Guide to Getting the Most out of ASTR344
(Formerly known as the Syllabus)

Andrea’s Office Hours:  Mondays 1:30-3:30pm, Tuesday 10-11am, Thursday 11am-Noon, and by appointment. (I’m never on campus on Wednesdays.) I’d tell you my phone number if I knew what it was – they haven’t set up my phone yet. I promise you’ll be the first 11 people I tell.

What can I get out of this course?

Astronomy is not a practical subject. When people hear my research is supported by the National Science Foundation and NASA, and therefore by the taxes of U.S. Citizens, they usually ask about the "spinoffs." "There must be something useful that comes out of your work," they say. And I say, "Actually, no. There aren't really direct spinoffs." I can stretch a little bit and say things like "without General Relativity the GPS system on your phone won't work." Or "Pulsar Timing is the only thing pushing on terrestrial time standards (atomic clocks)." Both these things are true, and we will talk about both of them. But that's not the reason I do what I do. I think if we stop trying to understand the universe we live in, something fundamental about human nature dies. So really, what you can get out of this course is exhilaration and aliveness at a basic human level.

This class contains a lot of stuff that's not in a textbook anywhere, but rather is in recently published scientific articles. If you haven't had a lot of experience reading such things (and even if you have) they can be intimidating. You will develop strategies for dealing with these manuscripts. Reading them is a craft. If you notice at the beginning of the course that you're terrible at it, that's right where you should be. In addition to learning how to read these edge-of-knowledge articles, you will also expand your understanding to the edge of human knowledge in this field.

In one particular area you will become the class expert as you complete your own project. We will explore a lot of different subjects in this class, and perhaps not all of them to the extent you would want to. If, as we are leaving a subject, you notice you want to explore it further consider forming it into your project. As you explore this area you will get a feel for what it's like to be surpassing the expertise of your advisor (me, in this case), which can be both thrilling and frightening at the same time. To whom will you turn when you don't know the answer? You'll rely on skills you have been acquiring throughout your scientific career to build a case from available evidence. You'll rely on a peer network (all of the rest of us in this class) to tell you when your case needs bolstering, or to help unstick you when you've gotten stuck. Even though you may know more about it than us at that point, we still may be able to ask you questions and make suggestions that help you. We also may know people outside of our immediate community (the class) who can help - either at this institution or elsewhere. The completion of this project will build problem solving skills that you will use for the rest of your life, not just as a professional scientist, but in any career. As you advance in any career, there will be fewer and fewer basic skills, credentials, and training to acquire, and more and more innovations, new ideas, and frontiers to go beyond, for which no one can give you a recipe
or road map. At that point you have to gather the relevant evidence, make a plan, position yourself for success as best you can using calculation, estimation, your peer network, and your intuition, and forge ahead. This course will allow you explore this liminal space, and hopefully allow you to start to feel some sense of home there - on the edge where no one really has the answers yet.

This course will change the way you think about gravity for the rest of your life. If you've already taken General Relativity (a couple of you) it will give you a chance to explore the edge of our knowledge of the implications of General Relativity. For the rest of you, you will start to be able to think like a General Relativist. When you throw something or see something fall, or collapse, I want you to think, “that's spacetime curvature.” I want you to think about it enough in this course that you never quite think about it the same way again.

The theoretical framework of gravitational waves is contained in General Relativity, but I am assuming no knowledge of General Relativity (GR). There will be 4 weeks devoted to GR toward the end of the course, but by then you will actually be using some of the key results of GR. What those 4 weeks will give you is an appreciation for the mathematical derivation of those results, a deeper sense of what we mean by "curvature of spacetime," and a mathematical sense of how GR relates to the Force of Gravity with which you are more familiar. I learn best by bumping up against the limits of my knowledge until I get so annoyed that I need to learn the next thing. So you could say that the first 8ish weeks of the course are designed to give you enough exposure to gravitational waves without actually getting into the rigor of GR, so much so that by week 8 you're begging for the rigor of GR. Ultimately the math of GR will allow you to think at a higher level about things you've already successfully been thinking about. (You may have noticed this is true about Newton's laws. You can explain them to a non-physicist friend and they get them up to a certain point, but then there's a point at which you know the math and they don't, and that knowledge allows you to predict measurements that they can't predict.)

Astronomy is in the media a lot, which is a great thing, and this course is happening in the dawning of the era of gravitational waves so gravitational waves specifically are in the news a lot. We are going to take advantage of that! It means that the public appreciates what we do, albeit somewhat superficially, and with a journalist's slant. ("Life could be possible elsewhere in the universe!" They love to say that when all we've done is discover a planet that could be at a temperature that could have liquid water.) For the rest of your life, you'll be able to read popular science articles with a critical eye, know where to get more information for yourself from scientific sources, and make up your own mind about the discovery. Also, if you see articles involving gravitational waves please bring them to my attention. I'm pretty good at catching them, but I'm not perfect.

