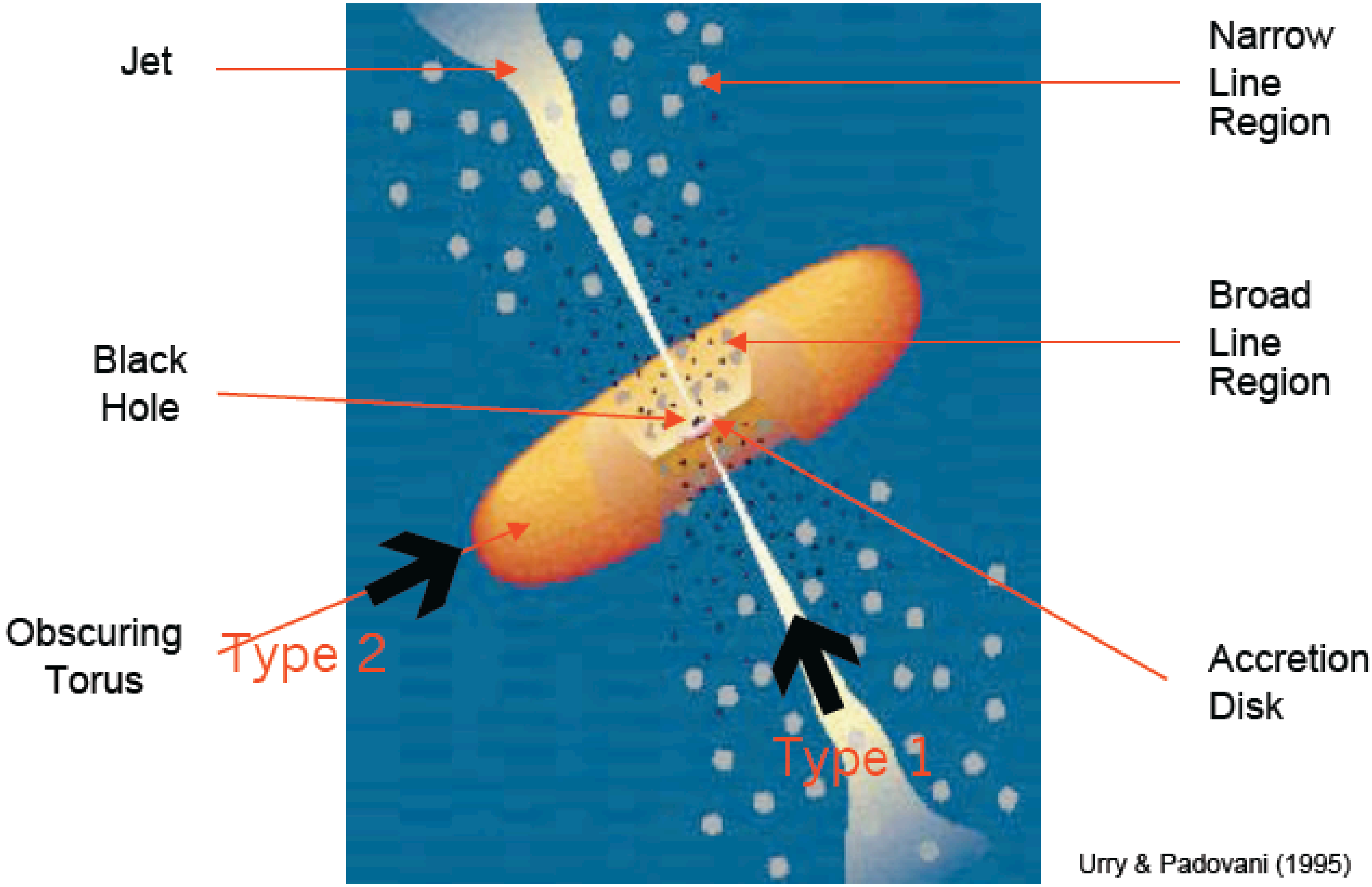
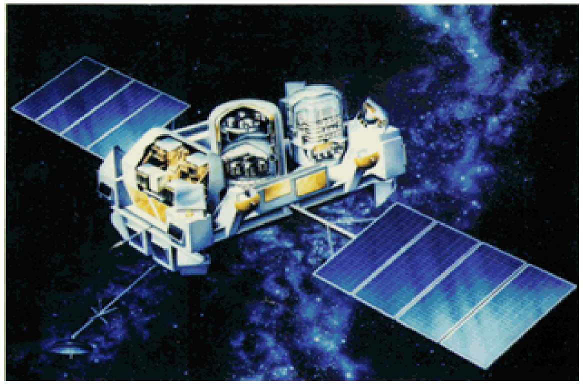
Gamma-ray absorption in quasars: a theoretical perspective

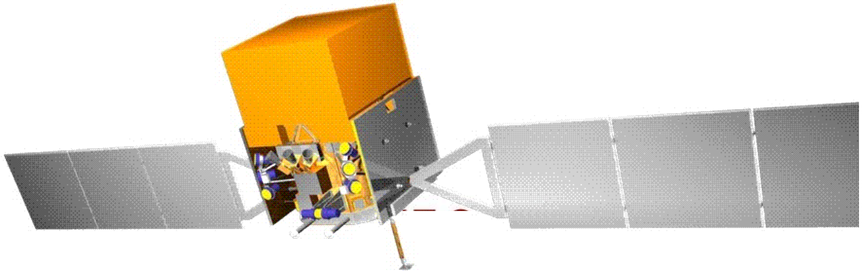


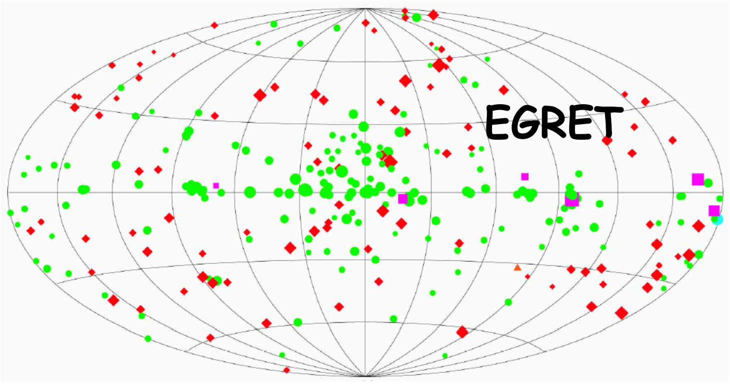
Urry & Padovani (1995)

