MAGIC Gamma-ray Binaries

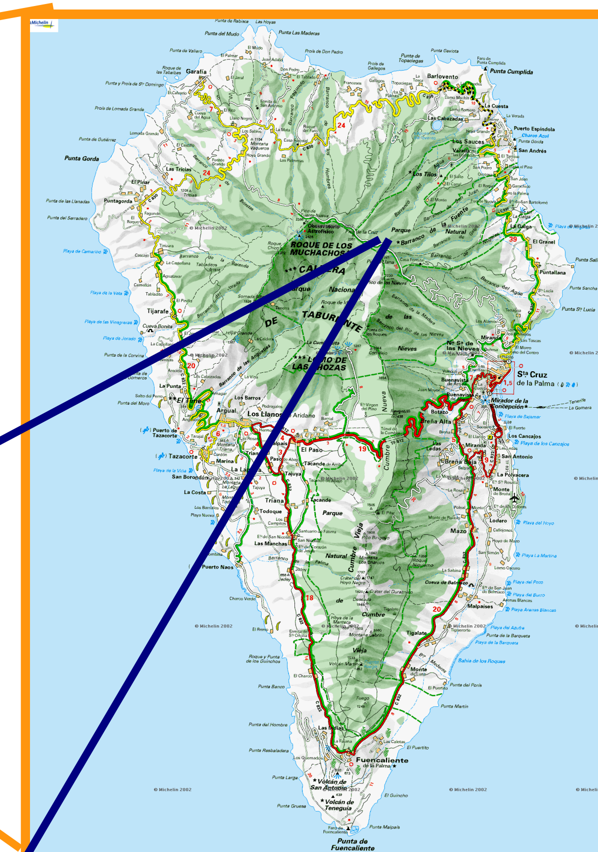
Oscar Blanch Bigas (IFAE)
for the MAGIC collaboration

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

Institut de Física
d'Altes Energies
IFAE

The MAGIC Telescopes

MAGIC is an Imaging Atmospheric Cherenkov Telescope system consisting of two 17m diameter telescopes, located on Canary island La Palma



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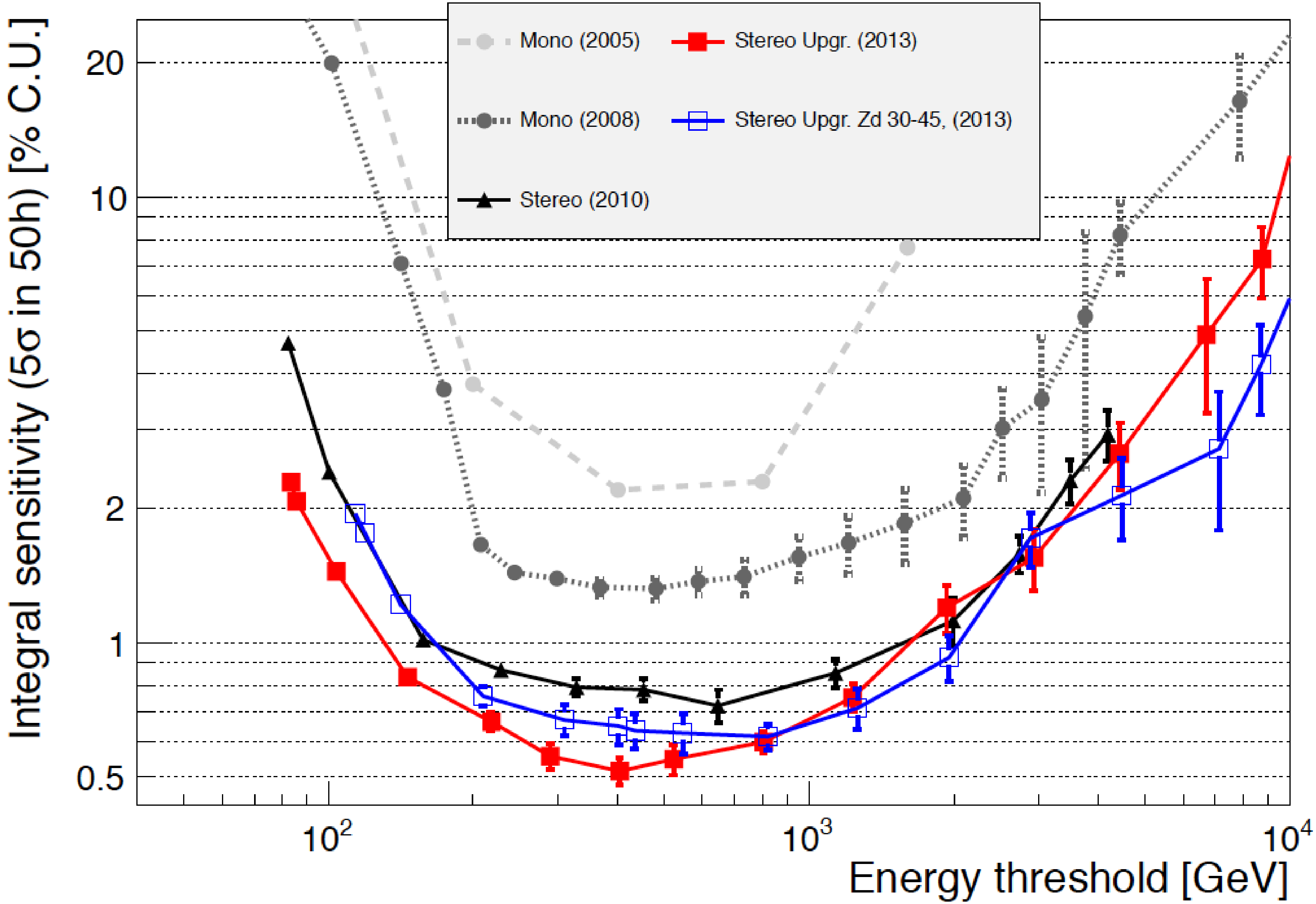
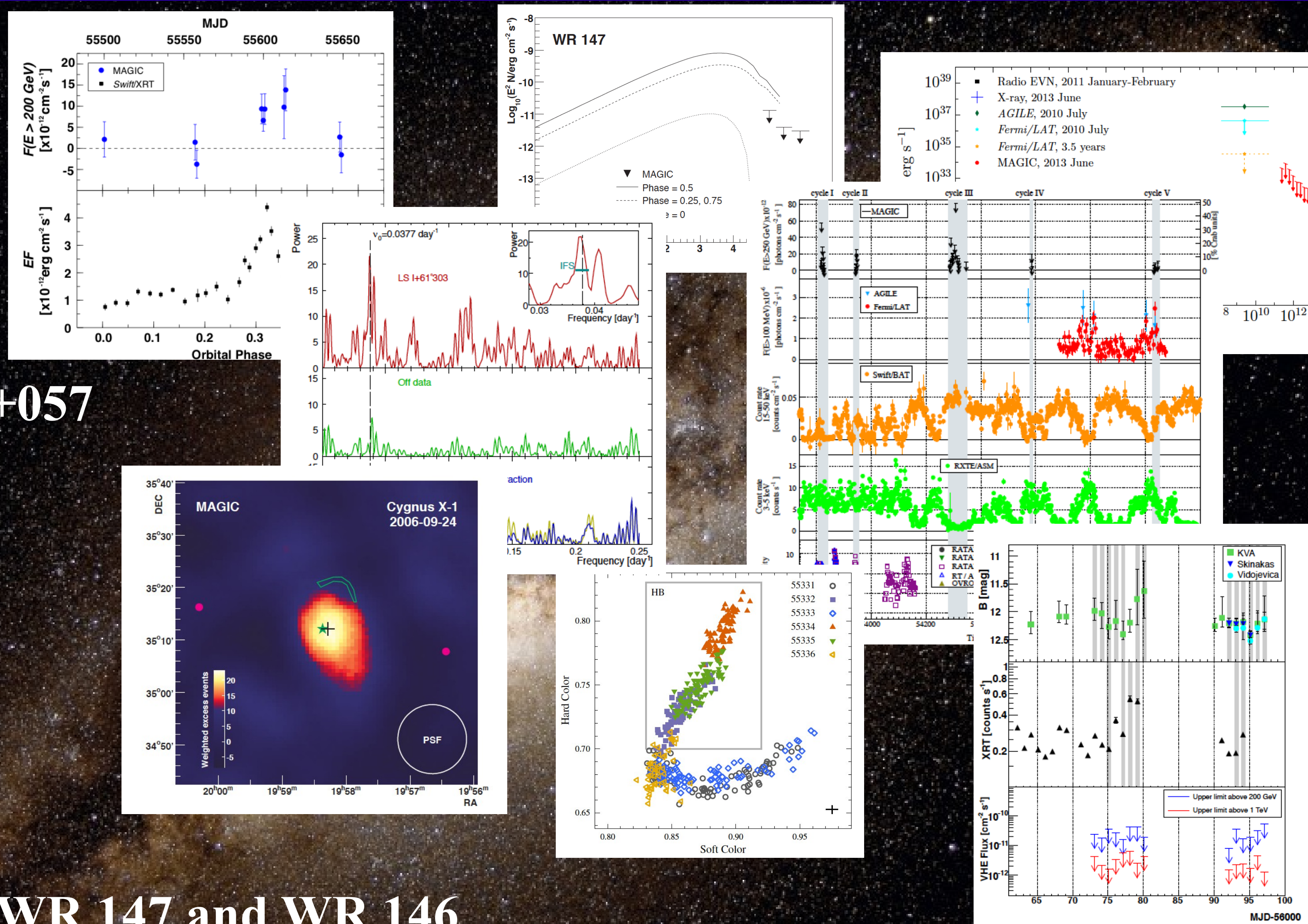
Aleksic et al. (MAGIC) Astropart.Phys



