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LETTER

*Letter to the Editor*

# The luminous 'Seyfert 1' type II Supernova 1997ab*

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**Abstract.** We report the discovery of SN 1997ab, a supernova with a Seyfert 1 type spectrum similar to SN 1987F. SN 1997ab was first seen at B=14.7±0.5 on a digitized objective prism spectrum taken on April 11, 1996 for the Hamburg Quasar Survey with the Calar Alto 80cm Schmidt telescope and was automatically selected as a low redshift QSO candidate. Spectra and images taken with CAFOS at the 2.2m telescope on Calar Alto on Feb. 28 and March 2, 1997 show the SN at B=16.2 with strong Balmer lines, broad Fe II emission bumps at $\lambda_{rest}$=5250 Å and 4580 Å, a strong IR Ca II triplet and the HeI 7065 Å and 5876 Å lines. The SN is located 3.″7 southwest off the center of the faint (B≈17.7) dwarf irregular HS 0948+2018. According to sharp H II region type [O III], [N II], [S II] lines and sharp Balmer line components, the radial velocity of the parent galaxy is 3750 km s$^{-1}$. This yields a brightness on April 11, 1996 of $M_B = -19.1$ (for $H_0$ = 65 km s$^{-1}$ Mpc$^{-1}$) and of $M_B = -17.6$ on March 2, 1997. With its high luminosity and slow fading SN 1997ab is similar to SN 1988Z and SN 1987F. SN 1997ab can be expected to be observable for several years.

**Key words:** Supernovae: general – Supernovae: individual: SN 1997ab

## 1. Introduction

The origin of type II supernovae (SNe) seems to be mainly well understood. The final collapse of the core of a massive star is followed by an SN explosion leaving behind a neutron star or a black hole. However, because of extensive mass-loss in the preceding stages it is not yet possible to predict which main sequence mass produce particular SNII subtypes, and whether the core collapse takes place in a red or blue supergiant. The light curves and spectra of SNe are also strongly influenced by the surrounding circumstellar medium. Clearly, systematic investigations and physical modelling of the spectral characteristics and time behaviour of the various SNII subtypes are required before the above mentioned questions can be answered.

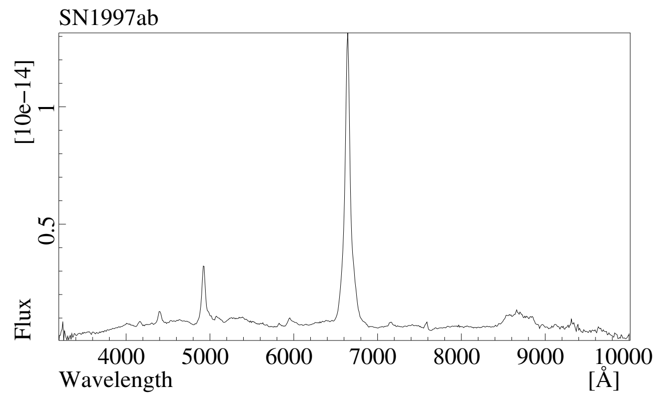


**Fig. 1.** Discovery spectrum of SN 1997ab. Resolution 15 Å

In recent years, besides the classical type II SNe, hydrogen rich subtypes have been discovered and studied, e.g. SN 1987F with a pure emission line spectrum which at certain phases was similar to Seyfert 1 spectra (Filippenko 1989), or SN 1988Z with pure broad and narrow emission features (Stathakis & Sadler 1991, Turatto et al. 1993). Both supernovae faded unusually slowly. Terlevich et al. (1992) have suggested that these characteristics originate from the interaction of SN explosions with dense circumstellar gas and have called these objects compact supernova remnants. In this letter we report on the serendipitous discovery (Hagen & Reimers 1997) of a further 'Seyfert 1' type II supernova which due to its brightness and apparently slow fading is a promising target for a study of the longterm behaviour of compact SN remnants.

