



Detection of Spider pulsars through stacking analysis

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Abstract

Spider pulsars are compact binary millisecond pulsar systems composed of a neutron star in a tight orbit with a low-mass companion. These systems are important laboratories for investigating intrabinary shocks and their potential production of TeV gamma-ray emission. We performed a stacking analysis of spider pulsars using LHAASO observations obtained between 2021 and 2025, combining data from both WCDA and KM2A. Targets were selected from SpiderCat and limited to sources with reported gamma-ray fluxes, yielding a final sample of 34 objects. The total stacked significance is below 2, indicating no statistically significant evidence for collective TeV emission from this sample. We therefore derive an upper limit on the average differential flux.

Introduction

Spider pulsars are compact binary systems in which a rapidly rotating millisecond pulsar is orbited by a very low-mass companion. These systems are termed “spiders” because the relativistic pulsar wind can progressively ablate the companion.

Spider binaries commonly exhibit radio eclipses, orbital X-ray modulation, and, in some cases, gamma-ray emission. They therefore provide important laboratories for studying pulsar winds, particle acceleration. A detection of high-energy emission from spider systems, especially at TeV energies, would offer direct insight into the physical conditions and acceleration processes in the system.

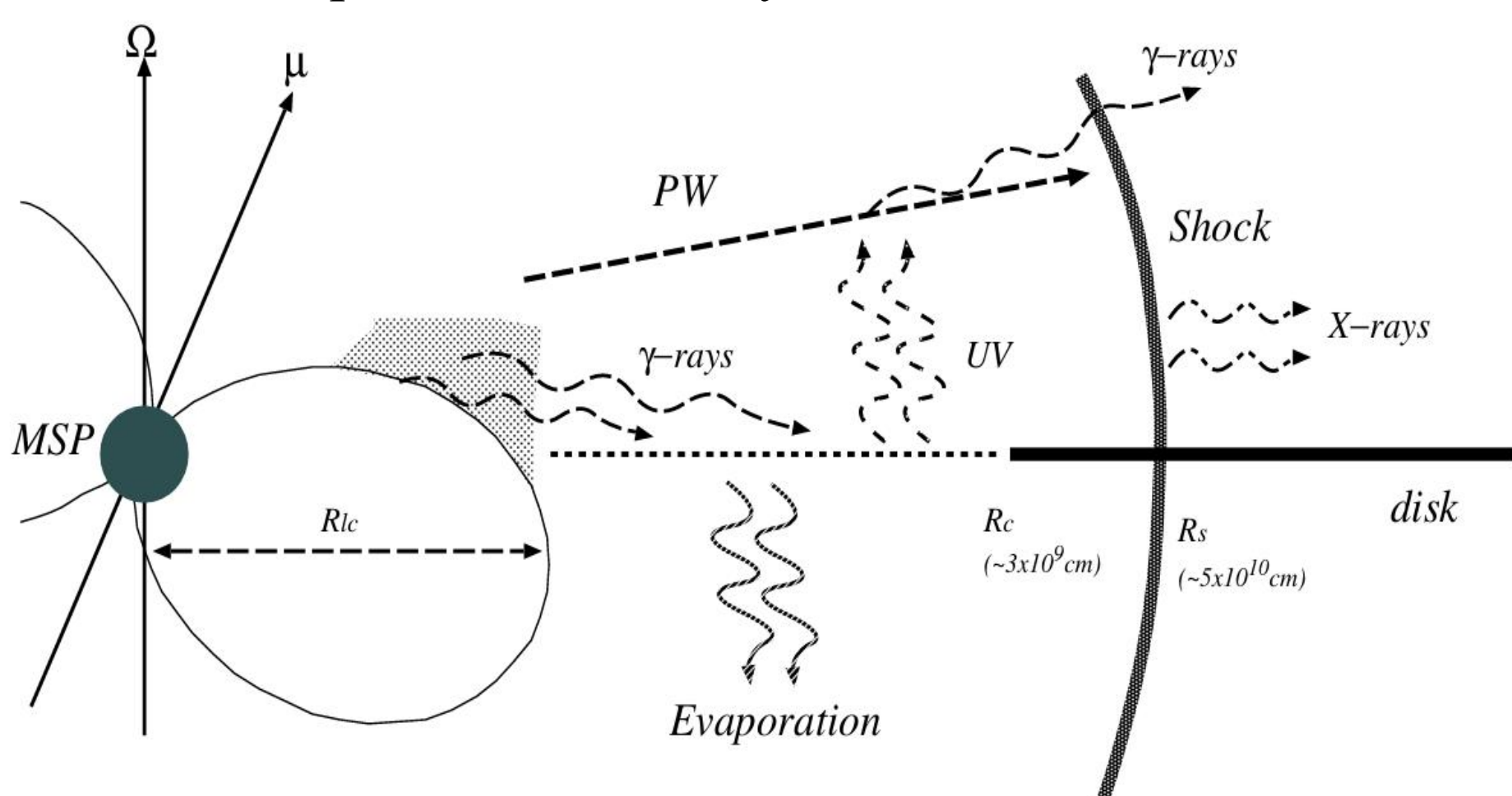


Figure 1. Schematic illustration of the emission scenario for PSR J1023+0038. Non-thermal X-ray emission is produced in the intrabinary shock, while the additional gamma-ray component arises from inverse-Compton scattering of disk photons. This high-energy emission component may be detectable by LHAASO [2].

Method

This work uses WCDA data collected between 2021 March 5 and 2025 July 31, together with KM2A data obtained between 2021 July 20 and 2025 July 31.

We selected targets from the SpiderCat, applying the following criteria:

1. Declination $\delta \leq 80^\circ$ and $\delta \geq -20^\circ$;
2. To avoid contamination from galactic diffuse emission, we select a conservative galactic latitude range: $b \geq 10^\circ$ or $b \leq -10^\circ$;
3. The availability of reported flux measurements in the gamma-ray band.

A total of 34 spider systems satisfy these selection criteria and are marked by cyan diamonds in Fig. 2.

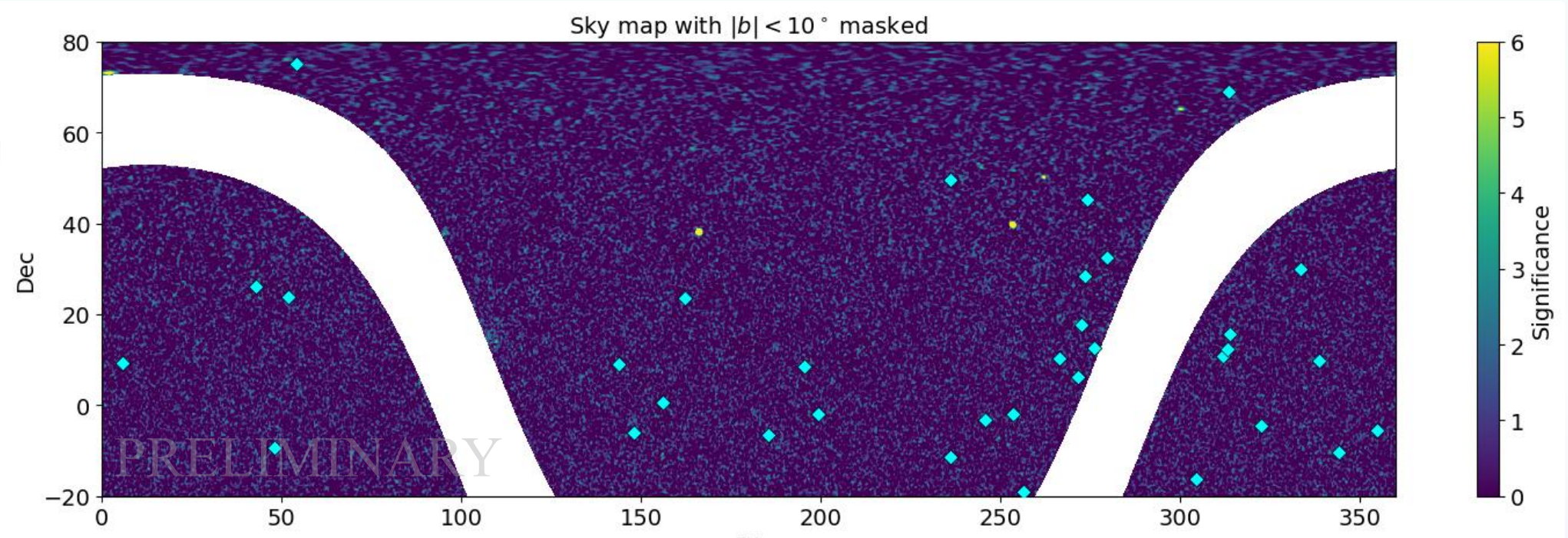


Figure 2. Distribution of the selected spider pulsars in the LHAASO sky. The cyan diamonds indicate the positions of the selected spider systems. The Galactic plane region is masked.

