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

Photometric Monitoring of confirmed and candidate Luminous Blue Variables

2. Abstract

Luminous Blue Variables are luminous (intrinsically bright, L $\sim 10^4 L_\odot$), blue (T $\sim 10^4$K) stars, which show diefferent kinds of photometric and spectroscopic variabilities. The spectral and photometric characteristics of LBVs and related stars indicate that their evolution is driven by variable stellar winds characterized by intense mass-loss rates (10^{-5} - $10^{-3} M_\odot yr^{-1}$), which can occur also in the form of eruptive events. Many LBVs were found to pass through hot (and fainter in visual) and cool/bright phases. But the transition has been well documented only in a few cases. Since this is a crucial point to understand the nature of the surface instabilities and, ultimately, the mechanism producing the massive stellar wind, a frequent photometric monitoring of a sample of LBV as larger as possible is essential.

Thus, we propose a photometric variability follow up, that will provide a large dataset of photometric LBV properties over a significant time range. This study has an additional valuable goal: build LBV template for next generation survey (e.g. LSST), to easily classify detected photometric variability.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
					49	49

3b. Observing modes

TNG:		Visitor		Service		ToO
REM:		Rapid Response	X	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:

b) Hours foreseen to complete the project: 79 h
(not including this request)

6. Principal investigator

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7. Co-investigators (name and institution)

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8. Status of the project

Telescope	Instrument	Date	Hours	Notes

Description

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 LBVs are rare luminous evolved massive stars that show distinctive photometric and spectral variabilities. It is believed that they represent a brief ($\approx 10^{-4}$ years; Lamers et al. 1998) transitional phase between the most massive stars and the Wolf-Rayet stage during which the star loses a significative fraction of its initial mass through wind and occasional giant eruption, leading the formation of extended circumstellar nebulae. Currently, their link to other advanced evolutionary phases of massive stars, such as supernovae, represents a hot topic of discussion, with recent observations suggesting that LBV stars may be (unde rcertain conditions) direct progenitors of type II supernovae (Groh et al. 2013). Despite their rarity, LBVs may play an important role in the chemical enrichment of the interstellar medium, due to the large amount of processed material injected by means of continuous winds and intense eruptions. In addition, growing interest on the study of LBV ejecta comes from their possible role as primordial dust producers.
Spectral and photometrical variability has been a defining characteristic of these objects from the very start of their study. LBVs, in fact, are known to show photometric variability in their brightness across a large range of amplitudes and timescales, which often produces significant changes in the spectrum of the star. In particular, "micro" and "moderate" variability and "giant" eruptions may be distinguished. The microvariability is characterized by small-amplitude features, up to few tenths of a magnitude over timescales of a few days-weeks; the moderate (or short S Doradus) outbursts result in variations in the visual magnitude (1-2mag) and colors at roughly constant bolometric luminosity on timescales of years-decades; the rare giant eruptions shows variations amplitudes (or long S Doradus) up to more than 2 mag, observed between prolonged period of quiescence, like P Cygni in the 17th century and η Carinae in the 19th century, indicative of an eruptive event. Although such events have been witnessed very rarely, the presence of nebulae around other Galactic LBVs suggests that they are a common aspect of LBV behavior. Even though most LBVs have been identified by their peculiar variability, more recently the progress in the mid-infrared survey (such as MSX, WISE, GLIMPSE, MIPSGAL, Herschel) allowed the discovery of several new Galactic LBV candidates (cLBVs) through the detection of the surrounding circumstellar nebulae that are formed from material ejected during previous eruption events, even if in some cases their photometric variability has not yet been detected. Nevertheless, with characteristic times of 10^4 years (Humphreys & Davidson 1994), the galactic population of LBV stars is extremely scarce, with less than twenty confirmed members and a few candidates which still require confirmation (Richardson & Mehner 2018).
Despite the growing attention that LBVs have attracted in recent years, the current picture of such transitional phase is still rather incomplete and no general understanding of the mass loss mechanism (wind-like, hydrodynamic, binary induced etc.) has been achieved. Photometric variability is thought to originate from several mechanisms, but none of them can account for all the observed features. The most proposed mechanisms causing the SD-phases are a drastic increase of mass loss leading to the formation of a pseudo-photosphere, or/and an increase/decrease in the ratio between the stellar ratio and the effective temperature. The physical changes that take place during the variable phases leave imprints in various observables that are accessible through all the electromagnetic spectrum, and that could be studied through a variety of technique. In the past years, our group started a systematic study of LBVs and cLBVs, aimed at a better understanding of the LBV phenomenon through the study of their stellar ejecta. Our approach is based on a synergic use of different techniques at different wavelengths, from radio to IR, that allows to model and mapping the several emitting components coexisting in the nebula. These studies evidenced how the LBVs (and related phenomena) are far from a homogeneous branch and revealed a number of components, such as dense stellar wind, circumstellar PDRs, and presence of a much more complex and extended nebulae, than previously known. Over the years, we have often found photometric variability in the central object of our targets, not only in the NIR but also in Mid-IR or radio images. The physical change taking place in the stellar/circumstellar environments leave, in fact, imprints in various observables that are accessible at different wavelengths. For instance, in fig.3 are reported the background-subtracted radial profile from the MSX(21 μm), WISE(22 μm) and MIPS (24 μm) maps of Wray17-96, evidencing a drastic variation of the emission from the central source, whose luminosity decreases by about 30%. Radio observations of Wray 15-751 are reported in fig. 2. While considering the differenches in the circumstellar emission that could be due to the different array configuration, the central source shows clear flux variability through the different observational epochs, which can point to mass loss changes. However, the lack of optical/photometric light curves covering the observational epochs prevent to correlate such events with magnitude and/or colors variations and thus understand the physical changes that take place at different distances from the stellar surface. In the past, we also conducted a two-years (April 2008-April 2010) multi-wavelength photometric monitoring of a sample of 25 LBVs and cLBVs by using the REM telescope (Buemi et al., 2010). In about the 50% of our well sampled flux curves we detected an evident long or/and short term variability, with amplitude from 0.4 up to 1.5 magnitude (fig. 2): this confirms the importance to have a track of the time evolution of these objects, expecilly when we try to put together multi wavelength data from different surveys/telescopes.
A time domain study of LBVs is fundamental to better understand the ongoing physics in this objects and it is necessary to move from occasional observations to a more systematic approach.

