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## Supporting Online Material for

### **Detection of Circumstellar Material in a Normal Type Ia Supernova**

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## Supporting Online Material

### S1. Materials and Methods

We have observed SN 2006X on 5 epochs spanning about 4 months (Table S1). High resolution spectra were obtained with the European Southern Observatory's (ESO) Very large Telescope (VLT) on Cerro Paranal (Chile), equipped with the Ultraviolet and Visual Echelle Spectrograph (UVES) (*S1*), and with the Keck I Telescope equipped with the High Resolution Echelle Spectrometer (HIRES) (*S2*). For UVES we have used the 390+580 setting, which covers simultaneously three wavelength ranges (3290-4500Å, 4780-5740Å and 5830-6800Å), with a full width half maximum (FWHM) resolution of  $7 \text{ km s}^{-1}$ . In the case of HIRES, we have used a setting optimized for the Na I D region, that covers the wavelength range 3900-8350Å with a FWHM resolution of  $6.8 \text{ km s}^{-1}$ . UVES data have been reduced using the UVES Data Reduction Pipeline (*S3*), while HIRES data have been processed using standard procedures for Echelle spectra. Wavelength calibration has been achieved using Thorium-Argon lamps. The final RMS accuracy is about  $0.15 \text{ km s}^{-1}$ . The wavelength scale was corrected to the rest-frame adopting a host galaxy recession velocity of  $1571 \text{ km s}^{-1}$  (*S4*). To compensate for the Earth's motion, a heliocentric velocity correction has been applied to the data (Table S1). The effect of atmospheric lines has been checked using a spectroscopically featureless bright star (HR 3239) observed with the same instrumental setup as for the science data. The spectral region of interest turns out to be essentially free of telluric features. Therefore, the broad absorption visible starting with day +61 and reaching  $v_h \sim -70 \text{ km s}^{-1}$  is real and not affected by atmospheric lines. Na I column densities have been estimated fitting Voigt line profiles with VPFIT (*S5*). Finally, epochs have been computed from *B* maximum light, which took place on February 20, 2006 (*S6*).

In order to set upper limits to  $\text{H}\alpha$  and He I 5876Å luminosities (Table S2), the UVES spectra have been calibrated by means of a reference response function. Since the observations have been obtained under sky transparency conditions that ranged from clear/photometric (epochs -2, +14, and +121) to thin cirrus (+61), taking into account the high instrument stability, the expected flux calibration accuracy is of the order of 20-30%. To the best of our knowledge, the upper limits on  $\text{H}\alpha$  and He I 5876Å presented here are the latest ever published. The signal-to-noise ratio on the continuum in the Na I D lines region ranges from  $\sim 70$  (day -2) to  $\sim 20$  (day +121). No SN Ia was ever observed at these spectral resolutions more than four months after the explosion.

To confirm the low mass of CSM estimated from the Na I observations, we have observed SN 2006X with the Very Large Array (*S8*), in the C configuration, at 6 cm (4.8 GHz) on November 17 and at 3.6 cm (8.4 GHz) on November 20, 2006, corresponding to +270 and +273 days after *B* maximum light, respectively. The SN was not detected at both wavelengths, and the 2 SD limits are 0.07 mJy and 0.09 mJy for the two bands respectively (*S9*), which are comparable to the best limits available so far (*S10*). At the epoch sampled by our observations, the SN ejecta

have reached a distance of  $\sim 10^{17}$  cm from the explosion site. Our upper limits on the radio flux constrain the corresponding CSM mass to be smaller than a few  $10^{-3}$  solar masses ( $M_{\odot}$ ), which is fully consistent with the estimates deduced from the observed Na I absorptions. Very similar upper limits have been set for standard SN Ia events like SN 1981B, 1989M, 1998bu and 1992A (*S10*).

From the low resolution spectroscopic data that we have obtained in parallel to the high resolution data set discussed in this paper, we confirm the results of the early classification spectroscopy (*S11*). SN 2006X appears to be a normal Ia, very similar to SN 2002bo (*S12*), with somewhat higher photospheric velocities. The derivation of photometric parameters is hindered by a rather strong reddening ( $E(B - V) > 1.1$ ) and an anomalous extinction law ( $R_V < 2$ ). However, the decline rate, the light and color curve shapes and the absolute magnitude are within the range of normal Type Ia SNe (*S6*).

## S2. The interstellar material

The apparent position of SN 2006X is very close to a spiral arm of NGC 4321, which is inclined by 28 degrees with respect to the line of sight (*S13*). Due to the relatively high extinction (*S11*), the SN most likely exploded within or behind the disk of the host galaxy. Moreover, the SN is projected onto the receding side of the galaxy, and the component of the rotation velocity along the line of sight at the apparent SN location is about  $75 \text{ km s}^{-1}$  (*S4*, *S13*), which coincides with the strongly saturated Na I D component (Fig. S1). This suggests rather unequivocally that the time-invariant, very deep absorptions arise within the disk of NGC 4321. The equivalent widths of the Na I D lines, measured in the first epoch spectrum, are  $670 \pm 5$  and  $625 \pm 4 \text{ m\AA}$  for the  $D_2$  and  $D_1$  components respectively. The implied total Na I column density, estimated fitting multiple Voigt line profiles with VPFIT (*S5*), is as large as  $\log N \sim 14.3$ . For a Milky Way-like dust mixture this would turn into a color excess  $E_{B-V} \sim 1.1$  (*S14*). Moreover, the CN lines clearly visible in our first two spectra at  $v_h = 73.6 \pm 1.0 \text{ km s}^{-1}$  (weighted average of the two epochs) have an unprecedented depth (see also ref. *S15*). On the first epoch spectrum the equivalent widths for the three lines are:  $EW[R(0)] = 91 \pm 2$ ,  $EW[R(1)] = 60 \pm 3$  and  $EW[P(1)] = 42 \pm 3 \text{ m\AA}$  that, after correcting for saturation effects, correspond to column densities of  $\log[N_{R(0)}] = 14.0 \pm 0.1$ ,  $\log[N_{R(1)}] = 13.6 \pm 0.1$  and  $\log[N_{R(1)}] = 13.6 \pm 0.1$  respectively. Stars having comparable column densities in our own Galaxy are known to have color excesses larger than  $E_{B-V} = 1$  (*S16*). Applying the usual curve of growth method (*S16*), an excitation temperature of  $3.0 \pm 0.2 \text{ }^\circ\text{K}$  is derived for this cloud.

