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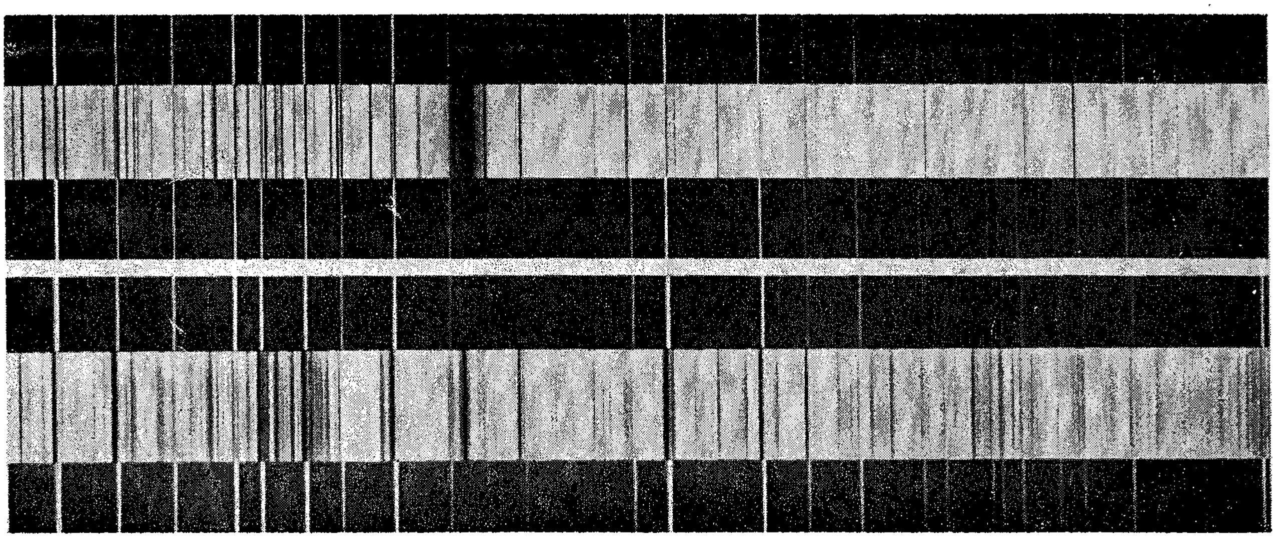
STARLIT SPECTROSCOPES

Astronomical knowledge was founded solely and simply on what the human eye could see. Although this means of investigation is still frequently effective it lacks the power of modern instrumentation and sometimes even leads us into error. In the first place it produces an illusion which only reasoned thought can destroy: that of the "celestial vault" whereby all heavenly objects seem to be placed side by side, like lights on the inside of a spherical dome of infinite radius at whose center we ourselves are placed.

Spectroscopy is one tool which enabled us to apply such reasoned thought and resolve a multitude of unknowns. The determination of chemical and physical properties of the stars seemed so chimerical a project until the middle of the 19th century that the French philosopher Auguste Comte, in his *Philosophie Positive* of 1825, had no hesitation in citing the chemical composition of the stars as an absolutely indisputable example of knowledge that mankind would never possess. Nonetheless spectroscopy, during the past century, has helped reveal not only chemical composition of stars but the radial velocities, temperatures, distances, dimensions, and masses of hundreds of thousands of celestial bodies.



The small displacements of the spectral lines of stars compared with the corresponding lines of an iron arc reveal their radial velocities of approach (—) or recession (+). Above Alpha Carinae, type FO, radial velocity + 12 mps. Below Alpha Centauri, type GO, radial velocity —15 mps. (Photos, Lick Observotary.)

Doppler Effect

Stellar motions were first detected by Halley in 1718. By comparing 17th century observations with those of antiquity he showed that the positions of Aldebaran and Arcturus had changed relative to the stars near them on the star sphere. Since that time about 40,000 proper motions have been detected and measured. But a star's proper motion is only a partial reflection of its real spatial motion, which cannot be perceived unless its projection on the line of sight can be evaluated.

In 1842 Doppler sought to show that the color of a star would depend on its motion towards or away from an observer

Editor's note:

The material for this article, apart from a few recent newspaper clippings, was abstracted directly from the Larousse "Encyclopedia of Astronomy", by Lucien Rudaux and G. De Vaucouleurs, with the permission of the publisher of the English edition (1959), Batchworth Press Limited, London NW 5, England. The book is available from Prometheus Press, New York, and contains 500 pages of fascinating facts and pictures, 495 pages of which we did not have room for here.—Harriet M. Mitteldorf.

