Reports

Mariner 6: Ultraviolet Spectrum of Mars Upper Atmosphere

Abstract. *Emission features from ionized carbon dioxide and carbon monoxide were measured in the 1900- to 4300-angstrom spectral region. The Lyman alpha 1216-angstrom line of atomic hydrogen and the 1304-, 1356-, and 2972-angstrom lines of atomic oxygen were observed.*

The flight of Mariner 6 past Mars on 31 July 1969 presented the first opportunity to measure the ultraviolet dayglow of that planet. The technique of using ultraviolet spectroscopy to study planetary atmospheres has been developed both theoretically and experimentally over the past 9 years (*1*). Rocket experiments have shown that the ultraviolet dayglow of the earth consists of the following emission features: the Lyman alpha 1216-Å line of atomic hydrogen; the 1304-, 1356-, and 2972-Å lines of atomic oxygen; the 1200-, 1493-, 1744-, and 3466-Å lines of atomic nitrogen; the Lyman-Birge-Hopfield, Vegard-Kaplan, and second-positive bands of molecular nitrogen; the gamma bands of nitric oxide; and the first-negative bands of ionized molecular nitrogen (*2*). These emissions are produced in the earth's upper atmosphere by resonance and fluorescence scattering of ultraviolet solar radiation and by photoelectron impact excitation.

The Mariner ultraviolet spectrometer was specifically designed to measure emissions from the sunlit atmosphere above the limb of Mars. Extensive baffling in front of the telescope suppressed off-axis light from entering the 250-mm Ebert-Fastie spectrometer (*1*). Two photomultiplier tubes simultaneously recorded the spectral scans which occurred repetitively every 3 seconds. The wavelength band at 1100 to 1900 Å was measured at a resolution of 10 Å by a cesium iodide tube, and the 1900- to 4300-Å band was measured at a resolution of 20 Å with a bialkali tube.

The first observation of the sunlit atmosphere of Mars occurred when Mariner 6 was 8300 km from the planet's center, the slant range to the limb was 7600 km, and the solar zenith angle at the limb was 27°. The telescope baffling rejected the off-axis light from the disc sufficiently well so that a spectrum rich in emission features was obtained. In the spectral interval from 1900 to 4300 Å, the bialkali photomultiplier tube recorded the spectrum shown in Fig. 1.

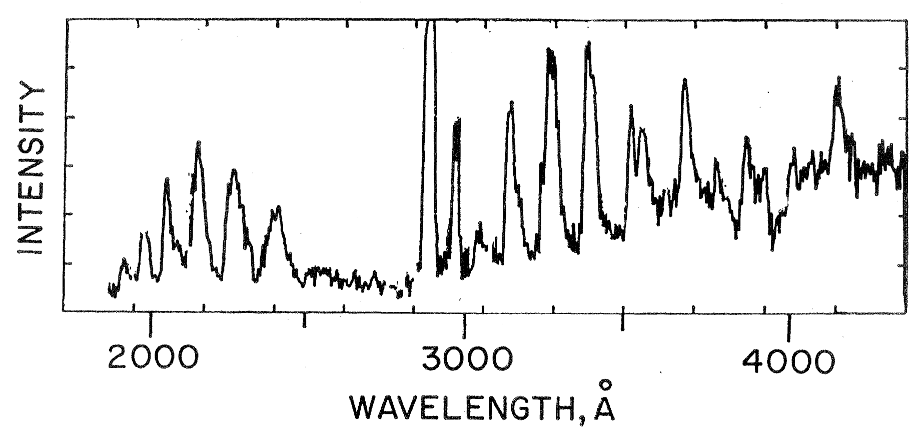

Fig. 1. Ultraviolet spectrum of Mars upper atmosphere. A nominal wavelength scale is shown on the abscissa. The ordinate is an arbitrary intensity scale uncorrected for the spectral response of the instrument. A number of spurious noise pulses have been edited out of this spectrogram.

