COMMISSION No. 47

COSMOLOGY (COSMOLOGIE)

Report of Meetings on 3 and 8 August 1988

PRESIDENT: G. Setti. VICE PRESIDENT: K. Sato.

I. BUSINESS MEETING

At the beginning of the meeting the president asked for a minute of silence to commemorate the recent deaths of two eminent members of the Commission, Professor G.C. McVittie and Professor Ya.B. Zel'dovich, also past Commission president, whose contributions to science, and to the advancement of cosmology in particular, have been outstanding.

The president informed the members that the great majority of the Commission members who answered the questionnaire circulated on March 19, 1987 expressed the opinion that the vice president should take over the office of president at the end of the 3-year term. Accordingly, he has proposed to the IAU Executive the nomination of Prof. Katsuhiko Sato (Japan) as president of Comm. 47 for the period 1988-1991. He also informed the members that in consultation with members of the Organizing Committee he has proposed Prof. R. Bruce Partridge (U.S.A.) as vice president. These nominations were endorsed by the participating members of the Commission, who also approved the new composition of the Commission's Organizing Committee as follows: A. Dressler (U.S.A.), L.Z. Fang (China), J.V. Narlikar (India), M.J. Rees (U.K.), H. Reeves (France), G. Setti (Italy), S. Shandarin (USSR), P. Shaver (Canada) and V. Trimble (U.S.A.). All new members have been contacted and have accepted to be "active" members of the O.C.

Membership of the Commission. The president indicated that according to the resolution approved at the time of the Gen. Assembly in New Delhi he had asked the Commission members to confirm explicitly their interest in remaining members of Comm. 47. 126 affirmative answers and one negative out of 279 members were received. With the recent additions, the Commission's membership has now grown to a total of just above 300 members. In view of the steadily increasing size of the Commission membership the incoming president should make a second and final enquiry, and the members who will persistently not answer will have to be automatically erased from the Commission membership.

II. SCIENTIFIC SESSIONS

Seven sessions were held on different topics, each of them introduced by a review of the main observational and theoretical developments obtained in recent years. Each session was chaired by the corresponding reviewer. The content of the sessions was as follows:

1) Microwave Background (rev., G. De Zotti)
   Sub-mm Spectrum of the CMB (T. Matsumoto)
   New Limits on CMB Anisotropies (R. Windhorst)

2) Very Early Universe (rev., K. Sato)
   Optimistic Cosmological Model (N.S. Kardashev)
   On Dirac's Large Number Hypothesis (F.A.N. Mohammed)
   A Temporally Homogeneous Approach to the Early Universe (I.E. Segal)

3) Primordial Nucleosynthesis (rev. H. Reeves)
   The Effects of Quark-Hadron Phase Transition on BBN (K. Sato)
   Lithium Abundances in Pop. II Stars (D.K. Duncan)

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4) Large Scale Distribution of Matter (rev., J.E. Peebles)
Filamentary Structure in 3-D Surveys and 2-D Wedges (S. Bhavsar)
Components of the Large Scale Velocity Field (A. Szalay)
Statistical Studies of Complete Galaxy Samples (J.F. Nicoll)

5) Distribution of Matter at Large Redshifts ($z \gtrsim 1$) (rev., A. Szalay)
Cosmological Constraints on the Clustering of XRB Sources (P. Mészaros)
Evolutionary Status of Galaxies at $z \sim 2.5$ (R.W. Hunstead)
4C41.17: a Radio Galaxy at $z = 3.8$ (K. Chambers, G. Miley)

6) Formation of Structures and Evolution (rev., S. Shandarin)
Primeval and "Rejuvenated" Galaxies: A New Search for Them (L. Ozernoy)
First-Ranked Cluster Galaxies: A Two Population Model (S. Bhavsar)

7) Quasar Evolution and Clustering Properties (rev., P. Shaver)
Limits on Dust in Damped Lyα Systems and the Obscuration of Quasars (M. Fall)
Quantization in Lyα Absorption Lines in QSOs: Determining q_o (W.G. Tifft)
Gravitational Micro-Lensing from Distant Masses (S. Refsdal)

III. ABSTRACTS

Following are the abstracts of some of the contributed papers. The two review papers by G. De Zotti and H. Reeves and the contribution by T. Matsumoto will be published in the "Highlights" of the IAU Gen. Assembly.