MAGIC results on gamma-ray binaries



- LS I 61+303
- HESS J0632+057
- SS 433
- MWC 656
- Cyg-X1
- Cyg-X3
- Scorpius-X1
- Wolf-Rayet: WR 147 and WR 146
- Cataclysmic Variables: AEAqr, V339Del, YY Her, ASASSN-13ax

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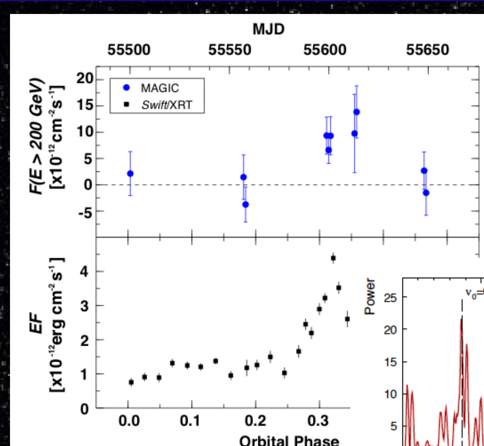

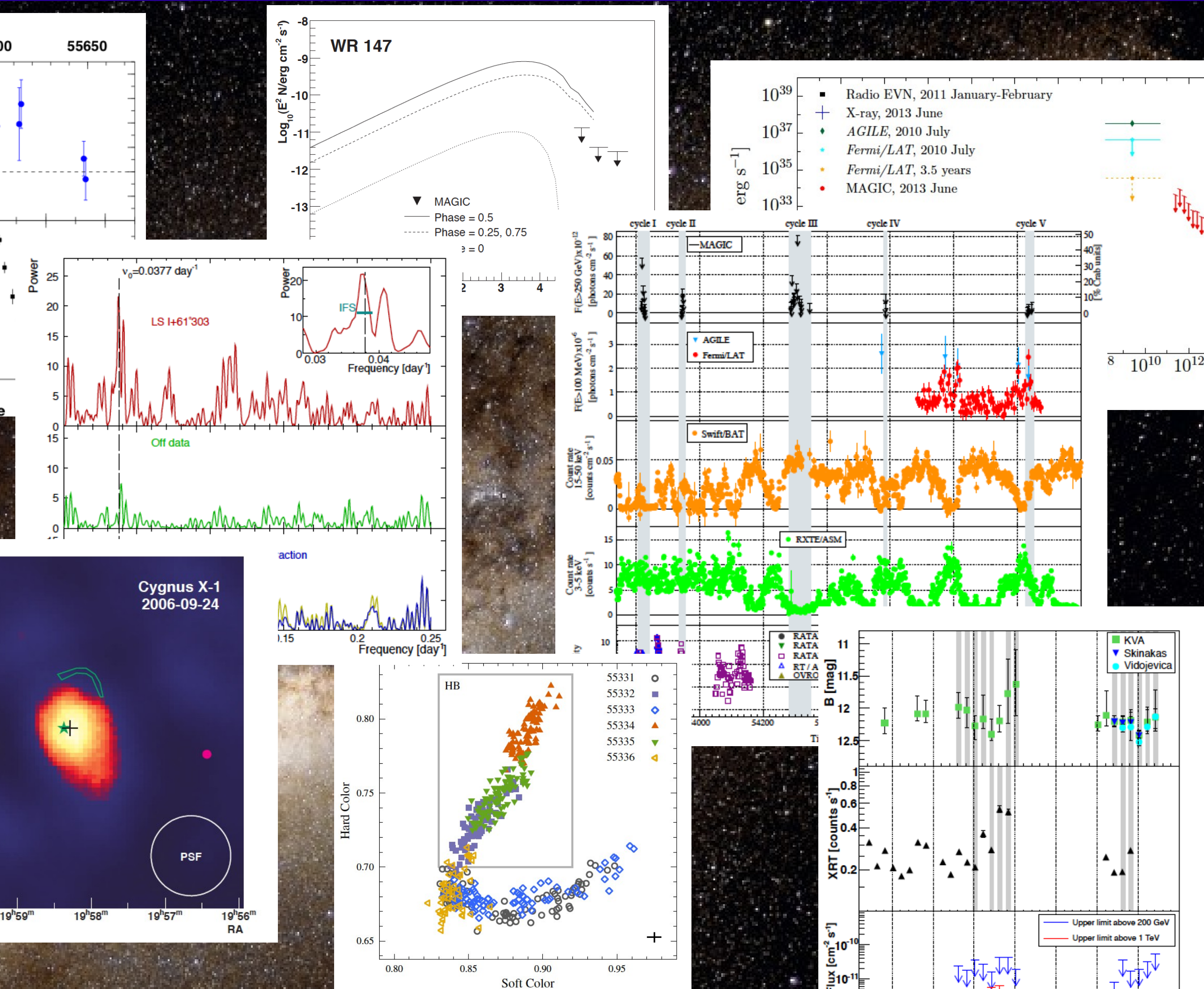

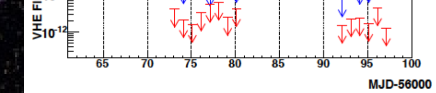

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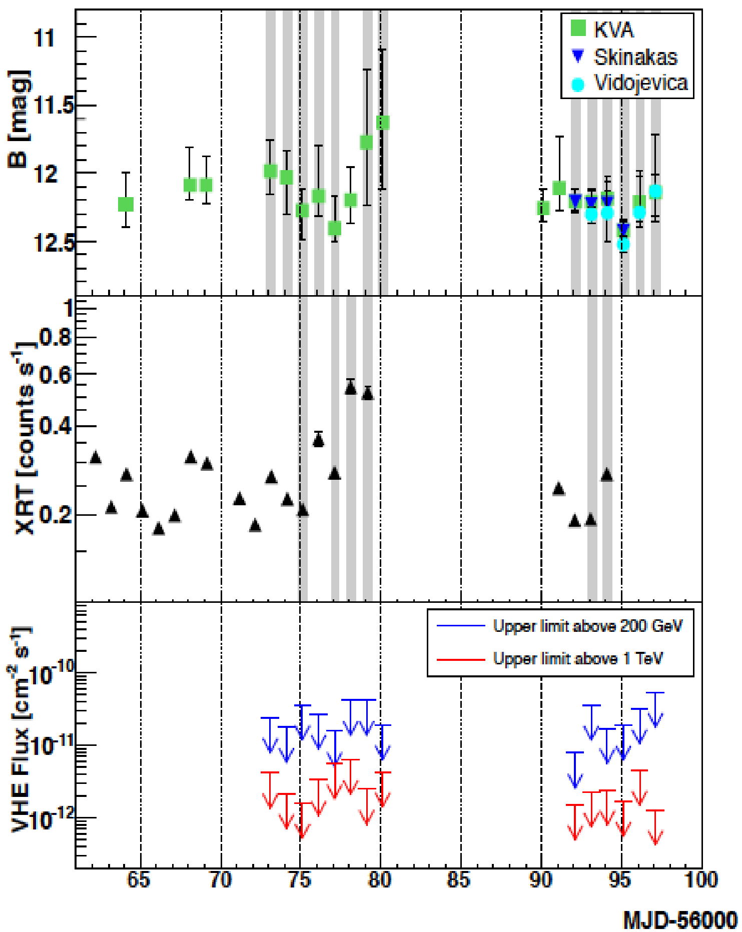
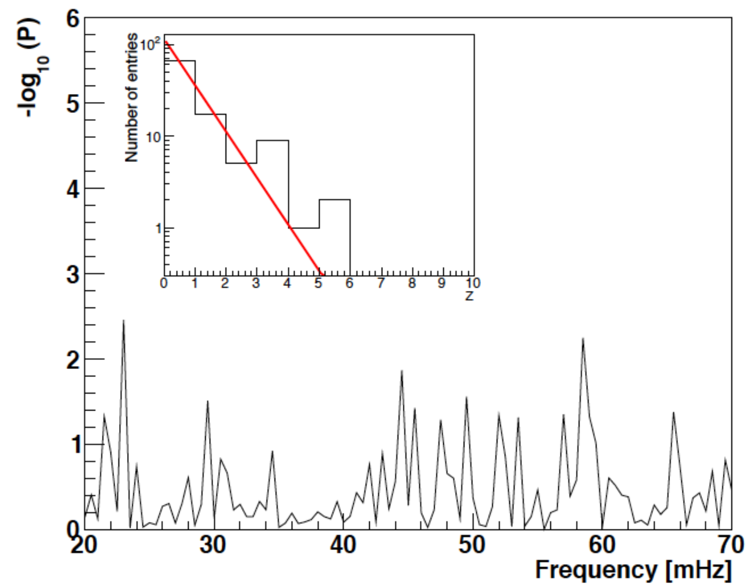
Cataclysmic Variables (CV): AE Aqr and ...

