Tuesday, May 1, 2018

WELCOME AND INTRODUCTION

8:45 a.m. USRA Conference Center

Chair: Nancy Chabot

8:45 a.m. Chabot Nancy L. *

Welcome and Logistics

Emily Lakdawalla
• 129 abstracts from international community.
• Debbie Mitchell from LPI is meeting organizer

9:00 a.m. Solomon Sean C. *

Mercury, MESSENGER, and Messages Still to Discover

(Sean ill, moving straight to next talk)

9:15 a.m. Benkhoff J. * (Talk given by Joe Zender)

BepiColombo — The Next Step of Mercury Exploration with Two Orbiting Spacecraft [#6007]

BepiColombo is a joint project between ESA and JAXA. The mission consists of two orbiters — the Mercury Planetary Orbiter and the Mercury Magnetospheric Orbiter. From dedicated orbits, the spacecraft will be studying the planet and its environment.

Emily Lakdawalla
• Zender is the deputy project scientist for BepiColombo
• Zender brought props to explain structure of spacecraft. MPO is 1200kg unpladen, 600kg of fuel
• MTM is also 1200 kg, sole purpose to bring spacecraft to Mercury.
• HGA has 2 axes of freedom, so if not in eclipse, comm with Earth is available. 1500 Gbit per year.
• An Italian provided accelerometer is measuring all the nongravitational forces on the spacecraft.
• Fluxgate magnetometer boom deploys after launch.
• Radiation panel has 3 openings for star trackers and a UV spectrometer PHEBUS measured EUV and FUV and has 2 channels.
• ...(more instrument descriptions)
• Whole spacecraft stack spins once per 12 minutes throughout cruise.
• 6 Mercury flybys!
• After MOI, go into MMO science orbit, then separate, then get rid of MMO protection shield, then get down to MPO and then spring 2026 will be in science orbit.
• Status as of today: had a few weeks ago Qualification Acceptance Review and got approval to ship. But life cycle test of ion propulsion has not been fully demonstrated.
• We have to move calibration period to a year after launch (did not follow why, something about testing of ion propulsion and safe operating thrust)
• Q: What science can be done during flybys? A: Most of the instruments are looking toward the transfer module. Magnetometer, MERTIS can be used. We are doing our best but don’t expect too much.

Steve Hauck
9:30 a.m. Murakami Go * Hayakawa H. Fujimoto M. BepiColombo Project Team

Overview of Mercury Magnetospheric Orbiter (MMO) for BepiColombo [#6058]

The next Mercury exploration mission BepiColombo will be launched in October 2018 and will arrive at Mercury in December 2025. We present the current status, science goals, and observation plans of JAXA's Mercury Magnetospheric Orbiter (MMO).

Emily Lakdawalla

- Shipping today!
- MMO has a 600 by 12000 km orbit, MPU 480x1500km
- Both spacecraft are always in the same plane.
- Spin controlled with 4s rotation period.
- At perihelion, periapsis is on nightside, and on aphelion, periapsis is on day side.
- Have 5 instruments: 3 for plasma, plus exosphere (sodium atmosphere spectral imager) and dust monitor.
- Differences to MESSENGER: plasma instruments see more low-energy electrons, and plasma imaging is new capability. Also energy range for plasma instruments is wider.
- Biggest advantage from MESSENGER is that we have 2 spacecraft. So we are planning coordinated observations (oral talk by Anna Milillo on Thursday). So for example we can observe the solar wind from MMO and the magnetospheric/exospheric response from MPO.
- Another difference from MESSENGER is the north/south symmetric orbit.
- Operations plan: Basically always on. But have thermal and electrical constraints. Near perihelion have thermal constraints, do only 1 in 3 orbits. Electrical constraint near aphelion have a 5 day eclipse peri helion.
- Downlink rate is a constraint. Can only downlink about 25% of data nominally, so we need to make strategy to downlink. We will update after launch.
- We are updating our science targets based on MESSENGER results. Have a Young Scientist Working Group of about 50 members, studying remaining issues and questions from MESSENGER to BepiColombo and corresponding observations required to solve them., generating an M2B science issue list.
- New members are welcome.
- Future science: we are thinking about exoplanets. Big question for us is how magnetospheres work in very extreme stellar environment. In red dwarf systems habitable zones are much closer, and planets are exposed to extremely strong stellar winds. So Mercury is best target as analog.
- Q: Flyby science? A: For us it's not good configuration because of sun shield we have small field of view. We will turn on some instruments, but main goal is functional checks.
- During cruise, instruments are not deployed. Will spin up after entering orbit at Mercury, and use spin to deploy booms.
- Q: Dust measurements during cruise? A: not good FOV.
- Q: Observations during eclipse are most important for magnetospheres. I know you've already designed your mission, but can't you observe then? A: no.
9:45 a.m. BREAK

Tuesday, May 1, 2018

SOLAR-WIND INTERACTIONS WITH MERCURY

10:00 a.m. USRA Conference Center

Chairs: Ronald Vervack, Jr
Suzanne Imber

10:00 a.m. Invited: Slavin Jim A. *

Mercury's Solar Wind Interaction: The View from MESSENGER [#6019]
MESSENGER’s three close fly-bys and four years of observations from orbit have revealed that Mercury possesses a highly dynamic and complex magnetic field and plasma environment.

Emily Lakdawalla

- There will be 3 recurring themes in the solar/planetary talks today.
  - 1. Magnetic field generated by induction
  - 2. Magnetic reconnection
  - 3. Particle precipitation and sputtering
- All 3 have to occur at all the magnetized planets, but Mercury especially.
- In planetary magnetospheric observations, half the signal can be due to magnetic induction in conductive rocks to which the instrument is attached
- Two factors make induction important at Mercury.
  - Weakness of Mercury's magnetic field -- only a couple hundred nanoteslas at equator, or there would be if you could see it over solar wind. At earth it's 32,000 nT
  - Mercury is essentially a perfectly conducting iron sphere with only a few hundred km of poorly conducting regolith scattered across the top. Connection to solar wind happens only a couple thousand km above that.
- Solar wind coming into planet compresses magnetic field into core. (Something about diffusion of magnetic field, don't understand)
- When do these effects come into play? With coronal mass ejections. They can increase intensity of solar wind pressure by an order of magnitude. On MESSENGER we've seen solar pressures that go up to several hundred nT.
- As soon as you get extreme compression, Alfven waves start to propagate toward planet. They carry current......(my understanding here is tenuous at best...)
- .....reconnection is also important at Mercury. Field lines get spliced into interplanetary magnetic field. These two processes (which two?) compete against each other.
- On MESSENGER, we found no solar wind events that were strong enough to compress dayside field down into planetary surface, but we got close. It may happen.
- Charged particule precipitation at Mercury includes a wide range of energies and species and it provides the only terrestrial planet (i.e. non-ice) surface for the study of sputtering and related phenomena including x-ray auroras.


10:15 a.m. Glass Austin N. * Tracy P. J. Raines J. M.

*First Identification of Foreshock Plasma Populations at Mercury [#6042]*

Observations of foreshock populations at Mercury are presented for the first time utilizing measurements from the Fast Imaging Plasma Spectrometer (FIPS) aboard MESSENGER, and plausible energization mechanisms are suggested and evaluated.

**Emily Lakdawalla**
- First year grad student!

**Caleb Fassett**
- Two acceleration zones – parallel to field lines and perpendicular. Get different shock behavior. There are differences with Earth in terms of magnetic environment, but the foreshock regions on Earth+Mercury behave similarly.
- Why do we care? Comparison of physics with other terrestrial/magnetized bodies, particularly Earth.
- In foreshock region H+ particles get boosted in energy (as expected) [FIPS data]
- Quasi-perpendicular: field aligned beams (“shock drift”)
- Quasi-parallel: diffuse acceleration
- Geometry matters (theta-bn: I think this is the angle between field lines and solar wind????) 32 events (classifying into two types -- these events are the cleanest separation).
- Are the particles from the solar wind, or leaked into the foreshock from the magnetic sheath? Mercury data might allow these two things to be distinguished.

**Steve Hauck**
- The foreshock is upstream (sunward) of the bow shock
- Shock surface is curved around the planet, talking about regions that are roughly perpendicular and parallel
- Wants to look at Mercury because of comparison with Earth and far more energetic system.
- Shock front obvious in magnetic field data
- FIPS data show incoming H+ before the shock in data
- See defining characteristics of field aligned beams (?
- Foreshock at Mercury is separated into the perpendicular and parallel populations like Earth


*Three-Dimensional, Ten-Moment, Two-Fluid Simulation of the Solar Wind Interaction with Mercury [#6128]*

We investigate solar wind interaction with Mercury's magnetosphere by using Gkeyll ten-moment multifluid code that solves the continuity, momentum, and pressure tensor equations of both protons and electrons, as well as the full Maxwell equations.
Caleb Fassett
-3D code/Model can reproduce magnetosphere interaction with solar wind well
-Behavior is very complicated looking
-Codes use fundamental physics (Maxwell’s eq.) at high resolution 0.04Radius_Mercury to simulate region from 25Rm to -25 Rm (in y and z) and -5R to 15R (in x).

Steve Hauck
- Talk largely about new code for studying reconnection in the magnetosphere.
- Unclear what the 10 moments are, but I think it has to do with the primary equations used to simulate solar ind/magnetosphere interactions. I think they are simulating more physical processes than is common, like including heat
- 3D simulation seemed to match well one of the MESSENGER flybys

10:39 a.m. Fatemi S. * Poirier N. Holmström M. Wieser M. Barabash S. (Rosemary Killen presenting)

Getting Ready for BepiColombo: A Modeling Approach to Infer the Solar Wind Plasma Parameters Upstream of Mercury from Magnetic Field Observations [#6014]

We have developed a model to infer the solar wind plasma parameters upstream of Mercury from magnetic field observations in Mercury’s magnetosphere. This is important for observations by MESSENGER and the future mission to Mercury, BepiColombo.

Emily Lakdawalla
- Dungey cycle (something to do with magnetic reconnection) occurs much faster (~2 min) at Mercury than at Earth (~1 hour)
- The bow shock is more sensitive to the solar wind parameters than magnetopause crossings
- Their model works on MESSENGER data, could apply it to BepiColombo.

10:51 a.m. Philpott L. C. * Catherine Johnson L. Anderson B. J. Winslow R. M.

The Shape of Mercury’s Magnetopause: What Can BepiColombo Tell Us? [#6046]

We investigate how limitations in MESSENGER magnetic field data coverage affect our ability to establish asymmetries in Mercury’s magnetopause and examine how BepiColombo observations will improve our understanding of the magnetopause shape.

Steve Hauck
- Why study magnetopause?
- Source of strong electric currents
- Relevant to flux of plasma to surface affecting space weathering
- Based on predicted SPICE kemels, Bepi orbits will give complementary measurements of the magnetopause and cusp compared to MESSENGER
Emily Lakdawalla

- (Lydia not available to present because baby)
- Why study the magnetopause?
- It is the source of strong electric currents that result in the largest magnetic fields after those from the core dynamo.
- If you’re a geologist, then the magnetopause is relevant because flux of solar wind plasma to surface can result in reddening and darkening of surface.
- Magnetopause is about half a Mercury radius above the surface.
- We expect and have observed a lot of dynamics.
- MESSENGER orbit geometry means magnetopause crossings happened in an elliptical donut shape around planet.
- To a first order, magnetopause has a typical shape described by two parameters: subsolar distance and the degree of tail flaring.
- BepiColombo orbits are complementary to MESSENGER orbit geometry.

11:03 a.m. Orsini Stefano * Mangano V. Milillo A. Plainaki C. Mura A. Raines J. M. Laurenza M. De Angelis E. Rispoli R. Lazzarotto F. Aronica A.

**Mercury Sodium Exospheric Emission as a Proxy for Solar Perturbations Transit [#6010]**

We report about recent results published on Scientific Reports @nature.com showing the first evidence of direct relationship between exosphere Na dynamics observed from ground and ICME transit at Mercury, as detected by MESSENGER.

Caleb Fassett

- Observations of Mercury are from THEMIS solar telescope in Canary islands (ground-based). Good for looking at Mercury’s Na emission over long period and broad perspective.
- Campaign over roughly the last decade; as a result some data overlaps with MESSENGER’s in situ measurement (FIPS/MAG)
- Observed two classes an equatorial peak + a two higher latitudes peak modes. For the equatorial mode, it is not clear how to connect this to the measured magnetic field environment around Mercury.
- Reconnection is a ~consistent process with ~25 nT field
- N=1 observations of clear sky, CME at Mercury, and observations from THEMIS+MESSENGER (9/20/2012)
- Created equatorial peak mode / distributed emission around Mercury. Idea is that shock due to interaction of solar wind/magnetosphere mobilizes atoms from everywhere, not just cusps. CME triggered this behavior.
- This type of observation is a potential monitor for CME passage at Mercury... (Scientific Reports paper Orsini et al. 2018)

*First In-Situ Observations of Exospheric Response to CME Impact at Mercury [#6038]*

We present the first in-situ observations of enhancements to Mercury's He exosphere generated by CME impact. These results have implications for understanding exosphere generation and loss processes, as well space weathering of the planet's surface.

Emily Lakdawalla
- Cusp process is a great meeting place between surface and solar wind, and it produces the exosphere by sputtering
- Other sources of material in the cusp -- they must be drawn into magnetosphere from outside (because of their speeds)
- MESSENGER witnessed a CME pass by Mercury over the course of 36 hours
- Comparing different instruments' views of the magnetosphere before and during the CME
  - Fluctuations at boundary of magnetosheath, kind of a mess, much more intense at cusp, hot plasma sheet, and magnetic field has all kinds of short-time-scale fluctuation of magnetic field, “magnetic reconnection is just tearing things up"
  - Near cusp see a LOT more sodium ions,
  - During passage of cavity behind the CMS, see lots of singly charged helium ions.
  - Looking at trends in He2+, He+, Na+, O+. All seem similar except He+ -- what's going on there?
- Comparing to different times on the mission, we didn't ever see anything like this event again.
- What do we think is happening?
  - Extreme He2+ flux temporarily increases He in surface regolith. Magnetic reconnection increases access of solar wind to surface. Enhances He in exosphere
  - But why the 36-hour delay? We don't know, looking for ideas.
  - This is the first in-situ measurement of solar wind-exosphere coupling at Mercury.

11:27 p.m. LUNCH

Tuesday, May 1, 2018

**MERCUERY’S INTERIOR STRUCTURE AND EVOLUTION**

1:00 p.m. USRA Conference Center

Chairs: Catherine Johnson
Erwan Mazarico
1:00 p.m. Invited: Genova Antonio * Goossens S. Mazarico E. Lemoine F. G. Neumann G. A. Kuang W. Sabaka T. J. Smith D. E. Zuber M. T.

**A Large Solid Inner Core at Mercury [#6036]**

New measurements of the polar moments of inertia of the whole planet and of the outer layers (crust+mantle), and simulations of Mercury’s magnetic field dynamo suggest the presence of a solid inner core with a Ric ~0.3-0.5 Roc.

**Emily Lakdawalla**

- (Summary of MESSENGER timeline)
- The radio system operated at X-band (7.2/8.4 GHz up/downlink) with phased array antennas (PPAs), medium gain fan beams, and low-gain antennas.
- We used range and doppler data to get MESSENGER dynamics to learn about Mercury interior. You get position and velocity of spacecraft with respect to station.
- Mercury is a planet with a very high uncertainty in its position.
- We implemented a novel technique that involved a co-investigation of orbits of planet and spacecraft.
- The range data are very sensitive to position of planet
- Main perturbations on Mercury’s orbit are
  - Sun’s interior properties (GM and its time variation that informs on the solar mass loss rate), and gravitational oblateness, J2
- Nature communications paper -- one of the first estimations of the solar mass loss rate.
- Since MESSENGER collected 7 years of data, we were able to measure how Mercury is receding from the Sun over time because of mass loss
- Also determined no violation of the Strong Equivalence Principle -- no detectable difference between gravitational and inertial mass.
- In 2015, we analyzed data from MESSENGER and tried to have preliminary gravity field, called HgM007, which has been archived with the PDS. But this is not a very good field
- Have reanalyzed to HgM008, and a lot of midlatitude stripiness has been removed.
- We also have a new crustal thickness map
- Looking at interior of planet, gravity can provide interesting results, especially wrt orientation of the planet.
- Diagram shows Mercury crust and mantle as on top of a solid layer of iron sulphide and then a fluid outer core
- Assume inner core is decoupled from outer layers, which allows us to use librations in obliquity to determine the moment of inertia of the crust plus mantle
- ...(lost the train in here somewhere)
- Current result has lower obliquity than previous results
- It is perfectly on the Cassini state
- So what's the interior structure? Many models, 1 km thick shells, have to assume compositions. Best fit is with an Fe-Si outer and inner core
- Crustal density is between 2600 and 2800 (lower density may be because of macroporosity)
- ...
- Solid inner core radius is about 0.44 +/- 0.18
- Lower CMB radius than previously retrieved
- Crust and mantle densities consistent with other independent studies
-
1:15 p.m. Huguet Ludovic * Hauck S. A. II Van Orman J. A. Jing Z.

Implications of the Homogeneous Nucleation Barrier for Top-Down Crystallization in Mercury’s Core [6101]

Crystallization of solids in planetary cores depends both on ambient temperatures falling below the liquidus and on the ability to nucleate crystal growth. We discuss the implications of the nucleation barrier for thermal evolution of Mercury's core.

Emily Lakdawalla

- How is Mercury's core crystallizing? Bottom-up as in Earth? Or top-down, in an iron snow regime (iron crystallizes at top and snows)
- Both models ignore the nucleation energy barrier to form the first crystal
- Extra energy is required to form a solid from a homogeneous liquid. Critical supercooling is the difference in temperature below the melting temperature required to initiate crystallization. Critical degree of supercooling for pure metals is about 20%.
- For pure iron, experiments show it to be 32%, up to 350 GPa
- Homogeneous nucleation of an inner core in Mercury requires about 500K of supercooling. It's probably not possible. We need another way.
- An inner core is unlikely formed in a bottom-up regime.
- Get growth of dendrites that fall and sediment into core.

1:27 p.m. Sarid G. *

When Mercury Smashed: Dynamics and Composition Through a Grazing Collision with a Larger Planet [6127]

Mercury emerges from a grazing collision with a larger proto-planet. Dynamics and composition evolution are consistent, but — Was it hit once? More? Where and when did it happen?

Talk Cancelled

1:39 p.m. King S. D. * Robertson S.

Geodynamics in a Thin Shell [6033]

At the pressure and temperature regime of Mercury's silicate interior, olivine deforms by dislocation creep (power law rheology). This allows Mercury to maintain a dynamic interior much later in time than earlier estimates using Newtonian rheology.

Emily Lakdawalla

- A lot of this work was doing by an undergrad named Serena Robinson who's being commissioned as a nuclear sub officer as we speak, so she's leaving planetary
- Key point of this talk: The pressure range of Mercury's silicate shell is entirely within the upper 200 km of Earth's mantle. That is the region above the Layman discontinuity, which is where seismologists see a lot of seismic anisotropy, which is related to dislocation creep. So it is almost certain that Mercury's mantle is in a dislocation creep flow.
- Lots of geodynamics is based on diffusion creep, which geodynamicists like because it's linear, easy to model
- In dislocation creep, relationship between stress and strain is nonlinear.
● It could even be grain boundary sliding
● Estimate that throughout much of solar system history, the mantle has been in stagnant lid mode -- below a lithosphere, there's a layer that behaves isoviscously with depth
● Shows a cool simulation, has lots and lots of plumes with really small anomalies that will be masked by whatever you can see in the crust of the lithosphere
● Tangentially: “olivine is the weakest mineral in the upper mantle” -- can't find a citation, and there is evidence that OPX is more likely to strain than olivine (see Brujin and Skeemer?)
● Larry Nittler asks: what if there were carbon as we've seen on the surface? Or sulfur? A: I have no idea. I've heard people suggest water is more important.

