

Photometric variability of nitrogen-rich Wolf-Rayet stars in Magellanic Clouds with OGLE

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ABSTRACT

Aims. We present a comprehensive analysis of the photometric variability of (presumably single) nitrogen-rich Wolf-Rayet (WN) stars in the Magellanic Clouds, using long-term observations from the OGLE survey.

Methods. Our sample comprises 47 stars with no nearby Gaia counterparts. We characterize both overall and short-term variabilities, examining data dispersion and identifying periodicities. To validate our findings, we also compare the OGLE light curves with data from the MACHO and TESS missions.

Results. Variability is ubiquitous in our WR sample: about one third of stars display high variability, or four fifths if we include cases with moderate variations. The observed changes are found to be periodic in 11 cases, with timescales of 2–56 d. Such periodic variations originate in corotating wind structures, binary effects, or pulsations, thereby increasing the number of systems known to show these phenomena. Surprisingly, nine targets display (quasi-periodic) outbursts, making such changes a new type of WR variability. The variability shows a transient character, in about 30% of the sample, with changing amplitudes for periodic signals or for outbursts (they even sometimes completely disappear from view). Finally, we identified six long-period variables, four of which have been confirmed by at least two independent surveys.

Wind

cross check of variability : MACHO, TESS

Clump

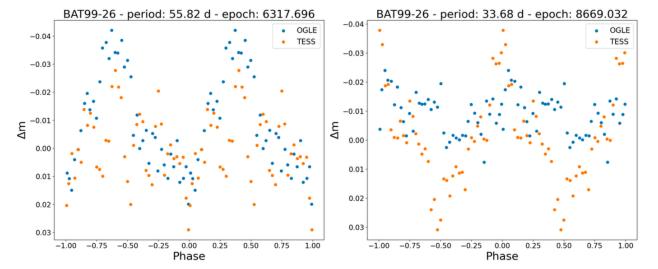
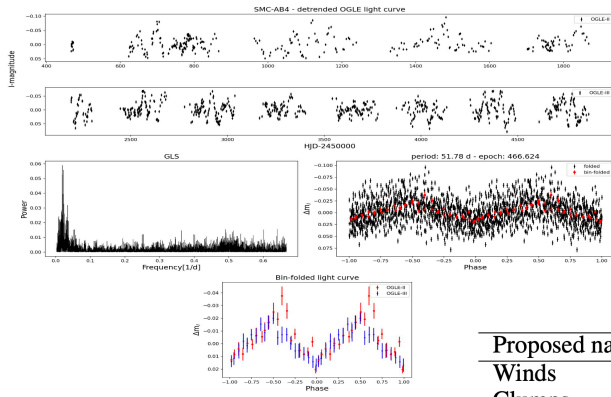
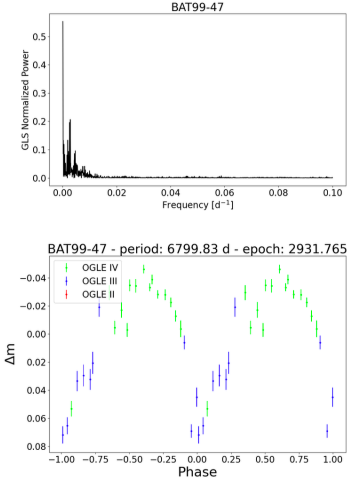


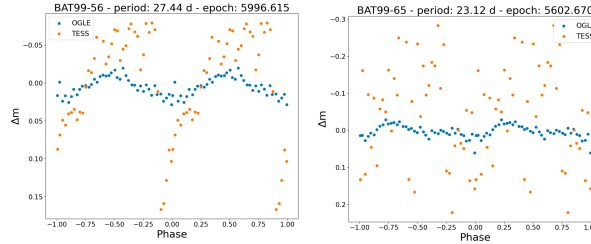
Table 2: Proposed nature of the stars with confirmed variability.

