Celestial mechanics: a study of orbits of extreme outer solar system objects

An extreme outer solar system object or, an extreme trans-Neptunian object (ETNO), is any minor planet in the Solar system with a perihelion (closest approach to the Sun) larger than 30 astronomical units (AU) and the semi-major axis larger than 150 AU. There are currently about 19 known ETNOs, 8 of them have a perihelion larger than 40 AU, which makes them only weakly affected by Neptune.

There are several irregularities related to the orbits of ETNOs, in particular, large eccentricities and inclinations to the ecliptic (T. Mukai et al, R. Gomez et al), and the fact that arguments of the perihelion are clustered in the range of 280 to 40 degrees.

S. Sheppard and C. Trujillo, and later R. and C. de la Fuente Marcos suggested that the irregularities are caused by a large Neptune size body which turns around the Sun at a distance 200 to 1500 AU via the so called Lidov-Kozai mechanism. The Lidov-Kozai mechanism is a perturbation of an orbit of a minor body by large distant body that causes oscillations about a constant value of the orbit’s argument of pericenter.

The Lidov-Kozai scenario has been modeled by K. Batygin and M. E. Brown for six ETNOs: their model explained most of the irregularities as the effect of large planet whose orbit has a semi-major axis between 200 and 2000 AU.

Currently, S. Sheppard, C. Trujillo, K. Batygin and M. E. Brown are using the Subaru Telescope of the National Astronomical Observatory of Japan to search for the proposed planet. Their research has been widely publicized in media as a pre-discovery of Planet Nine.

Very few alternative mechanisms (which do exist) have been studied. One possibility, is a massive, yet undiscovered, belt of minor planets (A-M. Madigan, M. McCourt).

The project would involve a critical mathematical study of all mechanisms which could be responsible for the observed orbits of the ETNOs. Hopefully, as in the nearest future, more ETNOs will be discovered to make any model statistically more meaningful (currently, the ETNOs are discovered at a rate of about one per two years).
Figure 1. The orbits of the ETNOs, only weakly affected by Neptune, are in red and green. The arguments of their perihilion are clearly clustered. (taken from Scott Sheppard’s webpage).