MW Observations of the Binary System PSR B1259-63/LS 2883 During the 2010/2011 Periastron Passage

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On behalf of the Fermi LAT Collaboration and the Pulsar Timing Consortium

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Fermi Symposium

Rome, May 9-12 2011

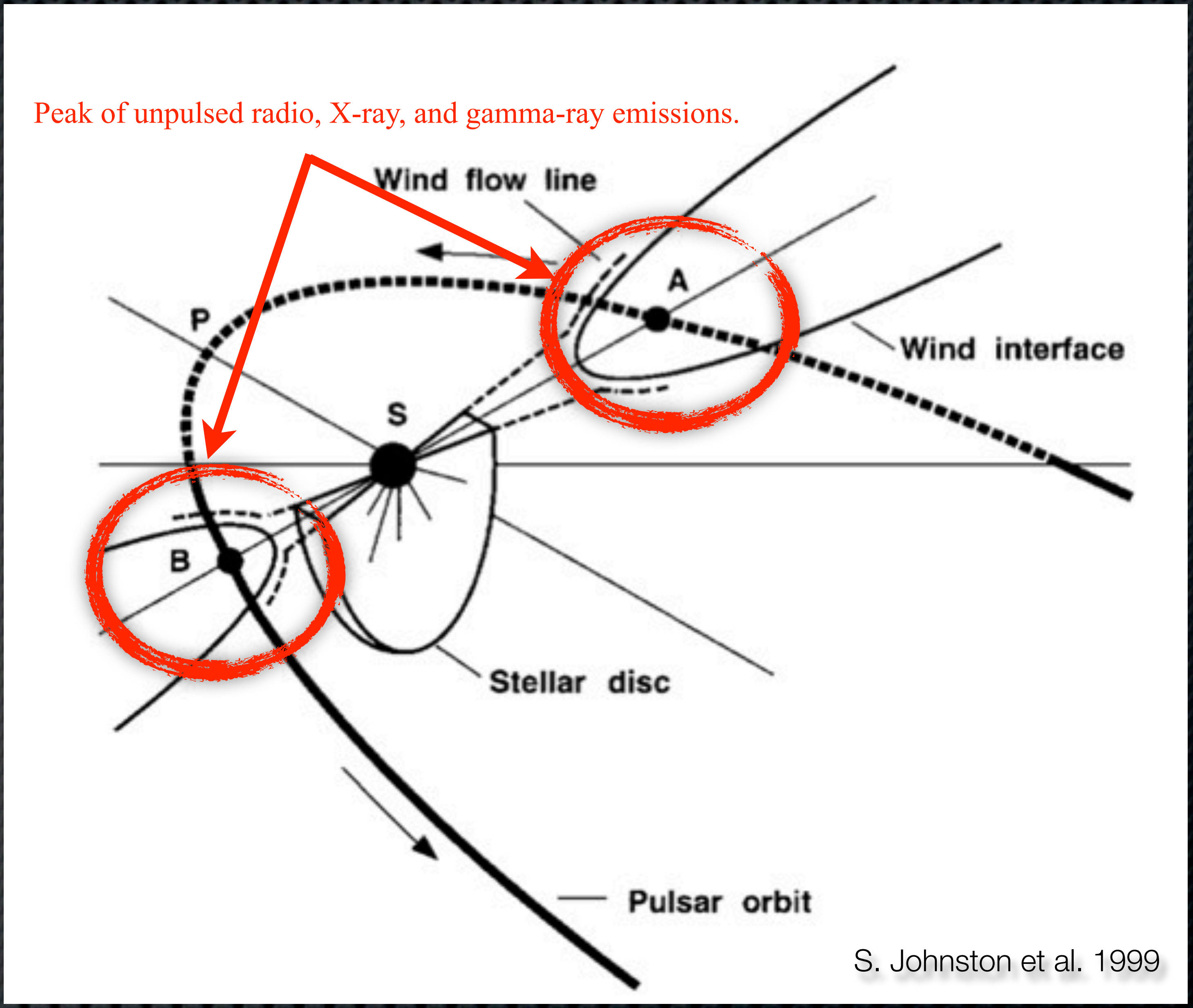
Why PSR B1259-63 ?

- X-ray binaries are binary star systems made of a compact object – a neutron star, a black hole, or a white dwarf – in orbit around a normal star
- A gamma-ray loud binary (GRLB) is an X-ray binary system that emit high-energy gamma-rays
- We know of 6 GRLBs:
  - LSI +61 303, LS 5039, Cyg X-3, PSR B1259-63, HESS J0632+057, and most recently 1FGL J1018.6-5856 (see talk by Robin Corbet tomorrow)
  - PSR B1259-63 system is the only one among the 6 GRLBs in which we know the nature of the compact star
  - Understanding this system and knowing the acceleration and emission mechanisms responsible for the non-thermal emission in it might allow us to decipher the nature of the compact objects in the other three systems

Not detected in the GeV band yet

Binary System Overview

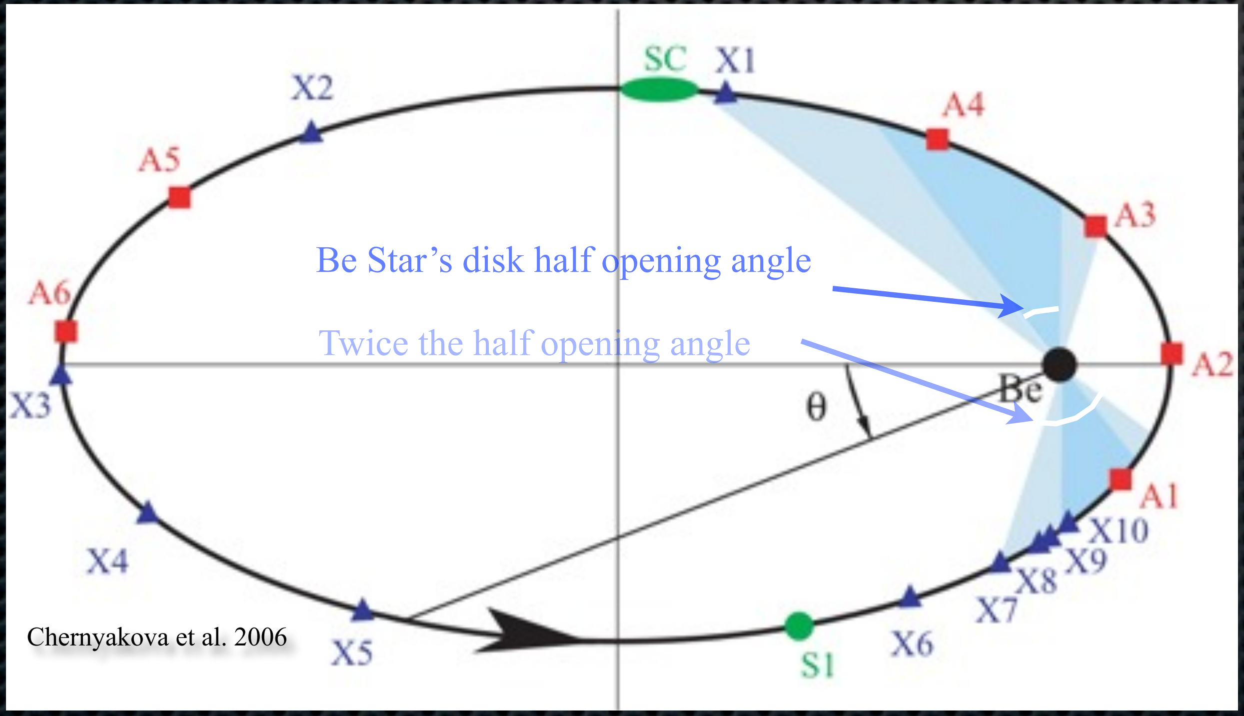
- System consists of a ~47 ms pulsar (PSR B1259-63) orbiting a massive Be star (LS 2883) in a highly elliptical orbit (e ~ 0.87) with an orbital period of ~ 3.4 years
- Unpulsed radio, X-ray, and TeV gamma-ray emission observed from the system during the periastron passage is likely due to the interaction of the pulsar wind with the stellar wind Be star.
- No detection in GeV gamma-rays prior to Fermi. Only upper limits in the GeV band existed from EGRET.

