Cosmology from very high energy γ -rays

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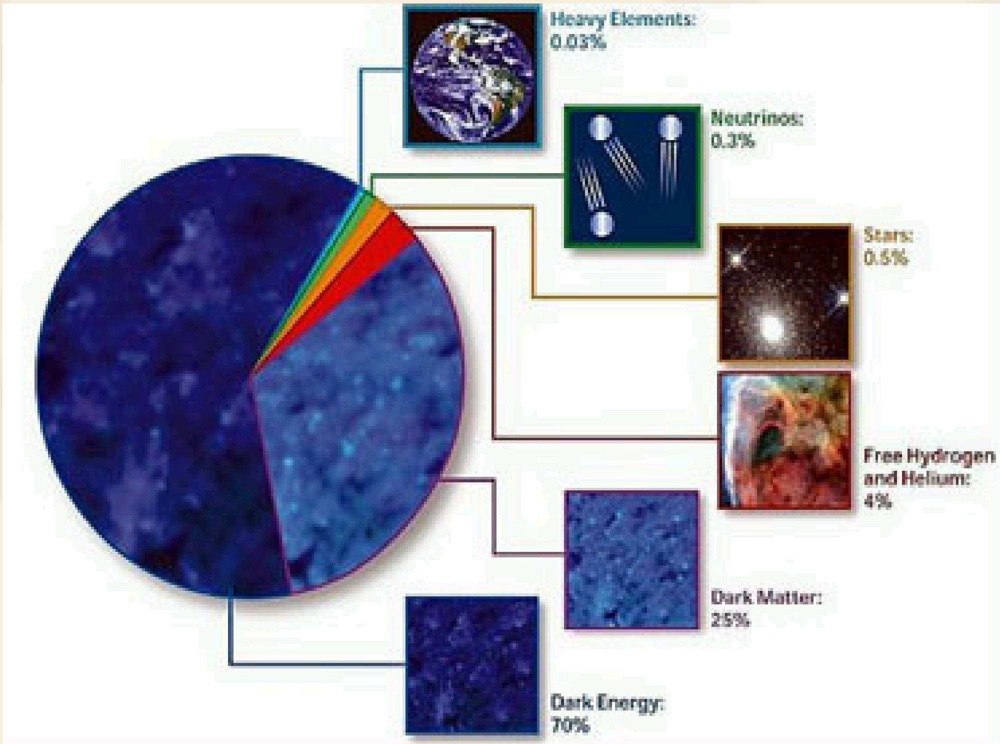
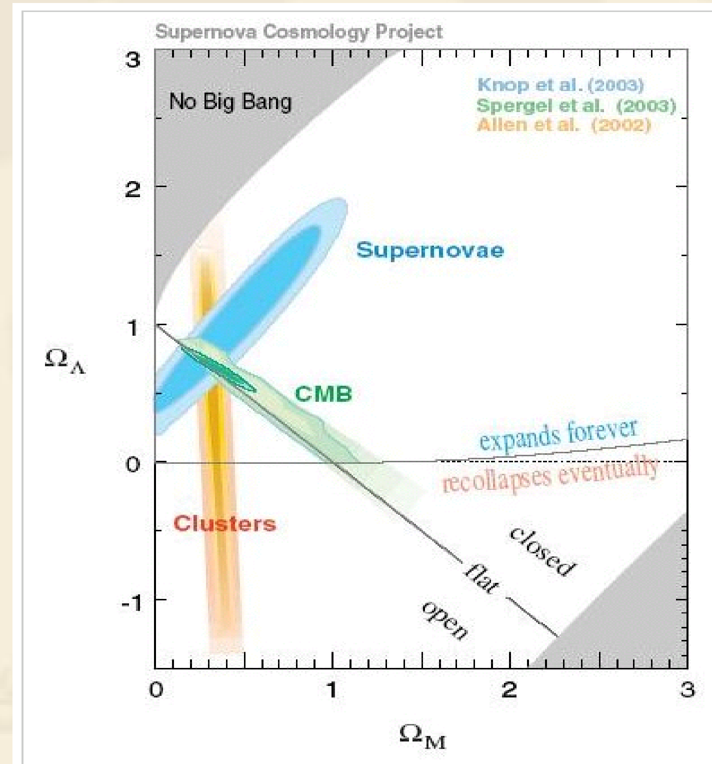
Outline

