COMMISSION 47. COSMOLOGY (COSMOLOGIE)

Report of Meetings on 20, 21, 22, 25 and 27 November 1985

PRESIDENT : J. Audouze
VICE PRESIDENT : G. Setti SECRETARY : V. Trimble

I. BUSINESS MEETING (20 November 1985)

Participating members of the Commission endorsed recommandations of the organizing committee that G. Setti (Italy) and K. Sato (Japan) serve as president and vice-president for the period 1985-1988 and that J. Audouze (France, retiring president) and Fang L.-Z. (China) be added to the organizing committee, bringing the total membership to nine.

Sixty-one new applications for commission membership were also approved, bringing the total to 283. It was suspected that some of the continuing members may no longer be active in cosmology, and the incoming president plans early in his term to circulate a letter to the membership requesting a verification of current scientific interests, in the expectation that this will somewhat reduce the total. We are not aware of any deaths or resignations from the commission membership during the previous three years.

The president announced that Commission 47 will cosponsor two symposia, 124 on Observational Cosmology (Shangai, China; August 25-29 1986) and 130 on Evolution of Large Scale Structure in the Universe (Balatonfured, Hungary; June 1987) in the coming few years. In addition, at least five other meetings of interest to cosmologists will occur between January and July 1986. We look forward to seeing each other often !

The business session concluded with a presentation on "Cosmological Research in China" by Zou Z.-L., incorporating material that had not been received in time for inclusion in the commission's report earlier this year. In the triennum 1982-85, our colleagues in China published nearly two dozen papers on the topics of the very early universe, anisotropy of the background radiation, cosmological parameters, large scale structure of the universe, non-standard cosmological models. Some of the highlights include :

Two investigations by Guo H.Y. et al. (1982 Ch.Astron.Astrophys. 6,243) and Xu D.Y. et al. (Scien. Sinica 27, 81, 1984) on the possible prevention of cosmological singularities when quantum and symmetry-breaking effects are included.

A derivation by Xu C.X. (1984, Ch.Astron.Astrophys. 8,340) of the solar velocity relative to the diffuse X-ray background as measured by HEAO 1 A2. The result, 387±159 km/s, is in good accord with the solar velocity relative to the microwave background.

Several investigations by Chen J.S. et al. (1984, Astron. Astrophys. 134, 306; 1984 Publ. Astron. Soc. Pac. 95, 335; and references cited therein) of the Lyman alpha absorption line forest in large-redshift quasars. They find evidence for moderate evolution in number density of the absorbing clouds and no evidence for power-law clustering like galaxies.

Two investigations by Zhou Y.Y. et al. (Ch.Astron.Astrophys. 9, 20, 1985) and Fang L.Z. et al. (1984 Ch.Astron.Astrophys. 8, 148) attributing the structure in plots of quasars numbers vs. redshift either to observational selection effects or to the universe being multiply connected with the present scale of compactified space being about 600 Mpc.

II. JOINT DISCUSSIONS (21 and 27 November 1985)

The commission cosponsored joint discussions IV (Radio Astronomy and Cosmology) and VII (Supernovae). Vol.7 of Highlights will include many of the

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talks presented at these. The most relevant to the interests of Commission 47 were (from Supernovae) a presentation by N. Bartel on the combining of optically-measured supernova expansion velocities with VLBI measurements of proper motion expansion, thus providing a dynamical parallax and a distance scale independent of the Hyades, Cepheids, etc; and (from Radio Astronomy and Cosmology) a suggestion by J. Baldwin that pancakes in the process of becoming protogalaxies will introduce a1000km/s wide, 21cm emission feature, now redshifted to near 150 MHz, and having a brightness temperature near 1K and angular size scales of a few minutes of arc. Modification of an existing NRAO installation to search for these emission features is underway.