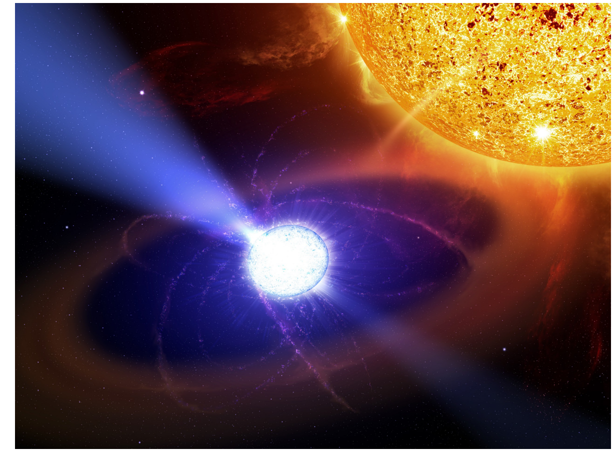
Aleksic et al. (MAGIC) A&A 568, 2014



- White dwarf + K4-5V @ 100pc
- T_O = 9.88 h; T_S=33.08 s
- Flaring (MWL) ~50% time
- Propeller model F>5%Crab @ 1TeV

(~10^{-12} $cm^{-2}s^{-1}$)





B [mag]	U.L. (95 % C.L.) [$cm^{-2}s^{-1}$] > 200 GeV	> 1 TeV
< 11.5	2.1×10^{-11}	1.6×10^{-12}
< 12	7.3×10^{-12}	1.2×10^{-12}

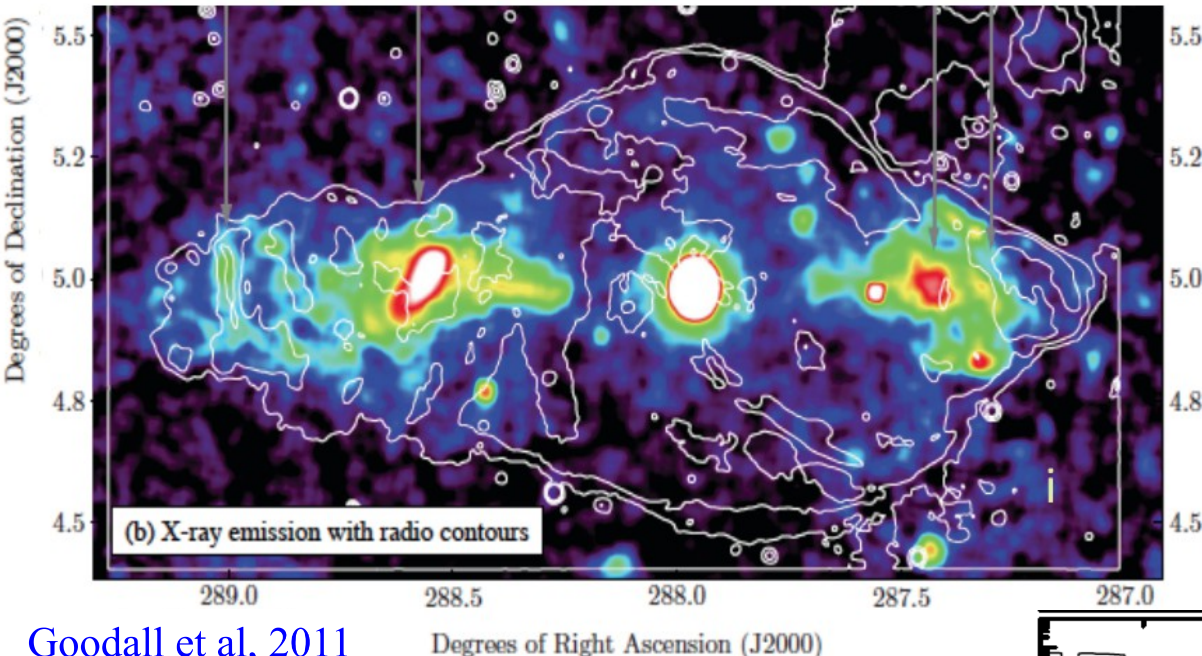
Frequency	U.L. (95 % C.L.) [$cm^{-2}s^{-1}$] > 200 GeV	> 1 TeV
30.23 mHz	2.6×10^{-12}	2.6×10^{-12}
60.46 mHz	2.1×10^{-12}	3.7×10^{-12}

