A Survey of Efficient Particle Accelerators

Cassidy Metzger, Andrea Gokus, and Manel Errando

Introduction

The eROSITA satellite is capable of surveying the entire night sky in a portion of the X-ray band (0.2- 8 keV). It was launched in 2019 and is expected to release its first all-sky survey soon. The previous all-sky survey in the X-ray band, ROSAT, was limited to the 0.1-2 keV energy band2. Therefore, eROSITA is able to explore the universe in the 2-8 keV band for the first time.

Figure 1: An artist's rendition of the eROSITA satellite.

Objective

As a population, blazars are not well studied. The majority of blazar surveys focus on the brightest or most variable objects. This project aims to provide an unbiased survey of TeV-emitting blazars by exploiting correlations between the X-ray, infrared (IR), and gamma-ray emissions. Using data from the eROSITA and WISE satellites, our goal is to produce a catalog of TeV-emitting blazar candidates. This catalog will provide scientists with a diverse population of blazars and will aid in the study of why some AGN produce relativistic jets and others do not. By answering this question, we will be better able to understand galaxy/black hole formation and evolution

Blazars & AGN

Supermassive black holes occupy the center of every galaxy in the Universe. When these black holes are in the process of accreting matter around them, they are considered **active galactic nuclei (AGN)**. Approximately 10% of AGN are capable of launching collimated streams of matter via magnetic fields. These streams consist of particles that are accelerated close to the speed of light and can travel for thousands of light years [1]. This phenomenon is dubbed a **relativistic jet**. These jets emit energies ranging across the electromagnetic spectrum, and the most powerful ones are capable of producing gamma-ray energies up to tera-electron volt (TeV) levels. These TeV-emitting AGN often reside in a subclass of AGN called **BL Lacertae (BL Lac) Blazars**.

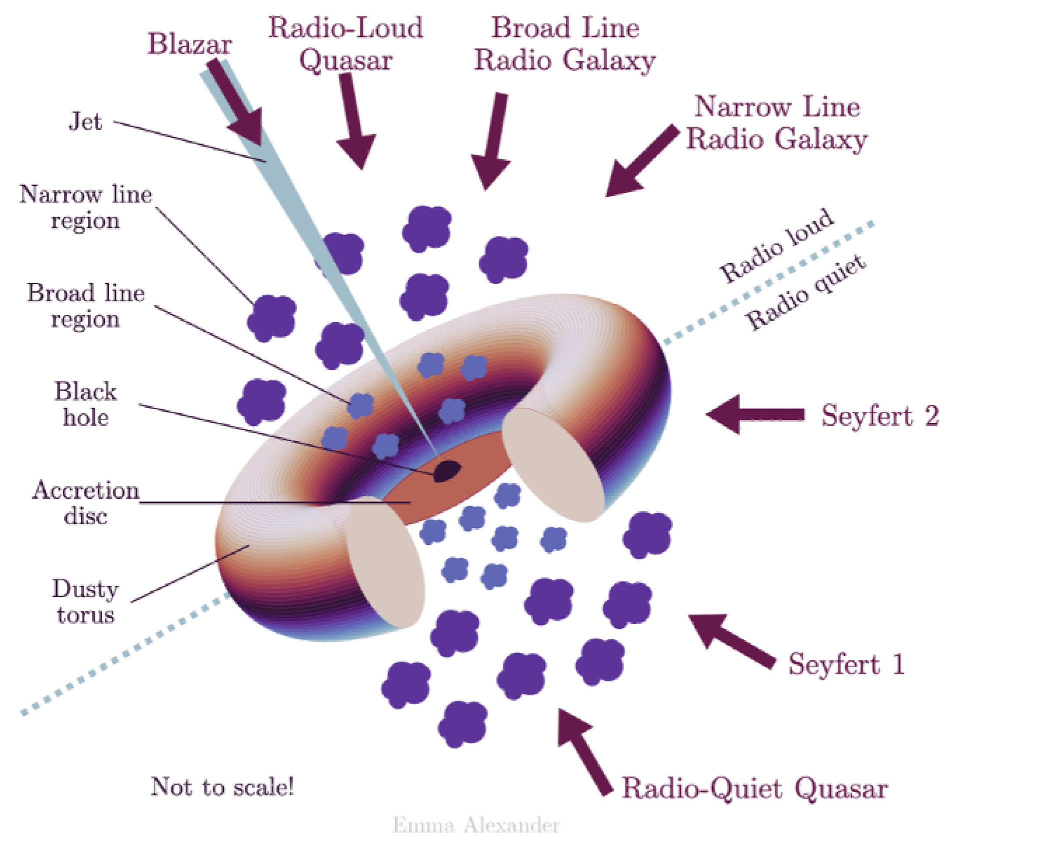

Figure 2: A graphical depiction of the Unified AGN model.

