A COSMOLOGIST'S VIEW OF THE UNIVERSE

Everyone sees the stars, the sky, the universe from a different standpoint. Astronomers are interested in the paths of the planets, the stars and their magnitudes – the patterns they manifest in the forms of constellations. For a cosmologist, the heavens present yet a different sort of fascination and puzzle. He strives to perceive the large-scale features of the universe – does it have a meaningful structure, what can it tell us about the laws of nature? For the cosmologist, the most basic and exciting data gleaned from astronomical observations lie in the provisional estimates that the mean density of matter in the universe appears to be about 10^{-30} gm/cc, and in the circumstantial evidence that the galaxies appear to be receding from one another according to a simple law discovered by Hubble. The Hubble Law suggests that the velocity of recession of any pair of typical galaxies is proportional to their distance of separation; the latest estimate of the constant of proportion – the so-called Hubble constant – is about 75 km/sec per megaparsec. (A megaparsec is an astronomical unit equal to about 3 x 10^{24} cm. For comparison, a light year is about 10^{18} cm.) One way of interpreting this is that the universe, seen as a system of galaxies, is expanding and has been doing so since it was in a highly dense state about 13,000 million years ago.

The Hubble Law, supported by other astronomical evidence, suggests that the observable universe does indeed exhibit a definite pattern in the distribution and behaviour of its galaxies; these, then, can be considered as the "fundamental particles" of the universe at large, and for purposes of discussion we assume also a set of "fundamental observers" associated with the expanding set of fundamental particles.

Cosmology must appear to many as a singularly useless and esoteric study having little relevance to the problems of our world and our lives. Yet there has been a remarkable boom in astronomy and cosmology over the last few decades. Why this burst in interest and activity? Undoubtedly an important factor has been the great progress in electronics since World War II, leading to many new and improved instruments for obtaining information about outer space. We can now obtain information about stars, galaxies and the space between them along the whole spectrum of energy. Radio-astronomy added tremendously to our store of knowledge, and now we also 'see' the heavens through micro-wave, X-ray and infra-red 'eyes'. Furthermore the long-established optical instruments have also benefited considerably in precision and sensitivity from the recent developments in technology.

As a result many spectacular advances have been made in our observation of the universe. Indeed with every new instrument employed have come new and unexpected findings providing fresh challenges to our understanding of nature. The problems to be solved have attracted a wide variety of scientists to combine and inter-relate the expertise of many disciplines, for the universe has become too large to fit into the confines of a single branch of science. Astronomers, physicists, engineers, chemists, mathematicians, biologists and etc., are all required to make sense out of the many and often apparently-conflicting observations which have come to the fore. This inter-disciplinary aspect of cosmology has its own fascination for many scientists who wish to expand their horizons and test their problems and hypotheses in a new context – a universal context.

Cosmology provides the ultimate challenge, and sometimes the promise of the ultimate solution, to all our concepts and conjectures. In attempting to understand the universe, we test our local laws to the limit – in the interior of stars and in the extrapolated conditions of the past and the future. In cosmology we come face to face with the very basic concepts of immediate experience and of nature – space, time, matter, energy; perhaps only through cosmology can these concepts be grasped and related, to illuminate our whole understanding of nature and our local problems as well? Man has always yearned to comprehend the heavens and beyond; he has gained immense satisfaction and great dividends from this yearning and he will surely gain even more in the future.

Probably the most spectacular of the recent astronomical discoveries has been the observation of new types of stellar bodies, for example, radio-stars and galaxies, quasi-stellar sources (quasars), pulsars and the hypothetical "black holes"; but other discoveries and deductions have been equally if not more important. The evidence that radio-sources were apparently more numerous in the past provided tangible support for an evolutionary universe. The Gamow "Big-Bang" model for such a universe received an unexpected fillip from the spectroscopic evidence for a universal 3^oK radiation background, and from the observations pointing to a far higher helium-hydrogen ratio (30%) in stars than could be accounted for from stellar evolution. The latter two discoveries had been predicted by Gamow in 1949 and could not be easily explained in terms of the so-called Steady-State Theory; hence, after being in vogue for twenty years, this Theory has now been almost entirely abandoned in favour of Gamow's model, which proposes that the universe has been expanding and evolving from a very dense state existing some thirteen thousand million (or more) years ago. Fashions and trends have their place in science as in other activities and can be just as ephemeral.

