Nomenclature in the Outer Solar System

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We define a nomenclature for the dynamical classification of objects in the outer solar system, mostly targeted at the Kuiper belt. We classify all 584 reasonable-quality orbits, as of May 2006. Our nomenclature uses moderate (10 m.y.) numerical integrations to help classify the *current* dynamical state of Kuiper belt objects as resonant or nonresonant, with the latter class then being subdivided according to stability and orbital parameters. The classification scheme has shown that a large fraction of objects in the "scattered disk" are actually resonant, many in previously unrecognized high-order resonances.

1. INTRODUCTION

Dynamical nomenclature in the outer solar system is complicated by the reality that we are dealing with populations of objects that may have orbital stability times that are either moderately short (millions of years or less), appreciable fractions of the age of the solar system, or extremely stable (longer than the age of the solar system). While the "classical belt" is loosely thought of as what early searchers were looking for (the leftover belt of planetesimals beyond Neptune), the need for a more precise and complete classification is forced by the bewildering variety we have found in the outer solar system.

1.1. Philosophy

The inner solar system is somewhat analogous, and from it we take some inspiration. In the main asteroid belt the recognized subpopulations are generically demarcated by resonances, be they mean-motion (the 2:1 is often taken as the outer "edge" of the main belt; the Hildas are in or near the 3:2) or secular resonances (which separate the Hungarias from the rest of the belt, for example). In contrast, once "out of the main belt," the near-Earth objects (NEOs) are separated from each other by rather arbitrary cuts in orbital element space; the semimajor axis a = 1 AU separation between Aten and Apollo has no real dynamical significance for these unstable orbits, but this well-accepted division makes discussion easier since, for example, Atens are a heavily evolved (both dynamically and potentially physically) component of the NEA population while Apollos will be on average much younger.

1.2. Classification Outline

For small-a comets, historical divisions are rather arbitrary (e.g., based on orbital period), although recent classifications take relative stability into account by using the Tisserand parameter (*Levison,* 1996) to separate the rapidly depleted Jupiter-family comets (JFCs) from the longer-lived Encke and Chiron-like (Centaur-like) orbits.

In the transneptunian region, for historical reasons the issue of stability has been important due to arguments about the primordial nature of various populations and the possibility that the so-called "Kuiper belt" is the source of the Jupiter-family comets. Already-known transneptunian objects (TNOs) exhibit the whole range of of stabilities from strongly planet-coupled to stable for >4.5 G.y. Because TNOs (like NEOs) might change class in the near or distant future, we adopt the fundamental philosophy that *the classification of a TNO must be based upon its current short-term dynamics* rather than a belief about either where it will go in the future or what its past history was. In addition, we accept the *fait accompli* that there will necessarily be a level of arbitrariness in some of the definitions. We have attempted to find a balance among historical intent, recent usage, and the need to tighten the nomenclature. We have liberally used ideas from the literature, with a goal of developing a scheme that has practical utility, while keeping an eye toward the intention that stability should be part of the nomenclature.

The classification scheme is a process of elimination (outlined in Fig. 1) based on either the object's current orbital elements and/or the results of a 10-m.y. numerical integration into the future. Using this flowchart, we have clas-

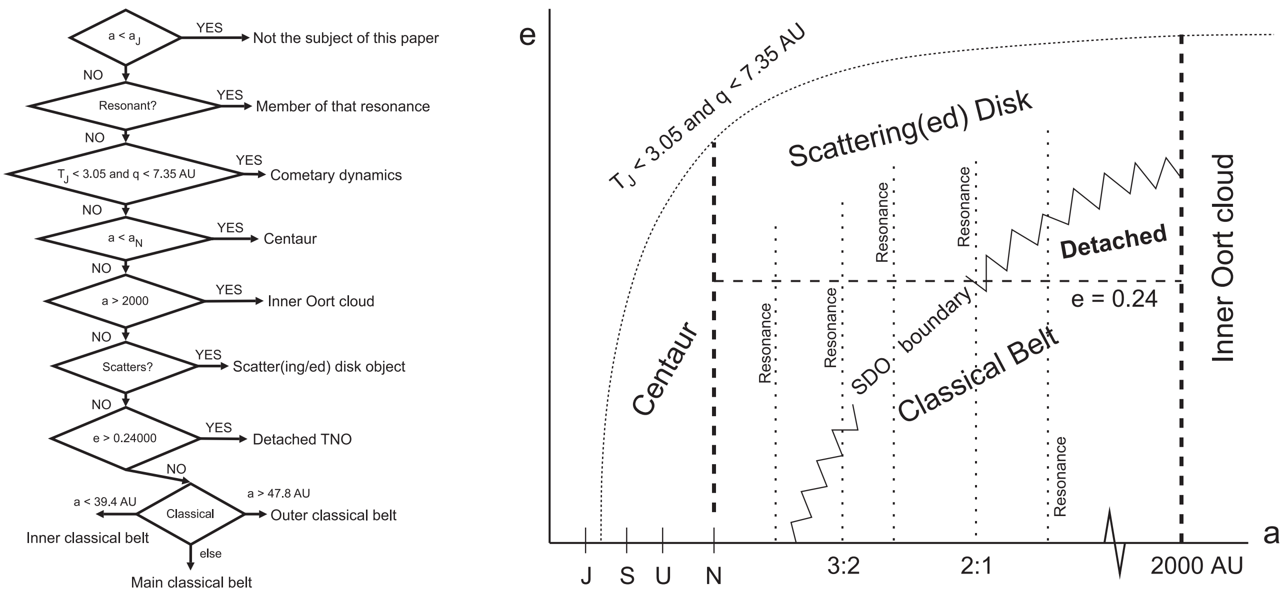

Fig. 1. *Left:* Flowchart for the outer solar system nomenclature. When orbital elements are involved they should be interpreted as the osculating barycentric elements. *Right:* A cartoon of the nomenclature scheme (not to scale). The boundaries between the Centaurs, JFCs, scattered disk, and inner Oort cloud are based on current orbital elements; the boundaries *are not* perihelion distance curves. Resonance inhabitance and the "fuzzy" SDO boundary are determined by 10-m.y. numerical integrations. The classical belt/detached TNO split is an arbitrary division.

sified the entire three-opposition (or longer) sample present in the IAU's Minor Planet Center (MPC) as of May 2006. The tables provide our SSBN07 classification for this *Solar System Beyond Neptune* book. Transneptunian objects that are now numbered also have their original provisional designation to aid their identification in previously published literature.

We have found that in order to make a sensible TNO dynamical classification, we were forced to define what is *not* a TNO; we thus begin with the regions that bound TNO semimajor axes (Centaurs and the Oort cloud) and eccentricities (the JFCs).

2. CENTAURS AND COMETARY OBJECTS

Historically, periodic comets were classified according to their orbital period P, with short-period comets having P < 200 yr and long-period comets with P > 200 yr. While there existed at one point a classification system that assigned the short-period comets to planetary "families" according to which of the giant planets was the closest to their heliocentric distances at aphelion, it became evident that there was little dynamical significance to such a classification, except in the case of the Jupiter family, which (by virtue of the typical orbital eccentricities involved) has tended to apply to comets having P < 20–30 years. This suggested it would be reasonable to cement this classification with the use of the Tisserand parameter with respect to Jupiter (first attempted by *Kresák,* 1972), defined by the Tisserand parameter T_J with respect to Jupiter

$$T_J \equiv \frac{a_J}{a} + 2\sqrt{\frac{a}{a_J}(1 - e^2)}\cos i \qquad (1)$$

where a, e, and i are the orbital semimajor axis, eccentricity, and inclination of a comet and a_J is the semimajor axis of Jupiter (about 5.2 AU). A circular orbit in the reference plane (approximately the ecliptic but more correctly Jupiter's orbital plane) with $a = a_J$ yields $T_J = 3.0$. Exterior coplanar orbits with $q = a_J = a(1 - e)$ (i.e., perihelion at Jupiter) have T_J just below 3, and thus as long as i is small the condition $T_J < 3$ is nearly the same as having q interior to Jupiter. However, if the inclination in increased or q pushed considerably below Jupiter, T_J drops well below 3 and can even become negative for retrograde orbits.

Because of this, *Carusi et al.* (1987) and *Levison* (1996) suggested that $T_J = 2.0$ provided a convenient lower boundary for a Jupiter-family comet (JFC). Comets with $T_J < 2$ include retrograde and other high-i, high-e comets, while high-e but low-i orbits can remain in the range $T_J = 2$–3. *Carusi et al.* (1987) considered a $T_J = 1.5$ lower boundary, which has the merit of including comets 96P and 8P as JFCs; the most notable comet that might be on the "wrong" side is then 27P/Crommelin ($T_J = 1.48$), although with $P \simeq 27$ yr this object could appropriately be relegated to the comet group variously categorized as of "Halley type" (HT) or of "intermediate period" (Comet 1P/Halley itself has $T_J = -0.61$). Since it is not directly relevant to our Kuiper belt nomenclature, we drop the issue of the lower T_J boundary.

TABLE 1. Centaurs and Jupiter-coupled objects (SSBN07 classification).

