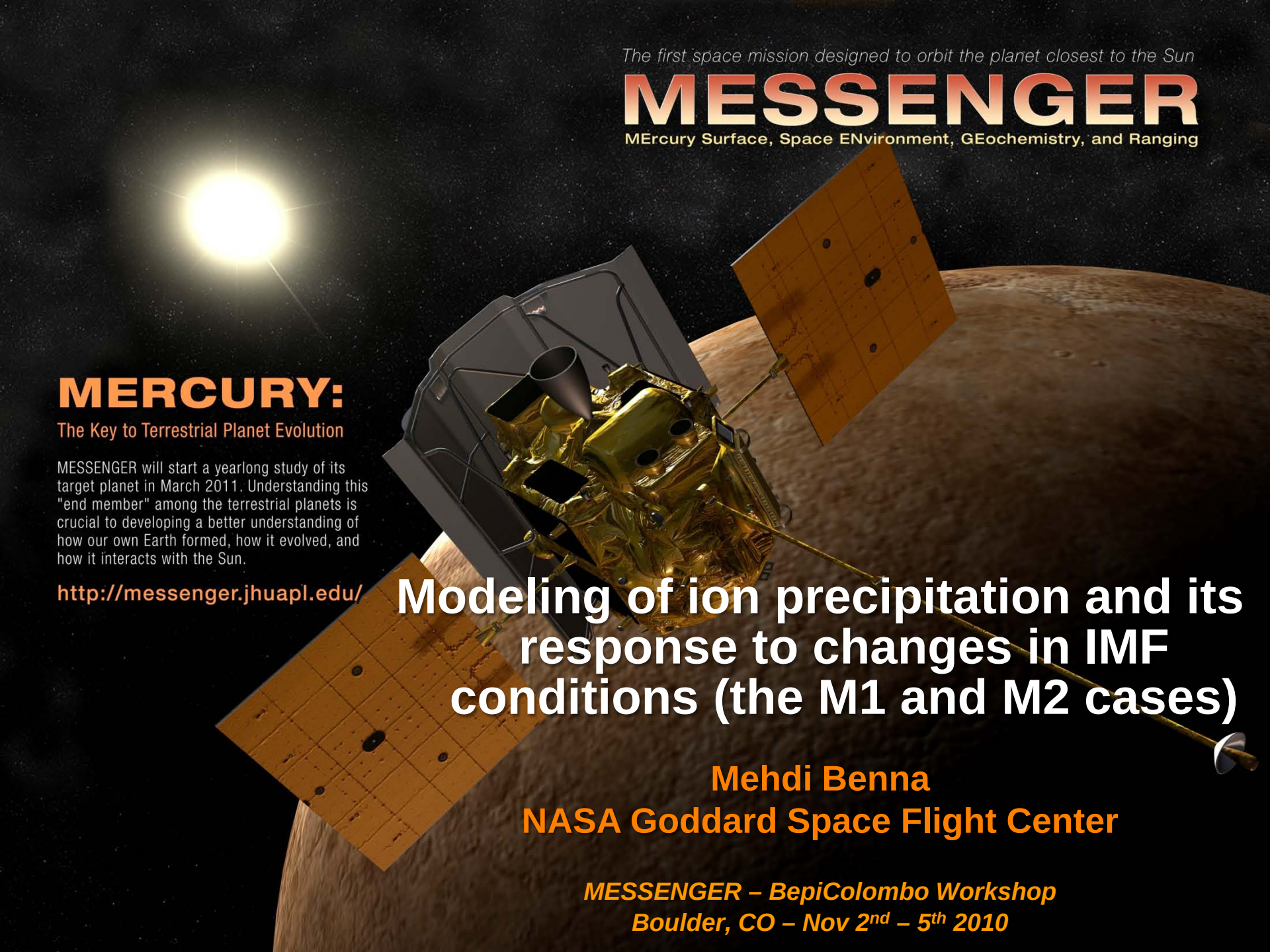


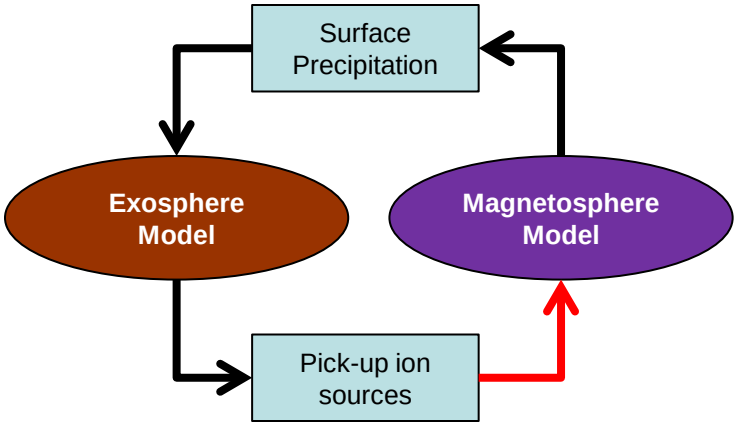
Modeling of ion precipitation and its response to changes in IMF conditions (the M1 and M2 cases)

Mehdi Benna
NASA Goddard Space Flight Center

MESSENGER – BepiColombo Workshop
Boulder, CO – Nov 2nd – 5th 2010

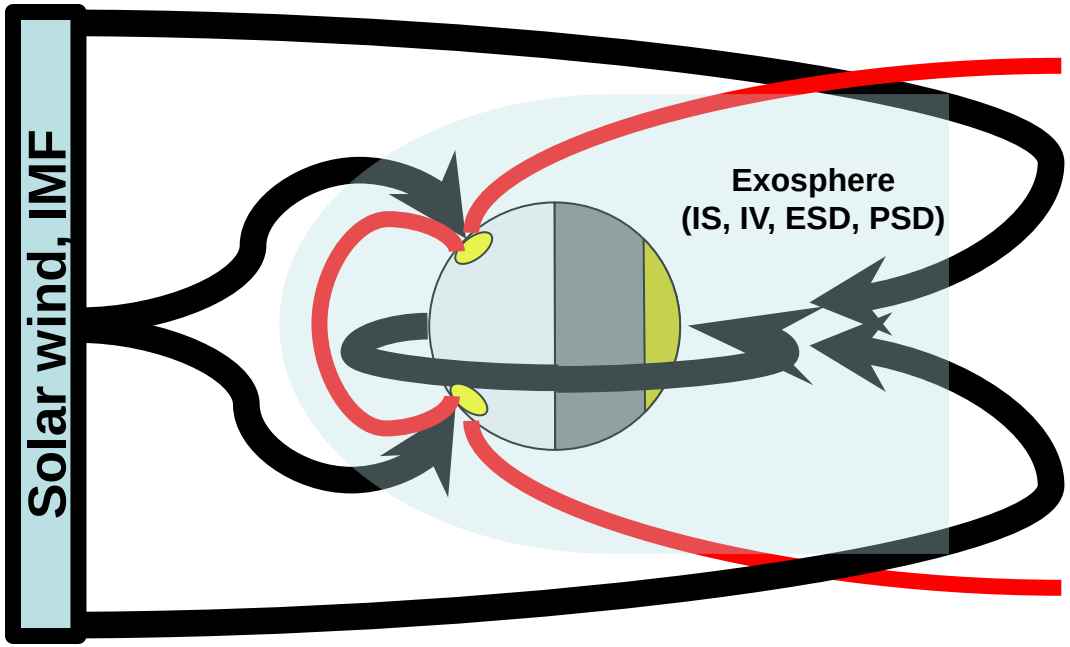
MESSENGER
Context

- Ion sputtering plays a role as a source or/and as a promoter of neutrals release into the exosphere.
- The topology of the magnetosphere drives the location of the exposed surfaces to ion precipitation.
- We need to understand the temporal and spatial variability of ion precipitation in order to constrain ion sputtering.
- M1 and M2 provided a first set of observations of the exosphere that can be linked to specific IMF and solar wind conditions.
- We use a Multifluid model to provide the topology of the magnetosphere during the M1 and M2 flybys and to derive precipitation maps that can feed into exospheric models.



MESSENGER
Sources of ion precipitation

- Ion precipitations are due to:
  - Solar wind ions precipitating through the cusps.
  - Plasmasheet ions convecting toward the dayside side.
  - Drifting ions in a belt like structure around the planet (hypothetical).



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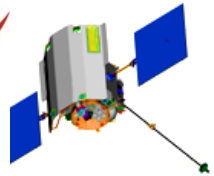
The Model

- Solves the **Multifluid** equations for four fluids (SW ion fluid, two pick-up ion fluids, & electron fluid). The model solves 23 conservation equations.
- The neutral exosphere can be subscribed analytically (i.e. Mura et al. 2007), or from a particle tracing model (i.e Burger et al . 2010).
- Uses a 3D Adaptive Mesh Refinement to generate and manage the grid.
- Uses the TVD Lax-Friedrichs solver.
- Second order in time and third order in space.
- Max resolution = 122 km with a computational domain ~ 10^5 km.
- Up to 7 levels of refinement and 2 millions computational cells.



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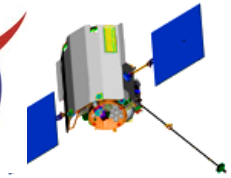
M1 vs. M2

- Low solar wind pressure ⇨ Magnetospshere at ground state. Well-shielded subsolar surface.
- Relatively steady solar wind and IMF conditions (not the case during M3) ⇨ Convenient for models that compute steady-state solutions.
- Large Bx component: promotes north-south asymmetry and tilted plasmasheet.
- North IMF condition during M1, and South IMF during M2.
- Shifted intrinsic dipole ⇨ Asymmetric cusp locations, and plasmasheet above the equator plane.



