Presidential Address

The Sevenoaks spectrohelioscope

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The Sevenoaks spectrohelioscope was first used in 1974. This paper describes the instrument as it is today.

Background

In the autumn of 1974 I collected a very large packing case from Preston. It contained the late Professor M. A. Ellison's spectrohelioscope, which was to be loaned to me from the BAA. It had not been examined for many years. Whilst the case did clearly contain the makings of a complete instrument, some of the parts were broken, others had been damaged by less than perfect packing materials, and there were no assembly instructions. I was lucky to be able to refer to Professor Ellison's description of this instrument[1] and to the memoir[2] of the Solar Section, compiled under the direction of F. J. Sellers. These two documents, and a bit of guesswork, enabled me to assemble the machine at Lynch House, and I first looked at the Sun through it in late 1974. By the early spring of 1975 observations were going smoothly and well, but it was becoming apparent that not all the components were of the same excellent quality. I fairly soon decided to replace the main image-making lens, whose figure had been lost, and the original grating, which was old and scattering far too much light into the wrong places.

Between late 1975 and the middle of 1986, the instrument worked very well indeed at Lynch House, producing both visual and photographic records over the period of sunspot maximum in 1979. In 1986, when the instrument was moved to Lynchets (Lynchets lies in the Lynch House garden, about 50 yards from Lynch House itself) I took the opportunity to rebuild parts of the machine. It is this latest version of the instrument that is desceibed here; it has been working well for the past two years.

Why use a spectrohelioscope?

Most people nowadays seem to buy an expensive filter if they want to observe the Sun in monochromatic light. These filters produce very fine images, which are better than those obtainable with a spectrohelioscope. But they have one major drawback: each filter works at one wavelength only, and although it can be tuned over a small range of wavelengths (perhaps 5 Å or so) this process takes time. Thus, the observer cannot, with a filter, easily detect objects on the sun whose light has been shifted by the doppler effect away from the wavelength of their surroundings, and he cannot observe at the wavelengths of, say, Hα and Hβ, without having two separate filters. Using the spectrohelioscope to be described here the observer can shift wavelength from Hα to Hβ (or any other wavelength) in approximately half a minute, and measure doppler shifts of several ångström units continuously and easily. No flare can develop such a large shift of wavelength that it cannot easily be followed. In no circumstances would the author swap his equipment for several monochromatic filters! Having said that, he must admit that his instrument is nearly 10 metres (31 feet) long, and is anything but portable. However, the optics can be folded, and one observer at least (F. J. Sellers) has operated high above ground level in an upper storey room.

Layout

In Fig. 1, mirror A, flat and figured to a quarter wave, is 140 mm ($5\frac{1}{2}$ inches) in diameter. A small synchronous motor rotates it once a day about an axis parallel to that of the Earth, so as to reflect light from the Sun down the line AB (which is also parallel to the Earth's axis) onto the mirror B. This arrangement departs from that adopted by most previous users of the spectrohelioscope, where the mirror A reflected light upwards onto the mirror B from a position somewhere between and below B and C. Here the sunlit image of A reflected on to B takes the shape of an ellipse, and some light is lost, particularly when the Sun is high in the sky; but in the author's view this disadvantage is greatly outweighed by the fact that the mirror A does not have to be moved at midday, as it did with the former arrangement. The image of the Sun produced by this arrangement rotates once a day at an even rate.

Mirror B, also flat and figured to a quarter wave, has a diameter of 115 mm ($4\frac{1}{2}$ inches). It can be rotated about vertical and horizontal axes, and is fitted with slow motions, which are controlled from the observers position at R. From B the sunlight is reflected through the 100-mm (4-inch) diameter non-achromatic lens C. This lens has a red (Hα) focal length of 5435 mm (214 inches); in the cyan light of Hβ its focal length is 5334 mm ($210\frac{1}{2}$ inches); its focal ratio is about f/54; it can be moved on a trolley along the line BCF by remote control from the observing position. All these components are housed outside in a watertight box (Fig. 2).

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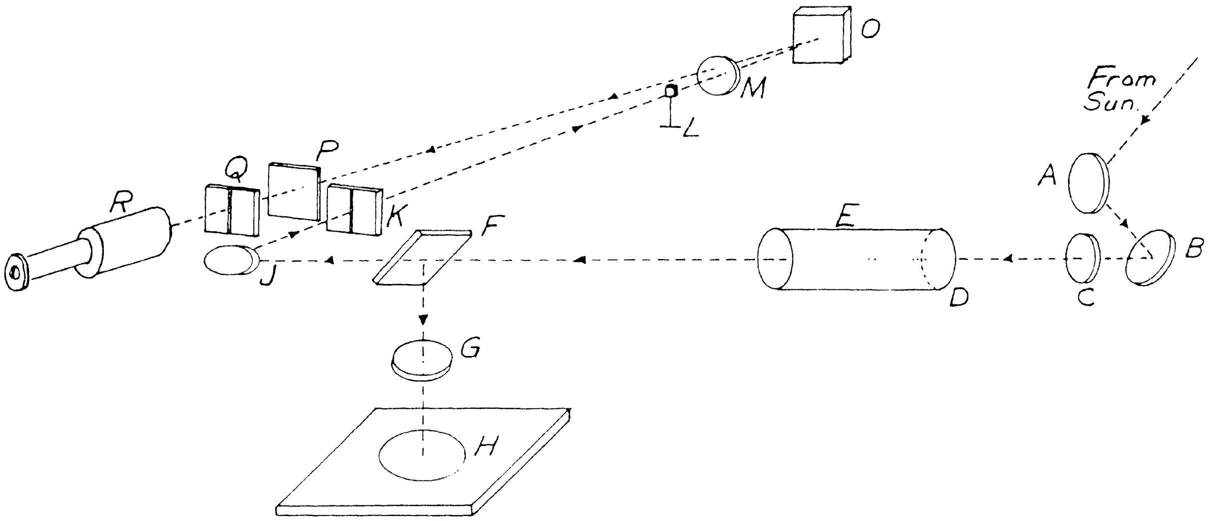


Figure 1. The general layout of the Sevenoaks spectrohelioscope.

