The wind of the LBV-WR Romano's Star

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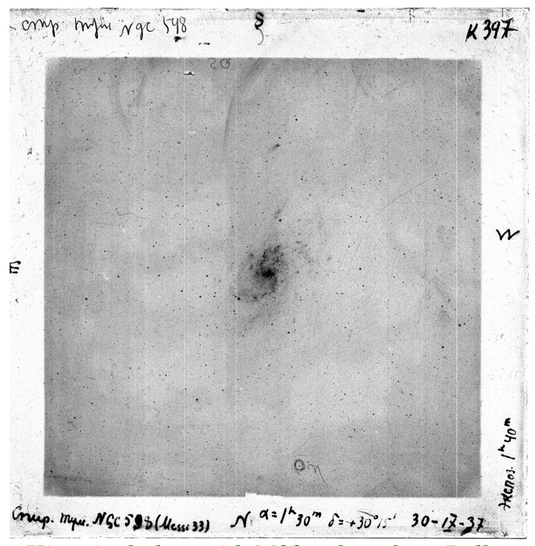

Historical plate with M33 galaxy from Pulkovo observatory glass library.

Abstract

We present new results on the spectral and photometric variability of the luminous blue variable Romano's star in the M33 galaxy (GR 290). It has been proposed that GR 290 is a massive star that is leaving the unstable evolutionary phase associated with the Luminous Blue Variables and is now transitioning towards the nitrogen-rich Wolf-Rayet stars (WN). Modelling of our new spectra has yielded an estimate of the current stellar parameters and some of the parameters of the nebula that surrounds it.

Introduction

GR290, also known as Romano's star or M33/V532, is one of the best studied high mass, strongly variable stars in M33 galaxy. The brightness of GR290 shows large and complex wave-like variations, with duration of the waves amounting to several years (Figure 1), while the spectrum of the object changes from late-B type in the optical maximum (Szeifert, 1996) through Ofpe/WN (WN10,WN11) and WN9 towards WN8h in deep minima (Maryeva et al., 2010).

Historical Light Curve

We have found many digitized images of historical photographic plates obtained by several observatories before 1940 and we used them for constructing the historical light curve of GR 290 (Fig. 1). The historical light curve covers a period of more than one century, including a long period of low luminosity at $17.5 < B < 18.5$ mag during the first half of the 20th century. Since 1960 strong photometric variability appeared. According to Fig. 1 one can identify at least five broad light maxima occurred since 1960, and five light minima. In addition, the light curve shows irregular photometric variations on time scales of weeks to months. Note that in the recent light curve there are no oscillations of such amplitude.

During the last cycles $(B-V)$ color index of GR 290 was basically constant. It is one more important characteristic of GR 290, suggesting that the blue-visual slope of the spectrum has remained substantially unchanged in spite of the ample spectral and luminosity variation. This behavior is different from what is generally expected for the S-Dor variations of LBVs.

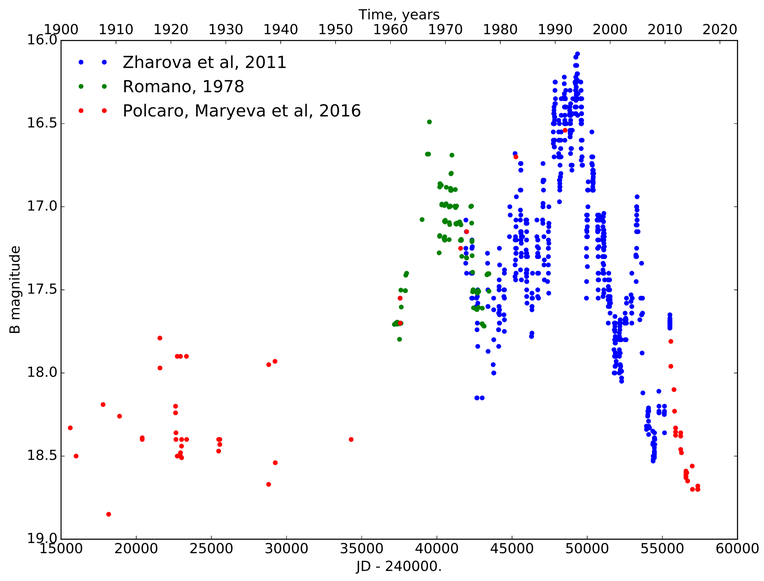

Figure 1: Historical light curve of GR290 from 1901 to 2015 year. Detailed description of used archival data is given in Polcaro, Maryeva, Nesci et al. (2016).

