TESTING FOR A COMPOSITIONAL DIFFERENCE BETWEEN PLUTO AND CHARON. C. J. Bierson[1], F. Nimmo[1], and W. B. McKinnon[2]. [1]Department of Earth and Planetary Sciences, University of California, Santa Cruz, CA 95064 (CThomas1@ucsc.edu); [2]Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130

Introduction: The *New Horizons* flyby has gathered a wealth of new information about the Pluto-Charon system [1]. New measurements of the radius of Pluto and Charon have allowed for updated density estimates of the two bodies. These new estimates confirm that Pluto and Charon have different densities ($\Delta\rho$=158+/-34 kg m^{-3}).

	Radius	Density
Pluto	1187+/- 4	1860 +/- 13
Charon	606 +/- 3	1702 +/- 21

Table 1: Radius and density estimates from the *New Horizons* encounter [1].

A difference in density between Pluto and Charon is can be explained in two ways; either Pluto and Charon are compositionally different (different ice-silicate fractions) or there is a difference in their porosity structure [2,3]. Whether Pluto and Charon are compositionally distinct is important for understanding the formation of the Pluto system. If Pluto and Charon formed by pebble accretion [4,5] it would be expected that they should have the same rock-ice fraction. If on the other hand they formed as the result of an impact after Pluto had differentiated, Charon would have preferentially formed from ice removed from Pluto's upper mantle in the impact [6].

In this work we address whether or not the density contrast between Pluto and Charon can be explained by differences in the porosity structure alone.

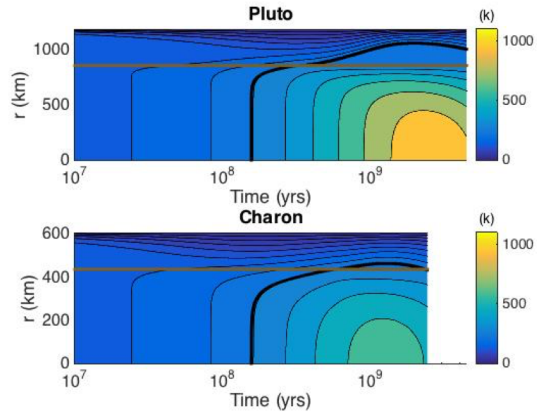

Figure 1: Thermal Histories for Pluto (top) and Charon (bottom). The brown lines mark the core boundary. The thick black lines contour the melting point of water (273 K). Where the black line extends into the ice mantle there exists a liquid ocean. The Charon run is terminated when the ocean freezes.

Models: Here we couple models for the thermal evolution of Pluto and Charon with a model of pore closure.

Thermal Model. The thermal model used in this work is that of [7,8]. This model assumes that Pluto and Charon form after the short-lived radioisotopes have already decayed. Because of this the main source of heat is long lived radioisotopes including ^{238}U and ^{40}K. Heat is assumed to flow via conduction in the core and ice shell, while convection maintains any ocean layer that forms at a uniform temperature. Changes in the thermal conductivity due to porosity in the upper ice shell are not included. The thermal histories used are shown in Figure 1.

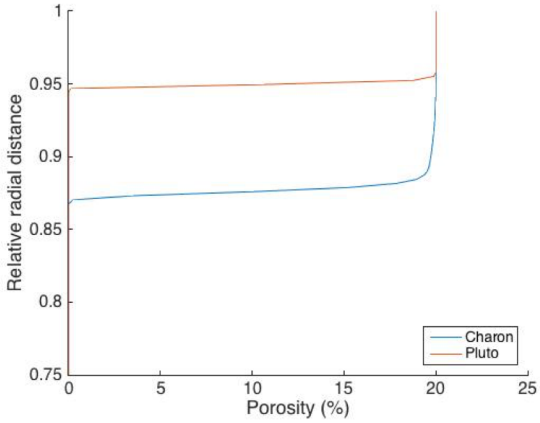

Figure 2: Porosity as a function of depth on both Pluto and Charon using an ice reference viscosity of 10^{14} Pa s. The y-axis is scaled to the radius of each body. For this run pore closure takes place at 65 and 75 km below the surface on Pluto and Charon respectively. Pore closure takes place at a greater depth on Charon because of the smaller pressure due to Charon's smaller gravity and the shallower temperature gradient on Charon.