B) Scientific aim We propose to start an optical infrared monitoring program with the aim to determine variability properties of a sample of confirmed and candidate galactic LBVs.
Up to now, the knowledge of the photometric behaviour of such kind of objects is based on a strongly varying degree of coverage of the light curves. Some of them, like AG Car, P Cyg or η Car, have been widely monitored,

but most of them have only sparse observations or no photometric light curve at all. On the basis of such limited database, it is possible that episodes of micro or moderate variability have been completely missed and it is difficult to say if LBVs showing no variability have turned into new WN stars or not. A systematic photometric and spectroscopic monitoring, extended to a large sample of LBV candidates appears to be necessary.

We propose to begin an extended program of photometric monitoring of the stars in three near-IR passbands to provide a stable basis for comparing data of all kinds and to keep track of the changes in these puzzling objects.

We are submitting this proposal in order to:

- hunt for photometric variability in object proposed as LBV candidates after the detection of surrounding circumstellar nebulae;
- better define the distribution of the light curve parameters and, through colour variability, distinguish between LBV-type and other kind of variability, derived from different physical mechanisms, like pulsation modes or changes in the contribution from stellar wind or circumstellar dust (Clark et al., 2005, A&A, 412, 185);
- trigger radio IR/observations when a variable phase is detected;
- building up a statistically significant database, that will be publicly available to the scientific community.

Figure1: Radio images of Wray15-751 obtained with the Australia Telescope Compact Array in 1994, 1996, 2001, and 2014 respectively.

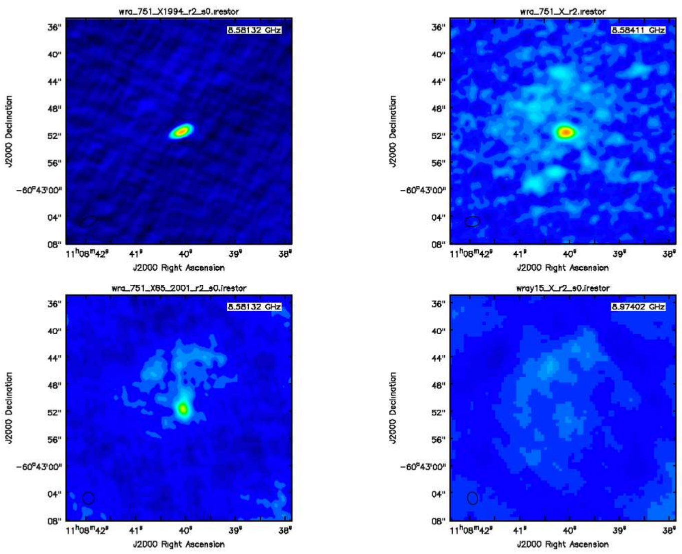


Figure2: REM light curves of Wray17-96 (EQ J1741-3006) and V481 Sct(Prog ID AOT21011, AOT20036, AOT19008, AOT18005)

