

# VERITAS Results on Variable Galactic Gamma-Ray Sources



**Gernot Maier for the  
VERITAS Collaboration**



## Fred Lawrence Whipple Observatory, Arizona

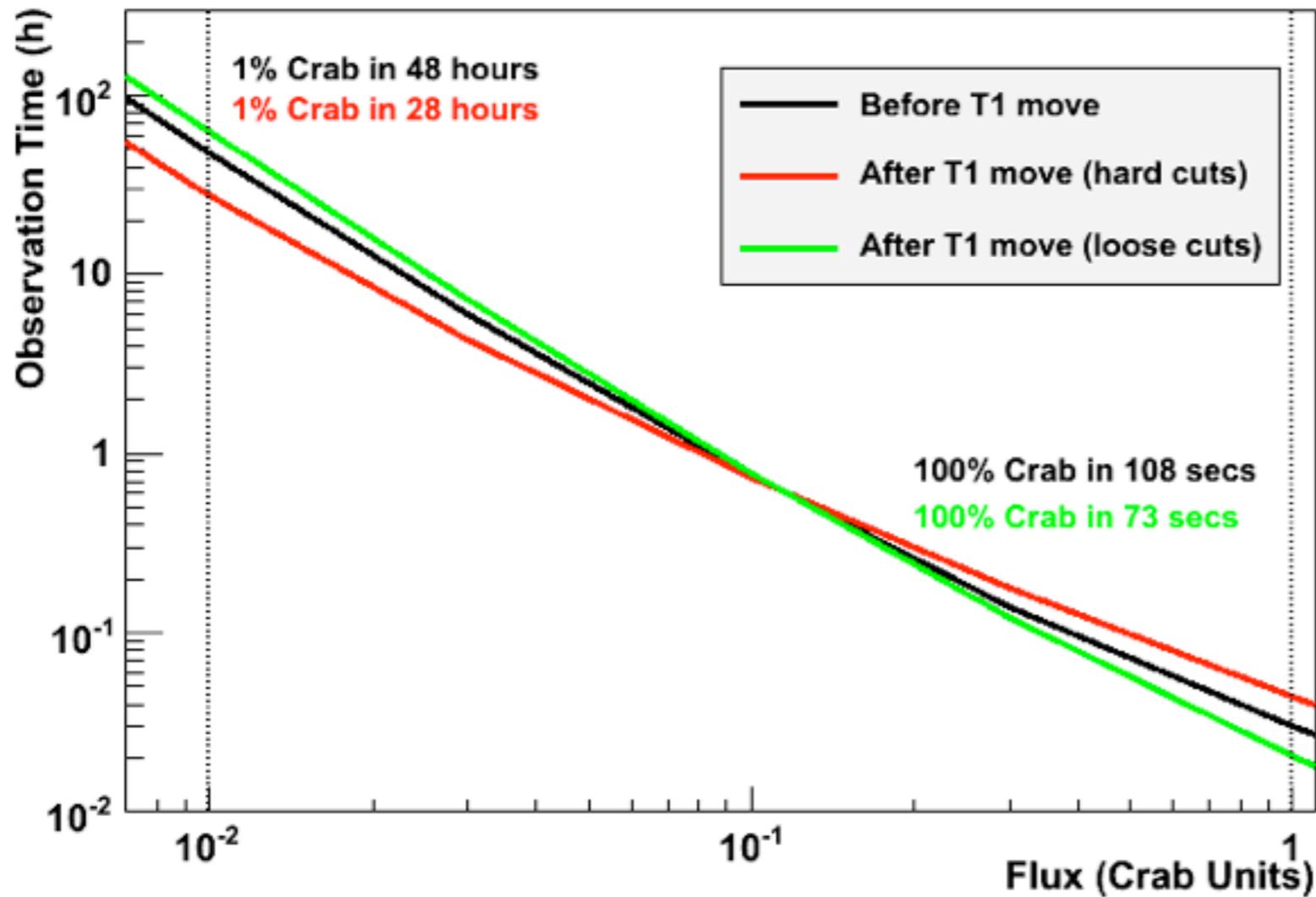


- > four 12 m Imaging Atmospheric Cherenkov Telescopes
- > **angular resolution:**  $<0.1^\circ$
- > **field of view:**  $3.5^\circ$
- > **energy range:** 0.1 to  $>30$  TeV
- > 1100 hrs/year of observations; summer shutdown
- >  **$>300$  h of binary data taken since Summer 2007**

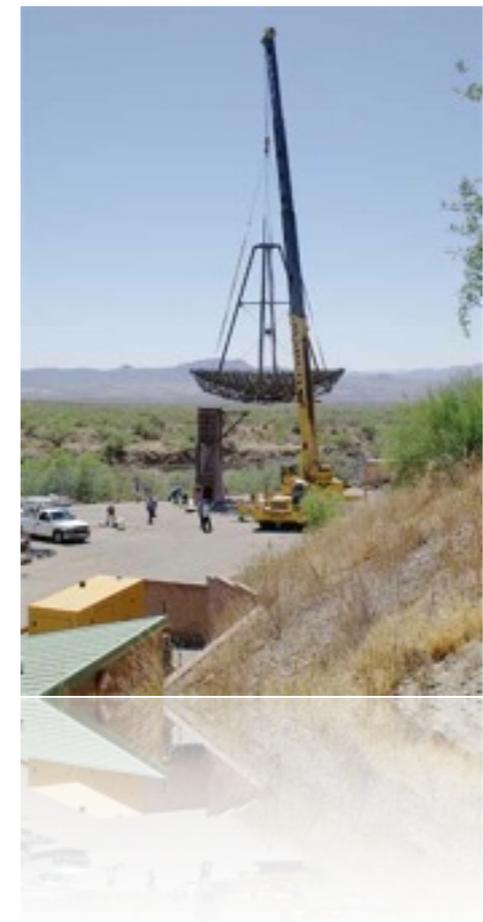


# VERITAS - sensitivity

major upgrade in Summer 2009:  
array layout and optics optimized



Summer 2011: trigger upgrade  
Summer 2012: major camera upgrade



# A new (?) variable Galactic source: the Crab Nebula

## > AGILE: Sept 19-21 2010

- flux > 100 MeV: ~2-2.5 times higher than average

## > Fermi LAT: Sep 18-22 2010

- flux > 100 MeV:  $(5.5 \pm 0.8)$  times higher than average flux
- hard spectrum with index:  $2.7 \pm 0.2$

## > ARGO-YBJ Sept 17-22 2010

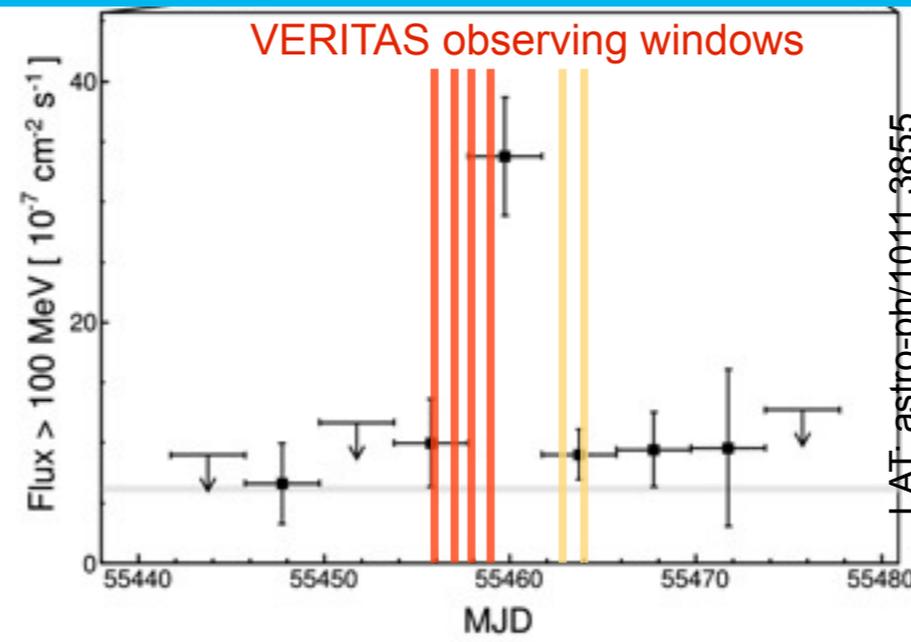
- flux > 1 TeV: ~3-4 times higher than average (but  $\sim 4\sigma$  'signal' only)

## > VERITAS observations Sept 17-20 2010 and Sept 24/25 (moonlight)

- ~2h+2h observations
- $40\sigma$  gamma-ray signal, combined statistical error < 10%
- flux > 200 GeV and > 1 TeV: no evidence for enhancement

## > MAGIC Sept 20th 2010

- no evidence for enhancement > 1 TeV



Observing conditions...



