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Two years of observations of LS I +61°303 with MAGIC

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Abstract: In 2005 and 2006, the MAGIC telescope has performed two observational campaigns on the X-ray binary LS I +61° 303. Observations during the first campaign covered 6 orbital cycles and resulted in the discovery of the source above ∼200 GeV. LS I +61°303 was also found to be variable. The second campaign spanned 4 orbital cycles, covering orbital phases which had not been explored before and allowing us to map variability. The total amount of ∼150 hours of observation time allowed for a very detailed study of this source. In this talk we report on the results of these campaigns.

Introduction

The X-ray binary system LS I +61°303 is composed of a B0 main sequence star with a circumstellar disc, i.e. a Be star, located at a distance of ∼2 kpc. A compact object of unknown nature (neutron star or black hole) is orbiting around it, in a highly eccentric ($e = 0.72 \pm 0.15$) orbit [1]. The orbital period is 26.496 days with the periastron passage at phase $\phi = 0.23 \pm 0.02$ [1].

Radio outbursts are observed every orbital cycle at phases varying between 0.45 and 0.95 with a 4.6-year modulation [2]; often a double-peak structure is visible.

X-ray outbursts, starting at around phase 0.4 and lasting up to phase 0.6, have also been detected [3]. Orbital X-ray periodicity has also been found using RXTE/ASM data [4], which currently reveal a broad maximum covering phases $0.4 - 0.6$. Similar results have recently been obtained at higher energies with INTEGRAL [5].

LS I +61°303 was first observed in soft gamma rays by the COS-B experiment [6]. Later, more precise measurements by EGRET showed hints of variability of the γ-ray flux [7].

Although previously considered a microquasar [8], a recent VLBA high resolution radio imaging of the source showed no evidence for extended jet-like features [9]. Indeed, it was observed an extended structure, which evolves with the orbital period and which may be related to the shock form by the interaction of the winds of a pulsar and the star.

Observation and Analysis

The Major Atmospheric Gamma Imaging Cherenkov (MAGIC) is a telescope for very high energy (VHE, $E \geq 50 - 100$ GeV) γ-ray observation exploiting the Imaging Air Cherenkov technique [10]. It is located on the Canary Island of La Palma (Spain) at, $28°45'30''$N, $17°\ 52'\ 48''$W and 2250 m above sea level.

LS I +61°303 was observed with MAGIC in the years 2005 and 2006. In the first observational campaign, 54 hours were recorded between October 2005 and March 2006 [11]. During the second

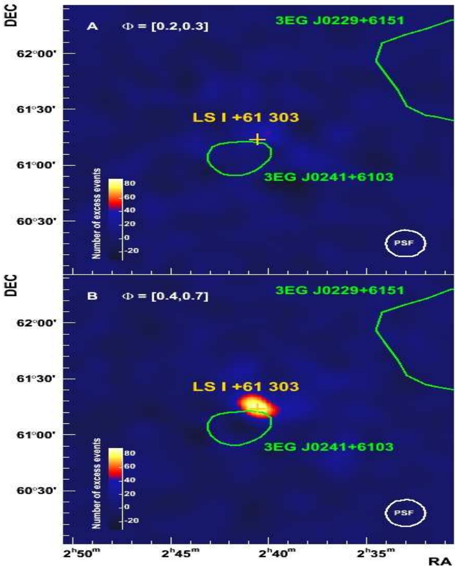

Figure 1: Smoothed maps of γ-ray excess events above 400 GeV around LS I +61°303. (A) Data around periastron ϕ $[0.2 - 0.3]$. (B) Data covering orbital phases ϕ $[0.4 - 0.7]$. The data correspond to the 2005-2006 observation campaign. The positions of the optical sources LS I +61°303 and the low-redshift quasar 4U 0241+61 (yellow crosses), together with the 95% confidence level contours for 3EG J0229+6151 and 3EG J0241+6103 (green contours), are also shown. From [11].

campaign 112 hours of data were recorded from September to December 2006.

LS I +61°303 is found to be a VHE γ-ray emitter. The reconstructed γ-ray sky map is shown in Figure 1. The distribution of the found γ-ray excess events is consistent with a point-like source located at (J2000): $\alpha = 2^{\mathrm{h}}40^{\mathrm{m}}34^{\mathrm{s}}$, $\delta = 61^\circ 15' 25''$, with statistical and systematic uncertainties of $\pm 0.4'$ and $\pm 2'$, respectively, in agreement with the position of LS I +61°303. Recently, the Veritas instrument has recently detected LS I +61°303 too [13] confirming MAGIC results.

Our measurements show that the VHE γ-ray emission from LS I +61°303 is variable. The integral γ-ray flux coming from the direction of LS I +61°303 in a day-by-day basis is presented in Figure 2 for both campaigns. The observations covers 10 different orbital cycles. A daily lightcurve with integral fluxes above energies $E = 400$ GeV is shown

