INAF – TIME ALLOCATION COMMITTEE

Application for observing time **Category: D**

Period AOT39 (April 2019 – September 2019) **Submit using: www.tng.iac.es/submit.html**

1. Title

Long-term infrared monitoring of the candidate TeV binary HESS J1832-093

2. Abstract

HESS J1832-093 is a spatially unresolved TeV source, with a point-like and variable X-ray counterpart and a spectral energy distribution dominated by the TeV emission. These properties suggest that this source is a non-accreting TeV binary. Currently seven systems of this type are known, and two of them are radio pulsars; their γ-ray emission is probably due to the particles accelerated at the shock between the wind of the massive star and the pulsar wind. The investigation of these objects is very important, since it provides new opportunities to study particle acceleration in astrophysical sources and to test the theories of high-energy astrophysical processes. Therefore, the identification of new TeV binaries is necessary to enlarge the sample of this type of sources. HESS J1832-093 is the only candidate TeV binary with an unknown orbital period. In 2018 this source was monitored with *Swift*, while its candidate IR counterpart was regularly observed with the REMIR along the whole visibility period. Our aim was to measure the X-ray and IR variability, to investigate the relation between the X-ray and IR emission and to search for possible orbital modulations. We ask to continue the monitoring program of this target with REMIR during the AOT39 observing period.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
0	0	0	0	0	92	92

3b. Observing modes

TNG:		**Visitor**		**Service**		**ToO**
REM:		**Rapid Response**		**Queuing**		**ToO**

4a. Preferred months

first choice: second choice:

4b. Other scheduling constraints (use also box 14)

5a. Past and future of the project

a) Hours already awarded to the project: 42

b) Hours foreseen to complete the project: (not including this request)

6. Principal investigator

Name Nicola La Palombara

Institute INAF - IASF Milano

Address Via E. Bassini 15, 20133 Milano (I)

e-mail nicola.lapalombara@inaf.it

Phone +39-02-23699324

7. Co-investigators (name and institution)

S. Covino, INAF - OA Brera
S. Mereghetti, INAF - IASF Milano
A. Paizis, INAF - IASF Milano
L. Sidoli, INAF - IASF Milano
A. Caccianiga, Universitá degli Studi Milano

8. Status of the project

Telescope	Instrument	Date	Hours	Notes
SWIFT	XRT	20 observations between 2018-02-16 and 2018-06-18	1.5	
REM	REMIR	114 observations between 2018-04-19 and 2018-09-30	0.1	

Description

During 2018 we obtained 20 $Swift$/XRT monitoring observations of the X-ray counterpart of HESS J1832-093 (XMMU J183245-0921539). The source was detected in 15 of these observations, at an average flux $f_{\rm X} \simeq 1 \times 10^{-12}$ erg cm^{-2} s^{-1}. The source flux showed a reduced variability among the different observations but, in one of them, it showed a sudden increase of a factor $\simeq$ 4 up to $f_{\rm X} \simeq 4.5 \times 10^{-12}$ erg cm^{-2} s^{-1}. This finding confirms that XMMU J183245-0921539 is a variable X-ray source. Currently we are analysing the REM data, 114 observations performed between April and September 2018, in order to assess if also the IR counterpart 2MASS J18324516-0921545 is characterized by a variability similar to that observed for the X-ray source.

Publications

9a. If this proposal is a part of a PhD thesis, write here the name of the student, the thesis title and briefly describe the relevance of these observations for the thesis goals.

9b. Is this, or a similar application submitted to other time allocation committees (e.g. ESO, TNG-CAT, ITP)? If yes, please specify which and explain if and why the proposals should be considered complementary.

10. Description of the programme (max. 3 pages, including references, tables, and figures.)

A) Scientific rationale

In the latest years the observations performed by the ground-based imaging atmospheric Cherenkov telescopes (IACTs), such as *VERITAS*, *MAGIC* and *HESS*, have detected very high energy (VHE, E $>$ 0.1 TeV) emission from some γ-ray binary systems (Dubus 2015, C. R. Ph. 16). Currently only seven TeV binaries are known: PSR B1259-63, PSR J2032+4127, LS 5039, LS I +61° 303, HESS J0632+057, 1FGL J1018.6-5856, and LMC P3. These sources are all identified as non-accreting binaries composed by an O or B main-sequence star and a compact object, with a wide range of orbital periods (from 3.9 days to $\sim$ 50 years). While PSR B1259-63 and PSR J2032+4127 have a radio pulsar, testifying the presence of a neutron star (NS), in the other cases the nature of the compact object remains unknown. The spectral and timing properties are similar in all TeV binaries, including the two containing radio pulsars (Dubus 2013, A&AR 21). Therefore, the γ-ray emission in TeV binaries is generally attributed to particles accelerated at the shock between the winds of the star and of the pulsar, a process which show a strong dependence on orbital phase and occurs more likely around the binary periastron. Hence, in this type of sources the γ-ray emission is ultimately powered by the spin-down of a magnetized rotating NS. The investigation of these objects is very important, since it provides new opportunities to study particle acceleration in astrophysical sources and to test the theories of high-energy astrophysical processes. Therefore, the identification and study of new TeV binaries is necessary to enlarge the sample of this type of sources.