1. Introduction to cosmological measurements
2. Basic issues of absorption of TeV γ -rays
3. Results to measure the universe using absorption effect
4. Summary & discussion

Cosmological measurements





Many methods to measure the universe: Supernova Ia, CMB, GRB, galaxy clusters, weak lensing, large scale structure, baryon acoustic oscillation

Λ CDM universe: h=0.72, Ω_M=0.28, Ω_Λ=0.72

VHE γ -rays will experience absorption during the propagation in inter-galactic space, and can be used to measure the universe.

Basic process: $\gamma + \gamma_{bk} \rightarrow e^{+} + e^{-}$

The observational spectra rely on:

1. cross section —— well known from quantum electrodynamics

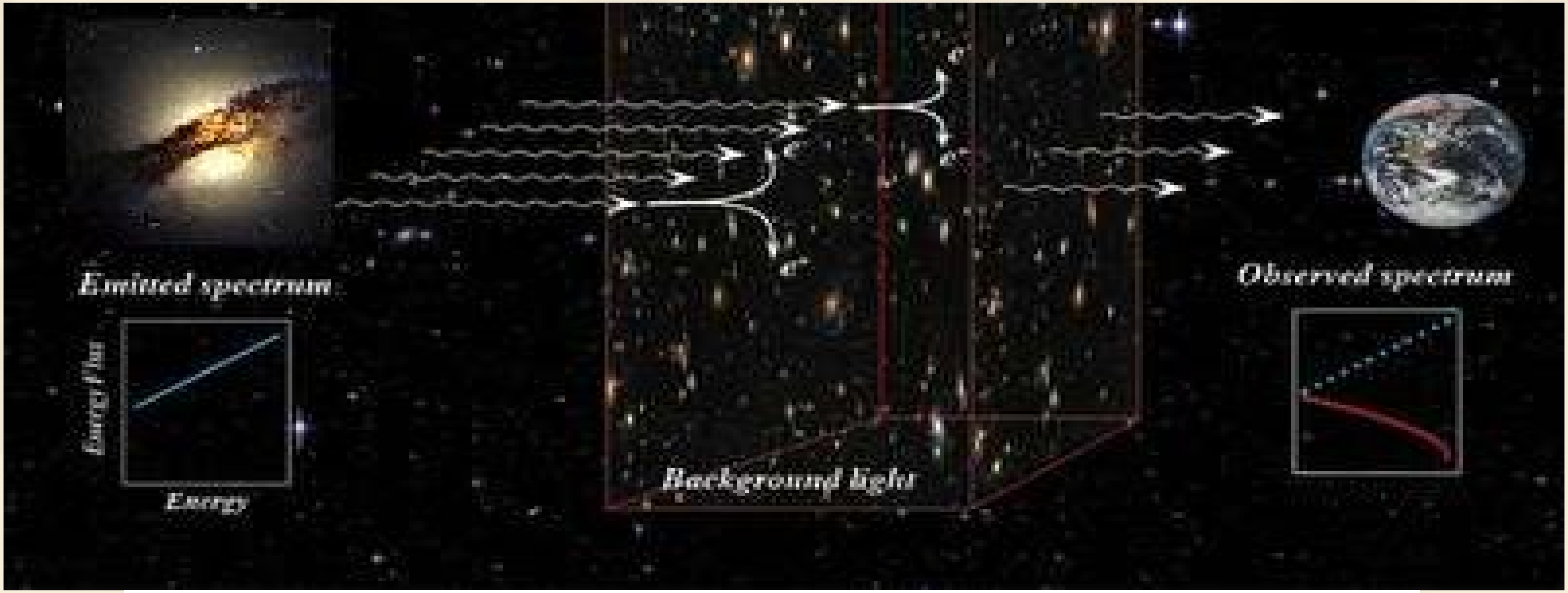
2. intrinsic spectrum —— unknown

3. background radiation field —— known to some extent

4. distance to us —— determined by cosmology and determine cosmology

Our point: employing 1 & 3 to derive 2 & 4

Measuring the universe with TeV γ -rays: a bit detail

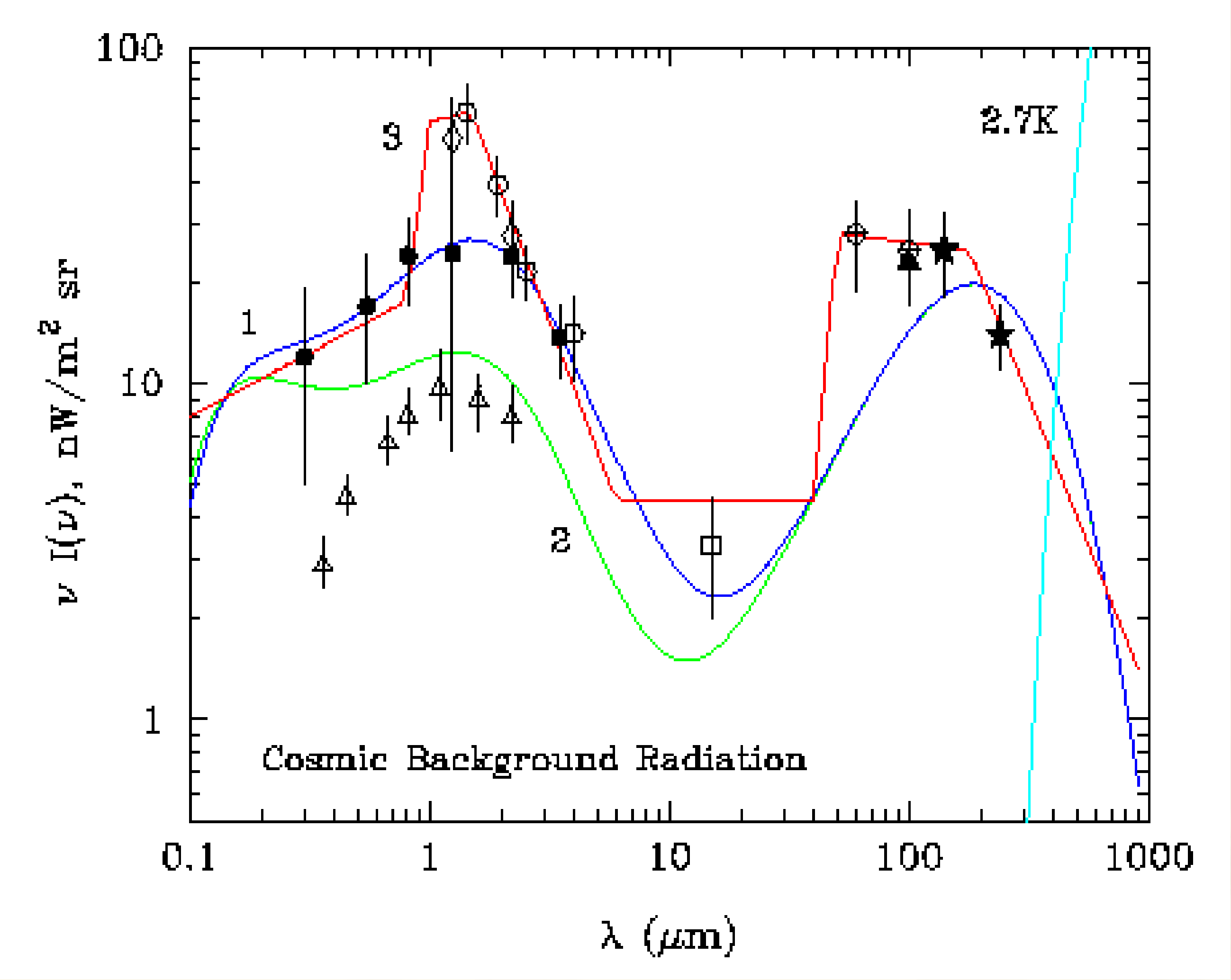


$$\tau(E) = \int \mathrm{d}l \int \mathrm{d}\cos\theta \frac{1-\cos\theta}{2} \int \mathrm{d}\epsilon n(\epsilon)\sigma(E,\epsilon,\cos\theta)$$

$$\mathrm{d}l = c\mathrm{d}t = \frac{c}{H_0}\frac{\mathrm{d}z}{(1+z)\sqrt{0.28(1+z)^3+0.72}} \propto \frac{1}{H_0}$$

