1. Introduction

Session B.3 received a partisan organisation, and was divided into sections corresponding to the main paradigms pervading modern cosmology. Three sub-sessions were allocated to cover inflationary cosmology, pre-big-bang scenarios, and topological defects in cosmology. Anything not fitting into these topics makes up the last section, covering miscellaneous topics.

Below I briefly review the current status in each subject covered in a sub-session after which I summarise the talks presented. These summaries reflect my personal understanding of the talks, and I apologise to the speakers if I accidentally missed the entire point.

2. Pre Big Bang cosmology

The pre-big-bang scenario was proposed by Veneziano in 1991 and Gasperini and Veneziano in 1993 and became the subject of much interest in the past year. It is inspired by string theory, and uses as a starting point the four-dimensional low energy effective action of string theory. Cosmological solutions to this action exhibit two branches. One starts in the weak coupling regime and is driven towards strong coupling and (super-)inflationary expansion. The other corresponds to the standard Big Bang model, with decelerated expansion. Strong coupling effects in string theory are usually invoked to justify the jump from one branch to the other. The ensuing scenario combines a super-inflationary branch, which solves the usual cosmological problems solved by inflation, with a “graceful exit” into a post-inflationary branch. Clearly a large number of details remain to be filled in. However attention in the past year has concentrated on how much fine tuning the model requires, regardless of its uncertainties. In particular there have been claims that the model requires fine tuning in the initial condi-
tions, eg: already a very flat Universe at the start, or homogeneity across a large number of Planck size regions.

Two very interesting talks were given in this session. Dominic Clancy presented work in which Pre Big Bang scenarios were reexamined within the broader class of anisotropic cosmological models. The pre big bang model was initially proposed using a flat Friedmann model as its setting. The model appeared to be considerably more contrived when the effects of curvature were considered. In the work presented in this talk it was found that the combined effects of curvature and anisotropy would tighten further the conditions for a successful model. It was found that in this class of models the onset of inflation may even be prevented. In general the conditions for a successful model appear to be more stringent than for isotropic models.

David Wands gave a talk on the perturbation spectrum in these scenarios. The graviton and dilaton perturbations produced on large scales were found to have steep blue spectra that leave essentially no perturbations on large scales. However other massless fields, including antisymmetric tensor fields also present in the low-energy string action, may have very different perturbation spectra. It was shown how the symmetries of the action can be used to calculate the perturbations spectra. In some cases (eg. axion fields) the perturbations on large-scales may have a scale-invariant Harrison-Zel’dovich spectrum suitable for producing large-scale structure in our universe.

3. Inflationary cosmology

Inflationary cosmology has become the mainstream of modern cosmology. It has become so trendy that quite frankly I can’t be bothered to review it, and I will proceed to summarise the talks given in the corresponding session.

A very interesting variation on inflationary scenarios, labelled warm inflation, was presented by Arjun Berera. In this scenario, the standard supercooling followed by reheating is bypassed. Instead, the radiation energy density smoothly decreases during an inflation-like stage and with no discontinuity enters the subsequent radiation-dominated stage. Scale factor solutions in this scenario which do not conflict with observations were presented. It was shown that these scenarios predict a unique feature, which should distinguish them from standard inflation: a large angle cut off in the cosmic radiation anisotropy. Likelihood fits to DMR 4 year maps were presented. Finally some discussion was given of thermally induced density fluctuations in these models.

Reheating in standard inflation was the subject of two talks. In the first
Bruce Basset discussed geometric reheating after Inflation. It was shown that purely gravitational couplings during reheating induce parametric production of scalar, vector and tensor particles from the vacuum due to the coherent energy density oscillations of the inflaton. Implications to baryogenesis were discussed. Furthermore the resonant amplification of the tensor perturbations was found to be wavelength dependent, thus breaking the scale invariance of the gravitational wave spectrum.

In the second talk on reheating, Stephan Ramsey talked on the non-equilibrium inflaton dynamics and reheating. An analysis of nonperturbative, nonequilibrium dynamics of a quantum field in the reheating phase of inflationary cosmology was presented. This included the full back reaction of the quantum field on the curved spacetime, as well as the fluctuations on the mean field. Several corrections and criticisms to the standard lore were presented.

Open inflation is another popular area of research, and Takahiro Tanaka gave a talk on the initial spectrum of cosmological perturbations in the one bubble open Universe. The dynamics of the quantum fluctuations of the inflaton field with $\lambda \phi^4$ potential was studied. Several results were presented aiming at verifying the ansatz of the quantum-to-classical transition that is often assumed in the standard evaluation of the amplitude of the primordial fluctuations.

Finally Valerio Faraoni examined the effects on inflation of non-minimal coupling of the scalar field. It was argued that the coupling $\xi$ of the scalar field to the Ricci curvature in a curved spacetime is not a free parameter. From this point of view the consistency of the most popular inflationary scenarios was evaluated. Observational constraints on $\xi$ were discussed.