A closer inspection of Fig. S1 shows that the deep Na I and Ca II absorptions are not due to a single cloud. In fact the Ca II H line, which is less affected by saturation, clearly displays at least two components that differ in velocity by  $\sim 10 \text{ km s}^{-1}$ . On the contrary, the CN lines appear as single, unresolved features (the velocity dispersion parameter is  $b \sim 2.3 \text{ km s}^{-1}$ ), indicating that this molecular absorption arises within an inner subset (as seen along the line of sight) of multiple clouds that most likely contribute to the strong Na I and Ca II absorptions.

The peculiarity of the interstellar material is indicated also by the unusual wavelength dependency of the continuum linear polarization shown by SN 2006X. This is in fact significantly different from that typically observed in extinguished stars within our own Galaxy (*S18*).

The presence of strongly saturated Na I D interstellar components could in principle mask the existence of weaker features, which happen to fall in the same velocity range but arise in a completely different region. Therefore, the presence of an absorption feature at the typical velocity of a RG wind ( $10 \text{ km s}^{-1}$ ) cannot be ruled out. Only the study of non-extinguished objects, i.e. free of strong interstellar absorptions, will allow us to detect slow moving material in the surroundings of Type Ia SNe.

### **S3. Lack of evolution in Ca II H&K lines**

The Na I D evolution is very clearly displayed by both  $D_1$  and  $D_2$  lines, which show practically identical profiles at all epochs (Fig. S2). Slight saturation effects are visible in the most intense components of the  $D_2$  line.

The behavior of the Ca II H & K lines is radically different from that of the Na I D lines. On the first epoch (day  $-2$ ), the profiles of Na I  $D_2$  and Ca II K show very similar intensity and velocity profiles (Fig. S3). In particular, components A and B can be easily identified. The differences become dramatic at the second epoch (day  $+14$ ), when Ca II K remains practically unchanged while Na I  $D_2$  develops deep absorptions for components B, C and D. The signal-to-noise ratio in the Ca II region is lower, but a variation similar to that taking place for the Na I lines would have been definitely detected, at least for components B, C and D. Due to the SN fading and its spectral evolution, the continuum in the Ca II H&K region becomes very weak as time goes by, making the detection of the K line more and more difficult. Even heavily binning our third epoch data (day  $+61$ ), the signal-to-noise ratio achieved on the resulting profile is not sufficient to draw any firm conclusion (Fig. S3). At later epochs, due to the very low SN continuum, the H&K lines could not be detected.

Geometric effects related to the fast expansion of the radiation ring and the consequent change in the covering factor coupled to the patchy structure of the intervening absorbing clouds, have been advocated to explain the time variability claimed for some Gamma Ray Bursts (GRB) (*S19, S20*). What emerges from this analysis is that a Ca II H&K evolution at the level seen in the Na I D lines can be definitely excluded. In turn, this rules out transverse motions or line-of-sight effects as responsables for the evolution observed in SN 2006X.

### **S4. The location of the absorbing material in SN 2006X**

After sodium is ionized by the SN radiation field, which drops quickly after maximum light (*S21*), it starts recombining with a time scale  $\tau_r$  which depends on the electron number density  $n_e$  and the radiative recombination coefficient  $\beta$ :  $\tau_r = (n_e \beta)^{-1}$ . Given the time scale of

the observed changes in the NaID features, we estimate  $\tau_r \sim 10$  days, which implies  $n_e \sim 10^5 \text{ cm}^{-3}$  for  $\beta \simeq 5 \times 10^{-12} \text{ cm}^3 \text{ s}^{-1}$  (S22). Such a high electron density can only come from partial ionization of hydrogen. Therefore, the maximum distance for the gas where the time-variable NaI features arise is dictated by the ability of the SN to ionize hydrogen, i.e. by the flux  $S_{UV}$  of photons at wavelengths shorter than  $912\text{\AA}$ , times the duration  $\Delta t_{SN}$  of the UV emitting phase.

An upper limit to the number of hydrogen atoms that are ionized is therefore given by the total number of ionizing photons,  $S_{UV} \Delta t_{SN}$ , which in turn must be equal to  $V_H n_e$ , with  $V_H$  being the volume of the layer responsible for the varying absorption. Thus, an upper limit to this volume is given by:

$$V_H \leq \frac{S_{UV} \Delta t_{SN}}{n_e}. \quad (S1)$$

Assuming that the absorbing material is confined within a thin shell of thickness  $\Delta r$  (with  $\Delta r \ll r_H$ ), the maximum radius of such a shell is:

$$r_H \leq \left[ \frac{S_{UV} \Delta t_{SN}}{4\pi n_e \Delta r/r} \right]^{1/3}. \quad (S2)$$

Using  $S_{UV} = 4.4 \times 10^{44} \text{ photons s}^{-1}$ , the value derived from the synthetic spectrum at maximum light (S23), and a light curve width of  $\Delta t_{SN} = 20$  days, one gets  $r_H \leq 4 \times 10^{15} \text{ cm}$  for  $n_e = 10^5$  and  $\Delta r/r = 0.01$ . The largest uncertainty in estimating  $r_H$  comes from the total fluence of ionizing photons ( $S_{UV} \Delta t_{SN}$ ). In fact, the synthetic spectrum we have used is a best fit to an HST spectrum of SN 1992A extending down to about  $1600\text{\AA}$  and obtained 6 days past maximum light and (S24), i.e. when the UV flux has significantly dropped (S21). Nevertheless, thanks to the cubic root dependency on it, even a  $10^3$  times higher fluence would result in an upper limit of  $\sim 5 \times 10^{16} \text{ cm}$ . This clearly demonstrates that the material responsible for the time-variable features is confined well within the circum-stellar domain.

This creates a very marked distinction between Type Ia SNe and GRBs, for some of which time-dependent UV absorption features have been claimed (S19, S20, S25). In fact, GRBs and their early after-glows have a very strong X-ray/UV radiation field, so that all possible circumstellar gas is completely ionized. For instance, GRB 021004 was shown to be able to completely ionize the interstellar material out to about 100 pc ( $\sim 3 \times 10^{20} \text{ cm}$ ) (S19), while for GRB 060418 the ionization was found to reach  $\sim 1.7 \text{ kpc}$  ( $\sim 5 \times 10^{21} \text{ cm}$ ) (S25).

