Numerical comparison of the precision of the two methods is given, as well as the dependence of the estimate on n , the number of stars.

Davis, H. T. 1933, *Tables of the Higher Mathematical Functions*, Vol. I (Bloomington, Ind., Principia Press).

*University of California,
Berkeley, Calif.*

Sen, Hari K. Radiation broadening of a shock front.

The material hydrodynamics of the structure of the shock front has been extended to include the propagation of energy by diffusion of radiation. Radiation by, and subsequent absorption in, the shock front is found to make the shock front wider than when the dissipation is by viscosity and heat conduction alone. The radiative contribution to the width of the shock depends primarily on the ratio of the mean free path of radiation to that of the material particles. The overall effect can be represented as a diminution of the Prandtl number. The proportional increment in width is a function of the Mach number of the shock and increases with it.

The analysis confirms and extends the physical intuition that absorption of radiation would tend to make the shock front broader. The widening of the front extends the range of validity of the Stokes-Navier equations towards higher Mach numbers. Experimental measurement of the shock width in the laboratory—in a shock tube, for example—should give an estimate of the mean absorption coefficient.

*Air Force Cambridge Research Center,
Bedford, Mass.*

Smith, Henry J. and Smith, Elske v. P. Chromospheric spectra outside eclipse.

Certain obvious advantages are to be expected from high dispersion spectral studies of the chromosphere outside eclipse, such as more accurate wave-length determination and the possibility of measuring line profiles with high precision. On the other hand, certain photometric problems greatly complicate the interpretation of results.

In early summer 1956 we obtained a series of such chromospheric spectra at Sacramento Peak Observatory. Visual inspection of such spectra reveals only a few of the chromospheric lines as emission features. The flash lines are for the most part engulfed and subdued by the corresponding Fraunhofer lines of the limb spectrum, which is of course superposed on the chromospheric spec-

trum through seeing excursions of the limb beyond the occulting disk. The true flash spectrum is revealed only after careful densitometry to remove the spurious background. We have been able to do this photometry by means of a direct intensity or log-intensity photometer designed by E. W. Dennison. The advantage of the logarithmic presentation is that a given line depth corresponds to a unique deflection regardless of the continuum density.

Thus far, the wave-length regions 3880–4090Å, 4290–4380Å, and 4830–5099Å have been studied. In these regions the following ionized rare earths are predominant in the flash spectrum, Ce_{II} , La_{II} , Nd_{II} , Sm_{II} , Y_{II} , Eu_{II} , Gd_{II} , and Dy_{II} , roughly in that order of prominence. Then follow Ti_{II} , Sc_{II} , Sr_{II} , Fe_{II} , Ba_{II} , Zr_{II} , and very faintly Mg_{II} . Finally certain neutral metal lines are salient, such as Al , Ti , and Ni . The spectra of neutral Fe , V , and Mn are inconspicuous. This confirms the finding of Adams and Burwell (1915). We plan to extend this study to greater wave-length coverage. Profiles of selected lines will be obtained from higher dispersion plates. Exploitation of the coronagraph should enable us to obtain spectra of the high as well as the low chromosphere.

Adams, W. S. and Burwell, C. G. 1915, *Ap. J.* **41**, 116.
*Sacramento Peak Observatory,
Sunspot, N. Mex.,
and Harvard College Observatory,
Cambridge, Mass.*

Spitz, Armand. Professional cooperation with the visual satellite observing program.

The personnel, instrumentation and observational techniques required for visual tracking of the satellite rule out project "Moonwatch" as a part of the program of most professional astronomers. However, some may wish to help as technical advisers to volunteer groups. They may be able to offer a site and physical facilities for an observing station. Some may accept the responsibility of training and leading teams of observers. All must certainly be prepared to accept the responsibility of interpreting the entire satellite program to the lay public in their communities.

*Smithsonian Astrophysical Observatory,
Cambridge, Mass.*

Sterne, Theodore E. A suggested analytical treatment of the orbit of a close satellite.