An initial spectroscopic analysis has been performed with the use of laboratory and theoretical data prepared before the Mars encounter. A comparison spectrum synthesized from three separate sources is shown in Fig. 2 together with the individual spectra. Figure 2a was obtained from a spectrum of the Martian disc measured later in the flight by the Mariner spectrometer. This spectrum is the result of Rayleigh scattering and ground reflection of solar radiation. The spectrum in Fig. 2b was produced in the laboratory by the bombardment of carbon dioxide at 10^{-3} torr by electrons with an energy of 20 ev. This spectrum contains the prominent ionized carbon dioxide emission feature at 2890 Å and the Fox-Duffendack-Barker bands. The spectrum in Fig. 2c was composed theoretically from calculations of how the Cameron bands of carbon monoxide appear in the fluorescence scattering of sunlight (*2*), and it has been adjusted for the response of the instrument. The three spectra were normalized individually and summed to form the composite spectrum in Fig 2d. In view of the way in which we put together the synthetic spectrum in Fig. 2d, the similarity between it and the Mars spectrum in Fig. 1 is remarkable. However, the excitation mechanisms which occur in the upper atmosphere of Mars may or may not be the ones we used to produce the synthetic spectrum.

We have identified an additional feature which appears in the Mars spectrum as the 2972-Å line of atomic oxygen. There may be further unidentified features in this spectrum.

The limb spectrum in the 1100- to 1900-Å region was recorded by the cesium iodide photomultiplier tube. The principal emission features that were observed were: the Lyman alpha 1216-Å line of atomic hydrogen, the 1304- and 1356-Å lines of atomic oxygen, and the fourth-positive bands of carbon monoxide.

One particularly important objective of the ultraviolet spectrometer experiment was to search for nitrogen in the atmosphere of Mars. This first analysis shows no evidence of nitrogen emissions in the ultraviolet spectrum of the upper atmosphere. The following emissions were searched for and found missing: second-positive and Lyman-Birge-Hopfield bands of molecular nitrogen, first-negative bands of ionized molecular nitrogen, gamma bands of nitric oxide, and 1200- and 1493-Å lines of atomic nitrogen. The final analysis of these data will allow an upper limit to be placed on the amount of nitrogen in the upper atmosphere of Mars.

Repetitive spectra were taken as the Mariner spectrometer crossed the limb of Mars. These data, which contain information about the scale height of individual spectral emissions will be used to construct a model of the Mars upper atmosphere. This first report is simply a record of our identifications in the ultraviolet spectrum of the upper atmosphere. The instrument also obtained spectra of the bright and dark parts of the disc, the terminator, and the atomic hydrogen corona.

