Gamma-ray Blazars at the Dawn of the Universe

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Blazars

• AGN with the relativistic jet aligned close to the line of sight ($\theta_v < 1/\Gamma$)
• Emitted radiation is predominantly non-thermal, variable, polarized, and relativistically boosted
• Dominates high energy extragalactic sky
• Due to relativistic beaming, they are observable even at high redshift ($z > 2$)
• Classified as FSRQ & BL Lacs

High Redshift Blazars

- Most powerful FSRQs
- Host $\sim 10^9 M_\odot$ black holes
- Synchrotron peak lies in IR whereas IC hump peaks at MeV energy range
- Shift in high energy peak causes them to be more luminous at hard X-rays than the $\gamma$-ray band
- In the latest LAT catalog (i.e., 3FGL), the farthest known $\gamma$-ray emitter has $z=3.1$

Motivation

• Our primary target is to study the general physical properties of high redshift MeV blazars

• Their contribution to the cosmic MeV background, & finally BH mass evolution at high redshift (e.g., Volonteri+, 2011, MNRAS, 416, 216)


LAT FSRQs, Ajello+12
MeV blazars, Ajello+09
Sample selection

• We start with Million Quasar Catalog, ~1.4 million quasars, updated on March 2, 2016

• First filter of redshift is applied and only $z > 3.1$ sources are retained

• Second filter of radio-loudness is used & only radio-loud objects ($RL > 10$) are considered

• This left ~1000 sources and we analyze LAT data for all of them
Data analysis

- Standard LAT data analysis procedure was adopted with a couple of the modifications
- Pass 8 dataset with all the four PSFs considered independently
- Energy range: 60 MeV to 300 GeV
- Component wise data analysis for the four PSFs
- Joint fitting for all the four components using ‘summed likelihood’ tool included in pylikelihood library
- TS maps were generated to identify unmodeled objects
Results: MW Association

- A total of 5 γ-ray emitters with TS>25 are found
- Likelihood ratio association method (as in 3LAC) is also adopted & the results are confirmed
- These objects have IR colors similar to WISE FSRQs (lie on or close to the WISE blazar strip, e.g., D’Abrusco+, 2012, ApJ, 748, 68)
Figure 2. Comparison of new $\gamma$-ray detected high-$z$ blazars with 3LAC objects in, left: $\gamma$-ray luminosity vs. photon index plane, and right: the redshift histogram.
Results: MW Properties

- SED modeling done for all objects that have multi-wavelength data available

- Modeling confirms these objects to have all the characteristics of powerful FSRQs, e.g., a hard X-ray spectrum, large Compton dominance, etc.
Results: BH Mass

- We found two objects to host more than a billion solar mass black holes, following the optical spectroscopic approach.

- The space density of the currently known billion solar mass black holes is $\sim 50 \text{ Gpc}^{-3}$ (Sbarrato+, 2015, MNRAS, 446, 2483).

- Our work has increased it to $\sim 70 \text{ Gpc}^{-3}$.

- This indicates that the radio-loud phase may be a key ingredient for quick black hole growth in the early Universe.
Summary

• A systematic search of the high redshift $\gamma$-ray emitting blazars has led to the detection of 5 new sources.

• Available MW observations indicates their similarity with the known powerful high redshift FSRQs.

• To increase the sample size further, the best approaches are
  • lowering the energy threshold of the LAT
  • use NuSTAR

• However, the optimal instrument would be a sensitive all sky MeV telescope, e.g., ComPair.
!!Thank you!!