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THE CLASSIFICATION OF SN 1987A

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RESUMEN. Se hace una comparación de las curvas de luz y color de la SN 1987A en los primeros 280 días con las de las supernovas del tipo II. Las implicaciones para la clasificación de la SN 1987A son explícitamante discutidas.

ABSTRACT; A comparison is made of the light and colour curves of the SN 1987A in the first 280 days with the mean properties of type II supernovae. The implications for classification of SN 1987A are explicitly discussed.

Key words: STARS-LIGHTCURVE — STARS-SUPERNOVAE

I. INTRODUCTION

Supernova 1987A (SN 1987A) in the Large Magellanic Cloud was the brightest supernova since Kepler's star (1604). It provided a spectacular confirmation of the physical theoretical scenario for the terminal explosions of massive stars i.e., the collapse of a core saturated of metals, emitting a detected neutrino pulse (e.g., Hirata et al., 1987; Svoboda et al., 1987; Alexeyev et al., 1987; and possibly Aglietta et al., 1987).

However, its photometric and spectroscopic evolution showed a number of peculiarities, due to the "non-canonical" character of its progenitor star (Sk-69°202, a blue supergiant in a low metallicity stellar population, instead a red supergiant with solar abundances).

In this paper we review the photometric behavior of SN 1987A in the first 280 days of evolution since core collapse, using high quality photoelectric data in the UBV system, and explicitly discuss the implications for inclusion of SN 1987A in the usual Minkowski-Zwicky (MZ) classification for supernovae.

II. UBV LIGHT CURVES

Figures 1 to 3 present the light curves in the Johnson's U, B, V bands constructed from the published observations by Hamuy et al. (1987), Menzies et al. (1987), Catchpole et al. (1897a,b) and Dopita et al. (1988). A total of 298 nights were selected. We have also added the results from 32 nights of BV photometry carried out at Observatorio do Morro Santana, operated by Departamento de Astronomia do Instituto de Fisica da UFRGS, at Porto Alegre, Brazil. The zero instant was taken coincident with the observed pulse of neutrinos (1987 Feb, 23.316 UT; J. D. 2446 849.82). We have restricted our analysis to the first 280 days because there is no significant statistical information about other supernovae beyond that period, suitable for comparison purposes.

SN 1987A was subluminous at maximum (M_U = -15.36 ± 0.12; M_B = -15.26 ± 0.06; M_V = -16.04 ± 0.01) relatively to the typical types I and II supernovae. The B light curve (fig. 2) shows a fast initial decline in flux,

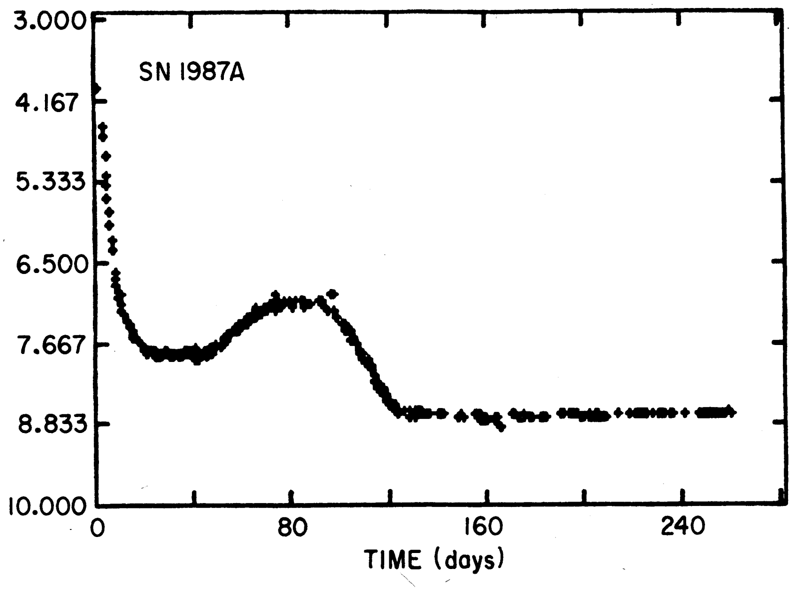

Fig. 1.- U light curve of SN 1897A during the first 280 days of its evolution.