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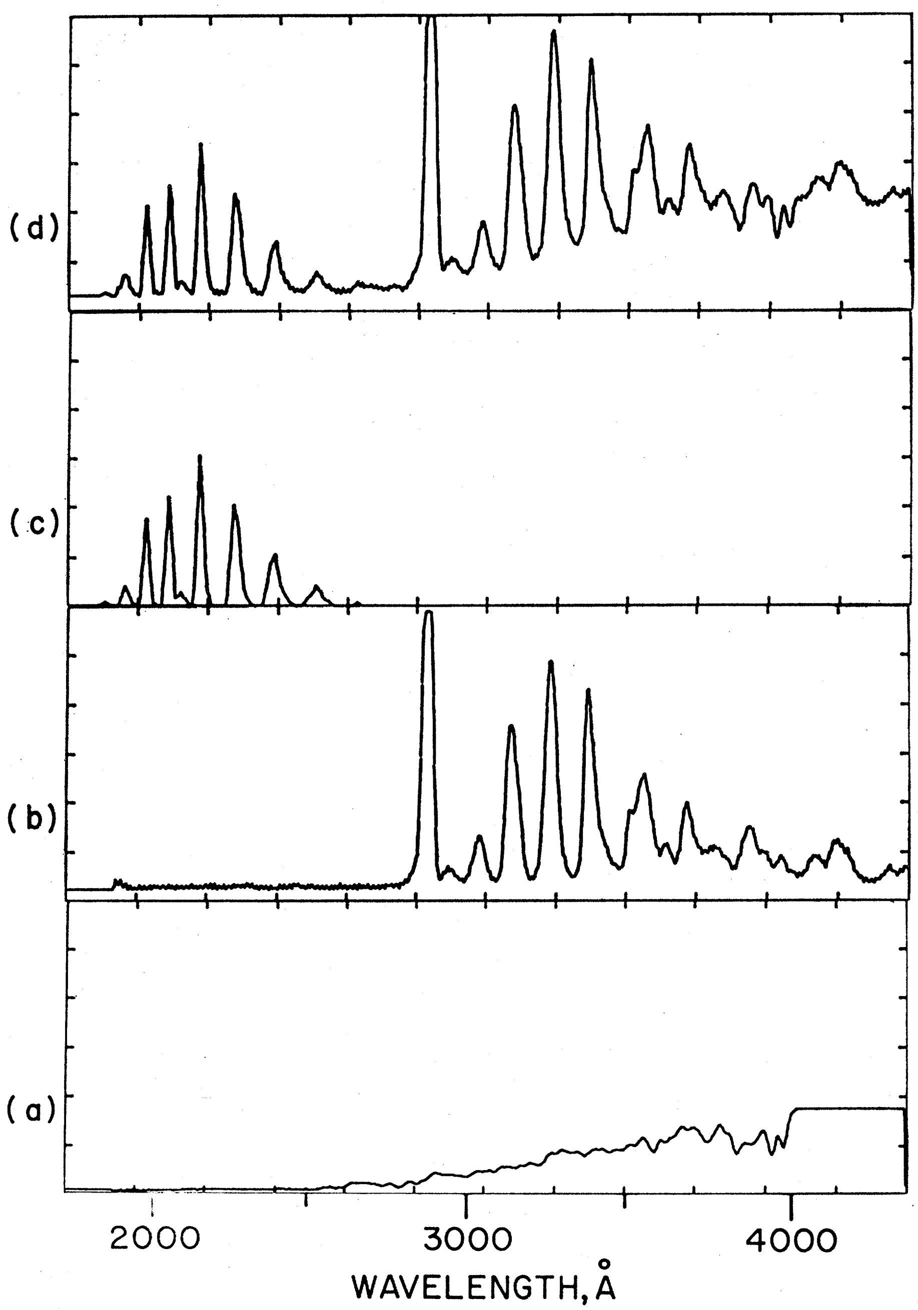

Fig. 2. Synthesis of comparison spectrum. (a) Off-axis light component from Mars disc. (b) Carbon dioxide spectrum from laboratory electron impact experiment. (c) Carbon monoxide spectrum from theoretical calculation of fluorescence scattering. (d) Composite spectrum synthesized by adding a, b, and c.

References and Notes

1. C. A. Barth, *Appl. Optics* **8**, 1295 (1969).
2. ———, in *The Middle Ultraviolet—Its Science and Technology*, A. E. S. Green, Ed. (Wiley, New York, 1966); W. G. Fastie, H. M. Crosswhite, D. F. Heath, *J. Geophys. Res.* **69**, 4129 (1964); C. A. Barth, *ibid.*, p. 3301; C. A. Barth and J. B. Pearce, *Space Res.* **6**, 381 (1966); unpublished results from a rocket flight, 13 June 1969.
3. The success of this experiment, which has been under preparation for 9 years, is the result of the efforts of a large number of people at NASA headquarters, the Jet Propulsion Laboratory, the University of Colorado, Johns Hopkins University, and elsewhere in the scientific community. The large scientific return from the Mariner 1969 mission is due to the technical and managerial skills of H. M. Schurmeier and the Mariner project staff at JPL and NASA headquarters. Supported by NASA under JPL contract 951790 and NASA grant NGL 06-003-052.

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Jadeite: Shock-Induced Formation from Oligoclase, Ries Crater, Germany

Abstract. *Jadeite (high-pressure sodium aluminum pyroxene) has been identified in a shock-phase assemblage of oligoclase. The shock assemblage consists of minute particles with high refractive indices that contain at least two phases: one (identified by x-ray) is a jadeite that is nearly pure* $NaAlSi_2O_6$*; the other has the chemical composition of oligoclase minus jadeite and appears to be largely amorphous.*

Jadeite has been identified as the major crystalline constituent of a shock-phase assemblage formed by the breakdown of sodic feldspar. Because plagioclase is the most widespread of the common rock-forming minerals, shock