Astron. Astrophys. 177, L21–L24 (1987)

ASTRONOMY AND ASTROPHYSICS

LETTER

Letter to the Editor

Early observations of Supernova 1987A with the International Ultraviolet Explorer (IUE)*

W. Wamsteker[1], N. Panagia[2,]**, M. Barylak[1], A. Cassatella[1], J. Clavel[1], R. Gilmozzi[1], C. Gry[1], C. Lloyd[3], J. van Santvoort[1], and A. Talavera[1]

[1] IUE Observatory, European Space Agency, Madrid, Spain**
[2] Space Telescope Science Institute, Baltimore, USA
[3] Rutherford Appleton Laboratory, SERC, Chilton, UK

Received March 26, accepted March 30, 1987

Abstract:

Early phase observations of the SN 1987A in the ultraviolet wavelength range are presented. Some general considerations on the behaviour of this supernova are given. Also, a comparison is made with other supernovae observed in the ultraviolet with the IUE Observatory.

Keywords: Supernovae - Ultraviolet - Visual-Spectrophotometry - Large Magellanic Cloud.

I. Introduction.

The discovery of a Supernova in the Large Magellanic Cloud (LMC), which was found independently by Shelton in Chile and Jones in New Zealand (IAU Circular #4316), has provided a special opportunity to obtain observations which will most likely be unique for quite some time to come. This Supernova -designated 1987A - is the first one in 383 years to reach naked eye visibility. Its discovery at a time when many modern ground-based observatories are operational in the Southern Hemisphere with high sensitivity instrumentation, while the International Ultraviolet Explorer satellite (IUE) is still fully operational and the Ginga X-Ray satellite had just been launched, combined with the existence of large under-ground neutrino detectors, has allowed a coverage of the energy spectrum over a range unprecedented for a single astronomical event. The first observational results from all these instruments have been reported in the record number of 35 IAU Circulars from the Central Bureau of Astronomical Telegrams in one month (IAU Circ #4316 to #4353), all relating to SN1987A.

In this letter we report early observations of SN1987A with the IUE and present some general considerations on the results obtained. A more detailed discussion based on these observations can be found in Panagia et al.(1987), Cassatella et al.(1987), de Boer et al.(1987) and Fransson et al.(1987).

(*)Based on IUE observations collected at the Villafranca ESA Satellite Tracking Station, Madrid,Spain and at NASA-GSFC.

(**)Affiliated with the Astrophysics Division, Space Sciences Department.

II. The Observations.

All observations reported here have been made with the International Ultraviolet Explorer satellite from the ESA IUE Observatory. The IUE is a general guest Observer facility for spectrophotometry at ultraviolet wavelengths ($\lambda\lambda$ 1152A to 3200A). It supplies spectroscopic capabilities at two resolutions of resp. $\lambda/\Delta\lambda \simeq 300$ and $\lambda/\Delta\lambda \simeq 12000$. Detailed descriptions of IUE, its scientific instruments and performance can be found in Boggess et al. (1978). All previous UV spectroscopic observations of supernovae have been made with IUE. These concerned the type II supernovae 1978G, 1979C ,1980K, 1985L; and the type I supernovae 1980N, 1981B, 1982B, 1983G, 1983N, 1985F and 1986G. Except for SNe 1980K and 1983N all observations have been made at low resolution. For these last two SNe a major

