ON THE PHYSICAL MODEL OF SUPERNOVAE CLOSE TO LIGHT MAXIMUM

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Abstract. One of the principal sources of information about supernovae are the spectra of these stars. Thus we are going to discuss mainly the spectra of type I and type II supernovae around light maximum ($t_{\max}$).

1. Type I Supernovae

The identification. During several decades it was accepted that the spectrum of a typical type I supernova around light maximum is composed mainly of a large number of very wide overlapping emission bands (Minkowski, 1939). However all the attempts to identify these bands were not successful. In this connection McLaughlin (1963) suggested that the principal element of the spectra of type I supernovae are the *absorptions* (intensity minima) but *not* the emissions. This hypothesis was confirmed by Pskowskij (1968) who identified several absorptions in the spectra of type I supernovae with certain sufficiently strong and heavily displaced absorption lines of the spectra of supergiants of the spectral classes B and A. A comparison of absorptions in the spectra of type I supernovae with the absorption lines in the spectra of closely related objects, namely Novae permitted to confirm the 'absorption hypothesis' of the origin of the spectra of type I supernovae and to explain the peculiar evolution of the spectra of these objects with time (Mustel, 1971a, 1972a; Mustel and Chugay, 1974). Then a comparison of the spectrum of a type I supernova 1966j in NGC 3198 (Chalonge and Burnichon, 1968) with the principal *absorption* spectrum of DQ Her permitted to explain practically all the features of the spectrum of this supernova, see Figure 1a, taken from the article of Mustel (1972b). The Doppler displacement $\kappa = \Delta\lambda/\lambda = v/c$ is equal for this supernova to: $\kappa = -0.0255$. Only the lines of the principal absorption spectrum of DQ Her were used which according to McLaughlin (1937) had intensities $I \geqslant 2$. Two exceptions from this rule were: Ba II 5854(1) and Fe II 5425(0).* The intensity of all the absorption lines in the spectrum of DQ Her is indicated in round brackets. Figure 1b gives a similar identification made on the base of photographic tracings of the spectrum of the supernova, reproduced in the paper of Chincarini and Perinotto (1968). This spectrum was also taken on the 9th January 1967. The displacement factor κ in Figure 1b is the same (-0.0255).

Finally it is necessary to mention an analysis of Branch and Patchett (1973) who also confirmed the 'absorption hypothesis' of type I supernovae.

All these studies permitted to determine the expansion velocities of the envelopes ejected by different type I supernovae. These velocities range from $\simeq 6000$ km s^{-1} to

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* According to Mustel and Baranova (1965) the intensity of this line Fe II, 5425 Å in the spectrum of DQ Her was quite perceptible.

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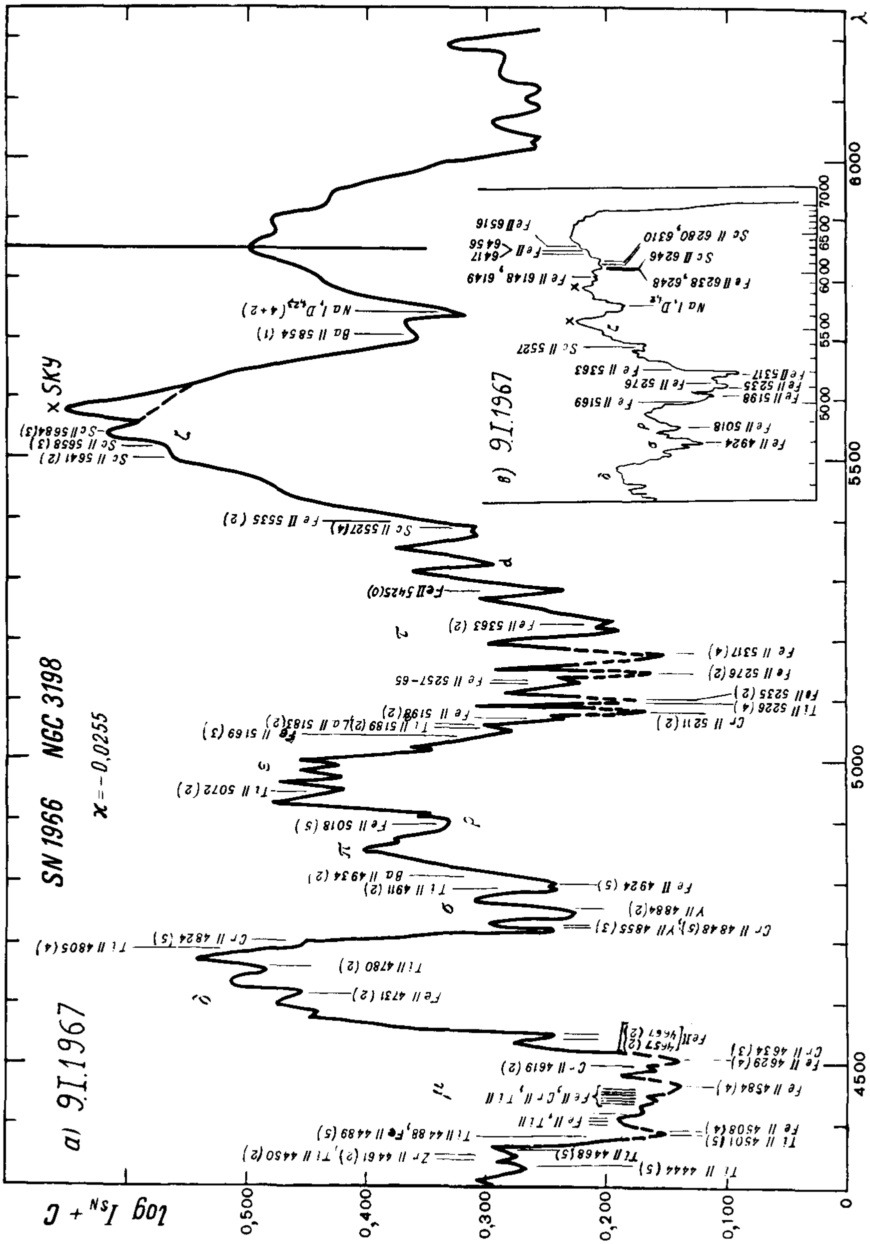

