1FGL J1018.6-5856 and the Galactic Population of Gamma-ray Binaries

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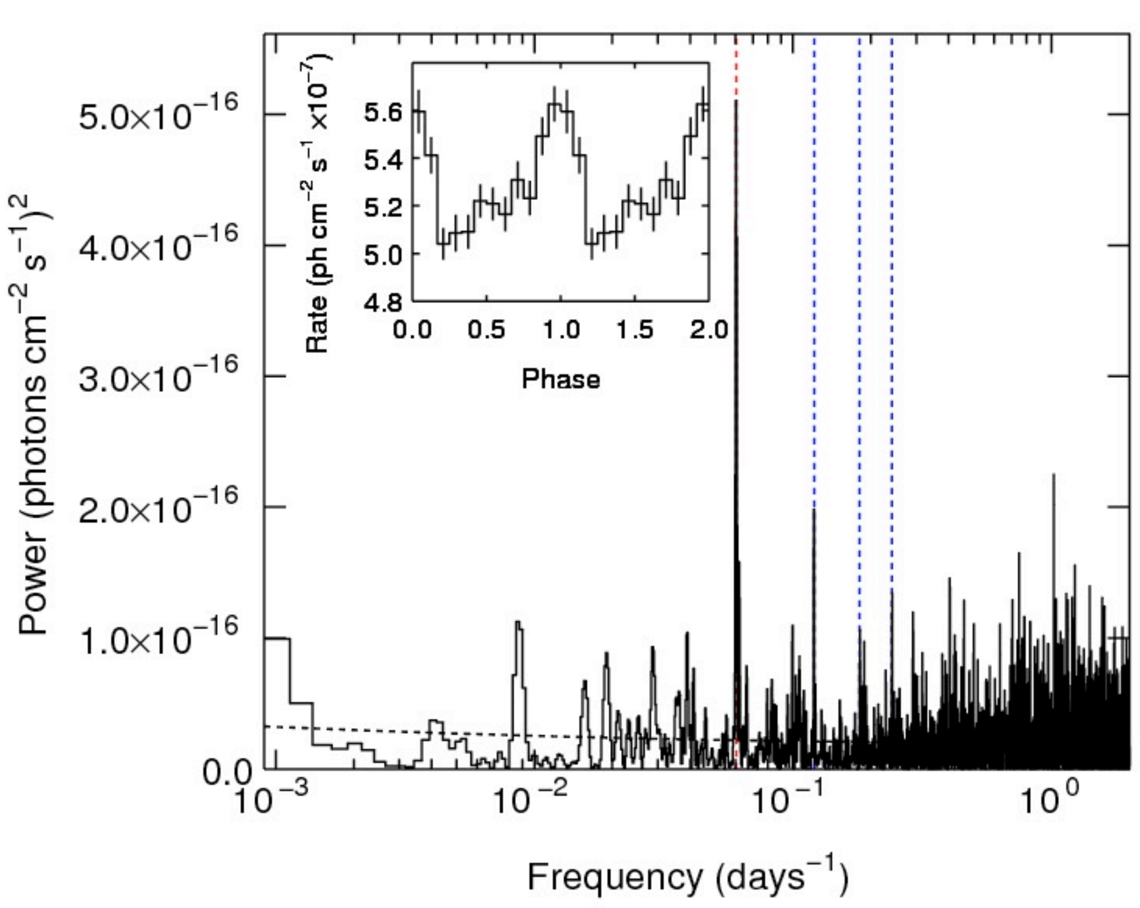
We present the discovery of a new gamma-ray binary system from the search for periodic modulation in the Fermi LAT light curves of all sources in the first Fermi-LAT catalog. 1FGL J1018.6-5856 was found to have a 16.6 day modulation in its gamma-ray flux that is accompanied by spectral variability. We identify counterparts in the X-ray, radio, and optical wavebands using data from the Swift XRT, ATCA, and telescopes at SAAO and LCO. The X-ray and radio counterparts are highly variable: the X-ray flux appears to be modulated on the orbital period with maximum X-ray flux coinciding with the phase of maximum gamma-ray flux. The optical counterpart has a spectral type of approximately O6V((f)) and shows little variability in a series of Swift UVOT observations. The overall properties of 1FGL J1018.6-5856 indicate that it is a member of the rare gamma-ray binary class of objects, and that it shares several properties with LS 5039. However, there are some differences from LS 5039, including the relative phasing of the gamma-ray flux and spectral modulation and the shape of the X-ray light curve. We conclude that 1FGL J1018.6-5856 is a new gamma-ray binary, and its discovery suggests that Fermi has begun to reveal the predicted population of such objects.

