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Using open datasets and simulations in laboratories

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Outline

What are open data sources?

Open data

- Open data is a term similar to "Open Source" or "Open Access Journals".
- Open science data is available for many areas.
- Much of the data is from government sources.
- Comes with a huge range of support.

Uses of open data

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What I use open data for:

Labs:

- Introductory astronomy
- Junior physics major lab
- Independent project (pre-thesis)

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Why I use open data:

- Play with current research
- Work in different research areas
- Build data analysis skills

Where can you find open data?

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All over the place

- Data.gov — A site linking to open data sources from across the US federal government.
- ScienceCommons — A part of CreativeCommons which includes links to other parts of open science besides data.
- List of data repositories — from Physics-Astronomy-Mathematics Division, Special Libraries Association

Martian Rover data

Project using Maestro software

- Java based software to browse and analyze Spirit and Opportunity martian rover data
- Used in a Solar System astronomy lab
- Had students dig through data to look at:
  - examples of various signs of water ("blueberries", "ancient beaches", "vugs", etc.)
  - eclipses captured by the rovers' cameras
  - "areology" structures and compare them Earth bound geology

Newer data

New (2012) Curiosity rover is active and Opportunity is still active

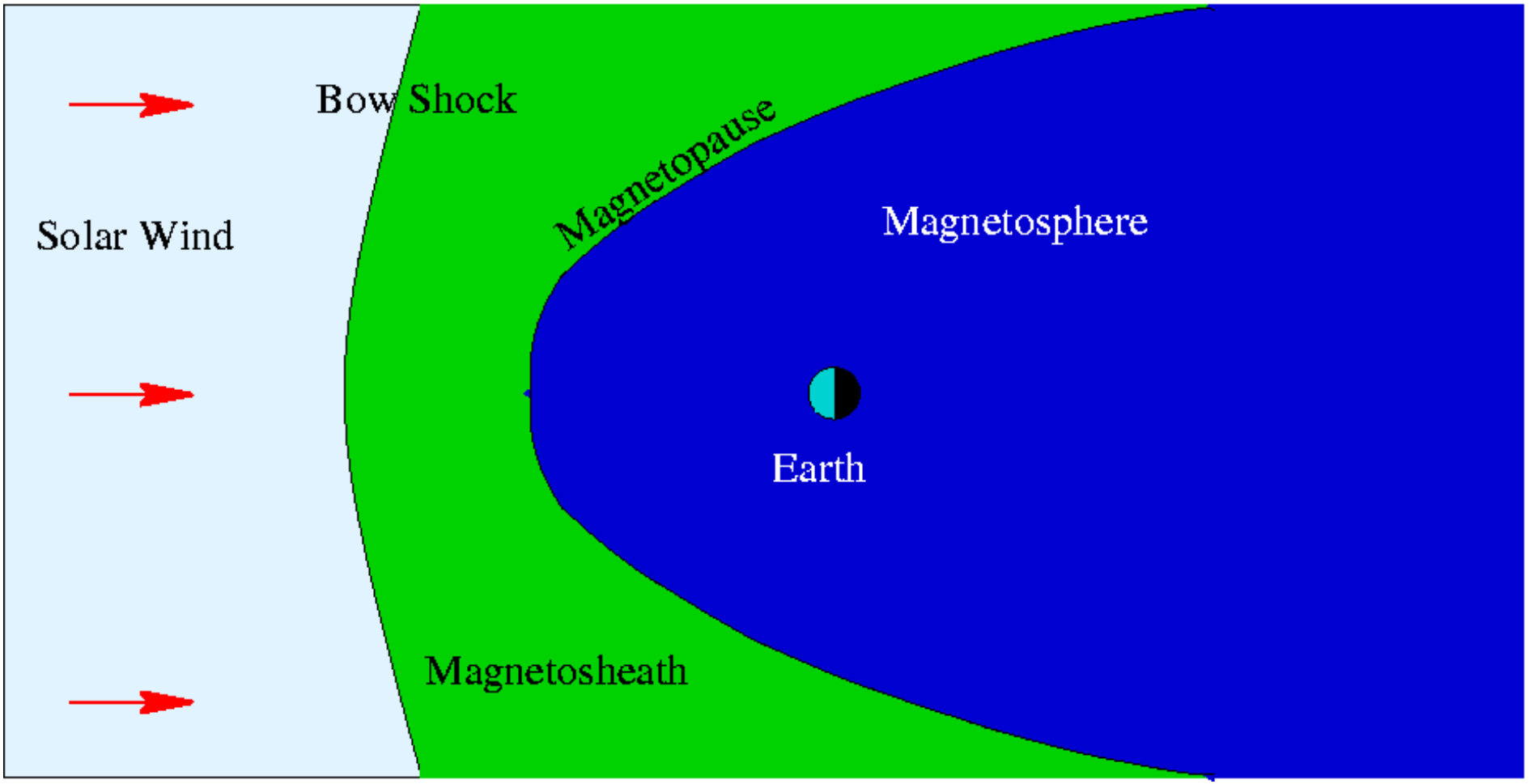
Extra-solar planets

Planet Finders — a Zooniverse project

- Teaches users how to mark possible planets in Kepler spacecraft data
- Kepler finds planets by looking for changes in stellar brightness caused by planets passing in front of stars.
- Users of site take place of AI.
- My students are also using the data to duplicate calculations on previously found planets.

Other Zooniverse projects are related to space, climate, humanities, and biology.

