united only by a complex, yet zealous patriotism, nationalism has more and more tended to exceed the satisfying of political necessities. To-day, the evils of an exaggerated and perverted nationalism in various quarters, linked with the ever-increasing obliteration of world barriers and distances, appear to be hastening the completion of a cycle back to universalism. We have seen that internationalistic proposals have been made with increasing frequency over six centuries, but none put on actual trial till the League of Nations. We see that benevolent and logical proposals have not been enough, even when backed by high authority. However, an ever-increasing informed public opinion has already made its influence felt. On the other hand, the industrial age and man's greater control over the forces of nature have so charged the situation with world danger that unless it is efficiently met, modern civilization would appear to be doomed to the worst setback in its entire course. It would seem that a lasting solution of the international problem will only be found in the achievement of a plan based on justice to all and containing adequate provision for restraining the transgressor. This, then, is indeed a critical period of world's progress, but one which, wisely comprehended and handled, may so combine a rational nationalism with the internationalism of my original definition that the coming one hundred years may register the steepest curve yet recorded of man's upward progress.

I am near the end of my address, yet you will notice that I've not even mentioned the internationalism of science, of religion, of art, of commerce, of economic trends, in most of which we may take just pride. Every scientist knows that the scientist has culled his information from whatever land can provide it ever since there has been a science; and that, in normal times, his discovery as soon as published is broadcast throughout the scientific world. We can note with satisfaction that even to-day, astronomy pursues its customary international course, and a discovery, though perhaps made by a citizen of a warring country, is telegraphed to a neutral and thence to all the world. The ambitious student, if he has the necessary means and wisdom, goes to whatever center can give him the best education, regardless of country, and the historian of science as readily gives credit to a German as to a Frenchman, Swede, Britisher or American. Internationalism in art and literature has been accepted as matter of course for centuries. Masterpieces are recognized and eagerly collected regardless of their country of origin; art students flock to the center where they expect to find the best training regardless of its location, and pride in one's own country—a desirable form of nationalism—is but little apparent in artistic matters.[10] Commerce existed between nations long before nations existed—if you will pardon an Irishism—hampered at times, to be sure, when ideas of self-preservation raised tariff barriers; though I believe that economists generally accept the theoretical superiority of free trade over protective tariffs.

To-day you can talk with the ends of the earth more quickly than our Revolutionary great-grandfathers could get in touch with a neighboring village; and Jules Verne's Phineas Finn could now go round the world in nearer eighty hours than eighty days. Just as we are so much nearer to our neighbors, so also life's tempo increases, for bad as well as for good. The world's ability to produce, distribute and communicate has been vastly increased; but in its political arrangements it has sadly lagged. International comprehension, also, is conspicuously inadequate. As we have no way of estimating the intellectual capacity of the peoples of the world, how arrogant to assume a permanent inequality of races, with our own of course at the top! Thus, provocations and wars can and do arise more frequently and ever more devastatingly. The more imperative has it become, therefore, that the nations of the world set up an adequate framework, backed by the same sort of compelling force that each nation requires for preservation of its internal peace, to repress or chastise the international law breaker. We have now seen the catastrophic effects of this political lag twice in one generation. It would seem but common sense then, at no matter what cost, for the civilized world to make a third and worse catastrophe impossible. May God give those in authority the wisdom to erect such a just international structure that the world may shortly attain to a lasting peace!

THE WHITE DWARFS

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THE discovery by Adams in 1915 that the faint companion to Sirius, the brightest star in the sky, was *white* caused a minor revolution in astronomical and physical thinking. In a sense this faint star had been discovered before it had been seen, for its existence had been proved by Auwers from the gravitational effect it produced in the motion of Sirius itself. By 1915 the orbits in which Sirius and this faint com-

[10] W. G. Leland, "The Internationalism of American Scholarship," Providence, R. I.: Brown University, 1940.

panion revolved around their center of mass were accurately known; likewise we knew the distance of the system from us, and thus from the apparent brightness could calculate the real, intrinsic luminosity. In this way it was found that the companion had a mass only slightly less than that of the sun, but a luminosity 400 times smaller. Taken by themselves neither of these figures appeared out of ordinary, but when Adams found that the star was much whiter than the sun, with a surface temperature of some 8,000° K, the situation took on an entirely different aspect. From the temperature we could calculate the surface brightness and found that the star gave out about three times as much light as the sun does per square inch and since the total luminosity is 400 times smaller than that of the sun, it follows that the surface of this faint companion must be 1,200 times smaller than that of the sun, and hence its volume 42,000 times smaller, or smaller than that of the planet Uranus. Yet in this space is concentrated virtually as much matter as there is in the sun, leading to a density 50,000 times that of water.

