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THE Hα LINE INITIAL EVOLUTION IN THE SN 1987A

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RESUMO. Neste trabalho apresentamos os resultados observacionais de espectroscopia óptica em alta resolução, da linha Hα da SN 1987A, obtidos no Laboratório Nacional de Astrofísica (LNA), de 27 de fevereiro a 30 de março de 1987. De nosso conhecimento, estes espectros são os únicos observados em alta resolução. Este fato nos permitiu fazer um estudo mais detalhado dos perfis de Hα, onde pudemos observar estruturas finas da linha. Também medimos as velocidades radiais das componentes da linha para acompanhar o processo de desaceleração da matéria ejetada pela explosão.

ABSTRACT: High resolution spectral observations of the Hα line in the SN 1987A are presented. These spectra were obtained at the Laboratório Nacional de Astrofísica (LNA), from February 27 to March 30, 1987. As far as we know these are the only very high resolution spectra sistematically taken from this object. This situation enabled us to study the evolution of the fine structures of the Hα line. We measured the radial velocities of the different components of the line in order to follow the desacceleration process of the ejected matter of the supernova explosion.

Key words: LINE-PROFILE — STARS-SUPERNOVAE

I. INTRODUCTION

As hydrogen is the main component of the photosphere of the supernova, the Hα line, which is formed in a large part of this atmosphere, is the best candidate to study the explosion mechanism. For that, it is very important to dispose of a complete temporal series, obtained with a sufficient high resolution, in order to detect the evolution of small scale features.

The Hα line presented a wide P Cygni profile since the first day of observations. This may be understood as a consequence of the high velocities of the atmospheric ejected layers. After an initial very fast acceleration, the matter went into a comparatively slower cooling and desacceleration process. This process is shown by the gradative narrowing of the whole line. Superposed to this whole typical P Cygni profile, there are several small scale features, which belong to the line as we will show later. The measurements of the different components show the desacceleration of the corresponding layers. These measurements will be later compared to those found in the literature.