The plastic tube E is built into the wall of the house. Inside it a smaller plastic tube, 120 mm (4 inches) in diameter and at least 500 mm (18 inches) long can be adjusted so that its long axis lies nicely along the line CF. An optical window (in this case a 120-mm (4-inch) Pentax UV glass filter) is fitted at D, to prevent tube currents degrading the image; this window also keeps the cold winter air from entering the darkened room to the left of the tube. The space between the two plastic tubes is filled with glass fibre wool.

At F a 'flat' of 9-mm ($\frac{3}{8}$ inch) translucent perspex pivots into or out of the incoming cone of light, about a vertical axis. When in use it reflects the light vertically downwards to the non-achromatic Barlow lens G, which can be adjusted to project a white light image of the Sun 150 mm (6 inches) in diameter on to the card H. This image is not perfectly defined, since it is not 'achromatic'; its quality can be improved by inserting a deep yellow or orange filter between F and G. It rotates once a day at a steady rate. It can be orientated by stopping mirror A's drive motor and letting the Sun drift from east to west. In practice, H consists of a baseboard which carries a piece of circular card, pivoted about its centre, and divided into small squares each one tenth of the Sun's radius. This card may be set to the time of the observation against an index fixed to the baseboard, and thus, once the original orientation has been made, the Sun's projected image will always be correctly orientated. Allowances can esily be made for variations in the equation of time. Once the card has been set to the time of observation, and the image centred on it, the positions of sunspots can be read off in units of northing and easting; these values are easily converted to solar latitude and longitude using a Stoneyhurst disc. As an additional feature, the centre of the disc, about which it pivots, can be adjusted in two directions at right angles to each other, and lined up with a set of crosswires, which may be swung into the line of sight between the eyepiece R and the second slit Q. One needs a fairly prominent sunspot, which can be seen in white light and monochromatic light, to do this. It is then possible to measure the positions of features seen in monochromatic light by lining them up on the crosswires, switching to the white light image at H, and measuring the position of the centre of the disc against the Sun's image.

To obtain a spectrum, the flat F is swung out of the way, and the converging cone of light from C is reflected through 90° by the aluminised flat J (elliptical with a 57-mm ($2\frac{1}{4}$-inch) minor axis) on to the first slit K, where the primary image of the Sun, 50 mm (2 inches) in diameter is formed. When observing in the light of Hα, a red filter made of glass or gelatin (Wratten 29 is very suitable – it will not be damaged, as there is very little heat at this point) may be placed between J and K, to cut out unwanted light. Other coloured filters may of course be used to select different parts of the spectrum. The jaws of the slits K and Q are 25 mm (1 inch) high. The author made them out of German Silver 3 mm ($\frac{1}{8}$ inch) thick. It is not difficult to do this but care must be taken to bevel them down to a final edge perhaps 0.1 mm (0.005 inches) thick, and to make this edge nice and smooth. The finest grinding powder, followed by ordinary toothpaste, can be recommended. Final grinding and smoothing of the jaws should be done by

Figure 2. The box containing the outside optics.

placing them on a sheet of plate glass and rubbing them gently against each other; continue this process until they shut out all the light when closed. Stainless steel razor blades also make good slit jaws. The slit width may be set to the observer's taste; the author finds that 0.13 mm (0.005 inches) gives very good results.

The white light passing through the slit K falls upon the non-achromatic lens M, which has a diameter of 100 mm (4 inches). This lens has a red (Hα) focal length of 3988 mm (157 inches), and can be moved on a trolley towards or away from K and Q, to allow for variations in focal length with colour. Its cyan (Hβ) focal length is 3911 mm (154 inches). The grating O behind it has a ruled area of 76 × 65 mm (3 × 2½ inches), and therefore a mask of this size is fitted in front of M. Since M lies its own focal length away from the slit K, it will project parallel rays of light on to the Bausch and Lomb replica grating O, ruled with 14,000 lines per inch, and blazed in the green; this means that it concentrates light best in the green part of the spectrum, whilst also performing very well at all other wavelengths. The spectrum produced by O passes back through the lens M, and is brought to a focus again at Q. At this point it is about 1 metre (39 inches) long and 25 mm (1 inch) high, and consists of many thousands of images of the slit K, each in a slightly different colour, with red at one end and blue at the other. The observer can rotate the grating O about a vertical axis, and bring any part of the spectrum on to the second slit Q; fine adjustments of about ±3Å can be made with the line shifter P. This consists of a plane parallel disc of glass abot 3 mm (⅛ inch) thick, placed in the line of sight between Q and M, and close to Q. If the rays of light pass through this disc at right angles, they will not be deflected; if P is rotated about a vertical axis so that the rays pass through it obliquely, they will be deflected to one side or the other by a small and measurable amount. The rotation of the grating and use of the line shifter to tune light are exactly analogous to the tuning of an ordinary radio set with its coarse and fine tuning controls. A plano-convex lens of about 150-mm (6-inch) focal length is held in the eyepiece holder R; the observer may use it either to examine the spectrum directly (by looking to one side of the slit Q), or to examine the slit Q itself.

