EXTREME BLAZARS AND THE EXTRAGALACTIC BACKGROUND LIGHT

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- The EBL at long (IR) wavelengths: scientific motivation
- The IR EBL and the cosmic γ-γ opacity
- Prospects for Extreme Blazar (& other) observations

THE EXTREME BLAZAR CONFERENCE – PADOVA 2019

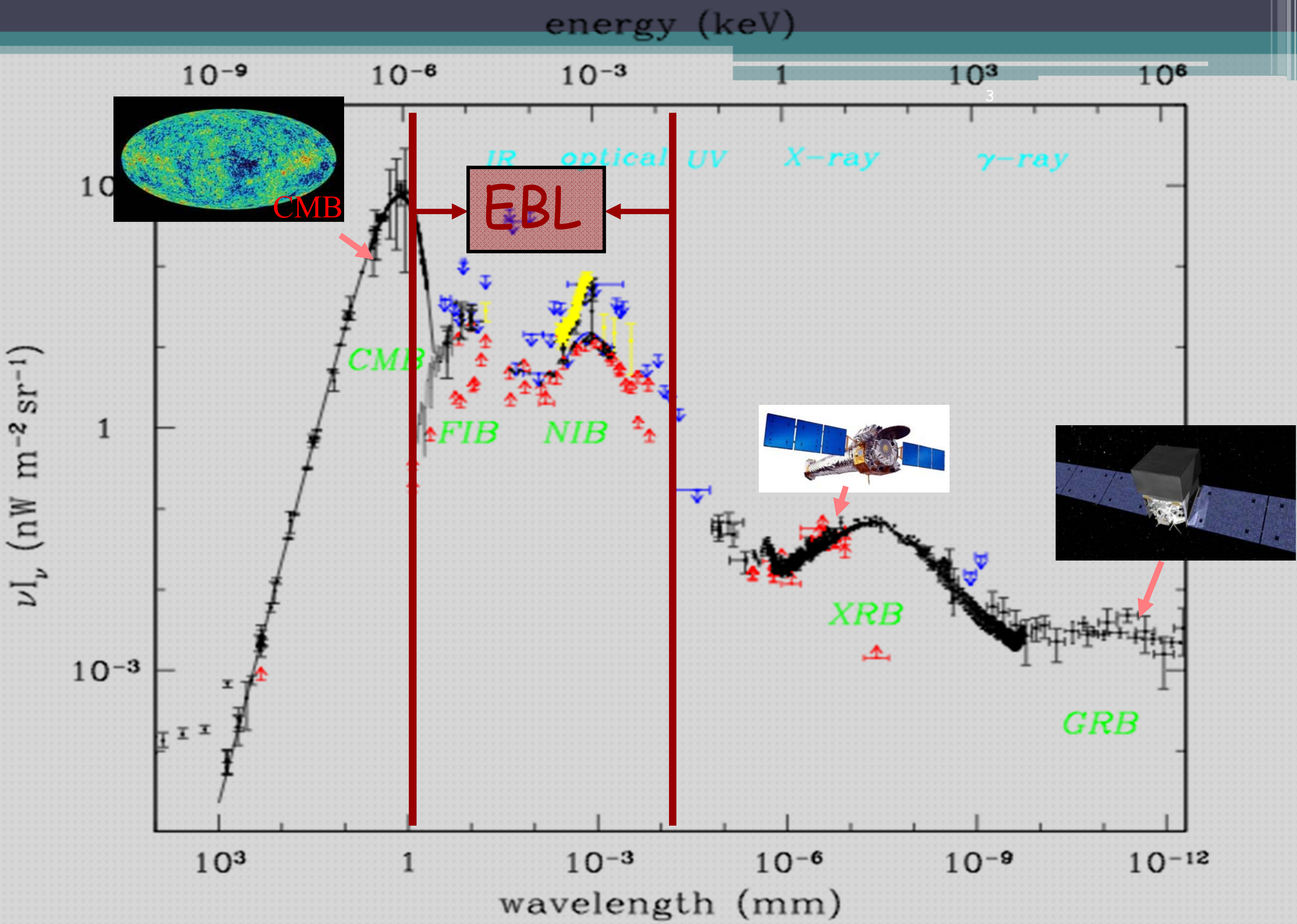
The Extragalactic Background Light

- Background radiations concern the whole history of astrophysical sources,
- They are the repository of all radiant energy produced by cosmic sources and cosmic structures since the Big Bang
- -- Point sources
- -- Diffuse structures and components
- Essential data to understand how the Universe has taken shape and evolved.
- Three main physical processes for generating energy (and light):

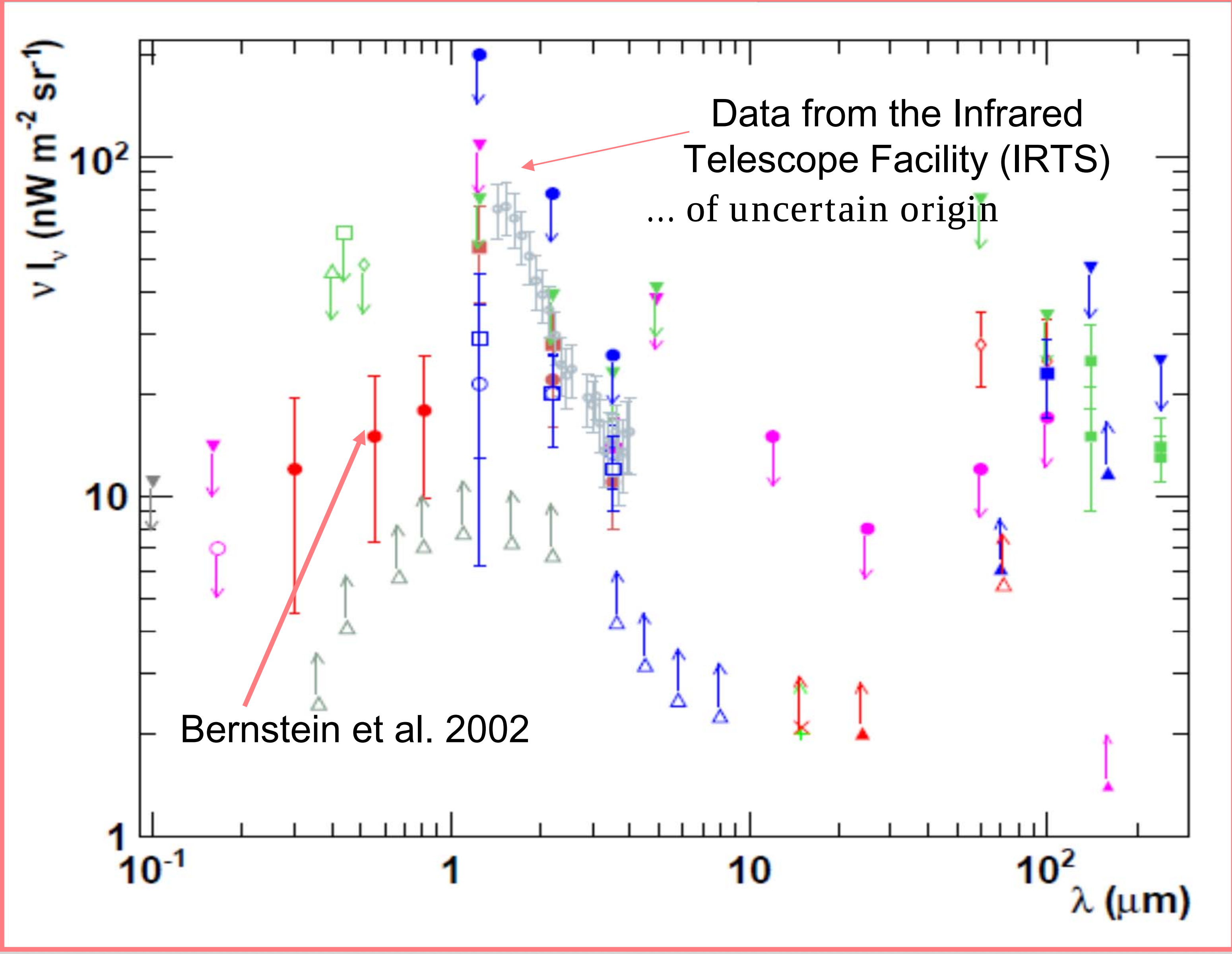
  -- Thermonuclear reactions (in stars)

  -- Gravitational accretion (in galaxy nuclei – Active Galactic Nuclei)

  -- Decaying particles (generated in the early phases of cosmic expansion - still speculative)

