

Multiwavelength Observations of Gamma-ray Binary Candidates

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A rare group of high mass X-ray binaries (HMXBs) are known that also exhibit MeV, GeV, and/or TeV emission (“gamma-ray binaries”). Expanding the sample of gamma-ray binaries and identifying unknown Fermi sources are currently of great interest to the community. Based upon their positional coincidence with the unidentified Fermi sources 1FGL J1127.7–6244c and 1FGL J1808.5–1954c, the Be stars HD 99771 and HD 165783 have been proposed as gamma-ray binary candidates. During Fermi Cycle 4, we have performed multiwavelength observations of these sources using *XMM-Newton* and the CTIO 1.5m telescope. We do not confirm high energy emission from the Be stars. Here we examine other X-ray sources in the field of view that are potential counterparts to the Fermi sources.

1. Introduction

There are a small but growing number of high mass X-ray binaries (HMXBs) that also exhibit emission above 100 MeV. Currently, this category of “gamma-ray binaries” includes: LS I +61 303 [Abdo et al. 2009a, Albert et al. 2006], LS 5039 [Abdo et al. 2009b, Aharonian 2006], Cygnus X-3 [Abdo et al. 2009c], 1FGL J1018.6–5856 [Ackermann et al. 2012], PSR B1259–63 [Abdo et al. 2011, Aharonian et al. 2005], HESS J0632+057 [Aharonian et al. 2007, Hinton et al. 2009], and possibly Cygnus X-1 [Albert et al. 2007, Sabatini et al. 2013].

Each of the γ -ray binaries contain a hot, young star (either Wolf-Rayet, O, or Be spectral class) and exhibit variable emission across the electromagnetic spectrum. In the first four systems, the MeV–GeV light curve is modulated with the orbital period determined from optical spectra and/or radio flux measurements. Furthermore, all three were identified in the *Fermi* Year 1 Point Source Catalog (1FGL) using the binary orbital period as a key signature [Abdo et al. 2010]. The MeV–TeV emission of PSR B1259–63 also correlates with the source orbital phase in that it has only been successfully detected close to the periastron phases (Aharonian et al. 2005; Abdo et al. 2011). The high energy emission of HESS J0632+057 is also variable with a period of 321 days, similar to the proposed optical counterpart (Bongiorno et al. 2011; Casares et al. 2012).

About 60% of HMXBs are Be/X-ray binaries (BeXRBs) that contain a B-type star with a circumstellar mass-loss disk (a Be star) with a compact companion, usually a neutron star [Liu et al. 2006]. Be star systems also comprise about 50% of the known gamma-ray binaries: LS I +61 303, PSR B1259–63,

and HESS J0632+057. The high energy emission is powered by either wind accretion onto the compact star, or by the collision of stellar and relativistic pulsar winds in a shock region [Dubus 2006]. All of these sources present a unique opportunity to study particle acceleration in nearby, Galactic sources.

We have cross-correlated the 1FGL Abdo et al. [2010] with the Jaschek & Egret [1982] catalog of known Be stars, and we discovered two Be stars within the 95% error ellipse of 1FGL sources. Using *XMM-Newton* images, we find that the Be stars are not significant X-ray sources and are unlikely counterparts of the very high energy emission.

2. Observations of 1FGL J1808.5–1954c (2FGL 1808.6–1950c)

The GeV source position is known to within 4.7 arcmin (95% confidence) and may be associated with the Be star HD 165783. The optical star has been correlated with a serendipitous *XMM-Newton* source [Watson et al. 2009], but the pipeline images suffer from very high background and the source lies near the chip gaps. Therefore we obtained new *XMM-Newton* observations of the field on 2012 March 24, shown in Figure 1. No keV emission is detected at the position of the proposed optical counterpart HD 165783.

