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Summary of classical general relativity workshop

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Abstract. This is a summary of the presentations at the parallel session in the classical general relativity workshop of the ICGC-2004.

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In the classical general relativity workshop, ten lectures were presented on various topics. The topics included aspects of black-hole physics, gravitational collapse and the formation of black holes, specific stellar models like a superdense star, method of extracting solutions by exploiting Noether symmetry, brane world and its application in the building up of cosmological models, dynamics of extended bodies in a gravitational field and Sagnac effect.

B S Ramachandra spoke on his work in collaboration with C V Vishveshwara and K R Nayek on Vaidya–Einstein–Kerr (VEK) black holes. These are actually axially symmetric black holes placed against the background of a non-flat Einstein universe. Naturally, these black holes, unlike the Kerr black holes, are asymptotically non-flat. They investigated the geometry of the event horizon by computing the equatorial and polar circumferences and the oblateness of the horizon. The surface area of a VEK black hole is seen to be non-trivially coupled to the rotation in sharp contrast to the Kerr black hole in an otherwise empty universe. The Gaussian curvature and the global embedding of a VEK black hole were discussed. The motion of a test particle in a circular geodesic and the gyroscopic precession were also studied in detail. The geodesic was quite different from that in a Kerr black hole. The gyroscopic precession was found to be affected by the background directly and also in diguise in the form of its coupling with the rotation of the black hole. Ramachandra also showed that these VEK black holes are type D. Using the Newman–Penrose formalism, the spin coefficients were calculated and compared with those of a Kerr black hole. The Killing spinor and the Killing Yano tensor were also calculated. As a special case, in the absence of rotation, the Vaidya–Einstein–Schwarzchild black holes was also discussed.

Soumen Basak talked about the acoustic analogue of a black hole. The possibility of the formation of an 'acoustic event horizon' from the regions of flow of fluid with a barotropic equation of state was pointed out by Unruh. Basak used the analogy between a shrinking fluid vortex with a sink at the origin and a rotating black hole with an ergosphere and showed that a sound wave is indeed reflected from the vortex with some amplification, depending on the angular velocity of the vortex. This is analogous to the super-radiant scattering by a rotating black hole in an asymptotically flat background and is hence termed as 'super-resonance'. He also discussed the possibility of observation of this phenomenon, particularly for inviscid fluids, where vortices with quantized angular momenta may occur.

P I Kuriakose reported his work with V C Kuriakose on the quantization of a massive scalar field in the space-time of a Reissner–Nordstrom black hole. The Hamiltonian density in the given space-time is found to be non-trivially affected by gravity. They calculated the partition function and the state equation of radiation.

Rituparna Goswami presented the work done in collaboration with Pankaj Joshi and Naresh Dadhich on the role of shear in gravitational collapse. In the case of an endless gravitational collapse of a bounded matter distribution, the final product could be either a black hole or a naked singularity. As quite a few examples of the possibility of the formation of a naked singularity were worked out, it is important to identify the physical process which separates the formation of these two final products. Starting from a very general form of matter and physically reasonable initial data, Goswami showed that the end result of such a collapse will be a black hole if it is homogeneous and shear-free. But when a naked singularity is formed, there has to be non-vanishing shearing stresses. They also showed that in the vicinity of the singularity, homogeneity and isotropy imply each other. In the absence of shear, the collapse proceeds at the same rate in different directions and gives rise to a covered singularity whereas, a shear creates a distortion which in turn delays the formation of an apparent horizon and thus produces a naked singularity.

Ramesh Tikekar spoke on the work on superdense star models in collaboration with Kanti Jotania. For a typical matter distribution for the interior of a star, which has long been in use after the Vaidya–Tikekar superdense star model, they presented a general solution for the metric in hyperboloidal space-time. Tikekar indicated that these solutions would be useful in the description of a superdense star in many a realistic case. Through some numerical computations carried out by them, it was shown that physically relevant models of compact and ultra-compact stellar objects could be obtained through their work if the values of quantities like the surface density, mass-to-radius ratio etc. of the star were known.

Abhik Sanyal talked about the method developed by him along with Bijan Modak, E Piedipalumbo and C Rubano for obtaining solutions for the metric by exploiting Noether symmetry. He explained the method with a particular example where the action contains a square term of the curvature scalar and is non-minimally coupled to a scalar field. The coupling and the scalar potential are arbitrary to start with. By demanding that the action admit a Noether symmetry, they could obtain coupling between the gravity and the scalar field and the form of the scalar potential

The solutions for the metric could also be obtained. The interesting feature of this technique was that the solutions were obtained directly from the Noether symmetry consideration and one did not have to handle the Einstein equations. Sanyal also mentioned that the solutions they obtained admitted a power law inflation.

Ratna Koley reported the investigations done along with Sayan Kar on scalar kinks and fermion localization in warped space-time. They derived the solution for the scalar field in the background of a negative Ricci curvature for various scalar field potentials. The solutions looked the same as those in a flat background without warping. However, these were not the solutions for the full non-linear Einstein-scalar field equations. With a sine-Gordon potential, they derived a class of solutions for the full Einstein-scalar field system. In this case, the contribution from a negative cosmological constant plays a crucial role. She discussed the localization of spin-half fermions on the brane in the presence of the exact sine-Gordon kink and the warp factor with particular emphasis on massive fermions.

Lefteris Papanatanopoulos brought the brane-world scenario once again into picture when he discussed a cosmological model in the Randall–Sundrum brane world. In this work, the Einstein–Hilbert action was modified by curvature correction terms, e.g., a four-dimensional scalar curvature from induced gravity on the brane and a five-dimensional Gauss–Bonnet term. The combined effects of the curvature terms could remove the infinite density Big Bang singularity by fixing some parameters. An interesting feature was that a radiation brane could give rise to an accelerated expansion near the minimal scale factor. This acceleration was driven by geometric effects alone and not by any inflaton field or an effective negative pressure. The late-time behaviour of the cosmological model was shown to be more like the conventional scenario.

In general relativity, a gravitating object can be of any arbitrary shape or size, but the dynamics one describes is that of a test particle. Parampreet Singh talked about the way in which the dynamics of an extended object can be described in an action-based method. An action could be constructed for a body with multipole moments and it yields the equations of motion of the body in the weak field limit. The quantum phase shifts in the wave function of an extended object, due to the coupling between these multipole moments and the background gravitational field, were obtained. These were indicated to have some observable effects. The speaker also indicated that this theory could be quantized and thus might play a useful role in the interface between general relativity and quantum mechanics. This work was done by the speaker with Naresh Dadhich and Jeeva Anandan. Unfortunately, Jeeva Anandan passed away after the completion of the work. Naresh and Parampreet dedicated this work to the loving memory of Jeeva Anandan.

Swapan Ghosal talked about synchrony gauge in classical and relativistic Sagnac effect. His work along with B Raychaudhuri, M Sarkar and S Nepal showed how the gauge term corresponding to the 'standard synchrony' in the classical world is reflected in the expression for the phase shift in Sagnac effect. A recently posed paradox concerning the anisotropy of the speed of electromagnetic radiation was discussed in the light of their work. They also refuted the apparently widely supported view that the desynchronization of clocks is the root cause of the Sagnac effect.