A Search for Optical/Infrared "Orphan Flares" in the SMARTS Sample of Fermi-Bright Blazars

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SMARTS-FERMI OBSERVATIONS

Abstract: Using simultaneous, multiwavelength observations of Fermi-bright blazars from the Small and Moderate Aperture Research Telescope System (SMARTS) 1.3m+ANDICam and Fermi Gamma-Ray Space Telescope+LAT, we construct optical/near-infrared (OIR) and gamma-ray light curves to identify OIR flares with no accompanying gamma-ray counterparts, i.e. "orphan flares." An OIR orphan flare was first reported in PKS 0208-512 (Chatterjee et al. 2013), and thought to be due to either 1) a change in the magnetic field without a change in particle number or Doppler factor, or 2) an outburst located closer to the black hole with a smaller bulk Lorentz factor and less Compton upscattering. We will extend the Chatterjee et al. (2013) analysis to include 35 blazars in total, but report preliminary results for 4 blazars below.

METHODS

We define a candidate orphan flare as one that is not correlated in the OIR and gamma-ray bands. In principle, there are two types of orphan flares: one that only occurs in the OIR (orphan optical flare) and one that only occurs in the gamma-ray band (orphan gamma-ray flare). We do not expect an orphan IR flare because the IR is strongly correlated with the optical band due to the presence of synchrotron radiation. These preliminary results can only be classified as "candidate" orphan flares until we complete a full likelihood analysis on the Fermi data, and include the IR data in the analysis. The complete analysis will be reported in Hood et al. (2017). Candidate orphan optical flares are defined as flares lasting approximately 100-200 days, that show an increase of B $\geq$ 0.5 mag with no accompanying gamma-ray flare present in the Fermi quicklook data. Similarly, a candidate orphan gamma-ray flare has a flux increase of $\geq$ log 0.2 ph cm $^{-2}$ s $^{-1}$ with no accompanying optical flare, over the same time frame.

BACKGROUND

As can be seen in Figure 2 (lightly shaded red and purple regions), Chatterjee et al. (2013a) report the presence of two flares that are correlated in OIR and gamma-rays and one anomalous OIR flare with no accompanying gamma-ray flare, i.e. an orphan optical flare. They suggest that this orphan flare could be caused by either a change in the magnetic field or a change in the location of the emission region during that flare. To address that difference, Chatterjee et al. (2013b) then modeled the SEDs for the three flares (see Figure 1), and it can be seen that the three flares have different Compton Dominance factors, $q = L\gamma/L_{IR}$ (q_1 =20.9, q_2 =5.2, q_3=8.0). The Compton Dominance parameter varies by a factor of 4 between flare 1 and flare 2, but generally only varies by a factor of 2 for FSRQs (Finke et al. 2013). Thus, while the location of the emitting region could cause the observed orphan flare, the bulk Lorentz factor required is too low, so the authors suggest that a change in magnetic field direction or orientation could account for the reported orphan flare.