Introduction

Two types of interacting binaries containing compact objects are expected to emit gamma rays[1]: microquasars - accreting black holes or neutron stars with relativistic jets[2] - and rotation-powered pulsars interacting with the wind of a binary companion[3]. Microquasars should typically be powerful X-ray sources when active, and hence may already be known X-ray binaries as in the case of Cygnus X-3[4,5]. The existence of pulsars interacting with early spectral type stellar companions is predicted as an initial stage in the formation of high-mass X-ray binaries (HMXBs) containing neutron stars[6]. These interacting pulsars are predicted to be weak X-ray emitters, and may not yet be known, or classified, X-ray sources. Gamma-ray binaries may thus not be as rare as it appears, and many systems may await detection.

Detection of 16.6 day Period



Power spectrum of the LAT light curve of 1FGL J1018.6-5856. The red dashed line marks the 16.6 day period and the blue dashed lines harmonics of this. The dashed black line is a fit to the continuum power. The inset shows the light curve folded on the 16.6 day period.

Hunting for New Binaries

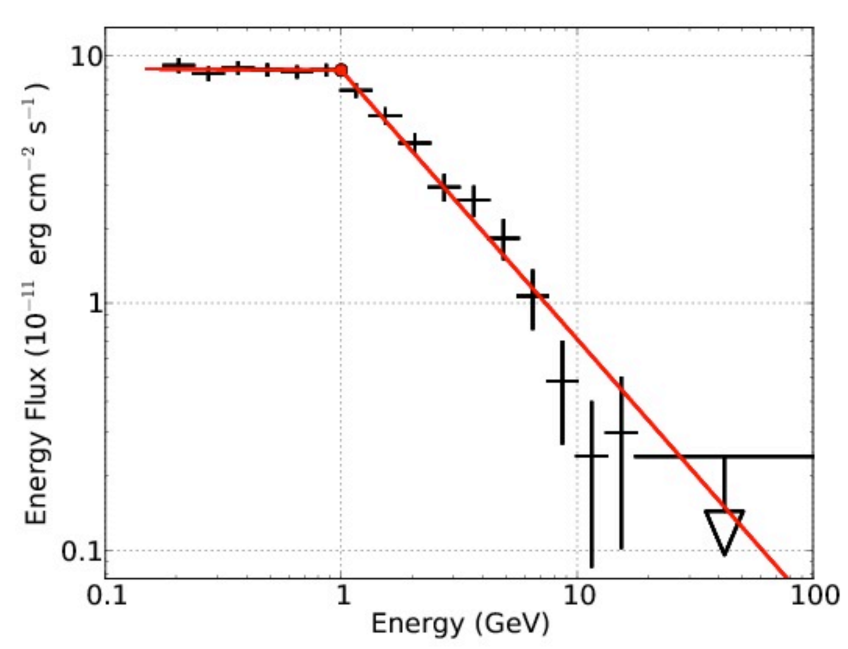
A gamma-ray binary is expected to show orbitally-modulated gamma-ray emission due to changes in viewing angle and, in eccentric orbits, the degree of the binary interaction. Periodic modulation has indeed been seen in LS 5039 (3.9 day period), LS I +61 303 (26.5 days), and Cygnus X-3 (4.8 hours)[7,8,4], and emission is orbital phase dependent for PSR B1259-63 (3.4 years)[9]. A search for periodic modulation of gamma-ray flux from LAT sources may thus yield further gamma-ray binaries, potentially revealing the predicted HMXB precursor population. The first Fermi LAT catalog of gamma-ray sources ("1FGL") contains 1451 sources, many of which do not have confirmed counterparts at other wavelengths and thus are potentially gamma-ray binaries.

In order to search for modulation we made 0.1 - 200 GeV light curves for all 1FGL sources and calculated power spectra of these. In addition to detecting modulation from known binaries, we found a strong signal near 16.6 days from 1FGL J1018.6-5856[10].

1. I. F. Mirabel, Science, **312**, 1759 (2006).
2. J. M. Paredes, *et al*., Science, **288**, 2340 (2000).
3. G. Dubus, A&A, **456**, 801 (2006).
4. Fermi LAT Collaboration, Science **326**, 1512 (2009).
5. M. Tavani *et al.*, Nature **462**, 620 (2009).
6. E. J. A. Meurs, E. P. J. van den Heuvel, A&A **226**, 88 (1989).
7. A. A. Abdo *et al.*, ApJL **701**, L123 (2009).
8. A. A. Abdo *et al.*, ApJL **706**, L56 (2009).
9. A. A. Abdo *et al.,* ApJL **736**, L11 (2011).
10. R. Corbet *et al*., ATel 3221, 1 (2011).

