



# H.E.S.S. results on Gamma-ray binaries



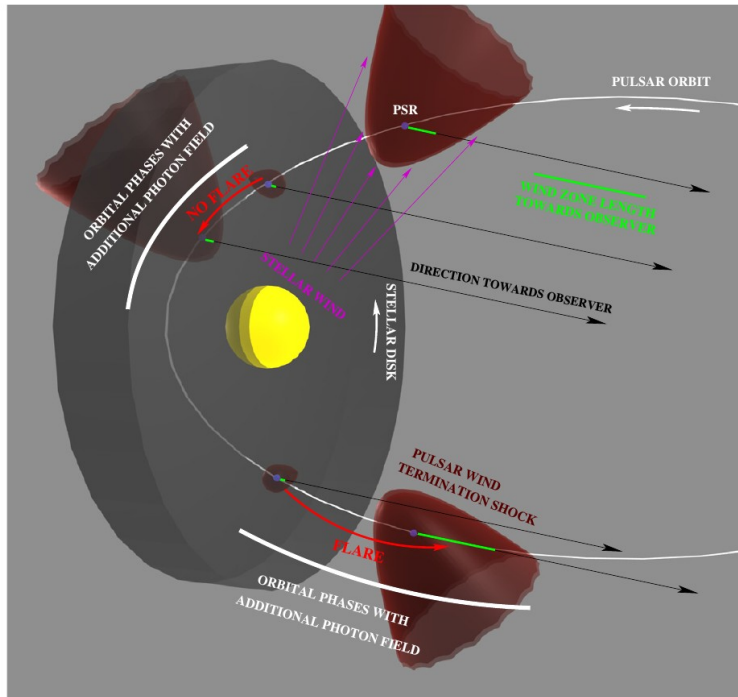
# Binaries

Described in this talk

North

Name	C. O.	Star	Porbital	HE $\gamma$	VHE $\gamma$	VHE Variability
PSR B1259-63	pulsar	Oe	3.4 y	yes	yes	yes
LS 5039	?	O6.5V	3.9 d	yes	yes	yes
1FGL J1018.6-5856	?	O6V	16.6 d	yes	yes	yes
HESS J0632+057	?	Be	317 d	no	yes	yes
LMC-P3	pulsar ?	O5III	10.3 d	yes	yes	yes
Eta Carinae	LBV + O/B type		5.5 y	yes	yes	no
HESS J1832-093	non-accreting NS binary system according to Mori et al, 2017, ApJ, 848, 80 (NuStar+other X-ray instruments)			no	yes	No. Variability from X-ray studies, Eger et al, MNRAS 457, 1753, 2016
LS I +61 303	?	Be	26.5 d	yes	yes	yes
PSR J2032+4127	pulsar	Be	50 y	yes	yes	yes
<b>Transient sources. H.E.S.S. Target of Opportunity observation program for X-ray binary systems and Cataclysmic Variables.</b>						
XRBS with BH/NS	BH/NS	<b>So far, ULs set with H.E.S.S.</b> 2018 : MAXIJ1820+070 observations MAGIC/VERITAS/HESS reported here. Redbacks: promising targets, see Zorawar's talk.				
Black widows/redbacks	NS					
Cataclysmic variables	White Dwarf					
Transitional ms pulsars	NS					

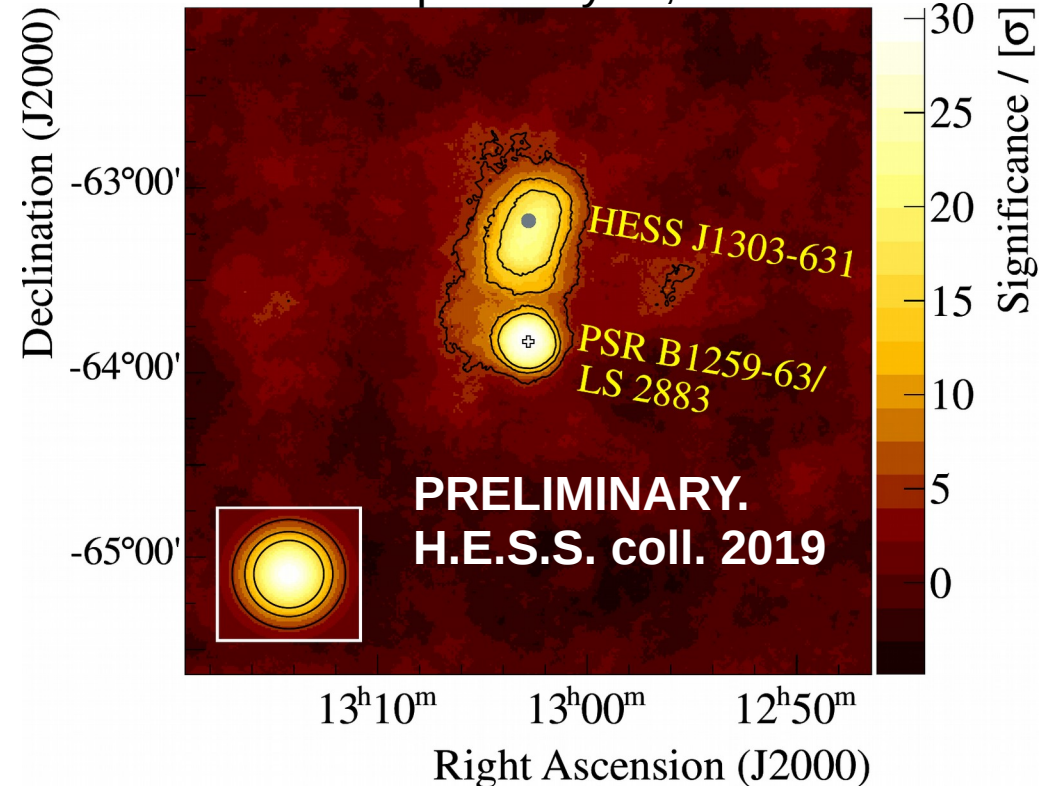
# PSRB1259-63



D. Khangulyan et al, The Astrophysical Journal Letters, 752:L17, 2012

2.3 kpc, 3.4 years orbital period,  
Oe star with circumstellar disk

Stereoscopic analysis, 2014



Forthcoming H.E.S.S. publication

*Thanks to Th. Murach, P. Bordas, Ch. Mariaud,  
C. Romoli, H. Prokoph*

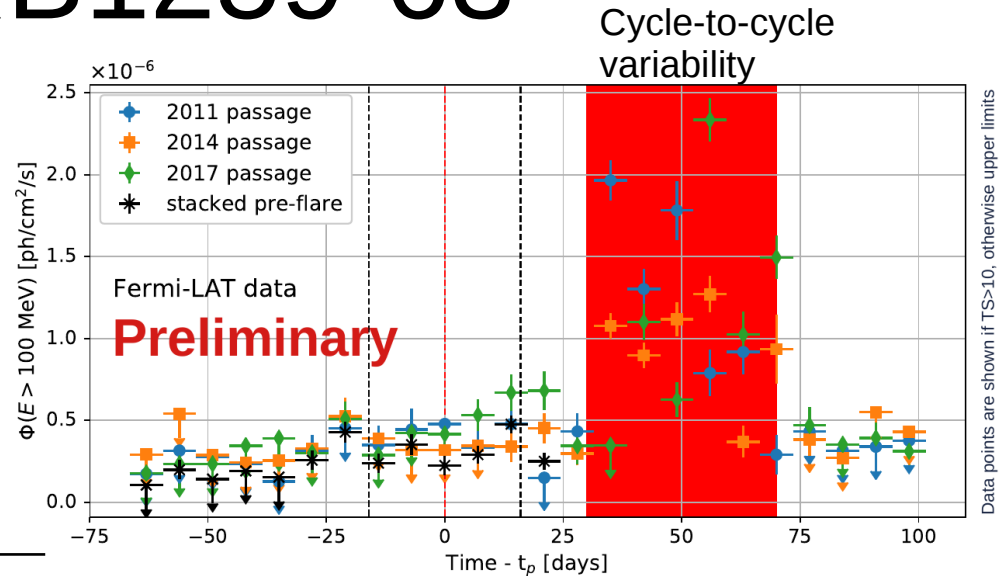


# PSRB1259-63

**HE gamma-ray light curve.**  
*Sc. T. v10r0p5+PASS8* stacked analysis before and after GeV flare:

Strong evidence for  $\gamma$ -ray emission  
 ~@ disk crossings and @ periastron

