NATIONAL NEWSLETTER

Stellar Photoelectric Photometry for Amateurs

Introduction. Many amateur astronomers have long been active visual observers of variable stars. Organizations such as the American Association of Variable Star Observers (AAVSO) have collected and reduced amateur observations of this type for many years and the amateur has contributed much to this interesting and rewarding field of astronomical research.

Visual techniques are fine for the study of long period variable stars, but if one wishes to expand his observational activities in this and other areas he must adopt more accurate methods of observation if these observations are to be of use to the professional astronomer. One method is to employ photoelectric techniques. The professional designs his instrumentation with a particular purpose in mind, and the amateur should follow this example if he wishes to contribute the maximum from his efforts.

Photoelectric Photometry. Photoelectric observational methods are not new. The professional and many advanced amateurs have used these methods for years. Many amateurs have been slow to adopt these methods of observation either through lack of information or through assuming that these methods are too difficult or too expensive to use. True, most professional instrumentation is expensive, complex and well beyond the means of the average amateur. There does, however, exist photoelectric equipment within the capabilities and means of the amateur.

Many small professional and university observatories still use this type of observational equipment—namely, direct current photoelectric photometers—in their work. Not all have the funds to use complex, automated techniques of observation, yet they are still contributing a considerable amount to this discipline of research. The amateur astronomer should always be looking for ways to improve upon the accuracy of his observations and to expand upon his programs of research. If he does not do this, modern technology will soon make his activities obsolescent and he will be left behind. The purpose of this paper is to offer general suggestions for improvements of techniques and instrumentation and where to locate detailed information on photoelectric methods.

Photoelectric photometers are available from a number of manufacturers. Most of these are expensive, however, although some basic units are in the range of the serious amateur's budget. Nevertheless, one who has constructed a good telescope should be capable of constructing a photoelectric photometer of his own at a considerable saving, particularly if one can obtain surplus electronic components. If one is not familiar with construction techniques in electronics, one should seek out the help of an amateur radio ham or a local electronics or TV technician. Often such people are already members of a local astronomical society and may in fact already be active in photoelectric work. One should try and seek out these people, as first-hand information is always better than any text book or article on the subject. Good construction techniques are a must, or the unit will not function properly.

Photoelectric Telescopes. Let us first look at the telescope necessary for this work. Any good telescope can be used effectively, provided that it is of six-inch aperture or larger and has an accurate clock drive with provisions for guiding. The larger the instrument the better. For amateur use, an eight- to sixteen-inch instrument would be ideal particularly if one wishes to construct the more complex version of the photoelectric photometer. Instruments of this size would more than justify the added expense.

The aluminized reflector is preferred over the refractor for this work, as it does not suffer from chromatic aberrations. The compound reflector such as the Cassegrain is preferred over the Newtonian as it is easier to obtain the necessary rigidity due to the short tube length. Long focus instruments are usually better, particularly as long focus instruments generally have larger f-ratios; the design of the photometer head is simplified due to the large image scale at the focus thus admitting less sky background. There is also more room for the viewing eyepiece and prism. With a long focal length instrument, the aperture diaphragm can be made physically larger and is easier to construct. The Newtonian can still be used, however, if the photometer head is designed for this purpose.

Regarding the overcoating of reflectors: this process has definite advantages, as it allows the mirror to maintain its reflectivity much longer. However, one must be careful to use the proper chemicals to remove the overcoating, if this is done, otherwise irreparable damage may be done to the optical surface.

Many amateurs have constructed or are considering constructing advanced catadioptric telescopes such as the Maksutov or flat-field Schmidt-Cassegrain types, employing a lens element corrector. For photoelectric work, the corrector should be made of quartz, particularly if the amateur wishes to make observations in the various regions of the spectrum. For three-colour photometry (the *UBV* system, for instance), quartz correctors are a must. The glass employed as the usual corrector will have serious absorption effects at the ultraviolet end of the spectrum. The *U* or ultra-violet filter has an effective wave-length of 3550 Å and its cutoffs are 3100 Å and 4000 Å. The glass used for the corrector must be transparent to these wave-lengths and quartz is the only commonly-used material that will meet these specifications. Quartz is transparent to about 2000 Å. Unfortunately quartz is expensive, particularly in the large sizes required. If cost is a factor, one should stick to the conventional Cassegrain design.