At first sight it was unbelievable, and it appeared that an impasse had been reached especially when a faint star in the constellation Eridanus, found white the year before, and still another similar star found in 1917 joined to make up the first three "White Dwarfs." The answer to the riddle came a few years later when Eddington showed that these stars are largely composed of or contain central cores of "degenerate matter" raised to such a high temperature that not merely the outer shells of electrons have been removed by ionization, but that in many cases all electrons have been stripped off and the atoms are reduced to their bare nuclei. In the words of Oliver Lodge, under ordinary circumstances when the atomic nuclei are surrounded by shell after shell of fast-moving electrons, matter can be compared to flies buzzing in a cathedral. But when the temperature is raised to several hundred million degrees the electrons become ionized away—the cathedral walls collapse and all there is left are the flies. And, naturally, one can pack a good many more flies than cathedrals in a cubic mile.

A great deal more theoretical work has been done on the physical nature of these stars by Eddington, Milne, Chandrasekhar and others, as a result of which there is now fair agreement as to the internal constitution of these stars or rather, to be on the safe side, as to what should be the internal constitution of the white dwarfs; many astronomers even feel that we understand the structure of these freak stars better than that of ordinary stars.

Right at the beginning came Eddington's startling prediction that, because of the high density and the consequent high value of surface gravity of these stars, the light rays leaving their surface should, if Einstein's relativity is correct, be slowed down in their vibrations. Thus spectral lines produced by any given chemical element should be shifted toward the red as compared to the same lines produced by sources on the earth. The verification of this prediction at Mt. Wilson by observations on the companion of Sirius killed two birds with one stone, since it not only proved that Eddington's picture of the structure of the white dwarfs was correct but also that Einstein was right.

In the present article I should like to stress more the observational aspect of the situation, since this is one in which my own work has been primarily concerned. When I began in 1921 to observe the spectra of stars of low luminosity only one star out of one hundred observed proved to be a white dwarf—and even that one was not generally so recognized until twenty years later. It was evident from this that the majority of white dwarfs must be found among the very faint stars. To get their spectra was not only beyond reach of the then existing equipment, but our surveys of the sky for such stars were as yet very incomplete.

In order to remedy this situation I undertook first a survey of the entire southern hemisphere as well as of large parts of the northern hemisphere in a search for stars of low luminosity. Planned, and initiated in 1923 while I was at Harvard, it was continued under the auspices of the Guggenheim Foundation during 1928–30 while at the South African station of the Harvard Observatory. The series of photographic plates obtained there were examined after I went to Minnesota in 1931, and this survey was completed in 1936.

In the course of this survey some 30 million stars were examined and from among them some 100,000 were selected because of a conspicuous displacement across the sky, a "proper motion." This, of course, is an angular displacement, and, other things being equal, a swift angular displacement must mean that the star in question is comparatively near, and a star which is both near and very faint in appearance must be a star of low luminosity. After this first screening test, the search was narrowed down still further by selecting from among the 100,000 stars with appreciable motion, the 3,000 stars of *largest* angular motion. These 3,000 stars constitute the most likely selection of really intrinsically faint stars from among the entire 30,000,000. Finally, it is evident also that since white dwarfs are to be found among stars of low luminosity this final list of 3,000 faint stars with large proper motion constituted by far the richest potential source of white dwarfs.

