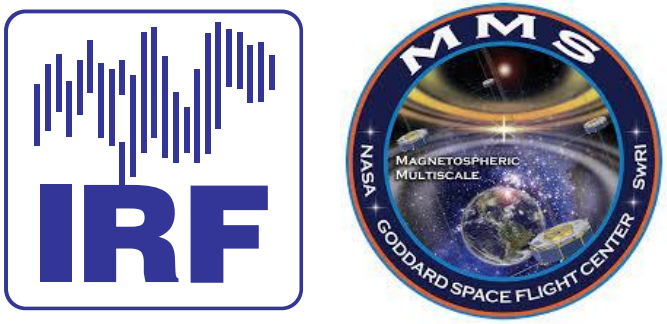
Spacecraft observations of shocks



Andreas Johlander

Swedish Institute of Space Physics

L'Aquila, Italy

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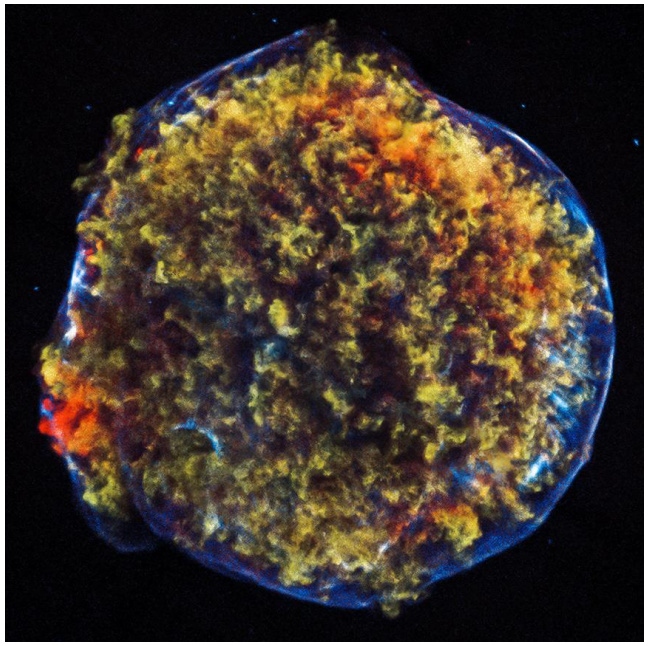
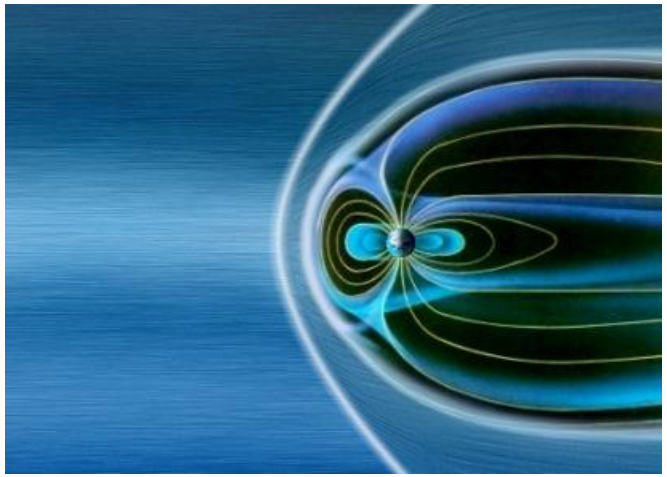
Shocks in space plasma

- Shocks are common in the Universe.
  - Supernova remnants
  - Stellar termination shocks
  - Stellar bow shocks
  - Planetary bow shocks
- Very efficient particle accelerators.
  - Cosmic rays



