Inner Core Translation, True Polar Wander, and Mercury's North-South Asymmetric Magnetic Field. J. N. H. Abrahams[1], H. Cao[2], and D. J. Stevenson[3], [1]Division of Geological and Planetary Science, California Institute of Technology, Pasadena, CA, USA (jabraham@caltech.edu) [2]Division of Geological and Planetary Science, California Institute of Technology, Pasadena, CA, USA (haocao@caltech.edu) [3]Division of Geological and Planetary Science, California Institute of Technology, Pasadena, CA, USA (djs@gps.caltech.edu)

Introduction: Recent seismological studies [1,2] have shown an East-West asymmetry in the Earth's inner core. One possible explanation [3] for this asymmetry is differential nucleation rates (or even freezing and melting) on opposite sides of the inner-core. Any density asymmetry in the inner-core will cause it to move with respect to the outer-core adiabat, causing differential growth that serves to amplify itself. This differential growth has the potential [4] to create a corresponding East-West asymmetry in the Earth's magnetic field.

One of the many surprising findings of the MESSENGER mission is the strong North-South asymmetry in Mercury's axial dipolar magnetic field [5,6]. Here we explore the possibility of a translating inner-core inside Mercury and its impact on the symmetry properties of Mercury's magnetic field.

Moments of Inertia for a Translating Inner Core: Because inner-core nucleation preferentially removes dense material from the outer-core, younger inner-core material tends to be less dense. Thus, a unidirectional translating inner core will have a layered density structure in the direction of the translation. Such a density structure causes the inner-core's maximum moment of inertia to align normal to the direction of translation. This means that once unidirectional translation begins, the inner-core will tend to realign itself so that the translation is in the equatorial plane to maximize the moment of inertia about the spin-axis. This is a classical example of True Polar Wander (TPW), and provides a natural explanation of the Earth's inner core asymmetry being oriented East-West.

We then considered the scenario in which the inner-core translation undergoes a reversal, which could be caused by melting induced stable stratification on the top of the inner core. In this scenario, the densest material is formed into a prolate shape and then is shifted toward the center of figure of the inner-core. This changes the relative magnitudes of the moments of inertia: the maximum moment of inertia can now be aligned with the direction of translation. The equatorially translating inner-core will undergo TPW and align its translation direction with the spin-axis.

The Possibility of a North-South Translating Inner Core: We explored the scenario in which the inner-core changes the translation direction once to evaluate the possibility of a North-Soth translating inner-core due to TPW. In our experiments, we choose a ran-

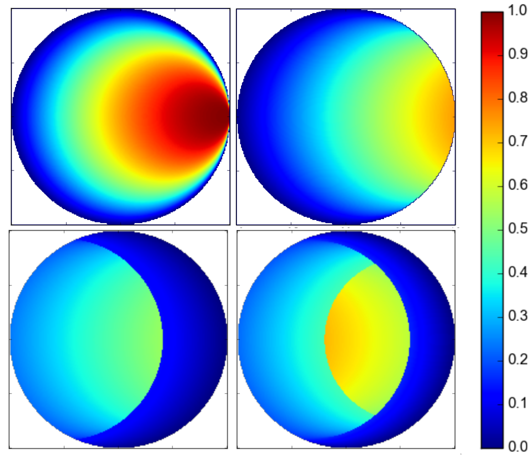

Figure 1: Examples of age distributions of translating inner cores. Color represents normalized age of material. The top two panels show unidirectional inner-core translation initiated at the same time as the inner-core growth. In the top left panel, the inner core is translating at the same speed as it is growing. In the top right panel, the inner-core is translating at triple its growth speed. The bottom two panels show scenarios in which the inner-core translation reversed its direction. In the bottom left panel, the inner core translated East and then West. In the bottom right panel, the inner core translated West, East, and then West again. Both cases shown on the bottom have translation velocities significantly larger than the corresponding growth velocities.