The apparatus as described so far might work quite well in theory, but in practice and until Professor Ellison introduced the addition to be described, it did not produce acceptable results at all. For the white light issuing from the slit K is very bright indeed, and will be reflected off the front and back surfaces of the lens M. The light reflected off the front (very nearly flat) surface of M can be kept out of the observers eyes by arranging that M is not quite at right angles to the line of sight; the adjustment is easy; the author parks the pool of white light nicely out of the way to the right of K in the diagram. The penalty is a slight amount of astigmatism, which the author cannot detect. If nothing were done about it the light reflected off the rear (concave) surface of M would come back in the shape of a cone, and blind the observer nicely. Fortunately all this light can be intercepted by a small 12-mm (½ inch) square stop placed at L, the point at which the rear surface of M forms a real image of the slit K. Once again the adjustment is easy; the author has arranged for the stop L to move back and forth with M, so that it stays more or less in the focal plane of the image of K.

The instrument used as a spectroscope

If the eyepiece holder R is moved to the left in Fig. 1, so that it looks at M directly, then, provided the Sun's image lies on K, part of the spectrum will be seen. The image may be focussed by moving M to and fro, or by moving R. If the grating is rotated using the coarse tuning control the spectrum will move from side to side. The linear extent of the spectrum depends on the dispersion of the grating (which is proportional to the number of lines per inch ruled on it) and the focal length of M (the longer the focal length the greater the extent of the spectrum). The contrast and resolution of the image will depend almost entirely upon the quality of the grating, provided the other optical components are reasonable. The equipment described here produces an Hα line in the first order with a width of about 0.3 mm (0.012 inches); this line is in fact about 1Å wide. It is quite possible to rotate the grating so as to bring the second order spectrum into view; dispersion becomes greater, but brightness becomes less, and filters are needed to deal with the overlaps between the various orders. The author does not himself use anything but the first order. Whilst a perfectly presentable spectrum of 'integrated sunlight' will be produced even if the primary image formed on the slit K is out of focus, careful focussing of the lens C is necessary if the best results are wanted. With careful focussing one may isolate the spectra of solar features simply by placing them on the slit K; spectra of sunspots, flares, and prominences can all be isolated in this way.

Photographic records of spectra may be obtained by placing a camera body (without a lens) just to the left of the slit Q in Fig. 1. The image is then focussed by moving the lens M, the camera, or both. Typical exposures with this equipment, and using 60 ASA colour film, are about $\frac{1}{60}$th second. Some colour emulsions do not record the Hα line very will; most black and white emulsions refuse to record it at all. The Kodak Ektachrome slide emulsions, and Kodak Technical Pan 2415 black and white emulsion can be recommended.

The instrument used as a spectrohelioscope

Referring to Fig. 1, imagine that the Sun's image has been placed on the slit K, and focussed carefully by moving the lens C as necessary. The Hα line of the spectrum can now be made to coincide with the slit Q, by rotating the grating O, and perhaps using the line shifter P to make the final adjustment. To make this task easier a small window about 6 mm (¼ inch) wide

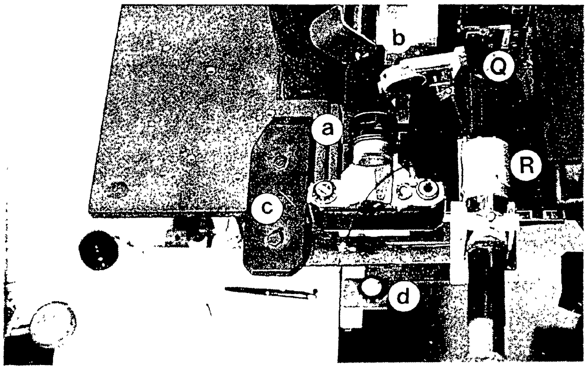


Figure 3. Looking down on the observer's position – visual.

lies at the top of slit Q; this can be covered with a sliding shutter once the adjustment has been made.

Now let slit K move slightly to the right. The Hα line, which was over slit Q and which is of course an image of slit K reflected in the grating, will move to the left. Let Q move to the left so that it covers the new position of the Hα line. Now arrange for K to move backwards and forwards, so as to scan part of the primary image of the Sun that lies on it, and let Q move in unison so that it always covers the Hα line. Arrange for the amplitude of these movements to be perhaps 12 mm ($\frac{1}{2}$ inch) or so, and for their frequency to be about 20 cycles per second. The observer, looking at Q through the eye lens R, will by persistence of vision apparently see a window 25 mm (1 inch) high and 12 mm ($\frac{1}{2}$ inch) wide, and since he is in fact looking all the time at the Hα line, he will see detail only visible at this wavelength. By using the fine tuning provided by the line shifter P, he will be able to 'walk about' inside Hα, and will see changes in detail as he does so. In practice, and once the initial adjustments have been made, it is very simple to tune, even when the slits are vibrating at full speed. The experienced observer can also change wavelength, perhaps from Hα to Hβ, without stopping the slits, and in less than half a minute.