1:51 p.m. Roberts James H. * Peplowski P. N. Stickle A. M. Stockstill-Cahill K. R. Denevi B. W. Buczkowski D. L. Barnouin O. S.

Thermochemical Evolution of Mercury's Mantle and the Formation of the Volcanic Plains [#6122]

Impacts, convection / Sample different regions / Plains diversity.

Emily Lakdawalla

● Smooth plains cover about 30% of the surface
● 4 key observations that any origin story has to be able to reconcile.
  ○ Volcanism was either long-lived or episodic (they don't all have the same age).
  ○ Compston varies from unit to unit.
  ○ Silicate portion of Mercury is absurdly thin, so you don’t have much to work with.
  ○ Mercury has undergone substantial global contraction (something like 7 km)
● Take Caloris as an example.
  ○ Has volcanic plains inside and outside it, and they're not the same color or the same age. Exterior plains are younger than interior, and XRS reveals different major element compositions.
● Core radius is something on the order of 2000 km, so mantle can’t be more than 400.
● There may be an iron sulfide dense layer on the top of the core, but it sounds like that may no longer be the preferred model.
● As the planet contracts, it will generate large compressive stresses that will prevent magma from either forming or ascending. Cracks may provide conduits, but compression eventually shuts it down.
● So we really need to understand thermochemical evolution of Mercury’s mantle.
● Impacts are the last refuge of the scoundrel, but in my defense, Caloris exists.
● …
● Impact heating may explain differences in timing and composition of Caloris plains units. This requires a large and thus relatively slow projectile.

2:03 p.m. Oliveira Joana S. * Hood L. L.

Unveiling the Early History of Mercury by Studying Its Crustal Magnetic Field [#6069]

We study different anomalies that are found on Mercury that were very likely thermoremanently magnetized, to look for true polar wander events and/or understand if they aren't entirely induced in origin.

Emily Lakdawalla

● Only have magnetic field map from 35 to 75 degrees north
● Some anomalies are not correlated with magnetic field features, but a few of them are. Rustaveli and Vyasa and 3 other craters.
● Are the magnetic anomalies induced or thermoremanent in origin?
● Thermoremanent = melt in crater slowly cools and records magnetic field that was present during crater formation.

2:15 p.m. Hood L. L. * Oliveira J. S. Spudis P. D. Galluzzi V.

Further Mapping of Mercury’s Crustal Magnetic Field Using MESSENGER Magnetometer Data [#6079]

Further mapping of Mercury's crustal magnetic field shows that anomalies are associated with some impact craters but not others. Differences in impactor composition (e.g., iron content) may be indicated by this new observation.

Emily Lakdawalla
● Magnetic anomalies are concentrated around Caloris.
● Distribution around Caloris is asymmetric.
● Stronger anomalies on western than on eastern side.
● There is a concentration of anomalies around a much older basin, the Sobkou basin underneath the Sobkou planitia.
● If anomalies in Caloris are at least partly remanent, then Mercury had a core dynamo when Caloris formed.

Caleb Fassett
- Magnetic anomalies over the Rustaveli and Steiglitz, two fairly large, pretty well-preserved craters in the northern hemisphere
- Analogy to the lunar crater-related anomalies (Leibniz, Crisium [though that's large])
- Cites Mark Wieczorek's hypothesis for an impact explanation for the lunar magnetic anomalies
- Hood: Assymetry in anomaly shape might be related to impactor iron distribution (and variations due to impact obliquity / angle: e.g., Rustaveli is ~close-ish to more vertical and Steglitz is more oblique
- If true, Hood argues that the crater-associated anomalies are remanent [not induced from the present-day field]. Absent of anomaly might be due to iron poor impactors.
[Question from Jack Wright: might this be chance? Hood: No]

2:27 p.m. Johnson C. L. * Plattner A. M. Phillips R. J. Philpott L. C. Kinczyk M. Prockter L.

The Distribution and Origin of Mercury’s Lithospheric Magnetization [#6052]

We use low-altitude MESSENGER data to model the spatial distribution of Mercury’s lithospheric magnetization and discuss constraints on its origin.

Emily Lakdawalla
● Estimate the global field as a field produced by many tiny dipoles, estimating their strength and orientation.
• Assume a 10 km thick layer.
• Get a good fit with low residuals, indicating that these fields are in the crust.
• Surface fields have lots of high frequency structure. Very localized.
• Magnetic field strength and crustal thickness are uncorrelated. Magnetized layer is insensitive to the base of the crust.
• Short wavelengths suggest it’s located close to surface.
• Strongest fields are located near Caloris in association with the smooth plains there. But smooth plains elsewhere are not correlated with magnetic field.
• There are localized spatial variations in magnetic field carrier -- maybe impact related? (Bring your own magnetic carrier)
• If you have only satellite observations, it’s very difficult to tell an induced field from a remanent field.
• So could this just all be induced in the present field?
• Much of the NH of Mercury could have a magnetic field that is induced, but there are areas near Caloris for which that may not be the case.

Caleb Fassett
-To get at measurements relevant to crustal field, you have to subtract off a current core dynamo model, behavior of magnetosphere (magnetopause+magnetotail), and field-aligned currents related to the magnetosphere. Last step is an along-track filtering.
-Regularize problem, use little dipoles, predict crustal magnetizations. Getting surface fields of a few nT to a few tens of nT. So upward continued to 40 km distance, even smaller.
-Spatial distribution of magnetization: no real difference in magnetization strength between smooth and intercrater plains. More magnetization around Caloris (NW circum-Caloris plains, impressive).
-Also sees Rustaveli + (NW of) Steiglitz anomaly discussed by Hood.
-"BYOMC" Bring your own magnetic carrier
-Big question: Induced (present-day) or remanent field
-To test induced, you know the present field distribution and make assumptions about magnetic susceptibility of materials (with a parameterization of composition). The background field seen in the crust actually matches this pretty well. How about the enhanced areas? Hard to get enhancements of >20 factor of enhancement {i.e. by boosting Fe or changing depths}. So the leftovers that have f>>20 in the maps (e.g. around Caloris) are probably remanent.
-Predicts ubiquitous ~1-2% Fe in the crust {interesting because of the lack of Fe in spectral observations}. Question about whether Fe-sulfides might be the magnetic carrier at Mercury, Johnson speculates that carbides are good idea.

2:39 p.m. Plattner A. M. * Johnson C. L.

Regional Modeling and Power Spectra of Mercury’s Crustal Magnetic Field [#6023]

Mercury’s crustal magnetic field and magnetic power spectra for select regions show distinct patterns for regions without magnetized impact craters, regions with magnetized impact craters, and the region north of Caloris.
Caleb Fassett
- Per previous Johnson et al. talk, this talk describes how the subtraction of the non-crustal fields is critical for examining crustal fields. The earlier method was to do along-track filtering of every orbit, but since the magnetic anomalies that result are perpendicular to the orbits, its good to verify this isn't a consequence of the filtering process (i.e., is real). So here, they test a different method for filtering, something called spatial Slepian filters. (https://github.com/Slepian/Slepian). The resulting map looks very much like the along-track method, which builds confidence that the crustal magnetizations are real.

- It's tricky to pull out information about depth of magnetic carriers, but one possible source of information is the apparent strength that sources of different depth (/scale?) behave at different orbital altitudes. Power spectra should look different as big deep sources will decay less at altitude than small shallow sources.

- Caloris region and Rustaveli region look different in their power-spectral behavior (Caloris notionally deeper), but the absolute values quoted for depth are overestimates [for reasons I didn't catch: note that these depths were also simplified because I believe the carrier was assumed to be a thin plate].

2:51 p.m. Wardinski I. Langlais Benoit * Thébault E.
Correlated Time-Varying Magnetic Fields at Mercury [#6077]
Time variation of the Heman internal and external magnetic field are analyzed and correlated to several orbital parameters, suggesting a variety of external sources for their origin.

Emily Lakdawalla
- Observe large variations in strength of dipole, more for external than for internally generated dipole
- (getting very sleepy)

3:03 p.m. BREAK

Tuesday, May 1, 2018

MERCURY:
ORIGIN, GEOLOGIC HISTORY, AND VOLCANISM

3:20 p.m. USRA Conference Center

Chairs: David Rothery
Christopher Malliband

3:20 p.m. Invited: Kamata Shunichi * Kuramoto K.

Mercury as a Probe for the Early Inner Solar System [#6068]
Surface chemistry of Mercury infers the early solar system environment not only at its inner edge but also at an outer region including the Earth and asteroids.

Emily Lakdawalla
• How to infer Mercury’s past
• Mercury condenses in a high temperature nebula.
• Iron condenses as iron metal at a high temperature. Iron oxides condense at less than 1000K; iron sulfide at lower than 800K.
• MESSENGER observed no strong absorption at 1 micron, depleted in FeO.
• However, MESSENGER found a significant amount of sulfur on the surface, which seems inconsistent with a high-T origin of building blocks. Especially since S should go to the core.
• Need to consider redox state.
• Low FeO and high S content required a low oxygen fugacity. Also, sulfur content indicates Mercury is highly reducing.
• One simple idea is that the inner solar nebula is rich in carbon. If you add carbon to the system, it consumes oxygen by forming CO as a gas at high temperature. So you can create an oxygen poor condition.
• You condense FeS, MgS, and CaS.
• Consistent with MESSENGER – a correlation between Ca and S.
• How do you get enough carbon?
• Consider spiral infall of dust particles. Their ices evaporate first, leaving organic materials as the last to evaporate in the inner nebula.
• We need a Mercurian sample.
• An uncommon type of meteorite called enstatite chondrites was formed in a highly reducing condition.
• These have the same isotopic ratios as Earth.
• Giant planet migration mixed up the planetesimals
• According to the Grand Tack scenario, not only are enstatite chondrites major building blocks of Earth, they are Mercury and Venus also.
• So now we wonder not why Mercury is reducing but why Earth is oxidized.
• Answer: because Earth is big. As Earth grows, its mantle oxidizes. SiO2 + 2Fe = Si metal + 2 FeO
• The early Earth may have been as reducing as Mercury. Giant impact on Mercury turned its redox state back; Current Mercury may be like the growing stage of the Earth.
• Next steps: understanding isotopic composition and abundance of carbon on Mercury
• High T/P experiments to understand chemical composition of cores

3:35 p.m. Boukare C.-E. Parman Steve W. * Parmentier E. M. Anzures B. A.

Production and Preservation of Sulfide Layering in Mercury’s Magma Ocean [#6105]

Mercury’s magma ocean (MMO) would have been sulfur-rich. At some point during MMO solidification, it likely became sulfide saturated. Here we present physiochemical models exploring sulfide layer formation and stability.

Emily Lakdawalla
• "Follow the sulfur"
• How much sulfur was there to begin with? When did sulfide phases begin to nucleate? What were they? Did they float or sink? Did they take the heat-producing elements (K, U, Th, etc) with them? How do they affect the rheology and the mantle’s convection pattern?
• Sulfur is highly soluble at low oxygen fugacity.
• The fact that you have weight percent sulfur on the surface is beyond crazy.
• Oxygen fugacity is at least at -3 or -4 relative to Moon and Earth.
5% wt% sulfur -- mantle is 400 km -- that's 20 km of sulfur!

Caleb Fassett
-Sulfur could potentially float or sink in a Mercurian magma ocean (density relative to melt unknown).
-If it sinks, then how close to saturation S is given the oxygen fugacity in the melt controls the depth of any sulfur layer that forms. Could form in the conductive part of the lithosphere and survive, or in the convecting mantle and get mixed.
-Chabot comment in questions: iron at Mercury's surface might mean that the oxygen fugacity isn't -4 or -6 below iron wustite, but instead is less reducing. Parman agrees that if iron at surface is actually from a mantle-derived melt, then -2.5 is more likely than the more reducing conditions he was mainly focusing on in his talk.

3:47 p.m. Anzures B. A. * Parman S. W. Milliken R. E.
Effect of Sulfur Speciation on Chemical and Physical Properties of Reduced Mercurian Melts [#6017]
Changes in sulfide speciation (FeS, MgS, CaS, Na2S) influence activities, stability of phases, polymerization, and viscosity.

3:59 p.m. Malliband C. C. * Rothery D. A. Balme M. R. Conway S. J.
Small Smooth Units ('Young' Lavas?) Abutting Lobate Scarpson Mercury [#6092]
We have identified small units abutting, and so stratigraphy younger than, lobate scarps. This post dates the end of large scale smooth plains formation at the onset of global contraction. This elaborates the history of volcanism on Mercury.

Emily Lakdawalla
- Mercury has smooth plains and intercrater plains.
- Mercury's smooth plains have sharp boundaries, assumed to result from volcanic processes.
- Intercrater plains are very highly textured and have craters with a variety of degradation states.
- Mercury is a shrinking planet with global contraction over the surface. Smooth plains have wrinkle ridges, while intercrater plains have lobate scarps.
- We see some small-scale smooth units in intercrater plains which abut lobate scarps. Therefore they have to be younger than lobate scarps.
- This is really quite interesting, because most plains units, most effusive magmatism was thought to have finished a long time ago.
- See for example 19N, 42 E, box about 4deg square
- Can tell young plains -- has no degraded craters, only fresh superimposing craters. Seem to be bound by topography, with areas of high topography not flooded. And they have gradational boundaries into intercrater plains, with flooded, subdued ghost craters.
- We're trying to map these, because one of the obvious interpretations is this is impact melt. Then it should be clustering around large impact basins, but that doesn't seem to be the case.
- How did this happen? Possible that faults provide ascent pathways. Lobate scarps are curvilinear, may provide some local stress release.
- Demonstrates late effusive volcanism outside impact basins, after large scale effusion had stopped.
- Found a few other examples in degraded impact structures.
- Brett Denevi: Be cautious about assuming that these are not related to impacts; some light plains on the Moon are located 1000 km away from an impact but are still associated with it (Orientale)

4:11 p.m. Head J. W. * Wilson L.

*Magmatic Ascent and Eruption Processes on Mercury [#6102]*

MESSENGER volcanic landform data and information on crustal composition allow us to model the generation, ascent, and eruption of magma; Mercury explosive and effusive eruption processes differ significantly from other terrestrial planetary bodies.

Emily Lakdawalla

- When Mariner 10 flew, we learned it was a one-plate planet. Weren’t sure if there was volcanism on Mercury.
- MESSENGER has shown extensive plains volcanism, a great volume of eruptions, and pyroclastic activity.
- What we don’t see: no evidence for low density anorthositic primary crust. This enhances mafic magma buoyancy and influences the lithospheric growth rate.
- What we do see: rapidly emplaced flood lavas. It means there’s large volumes of magma available, and there are big lithospheric cracks allowing rapid emplacement

4:23 p.m. Besse S. * Dorresoundiram A. Griton L.

*Analysis of Pyroclastic Deposits Using MESSENGER MASCS Observations [#6063]*

Pyroclastic Deposits on the surface of Mercury are analysed using MASCS observations and an optimised calibration procedure. Pyroclastic Deposits show similar spectral properties that is explained by isotropic distribution of the ashes.

Emily Lakdawalla

- MASCS data set includes lots of apparent pyroclastic deposits
- Have an automated processing that maps footprints
- Still have not find mafic absorptions
- Do see a downturn in the UV
- Looking specifically at amount of UV downturn and at VIS slope
- Consider Rachmaninoff, do radial profile with distance from vent.
- Away from vent, see a dropoff of both UV downturn and VIS slope with distance from the vent.
  (Followup to similar observations performed on the moon.)
- Hesiod E has highly asymmetric deposit
- So UV downturn and VIS slopes are a good proxy for mapping pyroclastic deposits
- In fact, may be better than MDIS albedo at detecting edges of deposit
- Looking at several and plotting UV downturn vs vis slope, UV downturn is pretty consistent (3.1 to 3.3), but much more variation in VIS slope
4:35 p.m. Jozwiak L. M. * Izenberg N. R. Olson C. L. Head J. W.

Investigating the Age of Mercury’s Pyroclastic Deposits [#6089]

We use a combination of stratigraphic and comparative spectral analysis to investigate the ages of Mercury’s pyroclastic deposits. We find that pyroclastic deposits have continued to form into Mercury’s recent geologic history.

Emily Lakdawalla
- Surprising that Mercury has enough volatiles to drive explosive volcanism.
- They are globally distributed and anticorrelated with smooth plains deposits.
- Mercury’s history: switches over from effusive volcanism to thrust fault activity at around 3.6 Ga; where does explosive volcanism occur? And what was its duration?
- Variations among spectral characteristics could be caused by space weathering (age), metal content (composition, which could lead to UV downturn), or particle size effects.
- Regardless, space weathering darkens things; can we pull that signal out and do age dating?
- Student (Caroline Olson) went through VIRS data set and extracted footprints crossing vents. Ratioed it to local background material.
- We find same four groups.
- There is no trend relating stratigraphic age of the host crater to spectral parameters of the vent.
- However, the very youngest ones do cluster a little bit. But there could be a floor of reflectance from stratigraphic tie points.
- Observation of vents in Mansurian and Kuiperian/Mansurian period craters suggests explosive volcanism continued into the very recent past on Mercury.
- Rotheny: What are your thoughts about duration of venting at a single vent?

4:50 p.m. Kinczyk M. J. * Byrne P. K. Prockter L. P. Susorney H. C. M. Barnouin O. S.

Crater Degradation on Mercury: A Global Perspective [#6116]

Results from a global catalog of crater degradation are explored and implications for our understanding of Mercury’s geological history are discussed.

Emily Lakdawalla
- …
- We broke craters into degradation classes. First looked through literature to identify a systematic definition of degradational class.
- We see a uniform increase in the number of craters for each older crater class except for calss 1 and class 2.
- Why? Maybe it’s hard to tell 1 and 2 apart for mid-sized craters.
- We looked at the spatial distribution of classes, and we see a fairly uniform distribution of crater types except for oldest type. And if you look at biggest basins, you see that the big basins may have eliminated class 1 craters in certain locations. Particularly from 0 to 45 east and in SH near 90W.
- We also wanted to see if we could correlate ejecta roughness with crater degradation state.
- Young lunar craters do appear rougher than old craters.
- Preliminary roughness analysis suggests no significant difference between Class 3 and Class 4 craters.
5:02 p.m. Banks M. E. * Xiao Z. Marchi S. Chapman C. R. Barlow N. G. Fassett C. I.  
Revised Age Constraints for Mercury’s Kuiperian and Mansurian Stratigraphic Systems[6124]

Crater statistics constrain the onset of Mercury's two most recent periods. The Kuiperian likely began \(\sim280 \pm 60\) Ma and the Mansurian \(\sim1.7 \pm 0.2\) Ga. Results indicate younger Kuiperian and Mansurian periods than previously assumed.

Emily Lakdawalla
- Motivation: analogy to lunar chronology is only that, an analogy.
- I made it my goal to revise age constraints for Kuiperian and Mansurian.
- We looked at 40 degrees north/south latitude. Independent count for comparison from Strom et al 2015. Counted down to 5 km in diameter, but only used craters >20km in diameter.
- We assume that our population of fresh craters is a COMPLETE catalog that formed since the onset of the Mansurian.
- We don't think we have secondaries because the K/M craters weren't large enough to produce secondaries larger than 5km.
- All are assumed to have formed since widespread plains volcanism ended.
- Not likely to be imaging bias; rayed crater populations similar across latitude bands.
- Our interpretations are consistent with other reseaarchers.
- DO smaller craters degrade faster? Size dependent effects are assumed to be minimal for craters larger than 20km in diameter.
- Estimated model age for the Mansurian population is 1.7 +/- 0.2 Ga
- Kuiperian: 280 +/- 60My
- These are consistent with Le Feuvre and Wieczorek ats being younger than ages assumed by Spudis and Guest by analogy with the Moon.
- With BepiColombo we'll no doubt revise these models. As long as we don't redefine ages, we can just use these same crater populations and revise the ages as we move forward.
- Results present that the Calorian period may have been 2x longer than previously assumed, extending in duration roughly another 2 billion years after the cessation of volcanism associated with Mercury's youngest widespread smooth plains.
- Younger onst ages are relevant to the timing of Mansurian events like hollows.

