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GRILLE SPECTROMETER (Grille)
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The Grille spectrometer ~~has been~~ designed and flown on Spacelab 1 by two organizations: The Office National d'Etudes et de Recherches Aerospatiales in France and the Belgian Institute for Space Aeronomy in Belgium. Its purpose is to study, on a global scale, atmospheric parameters between 15 and 150 km altitude. The investigation uses high-resolution (better than 0.1 cm^{-1}) spectroscopic observations of the Earth's limb in the wavelength range characteristic of the vibrational-rotational lines of the relevant atmospheric constituents.

The observation of the vertical distribution of molecules from the stratosphere to the thermosphere allows a better understanding of atmospheric chemistry, dynamics, and radiation. Strongly coupled cycles such as the interactions of chlorine or nitrogen compounds with ozone in the stratosphere are influenced by productions and losses taking place at much higher altitudes while the penetrating radiation that promotes photochemical activity depends on the vertical distribution of all atmospheric constituents. Presently, only the lower stratosphere has been monitored on a global scale and that was done by several aircraft campaigns. For the higher stratospheric altitudes, most of the information available has come from balloon flights at the 32°N and 43°N latitudes corresponding to Palestine, Texas, and Aire-sur-l'Adour, France, respectively. For the mesosphere and thermosphere, except for rare rocket flights, the available results have been obtained from spaceborne platforms, most notably, Nimbus 7, Solar-Mesosphere-Explorer, SAGE (Stratospheric Aerosols and Gases Experiment), and Spacelab 1. The weight and power available on the Spacelab pallet permit investigators to fly much heavier instruments than on previous platforms and should permit them to overcome the trade-offs which had to be accepted on lighter satellites. Suitable orbits allow the monitoring of the equatorial and polar regions, together with better-known middle latitudes.

Homonuclear molecules like N_2, O_2, H_2, and rare gases like argon absorb little in the infrared. However, the other minor atmospheric species are very effective absorbants in this spectral range. During its first flight, the grille spectrometer limited itself to ten constituents: O_3, CO, CO_2, CH_4, H_2O, NO, NO_2, N_2O, HF, and HCl. For the ATLAS 1 flight, as the optical characterstics of the instrument have not been modified, this list will be the same except that an observation of lines of the hydroxyl radical OH will be attempted. As during Spacelab 1, small spectral intervals will be used, either preprogrammed in the experiment processor or loaded through commanding or transferred from a Spacelab mass memory unit. During an occultation, different intervals will be scanned depending on limb altitudes. The technological data obtained on the instrument sensitivity during the first flight in real outer space conditions have permitted a reduction in the number of internal contingency spectral windows and an increase in the number of scientific options. The main changes compared to the first flight give a higher priority to spectral lines which proved to be uncontaminated by solar features as surveyed for the first time during Spacelab 1. Whenever possible, the spectral intervals were broadened in order to gain accuracy by increasing the number of lines used in the interpretations. Intervals in which the signal-to-noise ratio was maximum were also determined in order to lower the detectability limit and to extend the results obtained on Spacelab 1 to even higher altitudes. As an example, absorption spectra showing the growth of water vapor lines in the mesosphere are shown in Figure I-6.

Measurements will also be performed in the emission mode: emissions of molecules that are in excited states and that are located in the mesospheric and/or thermospheric limb will be surveyed at the same 0.1 cm^{-1} resolution as for occultation data.

The grille spectrometer possesses the advantage of a luminosity approximately 25 times better than the conventional slit spectrometer and has the practical advantage of directly recording the spectral information in the very narrow spectral range where this information is relevant. With a classical spectrometer, the entrance and exit slits make the luminosity and resolving power strictly dependent on each other. In fact, high luminosity requires a large throughput for the spectrometer, and a high resolving power requires a large range of transmission for the spatial frequencies in the focal plane of the spectrometer. The instrumental parameters determining these two properties can be made independent by replacing the slits with a plate (grille) that has a large area and a set of alternating reflective and transparent zones, limited by equilateral hyperbolas (Fig. I-7). The grille, acting as a broad bandwidth spatial filter, works by transmission at the entrance and by reflection at the exit. The luminosity depends on the area of the grille, and the resolving power depends on the width of the zones. The actual grille used on the instrument is a 15 x 15 mm square with a minimum step of 0.1 mm.

