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INFRARED COLORS OF THE GAMMA-RAY-DETECTED BLAZARS

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ABSTRACT

Blazars constitute the most enigmatic class of extragalactic γ -ray sources, and their observational features have been ascribed to a relativistic jet closely aligned to the line of sight. They are generally divided in two main classes: the BL Lac objects (BL Lacs) and the flat-spectrum radio quasars (FSRQs). In the case of BL Lacs the double-bumped spectral energy distribution (SED) is generally described by the synchrotron self-Compton (SSC) emission, while for the FSRQs it is interpreted as due to external Compton (EC) emission. Recently, we showed that in the $[3.4]–[4.6]–[12] \mu\text{m}$ color–color diagram the blazar population covers a distinct region (i.e., the *WISE blazar Strip* (WBS)) clearly separated from the other extragalactic sources that are dominated by thermal emission. In this paper, we investigate the relation between the infrared and γ -ray emission for a subset of confirmed blazars from the literature, associated with *Fermi* sources, for which *WISE* archival observations are available. This sample is a proper subset of the sample of sources used previously, and the availability of *Fermi* data is critical to constrain the models on the emission mechanisms for the blazars. We found that the selected blazars also lie on the WBS covering a narrower region of the infrared color–color planes than the overall blazar population. We then found an evident correlation between the IR and γ -ray spectral indices expected in the SSC and EC frameworks. Finally, we determined the ratio between their γ -ray and infrared fluxes, a surrogate of the ratio of powers between the inverse Compton and the synchrotron SED components, and used such parameter to test different blazar emitting scenarios.

Key words: BL Lacertae objects: general – gamma rays: galaxies – infrared: galaxies – radiation mechanisms: non-thermal

Online-only material: color figures

1. INTRODUCTION

Blazars are an intriguing class of active galactic nuclei (AGNs), dominated by non-thermal radiation over the entire electromagnetic spectrum. Their emission extends from radio to TeV energies with a broadband spectral energy distribution (SED) typically described by two main components, the first peaking from IR to X-ray bands while the second often dominating the γ -ray energy range in which blazars are the most commonly detected extragalactic sources (e.g., Abdo et al. 2010; Massaro et al. 2011b).

The distinguishing observational properties of blazars also include flat radio spectra, high observed luminosity coupled with rapid variability at all frequencies, and highly variable radio to optical polarization. In particular, they are a dominant class of extragalactic sources at radio, microwave, and γ -ray frequencies where thermal emission processes do not produce significant amounts of radiation (Giommi et al. 2011). Adopting the blazar classification scheme given in the ROMA-BZCAT catalog⁵ (Massaro et al. 2009, 2010), based on the width of optical spectral lines, blazars usually come in two flavors: the BL Lac objects (BL Lacs) and flat-spectrum radio quasars (FSRQs), with the latter more or less equivalent to the former population except for stronger emission lines, higher radio to optical polarization, and higher redshift. In addition, the high-energy component of blazar SED is usually found in the GeV band for FSRQs, while it can extend to TeV energy for BL Lacs. Hereafter, we adopt the naming convention of the ROMA-BZCAT catalog, referring to BL Lacs as BZBs and to the FSRQs as BZQs.

These extreme features have been interpreted as radiation arising from a relativistic jet closely aligned to the line of sight and emitting continuous, Doppler-boosted spectra (Blandford & Rees 1978). For both classes of blazars, according to the widely accepted synchrotron self-Compton (SSC) scenario, the low-energy component is produced by inverse synchrotron emission from highly relativistic electrons, while the high-energy bump can be attributed to inverse Compton scattering of synchrotron photons by the same population of relativistic electrons that produce the synchrotron emission (Marscher & Gear 1985; Inoue & Takahara 1996). A different theoretical interpretation of the high-energy γ -ray bump characteristic of the BZQ broadband emission invokes the inverse Compton emission of seed photons arising from regions external to the jet (e.g., the broad-line region, accretion disk) as emission mechanism for such feature of the SED. This model is known as the external Compton scenario (EC; e.g., Dermer & Schlickeiser 2002; Cavaliere & D’Elia 2002).

Recently, we showed that in the $[3.4]–[4.6]–[12] \mu\text{m}$ color–color diagram the blazars, which are dominated by non-thermal emission mechanism, cover a distinct region (hereafter the *WISE blazar Strip* (WBS)), well separated from the locus of other extragalactic sources which are dominated by the contribution of thermal radiation (Massaro et al. 2011a).

This result has been obtained using the blazars listed in the ROMA-BZCAT catalog. In the IR, we used data from *WISE* (Wright et al. 2010). The *WISE* mission observed the sky at 3.4, 4.6, 12, and 22 μm in 2010 with an angular resolution of $6''.1$, $6''.4$, $6''.5$, and $12''.0$ in the four bands, achieving 5σ point source sensitivities of 0.08, 0.11, 1, and 6 mJy in unconfused regions on the ecliptic, respectively (Wright et al. 2010). The

⁵ <http://www.asdc.asi.it/bzcat/>

astrometric accuracy of *WISE* is $\sim 0''.50$, $0''.26$, $0''.26$, and $1''.4$ for the four *WISE* bands, respectively (Cutri et al. 2011).

A previous attempt to compare the infrared behavior of blazars with normal galaxies in the $J - H - K$ color-color diagram was performed using the Two Micron All Sky Survey (2MASS) archival data (e.g., Chen et al. 2005). However, our new approach has three advantages over the study performed using 2MASS: (1) mid-IR selection is dominated by dusty objects, in particular spiral and starburst galaxies; (2) the blazar population covers a noticeably narrow region in the $[3.4] - [4.6] - [12] \mu\text{m}$ color-color plot that is clearly statistically separated from the locus dominated by other extragalactic sources (Massaro et al. 2011a); and (3) *WISE* covers a much larger interval of frequencies and reaches to larger wavelengths than 2MASS, yielding a color-color distribution where stars occupy a narrow and well-defined locus.

The *Fermi* Large Area Telescope (LAT) Collaboration has recently released the *Fermi*-LAT second source catalog (2FGL; e.g., The *Fermi*-LAT Collaboration 2011) including about 800 γ -ray sources associated with blazars to a high level of confidence; 571 of these blazars are also present in the ROMA-BZCAT. In this paper, we investigate how the infrared emission of blazars is related to their high-energy γ -ray radiation by cross-matching the sample of ROMA-BZCAT blazars associated with *Fermi* sources with the *WISE* data archive (Wright et al. 2010). In Section 2, we present the blazar sample used throughout our investigation. In Section 3, we show how the *Fermi*-detected blazars lie on the WBS and we determine the distributions of their IR colors. Then, in Section 4, we investigate a possible relation between the blazar IR and γ -ray emissions, as predicted in the SSC and EC radiative scenarios. In Section 5, we estimate the Compton dominance (CD) parameter for both the BZQs and the BZBs and we also examine the apparent correlation between the CD and the γ -ray spectral index for BZBs. In Section 6, we focus our analysis on the BL Lac population and its subclasses. Finally, our summary and discussion are given in Section 7.

Throughout this paper, we assume that the spectral indices, α , are defined by flux density, $S_\nu \propto \nu^{-\alpha}$. Unless otherwise stated, we use cgs units.

2. SAMPLE SELECTION

We considered all the blazars in the ROMA-BZCAT that have been associated with a *Fermi* source, as reported in the 2FGL (The *Fermi*-LAT Collaboration 2011), for a total number of 571 sources (i.e., 330 BZBs and 241 BZQs). The second edition of the ROMA-BZCAT catalog (Massaro et al. 2009) assembles blazars known in the literature and carefully verified by inspection of their multi-wavelength emission. Members of the ROMA-BZCAT catalog are selected on the basis of a set of criteria involving the presence of detection in the radio band down to 1 mJy flux density at 1.4 GHz ($2.1 \mu\text{m}$), the optical identification and availability of an optical spectrum for further spectral classification, and the detection of X-ray luminosity $L_X \geq 10^{43} \text{ erg s}^{-1}$. Such criteria do not produce a statistically homogeneous or complete sample of blazars because of the spatially uneven distribution and the variable depths of observations available, but provides the largest and most carefully selected sample of confirmed blazars available to date. The selection and spectral classification of blazars can be difficult due to the absence of typical spectral emission features and to the variability of the emission on timescales of a day or even a few hours. In the ROMA-BZCAT, blazars are also classified into three classes, based on the prominence of the

emission features in the optical spectra of these sources. The three classes of such classification are: BZB for the BL Lac sources, i.e., AGNs with featureless optical spectra and narrow emission lines; BZQ for FSRQs with optical spectra showing broad emission lines and typical blazar behavior; BZU for blazars of uncertain type, associated with sources with peculiar characteristics but also showing typical traits of the blazars. This spectral classification will be used throughout this paper. The distinction between BZB and BZQ depends on the choice of an arbitrary threshold value of the equivalent width of the emission lines in the optical spectra of the sources.

The 2FGL catalog contains primarily unresolved sources detected in the all-sky *Fermi* observations obtained throughout the second year of operation. The sources, after detection and the localization in the sky, are assigned an integrated flux in the 100 MeV–100 GeV energy range, a spectral shape, and a significance parameter TS based on how significantly each source emerges from the background. Only sources with $TS \geq 25$, corresponding to a significance of 4σ , have been included in the catalog. Each of the 1873 2FGL sources has been considered for identification with already known astronomical sources available in the literature on multi-wavelength observations (The *Fermi*-LAT Collaboration 2011). For 127 of the 2FGL sources firm identifications have been produced (namely, reliable identifications based on synchronous periodic variability of the sources, coincident spatial morphologies for extended sources, or correlated aperiodic variability). The remaining sources have been investigated for association with sources contained in a list of source catalogs based on different multi-wavelength observations. The ROMA-BZCAT catalog is one of the catalogs used for the association of the 2FGL sources, and 571 *Fermi* sources have been associated with a BZCAT-ROMA blazar.

We selected all blazars in the ROMA-BZCAT reliably associated with a γ -ray source of the 2FGL catalog. Then, using the more accurate radio position of the ROMA-BZCAT in place of the coordinates from the *Fermi* catalog, we searched for infrared counterparts of the above blazars in the *WISE* archive.

The total number of ROMA-BZCAT blazars in the 2FGL footprint falling in the area surveyed by *WISE* during the first year (corresponding to 57% of the whole sky) is 332 (mostly due to the incompleteness of the sky coverage of the ROMA-BZCAT). In order to search for the positional coincidences of blazars in the observed *WISE* sky, we considered a search radius $2''.4$, obtained by combining the $1''$ error assumed for the radio position reported in the ROMA-BZCAT (Massaro et al. 2009) with the error on the fourth *WISE* band at $22 \mu\text{m}$ (i.e., $1''.4$; see also Wright et al. 2010 for more details). Using a conservative approach in our analysis, we only considered sources in the *WISE* Preliminary Source Catalog (WPSC)⁶ with a minimum signal-to-noise ratio (S/N) of 7 in at least one of the four infrared bands.

The number of *Fermi*-BZCAT blazars with a *WISE* counterpart within the first region of $2''.4$ is 296, corresponding to $\sim 45\%$ of the *Fermi*-*WISE* blazar sample in the WPSC, detected with a chance probability of $\sim 3\%$ (see Maselli et al. 2011; Massaro et al. 2011a for more details). We did not find any multiple matches using $2''.4$ as search radius. We have used only these 296 blazars for our investigation. The remaining 12 sources with no apparent corresponding *WISE* sources within $2''.4$ can be associated with at least one source contained in the *WISE* catalog using a search radius of $12''$, but have not been

⁶ <http://wise2.ipac.caltech.edu/docs/release/prelim/preview.html>

used in our study. By definition, the *Fermi*–*WISE* blazar sample is a proper subset of the sample of ROMA-BZCat blazars with *WISE* counterparts discussed in the previous paper (Massaro et al. 2011a). The table containing the main parameters of the 296 sources of the *Fermi*–*WISE* blazar sample is can be found in Appendix B.

