THE NATURE OF EXTRAGALACTIC UNIDENTIFIED GAMMA-RAY SOURCES (UGSs): THE KEY ROLE OF SWIFT/XRT

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AIM OF THE PROJECT

Over the past decade, the Swift satellite has observed unassociated gamma-ray sources (UGSs), which make up ~30% of Fermi detections. These may conceal new blazars, the most numerous class of extragalactic gamma-ray sources and potential neutrino emitters, or other AGNs. We conducted a multi-wavelength search using Swift/XRT images to identify their lower-energy counterparts.

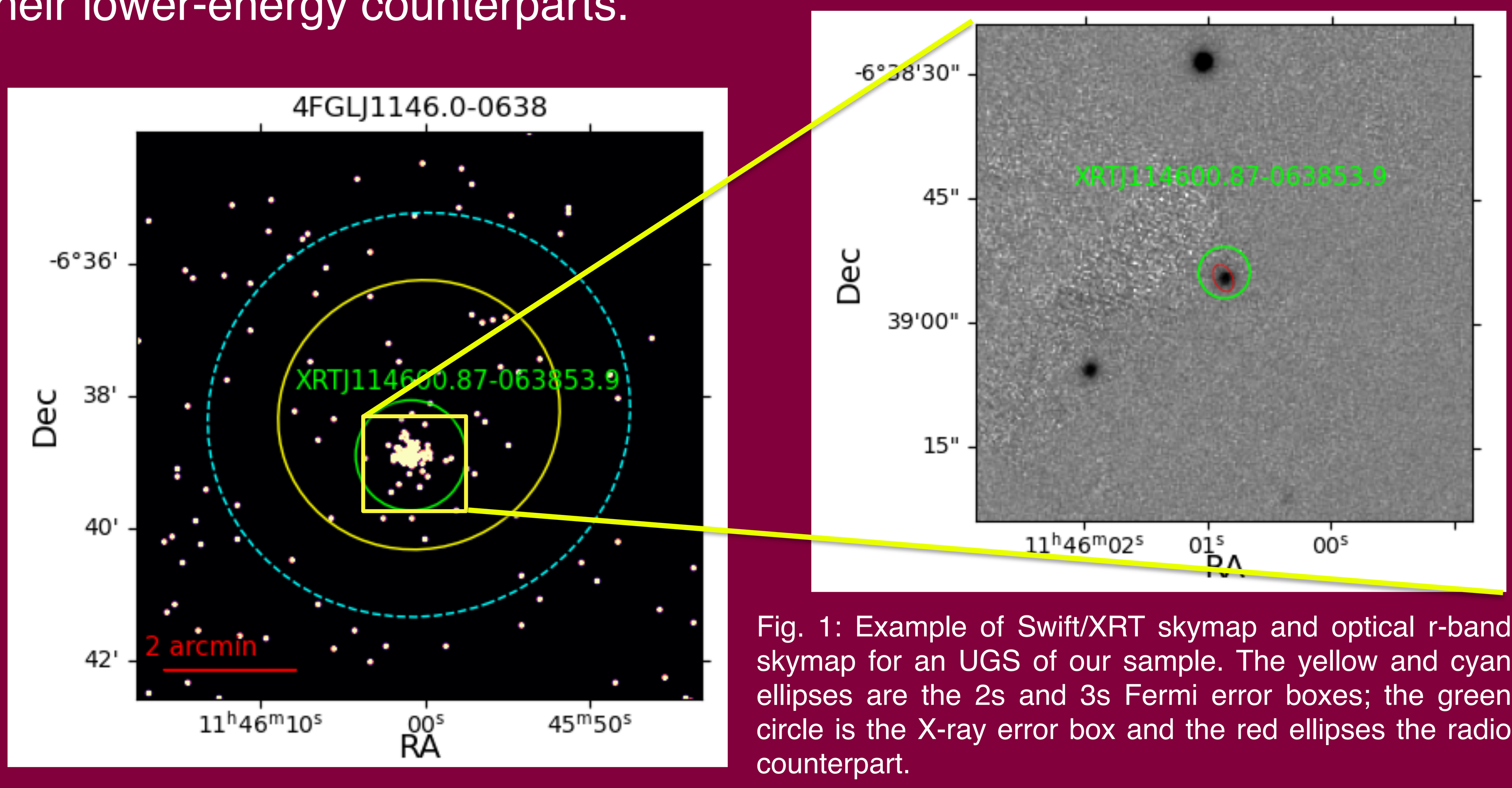

Fig. 1: Example of Swift/XRT skymap and optical r-band skymap for an UGS of our sample. The yellow and cyan ellipses are the 2s and 3s Fermi error boxes; the green circle is the X-ray error box and the red ellipses the radio counterpart.

UGS ASSOCIATION PROCEDURE AND MULTIWAVELENGTH COUNTERPARTS

We focus on the 1200 Fermi UGSs outside the Galactic plane (|b| > 10°).

~715 UGS with Swift Observations

The Swift/XRT provides crucial X-ray follow-up for γ-ray objects. Our association process uses Swift data covering the Fermi error-box (a few arcminutes).