Jupiter-Coupled			
60558 = 2000EC$_{98}$ = Echeclus	52872 = 1998SG$_{35}$ = Okyrhoe		
Centaurs			
02060 = 1977UB = Chiron	05145 = 1992AD = Pholus	07066 = 1993HA$_2$ = Nessus	08405 = 1995GO = Asbolus
10199 = 1997CU$_{26}$ = Chariklo	10370 = 1995DW$_2$ = Hylonome	31824 = 1999UG$_5$ = Elatus	32532 = 2001PT$_{13}$ = Thereus
49036 = 1998QM$_{107}$ = Pelion	54598 = 2000QC$_{243}$ = Bienor	52975 = 1998TF$_{35}$ = Cyllarus	55576 = 2002GB$_{10}$ = Amycus
63252 = 2001BL$_{41}$	83982 = 2002GO$_9$ = Crantor	88269 = 2001KF$_{77}$	95626 = 2002GZ$_{32}$
119315 = 2001SQ$_{73}$	119976 = 2002VR$_{130}$	120061 = 2003CO$_1$	121725 = 1999XX$_{143}$
J94T00A = 1994TA	K00CA4O = 2000CO$_{104}$	K00F53Z = 2000FZ$_{53}$	K01XP5A = 2001XA$_{255}$
K02D05H = 2002DH$_5$	K03W07L = 2003WL$_7$	K05Uh8J = 2005UJ$_{438}$	

So what is the *upper* limit of T_J for a JFC, beyond which are Centaurs and scattering objects? *Levison* (1996) used an upper limit of $T_J = 3.0$. For a circular jovian orbit, objects with $T_J > 3$ do not cross Jupiter's orbit, but Jupiter's e is sufficiently large that this approximation is not good enough to prevent complications. Not only are there several comets with T_J slightly greater than 3.0 that according to any reasonable definition should be called JFCs, but in some cases T_J oscillates about 3.0 within a matter of decades. Comets like 39P/Oterma, which over a quarter-century interval moved from an osculating orbit entirely outside Jupiter to one entirely inside Jupiter *and back* (with T_J remaining in the range 3.00–3.04), lead us to solve the problem by allowing JFCs to have T_J up to 3.05. We note in passing that the Centaurs (60558) Echeclus (q = 5.8 AU, $T_J = 3.03$) and (52782) Okyrhoe (q = 5.8 AU, $T_J = 2.95$), which already bear the names of Centaurs, are reclassified as Jupiter coupled; our numerical integration confirms these objects to be rapidly perturbed by Jupiter.

Finally, there is a terrible generic problem with the Tisserand invariant (leading us below to reject its use in the main Kuiper belt); orbits with perihelia far outside Jupiter but sufficiently high i eventually have $T_J < 3.05$ since the second term of equation (1) becomes small. The TNO 127546 = 2002 XU$_{93}$ has a/q/i = 66.5/21.0/77.9° and T_J = 1.2 but clearly is not remotely coupled to Jupiter. We thus feel that a pericenter qualifier must be added to the $T_J < 3.05$ condition to keep large-i outer solar system objects out of the dynamical comet classes. In analogy with the upper Aten q boundary (about halfway to Mars), we simply use q < 7.35 AU (halfway to Saturn) as an additional qualifier. With this definition, the combined T_J and q condition (Fig. 1) tells us what is beyond Jupiter's reach and in need of classification (Table 1) for our present purposes.

This brings us to the Centaurs, whose perihelia are sufficiently high that they are not JFCs. The prototype (2060) = 95P/Chiron (q = 8.5 AU, a = 13.7 AU, i = 6.9°, and T_J = 3.36) is a planet-crossing object, as is (5145) Pholus (q = 8.7 AU, a = 20.4 AU, i = 24.7°, T_J = 3.21). Indeed, while a Centaur has historically been broadly defined as an object of low i and low-to-moderate e in the distance range of the giant planets, the historical intent was that its evolution was not currently controlled by Jupiter. Since the JFC definition essentially takes care of this latter condition, we are left with the question of where the Centaurs stop. While there were historical definitions that involved aphelion distance Q > 11 AU, it is useful to have an outer bound on Q so that Centaurs retain their identity as objects mostly *between* the giant planets. We do this by using $a < a_N$ (Neptune's semimajor axis) as the boundary; the resonant (see below) Neptune Trojans fall on the boundary between the Centaurs and the SDOs.

3. THE INNER OORT CLOUD

We will not spend a great deal of time dealing with Oort cloud nomenclature, but feel obligated to put an outer bound on the scattering disk. Although the production mechanism of the Oort cloud and the past galactic environment of the Sun are unclear, since we are basing our definitions on the *current dynamics* we ask the question: Where does the current dynamics of a distant object become dominated by external influences? *Dones et al.* (2004) show that a very evident transition in the dynamics begins at a = 2000 AU for TNOs scattered out by the giant planets; for a > 2000 AU the galactic tidal field and passing stars cause appreciable alteration of the perihelia and inclinations. We thus adopt a = 2000 AU as the formal (somewhat arbitrary) beginning of the inner Oort cloud (and thus end of the Kuiper belt). Objects with a > 2000 AU but with $T_J < 3.05$ and q < 7.35 AU would be considered JFCs since their evolution is dominated by Jupiter (see chapter by Duncan et al.).

Note that the definitions above give, for the first time, a formal sharp demarcation of the Kuiper belt, which is bounded on the inner and outer "a" boundaries by the Centaurs and Oort cloud, and above in eccentricity by the JFC population (defined by the Tisserand parameter). This definition makes SDOs (see below) part of the Kuiper belt.

4. RESONANT OBJECTS

While the Centaurs and JFCs are rapidly evolving, the resonant TNO populations may be critical to our understanding of the region's history. We adopt the convention that the p:q resonance denotes the resonance of p orbital periods of the inner object (usually Neptune) to q periods of the TNO (and thus external resonance have p > q). The "order" of the resonance is p–q, with high-order resonances being weak unless e is large. After the suggestion in 1994 that there were TNOs other than Pluto in the 3:2 resonance with Neptune, a host of other resonances have been shown to be populated (although in this chapter we search only for mean-motion, rather than secular, resonances). These resonances are important to the structure of the belt because (1) they allow large-e orbits to survive for 4.5 G.y despite approach or even crossing of Neptune's orbit; (2) the chaotic nature of the resonance borders allow both (a) the temporary trapping of SDOs near the border of the resonance (*Duncan and Levison,* 1997) or (b) nearly resonant objects to escape into the Neptune-coupled regime (*Morbidelli,* 1997); and (3) the relative population of the resonances may be a diagnostic of the amount and/or rate of planet migration (*Chiang and Jordan,* 2002; *Hahn and Malhotra,* 2005).

Resonant occupation (or proximity) can really only be addressed by a direct numerical calculation of the orbital evolution, because simply having a TNO with corresponding period near a rational ratio of Neptune's (one-half for the 2:1 resonance, for example) is not at sufficient condition to be in the resonance. The angular orbital elements must also be appropriately arranged so that a resonant argument, for example, of the form

$$\phi_{94} = 9\lambda_N - 4\lambda - 5\varpi \tag{2}$$

oscillates ("librates") around some value, rather than progressing nearly uniformly ("circulating"). Equation (2) gives a resonant argument of the 9:4 mean-motion resonance (the "plutinos" are found in the 3:2); λ_N and λ are the mean longitudes ($\Omega + \omega + M$) of Neptune and the TNO, and ϖ is the longitude of perihelion ($\Omega + \omega$) of the TNO. It is the geometrical relation between the angles embodied by the resonant angle that prevents the resonant TNOs from approaching Neptune even if they have high e. (Other 9:4 resonant arguments than ϕ_{94} exist; these involve ϖ_N, Ω, and Ω_N. However, these tend to be weaker because $e_N \ll e$ and inclinations are usually small.)

4.1. Classification Algorithm

Because we are involving a numerical integration in a dynamical classification, it is worth pausing to discuss possible weaknesses of this approach. One could say that instead of classifying objects, one is actually classifying nominal orbits, since the object's orbital elements are necessarily only known to some finite precision. With a nomenclature involving an arbitrary cut in orbital parameter space, even the orbit-fitting method influences the potential classification. We believe that TNO dynamical classifications are only reliable for objects with observations in (at least) *each and every* of three or more oppositions; two-opposition orbits may still have a-uncertainties of an AU or more (and two-year arcs with no observations one year after discovery are also insufficient). Since a numerical integration is involved in resonance classification, even a reasonably well-observed object with an orbit near the boundary of a resonance could have enough uncertainty in its orbital elements to straddle the border. In principle the numerical integration algorithm could influence the result, especially for these objects on the border. We view these practical difficulties as unavoidable problems whose shortfalls are far outweighed by the need to establish a classification based on stability.

Our resonance identification algorithm is similar to that proposed by *Chiang et al.* (2003) and *Elliot et al.* (2005), but with modifications related to both the definitions of the scattering populations (to be discussed later) and to the evaluation of uncertainty in the TNO orbital parameters. For each three-opposition object, the best-fit orbit is integrated, along with two other nominal orbits that are the extremes of the orbital uncertainty in semimajor axis; the details of this procedure are discussed in the following subsection. If in a 10-m.y. integration a particular resonance argument librates for all three initial conditions, the object has a "secure" resonant classification. If two of these initial conditions show the resonant behavior the object will be classified as "probably" in the resonance; if only one of the arguments is resonant, we classify the object according to the behavior of the other two trajectories, noting the vicinity of the resonance. This is important for objects near resonance borders or near the portions of those resonances where the semimajor axis range of that resonance is small (at low-e, for example), as this will flag the object as being especially in need of further observation despite having a reasonably high-quality orbit.

As already concluded by *Chiang et al.* (2003), diagnosing the maximal semimajor axis variation is the most important element for determining resonance occupancy since resonances are confined to small ranges of a. Currently only the eccentricity-type mean-motion resonances between TNOs and Neptune are securely known to be populated, ranging from the 1:1 Trojan resonance with Neptune (*Chiang et al.,* 2003; *Marsden,* 2003) to the 3:1 at a = 63.0 AU (*Marsden,* 2005). In principle there is no limit to the order of the resonance that could be occupied (and thus classified). In particular, the a > 50 AU population is often discovered near perihelion and thus on orbits of large eccentricity, which allows higher-order resonances (like the second-order 3:1 or the third-order 5:2) to be occupied. We have examined all eccentricity-type resonant arguments up to sixth order routinely, and searched to much higher order for objects with perihelia q < 38 AU that show stable behavior in the 10-m.y. numerical integration, as we find their relative stability is often due to resonance occupation.