For the stacking analysis, we adopted a $4^\circ \times 4^\circ$ region of interest for each target and employed a point-source model to evaluate the TS values and construct the significance maps.

Results

We stacked the data from 34 spider systems and obtained a TS value of 1.9, which is significantly below the threshold for a reliable detection. The stacked TS map is presented in Fig. 3. Upper limit is plotted with a classical spider pulsar PSR J1023+0038's Broadband spectrum in Fig. 4 [6].

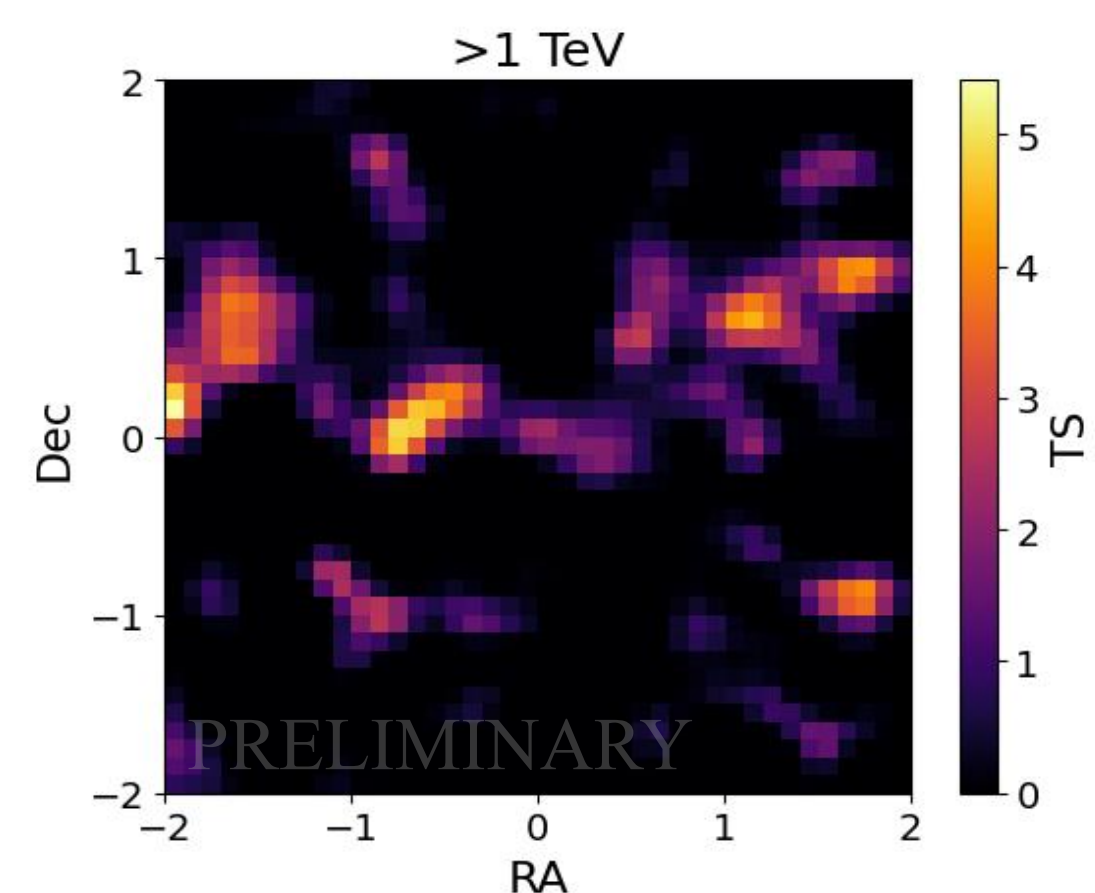


Figure 3. TS map from the stacking analysis of 34 spider systems. The stacked TS value was derived using a Gaussian point-source model at the map center.

