Millimetric Photometry of Planets on La Silla

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Most people think of the ESO La Silla observatory as a place that is exclusively dedicated to optical (and infrared) observations. Now, however, what can perhaps best be termed as very short wavelength radio *observations have been carried out at the 3.6 m telescope by a group of French specialists, headed by Dr. Régis Courtin and based at the CNRS Laboratoire de Physique Stellaire et Planétaire (LPSP), Verrières-le-Buisson in France. Although the weather was somewhat uncooperative, good observations were obtained in four wavebands (0.7–4.0 mm) of Venus, Jupiter and Saturn. This is their preliminary report.*

Planetary Atmospheres

During the last decade, far-infrared photometry of planets has become a most powerful tool in the determination of their atmospheric thermal structures. Because of the rather strong variation of the opacity of their gaseous components with respect to wavelength, these atmospheres can be sounded in the altitude range by achieving either spectral measurements or multiband photometric observations. For instance, the knowledge of the thermal structure at high pressure levels in the giant planets is of great importance since it leads to an estimate of the internal source of power which constitutes one of the essential parameters in the modelling of solar system evolution. Furthermore, once the temperature profile is known, it becomes possible to investigate the abundances of minor constituents such as ammonia, phosphine or water.

The millimetric and submillimetric spectral ranges are particularly suitable for the sounding of deep atmospheric layers since the opacity has a trend to decrease at these wavelengths.

In the case of the outer planets, the dominant opacity is the result of absorption by molecular hydrogen, except for Jupiter where non-condensed ammonia is the main absorber beyond 40 microns. What concerns Venus, the atmospheric opacity is dominated by the properties of sulfuric acid droplets mixed with water vapour. For the giant planets, the maximum of the weighting functions calculated at $\lambda = 1$ mm locates between 2 and 3 atm, within the convective regions which extend below the tropopause (minimum temperature layer). In Venus, the sounded zone corresponds to the bottom of the dense cloud cover composed of sulfuric acid and water.

