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A sample performance of the grille spectrometer aboard Spacelab

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FOREWORD

This is a draft of a short article which will be part of a special issue of the "Science" journal to be dedicated to the Spacelab One mission.

AVANT-PROPOS

Ce texte sera proposé pour un numéro spécial de la revue "Science" consacré à la première mission Spacelab.

VOORWOORD

Deze tekst zal deel uitmaken van een speciaal nummer van het tijdschrift "Science" dat zal gewijd worden aan de eerste vlucht van Spacelab.

VORWORT

Dieser Text wird vorgestellt werden für eine Spezialausgabe der Zeitschrift "Science", geschrieben für den erten Flug Spacelabs.

A SAMPLE PERFORMANCE OF THE GRILLE SPECTROMETER ABOARD SPACELAB

by

M.-P. LEMAITRE*, J. LAURENT*, J. BESSON*, A. GIRARD*,
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Abstract

This short article on preliminary results of the grille spectrometer flown on the Spacelab One mission intends only to show the quality of the obtained spectral data. Among ten trace species observed in the atmosphere, methane has been choosen for the spectacular aspect of Q branch of the intense ν_3 band. Other molecules, as well as the atmospheric significance of the results, will be discussed elsewhere.

Résumé

Ce court article sur les résultats préliminaires du spectromètre à grille embarqué sur la première mission Spacelab se limite à montrer la qualité des données spectrales obtenues. Parmi dix constituants minoritaires observés dans l'atmosphère, le méthane a été choisi pour l'aspect spectaculaire de la branche Q de sa bande intense ν_3. D'autres molécules, ainsi que la signification atmosphérique des résultats, seront discutés ailleurs.

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Samenvatting

Dit korte artikel over voorlopige resultaten van de raster-spectrometer tijdens de eerste vlucht van Spacelab wil enkel de kwaliteit van de bekomen spectra aantonen. Onder de tien minoriteits-constituenten waargenomen in de atmosfeer werd methaan uitgekozen omwille van het spectaculair aspect van de Q-tak van zijn ν_3 band. De andere molecules en de betekenis van de resultaten voor de atmosfeer zullen elders besproken worden.

Zusammenfassung

Diese kurze Artikel über den provisorischen Resultaten vom Grille-Spektrometer mitgeführt während des ersten Fluges Spacelabs, beschränkt sich die Qualität der bekommen spektralen Daten nach zu weisen. Zwischen 10 Minoritätsbestandteile beobacht in der Atmosphäre, wurde das Methan gewählt für den auffallenden Aspekt des Q-Zweiges seines intensiven ν_3 Bandes. Andere Molekülen wie auch die atmosphärische Bedeutung der Resultaten, werden anderswo besprochen werden.

Infrared absorption spectrometry of the atmosphere using the sun as a light source at sunrise or sunset has, for the past 15 years, proven to be a powerfull method for studying vertical distributions of trace species (1). The largest possible amount of light absorbing molecules is so observed on the optical path tangent to the earth surface at various altitudes allowing the deconvolution of very low concentrations versus altitude. Much information has already been gathered through this method from high altitude platforms such as aircraft and balloon. An orbiting platform provides access to higher altitudes and to geographic locations leading to a nearly global coverage in various seasons of great interest for geophysical purposes. While on previously used platforms the earth rotation provides the altitude scan at sunrise or at sunset it is achieved at a much higher rate from orbit by the spacecraft motion itself requiring a fast spectral scanning, thus high throughput instrument.

The choice of instruments satisfying these requirements is rather limited (2). The grille spectrometer (3) is well adapted as eventually demonstrated by the first Spacelab flight. A single grille mounting, acting as entrance and exit light ports for the spectrometer was selected. The instrumentation description and operation (4) can be summarized as follows.

- Optics : a two axis steerable frontal plane mirror tracks the sun in front of the 30 cm aperture, 6 meters focal length Cassegrain telescope imaging the sun on the grille which intercepts a square portion of the solar image (8 arc minutes). The spectrometer uses a 59 grooves per mm grating illuminated by a parabolic mirror oscillating at 436 Hz with an amplitude of ± 20 arc seconds, its average position being controlled within 5 arc seconds. The exit light flux, split in two beams, reaches through interference filters the two detectors (InSb, 2.5 to 5.5 μm and HgCdTe, 2.5 to 10.5 μm). The spectral resolving power was 1.3×10^4 (instrumental line width at half peak height).