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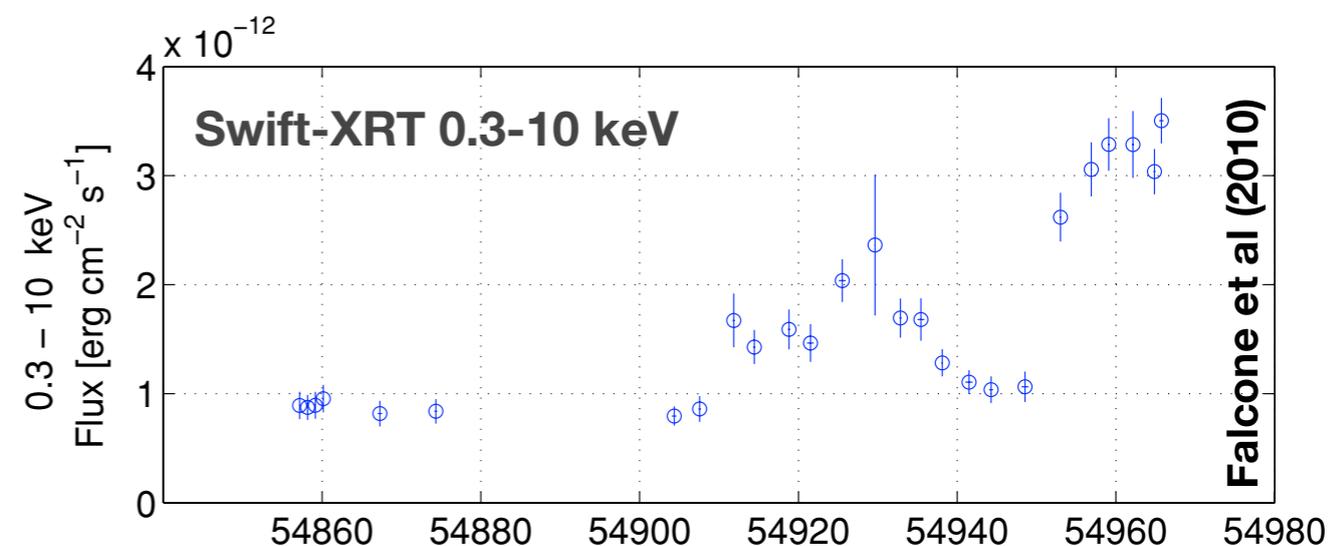
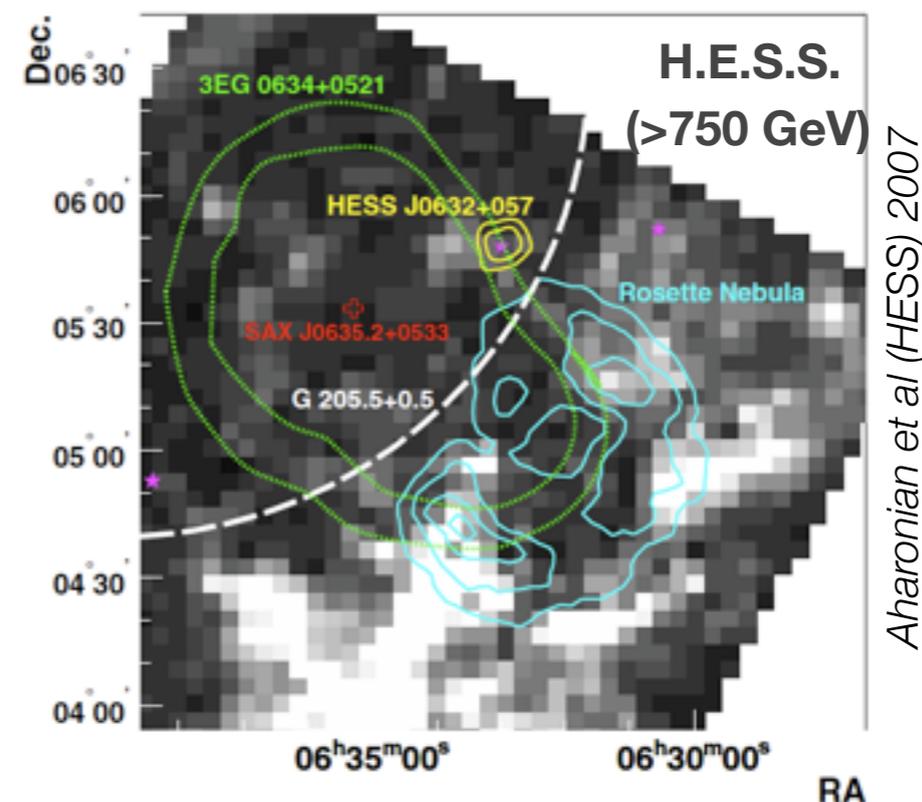


Observing conditions...

ATel #2968

# HESS J0632+057 - a new VHE binary?

- > discovered by H.E.S.S. in 2004/2006 ( $\Gamma=2.53$ ,  $F(>1 \text{ TeV}) \sim 3\% \text{ CU}$ )
- > coincident with massive B-star MWC 148
- > no binary system identified (e.g. Aragona et al 2010)
- > variable hard-spectrum ( $\Gamma=1.2-1.9$ ) X-ray source (hours: *XMM-Newton* (Hinton et al 2009), weeks/months: *Swift-XRT* (Falcone et al 2010))
- > faint point-like, variable radio source ( $<2''$  extension, 0.2-0.4 mJy, Skilton et al 2009)
- > not detected by Fermi LAT
- > **What is it?**
  - **a new TeV binary?** (Hinton et al 2009)
  - **an unusual isolated massive star?** (confined stellar wind, Townsend et al 2007)

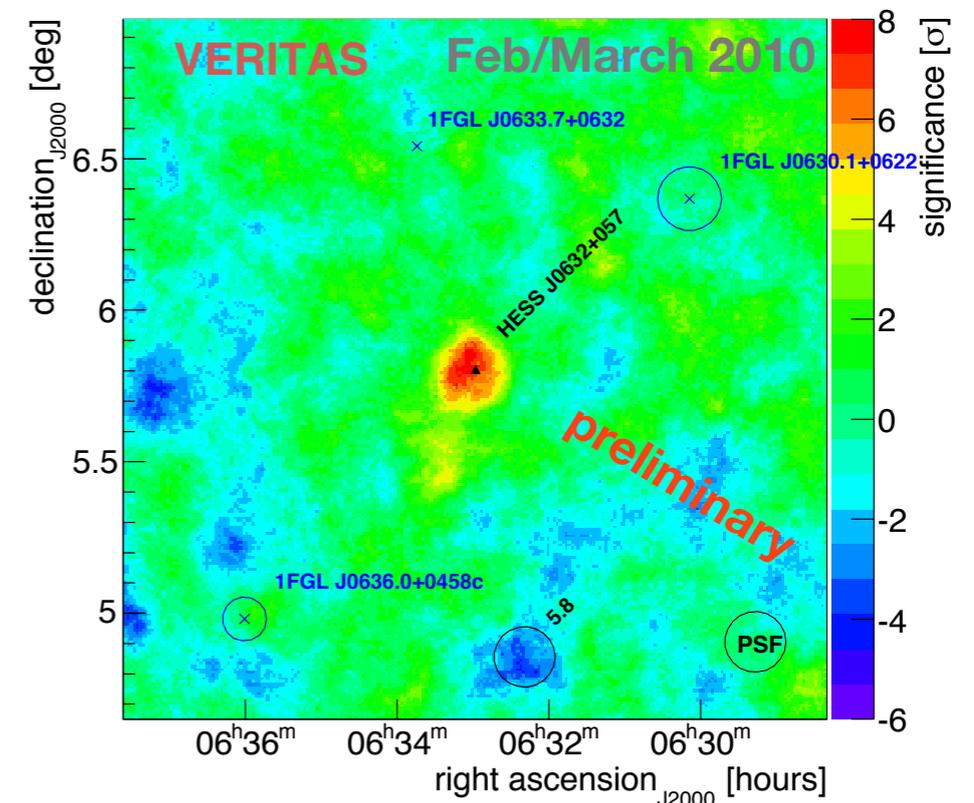
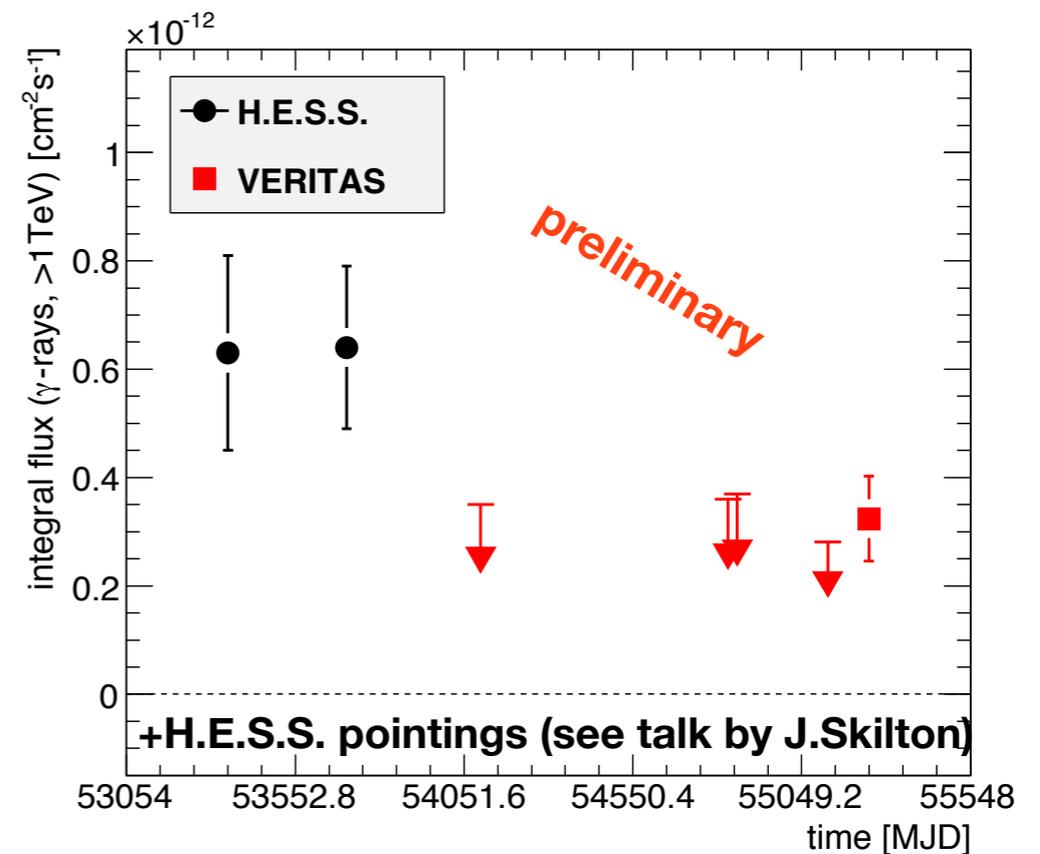


