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The Spectroscope in Celestial Physics

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The Spectroscope & Celestial Physics

It shall be the aim of this treatise to discuss the principles and the development of the Spectroscope and its application to Celestial Physics.

Molecular Energy

It will be necessary to notice briefly the molecular constitution of matter in its various states and the consequent theory of light as explaining attendant phenomena.

The smallest physical division of matter is the molecule, whose degree of stability gives rise to the different states of matter—namely, solid, liquid, and gaseous. It is an accepted theory that molecular constituents of matter are never at rest, or that the absolute temperature of a gas is never reached. In solids, however, this state of the molecule is more nearly reached; yet while relatively stationary, absolutely, they are not, but have regular
oscillatory motion. By doubtless, the atoms composing these molecules are in a constant state of vibration, so that its center of gravity may make a trochoidal curve. The molecules of liquids, being free to move in the various paths and so doing attract their neighbors. A molecule may thus travel a long journey and still be comparatively near its starting point. It is evident in this free motion of molecules that there must be many collisions, each followed by a bounding apart to come in contact with another neighbor. Here again, atoms of doubt are in motion within the molecule.

In gases, the motion of molecules is much freer and more rapid. Molecules too, must be much farther apart so that the free path must be greater; the attraction of its neighbor evidently less would give the molecule
A comparatively straight path and altering matter and the air like bees in a barrel collide and rebound, followed by repeated collisions.

These are furnished the foundation of the substance of the kinetic theory of gases. Thus do we account for the pressure, i.e., that the outer molecular of a volume of gas collide with the containing vessel and are thrown back.

An element which adds to the effectiveness of these collisions is the perfect elasticity of molecules and still another is the greatest number of molecules in any finite volume. According to Boyle's law, all gases, under the same conditions, contain the same number of molecules in any assigned volume. Various authors compute that one cubic centimeter at zero centigrade contains seven quintillions if this moved a mile a second or faster than a
Cannon bullet, there would be a collision a million times a second.

Consequently there is the "Elastic Solid Theory of Light.

It is agreed, (1) that light travels with a finite speed; (2) that light is due to some periodic disturbance; consequently there must be some substance throughout interstellar space, and this substance we call ether. The theory then is that the molecular movement of bodies cause vibrations in the ether, which vibrations if comparatively slow give radiant heat, if fast enough to affect the retina of the eye, constitute light. Still faster rapid waves produce the ultra-violet, constituting actinice X, and other rays. Phenomena in astronomy and physics show that matter may pass through ether without resistance. Yet matter cannot transmit molecular motion.


ether; and we must conclude that it is the internal vibratory energy that is transmitted, which atomic motion we have above accounted for. We may conclude that the kinetic energy of the molecule consists, in various translations and rotations either of the molecules as a whole or of its parts, or of the elastic vibratory motion within. The former is not impeded by the ether, but the latter imparts its vibrations to the ether which bear it away at radiant energy.

Incandescence.

There are various methods of heating bodies to a luminoactive state necessary for spectroscopic analysis; each has its peculiar advantage. Of the Bunsen Burner is much used because it is capable of reducing many substances to a gaseous condition.
and thus rendering them susceptible of spectroscope analysis.

(2) The oxyhydrogen Blow Pipe is the most effective source of heat yet known in chemistry and is therefore nowhere else wherein fail. (3) Drummond's line sight is also used in connection with the oxyhydrogen flame, thus increasing the intensity of light.

(4) Superior in point of the amount of heat given to the oxyhydrogen blow pipe is the electric stove, which is beginning to figure prominently as an accessory to the spectroscope. The incandescent carbon electrodes are very important aid in spectrum analysis.

Nature of Light

Based upon the foregoing conclusions it is the following theory of light waves. And light is to sound waves, light waves travel to the eye and then to the brain which records the
vibrations as having a certain intensity and stability. The intensity is due to the amplitude of the wave, which in turn is due to the amount of kinetic energy generated in the collision of molecules and atoms of the vibrating substance. Stability is due to the length of the wave, or the shot time, of the period during which each molecule completes its vibrations, which is due to the atomic and molecular constitution of the matter which is the source of the light. Moreover, in composite substance, each elemental substance has a molecular and atomic structure peculiar to itself. Thus, a ray of light may be a compound, emanating from a compound substance, and it is the function of the electroscope to analyze this compound into its elements.
Theory of the Spectroscope.

