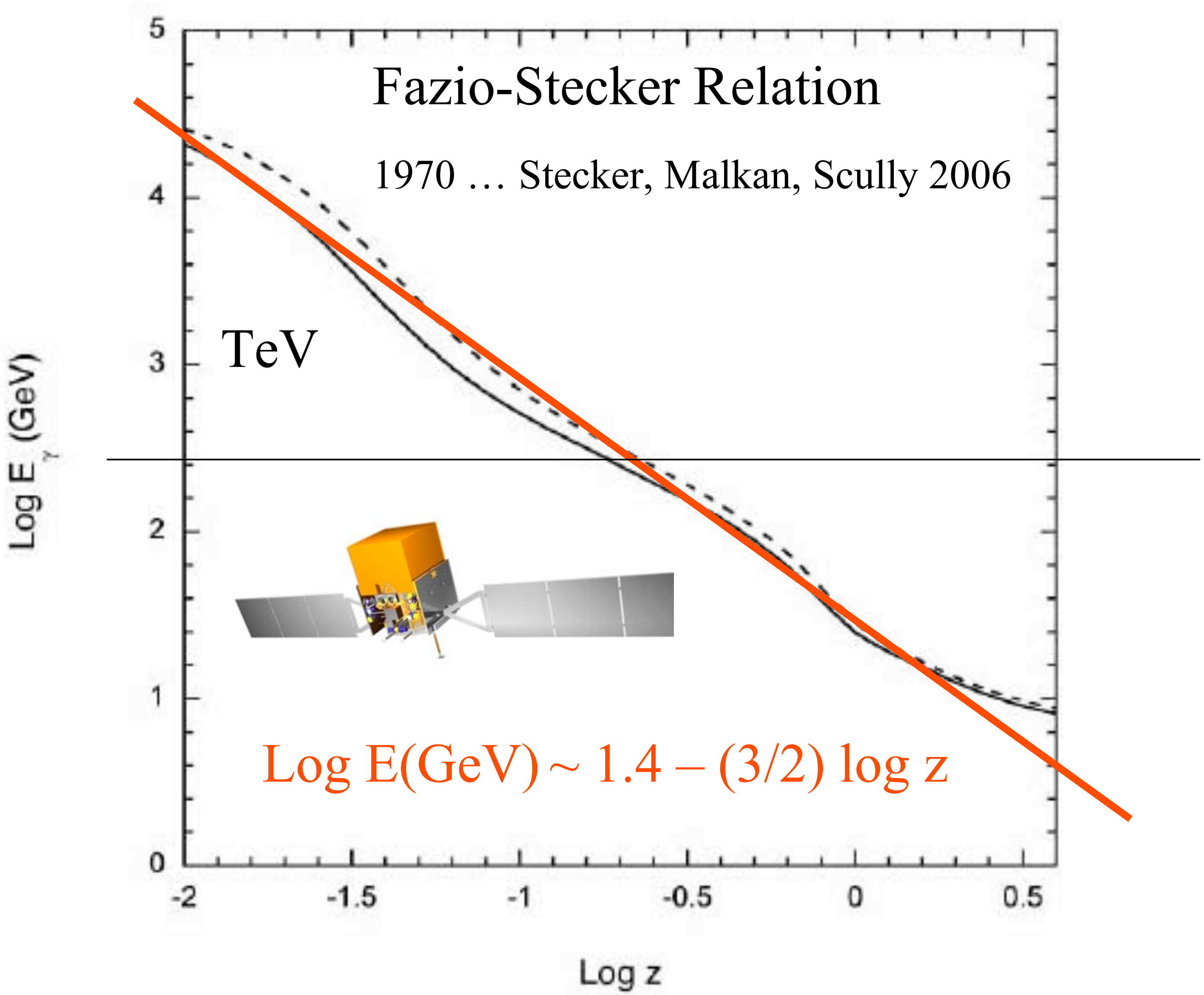
$$\beta \equiv \sqrt{1-\frac{\epsilon_{th}}{\epsilon}},$$

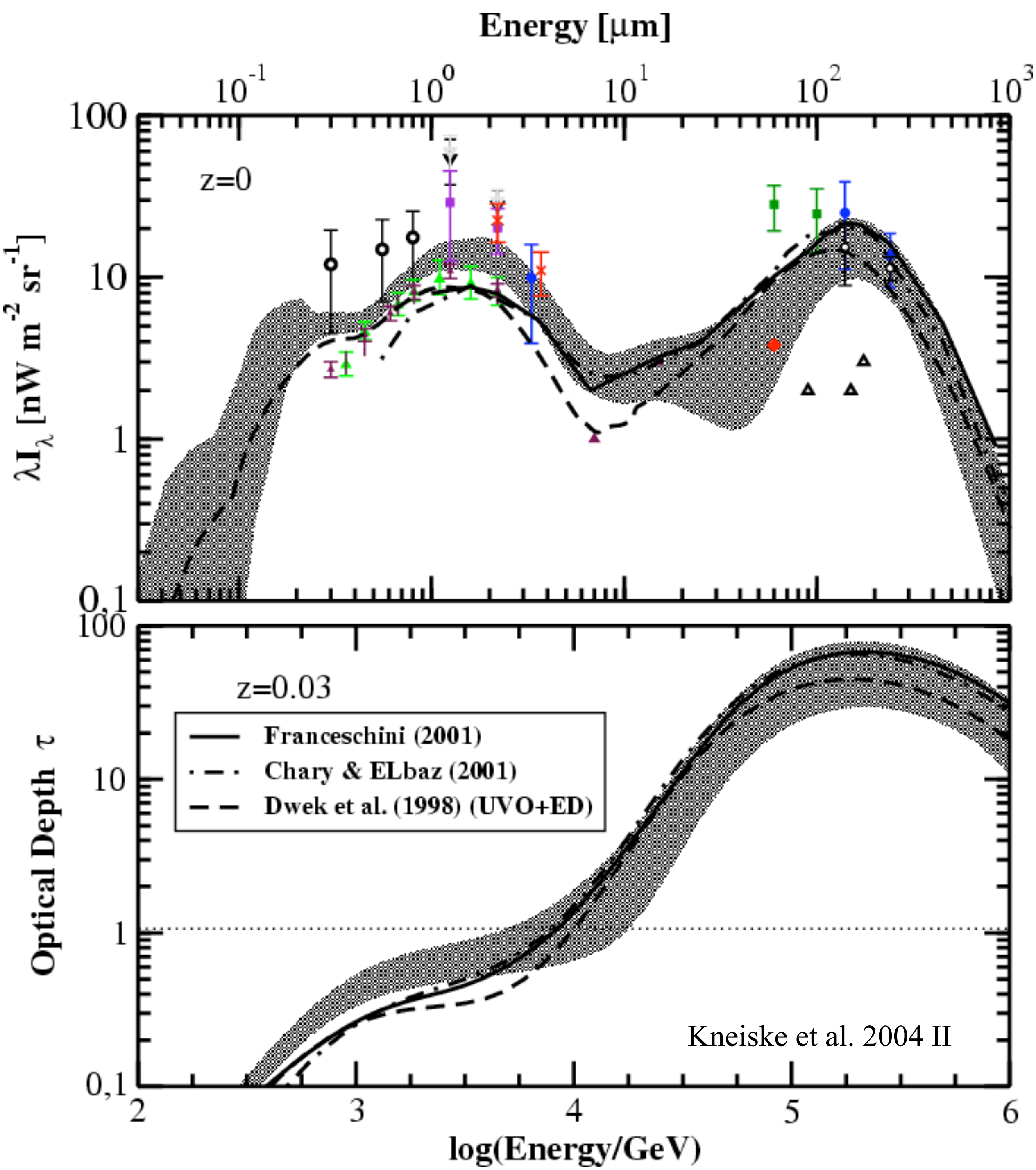
$$\epsilon_{th}(E_\gamma,\ \mu) = \frac{2\,(m_e c^2)^2}{E_\gamma\,(1-\mu)},$$

EBL(z)

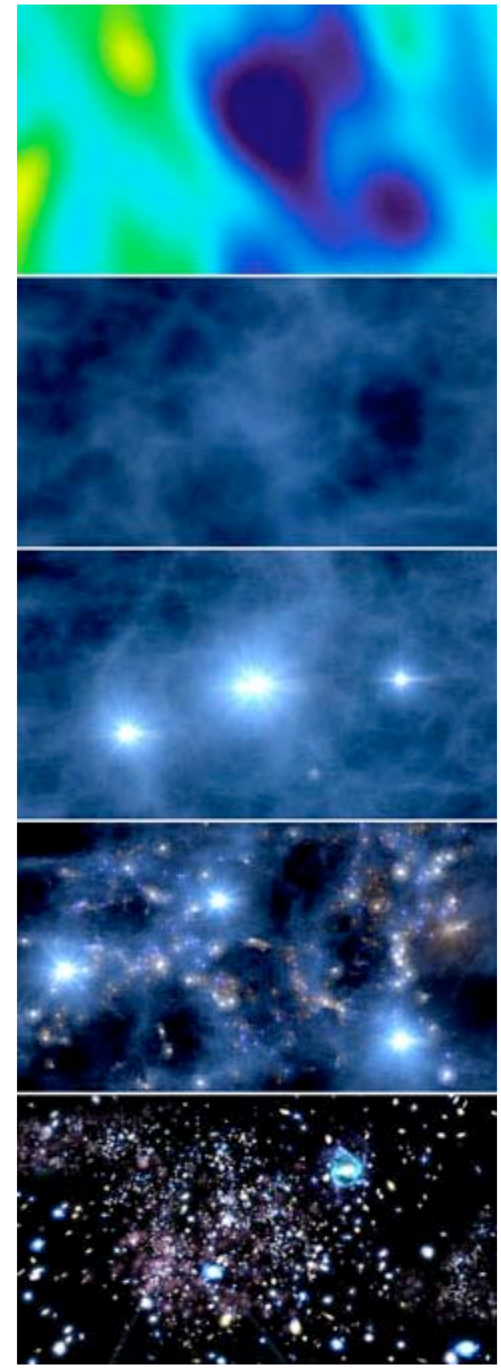
$$\tau_\gamma(E_\gamma,\ z) = \boxed{\int_0^z \left(\frac{dl}{dz'}\right) dz'} \int_{-1}^{+1} d\mu \frac{1-\mu}{2} \int_{\epsilon'_{th}}^{\infty} d\epsilon' n_\epsilon(\epsilon',\ z')\sigma_{\gamma\gamma}(E'_\gamma,\ \epsilon',\ \mu),$$

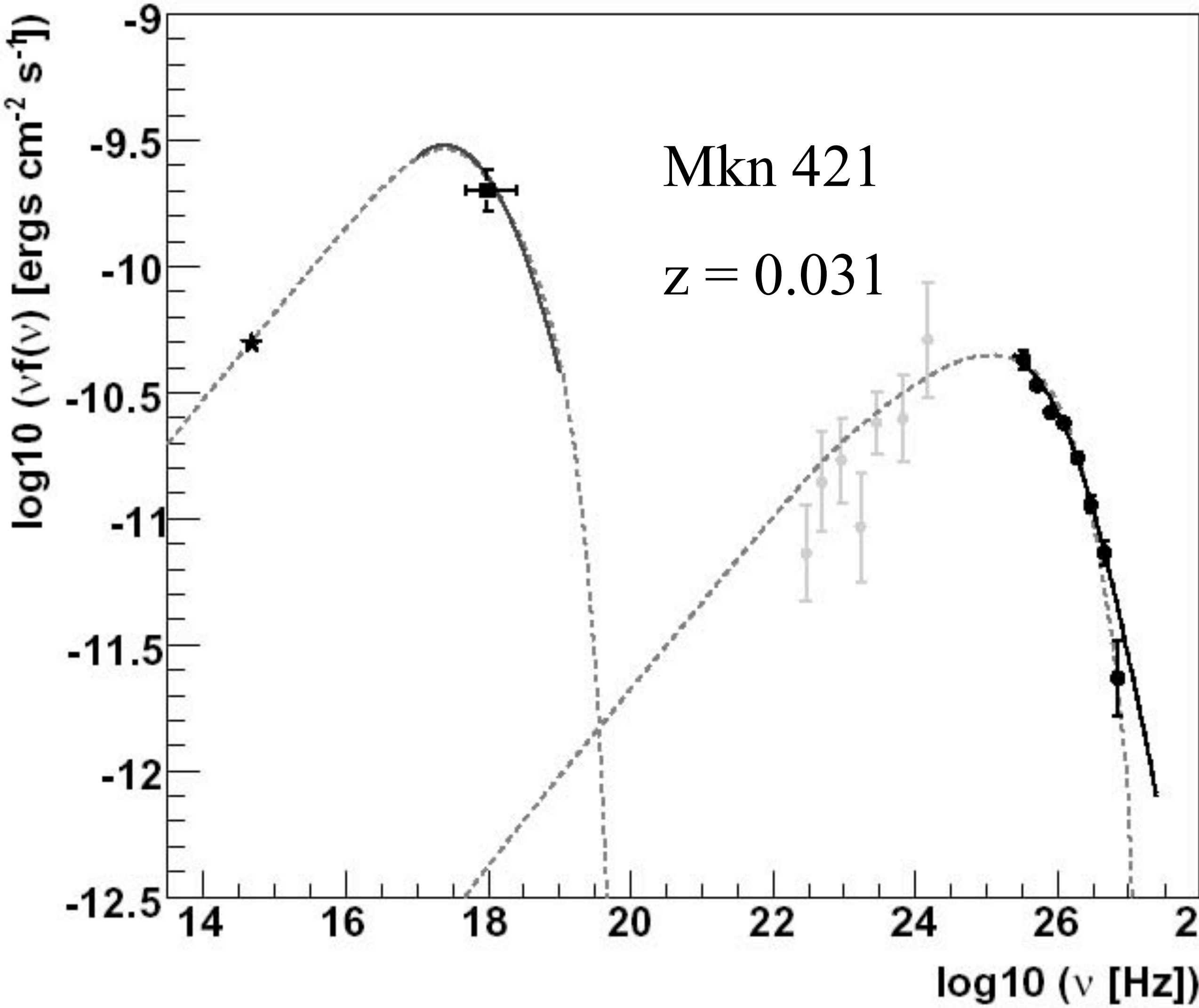
The gamma-horizon: $\tau_{\gamma\gamma} = 1$