Fig. 1. Identification of absorptions in the spectra of type I supernova 1966j in NGC 3198 with relatively strong absorption lines of metals (Int ⩾ 2) in the principal spectrum of DQ Her. It seems that the absorption *d* is spurious. The spectral energy distribution is taken from Chalonge et Burnichon (1968).

$\simeq 15000$ km s^{-1}. On the *average* the expansion velocity of the envelopes of type I supernovae is of the order of 10000 km s^{-1}. This magnitude of v coincides well with expansion velocities of the supernova *remnants*: shell sources MSH14–415, Tycho, Kepler (van den Bergh, 1973). As to the Kepler's remnant see in more detail Mustel (1974).

It is very important to mention that for the majority of spectra of type I supernovae the Doppler factor κ is practically constant for *all* the available ranges of wave-lengths.

The next very essential progress in the analysis of spectra of type I supernovae is connected with the bright supernova 1972e in NGC 5253 the epoch of light maximum of which was close to the 5th of May. I have in mind the large number of the absolute spectral energy distributions which were obtained for this supernova by Kirschner *et al.* (1973b) and by Kirschner (1974). These distributions were obtained in the range from 3200 to 11000 Å. The authors of this article write: "The smooth and gradual change with time of the overall shape of the *spectrum* is a very striking phenomenon and clearly shows that the SN I spectrum is not a superposition of emission bands but that just as in type II's the bulk of the energy radiated by the supernova is contained in a continuum; the net flux in line radiation is relatively insignificant." This conclusion agrees with the principal starting point of the absorption hypothesis. Moreover an identification of absorption lines in the spectrum of supernova in NGC 5253 carried out by Mustel (1973) also confirms this hypothesis.

However there is one point which deserves some discussion. Namely, Kirschner *et al.* (1973b) consider that the spectra of type I supernova contain not only absorption lines but also emissions and that these spectra are similar to the spectra of P Cygni. They write: "The hypothesis of blended absorption lines without associated emission lines cannot account for the fact that the minima in the spectra of SN I's are so frequently displaced from their neighbouring redward* maxima *by the same velocity shift*." However we have to take into account the fact that the *principal* property of spectra of type I supernovae are the extremely wide absorptions. Therefore in the majority of cases the intensity maxima are produced by *neighbouring* absorptions and it is extremely difficult to distinguish the true line emissions and these maxima! This statement follows from the analysis of the evolution of the absorption spectra of type I supernovae. It is shown in the paper of Mustel (1973) that many changes in the intensity maxima of the spectra of the supernova in NGC 5253 are mostly due to time-evolution of the *absorption* component of the spectra.

In this connection we give Figure 2 which is based on the absolute spectral energy distributions presented in the paper of Kirschner *et al.* (1973b). These distributions are here transformed to the usual system of coordinates (I_λ vs λ). The line-identifications are from the paper of Mustel (1973). The line of the continuous spectrum (dashed line) is drawn in accordance with the absorption hypothesis.

