KUIPER BELT OBJECTS 1997 SZ10 AND 1996 TR66. R. Malhotra, *Lunar and Planetary Institute, Houston, TX.*.

In December 1998, the Minor Planet Center (MPC) reported revised orbits of two previously known Kuiper Belt objects (KBOs), 1997 SZ10 and 1996 TR66, identifying these as ''almost certainly'' librating about the 2:1 mean motion resonance with Neptune. Orbital parameters have been derived from observations spanning approximately one year and two years for 1997 SZ10 and 1996 TR66, respectively. The nominal ''best fit'' orbital elements are reported at the MPC website (http://cfa-www.harvard.edu/cfa/ps/lists/TNOs.html). Brian Marsden of the MPC also made available to us several sets of orbital elements (5 sets for 1997 SZ10 and 11 sets for 1996 TR66) which are all within observational errors, but differ slightly from the ''best fit''. We report here on the results of 10 Myr integrations of these candidate orbits.

We treat the KBOs as massless test particles and integrate self-consistently the equations of motion for the system consisting of the Sun, the four giant planets and the KBOs, including the mutual gravitational forces amongst the planets and the planets' perturbations on the KBOs. Masses and initial conditions of the Sun and planets were obtained from the JPL planetary ephemeris (http://ssd.jpl.nasa.gov/horizons.html). The integration method is a second-order mixed variable symplectic integrator (Wisdom & Holman, *AJ* 102:1528-1538(1991)), with a fixed step size of 0.5 yr.

Because of the space limitations here, we show in Figures 1 and 2 the evolution of only two candidate orbits for each of the two KBOs. The two orbits chosen span the range of behaviors exhibited by the candidate orbits. The top panel shows the semimajor axis and perihelion distance, the second panel shows the inclination, the third shows the argument of perihelion ω, and the fourth shows the resonance angle $\phi = 2\lambda - \lambda_N - \varpi$ (where λ and λ_N are the mean longitudes of the KBO and Neptune, respectively, and ϖ is the longitude of perihelion of the KBO). The resonance angle measures the longitude of perihelion relative to Neptune's mean longitude.

In both cases, we found that the 'best fit' orbits are the least stable of the candidate orbits. In Figure 1, the evolution of the best fit orbit of 1997 SZ10 is shown in red. We do not display the evolution of the best fit orbit of 1996 TR66 because this orbit becomes violently unstable, approaching Neptune within a distance of 2 AU, in less than 1 Myr. The orbit shown in red in Figure 2 shows qualitatively the same behavior as the best fit orbit, but on a somewhat longer timescale. The orbits shown in green can be termed the 'most stable' candidate orbits as they exhibit the smallest amplitude of libration of the resonance angle, ϕ, and thus maintain a distance $\lesssim 30$ AU from Neptune even near perihelion. The other orbits not shown here span this range of behaviors on the 10 Myr timecale, in the sense that they exhibit larger libration amplitudes and chaotic variations in eccentricity and inclination on longer timescales. Theoretically, owing to the 'stickiness' of Neptune's mean motion resonances in the Kuiper Belt, the less stable orbits may actually remain in the vicinity of the 2:1 resonance with Neptune on billion year timescales, allowing the KBO to survive in the Kuiper Belt without having a 'catastrophic' close approach to Neptune during its entire history. H.F. Levison (personal communication) has integrated the five candidate orbits of 1997 SZ10 for 1 Ga, finding that three are stable on that timescale.

There are remarkable similarities in the orbital properties of these two KBOs (although of course their current spatial separation is large, approximately 8 AU). Both have similar orbital eccentricities (0.36 and 0.4, thus perihelion distance near Neptune's orbital radius), and similar inclinations (~ 12 deg). In both cases, the most stable candidate orbits exhibit longitude of perihelion libration about a center which is near 65 deg ahead of Neptune in longitude, as well as argument-of-perihelion libration (the Kozai resonance) about ~ 320 deg. In these stable orbits, perihelion occurs near the leading Lagrange point (L4) of Neptune but below the ecliptic plane.

We note that the apparent motion differences amongst the sets of candidate orbital parameters are < 0.004 arc-sec/hr for 1997 SZ10 and < 0.01 arc-sec/hr for 1996 TR66. These differences accumulate into sky-position deviations of less than 1 arc-min over a one year time interval between observations at opposition. Clearly, to distinguish between small-amplitude stable librators and chaotic orbits (indeed, even between different resonances) requires recovery of the KBOs at several successive oppositions. We strongly urge observers to continue recovery efforts for these as well as other previously discovered KBOs.

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Fig. 1: 1997 SZ10 Fig. 2: 1996 TR66