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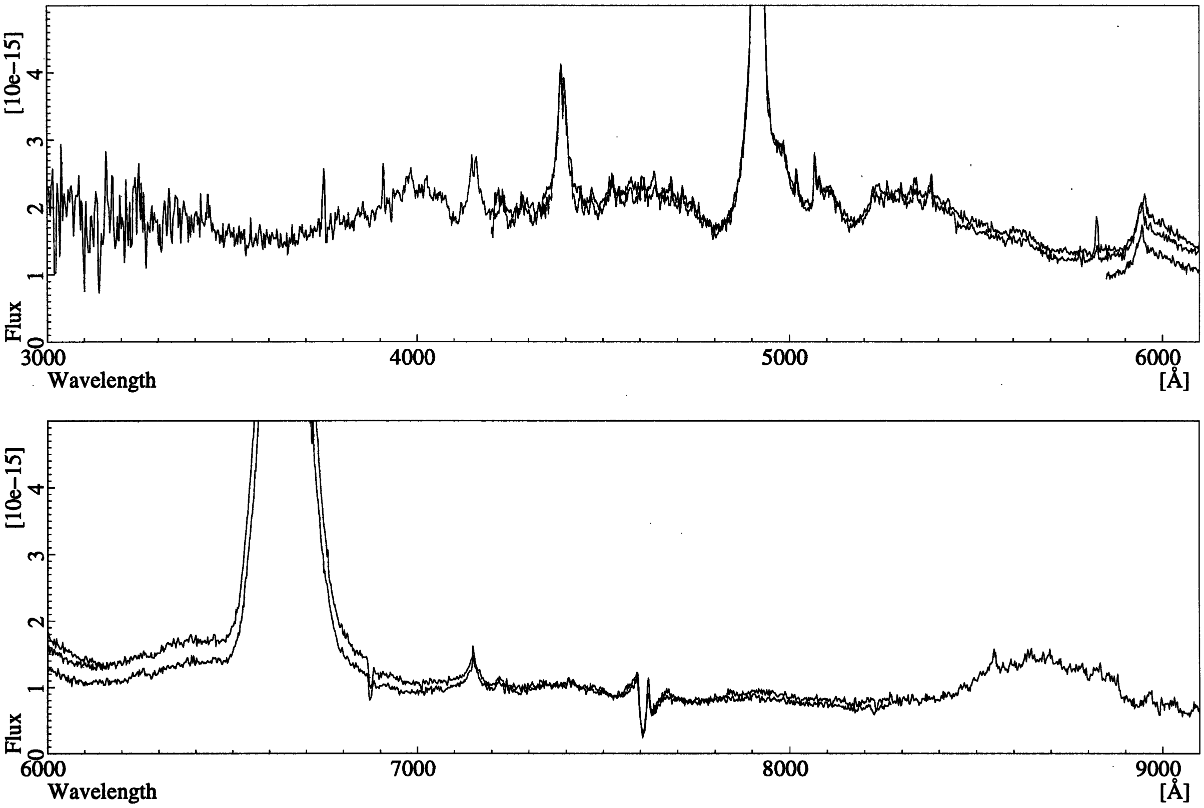


**Fig. 2.** Spectrum of SN 1997ab observed on March 2, 1997 in three settings independently calibrated (resolution 3 Å).

## 2. Observations

### *2.1. Discovery*

The SN was discovered by the Hamburg Quasar Survey (Hagen et al. 1995) on an objective prism plate taken on April 11, 1996 with the 80cm Calar Alto Schmidt telescope. Because of its blue continuum and strong H$\beta$ emission line it was considered as a low redshift QSO candidate. It was recognized, however, that the object was not centered on the faint parent galaxy, named hereafter HS 0948+2018. The coordinates of the galaxy are $\alpha$ = $09^h48^m13^s\!.5$ $\delta$ = +20°18′28″ (1950) with an accuracy of ±2″. The candidate was also astonishingly bright with B=14.7±0.5, as determined from the objective prism plate. Moreover, inspection of an earlier Schmidt plate taken in 1995 revealed that the object must have brightened considerably since then.

