PHOTOMETRIC VARIABILITY OF LUMINOUS BLUE VARIABLES IN M33 ON SHORT TIMESCALES

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Abstract

We used SDSS *r*-band aperture photometry and astrometry of ~500 000 stellar-like objects in the M33 galaxy performed by the CASU (Cambridge Astronomy Survey Unit) Astronomical Data Centre in the Institute of Astronomy, University of Cambridge. The observations were carried out with the 2.6m VISTA telescope at the Cerro Paranal, Chile. More than 500 images in that passband were obtained with the OmegaCAM, a large format (16k x16k pixels) CCD camera, and each of them covers a field of view of 1°x1°. The current time span of the data is 2.1 yrs until the end of 2014.

The structure function analysis (Hughes et al. 1992) was applied in order to study the variability of ~30 known or suspected LBVs in the M33 galaxy (Massey et al. 2007) on different time scales. In some cases like Var C the time resolution of the data allows us to confirm an enhanced weekly variations $\Delta m \sim 0.3^m$ which is somehow shorter than the previously know typical monthly variations with the same maximum amplitude thought to be caused by non-radial pulsations.

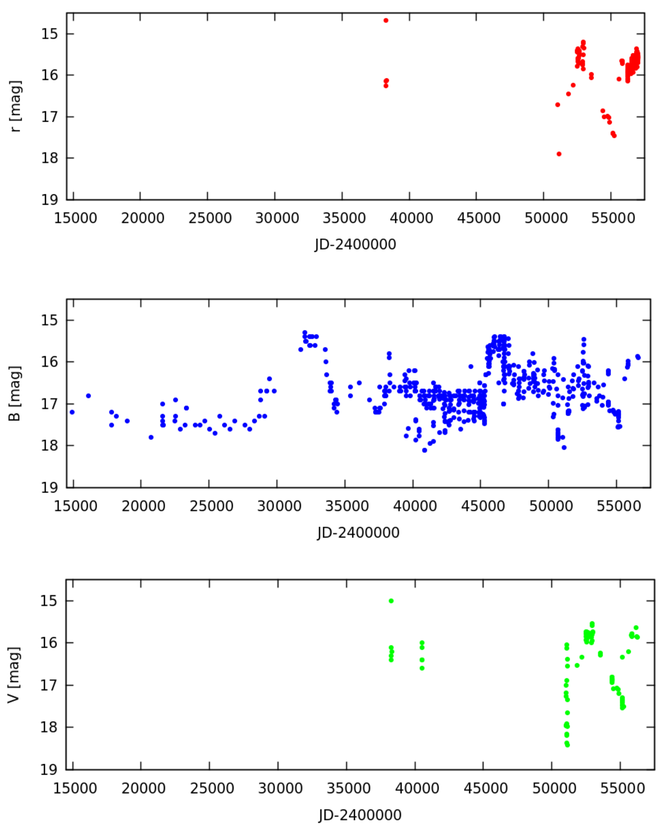


Fig. 3 Light curves of Var C in three different bands (B and V are from Burggraf and r is from OMEGACAM)

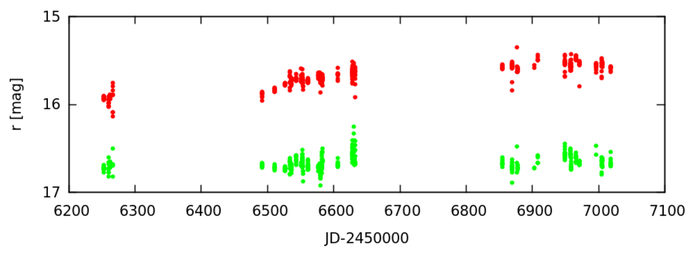


Fig. 5 Comparison light curves for VarC with the OMEGACAM data only in order to compare VarC (a variable star) to an almost standard nonvariable star in the same field