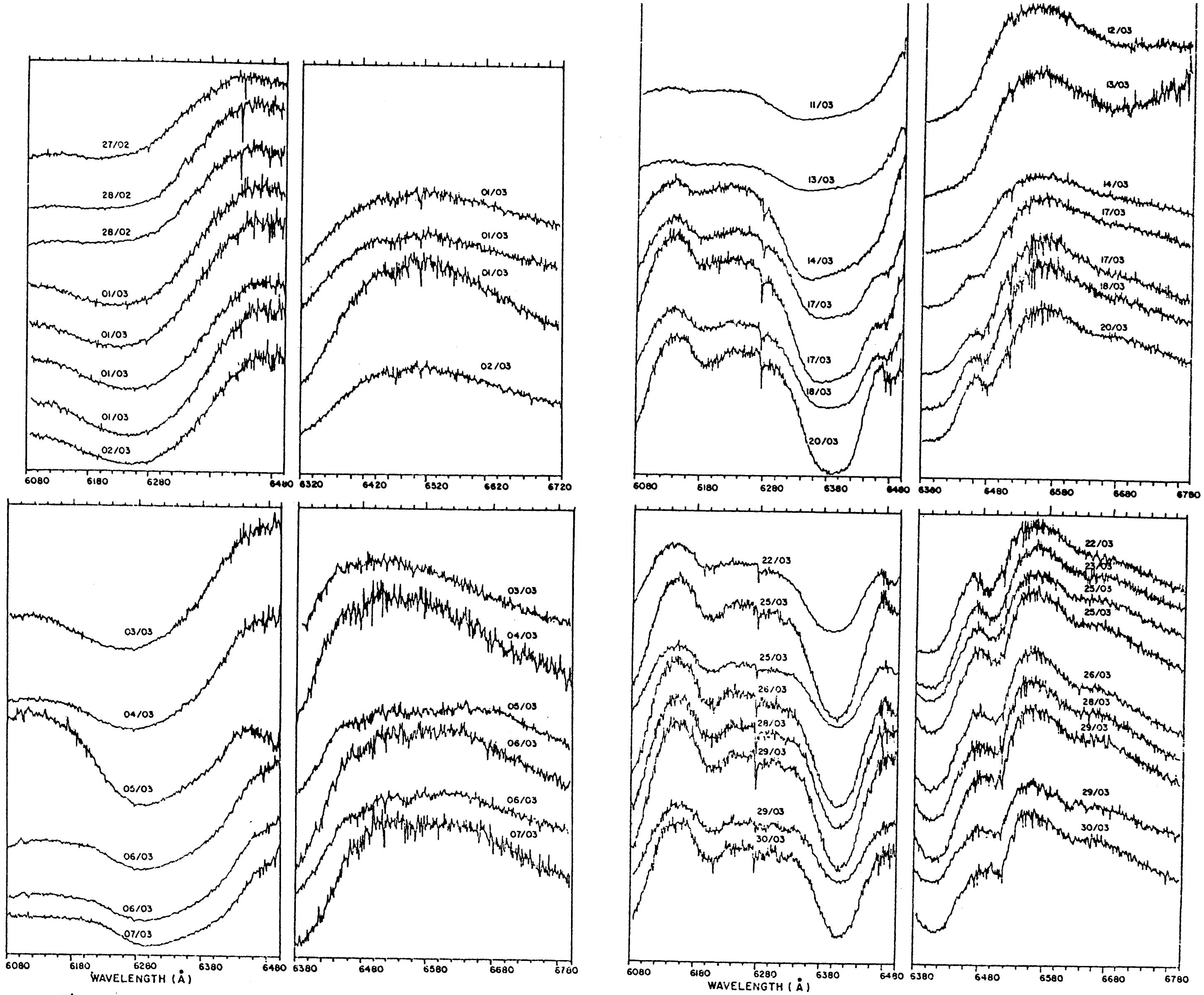

Figure 1. The spectra (not normalized in intensity) of the Hα line of the SN 1987A. The spectra are presented in cronological sequence and for each spectrum are indicated the date (day/month) of the observation.

II. OBSERVATIONS

All the spectra used in this work were obtained at the Laboratório Nacional de Astrofísica (LNA), located at the Pico dos Dias, Minas Gerais, Brazil, between February 27 and March 30, 1987. It was used an intensified photon-counting Reticon detector coupled to the Coudé focus of the 1.60 m telescope. First order spectra with a dispersion of near 18 Å/mm were taken in a spectral range of 420 Å, with a resolution of approximately 0.74 Å.

Since the beginning, the whole Hα P Cygni profile was larger than the 420 Å used interval. In that conditions, two intervals, centered at 6300 and 6600 Å, were used to cover all the line. Both intervals were taken with a mean difference of approximately 10 minutes. In figure 1 we present the spectra (not normalized in intensity) in a chronological sequence. The wavelengths are given in angstroms.

III. DISCUSSION

In figure 1 we can observe the narrowing effect that characterises the desacceleration of the photospheric layers ejected by the SN 1987A. In the region of 6080 to 6500 Å we can see the main absorption component, and in the region of 6380 to 6800 Å, the emission component. These both components are blueshifted at the beginning. However, the absorption minimum can be seen in the 6380 to 6800 Å region since March 22, showing the redshifting tendence. The emission maxima has also redshifted, remaining after March 12 up to March 30 at a more or less fixed wavelength (see radial velocities of the components in figure 2).

We detected the following secondary structures in the Hα line:
(1) In the spectra of March 1 and 2 we can detect a small absorption at the emission peak in 6460 Å approximately. This absorption feature is not visible in low dispersion spectra (Ashoka *et al.* 1987, Hanuschik and Dachs 1987, Menzies *et al.* 1987, Hearnshaw *et al.* 1988, Phillips *et al.* 1988).
(2) An emission peak begin to be formed between the main absorption and emission components in March 17. As days passed, this emission peak redshifts. It reachs a maximum near March 22, and it begins to disappear in March 26, but it is still present in March 30.
(3) In March 18 we can see the formation of a plateau in the red side of the main emission peak. This plateau is maintained up to March 30.

In figure 2 we present the radial velocities measurements of all the components of Hα. These values were corrected by a term corresponding to the movement of the SN 1987A progenitor. We assume this term as the mean value of the nebular and stellar velocities on the 30 Dor region, i.e. 265 km/sec (Elliot *et al.* 1977).

