The Stellar Content of Local Group Galaxies
IAU Symposium, Vol. 192, 1999
Patricia Whitelock and Russell Cannon, eds.

Spectroscopy of Blue Stars with Hα Emission in M33

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Abstract. Results of follow-up multi-object spectroscopy of 173 blue stars with Hα emission in the galaxy M33, carried out on the 6-m telescope, are presented. The stars have been originally selected as candidates for LBV and SS 433-type stars. The spectra have been obtained in the region of Hα. All the objects have fallen into two groups – stars with probable intrinsic Hα emission and stars where this emission may belong to HII regions. A number of criteria have been used at the selection, the principal one being the width of Hα emission. 57 stars in whose spectra the Hα line was broad have been selected. Spectra of the most interesting stars are presented. On the basis of luminosity and spectral type, stars were selected which may be considered as hypergiants or LBV candidates (3 of them – N 41, N 512, N 517 are the most reliable). Two stars (v 532, N 35) have spectra similar to MCA1-B (Ofpe/WN9). The object I 322 is discussed as a candidate for an SS 433-type star.

1. Introduction

We performed this study (Sholukhova et al. 1997; 1998) as part of a program to search for unique objects in nearby galaxies which was initiated by Fabrika & Sholukhova (1995). We search for SS 433 objects; luminous blue variables (LBVs: Hubble-Sandage objects, S Dor, P Cyg, and similar stars); blue hypergiants and the brightest WR stars. Methods and criteria of candidate selection are discussed by Fabrika & Sholukhova (1995) and Fabrika et al. (1997). Our list contains 678 objects.

2. Observations

The follow-up spectroscopy of selected candidates was carried out on the 6-m telescope at the Special Astrophysical Observatory (Russia). 173 spectra were obtained during the 1994/1995 observing seasons with the multi-object spectrograph (Afanas'ev et al. 1995) and 530×580 pixel CCD. Typical integration time was 90 min. The spectra have the following properties: spectral resolution: 7 to 8 Å; typical signal-to-noise ratio in continuum: 10 to 20; wavelength coverage: $\lambda\lambda$ 5500 to 7600.

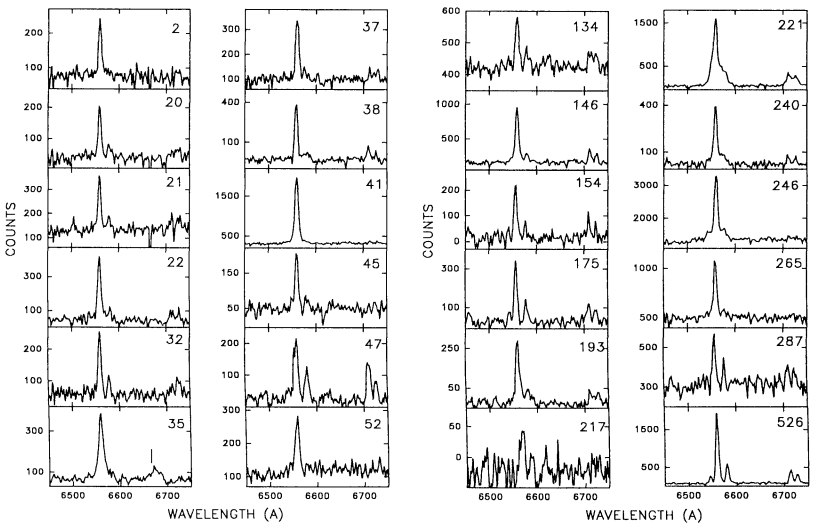

Figure 1. Portion of the spectra of some of the objects.

3. Analysis

The spectral resolution was enough to confidently separate Hα emission, [N II] $\lambda\lambda$ 6548, 6583, and [S II] $\lambda\lambda$ 6716, 6731 doublets. The Hα emission line is most informative, because the site of its formation — a stellar atmosphere (a wind) or nebula — may be inferred after instrumental profile correction from the line width and profile.

The prime objective of this study is to identify stars with an intrinsic (broad) Hα emission line. The intensity of nitrogen and sulfur lines can serve as additional criteria of selection. We divided all stars according to Hα line width — those with a broad, narrow, and probable broad line. Spectra of some of the objects are shown in Fig. 1. They cover the range 6450 – 6750 Å, which includes Hα, [N II] $\lambda\lambda$ 6548, 6583 and [S II] $\lambda\lambda$ 6716, 6731 lines. The spectra are given in relative intensities. Some of the objects exhibit the He I λ6678 line (indicated in the spectra by vertical bars).

WR Stars

Our sample (Fig. 2) contains two well-known WR stars, L 225 (Lequeux et al. 1987) and N 5. The first star is WC, it is known as MC 79 (Massey & Conti 1983). Star N 5 is known as MCA1-B. It belongs to the Ofpe/WN9 type. Smith et al. (1995) carried out a detailed study of MCA1-B and showed that this object is a WN9 star (probable dormant LBV). Thus far, MCA1-B remains the only known star of this type in M33.