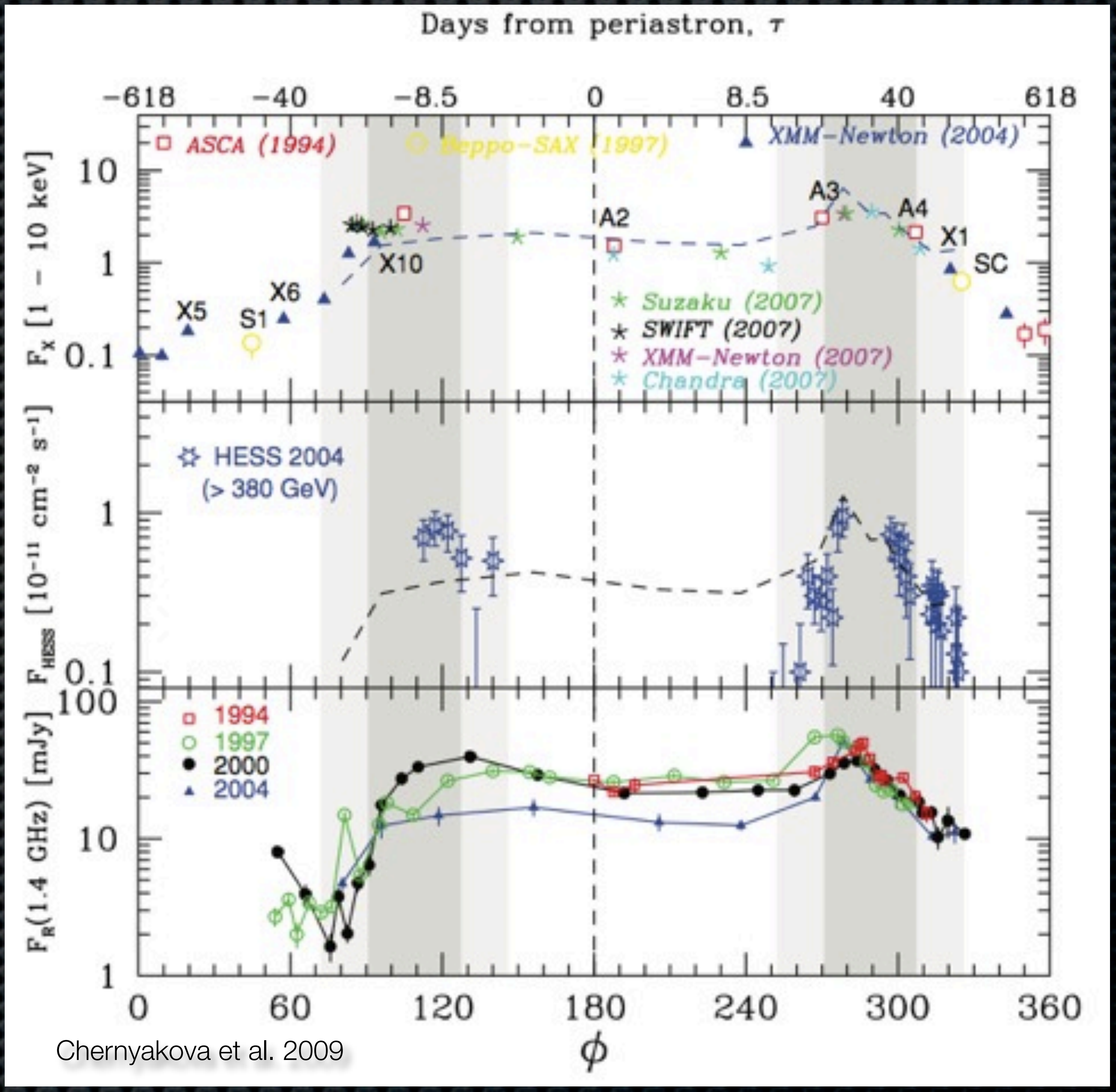


- Eclipse of radio pulsations for a period of 5 weeks centered around periastron

Previous Passages

- Unpulsed radio and X-ray fluxes double peaked around periastron (~t_p-10, t_p+20)
- X-ray flux observed throughout the orbit
- TeV flux around periastron only





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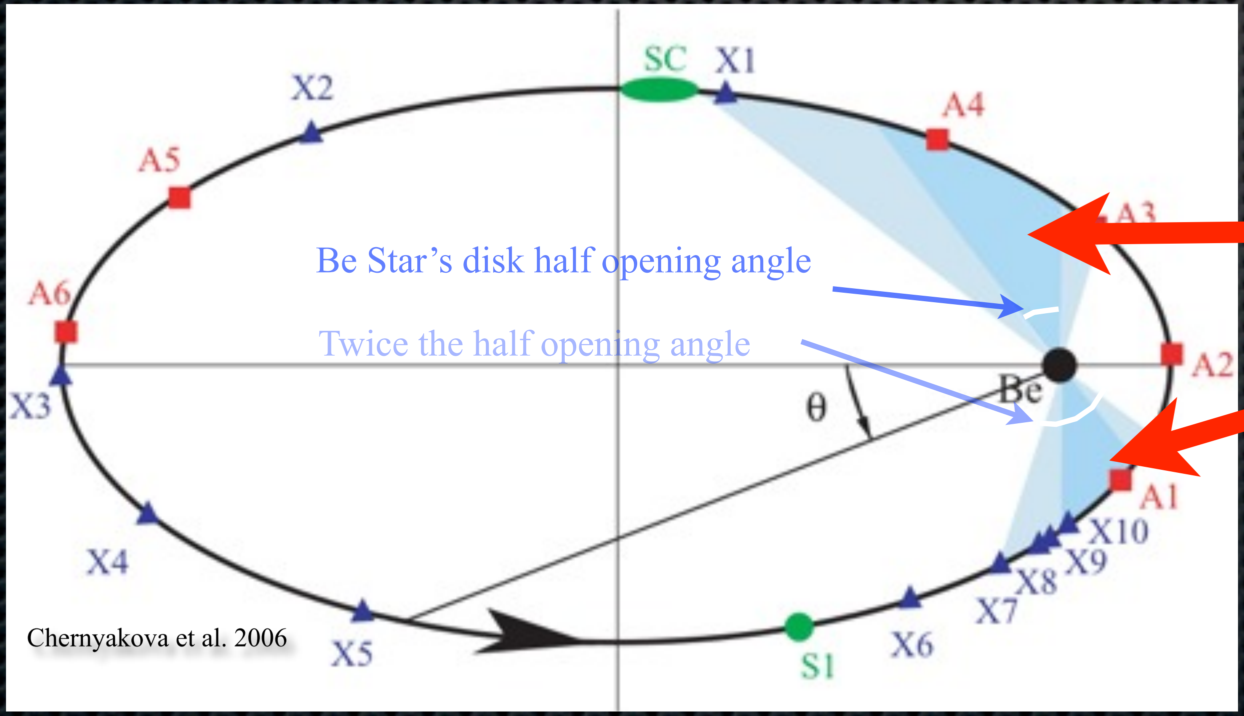
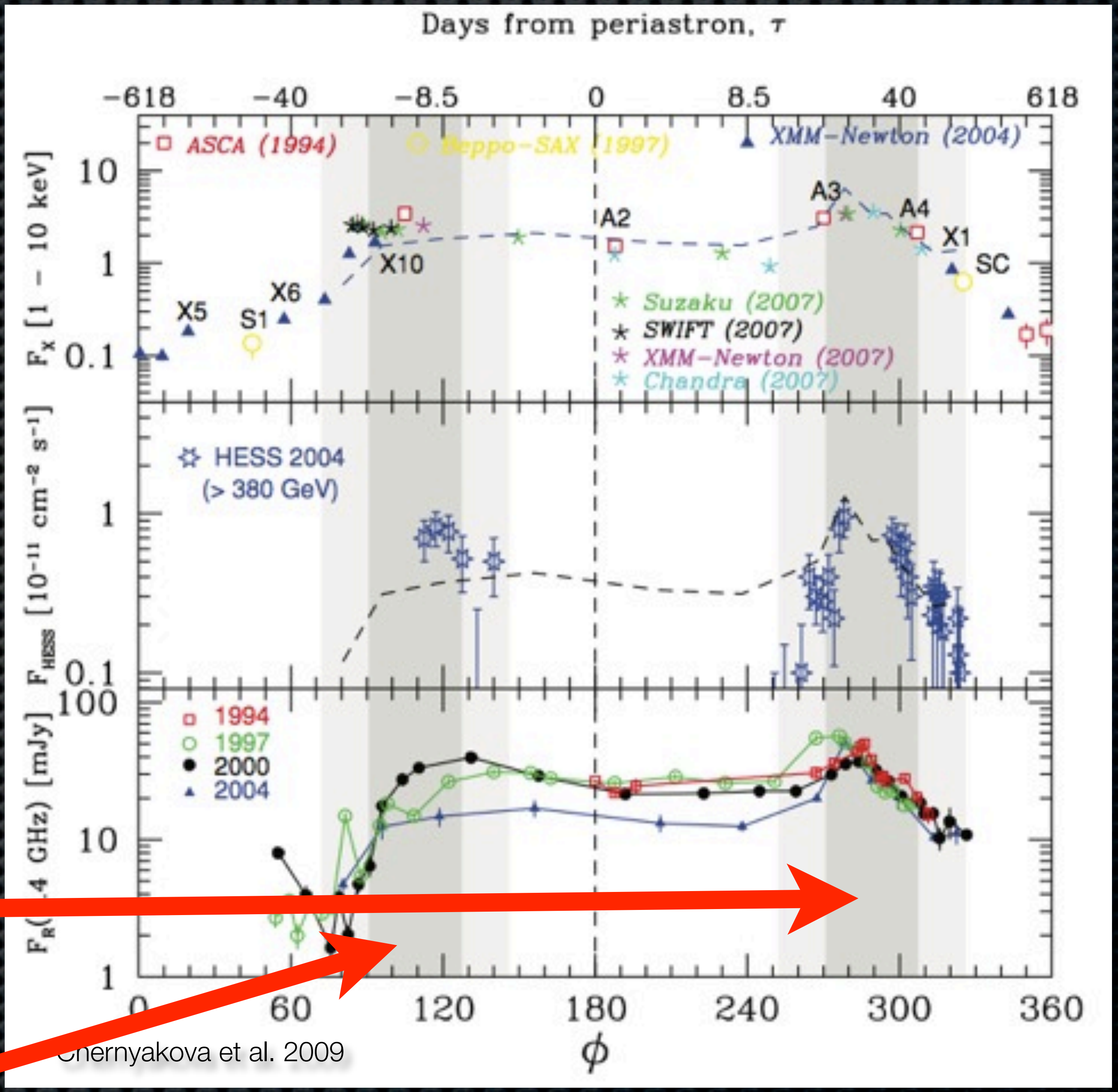