The resolved spectral signal is selectively modulated by a vibrating collimator that produces a small amplitude oscillation on the dispersed light coming from the spectrometer.

The spectrometer (Figs. I-8 and I-9) operates in the wavelength range from 2.5 to 10 μm. The light coming from the Sun through the Earth's atmospheric limb or from the atmospheric limb itself is reflected toward a telescope by an orientable rectangular plane mirror. The telescope that transmits the light to the spectrometer has a 0.3-m diameter and a 6-m focal length. Two detectors are used simultaneously to cover the entire spectral range. All functions of the instrumentation are programmable through a microprocessor that is a part of the instrument electronics. The instrument is closed when not in operation. A built-in calibration light source allows testing to be performed at any time before and during flight.

The only fundamental hardware change to the Spacelab 1 configuration of the grille spectrometer is the addition of a NASA-provided bottle of pressurized nitrogen to be used for the cryogenic cooling of the detectors. This will allow much longer operation than the internal nitrogen vessel used on Spacelab 1. In addition, an electronics box that was in the Spacelab module will be moved to the pallet.

With these modifications, a comprehensive preplanned geophysical program can be accomplished during the ATLAS 1 mission that will thoroughly address the questions associated with the seasonal and spatial variations of stratospheric, mesospheric, and thermospheric constituents.

