Theme 1: Space Plasmas

From Sun to Earth and Beyond: the Plasma Universe

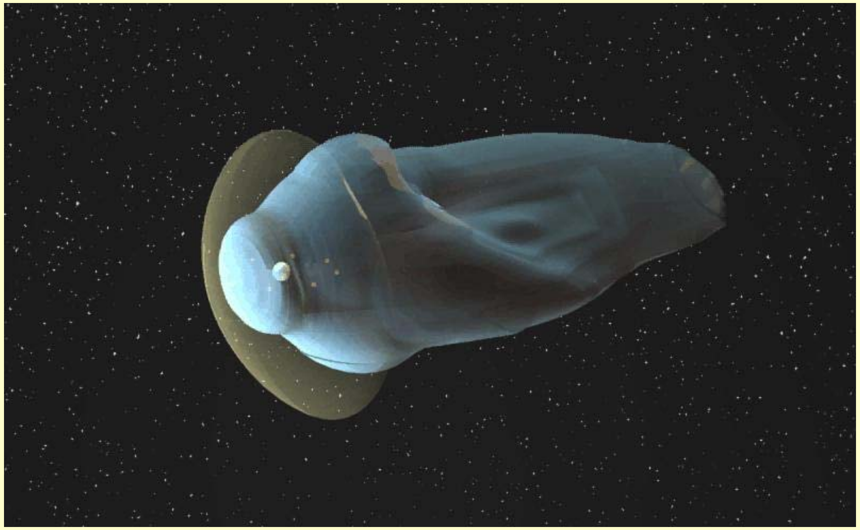
- coupling from electron to interplanetary scales
- solar magnetic fields and solar particle acceleration
- dynamics of non-terrestrial magnetospheres

➢ ➢ ➢ ➢ heliospheric boundaries and LISM

Robert F. Wimmer-Schweingruber & the SSWG

Cross-Scale Coupling

Coupling from electron to interplanetary scales

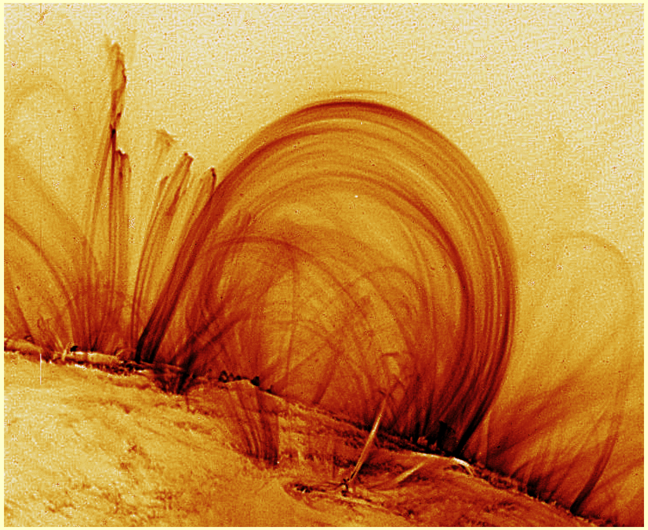


- small-scale structures drive the magnetosphere
- large scales set the outer boundary conditions
- multitude of scales inbetween
- e^- and ion scales in magnetosphere 0.1/5 s

➢ ***how do small scales couple to large scales & vice versa?***

Cross-Scale Coupling

Coupling from electron to interplanetary scales



- small-scale structures drive the corona --> loops, schocks, etc., down to resolution limit
- large scales set the outer boundary conditions --> streamers, holes,...
- multitude of scales inbetween
- e^- and ion scales dramatically different
- many different scales involved
- ***how do small scales couple to large scales & vice versa?***

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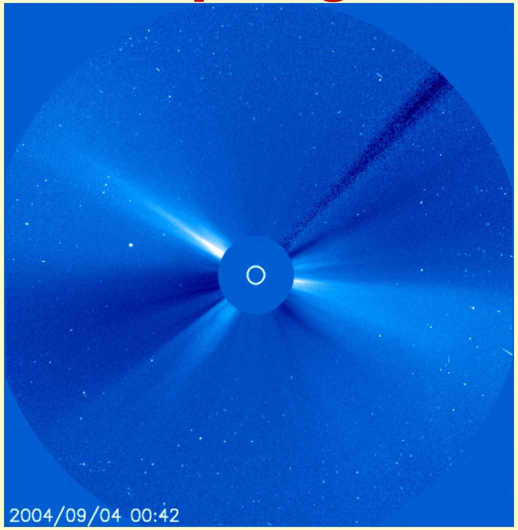
Cross-Scale Coupling