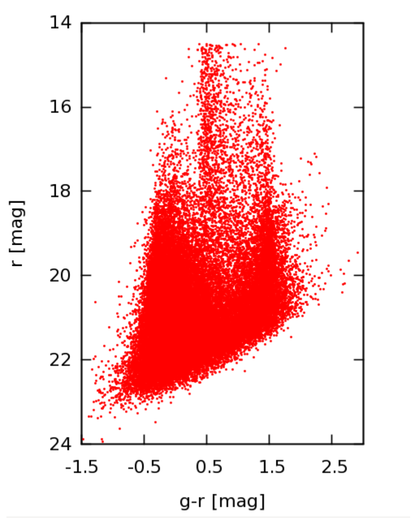
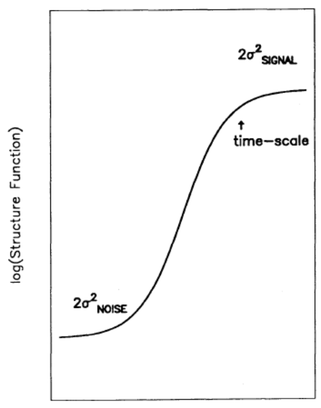


Fig. 7 Magnitude-color diagram for all the stars in the VISTA OMEGACAM survey

#	RA	DEC	V(LGGS)	V(old)	delV	
1	01 32 35.25	+30 30 17.6	18.01			Hot LBV candidate
2	01 32 37.72	+30 40 05.6	17.63	17.50	0.13	Ofpe/WN9 M33WR2
3	01 32 42.26	+30 21 14.1	17.44	18.30	0.86	Hot LBV candidate
4	01 32 45.41	+30 38 58.3	17.61	17.40	0.21	Ofpe/WN9 M33WR5
5	01 32 48.26	+30 39 50.4	17.25			Hot LBV candidate
6	01 33 00.02	+30 33 32.4	18.32	18.00	0.32	Hot LBV candidate
7	01 33 09.14	+30 49 54.5	17.91	17.81	0.10	Ofpe/WN9 M33WR22
8	01 33 24.62	+30 23 28.4	19.58			Hot LBV candidate
9	01 33 27.26	+30 39 09.1	17.95			Ofpe/WN9 M33WR39
10	01 33 32.64	+30 41 27.2	18.99	19.20	0.21	Hot LBV candidate
11	01 33 33.22	+30 33 43.4	19.40			Hot LBV candidate
12	01 33 35.14	+30 36 00.4	16.43	15.20	1.23	LBV Var C
13	01 33 39.52	+30 45 40.5	17.50	17.68	0.18	P Cyg LBV candidate
14	01 33 40.60	+30 41 37.1	18.31	18.20	0.11	Hot LBV candidate
15	01 33 41.28	+30 22 37.2	16.28	16.10	0.18	P Cyg LBV candidate
16	01 33 49.23	+30 38 09.1	16.21	16.40	0.19	LBV Var B
17	01 33 50.12	+30 41 26.6	16.82	16.60	0.22	Hot LBV candidate
18	01 33 50.92	+30 39 36.9	14.17			Hot LBV candidate
19	01 33 51.46	+30 40 57.0	17.73	17.80	0.07	P Cyg LBV candidate
20	01 33 53.60	+30 38 51.6	18.09	18.50	0.41	Ofpe/WN9 M33WR103
21	01 33 55.96	+30 45 30.6	14.86	15.20	0.34	Cool LBV candidate
22	01 33 57.73	+30 17 14.2	17.39			Cool LBV candidate
23	01 34 06.63	+30 41 47.8	16.08	16.30	0.22	Hot LBV candidate
24	01 34 10.93	+30 34 37.6	16.03	16.48	0.45	Hot LBV candidate
25	01 34 16.07	+30 36 42.1	17.95	18.10	0.15	P Cyg LBV candidate
26	01 34 16.10	+30 33 44.9	17.12	16.70	0.42	LBV candidate
27	01 34 16.44	+30 31 20.8	17.10	17.00	0.10	Cool LBV candidate
28	01 34 18.74	+30 34 11.8	19.58	19.20	0.38	Ofpe/WN9 M33WR132
29	01 34 22.91	+30 44 11.0	17.22	17.08	0.14	Cool LBV candidate
30	01 34 24.78	+30 33 06.6	16.84			Cool LBV candidate
31	01 34 26.11	+30 34 24.7	18.97	18.85	0.12	Hot LBV candidate
32	01 34 29.64	+30 37 32.1	17.10	17.42	0.32	Cool LBV candidate
33	01 34 32.76	+30 47 17.2	19.09	18.90	0.19	Ofpe/WN9
34	01 34 42.14	+30 32 16.0	17.34			Hot LBV candidate
35	01 34 59.47	+30 37 01.9	18.37	17.94	0.43	Hot LBV candidate
36	01 35 00.30	+30 41 50.9	19.30			Hot LBV candidate
37	01 35 09.73	+30 41 57.3	18.04			Ofpe/WN9 Romano's Star