Anita Reimer, HEPL & KIPAC, Stanford University
"Obscured AGN across cosmic time", Seeon, 5-8 June 2007

γ-ray instrument capabilities







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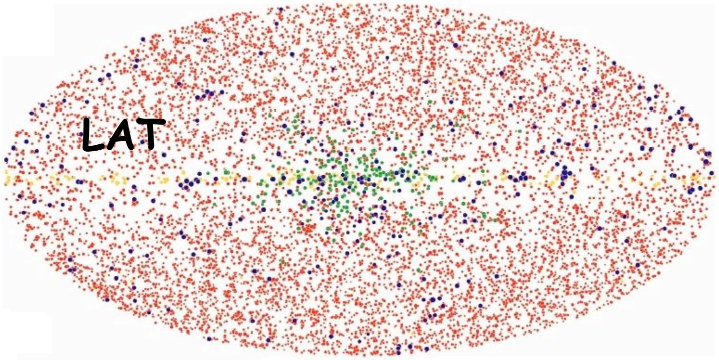
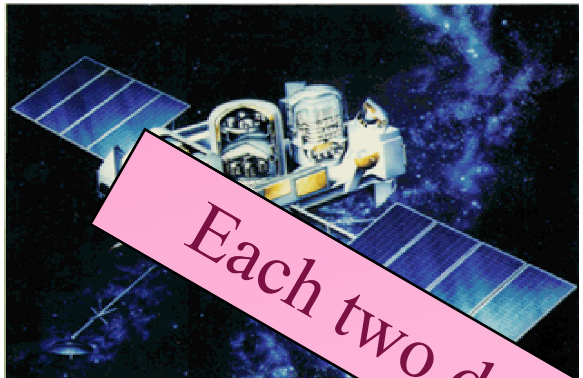


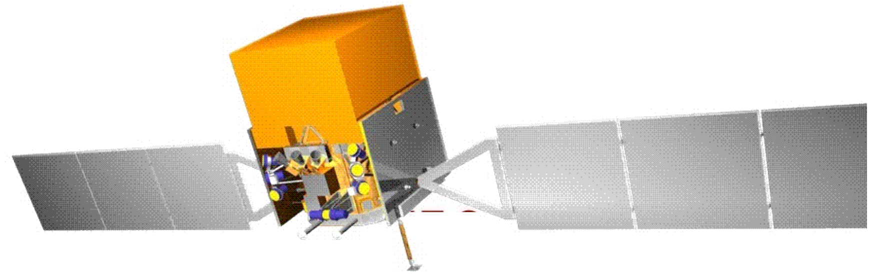
significant improvements in:

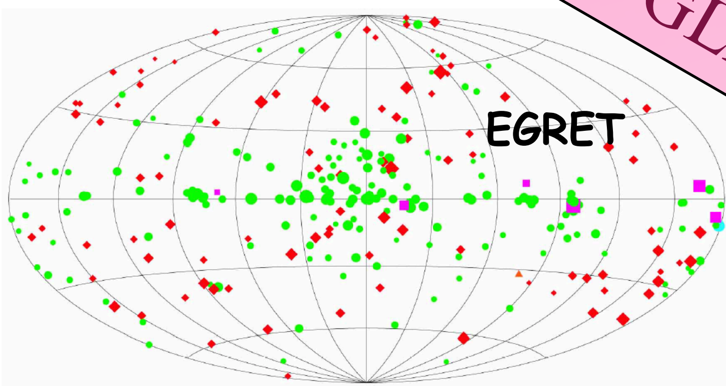
energy range & resolution

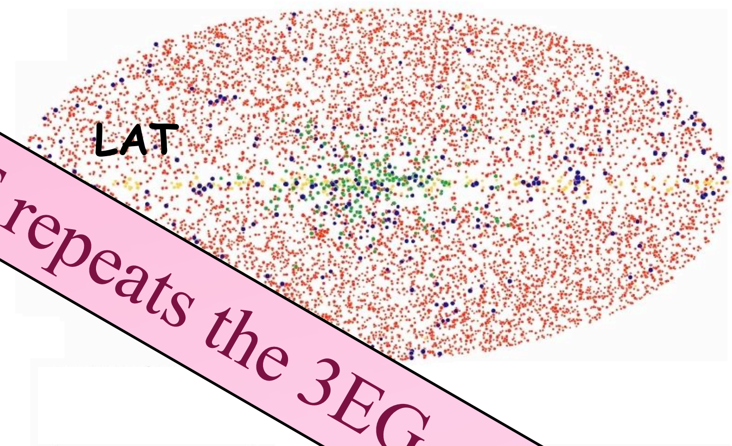
sensitivity, field-of-view, etc.

γ-ray instrument capabilities









Each two days GLAST-LAT repeats the 3EG catalog !

significant improvements in:

energy range & resolu

sensitivity, field-of-view, etc.

