COMMISSION No. 47

COSMOLOGY(COSMOLOGIE)

Report of Meetings on 25, 26 and 27 July 1991

PRESIDENT: Katsuhiko Sato VICE PRESIDENT: R. B. Partridge

I. BUSINESS MEETING

At the beginning of the meeting, the president asked for a short silence to commemorate the recent death of an eminent member of the Commission, Dr. Hidekazu Nariai, Professor of emeritus, Hiroshima University, whose contribution to the advancement of cosmology has been outstanding. He served as a member of the organizing committee in term of 1970- 1976.

The president informed that all the commission members who answered the questionnaire circulated on April 1990 expressed the opinion that the vice president R. B. Partridge takes over the office of the president. Accordingly, he has proposed to IAU Executive Committee the nomination of R. B. Partridge (U.S.A.) as the president commission 47 for the period of 1991 - 1994. He also informed members that he has proposed J. V. Narlikar (India) as vice president following the result of questionnaire. These nominations were endorsed by the participating members of the commission.

Following new members of the organizing committee were elected in this meeting: J. Bond (Canada), M. Geller (U.S.A.), A. Szalay (Hungary) and D. Jauncey (Australia). Including members who remain in office, A. Dressler, M. Rees, H. Reeves, P. Shaver and S. Shandarin and K. Sato as the outgoing president, ten people serve as the members of organizing committee.

The president asked participating members to discuss the rule of nominating new vice president and new organizing committee. He reported rules of other commissions and also the opinion of the president of commission 35 in the commission president meeting held on 23 July that they should be elected by ballot. It was agreed that 1)at present stage commission 47 does not adopt the direct ballot, but 2) according to the organizing committee, next president, R. B. Partridge investigates the rule including the possibility that the new vice president is nominated by ballot in the organizing committee.

II. SCIENTIFIC SESSIONS

Four sesssions were planned originally, but the last sesssion was cancelled by fire accident. The first two sessions (25 July), Early Universe, which were organized K. Sato and chaired by him and J. V. Narlikar. The last two sessssion, Cosmological Parameters, were organized and chaired by V. Trimble.

EARLY UNIVERSE

Primordial Nucleosynthesis in Inhomogeneous Universe

Katsuhiko Sato (The University of Tokyo) and N. Terasawa

From recent studies of nucleosynthesis in inhomogeneous universe, It has been pointed out that 1) $\Omega_B = 1$ model becomes consistent with light element observations, 2) heavy elements including r-process elements are abundantly synthesized, and 3) ^{9}Be plays a role of the indicator of inhomogeneity since ^{9}Be is also abundantly synthesized. These suggestions were, however, based on a simple two-zone model in which back diffusion of neutrons are neglected during the nucleosynthesis. In this short review, It is shown that 1)the upper limit of Ω_B which is consistent with light element observations is almost the same as that of homogeneous case, 2) the ^{9}Be abundance in the simple two-zone model is overestimated at least two orders of magnitude in plausible parameter space and 3) the abundances of CNO elements are very small in the proper range of baryon/photon ratio consistent with the abundances of light elements.

Baryon Isocurvature Scenario in Inflationary Cosmology

J. Yokoyama (Fermilab/U Tokyo), M. Sasaki and Y. Suto

We derive a proper expression of the power spectrum of baryon- number fluctuations arising from models of baryogenesis with both intrinsic and spontaneous CP violation. It is explicitly calculated in a power-Law inflation model and found to be almost scale-invariant on small scales and white-noise on large scales. Under appropriate choice of particle physics model, it is possible to account for the necessary initial condition for the baryon isocurvature scenario proposed by Peebles.

