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THE MARINER JUPITER/SATURN IRIS EXPERIMENT

The principal investigator of the infrared spectroscopy and radiometry investigation is Dr. R. A. Hanel of Goddard Space Flight Center. Unfortunately, he was not able to be here today.

Figure 1 is a schematic representation of the Jovian spectrum from the near ultraviolet to the thermal infrared regions. The spectrum for Saturn should not be markedly different except, of course, for the radiance levels. The incident solar energy is shown by the solid line at the right of the diagram. Some of the solar energy is absorbed (the dashed line), and the remainder is reflected or scattered. The energy that is absorbed is reemitted in the thermal infrared, together with any energy from internal sources.

The IRIS instrument (an acronym for infrared interferometer spectrometer) consists of a coaxial interferometer and radiometer. The bandpass of the interferometer extends from 200 cm^{-1} to 3300 cm^{-1} (50 to 3.3 μm); the bandpass of the radiometer extends from 5000 cm^{-1} to 33 000 cm^{-1} (2.0 to 0.3 μm). These bandpasses are indicated by the solid horizontal lines near the top of figure 1. We are considering the possibility of extending the high-frequency cutoff of the interferometer out to 4000 cm^{-1} (2.5 μm).

The optical layout of the MJS IRIS is depicted in figure 2. An f/8 Cassegrain telescope provides large energy throughout and a narrow field of view (0.25°). The diameter of the primary mirror is 51 cm. A dichroic element is used to separate the energy for the radiometer from that for the interferometer. Near infrared and visible energy ($\gtrsim 5000$ cm^{-1}) is passed by the dichroic element to a focusing mirror and to the radiometer detector. Near and thermal infrared radiation ($\lesssim 4000$ cm^{-1}) is reflected, collimated, and passed to the interferometer. The radiating surface and the various blankets and baffles are also depicted.

The optical layout of the Michelson interferometer that was used on the Nimbus 3 and 4 spacecraft is depicted in figure 3. The layout of the MJS interferometer

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Jet Propulsion Laboratory.

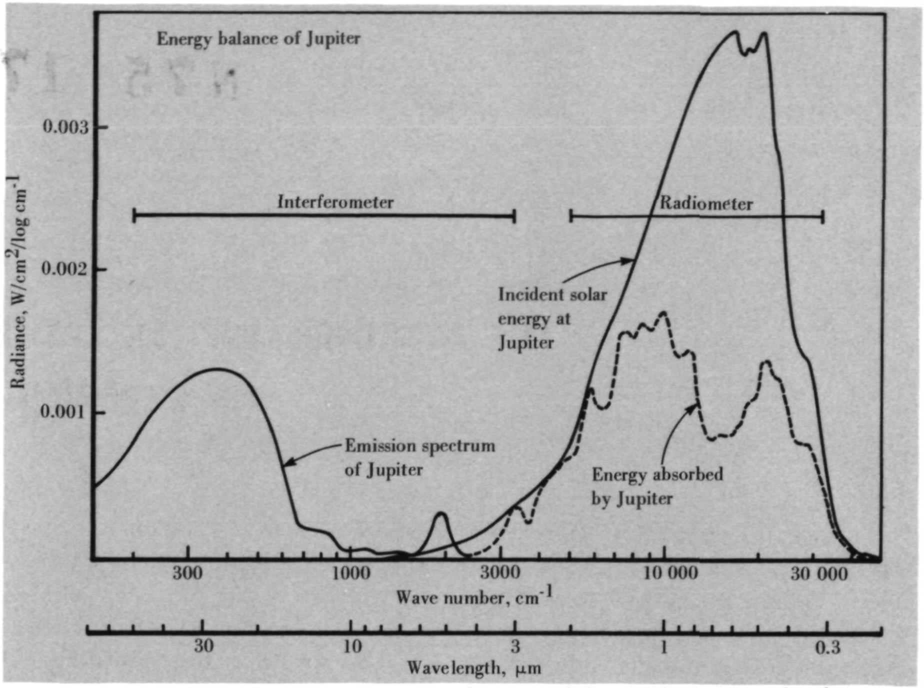

FIGURE 1.—*Energy balance of Jupiter. The spectral ranges of the interferometer and radiometer are superposed on the thermal emission spectrum and upon the reflected solar spectrum.*