HESS J1832-093 is a VHE source discovered by *HESS* close to the supernova remnant (SNR) W41 (HESS Collaboration 2015, MNRAS 446). It shows no significant spatial extension and the upper limit on the source size is 0.074° at a 99 % confidence level. The source is detected in the energy range 0.4-5 TeV at a flux level $\simeq$ 1 % of the Crab nebula flux (Aharonian et al. 2006, A&A 457). Very interestingly, no *Fermi*-LAT source is reported at the position of HESS J1832-093 in the *Third Fermi Catalogue* (3FGL; Acero et al. 2015, ApJS 218); moreover, no significant temporal variability was detected in the *HESS* data set.

A follow-up observation with *XMM–Newton* detected a single X-ray source (XMMU J183245-0921539) within the 90 % c.l. contour of the *HESS* best-fitting position, and its observation with *Chandra* proved that it is pointlike. Moreover, the *Chandra* position is only 0.3 ″ offset from the source 2MASS J18324516-0921545 (Eger et al. 2016, MNRAS 457), while there are no optical counterparts (likely due to strong extinction); the apparent magnitudes of the IR source are $m_J = 15.52 \pm 0.06$, $m_H = 13.26 \pm 0.04$, and $m_K = 12.17 \pm 0.02$ (Skrutskie et al. 2006, AJ 131), and the probability of a chance association between 2MASS J18324516-0921545 and XMMU J183245-0921539 is around 2 %. Therefore, this IR source is the candidate counterpart of HESS J1832-093.

Recently, a NuSTAR observation of XMMU J183245-0921539 has revealed non-thermal X-ray emission up to about 30 keV. The analysis of archival *Chandra* and *XMM–Newton* data has shown that the X-ray source is variable, but no periodic modulations were found (Mori et al. 2017, ApJ 848). These results suggest that XMMU J183245-0921539 is a non-accreting binary system. This suggestion is further supported by the similarities between HESS J1832-093 and HESS J0632+057, which is a confirmed TeV γ-ray binary (Aliu et al. 2014, ApJ 780). In fact, the TeV and X-ray spectra as well as the overall flux level seen from HESS J1832-093 are remarkably similar to this γ-ray binary. Moreover, HESS J0632+057 shows the same X-ray flux ratio of HESS J1832-093 and a comparable time-scale of rise and decay.

Alternative emission scenarios are very unlikely. Due to the hard spectral index in the TeV regime and the lack of HE emission in the GeV band, HESS J1832-093 would be a very unusual extragalactic object, belonging to a yet unknown class of TeV γ-ray emitting AGNs. A possible hadronic origin of the observed TeV emission, which might be related to protons interacting in dense molecular clouds near G22.7-0.2, is disfavoured by the point-like nature of the source. For the same reason, it is unlikely also that both the X-ray and TeV sources are related to a pulsar wind nebula (PWN) powered by a yet unknown pulsar. Therefore, there are strong arguments in favour of the binary nature of HESS J1832-093.

B) Scientific aim

HESS J1832-093 is a candidate TeV γ-ray binary without a measured orbital period; XMMU J183245-0921539 is variable, while no timing information is available for 2MASS J18324516-0921545. Between February and June 2018 we performed regular monitoring observations of this source with *Swift*/XRT, with the aim to investigate its variability and search for possible orbital modulations. In Fig.1 we report the light curve of the performed observations. It shows that the source was clearly detected in most of the observations, at a flux level which varied between $\simeq$ 0.5 and $\simeq 5 \times 10^{-12}$ erg cm^{-2} s^{-1}. In parallel, we used REMIR to perform daily photometric observations of 2MASS J18324516-0921545, since it could be variable due to the binary orbit: in fact, in binary systems with an eccentric orbit the periodic passage of the compact companion at the periastron could produce a deformation of the primary star and, then, a variation in the observed brightness. This type of effect was already observed in LS I +61° 303, for which Paredes et al. (1994, A&A 288) detected a periodic modulation of $\sim$ 0.2 magnitudes in the J, H, and K magnitudes of the primary star (Fig.2); moreover, they were able also to estimate the orbital eccentricity and the phase of the periastron (Martí & Paredes 1995, A&A 298). Therefore, a detection of variability in the IR counterpart of HESS J1832-093 would provide useful information on the binary orbit of this system and on the relation with the X-ray emission.