Proposed nature	Name
Winds	SMC-AB4
Clumps	BAT99-26
Pulsation	BAT99-47
CIRs	BAT99-3, BAT99-24, BAT99-48, BAT99-56, BAT99-65, BAT99-124
Binary candidate	BAT99-31, BAT99-51, SMC-AB4
Long-period binary candidate	BAT99-41, BAT99-47, BAT99-94

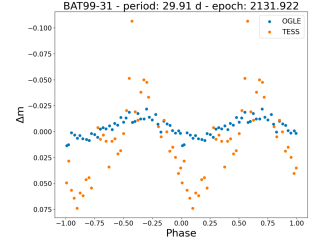
Pulsation



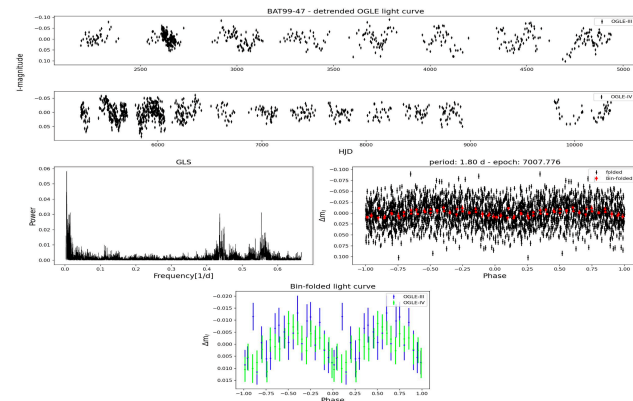
CIRs



Binary candidate



Long-period binary candidate



Outburst (9)

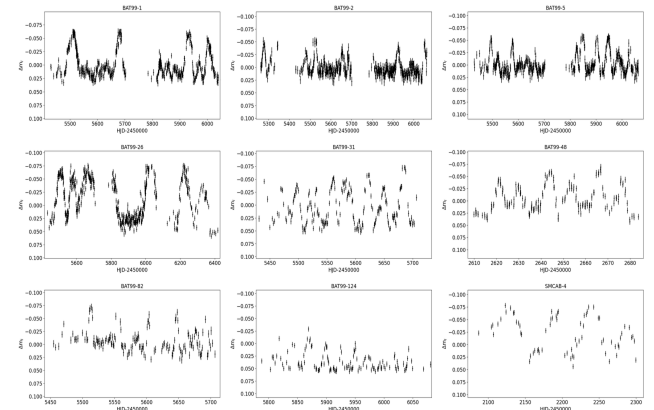


Fig. F.1: Examples of light curves of the nine stars exhibiting frequent outbursts.

Overall, these results underscore the complexity and diversity of variability in WR stars and emphasize the need for dedicated spectroscopic campaigns and continued photometric monitoring to better understand the underlying physical processes.

Appendix A: Physical characteristics of the sampled nitrogen Wolf-Rayet stars

Table A.1: Physical characteristics of the sampled nitrogen WR stars.

