Masses of Nix and Hydra

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We have used the two discovery observations of Nix and Hydra from 2005, the two confirmation observations from 2006, and the twelve prediscovery observations from 2002 and 2003, as well as available observations of Charon, to perform a four-body orbit solution for the Pluto system. Mutual perturbations have placed constraints on the masses of each member of the system. Previous work had already placed useful limits on the masses of Pluto and Charon, as well as their densities, given the known sizes of the bodies based on stellar occultation and mutual event observations, therefore our new work is aimed at placing constraints on the masses of Nix and Hydra. The best-fit GM values for Nix and Hydra are 0.036 ± 0.037 and 0.021 ± 0.042 km^3 sec^{-2}, respectively. At the one-sigma level, it appears that we can rule out masses near the upper limit of what is physically reasonable (corresponding to a combination of low albedos and high densities) for both satellites. Unfortunately, we do not yet have a useful lower limit on the mass of either satellite, though new HST data may be sufficient to do so. We have determined empirically that the rate of precession of the line of apsides of Charon's slightly eccentric orbit is proportional to the combined mass of Nix and Hydra, but in no case is the rate high enough to explain the difference in the longitude of periapsis derived from the 1992-1993 and the 2002-2003 observations. Instead, we believe that offsets between the center of mass and the center of light have adversely affected the earlier orbit solution for Charon. The orbits of the three satellites are coplanar to within a fraction of a degree, which argues for a common formation mechanism. Although the mean orbital periods of Hydra, Nix, and Charon are in the ratios of 6.06 : 3.99 : 1, we have not identified any state of resonance between them.