4. Topological defects in cosmology

The last year saw a number of papers dismissing topological defects as candidates for structure formation. Ruling out defects even became fashionable among certain levels of society. Improved calculations on more powerful computers are normally blamed for this. In some cases it also now appears that defects’ inability to generate large scale structure is a generic feature of scaling defects. The fact that the population of scientists working in the field has by no means decreased testifies to how seriously these claims are being taken. On the other hand it is true that concrete rebuffal of these claims, based on quantitative work of comparable quality, has been slow to emerge.

In any case there is clearly room for plenty of work on the field. In particular it is clear that the uncertainties plaguing calculations, most notably for cosmic strings, are still there as much as they were before. A better
assessment of the systematic errors in all the simulations is still required. In fact in the case of local cosmic strings a proper computer simulation is still missing. As for the arguments concerning generic defects, it is clear that the parameter space surveyed is rather limited. In fact it is not even clear that it covers local cosmic strings.

A most interesting talk was given by Supratim Sengupta, in which a new mechanism for defect-antidefect pair production was discussed. The mechanism was illustrated by numerical work on first order phase transitions in a global U(1) theory, but the results may be applicable in more general theories, and in second order phase transitions. It was shown that as the true vacuum bubbles grow and collide, the kinetic energy released may flip the phase of the order-parameter field, resulting in the formation of a vortex-antivortex pair. Conditions for this process to take place were identified, and its efficiency compared with the Kibble mechanism. It was found that if the nucleation rate is low, and damping not too important, this mechanism may dominate over the Kibble mechanism. If this is the case, no doubts the standard picture of defect formation will require extensive revision. More interesting still is the possibility that a different scaling solution will be achieved if, as is the case with this mechanism, only string loops are formed during the phase transition.

Brandon Carter then presented some work on string loop dynamics and vorton formation. Recent progress in the treatment of the dynamics of conducting cosmic strings was reviewed, with emphasis on the allowance for electromagnetic self interaction. This formalism was then applied to the problem of evolution of circular loops towards “vorton” equilibrium states.

There were two talks in which topological defects and inflation appeared combined together. Nobuyuki Sakai discussed a particular brand of inflationary scenarios in which inflation starts inside a topological defect, most notably Planck scale monopoles. In this talk, this so-called topological inflation, was reanalysed in the context of Brans-Dicke gravity. It was found that any expanding monopole eventually turns to contract and becomes stable, contrary to the case in the Einstein theory. It was then stressed that as a realistic model, however, this model could not avoid fine-tuning of the coupling constant. Shinta Kasuya, on the other hand, discussed the formation of topological defects during preheating. The dynamics of a scalar field $\Phi$ with potential $g(|\Phi|^2 - \eta^2)^2/2$ was studied, and fluctuations due to different effects were examined: namely fluctuations due to parametric resonance and the negative curvature of the potential. It was found that over a large parameter region GUT defects will not be produced after inflation.

Finally Anjan Ananda Sen reported work on the gravitational fields of both local and global cosmic strings in the context of Brans-Dicke theory. A class of solutions for global strings was presented, and inconsistencies
plaguing the local string case were pointed out. The motion of photons and material particles in these space-times was also examined.

5. Miscellaneous

The session closed with four talks in which various general problems in cosmology were addressed. Daksh Lohiya reexamined nucleosynthesis in his alternative cosmological scenario. Neeraj Upadhyaya addressed the baryogenesis problem from the point of view of primordial black holes. Amitabh Mukerjee presented a study of a phase transition. Yasusada Nambu talked on cosmological perturbation theory.

In Daksh Lohiya’s model of the Universe the scale factor $a$ is proportional to the cosmic time $t$. The flatness, horizon, and cosmological constant problems appear to be avoided. However in this talk the focus was on how nucleosynthesis proceeds in this scenario. It was found that right amounts of Helium and other heavy elements are obtained. On the other hand, deuterium, and other light elements, are not produced in sufficient amounts.

Neeraj Upadhyaya gave a talk on black hole baryogenesis. The evolution of the masses of a collection of black holes created immediately at the end of inflation was studied, taking into account both the accretion of background matter by the black holes as well as the mass loss due to Hawking emission. The baryon excess produced in this scenario was evaluated and the implications for the current matter-antimatter asymmetry discussed.

Amitabh Mukerjee gave a very interesting report on work under way aiming to study a phase transition in $\varphi^4$ theory with $\varphi^3$ symmetry breaking. This numerical work is motivated by recent work on the one-loop effective potential in $\varphi^4$ field theory at finite temperature. The main purpose of this work is to determine the nature of the phase transition.

The session closed with a talk by Yasusada Nambu on the solution of the gauge invariant cosmological perturbation equations in long-wavelength limit. A new method for deriving exact solutions of the gauge invariant perturbation equations in a flat FRW universe with scalar fields was presented. This method finds pertinent application in the case where there are many scalar fields.

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