

ART. XXVI.—The relative numbers of Shooting Stars seen in a given period by different numbers of observers; by H. A. NEWTON.

It is often desirable to compare the hourly number of shooting stars seen by one or more observers at one time and place, with the hourly number seen by observers at some other time and place. Allowance in such cases must be made for the state of the sky, for the moonlight or twilight, for the hour of the night, and still more for the number of persons counting. In order to obtain constants for eliminating as nearly as possible this last element, I arranged, and with the assistance of others carried out, a series of observations on two nights, the 15th and 16th of August, and the 14th and 15th of November, 1865.

Evidently two persons will not see quite twice as many as one, since some meteors will in general be seen by both. Still less will three or four persons see three or four times as many as one person. Experience has moreover shown that a small number of persons cannot see all that are visible, since each one usually catches some not noticed by the others. There must, however, be some finite limit toward which, as the number of observers increases indefinitely, the hourly number seen approaches asymptotically. For we cannot regard as infinite the whole number visible at one place in a finite time.

On the night of Nov. 14th and 15th, we began our watch at midnight, and continued it until three o'clock, twelve observers counting in that time 186 shooting stars. We were stationed upon the top of one of the towers of Graduates' Hall, from which there is an unobstructed view of the heavens. Most of my assistants were students in the college. They were directed to keep their eyes constantly upon the heavens. I made the record, and did not attempt to observe. Whenever a meteor was seen each person perceiving it called out his own name, and I entered it (or rather an initial letter of it) on the record.

The heavens were divided as follows among the several observers: Mr. C. G. Rockwood (R) looked toward the south, Mr. N. P. Hulst (H) to the west of south, and so on, following around the horizon, Messrs. J. J. DuBois (D), M. D. Mann (M), A. H. Adams (A), G. H. Perkins (G), J. H. Tallman (T), E. W. Miller (E), A. Warren (W), and F. W. Russell (F). Mr. L. T. Brown (B) and Mr. W. A. Peck (P) looked to the zenith. The letters in parentheses were used to denote the several observers. Their arrangement is represented in the diagram.

The following is a summary of the observations. We denote by Δ the number of shooting stars seen during the three hours by Adams that were not seen by any other person; by ΔE the number seen by both Adams and Miller, but not seen by any one else; and so on.

A=8	BR=1	AMT=1	ABTW=1	AGMTW=1
B=7	DH=1	DDR=1	AMPT=1	BEFPR=2
D=5	DM=3	BPH=1	BDNR=1	BEOTW=1
E=5	EM=1	BVF=1	BFHP=1	BFHPR=3
F=0	ET=1	BVR=2	DHMR=1	BFPRW=1
G=11	EW=1	DFW=1	EFPR=1	DHMPR=1
H=10	FB=3	BEF=1	EFPT=1	EPQPW=1
M=7	GT=2	BHR=2	EFNW=1	EFHPR=1
P=4	HM=1	DFH=1	EFTW=1	EFPRW=1
R=6	HR=5	DHM=3	EGTW=1	FHMPR=1
T=9	PR=2	DNR=3	FHPR=2	ABFMPR=1
W=2	PW=1	EQW=1	FMTT=1	AEFPTW=1
AE=3	ADM=1	EPW=1	GMTW=3	AEOMTW=2
AG=1	ADR=1	ETW=1	ABDGM=1	EFHMPR=1
AM=2	AEQ=2	FHD=2	ABEPW=1	AEFFPRW=1
AR=2	AGM=1	ABOT=1	ADEMP=1	AEFHPRW=1
AW=1	AGT=1	ADHM=1	AEFPW=1	BDHMPR=2
BF=2	AGW=1	AEOP=1	AEOMT=1	
BP=1	AMN=1	AEQW=1	AEOTW=1	

If we denote by Δ the whole number seen by Adams, and so of the others, we find from this table the following equations:

$$\begin{array}{llllll} A=45, & B=36, & D=27, & E=42, & F=39, & G=36, \\ H=45, & M=41, & P=40, & R=52, & T=32, & W=31. \end{array}$$

The mean is 38.75, which is the average number seen by each observer. Hence we have the proportion,

$$\text{No. seen by one person : No. seen by twelve :: } 38.75 : 186.$$

The numbers seen by individual observers vary between 27 and 52. The difference in the state of the sky in different directions as to haziness and clouds, and the difference in powers of vision of the observers, and in fixedness of attention, may account for this variation. In the mean of the results these

peculiarities of observers and of direction, are evidently to a great extent eliminated.