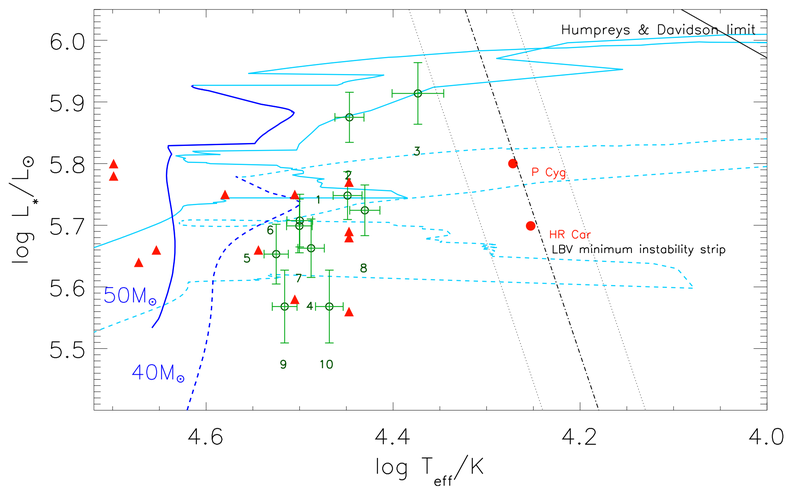

Figure 2: Position of GR290 in the HR diagram. 1 – Oct 2002, 2 – Feb 2003, 3 – Jan 2005, 4 – Sep 2006, 5 – Oct 2007, 6 – Dec 2008, 7 – Oct 2009, 8 – Dec 2010, 9 – Aug 2014, 10 – Jul 2016. The Geneva tracks with rotation are shown by blue lines. Triangles mark late-WN stars from LMC. Data were taken from Hainich et al. (2014).

GR290 in maximum of brightness (V=17$^{\rm m}$.24, Feb. 2005) lies on the LBV minimum instability strip and it moves to the "WR region" in the minimum of brightness.

Acknowledgments

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Investigation of spectral variability

For study of spectral variability of GR290 we used new spectral data as well as archival data obtained at the Cima Ekar (Padova Observatory), Loiano Station (Bologna Observatory), Russian 6-m telescope of Special Astrophysical Observatory, 4-m William Hershel Observatory, and WIYN 3.5-m Observatory (Kitt Peak) telescopes.

We have used the CMFGEN atmospheric modeling code (Hillier & Miller, 1998). In order to see how parameters of GR290 changed with time we constructed ten models for most representative spectra with best quality, obtained between 2002 and 2016. Table 1 lists the parameters of the models, while the model spectra themselves are shown in Fig. 3.

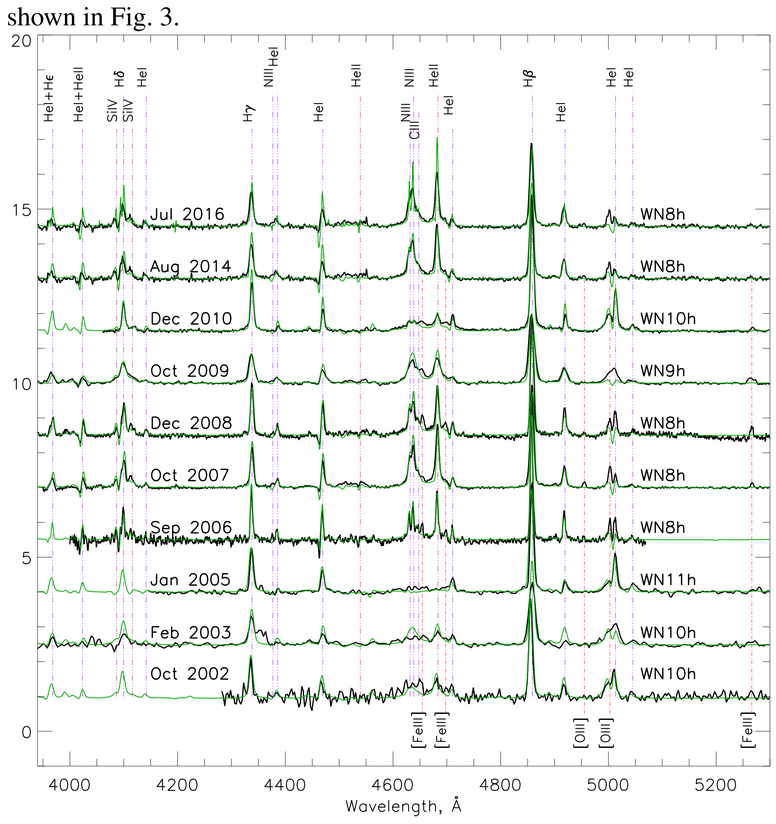

Figure 3: Normalized optical spectra of GR290 compared with the best-fit CMFGEN models (green line). The model spectra are convolved with a Gaussian instrumental profile.