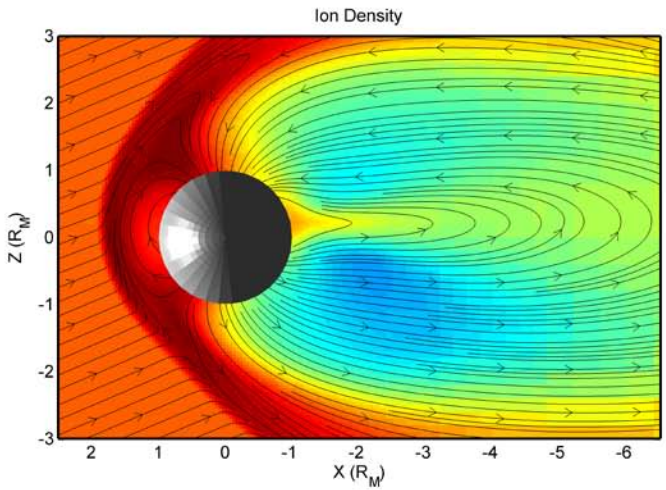
MESSENGER
Simulation Parameters

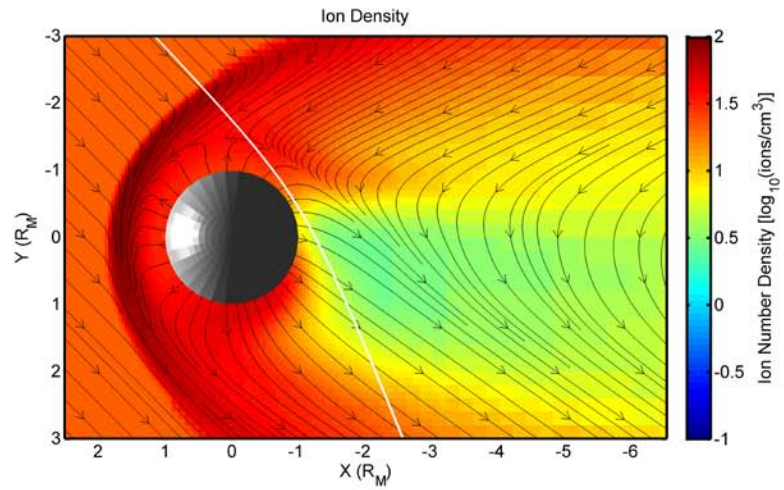
Parameter	M1	M2
Solar wind number density	20 ions/cc	10 ions/cc
Solar wind mean molecular mass	1 amu	1 amu
Solar wind speed	450 km/s	400 km/s
Solar wind ram pressure	6.8 nPa	2.7 nPa
Solar wind proton temperature	10 eV	10 eV
Solar wind proton temperature	15 eV	15 eV
Interplanetary magnetic field	(-12 12, 5) nT	(-10, 4, -14) nT
Intrinsic magnetic field magnitude	214 nT R_M^3	214 nT R_M^3
Intrinsic magnetic field offset	+ 440 km	+ 440 km