If an X-ray source is found within the error-box, we search for radio, infrared, and optical counterparts to establish positional associations and construct its SED using available multi-wavelength fluxes.

274 UGSs with at least one X-ray counterparts

OPTICAL SPECTROSCOPY AND CLASSIFICATION

A key step in classifying UGSs is obtaining optical spectroscopy of their low-energy counterparts to determine their nature. This allows us to determine their nature, the redshift and estimate luminosity.

Over the past decade, we used 8-10m class optical telescopes (GTC, LBT) to obtain high-quality optical spectra (S/N > 100), assessing the AGN nature.

Till now we obtained spectra for 140 UGS counterparts and all published spectra are available in our database ZBLLAC:

https://web.oapd.inaf.it/zbllac/

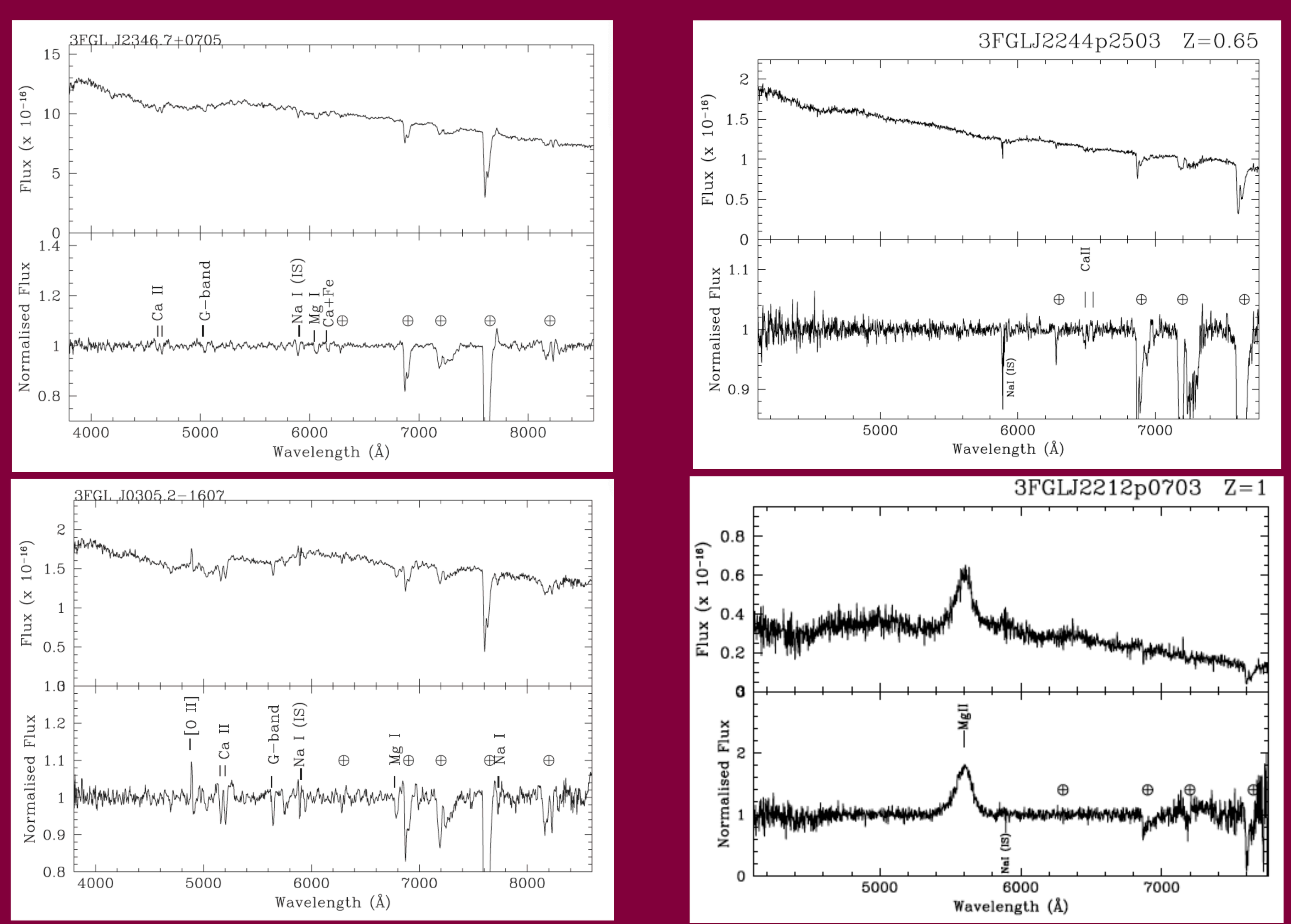

Fig. 2: Examples of optical spectra of UGSs.

MWL SED STUDY AND CHARACTERIZATION

For each UGS, XRT analysis enables to construct of the whole MLW SED from radio to g-rays.

Blazars were classified as low-, intermediate-, or high-synchrotron peaked (LSP, ISP, HSP) objects. We also searched for masquerading BL Lacs, a peculiar class of flat-spectrum radio quasars where broad emission lines are swamped by the jet emission and for which the neutrino production could be enhanced compared to the low-excitation galaxies.