Magnetosphere



Organization of the Lab

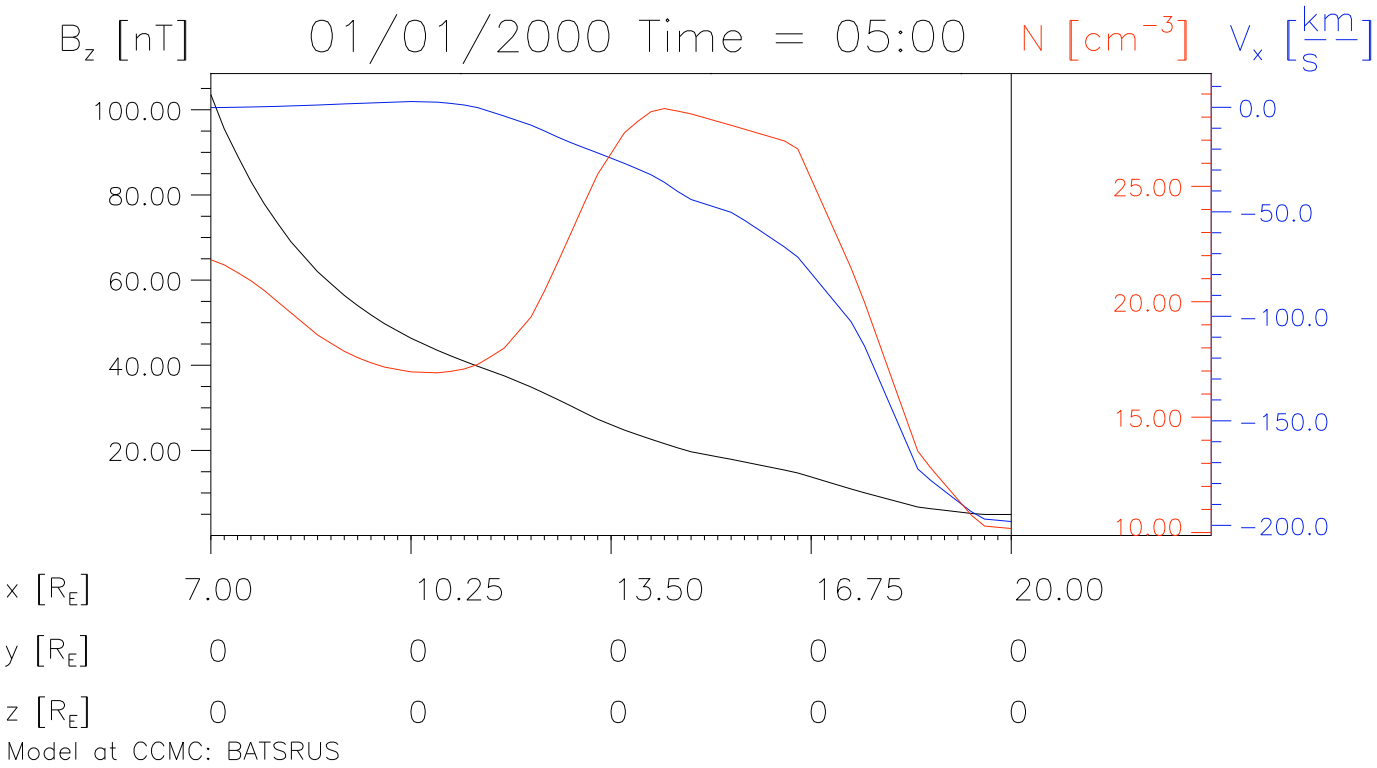
Supercomputer Simulations

1. Students run BAT-R-US Hansen et al. [2002] simulation on NASA supercomputer through the Community Coordinate Modeling Center NASA [2005].
2. CCMC hosts a variety of space physics models.
3. Students run simulations under different solar wind conditions.
4. Students find the subsolar point of the magnetopause in results.
5. Students visualize results using web tools.

Spacecraft Observations

1. Students analyze NASA spacecraft data from CDAWeb looking for magnetopause crossings.