III. SCIENTIFIC SESSIONS (20, 22 and 25 November 1985)
In the course of the six sessions, 19 papers were presented, as follows:

Large Structures and Radio Sources

1 C.R. Subrahmanya (Australia): The cosmological evolution of radio sources
2 D.N. Schramm (USA): Large scale structures and galaxy formation- fractals and strings

Quasars

3 X.T. He (PRC): Quasars in the Virgo cluster region
4 V. Petrosian (USA): Evolution of quasars
5 P.A. Shaver (ESO): Quasar pairs

Anisotropy of the Blackbody Radiation

6 G.F. Smoot (USA): On the cosmic background radiation
7 K. Shivanadan (USA): Measurements of the cosmic infrared backgroung radiation
8 R.B. Partridge (USA): Aperture synthesis observations of the microwave background

Clusters of galaxies

9 W. Saslaw (USA): Gravity and clustering of galaxies
10 M. Mosconi (Argentina): Clusters of galaxies
11 S.P. Bhavsar (India): Are the filaments real ?
12 R. Cowsik (India) : Self-consistent distribution of galaxies in clusters
13 I.E. Segal (USA): Recent extragalactic observations and rational comparative cosmology

Primordial Nucleosynthesis

14 G. Steigman (USA) : Primordial nucleosynthesis: a status report
15 J. Audouze (France): Primordial nucleosynthesis and strange particles
16 G. Burbidge (USA): How much of the helium is really primordial?
17 G. Steigman (USA): Dark matter and exotic particles: in search of the perfect WIMPS
18 K. Sato (Japan): Baryogenesis in the inflationary universe
19 J.P. Luminet (France): Nucleosynthesis induced by stellar pancakes.

IV. ABSTRACTS OF SOME OF THESE PRESENTATIONS

3. QSO research in China (X.T. He - Dept of Astronomy, Peking Normal Univ., Beijing, China)

There are about 30 astronomers or physicists interested in QSO research in

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China. About 150 papers have been published concerned with QSOs. Some observing projects co-operatively with other countries or to apply big telescope time in the world start since 1980's. We are trying to use chinese telescope for QSO observation.

The data have been used from the UK Schmidt and Palomar Schmidt for QSO survey in large area, for example, in Field 297 (1^h44^m, $40^\circ00'$) 1092 QSO candidates have been found in ≈ 40 square degrees. 36 of the candidates were observed spectroscopically 21 of the objects are confirmed as QSOs. 35 new QSOs have been discovered in the Virgo Cluster Region. The bright background QSOs provide a network of probes of absorbing material both in the cluster and surrounding individual galaxies.

Other works include clustering test, 90 determination, identification of redshift systems, mechanism of line formation, X-ray studies and so on.

We are doing emission line object and UVX object survey and to observe some BL Lac and active galaxies using the Chinese facilities.

4. Evolution of quasars (V. Petrosian - Stanford Univ., Stanford, California USA)

The relation between the evolution of the luminosity function, derived from statistical analyses of complete samples of quasars (optically selected), in an assumed cosmological model, and the physical evolution of the luminosity and the formation rate of the object were described. It was reiterated that the observed data on optically selected sample disagrees with the requirements of either a pure density or pure luminosity evolution of the luminosity function.
Furthermore, it was stressed that only very special physical evolutions could give rise to such pure evolutionary forms.

In general, at low and moderate redshifts ($z \leq 2$) the low luminosity objects show weak or very little evolution while the high luminosity objects show the strong evolution commonly attributed to all quasars. Such changes in the luminosity function can come about if, for example, the lifetime of the object at each luminosity decreases rapidly with increasing luminosity.

At larger redshift, where only the brightest objects can be studied, the deduced evolution of the luminosity function and, in particular, the rate of the decrease of the evolution or the existence of a redshift cutoff depends critically on the cosmological model.

