TUESDAY 21 APRIL, AFTERNOON SESSION

Stan Vasilevskis presiding

THE INITIAL PERFORMANCE OF THE GALAXY MACHINE

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The GALAXY (General Automatic Luminosity and X, Y) measuring machine of the Royal Observatory, Edinburgh was completed in 1969 and has been in continuous use since October. It scans a plate, notes the position of all images between preassigned limits and measures some, or all, of these for magnitude and position. The machine was conceived as an attempt to answer the "Schmidt Problem": how best to handle the immense amount of data that plates taken with Schmidt cameras contain. The general concept of the present machine is due to Professor P. B. Fellgett but the credit for actually bringing the concept to fruition belongs to Dr. V. C. Reddish of the Royal Observatory, Edinburgh and a small design team of what is now Faul Coradi Scotland Ltd.

The heart of GALAXY is a highly accurate two dimensional coordinate table which carries the plate and whose position is read off in units of one micron by two Moiré fringe grating systems. Two cathode ray tubes of the micro-spot type with their scanning assemblies and optical systems are rigidly mounted on a heavy casting spanning the carriage. The star images are brought in turn within the optical field of one or other of these systems by the appropriate automatic mechanism. One of the systems is used for the preliminary scanning, the other for precise measurement.

For scanning, the light produced by the first tube is projected down to a small spot, (8, 16, 32 or 64 microns in diameter depending on the size of the images under examination), passes through the plate and on to a photoelectric cell. The passage of the spot of light over a star image is detected as a reduction in the brightness of the spot. There is a memory of successive scans over the same image and when the image has been finally passed its X, Y coordinates are punched out on eight-channel paper tape with a precision about equal to the size of the scanning spot. The plate is scanned in columns eight millimetres wide by the combination of a line scan on the cathode ray tube and mechanical indexing of the carriage in the orthogonal direction. With a resolution of sixteen microns, the Edinburgh Schmidt plates currently being measured are searched at the rate of thirty square millimetres per minute and, on an average, some ten thousand stars found per hour.

The precision measurement of the plate is carried out as a separate operation controlled by a punched tape giving the approximate coordinates of the stars to be measured. This tape can be either that produced during

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the search phase or, if only selected stars are of interest, one prepared quite independently. The projected spot of light produced by the measurement cathode ray tube, only one micron across, is scanned in a spiral pattern either 256 or 2048 microns in diameter depending on the range of sizes of the images to be measured. If the approximate setting coordinates do not bring the image precisely to the centre of the spiral pattern, more light passes one side of it than the other. This actuates a servo mechanism which moves the carriage until centering is achieved. At the same time the density-radius profile is compared with 1024 programmed profiles chosen to be appropriate to the particular plate and contained in a core store. The profile matching and the centering are both weighted by a function related to the distribution of information within the image. Finally the coordinates of the image centre and the address of the matching profile, which is a measure of the magnitude, are punched out on eight-channel paper tape ready for subsequent computer analysis. The repeatability of the measures is $\pm$ 1/2 micron (r.m.s.) in position and $\pm$ 0.017 in magnitude. Moreover, this repeatability is independent of the magnitude over the ten magnitude range measured, while the machine measure of image strength is almost linearly related to magnitude over the same range.

To provide the data for the reductions, it is essential to include amongst the stars measured a number whose positions and magnitudes are already known. In practice this group of selected stars is measured not only at the beginning but also every hour, i.e. after each 900 stars, to check on the stability of the measures and to allow for the correction of any residual systematic drift. Gross systematic drifts are not to be expected since the machine is operated within a dust free, air conditioned enclosure whose temperature is controlled to within $\pm$ 1/2° C.

GALAXY has now been in continuous use for over six months and has given remarkably little trouble though it is being run for an average of over twenty hours per day. It has been used for a number of different programmes, the order of measurement being mainly determined by the availability of the appropriate soft ware for processing the measures on the computer. Among the investigations scheduled for the machine are searches to faint magnitudes for heavily reddened OB stars, for stars with infrared or ultraviolet excesses, or with strong emission in spectral regions selected by narrow band filters; polarimetry of some tens of thousands of stars in cluster, associations and the Magellanic Clouds; parallax surveys by the measurement of all stars down to a prescribed magnitude. As a pilot scheme for these latter, an area close to S.A.8 containing a number of stars of appreciable parallax is under observation.

From the first group of nine plates, three in each of U, B, V of an area surrounding Stock 2, a photometric catalogue of some 25,000 stars was virtually produced based on the measures of over 1/4 million images. From these the heavily reddened stars B5 and earlier were selected and listed. There were over 1000 such stars down to V magnitude sixteen as

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compared with the fifteen previously known from the Hamburg-Cleveland survey which went down to magnitude thirteen.

GALAXY is being made available for processing material from other observatories. It is visualised that the plates together with identification charts, standard magnitudes and positions will be received from investigators and that after processing these will be returned with the measures already reduced to positions, magnitudes and colours, with colour-magnitude and two colour diagrams as requested already plotted, and with printed lists of specially designated groups of stars, etc. The provisional schedule for the next six months includes time for material from the Cambridge, Lund, Oxford, Greenwich, Padua and Yerkes-Göttingen observatories.

DISCUSSION

Dieckvoss: Is it possible to measure a plate with the emulsion down?

Stoy: No. The precision measuring system has too short a focal length to permit this. In fact the focal length is so short that it has been necessary to incorporate a device to maintain the focus in spite of variations in the thickness of the photographic emulsion. An air balancing system allows the lens unit to rest on the emulsion surface with a downward thrust of about three grams.

