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Blazars as beamlights to probe the EBL

Problem: EBL, emitted SED: both unknown !

Aim: measure $n_{EBL}(z)$ at different redshifts
→ local normalization, cosmic evolution

Tools: homogeneous set @ different redshifts

- one same model (parameters) at all *z*
  - → **blazars** (*e.g.*, **High-Peaked BLs** [HBLs])

B.Lott's talk

Emission physics: simple → one-zone **SSC** emission

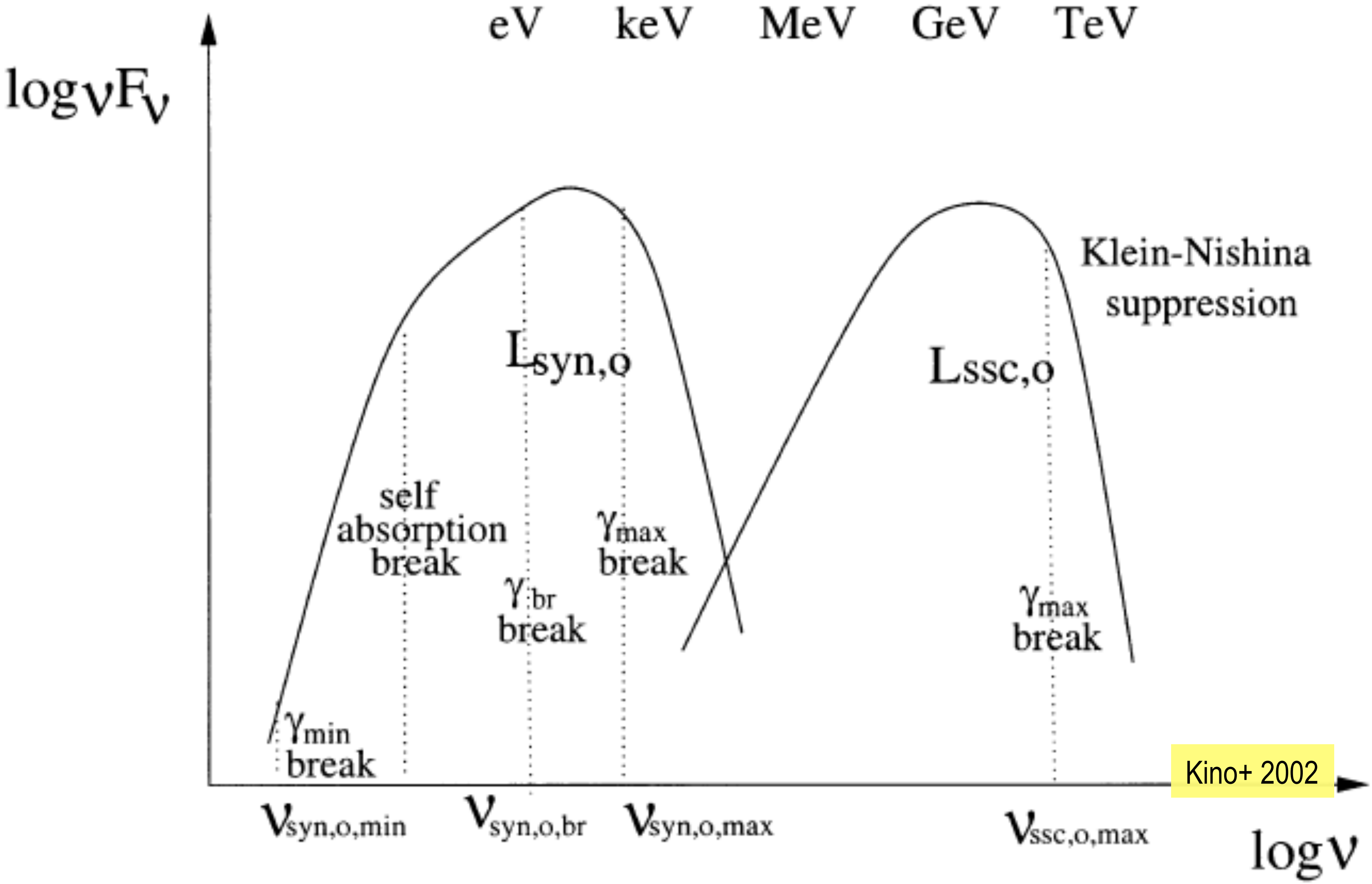
- synchrotron + compton, PL electron spectrum