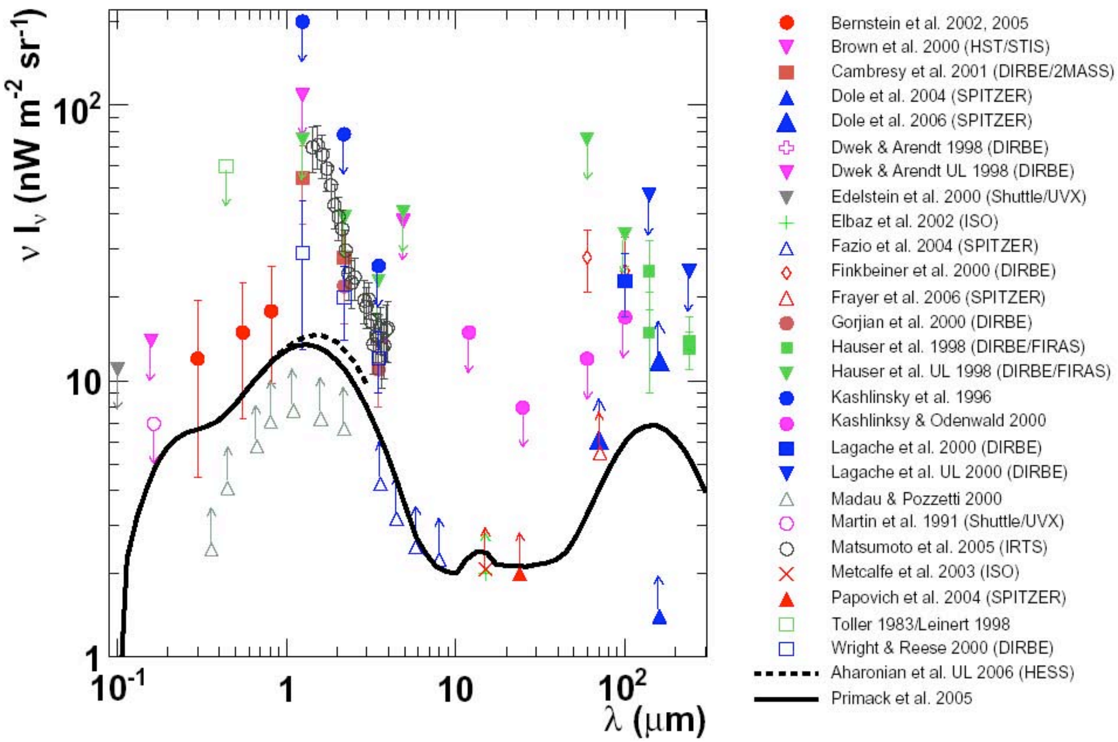


Energy [μm]
10^-1
10^0
10^1
10^2
10^3
100
10
1
0,1
z=0
λI_λ [nW m^-2 sr^-1]
z=0.03
Franceschini (2001)
Chary & ELbaz (2001)
Dwek et al. (1998) (UVO+ED)
Optical Depth τ
100
10
1
0,1
Kneiske et al. 2004 II
2
3
4
5
6
log(Energy/GeV)