The way in which the slits are made to oscillate is, of course, quite critical. There must be no backlash, and no vibration; errors of correspondence between them must be of the order of 0.002 mm (0.0001 inches) at most. Normal amateur engineering practice will not do. Fortunately F. J. Sellers designed and made an excellent mechanism some 40 years ago. The present equipment contains a set of Sellers oscillating slits, made many years ago by Professor Ellison and refurbished and slightly modified by the author; it has been working most successfully for the past ten years, and can be thoroughly recommended.

the way as required. The crosswires previously referred to can be seen at b; they can be swung into and out of the line of sight between Q and R. A single lens reflex camera is mounted on a cradle that slides along an aluminium channel bar, which can best be seen in Fig. 4. The camera's 50-mm (2-inch) focal length, f/1.8 lens is mounted on an extension tube to produce an image scale of 1:1, and adjusted so that the slit Q is sharply focussed when the camera is in position.

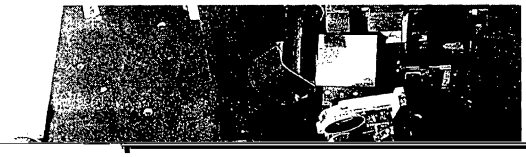
To take a photograph in the light of Hα proceed as follows:

i) Adjust the equipment so that a nice visual picture in Hα is seen through R; use the line shifter to obtain the best quality image. Place the cradle which carries the camera in the channel bar. Fig. 3 shows everything ready to take a photo.
ii) Swing R of of the way. See Fig 4.
iii) Slide the camera across so that it is looking at the vibrating slit, and release the shutter. With 60 ASA colour film exposures vary from $\frac{1}{8}$ second for flares, to 15 seconds for some faint prominences.
iv) Move the camera out of the way again, and check with the eyepiece that all is still well.

A picture may be taken in less than five seconds once the equipment has been set up.

Useable wavelengths

The nicest, most contrasty images are obtained at the wavelength of Hα. If an event is fairly energetic it will very probably be visible inHβ also, but there will be less detail and less contrast. Although Hβ is very bright visually, it may be much less bright than Hα photographically, and may require at least twice the Hα exposure. Activity can be seen visually, and photographed, in the yellow emission line of helium (5876 Å). Many people can also observe and take photographs in the deep blue H and K lines of Calcium; unfortunately the author cannot do this, since his vision shuts right off at a wavelength a few ångströms longer than that of the lines. Detail should be visible on occasions in the light of Hγ and Hδ, but the author has no experience at these wavelengths. There is more than enough to do in Hα, Hβ, and helium.



The Sellers oscillating slit mechanism

In Fig. 5 the rigid strip A′ is supported on the leaf springs A and B, which are themselves attached to hardwood blocks secured to the baseboard. It can move up and down only. A light connecting rod is attached to the brass block B′ by a weak actuating spring; it is driven by a small electric motor whose crankshaft also carries the brass flywheel and fan blades. It is very necessary that this driving motor should rotate smoothly and evenly, at a speed which can be varied over a small range – hence the brass flywheel and fan blades, and the special motor control circuit, which is described below. In this instrument springs A and B, and all the other leaf springs, have been cut from a portable gramophone spring of the type readily available in the 1940s; phosphor bronze would be equally suitable. If the flywheel is rotated slowly by hand, A′ moves up and down with an amplitude of perhaps 1.5 mm ($\frac{1}{16}$ inch); this amplitude depends on the strength of the weak actuating spring and is not critical, although it should not be much greater than the figure quoted. The two steadying springs steady the connecting rod when it is moving fast.

Leaf springs C and D connect the brass block B′ to the two bell cranks G and K, which are themselves supported by leaf springs E and F, and H and J, whose far ends are attached to hardwood blocks. As B′ goes up and down, the lower ends of the bell cranks, attached to the springs L and M, will move sideways in opposition by equal amounts. There will be no backlash, since there are no bearings. Leaf springs L and M drive the two slit asemblies R and S from side to side. These two assemblies, supported on the springs N and O, and P and Q (note that these four springs are wider than the others) can only move sideways; once again there is no backlash, and they must always move in opposition by equal amounts.

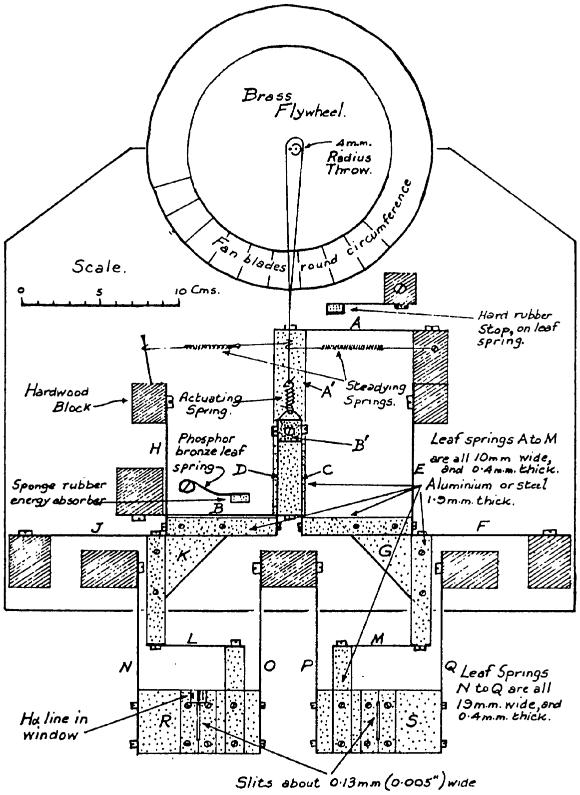


Figure 5. The Sellers vibrating slit mechanism.

