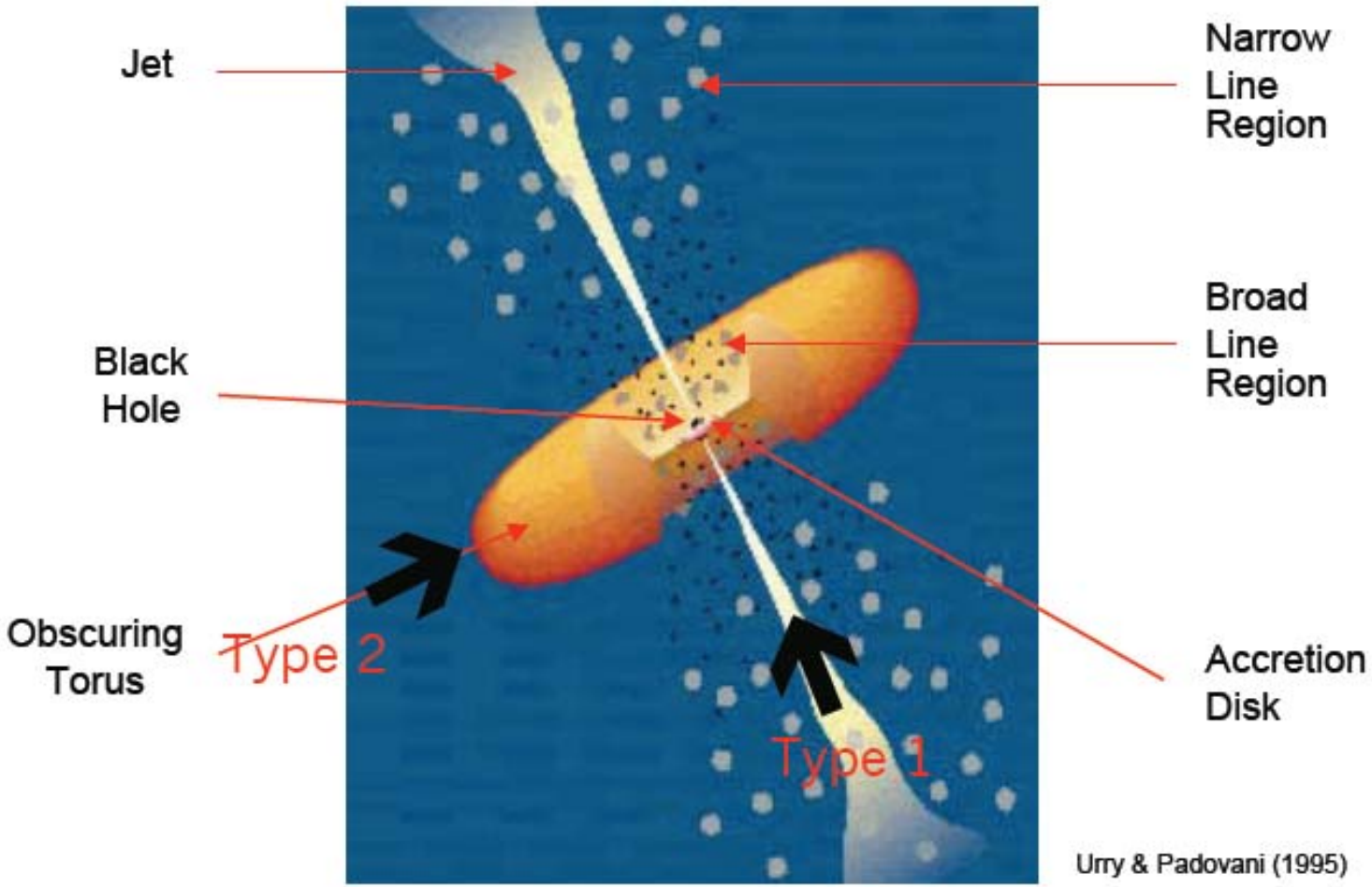
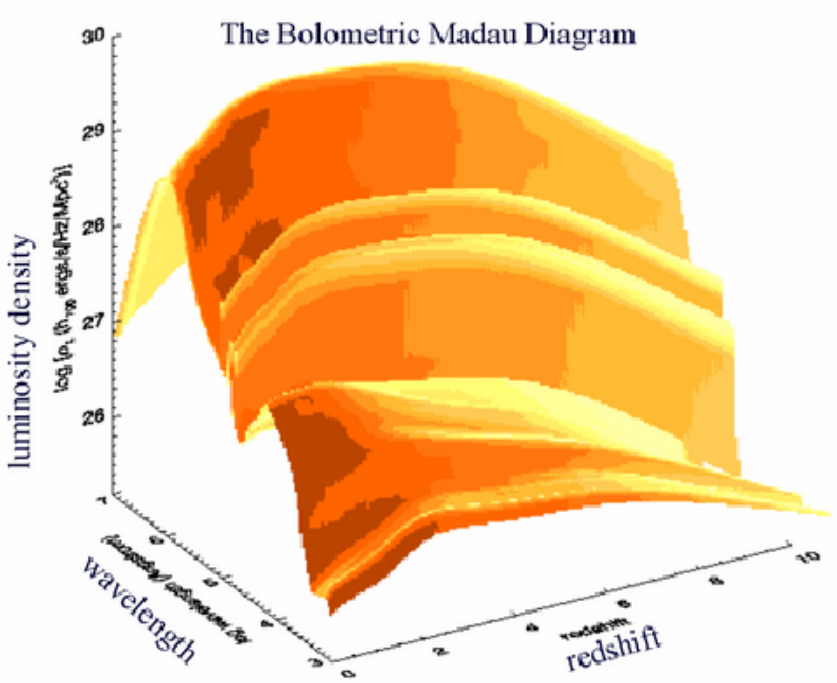
GeV-photon absorption in cosmologically evolving quasar environments

