VERITAS observations of TeV J2032+4130 and the Be-star/pulsar binary PSR J2032+ 4127

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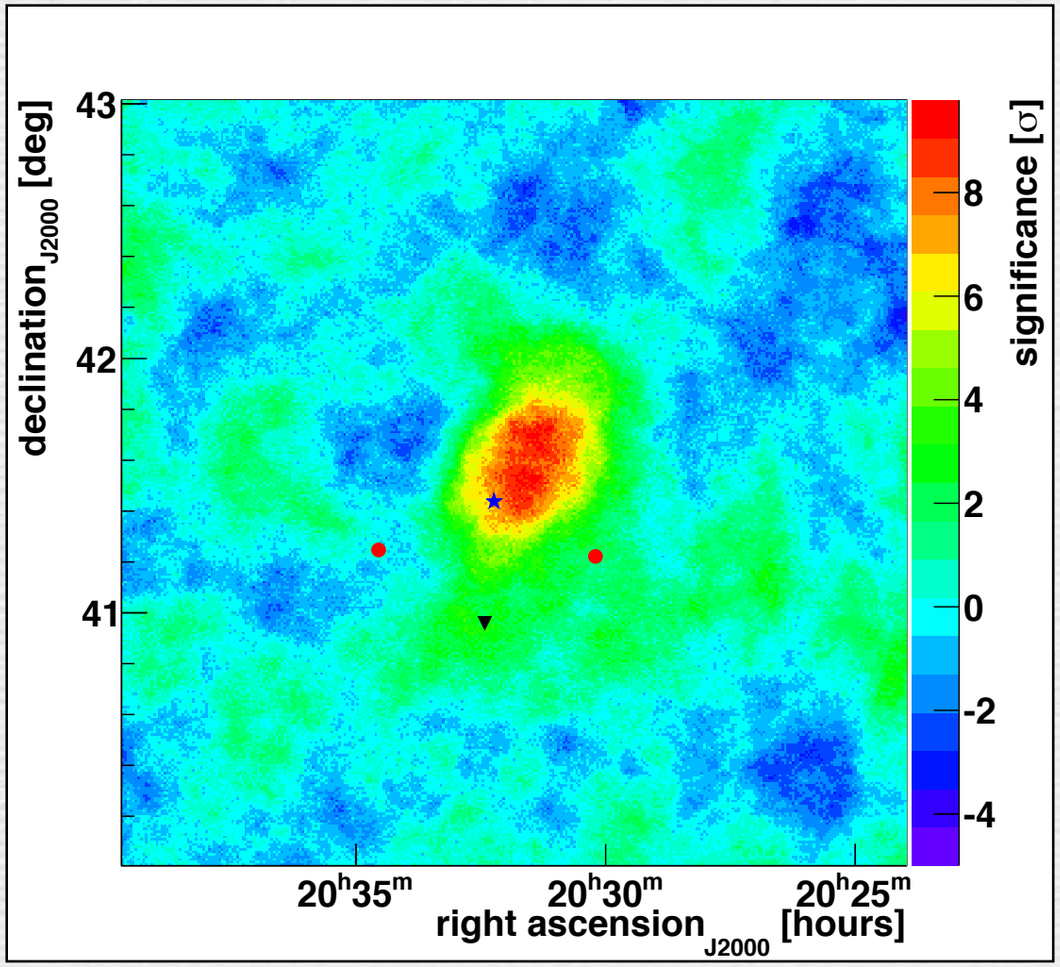
TeV J2032+4130

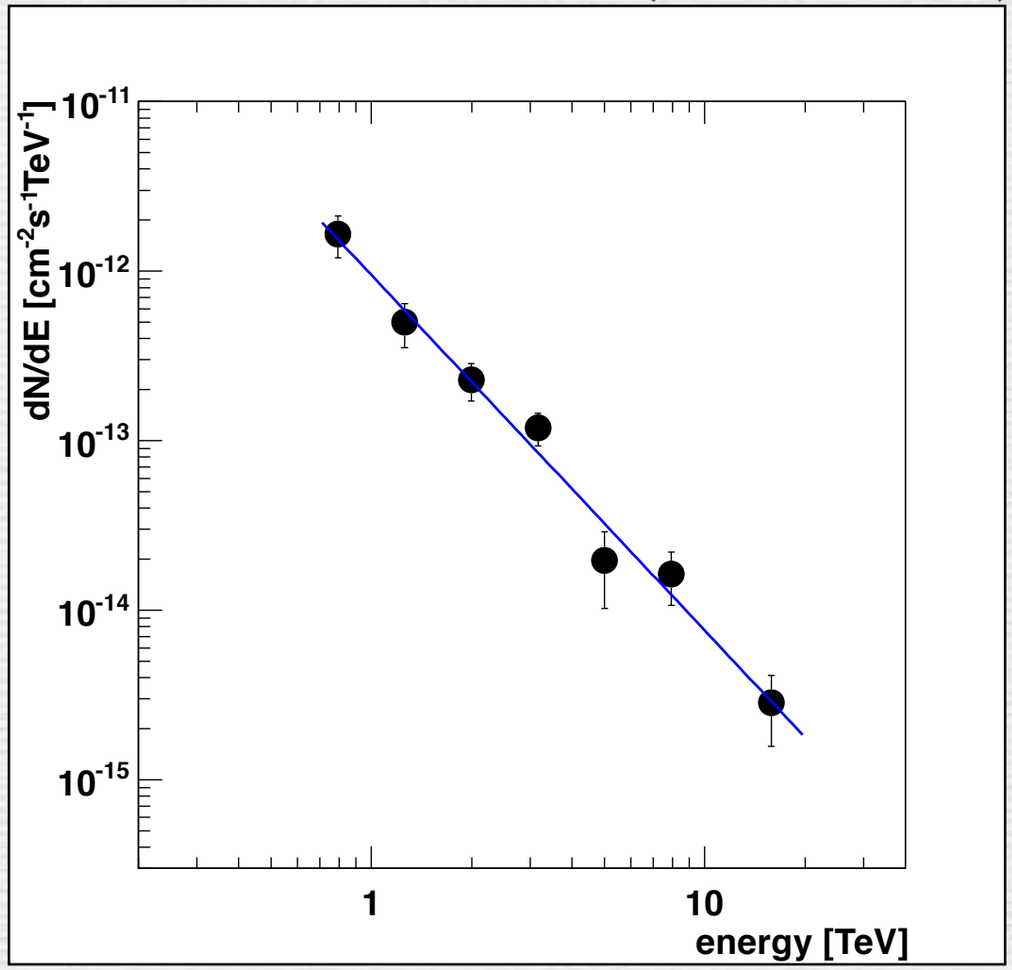
- Extended source of very high-energy(0.1-100 TeV) gamma rays in the Cygnus region
- First discovered by HEGRA
- No obvious counterpart at the time, source type unclear

TheVERITAS array

- Array of four 12 meter Cherenkov telescopes
- Sensitive to very high-energy gamma rays (~ 50 GeV-30 TeV)

VERITAS Observations (2012)