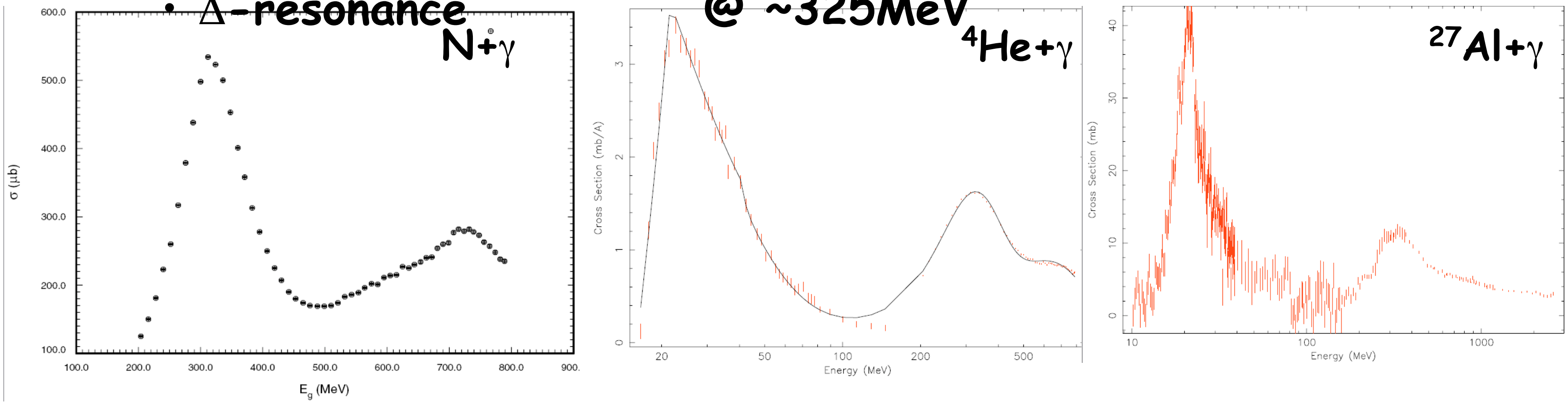
γ-ray absorption in (baryonic) matter

[Iyudin, Reimer, Burwitz et al. 2005, A&A]

➔ nuclear resonant absorption of γ-ray beams by atomic nuclei:

(independent of ionization and chemical state!)

- pygmy dipol resonance @ ~7MeV
- giant dipol resonance @ ~20-30MeV
- Δ-resonance @ ~325MeV

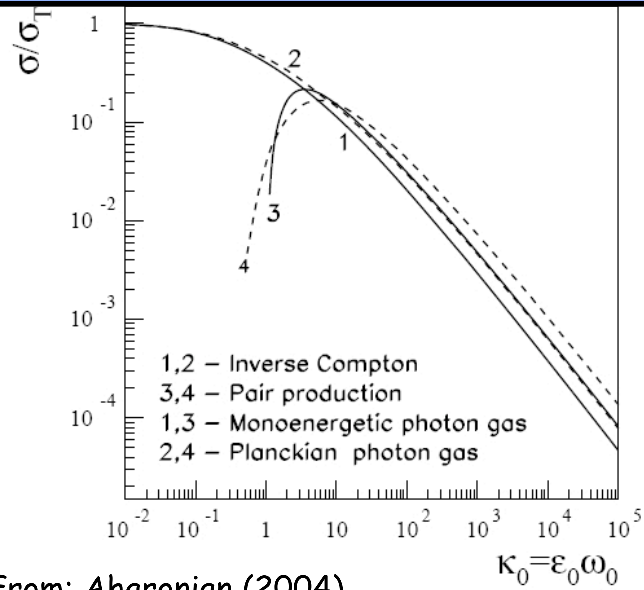


➔ probes baryonic absorption columns along sight line of $N_H \geq 10^{26} cm^{-2}$

[X-rays: $N_H \leq 10^{25} cm^{-2}$, UV/opt: $N_H \sim 10^{21} cm^{-2}$]

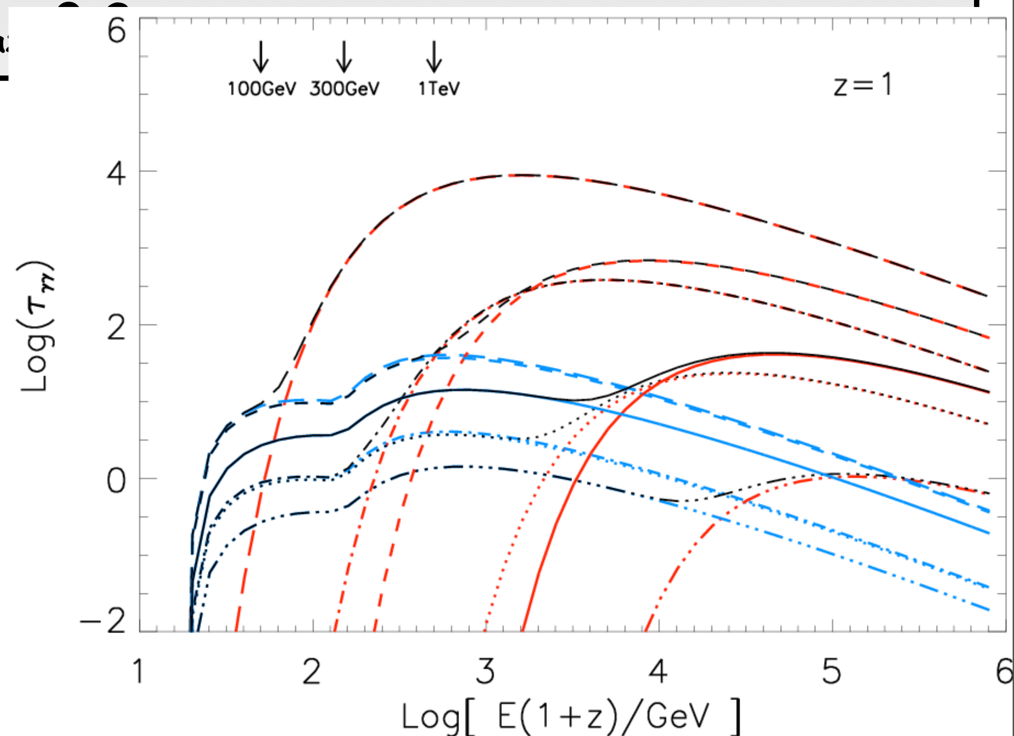
Any solid measurements of absorption troughs in high-resolution γ-ray spectra indicates existence of $N_H \geq 10^{26} cm^{-2}$ baryonic absorbing columns.