5:14 p.m. Invited: Denevi B. W. * Ernst C. M. Klima R. L. Robinson M. S. 
Mercury's Early Geologic History[6055]

A combination of geologic mapping, compositional information, and geochemical models are providing a better understanding of Mercury's early geologic history, and allow us to place it in the context of the Moon and the terrestrial planets.

Caleb Fassett
- Mercury was in some respects well-described by Mariner 10: smooth plains (probably volcanic) + intercrater plains.
- Big question is what the intercrater plains is, and whether intercrater plains resurfacing means that we cannot see further back in time.
Clues: (1) resurfacing was extensive but some areas of early crust may be exposed at the surface in a
gardened form. Argument is based on how at N(65) parts of Mercury get closer to Moon than the N(20)s.
(2) The geology of the areas with the highest N(65) on Mercury are preferentially LRM (darker stuff).
Patchy resurfacing from volcanism.
(3) LRM ~ graphite
(4) graphite could form in a flotation crust. (Vander Kaaden and McCubbin 2015...important) [note I think
that other darkening agent origin stories exist such as exogenic addition, Syal et al. 2015 paper]
Graphite may be the only buoyant mineral in the magma ocean, yet LRM is thought to contain <5 wt
percent graphite. How to get the silicates mixed in?
-Understanding whether sparsely cratered, low-reflectance areas like the Caloris exterior plains are
volcanic or impact might help test the flotation crust story.
In questions, Parman points out that the sulfides might float too. Reconciling mixed product is tricky.

Tuesday, May 1, 2018
POSTER SESSION: MERCURY
5:30–7:30 p.m. USRA Education Gallery

Malliband C. C. Rothery D. A. Balme M. R. Conway S. J.
1:3M Geological Mapping of the Derain(H-10) Quadrangle of Mercury [#6091]

We are making a high resolution geological map of the Derain quadrangle of Mercury. This is part of a
coordinated project to create a global set of geological maps for BepiColombo.

Mangano V. Milillo A. Massetti S. Orsini S.

New Results of Statistical Analysis of the Na Exosphere Earth-based Observations of Mercury

The THEMIS database of Na exosphere is re-analyzed in view of the most recent papers in the field of both
magnetosphere and plasma interactions.

Heilbert J.

Spectroscopy of Synthetic Planetary Analogs for MERTIS on the BepiColombo Mission [#6078]

We present an overview of our work on a database of mid-infrared spectra of synthetic analogs for the
MERTIS instrument on the BepiColombo mission.

Neumann G. A. Sun X. Cao A. Deutsch A. N. Head J. W.

Reflectance of Mercury’s Polar Regions: Calibration and Implications for Mercury’s Volatiles [#6115]

Calibration of laser altimeter reflectances under widely varying conditions is supported by laboratory data
from an engineering simulator to address the distribution of volatile deposits in Mercury’s polar cold traps.

Peterson G. A. Johnson C. L. Byrne P. K. Phillips R. J.

Distribution of Areal Strain on Mercury: Insights into the Interaction of Volcanism and Global
Contraction [#6056]

Wrinkle ridges within volcanic plains on Mercury host just as much shortening strain as lobate scarps and
high relief ridges, suggesting that wrinkle ridges have accommodated much more strain from global
contraction than previously thought.

The MIA (Mercury Ion Analyzer) Instrument Onboard Bepi Colombo MMO (Mercury Magnetospheric Orbiter) [#6005]

Current status and future observation plan of MPPE-MIA (Mercury Plasma Particle Experiment — Mercury Ion Analyzer) on BepiColombo/MMO will be presented.

Pegg D. L. Rothery D. A. Balme M. R. Conway S. J.

Geological Mapping of the Debussy Quadrangle (H-14) Preliminary Results [#6021]

We present the current status of geological mapping of the Debussy quadrangle. Mapping underway as part of a program to map the entire planet at a scale of 1:3M using MESSENGER data in preparation for the BepiColombo mission.

Schmude R. W. Jr.

Wideband Photometry of Mercury in the U, B, V, R, I, J, and H Filters: A Review [#6066]

I review brightness measurements of Mercury made since the 1960s. New J and H band brightness results are also presented.

Shread E. E. Chabot N. L.

Investigating Mercury’s South Polar Deposits with High-Resolution Determination of Illumination Conditions [#6008]

High-resolution images acquired by MESSENGER’s Mercury Dual Imaging System were used to investigate the illumination conditions of Mercury’s south polar deposits and to map the areas of permanent shadow in the region to compare with radar imaging.

Stark A. Oberst J. Preusker F. Burmeister S. Steinbrügge G. Hussmann H.

Mercury’s Reference Frames After the MESSENGER Mission [#6114]

We provide an overview of Mercury’s reference frames based on MESSENGER observations. We discuss the dynamical, the principal-axes, the ellipsoid, as well as the cartographic frame, which was adopted for MESSENGER data products.


Placing Tighter Constraints on Mercurian Surface Fe Abundances Through the Synthesis and Characterization of Fe-Poor Silicates [#6011]

We have crystallized and characterized synthetic Fe-poor minerals to make advancements towards reconciling the discrepancy between the lack of a 1-μm absorption band observed on the surface of Mercury, despite wt% levels of Fe observed by XRS.

Varatharajan I. Maturilli A. Helbert J. Hiesinger H.

Emissivity of Ca-Sulfide in Mid-Infrared Under Simulated Extreme Thermal Environment of Mercury [#6065]

Spectral evolution of emissivity of calcium sulfides in mid-infrared is studied for four Mercury daytime temperature cycles under simulated extreme thermal environment of Mercury.

Nano-FTIR Spectroscopy to Investigate the Silicate Mineralogy of Mercury Analogues: Supporting MERTIS Onboard BepiColombo Mission [#6067]

Nano-FTIR Spectroscopy is used to investigate the silicate mineralogy of synthetic Mercury analogues produced under reduced conditions representing different Mercury terrains. The study will support MERTIS payload onboard BepiColombo mission.

Wilbur Z. E., Udry A., McCubbin F. M., Vander Kaaden K. E., Rahib R. R., McCoy T. J.

Aubrite and Enstatite Chondrite Impact Melt Meteorites: Analogs to Mercury? [#6034]

We study aubrite and enstatite chondrite impact melt meteorites and compare these data to the mercurian surface data collected by MESSENGER to better understand the mineralogy of Mercury.

Wright J. Rothery D. A., Balme M. R., Conway S. J.

Geological Mapping of the Hokusai (H05) Quadrangle of Mercury: Status Update [#6062]

We present the current working version of the first geological map of the Hokusai quadrangle of Mercury.

Wright J. Rothery D. A., Balme M. R., Conway S. J.

Candidate Constructional Volcanic Edifices on Mercury [#6064]

We describe two candidate constructional volcanoes on Mercury and suggest how they may have formed on a planet whose effusive volcanism has overwhelmingly generated plains.

Aizawa S., Delcourt D., Terada N.

Sodium Ion Dynamics in the Magnetospheric Flanks of Mercury [#6090]

We examine the particle transport via the Kelvin-Helmholtz instability by using simulation. The heavy ions of planetary origin such as Na+ may experience prominent nonadiabatic energization as they ExB drift across large-scale rolled up vortices.


The Mercury Electron Analyzers Onboard the Bepi Colombo Mercury Magnetospheric Orbiter [#6003]

Onboard the Bepi Colombo Mercury Magnetospheric Orbiter (MMO), the Mercury Electron Analyzers (MEA) sensors constitute the experiment dedicated to fast electron measurements between 3 and 25,500 eV.

Anzures B. A., Parman S. W., Milliken R. E., Head J. W.

Interior Volatile Reservoirs in Mercury [#6113]

More measurements of 1) surface volatiles, and 2) pyroclastic deposits paired with experimental volatile analyses in silicate minerals can constrain conditions of melting and subsequent eruption on Mercury.
Besse S. Benkhoff J. Bentley M. Cornet T. Moissl R. Munoz C. Zender J.

*Mercury Science Objectives and Traceability Within the BepiColombo Project: Optimising the Science Output of the Next Mission to Mercury [#6083]*

The BepiColombo Science Ground Segment is developing, in collaboration with the instrument teams, targeted science traceability matrix of each instrument. They are defined in such a way that they can be tracked during the observation lifecycle.


*Spectroscopy of Minerals Analogs of Mercury Under the Hermean Conditions: The Effect of the Temperature [#6043]*

We present a preliminary study of the effects of the strong variations of temperature on minerals of the surface of Mercury. We measured a loose powder (75-100 μm) of plagioclase and 5 mm diameter pellets made with the same powder.

Daniels J. W. Neish C. D.

*Impact Melt Emplacement on Mercury [#6018]*

This work proposes that fresh craters on rocky bodies may deposit impact melt externally ultimately according to the strength of its surface gravity, regardless of the body's surface topography and melt abundance.


*The MSA Instrument (Mass Spectrum Analyzer) Onboard Bepi Colombo MMO (Mercury Magnetospheric Orbiter) [#6002]*

The paper describes the ion spectrometer that will be flown on Bepi Colombo MMO as part of the MPPE consortium and that will provide information on the magnetospheric plasma composition.

Deutsch A. N. Head J. W.

*Production Function of Outgassed Volatiles on Mercury: Implications for Polar Volatiles on Mercury and the Moon [#6121]*

We are interested in the flux of volatiles delivered to the polar regions of Mercury and the Moon through time. We integrate the production functions for volatile delivery from impacts, solar wind, and volcanism, which we focus on initially.

Fastook J. L. Head J. W.

*Cold-Based Glaciation on Mercury: Accumulation and Flow of Ice in Permanently-Shadowed Circum-Polar Crater Interiors [#6059]*

Examining the potential for dynamic flow of ice deposits in permanently-shadowed craters, it is determined that the cold environment of the polar craters yields very small velocities and deformation is minimal on a time scale of millions of years.

The Making of the 1:3M Geological Map Series of Mercury: Status and Updates [#6075]

A complete global series of 1:3M-scale maps of Mercury is being prepared in support to the ESA/JAXA BepiColombo mission. Currently, ~35% of Mercury has been mapped and ~55% of the planet will be covered soon by the maps in progress.

Goossens S. Mazarico E. Genova A. James P. B.

High-Resolution Gravity Field Modeling for Mercury to Estimate Crust and Lithospheric Properties [#6048]

We estimate a gravity field model for Mercury using line-of-sight data to improve the gravity field model at short wavelengths. This can be used to infer crustal density and infer the support mechanism of the lithosphere.

Grava C. Livi S. A.

Modeling of Metals in the Hermean Exosphere: Predictions for the Mass Spectrometer Strofio Onboard BepiColombo [#6039]

We modeled metals in Mercury’s exosphere with a Monte Carlo code. We predict altitude profiles of density for comparison with in situ measurements of Strofio mass spectrometer onboard BepiColombo.

Guzzetta L. Galluzzi V. Ferranti L. Palumbo P.

Geologic Map of the Shakespeare Quadrangle (H03), Mercury [#6107]

A 1:3M geological map of the H03 Shakespeare quadrangle of Mercury has been compiled through photointerpretation of the MESSENGER images. The most prominent geomorphological feature is the Caloris basin, the largest impact crater on Mercury.

Ivanovski S. L. Milillo A. Kartalev M. Massetti S.

Coupled Kelvin-Helmholtz and Tearing Mode Instabilities at the Mercury’s Magnetopause [#6074]

A MHD approach for numerical simulations of coupled Kelvin-Helmholtz and tearing mode instabilities has been applied to Mercury’s magnetopause and used to perform a physical parameters study constrained by the MESSENGER data.

Jozwiak L. M. Head J. W. Wilson L.

Characterizing the Morphology, Distribution, and Formation Geometry of Mercury’s Pyroclastic Vents [#6088]

We present a final catalog of pyroclastic vents on Mercury, identifying 104 candidate pyroclastic vents. We then assess the vent distribution, morphologic variation, and probable formation geometries.

Kinczyk M. J. Prockter L. M. Denevi B. W. Ostrach L. R. Skinner J. A.

A Global Geological Map of Mercury [#6123]

An update on mapping progress for the global geological map of Mercury.
Spectral Clustering and Geomorphological Analysis on Mercury Hollows [#6028]

Characterization of hollows located in different craters to understand whether there is a similar trend from a compositional point of view, and whether a possible correlation exists between spectral behavior of hollows and geomorphological units.

Wednesday, May 2, 2018

MERCURY’S POLAR DEPOSITS

8:30 a.m. USRA Conference Center

Chairs: Carolyn Ernst
Lior Rubanenko

8:30 a.m. Neumann Gregory A. * Sun X. Mazarico E. Barker M. K. Smith D. E. Zuber M. T. Head J. W.

Mercury Laser Altimeter: Highlights from 10 Years in Space [#6120]

The Mercury Laser Altimeter made discoveries contributing to our knowledge of the surface environment, geology, tectonics, impact history, volcanism, and interior structure of Mercury.

Emily Lakdawalla

- As of the end of the mission, April 30 2015, we were able to range right down to last orbit, 41,866,584 laser shots in 3,280 ranging orbits, 27,082,200 radii. We ranged to distances as low as 1.28km on final orbit.
- We were able to get continuous profiles practically through the end of the mission.
- MLA provided first MESSENGER orbital observations of Mercury’s librations (Stark et al, 2015)
- From the first flyby in 2008 we measured a tilt of crater floors, important to constraining chronology of events on Mercury.
- High-fidelity DEM in north pole will be put out from USGS in a few months (M. A. Hunter et al 2018)
- MLA profiles have constrained thickness of radar-bright deposits
- Shape has very small 0.14-km offset from center of mass. Mercury is oblate and elongated, 10x more so than its geoid.
- ??Clearly there was a brief period of expansion during the MESSENGER mission, followed by contraction (????) [joke] [thank you]
- An early discovery of a 1.5 km domical swell in the northern smooth plains that is not compensated by thickened crust or shallow low-density mantle layer. Tilted crater floors suggest late-stage formation via uplift. Deep-seated upwelling? James, this meeting and 2015.
- Poleward slews in 2nd year revealed bright deposits in Prokofiev, Kandinsky, and crater Z
- Outstanding question: why do we see these large volatile deposits on Mercury and not the moon? [IIRC James Tuttle Keane has shown why with TPW]
- Coming attractions: Will BELA confirm MESSENGER north pole stuff in south?
- Will volume of ice be asymmetric in north and south?
- Will global shape be substantially revised, especially near south pole?
- What the heck is the northern rise?
• Can we do GRAIL at Mercury?
• Q: Axial tilt of solid body was confirmed by altimetry

Caleb Fassett
-measured distances from spacecraft to Earth from 24 million miles away to 20 cm precision with millijoules of energy [two way link -- using MLA to transmit to Earth, and at a different time, Earth to MLA]
-Reference radius of Mercury 2439.7 (IAU, 1997), 2440.0 MESSENGER project, 2439.4 (Perry et al. 2014).
Note that this means that many of my previously processed data are now referenced to the wrong datum.
-Center of mass and center of figure not offset
-Chabot question: were low-altitude orbits useful? Answer: returns were rather saturated, so effective spot size was a factor of 100 bigger than desirable

8:42 a.m. Invited: Deutsch Ariel N. * Head J. W. Neumann G. A.

Differences Between Surface Ice Deposits at the Poles of Mercury and the Moon: Insights into Ages of the Ice [#6118]

The poles of Mercury and the Moon both show evidence for water ice, but the deposits on Mercury have a greater areal distribution and a more pure concentration. We explore how these differences may be related to the ages of the ice.

Emily Lakdawalla
• PSRs are stable regions for ground ice on billion year time scales
• NS on MESSENGER showed nearly pure water ice in Mercury, while LEND showed only a few wwt% at Moon
• What are the ages of ice deposits on Mercury? Counting small craters -- has small statistics problems -- but shows very young ages, ca 50 Ma
• Young ages are consistent with sharp albedo boundaries, regolith gardening rates, and delivery by a single, young impactor.
• Why is moon polar ice so patchy by comparison?
• Vondrak and Crider (2003): over time, ice is broken up and buried, and covered up.
• New goal: determine relationship between patchiness of lunar ice deposits and age of cold traps. We define an ice occupancy factor: the percent of cold trap area occupied by surface ice.
• Using Shuai Li et al (in review) maps of ice distribution.
• We find:
  o Oldest craters have patchiest ice (Shoemaker, Haworth, Nobile, Slater, Amundsen
  o Middle-aged craters tend to host more spatially coherent ice deposit. (Shackleton, Sverdrup, Rozhdestvenskiy U)
  o Youngest craters show no evidence of surface ice.
• Surface ice patchiness may be controlled by ice supply rate, impact destruction rate, and true polar wander.
• Conclude ice was delivered to Moon a long time ago, more than 2.5 Ga; Mercury more recently, 280 Myr

Steve Hauck
- Mercury polar ice deposits appear more extensive in concentration than lunar polar deposits, which appear more like frost
- High reflectance halos in around craters in ice deposits are indicative of ejecta that is more ice rich and can be used to derive ages
- Why are lunar ice deposits more spatially heterogeneous?
- Define cold traps as $T<110 \text{ K}$ from Diviner data for lunar traps
- Ice retention on the moon is controlled both by gardening and true polar wander (Siegler et al) as well as supply rates which has decreased with time. Currently lower than gardening rates.

Caleb F assett

This is an exciting result because it could help explain a current mystery: why are the very cold areas of Mercury and the Moon different? This talk makes the case that its age. Most of the delivery on Mercury coming late is a big deal, and the arguments related to the Moon are very novel. The results also are an independent line of evidence for supporting the Siegler et al. hypothesis for polar wander on the Moon, which is cool.

[Question from Emily: Does this talk suggest that ice was delivered to Mercury only once? Could the same be true of the Moon?]

[Caleb: I think the answer will be in the next talk...and I’m guessing they say possibly yes. On the Moon, the polar volatiles could be cometary or might even be volcanic (per my colleague Debra Needham’s recent work). The consistency in timing of delivery on the Moon with the period of maria emplacement is at least intriguing.]

[Emily: Cool, now we’re getting into some real geologic storytelling :)]

8:57 a.m. Ernst Carolyn M. * Chabot N. L. Barnouin O. S.

Could the Hokusai Impact Have Delivered Mercury’s Water Ice? [#6094]

Hokusai is the best candidate source crater for Mercury’s water-ice inventory if it was primarily delivered by a single impact event. The Hokusai impact could account for the inventory of water ice on Mercury for impact velocities $<30 \text{ km/s}$.