Natural Inflation and Large-Scale Structure

Joshua Frieman (NASA/Fermilab Astrophysics Center)

For ten years now, the inflationary scenario has been in a state of theoretical limbo: it is a beautiful idea in search of a compelling model. The problem arises from the required tiny self-coupling of the inflation scalar field, $\lambda_\phi \lesssim 10^{-14}$. In most models, this small number is either unnatural or unexplained. We show that a pseudo-Nambu-Goldstone boson, with a potential of the form $V(\phi) = \Lambda^4[1 \pm \cos(\phi/f)]$, can naturally give rise to inflation if $f \sim m_{pl}$ and $\Lambda \sim M_{GUT}$. In addition, the primordial power spectrum $|\delta_k|^2 \sim k^n$, with spectral index $n = 1 - m_{pl}^2/8\pi f^2$, can have substantial extra power or large scales (compared to the scale-invariant, Harison-Zeldovich $n = 1$ spectrum). In order to fit the galaxy angular correlation function $w_{gg}(Q)$ measured by the APM survey, we find that a spectrum with $n \simeq 0 - 0.4$ is required, within the context of inflation. However, microwave quadrupole anisotropy limits from RELICT and COBE require $n \geq 0.3$ (for a bias parameter $bleq2$). As a result, the current anisotropy bonds must be nearly saturated if the extra power seen an $30 - 100h^{-1}$Mpc scales is to be explained by inflation and cold dark matter, without additional ingredients.

Galaxy Clustering in a Bubbly Universe

Angela V. Olinto (Univ. of Chicago)

Recent redshift surveys suggest that most galaxies are distributed on the surface of bubbles surrounding large voids. To investigate the quantitative consistency of this qualitative picture of large-scale structure, we study analytically the clustering properties of galaxies in a Universe filled with spherical shells. This phenomenological model comprises three galactic populations: shell galaxies, placed at random on

spherical shells distributed randomly in space; cluster galaxies, located at the points where three shells intersect; and a random, unclustered component of background galaxies. We calculate the two-point galaxy correlation function, the three point galaxy correlation function, the galaxy-cluster cross-correlation function, and the void probability function for models with an arbitrary distribution of shell sizes. With 20% of galaxies in clusters, the observed $\xi_{gg}(r)$ can be reproduced with the same power law distribution of shell sizes ($\sim R^{-\alpha}$, $\alpha \simeq 4$) which fits the cluster-cluster two-point correlation function, $\xi_{cc}(r)$.

Large Scale Anisotropies of the Cosmic Microwave Background

N. Sugiyama (The Univ. of Tokyo), N. Gouda and M. Sasaki

We formulate a general method to calculate systematically any multipole moment of the cosmic microwave background anisotropy in an open universe. Using this method, we evaluate the effect of negative curvature to the quadrupole moment in the three representative cosmological models, pure baryonic, cold dark matter and hot dark matter models, for both adiabatic and isocurvature initial density fluctuations with power law. The anisotropy can be divided into three parts, namely, the intrinsic photon fluctuation at decoupling time, the Sachs-Wolfe term which can be written as the difference of the gravitational potential between present and the decoupling time and the effect caused by a time derivative of the potential. Sometimes the last two terms are called the generalized Sachs-Wolfe term. From numerical calculations, we find that the generalized Sachs-Wolfe effect dominates the quadrupole moment in almost all of the low density model. On the other hand, the intrinsic term plays an important role for the isocurvature models and dominates on low density. Though constraints obtained by comparing our numerical results with recent observations for quadrupole moment are still compatible with those of small angle observations, our constraints are severer since the quadrupole anisotropy would hardly be affected by phenomena which might have occurred after decoupling, such as reionization or gravitational lensing.

On the Interpretation of Observations of Cosmic Background Radiation

V. G. Gurzadyan (Yerevan Physics Institute)

The high level of isotropy of Cosmic Microwave Background Radiation is one of the basic facts of observational cosmology. According to the conventional viewpoint the perturbations of MwB should be the same since the epoch of last scattering. However, in our recent paper (Gurzadyan V.G., Kocharyan A.A. *Preprint ICTP*, 90/318, 1990, Trieste, *Astr. Ap.*, in press) an effect leading to decrease of perturbations of MwB at postscattering epoch is investigated. The consideration of the behavior of correlation functions for a flow of null geodesics by means of the methods of ergodic theory enables one to evaluate this effect based purely on geometrical and topological properties of the Universe. The anisotropy of MwB is shown to decrease in open Friedmannian Universe to a level far below present experimental accuracy; dependence of angular scale and the value of Ω ($\Omega \leq 1-\epsilon; \epsilon \ll 1$) is weak. This effect can have great consequences for the interpretation of the observations. In particular, anisotropy at a level $10^{-5} \div 10^{-7}$, if discovered in near future, will probably indicate that our Universe is closed, $\Omega > 1$, and thus at least by 90% is filled with dark matter. The absence of such anisotropy should not have as simple influence on the theories of formation of galaxies as it is considered at present.