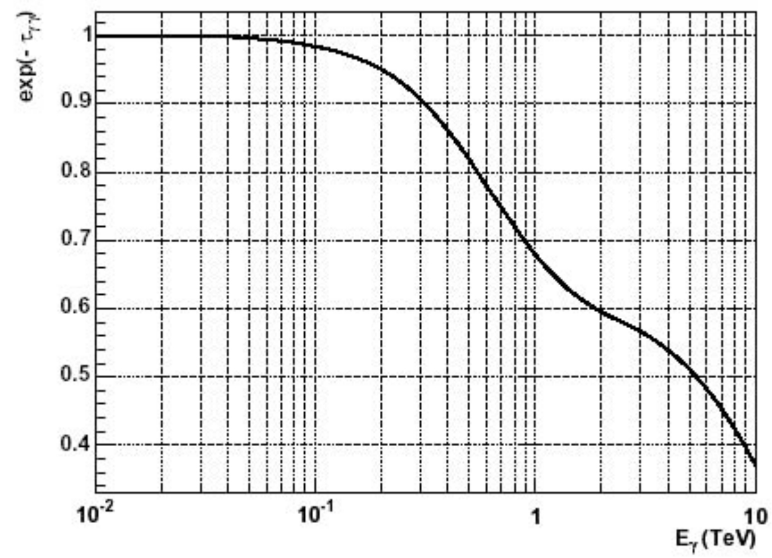




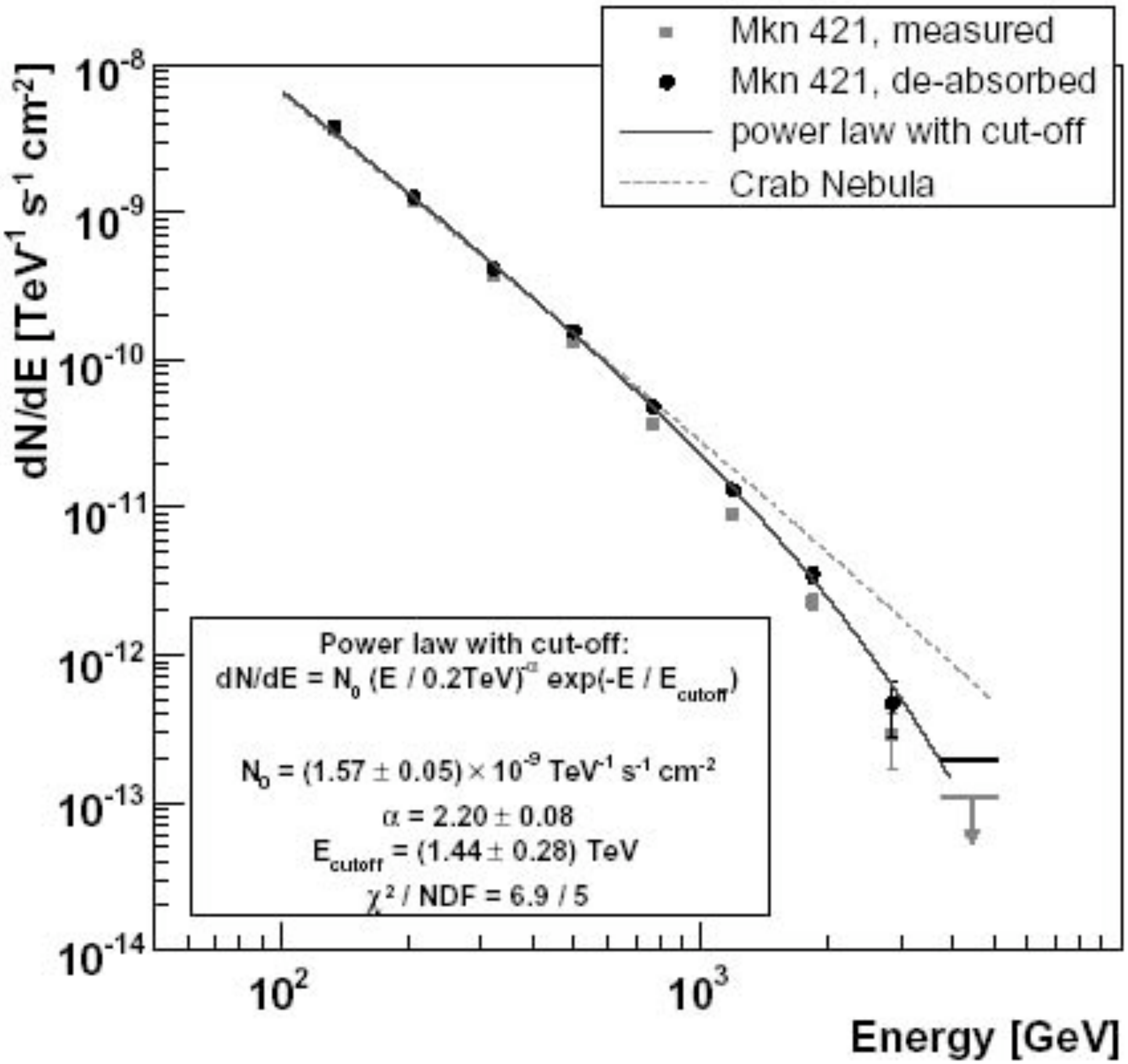
Albert et al. 2006, ApJ, submitted



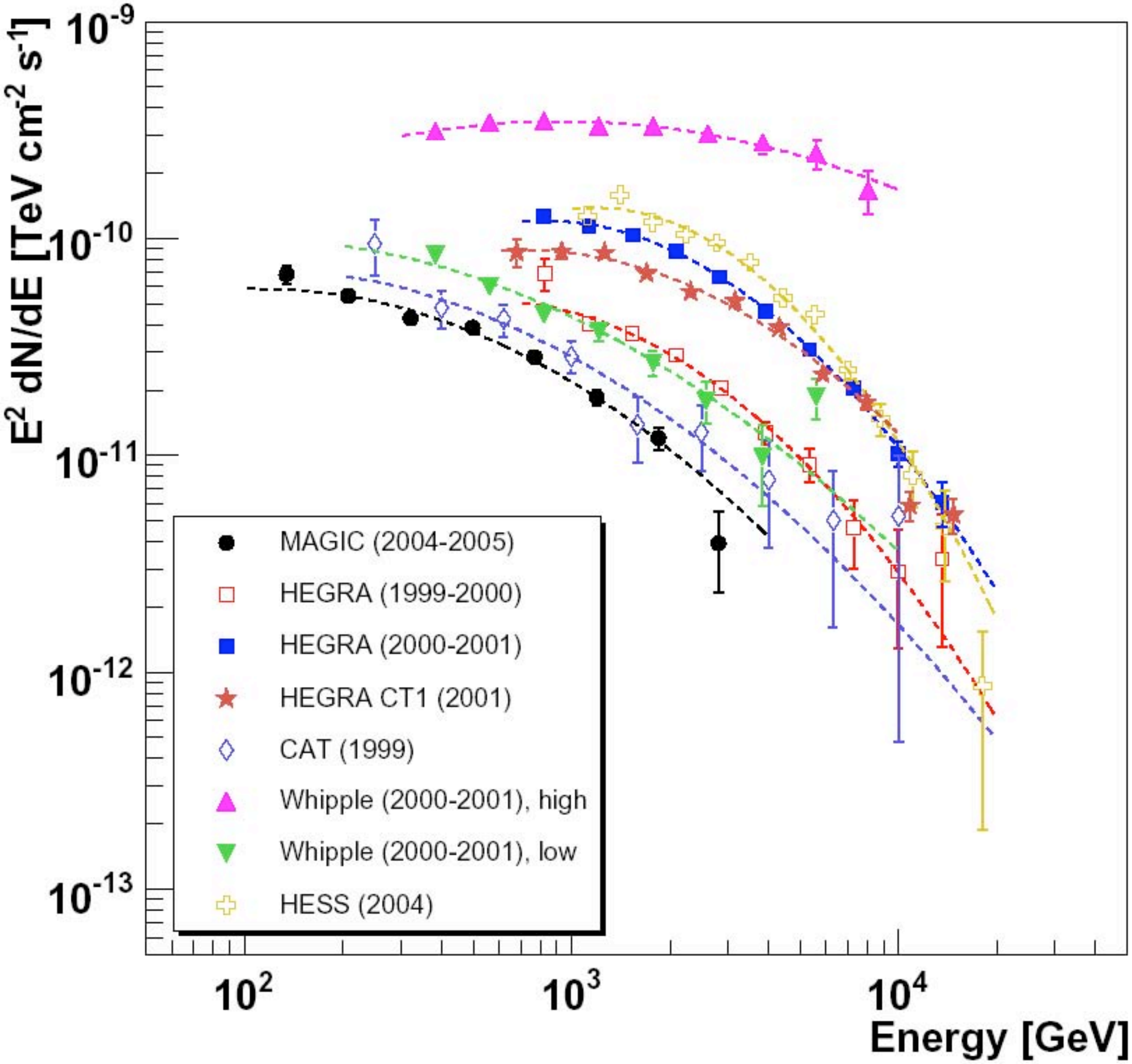
z(Mkn 421) = 0.031



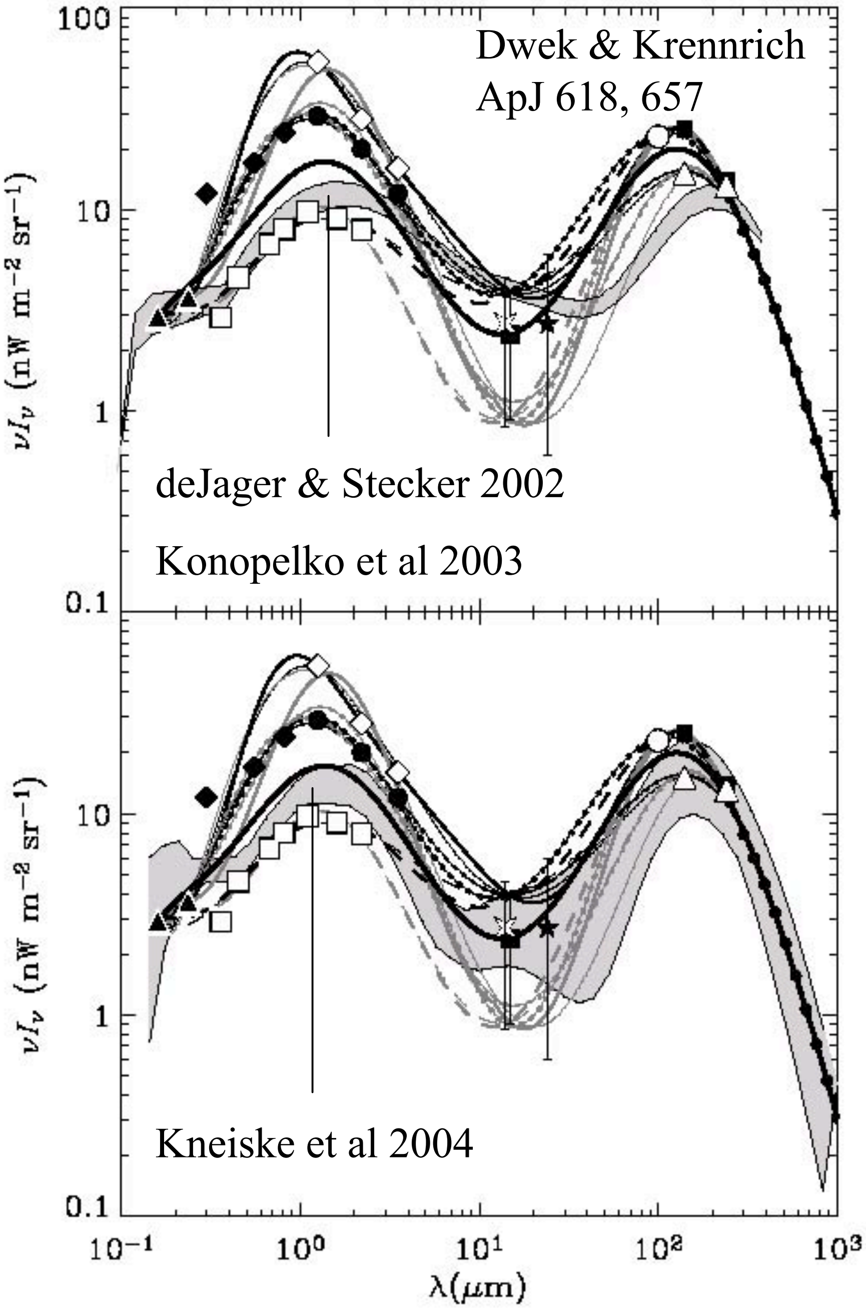
Albert et al. 2006, ApJ, submitted

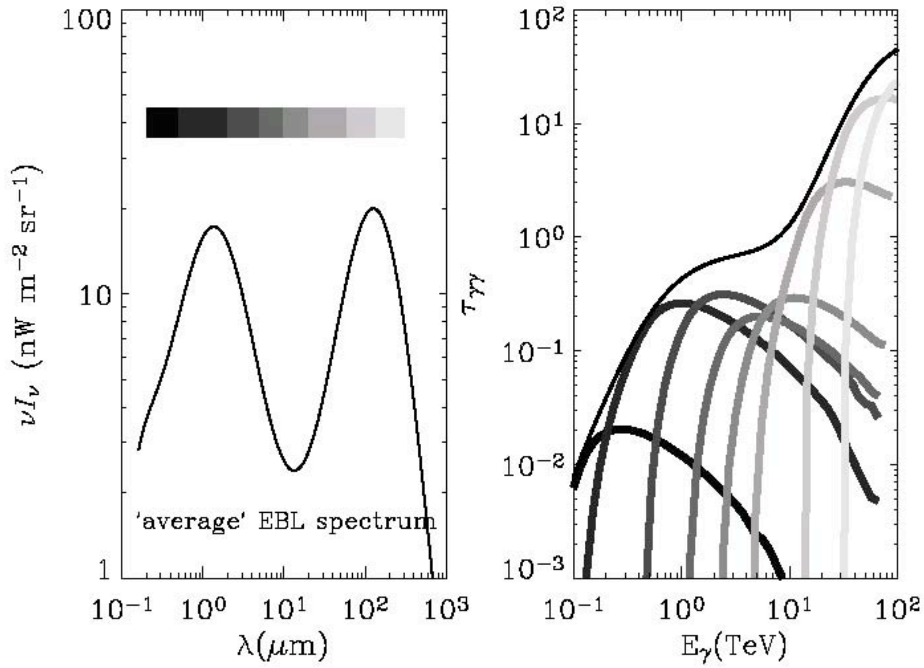


Albert et al. 2006, ApJ, submitted

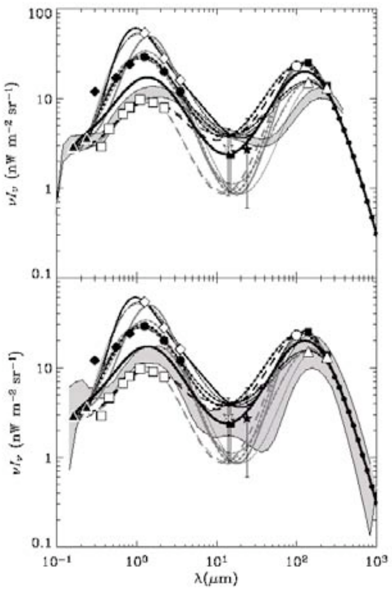


Albert et al. 2006, ApJ, submitted



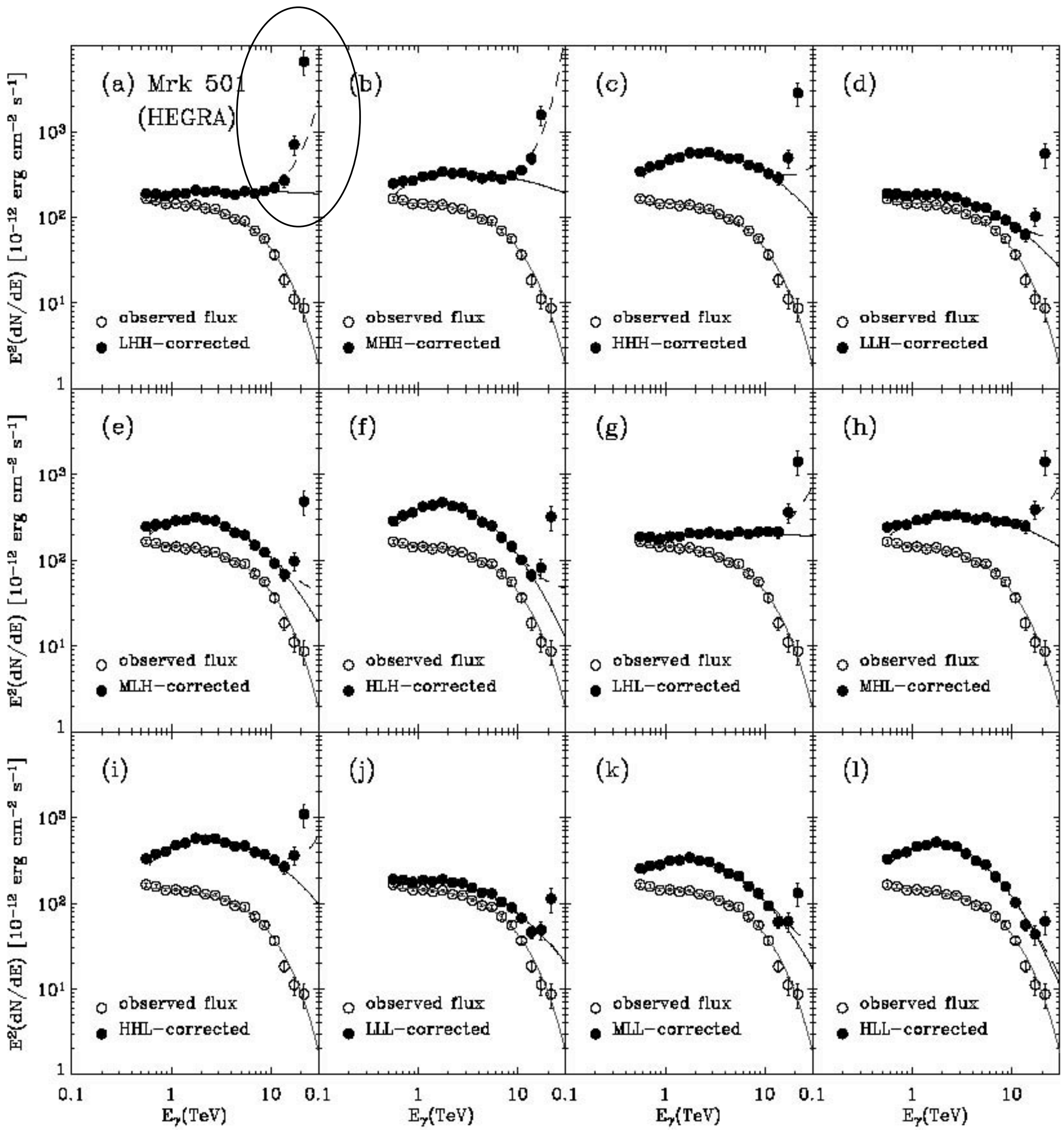


An ensemble of EBL options

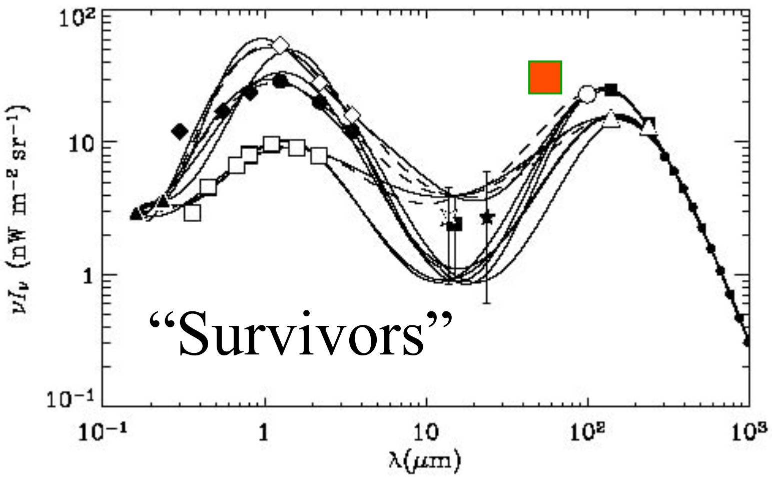


νI_ν (nW m⁻² sr⁻¹)
λ(μm)

z = 0.034



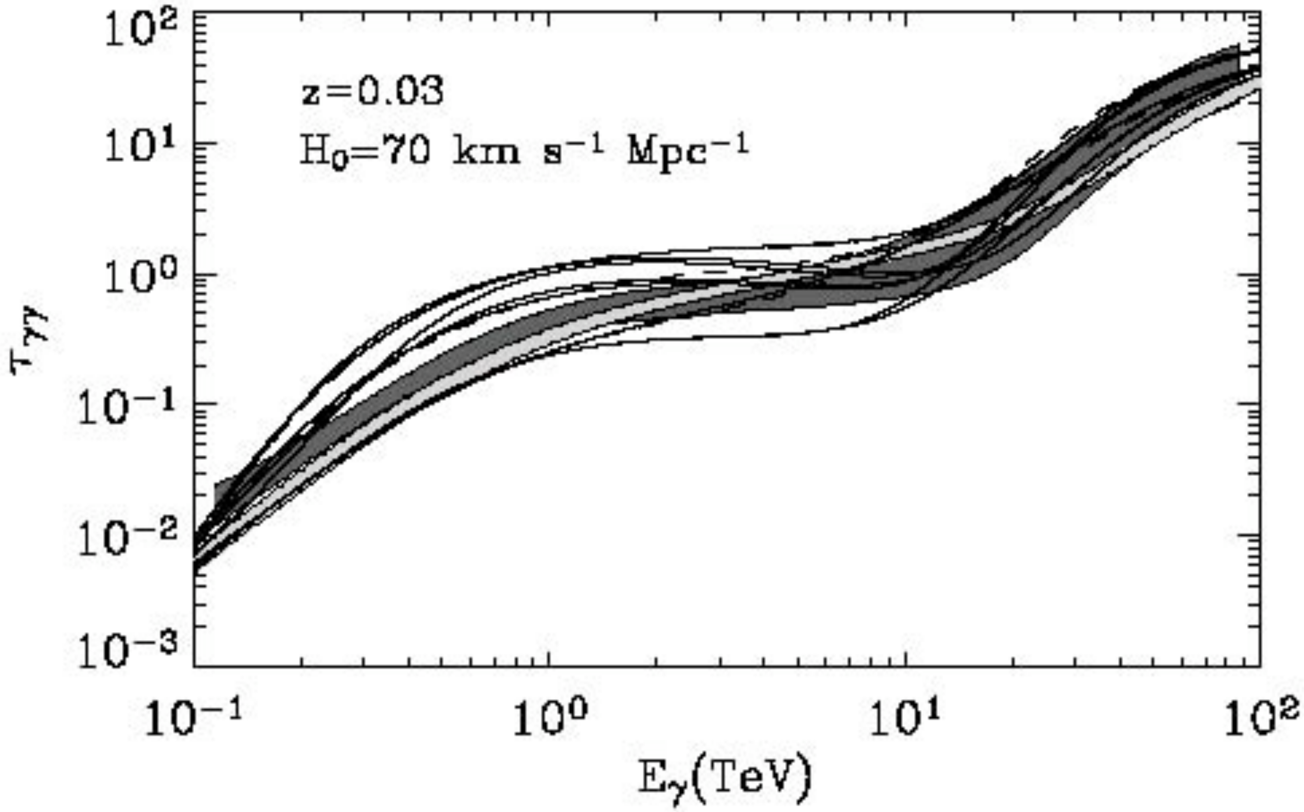
(a) Mrk 501
(HEGRA)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
observed flux
LHH-corrected
MHH-corrected
HHH-corrected
LLH-corrected
MLH-corrected
HLH-corrected
LHL-corrected
MHL-corrected
HHL-corrected
LLL-corrected
MLL-corrected
HLL-corrected
E²(dN/dE) [10⁻¹² erg cm⁻² s⁻¹]
E_γ(TeV)



28 60 COBE/DIRBE

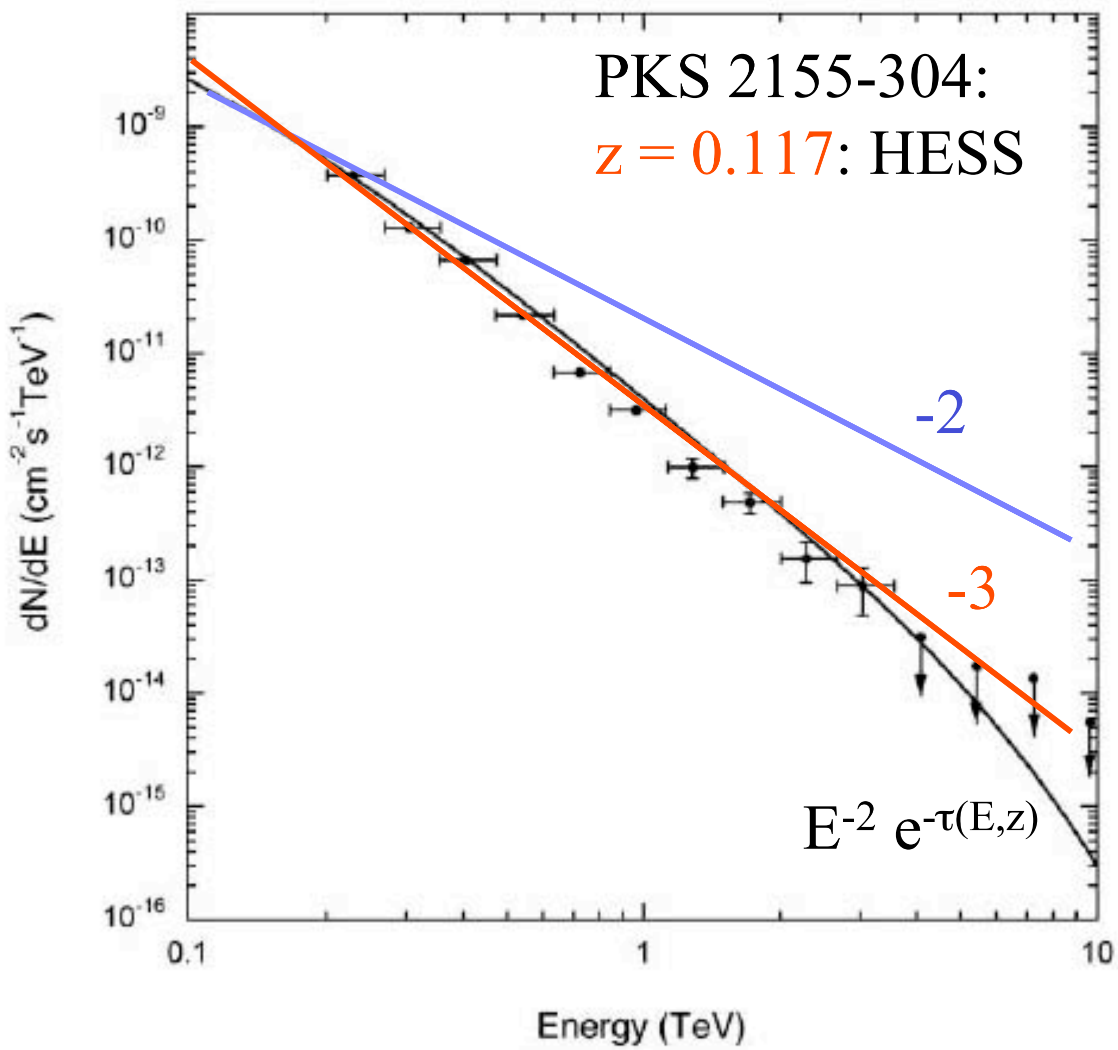
μ Finkbeiner et al. 2000

Optical Depth of the universe

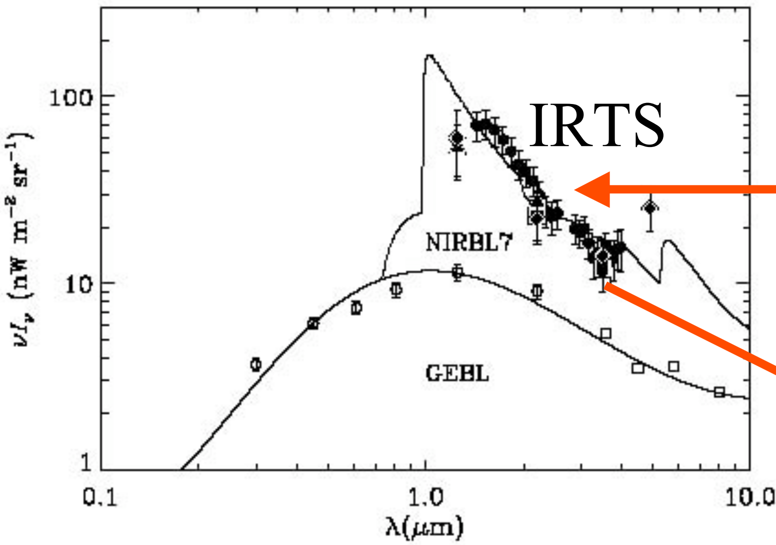


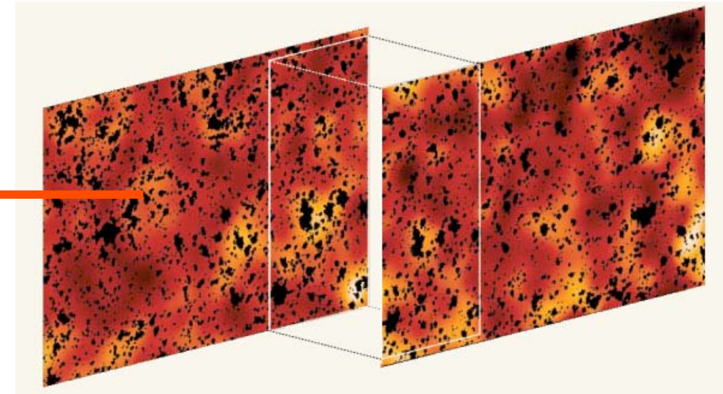
From : “Trouble at first light” P. Madau 2006, Nature 440, 1002 (April 20)