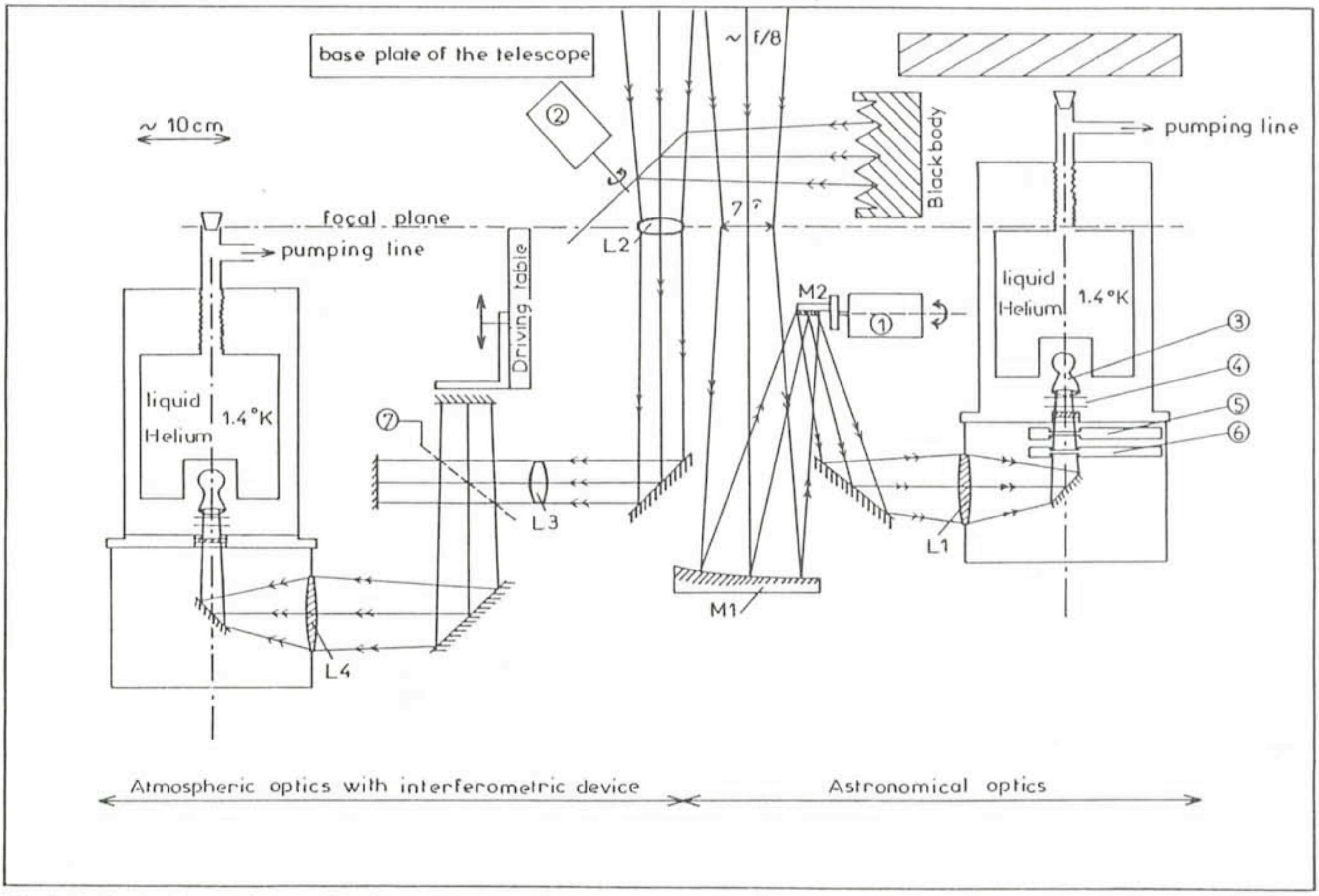

Fig. 1: *Optical schema of the millimeter photometer with sky emission spectral measurement. ① Scanner motor for sky modulation; ② Chopper; ③ Detector with light-cone; ④ Cold filters; ⑤ & ⑥ Filter wheels; ⑦ Beam splitter; M1 Parabolic mirror; M2 Wobbling mirror for sky modulation; L1 & L4 Quartz lenses; L2 & L3 TPX lenses.*

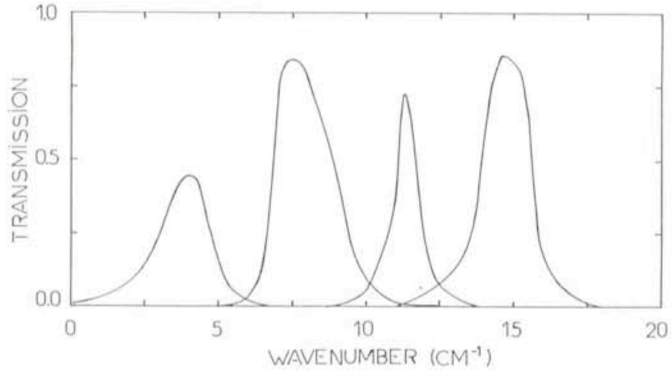

Fig. 2: *Spectral shape of the band-pass filters used for astronomical sources.*

Instrumentation and Observations

The fundamental problem in far-infrared photometry is to eliminate the intense atmospheric thermal emission superposed on the radiation coming from any astronomical source. Moreover, in the submillimetric and millimetric wavelength range, the presence of strong absorption bands of water vapour severely restrains the spectral ranges accessible from the ground and also produces large fluctuations of transmission related to meteorological conditions.

For these reasons, our instrument is designed as a dual-channel system, one channel being devoted to the measurement of astronomical fluxes using a sky modulation technique, the second one being restricted to the spectral monitoring of the sky emission modulated with the radiation of a blackbody source. The schematic optical design of the instrument, operating at the Cassegrain focus (f/8), is shown in figure 1. Focal plane sky chopping is achieved through the wobbling mirror M2 at a frequency of 20 Hz. The field of view in the astronomical channel is 7 arcmin. Spectral analysis of sky emission is made with a Michelson interferometer using a thin metallic grid as a beam splitter. Both detectors are composite Germanium bolometers (developed at LPSP) cooled by a liquid Helium bath at 1.4°K.

At the altitude of the La Silla Observatory, four atmospheric transmission windows can be utilized between 700 microns and 4 mm. The shapes of the corresponding