Correlated Fluctuating Signals in the Analysis of the Large Scale Struvture of the Universe

M. D. Suran (Astronomical Institute of Romanian Academy)

Recent observations of the large scale of the Universe suggest inhomogeneities on scale larger than previously though, for example: filaments, Great Walls and some other "monsters". We are interested in the studies of the signature of such types of inhomogeneities. As an observational method, we purpose to study the fluctuations in the long tail of the correlation function, as sign of inhomogeneities. As observational material we have used three different 3D catalogs Las Campanas Deep Redshift Survey in polar caps, for galaxies, The Northern Cone of Metagalaxy, for clusters and The Northern Cone of Superclusters, for superclusters distribution. For these catalogs we have compared the two point correlation function in the long tail. In this case the signal processing is in the form: $\xi(r) = \xi_N + \xi_S, r\ r_i,\ r_i = r_g,\ r_c,\ r_{sc}$ and where the noise signal: $\xi_N(r) = \xi_{cat} + \xi_{gal}$ is a sum of the catalog and the galaxies signals. We demonstrate that the signal, compared between the three 3D catalogs, shows: *periodical* and *phase correlated fluctuations, in the long tail of correlation function.* For revealing such effects we have used two different methods: Fourier analysis and the statistical Whittaker-Robinson method. We show that in the long tail of the correlation function we can decelate two types of periodicities: one on scale $\sim$ 30Mpc(the same as ξ_{gal}) and the second on scale 130Mpc(possible related to supercluster objects). The comparison between the 3D catalogs with the 1D coherent signal (BEKS 1991) demonstrate also that the fluctuations are correlated in phase. The comparison with the theoretical model of 3D lattice topology (Peebles 1989) show two adiacent differences: a possible phase retard of Peebles model and a possible 3D unamortized signal.

Abundances of *Li* and *Be* in Helo Stars

P. Demarque

The physical processes responsible for the surface dilution of *Li* in halo dwarfs during pre-main sequence and post-main sequence evolution are discussed. In addition to standard stellar evolution theory, the effects of diffusion of *Li* and *He* (primarily gravitational settling and thermal diffusion), and also of rotation are considered. The initial Li_p abundance derived from the standard models is $2.17^{+0.04}_{-0.13}$ (2σ)(Deliyannis, Demarque and Kawala 1990 *Ap.J.S.* **73**, 21); for diffusive models $Li_p \leq 2.35$ (Chaboya et al. 1991, *BAAS*, **22**, 1205); for rotating models $Li_p < 3.1$ (Pinsonneauet, Deliyannis and Demarque 1991 *Ap.J.* in press). Constraints on the combined effects of diffusion and rotation can be placed by the flatness of the observed Spite plateau in the ($LivsT_{eff}$)-plane- consequences for cosmology are considered. In the case of *Be*, there is no depletion during stellar evolution (Deliyannis and Pinsonneauet 1990 *Ap.J.L.* **326**, L23). There is also evidence for galactic enrichment in *Be*. Recent work by Ryan et al. (1991) shows possible evidence for a plateau at very low metalicity, corresponding to a *Be* abundance several orders of magnitude larger than predicted by standard BBN.

The Spectrum Distortion of Relic Radiation in Moment of Universe Recombination

V. V. Burdyuzha (Lebedev Physical Inst.), A. N. Chekmezov (Inst. of General Phys.) V. N. Lukash (Lebedev)

The distortion of the CMB from the Planck spectrum may necessarily arise because of the production of energetic quanta in the process of recombination, which leads to its retarding and the distortions in the Wein and R-J regions. We reanalyzed the recombinational dynamics from point of view of the nonequilibrium kinetics after

the papers Peebles (1968), Zeldovich, Kurt and Sunyev (1969), Jones and Wyse (1985) and Krolik (1989, 1990). We argue that the CMB distortion in L_α line takes place in the region $\lambda \sim 100 - 150\mu$. This is caused by the deviation of a population of the ground state of H from the equilibrium population which can be calculated due to the Saha formula. We present the dependence of a distortion from baryonic densities.