- Electronics : the electronics in the Spacelab module interfaces the pallet instrument with the Command and Data Management Subsystem (CDMS) and the high rate multiplexer (HRM). Using data originating from the orbiter (time, attitude, orbit parameters) and from Spacelab (timeline, on board and ground commands, sun ephemeris) it manages the execution of the stored as well as in-flight updated measurement programs. The electronics on the pallet instrument provides the electro-mechanical control and the signal detection and formating functions. The main role of the crew for this flight was to check the instrument wavelength calibration, spectral resolution and sensitivity by monitoring the display of a calibration spectrum generated inside the spectrometer by means of a calibration lamp shining through a gas cell. The mission specialist in charge of this task performed a wavelength alignment 12 hours after launch.

The pallet instrumentation weighting 122.8 kg, stood 1.8 meter high, occupying 0.7 square meter. The weight of the module equipment was 15 kg. The data rate in operation was 51.6 kbits per second.

Due to the multidisciplinary philosophy of Spacelab One only 25 solar occultation runs were allocated. Due to the "launch window time-season" combination the runs were scheduled in the first days of the mission since the full orbit was in sunlight during the last five days. Performances took place at sunset in the northern hemisphere at latitudes ranging from 56° to 30°. The sunrise observations took place at high southern latitudes providing information pertinent to inter-hemispheric-seasonal variations of the observed atmospheric species; thermospheric CO, for instance.

In addition to solar infrared absorption features, many of which had not been observed before, telluric spectral absorption due to CO and CO_2 spectra were observed at thermospheric tangent heights (H) (H > 85 km); O_3, H_2O, CH_4 and N_2O added their contributions in the mesosphere (H > 50 km) while the strongly coupled molecules NO - NO_2 and HCl - HF were simultaneously observed by pairs in the same stratospheric air parcels.

The scope of this article being limited and the data interpretation still being a preliminary state, we will present only the first results on methane in the mesosphere, where it had never been measured before.

Since the only atmospheric methane source is at ground level, it has been used by atmospheric modelers as a vertical transport indicator. Its increasingly efficient oxidation at higher altitudes in the stratosphere leads to a continuous reduction of its volume concentration with altitude. CH_4 absorptions were observed from Spacelab in three sunset runs at two different spectral intervals in the 3.3 μm ν_3 fundamental band. A spectrum of most of its Q branch, recorded in 2 seconds while the line of sight to the sun center was grazing at 26 km altitude above the geoid's sea surface is shown in Figure 1a. Figure 1b shows a synthetic spectrum of the same spectral region computed using the results of the inversion of the measured absorptions.

Figure 2a shows the measured equivalent width of the absorption feature at 3017.8 cm^{-1}. It is essentially due to five absorption lines which parameters (5) have been used to deduce the vertical distribution shown on figure 2b. The verification of this result using synthetic spectra of the whole region confirms it except below about 30 km where it leads to slightly lower values, this discrepancy could originate from the saturation of these lines at very low altitudes. Figure 2c shows the equivalent widths versus altitude of the CH_4 manifold centered at 2979 cm^{-1} and figure 2d shows the corresponding inverted data and allows the comparison between the volume concentration profiles deduced in two wavelength ranges.

