LETTERS TO NATURE

Presence of Two Fe³⁺ Bearing Minerals in Interstellar Dust

The spectrum of the 1961 supernova in NGC 3003 (Fig. 1), classified by Zwicky^{1,2} as the sole example of a Type IV supernova, contains approximately a dozen bands between wavelengths 3300 Å and 5000 Å. The band halfwidths (~100 Å) suggest that they are of similar origin to the crystal-field absorption bands of Fe³⁺ observed in spectra of Type I supernovae^{3,4}. The spectrum of SN-NGC-3003 is resolved to shorter wavelengths than is the case with the spectra of Type I supernovae, with the result that three additional prominent features are evident at 3400 Å (29,400 cm⁻¹), 3520 Å (28,400 cm⁻¹) and 3680 Å (27,200 cm⁻¹). Here I suggest that these three bands, together with another additional band in the visible region at 4240 Å (23,600 cm⁻¹) and two known Fe³⁺ bands, are indicative of Fe³⁺ ions in two different octahedral sites.

In keeping with earlier assignments^{3,5} of bands at similar wavelengths in supernova spectra, the bands in the spectrum of SN-NGC-3003 at 4470 Å (22,400 cm⁻¹) and 3850 Å (26,000 cm⁻¹) mark the transitions ${}^6A_1 \rightarrow {}^4A_1$ ${}^4E(G)$ and ${}^4E(D)$ in octahedral Fe³⁺ ions (in what I shall call the first site), whereas bands at 4102 Å (24,400 cm⁻¹), 4760 Å (21,000 cm⁻¹) and 4940 Å (20,200 cm⁻¹) mark transitions in tetrahedral Fe³⁺ ions. Ignoring the tetrahedral Fe³⁺ bands, a noticeable feature of the spectrum in Fig. 1 is that six of the remaining prominent bands are grouped in pairs, the component bands of each pair being separated by ~1,000 cm⁻¹. These pairs are at the wavelengths 4472 Å and 4240 Å, 3850 Å and 3680 Å, and 3520 Å and 3400 Å. It seems reasonable to suggest that the 4240 Å (23,600 cm⁻¹) and 3680 Å (27,200 cm⁻¹) bands mark transitions to the 4A_1 ${}^4E(G)$ and ${}^4E(D)$ levels in Fe³⁺ ions in a second octahedral site, the separation of the two levels (3,600 cm⁻¹) being entirely reasonable for Fe³⁺ ions in silicates³. Furthermore, the ${}^4E(D)$ level is commonly observed at ~3700 Å in silicates⁷. The bands at 3520 Å (28,400 cm⁻¹) and 3400 Å (29,400 cm⁻¹) could mark transitions to a higher energy level (${}^4T_1(P)$)⁶ in Fe³⁺ ions in the first and second sites respectively. Lehmann and Harder⁸ have observed the

${}^6A_1 \rightarrow {}^4T_1(P)$ transition at 3450 Å (29,000 cm⁻¹) in Fe³⁺ ions in corundum. The six absorptions are therefore compatible with Fe³⁺ ions in two different octahedral sites.

The third field-independent transition ${}^6A_1 \rightarrow {}^4A_2(F)$ in Fe³⁺ is expected^{6,9} at the energy $22B + 5C$, where B and C are Racah interelectronic repulsion parameters. Values of B and C can be calculated from the energies of the transitions ${}^6A_1 \rightarrow {}^4A_1$ ${}^4E(G)$ and ${}^4E(D)$, which are given by $10B + 5C$ and $17B + 5C$ respectively^{3,9}. For Fe³⁺ in the first and second octahedral sites we obtain the values $B = 515$ cm⁻¹ and 515 cm⁻¹, and $C = 3,450$ cm⁻¹ and $3,690$ cm⁻¹, respectively. Hence the transition ${}^6A_1 \rightarrow {}^4A_2(F)$ is expected at ~36,000 cm⁻¹ (2780 Å). A shoulder is observed on the interstellar extinction curve¹⁰ at ~37,000 cm⁻¹, in reasonable agreement with expectation.

It seems that Fe³⁺ ions can account for most absorption bands in spectra of Type I and Type IV supernovae. It is not possible as yet to identify the two Fe³⁺-bearing minerals with any certainty, but the energies of the bands and the values of the B parameter⁷ do not eliminate garnets. The measurement of spectra of terrestrial oxides and silicates at cryogenic temperatures may lead to reliable identifications.

P. G. MANNING

Inland Waters Branch,
Department of Energy, Mines and Resources,
No. 8 Temporary Bldg,
Carling Avenue,
Ottawa, Ontario

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Fig. 1 Microphotometer record of the spectrum of the supernova in NGC 3003. Sharp peaks such as H_γ and λ3727 originate in parent galaxies.

Age of the Ethiopian Flood Basalt Succession

THE age and nature of the volcanism associated with the growth of the African Rift System give some indication of its development but, unfortunately, relevant information is not available for all sections of the rift and in Ethiopia the history of the Main Ethiopian Rift and its associated flood basalt volcanism are only poorly known. We report here two new K/Ar dates which throw some light on this complex history.

The thick sequences of flood basalts, commonly known as the Ethiopian and Yemen Traps, are the most important element of the volcanism associated with the development of the rifts in the Ethio-Arabian area¹. The lava succession