As far as calcium is concerned, we note that the flux of photons capable of ionizing Ca II computed from the synthetic spectrum (S23) is  $\sim 3.5 \times 10^{46} \text{ photons s}^{-1}$ . This is more than four orders of magnitude smaller than the corresponding Na I ionizing flux. As a consequence, the ionization fraction of Ca II is significantly smaller and hence, as it recombines, no detectable effect on the depth of Ca II H&K lines is expected, as shown by the observations (see S3 and Fig. S3). The same mechanism has been proposed to explain the inter-stellar line variability observed in galactic stars which, due to the much lower densities, take place on timescales of years to decades (S26).

An alternative explanation for the presence of expanding shells in the immediate surroundings of SN 2006X is that they have been lost by a nearby star, physically not related to the progenitor system but close enough to be influenced by the SN radiation field. In fact, shells expanding with velocities up to several tens of  $\text{km s}^{-1}$  are known to be present, for instance, around many galactic OB associations (S26). Since the material has to be relatively close to the SN in order to be influenced by its UV radiation, this alternative scenario requires that the SN exploded within a cluster or a star association.

In order to study the immediate surroundings of the explosion site, we have used a deep pre-explosion image obtained with the ESO-VLT FOcal Reducer and low dispersion Spectrograph (FORS1), (S28). Observations were performed on May 12, 1999 in the  $R$  passband (S28), with an exposure time of 600 seconds and a seeing of 0.8 arcsec (FWHM), corresponding to a limiting magnitude  $R \sim 24.0$  (5 SD level) at the SN location (Fig. S4, left panel). To better characterize the SN environment, we have searched the Hubble Space Telescope Archive for high resolution imaging. The only suitable data we could find were obtained with the Advanced Camera for Surveys (ACS), (S29) on May 21, 2006 (S30) in high resolution mode ( $0.027 \text{ arcsec pixel}^{-1}$ ) with the F435W (1480 seconds), F555W and F775W (1080 seconds) filters. In order to increase the signal-to-noise ratio, the three images have been registered and stacked (Fig. S4, right panel). The resulting image reveals a wealth of resolved objects, which can be identified as red, blue super-giants, groups of O stars and OB associations, with typical sizes of  $\sim 100 \text{ pc}$ . All such associations and stellar groups (like those marked with labels A and B on the ACS image) are clearly detected in the deep FORS1 image, which shows also some of the brightest single stars.

Unfortunately, the ACS image was obtained after the explosion, when the SN was still bright, and hence it is not possible to directly inspect the SN surroundings. Nevertheless, the presence of groups like that marked with A in Fig. S4 can be excluded. This is confirmed by the deep FORS1 pre-explosion image, which does not show any trace of stellar associations (like A) or even more compact groups (like B) at the SN location. This makes the presence of an isolated star losing material in the immediate vicinity of the SN progenitor system very unlikely.

## **S5. Evidences of blue-shifted Na I absorption lines in other SNe Ia**

Due to the large required exposure times, high resolution spectroscopy of SN Ia is rather rare. Additionally, since the main aim of those investigations was the study of the supposedly time-invariant inter-stellar medium, data were usually obtained on one single epoch around maximum light (S31, S32). Only in recent times, with the advent of 8-10m class telescopes, multi-epoch high resolution spectroscopy has been performed, with the aim of detecting possible emission lines produced by the SN ejecta-CSM interaction (S33, S34). Nevertheless, due to the underlying scientific driver of these projects, observations were carried out during the pre- and near-maximum phase, when the Na I D features are at their minimum intensity in SN 2006X

(Fig. S1). For example, the spectra of SN 2001el, observed some days before maximum light, do not show any clear signs of Na I D blue components. Interestingly, they do show at least two blue components in the Ca II H profile at  $\sim -18$  and  $-34$  km s $^{-1}$  with respect to the deep Na I D absorption (S33).

In the course of our long term nearby SN monitoring, we had the chance to obtain high resolution spectroscopy of two SN Ia, namely SN 1991T (S35) and SN 1998es (S36). Both spectra are unpublished. SN 1991T was observed on Jun 08, 1991 (day +40) with the ESO 1.4m Coudé Auxiliary Telescope (CAT) equipped with the Coudé Echelle Spectrograph (S37), while the spectrum of SN 1998es was obtained on Nov 24, 1998 (day  $-1$ ) with the ESO 1.5m telescope equipped with the Fiber-fed Extended Range Optical Spectrograph (S38). The Na I D line profiles of these two objects are remarkably similar to that of SN 2006X (Fig. S5). Besides a strong absorption, which is most likely generated within the disk of the host galaxy, some blue components are clearly visible.

To the best of our knowledge, the only other SN for which a data set somewhat similar to that of SN 2006X has been obtained is the core-collapse, Type IIn SN 1998S (S39). High resolution spectroscopy of this object has revealed a number of Na I D components within the host galaxy, the bluest of which ( $v_h \sim -100$  km s $^{-1}$ ) deepened significantly during the 19 days spanned by the two epochs available, implying a Na I column density increase of about 1 dex. This fact, together with the detection of time-evolving narrow H and He P-Cyg profiles at the same Na I velocity, was interpreted as a signature of the outflows from the super-giant progenitor of SN 1998S, arising in a dense shell, expanding at about 50 km s $^{-1}$  (S39, S40).

## S6. The CSM structure around SN 2006X: swept-up nova shells?

A possible interpretation of the distinct features in the CSM is that they arise in the remnant shells of successive novae (S41). The recurrent ejection of a few  $10^{-7} M_\odot$  of H at velocities of  $\sim 4000$  km s $^{-1}$  can create dense shells in the slow moving material released by the companion, evacuating significant volumes around the progenitor system (S42). This explanation requires that the high-velocity nova ejecta have, by sweeping up the stellar wind of the donor star, been slowed down to speeds several times lower than the asymptotic shell velocities seen, for instance, in RS Ophiuchi, i.e.  $\sim 300$  km s $^{-1}$  (S43, S44). For SN 2006X, if we assume that the observed shells have all been swept up in the energy-conserving phase (S45), and if we take an upper limit of the wind-mass loss rate from the companion,  $\dot{M}_{\text{wind}}$ , as  $10^{-7} M_\odot \text{ yr}^{-1}$  from the radio observations, we obtain an upper limit on the mass ejected in each nova outburst:

$$M_{\text{nova}} < 2 \times 10^{-8} M_\odot \frac{\dot{M}_{\text{wind}}}{10^{-7} M_\odot \text{ yr}^{-1}} \left( \frac{V_{\text{shell}}}{75 \text{ km s}^{-1}} \right)^2 \left( \frac{V_{\text{nova}}}{1000 \text{ km s}^{-1}} \right)^{-2} \frac{\Delta t_{\text{nova}}}{10 \text{ yr}}, \quad (\text{S3})$$

where  $M$  and  $V$  refer to mass and velocity, and the subscripts *nova* and *shell* refer to the mass ejected in each nova outburst and the shell formed as the nova ejecta sweep up the wind, whilst  $\Delta t_{\text{nova}}$  represents the nova recurrence time.