One-zone SSC: model parameters:

Plasma blob: R, B, δ_j

Electron pop: n_0, α_1, α_2, E_{br}, E_{min}, E_{max}

Tavecchio + 2001
ApJ, 554, 725



The method (1)

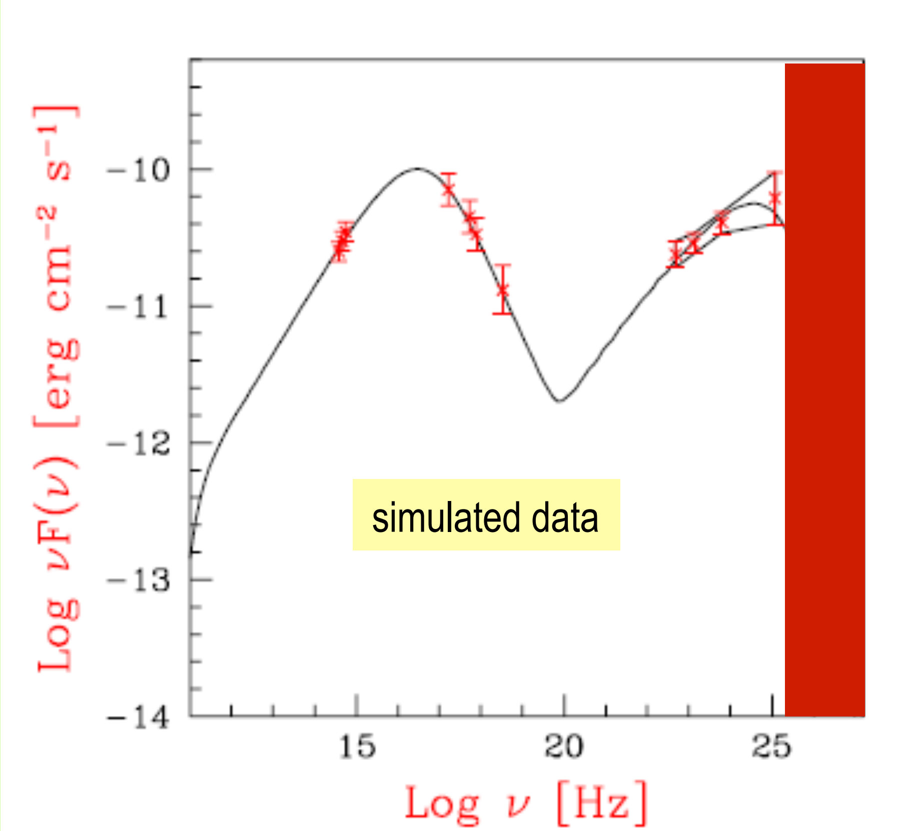
Simultaneous multi-ν obs's:

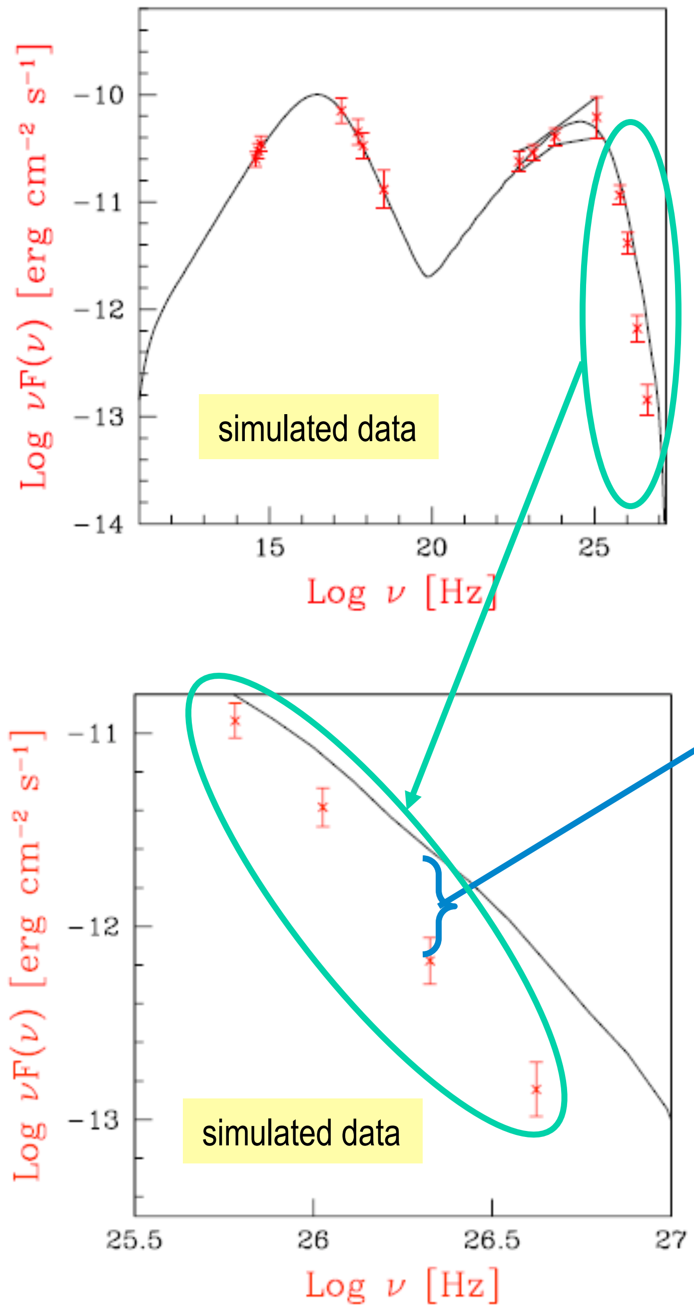
❖ optical + X-rays + HE γ-ray + VHE γ-ray

Model SED: use SED w/out (EBL-affected) VHE γ-ray data:

→ χ^2-minimization → SSC model

(check structure of multi-D parameter space)





...the method (2)

Extrapolate model SED into VHE regime

→ **"intrinsic" blazar VHE emission**

Observed vs "intrinsic" emission

→ $\tau_{\gamma\gamma}(E,z)$

Assume (concordance) cosmology

→ $n_{EBL}(\varepsilon, z_j)$ (parametric: $\sum a_{nj}\, \varepsilon^n$)