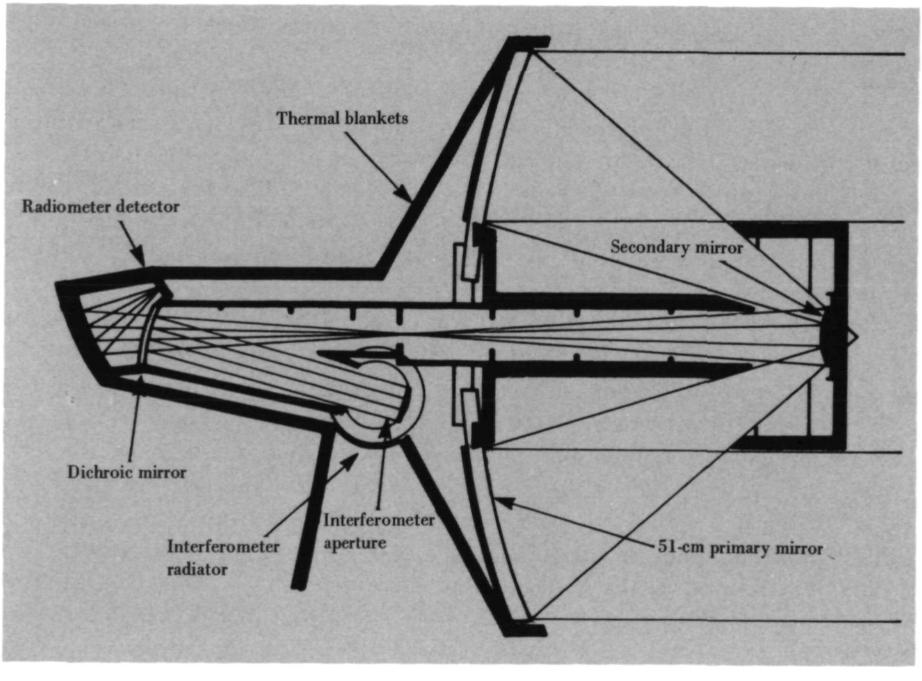

FIGURE 2.—*Optical schematic diagram of the MJS IRIS.*

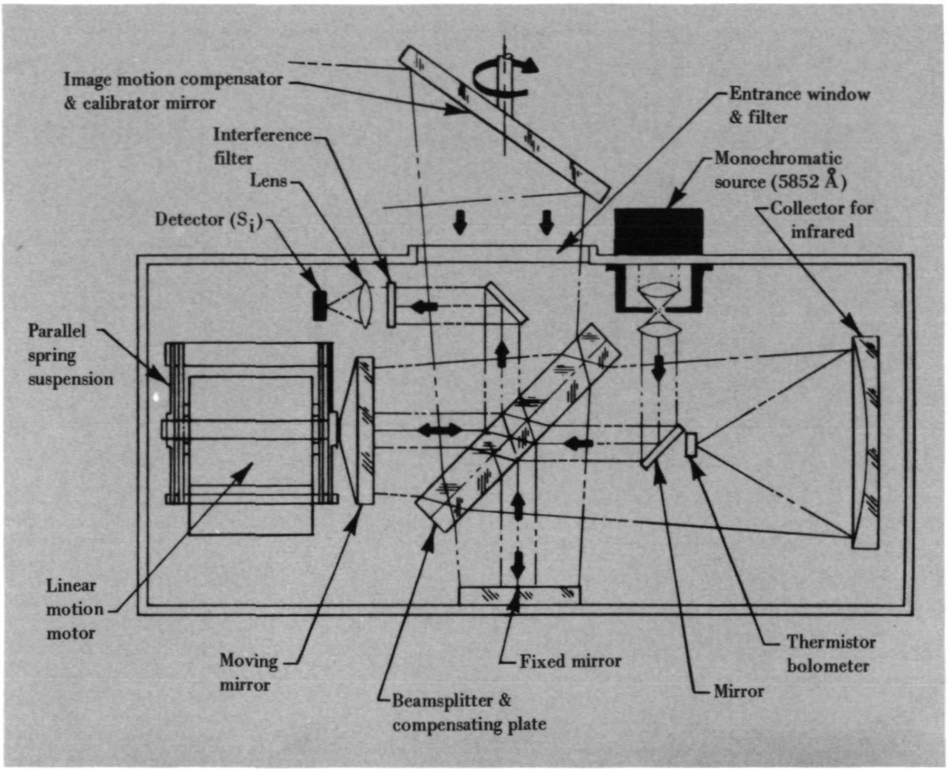

FIGURE 3.—*Optical schematic diagram of the Michelson interferometer.*

will not be substantially different: the image motion compensator and calibrator mirror will be replaced with the Cassegrain telescope; the entrance window/filter and the beamsplitter compensator will be deleted; and the thermistor bolometer will be replaced by a detector with lower noise equivalent power—either a thermopile or a pyroelectric detector. Note that the interferometer has a coaxial interferometer using the 585.25-nm neon line for wavelength calibration.

Figure 4 indicates the approximate magnitude of the signals expected at Jupiter and Saturn. The thermal emission curves are blackbody curves for various temperatures (130 K for Jupiter and 96 K for Saturn). The reflected solar radiation curves are based on an albedo of 0.5. The noise equivalent radiance (NER)—the level of radiance for which the signal-to-noise ratio is unity—is indicated on the figure. One can infer the signal-to-noise ratio as a function of frequency from the expected signals and the NER: near the peaks of the blackbody curves the signal-to-noise ratio is in excess of 1000, and near the crossover between emitted and reflected energy the signal-to-noise ratio is not significantly greater than unity. However, I would emphasize that the instrument has a spectral resolution of 4.5 cm^{-1}. The NER can be lowered by degrading the spectral resolution.

I would like to briefly review some of the objectives of the IRIS investigation.

Measurements of reflected solar radiation and thermally emitted radiation over a wide range of latitudes and phase angles will permit determination of the energy

