consciousness, irreducible to complexes of sensations and images, and of a kind hitherto unrecognized by most psychologists. Our author disbelieves altogether in the elementary character of such thoughts; he emphasizes the crudeness of the methods employed, and believes that more refined study will probably reveal vestiges of images and sensations of bodily attitudes, as components of what has been called imageless or non-sensorial thought.

In addition to its main purpose, the book is valuable as throwing a clearer light than any of his previous writings on the author's guiding principles in psychologizing.

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## SOME SUGGESTIONS FOR THE STUDY OF COMETS[1]

COMETS are, probably, the most mysterious of all celestial objects. Whence they come; whither they go, when they leave forever; where they gather fresh material, if they do, and how; their mechanical structure; the forces that commonly bind them together; the other forces that sometimes tear them apart; the origin of the curious knots, twists and streaks in their tails; and why it is that they are self-luminous, are among the things concerning comets we should like to know, but which, at present, no physicist and no astronomer can tell us.

It is but natural therefore that the return and near approach of Halley's comet should arouse unusual interest and activity in the study of these strange objects, for it is bringing us a rare chance, especially if, as seems likely, the earth should pass through its tail, of learning much that we would like to know in regard to comets and their accompanying phenomena. But to make such a study most efficient it is necessary to consider what phenomena may possibly be expected, and how they can be observed.

These form two distinct groups, namely: (1) celestial, astrophysical in the main; (2) terrestrial, chiefly meteorological. Among the former are:

(*a*) *Gross Appearances.*—This includes all distinctive markings, such as bright patches; streaks, both straight and twisted; number, direction and shape of tails; time and manner of beginning and ending of tails; and any other such phenomenon as may present itself to the observer. A photographic record, as nearly as practicable continuous, should be taken of these phenomena for future study, but it would be well to supplement the photographs by numerous eye observations.

Any one expecting to do work of this nature, and there are many observatories adequately equipped for it, would do well to consult Professor E. E. Barnard, of the Yerkes Observatory, either directly or through his papers on comets.

(*b*) *Spectrum.*—Visual and photographic analysis of the light should be applied to the comet in detail—to the jets and envelopes in and about the head, to the streaks in the tail and to all portions bright enough to yield results.

Such a program, while of decided value, can not profitably be undertaken except by those observatories especially well equipped for this sort of work.

(*c*) *Polarization.*—It is known that the light of comets is polarized to some extent, from which it is inferred that a part of their luminosity is due to reflected sunlight, but this phenomenon needs further examination, and, in particular, separation from sky polarization. It would be well to compare the polarization of that part of the comet where a right angle exists between the directions from it to the sun and the earth, respectively, with the polarization of other portions. If the particles of the comet are small in size, compared with the cube of an average wave-length of light, then, as Rayleigh has shown, there will be

[1] This paper was prepared at the request of the comet committee of the Astronomical and Astrophysical Society of America for inclusion in its circular respecting observations of Halley's comet. Through causes for which its author is in no way responsible it did not reach its destination in time to be so used and the committee now seeks to give it publicity through the pages of SCIENCE and such other journals as may choose to reproduce it.

marked polarization that is a maximum in a direction at right angles to the incident radiation. It is true that we have in the turning of the tail always away from the sun strong evidence (since this is due, we believe, to light-pressure) of the minute size of the luminous particles; but, nevertheless, such evidence as the phenomena of polarization can give on this point is worth having.

It would also be desirable to determine the relative amount of reflected to intrinsic light, though the method of accurately doing this is not obvious.

Polarization work can be done with any *refracting* telescope of large light-gathering power. A reflecting telescope could not be used for this purpose because of the polarization effects that it itself would introduce.

(*d*) *Light-fluctuation.*—It is well known that the light of comets often varies irregularly and without obvious cause. These variations should be studied in connection with the formation of jets and envelopes, and especially observed to see where the changes in brilliancy have their origin and how rapidly they spread to other parts.

