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SPECTROPHOTOMETRY OF THE SUPERNOVA IN NGC 5253 FROM 0.33 TO 2.2 MICRONS

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ABSTRACT

Combined infrared and optical measurements are presented of the energy distribution of the Type I supernova in NGC 5253 from 1972 May 16 to 1972 July 31. The overall shape from 0.4 to 2.2 μ could be represented by a blackbody which decreased in temperature from about 10,000° K on May 23 to 7500° K on June 5, then remained at about 7000° K until at least July 8.

Subject headings: infrared — photometry — spectrophotometry — supernovae

Immediately upon Kowal's (1972) discovery of the bright supernova 1972e in NGC 5253, an intensive spectrophotometric and infrared photometric study of its development was begun at the Hale Observatories. This paper reports infrared and optical data bearing on the overall properties of the energy distribution during the interval 1972 May 16–1972 July 31 [UT] (JD 2441453–JD 2441529). Although we defer a discussion of the small-scale spectral features to a later paper (Kirshner *et al.* 1973), the observed features correspond very closely to those of a Type I supernova (Minkowski 1939).

Observations at wavelengths shorter than 1.0 μ were obtained either with the 200-inch (508-cm) Hale reflector and the multichannel spectrometer (Oke 1969) or with the Palomar 60-inch (152-cm) reflector and a single-channel scanner. The multichannel scans had bands 20 Å wide for $\lambda \leqslant 5950$ Å and 40 Å for $\lambda > 5950$ Å, and were obtained in about 10 minutes. The 60-inch observations shown employed 40 Å bands and an S-17 cathode in the blue, or 80 Å bands and an S-1 in the red. Because the available observing time was brief, and the single-channel scans took much longer than the multichannel scans, the 60-inch observations for June 15 and June 25 are the result of combining a red and blue scan from successive nights.

Standard deviations for multichannel observations are 0.01–0.02 mag except in the far-violet and near-infrared. The standard deviations for the 60-inch observations are much less than 0.1 mag, except in the deepest absorption features, and in the vicinity of 1.0 μ where the errors may be as large as 0.3 mag. The extreme southern declination of the supernova required an investigation of the corrections employed to account for atmospheric extinction. Observations of suitable nearby stars demonstrated that extinction effects had been properly dealt with, so that observations could be put on the absolute calibration scale based on α Lyr (Oke and Schild 1970). Because atmospheric water-vapor emission dominated the star's radiation between 9000 and 9600 Å, these wavelengths have been deleted.

The infrared measurements at 1.25 μ (1.15–1.4 μ), 1.65 μ (1.5–1.8 μ), and 2.2 μ (2.0–2.4 μ) were obtained with the 200-inch and the Mount Wilson 100-inch (254-cm), with additional 2.2-μ observations with the Mount Wilson 24-inch (61-cm). With only one exception, the supernova magnitudes were established by comparison with the nearby star HR 5097, which was measured on several nights relative to a standard system in which the infrared magnitude of α Lyr is 0.00 in each band. The adopted magnitudes of HR 5097 are [1.25 μ] = 5.65, [1.65 μ] = 5.55, [2.2 μ] = 5.62.

Figure 1 presents light curves at five frequencies, where the flux density is represented by an AB magnitude: $AB = -2.5 \log f_\nu - 48.60$, where f_ν is in units of ergs s^{-1} cm^{-2} Hz^{-1}. $AB(4400)$ and $AB(5500)$ represent the flux density obtained from the scans near 4400 Å and 5500 Å, respectively. $AB(5500)$ corresponds very closely to the standard V magnitude. Infrared measurements were converted to AB magnitudes through $AB(1.25\ \mu) = [1.25\ \mu] + 0.94$, $AB(1.65\ \mu) = [1.65\ \mu] + 1.42$, $AB(2.2\ \mu) = [2.2\ \mu] + 1.92$. All the light curves, except $AB(4400)$, show the same general behavior. The magnitudes are constant from the earliest observation to about June 5, then all decline, at about the same rate of 0.045 mag per day. The $AB(4400)$ curve descends rapidly until about June 5, then shows about the same rate of decrease as the light curves at other frequencies. The decrease in the infrared continued through 1972 September, when a limit of $AB(2.2\ \mu) > 14.2$ was set from 40-inch observations at Las Campanas. To increase the signal-to-noise ratio of this observation, data were taken in a broad band covering both the 1.65-μ and 2.2-μ bands. The flux in the 2.2-μ band was derived assuming the same ratio between the 1.65-μ and 2.2-μ flux as observed from May through July. These results disagree with

