Publication
Figures
Most journals have guidelines for graphics. Follow them.
**IMAGE TYPES**

The best format for any particular figure depends partly on what sort of image it contains. Images fall into two basic categories: rasterized images (flattened image) and line (or vector) art which is in a layered format.

- Do not rasterize line art or text in submitted figures.
- Wherever possible please supply editable, unflattened vector artwork.
- The example below shows the difference in quality between text and lines that have been rasterized and text and lines that are still editable.

**Typical examples of raster artwork**

**Typical examples of vector artwork**
We recommend supplying your artwork in the RGB colour spectrum. This provides a wider gamut than the CMYK print format and allows more faithful reproduction of fluorescent colours when viewed digitally.

Your artwork will be automatically converted to CMYK to be printed in the journal but the online PDF will retain the RGB colour space.

You can supply your artwork in CMYK instead, if you wish to ensure the printed figures are replicated faithfully.

The example below shows the shift in colour between RGB and the equivalent colour shown in CMYK-subtle details are often lost during the conversion.
ARRANGEMENT

- Try to keep white space to a minimum where possible.
- *Nature* will be guided by your suggested layout of parts within figures, but may rearrange parts if necessary.
- Essential layout features should be indicated when submitting — for example, particular alignments of panels within a figure.
Not all lines are equal.

* All lines must be at least 0.5 point (i.e., do not use hairline rules)

A figure using (left) hairline lines and (right) the correct 0.5 point lines.
publication figures ≠ poster figures ≠ talk figures ≠ figures on monitor

Figure you might make on the monitor (which might be okay for a talk or maybe a poster).

Figure at right, shrunk down to publication size.

Publication ready (in terms of font size, image size, etc.)
Get Illustrator.

https://softwarelicense.arizona.edu/faculty-and-staff
Try to make plots visually consistent

which allows for a considerable reduction of computational costs and thereby enables coverage of the full polar angle with one degree resolution. The radial grid is the same as in the previous section, covering the distance from 0.3 to 100 au. Figure 2 displays the applied inner boundary conditions depending on colatitude. The top row shows the background quantities (velocity, number density, magnetic field strength, and temperature), in setting which we are guided by Ulysses measurements (McComas et al. 2000). This includes a small latitudinal gradient (45 km/s) of solar wind speed in the fast wind regime, constant mass flux, and a Parker spiral magnetic field structure that neglects a polarity reversal and current sheet. The latter would be under-resolved in these non-AMR simulations and would affect the equatorial results more strongly as appropriate. The bottom row shows the turbulence quantities (turbulent energy density, lengthscales and cross helicities). There is considerable spread and uncertainty associated with spacecraft measurements of these quantities (see Figure 5) and boundary values were chosen to give a reasonable fit to the available data, with the 90%–10% partitioning for $\overline{\mathbf{v}}^2$ guided by observation-based studies (e.g., Bieber et al. 1996; Hamilton et al. 2008). Such studies report a range of values but typically find a dominant quasi-2D component; see Oughton et al. (2015) for a recent review.
Try to make plots visually consistent.
~8% of men are red-green colorblind.

jet is evil.
Experiment with different ways to view data.
Figure 3. Our proposed model for the formation of the Moon’s fossil figure. (a) The Moon coalesced from the debris of giant impact. (b) Under the action of tides, the Moon migrated outward and cooled from a magma ocean, perhaps experiencing periods of non-synchronous rotation or high eccentricity. (c) As the moon cools, it forms an elastic lithosphere capable of supporting long-term deformation, resulting in the fossil figure. (d–e) The South Pole-Aitken (SPA) basin forming impact occurs, resulting in ≈15° of reorientation, placing SPA closer to the south pole. (f) Subsequent large impacts and mare volcanism occur but do not significantly alter the lunar figure. (g) Ultimately, the Moon migrates to its current orbital configuration.
Posters
I. INTRODUCTION

The Moon’s figure is triaxial, due to the combination of rotational deformation (which acts to create an ellipsoidal body), and tidal deformation (which acts to create a tidal bulge along the Earth-Moon vector). However, the observed deformation is significantly larger than what would be predicted from hydrostatic equilibrium and the Moon’s current rotation and tidal state. The amount of deformation can be quantified using the principal moments of inertia, $A > B > C$, and the mass moment of inertia, $I$. These quantities are directly related to degree-2 harmonic normal modes (inferred from tide-gauge measurements), $A$, $B$, and $C$, and bulge parameters ($A_{1}$, $B_{1}$, $C_{1}$).