In the spectroscope, the prism is the active agent in the dispersion of a compound ray. According to the law of refraction of light, a ray is bent out of its course in passing from one medium into another. Figure (1) will illustrate the path of a simple ray in passing through a prism.

Let Dc be the incident ray, and its course as deflected while entering the prism, be the direction as deflected in leaving the prism. This refraction varies with the rapidity of vibration of the ray, and consequently upon the wave length, so that a compound ray, made up of elements of various wavelengths...
will be dispersed, since each element will meet with a different degree of resistance and consequent refraction, as illustrated by figure (2).

Fig. (2)

Let ABC be a prism and Dc be a compound incident ray of light; ef will represent the component of longest wavelength and bh the component of shortest wavelengths. The usefulness of the prism is thus based upon the different degree of refrangibility of the rays of light of different colors.

Figure (3) represents a simple form of the spectroscope in which S is the source of light which may be the focus of the object glass.
of a telescope, $s$ is the slit through which the light is admitted, $l$ is the collimating lens, $p$ is the prism, $d$ represents the spectrum seen through the telescope $t$ and $e$ is the eye of the observer.

The purpose of the slit is to give a pure spectrum. Figure 8 illustrates this point.

Let $aa, bb, cc$ be rays of light entering a wide slit whose length...
is perpendicular to the plane of the paper and traveling through a prism P. Upon the screen SS will be a complete spectrum of each; from 0 to r, the spectrum of red; from r to k, the spectrum of blue; and from k to l, that of e. It is evident that the spectra overlap and hence they are confused.

The purpose of the collimating lens is to render the rays parallel; that of the telescope is to magnify the spectrum as it emerged from the prism. The source of the spectroscope is most convenient if those are arranged that the source of light and the direction of the telescope are in the same straight line. This may be produced by using several prisms. In figure 13, if ab be a ray of light passing through the three prisms, it will emerge in the same direction.
that it entered. The greater the number of prisms, however, the more light would be absorbed and hence the less effectual for weak lights.

**Uses of the Spectroscope**

We shall now consider the applications of the spectroscope to celestial physics.

A compound ray of light, on passing through the spectroscope, throws upon the screen a spectrum, exhibiting the various prismatic colors of which it is composed.

If the slit be wide, the spectrum will be continuous, a gradual shading of one color into another; while if the slit be narrow, say 1/6 inch, the
Spectrum will be crossed by dark lines and bands. They had been discovered in 1802 by Bunsen, but were first carefully examined and mathematically treated by Fraunhofer in 1814. He distinguished 600 lines and also found that with the same instrument they always kept the same relative order and position. He therefore concluded that these lines would serve the purpose of locating any given set of colored bands. It was left to Kirchhoff to discover the origin, and figure, the dark lines and bands. In his researches on this subject, he allowed a ray of the sun to pass into the spectroscope, and he noticed that the dark D line, according to the graph, stood out very prominently; then he placed Drude's lodestones, which always gave a continuous
Spectrum, through the sodium flame and the dark D line, again
was shown in the same place.
I did likewise with the line light and obtained a similar
result, whereupon I concluded
that sodium must be present
in the Sun's atmosphere.
I proceeded in a similar
manner to show the presence of other
elements in the Sun by a compara-
tion of the solar spectrum with
the spectra of various terrestrial objects.
It is evident, therefore, that
light from any highly heated
condensed liquid or compressed gas
will give dark lines wherever it
passes through an incandescent
low-temperature gas composed of
the same element, which then
absorbs light waves of the same
wave length, i.e., reduces their intensity.
A bright band will be given whenever the light of any element,
not compressed and heated to incan-
descence, passes through a narrow
At and then through the prism.