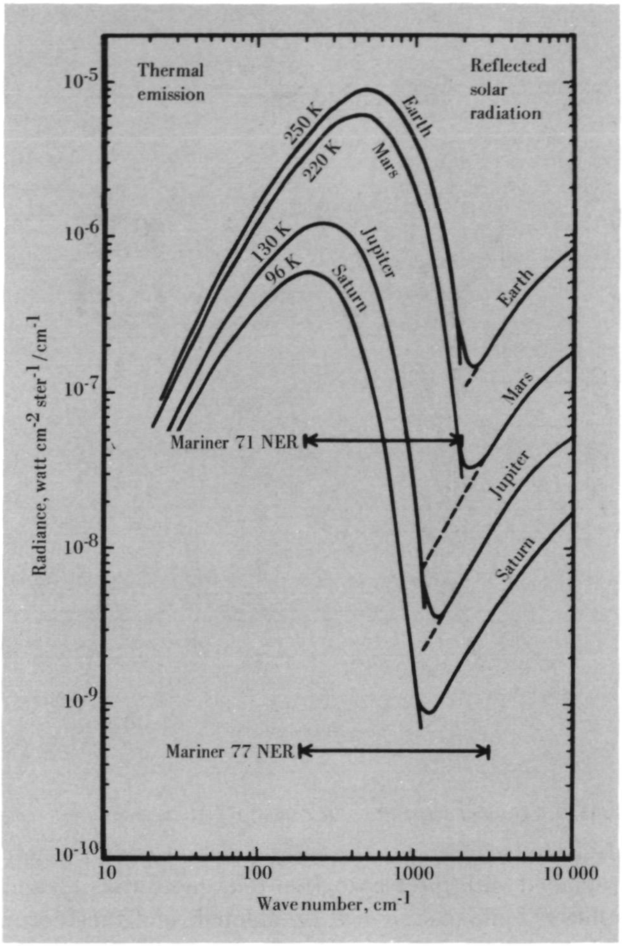

FIGURE 4.—*Radiance vs frequency for Jupiter and Saturn. The noise-equivalent-radiance (NER) for the MJS-IRIS (Mariner 77) is shown.*

balance of Jupiter and Saturn (i.e., the existence of internal heat sources and their magnitude).

The IRIS will provide information about the quantities (or upper limits) of methane, ammonia, hydrogen, and water vapor. The high spectral resolution and low NER of the IRIS will permit a search for a variety of minor constituents, including the so-called prebiotic molecules. The IRIS will provide information about the hydrogen-helium ratio as well as about isotopic ratios, H/C, C/N, and C/O.

The IRIS will permit determination of the three-dimensional temperature fields (latitude, phase angle, and height) of the planets, Titan, and perhaps other satellites. The three-dimensional temperature fields will be used in investigations of atmospheric dynamics.

The IRIS will provide information concerning the presence of water ice, silicates, and chondritic materials in solid bodies and in aerosols. Since these items are particularly germane to the ring investigations, I would like to show some of the relevant Mariner Mars 1971 results.

Figure 5 depicts the average of approximately 2000 spectra that were acquired during the Martian dust storm. One can readily see the wing of the 15 μm CO_2 absorption band, several other CO_2 features, H_2O lines, and a very broad absorption feature between 800 and 1400 cm^{-1}. This latter feature is due to the silicates that were present in the atmosphere. The position of the transmission minimum, characteristic of the silicate content of the material, permits one to distinguish between the so-called acidic and basic silicates. A synthetic spectrum for a Martian atmosphere consisting of only CO_2 and H_2O is superposed on the same figure.

During the latter part of the mission, a spectrum was acquired over a cloud-free region of Arcadia; shortly thereafter, another spectrum was acquired over a cloud-covered region of the Tharsis ridge. These spectra are shown in figure 6, displaced for clarity. R. Curran of Goddard Space Flight Center has calculated the absorption characteristics of a water-ice cloud from the complex refractive index of water ice and an assumed particle size distribution. One can readily see the good agreement. The discontinuity in the calculated spectrum is caused by the use of two sources of refractive index data.

The previous remarks of C. Lillie and B. Smith are also applicable to the IRIS investigation. The IRIS has a circular field of view (0.25° full cone) that is the same as the narrow field of view of the photopolarimeter and about one-half the size of the proposed long focal length imaging system. At closest approach, the 0.25° field of view will permit a number of observations that are completely within the extent of the A and the B rings.

