General gravitational lenses of cosmological systems

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One of the main observational tools in astrophysical systems is through the study of the gravitational lens effects caused by the object of interest. So, there are numerous works that tackle the problem of weak gravitational lenses under different assumptions; but in [1] we were able to generalize previous works by relaxing the severe assumptions of Newtonian behavior in the usual weal lens studies[2, 3]. However, there are just few works that deal with weak gravitational lenses that work with this considerations and include the effects of the cosmic environment into account. We present here a detail study from first principles of the weak gravitational lens effects when the system is embedded in a cosmological framework. Our formulas have the advantage of being explicitly gauge invariant and allow us to include more general forms of matter distributions than those discussed in most standard references on the subject.

We present new results on gravitational lensing over cosmological Robertson–Walker backgrounds which extend and generalize previous works. Our expressions show the presence of new terms and factors which have been neglected in the literature on the subject. We make no a priori assumptions on the nature of the lens so, the new equations derived here for the optical scalars allow to deal with more general matter content including sources with non-Newtonian components of the energy–momentum tensor and arbitrary motion. We have been able to make all calculations without referring to the concept of deviation angle. This in turn, makes the presentation shorter but also allows for the consideration of global effects on the Robertson–Walker background that have been overlooked in the literature.

We also discuss two intensity magnifications that we define in this article; one coming from the natural physical construction in terms of observed flux and the affine distance, that we here call $\tilde{\mu}$, and the other adapted to cosmological discussions in terms of the redshift, that we call μ'. We show that the natural intensity magnification $\tilde{\mu}$ coincides with the standard angular magnification (μ).

The expressions that we present are a tool to study in more detail the missing mass problem; since we introduce equations describing gravitational lenses that describe more general situations; enabling the characterization of more general energy momentum tensors, in contrast to the usual Newtonian description of the dark matter phenomena. Our expressions do not neglect spacelike components of the energy momentum tensor.

An interesting new result is for example the presence of a redshift factor correcting the widely used expressions of thin lenses as appears in eq. (51), part 1 of reference [4] or eq. (16) of reference [5].

References

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