Cross-match between the Latest Swift/BAT and Fermi/LAT Catalogs toward MeV All-sky Simulation

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1. Abstract

We report the results of cross-match between the latest 105-month Swift/BAT and 10-yr Fermi/LAT catalogs, respectively. The 151 firmly matched sources consist of blazars (>60%), pulsars and pulsar wind nebulae (~10%), radio galaxies (~7%), binaries (~5%), and others. The matched sources are characterized by double-peaked photon index distributions and higher flux. This difference arises from the different population of sources, particularly the large proportion of blazars (i.e., FSRQs and BL Lac types). We also report 13 cross-matched and unidentified sources. The matched sources in this study would be promising in the intermediate energy band between the hard X-ray and GeV gamma-ray observations, that is the unexplored MeV gamma-ray domain.

2. Catalogs

■ Hard X-ray sky
• Covered by Swift/BAT since 2004
• 1632 sources in 14–195 keV (Swift/BAT 105-month catalog [1])

■ MeV gamma-ray sky
• Covered by COMPTEL >20 yrs ago [2]
• 32 steady sources and 31 GRBs (COMPTEL)

■ GeV gamma-ray sky
• Covered by Fermi/LAT since 2008
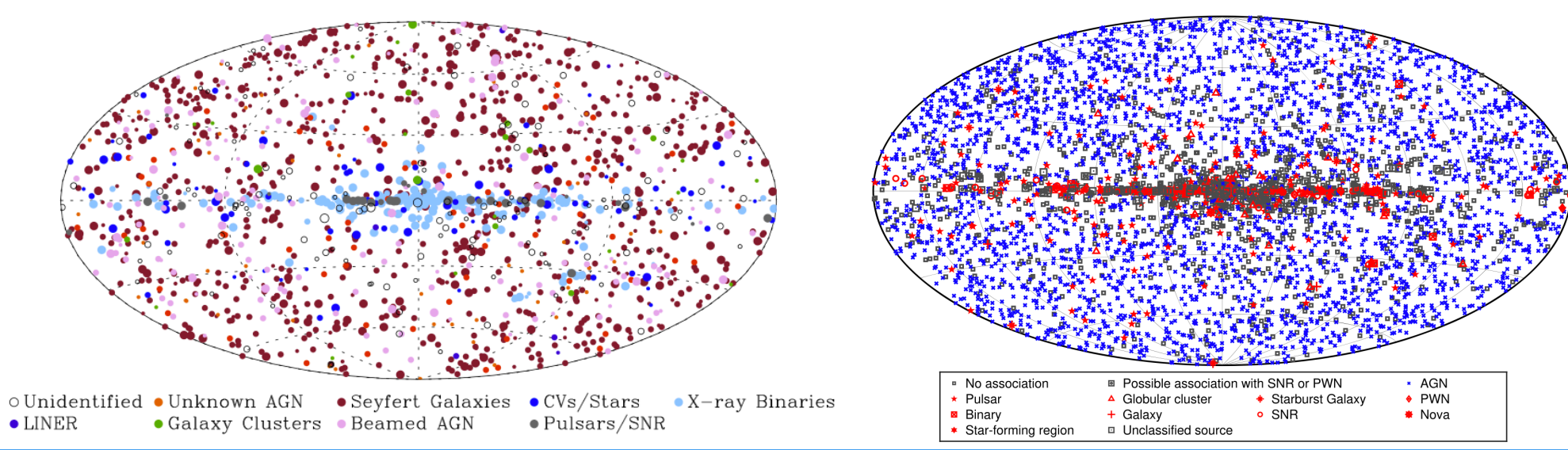• 5788 sources in 0.05–1000 GeV(Fermi/LAT; 4FGL-DR2 [3])

Fig.1: All sky maps of the BAT[1] (left) and LAT [3] (right) sources.