Assuming the intrinsic spectrum is power-law, we use observations to fit the power-law index and distance (Hubble constant here) VHE γ -rays cross.

Cosmic infrared background (CIB) : from star and dust in galaxies

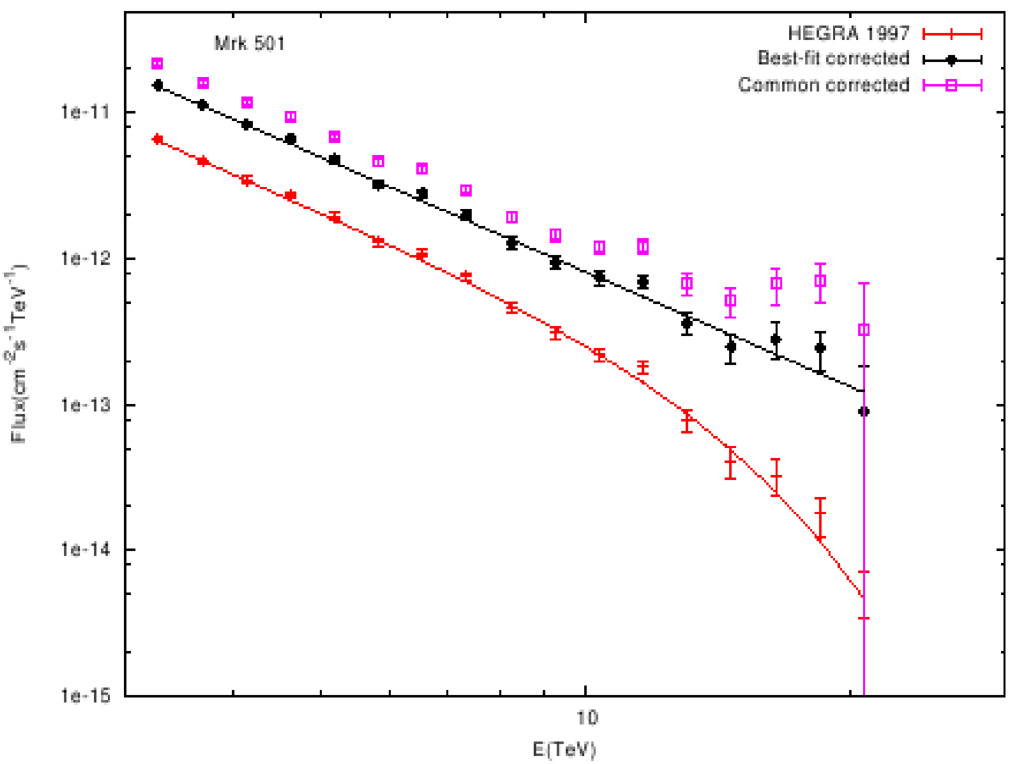


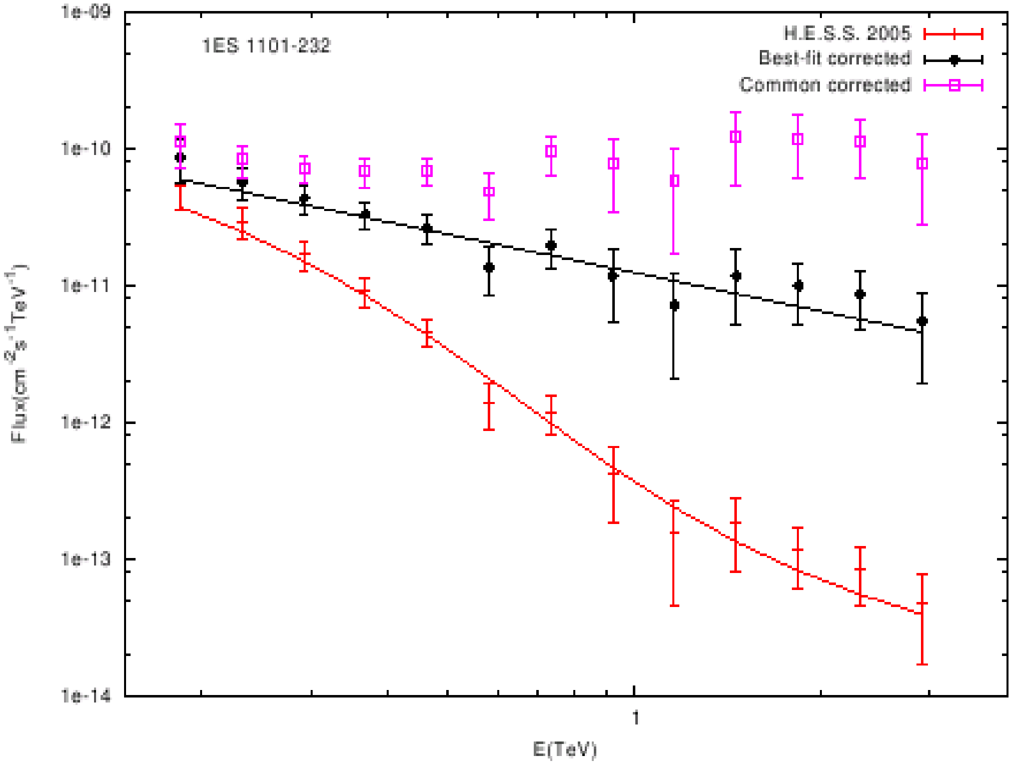
Aharonian, 2001, ICRC

1. model of choice
2. lower limit
3. upper limit

Difficult to determine from direct measurements due to Galactic foreground

