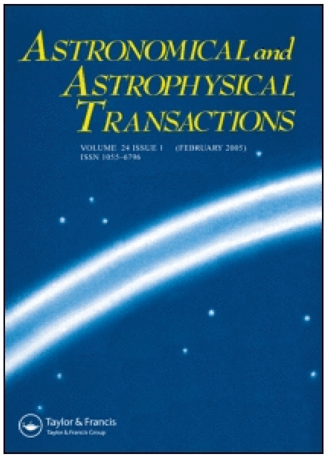

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OBSERVATIONS OF THE TYPE IIn SUPERNOVA 1999EL IN THE NEAR INFRARED

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We present the preliminary results of near-infrared photometric observations of the type IIn SN1999EL covering the period between 5 to 80 days after discovery. These infrared data represent the second time that such extensive time and wavelength coverage has been achieved for a type IIn SN event. We estimate the absolute magnitudes of the SN at the moment of brightness maximum in J, H and K bands. If the luminosity of the SN event in the K band is powered mostly by the deposition of redioactive decay energy, the mass of radioactive ^{56}Ni is estimated as $0.2M_{\odot}$. The effect of blueing of the J, H, K light curves is discovered and explained by the interaction of the explosion shock and UV/optical flash with pre-existing dust in the circumstellar medium of the progenitor.

KEY WORDS Supernovae: near-infrared observations, SN1999EL

1 INTRODUCTION

The Astronomical Observatories of Rome (OAR), Teramo (OACT) and the Central Astronomical Observatory at Pulkovo (St. Petersburg, GAO) are currently involved in the SWIRT project (Supernova Watchdogging Infrared Telescope), for the search and observation of extragalactic Supernovae in the near infrared (Battinelli *et al.*, 1994; Vitali *et al.*, 1995). The instrument used for this project is the Russian AZT-24 1.1 m telescope that was installed during the Summer of 1996 in the East dome of the Astronomical station at Campo Imperatore at an altitude of 2100 m above the sea level, at about 42° latitude. The telescope is equipped with a SWIRCAM NIR 256 × 256 pixels imaging camera which was mounted at the focal plane.

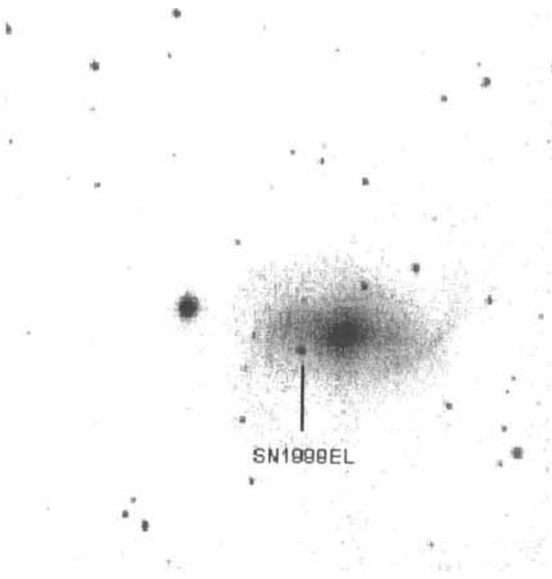

Figure 1 Image of NGC6951 and SN1999EL in H band, taken on 26.10.1999.

This camera was built at the Infrared Laboratories (IRL) in Tucson (Arizona, USA) and was delivered in mid-June 1997 to the laboratories of OAR in Monte Porzio.

The SWIRCAM is equipped with a PICNIC array, an upgrade of the NICMOS detector, with a working range of 0.9–2.5 μm. On the basis of the first results the limiting magnitudes detectable by the telescope within an exposure time 60 s and S/N ratio of 3 were found to be:

$$J = 17^{\mathrm{m}}.8, \quad H = 17^{\mathrm{m}}.0, \quad K = 16^{\mathrm{m}}.5.$$

2 OBSERVATIONS: INFRARED PHOTOMETRY OF SN1999EL

Infrared photometric observations of the type IIn SN1999EL presented here cover the period between 5 to 80 days after its discovery on 1999 October 20.45 (see Cao *et al.*, 1999; IAU Circ. No. 7288). This SN is located $21''.8$ east and $8''.4$ south of the nucleus of the barred spiral galaxy NGC 6951 (see Figure 1). Its V magnitude at the moment of discovery was $15^{\mathrm{m}}.4$.

NGC 6951 is a face-on barred spiral galaxy of low surface brightness. It is classified as a Seyfert galaxy because of its bright star-like nucleus. An image taken by the HST shows that NGC 6951 has a ring of new star formation surrounding the bright central nucleus. This ring contains several bright knots that HST observations have shown to be giant stellar clusters. This galaxy is $11^{\mathrm{m}}.9$ in V and its size is $3'.9 \times 3'.3$.