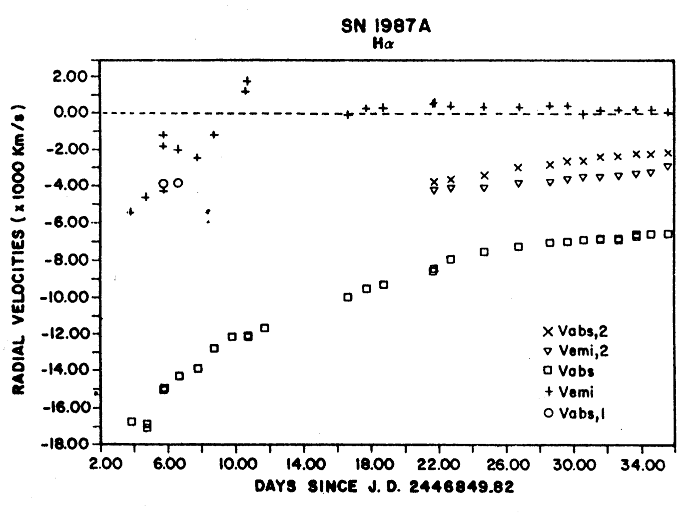

Figure. 2 Radial velocities (in 1000 km/s) of the components of the Hα line versus days after the collapse of the nucleus (JD 2446849.82).
V_{abs} - Minimum of the main absorption; V_{emi} - Maximum of the main emission; $V_{abs,1}$ - Absorption present in the emission peak; $V_{abs,2}$ - Minimum of the secondary absorption peak; $V_{emi,2}$ - Maximum of the secondary emission peak.

By means of figure 2 we can see that the secondary peak have the same desacceleration rate as the total absorption, what shows that this feature belongs to the Hα line. Hanuschik *et al.* (1988), with smaller resolution spectra, reached to the same conclusion. Therefore we may state that this structure is part of the Hα line and is not a FeII line in 6456 Å as has been suggested by Ashoka *et al.* (1987).

In figures 3 and 4 is presented the comparison of our radial velocities measurements of absorption and emission components of Hα with the results of Hearnshaw *et al.* (1987) and Phillips *et al.* (1988). Our velocities values of these main components of Hα are in agreement with the values of these authors. Nevertheless, some of the emission values differ by a small amount. We believe that this is due to the difficulty to place precisely the point of maximum emission. The radial velocities are in general smaller. The differences are more clearly present in the last days where the line, being narrower than before, enabled us to do more precise measurements.

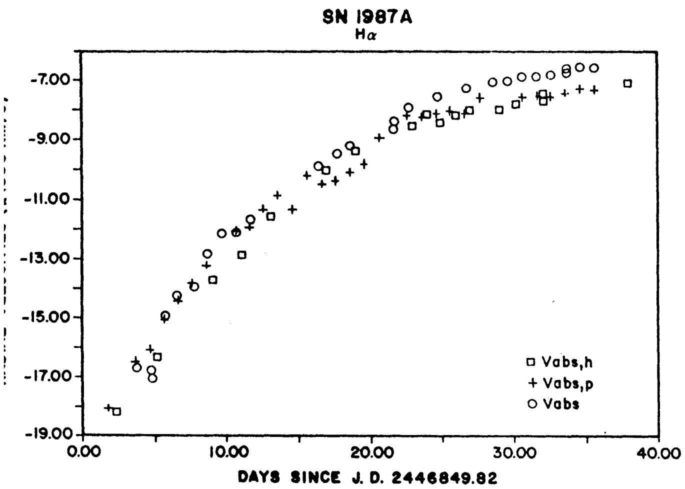

Figure. 3. Comparison of radial velocities (in 1000 km/s) of the main absorption minimum versus days after the collapse of the nucleus: V_{abs} – this work; $V_{abs,h}$ – Hearnshaw et al. (1987); $V_{abs,p}$ – Phillips et al. (1988).

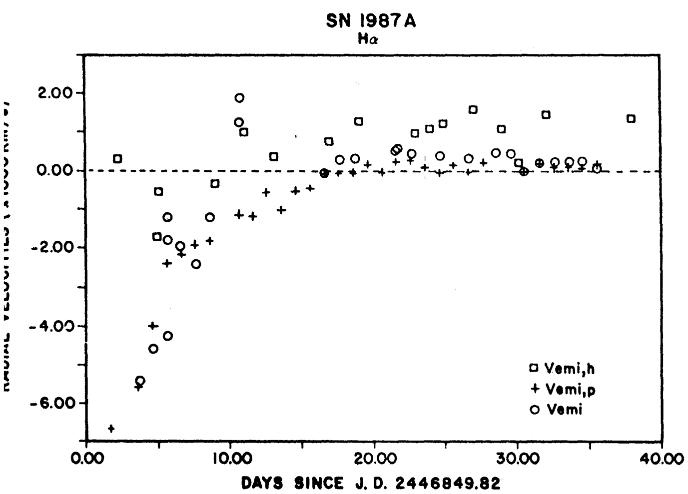

Figure. 4. Idem as figure 3 for the main emission maximum.

By the study of the evolution of the different features of the Hα line, we conclude that the desacceleration process has to be studied as a multilayer phenomena, in which each layer has its characteristic velocity and temperature.

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