NASA/CXC/SAO

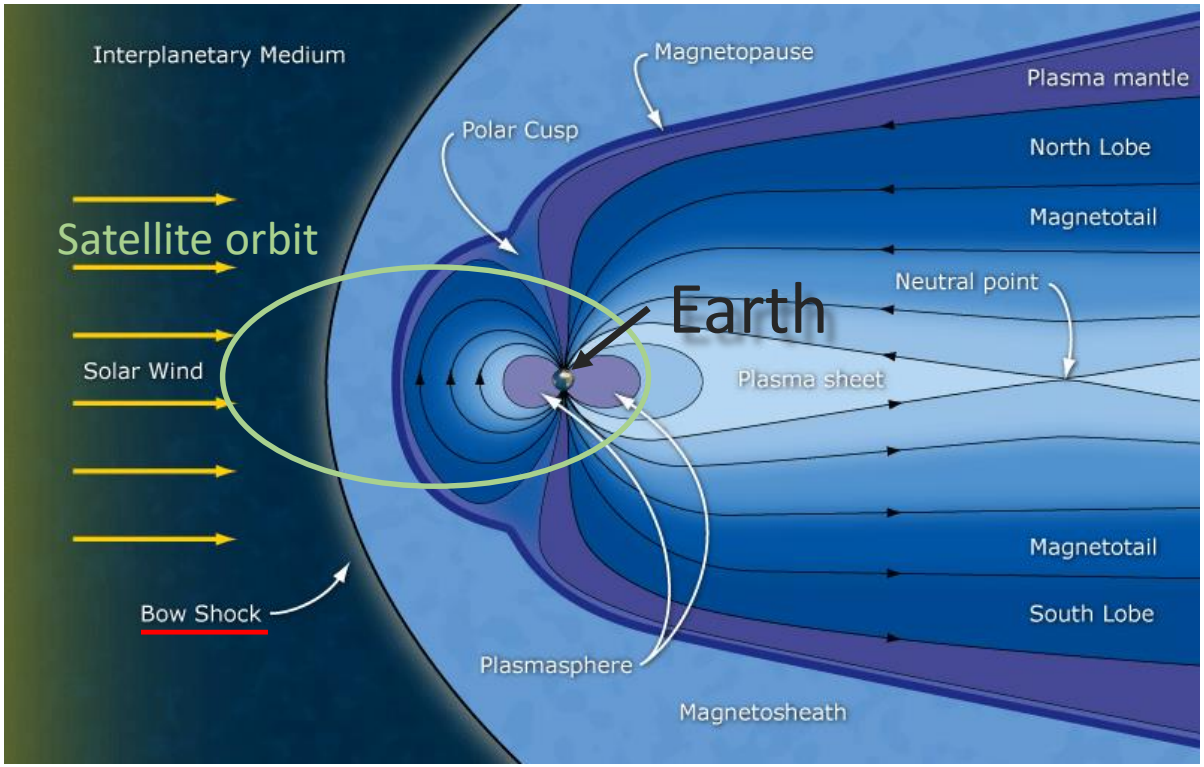
NASA/HUBBLE



ESA

Earth's Bow shock

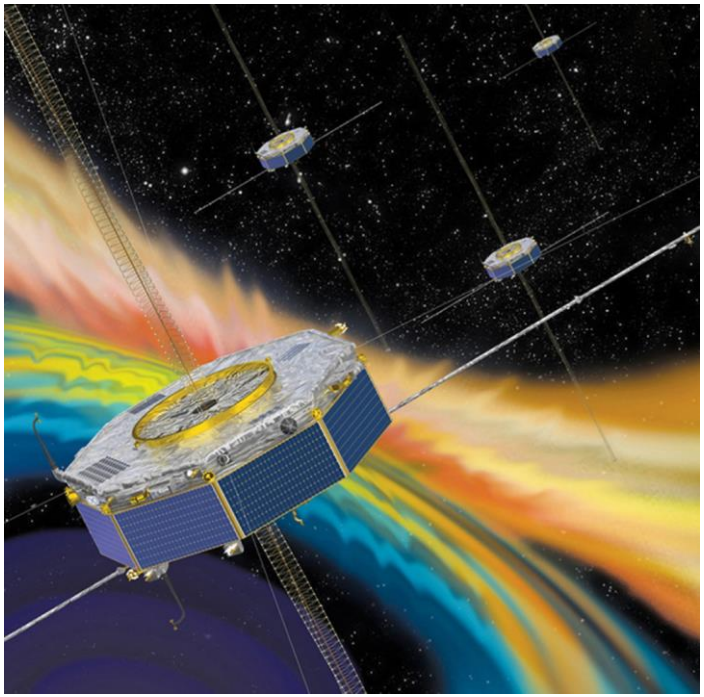
- Formed when the supersonic solar wind hits the Earth's magnetosphere
- A good laboratory to study collisionless shock physics.