MESSENGER

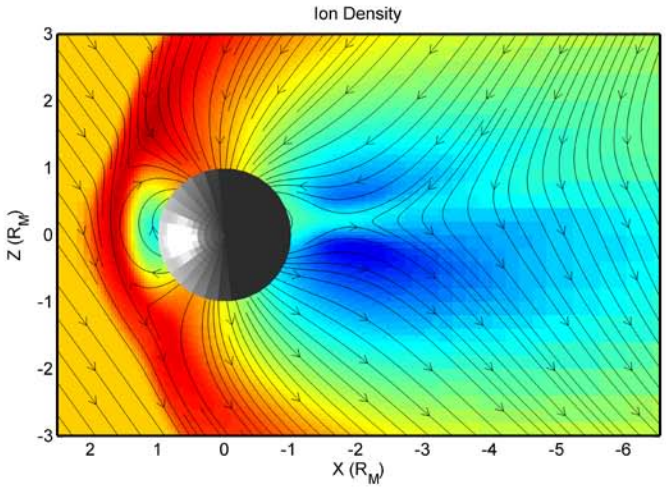
Solar wind Ion density

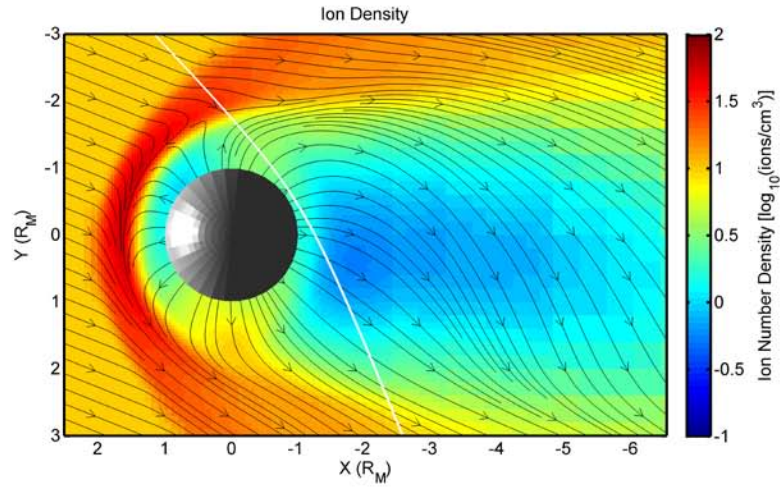
M1 Flyby





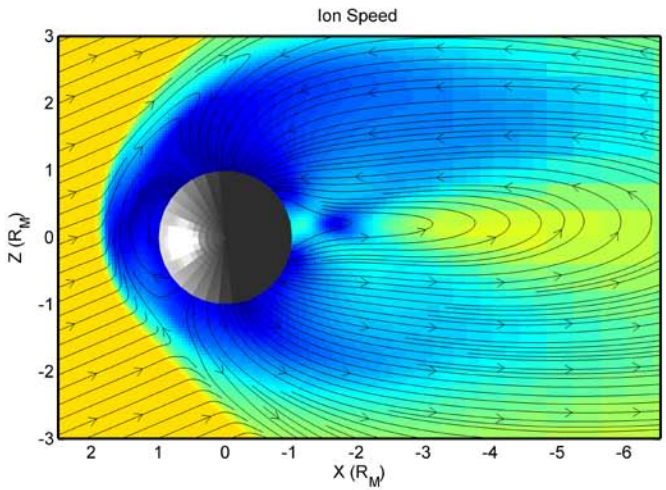
M2 Flyby

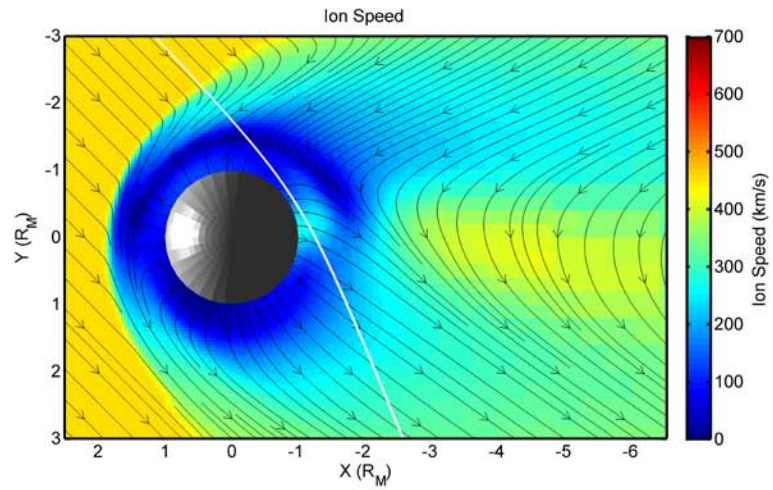




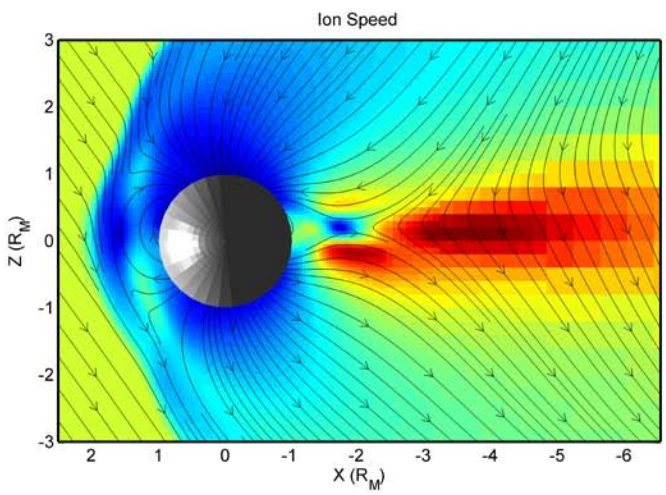
MESSENGER
Ion Velocity

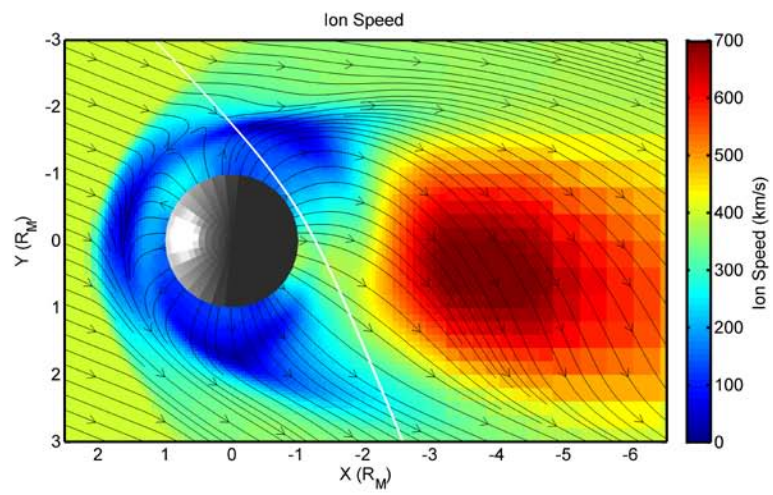
M1 Flyby





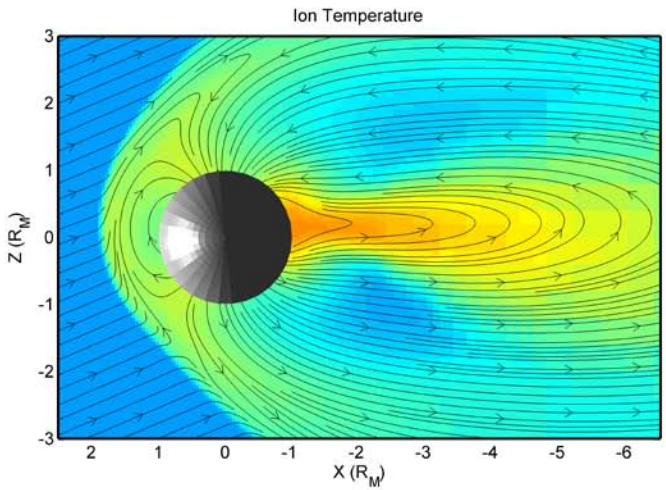
M2 Flyby

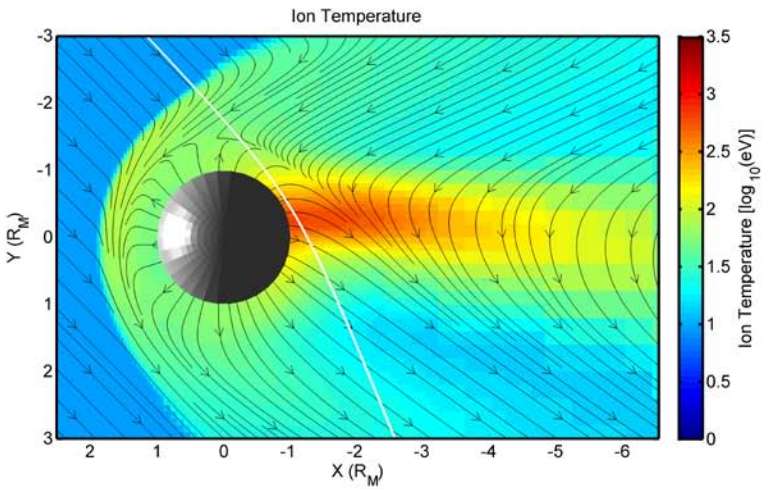




MESSENGER
Ion Temperature

M1 Flyby





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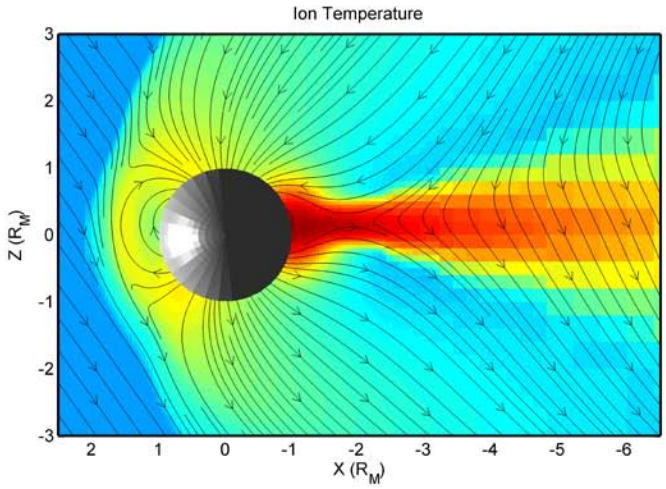
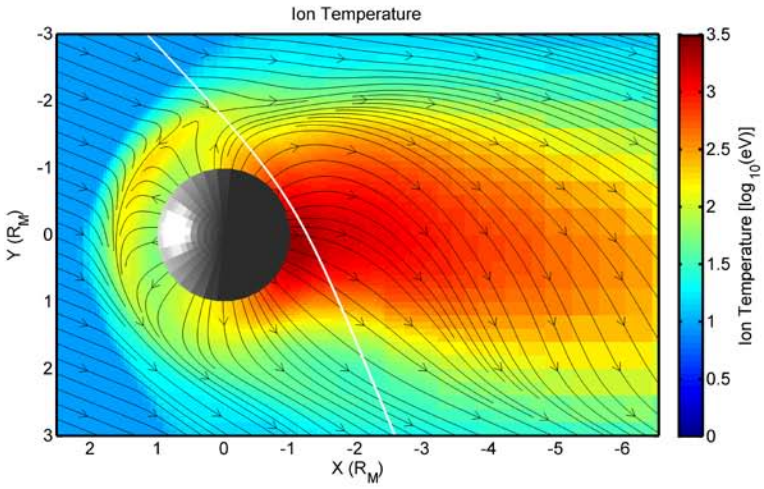
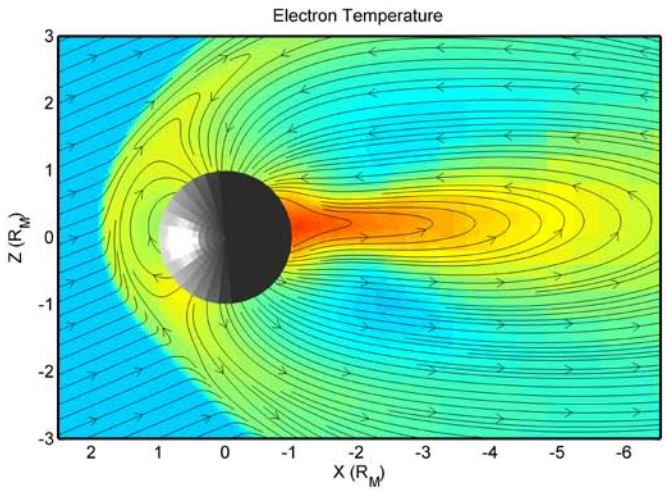
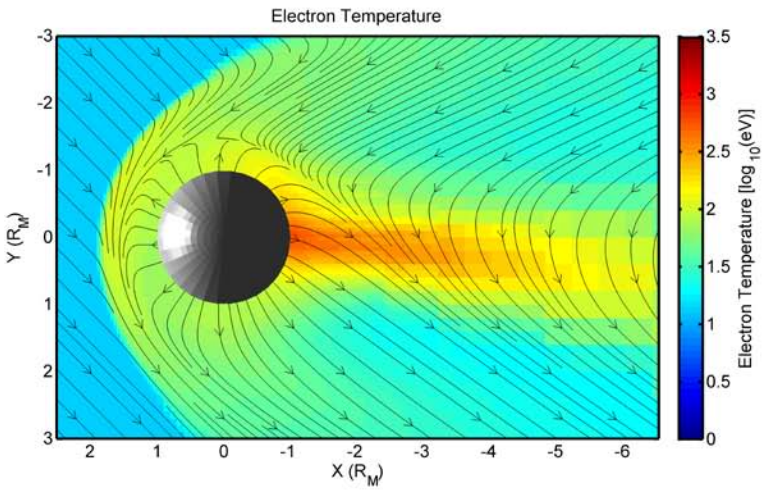