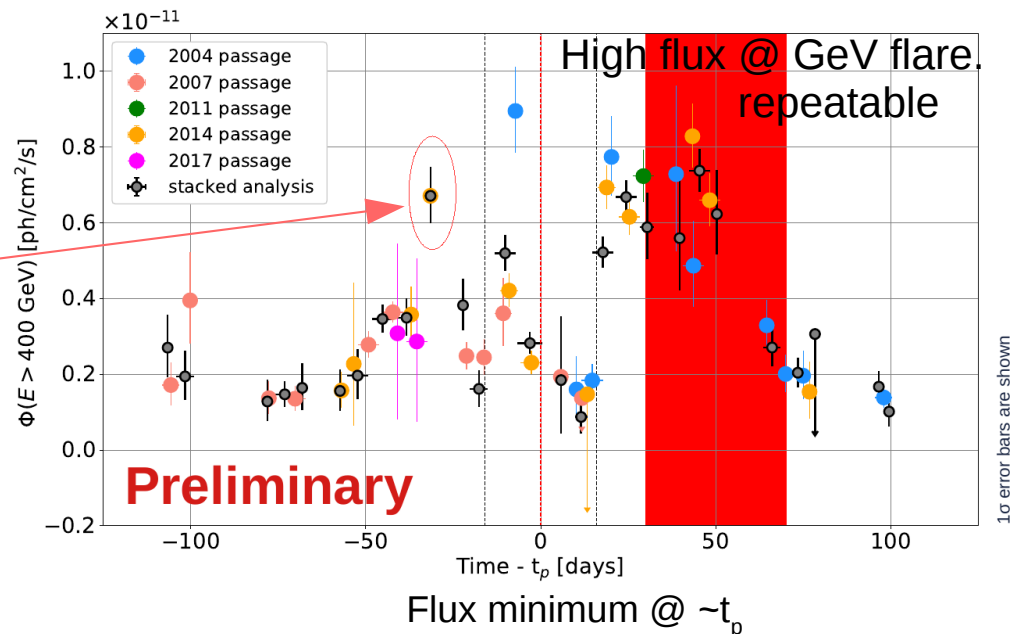
Pre-flare  $\rightarrow$  photon index  $3.1 \pm 0.2$



**H.E.S.S.** : stacked analysis of HESS I-type data, 7-days bins.

Unexpectedly high flux before the first disk crossing; not seen in other WLS

Fluxes after periastron  $2.0 \pm 0.1$  times higher than fluxes with a symmetric phase w.r.t. periastron

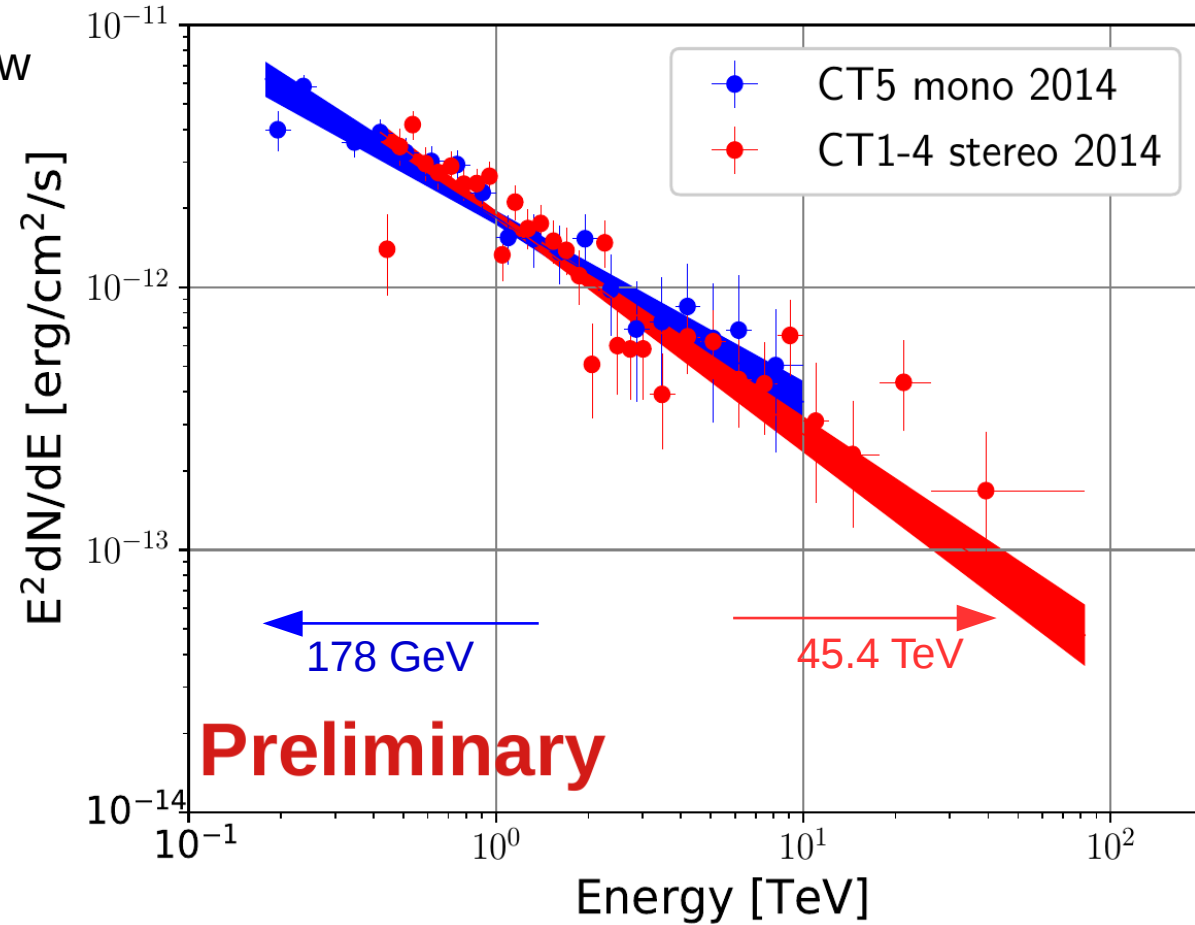


ICRC 2019: Th. Murach, P. Bordas, Ch. Mariaud, C. Romoli, H. Prokoph

# PSRB1259-63

No deviation from power law

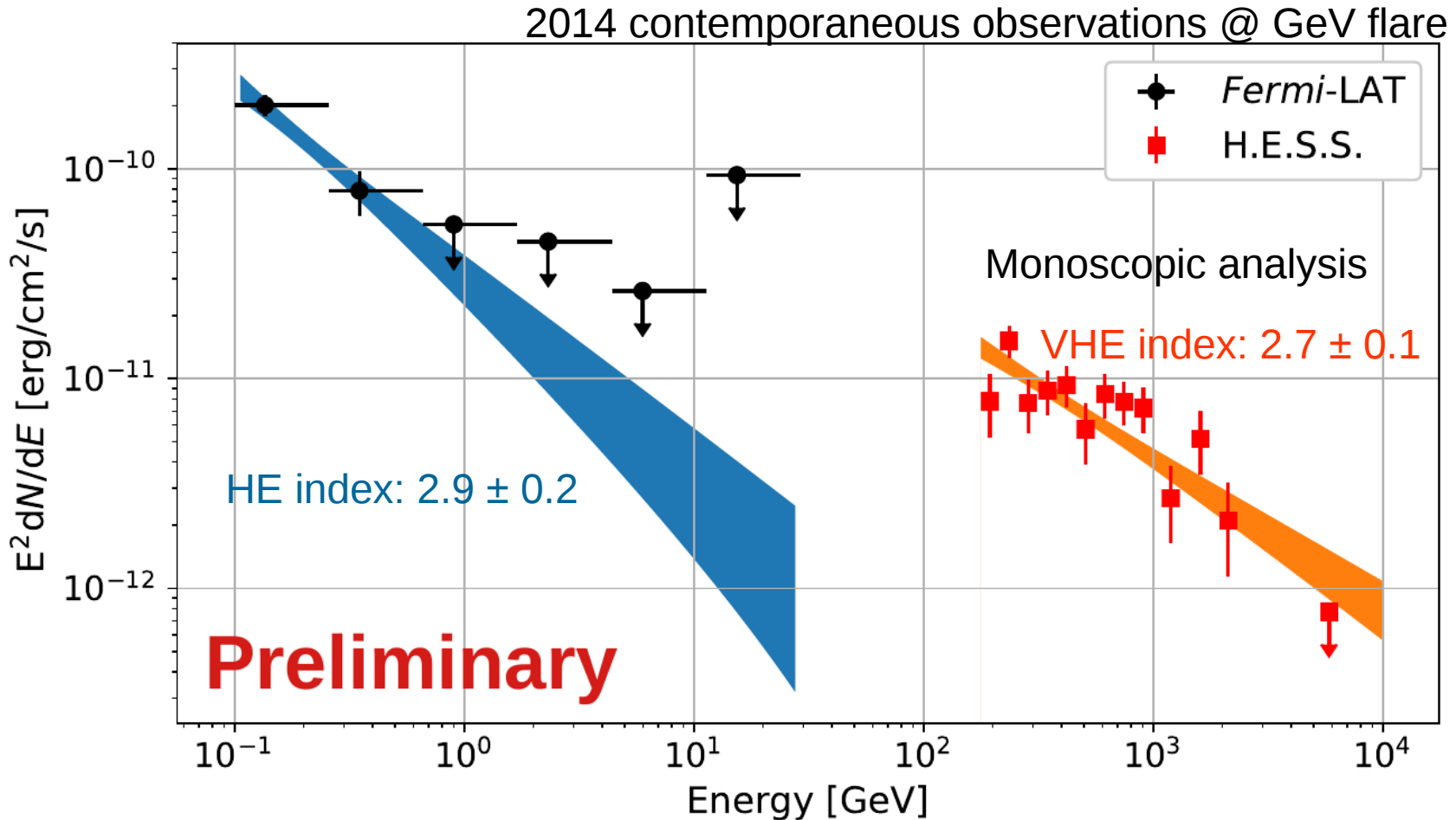
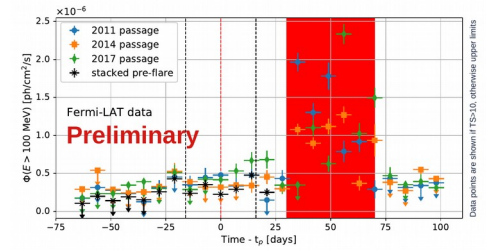
Expo. cut-off > 39.0 TeV  
@ 95% C.L.



