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Is there a blazar behind GLIMPSE-C01?

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GLIMPSE C01 is a globular cluster that has been associated with a Fermi gamma-ray source for decades. However, a close multiwavelength analysis of this region has revealed the plausible existence of a blazar that could be behind the high-energy emission in the direction of GLIMPSE-C01.

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1. Introduction

When the Fermi collaboration released the 0FGL catalog [1] based on the first three months of observations with the Fermi Large Area Telescope (LAT), many of the sources remained already unassociated. In that context, some of the present authors [2] proposed that the collective action of millisecond pulsars inside the globular cluster GLIMPSE-C01 (G01) [3] could stand behind the gamma-ray emission of 0FGL J1848.6−0138. G01 has a mass of 2.81×10^4 $M_\odot$ and an age of less than 2 Gyr, and is located at a few kpc with a high absorption [4, 5]. Twelve years later, the current 4FGL-DR3 catalog [6] still keeps G01 as the gamma emitter responsible of the source 4FGL J1848.7–0129, with an error ellipse 5 times smaller than that of the original 0FGL J1848.6−0138. Remarkably, this association has been recently used to estimate the millisecond pulsar population [7, 8]. Here, we present the result of a multiwavelength study of the region around 4FGL J1848.7–0129 based on the more recent available data. A new non-thermal radio emitter has been found, whose nature could be compatible with a blazar. The gamma and X-ray emission is compatible with this hypothesis, thus suggesting an extragalactic origin for the Fermi source 4FGL J1848.7–0129.

2. Observations

2.1 Radio

Although a marginal and extended detection from NRAO VLA Sky Survey (NVSS) [9] at 20 cm was associated to G01 in the past [3], whose nature could be related to the combined effect of faint point-like radio sources [2], the location of the source at very low latitudes in the Galactic Plane could be playing down the confidence of this result. When analyzing higher resolution data from the Giant Metre Radio Telescope (GMRT) 150 MHz All-sky Radio Survey [10], a conspicuous low-frequency radio source was found lying well inside the 95 % confidence ellipse of the gamma-ray source 4FGL J1848.7-0129 (see left map in Fig. 1). This radio source is clearly extended and oblong, with its peak located at about 0.5 arc-minute from G01 core. Thus, this new emitter is difficult to relate neither to G01 nor to the recently reported MeerKAT point-like radio source [11]. On the other hand, we examined the Multi-Array Galactic Plane Imaging Survey (MAGPIS) [12] to find a weak emission at 20 cm compatible with the elongated part of the GMRT source, and hints of emission at 90 cm close to its peak.

2.2 Infrared

We inspected the archival data in infrared in quest for potential infrared counterparts close to the radio peak of the GMRT emitter. The deepest observations were those of the Wide Field Camera 3 (WFC3) on board of Hubble telescope [5]. No obvious counterpart was found. Upper limits on the infrared emission were taken from the measured fluxes at the 12.7, 13.8 and 15.3 μ filters of the WFC3. A negligible correction due to Galactic interstellar absorption is expected given the neutral absorption column of Hydrogen $n_{\rm H} = 10^{22}$ at G01 position [13].

2.3 X-rays

Chandra first observations of G01 in X-rays with ACIS gave rise to 17 point-like sources of different nature [13]. We have reanalysed these data, together with 6 more recent ACIS observations,