We observed HD 165783 using the CTIO 1.5m telescope, operated by the SMARTS consortium, and CH-IRON spectrograph between 2011 August and 2011 November. The star has a spectral type of B3/5 Ve. It has a high proper motion of $6.4 \mu\text{s yr}^{-1}$. We are unable to determine its radial velocity due to the very complex structure of the $H\alpha$ emission, shown in Fig-

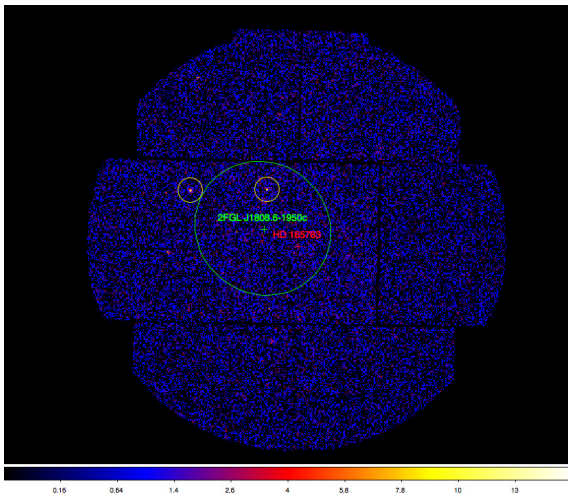


Figure 1: A 17.8 ks XMM-Newton MOS1 image of the HD 168783 field of view. The GeV source position and 95% error ellipse are shown in green. The position of the Be star is marked as a red cross, but no keV emission is detected at that position. However, two unidentified keV sources lie within or near the 2FGL error ellipse.

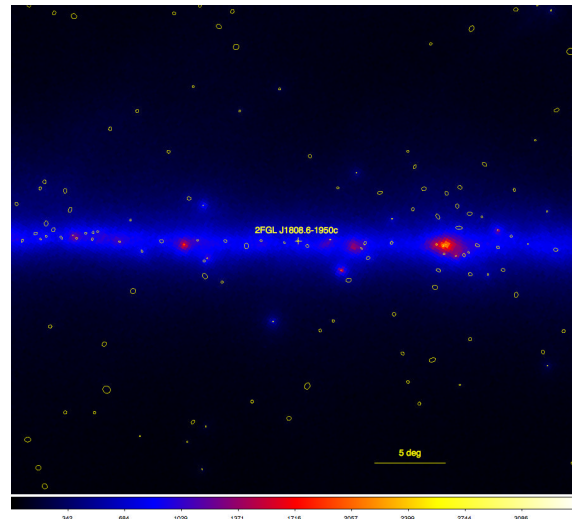


Figure 3: Fermi counts map of 1FGL J1808.5-1954c. Error ellipses of nearby sources from the 2FGL are shown in yellow.

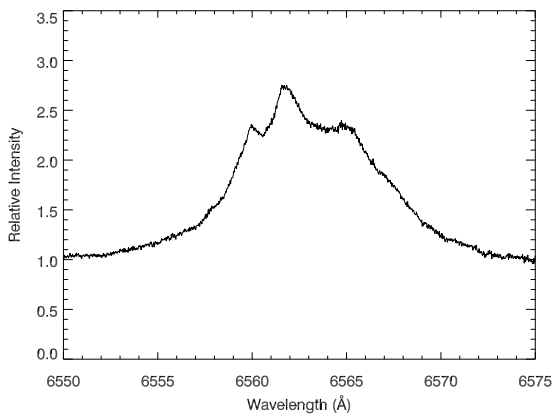


Figure 2: The $H\alpha$ line profile of the Be star HD 168783 reveals a complex circumstellar disk structure that makes it difficult to determine the stars radial velocity.

ure 2, so its runaway nature cannot be determined. No orbital period is known. This star may be a post-supernova runaway system.

The counts map of 1FGL J1808.5-1954c reveals this source within the crowded Galactic plane region. Since the time our Fermi Cycle 4 proposal was written, the GeV source has been associated with a globular cluster [Nolan et al. 2012].

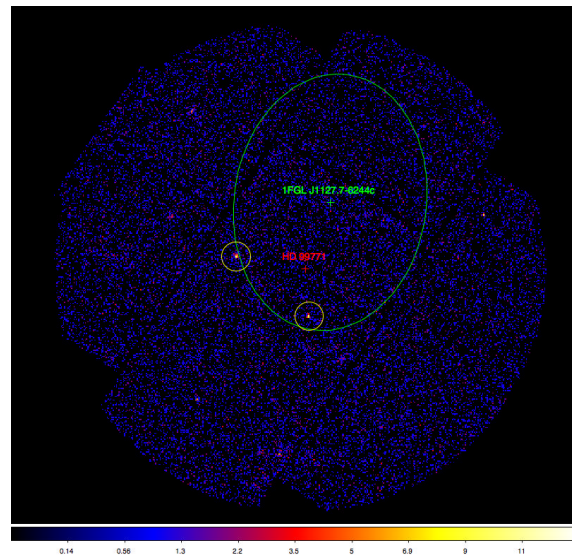


Figure 4: A 13.5 ks XMM-Newton MOS2 image of the HD 99771 field of view. The GeV source and Be star positions are marked in the format of Figure 1. Once again, no keV emission is detected at that the Be stars position. Two unidentified keV sources lie within or near the 1FGL error ellipse.