When two persons count the number of shooting stars which they can see, they naturally look in opposite directions. We shall therefore take account only of such couples, of which there are five. Designating by the symbol *HT* the number of shooting stars which were seen by one or both of the two observers Hulst and Tallman, and so of like symbols, we have the equations,

$$HT=77, \quad DE=68, \quad MW=66, \quad AF=79, \quad GR=87.$$

The several observers, except the two looking to the zenith, enter symmetrically into these equations. One of these two saw 36, and the other 40 meteors, while the average number seen by each of the twelve is 38·75. Hence, only a small error will result from their omission from the equations. In the mean of the numbers above given we should have, therefore, the number seen by two observers looking to opposite quarters of the heavens, freed very nearly from personal peculiarities. This mean is 75·4. Hence,

$$\text{No. seen by two persons : No. seen by twelve persons :: } 75\cdot4 : 186.$$

The following equations contain the same ten observers arranged in groups of threes, each observer included in three equations, and each group of three persons arranged very nearly symmetrically around the horizon. The zenith observers as before are omitted.

$$\begin{array}{llll} ENR=113, & GHW=97, & DCW=79, & DFG=96, \quad AHW=105, \\ AEH=109, & AER=108, & DFT=91, & FMT=93, \quad HRT=106. \end{array}$$

The mean of these is 99·7. Hence,

$$\text{No. seen by three persons : No. seen by twelve persons :: } 99\cdot7 : 186.$$

Again, selecting groups of four observers that shall be arranged as nearly as possible symmetrically around the horizon, we have,

$$\begin{array}{lll} DEGR=123, & GMRW=124, & HMTW=118, \\ AFHT=124, & ADEF=112, & \text{Mean}=119\cdot2. \end{array}$$

Hence,

$$\text{No. seen by four persons : No. seen by twelve :: } 119\cdot2 : 186.$$

In selecting groups of five or more observers we may include those looking to the zenith :

$$\begin{array}{llll} ABDEF=123, & AFHPT=134, & BHMTW=131, & GMPRW=133, \\ DEGPR=134, & ADRTW=133, & EFGHM=135, & \text{Mean}=131\cdot86, \end{array}$$

the number seen by five persons.

Again,

$$ADPRTW=141, \text{ and } BEFGHM=145. \quad \text{The mean}=143,$$

the number seen by six persons.

For seven observers we find the numbers for the seven groups formed by leaving out of the whole twelve successively the groups of fives given above. The mean of the seven numbers is 152·86.

For eight observers we form three groups by omitting successively from the twelve, DGPW, BEMR, and AFHT. The mean of the three numbers is 160·67.

For groups of nines we omit successively BDE, GPR, FMT, and AHW. The mean result is 166·75.

For groups of tens we omit in succession HT, DE, MW, AF, BR, and PG. The mean result is 173·5.

For eleven observers we omit each one of the twelve in succession. The mean result is 179·83.

These means are given in column A of the following table. Column B shows how many would be seen by a number of observers in a period during which four of them would see 1000 meteors. It is obtained by dividing the numbers in column A by the decimal 1192 :

	A.	B.	C.
Seen by one observer,	38·75	325	359
“ two observers,	75·40	633	651
“ three “	99·70	836	856
“ four “	119·20	1000	1000
“ five “	131·86	1106	1136
“ six “	143·00	1200	1249
“ seven “	152·86	1282	
“ eight “	160·67	1348	
“ nine “	166·75	1399	
“ ten “	173·50	1451	
“ eleven “	179·83	1509	
“ twelve “	186·00	1560	

In column C are given the results of a discussion similar to that just detailed, of observations made on the night of Aug. 15th–16th, 1865. Six persons, in three hours ending at two o'clock, saw on that night 172 shooting stars. Five of them were looking in different azimuths, and one to the zenith.

It should not be forgotten that these numbers are in each instance obtained from observations continued for only three hours, a period too short to furnish a result free from accidental irregularities.

These numbers depend evidently to some extent also upon the intrinsic brilliancy of the shooting stars on the night of observation; upon their uniformity, or want of uniformity, of brilliancy; upon the clearness, or haziness, or cloudiness of the sky; upon the power and quickness of vision of the observers; and upon the degree of fixedness of their attention during the watch. The essential agreement of the two series in columns B and C, however, justifies confidence in them as a first approximation,

Toward what limit the series of numbers in column B would approach as the number of observers increases indefinitely we cannot say. The uniformity of increase in the last part of the series is due, in part, to the fact that in dividing up the heavens among the observers, to each was left a comparatively unoccupied field. It seems probable, however, that the number would attain to, and even exceed, 2000, and hence that four persons do not see more than about half of the visible meteors. The table also shows that four persons see about three times as many as a single observer.

Observers may easily furnish materials for correcting the results in this table. The n th number of column B, should be to the first number of the column, as the total number of shooting stars seen in a given period by n observers, to the average number seen by each observer. The last two terms of this proportion being furnished by observation, the ratio of the first two is computed. The following method is suggested when two or more persons undertake to count the meteors visible. Let the observers look in different directions, so as to divide the heavens, as nearly as may be, symmetrically among them. Let the whole number of shooting stars seen be counted aloud to prevent duplication. At the same time, let each observer note how many are seen by himself. To prevent confusion this may be done by marking upon a card, the eyes meanwhile not being turned from the heavens.