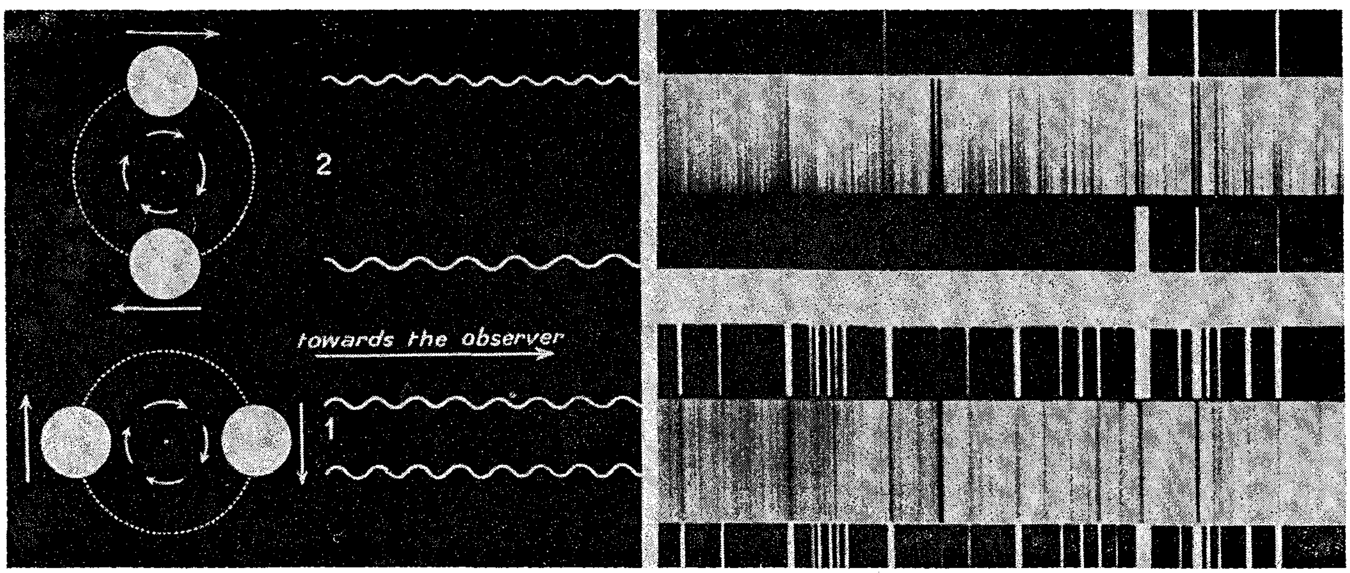
(radial velocity). Perfectly sound in principle, this idea was impractical when applied since the velocities of the stars relative to the earth are too small (a few hundred mps at most) compared with that of light to produce any perceptible modification of color. Some years later, however, the French physicist Fizeau showed that the effect might be detected by measuring the positions of the spectral lines. Since motion of the observer will produce the same effect as that of the source, displacements produced by the Earth's annual revolution about the Sun had also to be considered. When the Earth is moving towards a star at its orbital velocity of 18.5 mps the lines are displaced by an amount equal to one ten-thousandth of their normal wavelengths. Thus the D lines of sodium (5890A and 5896A) will be displaced by about 0.6A or one tenth of their separation. Six months later, then, the displacements will be equal but in the opposite direction and the mean of the two measurements will give the star's radial velocity relative to the Sun.

In 1871 the German astronomer, Vogel, demonstrated the accuracy of Doppler's principle by determining the tiny relative displacement of the solar lines at the east and west limbs of the Sun. The value of the Sun's rotation period derived by Vogel in this way agreed perfectly with that based on visual observations of sunspots. Later, the American astronomer Young showed that the telluric lines in the solar spectrum do not partake of this displacement; this is exactly what would be expected since they originate in the Earth's atmosphere which is stationary relative to the observer.

The Doppler principle having been established, problems then arose interpreting measurements made by many people at different times and places. Variations in radial velocities determined by different observers can now be assigned to one or two main causes. The first is analogous to that produced by the Earth's annual revolution and indicates the spectrum is that of a binary star. The phenomenon is particularly noticeable when the spectra of both components are visible, for the lines then appear alternately single and double. In the course of the revolution of the two stars about their common center of gravity their radial velocities are directed alternately along the observer's line of sight and at right angles to it. Each spectral line will thus oscillate back and forth on either side of its mean position during the course of one revolution and the relation between the maximum displacements at once gives the relative masses of the two stars. Detailed mathematical analysis of the radial velocity curves obtained by plotting the successive velocities throughout a revolution is even capable of revealing the various other characteristics of the system as surely as if the two components were individually visible.

Even when one component is much brighter than the other, so that its spectrum alone is visible, the fact that it belongs to a binary system is betrayed by the regular variations of its radial velocity. It was therefore believed for a long time that all stars with variable radial velocities were components of binaries. But as soon as the progress of physics allowed the linear dimensions of certain stars to be measured, it became apparent that some of the calculated orbits were actually smaller than the stars themselves. It is now generally agreed that (as originally proposed by the American astronomer Shapley and the English astrophysicist Eddington) these variations of radial velocity are produced by the rhythmic pulsations of a single star whose surface therefore actually advances toward and recedes from the terrestrial observer. Analysis of the light and radial velocity curves, together with the study of the synchronous color changes, has shown that such a star (called a Cepheid) attains its greatest brightness a short time before attaining its greatest size, for as it expands it cools, with consequent reduction of its surface brightness.

Other variable stars present more complex problems, since the displacements of the lines of different elements indicate neither the same value nor sign of radial velocity. The interpretation of this extraordinary state of affairs is based on the fact that the stars concerned are all giants which are transparent to considerable depths allowing the different motions of their component gases to be observed. Similar phenomena exist with novae. Their spectra, during the explosive phase, characteristically contain bright and very wide lines, often multiple, which are flanked on their short-wave side by absorption lines of the same element. Later, when the nova has faded considerably, bright nebular lines, produced by the expanding gaseous envelope, are observed to be doubled—a phenomenon that is seen even more clearly in the spectra of planetary nebulae. This is easily explained on the assumption that these immense, expanding bubbles of gas are transparent, so that we receive radiation from both the near side and the far side, one approaching, the other receding. The making of such determinations was, until quite recently, a long and arduous un-