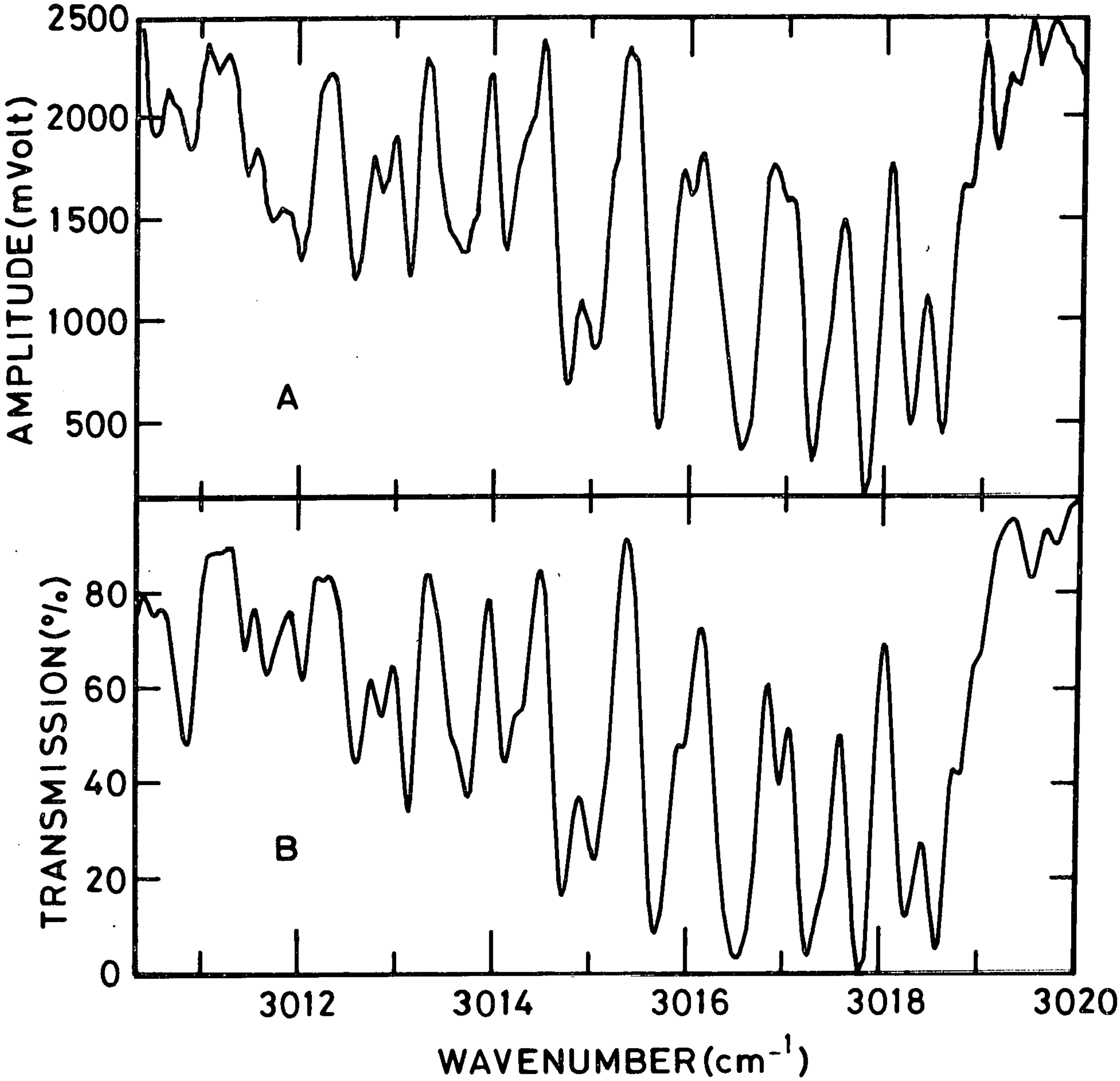

Figure 1 A. Spectrum of the CH_4 Q branch of the 3.3 μm band recorded in 2 seconds on December 3, 1983 at 3 hours, 47 minutes and 49 seconds G.M.T. The signal amplitude is shown versus wavenumbers in cm^{-1}. B. Synthetic spectrum of the same absorption feature computed using the AFGL molecular parameters (5) and the CH_4 vertical distribution deduced from the spectra themselves.