COSMOLOGICAL PARAMETERS (reported by V. Trimble)

Twelve papers were scheduled for these sessions, focusing primarily on distance indicators, age indicators, and handles on dark matter, including baryonic dark matter from nucleosynthesis constraints. Six of the papers were delivered and six pre-empted by the fire. Abstracts of one of the papers presented and five of the six not presented (provided by the authors) come at the end of this section. Highlights of the other papers presented include:

The Hubble parameter (R. Terlevich). Astronomers have considered a very large number of distance indicators in the effort to calibrate H_0. All of these are subject to both random and systematic errors, including the speaker's own work on H-beta flux vs. line width in HII regions. Two controversial suggestions were made: first, that (despite the large number of careful investigations that have found largish values of H_0) the correct value must be at the small end of the possible range; and that additional standard candles in field galaxies are unlikely to be useful, and investigators should focus on clusters.

D/H in the interstellar medium (J. Pasachoff). The D/H ration is a strong constraint on the cosmic density of baryonic material. The Lyman alpha line has been seen, but is difficult to separate from the stronger H^1 line; better data will probably come only with FUSE. A tentative detection of the 92 cm analog of the 21 cm line has recently been reported, in absorption against Cas A. It shares the local H_2, not neutral atomic gas, velocity, which may be grounds for concern. Initial analysis indicates 11% of closure density in baryons, for $H = 50$.

Helium in HII galaxies (E. Terlevich). A recent reanalysis of the galaxy SBS 0335-052 (claimed by others as more metal deficient than I Zw 18) shows that they are actually about the same. The new galaxy, however, yields a somewhat lower helium abundance associated with $O/H = 0.022$ solar, and so implies a very low primordial value for $Y = 0.21 \pm .005$.

Primordial(?) boron and inhomogeneous nucleosynthesis (D.L. Lambert). The presence of boron has recently been established in stars with Z only about 1% that of the sun. There is currently no evidence for a minimum boron abundance, uncorrelated with Fe/H, that might be evidence for a primordial (inhomogeneous) contribution but the B/Be ratio in metal-deficient stars differs slightly from the best predictions of the abundances due to cosmic ray spallation, leaving open the possibility of a primordial contribution to one or both.

Do we need baryonic dark matter? (J.E. Felten). The "best- fit" value of the total mass density of the universe based on dynamical considerations appears to exceed significantly the best estimate of the density in luminous matter, based on a luminosity density and the mass-to light ratio appropriate for a normal stellar population. The speaker believes, however, that the error bars are large enough that the case for non-luminous baryonic material has not yet been firmly made. The issue is somewhat confused by disagreement about whether X-ray emitting gas in rich clusters of galaxies should or should not be counted as "dark".

Are SNIa good Standard Candles?

S. van den Bergh

All published UBV photometry of $SNIa$ has been used to form a list of 31 objects for which the error of m(max) is less than about $0.5mag$. A Hubble diagram for these objects shows large scatter, partly due to dust absorption and, probably, Malmquist bias. For the five objects in E/So galaxies (SN 1986G excluded), the dispersion at maximum light is $0.9mag$. Allowing for observational errors and deviations from smooth Hubble flow probably reduces the real dispersion in m(max) for SNIa to below $0.9mag$. For 6 SNIa in the Virgo cluster, $11.2 \leq m(\max) \leq 14.05$, or $11.2 \leq m(\max) \leq 1.27$ if SN 1971G in the edge-on galaxy NGC 4165 is excluded. It is noted that the apparently unreddened SN 1984A (described by Hamuy in another session) has $B(\max) = 12.7$, which is $1.5mag$ fainter than SN 1961H, which occurred in the Virgo E galaxy NGC 4564. It is concluded that neither the Hubble diagram nor the SNe in Virgo yet give strong support for the hypothesis that SNIa are good standard candles. Clearly, more photometric observations are needed to establish whether SNIa are standard candles with a small luminosity dispersion at maximum light.