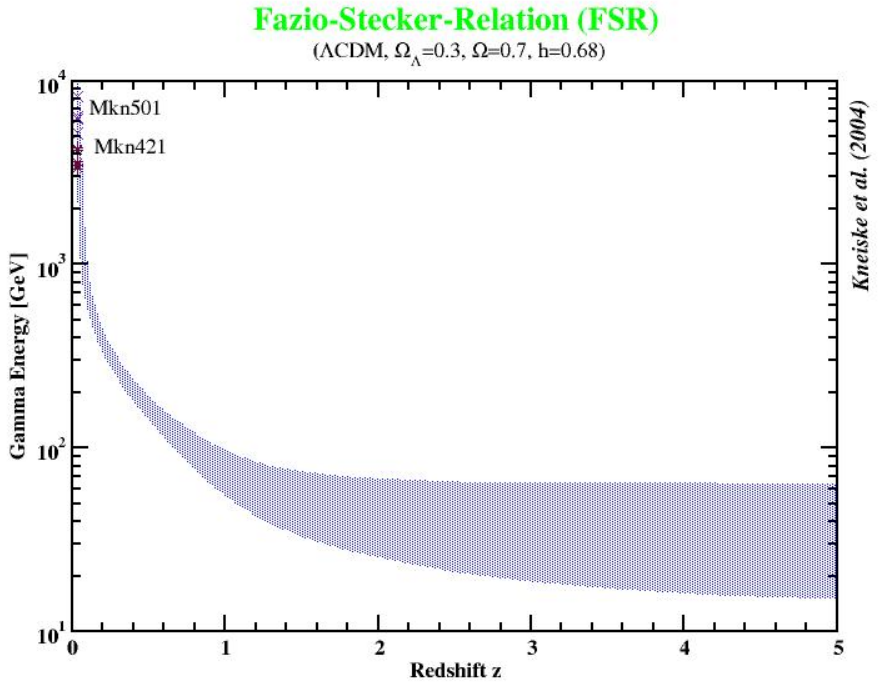


Anita Reimer, HEPL & KIPAC, Stanford University

GLAST-lunch talk, 1 March 2007

Motivation





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DETECTING THE ATTENUATION OF BLAZAR GAMMA-RAY EMISSION BY EXTRAGALACTIC BACKGROUND LIGHT WITH THE *GAMMA-RAY LARGE AREA SPACE TELESCOPE*

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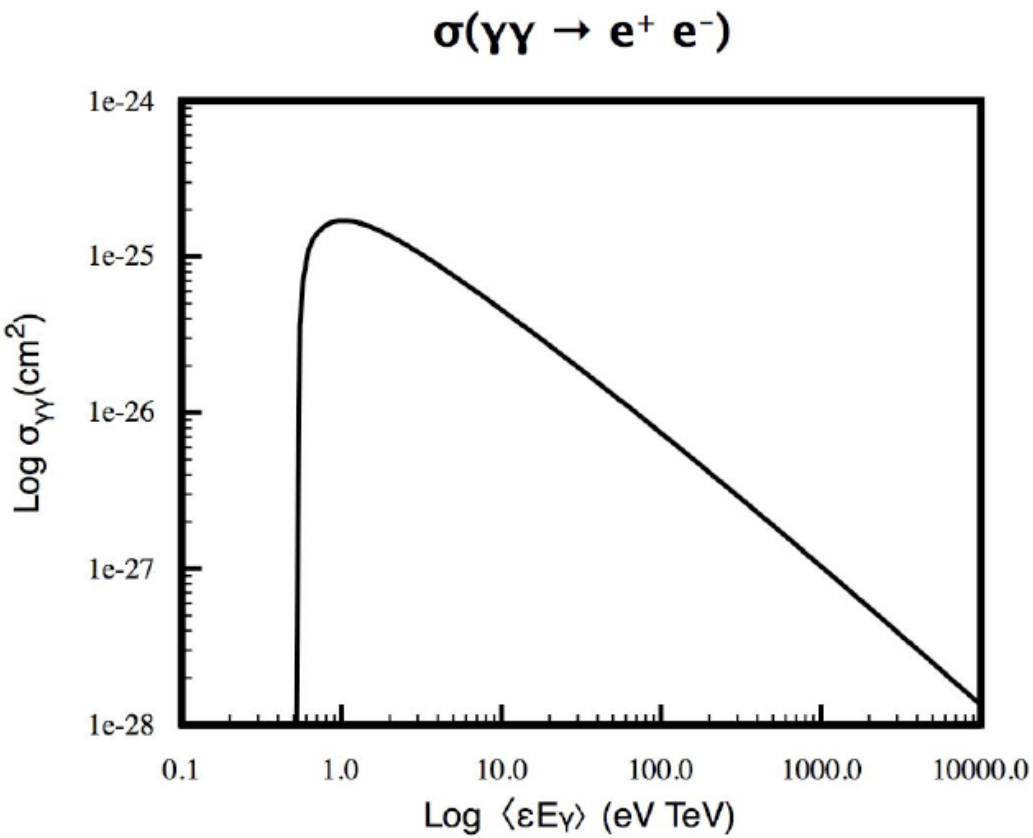
" Even after observation of a redshift-dependent effect, the possibility would remain that the spectral evolution of gamma-ray blazars might coincidentally mimic redshift-dependent EBL absorption. For example, if blazars that formed in the early universe suffered more internal attenuation than blazars that formed later, the same effect could be produced. Note that