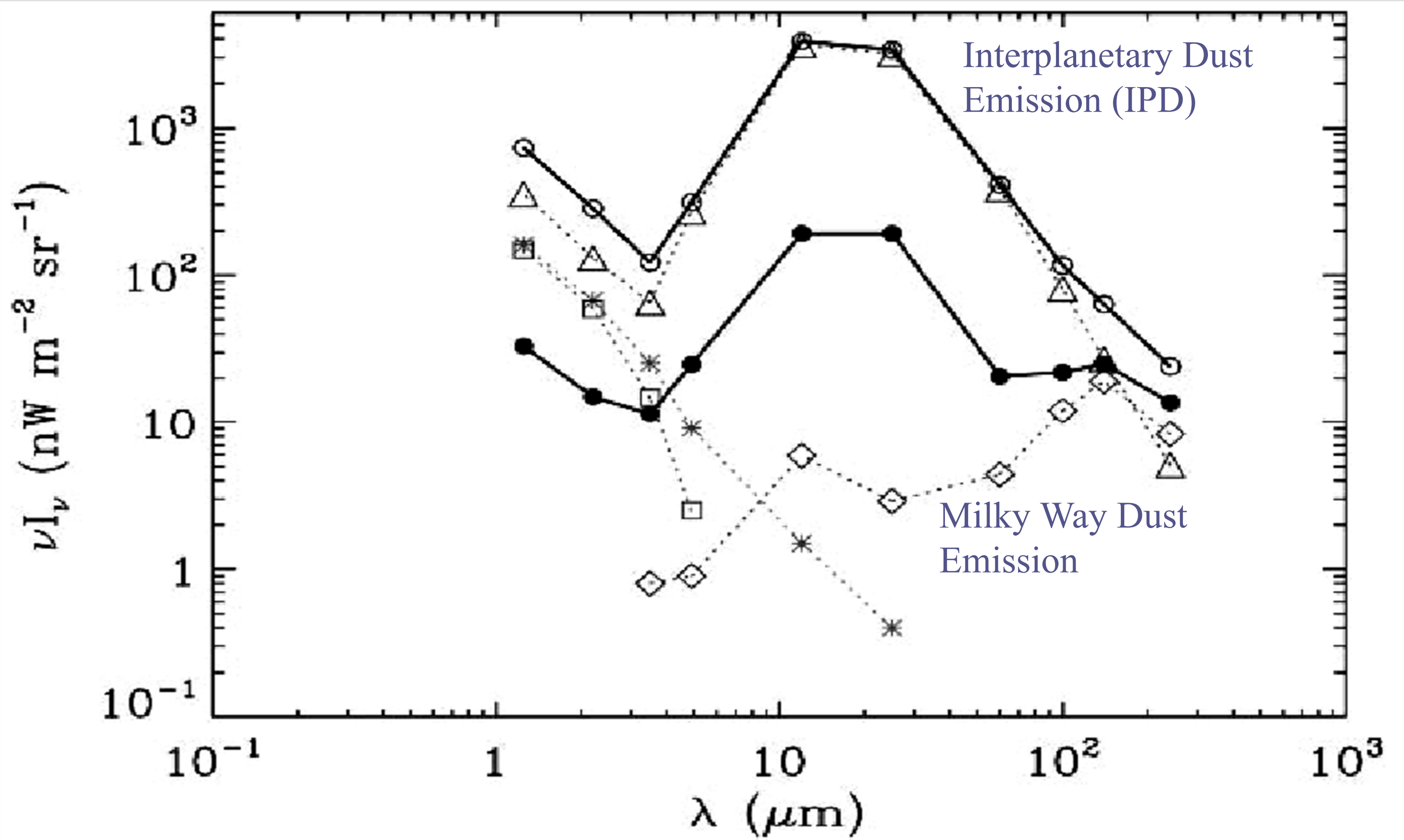


The Global Background Radiation & the EBL



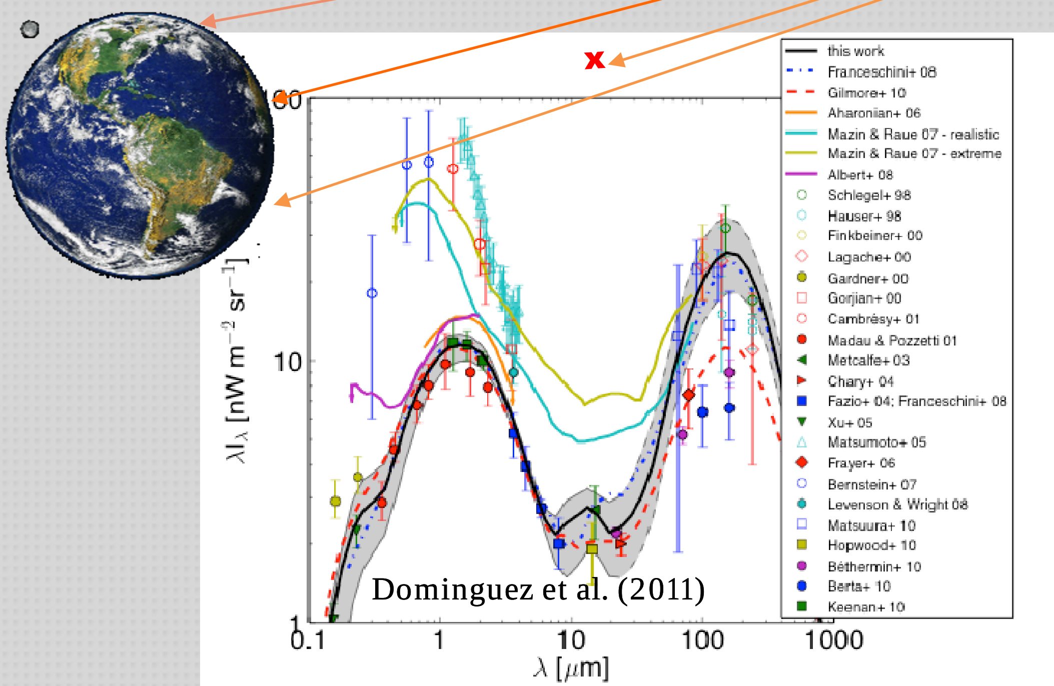
Mazin & Raue (2007)

EBL direct measurement: hard challenge



Foreground contributions in the Lockman Hole area: observed sky brightness (*open circles*), interplanetary dust (*triangles*), bright Galactic sources (*squares*), faint Galactic sources (*asterisks*), and the interstellar medium (*diamonds*). (*Solid circles*): the residuals after removing all foregrounds. (Hauser & Dwek ARAA '98)

CONSTRAINING THE EXTRAGALACTIC BACKGROUND LIGHT (AND TESTING MODELS OF) FROM VHE OBSERVATIONS (WITH CONSEQUENCES FOR PHYSICS AND COSMOLOGY)



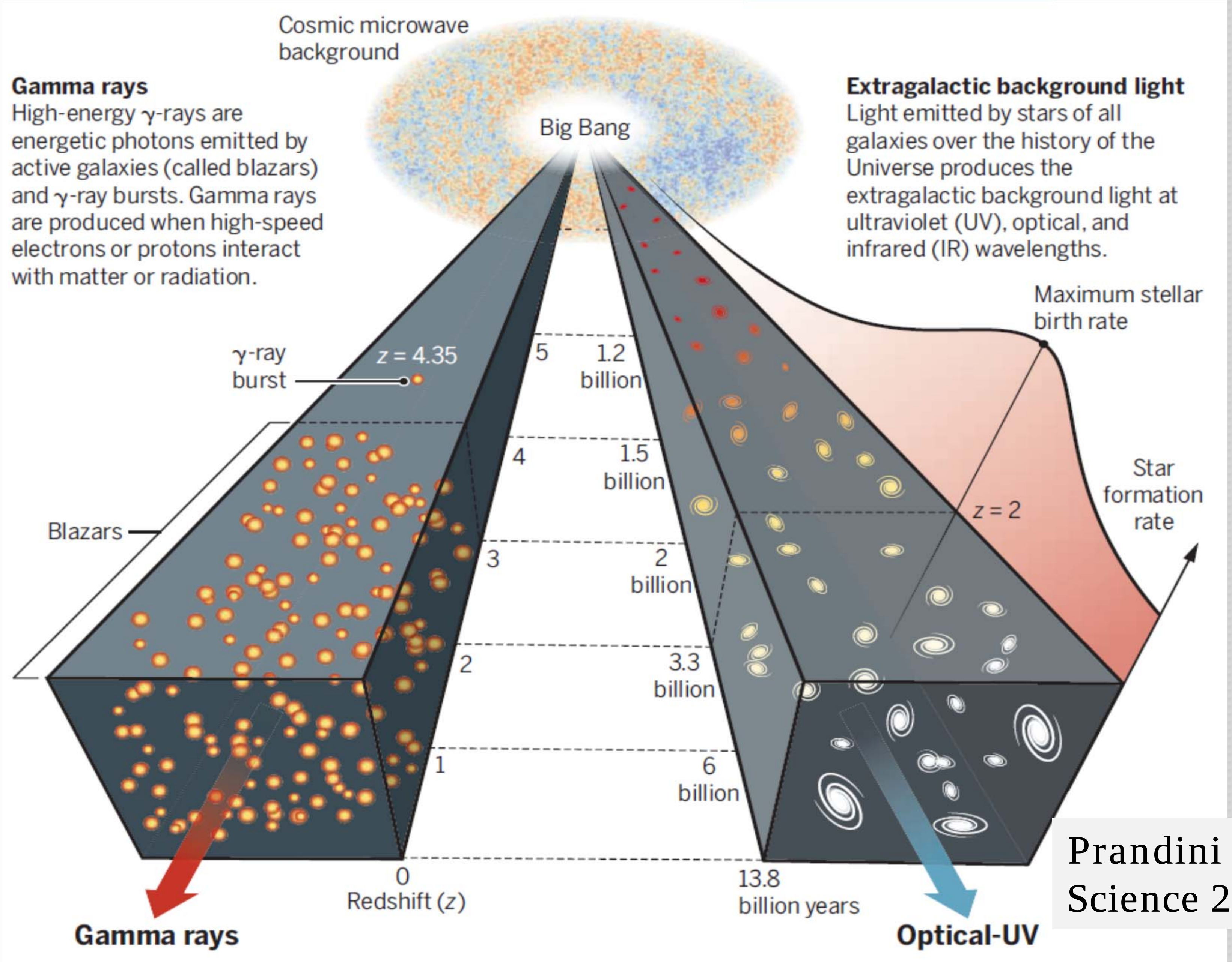
VHE photon + diffuse light → electron-positron pair production

