Search for LBV Stars in the Local Volume Galaxies

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Abstract. We consider methods for searching for Luminous blue variable (LBV) stars in the Local Volume galaxies. We present new results of monitoring of two objects in M31 galaxy. In Local group galaxies, the search for LBV stars has only recently begun. We present two very reliable LBV candidates in NGC 247 and NGC 4736 galaxies. Based on the obtained data, we discuss the masses and possible evolutionary status of the studied stars.

Keywords: stars: variables: S Doradus; stars: massive; galaxies: individual: M 31, NGC 247, NGC 4736

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1 Introduction

Luminous Blue Variable (LBV) stars are evolved massive objects, which are previous to core-collapse supernova LBVs are characterized by photometric and spectroscopic variability, produced by strong and dense winds and mass-loss events.

The first LBV stars were discovered in our and nearby galaxies by photometric variability in the optical band based on photographic methods (Hubble 1926, 1929).

The most effective way to detect LBV stars in our galaxy now is searching in the infrared range, since most LBVs are surrounded by compact circumstellar gas and dust envelopes. Several new LBVs and cLBVs in the Galaxy were found using the data of IR telescopes (Gvaramadze et al. 2010, 2015; Kniazev et al. 2016). It's possible search for cLBV as hot stars by photometry in the far UV range (Massey et al. 1996).

One of the most commonly used searching method includes looking for blue stars with Hα emissions (Sholukhova et al. 1997; Valeev et al. 2010; Massey et al.

2006). We successfully used this method for the LBV search in M31 and M33 galaxies (Sholukhova et al. 2018).

Applying the same method, we have expanded the range of our search to the boundary of Local Volume. We search for LBVs and similar objects using the archival broadband and near Hα narrowband images, obtained with Hubble Space Telescope (HST). Our survey of Local Volume galaxies which aim to detect of LBVs is presented in the papers of Solovyeva et al. (2019, 2020c,b).

2 Monitoring

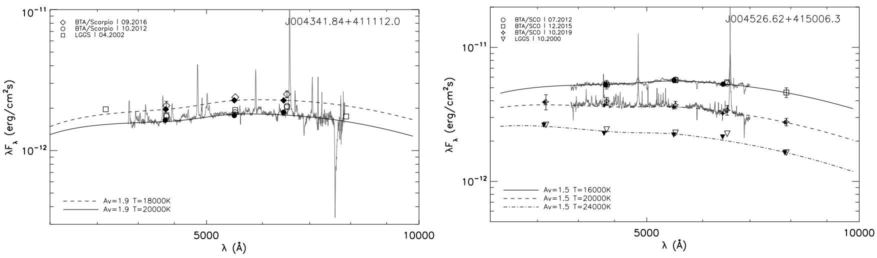

Fig. 1. Left:The SED of J004341.84+411112.0 in the optical range. The model spectra are shown with the solid (for the 16.10.2012 epoch) and dashed (for the 26.09.2016 epoch) lines. Right: The SED s of J004526.62+415006.3. The model spectra are shown with the solid (for the 15.07.2012 epoch), dashed (for the 26.09.2019 epoch) and dash-dotted (for the 10.2000 epoch) lines. The filled symbols designate the approximated data sets corrected for the emission lines. The legends in the panels indicate the best fitting temperatures and reddening. The error bars for the photometric data points could be less than the symbol size.

Object **J004341.84+411112.0** in M31 was detected as LBV candidate by Massey et al. (2007). We perform its photometric and spectral monitoring on the BTA telescope and use available archival data to study it. J004341.84+411112.0 demonstrates photometric variability (about 0.3^m in R band), which allows us to classify it as a LBV. The results are presented in the articles of Sholukhova et al. (2015); Sarkisian et al. (2020). Here we show spectral energy distributions (SED) in Fig. 1 and temperature and luminosity estimates from these works.