The REMIR observing program, which complemented the *Swift* monitoring campaign, has just finished and the data analysis is now in progress. The on-going work is revealing some difficulties in the analysis of the performed observations. In particular, since the sky region around our target is very crowded, it is difficult to obtain a reliable photometric calibration of the collected images. Therefore, we ask to continue the monitoring program also during the visibility period in AOT39 using a different observational strategy, which shall allow us to better exploit the obtained data.

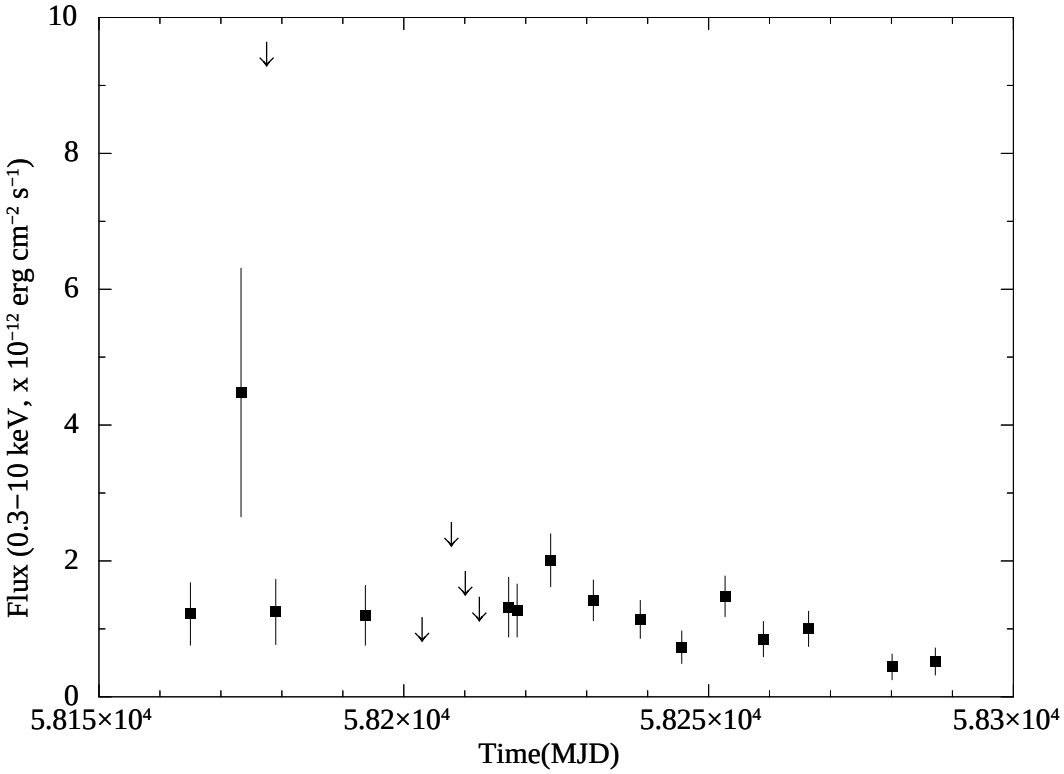

Fig.1: Estimated flux of XMMU J183245-0921539 in the energy range 0.3-10 keV (or its upper limit), obtained based on the *Swift* observations performed in 2018.