Stecker, Malkan, Scully 2006, ApJ 648, 774

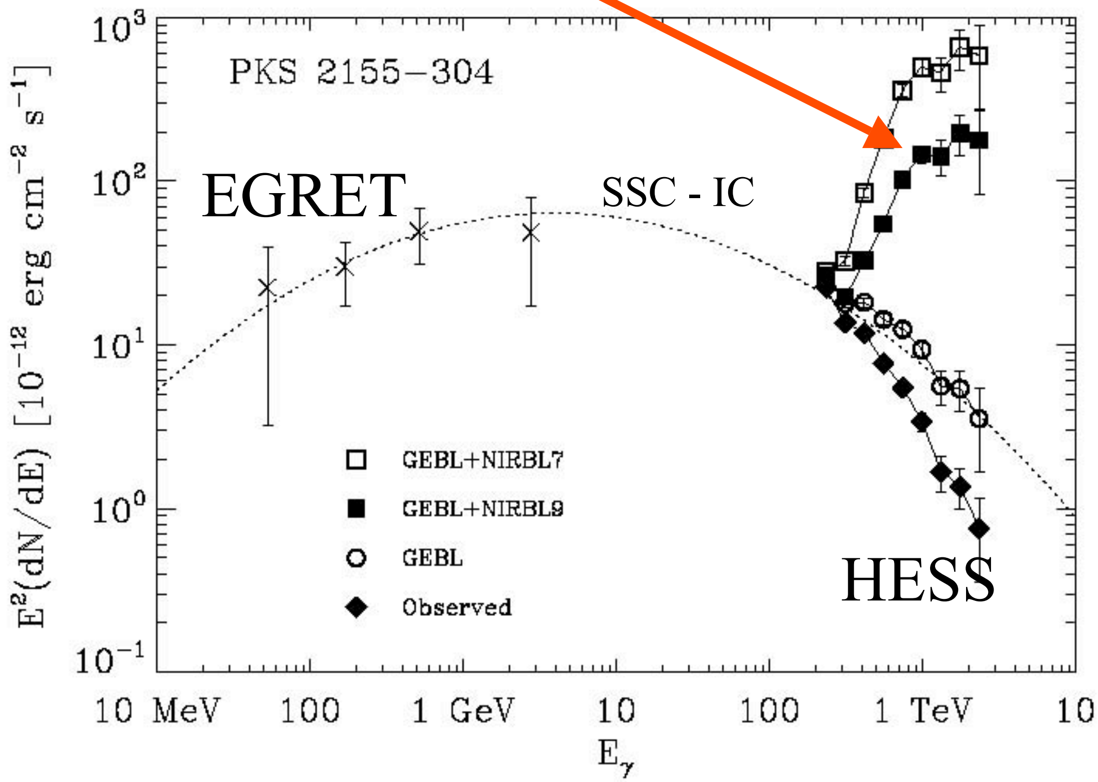


⇒ A simple analytic fit: Stecker & Scully 2006, ApJ 652, L9

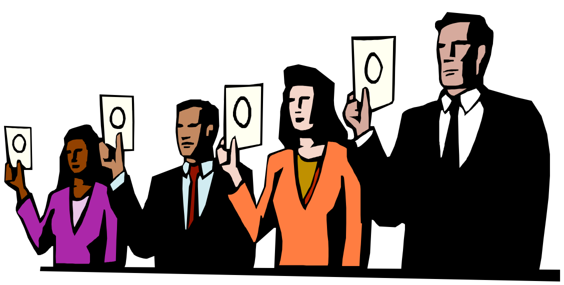




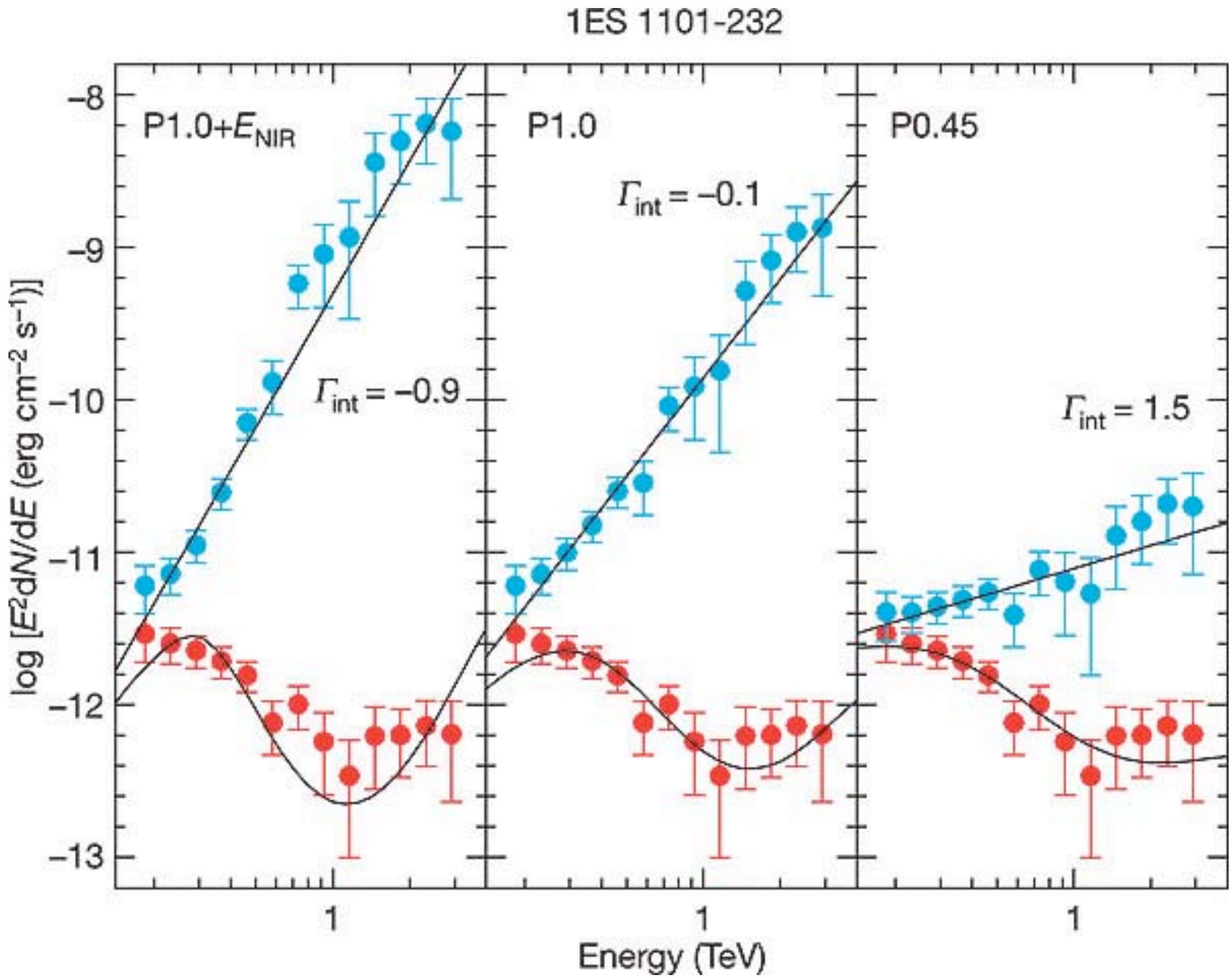
Pop III?



Dwek, Krennrich, & Arendt 2005, ApJ 634, 155

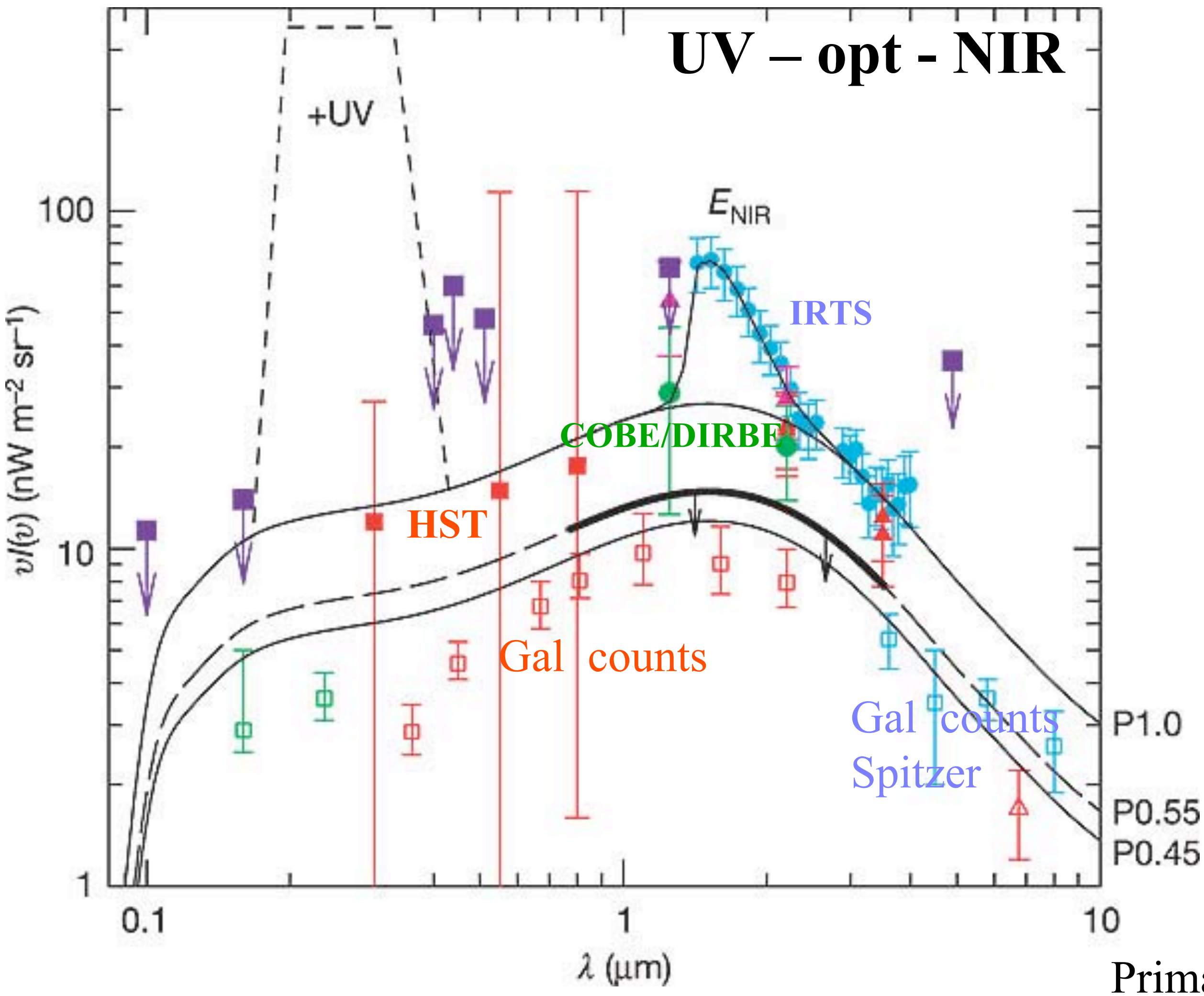


z = 0.186



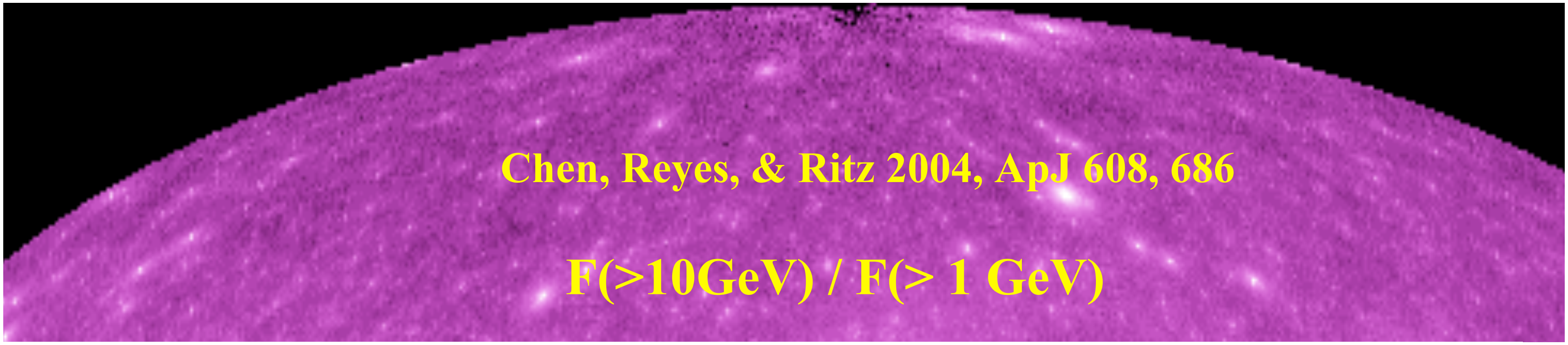
From : “A low level…” F. Aharonian et a. 2006, Nature 440, 1018 (April 20)