5. Quasar clustering (P.A. Shaver - ESO, Garching, RFA)

The physical clustering of quasars has been studied by applying a novel technique to a catalogue of nearly 3000 quasars with known redshifts. Clustering is detected on scales less than 10 Mpc, but on larger scales the distribution appears to be random. The same technique has been applied to two large samples of galaxies, permitting a direct comparison. From this it appears that quasars at high redshifts are clustered similarly to galaxies today, suggesting that structure on these scales has not evolved significantly since $z \sim 2$.

6. Large angular scale anisotropy (G. Smoot - Univ. of California, Berkeley, USA)

A review of recent large-angular-scale anisotropy experiments, Berkeley, Princeton and Russian Prognos 9.

The old and new experiments agree roughly about the magnitude and direction of the first order (dipole) anisotropy. The three maps are are shown with and without the host fitted dipole anisotropy. Expected future experiments by Berkeley, Princeton, Cosmic Background Explorer (COBE) are mentioned.

8. Aperture synthesis observations of the Microwave Background (R.B. Partridge, Haverford College, Pennsylvania, USA)

Colleagues from the National Radio Astronomy Observatory, TESRE Bologna, and the Center for Astrophysics and I have used the Very Large Array (VLA) to wake two different sorts of observations of the cosmic microwave background.

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1) We searched for fluctuations in the microwave background on scales smaller than usually observed, down to 4". The most recent and sensitive results are at scales 18" - 40". Our technique permits us to subtract instrumental noise to high occuracy. We can also remove evident discrete sources. Even after these corrections are made, a non-zero signal remains. We assume some of this sky noise may be ascribed to weak sources ; we are currently attempting to model and to subtract such effects. Until this process is complete, we prefer to give our preliminary results as upper limits on fluctuations in the cosmic microwave background (at the 95% confidence level) :

On an angular scale of 18", $\Delta T/T \leq 3 \times 10^{-4}$

On an angular scale of 40", $\Delta T/T \leq 2 \times 10^{-4}$

Earlier work at higher resolution (Knoke, Partridge and Rotner, Ap.J. 1984) allows us to fix a limit at 4" : $\Delta T/T \leq 3.2 \times 10^{-3}$.

These results are in good agreement with the results of a similar experiment reported at this assembly by Dr K. Kellerman. They are also close to the predictions discussed here by Dr J. Ostriker (work with E. Vishniac). These predictions are of particular interest since they suggest values of $\Delta T/T = \theta(10^{-5})$ at smaller angular scales than emerge naturally from inhomogeneities at the epoch of recombination. [work with Dr H. Martin and M. Rotner].

2) The VLA was used at λ=4 cm to look for the Sunyaev-Zel'dovich effect (the "cooling" of microwave photons by scattering from hot electrons in plasma in clusters of galaxies in one well-studied cluster, Abell 2218. Instrumental effects and the presence of sources limited the accuracy of this preliminary study to ~0.5mK. No convincing evidence for the Sunyaev-Zel'dovich effect was seen at either the nominal cluster center given by Abell, or the center used in the observations of Birkinshaw, Gull and Hardebeck (Nature, 1984), but the errors are such that the value reported for the effect by Birkinshaw et al., $\Delta T_{central} = -0.8$mK cannot be excluded by our data in its present form. [work with Dr N. Mandolesi and R. Perley].

9. Gravity and galaxy clustering (W.C. Saslaw - N.R.A.O, Univ. of Virginia, USA and Inst. of Astronomy, Cambridge, GB)

The asymptotic relaxed state of a statistically homogeneous gravitating distribution of point galaxies in the expanding universe can be described by a distribution function

$$\nabla^2\phi_g = 4\pi G p_g(o)\, exp\{-\frac{m_g}{kT_g}(\phi_g + \phi_\nu)\}$$

$$\nabla^2\phi_\nu = 4\pi G p_\nu(o)\, exp\{-\frac{m_\nu}{kT_\nu}(\phi_g + \phi_\nu)\}$$

for the probability of finding any number, N, of galaxies in a volume whos size is related to the average number density of galaxies by N = nV and where $b \equiv -W/2K$ is a ratio of the gravitation correlation energy W to the kinetic energy K of peculiar galaxy motions. This distribution is in good agreement with both N-body computer experiments and with the observed clustering of galaxies in the Zwicky catalog. It includes the distribution of voids and contains much more information than just the low order correlation functions.

