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Revisiting Stellar Orbits and the Sgr A* Quadrupole Moment

The "no-hair" theorem can, in principle, be tested at the center of the Milky Way by measuring the spin and the quadrupole moment of Sgr A* with the orbital precession of S-stars, measured over their full periods. Contrary to the original method, we show why it is possible to test the no-hair theorem using observations from only a single star, by measuring precession angles over a half-orbit. There are observational and theoretical reasons to expect S-stars to spin rapidly, and we have quantified the effect of stellar spin, via spin-curvature coupling (the leading-order manifestation of the Mathisson-Papapetrou-Dixon equations), on future quadrupole measurements. We find that spin-curvature coupling is generally a minor effect that causes errors only of order a few percentage points, but for some orbital parameters, the error can be much higher. We re-examine the more general problem of astrophysical noise sources that may impede future quadrupole measurements, and find that a judicious choice of measurable precession angles can often eliminate individual noise sources. We have derived optimal combinations of observables to eliminate the large noise source of mass precession, the novel noise of spin-curvature coupling due to stellar spin, and the more complicated noise source arising from transient quadrupole moments in the stellar potential.

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