The Moon was in equilibrium with the present rotational and tidal potentials (Matsuyama & Moriya 2009, Matsumura 2018). The degree-2 mass anomaly was also a significant consequence of this analysis to the Moon’s tidal force, and the Moon was in equilibrium with the present rotational and tidal potentials. This analysis has been shown to be consistent with the observed topography of the Moon, which appears to be described by the normal modes of the Moon from a low-order, spherical potential.

II. METHOD

We model each lunar mass using a linear combination of uniform surface density spheroidal caps. The spherical harmonic gravity coefficient for an assignment of spherical caps are given by:

$$C_{20} = \sum_{i=1}^{n} \frac{C_{20,i}}{r_{i}^{2}}$$

where $C_{20,i}$ is the degree 2 coefficient for the $i$-th cap, and $r_{i}$ is the radius of the $i$-th cap.

The surface density, $\rho$, and the surface gravity, $g$, are then calculated from these caps.

III. RESULTS

The final results are compared to the observed topography of the Moon, which were determined by a combination of laser altimetry and radar interferometry. The results show good agreement with the observed topography, indicating that the model is consistent with the observed mass distribution.

ACKNOWLEDGMENTS

This work was supported by the NASA New Frontiers Mission and the Japan Aerospace Exploration Agency (JAXA) program.

REFERENCES


THE CONTRIBUTION OF IMPACT BASINS & MASCONS TO THE LUNAR FIGURE
EVIDENCE FOR LUNAR TRUE POLAR WANDER, AND A PAST LOW-ECCENTRICITY, SYNCHRONOUS LUNAR ORBIT

James Tuttle Keane (jkeane@pl.arizona.edu) & Isamu Matsuyama
Lunar and Planetary Laboratory, Department of Planetary Sciences, University of Arizona

KEY RESULTS
1. The lunar figure (degree-2 gravity / inertia tensor) is significantly larger than expected from hydrostatic equilibrium.
2. This degree-2 excess results from the combination of a fossil figure and fossil healing and resurfacing.
3. The formation of the South Pole-Aitken basin reoriented the Moon -15°.
4. Removing impact basins reveals a degree-2 figure consistent with a fossil spin equilibrium.

I. INTRODUCTION

II. HYPOTHESIS

III. METHODS

IV. RESULTS

V. ACKNOWLEDGEMENTS
HIDDEN IN THE NEUTRONS: PHYSICAL EVIDENCE FOR LUNAR TRUE POLAR WANDER

James T. Keane1, Matthew A. Siegel2, Richard S. Miller3, Matthieu Laneville4, David A. Paige5, Isamu Matsuyama1, David J. Lawrence1, Arlin Crotts6, Michael J. Poston3

1. OBSERVATIONS

- Satellite-based neutron detection revealed the possible presence of polar wander on the Moon.

2. TRUE POLAR WANDER

- Antihydrogen distribution suggests a fundamental asymmetry that could be linked to polar wander on the Moon.

3. LINKING POLAR WANDER TO THE PROCELLARUM

- Models of the Moon's interior that include the presence of a 'true polar wander' could explain antihydrogen distribution related to polar wander.

---

**KEY FEATURES IN THE DISTRIBUTION OF POLAR HYDROGEN**

1. The polar hydrogen distribution suggests a polar wander.
2. The observed distribution implies an orientation that aligns with the lunar interior model.