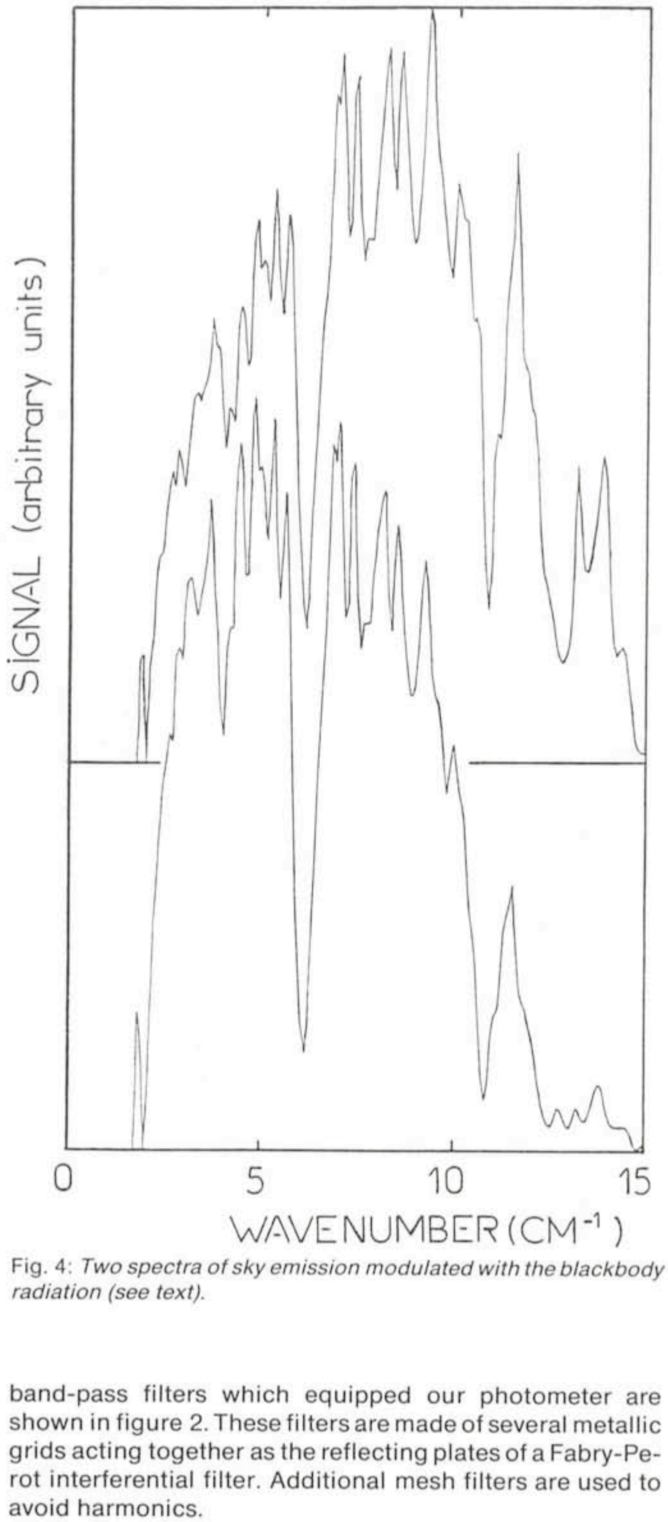

Fig. 4: *Two spectra of sky emission modulated with the blackbody radiation (see text).*

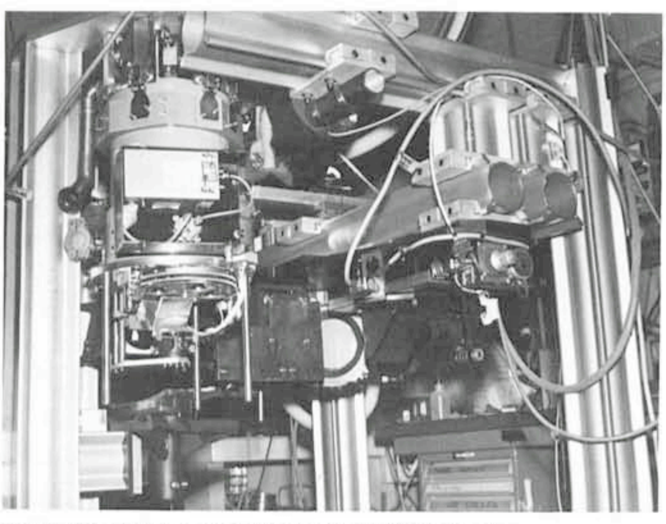

Fig. 3: *The instrument being tested in the laboratory.*

band-pass filters which equipped our photometer are shown in figure 2. These filters are made of several metallic grids acting together as the reflecting plates of a Fabry-Perot interferential filter. Additional mesh filters are used to avoid harmonics.

Some of the elements represented in figure 1 or described in the text can be seen on the photograph of figure 3: Parabolic mirror M1 (lower left), Astronomical photometer with preamplifier and filter wheels (left), Blackbody source and chopper (top), Interferometer with driving table and beam splitter (centre).

The observations were carried out with the 3.6 m telescope on La Silla at the beginning of March 1979. The meteorological conditions were very good during the few days preceding our run and on the first 24 hours of our observing period. Unfortunately, the water vapour content in the atmosphere steadily increased from the second day and consequently the average transmissions in the four filters dramatically dropped. This effect is much more pronounced in the two bands at shorter wavelengths ($\bar{\lambda}$ = 730 and 860 microns) for which the atmospheric zenithal transmissions varied from about 0.35 and 0.70 to about 0.03 and 0.15. This may be illustrated by the two spectra shown in figure 4. These curves represent the variation of the following quantity:

$$S_\nu = K\,[T_A(\tau_\nu)\,e^{-\tau\nu} + (T_{BB} - T_A(\tau_\nu))]$$

where K is a constant,
$T_A(\tau_\nu)$ is the emission temperature of the sky depending on the optical depth τ_ν, and
T_{BB} is the blackbody temperature.