Name	Spec. type	$T_{\text{eff}}(kK)$	X-ray (erg/s)	LV	SV	OGLE variability	Bin?
BAT99-1	WN3b	89		H (0.023)	H (0.024)	F_s, O	
BAT99-2	WN2b(h)	141		M (0.017)	M (0.018)	F_s, O	
BAT99-3	WN4b	79		H (0.042)	H (0.038)	$P_s + \text{subH}, \text{Ch}$	
BAT99-5	WN2b	141		M (0.020)	M (0.022)	F_s, O	
BAT99-7	WN4b	158		L (0.005)	L (0.005)		
BAT99-18	WN3(h)	71		L (0.009)	L (0.009)		
BAT99-23	WN3(h)	71		L (0.016)	L (0.016)		
BAT99-24	WN4b	100		L (0.009)	L (0.009)	$P_s + H$	
BAT99-25	WN4ha	67		L (0.009)	L (0.010)		
BAT99-26	WN4b	71		H (0.035)	H (0.034)	F_s, O	
BAT99-30	WN6h	47	$< 1.9 \times 10^{33}$	H (0.020)	H (0.022)		
BAT99-31	WN3	75	diffuse	H (0.032)	H (0.030)	P_s, O, Ch	1
BAT99-35	WN3(h)	71		L (0.009)	L (0.010)		
BAT99-37	WN3o	79		H (0.033)	H (0.029)	Ch	
BAT99-40	WN4	63	$< 2 \times 10^{30}$	M (0.012)	M (0.013)		Gaia
BAT99-41	WN4b	100		H (0.033)	H (0.022)	P_l, Ch	
BAT99-44	WN8ha	45	$< 1.6 \times 10^{33}$	M (0.017)	M (0.019)		
BAT99-46	WN4o	63		M (0.011)	L (0.010)		
BAT99-47	WN3	89	$(4.2 - 1.6) \times 10^{33}$	H (0.047)	H (0.028)	P_l, P_s, Ch	2
BAT99-48	WN4b	89		H (0.029)	H (0.028)	$P_s + \text{subH}, O$	
BAT99-50	WN4h	56		M (0.014)	M (0.016)		
BAT99-51	WN3b	89		M (0.012)	M (0.011)	P_s	
BAT99-54	WN8ha	38	$< 1.5 \times 10^{33}$	M (0.015)	M (0.014)	P_l	
BAT99-56	WN4b	71		H (0.035)	H (0.035)	$P_s + \text{subH}$	
BAT99-57	WN4b	79		M (0.012)	M (0.011)		
BAT99-58	WN7h	47	$< 5.5 \times 10^{33}$	M (0.018)	M (0.019)		
BAT99-60	WN4(h)a	63		L (0.008)	L (0.008)		3
BAT99-62	WN3(h)	71		M (0.015)	M (0.013)	P_l	
BAT99-63	WN4ha:	63		M (0.012)	M (0.013)		
BAT99-65	WN4o	67		H (0.043)	H (0.041)	$P_s + \text{subH}, \text{Ch}$	
BAT99-66	WN3(h)	89		M (0.011)	M (0.012)		
BAT99-67	WN5ha	47	1.7×10^{33}	H (0.030)	M (0.020)	P_l, P_s, Ch	2
BAT99-73	WN4ha	60		M (0.010)	M (0.011)		
BAT99-74	WN3(h)a	79		L (0.008)	L (0.009)		
BAT99-75	WN4o	71		H (0.030)	H (0.032)		
BAT99-81	WN5h	47		M (0.014)	M (0.015)		
BAT99-82	WN3b	100	1.6×10^{33}	M (0.021)	M (0.021)	O	2
BAT99-89	WN7h	50	$< 7.4 \times 10^{33}$	M (0.011)	M (0.012)		
BAT99-94	WN4b	141		L (0.005)	L (0.004)	P_l, Ch	
BAT99-124	WN4	63		H (0.033)	H (0.026)	$P_s + H, O, \text{Ch}$	
BAT99-128	WN3b	112		H (0.028)	H (0.027)	Ch	
BAT99-131	WN4b	71		H (0.022)	H (0.020)	Ch	
SMC-AB1	WN3ha	79		M (0.020)	M (0.014)		
SMC-AB2	WN5ha	47		M (0.015)	M (0.015)		
SMC-AB4	WN6	45		H (0.033)	H (0.029)	P_s, O	2, Gaia
SMC-AB9	WN3ha	100		M (0.013)	M (0.014)	P_s	3, Gaia
SMC-AB10	WN3ha	100		M (0.018)	L (0.010)		

Notes. Spectral types were taken from Neugent et al. 2018, Foellmi et al. 2003a, Foellmi et al. 2003b; T_{eff} has been extracted from Hainich et al. 2014 and Hainich et al. 2015, and X-ray emission from Gosset et al. 2005, Guerrero & Chu 2008, Guerrero & Chu 2008 and Schnurr et al. 2008. The columns LV and SV mark whether a star is classified as low (L), moderate (M), or highly (H) variable overall or on short timescales, respectively. Numbers in parentheses next to it are the scatter in mag. The seventh column provides information about the variability detected in OGLE data (see Sect. 4.1 for details). The letter "O" indicates outbursting cases, whereas "Ch" denotes cases of changing variability. If a star exhibit one significant peak in its periodogram, letters "P" (for a small number of peaks) or "F" (for a forest of peaks) are used, with subscripts s or l for short- and long-term signals, respectively (see Table C.2 for ephemeris). Furthermore, P+(sub)H indicates the presence of (sub-)harmonic. The last column indicates whether the star was previously suspected to be a binary according to the following references: [1] Foellmi et al. 2003b, [2] Hainich et al. 2014, [3] Shenar et al. 2019 [4] Morgan et al. 1991, or if its Gaia astrometric parameters suggest a possible binary nature (indicated as "Gaia").