# Syllabus for Space 574 Solar Terrestrial Relations Fall 2024

## Course description

S574 is a graduate-level course on solar-terrestrial relations and the basic plasma physics needed to understand the Sun-Earth system. The course targets first year PhD students, Masters students, and senior undergraduates.

The course covers the structure and dynamics of the Sun, the solar wind, the Earth's magnetosphere, ionosphere and upper atmosphere. The plasma physics covers individual particle motion under electromagnetic fields as well as kinetic and fluid plasma descriptions

## Learning outcomes

After taking this course, you should be able to:

* Recognize geoscience phenomena relevant to the Solar Terrestrial relations. Understand basic concepts of the structure and dynamics of the Sun, solar wind, magnetosphere and ionosphere; geomagnetic activity and its drivers
* Recognize space weather phenomena and their impacts on satellites, humans in space, communication systems, and ground-based (power) systems.
* Recognize physical laws relevant to the solar wind – magnetosphere – ionosphere system; understand the theoretical foundation and basic concepts of space plasma physics including particle motion under electromagnetic fields, kinetic and magnetohydrodynamic plasma descriptions; and apply the relevant laws to solve problems related to the structure and dynamics of the Sun, solar wind, magnetosphere and ionosphere.
* Acquire and interpret data related to space weather events, and present analysis and results orally and in writing.

## Prerequisites

* Geoscience: none
* Physics: basic knowledge of electrodynamics, statistical physics, and fluid dynamics
* Mathematics: calculus, vector (and elementary tensor) algebra, and basic principles of differential equations and complex variables

## Textbooks

* Gombosi: Physics of Space Environment, Cambridge, 1998
* Koskinen: Physics of Space Storms, Springer, 2011
* Kilpua & Koskinen: Introduction to Plasma Physics, Limes, 2017

All available electronically through UM library

## Other reading

Knipp: Understanding Space Weather and Physics Behind It, McGraw-Hill, 2011

https://store.spacetechnologyseries.com/ebooks/17-understanding-space-weater-and-the-physicsbehind-it.html

Kivelson and Russell: Introduction to Space Physics, Cambridge, 1995

## Instructor

Professor Tuija Pulkkinen

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Office hours Monday 11 am - 12 noon, CSRB 1521b

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## Class hours

Tuesday, Thursday 1:30-3:30 pm, CSRB 2424

Modality: in person (see me if you need special arrangements)

Lecture capture available on canvas after the lecture (viewing lecture capture does not count as

attendance)

## Grade contributions

Class participation 25% (requires uploading 75% of classroom work to Canvas)

Homework 25%

Midterm exam 25%

Final exam 25%

## Homework assignments

All homework is due at the beginning of class on the date posted on Canvas. Late homework will be accepted before the next HW set is due, but the credit will be reduced by 25%. Explain the reasoning behind your calculations – credit is given for the method. Homework is submitted to Canvas as electronic files (scanned copies of handwritten solutions are ok).

You are encouraged to form study groups to work on homework problems and to study together in other ways. You are allowed to consult with other students during the conceptualization of a problem. However, all written work, whether in scrap or final form, is to be generated by you individually. You are not allowed to possess, look at, use, or in any way derive advantage from the existence of solutions prepared in prior years, whether these solutions were former students' work product or copies of solutions that had been made available by others.

## Exams

Midterm (tentative Oct 17), final (tentative Dec 3).

For a makeup test, you will need a doctor's certificate.

## Course outline

Part 1: Introduction to Solar-Terrestrial science

* Introduction to space physics (brief recap of electromagnetism, plasma state, solar-terrestrial relations and space weather)
* Plasma state
* The Sun as an energy source for the Earth
* The solar cycle

Part 2: Ionosphere-Magnetosphere system; Charged particle motion

* Atmospheric layers
* Ionospheric layers
* Magnetospheric structure
* Single particle motion: drifts, invariants of motion, kinetic theory

Part 3: Sun and solar wind; Fluid plasma theory

* The Sun and how it drives space weather
* Solar wind and its structures driving space weather
* Fluid plasma theory: ideal MHD, shocks and discontinuities

Part 4: Solar wind - magnetosphere coupling and dynamics; Plasma waves

* Magnetospheric storms, substorms, and other dynamics
* Ionospheric and magnetospheric impacts of space weather
* Plasma waves: sound waves, Alfven waves, dispersion equation

## College of Engineering Honor Code

The College of Engineering has an honor code. This is taken seriously (see

https://ecas.engin.umich.edu/wp-content/uploads/sites/19/2019/03/Honor-Code-Pamphlet-

2018.pdf). Violation of this policy is grounds for the initiation of a report filed with the Dean's office and the case would come before the Honor Council of the College of Engineering. You are

encouraged to contact me for any questions about this policy.

## Policy on harassment and discrimination

The University of Michigan is committed to maintain a work environment free of harassment and discrimination based on e.g. race, color, national origin, age, marital status, disability, religion, height, weight, sex, sexual orientation, gender identity, or gender expression. Discrimination and harassment diminish individual dignity and undermine students' academic success, and is not tolerated in any form. Alleged violations can be non-confidentially reported to the Office for Institutional Equity (OIE) at institutional.equity@umich.edu.

If you witness harassment, discrimination or any kind of misconduct, please act so that we can develop a healthy and safe environment for everybody. In the situation, focus discussion or attention to non-sensitive topics. After the situation, report to class instructor / student services / OIE (https://oie.umich.edu/ (https://oie.umich.edu/) ). Do what you can to help the victim seek the help that they might need.

I am always available for discussion of these topics. Note that professors are obliged to report Title IX violations. However, in handling the reports, I and others do our best to maintain confidentiality and privacy of those involved.

## Policy on religious absence

If you expect to miss classes as a consequence of religious observance, you will be provided with a reasonable alternative opportunity to make-up missed academic work. It is your obligation to provide the dates of absence within the first three weeks of the semester. When the absence

coincides with assignment due dates, the options to make up may be limited.

## Policy on disability

If you may need an accommodation for a disability, please inform me at the beginning of the term. You should contact the Services for Students with Disabilities (SSD) office. Once the eligibility for an accommodation has been determined, you will be issued a Verified Individual Services Accommodation (VISA) form after which an accommodation can be arranged. Any information provided is private and confidential and will be treated as such. Please present the VISA form to me at your earliest convenience, but no later than two weeks prior to the need for the accommodation so that there is enough time to make the appropriate arrangements.

Mental health and well-being It is important to take care of yourself. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For a listing of mental health resources available on and off campus, see http://umich.edu/~mhealth/ (http://umich.edu/~mhealth/)