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A jumping-film camera for meteor photography

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A camera system is described in which the film advances by short, sudden jumps. Three similar cameras are described, in which the film is advanced 10, 100, and 150 times per minute respectively. The cameras were designed for use in meteor spectroscopy, but the technique should prove useful in other applications.

1. Introduction

The instruments described in this paper were designed in order to investigate particular problems in meteor spectroscopy. The general features of the instruments, however, appear to have applications to other problems of night-sky photography, particularly in the observation of satellites or rockets from ground stations.

When the auroral green line (λ5577) was first detected in meteor spectra (Halliday 1958) it was suspected that the duration of the emission of this forbidden line was quite short, probably only a small fraction of a second. Later however (Halliday 1960), when observations of the line were made through rotating shutters, the absence of a perceptible decay in the occulted portions of the trail showed that the duration of the luminosity was long compared to the length of an individual exposure (about 0·1 sec) and quite possibly was as long as the expected lifetime of the metastable state, i.e. 1·0 sec.

Two meteor spectrographs have been constructed with which it is hoped to record multiple images of λ5577 during the decay after the passage of the meteor itself. A third, similar instrument has been adapted to the problem of photographing the spectrum of a persistent meteor train. Basically the instruments consist of a transmission diffraction grating mounted in front of the objective of an extremely fast camera system. Instead of advancing the film a whole frame at intervals of one to several minutes the film is advanced a short distance at quite frequent intervals. For the two 'green-line' spectrographs the film advance rates are 100 and 150 per minute, while for the train spectrograph a much slower rate of 10 advances per minute is employed. The cameras may conveniently be designated by these film advance rates, i.e. cameras 10, 100 and 150.

2. The optical components

The camera lens in each case is a Super-Farron lens with a focal length of 76 mm and a focal ratio of *f*/0·86. The angular diameter of the circular field is 30° and the lens maintains good definition over this field. As in other lenses of extreme speed the focal plane is situated close to the last element of the optical system, in this case 3 mm from the rear face of the lens.

The table lists details of the three instruments. The gratings are Bausch and Lomb replica transmission gratings with the number of rulings and blaze wavelengths shown in the table. The blaze for the grating on camera 100 is particularly efficient for several hundred ångströms on both sides of the blaze wavelength. The dispersions of the first-order spectra are also shown in the table.

Description of the instruments

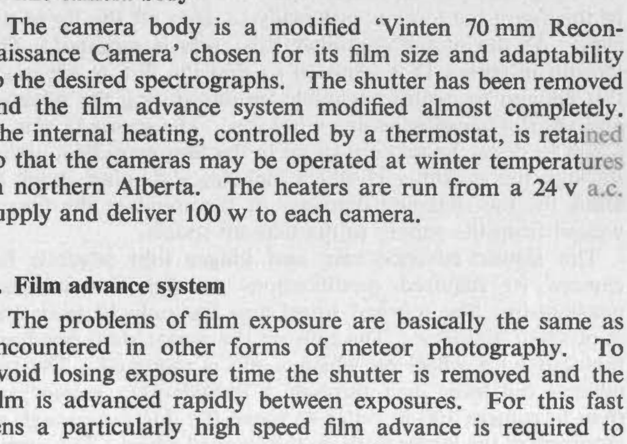
	Camera 10	Camera 100	Camera 150
Focal length (mm)	76	76	76
Grating (lines per mm)	400	85·7	400
Blaze λ (Å)	5000	4800	5000
Dispersion (Å mm^{-1})	328	1530	328
Film advance time (sec)	0·02	0·023	0·012
Effective exposure (sec)	5·98	0·577	0·388
Length of advance (mm)	6·25	0·646	0·646
Duration of 100 ft roll (h)	8·13	7·86	5·24

3. The camera body

The camera body is a modified 'Vinten 70 mm Reconnaissance Camera' chosen for its film size and adaptability to the desired spectrographs. The shutter has been removed and the film advance system modified almost completely. The internal heating, controlled by a thermostat, is retained so that the cameras may be operated at winter temperatures in northern Alberta. The heaters are run from a 24 v a.c. supply and deliver 100 w to each camera.

4. Film advance system

The problems of film exposure are basically the same as encountered in other forms of meteor photography. To avoid losing exposure time the shutter is removed and the film is advanced rapidly between exposures. For this fast lens a particularly high speed film advance is required to



Details of film advance mechanism.

avoid trailing of images between exposures. Also, for full frame exposures of less than one second the film consumption would be enormous. Because of the relatively few strong lines in the meteor spectrum and the fact that the auroral green line is normally confined to the upper portion of the trail where other lines are weak or absent, it was found that by advancing the film small calculated intervals in the direction of the dispersion serious overlap of spectral images should be avoidable. The mechanical problems of rapid film advance and the excessive consumption of film are then reduced greatly. The slower film advance rate for camera 10 permits a much longer length of film to be advanced each time.