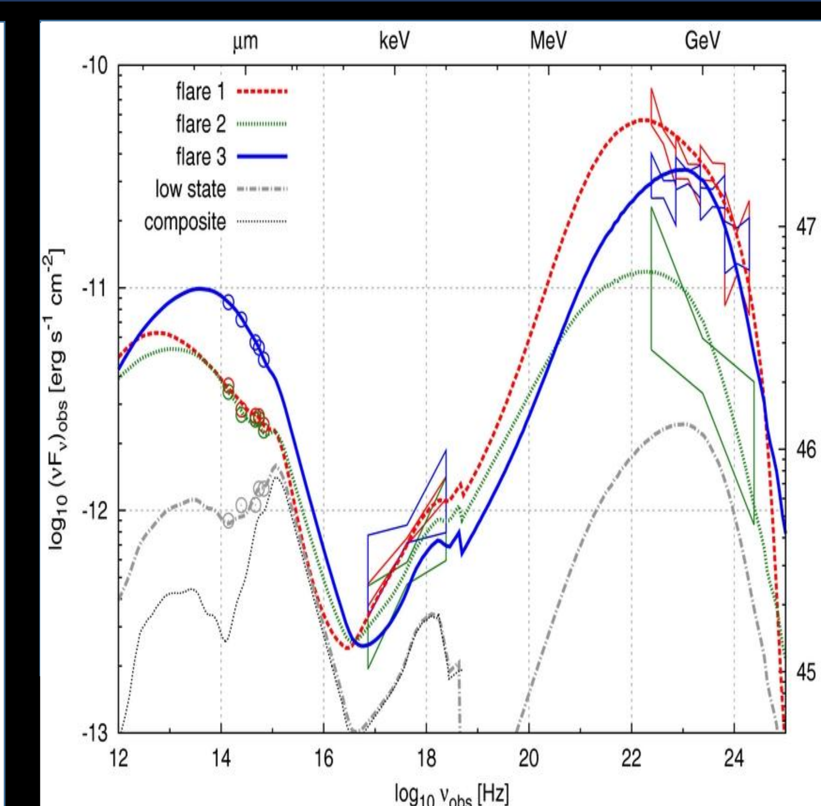

Figure 1: Spectral Energy Distributions for each of the observed flares as published in Chatterjee et al. (2013b). The blue and green solid lines correspond to flares 3 and 2, while the red dotted line refers to flare 1. The grey dotted and solid lines correspond to blazar composite spectrum and Leptonic models, respectively. Note that the Compton Dominance parameter varies by a factor of 4 between flares 1 and 2.

PRELIMINARY RESULTS

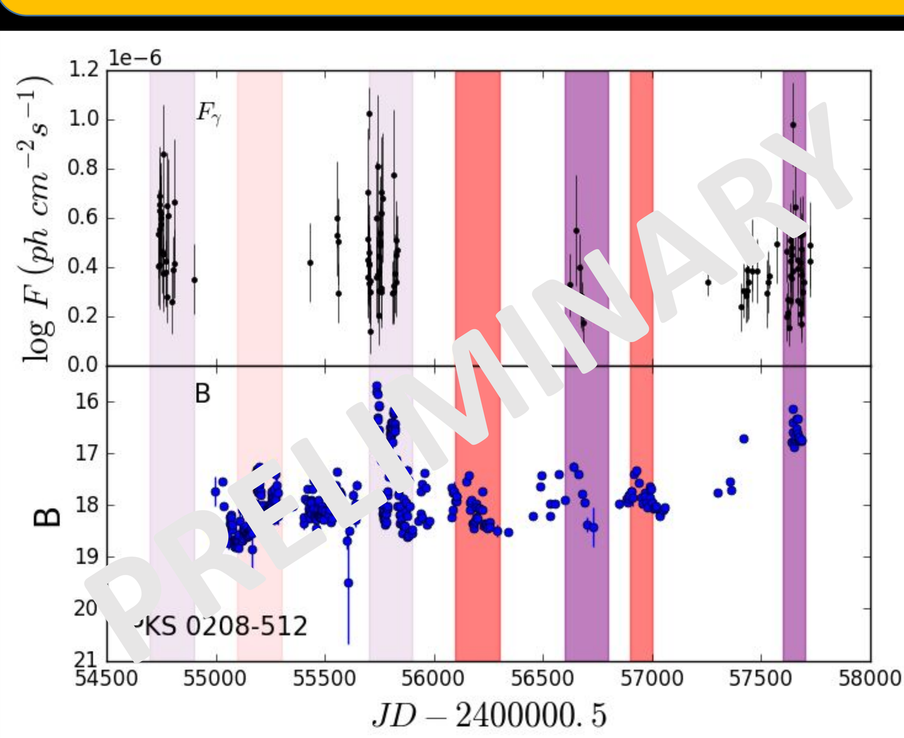

Figure 2: Optical and Fermi gamma-ray light curves of PKS 0208-512 from August 2008 - May 2017. The top panel is the Fermi 0.1-300 GeV gamma-ray flux in daily bins and units of ph cm^{-2} s^{-1}. The gamma-ray data are taken from publicly available quick-look data. The bottom panel is the SMARTS B- band magnitude. The purple shaded regions indicate flares that are correlated in the OIR and gamma-ray bands, while the red shaded regions represent candidate orphan optical flares, that is, optical flares with no accompanying gamma-ray flare. The lightly shaded regions between MJD 54500-56000 represent the regions published in Chatterjee et al. (2013), which are described above. PKS 0208-512 appears to have undergone 2 additional candidate orphan optical flares at approximately MJD 56100-56300 and MJD 56900-57000, after the initial study. A complete analysis of these sources, with Fermi data that has undergone full likelihood analysis, will be reported in Hood et al. (2017).