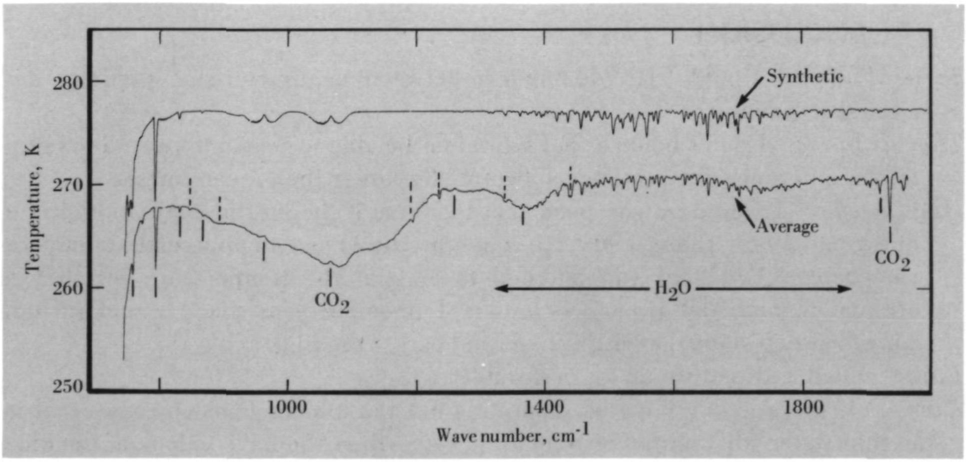

FIGURE 5.—*Mariner 9 spectra showing broad silicate feature between 800–1200 cm^{-1} and atmospheric CO_2 and H_2O features.*

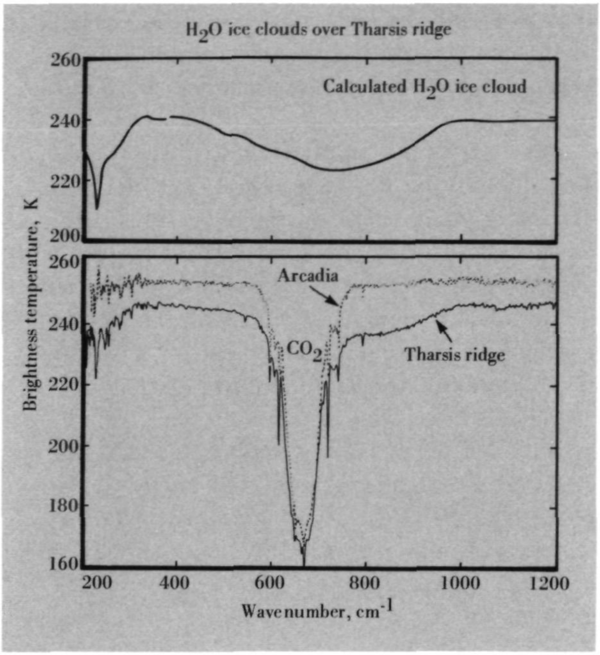

FIGURE 6.—*Experimental and theoretical H_2O ice cloud spectra.*

The IRIS will be used to measure the equilibrium temperature of ring particles prior to their shadowing by Saturn and to measure their minimum temperatures just prior to exiting Saturn's shadow. From these measurements we hope to determine the thermal inertia of the ring particles and, perhaps, to infer their size and density. The particle sizes for which we expect this sort of measurement to be applicable run from several millimeters to the order of a centimeter.

DISCUSSION

James Pollack Could IRIS distinguish between centimeter-size particles and meter-size particles?

Thomas Burke I don't believe that we would be able to see an appreciable temperature difference for particles substantially larger than a centimeter.

Hugh Kieffer I would maybe push that to 10 cm if the inertia were appropriate, but beyond 10 cm there is just too much inertia to see an appreciable temperature change. You said you planned to look at the temperature just before entrance to and exit from occultation. I presume your plans would include trying to sweep along the entire shadowed part of the ring?

Burke Such a sweep would be preferable.

Kieffer If there is any hope of separating out the inhomogeneous case—that is, the thin water frost on top or something else—then you have to look at the knee of the curve (see contribution by Kieffer) after the particles enter the shadow. Hopefully that would be part of the plan.

Pollack Have you given any thought to trying to measure the temperature when looking on the sunlit side, as contrasted with looking at the shadowed side?

Burke Yes, we have. This is an observation we hope to make.

I would like to mention one other ring experiment that we are considering. We would like to use the radiometer to determine the optical thickness of the rings when the spacecraft passes behind the rings.

Kieffer Your instrument has very good spectral resolution. Has any thought been given as to what you might infer based on the departure from a single blackbody curve for the ring particles?

Burke I don't think that has been considered at this point.