### *2.2. Optical spectroscopy and imaging*

The target was observed during a regular QSO candidate follow-up observing run using the Calar Alto 2.2m telescope equipped with the CAFOS spectrograph allowing spectroscopy and imaging with a 2048x2048 CCD detector. A first low resolution spectrum taken on Feb. 28, 1997 with a resolution of 15 Å covering $\lambda\lambda$ 3000 to 10000 Å showed the QSO type spectrum (Fig. 1). Two nights later follow-up spectra of higher resolution ($\Delta\lambda$=3 Å) and good S/N were taken in three settings covering $\lambda\lambda$ 3000 to 9100 Å (Fig. 2). Flux and wavelength calibration followed standard procedures. An image of the galaxy HS 0948+2018 was taken in the Johnson B band (Fig. 3). The SN is located $3''\!.7$ south-west off the center of the parent galaxy at a position angle of about 260°.

## 3. Analysis

### *3.1. Pre-SN light curve*

According to the CCD images, to direct Schmidt plates taken in January 1992 and to the POSS 1 blue print, the parent galaxy is a dwarf galaxy with B≈17.7 which corresponds to $M_B \approx -16$ for z=0.0125 (see below) and $H_0$=65 km s$^{-1}$ Mpc$^{-1}$. A striking feature is the enormous brightness of SN 1997ab at the discovery date ($M_B = -19.1$) which outshone the parent galaxy by more than 2 magnitudes. Since HS 0948+2018 is fortunately located in the overlapping area of three survey fields, several Schmidt plates are available to study the brightness evolution before 1996. Brightness estimates from our direct Schmidt plates, the objective prism plates, a CCD image taken on Feb. 28, 1997 and from the POSS 2 B plate are given in Table 1.

For the objective prism spectra, the routine brightness calibration procedure which is accurate to $\pm0^m\!.5$ has been described by Hagen et al. (1995). For the direct Schmidt plates (D2220 and D2232) and for the POSS 2 B plate (the film copy) a relative brightness calibration has been performed by digitizing the

**Table 1.** Journal of brightness measurements. Integrated brightnesses of the parent galaxy + supernova are given. Absolute errors of the magnitudes from Schmidt data are 0.5 mag.

| Telescope/Mode | Plate No. | Date | B |
|---|---|---|---|
| Schmidt/direct | D2220 | Jan. 3/4, 1992 | 17.1* |
| Schmidt/direct | D2232 | Jan. 4/5, 1992 | 17.3* |
| Schmidt/prism | H2326 | Jan. 5/6, 1992 | 17.7 |
| POSS 2 | | Dec. 11, 1993 | 15.4 |
| Schmidt/prism | H2753 | Apr. 11/12, 1994 | 17.7 |
| Schmidt/prism | H2858 | Jan. 28/29, 1995 | 17.5 |
| Schmidt/prism | H2937 | Apr. 2/3, 1995 | 17.7 |
| Schmidt/prism | H3052 | Apr. 11/12, 1996 | 14.7 |
| 1.2m | CCD | Feb. 10/11 1997 | 16.1 |
| 2.2m | CCD spect. | Mar. 2, 1997 | 16.2 |

*Notes:* $U_J$ magnitudes from unfiltered IIIaJ plates

plates and transforming photographic densities into intensities, using several objects in common with the 2.2m CCD B image. The absolute calibration was made relative to the spectrum shown in Fig. 2.

To our surprise, HS 0948+2018 shows on the POSS 2 B film copy (December 1993) an enhanced brightness, too. Could this be due to SN 1997ab more than 2 years before our discovery spectrum? An overlay of the position of SN 1997ab with the POSS 2 B film copy (Fig. 4) shows that the additional light on the POSS 2 does not come from the location of SN 1997ab. If real, the additional light can only be explained by another SN ($M_B = -18.4$), which faded quickly since 5 months later it was not detected on our prism plate H2753. On the other hand no additional point source can be detected on the film copy. Maybe the original photo plate shows more details. Nevertheless the possibility of a plate defect still exists.

In summary, from our data there is no further information on the date of the supernova outburst, except that it was not visible a year before. Owing to its high luminosity on April 11, 1996, we presume that the observation date of plate H3052 must have been close to SN maximum.