γ-ray absorption in radiation fields: $\gamma\gamma \rightarrow e^+e^-$



From: Aharonian (2004)

- prominent peak of $\sigma_{\gamma\gamma}$ close to threshold
- more than half the interactions occur in narrow target photon interval: $\Delta\varepsilon \approx (4/3 \pm 2/3)\,\varepsilon_*$, $\varepsilon_* \approx 0.8\mathrm{eV}(E_\gamma/\mathrm{TeV})^{-1}$
- σ_{ma}



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

Accretion disk radiation field:

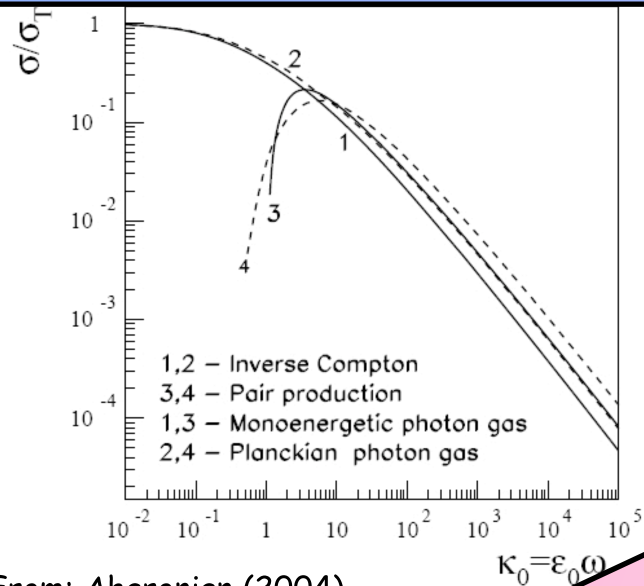
cool, optically thick bb solution of Shakura & Sunyaev (1973)

BLR radiation field (geom. thick shell)

- 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 etal.'97)
- average BLR spectrum (Francis etal.'91)

approx. as 2-line (H_α, Ly_α) spectrum

γ-ray absorption in radiation fields: $\gamma\gamma \rightarrow e^+e^-$



From: Aharonian (2004)

- prominent peak of $\sigma_{\gamma\gamma}$ close to threshold
- more than half the interac… narrow target photon i… 3) ε_*, $\varepsilon_* \approx 0.8$eV(E/T…
- σ_{m}…

If the γ-ray emission region is sufficiently close to the BLR, mandatory for γ-ray production that involve external photon fields, local γ-ray absorption features in quasar spectra have to be expected at $E(1+z) \gtrsim$ several tens of GeV.