Observations of Mrk 501 and 1ES 1101-232

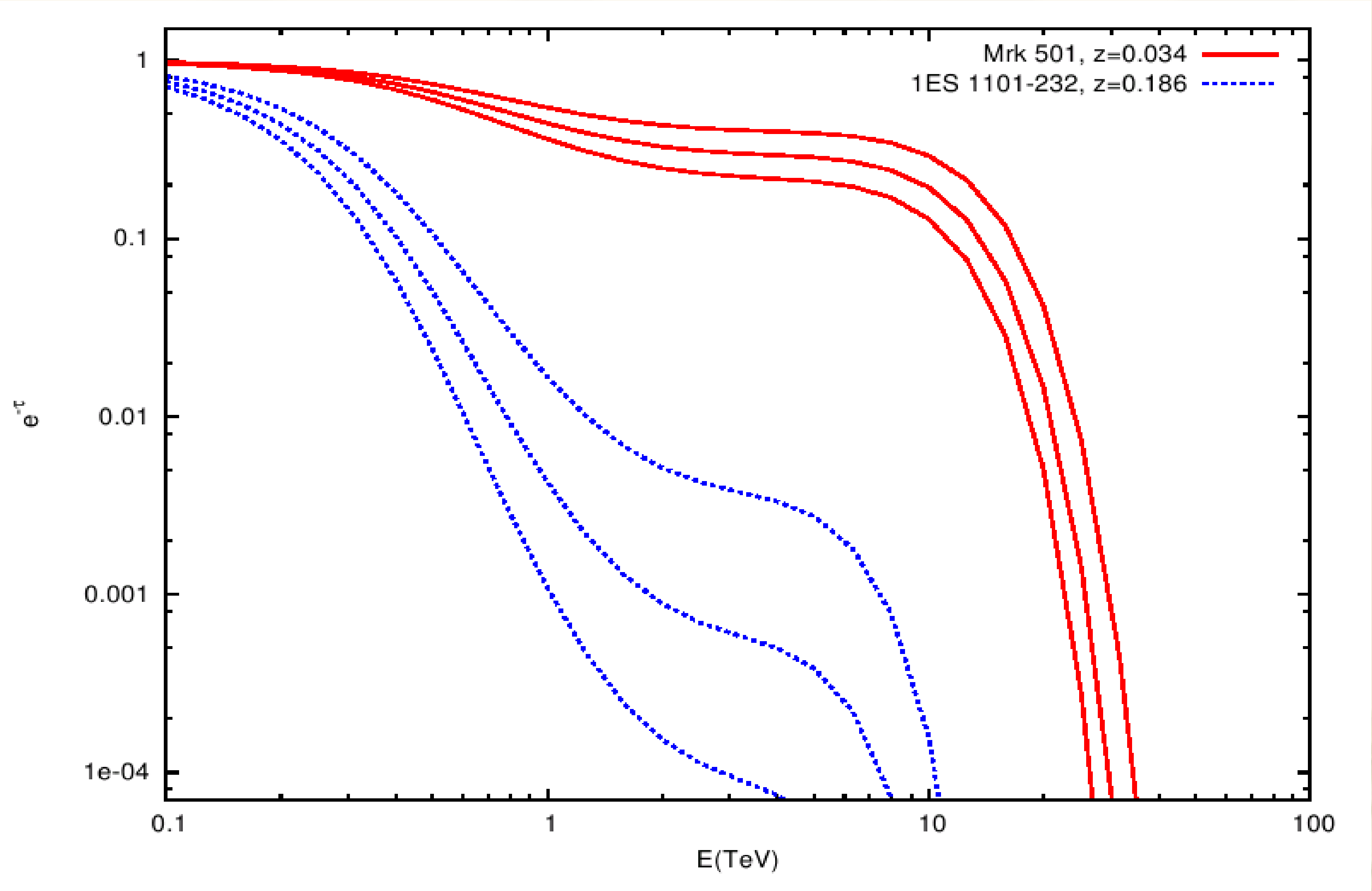




Aharonian et al., 2001, A&A, 366, 62

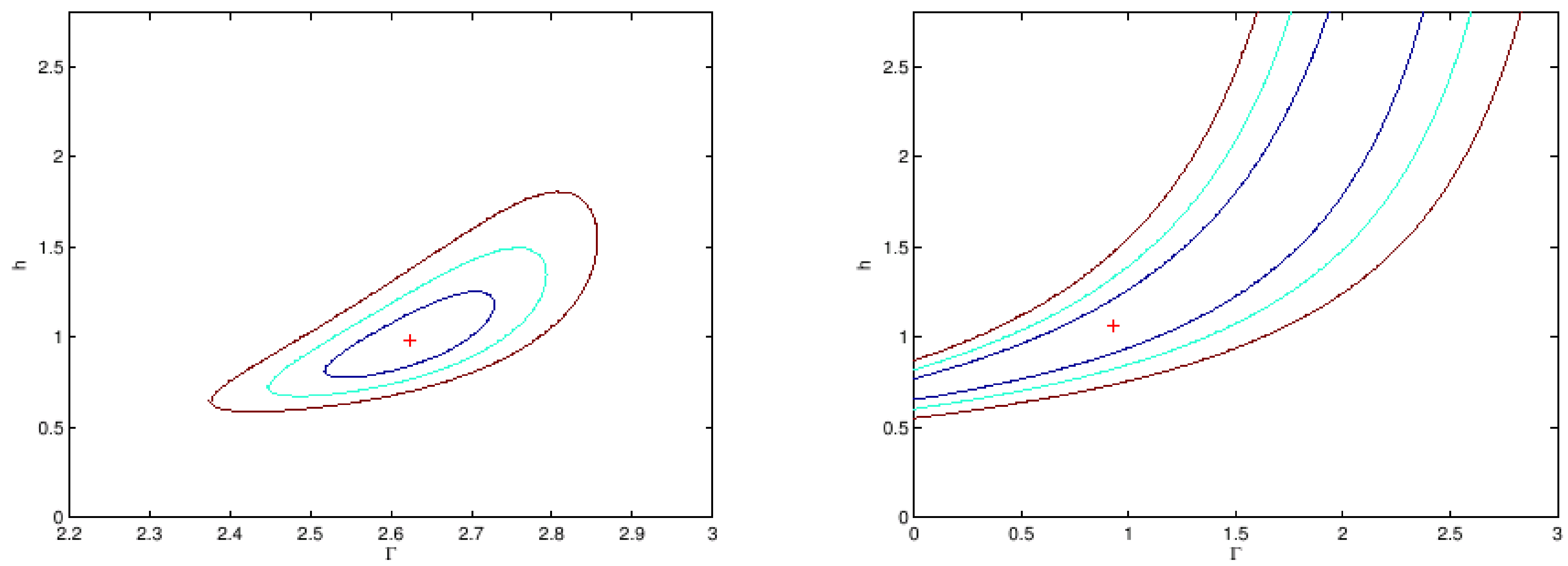
Aharonian et al., 2006, Nature, 440, 1018