Perhaps the simplest compound instrument for the amateur to construct for this work would be the modified Cassegrain employing a spherical secondary and ellipsoidal primary. Axially it is as good as the conventional Cassegrain, but its off-axis aberrations are not anywhere as good. It is a perfectly fine instrument for photoelectric work as it is used on-axis for this purpose and has even been used in some professional work. Of course the conventional Cassegrain is preferred as it can readily be converted to a wide-field Newtonian for visual observations.

A telescope for serious photoelectric work should be mounted on a very sturdy permanent mounting, with provisions for accurate guiding as one would use for photographic purposes. A guide telescope of large aperture and long focal length equipped with a cross-hair reticle can be used, but on-axis guiding is preferred. Externally-mounted guide telescopes are subject to flexure, resulting in guiding errors. On-axis guiding is accomplished by inserting a small prism or diagonal mirror into the unused portion of the light cone. Care should be taken when constructing such a system to prevent stray light from entering the photometer. This is particularly important if an illuminated reticle is used. A problem occurs if it is not possible to locate a convenient guide star in the field of view. The best system would be to employ both methods for guiding.

The Photoelectric Photometer System. The photometer head consists of a diaphragm in the focal plane, a finder diagonal behind the focal plane, a filter slide, a Fabry lens to minimize seeing effects, and a photomuliplier tube. The photomultiplier tube is operated using a high voltage (about 1000 volts) power supply, which must be well insulated. The signal from the photomultiplier tube is amplified using a stable D.C. amplifier, and displayed on a chart recorder or direct reading meter. The least expensive system is a battery-operated one such as is described by Dr. G. E. Kron in *Amateur Telescope Making*, *Book Three* (edited by A. G. Ingalls, published by Scientific American, Inc., 1953) in his paper "Two Direct-Coupled Amplifiers for Use with a Stellar Photoelectric Photometer". Several variations in circuit design of this type of amplifier exist but Kron's "Amplifier A" is one of the better units of this type and is also one of the least complex to construct. His paper is quite detailed, so that the average amateur should have little difficulty in constructing this unit. It is suggested here that the amateur construct one of these basic units first in order to obtain experience in this type of work. It is also suggested that the amateur use the 931–A photomultiplier tube to test his system. This tube is much cheaper than the 1P21 tube that is recommended for this work so that if an error has been made in the circuit and damage results to the photomultiplier tube, it won't hit the pocketbook so hard. If the unit functions properly, one can then purchase the better 1P21 tube. These tubes are directly interchangable so that the circuit will not have to be modified. It should also be noted that photomultiplier tubes of the same type vary widely in performance. One may indeed be fortunate enough to find a 931–A that will outperform the average 1P21. For best results one should have a number of these tubes on hand and select the best one for use. However, this is an expensive proposition and the average amateur will probably have to make do with the tube he has.

Once one is proficient in the use of the simple photoelectric photometer he should consider constructing the more complex version. This does away with relying on batteries. The battery-operated version can always be used as a portable unit or as a back-up unit. The more complex version is also described by Kron in *Amateur Telescope Making*, *Book Three* and is referred to as "Amplifier B". An up-dated unit of the same design is described in the AAVSO *Manual on Photoelectric Photometry*. This manual also describes associated equipment, observational methods and data reduction techniques. This manual is available from the Photoelectric Section of the AAVSO (187 Concord Ave., Cambridge, Massachusetts) at nominal charge and is a must for anyone seriously considering this type of work.

Another useful reference that should be in the amateur's library is *Photoelectric Astronomy for Amateurs* (edited by F. B. Wood, published by the Macmillan Co., 1963). This book is a collection of papers written by experts in this field and is particularly recommended for the serious amateur. It is a well-written guide for the construction of equipment, selection of observing programs and the analysis of results.

In the chapter on the construction of photometers by Dr. A. D. Code, a different D.C. photoelectric photometer system is described. It should be noted here that an error exists in the diagram of the D.C. amplifier and the high voltage power supply. Suggested corrections can be found in a review by Donald Engelkemeir of the AAVSO in *Sky and Telescope* **27**, 109 (February 1964).

