Detection of very-high energy gamma rays from RS Ophiuchi nova outburst with the Large-Sized Telescope of the Cherenkov Telescope Array

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cherenkov telescope array

ABSTRACT

The first Large-Sized Telescope (LST-1) of the future Cherenkov Telescope Array (CTA) is located in the northern site of CTA, the Roque de los Muchachos Observatory in the island of La Palma. The LST-1 started its commissioning phase in November 2019 and has been collecting data since then. In August 2021 an outburst from the recurrent nova RS Ophiuchi, a binary system consisting of a red giant and a white dwarf, was reported in optical and high energy (HE) gamma rays. The LST-1 observed RS Ophiuchi during several nights coincident with the outburst and detected a signal of very-high energy (VHE) gamma rays together with the current generation of gamma-ray observatories. This is the first time a nova is detected in the VHE range. In this contribution the results from the LST-1 observations will be presented.

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Introduction

The Cherenkov Telescope Array (CTA) is a future observatory for the detection of gamma rays located in two sites in the northern hemisphere and in the south. There will be three telescope sizes to cover a wide range of energies. Large-Sized telescopes are designed to observe in the lower range, reaching down to ~20 GeV. The first prototype of a Large-Sized Telescope, the LST-1, is currently operating in commissioning phase in the northern site of CTA, in the island of La Palma.

