OBSERVATION OF NEW EMISSION LINES IN THE INFRARED SOLAR SPECTRUM NEAR 12.33, 12.22, AND 7.38 MICRONS

F. J. Murcray, A. Goldman, F. H. Murcray, C. M. Bradford,1 AND D. G. Murcray
Department of Physics, University of Denver

AND

M. T. Coffey and W. G. Mankin
National Center for Atmospheric Research,2 Boulder, Colorado

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ABSTRACT

High-resolution infrared solar spectra reveal new emission features at 811.575, 818.058, and 1356.182 cm\(^{-1}\). The features width is \(\lesssim 0.02\) cm\(^{-1}\) and their intensity is \(\sim 10\%\) above the continuum. Coincidences with energy level differences of ionized light atoms are noted, but the identification and excitation mechanism are not yet firmly established.

Subject headings: infrared: spectra — Sun: spectra

Examination of high-resolution \((\sim 0.02\) km\(^{-1}\)) infrared solar spectra, obtained recently with a Michelson-type Fourier Transform interferometer at the South Pole by Murcray, Murcray, and Murcray (1981), showed two peculiar unidentified emission features near 12.33 and 12.22 \(\mu\)m (811 and 818 cm\(^{-1}\)). The same two features have been observed previously in \(\sim 0.06\) cm\(^{-1}\) resolution solar spectra obtained from Denver University (DU) with a different interferometer system. Some of these spectra were used for the New Atlas of Infrared Solar Spectra (Goldman et al. 1980a). However, in the solar atlas these features were handmasked prior to publication, because they were suspected to be unexplained instrumental or data processing artifacts. Thus, the solar atlas shows two short blank intervals at these frequencies. Since the features were observed with two different interferometers, the possibility that they were artifacts was greatly reduced. The fact that laboratory spectra taken with the same instruments (such as spectra in Murcray and Goldman 1981) revealed no such emissions also increased the probability that the features are real. Further evidence in support of the features was supplied by their presence in solar spectra taken with another interferometer system (resolution \(\sim 0.06\) cm\(^{-1}\)) used at the National Center for Atmospheric Research (NCAR) to obtain solar spectra from aircraft as well as from the ground (Coffey, Mankin, and Goldman 1981).

Typical spectra obtained with the three instruments in the 810–820 cm\(^{-1}\) region are shown in Figure 1. In each case, approximately the central 24' of the 32' subtended by the solar disk serves as a source, and each spectrum represents 3–10 coadded scans. Numerous other similar scans have been obtained both at DU and at NCAR. The atmospheric absorptions in this region are due to \(\text{CO}_2\) and \(\text{H}_2\text{O}\), and the \(\text{H}_2\text{O}\) absorptions are reduced significantly on the South Pole data.

From these results we conclude that these emission features are real features of the solar spectrum, and not instrumental artifact. The source could be atmospheric or solar. The lines are not observed when the instrument looks several degrees away from the Sun. It is probable that these features are of solar origin, but the possibility of atmospheric features is not excluded. If solar, these emission lines are expected to originate from the chromosphere or corona.

By comparison of the line with the nearby continuum, we estimate that the spectrally integrated radiance of the 811 \(\text{cm}^{-1}\) line is \(6 \times 10^{-6}\) W cm\(^{-2}\) sr\(^{-1}\), or a photon flux of \(4 \times 10^{14}\) photons cm\(^{-2}\) sr\(^{-1}\) s\(^{-1}\).

We do not have a satisfactory explanation of the formation of such solar emission lines, but we did notice possible frequency coincidences with transition frequencies of ionized light atoms that may exist in the chromosphere or the lower corona.

The available compilations of atomic energy levels (Moore 1949; Bashkin and Stoner 1975) show a possible coincidence between the observed feature near 811 \(\text{cm}^{-1}\) with the fine structure interval \(3d^4P_{1/2} \rightarrow 3d^4P_{3/2}\) of Si VIII at 810 \(\text{cm}^{-1}\). The other fine structure interval, \(3d^4P_{3/2} \rightarrow 3d^4P_{3/2}\), is given as 1360 \(\text{cm}^{-1}\). The theoretical ratio of the frequency times line strength \(\nu \times S(SLJ; SLJ-1)\) for the 810/1360 lines, as magnetic dipole lines in the \(LS\)-coupling approximation, is 0.55.