ESA/C. T. Russell

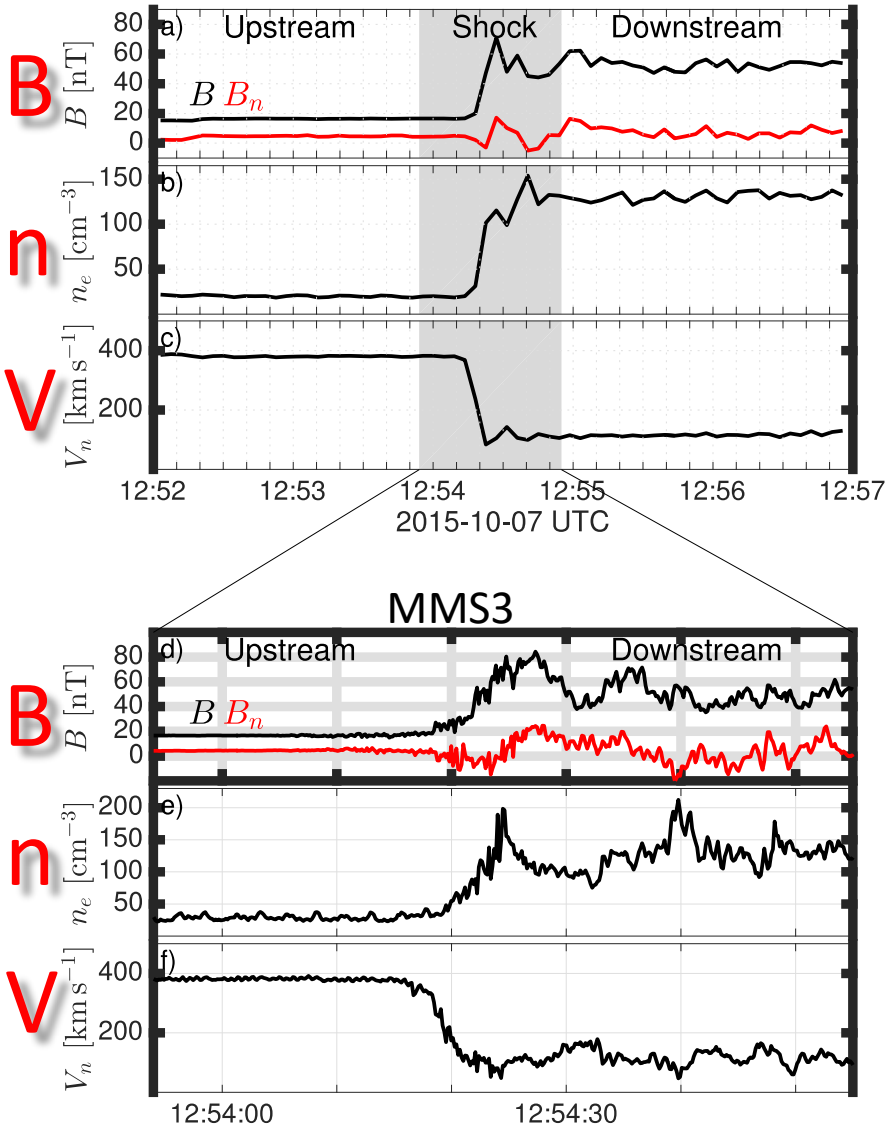
Magnetospheric Multiscale (MMS)

- NASA mission launched in 2015
- Four identical spacecraft flying in a tetrahedron (7-40 km)
- Measures fields, and particle distribution functions at very high cadance



