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The discovery of SN1998bv in blue compact galaxy HS 1035+4758

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1. Introduction

Supernovae (SNe) are spectacular explosions of some stars which have ran out of their thermonuclear fuel in the process of evolution. According to theoretical models, most massive stars (M > 10–15 $M_{\odot}$) almost inevitably end in such an explosion (Fowler and Hoyle, 1964; Woosley and Weaver, 1986). Since the life cycle of massive stars is very short (< 30 Myr), one can expect to observe more or less frequent SNe in galaxies where current intensive star formation takes place. Blue Compact Galaxies (BCGs), or HII-galaxies, are low-mass gas-rich galaxies where we are witnessing very intensive star formation (SF) events, lasting not longer than 10 to 100 Myr. Such events are usually called SF bursts since the SF rate during those periods is many times higher than the SF rate averaged over the whole life-time of a galaxy. It is curiuos that despite about 30 years of study the phenomenon of BCGs and various observations of about a thousand such objects, the first SN in BCG was discovered as late as 1995 (SN 1995ah in BCG HS 0016+1449, Popescu et al., 1997).

We report on the second SN in BCG, discovered in observations with the 6 m telescope of SAO (Kniazev et al., 1998). The observations were conducted in the frame of the follow-up spectroscopy of the candidates selected in the Hamburg/SAO Survey (HSS) for emission-line galaxies (Lipovetsky et al., 1996; Ugryumov et al., 1998; Pustilnik et al., 1998), which is based on the digitized plates of the Hamburg Quasar Survey (Hagen et al., 1995). The main goal of the HSS is the creation of a large new BCG sample in a large area of the sky.

The supernova SN 1998bv was discovered on April 6, 1998 in the galaxy HS 1035+4758 selected as an ELG candidate in the HSS. This galaxy had been previously catalogued in literature as NPM1G+47.0175 (Klemola et al., 1987) with the coordinates of the center R.A. = $10^h38^m25\overset{s}{.}71$, Dec. = $+47°42'36\overset{''}{.}5$ (J2000) and the estimate of blue magnitude B=$16\overset{m}{.}97$. Both the redshift and the type of this galaxy were unknown. In Fig. 1 we present its Digital Sky Survey (DSS) image.

Table 1: *Dates and instrumentation set-up for spectroscopic observations*

Date (UT)	April 6.914 1998	April 19.774 1998	April 24.783 1998
Dispers. (Å/pixel)	2.4	2.4	4.6
Resol. (Å)	6	6	12
Spectr. range (ÅÅ)	3700–6100	3700–7400	3600–8000
Expos. time (s)	300	300	600

2. Observations and reduction

Long-slit spectra in the range 3600–8000 ÅÅ were obtained during three runs. The spectra were centered on a star-like object at ≈ 3″ to the west and ≈ 4″ to the south of the galaxy center. The spectrograph SP-124 at the Nasmyth-1 focus of the 6 m telescope with UAGS camera and Photometrix CCD PM1024 (24 × 24μm pixel size) was used for the observations. The spatial scale along the slit was equal to 0.4″/pixel, the slit length was about 40″, and a slit width of 2″ was used. Gratings with 300 and 600 grooves/mm were used, resulting in a spectral resolution of approximately 12 and 6 Å (FWHM). Series of bias images were obtained twice — at the beginning and at the end of every night. Dark current and flat field were usually accumulated at the end of the night. At least two standard stars from the list of spectrophotometric standards (Massey and Strobel, 1988) were observed every night. A He-Ne-Ar lamp was used for wavelength calibration.