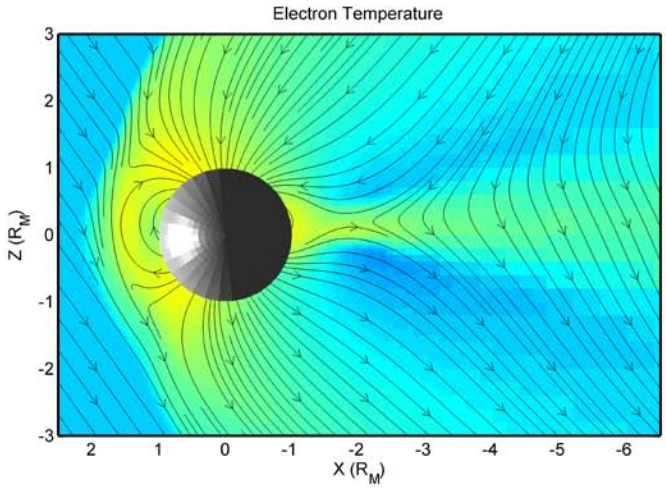
MESSENGER
Electron Temperature

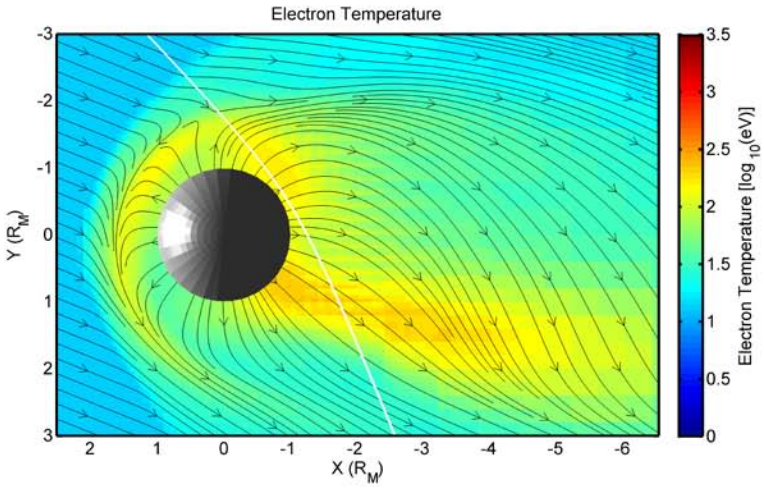
M1 Flyby





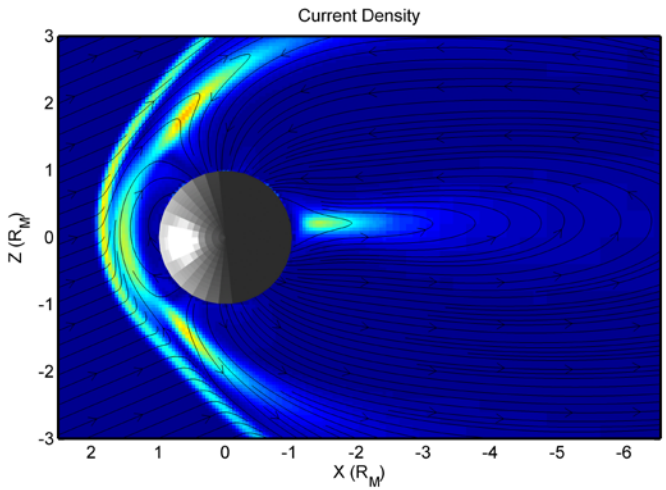
M2 Flyby

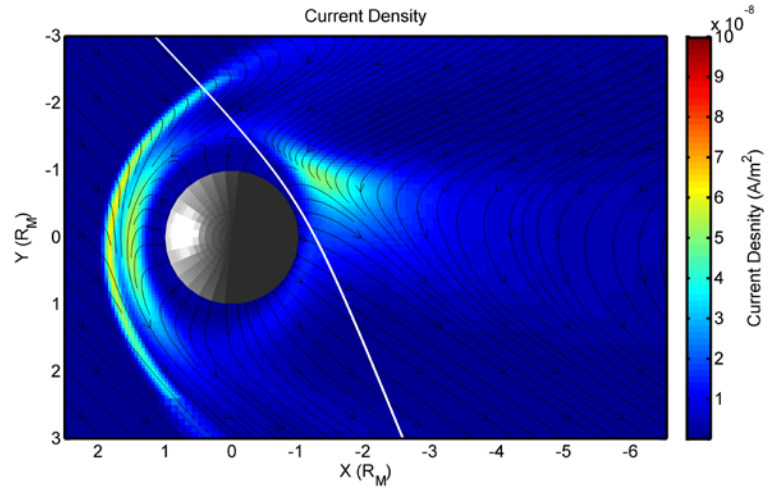




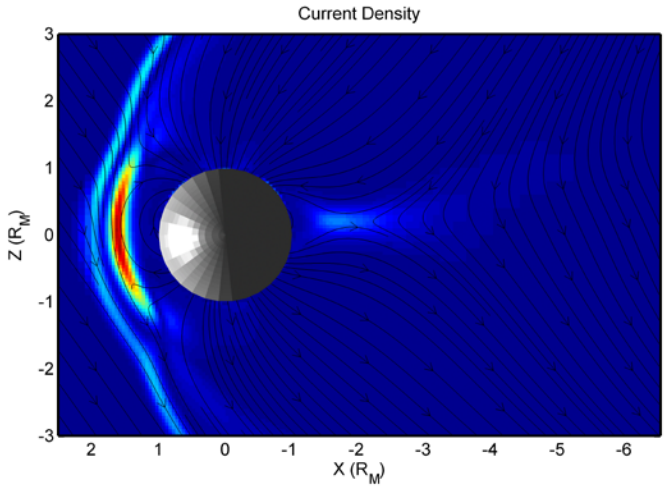
MESSENGER
Current Density

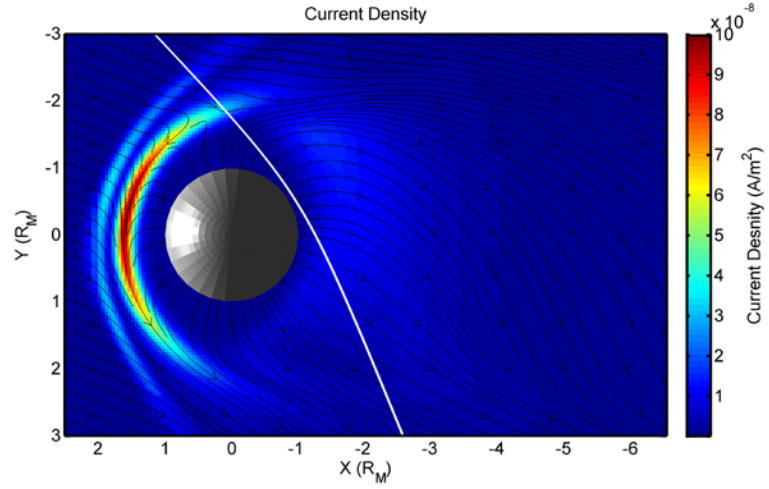
M1 Flyby



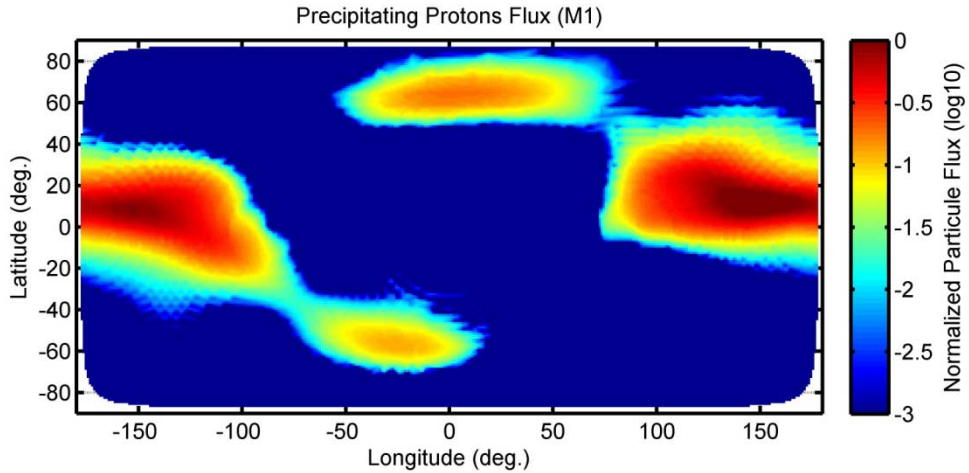


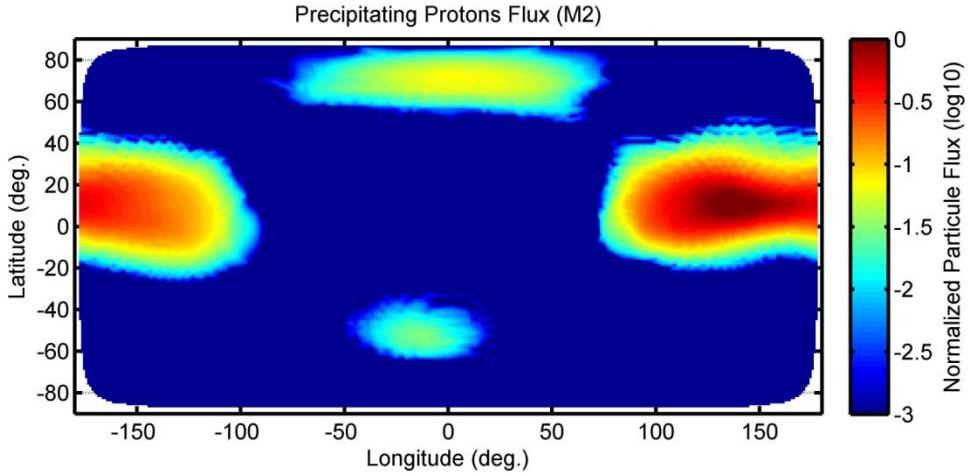
M2 Flyby



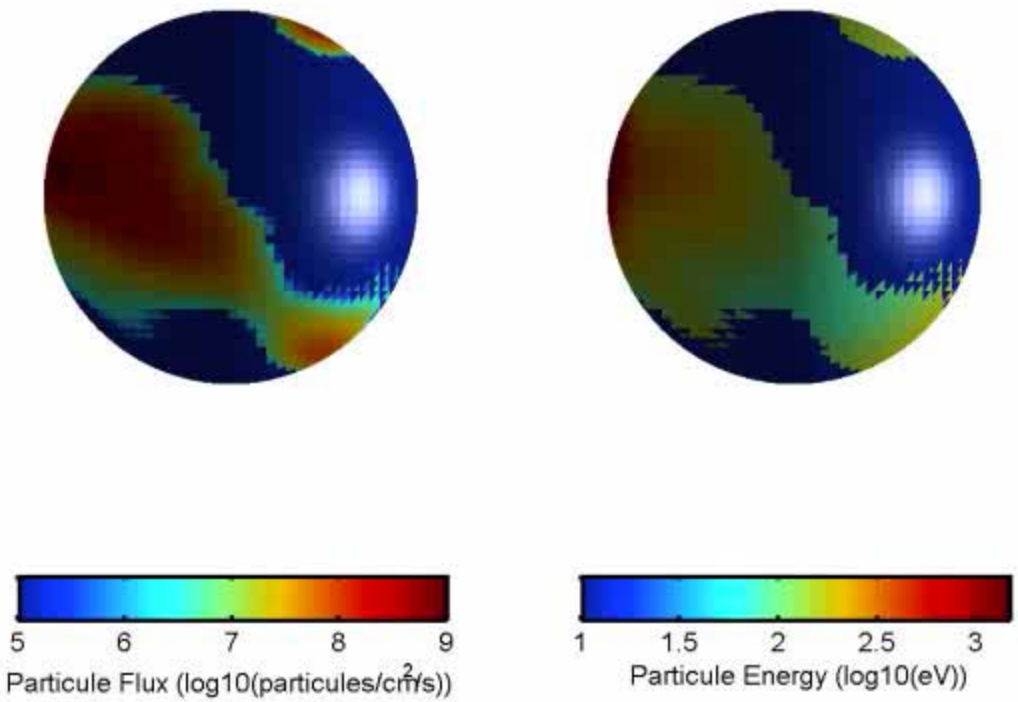


MESSENGER
