# MAGIC VHE γ-ray observations of transient and variable stellar objects

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## Variable systems – focus on a few





## NOVAE

# Novae follow-up program

- Fermi/LAT detected 5 novae  $\rightarrow$  New class of  $\gamma$ -ray emitters
- Possible interpretation: Inverse Compton process of electrons accelerated in a shock
- **Expectation**: **Protons** in the same conditions can be accelerated to much higher energies due to lower energy losses

 $\rightarrow$ Produce a second component in the  $\gamma$ -ray spectrum at TeV energies

- MAGIC conducted follow-up program to detect this possible VHE γray component
  - Classical nova: V339 Del
  - Dwarf nova: ASASSN-13ax
  - Symbiotic nova: **YY Her**

#### **Observed Novae**

- ASASSN-13ax & YY Her
  - No detection neither at GeV (Fermi/LAT) nor TeV (MAGIC)
- V339 Del: outburst in August 2013
  - Exceptional bright in optical (V~5 mag)
  - Detection in GeV by Fermi/LAT
  - 11.6 h MAGIC data  $\rightarrow$  no detection





ASASSN-13ax

# Modeling of V339 Del

- GeV γ-ray emission: Photosphere of the novae provides dominant target for IC process of electrons
- Protons with energies up to 1.1 TeV are expected to accompany the electrons
- Comparing MAGIC upper limits with the predicted γ-ray emission
  → Constraint on the total luminosity of protons being less than about 15% of the one of electrons





#### **AE AQUARII**

# Cataclysmic Variables: AE Aquarii

- Outbursts observed at Radio, IR, Optical and X-Ray at 50 % of time
- **Dubious detections** at  $\gamma$ -ray energies
- Orbital period T<sub>o</sub>=9.88 h / Rotating period T<sub>s</sub>=33 s (shortest known)
- Motivation: Non-thermal radio emission related to  $\gamma$ -ray emission  $\rightarrow$ Flares at different wavelength are expected to be correlated with the ones at  $\gamma$ -rays



# AE Aquarii: multi wavelength

- MAGIC established most constraining upper limits
  - Flux U.L. at the same level for all days, independently of the state of the source in the optical or X-rays
  - Upper limit well below certain model predictions and ancient detections
  - Ejecting white dwarf model consistent with upper limits, could be detected with CTA

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

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





#### **SS443**

### SS443 – the system

- Precessional and orbital periods constant over decades
  - P<sub>or</sub> ~13 days, P<sub>pre</sub> ~162 days
- Only galactic super-critical accretor
- Strongly-collimated persistent hadronic relativistic jets
- Embeded in W50 nebula
  - Interaction between jets and nebula: east & western blobs
  - X-ray emission & radio non-thermal emission



TeVPA 2015

# SS443 - Observation strategy

- Absorption of putative emission in ~80% orbit
- Best opportunity for observations: Φpre=0.91-0.09
- Observation campaign performed in collaboration with H.E.S.S.
  - No excess detected
  - Constrain model by Reynoso et al., 2008





#### **MWC 656**

#### MWC 656

- July 2010: AGILE detected a gamma-ray point-like source positionally coincident with MWC 656 (Lucarelli et al, 2010)
- Optical Spectroscopy has allowed to classify it as the first known case of a Be star/Black Hole system (Casares et al, 2014)
- Orbital period of 60.37±0.04 days



#### MWC 656

- No steady nor periodic emission observed
  - AGILE detection just transient event of unknown nature?
  - Different emission levels depending on the state where the system is, i.e; quiescence or accreting state?





#### LS I +61° 303

- GeV source discovered at TeV energies by MAGIC (2006); follow-ups by MAGIC and VERITAS
- Orbital period
  - 26.496 +/- 0.0028 days (Gregory et al. 2002)
- Periodic radio outbursts (Gregory et al. 2002)
  - Superorbital period: (1667 +/- 8) days
  - Recently found in X-rays & GeV energies
  - What about TeV energies?





## Superorbital TeV behavior



→ Amplitude of VHE periodic peak show modulation compatible with the superorbital phase

TeVPA 2015

## **Possible explanation**



#### Correlation TeV - H $\alpha$



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 - EWAY	0.32	0.80
3 hours	TeV IM HM	-0.24	0.74
3 hours	PTRev - 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

- **Possible tracer** for disk size: Equivalent width of  $H\alpha$  line
- Large variation of EW of H $\!\alpha$  line
- → Blurs possible correlation?

# Summary

- MAGIC has a dedicated running program aiming to detect Novae and Cataclysmic Variables
  - No detection up to now in TeV
- Looking for new Gamma-ray binaries
  - → UL on MWC 656, first known Be/BH binary
  - → Coordinated campaign (with H.E.S.S.) to observe SS433
- Deep study on LS | 61° +303
  - → Super-orbital modulation
  - → Long term (almost a decade) behaviour
  - → Coordinated campaign (with VERITAS) to keep monitoring