Before discussing Figure 2 we must mention the following fact. Observations show (see further) that the temperature of type I supernovae decreases rapidly after light

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* The same is true for violetward 'maxima' and all this is connected with the mechanism of the origin of absorption lines in these stars, see further.

maximum* during 30–40 days and then begins again to increase slowly. Correspondingly the temperature of supernova for the moment $t = 2441453$ JD (first moment of observations) was relatively high whereas for the moment 2441475 it was considerably lower.

Now we shall consider the two intensity maxima ζ' and ζ''; the position of the second maximum ζ'' on Figure 2a is indicated by an arrow. This arrow is above region A with reduced intensity. This region is due to the fact that it contains many sufficiently strong absorption lines of S II (see Pskowskij, 1968; Mustel, 1973; and especially Figure 6 in the paper of Mustel, 1972a). These absorption lines are relatively strong in B-type stars and their intensity decreases rapidly with the decrease of the temperature of the star.** Then, a blend of lines of N II, $\bar{\lambda}_0$ 5680 Å was also observed in the same region A for the moment JD... 453 and this was also due to the high temperature of the supernova at this moment. Thus we may consider that the intensity maximum ζ' on Figure 2a was only a part of maximum ζ'', which was displayed a little later.

In connection with the further decrease of temperature the absorption lines of S II and N II completely disappear near the moment $t = 2441470$ and therefore it may be suggested that the maximum ζ'' on Figure 2b corresponds to the undisturbed continuous spectrum of the star.

Later on this maximum ζ'' suffered new disturbances. This was due to the same absorption blend of N II, $\bar{\lambda}_0 = 5680$ Å which reappeared again and it was connected with the growth of the temperature of the star (see Figure 1b in the paper of Mustel, 1973).

All these transformations of the intensity maxima are more or less typical for the spectra of type I supernovae. Even the cases when an intensity maximum is keeping its position for a long period of time are easily explained. In those cases we deal with two neighbouring absorptions, the observed wave lengths and intensities of which are practically stable and as a result of this the space between them – the intensity maximum – occupies the same place.

Finally we should like to point out the following fact. From Figure 2 we see that absorption lines play a much more important role for the moment $t = \ldots 475$ than for the moment $t = \ldots 453$. This may be explained also from the point of view of the absorption hypothesis. In fact we know that the number of absorption lines and their depth grow rapidly when we go from hot B-stars to cooler stars, say stars of F-type. The same phenomenon is present in Figure 2.

Thus we may conclude that the principal feature of the spectra of type I supernovae are *very wide absorptions* and that in the majority of cases the line emission does not play an important role.

The next problem is the problem of a quantitative interpretation of the spectra of type I supernovae. This problem is discussed in the paper of Mustel and Chugay (1974). The first step is to choose a model of the supernova for the moments close to light maximum. Two of such models are shown in Figure 3. According to the first model

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* Some observations indicate that the same takes place before light maximum.

** The blend of Si II λ5970 also weakens fast after light maximum.

the supernova has a central star (central remnant) which is the principal source of the continuous spectrum. The line-absorption spectrum is produced by the expanding envelope of the supernova. It is not excluded that the central remnant (CR) has a very hot nucleus, indicated by a black circular spot. According to the second model the principal source of the continuous spectrum of the supernova are the inner layers of the expanding envelope. The high temperature of the central body, the black spot in Figure 3, may be the source of heating of these layers.

It seems that the first model is nearer to reality than the second one, though the 'possibilities' of the second model should be studied in more detail. Here we shall consider the first model.

