AST 392D: Math Methods (= Order of Magnitude Astrophysics)

Spring 2021
TTh 2:00-3:15 Zoom

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Office Hours: By appointment (we'll play it by ear)

Course Logistics

Philosophy: Official catalog name aside, the de facto course title is ”Order of Magnitude Astrophysics”. The goal of this course is to build our skill and experience in quickly taking some knowledge of an astrophysical object/system, and using it to infer other features or behavior of that system. Astronomers and physicists call these ”Order of Magnitude” calculations because that's often going to be our target precision - estimating something to the nearest factor of 10(ish). You might be surprised by how often this is good enough. The universe is an exponential place, and if you ask a question, the answer is often either 10^{10} or 10^{-10}. When distinguishing between those possibilities, you can get away with a whole lot of simplifying approximations.

This is an important, but often under-appreciated skill. The most apparent benefit is that it allows you to think in real-time about a broad range of astrophysical topics, which can be useful for critical appreciation of others' talks, answering questions about your own research, and generally participating in discussions with your colleagues about whatever might come up. However, it also will allow you to generate ideas and (approximately) evaluate them much more quickly. I think it's a truism of science, and certainly for my own experience, that one generates a lot of ideas that miss the mark (whether infeasible, based in incomplete understanding of the background astrophysics, or just not able to answer the question) for every idea that's genuinely worth pursuing. If you can winnow the non-starters more quickly, or save yourself from pursuing one of them for days/weeks(/months(/years!)), this makes it easier to identify those genuinely good ideas. For context, I feel like I have one of those every year or two, so to borrow some terminology that we'll be developing this semester, apparently I fall in a regime where this timescale really matters!

The way I think of this is that we'll be studying three types of interlocking topics:

1. Astronomical objects and systems. We're all here because we find the Universe interesting, so my goal is to make sure that we're constantly learning new things about what's out there. I'm more of a local-scale person (stars and planets), but I'll try to make sure we include plenty of galactic and extragalactic astronomy as well.
2. Astrophysics. You can cover a whole lot of ground, or at least reasonably approximate it, using a surprisingly modest portfolio of physical principles that map to the aforementioned wide range of actual astronomical objects/systems.

3. Methodological (or perhaps ”meta”) techniques. This establishes the foundation of the entire course, giving you a toolkit for quickly and quantitatively(ish) understanding the astrophysical effects that operate among astronomical objects and systems. These tools include estimation, scaling relations, dimensional analysis, linearization, approximate statistics, etc.

Format: My expectation is that I'll spend part of our class time introducing concepts under the various umbrellas that I listed above (methodological concepts, physics concepts, astronomical objects). However, a majority of the class time will be spent working to solve (hopefully entertaining) order-of-magnitude questions in small groups. I assume we'll start with two groups, one with 3 of you and one with 4, and then I'll probably mix things up every few weeks.

A key part of this process will be to work out math collaboratively within your group, and then share it out with the rest of the class. In a different semester, we'd be working at the blackboards in the Astro classroom or the Edmonds lounge. But this year being what it is, one of your first tasks will be to instead figure out your preferred method for being able to do math at whatever location you're currently social-distancing from, and then share it via Zoom. Having participated in several qualifying exam and thesis defense committees since March, I've seen various solutions to this, including:

1. Acquiring a whiteboard and pointing your webcam at it
2. Wallpapering a nearby wall with printer paper, and pointing your webcam at that (be careful - markers bleed through!)
3. Using a stylus with an iPad or other tablet
4. Aiming your phone downward from above at your desk, so that you can write on paper and broadcast it
5. Various online whiteboard apps

I don't have a preference which of these you choose, or if you find something else, as long as it works for you and allows you to share your work with the rest of the class. But please have one of the strategies ready to go ASAP. If you find it isn't to your liking, you can always switch it up in future classes, but we'll be diving into the group work quickly. And keep in mind that a large fraction of the class grade will be ”participation”, which basically means contributing to solving these problems. So to claim credit, I'll want you to screencap or otherwise take pictures of your group's work and post it on Canvas. (A note to the second-year students - you'll need a solution for working/sharing math before your qualifying exams in April-May anyway, and I assume we'll still be remote at that time. One of our goals for this class is to give you plenty of low-stakes practice leading up to your qualifying exam, so there's probably a payoff for using the exact same setup here. Be thinking about what you'll be most comfortable with.)

Text: There is no single textbook, per se - we'll be assembling written supplemental materials from a variety of sources. However, we'll start by basing our first few weeks on an excellent Order of Magnitude Physics textbook available online (written as somebody's PhD thesis!):

`http://www.inference.org.uk/sanjoy/thesis/thesis-letter.pdf`

Chapters 2 and 3 outline the core philosophy of courses like this, and then we'll draw specific topics from Chapters 4–6 as they fit into the overall plan.