In Table 1 the instrumental set-ups are presented for spectral observations of SN 1998bv and the galaxy HS 1035+4758. The spectroscopic data were reduced using the context LONG from the MIDAS software package. The reduction of the original two-dimensional CCD data included the standard steps such as bias and dark subtraction, flat-fielding, cosmic-ray removal. After wavelength mapping, the night sky background subtraction was performed. 1D spectra were extracted by adding some consecutive CCD rows centered on the object intensity peak along the slit. Then corrections for atmospheric extinction and flux calibration were applied. For the flux cal-

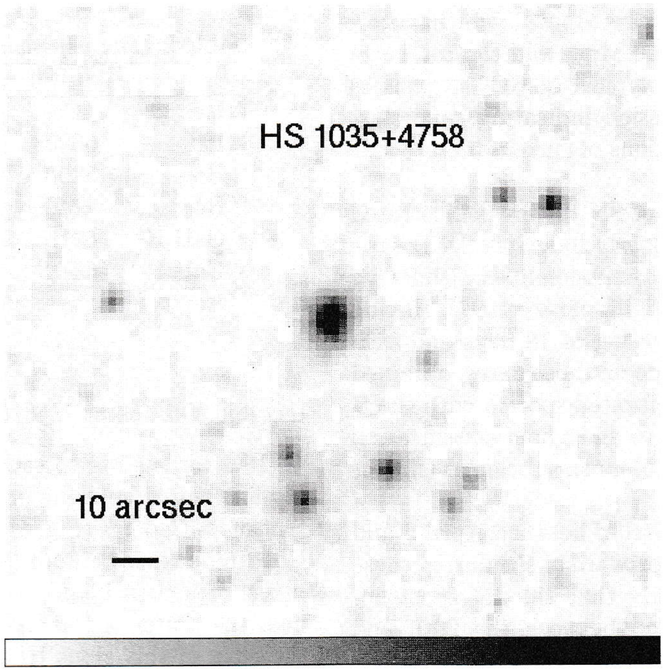

Figure 1: *DSS image of the galaxy HS 1035+4758. North is up, east is left.*

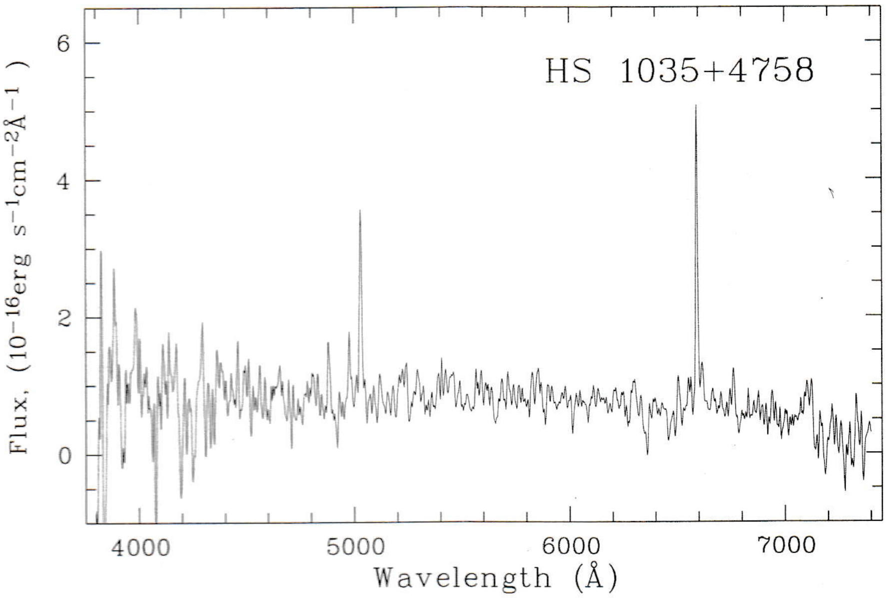

Figure 2: *Short exposure spectrum of the central part of the host galaxy HS 1035+4758.*

ibration we used the mean response curve obtained from the observations of standard stars.

3. Results and Discussion

In Fig. 2 the spectrum of the host galaxy HS 1035+4758 is shown, in which typical HII-galaxy narrow emission lines are seen: Hβ λ4861, [OIII] $\lambda\lambda$4959,5007, Hα λ6562, [NII] $\lambda\lambda$6548,6584 and [SII] $\lambda\lambda$6716,6731 Å. The equivalent widths of the strongest emission lines, Hβ, [OIII] 4959,5007 and Hα, are 20, 20, 60 and 90 Å, respectively. The galaxy redshift as measured using these strong lines is z=0.0054±0.0001.