3. THE *FERMI* BLAZARS AT INFRARED FREQUENCIES

As recently shown in Massaro et al. (2011a), the blazars, dominated in the infrared by their synchrotron emission, lie in a distinct region of the $[3.4] - [4.6] - [12]$ μm color-color diagram, and appear to be distinctly separated from the rest of the non-synchrotron-dominated sources populating the sky as observed by *WISE*. We randomly selected 14 not-overlapping regions of 4 deg^2 each for a total 56 deg^2 at high Galactic latitude (Massaro et al. 2011a), within the 116 deg^2 considered in the WPSC (Cutri et al. 2011). We collected all of the 453,420 sources detected by *WISE* in its first year catalog (hereafter called *WISE* thermal sources because most of them are dominated by thermal emission in the infrared energy range), having an $S/N > 7$ in at least one band, a conservative level for the WPSC release to emphasize the catalog reliability³ (Cutri et al. 2011). We have not excluded the stars from the sample of generic *WISE*-detected sources in the color-color diagrams shown in this paper, since at high galactic latitude, the majority of the observed sources are extragalactic with only little contamination from stars, and we have checked that their presence does not negatively affect the conclusions about the separation of the region of color space occupied by *Fermi*-detected blazars.

We built the $[3.4] - [4.6] - [12]$ μm color-color diagrams from the magnitudes reported in the *WISE* catalog⁷ for all the *WISE* thermal sources in the 56 deg^2 area described above, and for all the sources in the *Fermi*–*WISE* blazar sample. In Figure 1, we also show the location of different classes of objects and overlaid to five levels' isodensity contours for all the *WISE* thermal sources in the 56 deg^2 region. We plot the blazars of the diagram to characterize their infrared emission. Figure 1 shows that the *Fermi*–*WISE* blazars lie in an even more confined region than the general WBS shown in Figure 1 of Massaro et al. (2011a). We note that the relative errors for both the infrared colors are less than 10% for 97% of the *Fermi*–*WISE* blazar sample but less than 5% for ~85% of the sources.

The subregion of the WBS occupied by the *Fermi*–*WISE* blazars is well defined. Only two “outliers” out of a total number of 296 blazars are visible in this color-color plane: 2FGL J1506.6+0806 and 2FGL J1550.7+0526 (also known as 4C +05.64 or PKS 1548+056). While for these two specific sources the possibility of a wrong association in the 2FGL catalog cannot be ruled out, in general a possible explanation for these or other ROMA-BZCAT sources to lie outside of the WBS might be a thermal contribution from their host galaxy that is non-negligible with respect to the non-thermal IR emission. In general, however, the blazars of the *Fermi*–*WISE* blazar sample, dominated by synchrotron emission in the IR, are located in distinctly defined regions of the *WISE* color-color planes all well separated from the other non-synchrotron-dominated sources detected by *WISE*.

Assuming that the infrared spectrum of the sources in the *Fermi*–*WISE* blazar sample can be described by a power law, we derive the relation between the infrared colors and the spectral

Figure 1. $[3.4] - [4.6] - [12]$ μm color-color diagram of *Fermi*–*WISE* blazar sample sources. We plot the 296 blazars associated with a *WISE* source within a region of radius $2''.4$. The two blazar classes of BZBs (blue) and BZQs (red) are shown. The background gray dots correspond to 453,420 *WISE* sources detected in a region of 56 deg^2 at high Galactic latitude. The isodensity curves for the *WISE* sources, corresponding to 50, 100, 500, and 2000 sources per unit area in the color-color plane, respectively, are shown (see Section 3). The location of different classes of objects, namely the quasars (QSRs), the ultraluminous infrared galaxies (ULIRGs), and luminous infrared galaxies (LIRGs) is also shown in the plot.

(A color version of this figure is available in the online journal.)

slope α . Considering a source of apparent magnitudes m_1, m_2, m_3, m_4 in the four different *WISE* bands, with the zero-point magnitudes $m_{01}, m_{02}, m_{03},$ and m_{04} , respectively, the relation between one color, for example $c_{12} = m_1 - m_2 = [3.4] - [4.6]$, and the associated spectral slope α_{12} can be written as

$$c_{12} = m_1 - m_2 = 2.5 \alpha_{12} \log \left(\frac{\nu_1}{\nu_2} \right) + (m_{01} - m_{02}), \quad (1)$$

where ν_1 and ν_2 are the frequencies corresponding to the 3.4 and $4.6 \mu\text{m}$ wavelengths, respectively. We estimated the values of the spectral indices $\alpha_{12}, \alpha_{23},$ and α_{34} from the three infrared colors $c_{12}, c_{23},$ and c_{34} , respectively. Then we compared their distributions to test for the presence of spectral curvature for the sources in the *Fermi*–*WISE* blazar sample. We found that the median (1.07, 0.94, and 1.12 for $\alpha_{12}, \alpha_{23},$ and α_{34}), the peak values (1.06, 0.99, and 1.12), and variances (0.33, 0.22, and 0.26) of the distributions of the three IR spectral indices are consistent with each other. In the following analysis, we will consider the infrared spectral index $\alpha_{\text{IR}} = \alpha_{12}$, because the *WISE* 3.4 and $4.6 \mu\text{m}$ filters are the most sensitive. Unfortunately, given the *WISE*-restricted energy range we did not find any hint of a curved spectral shape. In Figure 2, we show the distribution of the spectral indices in each band, $\alpha_{12}, \alpha_{23},$ and α_{34} .

Since the sources in the *Fermi*–*WISE* blazar sample have been detected in all the four *WISE* infrared bands, we can also construct the $[3.4] - [4.6] - [12] - [22]$ μm color-color diagram, where the two colors are independent (see Figure 3). In this color-color diagram, the separation between the blazars and the generic *WISE* sources is even more evident than in the $[4.6] - [12] - [22]$ μm color-color diagram, even though the locus is less narrow than in the case of the $[3.4] - [4.6] - [12] - [22]$ color-color diagram shown in Figure 1. In this plot, we also report the line corresponding to a power-law spectrum of varying

⁷ All *WISE* magnitudes are in Vega system.

Figure 2. Histograms of the distributions of the infrared spectral indices α_{12} , α_{23} , and α_{34} for the *Fermi*-*WISE* blazar sample, derived by using Equation (1) for the three different colors (see Section 3 for more details).

(A color version of this figure is available in the online journal.)

Figure 3. Same as Figure 1 but with a different choice of infrared colors: $[3.4]-[4.6]-[12]-[22] \mu\text{m}$. We also report the black dashed line corresponding to the IR colors generated by a power-law spectrum of spectral index α_{IR} . The black cross shown in the right bottom represents the typical error bars on the infrared colors (see Section 3 for more details).

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indices α_{IR} described by the equation

$$c_{12} = \left[\frac{\log(v_1/v_2)}{\log(v_3/v_4)} (c_{34} - m_{03} + m_{04}) \right] + (m_{01} - m_{02}), \quad (2)$$

where $c_{34} = m_3 - m_4 = [12]-[22]$ is the infrared color corresponding to the bands at $12 \mu\text{m}$ and $22 \mu\text{m}$, respectively (see Figure 3).

The remaining $[4.6]-[12]-[22] \mu\text{m}$ color-color diagram is shown in Appendix A. In particular, we note that in Figure 3 (and Figure 12 in Appendix A), the regions covered by the *Fermi*-*WISE* blazar sample sources are also clearly separated from the thermal *WISE* sources.

Figure 4. Color-magnitude diagram built with the most sensitive infrared *WISE* bands, namely the $[3.4]-[4.6]$ color and the $[3.4]$ magnitude. The BZQ sources clearly show the value of the color $[3.4]-[4.6] \sim 1$ corresponding to a spectral index α_{IR} of -1 , as a consequence of the *WISE* observations sampling the peak of their synchrotron components. The black vertical line corresponds to the color value associated with a power law with spectral index $\alpha_{\nu} = -1$.

(A color version of this figure is available in the online journal.)

Finally, we present a color-magnitude diagram for the three *WISE* bands with highest sensitivity (Figure 4) where the flux limit of the *WISE* survey is clearly visible. In this plot, all *Fermi*-*WISE* blazar sample sources lie well above the value of the limiting magnitude at $3.4 \mu\text{m}$, and the blazars appear significantly brighter than all the other sources with similar values of the color. Nonetheless, as already discussed for $[3.4]-[4.6]-[12]-[22]$ color-color diagram shown in Figure 1, if on one hand the sources of the *Fermi*-*WISE* blazar sample are well separated from the *WISE* sources even in this color-magnitude plot, on the other hand the region of the plane occupied by the blazars is less compact and well defined than the WBS visible in the $[4.6]-[12] \mu\text{m}$ versus $[3.4]-[4.6] \mu\text{m}$ color-color plane (Figure 1). Other color-magnitude plots of the *Fermi*-*WISE* blazar sample are shown in Appendix A.

It is worth stressing that $\sim 95\%$ of the BZQs have $[3.4]-[4.6]$ color larger than the value of the color associated with a power-law spectrum of spectral index 1. This fact suggests that the peaks of the first component (i.e., the synchrotron emission) of these sources occur inside or very close to the *WISE* spectral range. The situation appears to be different for the BZB class, which displays infrared colors ranging between 0.5 and 1.2 (see Section 6 for more details). It is also interesting to note that all the sources in the *Fermi*-*WISE* blazar sample are consistently above the sensitivity limit of the *WISE* survey, even though this effect is most likely due to the luminosity distribution and selection limits of the *Fermi* observations.

4. THE $\alpha_{\text{IR}}-\alpha_{\gamma}$ CORRELATION

According to the SSC or the EC scenarios, usually adopted to interpret the blazar emission, the particles (i.e., electrons) that are emitting via synchrotron radiation at radio and infrared frequencies are also those that are scattering the photons to high energy, in the X-rays and in the γ -rays, via inverse Compton emission. Consequently, an empirical correlation between the spectral indices and the fluxes in the infrared and in the γ -ray

Figure 5. Distribution of the sample of 2FGL detected blazars from the BZCAT-ROMA catalog with *WISE* counterparts relative to the total γ -ray flux (from the 2FGL catalog) and the total IR *WISE* flux calculated from the magnitudes in the four *WISE* filters. BZBs and BZQs according to the spectral classification available in the ROMA-BZCAT catalog are plotted with red and blue, respectively. The histograms of the IR and γ -day fluxes distributions for the sample of blazars considered are shown in the two insets of the plot. All fluxes are expressed in cgs units.

(A color version of this figure is available in the online journal.)

energy range is expected, since they originate from the same electron distribution.

The relationships between radio, microwave, and γ -ray emissions of blazars are discussed by many authors (e.g., Giommi et al. 2011). A positive correlation between the radio and γ -ray fluxes has been observed, though with large scatter, using several samples (e.g., Kovalev et al. 2009; Giroletti et al. 2010; León-Tavares et al. 2011). However, a correlation between γ -ray and IR in the spectral range covered by *WISE* had not been observed to date. This could be mainly due to the lack of γ -ray observations for a sufficiently large number of blazars, now resolved by the availability of *Fermi* data. At the same time, the infrared frequencies observed by *WISE* had not been extensively investigated for blazars despite the fact that the SED frequency peak lies very close to or inside this spectral range, at least for most of the BZQs.