2. CDAWeb hosts data for most NASA spacecraft.
3. Students compare those crossings to magnetic field model predictions.
4. Students visualize data using local software.

Simulation Results



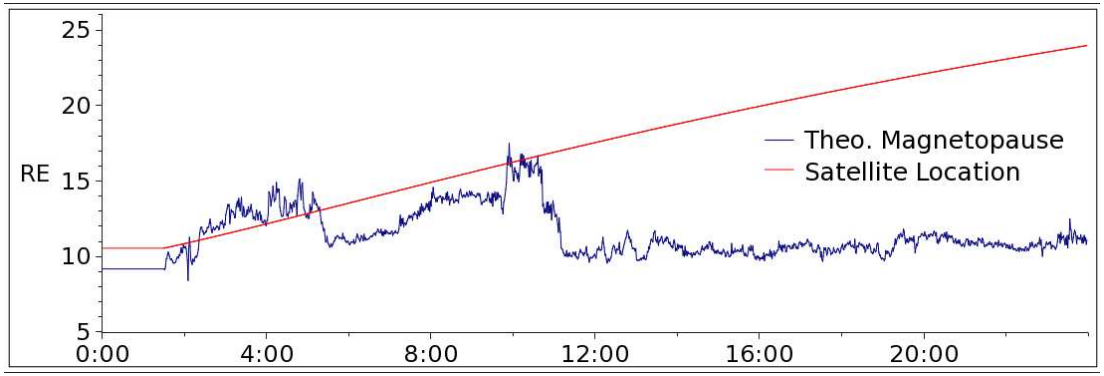
Plot above shows magnetopause crossing at roughly 11 R_E:

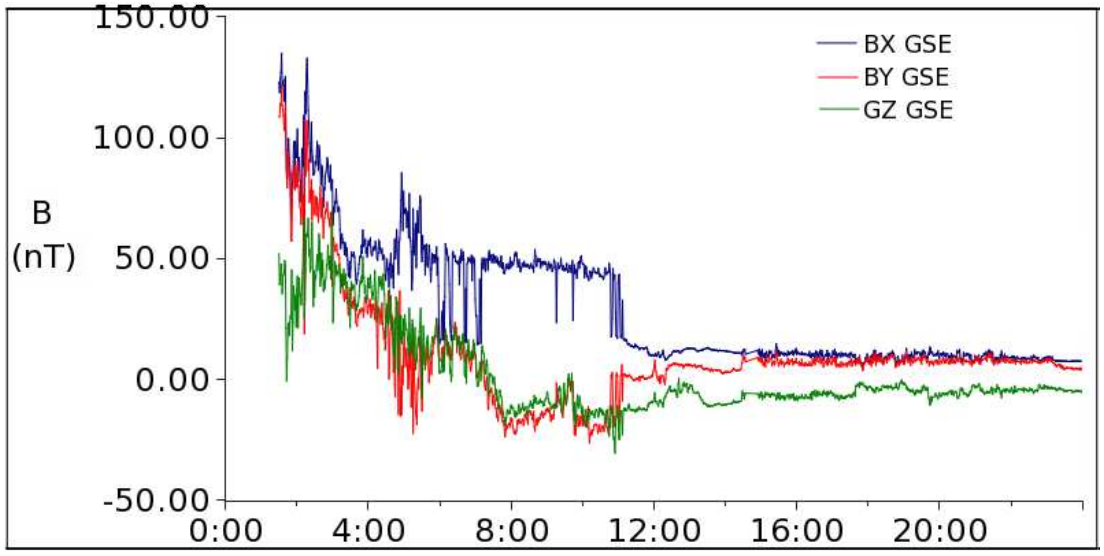
- N - the bump is the magnetosheath, so the magnetopause is just to the left of the bump.
- V_x - speed stagnates just inside magnetopause.
- B_z - has a subtle kink in shift from B_E to B_{sw}.