Important dates for the 2010/2011 Passage

- From pulsar timing:
  - Periastron: ***December 15 2010***
  - Disappearance of pulsed signal: ***Nov. 29 - Dec. 29 2010***
- Start of increase of unpulsed radio and X-ray emission: ***Mid November***
- Unpulsed flux going back to near-apastron levels: ***Mid April***

2010 Multi-wavelength Campaign

2010 Multi-wavelength Campaign

Parkes: pulsar monitoring

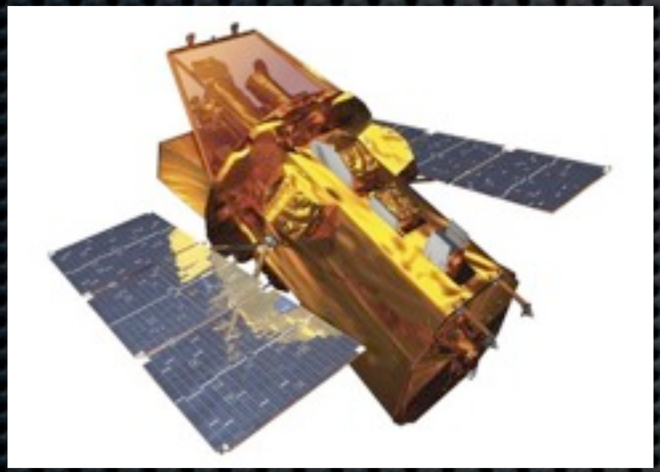
ATCA: Transient emission

SMARTS: IR and Optical

Fermi LAT: GeV

HESS: TeV. Post-periastron

SWIFT



XMM-Newton

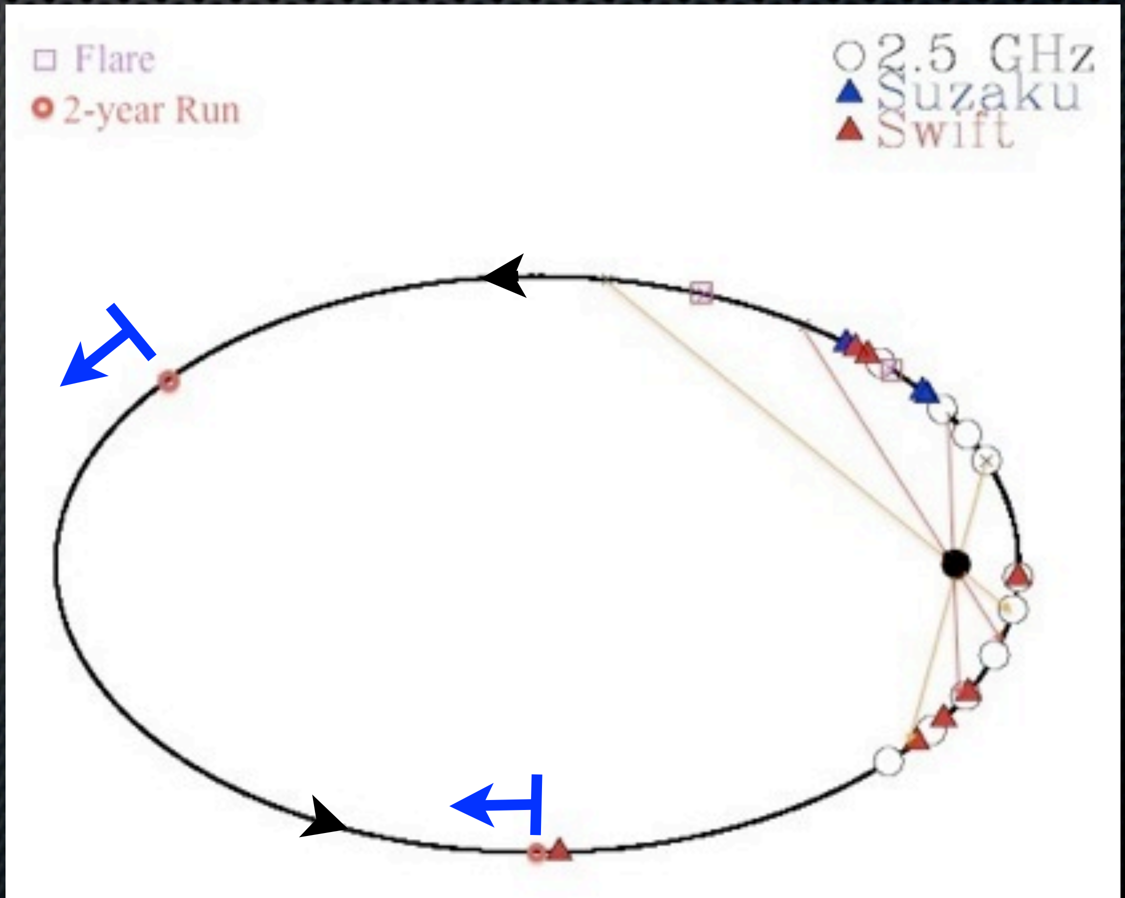
Suzaku

Fermi-LAT 2-Year Run

- ✦ No detection when the source was far from periastron (August 4 2008 - August 4 2010).

- The results of this fit were used to constrain the background source model for analyses on shorter timescales around periastron.