When the motor driving the flywheel is started, at first nothing will happen. But as the motor picks up speed the very small impulses transmitted to A′ through the actuating spring will sooner or later approach the resonant frequency of the whole sprung assembly, and the mechanism will start to respond. As resonance is approached, the amplitude of oscillation will increase, and eventually the sponge rubber energy absorber will provide just enough damping to produce a stable oscillation at the slits of perhaps 18 mm ($\frac{3}{4}$ inch). The hard rubber stop above A prevents the oscillations from becoming too large. The magnitude of the oscillations at the slits can be varied, by altering the speed of the motor; its range is between perhaps 3 mm ($\frac{1}{8}$ inch) and the maximum of about 18 mm ($\frac{3}{4}$ inch). This facility is most useful, since it enables one to examine very faint prominences through a narrow window, and return quickly to normal operation for ordinary features. It should be noted that the smaller the amplitude of oscillation the brighter the image becomes, simply because the available light is spread over a smaller area.

The resonant frequency of the equipment described here is about 20 hertz; this produces a nice flicker-free image at the eyepiece. It might be thought that all these oscillating components would produce a lot of vibration; in fact there is none, the reason being that most of the moving parts are balanced by similar ones moving in opposition. A very smooth running motor, and a good speed controller, are essential. The controller described below has been working well for eight years, and can be recommended.

The motor speed controller

The author's Sellers oscillating mechanism is driven by a small high quality DC motor, which can be seen at d in Fig. 10. Referring to Fig. 6, the output from an 8-volt bell transformer (available in most electrical shops) is rectified by the bridge rectifier W 005, and smoothed to provide a stable 8-volt supply. At the point x, the half-wave rectified voltage will vary between 0V. and 8V, with a frequency of 50 hertz. This voltage, being applied to the base of the first transistor, creates an 8-volt square wave of 50 hertz at y, and a sawtooth wave form of the same voltage and frequency at pin 3 of the 741 operational amplifier. Now the voltage at pin 2 of the 741 can be varied between just over 4 volts and about 6.3 volts by varying the preset resistor (2.2KΩ) and the speed control potentiometer (4.7KΩ). Whenever the voltage at pin 3 is lower than the variable voltage on pin 2, the output of the op-amp will be low, the two output transistors will be switched on, and power will be supplied to the motor. This power will

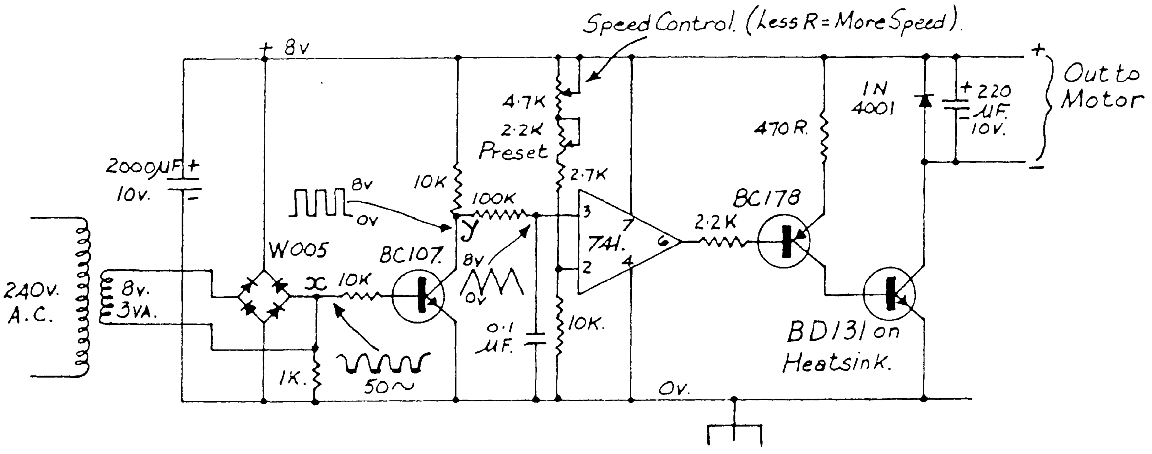


Figure 6. Speed control circuit diagram.

appear as a series of pulses at the full 8 volts, whose length will depend on the voltage at pin 2 of the op-amp, and therefore on the position of the speed control potentiometer; the motor speed will vary as the width of the pulses: the greater the width the faster the speed. This type of speed control is very sensitive and stable and, in the author's opinion, far better than that obtained with the usual variable resistance placed in series with the motor armature. Its introduction in 1980 improved the stability of oscillation a great deal. Each individual circuit must of course be tailored to fit the motor it is driving; this may be done by varying the resistors on the positive side of pin 2 of the 741, by trial and error, until a satisfactory arrangement is reached. The speed control potentiometer knob can be seen at d in Fig. 3.