Emily Lakdawalla

- If the ice was delivered to Mercury by a single, large, young impact, then we should see the crater on Mercury. We have images! And we have Hokusai. 97 km in diameter. Detected by radar.
- If Hokusai couldn’t have delivered the water to Mercury, no impactor could have, so let’s test this case.
- Is it young?
  - Yes, rays, so formed in the last 300 Myr
  - Has extremely high ratio of ray length to crater diameter. If related to age, then it may be youngest on planet.
  - Has very few superposed craters, maybe a couple of them 300 meters in diam.
  - May be as young as a few 10s of Myr.
- What was its impact angle?
  - Asymmetric distal ejecta, horseshoe shaped central peak, but circular cavity and no uprange zone of avoidance.
  - If we combine all these constraints we converge on a 30-40 degree impact angle
• So let's assume 35 degrees

• What was its impact velocity?
  • Difficult to constrain from observations
  • Mean impact velocity 42.5 km/s but broad distribution from 10-80 km/s
  • Suggestions of higher-than-average melt fraction
  • Terminal ramparts suggest action of a fluidizing agent (Barnouin et al 2015)
  • The maximum melt volume for a fixed crater size may be indicative of lower velocities.
    ■ Holding impact energy constant, a faster impact will be a smaller projectile depositing its energy in a smaller region, so less melt generated. Energy in slower impact has a larger projectile, distributes energy over a larger area, generates more melt.
    ■ An impact velocity of about 23-26 km/s would produce the largest quantity of melt for Hokusai’s size.

• What was the impactor size and mass?
  • Calculate projectile size for a fixed final crater
  • Mass estimated assuming density, % water by mass (6-33% for a comet, 5-10% water by mass asteroid)
  • I missed the number calculated but it matched polar deposits
  • BUT not all the water is going to be retained

• How much water is retained?
  • Heavily dependent on impact velocity
  • Only a few percent of water stays
  • Retained water has to get to cold traps, may be 5-15% migration survival

• Implications for water delivery
  • For lower velocities a water-rich asteroid or comet could have delivered the inventory of water ice to Mercury, less than 30km/s
  • Mean Mercury impact velocities are higher, but there is a broad range.

• Could Hokusai be the source?
  • Yes. But there’s been a lot of arm-waving.
  • Still, the single-impact scenario remains viable.

Caleb Fassett
- Parameters. V~25 km/s (but could be 10 to 80). From melt-production derived constraint. I don't get why all the early methods slope up (more melt from higher V) and new curves slope down (less melt from higher V). But the argument is geometric -- big and slow produces more melt. Impact angle=35 degrees.
- Temporary atmosphere around Mercury (e.g. Parvathy Prem's work on the Moon)
- Problem is super complicated. Big issue is how much water that is delivered is retained.

[Q from Emily: What could be a test of this hypothesis that BepiColombo would be capable of checking?] Ernst Answer: A good test would be looking in the southern hemisphere ... also the purity of the ice needs to be verified.
9:09 a.m. Susorney Hannah C. M. * James P. B. Johnson C. L. Chabot N. L. Ernst C. M. Mazarico E. M. Barnouin O. S. Neumann G. A.

*Measuring the Thickness of Radar-Bright Deposits on Mercury Using Individual Mercury Laser Altimeter (MLA) Tracks [#6013]*

We estimated the thickness of Mercury’s radar-bright deposits using individual MLA tracks and found an average thickness of radar-bright deposits of 24 m.

**Emily Lakdawalla**

- Many large, complex craters have only part of the crater floor covered by radar-bright deposits.
- Using individual MLA tracks, compare height of radar bright portion of floor to non-radar-bright.
- Requires hand-editing of tracks to remove contributions from unrelated topography — central peaks or small craters.
- Try method on Desprez and find thickness comparable to standard deviation (this is not good). Mean thickness of radar bright deposits is 24 +/- 27m (yikes).
- So we tried the same exercise on a crater without radar bright deposits.
- Lol, the non-radar-bright craters have deposits of 50 +/- 25m (yikes^2)
- Well, we can at least rule out thick deposits. Estimate the thickness is on the order of 10s of meters. These are not glaciers.
- Look forward to being able to try again in southern hemisphere with BepiColombo data.

**Caleb Fassett**

- MLA doesn’t seem like it has the ability to resolve the thickness of the radar bright portion of impact crater deposits. So the implication is that the upper limit is potentially very thin (<20m). Radar minimum is 7m.
- May make the Hokusai delivery problem easier by making the needed ice volume smaller.
- But Susomey emphasizes that this is only 4 craters that they are using to try and measure the thickness.
- [Why do they make conference rooms so cold.]

9:21 a.m. Rubanenko Luvoir * Mazarico E. Neumann G. A. Paige D. A.

*The Depth of Ice Inside the Smallest Cold-Traps on Mercury: Implications for Age and Origin [#6057]*

We use Mercury Laser Altimeter data and an illumination model to constrain the depth of the smallest ice deposits on Mercury. By comparing this depth to modeled gardening rates, we estimate the age and delivery method of this ice.

**Emily Lakdawalla**

- Mechanisms that control erosion of ice deposits
  - Accumulation
  - Gardening (does not destroy ice, just erodes it, may even protect ice)
  - Photolysis
  - Sublimation (driven by Sun reflected off of opposite wall)
- Integrate over topography to determine volume available for cold traps
● It is a MESSENGER result that surface darkens as latitude increases. Postulate that this results from micro cold traps
● Topographic analysis shows the craters are about 50% full of ice
● Also supporting: craters in “cold pole” wedges are a little shallower (hence, a little more full) than “warm pole”
● Checking the Moon: Do see evidence for shallower craters near poles of Moon -- by this same analysis, there is 50m of ice in some lunar craters! (Seems to doubt this result, “I welcome other explanations”)
● Conclusions
   ○ We find evidence for ice in micro cold traps of thickness less than a meter on Mercury. Since accumulation and near-surface erosion rates are comparable, episodic deposition (i.e. a comet) is more likely than a slow accumulation.
   ○ Craters on Mercury become shallower with latitude. Depth of infill is 10-50m, consistent with previous studies.
● Carolyn Ernst: Prokoviev is up there, I wonder how its secondaries are affecting your sample?

Caleb Fassett
-This is an interesting result -- the talk presents some statistical surveying of d/D in the 3 to 15 km size range on Mercury and the Moon. The ‘darker areas’ of Mercury at high latitudes which are thought to be lag deposits of ice sublimation turn out to potentially have a slightly shifted statistical distribution of depth versus diameter (towards shallower craters). I missed the minimum latitude of this transition presented in the talk but I think it was 83 degrees (based on the abstract). On the Moon the transition is at 87 (!) degrees.
-If this is due to ice infill, then the implied additional ice is ~10+ m.
-There is also support for this idea based on the hot-pole versus cold-pole longitude.

-[There are lots of other potential explanations. Note that despite all of the other explanations I’m about to list here, I think the one presented by the authors is potentially the best. But here are some things to be concerned with. (1) The orbit of LRO means that they have to shoot off nadir at the very very highest latitudes (as I believe did MESSENGER), so I it would be important to rule out subtle differences in inferred depth caused by that… (2) there is probably a presumption of the same age in the two latitude rings because otherwise a shift to shallower depths might be caused by longer exposure … (2.5) It would be good to verify that the SFDs of the two rings look similar because the d/D should transition across the simple to complex transition at ~12 km, which is within the diameter range looked at here. (3) secondaries, like Carolyn Ernst said … (4) this is a challenging measurement… (5) Misha Keslasky points out that it could be different material properties at very cold temperatures, which might affect d/D, and that dust trapping might occur analogous to cold trapping due to different electrostatic environment].

A Closer Look at Some of Mercury’s North Polar Deposits: Three Craters that Could Have Extensive Surface Ice but Don’t? [6045]
We investigate three of Mercury’s north polar craters that are predicted from their thermal conditions to be conducive to the presence of extensive water ice at the surface, but that may lack such ice.

Emily Lakdawalla
● [My question: are these three craters shallow?]
● Radar had good visibility into these craters, but did not detect bright deposits.
MLA shows limited high-reflectance regions.

WAC using light reflected off of crater walls to see in PSRs sees dark deposits, sometimes with sharp edges

Low reflectance surfaces are thought to be lag deposits on order of 10 cm thick

What does it mean to have low-reflectance surfaces without radar-bright signatures?

○ Maybe ice was completely lost -- small deposit, didn't contain enough lag to shield ice
○ Implies small amount of initial ice and an uneven distribution of ice in polar craters. A steady-state process (like micrometeorites) should deposit evenly.
○ Consistent with single impact hypothesis.

9:45 a.m. Keane J. T. * Matsuyama I.

True Polar Wander of Mercury [#6098]

We use new MESSENGER gravity data to investigate how impact basins and volcanic provinces alter Mercury's moments of inertia. We find that Mercury has reoriented tens of degrees over its history, affecting tectonics, volatiles, and more.

Absent.

9:57 a.m. Hussmann H. * Steinbrügge G. Stark A. Oberst J. Thomas N. Lara L.-M.
(Talk given by Frank Preusker)

The BepiColombo Laser Altimeter (BELA): Scientific Performance at Mercury [#6016]

We discuss the expected scientific performance of BELA in Mercury orbit. Based on a performance model, we present the measurement accuracy of global and local topography, surface slopes and roughness, as well as the tidal Love number h2.

Emily Lakdawalla

- At an altitude of 1050 km, spot to spot distance is 174 m
- At lower altitude, spot size is smaller, spot to spot distance larger
- Performance is driven mainly by probability of false detection, which is influenced by surface slope.
- Define horizontal resolution as largest grid scale without a laser spot. Near equator, about 3 km, within 10deg of poles, about 250m. (Note this includes extended mission)
- Compared to MLA, will have global coverage.
- About a year to get global coverage
- Instrument range error is <1m for most conditions, but pointing and orbit errors will increase this to several m.

Caleb Fassett

- Big advantage of BELA is that it will get global coverage, including southern hemisphere un-ranged by MESSENGER
- 250 m resolution at poles
- 40 million crossovers (mostly at high latitudes, which makes some sense): expect to improve estimate for Mercury's tidal Love number (h2). Combined with k2 may give a better sense of how big the core of Mercury is. Implication of this number of crossovers is that they'll probably have a factor of many more
points total than MLA, since MLA had 40 million points total -- I missed the total number they actually expect.]
-In questions, Christian Klimczak asked about whether looking at Chao Meng-Fu would be expected to be a really good polar volatile-hosting crater to study with Bepi. Chabot answers: yes.

10:09 a.m. BREAK

Wednesday, May 2, 2018

AN EXOSPHERE AND MAGNETOSPHERE SCIENCE POTPOURRI

10:25 a.m. USRA Conference Center

  Chairs: Francois Leblanc
           Lydia Philpott

10:25 a.m. Invited: Killen Rosemary M. * Vervack R. J. Jr.

  *Mercury’s Exosphere: Current Understanding and Conundrums [*6006]*

  Although MESSENGER provided an unprecedented view of Mercury’s exosphere, there is much that is not understood, particularly in terms of the physical processes that generate and maintain the exosphere.

Emily Lakdawalla

  ● Observability of atomic species is variable. Ca, Ca+, Ti, Na, Mg+, Mg, Al, K are easier to see, other species harder. Did not see Cl or Ni.
  ● Comet Encke dust may cause observed spike in Ca seen after perihelion


  *Volatile on Mercury: Lessons from the Moon [*6084]*

  Presenting observations regarding present day sources of water on the Moon for comparison with processes occurring on Mercury.

Emily Lakdawalla

  ● Hydrogen system on the Moon
    ○ H+ from the solar wind is incident on the Moon at a rate of 30 g/s
    ○ The Moon does not accumulate it at this rate. What is actual accumulation rate?
    ○ How much gets converted to water? - could be an ongoing source of water to Moon (an Mercury) pole.
    ○ Where does the rest go?
  ● On Mercury, solar wind access to the surface is modified by the magnetic field.
    ○ What happens to the solar wind H+?
    ○ Does it get implanted?
    ○ What is solar contribution to polar ice deposits?
○ How does that differ from the Moon?

- Have analyzed regolith grains from Apollo samples and have found implanted solar wind hydrogen.
  - H is surface correlated
  - Amount of H is correlated with exposure indices
  - Heating regolith sample drives off lots of volatiles, water among the first

**Cesare Grava**

- Meteors release water which escapes after melting point is reached (was already in material, not brought from the impactor)
- Remote sensing shows there's an ongoing hydrological cycle on the moon: latitudinal distribution, possibly diurnally varying. Sunshine+ 2009 Science paper: images of the Moon 2 weeks apart (Moon has rotated). An area that didn't have much water after 2 weeks has water. See also LAMP observations: drop in hydration at noon.
- Two paradigms of surface hydration:
  a. Instantaneous balance between creation and loss from solar wind
  b. Migration of water through exosphere with residence time related to temperature.
- In support of a), Li et al. submitted: no signature of H2O/OH in magnetic anomalies! Makes sense because that's where solar wind does not have access to surface (so it cannot produce water).
- But also contradictory observations: as moon goes into Earth’s magnetotail, LAMP on LRO doesn't show any change in hydration
- Supporting b: lat/lon distribution consistent with longer residence times.
- findings that contradict b: model shows symmetric distribution around noon (no dawn enhancement, as it would be predicted by migration). Also, no steady-state water detected with LADEE/NMS
- Of the several pathway for escape of H, on Mercury only H has been detected (exactly the one which is not observed on the Moon!)
- Mercury has a lower escape rate for water, because it's more massive
- Question from Killen: Tom Orlando was skeptical about water released directly as H2O from the lunar surface. Do you think that water would come off the lunar surface as water or H2? Answer Probably both: in the impact plume there’s chemistry that allows H2 to be created

10:52 a.m. Vervack Ron J. Jr. * Hurley D. M. Pryor W. Killen R. M.

**MESSENGER Orbital Observations of Mercury’s Hydrogen Exosphere [#6025]**

We present a complete analysis of the MESSENGER H Lyman alpha altitude profiles. These data confirm the two-temperature nature of the Mariner 10 observations of H and address long-outstanding questions on the origin of Mercury's H exosphere.

**Cesare Grava**

- MASCs limb scans to observe H. Need to have interplanetary emission subtracted
- Mercury’s H is confined to dayside
- am/pm shapes are similar. There is just less hydrogen in afternoon.
- Monte Carlo model of Dana Hurley: just one T, not 2 as required by Mariner 10 observations.
- So why Mariner 10 did require 2 temperatures? They don't know. Still work in progress. Maybe the UV spectrometer of Mariner 10 was affected by straylight from the surface

11:04 a.m. Invited: Imber Suzie M. *

**Mercury's Dynamic Magnetosphere [#6099]**
The global dynamics of Mercury's magnetosphere will be discussed, focusing on observed asymmetries in the magnetotail and on the precipitation of particles of magnetospheric origin onto the nightside planetary surface.

Cesare Grava
- Open flux lines close and create reconnection. This creates substorms.
- Dungey cycle at Mercury is much shorter than at Earth: Substorms last minutes at Mercury, hours at Earth.
- However change in magnetic field intensity is bigger: 10% in change at Earth vs 25% change at Mercury.
- Reconnection – related signatures at Earth: most are found at dusk. But at Mercury, they are observed at dawn (Sun+ 2016)
- There are also X-ray emissions from Mercury on the nightside (which instrument?)
- They occur between midnight and dawn: these are Mercury's auroras!
- MESSENGER also observed electron events at dawn
- Messenger in magnetotail observed electron events: also at dawn.

Emily Lakdawalla
- Focusing more on magnetotail
- "Miniature magnetosphere"
- Orbit goes close to the northern cusp and spends some time in the plasma sheet and more time in the southern lobe.
- "FTES" scruff in magnetosphere profiles are signatures of reconnection
- Korth et al 2017 shows model of magnetic field
- It's a dynamic magnetosphere, changes all the time.
- Magnetosphere has closed field lines and then reconnection with interplanetary field shows open field lines.
- There's a circulation of field lines through the system.
- ...
- We see X-ray emission from Mercury's surface
  - We think this is Mercury's aurora -- it doesn't have an atmosphere, so it happens on the surface
  - Lindsay et al 2016
  - MESSENGER sitting in magnetotail sees electrons hitting dawn side of planet at appropriate latitudes
  - He mapped them back into magnetotail to see likely places they came from -- likely dawn sector
- Looking forwards, we are interested in using data from MIXS on MMO
  - Will be great for X-ray aurora
- They have a LEGO model of their spacecraft.

11:19 a.m. Heyner D. *

Concerning the Offset Dipole Magnetic Field of Planet Mercury [#6072]

Critical revision of the internal field determination on basis of all available magnetic field data from MESSENGER and derived constraints on the dynamo process of Mercury.

Emily Lakdawalla
- Mercury's dipole is offset towards north of 0.19 Mercury radii.
- From dynamo theory, this is problematic. It's unlikely that a dynamo produces a single harmonic mode.
- ...(analysis)...pure dipole no longer required; have a new model.
● Why is the field so weak?
  ○ Assume radius of convective shell 1414 km, CMB 2020km.
  ○ ...?

11:31 a.m. Jia Xianzhe * Slavin J. Chen Y. Poh G. Toth G. Gombosi T.

An Integrated Modeling Suite for Simulating the Core Induction and Kinetic Effects in Mercury’s Magnetosphere [#6082]

We present results from state-of-the-art global models of Mercury’s space environment capable of self-consistently simulating the induction effect at the core and resolving kinetic physics important for magnetic reconnection.

Cesare Grava

● Kinetic Simulations must include core induction
● Particle in cell code into a MHD model, which includes induction effect (due to presence of conducting core relatively close to the surface) and Reconnection
● BATSRUS code: simulates the interior too.
● Mercury’s response to a pressure pulse, like solar wind compression, without induction: magnetopause is pushed to the surface. Southern hemisphere almost completely exposed to solar wind.
● Now include the core, and therefore the induction: solar wind not able reach all the way to the surface! [Austin Glass later explained this to me: a powerful and fast CME would be promptly opposed by the induction, so solar wind does not access the surface; however, a prolonged push, like a long-lasting CME or a streamer from a coronal hole, would strip off the magnetic field via reconnection on dayside. The magnetosphere does not never really touch the surface, but the first magnetic field line would be at ~0.05 Mercury radii of altitude; at that point, protons have access to the surface simply because they are gyrating close to it]
● Reconnection from dayside and induction from core play equal role in shaping Mercury’s magnetosphere.
● Tail very dynamic, with plasmoids being produced.

11:43 a.m. Barabash S. * Wieser M. Futaana Y. Holmström M. Asamura K. Saito Y. Wurz P.

Energetic Neutral Atom (ENA) Imaging of Mercury’s Magnetosphere Onboard BepiColombo [#6117]

We describe how energetic neutral atoms (ENA) are produced in Mercury’s magnetosphere, how they can be used to image the magnetosphere and surface, and how they are measured onboard the BepiColombo mission.

Cancelled

11:55 a.m. LUNCH

Wednesday, May 2, 2018

MERCURY’S CRUSTAL GEOPHYSICS

1:30 p.m. USRA Conference Center

Chairs: Peter James
Hannah Susorney

1:30 p.m. Mazarico Erwan * Genova A. Goossens S. Neumann G. A. Smith D. E. Zuber M. T.

The Crust of Mercury After the MESSENGER Gravity Investigation [#6027]

We present the results of an improved analysis of the entire MESSENGER radio tracking dataset to derive key geophysical parameters of Mercury such as its gravity field. In particular, we derive and interpret a new crustal thickness model.