It was to be expected that the vast majority of them would be ordinary red dwarfs with a surface temperature around 3,000° K and the problem was to find those that were not red but white. To distinguish between the two kinds it would be necessary only to compare two photographs, one taken in blue light, the other through a red filter: as compared with the average of the other stars shown on the plates the red dwarfs would be much brighter on the red plates, the white dwarfs much brighter on the blue plates. For some years I had no success in interesting other observatories in a program of observations of this nature. Since 1939, however, I have been able, through the kind permission and cooperation of Dr. E. F. Carpenter, to use the 36-inch reflector of the Steward Observatory of the University of Arizona for a few weeks each year. Since 1942 Dr. P. D. Jose at Tucson has collaborated on this program, while in addition Dr. Martin Dartayet at the National Observatory at Cordoba, Argentina, has collaborated in obtaining plates for stars too far south to be observed from Arizona.

In the meantime the spectra of many faint stars of large proper motion discovered by Wolf or Ross were determined at observatories possessing powerful spectroscopic equipment, and a number of white dwarfs were identified in this way, mainly by Kuiper.

Until recently this line of attack, *viz.*, that of first discovering the stars with large motions—with or without subsequent measurement of their distances, and hence of their luminosities—and secondly determining the star's color or spectral class seemed to provide the only systematic and fruitful approach to the problem. Within the past few years, however, a different and novel method has been developed by Zwicky at the California Institute of Technology. His method is based upon the well-known fact that the overwhelming majority of white stars are (a) much more luminous than the sun, and (b) largely concentrated near the central plane of our Milky Way System. Any star which is both white and faint in appearance must therefore be extremely distant if it is to be a normal, luminous white star. Zwicky therefore simply searched for white stars in regions of the sky where very distant stars are not visible either because there aren't any, as in the direction toward the poles of the Milky Way or in areas where a dense obscuring cloud is known to hide all distant stars from view. Any faint white star appearing in either region must then be very close to us; in other words, it must be a white dwarf.

In all these various ways a total number of 70 white dwarfs have now been discovered; for 38 of these the proper motions were found at Minnesota by the writer, and for 39 the whiteness of the star was first determined by the writer alone or with his collaborators.

Among those for which spectra are known the largest number are similar to the prototype o_2 Eridani B, *i.e.*, their spectra somewhat resemble those of Sirius and Vega. Some white dwarfs resemble the bluer B stars in their spectra, still others, and still fewer the yellower F and G type. Some show virtually no absorption lines at all, and their spectrum must be classified as "continuous"; for these stars the wave-length intensity curves may correspond to temperatures ranging all the way from the hottest O type to the much cooler K type.

The coolest white dwarf of them all is, perhaps, represented by the extremely faint companion to BD + 4 : 4048 discovered by Van Biesbroeck. The luminosity of this star is less than one half-millionth of that of the sun, but its color corresponds to that of a star of spectral class M, whose luminosity averages several thousand times greater. Perhaps, therefore, this very faint star, intrinsically the faintest star known, stands in the same relation to an ordinary M dwarf as a typical white dwarf compares to Sirius: it may begin to approach the *ne plus ultra* in smallness and degeneracy, the Black Dwarf.

Because of the peculiarities of their spectra it has long been recognized that these stars can not be classified in the same way as ordinary stars; one proposal is to give their spectra the same capital letter as that to which they roughly correspond but also the prefix "w," thus wA, wF, wG, etc. It seems to me that this is not only redundant but even illogical. Surely the significant thing about a white dwarf thus classified as wA is not that it is white—the letter A tells us that—but that it is an extreme dwarf. Since for many years we have designated ordinary dwarfs by the prefix "d" it would seem logical to extend that practice and classify all white dwarf spectra by the capital letter "D"—which possesses the double advantage of indicating "dwarf" as well as "degeneracy," thus describing the physical state of matter as well. Those stars whose spectra are devoid of lines could then be described by DC followed by a number expressing the surface temperature in thousands of degrees. Other, more normal stars could be described by DA, DF, DG, etc.

Enough white dwarfs are now known and enough distances have been determined for them to enable us to make some simple statistical analyses. First of all, it appears that those with a spectrum of the DA type are the most numerous and that these, on the average, are about 700 times less luminous than our sun, intrinsically; those with DB or DF and DG spectra are apparently rarer in space and both appear to be somewhat less luminous, averaging perhaps less than one thousandth of the sun's luminosity. Still fainter seem to be those whose spectra, while continuous, indicate temperatures equal to, or lower than that of the sun, and the faintest of all white dwarfs appears to be the star L 97–12, with a luminosity 20,000 times smaller than that of the sun, unless, of course, Van Biesbroeck's star should turn out to be a white dwarf.

