STRUCTURE AND GEOPHYSICAL EVOLUTION OF SPUTNIK BASIN ON PLUTO. S.A. Moruzzi[1], J.C. Andrews-Hanna[1], P. Schenk[2]. [1]University of Arizona, Tucson, AZ (smoruzzi@arizona.edu), [2]The Lunar and Planetary Institute, Houston, TX.

Introduction: Sputnik basin, an 1800 × 950 km elongated impact basin in the equatorial region of Pluto, has provided key insight into Pluto's interior since the basin's discovery by New Horizons in 2015 [1, 2]. The subsurface structure of Sputnik is unknown as we lack gravity data. However, the low-viscosity, N_2-rich ice deposit comprising Sputnik Planitia contained within the basin should readily flow to conform to an equipotential surface. Stereo-topography data from this surface can be interpreted as representing the geoid, which constrains the present-day subsurface structure and compensation state of the basin. The subsurface structure of the basin has important implications for the Sputnik-forming impact, its potential to drive true polar wander [e.g., 3, 4], and for the structure and evolution of Pluto itself.

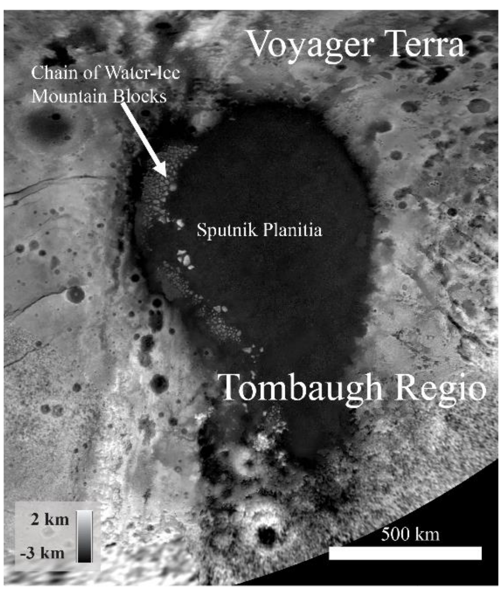

Fig 1: High resolution DEM of Sputnik Planitia referenced to mean planetary radius of 1188.3 km [2].

Previous studies have considered Sputnik to be analogous to giant impact basins such as Hellas on Mars [2, 3], though more recent work suggests that Sputnik basin is morphologically and topographically consistent with peak-ring/multiring basins in the inner Solar System [5]. The N-S trending chain of water-ice mountain blocks within the basin (Fig. 1, arrows) may be the topographic expression of the inner ring. If Sputnik basin is a peak-/multiring basin, any central ocean uplift or potential mascon [3, 6] would be confined within the inner ring and the subsurface structure of the ice shell may resemble the subsurface crustal structure of peak-ring basins in the inner Solar System. In contrast, if Sputnik is more analogous to giant impact basins, the shell thinning and any potential mascon would stretch across the entire basin interior. Here, we develop quantitative models to constrain the present-day subsurface structure of Sputnik basin, representing the basin as either a peak-/multiring basin or a giant impact basin, with the basin fill acting as a load. Our results are consistent with a negative geoid anomaly and suggest an uncompensated or partially uncompensated basin.

Methods: We consider two approaches for modeling the present-day subsurface structure of Sputnik basin. The first approach considers Sputnik to be a peak-/multiring basin with a central ocean uplift confined within the inner ring, surrounded by a sub-isostatic annulus with a thick, but depressed, shell within the outer ring, similar to basins such as Freundlich-Sharonov on the Moon [7]. The second approach considers Sputnik basin as giant impact basin, analogous to Hellas basin on Mars, with the central ocean uplift confined within the outer ring, extending beneath the entirety of the basin. To constrain the structure and compensation state of the basin, we use a thin-shell flexural model [8, 9] and compare the modeled geoids to observed topography profiles across Sputnik Planitia. We utilized the Digital Elevation Model (DEM) created from high resolution images obtained by the New Horizons Long-Range Reconnaissance Orbiter (LORRI) and the Multispectral Visible Image Camera (MVIC) at a horizontal resolution of ~300 m/pixel (Fig. 1) [2, 10].

The basin subsurface structure affects the net loading and the flexural response of the lithosphere [11]. We consider the net load from the combined effects of the basin topography, the N_2-rich ice deposit inside the basin, and the relief along the base of the ice shell. Lunar basins show that the pre-fill basin floor of peak-/multiring basins can range from isostatic to super-isostatic (a mascon) surrounded by a sub-isostatic annulus and thicker crust/shell between the inner and outer rings [7, 12]. To derive the net load within the basin, we use the pre-fill basin shape derived in [5], using the diameters of the polygonal pattern interpreted as convection cells [13] expressed in Sputnik Planitia to constrain the fill thickness (Fig. 2). We define the shell-ocean interface for a range of compensation states for the basin center (degree of compensation = 0.1-1.5), and assume a constant shell thickness between the inner and outer rings. We then add the N_2-rich ice deposit to the load, assuming a maximum pre-fill basin depth of ~ 6.5 km. For the giant basin interpretation, we assume a flat-floored pre-fill basin interior to the main topographic rim, and we again assume a range of degrees of compensation (0.1-1.5) to calculate the relief along the base of the ice shell. We assume a peak fill thickness within the basin of 7 km.