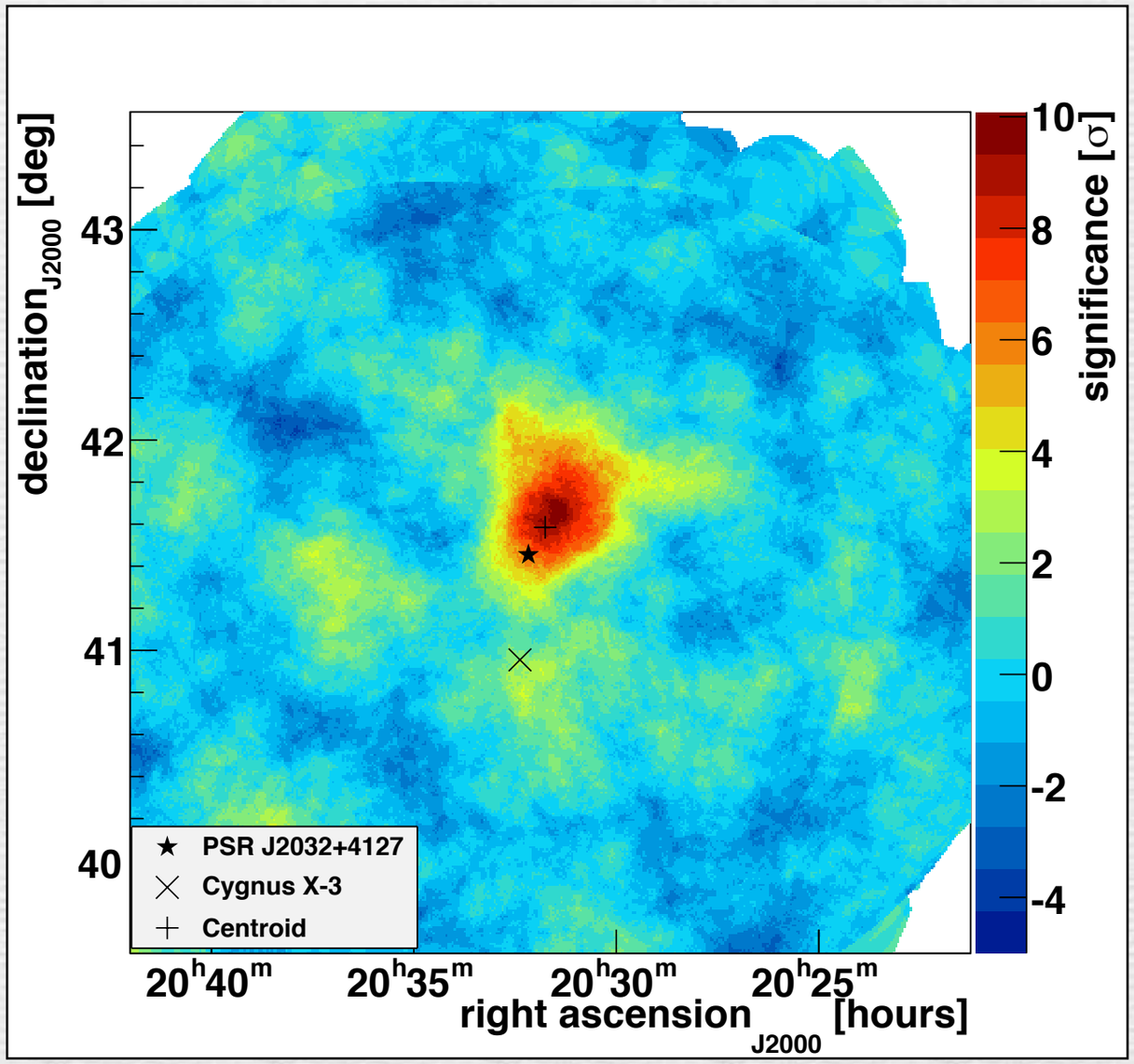


From Aliu et al (2014)

- 46 hours from 2009-2012
- 8.7 σ detection
- Power Law spectrum with Γ=2.10
- 4.3% Crab > 1 TeV

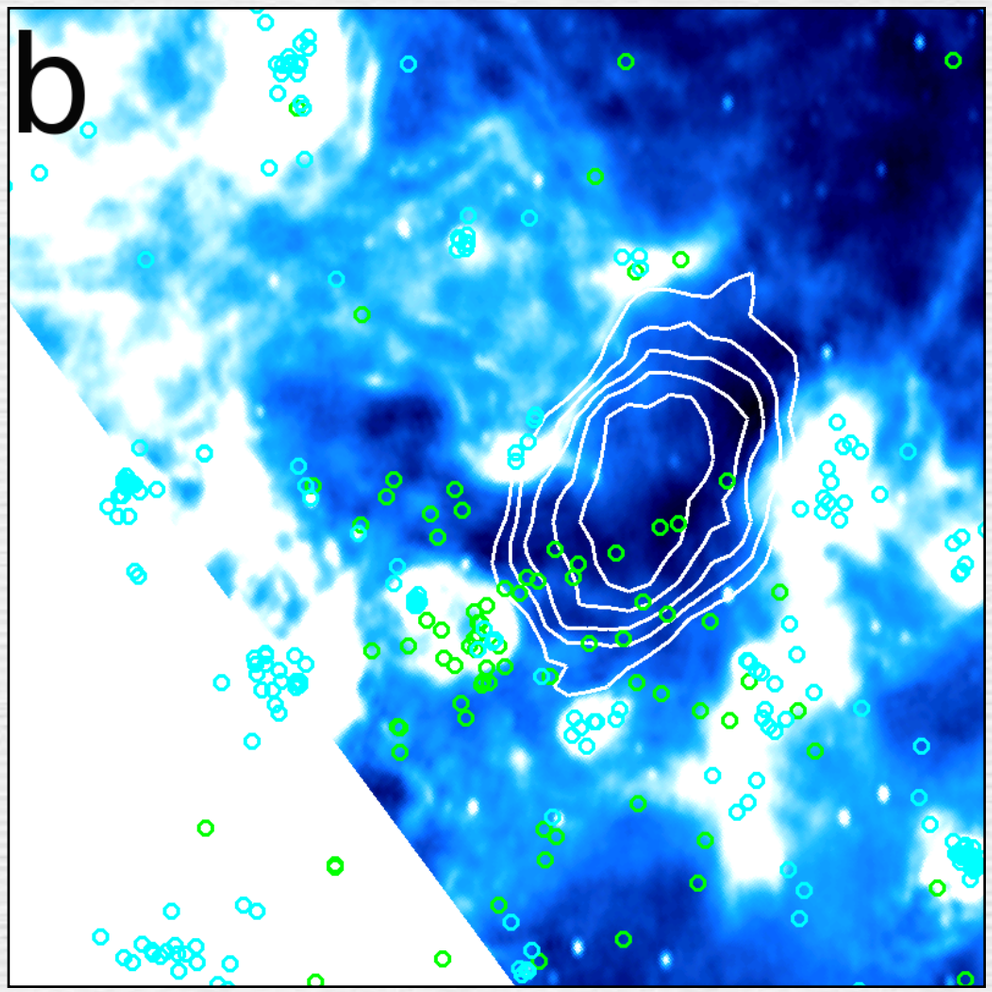
VERITAS Observations (2012)

- Second analysis
- 9.2 σ detection
- 0.3° extent along major axis



Interpretations

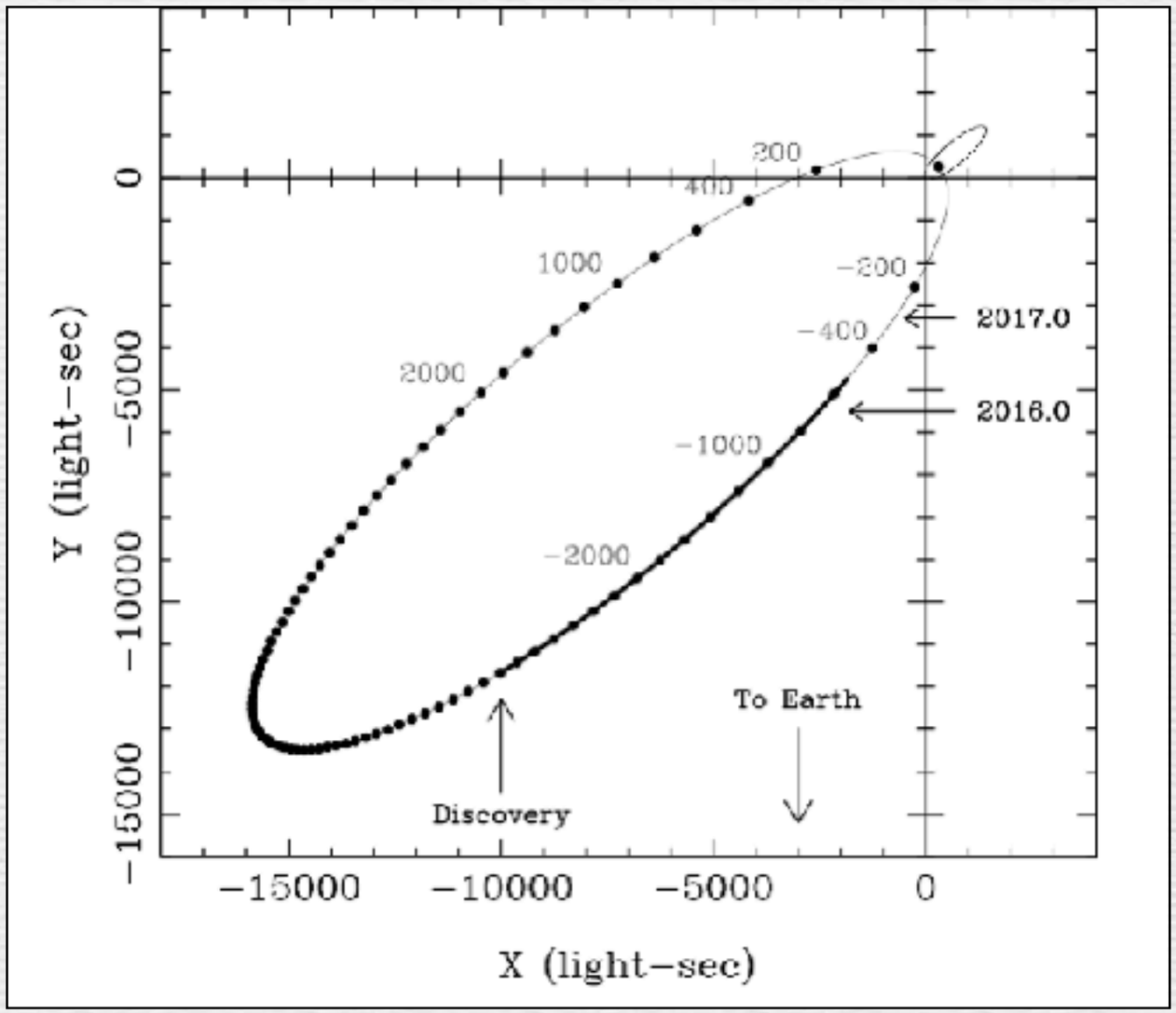
- PSR J2032+4127 located 0.07° from center
  - 1.5 kpc
  - Pulsed emission detected by FERMI-LAT
  - TeV J2032+4130 is a PWN driven by PSR J2032+4127



