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A Two Channel Rocket Photometer for 5577 Å OI Nightglow Measurements

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Abstract. A Description of a Two Channel Multiplex-Type Photometer for Small Rockets is given.[1]

Key words: Winteranomaly – OI 5577 Å Nightglow – Two channel rocket photometer.

1. Introduction

Rocket measurements of the atomic oxygen green line emission during nighttime showed a considerable variability of the emission layer in intensity, half width and height above sea level. Summaries were made by Greer and Best, 1967; Offermann and Drescher, 1973; Shefov and Kropotkina, 1975. Purpose of the rocket experiment was to detect variations in the nighttime emission layer, to correlate them with ground based observations of the spacial and temporal variations of the total green light intensity and to examine correlations to other parameters as the daytime winter anomaly events.

Further it was intended to calculate nighttime oxygen height profiles from the measured volume emission rate by the Chapman and/or the Barth excitation mechanism and to compare these calculated profiles with the daytime mass-spectrometric measurements of atomic oxygen.

The last comparison mentioned above can only be done with all the uncertainties in the knowledge of the excitation processes of the 5577 Å nightglow as discussed most recently by Slanger and Black, 1977.

The OI photometer had to be flown on a Skua IV rocket, as used by the Max Planck Institut für Aeronomie. The photometer had to be small, cheap, and rather rugged. The basic idea was to use two optical channels,

[1] Tests and calibration are described, and preliminary data of 5 flights are communicated

one direct and one chopped, and to give both signals simultaneously on the same photomultiplier, thus needing only one unit for reception and processing of the signal.

The use of two optical channels was though to be essential to determine background and its variations as caused by continuum emission and rocket coning. Both optical channels are upward-looking, parallel to the rocket axis with the same field of view.

2. Instrument Description

Both optical channels consist of field of view defining baffling entrace apertures A, one inch diameter interference filters I and focusing lenses as shown in Figure 1. In front of the filters are field of view widening lenses to reduce the importance of single stars in the background radiation. The etendue of each channel is 0.04 cm^2 steradian. The upper ray path is reflected by two mirrors, 1 and 2, nearly on the same region of the multiplier-photocathode as illuminated by the lower channel.

The upper channel is chopped by a hollow, sideward semiopen cylinder C. This cylinder is driven by a micromotor with gear M at a chopping frequency of 1.5 cps.

The photomultiplier P and the micromotor M are mounted each within cylinders of aluminum. The HV power supply and the single photon counter-discriminator are mounted alongside the two aluminum cylinders and not shown in Figure 1. All the other electrical system is contained within the cylindrical box E. The optical part of the photometer with the deflecting mirrors, and the electrical part with the chopping cylinder are each mounted separately and directly into the nosecone. This was done in a vacuum tight way to avoid high voltage break down during flight.

Mounted in front of the photometer is a split nose cone which was separated by a pyroelectric cablecutter in 70–75 km height. The optics had to be protected against oil and dust from the cablecutter.

The photomultiplier was an EMR 541 with high temperature bialkali photocathode, operated at $5 \cdot 10^6$ gain. High voltage power supply and pulse amplifier discriminator were from Spacom Electronics. All other electronic system was developed at the DFVLR Institut für Nachrichtentechnik. The TTL compatible output signal of the pulse amplifier is fed into a 16 bit binary counter with reset and parallel data transfer into a shift register every 32 ms. After impedance conversion and frequency filtering the signal is transmitted as 16 bit binary words in PCM format 32 times per second on FM-FM telemetry.

One data frame consists of 128 words, the last word being a synchronization signal. Bit synchronization is realized by use of a modified RZ-Code.

The following housekeeping values were telemetered as time multiplexed analog signal to the ground station: The pressure measured within the pressurized part of the photometer in the range from 20 to 800 Torr, the temperature in the vicinity of the photocathode, the temperature of one of the interference filters, each with a dynamic range from 10–70° C. The position of the chopper

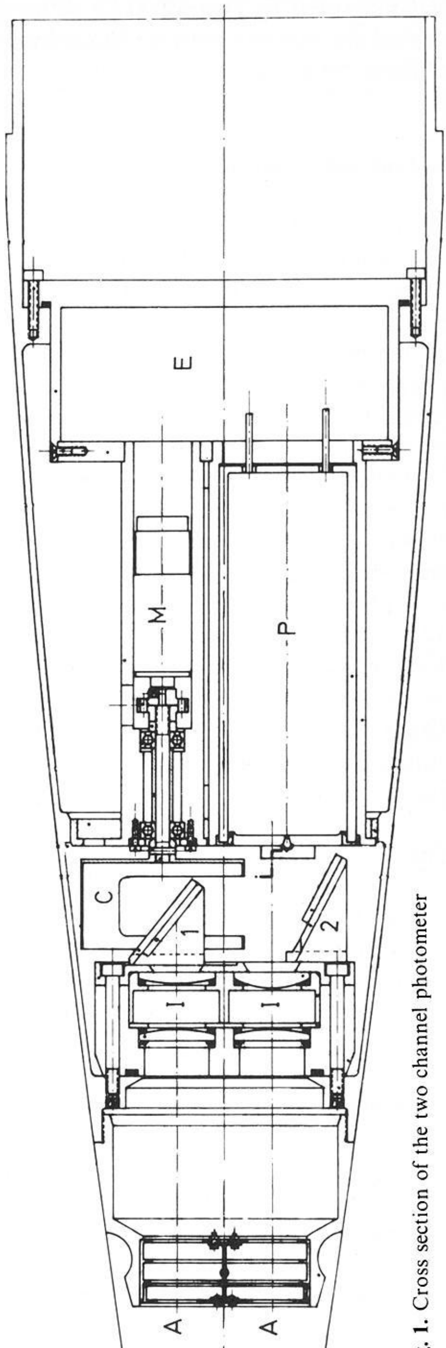

Fig. 1. Cross section of the two channel photometer

was measured by an optical IR reflex sensor and two small mirrors of different size on the cylinder botton. This signal was telemetered in realtime on a FM-FM channel of its own.