Emily Lakdawalla

- Duration of the mission allowed us to exceed our objectives.
- There are a lot more anomalies now in the northern rise than we initially expected, based on extended-mission mapping.
- Near n pole have degree strength up to 70ish
- Gravity is less than what you’d expect from topography; topography is compensated
- Make density assumptions to get at internal structure
- Fe-Si model has crustal density less than 2800kg/m3 and mantle about 3200
  - Compositional constraints may suggest higher grain density, but crust is expected to be porous based on comparison to Moon (2550) and Mars (2590)
- Is crust thin or thick?
  - Smith et al 2012 used mean crustal thickness of 50km
  - Padovan et al 2015 derived 35+- 18
  - Recent work used a value of 35
  - Sori et al (2018) advocated thin, dense crust (26 +/- 11)
  - But we lack necessary data like GRAIL has at moon
  - Thin crust is possible but...(lost track of argument here)
- Rachmaninoff has thinnest crust on Mercury.
- There is an unnamed mascon at 50N 60W
- There may be interesting, undiscovered mascons in south
- Genova et al manuscript has been submitted describing gravity field and interior structure modeling.
- There is a high Mg region around -90ish – may suggest higher density in that region

Caleb Fassett

-The gravity field reconstruction improved substantially during the extended mission. Higher degrees are better constrained (by looking at where the signal:noise is reliable) in new fields.
-Not much data in southern hemisphere yet (because of MESSENGER orbit); Bepi will help a lot.
-Average crustal thickness is 35 km. Genova et al. (2018), Padovan et al. (2018). Contrasts with recent Sori (2018) work arguing for thin, dense crust (26+/- 11 km) but Erwan is concerned with admittance/correlation. Pushes to low density. Other technique (GTR) pushes towards this too. And you don’t want negative crustal thicknesses to Rachmaninoff.
-Crustal density median is ~2800 kg/m3. ...
-bulk crustal porosity of Moon=10%, Mars=12%, hint that it is probably substantial on Mercury (probably ~10%)
-Rachmaninoff has very thin crust, few km thickness [CF: like Moscoviense on the Moon?].
- -60E/50N basin in crustal thickness
1:42 p.m. James Peter B. *

**The Enigma of Mercury’s Northern Rise [#6053]**

Various aspects of the “northern rise” make it hard to explain: Its composition and chronology don’t stand out from its surroundings, it seems to have uplifted late, and it has a huge gravity anomaly. We’ll discuss the possible formation mechanisms.

**Emily Lakdawalla**

- James’ wife cross-stitched the northern rise for his Ph.D. defense and he brought it with him (take a picture!)
- Northern rise
- Not distinct from remainder of northern smooth plains
- Ghost craters on the flanks of the northern rise have been tilted
- Including late-forming craters with intact melt sheets, which have also been tilted
- Long-wavelength gravity is correlated with topography, and the ratio of gravity over topography is high.
- Either this is volcanic top loading (volcanic construct on rigid lithosphere)
- Or mantle buoyancy -- mantle under rise is less dense and therefore buoyant.
- A problem with top loading is distribution of wrinkle ridges. They’re pretty isotropic; you’d expect it to be a bullseye pattern.
- So modify the cartoon to “blister top loading” -- a volcanic lens located just under the crust.
- But the low density mantle model seems to do best -- need only a few 10s of kg/m3 contrast
- Positive dynamic pressure [how does he figure out what this is] indicates upward buoyancy in the mantle -- which also appears at Caloris, Sobkou, and other places. Maybe it’s just that the northern plains one happens also to be a place with uniform crustal thickness, so the signal shows up better.
- “It’ll be great when BepiColombo gets gravity over the southern hemisphere. With any luck, we’ll find even more features that we can’t explain.”

**Caleb Fassett**

- Northern rise is “the most interesting feature on Mercury discovered by MESSENGER”, according to Peter James.
- Northern rise topography is decorrelated from its geology. Also, surface tectonic characteristics are decorrelated from the topography too.
- Northern rise might be similar to other weird rises/tilts (induced by loading or mantle) elsewhere on Mercury: Sobkou, famous Central Caloris rise. [analogy to other things we don’t understand :)]
- Things to sort this out: better crustal density, looking more at crustal magnetic remanence, more on tilts, more on long-wavelength southern hemisphere gravity. (Bepi will be useful for #2 and #4)
- Lithospheric strength/thickness would be useful to help think about this

**Indhu Varatharajan**

story - northern smooth plains formed - formed -- craters, impact melt sheets formed, sill flat --- and then northern rise happened

two possibilities
1. volcanic top loading -> lithosphere should be cold and rigid
2. mantle buoyancy - low density mantle below nrthm rise
--- positive dynamic pressure means - mantle buoyancy

additional data to constrain the nature of northern rise
1 better estimates of crustal densities
2. magnetic anomalies
3. tectonic surfaces
4. global gravity data (l<15) from bpicolombo

1:54 p.m. Baker David M. H. * Head J. W. Fassett C. I.

Impact-Basin Formation on Mercury: Current Observations and Outstanding Questions [#6085]

Mercury provides an important laboratory for understanding impact-basin formation on planetary bodies. MESSENGER observations improved our understanding, but much is still unknown about the formation and evolution of basin features.

Emily Lakdawalla
- As you go from 10 to 100 km, move from central peak to interior rings.
- Mercury is an ideal body to study these peak ring structures because there are so many of them compared to other bodies, like the Moon.
- Data: MDIS images for morphology, MLA for morphometry, MDIS for spectral properties.
- 3 Questions
  1. Why do large basins lack interior rings when they’re abundant in smaller ones?
     - <300km, peak rings are abundant. 70 protobasins, 110 peak-ring basins.
     - Examples: Vivaldi, 212 km. Better preserved than on the Moon (see Korolev, 417 km)
     - But bigger than 300 km, 46 “certain and probable” basins (D 300-1500 km) and 41 additional “suggested but unverified” (320-2000km)
     - Asymmetry in basin distribution -- because of spin state, volcanism, preservation?
     - But basins bigger than 300 km lack interior rings. (unnamed basin, not sure of location)
     - Also a paucity of large impact structures relative to the Moon.
     - Caloris basin (D=?) shows concentric ridges and graben
     - In order to reconcile this, need to do more numerical modeling of basin formation and evolution on Mercury, assess influence of volcanic resurfacing, and improve understanding of crustal properties, including composition, thickness, and thermal profiles.
  2. Why are the central cavities of peak ring basins so deep?
     - See Durer. Has 3.5-km deep interior basin (200 km)
     - But Velasquez (150 km), similar depth, no deeper center cavity
     - Large basins are shallow and show topographic benches. Interior smooth plains suggest volcanic resurfacing.
     - For these peak ring basins, could cooling impact melt or volcanic fill explain it? Some have central concentric graben structures
     - We need topography (especially in southern hemisphere) for basin morphometry, high res images and compositional information on basin floor materials, and modeling of post-impact cooling processes.
  3. Why such large overlap in crater/basin morphology from 75 to 150 km diameter?
     - On the Moon you don’t see this overlap.
     - Impact velocity likely plays a role. Velocity distribution is much broader on Mercury compared to the Moon.
     - But target properties might be important too (see Herrick paper)
• 4. What’s the composition at depth?
  ○ A lot of basins uplift and expose low-reflectance material
  ○ See Derain
  ○ See hollows in peak rings and walls
  ○ From the Moon we know that peak ring materials come from depths near max depth of excavation, near 0.1 d

• Phew

Indhu Varatharajan
10 km (complex craters) ---> 100 km (protobain)
MESSENGER - MDIS , MLA (morphometry), MDIS to conyrain impact popoulaton (spectral prop)

<300 km
70 - protobasins
110 - peak ring basins (Baker et al)

>300 km
46 - certain and probable_
41 - suggested but non proven
bains lack interior rings

Caloris basin shows concentric ridges and graben - shows only exterior ring structure
Rembrandt is the best three ring basin on Mercury

Required work
1. numerical modelling
2. assess influence of volcanic resurfacing
3. thermal, compositional,

most peak ring basins - with insuusal deep central cavities (Dürer - 3.5 km deep)
large basins (Sanai) - shallow, interior smooth plains, volcanic resurfacing

Rachmaninoff - cooling impact infill or volcanic fill

requires to answer: composition, post impact cooling , target properties

large overlap of interior structures in 75-150 km crater

Derain - exposes low reflectance material , hollows in peak rings & walls of basin

Summary - vast range of impact basins ; requires, improved modelling, morphometry geology, composition, crustal properties

2:06 p.m. Barlow N. G. * Banks M. E.
Constraints on the Timing of Tectonic Activity on Mercury’s Large-Scale Lobate-Scarp Thrust Faults
[#6126]
A crater analysis study of Mercury’s 30 largest lobate scarps provides new insights into the history of contraction on the planet.

Emily Lakdawalla
- Focusing on Mercury’s 30 named large-scale lobate scarps
- Main question: What is the timing of the most recent activity on these scarps?
- Or maybe: when did their peak activity end? [these seem like different questions to me]
- Identify craters transected or superposing the scarp face edge
- Restrict to main thrust fault segment as mapped on USGS website – sticking to structures as identified upon naming – we’re trying to isolate segments, since different parts could be active at different times.
- Emphasizes that fault activity can happen over extended time, while craters form only once. Craters crosscut by scarps don’t tell us when the scarp formed initially or when activity began.
- Also remember scarps can be active at different places in different times.
- …zoned out midway through this one. Afternoons are hard.

Caleb Fassett
Probably the most important conclusion of this study is that some amount of activity may have occurred on lobate scarps in the last period of Mercury’s geologic history. According to Banks, some scarps cross-cut craters or surfaces of Kuiperian age. None of the youngest examples are at high southern latitudes.

Indhu Varatharajan
lobate scarps - 500 km in length, 3 km in relief
large scale scarps - 30 named lobate scarps thrust faults
end of peak activity?
data: MDIS - trasected/superposing scap face edge
relative crater degradation age
identify the main structues when they are names in USGS planetary nomenclature
craters of only >5 km is used fo

what can we tell from below?
1. craters crosscutting scarp
2. craters superposing scarps

technique:
modified buffered crater counting technique (MBCCT) vs BCCT - eg blossom fault
tested surface ages - Beagle (M), Belgica (L. C or EM) Eltanin (C), Endeavor (C), Palmer (M) -- (age in brackets)
total lengths per time period
3100 km - C
1100 km - C/M
2900 km - M
2400 km - K
How Old are Mercury's Thrust Systems? New Results and Implications for the Thermal Evolution of the Planet [#6076]
We dated the activity of several thrust systems on Mercury. The results allowed us to better constrain the beginning of the contraction and, therefore, the thermal evolution of the planet.

Emily Lakdawalla
- A different approach to previous talk
- [...] Are those Mariner images of the scarps? I swear I recognized them...
- Several forms of global tectonism are expected on Mercury: Global contraction, tidal despinning (normal faulting at poles, shear in temperate lats, compression at equator), and structures resulting from mantle convection.
- Looking at several systems of structures: Al-Hamadhan, Thakur, Victoria, Villa Lobos, and Enterprise systems.
  - Al-Hamadhan system
    - Length 2000km, oriented NNE-SSW, from 10 to 60N, 90W
    - Get an age of 3.6 Ga using superposed craters, 3.8-3.9 using {a different method that I'm not sure of}
  - Victoria system: similar size, has vergence direction that changes along its length. Age?
  - Villa Lobos: 3.6 Ga
  - Enterprise system: even older, 3.7-3.8 Ga

Caleb Fassett
- Previous talk used non-porous model from Le Feuvre and Wieczorek, this talk uses porous model, looking at craters in basically the same size range. We need to know more about Mercury's crust (strength, single age estimate from somewhere) to sort this out.

Results heavy talk -- lots of early Calorian ages for big scarps.
- Totally in disagreement with previous talk, both quantitatively and qualitatively.
  - I need caffeine
The coffee that is out there is awful now, we need fresh

Indhu Varatharajan
two major tectonic features
1. lobate scarps
2. high relief structures
different processes -
  1. global contraction
  2. tidal dispending
  3. mantle convection

thrust systems (Giacomini et a 2014, GSL)
1. Al Hamadhan (2000 km -- NNE to SSW -- 3.6 Ga)
2. Victoria (3500 km, N-S, 3.7 Ga)
3 Thakur (1000 km?, 3.7 Ga,
4 Villa Lobos (1200 km, N-S, 3.6 Ga)
5 Enterprise (820 km, NE-SW, 3.7-3.8 Ga)
6 Blossom

dating thrust systems
buffer area = 2(S)L
S = 2R+0.5Wv

Dating - Le Feuvre abd Wieczorek & Neukum production fuctions)

implications for thermal evolution model
1. contraction started earlier than 3 Ga
2. global contraction is not the only process in Mercury's evolution -- tidal despinning and/or mantle convection also played a role)

what's the latest time contracted started - important qn ?? - we cannot say with this method

2:30 p.m. Herrick Robby R. *

The Nonrandom Distribution of Interior Landforms for ~100-km Diameter Craters on Mercury Suggests Regional Variations in Near-Surface Mechanical Properties [#6109]

There is great diversity of appearance in the interiors of ~100-km diameter craters. The spatial distribution of interior landforms is clustered and nonrandom, but does not clearly correlate with Mercury's surface geology patterns.

Emily Lakdawalla
- Classifying craters, interested in transition in central structure
  - Looking at craters 75 to 150 km
  - Central peak (Alencar)...multiple peaks (Lennon), ringed peak (Eminescu), protobasin (Equiano), peak ring (Scarlatti)
  - If you use a simple scaling law that diameter cubed is roughly proportional to impact energy you can compare apples to apples.
  - (Multiple peaks are dispersed peaks, not organized into a single peak, but not a continuous ring, either)
  - Our database classifies things differently from Baker.
- Color-coded thins to bias your interpretation of this graph (lol) I'm going to claim that things with rings are nonrandomly distributed within total population. Let me try to convince you:
  - Highlighting peak ring craters --7 of them, all at or above equator
- But there's no correlation between their locations and any other geology-related data set. Hopefully something will show up in the future. Can't understand why I see clustering.
- What would possible causes be?
- [editorial note: this seems like immature work.]

Caleb Fassett
-Goal of this talk is to look in in a single diameter 'bin' of ~75 km (ok: 74.9) to 128 km and plot out the different crater morphologies. Herrick notes that David Hollibaugh Baker has pointed out that on the Moon there is a pretty good separation between peak-ring basins and smaller central peak/multiple peak craters, but on Mercury not so much.
Herrick suggests that the ringed basins are probably clustered.

**Indhu Varatharajan**

- cratered
- 74.9 - 128 km --> studied diameter range
- factor of 5 variation (Alencar (central peak) 34% --> Lennon (multiple peak) 45% --> Eminescu 6.5% (ringed peak cluster) --> Equiano (protobasin) 12% --> Scarlatti (peak ring) 3.2% )
- total percentage of cratered within this diameter range
- peaks with rings (Scarlatti type) are non-randomly populated
- random distribution of MC simulation did not show any peak ringer clusters as observed -- suggesting that peak ring structures are not random in Mercury

conclusions
- 1. any kind of ring structures need target to be laterally homogeneous when impacted -- or else it will cause unorganised peaks
- 2. in terms of peak ring --> coherence of target for several kms matters & also layering
- 3. for craters of this type - excavation/modification upto upper 20 km crust influences


*The Chaotic Terrains of Mercury: A History of Large-Scale Crustal Devolatilization [#6054]*

Approximately 400 million years after the Caloris basin impact, extensive collapse formed Mercury's chaotic terrains. Collapse likely resulted from regionally elevated heat flow devolatilizing crustal materials along NE and NW extensional faults.

**Emily Lakdawalla**

- Motivating question: To what depth do volatile-rich materials associated with hollows on Mercury extend beneath the surface?
- Go to Mars. Martian chaotic terrains are regarded to be areas of complete landscape collapse into regions where volatile materials were removed from beneath the surface.
- The removal of the volatiles also produced areas of *incomplete* landscape destruction.
- Now we are talking about the Caloris antipodal terrain. But hypothesis of generation of "weird terrain" as antipodal to Caloris has problems: incompatible with numerical simulations, age relationships, and morphology.
- Simulations cannot reproduce the extent of collapse observed within the chaotic terrain.
- Our crater counts show that chaotic terrains formed at 2.1 Ga, 1.6 Ga after the caloris impact.
- To obtain this age we counted pristine craters only, ones that were not affected by collapse.
- (Terrain goes from 20 to 35 S, 10 to 40 W, with lobate margins)
- There are pretty well defined boundaries between chaotic terrain and nearby intercrater plains
- Argues that some of the observed morphology shows degradation of crater structures -- modification of original topography by collapse into subsurface, analogously to Mars.
- hmm.

**Caleb Fasset**
- This talk is going to challenge an old idea of Pete Schultz about chaotic regions on Mercury -- i.e., that it is seismic shaking related to material striking at the Caloris antipode in what was called the ‘weird terrain‘ by Mariner 10 folks. They were right. It is weird. Note that there is an area like this on the Moon too (Ingenii, postulated to be related to Imbrium)

- Analogy here is Mars chaos, which are sure something -- but do we see anything like this on Mercury!? On Mars, chaos are likely related to volatiles and collapse.

- Crater statistics compared to Caloris. 1.6 Gyr so according to Rodriguez so cannot be Caloris. CF note here is that this age is a tricky one to do: only interested in fresh craters superposed on this weird stuff, not all craters.

- Argument is that the weird terrain looks like it lost topography, not gained.

**Indhu Varatharajan**

Chaotic terrains on Mercury -->
1. diagnostic ancient volatile rich crust
2. massive removal of volatile material -- complete landscape destruction

early hypothesis -- meteorite hit in Caloris - seismic shaking + ejecta material -- contains inconsistencies

crater counts on chaotic terrain gives 1.6 Ga -- formed after Caloris impact

Mean surface elevation -- topography is reduced in observation, material is removed, crater rim is well preserved in one face, and removed in another face, well defined boundaries between chaotic terrain and surrounding region, gradual volatile loss history

chaotic terrain - removed thick materials

in addition to evidence of relief loss -> regions showing multiple grades fo modification

possible hollow connections with chaotic terrains -- heterogeneous distributed but tectonically aligned

how thick and how deep buried - 2.3 km layer volatile rich -->(constraints derived from 20 km craters)

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2:54 p.m. Preusker Frank * Stark A. Oberst J. Matz K.-D. Roatsch T. Burmeister S. Gwinner K.

*High-Resolution Topography from MESSENGER Orbital Stereo Imaging — The Southern Hemisphere [#6031]*

We will present the current status of the generation of topographic models of the southern hemisphere quadrangles H11 to H15.

**Emily Lakdawalla**

- (A talk that will hopefully be superseded early in the BepiColombo mission)
- Need topography complementary to MLA in northern hemisphere
- Using stereo photogrammetry
- In northern hemisphere, can co-register with MLA
- Each quad (there are 15) is covered by 10,000 images, 30,000 stereo image combinations
- After completion of the tiles we will “somehow merge them together”
- H6 – an equatorial one -- was chosen as prototype because not very well covered in MLA -- see Preusker et al 2017 in Pl. Sp. Sci.
- [methods slide, see his paper]
- DTM lateral spacing of 222 m/pixel
- H6 “Kuiper” quad. H7 “Beethoven” also delivered last year.
- These data are beautiful...
- H8 Tolstoj is incomplete, 80% covered so far, working on finishing it.
- Derain is last equatorial one. Has Holst. Is not so interesting, therefore I will skip to the next one
- Now to southern hemisphere
- “Discovery” H11 has some very nice chaotic terrain. Some really high topography. Finished
- …H14 Derain has a huge unnamed basin (wait it’s not derain, likely mistitled slide)
- Bach -- south pole -- is most difficult, because of illumination problem. (Interesting asymmetry in topography – very high near 235, low opposite)
- Southern hemisphere work should be done this year, equatorial in beginning of 2019.
- Then, Merging. This is a huge run. Adjustment of 80,000 images. Next target, the global, is for end of 2020, with 140,000 images.

Caleb Fassett
-Frank Preusker is making DTMs of Mercury globally using the images from MDIS. He is one of the most impressive processors of the stereo data gathered by MESSENGER; PDS released earlier results, but now working to do the whole globe. This is an incredible computationally intensive problem to do correctly.
-Insults Derain as “not interesting”, graduate student mapping that quadrangle in the audience groans
-H15 quad has a topographic step on the 90/270 line, so probably not yet finished.
-Targeting the global high res topographic base map for Mercury by end of 2020
-Working in his “spare time” to do this. This is doing something awesome because he can.

