The ionization process for the major neutral species, CO_2 and O, in the ionosphere of Venus can be represented by the reactions

$$hv + CO_2 \rightarrow CO_2^+ + e$$
$$\rightarrow CO + O^+ + e$$
$$hv + O \rightarrow O^+ + e$$
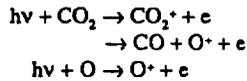
where hv represents an ultraviolet photon. h is Planck's constant and v is the photon frequency. hv must exceed the ionization potential of the molecule for these photochemical reactions to proceed.

A peak electron density in the Venus ionosphere of $\approx 6 \times 10^5$ cm^{-3} was observed on the dayside by the Pioneer Venus radio occultation experiment, as well as by the radio occultation experiments on other missions. The altitude of the peak is located at $z \approx 140$ km. The major ion species in the lower ionosphere of Venus was observed by the PVO ion mass spectrometer and by the retarding potential analyzer experiments to be O_2^+ and not CO_2^+, even though the abundance of neutral O_2 in the atmosphere of Venus is negligible, because of the following rapid ion-neutral reaction

$$CO_2^+ + O \rightarrow O_2^+ + CO$$
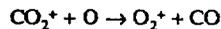
The O_2^+ ions are removed from the ionosphere by means of the following dissociative recombination reaction with ionospheric electrons

$$O_2^+ + e \rightarrow O + O$$
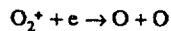
The neutral oxygen atoms produced by this reaction have energies of a few eV and are the source of the hot oxygen corona. The major ion species observed by instruments on PVO for altitudes above ≈ 160 km is O^+. Many minor ion species, including H^+, CO^+, N_2^+, CO_2^+, NO^+, He^+, C^+, and N^+, were observed by the PVO ion mass spectrometer.

Electron and ion temperatures of several thousand degrees were observed in the ionosphere of Venus by the PVO electron temperature probe and by the retarding potential analyzer. Theoretical models indicate that most of the energy required to heat the ionospheric plasma to these temperatures, which greatly exceed the neutral temperature, is derived from the solar wind interaction with the ionosphere.

The nightside ionosphere of Venus is quite variable, both spatially and temporally, with peak densities typically observed to be about 10^4 cm^{-3}. The main source of nightside ionization is thought to be transport of ions from the dayside to the nightside. O^+ ions drift upward on the dayside, then flow horizontally with speeds of several kilometers per second above 200 km, and then subside to lower altitudes on the nightside. Large ion drift speeds near the terminator of Venus were measured by the PVO retarding potential analyzer. Auroral ionization also contributes to the nightside ionosphere, especially during time periods of large solar wind dynamic pressure, when it is known that the nightside ionosphere at higher altitudes virtually disappears. A variety of other nightside ionospheric phenomena have also been observed, such as tall rays, ionospheric clouds, and ionospheric holes.

The solar wind interacts very strongly with the ionosphere of Venus. In fact, two types of ionosphere exist: (1) unmagnetized and (2) magnetized. The former ionospheric state is observed to be present whenever the solar wind dynamic pressure is low, and in this case large-scale magnetic fields are excluded from the ionosphere, although small-scale magnetic structures called flux ropes were observed to be present in the ionosphere by the PVO magnetometer.

The boundary between the solar wind and ionosphere, called the ionopause, is rather narrow and is located at higher altitudes for unmagnetized ionosphere cases. However, the dayside ionosphere is observed to be permeated by large-scale magnetic fields during conditions of high solar wind dynamic pressure. In this case, electrical currents flow throughout the ionosphere and both the density structure and the dynamics of the ionosphere are strongly affected by the solar wind interaction. The ionopause in this case is located below about 300 km and is rather broad.

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NEAR-INFRARED OXYGEN AIRGLOW FROM THE VENUS NIGHTSIDE. D. Crisp[1], V. S. Meadows[2], D. A. Allen[3], B. Bezard[4], C. DeBergh[4], and J.-P. Maillard[5], [1]Jet Propulsion Laboratory, USA, [2]University of Sydney, Australia, [3]Anglo-Australian Observatory, [4]Observ. Paris-Meudon, France, [5]IAP Paris, France.

Groundbased imaging and spectroscopic observations of Venus reveal intense near-infrared oxygen airglow emission from the upper atmosphere [1,2] and provide new constraints on the oxygen photochemistry and dynamics near the mesopause (~100 km). Atomic oxygen is produced by the photolysis of CO_2 on the dayside of Venus. These atoms are transported by the general circulation, and eventually recombine to form molecular oxygen. Because this recombination reaction is exothermic, many of these molecules are created in an excited state known as $O_2(^1\Delta)$. The airglow is produced as these molecules emit a photon and return to their ground state. Connes et al. [1] found that the airglow intensity is comparable on the dayside (1.5×10^{12} photons/cm^2/s) and nightside (1.2×10^{12} photons/cm^2/s) of the planet. They concluded that the $O_2(^1\Delta)$ emission is spatially uniform, and that chemical reactions involving $O_2(^1\Delta)$ provide a major pathway for the recombination of oxygen atoms in the venusian atmosphere. The intensity and apparent uniformity of this emission has puzzled atmospheric chemists for more than a decade because these properties cannot be explained by existing models [3].