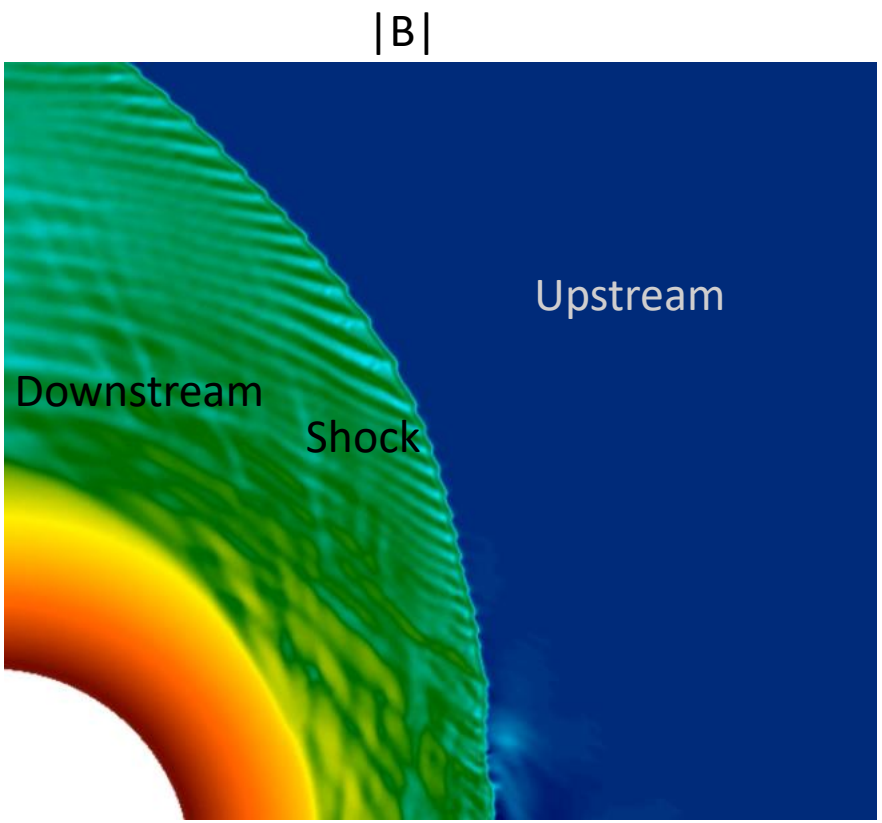
NASA/Goddard

Bow shock example

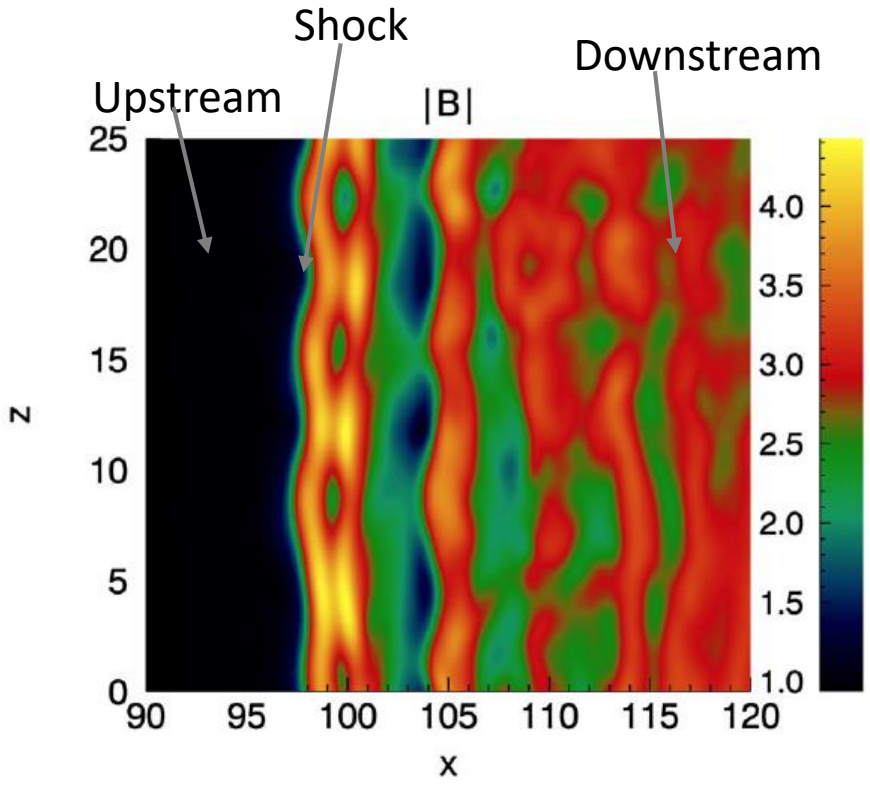


Shock ripples

- Surface waves propagating along the shock surface.
- Can influence how ion and electron dynamics.