Using the cosmic energy equation and the linear solution of the BBGKY hierarchy, one can derive a simple evolution equation for b(t).It applies most accurately to the case of an initially unclustered distribution. The asymptotic value of b for non-linear clustering is $b \to (2\alpha + 1)/(2\alpha + 2)$ where the cosmic scale length $R(t) \propto t^{\alpha}$. The observed value of b is 0.1±0.05 for the distribution of galaxies in our Universe and this agrees with the asymptotic distribution. The asymptotic value of b for non-linear clustering is $b \to (2\alpha + 1)/(2\alpha + 2)$ where the cosmic scale length $R(t) \propto t^{\alpha}$. The observed value of b is 0.1±0.05 for the distribution of galaxies in our Universe and this agrees with

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the asymptotic limit for α near the Einstein-de Sitter value of 2/3.

The high agreement between the predicted f(N) distribution of galaxies will set significant constraints on the amount and distribution of dark matter in our Universe.

10a. On the tidal origin of angular momentum in galaxies (D.G. Lambas[1], M.B. Mosconi[2], J.L. Sersic[3] - [1]CONICOR, [2]Observ. Astronomico, [3]CONICET, Argentina)

We present the results of numerical simulations of relaxating protogalaxies under the tidal action of other similar systems and also clusters of galaxies. It is found that the bimodal behaviour of the observed angular momentum of galaxies can be explained under the assumption of different initial dynamical conditions induced by the evolving structure of the Universe expected in the Adiabatic Picture.

10b. Dynamical effects of dark matter in systems of galaxies (J.F. Navarro[1], D.G. Garcia Lambas[1,2], J.L. Sersic[1,3] - [1]Observ. Astronomico, [2]CONICOR, [3]CONICET, Argentina)

Several N-body experiments were performed in order to simulate the dynamical behaviour of systems of galaxies gravitationally dominated by a massive dark background.

We discuss mass estimates from the dynamics of the luminous component (M_{VT}) under the influence of such a background assuming a constant dark/luminous mass ratio (M_D/M_L) and plausible physical conditions. We extend in this way previous studies (Smith, 1980, 1984) about the dependence of M_{VT} on the relative distributions of dark and luminous matter (Limber, 1959). We found that the observed ratio of the virial theorem mass to luminosity (M_{VT}/L) in systems of galaxies of different sizes could be the result of different stages of their post-virialization evolution as was previously suggested by White and Rees (1978) and Barnes (1983). This evolution is mainly the result of dynamical friction that dark matter exerts on the luminous component. Thus our results give support to the idea that compact groups of galaxies are dynamically more evolved than large clusters, which is expected from the "hierarchical clustering" picture for the formation of such structures.

11. Are the filaments real ? (S.P. Bhavsar - Raman Research Institute, Bangalore, India)

We suggest to treat with caution when interpreting and comparing the visual impressions of filaments in the large scale distribution of luminous matter, both in two and three dimensional data sets.Numerical experiments show how sensitive global impressions obtained by our eye are to minor perturbations which effect nearest neighbour distances. An objective and quantitative method for finding and assessing the significance of filaments is necessary. A graph theoretical construction, the Minimal Spanning Tree (MST) has proven very successful. The construction and preliminary results of applying this method to the Zwicky and CfA Catalogues are detailed in a 1985 paper by Barrow, Bhavsar and Sonada (Mon. Not. R. astr. Soc. 216, 17-35).