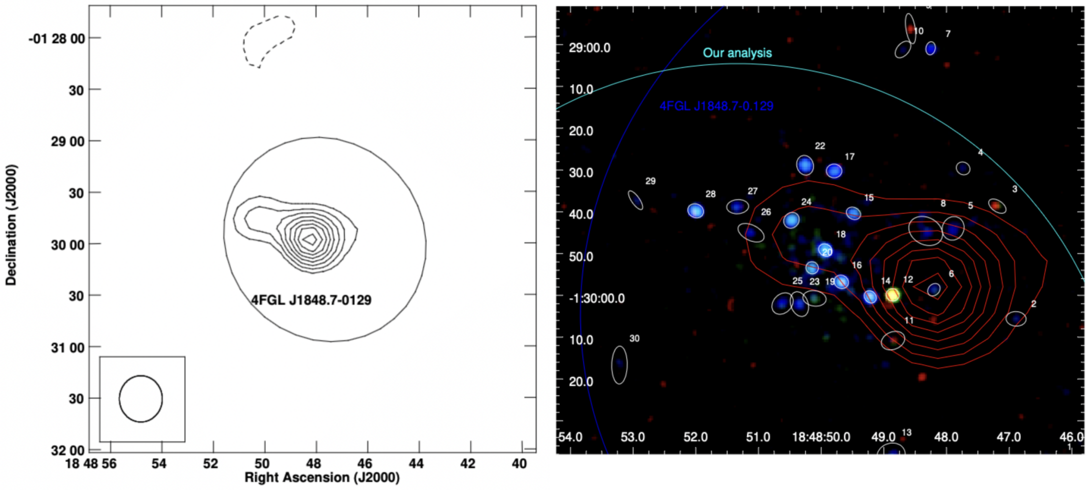

Figure 1: Left: GMRT 150 MHz radio emission towards the gamma-ray source 4FGL J1848.7-0129 whose 95% confidence ellipse is also plotted. Contours correspond to -3, 3, 4, 5, 6, 7, 8, 9 and 10 times 7 mJy beam^{-1}, the rms noise. The small bottom left ellipse illustrates the GMRT clean restoring beam. **Right:** Multiwavelength view of GMRT radio source (red contours) together with gamma-ray ellipse errors (4FGL J1848.7-0129 in blue, and our own result in cyan) and X-ray sources from our Chandra analysis (soft [0.5 – 1.2] keV emission in red, medium [1.2 – 2.5] keV in green, hard [2.5 – 8.0] keV in blue)

to obtain a more than 6 times deeper map of the region at these energies. A total of 30 sources were detected on a restricted field of view around the GMRT radio emitter, some of them coincident with the Pooley catalog (see right panel in Fig. 1). Among them, the one labeled as X6 in our survey (X17 in Pooley et al. paper) is consistent with the peak of the radio emission. Although only 16 X-ray photons were stacked, following the method of Albacete-Colombo et al. (2016) we were able to perform a statistical assessment of the X-ray spectral fitting procedure. As the source resembles a blazar we adopt a power-law emission model of index $\Gamma \simeq 2.0$ to simulate the X-ray spectrum with 16 photons and used a non-thermal absorbed model (TBABS × PO) [14] to get $n_{\rm H} = 10^{22.9\pm0.3}$ which seems reasonable, taking into account that for the Galactic G01 $n_{\rm H} = 10^{22}$ [13]. The model gives a corrected absorbed flux for the 2.0 to 10.0 keV energy range of $10^{-13.98\pm0.15}$ erg s^{-1} cm^{-2}. NuSTAR has also detected diffuse X-ray emission in G01 region [15] which could be related to the X-ray transient MAXI J1848–015 [16, 17]. We will take this source into account in our discussion as it is coincident with the position of GMRT radio emission.

2.4 Gamma rays

We reanalysed all the available Fermi LAT data towards 4FGL J1848.7-0129 at energies from 100 MeV to 500 GeV with 90° of maximum zenith angle, by applying the joint likelihood fitting method provided by the last FERMIPY PYTHON package [18]. As a result, a point-like source was detected in a position compatible with that of the GMRT emitter (see right panel in Fig. 1). A log-parabola spectral energy distribution (SED) typical for blazars gave the best fit to the data according to the Akaike's Criterion [19], and the corresponding parameter values are used in the discussion. In addition, in order to search for variability of the LAT source we computed light curves with different time bins.