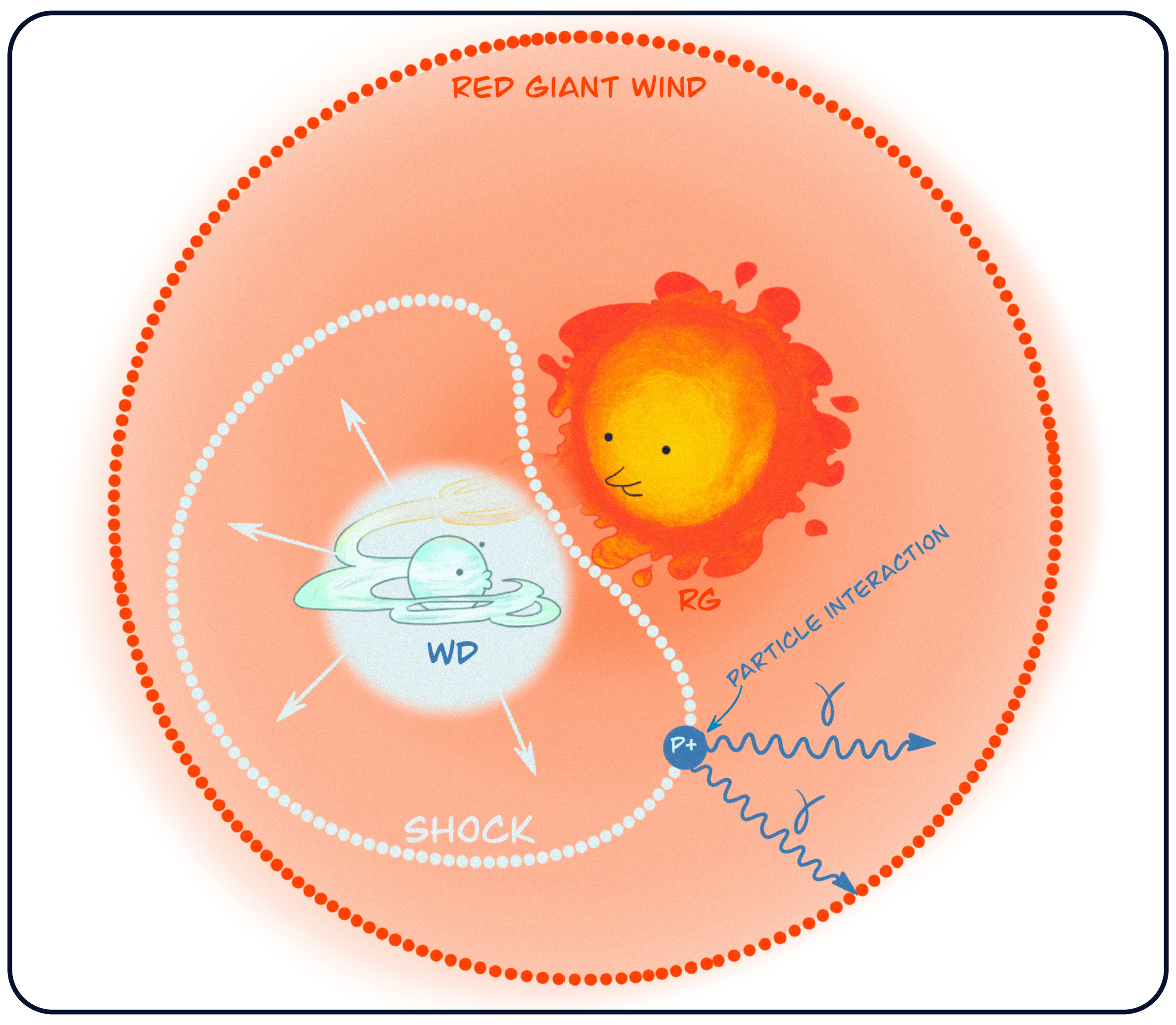

Fig. 1: Schematic representation of the nova during an outburst. Non-thermal radiation is produced in the shock when ejecta from the nova interacts with particles trapped in the magnetic field.

In August 2021, the recurrent nova RS Ophiuchi experienced an outburst which was detected over a wide range of energies, including the Very High Energy (VHE) range (from >100 GeV to ~100 TeV). This nova is a binary system composed by a Red Giant (RG) and a White Dwarf (WD). The WD constantly accretes material from the RG, which accumulates in its surface. When the pressure in the layer is too high, a thermonuclear explosion is produced, ejecting material and thermal radiation. The cataclysmic event produces the necessary conditions for particle acceleration and VHE emission. The LST-1 while in commissioning, observed the nova during the nights of 9th, 10th and 12th of August, right after the outburst, and was able to claim a detection with a total of 6.4 hours of data, getting results compatible to those of the current generation of Imaging Atmospheric Cherenkov Telescopes (IACTs) facilities.

ACKNOWLEDGEMENTS

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Analysis method and results

IACTs collect images of the electromagnetic showers produced by gamma rays interacting in the atmosphere. These images can be parameterized to reconstruct the primary energy and direction. Usually, more than one telescope work in stereoscopic mode to improve the energy and angular resolution, but LST-1 is currently operating in "mono" mode (fig. 2), which specially affects the angular resolution at lower energies. This effect can be reduced using a source-dependent analysis, where the true position of the source is assumed to be known.

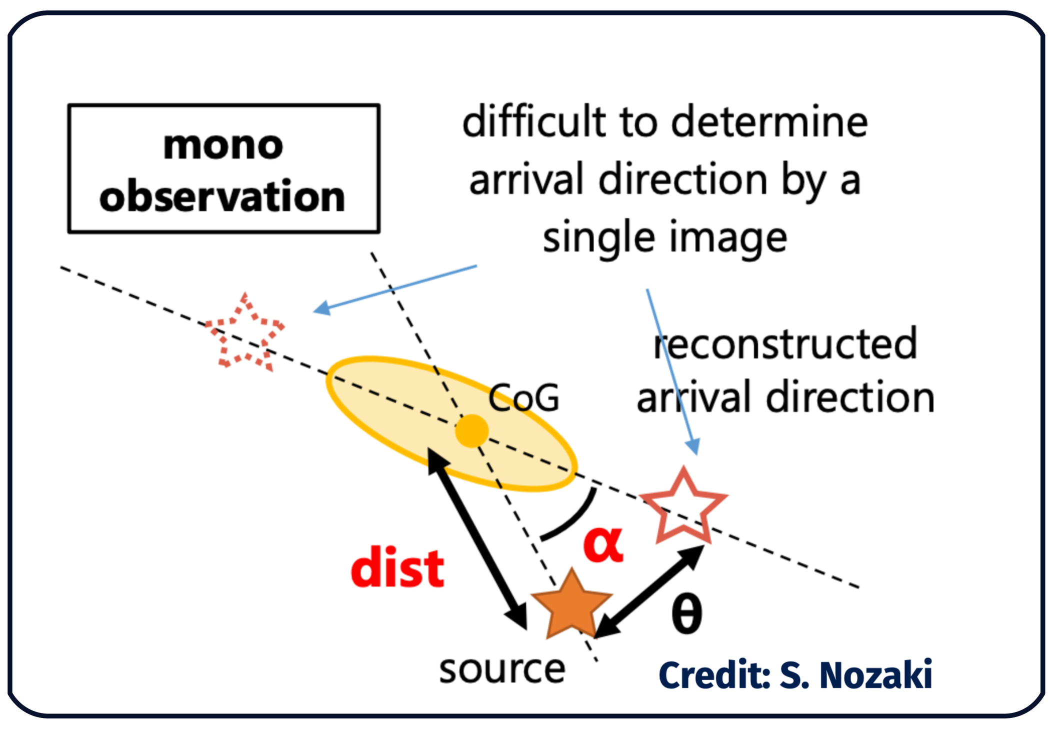

Fig. 2: Schematic of image parameterization and direction reconstruction for mono observations with IACTs.