From Aliu et al (2014)

A binary interpretation for PSR J2032+4127

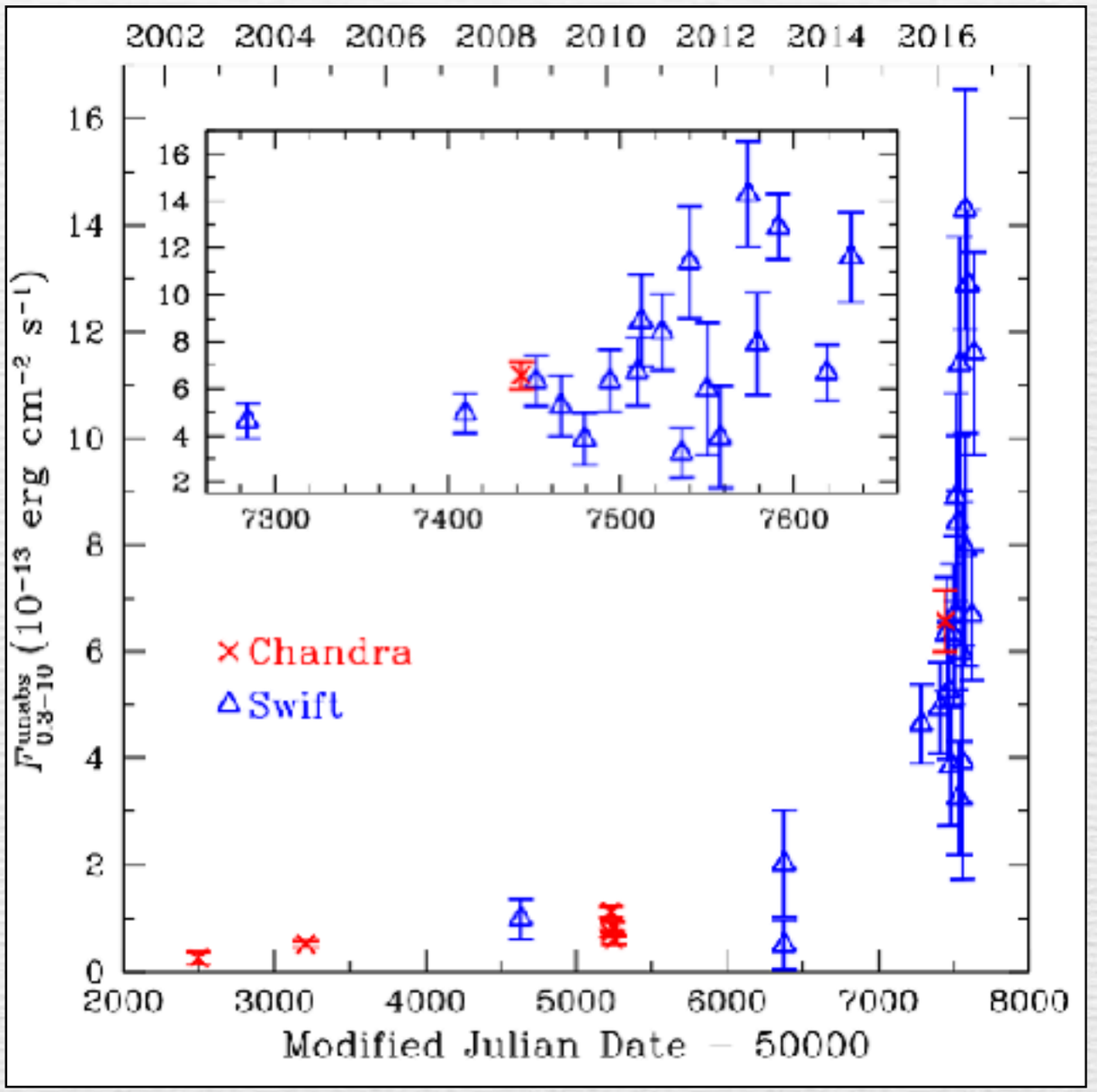
- Lyne et al (2015) and Ho et al (2016) found evidence for Doppler shifting in pulsar spin down rate
- PSR J2032+4127 in a binary orbit with a high mass Be star
  - P=45-50 years
  - Highly eccentric
  - Approaching periastron November 2017



From Ho et al (2016)

A binary model for TeV J2032+4130

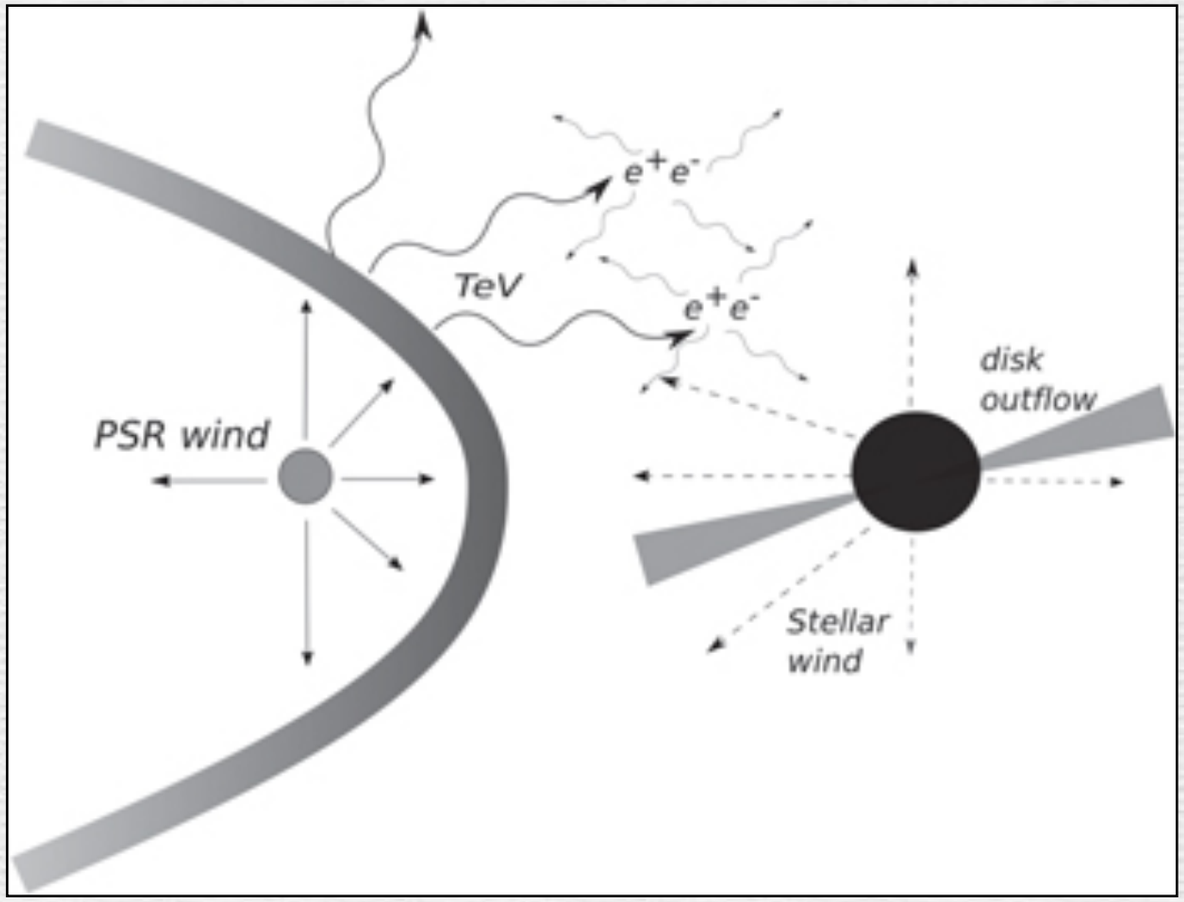
- Ho et al (2016) report increasing X-ray flux over the course of 2016
- Can a binary model explain the observations?