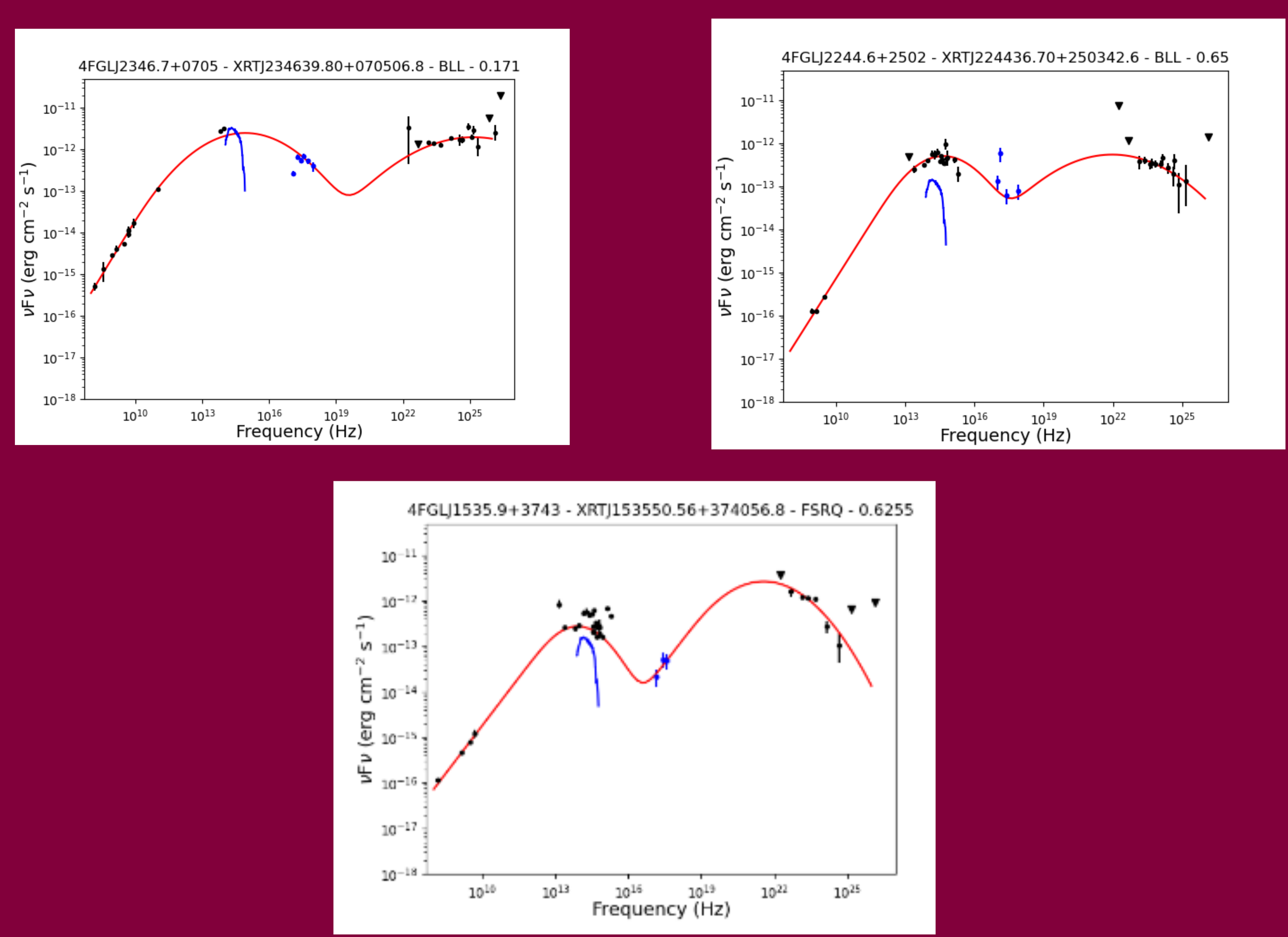

Fig. 3: Examples of Multiwavelenght SED of UGSs: Black points are data from VOU-Blazar and the blue points are X-ray data from our analysis.

OUR WORKS

Our study of UGSs are reported in:

Paiano et al., 2017, ApJ, 851, 135P;
Paiano et a.l, 2019, ApJ, 871, 162P;
Ulgiati et al., 2024, MNRAS, 530, 4626U;
Ulgiati et al, 2025a, A&A, 694A, 176U;
Ulgiati et al, 2025b (submitted);
Paiano et al, 2025 (in prep.)

CONCLUSIONS

We determined the redshift for ~80% of the UGS counteparts through the detection of emission and absorption lines, and set redshift lower limits for objects with featureless spectra.

Most UGSs are classified as blazars (mainly as BL Lac objects).

All UGS counterparts classified as BL Lacs are confirmed as radio-loud sources. In a number of clases, the UGS counterparts exhibits quasar-like prominent optical emission lines and are radio-quiet.