...

spectral softening will provide an important constraint. Theorists will have to decide the likelihood of an evolutionary conspiracy. "

Can one distinguish between "intrinsic" and EBL-caused absorption by redshift-dependence of optical depth?

$\gamma\gamma \rightarrow e^+e^-$



$$\tau(E_\gamma, z) = \int_0^{z_{Source}} dz \frac{dl}{dz} \int_0^2 dx \frac{x}{2} \int_{\frac{2m_e^2c^4}{E_\gamma x(1+z)}}^{\infty} d\varepsilon \; n(\varepsilon, z)\sigma(s)$$

$$s = 2xE_\gamma \varepsilon(1+z) \qquad E_\gamma = E_\gamma(z=0)$$

$$\varepsilon = \varepsilon(z)$$

$$x = 1 - \cos\theta$$

$$\sigma(s) = \sigma_0(1-\beta^2)\left[2\beta(\beta^2-2) + (3-\beta^4)\ln\left(\frac{1+\beta}{1-\beta}\right)\right]$$

$$\frac{dl}{dz} = \frac{c}{H_0}(1+z)^{-1}\left[\Omega_\Lambda + \Omega_m(1+z)^3\right]^{-1/2}$$

The cross section maximizes at $x=(1-y^{-1})^{1/2}\approx 0.7$, where $y=0.5\varepsilon_1\varepsilon_2(1-\cos\theta)>1$ ($\varepsilon_1,\varepsilon_2$ in m_ec^2, θ=photon interaction angle) is the threshold condition of the pair production process.

$\gamma\gamma \rightarrow e^+e^-$ in accretion disk & BLR radiation field of quasars

Accretion disk radiation field:

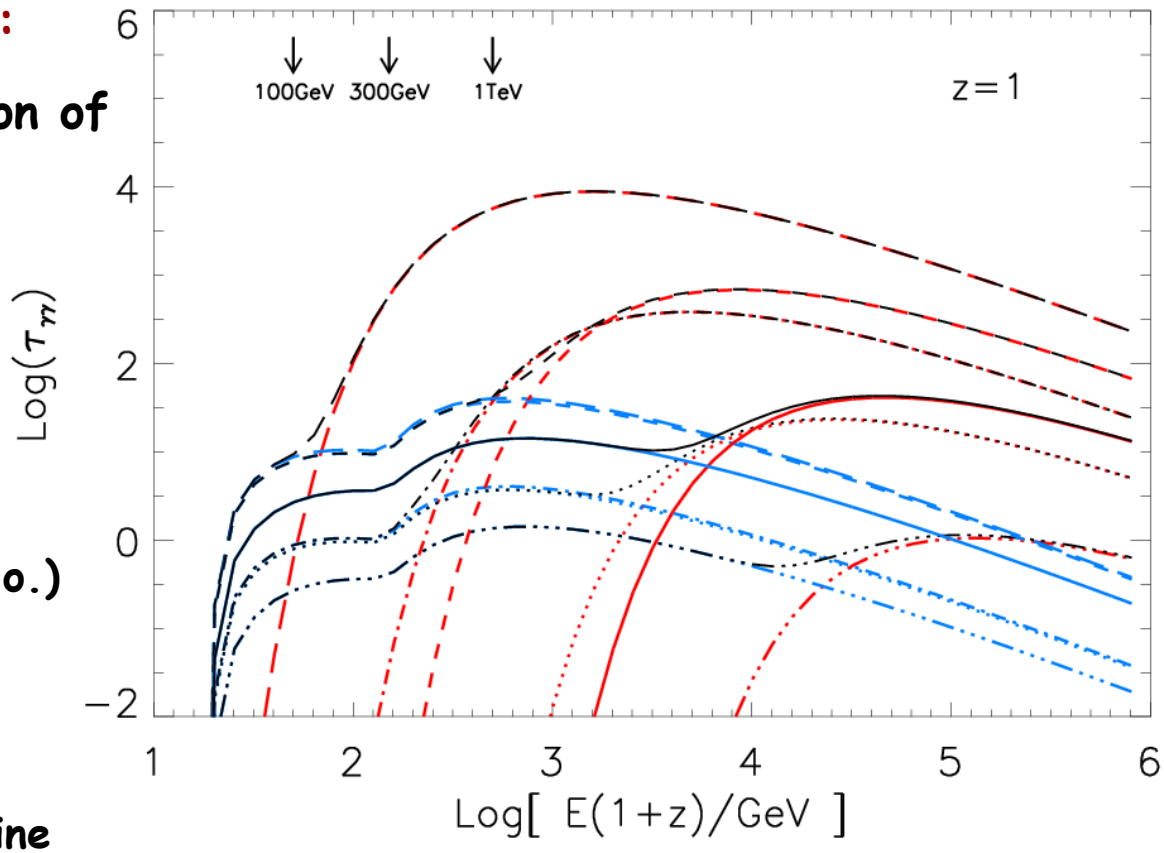
cool, optically thick bb solution of Shakura & Sunyaev (1973)