'long-term X-ray light curve study and search for orbital periods up to several months:: Falcone et al 2010/11 (soon to be submitted)



# HESS J0632+057 - VERITAS results

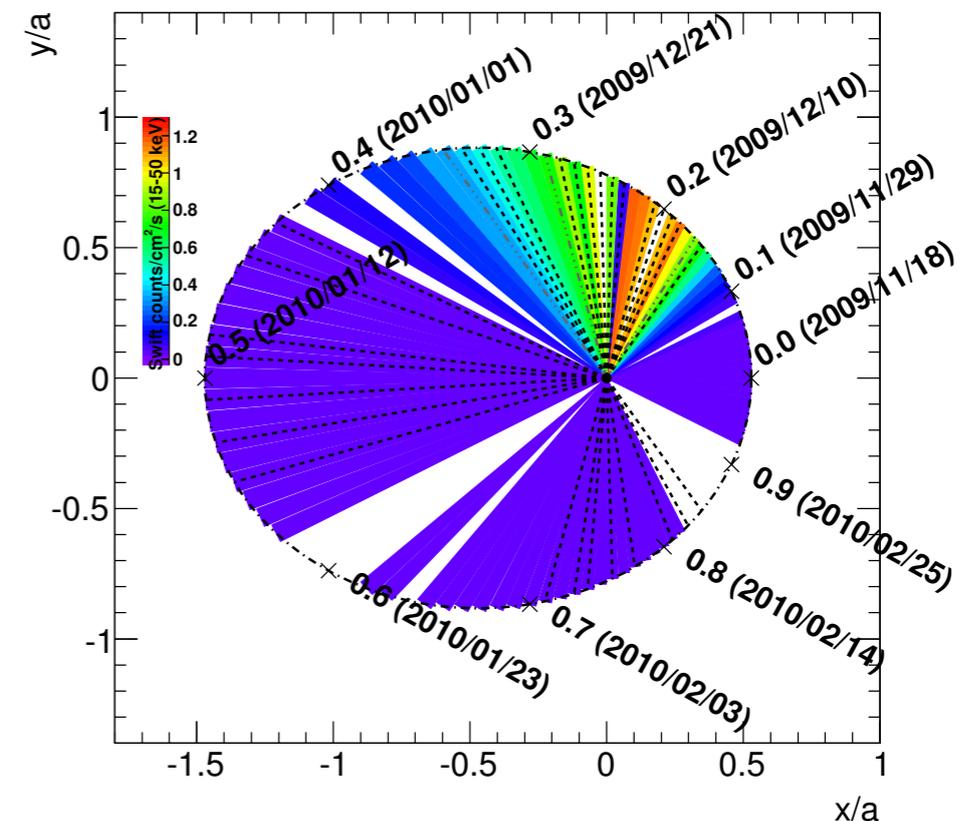
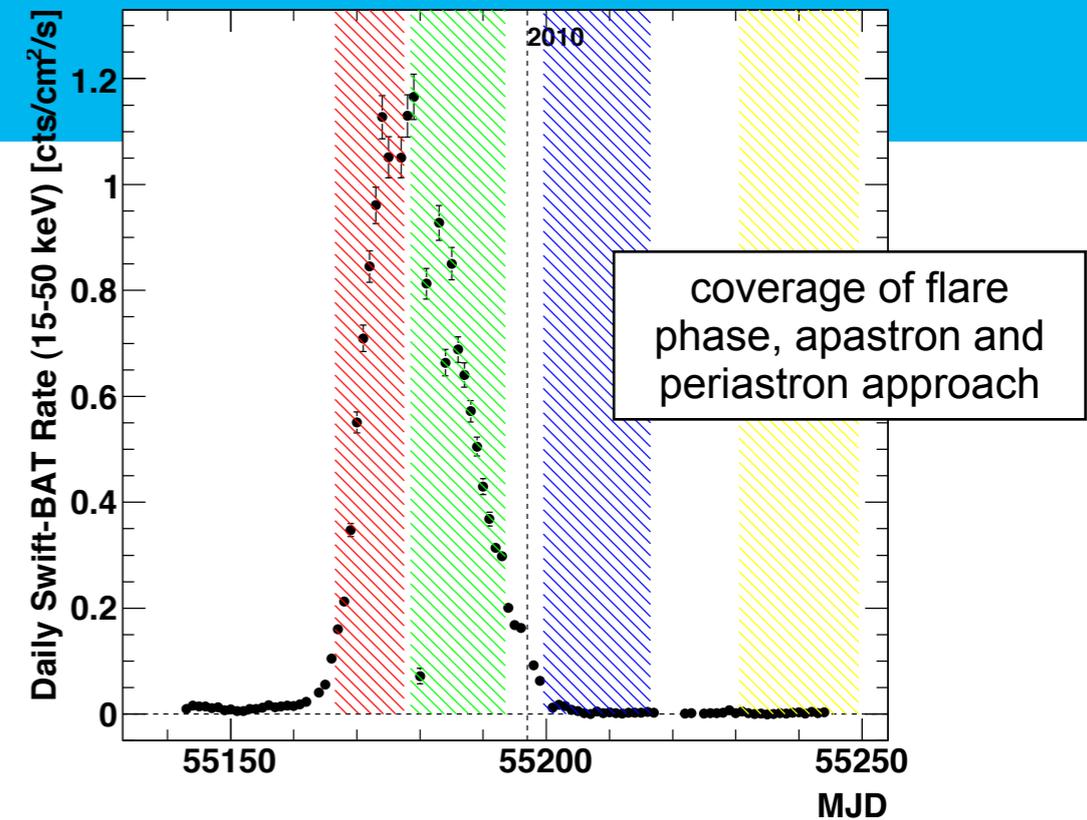
- > 30 h in Dec 2006 - Jan 2009:  
**not detected** by VERITAS  
(ApJ 687 L94 (2009))
- > excluded with  $\sim 4\sigma$  confidence that HESS J0632+057 is a steady gamma-ray emitter
- > H.E.S.S./VERITAS campaign in 2009/2010 (publication in prep)
- > 8h in Oct 2009: **no detection**
- > 20 h in Feb/March 2010:  
**clear detection** ( $7.5 \sigma$ )
- > VERITAS position in agreement with HESS J0632+057 and MWC 148
- > **clearly variable in VHE gamma rays**
- > **is it a VHE binary? Need detection of orbital modulation (at any wavelength)**



# 1A0535+262 - a flaring binary

- > HMXB, Be-star and X-ray pulsar ( $P_{\text{Spin}}=104\text{s}$ )
- > giant X-ray outbursts about every 5 years (October 1980, June 1983, March/April 1989, February 1994, May/June 2005, December 2009)
- > orbital period 110 d, eccentric orbit ( $e=0.47$ )
- > distance  $2.4\pm 0.4$  kpc
- > large magnetic field ( $\sim 10^{13}$  G)
- > no radio emission detected
- > VHE emission:
  - similar to PSR B1259-63/LS 2883 (?)
  - Cheng & Ruderman mechanism (acceleration of hadrons in the magnetosphere and subsequent interaction with the accretion disk; VHE maximum expected about 10-20 days after X-ray flare (Romero et al. 2001, Orellana & Romero 2004))

**But: no very detailed modeling for VHE emission, no flux prediction, SED, etc.**



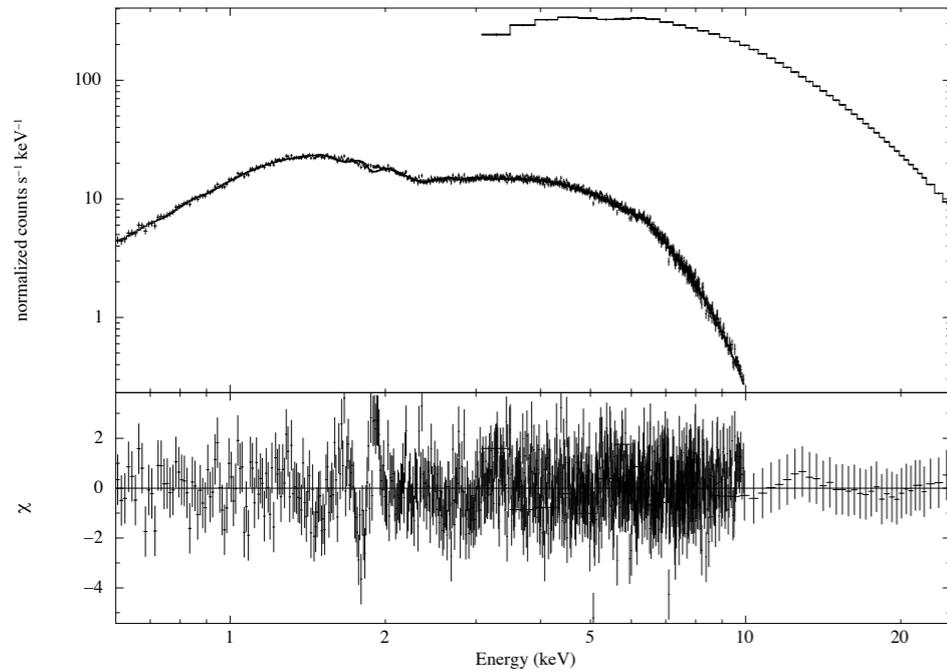
**VERITAS ToO on flaring Be binaries: 23 h of observations at >70 deg**