Table 2 List of the 35 LBV candidate stars and their types, LBV stars Var B and Var C with their corresponding coordinates and magnitudes (data from Massey 2006)

Fig. 1 Distribution of the available photometry for the stars in the M 33 galaxy, taken from with the SDSS catalog and the new VISTA OMEGACAM observations we are using in this work



Schematic showing the " ideal " structure function for a time series plus measurement noise. As shown in Hughes et al. 1992.

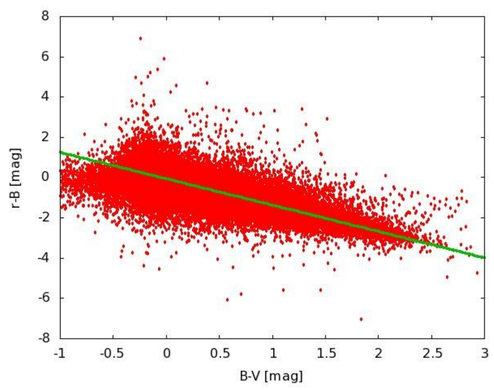


Fig. 8 Color-color diagram for all the stars in the VISTA OMEGACAM survey

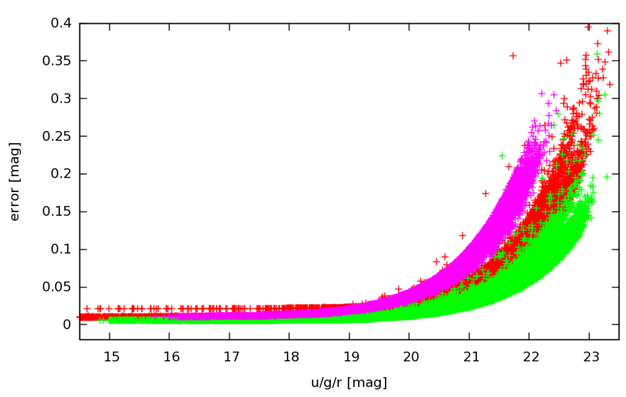


Fig. 10 Diagram representing the errors in measurement of the magnitudes of Var C in three different bands (u, g, r of OMEGACAM)

Conclusions

In our analysis here, we are concentrating mostly on the Luminous Blue Variable (LBV) Var C, one of the most well-studied and bright variable in the Local group. Two different data sets are taken into account, added and compared (Burggraf and OMEGACAM) .

We did two types of calibrations of the 30 LBV Candidate stars and the LBVs Var B and Var C, one with one magnitude zero point (mzp) for each image and one with differential magnitude zero points. The second one seems to add more noise in the raw data than the first one.

We observe that on the longest time scales Var C has the biggest variations in magnitude (more than 2^{mag}) and on the shortest ones, close to the sigma noise, we see only very little variations, when the star is observed for 100sec for example (duration of the exposures of the OMEGACAM).
We are still in the process of doing the same analysis for the rest of the LBV candidate stars and obtaining the corresponding structure functions with the main parameters: slope and time scale for each star.(Gantchev 2016)
We expect, with the different types of behavior in light curves and structure functions, to be able to confirm or reject the membership of the candidate star to this type or not and apply our structure function analysis to other candidates or type of variable stars.
True micro variations of the LBV at the time scales day-hour-minutes, if any, yet have to be proven; SF strongly depends on the photometry error thus the improvement of the calibration is crucial. The peak at 1.5 month is probably false (log(Time) ~ –0.9) and related to the maximum duration of a certain observational run. The multi wavelength picture (+u+g+Haplha) may help to resolve the problem