Object **J004526.62+415006.3** in M31 was detected as LBV candidate (Massey et al. 2007). Spectral studies of the object were carried out in 2000 (Massey et al. 2006), in 2010, 2015 (Humphreys et al. 2017), in 2011, 2012,

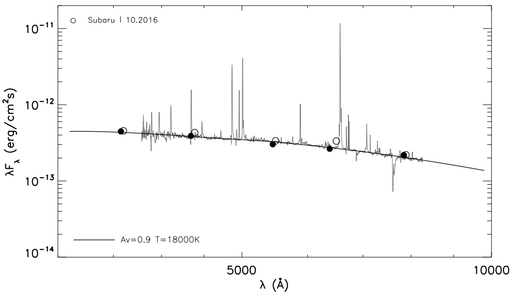

Fig. 2. SED of J004703.27-204708.4 in the optical and range. The filled circles indicate photometry from Subaru in 10.2016 with the contribution of bright emission lines, unfilled — excluding emission lines.

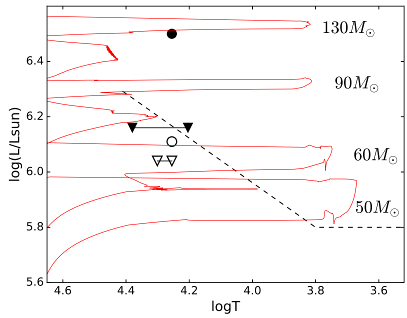

Fig. 3. Temperature – luminosity diagram with evolutionary tracks of massive stars for the metallicity of $Z = 0.01$ (Tang et al. 2014). Open circles – J004703.27-204708.4, filled circles – NGC4736_1, open triangle – J004341.84+411112.0, filled triangle – J004526.62+415006.3. A thick dash line indicates the Humphreys-Davidson limit.

2017, 2019 (Sholukhova et al. 2015, 2020). J004526.62+415006.3 demonstrates significant photometric and spectral variability. Our data suggest its clear LBV-like variability: the star becomes cooler and brighter or hotter and dimmer. All parameters which we estimated from SED modelling on Fig. 1 presented in Tab. 2.

The object **NGC4736_1** was detected as a result of realization of LBV search program in galaxies of Local Volume (Solovyeva et al. 2019). The object showed significant photometric variability about 1.18^m and 0.9^m in V and B band respectively. Later we also discovered the spectral variability on the work Solovyeva et al. (2020a). NGC4736_1 was concluded to be an LBV star based on photometric and spectral variability and luminosity. We took the temperature and luminosity estimates from Solovyeva et al. (2019) and show them in Tab. 2 and Fig. 3.

The object **J004703.27-204708.4** in the NGC 247 galaxy was first presented in the paper Solovyeva et al. (2020c). We have found that object shows brightness variations of 0.7^m and 0.9^m in B and V bands. We have not yet detected spectral variability and this object remains in the LBV candidate status. Here we provide SED, temperature and luminosity estimates by Solovyeva et al. (2020b).

According to their location on the Hershprung-Ressel diagram, LBVs are divided into two classes by Humphreys et al. (2016): bright classical LBVs with bolometric stellar magnitudes from -9.7 to -11.5 mag and initial masses of more than $50M\odot$, and less bright ones with M_{bol} from -8.0 to -9.5 mag and masses of $25-40M\odot$, which may pass the red supergiant stage during their evolution. All our objects have M_{bol} more -10^m and initial masses more $60M\odot$ (Fig. 3). This makes it possible to classify them as a subtype of bright classical LBV with rapid evolutionary variability, which makes their further monitoring very valuable for understanding their nature.

Table 1. Parameters of the studied stars

Star	A_V, ^{m}	T, K	$M_{\rm bol}$, ^{m}	$\log(L_{\rm bol}/L_\odot)$
J004526.62+415006.3	1.5 ± 0.2	16000	-10.6 ± 0.6	6.11 ± 0.2
J004526.62+415006.3	1.5 ± 0.2	24000	-10.6 ± 0.6	6.11 ± 0.2
J004341.84+411112.0	1.9 ± 0.12	18000	-10.3 ± 0.17	6.04 ± 0.1
J004341.84+411112.0	1.9 ± 0.12	20000	-10.3 ± 0.17	6.04 ± 0.1
J004703.27-204708.4	0.8 ± 0.1	18000	$-10.51^{+0.5}_{-0.4}$	$6.11^{+0.2}_{-0.16}$
NGC4736_1	0.9 ± 0.2	18000	-11.5 ± 0.5	6.5 ± 0.2

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