LETTERS TO NATURE

PHYSICAL SCIENCES

Origin of the Diffuse Interstellar Band at 4430 Å

MANNING[1] has suggested recently that the 4430 Å interstellar absorption line may be due to transitions in Fe^{3+} ions in a silicate matrix. I have considered this idea from a slightly different point of view, and it may be fruitful to compare the lines of argument. An absorption band at 4430 Å had been found in demantoid garnet, $Ca_3Fe_2(SiO_4)_3$, and a band at 4440 Å in chrysoberyl, $BeAl_2O_4$, both attributed to ferric iron[2]. Provided the coordination is octahedral the iron spectrum will be similar in many host lattices, and so it is not suggested that the interstellar particles must consist of either of these minerals. The possibility of silicates in space is indicated by the suggestion[3] that infrared absorption features at 9.7 μm and 10.6 μm are similar to those in the series of orthopyroxene inosilicates $(Mg, Fe)SiO_3$. Gilman[4] has suggested that circumstellar grains of oxygen-rich cool stars will be composed chiefly of refractory silicates such as Mg_2SiO_4 and Al_2SiO_5.

Seddon[5] has reported other interstellar absorption bands at 4870 Å, 5100 Å and 6180 Å, and Wilson[6] has listed bands at 4430 Å, 4760 Å, 4890 Å and 6180 Å. An identification would be more convincing if it explained more than one feature, although it is doubtful at this stage if all the bands have a common origin. From this point of view, iron is a possibility as the three bands at 4430 Å, 4870 Å and 5100 Å could all be due to iron. Turning again to the literature on gemstones, peridot, $(Mg, Fe)_2SiO_4$, has lines at 4530 Å, 4730 Å and 4930 Å, attributed by Webster[2] to ferrous iron. The match of the short wavelength line is not so good, but there is clearly the possibility of attributing all the absorption in the range 4000–5500 Å to iron. The division by Webster[2] of minerals into those containing ferrous and ferric ions seems somewhat arbitrary.

The emphasis on iron spectra follows an examination of other possibilities. Interstellar particles might consist of solid hydrogen or ice[7], but neither pure hydrogen nor ice is known to have absorption bands in the right region. Impurities or colour centres produced by irradiation are a possible source of the extra lines, but preliminary experiments at Harwell (unreported) do not show any sharp bands due to colour centres in either ice or solid hydrogen after electron and proton irradiation.

The interstellar extinction results[8] are shown in Fig. 1 and it can be seen that the theoretical curve of Van de Hulst[9] does not account for the full extinction beyond $\lambda^{-1} = 2.7 \times 10^4$ cm^{-1}. To see whether absorption can account for the difference the absorption spectrum of a chrysoberyl crystal is also shown. The absorption in the region of the interstellar line at 4430 Å is indicated by an arrow and the crystal thickness is such that the magnitude of the maximum absorption, 0.07, is similar to that found by Wilson[6] for the interstellar absorption. The weak interstellar absorption lines are not apparent in the curve for the overall interstellar extinction. There may also be a weak band around one micron in the chrysoberyl absorption spectrum due to the $^6A_1 \rightarrow {}^4T_1$ electron transition in the 3d^5 electron configuration of Fe^{3+}. There are stronger bands in the ultraviolet at 2.62, 2.665 and 2.735×10^4 cm^{-1}. The band at 2.62
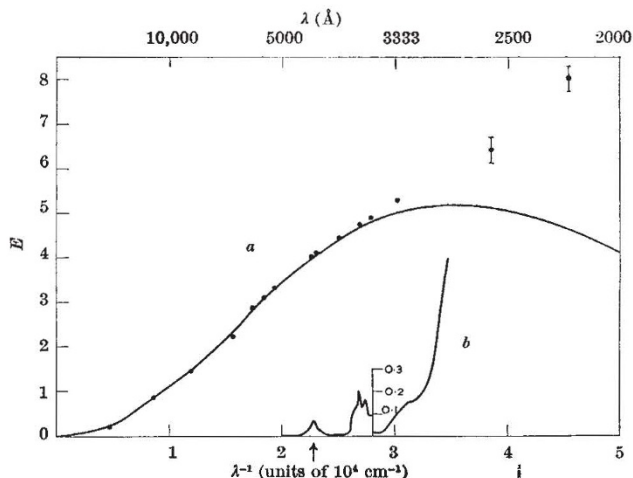

Fig. 1. a, The interstellar extinction results with a theoretical extinction curve as quoted by Boggess and Borgman[8]. b, The absorption spectra of natural single crystal of chrysoberyl, thickness = 1.2 mm, at room temperature. The left hand portion below $\lambda^{-1} = 2.8$ has a five-fold ordinate expansion.

appears as a shoulder at room temperature, but all the bands are fully resolved at liquid nitrogen temperature, 77 K, and show further fine structure. These bands are due presumably to transitions to higher levels of the Fe^{3+} ion. Another shoulder appears at 3.1×10^4 cm^{-1} followed by intense absorption, which is still rising at the instrumental limit in the experiment. It may be that a thinner sample with a higher iron concentration would give a greater ratio of absorption in the line at $\lambda^{-1} = 2.285 \times 10^4$ cm^{-1} (4376 Å) to the strong absorption edge. This depends on whether the very strong absorption edge is due to the host lattice or the iron impurity ions.

The wavelength match to the interstellar band at 4430 Å is not good for chrysoberyl, even though the literature indicates that a reasonable fit would be found. Manning also has been unable to get a very good wavelength match to this line, and the peaks of his spectra are at 4400 Å. It seems therefore that the identification is still inconclusive and that very careful measurements of the absorption spectra of iron-containing silicates, orthopyroxene inosilicates in particular, over a wide wavelength range will be needed before a convincing case can be made. The range of the interstellar extinction curve has been extended to much shorter wavelengths[10,11], but as it seems that the curve may show absorption features, the extinction curve is required at higher resolution for alternative suggestions to be tested, with emphasis on the range $\lambda^{-1} = 2.6$–2.8×10^4 cm^{-1} (3600–3850 Å). The curve has been examined closely between 4000 and 6500 Å (ref. 12), and an extension to shorter wavelengths is still required.

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