A continuous spectrum will be given whenever an incandescent solid, liquid or highly compressed gas at a high temperature is not intercepted by any incandescent gas.

Instrumental Dispersion

While the prism was the earliest agent used in the dispersion of the elements of compound rays, yet it has some disadvantages, among which is the abnormal spectrum which it forms. Rays of different colors are not dispersed in proportion to wave-length as might be supposed from the fact that dispersion is due to the difference of wave-lengths. Besides there is no definite ratio existing between the different wave lengths and their distances from any fixed point in the spectrum, but in different prisms made from different
kinds of glass, the relative position of the different wave lengths vary.

In the later instruments, the diffraction grating is used which completely obviates the diffract just referred to, so that the spectrum there obtained shows the colors separated by intervals proportionate to the wave lengths producing them.

A diffraction grating is any system of very narrow, equal and equidistant translinear, slits, ordinarily produced by tracing a number of parallel equidistant lines on a glass or polished metal plate. Frequently as many as 20,000 to 70,000 lines to the inch are produced. The lines are opaque for glass and nonreflective for metallic reflectors, thus preventing the transmission or reflection of light. The light is thus transmitted through the transparent intervals, in the case of glass, the effect of which is to
produce a normal spectrum. 

Fig (c)

In figure (c), let MBB be a grating; O, the center of a lens, say the object glass of a telescope. Suppose the light to be incident perpendicular to the grating and pass through the apertures m, m', mn, &c. Let us consider the light which passes through the lens in the direction of and which is focused at P on the screen. Draw R & perpendicular to the direction OP, then each stream travels from this line to P in
the same length of time.
But the light is incident at
the grating at the same time,
and the tube on each side of the tube,
and the time required
to travel from their respective apertures
in the grating to $P$.
The true interference will in-
crease between successive ele-
ments, which, if the amount of
retardation, $m_{\lambda}$, is an even
number of half wave lengths,
amounts to a reinforcement,
since the consecutive elements
arrive at $P$ in the same phase.
If $m_{\lambda}$ is an odd number of
half wave lengths, the light from
the succeeding elements will de-
stroy each other and the illum-
ination at $P$ will be zero. If $m_{\lambda} = (a+b) \sin \theta$, in which $a$ equals the
width of an aperture, and $b$, the
width of an opaque, then $P$
will be very bright when
$(a+b) \sin \theta = 2n\lambda$, and very dark if
$(a+b) \sin \theta = (2n+1)\frac{\lambda}{2}$. ($\theta$ = angle of inclination)
of B.C. with the perpendicular to the
Let us suppose that the
light falls incident obliquely
to the grating as in figure (71)

![Fig. 71](image)

If $i$ is the angle the incident
light makes with the normal, the
retardation $d = (a+b) \sin \theta + \sin i$; for
$ND + ND = (a+b) \sin i + (a+b) \sin \theta$

From the formula $(a+b) \sin d = 2 \Lambda \delta$, we get
$\sin \delta = \sqrt{(a+b)} $ for the
first bright spot just above the cen-
tral image; $\sin \delta = 2 \Lambda (a+b) $ for the
second fainter spot. This shows that
bright spots are separa-
ted by intervals determined by
the successive values of $\delta$; or it
shows that $\delta$ increases and hence
that bright spots separate more
widely, as the denominator $(a+b)$
diminishes. This would in-
dicate that the finer the rulings,
or the greater the number to the inch, the greater the dispersion, hence the desirability of the finest possible ruling. It would also appear from the above that the brightness of successive spectra would be at intervals proportional to wave lengths, hence a normal spectrum results. In the case of a prism, each prism gives a dispersion peculiar to itself which leads me to speak of the irrationality of dispersion.

