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Dark Matter and Its Alternatives

ARTHUR KOSOWSKY, Rutgers University

Overwhelming evidence shows that systems ranging in size from dwarf galaxies to the universe as a whole experience much larger gravitational forces than can be accounted for by Newtonian gravitation from visible matter. Dark matter, which interacts gravitationally but not via the strong or electromagnetic force, explains many of these observations, and natural candidates for dark matter particles appear in common extensions of the standard model of particle physics. However, dark matter has not been directly detected, and some observations remain difficult to explain in the context of dark matter cosmological models. The alternative possible explanation, that we are observing a breakdown of Newton's law of gravitation on cosmological scales, has been far less studied. No successful cosmological model based on a modification of gravity has been proposed, but the hypothesis provides a simple explanation for some puzzling dark matter problems. I will review evidence favoring both hypotheses, and explain the kinds of observations which can provide definitive tests distinguishing between the two. Recent results from gravitational lensing and X-ray observations will be discussed.