New imaging and spectroscopic observations acquired during the summer and fall of 1991 show unexpected spatial and temporal variations in the $O_2(^1\Delta)$ airglow [4,5]. High-resolution (0.4 cm^{-1}) spectra of selected regions of the dayside and nightside of Venus were obtained with the Fourier Transform Spectrometer on the Canada-France-Hawaii Telescope (Mauna Kea Hawaii) on 27 June and 1 July 1991 (Fig. 1). Individual oxygen emission lines of the $O_2(^1\Delta)$ band near 7880 cm^{-1} (1.269 μm) were resolved, allowing us to distinguish the airglow emission from the deep-atmosphere thermal emission peak near 7830 cm^{-1} (1.277 μm). The intensity of the nightside $O_2(^1\Delta)$ emission increased by a factor of 4 between 10N to 5S latitude on 27 June. The emission measured near 15S latitude on 1 July was almost six times brighter than that seen four days earlier, and about three times brighter than that reported by Connes et al. [1]. Comparisons of intensities of individual rotational transitions in the P and R branches of the emission spectrum indicate a rotational temperature of 186 ± 6 K (Fig. 2).

This temperature is comparable to that derived from the $O_2(^1\Delta)$ observations made in the mid 1970s [1]. When Pioneer Venus arrived in 1978, the Venus mesosphere was characterized by an anomalous thermal structure, with warm poles and a relatively cool equator. Dynamical models showed that this temperature structure was consistent with a rapid decrease in the amplitude of the cloud-
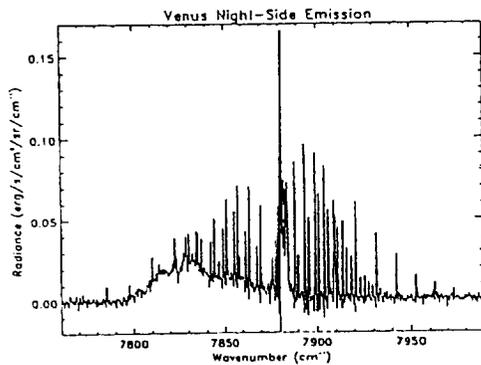
Fig. 1. High-resolution spectrum of the Venus nightside taken on 1 July 1991 at the Canada-France-Hawaii Telescope with the Fourier Transform Spectrometer. The broad emission peak centered near 7830 cm^{-1} (1.277 μm) is thermal emission from the lowest scale height (0–20 km) of the venusian atmosphere. The narrow emission lines and the sharp spike centered near 7880 cm^{-1} are $O_2(^1\Delta)$ airglow, which is produced in the upper mesosphere (~94 km).
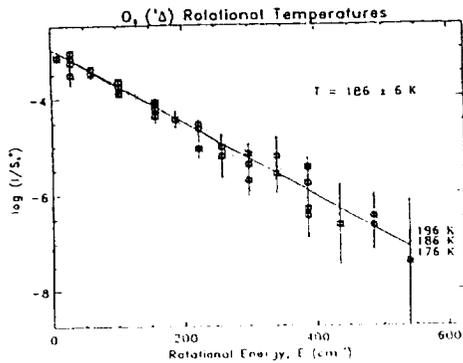
Fig. 2. The local kinetic temperatures can be inferred from the rotational energies of transitions in the P and R branches of the $O_2(^1\Delta)$ band. We find rotational temperatures of 186 ± 6 K.

Fig. 3. Images of the Venus nightside taken at wavelengths in the bright Q branch of the $O_2(^1\Delta)$ band on 19 and 20 September 1991. The intensity of the brightest region changed by about 20% between 20:39 and 21:54 U.T. This bright spot completely vanished the following day.

top superrotation at these altitudes [6]. Groundbased millimeter-wave observations indicate that this thermal structure may have changed dramatically in the mid 1980s, when low-latitude temperatures increased substantially in the upper mesosphere [7]. This warming may have produced tropical temperatures that were warmer than those at the poles, disrupting the anomalous thermal structure and allowing the high-speed cloud-top winds to extend throughout the mesosphere. If that change occurred, our recent $O_2(^1\Delta)$ observations suggest that the venusian mesosphere has since reverted to conditions like those seen in the late 1970s.

The first images of the Venus nightside at wavelengths within the narrow Q branch of the $O_2(^1\Delta)$ band were obtained with the InfraRed Imaging Spectrometer (IRIS) on the Anglo-Australian Telescope (Siding Spring Observatory) on 27 and 28 July 1991. Unlike the almost featureless deep-atmosphere thermal emission at 1.277 μm, the $O_2(^1\Delta)$ airglow occasionally has contrasts as large as 10:1 on the nightside. On 27 July, the brightest feature was centered between 30

and 40N latitude near the dark limb (3 a.m. meridian). The antisolar point was also relatively bright. Within one day, the locations and intensities of the airglow features had changed dramatically. Similar variations in the $O_2(^1\Delta)$ emission were seen on 19 and 20 September 1991 (Fig. 3). This transience and localized structure was not apparent in the earlier groundbased spectroscopic observations of $O_2(^1\Delta)$ emission [1], but similar features have been seen in Pioneer Venus Ultraviolet Spectrometer observations of NO emission [8], which is produced at much higher altitudes (~120 km). The implications of these observations for the composition and general circulation of the upper venusian atmosphere are not yet understood, but they provide important new constraints on comprehensive dynamical and chemical models of the upper mesosphere and lower thermosphere of Venus.

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