Upper Limit well below Propeller model and ancient detections

MAGIC follow up program → V339Del (Classical Nova), YY Her (Symbiotic Nova), ASASSN-13ax (Dwarf Nova)

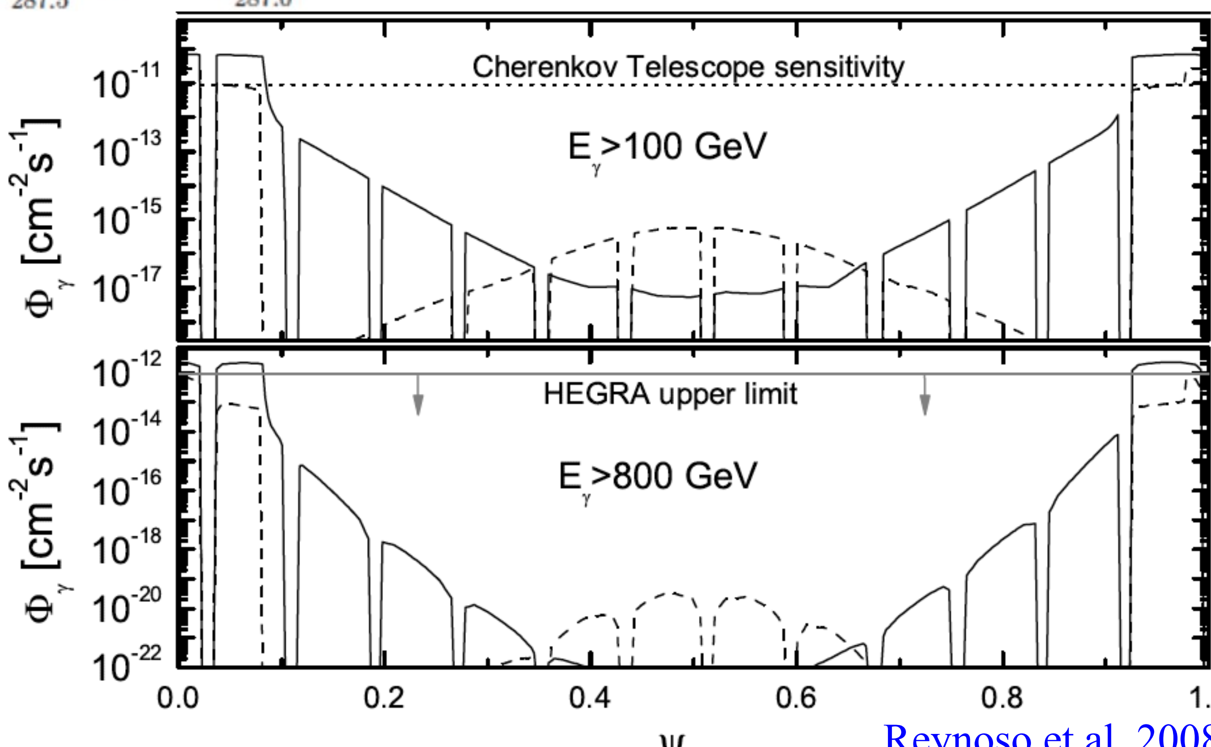
Ahnen et al. (MAGIC) to be submitted to A&A

SS 433



Goodall et al, 2011

- Super-critical accretion
- Strongly-collimated hadronic persistent relativistic jets
- Precessional and orbital periods have remained constant over decades



Reynoso et al, 2008

Observation campaign performed in collaboration with HESS

Analysis basically complete and working on a joint publication

MWC 656

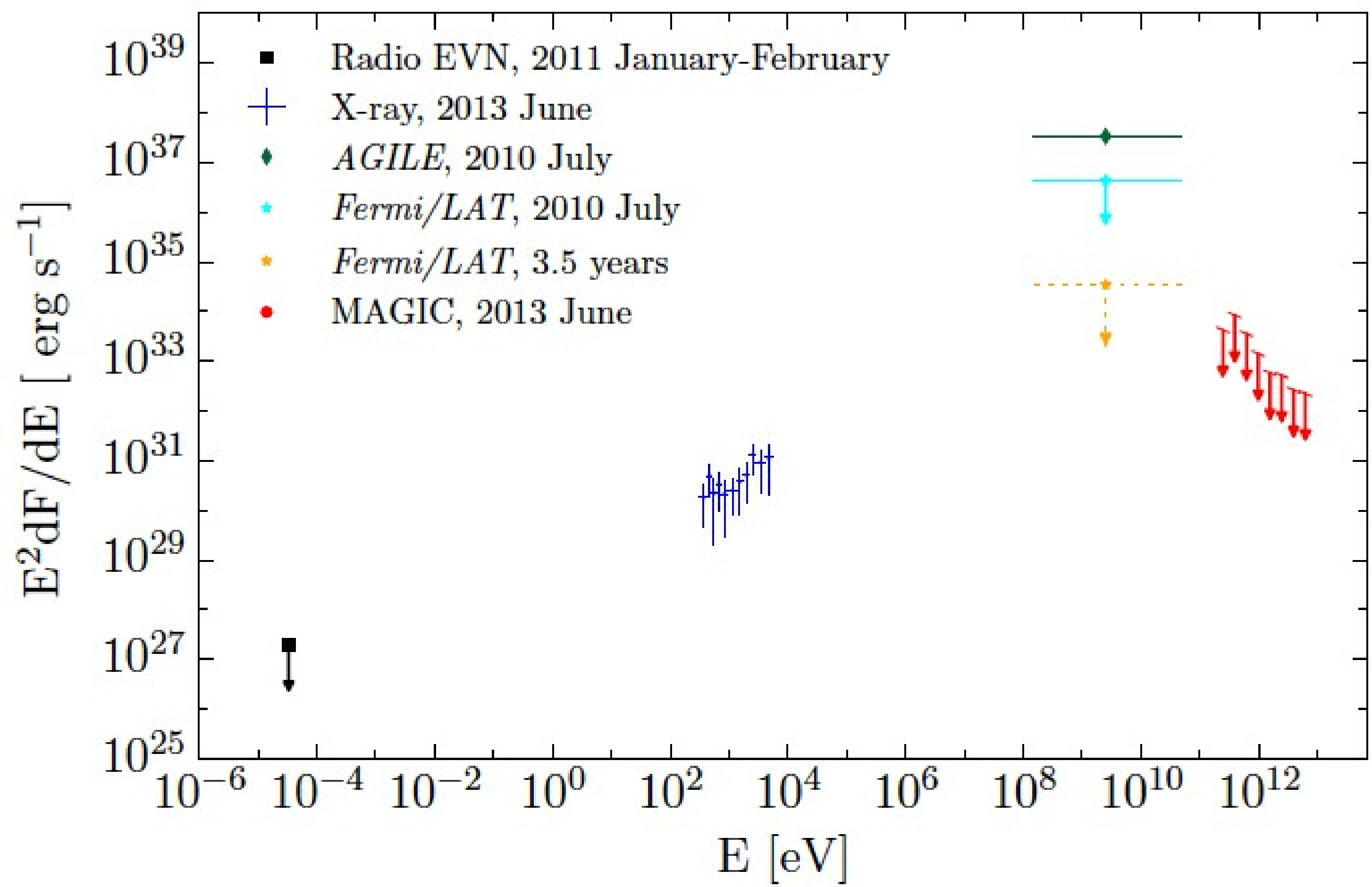
On July 2010, AGILE detected a gamma-ray point-like source positionally coincident with MWC 656