$$\gamma_{VHE}\gamma_{EBL} \rightarrow e^+e^-$$

Absorption:

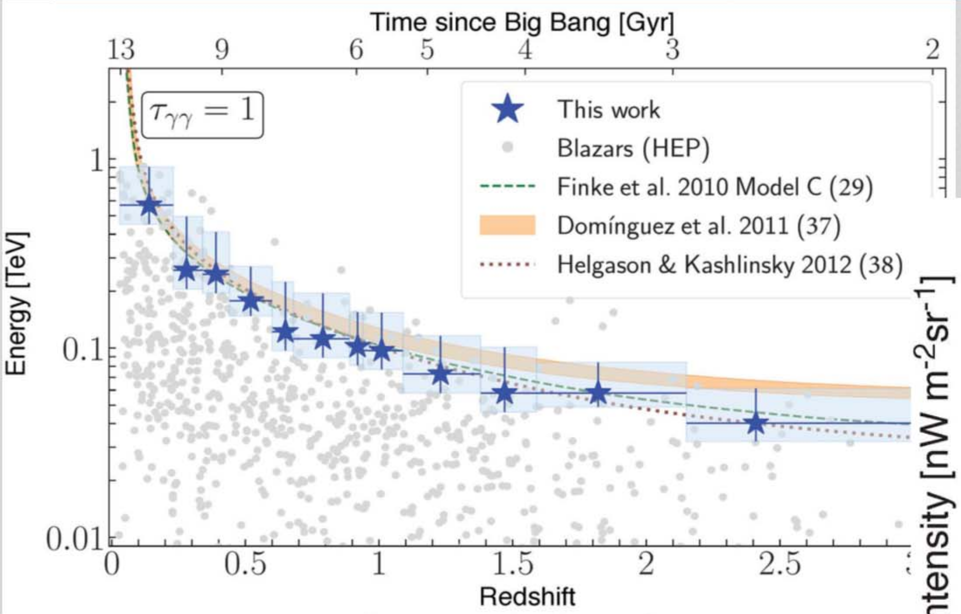
$$dF/dE_{OBS} = (dF/dE_{EM})\, e^{-\tau}$$

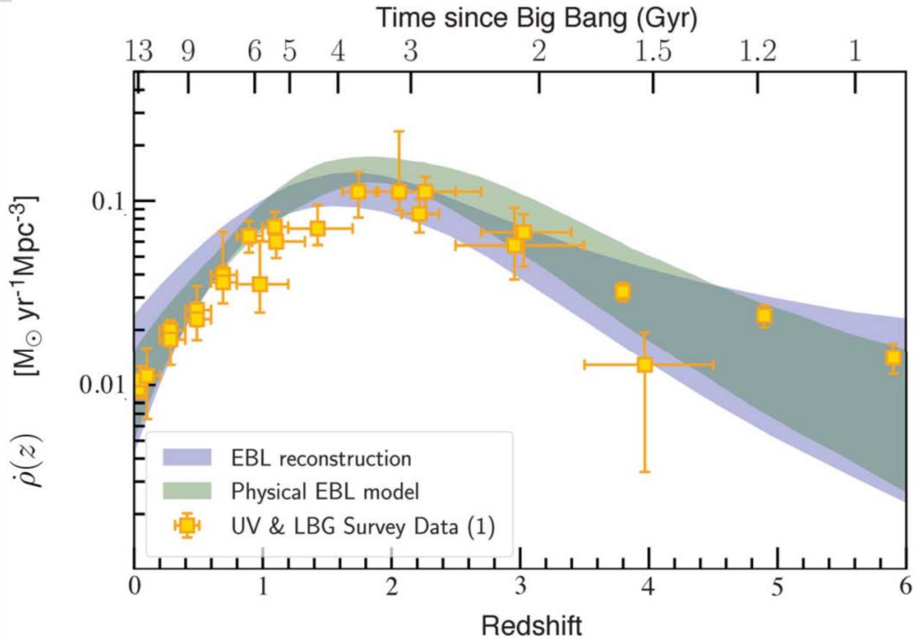
The Star Formation History from optical-UV

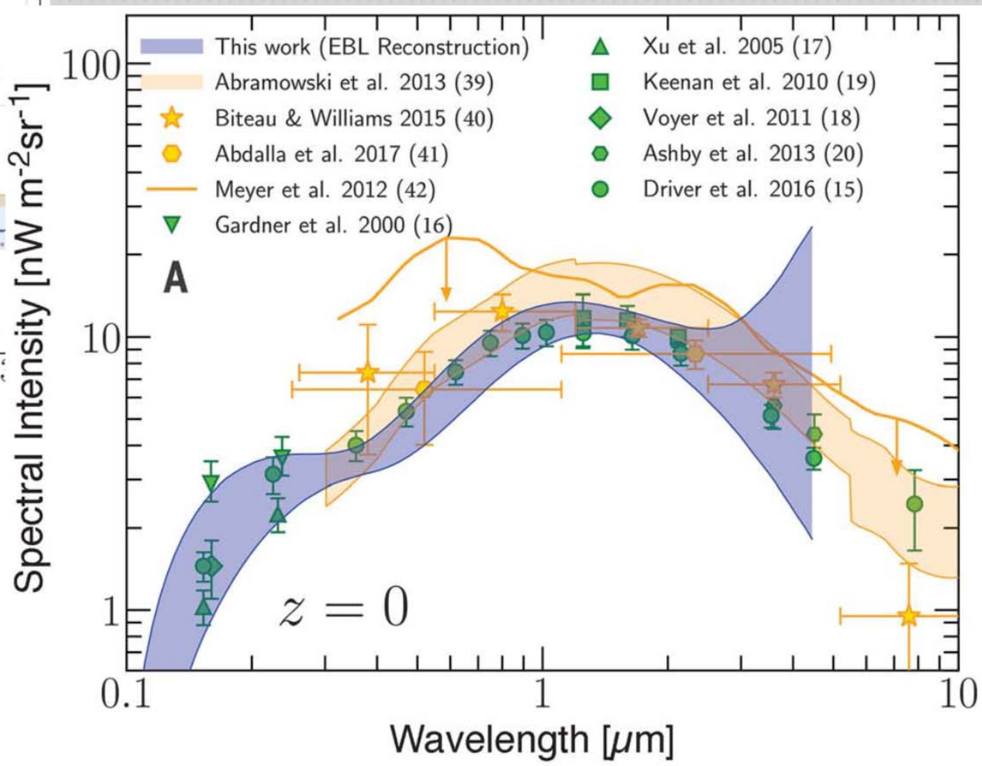


Prandini E.
Science 2018

A gamma-ray determination of the Universe's star formation history from the Fermi observatory



