A SPECTROSCOPIC SEARCH FOR OSCILLATIONS IN THE 769.9 nm POTASSIUM LINE OF PROCYON

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ABSTRACT. A double magneto optical filter attached to the Cassegrain focus of the 1.9 m reflector of the South African Astronomical Observatory was used to observe Procyon in the 769.9 nm line of potassium during all clear hours of six nights. Velocity calibration was provided by the rotational and orbital velocity changes of the observer as well as by a continuous magnetic modulation.

1. INTRODUCTION

The Birmingham spectroscopic work was initiated in 1969 with the aim of using optical resonance methods, developed some ten years earlier(1), to detect planetary companions of stars. It was diverted in 1971 to studies of the global Sun in order to demonstrate that Fraunhofer absorption lines, as well as the spectrometer, were stable at the ms^{-1} level. At that time it was realised that minute global solar oscillations, analogous to the gigantic stellar pulsations of variable stars, might make possible seismology of the solar interior, including the measurement of rotational splitting analogous to that detected in the Earth's modes a decade earlier(2). This work achieved its first successes in 1975(3) and in 1979(4) with the discoveries of slow and fast global solar oscillations and led to suggestions of extensions to main sequence stars via spectroscopic and photometric means(5). More recently other investigations(6,7) attempted to search for small stellar oscillations.

This short note reports on our first attempt to measure the Fourier spectrum of velocity oscillations of a bright star, Procyon, to serve as a test object for our apparatus. We report on the initial use of a double magneto optical filter, originally developed by Cimino, Cacciani and Sopranzi(8), and describe means of calibrating the velocity sensitivity throughout the observations using continuous magnetic scanning. Preliminary results pertaining to the detection of planetary companions and of small stellar oscillations are discussed.

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2. THE SPECTROMETER AND OBSERVATIONS

Figure 1 shows a schematic outline of the spectrometer. It was attached to the Cassegrain focus of the 1.9 m reflector at the South African Astronomical Observatory, Sutherland and observations were made of Procyon during all possible times between the 22nd and the 27th January 1986.

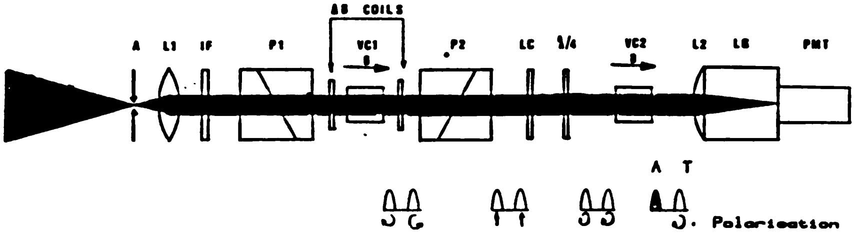

Figure 1. Schematic diagram of spectrometer.

The f/18 beam passes through an aperture (A) of typically 30 seconds of arc field of view, to a 1.4 nm interference filter (IF) carefully angle tuned and temperature stabilised for peak transmission at 769.9 nm. The beam then enters the first stage of the magneto-optical filter (MOF) consisting of crossed calcite polarisers P_1 and P_2 either side of a vapour cell VC1 in a longitudinal field of 0.16T provided by a permanent magnet. The magnetic field is square wave modulated by ±3.44 mT by reversing a constant current through a pair of coils (ΔB coils) every eight seconds. The output of the first MOF passes through a liquid crystal (LC) and quarter wave plate (λ/4) combination making it possible to switch between the two circular polarisation components. The beam is then incident on the second MOF. As the modulator is switched, one or other of the Zeeman components is absorbed. The transmitted beam is focussed onto a cooled photomultiplier tube with a dark counting rate of ~5 counts s^{-1} and a quantum efficiency of 17%. The pulses pass to a scaling system controlled by a microcomputer and are recorded on floppy discs.

Such a double MOF provides means of measuring the intensities in both wings of the spectral line making it possible to calibrate the spectrometer in terms of the diurnal variation of velocity of the observer.

The additional magnetic modulation, described separately[9], provides a continuous inter-calibration of the sensitivity which is then linked to the diurnal calibration.

In order to check the operation of the spectrometer it was used with a variety of light sources the output of which could be fed to it via a 25 metre long 600 μm silica optical fibre to the input aperture. During sunny conditions a small coelostat supplied sunlight to the fibre and the diurnal variation together with the offsets[3], could be measured. When the weather was poor, day or night, a spectral lamp or a white light source with an artificial Fraunhofer absorption line provided means of checking sensitivity and stability.

The throughput of the spectrometer in a bandwidth of 3.7 pm is 1.5%. The sensitivity is 6700 ms^{-1} for unit ratio of the normalised intensities in the red and blue wings of the solar Fraunhofer line ((BLUE-RED)/(BLUE+RED)). The stability of the solar gravitational red shift is well within 3 ms^{-1}. It is difficult to be more precise as there are, so far, few overlapping days when comparisons can be made with resonant scattering spectrometers, and also because of the presence of variations of the gravitational red shift over 13 days(10).