Another decided advantage of the diffraction grating is the purity of the spectrum thus obtained. To show this, let us take a monochromatic ray of light. If we take P in figure 2 as a point of maximum brightness, and OP as the direction of light, suppose we consider an element of light incident on the line in a direction a little above OP.
This light would be brought to a focus near P. Now if m, be an even number of half-wave lengths, m, is a little above m, and a small fraction more than the same number of half-wave lengths. If we take this fraction as good, the light from the first aperture is in advance of that from the second by an amount (m+1/20); then the light from the first aperture is 20 times this amount in advance of the 501st aperture, or by (600m+1/20), that is by an odd number of half-wave lengths. Consequently, the light from the first aperture is destroyed by that from the 501st, and that from the second by the 502d &c. It is evident, therefore, that if P is a bright point, there is no illumination at points even very near it and consequently the spectrum is perfectly pure. In using the plane grating, a lens is not necessary.
Besides the inconvenience and complication thus produced, the lens also destroys a certain amount of light; hence, instead of the plain grating, the curved grating is used. Here, obviating the use of the lens, Rowland's concave gratings are the ones in most general use.

Among the other advantages of a diffraction grating might be mentioned, that it enables one to determine the wave length producing the color in the spectrum. From the formula \( n = (d \times b) \sin \theta \), the wave length depends jointly upon the number of rulings to the inch, and likewise upon the degree of separation of the colors of the spectrum. This latter point could avail nothing, in the case of the prien, since it produces an abnormal spectrum. Some difficulties are encountered...
erred in measuring wave lengths, namely, moisture in
the atmosphere, change of pressure, and variation in the tem-
perature of the grating.

In connection with the cons-
ideration of wave lengths, may be
discussed Doppler's principle which
is as follows: (1) The approach of a
body, which is the source of
light, causes a shortening of
the waves, or, what amounts
to the same thing, the imping-
ing of a greater number of the
spectrum per second, and a
consequent shifting of its color
towards the violet; (2) A body re-
ceding, which is the source of
light, causes a lengthening of
the waves and a consequent
shifting of its color towards the
red.

Based upon these facts is his
formula, \( \frac{\Delta \lambda}{\lambda} = \frac{v}{c} \), in which \( \Delta \lambda \) is the
change of wave length; \( \lambda \) is the wave
length as changed; \( v \) is the velocity.
of the body, which is the source of the light; \( v \) = the velocity of the light per second. From this we obtain \( c \), the velocity of the body: \( c = \frac{\Delta v}{\Delta \lambda} \). If we suppose that \( \lambda \) = the wavelength of a certain hydrogen line; \( \Delta \lambda \) = the observed diminution of \( \lambda \) as shown by the distance the line is raised \( \lambda \) and \( \Delta \lambda \) = 300 miles; then \( c \) = the velocity of the body.

Doppler's principle gives the velocity per second of the approach or the recession of a star along the line joining the star and the observer. This line is called the line of sight. This \( v \) itself gives nothing of the real velocity of the star nor the direction of its movement, but only its velocity along the line of sight.

In figure (3), let \( O \) be the observer; \( S \) the star; \( S'B \) or \( S'B' \), the real path; \( S'A \) the component toward or from the observer \( O \); \( S'C \) the component perpendicular to the line of sight \( SO \).
Now, $V_2$ is found by means of the electroscopes and $v_1$ by the method, as demonstrated in figure (2).

Let $S$ be a star; $E_1$ and $E_2$, the diameter of the earth's orbit; $\theta$, the angle of annual parallax, found by getting the difference of the positions of $S$ as seen from $E_1$ and six months later, as seen from $E_2$; $R = 93,000,000$ miles; $D = \frac{25265 \times R}{\cos \theta}$ is the distance of the sun from the star and, consequently, of the star from the observer. In figure (18), $\alpha$ = the apparent angular.
motion of S in one year divided by the number of seconds in a year; \( \tau = \frac{26636.3 \times 10}{24360} \). Now, having \( \tau \) and \( \nu \), each in miles per second, the velocity along the direct real \( \nu \); the direct real \( \frac{1}{\sqrt{1 + \frac{\nu^2}{\tau^2}}} \) or \( \frac{\nu}{\tau} \), the actual velocity per second; \( \beta \) or \( \| \beta \| \), the real path; and \( \tan \theta = \frac{\nu}{\tau} \), gives the angle which the star's path makes with the line of sight \( \phi \).