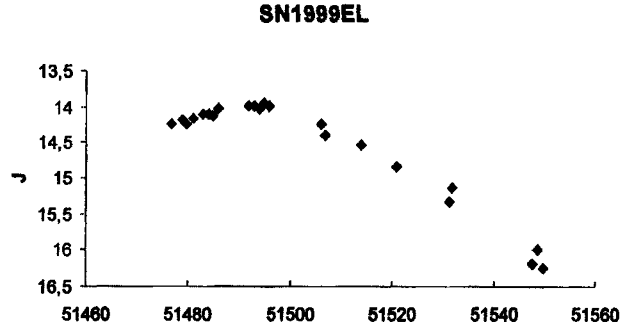

Figure 2 SN1999EL light curve in J band.

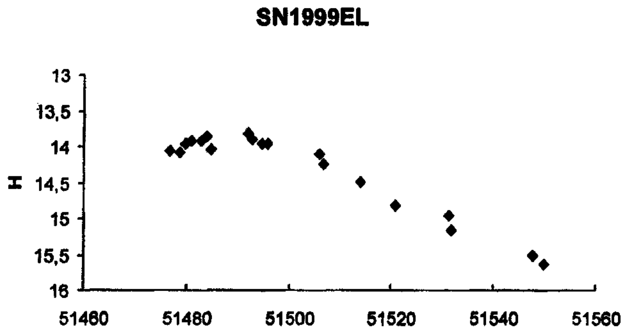

Figure 3 Same as Figure 2 in H band.

Based on the published redshift, the distance to NGC 6951 and SN1999EL is roughly estimated as 7.5×10^7 l.y. or about 25 Mpc with the galaxy being 8.5×10^4 l.y. in diameter.

The distinct subclass of type II supernovae to which SN1999EL belongs, has been claimed by Schlegel (1990) as supernovae type IIn. In these events, broad absorption components of all lines are weak or absent (see Filippenko, 1997). Their spectra are dominated by strong narrow emission lines. Chugai and Danziger (1994) explained the appearance of these narrow lines to be attributed to the dynamical interaction of the ejected envelope with a dense circumstellar wind emitted by the progenitor. Chugai (1997) has estimated the progenitor mass-loss rate as high as $10^{-3} M_{\odot}$ year^{-1}. The mass loss period is lasted until the time of explosion.

The images obtained with the AZT-24 telescope and SWIRCAM IR camera have angular dimensions of 4.4×4.4 arcmin with the scale of 1.03 arcsec pxl^{-1}. Each image consists of 5 added frames. The integration times for each frame were 1 min for the J and H bands and 2 min for the K band. Immediately before and after the SN image a sky image was obtained in each band with the same exposure time.

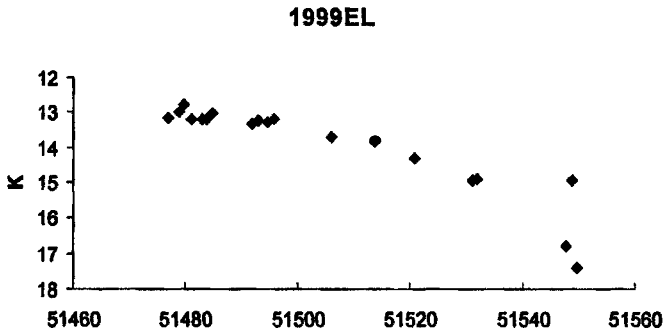

Figure 4 Same as Figure 2 in K band.

The usual routine of image processing had two stages. First, we combined the initial images into the final frame using the PREPROCESS software developed by A. Di Paola, carried out flat-fielding and sky subtraction. The photometry of SN and comparison stars was accomplished with the SExtractor program written by E. Bertin (Paris Observatory) and additional software developed by V. Larionov. The resulting photometric accuracy is of the order of 0.03–0.04 mag. Standardization of the comparison stars was done using nearby standard fields.

The light curves in J, H and K bands were obtained for all the observational period (Figures 2, 3, 4). It should be noted that to obtain the final data we had to subtract the contribution of two nearby stellar-like objects, located only several arcseconds away from SN1999El, with B magnitudes $\sim$ 17 and $\sim$ 18. We are thankful to H. Wozniak from Obsevatoire de Geneve who kindly gave us JHK images of NGC 6951 taken with the Steward Observatory 2.3m telescope in 1996 (see Friendly *et al.*, 1996). We carried out photometry of these images and obtained the JHK magnitudes of these stars which are $J(1) = 16^{m}\!.08$, $H(1) = 15^{m}\!.64$, $K(1) = 15^{m}\!.17$ and $J(2) = 17^{m}\!.80$, $H(2) = 17^{m}\!.40$, $K(2) = 16^{m}\!.85$, correspondingly. We note that close to the end of our observations the input of these stars to the total flux was more than 70%.

3 ANALYSIS AND DISCUSSION

Figure 5 presents the evolution of the J–H and J–K colours of SN1999EL. An interesting and unexpected result is the 'blueing' of the colours between JD24451476 and JD24451531. This is an unusual situation compared to the reddening of colours of previously observed type IIn SN1998S (Fassia *et al.*, 2000) and SN1998Z (Turatto *et al.*, 1993).