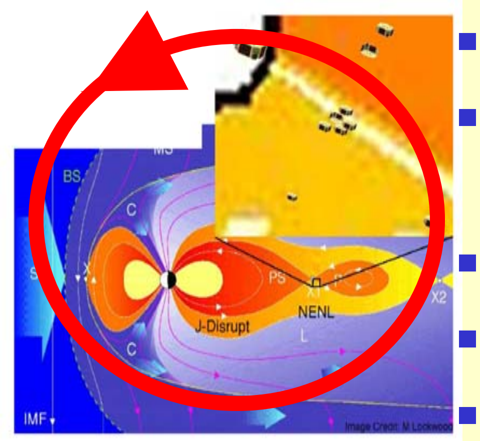
Coupling from electron to interplanetary scales



- small-scale structures drive corona, etc.
- discontinuities in interplanetary space, CIRs, current sheets, stream interfaces
- MHD turbulence, kinetic processes
- fast (<1s) growth of instabilities in interplanetary space
- outer boundary conditions set by ISM
- ***how do small scales couple to large scales & vice versa?***

Cross-Scale Coupling

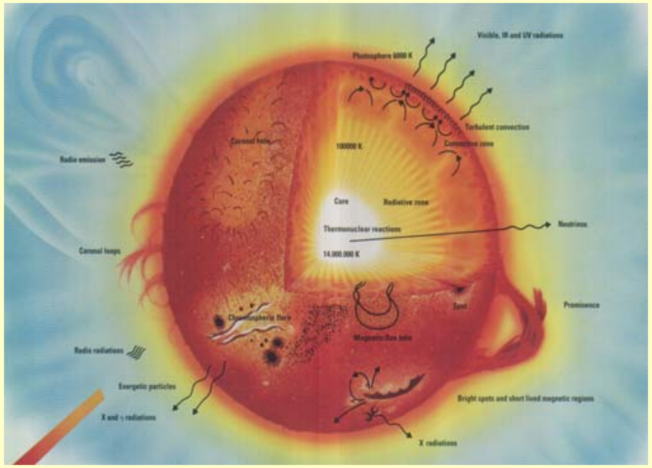
Coupling from electron to interplanetary scales



- IP medium sets outer boundary conditions
- bow shock stabilizes at largest scale that allows stabilisation, dito for other boundaries
- these scales are much smaller than boundaries
- small scales mediate large scale requirements
- Cluster measures one scale at a time
- ➢ ➢ ➢ high-resolution, high-cadence measurements
- ➢ ➢ ➢ multi-scale/multi-spacecraft measurements

Solar Magnetic Fields

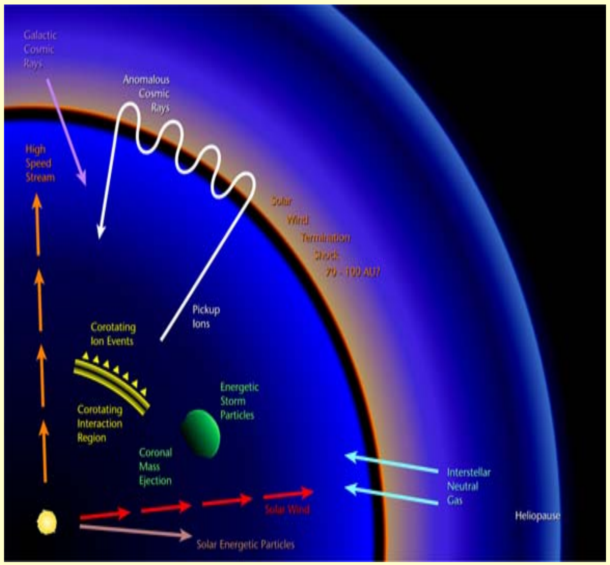
Solar Magnetic Fields from Core to Corona



- origin of solar magnetic field: Measure polar subsurface flows
- interface solar interior to atmosphere: local helioseismology
- continue field into corona including kinetic effects, coronal heating
- SOHO has set the stage, snapshots with Solar Orbiter
- ➢ ➢ ➢ measure solar magnetic field vectors!

