Spectropolarimetry and modeling of Galactic Wolf-Rayet star WR156

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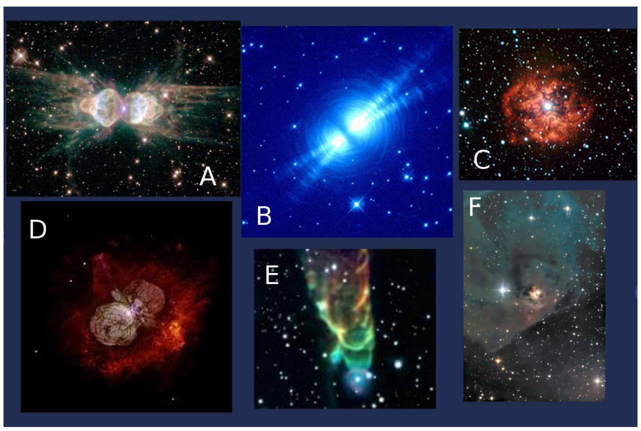
For the first time spectropolarimetric observations of Wolf-Rayet star WR156 (WN8h sub-class) were conducted. Medium resolution spectropolarimetric data in the range of 3500-7200 ÅÅ were obtained at 6-m BTA telescope of Special Astrophysical Observatory. These data show that the light from the star is significantly polarized, with the degree of polarization $P = 1.38 \pm 0.06\%$, and the position angle $\Theta = 77.4° \pm 1.2°$. This polarization is, most probably, has an interstellar origin, as its magnitude and orientation are similar to the ones of field stars. Also, we present results of numerical modeling of WR156 atmosphere performed using CMFGEN code. According to it, WR156 is the richest hydrogen Wolf-Rayet star of WN8 type in the Galaxy.

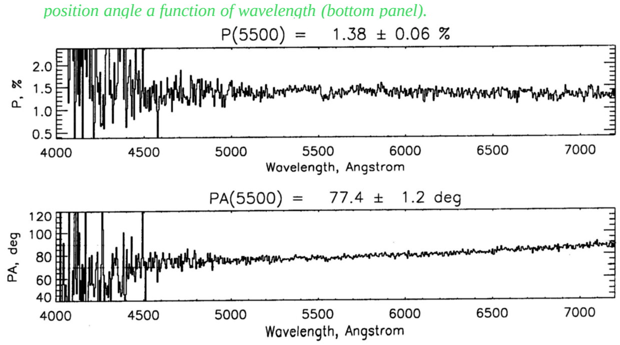
Even for spatially unresolvable objects, linear spectropolarimetry with moderate resolution is a powerful tool to detect and investigate the asymmetric structure of the object. Angel (1969) demonstrated that an axisymmetric source can produce a linear polarization in the continuum (up to 1-5%) due to the Thomson scattering, as for an oblate spheroid the angle of the electric vector is a function of the optical depth. Since the continuum radiation is formed at smaller radii than the line emission (at a given wavelength), continuum photons collide with more free electrons than line photons. The continuum radiation will be more polarized than the emission in spectral lines. This leads to the so-called "line effect", a reduction of observed polarization at wavelengths corresponding to emission lines. The line effect has been discovered in classical Be stars, O stars and Wolf-Rayet stars. If we assume that for isolated WR stars the line effect is related to rapid rotation of the star (Harries & Howarth, 1996; Gräfener et al., 2012), we get a new method to search for rotating WR stars – progenitors of Long-Duration Gamma-Ray Bursts (LGRBs).

Fig. 1 *The most suitable objects to spectropolarimetric studies. A – the planetary nebula Mz3 ("Ant nebula"), B – protoplanetary nebula RAFGL 2688, C – Wolf-Rayet star WR124, D – LBV star η Car, E – Herbig Ae/Be stars, F – T Tauri*



Spectropolarimetric of of WR156 were performed at the 6-m BTA telescope of SAO. Figure 2 shows results of spectropolarimetric observations. The spectrum does not show any signs of reduction in polarization at the wavelengths corresponding to emission lines, i.e. lines effects are not detected

Fig. 2 *The degree of polarization as a function of wavelength (top panel) and the position angle a function of wavelength (bottom panel).*



Estimation of interstellar polarization (ISP) is very important for the study of stellar polarizations. Using the field stars we created a map of the interstellar polarization and we concluded, that, most likely, the polarization measured by us has an interstellar origin.