An analytical treatment of the motion of a particle near an oblate earth would be useful in

applications to close artificial satellites. General planetary perturbations conventionally start with the Keplerian motion that would occur in an ideal, central, inverse-square field as the undisturbed motion; all other forces are then regarded as causing perturbations. For a close terrestrial satellite the inverse fourth-power forces due to oblateness are so large—about a thousandth of gravity—that such forces and others may require perturbations of high order for their adequate inclusion.

However, the distinction between undisturbed and disturbed motion is partly artificial, since it depends on the selection of what is regarded as the undisturbed motion. The Hamiltonian

$$H_0 = \frac{1}{2} \left(p_r^2 + \frac{p_\alpha^2}{r^2 \cos^2 \delta} + \frac{p_\delta^2}{r^2} \right) - \frac{\mu}{r} - \frac{\mu B A^2}{r^3} + \frac{3\mu B A^2}{r^2 a} \sin^2 \delta \quad (1)$$

represents the principal oblateness effects perfectly in equatorial orbits of all eccentricities, and very well in inclined orbits that are nearly circular. Here r , α , and δ are the geocentric distance, right ascension, and declination, respectively, and the p 's are the conjugate momenta. B and μ are physical constants describing the oblateness and gravity, while the best value of the arbitrarily disposable constant a probably about equals the mean distance. Without the last two terms, the equation would yield Keplerian motion. The non-Keplerian problem described by the full equation can be solved exactly, since the corresponding Hamilton-Jacobi partial differential equation is solvable by inspection. The solution resembles the real motion much more closely than does any Keplerian motion, because most of the oblateness effects are already present in the equation and only residual oblateness effects remain to be allowed for by a perturbation treatment.

It is suggested that the solution of (1) be chosen as the undisturbed motion in a general perturbation treatment. Then it will hold exactly in the real situation, provided that the six canonical constants of the solution are considered to undergo time variations defined by Hamiltonian equations, with the constants as the variables, and involving a disturbing Hamiltonian. The residual oblateness terms cause a much slower time-variation, of the canonical constants, than the time variation of the conventional Keplerian elements caused by the whole of the oblateness,

ignored in the Keplerian undisturbed motion. It is possible that the application of perturbations of only the first order to the undisturbed motion (1), to allow for residual oblateness terms and all other forces, may lead to analytical orbits as accurate as those yielded by second-order perturbations applied to a conventional and less appropriate Keplerian undisturbed motion. Such first-order orbits may be adequate for many physical comparisons.

The author plans to publish this suggestion in detail, but not to follow out its consequences himself.

*Smithsonian Astrophysical Observatory,
Cambridge, Mass.*

Stock, Jurgen and Wehlau, William. Light variability for a sample of M-type stars.

The purpose of this investigation is to provide information on the frequency of light variability among M-type stars. Approximate values for the periods and ranges will also be derived for variables for which the data are adequate.

A sample of 300 of the brighter M stars covering the range from M2 to M8 and 15 C stars has been selected on an infrared objective-prism plate taken with the Schmidt telescope of the Warner and Swasey Observatory. In addition 18 stars of earlier type which may be expected to be non-variable have been included for comparison. These stars are in a region of 12 square degrees in Lacerta and Cepheus for which a series of direct photographs covering ten years was available. Magnitudes are derived by visual comparison of the images with a graded scale of images.

Stars are considered variable if they show variation in the blue and in the red and both variations are in the same sense. Preliminary data for seven epochs in the red give 58 stars which show variations greater than or equal to 0.9 mag. and may be considered real variables. For 29 of these stars data are available in the blue for 4 epochs and generally confirms the variability. In addition some of the stars which show smaller ranges are really variable; however, the effect of errors in the magnitudes must be allowed for in this case. The increase in the percentage of variables for the late M stars as compared with the earlier M's is clearly shown. Additional epochs are being added.

*Warner and Swasey Observatory,
East Cleveland, Ohio,
and University of Western Ontario,
London, Canada.*