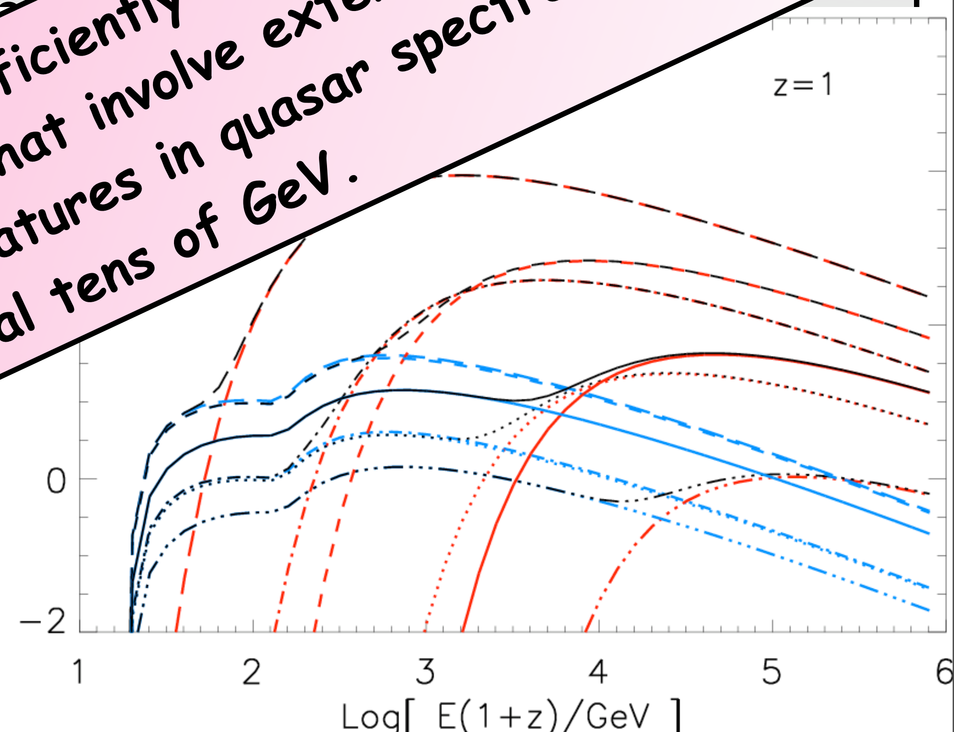
Accretion disk…

cool, op…

Sh…

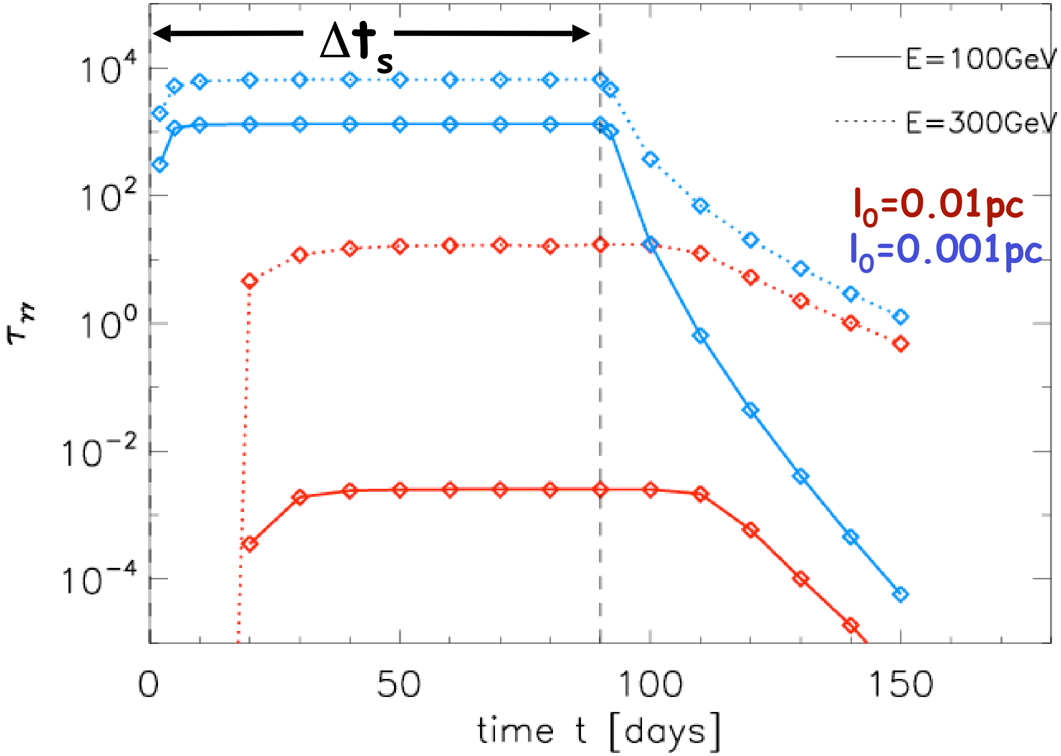
BLR … thick shell)

- sphe… (R=0.01… 0.4pc, … n.o.)
- $L_{BLR}=\tau_{BLR} L_{disk}$, $\tau_{BLR} \approx 0.01$ (Celotti etal.'97)
- average BLR spectrum (Francis etal.'91) approx. as 2-line (H_α, Ly_α) spectrum



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

... constrain location of γ-ray emission („reverberating soft photons")



[see also:

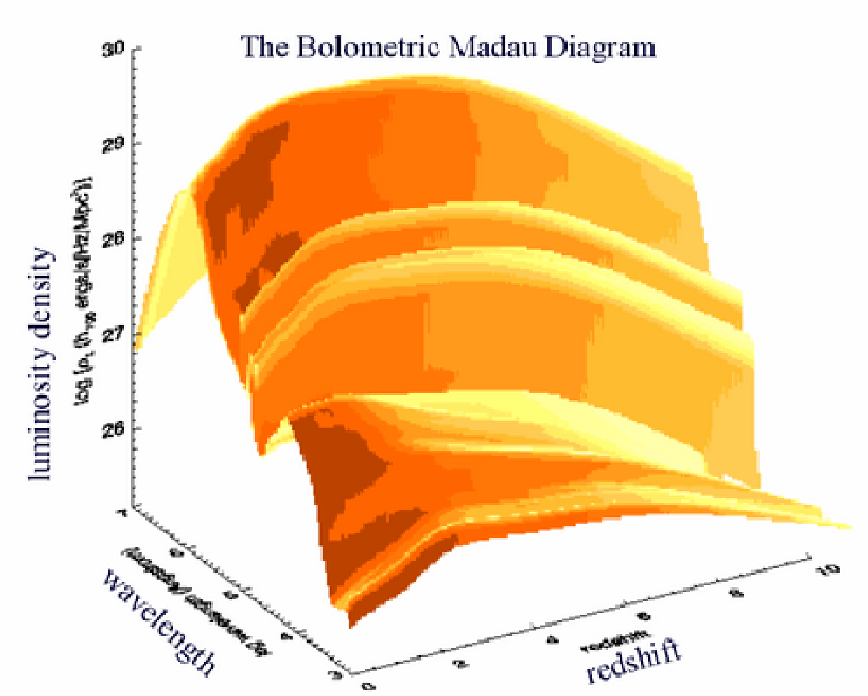
Bottcher & Dermer 1995]