If the amateur is interested in reading about advanced professional techniques, he should consult *Astronomical Photoelectric Photometry* (edited by F. B. Wood, published by the American Association for the Advancement of Science, 1953, and available in reprint form from University Microfilms, Inc., Ann Arbor, Michigan). This book is a collection of papers presented at a symposium on December 31, 1951 at the Philadelphia meeting of the Association. These papers describe various photoelectric and visual techniques used by professionals. It is directed mainly at the professional but the advanced amateur will find it most interesting even though the techniques described are beyond the means of the average amateur.

Conclusion. The photoelectric section of the AAVSO or other astronomical societies should be contacted for assistance in preparing an observational program. They can supply a list of stars that require observation, and can offer suggestions on techniques and instruments. Professional observatories operate largely on independent programs but once it becomes known that an amateur is skilful in this field he may be approached for assistance in some of their programs. Your results can be offered for publication in such astronomical journals as the JOURNAL of *The Royal Astronomical Society of Canada* and *Sky and Telescope*.

Do not be discouraged by initial failure. Experience will come in time and your results will be accepted by the professional astronomer. This type of observation can be most rewarding once one develops the necessary skills. Hopefully this paper and the references listed therein for further study will assist you in organizing a most interesting astronomical research program.

NORTH BAY. E. P. MAJDEN

A Suggested Eclipse Experiment

With particular reference to the rapidly approaching Alcan total solar eclipse, we would like to suggest a well-known eclipse experiment which the amateur astronomer might consider undertaking. This is the attainment of the spectrum of the solar chromosphere visible during a few fleeting seconds before and after totality. Hence the term flash spectrum is used. Such an experiment may bring to mind complex equipment and the possibility of not even seeing the eclipse because of the equipment. However this need not be true. The flash spectrum experiment is one which can be conducted at virtually any level of complexity. For a simple yet dramatic experiment only a replica diffraction grating and a camera are needed.

The very shape of the chromosphere lends itself well to the formation of a slitless spectrum. Therefore the spectrograph need only consist of a transmission diffraction grating properly mounted in the optical train of a camera, or a relatively wide field telescope with a camera body directly attached.

The diffraction grating will do two things. First, it will act like a transparent glass flat and transmit (for transmission gratings) the primary image virtually unchanged. In addition it will provide repeated spectra of the primary image (the chromosphere) on either side of the image. These consecutive spectra are referred to by denoting those two nearest the image as first order, the next two as second order, etc., increasing outwards.

Obviously a very important consideration is where the grating is to be mounted. This will be determined largely by the size of the film, the number of lines per centimeter on the grating, and the ingenuity of the experimenter. If the grating is too far from the film the spectra will be too extended and will go beyond the frame. On the other hand if the grating is too close the spectra will be too compact. Also the greater the number of lines per centimeter on the grating the larger the extent of the spectra. In order to capture spectra on both sides of the central image the maximum allowable distance in centimeters from the film to the grating is roughly 7,000 times the film size in centimeters divided by the number of lines per centimeter on the grating. To photograph the spectrum on just one side of the image a maximum of approximately twice this value applies, or somewhat greater if the central image is unwanted. To obtain second order spectra the maximum distance is roughly halved. In practice it is best to stay well within these maximum values. Also the grating must be mounted where most of the light rays will pass through it and not around it. As long as the grating is mounted as specified above it can be located anywhere in the light path of a telescope or camera. For example it could be located on either side of a camera lens. With telescopes it will usually be best mounted somewhere between the telescope and camera.

Another important consideration is that the lines of the grating must be aligned perpendicular to the direction in which the spectra are to be formed.

Finally a word about safety is in order. For well-known reasons the telescope or camera should not be pointed at the sun until the photosphere is completely obscured.

We have successfully carried out this experiment at the March 7, 1970 total solar eclipse using a replica diffraction grating of 5280 lines per centimeter mounted 9 centimeters in front of the focal plane of a Pentax 35 millimeter camera. The lens was a 1000 millimeter focal length Nikor, which conveniently allowed the grating to be mounted on an internal filter wheel. The film was high speed Ektachrome (ASA 160) with an exposure time of 1/15 second. The resulting flash spectra clearly showed the hydrogen lines of the Balmer series, magnesium and sodium lines, and the calcium H and K lines, as well as the green coronal line of iron XIV at 5303 angstroms. For information on identifying lines in the flash spectrum see page 308 of the May 1970 issue of *Sky and Telescope*, or page 2625 of the December 1970 issue of *Applied Optics*.