From Ho et al (2016)

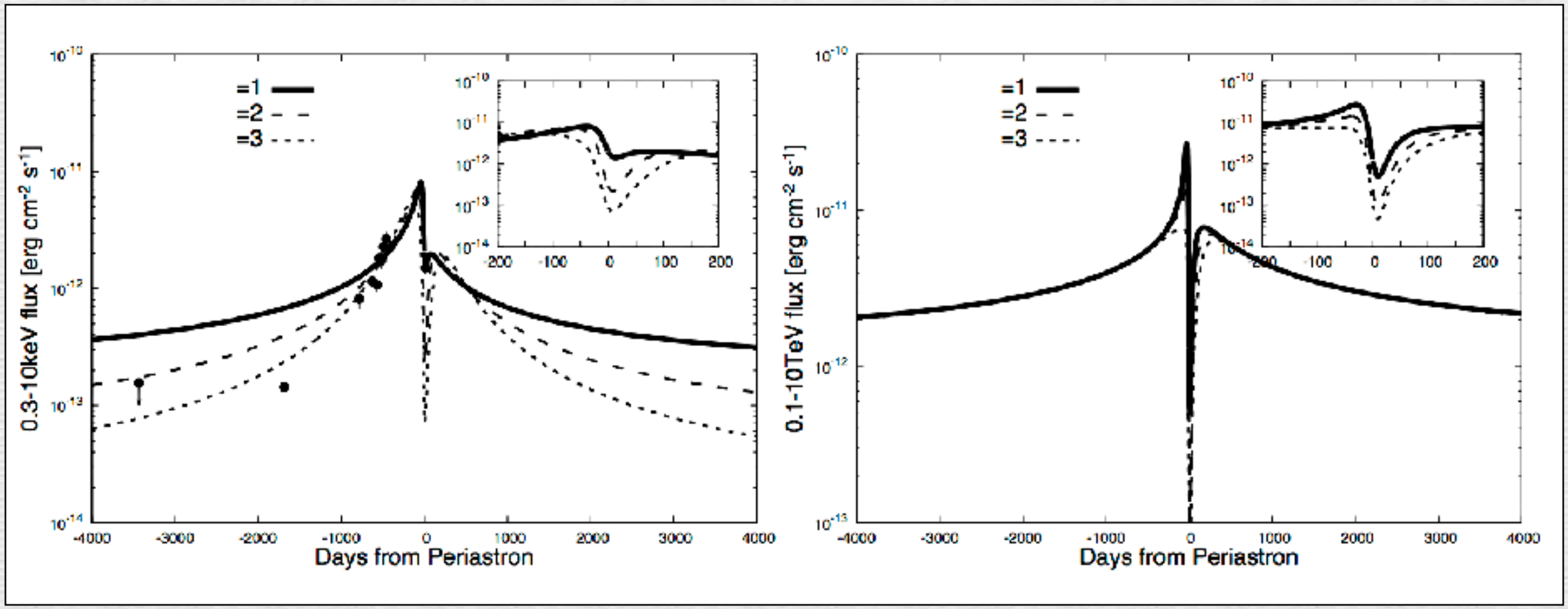
Gamma ray binaries

- Compact object + B star (model investigated by Takata et al (2017))
  - Shock acceleration at pulsar wind / stellar wind collision
    - Synchrotron emission at shock -> X-rays
    - Inverse Compton scattering of shocked wind and stellar photons -> TeV gamma rays
- Possibility for interaction with B star disk
- Expect significant orbital modulation as a function of orbital geometry



From Takata et al (2017)

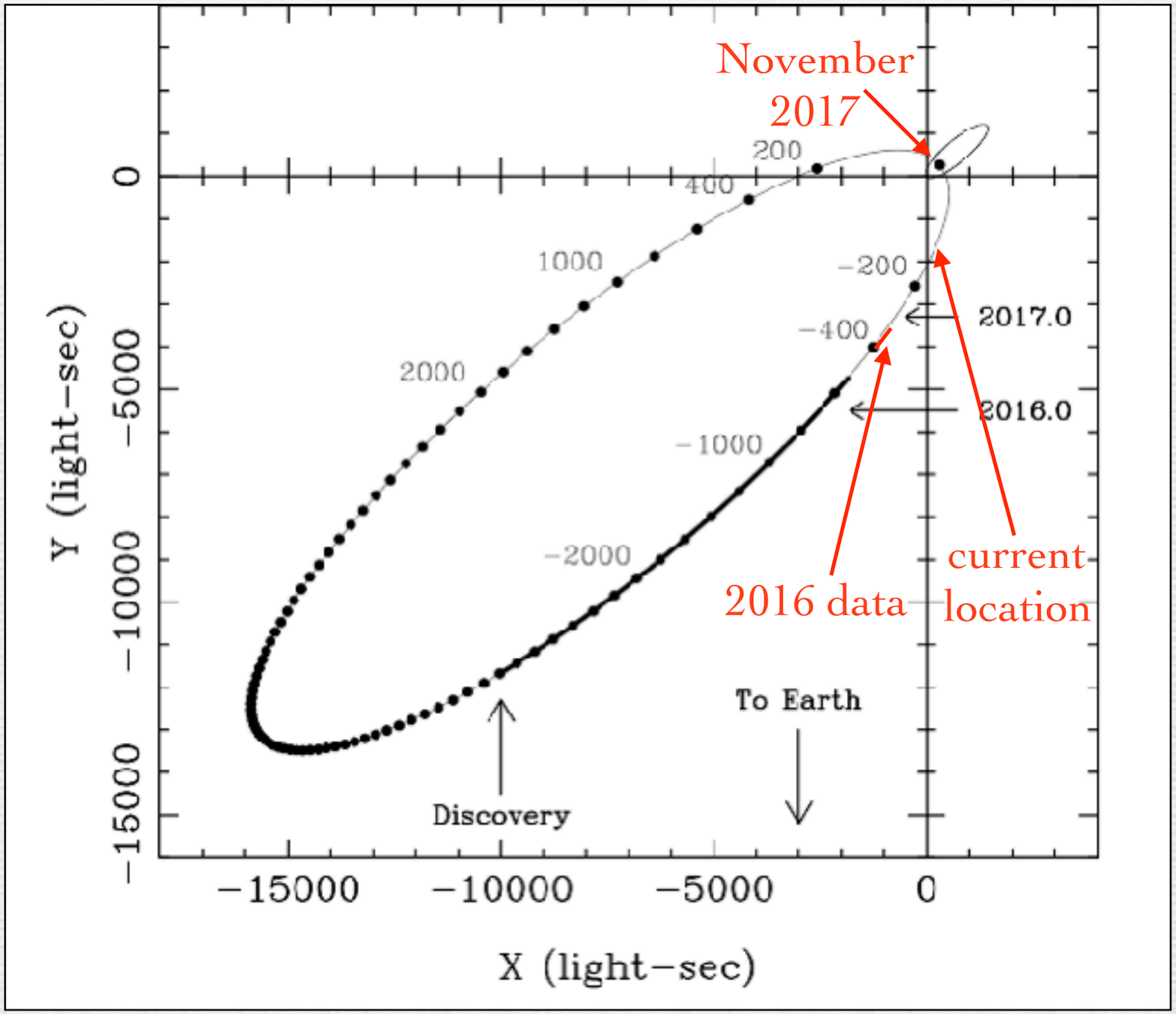
Expectations from PSR J2032+4127



- Model prediction from Takata et al (2017)
- One of several models

Where are we now?

- We are currently 154 days from expected periastron
- What does recent x-ray and TeV data look like?