Checking the method … locally

PKS 2155-304

z = 0.12

Aharonian+ 2009
ApJ, 696, L150

SSC param's

$\gamma_{min} = 1$

$\gamma_{br1} = 1.4\times10^4$

$\gamma_{br2} = 2.3\times10^5$

$\gamma_{max} = 3\times10^6$

$\alpha_1 = 1.3$

$\alpha_2 = 3.2$

$\alpha_3 = 4.3$

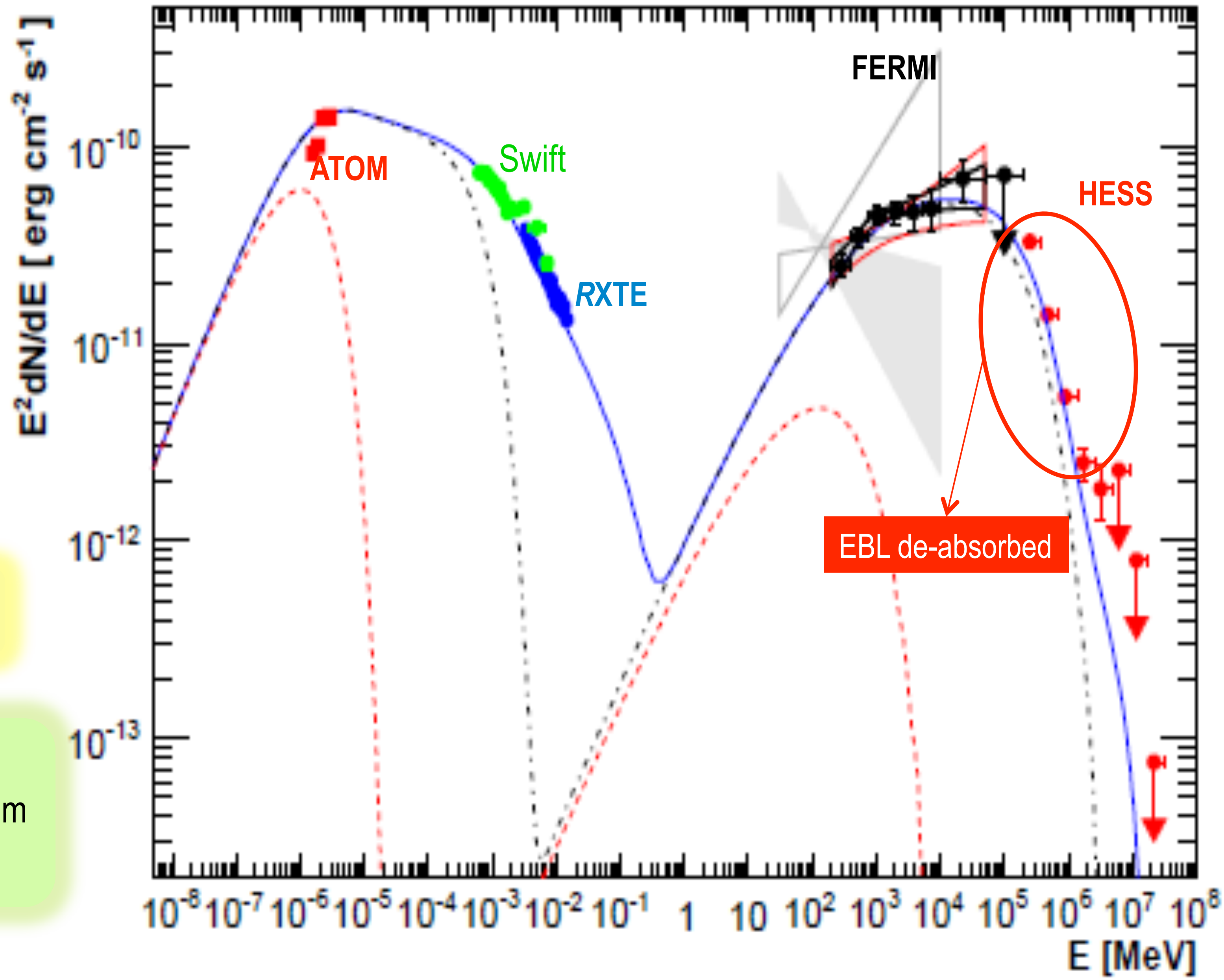
$B = 0.018$ G

$R = 1.5\times10^{17}$cm

$\delta = 32$

… caveat…