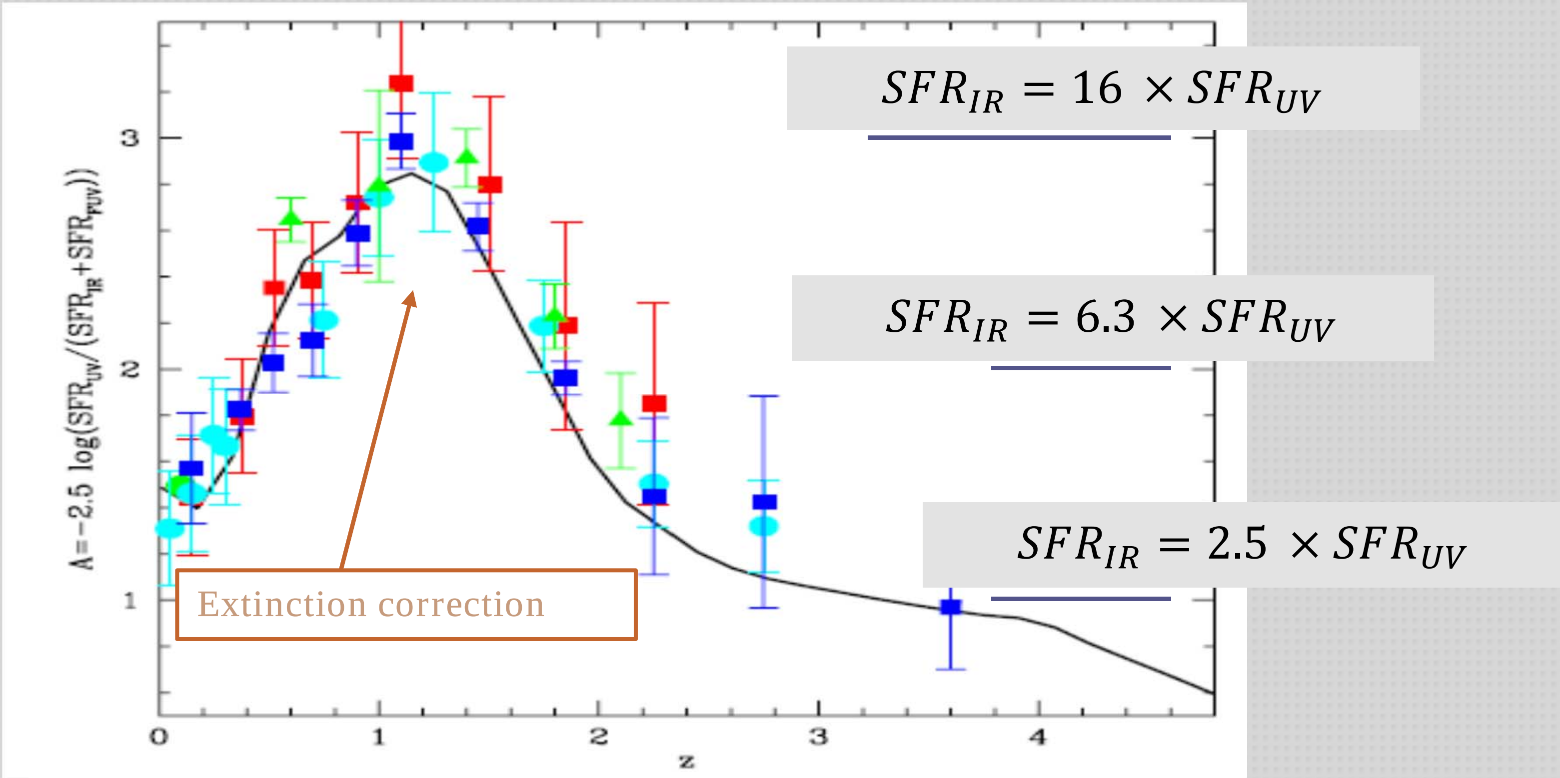




Fermi collaboration
Science 2018

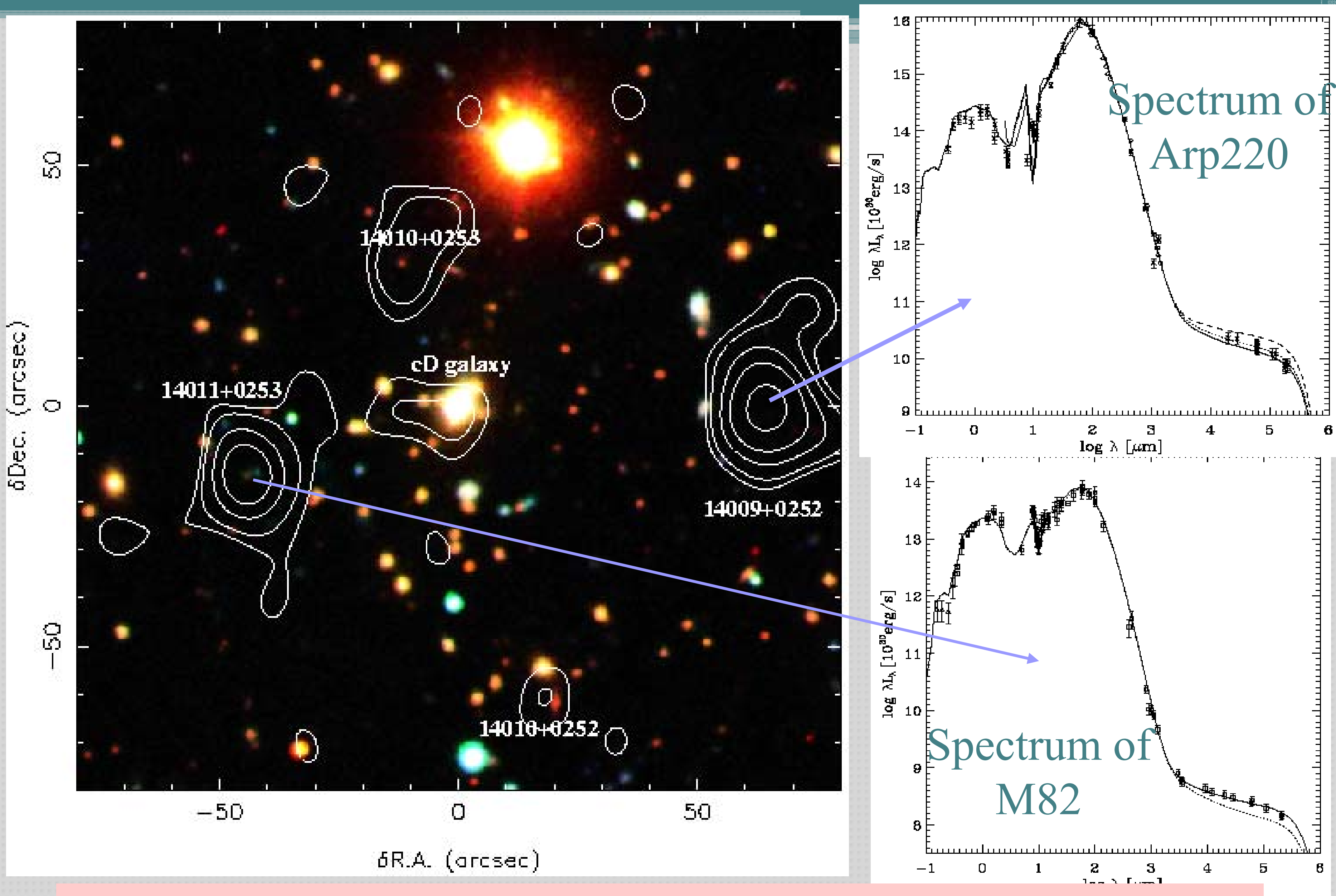
However, problem. Large effects of dust extinction in cosmic structures !

- Large extinction corrections.
- All inferences based on optical-UV (like from Fermi obs.) are highly uncertain.



Very luminous high-redshift sources (ULIRG): ancestors of local massive galaxies

Ultraluminous Infrared Galaxy Arp 220 HST • NICMOS
PRC97-17 • ST ScI OPO • June 9, 1997
R. Thompson (University of Arizona),
N. Scoville (California Institute of Technology) and NASA