Note that the 10-m.y. future window used here does not require the object to be resonant over the age of the solar system, but only for a small number of resonant librations. This is in keeping with the philosophy that it is the *current* dynamics of the TNOs that we are classifying. For example, it is immaterial whether an object in the 2:1 resonance with $e \simeq 0.3$ arrived there by (1) eccentricity pumping after trapping in resonances during an outward migration of Neptune (*Malhotra,* 1993), (2) being trapped into the 2:1 from a scattered orbit (e.g., *Duncan and Levison,* 1997; *Gomes,* 2003; *Hahn and Malhotra,* 2005), or (3) diffusing up to $e \simeq$

0.3 from an e ≃ 0 orbit due to slow dynamical diffusion over the age of the solar system. Despite these rather different orbital histories (which will of course be impossible to discriminate among for a given object) the nomenclature classifies the object as 2:1 resonant because its *current* dynamical state is resonant.

4.2. Numerical Method

For a given object, we begin with the astrometric observations from each and every one of three oppositions (or more), and perform a best fit *barycentric* orbit solution using the method of *Bernstein and Khushalani* (2000). That is, the position and velocity vectors at the time of the first observation are computed, giving osculating elements relative to the center of mass of the giant planets and the Sun. The orbital elements are thus determined to a fractional precision of $\sim 10^{-5}$, several orders of magnitude more precise than the uncertainty in the orbital elements.

Our method then asks the question: What is the set of possible orbits that are consistent with the orbit solution, as judged by the residual quality of the best-fit orbit? *Chiang et al.* (2003) approached this question by diagonalizing the covariance matrix around the best fit and using the diagonal elements to generate a set of new orbits that are on the 3σ surface, assuming that all astrometric observations have the same error. Inspection of the residuals from the best-fit orbits for our MPC object sample shows enormous variance in the astrometric quality of the observations. While there are objects like K03QB3X (= 2003 QB_{103} = CFEPS L3q03) with maximum residuals of 0.22" over the entire three-year arc, most TNOs have many residuals of 0.6–0.9", and others have observations with >2" residuals and RMS residuals signficantly more than 0.5". In our algorithm, classification certainty is based on the actual orbit quality of the object in question, as shown by its internal consistency. We therefore search in parameter space for other orbits (1) that have no residuals >1.5× the worst residual of the best fit and (2) whose RMS residual is <1.5× the residual RMS of the best fit.

We accomplish this search with a set of numerical subroutines, some of which are taken from the latest release of the *Bernstein and Khushalani* (2000) package. Using the best-fit orbit expressed in their (α, β, γ) coordinate system, corresponding to two on-sky axes and one radial axis through the observation (along with three velocity axes), the diagonal elements of the covariance matrix in these axes are used as the step size in our Monte Carlo parameter search. A search for the largest semimajor axis orbit is then begun. A random displacement in all six axes is made, with a variation in each of those coordinates of up to $\pm 3\sigma$ (as determined by the covariance matrix), yielding a candidate orbit. If this candidate orbit passes the consistency checks based on its residuals relative to the observations, and if the test orbit's a is larger than the current highest-a orbit (or smaller than the current lowest-a) orbit, it becomes the new high-a orbit and the search is repeated using this new orbit as the starting point. The maximum-a orbit is the last one for which 10^6 trials yield no consistent orbit with a still-larger a. At this point a search is begun for the lowest-a orbit starting from either the best-fit orbit or a lower-a orbit that might have already been discovered in the high-a search. Figure 2 shows the result of the process for the TNO 2001 KG_{76}; the parameter-space search shows that this low-i TNO has an a known to ≃±0.1 AU (about 2%) with an e accuracy of about 0.0015. As is usual for TNOs, the orbital inclination and ascending node are known extremely precisely, while the argument of pericenter ω and time of pericenter passage T (or mean anomaly) are known to a fractional accuracy several times worse.

Once the extremal orbits are found, we generate heliocentric position and velocity vectors for the best fit and two extremal orbits at the instant corresponding to the first observation, along with the planetary position and velocity vectors for the giant planets for that epoch (we add the mass of the terrestrial planets to the Sun). We then numerically integrate forward in time using the swift-rmvs3 integrator (*Duncan and Levison,* 1994) based on the mixed-variable symplectic algorithm of *Wisdom and Holman* (1991). The three orbits are followed for 10 m.y. and mean-motion resonances with Neptune up to at least sixth order are routinely examined. If all three test particles librate in a resonance for 10 m.y., the object is classified securely in that resonance (see Table 2). If two of the three test particles librate then the resonance identification is insecure; this is indicated by the classification list being in "( )". Insecure TNOs require further observation to reduce the orbital uncertainty. (As Table 5 shows, most insecure resonant classifications are associated with high-order resonances, which are "thin" in semimajor axis.) If only one of three test particles librates the object is classed as nonresonant; we do not here record all such cases of potential resonance, which will only be identified with the help of further observation. In our philosophy, insecure classifications mean *more observations are needed* to remove the uncertainty; this is a simple matter for these objects, as their positions are known to the level of a few arcseconds in almost all cases.

If we had used only 3-m.y. integrations, 5 of the 584 TNOs would have been classified slightly differently, although this is not disturbing since all 5 were insecure under the 10-m.y. analysis. Four resonant TNOs had a high-a or low-a clone become nonresonant in the 3–10-m.y. period (becoming insecurely resonant instead of securely), and one insecurely scattering TNO became insecurely resonant. These objects are not ready to be securely classified and the solution is to acquire more observations.

For Deep Ecliptic Survey TNOs classified as resonant by *Elliot et al.* (2005) using a very similar method, we find the same resonant classification. However, with longer arcs available, we now recognize some other objects (e.g., 2002 PA_{149}) as low-order resonant. Since we search to much higher order when we see what is clearly resonant behavior in our inspection of the orbital history, we have also found a suite of objects in resonances of order >4 (e.g., the

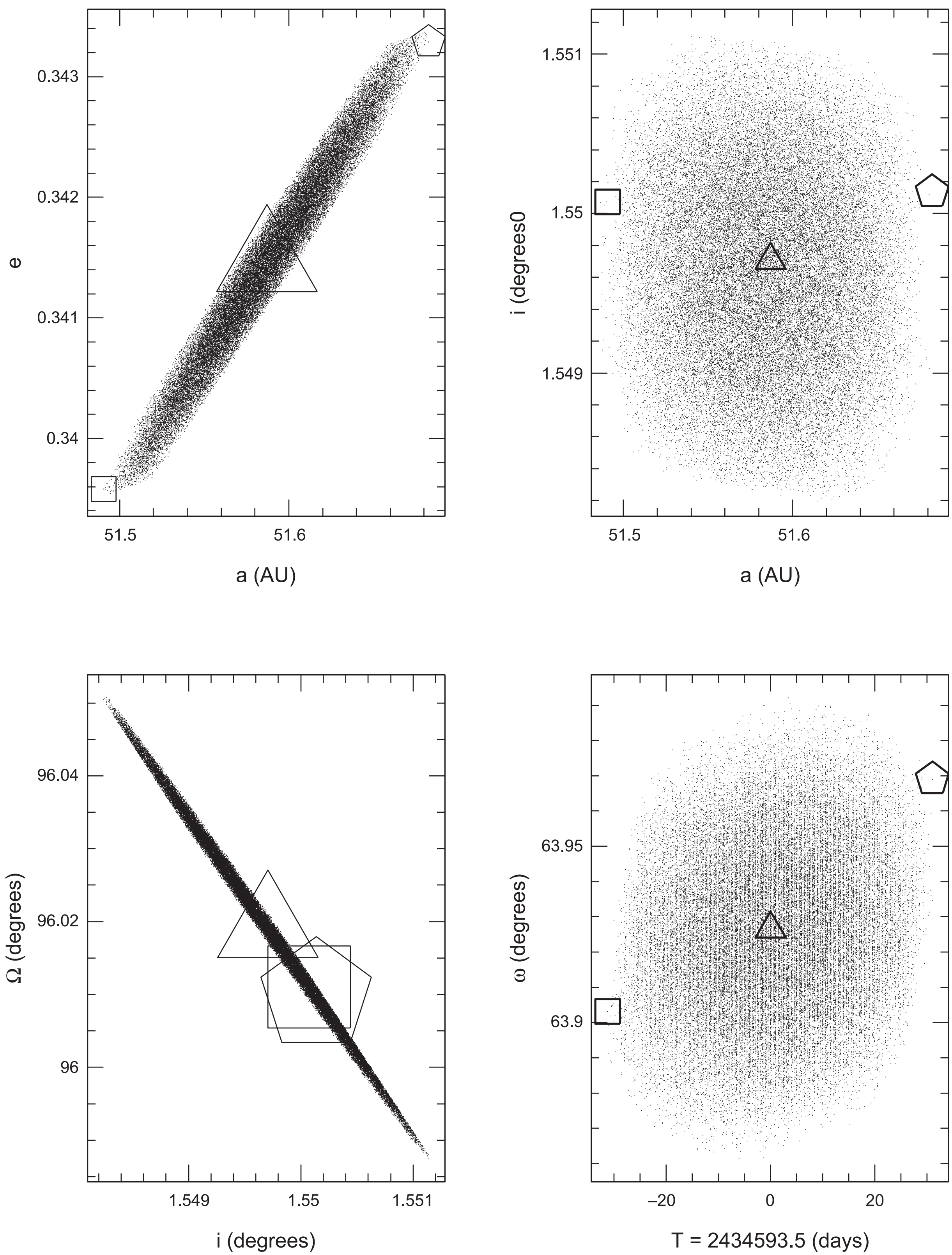

Fig. 2. Example of the determination of the bounds on the orbital elements for an object before classification (here 2001 KG_{76}). Starting at the best-fit orbit (large triangle), we search for the highest (pentagon) and lowest (square) semimajor axis orbits (using the procedure described in the text) that give acceptable orbit fits (upper left), where dots show all orbits that were discovered. As is often the case, the extremal orbits also have nearly the maximal variation in e. The values of the other orbital parameters for each viable as well as the best-fit and extremal orbits are in the other panels.

TABLE 2. Resonant objects (SSBN07 classification).