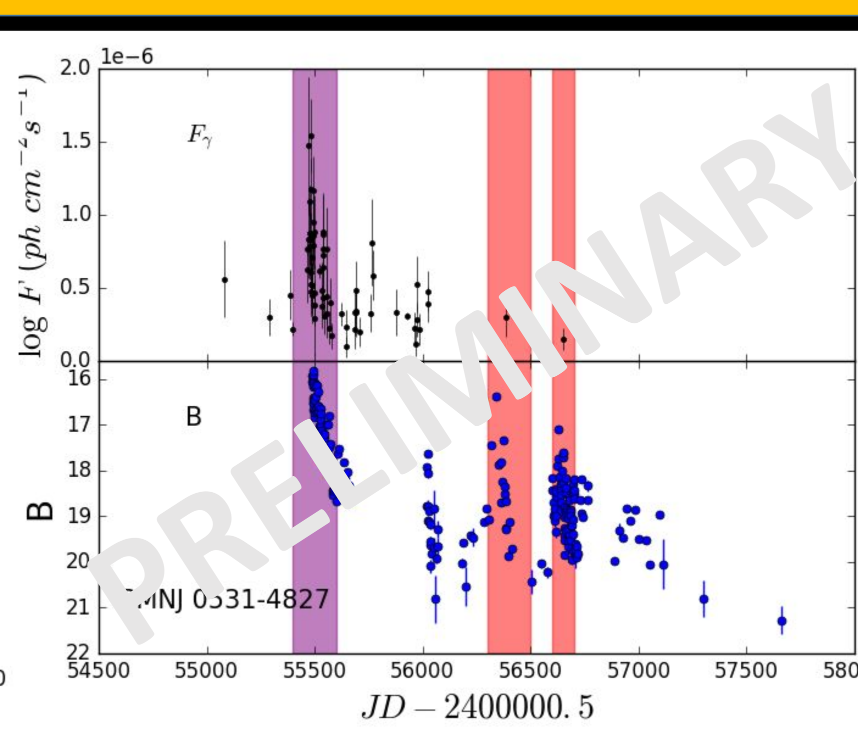

Figure 3: Optical and Fermi gamma-ray light curves of PMNJ 0531-4827 from August 2008 - May 2017 with axes and data as in Figure 2. There are two candidate orphan optical flares suspected in this source at approximately MJD 56400-56500 and MJD 56600-56650, which will be fully evaluated once a full likelihood analysis of the Fermi gamma-ray data is complete.

