Weak lensing in terms of curvature scalars and energy momentum tensor for pure gravity and plasma media

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Usually the expressions for the different optical scalars associated with the phenomenon of gravitational lensing are written in terms of components of the metric. That has the disadvantage that one has to verify if the results obtained from those expressions are really gauge invariant, especially when working at the second order in perturbation of a flat metric (weak regime). In the past[1], we have shown how the different optical scalars and the deflection angle can be written at linear order in terms of curvature scalars and the different components of the tensor energy moment. That work was recently generalized by us to include second order perturbations[2]. All these results were valid for a pure gravity situation where the possible presence of plasma media are not considered and it is assumed that light rays follow null geodesics. However, it is known that most of the astrophysical objects are surrounded by plasma, and in this case the light rays do not follow null or timelike geodesics (they follow timelike geodesics only in the homogeneous plasma case [4]).

Although recently we have shown how optical scalars can be written in terms of certain curvature scalars associated with a apropiate two dimensional optical metric [4,5], in this work we generalize the formalism of [1] and [2] to the case of dispersive media using an appropiate 4-dimensional lorentzian metric, obtaining as a corollary not only invariant expressions for the optical scalars valid for general plasma media but also for massive test particles that follow timelike geodesics of the spacetime under study. On the other hand, it is known that there exist a one-to-one correspondence between the motion of test massive particles in a pure gravitational field and that of photons in the gravitational field of a compact object surrounded by an homogeneous plasma[4]. Here we show for the first time that such correspondence can be generalized to describe the dynamics of non-geodesic motion of massive particles. As an application we show that the non-geodesic motion of an electric charged particle governed by the Lorentz force in a spherically symetric Eintein-Maxwell gravitational field can also be put in one-to-one correspondence with the motion of a photon in a non-homogenous dispersive medium. We also show that these results can be equivalently obtained by following the alternative method of Gibbons-Werner and extended to us recently by dispersive media[4].

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