BLR radiation field
(geometr. thick shell case:
Donea & Protheroe 2003)

- spherical shell of clouds
(R=0.01…0.4pc, l_0=0.01pc i.n.n.o.)

- $L_{BLR}=\tau_{BLR}L_{disk}$, $\tau_{BLR}\approx 0.01$
(Celotti et al. '97)

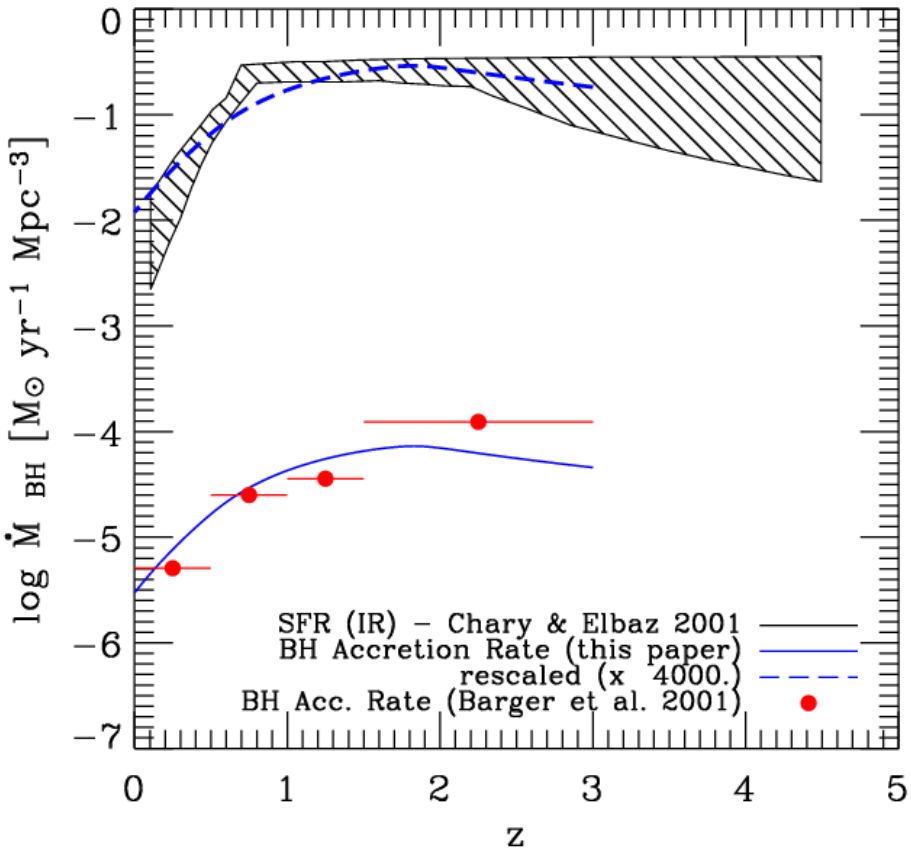
- average BLR spectrum
(Francis et al. '91) approx. as 2-line
(H_α,Ly_α) spectrum



$M_{BH}=10^8,10^9M_o$, l_0=0.1,0.01,0.001pc, $L_{disk}\approx 0.2L_{edd}$

If the γ-ray emission region is located not well beyond the BLR, mandatory for γ-ray production that involve external photon fields, intrinsic γ-ray absorption features in FSRQ spectra have to be expected at E(1+z) ≥ several tens of GeV.

