this connection, but precise data concerning these are not available.

4. Pneumatic belts. Mechanical constriction of the abdomen as well as of the lower extremities has also been proposed in both the German and English literature to minimize the rush of blood from the head to the visceral bed and the lower extremities. Of these mechanical devices, pneumatic belts and pneumatic trousers have been most under discussion. The Germans state that a pneumatic belt may increase g tolerance by 1 to 1.5, but no one of the present belligerent countries has permitted publication of detailed reports concerning the actual effectiveness of this equipment.

5. Water suits. The Germans have also reported on a "water suit" designed for the prevention of blacking out, and while they claim it notably improves resistance to positive acceleration they state that it is unsatisfactory for other reasons. To quote Grow and Armstrong (1941, pp. 276–277):

> The water suit is a closely fitted water-proof garment which is worn next to the skin. What little space is left in the suit after it is put on is filled with water or other suitable fluid. This causes the flier to ''float'' in the suit, and during accelerations the water presses on the body equally in all directions. As a consequence the normal effects of acceleration are replaced by a uniform compression of the body which, it is estimated, could be tolerated without difficulty up to 15 gs or more.

6. Posture. In a recent paper by Ruff (1940) in *Medizinische Klinik* the problem of posture in relation to acceleration was discussed. The Germans, it appears, favor a crouching posture with flexion of the legs against the abdomen as one particularly suited for protection of the pilot against acceleration. This would bring the hydrostatic column of blood in the leg veins nearer to the heart level. If the pilot lies supine or prone at the end of a dive-bombing manoeuvre, he is also less subject to negative accelerations, but in these postures he is unable to see out or to manoeuvre his plane without special redesigning of the cockpit and the cockpit controls.

It should be noted that all factors tending to improve the body's resistance to positive acceleration are those which tend to keep blood in the head. From this it may be concluded that the phenomenon of blacking-out and loss of consciousness which may occur within 5 seconds of the beginning of the acceleration is probably due solely to acute anoxia, and can not be attributed to any direct effect of acceleration *per se* upon the cortical neurons.

V. CONCLUSION

Many other phases of aviation medicine might be discussed, but since there are certain topics that can not be gone into fully at the present time—having in mind Rasselas's "Security of the good"—I have omitted mention of night vision, instrument lighting, the oxygen mask, the adrenals and Drs. Nims and Clarke's studies of pH in anoxia, until some later time when restrictions are less imperative than at present. I hope, however, that I have been able to indicate some of the more important developments as well as the intensely fascinating character of the problems encountered.

I believe that the successful solution of several problems in aviation medicine will determine in large measure the outcome of the present war.

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THE PROBLEM OF THE EXPANDING UNIVERSE[1]

By Dr. EDWIN HUBBLE

MOUNT WILSON OBSERVATORY

MATHEMATICS deals with possible worlds, with the infinite number of logically consistent systems. Observers explore the one particular world we inhabit. Between stands the theorist. He studies possible worlds but only those which are consistent with the information furnished by the observer. In other words, theory attempts to segregate the minimum number of possible worlds which must contain the world we inhabit. Then the observer, with new factual information, reduces the list still further. And so it goes, observation and theory advancing together toward the common goal of science, the structure and behavior of the physical universe in which we live.

The relation is evident in the history of cosmology. The study at first was pure speculation. But slowly, as the exploration of space moved outward, a body of

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positive knowledge was assembled which regimented the speculation. The explorations were once confined to the system of the planets. Then, about a century ago, they reached a few of the nearest stars, and, thereafter, ranged through the stellar system. Finally, in our own times, the explorations pushed beyond the stars and swept through the realm of the nebulae, out to the extreme limits of the telescopes. To-day we study a volume of space so vast and so homogeneous that it may represent a fair sample of the universe.