Inexpensive replica transmission diffraction gratings may be obtained from Edmund Scientific Co., 300 Edscorp Building, Barrington, New Jersey 08007.

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An Evaluation of Cameras for Photographing Stars

Purpose. In observational programs such as patrolling the sky for novae or monitoring large numbers of variable stars, the major concern is to record as many stars as possible at the lowest cost. In this survey, I have investigated seven cameras of the sort which might be available to amateurs, and I compare the number of stars recorded, the rates of recording them, the costs of recording them, in hopes of finding the optimum methods of obtaining such data.

Method. Photographs of the same region of sky were obtained with each of the cameras listed below. Enlargements great enough to show the grain structure of the emulsion in each case were prepared, and from these the total number of stars were counted inside a one-square-degree region in the North America Nebula in Cygnus. Most of the negatives were chosen from series of increasing exposure, and the star counts were taken from the optimum one. The region counted is in a rich part of the Milky Way, hence the number of stars tabulated will actually be found only on photos taken near the galactic plane. Data for the Schmidt camera were obtained from Vehrenberg's *Atlas of Deep Sky Splendors*: the stars on the high-quality reproduction were counted in the same manner as on the direct photographs. The tabulated field sizes include only regions of reasonably good image quality, and the blur sizes refer to the blur formed by a faint star near the optical axis.

The Lenses. a) "Wideangle"—a 28mm Vivitar lens. This records the greatest number of stars per cent. Its usable field is over 60°, but the resolution is poor. Very easy to guide. Cost: $60.
b) "Normal"—a 50mm lens for the Canon camera. Very good image quality near the centre, but deteriorating and vignetting off-axis. This lens is the fastest—recording 5000 stars per minute—and is capable of recording the whole sky in one night on 80 frames. Limiting magnitude around 11.5 or 12. Cost: $50; camera body: $100.

	Wide-angle	Normal	Folding	Metrogon	Telephoto	Aerotessar	Schmidt
focal length (mm)	28	50	105	150	180	610	1010
aperture (mm)	10	25	23	20	52	87	300
f-ratio	2.8	2.0	4.5	7.5	3.5	7.0	3.3
type of film	Tri-X	Tri-X	Tri-X	Royal X	103aF	Royal X	HPS
exposure (minutes)	15	6	15	60	15	60	75
stars/square °	15	47	55	105	93	320	1650
angular coverage (square °)	3000	600	600	2500	100	500	40
stars/exposure	45,000	30,000	35,000	175,00	10,000	150,00	67,000
stars/minute	3000	5000	2300	2900	670	2500	900
blur (microns)	50	35	50	70	100	60	25
resolution	6′	2.5′	1.7′	1.7′	1.7′	0.25′	0.08′
cost/exposu	re6¢	6¢	9¢	80¢	6¢	80¢	50¢
stars/cent	7500	5000	4000	2300	1700	1900	1400
stars/8 hour night	1,450,000	2,400,000	1,100,000	1,400,000	320,000	1,200,000	400,000

c) "Folding"—an old-fashioned Kodak Tourist Camera—better resolution than the 50mm lens, but slower. Less vignetting and falloff of image quality than the normal lens. Large film and high resolution make this camera ideal for a beginner. Cost (used): about $20.

d) "Metrogon"—war surplus topographic and mapping camera. Covers an enormously wide field (64° by 74° and 90° across the diagonal). Despite the small aperture, goes fainter than the 35mm camera because the permissible exposure is longer. Records the greatest number of stars per exposure. Image quality not too good; astigmatism builds up rapidly off-axis, but records 80 per cent as many stars 30° off-axis as it does on-axis. Film cost rather high. Cost (surplus): about $50.

e) "Telephoto"—180mm Soligor lens, to fit 35mm camera. Really poor images for a "precision" lens; covers a narrow angle also. Vignetting, but not severe. Exposures would be longer with Tri-X, so its overall efficiency would fall lower still. Cost: $50.

f) "Aerotessar"—another surplus bargain; large aperture uncoated lens designed for 9″ by 18″ film. Most amateurs using this lens use 4″ by 5″ film, but the image quality is good even on 8″ by 10″ film. Best stopped down 0.5 stop. Reaches 15 to 15.5 magnitude stars; well suited for variables. Can cover about 10 per cent of the sky per night. Cost (surplus): $50.

g) "Schmidt"—professional-sized instrument; reaches magnitude 17. The field coverage is very small because the film lies in the path of incoming light, limiting the field to about (30/f-number) degrees. Excellent for work that does not involve recording large amounts of sky quickly. Cost: $500+.