# 1A0535+262 - multi-wavelength results

no detection at VHE

## Joint Swift/XRT and RXTE/PCA spectral modeling

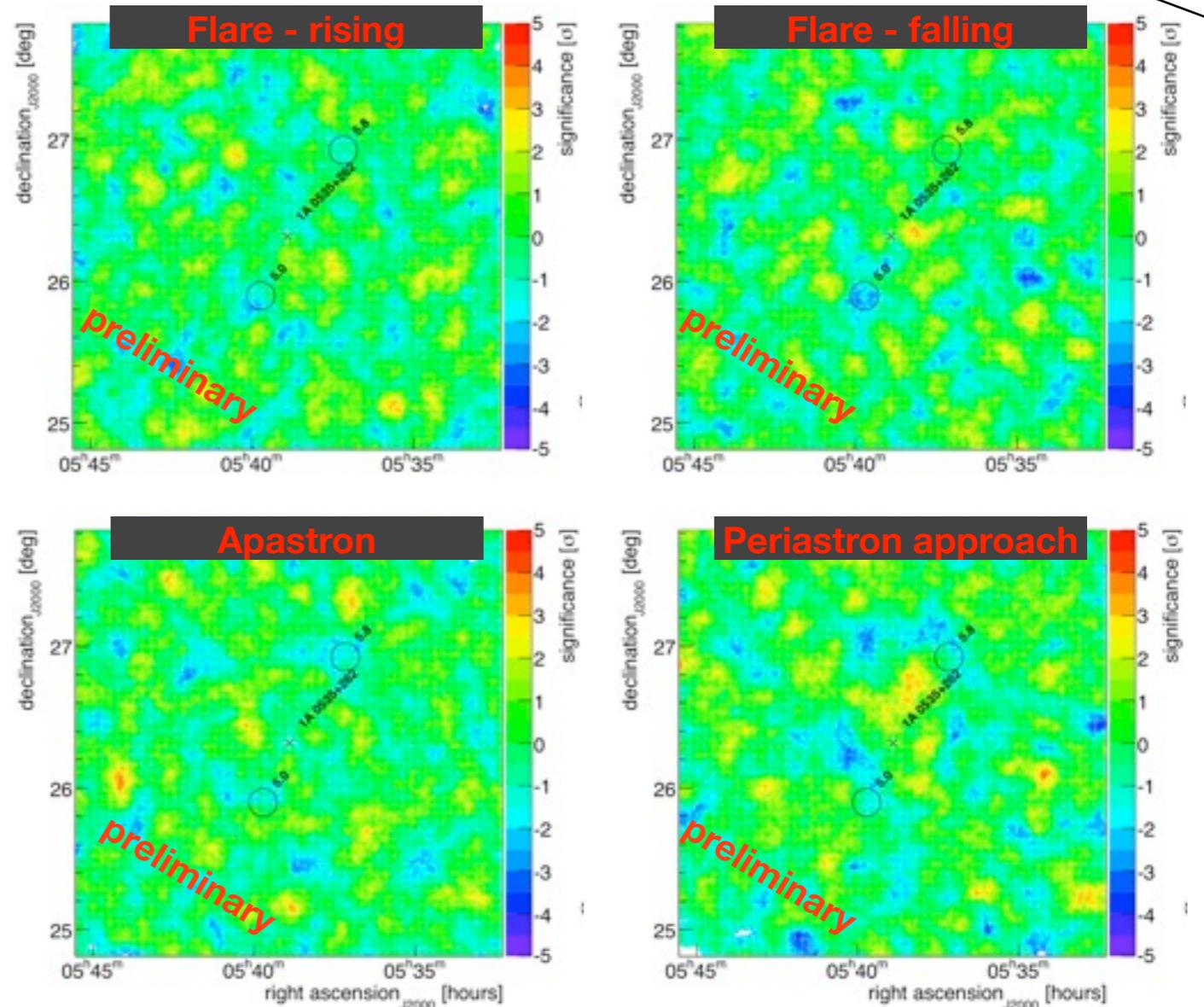


good fit with blackbody+thermal Comptonization for all observations

## Fermi LAT

no detection during VERITAS observing periods  
upper limits E>200 MeV:  
 $\sim 2 \times 10^{-8} \text{ ph cm}^{-2} \text{ s}^{-1}$

## VERITAS E>300 GeV

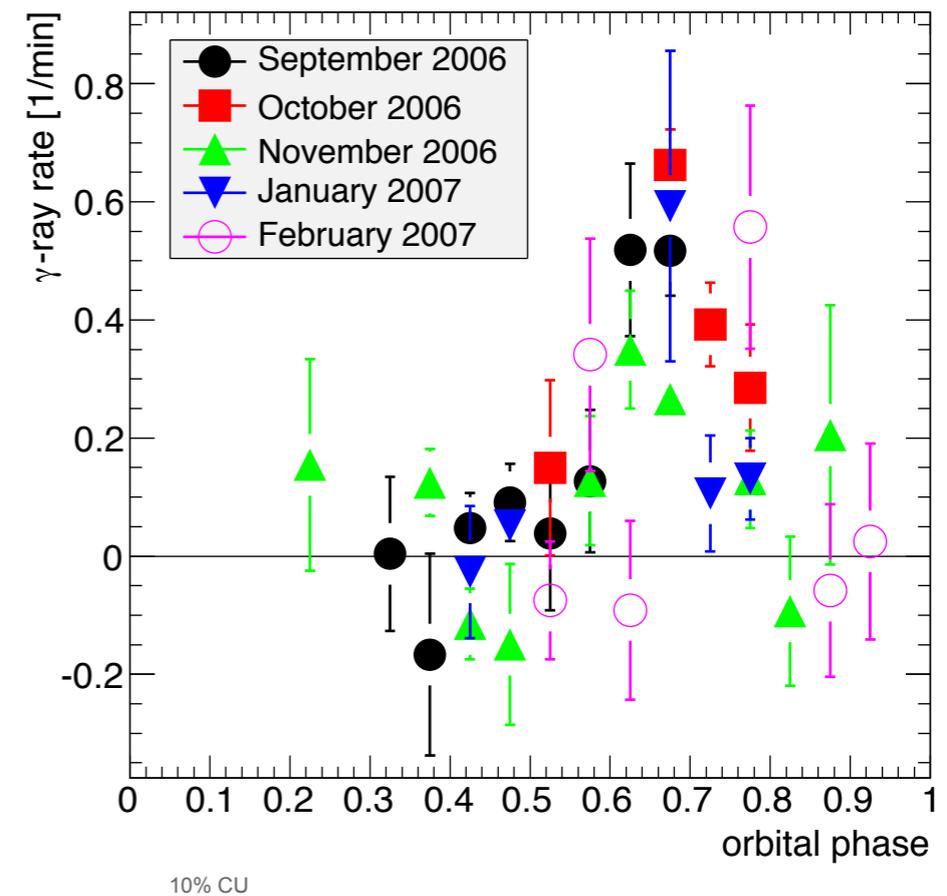
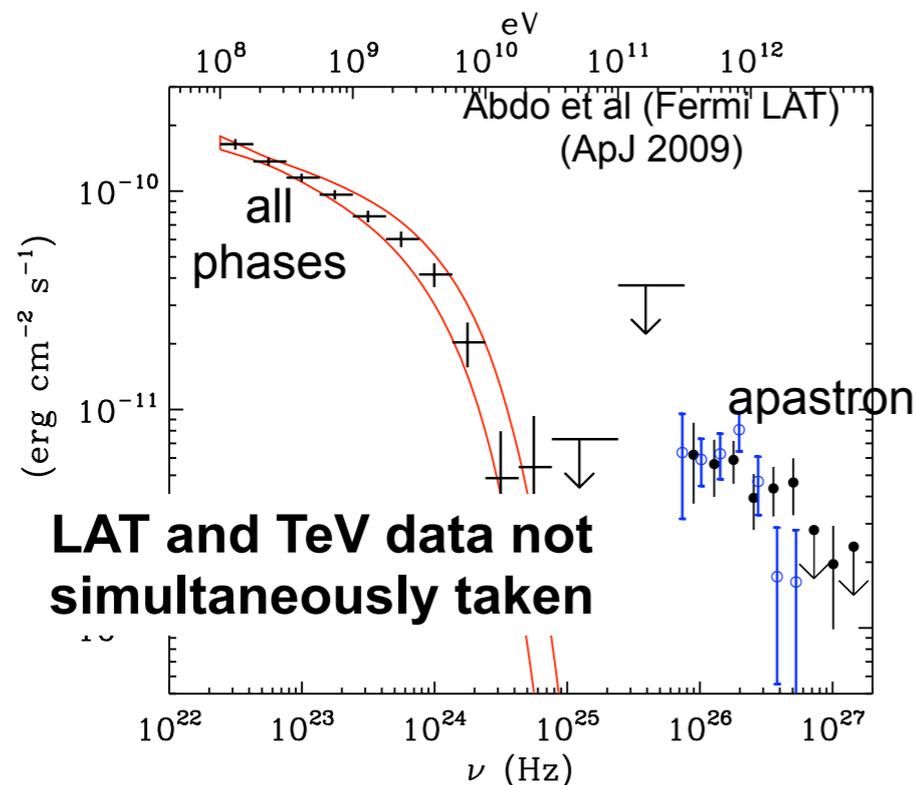
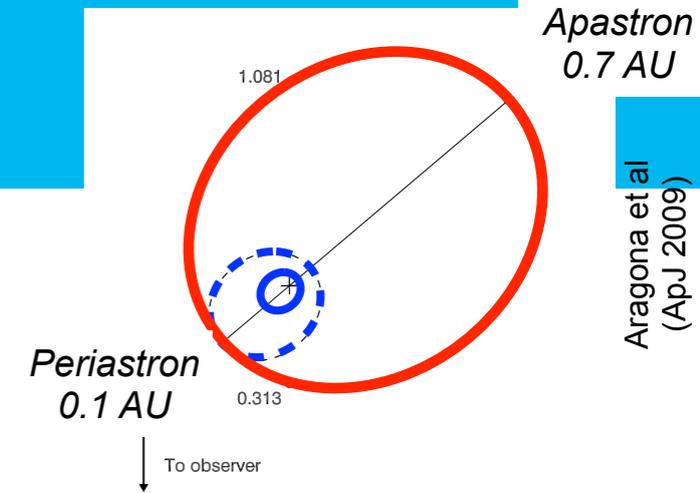


