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Summary Talk: Cosmology and Gravitation

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The works on Cosmology and Gravitation presented during the XXI Brazilian National Meeting on Particle and Fields (BNMPF) are briefly reviewed.

I Introduction

The Brazilian National Meeting on Particle and Fields (BNMPF) is certainly one of the most important annual scientific events in Brazil. It brings together more than 250 researchers working in the area and, specially for graduate students, it is an excellent school and a great opportunity to present and discuss work done and in progress with a broad audience.

As concerns the number of participants and presentations, Cosmology and Gravitation is traditionally the second sub area of the BNMPF. Field Theory is the first one. During the XXI meeting a total of forty six works in Cosmology and Gravitation were reported. The number of total presentations during the last five years was roughly the same. This year, however, due to modifications in the selection criteria of the submitted works, the number of panels surpassed the oral ones. We had 16 oral communications and 30 panels.

Is the BNMPF representative of the research done in Gravitation and Cosmology in Brazil? I believe it is very representative of the research done on Gravitation, mainly if we consider the works presented during two or three consecutive years. The emphasis of the vast majority of the presentations is theoretical but we are beginning to witness a welcome change with increasing number of experimental and more phenomenological works. Besides the BNMPF meeting (that is organized by the Brazilian Physical Society), the Brazilian Astronomical Society (SAB) also organizes an annual meting. Therefore, in Cosmology the research is not so representative (as in Gravitation) of the totality of the community work, since some researchers working, for instance, in extragalactic astronomy, prefer to present their works in the SAB meeting. I believe it would be interesting if we could find ways to diminish this gap.

On Cosmology and Gravitation we had one plenary and two parallel talks during the meeting. In a pedagogical plenary talk, R. H. Brandenberger presented a review of the inflationary scenario. He emphasized recent progresses done and outlined some conceptual problems that still remain in inflationary cosmology. With considerable detail, he discussed the role of parametric resonance in the reheating phase at the end of inflation. He considered the fluctuation problem, or the necessity to fine tune a parameter in potential driven inflation to make theory compatible with observations. The fine tuning is necessary in order to have a sufficiently small amplitude of the mass fluctuation corresponding to some wavelength λ, when this mode re-enters the Hubble radius. He also discussed the trans-Planck-scale physics problem (that appears in some models of inflation) and the cosmological constant problem that is even more severe in inflationary cosmology than usually [1].

R. Opher presented a provocative parallel talk where he critically discussed the role of dark matter in Cosmology [2]. The idea of dark matter appeared in the 30's when F. Zwicky suggested that galaxy clusters should have a large amount of matter in some nonluminous form. Since then the search for this component in large and galactic scales has dominated cosmology. However, after more than sixty years the exact nature of the dark matter is still unknown. For instance, the bulk of it can not be baryonic. Standard Big-Bang nucleosynthesis is not compatible with the total amount of dark matter inferred from large scale observations being baryonic. More recently, the very existence of dark matter is beginning to be challenged by some cosmologists. Their motivation is the following. Although inflationary cold (at decoupling) dark matter (CDM) models with a cosmological constant successfully explain the large scale structure of the Universe, the cosmic acceleration and the Cosmic Microwave Background anisotropies, there are some observations, on galactic scales, that collisionless CDM models seem not be able to account for. For instance, high resolution simulations with collisionless dark matter show cuspy halo density profiles, while observations indicate uniform density profiles. Further, these simulations also show much more sub-structure in the halo of a typical galaxy than observed. There are currently two ways to deal with these problems. One is to assume that dark matter is self interacting. A candidate for self-interacting dark matter is suggested, for instance, in ref. [7]. A more extreme possibility is to modify the Newtonian force law for small accelerations as in the modified nonrelativistic dynamics (MOND) suggested by Milgrom more than fifteen years ago. Opher took the later point of view and I direct the interested reader to see his contribution in this volume [2].

Finally, in the second parallel section W. Wang discussed critical phenomena in gravitational collapse [3].

