## Fine and Hyperfine Structure of Twilight Lithium Emission, November 1962

THIS communication describes the results of observations made on the fine and hyperfine structure of the lithium resonance line in the twilight-glow. These observations were made during the large increase in lithium abundance of November 1962, which Hunten and Gault (preceding communication) have concluded arose from a thermonuclear explosion. From the results it is concluded that the thermonuclear explosion of October 26, 1962, deposited only one isotope, lithium-7, in appreciable amounts. Observation of the fine structure of lithium-7 provided a positive check on the identification of this emission.

When in November 1962 it was learned that an unusually large amount of lithium was present in the upper atmosphere (preceding communication), interferometric observations were begun, with two aims in mind. The first was to detect the fine structure components of the emission, providing a more positive identification of the source than has yet been made. The second was to look for any change of lithium-6 from its natural abundance ratio of 7·5 per cent. The latter measurement could possibly help determine the importance of thermonuclear sources. Spectra of the lithium resonance line at 6708 Å were obtained at Saskatoon on November 23 and 24, using a photoelectric Fabry–Perot spectrometer which has been described elsewhere[1,2]. For this work, an etalon spacing of 3·3 mm was used, giving a free spectral range of 1,500 m$K$ and a pass-band half-width of about 110 m$K$ (1 m$K$ = $10^{-3}$ cm$^{-1}$). An interference filter of 15 Å half-width, a red gelatin filter, and a dichroic filter reflecting wave-lengths greater than 8000 Å were also used. It was necessary to accumulate about ten successive 1-min scans to obtain a tolerable signal-to-noise ratio. This was done with a 32-channel condenser memory unit designed and provided by Dr. D. M. Hunten[3].

The lithium resonance transition has a fine-structure splitting of about 325 m$K$. The isotope shift between lithium-6 and -7 is practically the same, about 355 m$K$ (ref. 4). Each of these components has a further hyperfine-structure splitting of about 30 m$K$; compared with the Doppler width this is narrow enough to be neglected here. The observed structure is thus a triplet of about equal spacings, with the central line consisting of two components. The identifications are, in order of increasing wave-length: $^7$Li($^2P_{3/2}$–$^2S_{1/2}$); $^7$Li($^2P_{1/2}$–$^2S_{1/2}$) and $^6$Li($^2P_{3/2}$–$^2S_{1/2}$) superimposed; and $^6$Li($^2P_{1/2}$–$^2S_{1/2}$)[5]. In what follows these three features will be referred to as $I_1$, $I_2$ and $I_3$, respectively.

The relative intensity of the two fine structure components for a single isotope is determined only by the statistical weights of the $^2P_{1/2}$ and $^2P_{3/2}$ levels since absorption in the lithium layer is negligible[1]. If the ratio of lithium-6 to lithium-7 is denoted by $r$, then the line intensity ratios are $I_2/I_1 = 0·5 + r$ and $I_3/I_1 = 0·5\ r$. For the natural abundance of $r = 0·08$, $I_2/I_1 = 0·58$ and $I_3/I_1 = 0·04$. With a low signal-to-noise ratio, this could not be distinguished from pure lithium-7. Appreciable increases in $r$ would be readily observed, however. For $r = 0·5$, $I_2/I_1 = 1·0$ and $I_3/I_1 = 0·25$; for $r = 1·0$, $I_2/I_1 = 1·5$ and $I_3/I_1 = 0·5$.

Two spectra obtained on the evening of November 23 are shown in Fig. 2, along with the predicted positions of $I_1$, $I_2$ and $I_3$ as determined using a laboratory lithium source. A large amount of background signal has been subtracted from each of the records. Fig. 2$a$ was taken during late twilight and contains 10 scans. Fig. 2$b$ contains 14 scans; it was taken during early twilight when the white light background was changing more rapidly. Three emission lines are readily apparent, at positions very close to those predicted. In order to determine their relative intensities, the background-level must be determined. If this were taken at the level of the channel having the least signal, it would be as indicated by the

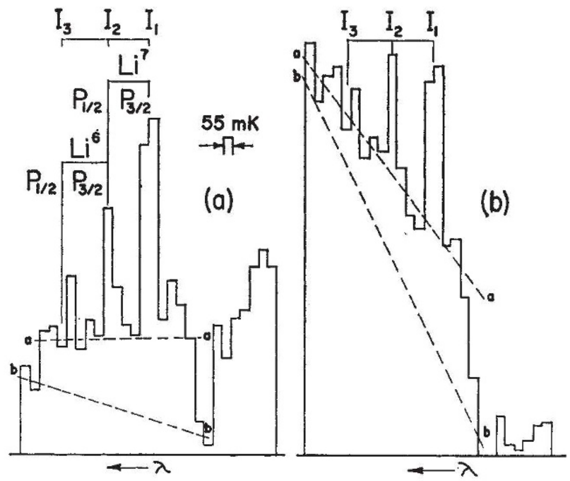


Fig. 2. High-resolution spectra of the lithium resonance line in twilight, obtained at Saskatoon on November 23, 1962. The arrows indicate the predicted positions for the following lines: $I_1$, $^7$Li($^2P_{3/2}$–$^2S_{1/2}$); $I_2$, $^7$Li($^2P_{1/2}$–$^2S_{1/2}$) and $^6$Li($^2P_{3/2}$–$^2S_{1/2}$) superimposed; $I_3$, $^6$Li($^2P_{1/2}$–$^2S_{1/2}$). The histogram-like appearance is imposed by the 32-channel memory used. $a$, Ten scans taken during late twilight; $b$, fourteen scans taken during early twilight

lines $b$–$b$ (this channel appears twice, in successive orders). This possibility was ruled out on the basis of expected line shapes. The channel width is about 55 m$K$ and the instrumental spectral width about twice this. For an emission line centred on one channel, that channel will contain about 70 per cent of the total signal for that line. For an emission line centred halfway between channels, the sum of the signals from those two channels will be equal to 85 per cent of the total signal. On this basis, the background level must correspond more closely to the lines $a$–$a$.

Choosing $a$–$a$ as the background-level, the following intensity ratios were obtained: $I_3/I_1 = 0·19$ and $I_2/I_1 = 0·39$. The $I_3/I_1$ value suggests $r = 0·38$, but the $I_2/I_1$ value implies the impossible result that $r$ is less than zero. Of the two values, the first is the less reliable. The identification of the observed line as $I_3$ is questionable for two other reasons. First, the signal-to-noise ratio is low; and secondly, the observed line is displaced by one channel from its predicted position. It seems reasonable to conclude that the observed feature is not lithium-6 but is spurious, so that $I_3 = 0$ and $r = 0$. The difference of $I_2/I_1$ from its expected value of 0·5 can be attributed to the low signal-to-noise ratio. The spurious feature may result from an instrumental effect, but is more likely background contamination from artificial lights.

It follows that the abundance of lithium-6 is less than, or possibly equal to, its natural value. The observations were made about 12 days after the enhancement reached its peak, and the brightness had dropped from about 3,000 down to 700 rayleighs. The date of our observations is indicated on Fig. 1 of the preceding communication; they believe that most of the lithium present then was still of artificial origin. Apparently the thermonuclear explosion of October 26, 1962, deposited mainly lithium-7 in the atmosphere.

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