In Figure 5, we show the distribution of the sample of blazars considered in this paper in the plane of the total *Fermi* energy flux in the 100 MeV–100 GeV energy interval obtained by spectral fitting in the same range (from the 2FGL catalog), and of the total *WISE* IR flux derived from the *WISE* magnitudes. The total IR fluxes have been calculated by summing the fluxes in the four *WISE* filter obtained as $\nu f(\nu)$ and accounting for color corrections as discussed in Wright et al. (2010). BZBs and BZQs are plotted with different colors in this plot. A correlation between γ -ray and IR fluxes is statistically significant for the whole sample of sources (with correlation coefficient $r_s = 0.57$) and for both classes of BZBs and BZQs separately ($r_s = 0.64$ and $r_s = 0.61$, respectively).

In Figure 6, we report the $\alpha_{\text{IR}}-\alpha_\gamma$ scatterplot with the black line obtained by linear regression on the two spectral indices for BZBs and BZQs together. The associated correlation coefficient is $r_s = 0.71$, corresponding to a negligible; this implies that the two spectral indices are correlated at a very high

Figure 6. Scatterplot of the $\alpha_{\text{IR}}-\alpha_\gamma$ distribution, with the two classes of blazars BZBs (blue) and BZQs (red) shown. In the inset, the histogram of the two distributions of α_{IR} is plotted, clearly showing the dichotomy between the two classes (see Section 4 for more details). Three linear regression lines with different colors are shown: the black has been obtained by linear fitting on the whole sample of BZBs and BZQs, while the blue and red lines are associated with the regression evaluated for BZBs and BZQs alone, respectively.

(A color version of this figure is available in the online journal.)

level of significance. We have also evaluated the best-fitting linear relations for BZBs and BZQs separately (blue and red lines respectively) and the Spearman's correlation coefficients for these two subsamples of sources. While the correlation between the two spectral indices for the BZBs has a high level of significance with $r_s = 0.59$ and negligible p -value, the correlation for the BZQs is associated with lower values of the correlation coefficient $r_s = 0.14$, so that the hypothesis that the two parameters are uncorrelated can be rejected at an 80% level of significance. Overall, the correlation between the IR and γ -ray spectral indices is dominated by the BZBs. The dichotomy between the BZB and BZQ classes of objects is evident from this plot, not only in the α_γ distribution and in the comparison of the linear regression lines for the two classes of sources separated (e.g., The *Fermi*-LAT Collaboration 2011), but also in the α_{IR} distribution (see the histogram in Figure 6). We performed a Kolmogorov–Smirnov (K-S) test and we found that the distributions of the α_{IR} for the BZBs and the BZQs differ at 97% level of significance. We also report in Figure 7 the three-dimensional plot of the two main infrared colors used to build the $[3.4]-[4.6]-[12] \mu\text{m}$ color-color diagram and the γ -ray spectral index α_γ , to highlight the distinction between the two classes of blazars. The two colors can be here considered as surrogates of the infrared spectral index α_{IR} (see Section 3 for more details).

5. THE COMPTON DOMINANCE

The CD parameter, defined as the ratio between the inverse Compton and synchrotron peak luminosities, can be used to identify the main radiative loss process for the emitting particles, either synchrotron or inverse Compton emission. In particular, since for the majority of the BZQs the *WISE* and the *Fermi* spectral ranges are directly sampling or are very close to the peak frequency for both the inverse Compton and

Figure 7. Three-dimensional scatterplot of the distribution of *Fermi* blazars in the $[4.6]–[12]–[3.4]–[4.6]–\alpha_\gamma$ space. The two different classes of blazars, namely the BZBs (blue points) and BZQs (red points), are shown (see Section 4 for more details). The lines extending downward are meant to show the position of the projections of the points on the $[3.4]–[4.6]$ vs. $[4.6]–[12]$ color-color plane.

(A color version of this figure is available in the online journal.)

the synchrotron components, the ratio between the infrared and the γ -ray fluxes provides a good estimate of the CD parameter for the *Fermi*–*WISE* blazars’ sample sources.

In Figure 8, we show the two distributions of the CD parameter for the different classes of BZBs and BZQs. We

performed a K-S test on the CD distributions of BZBs and BZQs and we found that these differ by a 78% level of significance. Finally, we report the relation between the CD parameter and the α_γ , for both classes of blazars in Figure 9.

6. THE TWO FAMILIES OF BL LAC OBJECTS

BL Lacs were originally subclassified into two families on the basis of their radio to X-ray spectral index (Padovani & Giommi 1995). This classification scheme has been recently extended to all types of non-thermal-dominated AGNs (Abdo et al. 2010), on the basis of the position of the peak of the first SED component, generally assumed to be synchrotron emission. This gives rise to the distinction between the “Low”–“Intermediate”–“High” *Synchrotron peaked* non-thermal sources (LSPs, ISPs, HSPs), whenever the peak of the synchrotron component lies below 10^{14} Hz ($\sim 3 \mu\text{m}$), between 10^{14} Hz and 10^{15} Hz ($\sim 0.3 \mu\text{m}$), or higher than 10^{15} Hz, respectively (Abdo et al. 2010). Even if blazars should most appropriately be classified on the basis of a complete SED, built with simultaneous data, this is not possible in the majority of the cases, but LSP or HSP BL Lacs can still be identified by using radio–optical–X-ray spectral indices (Padovani et al. 2003; Giommi et al. 2005). The frequency of the synchrotron peak is estimated using the broadband spectral indices between radio and optical wavelengths (α_{ro}) and the optical and X-ray wavelengths (α_{ox}) and extrapolating the spectral shape of BL Lacs to infrared frequency, where the peak is expected to be located according to accepted BL Lacs SED

Figure 8. Histogram of the distributions of the CD parameter for the BZBs (black) and the BZQs (blue) (left panel), and their cumulative distribution (right panel; see Section 5 for more details).

(A color version of this figure is available in the online journal.)

Figure 9. Scatterplot of the α_γ and the CD parameter for the BZBs (blue symbols) and the BZQs (red symbols).

(A color version of this figure is available in the online journal.)

model. *WISE* allows to directly observe the peak or a spectral interval very close to where the synchrotron emission peaks are expected.

In this paper, we adopt the SED classification criterion for the BL Lacs for the *Fermi*–*WISE* blazars sample distinguishing HSPs, ISPs, and LSPs according to the 2LAC sample (Ackermann et al. 2011). For these three families of BL Lacs we studied the relation between the two spectral indices α_γ – α_{IR} . We note that, as shown in Figure 10, there is a clear distinction between the two classes in the α_γ ; however, it is more evident in the α_{IR} distribution (a 94% level of significance has been obtained with a K-S test). A similar distinction between BL Lacs subclasses is visible in the color–magnitude plot produced using the $[3.4]$ – $[4.6]$ μm color and the $[3.4]$ μm magnitude in Figure 13 in Appendix A. The three families have clearly separated color distributions, with HSPs, ISPs, and LSPs with average values of the $[3.4]$ – $[4.6]$ μm color 0.72, 0.94, and 1.02, respectively. Finally, we calculate the correlation coefficient between the variables α_γ and α_{IR} , finding $r_s = 0.61$ (p -value negligible), implying that the two variables are correlated within a high level of significance. In Figure 11, the three different BL Lacs classes in the CD versus α_γ plane are shown. In this case, the CD distributions of the HSPs and LSPs are similar (at a 70% level of confidence, obtained with a K-S test), while, for the ISPs and the HSPs, the null hypothesis can be rejected to an 87% level of significance.

7. SUMMARY AND DISCUSSION

We have presented the infrared characterization of a sample of blazars detected in the γ -ray. In order to perform our selection, we considered all the blazars in the ROMA-BZCAT catalog (Massaro et al. 2010) that are associated with a γ -ray source in the 2FGL (The *Fermi*–LAT Collaboration 2011). Then, we searched for infrared counterparts in the *WISE* archive adopting the same criteria described in Massaro et al. (2011a; see also Section 2 for more details). The 296 *WISE* counterparts of the ROMA-BZCAT–*Fermi* blazars constitute our sample (i.e., the *Fermi*–*WISE* blazars’ sample). This more accurate characterization of a sample of blazars, as obtained by combining

Figure 10. Scatterplot of the α_{IR} – α_γ distribution for BL Lacs. The three BL Lac subclasses of HSPs (green points), LSPs (black points), and ISPs (yellow points) are shown. We also report the histogram of the two distributions of α_{IR} and α_γ that clearly show the dichotomy between the three subclasses.

(A color version of this figure is available in the online journal.)

Figure 11. Scatterplot of the CD– α_γ distribution for BL Lacs. The three BL Lac subclasses of HSPs (green points), LSPs (black points), and ISPs (yellow points) are shown (see Section 6 for more details).

(A color version of this figure is available in the online journal.)

infrared and γ -ray observations, will provide crucial clues for the understanding the unassociated *Fermi* objects (Massaro et al. 2011c), since we expect most of them to be blazar candidates.

We find that the *Fermi*–*WISE* blazars cover a very limited region of the $[3.4]$ – $[4.6]$ – $[12]$ – $[22]$ μm color–color plane, narrower than the similar locus found for the complete blazars population of the ROMA-BZCAT seen by *WISE* (i.e., the so-called WBS; Massaro et al. 2011b; see Figure 1). In particular, we show how the separation between the *Fermi*–*WISE* blazars sample and the other extragalactic sources, not dominated by synchrotron emission, is evident even with different choices of infrared colors (see Figures 3 and 12). From the three independent infrared colors obtained with *WISE* magnitudes, we have derived the values of the spectral indices, finding that the IR spectrum of blazars is clearly consistent with a simple power law and does not show any evidence of deviation from that.

We investigate the properties of the relation between the spectral indices in the γ -rays and in the infrared. We found a clear trend between $\alpha_{\text{IR}}-\alpha_{\gamma}$ consistent with the expectations of the SSC or the EC scenarios. In particular, in the $\alpha_{\text{IR}}-\alpha_{\gamma}$ plot the dichotomy between the two main classes of blazars, BZBs and BZQs, is apparent. We also calculate the ratio between the infrared flux, integrated over the four *WISE* bands and the total γ -ray flux as reported in the 2FGL (The *Fermi*-LAT Collaboration 2011). This ratio can be used to estimate the CD parameter. We find that the CD distribution for the BZB population is more consistent with a synchrotron-dominated scenario; the BZQs, as expected, show values of CD typically higher than unity, in agreement with an inverse Compton framework and with the widely accepted EC emission model.

We also considered the BZB subclasses (i.e., HSPs, ISPs, LSPs) as defined in (Abdo et al. 2010) and we investigated their IR-to- γ -ray properties. We find a strong correlation between the spectral indices and the classification in BZB families; in particular, the HSP class appears to be very different from the LSPs in the α_{IR} distribution.

As already shown in Massaro et al. (2011a), blazars can be separated in the *WISE* IR colors from other sources not dominated by synchrotron emission; however, this distinction appears to be more evident when considering those selected on the basis of their γ -ray properties. For this reason, while we are aware that the results discussed in this paper cannot be generalized, in principle, to all γ emitting blazars because of the inhomogeneity of the parent catalog, we deem the peculiar IR features of this large sample of confirmed blazars worth investigating and interesting per se. Moreover, since blazars constitute the most detected extragalactic sources at γ -ray energies, unidentified *Fermi* AGN candidates or *Fermi* unassociated objects (The *Fermi*-LAT Collaboration 2011) are likely to be unknown blazars. For this reason, we are investigating the possibility of employing these new infrared correlations as diagnostic tools to associate otherwise unassociated *Fermi* sources with blazars, and to better categorize this interesting class of extragalactic sources (Massaro et al. 2011c).