ICRC 2019: Th. Murach, P. Bordas,  
Ch. Mariaud, C. Romoli, H. Prokoph

VHE Photon indices compatible with a constant ( year-to-year and intra-cycle ):  
 $2.5 \pm 0.1 \rightarrow 2.9 \pm 0.2$  (2004-2014)

# PSRB1259-63



HE / VHE spectrums not connected: different acceleration/emission/absorption processes in play.

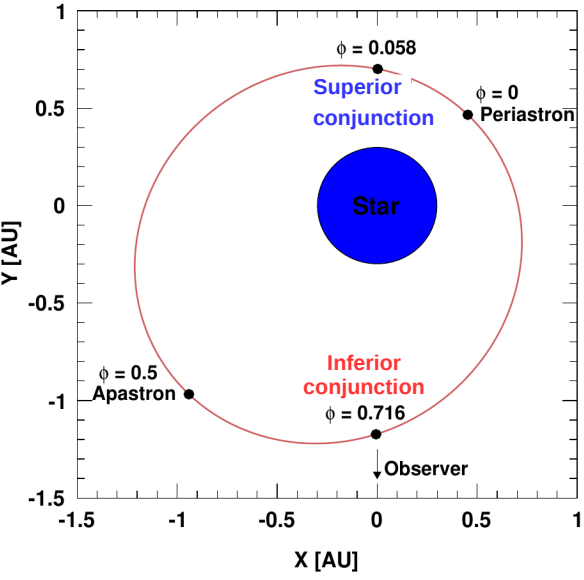
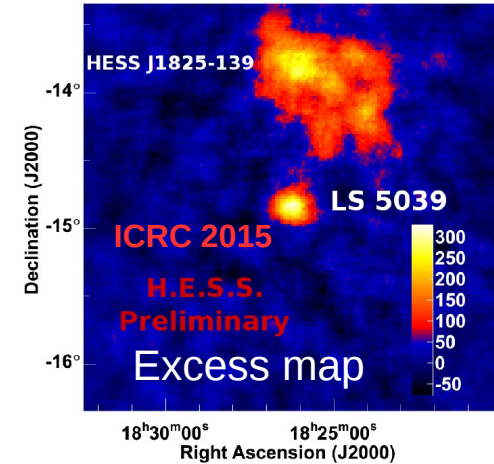
ICRC 2019: Th. Murach, P. Bordas,  
Ch. Mariaud, C. Romoli, H. Prokoph



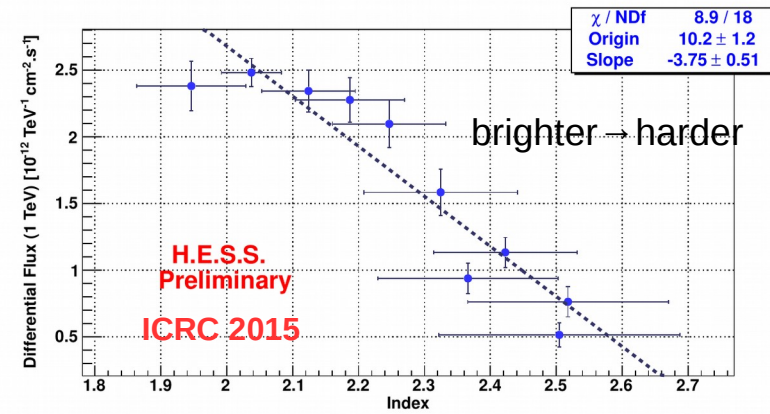
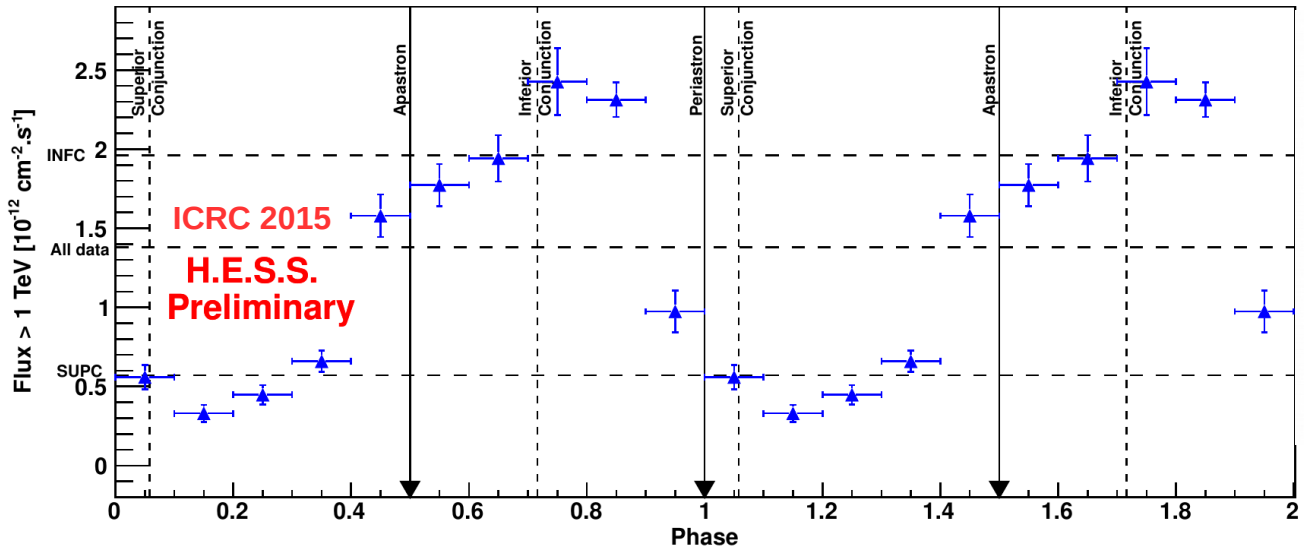
# LS5039

Ch. Mariaud, P. Bordas, F. Aharonian, M. Boettcher, G. Dubus, M. de Naurois, C. Romoli, V. Zabalza:  
**ICRC 2015 : figures shown here.**

~ 3.5 kpc.  
 O6.5V star,  $m \sim 23$  solar masses,  $R \sim 9.3$  solar rad.  
 $P_{orb} = 3.9078 \pm 0.0015$  d (VHE  $\gamma$  rays),  $e = 0.35$ .  
 Inclination  $i \sim 20 - 65$  deg.  
 Compact object:  $m \sim 3.7$  solar masses, not known.



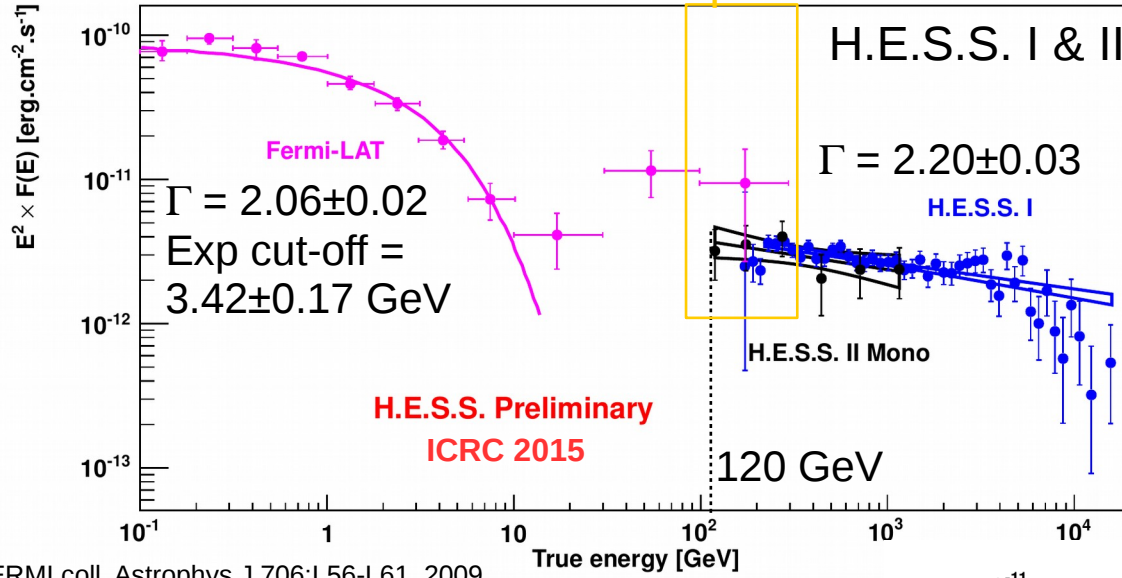
Data 2004 - 2014



P.L. fit in each phase interval (0.1)  
 → index of PL.  
 Anti-correlation with flux.