The velocity \( \nu \), of a few stars nearest the Earth, and of these only approximately, can be known, since almost at the annual parallax of the more remote cannot be found. The displacement of the spectral lines due to the altered refrangibility of the ray, is the only accurate method known to astronomers for determining the motion of a celestial body in the line of sight.

It is evident, also, that the motion of radial rotation of a celestial body should produce a displacement, since one limb
through as they approach along the line of sight. The
star is the only body upon which successful observations
have been made. The result of these observations agree
very closely with those made in connection with sun-spots
which is conclusive evidence of the validity of Doppler's principle.
The observed velocity is due
both to the motion of the star and
also to the observer. In order
to determine the star's motion
with reference to the sidereal sys-
tem, four components must be
taken into account. (1) The rotation of
the earth on its axis. (2) The rev-
olution of the earth around the
common center of gravity of
the earth and sun. (3) The rev-
olution of the earth around the sun.
(4) The motion of the solar sys-
tem as a whole.

We shall now proceed to the
solar spectrum. It exhibits three
phases: that of a continuous spectrum, due to the incandescent particles of the photosphere, heated to 8,000° to 20,000° Fahrenheit; that of the absorption lines caused by this light passing through a low temperature layer outside of the photosphere as also through our own atmosphere; that of the bright lines, due to incandescent gases being outside of the sun's disk. These latter are not seen in the spectrum, being destroyed by the superior light of the continuous spectrum.

Beyond the visible solar spectrum are the infrared and the ultra violet. There is no limit to the infrared inasmuch as waves of greater lengths are emitted at very low temperatures. The limit of the ultra violet is more definite, being dependent upon the temperature to which we may raise the incandescent body. This fact too enables us to come to some approximation of the heat of a body.
In the use of the grating, one source of error is the determination of the true distance between the rulings; another more dangerous source is the irregularities of the ruling. A small error in either of the instances would cause great discrepancies.

In February, 1871, Rowland published a table which, when compared with that of the earth, gives thirty-six certain, eight doubtful, five elements not yet tried and fifteen not present. These elements are designate belonging to the sun by means of a comparison bridge through which the light of any volatilized substance. The spectra of the sun and of that of the volatilized substance are compared, and if a line in the one is coincident with that of the other, it indicates the presence of the substance in question in the sun.
If the earth were heated to the same temperature as that of the sun, there is little doubt that it would exhibit the same spectrum.

In the study of the spectra of heavenly bodies it is important to take into account the spectrum of our own atmosphere. Large quantities of gases, such as nitrogen, argon, carbon dioxide, and water vapor have the effect of absorbing like elements of a ray passing through them and thereby producing dark lines. The degree of intensity of absorption likewise would be dependent upon the length of the ray’s path through such gases; consequently, the spectrum obtained from the sun in the zenith and near the horizon would differ.

By observing the spectrum at the same hour on successive
days, a change in the chief
atmospheric influence on a
variety of the amount of
the humidity of the atmosphere.
It can thus be shown that it might
be a method of weather prediction.
An interesting method of
investigation is that of the shot.
The difference between the spectrum
of a shot and that of any other posi-
tion of the shot, where its due per-
nably, to the increased absorption of
the shot, very faint lines sometimes
becoming broad and black.
At times, dark lines are changed
into bright ones, also dis-
placement and distortion of lines
are noticed, as a result of oxoid
motions in the line of sight.
This is especially noticeable in
the iron lines. This can be ex-
plained where the fact that the
metal- especially iron—combine
with the metaloids at the lower
temperature of the sun at these
points. This same phenomenon
red ridges indicate, also, the outside of the metal, thus suggesting the presence of oxygen in the sun.

Bright hydrogen lines are also seen in the spot spectrum and can be explained only on the theory that hydrogen heated, and condensed, would hydrogens that, at a higher temperature than the rest of the spot, is located above the spot. The phenomenon is similar to that of prominences on the limb. These prominences can only be observed successfully during eclipses and by an instrument constructed for this purpose. Just some new money have been expended by these researchers, and with some limited success, proving to the short duration of time of the eclipses, and their uninteresting skies. It is probable that these prominences do not extend more than 1000 miles beyond the sun's limb.
In composition, the prominences are probably chiefly hydrogen, helium, and calcium. Sodium, barium, titanium, vanadium, manganese, chromium, and magnesium are also certainly present.

