Search for γ-ray Emission from Radio-Quiet Seyfert AGN

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Abstract

In contrast to radio galaxies with luminous relativistic jets, radio emission from Seyferts is generally weak, usually dominated by diffuse emission of the interstellar medium. Low-power radio-emitting outflows have been resolved in some Seyferts, but little is known about their γ-ray properties. We report results from a systematic investigation of Seyfert AGN at MeV-GeV photon energies, utilizing two years of *Fermi*-LAT data, and a uniform sample of objects selected from the *Swift*-BAT 58-month catalog. Our preliminary results indicate that radio-quiet Seyferts are `γ-ray quiet' as a class of AGN. The derived upper limits in the MeV-GeV range exclude γ-ray emission from Seyfert nuclei exceeding 1% of their X-ray luminosities.

Seyfert Galaxies

Recent discoveries of γ-ray emission from non-blazar AGN by *Fermi*-LAT raise the question: ***Are there galaxies capable of producing strong γ-ray emission without luminous relativistic jets and/or starburst activity?***

Obvious candidates might be AGNs generally devoid of prominent jets, e.g. **Seyfert galaxies,** identified in the optical regime as AGN hosted by late-type galaxies with bright unresolved nuclei. Seyferts are also bright in X-rays, and both the optical and the X-ray emission components are produced by matter accreting onto supermassive black holes.

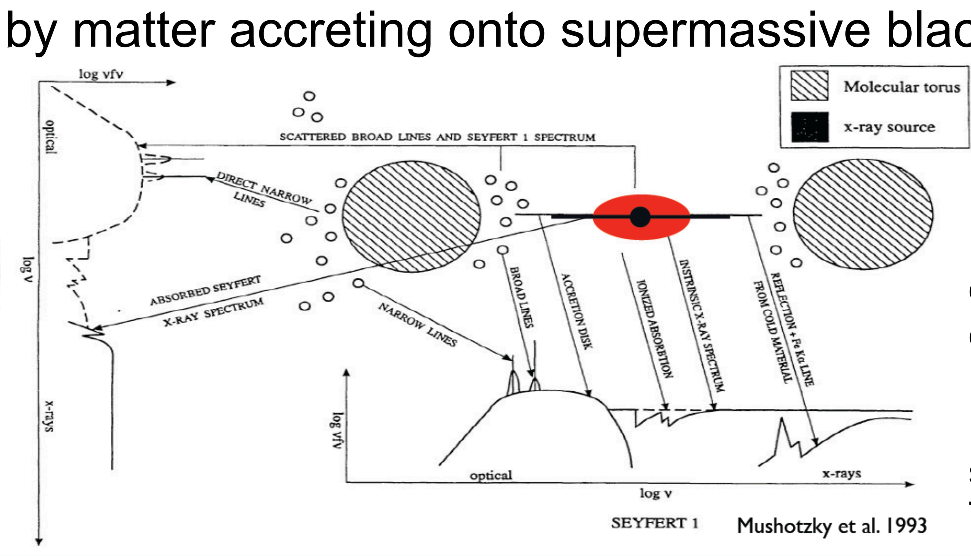

Figure 1. Schematic diagram of optical to X-ray emission ingredients in radio-quiet AGN powered by accretion onto supermassive back holes. Taken from [1].

Sample Selection

Hard X-ray observations are used to select a **complete** and **unbiased** sample of Seyfert galaxies because hard X-ray emission is a clear and common signature of AGN activity. The galaxies are selected on a basis of the *Swift*-BAT 58 month catalog [2]. In order to extract `radio-quiet' objects, we defined `**hard X-ray radio loudness**' as follows:

$$R_{\rm rX} = \frac{[\nu F_\nu]_{1.4\,\rm GHz}}{[\nu F_\nu]_{14-195\rm keV}}$$

The 1.4 GHz radio fluxes are gathered from catalogs such as NVSS, FIRST and PKSCAT90.