The host of new astronomical observations has encouraged many speculations and esoteric interpretations of both what we 'see' and what they mean. We tend to hear mainly of the more spectacular discoveries and of the most news-worthy speculations. However not all our knowledge of the universe is of this nature. Certain salient features have been long in evidence, and no matter how deeply we peer into space and time these features appear to hold for all parts of the observable cosmos, and they are generally accepted as a basis for any cosmological model of our universe. We may describe them as follows:

I The distribution of observable galaxies (the 'fundamental particles') appears to be isotropic and homogeneous, though the observed density of radio-sources appears to increase with distance.

II Over and above their random motions and clustering tendencies, the galaxies appear to be receding from one another according to Hubble's Law, viz

$$w = Hr,$$

that is, for any pair of typical galaxies, the mutual velocity of recession, w, is proportional to their distance apart, r, in terms of the universal proportionality factor H.

III Our own galaxy and our part of the universe appear to be fairly typical, and this suggests a "Cosmological Principle" that, apart from local irregularities, the appearance of the universe and the laws of nature are the same from the viewpoint of any typical galaxy or 'fundamental observer'.

These assumptions are accepted by most observational and theoretical cosmologists. By making two more simple assumptions, consistent with observation, we can build a model of nature which has far-reaching consequences. These are:—

IV The propagation of energy in our universe is not arbitrary but takes place relative to the (expanding) set of fundamental particles, so that light passes every fundamental particle (and fundamental observer) in its path with the same velocity c. This assumption, first enunciated by McCrea (1962), has many unexpected consequences, for we have proposed an expanding universal 'substratum' for the propagation of energy, which implies that such propagation must also partake in the expansion of the universe! This provides, for instance, an immediate and exact interpretation of the cosmological Doppler red-shift effect which we observe in light from distant galaxies.

V We interpret Hubble's Law to mean that the expansion of the universe is strictly uniform, such that for any pair of galaxies w remains constant whilst r is increasing, whence H must be decreasing with time and its reciprocal provides a measure of 'cosmic time' and tells us how long the universe has been in its present expanding state of evolution.

The problem of how light is propagated in nature is a central problem of science and particularly of Relativity. Our cosmological assumption IV together with V enables us to provide a consistent and intelligible interpretation of Einstein's Special Relativistic Principles and their consequences (e.g. as outlined in "The Logic of Special Relativity" M.U.P., 1967).

Observation has so far found no limit to our universe, and our approach specifies no horizon beyond the limitation of our instruments and resources. McCrea's Hypothesis IV about light-propagation in our universe, allows light to reach us no matter what the recession velocity of the sources.

Hence we accept freely the possibility of an infinite universe – infinite when it was very dense, and no more or less infinite as it is expanding. Every point of such a universe can be considered as its centre, and every other point is reachable, ultimately, by light signals. Such a universe may be difficult to imagine, but is it any easier to imagine a finite or 'bounded' universe? Or finite time in the past or future? There is nothing to suggest that time is not infinite in both directions. Hubble's Law suggests that the present stage of the evolution of the universe has occupied perhaps about thirteen thousand million years. What went on before we can only speculate; what will happen after we do not know.

Cosmology teaches us to be very humble in the face of our immense ignorance of the wonders of nature – of the cosmos, of the nature of matter and energy. Yet we can also marvel and be proud of our remarkable minds which can encompass 'models' of the universe which attempt to imitate the immensities and complexities of nature. The model described is based on the work and ideas of many people, including W.H. McCrea (his Light hypothesis), E.A. Milne (Kinematic Relativity based on a uniformly expanding universe), G. Builder (a highly original Australian physicist), and many others. Future cosmologists are reminded that *Scientific American* often contains articles of interest. For example, see "Will the Universe Expand Forever" by Gott, Gunn, Schramm and Tinsley which appeared in March issue this year.

Prof. S.J. Prokhovnik,
School of Mathematics,
University of N.S.W.