… assumed electron spectrum is **triple**-PL …



… our effort

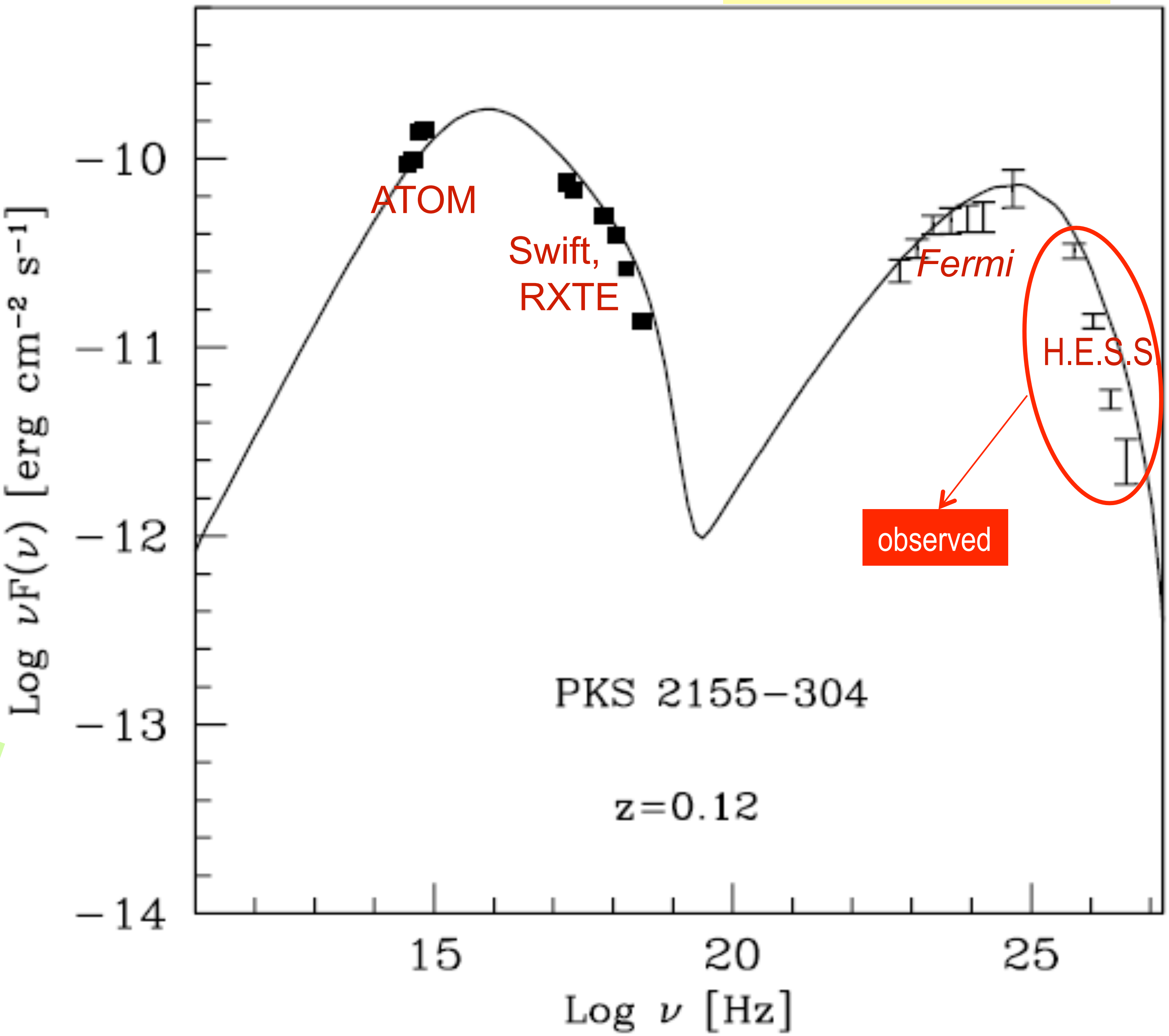
data: Aharonian+ 2009
ApJ, 696, L150

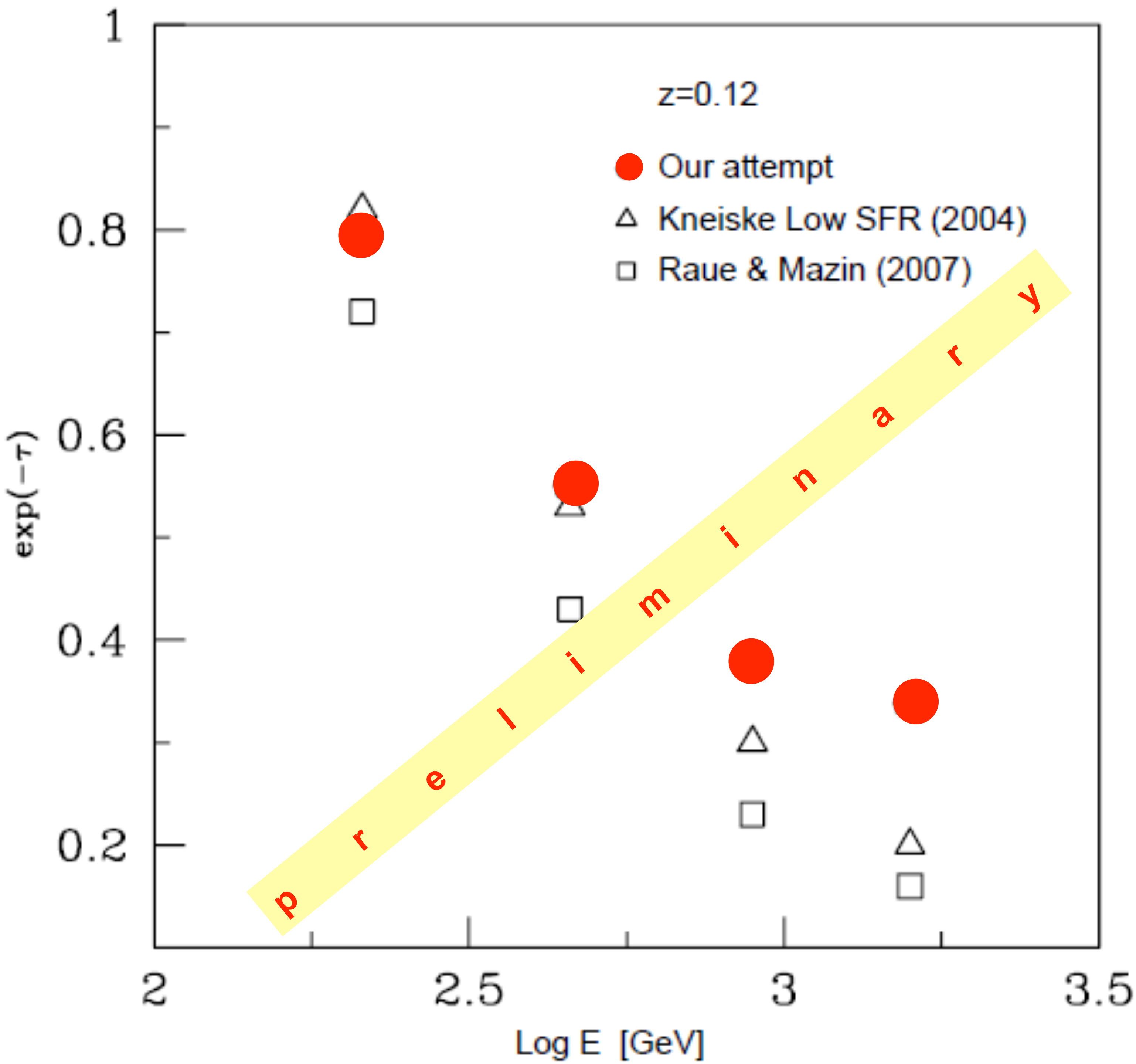
SSC parameters from χ^2 minim.

