

VHE gamma-ray observations of transient and variable stellar objects with the MAGIC telescopes

**ALBA FERNÁNDEZ BARRAL
FOR THE MAGIC COLLABORATION**

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**Institut de Física
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*INTERNATIONAL COSMIC RAY
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THE HAGUE, AUGUST 1ST 2015*

THE MAGIC TELESCOPES

- * Stereoscopic system of two 17 m diameter IACTs
- * Located at La Palma (Canary Islands)



2004-2009 → Stand-alone MAGIC I

2009 → Construction of MAGIC II

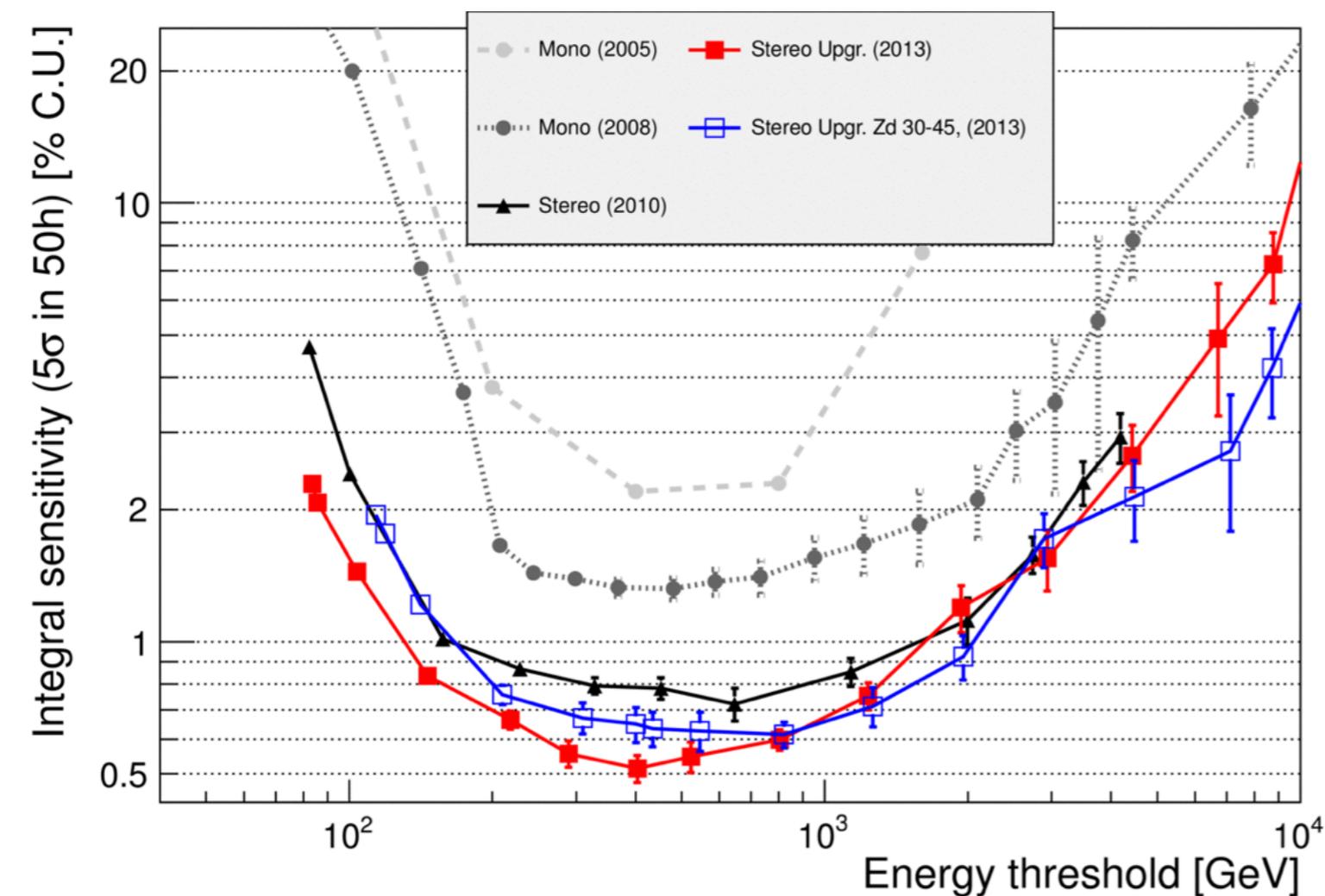
2011-2012 → Major upgrade

THE MAGIC TELESCOPES

* Integral sensitivity

Stereoscopic mode: $0.67 \pm 0.04\%$ Crab Nebula flux ($E > 290 \text{ GeV}$)
in 50h