The film advance system of camera 100 is shown in the figure. The system is identical for cameras 100 and 150 except for the variation in speed. The spiral cam A is driven by a 100 rev min^{-1} synchronous motor. As it rotates, the lever B, on which is mounted a spring-loaded dog C, is drawn back against the tension of a spring D. As the lever B is forced fully back by the cam, the dog C drops behind a tooth of the escapement wheel E, which has 96 teeth and is mounted on the end of the film advance sprocket. During this motion a flat spring F engages in the escapement wheel, preventing the wheel from rotating backwards. When the cam A is rotated further, the lever B, under tension of the spring D, drops off the lip of the cam, and the dog C advances the escapement wheel E and hence the film. In the position of the figure the lever is just ready to drop off the lip of the cam. As the motor continues this cycle is repeated. The tension in spring D is adjusted so that the film is advanced fast enough to assure negligible trailing during the advance and yet not cause excessive vibration. The spring G acts as a belt to drive the take-up spool in the film magazine, acting through the assembly H which includes a slipping clutch to allow for the changing diameter of the spool as the film is wound from the supply to the take-up spools.

The slower advance rate and longer film advance for camera 10 required modifications to the film advance mechanism. The toothed wheel now has only 10 teeth and is of small diameter. The cam on the motor shaft has been replaced by a wheel on which a pin is mounted. The pin deflects the lever arm through a considerably greater arc than in camera 100 in order to move the dog far enough to clear one of the larger teeth on the toothed wheel. The spring drive to the take-up spool has been replaced by a rubber belt drive.

Tests of the film advance mechanisms indicate that the advance is accomplished in a small fraction of the total exposure time. The times required for film advance and the effective duration of the exposures between advances are shown in the table. Also shown in the table are the lengths of each film advance and the time in which a 100 ft roll of film would be exposed, neglecting the slight loss due to loading the film.

5. Altitude–azimuth mount

The mount used for this camera is in part the conventional altitude–azimuth mount, with a rotating turntable for azimuth adjustment and a fork in which the camera rotates in altitude. It has been mentioned that the film must be advanced in the direction of dispersion of the grating. In meteor spectroscopy the meteor itself acts as the line source and the grating is oriented so its lines are parallel to the most probable direction of a meteor during meteor showers. The mounting is designed to be able to fulfil both of these conditions. Once the camera has been focused the grating is aligned so that the dispersion is in the direction of film motion. The camera, including lens and grating, is fastened to a circular collar which can be rotated in a cross member to fulfil the second condition. The cross member is mounted on pivots which rotate in 'V' grooves cut in the brass plates on top of the fork.

6. Discussion

Cameras 100 and 150 were designed specifically for measuring the decay of the emission from λ5577. The ratio of 3 to 2 in exposure durations is an attempt to reach a balance between the good time resolution one would desire and the exposure time required to secure an image of a faint source. Any fast, green-sensitive emulsion would be suitable for these cameras. With the gratings aligned as described the spectra of those stars which are bright enough to record are smeared out into a continuous streak by the overlap of successive exposures.

It is hoped that these cameras will record meteors as faint as magnitude 0 or +1. From the existing evidence it appears that λ5577 may be a relatively stronger contributor for these meteors than for the group of very bright meteors. With an expected duration of about 0·3 sec for meteors in this range there is an appreciable chance that the film will be advanced while the meteor is still in flight. In many cases the break produced in the normal meteor spectrum can be used to infer the duration of the first (incomplete) exposure on λ5577.

Camera 10 has been designed to attack the difficult problem of recording photographically the spectrum of an enduring meteor train. Since the train may well be a diffuse line in this case, spectral resolution may be achieved by increasing the number of rulings per millimetre on the grating but not by increasing the focal length of the camera. From attempts to record trains on blue-sensitive emulsions it is known that they are deficient in blue light and from early visual spectral observers (Herschel 1881) it is expected that trains will show lines in the green, orange and probably red regions. A fast, panchromatic film is required. For enduring trains there is a chance that a visual observer spotting a train outside the field of the camera will have sufficient time to swing the instrument in its altitude-azimuth mounting to record the decay of the train luminosity.

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