Scuola di Dottorato in Fisica
Dipartimento di Fisica Enrico Fermi – Università di Pisa

Corso Avanzato di Struttura della Materia – a.a. 2013/14

Wed, March 5, 2014 – 11.00-13.00 – room 163 building C
Fri , March 7, 2014 – 11.00-13.00 – room 248 building C

Space plasmas: from spacecraft observations to plasma theory.

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Our understanding of physics increases with the confrontation of theory with experiments. In some cases, laboratory experiments can be limited because of technological issues that may limit the range of available parameters or impose the use of boundary conditions and/or probes that may strongly influence the phenomena under study. In such cases, observations of natural phenomena such as geophysical or astrophysical measurements have proven to be an excellent alternative to laboratory experiments.

The case of plasma physics is a particularly interesting one, as we have a direct access, through in situ spacecraft measurements, to a variety of ionised media (solar wind, magnetospheres, ionospheres) that can be considered as different natural plasma laboratories. The typical lengthscales and timescales in space plasmas differ by orders of magnitude with laboratory plasmas; moreover space plasma act as in situ probes that have the enormous advantage, compared to many laboratory plasma probes, not to disturb the plasma flow in which the spacecraft is embedded.

What can be learnt on plasma physics from space missions? I do not intend to give an extensive answer to this question, but rather give a few examples of combined space observations with the associated plasma physics concept. To properly make use of both experimental/observational and theory/simulations studies, it is important to understand both language and concepts. I will thus alternatively discuss space observations and plasma physics notions.

After discussing the peculiarities of space instrumentation (electromagnetic fields and particle measurements), I will introduce the basics of space missions: time scales, operations vs. science, flight dynamics issues, etc., using the recent examples of the NASA mission STEREO (in the solar wind) and the ESA mission ROSETTA (in a cometary plasma). The importance of creating and making use of data archives will be emphasised.

I will discuss different in situ measurements of particles distribution functions as well as remote and in situ radio observations of propagating solar disturbances to illustrate some kinetic plasma effects (temperature anisotropies, beam-plasma interactions) associated to the fact that the media is out of thermodynamic equilibrium.

In situ space observations can also be a laboratory to test fundamental nonlinear processes such as wave-particle interactions, wave-wave interactions or developed turbulence. I will illustrate some of them.

I will finally discuss some basic principles of spacecraft-plasma interactions, often considered as a major source of unwanted measurements artefacts, to give an example of how "dirty" measurements can be used to extract new science results.

The plasma physics notions useful for the understanding of this course will be introduced during the course so that *no advanced plasma physics knowledge is required*.

Although the course is addressed to Ph.D. students, *master students are welcome* (especially those interested in plasma physics or astrophysics).