Does the Pluto System Contain Additional Satellites? S.A. Stern, Department of Space Studies, Southwest Research Institute, 1050 Walnut Street, Suite 400, Boulder, CO 80302, astern@swri.edu.

Introduction: It is not known if Pluto has other satellites besides its binary partner, Charon. However, the very large solar-tidal stability radius of the Pluto-Charon system (i.e., out to ~2x10^6 km or ~90 arcsec from Pluto), combined with the recent detection of numerous KBO satellites, and the development of NASA's New Horizons Pluto-Kuiper Belt mission (http://pluto.jhuapl.edu/), each serve to motivate renewed searches.

Background: Pluto has only one known satellite, Charon (e.g., [1]), which orbits Pluto in an essentially circular orbit with a period of 6.387 days. This orbit period is precisely synchronous with Pluto's rotation period. Charon's orbit is in the plane of Pluto's equator, with a semi-major axis near 19,600 km [2].

The detection of one or more new satellites of Pluto would, like any other planetary satellite, be of intrinsic scientific interest. More importantly, such a find could also provide important clues to dynamical evolution of the Pluto-Charon binary, and a potentially powerful dynamical tool for probing the relative densities, gravitational moments (e.g., J_2), and therefore the internal mass distribution of Pluto and/or Charon. It could also provide new constraints on the mechanisms of satellite formation ([3-5]) and/or capture [6-7] in the Kuiper Belt, and make attractive targets for study by the New Horizons Pluto-Kuiper Belt mission (see [8]).

Existing Constraints: The existing constraints on possible undiscovered satellites of Pluto come in two broad forms: observational and dynamical [9-10]. I now briefly summarize each, in turn.

Observational: Using archival HST images obtained in 1991, high confidence detection limits were set for satellites with V=19.3 mag inside the Charon instability strip, V=21.7 mag between 1 arcsec (i.e., Charon's orbit) and 2 arcsec from Pluto, and V=21.9 mag beyond 2 arcsec from Pluto. These constraints correspond to satellite radii of 140 km, 46 km, and 42 km, respectively, for bodies with a Charon-like albedo of 0.4. Although superior to previous results, these constraints allow for objects far larger than the small satellites of the giant planets, and indeed, even objects larger than some already-detected KBO satellites (e.g., [11]).

Dynamical: Charon's orbit is deep in Pluto's potential well; indeed, it lies only ~1% of the way to the Pluto system's solar tidal stability radius of ~2x10^6 km. Virtually all of this space can harbor undetected satellites.

The main exceptions to this lie in the region between Pluto's surface and about twice Charon's orbital radius. Very close to Pluto, of course, there is the Roche zone, extending out to perhaps as far as 2 Pluto radii above the planet's surface. There is also a torus around Charon's orbit in which orbits are unstable to perturbations and rapidly become Charon crossing. For low inclination, prograde orbits, this region extends from ~0.47a_C to 2a_C, where a_C is defined as the Pluto-Charon separation distance. For retrograde orbits the Charon-induced instability strip extends from ~0.65a_C to 1.6a_C. Further, test integrations have revealed that no satellite with mass >10^{-4} of the combined mass of the Pluto-Charon system (i.e., corresponding to R>57 km for bulk density 2 g cm^{-3}) can exists in the region interior to the Charon instability strip, else it would have induced detectible orbit perturbations on Charon, even if the satellite itself remained unseen. A similar mass constraint was obtained for orbits just outside the Charon instability strip, however, for orbits further out, this mass constraint quickly degrades; for example, at 2a_C, the constraint is near 10^{-2} the combined mass of Pluto-Charon (corresponding to satellites as large as 150 km in radius for plausible densities). At these larger distances, the observational results are significantly more constraining than the dynamical simulation constraints.

One might speculate that undiscovered small satellites of Pluto, particularly those exterior to Charon, could be captured KBOs. However, this need not necessarily be the case, as tidal evolution of the Pluto-Charon binary could have evolved native satellites significantly outward.

Renewed Searches: The results summarized above constrain but very clearly do not eliminate the existence of one or more undiscovered satellites in the Pluto-Charon system, including objects of considerable size.

In order to further constrain the possibility of additional satellites in the Pluto system, new observations are required. Searches down to V=26 are now the common staple of deep Kuiper Belt work, and which were not feasible when the most recent published Pluto satellite searches were conduced, over a decade ago. Such new searches would detect satellites as small as ~6 km with a Charon-like albedo of 0.4, and ~20 km with a darker, comet-like albedo of 0.04. With intensive effort, searches as deep as V=28 might be made, allowing one to probe down an additional factor of 2.5 in size. HST's strength is its ability to detect or constrain the presence of very faint objects interior to Charon's 0.9" orbit using its narrow point spread function and coronographic facilities.

Although New Horizons itself will be capable of detecting even dark (p=0.04) satellites as small as 1 km in radius during its approach to Pluto, the value of earlier detection is obvious.

Therefore, the New Horizons project team is undertaking such searches using both groundbased and (if time is awarded) the Hubble Space Telescope (HST). Owing to Pluto's approach to increasingly crowded fields near the galactic center, it is important that such searches occur before 2006.

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