Although this value is around an order of magnitude smaller than might be expected from recent nova calculations, we note that the ejecta mass is a steeply decreasing quantity as the white dwarf approaches explosion (*S41, S46*). In addition, the estimate above assumes that the wind from the companion is spherically symmetric. If the wind is concentrated towards the orbital plane, and if we are observing the shell structure close to the orbital plane, the shells in our line-of-sight would be slowed down more than in the spherically symmetric case. The discrepancy would be further reduced if the nova shell is mainly slowed down in the momentum-conserving phase rather than the energy-conserving phase, which is made more likely in this asymmetric case where the mass is concentrated in the orbital plane. Exactly such an axisymmetric geometry and rapid deceleration is suggested by recent observations of RS Oph (*S47*).

Indeed, the fact that there is neutral Na around the progenitor of SN 2006X requires cool material and suggests that the shell must have cooled down sufficiently and be in the momentum-conserving phase.

If the recurrent nova interpretation requires an aspherical geometry, then this implies that the apparent shell structure with the velocities we have observed would only be seen in SNe Ia which are observed close to the orbital plane of the system. This may be a useful future discriminant for this model. We also suggest that this interpretation is made more satisfying if the loss of the strong Na line at  $\sim 40 \text{ km s}^{-1}$  (components C and D in Fig. 2) is due to the interaction of the supernova ejecta with that nova shell, as that places a useful scale on the distance of the shell from the supernova. As a typical SN velocity of  $\sim 10^4 \text{ km s}^{-1}$  is some 250 times faster than the shell, the interaction after 1 month corresponds to a recurrence time of  $\sim 25 \text{ yr}$ , which is a plausible value. The actual recurrence time could well be less, as that shell is not guaranteed to be the innermost shell, merely the innermost visible one.

As a check on the consistency of this model, we can combine our inferred electron density of  $n_e \sim 10^5 \text{ cm}^{-3}$  with the dimensions of the nova shell to produce an estimate of the mass of the shell:

$$\left(\frac{M_{\text{shell}}}{M_{\odot}}\right) \sim 1.0 \times 10^{-7} \left(\frac{0.1}{X}\right) \left(\frac{\Delta r}{10^{13} \text{ cm}}\right) \left(\frac{n_e}{10^5 \text{ cm}^{-3}}\right) \left(\frac{r_{\text{shell}}}{10^{15} \text{ cm}}\right)^2, \quad (\text{S4})$$

where, somewhat arbitrarily, we have taken a shell thickness ( $\Delta r$ ) that is  $\sim 1\%$  of the radius of the shell. Our greatest uncertainty is probably contained within the ionisation fraction  $X$ , which is needed to obtain the mass per free electron, though the quadratic dependence on  $r_{\text{shell}}$  alone leads to considerable uncertainty in the estimate of  $M_{\text{shell}}$ . Note that we have assumed the shell is spherical; a wind concentrated in the equatorial plane may be  $\sim 10$  times less massive.

If we assume that the mass in the shell is dominated by mass swept up from the wind (i.e.  $M_{\text{wind}} \gg M_{\text{nova}}$ ) and then take the shell radius to be the product of the recurrence time and shell velocity we can write:

$$\left(\frac{\dot{M}_{\text{wind}}}{M_{\odot}/\text{yr}}\right) \sim 2.5 \times 10^{-8} \left(\frac{0.1}{X}\right) \left(\frac{\Delta r}{10^{13} \text{ cm}}\right) \left(\frac{n_e}{10^5 \text{ cm}^{-3}}\right) \left(\frac{v_{\text{shell}}}{50 \text{ km/s}}\right)^2 \left(\frac{\Delta t_{\text{nova}}}{10 \text{ yr}}\right), \quad (\text{S5})$$

The wind loss rate derived in this way is consistent with our expectation in Equation S3.

UT Date (2006)	Phase (days)	Instrument/Telescope	Total Integration Time (seconds)	Heliocentric Correction (km s <sup>-1</sup> )
18/02	-2	UVES/VLT	4175	+14.6
06/03	+14	UVES/VLT	8940	+7.2
22/04	+61	UVES/VLT	15025	-15.4
06/06	+105	HIRES/KECK	3600	+5.0
25/06	+121	UVES/VLT	15025	-28.0

Table S1: High resolution spectroscopic observations of SN 2006X. Phase refers to *B*-band maximum light, attained on February 20, 2006 (*S6*)

Phase	H $\alpha$		He I 5876	
	7 km s <sup>-1</sup>	50 km s <sup>-1</sup>	7 km s <sup>-1</sup>	50 km s <sup>-1</sup>
-2	2.2	16.0	2.4	17.0
+14	1.1	8.0	1.1	7.6
+61	0.6	4.0	0.6	4.4
+121	0.3	2.2	0.4	2.6

Table S2: Upper limits (3 SD) for H $\alpha$  and He I 5876Å luminosities measured on the UVES spectra. Luminosities are expressed in 10<sup>37</sup> erg s<sup>-1</sup> and were computed for two Gaussian line profiles with FWHM 7 km s<sup>-1</sup> (matching the instrumental resolution) and 50 km s<sup>-1</sup>, assuming a distance of 16.1 Mpc for NGC 4321 (*S7*).

Figure S1: Comparison between the profiles of CN R(0), Na I D<sub>1</sub> and Ca II K lines for the first UVES epoch (day -2). The vertical dashed line marks the velocity of the R(0) absorption center ( $v_h=73.6$  km s<sup>-1</sup>).

Figure S2: Comparison between the NaI D<sub>1</sub> and D<sub>2</sub> line profiles on days -2, +14, +61 and +121. For presentation, the intensity of the D<sub>1</sub> line has been multiplied by 2.0, that is the D<sub>2</sub>/D<sub>1</sub> ratio expected from the spin orbit statistical weights of the Na(<sup>2</sup>P<sub>3/2</sub>) and Na(<sup>2</sup>P<sub>1/2</sub>) transitions. In each panel, the dotted curve traces the atmospheric absorption spectrum in the D<sub>2</sub> region. In order to account for the different heliocentric corrections applied to the SN data, the telluric absorption spectrum has been shifted in velocity to match the atmospheric features visible in the SN spectra. The vertical dashed lines mark the main velocity components.