Optical Spectroscopy has allowed to classify it as the first known case of a Be/BH system

Lucarelli et al, 2010

Casares et al, 2014

Aleksic et al. (MAGIC) A&A 576, 2015



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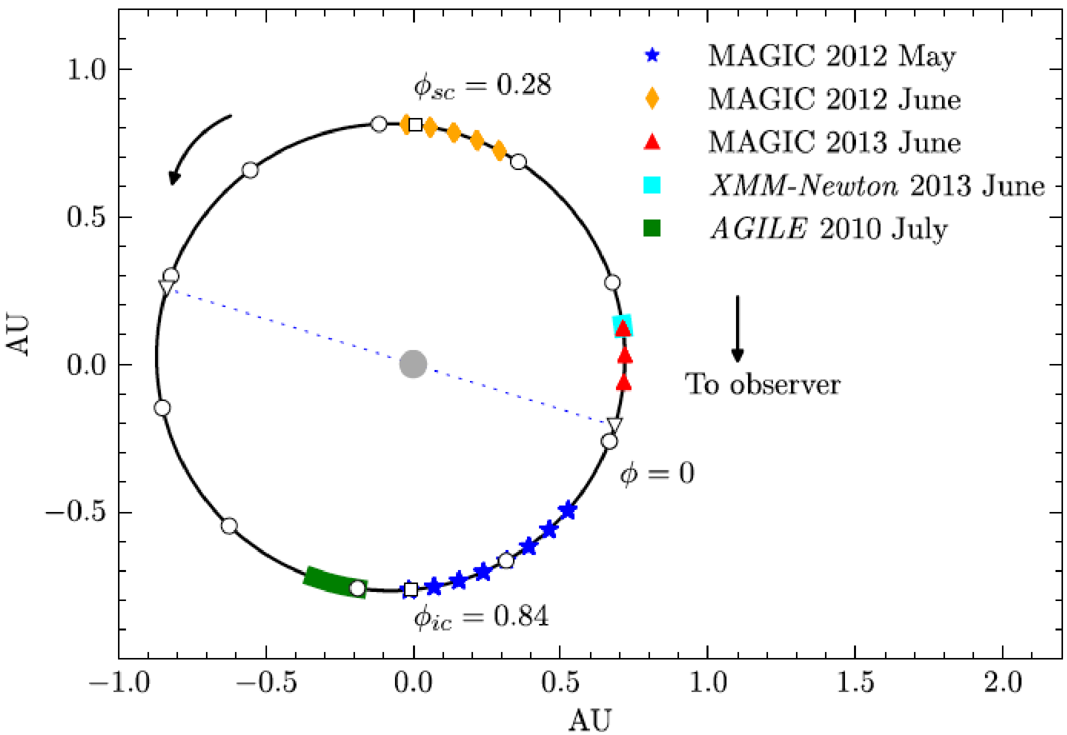
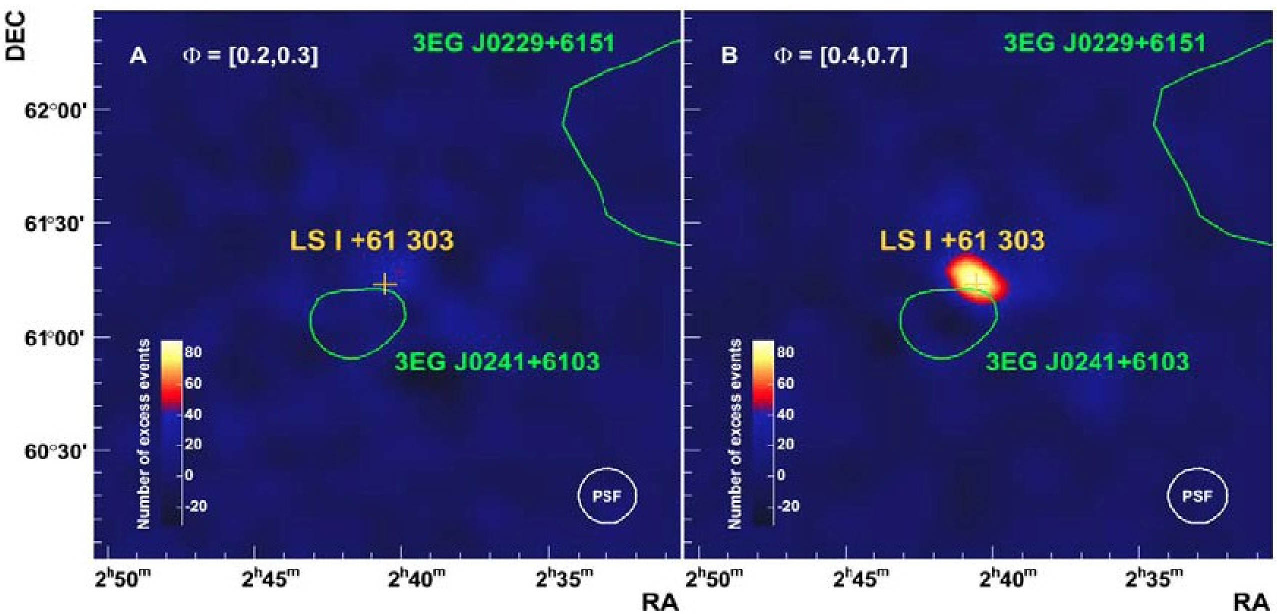
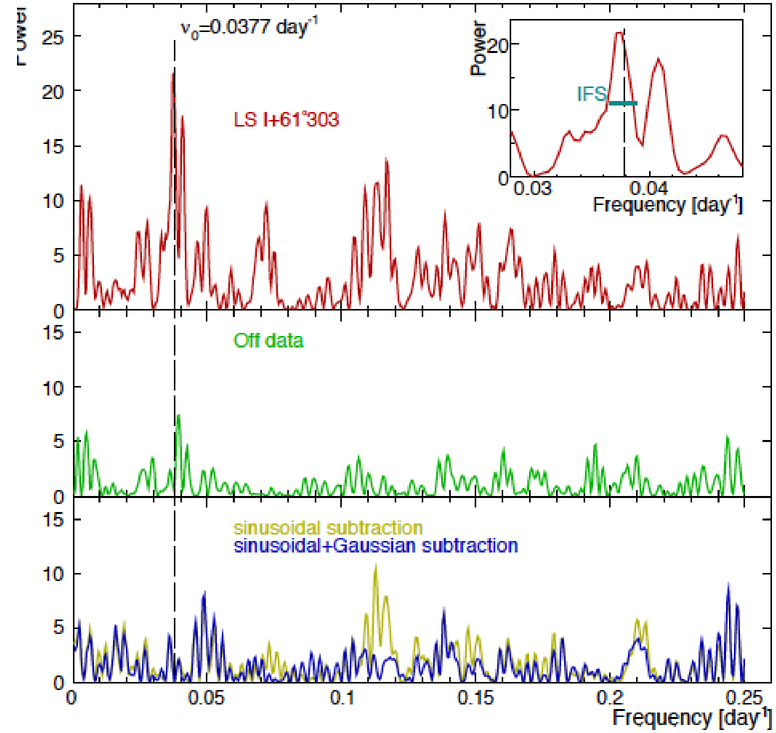