II Cosmology

A total of sixteen presentations on Cosmology were exhibited during the meeting. Almost half of them were related to different aspects of the inflationary scenario. In three projects, developed by I. D. Soares, H. P. Oliveira and collaborators, the dynamics of a preinflationary phase of the Universe, and a possible chaotic exit to inflation are investigated [4]. In other three works J. A. S. Lima, J. M. F. Maia and collaborators analyzed some thermodynamics properties of inflationary models, specially during the reheating phase and deflation [5]. A. Maia Junior and F. R. V. B. de Melo also considered the possibility of exponential growth of particle in a regime out of parametric resonance.

We had three works on structure formation and perturbation theory. M. Makler *et al.* showed a comparative analysis of four local Lagrangian approximations for the non linear evolution of large scale structures [6]. V. T. Zanchin *et al.* derived equations describing the growth of energy density perturbations for a class of Λ-decaying cosmologies and discussed some properties of the models. A study of how the software Maple can help in obtaining correct equations of perturbation theory was presented by M. G. C. Batista.

In the interface between particle physics and cosmology we had two works by R. Rosenfeld and collaborators. In the first one a scalar gauge singlet coupled to the Higgs boson is suggested as a candidate for self-interacting dark matter [7]. In a second presentation, now with L. L. Lengruber, by using the detected flux of ultra high energy cosmic rays, and two different models for the X particle distribution, they obtained constraints on τ_X, M_X and $\Omega_X h^2$.

By taking into account corrections due to linear deviations from the Hubble flow, Calvão *et al.* showed that the Alcock-Paczynski test, as applied to the quasar correlation function, is a powerful test to constrain cosmological parameters. The method of Cosmic Crystallography applied to incomplete catalogs of cosmic sources was also discussed by A. Bernui [8].

On mathematical cosmology two works were presented. M. L. Bedran *et al.* generalized the Mattig's equation for a single fluid with an equation of state of the form $p = w\rho$. G. Oliveira-Neto showed a solution to the Einsteins's equations in 2+1-dimensions for a spacetime with line symmetry and where the matter content is a massless scalar field minimally coupled to gravity.

III Gravitation

Thirty works on gravitation were exhibited during the meeting . This represents $\sim 2/3$ of the total works presented in the area. One important project, lead by O. D. Aguiar, is the GRAVITON project. It has seventeen members and collaborators from several Brazilian research institutes (INPE, IFUSP, ITA, UNIBAN and CEFET) and one member from Leiden University (Holland). The goal of the project is to build a spherical resonant mass antenna to detect gravitational waves. In the first phase of the project, the Mario SCHENBERG detector will be built. It will have a radius $r \sim 60$ cm, mass $M \sim 1200$ kg and will operate in very low temperatures ($15 - 20$ mK). It will be sensitive to waves in the bandwidth 3.0 to 3.4 kHz of quadrupole modes that arrive on earth with amplitude $h > 10^{-22}$ Hz$^{-1/2}$. In this band its sensitivity will be comparable or even better than those from large laser interferometers (as LIGO and VIRGO). Two similar antennas are also being built, one in Frascati (Italy) and the other one in Leiden (Holland). One of the main advantages of the detector is that it will be possible to localize the gravitational source as well as the wave polarization. Possible sources to be detected are: supernovae collapse, quakes and neutron stars oscillations, excitations of quasi-normal quadrupole modes of black holes with mass $\sim 3.8\, M_\odot$ and coalescence of neutrons stars and black holes.

Three works were presented by the GRAVITON group. The first phase of the project was reported by O. D. Aguiar. C. Frajuca considered three different kinds of transducers and discussed the reason why the inductive superconducting one is the best option for the project. L. A. Andrade *et al.* calculated the expected noise of a spherical gravitational wave detector coupled to optical transducers. Two related theoretical works were presented by F. Kokobun and collaborators.

Seven works on topological defects, showing different aspects of how condensed matter can be a laboratory for gravitation were reported during the meeting. This interesting subject is currently being developed, mainly, in two universities located in the northeast of Brazil (UFPe and UFPb). For a review see ref. [9]. Also on gravitational analogs V. A. De Lorenci *et al.* discussed some geometrical aspects of nonlinear light propagation [10].