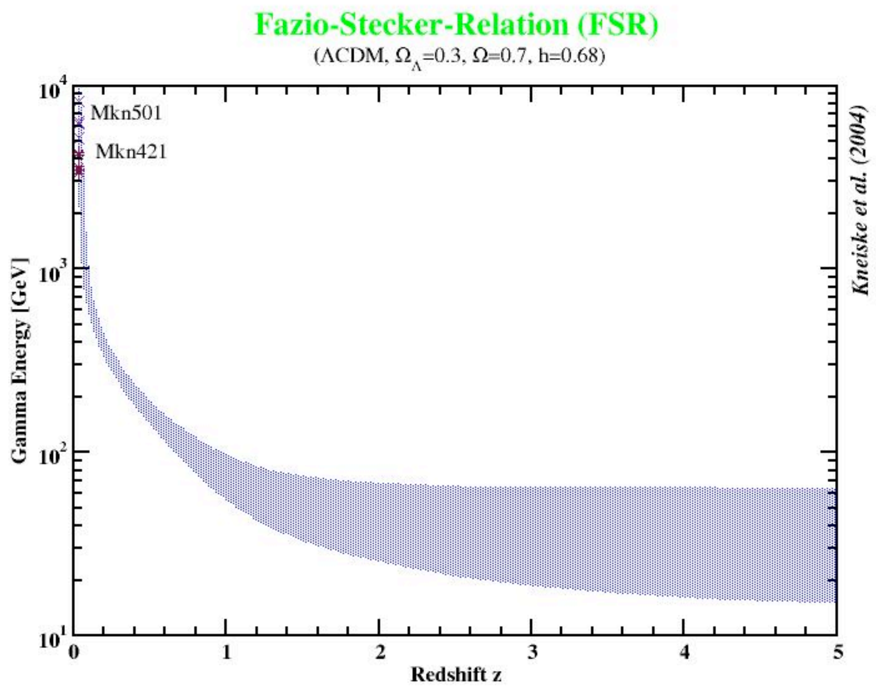
Target photon field: accretion disk photon "flare" Δt_s

(Shakura-Sunyaev, L_{disk}=2.5 10^{46}erg/s, M=5.3M_o/yr, M_{BH}=10^9M_o, z=1)

The temporal behaviour of the γ-ray opacity cutoff in conjunction with the accretion flare time history can constrain the location of the γ-ray emission site l_0.

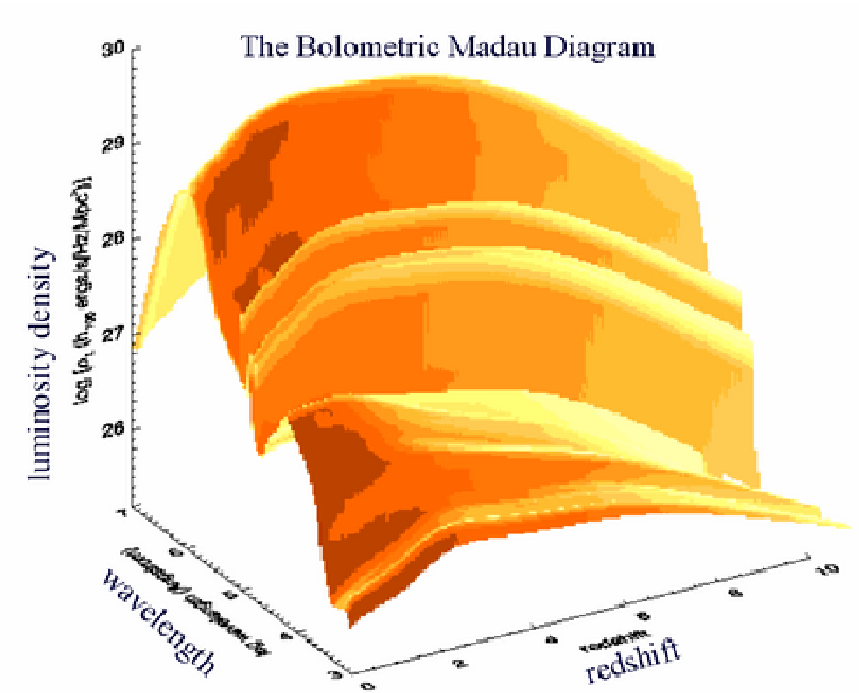
... constrain the EBL & its evolution

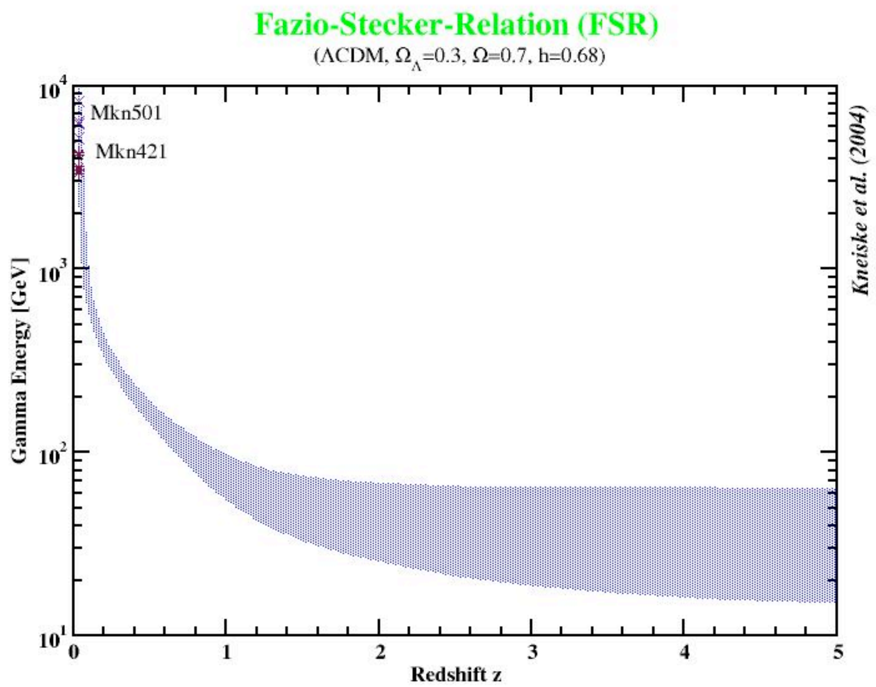




- fill in FS- or S_{10GeV}/S_{1GeV} – redshift diagram with a large number of sources (large statistics of bright, hard sources is key!)
- systematic increase of opacity with redshift unique signature of absorption in EBL