Procedure

We exploited the correlation between X-ray, IR, and gamma-ray emission ([2]). We searched for sources that show X-ray and IR emission that is characteristic of TeV-emitting objects ([3]). We utilized the eROSITA satellite to retrieve X-ray data and the WISE satellite to retrieve IR data. Both satellites span the entire sky. We began with the following steps which were derived from [3]

1. From the WISE data set, select only sources that display IR emission typical to that of an AGN
2. In the eROSITA data set, find the X-ray counterpart to the IR source. A counterpart must be separated from the original source by less than the positional error within the eROSITA data set.
3. Perform a fit correlation of the IR spectral slopes
4. Select sources closest to the best-fit line
   - This is true when $\delta < 1$ where $\delta = |D \cdot \frac{1}{D_{max}}|$
5. Select bright X-ray sources
   - $F_{X-ray} < 2.45 \times 10^{-12}$ erg cm^{-2} s^{-1}

Results:

The first all-sky survey using the eROSITA satellite (eRASS1) will be released at the end of January. So, to compensate for this lack of data, we utilized a small portion of the sky ($\sim$ 140 deg^2) called the eFEDS field. This field provides a glimpse into what the eRASS1 data will look like. However, given the small size of the field, only 33 sources from the WISE catalog fell within its region at all. Of those 33 sources, only IR source was found to have an X-ray counterpart. As a result, we were unable to perform a fit correlation, so the algorithm could not be properly executed. We skipped to step 5 to investigate the brightness of the source and found that the gamma-ray flux, extrapolated from the given X-ray flux, was below the detection limit for current and future gamma-ray telescopes. To continue to investigate the efficacy of our algorithm, we utilized the ROSAT all-sky survey. We found that 182 IR sources had X-ray counterparts. We performed a fit correlation and select 157 sources to fall within the criteria of step 4. Of these 157 sources, 139 of them exhibited X-ray fluxes above the threshold defined in step 5.

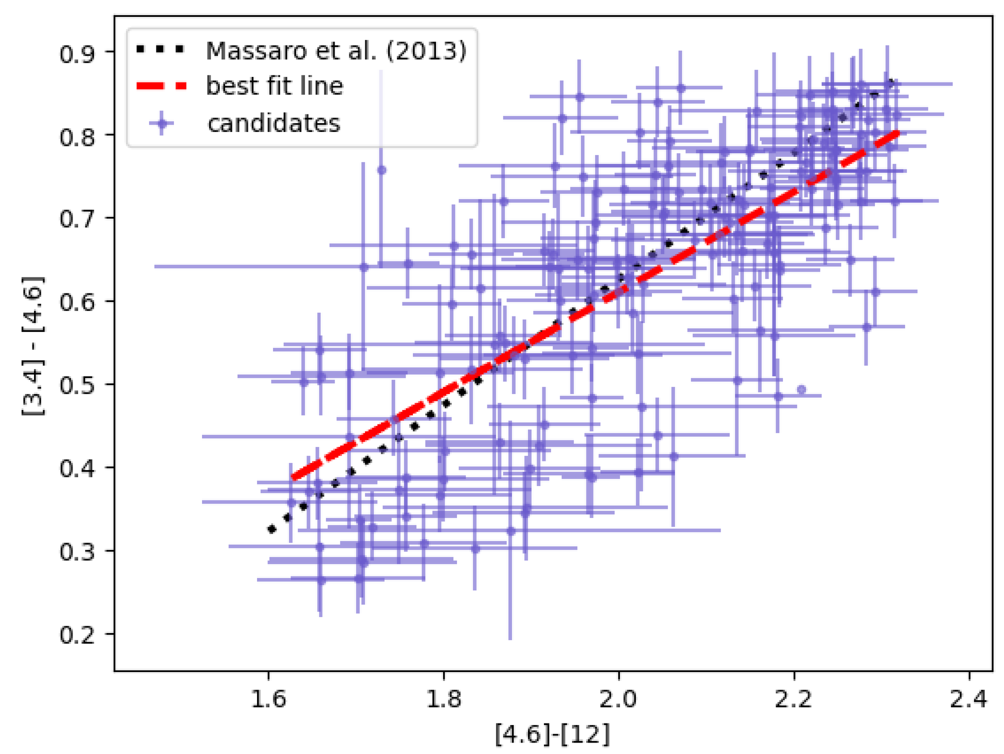

Figure 3: 157 TeV-emission candidates. Our best-fit line is displayed in red and [3]'s is shown for comparison (dashed line).

For the 139 candidates, multi-wavelength data was available for the majority of them. This allowed us to confirm these candidates as BL Lac objects.

Conclusion

Though we were unable to fully evaluate the algorithm in terms of the eROSITA data set, our results are strikingly similar to that of Massaro et al. (2013). This gives us confidence, that upon the release of eRASS1, this algorithm will be able to effectively handle the large amounts of data and rapidly produce a list of TeV-emitting candidates.

Future Studies

As stated, this algorithm will be applied to the eRASS1 data that is to be released at the end of January. It will produce a list of TeV-emitting candidates. Of these candidates, we plan to judge which ones are the most promising by evaluating their X-ray flux. We will then compile a list of the most promising candidates and publish this list in a peer-reviewed journal so it can serve as a target list for future gamma-ray observatories, such as the Cherenkov Telescope Array. By making this list public, we hope to aid in the discovery of the mechanisms that power relativistic jets.

References

[1] R. Blandford, D. Meier, and A. Readhead. Relativistic jets from active galactic nuclei. *Annual Review of Astronomy and Astrophysics*, 2019.

[2] F. Massaro, R. D'Abrusco, G. Tosti, and et al. The wise gamma-ray strip parametrization: The nature of the gamma-ray active galactic nuclei of uncertain type. *ApJ*, 2012.

[3] F. Massaro, A. Paggi, M. Errando, and et al. Bl lac candidates for tev observations. *ApJSS*, 2013.

Contact Info

Web: `https://sites.wustl.edu/errando/`
Email: `c.m.metzger@wustl.edu`