The position and size of sun spots, and other solar phenomena, should also be observed and studied in connection with the light changes. Evidently the luminescence of comets is, in some way, largely dependent upon the sun, and it has been claimed that it is greatest during periods of sun-spot maxima. If so, then it may change with the size and orientation of the spots. At any rate, this is a phenomenon that can easily and, perhaps, profitably be studied with the aid of even a very modest equipment.

All the above phenomena can be observed at any time the comet is brightly visible, but there are a number of other phenomena which possibly may appear or be modified during the passage of the earth through its tail, if, fortunately, such an occurrence should happen, and which, therefore, ought to be carefully watched at that time. These form the second or terrestrial group, above mentioned, some of which are:

1. *Electrical Potential.*—In reality it is the difference between the electrical potentials of two points a given vertical distance apart in the atmosphere that is here referred to. This would be modified by the bringing of an electrical charge from some extraneous source to the atmosphere, and, conceivably, might therefore help to give some idea of the electrical condition of that part of a comet's tail through which we happened to pass. But, as the electrical state of the atmosphere changes so greatly from place to place and from day to day, it does not seem that observations of this nature can afford much definite information.

2. *Atmospheric Conductivity.*—This comes, essentially, to the same thing as the ionization of the atmosphere, and would be modified by the entrance into the air of charged particles or other ionizing agents.

Like the electric potential of the air this too is subject, ordinarily, to such changes that, seemingly, no trustworthy inference in regard to the electrical condition of a comet's tail, should we pass through one, could be drawn from such observations.

However, if any one, not entirely familiar with them, wishes to take up either or both of these lines of work he will find Gockel, "Die Luftelektrizität," a good guide.

3. *Damping of Electrical Waves.*—It is well known that the distance a wireless message can be received changes irregularly, owing, presumably, to the intensity and distribution of the ionization of the atmosphere. The ease or difficulty of transmitting wireless messages, especially over the ocean, say from San Francisco to Honolulu, might, therefore, give some hint about the electrical state and the ionizing action of the material of a comet's tail through which the earth at that time might chance to be passing. Probably the hint would not be a very distinct one, but observations of this phenomenon seem to the author much more promising of results than do those of either the potential or the conductivity of the atmosphere.

4. *Earth Currents.*—A marked change in the electrical condition of the atmosphere is likely to lead to earth currents of greater or less magnitude. It might therefore be well to

request telegraph and telephone companies to report any such disturbances as may occur during our passage through the comet, should this happen. However, such currents should be considered only in connection with other phenomena, since alone they can have but little meaning.

5. *Diurnal Variation of the Earth's Magnetism.*—It has been known for a long time that there is regularly both a diurnal and a semidiurnal variation in all the elements of terrestrial magnetism; and it has been shown by Schuster[2] that the origin of these daily disturbances is outside the surface of the earth. The origin of this variation is, probably, the Foucault currents caused by the sweep of the ionized, and therefore conducting, air across the lines of magnetic force. The more ionized, or the better conducting the air, other things being equal, the greater these currents and, if this theory is correct, the greater the resulting diurnal variation in the records obtained at magnetic observatories.

If then the particles of a comet's tail are highly electrified, or should in any way produce, on our coming into them, an ionizing action on the atmosphere, there must result corresponding changes in the diurnal variations. The action of the cometary particles, presumably, would be on the outer layers of the atmosphere where any change in the conductivity is most effective. Also since, in general, the winds increase with latitude and the lines of magnetic force become more concentrated and more nearly vertical, therefore any change in the diurnal variation, especially of the declination, that may be due to the action of a comet's tail probably would be most marked in the higher latitudes.

It seems, therefore, that it would be especially well to study and compare the diurnal variations obtained at the many excellent magnetic observatories just before, during and just after the coming passage of the earth through the tail of Halley's comet—assuming, of course, this event to take place.

6. *Auroral Displays.*—Auroras serve as rather delicate indicators of the electrical state of the outer atmosphere, and therefore should be carefully watched for and minutely noted during a continuous period of several days equally overlapping the supposed epoch of our intersection with the material of the comet.