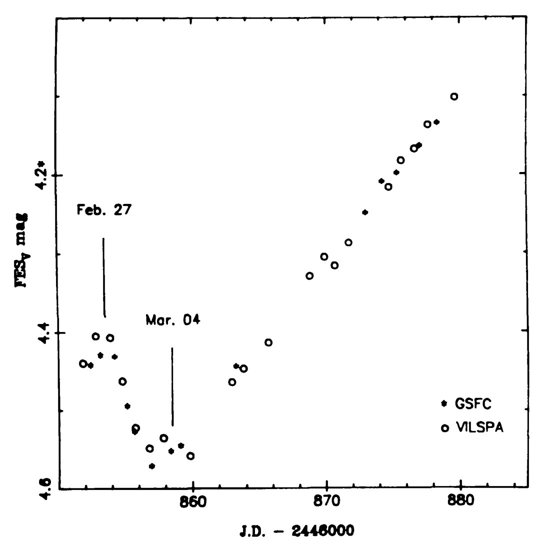

Figure 1. The optical lightcurve of SN1987A from the data in Table 1 with the FES.Note the shallow but well defined minimum reached at March,4. The far UV has not been followed this far since the stellar flux dominated the the $\lambda\lambda$1150A-l11600A range already after 4 days. The UV in the range from $\lambda\lambda$2750A-3200A did not follow this reversal, but has stayed nearly constant during the linear increase of the optical brightness.

investment of observing time was made to obtain some high resolution spectra needed for the analysis of the interstellar line spectra for these objects (Pettini et al. 1983 for SN1980K and unpublished data on SN 1983N). These data had a low S/N ratio, while the high resolution data for SN 1987A (de Boer et al.,1987) are of very high quality.
The first UV observations of SN1987A were made by Sonneborn and Kirshner (1987) on Feb 24.8, about 13 hours after the discovery by Shelton. Thence, a nearly continuous series of observations has been made for about four full days at both the ESA and the NASA IUE Observatories. Later a somewhat looser monitoring program was adopted which guaranteed an appropriate coverage of the event while avoiding unnecessary duplication of observations. The European Observations were made by the ESA Target of Opportunity (ToO) Team for Supernovae, under the ToO allocation for IUE observing, In Table 1 we present the log of the IUE observations of SN 1987A made from VILSPA. Included in Table 1 are the observations made with the Fine-Error-Sensor (FES) of IUE. This instrument has been shown by Stickland (1980) to be very useful as an optical photometer at an effective wavelength of l= 5100A. Figure 1 displays these data combined with those from Sonneborn and Kirshner (1987a and b) and Wamsteker et al. (1987) converted into a mag(FES), using the calibration from Barylak and Gry (1986). No attempt is made here to reduce them to the standard V-band because this would require a correction for the color effects caused by the relatively broad bandwidth (Wamsteker et al.,1987) and the rapid color evolution of SN 1987A reported by e.g. Steeman et al. (1987).

III. Discussion.

Supernova 1987A has shown, from its early detection, a number of peculiar characteristics, some of which will in the future, undoubtedly be found to be the consequence of the fact that the quality of the data obtained now is so much better than those existing for any previous Supernova. As such we mention the observation of the neutrino burst from SN1987A (Koshiba,1987), confirmed by Svoboda (1987) and thought to be associated with the explosion of the supernova, as predicted by Bachall,Darr and Piran (1987). On the other hand a number of phenomena of this Supernova seem to indicate that it might represent a class which has not yet been identified before, even though SN theory may have suggested the existence of such objects (see Fransson et al.,1987). One of the problems, shortly after the discovery has been in the classification of SN1987A. On the basis of the presence of strong Balmer lines in the optical spectra, a Type II was assigned by Madore (1987). On the other hand the UV spectra show a strong similarity to those of type I SNe (Gry et al.,1987). In Figure 2 we show the comparison of the UV spectrum of SN1987A on 26 Feb. with the spectrum of the SN1983N (type Ib) on July 4 ,about one day before maximum was reached at