A Systematic Effect in the Use of Planetary Nebula as Standard Candles

L. Bottinelli(Observatoire de Paris and Universite Paris XI) , L. Gougurnheim, G. Paturel AND P. Teerikorpi

The distances determined by Jacoby et al.(1990a) for 6 early type galaxies members of the Virgo cluster of galaxies, using the method of the planetary nebulae luminosity function (PNLF) are correlated with the magnitude of the parent galaxy. A similar trend is found within the Leo I group of galaxies and is confirmed by a comparison between the PNLF distances and distance estimates from the surface brightness fluctuation method. This effect works in the sense that more luminous galaxies are derived smaller distances. Another strange systematic feature is the increase of the specific PN density from luminous to faint galaxies, clearly seen in Virgo and Leo I data. We show that both these systematic trends can be due to an exponential part in the bright end of the PNLF. If this is the case, the short value derived for the Virgo distance by the PNLF method should be regarded uncertain. We analyze shortly the use of an exponential Lf as a distance indicator and note that if it is applied to the planetary nebulae, one should select the calibrators to match at least the Hubble type of the measured galaxies. As a preliminary example the relative distance $\mu_{Vir} = \mu_{Leo}$ is derived by the exponential LF method to be 1.15 ± 0.04 (with a fixed value for the slope of the LF). We emphasize the need of a detailed study of the PNLF in galaxies within Virgo and closer with a large luminosity and type range.

Tully-Fisher Distances

L. Gouguenheim (Observatoire de Paris and Univ. Paris), P. Teerikorpi, L. Bottinelli and G. Paturel

We have investigated the velocity-distance relation close to the direction of the Virgo cluster, with distances from the Tully- Fisher relation, and with attention to the Malmquist bias. For $\Theta > 8$deg a behaviour is releaved which is as expected from the Tolman-Bondi solutions for an expanding spherical mass distribution, previously discussed by Tully and Shaya (1984;TulSha) using a smaller sample of galaxies. 1) Various density distributions, constrained by the mass inside the Local Group distance (required to produce V_{vir}), agree with the observations, but only if the mass

within the Virgo 6 degree region is close to or larger than the standard Virgo virial mass values. This is so independently of the value of q_0, of the slope of the density distribution outside of Virgo, and of the values adopted for Virgo distance and velocity. The v vs. d relation (velocity and distance from the Virgo center) shows directly that the "zero velocity surface" lied at $d \simeq 0.45$. 2)Generally, the observations imply that the central 6 deg mass has the standard M(virial) as a rough lower limit. From this follows, together with the light ratios within the local supercluster and the light enhancement relative to the general field, that light does no trace mass. Analysis of the data below $\Theta = 8$deg and inside the standard 6 deg circle led to the following conclusions; 3)The Tolman-Bondi behaviour may be discerned close to the Virgo center, producing high velocities $V_0 > 2000$km/s for infalling galaxies with distances somewhat smaller than the Virgo distance. 4)An expanding component, as proposed by de Vaucouleurs (1982), causes the negative velocities for several galaxies nearer than r_{Vir}. Hydrogen deficient galaxies prefer this expanding component, and there is evidence that HI deficiency causes underestimates of Tully-Fisher distances, e.g. transferring negative-velocity galaxies too much to the foreground. 5)Background contamination produces an asymmetrical distribution of velocities behind r_{Vir} (behind the high-velocity expanding component). Hence the large spiral velocities in the Virgo cluster, $V_0 > 1800$km/s, can be ascribed to three origins: TB-infall, expanding component, Malmquist-biased background. Small velocities are mostly due to the expanding component. 6)The dynamical components of the Virgo region are differently distributed in the sky: The expanding component has a flattened distribution along the line M87/M84-M59. The infalling high-velocity galaxies show a distribution which is a continuation into the 6 deg circle of the Southern Extension infall previously suggested by TulSha. The other spirals do not show a concentration in the 6 deg circle. 7)The tight angular concentration of negative-velocity galaxies can be understood by a combined effect of projection and quick deceleration of the initial high expansion velocities (when the central mass is high enough, close to that required by the TB inflow).