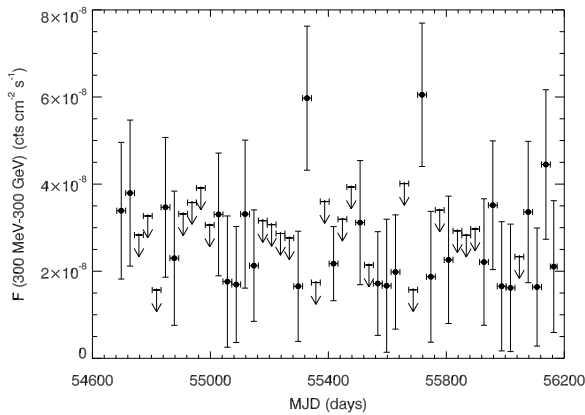


Figure 5: A binned light curve of 1FGL 1127.7–6244c reveals two significant flaring episodes since the Fermi mission began.

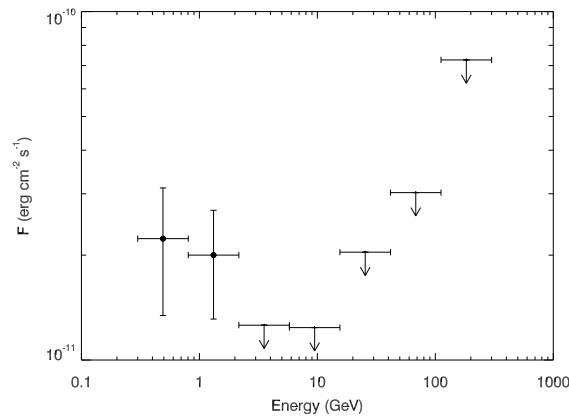


Figure 6: *Fermi* GeV spectrum of 1FGL 1127.7–6244c during the bright flares.

3. Observations of 1FGL J1127.7–6244c

The second correlation between the 1FGL and the Jaschek & Egret [1982] catalog is the star HD 99771. Little is known about the Be star other than its spectral type (B7 Vne), and no previously known X-ray sources lie within the Fermi 95% error ellipse (7.5 arcmin; [Nolan et al. 2012]). We observed the field with *XMM-Newton* on 2012 February 4. The resulting MOS2 image is shown in Figure 4, and we find no keV source coincident with the Be star’s position.

Since the Fermi mission began, 1FGL 1127.7–6244c has experienced two significant flaring episodes. The 0.3–300 GeV light curve is shown in Figure 5. The GeV spectrum and counts map of the source are shown in Figures 6 and 7, respectively. No counter-

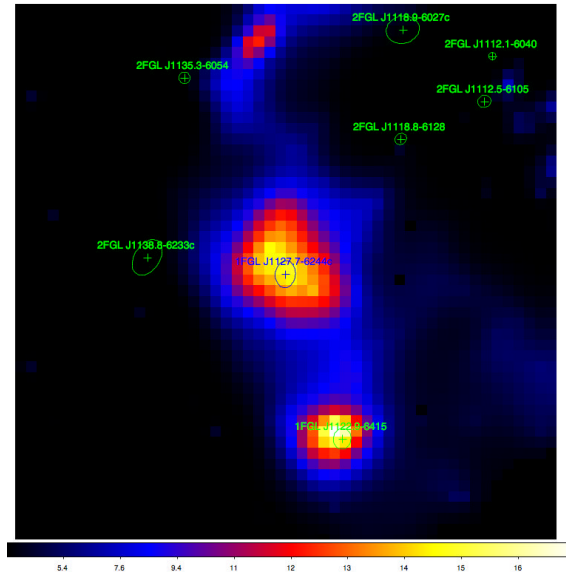


Figure 7: A counts map of 1FGL 1127.7–6244c during the bright flares. Other nearby sources from the 1FGL and 2FGL catalogs are also labeled.

part to this source was noted in the 2FGL catalog [Nolan et al. 2012].

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