Solar Particle Acceleration

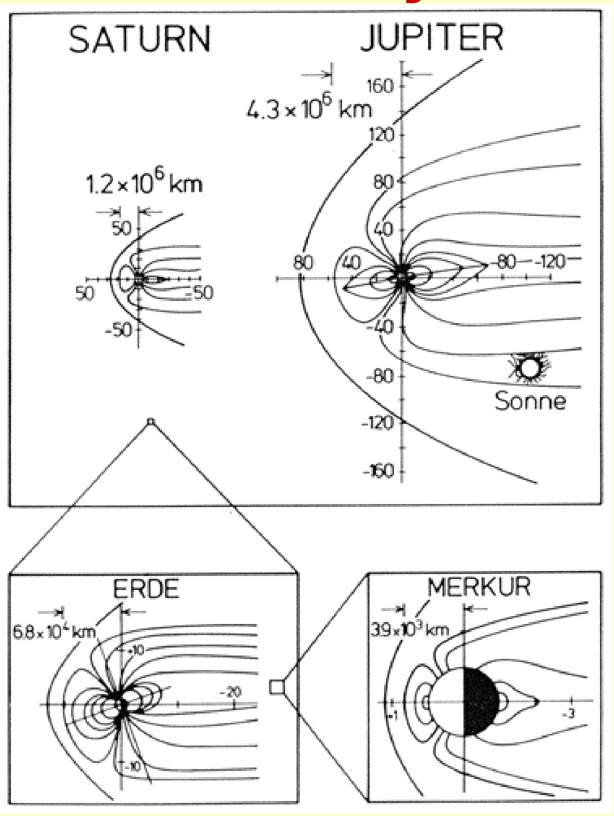
Particle Acceleration in Corona and Beyond



- origin of flares and of coronal mass ejections (reconnection: --> cross-scale coupling!)
- fast particle acceleration to high energies (GeV) in corona, much less in IP space
- ion vs. electron acceleration
- origin and injection of seed particles
- the role of kinetic processes in coronal heating
- SOHO, Ulysses, etc. limited to single point
- ➤ ➤ ➤ measure particles in-situ near and at the acceleration site
- ➤ ➤ ➤ multi-spacecraft measurements
- ➤ ➤ ➤ high-resolution, high-cadence measurements

Comparative Magnetospheres

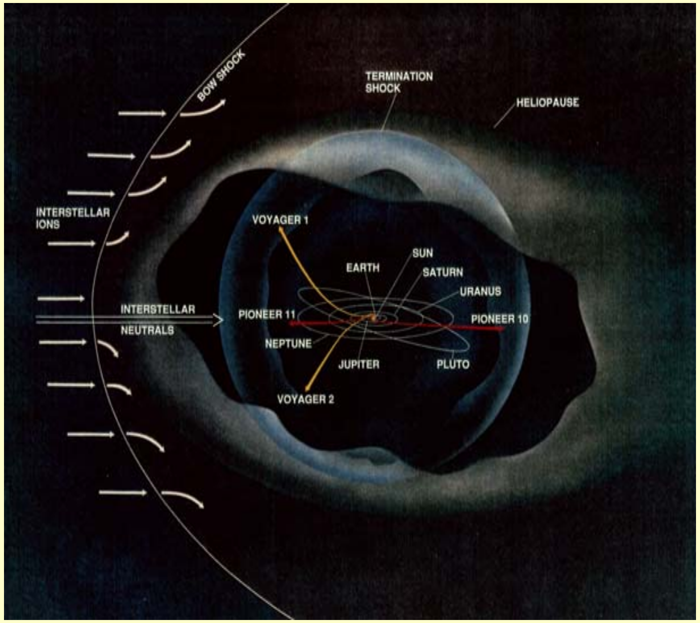
Dynamics of non-terrestrial magnetospheres



- different controlling mechanisms operate in different magnetospheres
- controling parameters? timescales?
- magnetic bodies vs. non-magnetic
- implications for atmospheric losses
- ionosphere vs. no ionosphere
- Galileo plagued by low telemetry
- ➤ ➤ ➤ investigate different magnetospheres (expand parameter space)

Heliospheric Boundaries

Go to the Edge of the Heliosphere and Beyond!