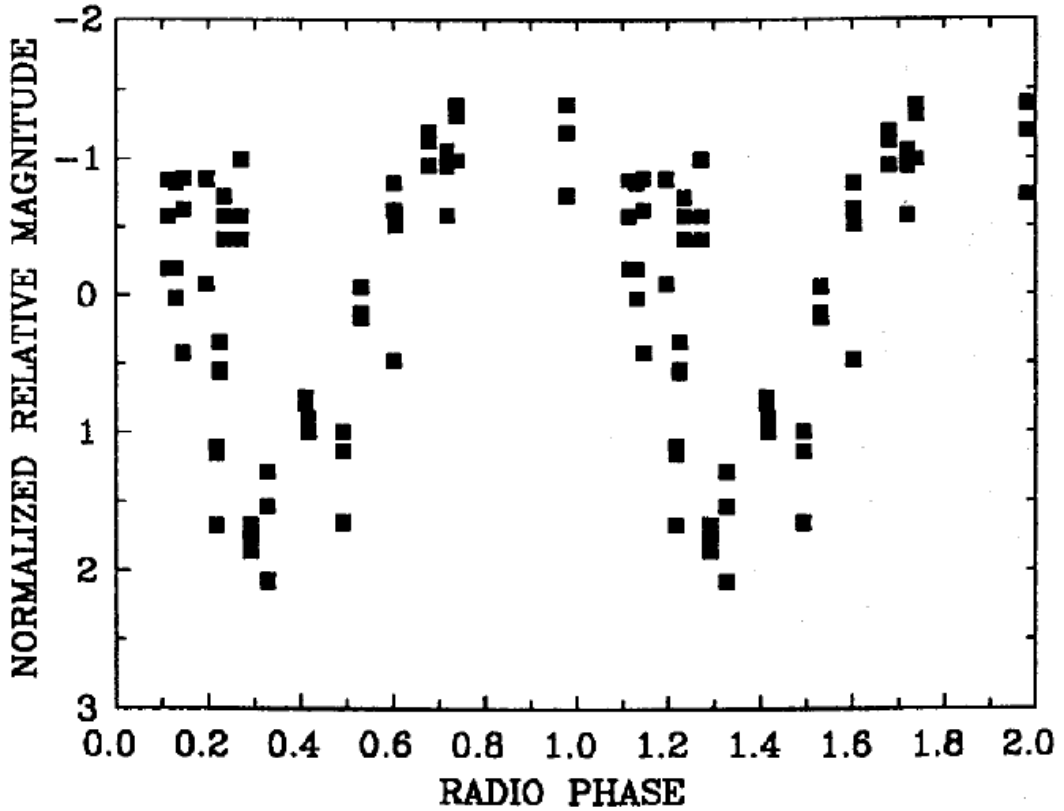

Fig.2: JHK infrared observations of LS I +61° 303 after subtracting the mean magnitude of each filter, normalizing with their respective r.m.s. dispersion, and folding on the 26.496 radio period (from Paredes et al. 1994, A&A 288).

11. List of targets (note that the absence of a proper object list and information may weaken the proposal)

Name	α	δ	Epoch	Mag.	Time	Additional Information
2MASS J18324516-0921545	18 32 45.162	-09 21 54.55	J2000	J=15.5	92 h	no optical counterpart

12. Observational strategy and justification of requested time, including overheads.

The infrared counterpart of HESS J1832-093 will be visible for REM during the whole AOT39 period (April 2019 - September 2019). Therefore, we ask to perform a daily source observation during this period, in order to obtain an accurate IR monitoring. Since HESS J1832-093 has an IR counterpart but is not detected in the visible range, we ask to perform the requested monitoring with the REMIR instrument, using the J, H, and K filters. For each observation and filter we ask to perform the usual cycles of 5 dithered exposures. In this way, with each filter our target will be detected with a $signal\text{-}to\text{-}noise$ ratio above 10. Experience with data obtained during past observing period allowed us to propose here a better observing strategy. Therefore, we ask to carry out more cycles of 5 dithered exposures with a small (0.1 arcmin or so) jittering at the beginning of each cycle. This allows us to better subtract the sky and obtain a more reliable photometry for sources in crowded fields. REM is able to manage this kind of observations as we have directly checked with the REM team. For each filter we ask to apply the maximum allowed exposure time, i.e. 60, 30, and 15 s, for the J, H, and K filters, respectively. Taking into account 60 s of overhead for the telescope pointing and the target acquisition, and 57 s of overhead for the CCD readout, for each observation cycle the total requested time is (60 + 30 + 15) x 5 + 60 + 57 = 642 s. We ask to typically perform three cycles (of 5 dithered exposures each) per night. The required time for three cycles is [(60 + 30 + 15) x 5 + 57] x 3 + 60 = 1806 s. Since there are 183 nights between April and September, the total requested time for the whole monitoring program is 183 x 1806 = 330498 s, corresponding to approximately 92 hours.

Although there are no optical counterparts of HESS J1832-093 (at least down to magnitudes of $\sim$ 18), we ask to observe it also with the ROS2 camera, in order to check if there is any optical source coincident with the 2MASS target. To this aim, we ask ROS2 observing times no longer than those of REMIR, which is the primary instrument.

For the REMIR observations the Moon has a negligible impact and, hence, there are no constraints from this point of view.

The analysis of the data obtained with the proposed observations will be performed by members of the proposing team having a notable experience with REM, well proven by a remarkable set of REM-based publications. This will ensure the full exploitation of the collected data.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information
1	REMIR	none	J,H,K	none	none	92 h	
2	ROS2	none	g,r,i,z	none	none	92 h	

14a. Moonlight constraints

Max. # of days from new moon ☐

14b. Scheduling constraints, special requirements and other remarks
(please include justification of constraints in 14a)

15. Observational background of the applicants

Name of the observer(s) at TNG:

Experience of the observer(s) with the requested TNG instrument(s)

Experience of the observer(s) with other telescopes/instruments

FGG-INAF complies with the Spanish law for sensible data management (LOPD). Please read the page www.tng.iac.es/info/lopd/lopd-aot.html