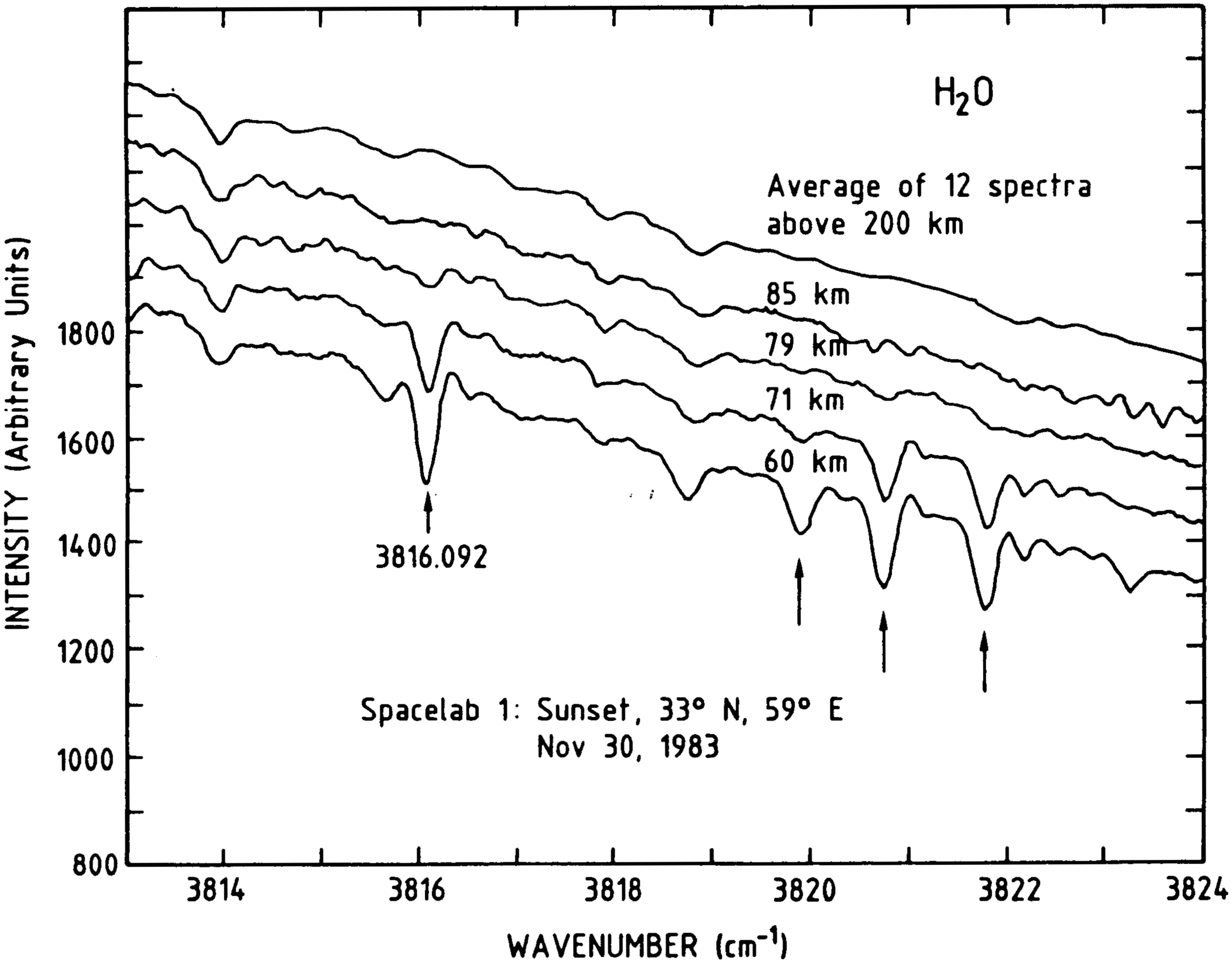

Figure I-6. Spectra of water vapor bands obtained in the range of 2.7 μm as the Sun sets. The upper spectrum is an average of water vapor spectra measured when the minimum altitude of the solar rays is between 200 and 250 km while grazing ray altitudes are indicated on the lower spectra. The strongest H_2O lines have also been indicated.