- structure and solar-cycle variation of outer heliosphere (solar mag. field!)
- structure of heliospheric boundary region (X-scale coupling, acceleration!)
- turbulence generation in the outer heliosphere (acceleration!)
- properties and influence of the interstellar medium
- Voyager instruments not built for this
- ➢ ➢ ➢ Explore edge of heliosphere and beyond!

Space Weather

Is Space Weather a scientifically viable vehicle for space plasma physics?

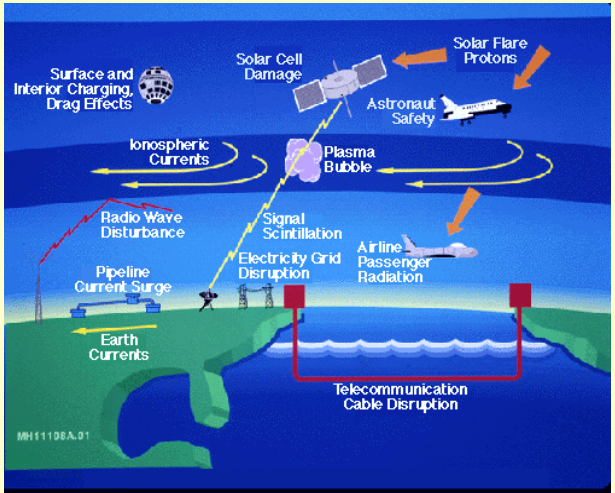


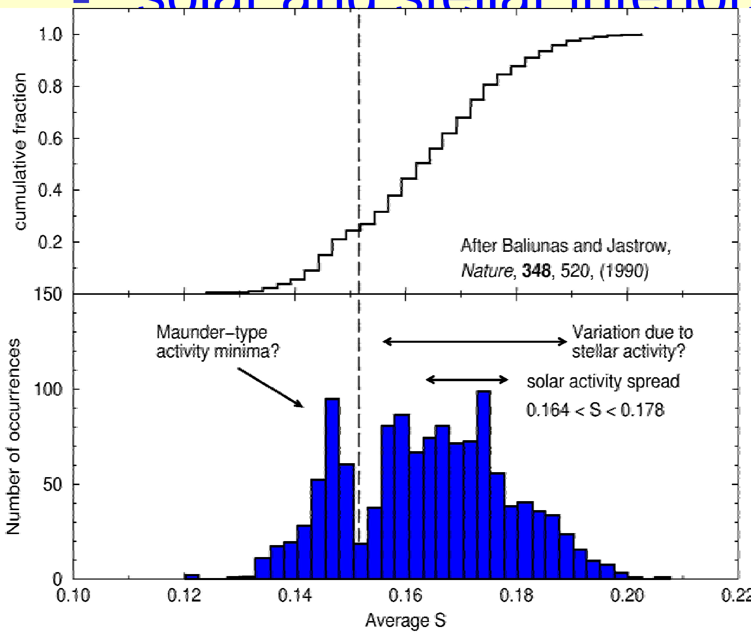
Image Credit: L. J. Lanzerotti, Bell Laboratories, Lucent Technologies, Inc.

- Value for technology/human protection
- relevance to climate discussion?
- targeted research (meteorology < --> hydrodynamics)
- ➤ ➤ ➤ Contributions to space weather fror all aspects of this theme

The Sun as a Star

What does the Sun teach us about other stars?