At 1360 \(\text{cm}^{-1}\), ground-based solar spectra, such as in Figure 1, are masked by strong atmospheric absorptions.
Fig. 1.—Ground-based solar spectra in the 810–820 cm$^{-1}$ region obtained with three different interferometers. The zero level is offset between scans for clarity. Note that the amplitude of the features may depend on the resolution. A: obtained on 1980 December 5 from the South Pole with ~0.02 cm$^{-1}$ resolution at 1.9 air masses. B: obtained on 1976 February 12 from Denver, Colorado, with ~0.06 cm$^{-1}$ resolution at 1.6 air masses. C: obtained on 1978 September 23 at NCAR, Boulder, Colorado, with ~0.06 cm$^{-1}$ resolution at 9.6 air masses. A residual channel spectrum remains in the spectrum.

Fig. 2.—Solar spectra in the 1350–1360 cm$^{-1}$ region, obtained during a balloon flight on 1979 October 10 from Alamogordo, New Mexico, with an interferometer at ~0.02 cm$^{-1}$ resolution. The altitude and the solar zenith angles are indicated on the spectra. Zero levels are offset for clarity.
However, balloon-borne solar spectra have been recently obtained by DU in the 850–2000 cm\(^{-1}\) region at \(\sim 0.02\) cm\(^{-1}\) resolution, with the same interferometer used to record the South Pole data. (A number of publications describe portions of these spectra, the most recent of which is Goldman et al. 1980b.) Examination of these data show a similar emission feature near 1356 cm\(^{-1}\), as shown in Figure 2. In these spectra, the central 8' of the solar disk was used as a source. These spectra represent single scans and are somewhat noisier than the ground-based spectra in Figure 1. The atmospheric absorptions in this region are due to CH\(_4\) and H\(_2\)O. No other emission features of this magnitude could be found over the entire 850–2000 cm\(^{-1}\) region (several intervals in this region are still masked by atmospheric absorptions). However, a few weaker features, such as the one at 810.3 cm\(^{-1}\), consistently appear on the data from more than one instrument. It is not clear to us why many similar transitions in the same spectral region are not detectable in the spectra.

In a similar manner, a possible coincidence may exist between the observed 818 cm\(^{-1}\) feature and 824 cm\(^{-1}\) interval of Mg \(\text{viii} 3p^2D_{5/2} \rightarrow 3p^2D_{3/2}\). Both the Si \(\text{viii}\) and the Mg \(\text{viii}\) terms are near 1,500,000 cm\(^{-1}\) and have allowed transitions to lower levels, and the above transitions are not necessarily the preferred ones. Yet, the 811 cm\(^{-1}\) line photon flux appears larger by approximately two orders of magnitude than the photon flux from strong XUV lines. More accurate term values are necessary before these coincidences can be verified.

The observed line positions, accurate to \(\pm 0.002\) cm\(^{-1}\), are: 811.575, 818.058, and 1356.182 cm\(^{-1}\). The other weaker line is at 810.351 cm\(^{-1}\). The lines are quite narrow (less or equal to the instrumental width of \(\sim 0.02\) cm\(^{-1}\)), which is not inconsistent with chromospheric-coronal half-width of \(\sim 0.5\) Å at \(\sim 5000\) Å, when only Doppler broadening is considered. However, the corresponding thermal Doppler width implies a temperature of \(\lesssim 10^5\) K, which may be too small for such high ionizations. From the available solar spectra, it is not clear if there are significant temporal and spatial variations in the observed emission peaks. However, since the intensity of these peaks is \(\approx 10\%\) above the continuum, it will be quite difficult to see them on low-resolution solar spectra.

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REFERENCES


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**Note added in proof.** — It was later discovered that the spectra in Figure 1 also contain a solar OH absorption quartet (Goldman et al. 1981, Ap. J., in press).

C. M. Bradford, A. Goldman, D. G. Murcray, F. H. Murcray, and F. J. Murcray: Department of Physics, University of Denver, Denver, CO 80208

M. T. Coffey and W. G. Mankin: National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307