Overview: The geographic location of Sputnik Planum (the large, N$_2$ ice filled, convecting “heart” of Pluto [1]) is suspiciously close to the tidal axis of Pluto (Fig. 1). If Sputnik Planum (SP) were a large positive mass anomaly—perhaps due to loading of N$_2$ ice—then SP would naturally migrate to the tidal axis as Pluto approaches a minimum energy state. In this work, we investigate the feasibility of reorientation (i.e. true polar wander) of Pluto by Sputnik Planum, and its implications for Pluto’s interior structure, global tectonic patterns, and volatile cycling.

Reorientation due to Sputnik Planum: SP is a large, ~20° radius, ~4 km deep, probable impact basin [2] located near the anti-Charon point, at 176°E, 24°N. This location, near the anti-Charon point, is consistent with SP being a positive mass anomaly, which resulted in true polar wander (TPW) of Pluto, placing it near the tidal axis in order to minimize rotational and potential energy. There is only a 10% probability of placing an anomaly this close to a tidal axis by chance.

On other solar system bodies, the formation and evolution of a large impact basin can easily produce positive, neutral (i.e. compensated), or negative mass anomalies that result in TPW [3-5]. For this preliminary work, we assume that the underlying basin is predominantly compensated, and instead focus on reorientation due to the subsequent infill of several kilometers of N$_2$ ice [6-7].

The ability of any mass anomaly to reorient a body is counteracted by the planet’s elastic lithosphere, which may preserve an earlier rotational or tidal bulge. At present, no bulge (fossil or otherwise) has been detected at Pluto [1]. We assume that Pluto has a rigid fossil figure, formed in its present spin/orbit configuration with Charon, consistent with the upper limit of Pluto’s oblateness [1]. Under this assumption, we determined the possible initial formation locations of SP, as a function of the thickness of N$_2$ ice within the basin (Fig. 2). If the underlying basin is not compensated, then these thicknesses are lower limits if it is a negative anomaly, and upper limits if it is a positive anomaly. Similarly, the degree of differentiation, strength of the lithosphere, magnitude of fossil bulge, and presence of an ocean can modulate these results (although the general patterns in Fig. 2 will remain the same). In this work, we assume a nominal Pluto interior structure; with a 250 km thick ice crust, with elastic thickness of 50 km, overlying an ocean. Nonetheless, the non-zero latitude of SP places interesting constraints on the initial location of SP, and any subsequent reorientation. Not just any mass anomaly will reorient Pluto to place SP at its present location. SP likely formed at higher latitude, either at 90°E or 180°E.

Tectonic Stresses due to True Polar Wander: Reorientation of a planet generates stresses in the lithosphere, which can result in characteristic global tectonic patterns [8-9]. Pluto indeed shows a global, non-random system of extensional faults and graben (Fig. 3a-b) [1]. The lack of obvious thrust or strike-slip faulting likely reflects global extensional stresses associated with the freezing of a subsurface ocean, and the resulting expansion of Pluto [10]. Using our initial locations of SP (Fig. 2), we calculated tectonic patterns for a range of possible reorientation scenarios (Fig. 3c-
is a localized cold-trap. SP is initially located further North and West than its present location. We then randomly select \( N \) grid points, based on the probability of sublimation, and redistribute a fraction of the \( N_2 \) ice in those grids to an equal number of grid points randomly selected based on the probability of condensation. Following each time-step, we evaluate the new global inertia tensor due to volatile redistribution, and determine how the planet would reorient, which then changes the insolation pattern in the subsequent time-step. Fig. 4 shows an example output of this model. Over orbital timescales, volatiles migrate from the equatorial cold traps and become sequestered into SP. As SP loads with \( N_2 \), it migrates towards the equator and tidal axis, further enhancing its ability to trap volatiles. The final latitude and longitude is set by the efficiency of this process, the total reservoir of mobile volatiles, and Pluto’s fossil figure.

**References:**