Precipitation during M1 and M2

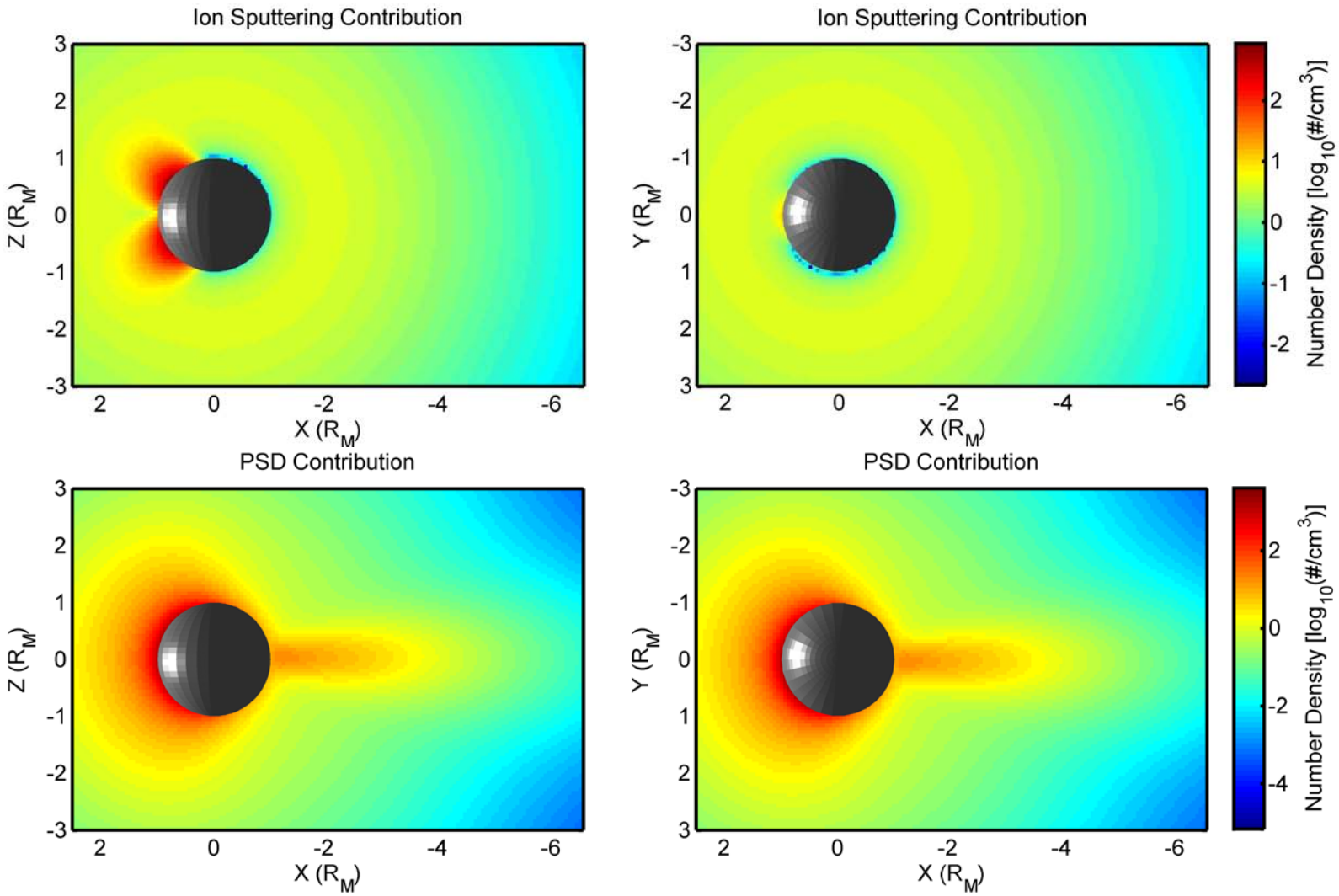




MESSENGER
Ion precipitation during M1

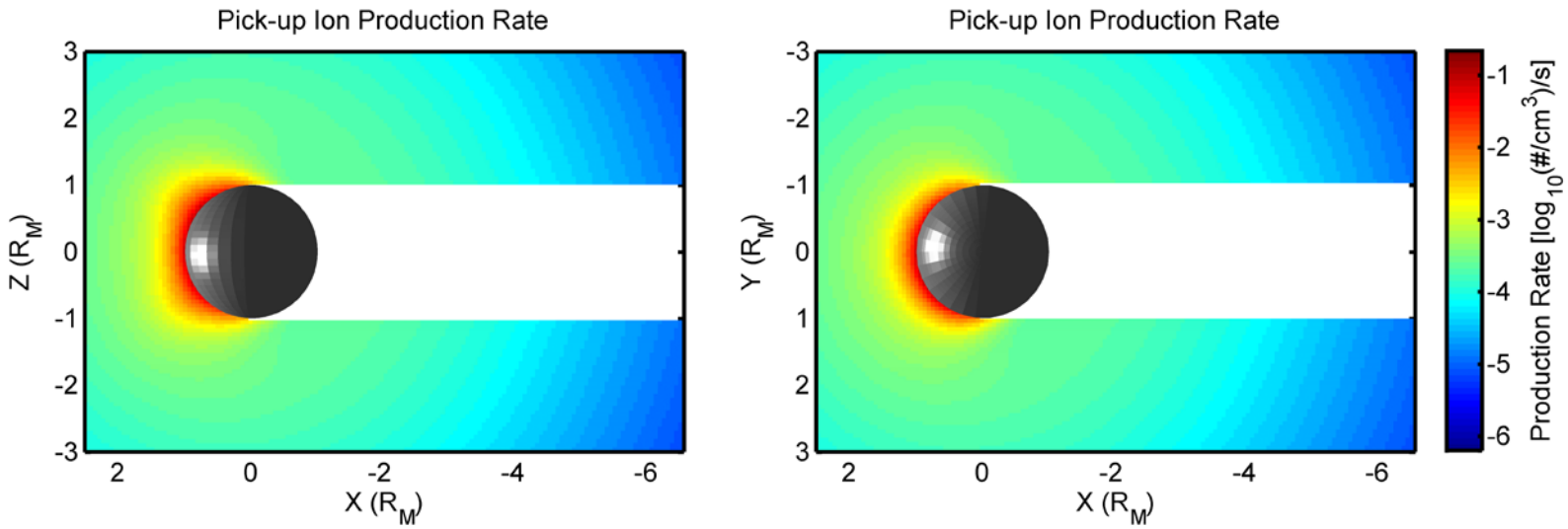


MESSENGER
Na Exosphere model



Mura et al., Planet. & Space Sci., 2007

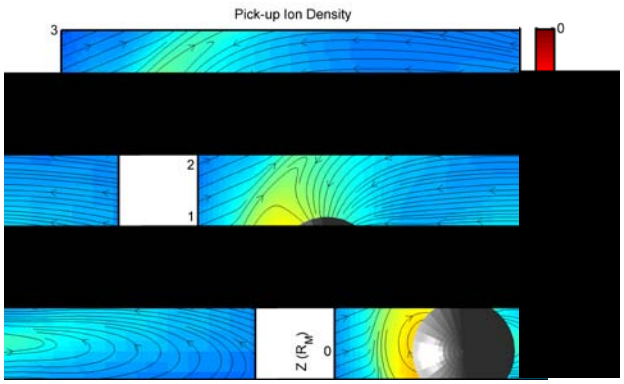
MESSENGER
Na Exosphere model

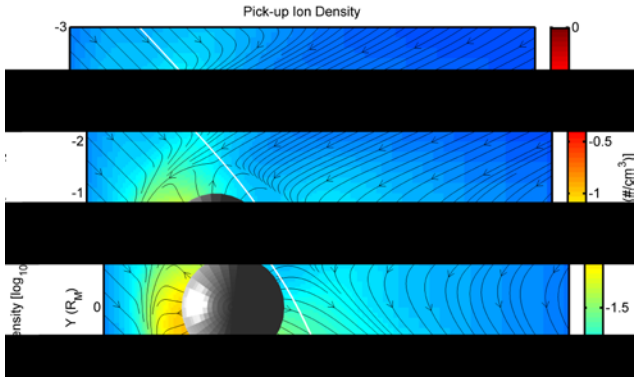


MESSENGER

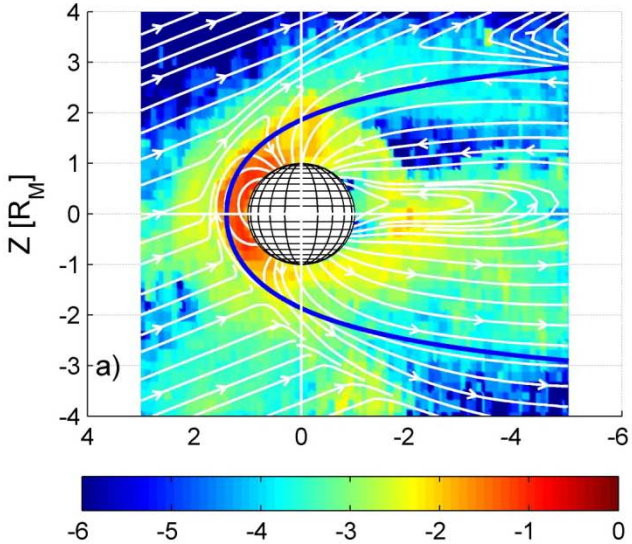
Pick-up Ion density

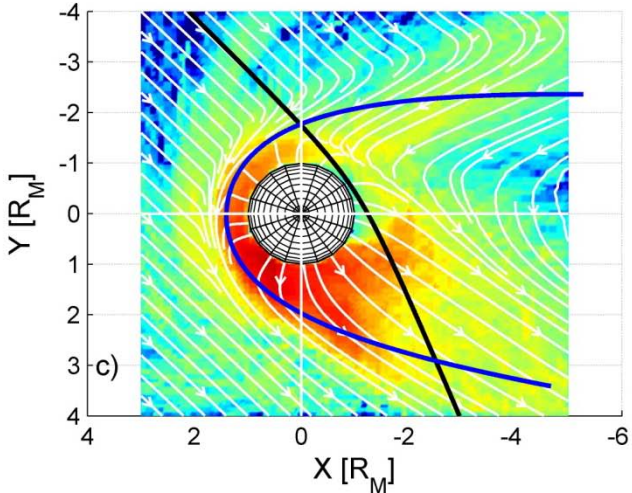
Multi-Fluid





Particle Tracing (Sarantos)