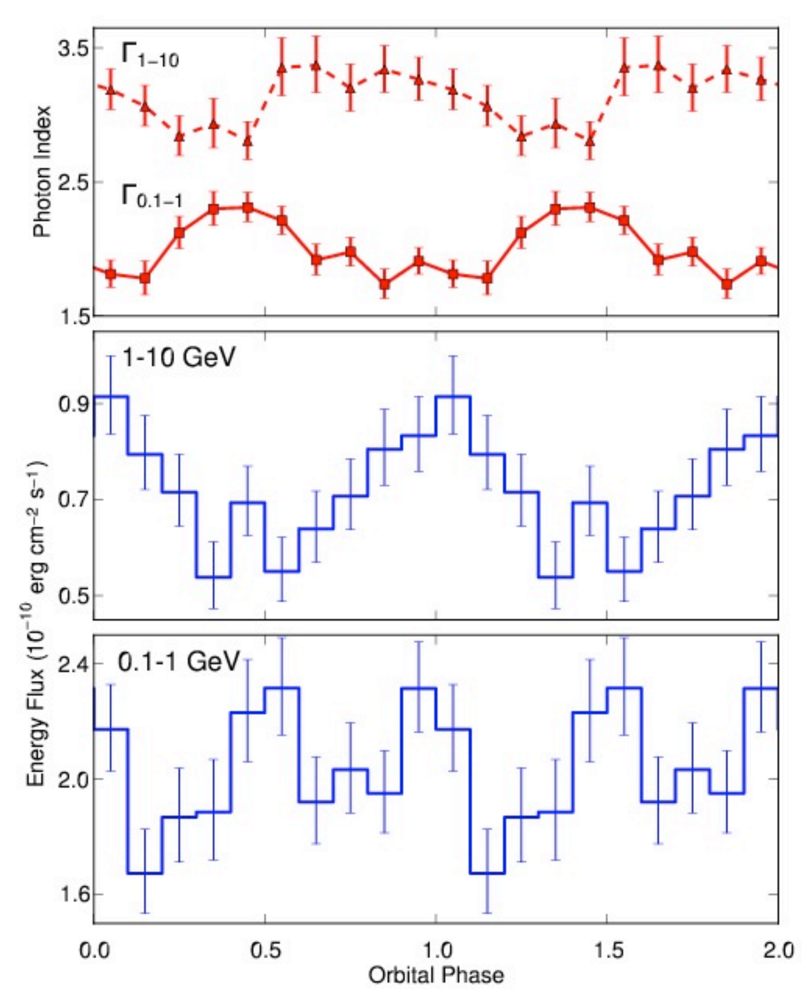
See this and other Fermi results at http://fermi.gsfc.nasa.gov/ssc/library/austinaas2012.html

Gamma-ray Spectrum



The LAT gamma-ray spectrum of 1FGL J1018.6-5856 and best-fit broken power-law model.

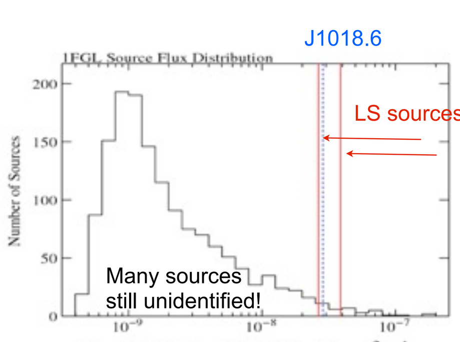
LAT Spectral Modulation



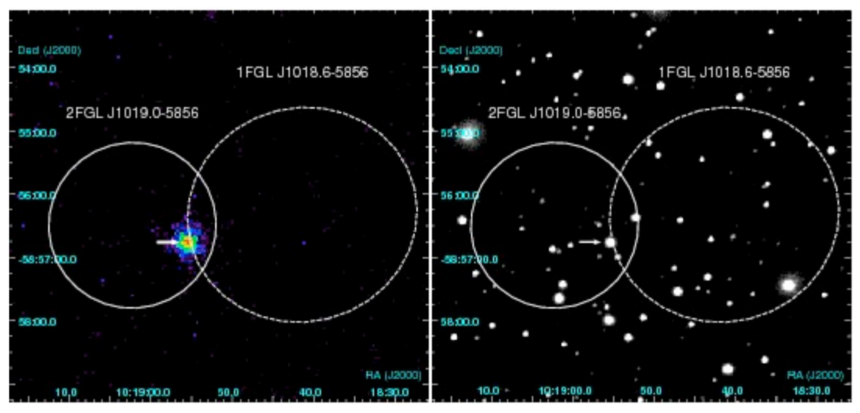
The orbital modulation of the flux and spectral indices of 1FGL J1018.6-5856 in the 0.1 - 10 GeV band as measured with the Fermi LAT. Gamma $\Gamma_{0.1-1}$ and Γ_{1-10} are photon spectral indices for energies below and above 1 GeV, respectively, using a broken power law model.