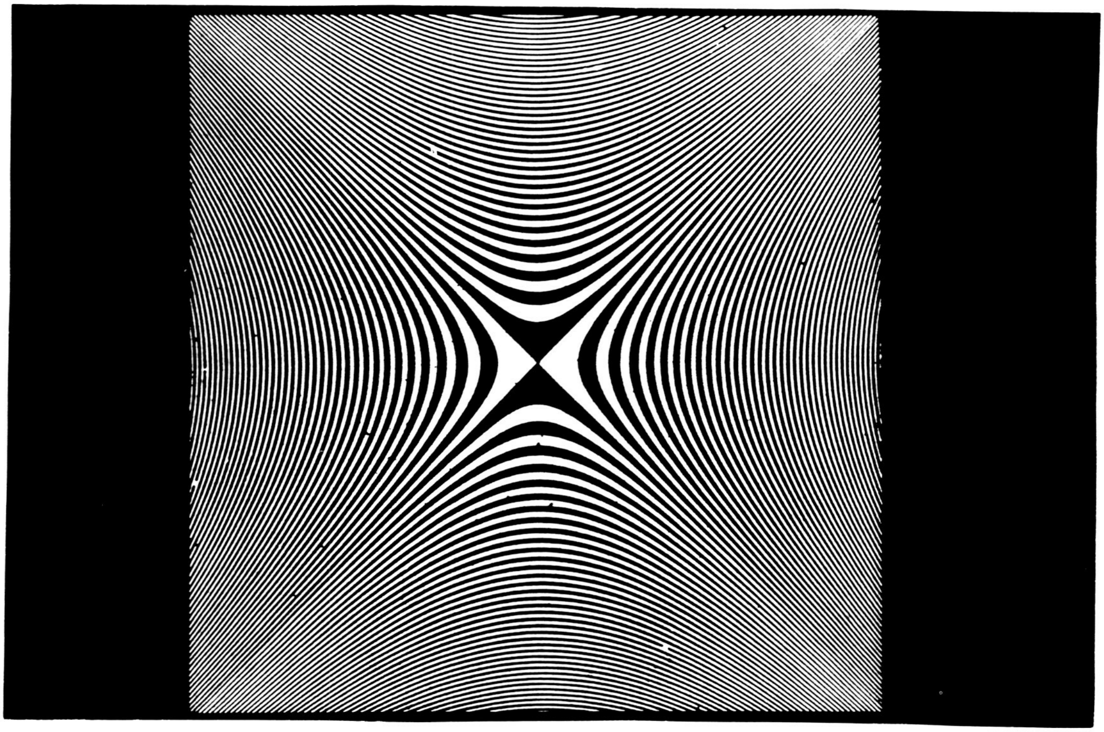

Figure I-7. Drawing of a hyperbolic grille. The minimum step defines the resolution while the luminosity is determined by the entire transmitting surface of the grille.

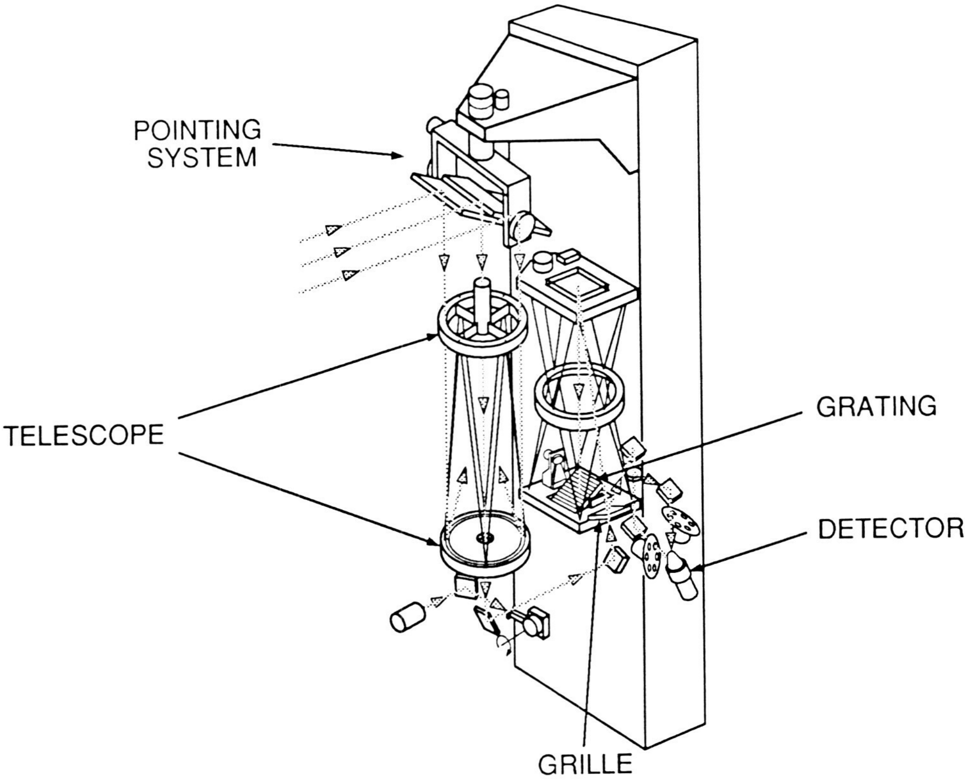

Figure I-8. Optical diagram of the grille spectrometer.

