Golden Jubilee meeting on gravitational radiation

The Raman Research Institute hosted a very pleasant and informative meeting on 11–12 December 1997, covering a number of topics of key importance in gravitational wave astrophysics. The meeting consisted of ten plenary sessions providing an overview of theoretical and observational aspects of gravitational radiation.

The construction of LIGO, VIRGO, GEO and other interferometric gravitational wave detectors has opened up the possibility of making astronomical observations using gravitational radiation. Harald Lüeck presented a historical overview of the development of the experimental techniques and technological improvements have made these detectors possible. The signal-to-noise ratio for these detectors will be quite low so sophisticated data analysis methods will be needed. Addressing this problem, S. Dhurandhar discussed how the matched filter method will be used to detect gravitational wave signals. He reviewed recent work in detecting signals artificially injected into sample background noise. B. Sathyaprakash provided us with an overview of the types of sources which LIGO may be able to detect, including the inspiral of compact binaries, pulsars and supernovae, to name a few. One of the possible sources is rapidly rotating neutron stars which become unstable due to the Chandrasekhar–Friedman–Schutz mechanism. Nils Anderson provided an introduction to this instability and described his recent work that suggests that axial perturbations may play as important a role as the polar modes. In the discussion of possible sources of gravitational radiation it is usually assumed that general relativity is, in fact, the correct theory of gravity. Gilles Esposito-Farese reviewed the extent to which general relativity has been tested. He stressed that although general relativity has been successfully tested in the weak field limit, there are scalar–tensor theories which agree with general relativity in the weak field but provide different strong field predictions, such as boson stars.

The bulk of our knowledge of gravitational wave sources (e.g. compact binary systems) comes from perturbation theory. The main problem of interest is to find the relation between the outgoing radiation and the matter and motion of the source. The remaining speakers discussed different aspects of this problem with reference to the inspiral of neutron star and black hole binaries. Blanchet discussed a method based on matching of expansions in near, exterior and wave zones which he calls the multipolar-post-Minkowskian approach. This approach allows one to calculate various nonlinear nonlocal effects such as tail radiation, tails of tails and memory terms. Clifford Will presented a different approach which he has dubbed DIRE (Direct Integration of the Relaxed Einstein equations). DIRE addresses the problem of divergent integrals in the near and far zones and has been used to compute post-Newtonian corrections to 2.5 order, agreeing with results discussed by Blanchet. Given that we know the radiation emitted by a source, can we predict the backreaction onto the system caused by this emission? This problem, known as radiation reaction, was discussed by Bala Iyer. He presented an approach which assumes the validity of the principle of energy balance: the work done by the reactive force is equal to the negative of the energy flux. It is important to verify that perturbation theory provides the correct results for all problems which can be solved exactly. Misao Sasaki discussed black hole binary inspiral in the limit that one of the black holes is much less massive than the other. This approach has been used to show the validity of the post-Newtonian expansion in this limit. The holy grail of numerical relativity is the exact computation of binary black hole mergers, and Ed Seidel reported on recent progress in this direction. In particular, he focused on highly distorted isolated black holes, and showed that the full nonlinear evolution agrees well with the results of perturbation theory in the regimes where perturbation theory should be valid. I thank our hosts, Bala Iyer, Joseph Samuel and all the students at the Raman Research Institute for organizing such an enjoyable and interesting conference.

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Golden Jubilee meeting on quantum general relativity

On 13–14 December 1997 just prior to GR15, the Raman Research Institute, Bangalore hosted a discussion meeting on quantum general relativity as part of its Golden Jubilee celebrations. The plan was to have three talks each morning and one in the afternoon, then followed by longer discussion sessions. The beautiful setting of the Institute, together with the unforced and smooth organization indeed created a perfect atmosphere for inspiring discussions. The topics covered a fairly wide range, from $(2+1)$-dimensional quantum gravity, loop gravity, lattice approaches and 3-dimensional topology to the quantum theory of black holes and, in particular, the issues associated with black hole entropy. Canonical approaches dominated the scene, but this was partly due to the unfortunate fact that Ashoke Sen had to cancel his talk on string calculations of black hole entropy.