3. Test and Calibration

All testing of components and the whole instrument was done at DFVLR. Instrument tests have been made for vibration, temperature and vacuum. The chopper mechanism had been qualified separately before. Interference filters had been tested for absolute transmission curve and their relative dependency on temperature and angle of incidence. Photomultipliers have been tested for quantum-efficiency, gain, dark current and noise in signal. In comparison with such measurements made for earlier missions at DFVLR no severe discrepancies between producers data and our measurements were found this time.

Optimal performance of the multipliers in pulse counting mode had been found at about 60–70% pulse counting efficiency as compared to the dc-signal. Higher values of the pulse counting efficiency generated excessive noise in signal and strongly enhanced dark counting rates.

Calibration of the instrument was performed over two decades of intensity by using two different calibrated tungsten ribbon lamps projected by a focusing lens upon a Barium-sulphate white standard. Further we used neutral density metal filters and a small bandwidth 5577 Å filter for emission line simulation. The characteristics of the filters had been measured before and were crosschecked during the photometer calibration process. The tungsten ribbon lamps have also been measured with a calibrated detector and controlled interference filters.

The two channels of each photometer were calibrated separately and together. The characteristic curve of intensity with time for the chopped operation of the photometer was determined at low chopper speed with a digital to analog converter for every photometer.

During calibrations lasting for two months, the photometers showed good stability in the ratio of the two channels but up to more than 5% drift in total responsivity, different for the individual instruments.

4. Preliminary Results

To allow van Rhijn correction of the photometer data, a simple, small horizon sensor was developed for the BV payload at DFVLR-Institut für Nachrichtentechnik in cooperation with Bonn university. The horizon sensor consisted of a 1″ germanium lens, a Molectron 4 mm^2 pyroelectric detector followed by a FET-amplifier in source follower connection. The field of view of the sensor was ± 20 mrad.

The first OI photometer was flown on January 4, 1976 at 22.58 U.T. The apogee of 95.8 km was to low according to a weak rocket motor. The rocket did not penetrate the emission layer. As this flight showed excessive payload heating the interference filters in the other photometers were interchanged so

Table 1.

Date	U.T.	Apogee.	$\Delta\lambda$5577 Å	background		horizon sensor applied
				λ	$\Delta\lambda$	
4.1.76	22.58	95.8	20.3	5468	44	+
21.1.76	22.30	109.1	20.1	5641	25	−
5.2.76	22.30	103.1	22.1	5468	44	+
4.5.76	21.30	109.3	23.2	5645	21	−
5.5.76	21.30	104.4	19.8	5644	21	+

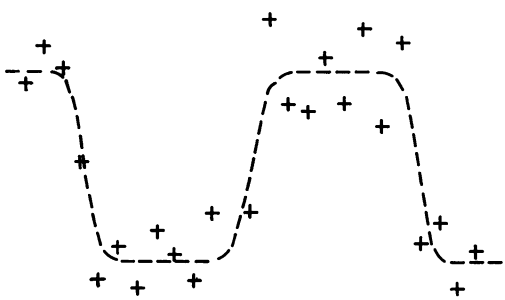

Fig. 2. Intensity versus time on downleg below the emission layer at January 21, 1976. The dotted curve is the characteristic curve of the chopped signal as determined in the calibration process

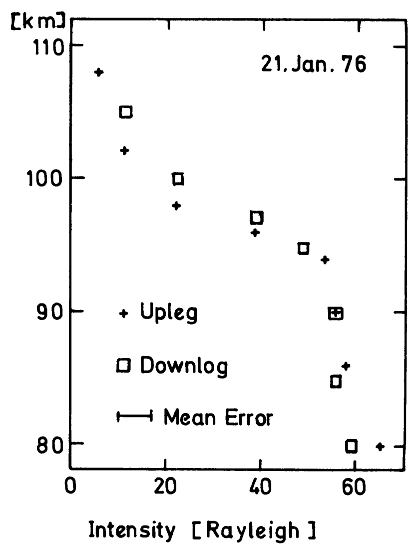

Fig. 3. Relative intensity for upleg and downleg of the flight of January 21, 1976 as determined in a handprocedure by use of half of the data rate and without correction for background variation. The probable error is nearly the same for all data points shown

that the 5577 Å filter was incorporated in the chopped channel and the background filter in the direct channel. Before and after this filter interchange the photometers were calibrated with a radioactivated phosphor to determine the new calibration factors. These measured values were in accordance with the old calibration values and our measured filter and mirror characteristics.

The second flight was in the night of January 21, 1976, at 22.20 U.T. A better rocket motor and lack of the horizon sensor brought an apogee of 109.1 km. Data on all launches are given in the following table.

In all five launches no technical failures occurred. The data were rather noisy according to the high payload temperatures. An example is given in Figure 2. Digital tapes have been constructed from the analog telemetry data. A computer program to minimize noise effects and to determine background signal variations caused by rocket attitude variations is not yet finished. So only some handdata can be presented in Figure 3.

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