Figure S3: Comparison between the evolution of NaI D<sub>2</sub> and Ca II K lines during the first three epochs covered by our observations. In order to increase the signal-to-noise ratio on day +61 the Ca II K data have been binned to a 0.3 Å step, corresponding to about 23 km s<sup>-1</sup>. The error bars indicate ±1 SD level, estimated from the data within each single bin, composed by 21 original data points. In each panel, the dotted curve traces the atmospheric absorption spectrum in the D<sub>2</sub> region.

Figure S4: The host galaxy imaged before (left, VLT-FORS1) and after (right, HST-ACS) the explosion of SN 2006X. The field of view is 26.5×22.5 arcsec for both images. The SN position in the FORS1 image is marked by a circle. The spatial scale on the ACS images is about 2.1 pc pixel<sup>-1</sup>.

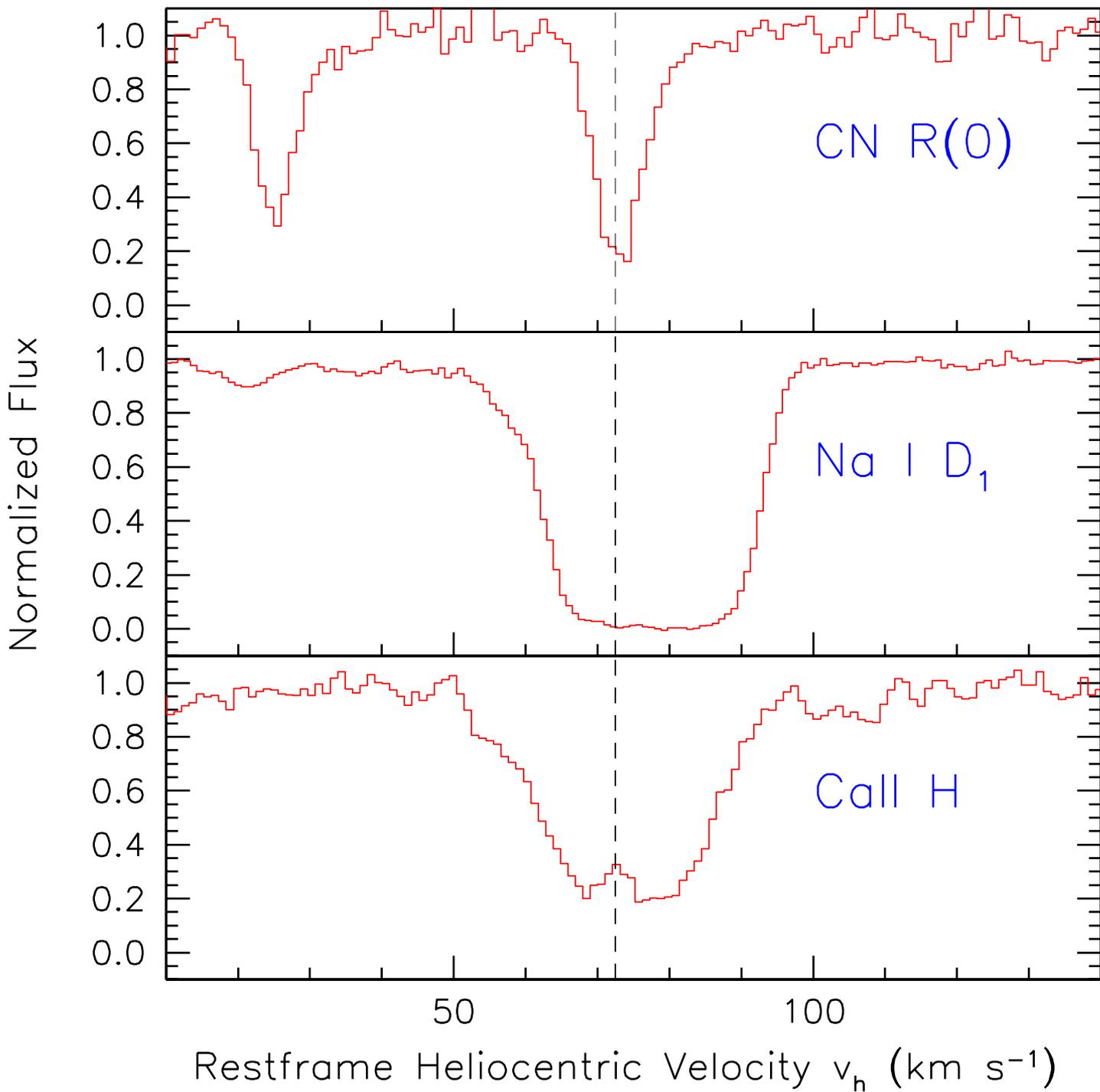
Figure S5: Comparison between the Sodium D<sub>2</sub> line profiles for three SN Ia: 1991T (upper), 1998es (middle) and 2006X (lower). For the sake of clarity, spectra have been arbitrarily shifted in the horizontal direction in order to place the center of the strongest D<sub>2</sub> component at zero velocity.

