PART I

Invited Reviews

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Introductory Remarks

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Those of us who were around a few decades ago, frequently became initiated into cosmology by a very clear and concise small book, written by Herman Bondi, entitled "Cosmology" (1952/1960). It is interesting to see the list of chapter headings:

Physics and Cosmology
The Cosmological Principle
Observational Evidence:

The background light of the sky	(Olbers' paradox)
The problem of inertia	(Mach's principle)
Observations of distant nebulae	(isotropy, $m < 19$, $z < 0.2$)
Astrophysical and geophysical data	(ages, abundances)
Microphysics and Cosmology	(large numbers)

Theories:

Newtonian Cosmology	
Relativistic Cosmology	(Friedmann/Lemaitre models)
Steady State Cosmology	
Milne/Eddington/Dirac/Jordan.	

Today we still believe in the cosmological principle, the background light is the main topic of this symposium, Mach's principle still has an uncertain status, and distant nebulae now are found at $B = 26$ and fainter and at $z = 4$ or more. A particular problem at the time concerned ages, with the earth at 4 Gyr being about twice as old as the Universe. Today we worry about the same problem with the globular clusters at some 15 Gyr perhaps older than the Universe, at

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least if the short distance scale were correct. The "large numbers" ("radius" of Universe / "radius" of electron, etc.) nowadays tend to be used in support of "anthropic" ideas according to which there would be nobody to observe the Universe if these numbers were very different. If one believes that it is legitimate to consider ensembles of universes this would appear to make sense. The relativistic cosmologies are still with us with gradually more physics incorporated; the strict Steady State being at variance with the evidence for evolution everywhere in the Universe has been replaced with a steady state on average with more active episodes. The theories of the "heretics" from Bondi's book have been forgotten, but not surprisingly others have taken their place. On the whole one can say that the main stream models of the Universe have not changed all that much, but the current problems are more connected to the very early phases (inflation, etc.), the formation of galaxies, the origin of some chemical elements and other aspects of the physical content of the Universe.

Sociologically cosmologists have become a more abundant species, which is no surprise since the subjects mentioned offer ample opportunity for a wide variety of quantitative researches. Whereas the Astrophysical Journal 25 years ago contained about 1 % of cosmology, today the figure is around 6 % in a very much enlarged journal.

Perhaps the greatest progress has been made in the observation and analysis of the extragalactic background light and its implications for the physics of the Universe. This light has been observed in two spectral domains: first in X-rays in 1962 by Giacconi, Gursky, Paolini and Rossi (1962), and a year later in the microwave region by Penzias and Wilson (1965). The former appears to be due largely to discrete sources at modest redshifts, while the latter is more likely to be truly diffuse, mainly reflecting conditions at redshifts of 1000.

The first satisfactory calculation of the likely background due to sources was made by Loys de Cheseaux in 1744, long before Olbers (1823) published his account of the "paradox". It is interesting to compare the two accounts. Whereas Olbers gives a long philosophical introduction, de Cheseaux gives the calculation in a few lines which are very clear and in a form in which we can use it to calculate the X-ray background. Starting out from shells of equal thickness containing stars at a fixed density, he shows that each shell contributes the same amount to the background (if the inverse square law holds) and then calculates at which radius of his "universe" the surface brightness becomes equal to that of the sun. Obviously the night sky is much less bright than that, and he therefore concluded that either the volume in which the fixed stars are contained has a much smaller cutoff radius or absorption invalidates the inverse square law; since not much absorption per light year would be needed, he concluded that the latter is the more probable reason why the sky is so dark.

Exactly this same reasoning may be applied to the X-ray background. Early suggestions (Setti and Woltjer 1973) that this background could be due to the integrated effect of sources have been amply confirmed. In fact, as reported at this symposium, at least 2/3 of the background is due to unresolved sources, mainly AGN. Since intergalactic space should be transparent to X-rays it follows that the limited surface brightness of the background implies a maximum radius for the volume in which the sources are contained - at least if a Newtonian calculation is valid. Of course, the maximum radius is globally the radius where redshift effects terminate that validity. The implication of this is that the X-ray sources responsible for most of the background must be at a cosmological redshift of order unity as, in fact, they are observed to be. However, if we were to believe that the observed AGN have intrinsic redshifts and that they are much closer by then the background due to more distant sources would become too large. This simple argument has never been dealt with by the proponents of "local" quasars.

In a way it is unfortunate that the source contribution to the X-ray background is so large. It makes it very difficult, if not impossible, to determine if there is also a truly diffuse component, due to hot gas in the Universe.

Of a much more fundamental importance is the microwave background which will be extensively discussed at this symposium. Gamov predicted this background as a result of an expanding initially very hot universe and made the connection with nucleogenesis and with the decoupling of radiation and matter in the recombination epoch. Alpher, Gamov and Herman in various papers, published between 1948 and 1956, predicted values for the temperature of the black body radiation in the order of 5 K (see Alpher and Herman 1988). Because the nucleogenesis proposed turned out to be not very satisfactory , these predictions were forgotten remarkably soon. In 1957 Denisse, Lequeux and Le Roux not only determined that T_B at 0.9 GHz was less than 3 K, they also determined that the fluctuations on a 40 deg^2 beam were less than 0.5 K, not surprising in view of the fact that COBE found values about 10^5 lower. It remains remarkable that no connection was made to the then recent results of Gamov et al.

The 3 K microwave background finally was discovered by Penzias and Wilson in 1963. Small improvements followed thereafter until in 1992 the COBE satellite determined the spectrum and angular distribution with unprecedented accuracy. The perfection of the black body fit to the spectrum places interesting limits on the energy input following recombination. The main aspect of the angular distribution corresponds to a dipole, generally associated with the motion of the sun with respect to the local rest frame, while the fluctuations around the mean dipole contain interesting, but as yet inconclusive, information on galaxy formation. A major question that remains is why the solar motion with respect to the galaxies within 100 Mpc is so different from that inferred for the dipole (Mathewson et al. 1992).

Cosmology has always been a subject where strong opinions are generally far ahead of the facts and where the tolerance for diverging opinions is low. It is true that some of the diverging opinions show a remarkable ease in forgetting certain facts. Nevertheless, the publication problems of some papers which presented many solid new facts, but hinted at the possibility that the canonical view could be incomplete, is somewhat worrisome. It would after all be remarkable if the present consensus picture of the Universe turned out to be definitive.

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