1) New Limits to Fluctuations in the CMB (R.A. Windhorst, J. Kristian, E.B. Fomalont and K.I. Kellermann):

We present the first part of a long term, 250 hour, deep survey with the VLA at 6 cm. The field is centered at the Palomar Ultradeep Survey Area, PUDS-2 ($14^h\ 16^m + 53°$), for which we collected ~ 30 hours of direct CCD data with the Palomar 200 inch four-shooter. This field will also be observed for ~ 40 hours with Space Telescope by the WFPC-team in their GTO time.
Currently, we have completed the observation, calibration, and reduction of 50 hours in the D (1987), and 50 hours in the C-array (1988). The full synthesis will be achieved through an additional 50 hours in the B-array (1989) and A-array (1990), followed by a final D-array integration to increase sensitivity on MWBG fluctuations. The combined 100 hours D+C array map has an rms noise of 4.5 μJy. This extends the normalized, differential 6 cm source counts down to ~ 20 μJy directly, and down to ~ 4 μJy through a P(D) analysis, both with a slope of -2.1 ($N(>S) \propto S^{-1.1}$). This confirms the steep slope of the upturn discovered in the 21 cm counts. We subtracted this discrete source population from the noise distribution and performed a careful variance analysis of the remainder, in comparison with a previous deep 50 hour D-array integration. The resulting 2σ upper limits to fluctuations in the MWBG are now lowered to 12×10^{-5} at 18", and 6×10^{-5} at 60" scales.

2) Very Early Universe (review by K. Sato):

The research on inflation in the inhomogeneous universe has been reviewed. The inflation, which was proposed for the explanation of flatness and horizon problem, paradoxically, has been investigated usually in the context of R-W (homogeneous, isotropic) models. It has been concluded that: a) Strict cosmological "no hair theorem" (all the inhomogeneities are damped by inflation) does not hold, but "weak no hair theorem" works. b) Inhomogeneities evolve to wormholes and become child universes (causally disconnected region) if suitable conditions are satisfied. In this scenario, the universe we are now observing is one of the locally flat regions.

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3) Optimistic Cosmological Model (N.S. Kardashev):

It was demonstrated that for a certain type of hidden mass (negative vacuum density and flat domain walls) in positive curvature models a regime of periodic oscillations of the Universe without approaching the singularity, and even a regime of steady-state, can be realized. A possibility of evolution from inflation and phase-transition stage to periodic oscillation and steady-state was considered. An opportunity for observational testing and some unresolved problems for the model were also considered.

4) On Dirac's Large Number Hypothesis (F.A.N. Mohammed):

The expression for redshifts is a dimensionless number containing Hubble's constant, hence inverse of Hubble's constant is inserted in Planck's relation to get a dimensionless number dependent on the frequency of a photon. For photons available in (p,p) annihilation this number approaches numerical coincidences.

5) A Temporally Homogeneous Approach to the Early Universe (I.E. Segal):

The chronometric theory explains many observed phenomena without any adjustable parameters such as q_0 or Λ, or evolution, and is not in disagreement with any directly observed complete samples of galaxies, quasars, or radio sources. In particular, it directly predicts the isotropy of the background radiation and the Planck-law spectrum at low frequencies; the redness of the observed spectral shift; the relation to redshift of flux, angular diameter, superluminal proper motion, and number counts, for specified classes of sources, in complete samples; etc.
With the adjunction of further, testable, simple and natural hypotheses, it is explanatory of galaxy formation without observable effect on the background radiation (via infrequent but stochastically inevitable development of regions of extreme temperature and density); the relative flatness of the spectrum of the X-ray background (by implying the capacity for repeated circuits of the universe by sufficiently energetic photons); the missing mass in clusters (by compatibility with a partially distance-dependent attribution of the redshifts of apparent cluster members). Among other determinations, it provides an explicit estimate for the extragalactic distance scale (or radius of the universe) from observations on a random sample of superluminal proper motions, which in conjunction with recent data provides effective reconciliation of disparate estimates of the Hubble parameter.
On an objective scientific basis it therefore appears quite preferable to primeval explosion scenarios and the Doppler theory of the redshift.

6) Filamentary Structure in 3-D Surveys and 2-D "Wedges" (S.P. Bhavsar):

We test the reality of linear features apparent to the eye in the distribution of galaxies in the CfA redshift survey. A filament finding algorithm - the Minimal Spanning Tree (MST) - is used to identify the filaments, and a data permuting technique, that leaves intact small scale structure but randomizes it on large scales, is used to determine the statistical significance of filamentary features. We find that the filaments are real. This is the first objective, statistical evidence of their physical existence, in a general 3-D survey.
Tests are also performed on numerical simulations (by Mellott) with various initial conditions having hot and cold dark matter. Comparisons are made among both 3-D cubes extracted from the numerical models, and 2-D "wedges" of data. Ways of identifying and quantifying the significance of filamentary and other non-specific patterns are discussed.