Instrumental detail and adjustment

a) The outside equipment

Fig. 7 shows the outside equipment with the cover removed. The mains synchronous motor driving the primary mirror A rotates once an hour, and is connected to the polar axis through 4:1 and 6:1 reduction gears, and a simple cork-lined friction clutch. The mirror can be adjusted in declination by means of a similar friction clutch and the fine control, and is normally set by hand in hour angle to reflect the sunlight on to mirror B. The lower base plate supporting mirror B rotates about a vertical axis on a 75-mm (3-inch) tapered roller bearing. A small DC motor and integral gearbox (seen between the mirror and the white switch) drives this base plate through a friction clutch and spring loaded tangent arm, to provide fine horizontal slow motion. The two triangular supports secure the mirror cell to the upper baseplate, which itself is hinged along its right hand edge (just to the right of the mirror) to provide vertical slow motion. The vertically mounted actuating motor and gearbox can be seen just to the left of the mirror cell, between the triangular cheek pieces. Both these slow motion motors are controlled from the observer's position inside; they run nicely on about 4 volts.

The main lens C is carried on a three-wheeled trolley. The two near wheels have a vee groove cut into their rims, and run along a brass rail, thus providing directional stability. The far wheel has a plain flat rim, and runs on a brass strip. This arrangement ensures that there is no rocking or yawing as the trolley moves back and forth along the track. The driving motor, with its integral gearbox, can be seen to the right of the lens; it drives the trolley through an endless nylon cord, and is mounted on a brass spring to provide tension. Three microswitches are secured to the base plate beside the trolley track; they can be seen just beneath the trolley wheels in the picture. As the trolley moves back and forth on the rails, a shoe fitted to its side trips each microswitch as it passes, and lights up a corresponding red LED at the observing position, to indicate that the lens is at the correct focus for Hα, helium, and Hβ wavelengths respectively.

The small light bulb just below the primary mirror is switched on during the winter, when the equipment is not being used. It provides enough heat to keep the optics from getting too cold, so that they do not dew up when exposed to the comparatively warm morning air, after a very cold night. Before this heater was fitted, winter operations were frequently held up for many

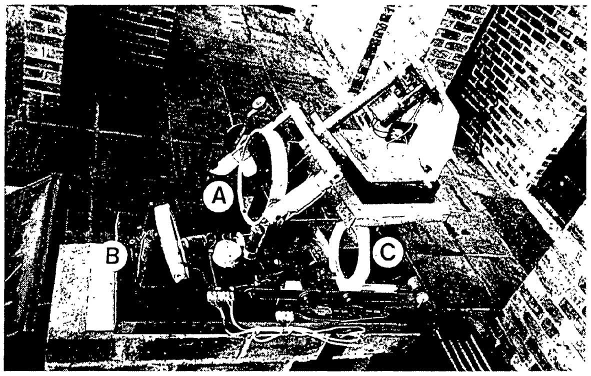


Figure 7. The outside optics with the box removed.

minutes whilst the dew on the mirrors and lens dispersed.

b) The inside equipment

Fig. 8 shows the inside equipment. The perspex flat, F in Fig. 1, can be seen at a. It pivots about a vertical axis; fine adjustment is provided by a spring-loaded three-point suspension, using 6 BA screws and phosphor bronze leaf springs. The Barlow lens, G in Fig. 1, is housed inside the box at b; it can be moved vertically for focussing. The Sun's white light image falls on the circular card, H in Fig. 1, at c; this card pivots about its central point and is set to the time of observation. The baseboard holding the card can be adjusted horizontally in two directions at right angles, so that the eyepiece crosswires and the centre of the card can be lined up. The elliptical flat, J in Fig. 1, lies just inside the black wooden cover at d. It can be pivoted about a vertical axis, and rocked back and forth in a plane at right angles to this axis; these adjustments are vital, not only to bring the Sun's image onto the first slit, but also to ensure that the light passing through the slit falls nicely on to the collimating lens. This collimating lens, the grating, and associated equipment are all housed in the box at e. The non-stretch terylene cord, which operates the coarse tuning, travels, via pulleys, up to the ceiling from the operating position, and down again to the grating mounting; it can be seen just to the right of the perspex flat.

The various operators controls can best be seen on Fig. 9. Slow motion control for the second outside flat mirror, B in Fig. 1, is provided by the joystick a, which actuates a set of four microswitches. The coarse tuning handwheel lies at b. It controls the rotation of the grating via a set of pulleys and the non-stretch terylene cord referred to above. The tension in the control system can be adjusted by mounting one set of pulleys on an adjustable spring-loaded platform. Handwheel b is graduated in ångström units, and also drives the coarse setting dial c. The use of these two dials enables the observer to get somewhere near the correct setting, but fine control is best achieved by using the line shifter control d. This control covers a range of about 5 Å, which is reasonable for everyday use. An auxiliary line-shifting disc can be clipped on to the one in everyday use to cope with very large doppler shifts; it roughly doubles the deflections; it has not been needed so far in many years of observation, but it could be vital if very powerful flares were observed. The three LEDs, which show where the main lens is, can be seen just below e. The round meter which lies just above them is not at present used for any special purpose; in the past it served a similar function to the three LEDs. A length of ordinary sewing thread is attached to the cradle that carries the collimating lens (M in Fig. 1); this runs through brass eyelets and, finally, supports the small triangular weight at f. As the collimating lens moves backwards and forwards this weight moves up and down, thus providing control for the focussing arrangements.

Fig. 10 shows the white light Barlow lens at a, the coarse tuning control line at b, the aperture on the grating side of the first slit at c with a filter holder just to the right of it, the Sellers mechanism driving motor at d, the aperture for the second slit at e, a pivoted flap, which may be opened to enable one to examine part of the spectrum, at f and a sheet of white glossy photographic paper on to which the spectrum may be projected at g. Note that this sheet does not lie at right angles to the rays of light coming back from the grating and collimating lens; it is inclined so that the different colours of the spectrum will all fall into focus at the same time.