Stand-alone mode: $1.60 \pm 0.03\%$ Crab Nebula flux ($E > 280 \text{ GeV}$)
in 50h



[Aleksić et al. DOI: 10.1016/j.astropartphys.2015.02.005](https://doi.org/10.1016/j.astropartphys.2015.02.005)

MAGIC RESULTS ON TRANSIENT AND VARIABLE STELLAR OBJECTS

* Sources observed with the MAGIC telescopes

X-ray binary systems

Cygnus X-1
LS I +61 303
MWC 656
Cygnus X-3
SS 433

Wolf-Rayet Stars:

WR 146
WR 147

Cataclysmic Variable

AE Aqr
V339Del
YY Her
ASASSN -13ax

Supernovae:

SN 2014J

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CYGNUS X-1

- One of the brightest HMXBs → $17-31 M_{\odot}$ O9.7 lab + $15 M_{\odot}$ BH
- Located in the Cygnus region at 2.15 ± 0.2 kpc
- Microquasar → one-sided radio-emitting jet (opening angle < 2 deg, $v > 0.6c$)
- Typical BH transient system → soft & hard state

Hint 4.1σ MAGIC I, Sept 2006

$$dN/(dAdtdE) = (2.3 \pm 0.6) \cdot 10^{-12} (E/1 \text{ TeV})^{-3.2 \pm 0.6} \text{ cm}^{-2} \text{ s}^{-1} \text{ TeV}^{-1}$$

[Albert, J. et al. 2007, ApJ, 721, 843](#)

* Observations

5 campaigns during 5 years: June 2007-September 2014

83 hrs of good quality data, $z_d = (6, 50)$ deg: 69hr hard state & 14 hr soft state

* Results

Searches for the full data sample, on daily basis and as a function of X-ray states and → **No significant excess**

MWOC 656

- July 2010, γ -ray flare locally coincident (AGILE) [*Lucarelli et al. 2010, ATel 2761*](#)
- Unique binary \rightarrow Be star + $3.8-6.9M_{\odot}$ BH [*Casares et al. 2014, Nature, 505, 378-381*](#)
- Located at 2.6 ± 0.6 kpc
- Orbital period of 60.37 ± 0.04 days and periastron at $\Phi_{\text{per}} = 0.01 \pm 0.10$

* Observations

2 campaigns: May-June 2012 & June 2013 at $z_d = (20, 50)$ deg

21.3 hrs with MAGIC II ($\Phi = 0.2-1.0$) and 3.3 hrs in stereo ($\Phi = 0.0-0.1$)