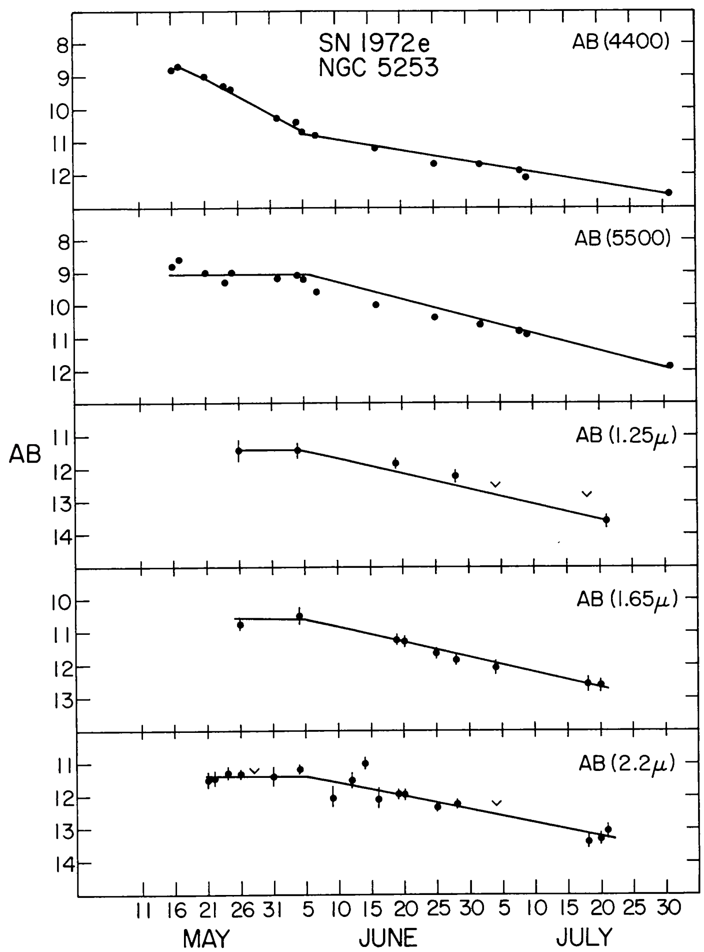

FIG. 1.—Flux density in AB magnitudes at five wavelengths, in 1972 from May 16 to July 31 for supernova 1972e. The solid lines have an arbitrary break at June 4, and are intended to emphasize the similarities among frequencies. (a) $AB(4400)$ from scans; (b) $AB(5500)$ from scans; (c) $AB(1.25\ \mu)$; (d) $AB(1.65\ \mu)$; (e) $AB(2.2\ \mu)$.

those of Lee *et al.* (1972) who reported no decrease in infrared flux between May 22 and June 29.

At longer wavelengths, upper limits to the flux were set at $AB(3.5\ \mu) > 12.27$ on June 4. On June 20, $AB(4.8\ \mu) > 9.04$ and $AB(10.0\ \mu) > 8.97$.

Figure 2 combines averaged scan data and infrared photometry for the nights when data were obtained at 1.2, 1.65, and 2.2 μ. Each scan shown is that made closest in time to the infrared measurement—the time difference never exceeds four days. By chance all scans shown were obtained with the 60-inch telescope. Blackbodies are shown which assume that both emission and absorption features exist in the optical region. There appears to be a very strong absorption feature within the 1.2-μ band.

