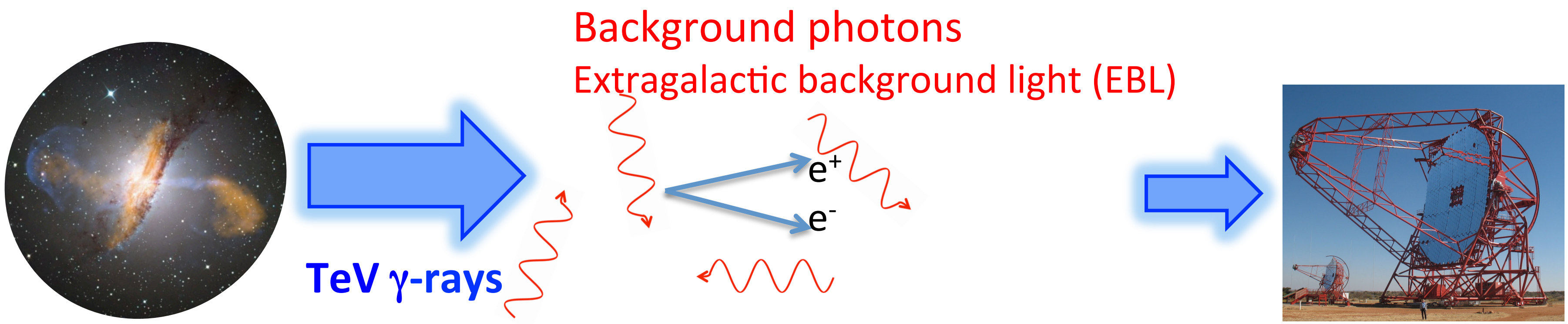
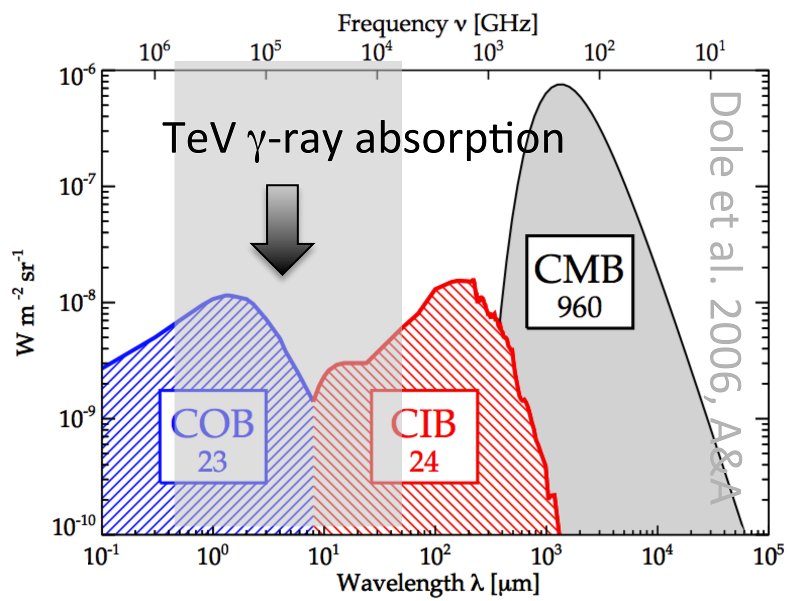
Measurement of the expansion rate of the universe from γ–ray attenuation

A. Dominguez & F. Prada

Universe opacity at very high energies (VHE):



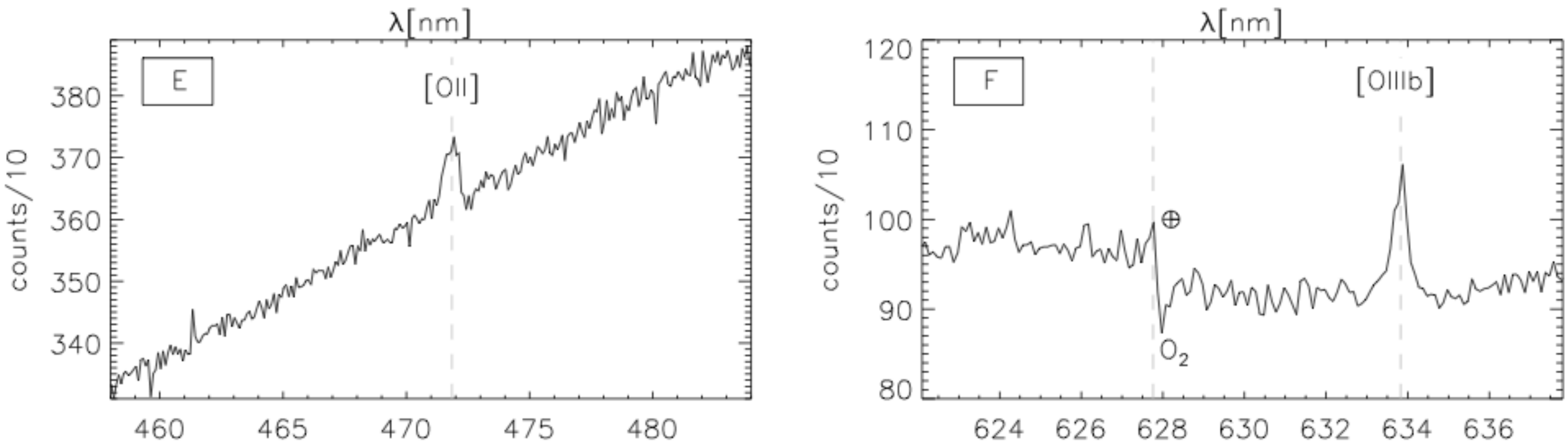


$$\varepsilon_{th} \equiv \frac{2m_e^2c^4}{E\mu}$$

1 TeV ⬄ 1 eV

$$\mu = (1 - \cos\theta)$$

- Redshift measured with spectroscopy (not easy for blazars)