Discussion. From the tabular data, it is possible to pick out the factors which result in high star-recording efficiency. First is focal length: the longer the focal length, the more stars that are recorded in a given area of sky. (Notice, in the table, that the focal length and number of stars per square degree both increase continuously, excepting in the case of the telephoto lens, because of its poor images, while aperture and number of stars are poorly correlated.) This exemplifies a fact not often known to amateurs: that limiting magnitude depends only on focal length, and not on aperture. The second factor is field coverage: how big a piece of sky can you record per exposure? It is obvious that several of the cameras lose efficiency considerably due to the small angular size of the picture they take. However, the wide-angle cameras tend to have shorter focal lengths, and poor images off-axis. We must look for a compromise between focal length and angular coverage. The last important factor is image quality. A comparison of the data for the Metrogon and the telephoto lens shows the loss in stars per square degree due to a larger blur. Actually, the telephoto should be able to record more stars. The Schmidt would be nowhere near as efficient if its image quality were as poor as the Aerotessar, and the Aerotessar would triple its recording rate if its images were as good as those of the Schmidt.

Costs for film are based on "drugstore" film prices, and are at best, good estimates. It will be noticed that the cost of recording stars drops with shorter focal length, and we have also seen that the limiting magnitude also drops with focal length. Thus we can infer that it is cheaper to photograph bright stars, and more expensive to photograph faint ones. The faint ones are generally the more interesting ones, if only because they have been studied less, so we must end up paying the higher price, around 2000 stars per cent, for the better-quality stars.

Conclusions. The compromise between focal length and angular field is not difficult to find To obtain good image quality over the field, we are limited to normal lenses, around 1000 square degrees. In order for both the angle and focal length to be large, we must use large-size films. 8″ by 10″ film is the largest readily-obtainable sheet film, so this sets the focal length somewhere between 10″ and 14″. Thereafter, we need only haunt the used-camera shops until a high-quality, but decrepit, view camera or process lens (cheaper without a shutter) pops up. Test it before buying it! The Aero-Ektar aerial lens of 12″ focus may be a good choice, but they are expensive ($150). The lens would record around 200 stars per square degree, over 1000 square degrees, or roughly 200,000 stars per exposure; perhaps 2,000,000 per night. Before getting carried away, it will be necessary to work out methods of utilizing this information, whether simply searching for novae, or estimating brightnesses for the hundreds of variable stars it is possible to record in a single exposure.

TORONTO RICHARD BERRY

Vancouver/Victoria General Assembly

"Joie de vivre" is the theme of this year's General Assembly in Vancouver. The centre of activities will be at the beautiful campus of the University of British Columbia, where delegates will be housed in modern residences, presently in the final stages of construction.

On Sunday, May 21, delegates will board a ferry for a scenic and relaxing trip to Vancouver Island, where the Victoria Centre will be hosting us for the day, including a tour of the Dominion Astrophysical Observatory at Saanich. Careful planning for a variety of activities will make this the most exciting General Assembly ever—besides being the first on the west coast.

Members are invited to contribute to the Session for Papers on such topics as historical astronomy, instrumentation, results of original observational programs, etc. A reminder—members attached to Centres must have their papers approved by the Executive of their Centre *before* submitting. "Unattached" members should send an abstract of about 150 words *not later than 31 March* direct to:

Dr. J. L. Climenhaga,
Faculty of Arts and Science,
University of Victoria,
Victoria, B.C.

Further information will be sent to each member soon. PLAN TO ATTEND THIS GENERAL ASSEMBLY—MAY 19-22 INCLUSIVE!

General Assembly Committee,
c/o 3889 West 26th Ave.,
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