Doubling of the spectral lines of a spectroscopic binary with similar components (Doppler Effect).

dertaking—each star had to be dealt with individually with a slit spectrograph, which is always a bothersome instrument to use. But within the last few years the French astronomer Fehrenbach has developed a method of making sufficiently accurate determinations of stellar radial velocities from photographs taken with an objective prism. Each such photograph carries the spectrum of every star in the field. He photographs the field once then inverts the prism to take a second photograph slightly displaced from the first in a direction at right

Spectra and inverted spectra of stars observed with an objective prism by Fehrenbach's method. The displacement of corresponding lines permits the star's relative radial velocities to be calculated.

angles to the dispersion of the spectra. The relative displacements of the lines of the same elements are then measured and will correspond to double the distance that would separate the images of a reference line that had undergone no shift during the rotation of the prism. With prisms in use at the present time it is possible to reach magnitude 10, the mean accuracy being of the order of 2 mps for a single star. A new prism, whose refracting edge measures 12 inches, is at present under construction, and will in the near future provide a mass of new data.

Spectroscopic Classification of Stars

The best and most certain determinations of stellar temperatures are those that are based on the detailed spectroscopic analysis of their light. Since a light ray of any wavelength which penetrates the exterior will sooner or later be totally and irremediably absorbed, a stellar photosphere may be regarded as constituting a black body. In principle, therefore, it is only necessary to compare the energy distribution of the continuous component of a star's spectrum with those of theoretical black bodies at different standard temperatures in order to measure its temperature. Derived in this way, however, it is not necessarily the true temperature of the star's radiating layers:

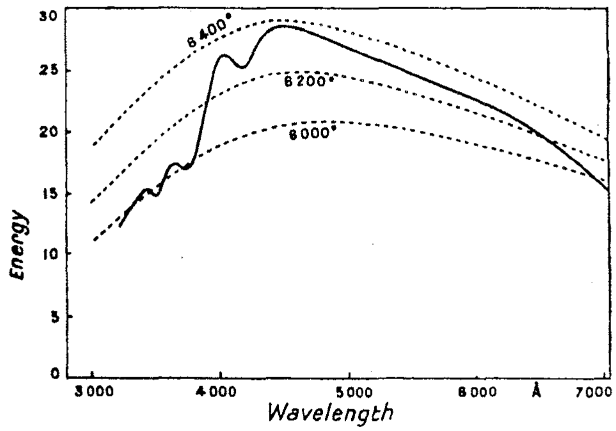
1) Because the observed radiation is emitted at different levels within the star, whose temperatures are themselves different;

2) Because the distribution of energy in a continuous spectrum is often difficult to plot accurately if the spectrum is cluttered with innumerable absorption lines (often intense molecular bands of the star's own atmosphere);

3) Most important of all because it is by no means certain that the continuous spectrum as observed is a true reflection of the photospheric radiation and is not materially influenced by "continuous absorption" caused by unsuspected components of the stellar atmosphere. One such component the negative hydrogen ion has been recognized as exerting absorption throughout the whole visible and infrared regions of many stellar spectra.

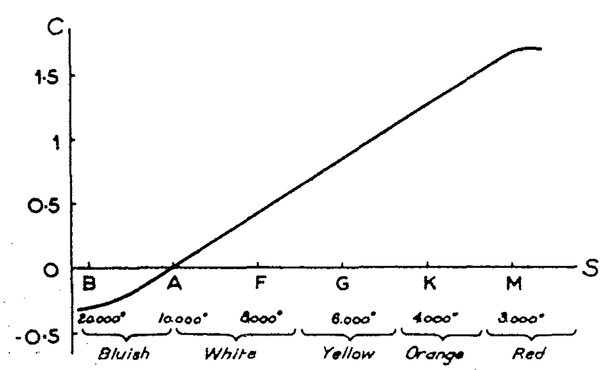
The upshot of all this is that the observed color of a star has a rather tenuous connection with its actual temperature and the derived values do in fact differ rather widely according to whether the measurements are made in the ultraviolet or the blue-violet region of the spectrum.

However stellar temperatures may also be determined from a study of line intensities. The relative intensities of the



Energy distribution in the continuous spectrum of the center of the Sun's disc, compared with the energy curves of a black body at different temperatures. (Photo,Pettit, Mount Wilson Observatory.)

different lines of a single element in the spectrum of a star reveal the degree of ionization of that element, and hence the temperature of the radiating layer. Such spectra are used to divide the stars into a small number of well defined groups. The classification is built up of a series of small, progressive spectral differences in such a manner that the majority of stars are arranged in order of decreasing temperature. The system universally employed at present was developed during the early years of this century as a result of the herculean investigations of stellar spectra undertaken at Harvard College Observatory. The spectra were distributed among ten principal classes originally designated by letters in alphabetical order but, owing to the suppression of some and the insertion of others necessitated by our rapidly expanding knowledge of stellar spectra, the series now runs: O, B, A, F, G, K, M, R, N, S. A useful mnemonic for this is "Oh Be A Fine Girl, Kiss Me Right Now Sweetheart."



Variation of stellar color index as a function of temperature.

Principal characteristics of each type are:

Type O: Lines of ionized helium and those (doubly or trebly ionized) of oxygen and nitrogen; temperature of 30,000° and upward. Hardly a hundred of these stars are known and only three can be seen with the naked eye—Gamma Velorum, Zeta Puppis, Zeta Orions.