1:1	K01QW2R = 2001QR$_{322}$			
5:4	79969 = 1999CP$_{133}$	127871 = 2003FC$_{128}$	131697 = 2001XH$_{255}$	
4:3	15836 = 1995DA$_{2}$	J98U43U = 1998UU$_{43}$	J99RL5W = 1999RW$_{215}$	(K00CA4Q = 2000CQ$_{104}$)
	K03SV7S = 2003SS$_{317}$			
11:8	(131695 = 2001XS$_{254}$)			
3:2	15788 = 1993SB	15789 = 1993SC	15810 = 1994JR$_{1}$	15820 = 1994TB
	15875 = 1996TP$_{66}$	19299 = 1996SZ$_{4}$	20108 = 1995QZ$_{9}$	24952 = 1997QJ$_{4}$
	28978 = 2001KX$_{76}$ = Ixion	32929 = 1995QY$_{9}$	33340 = 1998VG$_{44}$	38628 = 2000EB$_{173}$ = Huya
	47171 = 1999TC$_{36}$	47932 = 2000GN$_{171}$	55638 = 2002VE$_{95}$	69986 = 1998WW$_{24}$
	69990 = 1998WU$_{31}$	84719 = 2002VR$_{128}$	84922 = 2003VS$_{2}$	90482 = 2004DW = Orcus
	91133 = 1998HK$_{151}$	91205 = 1998US$_{43}$	118228 = 1996TQ$_{66}$	(119069 = 2001KN$_{77}$)
	119473 = 2001UO$_{18}$	120216 = 2004EW$_{95}$	126155 = 2001YJ$_{140}$	129746 = 1999CE$_{119}$
	131318 = 2001FL$_{194}$	133067 = 2003FB$_{128}$	J93R00O = 1993RO	J95H05M = 1995HM$_{5}$
	J96R20R = 1996RR$_{20}$	J98HF1H = 1998HH$_{151}$	J98HF1Q = 1998HQ$_{151}$	J98U43R = 1998UR$_{43}$
	J98W31S = 1998WS$_{31}$	J98W31V = 1998WV$_{31}$	J98W31Z = 1998WZ$_{31}$	J99CF8M = 1999CM$_{158}$
	J99RL5K = 1999RK$_{215}$	K00CA5K = 2000CK$_{105}$	K00F53V = 2000FV$_{53}$	K00GE7E = 2000GE$_{147}$
	K00Y02H = 2000YH$_{2}$	K01FH2U = 2001FU$_{172}$	K01FI5R = 2001FR$_{185}$	K01K76Y = 2001KY$_{76}$
	K01K77B = 2001KB$_{77}$	K01K77D = 2001KD$_{77}$	K01K77Q = 2001KQ$_{77}$	K01QT8F = 2001QF$_{298}$
	K01QT8G = 2001QG$_{298}$	K01QT8H = 2001QH$_{298}$	K01RE3U = 2001RU$_{143}$	K01V71N = 2001VN$_{71}$
	K02CP1E = 2002CE$_{251}$	K02CM4W = 2002CW$_{224}$	K02G32F = 2002GF$_{32}$	K02G32L = 2002GL$_{32}$
	K02G32V = 2002GV$_{32}$	K02G31W = 2002GW$_{31}$	K02G32Y = 2002GY$_{32}$	K02VD0U = 2002VU$_{130}$
	K02VD0X = 2002VX$_{130}$	K02X93V = 2002XV$_{93}$	K03A84Z = 2003AZ$_{84}$	K03FC7L = 2003FL$_{127}$
	K03H57A = 2003HA$_{57}$	K03H57D = 2003HD$_{57}$	K03Q91B = 2003QB$_{91}$	K03Q91H = 2003QH$_{91}$
	K03SV7O = 2003SO$_{317}$	K03SV7R = 2003SR$_{317}$	K03T58H = 2003TH$_{58}$	K03UT2T = 2003UT$_{96}$
	K03UT2V = 2003UV$_{96}$	K03WJ1A = 2003WA$_{191}$	K04E96H = 2004EH$_{96}$	K04FG4W = 2004FW$_{164}$
	K05TI9V = 2005TV$_{189}$		134340 = Pluto	
5:3	15809 = 1994JS	126154 = 2001YH$_{140}$	J99CD1X = 1999CX$_{131}$	K00P30L = 2000PL$_{30}$
	K00QP1N = 2000QN$_{251}$	K01XP4P = 2001XP$_{254}$	(K02G32S = 2002GS$_{32}$)	K02VD1A = 2002VA$_{131}$
	K02VD0V = 2002VV$_{130}$	K03UT2S = 2003US$_{96}$	K03YH9W = 2003YW$_{179}$	
7:4	60620	118378 = 1999HT$_{11}$	118698 = 2000OY$_{51}$	(119066 = 2001KJ$_{76}$)
	(119067 = 2001KP$_{76}$)	119070 = 2001KP$_{77}$	119956 = 2002PA$_{149}$	134568 = 1999RH$_{215}$
	135024 = 2001KO$_{76}$	(135742 = 2002PB$_{171}$)	(J99CF8D = 1999CD$_{158}$)	J99H12G = 1999HG$_{12}$
	J99K18R = 1999KR$_{18}$	(K00F53X = 2000FX$_{53}$)	K00O67P = 2000OP$_{67}$	(K00Y01U = 2000YU$_{1}$)
	K01QT8E = 2001QE$_{298}$	K01K76N = 2001KN$_{76}$	(K03QB1W = 2003QW$_{111}$)	
9:5	K01K76L = 2001KL$_{76}$	K02G32D = 2002GD$_{32}$		
11:6	(K01K76U = 2001KU$_{76}$)			
2:1	20161 = 1996TR$_{66}$	26308 = 1998SM1$_{65}$	119979 = 2002WC$_{19}$	130391 = 2000JG$_{81}$
	J97S10Z = 1997SZ$_{10}$	J99RL5B = 1999RB$_{215}$	J99RL6B = 1999RB$_{216}$	K00QP1L = 2000QL$_{251}$
	K01FI5Q = 2001FQ$_{185}$	K01U18P = 2001UP$_{18}$	K02PH0U = 2002PU$_{170}$	
19:9	(K03QB3X = 2003QX$_{113}$)			
9:4	42301 = 2001UR$_{163}$	K01K76G = 2001KG$_{76}$		
7:3	131696 = 2001XT$_{254}$	(95625 = 2002GX$_{32}$)	(J99CB8V = 1999CV$_{118}$)	
12:5	(79978 = 1999CC$_{158}$)	119878 = 2002CY$_{224}$		
5:2	26375 = 1999DE$_{9}$	38084 = 1999HB$_{12}$	60621 = 2000FE$_{8}$	69988 = 1998WA$_{31}$
	(84522 = 2002TC$_{302}$)	119068 = 2001KC$_{77}$	135571 = 2002GG$_{32}$	K00SX1R = 2000SR$_{331}$
	K01XP4Q = 2001XQ$_{254}$	K02G32P = 2002GP$_{32}$	K03UB7Y = 2003UY$_{117}$	
8:3	82075 = 2000YW$_{134}$			
3:1	136120 = 2003LG$_{7}$			
7:2	(K01K76V = 2001KV$_{76}$)			
11:3	(126619 = 2002CX$_{154}$)			
11:2	(26181 = 1996GQ$_{21}$)			
27:4	(K04PB2B = 2004PB$_{112}$)			