... constrain the EBL & its evolution





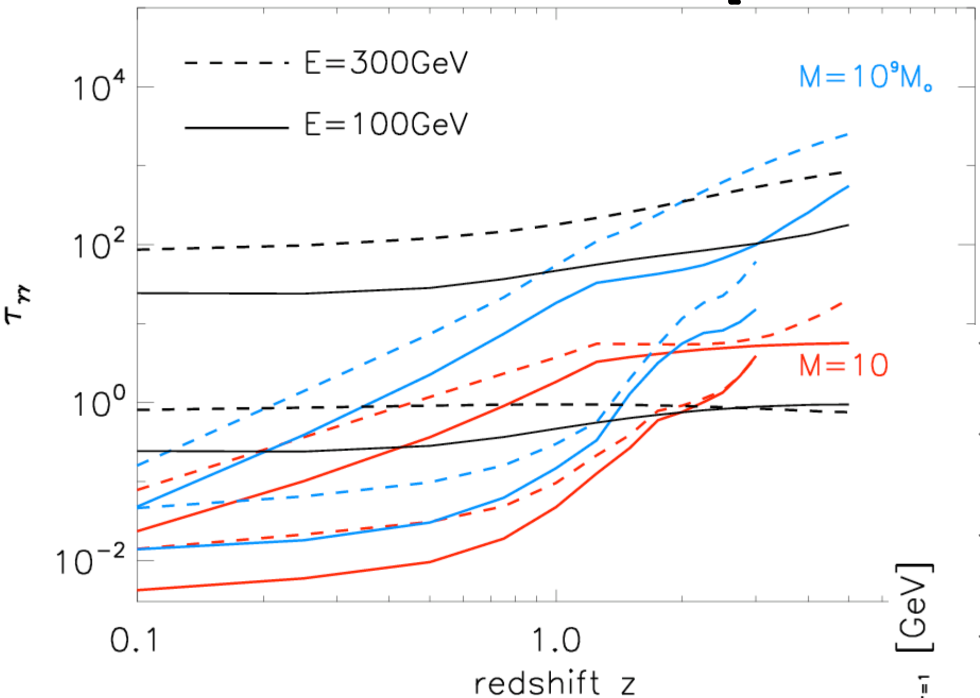
• fill in FS- or S_{10GeV}/S_{1GeV} – redshift diagram with a large number of sources (large statistics of bright, hard sources is key!)

• systematic increase of opacity with redshift unique signature of absorption in EBL ??

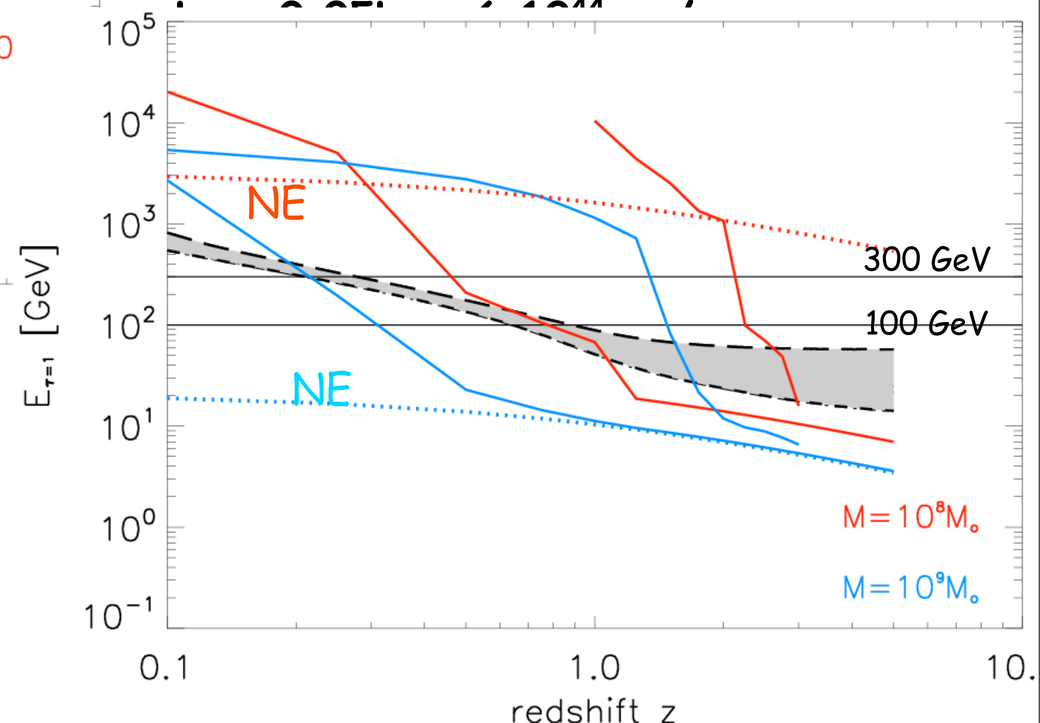
BUT:

Is AGN-intrinsic/local absorption redshift-dependent, too?