Type B: Neutral helium but ionized oxygen and nitrogen present; temperature between 25,000° and 12,000° (characteristic series of hydrogen lines are the most notable feature of stars in this type). They are comparatively infrequent in space although they figure prominently in our star catalogs due to their high luminosities. The brightest of this group and most familiar to us is Beta Orions (Rigel).

Type A: Known as hydrogen stars; temperatures 12,000° to 8,000°. These stars are bright and abundant in space; easily recognized examples are Alpha Canis Majoris (Sirius) and Alpha Lyrae (Vega).

Type F: The two lines of ionized calcium in the extreme violet and ultraviolet are prominent in this group with hydrogen lines weakening; temperatures from 8,000° to 6,000°. Most renowned in this group is Alpha Ursae Minoris (Polaris, more familiarly known as our North Star).

Type G: Very strong ionized calcium lines and abundance of metallic lines; temperatures of 6,000° to 4,000° are too cool to produce ionization in majority of elements. Our warm personal feelings for this group are evidenced by our attachment to the Sun which is among the very numerous dwarfs of this type.

Type K: Sometimes called "sunspot stars" because of the spectral resemblance; metallic lines especially iron are intense; neutral calcium lines also become more prominent; temperatures 5,000° to 3,500°. Well known examples are Alpha Bootis (Arcturus) and Alpha Tauri (Aldebaran).

Type M: Titanium oxide produces fluted bands fading on the red side; temperatures 3,500° to 2,000°. A typical star is Alpha Orionis (Betelgeuse), fondly referred to by second year astronomy students as "Beetle Juice".

Types R and N: Carbon stars in which CN and C-13 appear in great quantities; all rare giants; temperatures probably 3,000° to 2,000°. None are visible to the naked eye.

Type S: Zirconium oxide stars; rare giants mostly variable; practically none visible to the naked eye.

In 1920 M. N. Saha, an Indian astrophysicist, established a formula which gives the relative proportion of ionized to neutral atoms of a given element as a function of its ionization potential and of temperature. It also takes into account the electron pressure in the gas. Since at high temperatures these electrons have violent random motions and are constantly involved in collisions with atoms and ions, the latter will often recapture an electron it may have lost as result of an earlier collision. This contrary effect will be maximal when the electrons are most numerous so that the pressure they exert by their collisions is high. A remarkable consequence of this leads to the spectroscopic determination of absolute magnitudes. Absolute magnitude is here taken as the apparent magnitude (as measured photographically by luminosity) that a star would have at a distance of 10 parsecs (about 33 light years). Two stars of the same type and roughly the same temperature may yet be one a giant and the other a dwarf. We know that the pressure in the distended atmosphere of the giant is almost negligible compared with that in the enormously dense reversing layer of the dwarf. As a result of lesser opportunity for collisions, other things being equal, ionized atoms will be relatively more numerous in the giant than the dwarf. As a further result the lines of ionized atoms will be more intense in the spectrum of the giant than in that of the dwarf. This difference has to be calibrated by means of stars whose absolute magnitudes have already been determined by some independent method. But once this has been done a simple comparison of the relative intensities of two of the standard lines (of ionized atoms) will immediately yield the absolute magnitude and thereby, incidentally, the distance of the star.

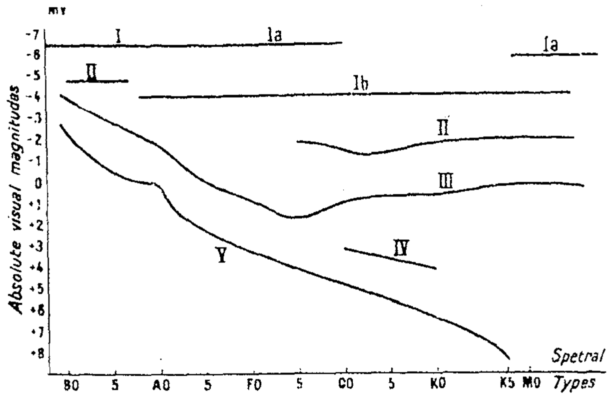
If we digress a moment from spectrographic applications, we learn that stellar masses can be determined through the study of the motions of the component of binary or multiple systems. Since these motions conform with the law of universal gravitation, we can deduce the masses of the bodies from the observation of their mutual motions, just as the mass of a planet can be accurately derived from the motions of its satellites. It has thus been found that the amplitude of variation of stellar masses is very restricted. It will then follow that their densities, being inversely proportional to their volumes for a given mass, must vary over the same wide range as their volumes. A giant star might have a diameter 480 times that of the Sun but its mass would be no greater than 20 times that of the Sun and a quick calculation will show that its density is less than 2 ten-millionths that of the Sun, or roughly 0.0001 that of our ordinary air.

The outer layers, at least, of so enormous and rarefied a globe must be, to all intents and purposes, completely transparent to the radiation passing through them from the lower levels of the interior as well as that of any body happening to pass behind. Such a state has been observed in the case of the type K4 super-giant, Zeta Aurigae, when its brilliant comes (fainter companion star) passes into eclipse behind it For several weeks, at the beginning and end of the eclipse, the comes can be observed through the transparent outer layers of the supergiant which only very gradually blots it out. The spectrum of the light that is thus filtered through the atmosphere of the primary contains the characteristic absorptions of these layers. This intriguing and important observation was made by O. C. Wilson in 1939 and, for the first time, permitted us to explore directly the atmosphere of a star, though admittedly under rather special circumstances.