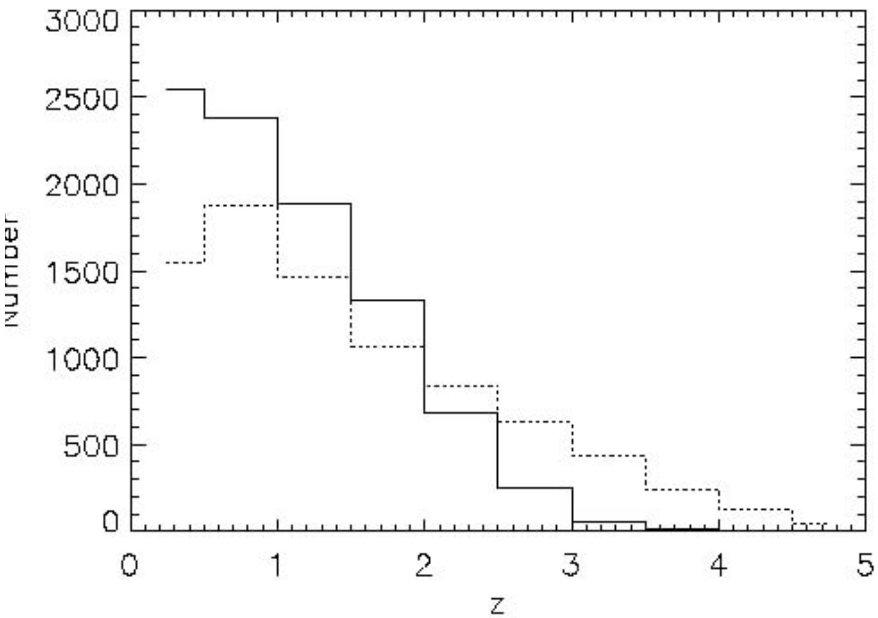
F. Aharonian et a. 2006, Nature 440, 1018 (April 20)

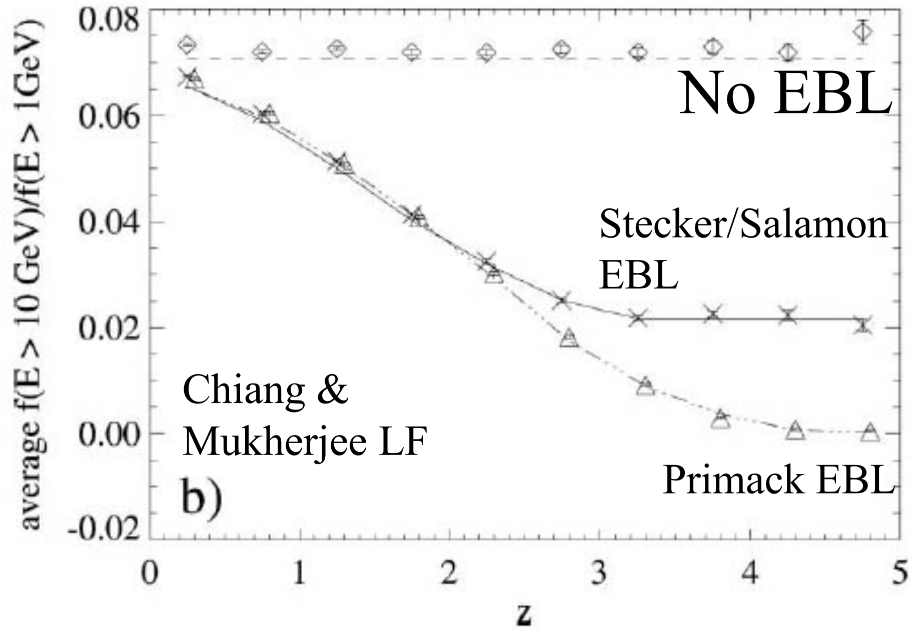


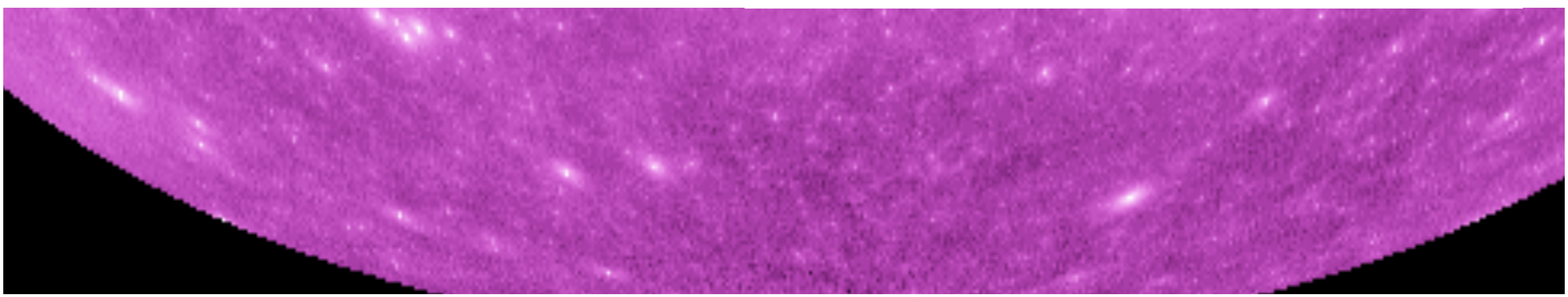
Primack

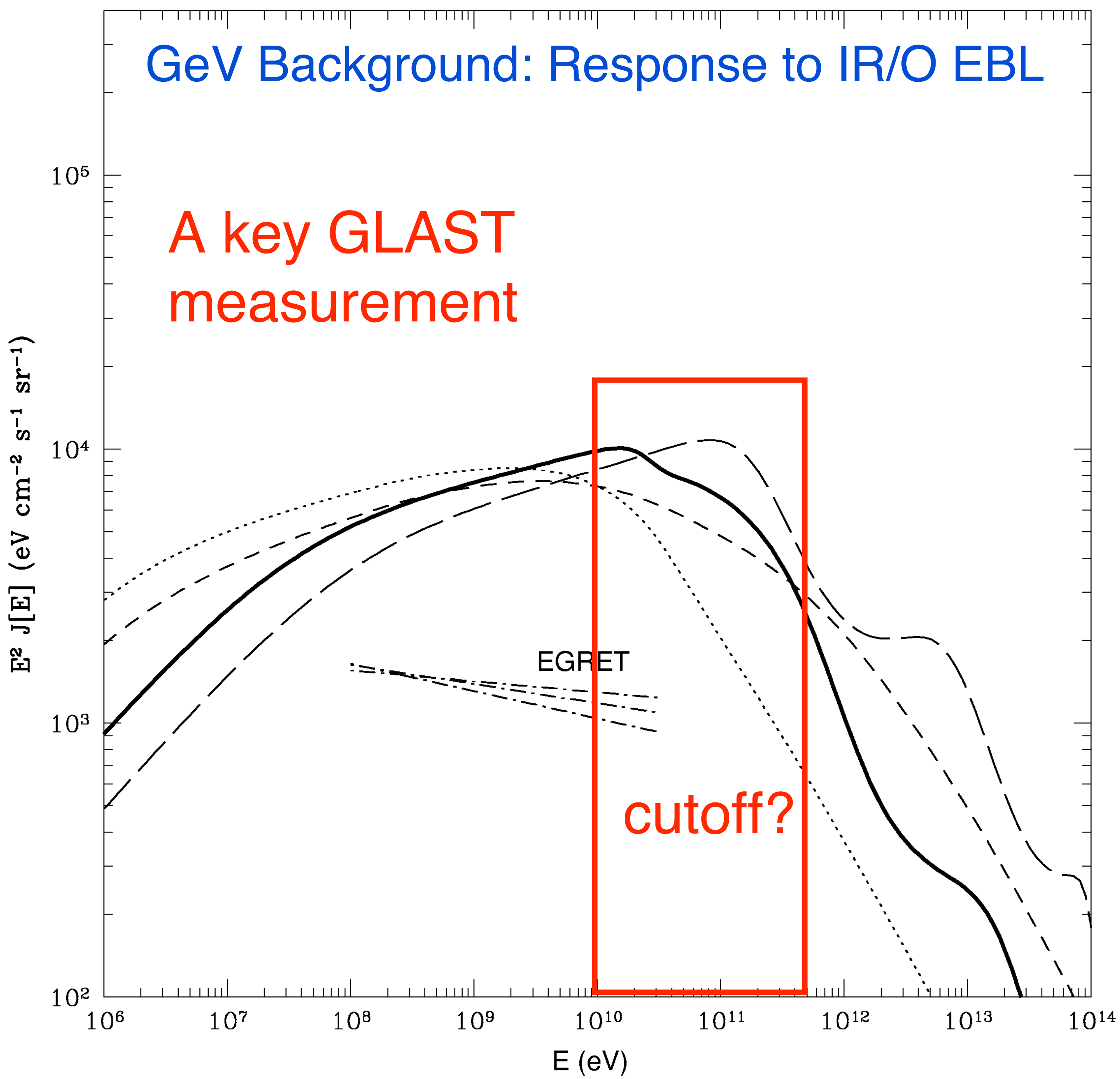

The GLAST is more than half full!
Mrk 421 (0.031)
Mrk 501 (0.034)
Mrk 180 (0.045)
PKS 2005-489 (0.071)
PKS 2155-304 (0.117)
H2356-309 (0.165)
1ES 1218+30 (0.182)
1ES 1101-232 (0.186)
PG 1553+113 (0.36)
GLAST (GeV)
Many sources
(Population studies &
source physics)
Detected to high z
Evolution of the EBL
Ground (TeV)
Few sources
Detected to "small" z
Local EBL


Chen, Reyes, & Ritz 2004, ApJ 608, 686
F(>10GeV) / F(> 1 GeV)


Number
z


average f(E > 10 GeV)/f(E > 1GeV)
z
No EBL
Stecker/Salamon
EBL
Chiang &
Mukherjee LF
b)
Primack EBL




GeV Background: Response to IR/O EBL
A key GLAST measurement
cutoff?
EGRET
E² J[E] (eV cm⁻² s⁻¹ sr⁻¹)
E (eV)
10²
10³
10⁴
10⁵
10⁶
10⁷
10⁸
10⁹
10¹⁰
10¹¹
10¹²
10¹³
10¹⁴

Coppi

Summary:

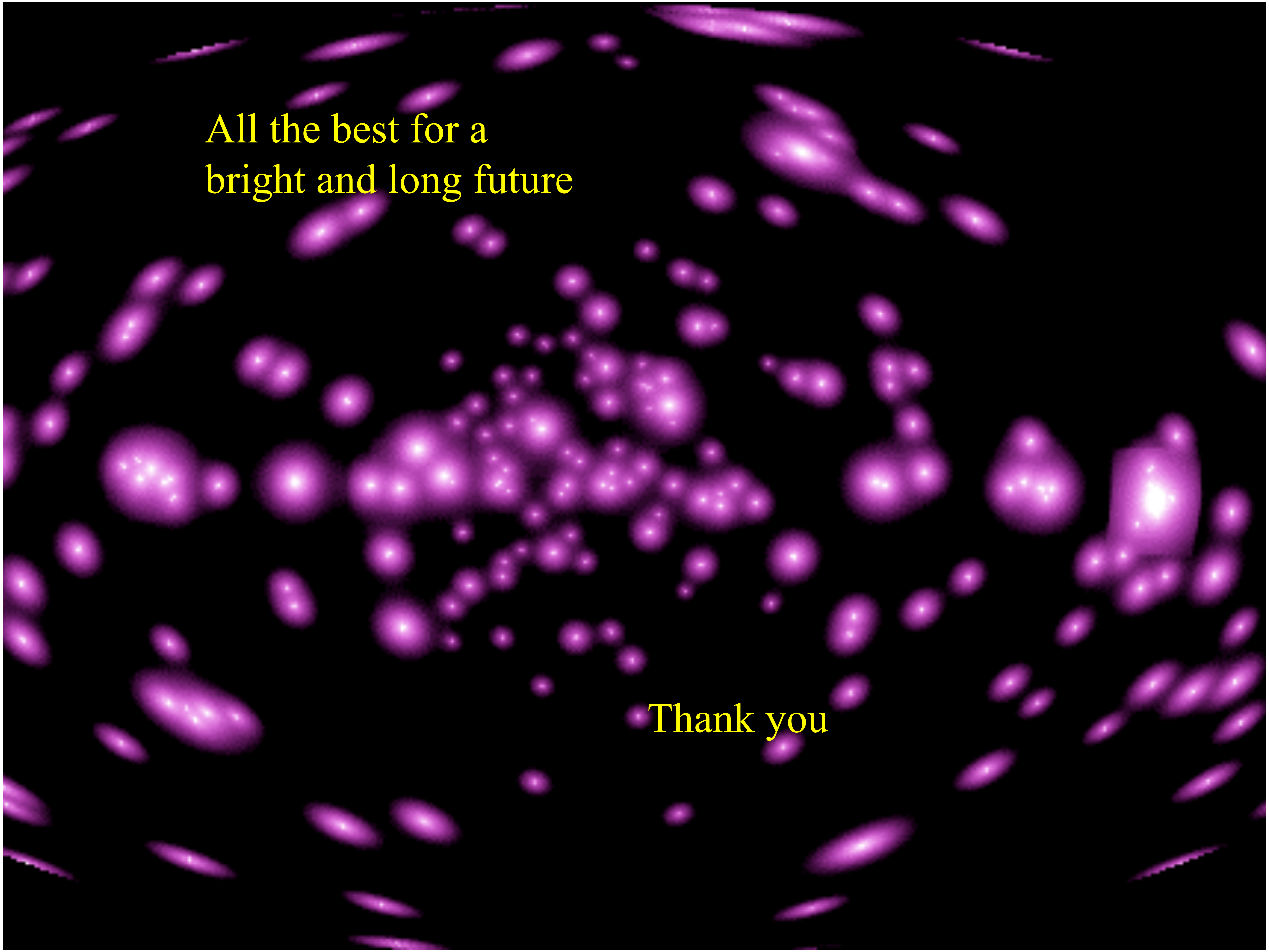
*G*amma-ray absorption in many distant sources (GRBs and blazars) probe UVOIR EBL evolution: probe of cosmic light production history.