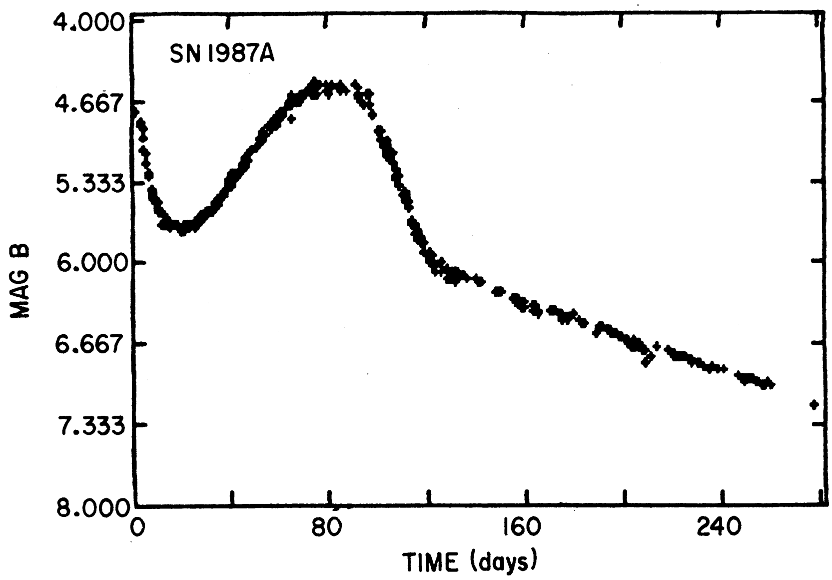

Fig. 2.- B light curve of SN 1897A during the first 280 days of its evolution.

due to the anomalously fast cooling of the compact progenitor, and an exponential luminosity decay of dB/dt = 0.0081 mag/d after the inflection point around t = 120 days.

The V light curve has five well defined parts. The first one corresponds to the fast initial increase in magnitude, with a secondary maximum around V = + 4.5, due to the diffusion of energy shock wave in the

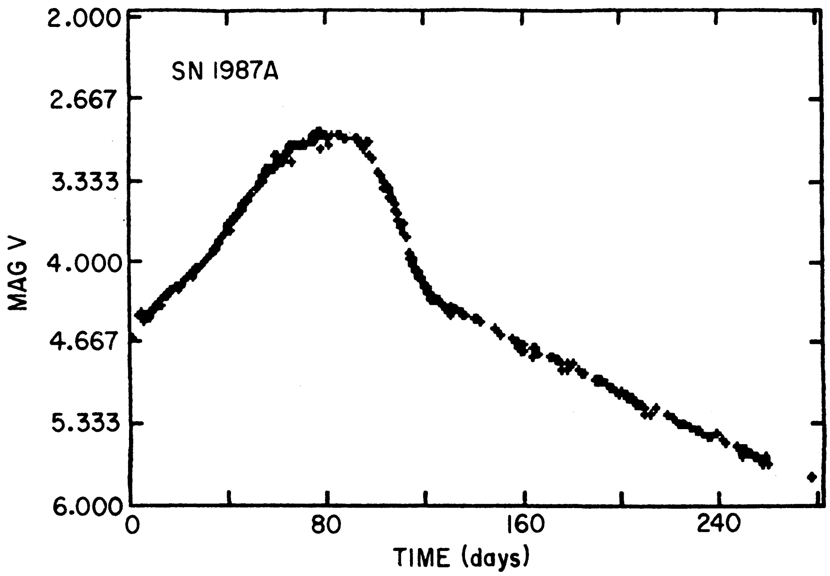

Fig. 3.- V light curve of SN 1897A during the first 280 days of its evolution.

expanding surface of the star, The following part is a linear increase of dV/dt = -0.0280 mag/d between t ≃ 15 and t ≃ 80 days. This behavior was unique among the well observed supernovae. The principal maximum occurred around t = 80-100 days and, besides subluminous, had a plateau-like morphology. The fast decline between t ≃ 120 days was linear (dV/dt = 0.053 mag/d) and, after the inflection point, we observe a slow exponential decay in brightness with dV/dt = 0.0105 mag/d.

III. COLOUR EVOLUTION

Figures 4 end 5 present the (R-V)o and (U-B)o colour curves for the same period, constructed from selected photoelectric measurements. We have used E(B-V) = 0.15 (Hamuy et al., 1987), and E(U-B) = 0.11 derived from Lahulla (1987).

The (U-B)o and (B-V)o colours showed a strong reddening from t = 0 through t = 10 days, being relatively constant after. Around t = 120 days, (U-B)o and (B-V)o showed a small increase, followed by a slow linear decay in magnitude, with d(U-B)o/dt = -0.0074 mag/d, and d(B-V)o/dt = -0.0024 mag/d.

IV. COMPARISON WITH OTHER TYPE II SUPERNOVAE

Barbon, Ciatti and Rosino (1979) have discussed the photometric properties of 38 type II supernovae, deriving mean blue light and colour curves. In their sample, 65% of all supernovae (called II-P) showed an intermediate phase in the descending branch of the light curve, characterized by a relatively constant magnitude (a "plateau").

A small group of supernovae (called II-L) did not show a plateau, but a linear decline after maximum, with a rate of 0.05 mag/d during about 100 days. More recently, Doggett and Branch (1985) also discussed the BV light curves morphologies of type II supernovae, and found late declines with rates of 0.0075 (II-P) and 0.012 mag/d (II-L) for the B light curves.