Indhu Varatharajan
15 quadrangle - each quad covers 10000 NAC/WAC images -- 30000 stereo images
prototype - H6 Kuiper - (Preusker et al 2017, PSS)
refer pub for more details

- successfully delivered - H7, H3, H5, H7
More - H8 (Tolstoj; had only 80% coverage for now), H9 (Eminescu), H10 (Derain; not so interesting in terms of topography), H11 (Discovery; chaotic terrain), H11 (Michelangelo), H13(Neruda), H15 (Bach; difficult)

summary - southern hemisphere !!! - 90% covered

global highRes topographic map of Mercury is targeted for end of 2020
Coarse Resolution reaches to 3-5 km
3:06 p.m. Kreslavsky Misha A. * Zharkova A. Yu. Head J. W.

Decameter-Scale Regolith Textures on Mercury [#6050]

Like on the Moon, regolith gardening smooths the surface. Small craters are in equilibrium. “Elephant hide” typical on the lunar slopes is infrequent on Mercury. Finely Textured Slope Patches have no analog on the Moon.

Emily Lakdawalla

- Looking at highest possible resolution. Late in the mission, MDIS obtained very high resolution images better than 1m/pixel. They allow us to distinguish features we haven’t seen in any image before.
- It is interesting to compare this to what we see on the Moon.
- Developed a comparison set of LROC NAC images, randomly extracted and degraded for comparison to MDIS to see how similar and how different the morphologies were at very small scale.
- The MDIS images were small (0.25 Mpix), down to 0.7 m/pixel, low S/N because spacecraft wasn’t designed to do this.
- We looked systematically through all of them,
- Conclude:
- Superficially, Moon and Mercury are very similar. There is regolith. Typical surface is covered by small smooth craters of different degree of degradation.
- Regolith is gardened like on the Moon.
- Small craters are aging and disappearing. So these processes are similar at least in principle.
- We see places where regolith is disrupted. Very fresh craters.
- But unlike the Moon, Mercury has hollows down to very small sizes, ~10m diameter
- We see features that are not found on the moon. For instance, “Finely-textured slope patches,” a descriptive term because we don’t know how they form. Sharp outlines, fine texture, on slopes only. They avoid high latitudes and avoid pole-facing slopes. In intercrater plains and old basins, not associated with fresh craters or hollows. We don’t know what these are, might be removal of volatiles but not like hollows. Could be landslides of regolith. They are young, do not have superposed craters.
- We looked for boulders, rocks. There are plenty of them on the Moon, hard to find one on Mercury. Found like 10 images with boulders.
- This is consistent with short boulder lifetime on Mercury – either temperature effect, or higher meteorite flux, or maybe deeper regolith.
- “Elephant hide” texture is common on slopes on the Moon, with unknown formation mechanism. Similar morphology on Mercury, but much less common.

Indhu Varatharajan

MDIS
- scattered along orbots
- cannot be put in context
- 3000 images, 2.5 m/pixe, smear < 10 pix

crater degradation is similar to Moon due to regolith gardening

We see
- fresh impact craters,
- hollows,
- finely textured slope patches (we don't know how they are formed -- young, short, small, fine texture, in slopes only; avoid high latitudes and not in polar facing slopes; in inter crater plains and old basins but not associated with fresh craters/hollows)
- craters are preserved but boulders disappear (5-10km) – very rare compared to Moon, are associated with young craters (>0.4 km)
- boulders are much less frequent - factor of 30 compared to Moon
- regolith is thicker, boulder life time shorter
- elephant hide (leathery) texture - rare, but similar morphology to Moon

3:18 p.m. BREAK

Wednesday, May 2, 2018

FUTURE MERCURY EXPLORATION — BEYOND BEPICOLOMBO

3:35 p.m. USRA Conference Center

Chairs: Nancy Chabot
       Steven Hauck II

Solomon Sean C. *

Mercury, MESSENGER, and Messages Still to Discover

Emily Lakdawalla

- Sean was ill yesterday, is giving a truncated version of the talk he meant to give yesterday.
- A new analysis of MESSENGER radio tracking data (Genova et al 2018) has yielded new values for Mercury's moments of inertia. An inner core having a radius 0.3-0.5 that of outer core is implied.
- Mercury's core contains Si and S along with the Fe. Difference in density between the solid inner core and fluid outer core depends on core composition. Inner core growth reduced the volume of the core (and hence contributed to global contraction of the planet).
- Cumulative global contraction is a factor of 5 greater than previously thought. It's the only planet with this clear evidence of global volume change. It's also the only planet where the core occupies more than 50% of the volume of the planet.
- Solid inner core formation could've been a later-stage event, which would've influenced timing of global contraction.
- Dynamo models: core dynamo models that yield a dipole field offset along the spin axis invoke long-wavelength variations in heat flux at the CMB at harmonic degree 1 or 2
- Brett Denevi's smooth plains map -- there's a hemispheric dichotomy. Centered at N rim of caloris, see most of the smooth plains; opposite hemisphere lacks much. (Huh, looked at this way it's kinda lunar looking) -- Sean thinks this is best evidence for some degree-1 geophysics.
- Magnetospheric asymmetry -- surface area of open magnetic flux in the southern hemisphere is 4x larger than in north. Should be more rapid space weathering in southern polar regions.
- ...zoned out...
- We've discarded all the mechanisms mentioned in the literature for the last 30 years for how to form Mercury as a metal-rich planet.
Cesare Grava

- Review of relevant MESSENGER papers
- Chabot+ 2014: core of Mercury contains Si and S and Fe.
- Byrne+ 2014: Mercury tectonic features are dominated by shortening structures, some organized into large-scale belts. This is the only planet where you can see reformation. Only planet where core occupies more than half the radius. Cumulative global contraction 5x greater than previously thought. Mercury contractional history constraints inner core growth and thus core composition.
- Anderson+ 2011: offset dipole or dipole + quadrupole? Dipole is offset northward by 479 km. This offset implies very low harmonic degree 1 (Tian+ 2015) or harmonic degree 2 (Cao+ 2014).
- Plain units (Denevi+ 2013) overlain with MDIS WAC mosaic reveal that smooth plain magmatism was hemispherically asymmetric, albeit at 3.8-3.5 Gyrs.
- Anderson+ 2011: surface area in open magnetic flux in southern hemisphere is 4x larger than northern. Weak southern polar filed and larger open field area imply greater particle-stimulated surface sputtering and more rapid space weathering in southern polar regions.
- Tomorrow: paper by Merkel: high-Mg region is a distinctive geochemical terrane identified from XRS data.
- Peplowski+ 2012: enhanced K (but also Na and Cl) near north pole could be result of compositional variations or mobility from hotter regions at low latitudes.
- Bepicolombo could test for equatorial asymmetry, like the one shown earlier today by Killen for Na.
- Mercury informs the study of high-density exoplanets: Santerne+ 2018. Cool graph of planetary radius vs planetary mass, subdividing planets in gaseous and non-planetary! Where is Mercury?! It should be on the right side...

Caleb Fassett

- Apparently we should all avoid “Stanford Grill” (I presume in Columbia) because Sean got food poisoning there.
- Highlighting the Genova gravity results -- exciting indeed.
- Mercury’s core composition is unknown (could have an unknown proportion of S and Si along with Fe)
- Highlighting Paul Byrne et al.’s contraction estimates (2014). The big contraction may relate to the core.
- Highlighting that the Banks and Giacomini talks which he notes are interesting because they tell us something about when global contraction happened. (CF: Though to be fair, what this something is remains a little obscure)
- Dichotomy in distribution of smooth plains if you choose a hemisphere 60N 150E versus 60S 330E.
- Sean asks for aspherical models for the coupling of the interior to the surface that might explain this discrepancy.

Indhu Varatharajan

Southern Mercury may experience rapid space weathering than the northern hemisphere due to weak magnetic field
1. K enhancement in north poles (along with Na & K) could be due to compositional variations and/or transport from low latitudes due to difference in temperature
3:40 p.m. Invited: Hauck S. A.  || * Blewett D. T.

*Lessons from the Mercury Lander Study for the 2013-2022 Decadal Survey [#6024]*

In situ exploration of Mercury is a logical next following the orbital investigations of the planet by MESSENGER and the upcoming BepiColombo mission.

**Emily Lakdawalla**

- One of the things we did as part of the last decadal survey was to study the concept of placing a lander on the surface.
- Visions and Voyages decadal survey was released literally days before MESSENGER entered orbit.
- Mercury fell under Inner Planets Panel (Moon, Venus, Mercury). Mars had its separate panel.
- There were 199 white papers submitted, of which zero were Mercury specific. Only Mercury-related input to the panel was a presentation by Sean about Mercury after MESSENGER.
- The main questions that existed at the time of the lander study were the same ones that motivated MESSENGER. Because those were the questions we knew how to ask at that point in time.
- Mission concept: land at dusk, 22 day primary mission, operations possible until dawn, do science by starlight. (We know how to handle cold, but not heat)
- Next decadal survey we need to advocate more for Mercury science. Consensus from within community has weight in the Decadal Survey. Credible and mature exploration ideas matter.
- 2009 lander study has valuable ideas for science and mission ops for future concepts. Science questions must be driven by MESSENGER results -- won't have BepiColombo results yet. New technology can open new doors (FH, new instruments, etc.)
- We need to make sure we continue to be creative.
- McKinnon: If you want to influence decadal, you need to get organized fast. I agree next step is to land; unlikely that it will be priority; need to find something that will fit in the NF box; NASA wants to spend money to do study now. Advocacy to NASA now will get studies going.
- Sean Solomon: Venus has an AG...what lessons can we learn from their experience?
- Hauck: Leave it to Sean to ask the 4000 ton question.
- Nancy Chabot: Well, they get to be on the list, and then disappointed every year.
- Hauck: I think they've lacked focus, need to avoid Christmas trees, be reasonable.

**Indhu Varatharajan**

1. Lander on Mercury
2. IPP - Inner Planets Panels of Decadal Survey
3. 0 out of 199 white papers submitted which is Mercury related
4. Main Qns? bulk composition, magnetic field, history of mercury surface, internal structure of mercury, and characteristics of Mercury surface
5. Mission concept: land at 2-3 days at sun-set; 22 days primary mission; access to large landing assets
6. Science payloads - PanCAM, MiniTES, Radio science, Descent imager, APXS, Raman, Microscopic imager, Magnetometer,
7. New technology - Falcon ? new instruments ?
8. Drive the proposal using MESSENGER knowledge as BepiColombo is much further
3:55 p.m. Eng Doug A. *

Mercury Lander Mission Concept Study Summary [#6070]

Provides a summary of the Mercury Lander Mission Concept Study performed as part of the last Planetary Decadal Survey. The presentation will focus on engineering trades and the challenges of developing a Mercury lander mission.

Cesare Grava
- Report of the lander study is available online! Check it here:
  https://solarsystem.nasa.gov/studies/199/mercury-lander-mission-concept-study/

Emily Lakdawalla
- People on Twitter are commenting that the brief summary of the proposed lander sounded very similar to proposals for the original BepiColombo lander.
- E.g. https://twitter.com/PlanetGuy_Bln/status/991773337541136384
- (think I'm going to skip notetaking on this talk)

Indhu Varatharajan
1. “Technically its all about energy”
2. 2018-2023
3. 2 mission options a) ballistic/chemical trajectory - 5 years  b) SEP trajectory - 4.8 years
4. 3 stage system -> cruise - braking - lander
5. SEP - more efficient ; ballistic - smaller payloads
6. Cruise - SEPs- large solar arrays, high temperature arrays
7. Braking - High thrust to weight ratio is needed for landing - would need store solid for entire cruise
8. Landed - RTGs may be required to power up the instruments during night
9. Cost - SEP more payload but high cost (1.6 billion dollars) - Atlas V 541 launcher
10. Today’s technology is feasible; requires large delta(v) for mission;
11. SEP is the most mass efficient choice but may not be cheapest (large number of ION thrusters)

4:10 p.m. Raines J. M. *

Planetary Ions at Mercury: Unanswered Questions After MESSENGER [#6087]

We will discuss the key open questions relating to planetary ions, including the behavior of recently created photoions, the near absence of Ca+ / K+ in MESSENGER ion measurements, and the role of ion sputtering in the system.

Indhu Varatharajan
1. (some) Unknowns
   a. how much of dayside is exposed to solar wind ?
   b. How eV ions are accelerated to keV ?
   c. How often planetary ions influence to magnetotail dynamics and do they govern?

4:15 p.m. Klimczak C. * Byrne P. K.

Open Questions on the Global Contraction of Mercury [#6049]

Substantial progress has been made on determining the amount, timing, and rate of global contraction on Mercury. But many open questions remain to be answered about the process itself, associated landforms, and interactions with other processes.
Emily Lakdawalla
- 7km has been mentioned at this meeting as a higher bound, but if you take it into account that it takes a while to build up stresses before thrust faults form, it could be as high as 9 km
- Question: Is tectonic activity detectable on Mercury at present?
  - In geologic record we can detect very small scale features that are thrust faults.
  - May have dramatically reduced rate over time – can we detect seismicity now? Is strain now partitioned into very small scale landforms, or do we also have strain continue to be accommodated on large thrust faults?
  - Is it aseismic or are there active major faults
- Question: What was rate of contraction in the lithosphere versus rate of contraction of planet as a whole? GRAIL detected structures no longer preserved at the surface, do same exist at Mercury?
- How does tidal despinning overprint on global contraction?

Indhu Varatharajan
1. Long term cooling of the planet - stress is high enough to produce thrust faults -
2. There have been higher numbers that have suggested only 9 kms of thrust faults
3. Time and rate of global contraction?
4. Is tectonic activity is detectable on Mercury?
5. Variability of morphology of shortening structures?
6. Global contraction/tidal despinning/thermal stresses/solar tidal stresses??


Volcanism on Mercury: (Some) Open Questions After MESSENGER [#6100]

From MESSENGER data we know, of eruptions, explosions, and flows. But details we lack, so when we go back, here are some questions to pose.

Emily Lakdawalla
- What do we know? Most smooth plains are lava. We think probably the intercrater plains are also probably lavas.
- Explosive volcanism has occurred (weird rimless irregular depressions with funny colors)
- Most big effusions ended by 3.5 Ga -- this was predicted
- Are all smooth plains volcanic? Are all intercrater plains volcanic? Are there subunits? How old are the other smooth plains? Are all faculae pyroclastic?
- What is the interior stratigraphy of the crust?
- Some mercury lavas are very buoyant. (Cites a paper I didn't catch)
- Is Borealis Planitia a key to crustal growth? Is this how planetary crusts get built?

Indhu Varatharajan
1. We know that
   a. Smooth plains are lavas
   b. Intercrater plains are volcanic as well
   c. Explosive volcanisms - pyroclastics/hollows
   d. None of the major volcanic plains are younger than 3.6 Ga
4:25 p.m. Ernst C. M. * Klima R. L. Denevi B. W. Peplowski P. N. Murchie S. L.

**Landed Reconnaissance of Mercury in the Low-Reflectance Material (LRM2)** [#6125]

Someday, humans will send a landed mission to Mercury. It should explore the low-reflectance material!

Indhu Varatharajan

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4:30 p.m. Chabot N. L. * Lawrence D. J.

**The Big Science Questions About Mercury’s Ice-Bearing Polar Deposits After MESSENGER** [#6044]

Mercury’s polar deposits provide many well-characterized locations that are known to have large expanses of exposed water ice and/or other volatile materials — presenting unique opportunities to address fundamental science questions.

Cesare Grava

- Big science questions on radar-bright deposits.
- Evidence for water ice on Mercury came from Goldstone and Arecibo, already in 1992!
- What is origin of Mercury’s water ice? Is it Ancient?
- What other volatiles are present at Mercury? Can organic rich materials be delivered to inner planets?
- What processes act in PSR? Do they destroy or produce water ice?
• How do mercury polar deposits relate to the inventory of inner solar system volatiles? What are implications for moon, earth, and other terrestrial planets?
• Mercury has large expanses of exposed water ice!! Like at Fuller and Prokofiev
• Ice beneath 10 cm of low reflectance (organic-rich?) volatiles

Indhu Varatharajan
1. What are the origin of water ice?
2. What are the other volatiles?
3. What process act in permanently shadowed regions?
4. How does the Mercury volatiles relate to interplanetary volatile systems?

4:35 p.m. Knibbe J. S. * Luginbhuel S. M. Rivoldini A. Kono Y. Van Hoolst T. van Westrenen W.

Future Seismic Constraints on Mercury’s Core Composition [#6029]
The composition of Mercury’s large core is strongly linked to the planet’s origin and magnetic field generation. We present P-wave velocity measurements for liquid Fe-Si and Fe-S metals. A future seismic mission can constrain the core composition.

Indhu Varatharajan
1. How did Mercury’s core formed? - adding S or Si to core?
2. Compositional evolution or thermally driven magnetic field?
3. P-wave velocity decreases with increase in S and increases with increase in Si --- for Mercury core
4. Seismic data will be helpful to discriminate between Fe-Si and Fe-S signal
5. Mercury core formation → Mercury’s formation, thermal evolution and core dynamics

4:40 p.m. Mazarico E. * Goossens S. Genova A. Sun X. Yang G.

GRAIL at Mercury: Coherent Laser Tracking for Geophysics [#6026]
We present an instrument concept for satellite-to-satellite tracking at optical wavelength to measure the gravity field of Mercury with sufficient accuracy and resolution to significantly advance our understanding of its geophysical evolution.

Indhu Varatharajan
1. Current gravity data >300 km in resolution; best resolution is 100-125 km over 4% surface
2. GRAIL in mercury will tell us
   a. Thermal evolution of Mercury’s lithosphere and crust
   b. Deep interior
   c. Impact formation and modification
3. Method: Satellite to Satellite tracking (SST) with Compact Coherent LAser Ranging (CCLR)
4. CCLR system to enable a new class of small-footprint gravity mapping instruments and satellites

4:45 p.m. Discussion and Future Plans

Indhu Varatharajan
1. Chinese mission plans to soft landing on Mercury - David Rothery
2. What volatiles are driving the pyroclastic- more experiments and models - Kathleen Vander kaaden
3. Nittler - why Mercury has giant core - very big question - no new mission could prove that - what is needed is more models ;;;;;; from Rosemary's talk - more knowledge of exosphere but we least know why that happens
4. Nancy/Kathleen - land on surface volatiles to explore the nature of volatiles
5. Daniel Salmon (Columbia university) - solar wind ion sputtering; laboratory measurements for solar wind interactions on Mercury surface regolith
6. What are the carriers of magnetic field on the Mercury surface - Steve Hauck
7. Do we need an AG ?? -- must be something easy to bring up. Email PAG !!
8. Mercury 2020 meeting ? time scale in two years ? -- bridge the gap between MESSENGER and BepiColombo !!
9. We need to explore the available unexplored MESSENGER data until we reach Mercury with BepiColombo

Cesare Grava
● One of the biggest discoveries of messenger was that there are many more volatiles than what we thought.
● Mercury is the only planet without an “AG” (LEAG, MEPAG, VEXAG, OPAG).
● Byrne: we should have meeting like this every 2.5 years, like Venus international meetings.
● Chabot: we used to have bepicolombo – messenger meetings.
● Hauck II: Maintaining vitality in community is key. Before MESSENGER, the mercury community occupied probably 1/3 of this room. And it’s not that there weren't data!
● Vander Kaaden: submit abstract to LPSC. There will be an AGU session on Mercury too. [and EPSC too, I add…]
● Chabot:

5:15 p.m. Chabot N. L. *
Session Wrap-up

Cesare Grava
● feel empowered and be proactive!