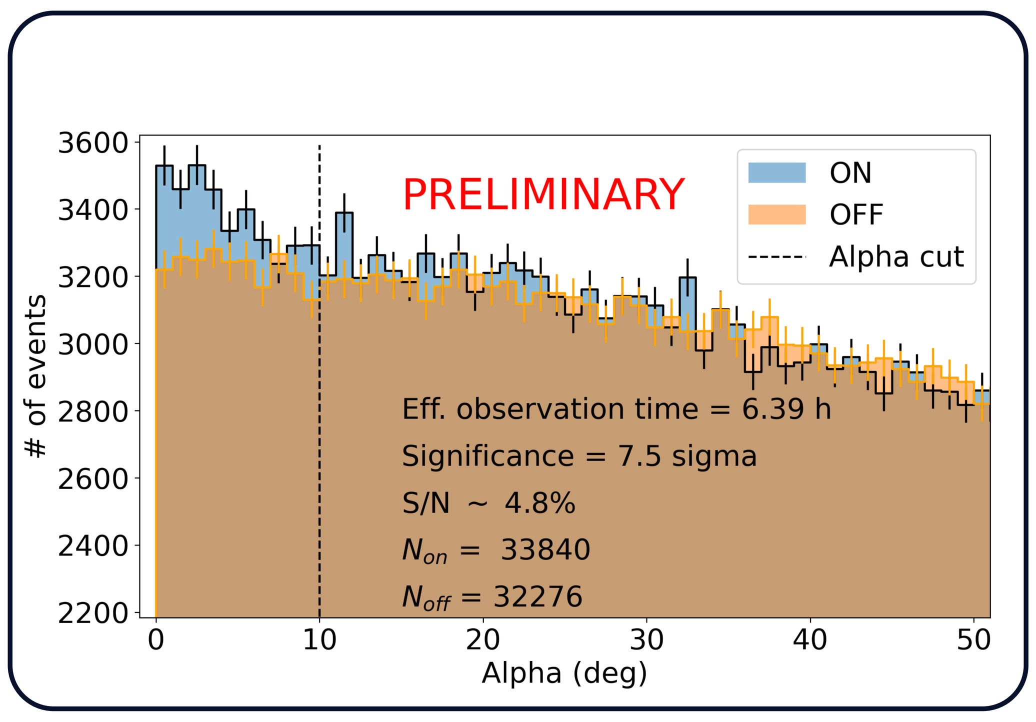

Fig. 3: Alpha plot of RS Ophiuchi data observed with LST-1.

To reconstruct the energy and arrival direction, and separate gammas from background cosmic rays, a set of Random Forests (RF) are trained with Monte Carlo (MC) simulations which then are applied to the data. The MC used for this analysis is generic, but a special production adapted to RS Ophiuchi is being currently used and performance is expected to be improved significantly. The alpha plot in fig. 3 (where alpha is the angle defined in fig. 2) of the three nights right after the burst shows a significant signal in the direction of RS Ophiuchi. The spectral energy distribution (SED) of the data follows a power law with a negative index, compatible with results published by MAGIC and H.E.S.S. as shown in figure 4. The lightcurve of figure 5 was produced calculating the flux for each individual night. Data after the moon break following the burst showed not signal.