U.L. of $F_{100} < 9 \times 10^{-9}$ photons $cm^{-2}\ s^{-1}$



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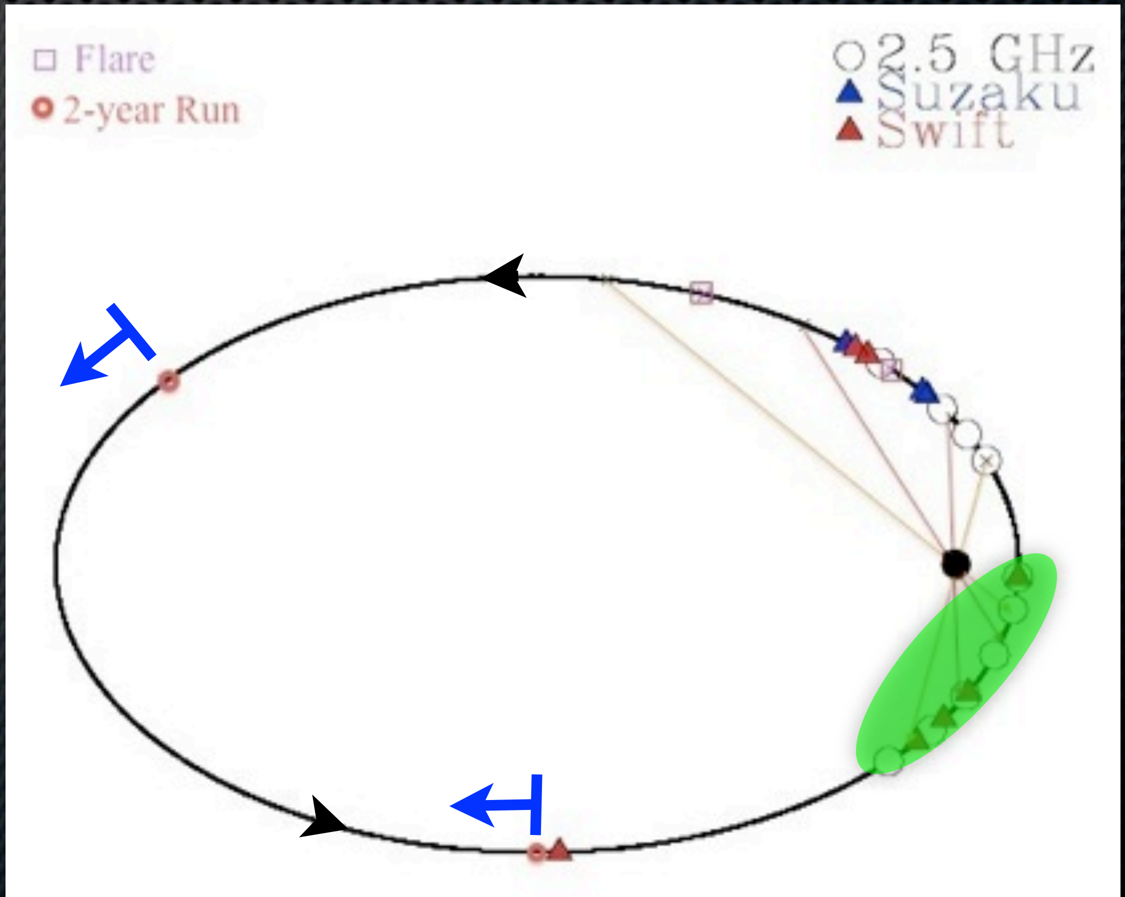

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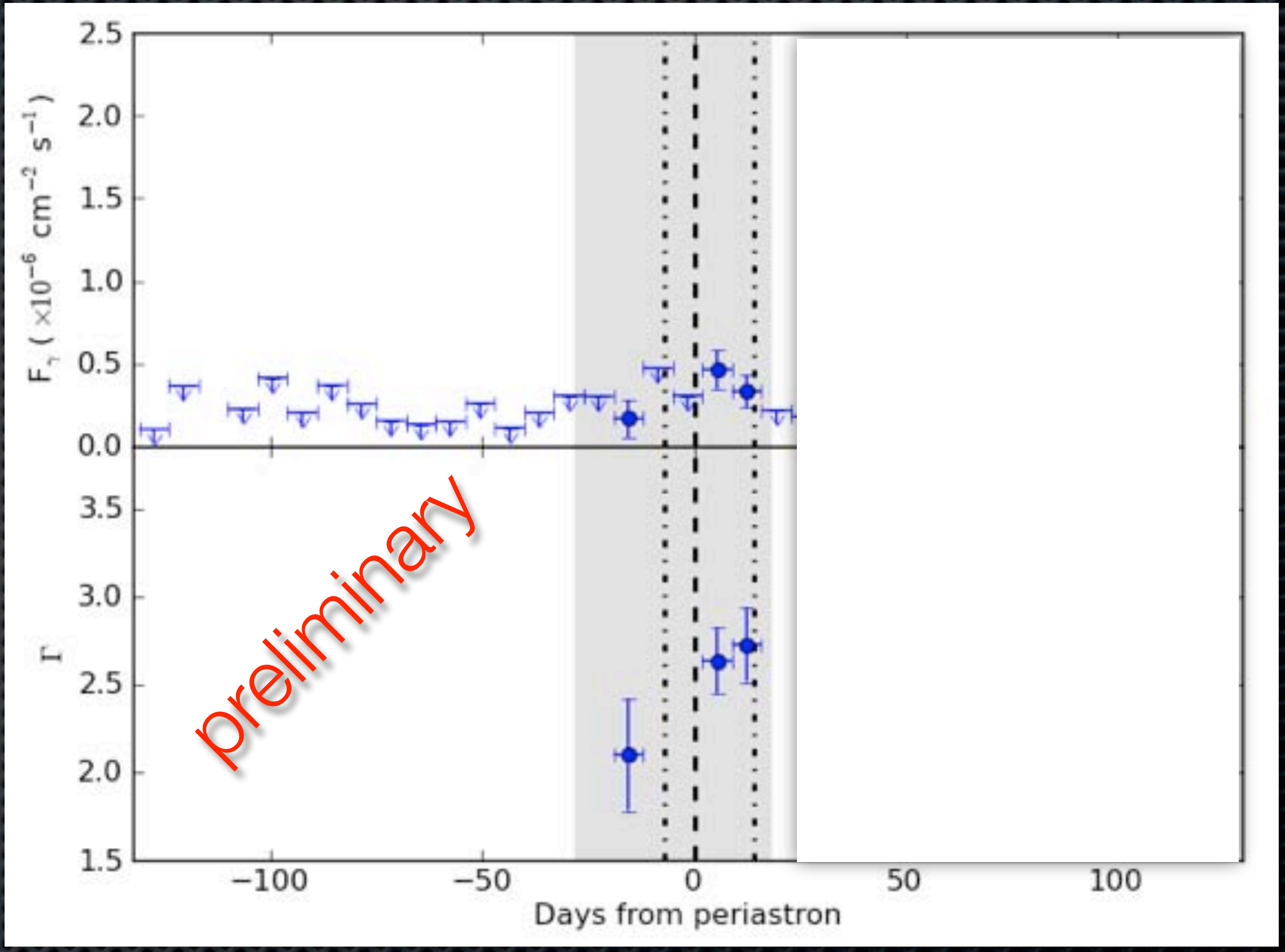
Detections with the LAT

- Detection at the level of 7 sigma of a faint flux F(E > 100 MeV) = (1.9+/-0.5) E^{-7} photons cm^{-2} s^{-1}



