

Importance of Discovering the Nature of Dark Energy

The task of discovering the nature of the “dark energy” is of obvious importance to cosmology. The apparent acceleration of the expansion of the universe is attributed to a dark energy residing in space itself, which also balances the kinetic energy of the expansion so as to give the universe zero spatial curvature, as observed in mapping fluctuations in the cosmic microwave radiation background. If the dark energy is a constant (the so-called cosmological constant) or growing then the fate of the universe is sealed: it will continue expanding forever. If the dark energy is decreasing (as in some “quintessence” theories) then it was even more important in the past, and may have played a part in limiting the formation of the largest gravitationally bound structures. In any case, through its effect on the expansion of the universe, the dark energy affects all observations of astronomical objects at large redshift.

The problem of the dark energy is also central to today’s physics. Our best attempts at a fundamental theory suggest the presence of a cosmological constant that is many (perhaps as many as 120) orders of magnitude greater than the upper bound set by astronomical observations. For decades the problem seemed to be to find a symmetry or cancellation mechanism of some sort that would make the cosmological constant precisely zero. The single greatest failure of our most promising theories (such as string theories) is that they do not satisfy this requirement. Now that a dark energy has apparently been found, the problem is even harder: not just to explain why the dark energy is so tiny compared with what would have been expected theoretically, but also to explain why it happens to be of the same order of magnitude (roughly twice) as the energy in matter at the present moment in the history of the universe. It is difficult for physicists to attack this problem without knowing just what it is that needs to be explained – a cosmological constant or a dark energy that changes with time as the universe evolves – and for this they must rely on new observations by astronomers. Until it is solved, the problem of the dark energy will be a roadblock on our path to a comprehensive fundamental physical theory.

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