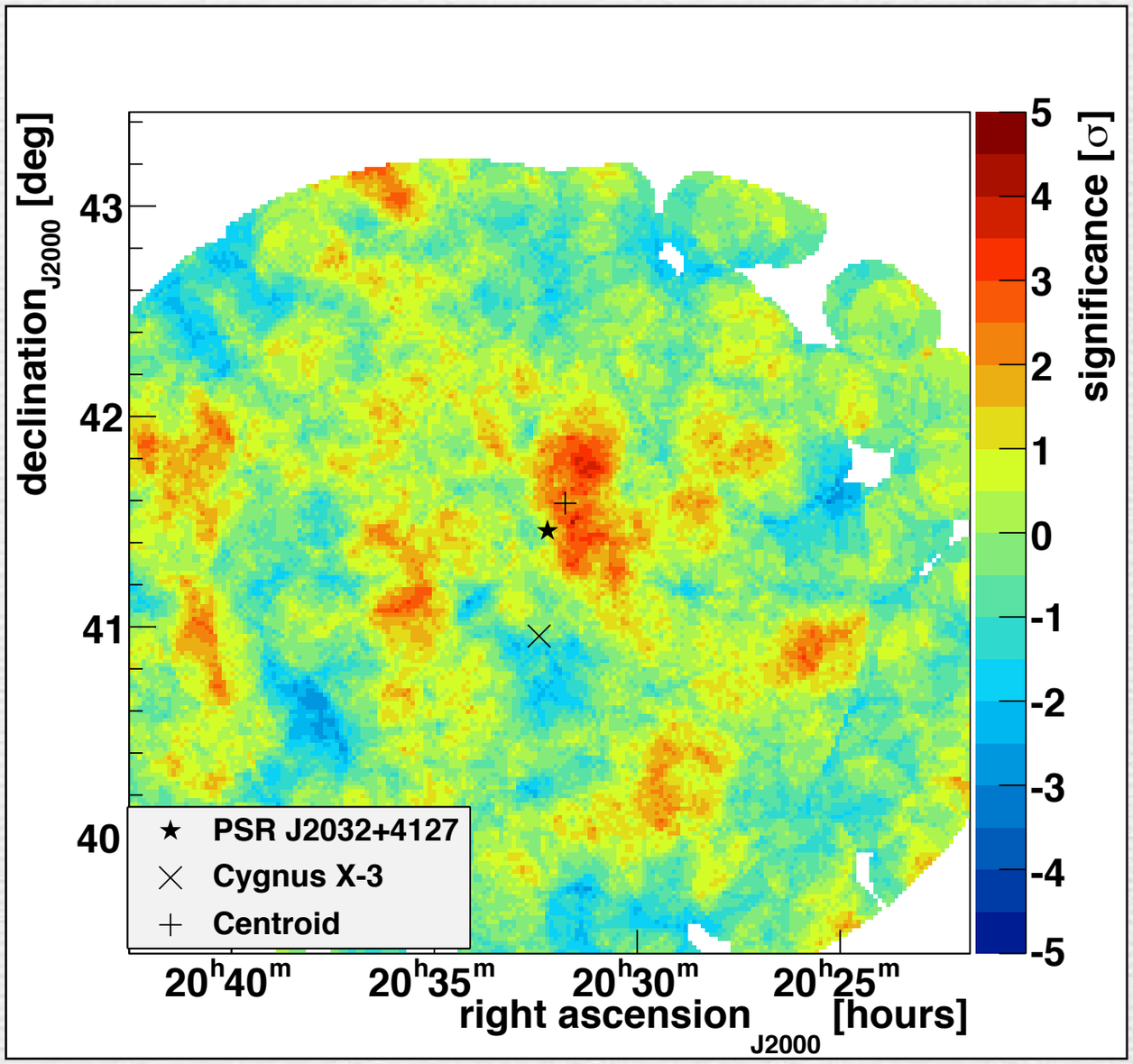
From Ho et al (2016), annotations mine

VERITAS Observations (2016)

- New VERITAS observations
  - 10 hours from September-November 2016
  - Periastron -403 to -344
- Two analyses
  - Extended analysis to examine diffuse emission
  - Point source analysis to look for emission from the binary

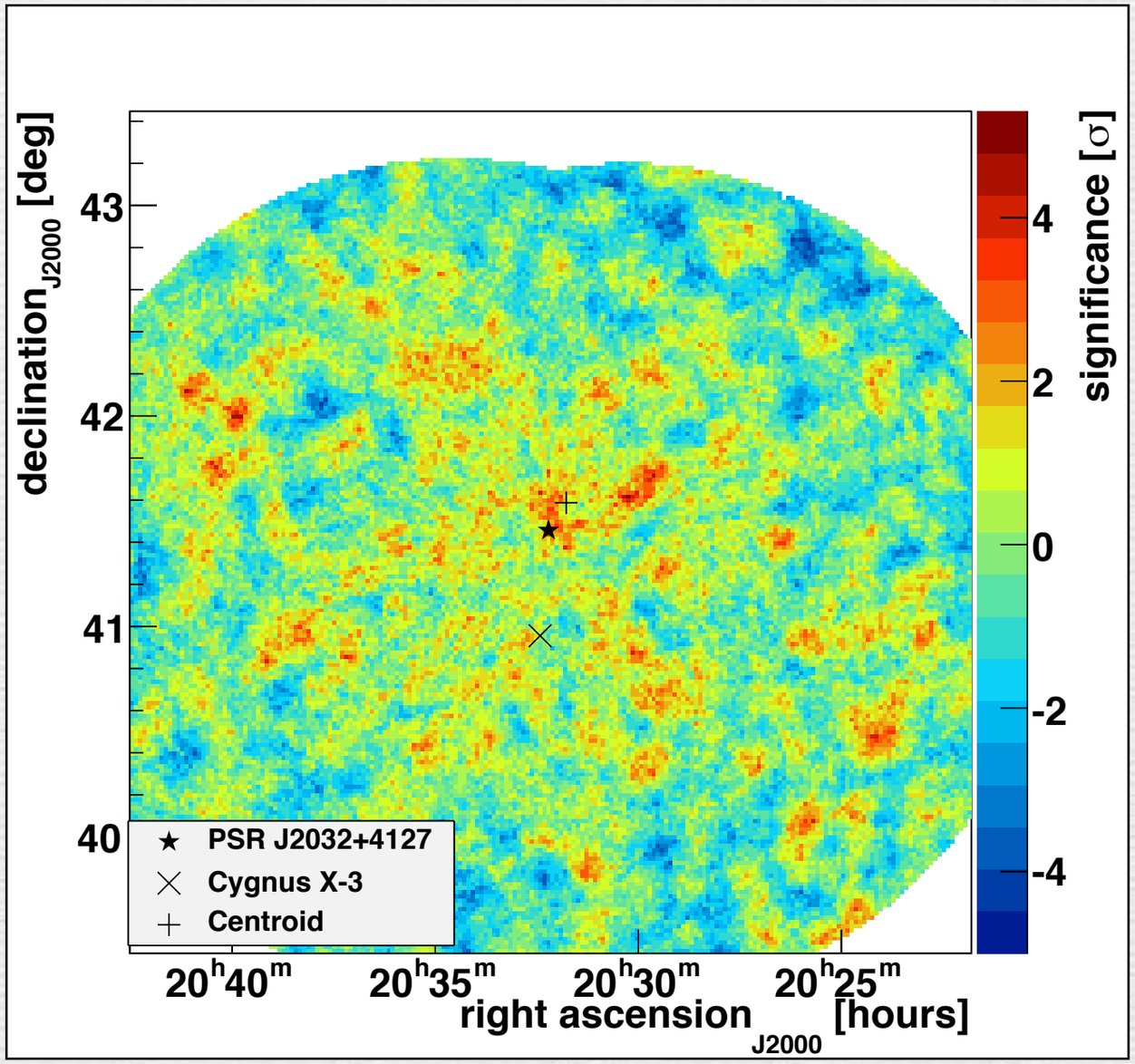
VERITAS Observations (2016)

- 10 hours
- Extended source analysis
- No significant detection - consistent with expectations.
- 0.5 σ at pulsar