The observable region is a sphere about 1,000 million light years in diameter, throughout which are scattered 100 million nebulae, each a stellar system, comparable with our own system of the Milky Way. These nebulae average about 100 million times brighter than the sun, and several thousand million times more massive. The nebulae are scattered singly, in groups and in clusters but, when large volumes of space are compared, these minor irregularities are not important. On the grand scale, our sample of the universe is approximately homogeneous—very much the same everywhere and in all directions. The smoothed-out average distance between neighboring nebulae is about two million light years, and the intervening space is sensibly transparent.

Another general characteristic of the sample is the law of red shifts. Lines in the spectra of distant nebulae are always found to the red of their normal positions, and these red shifts are directly proportional to the distances of the nebulae—the more distant the nebula, the larger the red shift. The red shifts are frequently explained as velocity shifts (Doppler shifts), indicating actual recession of the nebulae at the rate of about 100 miles per second for each million light years of distance. The phenomenon has been observed out to about 240 million light years where the apparent velocities are nearly 25,000 miles per second. It may be stated with confidence that red shifts either are velocity shifts or they must be referred to some hitherto unrecognized principle in nature.

With this preliminary sketch in mind, let us now turn to the theoretical approach to the problem. Modern cosmological theory attempts to segregate the possible worlds which are consistent with two fundamental principles, general relativity and the cosmological principle. General relativity asserts that the geometry of space is determined by the contents of space. Space is "curved" in the vicinity of matter, and the amount of curvature depends upon the quantity of matter. If the large-scale distribution of matter in the universe is approximately uniform, we may assume a constant curvature or, as it were, "spherical" space. Local irregularities may be disregarded just as mountains and ocean basins are disregarded when we speak of the spherical surface of the earth. The cosmological principle is the simple assumption that there is no favored position in the universe, no center, no boundary. The large-scale aspects of the universe will appear much the same from whatever point they are inspected. This principle implies homogeneity and isotropy.

Possible universes, consistent with the two principles, are found to be unstable. They might be in momentary equilibrium but the balance could not persist. In general, these universes would be either contracting or expanding. At this point, the theorist turns to observations, and accepts the red shifts as visible evidence that our universe is expanding at a rapid rate. Thus arose the concept of homogeneous expanding universes of general relativity.

The problem now passes to the observer. He attempts first to test the assumptions on which the theory is founded and, second, to assemble new information which will identify, among the limited number of possible types, the universe we actually inhabit.

Investigations of this nature have been made during the last five or six years. On the one hand, the assumption of large-scale homogeneity has been reexamined by precisely controlled counts of nebulae to successive limits of apparent faintness. On the other hand, attempts have been made to determine empirically whether or not red shifts do represent actual recession.

The assumption of homogeneity appears to be fairly well established both by deep sampling surveys made at the Mount Wilson and the Lick Observatories, and by those portions of the later counts made at Harvard which are adequately calibrated. If the observable region were divided into a thousand equal parts, their contents would probably be sensibly the same.

The question of red shifts may be examined by means of the dimming effects of recession. A rapidly receding nebula will appear fainter than a similar but stationary nebula at the same momentary distance. The stream of light quanta from the receding nebula is thinned out, and fewer quanta reach the observer each second. Since the rate of impact of the quanta measures the apparent brightness, the receding nebula appears fainter than it would if it were stationary. The dimming factor—the factor by which the normal stationary luminosity is reduced—is merely the velocity of the nebula divided by the velocity of light or, in other words, the red shift expressed as a fraction of the normal wave-length of the light observed. Thus the dimming factor is negligible for the nearer nebulae but reaches about 13 per cent. at the greatest distance reached by the spectrograph, and, presumably, more than 25 per cent. at the limits of direct photography with the 100-inch reflector.

Since we know the intrinsic luminosity (or candle power) of nebulae, the dimming effect could be readily detected if we knew the precise distances of very remote nebulae. At present, however, such distances are estimated from the apparent faintness itself, which we wish to use for the test. Therefore the direct search for dimming factors ends in a vicious circle.

