INAF – TIME ALLOCATION COMMITTEE

Application for observing time **Category: C**

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

1. Title

Photometric variability study of R CrA

2. Abstract

We propose here a photometric survey, both in visible and near-IR, of the star R CrA, with the scientific aim of characterize its variability in luminosity. This is a fundamental step for determining the origin of the variability and link it to the different structures that were recently imaged around this star through VLT/SPHERE, such as a very bright jet-like structure North-East of the star and a fainter counter-jet-like structure on the opposite direction. A very red companion was also imaged at around 0.184" from the star. The SPHERE observations also gave some hints about the presence of a disk at larger separation than the stellar companion. The presence of an inner disk was also deduced through former NIR observations but not resolved through the SPHERE observations.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
					3.8	3.8

3b. Observing modes

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

4a. Preferred months

first choice: all second choice:

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

5a. Past and future of the project

a) Hours already awarded to the project: 2.1

b) Hours foreseen to complete the project: 0
(not including this request)

6. Principal investigator

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7. Co-investigators (name and institution)

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V. D'Orazi, INAF – Osservatorio Astronomico di Padova
E. Rigliaco, INAF – Osservatorio Astronomico di Padova

8. Status of the project

Telescope	Instrument	Date	Hours	Notes
REM	ROSS	aug-sep 2018	1.03	considering 60 sec pointing, VIS data already reduced
REM	REMIR	aug-sep 2018	1.23	considering 60 sec pointing, IR data already reduced

Description

Data from both the instruments were already reduced and analyzed and show the expected variability. However we were not able to sample the whole phase of variability.

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 Young stars surrounded by a protoplanetary disk are today considered as the main environment where searching for exoplanets that are undergoing their formation phase (see e.g.Chen et al. 2012; Marshall et al. 2014). Moreover, it is becoming clear that giant planets are more frequent around intermediate mass stars than around solar-mass stars (see e.g. Johnson et al. 2010). Herbig AeBe (HAeBe) (Herbig 1960; Hillenbrand et al. 1992) are the more massive counterpart of T Tauri stars: young (<10 Myr), intermediate mass (1.5-8$M_{\odot}$) with spectral type typically A and B, which are still embedded in their gas and dust envelope. They are characterized by a strong infrared excess (The 1994) due to the presence of a circumstellar protoplanetary disk. Also they are experiencing accretion processes and their spectral line profiles are normally very complex. These characteristics make these objects very valuable in the field of the extrasolar planets research given that they allow to explore the very first stages of the formation of the planetary systems. The Coronae Australis (CrA) molecular clouds compleX is one of the nearest region with ongoing star formation (distance ~130 pc, Neuhauser et al.2008). In the center of the molecular cloud there is the Coronet protostar cluster characterized by a very high and variable extinction (A_V up to 45 mag). RCrA (HIP93449) was the first variable star identified in the CrA molecular cloud. Its spectral type is largely debated and varies from F5 (e.g. Hillenbrand et al. 1992) and A5 (e.g. Chen et al. 1997), to B5III peculiar (Gray et al. 2006) to B8 (e.g. Bibo et al. 1992). It is much brighter in the NIR (J=6.94; H=4.95; K=3.46, Ducati 2002; Cutri et al. 2003) than in the visual (V=11.92 Koen et al. 2010). Its luminosity is varying with time (up to 4 mags) and its spectrum appears very reddened. Takami et al. (2003) proposed the presence of a stellar companion and of an outflow based on their spectro-astrometric observations at Anglo-Australian Telescope using the RGO spectrograph. They estimated for the binary a separation of 8 au and a period of ~24 years. The presence of a companion was also proposed by Forbrich et al. (2006) to explain the X-ray spectrum of R CrA based on the fact that strong X-ray emission is not expected from HAeBe stars. RCrA has also been observed as part of SHINE (SpHere INfrared survey for Exoplanets) survey, the main GTO program of SPHERE@VLT (Spectro-Polarimetric High-contrast Exoplanet REsearch). The images acquired with SPHERE reveal a quite complex system, which include a new stellar companion (Mesa et al., submitted), together with bright jet-like structure and the possible presence of a circumstellar disk outside the stellar companion. Further observations with SINFONI allowed to classify the stellar companion as an early M-spectral type object. Moreover, the SINFONI spectrum will be used to better define the nature of the extended structures found around the star. These structures, together with an inner disk not imaged by the SPHERE observations, might be responsible of the highly variable luminosity of the star. So far, the only published homogeneous photometric survey of R CrA was carried out at visible wavelengths exploiting the Maidanak Observatory in Uzbekistan starting form 1983, and was published in 1999 by Herbst (Herbst et al. 1999). In Fig. 1 an analysis of these data using a generalized Lomb-Scargle periodogram (GLSP-Zechmeister & Kürster 2009) shows several significative peaks, with separations in frequency corresponding to one year (0.00276 dex). The two highest power frequency are those of 55.7 days and 65.9 days, and cannot be due to the sampling. Furthermore, Percy et al. (2010) studied the photometic stability of RCrA exploiting a 100-year long sequence provided by the American association of variable star observers (AAVSO) visual data. They found a period of 66 days, stable in time but slightly variable in amplitude. The observed V magnitudes vary from 10.5 to 14.5. We obtained 48 photometric data points per filter with REM from Aug 7th to Sep 30th, 2018 in AOT38. Observations allow as to follow the photometric variation at 7 different wavelenghts: g, r, i, z with ROS2 and J, H, K with REMIR. We propose here to continue the photometric survey of R CrA, both in visible and near-IR, with the scientific aim of linking the variability in luminosity with the different structures imaged in the source.