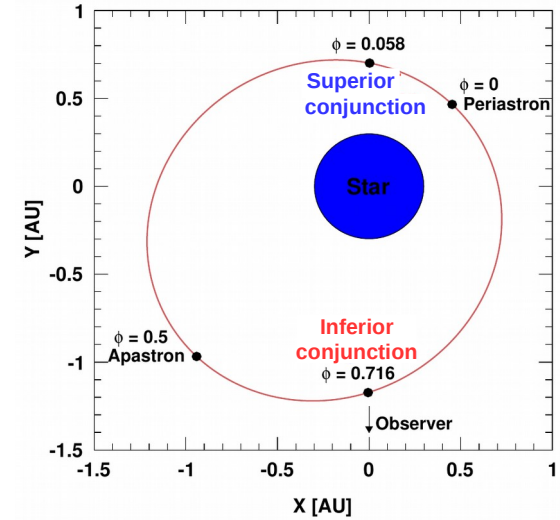


# GeV-TeV LS5039 overlap

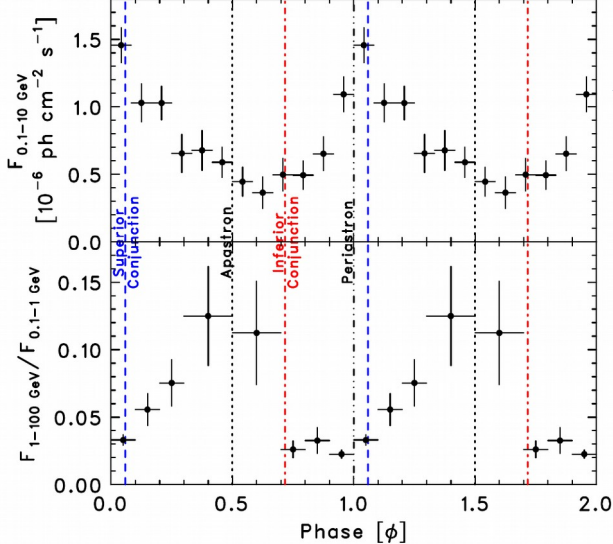


H.E.S.S. (2006) A&A, 460, 743

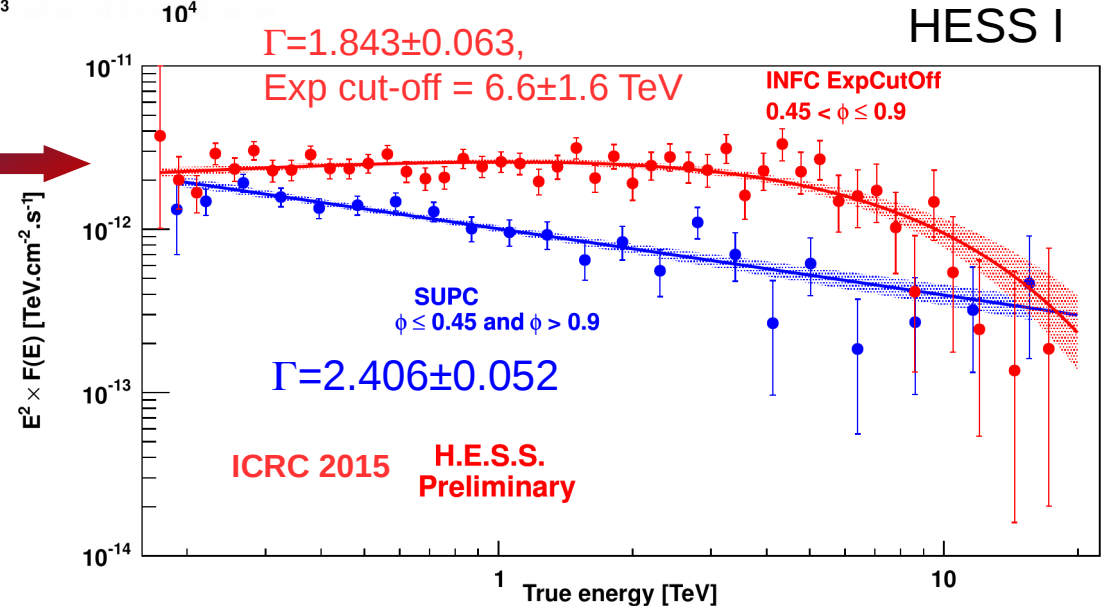
Ch. Mariaud, P. Bordas, F. Aharonian, M. Boettcher, G. Dubus, M. de Naurois, C. Romoli, V. Zabalza: ICRC 2015 : figures shown here.



FERMI coll, Astrophys.J.706:L56-L61, 2009



**Hardness & intensity anti-correlated HE w.r.t. VHE**



September 4, 2019

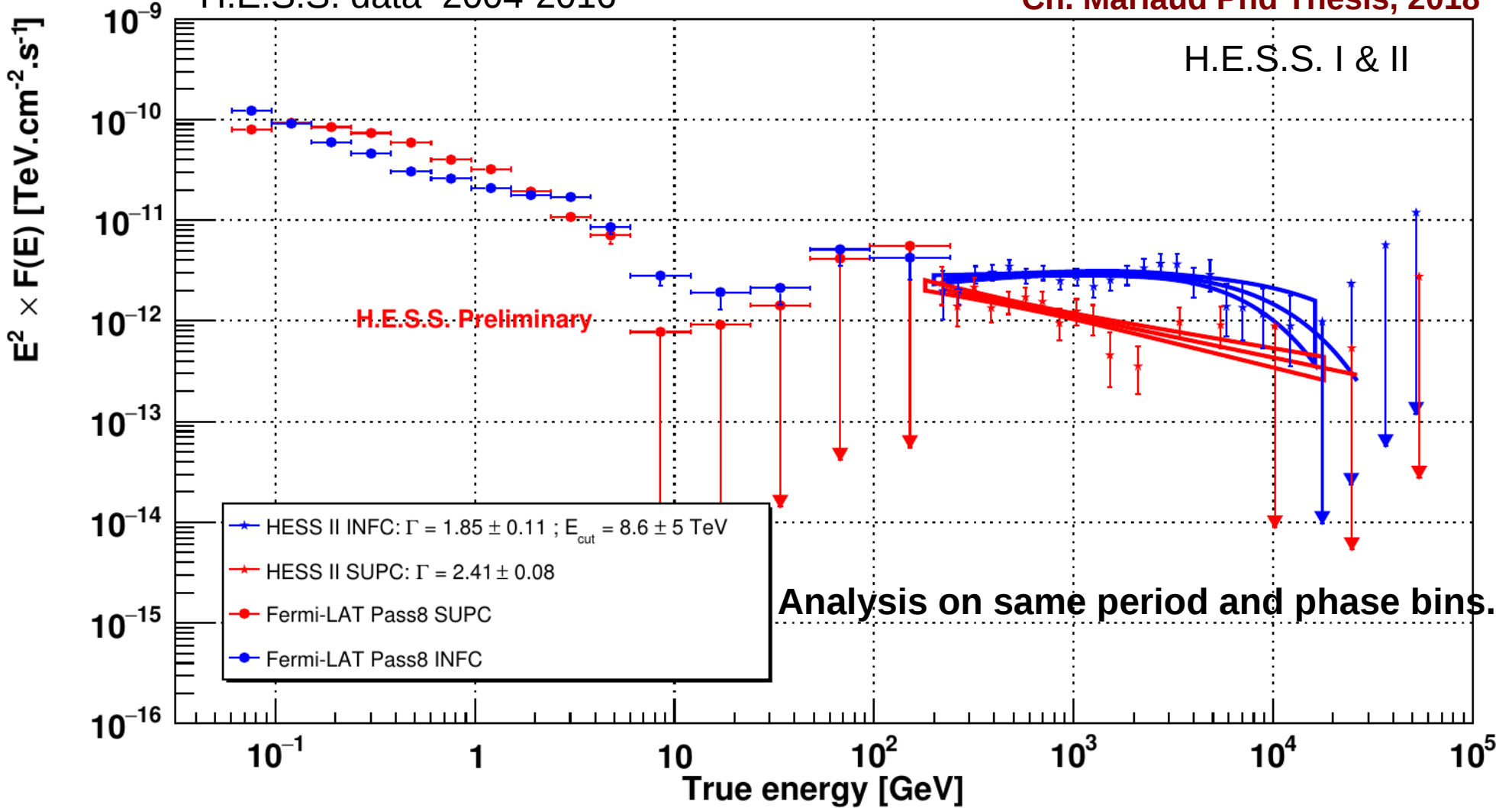
Variable Galactic Gamma-Ray sources V



# LS5039

H.E.S.S. data 2004-2016

Ch. Mariaud Phd Thesis, 2018





# 1FGL J1018.6-5856

A&A 577, A131 (2015), Discovery of variable VHE  $\gamma$ -ray emission from the binary system 1FGL J1018.6–5856  
Corresponding Authors: Emma de Ona Wilhelmi, V Zabalza.