---

**Anomalies**

- The observed anomalies in hydrogen distribution cannot be explained by current models.
- Further investigation is needed to understand the cause of these anomalies.
HIDDEN IN THE NEUTRONS: PHYSICAL EVIDENCE FOR LUNAR TRUE POLAR WANDER

James Tuttle Keane — jkeane@ipl.arizona.edu — @jtuttlekeane
Matthew A. McKinnon — matthew.mckinnon@nasa.gov

Key Point 1/4: Lunar polar volatiles* are off-polar, and antipodal!

Key Point 2/4: We interpret this antipodal, off-polar volatile enhancement as a previous lunar spin pole (a paleopole).

The only large geologic feature that is in the right location to drive this true polar wander is the Procellarum KREEP Terrane (PKT).

The thermal evolution of the Procellarum KREEP Terrane naturally produces true polar wander paths that pass through the volatile paleopole.
SURPRISE! the Moon is actually important for changing the spins of asteroids during Earth flybys

James Tuttle Keane
University of Arizona, Lunar and Planetary Laboratory

Ho Chit Siu (MIT), Nicholas A. Moskovitz (Lowell), & Richard P. Binzel (MIT)

SUMMARY

1. Asteroids with MOIDs < 11 lunar distances have systematically larger spin inclinations. This sharp transition at this distance is surprising.
2. We investigated whether the two-body influence of the Moon could significantly alter flyby distances (which are typically too short for significant changing precessions) and found that the sharp transition is not due to this influence.
3. It works! (although more work needs to be done...)

I. OBSERVATIONS

Asteroids with MOIDs (Minimum Orbit Intersection Distances) less than 11 lunar distances have spin inclinations ~2 times larger than asteroids with larger MOIDs. Global scale torque during its flyby can alter the spins of asteroids by 20 degrees at MOID = 10 lunar distances, these torques drop off very rapidly (and smoothly) with fully distance.

II. MODEL

One way for an asteroid to escape the Moon’s capture is to have a close encounter with a planet (e.g. Schenk et al., 2010, 2012, Journal). We hypothesized that three-body effects between the Earth, Moon, and the close approach distance of asteroids during such perturbations accounts for the Earth-Moon system. To test this, we used the circular restricted three body problem.

III. RESULTS

Asteroids with MOIDs < 13 lunar distances can be strongly perturbed by the Moon in the three-body problem, and not have their close approach distance altered. The three-body effect can still produce a short three-body effect

For more information, see the following talk:

402.03 "Effects of Earth Encounters on the Rotational Properties of Near-Earth Objects" Ho Chit Siu et al.
8:50AM – 9:00AM Thursday Session 1
1. INTRODUCTION

Explanations of specific exhausts may result from the recombination of exothermic interactions that can be observed with the instruments. This leads to an overall reduction of the number of impacts, resulting in the potential of planetary flybys. We present a model that explains the formation of the asteroids and their evolution over time. The model incorporates the effects of tidal forces, gravitational interactions, and the role of planetary flybys. We show that the asteroids in our system are subject to periodic perturbations that could lead to the rejuvenation of the asteroids. We present evidence that supports the rejuvenation of the asteroids due to these flybys.

2. TIDAL RESURFACING MODEL

The tidal forces exerted by a nearby planet cause the asteroids to deform and resurface. We use a numerical model to simulate the resurfacing process and show how the asteroids change over time. We find that the tidal forces are strong enough to cause significant resurfacing events. We also show that the resurfacing process is sensitive to the orbital parameters of the planets and the asteroids.

3. PRELIMINARY RESULTS

We have performed a preliminary assessment of the rejuvenation process using a set of synthetic asteroid models. We find that the rejuvenation process is sensitive to the orbital parameters of the asteroids and the planets. We show that the rejuvenation process can significantly change the shape and size of the asteroids. We also find that the rejuvenation process is not uniform, with some asteroids being rejuvenated more than others. We present a set of predictions for the rejuvenation of the asteroids and the implications for future missions to the asteroids.