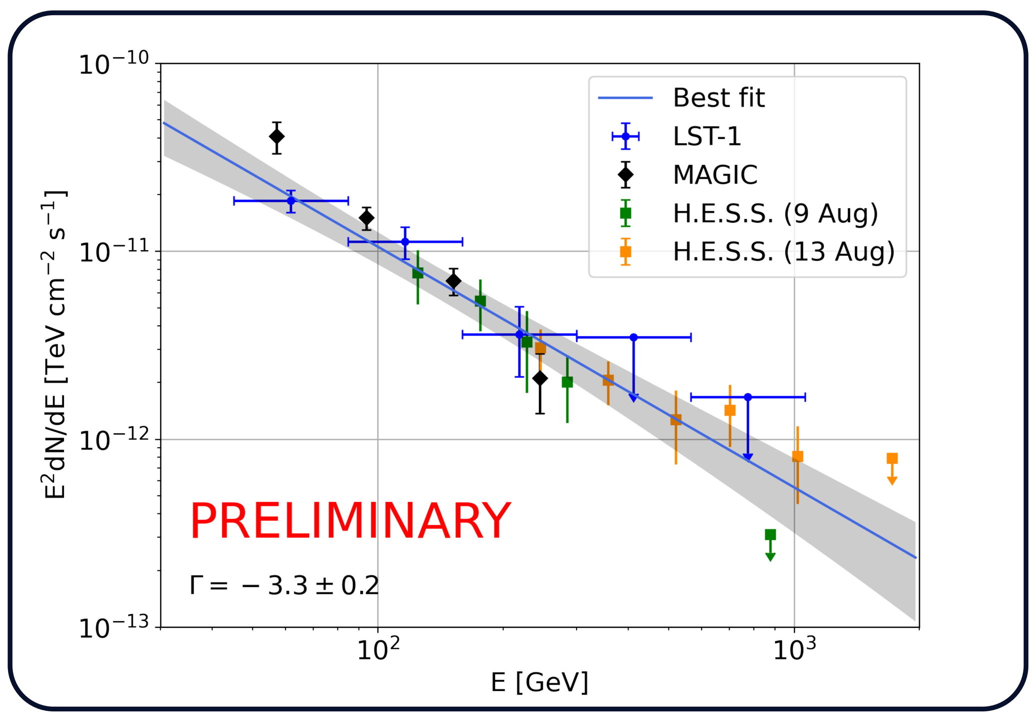

Fig. 4: SED from LST-1 analysis compared to other IACT facilities results.

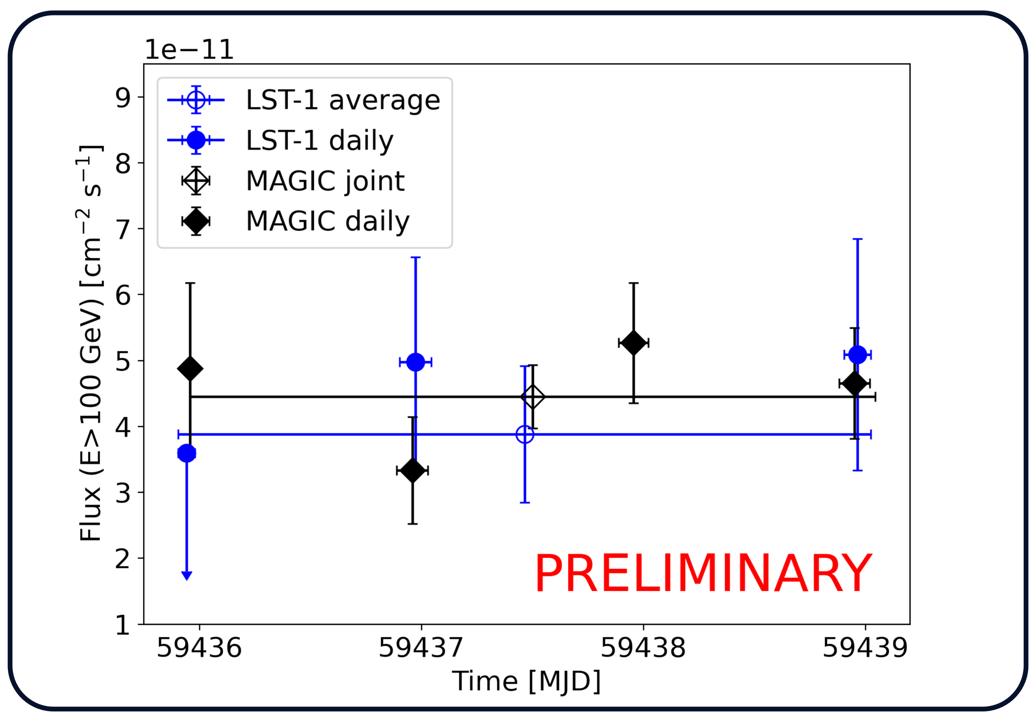

Fig. 5: Lightcurve of RS Ophiuchi from LST-1 data compared to that of MAGIC telescopes.

Conclusions

The LST-1 during its commissioning phase observed the RS Ophiuchi nova outburst of August 2021, and has been able to claim a positive detection and produce a spectrum and a lightcurve, which are compatible with those of the current generation of IACT facilities. The LST-1 has contributed to the first detection of a nova in the VHE range. This achievement validates the performance of the LST-1 observing transient sources at the lower part of the VHE spectrum. Large improvements are expected when the rest of the telescopes of CTA North are installed and start observing in stereo mode.

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