Table 1: IUE Observations of SN 1987A from VILSPA

Camera & Image	Obs.date DD/MM	Time (UT)	FES(1) cts/mode	Exp.time (secs)	Dis	Ap.	ECC(2)
SWP 30380	25/02	03:41:41	343 FU	10	L	L	551
SWP 30381		04:24:00	351 FU	1 800	H	L	771
LWP 10193		04:58:40	351 FU	1.3	L	L	561
LWP 10194		05:30:23	320 FU	300	H	L	772
SWP 30382		06:39:22	370 FU	30	L	L	772
LWP 10195		06:42:57	370 FU	3.9	L	L	772
LWP 10196		07:52:32	356 FU	480	H	L	772
SWP 30383		08:09:03	343 FU	2 700	H	L	882
LWP 10197		09:01:29	28304 FO	100	H	L	551
SWP 30384		09:30:57	356 FU	660	H	L	551
LWP 10198		10:08:00	361 FU	1.3	L	L	551
SWP 30385		10:33:43	349 FU	10	L	L	551
SWP 30394	26/02	04:14:49	362 FU	2 400	H	L	661
SWP 30395		05:25:40	382 FU	20	L	L	441
		05:31:03		120	L	S	66
LWP 10202		05:36:56	362 FU	1.5	L	L	441
		05:40:46		9	L	S	77
LWP 10203		06:15:40	365 FU	13	L	L	881
SWP 30396		06:55:29	382 FU	1 800	H	L	882
		07:48:48	364 FU	3 600	H	L	
		09:09:51	359 FU	1 800	H	L	
LWP 10204		07:38:58	368 FU	180	H	L	551
LWP 10205		09:01:47	359 FU	3	L	L	551
LWP 10206		09:47:57	360 FU	1 320	H	L	882
SWP 30397		10:17:37	357 FU	30	L	L	551
		10:23:09		360	L	S	881
SWP 30405	27/02	07:51:46	359 FU	1 320	H	L	301
		08:42:35		1 500	H	L	
LWP 10215		08:34:25	367 FU	3	L	L	301
		08:37:09		3	L	L	
LWP 10216		09:17:06	375 FU	5	L	L	501
SWP 30406		09:47:48	361 FU	90	L	L	301
LWP 10217		10:24:21	362 FU	480	H	L	401
SWP 30412	28/02	03:50:40	345 FU	17 358	H	L	
		09:09:23		1 626	H	L	
		10:38:56		18 480	H	L	
LWP 10223		08:49:44	348 FU	840	H	L	402
SWP 30416	1/03	03:57:42	325 FU	2 400	L	L	441
LWP 10229		04:50:45	:362 FU	30	L	L	551
		04:55:57		30	L	L	
SWP 30417		05:23:53	:352 FU	1 800	L	L	
		06:09:13		1 500	L	L	
		07:00:44		1 800	L	L	
		07:45:57	26770 FO	1 800	L	L	
		08:41:56		2 700	L	L	
		09:46:14		600	L	L	778
LWP 10230		05:59:01	:328 FU	38	L	L	551
		06:04:53		38	L	L	
LWP 10231		06:48:32	331 FU	120	L	L	881
		06:54:56		120	L	L	
LWP 10232		07:35:51	:330 FU	38	L	L	551
		07:40:56		38	L	L	
LWP 10233		08:29:21	27302 FO	390	L	L	881
LWP 10234		09:32:07	:357 FU	38	L	L	551
		09:36:40		38	L	L	
LWP 10235		10:17:34	:359 FU	40	L	L	551
		10:22:20		40	L	L	
SWP 30422	2/03	03:59:32	:323 FU	1 320	L	L	
		04:38:48		1 620	L	L	
		05:34:08		1 800	L	L	
		06:23:55	:372 FU	1 620	L	L	551
LWP 10241		04:26:34	:326 FU	70	L	L	551
		04:32:12	:357 FU	70	L	L	
LWP 10242		05:12:02	317 FU	75	L	L	551
		05:17:40	:352 FU	75	L	L	