B) Scientific aim We ask to observe R CrA with REM in order to carry on our new photometric monitoring of this target, started in AOT37. With the aperture photomethy method we were already able to trace the variability at all wavelengths as shown in Fig. 2. In the right panel of Fig. 2, zero points of the magnitude were varied to allow a better visualization of the results. With the new, more accurate, observations that we intend to take with REM we aim to conclude the sampling of the phase and check the luminosity cycle of this source both in VIS and in the NIR. Simultaneous VIS and NIR observations will allow us to pin down the source of variability: periodic obscuration by a dust ring, variations in the accretion luminosity etc.. At short wavelengths (e.g. g'), luminosity is mainly due to accretion, while in the NIR (e.g. H band) is mainly due to the hottest part of the circumstellar disk. At intermediate wavelengths (e.g. i'), we expect that the contribution by the photosphere dominates. r' may be dominated by emission in $H\alpha$. In addition, the wide spectral coverage of REM may help to model the (possibly variable) dust obscuration by the disk itself, that is seen at an inclination of ~ 70 degrees. The results of this survey will be the basis of a future proposal for R CrA high-resolution spectra (with FEROS) with which we will ask to collect R CrA spectra at significant epochs of its luminosity cycle. To this purpose, knowing the accurate period and phase is of high importance. Moreover, given the dimensions of the Coronet cluster, this survey will also provide photometric data of other bright sources of the Coronet region. The bright star HD 176386A (α :19 01 39 δ :-36 53 27) can be used as photometric calibrator. In fact, the REM data so far collected allowed us to check that since its luminosity is stable with respect to the photometric variations of R CrA we are interested in.