3. Cross-matching method

■ Spatial match of point-like sources
• Use coordinates in the catalogs
• Separation threshold of 0.08 degree is applied in order to reduce false-matches to ~5%.
• →132 sources (115 firmly matched)

■ Spatial match of extended sources
• 4FGL-DR2 has 75 extended sources
• Pick up BAT sources in the gamma-ray (Fermi) extent
• →31 sources (15 firmly matched)

■ Source identification match
• Pick up sources missed above
• →24 sources (21 firmly matched)

4. Results

4.1. Breakdown

		Swift/BAT	Fermi/LAT
AGN	BL Lac		32
	FSRQ	101	47
	BCU		15
	Radio galaxy		10
	Seyfert galaxy	8	2
HMXB		5	5
Pulsar		19	9
PWN		0	10
SNR		6	4

Tab. 1: Numbers of the firmly matched sources
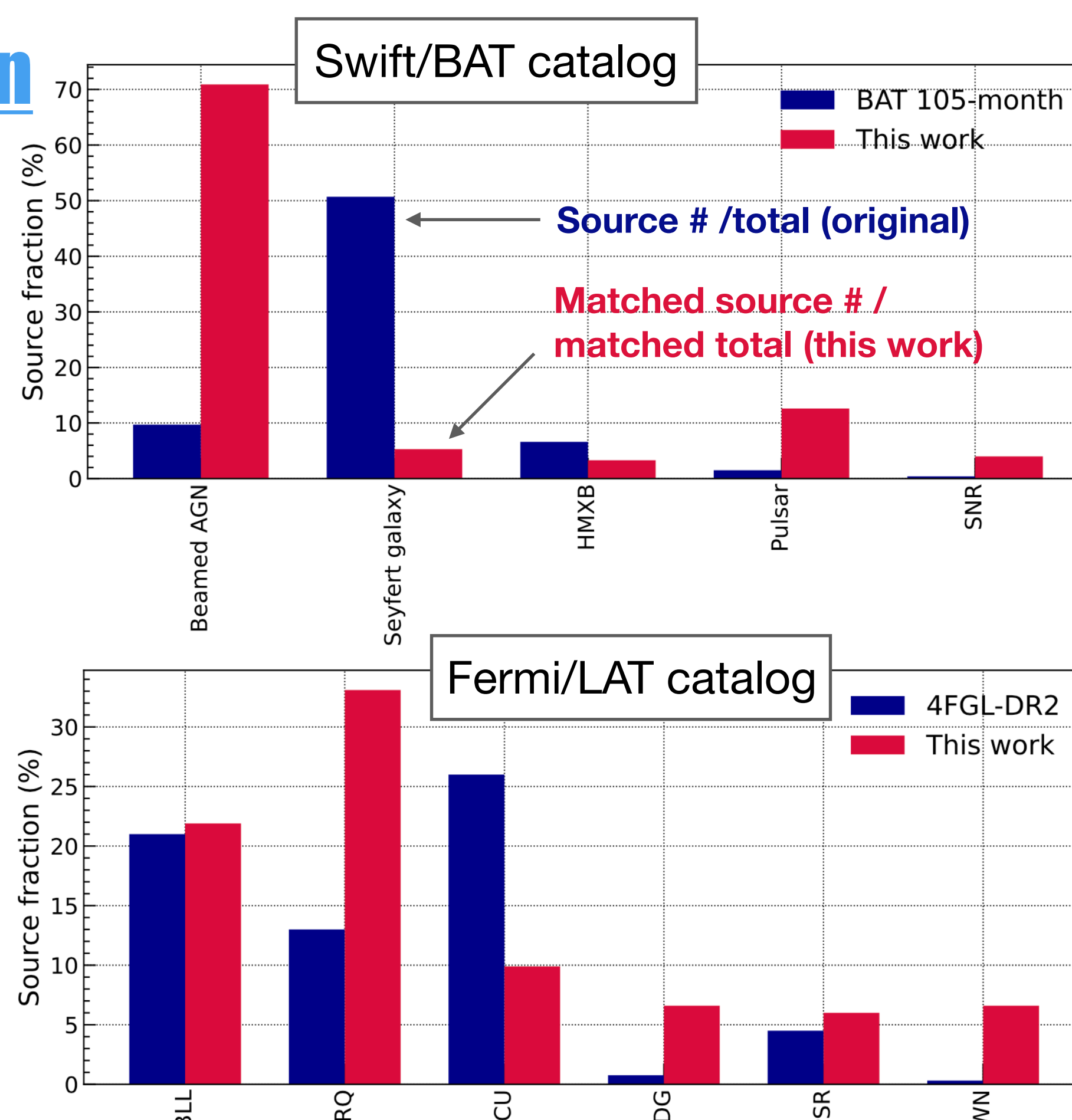
4.2. Source fraction

Fig. 2: Source fraction of the matched sources, compared to the BAT (top) and LAT (bottom) catalogs.