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⁸ <http://www.star.bris.ac.uk/~mbt/topcat/>

Figure 12. $[4.6]-[12]-[22]$ μm color-color diagram of *Fermi*-*WISE* blazars sample sources. The two blazars classes of BZBs (blue) and BZQs (red) are shown. The background gray dots correspond to 453,420 *WISE* sources detected in a region of 56 deg^2 at high Galactic latitude. The isodensity curves for the *WISE* sources, corresponding to 50, 100, 500, and 2000 sources per unit area in the color-color plane, respectively, are shown (see Section 3). The black cross shown in the right bottom represents the typical error on the infrared colors.

(A color version of this figure is available in the online journal.)

Figure 13. $[3.4]-[4.6]$ vs. $[3.4]$ color-magnitude diagram of the sources in the *Fermi*-*WISE* blazar sample. The BZQs (red symbols) and the HSPs, ISPs, and LSPs BL Lacs classes (see Section 6) are shown (green, orange, and gray symbols, respectively). The black vertical line corresponds to the color value associated with a power law with spectral index $\alpha_{\nu} = -1$.

(A color version of this figure is available in the online journal.)

APPENDIX A ADDITIONAL PLOTS

In this Appendix, we present additional plots for the *Fermi*-*WISE* blazars sample, namely the $[4.6]-[12]-[33]$

Figure 14. Color–magnitude diagrams of the *Fermi*–*WISE* sample sources. From top left: [3.4]–[4.6] vs. [4.6] plot, [4.6]–[12] vs. [4.6] plot, [4.6]–[12] vs. [12] plot, [12]–[22] vs. [12] plot, and [12]–[22] vs. [22] plot. The BZQs (red symbols) and BZBs (blue symbols) are shown in all plots. The black vertical lines correspond to the color value associated with a power law with spectral index $\alpha_\nu = -1$.

(A color version of this figure is available in the online journal.)

color–color plot (Figure 12) for BZBs and BZQs, the color–magnitude plot built using [3.4]–[4.6] color and [3.4] magnitude with the different classes of BL Lacs (Figure 13), and several color–magnitude plots with BZBs and BZQs (Figure 14) obtained using *WISE* photometric data.

APPENDIX B

Table 1 shows the parameters of the *Fermi*–*WISE* blazars sample.

Table 1
Parameters of the *Fermi*–*WISE* Blazars Sample

ROMA-BZCat Name	2FGL Name	m_1	m_2	m_3	m_4	Γ_γ	α_{IR}
BZBJ0035+5950	IES 0033+595	12.26(0.03)	11.57(0.02)	9.56(0.05)	7.5(0.15)	1.87(0.07)	0.17(0.06)
BZBJ0123+3420	IES 0120+340	13.92(0.02)	13.31(0.03)	11.5(0.21)	8.29()	1.53(0.21)	−0.09(0.06)
BZBJ0136+3905	B3 0133+388	11.9(0.02)	11.09(0.02)	8.99(0.03)	7.33(0.09)	1.69(0.04)	0.51(0.06)
BZBJ0154+0823	GB6 J0154+0823	11.91(0.02)	11.0(0.02)	8.52(0.03)	6.57(0.07)	1.86(0.07)	0.81(0.06)
BZBJ0154+4433	GB6 J0154+4433	13.25(0.03)	12.31(0.03)	9.98(0.05)	8.03(0.2)	2.01(0.26)	0.87(0.06)
BZBJ0159+1047	RX J0159.5+1047	12.85(0.02)	12.06(0.02)	9.96(0.06)	8.24(0.3)	2.15(0.11)	0.44(0.06)
BZBJ0203+7232	S5 0159+723	11.28(0.02)	10.55(0.02)	8.04(0.02)	5.89(0.04)	2.02(0.13)	0.25(0.05)
BZBJ0212+2244	MG3 J021252+2246	12.36(0.02)	11.52(0.02)	9.29(0.05)	7.47(0.21)	2.03(0.11)	0.59(0.06)
BZBJ0217+0837	ZS 0214+083	10.69(0.02)	9.78(0.02)	7.26(0.02)	5.25(0.03)	1.94(0.09)	0.78(0.06)
BZBJ0222+4302	3C 66A	9.55(0.02)	8.7(0.02)	6.42(0.02)	4.54(0.03)	1.85(0.02)	0.6(0.05)
BZBJ0238+1636	AO 0235+164	11.78(0.02)	10.66(0.02)	7.7(0.02)	5.39(0.03)	2.02(0.02)	1.39(0.05)
BZBJ0243+7120	S5 0238+711	12.95(0.03)	11.89(0.02)	9.33(0.03)	7.03(0.09)	1.9(0.16)	1.23(0.07)
BZBJ0258+2030	MG3 J025805+2029	12.84(0.03)	11.82(0.02)	9.48(0.05)	7.52(0.22)	2.19(0.17)	1.1(0.06)
BZBJ0303−2407	PKS 0301−243	11.11(0.02)	10.28(0.02)	7.96(0.02)	6.09(0.05)	1.94(0.03)	0.57(0.06)
BZBJ0303+4716	4C +47.08	11.08(0.02)	9.98(0.02)	7.02(0.02)	4.76(0.02)	2.24(0.07)	1.35(0.05)
BZBJ0304−2832	RBS 0385	15.04(0.04)	14.44(0.06)	12.5()	8.65()	1.62(0.21)	−0.13(0.12)
BZBJ0316−2607	RBS 0405	12.99(0.03)	12.24(0.02)	10.06(0.05)	8.45(0.24)	1.87(0.14)	0.33(0.06)
BZBJ0316+0904	GB6 J0316+0904	11.56(0.02)	10.74(0.02)	8.47(0.03)	6.58(0.07)	1.81(0.07)	0.54(0.06)
BZBJ0319+1845	RBS 0413	13.31(0.03)	12.64(0.03)	10.55(0.09)	8.49()	1.55(0.11)	0.09(0.07)
BZBJ0321+2326	MG3 J032201+2336	12.67(0.03)	11.88(0.02)	9.77(0.05)	7.46(0.13)	2.09(0.12)	0.43(0.06)
BZBJ0325−1646	RBS 0421	13.15(0.02)	12.42(0.03)	10.37(0.06)	8.38(0.27)	1.97(0.16)	0.26(0.06)
BZBJ0326+0225	1H 0323+022	12.98(0.03)	12.38(0.03)	10.24(0.07)	8.36(0.28)	2.06(0.1)	−0.11(0.06)
BZBJ0334−4008	PKS 0332−403	11.94(0.02)	10.84(0.02)	7.92(0.02)	5.65(0.03)	2.19(0.04)	1.33(0.06)
BZBJ0334−3725	PMN J0334−3725	11.47(0.02)	10.49(0.02)	7.87(0.02)	5.78(0.04)	1.99(0.05)	0.99(0.06)
BZBJ0340−2119	PKS 0338−214	11.99(0.02)	11.0(0.02)	8.22(0.02)	6.03(0.04)	2.43(0.14)	1.02(0.06)
BZBJ0357−4955	PKS 0355−500	12.32(0.02)	11.38(0.02)	8.81(0.02)	6.87(0.06)	1.74(0.18)	0.87(0.06)
BZBJ0424+0036	PKS 0422+00	11.15(0.02)	10.15(0.02)	7.47(0.02)	5.38(0.03)	2.3(0.07)	1.05(0.06)
BZBJ0428−3756	PKS 0426−380	10.84(0.02)	9.81(0.02)	7.11(0.02)	4.9(0.03)	1.95(0.02)	1.13(0.05)
BZBJ0430−2507	PMN J0430−2507	13.69(0.03)	12.85(0.03)	10.32(0.06)	8.44(0.27)	2.2(0.19)	0.56(0.07)
BZBJ0433+2905	MG2 J043337+2905	15.01(0.06)	13.9(0.06)	11.3(0.18)	8.43()	2.04(0.05)	1.35(0.13)
BZBJ0434−2015	TXS 0431−203	13.39(0.03)	12.41(0.03)	9.8(0.04)	7.59(0.14)	2.22(0.13)	1.01(0.06)
BZBJ0448−1632	RBS 0589	13.93(0.03)	13.12(0.03)	10.89(0.08)	8.97(0.33)	1.91(0.12)	0.49(0.07)
BZBJ0449−4350	PKS 0447−439	10.43(0.02)	9.58(0.02)	7.28(0.02)	5.44(0.03)	1.86(0.02)	0.61(0.05)
BZBJ0507+6737	IES 0502+675	12.56(0.03)	11.83(0.02)	9.85(0.04)	8.3(0.23)	1.49(0.07)	0.26(0.06)
BZBJ0509+0541	TXS 0506+056	10.71(0.02)	9.78(0.02)	7.28(0.02)	5.27(0.03)	2.06(0.04)	0.84(0.05)
BZBJ0536−3343	1RXS J053629.4−334302	12.98(0.02)	12.28(0.02)	10.22(0.05)	7.95(0.15)	2.39(0.06)	0.19(0.06)
BZBJ0538−4405	PKS 0537−441	9.09(0.02)	8.0(0.02)	5.21(0.02)	3.04(0.02)	2.01(0.02)	1.3(0.05)
BZBJ0558−7459	PKS 0600−749	12.25(0.02)	11.28(0.02)	8.67(0.02)	6.6(0.05)	2.09(0.14)	0.98(0.06)
BZBJ0607+4739	TXS 0603+476	11.18(0.02)	10.26(0.02)	7.8(0.02)	5.83(0.04)	2.05(0.06)	0.81(0.06)
BZBJ0612+4122	B3 0609+413	11.82(0.03)	10.81(0.02)	8.12(0.02)	6.02(0.04)	2.03(0.05)	1.09(0.06)
BZBJ0617+5701	87GB 061258.1+570222	11.97(0.03)	10.98(0.02)	8.36(0.02)	6.33(0.05)	1.9(0.1)	1.02(0.06)
BZBJ0625+4440	GB6 J0625+4440	12.92(0.03)	11.94(0.02)	9.3(0.03)	7.29(0.1)	1.91(0.14)	1.0(0.06)
BZBJ0629−1959	PKS 0627−199	12.38(0.03)	11.26(0.02)	8.41(0.02)	6.16(0.04)	2.19(0.06)	1.42(0.06)
BZBJ0650+2503	IES 0647+250	12.2(0.03)	11.47(0.02)	9.37(0.04)	7.72(0.17)	1.59(0.08)	0.27(0.06)
BZBJ0710+5908	1H 0658+595	12.59(0.02)	12.08(0.02)	10.22(0.06)	8.18(0.19)	1.53(0.12)	−0.38(0.06)
BZBJ0712+5033	GB6 J0712+5033	12.27(0.02)	11.22(0.02)	8.46(0.02)	6.27(0.06)	2.06(0.07)	1.19(0.06)
BZBJ0721+7120	S5 0716+71	9.1(0.02)	8.13(0.02)	5.44(0.02)	3.4(0.02)	2.01(0.02)	0.98(0.05)
BZBJ0730+3307	1RXS J073026.0+330727	12.79(0.03)	11.94(0.02)	9.67(0.05)	8.0(0.2)	1.89(0.18)	0.6(0.06)
BZBJ0738+1742	PKS 0735+17	11.3(0.02)	10.34(0.02)	7.74(0.02)	5.72(0.04)	2.05(0.03)	0.92(0.05)
BZBJ0744+7433	MS 0737.9+7441	13.37(0.03)	12.72(0.03)	10.74(0.09)	8.83()	1.8(0.14)	0.05(0.07)
BZBJ0753+5352	4C +54.15	13.87(0.03)	12.79(0.03)	9.86(0.05)	7.49(0.13)	2.01(0.09)	1.27(0.07)
BZBJ0754+4823	GB1 0751+485	11.97(0.03)	10.92(0.02)	8.15(0.02)	5.91(0.04)	2.19(0.09)	1.19(0.06)
BZBJ0757+0956	PKS 0754+100	12.0(0.02)	10.92(0.02)	8.04(0.02)	5.66(0.04)	2.19(0.06)	1.28(0.06)
BZBJ0805+7534	RX J0805.4+7534	12.42(0.02)	11.86(0.02)	9.8(0.04)	8.04(0.16)	1.68(0.07)	−0.21(0.06)
BZBJ0809+5218	IES 0806+524	11.78(0.02)	11.07(0.02)	8.96(0.03)	7.11(0.11)	1.94(0.06)	0.18(0.05)
BZBJ0811+0146	OJ 014	13.88(0.03)	12.77(0.03)	9.65(0.05)	7.17(0.1)	2.26(0.08)	1.38(0.07)
BZBJ0814+6431	GB6 J0814+6431	11.29(0.02)	10.36(0.02)	7.84(0.02)	5.86(0.04)	2.26(0.08)	0.86(0.05)
BZBJ0816−1311	PMN J0816−1311	12.9(0.03)	12.12(0.02)	10.12(0.05)	8.15(0.21)	1.8(0.06)	0.4(0.06)
BZBJ0816+5739	SBS 0812+578	12.76(0.02)	11.91(0.02)	9.51(0.04)	7.41(0.1)	1.98(0.11)	0.63(0.06)
BZBJ0817+3243	RX J0817.9+3243	14.18(0.03)	13.41(0.04)	11.02(0.12)	8.99(0.44)	2.19(0.15)	0.39(0.08)
BZBJ0818+4222	S4 0814+42	12.7(0.03)	11.58(0.02)	8.59(0.03)	6.27(0.05)	2.14(0.03)	1.41(0.06)
BZBJ0817−0933	TXS 0815−094	12.43(0.03)	11.42(0.02)	8.78(0.03)	6.51(0.06)	2.04(0.09)	1.06(0.06)
BZBJ0819+2747	5C 07.119	13.3(0.03)	12.24(0.02)	9.43(0.04)	6.99(0.08)	2.26(0.22)	1.23(0.06)
BZBJ0819−0756	RX J0819.2−0756	14.21(0.03)	13.64(0.04)	11.49(0.16)	8.12(0.26)	1.58(0.24)	−0.19(0.08)
BZBJ0834+4403	B3 0831+442	12.85(0.03)	11.91(0.02)	9.31(0.04)	7.2(0.09)	2.04(0.19)	0.87(0.06)
BZBJ0839+1802	TXS 0836+182	12.76(0.03)	11.88(0.02)	9.39(0.04)	7.39(0.12)	2.46(0.2)	0.72(0.06)