In the early part of this century Hertzsprung and Russel, a Dane and an American, constructed the first diagram linking the various stellar characteristics to one another. Although it has since been extensively modified, it was nonetheless the foundation which enabled us to arrange the stars in sequence. They plotted luminosities as ordinates and spectroscopic types as abscissae and found their points nearly all lying along or close to a line running obliquely across the diagram from the upper left to the lower right. This line, along which luminosity and temperature decrease steadily and simultaneously, is known as the Main Sequence. Since stellar distance determinations set the limit of accuracy and the quality of these is steadily improving, a recent series of investigations undertaken at Yerkes Observatory (in particular, those under the direction of W. W. Morgan) has refined the data very considerably. Using the Morgan diagram absolute magnitude, and hence distance, can be derived (with an accuracy which is constantly being improved) with the knowledge of spectroscopic type and luminosity class obtained from examination of a stellar spectrum. The scope of this method is limited by:

1) The necessity of obtaining spectra whose dispersion and clarity are both adequate;

2) The inapplicability of the Russel and Morgan diagrams to the stars in type M and cooler, as well as certain other categories such as globular clusters.



Morgan's diagram recognizes five different classes of stars: the new ones, II and IV, are respectively intermediate between supergiants and giants, and between giants and dwarfs. The curves corresponding to these classes are not more than 0.5 absolute magnitudes wide, representing a very notable gain in precision.

Effects of Magnetic, Electric, and Gravitational Fields

From a study of the Zeeman effect, theory and experiment have shown that in magnetic fields whose intensities do not exceed a few thousand gauss there is a separation of the spectrum lines of a radiating body proportional to the field strength. The first such extra-terrestrial magnetic field to be detected by this method was that of the sunspots. Hale, at Mount Wilson in 1908, found that the separations of the components indicated field strengths of the order of 4000 gauss—attributed to the vortical motions of electrons in the sunspots.

Hale further succeeded in detecting a general equatorial magnetic field on the Sun of about 50 gauss. In 1945 the German astronomer G. Thiessen repeated and vindicated these measurements, and the question then arose as to whether other stars are not also surrounded by measurable magnetic fields. Choosing a star whose narrow lines suggested orientation of its axis pointing towards the earth (so there would be no Doppler effect to widen its lines), an American astronomer, H. W. Babcock detected the existence of a 1500 gauss magnetic field surrounding the star.

Large-scale electrical fields do not occur in stellar atmospheres but at these high temperatures large proportions of the atoms are ionized creating small electrical fields around themselves. Other atoms, continuously passing in random directions, are then modified by the Stark effect. Such is the origin of the characteristic differences of appearance of the lines in giant and dwarf spectra already referred to.

The influence that gravitational fields exert on the period of vibration of different radiations was predicted by the theory of general relativity. This Einstein effect concerns the increase of period, or shift of the spectrum toward the red, in reaction to a gravitational field. The earliest attempts to obtain observational evidence of this effect were concentrated on the Sun, whose surface gravity is 28 times that of the Earth. But it became evident that the tiny spectral shift produced by a gravitational field of this strength would be effectively masked by the Doppler shifts produced by the motions of the gases in the Sun's atmosphere. Happily, however, there are stars—the white dwarfs—whose surface gravitational fields are incomparably more intense than the Sun's. Sirius B, although its mass is equal to that of the Sun, has a radius hardly exceeding 2-3 times that of the Earth. The atoms at its surface then are subjected to a gravitational field about 30,000 times that of the Earth. Observation is hampered, however, by the proximity of its companion giant whose light tends to swamp that of the dwarf in the spectroscope slit. Stark effect shifts, which are generally strong in white dwarfs, also create a problem. Nonetheless, Adams, in 1925 at Mount Wilson, was able to confirm that when allowance is made for Sirius' radial velocity and the orbital motion of its companion (both of which are well determined) there is a residual red shift which agrees exactly with that predicted by Einstein. Adams' observation demonstrated simultaneously the validity of Einstein's equations and the reality (by no means well established at that time) of hyperdense dwarf stars. Since then the Einstein effect has been detected in other white dwarfs and has even been used to determine the masses of such stars when they are not members of binary systems.

Next Stop: Extraterrestrial Satellites

One limiting factor we are on the threshold of eliminating is the handicap of having to make observations through the Earth's atmosphere. During the past few decades tremendous strides have been made in quantitative chemical analysis of celestial bodies but more precise determinations of the elements in planet and star atmospheres and in the cosmic "dust" in space are necessary before we can acquire a better understanding of the evolution of the universe.

At present the atmosphere of Mercury is considered negligible, and, until this year, that of Venus was considered water-and-oxygen-free. In an experiment designed by Strong of Johns Hopkins University, a 172 ft. diameter balloon lofted a 7 ft. diameter pressurized spherical gondola to 80,000 feet from which perch absorption by the Earth's obscuring vapors is essentially eliminated. Infrared absorption readings, taken there, of sunlight passing through Venus' atmosphere indicated the unmistakeable existence of water in its atmosphere. To date there has been no spectroscopic evidence of water on Mars but high altitude observatories may soon alter that, too.

The Smithsonian Astrophysical Observatory is designing a satellite-mounted telescope with attached television equipment for an ultraviolet survey of the skies. The instrument is to televise spectra of the stars to monitoring stations on the ground and is capable of "seeing" ultraviolet radiation that cannot penetrate our atmosphere. Through such "windows" and those recently beginning to be opened in radio and radar regions of the electro-magnetic spectrum we can look forward to an ever increasing view of the wonders nature has spread out before us.