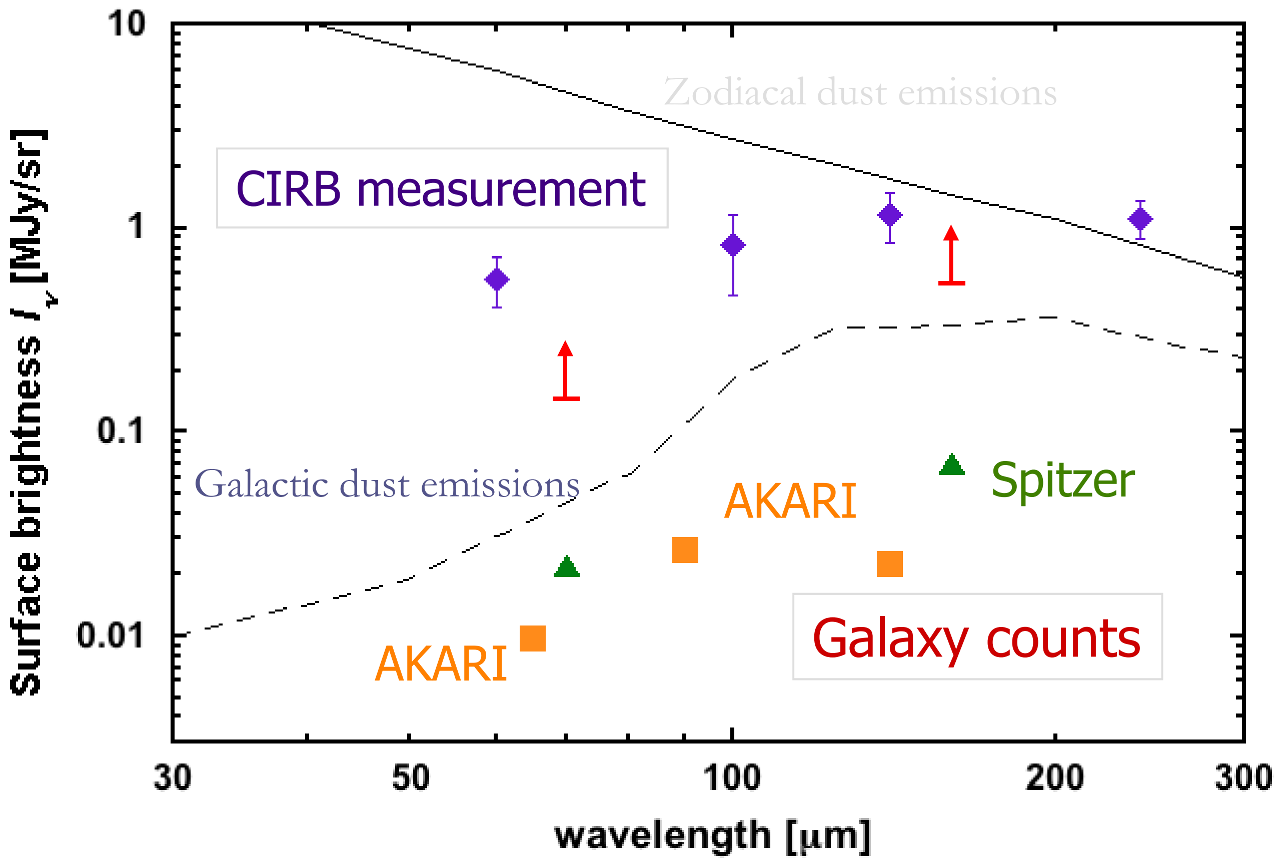
... fully hidden in the optical (galaxy cluster field of A1835)

EBL in the infrared (CIRB)

- Direct measurements of CIB with COBE/DIRBE
- Stacking analysis for Spitzer MIPS 24um sources
- Integrated flux of galaxy counts with Spitzer & AKARI

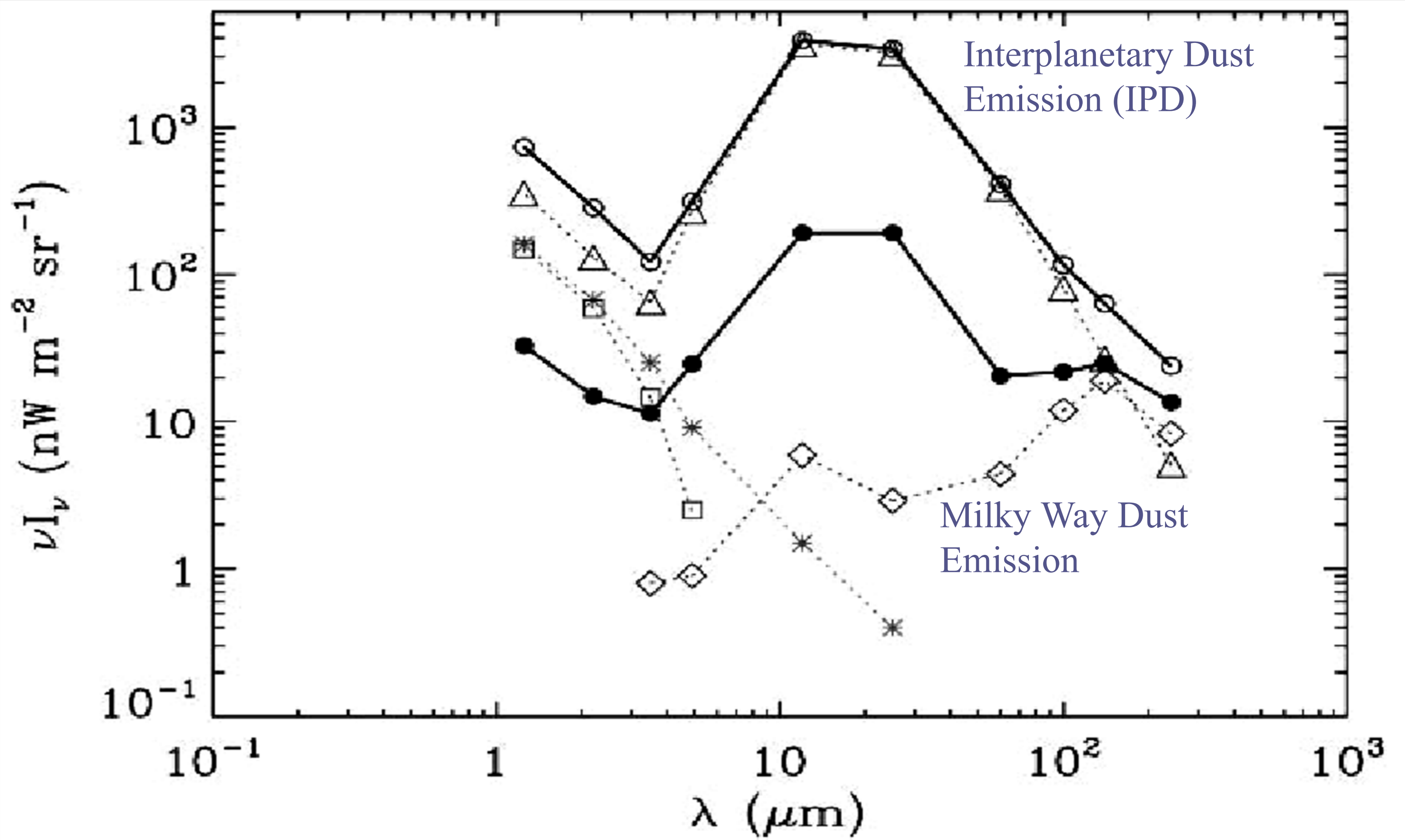
Only ~5% of CIRB is resolved into individual sources.

Our aim is to know what the unresolved sources are.

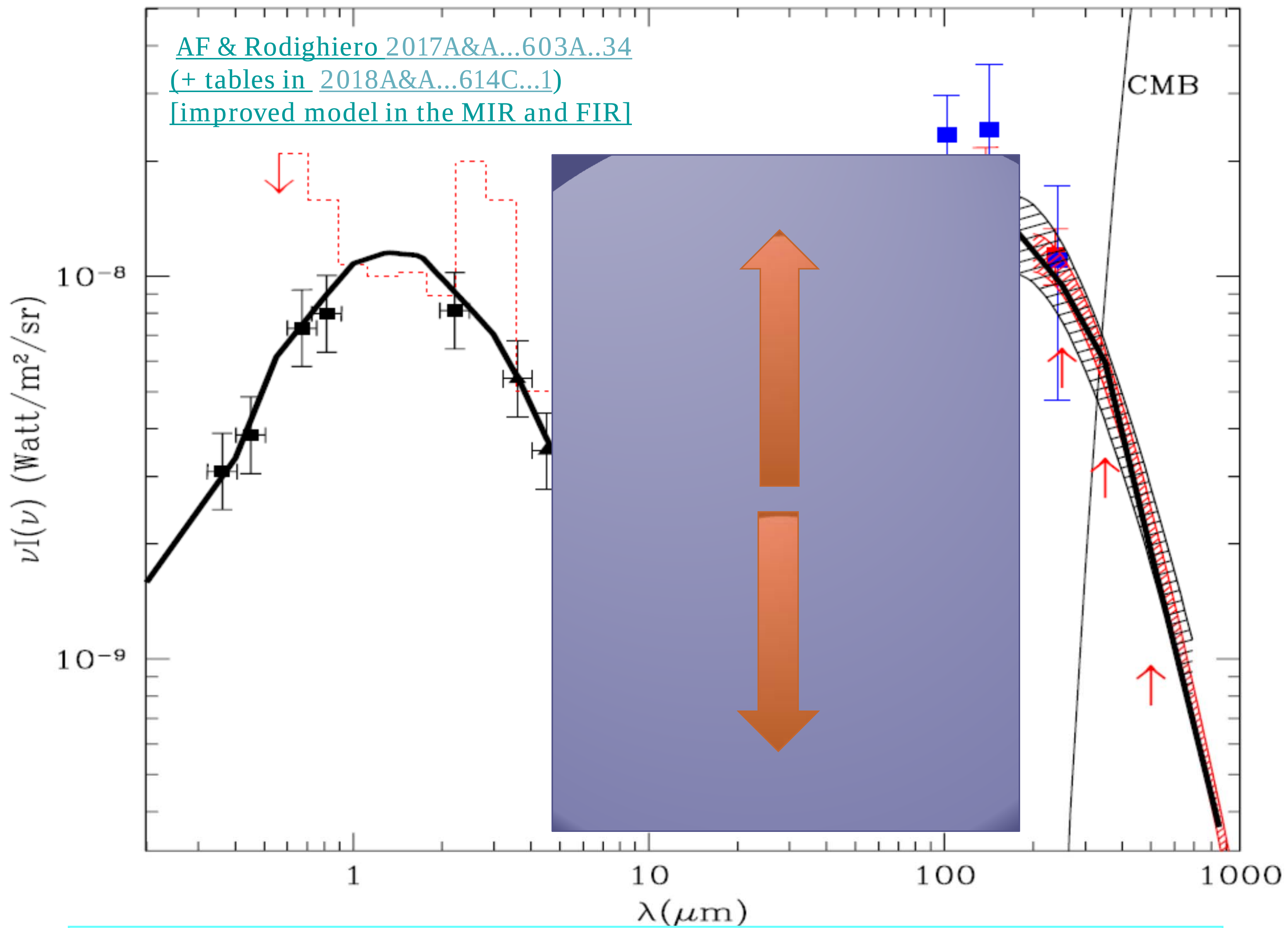


Hauser et al., ApJ, 508, 25 (1998), Lagache et al., A&A, 354, 247 (2000)
Dole et al., ApJS, 154, 93 (2004, 2006)