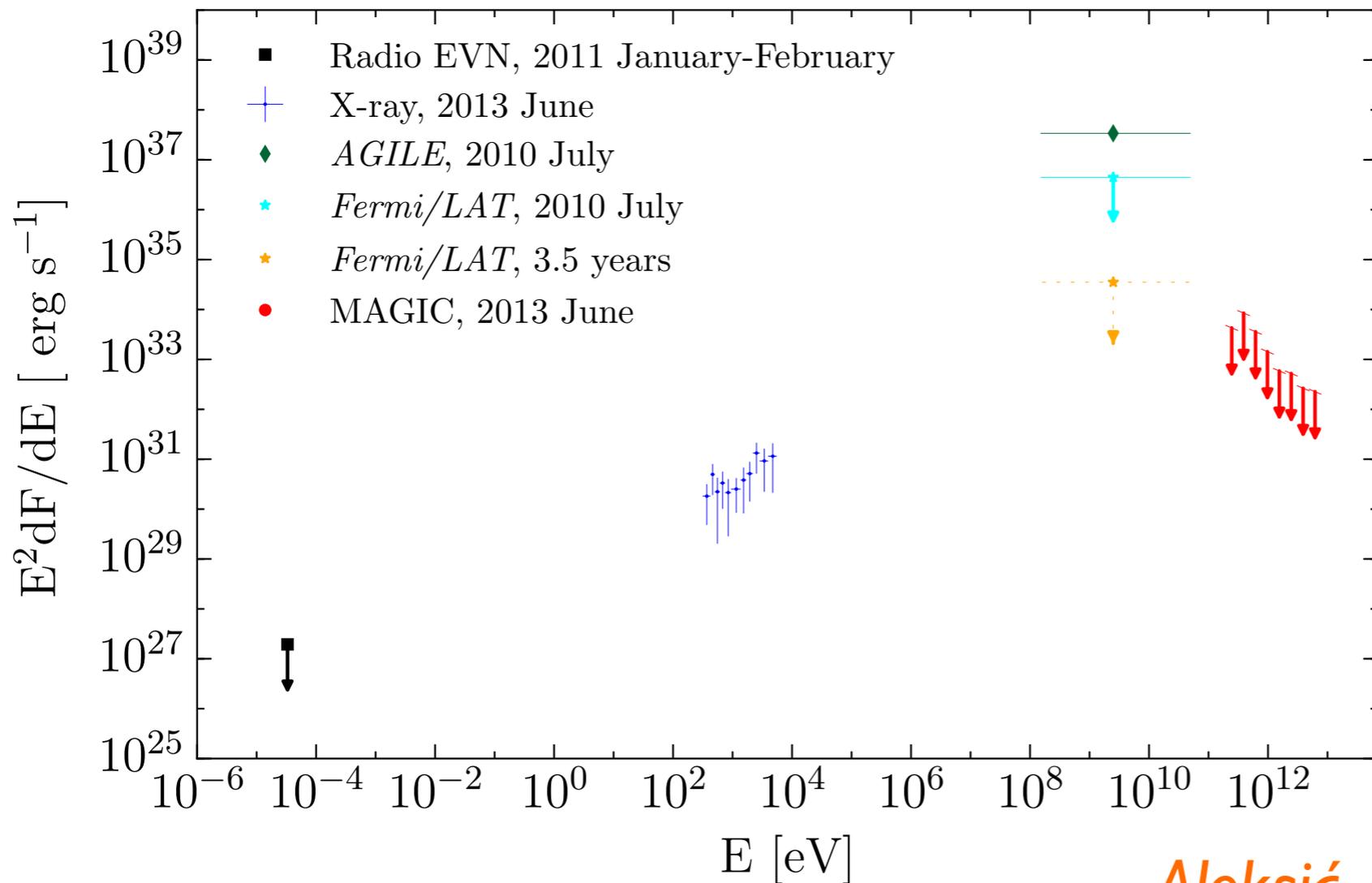
XMM-Newton right after MAGIC observations (June 4th, $\Phi = 0.8$, 1 hr)
STELLA-I observations (June 2nd-8th)

MWC 656

* Results

Searches on daily basis, steady emission with data distributed along a phase binning width of 0.1 → No significant excess ⇒ **Integral UL of**

$2.0 \cdot 10^{-12} \text{cm}^{-2} \text{s}^{-1}$ (95% CL, $E > 300 \text{GeV}$, $\Gamma = 2.5$)