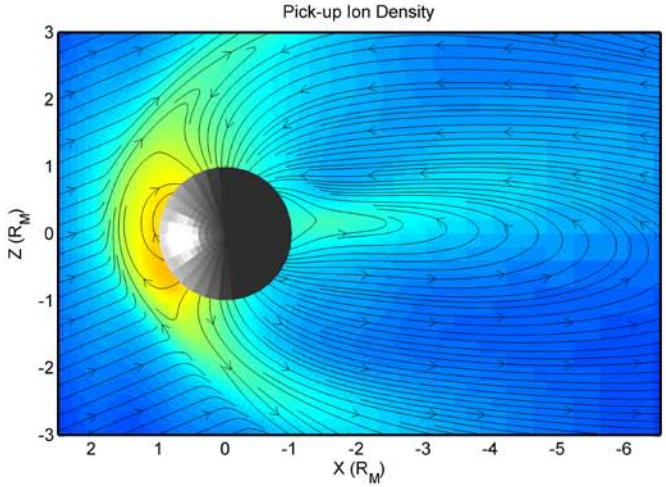


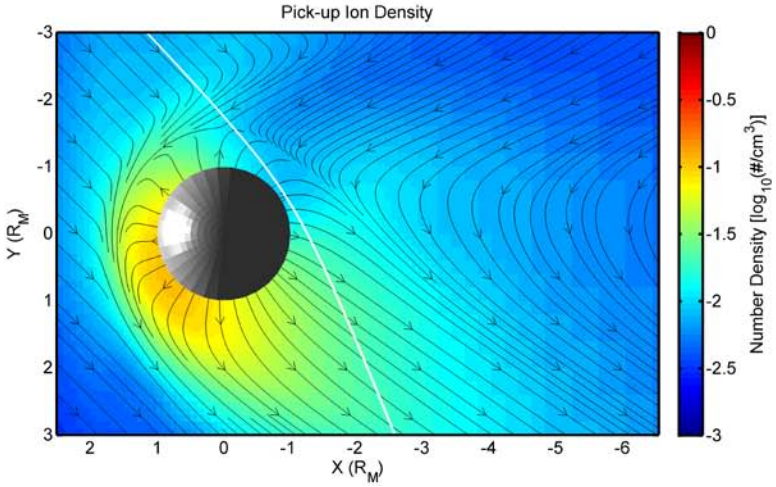


MESSENGER

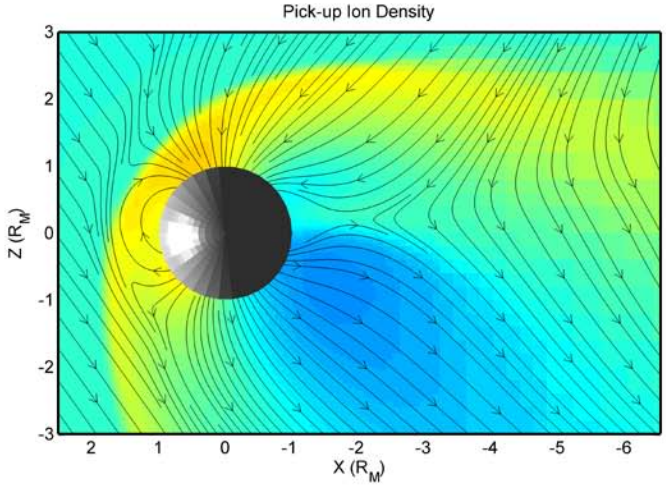
Pick-up Ion density

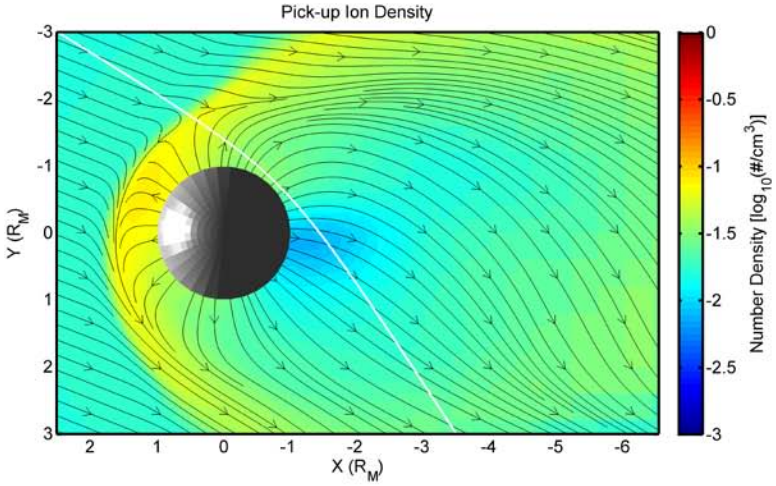
M1 Flyby





M2 Flyby



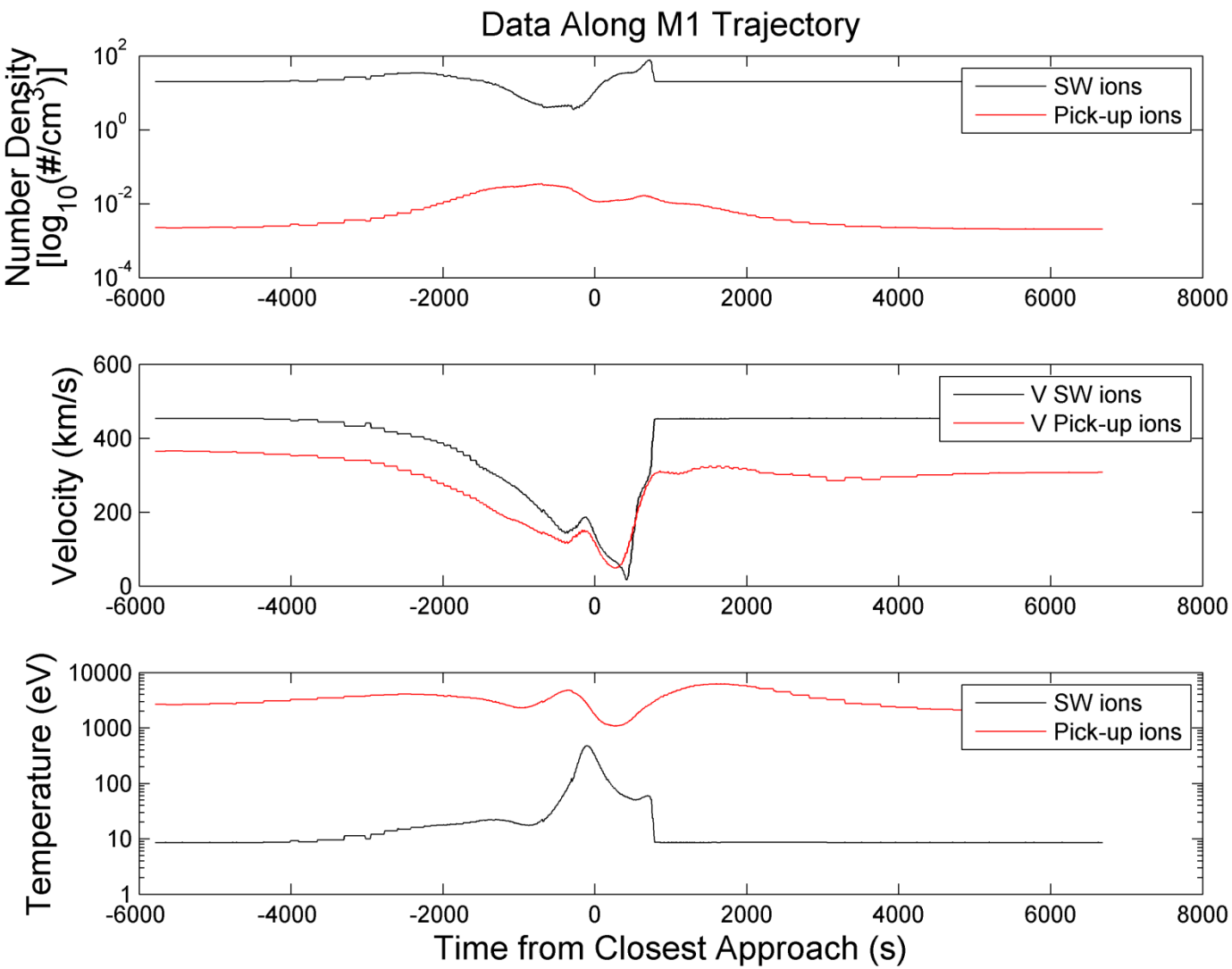


MESSENGER
Summary and Conclusions

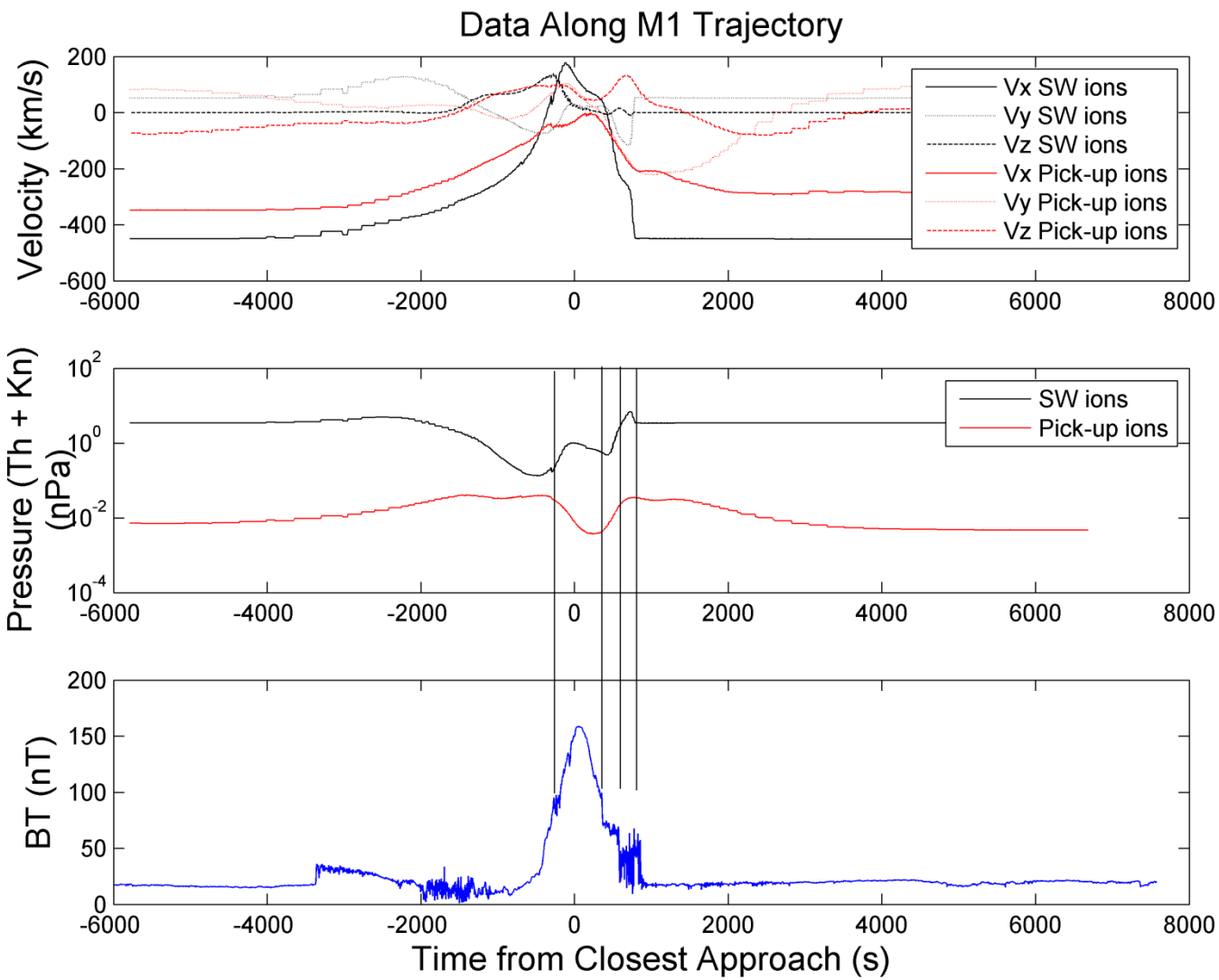
- **The impact rate at the north cusp is higher than at the south cusp due to the presence of a strong B_x component in the IMF during the M1 and the M2 flybys.**
- **Intense night precipitation may have existed during both flybys by plasmasheet ions that convect toward the dayside of the planet.**
- **We have to look at more IMF and solar wind conditions to discriminate between regions that get occasionally sputtered from regions that are subjected to a constant ion bombardment.**
- **Precipitation patterns were comparable during M1 and M2. This can suggest that the IS contribution to the exosphere is comparable at the time of the two flybys. Make it easy to compare exospheric data.**
- **Outputs of global magnetosphere models can be used as input to constrain IS and to derive a consistent exosphere.**
- **Pick-up ion structures derived from Multifluid modeling are well in agreement with results from ion tracing simulations.**
- **We can now compare UVVS pick-up ions observations with modeled profiles.**

