Space Physics for a Small Program: What topics need to be covered?

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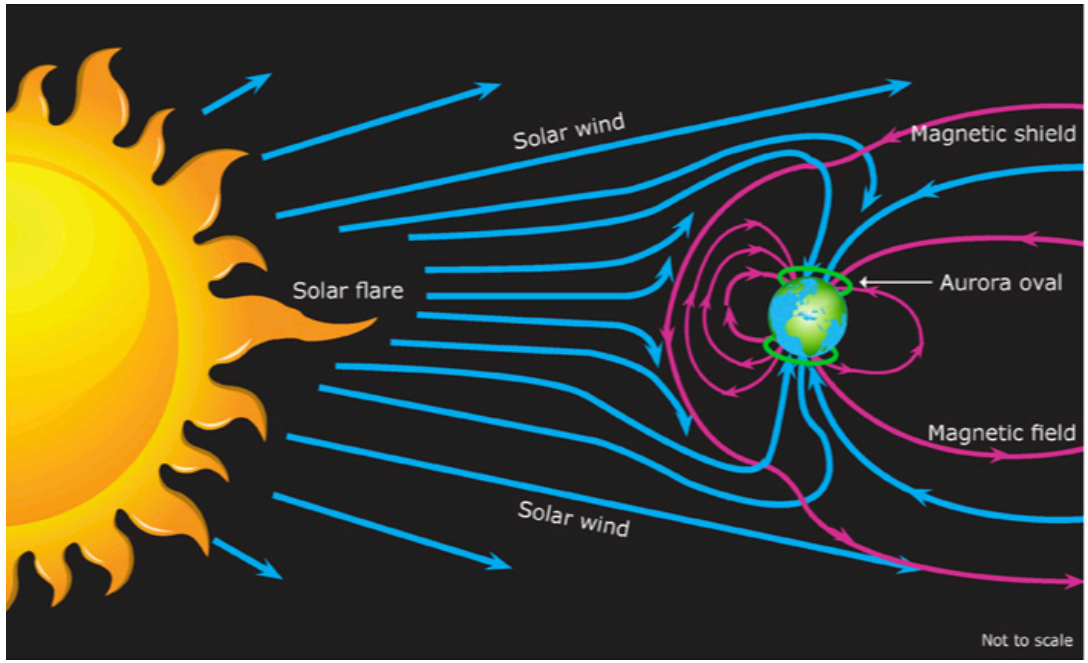
What is space physics as a discipline?

- The basic goal of space physics, including its subfields solar physics, heliospheric /solar wind physics, magnetospheric physics, upper atmospheric and ionospheric physics is to follow the flow of energy, momentum, and material from the Sun to the Earth and to understand the processes underlying this flow, and the practical consequences for Earth and its environment, both natural and man-made. Solar-terrestrial physics and space weather can be included in this broad definition.

The Solar-Terrestrial Environment – Space Physics



- The following scientific disciplines are supported by the NSF Division of Atmospheric and Geospace Sciences (AGS): **Aeronomy (upper atmospheres and ionospheres and electrodynamics)*, **Magnetospheres*, **Solar Physics*, **Solar-Terrestrial Physics*, and **Space Weather.*

KU Program

- In the Physics and Astronomy Dept.: T. E. Cravens (space and planetary physics) and M. V. Medvedev (plasma astrophysics and space physics). D. Besson is primarily a high energy physicist but is working on a cosmic ray detection cubesat in cooperation with Aerospace Engineering.
- In the Aerospace Dept.: C. A. McLaughlin (upper atmosphere and space physics/weather)….
- Specific space physics courses at graduate level: PHSX 795 (Space Plasma Physics) and PHSX 895 (Plasma kinetic theory), AE 767 (Spacecraft Environments).

Space Physics in the Physics and Astronomy Dept.