An indirect approach to the problem is still possible. Apparent faintness of nebulae furnish reliable, statistical distances on two different scales, depending upon whether the dimming factors are included or omitted. Thus we analyze our observational data, determine the precise form of the law of red shifts and the large-scale distribution of nebulae, using first one scale of distance, and then the other scale. The correct scale should lead to a consistent picture of the observable region, while the wrong scale may lead to contradictions or at least to serious difficulties. The procedure has been carried out, and one scale does seem to lead to difficulties. That scale is the one which includes the dimming factors.

If the dimming factors are omitted, the law of red shifts is sensibly linear. In other words, each unit of the light path contributes the same amount of red shift. Furthermore, the large-scale distribution of nebulae is approximately homogeneous. Thus the assumption that red shifts are not velocity shifts but represent some hitherto unknown principle operating in space between the nebulae leads to a very simple, consistent picture of a universe so vast that the observable region must be regarded as an insignificant sample.

On the other hand, when the dimming factors are applied, the scale of distance is necessarily altered. The law of red shifts is no longer linear and the large-scale distribution is no longer homogeneous. These new features specify a particular type of expanding universe but one so small and so young that we hesitate to accept it as the universe we actually inhabit.

The law of red shift is altered in the sense that velocities of recession increase more and more rapidly with distance. Since light we observe to-day left the very remote nebulae far back in past ages, hundreds of millions of years ago, we must conclude that the rate of expansion of the universe has been slowing down. This result is disconcerting.

The present distribution of red shifts could be adequately described on the assumption that all the nebulae were once jammed together in a small volume of space. Then, at a certain instant, about 1,800 million years ago, an explosion occurred, the nebulae rushing outward in all directions and with all velocities. To-day, of course, we find the nebulae distributed according to their initial velocities, those moving most rapidly have reached the greatest distances, while the laggards are still in our vicinity.

Although this picture is over-simplified, it suggests the importance attached to the so-called "age of the universe"—1,800 million years. If the rate of expansion has been diminishing, if the initial velocities have been slowing down, the "age of the universe" must be still further shortened, probably to less than 1,000 million years. Such an interval is a brief moment on the cosmic time scale; it is but a fraction of the age of the earth and is even less than the history of life on the earth. Thus the universe, if it is expanding, is very young indeed—improbably young.

Equally disconcerting results are derived from the studies of nebular distribution. If dimming factors are included, the new scale of distance eliminates the apparent homogeneity. The density, that is the number of nebulae per unit volume of space, increases systematically with distance, in all directions. Such a distribution is not only improbable but it violates the cosmological principle—it suggests that the earth is in a favored position. Therefore, we must assume that the departure from homogeneity is not real but only apparent, and then find a satisfactory explanation.

The only available explanation is a positive spatial curvature which, by a sort of optical foreshortening, would introduce an apparent crowding together of nebulae in a really homogeneous universe. Thus, if the universe is expanding, it is presumably a closed universe of finite volume. Furthermore, the amount of curvature necessary to restore homogeneity is quite large; it leads to a universe so small that we already observe a sensible fraction, perhaps one fourth, of the total volume. Finally, the curvature implies a density of matter in space much greater than can be reasonably accounted for by the observed nebulae alone.

Thus the empirical studies of the law of red shifts and the large-scale distribution of nebulae lead to a dilemma. Red shifts are due either to recession of the nebulae or to some hitherto unrecognized principle operating in internebular space. The latter interpretation leads to the simple conception of a sensibly infinite homogeneous universe of which the observable region is an insignificant fraction.

The alternative interpretation of red shifts as velocity shifts leads to a particular type of an expanding universe which is disconcertingly young, small and dense. Moreover, the strange features of this universe are merely the dimming effects of recession expressed in other terms. Under these circumstances, the inclusion of the dimming factors seems to be a questionable procedure. In other words, the empirical evidence now available does not favor the interpretation of red shifts as velocity shifts.

Two further points may be mentioned. In the first place, the conclusion has no vital effect upon the theory of expanding universes; it merely removes the theory from contact with observations. If red shifts do not represent actual motion, we may still assume that our universe is either contracting or expanding at a rate that can not now be measured by the observer.