Backup Slides

MESSENGER
Data along M1 Trajectory

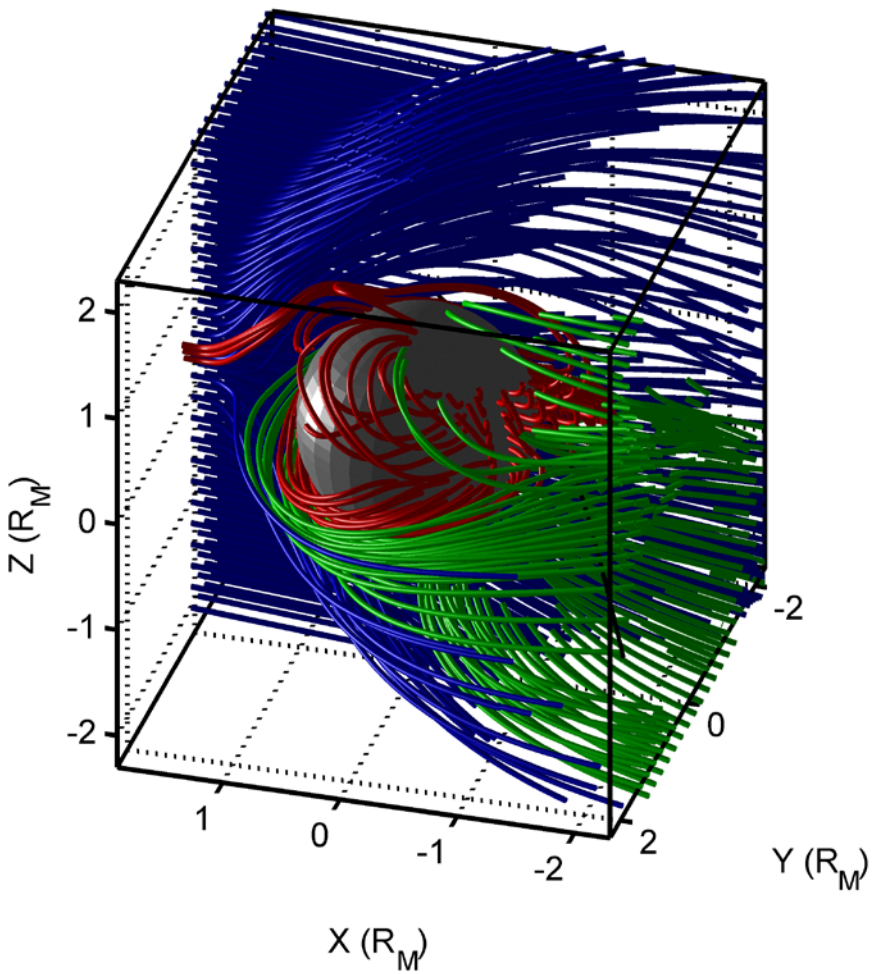


MESSENGER
Data along M1 Trajectory

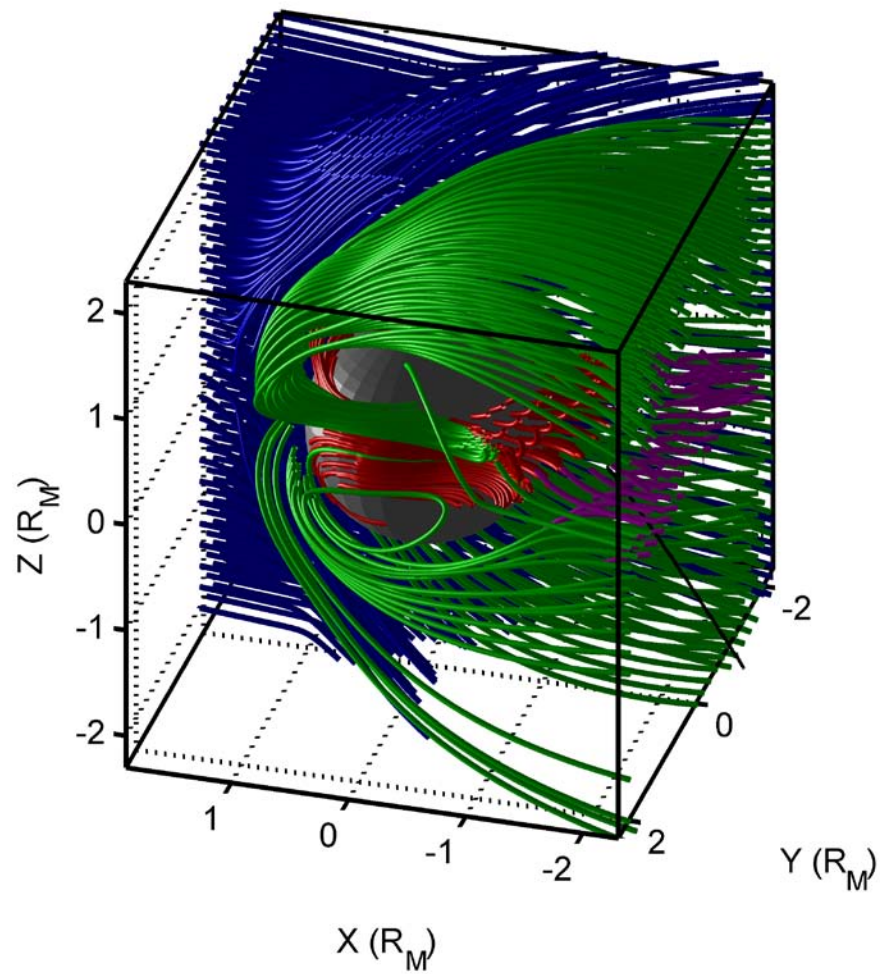


MESSENGER
Magnetosphere Flow

M1 Flyby

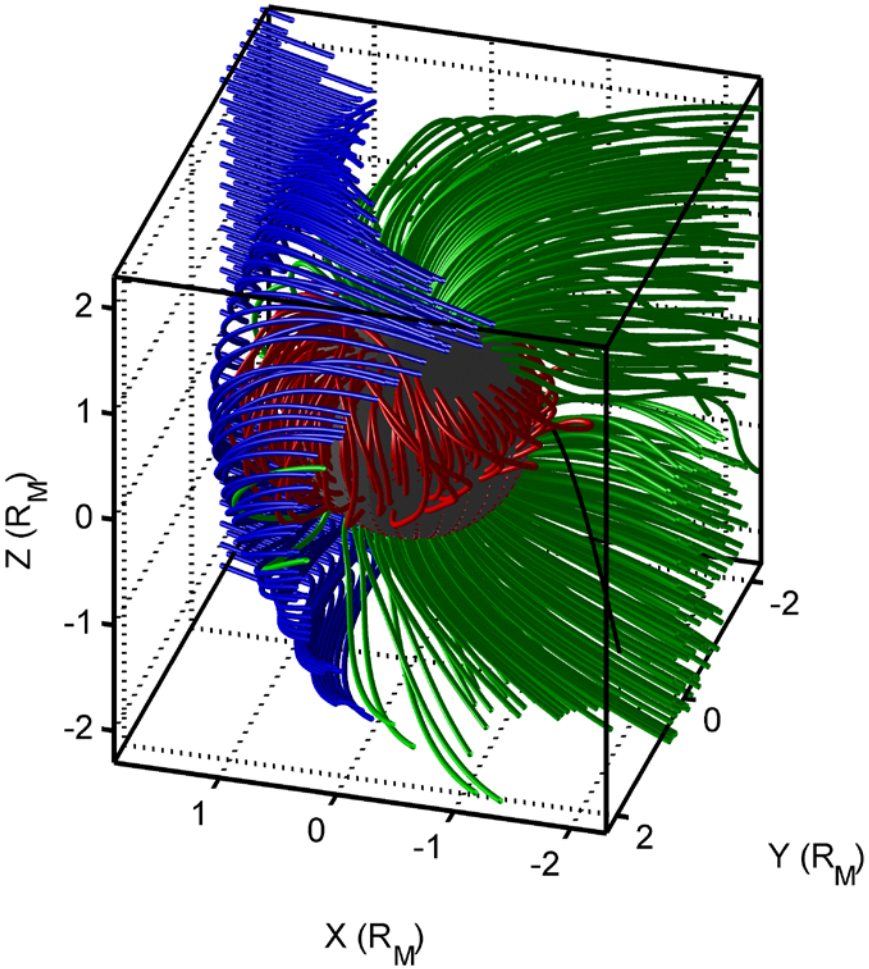