[Reimer 2007, ApJ]



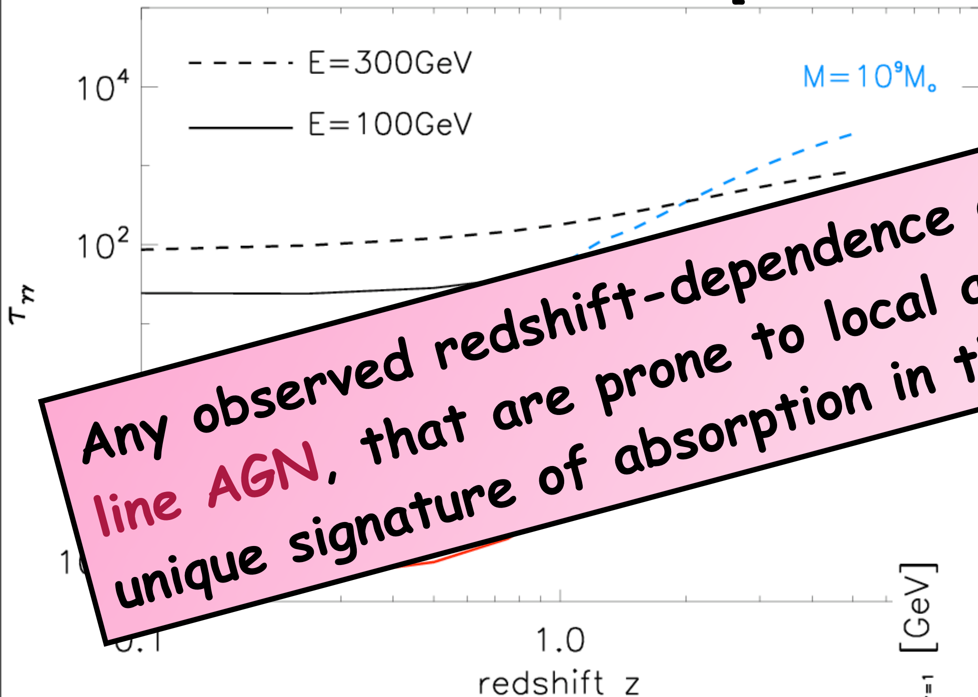
Parameters for non-evolving (NE) accretion rate curves: $M_{BH}=10^9M_o$, $L_{disk}=0.5L_{edd}=6\ 10^{46}$erg/s, $M_{BH}=10^8M_o$,



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

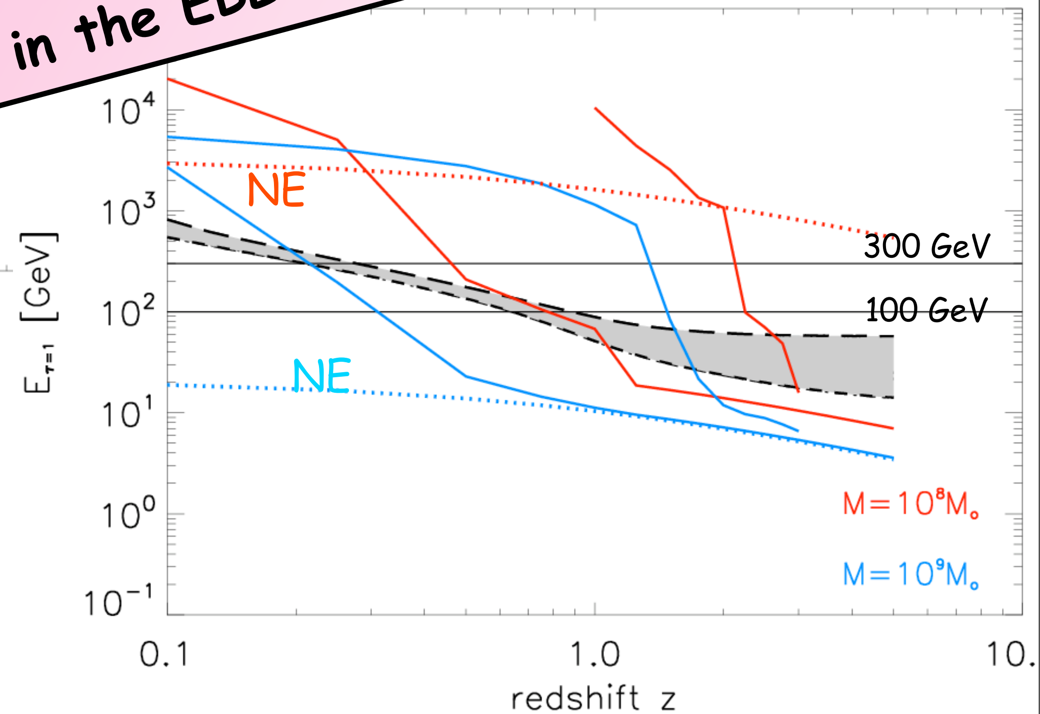
BUT: **Is AGN-intrinsic/local absorption redshift-dependent, too?**

[Reimer 2007, ApJ]



Parameters fo...

Any observed redshift-dependence of absorption features in strong-line AGN, that are prone to local absorption, can NOT serve as a unique signature of absorption in the EBL radiation field.



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

Conclusion

Gamma-ray absorption in the GLAST-era can probe:

• Intervening baryonic matter with $N_H > 10^{26} cm^{-2}$ through resonance absorption

→ obs. diagnostic: absorption troughs at MeVs-GeVs

• Location of γ-ray emitting region in jet sources

→ obs. diagnostic: 'reveberating' soft (accr.disk/BLR) photons

• Extragalactic background light (EBL), & possibly its evolution

→ BUT: 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.