Dieckvoss: Is it possible to program the machine so that it could measure black crosses such as the réseau marks on many of the astographic plates?

Stoy: This is possible but the precision would depend somewhat on the nature of the cross. The machine is not confused by the diffraction pattern round bright stars.

Murray: As the Greenwich use of the machine has been alluded to and as this is a proper motion conference, there is one program I would like to mention. For several years now I have advertised the fact that we are re-determining the proper motions in the Kapteyn Selected Areas using the old Radcliffe-Oxford plates, and these will be measured on GALAXY with modern plates which have been taken at Herstmonceux. In fact our pilot program consists of those seven Selected Areas for which photoelectric standards have recently been published.

Stoy: Included in the provisional schedule for the machine this year are allocations of time to:

Yerkes and Göttingen for the measurement of proper motions in the regions of M 39, IC 4756 and two other clusters.

Oxford (Dr. Ingham) for the measurement of magnitudes in part of M 31.

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Padua for the measurement of quasar positions.

Cambridge (Dr. Argue) for parallax measurements in the region of the Hyades.

H. M. Johnson for measurements in connection with X-ray sources.

Wesselink: What is the maximum size plate the instrument takes?

Stoy: The present one, I think, is 10 x 10 cm, but it can be enlarged to about 35 x 35.

Wesselink: I thought it was fourteen inches by fourteen inches.

Stoy: I think that the makers have realized that ten by ten was an unnecessary limitation to the plate size, and, as a result of recommendations by other people, they are now making a plate holder that will take fourteen by fourteen inches, and will measure twelve by twelve inches. So you would lose an inch around the edge of a fourteen inch plate. But this is just a minor modification to the existing hardware. Any future machine, including the one that we are helping to build for Herstmonceux, will have this larger plate carriage.

Fricke: I wonder, you have not mentioned actually the metric problem which could be tackled. I would be very interested whether there is a plan for measuring position on a larger scale.

Stoy: I am hoping that we are going to measure some of the plates as well as the tape with a positional camera. It just depends, I think, on the Greenwich people and Clube in particular. But when we are taking the plates with the tape four to seven hemisphere reference catalogue, we had GALAXY very much in mind. Incidentally, I might mention that between 21 September and 30 October of this year the machine will be used for the Yerkes-Nottingham program of proper motions of M 39 and that area. Later in the year, when the plate holder is available, it will be used on M 31, a portion for Ingham of Oxford; some quasar measurements for Percherer; some parallax measurements for Hyades of Cambridge; some X-ray sources for H. M. Johnson. So you see that even if we run the machine full time for a year we shall measure only one-quarter of the year's observational output even in a climate like Edinburgh. There is still a variety of work the machine can do.

Mohr: Once you have decided which profile matches most closely the profile of the star which you have, how do you go about assigning a magnitude?

Stoy: That is where the reference stars come in. You must at least put some data into the plates.

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Mohr: So you must know the magnitudes of the reference stars. Do you have any results available which show how reproducible the profiles are with regard to magnitude?

Stoy: Most of the measurements made so far have been on regions that have been well studied at Edinburgh, e.g. the end of the Perseus arm at galactic longitude 140. And there the indications are that the connection between the profile number and the magnitude is linear over the whole range of magnitude. Far more linear than when the measurements are made with the Decca machine and our star plate machine.

Murray: May I make a point about this. The philosophy of the machine is to have a library of profiles that you can fit to the star images as you have them on the plate. But you can change the system profiles as you like. So you can put in 1,024. You can make your library profiles fit the particular plates you have. The plates Stoy has been talking about are Schmidt plates, and I am more interested in measuring astrometrically, as it happens, all the long focus plates, and the profiles will not be the same. The image structure is different. But, the photo-electric standards that we have been able to measure on one set of plates show also the same linear relationship for a different profile system. You still get a linear relationship between the profiles and the photo-electric magnitudes, and you can change your profile system according to the plates you have.

Eichhorn: What is the speed of the machine with its coordinate measuring? How many stars an hour?

Stoy: Roughly it is 900 an hour in the measurement phase and 10,000 an hour in the search phase. The 1,000 feet of tape handle something of the order of 20,000 in the search phase and 15,000 in the measurement phase. That, of course, is punch tape. Then comes the real software work - feeding this tape into the computer, and getting out the results that you want.

Vasilevskis: What is centered when you have asymmetric images say, affected by coma, or, what I am interested in, galaxies which are not always symmetric as you know?

Murray: What the scanning spot does - you see it is a spiral scan, it starts from the outer regions and gradually works in, and it differences the density of the profile image stored with what it measures. But if you have a perfectly round image then you get a nice thin trace as you saw on the cathode ray display. If you have anything which is not symmetrical, then you do not get a unique trace, you get rather a fat looking object, and a double star would have quite a wide scan. It would not converge to a particular profile.

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I think I am right in saying, that there is a time limit beyond which, if it does not produce the proper balance between a profile in the store and the observed profile, then it punches out an answer and puts a note against it saying it does not like the looks of it. Provided that it is satisfied with its match and it has achieved a unique profile within a limited time - something like one or two seconds - then that is considered to be a good match. So I think the answer is that if it has a double star, it will put a flag on it but it will not tell you it is a double star. Similarly with achromatic image. And, in fact, it punches out the search coordinates so you can not really believe the coordinates that you get if it has one of these dud images. It is just that the coordinates which it got from the search might be 32 or 64 microns different from the center of gravity.

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