From June 4 to June 25 changes in the shape of the energy distribution are small, while the flux decreases. This is the behavior of an object whose photosphere shrinks while remaining at a constant temperature. If NGC 5253 has a distance of 4 Mpc (Sérsic, Pastoriza, and Carranza 1972), the temperatures and magnitudes indicated in figure 2 correspond to photospheric radii of 1.1×10^{15} cm on May 24, 1.6×10^{15} cm on June 4, 1.1×10^{15} cm on June 15, and 1.0×10^{15} cm on June 25.

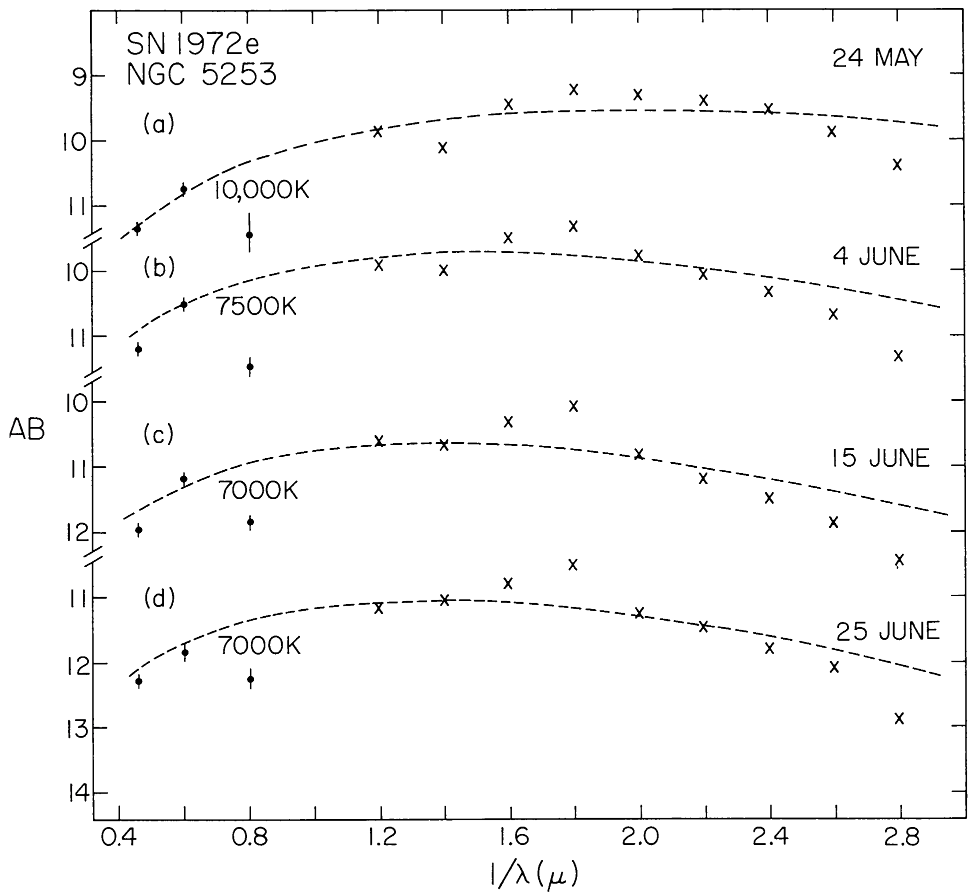

FIG. 2.—Energy distributions for SN 1972e. (*a*) Infrared measurements on May 26, averaged scan data (×) from May 24; dotted line is a blackbody at 10,000° K. (*b*) Infrared measurements on June 4, scan from June 4; dotted line is a blackbody at 7500° K. (*c*) Infrared measurements on June 19, scan from June 15; dotted line is a blackbody at 7000° K. (*d*) Infrared measurements on June 28, scan from June 25; dotted line is a blackbody at 7000° K. Standard deviations are shown for the infrared photometric data. Errors for the scan data are less than 0.1 mag, and are not shown.

The rapid increase in photospheric radius followed by a decrease could be the natural result of the increasing transparency of the expanding supernova envelope. The temperature constancy suggests that the prevailing source of continuous opacity becomes important at that temperature so that the visible photosphere is always at the same temperature.

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