n_e=150 cm^{-3}
γ_{min}= 1
γ_{br} = 2.9×10^4
γ_{max}= 8×10^5
α_1 = 1.8
α_2 = 3.8

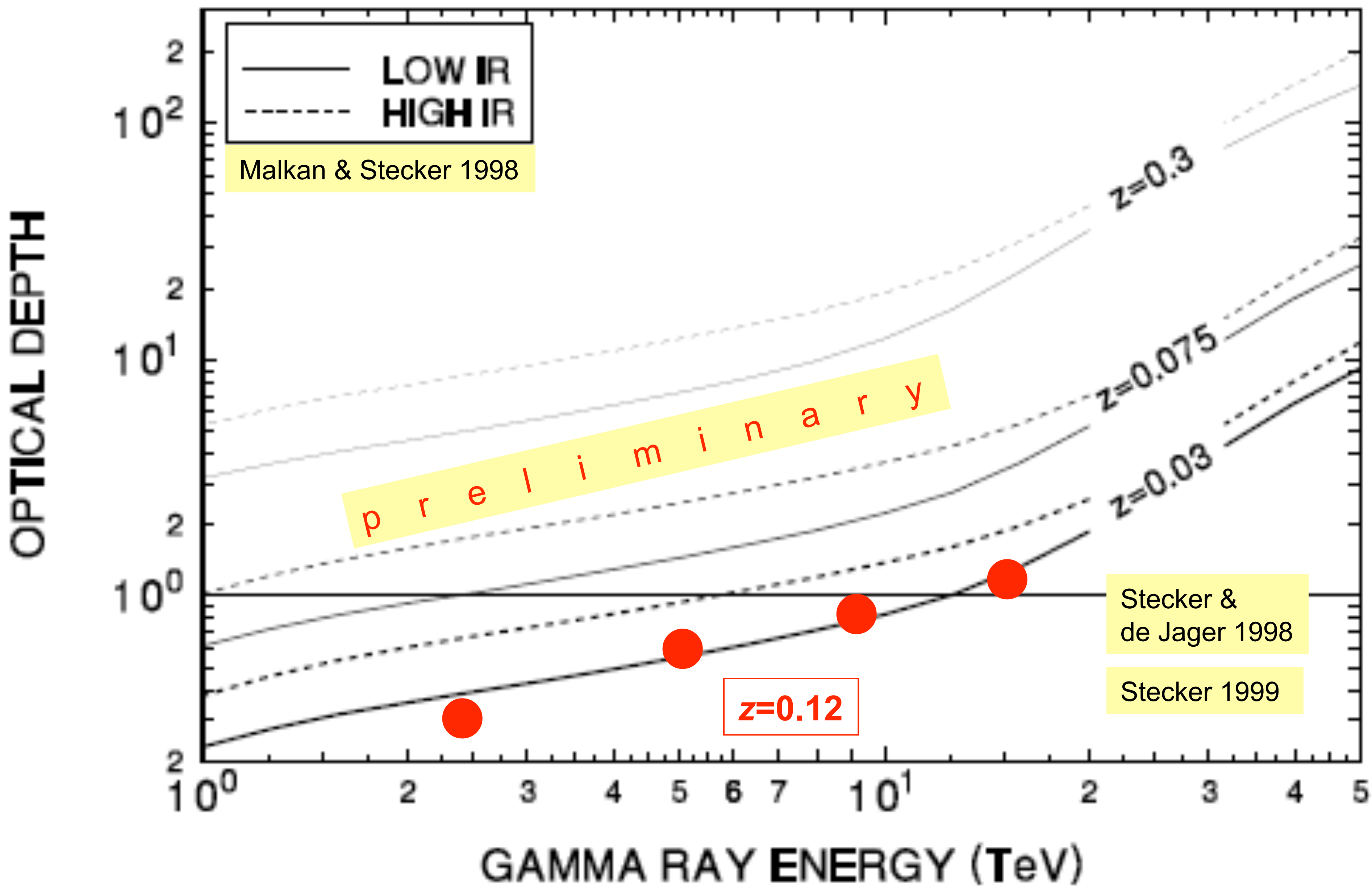
B = 0.056 G
R = 3.87×10^{16} cm
δ = 29.2