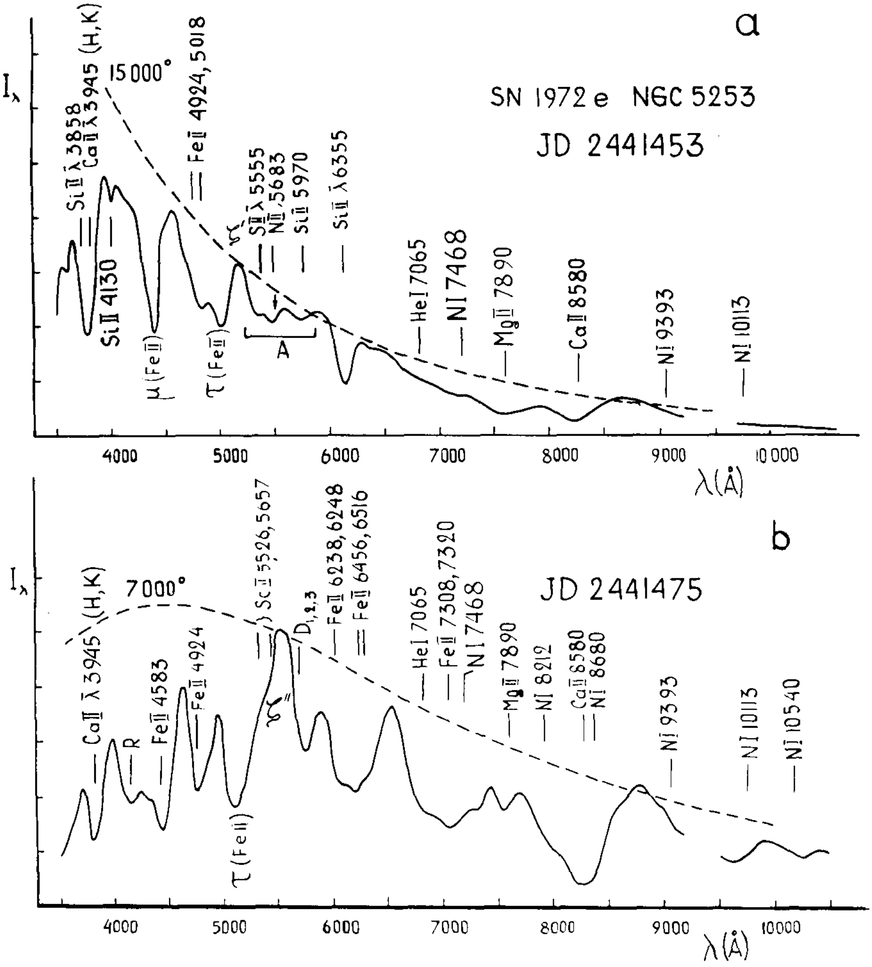


Fig. 2. Interpolated continuous spectrum and the suggested identifications for type I supernova 1972e in NGC 5253 for two moments. The region A in Figure 2a with reduced intensity is due to absorption lines of S II, Si II and N II. The absolute spectral energy distribution in this Figure is taken from the paper of Kirshner *et al.* (1973).

The first model was already discussed by Mustel (1971b). The available data permit to suggest that the emission from CR is approximately Planckian and that there is a correspondence between the temperature of CR and the line-absorption spectrum (the spectral class) of the supernova.

According to Pskowskij (1970) the change of $B-V$ and $U-B$ with time indicates a decrease of the temperature of a typical type I supernova after light maximum during 30–40 days. Then the temperature begins to increase again. The same results are obtained by Barbon *et al.* (1973). The type I supernova 1972e has shown a drop in temperature after light maximum also, see the article of Kirschner *et al.* (1973a) as well as Figure 2 of this paper. Finally we may mention the results of Holm *et al.* (1973) according to which the UV-luminosity (down to 1900 Å) of the supernova in NGC 5253 was decreasing during the first period of its evolution. Moreover several facts show that the changes in the line-absorption component of type I supernovae correspond more or less to the changes of their colour temperature. We may mention again the blend of N II, $\lambda_0 = 5680$ Å, which was sufficiently strong just after light maximum and approximately 140 days after it.

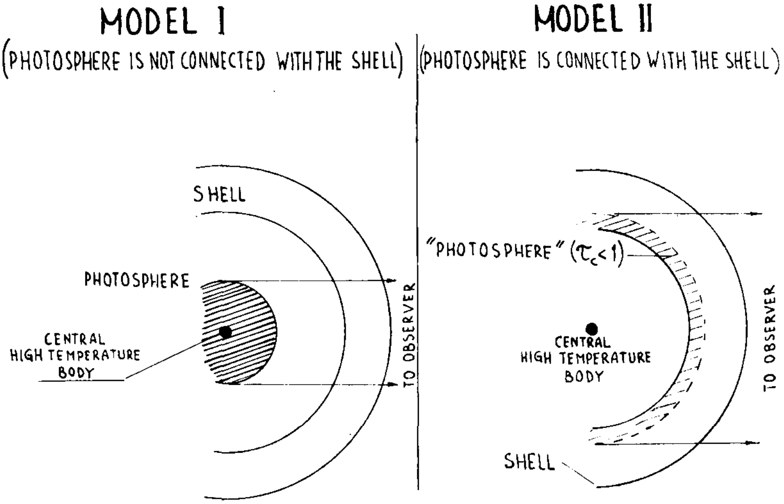
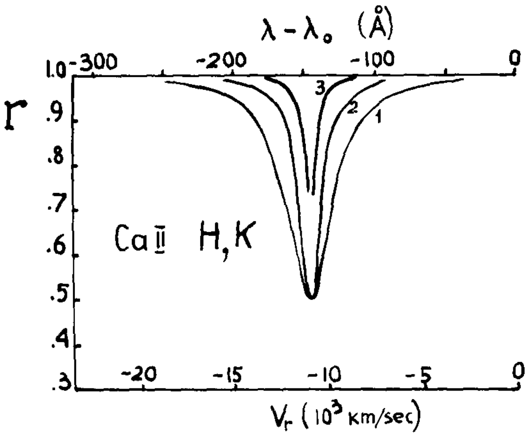


Fig. 3. Two possible models of type I supernovae close to light maximum.