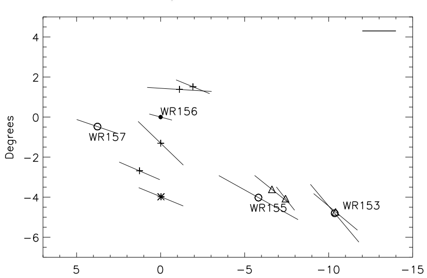


Fig. 3 *The interstellar polarization map around WR156.*

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Using CMFGEN code we constructed the model of the WR156 atmosphere, the parameters are listed in Table . Also the table shows parameters of other Galactic WN8h whose are derived using CMFGEN. Luminosity and mass-loss rate of WR156 are similar to ones of WR40 and WR16 stars, displaying the line effect, but the temperature and the abundance of hydrogen are significantly different from them. Apparently, present statistics on WR stars with line effects is so small that it does not allow to define any relation between the line effect and some parameters of the stellar atmosphere.

Table 1 *Parameters of atmospheres of WR156 and other WN8h stars in the Milky Way and M33 galaxy. X_H, X_{He}, X_C and X_N are the mass fractions of hydrogen, helium, carbon and nitrogen, respectively*

	T_*	R_*	$\log L_*$	$\log \dot{M}_{cl}$	v_∞	X_H	X_{He}	X_C	X_N
				[M$_\odot$/				10^{-2}	
	[kK]	**[$R_\odot$]**	**[$L_\odot$]**	*year*]	**[km/s]**	**[%]**	**[%]**	**[%]**	**[%]**
WR124	32.7	18.0	5.53	-4.7	710	15			
WR40	45.0	10.6	5.61	-4.5	840	15	83	1.2	1.12
WR16	41.7	12.3	5.68	-4.8	650	23	75		
WR156	36	18.7	5.72	-4.82	650	33	65.8	6	0.7
WR156	36	14.8	5.52	-5	650	33	65.8	6	0.7

The Figure 5 shows a comparison of the normalized observed spectrum with the model in optical range, and Figure 4 – comparison of the model spectrum in the ultraviolet (UV) range with spectra obtained with IUE.

Fig. 4 *The spectrum of WR156 (green line) in UV range compared with the best-fit* CMFGEN *model (black line).*

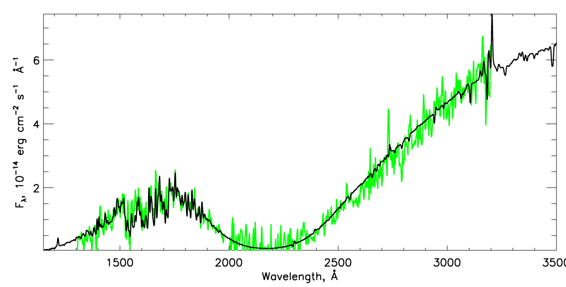
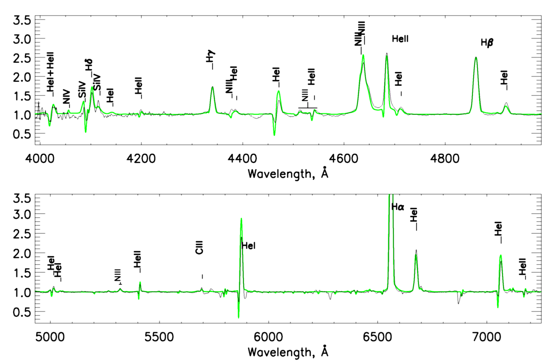


Fig. 5 *The normalized spectrum of WR156 (black line) compared with the best-fit* CMFGEN *model (green line).*



Results and conclusions

Spectropolarimfetric observations of the Galactic Wolf-Rayet star WR156 (WN8h type) were carried out for the first time. Measured degree of polarization is $P = 1.38 \pm 0.06\%$, position angle is $\Theta = 77.4 \pm 1.2°$, the line effects were not found. We created the the map of the interstellar polarization in the direction of WR156 using the field stars and compared these values with it. Most likely, the polarization detected by us has an interstellar origin.

Spherically symmetric wind model of WR156 was constructed, physical parameters and chemical composition of the atmosphere WR156 were derived. By its parameters WR156 is similar to other WN8h stars, displaying the line effect. There is a significant (33%) excess of hydrogen in the atmosphere of WR156. According to the results of modeling WR156 is the richest hydrogen Wolf-Rayet star of WN8 type in the Galaxy.

References

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