Summary

- **1FGL J1018.6-5856 is a new gamma-ray binary in a 16.6 day orbit with X-ray, optical, and radio counterparts.**
- **We <u>don't</u> definitely know what is driving the gamma-ray emission. 1FGL J1018.6-5856 <u>may</u> contain a rapidly rotating pulsar interacting with the wind of an O star.**
- **So far, we've only found binary periods in bright sources.**
- **LAT binary search sensitivity is improving as more data accumulates.**
- **Evolutionary models predict we should see more binaries in the "iceberg" of LAT sources...**

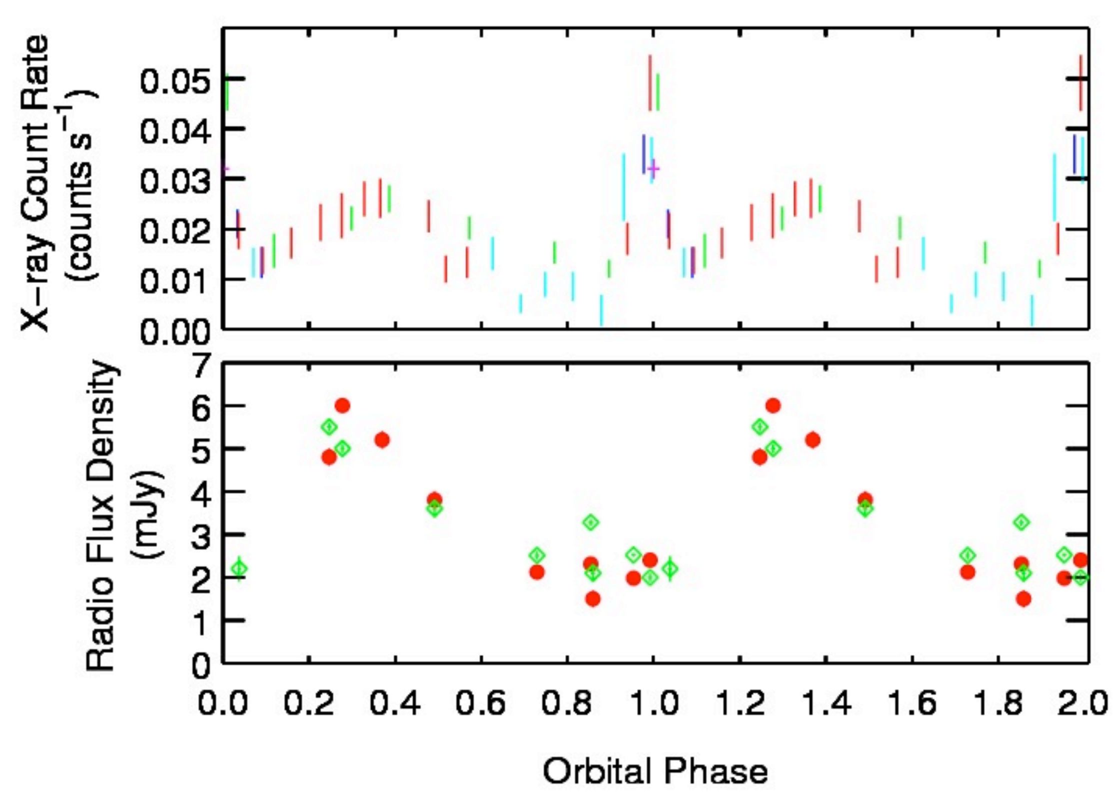


X-ray/Optical Counterparts



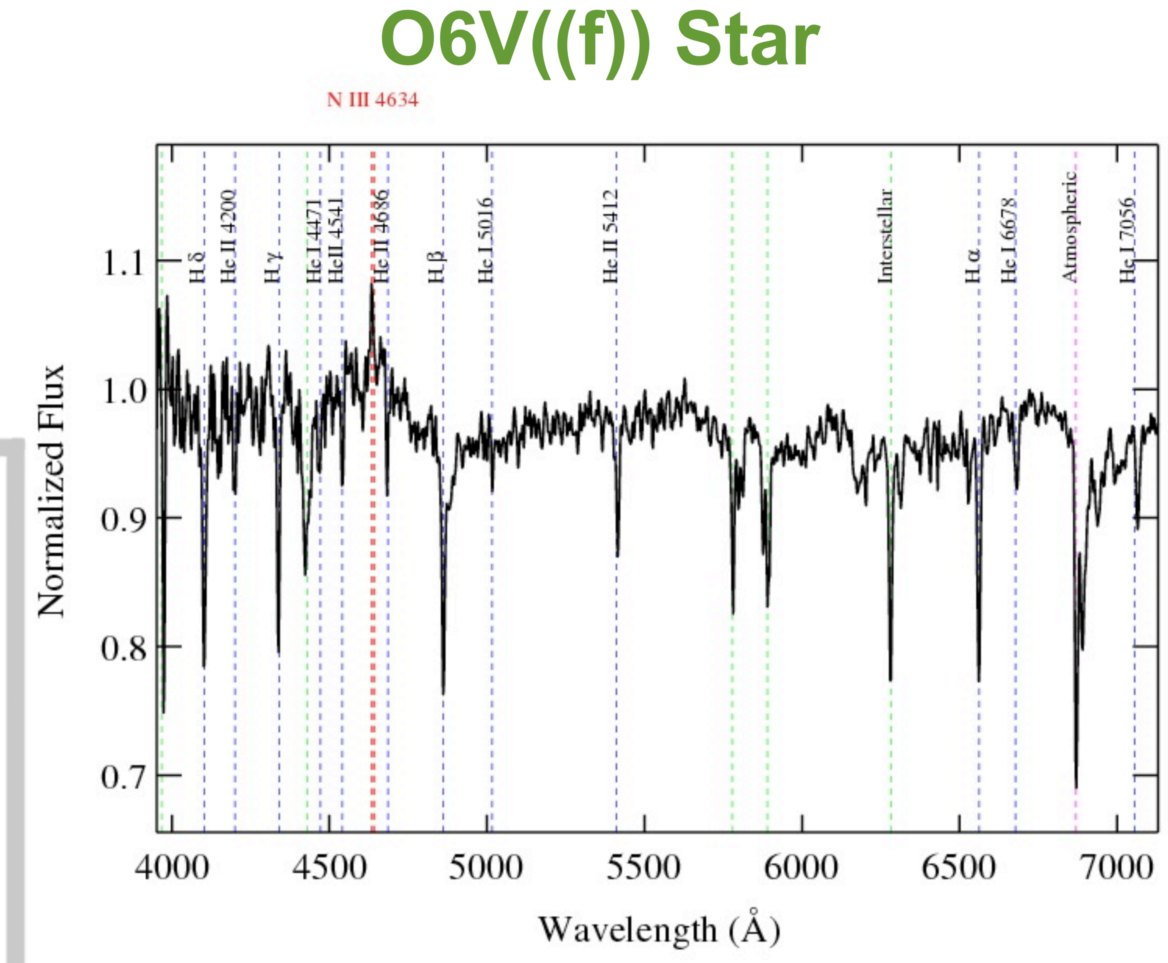
Swift XRT X-ray (left) and UVOT (right) images of the region around 1FGL J1018.6-5856. The X-ray/optical counterpart is marked by an arrow near the center of both images. 95% confidence regions from the 1FGL and 2FGL catalogs are marked.

X-ray and Radio Variability



X-ray (upper panel) and radio (lower panel) observations of 1FGL J1018.6-5856 folded on the orbital period. Note that the X-ray peak coincides with gamma-ray maximum, unlike the radio modulation.The X-ray data are from the Swift XRT and cover the energy range 0.3 to 10 keV. For the X-ray observations the different colors indicate data taken from different 16.58 day orbital cycles. For the radio data, obtained with ATCA, the green diamonds indicate 9 GHz and red circles5.5 GHz data.

O6V((f)) Star



Optical spectrum of the counterpart of 1FGL J1018.6-5856 obtained with the SAAO 1.9m telescope. Line identifications are marked: blue = stellar absorption, red = stellar emission, green = interstellar absorption, magenta = atmospheric. The spectral type is almost identical to the counterpart of LS 5039.