The absolute blue magnitude $M_B = -15^{m}.5$ (for linear model of Virgo flow correction and adopted

Hubble constant 75 km s^{-1} Mpc^{-1}, which corresponds to a distance of 29.6 Mpc) and the total size of about 20″ (2 kpc) are typical of BCGs, galaxies with strong HII-type emission indicating superclusters of massive stars in regions of current intense star formation.

The spectral evolution of SN 1998bv is illustrated in Fig. 3. The spectrum clearly indicates SN II type with strong broad hydrogen emission lines with P Cyg profiles (see e.g. review by Filippenko, 1997). Having 3 spectra with a total time lag of 18 days and estimates of the blue magnitude on those dates, obtained through convolution of calibrated spectra with the B passband, we can attempt to make finer classification of this SN as one of the well known subclasses (*Linear or Plateau*).

The change of the spectrum between April 6 and 19 with clear reddening shortward of Hβ during these 2 weeks indicates seemingly that the 1st spectrum was observed in the period between the 20th and 30th days after the peak of the light curve. Spectra for April 6 and 24, 1998 were obtained under photometric conditions. Thus we can use the estimates of B-magnitudes obtained to get an idea on the decline rate β^B_{100} (in mag/100^d) which discriminates by its value of 3.5 between *Plateau* and *Linear* shapes of the light curve (Patat et al., 1994). The calculations give B(SN)=16.99±0.10 on 6.04.1998 and B(SN)=17.20±0.07 on 24.04.1998, where r.m.s. errors are intrinsic ones estimated from the noise counts. We estimate that the external accuracy is about $0^m_.15 - 0^m_.2$. This leads to ΔB=$0^m_.21$ and $\beta^B_{100} = 1.17$ mag/100^d. This value is so much less than 3.5 that even allowing for a possible uncertainty in ΔB of up to $0^m_.2 - 0^m_.3$ it would not change the classification of this SN II as *Plateau* subclass. The absolute blue magnitude for this SN on the discovery date is M_B=–15.4. Then $M^B_{max} \approx -16.4$, which agrees well with parameters of *Regular* SNe II-P.

Now we briefly describe some characteristic spectral features and their parameters related to ejecta motion. Hydrogen Balmer lines with pronounced P Cyg profiles are the most prominent features which are used for determination of the expansion velocity.

The characteristic expansion velocities of the ejected shells are measured from the positions of the deepest features of the P Cyg absorption. They are presented in Table 2 for the 3 dates of observations. The upper limit of the expansion velocity was derived from the wavelength of the blue wing edge of the Hα absorption.

Besides the P Cyg absorptions in the Balmer series, several other broad absorptions are observed, including some FeII multiplets and CaII H and K lines (also typical of the *Plateau* phase, which is transitional between photosphere and nebular phases). A remarkable feature of this SN is the absence of detectable HeI line at λ 5876 Å.

Table 2: *The expansion velocities (km s^{-1})*

	April 6	April 19	April 24
Hα	...	6350	6125
Hβ	6600	5500	4940
Hγ	5800	5050	4115
Hδ	4740	...	...
CaII K	6215	...	...
CaII H	6419	5597	...

It is interesting to estimate the extent of narrow Hα line emission in the host galxy, indicating the extent of ionized gas (Fig. 4). The region which emits in Hα can be traced on our long–slit spectrum over ≈24 pixels = 9.″6 (≈1 kpc) with the peak of brightness near the center of this interval. The SN is located at the edge of this giant HII-region, at a distance of ≈ 0.5 kpc from the center of the galaxy. The intensity distribution of the narrow [OIII] line λ5007 Å is similar to that of narrow Hα, hence the excitation of HII region is more or less similar to that near the current SF region and near the position of the SN.

At first glance there is apparent analogy of the periphery position of the SN 1998bv in the galaxy HS 1035+4758 with the periphery positions of the majority of other SNe II observed in spiral galaxies. However, the deeper insight into the situation shows that such an analogy will lead rather to a more central position of the SN in HS 1035+4758. The periphery positions of SNe II in spirals are related to the regions of high current SF rate (and of massive stars, progenitors of SNe II, in particular) in spiral arms. The displacement of the SN 1998bv position by ≈0.5 kpc from the central supercluster of massive stars which formed in the course of the current SF burst is therefore quite suprising and needs more careful elaboration of possible models of SF propagation. Observations of the area around the SN position after SN fading will allow one to elucidate the status of the underlying stellar population and probably better understand such apparent spatial discontinuity in production of massive stars.

