ASTRONOMISCHE NACHRICHTEN.

N^o 3069.

Distribution of Energy in Stellar Spectra.

By Prof. *Edward C. Pickering*.

The relative brightness of stars or other luminous objects of different colors cannot be correctly indicated by any single number or ratio. It is necessary to employ a curve or series of numbers which shall give a measure of the energy of rays of each different wave-length. Stellar magnitudes only have a value so long as we can neglect the differences in distribution of the light according to the wave-length. Therefore when we compare the results of different processes, as photography and visual observations, entirely different results will be obtained for objects of different colors. If however we deal with rays of a single wave-length all methods should give the same relative intensities. The intensities of rays of different wave-lengths may be determined by comparing the densities of different portions of a photographic spectrum. But large corrections must be applied for various sources of error or rays of each wave-length. Among these may be mentioned the absorption of the earth's atmosphere, the absorption of the prisms and lenses, the unequal sensitiveness of the silver salts and the dispersion of the prisms by which the violet rays are spread over a larger surface than the red rays. The direct determination of all these quantities would be a matter of no little difficulty. Fortunately, this problem is greatly simplified by making the measures differential and comparing them with the elaborate determination of the distribution of the energy in the solar spectrum made by Professor Langley with the bolometer. He was aided in this research by Professor F.H. Very and has kindly furnished approximate values of their results, from which the quantities given in the accompanying table are derived. The values of the wave-lengths are given in the first column and the logarithm of the corresponding amount of energy in the second. The unit of energy is here assumed to be that of the hydrogen line *G*, this point being selected since it is near the centre of the photographic spectrum. Instead of the usual logarithmic expressions corresponding to numbers less than unity, the equivalent negative expressions have been used. Thus -0.26 is substituted for 0.74 etc. to make the table conform to the usual method of representing negative quantities. They can thus be readily converted into intervals on the scale of stellar magnitudes if desired by dividing by 0.4 . Thus the logarithmic interval -0.26 would correspond to 0.65 of a unit of stellar magnitudes.

From the collection of photographs of stellar spectra forming part of the Henry Draper Memorial nine were selected, all taken under similar conditions. They represent α Virginis, γ Cassiopeiae, α Canis Majoris, α Canis Minoris, α Aurigae, Saturn, α Tauri, α Orionis and the Sun. The spectrum of α Virginis is of the first type but the Orion lines are well marked; γ Cassiopeiae contains bright lines; α Canis Majoris is a typical first type star, α Canis Minoris is intermediate between the first and second types; α Aurigae is of the second type; Saturn's spectrum closely resembles that of our Sun, so also does that of α Bootis; α Orionis is of the third type, or intermediate between the second and third. The spectrum of the Sun was obtained by reflecting its rays through a narrow slit and then rendering them parallel by means of a concave mirror having an aperture of 15 inches and a focal length of 150 inches. Measures were then made by Mrs. Fleming of twenty points in each of the spectra, by comparison with a standard photographic wedge (Harvard Observatory Annals XXVI p. 6). These measures were converted into logarithmic intervals and the measure corresponding to the wave-length 434 which is that of the hydrogen line *G* was subtracted from each. The values of the logarithm of the energy of the solar light taken from the second column of the table was next subtracted. The remainder will show the excess or deficit of energy of the star as compared with that of the Sun eliminating the various sources of error enumerated above. Finally the observed points were plotted and smooth curves were drawn through them. From these curves the values were found for each of the wave-lengths given in the table. The results for the various stars observed are given in the successive columns of the table. Thus in the case of α Orionis the energy for the wave-length 390 or near the line α , is -0.57 as compared with that of sunlight. The numerical ratio is 0.27 , whose logarithm is 9.43 . The absolute energy is found by adding the tabular number to that given for sunlight in the second column. Thus $-0.26 - 0.57 = -0.83$ corresponding to the ratio 0.15 . In the case of α Orionis therefore the energy of the light of wave-length 390 is only about one seventh of that of wave-length 434. The numerical values of the energy of sunlight is given in the last column of the table. It therefore equals the antilogarithm of the second column.