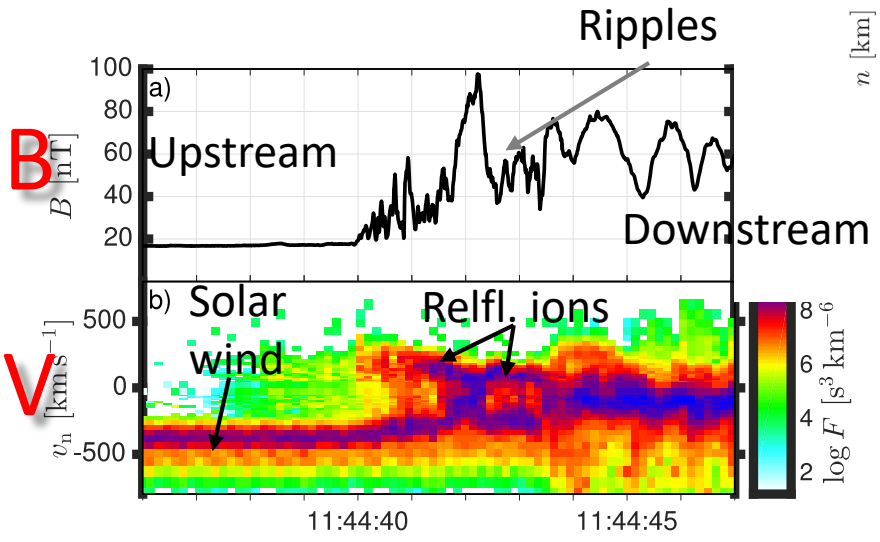


[von Alfthan et al., 2014]
http://vlasiator.fmi.fi/

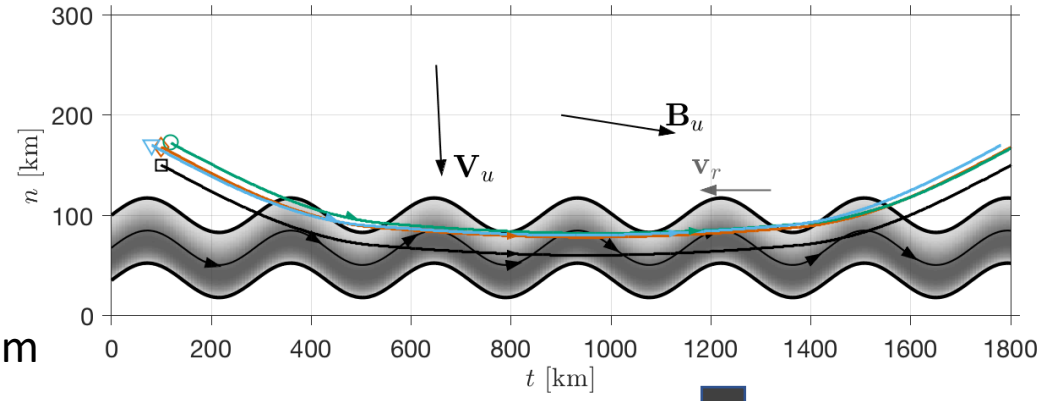


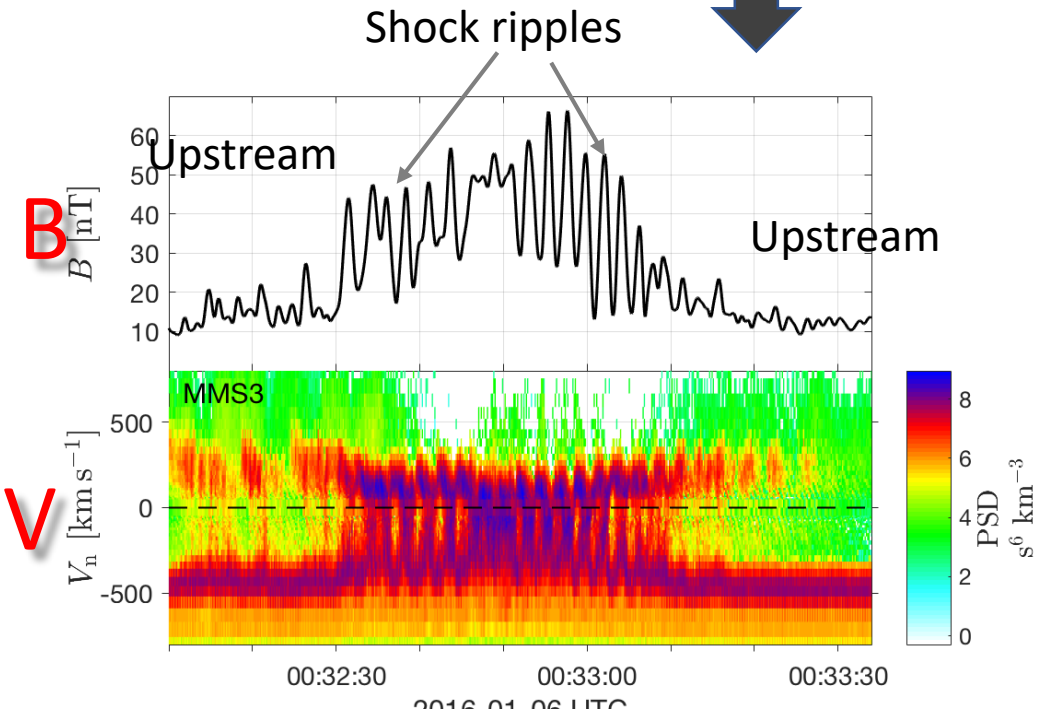
Ofman & Gedalin (2013)

Results



Adapted from [Johlander et al., 2016, PRL]





- We observe kinetic-scale shock ripples that match 2D hybrid simulations
- The ripples affect the amount of reflected ions, which suggests that they can play an important role in ion dynamics and acceleration processes at shocks.