Through Astronomy, the enquiring spirit of man has discovered the status of humanity in the Universe: a mere atom, but a thinking atom, situated on a microscopic planet, one of several revolving about a small common-place star, itself indistinguishable from hundreds of thousands of others, in the heart of a galaxy which in turn is lost among the millions that populate the tiny corner of space that we have been able to explore.

This atom, man, far from feeling crushed and lost in the midst of this immensity, should on the contrary feel the less bewildered simply because he has been able to explore it and even to begin to understand it.

ENCLOSED STALLWOOD JET

One recent development appears to come under the heading "Regress" rather than "Progress". We have discontinued the Enclosed Arc Chamber listed under our No. 9015 in favor of a much simpler device. The No. 9015 was first designed with two objectives: 1) the chamber should be as air-tight as possible; 2) light should pass through a plane quartz window. Independently, three spectrographers, D. L. Nash of the Bell Telephone Labs., D. R. Baesecker of Monsanto Research Labs., and Richard Sussman of Republic Aviation found neither of these specifications valid. Each devised a very simple chamber made from a quartz cylinder topped with a plate in which a hole was drilled to accommodate the upper electrode. Each found independently that when such a device was perched atop our No. 9014 Stallwood Jet, it worked as well as the more cumbersome No. 9014-9015 combination. At the suggestion of Mr. Sussman, we went one step further, cutting an opening in the quartz for the light path. Instead of the light passing through a cylindrical quartz section, it now passes through the opening. As long as a positive pressure of gas excluding nitrogen is maintained, the cyanogen bands disappear almost entirely. In fact, if traces of nitrogen appear they may be due to impurities in the flushing gas mixture, the sample, or the graphite electrodes.

To convert existing Stallwood Jets to the new enclosed type, we are supplying caps with a recessed groove to accommodate the quartz dome. These caps are available either with or without a water-cooling loop, the former being particularly useful in production operations or when high currents are used.

Gases Used—The principal consideration is the use of a gas which is nitrogen-free in order to eliminate the cyanogen band structure and many so-called air bands which are extensive throughout many regions of the spectrum. Shaw (D. M. Shaw, G. Wickremasinghe, C. Yip, *Spec. Acta*, 13, 197, 1958) after trying carbon dioxide, argon, and mixtures of argon and oxygen, settled on a 1:1 mixture of argon-oxygen. Landon and Mitteldorf (Ottawa Conference, Oct. 1960) used a 30:70 mixture of oxygen-argon, and Shaw recently (private communication) indicated that 100% oxygen has some definite advantages. Cylinders of pre-mixed gases, incidentally, are commercially available.

Gas flow control can be obtained in a variety of ways and most spectrographers may be able to rig the required regulator, flow meter and valve. For convenience, it is a good plan to have a toggle valve on the low-pressure side. This permits the operator to preset the flow rate and merely flip a switch between burns. On our No. 9010 arc/spark stand we provide an optional flow-meter and toggle valve. For users of other arc stands we also supply, under Cat. No. 9024, an assembly which when attached to a cylinder of high-pressure gas provides all of the necessary components for controlling the flow.

9025 **Enclosed Stallwood Jet Assembly,** rhodium-plated bronze; includes adapters for 1/8", 3/16", and 1/4" dia. electrodes; 1 fused quartz dome; 2 alternate mechanisms for adjusting electrodes as they burn away ....Each **$ 96.00**

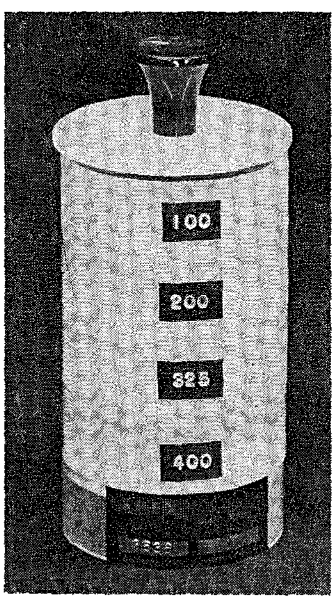
9026 **Quartz Dome,** spare, about 2" dia. x 1-5/8" high with cut-out for light path and hole to accommodate upper electrode. (It is recommended that several of these be purchased so a clean one can be conveniently used for each burning) ....Each **$ 13.00**
Package of 10 **$120.00**

9027 **Water-cooled Enclosed Stallwood Jet,** same as 9025 but with internally-brazed water loop for cooling ....Each **$139.00**

9025-2 **Cap,** for existing Stallwood Jets: permits simple change to accommodate quartz domes ....Each **$ 21.00**

9027-2 **Cap,** water-cooled; same as 9025-2 but water-cooled ....Each **$ 73.00**

9024 **Regulator-flow meter assembly,** including toggle valve; attaches directly to gas cylinder; no other "plumbing" required ....Each **$ 41.00**



No. 3536 Sieve Set

NYLON SIEVES

Every step in the handling of high purity materials is a potential source of contamination. To eliminate one such source of metallic impurities our new nylon sieves were designed. Each sieve consists of a sheet of monofilament nylon cloth stretched in an "embroidery" frame consisting of two telescoping Lucite rings. The cloth, available in four mesh sizes, meets ASTM specification E11-58T for size and uniformity of mesh.