It may be estimated that the average temperature of a typical type I supernova at light maximum is of the order of 10000°–15000°. For supernova 1960f in NGC 4496 it gives a 'photospheric' radius R_p of the order of $20000 R_\odot$. The radius obtained from the expansion velocity of the envelope is 2 or 3 times larger (Mustel, 1971b).

Now we shall consider a very important question – the *profiles* of absorption lines in the spectra of type I supernovae. These profiles are very wide, 10–50 times wider than the absorption lines of the same elements in the spectra of novae. The very large width of the absorption lines in the spectra of type I supernovae was the *principal* reason of the difficulty in the interpretation of the spectra of these objects. In fact the overlapping of the neighbouring very wide absorption lines (mostly metallic lines) produces sometimes so strong blends that the recognition of these blends becomes very difficult. For example a very wide blend τ, produced by an accumulation of metallic lines (mostly Fe II) in the range of wave-lengths from $\lambda_0$5169 (Fe II) to $\lambda_0$5414 (Fe II) does not usually show in the spectra of type I supernovae individual absorptions belonging to metals. Only in the spectrum of supernova 1966j with the unusually sharp lines* we can see some traces of metallic lines in the blend τ (see Figure I).



№	JD	R (km)	R/R☉
1	453	4×10^{15}	5.7×10^{4}
2	493	8×10^{15}	1.14×10^{5}
3	684	2×10^{16}	2.86×10^{5}

t=2441... J.D.

Fig. 4. An extrapolated decrease of the total width of the blend of absorption lines H and K, which is computed on the base of a simple model of an expanding envelope with velocity gradient. It is accepted that $N \sim R^{-2}$.

The effect of blending is especially strong in the *violet* parts of the spectra of the supernovae, where there are numerous strong absorption lines of once ionized metals; see for example the very noticeable depression in the spectrum of type I supernova 1972e (Figure 2). The same phenomenon of a strong crowding of absorption lines towards the ultraviolet part of the spectrum is observed in the spectra of normal stars of classes A, F, etc.

We cannot explain the very large width of absorption lines in the spectra of type I supernovae as a result of the very large mass of the envelopes of supernovae in comparison with the mass of the envelopes ejected by novae. It appears that due to the very large size of the envelopes around supernovae the mass of gas per cm^2 is approximately the same in both cases (Mustel and Chugay, 1974).

An analysis of different mechanisms which may be responsible for the strong widening of absorption lines in the spectra of type I supernovae is carried out in the article of Mustel and Chugay (1974). The results of this analysis are the following:

(a) The application of usual damping mechanisms leads to improbably high masses of the envelopes of type I supernovae (for example for Fe atoms) up to approximately 500 $M_\odot$.

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* It seems that this is due to a relatively small velocity gradient inside this envelope; see further.

(b) Doppler profiles for the turbulent motions of the gases inside the envelope must be rejected too since these turbulent motions would lead to a very strong heating of the envelope due to the dissipation of the turbulence.

(c) The next simple mechanism in which the widening of absorption lines is due to the presence of a strong velocity gradient inside the envelopes meets also a difficulty. It cannot explain the fact that very often the outermost parts of *both* wings of the sufficiently strong absorption lines in the spectra of type I supernovae occupy the same position during a very long period of time.* On the contrary it is expected that the width of all the absorption lines must diminish very rapidly, see Figure 4. This figure shows an estimated change of the profile of Ca II (H+K)-absorption lines in the spectrum of supernova 1972e. The computations are carried out for the case when the number of the absorbing atoms (per 1 cm^2 of the envelope) decreases according to the law: $N \sim R^{-2}$. The *first starting* profile (for the moment $t = \ldots 453$) is taken from the observations. This difficulty takes place also in case of widening mechanism (a).