Note how on Figs. 8 and 10 everything is enclosed in black painted boxes. These are very necessary, partly to keep dust off the very sensitive optics, but mostly to reduce unwanted scattering and reflection of light.

On Fig. 11 the small stop, L in Fig. 1, can be seen at a. It is mounted on a slide, and moves back and forth with the collimating lens b, so that it remains more or less in the correct place with changing focus. If its position is carefully adjusted for Hα there is no need to make additional adjustments in everyday use unless one is working in the deep violet. Note that the collimating lens is masked, so that the parts of the lens that do not transmit to the grating are not illuminated. The whole collimating lens grating assembly is carried on a strong wooden bracket, which is securely fixed to the wall.

Fig. 12 shows the collimating lens and grating in close-up. The lens holder is fixed to the two white plastic 'sleepers' by a three-point mount using antago-

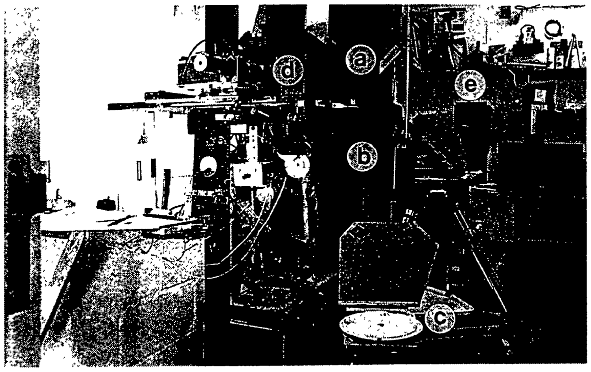


Figure 8. General view of the inside equipment.

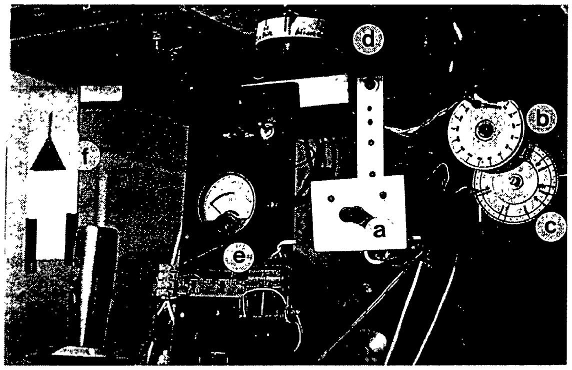


Figure 9. The various operating controls.

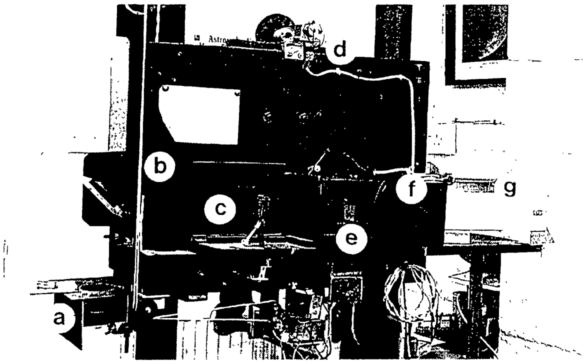


Figure 10. Looking towards the observer's position from the grating side of the slits.

nistic screws. The sleepers are mounted on a hard aluminium plate, which slides back and forth between the rails; this plate is about 225 mm (9 inches) long, which means that good sliding clearances do not entail an unacceptable amount of side-to-side backlash. The weight of the sliding plate is taken on 6 small ball bearings, themselves held in a thin plastic perforated plate so that they support it properly, and resting on a hard steel baseplate. Movement is very smooth and free running. The carriage is driven back and forth on an endless cord attached to a nylon wheel, which is driven by a small electric motor; these can be seen just to the right of the lens on Fig. 12. The thin focussing control thread, which runs between the lens and the operating position, can be seen at c in Fig. 11.

The grating, shown on the right in Fig. 12, must be carried on a robust mounting fitted with proper adjustments, if the whole machine is to work well. In this case the circular lower baseplate (taken from the clutch of an old motor mower) is attached to the very strong wooden baseplate by three equilaterally spaced spring loaded screws, which can be adjusted by hand. One of these screws lies in the optical axis on the side of the baseplate furthest from the collimating lens; the other two lie at right angles to this axis. This arrangement of the screws is important, as will be seen below. The centre section of a three-inch-diameter tapered roller bearing is fixed with 'Araldite' to the centre of this lower baseplate. The outer ring of this bearing is fixed in the same way to the upper baseplate; the arm of the 'tangent arm fine control' is attached to this outer ring with a friction tight brass band. The base of the grating cell is fixed to the upper baseplate with a set of three antagonistic screws, giving very fine adjustment. The grating itself is 12 mm ($\frac{1}{2}$ inch) thick, and is held securely but not too tightly in its cell, and covered by a sliding brass plate when not in use. The upper base plate and grating cell pivot about a vertical axis to provide course tuning of the spectrum. A spring loaded tangent arm is used for fine control; it works well; this mechanism and the driving cord can be seen in Figs. 11 and 12.

c) Fine adjustment of the spectroscope optics

If the equipment is to operate smoothly and conveniently, several conditions that are not usually encountered in ordinary telescope work must be satisfied:

i) the first and second slits must be parallel to each other, and to the rulings on the grating;
ii) it is most desirable that all three should be vertical;
iii) the axis about which the grating pivots must then be vertical in two directions at right angles to each other.

