The AST2000 Project (2022)

I. INTRODUCTION

Welcome to the project variant of the AST2000 course. The project is comprised of 10 parts that are divided into 3 major components: the spacecraft project (7 parts), exercises in relativity (2 parts) and a theoretical exploration of a star (1 part). During the course of this project you will encounter various topics from N-body simulation, spectral and image analysis to relativistic problems, stellar cores and celestial mechanics.

In order to succeed with this project you need to be sure you are very comfortable with programming. **You should not continue with the project if you have struggled with the programming in other courses before this.** Moreso than the standard variant of the course, the project variant relies on numerical computations to a large extent. Nonetheless, while a greater portion of your time working on AST2000 will go to programming, your grades will reflect your physical understanding of the programs. **To be absolutely clear, you will spend a lot of time programming.**

A large part of the grading of your project will be based on the final scientific report (or papers) or your blog posts. Although you will spend a lot of time programming, you will mostly be evaluated on your physical understanding of what you have been doing. For those of you who will deliver a report at the end (instead of blogging): It is very important that you start writing already from the first weeks. Neverteless, it is **even more important** that you write a log every time you work on the project. In this way it will be much easier to remember what you were doing and how you were thinking weeks or months earlier.

NOTE that in 2022 (and only for 2022) there is no blog-option. If you choose project, you will be writing scientific papers!

A. Programming Language

You are actually free to choose whatever programming language you like. However, you need to use `Python` when interacting with the `ast2000tools` package. If you haven't already, you should check out the "Overview" section of the `ast2000tools` documentation (https://lars-frogner.github.io/ast2000tools/) after reading this document. It is very possible that you will encounter bugs or inconsistencies in the `ast2000tools` package. If you think this is the case, then contact the group teacher responsible for this project, and hopefully this can be sorted out.

You should not consider trying a new language for this course. For those of you with prior experience programming in another language, it is only recommended to use another language if you are *much more comfortable* using said language rather than `Python`.

While you are free to choose, we are going to assume every student writes in `Python`.

II. THE SPACECRAFT PROJECT

Much like the name implies, The Spacecraft Project revolves around a spacecraft mission. The mission will take place in a simulated universe, generated by the `ast2000tools` package. You will be given your own personal solar system, including your very own "home planet". The spacecraft mission contains three sections: launch, interplanetary travel and landing, each of which you will delve into in great detail.

A. How the Project is Structured

The Spacecraft Project represents the bulk of the course with 7 of the 10 major parts. Ideally you would build all of the physical models on your own, but we simply don't have time for this. We have therefore designed a framework for you to work with. This framework manifests as a series of "challenges" that you need to solve in order to complete the project. The challenges help you build a model for each of the physical phenomena and situations you will encounter throughout the project, but don't expect the answers to be given to you on a silver platter.

Although we try to make this project as realistic as possible, we also make alot of simplifying assumptions. These assumptions are also used in the python package `ast2000tools` that you will use and interact with, so that these assumtions will be built into the virtual world that your spacecraft is exploring. This is so that some of the problems become easier to solve, but this also means that if you try to solve the problem in the "correct" way, e.g. by including forces that we specifically say that you should neglect, your results will be wrong. In other words, although it is generally good to be clever, don't try to be too clever!

The first 4 parts are only simple simulations to prepare you for the real launch in part 5-7. It's in these later parts where we actually launch the satellite and check if parts 1-4 work correctly, so don't spend too much time on the first parts as you may need to go back and adjust your plan according to what happens when you are in space.

B. The Final Product

Note that the challenges are only meant to help you with the actual task at hand: to model, simulate and execute (using `ast2000tools`) a spacecraft mission. This is why you are going to "answer the challenges" with a scientific report/scientific papers. The report/papers

a) must be written *without* referencing the challenges.

b) should follow the standard setup for scientific reports (see *The Basics of Writing a Report* on the course pages).

c) should explain your thought process and physical understanding.

d) should show critical thinking in that you always evaluate your own work and point to possible sources of errors.

It is important that you *do not* include your programs in the report, these will be delivered alongside the report as `.py` files. Unless it has an impact on the physical interpretation of the results, you should definitely **not** explain your programs to any level of detail. The programs are simply a means to an end. You should also *not* refer to the programs in any way other than *"the simulation yielded"*, *"we found A by simulating B"*, etc. You will never read an astrophysics article in which the author explains details of their code. Nonetheless, your choice of algorithm will have an effect on your results and should therefore be included and explained in a general manner with focus on the physics using words not programming language. It is also important to explain why the algorithm you have chosen is well suited for your given problem and if there were other options.

Lastly, The Spacecraft Project is comprised of a lot of very different challenges. Some students may want to separate the report into a series of smaller reports; this is, of course, completely fine. Our only requirement is that each report is consistent and self-contained. To use material from other reports you therefore need to properly reference the other report as a unique piece (as you would any other article, report or scientific text).

III. EXERCISES IN RELATIVITY

The relativity component of the AST2000 Project is the one most reminiscent of the standard variant of the course. Students following the standard variant of the course will be given a set of exercises at the end of the relativity chapters as usual. Fortunately for you, students following the project variant of the course only need to complete a subset of these exercises. Unfortunately for you, you also need to write a text explaining parts of your work. However, for many of the relativity exercises, it suffices to do these on paper as if it were an exam and scan these without further explanations.

IV. A THEORETICAL EXPLORATION OF A STAR

The final component of AST2000 (part 10) is a short theoretical exploration of the star in your personal solar system. Much like the relativity exercises, this part is also written as a series of exercises. However, you need to address all of these exercises with a single article. The intended audience for this article is someone who has a firm grasp of the necessary mathematics, but lacks a theoretical basis in stellar physics.