We would like to note that the situation with SN 1998bv is quite similar to that with SN 1995ah — the first SN in the blue compact galaxy. The only difference is the peak luminosity ($M_B \approx -18.5$) and the classification of its light curve as *Linear*. As described by Popescu et al. (1997), SN II is also displaced by about 0.7 kpc, approximately to the north of the center of BCG. But it is still situated inside the boundaries of a very large high excitation HII-region with a total size of ≈1.5 kpc.

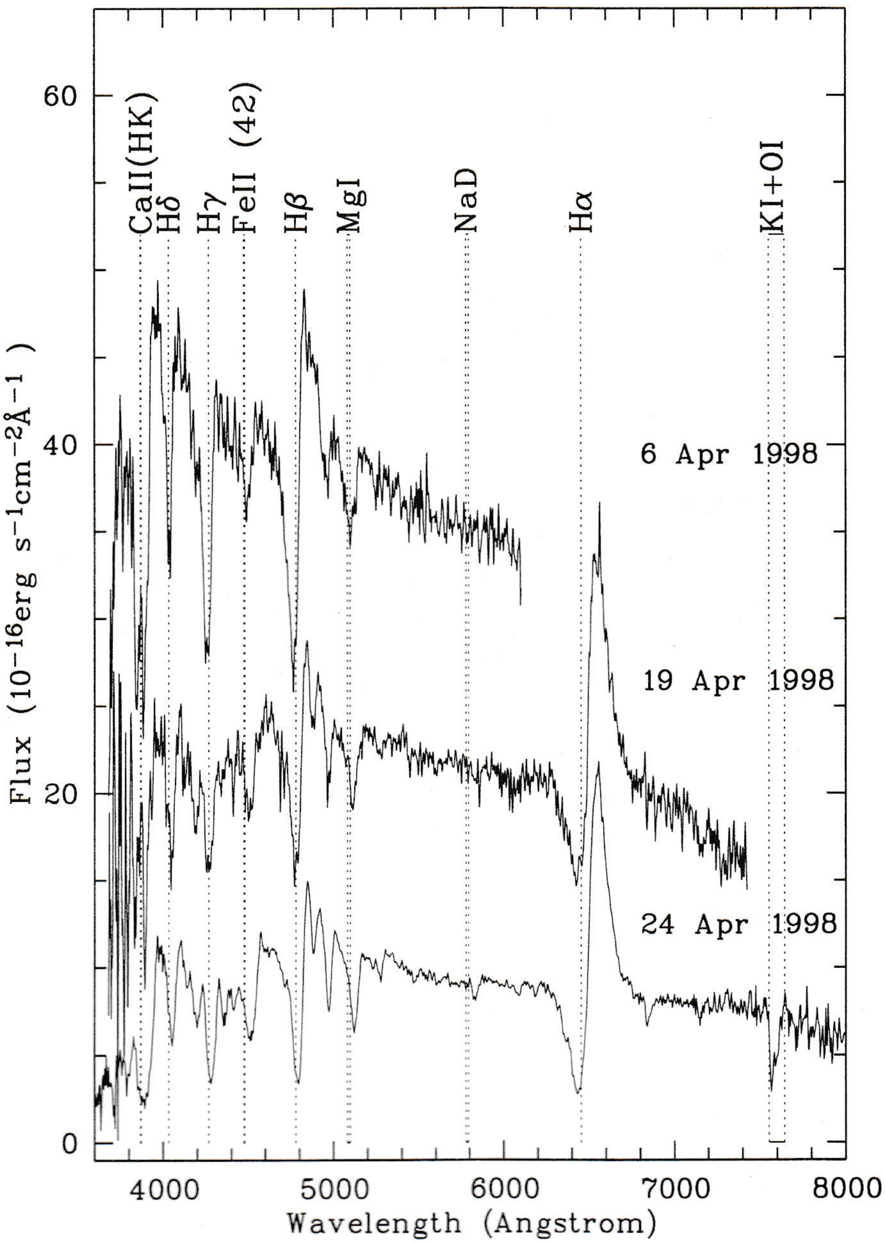

Figure 3: *Spectra of SN 1998bv obtained with the 6 m telescope. Spectra for April 6 and April 19, 1998 are shifted on the flux axis. The absorption line identifications are indicated, adopting an expansion velocity of 5000 km* s^{-1}. *The spectra are corrected to the galaxy rest frame.*