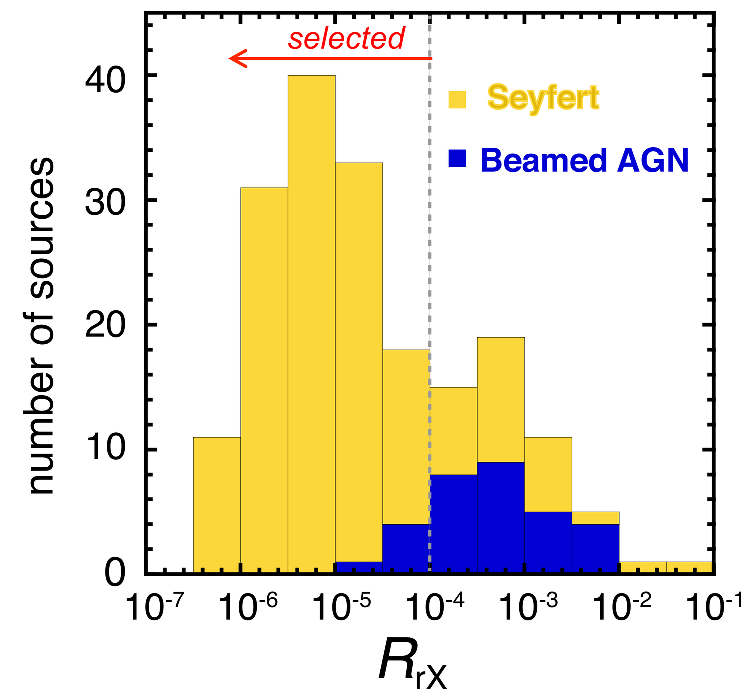

Figure 2. Distribution of 'hard X-ray radio loudness' parameter for Seyfert galaxies (both radio-quiet and radio-loud, yellow), and comparison sample of beamed AGN (known as radio-loud, blue) .

Summary of Selection Criteria (120 total objects in sample)

- Hard X-ray fluxes $[\nu F\nu]_{14\text{-}195\,\rm keV} > 2.5\times10^{-11}$ [erg/cm²/s] in *Swift*-BAT catalog
- Spectral classification as `galaxies' or `Seyfert galaxies' in *Swift*-BAT catalog
- Hard X-ray radio loudness parameter $R_{rx} < 10^{-4}$ (selects radio-quiet objects)
  - This happens to exclude two Seyferts with high star-forming rate, NGC 1068 and NGC 4945
- Galactic coordinates $|b| > 20^o$ for $-20^o < l < 20^o$, and $|b| > 10^o$ otherwise

LAT Data Analysis and Results

Analysis Parameters

- Observation times: August 4, 2008 - August 4, 2010
- IRF: P6_V11_DIFFUSE
- Photon events: 0.2-100 GeV, `diffuse' class
- Source fitting model: power law -> $dF/dE = N(E/E_0)^{-\Gamma}$

Results

- ***No significant excess is found positionally coincident with any Seyfert galaxies in the sample***
- 95 % upper limits (UL) calculated with a fixed photon index Γ=2.5 in a range of 0.1-10 GeV are presented
- Mean value of the UL: ~ 5×10^{-9} ph cm^{-2} s^{-1}

Comparison with EGRET Results

- $(0.5-1.5)\times10^{-7}$ ph cm^{-2} s^{-1} (individual sources) [3]
- $(0.3-1.5)\times10^{-8}$ ph cm^{-2} s^{-1} (stacking with brighest 32 Seyferts)[4]

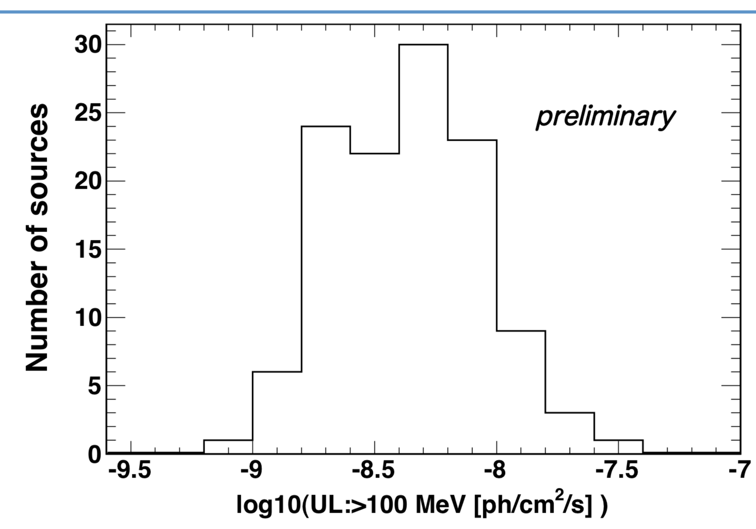

Figure 3. Histogram of γ-ray photon flux upper limits (95 % C.L.) for the analyzed Seyfert galaxies.

Multi-wavelength Comparison

We compare hard X-ray (14-195 keV) emission measured with *Swift*-BAT to derived ULs for γ-ray energy flux and luminosity. **GeV emission from Seyferts is excluded to the level of L_γ/L_X < 0.1 for most sources, and < 0.01 for several sources.** Since hard X-ray luminosity is expected to constitute about 10% of the bolometric AGN-related luminosity, L_{AGN}, of a typical Seyfert galaxy [5], the GeV emission probed in our analysis reaches L_γ/L_{AGN} < 0.001 in several examples.