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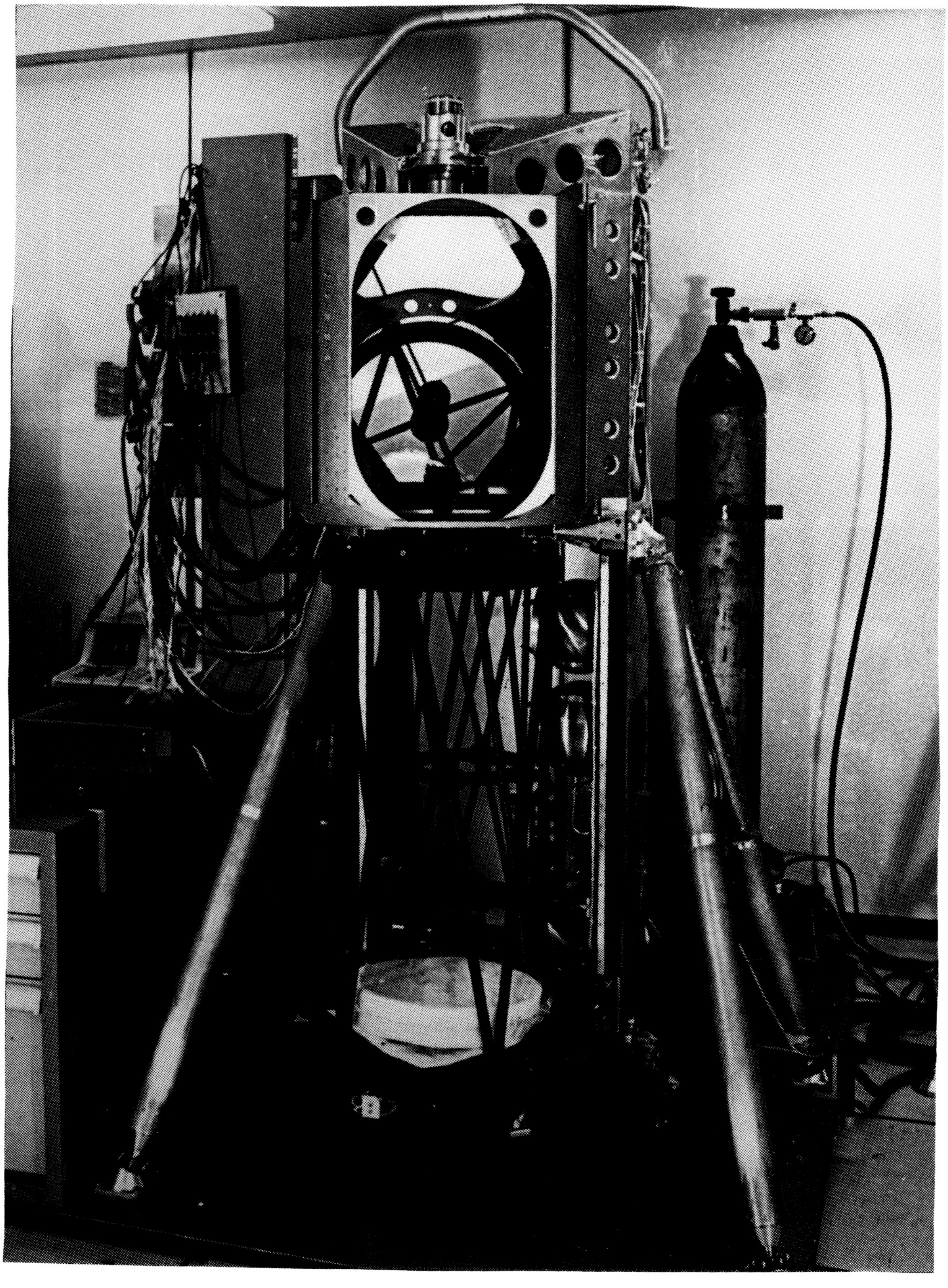

Figure I-9. The grille spectrometer photographed at the ETCA Company in Charleroi, Belgium before final testing at CNES (Toulouse, France), ERNO (Bremen, Germany), and integration of the Spacelab 1 payload at the Kennedy Space Center.