### *3.2. Spectroscopic properties*

The rather unusual nature of the SN spectrum can be seen in Fig. 2. It consists of a blue continuum on which a mixture of broad permitted and narrow (unresolved) forbidden lines is superimposed. In the broad component we identify H$\alpha$ to H$\delta$, the IR Ca II triplet, He I 7065 Å, 5875 Å, 4922 Å, and strong Fe II bumps around $\lambda_{\rm rest} \approx$5250 and 4580 Å. This part of the spectrum very much resembles the spectrum of the 'Seyfert 1' spectrum of SN 1987F taken on Dec. 26, 1987 (Filippenko 1989) although the infrared Ca II triplet and the He I lines appear stronger in our case. Unlike typical SN type II spectra, there are no absorption and P Cygni type lines.

Notice that the broad asymmetric emission line at 6000 Å cannot be He I 5875 Å alone. The asymmetry in the red wing is probably caused by at least additional NaI emission, similar

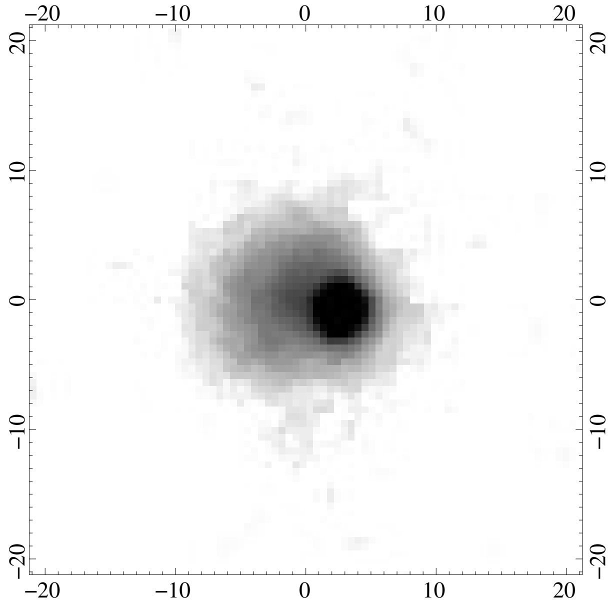


**Fig. 3.** Extract of the Johnson B band CCD image of SN 1997ab in dwarf galaxy HS 0948+2018 (logarithmic scaling)

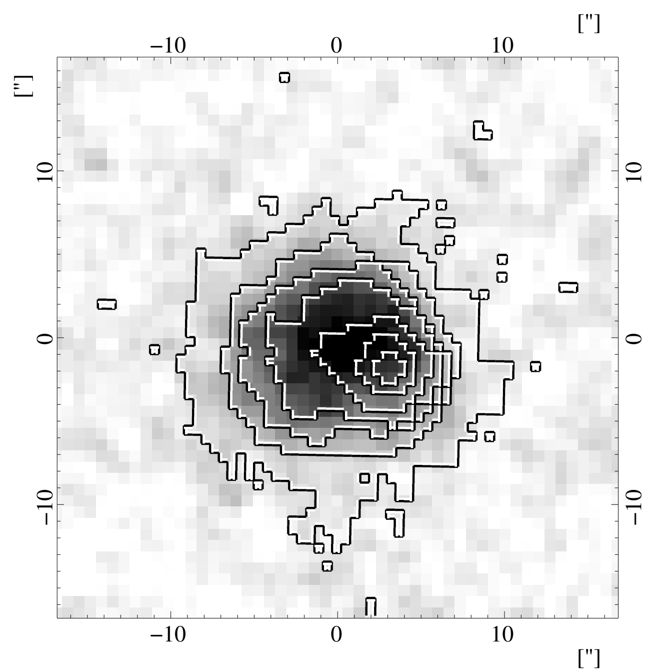


**Fig. 4.** Digitized POSS B overlaid with contours of Johnson B image (Fig. 3)

to what was found in SN 1987F (Filippenko 1989). He I lines are atypical for SNII spectra, though they have also been seen in SN 1988Z (Turatto et al. 1993).