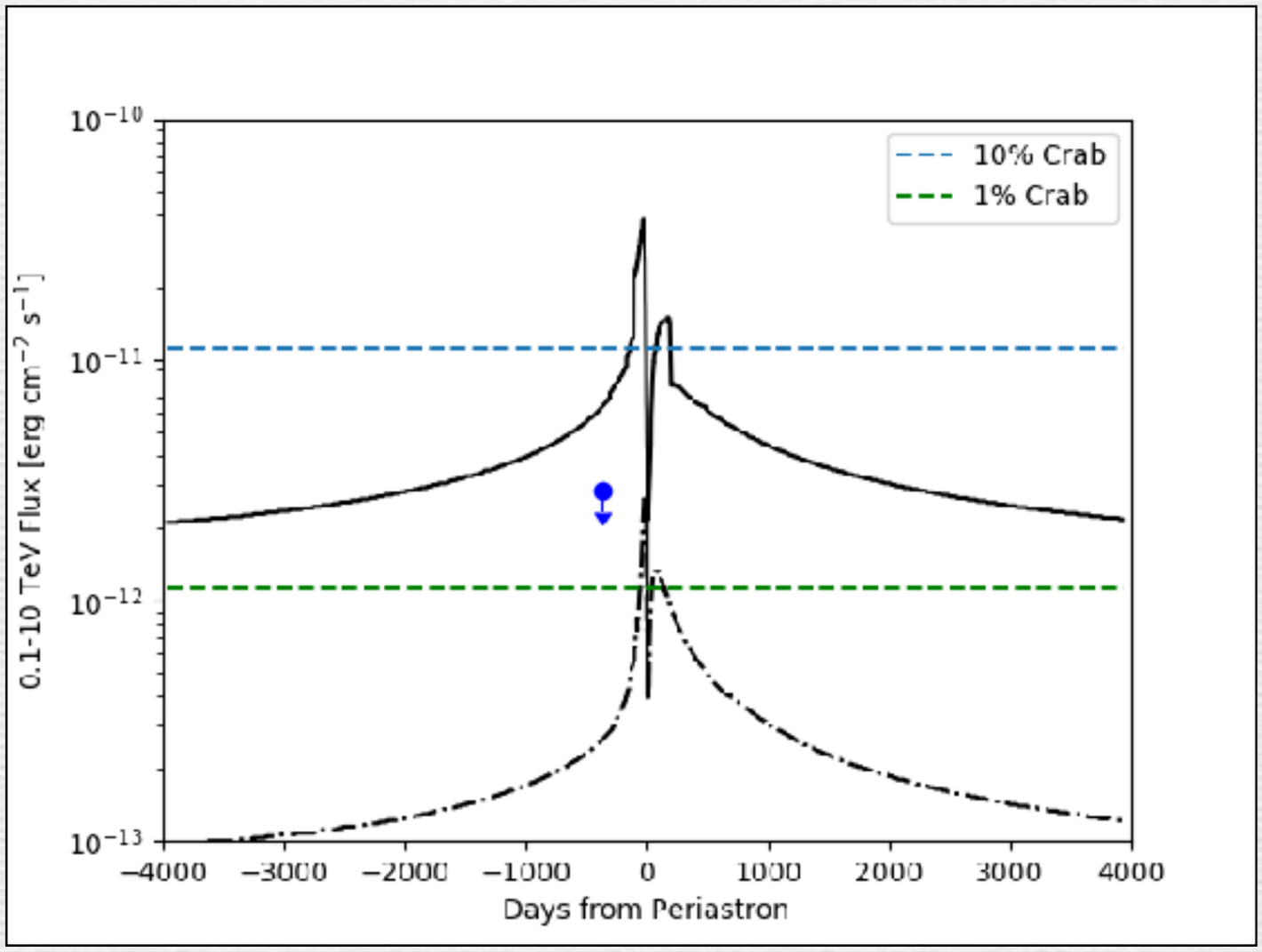
VERITAS Observations (2016)

- 10 hours
- Point source analysis
- No evident point source
- 1.9 σ at pulsar

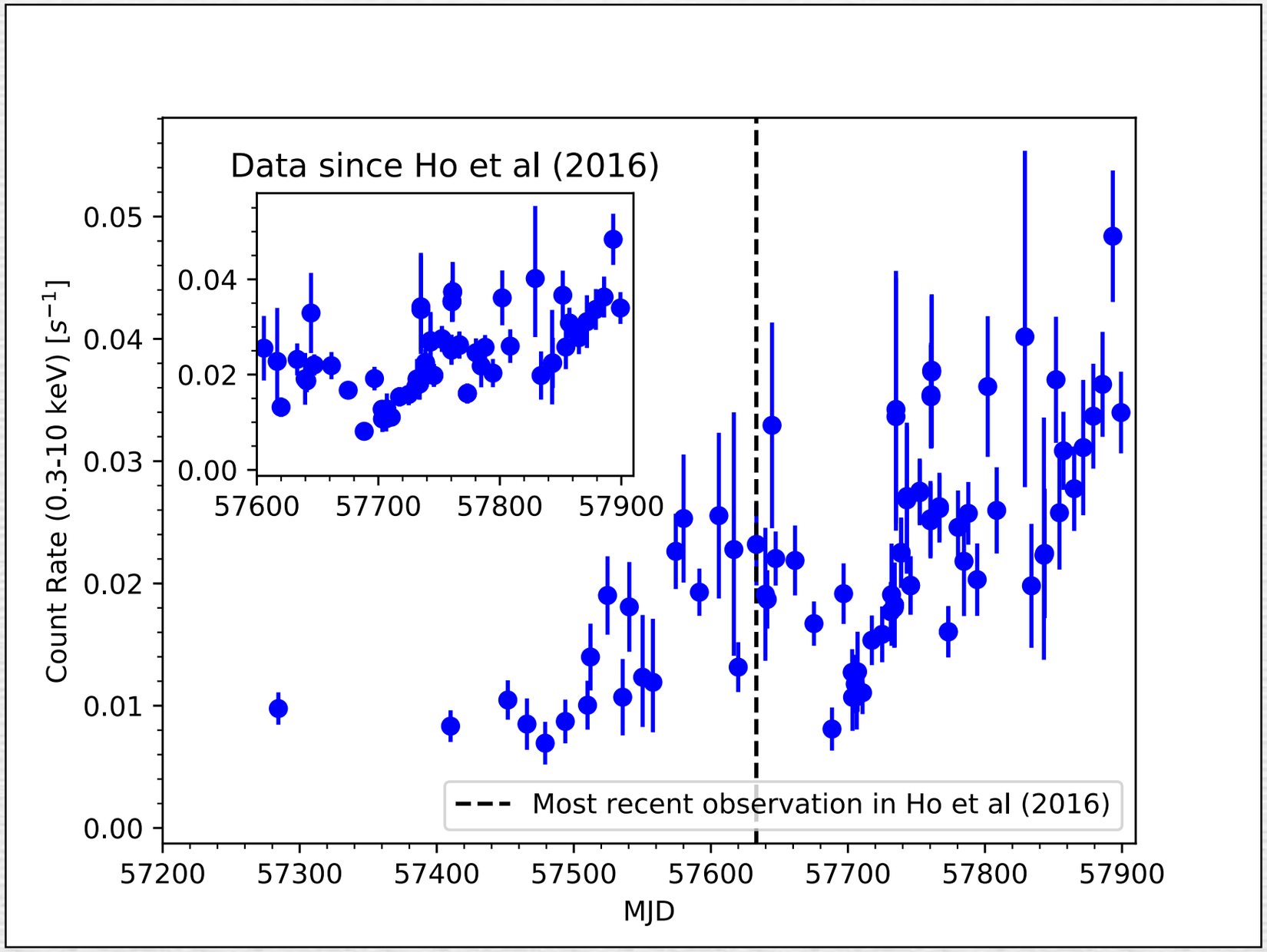


VERITAS Observations

- Unable to detect the source in 10 hours
  - Not surprising given observing window
  - More observing campaigns planned