The consistency of geometrodynamics and quantum field theory in the Bohm-de Broglie interpretation was discussed by E. S. Santini and N. Pinto-Neto [11]. A mini-review was presented by M. D. Maia on the quantum theory of Brane-worlds [12]. V. Mostepanenko and M. Novello considered a Yukawa type correction to the Newtonian gravitational potential of the form:

$$V(r_{12}) = -\frac{GM_1M_2}{r_{12}}(1 + \alpha\, e^{r_{12}/\lambda}).$$

Some theories predict such a modification to the Newtonian law in submillimeter range. In their work the application of the Casimir effect to constrain the parameters α and λ is discussed [13].

A new metric nonsymmetric unified theory of gravitation and electromagnetism was presented by S. Ragusa. It was obtained by requiring that, independently of the value of a new universal constant present in the theory, the usual Maxwell type of equations appear for the antisymmetric part of the metric $g_{[\alpha\beta]}$ in the flat spacelinear approximation [14].

D. Muller and R. Opher investigated the orbits in MOND theory within a dwarf galaxy ($M_d \sim 10^8 M_\odot$) at a distance ~ 100 kpc from a neighboring galaxy such as ours ($M_f \sim 10^{11} M_\odot$). By using the numerical technique of surfaces of section they analyzed the stability of the phase-space orbits in the dwarf galaxy [15].

L. C. T. Guillen *et al.* obtained a conserved energy-momentum gauge current for the gravitational field in the context of the teleparallel equivalent of general relativity [16]. By rewriting the gauge gravitational field equations, they showed that they become Einstein's equations and that the gauge current reduces to the usual energy-momentum pseudotensor of the gravitational field.

Two works were reported in classical field theory of spacetime. F. Parisio and F. Moraes discussed how magnetic field can control exotic matter in a special kind of wormhole. S.E.P. Bergliaffa and K. E. Hibberd investigated the restrictions that an axisymmetric and stationary spacetime should satisfy to have a perfect fluid as source of curvature. They showed that the rotating wormhole presented in the literature can not be described by a perfect fluid or by a fluid with anisotropic stresses [17].

Four works on quantum field theory in curved spacetime were presented during the meeting. D. A. T. Vanzella and G. E. A. Matsas investigated the influence of gravity on quantum processes which occur in the interior of neutron stars. They focused their analysis on the neutronization process, $p^+\, e^- \to n\, \nu_e$, which is important in cooling of neutron stars with temperatures up to $\sim 10^9$ K. By using a semiclassical approach and a two-dimensional toy model, they showed that the gravitational field plays a negligible role in the process. However, as they pointed out, in a more realistic calculation the results might change [18]. The dynamics of a massless scalar field in Reissner-Nordstrom spacetimes was investigated by C. Mendes [19]. Entropy bound for a rotating system from anti-de Sitter black hole was reported by B. C. Melgar [20]. H. Chávez and L. Masperi addressed the scattering of a Majorana fermion by a local cosmic string.

Three works on gravitational collapse were exhibited. By using techniques of qualitative theory of dynamical systems O. C. Castellani and H. P. Oliveira investigated critical phenomena in gravitational collapse in the theories of Relativity and Brans-Dicke. M. C. de Lima *et al.* studied the structure of Robinson-Trautman solutions of Einsteins's field equations in vacuo for which the angular dependency of the metric functions is not analytic. They showed that the non-analyticity produces new physical effects [21]. A study on the gravitational collapse of perfect fluid with the zeroth and second kinds of self-similarity were presented by J.F.Villas da Rocha *et al.*.

Two more mathematical works were also presented. Properties of the Levi-Civita solutions coupled with electromagnetic fields was investigated by A. Y. Migueloti *et al.*[22], and the study of spacetime structure from Weyl spinors and Clifford algebras by R. da Rocha and J. Vaz Jr..

IV Conclusion

There is much interesting activity in the area of Cosmology and Gravitation. This is certainly the main conclusion we can get from the XXI BNMPF. The quality of the works presented during the meeting also shows that our community is becoming more mature and we can feel a growing concern on more phenomenological and observational questions. In this respect I would like to emphasize again the importance of the GRAVITON project, that is the first experimental project on gravitation in Brazil.

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