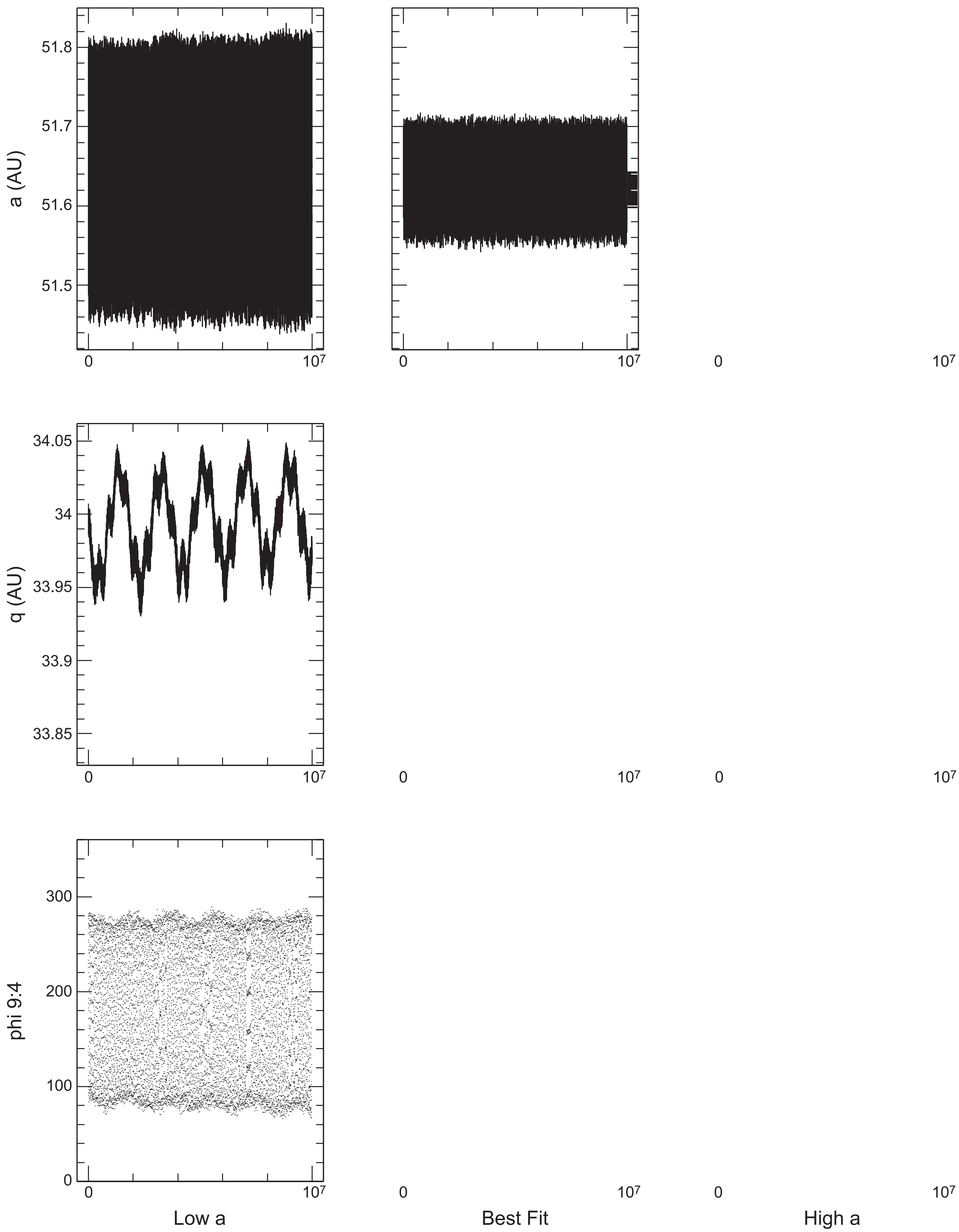

Fig. 3. The time evolution of the low-a (*left column*), best-fit (*center*), and high-a (*right column*) orbits for 2001 KG_{76} = K01K76G. Horizontal axis is time in years. The likelihood of a high-order resonance is indicated by the stability of a and periodic oscillations in q, despite q < 35. Indeed, all three integrated initial conditions librate in the fifth-order 9:4 mean-motion resonance, and this is thus a secure classification. Clearly the amplitude of the resonant argument is still quite uncertain and requires further observations.

seventh-order 12:5 libration of 119878 = 2002 CY_{224}). Figure 3 shows the occupancy of the fifth-order 9:4 resonance by 2001 KG_{76}.

Our study has revealed a surprisingly high number of a > 48.4 AU objects that appear to be resonant. Since many of these have been previously classified as SDOs, these are discussed in the following section. Figure 4 shows all the resonant TNO identifications inside a = 73 AU, along with the remaining classifications discussed below.

5. NONRESONANT OBJECTS

The TNOs remaining to be classified are those that the numerical integration shows are nonresonant. The problem is the desire to involve orbital stability in the nomenclature for historical and cosmogonic reasons, due to the great interest in knowing the source regions of comets. Unlike boundaries between two stable or two unstable populations, arbitrary cuts in phase space (e.g., simple cuts in perihelion

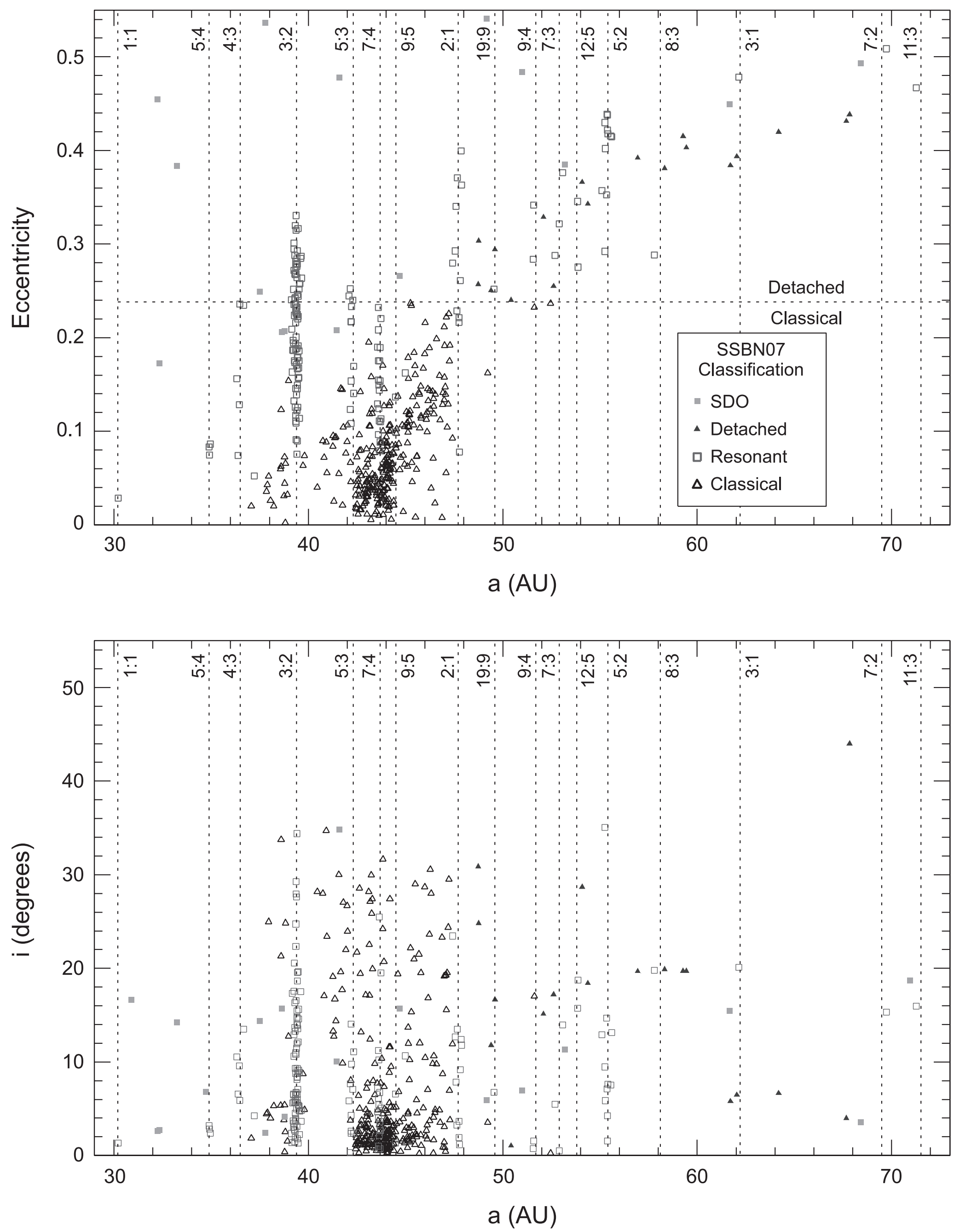

Fig. 4. The SSBN07 classification of the TNO region for a = 30–73 AU. Resonant semimajor axes are labeled and indicated by dotted lines. The horizontal dashed line gives the arbitrary division between the detached TNOs and classical belt. Beyond a = 73 AU all objects are detached or SDOs with the exception of two insecure resonant classifications (see tables).

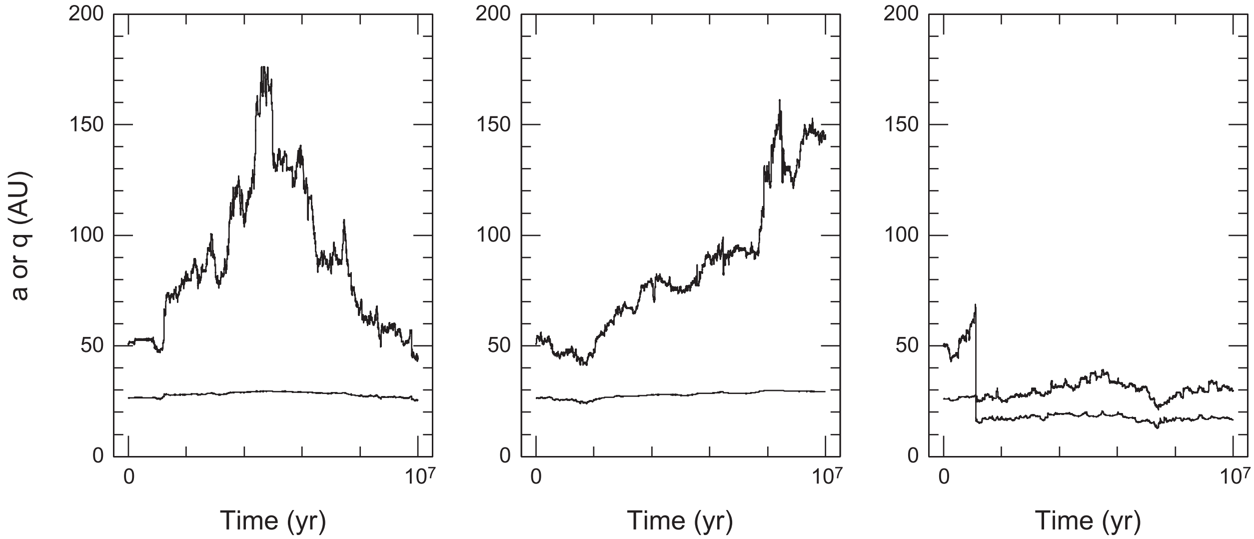

Fig. 5. The nonresonant (secure) classification of scattering(ed) disk object 2003 QW$_{113}$ = K03QB3W, for the low-a (*left*), best-fit (*center*), and high-a (*right*) orbit. The lower history shown in each panel is q = a(1 – e), the upper is a.

distance q) do not provide a satisfactory separation between the classical belt and the scattered disk.

Although a separation based on the Tisserand parameter with respect to Neptune (analogous to the JFC definition) is attractive (*Elliot et al.,* 2005), we have abandoned this. Unlike the JFC/Centaur and JFC/SDO boundaries that we use (which are between two unstable populations), the SDO/classical belt boundary is *not* well modeled by such a simple division because the border between the two populations is extremely complex, involving all orbital parameters. *Duncan et al.* (1995) show the very intricate nature of the boundary, which cannot be modeled as a constant q cut (especially since the inner q boundary varies with i). Since physical studies of TNOs would want to cleanly separate the unstable SDOs away from the classical belt objects in this region, we decided to exploit the integrations that had already occurred for all objects to decide if the objects are actually currently heavily interacting with Neptune.