CIRB measurement: a dramatic challenge



No way to obtain any direct measurements of EBL from 3 to 200 µm



Current view of the local EBL

The γ-γ cosmic optical depth

The optical depth for $\gamma\gamma$ collision of a high-energy photon with E_γ from a source at z_e:

$$\tau(E_\gamma, z_e) = c\int_0^{z_e} dz \frac{dt}{dz} \int_0^2 dx \frac{x}{2} \int_{\frac{2m_e^2c^4}{E_\gamma \epsilon x(1+z)}}^{\infty} d\epsilon \frac{dn_\gamma(\epsilon, z^*)}{d\epsilon} \sigma_{\gamma\gamma}(\beta)$$

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

$$\beta = (1 - 4m_e^2c^4/s)^{1/2}; \quad s \equiv 2E_\gamma \epsilon x(1+z); \quad x \equiv (1-\cos\theta),$$

For a flat universe, the differential of time to be used in eq. 1 is:

$$dt/dz = \frac{1}{H_0(1+z)}\left[(1+z)^2(1+\Omega_m z) - z(z+2)\Omega_\Lambda\right]^{-1/2}.$$

ϵ: energy of the background photon,

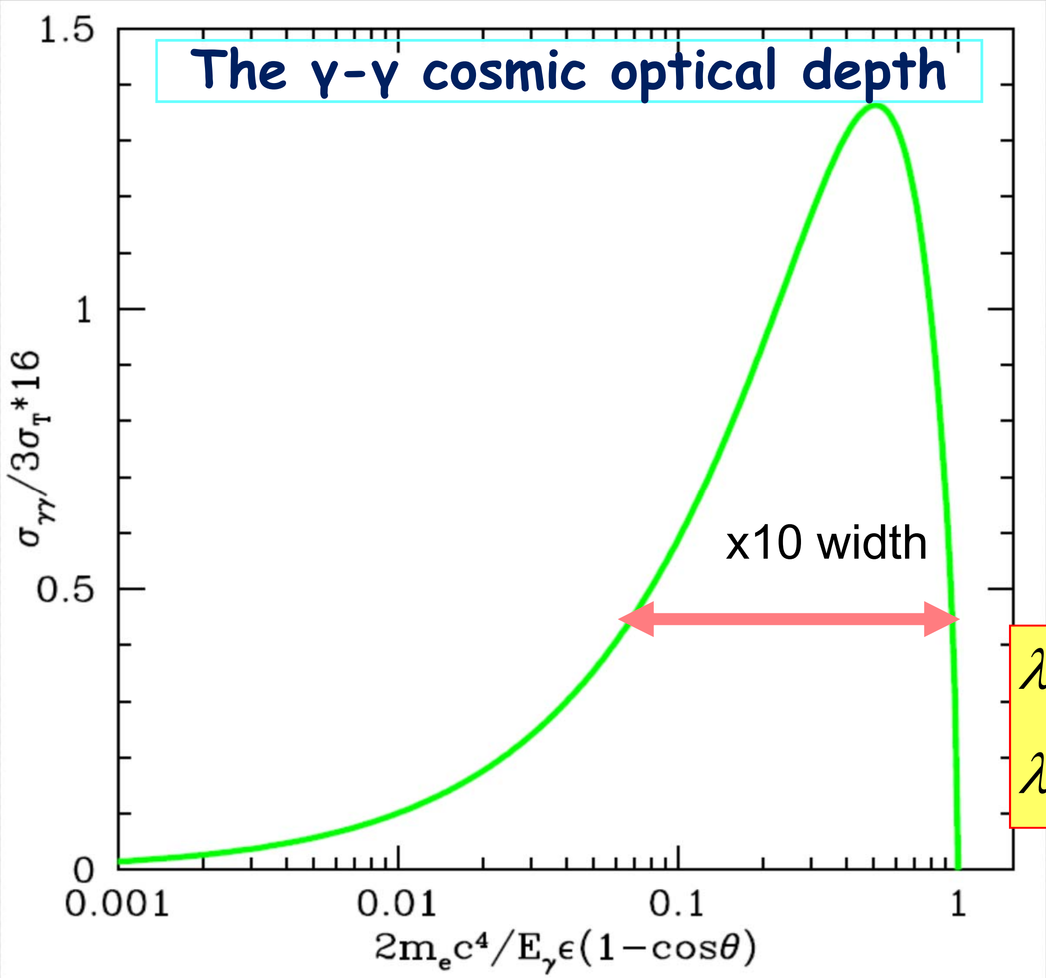
E_γ that of the high-energy colliding one,

θ being the angle between the colliding photons.

Constraining the EBL @ long IR wavelengths

- Constraining the EBL at long IR wavelengths via γ-γ opacity measurements not an easy task: going to long $\lambda \rightarrow$ high γ energies $\rightarrow$ strong opacity
- Requires to observe *blazars* at the highest VHE photon energies
- and the lowest reshift, most nearby, *blazars*

… not a full mapping of EBL and γ-γ absorption...



The γ-γ cross-section is quite broad and skewed...

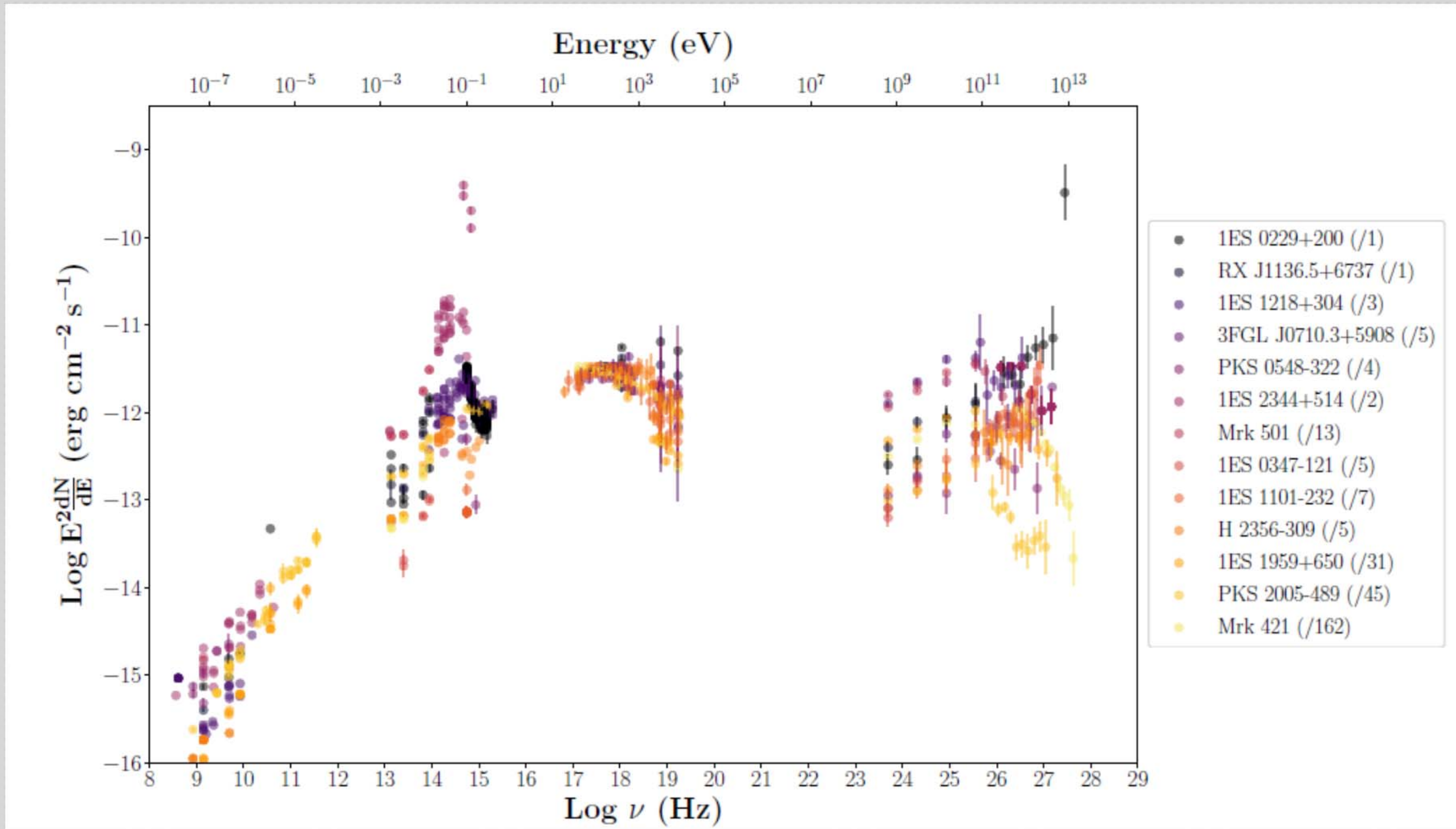
$$\lambda[\mu m] \simeq 1.2 E_\gamma [TeV] \times (1+z')^{-2}$$