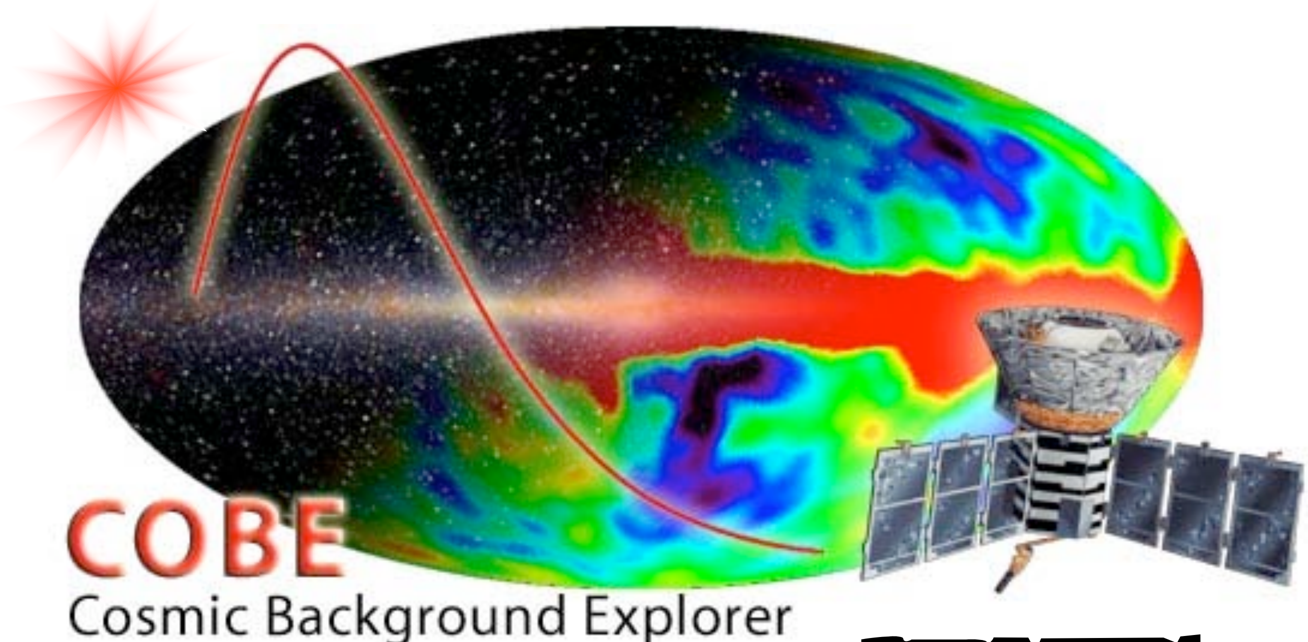
*M*easuring absorption is messy business. We need to know intrinsic source spectrum. We don't have good "spectral standard" yet. Don't assume power law spectra!!! GLAST may establish it.

GLAST and new Cherenkov telescopes increase source population: Luminosity function from a ~thousand points of light, evolution, variability, … source physics. Resolve the CGB in the GeV regime.

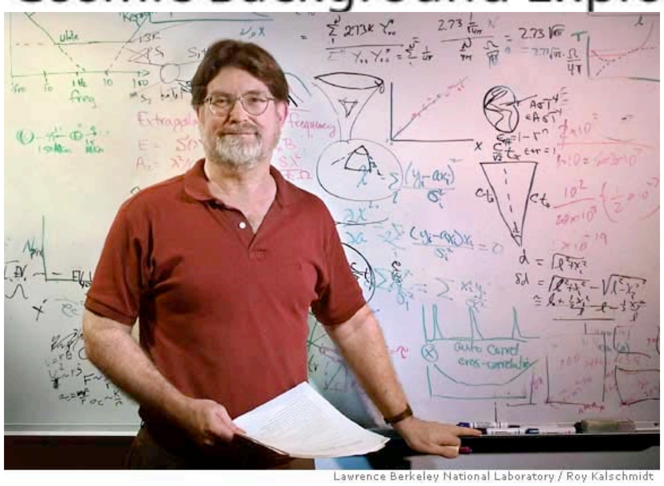
CGB Shape in 50 GeV – 1TeV (GLAST) range crucial, as it reflects the redshift distribution of the contributing sources. If no cutoff seen, we're not measuring *extragalactic* background, or something is wrong with our physics.

GLAST/GBM will advance the era of gamma-ray cosmology.


All the best for a
bright and long future
Thank you

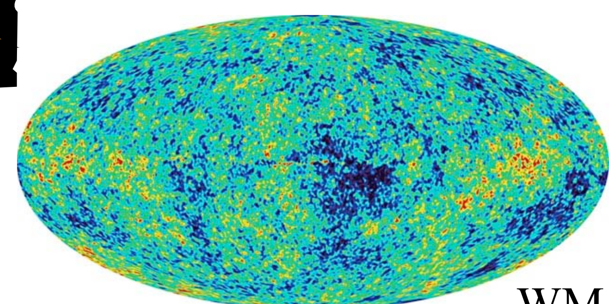


John Mather (GSFC)



George Smoot (UCB)

H_0, Ω_i, $w(z)$



WMAP

Precision & Concordance Cosmology: $h = 0.7$, $\Omega_m = 0.25$, $\Omega_b = 0.04$, $\Omega_\Lambda = 0.75$

Most distant quasars:

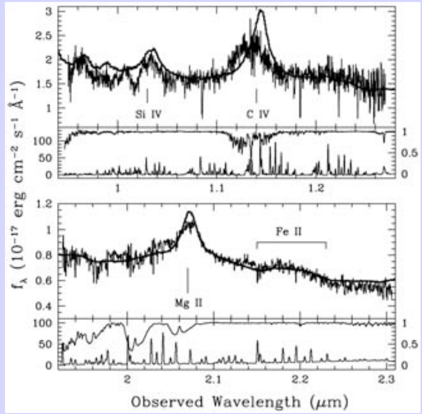
SDSS J1148+5251

z = 6.4,

$M_{SMBH} \sim 4\ 10^9\ M_o$

Growth from seed at

z ~ 20 at Eddington rate



Massive Poststarburst Galaxy:

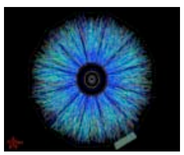
HUDF-JD2

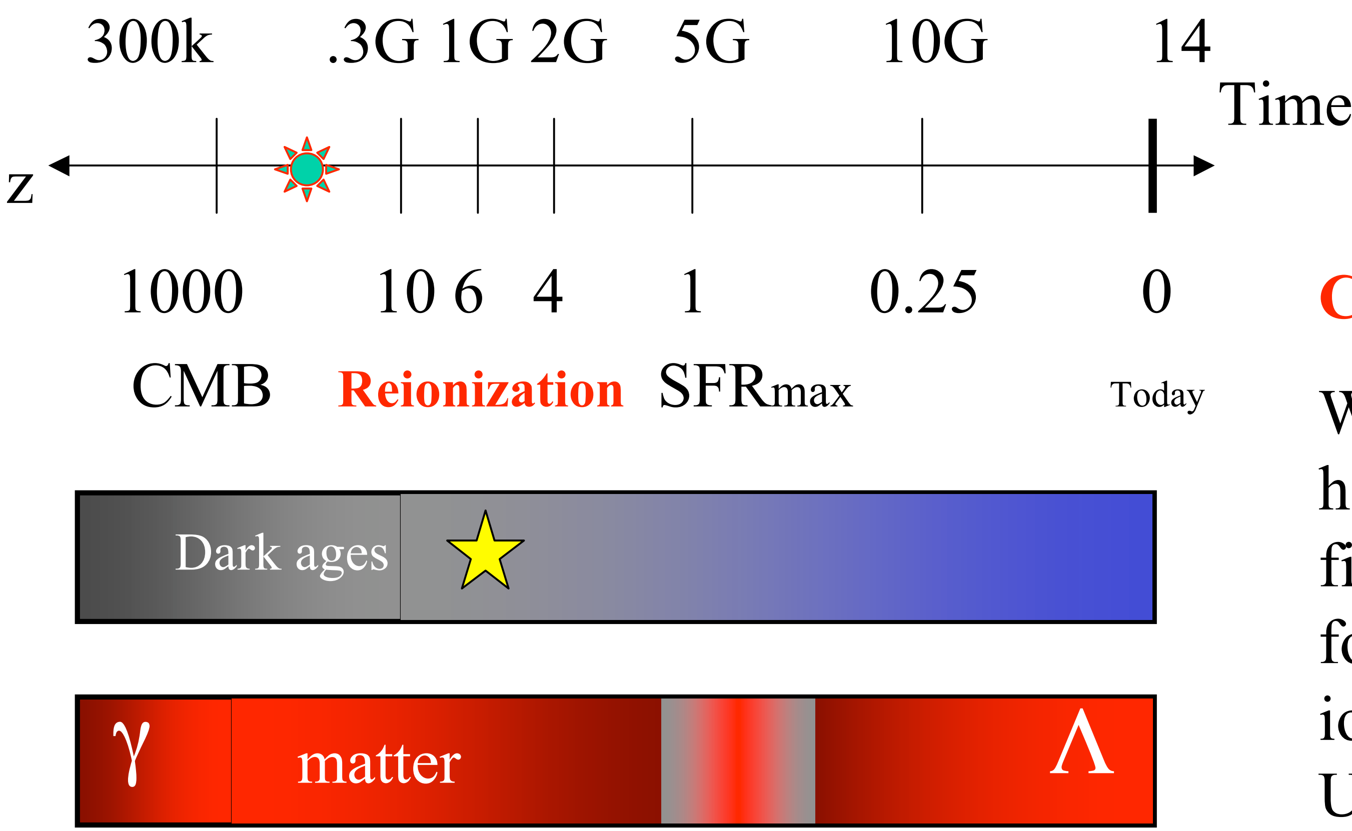
Mobasher et al. 2005, ApJ 635, 832

Perhaps z ~ 6.5 (from SED features),

Stellar Mass: $M_* \sim 6\ 10^{11}\ M_o$

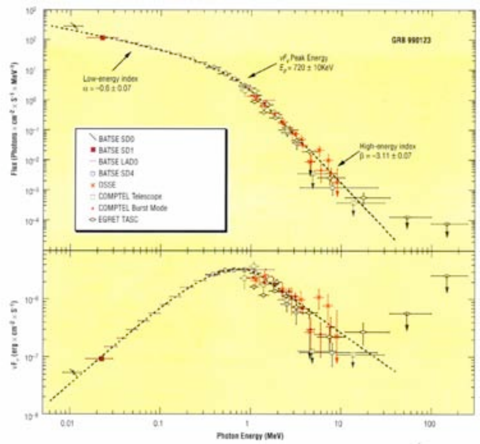
From a star burst 10^8 yrs earlier at z > 9

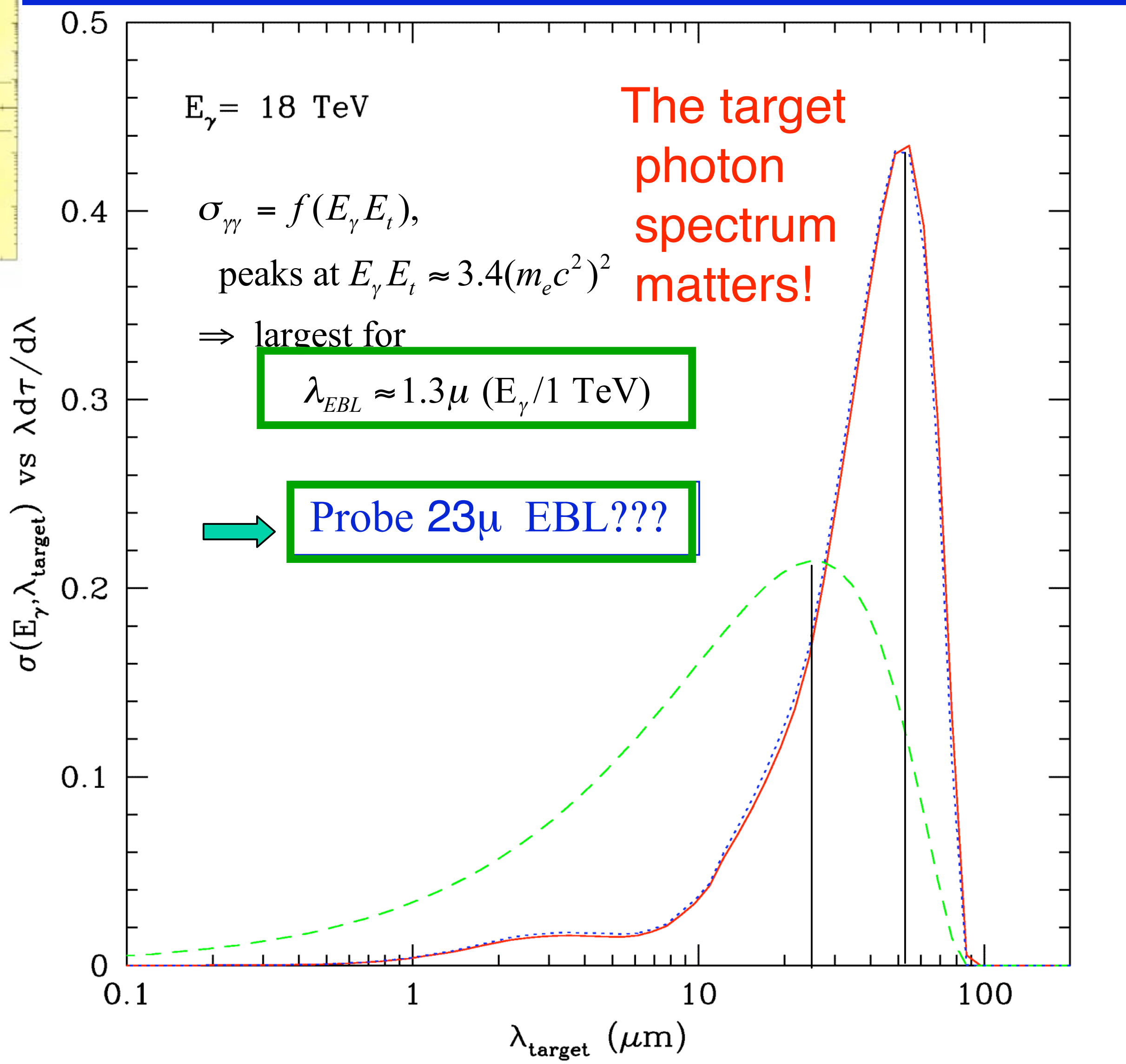




Challenge:

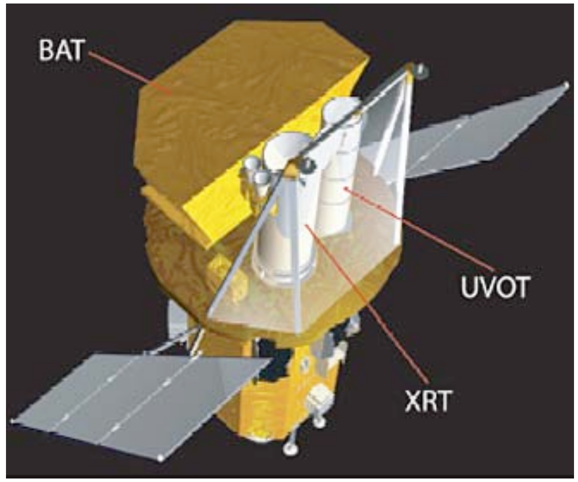
When and how did the first stars/BHs form and re-ionize the Universe?