R → $\Delta t \approx$12 hr → **OK**

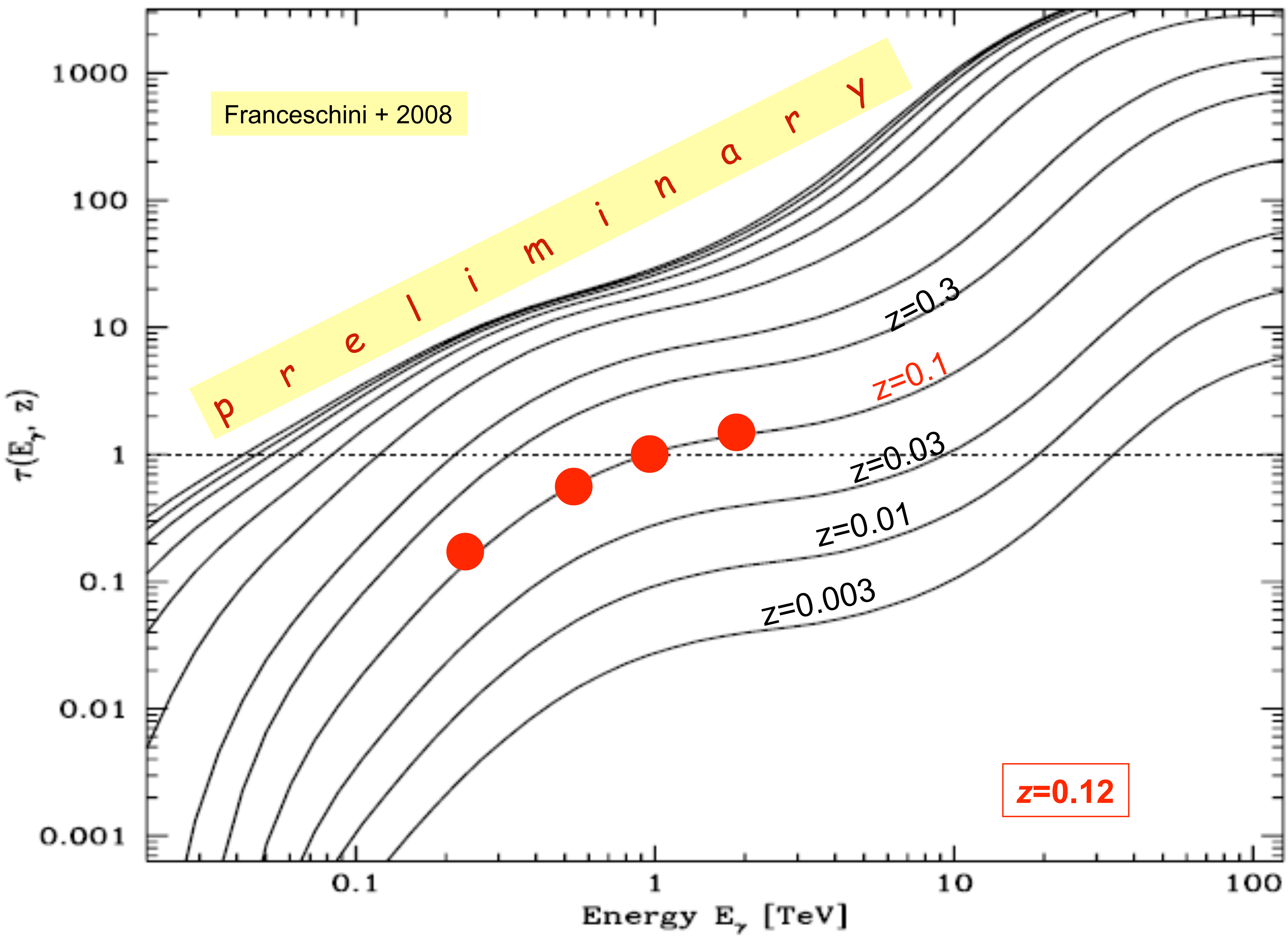




z=0.12
Our attempt
Kneiske Low SFR (2004)
Raue & Mazin (2007)
preliminary
exp(−τ)
Log E [GeV]
1
0.8
0.6
0.4
0.2
2
2.5
3
3.5



LOW IR
HIGH IR
Malkan & Stecker 1998
z=0.3
z=0.075
z=0.03
preliminary
z=0.12
Stecker & de Jager 1998
Stecker 1999
OPTICAL DEPTH
GAMMA RAY ENERGY (TeV)



Franceschini + 2008
p r e l i m i n a r y
1000
100
10
1
0.1
0.01
0.001
τ(E_γ, z)
z=0.3
z=0.1
z=0.03
z=0.01
z=0.003
z=0.12
0.1
1
10
100
Energy E_γ [TeV]

For EBL photon energies
$\varepsilon > 2(m_e c^2)^2 / E\,(1-\cos\phi)$

$\beta(E,\varepsilon,\phi) \equiv [1 - 2(m_e c^2)^2 / E\varepsilon\,(1-\cos\phi)]^{1/2}$

$$\sigma(E,\varepsilon,\phi) = 1.25 \times 10^{-25}(1-\beta^2) \times \left[2\beta(\beta^2-2) + (3-\beta^4)\ln\left(\frac{1+\beta}{1-\beta}\right)\right] \text{cm}^2$$

Heitler 1960

$\sigma(E,\varepsilon)$ max by (for head-on collision) $\epsilon_{IR} \sim \frac{2(mc^2)^2}{E_\gamma} = 0.5\left(\frac{1\ \text{TeV}}{E}\right)\text{eV} \approx 2.5\, E_{\gamma,\,\text{TeV}}\ \mu\text{m}$

IACT: 0.05 – 100 TeV → 0.12 – 250 μm

Optical depth

$0 \le z \le z_s$

$x \equiv 1-\cos\phi$

$\varepsilon > 2(m_e c^2)^2 / [Ex(1+z)^2]$

$$\tau(E_\gamma,z) = \int dl/dz \int x/2 \int n_{EBL}(\varepsilon)\, \sigma(2xE\varepsilon/(1+z)^2)\ d\varepsilon\, dx\, dz$$

Stecker 1971

$= c/(1+z)\ dt_{lookback}/dz$ → cosmology

⇨ $n_{EBL}(\varepsilon,z)$ unknown → parameterize

... work in progress ...

$$n_{EBL}(\varepsilon_n,z_j) = \sum a_{n,j}\,\varepsilon^n$$

Stecker 1999

Conclusion

Cons:
- indirect measurement of EBL
- method depends on blazar model

Pros:
- unbiased method
- no assumptions on EBL, blazar SED
- SSC well tested locally on different emission states

Check:
- on local (z=0.12) blazar PKS 2155-304
- deduced τ's within reasonable range

OK

Aim:
- to probe EBL out to $z \approx 1$ with *Fermi*/LAT + current/upcoming enhanced IACTs (+ x-ray, optical tel's)

(→ long live *Fermi* to see CTA / AGIS !!)

Need:
- simultaneous multi-ν obs's of several blazars in shells of z
- possibly each source seen @ different levels of activity (to increase statistics)

→ plan simultaneous obs's involving IACTs + Fermi + X-rays + optical

Thanks