In the second place, the conclusion assumes that the measures on which they are based are reliable. They are all the measures we have which bear on the critical questions and, by the usual criteria of probable errors, they seem to be sufficiently consistent. Nevertheless, the operations are delicate, and the most significant data are found near the extreme limits of the greatest telescopes. Under such conditions, it is always possible that the results may be affected by hidden systematic errors, the nightmare of all observers. This possibility will persist until the critical investigations can be repeated with improved techniques and more powerful telescopes. Ultimately, the matter should be settled beyond question by the 200-inch reflector destined for Mount Palomar.

Meanwhile, on the basis of the evidence now available, a choice seems to be presented, as once before in the days of Copernicus, between a small, finite universe, and a sensibly infinite universe plus a new principle of nature. And, as before, the choice may be determined by the attribute of simplicity.

OBITUARY

SOMA WEISS

DR. SOMA WEISS, of Cambridge, Massachusetts, died suddenly on January 31, 1942, after a brief illness, just having passed his forty-third birthday. At the time of his death he occupied two nationally important medical posts: he was the eighth physician to be Hersey professor of the theory and practice of physic in Harvard University, and the second to be physician-in-chief of the Peter Bent Brigham Hospital in Boston.

He was born in Bestercze, Hungary, but came to the United States as a young man. He graduated from Columbia University in 1921 with the degree of bachelor of arts, and received his medical diploma from Cornell University in 1923. But before this, already he had displayed ability as a teacher and student at the Royal Hungarian University at Budapest, where he served as demonstrator and research fellow in physiology and biochemistry. From the very outset of his career, therefore, he displayed an interest in these two fundamental sciences, and this persisted. He seemed to ask himself continually how things pertaining to medicine happened and how they might be influenced by physiologic and chemical approaches.

In 1925, the Harvard Medical School was able to attract him to Boston by appointing him research fellow in medicine. The opportunities for the investigation and study of disease afforded by the Thorndike Memorial Laboratory of the Boston City Hospital were bound to appeal to a man of his ideals, and here he worked until 1939. His career there served well to illustrate the qualities of imagination and industry which were so prominent in his make-up.

In the Boston City Hospital, he rose from research fellow to assistant director of the Thorndike Memorial Laboratory and physician-in-chief of the Fourth Medical Service—no mean achievement in the course of eleven years for a stranger to Boston. As he grew accustomed to Boston and its medical ways, and as he grew older, besides becoming a master clinician and investigator, he developed also remarkable skill in inspiring men younger or older than himself to learn more: medical students, interns or colleagues. These abilities were so impressive that he ascended the academic ladder of Harvard with equal promptness. He started as an assistant in the department of medicine and became associate professor seven years later.

During the years at the Boston City Hospital, his industry bore fruit in many ways: The patients liked him, for his conscience never allowed him to forget that the patient in the hospital was a human being who might be, like any one else, homesick or lonely, ill in mind as well as body; his colleagues on the staff of the hospital admired and respected him, for he was easy to deal with, unselfish and always honest and straightforward; his students adored him. Whenever he made ward rounds, there would be an enthusiastic following; and one of the important teaching exercises which he conducted with painstaking regularity was that of meeting the house officers of the entire hospital one evening each week, when he would visit other wards than his own and discuss medical problems with others than his own group.

His pen was busy constantly; well over a hundred papers were written during his Boston City Hospital years; and they cover a wide range of subject-matter. They were written only as a man with scientific conscience allows himself to write—always with a careful analysis of what other workers had done previously on the problem under discussion, an account of what his own observations entailed and what he believed they added. To work and teach as he did required not only remarkable industry but also omnivorous reading. On top of all this, he found time to take a sincere interest in various scientific medical societies—the American Association for the Advancement of Science, the American College of Physicians, the American Heart Association, the Association of American Physicians, the Association of Research in Nervous and Mental Diseases, and many others.

In 1938, when the Peter Bent Brigham Hospital needed to appoint a new physician-in-chief, and when