Pita et al. 2012

- Distance estimated with the γ-ray attenuation

optical depth:

EBL density

$$\tau(E,z) = \int_0^z \left(\frac{dl}{dz'}\right) dz' \int_0^2 d\mu \frac{\mu}{2} \int_{\varepsilon_{th}}^{\infty} d\varepsilon' \; \sigma_{\gamma\gamma}(\beta') n(\varepsilon', z').$$

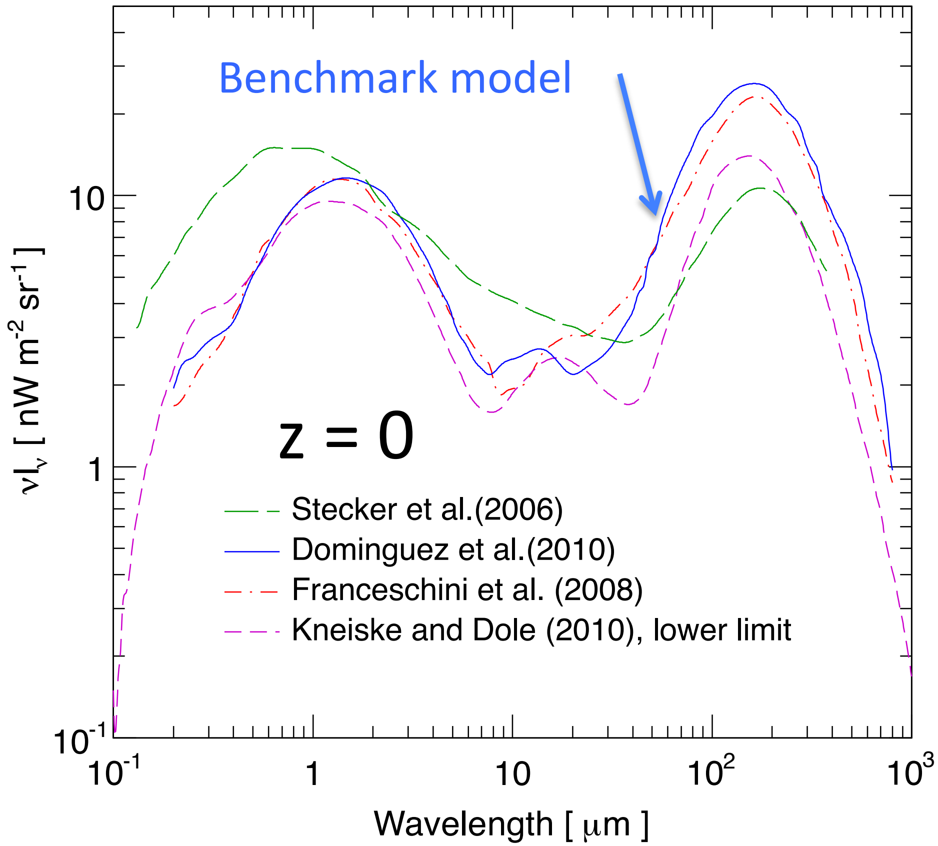
$$\phi_{\mathrm{observed}} = \phi_{\mathrm{intrinsic}} \; e^{-\tau}$$

Cosmology

1st Problem: The EBL is poorly knwon

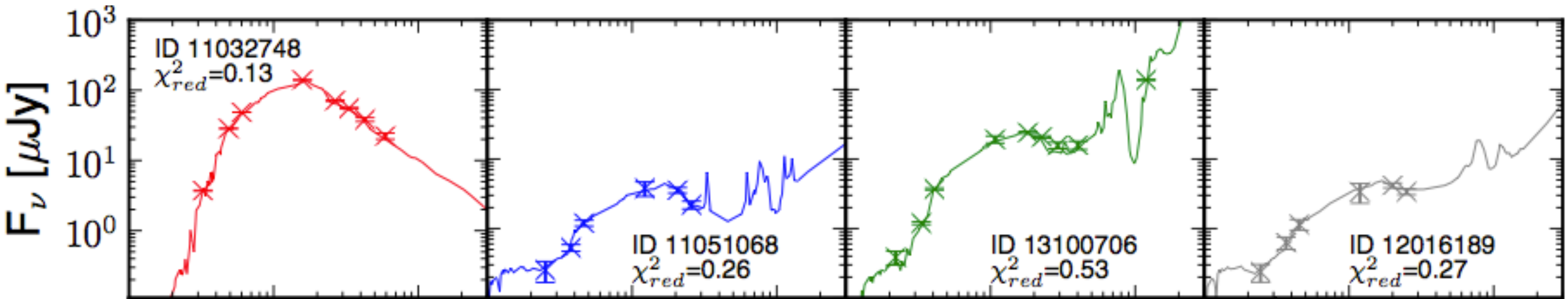
No measurement possible (zodiacal light)

Evolution with redshift complicated, modeling tricky



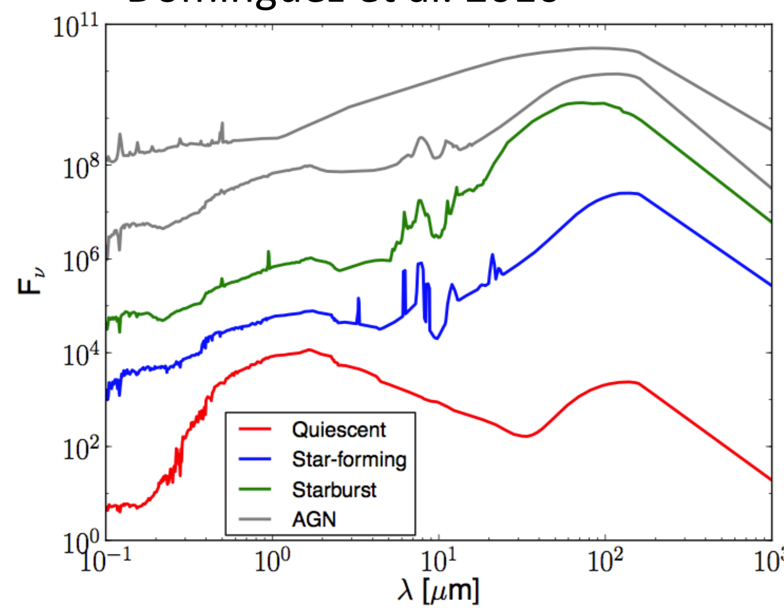
Dominguez et al. 2010 EBL model:

- AEGIS Galaxy SED-types (5000 galaxies) for 0 < z < 1



- 25 SED templates

Dominguez et al. 2010



- Luminosity Function

in K band from Cirasuolo 2010

Depends on cosmology

+ Dependence when integrating over redshifts

The model depends on the cosmological parameters (mostly for h < 0.3)

Model predictions for different values for h:

Cosmic γ-ray horizon (CGRH) E_0: Energy for which $\tau = 1$

→$E > E_0$, significant absorption occurs, $\tau > 1$

→$E < E_0$, small absorption, $\tau < 1$

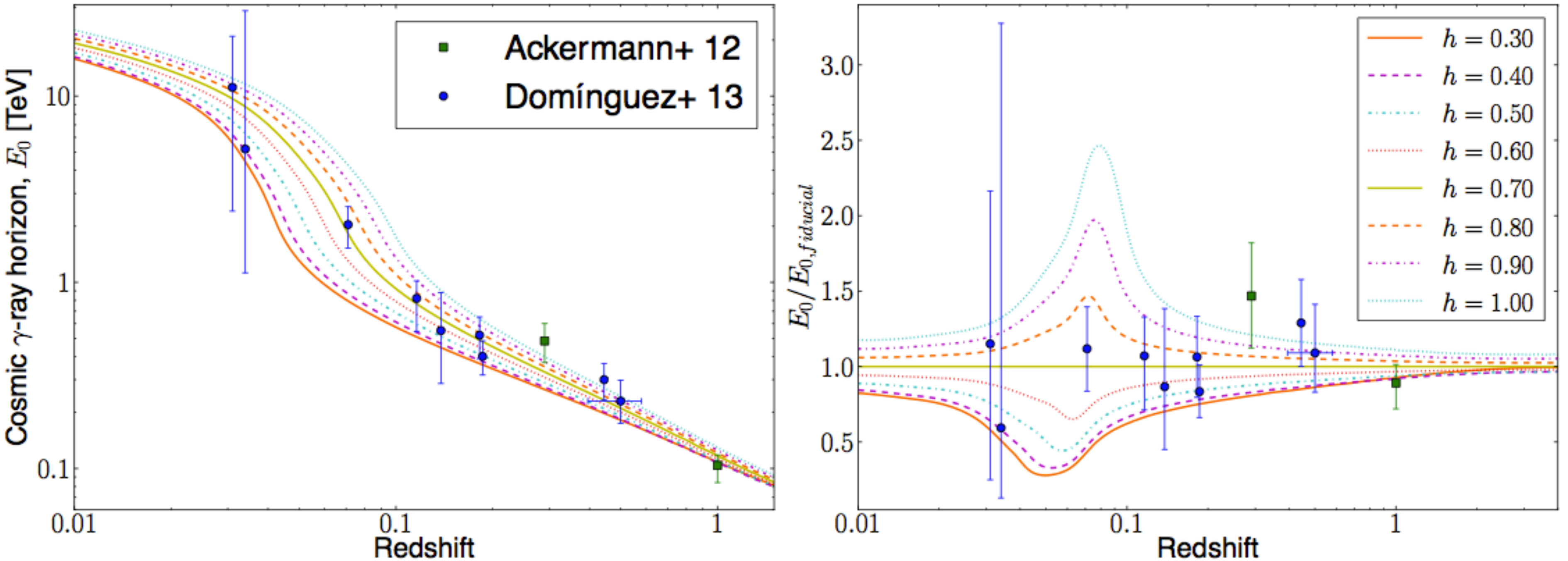
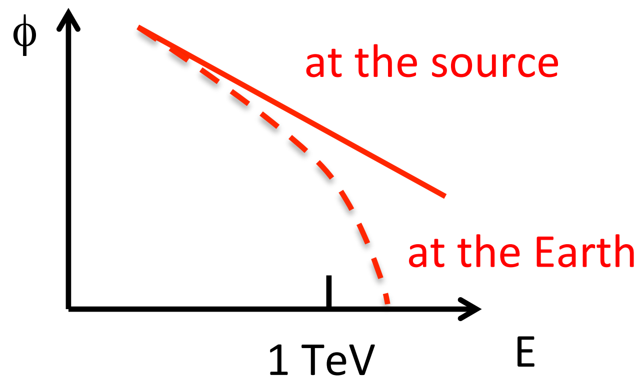


figure 1

Measurement of the CGRH:

Problem 2: What is the spectrum at the source?



Ackermann et al. 2012 (Fermi-LAT collaboration)

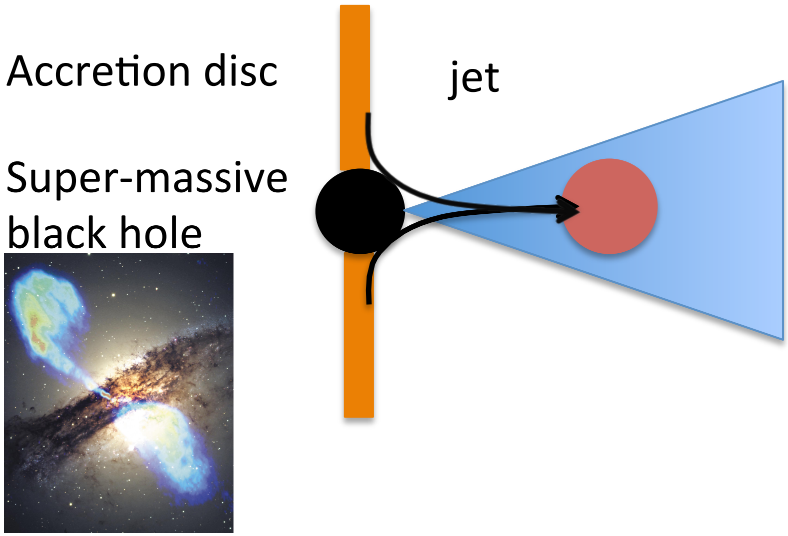
➔ Intrinsic spectra parameterized with log-parabola