5.1. Scatter(ing/ed) Disk Objects

The term "scattered disk" was originally intended for TNOs scattered to large-e orbits with q near Neptune. While not stable, because of the long orbital periods and sometimes near-resonant behavior with Neptune, some SDOs can survive ~4.5 G.y. (*Duncan and Levison,* 1997). Given that there is also a well-populated "extended scattered"/detached disk (section 5.2), it is not entirely clear how the scattered disk was produced. For example, it may be possible that a passing star, rogue planet(s), or sweeping resonances have emplaced objects in this region, rather than direct scattering by Neptune. Therefore, our philosophy is that the SDOs are those objects that are *currently scattering actively off Neptune*, rather than ascribing to this population any specific ideas about their origin.

Fortunately, the 10-m.y. numerical integrations (already executed to look for resonance occupancy) cleanly identifies SDOs due to their rapid variation in semimajor axis. Figure 5 shows a prototype example of the orbit evolution of an SDO. We adapt a criterion similar to *Morbidelli et al.* (2004): An excursion in a of ≥1.5 AU during the 10-m.y. integration classifies the object as an SDO. We find that the exact value used (1–2-AU variation) makes little difference, as SDOs suffer large-a changes in short times. Although in principle SDOs can be "on the edge" of showing significant a mobility, we rarely find any confusion. Thus, SDOs in this definition (Table 3) are "scatter*ing*" objects rather than "scatter*ed*," even though we acknowledge that the latter term is entrenched in the literature.

We have found many cases of objects currently classified as SDOs that are in fact resonant (cf. *Hahn and Malhotra,* 2005; *Lykawka and Mukai,* 2007). For example, the TNO

TABLE 3. Scatter(ing/ed) disk objects (SSBN07 classification).

15874 = 1996TL$_{66}$	29981 = 1999TD$_{10}$	33128 = 1998BU$_{48}$	42355 = 2002CR$_{46}$
44594 = 1999OX$_{3}$	54520 = 2000PJ$_{30}$	59358 = 1999CL$_{158}$	60608 = 2000EE$_{173}$
65489 = 2003FX$_{128}$	73480 = 2002PN$_{34}$	78799 = 2002XW$_{93}$	82155 = 2001FZ$_{173}$
82158 = 2001FP$_{185}$	87269 = 2000OO$_{67}$	87555 = 2000QB$_{243}$	91554 = 1999RZ$_{215}$
120181 = 2003UR$_{96}$	127546 = 2002XU$_{93}$	J99CB8Y = 1999CY$_{118}$	(K00QP1M = 2000QM$_{251}$)
(K01K77G = 2001KG$_{77}$)	(K01OA9M = 2001OM$_{109}$)	K02G32B = 2002GB$_{32}$	K02G32E = 2002GE$_{32}$
(K03FC9H = 2003FH$_{129}$)	K03H57B = 2003HB$_{57}$	K03Q91Z = 2003QZ$_{91}$	K03QB3W = 2003QW$_{113}$
K03WH2U = 2003WU$_{172}$	(K04D71J = 2004DJ$_{71}$)		

in Figs. 2 and 3 is currently classified as an SDO in the MPC lists, but is really in a fifth-order resonance. We find that the orbital evolution of a resonant TNO with q < 38 AU exhibits a much-muted semimajor variation compared to a nonresonant object, and upon hunting we usually identify a high-order resonance. Figure 6 shows one of the few boundary cases we have found, where the TNO might either be (1) resonant in the 5:1 if a drops slightly given further observations, (2) a detached object (section 5.2) that migrates only slowly due to the 21° inclination, or (3) conceivably an object that has "stuck" temporarily to the border of the mean-motion resonance (see *Duncan and Levison,* 1997, for a discussion).

Owing to the use of the numerical integration, in this nomenclature SDOs exist over a large a range and are not confined to a > 50 AU as has often been done in the literature; instead the SDO population extends down to a = 30 AU where the Centaurs begin. There is essentially an SDO upper-e limit where coupling to Jupiter occurs. At very large a, where external influences become important, the inner Oort cloud begins.

5.2. The Detached Transneptunian Objects

After the recognition that there must be a large population of objects in the outer Kuiper belt with pericenters decoupled from Neptune (*Gladman et al.,* 2002), the boundaries of this region have expanded as more large-a TNOs are discovered. We have dropped the term "extended scattered" because it is unclear if this population was emplaced by scattering. In any case the term "detached" (adopted from *Delsanti and Jewitt,* 2006) can be understood in the present tense and keeps with our philosophy of using an TNO's current dynamical behavior for the classification. We have elected not to adopt the Tisserand value with respect to Neptune (*Elliot et al.,* 2005) as part of a definition, since the prevelance of high-i TNOs here and in the classical belt makes for a very messy mix (where large i forces $T_N < 3$ for orbits with essentially no dynamical coupling to Neptune). The numerical integration of each object separates the SDOs from the detached TNOs. But we are left with the thorny problem of where the detached population should end at low eccentricity. While in principle one could call all nonresonant, nonscattering TNOs "classical," having 2000 CR_{105} or Sedna lumped in with a circular orbit at 44 AU is both not useful and not in line with the recent literature. *Elliot et al.* (2005) proposed using the arbitrary lower bound of e = 0.2 on the population; we amend this to e = 0.24 because at moderate inclination (10°–20°) there are stable orbits interior to the 2:1 resonance (*Duncan et al.,* 1995) that are more comfortably thought of as classical belt objects than detached objects (see Fig. 4). The e = 0.24 division thus gives the symmetry that stable TNOs with identical e but on either side of the 2:1 resonance will both be considered classical belt objects.

This definition results in the detached TNOs (Table 4) being those nonscattering TNOs with large eccentricities (e > 0.24) and not so far away that external influences are important to their current dynamics (a > 2000 AU). The mechanisms that emplaced the detached TNOs on these orbits are undergoing active current research (see chapters by Gomes et al., Levison et al., Kenyon et al., and Duncan et al.). We hypothesize that as future work extends the observed arcs of some of these detached TNOs, more of them will be securely identified as being in high-order mean-motion resonances, with interesting cosmogonic implications.

5.3. The Classical Belt

By the process of elimination (Fig. 1), those objects that are left belong to the "classical belt," whose previous definitions have usually had no clear outer or inner boundaries. Here, the classical belt is not confined between the 3:2 and 2:1 resonance, to which it was sometimes limited to. Rather, it also extends inward to the dynamically stable low-e region inside the 3:2 (*Gladman,* 2002; *Petit and Gladman,* 2003), and out to the lightly populated low-e orbits outside the 2:1 resonance. There may be a popular misconception that the stable classical orbits with a < 39.4 AU (i.e., interior to the 3:2 resonance) are somehow "disconnected" from the stable phase space of the a = 42–48 AU region; the "gap" present in the often-used low-i stability diagram of *Duncan et al.* (1995) is only present at low-i and is (as those authors showed) due to the ν_8 secular resonance. The ν_8 is located at a ≃ 41 AU for low-i, but then moves to lower a at i ≃ 10°, thus stablizing the a = 39.4–42-AU region for moderate and high inclinations.

Although formally we take all the nonresonant low-e TNOs to be in the classical belt (removing any SDOs, of course), it may be useful terminology to divide the classical belt into an *inner* classical belt (a < 39.4 AU, nonresonant), an *outer* classical belt (a > 48.4 AU, nonresonant, and e < 0.24), and a *main* classical belt (sometimes called cubewanos). There is a continuous region of stable phase space connecting the inner classical belt to the main classical belt, and only the 2:1 resonance separates the main belt from the outer classical belt. The utility of these terms is thus simply descriptive, but has the practical advantage of giving an adjective to isolate these cosmogonically interesting semimajor axis regions. While these subclasses serve no strong nomenclature purpose, as there is little current *dynamical* difference between these regions, we flag these objects as such in Table 5.

The outer classical belt is currently inhabited only by the high-quality-orbit TNOs 2003 UY_{291} and 2001 QW_{297}, which the discoverers classified as detached (*Elliot et al.,* 2005), and 48639 = 1995 TL_8, classified as detached by *Gladman et al.* (2002). They will soon be joined by 2004 XR_{190} [aka Buffy (*Allen et al.,* 2006)] with a ≃ 57.5, e ≃ 0.10. While TL_8 and UY_{291} have inclinations below 5°, one may be uncomfortable with i = 17° or 47° TNOs being in the classical belt; there are objects with similarly high i in the main classical belt (e.g., 2004 DG77 with i = 47.6°), and thus i cannot be a guide for membership in the classical belt even if the dynamically hot state of the classical belt is somewhat of a surprise. It may not be generally realized