Black hole (BH) evolution and accretion rates



From: Marconi et al. 2004

Cosmic accretion history has similar redshift dependence as cosmic star formation rate

- **accretion onto SMBH seems proportional to star formation rate on cosmic level**

→ models for co-evolution of SMBHs and host galaxies

BH evolution and accretion rates

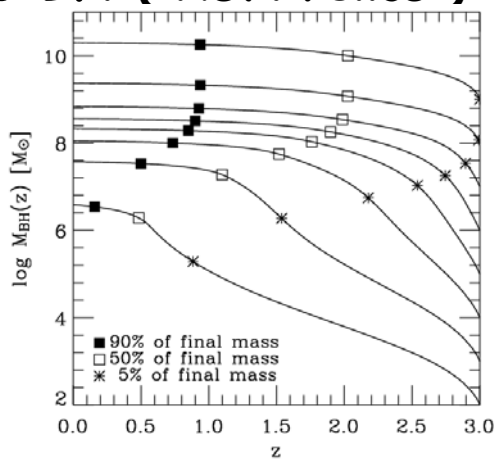
Netzer & Trakhtenbrot (2006):

- sample: ~10^4 SDSS type-I AGN (RL & RQ) spectra, $z \lesssim 0.75$
- study of 4D-space: M_{BH}, L_{acc}/L_{edd}, z, (metallicity)
- M_{BH} (L_{5100}, FWHM(H_β)) from reverb. mapping result of Kaspi etal. '05
- L_{acc}/L_{edd} (L_{5100}, M_{BH}, f_L=7)
- Results: $L_{acc}/L_{edd} \sim z^{\gamma(M)}$

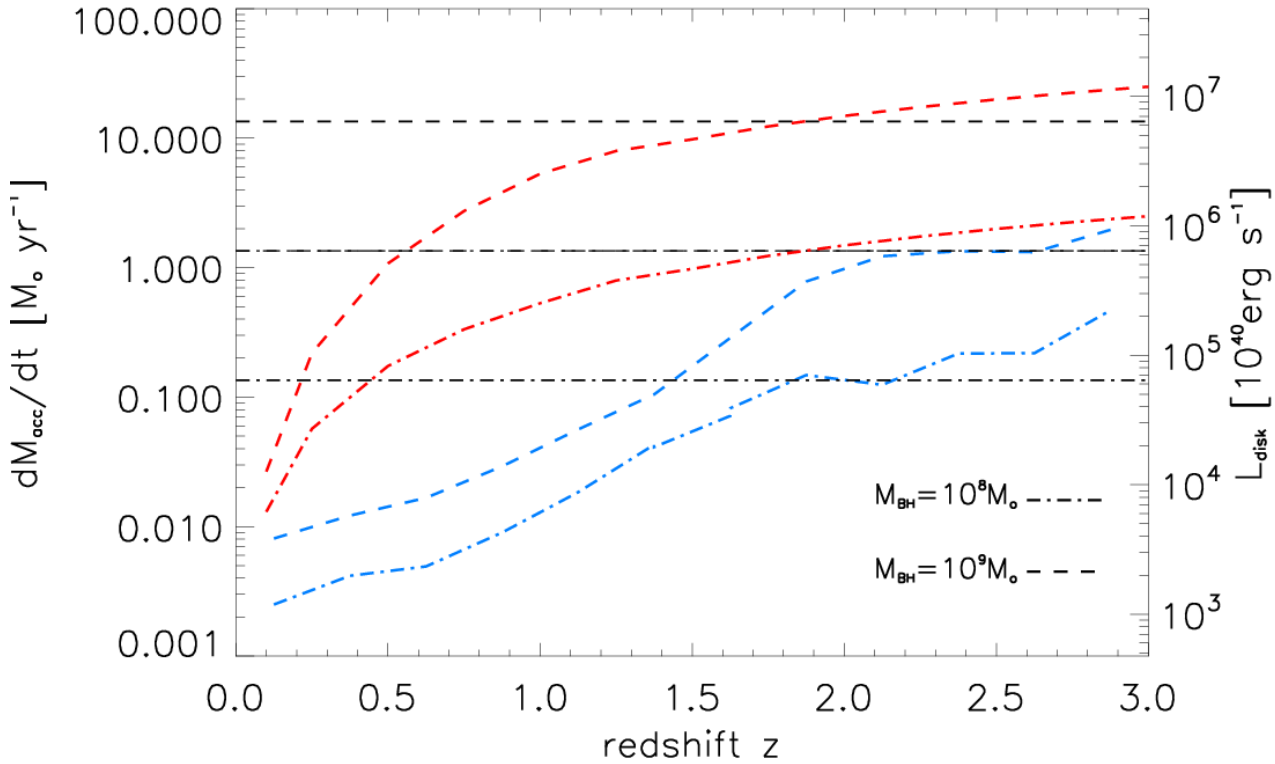
Marconi et al. (2004): *[see also: Granato etal '04, Lapi etal '06, Fontano etal '06, etc.]*

- assume: AGN activity caused by mass accretion onto BH ("AGN relics")
- estimate evolution of BHMF of AGN relics using continuity equation (relates LF & accretion rate; *BH duty cycle, accretion efficiency, Eddington ratio as parameters*) & constraints from local BHMF, energetics from XRB
- estimate accretion history (& aver. BH lifetime)