We estimate the absolute magnitudes of SN1999EL as

$$M_J = M_H = -18^{m}\!.0, \quad M_K = -18^{m}\!.8. \tag{1}$$

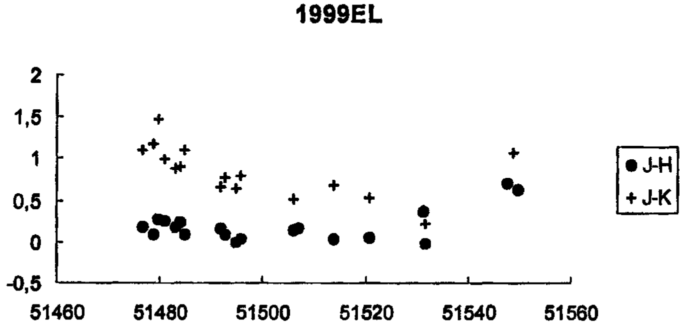

Figure 5 Infrared colour evolution of SN 1999EL.

The distance to SN1999EL was adopted as $D = 25$ Mpc. This allows us to estimate the luminosity of the SN in the K band at the moment of the brightness maximum:

$$L_k = 3 \times 10^{42} \text{ erg s}^{-1}. \tag{2}$$

If the luminosity is powered mostly by the deposition of radioactive energy one can estimate the value of mass of radioactive ^{56}Ni which was produced in the explosion. According to Kozma and Fransson (1992),

$$L_{\rm SN} = 1.27 \times 10^{42} (M_{\rm Ni}/0.1 M_\odot) \text{ erg s}^{-1}. \tag{3}$$

From (2) and (3) one can obtain: $M_{\rm Ni} \sim 0.23 M_\odot$. This value is quite close to the mass of radioactive Ni for SN 1998S that was determined by Fassia *et al.* (2000).

The values of the decay rates of brightness are estimated as:

$$\frac{dJ}{dt} \sim 0\overset{m}{.}035 \text{ day}^{-1}, \quad \frac{dH}{dt} \sim 0\overset{m}{.}03 \text{ day}^{-1}, \quad \frac{dK}{dt} \sim 0\overset{m}{.}06 \text{ day}^{-1}, \tag{4}$$

These values show that the decay rates of light curves in NIR bands are higher than the decay rate of ^{56}Co which is 0.01 mag day^{-1}.

The effect of blueing can itself be explained in the framework of the commonly accepted classical model of the interaction of the SN shock and UV flash with the circumstellar matter of the strong presupernova wind with a density $n_w > 10^7$ cm^{-3}, this wind being enriched by dust particles, i.e. the presupernova wind is a real dusty wind. Two physical mechanisms may provide the blueing effect: the emission of FeII ions that are generated via the destruction and sublimation of dust particles and the Rayleigh scattering of SN light by small particles that also originate as a result of the destruction of large dust grains of the presupernova wind by the SN shock and UV flash.

The main emission Fe II lines are originated via the transitions:

$$\begin{aligned} a^6 D_{9/2} &\Rightarrow a^4 D_{7/2} \quad \lambda = 1.257\,\mu m\ (J), \\ a^4 F_{9/2} &\Rightarrow a^6 D_{7/2} \quad \lambda = 1.644\,\mu m\ (H). \end{aligned} \tag{5}$$

The characteristic size of the region of sublimation and destruction R_0 can be easily estimated (see, for example, Waxman and Draine, 2000):

$$R_0 \sim (Q_{\rm abs} L_{42}/a_{-1})^{1/2} \text{ pc}, \tag{6}$$

where $Q_{\rm abs}$ is the absorption efficiency factor for UV photons, L_{42} is the maximum luminosity in 10^{42} erg s^{-1}, and a_{-1} is the radius of a particle expressed in units of 0.1 μm. In our case $L_k \approx 3 \times 10^{42}$ erg s^{-1}, the size of the sublimation region is estimated as

$$R_0 \approx 5 \times 10^{-3} \text{ pc}.$$

It should be mentioned that the process of evaporation of Fe II ions from dust grains is usually considered to be an important factor in SNe explosions in starburst galaxies.

4 CONCLUSION

We have presented a preliminary discussion of infrared photometric observations of SN 1999EL covering the first 80 days after explosion. This is the second time (after Fassia *et al.*, 2000) that such extensive wavelength coverage has been achieved for a type IIn event. We have shown that the IR luminosity is dominated by the release of shock-deposited energy in the ejecta. The light curve decline rate proved to be faster than the radioactive decay rate of ^{56}Co. If we suppose that the bolometric luminosity is dominated by the deposition of radioactive decay energy we estimate that $\sim 0.2 M_\odot$ of ^{56}Ni was produced in the explosion. The strong IR excess and blueing effect in the NIR bands can be explained by the destruction and sublimation of pre-existing dust in the circumstellar material of SN 1999EL. The dust could be destroyed by the initial UV/optical flash and shock of the supernova. The X-rays originating from the CSM-shock front interaction could also be responsible for the destruction of CSM dust grains. A detailed analysis of the SN1999EL behavior will be published in a separate paper.

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