Problem Solving Promises

(The following are promises I put on all my syllabi. These are the promises of every physics/astrophysics course whether or not they are explicitly listed on the syllabus.)

How do you solve problems you've never seen before based on problems you have seen before? Let's say you're a medical doctor instead of a physicist. A patient comes to you with 4 symptoms you have
a lot of experience with and 3 more that you don't. How do you determine which details are nuisances that will take you down rabbit holes and which details give you clues to the solution you seek? In this course you have the opportunity to develop your ability to tackle problems you have never seen before.

Furthermore, in solving problems, everyone (doctors, musicians, biologists, computer scientists...) goes down paths that ultimately prove wrong. How can you use those (wrong) paths to gain important insights into the ultimate solution? In this course you have the opportunity to develop these skills. In this course you have the opportunity to develop your ability to make profitable "wrong turns" in problem solving.

How do you break down a really complex problem into solvable parts? Some parts you can separate and some you cannot. In this course you have the opportunity to develop your ability to tackle really complex problems by breaking them down, wisely, into parts.

What do you do with problems that are presented to you in a misleading way? This happens unintentionally all the time. One of your collaborators or a team member comes to you with problem that he/she is sure is caused by another person. Or a patient comes in with a set of symptoms and is sure she/he has strep throat and is prepared to convince you of this. You need to be the person who has enough perspective to consider that "Do you have strep throat?" is the wrong question. What's the right question? In this course you have the opportunity to develop your ability to deal wisely with the different pieces of information provided to you.

Finally, after you've come up with a solution to a problem, how do you determine if it is the right one? What checks can you do to confirm that your solution is the best one? In this course you have the opportunity to develop your skill at checking your answer, determining if its reasonable, and relating it to other things you know (without having a "back of the book" to check!)

Whew that was a lot. Here are the promises distilled down to a list of 11 things. (Anyone can go to 10. This one goes to 11!)

Promises of the Course. You will:
1. Experience exhilaration at a basic human level.
2. Learn how to read scientific articles.
3. Expand your knowledge to the edge of human understanding in the field of gravitational waves.
4. Become an expert in an area (a particular aspect of gravitational waves).
5. Develop problem solving skills, specifically in solving problems you've never seen before.
6. Think about gravity differently.
7. Develop a mathematical sense of what the "curvature" of spacetime is.
8. Evaluate and criticize the media's representation of science.
9. Develop your ability to make profitable wrong turns in solving problems. In other words, learn from your mistakes.
10. Develop your ability to break down complex problems into doable parts.
11. Develop your ability to determine if your answer is reasonable.
How to fulfill on the Promises of the Course

In order for me to deliver on the promises I just made, we need to engage in much more than me talking and you listening and you writing some stuff down and you handing it in. We need to be a team. Each of you has something to contribute to the operation of this team. Thank goodness not all of you has the same thing to contribute to the operation of the team. That would be boring and it wouldn't work very well. So first, please when you notice someone has something to contribute that isn't currently in your skill/knowledge set please practice saying something like, "This team is great! I'm glad we all have different skills."

Research shows that the more different ways you engage you with concepts, the more likely you are to be able to use that concept in the future. I am providing many different ways for you to engage the material.

Prepare for class by doing what I recommended you do after the previous class. (The grid associated with the syllabus has a column for this.) I will try to advise you in advance about which parts to pay special attention to, but knowing me I will forget sometimes, and in those cases please give some parts a try and come to class with questions. Class discussions will then clarify and strengthen your understanding of the material.

Homework. There are a variety of activities I will assign as homework, some of them will be more traditional homework problems, some of them will be coding (computer programming) assignments, some will be essays, some will be collaborative, and some will be presentations.

The goal of having a variety of exercises is to get you to think about the material in as many different ways as possible so as to deliver on the promises of the course. The more you work through things on your own, your retention of the information is significantly better. Ultimately to learn new things you have to build scaffolding in your own brain. Each member of our team will do this differently and we need to respect all of them.