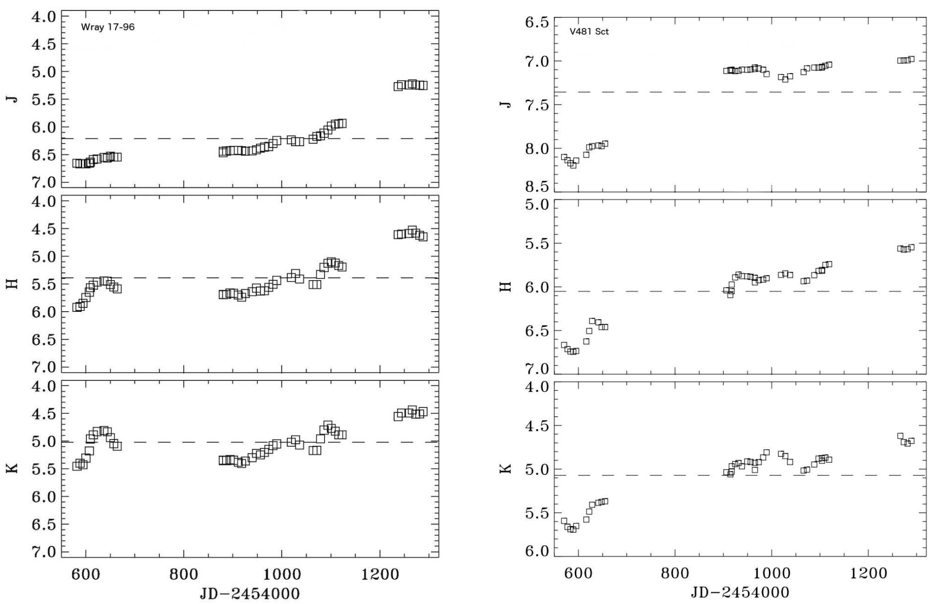
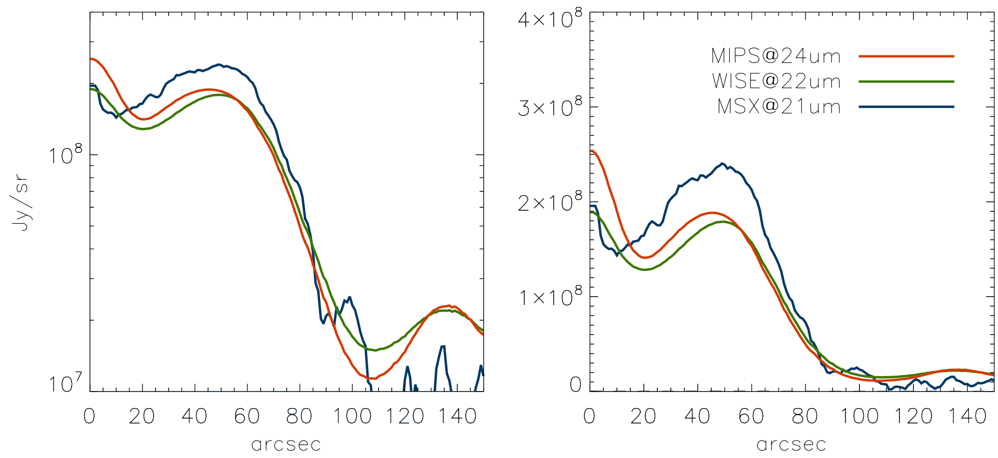


Figure3: Background-subtracted surface brightness obtained averaging over 36 cuts of the nebula of Wray17-96 (EQ J1741-3006), from MSX,WISE and MIPS images.



1 References

Buemi C., Distefano E., et al., 2011, BSRSL, 80, 351
Clark, J.S., Larinov, V.M. and Arkharov A., 2005, A&A, 435, 239.
Groh, J. H., Meynet, G., Georgy, C., Ekstrm, S., 2013, A&A, 558, 24.
Humphreys, R., Davidson, K., 1994, PASP, 106, 1025.
Lamers, H.J.G.L.M., et al., 1998, , A&A, 340, 117
Richardson, N. D., Mehner, A., 2018, RNAAS, 2, 121

