Revisiting the cosmological evolution of X-ray selected blazars with the Swift/BAT 70-month all sky survey data

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Abstract

Blazars constitute the most extreme class of active galactic nuclei. Recent multi-wavelength observations allow us to understand the emission processes in blazars. In contrast, the cosmic history of blazars is still veiled in mystery. The keys to understand their evolution is the cumulative source count distribution and the luminosity function with which we are able to obtain the trend of evolution and the peak of blazar formation epoch in the universe. In this talk, we report our study on the cosmological evolution of blazars utilizing the 70-month data from the Swift/Burst Alert Telescope (BAT) survey. Our sample comprises 41 flat-spectrum radio quasars (FSRQs) and 27 BL Lacertae (BL Lac) objects. Our sample size is a factor of ~ 2 bigger than that of the previous study with the 22-month Swift/BAT survey data (Ajello et al. 2009). Although Ajello et al. 2009 reported the peak of the FSRQs density at $z \sim 4$, we suggest that the FSRQs density has a peak $z < 4$; that is, the redshift evolution of FSRQs is not stronger than the previous study. Furthermore, we will discuss prospects for blazar detectability by future X-ray survey missions such as eROSITA satellite.

Key words: AGN:Blazar — Luminosity function

1. Introduction

Blazars constitute the most extreme class of active galactic nuclei (AGNs). Blazars have a relativistic jet that is pointing toward the line of sight and emit with radiation from radio waves to gamma-rays. Astronomers currently recognize two types of blazars. Those are known as FSRQs and BL Lac objects. FSRQs have high luminosity and high redshift, and furthermore, its Equivalent widths (EW) of optical lines is greater than $5\mathring{A}$. In contrast, BL lac objects have low Luminosity and low redshift, and furthermore, its EW of optical lines is less than $5\mathring{A}$.

In previous study, the density of the gamma-ray blazars peaks at $z \sim 1 - 2$ in the history of the universe (Ajello et al. 2012). However, the density of X-ray blazars peak are reported to be peaked at $z \sim 4$ (Ajello et al. 2009).

In the previous study, the number of X-ray blazar sample, which comprises 26 FSRQ samples from Swift/BAT 22-month catalog, is less than that of gamma-ray blazar sample, which comprises 168 FSRQ from the Fermi first year catalogue. Then, it is important to derive number density of FSRQs utilizing more X-ray blazars.

Therefore, the purpose of this study was to explore the cosmological evolution of blazars utilizing the 70-month data from the Swift/BAT survey which is the newest hard X-ray all sky survey map.

2. Sample Selection

In this work, we used the Swift BAT 70-Month Hard X-ray Survey data (Baumgartner et al. 2013). This survey comprises 1211 X-ray objects which was detected by Swift/BAT within 70 months. In order to securely identify and classify BAT sources as blazars, we relied mainly on the blazar catalog (BZCAT) (Massaro et al. 2009) which contains only bona fide blazars. As a result, our blazar sample comprises 41 FSRQs and 27 BL Lac objects and the size of our sample is a factor of ~ 2 bigger than that of the previous study with the 22-month Swift/BAT survey data (Ajello et al. 2009).

3. Result

3.1. logN-logS distribution

We derived logN-logS distribution. This distribution is generally expressed as $N(> S) = AS^{-\beta}$,where S is a

source flux. If the source population is uniformly distributed, a β =1.5 is expected.
The logN-logS distributions we derived is shown in Figure 1 and Table 1. This logN-logS distribution indicates that FSRQs is positive evolution and BL Lac obejacts is negative evolution.

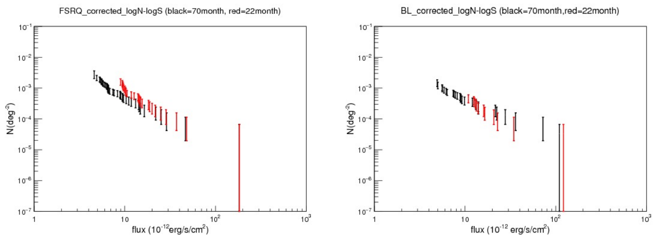

Fig. 1. LogN-LogS distribution of FSRQs (left) and BL Lacs (right). The red line shows the result of previous study (Ajello et al. 2009) and black line shows the result of this study.