LWP 10243		06:11:26	:318 FU	75	L	L	551
		06:16:54	:352 FU	75	L	L	
LWP 10244		06:57:58	323 FU	240	L	L	771
LWP 10251	3/03	03:29:46	27997 FO	85	L	L	441
SWP 30427		03:46:03	26298 FO	1 620	L	L	
		04:28:41	27369 FO	1 620	L	L	
		06:37:46	28340 FO	3 000	L	L	
		07:41:09	27047 FO	1 800	L	L	
		08:24:57		1 620	L	L	551
LWP 10252		04:18:58	27891 FO	120	L	L	551
LWP 10253		05:01:06	27454 FO	5 400	L	L	882
LWP 10254		07:32:59	324 FU	130	L	L	551
LWP 10255		08:16:42	27437 FO	150	L	L	551
LWP 10256		08:58:49	27219 FO	6 000	H	L	442
LWP 10261	4/03	03:16:08	27205 FO	180	L	L	551
SWP 30429		03:27:35	27035 FO	2 160	L	L	
		04:16:09	26947 FO	1 680	L	L	
		04:57:38	27128 FO	1 740	L	L	
		05:39:01	26920 FO	1 740	L	L	
		06:21:58	26904 FO	1 860	L	L	
		07:13:03		2 700	L	L	441
LWP 10262		04:09:11	26819 FO	180	L	L	551
LWP 10263		04:50:33	26907 FO	180	L	L	551
LWP 10264		05:32:10	27188 FO	180	L	L	551
LWP 10265		06:15:04	26602 FO	180	L	L	551
SWP 30433	5/03	07:14:35	317 FU	3 600	L	L	402
		08:25:06		8 100	L	L	
LWP 10277		08:08:17	27551 FO	220	L	L	501
LWP 10299	8/03	10:12:23	345 FU	21 600	H	L	
SWP 30472	9/03	05:16:35	351 FU	1 800	L	L	402
		06:07:09		7 200	L	L	
		08:21:52		1 800	L	L	
LWP 10302		05:51:57	348 FU	420	L	L	501
LWP 10303		08:09:22	349 FU	360	L	L	501
LWP 10304		08:58:06	353 FU	6 000	L	L	802
LWP 10314	11/03	03:54:26	361 FU	24 120	H	L	405
LWP 10321	14/03	03:59:42	:400 FU	450	L	L	502
SWP 30522		04:17:09	:377 FU	1 800	L	L	
		05:14:30	385 FU	1 740	L	L	
		06:03:38	392 FU	2 100	L	L	
		08:35:06	:412 FU	3 600	L	L	
		09:55:59	:401 FU	1 620	L	L	401
LWP 10322		04:52:50	:388 FU	900	L	L	601
LWP 10323		05:48:56	377 FU	420	L	L	501
LWP 10324		06:56:18	389 FU	5 400	L	L	704
LWP 10325		09:41:21	392 FU	420	L	L	501
LWP 10326		10:29:41	:387 FU	420	L	L	501
LWP 10332	15/03	09:27:21	398 FU	405	L	L	501
LWP 10340	16/03	04:21:57	394 FU	405	L	L	501
LWP 10349	17/03	03:41:08	406 FU	405	L	L	502
LWP 10350		04:24:27	401 FU	3 000	L	L	704
SWP 30551		05:21:06	406 FU	3 240	L	L	301
		06:34:03	:411 FU	1 980	L	L	
LWP 10351		06:21:14	:419 FU	415	L	L	501
LWP 10352		07:18:00	405 FU	5 400	L	L	704
LWP 10373	20/03	05:40:58	431 FU	420	L	L	
SWP 30584	21/03	03:18:34	447 FU	600	L	L	201
LWP 10379		03:45:10	442 FU	450	L	L	503
LWP 10386	22/03	03:10:36	452 FU	450	L	L	503
SWP 30591		03:33:10	448 FU	1 500	L	L	201
LWP 10387		04:19:18	451 FU	22 680	H	L	406
LWP 10398	23/03	03:48:15	463 FU	420	L	L	502