$$\lambda \simeq (0.1-2.4)\mu m\, E_\gamma [TeV] \times (1+z')^{-2}$$

z' is where the γ-γ interaction happens

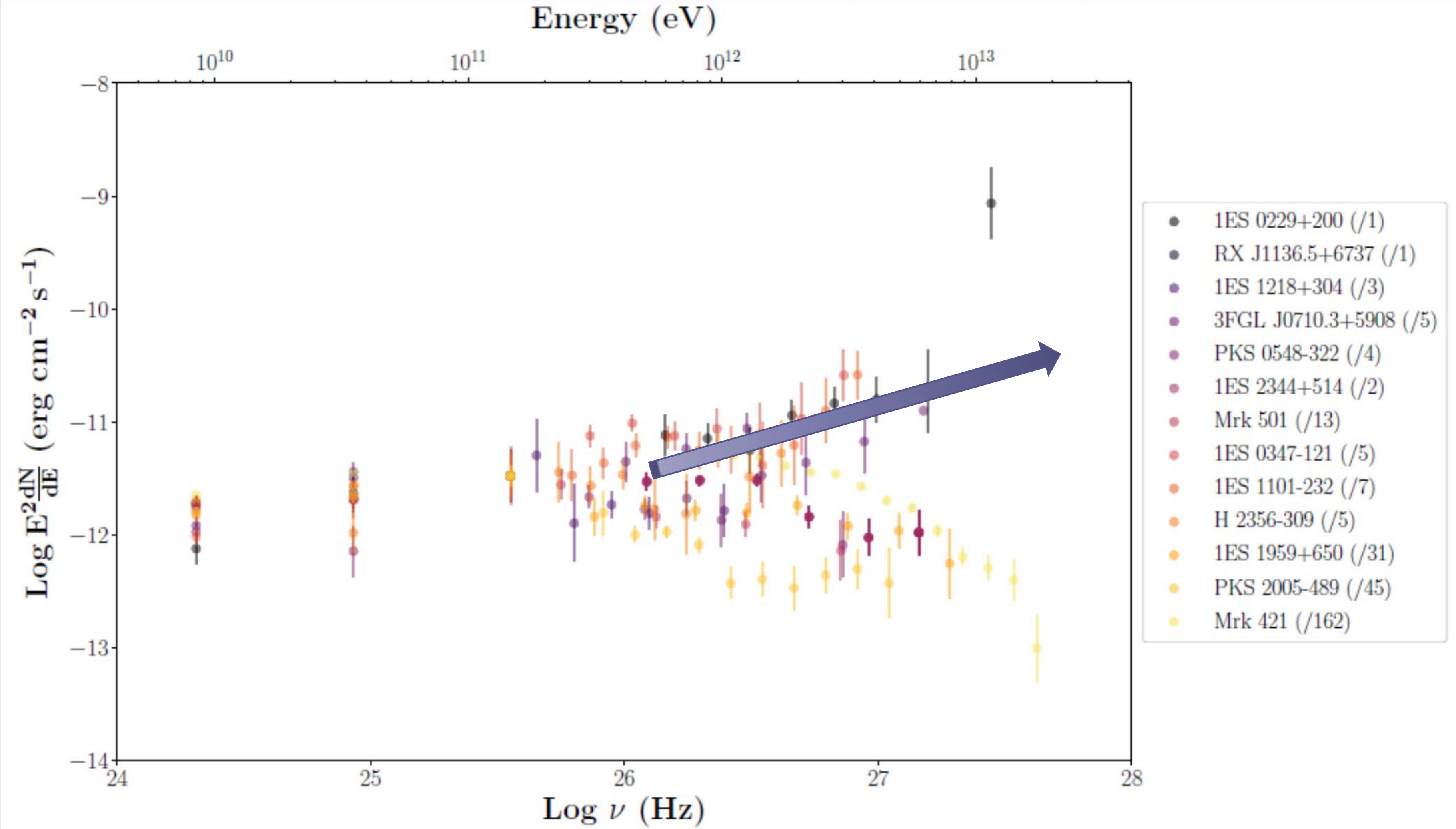
Normalized EHBL source multi-wavelength spectra

Foffano et al. (2019)

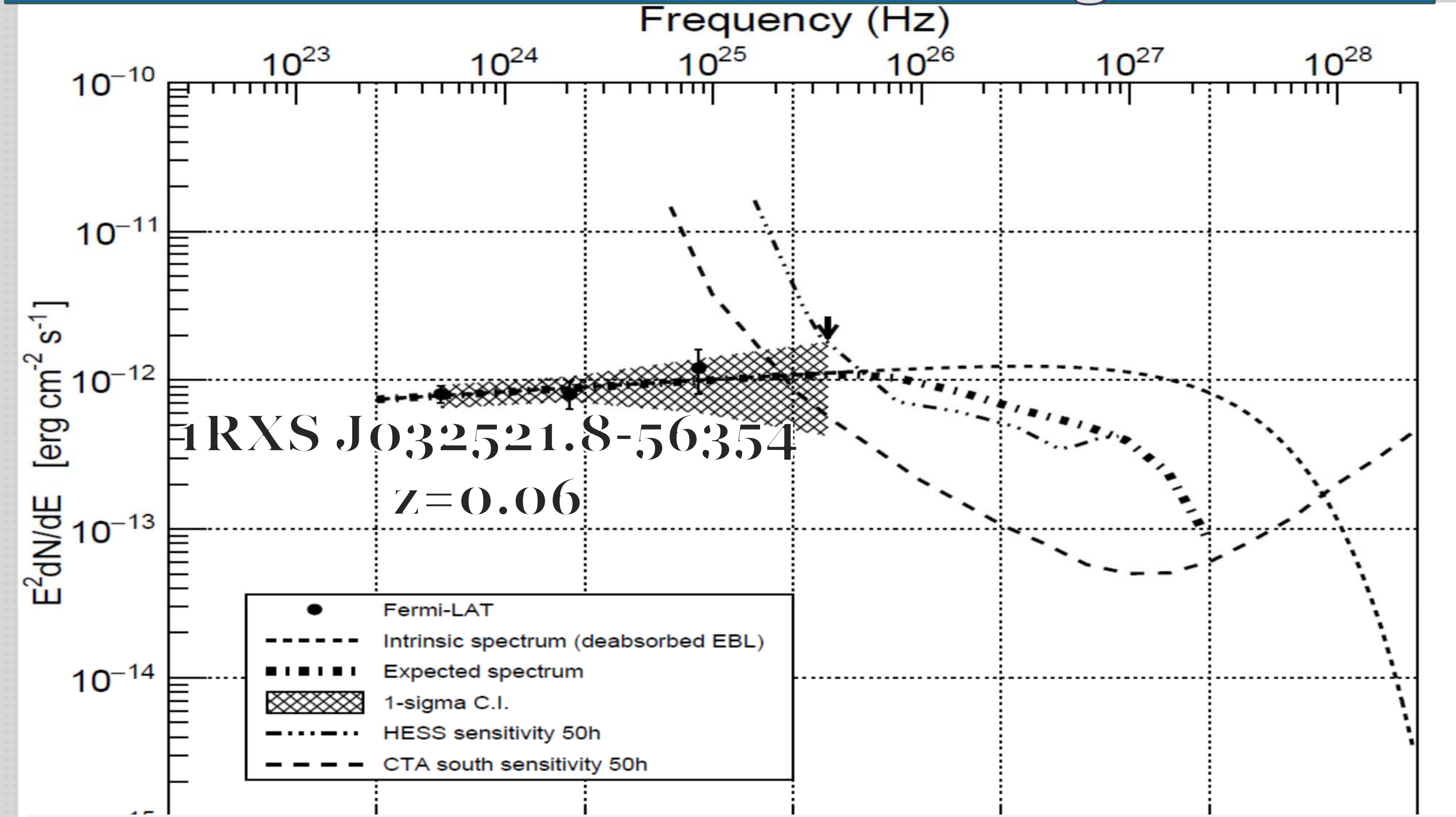


Normalized EHBL source spectra (cnt)