→ "anti-hierarchical" BH growth →see Lapi's ABC model



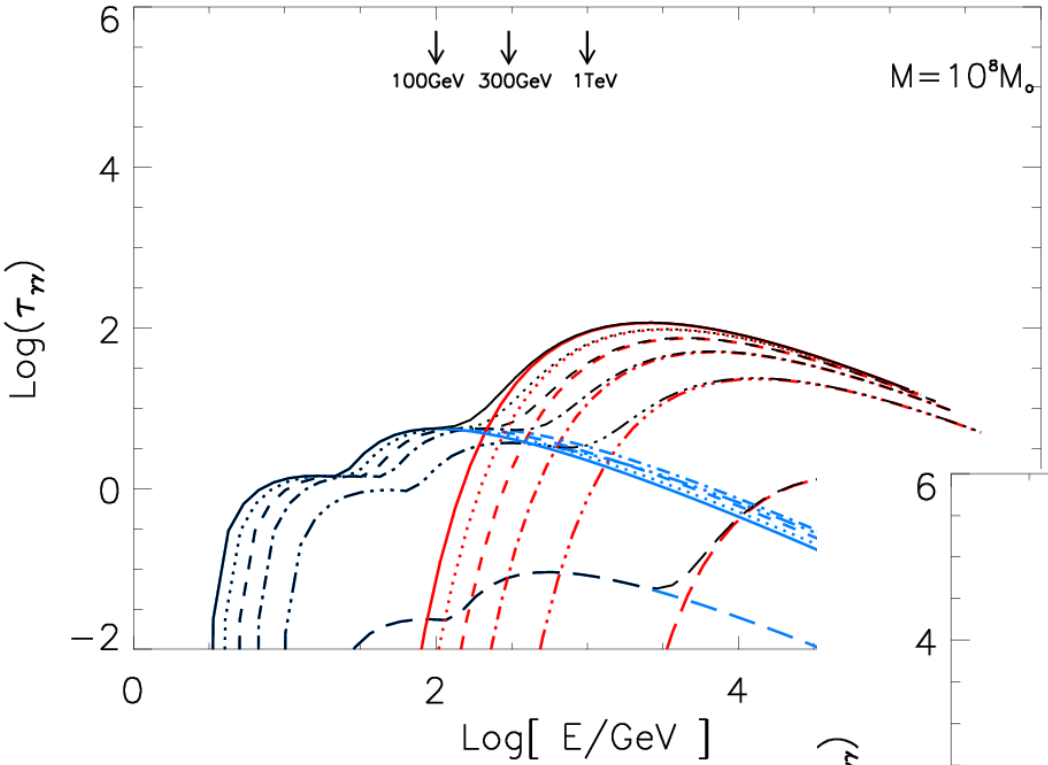
Black hole evolution and accretion rates



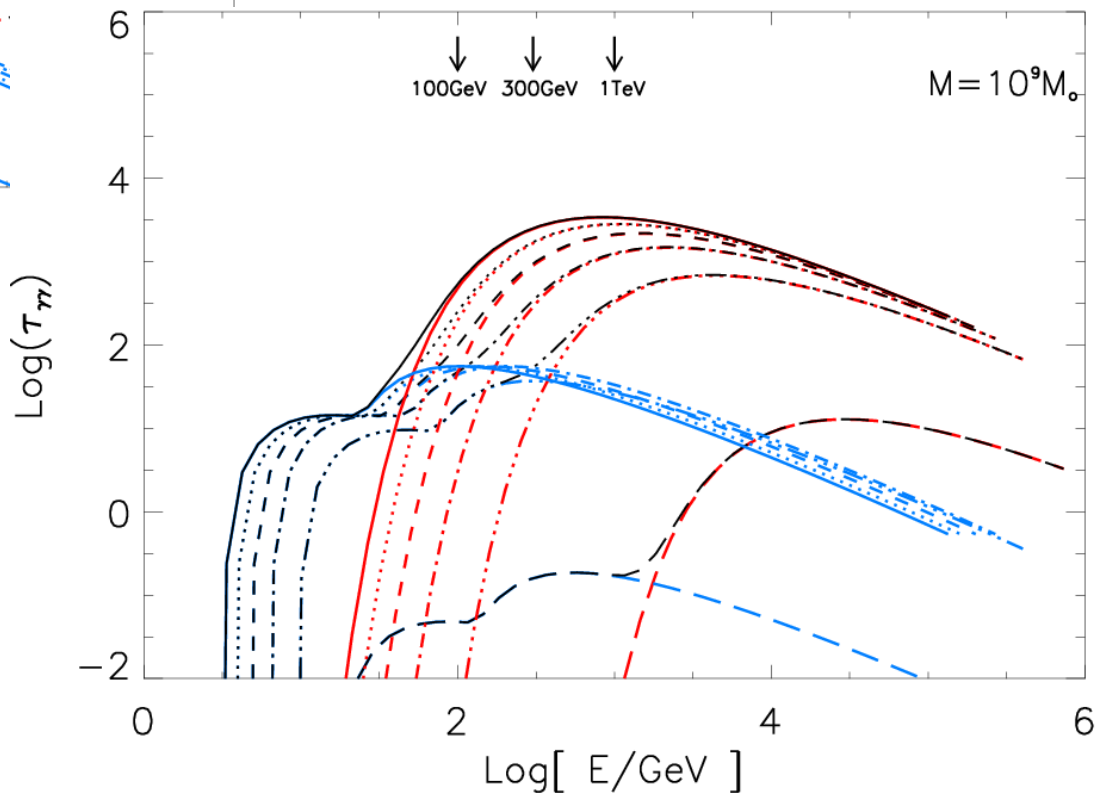
Three evolution models: Netzer et al 2006 (complemented by Lapi etal) , Marconi et al 2004, no evolution ($\dot{M}_{acc}$=0.1...1M_{edd})

BH demographics implies: redshift-dependent BH growth/accretion rates with higher rates at larger redshifts.