Table 1: Derived properties of GR290. Hydrogen number fraction relative to helium H/He=1.7 ± 0.2. Filling factor $f = 0.2 \pm 0.1$. In calculations we assume that the distance to the M33 galaxy is $D = 847 \pm 60$ kpc.

Date	V	Sp.	T_{eff}	$R_{2/3}$	$L_*, 10^5$	$\dot{M}_{cl}, 10^{-5}$	v_∞
	[mag]	type	[kK]	[$R_\odot$]	[$L_\odot$]	[$M_\odot$ yr^{-1}]	[km/s]
Oct 2002	17.98	WN10h	28.1	32	5.6	1.9	200
Feb 2003	17.70	WN10.5h	28	37	7.5	2.2	200
Feb 2005	17.24	WN11h	23.6	54	8.2	3.5	200
Sep 2006	18.4	WN8h	31	24	4.6	1.3	200
Oct 2007	18.6	WN8h	33.5	20	4.5	1.55	400
Dec 2008	18.31	WN8h	31.6	23.5	5.0	1.9	400
Oct 2009	18.36	WN9h	31.6	24	5.1	1.7	300
Dec 2010	17.66	WN10h	26.9	33	5.3	2.05	200
Aug 2014	18.74	WN8h	32.8	19	3.7	1.43	400
Jul 2016	18.77	WN8h	30	23	3.7	1.5	620

Fig. 4 illustrates the structure of the wind-filled envelope of GR290 during different luminosity phases. It is clear that wind structure of GR290 during the minimum of brightness is similar to the one of typical WN8h star, who does not show spectral or photometric variability. The mass loss rate of GR290 is also similar to $\dot{M}$ of WN8h stars. According to the data obtained in 2016 the wind velocity increases and now is almost comparable with v_∞ for WN8h stars (typical values are $v_\infty = 700 - 800$km/s).

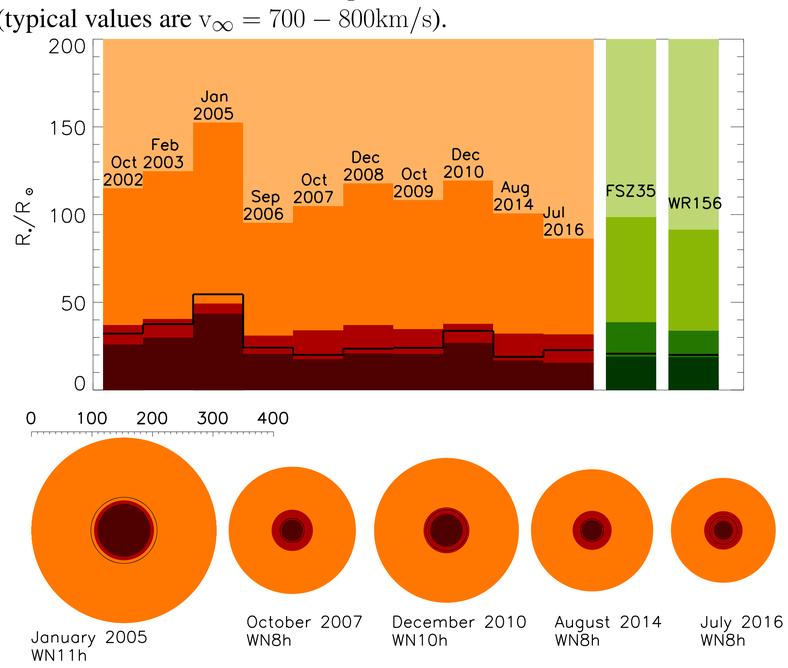

Figure 4: Change of wind extent with time. Region where $n_e \geq 10^{12}\ cm^{-3}$ is shown by dark red, $10^{12} \geq n_e \geq 10^{11}\ cm^{-3}$ – red, $10^{11} \geq n_e \geq 10^{10}\ cm^{-3}$ – orange, $10^{10} \geq n_e\ cm^{-3}$ – light orange. Solid black line shows radius where Rosseland optical depth (τ) is 2/3. WN8h stars FSZ35 and WR156 are also shown for comparison in green tone color.