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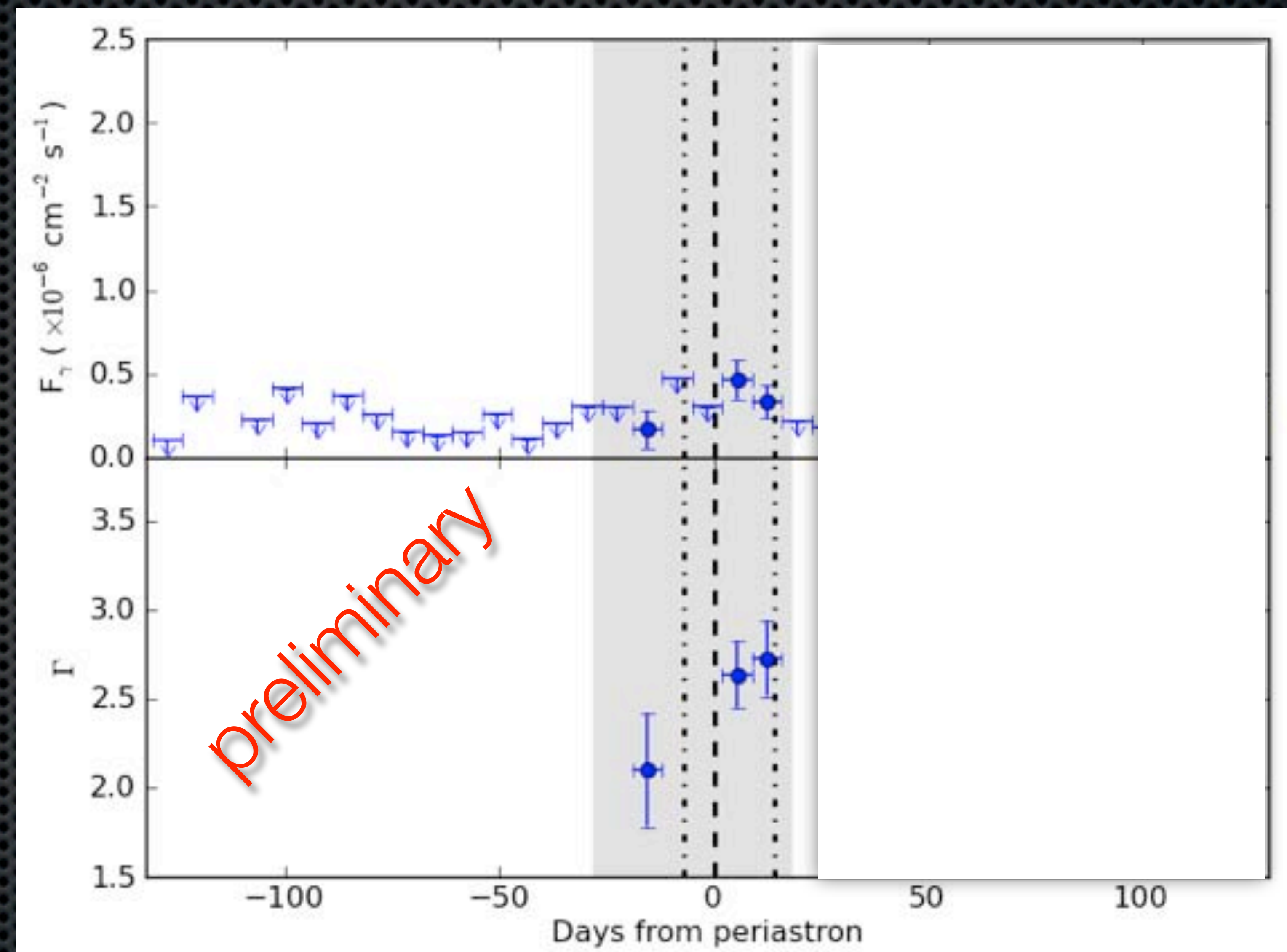
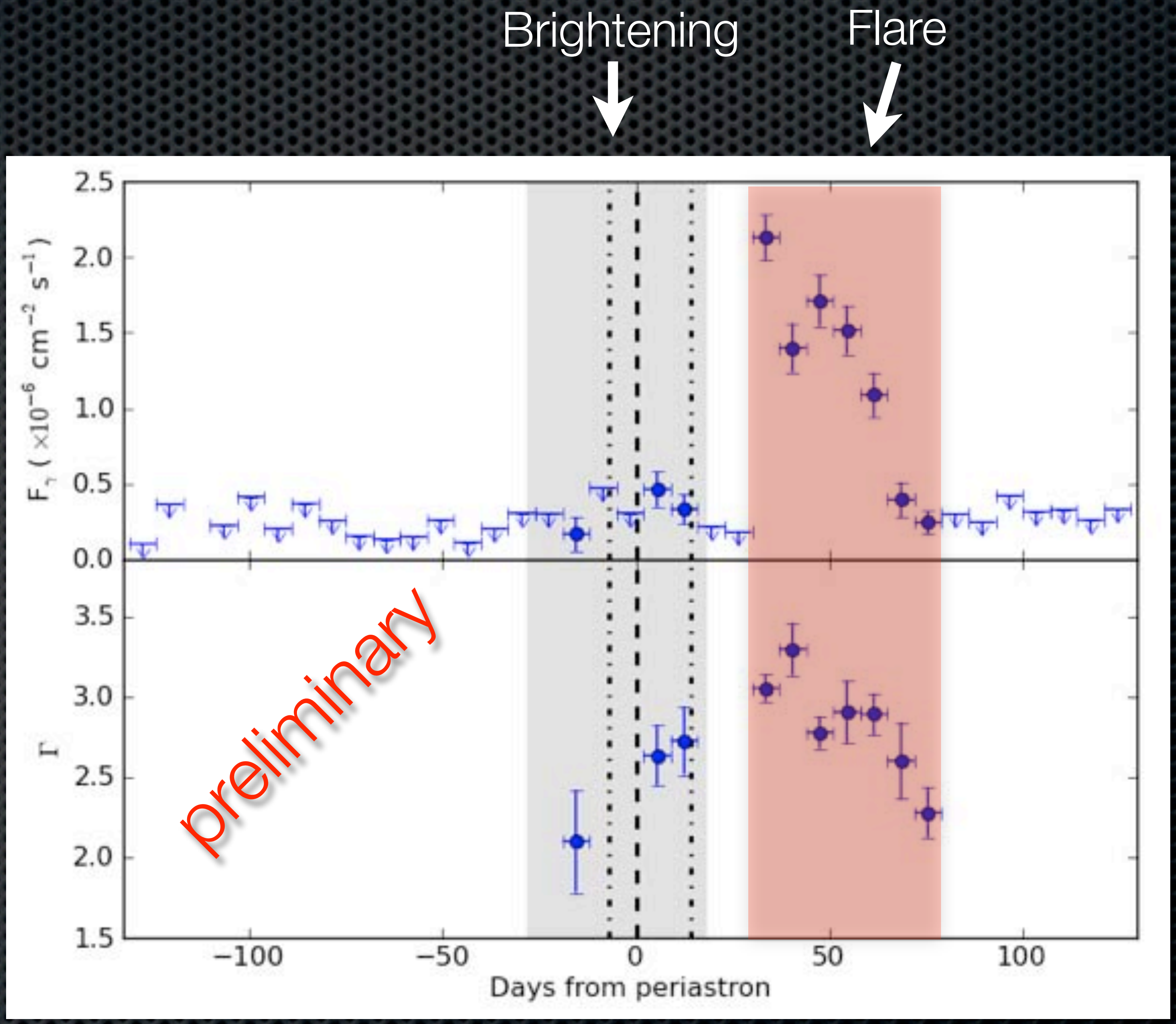
Brightening



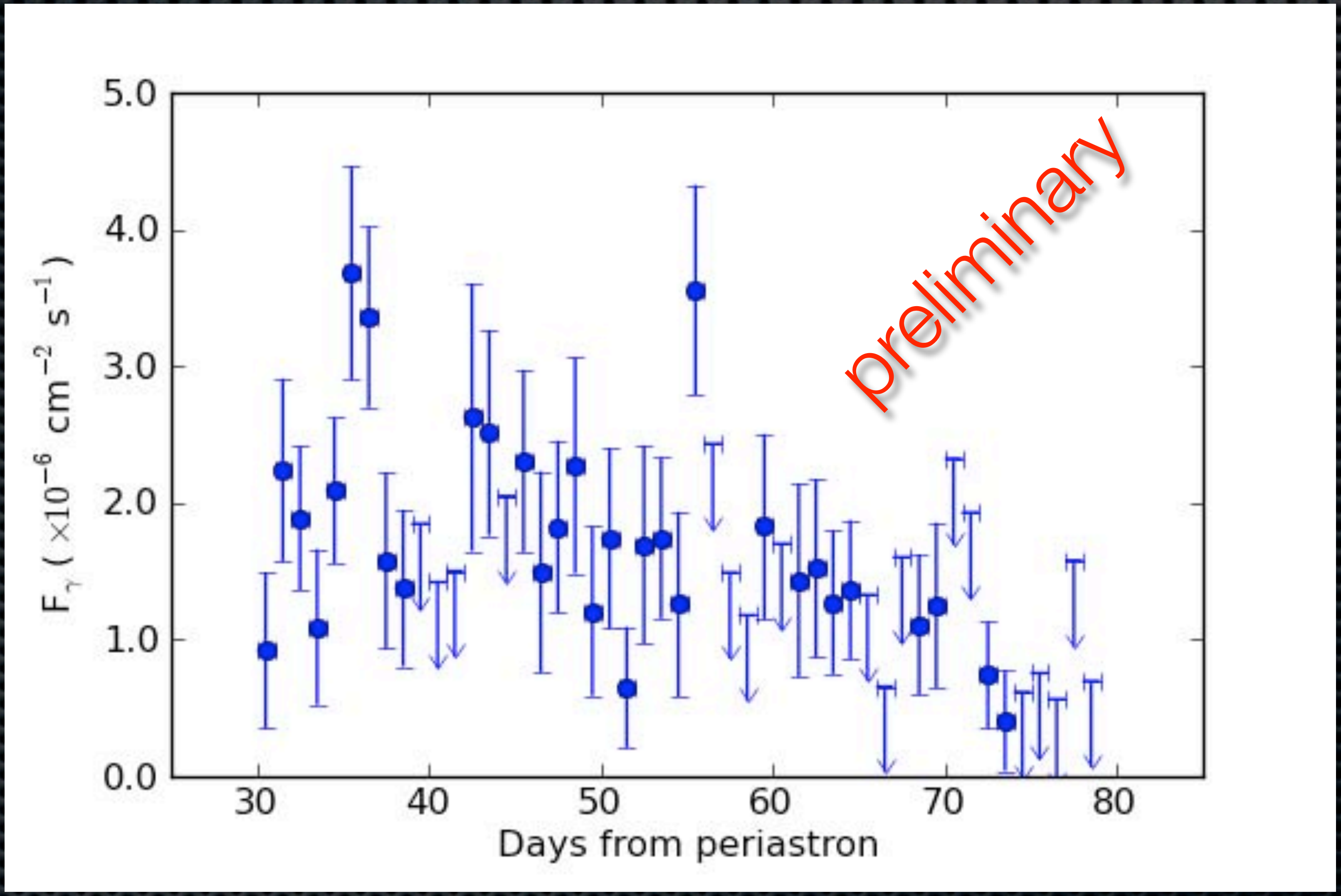
Detections with the LAT

- Detection at the level of 7 sigma of a faint flux F(E > 100 MeV) = (1.9+/-0.5) E^{-7} photons **cm^{-2} s^{-1}**
- Strong highly-variable flare with flux ~10-20 x that seen during the brightening: F(E > 100 MeV) = (13.5+/-1.0) E^{-7} **photons cm^{-2} s^{-1}**
- EGRET observed for 3 weeks around periastron with no detection (dashed-dotted line)