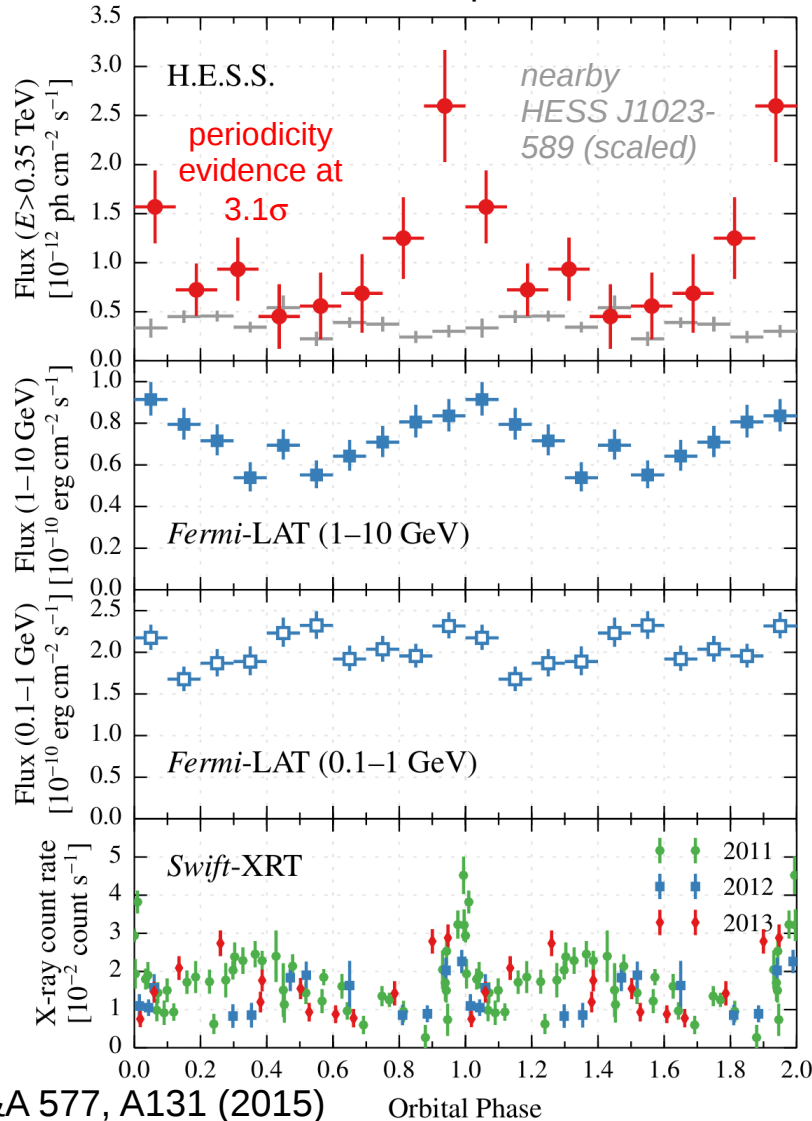
- Source HESS J1018–589 A = Fermi-LAT  $\gamma$ -ray binary 1FGL J1018.6–5856.  
5 $\pm$ 2 kpc. O6V star. Orbital period assumed at 16.58 $\pm$ 0.02 days from HE  $\gamma$  rays (is 16.544 $\pm$ 0.008 from *Swift* data).  $\frac{1}{2}$  major axis  $\sim$  LS5039 one  $\times$  2.5 .
- 7.5 $\sigma$  H.E.S.S. post-trial detection. 1% Crab flux.
- Power law, index=2.2 $\pm$ 0.14 $\pm$ 0.2
- emission up to 20 TeV  $\rightarrow$  0.001<B<0.1 G (IC scenario)
- Spectral shape above 350 GeV  $\rightarrow$  optical depth  $\tau(300 \text{ GeV}) \lesssim 1$
- 4.3 $\sigma$  variability.
- Phaseogram in phase with HE  $\gamma$  ray and X rays.
- No spectral modulation seen in the available statistics.
- Model by H. An, R. W. Romani (2017, ApJ, 838, 145) : young pulsar, GeV from pulsar magnetosphere, X-ray and TeV dominated by synchrotron and IC from intrabinary shock.



# 1FGL J1018.6-5856

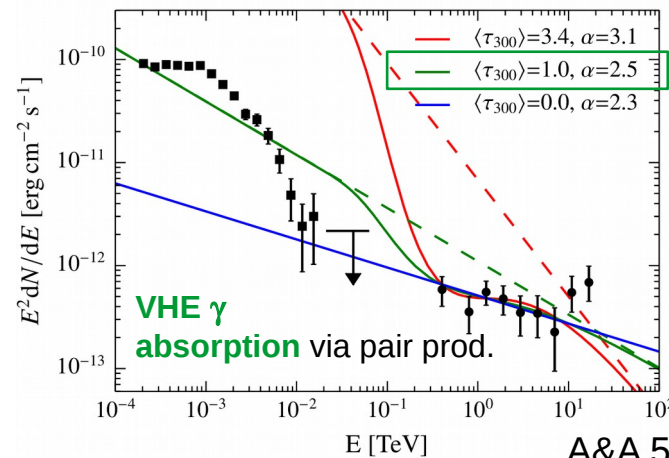
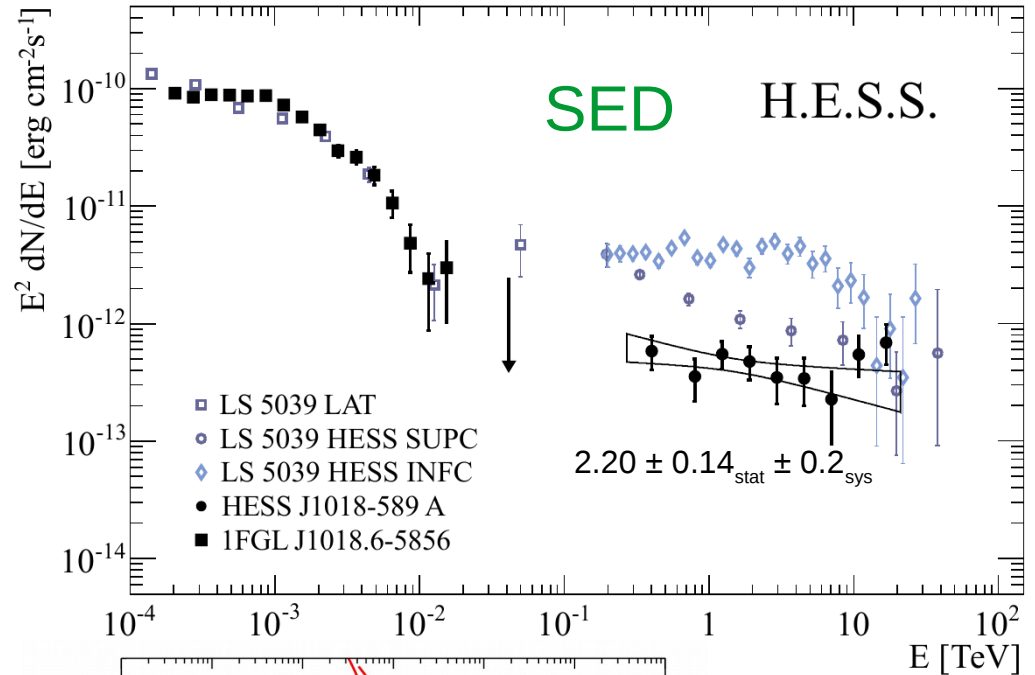
fluxes folded with the orbital period 16.58d from HE obs.

A&A 577, A131 (2015)



A&A 577, A131 (2015)

Orbital Phase



$$E^{-\alpha} \exp(-\langle \tau_E \rangle)$$

LS5039 stellar params.

A&A 577, A131 (2015)