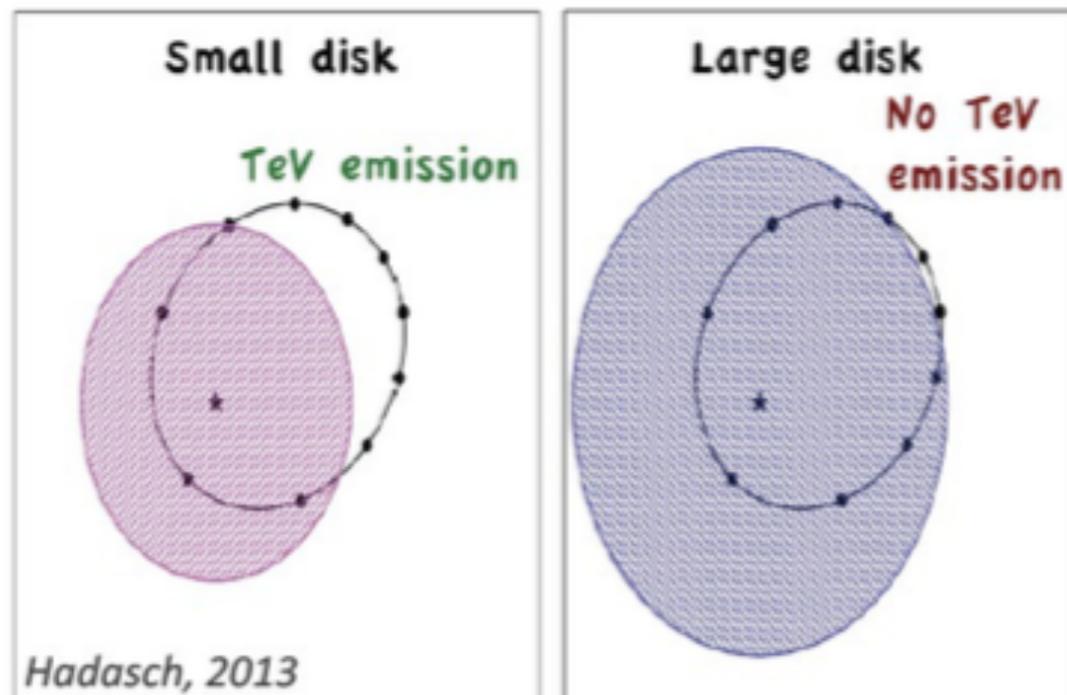


Differential UL from 245 GeV to 6.3 TeV, 95% CL, 5 bins per decade, $\Gamma = 2.5$ (2013 campaign)

[Aleksić, J. et al. 2015, A&A, 576, A36](#)

LS I +61°303

- Gamma-ray binary (detected from radio to VHE γ rays) \rightarrow Be star (B0Ve) with circumstellar disk + NS or BH
- Orbit eccentricity of 0.54 ± 0.03 , period of 26.4969(28) days, $\Phi_{\text{per}} = 0.23 \pm 0.03$
- First VHE on 2006 detection by MAGIC [Albert, J. et al. 2006, Science, 312, 1771-1773](#)
periodic outburst at 0.5-0.75, sporadic emission at 0.75-1.0 and at 0.081 (seen by VERITAS just once)
- Superorbital variability (optical, radio and HE) of 1667 ± 8 days \rightarrow Does it appear at VHE?
- Nature of the VHE emission unknown \rightarrow possible scenario: *flip-flop magnetar model* [Torres, D. F. et al. 2012, ApJ, 744, 106](#)



- It could explain superorbital variability
- Size of the disk-VHE emission anticorrelation expected

LS I +61°303

* Observations

Superorbital variability studies: Aug 2010-Sept 2014, $\Phi=0.5-0.75$ + archival MAGIC data (8-year campaign) and VERITAS published data