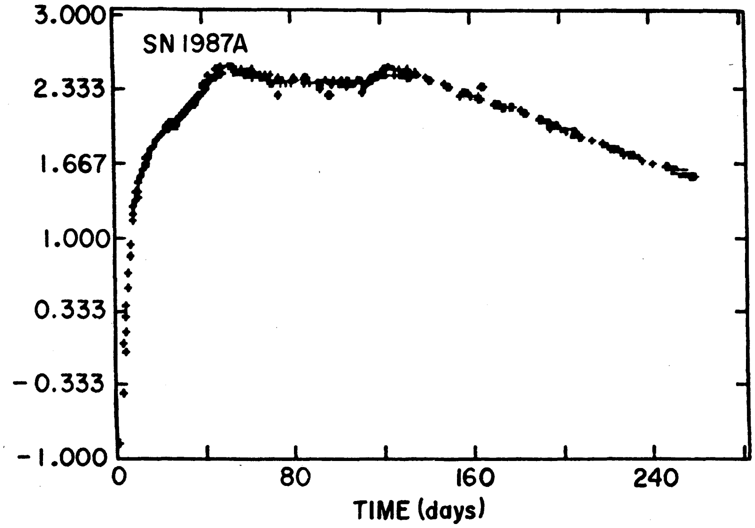

Fig. 4.- $(U - B)_0$ color curve of SN 1897A during the first 280 days of its evolution.

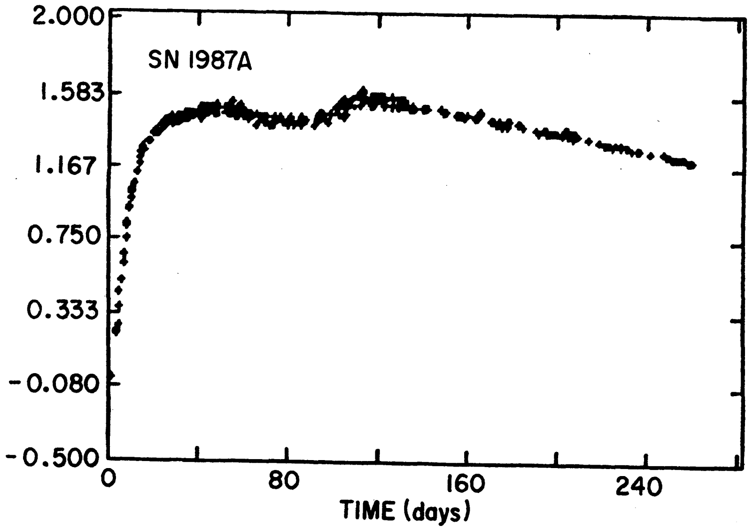

Fig. 5.- $(B - V)_0$ color curve of SN 1897A during the first 280 days of its evolution.

The (U-B)o and (B-V)o colour curves constructed by Barbon, Ciatti and Rosino (1979) without distinguishing between II-P and II-I subtypes showed trends to a progressive reddening from ≃ -1 to +1 in ≃ 100 days after maximum for (U-B)o, and from ≃ 0 to +1 in ≃ 50 days, levelling off after this for (B-V)o.

Rosino (1987) presented arguments for the inclusion of SN 1987A among the type II-P supernovae. However, the behavior summarized here for the light and colour evolution of SN 1987A is incompatible with such a classification.

The recent paper by Young and Branch (1989) also considered SN 1987A as a subluminous II-P supernova. Such an approach, besides morphological discrepancies in the light and colour curves, forces one to admit that those supernovae have a very wide range (about 6 magnitudes!) in the absoluie magnitude at maximum. If we consider the subluminous type II supernovae as a separate subgroup, that dispersion may be reduced to, perhaps, one magnitude. Also, there is evidence that at least two physical types of progenitor stars are involved: luminous II-P supernovae are probably derived from red supergiants, while subluminous ones would be produced by blue supergiants. It seems better to classify these two subtypes separately.

V. DISCUSSION

We conclude that the photometric evolution of SN 1987A in the first 280 days after the core collapse doesn't permit us to classify it neither as type II-P nor II-L, which are the only generally accepted subdivisions for type II supernovae. On the other hand, the presence of hydrogen lines in the optical spectra makes SN 1987A, by definition, a type II supernova, in the context of MZ classification. Thus, it has to be considered as a peculiar object.

By use of arguments essentially analogous to those employed by Zwicky (1964, 1965), it would be possible to suggest SN 1987A as the prototype of a new type of supernovae, or "type VI", extending the usual MZ scheme. Houever, it seems more interesting to insert it inside type II. This would force an additional subdivision, namely, a third photometric subtype, which shows a bump in the B and V light curves. Such supernovae, derived from compact progenitors like Sk-69°202 must be subluminous and probably common in irregular galaxies containing low metallicity stellar populations, being affected by an effect of observational selection. Another possible example of this class might be SN 1909A (Milone et al., 1988). We suggest the expression "II-Bump", or "II-B" for these supernovae,

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