Table 1
(Continued)

ROMA-BZCat Name	2FGL Name	m_1	m_2	m_3	m_4	Γ_γ	α_{IR}
BZBJ0839+3540	FIRST J083943.3+354001	13.54(0.03)	12.64(0.03)	10.31(0.08)	8.36(0.33)	1.92(0.18)	0.73(0.07)
BZBJ0844+5312	BZB J0844+5312	13.64(0.03)	12.77(0.03)	10.25(0.06)	8.25(0.3)	2.09(0.15)	0.66(0.06)
BZBJ0847+1133	RX J0847.1+1133	13.38(0.03)	12.76(0.03)	10.87(0.12)	8.68(0.42)	1.48(0.16)	-0.03(0.07)
BZBJ0856+2057	PMN J0856-1105	13.5(0.03)	12.6(0.03)	10.06(0.08)	7.9()	2.14(0.14)	0.76(0.07)
BZBJ0902+2050	NVSS J090226+205045	12.05(0.03)	11.13(0.02)	8.71(0.03)	6.7(0.07)	2.01(0.11)	0.79(0.06)
BZBJ0910+3329	Ton 1015	12.2(0.02)	11.31(0.02)	8.89(0.03)	6.97(0.08)	1.94(0.11)	0.71(0.06)
BZBJ0915+2933	B2 0912+29	12.07(0.02)	11.32(0.02)	9.05(0.03)	7.19(0.1)	1.87(0.06)	0.32(0.06)
BZBJ0929+5013	GB6 J0929+5013	12.93(0.03)	11.93(0.02)	9.13(0.03)	6.85(0.06)	1.98(0.14)	1.07(0.06)
BZBJ0929+8612	S5 0916+864	12.86(0.02)	11.84(0.02)	9.09(0.03)	6.84(0.06)	2.05(0.09)	1.13(0.06)
BZBJ0940+6148	RX J0940.3+6148	13.83(0.03)	13.32(0.03)	11.52(0.14)	8.62()	2.08(0.14)	-0.36(0.07)
BZBJ0945+5757	GB6 J0945+5757	12.52(0.02)	11.75(0.02)	9.39(0.03)	7.46(0.08)	2.16(0.14)	0.37(0.06)
BZBJ0958+6533	S4 0954+65	11.06(0.02)	10.02(0.02)	7.22(0.02)	5.08(0.03)	2.42(0.07)	1.16(0.06)
BZBJ1018+5911	TXS 1015+594	13.54(0.03)	12.78(0.03)	10.3(0.06)	8.2(0.21)	2.18(0.19)	0.35(0.07)
BZBJ1019+6320	GB6 J1019+6319	12.82(0.02)	11.81(0.02)	9.1(0.03)	6.96(0.06)	2.18(0.19)	1.09(0.06)
BZBJ1058-8003	PKS 1057-79	11.52(0.02)	10.45(0.02)	7.6(0.02)	5.4(0.03)	2.05(0.09)	1.27(0.05)
BZBJ1110+7133	87GB 110723.4+715023	13.73(0.03)	12.89(0.03)	10.67(0.07)	8.61(0.26)	2.1(0.22)	0.6(0.07)
BZBJ1136+7009	Mkn 180	11.12(0.02)	10.69(0.02)	8.69(0.02)	6.75(0.06)	1.74(0.08)	-0.62(0.05)
BZBJ1223+8040	S5 1221+80	13.52(0.03)	12.4(0.02)	9.44(0.03)	7.11(0.07)	2.26(0.08)	1.4(0.06)
BZBJ1312-2156	PKS 1309-216	12.06(0.03)	11.12(0.02)	8.79(0.03)	6.9(0.1)	2.02(0.07)	0.9(0.06)
BZBJ1352-4412	PKS 1349-439	12.6(0.03)	11.51(0.02)	8.69(0.03)	6.52(0.07)	2.13(0.17)	1.32(0.06)
BZBJ1357+0128	RX J1357.6+0128	13.68(0.03)	12.85(0.03)	10.45(0.08)	8.46(0.37)	2.28(0.16)	0.56(0.07)
BZBJ1359-3746	PMN J1359-3746	12.74(0.03)	11.86(0.02)	9.31(0.03)	7.23(0.1)	1.63(0.17)	0.7(0.06)
BZBJ1418-0233	BZB J1418-0233	11.95(0.02)	11.08(0.02)	8.79(0.03)	7.07(0.1)	1.7(0.07)	0.68(0.06)
BZBJ1427+2348	PKS 1424+240	10.22(0.02)	9.38(0.02)	7.08(0.02)	5.21(0.03)	1.78(0.02)	0.59(0.05)
BZBJ1439-1531	PKS 1437-153	13.41(0.03)	12.33(0.03)	9.38(0.04)	7.17(0.12)	2.4(0.16)	1.28(0.07)
BZBJ1440+0610	PMN J1440+0610	13.01(0.03)	12.18(0.03)	9.81(0.05)	8.42(0.3)	2.16(0.11)	0.54(0.06)
BZBJ1442+1200	1ES 1440+122	12.77(0.02)	12.26(0.02)	10.38(0.07)	8.37()	1.41(0.18)	-0.38(0.06)
BZBJ1443-3908	PKS 1440-389	11.7(0.02)	10.97(0.02)	8.79(0.03)	6.89(0.08)	1.77(0.06)	0.24(0.06)
BZBJ1501+2238	MS 1458.8+2249	11.39(0.02)	10.55(0.02)	8.21(0.02)	6.33(0.05)	1.77(0.07)	0.6(0.05)
BZBJ1503-1541	RBS 1457	13.74(0.03)	13.12(0.03)	10.93(0.13)	9.08(0.54)	1.8(0.15)	-0.08(0.07)
BZBJ1506+0814	PMN J1506+0814	12.9(0.03)	12.15(0.02)	9.98(0.05)	7.87(0.16)	1.96(0.16)	0.34(0.06)
BZBJ1516+1932	PKS 1514+197	12.26(0.02)	11.2(0.02)	8.3(0.02)	6.09(0.05)	2.46(0.16)	1.23(0.06)
BZBJ1517-2422	AP Librae	10.0(0.02)	9.11(0.02)	6.46(0.02)	4.34(0.02)	2.05(0.04)	0.72(0.06)
BZBJ1522-2730	PKS 1519-273	13.84(0.12)	12.82(0.08)	9.83(0.1)	7.61(0.36)	2.22(0.05)	1.09(0.24)
BZBJ1534+3715	RGB J1534+372	13.45(0.03)	12.81(0.03)	10.84(0.09)	8.7(0.37)	2.15(0.16)	0.0(0.07)
BZBJ1540+8155	1ES 1544+820	12.9(0.02)	12.2(0.02)	10.15(0.04)	8.26(0.17)	1.48(0.16)	0.16(0.06)
BZBJ1546+0819	1RXS J154604.6+081912	13.58(0.03)	12.76(0.03)	10.59(0.08)	8.97(0.42)	1.57(0.21)	0.51(0.07)
BZBJ1548-2251	PMN J1548-2251	12.49(0.02)	11.76(0.02)	9.64(0.04)	7.78(0.15)	1.93(0.13)	0.26(0.04)
BZBJ1552+0850	TXS 1549+089	12.28(0.03)	11.29(0.02)	8.57(0.03)	6.44(0.06)	2.0(0.16)	1.02(0.06)
BZBJ1555+1111	PG 1553+113	10.63(0.02)	9.82(0.02)	7.62(0.02)	5.82(0.04)	1.67(0.02)	0.51(0.06)
BZBJ1607+1551	4C +15.54	13.31(0.02)	12.29(0.02)	9.41(0.04)	7.0(0.08)	2.23(0.06)	1.12(0.06)
BZBJ1610-6649	PMN J1610-6649	12.46(0.03)	11.69(0.02)	9.59(0.04)	7.85(0.15)	1.7(0.06)	0.4(0.06)
BZBJ1630+5221	TXS 1629+524	13.63(0.03)	12.81(0.02)	10.66(0.06)	8.8(0.26)	2.03(0.1)	0.52(0.06)
BZBJ1642-0621	TXS 1639-062	13.45(0.03)	12.26(0.02)	9.18(0.03)	6.82(0.08)	2.37(0.13)	1.59(0.06)
BZBJ1653+3945	Mkn 501	9.86(0.02)	9.4(0.02)	7.34(0.02)	5.4(0.03)	1.74(0.03)	-0.52(0.05)
BZBJ1719+1745	PKS 1717+177	12.48(0.03)	11.38(0.02)	8.46(0.02)	6.24(0.04)	1.84(0.06)	1.33(0.06)
BZBJ1725+1152	1H 1720+117	11.77(0.02)	10.95(0.02)	8.76(0.03)	6.97(0.08)	1.93(0.06)	0.53(0.06)
BZBJ1725+5851	7C 1724+5854	12.59(0.02)	11.68(0.02)	9.2(0.03)	7.33(0.08)	2.26(0.17)	0.79(0.06)
BZBJ1728+5013	I Zw 187	12.02(0.02)	11.39(0.02)	9.17(0.02)	7.15(0.07)	1.83(0.13)	-0.02(0.05)
BZBJ1730+3714	GB6 J1730+3714	13.14(0.02)	12.41(0.02)	10.17(0.04)	8.18(0.18)	2.09(0.14)	0.27(0.06)
BZBJ1739+4737	S4 1738+47	13.26(0.02)	12.18(0.02)	9.25(0.03)	6.94(0.06)	2.09(0.15)	1.26(0.06)
BZBJ1742+5945	RGB 1742+597	12.3(0.02)	11.36(0.02)	8.78(0.02)	6.78(0.05)	2.23(0.17)	0.88(0.05)
BZBJ1743+1935	S3 1741+19	11.61(0.02)	11.16(0.02)	9.22(0.03)	7.3(0.1)	1.62(0.15)	-0.57(0.05)
BZBJ1748+7005	S4 1749+70	11.96(0.02)	10.92(0.02)	8.14(0.02)	5.96(0.03)	2.04(0.06)	1.16(0.05)
BZBJ1749+4321	B3 1747+433	13.22(0.03)	12.1(0.02)	9.07(0.03)	6.8(0.06)	2.22(0.08)	1.39(0.06)
BZBJ1756+5522	1RXS J175615.5+552217	14.07(0.03)	13.45(0.03)	11.45(0.09)	9.4(0.48)	1.79(0.17)	-0.06(0.07)
BZBJ1800+7828	S5 1803+784	10.91(0.02)	9.79(0.02)	6.8(0.02)	4.54(0.02)	2.23(0.03)	1.4(0.05)
BZBJ1806+6949	3C 371	10.15(0.02)	9.29(0.02)	6.77(0.02)	4.75(0.02)	2.19(0.04)	0.64(0.05)
BZBJ1809+2910	MG2 J180948+2910	12.33(0.02)	11.37(0.02)	8.77(0.03)	6.74(0.06)	2.04(0.11)	0.95(0.06)
BZBJ1813+3144	B2 1811+31	12.4(0.02)	11.61(0.02)	9.4(0.04)	7.72(0.15)	2.11(0.07)	0.45(0.06)
BZBJ1813+0615	TXS 1811+062	12.98(0.03)	11.91(0.02)	9.12(0.03)	6.84(0.07)	1.97(0.13)	1.24(0.07)
BZBJ1824+5651	4C +56.27	12.24(0.02)	11.19(0.02)	8.22(0.02)	5.92(0.04)	2.43(0.04)	1.18(0.06)
BZBJ1829+5402	1RXS J182925.7+540255	13.21(0.02)	12.38(0.02)	10.21(0.04)	8.32(0.14)	1.88(0.13)	0.56(0.06)
BZBJ1832-5659	PMN J1832-5659	13.11(0.03)	12.14(0.02)	9.39(0.04)	7.23(0.09)	2.3(0.13)	0.95(0.06)
BZBJ1838+4802	GB6 J1838+4802	12.87(0.03)	12.11(0.02)	10.0(0.04)	8.04(0.12)	1.72(0.1)	0.34(0.06)
BZBJ1849-4314	PMN J1849-4314	11.93(0.03)	10.97(0.02)	8.4(0.02)	6.34(0.05)	2.02(0.09)	0.93(0.06)