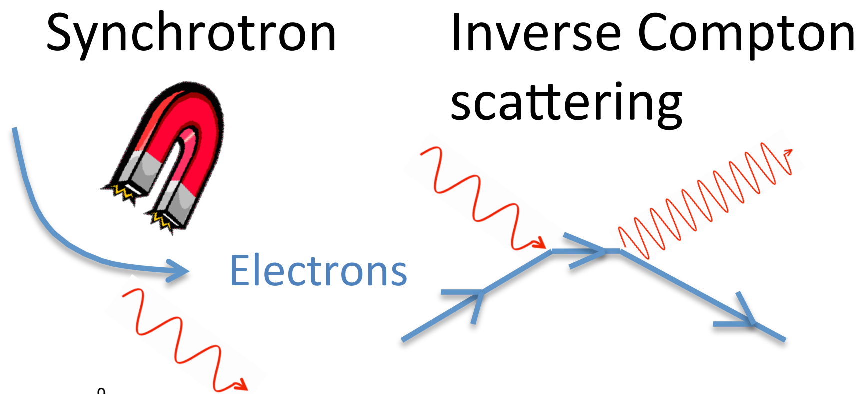
- 150 sources (BL Lacs) distributed in 3 bins in redshift
- Fit EBL normalization * log-parabola on data

Caveats:
- Wong result if log-parabola not a correct assumption (cut-off in the source? : Klein-Nishina suppression, e^- dist.)
- Depends on a peculiar EBL model (Franceschini et al.)

<u>Dominguez 2013:</u>

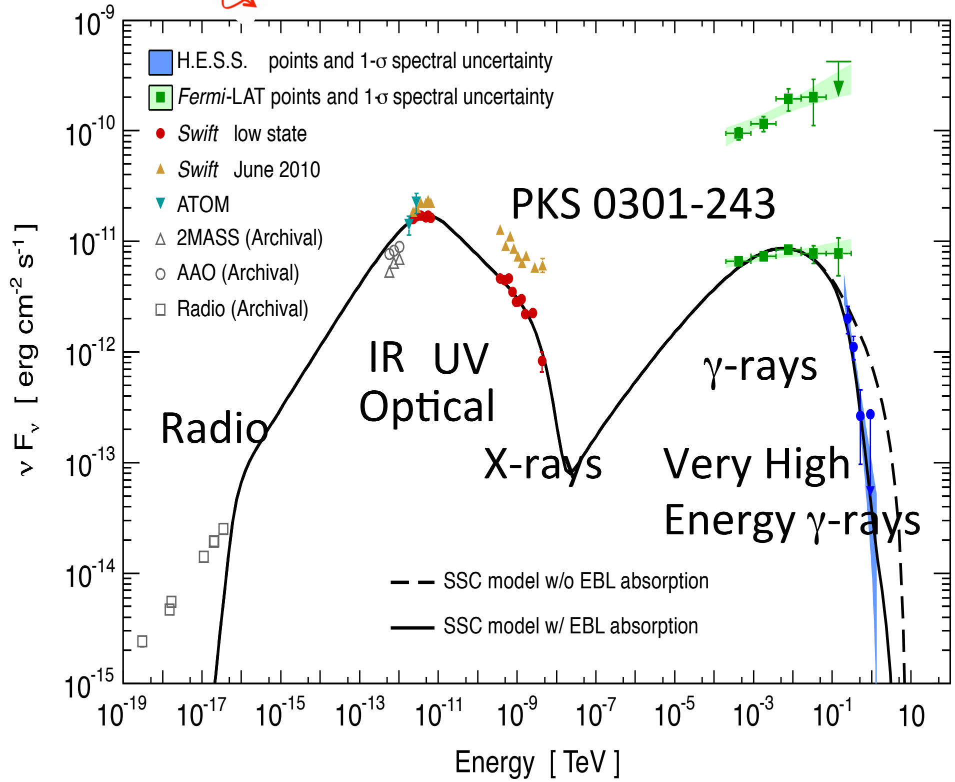
Physical emission model for the source: Synchrotron-Self Compton model (SSC)