Is the „intrinsic opacity" redshift-dependent?

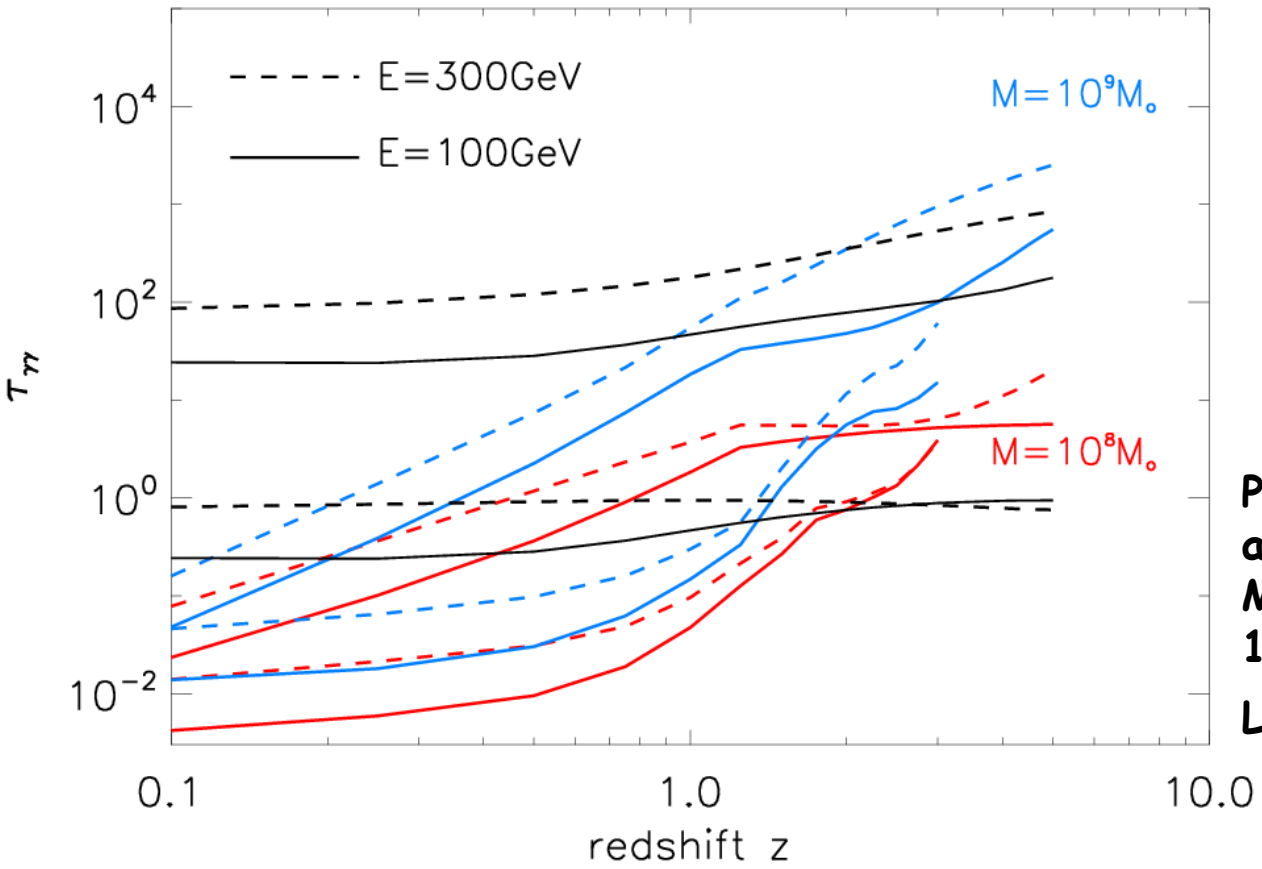


Opacity curves for redshift z=0.1, 1, 2, 3, 4, 5 with accretion rates following Netzer-Lapi



γ-ray absorption in LAT energy range mostly in increasing part of $\tau_{\gamma\gamma}(E)$ near threshold

Is the „intrinsic opacity" redshift-dependent?