(d) In spite of the difficulty of the previous mechanism (c) and taking into account very serious difficulties of mechanisms (a) and (b) we are forced to accept a model with a large velocity gradient. In order to explain in this case a very slow evolution of the profiles of strong absorption lines (Figure 4) we should modify the previous mechanism (c) and admit that during a long period of time the optical depth τ_ν of the envelope is very large,** even in the wings of the absorption lines. Here the total width of the absorption line will remain constant also for a long period of time. However for the explanation of the observed profiles of the strong absorption lines we introduce the following additional assumptions: (1) The mass of the envelope must be sufficiently large (in comparison with the mass in the model (c) in order to fulfill the requirement $\tau_\nu \gg 1$ during many months.† (2) Inside the envelope there must be a considerable inhomogeneity. This 'patchiness' of the envelope explains *noticeable* observed residual intensity r_ν in the profiles of strong absorption lines. (3) Besides, in order to explain the variation r_ν inside the profiles, we should suggest that the filling factor (see, for example, Peimbert, 1971) is a maximum in the *middle* part of the envelope and decreases in both (opposite) radial directions. All these suggestions are quite natural.

Now we may try to describe the time-evolution of the spectrum of a typical type I supernova; see also the article of Mustel (1972a). This evolution is due to the following factors:

(a) The *temperature changes of* CR. As we mentioned above, the temperature of CR at light maximum and before it is rather high and decreases after the light maximum, during a period Δt_0 of 30–40 days. Then it begins to rise again. Thus immediately after light maximum the ionization of elements is expected to drop, to grow again

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* In other words the total width of a strong absorption lines may be practically constant during a very long period of time.

** In this case the total width of strong absorptions is determined by the velocity gradient. This explains the fact that the wave length distance between minima and neighbouring 'maxima' in the spectra of supernova 1972e corresponded for different absorptions to the same velocity shift, see page 547.

† Calculations show that this mass is considerably less than that in the damping mechanism (a).

after the period Δt_0. We already described such a case – the behaviour of a blend of absorption lines of N II, $\bar{\lambda}_0 = 5680$ Å. It is very interesting to note that certain sufficiently clear and intense lines of N I appeared *after* the disappearance of this blend of N II. Probably there are other similar examples but the effects of blending are so strong that any definite conclusions are inadequate. Moreover it seems that only the nitrogen atoms have more or less clear absorption lines for two stages of ionization: N I and N II.

The changes of T (CR) produce also certain changes in the state of atomic excitation. But it is necessary to take into account the fact that the central remnant is a star with quite unusual properties and it is expected from analogy with similar objects that this star should emit anomalously high radiation in the regions of high frequencies, in the far ultra-violet regions of the spectrum. It seems that the lines of He I 5875 and 7065 in the spectrum of supernova 1972e are connected with this high-frequency emission. The correctness of this suggestion is confirmed by the following considerations. It is described in a paper of Mustel (1972a) that there is usually a good agreement between observed wave-lengths of the absorptions in the spectra of type I supernovae and the calculated positions of the corresponding spectral lines of different elements. Only the absorption with $\lambda \simeq 5700$ shows in some cases relatively small velocity v. This effect may be naturally explained if we admit that the principal contributor of the absorption at $\lambda \simeq 5700$ Å is the He I line D_3 and not the $D_{1,2}$ lines of Na I. In fact the strongest influence of high-frequency radiation must be for the *internal* (relatively transparent) parts of the envelope which expand with the smallest velocity and therefore the deviations from the calculations and observations may be due to the fact that the absorption $\lambda \simeq 5700$ Å is formed in these internal parts of the envelope.

(b) *The expansion of the envelope of the supernova.* This produces a continuous decrease in the gas density inside the envelope and a decrease of the dilution factor W. Thus we expect that there must be a continuous accumulation of atoms on metastable levels. This prediction is completely confirmed by observations. For example, at light maximum we observe mostly the lines of Fe II, similar to the lines 5018, 4924, the low level of which has an E.P. $\approx$ 2.9 eV. At the same time in ten or fifteen days after the light maximum the lines of multiplets N73 and 74 of Fe II appear, for which E.P. $\simeq$ $\simeq$ 3.9 eV. A similar situation is observed with the Sc II lines 5526 and 5657. They attain their maximum intensity only after the light maximum and their behaviour is the same as the behaviour of these lines in the spectra of DQ Her.

The last question is the question of the chemical composition of the envelopes of type I supernovae. This question is discussed in more detail in the papers of Mustel (1973, 1974) and we shall reproduce some principal results. First, it is necessary to say that from a quantitative point of view this question is a very difficult one: (1) Owing to a very strong blending of the absorption lines the line of the continuous spectrum is very uncertain and this uncertainty may introduce considerable errors into the equivalent widths W_λ of the absorption lines; (2) There are only a few sufficiently clear and relatively isolated absorption lines in the spectra. In particular it is very difficult to identify weak absorption lines and therefore the usual method of the curve of growth is practically inapplicable here. Therefore it is necessary to work out a special method for the chemical analysis of the envelopes of type I supernovae. It must take into account the presence of a strong velocity gradient inside the envelopes of these stars and other considerations, as described above.