12. Distribution of visible and dark matter in clusters and galaxies (R. Cowsik, P. Ghosh - Tata Institute of Fundamental Research, Bombay, India)

The question as to how the galaxies and the dark matter are distributed in clusters important in understanding their dynamics and in estimating Ω of the universe. Nothing that both the galaxies and the constituents of dark matter (referred to here as neutrinos for bravity) satisfy the collisionless Boltzmann equation an attempt is made to derive their distributions self consistently. To this end one assumes that their distributions are Maxwellian, consistent with Jean's theorem, and obtains the equations (with obvious notation) :

$$f(N) = \frac{\bar{N}(1-b)}{N!}[\bar{N}(1-b)+Nb]^{N-1}e^{-\bar{N}(1-b)-Nb}$$

These equations are coupled through the potential term in the exponential and yet their solution is effected in a manner similar to the Lane-Emden equation. The densities calculated thus are projected to get surface densities which reproduce well the observed profiles of galaxies in clusters. The distribution of dark matter, also displayed, is broarder and averages to $\Omega \simeq 1$ over distances of $\sim$ 20 Mpc corresponding to typical seperation between clusters.

13. Recent extragalactic observations and rational comparative cosmology (I.E. Segal - Dept of Mathematics, MIT, Cambridge,USA)

An equitable, non-parametric, and statistically efficient method is described for comparative testing of alternative cosmologies, on the basis of complete samples of designated discrete sources. In particular, objective determinations are possible via Monte Carlo statistics for the probabilities of deviations from a non-evolutionary Friedmann model observed in the magnitude-redshift relations of discrete sources. These significantly low probabilities can be considered to establish evolution, which is however incapable of direct observation. Moreover, the Friedmann deviations are just as predicted by the non-parametric, non-evolutionary chronometric theory, which itself fits the observations closely, for which the Friedmanntheory has no explanation. In addition the isotropy and other basic features of the microwave and X-ray cosmic backgrounds are direct non-parametric consequences of the chronometric theory, in which galaxy formation and nucleosynthesis result from large random deviations in a temporally homogeneous stochastic process modelling the Universe. For these and other reasons, the verifiably scientific character of the Friedmann model appears questionable.

14. Primordial Nucleosynthesis : A Status Report (G. Steigman - Bartol Res. Foundation, Univ. of Delaware, USA)

Primordial nucleosynthesis provides a unique probe for testing the standard, hot big bang model of cosmology. A detailed comparison of the theoretical predictions with the primordial abundances of the light elements inferred from observational data permits a test of the consistency of the standard model. As summarized by Boesgaard and Steigman (Ann. Rev. Astron. Astrophys. 23, 319 (1985)), the hot big bang model passes this test with flying colors. Provided that the nucleon to photon ratio exceeds $3\text{-}4\times10^{-10}$, the observed abundances of D, ^{3}He and ^{7}Li can be accounted foir by primordial nucleosynthesis. The final key test is to compare the predicted a abundance of ^{4}He with the observational data. Recent work of Gallagher, Schramm and Steigman suggests that the SMC should have a nearly primordial abundance of ^{4}He and finds $Y_P \simeq 0.235$. This is consistent (within the uncertainties) with the standard model provided that there are at most four flavors of light neutrinos, a result consistent with the limit to neutrino flavors from collider experiments. Accounting for the uncertainties in the Hubble parameter ($45 \leq H_0 \leq 100$) and the microwave temperature ($2.7 \leq T_0 \leq 2.8$K), the above range for the nucleon to photon ratio corresponds to a present nucleon density between 1 and 20 per cent of the critical density ; nucleons may account for all the mass -including the dark mass- inferred from dynamical studies of galactic halos, groups, clusters and superclusters of galaxies.

15. Primordial nucleosynthesis and strange particles (J. Audouze - Institut d'Astrophysique de Paris and Laboratoire R. Bernas, Orsay, France)

Several attempts are currently made to reconcile the predictions of the Big Bang nucleosynthesis regarding the production of D, ^{3}He, ^{4}He and ^{7}Li with the

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existence of dark matter able to close the Universe or such that $\Omega = 1$ (as favoured by the inflation models). Several possibilities have been investigated by our group : massive neutrinos or gravitinos (Audouze, Lindley and Silk 1985), quark nuggets (Shaeffer, Delbourgo-Salvador and Audouze 1985) and photinos (Salati, Delbourgo-Salvador and Audouze 1986).