A peculiar and interesting feature of solar prominences is the various shapes which they assume, according to which shapes many investigators have classified them. It is more reasonable, probably, to classify them upon the basis of source or cause, viz., hydrogen and metallic bromine. Those which are light and cloud-like belong to the hydrogen.

The corona, or the dome at the top of the atmosphere, can be observed only during an eclipse. Since at any other time it is cut off by the illuminated terrestrial atmosphere, the extent of the corona and varies apparently, being...
greater in the neighborhood of Sun-spots. There have been many theories advanced in reference to the extent and the source of the Sun's corona.

Janssen's explanation in 1871 seems to be generally accepted even today. He held that the spectrum of the corona is composed of four elements: (1) A continuous spectrum without lines, either bright or dark, due to incandescent dust. Any such dust or meteoric substance coming within 250,000 miles of the solar surface must become incandescent; (2) A true gaseous spectrum, consisting of a more or less bright continuous background with well marked maxima or well marked bright lines, including the common line and several due to hydrogen. As far as the telescopic evidence goes, this gas may be simpler than vapor.
of the meteoric dust, blended in the heat of the sun. The circumstances indicate, however, that the gases are of a more permanent character, being a true solar atmosphere in which and through which the meteoric particles can move, as foreign bod-
ies; (3) A true sunlight spectrum with its dark lines formed by photospheric light reflected from the Solar atmosphere and meteoric dust; (4) Another component spectrum is due to the light reflected from the partic-
ular Solar atmosphere. This is a structure of the three, already
named, with the addition of the chromosphere reflected

The spectrum of the sun furnishes the basis for that of the various planets. Even the light of the latter is but solar light reflected. The spectrum of the planet, however, would include the added component of the
absorption lines, due to the partial shading of the light through the planets' atmospheres. Comparison of dark bands, as seen, indicates that there must be present in the planets' atmospheres an abundance of the absorbing elements.

In the case of the moon's spectrum, no absorption lines appear, showing, as we would expect, that it has no atmosphere.

Mercury, on account of its close proximity to the sun, and therefore difficult visibility, gives a spectrum differing from that of the solar spectrum as we see it, except that the absorption lines are somewhat intensified, indicating that Mercury's atmosphere is similar to that of the earth, and the increased darkness of the absorption lines are due to the rays passing through a double layer of the earth's atmosphere.
that of the earth.

Observations on Venus can be made with much greater ease. Its spectrum indicates very similar atmospheric conditions to that of Mercury. The absorption lines, however, are much fainter, which would lead one to infer that the atmosphere is much rarer, or else that it is so dense that the sunlight can pierce but a short distance into it, being thus reflected before it reaches the red planet. The latter explanation more nearly agrees with recent astronomical observations. We are led to conclude that Venus is surrounded by dense vaporous clouds, which show a similar spectrum to that of Venus. The former is surrounded by an atmosphere厚厚的 but full of openings and changeable, as is the case of the earth, the latter surrounded by an atmosphere densely
The spectrum of Jupiter, though difficult to obtain an account of its faint light, reveals what we might expect, as relates its structure and atmosphere. Its small specific gravity had led astronomers to conclude that it must be surrounded by a dense atmosphere, and that telluric lines in the spectrum, as obtained by Huggins, would point to the same conclusion. The spectroscope furnished little information as to the self-luminosity of the planet. We could not expect any high degree of temperature manifested, and a faint red tint would correspond to that which the absorption of the planets' atmosphere would produce, and hence they could not be distinguished. The red belt and spots that have attracted so much attention could be accounted for on the theory that
The denser rays, breaking through the dense clouds, or reflection, are subjected to increased absorption, as well as that light from the luminous planet is transmitted.