The main semiquantitative results of the papers mentioned above are the following:

(a) There is abundance of metals in the envelopes of these supernovae; see for example Figure 1.

(b) There are reasons to state that some of the intense absorption lines in the spectra of type I supernovae are due to He I. Since the E.P. of the low levels of the corresponding transitions in the He I atoms is high ($\simeq 20$ eV) it is concluded that the abundance of He I in the envelopes of these supernovae is relatively high.

(c) It is concluded that nitrogen is noticeably more abundant than carbon and oxygen.

(d) Observations do not show any hydrogen lines in the spectra of type I supernovae. In particular the absence of the absorption lines of the Balmer series and the simultaneous presence of relatively strong lines of N I, show that the abundance of H atoms is noticeably lower than the abundance of N atoms. An analysis of the supernova remnants confirms the excessive abundance of nitrogen in the envelopes of supernovae.

2. Type II Supernovae

The spectra of type II supernovae are *similar* to the spectra of common novae. The spectral lines of these supernovae have usually absorption and emission components. Here the problem of the identification was not so difficult as the problem for type I supernovae. In particular hydrogen (absorption + emission) plays an important role in the spectra of type II supernovae. Nevertheless there are many specific properties in the spectra of these objects:

(a) For type II supernovae different observers find different velocities of expansion, ranging from $v \approx 5000$ km s^{-1} to 10000 km s^{-1}. It may be that this is partly due to the fact that for example in the spectra of the type II supernovae 1969l in NGC 1058 there was a progressive drift with time toward the red of all absorption and emission features (Ciatti *et al.*, 1971). After light maximum the mean expansion velocity was decreasing during two months (!) from $v \simeq 9500$ km s^{-1} to 5500 km s^{-1}. It would be very important to find out whether this phenomenon (even on a smaller scale) is inherent to all type II supernovae. In addition it may be mentioned that different groups of absorption lines (for example hydrogen and metals) show somewhat different velocities (Ciatti *et al.*, 1971; Patchett and Branch, 1972).

(b) The time-evolution of the spectra of type II supernovae is much faster than the time-evolution for type I supernovae, see for example Figure 5 taken from the article of Kirschner *et al.* (1973b). We see that the changes in the spectrum of the supernova 1970g in M101 from JD 2440802 to JD 2441056 are very strong; for this second moment the spectrum is already practically an emission spectrum.

(c) The problem of the temperature of type II supernovae and generally the problem of the continuous spectrum of these objects is very complex. According to Arp (1961) the temperature of the supernova of 1959 in NGC 7331 at light maximum was

≈25000° and the radius R of the envelope for this moment was $\approx 6\times 10^{14}$ cm. According to Ciatti *et al.* (1971) the pattern of the supernova 1969l in NGC 1058 in the first 30 days after light maximum followed rather closely that of a supergiant with decreasing temperature from 15000° downward. According to Kirschner *et al.* (1973b) the continuum of type II spectra at light maximum resembles that of a blackbody at about 9500°. They found that when a supernova ages the continuum becomes fainter and the temperature of the best fitting blackbody drops rapidly to a value of about 5000°.