Thursday, May 3, 2018
Room has about 50% or 66% the # of people as yesterday

SODIUM: A MAJOR PLAYER IN THE EXOSPHERE AND MAGNETOSPHERE
8:30 a.m. USRA Conference Center

Chairs: Valeria Mangano
Jim Raines
8:30 a.m. Invited: Leblanc F. * Chaufray J. Y.

*Mercury’s Exosphere: Ground Based Observations as a Support to the Forthcoming Bepi-Colombo [#6004]*

We will summarize the still open questions regarding Mercury’s exosphere, highlighting which new topics Bepi-Colombo set of instruments might be able to address and how ground based observations should contribute to further improve our understanding.

Caleb Fassett

Goal is to talk about ground based observations that might be useful to support Bepi, and give open questions around Mercury’s exosphere. Not a complete summary but a sampling. Some of these are cool results because they give context in Mercury’s space environment in a way that is impossible close up from Mercury because of the perspective from Earth.

Major discoveries of last decade:
(1) Bida and Killen (2017) reported discovery of aluminum (s/n a bit greater than 3 at 3961 angstroms and a bit less than 2 at 3944 angstroms. Lots of null observations as well.
(2) also, Fe at 3719.
(3) Schmidt et al. 2010 observed Mercury’s Na tail (>100 radius of Mercury). Evolves with time in orbit; allows direct estimates for escape rate of Na, energy, and photoionization rate. (Uses a coronograph to block Mercury itself).
(4) Transits of Mercury. There is one coming up in 2019...preview of 9 AM talk discussing a 2016 transit observation as well.
(5) High spectral resolution observations of Mercury...look at Na velocity distribution (missed some details)
(6) Lopez-Arste et al. 2012 allows measurements of polarization of Na’s D2 resonant line. Could potentially learn something about magnetic field (but kind of messy?)
(7) Re-highlight of Orsini talk from Tuesday that CME crossings at Mercury can be detected from ground-based observations.

Open questions:
(1) Why is there no thermal Na? Test with high spectral and spatial
(2) Why is there no variabile high latitude component [missed measurement]
(3) What is the cause of high latitude peaks[missed measurement]
(4) How does cold longitudes couple to Na exosphere...seasonal coverage
(5) What are sources of the exosphere...seasonal coverage, tail observations
(6) Is Mercury eroding? Can this be figured out from tail? … tail observations
(7) Where is calcium coming from? … global 2D imaging/diurnal coverage
(8) What are the signatures of sputtering? Ejection? Radiolysis?… global 2D imaging/diurnal coverage
(9) How does Mercury’s surface get altered by these exosphere-related processes?… global 2D imaging of exosphere and surface

In questions, Besse highlights the need to archive telescopic observations. Orsini highlights desire to coordinate and plan future observations.
Indhu Varatharajan
1. McDonald observatory detecting the tail of Na (Schmidt et al 2010)
2. Different position of Mercury around the sun showing the evolution of Na tail
3. Direct measurement of escape rate of Na will help understand the Na in the exosphere
4. FISS/1.6 m New Solar Telescope, Big Bear California (BBSO) is used to observe the Mercury transit (will be talked by Schmidt et al today at 9 AM)
5. McMath Pierce Solar Telescope & Harlan Smith Telescope is used to measure the high spectral resolution of Na in exosphere
6. Lopez-Ariste et al 2012 - THEMIS solar Telescope to measure the polarisation of Na in regolith (?) which depends on optical depth, phase angle
7. Orsini et al 2018 - THEMIS Solar Telescope - on space weather on Mercury
8. High spectral & spatial resolution is needed with global 2D imaging to understand the seasonal coverage of Na exosphere and in tail

Orsini - US-Japan-Europe collaboration for a working group for Mercury Science
Sebastian Besse - ESA PSA (Planetary Science Archive)- archive the telescope data along with the planetary data

Cesare Grava
- Ground-based telescope can still provide extremely useful monitor of Mercury’s dynamic exosphere
- Latest example: Bida & Killen [2017], which detected Fe and Al.

8:45 a.m. Invited: Kameda S. * Kagitani M.

Ground-Based Observation of Mercury’s Sodium at Haleakala Observatory in 2013–2017 [#6035]

In this study, daily variation in Mercury’s sodium exosphere was observed at the Haleakala Observatory in Hawaii. We confirmed the seasonal variation of the column density of sodium atoms over the dawn side differs from that over the dusk side.

Caleb Fassett
- Been using Haleakala observatory (must be a pretty place to work -- though we find out later in the talk that the telescope is usually remotely operated from Japan, at ridiculous hours in their morning). High dispension spectrograph (10 pm resolution)
- Summary of observations is that Mercury sodium is quite stable (with 5 minute sampling/averaging from data before 2013)
- 2012 event -- Solar wind flux (protons?) went up by an order of magnitude (FIPS) and Na density observed from Haleakala only increased by 5%
- No sign of change in exosphere from MESSENGER impact (alludes to a possible contrast with an Orsini result that I’ve never seen)

Indhu Varatharajan
1. For supporting MMO/MSASI, Hayabusa 2/ONC()
2. 40 cm Schmidt Cassegrain telescope - high dispersion spectrograph (spectral resolution of 10pm) showing stable Na (avg density) in short time
3. With increase in solar wind flux of one order - the increase in Na is observed only to ~5.5%
4. MESSENGER/GRNS - shows higher Na abundance in high altitudes
5. Changed the instrument to a long slit spectrometer to fiber optics to study the seasonal variability -- interplanetary dust is very thin near Mercury orbit but denser farther from the sun
6. Feb 2013-Jan 2015 observations suggesting Na (---gardening effect) and Ca (---impact vapourisation)
8. 2018-2027 -- automating the observation at Haleakala
9. Ryugu C type asteroid in July 2018 - observing Na - supporting Hayabusa 2/ONC

One should be careful about comparing Ca and Na - as the processes are different

Cesare Grava
- 40-cm Schmidt-Cassegrain on Haleakala with very high spectral resolution: 0.01 Angstrom!
- Now it has been automated.
- Seasonal variability of sodium: higher sodium density near interplanetary dust plane

9:00 a.m. Schmidt C. A. * Leblanc F. Reardon K. Killen R. M. Gary D. E. Ahn K.
Absorption Spectroscopy of Mercury’s Exosphere During the 2016 Solar Transit [#6022]

Solar transits of Mercury provide a rare opportunity to study the exosphere in absorption and a valuable analog to transiting exoplanet studies. This presentation will characterize the sodium exosphere during the 2016 transit.

Caleb Fassett
-Trying to see the absorption in sodiums very undense atmosphere during transits. First observations were in 2003, also done in 2006. Get a very tiny residual sodium absorption signature that is a residual from changes induced by the Sun’s upper atmosphere (which is also convecting, causing Doppler shifts in the Na lines. Cassidy et al. 2016
-Same distribution/structure in Na observed in 2003 and 2016 transits.
-Tentative variability ~10-20% on hourly timescale
-Scale heights of Na inferred (~100 km in agreement with MESSENGER though maybe a little higher at poles)
-2019 transit is favorable for European observations

Indhu Varatharajan
1. Schleicher et al 2004 - first demonstration
2. THEMIS Solar observatory is used for measure Sodium D2 (2.5 hours)
3. 483 data cubes are collected - high spatial & spectral resolution
4. Cassidy et al 2016 - Removing Residual from Exosphere by comparing with Annulus – average of all Residual spectra will give the Na exosphere map
5. Polar enhancement of Na was observed -- cold pole longitude at 10 AM is coupled with this phenomena. Most of the sources of exosphere is due to solar activity and local time/temperature of Mercury
6. Na enhancement at the poles - is much less expected via sputtering
8. 2019 - Mercury transit → European Solar telescopes (THEMIS, GREGOR,SST) -- next chance is only 2032 !!!

Regolith is cold under cold poles !!!!! - temperature effect is complicated !!!
Cesare Grava
- 2016 transit of Mercury in front of the Sun observed from 1.6m Goode Solar Telescope at Big Bear Solar Observatory
- To be compared with previous transits of 2003 (Schleicher+ 2004) and 2006 (Potter+ 2013). Next transit will be in 2019, observable by European telescopes like GREGOR and THEMIS. Then... 2032!
- Observed D2 line of Na.
- Enhancement at dawn, especially at the poles, just like Schleicher+ 2004: is it due to magnetospheric sputtering or to projection effects? No Na at dusk.

9:12 a.m. Gamborino D. * Wurz P.
Statistical Analysis of PDF’s for Na Released by Photons from Solid Surfaces [#6001]
We analyse the adequacy of three model speed PDF’s previously used to describe the desorption of Na from a solid surface either by ESD or PSD. We found that the Maxwell PDF is too wide compared to measurements and non-thermal PDF’s are better suited.

Caleb Fassett
- Work is in press in PSS
- There is some interest in trying to understand why sodium atmosphere is so hot around Mercury
- Big equations (maxwell / boltzmann: requires thermodynamic equilibrium and symmetry, which is probably not true at Mercury; or empirical PSD see Wurz et al 2010. Even more complicated]
- Then another very very big equation (a Weibull distribution). Note this is often used for fragmentation, not sure why it should apply for Na PSD. Here assumption is that the surface temperature is the main controlling parameter.

Indhu Varatharajan
2. Mercury is just like Lindt chocolate
3. ESD/PSDs for Sodium
4. Why Na is so hot ?
5. Silicate substrate + lunar basalts - experiments to understand the Na - observation is Na is suprathermal !
6. Maxwell-Boltzmann to experiments requires - thermal equilibrium & symmetry --- function which consists of arbitrary shift wrt arbitrary temperature
7. E and p bombarding the surface → we need non thermal distribution, high energy tail, asymmetry, reduce free parameters
8. Weibull method is used - as we don't have to assume high thermal energy
9. 250K,100K substrates -- Weibull does it fit well - arbitrary temperature is not added -- as PSDs/VSDs don't involve high temperature (??)

Cesare Grava
- Main Result: Weibull distribution is a better distribution function than e.g. Maxwell-Boltzmann in photon- or electron-stimulated desorption
A Combined Experimental and Modeling Program to Study the Impact of Solar Wind Ions on the Surface and Exosphere of Mercury [#6012]

We aim to improve the interpretation of in-situ and remote-sensing data of Mercury. We will use updated exosphere and spectrophotometric models incorporating new data from lab simulations of solar wind ion irradiation of Mercury's regolith surface.

Caleb Fassett
- Key takeaway from the talk is that the speaker is funded and looking for a postdoc to do lab work :) There are no results here, just a plan for useful new results.
- Sputter data exists mostly for slabs, not powders, because semi-conductor industry is interested in the results. But for planets we have no idea how regolith actually sputters
- Funded to build a novel apparatus ("everytime I build something new I call it novel"). It's kind of fancy looking. Basically an ion beam (1-20 KeV // H+ and HE+), then sent through optics, hit target of loose powders. Will do ion beams at different angles (15/45/75). Plan to do VNIR (350 nm to 2500 nm) over a range of phase angles/maybe future XPS detector, plan also to do catcher foils at multiple different polar/azimuthal angles from beam to look at species that are sputtered
- Initially plan to look at a neutral surface (avoid charging; eventually might evolve to allow for charging).

Indhu Varatharajan
1. Limitations of past experimental work -> proposed experiment → postdoc wanted!
2. Sputtering ideas exists fro slabs -- but we have no idea about powders
3. Novel apparatus to study the ion sputtering of loose powders
4. For VIS-NIR spectroscopy, Mass spectrometer, XPS, electron flood gun —
5. Design → 1-20 KeV → 10^18 particles cm-2
6. In-situ reflectance measurements (0.35-2.5 microns)
7. Phase angle 15-90 deg – need more ??
8. Catcher foils for ex-situ analysis
9. Foils cover - polar + azimuthal angles
10. Starting with labradorite feldspar (as it contains Na)

Cesare Grava
- Upcoming laboratory measurements at Columbia University of sputtering yield as a function of incidence angle
- Not on slabs, like all laboratory measurements so far, but on powders
- Looking for a postdoc!
9:36 a.m. Cooper R. * Grande M. Martindale A. Bunce E.
Observational Conditions for the Detection of X-Ray Fluorescence from Sodium by the MIXS Instrument on BepiColombo [#6080]

We model the expected fluorescence from the exosphere and surface of Mercury, as observed by the Mercury Imaging X-ray Spectrometer (MIXS) on the upcoming BepiColombo mission, using code modified from that used for the SMART-1 D-CiXS instrument.

Caleb Fassett
-Main takeaway for this talk (for the exosphere) is that exosphere fluorescence is going to be very hard to observe because of low-density; might be able to do something with a big flare.
-MIXS will mostly be useful for surface observations (like was done with XRS on MESSENGER)

Indhu Varatharajan
1. MIXS-C, MIXS-T, SMART-1
2. Compared with simulated X-ray spectra of K-rich lunar basalts
3. Optimising viewing position for BepiColombo to maximise the Na/exosphere species detections
4. MIXS-C resolution is 75ev - 8 KeV (??)

9:48 a.m. Jasinski J. M. * Raines J. M. Slavin J. A. Regoli L. R. Murphy N.
Sodium Pick-Up Ion Observations in the Solar Wind Upstream of Mercury [#6110]

We present the first observations of sodium pick-up ions upstream of Mercury’s magnetosphere. From these observations we infer properties of Mercury’s sodium exosphere and implications for the solar wind interaction with Mercury’s magnetosphere.

Indhu Varatharajan
1. Solar wind interation with cometary neutral atmshere - these get photoionsided, they experiences EM forces with solar wind and picked up solar winds; as these ions pick up - they have O (higher mass than H) -- magnetic field dispersion draping around comet - causing magnetic tail -- gerating with interplanetary magnetic field
2. Pitch angle of pick ions - controls the direction of particles wrt to magnetic field
3. We see these pick ions outside the bow shock - in MESSENGER
4. There are total 23 pick ion observations with MESSENGER
5. Extentned Na exosphere is very transient --- what causing nestrals being observed far from planet ?

Look into low frequency waves – Rosetta !!
It will be interesting to see what is true anomaly angle.
10:00 a.m. BREAK

Thursday, May 3, 2018

MERCURY GEOCHEMISTRY: OBSERVATIONS AND LABORATORY CONSTRAINTS

10:15 a.m. USRA Conference Center

Chairs: Kathleen Vander Kaaden
Brendan Anzures

10:15 a.m. Invited: Charlier B. * Namur O. Cartier C.

Perspectives on Magmatic Differentiation of Mercury [#6009]

Silicate/metal liquid immiscibility, crystallization of a magma ocean, partial melting of mantle rocks, and surface crystallization have shaped Mercury as we know it today. We review these processes based on high-T experiments at reducing conditions.

Caleb Fassett

-Talk will initially review previous work that Charlier has done on phase equilibria of Mercury’s composition
-General history of Mercury looks something like this:
  1) Global melting/global ocean
  2) Planetary colling / crystallization of inner core
  3) Partial melting of the mantle / production of secondary crust
  4) After 3.6-3.8, contraction etc.
-Goal is to take compositions from MESSENGER data and enstatite chondrites and due crystallization experiments at reducing conditions in laboratory
-Mineralogy map of Mercury (Namur and Charlier/2017, Nature Geo)...inferred mineralogies
-Converted these mineralogies to densities...get crustal mineral (grain) densities of 2.8-3.15 g/cm3 (interesting implications for porosity in comparison with results presented on Tuesday by Genova et al.)
-Fit best with maybe 10% porosity (didn’t follow this argument completely)
-Oldest rocks have highest degree of partial melting (high Mg?); NVP lower. 50% partial melts in Mg region, implies high mantle potential temperature.

Indhu Varatharajan

1. Highest density around HMR and lower density around NVP
2. Mantle composed of ol and opx
3. What controls the crustal thickness?
   a. Melting of mantle (Naumer et al 2016 EPSL
   b. 1300-1500C; deg of melting 10-20% NVP ; 40-55% - HMR
   c. Oldest rocks - higher degree of partial melting
   d. High deg of partial melting - thick crust and vice versa
   e. Mg-rich lava would need higher deg of partial melting
   f. Pure forsterite and pure enstatite -- dont find big density variations even if we have different proportions -- relating to gravity data

*Heterogeneous Distribution of Chromium on Mercury* [#6095]

Mercury's surface has an average Cr/Si ratio of ~0.003 (Cr~800 ppm), with at least a factor of 2 systematic uncertainty. Cr is heterogeneously distributed and correlated with Mg, Ca, S, and Fe and anti-correlated with Al.

**Indhu Varatharajan**

1. Nittler et al in press (elemental composition across the surface)
2. XRS Cr measurements continuum between Fe and Ca peak - constraints Cr observations - XRS data
3. 133 XRS flare spectra - Cr/Si map -- corrected for phase angle
4. We looked at S hemisphere lots of time - though it was coarse resolution
5. Cr is distributed heterogeneously -- with enhancement in HMR ; lower in Caloris ; we dont have data for NVP
6. S with only 3% may not affect the silicate mineralogy
7. Cr2+ likely to go into basalts (Cr has multiple valence states)
8. Can Cr provide independent oxybarometer ??? - answer is may be !
9. Low FO2 - low Cr in aubrites → requires understanding of Cr partitioning
10. On going work - Ti/Si map, K?, Mn?
11. Future MIXS - much better resolution
12. Cr most likely present as sulfides
13. Cr generally correlates with Fe !


*Experimental Investigation of Chromium Behavior During Mercury’s Differentiation* [#6112]

We use experimental data on Cr partitioning and its concentration on Mercury's surface to constrain on Mercury's oxidation state. We found that Mercury's bulk Cr composition can be chondritic and its core segregated at an fO2 of IW-4.5 to IW-3.

**Indhu Varatharajan**

1. Cr in core ? mantle? Bulk Mercury chondritic or not ??
2. Experiments – starting composition - synthetic enstatite chondrite
3. Lower fO2 -> Cr going to Metal phase rather in silicates
4. Cr partitioning between mantle and crust - no clear trend with P,T, fO2
5. Cr in sulfide phases - 2-7 wt%
6. Mercury; s differentiation → core - sulfide phase -> mantle > crust
7. Si concentration in mantle (Bulk Silicate Mercury) is 53%
8. If Mercury did not have sulfide layer and form at fO2 at lower than -4, then it could be chondritic
9. Uncertainty in Si in core - leads to difficult to assign the nature of chondritic behavior of Mercury

Maximum of sulfides in surface could be 2wt% – types of sulfides (Mg, Ca, Fe, Cr?)

*Investigating Reflectance Properties of Mercury’s Surface Material: Effect of Swift Heavy Ion Irradiation* [#6037]

Mercury’s surface is affected by space weathering processes, interesting mineral properties. Here, we present a spectral study of swift heavy ion irradiation of two minerals, olivine and nepheline, as a simulation of heavy ion irradiation at Mercury.

**Indhu Varatharajan**

1. Space weathering of material - close to Sun - very active SW - high energy ions -
2. Facilities - GANIL, IRRESE, AIBE, SME, SOLEIL, Raman
3. Nepheline
4. 10 miron of silicates changes with fluorescence – RF shifts to lower wavenumber, CF don’t change – all in amorphous?
5. Reduced reflectance in olivine with addition of C

11:06 a.m. Izenberg N. R. * Denevi B. W.

*Exploring Space Weathering on Mercury Using Global UV-VIS Reflectance Spectroscopy* [#6081]

We apply UV analysis methods used on lunar LROC data to Mercury to explore space weathering maturity and possibly evidence of shocked minerals. What says the UV //about shock, maturity //on dear Mercury?

**Indhu Varatharajan**

1. Fresh materials have UV downturn at longer wavenegths (400 nm) as compared to space weathered ones
2. Kuiper has higher wavelength UV downturn than Copley
3. 321,358,414 nm - three key wavelengths to compare Moon and Mercury H11 (Discovery)
4. UV downturn - proxy to OMAT of Moon


*Carbon on Mercury’s Surface — Origin, Distribution, and Concentration* [#6097]

Low-reflectance material on Mercury, excavated from depth, may contain up to 5wt% carbon in some areas of the planet. We interpret this as endogenic carbon associated with the earliest crust of Mercury.

