Astronet Symposium
Panel D/ Chapter 5

How do we fit in?

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- Our Method:
- Start from the ASTRONET chapter 5
- Draft of modifications of the ASTRONET document
- Discussion of the draft in the board of the SPS of the EPS/EAS (chair G. Poletto, Arcetri) and in the board of the French National Program on Solar Terrestrial Physics (PNST)
- Specific inputs from G. Poletto, G. Aulanier (Paris Observatory), M. Maksimovic (Paris Observatory), T. Passot (Nice), D. Fontaine (CETP)

Chapter 5: How do we fit in?

- What can the Sun teach us about fundamental astrophysical processes?
- What drives solar variability on all scales?
- What is the impact of Solar activity on life on Earth?
- What is the dynamical history of the solar system?
- What can we learn from Solar System exploration about its formations and evolution?
- Where should we look for life in the Solar System?

Chapter 5: How do we fit in?

- *What can the Sun teach us about fundamental astrophysical processes?*
- *What is the structure and the composition of the « quiet » solar atmosphere and wind?*
- ***What are the fundamental mechanisms of solar variability on all scales and how is it driven?***
- What is the impact of Solar activity on life on Earth? (see comments from Hapgood et al)

- 3 parts in each section:
- Background- Key questions – Experiments

- Present draft focused on optical observations and MHD
- Need to go beyond (radio, UV, X, in situ, kinetic plasma physics)
- Need to include heliospheric and magnetospheric physics (a star and its planetary environment) (a few suggestions at the end)

Chapter 5: How do we fit in?

- *What can the Sun (and the heliosphere and the terrestrial environment) teach us about fundamental astrophysical processes?*

- *Specific inputs from solar and heliospheric physics:*

  In situ measurements of solar wind and perturbations (and terrestrial environment)

Study of processes present in astrophysical objects with complementary sets of remote sensing observations at small scales and of in situ measurements of particles and fields

magnetic field generation

energy conversion and particle acceleration in natural plasmas

magnetic reconnection, turbulence

Key questions

- How do global stellar dynamos work?
- What is the origin of stellar differential rotation?
- What is the structure of the magnetic field at the solar poles?
- ***What are the fundamental processes of energy storage and energy conversion on small scales?***
- ***How can we understand the existence of « hot » outer atmospheres and winds in the Sun and solar-like stars?***

What is the structure and the composition of the « quiet » solar atmosphere and wind?

The solar corona, if Maxwellian, is multi-temperature plasma

Ubiquity of non-thermal particles in the solar wind, in the solar corona??

- Origin of these supra-thermal populations in the solar wind, in the quiescent corona??

Need for a non MHD view of coronal heating and solar wind acceleration

What is the structure and the composition of the « quiet » solar atmosphere and wind?

- Key element for the structure of the corona and of the heliosphere: the magnetic field

  - measured at photospheric levels

    some measurements in the IR and in radio

  - coronal B field mostly unknown:

    use of potential or force free extrapolations

  -key role for coronal heating, continual magnetic reconnection between coronal holes and neighbouring magnetic fields , structure of the interplanetary medium

Need for measurements of coronal magnetic fields and of more realistic models for magnetic fields in the corona

What is the structure and the composition of the « quiet » solar atmosphere and wind?

- Different regions of the Sun have different elemental composition (photosphere, corona, solar wind(s), energetic particles…)
- Low FIP elements 3-4 times in the slow wind compared to the fast wind where abundances are nearly photospheric.

- *Spatial variation of coronal/wind abundances: open problem in solar physics*

Key questions

- *What is the elemental composition of the corona and how do the distribution functions of different species look like?*
- *What is the role of kinetic effects and wave-particle interactions for the understanding of coronal heating (chromospheric heating?)*
- *What is the coronal magnetic field structure? How does magnetic reconnection contribute to coronal structuring (e.g. at coronal hole boundaries)?*
- *How is the low atmosphere linked to the heliosphere?*
- *How does magnetic field emerge from the convection zone into the corona?*

What are the fundamental mechanisms of solar variability on all scales and how is it driven?

- Go beyond optical observations to include radio and in situ data, mention the existence of non-Maxwellian particle populations

- *Modulations of the solar output most prominent in the higher atmospheric layers (UV, X-ray, radio)*
- *Continual evolution (restructuring) of the solar atmosphere observed in EUV (also X-rays, radio) and in situ in the wind*
- *Transient events (flares, CMEs) EUV, X-rays radio , in situ measurements*

- *Need of a close cooperation between remote sensing and in situ diagnostics*

What are the fundamental mechanisms of solar variability on all scales and how is it driven?

- *Non thermal particle populations are ubiquitous in the solar atmosphere*
- *Flares : The Sun is a powerful particle accelerator : energetic particles up to relativistic energies may be produced*
- *Production of non-thermal populations in the low and middle corona linked with minor activity*
- *Non Maxwellian distributions in the solar wind*
- *Processes such as shock acceleration, magnetic reconnection can be investigated in details with e.g. in situ measurements in the Earth's magnetosphere and solar wind and a broad range of remote sensing techniques in the solar atmosphere*

Key questions

- *What are the sources of energetic particles in the solar atmosphere? What is the role of small scales processes, of shocks in the flare acceleration process?*
- *How do coronal energy release sites couple with lower atmospheric layers? How is the energy transported from the corona to the chromosphere (photosphere) during flares?*
- *What determines energy partition between plasma heating, particle acceleration, mass motions and CMEs? Can we understand the large fraction of flare energy going to non-thermal particles?*
- *How do CMEs affect the interplanetary and terrestrial (planetary) magnetic fields?*

Recommendations chapter 6

- Measure B and V in the Sun's convective interior and atmosphere
- Detect and identify the mechanism by which energy is transferred from the surface to the atmosphere and eventually accelerates the solar wind
- Characterize the distribution function of particle populations in the quiet and active solar atmosphere and identify the mechanism of particle acceleration

- Principal facilities

Large aperture 3-5m solar telescope with AO and spectro-polarimeters

Space mission such as Solar Orbiter: in situ measurements close to the Sun combined with remote sensing capabilities and capabilities of observing polar regions

Radio spectral imaging over an extended spectral range (cm to m) to measure coronal B, identify sites of particle acceleration in flares, and track travelling disturbances in the corona towards the interplanetary medium)

Recommendations chapter 6

- Supporting facilities:

- Monitoring of flare emissions: crucial observations for the understanding of solar disturbances and impact on the heliosphere and space weather activities: H alpha, broad range of radio wavelengths

- Radio interferometers such as ALMA and LOFAR to study the quiet and active Sun with high spatial and temporal resolution and provide diagnostics from the low chromosphere to the high corona.

Magnetospheric physics

What is the role of the magnetic and atmospheric shields in the development of the life on Earth? Comparison with other planets of the solar system?

Specific inputs to common astrophysical processes:

Magnetic reconnection and particle acceleration -- multispacecraft measurements at different scales: electron, ion gyroradii (a few km to a few 1000 km in the plasma sheet)

larger scales (MHD scales) 10000km

Turbulence: energy dissipation from large scales to small scales

Experiments: CLUSTER (large scales)

THEMIS (NASA SMEX) 2007

MMS (small scales)

CROSS SCALE (small, medium and large scales)

Ground-based experiments: SuperDARN/EISCAT radars

ionospheric convection, N, T, V with height