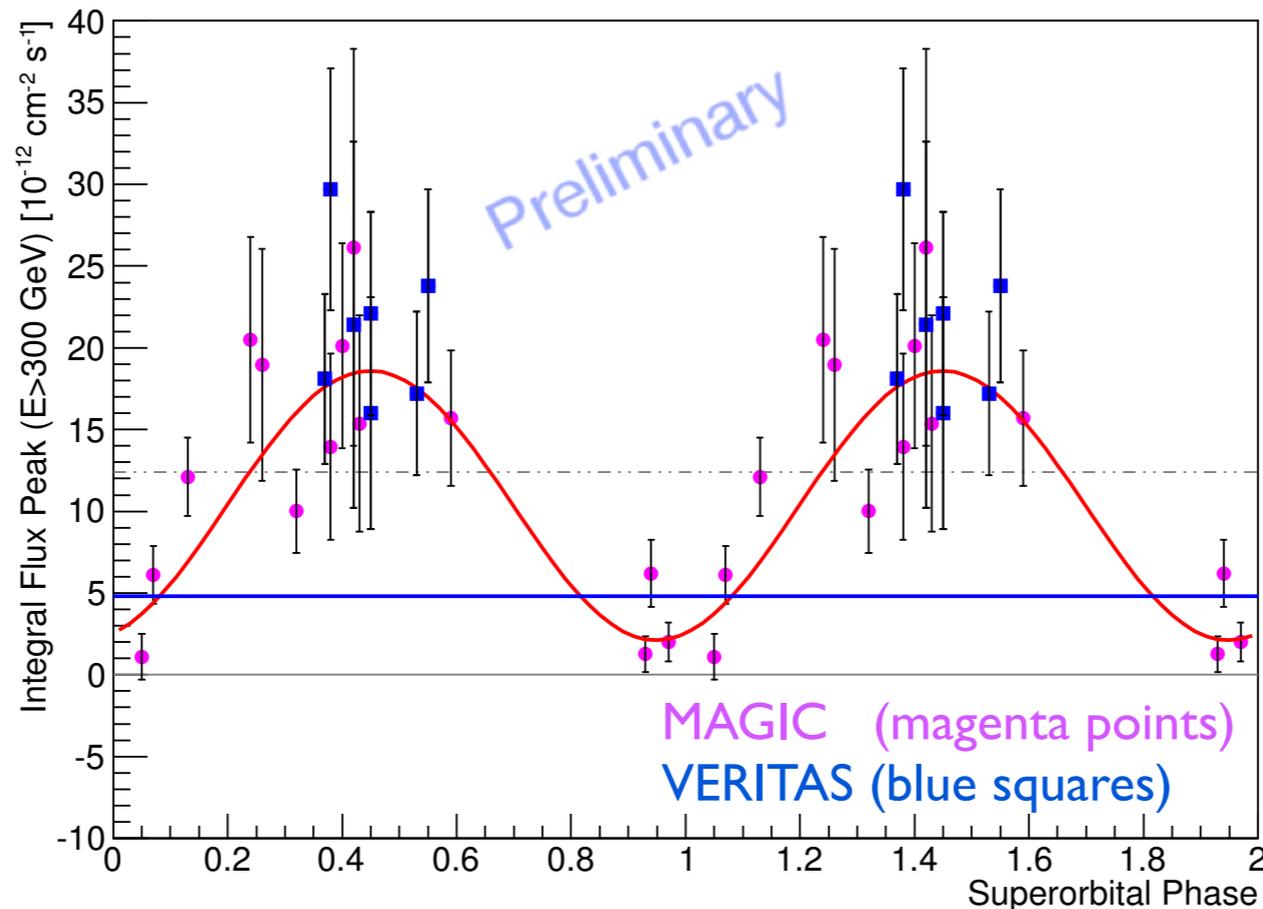
Viability of the flip-flop scenario: Searches on (anti-)correlation between TeV emission and the Be star mass-loss rate
MAGIC data from $\Phi=0.75-1.0$ + LIVERPOOL optical data

Spectral studies (different gamma-ray mechanisms production?): Entire sample, data split according superorbital and orbital phase and flux level

LS I +61°303

* Results

Superorbital variability studies: **Superorbital signature found** in the TeV regime compatible with the modulation found in radio.



Viability of the flip-flop scenario: **No (anti-)correlation found**. However, the different timescales between optical and TeV observations might blur the existence of (anti-)correlation between these bands.

Spectral studies (different gamma-ray mechanisms production?): All sample and subdivisions with spectral index compatible with **2.43 ± 0.04** .

SN 2014J

- First detected by UCL Observatory on January 21st, 2014
- The nearest SN Type Ia in the last 4 decades
- Located in M82 at 3.6 Mpc
- M82 detected by VERITAS ($E > 700 \text{ GeV}$), $(3.70 \pm 0.8_{\text{stat}} \pm 0.7_{\text{sys}}) \cdot 10^{-13} \text{ cm}^{-2} \text{ s}^{-1}$
[Acciari, V.A. et al. 2009, Nature, 462, 770-772](#)