no indication for a non-thermal particle population at any wavelength  
need order of magnitude more sensitive observations to constrain theoretical models



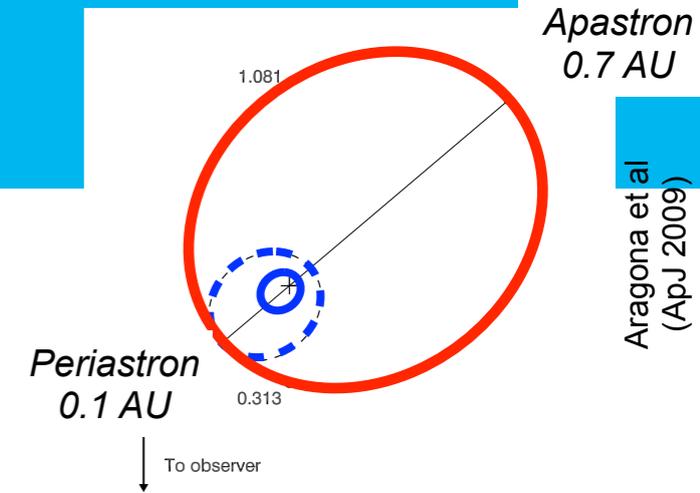
# LS I +61 303

- > compact object orbiting a Be companion star
- > 26.5 day, inclined orbit,  $e=0.54$ , circumstellar disk
- > extended radio structure; microquasar?  
(but radio images shows orbital morphology change)
- > **strong VHE emission only near apastron:**  
**15-20% of Crab Nebula Flux** (MAGIC/VERITAS)
- > GeV emission peaks **near periastron**;  
6 GeV cut-off; orbital modulation; orbit-to-orbit variations;
- > GeV spectrum looks like a pulsar (?)

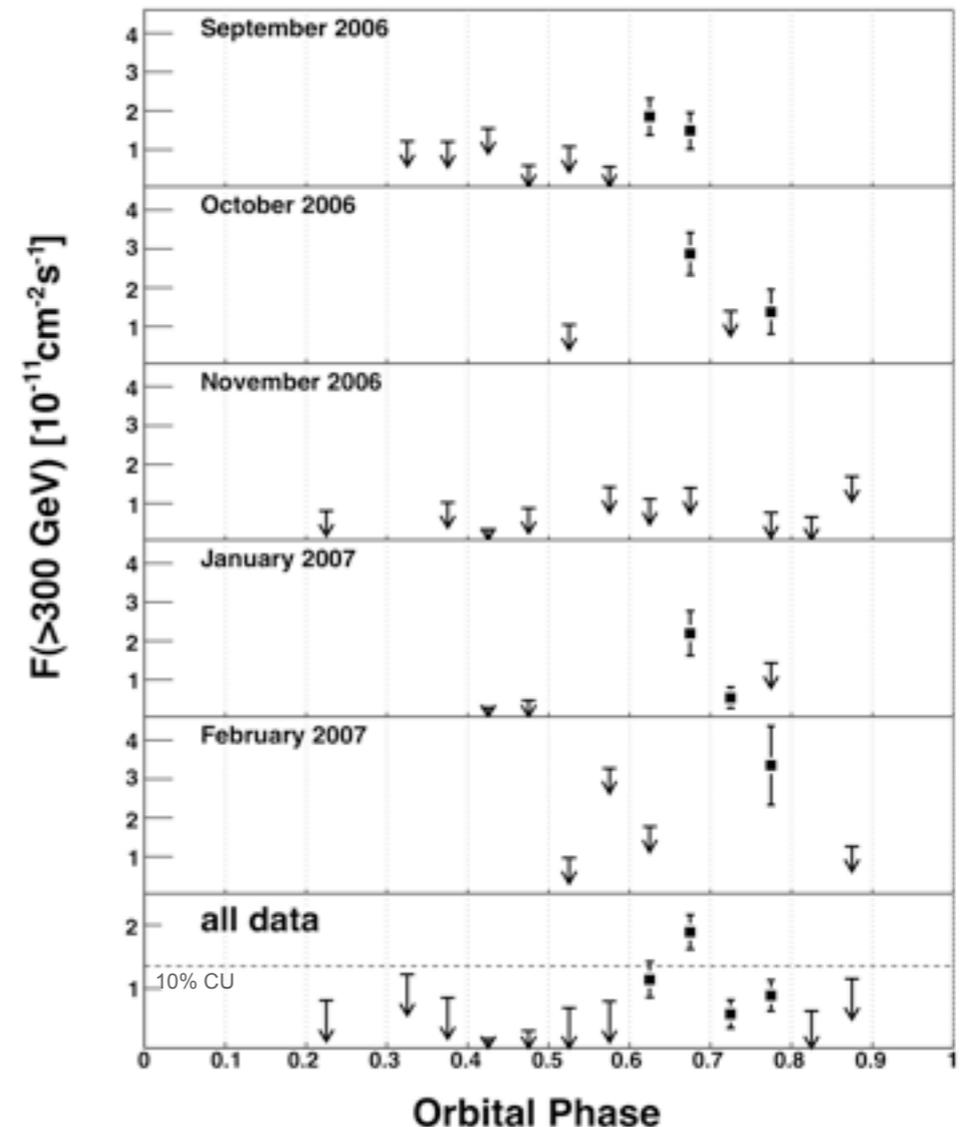
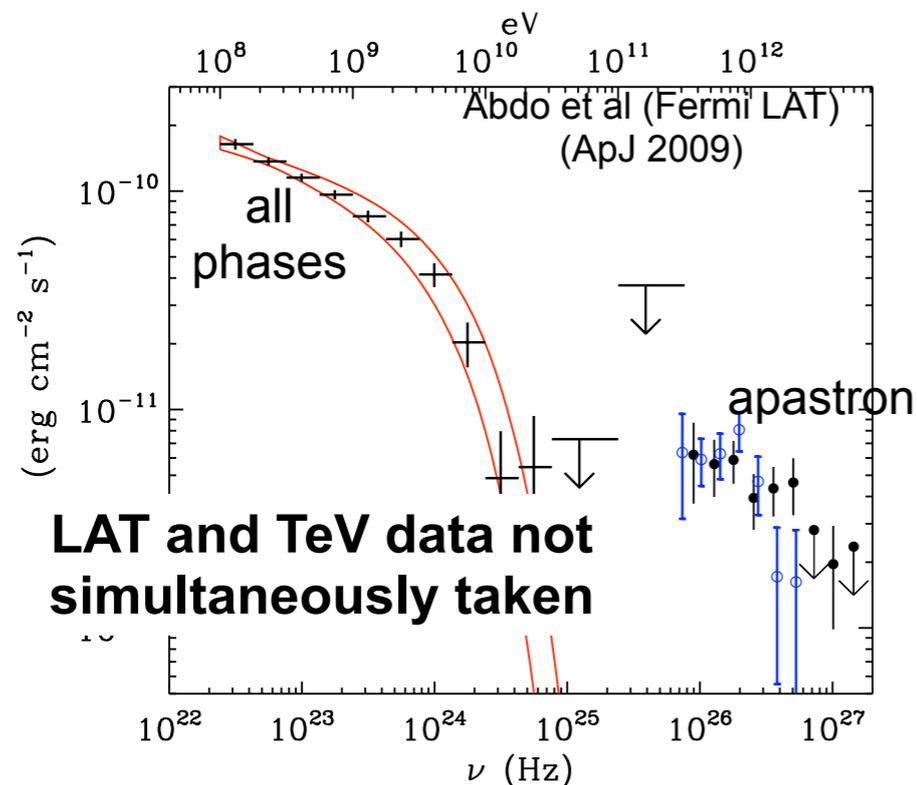