3530 **Sieve frame,** consisting of two telescoping Lucite rings, 70 mm dia. x 25 mm high....Each **$ 8.00**

Screen, nylon monofilament cloth, 85 mm square:

3531 **100 mesh** (each opening 149 microns) .....12 **$ 6.00**

3532 **200 mesh** (each opening 74 microns) ......12 **$ 8.00**

3533 **325 mesh** (each opening 44 microns) ......6 **$ 6.00**

3534 **400 mesh** (each opening 37 microns) ......3 **$ 7.50**

3535 **Tray, plastic,** 70 mm dia. x 25 mm high..Each **$ 3.00**

3536 **Sieve Set,** consisting of 4 frames and 1 tray with 1 each of the above screens ....Set **$35.00**

INVERTING OPTICS ON GENERAL ELECTRIC X-RAY SPECTROMETERS

For the analysis of liquids it is advantageous to have the x-ray beam emerge upwards to the sample contained in a cell such as our No. 3515. On G.E. XRD-3 and XRD-5 instruments it is possible to invert the optics in order to accomplish this by using a kit especially designed for the purpose by K. H. Storks, T. C. Loomis and C. R. Geith of the Bell Telephone Laboratories. The kit, consisting of stands on which the sample drawer, the crystal holder, the Soller slits and the detector are mounted, can be mounted in less than one-half hour. Ordinarily, it is not necessary to convert the instrument back to its original optics.

3521 **Kit** for Inverting Optics on GE Spectrometers XRD-3 or XRD-5 .... **$245.00**

EXPENDABLE LIQUID CELLS FOR X-RAY ANALYSIS

In many laboratories the x-ray spectrograph is a production tool grinding out analyses just as fast as possible. For liquid samples one bottleneck often is the cell itself. When machined of metal, it is much too expensive to discard after a single use and a good deal of trouble to clean between samples. Our new liquid cells are inexpensive enough to discard after a single use. Molded of rigid, inert plastic (insoluble in most organic solvents and mineral acids), they are assembled simply by placing a piece of 1/4-mil Mylar on top and pushing a Teflon ring over the upper tapered section of the cell until it snaps into a groove. The fit is such that no liquid will seep out even if the cell is turned upside down as in the newer "inverted optics" spectrometers.

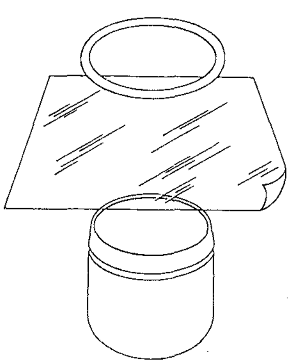
Dimensions of the cells were chosen after consulting with the major manufacturers as well as several users of commercial spectrometers. The depth (31/32″) is somewhat too great for the sample drawer of G.E. instruments. A leaf-spring in the drawer, however, may readily be bent (or removed if our No. 3521 Inverted Optics Kit is used) to accommodate the cell.

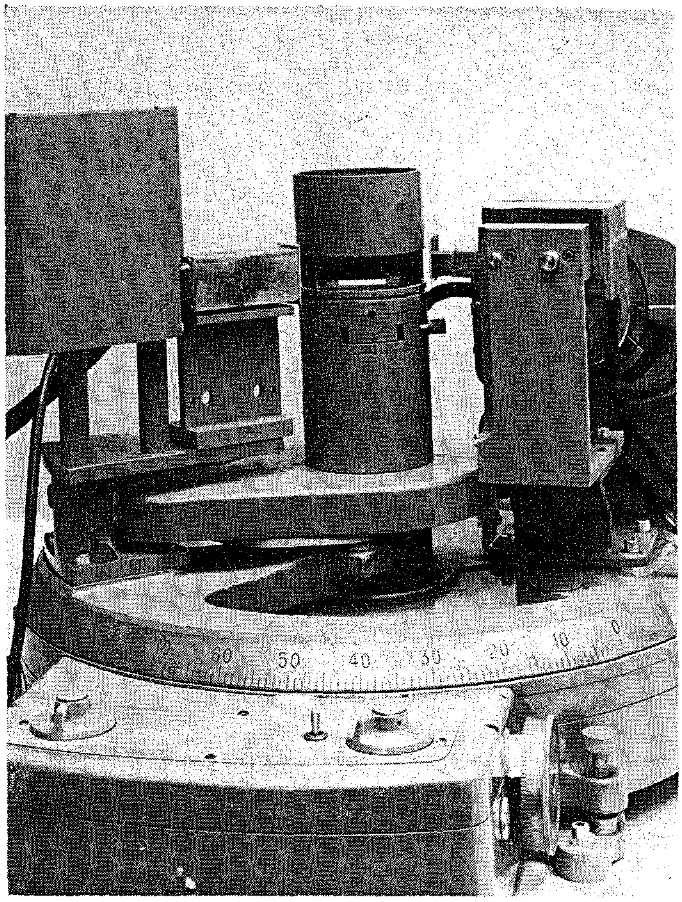
3515 **X-Ray Liquid Cells,** polypropylene, 1-1/4″ dia. x 31/32″ deep.
100 .... **$ 8.00**
1000 .... **$53.00**

3516 **Teflon Ring,** reusable, to hold 1/4 mil Mylar window on 3515.
6 .... **$ 5.00**
100 .... **$70.00**