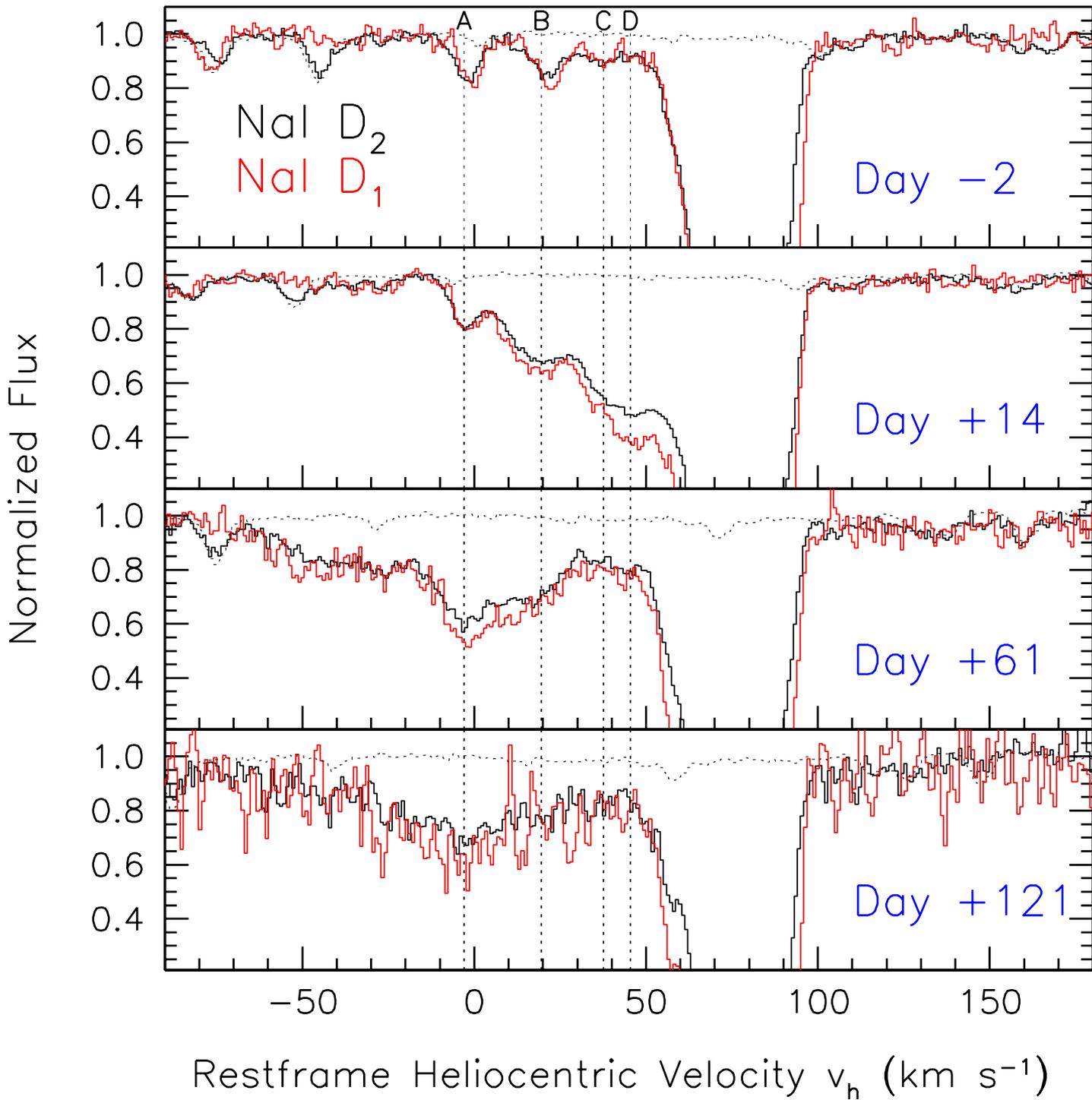
## References

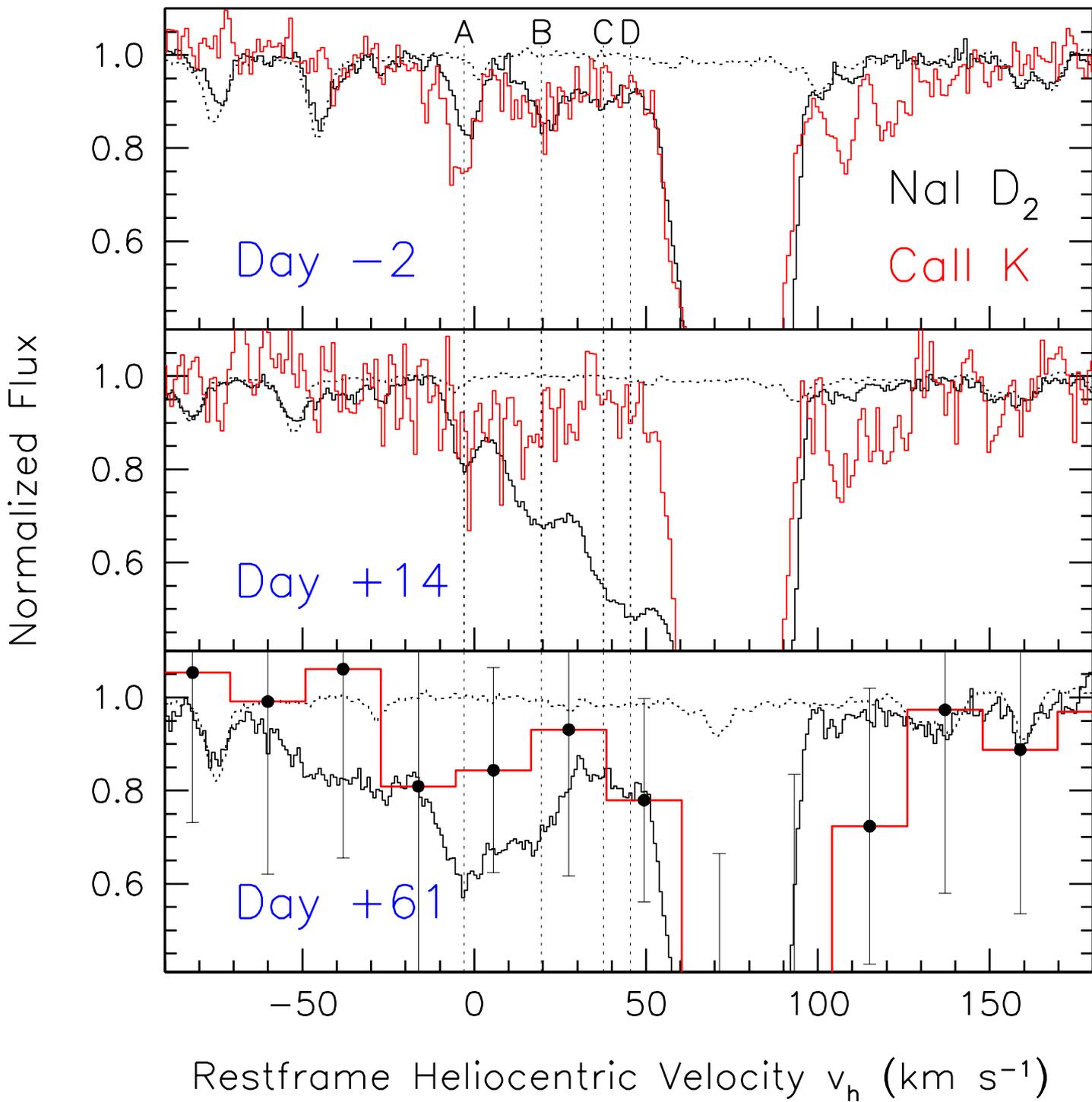
- S1. H. Dekker *et al.*, *Proc. SPIE* **4008**, 534 (2000).
- S2. S. Vogt *et al.*, *Proc. SPIE* **2198**, 362 (1994).
- S3. P. Ballester *et al.*, *The Messenger* **101**, 31 (2000).
- S4. R.J. Rand, *Astrophys. J.* **109**, 2444 (1995).
- S5. VPFIT has been developed by R.F. Carswell and can be freely downloaded at <http://www.ast.cam.ac.uk/~rfc/vpfit.html>
- S6. K. Krisciunas, private communication.
- S7. L. Ferrarese *et al.*, *Astrophys. J.* **464**, 568 (1996).
- S8. The Very Large Array telescope of the National Radio Astronomy Observatory is operated by Associated Universities, Inc. under a cooperative agreement with the National Science Foundation.
- S9. P. Chandra, R. Chevalier, F. Patat, *ATel* **954** (2006).
- S10. N. Panagia *et al.*, *Astrophys. J.* **469**, 396 (2006).
- S11. R. Quimby, P. Brown, C. Gerardy, *CBET* **421** (2006).
- S12. S. Benetti *et al.*, *Mon. Not. R. Astron. Soc.* **348**, 261 (2004).
- S13. B. Canzian, R.J. Allen, *Astrophys. J.* **479**, 723 (1997).
- S14. L.M. Hobbs, *Astrophys. J.* **191**, 381 (1974).
- S15. J.T. Lauroesch, A.P.S. Crotts, J. Meiring, P. Kulkarni, D.E. Welty, D.G. York, *CBET* **421** (2006).
- S16. R.M. Crutcher, *Astrophys. J.* **288**, 604 (1985).
- S17. D.M. Meyer, M. Jura, *Astrophys. J.* **297**, 119 (1985).
- S18. L. Wang, D. Baade, F. Patat, J.C. Wheeler, *CBET* **396** (2006).
- S19. D. Lazzati, R. Perna, J. Flasher, V.V. Dwarkadas, F. Fiore, *Mon. Not. R. Astron. Soc.* **372**, 1791 (2006).
- S20. H. Hao *et al.*, *Astrophys. J.* **659**, L99 (2007)