Whether these several groups are isolated from each other or whether all the white dwarfs are related in one continuous sequence it is too early to say. In so far as their motions are concerned, the white dwarfs appear to resemble the stars of high velocity, but this was to be expected, since the majority of them were found among the stars of large angular motion.

In their distribution over the sky the white dwarfs do not show any pronounced idiosyncrasies except, perhaps, for a slight concentration near the south pole of the galaxy, but this may be only apparent, or accidental.

Among the most interesting white dwarfs are those which form part of binary systems; ultimately these will become very important, for it is only from the orbital motions of such double stars that we can really determine that crucial quantity—the mass of a star. Sirius is, of course, the classical example and in this case both the orbit of the faint white dwarf around the normal primary and the radio of the masses are accurately known, yielding the only really accurate value for the mass of a white dwarf we possess. In the case of Procyon the mass and luminosity of the faint companion are known, but neither its color nor its spectrum have been observed, and while we suspect it to be a white dwarf because of its much larger mass than expected from its luminosity, we can not be sure. The faint companion to the giant variable star Mira Ceti may be a white dwarf, but if so, it appears to be considerably more luminous than any others now known. One of the components of o_2 Eridani is unquestionably a white dwarf, and while at present neither the orbit nor the mass ratio are accurately known we expect to clear up both these deficiencies in a few decades. In addition to these four systems seven other double stars are known to contain one white dwarf, but in most of these the two components are so far apart and hence the orbital motions so slow that certainly decades and perhaps centuries must elapse before we can accurately determine their orbits and mass-ratios.

To all these may now be added the double white dwarf found by the present writer. To date it is the only double star of which both components are white dwarfs. Situated in the constellation Antlia, nearly 50 degrees due south of the bright star Regulus in Leo, it was first found on Harvard plates to possess the large proper motion of 0″.37 annually. Further observations I made at Tucson then showed the star to be both white and double; other plates taken by Baade at Mt. Wilson and Van Biesbroeck at MacDonald, and kindly sent to Minnesota for examination, have led to the following conclusions:

The two components are very nearly equal in brightness, and probably 1,600 times less luminous than the sun; they are both white or blue in color, and would appear to have a diameter smaller than that of the earth. If they are of normal mass, about equal to that of the sun, their density would be of the order of one million times that of water, or about 25 tons per cubic inch. They appear separated by about 4 seconds of arc, which, if our guess as to their distance is correct, would mean about fifty times as far apart as the sun and the earth. Insufficient time has elapsed since the discovery to enable us to do more than estimate the period of orbital revolution at around 250 years. Within the next ten years it should be possible to determine this quantity, as well as the star's distance from us with much precision: from these we shall then obtain the combined mass of the system. In all other binaries involving a white dwarf component the ratio of the masses would also be necessary —and to determine this even approximately would take much longer than a decade—because in all other systems the two components are very dissimilar. In the present binary, however, the two components appear to be so nearly identical in color and in luminosity that one may safely assume that their masses are also virtually equal, and this new double white dwarf therefore seems destined to play an important role in our search for knowledge concerning the white dwarfs.

SCIENTIFIC EVENTS

THE NEW YORK BOTANICAL GARDEN

POST-WAR plans for the greater development of the New York Botanical Garden, in conformity with the post-war plans of the City of New York, were outlined by Dr. William J. Robbins, director, in presenting his annual report on January 16 to members of the Corporation and the Board of Managers. These plans, he pointed out, have occupied much of the time of the staff members and officials of the garden during the past year, and their consummation will provide the means for carrying on more work of world-wide scope in botanical research, as well as providing for the people of New York ornamental displays and recreational and educational facilities in the field of botany and gardening. In the preparation of these plans, the garden has had the cooperation of the Park Department of the City of New York, of Major Gilmore Clarke and of the architectural firms of Aymar Embury II and Skidmore, Owings and Merrill.

The recent rehabilitation of the growing greenhouses