5. Discussion

5.1. Photon index and flux

• Photon index and flux distributions of the matched sources are different from those of Swift/BAT catalog and 4FGL-DR2
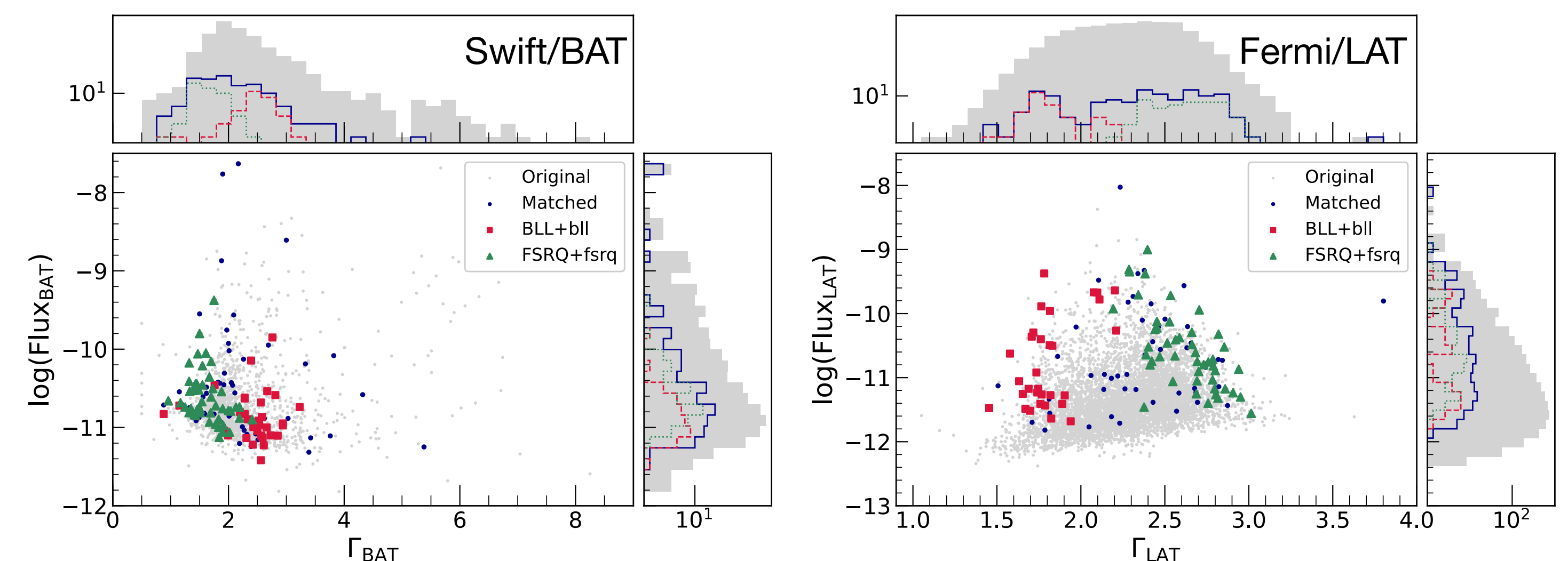• BL Lacs and FSRQs are responsible for these features

Fig. 3: Photon index v.s. flux of the BAT (left) and LAT (right) catalogs.

5.2. Comparison with other catalogs

■ COMPTEL (32 steady sources):
• Most are included in this cross-matched catalog
• Some extended and transient sources are missed in BAT and LAT
■ INTEGRAL/IBIS ([4] 1277 sources; ver.43) and SPI (277)
• 12 IBIS-LAT matched sources are added to BAT-LAT cross-match
• 26 SPI-LAT matched sources are in BAT-LAT cross-match
■ 1FLE ([5] 1st Fermi low-energy catalog <100 MeV; 198 sources)
• 40 sources are in BAT-LAT cross-match
■ Maselli+ 2011 [6] (104 sources)→improved in this study