Fig. 2 Distribution of the stars on the 24 CCD detectors of the OMEGACAM

Log(S)	σnoise
0	~2.2^m
-0.5	~0.4^m
-1	~0.2^m
-2	~0.07^m
-3	~0.02^m

Table 1 Variation of magnitude on different time scales for Var C. (see Fig. 4 for results)

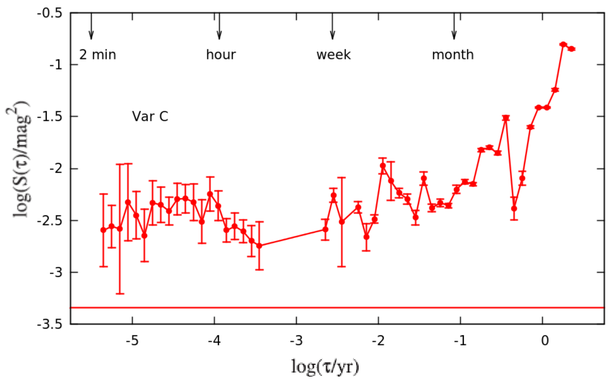


Fig. 4 Structural function analysis for the full data sets of Var C (Burggraf and OMEGACAM) showing different types of variations at different time scales (hours, weeks, etc.)
The lower limit of the sigma noise is also shown (red line)

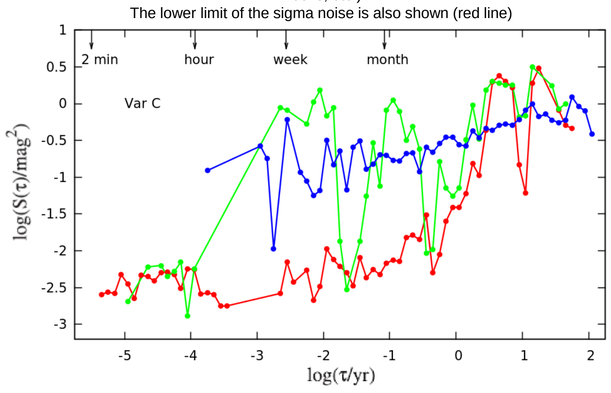


Fig. 6 Structural function analysis for the full data sets of Var C (B and V from Burggraf and r from OMEGACAM) in the three available bands showing the variations on different time scales

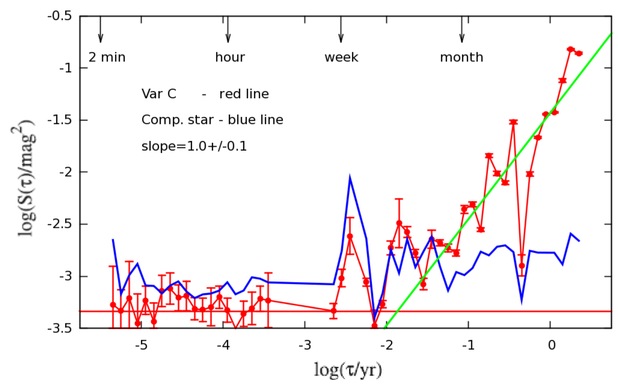


Fig. 9 Comparison between two structure functions, one of the LBV Var C (seen in Fig. 6 in r band) and one of a comparison standard star showing close to none variations, especially at the shorter time scales (less than a week)

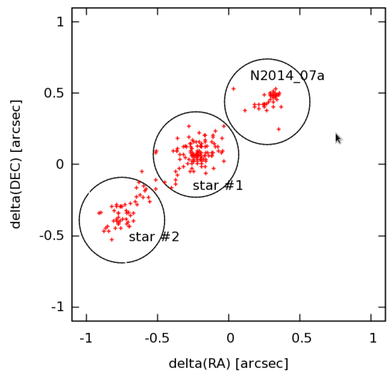


Fig. 11 Zoomed in regions for two detected stars and a Nova star in a portion of a given CCD detector. Each dot represents a measurement for the given star around its centered coordinates

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