New Spectral Data

Spectral variability of Romano's star differs from ones of "normal" LBVs. "Normal" LBVs oscillate between B and A-F spectral types, while spectral type of GR290 changes between WN11 and WN8. Only HD 5980 has been documented to oscillate between WN and B-type spectra (Koenigsberger, 2004). HD 5980 is a triple system (Koenigsberger et al., 2014). Similarity of spectral variability of GR290 to the one of HD 5980 was the reason for our new investigation and search of evidences for its binarity. The small binary fraction among LBVs (only 27 percents, as estimated by Martayan et al. (2016)) with much higher one for O-type stars has recently led to the discussion on evolutionary status of LBV stars. Therefore, the direct investigation of their multiplicity is indeed quite important task.

New spectra of GR 290 were obtained with the Gran Telescopio Canarias (GTC) and OSIRIS on 2016 July and August.

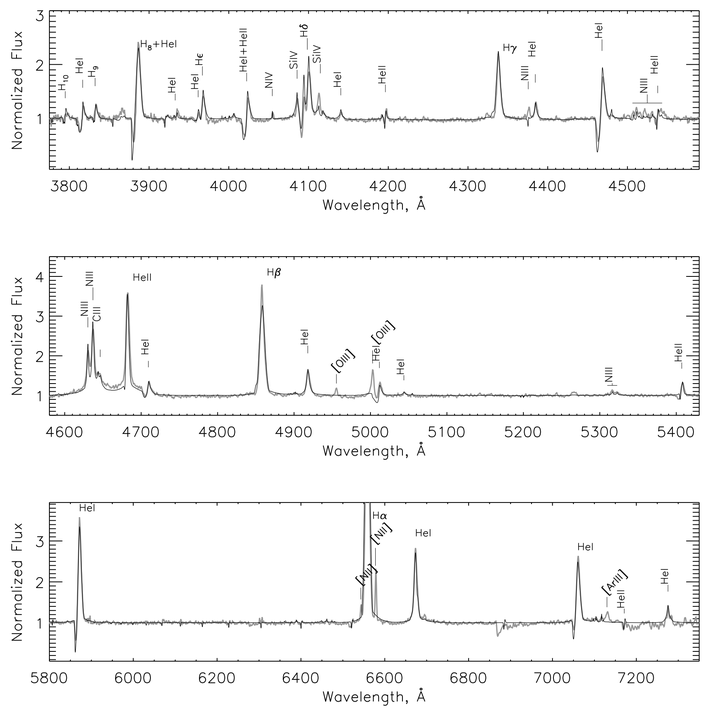

Figure 5: Normalized optical spectra of GR290 (grey line) obtained at GTC compared with the best-fit CMFGEN model (black line).

Fig. 5 shows GR290's spectrum obtained at GTC. Like in data obtained earlier we do not find spectral details which may be an evidences of second component.

Nebula

New spectrum obtained at GTC gives us possibility to investigate the circumstellar nebula around GR290. According to first results of CLOUDY modeling GR 290 is surrounded by compact nebula with size $\simeq 1$ pc and density 30-60 cm^{-3}. Estimations of nebula's size are consistent with non-detection of the nebula on direct images from e.g. Wide-field Infrared Survey Explorer (WISE).

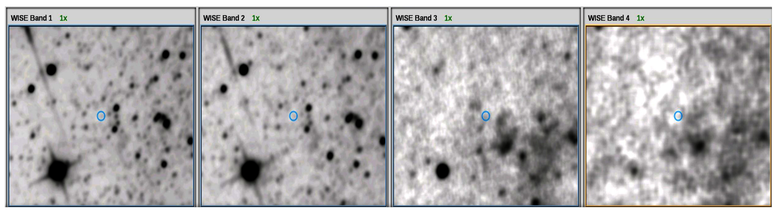

Figure 6: Direct images of GR290 (marked by blue circle) obtained by WISE.

Conclusions

All these facts lead us to conclusion that GR 290 is presently in a short, and thus very rare, transition phase between the LBV evolutionary stage and the nitrogen rich W-R stellar class. Thus the continuing monitoring of the object is very important for both the refinement of stellar evolution theory and the reasons behind the flaring instability of such objects.

Results was published in Polcaro, Maryeva, Nesci et al. (2016)

References

Hainich R., Rühling U., Todt H., et al., 2014, A&A, 565, A27
Hillier D. J., Miller D. L., 1998, ApJ, 496, 407
Koenigsberger G., 2004, Rev. Mex., 40, 107
Koenigsberger G., Morrell N., Hillier D. J., et al., AJ, 148, 62
Martayan C., Lobel A., Baade D., et al., 2016, A&A, 587, A115
Maryeva O., Abolmasov P., 2010, Rev. Mex., 46, 279
Polcaro V. F., Maryeva O. V., Nesci R., et al., 2016, AJ, 151, 149
Szeifert T., 1996, 33, 459