5.3. Unidentified sources

■ Unidentified point-like sources: 9 objects
• 3 FSRQ-like SEDs, 4 possible LMXB candidates, and 2 Seyfert-like sources
■ Unidentified extended sources: 4 objects
• 1 false match, 1 pulsar-like, and 2 ambiguous (all need more investigations)
• →See the paper (Tsuji et al. submitted; in revision) for details
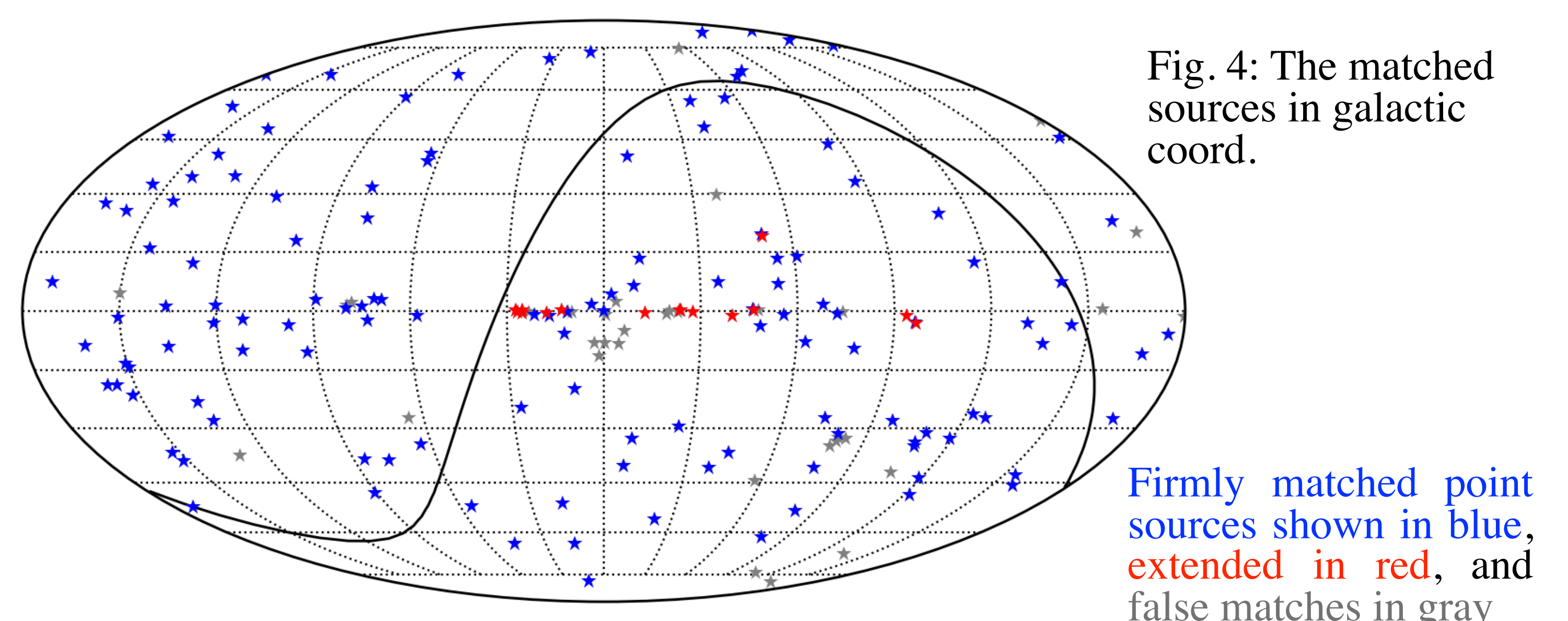
6. Summary and Future Work

Fig. 4: The matched sources in galactic coord.

Firmly matched point sources shown in blue, extended in red, and false matches in gray

■ 0th MeV source catalog (this work)
• The matched sources = hard X-ray and GeV gamma-ray emitters
• Fig. 4 shows the all-sky image of the matched sources.
• The catalog *will* be available in GRAMS [7] homepage [link].
• Good targets for MeV projects (COSI, AMEGO, GECCO, MeVCute, SMILE, GRAMS, etc.)

■ MeV gamma-ray all-sky simulation (future work)
• Estimate MeV flux of each source from source-dependent models
• Estimate MeV diffuse emission by GALPROP

Reference
[1] Oh et al. 2018, ApJ 235, 4 (BAT)
[2] Sch"onfelder et al. 2000, A&A 143, 145, (COMPTEL)
[3] Ballet et al. 2020, arXiv:2005.11208 (4FGL-DR2)
[4] Bird et al. 2016, ApJ, 223, 15 (IBIS)
[5] Principe et al., 2018, A&A, 618, A22 (1FLE)
[6] Maselli et al. 2011,
[7] Aramaki et al., 2020, Astropar Phys., 114, 107 (GRAMS)