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TIME DELAY OF GRAVITATIONAL LENSING IN A DARK ENERGY DOMINATED UNIVERSE

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Bending of light in the vicinity of a massive object is a prediction of Einstein's theory of general relativity. In a cosmological setting, light bending by intervening matter (lens) leads to the formation of multiple images of a more distant object like a galaxy. This phenomenon is known as gravitational lensing (GL). The light travel time from these multiple images to our location differs from image to image. The total time delay, which is the sum of geometric and gravitational time delays, is a measure of the overall geometry of the GL system. Thus, the time delay tells us quite a lot about the geometry of our universe because such lens systems are of cosmological extent.

The present cosmological observations indicate that about 73% of the total energy of the universe is due to dark energy. In this study, we take the dark energy into account and theoretically calculate how the GL time delay is modified in a universe dominated by dark energy, assuming a point-mass lens.

We find significant modifications to the GL time delays when dark energy is present. The time delay for the present universe with ~ 0.73 dark energy is about 3 times the time delay without any dark energy. This is a substantial change for GL time delay. In addition, we infer that the time delay is very sensitive to the vacuum energy density. Therefore, we propose that by measuring GL time delays accurately, we should be able to determine the amount of dark energy in the universe.

According to the standard big bang cosmological model, the cosmic fluid of dark energy should be isotropic as seen by any observer in the cosmos. By measuring time delays of GL systems in various directions in the sky, one should be able to deduce if the dark energy is distributed isotropically.

We also find that for a given lens with dark energy, the time delay ratio steadily diminishes as the source redshift increases. No matter how large the source redshift is, the time delay factor is about 2.4, which is a significant modification to the value of time delay without any dark energy.