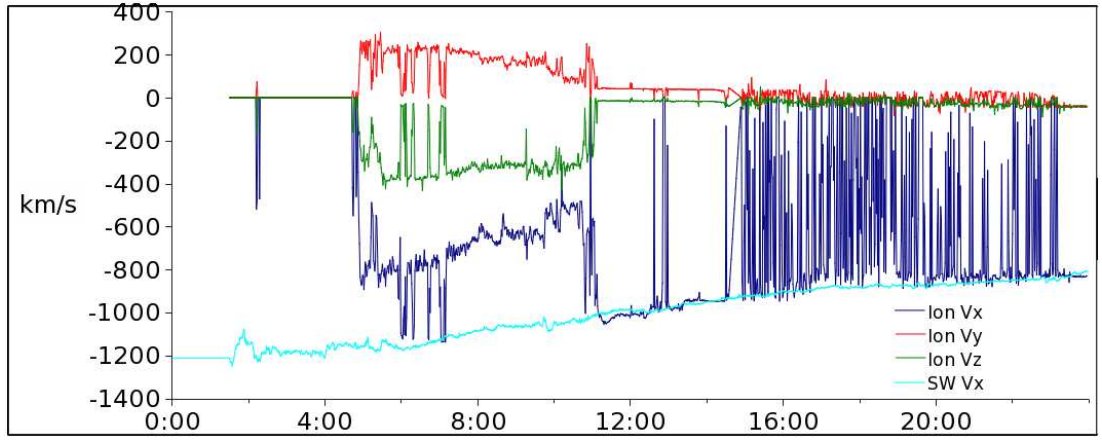
Predicted and actual Geotail locations

Geotail magnetic field measurements

Geotail and solar wind ion speed







Summary

- Open data makes possible different sorts of labs with limited resources required.
- Many types of data available from many sources.
- Open data can be used at a wide range of skill levels.

References and links

References

K. Hansen, G. Tóth, A. Ridley, and D. DeZeeuw. *BATS-R-US User Manual: Code Version 7.5.0*, 2002. URL `http://csem.engin.umich.edu/docs/HTML/USERMANUAL/USERMANUAL.html`.

NASA, 2005. `http://ccmc.gsfc.nasa.gov/`.

Links

- Data.gov — `http://www.data.gov/`
- ScienceCommons — `http://creativecommons.org/science`
- SLA List of Data Repositories — `http://pam.sla.org/subjects/data/`
- Maestro software —`http://marsrover.nasa.gov/relatedsites/`
- Curiosity rover —`http://mars.jpl.nasa.gov/msl/participate/`
- Planet Finders — `http://www.planethunters.org/`
- Zooniverse — `https://www.zooniverse.org/`
- CDAWeb —`http://cdaweb.gsfc.nasa.gov/`

Acknowledgments

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People

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Finally, thanks to the students in my courses who beta tested these labs.