* Observations

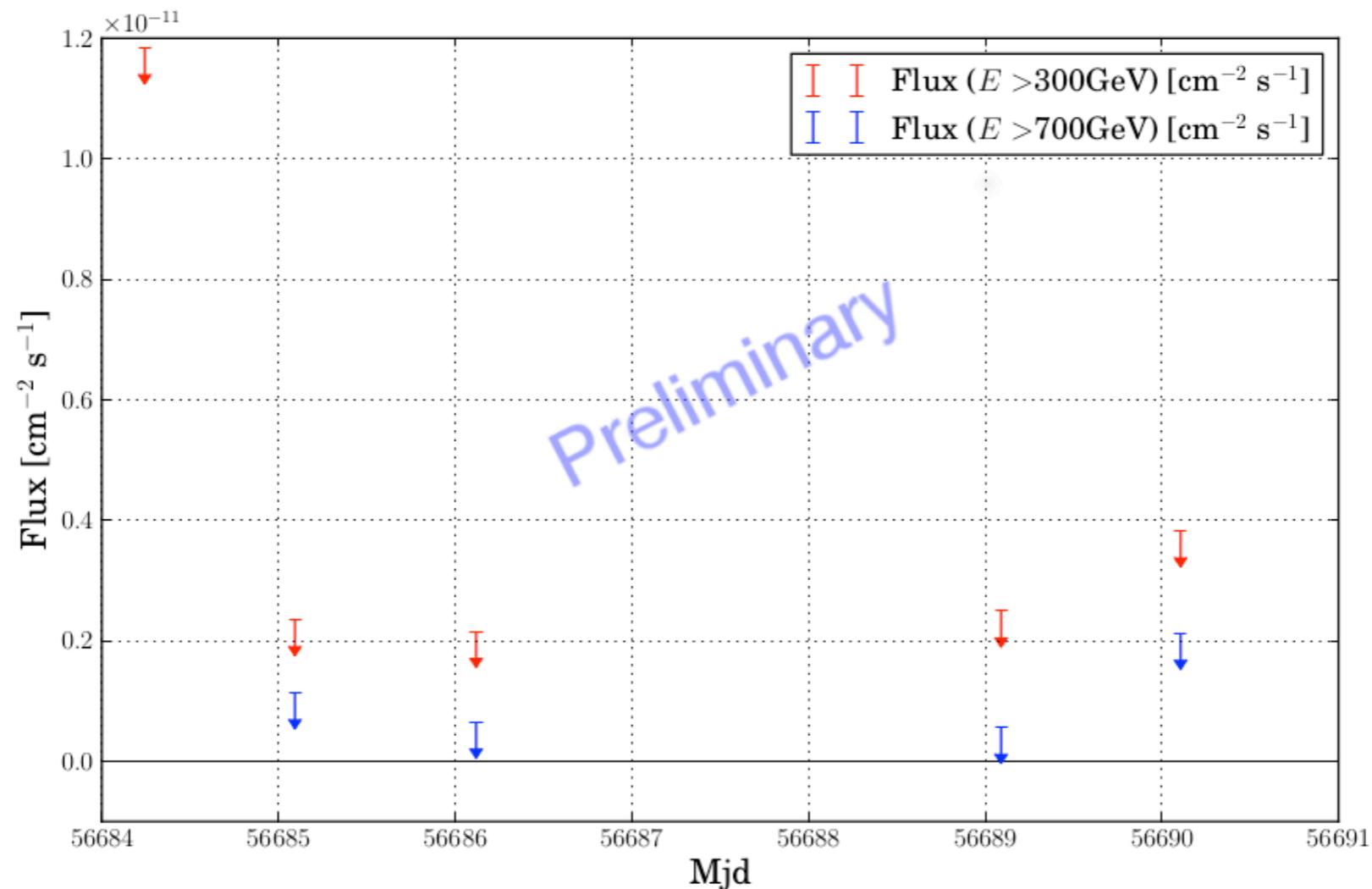
6 days after the explosion → from Jan 27-29 (moderate moon conditions) & on Feb 1 and 2 (dark conditions)

6 hrs of good quality data, $z_d = (40, 52) \text{ deg}$

SN 2014J

* Results

No significant excess \Rightarrow **Integral UL of $1.50 \cdot 10^{-12} \text{cm}^{-2} \text{s}^{-1}$** for $E > 300 \text{ GeV}$
and **$3.90 \cdot 10^{-13} \text{cm}^{-2} \text{s}^{-1}$** for $E > 700 \text{ GeV}$ (95% CL, $\Gamma = 2.6$)



CONCLUSIONS

- * Deep and long-term studies of gamma-ray binaries

LS I +61°303

- * Search for emission on other X-ray binaries

Cygnus X-1

MWC 656

No detection: **Keep trying**

- * Observation of transient systems

SN 2014J

THANK YOU

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