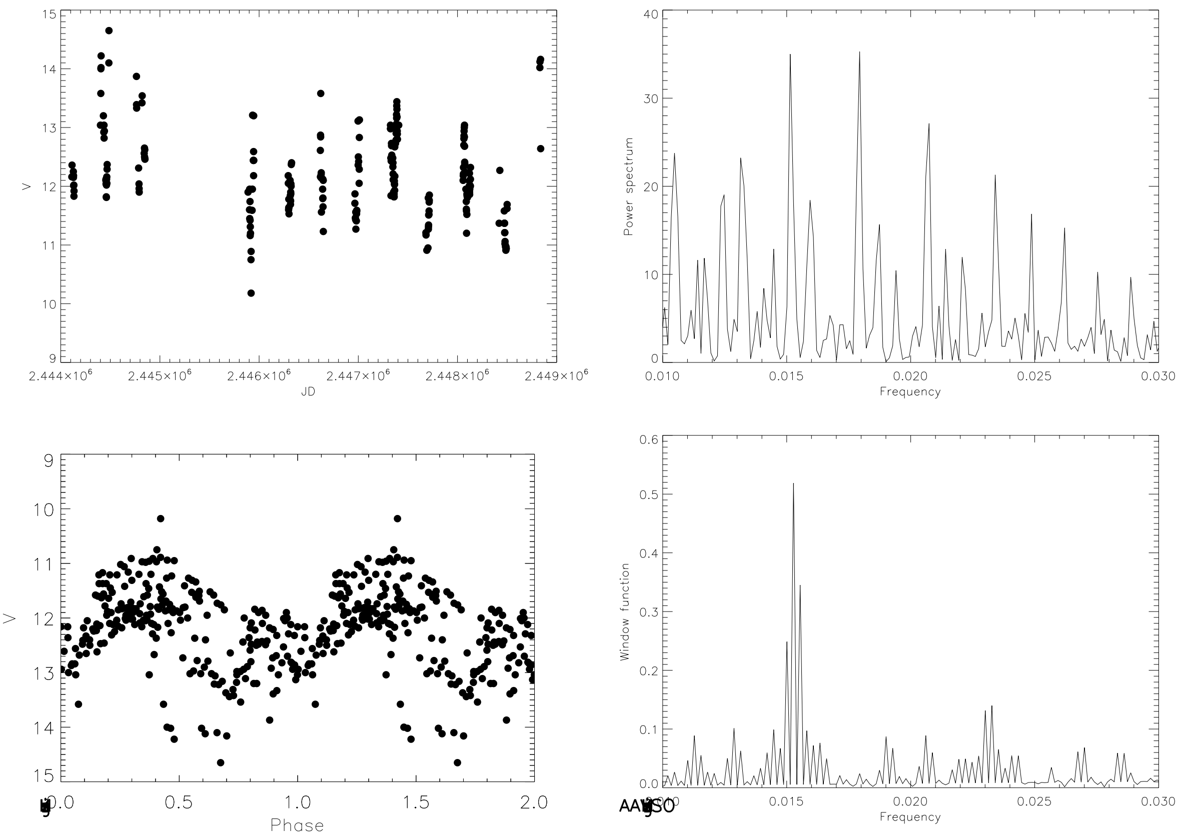

Figure 1 Clockwise: photometric data in V band obtained by Herbst et al. (1999); Generalized Lomb Scargle periodogram for R CrA photometric data; The related Window Function; The data rephased at 66 days.

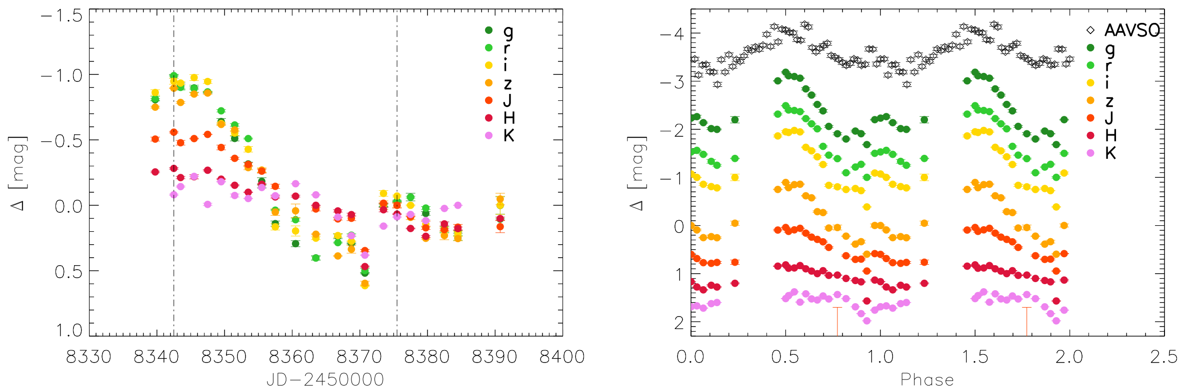

Figure 1 Left: photometric variation of R CrA from REM images. Right: same as left but phased to the 65.9 day period according to the AVVSO sequence (black). For a better visualization, we applied a zero point magnitude to each sequence and triplicate AVVSO signal amplitude.

References

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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
R CrA	19 01 54	-36 57 08	J2000	V11.91	7520	variable star, V luminosity varies between $\sim$10.5 and $\sim$14.5
R CrA	19 01 54	-36 57 08	J2000	H4.95	7440	variable star

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

To observe our target, we plan to exploit ROSS and REMIR simultaneously using the g'r'i'z' and JHK band filters. We ask for one telescope pointing on each available night (estimated 40 nights, if possible) distributed in a time interval of 3 months. Observations should cover the expected period of 66 days and therefore should not be clustered. ROSS should take three consecutive exposures of 10 seconds that leads to 282 sec/night, considering read-out overheads. REMIR should run 4 dithers cycles of 1 second that leads to 248 sec/night considering read-out overheads. Assuming 60 sec/night for the pointing and acquisition, the total amount of this request is of 3.8 hr. These values should allow a good S/N and avoid saturation. However, exposure time can be varied during the campaign according to the phase, after the acquisition of the first points. The bright star HD 176386A (α :19 01 39 δ :-36 53 27, V=7.326 mag, H=46.809 mag, separation of $\sim$310 arcsec from R CrA) can be used as photometric calibrator, since its luminosity is stable with respect to the variations we are interested in. So that, it must be included in the FoV.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information
1	ROSS	1x1	g'			3.8hr	include HD 176386A in the FoV
1	ROSS	1x1	r'			3.8hr	see above
1	ROSS	1x1	i'			3.8hr	see above
1	ROSS	1x1	z'			3.8hr	see above
2	REMIR	1x1	J			3.8hr	see above
2	REMIR	1x1	H			3.8hr	see above
2	REMIR	1x1	K			3.8hr	see above

14a. Moonlight constraints

Max. # of days from new moon

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

Only one telescope pointing per available night distributed in 3 months.

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

S. Benatti and I. Carleo took part to the commissioning runs of GIANO-B and GIARPS at TNG and are then fully familiar with the new instrumentation. They also observed with HARPS-N for several nights. S. Benatti observed at the 182 cm Copernico Telescope at the Asiago-Cima Ekar Observatory (Vicenza, Italy) with the AFOSC spectro-photometer for several runs. E. Sissa has experience with the 122 cm telescope in Asiago with the Boller & Chivens spectrograph and also with SPHERE (Spectro-Polarimetric High-contrast Exoplanet REsearch) at VLT. I. Carleo has experience with the NIR spectrograph IGRINS at McDonald Observatory in Texas.