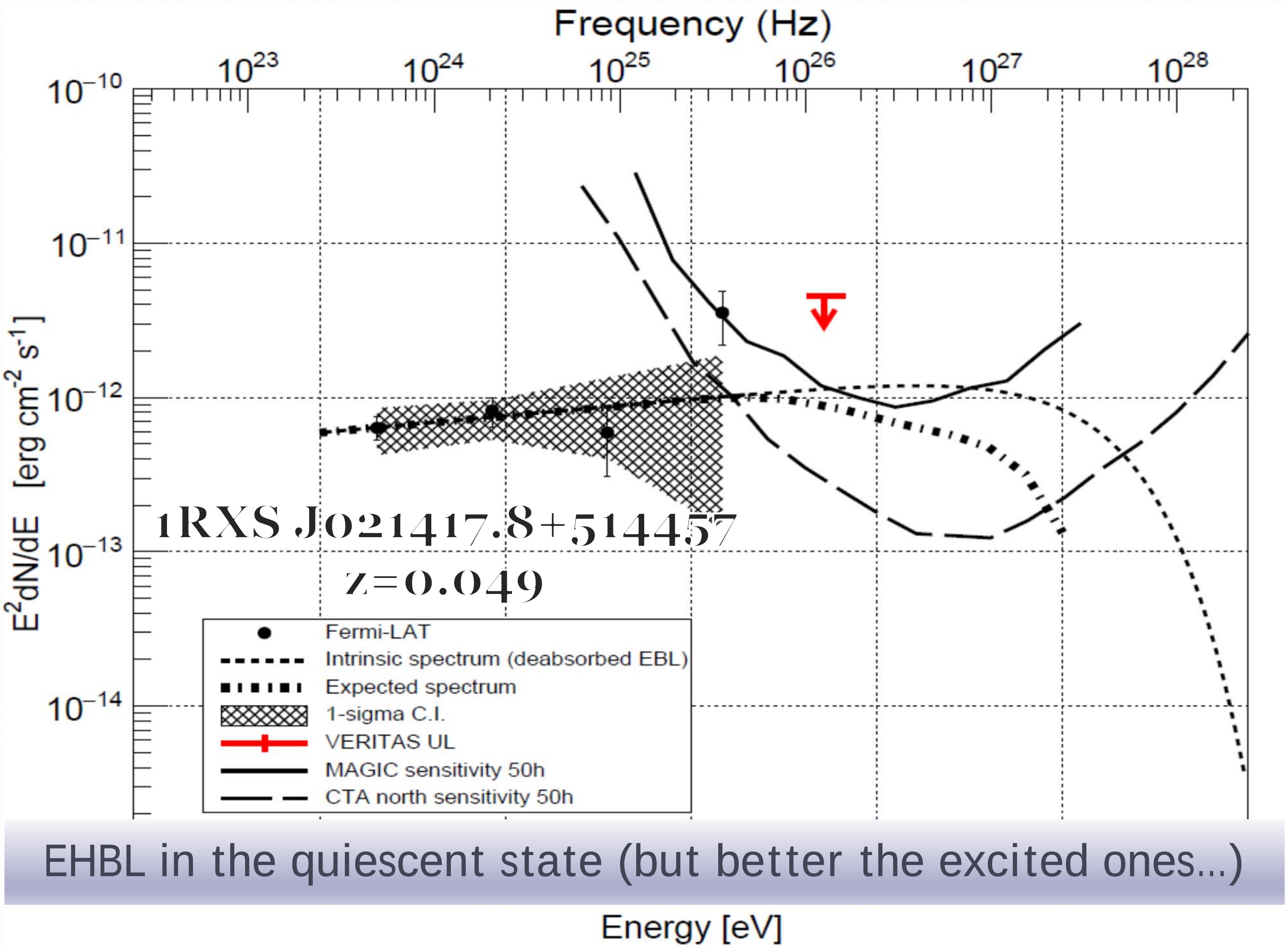
Foffano et al. (2019)



The potential of EHBL to constrain the EBL at IR wavelengths

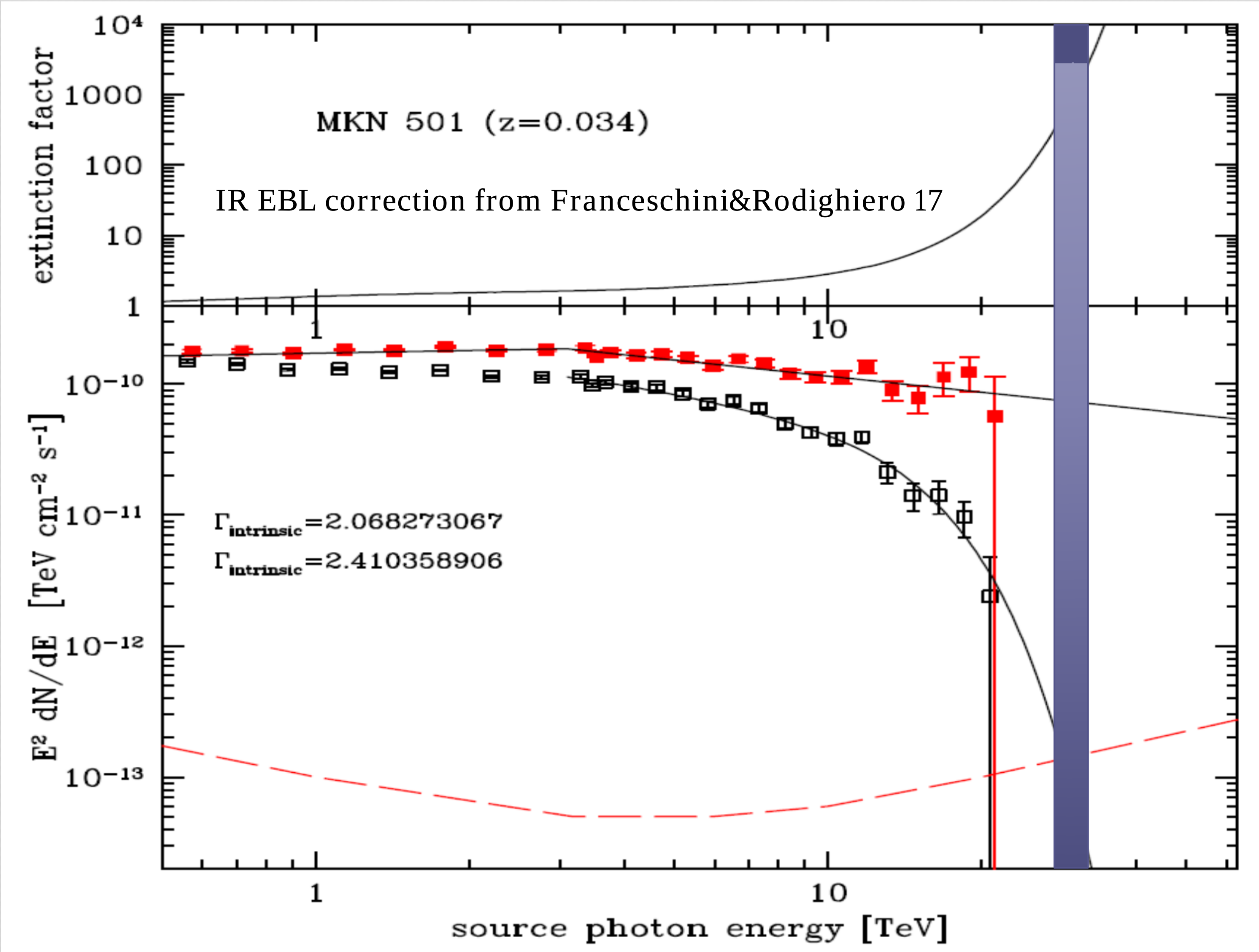


EHBL in the quiescent state



EHBL in the quiescent state (but better the excited ones…)

MKN501 during the 1997 flare



Conclusions

- The far-infrared background is a major cosmological radiative component. Totally unobservable directly, because of the IPD foreground.
- Extreme highly peaked BL Lacs offer interesting chances to constrain the Fair-IR EBL.
- Difficult task because going to long $\lambda \rightarrow$ high γ energies $\rightarrow$ strong opacity.
- Then low-redshift high energy emitters are needed. Current EHBL useful to ≈10 μm (10 TeV, low state).
- Better chances to attain the ≈30 μm (30 TeV) limits would be offered by major outbursts of local *blazars* (Mkn501+421, turning EHBL during such phases).
- Or even more local AGNs (M87, Cen A) !