(1) Note that FU and FO indicate different scan modes of the FES. The data shown in Fig.1 exclude FO data and data marked with ':'.
(2) Exposure Classification Code - for an explanation see IUE Merged Log.

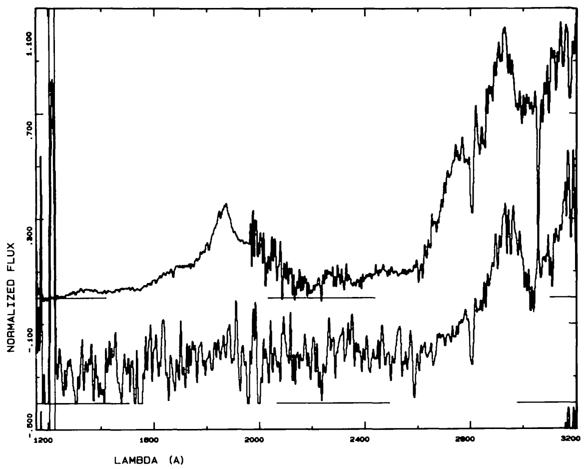

Figure 2. The λλ 1150-3200A spectrum of SN 1987A on Feb,26,1987(top) and that of SN 1983N (type Ib) on July,4 1983 (bottom). Both are normalized to unity (individual zero levels are indicated in the figure) and that of SN 1983N (type Ib) on July,4 1983 (bottom). Both represent a composite of a few spectra to avoid the large noise in a single low resolution exposure with the LWP camera of IUE. Note the striking similarity in the two spectra both in the overall specrtal energy distribution and the detailed features. For SN1983N the epoch of the spectrum corresponds to about 10 days before optical maximum and about one day before the maximum at λ≃2700A.

λ 2700A and ten days before optical maximum. Although the spectra in Figure 2 show the strong similarity between the two SNe at this epoch, both in the typical UV deficiency and in the details of the spectral features, subsequent developement of the UV spectrum rapidly showed deviations from what was considered a typical supernova Type I ultraviolet spectrum (note that in the past at least 2 SNe had been first classified as Type I on the basis of their UV spectra only). Earlier spectra in the far UV did show the presence of a strong far UV flux. This has never been observed in a type I SN before, even though e.g. SN1983N was discovered considerably before maximum. Of course the luminosity shown by SN 1987A is quite low for either type I or type II, giving rise to suggestions that the supernova might be a type IIp, discovered at its pre-maximum halt as was proposed by de Vaucouleurs (1987). Although it is at this moment not yet fully understood to which subclass SN1987A belongs, the bulk of the evidence does indicate that it is most likely associated with what theoretically are considered type II events. Also the presence of early radio emission, as reported by Bunton (1987) for SN 1987A, has been revealed for most Type II and Ib events observed in the UV, while for none of the classical type Ia SNe radio emission has ever been detected. Since it is quite likely that the UV spectra of SNe are strongly influenced by the mass loss history of the star (see Fransson et al.,1987), it must be concluded that the spectroscopic classification of supernovae on the basis of their UV spectra is not

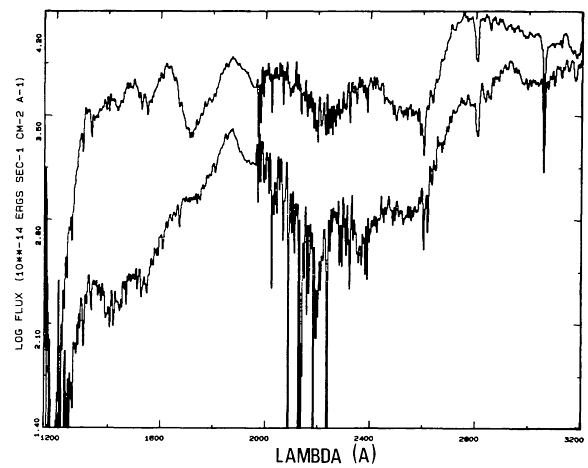

Figure 3. Absolute logarithmic flux spectra of SN19087A on Feb,25 and 26. These IUE low resolution spectra are composite (see also figuure 1). This figure demonstrates dramatically the very strong wavelength dependence of the rate of decrease in SN1987A, which dropped in the far UV faster than any supernova observed before with IUE.

conclusive but is at best indicative of the presence of heavy elements in the SN ejecta. It will however not allow the discrimination of the SN progenitor in a Pop.I or Pop.II object.