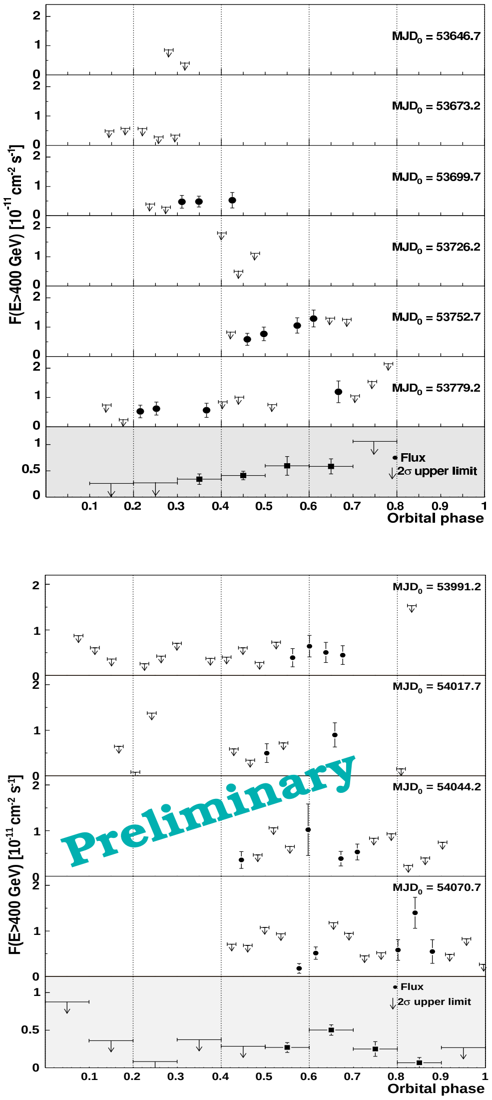

Figure 2: VHE gamma-ray flux of LS I +61°303 as a function of the orbital phase for each observed orbital cycle and averaged for each observational campaign (grey panels). The upper panel shows the data of the first campaign and the lower panel that of second campaign. The Modified Julian Date (MJD) corresponding to orbital phase 0 is indicated for every orbital cycle. Only data points with more than 2σ significance are shown, and 2σ upper limits [12] are derived for the rest.

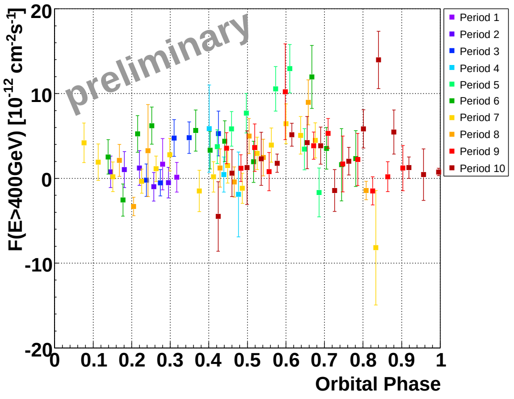

Figure 3: Integral γ-ray flux ($E > 400$ GeV) lightcurve on a day-by-day basis folded with the orbital period of 26.496 days phaseogram. Each color represent a different orbital period.

in a phaseogram in Figure 3. The maximum flux is detected around phase $\Phi = 0.6 - 0.7$. This points to the possible periodicity of the VHE signal. Deeper studies on the matter will be presented elsewhere in the near future.

We have searched the data set for intranight variability, covering 87 different observation nights, on time scales from 15 to 75 minutes. Most of the observation slots last 2-3 hours except for two of them, lasting more than 4 hours. All obtained nightly lighcurves are well fitted by a constant flux level. The chi-square distribution for all different time binnings indicates that no flux level variations on time scales between 30-75 min occur in the source within the sensitivity of the MAGIC telescope.

The spectrum of LS I +61°303 does not exhibit changes in the spectral shape during different observed phases on time scales of one year. The VHE spectra derived from both campaigns between ~200 GeV and ~5 TeV are shown in Figure 4. The reference red dotted black line corresponds to first campaign data (averaged for phases 0.4-0.7), fitted by a power law with spectral index 2.6 ± 0.2(stat)± 0.2(syst). For the second campaign, the spectra for phase [0.5-0.6] and [0.6-0.7] are presented. The spectral slopes obtained from the power law fits are in agreement with that of first campaign spectrum.

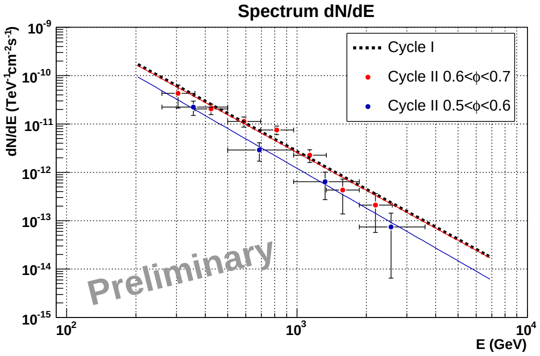

Figure 4: Differential energy spectrum of LS I +61°303 for energies between 200 GeV and 4 TeV and averaged for maximal flux orbital phases. The dashed line corresponds to the power law fit to fluxes in the first campaign [11]. The blue and red points correspond to measured fluxes in the second campaign for orbital phases 0.5-0.6 and 0.6-0.7 respectively.

Conclusions

Here we report the discovery and detailed study of very high energy (> 100GeV) γ-ray emission from the radio emitting X-ray binary LS I +61°303 with the MAGIC telescope.

The source was observed in two consecutive years for 54 and 112 hours respectively.

We briefly discussed the observational technique and analysis and derived a daily light curve. The flux was found to be variable and the maximum of the emission happens typically 1/3 of the orbit away from periastron. Our measurements show that the VHE γ-ray spectra is stable over 2 years of observations and for phases 0.5 to 0.7.

Two different scenarios have been considered to explain this high energy emission: the microquasar scenario where the γ-rays are produced in a radio-emitting jet or the pulsar binary scenario, where the γ-rays are produced in the shock, which is generated by the interaction of a pulsar wind and the wind of the massive companion.

Future simultaneous multiwavelenth measurements will bring a better understanding on the correlation between the different energy regimes and the nature of the system emission.

Acknowledgments

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