Table 1
(Continued)

ROMA-BZCat Name	2FGL Name	m_1	m_2	m_3	m_4	Γ_γ	α_{IR}
BZBJ1917–1921	1H 1914–194	11.53(0.03)	10.66(0.02)	8.33(0.02)	6.38(0.06)	1.91(0.06)	0.66(0.06)
BZBJ1918–4111	PMN J1918–4111	12.95(0.03)	11.96(0.02)	9.41(0.04)	7.32(0.09)	1.84(0.06)	1.02(0.06)
BZBJ1921–1607	PMN J1921–1607	12.38(0.03)	11.6(0.02)	7.92(0.06)	7.35(0.24)	1.74(0.1)	0.39(0.06)
BZBJ1931+0937	RX J1931.1+0937	11.79(0.04)	11.12(0.03)	9.26(0.04)	7.57(0.12)	2.36(0.07)	0.09(0.08)
BZBJ1936–4719	PMN J1936–4719	13.52(0.03)	12.88(0.03)	10.78(0.09)	8.73(0.37)	1.64(0.16)	–0.0(0.07)
BZBJ1945–3111	PKS 1942–313	13.41(0.04)	12.3(0.03)	9.68(0.05)	7.42(0.15)	2.29(0.15)	1.36(0.08)
BZBJ2005+7752	S5 2007+77	11.06(0.02)	10.02(0.02)	7.26(0.02)	5.06(0.02)	2.22(0.09)	1.16(0.05)
BZBJ2009–4849	PKS 2005–489	10.23(0.02)	9.49(0.02)	7.23(0.02)	5.36(0.03)	1.78(0.05)	0.29(0.05)
BZBJ2009+7229	4C +72.28	13.16(0.02)	12.06(0.02)	9.21(0.03)	6.88(0.05)	2.3(0.08)	1.35(0.06)
BZBJ2015–0137	PKS 2012–017	12.67(0.02)	11.7(0.02)	8.98(0.03)	6.88(0.07)	2.25(0.11)	0.96(0.06)
BZBJ2022+7611	S5 2023+760	12.2(0.02)	11.15(0.02)	8.25(0.02)	6.04(0.03)	2.32(0.07)	1.2(0.06)
BZQJ0044–8422	PKS 0044–84	13.73(0.03)	12.65(0.03)	9.81(0.03)	7.44(0.09)	2.53(0.11)	1.28(0.06)
BZQJ0102+4214	CRATES J0102+4214	14.58(0.04)	13.5(0.04)	10.45(0.07)	8.0(0.18)	2.61(0.09)	1.29(0.08)
BZQJ0113+4948	S4 0110+49	12.48(0.02)	11.37(0.02)	8.43(0.02)	6.12(0.05)	2.26(0.12)	1.37(0.06)
BZQJ0128+4439	GB6 J0128+4439	14.82(0.04)	13.87(0.04)	11.72(0.21)	8.68()	2.25(0.13)	0.9(0.1)
BZQJ0136+4751	OC 457	11.53(0.02)	10.38(0.02)	7.31(0.02)	4.93(0.03)	2.15(0.04)	1.48(0.06)
BZQJ0205+3212	B2 0202+31	14.47(0.04)	12.89(0.03)	9.64(0.05)	7.2(0.1)	2.66(0.14)	2.75(0.08)
BZQJ0217+7349	S5 0212+73	13.99(0.03)	12.9(0.03)	9.56(0.04)	7.21(0.08)	2.82(0.11)	1.3(0.08)
BZQJ0217+0144	PKS 0215+015	11.41(0.02)	10.26(0.02)	7.28(0.02)	4.96(0.03)	2.15(0.03)	1.47(0.05)
BZQJ0230+4032	B3 0227+403	13.78(0.03)	12.58(0.03)	9.66(0.04)	7.43(0.12)	2.63(0.06)	1.62(0.07)
BZQJ0237+2848	4C +28.07	12.51(0.02)	11.37(0.02)	8.43(0.03)	6.09(0.05)	2.16(0.06)	1.44(0.06)
BZQJ0245+2405	B2 0242+23	15.48(0.05)	14.45(0.07)	11.09(0.14)	8.63(0.34)	2.54(0.08)	1.14(0.15)
BZQJ0250+1712	NVSS J025037+171209	12.95(0.03)	12.33(0.03)	10.27(0.07)	8.42(0.33)	1.84(0.17)	–0.05(0.06)
BZQJ0252–2219	PKS 0250–225	14.28(0.03)	13.04(0.03)	9.81(0.05)	7.38(0.12)	2.19(0.05)	1.76(0.07)
BZQJ0257–1212	PB 09399	14.26(0.03)	13.08(0.03)	10.17(0.05)	8.09(0.17)	2.39(0.14)	1.57(0.07)
BZQJ0303–7914	PMN J0303–7914	14.28(0.03)	13.06(0.03)	10.02(0.04)	7.53(0.09)	2.2(0.13)	1.7(0.07)
BZQJ0309+1029	PKS 0306+102	12.26(0.02)	11.15(0.02)	8.12(0.02)	5.78(0.04)	2.26(0.08)	1.39(0.06)
BZQJ0310+3814	B3 0307+38	14.06(0.04)	12.92(0.03)	9.81(0.05)	7.25(0.1)	2.25(0.16)	1.46(0.08)
BZQJ0312+0133	PKS 0310+013	13.51(0.03)	12.41(0.03)	9.61(0.04)	7.05(0.08)	2.26(0.08)	1.34(0.06)
BZQJ0315–1031	PKS 0313–107	15.77(0.06)	14.72(0.08)	11.49(0.18)	9.11()	2.18(0.13)	1.22(0.17)
BZQJ0325+2224	TXS 0322+222	13.68(0.03)	12.42(0.03)	9.16(0.04)	6.75(0.09)	2.41(0.12)	1.82(0.07)
BZQJ0336+3218	NRAO 140	12.56(0.03)	11.25(0.02)	8.63(0.03)	6.38(0.06)	2.59(0.1)	1.97(0.06)
BZQJ0339–0146	PKS 0336–01	12.7(0.03)	11.54(0.02)	8.58(0.03)	6.16(0.05)	2.48(0.07)	1.51(0.06)
BZQJ0348–2749	PKS 0346–27	13.98(0.03)	12.88(0.03)	9.78(0.04)	7.46(0.11)	2.32(0.13)	1.35(0.07)
BZQJ0349–2102	PKS 0347–211	15.59(0.05)	14.42(0.06)	11.29(0.13)	8.57(0.3)	2.23(0.09)	1.55(0.13)
BZQJ0402–3147	PKS 0400–319	14.05(0.03)	12.97(0.03)	10.02(0.05)	7.75(0.14)	2.52(0.22)	1.28(0.07)
BZQJ0403–3605	PKS 0402–362	11.49(0.02)	10.27(0.02)	6.99(0.02)	4.52(0.02)	2.3(0.04)	1.69(0.06)
BZQJ0405–1308	PKS 0403–13	12.33(0.02)	11.22(0.02)	8.75(0.03)	6.66(0.06)	2.35(0.16)	1.39(0.06)
BZQJ0413–5332	PMN J0413–5332	15.18(0.04)	14.08(0.04)	11.09(0.08)	8.53(0.23)	2.41(0.09)	1.34(0.09)
BZQJ0416–1851	PKS 0414–189	14.86(0.04)	13.56(0.04)	10.35(0.06)	7.99(0.17)	2.2(0.09)	1.92(0.09)
BZQJ0422–0643	PMN J0422–0643	12.56(0.02)	11.58(0.02)	8.78(0.03)	6.54(0.06)	2.39(0.12)	0.99(0.06)
BZQJ0423–0120	PKS 0420–01	10.84(0.02)	9.72(0.02)	6.62(0.02)	4.25(0.02)	2.3(0.03)	1.41(0.05)
BZQJ0426+0518	PKS 0423+051	14.79(0.04)	13.52(0.04)	10.59(0.08)	8.22(0.24)	2.66(0.12)	1.85(0.09)
BZQJ0438–1251	PKS 0436–129	14.23(0.03)	13.1(0.03)	10.14(0.05)	7.84(0.15)	2.35(0.17)	1.45(0.07)
BZQJ0442–0017	PKS 0440–00	12.9(0.02)	11.84(0.02)	8.94(0.03)	6.6(0.05)	2.44(0.03)	1.22(0.06)
BZQJ0448–2109	PKS 0446–212	14.51(0.03)	13.5(0.04)	10.52(0.08)	8.23(0.25)	2.33(0.18)	1.09(0.09)
BZQJ0453–2807	PKS 0451–28	13.49(0.03)	12.4(0.02)	9.15(0.03)	6.59(0.06)	2.66(0.05)	1.32(0.06)
BZQJ0455–4615	PKS 0454–46	13.45(0.03)	12.23(0.02)	9.09(0.03)	6.65(0.05)	2.62(0.06)	1.69(0.06)
BZQJ0456–3136	PMN J0456–3135	14.37(0.03)	13.29(0.03)	10.34(0.05)	7.7(0.11)	2.42(0.14)	1.28(0.07)
BZQJ0457–2324	PKS 0454–234	12.27(0.02)	11.14(0.02)	8.15(0.02)	5.81(0.03)	2.03(0.02)	1.41(0.06)
BZQJ0501–0159	S3 0458–02	13.19(0.03)	12.01(0.02)	8.89(0.03)	6.44(0.06)	2.52(0.1)	1.59(0.06)
BZQJ0502+0609	PKS 0459+060	14.43(0.04)	13.2(0.03)	10.31(0.07)	7.99(0.21)	2.46(0.17)	1.72(0.08)
BZQJ0505–0419	S3 0503–04	14.93(0.04)	13.81(0.04)	10.52(0.08)	8.41(0.28)	2.21(0.14)	1.38(0.1)
BZQJ0507–6104	PMN J0507–6104	14.1(0.03)	12.99(0.02)	10.11(0.03)	7.77(0.1)	2.36(0.08)	1.37(0.06)
BZQJ0509+1011	PKS 0506+101	14.26(0.03)	13.23(0.03)	10.45(0.08)	7.89(0.19)	2.33(0.09)	1.14(0.08)
BZQJ0510+1800	PKS 0507+17	11.9(0.03)	10.8(0.02)	7.91(0.02)	5.63(0.04)	2.29(0.1)	1.36(0.06)
BZQJ0515–4556	PKS 0514–459	12.73(0.02)	11.76(0.02)	8.93(0.02)	6.56(0.04)	2.47(0.18)	0.96(0.05)
BZQJ0526–4830	PKS 0524–485	13.68(0.02)	12.53(0.02)	9.5(0.03)	7.2(0.07)	2.2(0.09)	1.5(0.06)
BZQJ0530+1331	PKS 0528+134	14.7(0.04)	13.65(0.04)	10.5(0.09)	7.74(0.16)	2.22(0.09)	1.18(0.1)
BZQJ0529–0519	PMN J0529–0519	14.3(0.03)	13.42(0.04)	10.19(0.06)	7.83(0.17)	2.3(0.39)	0.71(0.09)
BZQJ0532–3848	PMN J0532–3848	15.34(0.04)	14.11(0.04)	11.04(0.09)	8.62(0.27)	2.61(0.15)	1.73(0.1)
BZQJ0532+0732	OG 050	13.62(0.04)	12.42(0.03)	9.24(0.04)	6.7(0.07)	2.31(0.04)	1.64(0.09)
BZQJ0533+4822	TXS 0529+483	12.7(0.03)	11.45(0.02)	8.26(0.02)	5.8(0.04)	2.31(0.05)	1.78(0.06)
BZQJ0539–2839	PKS 0537–286	15.79(0.06)	14.75(0.06)	11.41(0.13)	8.59(0.28)	2.83(0.1)	1.18(0.14)
BZQJ0607–0834	PKS 0605–08	11.94(0.02)	11.36(0.02)	9.06(0.03)	6.81(0.06)	2.36(0.08)	–0.19(0.06)
BZQJ0610–6058	PKS 0609–609	16.17(0.05)	14.92(0.05)	12.1(0.14)	9.19(0.3)	2.36(0.16)	1.76(0.11)

