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On the effects of finite source and wave optics in gravitational microlensing magnification

In the geometric optics regime gravitational lensing is an achromatic phenomenon. However, certain physical situations require wave optics to be taken into account, such that the deflection angle becomes wavelength dependent and the interference between multiple images must be taken into account. These effects are particularly relevant in the case of lensing by low mass compact objects, such as Primordial Black Holes (PBHs), which could constitute the dark matter. For PBH of masses $lesssim 10^{-10} M_{Sun}$, i.e. objects with asteroid masses, the Einstein radius becomes of the same order or smaller than the light wavelength, so that wave optics must be used. This effect could, in principle, be detected in the spectrum of distant sources (stars in other galaxies or compact objects on cosmological scales) or even in the magnification of these sources. However, the finite source size impacts the wave optics signatures. In this work we study the impact of the combination of wave optics and finite sources on gravitational microlensing through the magnification. In the low-frequency limit, the light deflection does not depend on the source size, but strongly differs from geometric optics. As for high frequencies, the magnification has an oscillatory behavior, which is attenuated for higher frequencies and increasing source size. As the magnification calculation in this context is computationally intensive, we derive approximations valid for different frequency regimes and source sizes. We can use these results to optimize numerical calculations for the study of femtolensing and microlensing of low-mass PBHs, contributing to set more stringent limits on the abundance of dark matter in the form of compact objects lensing stars and extragalactic object of different sizes and distances.

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