A NEW OBSERVING STATION AT THE PIC DU MIDI OBSERVATORY FOR THE ABSOLUTE CALIBRATION OF STELLAR RADIATION

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ABSTRACT. A new observing station designed for the absolute calibration of stellar and solar radiation has been built in the last few years at the Pic du Midi Observatory, France, at an elevation of 2860 meters. The stellar observations may begin next summer. The main improvements with respect to the calibration experiments carried out during the last decades are the use of a new type of blackbody source and an optical arrangement which is free of systematic errors in the measurements of the star/blackbody ratio. The aim of the experiment is to establish a set of homogeneous standards (about 10 B and A stars) covering the whole northern sky.

1. INTRODUCTION

In the last decade a number of fundamental stellar calibrations have been made by Oke and Schild (1970), Hayes (1970), Hayes, et al. (1975), Hayes and Latham (1975), Tüg, et al. (1977), Tüg (1979), Terez and Terez (1979), and Kharitonov, et al. (1980). Despite the number and quality of these studies, important discrepancies still exist. For example, in the case of Vega, discrepancies as high as 7-8 percent are found. These discrepant values appear too large when compared with the accuracy reached in metrological measurements and with the accuracy of stellar energy distributions that are desirable for astrophysical applications.

For these reasons and to take into account the long tradition of radiation measurement of the Institut d'Astrophysique, we decided to undertake a new experiment in stellar calibration. Our attempt was not to reproduce the preceding experiments, but to produce an instrumentation free from systematic errors. Moreover, our aim involved establishing a set of homogeneous standards covering the whole northern sky. Therefore, a permanent high altitude location was needed which would be available for at least several years. Such a location was found at the Pic du Midi Observatory (2860 m).

D. S. Hayes et al. (eds.), Calibration of Fundamental Stellar Quantities, 475–478.

In the following sections of this article, we shall describe the method and instrument used and estimate the precision that can be obtained in the measurement of absolute fluxes.

2. THE RADIATION SOURCE

2.1. Choice of the source.

In recent work blackbody sources operating at the melting point of a metal like copper (1358K) or platinum (2045K) have often been used. However, it seems that a better solution would be the use of a blackbody source with adjustable temperature. Of course, this requires the use of an accurate pyrometer. With such a source we can adjust the temperature according to the star brightness and the spectral range in order to obtain a star/blackbody ratio not too far from unity (e.g., between .1 and 10). For that reason we decided to build a new type of blackbody specifying that its temperature stability would not be worse than that of a blackbody operating at the melting point of a metal.

2.2 Description of the blackbody source.

The essential part is a graphite tube containing two main cavities, as seen in Fig. 1. The central cavity (a) produces the radiation to be observed through a quartz window. The cavity (b) emits radiation through another quartz window to a photodiode used for the temperature servo control. The tube is surrounded by heat insulating graphite felt and is heated by the Joule effect to 2500K in a vacuum (10^{-2}mm Hg) achieved by a pump operating continuously. To fulfill the blackbody conditions the temperature of the cavity (a) must be uniform and the hole must be small enough with respect to the internal area of the cavity. To achieve the first condition the profiles of the tube and of the surrounding felt are not cylindrical. They must be adjusted empirically until the central hole is no longer visible when the tube is hot. Then the gradient along

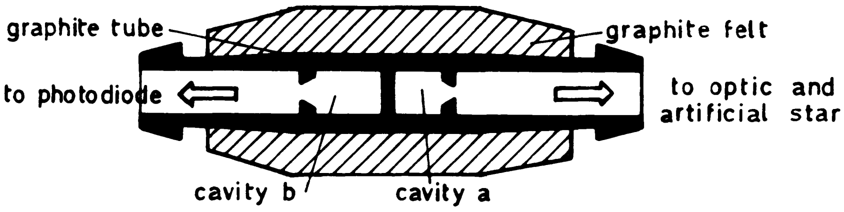

Fig.1. The blackbody source - The radiation from the cavity (a) is used for the absolute calibration. The one from the cavity (b) is used for the servo control of the temperature.

the cavity is less than 0.2K at 1800K.

The hole cannot be too small and a theoretical calculation is necessary to evaluate the error introduced. Several methods have been proposed for this calculation but none is perfect. Averaging the results we can say that ε is better than .9995 for the visible and the near UV.

2.3. Measurement of the temperature.

The temperature is measured with a polychromatic photoelectric pyrometer that we have designed and built. It is calibrated against a blackbody at the melting point of gold. It can measure the brightness temperature at several wavelengths through the optical system associated with the blackbody. Some corrections are necessary to take into account the spectral transmission of the optical system.

3. OPTICAL ARRANGEMENT OF THE OBSERVING STATION

The photometric equipment includes a 55 cm telescope built for that purpose and a spectrometer at the f/3 prime focus. This spectrometer includes a 1200 l/mm grating for the wavelength range 3000 - 6800Å in the first order. The grating can be replaced easily by another one for another wavelength range. The dispersion is 60 Å/mm and the true resolution is about 1Å. The detector is a photomultiplier with a S-20 response curve. Two modes are possible: scanning with 2Å or longer steps and measurements at discrete wavelengths with a typical band width of 30Å.

The artificial star is a hole illuminated by the blackbody through an optical system. The hole is located at the focus of a collimating mirror which has the same diameter as the telescope and a focal length of 5.5 m. The blackbody and its associated optical system are located in the dome. The collimating mirror is outside moving on a railway in a 10 m horizontal tunnel. With this arrangement the mirror can be moved from the position for calibration to the bottom of the tunnel. Then the center of curvature can be reached for the measurement of the reflectivity of the mirror. This measurement is achieved with the aid of a specially designed photometer. The hole has a diameter of 50µ in order to obtain a size of image at the focus of the telescope comparable to the size of a stellar image. This hole is calibrated by a photometric method by comparison with several diaphragms of much larger diameters which can be measured on a measuring machine. The overall accuracy of this calibration is about 2×10^{-3}.

4. CONCLUSION

In this experiment, the beam sizes for the star and blackbody source are exactly the same and the need for a horizontal extinction determination is removed. Of course, the elimination of this problem incurs the introduction of the transmission of the 55 cm collimating mirror. However, the essential difference is that the horizontal extinction is not a measurable quantity, while the reflectivity of a concave mirror can be determined with a high degree of precision. Taking into account the several causes of errors, especially in the measurements of the temperature of the blackbody (.5K at 2000K) and of the vertical extinction by the Bouguer's law, we feel that a global accuracy of about 1% in stellar absolute fluxes is not beyond the scope of the experiment.

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DISCUSSION

NECKEL: Why do you use a blackbody instead of a lamp calibrated against a blackbody? It is much easier to handle.

PEYTERAUX: The black body with adjustable temperature is an alternative to other methods (striplamp or a blackbody at the melting point of a metal) and I have a long experience of this kind of method. On the other hand I don't think the lamp is easier to handle in a dome.

NECKEL: Why do you run the black body in a vacuum and not e.g., in an argon atmosphere of normal pressure? This would enable much higher temperatures and operation without any window, which is in any case a source for systematic errors (contamination, etc.).

PEYTERAUX: The use of argon is not excluded for the future. The window is included in the optical system and I measure the temperature for several wavelengths through the optical system.

NECKEL: What is the lifetime of the blackbody cavity?

PEYTERAUX: Typically 100 hours at 2000 K. The tube can be replaced very easily by another one.