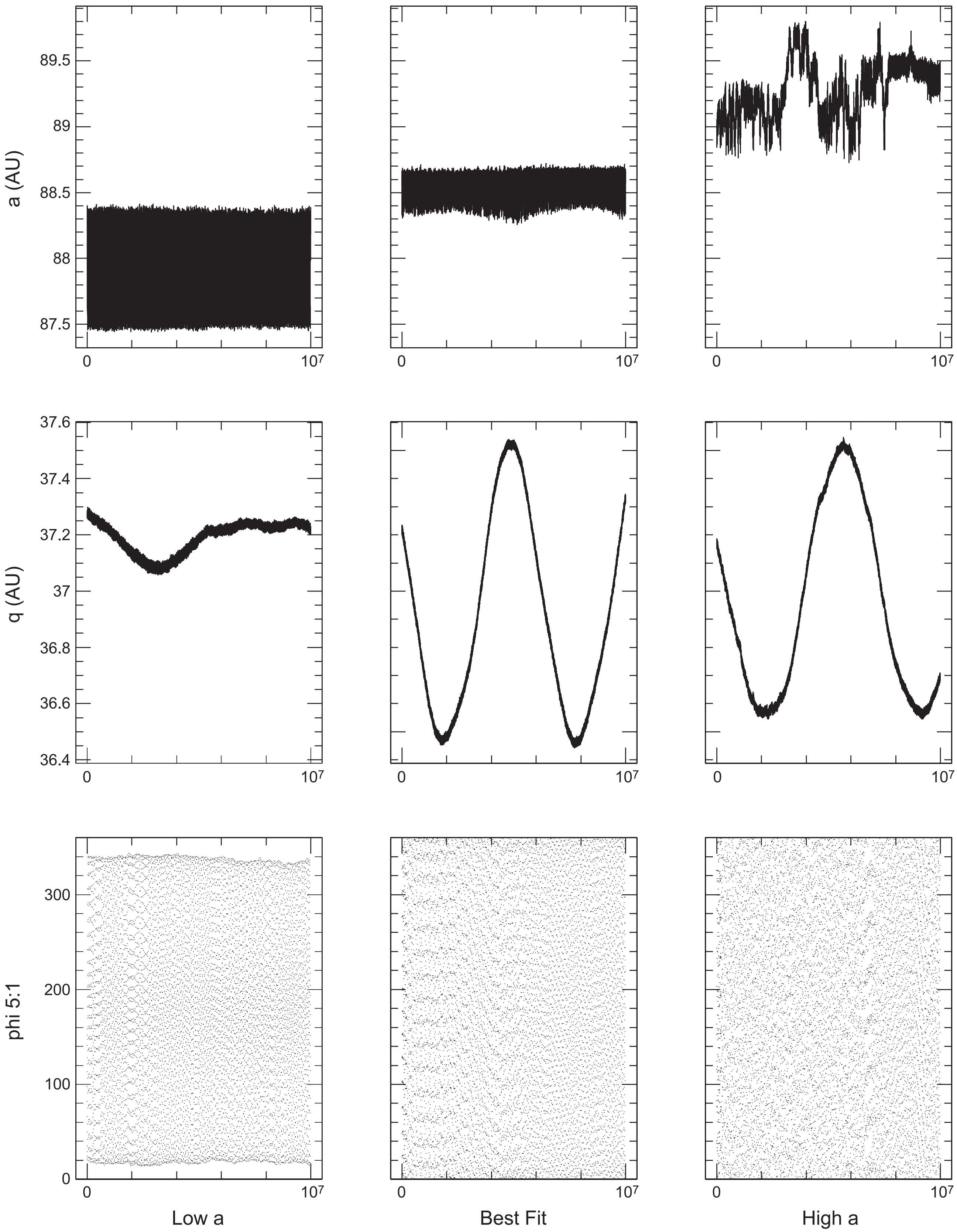

Fig. 6. The nonresonant (but unsecure) classification of detached TNO 2003 YQ_{179}. The left, center, and right columns correspond to the orbital histories from the numerical integration of the lowest-a, best-fit, and highest-a orbits from the orbit uncertainty calculation. The best-fit and highest-a orbits show nonresonant behavior, and the nominal classification is "detached." However, with the roughly ±0.4 AU semimajor axis uncertainty, we find that the lowest-a orbit exhibits large-amplitude libration in the 5:1 mean-motion resonance. Further observations are needed to ensure that the true orbit is not in the 5:1.

TABLE 4. Detached TNOs (SSBN07 classification).

(40314 = 1999KR$_{16}$)	60458 = 2000CM$_{114}$	90377 = 2003VB$_{12}$ = Sedna	118702 = 2000OM$_{67}$
120132 = 2003FY$_{128}$	134210 = 2005PQ$_{21}$	136199 = 2003UB$_{313}$ = Eris	(J98X95Y = 1998XY$_{95}$)
(J99CB8Z = 1999CZ$_{118}$)	J99CB9F = 1999CF$_{119}$	(J99CB9G = 1999CG$_{119}$)	J99H11W = 1999HW$_{11}$
J99RL4Z = 1999RZ$_{214}$	(J99RL5D = 1999RD$_{215}$)	(J99RL5J = 1999RJ$_{215}$)	K00AP5F = 2000AF$_{255}$
K00CA5Q = 2000CQ$_{105}$	K00CA5R = 2000CR$_{105}$	K00P30E = 2000PE$_{30}$	K00P30F = 2000PF$_{30}$
(K00P30H = 2000PH$_{30}$)	(K00Y02C = 2000YC$_{2}$)	(K01FJ4M = 2001FM$_{194}$)	(K02G31Z = 2002GZ$_{31}$)
(K02G32A = 2002GA$_{32}$)	K03FC9Z = 2003FZ$_{129}$	(K03Q91K = 2003QK$_{91}$)	(K03YH9Q = 2003YQ$_{179}$)

TABLE 5. Classical objects (SSBN07 classification; italics indicate inner belt, bold indicates outer belt).

15760 = 1992QB$_{1}$	15807 = 1994GV$_{9}$	15883 = 1997CR$_{29}$	16684 = 1994JQ$_{1}$
19255 = 1994VK$_{8}$	19308 = 1996TO$_{66}$	19521 = 1998WH$_{24}$ = Chaos	20000 = 2000WR$_{106}$ = Varuna
24835 = 1995SM$_{55}$	24978 = 1998HJ$_{151}$	33001 = 1997CU$_{29}$	*35671 = 1998SN$_{165}$*
(38083 = 1999HX$_{11}$ = Rhadamanthus)		45802 = 2000PV$_{29}$	**48639 = 1995TL$_{8}$**
49673 = 1999RA$_{215}$	50000 = 2002LM$_{60}$ = Quaoar	52747 = 1998HM$_{151}$	53311 = 1999HU$_{11}$ = Deucalion
55565 = 2002AW$_{197}$	55636 = 2002TX$_{300}$	55637 = 2002UX$_{25}$	58534 = 1997CQ$_{29}$ = Logos
60454 = 2000CH$_{105}$	66452 = 1999OF$_{4}$	66652 = 1999RZ$_{252}$	69987 = 1998WZ$_{25}$
(76803 = 2000PK$_{30}$)	79360 = 1997CS$_{29}$	79983 = 1999DF$_{9}$	80806 = 2000CM$_{105}$
82157 = 2001FM$_{185}$	85627 = 1998HP$_{151}$	85633 = 1998KR$_{65}$	86047 = 1999OY$_{3}$
86177 = 1999RY$_{215}$	88267 = 2001KE$_{76}$	88268 = 2001KK$_{76}$	88611 = 2001QT$_{297}$
90568 = 2004GV$_{9}$	118379 = 1999HC$_{12}$	*119951 = 2002KX$_{14}$*	120178 = 2003OP$_{32}$
120347 = 2004SB$_{60}$	*120348 = 2004TY$_{14}$*	123509 = 2000WK$_{183}$	126719 = 2002CC$_{249}$
(129772 = 1999HR$_{11}$)			
J93F00W = 1993FW	J94E02S = 1994ES$_{2}$	J94E03V = 1994EV$_{3}$	J95D02B = 1995DB$_{2}$
J95D02C = 1995DC$_{2}$	J95W02Y = 1995WY$_{2}$	J96K01V = 1996KV$_{1}$	J96R20Q = 1996RQ$_{20}$
J96T66K = 1996TK$_{66}$	J96T66S = 1996TS$_{66}$	J97C29T = 1997CT$_{29}$	(J97C29V = 1997CV$_{29}$)
J97Q04H = 1997QH$_{4}$	J97R05T = 1997RT$_{5}$	J97R09X = 1997RX$_{9}$	
J98FE4S = 1998FS$_{144}$	J98HF1L = 1998HL$_{151}$	*J98HF1N = 1998HN$_{151}$*	J98HF1O = 1998HO$_{151}$
J98K61Y = 1998KY$_{61}$	J98K62G = 1998KG$_{62}$	J98K65S = 1998KS$_{65}$	J98W24G = 1998WG$_{24}$
J98W24V = 1998WV$_{24}$	J98W24X = 1998WX$_{24}$	J98W24Y = 1998WY$_{24}$	J98W31T = 1998WT$_{31}$
J98W31W = 1998WW$_{31}$	J98W31X = 1998WX$_{31}$	J98W31Y = 1998WY$_{31}$	
J99CB9B = 1999CB$_{119}$	J99CB9C = 1999CC$_{119}$	J99CB9H = 1999CH$_{119}$	J99CB9J = 1999CJ$_{119}$
J99CB9L = 1999CL$_{119}$	J99CB9N = 1999CN$_{119}$	J99CD3Q = 1999CQ$_{133}$	J99CF3M = 1999CM$_{153}$
(J99CF3O = 1999CO$_{153}$)	J99CF3U = 1999CU$_{153}$	J99CF4H = 1999CH$_{154}$	J99CF8K = 1999CK$_{158}$
J99D00A = 1999DA	J99D08H = 1999DH$_{8}$	(J99G46S = 1999GS$_{46}$)	J99H11S = 1999HS$_{11}$
J99H11V = 1999HV$_{11}$	J99H12H = 1999HH$_{12}$	J99H12J = 1999HJ$_{12}$	J99O03Z = 1999OZ$_{3}$
J99O04A = 1999OA$_{4}$	J99O04C = 1999OC$_{4}$	J99O04D = 1999OD$_{4}$	J99O04E = 1999OE$_{4}$
J99O04G = 1999OG$_{4}$	J99O04H = 1999OH$_{4}$	*J99O04J = 1999OJ$_{4}$*	J99O04K = 1999OK$_{4}$
J99O04M = 1999OM$_{4}$	J99O04N = 1999ON$_{4}$	J99RL4T = 1999RT$_{214}$	J99RL4Y = 1999RY$_{214}$
J99RL5E = 1999RE$_{215}$	J99RL5G = 1999RG$_{215}$	J99RL5N = 1999RN$_{215}$	J99RL5U = 1999RU$_{215}$
J99RL5X = 1999RX$_{215}$	J99RL6A = 1999RA$_{216}$	J99XE3Y = 1999XY$_{143}$	
K00CA4L = 2000CL$_{104}$	K00CA4P = 2000CP$_{104}$	K00CA5E = 2000CE$_{105}$	K00CA5F = 2000CF$_{105}$
K00CA5G = 2000CG$_{105}$	K00CA5J = 2000CJ$_{105}$	K00CA5L = 2000CL$_{105}$	(K00CA5N = 2000CN$_{105}$)
K00CA5O = 2000CO$_{105}$	K00CB4N = 2000CN$_{114}$	K00CB4Q = 2000CQ$_{114}$	K00F08A = 2000FA$_{8}$
K00F08C = 2000FC$_{8}$	K00F08F = 2000FF$_{8}$	K00F08G = 2000FG$_{8}$	K00F08H = 2000FH$_{8}$
(K00F53R = 2000FR$_{53}$)	K00F53S = 2000FS$_{53}$	K00F53T = 2000FT$_{53}$	K00GE6V = 2000GV$_{146}$
K00GE6X = 2000GX$_{146}$	K00GE6Y = 2000GY$_{146}$	K00GI3P = 2000GP$_{183}$	K00J81F = 2000JF$_{81}$
K00K04K = 2000KK$_{4}$	*K00K04L = 2000KL$_{4}$*	*K00O51B = 2000OB$_{51}$*	K00O67H = 2000OH$_{67}$
K00O67J = 2000OJ$_{67}$	K00O67K = 2000OK$_{67}$	K00O67L = 2000OL$_{67}$	K00O67N = 2000ON$_{67}$
K00O69U = 2000OU$_{69}$	K00P29U = 2000PU$_{29}$	K00P29W = 2000PW$_{29}$	K00P29X = 2000PX$_{29}$
K00P29Y = 2000PY$_{29}$	K00P30A = 2000PA$_{30}$	K00P30C = 2000PC$_{30}$	K00P30D = 2000PD$_{30}$
(K00P30G = 2000PG$_{30}$)	K00P30M = 2000PM$_{30}$	K00P30N = 2000PN$_{30}$	K00QM6C = 2000QC$_{226}$
(K00Sb0Y = 2000SY$_{370}$)	K00W12V = 2000WV$_{12}$	K00WG9T = 2000WT$_{169}$	K00WI3O = 2000WO$_{183}$
K00Y01V = 2000YV$_{1}$	K00Y01X = 2000YX$_{1}$	K00Y02A = 2000YA$_{2}$	*K00Y02B = 2000YB$_{2}$*
K00Y02E = 2000YE$_{2}$	K00Y02F = 2000YF$_{2}$		