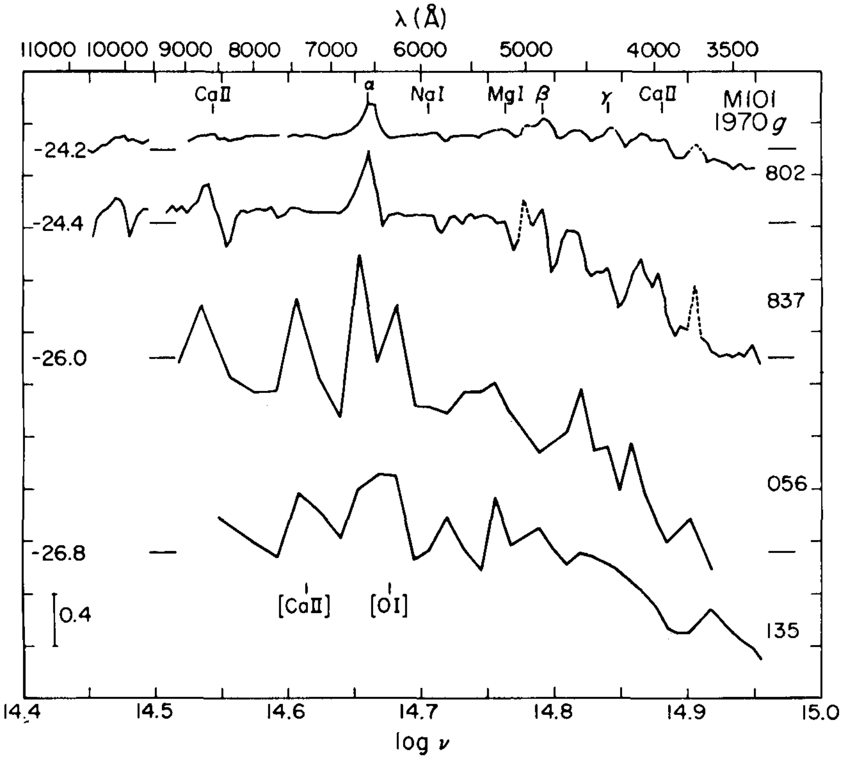

Fig. 5. The time-evolution of the spectrum of type II supernova 1970g in M101 according to Kirshner *et al.* (1973b).

In order to understand these observational results let us consider again Figure 5. The energy distribution for the moment $t = 2440802$ (JD) is more or less 'flat' and shows a noticeable extension into the ultraviolet. This fact was already mentioned by many observers. But at the moment $t = 2440837$ the situation is quite different. The energy distribution in the spectrum for $\lambda \geqslant 5000$ Å remains practically the same, but for the region with $\lambda < 5000$ we observe a very noticeable reduction of intensity I_ν. This reduction is reflected in the difference between the U and V-light curves of type II supernovae. The drop in the U-brightness immediately after light maximum is much steeper than the drop in the V-brightness (see, for example, Ciatti *et al.*, 1971). It seems that this phenomenon of such a noticeable intensity reduction in the region $\lambda < 5000$ Å is mostly responsible for the 'apparent' temperature decrease mentioned above. Another specific property of the 'short' wave-length part of the spectra of type II supernovae ($\lambda < 5000$ Å) is that at intermediary stages of evolution* this part of the spectrum becomes more or less similar to the spectra of type I supernovae, of course, for the same wave-lengths; see the energy distribution for the moment $t = 2440837$ on Figure 5.

We may suggest the following explanation for all these effects. It is expected that the *outer* layers of the massive and semi-transparent envelopes of type II supernovae are rapidly cooling, more rapidly than the internal parts of these envelopes which are exposed directly to radiation emitted by the relatively hot 'central remnant' of the supernova. As a result of this cooling many absorption metallic lines due to Fe II, Cr II, Ti II, Ca II etc. are expected to appear in the short wavelength part of the spectra of supernovae where these lines are especially numerous, see for example Figure 1. These lines will originate mostly in the outer directly observable layers of the envelope and this explains the temporary similarity between the spectra of type I and type II supernovae.

Now the strong blending of wide metallic lines in the short wavelength part of the spectrum ($\lambda < 5000$ Å) will produce practically a continuous opacity. On the contrary the envelope for $\lambda \geqslant 5000$ Å will remain more or less transparent** and we shall be able to see the 'central remnant'. Therefore, approximately the same energy distribution in the long-wave-length part of the continuous spectrum ($\lambda \geqslant 5000$ Å) of the supernova in M101 suggests for the first two moments on Figure 5 that the 'central remnant' of a supernova keeps practically the same temperature during this period. This may explain the apparent 'contradiction' between the appearance of relatively strong emission lines and the relatively low 'apparent' colour temperature of $\approx 5000°$ for type II supernovae during the later stages of their evolution (see the two last moments on Figure 5).

In terminating this discussion on the spectra of type II supernovae we may mention two facts: (a) the radioemission from supernova 1970g in M101 (Goss *et al.*, 1973); (b) An infrared excess observed for the first time in supernova 1969l in NGC 1058 (Ciatti *et al.*, 1971).

There is no detailed chemical analysis of the envelopes of type II supernovae. In contradistinction to type I supernovae the spectra of type II supernovae have sufficiently strong absorption and emission lines of hydrogen. The article of Kirschner *et al.* (1973b) contains the identification of lines of Ca II. The identification of lines of He I, He II, N II, N III is made in the article of Ciatti *et al.* (1971). The absorption lines of Fe II in the spectra of type II stars are identified in the article of Patchett and Branch (1972).

The supernova remnants give another possibility to study the chemical analysis of gases ejected by supernovae (Mustel, 1974).

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* Later on these spectra become purely emission spectra.

** Except for a few relatively isolated absorptions.

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