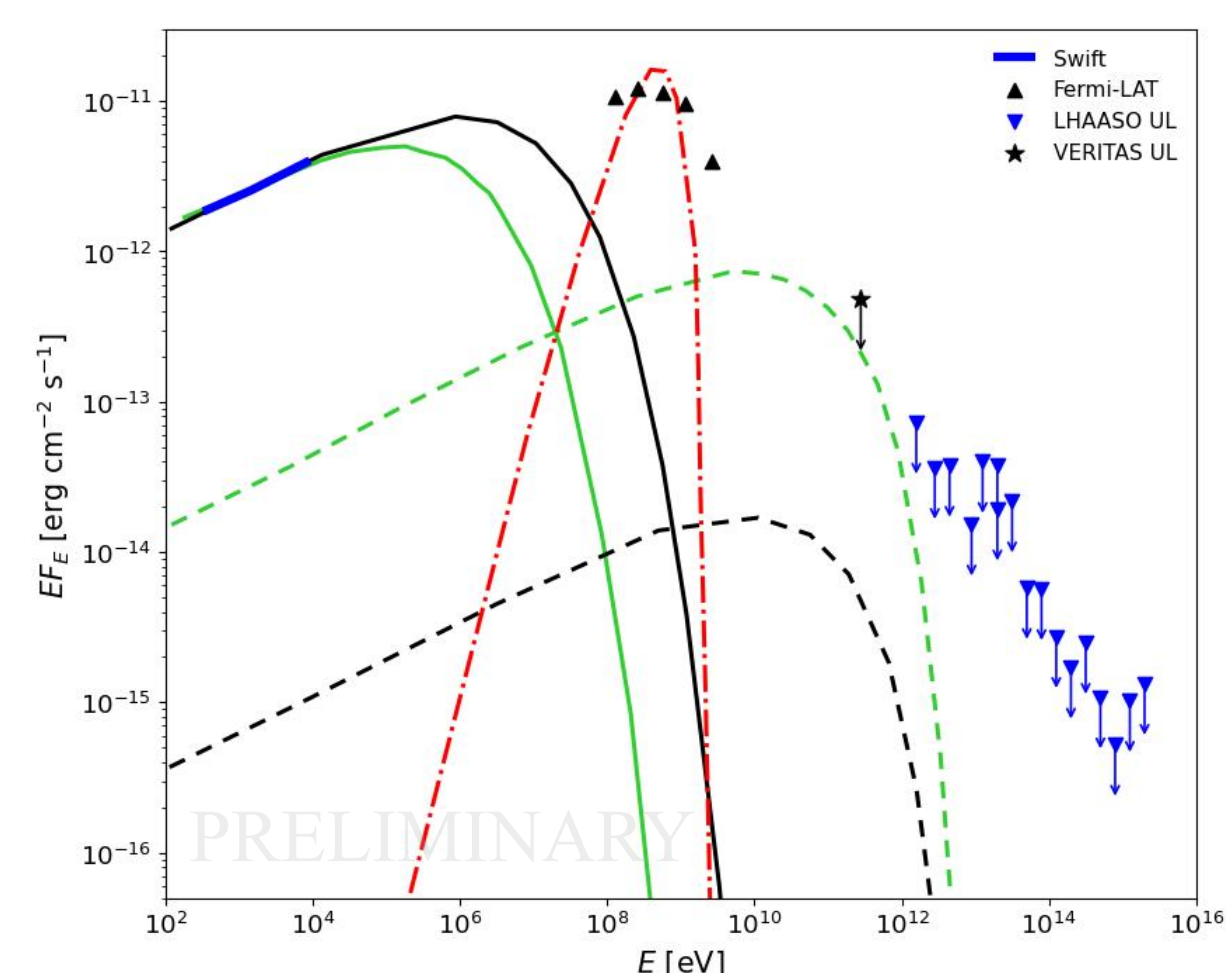


Figure 4. Broadband spectrum of a classical spider pulsar PSR J1023+0038 compared with VERITAS's upper limit and LHAASO's upper limit is plotted [6]. Upper limit derived from the LHAASO stacking analysis with blue triangles.

Reference

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