Acknowledgments: This work is funded by NASA Earth and Space Science Fellowship (PFS-1633).
PLUTO FOLLOWED ITS HEART: REORIENTATION AND FAULTING OF PLUTO DUE TO VOLATILE LOADING IN SPUTNIK PLANUM

James T. Keane (keane@lpl.arizona.edu, U. Arizona), Isamu Matsuyama (U. Arizona), Shunichi Kamata (Creative Research Institute, Hokkaido University), & Jordan K. Steckloff (PSI)

The Curious Alignment of Sputnik Planum and the Pluto-Charon Tidal Axis

The alignment of large geology features with principal axes of inertia in the hulk of true polar wander. True polar wander occurs when mass is redistributed within a planet, causing the geodetic locations of the principal axes of inertia to change. In order to remain in a mind motion state, the planet maintains an equatorial orientation. In this case, the planet appears to be rotating about the geodetic longitudes 110.3 degrees (s.d. 2.2 degrees) and 279.7 degrees (s.d. 2.2 degrees). The geodetic pole of the planet is located at 140.0 degrees (s.d. 2.2 degrees) and 17.0 degrees (s.d. 2.2 degrees). The pole of inertia is located at 120.0 degrees (s.d. 2.2 degrees) and 50.0 degrees (s.d. 2.2 degrees). The pole of inertia is located at 100.0 degrees (s.d. 2.2 degrees) and 30.0 degrees (s.d. 2.2 degrees).

True Polar Wander Solutions for Sputnik Planum

Reorientation is counteracted by Pluto's non-hydrostatic, obliquely supported tidal deformations which can precess a planet's rotational potential—pre-cited remanent figure, such as this figure, would be extended by New Horizons. Since one period of a 12-year orbit, there is no automated model of Pluto's interior structure. With our nominal model, we determined the possible initial locations of Sputnik Planum as a function of Sputnik Planum's mass anomaly, as well as specifying how Sputnik Planum perturbs Pluto's inertia tensor, and can be related to degree a gravitational harmonic proper mass.

Tectonic Patterns Predicted by True Polar Wander

The combination of reorientation, global expansion, and volatile loading as a result of internal pressure changes in the core/mantle, plus the horizontal hydrostatic and non-hydrostatic loading of Sputnik Planum, results in a great deal of variability in the patterns of surface patterns. The patterns of surface patterns are not simply determined by the geodetic axes of Pluto's rotation, but are also influenced by the geodetic axes of Pluto's rotation, as well as the geodetic axes of Pluto's rotation.

Volatiles-Driven Reorientation of Pluto

If Sputnik Planum is an intrinsic cold trap (resulted in magenta area), volatile loss has been gradually sequestered into the basin, reducing the planet's mass, present, and future orientation is controlled by feedbacks between volatile transport and reorientation.
Talks
MOTIVATION:
The Ordinary Chondrite – S-type Asteroid Conundrum

Reflectance spectra of the most common type of meteorites (ordinary chondrites) do not match the most common type of asteroids in the inner-half of the main belt (S-types).

This difference is due to space weathering, which rapidly darkens and reddens asteroid spectra on Myr timescales (Hapke 2001; Chapman 2004; and half the talks in this session).

Curiously, some near-Earth asteroids (Q-types) appear unweathered.
What about Mascons / Basins / Etc.?

Do mascons, basins, etc. have any contribution to degree-2? If so, they must be removed to properly identify the fossil figure.

I’ve developed a technique for fitting and isolating the degree-2 gravity of impact basins and mascons on planetary bodies.

Cleaning up Degree-2: The Contribution of Impact Basins and Mascons to the Gravity Fields of the Moon & Mercury (#2967) — LPSC 2015
James T. Keane (UA / LFL / jkeane@lpl.arizona.edu / @jtuttlekeane)
what is true polar wander?

- initial spin state
- obliquity change
- true polar wander
summary

- the location of Sputnik Planitia near the Pluto-Charon tidal axis is suggestive of global reorientation ("true polar wander")
- filling Sputnik Planitia with several kilometers of N₂ ice can easily reorient Pluto
- reorientation produces tectonic stresses that closely replicate the observed tectonic pattern on Pluto
- the past, present, and future orientation of Pluto is controlled by feedbacks between volatile transport, climate, and the interior structure of Pluto

thank you New Horizons