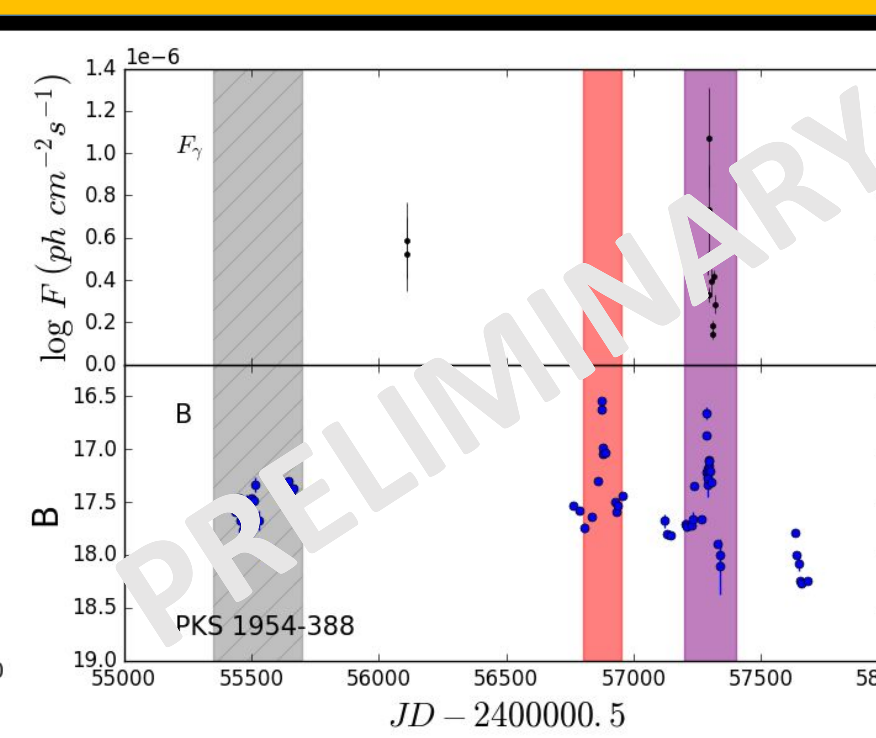

Figure 4: Optical and Fermi gamma-ray light curves of PKS 1954-388 from August 2008 - May 2017 with axes and data as in Figure 2. The grey hatched region at approximately MJD 55400-55600 represents a candidate orphan optical flare that requires further analysis, as this source was not on the Fermi quick-look data monitoring list (i.e. a minimum reported gamma-ray flux of 1x 10^{-6} ph cm^{-2} s^{-1}) at the time of the first reporting of SMARTS B-band data. However, as can be seen at approximately MJD 56800-56900 region, another candidate orphan optical flare is evident, which occurred after PKS 1954-388 reached the minimal Fermi flux to be included on the Fermi monitored source list.

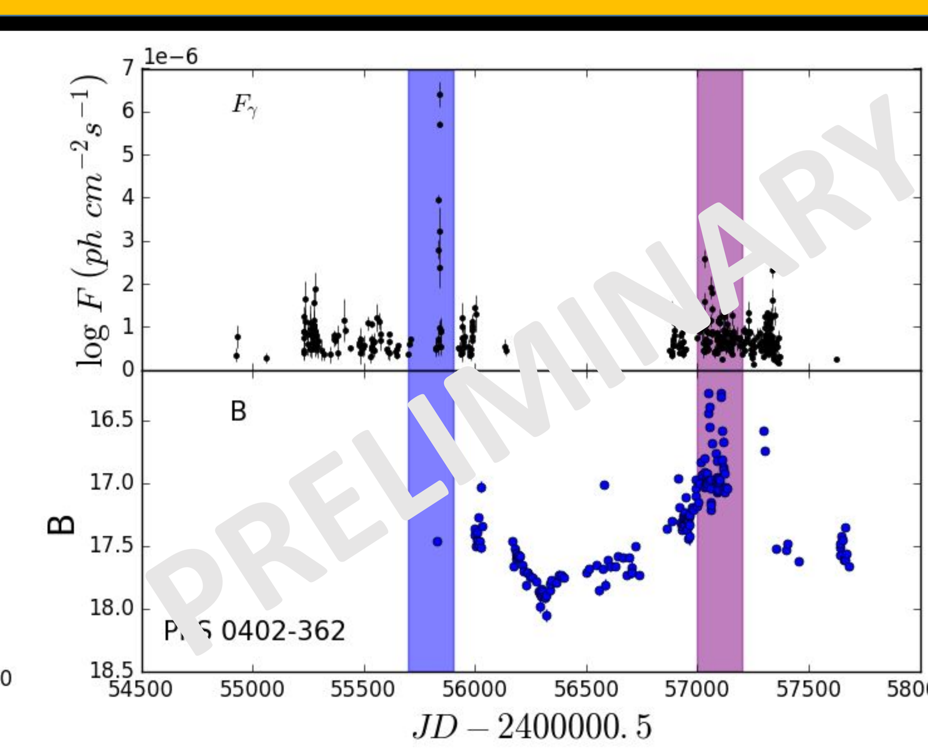

Figure 5: Optical and Fermi gamma-ray light curves of PKS 0402-362 from August 2008 - May 2017 with axes and data as in Figure 2. The blue shaded region at approximately MJD 56800-56900 represents a candidate orphan gamma-ray flare, that is, a gamma-ray flare with no accompanying OIR component. This candidate flare cannot be confirmed without additional OIR data near this epoch to rule out a lower-energy flare. However, if confirmed the physical mechanisms suggested by Chatterjee et al. (2013a), would not be sufficient to explain this candidate flare.

SUMMARY

We report 5 candidate orphan optical flares and 1 candidate orphan gamma-ray flare in 4 sources: PKS 0208-512, PMNJ 0531-4827, PKS 1954-388, PKS 0402-362, respectively. All candidate orphan flares will remain preliminary until a full Fermi likelihood analysis is complete. Results for the full sample of 35 sources will be presented in Hood et al. (2017). Future work includes the completion of the present analysis, as well as a statistical study of the frequency of orphan flares in gamma-ray bright blazars.

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This work has made use of SMARTS optical/near-infrared light curves that are available at www.astro.yale.edu/smarts/glast/home.php

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