7. *Line and Band Absorption.*—The atmospheric absorption lines and bands furnish about the best means we have for detecting changes in the composition of the atmosphere, especially of the outer portions. Therefore it may be desirable to compare the atmospheric lines and bands during the passage of the earth across the comet's tail with the lines and bands obtained at other times.

If the electrification of the outer air is materially changed during this passage there may result a corresponding temporary change in the amount of ozone in that region, that perhaps could best be detected through the great ozone absorption band[3] at wave-lengths $9\,\mu$ to $10\,\mu$.

8. *Atmospheric Transmission.*—In reducing the data obtained with integrating pyrheliometers it is customary to use, with certain corrections, the simple Bouguer equation,

$$I = I_0 a^m,$$

in which I is the observed solar intensity through the air mass $m$, $I_0$ the intensity outside the atmosphere, and $a$ the coefficient of transmission. This latter varies from day to day, but, assuming it to remain constant for a few hours, can be determined by observations taken with different values of $m$, or, as Kimball[4] has shown, by a single observation of the intensity, together with a simultaneous measurement of sky polarization.

Since $a$ is such a variable quantity its determination while, perhaps, of some value in this connection, can not be regarded as very promising of definite information concerning the material of a comet through which we might be passing.

9. *Meteoric Trails.*—Since the particles com-

[2] *Phil. Trans.*, A, Vol. 180, p. 467, 1889; Vol. 208, pp. 163–204, 1908.

[3] Angström, *Arkiv för Matematik, Astronomie och Fysik*, 1, 395, 1904.

[4] *Mount Weather Bulletin*, 2, pp. 55–65, 1909.

posing the tail of a comet presumably are excessively minute, any meteoric trails they may produce on coming in contact with the atmosphere must be small. However, it would be well, at the proper time, to watch for them with a telescope pointed nearly vertically and focused for a distance of from 100 to 150 miles. Presumably only faint scintillations, probably entirely too faint to be seen, need be expected, but only by such observations can we know definitely just what does or does not take place.

10. *Bishop's Ring.*—After the explosion of Krakatoa, and also after that of Mount Pelé, a faint reddish brown ring of the coronal type was seen about the sun. Its inner radius was about 12°, and its outer approximately 22°. It was due, almost certainly, in both cases, to finely divided matter thrown up to great altitudes and from there spread widely over the earth. The mean radius of these particles, assuming them spherical in shape, has been calculated to be about equal to the largest visible wave-length. They were therefore excessively minute, and it is possible that after passing through the tail of a comet something of this kind may be seen; at any rate, careful observation should be made for it, after such an event, by those of exceptionally sensitive eyes. Such observations are best made with the sun hidden behind an opaque object.

11. *Color of the Sun.*—The color of the sun, as is well known, depends upon the size and number of solid or liquid particles through which it is seen, and therefore may, possibly, be temporarily modified on our passing through a comet's tail.

12. *Atmospheric Polarization.*—This phenomenon depends mainly upon the scattering of sunlight by any minute particles in the atmosphere. The percentage of the polarized to the total sky light at any part of the sky, say where the polarization is a maximum, or 90° from the sun on the vertical circle passing through it, is a function of the dust content of the air. This percentage therefore should be carefully noted during our supposed coming passage through the tail of Halley's comet, as should also the positions of the so-called neutral points of Arago, Babinet and Brewster—the first especially, as it is the easiest observed and most accurately determined.

It might also be advisable to observe the polarization percentage of different colors, by the aid of suitable screens, since this depends upon the size of the particles that scatter the light.

13. *Twilight Phenomena.*—Twilight colors, and the gamut of changes through which they run, clearly are dependent upon the dust content of the atmosphere, as was strikingly evident after the eruption of Krakatoa, and therefore might, possibly, afford some information in regard to the tail of any comet through which the earth may pass.

14. *Luminous Clouds.*—After the eruption of Krakatoa there was seen for many years, but only in latitudes of 45° or more, faintly luminous clouds of, seemingly, great altitudes.

It is not at all certain that these so-called clouds were due in the least to the volcanic eruption; but still they should be closely looked for at the time of and after our passage through a comet's tail, since they might be modified by the material thus picked up.