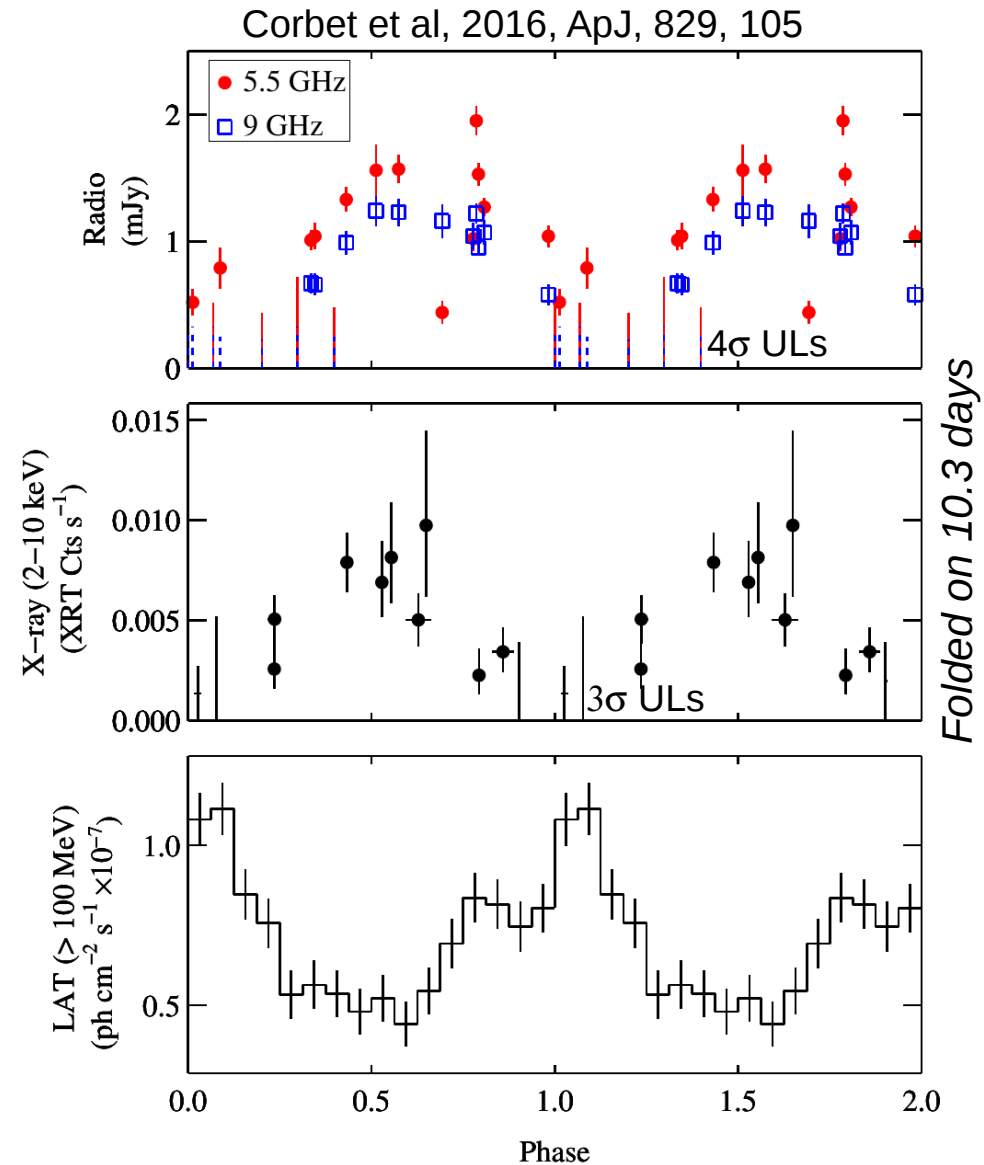


# HESS J0632+057

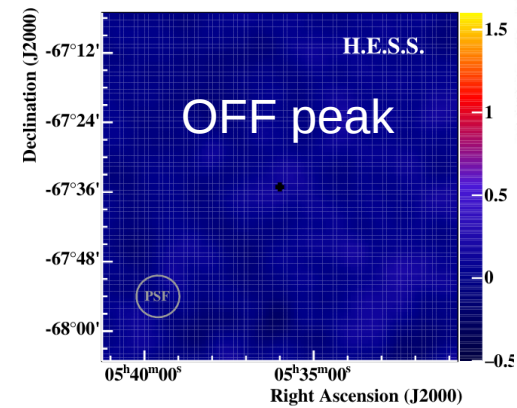
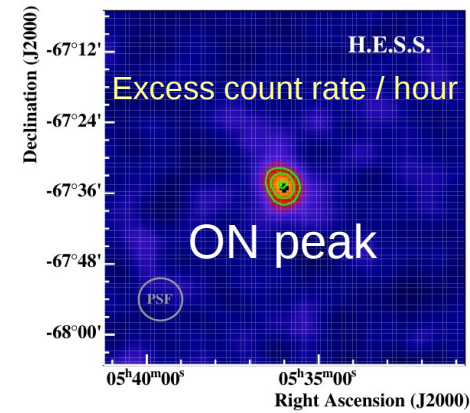
- See dedicated Daniela's talk.
- See ICRC 2019, MAGIC+VERITAS+H.E.S.S, and related forthcoming publication (2004-2019 data)
- 1.1-1.7 kpc
- Be star + unknown compact object.
- $P_{\text{orb}} = 316.8_{-1.4}^{+2.6}$  days (X-ray data). D. Malyshev, M. Chernyakova, A. Santangelo, G.Pühlhofer (2019), Decade-long X-ray observations of HESS J0632+057, ASNA, arxiv 1711.05001 .
- Phase-folded X-ray and VHE  $\gamma$ -ray light curves exhibit a similar pattern
- Jan 2018, exceptional event : VHE flux x2 w.r.t. expected one at this phase, followed by a fast decay.

# LMC-P3

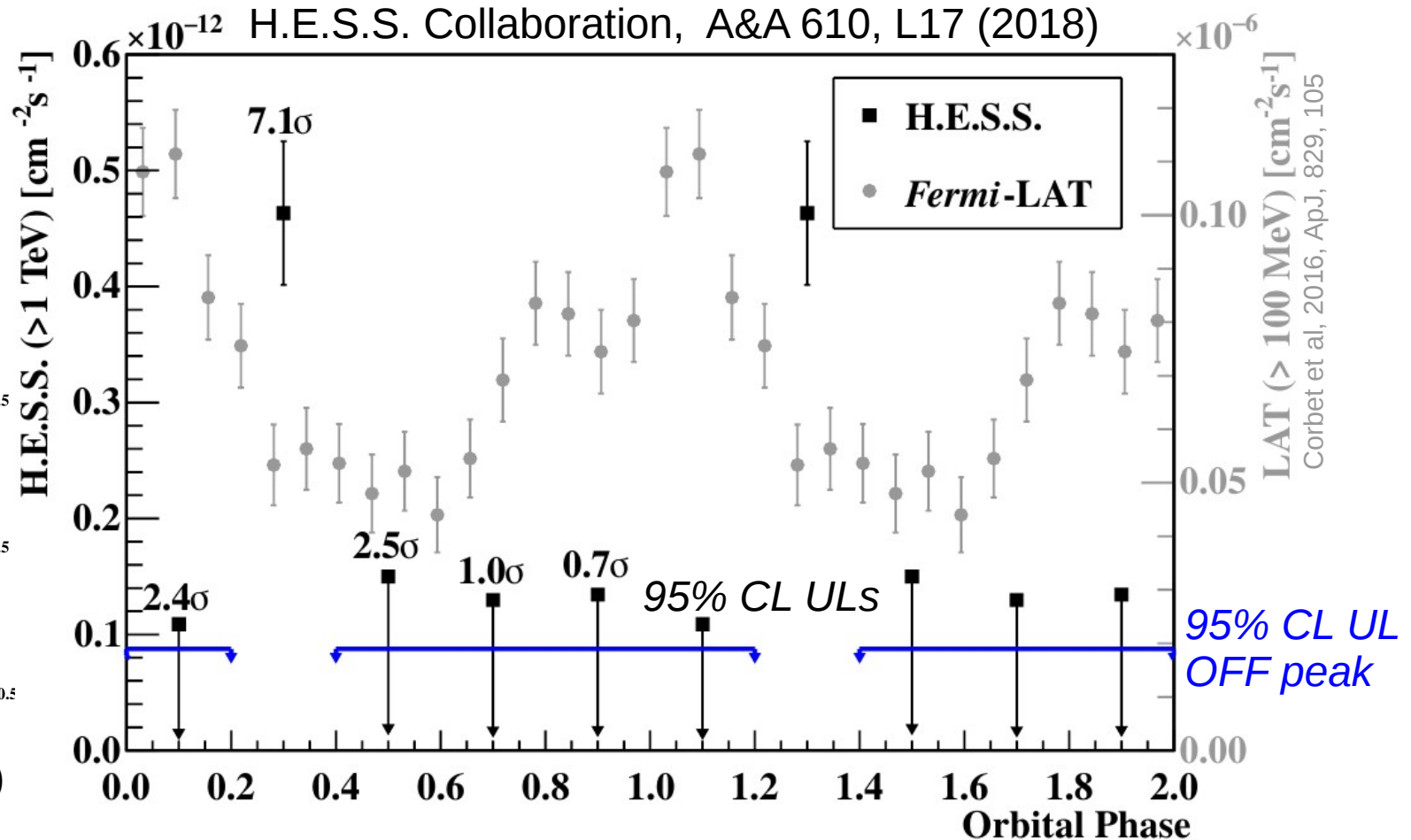
- In Large Magellanic cloud, discovered in FERMI data by Corbet et al, 2016, ApJ, 829, 105
- $P_{\text{orb}} \sim 10.3$  days : HE gamma, X-ray, radio, with phase opposition between HE gamma and others. O5III star ( $\sim 40$  sol. mass) + likely neutron star.
- More luminous in all WLs than known galactic binaries. In VHE  $\gamma$  rays: on 20% of the orbit  $L = (5 \pm 1) 10^{35}$  erg/s.
- $6.4\sigma$  VHE  $\gamma$ -rays detection for 100h exposure (A&A 610, L17 (2018), Corr. Authors M. Haupt and N. Komin),
- Variability in VHE  $\gamma$  rays detected at  $\sim 4\sigma$  ( $p_{\text{value}}$  of no variability =  $1.95 \cdot 10^{-5}$ )



# LMC-P3



A&A 610, L17 (2018)