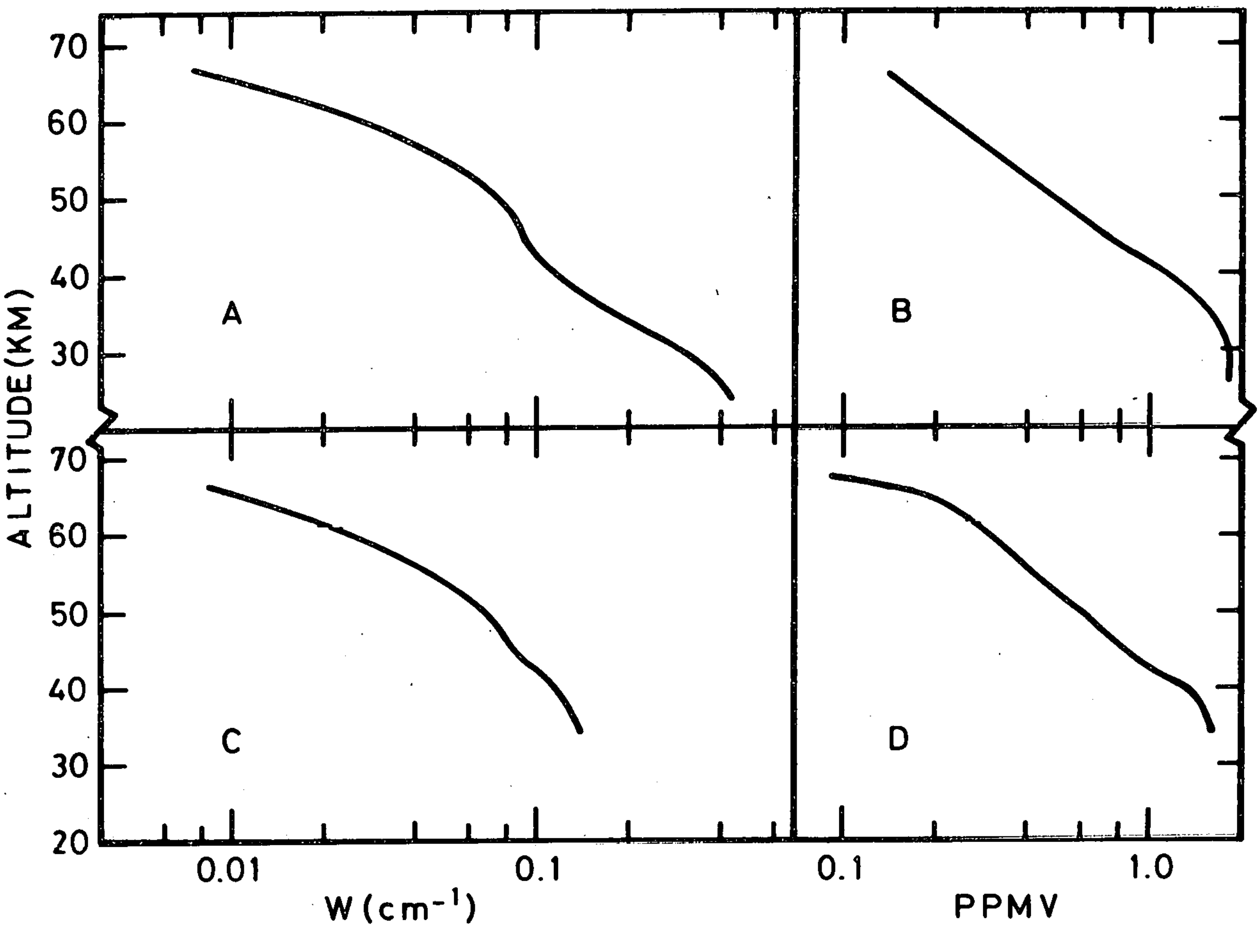

Figure 2 A : Equivalent width, W, in cm^{-1} of the absorption feature at $3017.8\ cm^{-1}$ versus tangent altitude (km) of the line of sight to the sun center. B. Inverted CH_4 volume mixing ratio computed on the basis of the U.S. standard atmosphere (1966) for the atmospheric temperature and total number density profile versus altitude. C. Equivalent width of the $2979\ cm^{-1}$ CH_4 manifold versus tangent altitude. D. Deduced CH_4 vertical distribution.

These measurements taken at low latitudes agree with the previous data (6) reported for the 25° to 35° latitudes band in the stratosphere. At higher altitudes, where the chemical oxidation processes become less efficient an other destruction process must play a role in order to explain the mesospheric concentration decrease with altitude. The photodissociation of CH_4, in particular by the solar Lyman α radiation plays a dominant role in modeling this aspect as will be described elsewhere.

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