16. The very high luminosity infrared galaxies ; Are they primordial ? (G. Burbidge - Univ. of California, San Diego, USA)

Observations made by IRAS have given us a great deal of new information concerning the far infrared (25μ-100μ) radiation from galaxies. From those data it is now clear that, depending on their far infrared luminosity and bolometric luminosity they can be divided into three groups :

a) Normal spiral and irregular galaxies in which on the average about 30% of the total flux is in the far infrared.

b) Spiral and irregular galaxies in which the far infrared flux dominates, but whose bolometric luminosities in the normal range of 10^{10}-10^{11} L_0.

c) Galaxies in which the far infrared flux dominates, and the bolometric luminosities are very much higher than those of normal galaxies. They lie in the range of 10^{12}-5×10^{12} L_0, and are the most luminous stellar systems known.

It is the galaxies in category (c) that we are speculating are at very early stages in their evolutionary history and may be primordial.

It is very reasonable to suppose that the first stars that form are very massive. In this case they evolve very rapidly and make many heavier elements which are ejected and condense into dust. Thus it is proposed that these massive stars are responsible both for the high luminosity, and the dust which transforms the stellar ultraviolet radiation into far infrared flux from dust clouds with temperatures of about 60-100 degrees Kelvin.

About eight galaxies of this type are known including IC 4553 (Arp 220) and NGC 6240.

Calculations show that the minimum mass in stars with masses in the range 20-120M_0 required to produce a luminosity of $\sim10^{12}L_0$. Several generations of massive stars are required to produce the necessary conditions so that "ages" for the systems are about 10^8 years are indicated. We suppose that the initial star formation process is triggered by tidal interactions with companion galaxies.

Observational taks of this hypothesis are possible. If the idea is correct, these galaxies should have anomalous abundances of the heavy elements which should be detected both in optical spectra, and by studying the composition of the dust.

I would like to thank the National Science Foundation for research support.

17. Dark matter and exotic particles : In search of the perfect WIMP (G. Steigman - Bartol Res. Foundation, Univ. of Delaware, Newark, USA)

Various exotic particles have been proposed as candidates for the dark matter in the Universe but the nature and amount of dark matter remains a mystery. Dynamical studies of clusters and superclusters suggest a universal mass density only a fraction (0.2±0.1) of the critical density. Such a mass density could be dominated by ordinary (nucleonic) matter. Inflation and the smoothness of the cosmic background radiation argue for a higher density Universe which would require non-nucleonic matter. Hot, warm, cold and decaying dark matter scenarios are reviewed and it is noted that, under the standard assumptions of adiabatic density perturbations with a Harrison-Zeldovich spectrum, none are successful in accounting for the large scale structure of the Universe.

19. Stellar Pancake nucleosynthesis (J.P. Luminet - Groupe d'Astrophysique Relativiste, Observatoire de Paris, Meudon, France)

Currently discussed sites of explosive nucleosynthesis are the primordial universe, supernovae and the surfaces of accreting compact stars. Here I recall that quite ordinary stars, neither massive or compact, can suffer by accident

explosive nucleosynthesis when a strong external gravitational field acts as a detonator.

Giant black holes such as those expected in many galactic nuclei provide quite naturally such strong fields. As shown recently by Carter and Luminet, any star penetrating deeply inside the tidal radius of a massive black hole, or any couple of stars colliding at high velocity in the vicinity of a supermassive black hole, will undergo a short-lived phase of high compression and heating in flattened, "pancake" configuration.

The main astrophysical consequences are the ejection of a significant fraction of the stellar debris and the enrichment of the neighbouring interstellar medium in proton-rich isotopes.

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