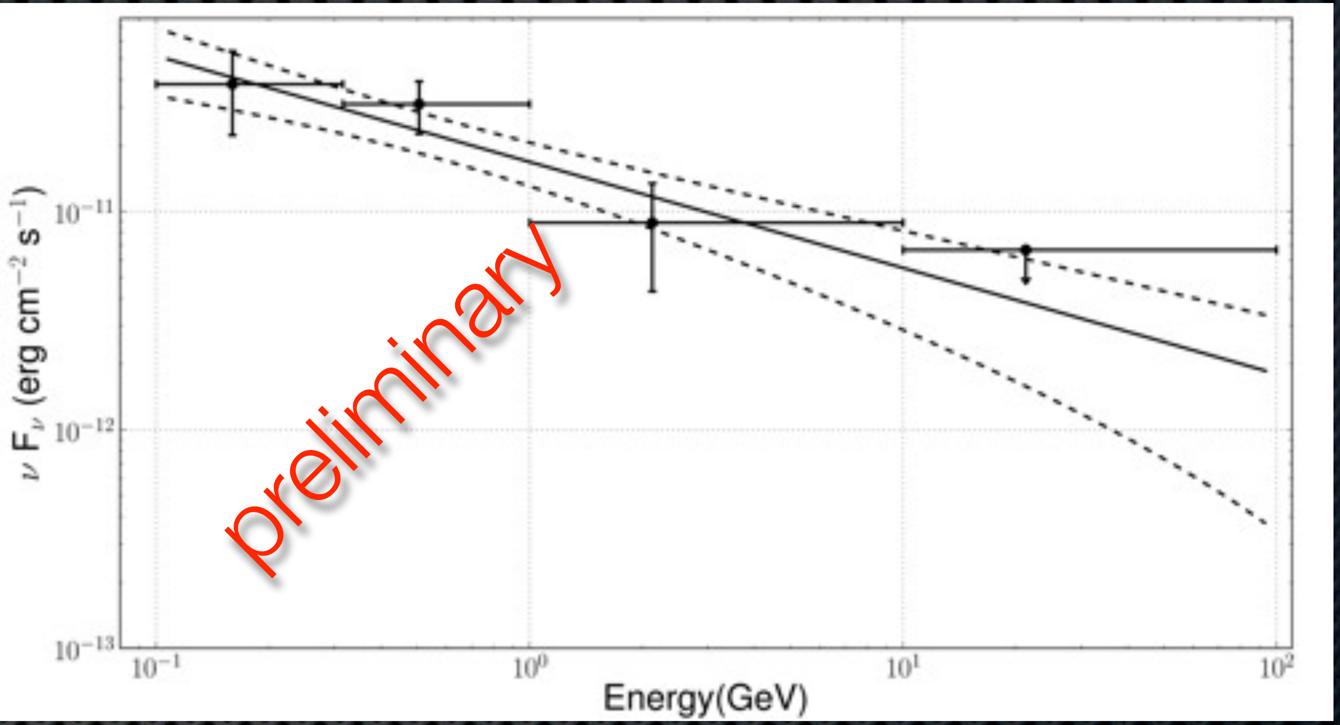
Gamma-ray Flux Variability During the Flare

- Strong variability in flux on daily time scales



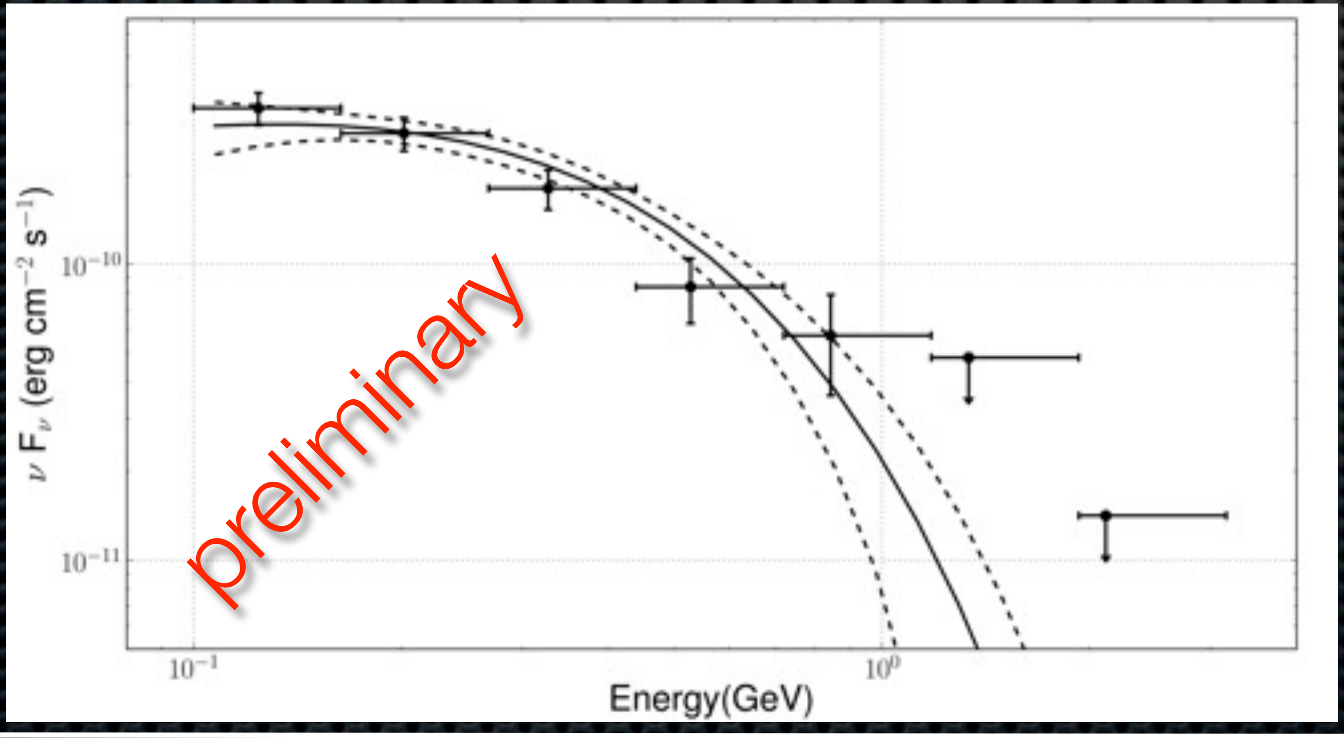
Spectral Analysis

Brightening



- ✦ Power law with index = 2.4 +/- 0.2
- ✦ Can't fit a PLEC due to low statistics.