3. RESULTS

Figure 2 shows the data of a test run on the Sun viewed as a star.

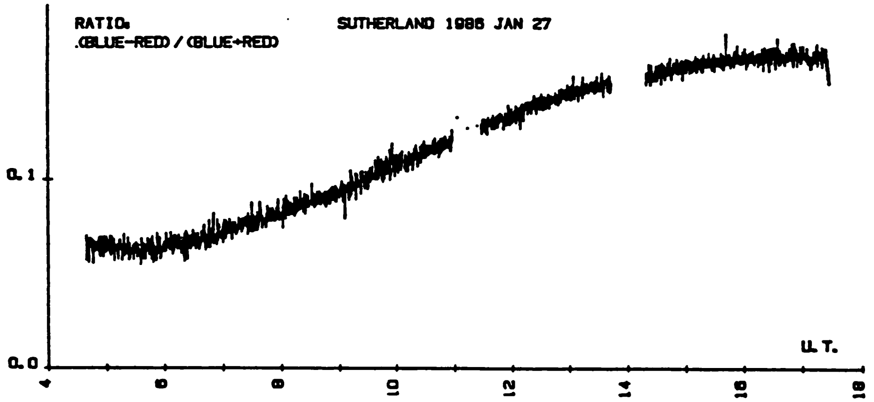

Figure 2. Observations of Sun seen as a star. The abscissa is in hours, U.T., the ordinate shows the normalised ratios of intensitiies in the blue and red wings of the spectral line.

Figure 3 shows the data measurements on the artificial Fraunhofer absorption lines.

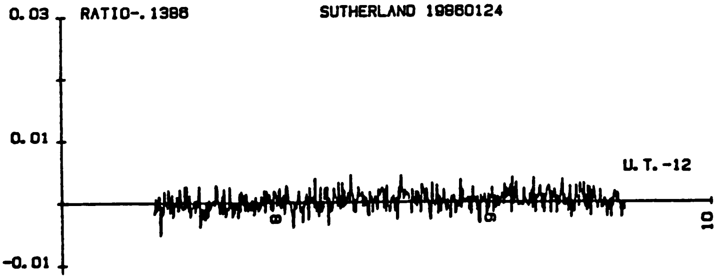

Figure 3 The normalised ratio is shown for a circularly polarised beam of white light viewed through a potassium vapour cell in a longitudinal magnetic field.

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Figure 4 shows the data of the observations on Procyon. During this night the vector sum of the radial velocity of Procyon relative to the solar system and the various orbital and spin velocities of the observer passed through zero. Such a null observation enables the radial velocity of Procyon to be measured with high precision. An analysis[11] yields a radial velocity, at that time, of -3.923 ± 0.015 Kms^{-1}.

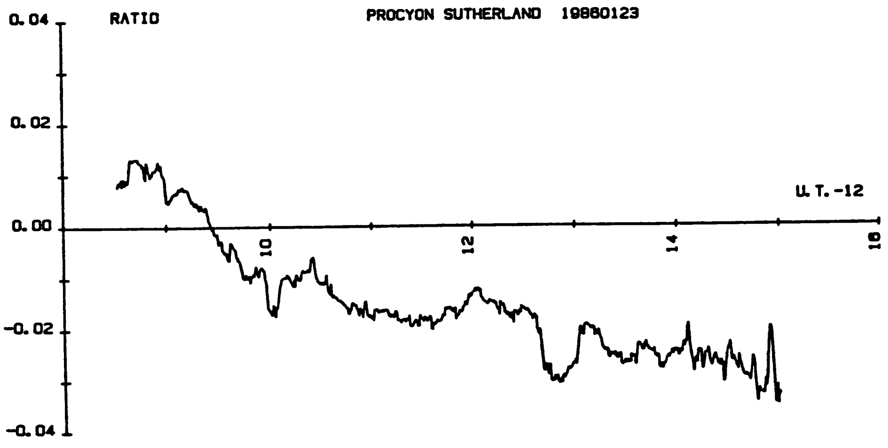

Figure 4. Observations of Procyon

A power spectrum of the best data shows no significant peaks at the 30 ms^{-1} level. A large part of the noise is due to scintillation and transparency fluctuations. Fast switching, e.g. using a photo-elastic modulator, will reduce this noise considerably in the future.

4. CONCLUSIONS

We believe that with improvements in the sensitivity and throughput of the spectrometer, long observational runs in conjunction with large telescopes will make possible measurements to below 1 ms^{-1} in each channel of the Fourier spectrum. Such sensitivity may help detect planets circling stars as well as intrinsic stellar oscillations.

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