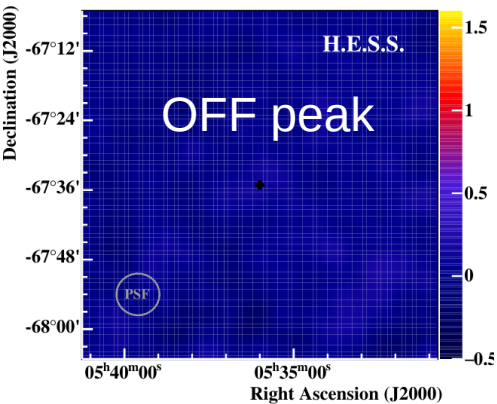
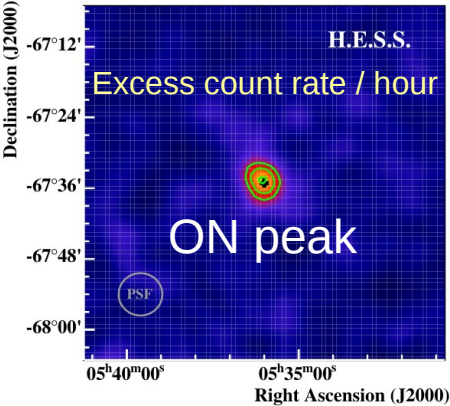
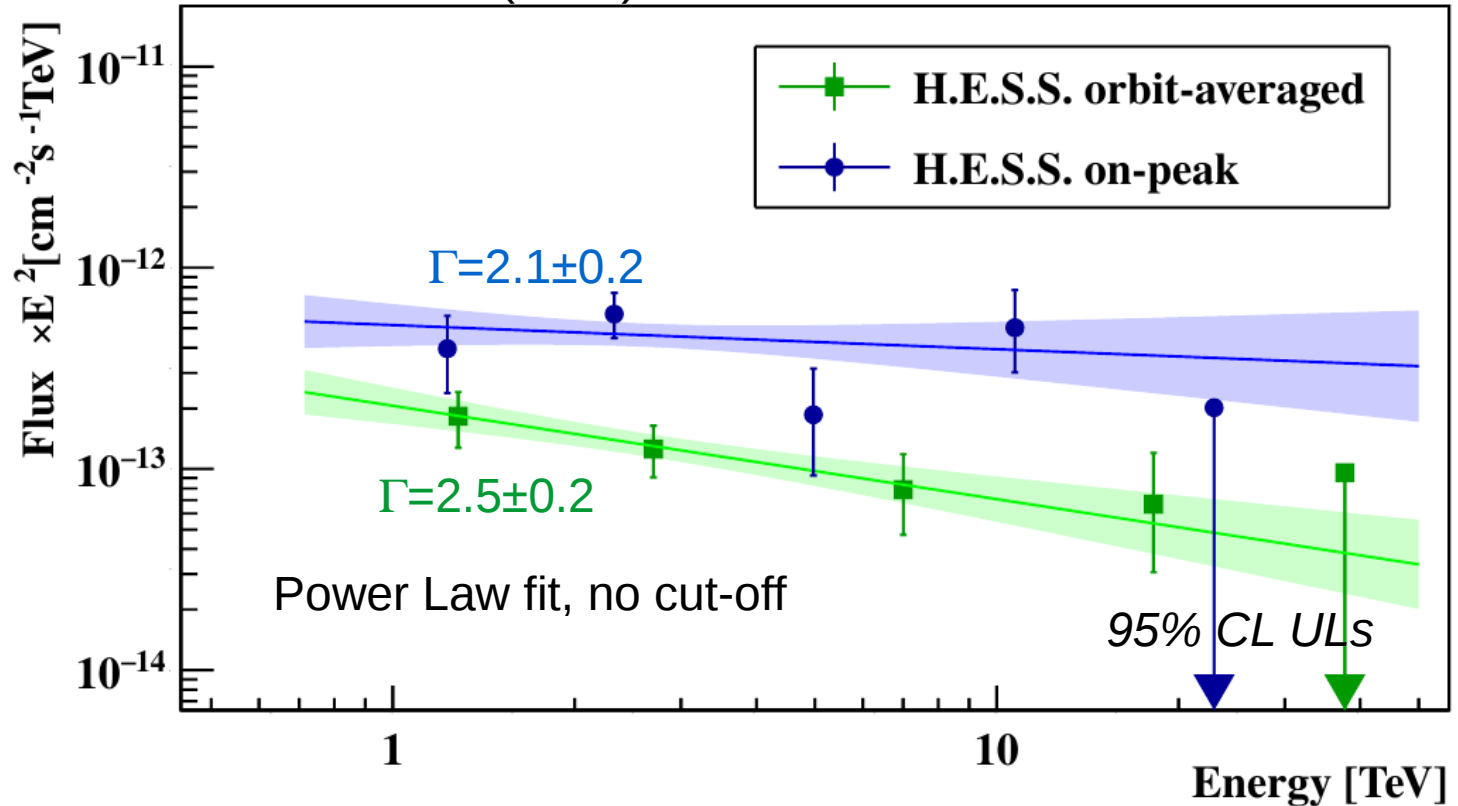
Folded on 10.3 days. 5 phase bins, with 18-21h exposure each.

*VHE / HE emission out of phase: VHE absorption via pair production or VHE/HE production by different regions of the system.*



# LMC-P3

A&A 610, L17 (2018)



A&A 610, L17 (2018)

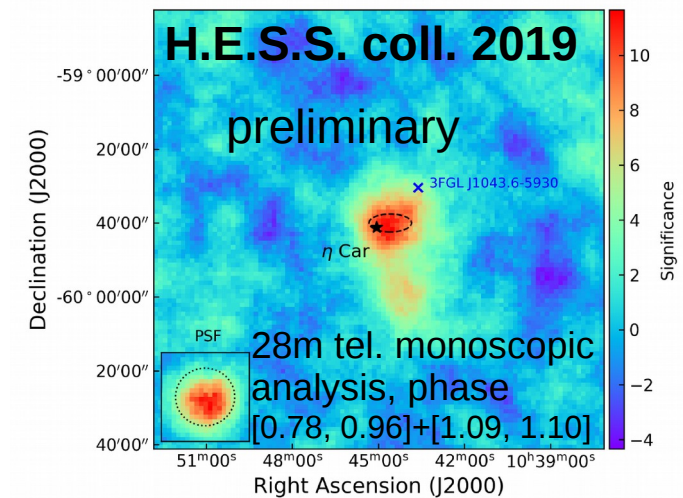
Pulsar wind scenario: pulsar's spin-down power needs to be at least 10<sup>36</sup> erg/s.

Accretion scenario onto neutron star: needs conversion efficiency from accretion power to  $\gamma \sim 1$ . A more massive compact object would be needed, but is not favoured by the mass function  $\rightarrow$  low inclination needed.

# Eta Carinae

*Special thanks to M. Fülling, E. Leser, S. Ohm*

- Forthcoming H.E.S.S. coll. paper.
- Colliding Wind Binary system
- Luminous Blue Variable primary star (100 sol. mass) + O/B type companion (30 sol. mass).  $P_{\text{orb}}=5.5$  years,  $e\sim 0.9$ . Passage at periastron in 2014 observed with H.E.S.S.
- Seen in HE  $\gamma$  rays, with variable emission, by AGILE and Fermi/LAT
- Colliding stellar winds  $\rightarrow$  strong shock in the contact discontinuity  $\rightarrow$  acceleration of charged particles  $\rightarrow$   $\gamma$  rays
- 2 energy components in HE, both variable. The [10,300] GeV component raised around 2009 periastron but not 2014 one.
- VHE emission now seen by H.E.S.S. (2014-2015,  $\sim 30$  hours) at  $\gtrsim 9\sigma$  thanks to the exploitation of the 28m telescope: low threshold (190 GeV) + recent analysis techniques including run-wise simulations to compute IRFs and to cope with high NSB in the sky region. VHE detected up to 400 GeV ( $\rightarrow B < 0.5\text{G}$  in case of IC).
- No VHE variability seen yet, as for HE  $\gamma$  rays in same epoch.
- VHE spectrum very steep (PL,  $\Gamma \sim 3.5 - 3.9$ ), arguing for VHE  $\gamma$ -ray absorption.