The first speaker was Steve Carlip who presented five main lessons that could so far be learned from $(2+1)$-dimensional gravity. He listed numerous consistent ways for quantization and pointed out their partial inequivalences. For example, consistent quantizations with or without topology change exist, hence topology change is consistent with, but not required by, quantum gravity. Another striking lesson concerns the Euclidian path integral approach. In $(2+1)$-dimensions it can be shown that the contribution from the many

arbitrarily complicated interpolating topologies cannot be neglected (as is sometimes assumed). Once more it became clear that, despite all differences to (3 + 1)-dimensions, (2 + 1)-dimensional gravity is an important and useful test bed to study concepts and expectations in quantum gravity.

Carlo Rovelli gave a large scale survey on progress and problems in loop quantum gravity. Recent progress in physical predictions at the Planck scale mainly originate from calculations of spectra of operators (on the auxiliary Hilbert space of pure gravity) representing area and volume of two- and three-dimensional subsets. In absence of any matter degrees of freedom these subsets are mathematically specified in a non-diffeomorphism invariant fashion. Progress on the mathematical side was also reported. The long standing problems concerning the lack of a scalar product, overcompleteness of the loop basis and the implementation of the reality conditions seem to be settled now. Anomaly-free regularizations of the super-hamiltonian have been constructed, but there is still ongoing debate as to its physical correctness, since it does not define a deformation of the classical constraint algebra and hence seems to reproduce the wrong classical limit. Rovelli ended by emphasizing the complementary strengths and weaknesses of loop quantum gravity and string theory.

Renate Loll reported on the status of discrete approaches to 4-dimensional quantum gravity based on the Einstein action. She discussed results from Hamiltonian path-integral approaches with connection variables and dynamical triangulations. The common open problem is the absence of appropriate measures on the discretized configuration spaces. The choices explored so far seem too simple to lead to an interacting, diffeomorphism-invariant field theory.

There were two talks on topological issues in (3 + 1)-dimensional canonical gravity. Domenico Giulini started with discussing the role and significance of three-dimensional topology in the classical and quantum theories. One of the issues addressed was whether and how classical topology leaves its fingerprints in the quantum theory. In this context the mapping class groups of three-dimensional manifolds were argued to be the natural objects to look at, since they carry significant amounts of topological information and also enter the quantum theory through the reduction procedure. Giulini concluded by listing some general properties of 3D mapping class groups, like finite presentations, residual finiteness and semi-direct product structures. Sumati Surya reported on some work using Mackey theory to find interesting representations of 3D mapping class groups and discussed their physical implications. Thinking of the 3-manifold as configuration of elementary 'geons' (i.e. prime-manifolds), she showed and discussed the general absence of spin–statistics correlations at the kinematical level, and also the possibility of novel 'cyclic' statistics types which she encountered with three RP-3 geons.

Two talks and an additional discussion session – filling the gap that the cancellation of Ashoke Sen's talk left – were devoted to black hole entropy. V. Frolov's talk centered around the problem of universality of black hole entropy which, despite some impressive derivations, like e.g. by counting states of D-branes, is still an open one. He discussed the idea of entanglement entropy, some of its problems, and how they can be solved in some models of induced gravity. He reported on recent work on such models showing that universality exists within a special class. In Parthasarathi Majumdar's talk the different approaches to understand black hole entropy were compared. In particular, the string calculations and viewpoints now came to their right. A final discussion session, solely devoted to all kinds of questions relating to black hole entropy, marked the end of this most pleasant meeting.

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RESEARCH NEWS

3-D circuit boards by a novel electrochemical process

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Electrochemical methods such as electroplating and electroless plating have been an integral part of micro electronic revolution. Electrochemical methods are used in printed circuit board fabrications and in precious metal plating which provide the substrate with the necessary electrical conductivity besides corrosion protection. With the ever-increasing complexity and component density in the electronic circuit boards, there is a need for miniaturization which has led to a great deal of research in the area of nanolithography. In this context, Jean-Claude Bradly *et al.*[1] offer an interesting alternative to the conventional techniques that has the potential for being a technique of choice in future.

The principle of this technique is based on the fact that the potential applied to a particle induces electrochemical reaction due to electric field-induced polarization. This method has been used to provide electrical contacts between metal particles physically isolated from an external circuit. In the experiments, the authors have aligned two copper particles perpendicular to platinum electrodes in an aqueous medium. For instance, one can use a small sized printed circuit board that is covered with a grid of holes capped by a copper ring[2]. When an electric field is applied, electrochemical oxidation of copper to cupric ions occurs on one particle while reduction of water occurs on the other particle electrode. This leads to a formation of a fractal wire of copper that is formed due to diffusion-limited aggregation that begins to interconnect the two particles. In other words, the particles