X-ray Flux



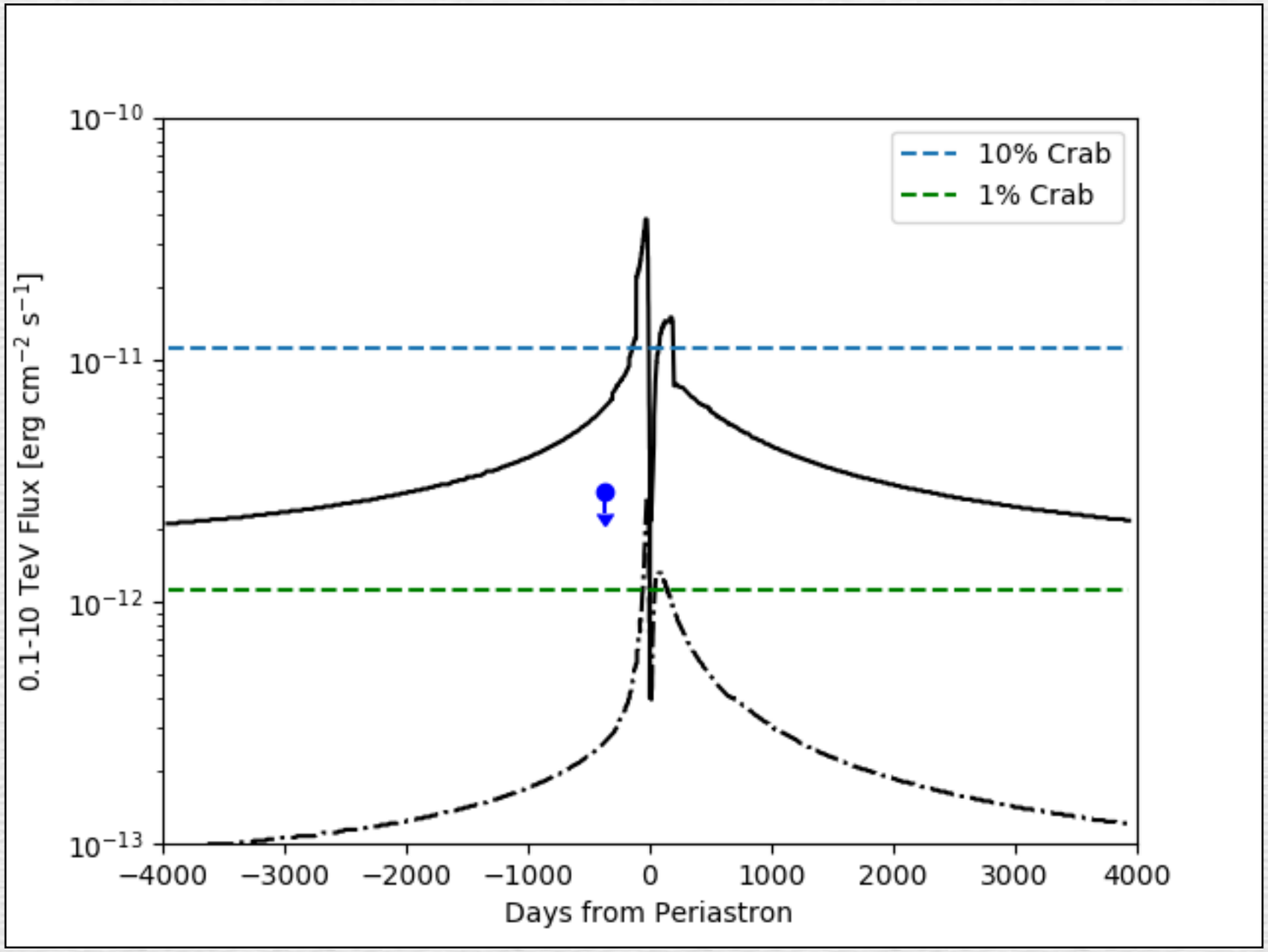
- SWIFT observations from September 2015 to May 2017

Conclusions

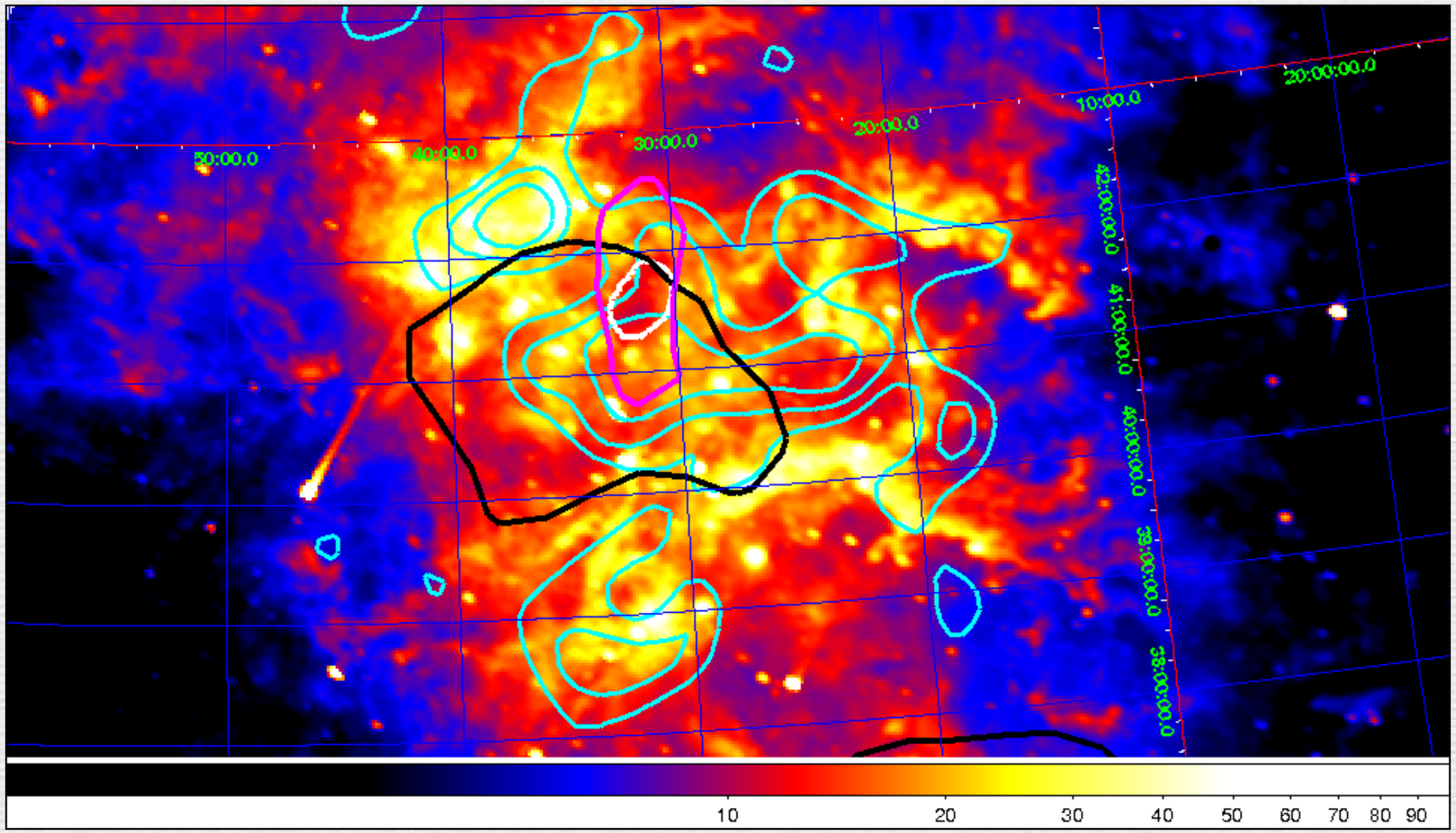
- Too early to draw firm conclusions
  - TeV analysis does not constrain binary emission model
    - Need continued X-ray observations
      - SWIFT will continue to observe
- Major observing campaigns planned as periastron approaches
  - SWIFT, FERMI, VERITAS all planning observations

Backup Slides

Upper Limit


10% Crab
1% Crab
10^{-10}
10^{-11}
10^{-12}
10^{-13}
0.1-10 TeV Flux [erg cm^{-2} s^{-1}]
−4000
−3000
−2000
−1000
0
1000
2000
3000
4000
Days from Periastron