Pressure Balance

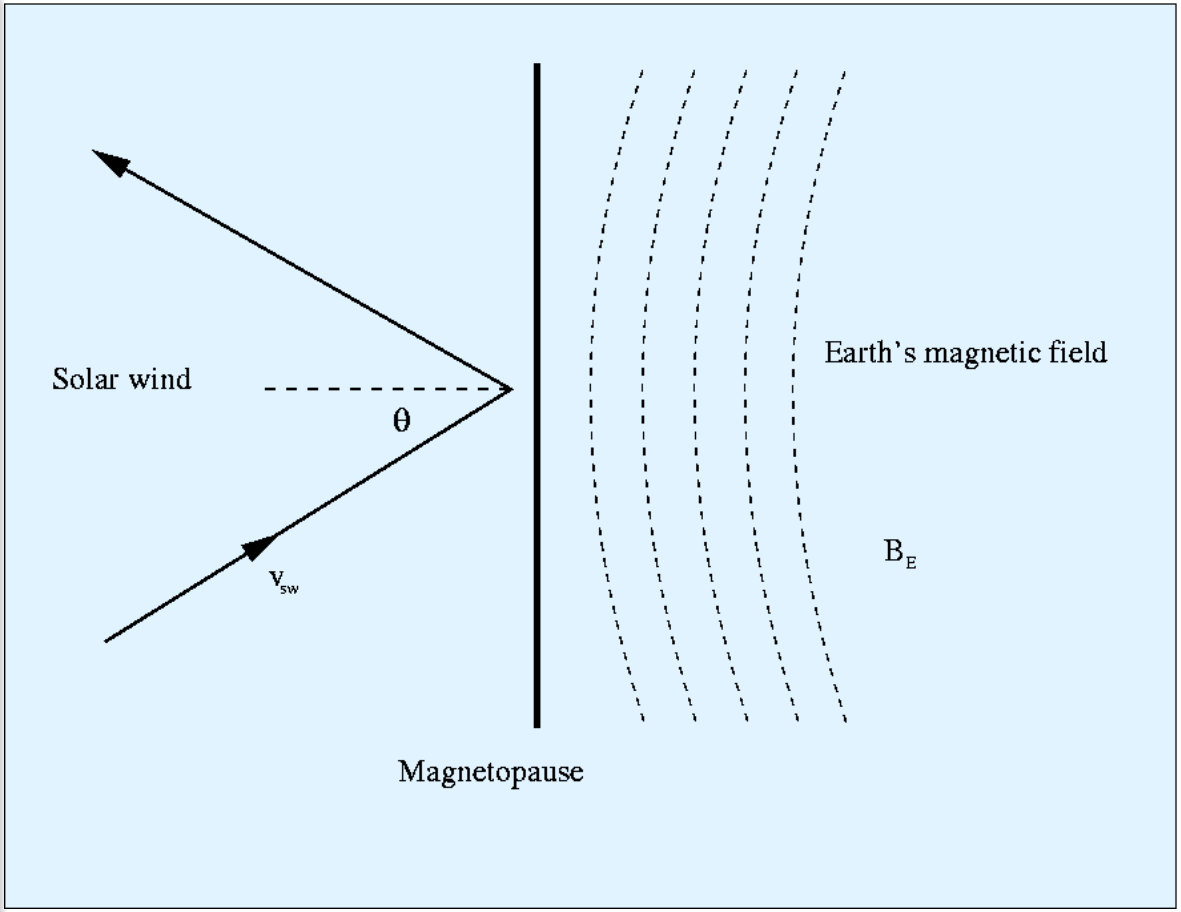
Simple Model

Set dynamic pressure of the solar wind equal to the magnetic pressure of the magnetosphere:

$$2\rho_{sw} v_{sw}^2 \cos^2\theta = \frac{1}{2\mu_0} B_E^2$$

Then substitute in Earth's dipole field and assume normal incidence:

$$r_o(R_E) = 107.4(n_{sw} v_{sw}^2)^{-\frac{1}{6}}$$



Choosing a Space Physics Lab Topic

Problems with coming up a with a Space Physics lab

- most students get little exposure to Space and Plasma Physics.
- advanced electricity and magnetism course is often late in the curriculum.
- little fluid dynamics and plasma physics in typical programs.
- applications are often complex, defying simple treatment.

The Magnetopause as Lab Topic

The Magnetopause boundary works well for a lab because:

- can be treated reasonably well with simple physics.
- accessible with both spacecraft data and computer simulations.
- though studied for some time, still an area of active research.

Simulation Usage

BAT-R-US

- Simulation used is called BAT-R-US Hansen et al. [2002].
- Simulation run on NASA supercomputer through the Community Coordinate Modeling Center NASA [2005].
  - BAT-R-US stands for Block-Adaptive-Tree-Solarwind-Roe-Upwind-Scheme.
  - Solves 3D fluid equations (Magnetohydrodynamics) in finite volumes using an adaptive grid.

Students:

1. upload simulation parameters.
2. visualize and analyze results online.

Spacecraft Observations

Analysis of Spacecraft Data

Students:

1. analyze three sets of spacecraft data (different events and spacecraft).
2. search for crossings in field and particle data.
3. compare to crossings predicted by magnetic field model.
4. discuss difficulties of interpreting data.