

The Determination and Long Term Integration of the Orbits of Caliban and Sycorax

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The first 2 irregular satellites of Uranus, Caliban and Sycorax, were discovered in late 1997 (Gladman *et al.* 1998 *Nature* **392**, 897). Subsequently, pre-discovery observations of both satellites were found on plates taken by D. Cruikshank in June of 1984. Recently, P. Nicholson, D. Tholen, and W. Offutt provided observations which they made in late 1998 at Palomar Mountain, Mauna Kea, and Cloudcroft, respectively. I fit a numerical integration perturbed by the Sun, Jupiter, Saturn, and Neptune to the set of available observations. For the 47 observations of Caliban the respective rms values of the $\Delta\alpha \cos \delta$ and $\Delta\delta$ residuals are 0''.60 and 0''.32, and for the 103 observations of Sycorax the analogous values are 0''.57 and 0''.59.

I extended the integration to span a 6000 year period and computed osculating orbital elements at yearly intervals. The table below contains the mean values of the elements over the 6000 years, the sidereal period, and the precession periods of the argument of periapsis and longitude of the ascending node. The osculating elements (except for a) exhibit a significant long period oscillation with a period roughly half that of the argument of periapsis.

| Element | Caliban | Sycorax |
|-----------------|---------|----------|
| a (km) | 7166840 | 12191450 |
| e | 0.168 | 0.520 |
| ω (deg) | 153.32 | 20.99 |
| i (deg) | 140.93 | 156.99 |
| Ω (deg) | 168.00 | 263.69 |
| P (day) | 579.46 | 1283.26 |
| P_ω (yr) | 8900 | 1390 |
| P_Ω (yr) | 6700 | 1860 |

Ephemerides for the satellites are available electronically from the JPL Horizons on-line solar system data and ephemeris computation service.

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