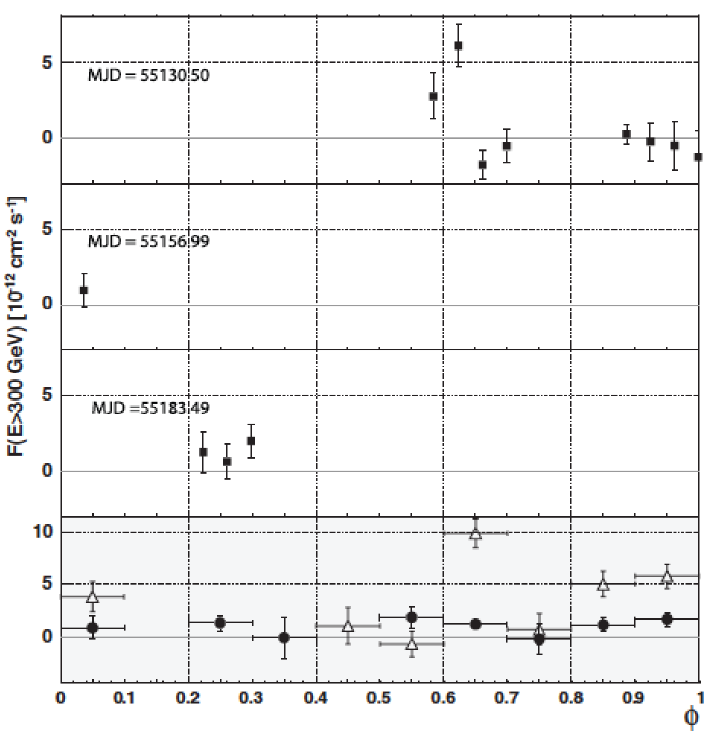
Mode	Phase bin	Integral UL (E >300 GeV) (10^{-12} cm^{-2} s^{-1})	Significance (σ)	t_{eff} (h)
stereo	0.0–0.1	2.0	1.0	3.3
mono	0.2–0.3	8.7	2.1	4.9
mono	0.8–0.9	6.5	1.0	11.5
mono	0.9–1.0	2.5	−1.1	4.9

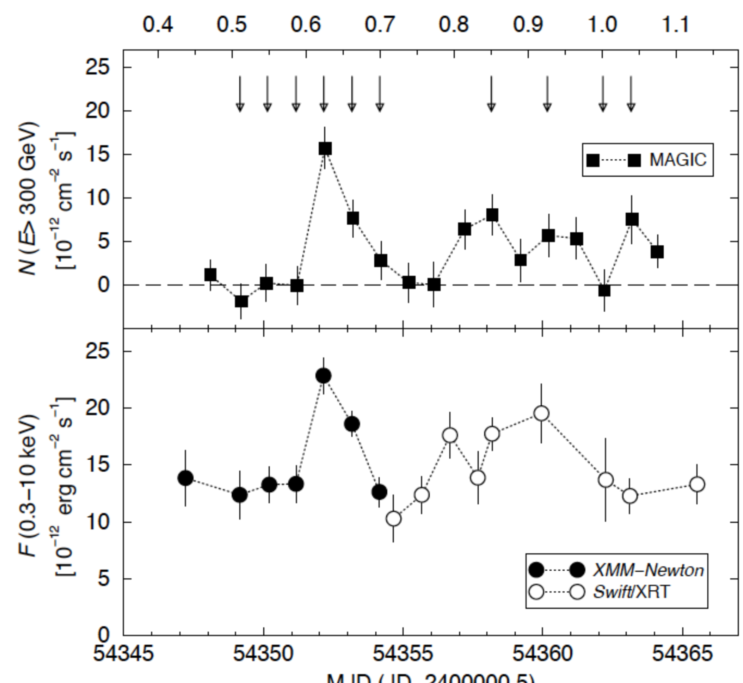
No steady neither periodic emission observed

LS I 61+303 : 2006 - 2009









LS I 61+303: Continuation

We kept monitoring the behaviour of LS I 61 +303 … already for almost a decade

Mainly in orbital phase from 0.5 to 1.0

Preliminary

Orbit Number	MJD Range	$\phi_{orbital}$ Range	$\phi_{super-orbital}$	Time hours	Number of days
1	55415.2	0.75	0.23	1.14	1
2	55441.2 - 55444.2	0.73 - 0.84	0.25	3.98	3
3	55471.1	0.86	0.27	0.76	1
4	55486.1 - 55500.1	0.42 - 0.95	0.28	3.63	4
5	55512.0	0.40	0.29	1.92	1
6	55543.0	0.57	0.30	2.06	1
7	55568.9 - 55574.0	0.55 - 0.74	0.32	10.81	6
21	55944.0 - 55945.0	0.70 - 0.74	0.55	2.56	6
22	55969.8 - 55977.8	0.68 - 0.99	0.56	3.91	6
32	56242.0 - 56243.0	0.95 - 0.99	0.72	2.20	2
33	56266.9 - 56267.9	0.89 - 0.93	0.74	2.10	2
34	56295.9 - 56296.8	0.99 - 0.01	0.77	4.04	2
44	56549.1 - 56550.1	0.54 - 0.58	0.91	5.67	2
45	56576.1 - 56579.1	0.56 - 0.67	0.92	7.90	4
46	56602.0 - 56607.1	0.54 - 0.73	0.94	9.90	5
48	56656.9 - 56663.9	0.61 - 0.87	0.98	15.65	8
57	56900.1	0.79	0.12	2.22	1
58	56920.1 - 56930.1	0.54 - 0.92	0.13	20.72	10