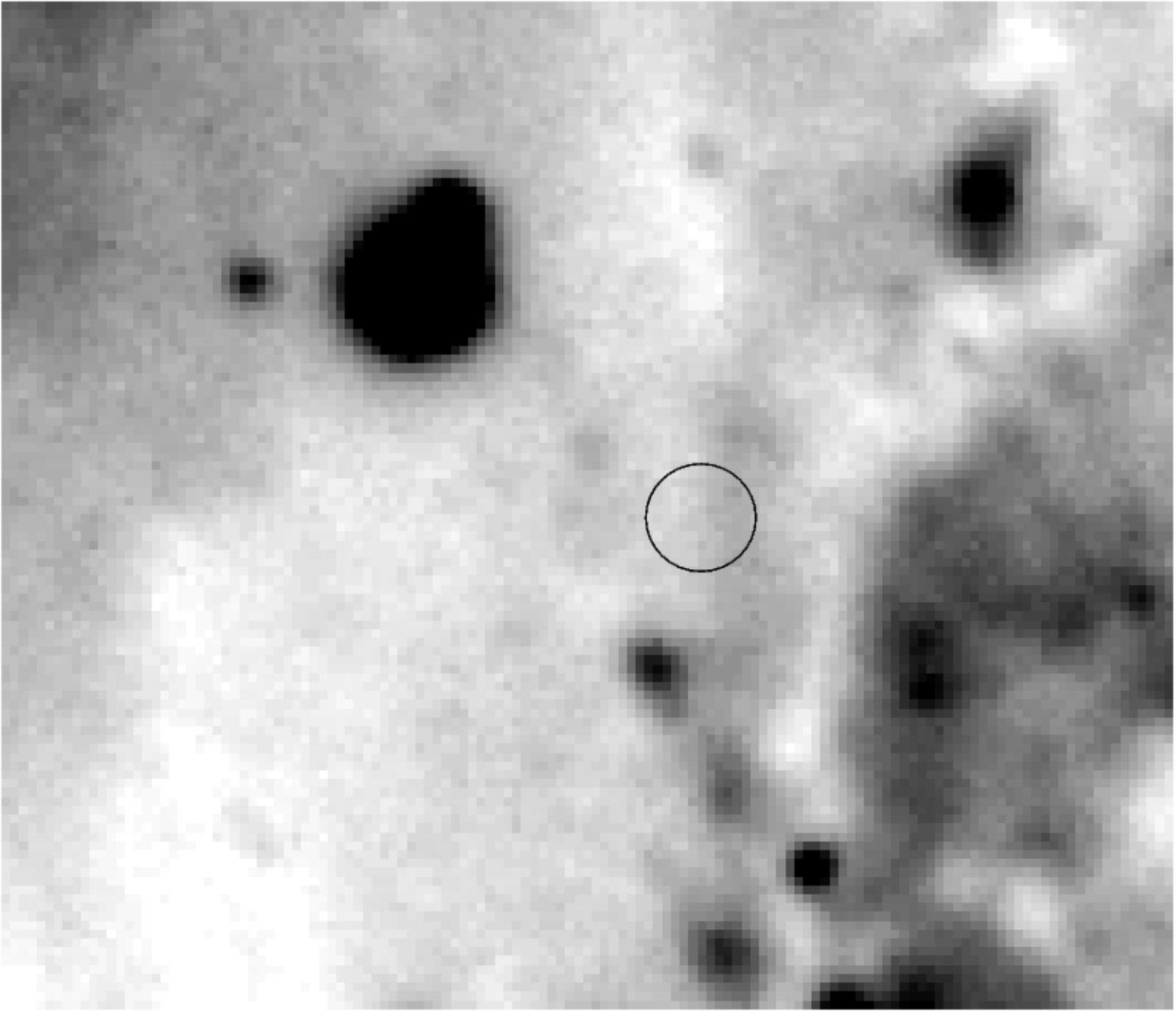
- S21. N. Panagia, *Supernova 1987A: 20 Years after: Supernovae and Gamma-Ray Bursters*, S. Immler, R. McCray and K.W. Weiler, Eds. (AIP Conf. Proc., 2007), in press; preprint available online (<http://arxiv.org/abs/0704.1666>).
- S22. D.A. Verner, G.J. Ferland, K.T. Korista, *Astrophys. J.* **465**, 487 (1996).
- S23. W.A. Pauldrach *et al.*, *Astron. Astrophys.* **312**, 525 (1996).
- S24. R.P. Kirshner *et al.*, *Astrophys. J.* **415**, 589 (1993).
- S25. P.M. Vreeswijk *et al.*, *Astron. Astrophys.*, in press; preprint available online (<http://arxiv.org/pdf/astro-ph/0611690>).
- S26. I.A. Crawford, *Mon. Not. R. Astron. Soc.* **328**, 1115 (2001).
- S27. I. Appenzeller *et al.*, *The Messenger* **94**, 1 (1998).
- S28. Data were obtained with ESO Telescopes at the Paranal Observatory under programme ID 063.H-0650(A), P.I. B. Leibundgut.
- S29. C. Pavlovsky *et al.*, *Advanced Camera for Surveys Instrument Handbook for Cycle 16, Version 7.1* (STScI, Baltimore, 2006).
- S30. Images were retrieved from the data archive at the Space Telescope Institute. STScI is operated by the association of Universities for Research in Astronomy, Inc. under the NASA contract NAS 5-26555. Data were originally obtained by A. Crots et al.
- S31. S. D'odorico *et al.*, *Astron. Astrophys.* **215**, 21 (1989).
- S32. R.J. Cumming *et al.*, *Mon. Not. R. Astron. Soc.* **283**, 1355 (1996).
- S33. J. Sollerman *et al.*, *Astron. Astrophys.* **429**, 559 (2005).
- S34. S. Mattila *et al.*, *Astron. Astrophys.* **443**, 649 (2005).
- S35. M.M. Phillips *et al.*, *Astron. J.* **103**, 1632 (1992).
- S36. S. Jha, P. Garnavich, P. Challis, R.P. Kirshner, *IAU Circ.*, No. 7054 (1998).
- S37. D. Enard, *Proc. SPIE* **331**, 232 (1982).
- S38. A. Kaufer *et al.*, *The Messenger* **95**, 8 (1999).
- S39. D.V. Bowen, K.C. Roth, D.M. Meyer, J.C. Blades, *Astrophys. J.* **536**, 225 (2000).
- S40. A. Fassia *et al.*, *Mon. Not. R. Astron. Soc.* **325**, 907 (2001).
- S41. I. Hachisu, M. Kato, *Astrophys. J.* **558**, 323 (2001).