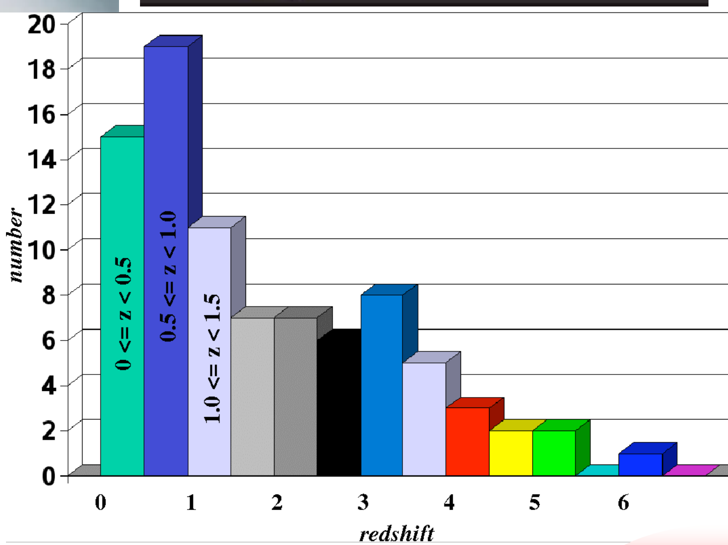


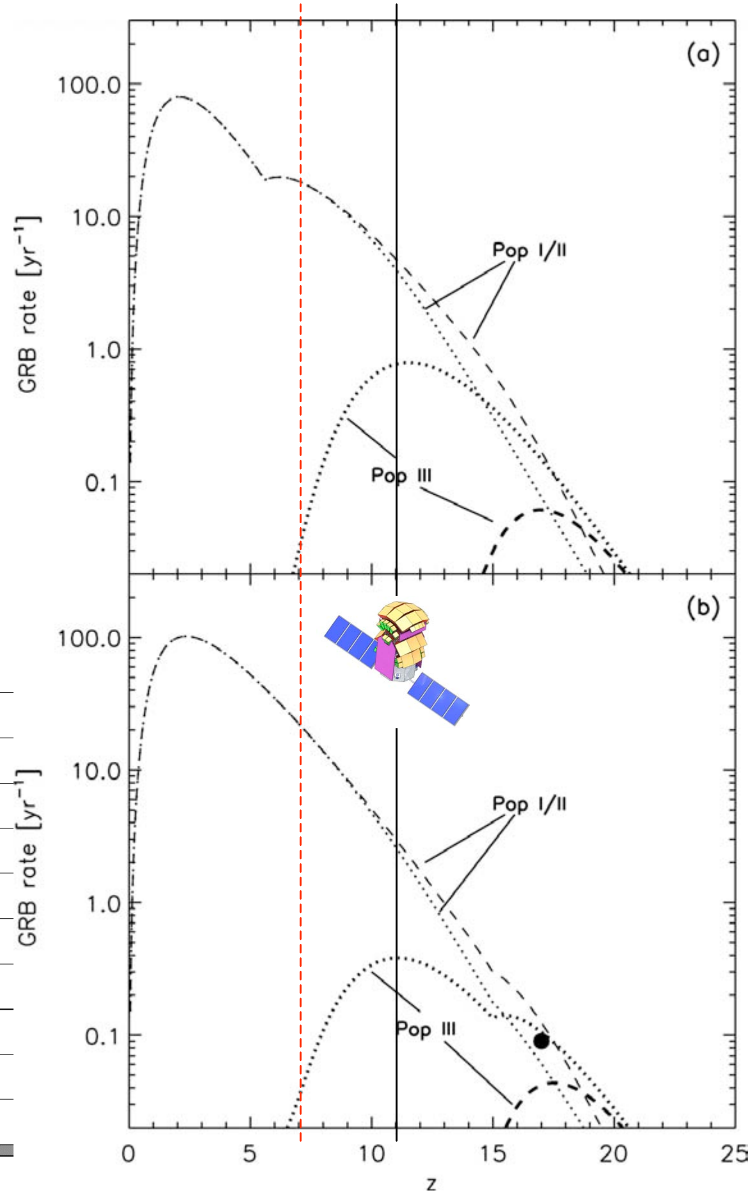


Optical depth at ~20 TeV actually very sensitive to 60 micron flux…
(Finkbeiner et al. “detection” of 60 micron EBL a big problem.)

Swift: Nov 20, 2004

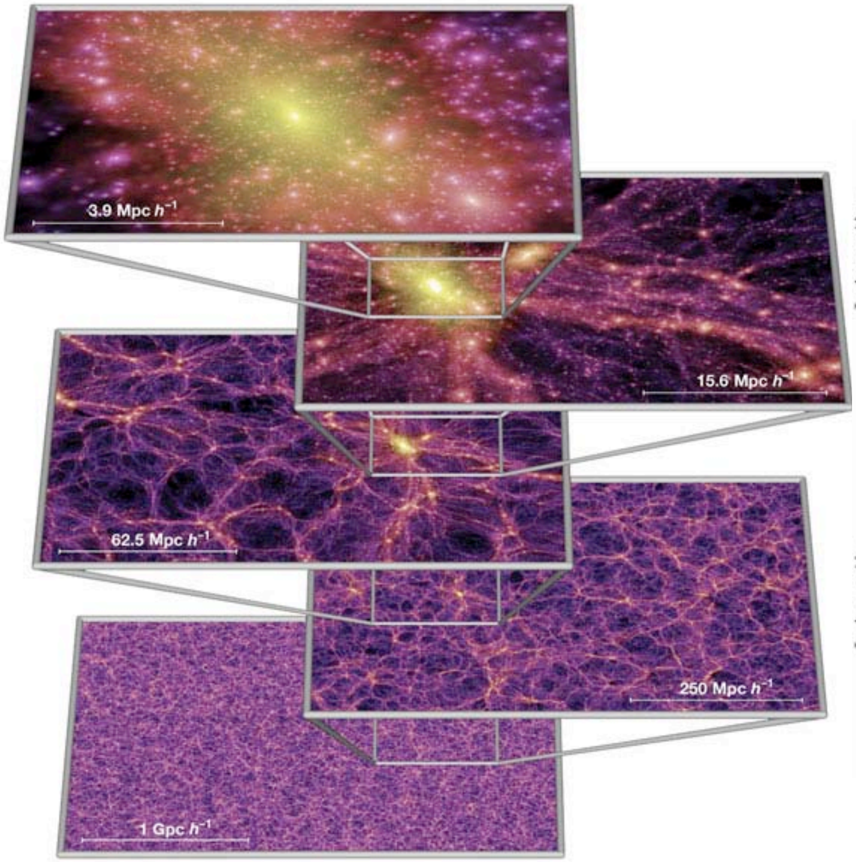


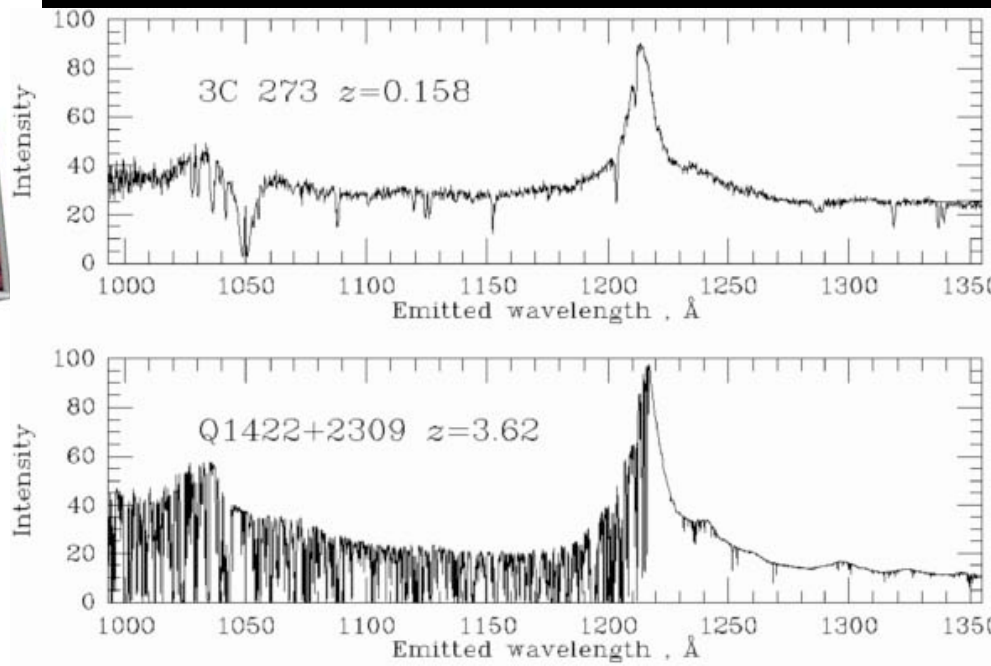


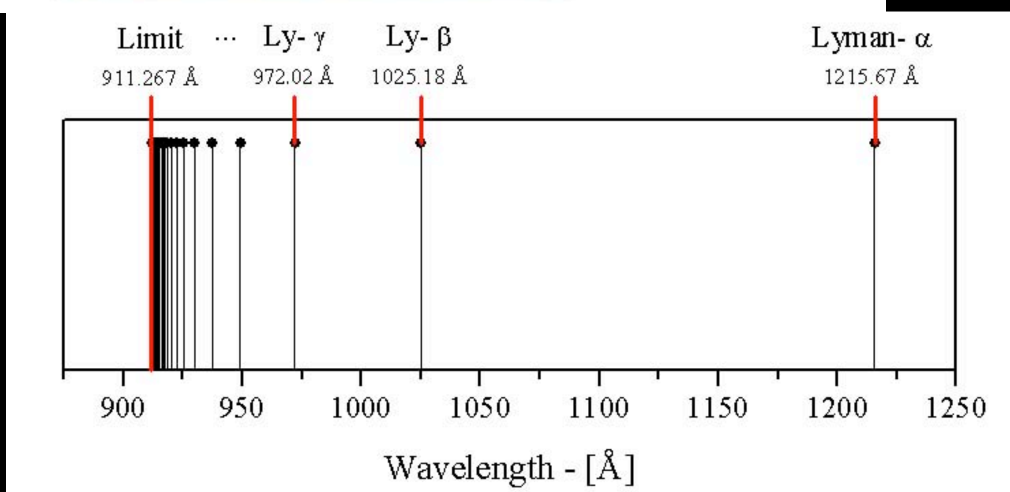


70% at z > 2

5% at z > 7







probing the cosmic web

The EBL in the 0.1 – 1000 μm range

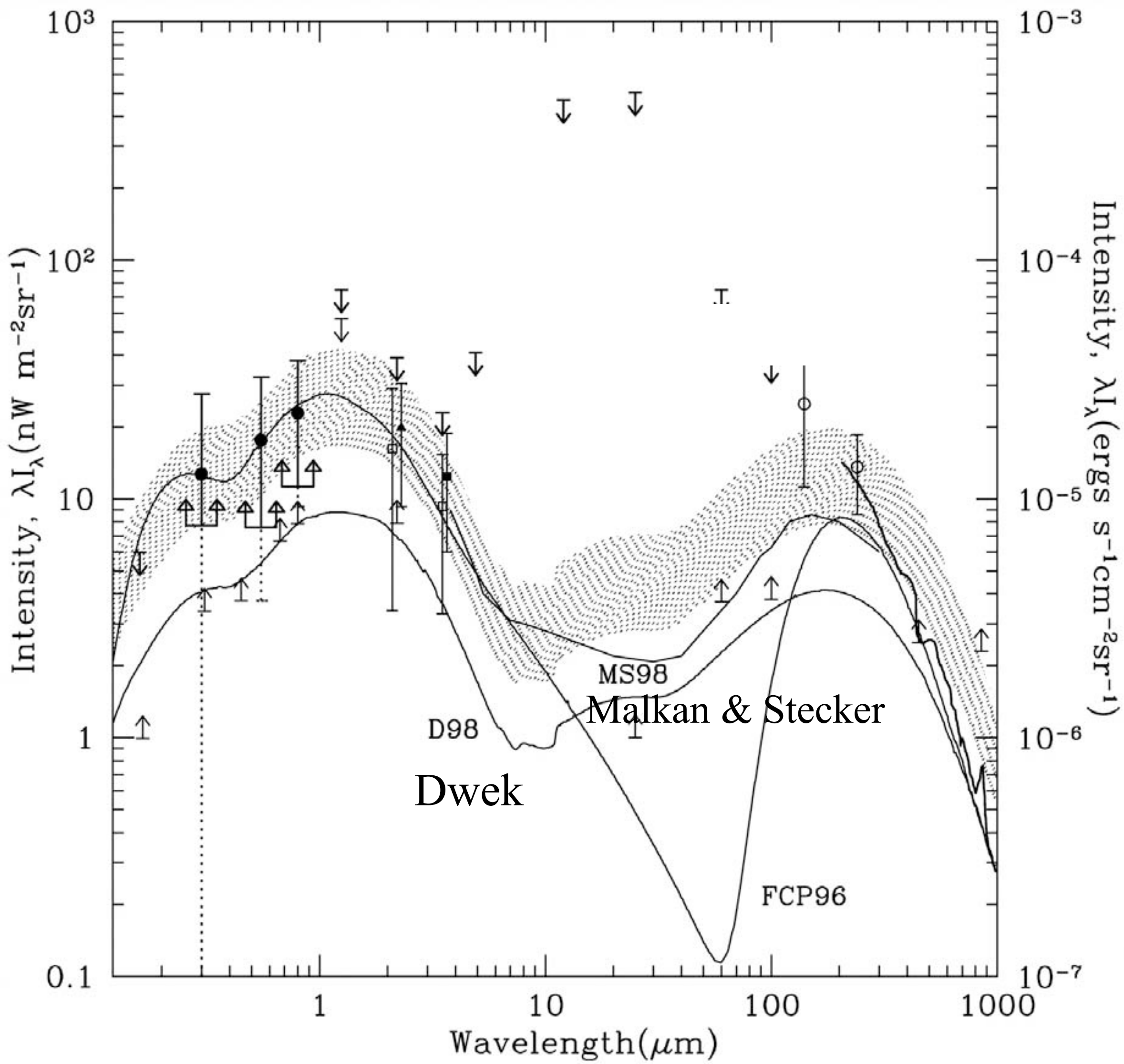
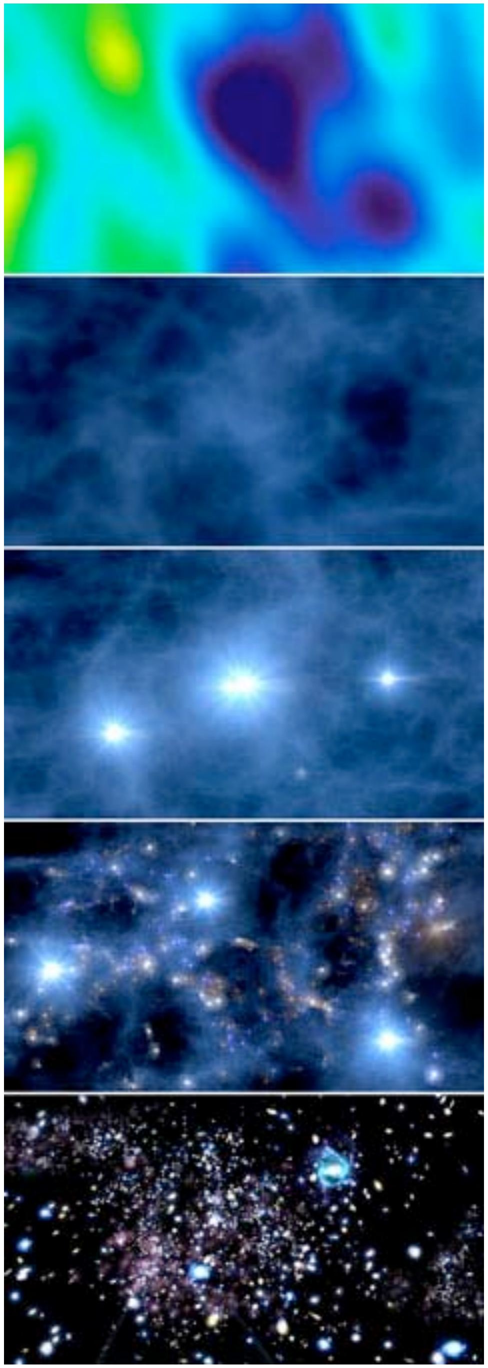
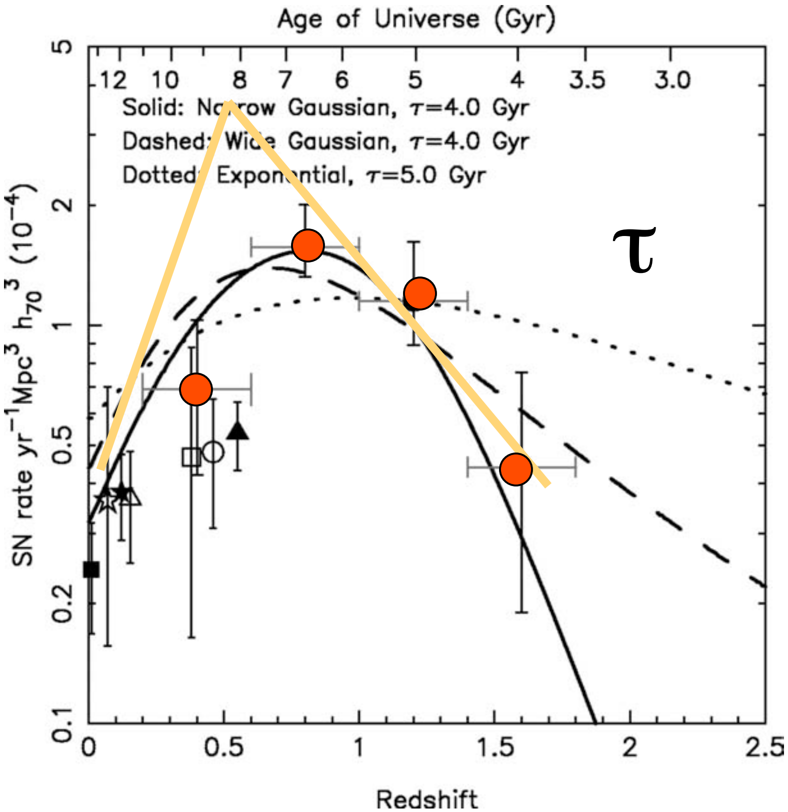