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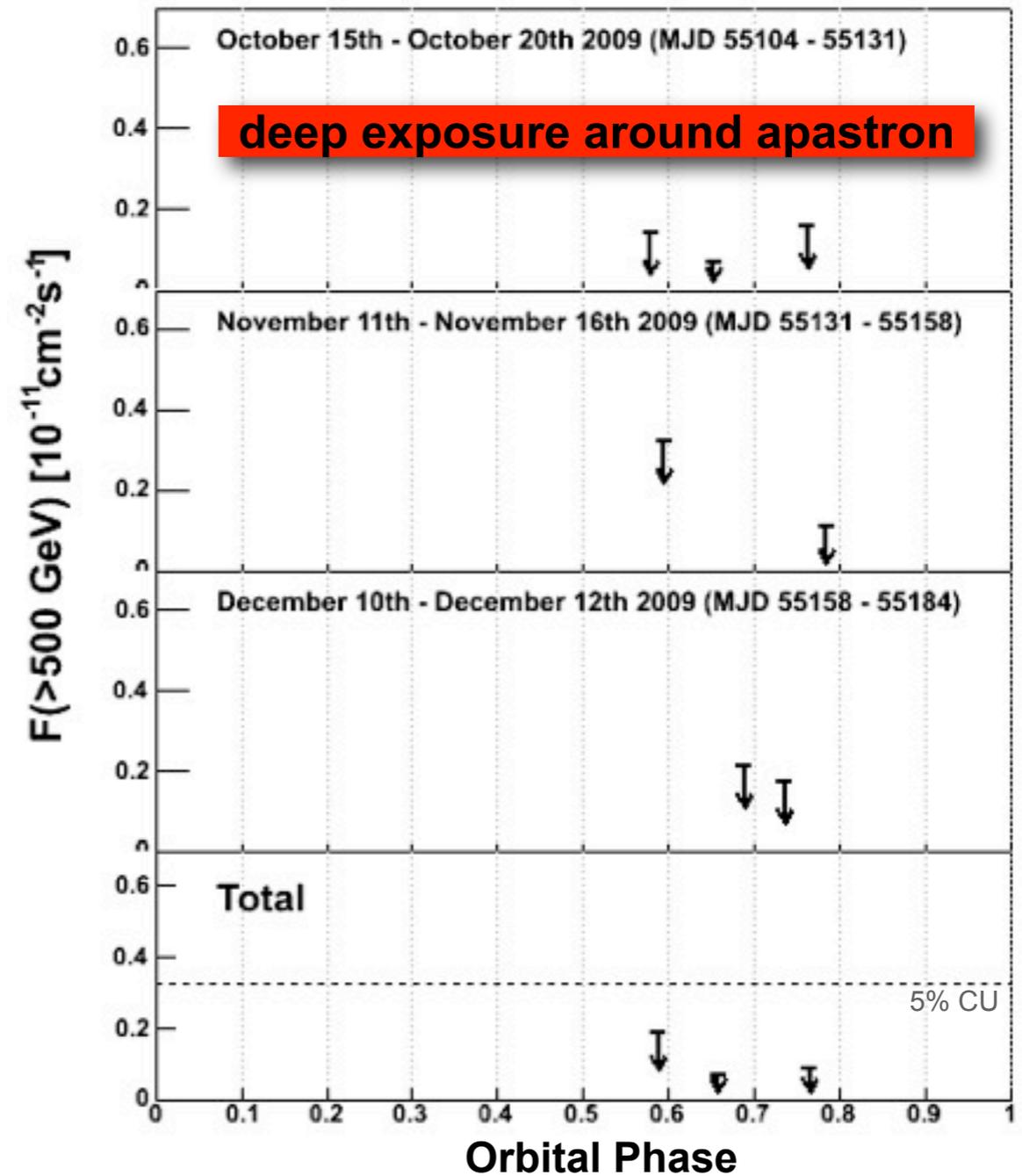
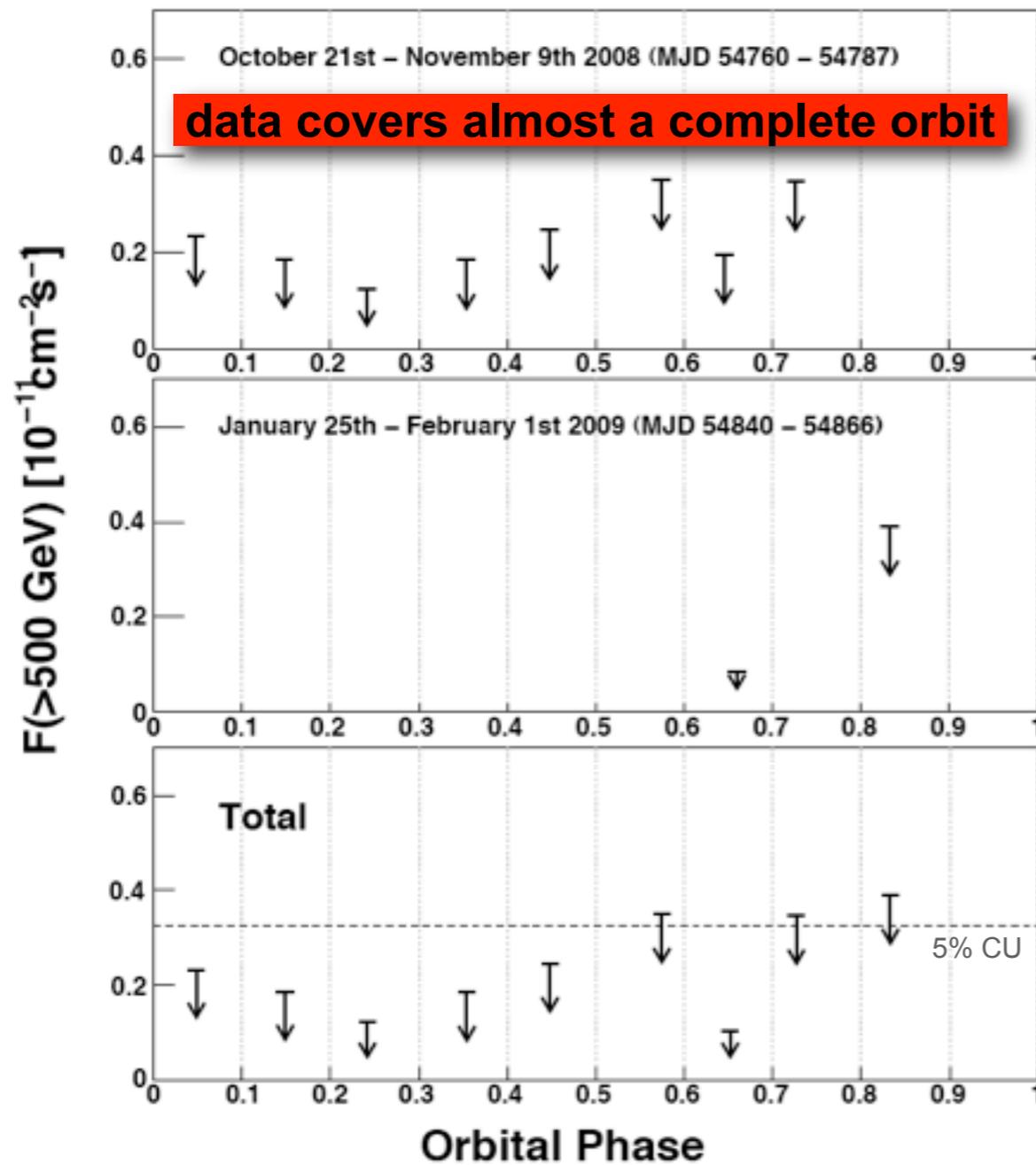
2006/2007: 45 h of 2/3 telescope data,  $8.4\sigma$