Table 1
(Continued)

ROMA-BZCat Name	2FGL Name	m_1	m_2	m_3	m_4	Γ_γ	α_{IR}
BZQJ0635–7516	PKS 0637–75	11.57(0.02)	10.49(0.02)	7.65(0.02)	5.36(0.03)	2.65(0.06)	1.28(0.05)
BZQJ0701–4634	PKS 0700–465	13.02(0.03)	11.83(0.02)	8.68(0.02)	6.28(0.05)	2.16(0.12)	1.62(0.06)
BZQJ0713+1935	MG2 J071354+1934	11.87(0.02)	10.84(0.02)	8.1(0.02)	5.89(0.04)	2.01(0.06)	1.13(0.05)
BZQJ0725+1425	4C +14.23	13.42(0.03)	12.31(0.03)	9.43(0.04)	6.98(0.08)	2.04(0.04)	1.37(0.06)
BZQJ0726+2153	TXS 0723+220	15.11(0.08)	13.76(0.06)	10.54(0.09)	8.44(0.31)	2.59(0.14)	2.08(0.17)
BZQJ0726–4728	PMN J0726–4728	14.02(0.04)	12.86(0.03)	9.75(0.04)	7.26(0.08)	2.34(0.09)	1.52(0.07)
BZQJ0730–1141	PKS 0727–11	11.91(0.02)	10.76(0.02)	7.68(0.02)	5.28(0.04)	2.11(0.02)	1.48(0.05)
BZQJ0733+5022	TXS 0730+504	13.78(0.03)	12.74(0.03)	9.95(0.05)	7.42(0.1)	2.35(0.12)	1.17(0.07)
BZQJ0739+0137	PKS 0736+01	11.04(0.02)	10.02(0.02)	7.24(0.02)	5.03(0.03)	2.23(0.08)	1.11(0.05)
BZQJ0746+2549	B2 0743+25	16.11(0.08)	14.9(0.09)	11.39(0.17)	8.48(0.28)	2.85(0.11)	1.66(0.2)
BZQJ0749+4510	B3 0745+453	11.98(0.03)	10.95(0.02)	8.07(0.02)	5.51(0.03)	2.24(0.16)	1.16(0.06)
BZQJ0750+1231	O1 280	12.3(0.02)	11.22(0.02)	8.37(0.02)	5.97(0.04)	2.42(0.07)	1.3(0.06)
BZQJ0805+6144	TXS 0800+618	15.59(0.05)	14.4(0.06)	11.02(0.1)	8.4(0.26)	2.74(0.07)	1.62(0.13)
BZQJ0808–0751	PKS 0805–07	11.56(0.02)	10.51(0.02)	7.7(0.02)	5.42(0.03)	1.93(0.03)	1.18(0.05)
BZQJ0824+3916	4C +39.23	14.18(0.03)	12.95(0.03)	9.75(0.04)	7.24(0.09)	2.64(0.17)	1.73(0.07)
BZQJ0824+5552	OJ 535	14.58(0.03)	13.33(0.03)	10.32(0.07)	7.74(0.16)	2.68(0.08)	1.78(0.08)
BZQJ0830+2410	S3 0827+24	13.14(0.03)	11.94(0.02)	8.8(0.03)	6.49(0.06)	2.67(0.07)	1.64(0.06)
BZQJ0833+4224	OJ 451	12.3(0.02)	11.26(0.02)	8.48(0.03)	6.26(0.05)	2.33(0.13)	1.19(0.06)
BZQJ0839+0104	PKS 0837+012	14.92(0.04)	13.68(0.04)	10.66(0.09)	8.18(0.25)	2.21(0.11)	1.75(0.1)
BZQJ0841+7053	4C +71.07	13.73(0.03)	12.59(0.03)	9.16(0.03)	6.68(0.06)	2.95(0.07)	1.47(0.06)
BZQJ0903+4651	S4 0859+47	14.36(0.03)	13.15(0.03)	9.98(0.05)	7.58(0.12)	2.27(0.18)	1.67(0.08)
BZQJ0912+4126	B3 0908+416B	15.18(0.04)	14.0(0.05)	10.94(0.09)	8.12(0.17)	2.3(0.17)	1.59(0.1)
BZQJ0916+3854	S4 0913+39	14.57(0.03)	13.43(0.04)	10.5(0.08)	8.39(0.29)	2.53(0.16)	1.47(0.09)
BZQJ0920+4441	S4 0917+44	13.59(0.03)	12.36(0.03)	9.09(0.03)	6.58(0.07)	2.11(0.03)	1.73(0.07)
BZQJ0921+6215	OK 630	14.3(0.03)	13.14(0.03)	10.02(0.05)	7.42(0.1)	2.51(0.09)	1.55(0.07)
BZQJ0937+5008	GB6 J0937+5008	13.19(0.03)	12.02(0.02)	8.91(0.03)	6.4(0.06)	2.5(0.15)	1.55(0.06)
BZQJ0957+5522	4C +55.17	12.91(0.03)	11.85(0.02)	8.94(0.03)	6.63(0.06)	1.83(0.03)	1.22(0.06)
BZQJ1044+8054	S5 1039+81	12.44(0.02)	11.33(0.02)	8.42(0.02)	6.12(0.04)	2.54(0.15)	1.39(0.06)
BZQJ1056+7011	S5 1053+70	14.86(0.03)	13.62(0.03)	10.22(0.05)	7.7(0.12)	2.64(0.1)	1.74(0.08)
BZQJ1058+8114	S5 1053+81	13.37(0.03)	12.2(0.02)	9.04(0.03)	6.64(0.06)	2.58(0.09)	1.57(0.06)
BZQJ1258–2219	PKS 1256–220	12.85(0.03)	11.65(0.03)	8.72(0.03)	6.55(0.07)	2.3(0.07)	1.61(0.06)
BZQJ1316–3338	PKS 1313–333	12.77(0.03)	11.65(0.02)	8.68(0.03)	6.34(0.06)	2.31(0.06)	1.41(0.06)
BZQJ1332–1256	PMN J1332–1256	15.51(0.06)	14.29(0.07)	11.36(0.22)	8.1(0.27)	2.38(0.04)	1.69(0.16)
BZQJ1337–1257	PKS 1335–127	12.6(0.03)	11.39(0.02)	8.2(0.02)	5.65(0.04)	2.44(0.07)	1.67(0.06)
BZQJ1342–2051	PKS B1339–206	14.72(0.04)	13.26(0.04)	10.05(0.06)	7.58(0.14)	2.63(0.13)	2.4(0.09)
BZQJ1344–1723	PMN J1344–1723	13.33(0.03)	12.19(0.03)	9.15(0.04)	6.9(0.09)	1.95(0.06)	1.47(0.06)
BZQJ1347–3750	PMN J1347–3750	14.47(0.04)	13.32(0.04)	10.33(0.06)	7.94(0.17)	2.32(0.12)	1.46(0.09)
BZQJ1351+0031	PKS 1348+007	13.94(0.03)	12.89(0.03)	10.15(0.07)	8.48(0.3)	2.29(0.11)	1.21(0.08)
BZQJ1354–1041	PKS 1352–104	13.42(0.03)	12.4(0.03)	9.3(0.04)	6.96(0.09)	2.57(0.08)	1.09(0.07)
BZQJ1357+7643	S5 1357+76	14.95(0.03)	13.76(0.03)	10.79(0.06)	7.99(0.13)	2.3(0.1)	1.63(0.07)
BZQJ1408–0752	PKS B1406–076	13.84(0.03)	12.54(0.03)	9.52(0.05)	7.2(0.13)	2.43(0.06)	1.93(0.07)
BZQJ1427–4206	PKS B1424–418	11.26(0.02)	10.17(0.02)	7.22(0.02)	4.94(0.03)	1.96(0.03)	1.32(0.05)
BZQJ1436+2321	PKS B1434+235	14.06(0.03)	12.79(0.03)	9.49(0.04)	6.86(0.07)	2.41(0.18)	1.84(0.07)
BZQJ1441–3303	PKS 1438–328	14.17(0.03)	13.04(0.04)	10.01(0.06)	7.62(0.15)	2.76(0.17)	1.44(0.08)
BZQJ1443+2501	PKS 1441+25	15.41(0.05)	14.34(0.06)	11.29(0.16)	8.73(0.4)	2.03(0.12)	1.25(0.13)
BZQJ1457–3539	PKS 1454–354	13.0(0.03)	11.92(0.02)	9.07(0.03)	6.89(0.07)	2.11(0.03)	1.28(0.06)
BZQJ1504+1029	PKS 1502+106	13.21(0.03)	12.05(0.02)	9.06(0.03)	6.62(0.06)	2.15(0.02)	1.54(0.06)
BZQJ1505+0326	PKS 1502+036	13.94(0.03)	12.95(0.03)	9.68(0.04)	7.03(0.09)	2.51(0.07)	1.0(0.07)
BZQJ1506+3730	B2 1504+37	13.9(0.03)	12.54(0.03)	9.56(0.04)	7.45(0.1)	2.57(0.1)	2.09(0.07)
BZQJ1509–4340	PMN J1509–4340	14.27(0.05)	13.14(0.04)	10.5(0.07)	7.74(0.14)	2.65(0.14)	1.44(0.11)
BZQJ1510–0543	PKS 1508–05	13.18(0.02)	12.01(0.02)	9.06(0.03)	6.59(0.07)	2.44(0.06)	1.55(0.06)
BZQJ1512–0905	PKS 1510–08	11.27(0.02)	10.17(0.02)	7.37(0.02)	5.06(0.03)	2.29(0.01)	1.32(0.06)
BZQJ1520+4211	B3 1518+423	13.15(0.02)	12.21(0.02)	9.48(0.03)	7.3(0.09)	2.5(0.31)	0.88(0.06)
BZQJ1521+4336	B3 1520+437	15.62(0.05)	14.5(0.06)	10.98(0.1)	8.74(0.31)	2.99(0.16)	1.4(0.13)
BZQJ1539+2744	MG2 J153938+2744	14.17(0.03)	12.95(0.03)	9.86(0.04)	7.41(0.1)	1.99(0.13)	1.68(0.07)
BZQJ1549+0237	PKS 1546+027	12.21(0.02)	11.13(0.02)	8.47(0.03)	6.22(0.05)	2.46(0.07)	1.27(0.06)
BZQJ1550+0527	4C +05.64	13.38(0.03)	12.2(0.02)	9.1(0.03)	6.61(0.07)	2.32(0.11)	1.6(0.06)
BZQJ1608+1029	4C +10.45	12.56(0.03)	11.46(0.02)	8.6(0.03)	6.23(0.04)	2.33(0.1)	1.34(0.06)
BZQJ1610–3958	PMN J1610–3958	11.98(0.03)	10.87(0.02)	7.95(0.02)	5.58(0.03)	2.61(0.1)	1.36(0.07)
BZQJ1613+3412	OS 319	14.02(0.03)	12.89(0.03)	9.91(0.04)	7.38(0.1)	2.31(0.17)	1.44(0.07)
BZQJ1617–7717	PKS 1610–77	13.23(0.03)	12.16(0.03)	9.07(0.03)	6.62(0.06)	2.5(0.05)	1.27(0.06)
BZQJ1635+3808	4C +38.41	13.09(0.03)	11.86(0.02)	8.51(0.02)	5.96(0.04)	2.25(0.03)	1.71(0.06)
BZQJ1637+4717	4C +47.44	12.63(0.02)	11.45(0.02)	8.35(0.02)	5.98(0.04)	2.41(0.06)	1.59(0.06)
BZQJ1640+3946	NRAO 512	15.0(0.04)	13.81(0.04)	10.72(0.07)	8.26(0.19)	2.36(0.06)	1.6(0.08)
BZQJ1642+3948	3C 345	11.8(0.03)	10.63(0.02)	7.52(0.02)	5.13(0.03)	2.49(0.06)	1.54(0.06)
BZQJ1656+6012	87GB 165604.4+601702	14.26(0.03)	13.26(0.03)	10.62(0.05)	8.18(0.14)	2.36(0.21)	1.03(0.06)

