Massive Stars Near and Far
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Metal-poor Wolf-Rayet star enriching the ISM by nitrogen in the galaxy NGC 4068

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Abstract. We discovered a nebula in the low-metallicity (Z=0.1 $Z_\odot$) nearby ($D = 4.4$ Mpc) dwarf galaxy NGC 4068, which reveals broad H_α line profile and unusual emission line fluxes in its spectrum. The object also shows significant nitrogen overabundance, not typical for metal-poor environment. We assumed that the nebula could be ionized by an evolved massive star with $M \approx 80\ M_\odot$, Wolf-Rayet or Blue Supergiant, and built models of the nebula using Cloudy and CMFGEN codes. Our models successfully reproduce the optical emission spectrum of the object, including the peculiar [SII]/[NII] ratio and the presence of the HeII λ4686 line.

Keywords. stars: Wolf-Rayet, stars: mass loss, ISM: abundances

1. Observations

Analysing the small-scale kinematics of the ionized gas in the galaxy NGC 4068 with a scanning Fabry-Perot interferometer at the SAO RAS 6-m telescope BTA, we found compact nebulae (Object #A) with both high surface brightness and line-of-sight velocity dispersion in the Hα line. We obtained four long-slit spectra of it. The spectra exhibit several peculiarities: unusually low [SII]/[NII] ratio, presence of HeII λ4686 line. To estimate the flux in [OIII] λ5007 line, we performed a photometry at the BTA with the narrow-band filter and obtained $m_{5007} = -5.42^{+0.29}_{-0.39}$ mags thus excluding its apearance as a planetary nebula. Hubble Space Telescope (HST) images of NGC 4068 clearly show that the Object #A is a nebula ionized by a single star instead of a small cluster.

Taking into account the high luminosity of the object ($M_{bol} = -10.97$ from HST photometry), its position in the colour-magnitude diagram, strong [OIII] λ5007 line and significant nitrogen overabundance ($\log(N/O) \approx -0.2$), we put forward a hypothesis about the ionization of the nebula by a massive star ($70 - 80\ M_\odot$) at a late stage of evolution (Blue Supergiant star (BSG) or Wolf-Rayet star – WR).

2. Modelling

We modeled the spectrum of the Object #A assuming it is a nebula ionized by a massive single BSG or WR star ($M \sim 80\ M_\odot$) with high mass loss rate. At the first step we created a model of the ionizing star using the CMFGEN code

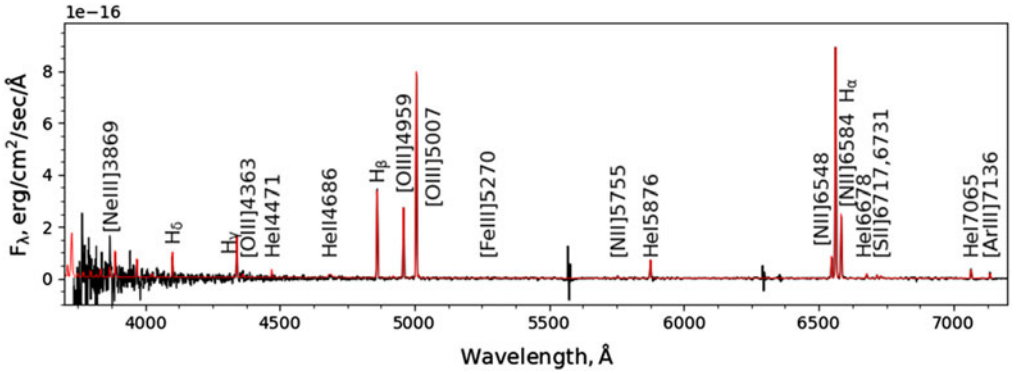

Figure 1. Comparison of the nebula model, ionized by WR star of $M = 80\ M_\odot$ with the spectrum observed with SCORPIO-2 (Afanasiev & Moiseev 2011) at the 6-m telescope BTA.

(Hillier & Miller 1998). The output spectrum was used as an ionization source for the next step, where we estimated parameters of the surrounding nebula using Cloudy photoionization code (Ferland et al. 2017).

Initially, we used calculated evolutionary tracks for massive stars at low metallicity from the work of Georgy et al. (2013). According to their calculations, metal-poor stars become colder and move along the track to the right side of the diagram after the end of hydrogen burning in the core and do not return to the left side of the diagram. Therefore, the most suitable point is the beginning of the BSG stage.

Changing the abundances scaling can dramatically change the massive star evolution. Grasha et al. (2021) calculated the grid of evolutionary tracks for massive stars in the wide range of metallicities implementing the Galactic Concordance abundances to the stellar evolution models, allowing stars with the initial mass of $M \geq 70\ M_\odot$ and rotation $V/V_{crit} = 0.2$ move to the right after the main sequence and then return to the left and to create high-mass WR stars for a low metallicity.

Our best-fit model fits well to the observations (Fig. 1). Our WR models describe the observed properties better than BSG. The in-details analysis of this object will be presented in Yarovova et al. (in prep.).

3. Conclusions

We describe and model the peculiar low-metallicity nebula identified in the nearby galaxy NGC 4068. We argue that it is a WR star of mass $\sim 80\ M_\odot$ in the transitional evolutionary stage, ionizing the nebula and enriching ISM with nitrogen. Such objects are not well-studied yet. High resolution 3D spectroscopy can help to identify such objects thanks to their high luminosity and velocity dispersion in the H_α line.

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