Globular Cluster Ages

P. Demarque (Yale University)

The ages of the oldest globular clusters provide a lower limit to the age of the Universe. Recent advances indicate that an age spread of up to $4 - 5gyr$ exists among globular clusters, suggesting a long time scale of formation for the galactic halo. Absolute ages are more uncertain; current research focuses on the effects of helium diffusion near the main sequence turnoff, the dependence of the RR Lyrae luminosity on metallicity, and the O/Fe ratio in the oldest stars. For the old cluster M92, the age is $16 \pm 3gyr$. An age below $13gyr$ for M92 would cause inconsistencies with several other pieces of astronomical data.

It was noted in conclusion that there is recent evidence, based on a comparison of the RR Lyrae distribution in the galactic bulge with synthetic HB models by Y.-W. Lee, that most the RR Lyrae variables in the bulge are older than M92 by about $1 - 1.5gyr$. Thus globular clusters may not contain the oldest stars in the Galaxy! These ages put a strong constraint on cosmological models.

Stellar Th/Eu Ratios and the Age of the Galaxy

B.E.J. Pagel

While the best estimate of the age of the universe comes from globular clus-

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ter HR diagrams, it would be desirable to have an independent check, e.g., from radioactive cosmochronology. However, solar system actinide ratios are of no use for this purpose, because one can get any age upwards of $6.5Gyr$ according to ones favourite model of Galactic chemical evolution. Butcher (1987) invented the Th/Nd method, which holds promise for age-dating individual stars, provided certain improvements are added: replaced Nd with Eu (r process) and correct for the line blend with CoI using new oscillator strengths after Lawler et al. (Nature 1990). Having done this, one can deduce ages in a way that is comparatively insensitive to galactic chemical evolution models, and Eu/Nd ratios measured by da Silva et al. plus Lawler et al.'s Th/Nd ratios give Th/Eu ratios completely consistent with ages of up to $19 \pm 4Gyr$, deduced from positions of eild stars of known parallax in the HR diagram, contrary to the result originally claimed by Butcher. Very recently, P. Francçis has measured Th/Eu ratios in halo stars which one would expect to have similar age to Butcher's oldest star HY 3018, with $[Fe/H] = -1.0$. Francçis's Th/Eu ratios agree, as expected, with HR 3018 down to $[Fe/H] = -2.5$ or so, but at stell lower metallicities (where Eu/Fe goes down), Th/Eu goes up, suggesting a change in r-process production ratios at the very lowest metallicities.

Nearby Galaxy Flows Modeled by the Light Distribution

E.J. Shaya, R.B. Tully, and M.J. Pierce

The observed distribution of light in the Local Supercluster has been used to determine the expected velocities of galaxies if the assumptions are valid that non-expansion motions are generated by gravitaional perturbations and that mass is distributed like the light. Since detailed knowledge of the light distribution extends to only 3000 km/s, three extra sources are added at large distances: one associated with the Great Attractor, one loosely with the Perseus-Pisces Supercluster region, and one with the Shapley Concentration at a distance corresponding to 13,800 km/s. The nearer two sources are motivated by improvements they offer to χ^2 fits while the distant source is required to get agreement with the cosmic microwave background dipole. Comparison is made with observed velocity field maps based on 301 high quality distance estimates in 142 groups and 53 individual galaxies. The assumption that gravitaional perturbations must dominate the generation of peculiar velocities is substantiated and $M/L \simeq 144h\Omega_o^{0.4}$ is found. A surprisingly strong conclusion can be drawn that the clumped mass is clustered on scales < 1Mpc with $M/L \sim 100$ and that an *insignificant* amount of additional mass is clustered on scales between 1 Mpc and $\sim$ 20Mpc. A value of $\Omega_{gal} \sim 0.08$ is associated with clumped mass. There are hints of velocity streaming with coherence over 20,000 km/s and mass fluctuations on $10^{17}M_\odot$ scales. The model provides a natural description of the 'local velocity anomaly'. The χ^2 fit for the preferred model results in an equivalent *rms* uncertainty in the difference between observed and model velocities of 18% of the observed distance.