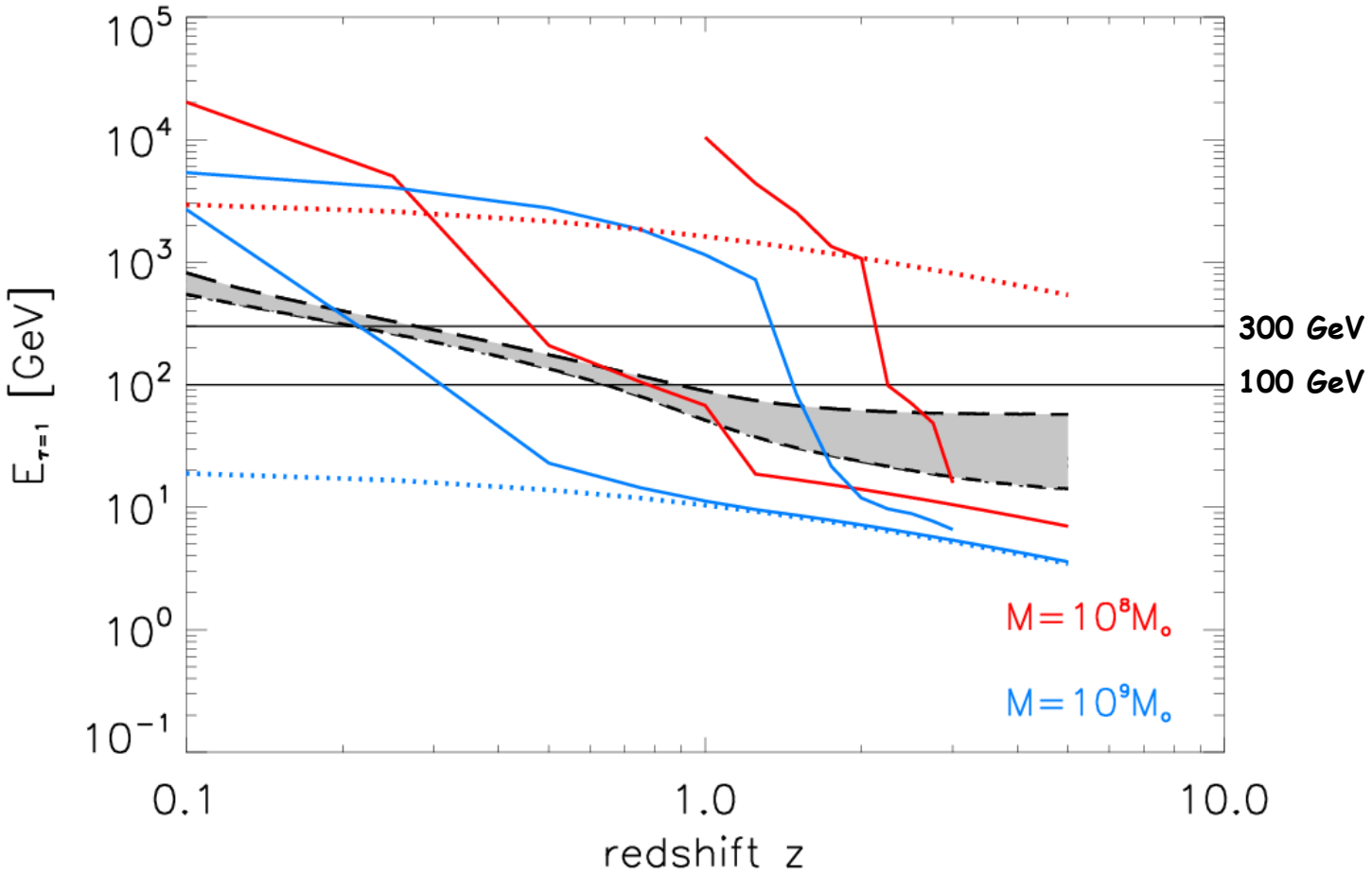


Parameters for non-evolving accretion rate curves: $M_{BH}=10^9 M_\odot$, $L_{disk}=0.5L_{edd}=6\ 10^{46}$erg/s, $M_{BH}=10^8 M_\odot$, $L_{disk}=0.05L_{edd}=6\ 10^{44}$erg/s

Redshift-dependence of opacity in almost all cases.

For case of non-evolving accretion rates: redshift-dependence due to interplay of pair production near threshold and cosmological energy red-shifting.

Is the „intrinsic opacity“ redshift-dependent?



In all cases $E(\tau_{\gamma\gamma}=1)$ due to intrinsic absorption decreases with redshift, similar to the FS-relation for EBL absorption.

⇨ …. “evolutionary conspiracy” approaches reality?

Conclusion

Any observed redshift-dependence of absorption features in FSRQs, that are prone to intrinsic absorption, can therefore NOT serve as a secure signature of absorption occuring in the EBL radiation field.

On the source selection ...

Only "naked" jet sources (i.e. AGN without noticable opt/UV external radiation fields close to the γ-ray emission region) are suitable for studies of the evolution of the EBL on the basis of a Fazio-Stecker relation (or similar approaches) using GLAST's LAT.

⇨ BL Lac objects?

BUT:

- EGRET identified blazars: ~20% BL Lacs, ~80% FSRQs

- "GLAST constraints on EBL will require bright, hard spectra blazars at z>2-3, e.g., 3C279-like, x10-100 more luminous (or like PKS0528+134, but with harder intrinsic spectrum)"