The spectroscope aids us indeed little in forming any definite conclusions regarding Saturn, Uranus, or Neptune, since their light is so faint. It is quite conclusive, however, that they are surrounded by an atmosphere. The outer planets, no doubt, possess atmospheres containing large quantities of an element foreign to ours, while the other are quite similar.

The spectroscope has revealed much of the composition and structure of comets. Because of their attractive phenomena, they have received a rather disproportionate attention, and many theories as well as many false theories have been
advanced. The first spectroscopic researches resulted in the decision that the component of comets is hydro-carbon, and recent investigations have only changed the composition by combusting hydro-carbons with monoxide. In 1882, May 27, Schwand noticed in the spectrum of that notable comet a line corresponding to the sodium line. It was so bright as to illuminate the whole head of the comet. In September of the same year, the same peculiarity was noted. The luminosity of these comets was due to electrical discharge in which the sodium, volatilized by its near approach to the sun, acted as electrical conductors; gases also which were before visible would now give place to the metals. The electric city of the comet, no doubt, was induced by the sun.
There instances of electrical phenomena in connection with comets, also accounts for the electrical disturbances so familiar during the passage of the earth in the neighborhood of a comet. A very plausible theory at present holds that the form and direction of the comet tail is due to electrical repulsion of the Sun.

Nature can be studied with but very little success by means of the telescope. We are not much interested in such investigations either, since we can study meteors as they fall to the earth.

Many interesting and valuable conclusions in reference to Nebulas have come to life through the spectroscope. It had long been maintained that all the Nebulas could be resolved into star clusters if we could but construct sufficiently powerful instruments.
Huggins, however, in 1864, demonstrated that there was a true nebulous substance, composed of gases principally of low density. The spectrum of the Nebulae consists of four bright lines, but we are not able to ascribe them to any known element. They are probably due to some modified form of elements already known. In 1868, Copley discovered a number of other faint lines.

Ever since the time of Fraunhofer, astronomers have been attracted by the fact that the planets, and the stars, do not fully coincide as to their spectra. The stars themselves do not agree in this particular, and hence it has occupied the attention of several astronomers in classifying the stars. Fraunhofer found in his researches that Sirius and Castor have very strong bands in the green, others showed decided bands...
in red and others in blue. Fraunhofer deserves much credit for the results which he attained with such a meagre equipment. Secchi later gave his energies to researches with the view of the classification of the stars, which was afterward completed and published by Rutherford in 1862, classifying the stars roughly as white, yellow, and red. He finally classified them into four types according to their spectra as follows: Type I. The white or blue stars—more than half of all the stars thus far observed. Sirius, Vega and many other of the bright stars belong to this type. The hydrogen lines are prominent, while the metallic lines are faint or absent.

Type II. The red and orange stars and most of the variable stars. The spectra of these stars are crossed by many dark lines sharply defined.
on the blue side and shaded off towards the red. Orion, Hercules, and Antares are good examples.

Type II. The yellow stars, like our Sun. The spectrum of these stars is characterized by many fine dark lines, similar to that of the Sun. Pollux, Capella, and Arcturus are examples.

Type IV. A small number of faint stars, of a deep reddish color. The spectrum resembles that of Type III, but the dark lines shade off in the opposite direction. Secchi's classification obtained for many years and is still used by many astronomers. Various other classifications have been made, differing but slightly. Any classification, at best can but serve as a scheme for the study of stellar phenomena.
The history of the spectroscope in celestial physics is brief but its importance, and its results, are enormous. Since 1859, its real introduction into this field of its usefulness, it has accomplished more varied and wonderful results than the telescope, in all its long history. It is the only agent known to us which can receive the message of light brought from our distant neighbors, and translate the message into language, familiar to us. What could we know of the composition of the atmosphere of Venus or Neptune but for the spectroscope? A ray of light from the fixed star, through the one and a half years in its flight, brings unerring reports of stellar composition. The absorption spectrum of the present and the future ideas of the nature and possibilities of other.
For the solution of this question we must likewise depend upon this wonderful instrument.

S. N. Barker
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