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Introduction

(G. Setti)

The number of pages allocated to the commission report has been very limited and certainly not sufficient to cover in any exhaustive manner the wide range of topics relevant to cosmology and to provide also extensive bibliographies. Because of the vast amount of material to be covered, the report is based on a number of contributions from different colleagues who have been asked to highlight the main trends in the triennium (mid 1984 - mid 1987), together with a list of references sufficiently comprehensive to serve as a guideline for further reading. Unfortunately, two of the expected contributions did not reach me in time for inclusion in the report, and consequently topics such as the large scale structure and streaming motions, the clusters of galaxies and the counts of extragalactic radio sources are not included. However, it is my understanding that a large portion, if not all, of these topics will be covered in the reports of Commissions 28 and 40, and if true, this will at least avoid unnecessary overlaps. It should also be mentioned here that several proceedings of very recent IAU conferences provide excellent, updated and exhaustive reviews of the research work relevant to cosmology. These are:

IAU Symp. 117 on "Dark Matter in the Universe", J. Kormendy and G.R. Knapp (eds.), Reidel, Dordrecht, 1987.
IAU Symp. 124 on "Observational Cosmology", A. Hewitt, G. Burbidge and L. Zhi Fang (eds.), Reidel, Dordrecht, 1987
IAU Symp. 130 on "The Structure of the Universe", J. Audouze and A. Szalay (eds.), Reidel, Dordrecht, to be published.

The Cosmological Parameters

(V. Trimble)

The traditional parameters of general relativistc cosmology number about five. H_o (Hubble's constant) measures the current expansion rate. Its value is probably between 30 and 120 km/s/Mpc, implying a characteristic time scale (its reciprocal, the Hubble time) of 8-30 billion years. The deceleration parameter, q_o, probably falls somewhere between -1 and +3, a value of ½ marking the line between continued expansion and eventual recontraction. The density parameter, Ω_o, is the ratio of total mass-energy density, ρ_o, to $\rho_c = 3H_o^2/8\pi G$, and is probably between 0.1 and 1. The cosmological constant, Λ, enters the equations like a vacuum energy density (positive or negative) and, if expressed in units of H_o^2/c^2 is almost certainly in the range +10 to -10. Finally, the curvature constant, k, takes on values of +1, 0, or -1 for positively curved, flat, or negatively curved space.

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These quantities are not completely independent of each other, but neither does any one suffice to determine the others, unless $\Lambda = 0$ or $k = 0$ is assumed ab initio. For instance, $-q_o = -\Omega/2 + \Lambda c_o^2/3H_o^2$, and $k/3H_o^2R^2 = \Omega_o + \Lambda c^2/3H_o^2 - 1$.

A factor of two uncertainty in H_o has persisted for some 30 years, almost all of it coming from the difficulty of measuring accurate distances to objects far enough away for their velocities to reflect primarily uniform expansion. The very promising Tully-Fisher method continues to have difficulties with establishing a zero point that does not depend on galaxy morphology[1] and with proper removal of Malmquist bias[2]. Various considerations of supernovae have yielded small[3], medium[4] and large[5] H_o's, not uncorrelated with the values found by the same authors by other methods. Type I supernovae are not, in any case, the perfect standard candles once hoped for[6]. A couple of relatively new methods, using globular cluster populations[7] and novae[8] yield intermediate values, but the discovery of very large scale streaming motions[9] leaves one in some doubt about whether these are really penetrating deep enough to see pure Hubble flow.

Ages of globular clusters and radioactive nuclides set lower limits to the age of the universe ($2/3\ H_o^{-1}$ if $q = \frac{1}{2}$). Globular clusters at about 16×10^9 yrs[10] are traditionally the most severe constraint, but this number can be reduced a couple of billion years if [CNO/Fe] ~ +1 and to as low as $6\text{-}8\times10^9$ yrs if there is significant mass loss on the main sequence[11]. Age limits set by the radioactive nuclides have at least as wide a distribution, from 10^{10} yrs[12] through intermediate values[13] to 18×10^9 yrs[14] or more[15]. Calculations of the cooling time for the faintest white dwarfs[16] should be taken to mean that the age of the Milky Way disc could be as small as $8\text{-}10\times10^9$ yrs, not that it has to be.

The traditional method of probing q_o, deviations from linearity in a Hubble diagram, continues to be plagued by uncertain corrections for galactic evolution and has nearly been abandoned in the past triennium. The surface brightness test[17] has the same problem and picks out a narrow range of values, centered unfortunately right around the critical $\frac{1}{2}$. Direct detection of dz/dt of some object[18] remains merely promising more than a decade after the discovery of narrow radio absorption lines made it cease to seem impossible. The use of galaxy counts to measure co-moving volume as a function of redshift[19,20] leads to very narrow error bars around $\frac{1}{2}$, modulo certain assumptions about the evolution of the galaxy luminosity distribution, but strictly this technique measures k, and says that space is nearly flat, which is not quite the same thing. One slightly non-standard approach leads to a firm value $q_o = 1.6$ [21].

The present writer has recently reviewed determinations of Ω_o [22] and will say here only that there are, on the one hand, ways around the nucleosynthetic limit on baryon density[23] and, on the other hand, some observational arguments against $\Omega_o = 1$ in any form[24] as well as the many theoretical arguments for it.

We have, at present, no direct observational handle on Λ, even very crudely. Where non-zero values have been suggested[25] it has been for the sake of reconciling otherwise inconsistent limits on H_o, ages, and q_o or k. The inflationary scenario, while it requires Λ to have been very large in the past and much smaller now, does not in fact predict zero or any other definite present value[26]. Attempting to calculate Λ from the vacuum energy of the electromagnetic field implied by the Lamb shift and the Casimir effect leads to numbers much larger than permitted by the dynamics of the universe. Gravitation or some other field must contribute a nearly equal and opposite density. Discussions of Λ are bedeviled by units; the limits are about ±10 in H_o^2/c^2 or $\pm10^{-56}$ in cm^{-2} or $\pm10^{-119}$ in Planck (dimensionless) units.

Finally, the geometric parameter, k, is, in principle, measurable, for instance via the distance-dependence of apparent angular diameters of standardsized objects. But, just as evolutionary effects keep us from having good enough standard candles to determine q_o directly, evolutionary changes in sizes of both radiosources and clusters of galaxies[27] dominate the cosmological effects in the angular diameter test. Measurement of comoving volume vs. redshift may possibly work better[28] and a first attempt [0] has found the observations consistent with flat space. A useful review of the relationships among the cosmological parameters and the functional shapes of R(t) implied by various possible combinations can be found in ref. 28.

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