If these conditions are not satisfied then the quality of the spectrum may be degraded and the spectrum itself will probably not cover the second slit properly when the wavelength is changed.

The author has found that the following setting-up procedure works well:

i) Carefully adjust the first slit so that it is vertical, using a level and a 90° square.
ii) Adjust the spring-loaded screws supporting the grating's lower baseplate so that the baseplate is horizontal in two directions at right angles, using a level.
iii) Make certain that the front face of the grating and the lines on it are both at right angles to the base of the grating cell. It is safe to assume that the lines on the grating are parallel to its sides. Use packing as necessary, but be careful not to strain the glass in any way; if in doubt err on the side of a little backlash.
iv) Attach the grating cell to the upper baseplate with the antagonistic screws, and adjust them until the face of the grating is vertical in two

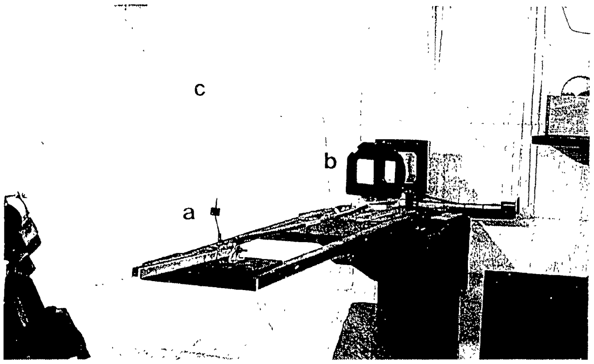


Figure 11. The collimating lens and stop and the grating.

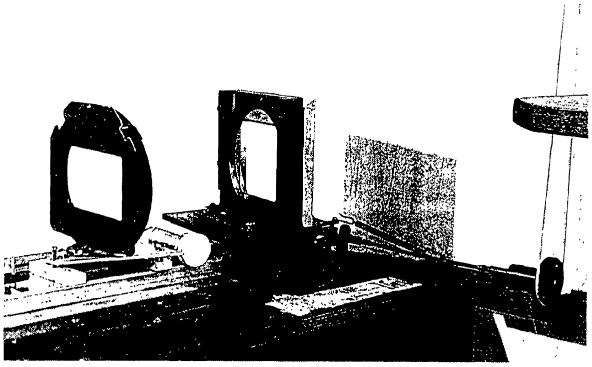


Figure 12. The collimating lens, grating and pivoting mechanism.

directions at right angles, using a level. Do not attach the tangent arm until this adjustment is complete.

v) Obtain a good spectrum; open up the second slit and carefully adjust one side of it to be parallel to the lines of the spectrum; then reset the slit to the corect width.

vi) Adjust the channel bar in which the small stop a (see Fig. 11) slides, in elevation and azimuth until the stop picks up the image of the stationery first slit at all working settings of the collimating lens. Note that adjustment of the channel bar in both elevation and azimuth is required, since the collimating lens is purpously slightly mis-aligned with the optical axis of the instrument.

vii) Make sure that all glass filters in the optical train do not lie at exactly right angles to the relevant optical axis. Precise alignment can cause unwanted interference patterns when monochromatic light is being handled.

Once these adjustments have been made properly they will last for a very long time. Failure to make them properly is almost certain sooner or later to lead to lost observations, probably at the most inconvenient time. In practice the author has found that even the most careful removal and replacement of the grating cover slide can cause slight movement in its mounting, so that the spectrum is shifted a little too high or too low on the second slit. If the lower baseplate spring loaded screws are positioned in the way described above it is easy to adjust the one that lies on the optical axis to correct any small shift.

Using the equipment

A routine observation usually lasts between ten and fifteen minutes. Observations are made daily if possible, at about 10.00 in summer and 11.15 to 11.30 in winter. Rather to his surprise, the author has not found that early morning observations are better than those obtained later in the day. Solar seeing seems to vary like any other seeing; some days are good; others are not so good, and some are awful. In general, the higher the Sun is the better.

The equipment can be prepared for observation in about two minutes. A count of sunspots, and a note of their positions, may take perhaps five minutes. A routine Hα observation consists of:

i) An examination of the entire solar limb, which takes about a minute.

ii) Examination of sunspot areas; details of associated plages are noted.

iii) Filaments are then counted, and the limb is examined again to see if there are any interesting prominences.

iv) By this time, the whole disc has been covered several times, and any specially interesting features can be examine again at leisure.

v) Photographs in Hα or any other chosen wavelength can be taken at any time.

When the Sun is very active, routine observations are not made every day, and concentration is centred on whatever of interest may be going on at a particular time. Flares and eruptive prominences can be particularly attractive; both respond well to photography, although it is not easy at times to decide whether to photograph a part of the spectrum or the extended image in the second slit.

Conclusions

A spectrohelioscope is not really a very suitable instrument for a very young person, or for someone who works all day or who may move house fairly frequently. A simple spectroscope would probably be a more appropriate instrument for these people. But it is ideally suited to someone of more mature years who can observe during the day, and who may be beginning to find the cold night airs a little less attractive than they used to be.

The observer of the sun in the light of Hα can be sure that not many other people will be making similar observations at the same time. Provided the observation is made before about 11.00 GMT he may be fairly certain that no one in the USA will be able to see what he is looking at, for the Sun will not yet have risen there. In the author's opinion, this last fact is the main reason why monochromatic observations of the Sun should continue to be made in the British Isles.

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