Table 1
(Continued)

ROMA-BZCat Name	2FGL Name	m_1	m_2	m_3	m_4	Γ_γ	α_{IR}
BZQJ1703–6212	CGRaBS J1703–6212	12.27(0.03)	11.26(0.02)	8.44(0.02)	6.19(0.04)	2.43(0.04)	1.07(0.06)
BZQJ1709+4318	B3 1708+433	13.5(0.03)	12.35(0.02)	9.31(0.03)	6.98(0.07)	2.31(0.05)	1.48(0.06)
BZQJ1722+1013	TXS 1720+102	12.42(0.02)	11.33(0.02)	8.33(0.02)	5.98(0.04)	2.23(0.06)	1.31(0.06)
BZQJ1724+4004	S4 1722+40	14.16(0.03)	13.09(0.03)	10.0(0.04)	7.66(0.1)	2.34(0.06)	1.25(0.06)
BZQJ1727+4530	S4 1726+45	13.67(0.02)	12.51(0.02)	9.37(0.03)	6.82(0.06)	2.58(0.06)	1.52(0.06)
BZQJ1728+1215	PKS 1725+123	13.66(0.03)	12.48(0.03)	9.42(0.04)	6.98(0.08)	2.09(0.2)	1.58(0.06)
BZQJ1728+0427	PKS 1725+044	12.3(0.02)	11.31(0.02)	8.45(0.03)	5.87(0.04)	2.53(0.08)	1.02(0.06)
BZQJ1730+0024	PKS 1728+004	12.85(0.03)	11.72(0.03)	8.78(0.03)	6.49(0.07)	2.31(0.07)	1.43(0.06)
BZQJ1733–1304	PKS 1730–13	12.14(0.03)	11.06(0.02)	8.1(0.02)	5.66(0.04)	2.24(0.09)	1.3(0.06)
BZQJ1734+3857	B2 1732+38A	13.49(0.03)	12.31(0.02)	9.15(0.03)	6.79(0.06)	2.24(0.04)	1.58(0.06)
BZQJ1739+4955	S4 1738+49	12.61(0.03)	11.5(0.02)	8.64(0.02)	6.37(0.04)	2.2(0.09)	1.36(0.06)
BZQJ1740+5211	4C +51.37	12.33(0.02)	11.16(0.02)	8.16(0.02)	5.89(0.03)	2.5(0.04)	1.54(0.05)
BZQJ1745+2252	TXS 1742+228	15.21(0.04)	14.05(0.05)	11.08(0.1)	8.55(0.28)	2.87(0.17)	1.52(0.11)
BZQJ1801+4404	S4 1800+44	13.23(0.02)	12.19(0.02)	9.16(0.03)	6.72(0.05)	2.66(0.14)	1.16(0.06)
BZQJ1818+0903	MG1 J181841+0903	13.08(0.03)	11.98(0.03)	9.11(0.03)	6.82(0.08)	2.32(0.08)	1.32(0.07)
BZQJ1848+3219	B2 1846+32A	13.36(0.03)	12.19(0.02)	9.13(0.03)	6.69(0.06)	2.38(0.09)	1.54(0.06)
BZQJ1852+4855	S4 1851+48	13.08(0.03)	12.0(0.02)	9.13(0.02)	6.89(0.06)	2.28(0.04)	1.28(0.06)
BZQJ1903–6749	PMN J1903–6749	13.46(0.03)	12.38(0.02)	9.49(0.03)	7.08(0.08)	2.49(0.1)	1.3(0.06)
BZQJ1911–2006	PKS B1908–201	11.27(0.02)	10.17(0.02)	7.16(0.03)	()	2.21(0.05)	1.36(0.06)
BZQJ1923–2104	TXS 1920–211	11.09(0.02)	10.08(0.02)	7.33(0.02)	5.02(0.03)	2.1(0.04)	1.08(0.05)
BZQJ1924–2914	PKS B1921–293	10.81(0.02)	9.65(0.02)	6.53(0.02)	4.1(0.02)	2.43(0.05)	1.52(0.06)
BZQJ1954–1123	TXS 1951–115	13.68(0.04)	12.5(0.03)	9.45(0.05)	7.08(0.12)	2.25(0.05)	1.57(0.08)
BZQJ1957–3845	PKS 1954–388	12.35(0.02)	11.19(0.02)	8.28(0.02)	5.87(0.04)	2.36(0.05)	1.51(0.05)
BZQJ1959–4246	PMN J1959–4246	13.62(0.03)	12.45(0.03)	9.48(0.04)	7.01(0.08)	2.41(0.05)	1.53(0.07)
BZQJ2007–4434	PKS 2004–447	13.37(0.03)	12.28(0.03)	9.42(0.04)	7.01(0.09)	2.47(0.12)	1.3(0.06)
BZQJ2023–1139	PMN J2023–1140	15.38(0.05)	14.63(0.08)	11.24(0.17)	7.96(0.21)	2.07(0.11)	0.32(0.16)
BZQJ2025–0735	PKS 2023–07	13.32(0.03)	12.08(0.02)	8.87(0.03)	6.33(0.06)	2.15(0.03)	1.75(0.06)
BZQJ2030–0622	TXS 2027–065	14.15(0.03)	12.93(0.03)	9.8(0.06)	8.03(0.26)	2.73(0.1)	1.7(0.08)
BZQJ2056–4714	PKS 2052–47	12.6(0.03)	11.31(0.02)	7.99(0.02)	5.54(0.04)	2.23(0.04)	1.89(0.06)
BZQJ2135–5006	PMN J2135–5006	16.0(0.08)	15.0(0.11)	11.53(0.21)	9.01()	2.58(0.1)	1.05(0.23)
BZQJ2147–7536	PKS 2142–75	11.01(0.02)	9.78(0.02)	6.61(0.02)	4.23(0.02)	2.52(0.04)	1.72(0.05)
BZQJ2202–8338	PKS 2155–83	13.82(0.03)	12.67(0.02)	9.7(0.04)	7.46(0.1)	2.2(0.08)	1.48(0.06)

Notes. Column 1 contains the name of the blazar in the ROMA-BZCat catalog; Column 2: the name of the associated source from the 2FGL catalog; Columns 3–6: the values of the magnitude in the four *WISE* filters ([3.4], [4.6], [12], and [22] μm , respectively); Column 7: the Γ_γ photon index of the sources from the 2FGL catalog; and Column 8: the IR spectral index α_{12} evaluated from *WISE* magnitudes ([3.4] and [4.6]). Errors are reported in parentheses.

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