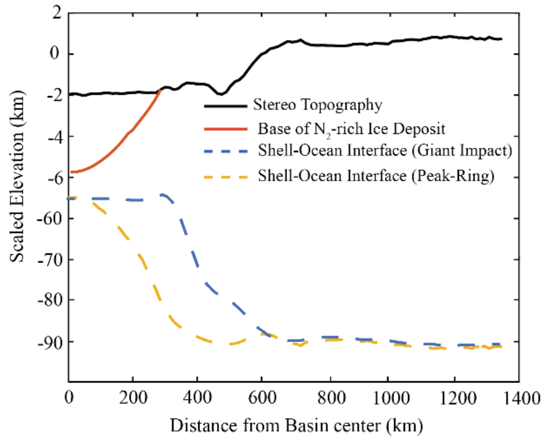

Fig 2: Average radial profile from the center of Sputnik Basin of major components of the membrane-flexural model.

We calculate the flexure of the ice shell from the net load using a global spherical harmonic membrane-flexure model [8, 14] (Fig. 1). For a conductive water ice shell above a eutectic ammonia-water ocean at a temperature of 175 K, ~60% of the total ice shell would behave elastically [15]. We test a lithospheric thickness (T_e) range of 50–200 km, corresponding to shell thicknesses of 80–330 km. We then calculate the gravity field and compare the modeled geoid to the observed topography along the surface of Sputnik Planitia.

Results: The topography across the floor of Sputnik Planitia, which should follow the geoid, is concave up, indicating a negative geoid anomaly (Fig. 3A). The peak-ring models show that an under-compensated basin provides the best fit with a degree of compensation of ~0.1. The corresponding free air gravity anomaly is approximately -100 mGal. The giant impact models also show that an under-compensated basin provides the best fit with a degree of compensation of ~0.1 (Fig 3B). The peak-ring basin geoid model provides a somewhat better fit to the surface of Sputnik Planitia. In contrast, geoid models corresponding to compensated or over-compensated pre-fill basins (i.e., with a central mascon gravity anomaly) after the addition of the fill are concave down in shape and do not match the surface of Sputnik Planitia. If this scenario were correct and Sputnik is a positive gravity anomaly today, then an additional process must be invoked to cause the surface of the low-viscosity N_2-rich ice deposit to depart strongly from the geoid.

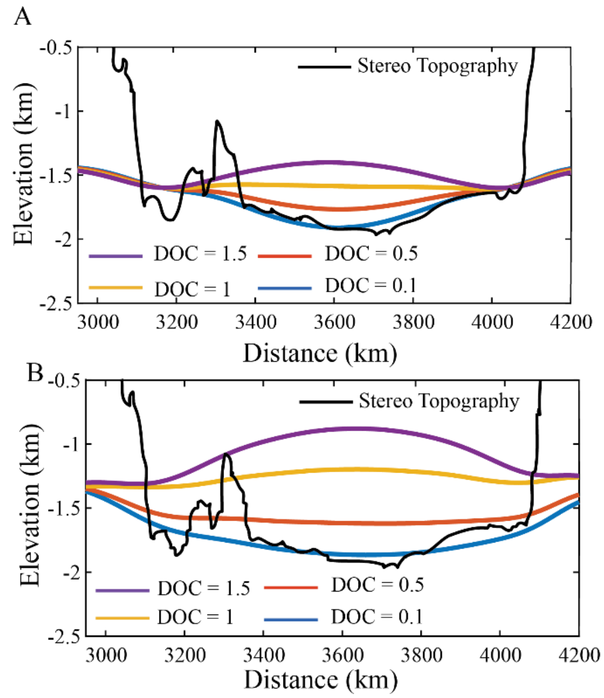

Fig 3: Stereo topography profile of Sputnik basin (black) compared to the modeled geoid results from the peak-ring approach (A) and giant impact approach (B) for a range of compensation states (colored). ***T_e*** **= 100 km for all models.**

Conclusions: Our results indicate that Sputnik basin can be interpreted as either a peak-/multiring basin or a giant impact basin. The basin today is at most partially compensated by an uplifted, dense liquid water ocean and is characterized by a mass deficit, rather than a mass excess as previously proposed [3,6]. However, the basin in the past may still have been overcompensated with a positive geoid anomaly but evolved to an under-compensated state due to refreezing of the subsurface ocean or viscous relaxation of the deeper, warmer ice. The subsurface structure and evolution of Sputnik basin can reveal information about the subsurface structure and evolution of Pluto as a whole.

References: [1] Stern, et al., (2015), *Science*, 350. **[2]** Schenk, et al., (2018), *Icarus*, 314, 400-433. **[3]** Nimmo, et.al., (2016), *Nature* 540, 94 [**4**] Johnson, et al., (2016) *68-77*. **[5]** Moruzzi, et al., (2022, March). In *53rd LPSC* No. 2678. [**6**] Keane, et.al., (2016), *Nature* 340, 90-93. **[7]** Neumann et al., (2015), *Science Advances*, *1*(9), e1500852 **[8]** Moruzzi, et al., (2021, March). In *52nd LPSC* No. 2548. [**9**] Wieczorek, (2007), *Treatise Geophys.* 10, 164-206. [**10**] Moore, et al., (2016), *Science 351*(6279), 284-1293. **[11]** Turcotte and Schubert (2002), Cambridge Uni. Press. **[12]** Andrews-Hanna, (2013), Icarus 222(1), 159-168. **[13]** McKinnon. et al., 2016, *Nature* 534, 82. **[14]** Johnson et al., (2000), *Icarus*, *144*(2), 313–328. **[15]** Dombard and McKinnon, (2006), JSG, 28(12), 2259-2269.