Characterization of the Inner Knot of the Crab: The Site of the Gamma-ray Flares?

(and introducing a new analysis technique)

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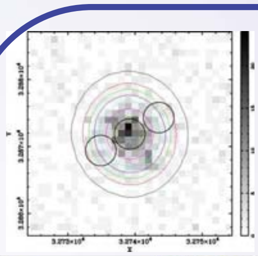
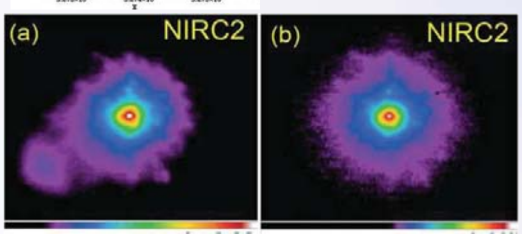
INTRODUCTION

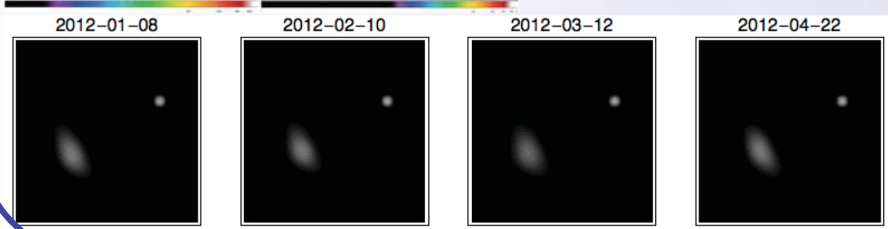
One of the most intriguing recent discoveries has been the detection of powerful γ-ray flares from the Crab Nebula. Such events, with a recurrence time of about once per year, can be so dramatic to make the system the brightest source in the gamma-ray sky as occurred, e.g. in April 2011. These flares *challenge* our understanding of how pulsar wind nebulae work and defy current astrophysical models for particle acceleration. We present here our study of the inner knot located within a fraction of an arcsecond from the pulsar with the aim of characterizing the feature and asking if this might be the site of the origin of the γ-ray flares. We took data using Keck, HST, and Chandra obtained as part of our multi-wavelength campaign to identify the source of the enigmatic flares. We set an upper limit as to the x-ray flux from the knot. We also find that the dimensions, surface brightness, flux, etc. of the optical and infrared knot are all correlated with distance of from the pulsar. This distance, in turn, varies with time. In addition to this most thorough characterization of the inner knot's properties, we examine the hypothesis that the knot may be the site of the flares by examining the knot separation versus the Fermi/LAT γ-ray flux. Finally, as part of this research, we make use of a new approach employing singular value decomposition (SVD) for analyzing time series of images and compare the approach to more traditional methods. Our conclusions are only refined but not impacted by using the new approach.



A Chandra HRC image at pulse minimum. The 3 circles show 0.3"- radius, extraction regions: the central estimates the pulsar flux, the circle, E of N is the average location of the knot, and that to the NW estimates background. The larger circles are at intensity levels of 10 to 640 cts/pixel increasing by factors of 2 and illustrate the PSF at the site of the knot i.e. slight but non-negligible. Our 3σ upper limit to the knot's X-ray flux, stated as a fraction of the pulsar's flux, is under 1%.

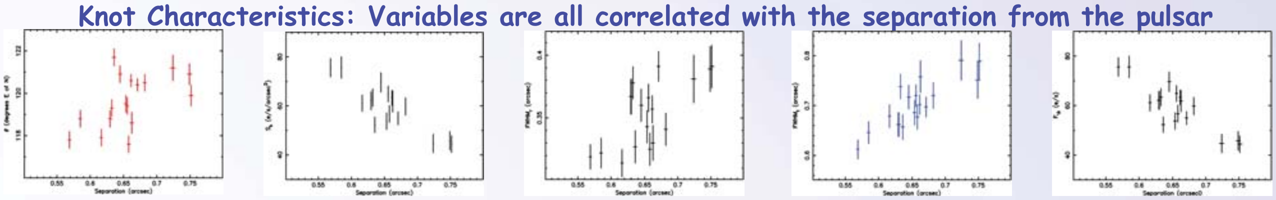


One of 13. Keck images of the Pulsar and knot (left) and a nearby star (right) taken with a H filter using the NIRC2 narrow camera, 0.01" pixels, and a 10"×10" field of view. The knot is clearly resolved.



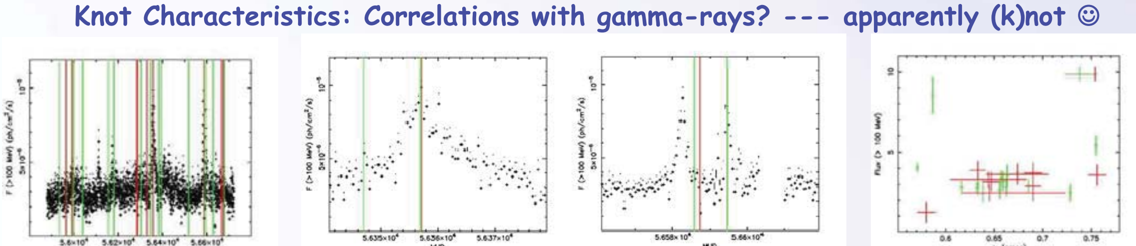
A subset of a series of 17 F550M filter HST-SVD-processed images of the Crab pulsar and inner knot *after* removing effects of the HST/ACS WFC point spread function.

Knot Characteristics: Variables are all correlated with the separation from the pulsar



Position Angle | Surface Brightness | FWHM (radial) | FWHM (tangential) | Flux

Knot Characteristics: Correlations with gamma-rays? --- apparently (k)not ☺



Red = Keck observation Green = HST Observation

The Team

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