M2 Flyby

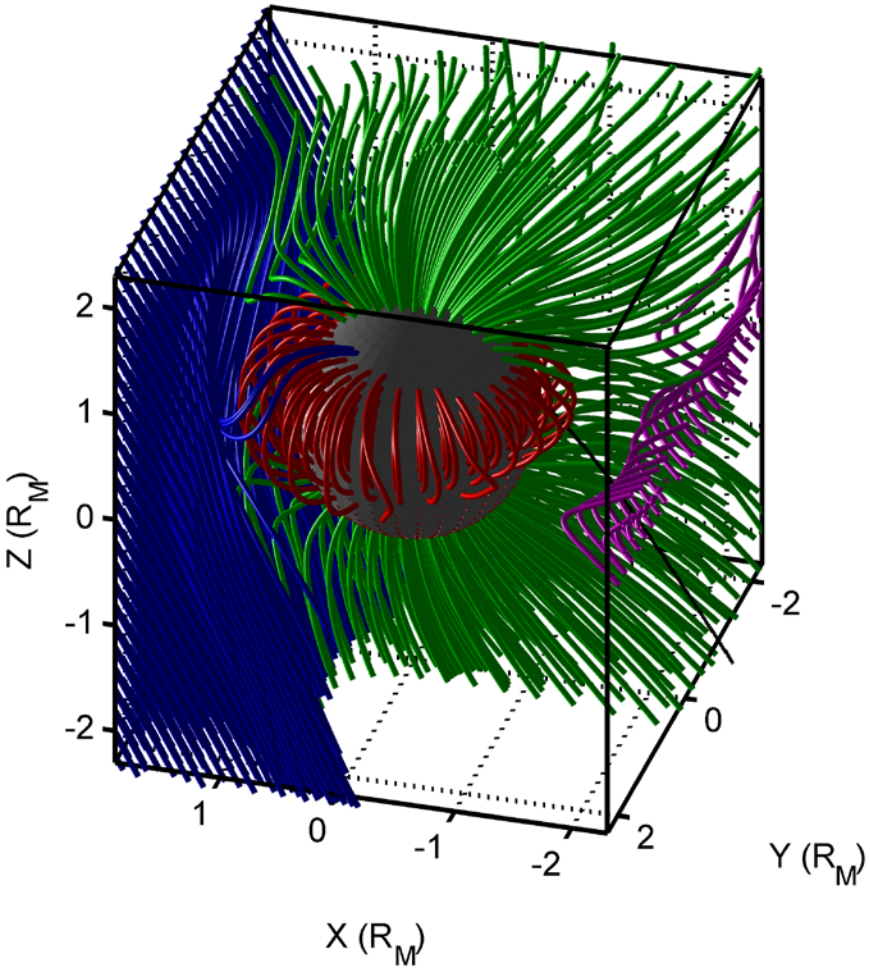


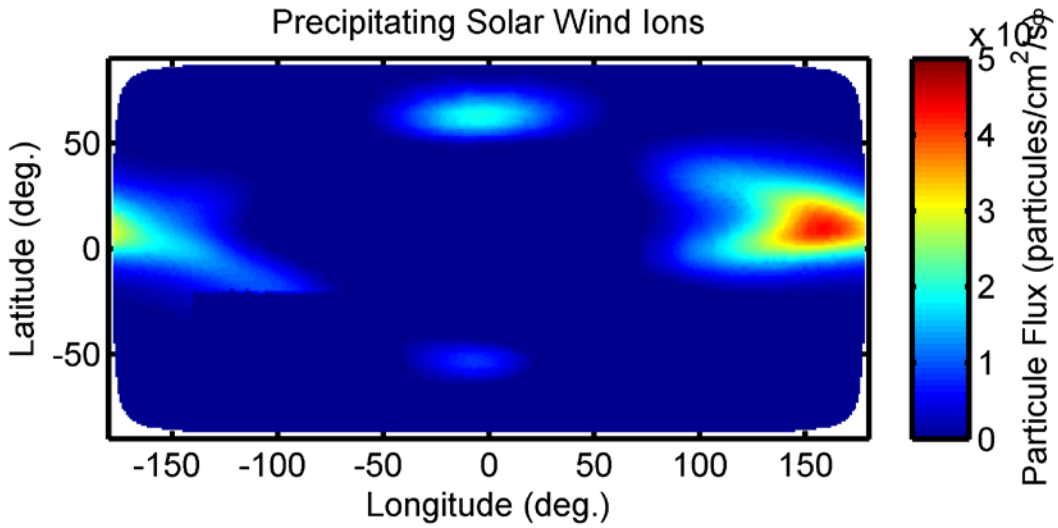
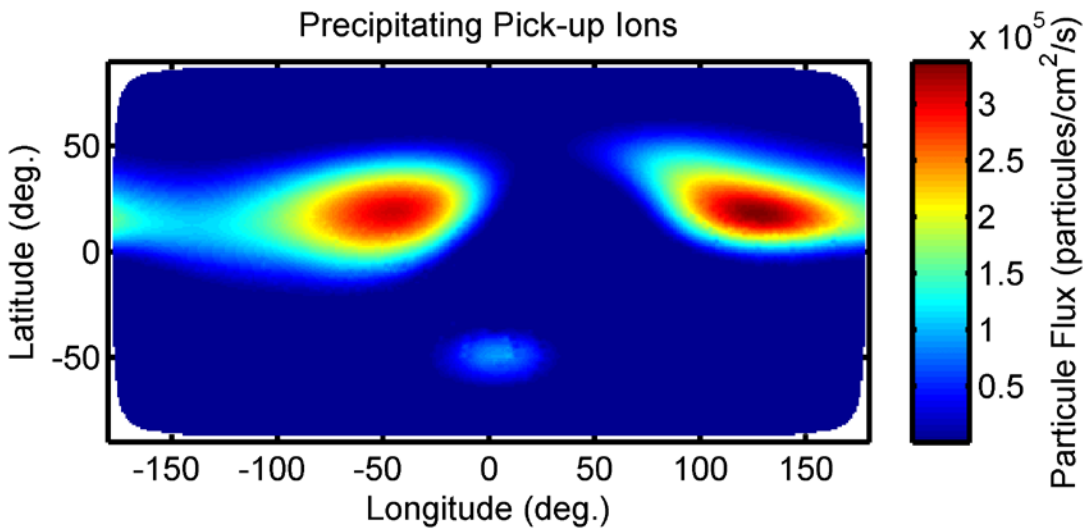
MESSENGER
Magnetic Field Lines

M1 Flyby



M2 Flyby



MESSENGER

Surface Precipitation M1