15. *Number of Dust Particles in the Air.*—The number of dust particles, especially in the outer portions of the atmosphere, may be greatly increased by the passage of the earth through the tail of a comet. Therefore it would be well to count the particles of dust per cubic centimeter say of air on the tops of high mountains, and in samples obtained by sounding balloons, before and just after the time of our entrance into the tail of Halley's comet.

16. *Zodiacal Light.*—While our knowledge of the zodiacal light, of the nature and location of the material to which it is due, and how this material is rendered luminous, is practically nil, it seems quite possible that its real or apparent brilliancy may be greater during our passage through even so rare a substance as the tail of a comet. Therefore the details of this phenomenon too should be recorded, at the proper time, by those so situated as to observe it to good advantage.

17. *Gegenschein.*—But little is known of the

cause or location, except in direction, of the *gegenschein*, but it seems not improbable that it may be more distinctly visible during the passage of the earth through the luminous particles of a comet's tail, and therefore it should be studied, at the proper time, with the greatest care by those in the habit of observing it.

18. *The Auroral Line.*—Arrhenius[5] says:

Whichever way we turn the spectroscope on a very clear night, especially in the tropics, we observe this peculiar green line. (The so-called auroral line.) It was formerly considered to be characteristic of the zodiacal light, but on a closer examination it has been traced all over the sky, even where the zodiacal light could not be observed.

Evidently the source of this line is not definitely known, but, conceivably, it may be rendered more brilliant by the passage of the earth through the tail of a comet, and therefore it would be well for some favorably situated observer carefully to measure its brilliancy on several consecutive nights, so selected as symmetrically to overlap the calculated date of our supposed passage through the tail of Halley's comet.

The most promising, in this connection, of the above phenomena are, in the author's opinion, those designated as *a, b, c, d,* 5, 6, 9, 10, 13, 16 and 17.

The above is not claimed as a complete list of the phenomena that may be associated with a comet, but it is hoped that they, together with others that they may suggest, will soon give us a better understanding of comets in general and of Halley's in particular.

W. J. Humphreys
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## SPECIAL ARTICLES

### SOME LONG-PERIOD DEVIATIONS OF THE HORIZONTAL PENDULUMS AT THE HARVARD SEISMOGRAPHIC STATION

The studies of Omori, Milne, Denison and many others, on the movements of horizontal pendulums due to other than seismic or microseismic causes, suggested a similar study of the movements shown by the pair of Bosch-Omori instruments at the Harvard station. These pendulums, which stand at right angles to each other on the meridian and parallel of the station, record through small tracers on sheets of smoked paper carried by drums that complete a revolution once in an hour. The drums travel laterally, causing each hour's record to appear as a single line spaced about an eighth of an inch from its neighbor on either hand. A complete day's record, undisturbed by seismic or other movements, appears as a series of twenty-four parallel lines. Any long-period deviations of the pendulums, therefore, are shown by a crowding of these lines toward one side of the sheet or the other.

The study was made to determine whether or not solar or cyclonic and anticyclonic conditions affect the pendulums, as has been suggested. Lack of time prohibited an investigation of tidal and other effects, except so far as to prove them entirely subordinate to the main controls. The records were examined for the months of April, May, October, November and December, 1908. The pendulum standing on the meridian of the station (the east-west component, so-called) is most sensitive, in the matter of long, non-periodic movements, to forces applied due east or west of the station. The same is true of the north-south component in reference to forces applied on the north or south.

Two types of deflection are shown by each component:

*The E.-W. Component: Type 1.*—A diurnal deflection. This is indicated by a more or less strong tendency of the pendulum to move east during the forenoon and west later in the day. It begins about sunrise, the more or less steady easterly travel dying out about noon and later becoming a westerly travel which often lasts well into the night. This type of deflection never persists from one twenty-four hours into the next; it occurs only on days when the sun shines, and is best shown on the least cloudy days. When the diurnal quality of the thermograph curve is most marked, the pendulum

[5] "Worlds in the Making," p. 116.