Pore Closure Model. The pore closure model used in this work is based on that of [9]. Pore closure is assumed to take place by viscous relaxation. This process removes porosity by the following equation [10,11]:

$$\frac{d\ ln(\varphi)}{dt} = \frac{-P}{\eta}$$

Here φ is the porosity, P is the overburden pressure, and η is the viscosity. The viscosity itself has a strong temperature dependence, parameterized by an activation energy (50 kJ/mol) and a reference viscosity at 270K, η_0. Because of the low surface temperatures pore space in the near surface is not removed. The resulting porosity profiles using the output from Fig 1 are shown in Figure 2.

For this model we assume Pluto and Charon are two layer bodies with silicate cores and an ice mantle. We use an ice density of 950 kg m^{-3} and a silicate core density of 3500 kg m^{-3}. We assume Pluto and Charon have the same initial bulk density of 1900 kg m^{-3}. This leads to core sizes of 855 and 436 km for Pluto and Charon respectively.

Results: As can be seen in Figure 3, our model consistently predicts a density contrast of $\Delta\rho$ ~45 kg m^{-3} from porosity alone. This contrast is caused by the fact that the depth of pore closure is shallower on Pluto than Charon (Figure 2). This difference is still much smaller than the density contrast observed by *New Horizons* (158 kg m^{-3}).

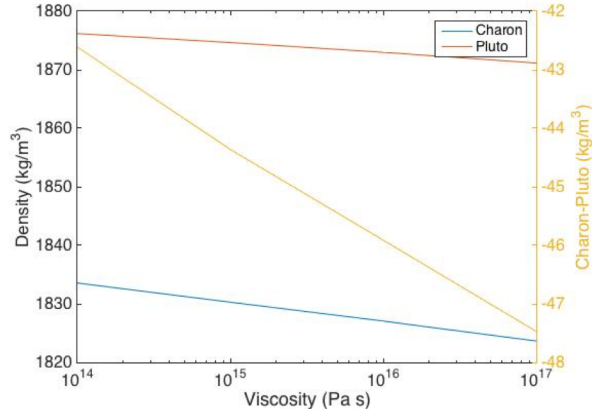

Figure 3: Density of Pluto and Charon as a function of the reference ice viscosity η_0. These runs use an initial porosity of 20%. Note that the difference between Pluto and Charon is only weakly affected by the assumed ice reference viscosity.

Implications: The failure of porosity structure alone to be able to produce the observed density contrast suggests that Pluto must have a larger silicate fraction than Charon. Given the models currently in the literature, this result favors an impact formation for the Pluto-Charon system [6].

Future Work: There is still work to do in fully coupling the thermal evolution and pore closure models. The largest effect not yet incorporated is the thermal conductivity effects of porosity [9].

References: [1] Stern, S. A., et al. (2015) Science 350 [2] Malamud, Uri, and Dina Prialnik. (2015) Icarus 246 21-36. [3] McKinnon W.B. 2015 AGU Fall Meeting [4] Morbidelli, A., and Nesvorny, D. (2012) Astronomy & Astrophysics, 546 [5] Levison, H. F., et al. (2015) Nature, 524, 322-324. [6] Canup, R. M. (2005) Science, 307, 546-550. [7] Robuchon, G., and Nimmo, F. (2011). Icarus, 216, 426-439. [8] Nimmo, F., and Spencer, J. R. (2015) Icarus, 246, 2-10. [9] Besserer, J. et al. (2013). JGR: Planets, 118, 908-915. [10] Fowler, A. C. (1985) Geophysical & Astrophysical Fluid Dynamics, 33, 63-96. [11] Nimmo, F. et al. (2003) Icarus, 166(1), 21-32.