λ	log E	α Virg.	γ Cass.	α Can. Maj.	α Can. Min.	α Aur.	Saturn	α Tauri	α Orion.	E
390	-0.26	+0.32	+0.25	+0.37	+0.07	+0.32	-0.36	-0.35	-0.57	0.55
400	-0.19	+0.14	+0.10	+0.10	-0.04	+0.08	-0.20	-0.14	-0.38	0.65
410	-0.12	+0.04	+0.03	+0.01	-0.03	+0.03	-0.11	-0.04	-0.23	0.76
420	-0.07	0.00	+0.01	0.00	-0.01	+0.01	-0.06	-0.02	-0.11	0.85
430	-0.02	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	-0.02	0.95
440	+0.02	+0.01	0.00	-0.01	+0.01	0.00	0.00	+0.01	+0.05	1.05
450	+0.06	+0.01	0.00	-0.02	+0.01	-0.01	+0.01	+0.02	+0.10	1.15
460	+0.09	-0.04	0.00	-0.03	-0.03	-0.03	+0.03	+0.02	+0.10	1.23
470	+0.12	-0.17	-0.04	-0.10	-0.10	-0.09	+0.04	-0.01	+0.08	1.32
480	+0.14	-0.37	-0.14	-0.21	-0.23	-0.22	+0.03	-0.12	+0.03	1.38
490	+0.16	-0.59	-0.26	-0.35	-0.40	-0.36	+0.02	-0.26	-0.04	1.45
500	+0.18	-0.83	-0.39	-0.51	-0.61	-0.51	+0.01	-0.43	-0.12	1.51
510	+0.20	-1.10	-0.54	-0.71	-0.84	-0.67	0.00	-0.63	-0.21	1.58

In the case of sunlight, a small correction should be applied for the selective reflection of the silvered glass mirror. This effect does not appear to be large, since the spectrum of Saturn gives nearly the same results as that derived from direct sunlight, except for rays of short wave-lengths. The negative values derived from these rays in the case of Saturn may be due to the selective reflection above mentioned. The corresponding residuals of the other spectra might be corrected by the amount thus indi-

cated. Perhaps, however, Saturn is really bluer than the Sun in which case the values already given are correct. The curve for α Aurigae is nearly the same as that of α Canis Majoris which shows that although its lines are the same as those of the Sun, the distribution of its light resembles that of a first type star. The red color of α Tauri and α Orionis as compared with α Virginis and α Canis Majoris is clearly shown by the change in sign of the residuals.

Observatory of Harvard College, Cambridge Mass. U. S. A., 1891 Oct. 31.

Edward C. Pickering.

On the Observation of North Polar Stars in the Vertical of Polaris.

By *Truman Henry Safford.*

It is comparatively quite easy to determine the right ascension of α Ursae minoris by double culminations. Other standard polars as δ Ursae minoris or γ H. Cephei are not so easily observed in the daytime, and therefore require a better organized service of observers than is found in many places.

It is not very easy, again, to connect other polars with double transits of Polaris. This is especially true in the region about 6^h and 18^h , but is quite sensibly felt on both sides of these right ascensions.

These difficulties would be of far less consequence if it were not quite important that there should be more independence in the various polar catalogues than now seems to exist. The form of the personal equation between slow and quick-moving stars depends — whatever method is employed in their observation — on so many complicated and little-studied psychophysical processes, that astronomers cannot be quite sure of the application of the formulae. I allude to this here only to emphasize the necessity which I myself feel of attempting to make more independent determinations of standard polar right ascensions.

As I have at my disposal only an unsymmetrical pair of collimators, the one an ordinary telescope with micrometer and fixed wires, and for declination pivots and a level, the other a lens of 100 feet focal length, with a mark mounted on a brick pier at that distance, I am somewhat

doubtful how far I can carry this independence in the limited time allowed by other occupations. It is quite easy to me, as for many others, to spend a good many evenings in observing; but not so easy (without neglecting other duties) so to employ other parts of the day.

In studying over these matters I have fallen upon a method which seems to me promising to be available some time in the future.

It is to observe a number of (not too close) polars in the Vertical of Polaris. The simplest case is that in which the greatest difficulties are felt in using the ordinary method. Let us suppose a portable transit with adjustable base to be fixed in such a position that Polaris shall be near its mid wire at the eastern elongation. This will occur about $19^h 23^m$ of sidereal time.

The two stars

Camelopardalis 25 H. Position 1891.0
 $7^h 8^m + 82^\circ 37'$

Schwerd 1172 = Carrington 2965 $19 29 + 83 15$ will pass the same vertical within about half an hour of this time; the latter, above pole, earlier than the pole star reaches its elongation; the former, below pole, later. Experience shows that a well made instrument will change its azimuth and polar deviation very little indeed during this period; so that, with or without level readings, the right ascension of the two smaller stars will be accurately obtained. The right ascension of Polaris does not enter into its azi-