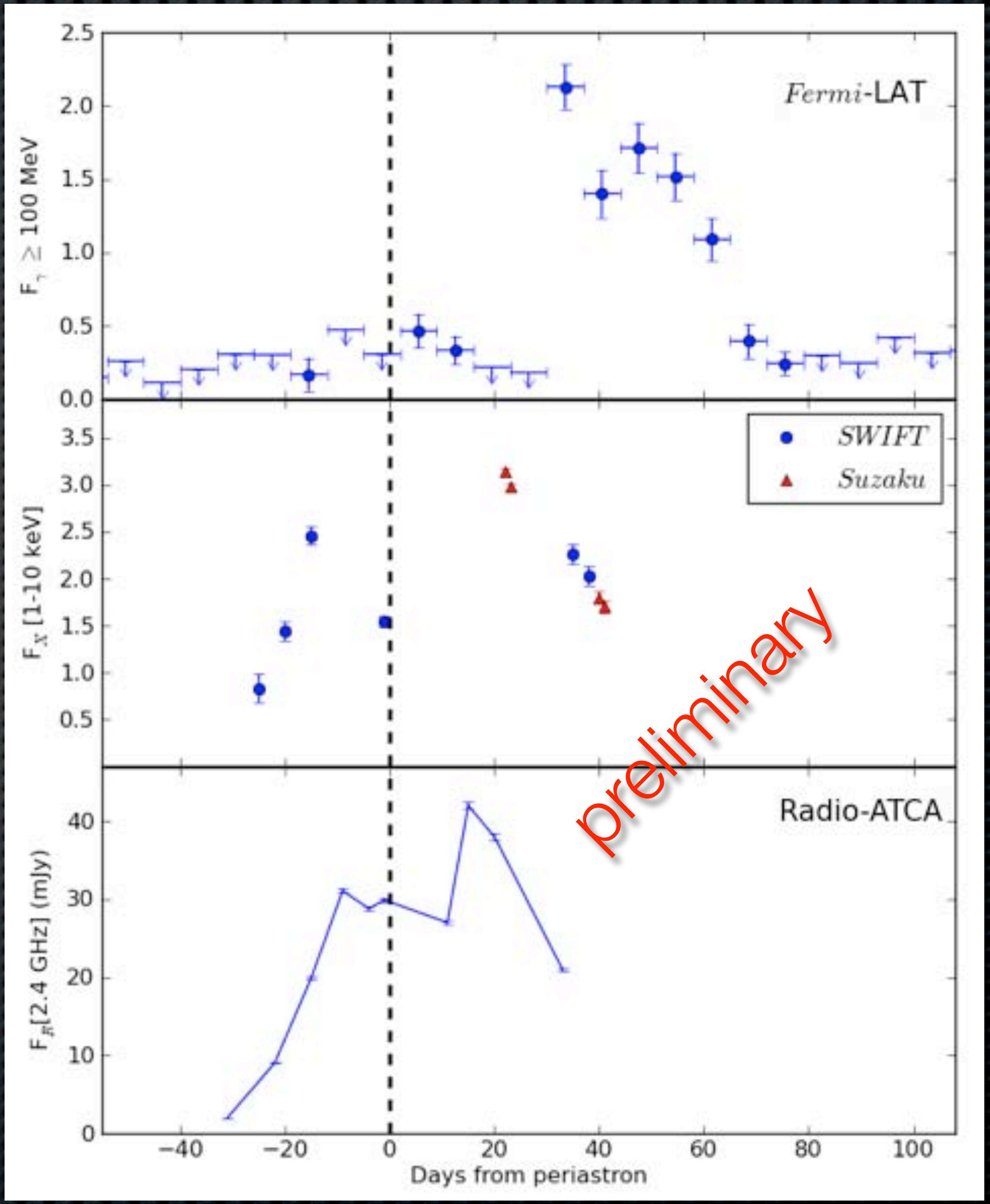
Flare



- ✦ Power law with exponential cutoff:
  index = 1.4 +/- 0.5
  E_c = 0.3 +/- 0.1 GeV
- ✦ PLEC is favored at the level of 4.7 sigma compared to PL.

The MW Picture

- Double peak feature seen in both the X-ray and radio light curves is clear. In both cases the second peak is a factor of 2 or so higher than that seen for the first peak.
- This is believed to be due to the build of emission from the second disk passage over the decaying emission from the first disk passage.
- The flare seen by the LAT is not coincident with the second peak in radio and X-ray and is much brighter in comparison to the faint brightening during the fist disk passage.



Gamma-ray Efficiency of the Pulsar

- No pulsations detected in the LAT photons
- Comparing this pulsar to the rest of the LAT-detected pulsars, we find that most detectability metrics predict that this should be a gamma-ray pulsar.
- Although the characteristic age of 333 kyr is fairly large, the spin period is short for a middle-aged pulsar
- E_{dot} of 8.2E35 erg s^{-1} and B_{LC} of 2.9E4 G are well within the range where gamma-ray pulsations are typically detected.
- All of this leads to a very low g-ray efficiency (0.7%) if we assume an f_{gamma} of 1.0. Recall that for this E_{dot} range the average efficiency is ~ 10%

Summary

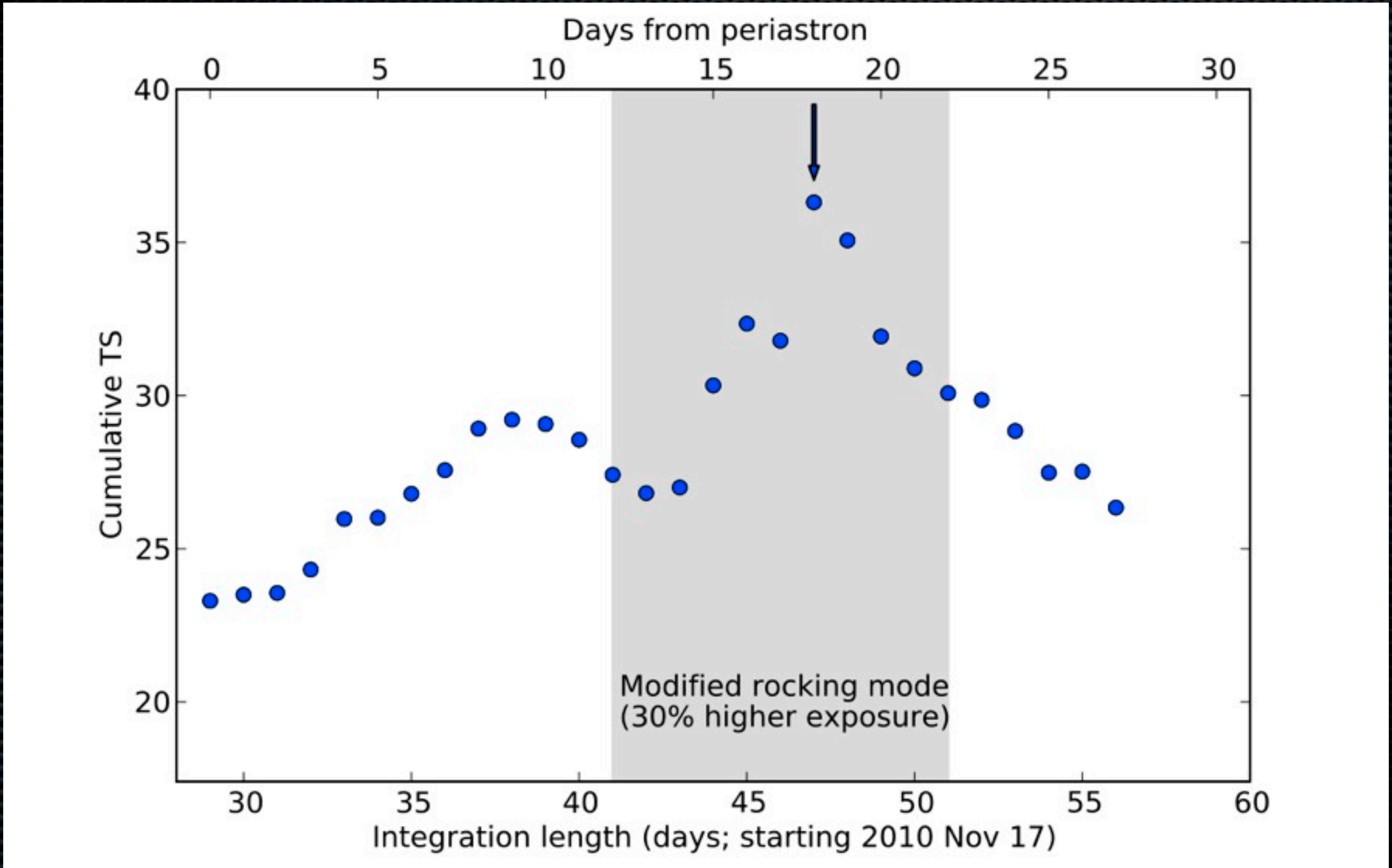
- Our Fermi observations revealed a puzzling behavior of the source in the GeV band, which was not predicted in any pre-existing model of γ-ray emission from the PSR B1259-63 system
- An unexpected strong flare, visible only in the GeV γ-ray band was observed some 30 days after the periastron passage and after the passage of the dense equatorial wind of the massive star
- Strong increase of the GeV flux and change of the γ-ray spectrum during the flare was not accompanied by noticeable spectral variations in the X-ray band
- The possibility of strong “orphan” flare was not considered in any of the existing theoretical models of the γ-ray emission from the source, so there is no straight forward theoretical interpretation of the observed phenomenon
- We continue to monitor the source and hope to be able to constrain the emission mechanism of the puzzling flaring activity discovered by Fermi.