7) Components of the Large Scale Velocity Field (A. Szalay):

The multipole expansion of the peculiar velocities in the elliptical galaxy sample of Davies et al. (1988) was discussed, with special emphasis on the monopole, dipole and quadrupole components. It was found that the subtraction of the Hubble flow has removed a major part of the monopole, but it remained there in the subsamples. Also, image processing of velocity pictures revealed alignment of the dipole and quadrupole anisotropies.

8) Statistical Studies of Complete Galaxy Samples (J.F. Nicoll and I.E. Segal):

Objective, reproducible, statistically efficient studies of complete samples of magnitude-redshift and angular diameter-redshift relations in complete galaxy samples in part invalidate (samples of Nilson and of Visvanathan) and in part contraindicate (RSA and CfA samples) the Hubble law, in the absence of further hypotheses postulating local irregularities responsible for the deviations between prediction and observation.
Computer simulations inclusive of major known types of local irregularities provide no indication that they can reconcile the Hubble law with observation, and indicate rather conclusively that peculiar velocities, superclustering, and motion of the Galaxy cannot do so. In contrast the Lundmark law (quadratic redshift-distance relation) is in excellent agreement with observations, optimal among power laws, and its relative superiority of fit is unaffected by any of the assumed local irregularities introduced into the computer simulation.
On an objective scientific basis, the Lundmark law therefore appears quite preferable to the Hubble law.

9) Cosmological Constraints on the Clustering of XRB Sources (Z. Bagoly, H. Mészaros and P. Mészaros):

We discuss limits on the large scale clustering of the sources of the X-ray background at redshifts $z > 0.5$. It is found that for structures of mean present separations around 30 Mpc, the comoving mean density of structures can be constant or may at most grow as the first power of the universal lengthscale. One can set an upper limit of about a factor 35 on the luminosity dispersion at a given redshift, if the density of sources is the present estimated lower limit $n = 5\ 10^3$/sq.deg., or a factor 10^2 if it is $n = 4\ 10^4$/sq.deg. If at $z > 0.5$ there exists a constant comoving number of structures of present mean separations about 60 Mpc and overdensity exceeding a factor two, then the closure parameter is limited to $\Omega_o < 0.4$. Clusterings on larger scales comparable to recently reported complexes or great attractors may not exist at such redshifts unless their filling factor is below about 0.03%.

10) Evolutionary Status of Galaxies at $z \sim 2.5$ (R.W. Hunstead, M. Pettini, A. Boksenberg and A.B. Fletcher):

QSO absorption systems in which the Lyman alpha profile shows damping wings have been interpreted as the H I disks of young intervening galaxies. Studies of heavy element enrichment in one such system [z(abs) = 2.309 towards PHL 957] indicates an abundance of only 1/20 solar with very little evidence for dust. In another system [z(abs) = 2.465 towards Q0836+113] we find narrow (≤ 50 km/s FWHM) Lyman alpha emission in the base of the damped Lyman alpha absorption line. The star formation rate inferred from the Lyman alpha luminosity may be as low as 1 $M_\odot$/year.

11) 4C41.17: a Radio Galaxy at $z = 3.8$ (K.C. Chambers, G.K. Miley and W. van Breugel):

Galaxies associated with powerful radio sources are among the most frequently used cosmological probes, because their enormous radio luminosities enable them to be easily pinpointed out to large distances. Based on groundwork laid with the Westerbork telescope during the mid-seventies (Tielens, Miley and Willis

1979; Blumenthal and Miley 1979), some of us have recently developed a unique technique for finding galaxies with extremely high redshifts. This method uses the fact that ultra-steep spectrum radio sources are systematically much more luminous than normal-spectrum sources. During the last two years we have conducted a multispectral investigation of a northern 4C sample of ultra-steep spectrum radio sources and their counterparts.

Of our 33 4C objects, 93% were identified with faint, presumably high-redshift galaxies. The spectroscopy has shown that about half of these objects have strong emission lines and are definitely at high redshifts. Preliminary analysis has resulted in 8 candidates for galaxies having $z > 2$, of which 8 are confirmed identifications with optically extended objects having more than one emission line. The confirmed redshifts are $z = 2.2$, 2.3, 2.5, 2.6, 2.9, 3.8, and 3.8. The largest redshift is associated with the radio galaxy 4C41.17. The lines and continuum in 4C41.17 both extend over several arcseconds proving the nature of the object beyond doubt. These redshifts should be compared with $z = 1.8$ for 3C326.1, the largest galaxy redshift known until about one year ago (McCarthy et al. 1987a).