- solar and stellar interiors and their evolution



links through corona into interplanetary

- activity cycle of Sun and other stars
- Why is Sun so X-ray "dull"?
- ➢ ➢ ➢ Contributions will come anyway

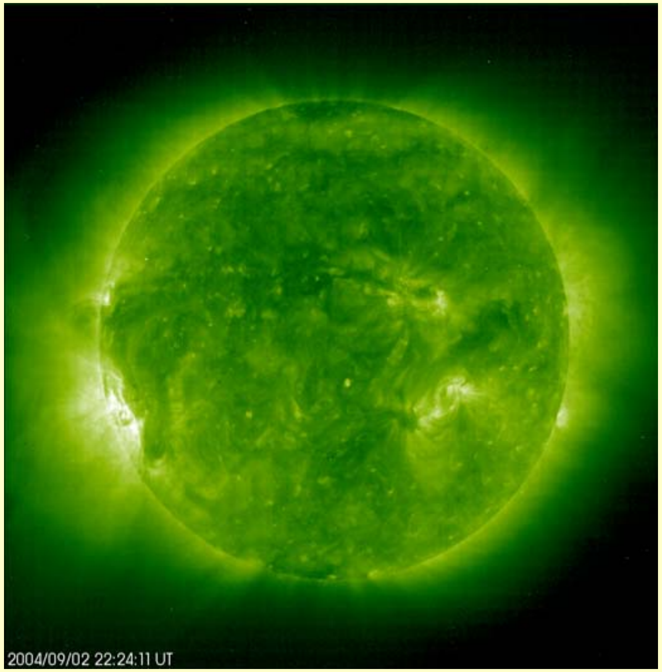
Challenge I

Understand the Coupling across Scales

- multi-spacecraft missions
- nano-sat concepts
- communication among spacecraft
- high-resolution and high-cadence remote sensing
- large data volumes and high telemetry rates

Challenge II

Understand the 3-d solar magnetic field



- "Holy Grail" of solar physics
- polarimetry from space
- high spatial resolution
- high cadence (fast processes)
- long-term helioseismology of polar regions
- high telemetry rates

Challenge III

Understand the ubiquitous particle acceleration

- high-resolution, high-cadence remote sensing (UV, X-ray, gamma-rays) of Sun
- measure in-situ at and around acceleration site
- multi-spacecraft measurements (L1 cluster?)

Challenge IV

Understand "non-terrestrial" Magnetospheres

- Mercury, Venus, Earth, Mars, Jupiter, Saturn "visited"?
- non-magnetic bodies (Moons and asteroids)
- distant outer solar system (Jupiter,Uranus, Neptune)

Challenge V

Leave the Heliosphere

- combine with outer solar system mission
- need to get there within 25 years
- technologically demanding, but doable

Propulsion

Propulsion Systems for Quick Interplanetary Travel

- want to get there faster
- electric propulsion (nuclear or solar)
- solar sails
- linked to power

Power

Power Supplies for long-duration missions

- quick interplanetary travel demands high power
- high-resolution/cadence demands high power
- power in the distant heliosphere/solar system
- RTGs or very large, rad-hard, high-efficiency solar panels

Multi-spacecraft flying

Cross-Scale coupling demands measurements on those scales:

- hierarchical multi-spacecraft systems
- targeted enhancements of flying missions
- high-precision position keeping or knowledge
- develop highly autonomous micro/nano-sat systems

Communication

Inter-Spacecraft Communication and European DSN Capability

- multi-spacecraft missions need inter-spacecraft communication
- dependence on US DSN with limited capacity and high cost
- large data flow requires large receiving capacity
- develop European low-cost, highly automatized, flexible DSN capability

Summary I

From Sun to Earth and beyond: the Plasma Universe

- scientific challenges
- technological challenges
- ➢ ➢ ➢ science and thechnology benefits for Europe

Summary II

Key science challenges:

- understand coupling across scales
- understand 3-d solar magnetic field
- understand ubiquitous particle acceleration
- understand "non-terrestrial" magnetospheres
- ➢ ➢ ➢ understand heliospheric boundaries

Summary III

Key technology developments:

- propulsion
- power
- communications
- micro/nano-sat systems including position keeping

Conclusions

From Sun to Earth and beyond: the Plasma Universe

- multi-spacecraft/multi-scale magnetospheric mission
- long-term high-resolution, high-cadence L1 monitor (cluster?, solar polar orbiter?)
- magnetospheric instruments piggyback on planetary missions (Moons, asteroids, and outer planets)
- ➤ ➤ ➤ leave the heliosphere!