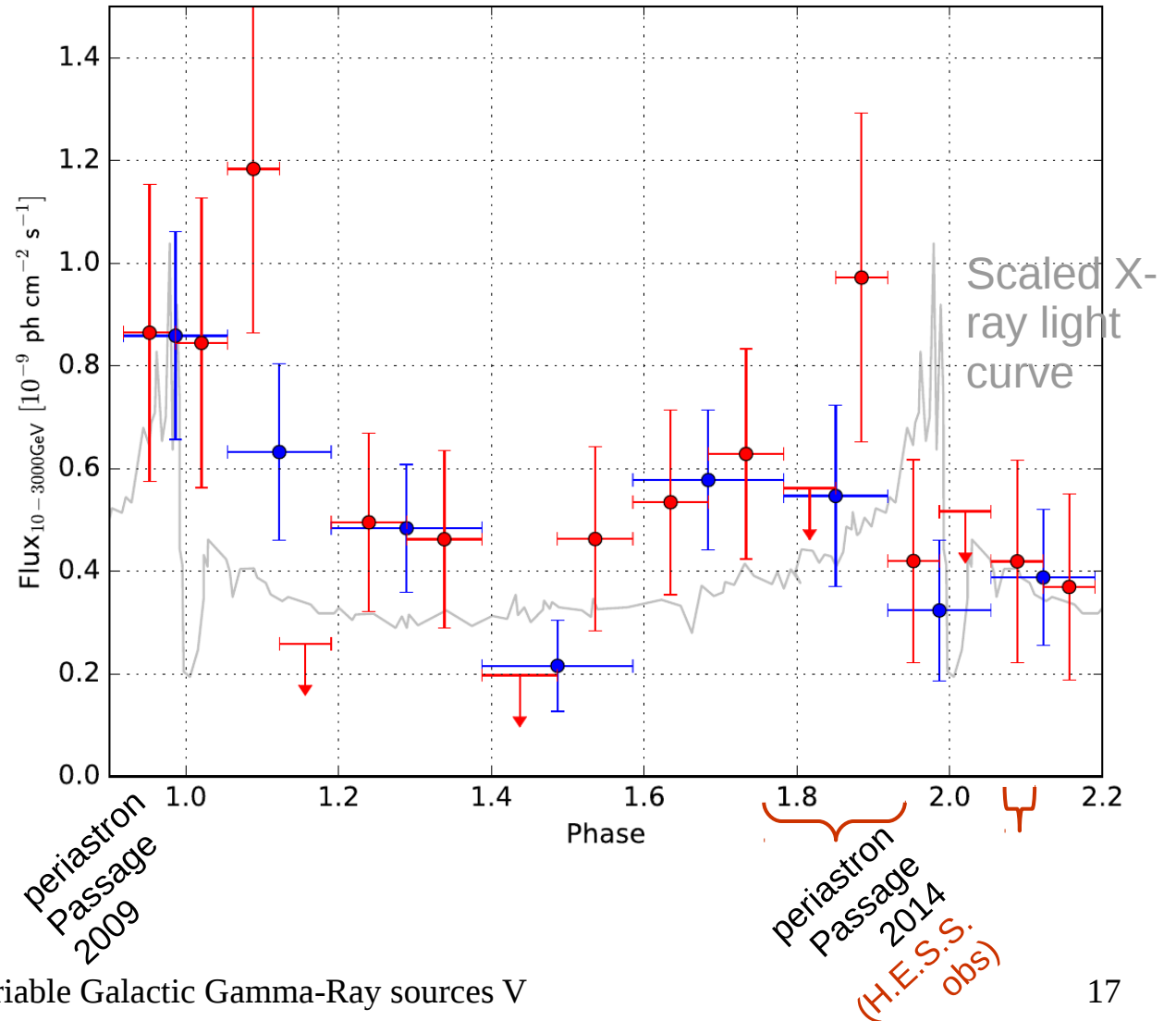
# Eta Carinae

## High Energy emission (10-300 GeV)

FERMI/LAT HE  $\gamma$  rays,  
7 years.  
Red/Blue for 2 widths of time bins.  
Error bars @  $1\sigma$ ,  
ULs @ 95% CL.

M. Balbo and R. Walter

A&A 603, A111 (2017)

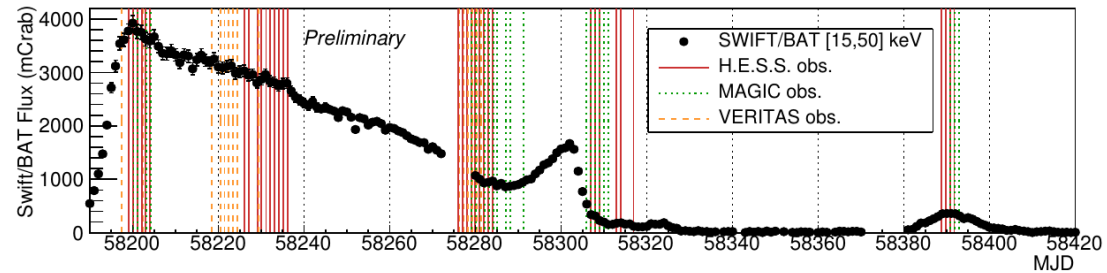
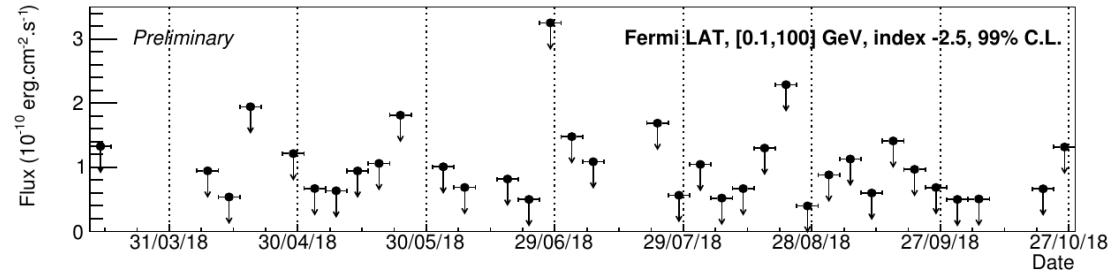
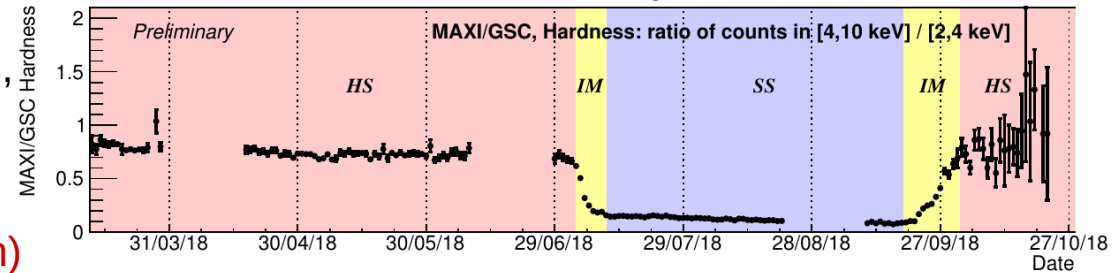
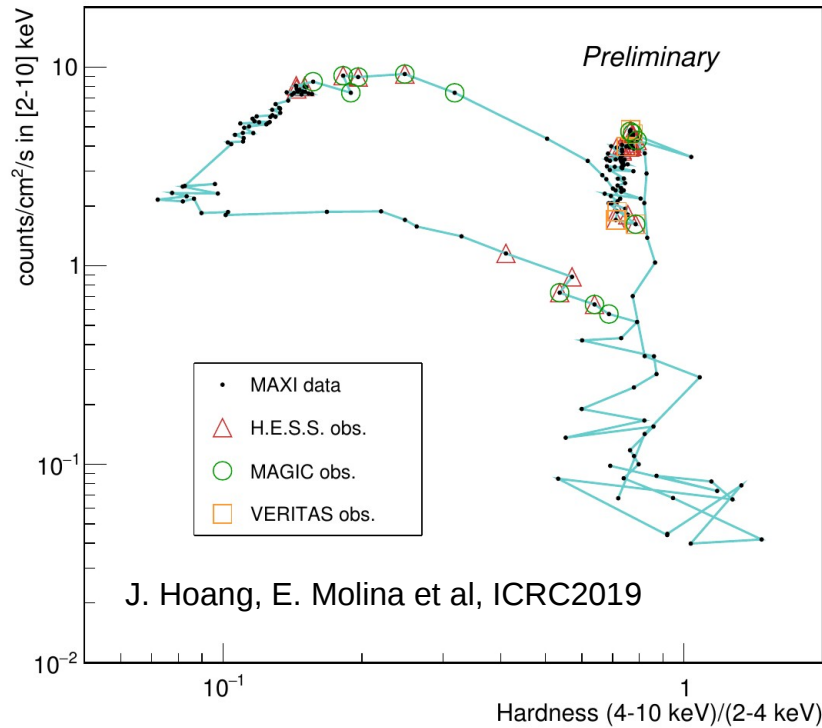




# XRB: MAXI J1820+070

J. Hoang, E. Molina et al, ICRC2019

- **LM XRB** with BH, at  $\sim 3.5$  kpc.  $M_{\text{BH}} > 5$  sol. mass,  $M_{\text{companion}} < 1$  sol. mass.
- Followed by **MAGIC(22.5h)/VERITAS(12.2h)/H.E.S.S.(26.9h)**
- 99%CL ULs in VHE: **4.7/2.5/1.1**  $10^{-12}$  ph/cm<sup>2</sup>/s



MAGIC/VERITAS/H.E.S.S. common paper in prep.



# Summary

- 9 VHE  $\gamma$ -ray binaries, 7 visible by H.E.S.S.
- GeV-TeV connection remains complex to interpret (SED, correlated/anti-correlated variability of fluxes; knowledge of the system parameters/nature).
- The CWB system Eta Carinae is now detected at VHE, thanks to H.E.S.S. instrument improvement. No variability seen. But this is compatible with contemporaneous HE observations (2014). Forthcoming H.E.S.S. publication.

New observations foreseen in 2020 for the next periastron passage.

- LMC-P3 @  $\sim 50$  kpc is the brightest binary observed so far, seen recently at VHE.
- PSR B1259-63 updated data-set and analysis will be published soon.
- HESS J0632+057 new and updated observations with H.E.S.S., MAGIC and VERITAS will be published soon.
- A ToO program to catch interesting events of transients ( $\mu$ Q, spider binaries, CVs, transitional ms pulsars) is conducted in H.E.S.S.