The optical lightcurve of SN1987A is shown in Figure 1 and illustrates clearly that this SN has not yet reached its maximum brigthness in the optical. No such reversal has been seen in the UV. The supernovae observed in the UV before or at maximum, have all shown the general trend to reach their maxima earliest at shortest wavelengths as a consequence of the rapid cooling of their photospheres. A similar effect is seen for SN1987A. Although a first optical maximum falls around Feb,27, the UV flux has been decreasing from the very first observation. The extremely rapid decrease in the far UV is discussed in detail by Panagia et al.(1987). This very rapid UV decay has gained additional importance since it showed already four days after discovery that a stellar object remained present at the position of the supernova (Gry et al.,1987). The possible nature and relation of this star to the B3 supergiant Sk -69 202 (Sanduleak,1969) are discussed in Panagia et al.(1987).

To illustrate the dramatic effects of the combined cooling and opacity increase (Cassatella et al.,1987) on the UV spectrum of SN1987A we show in figure 3 the absolute UV spectra for Feb,25 and Feb,26 1987 on a logarithmic scale. Both spectra are still essentially uncontaminated by the underlying stellar spectrum and demonstrate the rapid drop in far UV radiation for SN 1987A. This is in marked contrast with the "classical" type II SNe observed with IUE, such as SN 1979C and SN 1980K,which showed a strong UV flux with an excess over black-body radiation and quite strong emission lines until the end of the observability with IUE (Panagia et *al.,1980; Fransson et al.,1984). As can be seen in Figure 3 the time developement of the UV spectrum can be best described as a precipitous drop-out of the far UV flux accompanied by a remarkably fast time evolution of the discrete spectral features.*

References:

Bachall,J.,Darr,A.,Piran,T.,1987,IAU Circ. #4329.

Barylak,M.,Gry,C., IUE 3-Ag.Coordination Meeting Report, June 1986.

Boggess,A.,et al., 1978, Nature, 275,2.

de Boer,K.,et al.,1987,Astron. Astrophys., this issue.

Bunton,J.D.,1987, IAU Circ. #4321.

Cassatella,A.,et al.,1987,Astron.Astrophys. this issue.

Fransson,C.,et al.,1984,Astron,Astrophys., 132,1.

Fransson,C.,et al.,1987,Astron.Astrophys., this issue.

Gry,C.,1987,et al.,1987,IAU Circ. #4324.

Gry,C.,1987,et al.,1987a, IAU Circ. #4327.

Koshiba,M.,1987, IAU Circ. #4338.

Madore,B.,1987,IAU Circ. #4317.

Panagia,N.,et al.,1980,M.N.R.A.S.,192,861.

Panagia,N.,et al.,1987, Astron.Astrophys., this issue.

Pettini,M.,et al.,1982,M.N.R.A.S.,199,409.

Sanduleak, ,1969,Contr.CTIO No. 89.

Sonneborn,G.,Kirshner,R.,1987,IAU Circ.#4317.

Sonneborn,G.,Kirshner,R.,1987a, IAU Circ. # 4320.

Sonneborn,G.,Kirshner,R.,1987b, IAU Circ. # 4333.

Steeman,F.,Schwarz,H.E.,Monderen,P.,1987, IAU Circ. #4338.

Stickland,D.J.,1980,ESA IUE Newsletter,#5,30.

Svoboda,R.,1987, IAU Circ. #4340.

de Vaucouleurs,G.,1987,IAU Circ. #4334.

Wamsteker,W.,et al.,1987, IAU Circ. #4348.