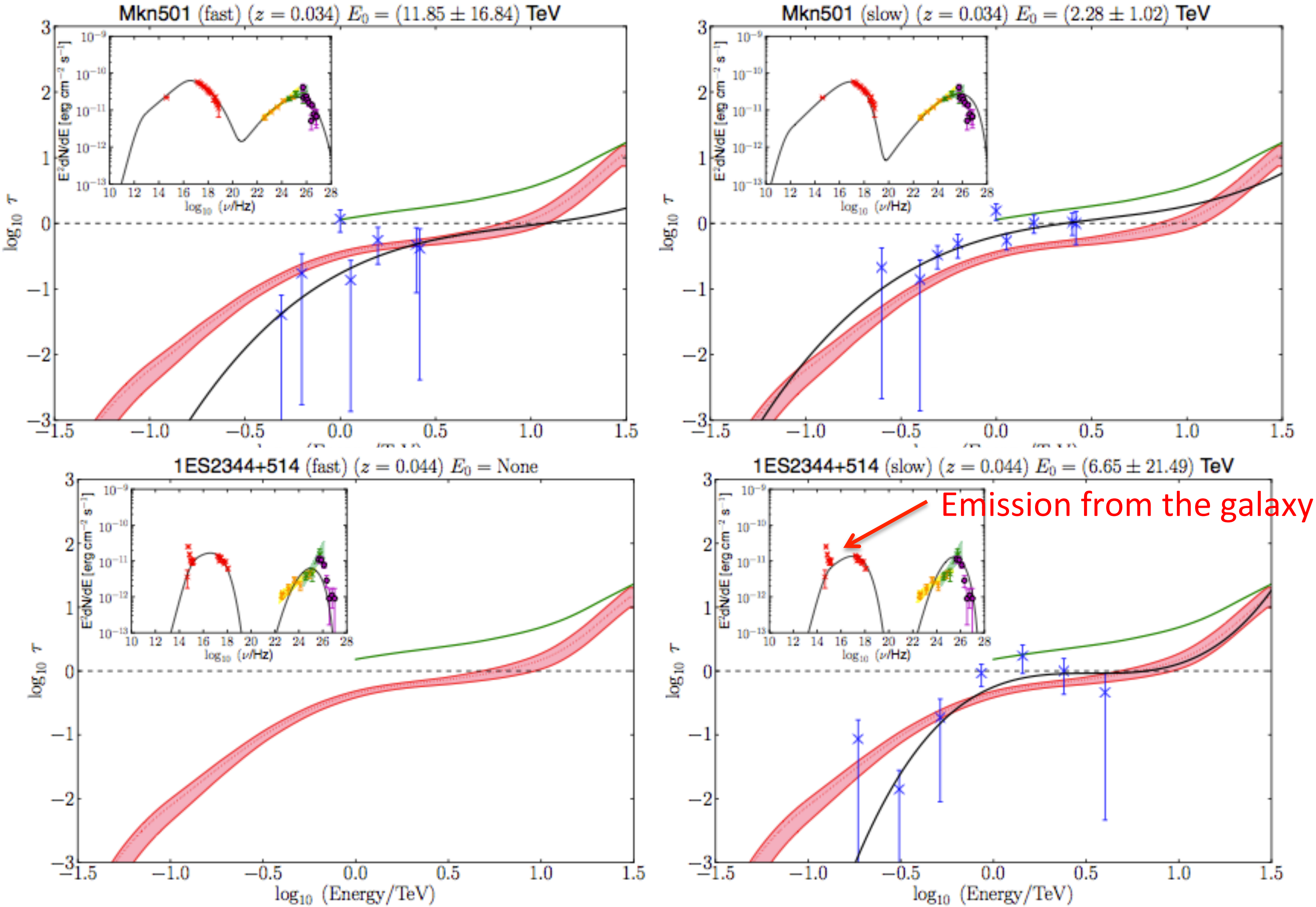
Model derived from multi-wavelength data from radio to γ-rays

