Gamma-ray absorption in quasars: a theoretical perspective

Jet

Black Hole

Obscuring Torus

Narrow Line Region

Broad Line Region

Type 2

Type 1

Accretion Disk

Urry & Padovani (1995)

Anita Reimer, HEPL & KIPAC, Stanford University

“Obscured AGN across cosmic time”, Seeon, 5-8 June 2007
γ-ray instrument capabilities

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 & resolution
- sensitivity, field-of-view, etc.
*γ-ray absorption in (baryonic) matter*


- 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 $N_H \geq 10^{26}\text{cm}^{-2}$

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

Any solid measurements of absorption troughs in high-resolution γ-ray spectra indicates existence of $N_H \geq 10^{26}\text{cm}^{-2}$ baryonic absorbing columns.
γ-ray absorption in radiation fields: \( \gamma \gamma \rightarrow e^+e^- \)

- prominent peak of \( \sigma_{\gamma\gamma} \) close to threshold
- more than half the interactions occur in narrow target photon interval: \( \Delta \varepsilon \approx (4/3 \pm 2/3) \varepsilon_* \), \( \varepsilon_* \approx 0.8 \text{eV}(E_\gamma/\text{TeV})^{-1} \)
- \( \sigma_{\text{max}} \approx 0.3 \)

**Accretion disk radiation field:**
cool, optically thick bb solution of Shakura & Sunyaev (1973)

**BLR radiation field (geom. thick shell):**
- spherical shell of clouds \( (R=0.01...0.4 \text{pc}, l_0=0.01 \text{pc i.n.n.o.}) \)
- \( L_{\text{BLR}} = \tau_{\text{BLR}} L_{\text{disk}} \), \( \tau_{\text{BLR}} \approx 0.01 \) (Celotti et al.'97)
- average BLR spectrum (Francis et al.'91) approx. as 2-line (H\(\alpha\),Ly\(\alpha\)) spectrum

**From:** Aharonian (2004)
If the $\gamma$-ray emission region is sufficiently close to the BLR, mandatory for $\gamma$-ray production that involve external photon fields, local $\gamma$-ray absorption features in quasar spectra have to be expected at $E(1+z) \geq$ several tens of GeV.
... constrain location of $\gamma$-ray emission ("reverberating soft photons")

Target photon field: accretion disk photon "flare" $\Delta t_s$
(Shakura-Sunyaev, $L_{\text{disk}}=2.5 \times 10^{46} \text{ erg/s}$, $M=5.3M_\odot/\text{yr}$, $M_{\text{BH}}=10^9M_\odot$, $z=1$)

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

[see also: Bottcher & Dermer 1995]
... constrain the EBL & its evolution

- fill in FS- or $S_{10\text{GeV}}/S_{1\text{GeV}}$ - 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

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

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

In all cases $E(\tau_{\gamma\gamma} = 1)$ due to local absorption decreases with redshift, similar to the FS-relation for EBL-caused absorption.
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. [Reimer 2007, ApJ]

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Conclusion

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

- Intervening baryonic matter with $N_H > 10^{26}\text{cm}^{-2}$ through resonance absorption
  
  → obs. diagnostic: absorption troughs at MeVs-GeVs

- Location of $\gamma$-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 $\gamma$-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.