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On the propagation of gravitational waves in matter-filled Bianchi I universe

In this paper we apply the Regge-Wheeler formalism to study the propagation of axial and polar gravitational waves in matter-filled Bianchi I universe. Assuming that the expansion scalar Θ, of the background space-time is proportional to the shear scalar σ, we solve the background field equations in the presence of matter (found to
behave like a stiff fluid). We then derive the linearised perturbation equations for both the axial and polar modes. The analytical solutions in vacuum spacetime could be determined in an earlier paper [1] in a relatively straightforward manner. However, here we find that in the presence of matter, they require more assumptions for their solution,
and bear more involved forms. As compared to the axial modes, the polar perturbation equations contain far more complicated couplings among the perturbing terms. Thus we have to apply suitable assumptions to derive the analytical solutions for some of the cases of polar perturbations. In both the axial and polar cases, the radial and temporal solutions for the perturbations separate out as products. We find that the axial waves are damped owing to the background anisotropy, and can deform only the azimuthal velocity of the fluid. In contrast, the polar waves must trigger perturbations in the energy density, the pressure as well as in the non-azimuthal components of the fluid velocity. Similar behaviour is exhibited by axial and polar gravitational waves propagating in the Kantowski-Sachs universe [2]. Our work is in contrast to the work done in [3], where the authors analysed anisotropic universes modelled by Kasner spacetime and Rindler wedges using the method of gauge-invariant perturbations in the RW gauge.

References:
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Email

suchetadatta93@mail.com

Affiliation

Department of Physics, St.Xavier's College (Autonomous), Kolkata, India

Author: DATTA, Sucheta (St.Xavier's College (Autonomous), Kolkata, India)

Co-authors: Mr CHAKRABORTY, Samarjit (Department of Physics, St.Xavier's College (Autonomous), Kolkata, India); Prof. GUHA, Sarbari (Department of Physics, St.Xavier's College (Autonomous), Kolkata, India)

Presenter: DATTA, Sucheta (St.Xavier's College (Autonomous), Kolkata, India)

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