This opens up an exciting opportunity for studying the properties of the early Universe. For the first time we can measure the spatial distribution of brightness and velocity for gas in objects out to at least a redshift of 4. This will provide unique information about young and forming galaxies. In addition statistics of the space density of these objects and its redshift dependence are capable of providing considerable leverage on the geometry and evolution of the Universe.

Our 4C sample covered less than a third of the sky and included only the brightest radio sources. The obvious next step is to extend our search technique to larger and fainter samples of radio sources. The spatial density distribution of these objects and its dependence on redshift is a topic of fundamental interest. The Lyman alpha emission and radio emission from 4C41.17 could easily be seen if it were at a redshift of 6, beyond which Lyman alpha would be shifted into the near-infrared.

We have therefore begun multiwavelength observations of several samples of objects carefully chosen so that dependence of subsequent results on the various radio properties can be disentangled and to find more $z > 2$ galaxies. Preliminary samples have been selected from the Parkes, and Texas surveys and comprise 431 objects. In addition we are planning similar selections of subsamples of Molonglo and Westerbork sources. Radio images are already being obtained with the VLA, or the Molonglo Synthesis Radio Telescope (MOST) in collaboration with Richard Hunstead (Univ. of Sydney). Eventually, it is intended to obtain higher resolution images of a subsample of the most interesting southern sources with the Australia Telescope (AT).

12) Primeval and "Rejuvenated" Galaxies: a New Search for Them (L.M. Ozernoy):

Current ideas on primeval galaxies are usually based on an implicit assumption that the environmental effects are not of crucial importance for both the formation and the early evolution of those galaxies. However, galaxies mostly belong to multiple systems and loose groups whose formation was presumably quite close in time to the formation of the galaxies themselves. Since distances between galaxies in such aggregates are of the order of galaxy sizes, and the velocity dispersions of galaxies are comparable to the intragalactic velocity dispersions, close interactions between the primeval galaxies, including merging, could play a decisive role in their early history.

An immediate result of this line of attack is that primeval galaxies should have some common features with ultraluminous starburst galaxies. In particular, their thermal continuum spectrum, after an initial short stage of dust formation, is expected to peak in the far infrared (at $\lambda_0 \sim 100$ μm, which is roughly independent of whether the grain temperatures are determined by radiation of O-B stars or by dissipation of kinetic energy in collisions). Such a peak redshifted to submillimeter wave range is a signature of primeval galaxies; it can be used for a crude dating of the epoch of galaxy formation.

The subsequent evolution of young galaxies could be accompanied by mutual encounters with the companions and, as a result, by recurrent bursts of star formation. Such an environmentally regulated evolution results in a non-monotonous character of both the star formation in, and luminosity evolution of, young galaxies. Obviously, the nearby starburst galaxies demonstrate one of these latest burst phases. Therefore, the starburst galaxies (including those which are to be found at larger redshifts) might be representatives of "rejuvenated" galaxies, i.e., of rather old galaxies with "fresh" stars formed. Some recent candidates for young galaxies seem to be rejuvenated, rather than genuine primeval, galaxies.

13) First-Ranked Cluster Galaxies: a Two Population Model (S.P. Bhavsar):

The brightest galaxies in rich clusters have become the classic standard yard-sticks in observational Cosmology because of their uniform luminosities. The dispersion in the absolute magnitudes is only 0.35 mag. It has been debated whether these galaxies belong to a special class of objects (Peach, Sandage, Tremaine and Richstone) or are just the tail end of a statistical luminosity function (Peebles, Geller). Bhavsar and Barrow have used results from extreme value theory to test the statistical hypothesis, and found it to be incompatible with the current observations. What then is the explanation for the distribution of M_1 for these galaxies?
The M_1 distribution of these galaxies can best be explained by a model in which they are drawn from two distinct populations - a population of "special" objects distributed normally with a small dispersion in magnitude; and a population of extremes of a statistical distribution, also with a small dispersion in magnitude. The maximum likelihood fit of this model with data gives valuable information on the statistics of these objects, with implications for cD galaxies. It is also an independent and unique way to probe the luminosity function of galaxies at the bright end, and suggests it to be much steeper than conventionally described.