3517 **Mylar,** 0.00025″ (1/4 mil) thick, 2-1/2″ wide x 100′ ....Roll **$ 3.50**

3518 **Spacer,** aluminum; one required for each port on Philips instruments. (Specify i.d. of sample holder 1-1/4″, 1-3/8″ or 2″) ....Each **$ .50**





No. 3521 *Inverted Optics Kit*

(Photo Courtesy International Research Laboratories)

CAST IRON STANDARDS CONTAINING MAGNESIUM

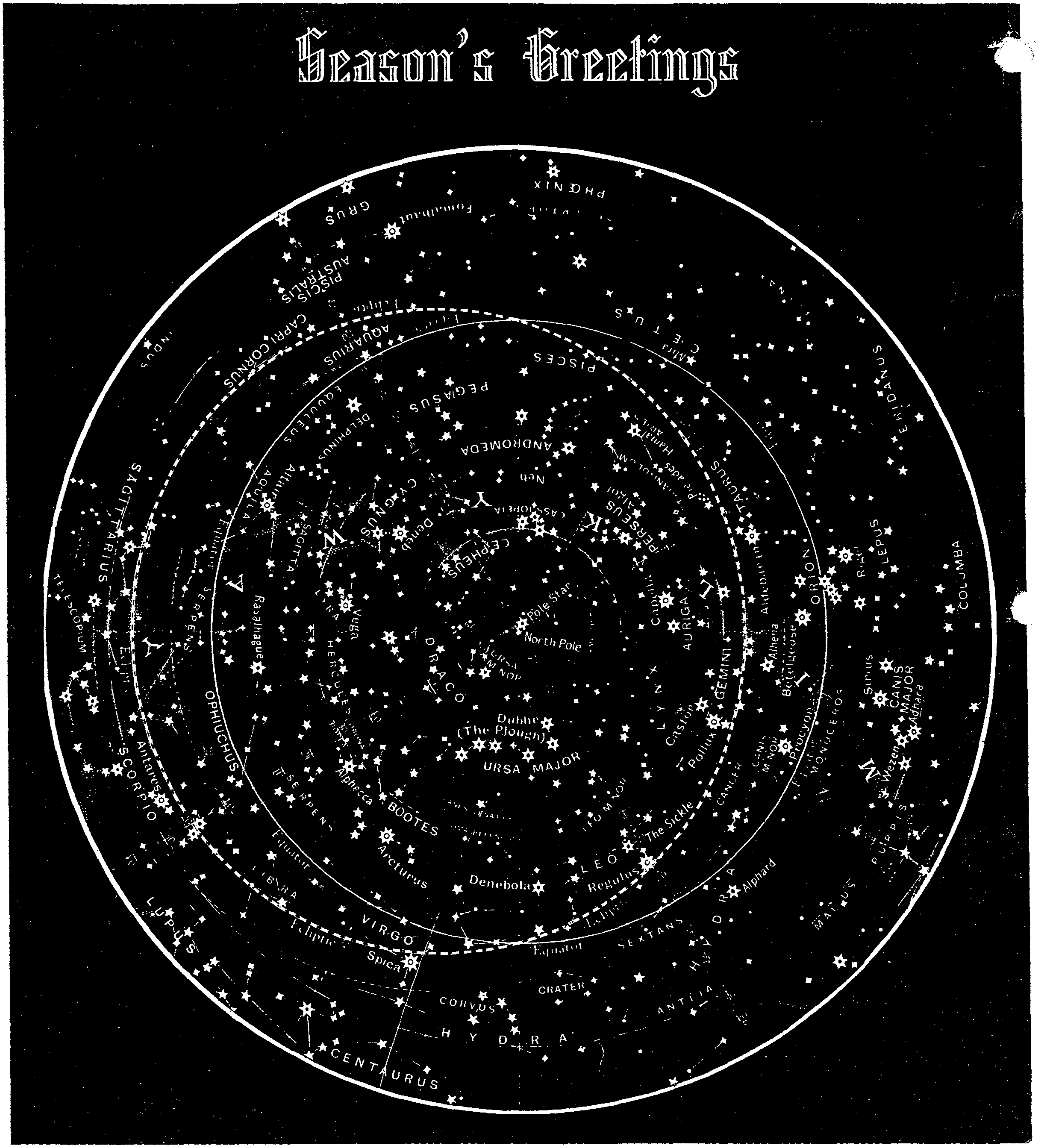
Just announced by the British Bureau of Analysed Samples, Ltd. is a set of cast iron standards commonly referred to as ductile iron. These were prepared by the British Cast Iron Research Association under controlled laboratory conditions (see Argyle, A., *B.C.J.R.A. Jour.* Vol. 8, No. 4, 537-544, 1960) and tested for homogeneity by direct reading spectrography. They were then standardized by analysis in Great Britain, Germany and the United States. The American analysts were C. M. Davis and R. G. Lomell of International Nickel Research Laboratories, Bayonne, N. J.

CAST IRON SERIES

No.	*Mg, %*	*Ni, %*
SS 41	0.012	0.32
SS 42	0.024	0.39
SS 43	0.039	0.52
SS 44	0.053	0.64
SS 45	0.078	0.96
SS 46	0.128	1.42

In addition to the above, the sulfur content is standardized at around 0.01% in each, carbon at 3.3% and phosphorus at 0.02%.

BSS 41-46—Cast Iron Standards, set of 6 bars 1-3/16″ dia. x 1-1/2″ long ....Set **$112.00**



THE CONSTELLATIONS OF THE NORTHERN HEMISPHERE

(Courtesy George Philip & Son, Ltd.)