Caleb Fassett
Results are in Klima et al GRL paper... basically extrapolates out the “excess” carbon of up to 5% in LRM regions. Based on a few neutron measurements from low altitude described in Peplooski et al 2016 Nature geoscience paper

**Indhu Varatharajan**
1. Dark spectra - lower reflectance material - Fe, Ti, C → darkening agents ?? GRS,XRS ruled out Fe, Ti → so carbon ?
2. Low altitude Neutron Detector (Peplowski et al 2016 NatGeo) → enhancement in thermal neutrons consistent with C (1.6-2.8 wt%) - direct evidence!
3. PCA captures diversity in spectral space (R-PC2,G-PC1, B430/900 nm)
4. Klima et al 2018 GRL - LRM map
5. Extrapolating carbon measurements with band depth -- LRM/High reflectance terrain
6. Correlation with Neutron measurements and band depth → Rachmaninoff >4.5wt% C
7. Carbon - exogenic (Bruck Syal et al 2015); endogenic - graphite floatation crust (Kathleen Vander Kaaden 2015)
8. Moderately large basins show this band
9. Possibility of C with additional phase contribute to the band
10. LRM - associating with sulfides ? additional data with XRS from Bepi!

11:30 a.m. Peplowski P. N. * Stockstill-Cahill K. R.

Mercury's Geochemical Terranes Revisited [#6032]

We applied analytical tools to redefine Mercury's major geochemical terranes. The composition and petrology of each terrane will be discussed, along with analyses of gamma-ray data aimed at deriving absolute abundances of Si and Mg in each terrane.

Caleb Fassett
- Takeaway is that they've created an unbiased new map of the Mercury geochemical terrane
- Rustaveli and Rachmaninoff stand out. Both may have high Mg in their ejecta
- There is not a 1-1 relationship between the northern geochemical terrane and the northern smooth plains. Peplowski says not to equate them.

Indhu Varatharajan
1. PCA for geochemical maps (Mg/Si, Al/Si Weider et al., K map - Peplowski et al.)
2. Procedure - smoothed to common resolution and feed it to PCA
3. Rachmaninoff + Rustaveli

11:42 a.m. Stockstill-Cahill K. R. * Peplowski P. N.

Geochemical Constraints for Mercury's PCA-Derived Geochemical Terranes [#6119]

PCA-derived geochemical terranes provide a robust, analytical means of defining these terranes using strictly geochemical inputs. Using the end members derived in this way, we are able to assess the geochemical implications for Mercury.

Indhu Varatharajan
1. Intercrater terrain is heterogenous.
2. Total Alkali - Silica diagram is used to classify the geochemical terranes of Mercury
3. NVP Lmg-HMg - Andesite
4. Normative analysis (after Vander Kaaden et al 2016) is applied to the data
5. Rustaveli is more pyroxene rich - intermediate (opx-cpx) (ternary - ol,plag,opx and ol,opx,cpx)
Caleb Fassett
Two questions (Jack Wright/Clark Chapman) about how the mixtures inferred from the Rustaveli and Rachmaninoff anomalies might reflect spatial (geographic) mixing (addition of volcanic plains to the interior of these craters after their formation), not just intimate mixing in a single area.

11:54 a.m. Meslin P.-Y. * Peplowski P. N. Deprez G.

*Radon Outgassing from the Surface of Mercury Evidenced by Its Low Th/U Ratio [#6111]*

The low, subchondritic Th/U ratio measured by MESSENGER can be explained by the release of radon from the Hermean regolith, and the corresponding exhalation rate is significantly larger than on the Moon, possibly indicating a thicker regolith.

Indhu Varatharajan
1. What's the story with U
2. Th/U - 1.7±0.7 (Peplowski et al 2011,2012)
3. Overestimation of U/heat budget ??
4. We don't directly measure U in GRS - we measure Pb and Bi
5. Rn is radioactive, radiogenic -- escape is called emanation process
6. U -> Ra -> emanation -> Rn -> short lived progeny -> long lived progeny -> Pb
7. Thermo physical properties of regolith will control the diffusion
8. Implantation of Rn progeny to the regolith/surface → radioactive veneer
9. Thickness of regolith is 3 times that of Moon -> more Rn diffusion from greater depth → increase in U
10. Thermal effects on more escape from mineral grains ?
11. Rn - a new gas n the inventory of Mercury's exosphere

12:06 p.m. LUNCH

Thursday, May 3, 2018

**EXOSPHERE/MAGNETOSPHERE:**
NEW RESULTS WITH A LOOK TO THE FUTURE

1:30 p.m. USRA Conference Center

Chairs: Carl Schmidt
Jamie Jasinski


*First Evidence Connecting Mercury's Magnesium Exosphere to the Regional Composition of Mercury's Surface from MESSENGER Observations [#6104]*

First results revealing a direct connection between the distribution of Mg in the exosphere and the regional distribution of Mg on Mercury's surface.

Caleb Fassett
This is an interesting result about how the Mg geochemical terrane on Mercury gets manifested in the MASCS data. [This was presented at AGU + LPSC, so I didn't take great notes here, unfortunately]. The gist is that once other considerations are taken into account, the Mg enhancement from the surface traces up into MASCS limb scan derived Mg abundances, at just the right magnitude to argue for a surface connection.

Cesare Grava

- Observations of MASCS of Mg are consistent with more Mg being produced at a particular region rich in Mg, according to XRS
- First evidence of a 1:1 correlation between exosphere and surface
- Paper in review

1:42 p.m. Pokorny P. * Sarantos M. Janches D.

A Comprehensive Model of the Meteoroids Environment Around Mercury [#6106]

We present a comprehensive dynamical model for the meteoroid environment around Mercury comprised of meteoroids originating in asteroids, short and long period comets. Our model is fully calibrated and provides predictions for different values of TAA.

Caleb Fassett

Able to compare the exosphere observations to impact rates. Good general agreement in model of rates versus true anomaly. Three major contributions -- long period comets, short period comets, and asteroids.

Can give everything important / useful for meteoroid rates for impact on Mercury (says they are happy to share)

Dave Blewett points out that you could recast this analysis in terms of geographic location rather than time of day.

Indhu Varatharajan

1. UVVIS Mg scattering at 285.2 nm
2. Chamberlain model to fit the Mg altitude profile (Merkel et al 2017)
3. Source of Mg from 7-8 Mercury year data -- impact vaporisation ??, sputtering is ruled out as all data are equatorial.
4. 3:2 resonance related to seasonal enhancement in Mg
5. Temperature is same - more Mg production is to more Mg available
6. Major source - impact vaporisation
7. Spatial Mg on the surface is important driver to Mg in exosphere
8. There are not as much Ca compared to Mg on the surface
1:54 p.m. Sarantos M. * Pokorny P. Janches D. MESSENGER UVVS Team

Correlation of Mercury’s Magnesium Exosphere with Micrometeoroids from Jupiter Family Comets [#6096]

We show that the peak density of Mg vapor observed by MESSENGER varies with Mercury True Anomaly Angle in the same way as the modeled micrometeoroid vapor from Jupiter Family Comets.

Indhu Varatharajan
1. Why Mg is peaking in morning?
2. Jupiter family (short period) comets contribute most micrometeorite impacts on Mercury – and they drive the local time dependence
3. When Mercury is heading towards Sun - most JFC meteorites impact the dayside near the subsolar point
4. Impactors arrive at different local times at different TAA (true angle anomaly)
5. Comparison MCMC results of mix of impactor populations
6. Comparison of two different methods to increase the confidence of the results
7. The movement of JFC vapour across the surface wrt to the local surface temperature
8. Local time dependence of Mg exosphere is consistent with impact vaporisation models with TAA > 180

2:06 p.m. Cassidy T. A. *

MESSENGER MASCS/UVVS Observations of Cold Exospheric Calcium [#6108]

Exospheric calcium is primarily ejected by a high energy process on the dawn hemisphere. UVVS data also show a sporadic cold component at low altitudes. Its temperature is consistent with laboratory measurements of photodesorption of calcium sulfide.

[CF: sorry, I was out of the room]

2:18 p.m. Al Asad M. M. * Johnson C. J. Philpott L. C.

The Topology and Dynamics of Mercury’s Tail Plasma and Current Sheets [#6047]

In Mercury’s environment, the tail plasma and current sheets represent an integral part of the dynamic magnetosphere. Our study aims to understand the time-averaged, as well as the dynamic, properties of these “sheets” in 3D space using MAG data.

Indhu Varatharajan
1. The bifurcated and the Harris type of plasma sheets is observed
2. 3D shape of plasma sheet showing bifurcation
3. 113 - bifurcated sheets (very common in Mercury) and only 36 Harris type sheets (however, 4000 orbits have been looked in total)
4. More loading in the magnetic tail - increases the distance between bifurcated sheets -- whereas Harris type sheets did not show any effect on magnetic pressure/load
5. Natural progression of Harris type to bifurcated sheets?
6. Magnetic field strength in the tail is ~50 nT

2:30 p.m. Dewey R. M. * Slavin J. A. Raines J. M. Baker D. N. Lawrence D. J.

Energetic Electron Acceleration, Injection, and Transport in Mercury's Magnetosphere [#6073]

Electrons are accelerated in Mercury's magnetotail by dipolarization events, flux ropes, and magnetic reconnection directly. Following energization, these electrons are injected close to Mercury where they drift eastward in Shabansky-like orbits.

Caleb Fassett
This was a nicely delivered argument for specific acceleration mechanisms being most important for electrons in Mercury's magnetotail.

Indhu Varatharajan
1. MESSENGER revealed rich energetic electrons (>10 keV) in Mercury
2. These electrons drifts the orbit multiple times before escaping
3. Acceleration region is the magnetotail and then drift apart as they move close the planet
4. Direct measurement - electron particle spectrometer (3s) Explosive nightside reconnexion in the collapse of the mid tail region
5. 538 events of depolarisation signatures is observed
6. The particle settling near the equator suggests that the effect s due to depolarisation and not magnetic reconnection
7. Dewey et al 2017 - depolarisation is the dominant process influencing the energetic electrons

2:42 p.m. Milillo A. * Murakami G. Zender J.

BepiColombo MPO-MMO Coordinated Observations for the Study of the Environment of Mercury [#6030]

This presentation intends to show the coordinated activity within the Mercury's environment science community for maximizing the BepiColombo science return.

Indhu Varatharajan
1. BepiColombo - for Hermean Environment Science
   a. Solar energetic particles - BERM, MPPE-HEP, SiXS-p
   b. Flares X rays
   c. Solar wind
   d. IMF
   e. Micrometeoroids
   f. Magnetosphere/EM field
   g. Penetrating solar wind
   h. Planetary ions
   i. Electrons
   j. High energy neutrons
   k. Thermal exosphere - SERENA, PHEBUS MSASI,
   l. Ion and electron precipitation mapping
   m. Mercury ejecta - MDM
2. Milillo et al 2015 - dynamics of Hemean environment
3. HEWG - 150 scientists
4. HEWG - subgroup - Young (active and energetic) Scientists WG
5. Planning -> observations -> downlink -> OLA both chains (MPO,MMO)
6. Open qns
   a. Exosphere - magnetosphere
   b. Role f heavy ions
   c. Role of micrometeoroids - Ca, Mg relation with dust distribution
   d. Sw- magnetosphere - interior coupling
   e. Convectiona of particles on the tail
   f. Reconnection rate in the tail

2:54 p.m. BREAK

Thursday, May 3, 2018

A VERITABLE SMORGASBORD OF MERCURY GEOLOGICAL DELIGHTS

3:10 p.m. USRA Conference Center

Chairs: David Blewett
       Indhu Varatharajan

3:10 p.m. Helbert J. * Maturilli A. D’Amore M. Varatharajan I. Hiesinger H. MERTIS team

MERTIS — Unleashing the Power of the Thermal Infrared on Mercury [#6061]

MERTIS combines an imaging spectrometer (7-14 μm at 500m spatial resolution) with a radiometer (7 to 40 μm at 2km). The compositional, temperature and thermo-physical properties maps provided will allow unique insights into the evolution of Mercury.

Caleb Fassett

Takeaway of this talk: MERTIS will give a unique and new look at Mercury in the thermal infrared and temperature. This should allow mineralogy of Mercury (!), but also new insights into polar deposits, etc. Most of the instrument is developed completely new; microbolometer isn't cooled actively (has a big radiator, also a heater!), onboard calibration which will be used on a regular duty cycle. Will need to do operational phasing to reduce data rate because Bepi is strongly data rate limited

3:22 p.m. Maturilli A. * Helbert J. Varatharajan I. D’Amore M. Hiesinger H.

A Spectral Library of Emissivity Spectra for MERTIS on BepiColombo [#6060]

At PSL we measured emissivity spectra in vacuum for a suite of Mercury surface analogues for temperatures from 100°C to >400°C. The spectral library is completed by reflectance on samples fresh and post-heating (0.2 to 200 μm spectral range).

Caleb Fassett
Talk given by Joern Helbert (Alessandro Maturilli back in the lab measuring things).
-shows off lab setup doing thermal effects measurements (published in various papers in the last five years; Maturilli/Helbert/Ferrari, etc)
-New paper on the theory for changes from Stangarone et al. 2018 *submitted
-Makes the case that the spectral changes discussed by Rachel Klima earlier is in LRM and not in the graphite
-Will try and make some measurements on the samples discussed by Charlier this morning (from Namur and Charlier 2017 paper)

3:34 p.m. Malliband C. C. Conway S. J. * Rothery D. A. Balme M. R.

*Potential Identification of Sublimation-Driven Downslope Mass Movement on Mercury [#6093]*

We have identified a further example of mass movement, in addition to the previously identified example in the pyroclastic vent NE of Rachmaninoff. Both examples show evidence of hollow sublimation being a cause of the mass movements.

**Caleb Fassett**

Talk given by Susan Conway…

Light toned slope streaks on Mercury. Three locations identified on Mercury by the authors -- one more example maybe presented by, um, somebody named Fassett [EN1044173928M]. They are at steep slopes, and generally associated with potential hollows.

Susan argues that these mass movements might be enabled by volatiles (given the channels in NE Rachmaninoff). Several folks in the audience (Denevi, Besse) are skeptical.

3:46 p.m. Blewett D. T. * Chabot N. L. Denevi B. W. Ernst C. M.

*The Nature of Mercury’s Hollows, and Space Weathering Close to the Sun [#6051]*

Hollows are a landform that appear to form by loss of a volatile-bearing phase from silicate rock. Hollows are very young and are likely to be forming in the present day. Hollows may be an analog for extreme weathering on near-Sun asteroids.

**Caleb Fassett**

Incredible images of hollows… (see Blewett et al. papers on this)

Idea is that they expand by a cm in a few thousands to less than ten thousand years. Expanding as scarps (tens of meters deep), faster than rocks on the Moon get destroyed by micrometeorites, but slower than carbon dioxide polar pits on Mars.

Talk listed several ideas for formation of the bright patches around hollows, but four models are outstanding.
3:58 p.m. Parman S. W. * Orlando T. M. Milliken R. E. Head J. W. Jones B. M. Anzures B. A.

**Experimental Study of Hollow Formation [#6103]**

Hollows are enigmatic features on the surface of Mercury caused by sublimation and/or space weathering. Here we propose a comprehensive experimental study in which candidate hollows materials are exposed to a range of relevant conditions.

**Caleb Fassett**
Takeaway of this talk is that Parman wants to get to work on experimental analyses of sulfides, which are a leading candidate for the hollow material.

According to Parman, one possibility suggested by Bennett et al. (2016) is that neutral Ca in the exosphere might be due to photo-stimulated disorption of hollow material. (CaS / MgS -- e.g., Vilas et al work)

Need to consider lots of different sulfide species and especially eutectic mixtures. Adding in an incompatible element into mixtures (e.g. FeS to MgS) will drop the melting temperature. Could end up with Mg/Ca/Mn S on the bottom, K/Na/ClS on the top

4:10 p.m. Wright J. * Conway S. J. Balme M. R. Rothery D. A.

**Post-Deposition (and Ongoing?) Modification of Caloris Ejecta Blocks [#6071]**

Caloris ejecta blocks have been modified by mass-wasting that has persisted long after their formation. Volatiles may be involved in this process. Block geomorphology therefore has implications for Mercury’s interior volatile content.

**Caleb Fassett**

Ooh, Odin knobs. I believe I spent a year staring at these.
- Conical and domal knobs
- Wright argues that there is later thin smooth plains that cover up some of the Odin (but not all of it)
- Some knobs have hollows: EN1045674576M
- Ejecta knobs have material actively being shed off them
- Conical shape might be hard to get from diffusive degradation/micrometeoritic bombardment
- Suggest that volatile loss may be involved to get conical shapes

4:22 p.m. Fassett C. I. * Hirabayashi M. Ostrach L. R. Watters W. A. Whitten J. L.

**The Nature and Mobility of Regolith on Mercury’s Smooth Plains from Observations of Crater Degradation and Equilibrium Size-Frequency Distributions [#6129]**

Measurements of the equilibrium size-frequency distribution and crater degradation jointly suggest a thick regolith on Mercury’s smooth plains.

**Caleb Fassett**

(1) Degradation is at least twice as fast on Mercury than the Moon
(2) Regolith is thick in places
(3) Saturation is important and happens at larger sizes on Mercury than the Moon

4:34 p.m. Whitten J. L. * Ostrach L. R. Fassett C. I.

*Analysis of Large-Scale Resurfacing Processes on Mercury: Mapping the Derain (H-10) Quadrangle [#6086]*

The Derain (H-10) Quadrangle of Mercury contains a large region of "average" crustal materials, with minimal smooth plains and basin ejecta, allowing the relative contribution of volcanic and impact processes to be assessed through geologic mapping.

**Caleb Fassett**
- Thinking about the question of how much impact melt gets mixed into the intercrater plains
- mapping H-10
- need to examine smooth plains to determine stratigraphic relationships

4:46 p.m. Bott N. * Doressoundiram A. Perna D. Zambon F. Carli C. Capaccioni F.

*The Shakespeare (H-03) Quadrangle of Mercury: From Color Mapping to Distinction of Lithological Heterogeneities [#6040]*

We analysed the spectral properties of the surface in the H-03 quadrangle of Mercury to define its compositional variability and identify spectral units constrained by opportune spectral parameters.

**Caleb Fassett**
- Using DLR DTM, doing photometric correction to mosaic
- Doing various statistical classifications in the quadrangle to identify units (e.g., things like Kmeans, etc)

4:58 p.m. Invited: Galluzzi V. * Rotherapy D. A. Massironi M. Ferranti L. Mercury Mapping Team

*Towards the Redefinition of the Global Stratigraphy of Mercury: The Case of Intermediate Plains [#6041]*

Observations based on an average mapping scale of 1:400k provide context for the redefinition of the global stratigraphy of Mercury. Results show that the Intermediate Plains unit should be re-introduced as an official mappable terrain.

[CF: sorry, I was dashing to the airport!!!!]

5:13 p.m. Adjourn

**MERCURY PRINT ONLY**

Pugacheva S. G. Feoktistova E. A. Shevchenko V. V.

*Photometry Estimation of the Structure of the Surface Layer of Mercury South Pole Relief [#6020]*

The photometry method searches out the intensity of reflectivity of planet's surface and provides studying of ground fine texture.
Steklov A. F. Vidmachenko A. P.

Areas for Comfortable Human Habitation on the Mercury [6015]

Under sub-face of Mercury at depth of 3-30 meters, thousands of endo – settlements, with suitable temperature for biological life +15-25 degrees C, can be accommodated.