# LS I +61 303 in 2008-2010 - VERITAS results

2008/2009: 37 h of data,  $3.4\sigma$  overall

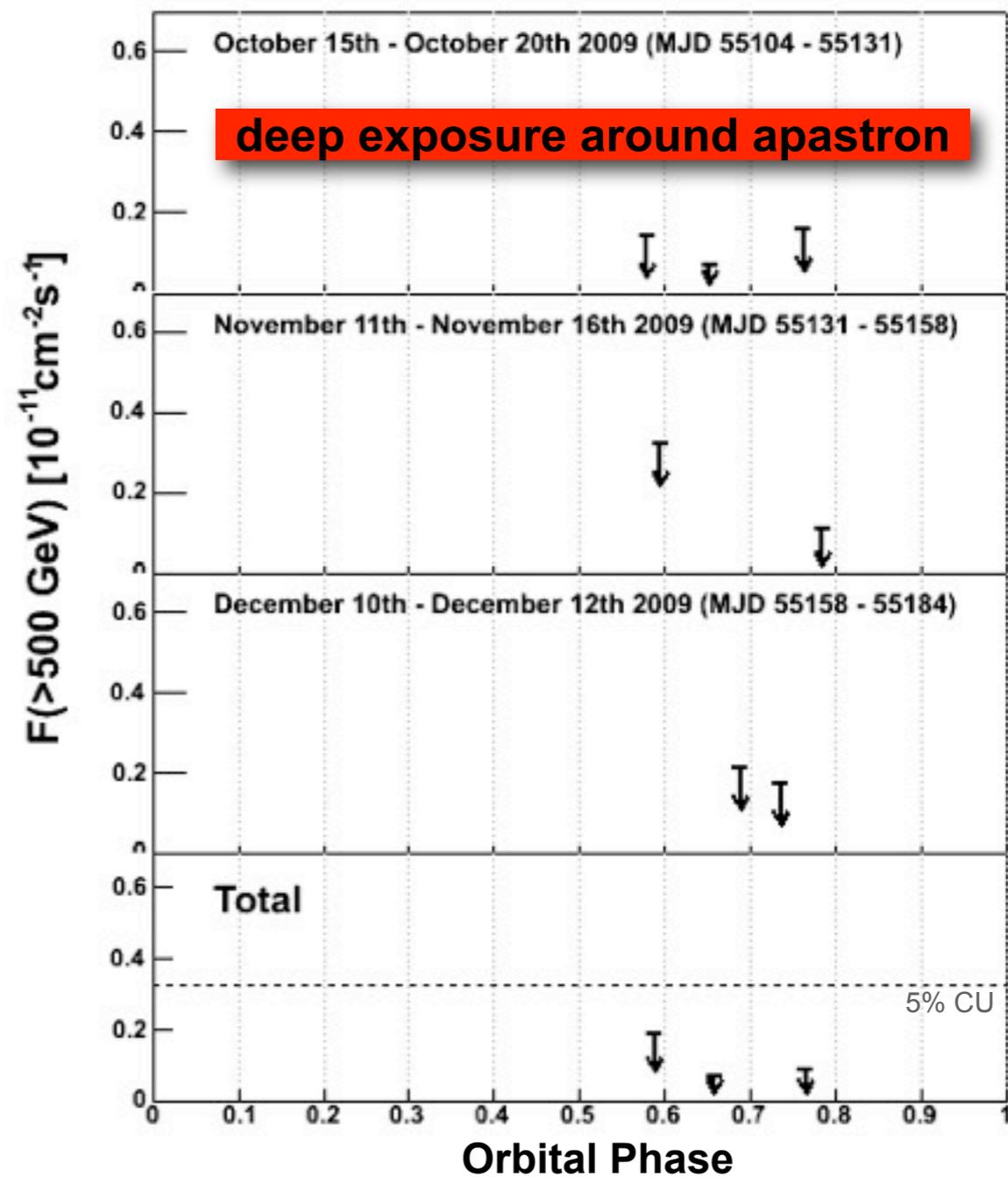
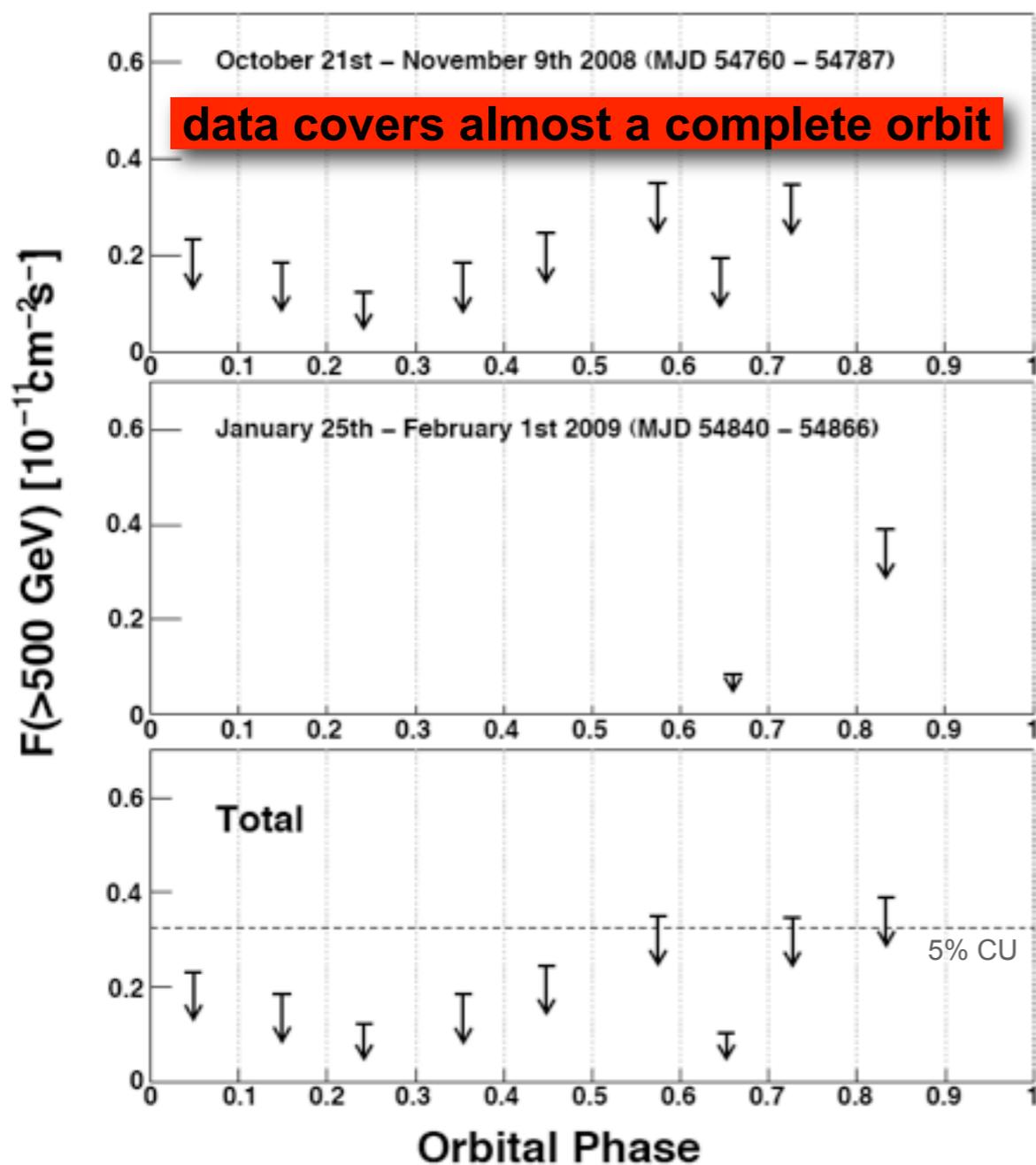
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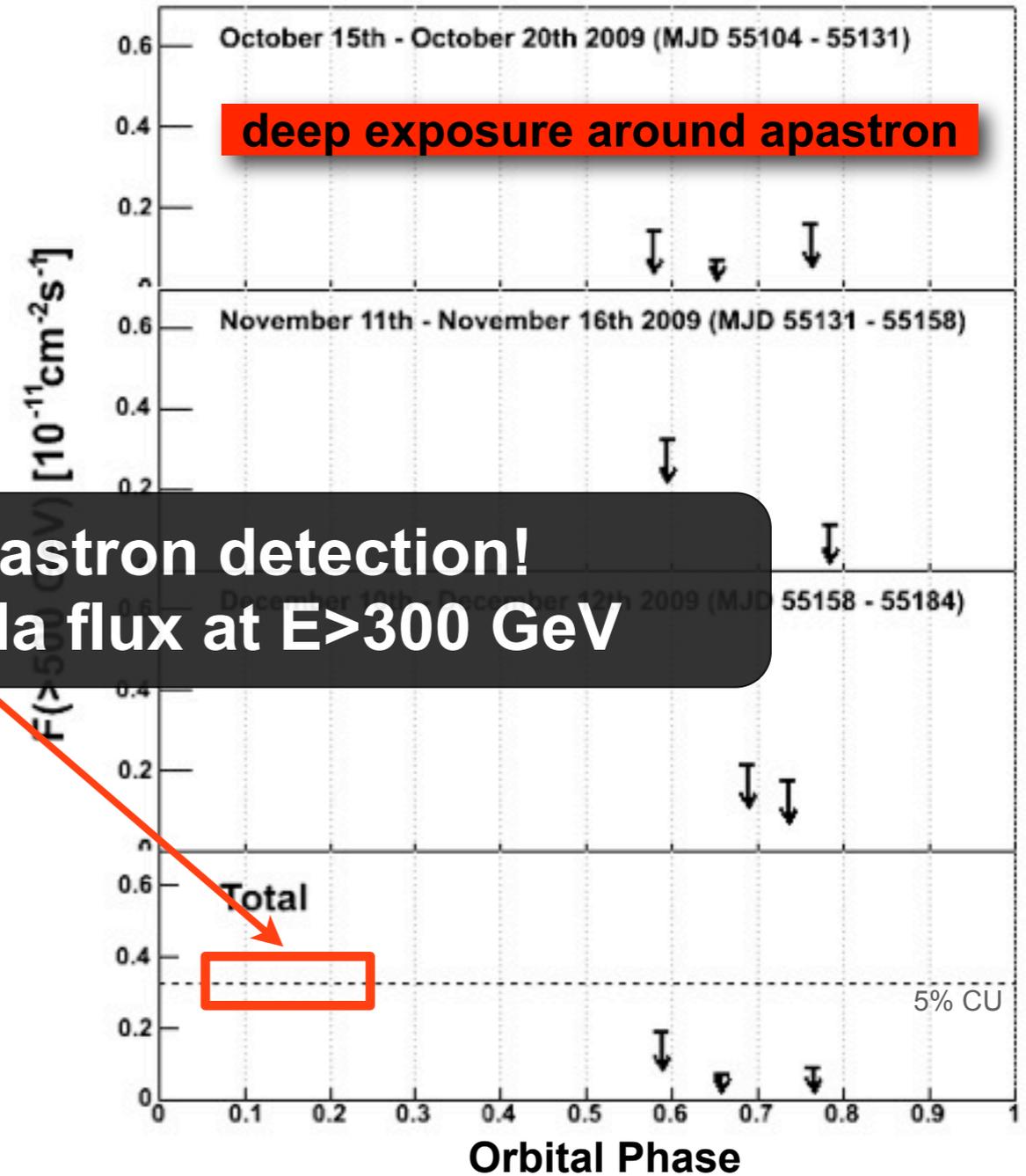
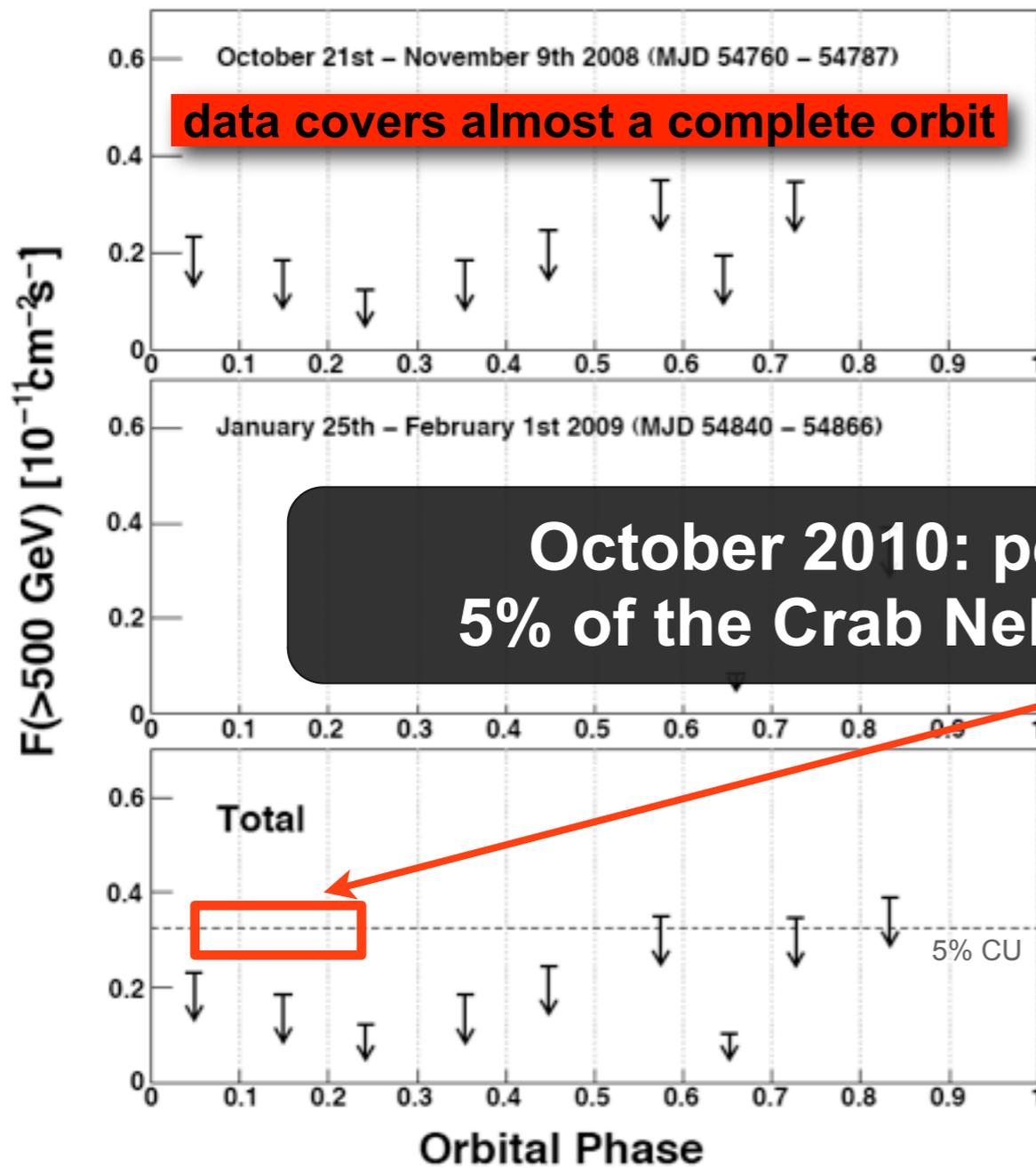
about 55h of VERITAS data since Fermi launch  
**no TeV detection Sep 2008- early 2010. Strict upper limits**