TABLE 5. (continued).

K01C31Z = 2001CZ$_{31}$	K01DA6B = 2001DB$_{106}$	K01DA6D = 2001DD$_{106}$	K01FI5K = 2001FK$_{185}$
K01FI5L = 2001FL$_{185}$	K01FI5N = 2001FN$_{185}$	K01FI5O = 2001FO$_{185}$	K01FI5T = 2001FT$_{185}$
K01FJ3K = 2001FK$_{193}$	(K01H65Y = 2001HY$_{65}$)	K01K76F = 2001KF$_{76}$	K01K76H = 2001KH$_{76}$
(K01K76T = 2001KT$_{76}$)	(K01K76W = 2001KW$_{76}$)	K01K77A = 2001KA$_{77}$	(K01K77E = 2001KE$_{77}$)
K01K77O = 2001KO$_{77}$	K01OA8K = 2001OK$_{108}$	K01OA8Q = 2001OQ$_{108}$	K01OA8Z = 2001OZ$_{108}$
K01OA9G = 2001OG$_{109}$	*K01P47K = 2001PK$_{47}$*	K01QT7O = 2001QO$_{297}$	K01QT7P = 2001QP$_{297}$
K01QT7R = 2001QR$_{297}$	**(K01QT7W = 2001QW$_{297}$)**	K01QT7X = 2001QX$_{297}$	K01QT7Y = 2001QY$_{297}$
K01QT7Z = 2001QZ$_{297}$	K01QT8A = 2001QA$_{298}$	K01QT8B = 2001QB$_{298}$	K01QT8C = 2001QC$_{298}$
K01QT8D = 2001QD$_{298}$	K01QT8J = 2001QJ$_{298}$	K01QW2Q = 2001QQ$_{322}$	K01QW2S = 2001QS$_{322}$
K01QW2T = 2001QT$_{322}$	K01QW2W = 2001QW$_{322}$	K01RE3W = 2001RW$_{143}$	K01RE3Z = 2001RZ$_{143}$
K01U18N = 2001UN$_{18}$	K01U18Q = 2001UQ$_{18}$	K01XP4R = 2001XR$_{254}$	K01XP4U = 2001XU$_{254}$
K02CF4S = 2002CS$_{154}$	K02CF4T = 2002CT$_{154}$	K02CM4X = 2002CX$_{224}$	K02CM5B = 2002CB$_{225}$
K02CO8Y = 2002CY$_{248}$	K02CP1D = 2002CD$_{251}$	K02F06U = 2002FU$_{6}$	K02F06V = 2002FV$_{6}$
K02F36W = 2002FW$_{36}$	K02F36X = 2002FX$_{36}$	K02G32H = 2002GH$_{32}$	K02G32J = 2002GJ$_{32}$
K02K14W = 2002KW$_{14}$	(K02M04S = 2002MS$_{4}$)	K02PE5Q = 2002PQ$_{145}$	K02PE9D = 2002PD$_{149}$
K02PE9O = 2002PO$_{149}$	K02PE9P = 2002PP$_{149}$	K02PF5D = 2002PD$_{155}$	K02PH0T = 2002PT$_{170}$
K02PH0V = 2002PV$_{170}$	K02PH0W = 2002PW$_{170}$	K02PH0X = 2002PX$_{170}$	K02PH0Y = 2002PY$_{170}$
K02PH1A = 2002PA$_{171}$	K02PH1C = 2002PC$_{171}$	K02VD0F = 2002VF$_{130}$	(K02VD0S = 2002VS$_{130}$)
K02VD0T = 2002VT$_{130}$	K02VD1B = 2002VB$_{131}$	K02VD1D = 2002VD$_{131}$	K02W21L = 2002WL$_{21}$
K02X91H = 2002XH$_{91}$			
(K03E61L = 2003EL$_{61}$)	K03FC7K = 2003FK$_{127}$	*K03FC8D = 2003FD$_{128}$*	K03FD0A = 2003FA$_{130}$
K03G55F = 2003GF$_{55}$	(K03H56X = 2003HX$_{56}$)	K03H56Y = 2003HY$_{56}$	K03H56Z = 2003HZ$_{56}$
K03H57C = 2003HC$_{57}$	K03H57E = 2003HE$_{57}$	(K03H57G = 2003HG$_{57}$)	K03H57H = 2003HH$_{57}$
(K03K20O = 2003KO$_{20}$)	K03L09D = 2003LD$_{9}$	(K03M12W = 2003MW$_{12}$)	K03Q90W = 2003QW$_{90}$
K03Q90X = 2003QX$_{90}$	K03Q90Y = 2003QY$_{90}$	*K03Q91Q = 2003QQ$_{91}$*	K03QB3F = 2003QF$_{113}$
K03SV7N = 2003SN$_{317}$	(K03SV7P = 2003SP$_{317}$)	K03SV7Q = 2003SQ$_{317}$	(K03T58G = 2003TG$_{58}$)
(K03T58K = 2003TK$_{58}$)	K03T58L = 2003TL$_{58}$	K03UB7Z = 2003UZ$_{117}$	**K03UT1Y = 2003UY$_{291}$**
K03UT2B = 2003UB$_{96}$	(K03YH9J = 2003YJ$_{179}$)	K03YH9K = 2003YK$_{179}$	*K03YH9L = 2003YL$_{179}$*
K03YH9M = 2003YM$_{179}$	K03YH9N = 2003YN$_{179}$	K03YH9O = 2003YO$_{179}$	K03YH9P = 2003YP$_{179}$
K03YH9R = 2003YR$_{179}$	K03YH9S = 2003YS$_{179}$	K03YH9T = 2003YT$_{179}$	K03YH9U = 2003YU$_{179}$
K03YH9V = 2003YV$_{179}$	K03YH9X = 2003YX$_{179}$		
K04XJ0X = 2004XX$_{190}$	K05F09Y = 2005FY$_{9}$		

that discovery of 2003 UY$_{291}$ has provided the first low-i, e < 0.2 TNO beyond the 2:1 resonance. The reason for the sparse population beyond the 2:1 is still an area of active research.

This brings us to a potential division of the classical belt into "hot" and "cold" components based on orbital inclination. While there are compelling arguments for interesting structure in the i-distribution (*Doressoundiram et al.,* 2002; *Gulbis et al.,* 2006), we do not feel the situation is yet sufficiently explored to draw an arbitrary division, especially since the plane with which to reference the inclinations is unclear (this choice of plane will move many objects in and out of the category). Although a cut near i_{cut} = 5° into hot and cold populations may eventually be useful, this cut reflects no dynamical separation. Although the high abundance of low-i TNOs is partially a selection effect of surveys being largely confined to the ecliptic (*Trujillo et al.,* 2001; *Brown,* 2001), an additional "cold" population does seem to be required, but strangely only in the a ≃ 42–45-AU region (see chapter by Kavelaars et al.); this cold component does not seem to be present in the inner or outer classical belt, or any of the resonant populations.

Elliot et al. (2005) essentially performed the hot/cold cut via their Tisserand parameter (with respect to Neptune) definition, which puts almost all TNOs with i > 15° into the SDO or detached populations. We are uncomfortable with calling extremely stable objects (e.g., a ~ 46, e ~ 0.1, i ~ 20°) SDOs, and thus propose that if a hot/cold division becomes enshrined, it be applied only to the classical belt and not SDOs.

6. CONCLUSION

The SSBN07 nomenclature algorithm defined herein separates outer solar system objects into unique groups with no gray areas to produce future problems. The term transneptunian region and the Kuiper belt become the same and the *transneptunian region* becomes defined as the union of the classical belt, SDO/detached populations, and the resonant objects exterior to the Neptune Trojans. There is a very large fraction of the a > 48 TNOs that are resonant, and further observations are required to hone their orbits.

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