4. Conclusions

Summarizing the description above, we draw the following conclusions:

1. The SN 1998bv discovered on April 6, 1998 in the blue compact galaxy HS 1035+4758 is the second supernova observed in a low-mass galaxy with intense SF burst. It was discovered in the course of Hamburg/SAO survey for emission-line galaxies.

2. According to its characteristic spectrum, SN 1998bv is a type II supernova with estimated peak absolute brightness $M_B \approx -16.3$. The very slow fading of its brightness suggests that the SN was discovered at the *Plateau* phase, 20–30 days after the peak of the light curve. The most probable classification of SN 1998bv is regular SN II-P.

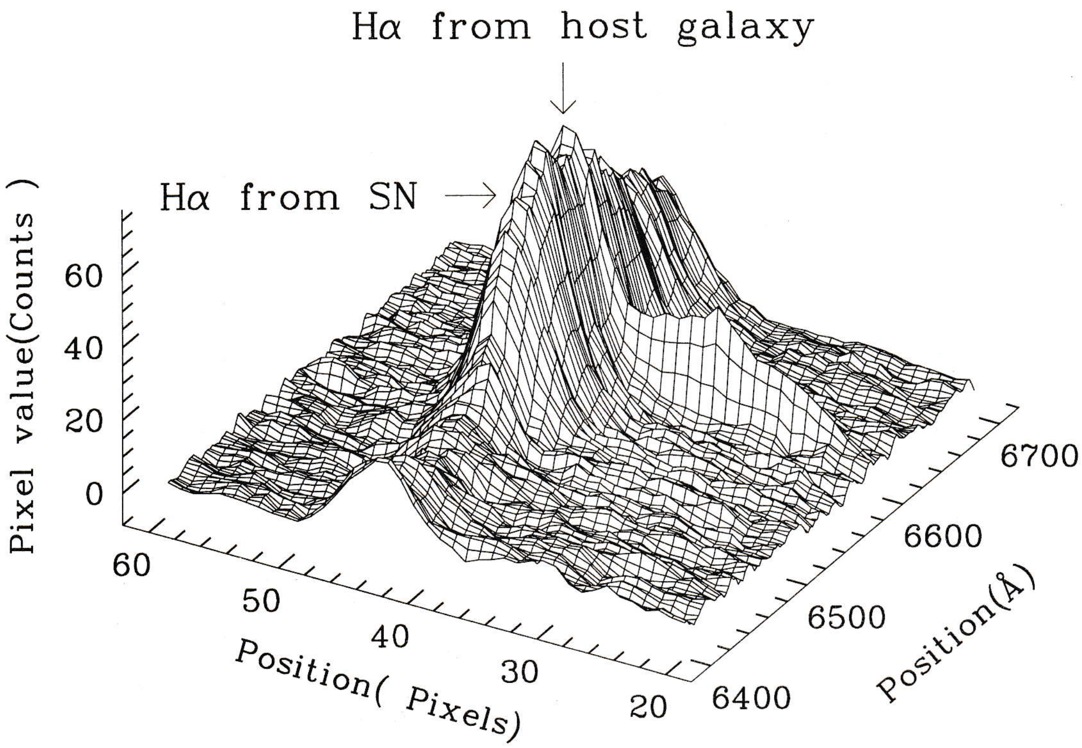

Figure 4: *Perspective view of two-dimensional spectrum near Hα region (the range 6400–6700 Å). The broad Hα of SN and narrow Hα through the body of host galaxy are shown.*

3. At the redshift of the host galaxy z=0.0054 (Virgo-flow corrected distance 29.6 Mpc) SN 1998bv is situated at ≈0.5 kpc (5″) from the central super-cluster of currently forming massive stars, at the edge of the large HII region.

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