Fig 19 from Bernstein et al. 2002 III



The γ-ray Background

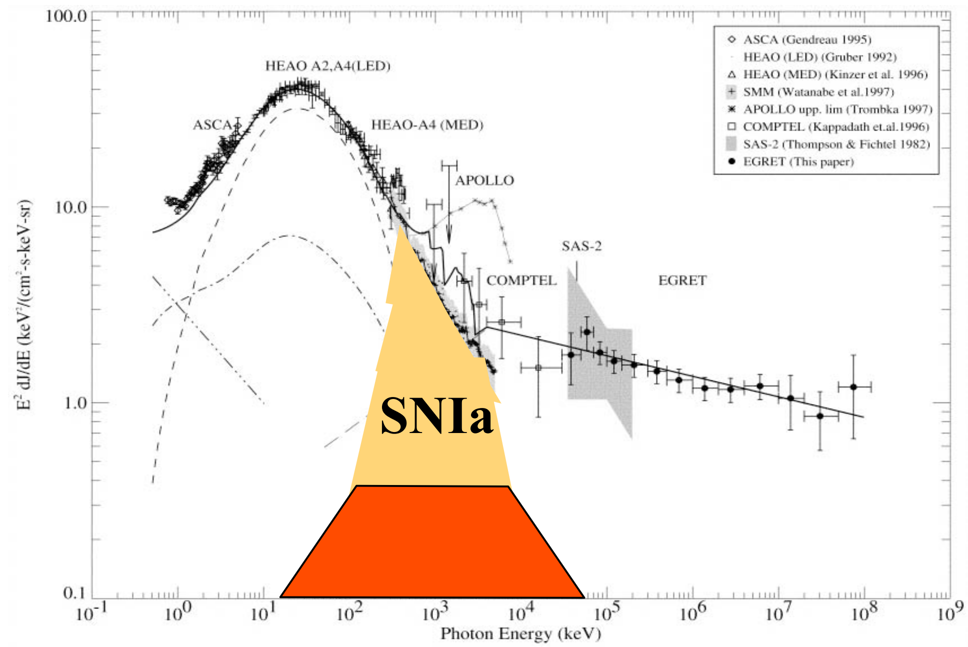


Dahlen et al. 2004, ApJ 613, 189
ACS/HST-HDF/CDF: GOODS
17 ccSNe – 25 SNIa
Ahn, et al. 2005, astro-ph/0506126
10% of COMPTEL flux

- **Low-z SNe dominate**
- **τ ~ 2-4 Gyrs**

Belczynski, Bulik, Ruiter 2005 → double degenerates

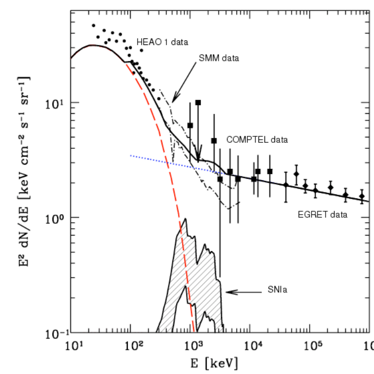
CGB (^{56}Co): Clayton & Silk 1969, ApJ 148, L43



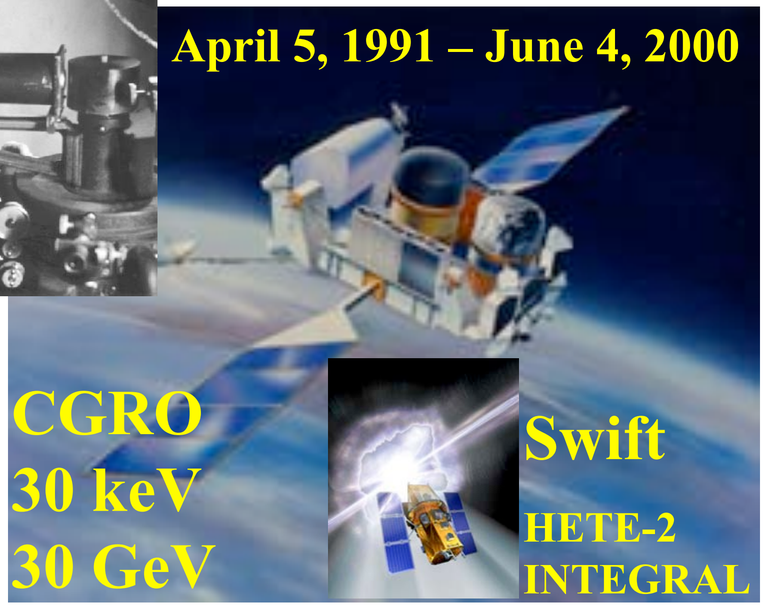
Watanabe, Hartmann, Leising, The 1999, ApJ 516, 285

100% of SMM flux possible

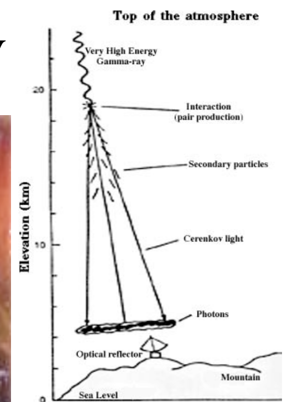
Strigari, Beacom,Walker, Zhang
2004, JCAP 0504, 017



MeV Blazars
Light DM

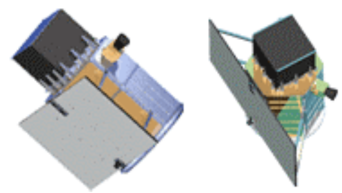


10 keV – 300 GeV

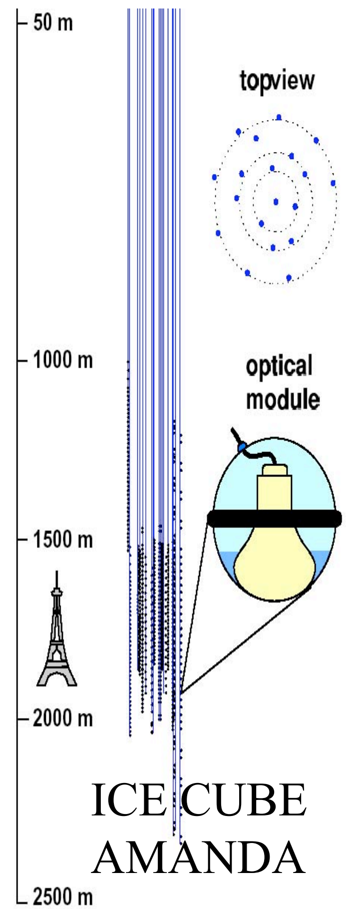


Neutrinos

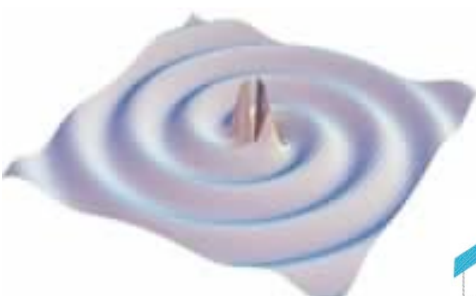
AGILE

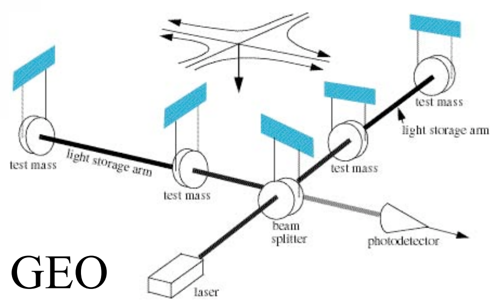


TeV…..



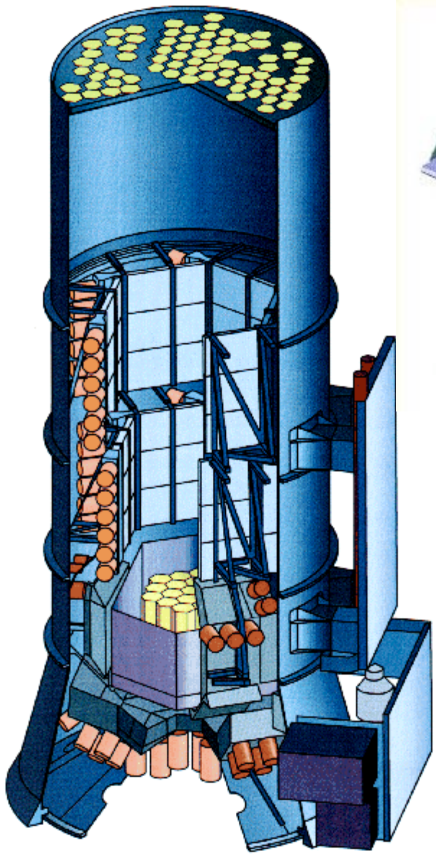
ICE CUBE
AMANDA



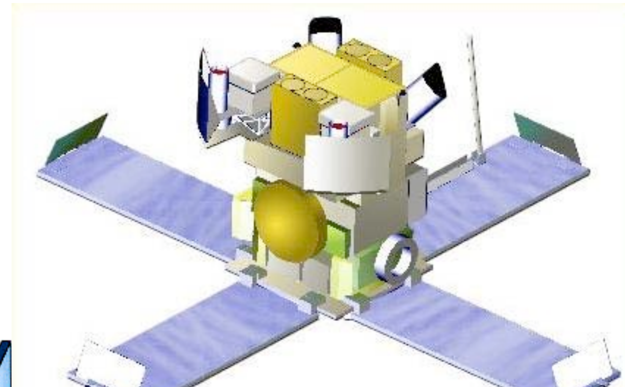


Gravity waves:

LISA, LIGO, VIRGO, GEO

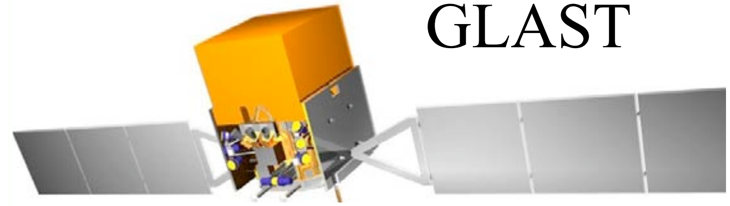


INTEGRAL

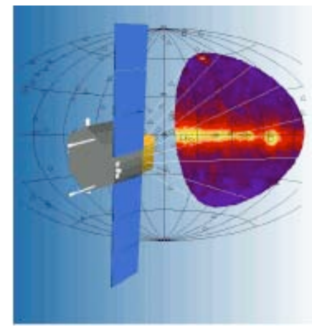


HETE II

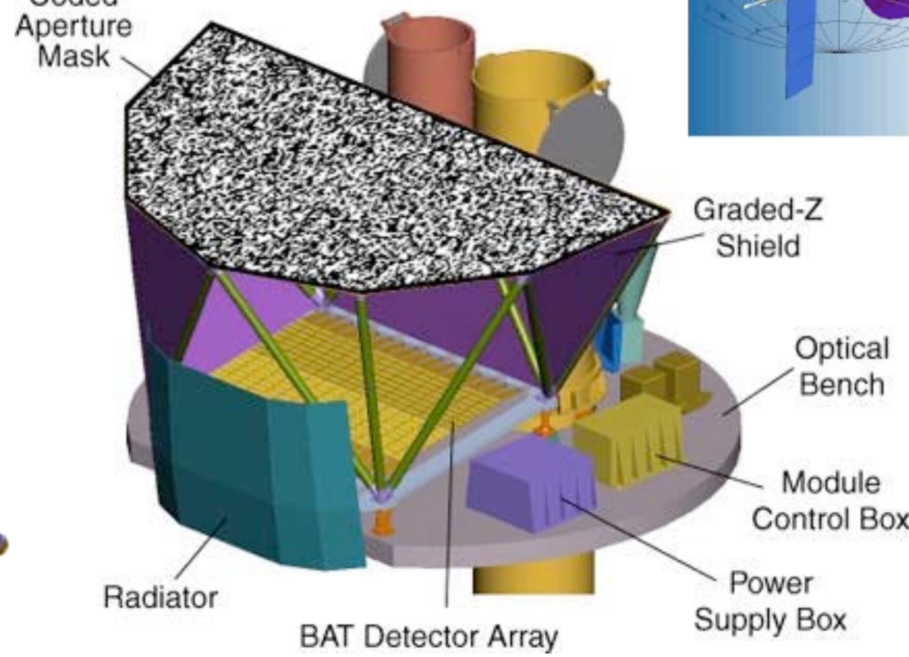
GLAST



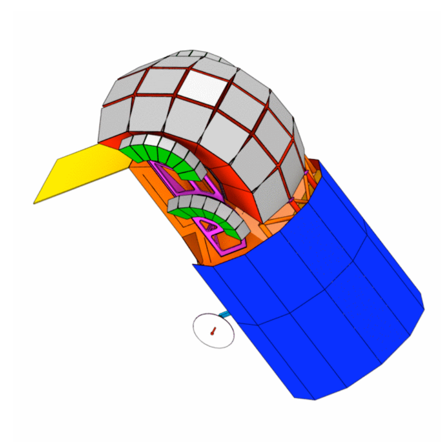
AGILE



SWIFT



EXIST



RHESSI