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Astronomical Distance Scales

Galaxy Distances and Deviations from Universal Expansion. BARRY F. MADORE and R. BRENT TULLY, Eds. Reidel, Dordrecht, 1986 (U.S. distributor, Kluwer, Norwell, MA). xviii, 301 pp., illus. \$64. NATO Advanced Science Institutes Series C, vol. 180. From a workshop, Kona, HI, Jan. 1986.

The universe is still expanding. It would not be fair to say that this is the only issue upon which participants in the workshop whose proceedings are reviewed here agreed, but there are still substantial disagreements about the rate of the expansion (Hubble constant, H_0), the scale on which it becomes smooth, and the relationship between non-smoothness and the processes that form galaxies and larger structures in the universe. The proceedings address many of these questions, and J. P. Ostriker provides a thoughtful summary of the issues in his concluding remarks.

Of the 49 contributions, about three-eighths deal directly with distance indicators (from RR Lyrae stars to line widths and surface brightnesses of galaxies) and the scales implied by them. Different indicators (or at least different astronomers) continue to give scales differing by a factor of two,

corresponding to a Hubble constant of 50 or 100 km sec⁻¹ Mpc⁻¹, and so to age limits of 20 or 10 billion years. Curiously, this difference persists even after long-standing disagreements about distances within our own Local Group have been reconciled (with Andromeda at 685 kpc and the Large Magellanic Cloud at 50 kpc, known to within about 10% in each case). Long distance scales (small H_0 and large age) come from supernovae (Wheeler and Harkness) and 21-cm line widths of spiral galaxies (Huchtmeier; Kraan-Korteweg *et al.*) and short distance scales (large H_0) from a variety of stellar and galactic properties (summarized by de Vaucouleurs).

Three contributions pertain to the closely related issue of the oldest objects in the universe and concur that globular clusters (Renzini), elliptical galaxies (Windhorst *et al.*), and radioactive nuclides (Thielmann and Truran) all seem to be at least 13 ± 3 billion years old and are, therefore, very difficult to understand in a universe with the short distance scale and no cosmological constant.

Optimism continues to be expressed that the ancient H_0 controversy will be resolved by the Hubble Space Telescope (studying, for instance, Cepheids in the Virgo clusters) or even earlier from ground-based observations of novae in Virgo (van den Bergh). Unfortunately, as addressed by Burstein *et al.*, Collins *et al.*, J. Mould, and Meiksin and Davis and in about eight other contributions, it now seems exceedingly unlikely that a definitive global value of H_0 can be extracted from observations extending out only as far as Virgo (10 or 20 Mpc on the two scales). The problem is that these groups have assembled a considerable body of evidence indicating that there are large scale deviations from smooth Hubble expansion, amounting to at least 500 to 700 km sec⁻¹ and applying coherently to regions as large as 50 (100 H_0^{-1}) Mpc. Lumpiness in the space density of galaxies also persists out to scales at least as large, according to data presented by Haynes and Giovanelli and by N. Bahcall (whose contribution unfortunately did not make it into the proceedings), and perhaps out to 400 (100 H_0^{-1}) Mpc, which would take in some 10^{18} solar masses (Tully). The extent to which the large scale velocity structure is associated with, produced by, or the cause of the large scale density structure remains to be determined, although the motion of the Local Supercluster may be attributable to the gravitational effects of the even larger adjacent Hydra-Centaurus supercluster.

In any case, as emphasized by Vittorio, Bond, and other participants, most current, popular models of galaxy formation have

difficulties in accounting for this very large scale structure and streaming without at the same time producing larger inhomogeneities in the microwave background radiation than data (summarized by Lubin and Vilella) permit.

A third major issue addressed at the workshop is the amount of gravitating mass implied by superclusters and larger structures and how close it comes to the critical density needed to close the universe. Most optical studies (Shaya and others) concur that scales up to superclusters contain only $20\% \pm 10\%$ of the critical density, though the robustness of this conclusion is still under active debate (Melott and others). But data from the IRAS satellite imply a much larger baseline density upon which these structures are superimposed (Yahil) and so a total density within striking distance of closure. This is a real discrepancy that will require further study.

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