Thus, after the appropriate baseline correction and with the assumption of the atmospheric thermal profile, these spectra give access to the transmission. The upper spectrum was recorded on the first night at zenith, whereas the lower one corresponds to an air mass m = 1.29 at the end of the second night. The drastic changes seen between the spectra arise from both the changes in air mass and in the humidity content since the relative humidity at the ground level varied from 25 % to 52 % between the measurements.

Despite the unfavourable climatic conditions, we have acquired numerous high signal-to-noise ratio measurements of the fluxes of Venus, Jupiter and Saturn in the four bands. Uranus and Neptune, which are much fainter sources, hardly showed up in the 7–9 cm^{-1} filter.

Because of the simultaneous monitoring of sky emission in the direction of each source, and the intrinsic quality of the raw data, an improved precision on short millimetric brightness temperatures of the bright planets can be expected from these observations. This is of great interest in relation with the present and future space probe missions to Jupiter and Saturn (Voyager missions) and to Venus (Venera project) which will provide accurate measurements of the fluxes in the intermediate and near infrared (from 2 to 50 microns for Voyager and from 70 to 200 microns for Venera). The exploration of such a wide spectral range is obviously of great benefit to our knowledge of the atmospheric structures of these planets.

Simultaneous Spectroscopic and Polarimetric Observations of Be Stars

K. Metz and G. Pöllitsch

Some of the most enigmatic objects in our galaxy are the Be stars. They display a remarkable variety of features, ranging from variable emission lines to high degrees of polarization. How do they look like? Drs. Klaus Metz and Gerd Pöllitsch from the München Institute for Astronomy and Astrophysics visited La Silla in 1977 and this year and observed southern Be stars. They do not provide the final answer to the problem, but they here report interesting new results.

In 1866 A. Secchi reported that the stars γ Cassiopeae and β Lyrae showed very brilliant spectra which seemed to be inverse to those of other blue stars. This was the first discovery of emission in stellar spectra, but almost twenty years had to pass until E. C. Pickering started an objective-prism survey in that field. In 1911, R. H. Curtiss followed with the first observations and classification of emission-line stars. As a consequence of his work, the International Astronomical Union introduced the name *Be star* in 1922 at its first General Assembly.

More than half a century has now passed and many famous astronomers, among them a surprisingly high number of women, have been working on the problems of Be and shell stars. During the last years they extended the classical observations to the far UV and IR using high-speed photometers and polarimeters as well as spectral line scanners.

The result of these efforts is that none of the various models proposed for Be stars can now satisfy all different aspects which have been brought in by the new observations.

This is due not only to difficulties in understanding the physics of extended shells, but also to the fact that many Be stars act like prima donnas: Sometimes they behave eruptively. Or they can, nobody knows why and when, completely lose their shell and then look like a normal B star. They have proven to be variable in spectrum and polarization within a relatively short time or even within hours. For an astronomer it is really fascinating to look at this performance and to see how it is developing with time (figs. 1, 3).

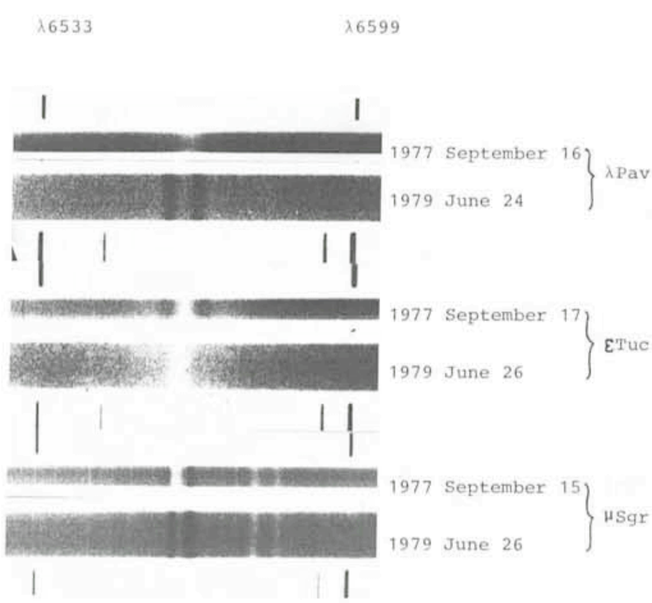

Fig. 1: *Hα line variation of three Be stars. The spectra have been taken with the ESO 1.5 m telescope, coudé, 12.3 Å/mm, 127-04 and IIIa-F emulsion respectively.*