Attenuation factors of two sources: Mrk 501 and 1ES 1101-232



Calculated using the "best" CIB together with ±25% uncertainties, h=0.7

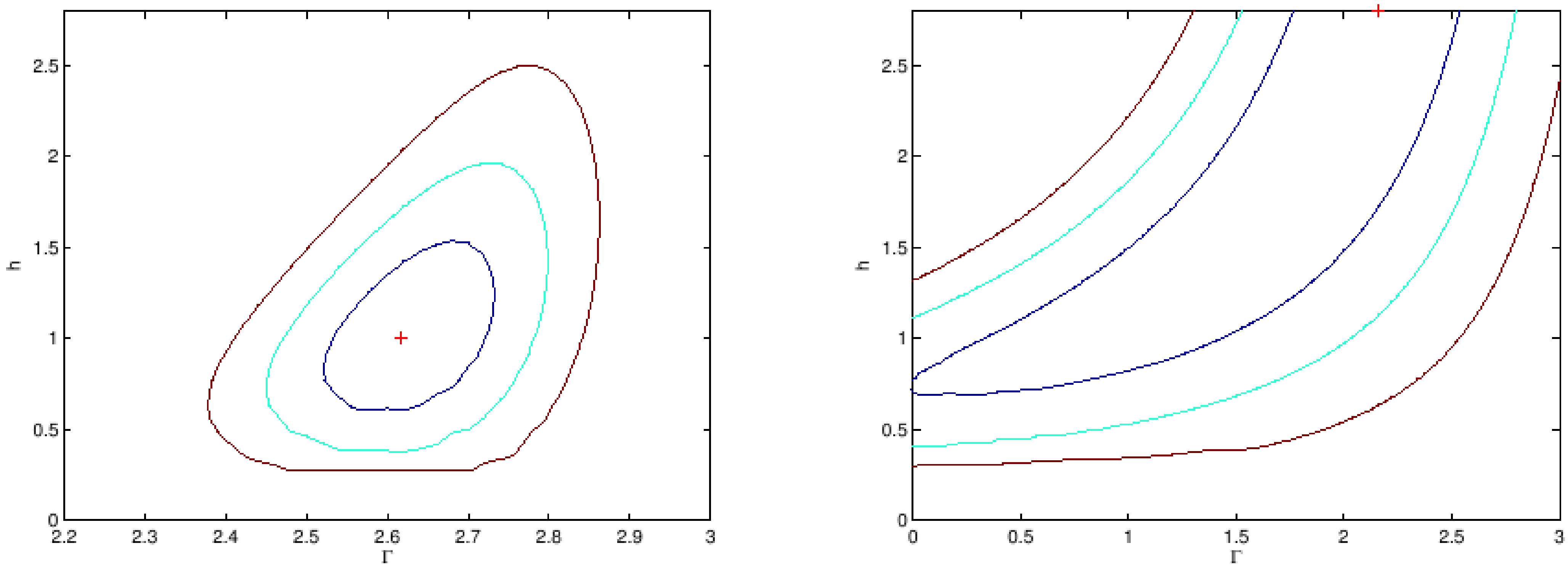
Fitting results: "best" CIB model



Mrk 501: h=0.98, Γ =2.62

1ES1101-232: h=1.09, Γ =0.93

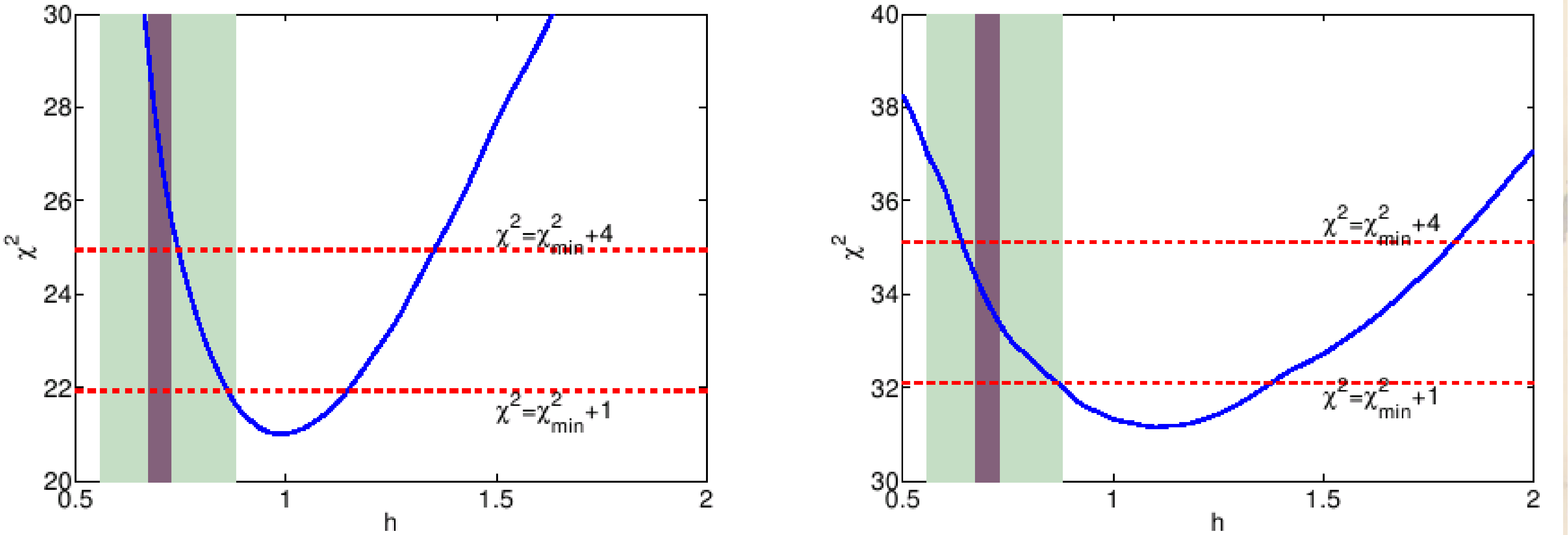
Fitting results: "best" CIB with ±25% uncertainties



Mrk 501: h=1.01, Γ =2.62

1ES1101-232: h=2.80, Γ =2.15

Fitting results: combination of two sources



"best" CIB: $h = 1.00^{+0.15}_{-0.14}$

"best" CIB with uncertainties:

$h = 1.05^{+0.35}_{-0.19}$

Summary & discussion

1. The absorption of VHE γ -rays by background radiation is a very important topic in astrophysics.

2. It is a useful tool to unveil the cosmic background radiation and can be used to measure the universe.

3. We show best fitting Hubble constant h~1, which is larger than result derived from other cosmological probes. It may imply the absorption is not as strong as we thought.

4. There are large uncertainties on the CIB model and measurements at present.

5. The intrinsic spectra of blazars might not be simply power-law. Multi-wavelength information will be helpful in understanding the emission mechanism and determining the intrinsic spectra.

6. Large sample, high precision spectra, wide redshift distributions by future experiments, e.g., GLAST (FGST) will shed new light on this problem.

7. Our prototype study shows that the absorption of VHE γ -rays can indeed be a potential cosmological probe, and be an independent and complementary method to measure the universe.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Thank you!