14) Limits on Dust in Damped Lyα Systems and the Obscuration of Quasars (S.M. Fall and Y. Pei):

The damped Lyα systems discovered in the spectra of quasars at high redshifts are natural places to search for dust. They have column densities of neutral hydrogen greater than 10^{20} cm^{-2} and may be protogalaxies or galactic disks in an early, gas-rich phase. We compare the spectra of quasars in the Wolfe et al. survey that have damped Lyα with those that do not have damped Lyα to obtain statistical information about the reddening by dust. Our results are given in terms of the dimensionless dust-to-gas ratio $k \equiv 10^{21} (\tau_B/N_H)$ cm^{-2}, where τ_B is the optical depth in the B band in the rest frame of an absorber and N_H is the column density of neutral hydrogen. Using non-parametric tests, we find, at the 95% confidence level, $k \le 0.41$ (Gal), $k \le 0.29$ (LMC) and $k \le 0.19$ (SMC), depending on whether the extinction curve is assumed to have the same shape as that in the Milky Way or the Large or Small Magellanic Clouds. Our upper limit on the dust-to-gas ratio in damped Lyα systems are half the observed value in the Milky Way but are several times larger than the observed values in the Magellanic Clouds. We also develop a new method to set limits on the mean and the variance of the optical depth along random lines of sight. This includes a correction for the effect, pointed out by Ostriker and Heisler, that highly obscured quasars are less likely to be included in optically-selected samples than quasars with little dust in the foreground. Our results for the mean optical depth in the B band of the observer can be approximated by the formula $\bar{\tau}_B(z) = 0.4\tau_*[1+z)^{5/2}-1]$; using the upper limits on the dust-to-gas ratio in the damped Lyα systems, we obtain $\tau_* \le 0.06$ (LMC) and $\tau_* \le 0.05$ (SMC). For comparison, the first models by Ostriker and Heisler predict $\tau_* = 0.4$ or 0.8 and their more recent models predict $\tau_* = 0.16$. We conclude that neither set of models is consistent with our limits. As a consequence, the apparent cutoff in the counts of quasars at $z \simeq 3$ is probably not caused by dust in the damped Lyα systems. All the limits derived in this paper could be reduced significantly or a positive detection could be made by determining more accurately the spectral indices of the quasars in the Wolfe et al. survey.

15) Quantization in Ly-α Absorption Lines in QSOs: Determining q_o (W.G. Tifft and W.J. Cocke):

Current versions of the theory of the quantization of extragalactic redshifts (e.g., Cocke 1985, Ap.J. 288, 22) all state that the basic quantization interval should - locally - be proportional to $H(t)^{1/2}$ where H(t) is the Hubble "constant" at time t. QSO Lyman-α forests are rich enough in absorption lines that one might hope to find quantization in them and thus be able to say something about H(t) at different epochs.
Standard cosmology gives the relation $H(t) = H_o(1+z)\ (2q_oz+1)^{1/2}$, where q_o is the present value of the deceleration parameter and H_o is the present value of the Hubble constant. Determining H(t) at any non-zero redshift therefore provides a value of q_o.
We have analyzed four independent sets of Ly-α forest data covering a wide range of redshifts ($1.8 \leq z \leq 3.7$). Velocity differences of $c\delta z$ between neighboring absorption lines were evaluated in the local rest frame by dividing by 1+z, where z is the averaged z of the line pair. We then normalized them back to the present epoch by multiplying by the expression $(H_o/H(t))^{1/2}$, in accord with the theoretical results quoted at the top of the panel. The result is a normalized velocity difference

$$\tilde{\delta}v = (H_o/H(t))^{1/2}\ c\delta z/(1+z) = (1+z)^{-3/2}(2q_oz+1)^{-1/4}c\delta z.$$

Then a histogram of the $\tilde{\delta}$vs should show the quantization at 24.15, 36.22, 48.30, and/or 72.45 km/s at some preferred value of q_o, since the dependence on H(t) has been normalized out. In fact, all four data sets show quantization at multiples of 24.15 km/s, like the dwarf galaxy samples analyzed in 1984. In all four data sets, one of the strongly preferred values of q_o is 1/2.

16) Gravitational Micro-Lensing From Distant Masses (S. Refsdal):

Recent observations of QSO 2237+030 show 4 images with identical spectra (Yee, 1988; Schneider et al., 1988; Roberts and Yee, 1988). This is convincing evidence for a gravitational lens system with the lensing galaxy unusually close to us ($z_G = 0.039$). For this system the expected effects from micro-lensing are larger, and can be more accurately estimated than for any other system presently known. For a quasar radius of ≈ 0.1 l.y., one tenth of the mass in stars and an effective transverse velocity in the observer plane of 600 km/s, we do expect for each of the 4 images a typical change of 0.05 magnitude per year due to micro-lensing. This estimate is based on theoretical calculations by Kayser, Refsdal and Stabell (1986) which cover the relevant parameter values. Since the time delay Δt between the images is only about 1 day or less, micro-lensing will produce a change in luminosity ratios, and an observed such change will be a proof of micro-lensing, since intrinsic variability will show up "simultaneously" in all images.