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Probing strong-field gravity at the galactic center using stellar motions[1]

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The center of our galaxy contains the nearest supermassive black hole, with a mass four million times that of the Sun. The black hole's location and mass have been accurately determined by tracing the motions of a handful of bright young stars that move in tight orbits about the Galactic center, some with periods as short as 15 years. Until now, the measured orbits have been found to be consistent with Keplerian ellipses about a Newtonian point mass. But the stellar orbits potentially contain much more information: about the distributed mass in the inner parsec (consisting of faint stars, dark stellar remnants, and possibly particle dark matter); and also about the non-Newtonian contributions to the gravitational potential from the supermassive black hole. For stars nearer than about one milli-parsec from the singularity, frame-dragging torques should induce precession of orbital planes at a rate that is potentially observable after a few years' monitoring using the next generation of optical astrometric instruments, allowing a direct determination of the black hole's spin. Even more challenging would be a test of 'no hair' theorems by comparing the frame-dragging precession with that induced by the black hole's quadrupole moment. Results of detailed numerical simulations of the nuclear star cluster that include relativistic terms will be presented, which demonstrate the feasibility of testing theories of gravity using stellar orbits, given the inevitable noise from star-star perturbations and perturbations due to the unseen stellar remnants.

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