- Relevant current course catalogue descriptions are:
- ASTR 691: Astrophysics I (3 credits): An introduction to radiation processes, thermal processes, and radiative transfer in stellar atmospheres and the interstellar medium.
- ASTR 692: Astrophysics II (3 credits): The formation and evolution of stars, nucleosynthesis of the elements, and the physical processes of high energy physics.
- **PHSX 795: Space Plasma Physics (3 credits): The physics of fully ionized gases in magnetic fields and their application to interplanetary processes, planetary radiation belts, and the surface of the sun. The motion of charged particles in magnetic fields, magnetohydrodynamic waves, the solar wind and the magnetosphere.**
- **PHSX 895. Space Plasma II. Kinetic Theory…..**

Aerospace Engineering Dept.

- AE 767 Spacecraft Environments (3 credits): Fundamentals of spacecraft environments. Description and analysis of the natural environment in which spacecraft operate post-launch. Includes optical, electromagnetic, corpuscular radiation, plasma and dust from low Earth orbit, through outer heliosphere.

- A significant challenge in AE is the lack of plasma physics, rarefied gas dynamics, electromagnetic theory is only covered in physics II. We cover fluid mechanics, basic orbital mechanics, and space systems. AE 767 is basically a survey course since we are trying to cover the major space physics topics where most of our students have a limited background. I bring some space environment topics into AE 360 Introduction to Astronautics and AE 560 Spacecraft Systems, but the coverage is limited to a little more than one lecture. Satellite drag topics are included as a project for AE 765 Orbital Mechanics.

Required Basic Knowledge for Space Physicists

(in our opinion)

- The basic underlying subjects that should be mastered by students of space physics are those required by most undergraduate physics programs nationally and internationally:
- Classical dynamics (including orbital motion),
- Electrodynamics,
- Quantum mechanics including some atomic and molecular physics,
- Thermodynamics and kinetic theory, and
- Some knowledge of electronics and electrical circuitry.
- Chemistry is also an important subject, and particularly relevant for some areas of solar-terrestrial studies (ionospheric chemistry and atmospheric chemistry).
- Prerequisite math courses include calculus, vector calculus, linear algebra, and complex variables.
- *For space engineers*: aero, EE,….,design courses…..
- Some astronomy or astrophysics?

What additional courses are then specifically required for the field of Space Physics, either at the advanced undergraduate or graduate levels?

- One category of courses is those that “complete” or “complement” the existing physics courses, and which of these is most relevant depends on the background of an individual student. For example, although thermodynamics is taught for physics majors, fluid dynamics and plasma physics (two important subjects for space physics) are not generally taught. Similarly, although quantum mechanics is taught applications to atomic and molecular physics is often minimal (at least in the physics department). A course that is now taught in the Department is PHSX 795 (Space Plasma I), which introduces fluid theory, basic plasma physics, magnetohydrodynamics (MHD), and gives several astrophysical and solar system examples. PHSX 895 is a course on plasma kinetic theory and introduces more advanced plasma physics topics such as quasi-linear theory. Sometimes the course, ASTR 792 Topics in Advanced Astrophysics, is relevant and the topic varies year to year.

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- A second category of courses is those for specific description and applications of physics and chemistry for the space environment. Examples could be a course on the structure of upper atmospheres and ionospheres or on magnetospheres, or a solar physics course. Due to limited faculty resources, very little pedagogy is provided on atomic and molecular processes as applied to solar physics or aeronomy (i.e., upper atmosphere and ionosphere); space physics instrumentation is entirely excluded (e.g., Langmuir probes, plasma spectrometers, magnetometers, ultraviolet spectrometers….). Specific courses on the solar wind and heliosphere (including the solar corona), on the magnetosphere, and on the upper atmosphere and ionosphere are candidates for inclusion in an expanded curriculum. Some of these topics are currently covered by AE 767 (Spacecraft Environments).

** This detailed type of course is not formally taught at KU at this time.

Why is space physics needed? Why smaller programs such as at KU?

- ***Training of Future Space Physicists in the US***
- Space physics is not well-represented by tenure-track faculty in this country, and those faculty that exist are spread throughout a wide range of departments and schools (Electrical Engineering, Aerospace Engineering, Physics and Astronomy,…). This presents a problem for the training of graduate students in this discipline, as, relative to other science disciplines, fewer faculty are proportionately available to supervise both Masters and Ph.D. research.