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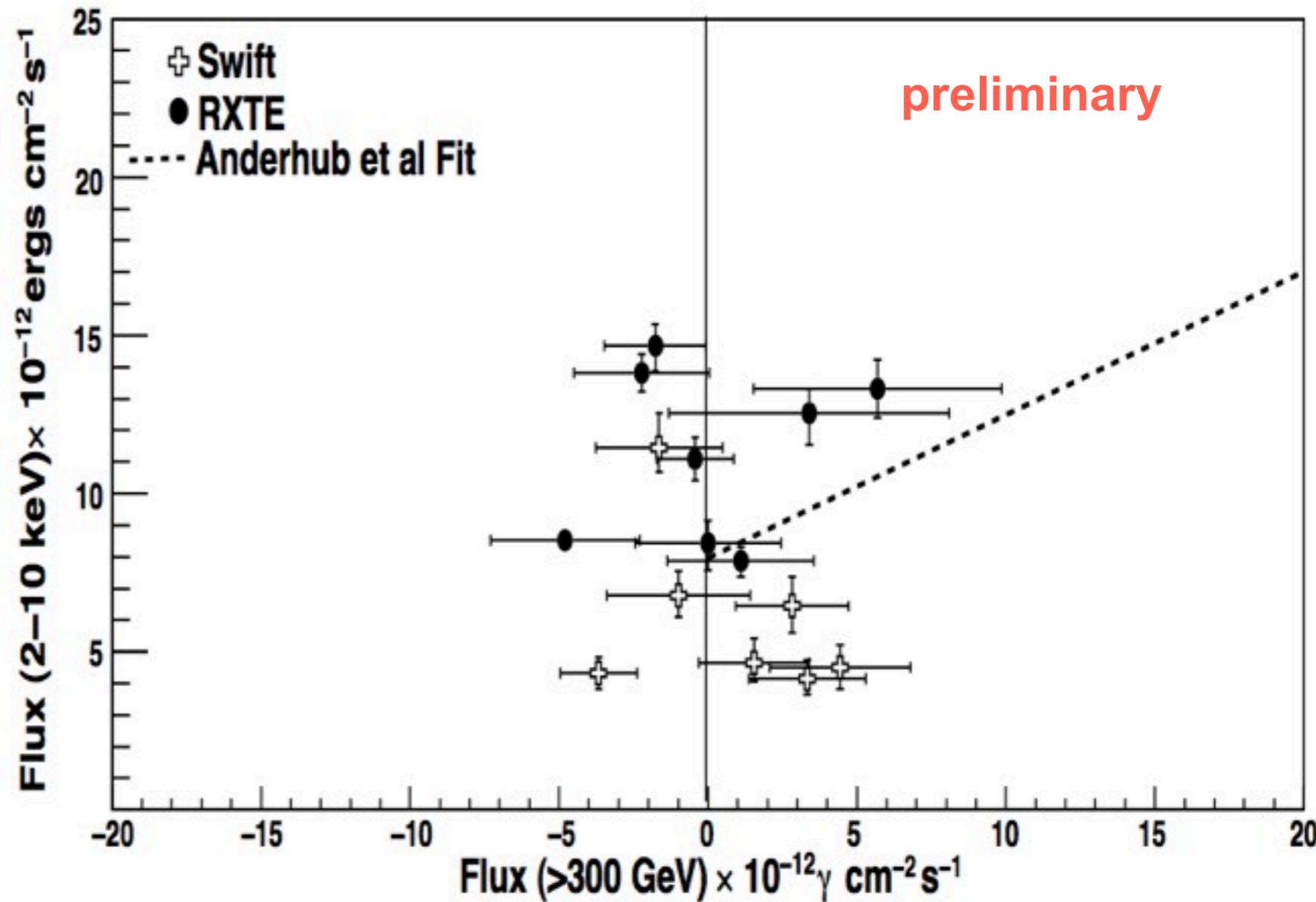
October 2010: periastron detection!  
5% of the Crab Nebula flux at E>300 GeV

about 55h of VERITAS data since Fermi launch  
no TeV detection Sep 2008- early 2010. Strict upper limits



# LS I +61 303 - VHE/X-ray correlation

- > 15 strictly overlapping RXTE-PCA, Swift-XRT and VERITAS observations
- > 2008-early 2010 measurements: no VHE detection
- > **no indication for X-ray/VHE correlation**  
(whatever this means for a non-detection at VHE...)



**LS I +61 303 shows variability on different time scales (intra-orbit, orbit-to-orbit, month and years, flares(?))**



# Summary

- > Binaries are an important part of the VERITAS science program
- > LS I +61 303
  - >120 h of data (2006-2010)
  - not detected in VHE since launch of Fermi despite reasonable coverage around apastron and a much more sensitive instrument; **periastron detection in Sept 2010**
- > HESS J0632+057
  - confirmed as a variable VHE source in Feb/March 2010; strong detection by VERITAS
  - still no clear identification; is it really a binary?
- > 1A 0535+262
  - major X-ray outburst of HMXB at best observing time for VERITAS
  - excellent coverage of flare and following orbit; strong upper limits above 300 GeV
  - no indication for non-thermal particle population in X-ray/HE/VHE data
- > Crab Nebula
  - no indication for variability detected in Sep 2010 at energies >300 GeV
- > Interested? Guest proposals welcome - next round: Summer 2011