Acknowledgement

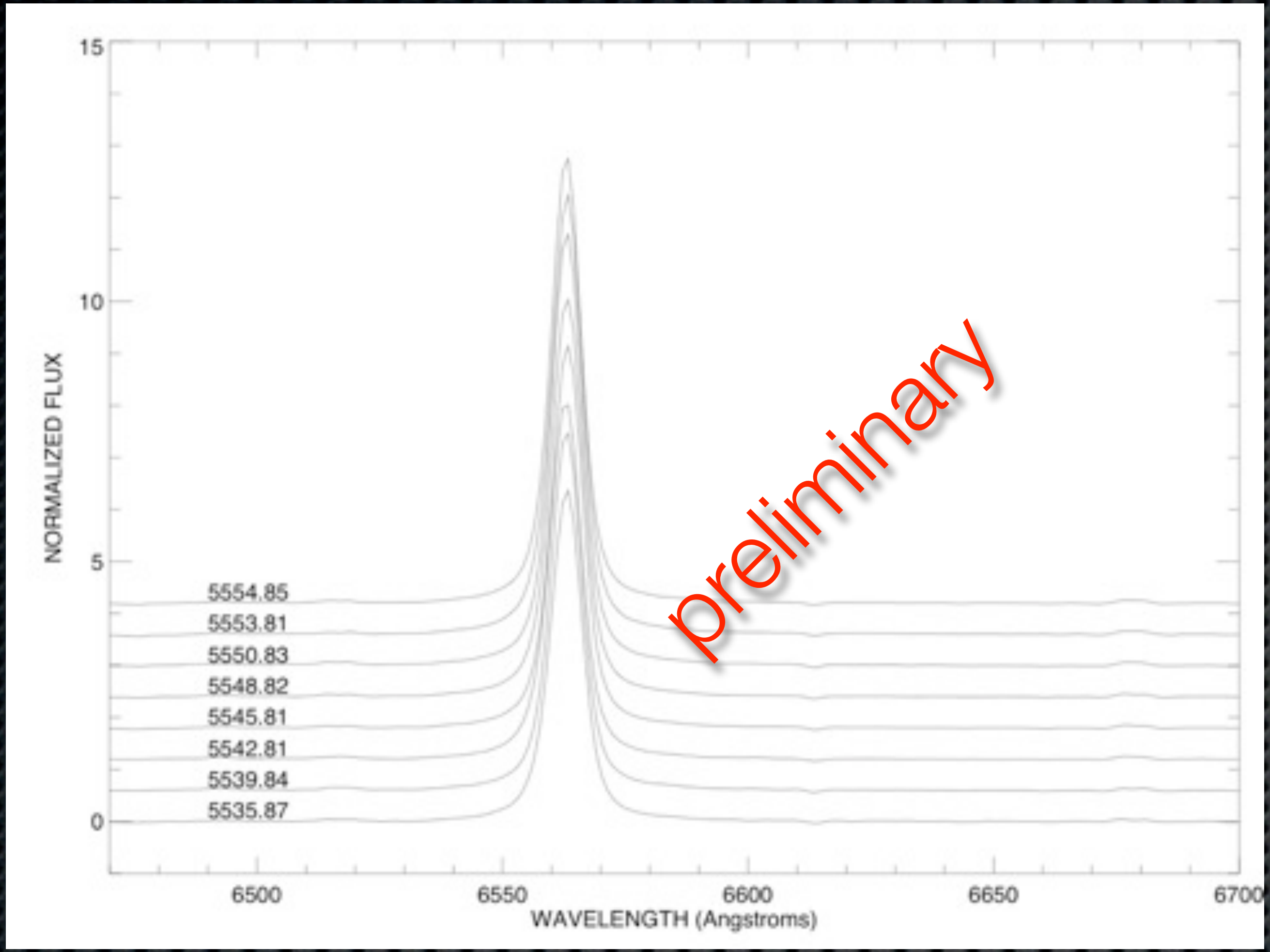
- The Fermi LAT Collaboration acknowledges generous ongoing support from a number of agencies and institutes that have supported both the development and the operation of the LAT as well as scientific data analysis. These include the National Aeronautics and Space Administration and the Department of Energy in the United States, the Commissariat à l'Energie Atomique and the Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules in France, the Agenzia Spaziale Italiana and the Istituto Nazionale di Fisica Nucleare in Italy, the Ministry of Education, Culture, Sports, Science and Technology (MEXT), High Energy Accelerator Research Organization (KEK) and Japan Aerospace Exploration Agency (JAXA) in Japan, and the K. A. Wallenberg Foundation, the Swedish Research Council and the Swedish National Space Board in Sweden.
- Additional support for science analysis during the operations phase is gratefully acknowledged from the Istituto Nazionale di Astrofisica in Italy and the Centre National d'Etudes Spatiales in France.

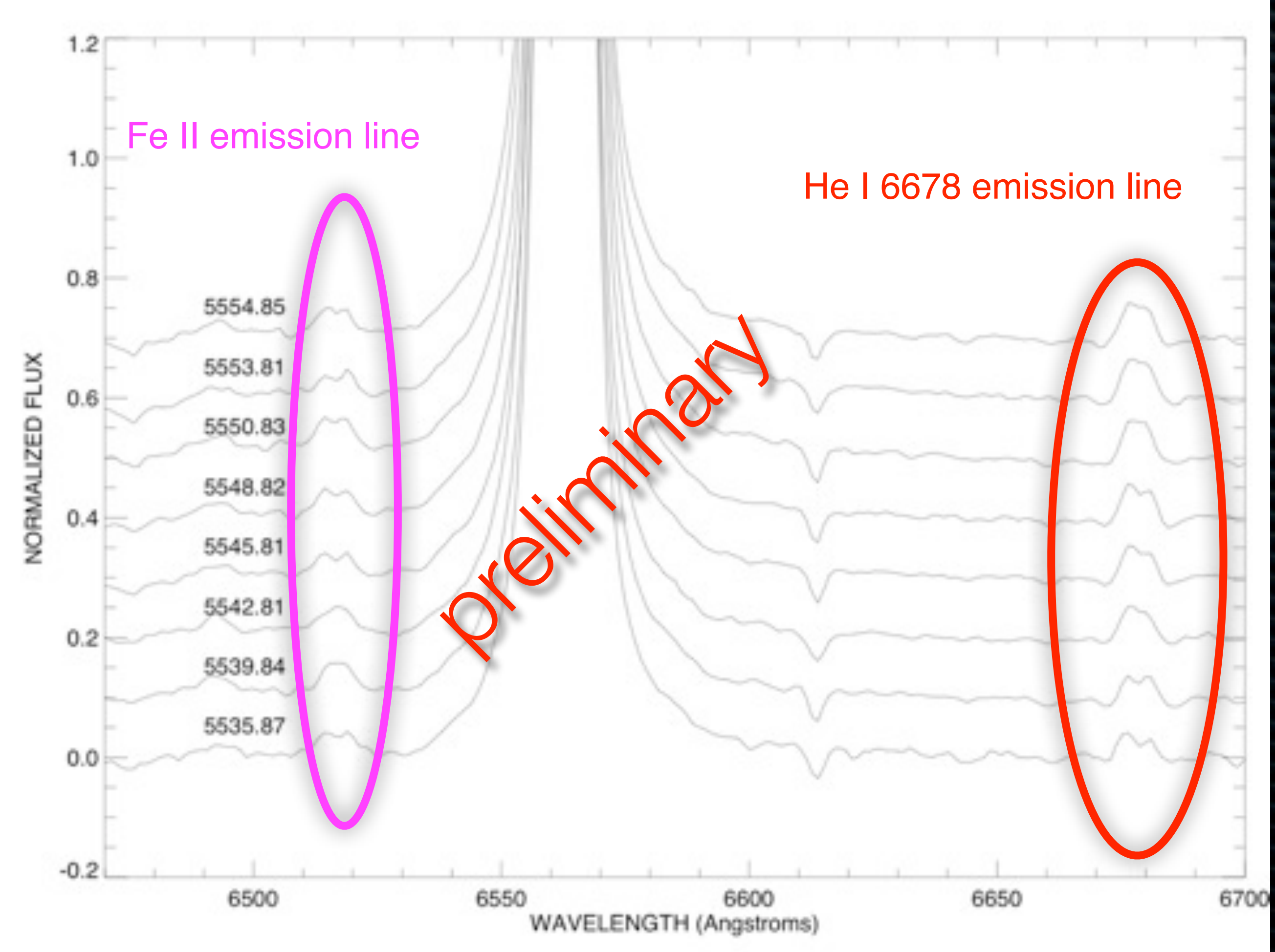
Backups

Cumulative TS



Optical Results





- H_{alpha} line is quite large and single peaked which is an indicative of a large disk

- He I 6678 line is double peaked --> indicative of a very large disk.
- Peaks show an asymmetry around and after the periastron passage which is an indicative of more material on one side of the star than the other (often interpreted as a spiral density wave)

Bow shock example: Zeta Ophiuchi