Fermi

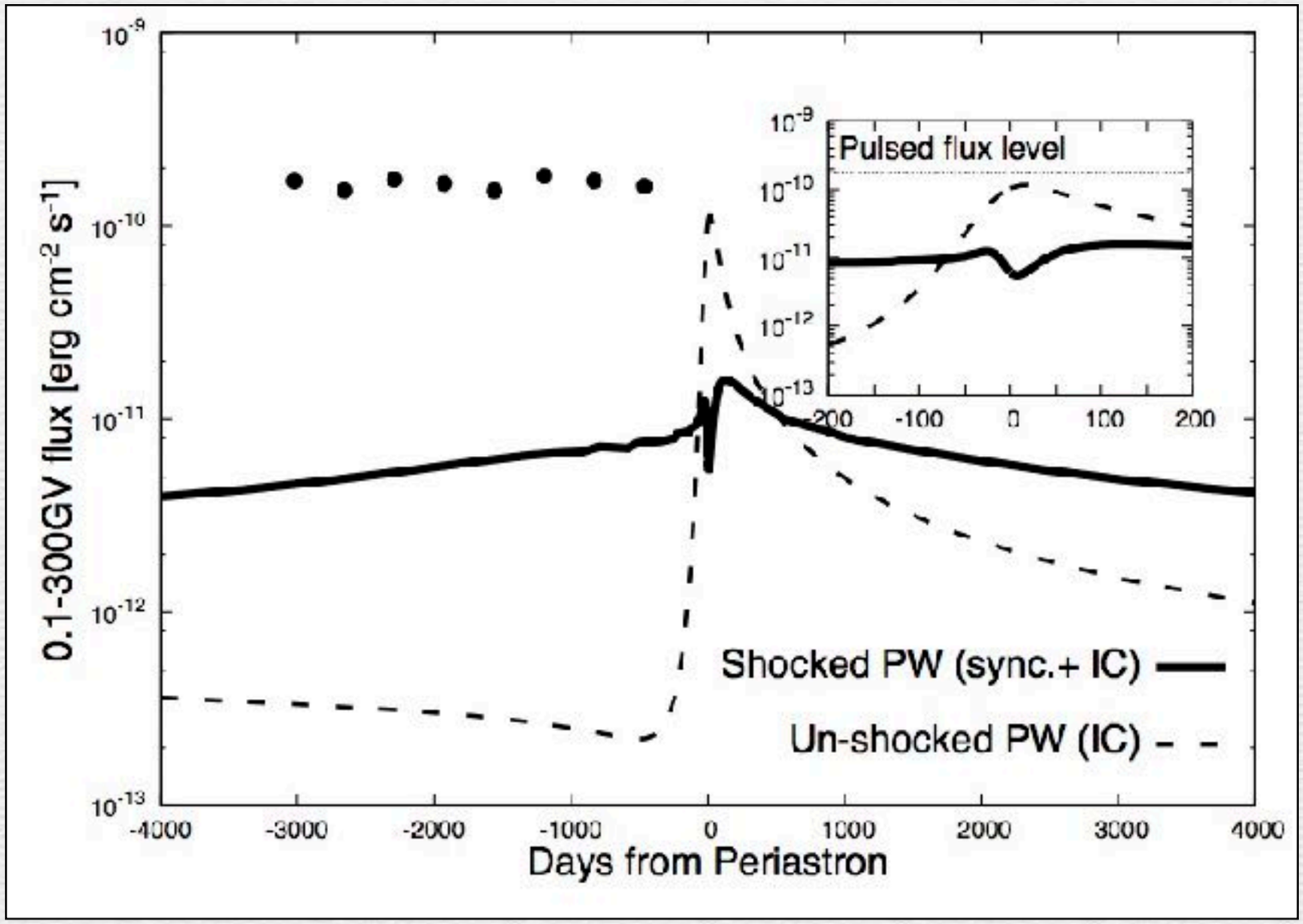


From Aliu et al (2014)

Gamma ray binaries

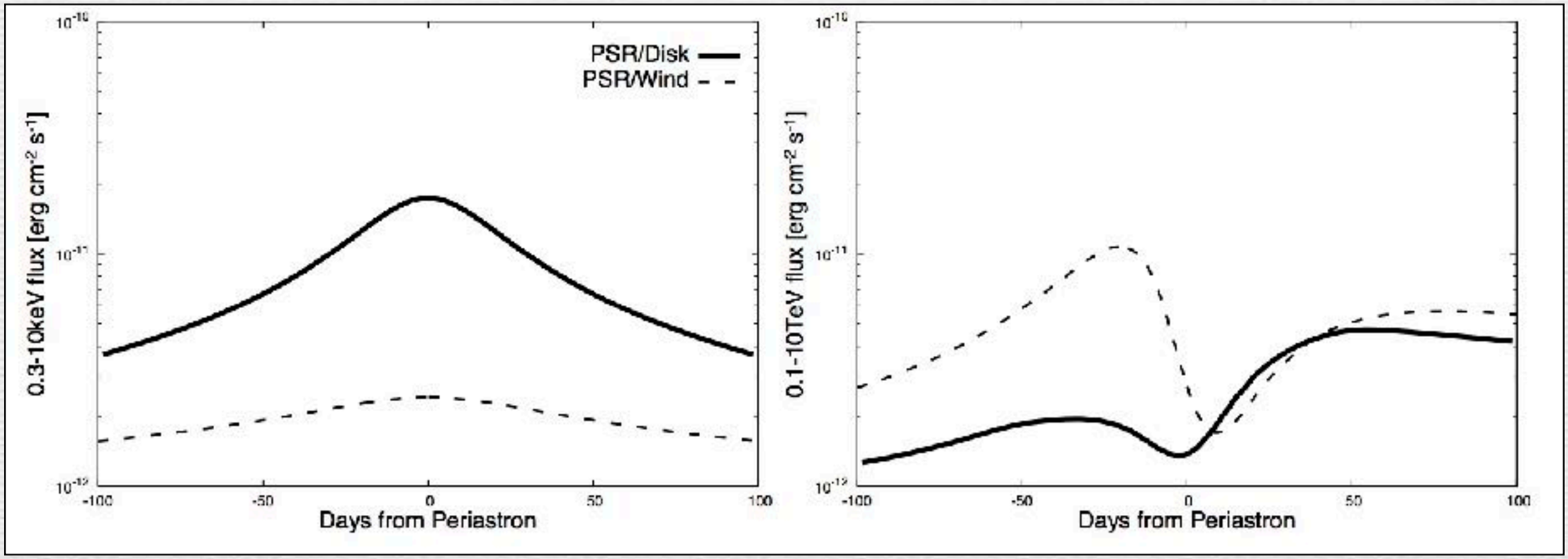
- Expected Orbital modulation
  - X-ray flux maximum near inferior conjunction (greater B field at shock + Doppler boost)
  - TeV flux maximum near inferior conjunction (Inverse Compton collision angle + optical depth of stellar photon field)
  - GeV flux maximum near superior conjunction (High energy synchrotron + Low energy Inverse Compton + lower optical depth)
  - Possible increase across all wavelengths near periastron from wind + disk interactions

GeV Flux



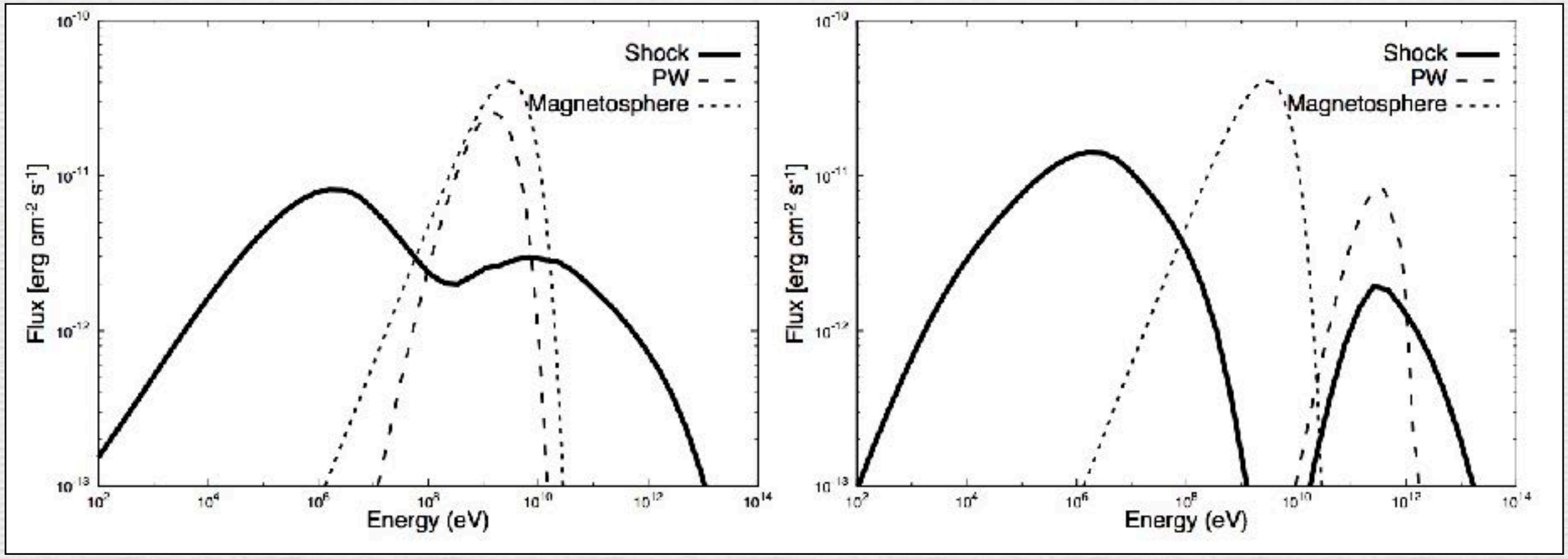
From Takata et al (2017)

Disc Interaction



From Takata et al (2017)

Spectrum



From Takata et al (2017)