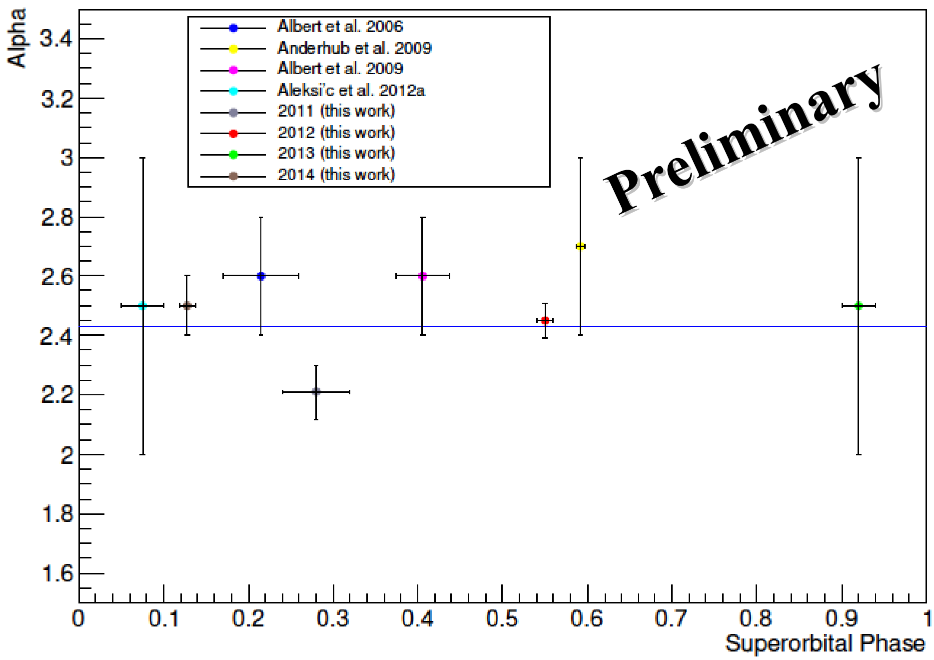
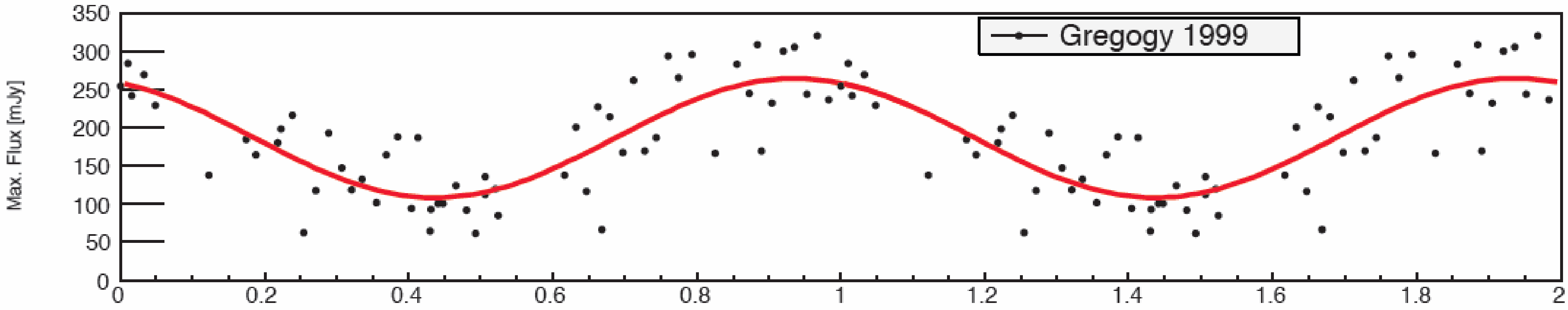
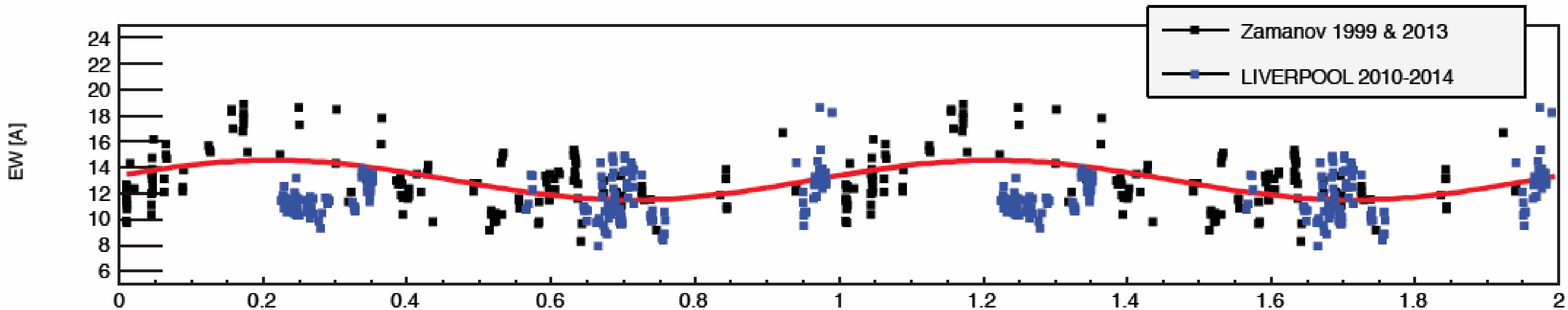


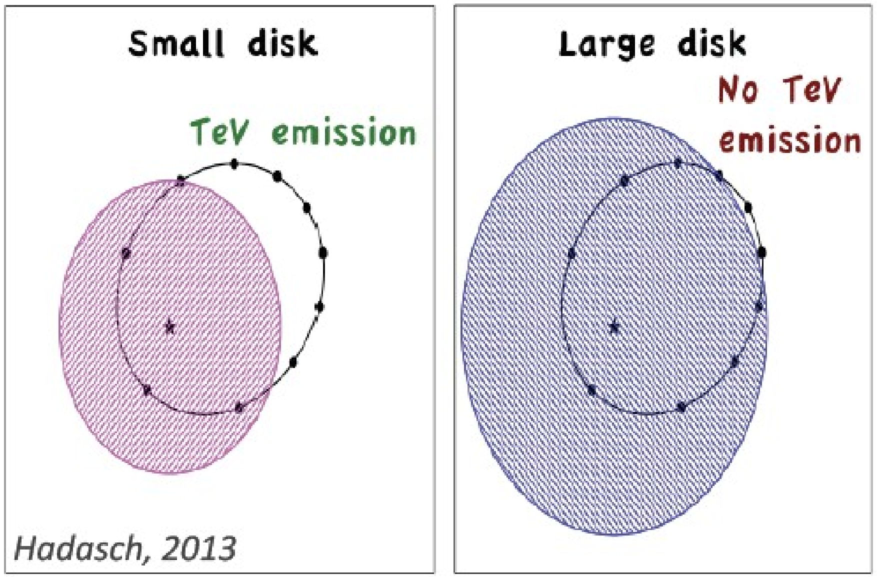
Fig. 1. Super-orbital dependence of the spectral index for all MAGIC campaigns of LS I +61°303, considering a 1667 days period. The blue line corresponds to the average value.

We already cover about two super-orbital periods
(found first in radio and confirmed in optical and HE gamma-rays)
Since end 2014, monitoring coordinated with VERITAS