Table 1. The expected number of blazar detected by eROSITA satellite

Sample	β^a	$\beta^b_{22month}$
FSRQs	1.87 ± 0.07	2.077 ± 0.269
BL Lac objects	1.32 ± 0.13	1.694 ± 0.316

Note.
[a] Best-fit exponent of the logN—logS distribution (e.g., $N(>S) = AS^{-\beta}$)
[b] Best-fit exponent of the previous study (Ajello et al. 2009)

3.2. Luminosity function of FSRQs

The luminosity function (LF) is defined as the number objects per unit comoving volume and per unit luminosity interval. The simple scenarios of evolution are pure luminosity evolution (PLE) and pure density evolution (PDE). We modeled the LF with eight widely used functions and applied the maximum likelihood method and Kolmogorov-Smirnov (KS) test to derive the LF of FSRQs.

3.2.1. KS-test

In this work, 3 LF-models was not rejected:1powPDE model, 2powMPDE model and 2powMPLE model. These LF-models are listed below.

1powPDE : $\frac{0.53\times10^{-7}}{10^{44}}\left(\frac{L_X}{10^{44}}\right)^{-2.8}\times(1+z)^{4.64}$

2powMPDE : $\frac{1.91\times10^{-7}}{L_X\times\log(10)}\left(\left(\frac{L_X}{1.26\times10^{44}}\right)^{3.06}+\left(\frac{L_X}{1.26\times10^{44}}\right)^{3.06}\right)^{-1}\times(1+z)^{17.5-1.7z}$

2powMPLE : $\frac{1.98\times10^{-7}}{L'_X\times\log(10)}\left(\left(\frac{L'_X}{1.25\times10^{44}}\right)^{3.06}+\left(\frac{L'_X}{1.25\times10^{44}}\right)^{3.06}\right)^{-1}$ $\left(\text{where } L'_X=\frac{L_X}{(1+z)^{4.3-0.4z}}\right)$

3.2.2. Number density of FSRQ

Based on 2powMPDE and 1powMPLE model, we can see that the peak of the FSRQ density at $z < 4$. This suggests that the redshift evolution of FSRQs is not stronger than the previous study which used 22month Swift/BAT data.

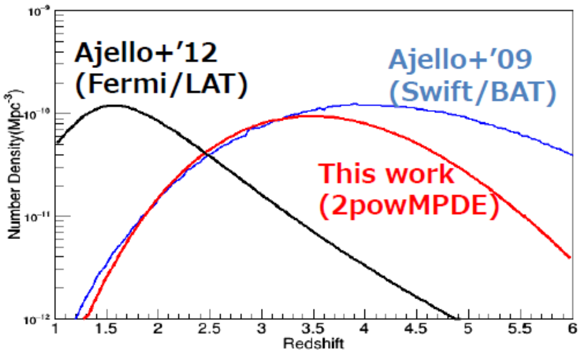

Fig. 2. Number density of FSRQs. The blue line are derived from the [15—55keV] LF (Ajello et al. 2009), the black line are derived from the gamma-ray LF obtained by Fermi/LAT (Ajello et al. 2012) and the red line are derived from the X-ray LF obtained by this work.

4. Blazar detectability by eROSITA satellite

From our logN-logS, we can estimate the expected number of blazers detected by eROSITA satellite. The results are given in Table 2

Table 2. The expected number of blazar detected by eROSITA

Observation time	Sensitivity $(erg/s/cm^2)$	FSRQs	BL Lac Objects
4 year survey	2×10^{-13} $@2-10keV$	13900	1900

Note. We assumed that logN-logS slope does not change in low flux range.

5. Conclusion

We suggest that the evolution of blazars is not stronger than the previous study (Ajello et al. 2009)) and the peak of the FSRQs density at $z < 4$. We will estimate the contribution of blazars to the cosmic X-ray background outside the energy range band of this survey using LF.

References

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