Superimposed on the broad Balmer lines is a narrow component redshifted by about 600 km s$^{-1}$ (Fig. 5). This narrow component has the same redshift (0.0125) as the unresolved forbidden lines [O III] 4959/5007 Å, [S II] 6716/6731 Å, and [N II]

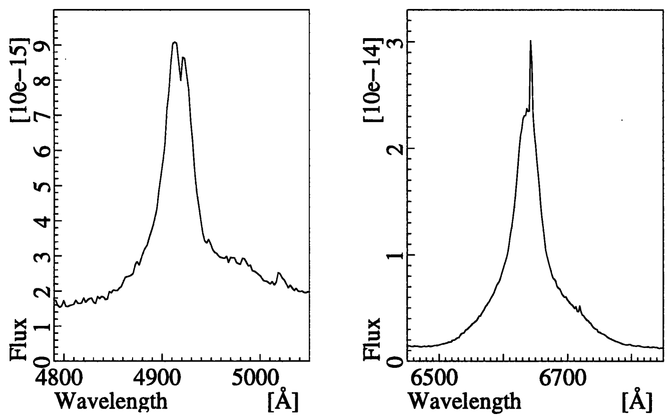


**Fig. 5.** H$\beta$ (left) and H$\alpha$ (right) showing narrow components at z=0.0125

5755 Å. We assume that the sharp z=0.0125 lines are formed in an H II region surrounding the SN and define the systemic redshift of the faint parent galaxy. This leads to a distance of 57 $h_{65}^{-1}$ Mpc, about three times the Virgo cluster distance. The continuum observed on March 2, 1997, which approximately follows $f_\lambda \sim \lambda^{-1}$ down to the atmospheric limit at 3000 Å, is similar to QSO continua and is quite unusual for SNeII, in particular since it is seen at least 323 days after maximum light.

SN 1997ab has a particularly high H$\alpha$ luminosity of $L_{H\alpha}$ = 7 $10^{41} h_{65}^{-2} ergs^{-1}$. This is roughly a factor of 2 higher than even the peak H$\alpha$ luminosity observed in SN 1987F and SN 1988Z (cf. Fig. 8 in Turatto et al. 1993).

The measured line width of H$\alpha$ is FWHM$\approx$2500 km s$^{-1}$. He I 7065 Å on the other hand has a broad base (FWZI$\approx$4660 km s$^{-1}$) and a sharp, unresolved core. The blue wing of He I 5875 Å is similar. The He I line profiles and strengths are distinctly different from those in both SN 1988Z and SN 1987F. Altogether the line widths are smaller in SN 1997ab than in the two other cases.

There is also a narrow feature at the expected wavelength of OI 8446 Å which may be the core of a broader line blended with the Ca II IR triplet. Although the S/N of our spectra in the red is excellent we do not detect any coronal lines like [Fe X] 6373/75 Å.

### 3.3. Light curve

Present evidence strongly suggests that SN 1997ab fades very slowly. Assuming that the discovery phase April 11, 1996 is close to maximum light, we can compare SN 1997ab with other SNeII. The observed decline of $\Delta$B= $1.5 \pm 0.5$ mag in 323 days is slower than in all other known SNeII, including SN 1988Z and SN 1987F (cf. Figs. 2+3 in Turatto et al. 1993) which faded by $\Delta$B=1.5 to 2 magnitudes in only 150 days.

Notice that the flat light curve, while based on the prism spectrum magnitude on April 11, 1996, is confirmed by our CCD image taken on February 10, 1997 with the Calar Alto 1.2m telescope. This slower fading is accompanied by a higher peak luminosity of $M_B \approx -19.1$ compared to $-18.3$ for SN 1988Z (Turatto et al. 1993) and $-18.9$ for SN 1987F (Filippenko 1989), all for $H_0$=65 km s$^{-1}$ Mpc$^{-1}$.

If the slow fading continues similarly as for SN 1988Z, SN 1997ab might be observable for a further 5 years.

## 4. Epilogue

The purpose of this letter is to motivate the community to observe the slowly fading SN 1997ab in the coming years. We believe that we have convinced the reader, that SN 1997ab is possibly the extreme case among the compact SN remnants known so far. SN 1997ab should therefore offer the possibility to help to verify, reject or finetune the theoretical predictions made by Terlevich et al. (1992) concerning the spectral evolution of compact supernova remnants. Observations over the whole electromagnetic spectrum from radio to X-ray wavelengths are promising.

For clarification of the question as to which progenitors produce these unusual SNe, it would also be important to take high-resolution HST images of the parent galaxy when the SN becomes faint enough again.

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