0.1 Why Heliophysics?

- **Define Heliophysics**
- **Know where to find assistance with a few key topics**
- **Recognize course norms.**

0.1a What is Heliophysics

Heliophysics is the study of the set of universal laws that give rise to the structures and dynamics that occur in the local cosmos. It is a unique blend of astrophysics with chemistry, physics, and meteorology, with its most critical inputs from plasma physics, thermodynamics, atomic physics, and pure mathematics. You'll recognize the most critical equations as those set up by Maxwell and his peers, but you probably will not have seen these in the way we will view them.

We'll adopt a new approach to these equations as we want to develop our basic understanding of plasma structure and dynamics, to a level akin to Neo from the Matrix

Mr Smith: "*Goodbye Mr Anderson*"
Then Trinity tells Neo he loves her
Neo wakes up and says: "*No*"
The next second is the part we're trying to get to - that is the understanding of plasma that'll we'll strive to achieve.

This is clearly an aspiration goal, one that should be important to you, no matter your path in astrophysics. In this course we will be see Heliophysics as more than "The Sun". It is not a collection of knowledge about the Sun, instead it is a method (like all sciences) of understanding plasma. The argument as to the relevance of this goal goes as follows:

1) The normal, universe is 99% plasma (lets ignore dark matter and dark energy)
2) Our equations describing this plasma have been near-completion for over 100 years
3) But plasma is not the norm in our everyday life.
4) As such the Sun is the only 'stable' plasma we can study with sufficient spatial, temporal, and spectral resolution AND in-situ measurements that we can use to really 'see' plasma structure and dynamics (just like Neo). It's also the one experiment we can use to test modern advances in plasma physics theory. It is the only real long lasting experiment we have, and are ever likely to have, in plasma physics.

Like all sciences, Heliophysics research requires a version of controlled imagination. The imagination part is simple, the control is the hard part. I want you to use this course to develop that control

0.1 Why Heliophysics?

It's all about imagination

"By the time you reach the end of this book, you will have the basic set of tools of scientific imagination involved in understanding what couples stars and planets. What you will learn is universal, literally: it does not matter which stars and planets we speak of: whether of those few nearby or of the many distant ones. Nor does it matter whether they are those few that we are long familiar with or the many that we know about, so far, only in a statistical sense. It does not matter either whether your particular interests lie within the Solar System or beyond it: the same principles apply in our local cosmos as in the most distant planetary system we shall ever have access to.

But looking forward to your science-based career, whether as a researcher or as a teacher, as a journalist or as a politician, you need to be familiar with what is known. That is particularly true in order to discover something new. And to appreciate the value of a discovery, you need to know how to apply what you know to what is not (yet) known. You will need to imagine things no one has ever seen, but not arbitrarily: science demands that you come up with what appears most probable, not merely with things that are possible. Richard Feynman (in The meaning of it all) said it this way: 'It is surprising that people do not believe that there is imagination in science. It is a very interesting kind of imagination, unlike that of the artist. The great difficulty is in trying to imagine something that you have never seen, that is consistent in every detail with what has already been seen, and that is different from what has been thought of.'

from Principals of Heliophysics (Shrijver, arXiv: 1910.14022v1)

0.1 Why Heliophysics?

0.1b The math of magnetism

Without math we have nothing.

As the Heliosphere is a magnetized environment, we will return again and again to a few basic mathematical operators that describe magnetism. These mathematical operators are the language of Heliophysics. As for any use of language, if we only possess a rudimentary knowledge, then the complex literature is incomprehensible. "*Even in translation so much of the original meaning and the nuance the author wished to convey are inevitably lost, or worse, misinterpreted by even the most conscientious translator. (Heliophysics, Volume 1)*". It is absolutely critical that you can translate the math yourself. It's the only way to avoid a misinterpretation. So it is explicitly assumed that you may need to avail of these links throughout the course.

The divergence theorem

https://www.khanacademy.org/math/multivariable-calculus/greens-theorem-and-stokes-theorem/divergence-theorem/v/3-d-divergence-theorem-intuition

There are differential and integral forms of equations

https://physics.stackexchange.com/questions/256739/what-are-the-differences-between-the-differential-and-integral-forms-of-e-g-ma

The Stokes theorem

https://www.khanacademy.org/math/multivariable-calculus/greens-theorem-and-stokes-theorem/stokes-theorem/v/stokes-theorem-intuition

Curl matters

https://www.youtube.com/watch?v=vvzTEbp9lrc

Magnetism is beautiful

https://www.youtube.com/watch?v=GKGd5RBfdDY

0.1 Why Heliophysics?

0.1c Course norms

You’ll find I have a very informal and flexible teaching style. I’ll adapt as needed throughout classes. You’ll find class norms require you, the student, to do certain things at certain times.

Critically you’ll note that I don’t assign homeworks.
More correctly, we do ‘homeworks’ in class.

This means you have to do some reading before each class. Everyday we will test the pre-class reading and the previous material. This testing is applied at a broad and general level. So, for example the ‘1.1 Gravity-Magnetism’ reading is clearly about how the dynamics and structures caused by magnetism compare to those caused by gravity. So there will probably be a question on that comparison topic. In ‘1.1 Gravity-Magnetism’ you’ll find three key things about magnetism. No doubt, there will be a question on this at some stage. As we adopt active learning in class, you will have to participate in the class. Don’t let this scare you. Instead it should comfort you as I’ll set up the reading in such a way that you’ll always know exactly what will be coming up each day. For example, in ‘1.1 Gravity-Magnetism’ Reading you’ll see it has lots of blanks spaces, like this

> 1.1c Applying the Divergence Theorem to the field equations
>
> The divergence theorem allows us to move between and point source (integral) and field (differential) form of our equations.
>
> *The integral form of Gauss’ law for gravity is*
>
> $\oiint_s \mathbf{g}.\mathbf{n}\, da = -4\pi GM$
>
> Apply the divergence theorem
>
> *[Application In Class]*
>
> *[Explanation In Class]*

The words in *[Italics]* are activities we’ll do in class. After class I will always give you a complete set of notes with all those blanks filled in, so during class you should not be taking notes. You do not need to write everything down while we talk in class. Instead focus on actively listening and actively participating. Finally, at the end of every class I’ll often ask you to use something you might already know to make an educated guess at what might come next. This part is just for fun, or sometimes, astronomy swag.