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
AG Car	10 56 11.58	-60 27 12.815	J2000	J8.43	30s	
V432 Car	11 08 40.06	-60 42 51.7	J2000	J9.93	65s	
V1104 Sco	17 06 53.91	-42 36 39.74	J2000	J8.22	20s	
EQ J1741-3006	17 41 35.45	-30 06 38.8	J2000	J9.09	40s	
V4650 Sgr	17 46 18.0	-28 49 03	J2000	J12.31	355s	
LBV 1806-20	18 08 40.31	-20 24 41.1	J2000	J13.66	695s	
V481 Sct	18 33 55.29	-06 58 38.7	J2000	J10.80	20s	
GAL026	18 39 32.24	-05 44 20.5	J2000	J10.40	20s	
V1672 Aql	19 00 10.9	+03 45 47	J2000	J13.70	310s	
WS1	13 36 28.62	-63 45 38.73	J2000	J9.48	100s	
MN30	15 48 42.07	-55 07 42.19	J2000	J7.93	20s	
IRAS16254	16 29 03.79	-47 46 26.64	J2000	J8.67	35s	
MN44	16 32 39.94	-49 42 13.69	J2000	J8.41	20s	
WRAY19-46	16 33 52.39	-48 06 40.48	J2000	J5.87	35s	
MN45	16 36 42.78	-46 56 20.73	J2000	J11.71	190s	
MN48	16 49 37.70	-45 35 59.24	J2000	J7.24	15s	
2massJ1708-3925	17 08 29.14	-39 25 07.66	J2000	J10.49	75	
MN55	17 11 00.94	-39 45 17.45	J2000	J9.73	45s	
WS2	17 20 31.76	-33 09 48.91	J2000	J6.62	40s	
MN61	17 42 14.018	-29 55 36.06	J2000	J13.38	690s	
MN58	17 37 47.6	-31 37 32	J2000	J11.77	220s	
LBV G0.120	17 46 05.62	-28 51 31.92	J2000	J12.53	450s	
MWC 930	18 26 25.23	-07 13 17.82	J2000	J6.65	45s	
MN80	18 33 39.55	-08 07 08.49	J2000	J13.0	645s	
MN83	18 39 23.01	-05 53 19.93	J2000	J13.19	655s	
MN84	18 41 59.65	-05 15 40.81	J2000	J7.96	20s	
MN46	16 43 16.37	-46 00 42.39	J2000	J6.26	25s	
MN101	19 06 24.57	+08 22 01.42	J2000	J9.66	45s	

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

We propose to observe a sample of confirmed and candidate galactic LBVs with the REM Telescope in the g′,r′,i′,z′,J, H and K filters, using ROSS and REMIR cameras simultaneously.
The targets have been selected from Richardson & Mehner (2018), who performed a census of confirmed and suspected LBVs in the Local Group. From the original sample, we rejected the sources having declination $\delta \geq +14°$ to assure that all the observations will be conducted at low airmass. We have then extracted from 2MASS image services a $1' \times 1'$ field centred at the target position and sources located in very high confusion region have been rejected. 25 LBVs/cLBVs have already been monitored with REM telescope from 2008 to 2010. Among these we select 11 sources that showed flux variability $>$ 0.5 mag in the J filter. From the remaining, to avoid saturation problems, we reject sources having J$<$ 5 mag. This reduces the original samples to 28 sources, whose name and position are reported in sec. 11.
When the source size greater than 2″, to estimate the integration time we assumed a mean magnitude for arcsec^2 calculated on the basis of 2MASS images, and reported in the targets list. For each source, we estimated the integration time needed to reach a S/N=500 in each band, on the basis of the REM Exposure Calculator, combined with the informations collected from our previous REM monitoring program (AOT21011, AOT20036, AOT19008, AOT18005). We provide the exposure times based on the near-IR fluxes, since optical emission of LBVs is more affected by circumstellar dust extinction that makes in many cases the magnitude of the objects uncertain. We account to adjust the time exposure in the optical bands based on the acquired new images.
We ask for a regular monitoring with one observation per week for the 9 sources that showed time variability on time scales of weeks, based on our previous monitoring. For the remaining targets, that have never been monitored,we ask for observations performed every approximately 2 weeks. We will ask for more frequent observations for sources that will show evidence of flux variability.
This is a pilot program that foresees a two years monitoring. Thus we plan to repeat these observations at every cycle of the telescope, to be able to reconstruct the light curve over years-timescale (a proposal will be submitted at each future deadline). On the basis of the source visibility chart, we need 49 hours for the April-September semester and 15 hours for the October-March period, for a total of 64 hours/year. The calculation of the needed time includes the telescope overheads.
The total time requested for the period February-July 2019 is of 49h for the REMIR and ROSS2 camera. If not all the requested time can be allocated, we plan to reduce the number of the targets to achieve the main goals listened in sec.10B.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information

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

INAF-TAC LaTeX style file vAOT39 October 2019.