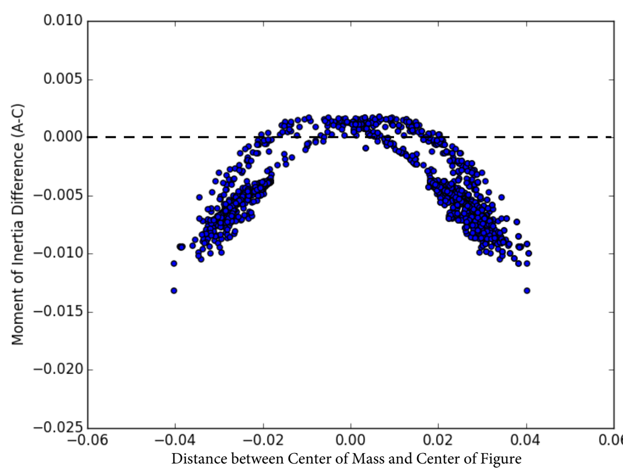

Figure 2: Moment of inertia difference as a function of Center of Mass shift from the Center of Figure for translating inner-cores. Shown here are scenarios in which the inner core has reversed its translation direction, and the two translating velocities are randomly chosen between 1 and 10 times the growth velocity during each regime, and the reversal time is randomly chosen as well. It can be seen that translating inner cores which tend to align their translation to be polar are possible but uncommon. Similar (~7%) frequencies for true polar wander to align the translation direction to be polar were found in our experiments with larger numbers of randomly chosen velocity regimes, indicating that less regularly translating inner cores will probably display a similar phenomenon.

dom reversal time and two random velocities distributed between 1 and 10 times the growth velocity. Figure 2 shows the moment of inertia differences as a function of the distance of the center of mass (CoM) is shifted from the center of figure (CoF) of the inner core. It can be seen that there is a non-zero chance for the inner core translation to be directed North-South in this scenario. In these data, about 7% of the random velocity pairs gave rise to inner-cores with a maximum moment of inertia in the translation direction.

Figure 3 presents a proxy for the time-evolution of the moment of inertia difference for a translating inner-core. It can be seen from Figure 3 that an inner core which has changed translation direction spends relatively little time with a density distribution that favors North-South translation following TPW. Notably, this same shape of curve was found for a wide range of velocity pairs. This indicates that although an inner-core under these conditions spends a fairly small amount of time aligning its translation with the planet's spin axis, essentially all inner-cores which reverse their translation direction once will pass through a regime in which this occurs.

Implications for Earth and Mercury: First, our analysis provides a very fundamental physical reason for the Earth's inner-core asymmetry to be equatorial, in particular if the asymmetry is caused by a translating inner-core. Moreover, we identified a plausible cause for Mercury's North-South asymmetric magnetic field: a growing inner core translating in the North-South direction. If this is indeed the case, the North-South asymmetric nature of Mercury's magnetic field is a recent phenomenon on geological time-scales, because the inner core will tend to only translate in the North-South direction for a relatively short portion of its existence.

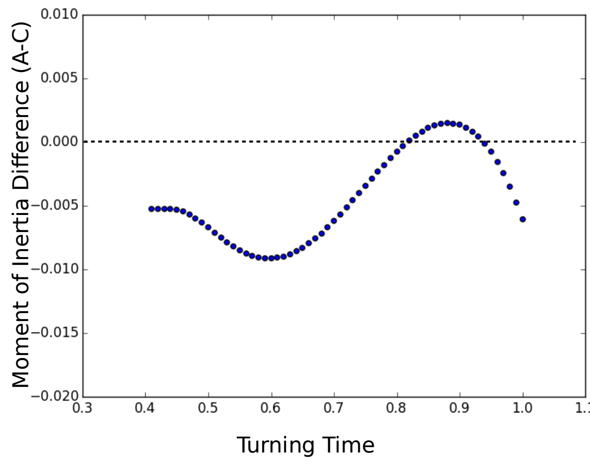

Figure 3: Moment of inertia difference as a function of time. MoI difference of inner-cores with the same translation velocity pairs are compared, with the time at which the velocity regime switches being varied. This is essentially viewing a single inner core evolving over time after its translation velocity reverses.

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