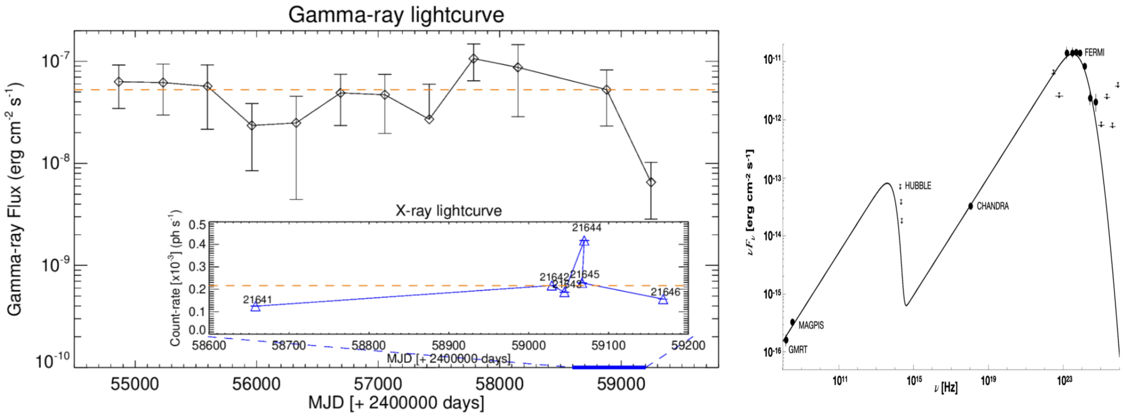

Figure 2: Left: γ-ray light curve of 4FGL J1848.7-0129 from the 4FGL DR3 release (0.1 - 500 GeV) with a time bin of one year. The inner-left panel shows the X-ray light curve at a shorter time scale. Both line-dotted lines indicate the respective median values. Labels over X-ray symbols refers to the Chandra Id. numbers. **Right:** Spectral Energy Distribution for the proposed blazar and tentative fit.

3. Discussion and conclusions

Given the observational results above, we are probably dealing with a single source with no infrared counterpart due to the strong absorption suggested by X-ray measurements. Assuming constant flux densities and a power law spectrum at radio wavelenghts we roughly estimate an almost flat spectral index, in accordance with the typical average value in blazar radio emission [20]. Hints of variability appear in the lack of radio emission at 20 cm, which suggests that the source was in a low state at the epoch of the observation. High-energy light curves also points to variability (see left panel in Fig. 2). In the X-ray domain, a KS test suggests that the source is not constant with a 99% probability, which is high enough to assure its transient nature in spite of the scarcity of the sample. In gamma-rays, the probability of the observed fluxes to come from a variable emitter is 70% which is not negligible, mainly taking into account that a notorious percentage of all Fermi blazars do not have a well-defined variability index. Therefore, we propose that the new discovered source is a highly obscured blazar. This rules out any association with the NuSTAR source because they exhibit no redshift in K_α Fe line [17]. The blazar SED is assembled in right panel in Fig. 2 based on our analyses, and tentatively fitted according to an approach designed to unveil blazars in Fermi unassociated sources [21, 22]. The resulting typical two-bump appearance seems consistent with a flat spectrum radio quasars (FSRQs), with a spectral index $\alpha = 0.50 \pm 0.01$ for both synchrotron and Compton bumps. The use of the classification method based on broad-band effective spectral indices [23] reinforces the FSRQ hypothesis. Moreover, energetic considerations points in this direction, as gamma flux from our analysis is $F_\gamma = (1.97 \pm 0.03) \times 10^{-10}$ erg cm^{-2} s^{-1}, while its luminosity may be assumed to be of the order of the mean luminosity of bright Fermi blazars, $i.e.$1.38 $\times 10^{47}$ erg s^{-1} [24]. This lead to a luminosity distance of about 2420 Mpc, equivalent to a plausible redshift $z \simeq 0.04$ if we take a Hubble constant of $H_0 = 69.6$ km s^{-1} Mpc^{-1}, and assuming a flat Universe with $\Omega_{vac} = 0.714$. In conclusion, we have presented a new blazar consistent with 4FGL J1848.7–0129 that could be partially responsible for its gamma-ray emission. This leads to revisit the G01 association with the Fermi source, and the role of its millisecond pulsars in the high-energy emission.

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