LS I 61+303



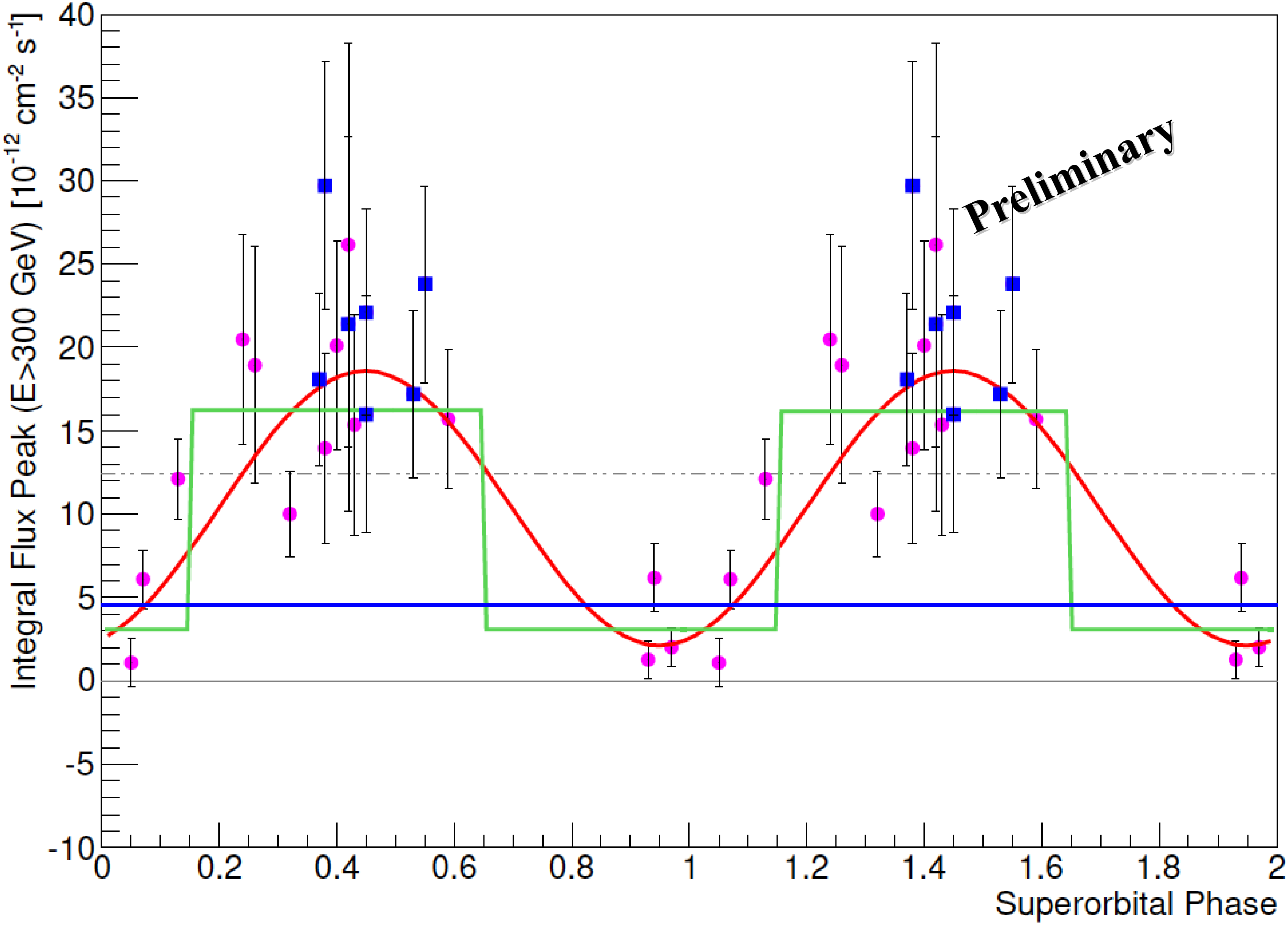




Torres et al, 2012

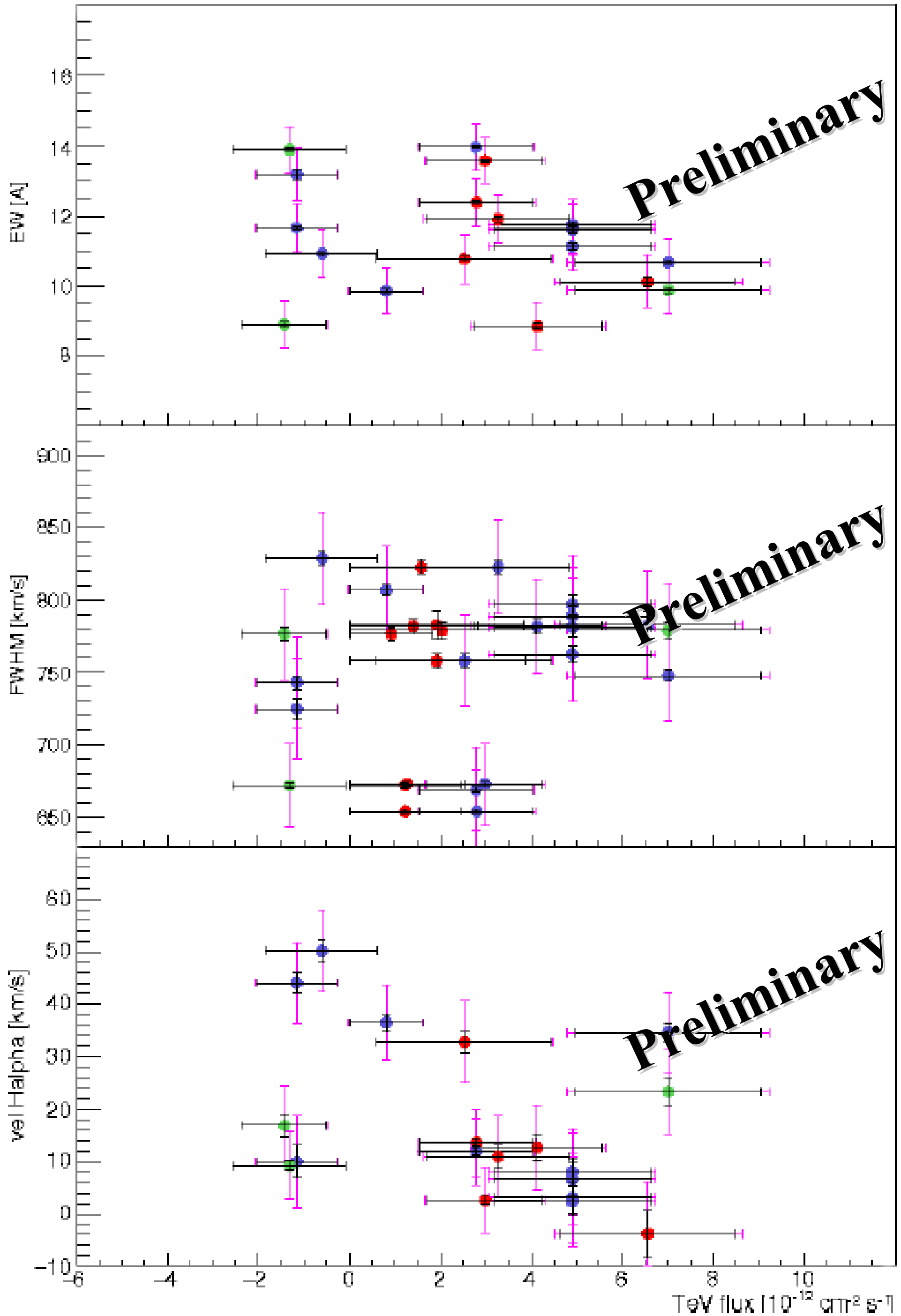
- Flip-flop model could explain super-orbital modulation
- Anti correlation HE and VHE
- The larger the mass lost rate, the lower VHE emission

LS I 61+303



Amplitude of VHE periodic peak shows modulation compatible with the super-orbital phase

LS I 61+303



Simultaneity	Parameters	*r*	Prob
Nightly	TeV - EW	-0.23	0.84
Nightly	TeV - FWHM	-0.14	0.72
Nightly	TeV - vel	-0.44	0.97
3 hours	TeV - EW	-0.32	0.80
3 hours	TeV - FWHM	-0.24	0.74
3 hours	TeV - vel	-0.45	0.90
Strict	TeV - EW	-0.25	0.58
Strict	TeV - FWHM	0.40	0.53
Strict	TeV - vel	0.95	0.24

Preliminary

Optical observation to measure mass loss rate

- Measurement through H-alpha lines
- Phase with sporadic emission observed
- Simultaneity critical (large variation from optical on hour scales)

Summary

- MAGIC has a large observation program on gamma-ray binaries since the beginning (and keeps devoting time to it):
  - ➔ Micro-quasar
  - ➔ X-ray Binaries
  - ➔ Cataclysmic Variables

- A dedicated running program aiming to detect Cataclysmic Variables (mainly Novae after Fermi detected them)

- Looking for new Gamma-ray binaries:
  - ➔ UL on MWC 656, first known Be/BH binary
  - ➔ Coordinated campaign (with HESS) to observe SS433

- Deep study on LS I 61 +303:
  - ➔ Super-orbital modulation
  - ➔ Long term (almost a decade) behaviour
  - ➔ Coordinated campaign (with VERITAS) to keep monitoring

The end