I'll keep you updated on other sources as we add them, in part driven by the demand from the class on what topics we cover. For the astrophysics topics, I suspect most of the material will ultimately be found in the highly recommended "Modern Astrophysics" textbook by Caroll & Ostlie. (AKA, the "Big Orange Book"). The entire conceit of this course is to be practicing calculations that can be finished fairly quickly on a blackboard, so we're more likely to be going broad than deep.

Web page: See Canvas for announcements, documents, readings, and assignments. We'll be making fairly heavy use of its discussion forum as a complement to our in-class exercises and for carrying out assigned exercises.

Grading

Course grades will use the plus/minus system, along with the standard cutoffs. There will be no rounding. The course grade will be driven almost entirely by participation with a couple of other small sources:

- Three in-class research summaries + problem solutions: 18%. There's an oft-repeated saying in academia that if you want to ask a few good questions, start by asking a lot of questions. So the idea here is to give you an opportunity to practice asking questions about others' research, as well as answering questions about your own research, in a low-stakes environment. Starting in week 3, we'll rotate through the class and each day, one person (starting with me!) will give a 10 minute summary of the research they're doing right now, or at least one piece of it. Each other person in the class will then have three days to post an Order-of-Magnitude question about the research talk to Canvas (in a discussion forum thread), and then the speaker will choose one of those questions (in consultation with me) and come back the next week (7 days later) to walk us through the Order-of-Magnitude solution.
- Participation: 85%. This is earned in equal amounts each day, and you can assume you've earned it unless I tell you otherwise. You earn this by attending class, participating in the group problem-solving exercises, and posting your relevant questions for your colleagues' research summaries. Among other things, to claim this I will expect pictures or screen caps of your work to be uploaded onto Canvas.

This may not add up to 100%, but the order of magnitude seems close enough.

I know that even without travel being allowed this semester, events can stop people from being able to attend class - observing runs, conferences, grad school visits, etc. Please check in with me ahead of time, and if it's for a justifiable reason, then it won't affect the participation grade.

Approximate Course Schedule

TBD. I have a fairly firm schedule for the first 5–6 weeks, but it gets fuzzier after that because I want to be able to respond to the interests of the class. My ideas are:

- Week 1: Estimation 101. (Number counts, sizes, time/size/velocity scales, etc.)
- Week 2: Scaling Relations (starting with OoM Applications of Kepler's Laws)
- Week 3-4: Dimensional Analysis
- Week 5: Cross-sections
- Week 6: Interaction Rates and Accretion
- Estimates from linearized differential equations
- OoM uncertainty estimation (and its limits)
- Observational planning
- Materials physics (chemical bonding, densities, etc)
- Wave Physics
- Virial theorem & applications
- Other topics requested by the class

The instructor reserves the right to change the course content as needed to match the pace of the class or to tell the class about breaking astronomical news.

Class Policies

- The course webpage and/or Canvas will be updated with announcements, reading assignments, and deadlines. It is your responsibility to check these on a regular basis. Please come to class prepared, having read the required reading assignments, since understanding the lectures and being able to take good notes will be crucial for doing well on homework and exams.
- Don't pack up or leave class early (or consistently come in late) unless you have talked to me in advance, as a consideration to me and your fellow students. There are $<$10 of you. I notice these things.
- Phones/tablets/laptops: We're all using some kind of computer, of course. I normally say that phone use during class is not allowed, and I'll emphasize that texting and social media are off limits. This is 2021, though, and we'll be talking about things where none of us necessarily knows the answer. Googling relevant topics is allowed. If you find something interesting, by all means, share.

Academic Dishonesty

University of Texas Honor Code: The core values of The University of Texas at Austin are learning, discovery ,freedom, leadership, individual opportunity, and responsibility. Each member of the university is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community. Students who violate University rules on scholastic dishonesty are subject to disciplinary penalities, including the possiblity of failure in the course and/or dismissal from the University. Standards for Academic Integrity are posted at http://deanofstudents.utexas.edu/sjs/acint_student.php.

In other words, you should turn in work that is your own.

Documented Disabilities

Please notify me of any modification/adaptation you may require to accommodate a disability-related need. The University of Texas at Austin provides upon request appropriate academic accommodations for qualified students with disabilities. For more information, contact Servies for Students with Disabilities at 471-6259 (voice) or 232-2937 (video phone) or http://www.utexas.edu/diversity/ddce/s

Email

Email is recognized as an official mode of university correspondence, so you are responsible for reading your email for university and course-related information and announcements. Please check your email regularly and frequently.