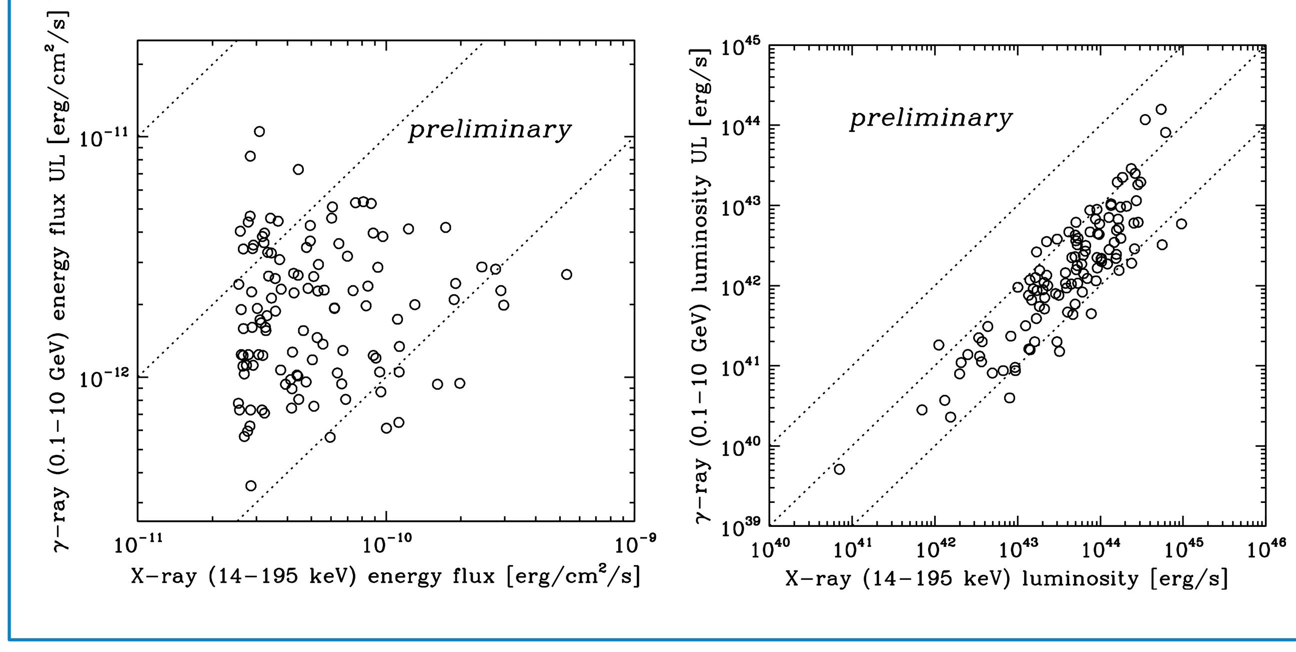

Figure 4. Hard X-ray (14-195 keV) versus UL for the γ-ray (0.1-10 MeV) for the analyzed sample of Seyferts. Dotted lines denote the ratios between γ-ray and hard X-ray emission of 1, 0.1, and 0.01, respectively.

Left: energy flux. *Right*: luminosity.

All points represent γ-ray upper limits

Discussion of Emission Models

Implications on γ-ray emission models from Seyfert galaxies based on our results of γ-ray upper limits :

- Any jet-related γ-ray emission components in radio-quiet AGNs, if present, is not prominent.
- Gamma rays from Seyferts could originate from a disk coronae involving a non-thermal electron population [e.g., 6, 7]. However, the non-thermal power-law tails in the MeV range should not constitute more than ~ 10 % of total energy radiation in the X-ray regime.
- GeV photons from Seyferts could also be generated through proton-proton interactions in the innermost parts of accretion disks [e.g., 8]. In the case of a maximally spinning black hole, some models predict that hadronic emission in the 0.1-10 GeV range could reach > 10 % of the disk/disk corona X-ray luminosity, but we did find any such signal in our analysis.

Conclusions

✓ ***Radio-quiet Seyfert galaxies are generally γ-ray quiet as a class of AGNs* (0.2-100 GeV)**

✓ *Upper limits in the MeV-GeV domain exclude the presence of γ-ray emission in Seyfert nuclei exceeding 1% of the X-ray luminosities*

✓ *MeV-GeV emission detected so far by Fermi-LAT from a few radio-quiet Seyfert galaxies (NGC 1068, NGC 4945, both well-known starburst galaxies) may be attributed to cosmic-ray induced emission in the interstellar medium of host galaxies*

References

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[2] http://heasarc.gsfc.nasa.gov/docs/swift/results/bs58mon/
[3] Lin et al. 1993, ApJL, 416, L53
[4] Cillis et al. 2004, ApJ, 601, 142
[5] Ho 2008, ARA&A, 46, 475
[6] Zdziarski & Lightman 1985, ApJL, 294, L79
[7] Inoue, Totani & Ueda 2008, ApJL, 672, L5
[8] Niedzwiecki, Xie & Zdziarski 2009, The Extreme Sky: Sampling the Universe above 10 keV