➔ Extrapolation at VHE



H.E.S.S. Collaboration 2013

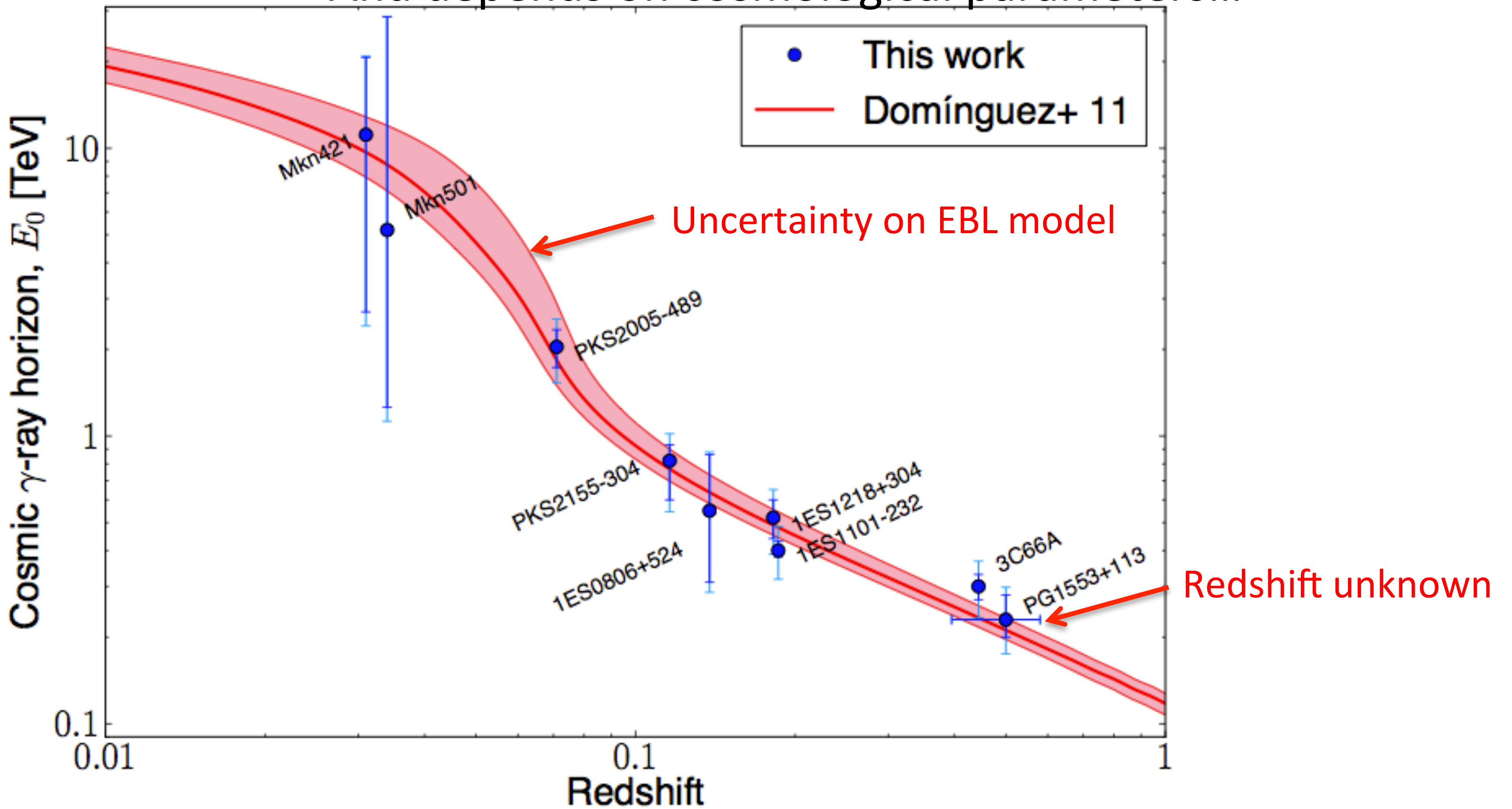
Dominguez 2013: Example for 2 sources



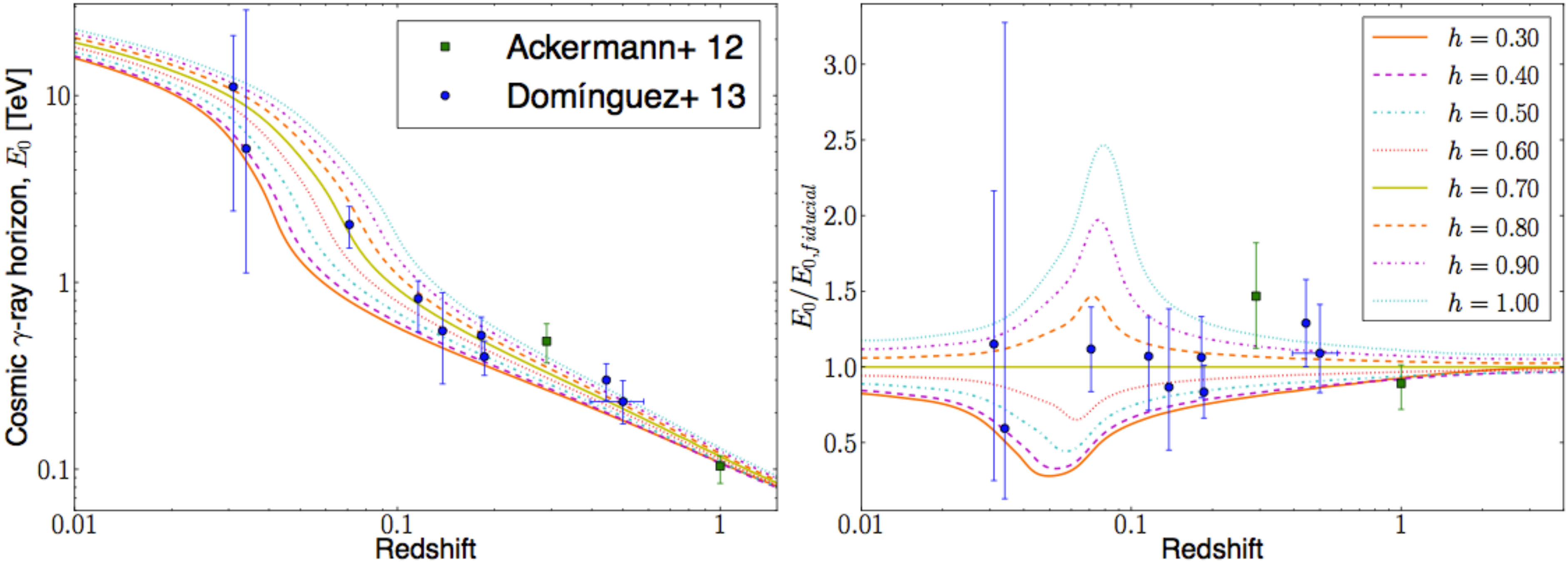
Dominguez 2013: Significant results

Caveats:
- Blazars are highly variable, even in « quiescent » states
- Models are too degenerate, needs to fit the electron spectrum, magnetic field, doppler factor, blob radius…

And depends on cosmological parameters…



Measurement of H_0:

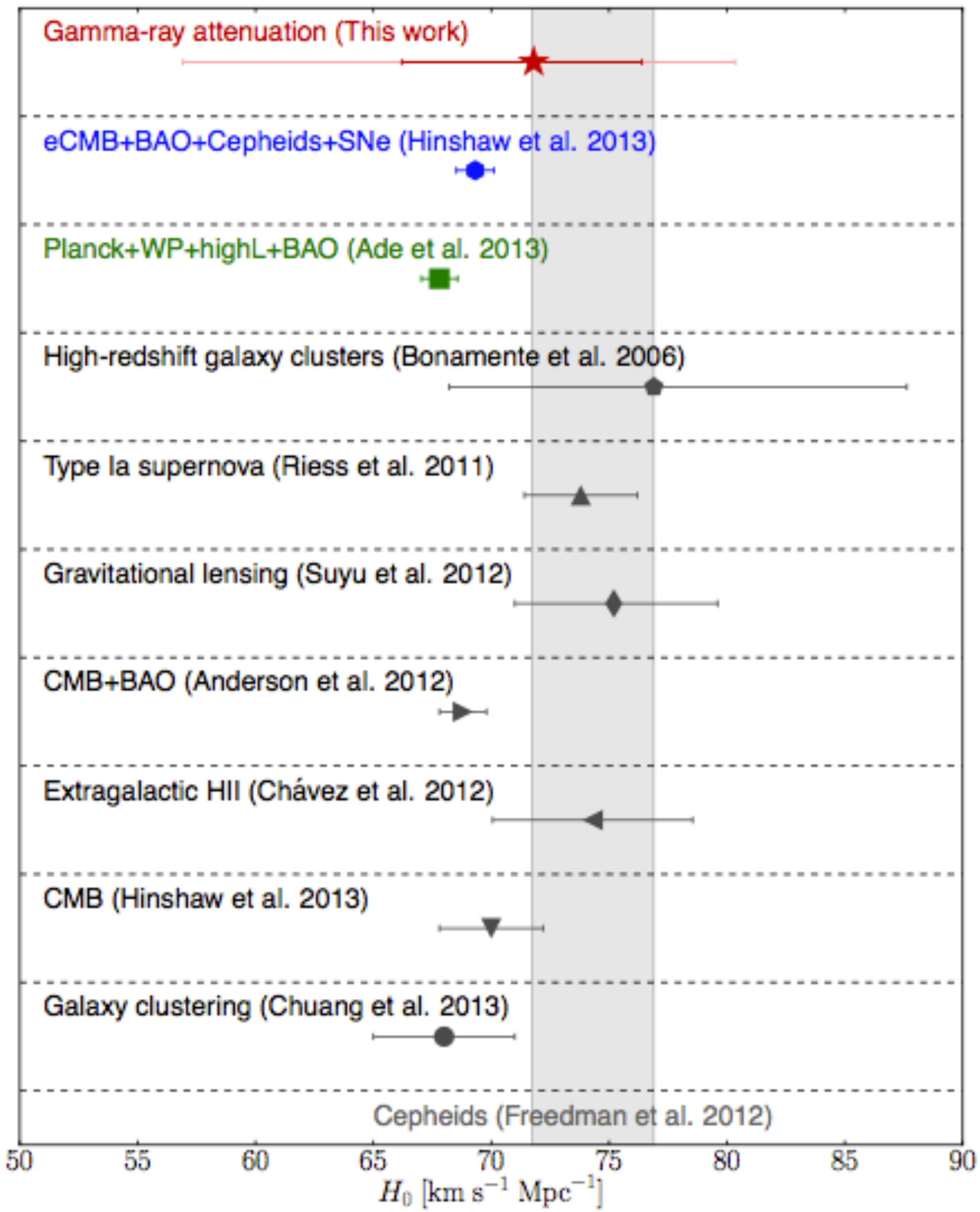


Assuming $\Omega_\Lambda = 0.7$ and $\Omega_m = 0.3$:

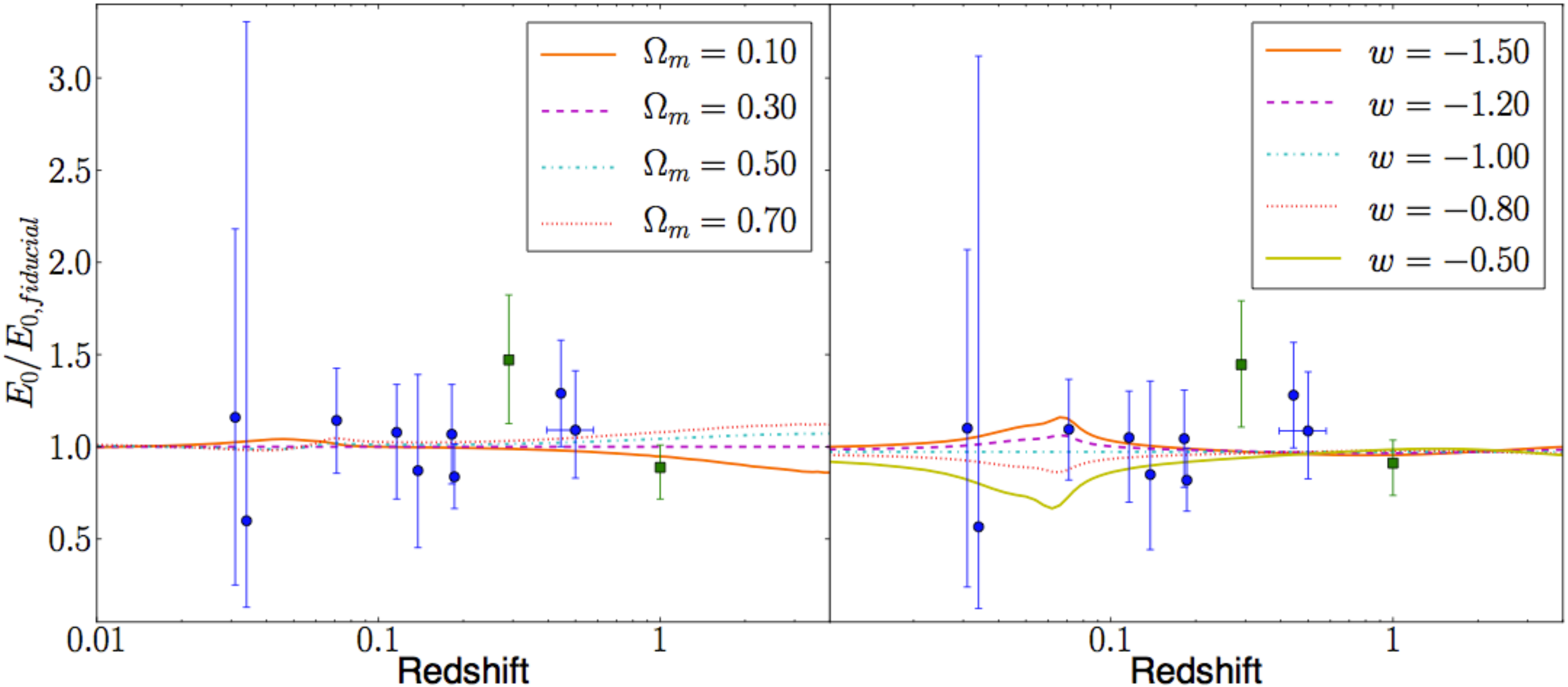
$$H_0 = 71.8^{+4.6}_{-5.6}\,(\text{stat})\,^{+7.2}_{-13.8}\,(\text{syst})\ \text{km s}^{-1}\ \text{Mpc}^{-1}$$

From EBL uncertainty

Comparison with other methods:

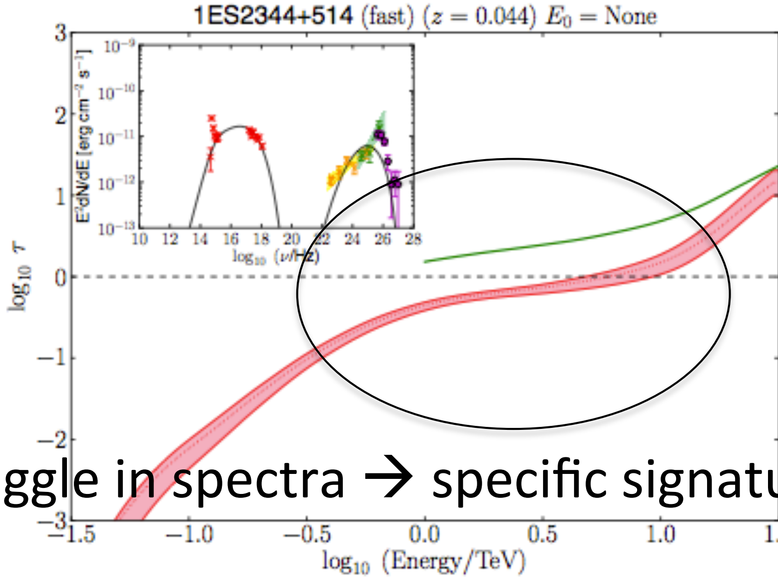


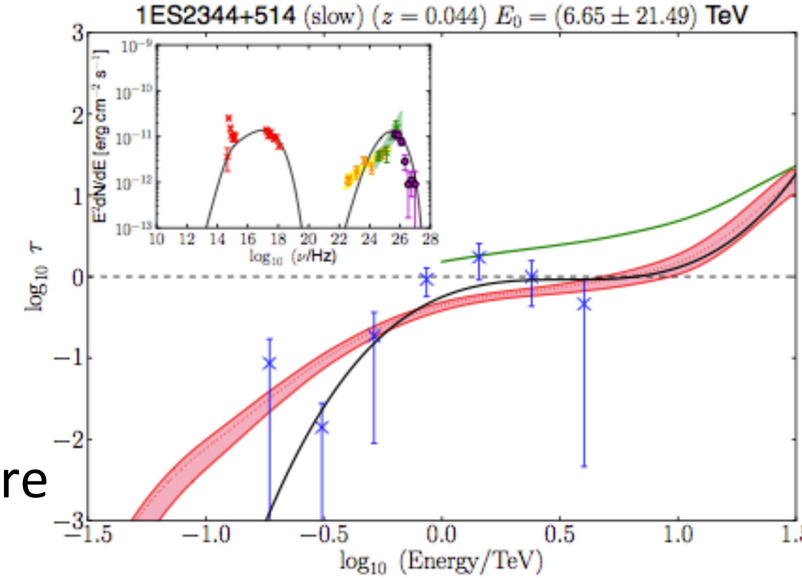
Other parameters:



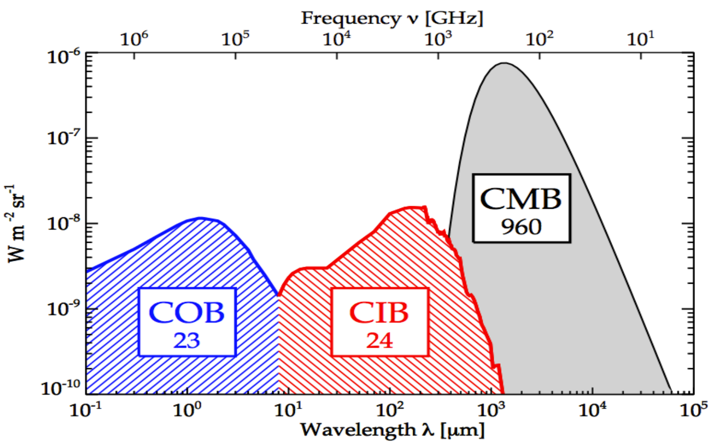
➔ Not sensitive

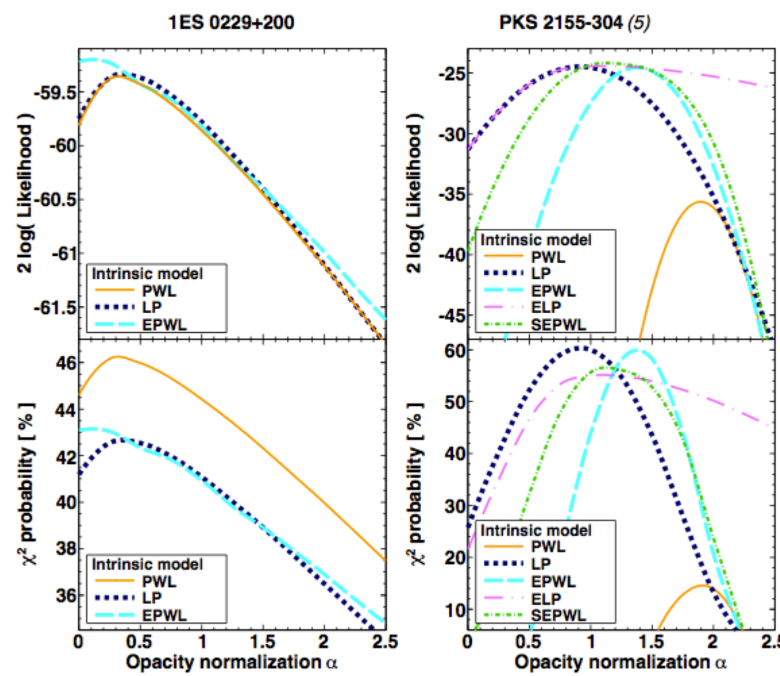
How to disentangle intrinsic cut-off from EBL absorption?





Wiggle in spectra → specific signature





In H.E.S.S. : sophisticated method with different parameterization for intrinsic spectrum

➔ Measure in range $0 < z < 0.2$