The variable star v 532 (Fig. 2) shows a remarkable spectrum. The width of Hα is 800 km s^{-1}; a broad He I line is prominent. For the mean absorption of the brightest blue–Hα stars in M33 ($A_V \approx 1$ mag, Fabrika & Sholukhova 1997)

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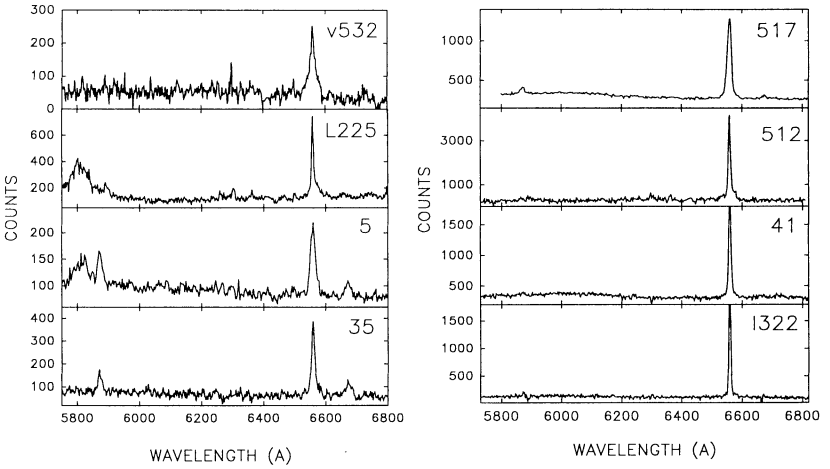

Figure 2. Spectra of LBV candidates and WR stars.

its luminosity lies in the range $M_V = -7.4$ to -8.7 mag. Based on the similarity of v 532 and N 5 spectra we therefore consider v 532 to be a candidate for WN — LBV stars. Object N 35 is a new WN star in M 33, its spectrum is very similar to that of MCA1-B (N 5). It shows two He I lines and Hα. The morphology of its Hα image corresponds to a bubble nebulae with a size of 17 pc (Fabrika et al. 1997).

LBV Candidates

N 517 exhibits a broad and asymmetric Hα line, whose blue wing appears to be distorted by absorption. The line profile is typical of an outflowing stellar atmosphere, but the amount of absorption is not enough to form a P Cyg profile. The spectrum shows the He I λ5876, λ6678 and λ7065 emission lines. In the color-magnitude diagram, N 517 lies on the hypergiant branch, its luminosity is $M_V \approx -8.1$ mag.

N 512 exhibits a very bright narrow Hα line, in whose profile broad and asymmetric wings are well seen. Weak emission lines of He I λ 5876 and He I λ 6678 are seen, though the λ 5876 line profile is distorted by not perfectly corrected sky emission λ 5890. In the color-magnitude diagram this object lies between hypergiants and BIa supergiants, its luminosity is $M_V \approx -7.8$ mag.

The blue star N 41 can also be considered to be an LBV candidate, its luminosity is $M_V = -7.8$ mag at the absorption $A_V = 0.5$ mag. N 41 exhibits a broad Hα line with asymmetric wings and He I λ 5876 and λ 6678 emission lines.

We can not identify LBV stars on the base only of luminosity, colors, and spectrum near Hα, but we can isolate candidates for objects of this type. For the brightest blue stars, photometric and spectroscopic variability appears to be a critical indicator, which allows a star to be assigned to this class (Humphreys & Davidson 1994); therefore, only further photometric and spectral studies can clarify these stars' nature.

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I 322 (X–3) — WN? — SS 433 Star?

The X-ray source X-3 lies in the giant H II region NGC 592. There is a supernova remnant SNR 013022+30233 in its box (Viallefond et al. 1986). For spectroscopy we took the blue star I 322 (Ivanov et al. 1993). The choice was made only because of the symmetrical location of this object in the H II region. Drissen et al. (1990) found that I 322 could be a WN star because it is bright in He II λ 4686 images. Its relatively narrow Hα line (FWHM = 80 km s^{-1}) has broad wings more than 1000 km s^{-1} wide. The spectrum in Fig. 2 shows two He I lines, but the λ 6678 line profile is distorted by a defect.

I 322 could be a WN-type star, but its spectrum has not even weak C IV λ 5800 emission and its He I emission lines are very weak in comparison with Hα. The most attractive idea is that on the basis of the spectrum and its central position in the NGC 592 region, we may include this star among the candidates for the SS 433 type. Formally the object I 322 satisfies all the observation criteria of similarity to SS 433 (OB star, Hα emission, He II emission, SNR in radio, X-rays).

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Discussion

Bohannan: The defining characteristics of the Ofpe/WN9 stars and others are located in the blue spectral region. Is it possible to obtain blue spectra to confirm your proposed identifications?

Sholukhova: Yes, it is possible with the 6m telescope, but this requires a lot of observing time.

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