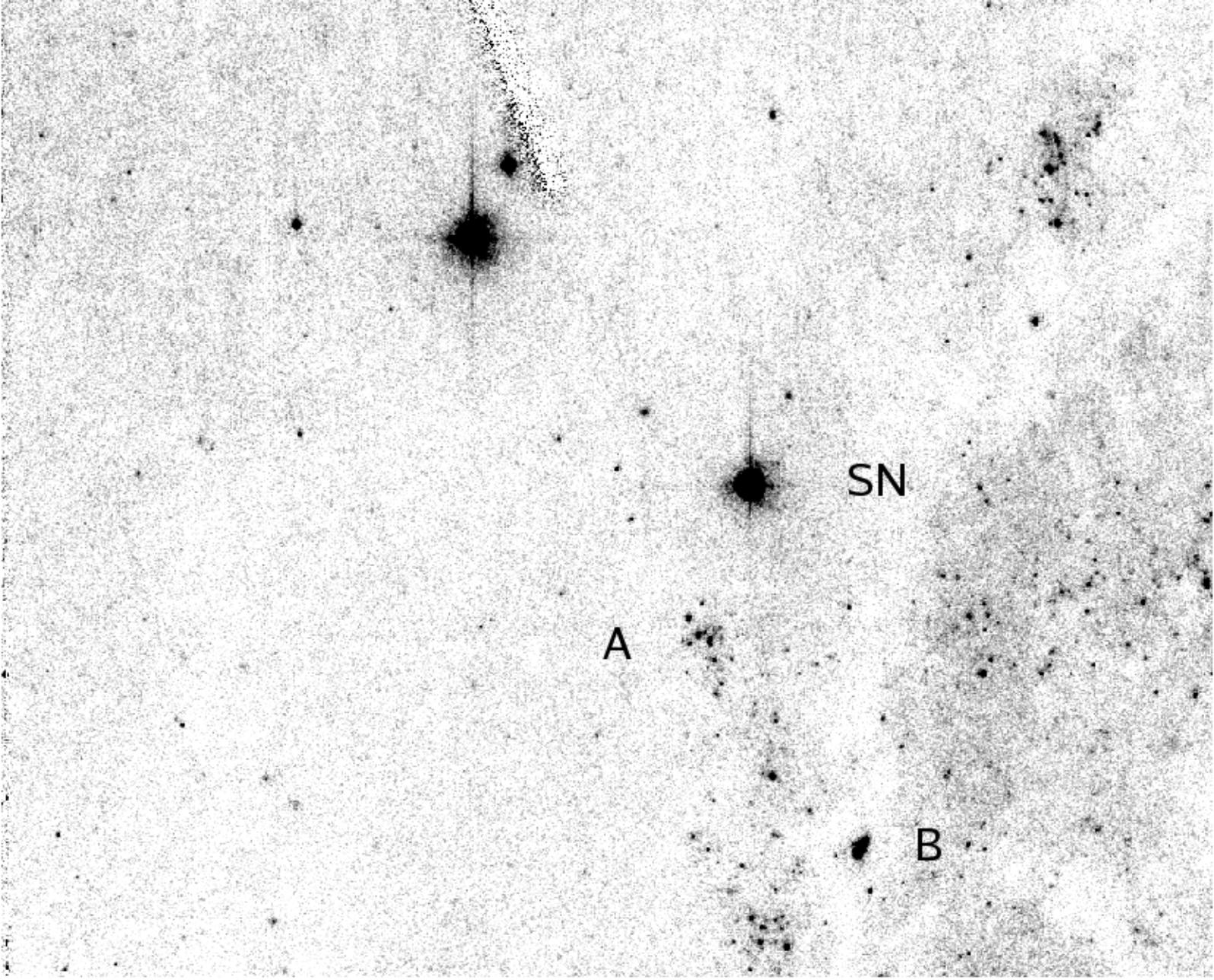
- S42. W.M. Wood-Vasey, J.L. Sokoloski, *Astrophys. J.* **645**, L53 (2006).
- S43. S.R. Pottash, *Bull. Astr. Inst. Netherlands* **19**, 227 (1967).
- S44. R.M. Hjellming *et al.*, *Astrophys. J.* **305**, L71 (1986).
- S45. L. Sedov, *Similarity and Dimensional Methods In Mechanics* (Academic Press, New York, 1959).
- S46. O. Yaron, D. Prialnik, M.M. Shara, A. Kovetz, *Astrophys. J.* **623**, 398 (2005).
- S47. T.J. O'Brien *et al.*, *Nature* **442**, 279 (2006).











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