I remember in college (Carleton) that when I would talk over a problem with my peer sometimes I would actually start to get mad, because I could tell they were thinking about it in a different way, and I wasn't ready to stop thinking about it my way yet. I knew I almost had a solution, and if I thought about it their way, I was going to have to take down my own scaffolding. At the time I doubt I could've articulated the idea of scaffolding. In any case, I hope I was pretty good at not actually getting mad at my friend, and saying "Thank you, I need to go work on this by myself a little bit now," and working by myself. Then when I had my scaffolding up - my way of understanding it, I could usually go back to that person and say, "could you tell me again how you solved it?" And then comparing my solution to theirs was really helpful and deepened my understanding of the problem.
Notice how you learn best. I suspect you each have different experiences solving problems and working with peers, so my point is that you should notice what ways of working deliver the largest gains in the promises of the course. I am asking nothing less than consciousness about the way you learn new things and you will write a paper about what you notice. I invite you to jot down some thoughts (starting with today’s paper, but also throughout the course) about what you noticed about your learning process at the end of each assignment and/or bring them up in class or office hours.

Peer Assistance: Overall I encourage you to work together with other students in the class on homework problems and get advice from each other about projects. Talking with other students about the problems is yet another way to engage with the material. It uses a different part of your brain and in particular will help you think about the different ways to do the problems. It can actually be disconcerting in a truly wonderful way to hear how classmates think about these problems. It makes you think critically at a really deep level. For example, your classmate may have arrived at the wrong answer using means that appear on the surface to be acceptable, or the right answer via a completely different method than what you used. You may get to discover together what is wrong or right! And if you don't, you should bring it to me and we can figure it out. The ability to notice that something is wrong is enormously important. When you notice that something has gone wrong please congratulate yourself that you know something has gone wrong instead of beating yourself up that you did something wrong. Honestly being able to smell a wrong answer is 75% of the way toward getting the right answer.

Working Together, Plagiarism, and the Honor Code. Working together means getting together to discuss problems, asking for help from other students on a step you are stuck on, or comparing solutions. I really encourage you to work together, and I know you will want to be mindful not crossing the line into plagiarism. Plagiarism is passing off someone else's work as your own. Let’s talk about this on the first day of class, and be sure to keep talking with me if you become concerned as you work with other students. We may come up with other solutions, but to start I’d like to start with the following suggestion: for the first couple of assignments I suggest you include very brief descriptions of where your ideas came from, e.g. “I got the idea to start the problem this way from Devon.”

How will my progress in accomplishing the promises of the course be adjudicated?

This is an interesting question, because the promises are enormous and some of them are impossible to test (like "you'll think about gravity differently for the rest of your life.") However, it's important to get feedback throughout the semester regarding what adjustments you need to make in order to fulfill on the promises. So how can I adjudicate whether or not you are making good progress toward what I promised you? I think of it like project management rather than grading. If I were Haverford's President and wanted a new building built by September 1st 2018, I wouldn't just say "Hey everybody, let's build this building by Sept 1 2018," and then check in with my team again a year later on Sept 1, 2018 and make sure it's done. I would have a lot of checkpoints along the way... we should
have bids by October, we should have a contract by November, the foundation should be dug by December, etc. You get the idea. Back to you. Getting feedback on your progress toward the promises is a multi-faceted task, just like your participation in the course in multi-faceted. In other words, I am looking at the whole constellation of your participation in this course, not just your performance on a few things.

Here is again a listing of the promises and in italics how I will assess your progress toward meeting them.

Goals:
1. Experience exhilaration at a basic human level. This is a little hard to test, but I will interview you individually during the course and attempt to detect the presence (or not) of exhilaration.
2. Learn how to read scientific articles. We’ll be doing this during class a lot, and then I’ll assess your progress with three assignments (early, middle, and late in the course) where you read an article and write critically about it. You’ll compile a portfolio of your work during the class, and I think you’ll see a lot of progress over the three assignments.
3. Expand your knowledge to the edge of human understanding in the field of gravitational waves. The assignments described in #2 (the article assignments) also assess this goal, because these articles will have been published very recently.
4. Become an expert in an area (a particular aspect of gravitational waves). This is assessed by your creation of your project presentation.
5. Develop problem solving skills, specifically in solving problems you've never seen before, and specifically problems in groups. You will get to demonstrate the progress of these skills on your regular homework assignments, and there will also be two take-home group assessment assignments (I supposed you could call them tests because you need to do them without me.) I want to be mindful of accommodations you may need during this assignment, and if it presents a hardship for anyone. Please let me know.
6. Think about gravity differently. You’ll write a very short paper for Thursday about your current idea of gravity, and a more formal paper toward the end of the course depicting your knew ideas for comparison.
7. Develop a sense of what the "curvature" of spacetime is. One of your regular homeworks, and one of the take-home group assessments will specifically deal with curvature.
8. Evaluate and criticize the media's representation of science. This will be a key part of the article assignments depicted in #2.
9. Make profitable wrong turns in solving problems. In other words, learn from your mistakes. You will invariably demonstrate this skill in the take-home assessments and also in the regular homework assignments.
11. Determine if your answer is reasonable. Ditto what I wrote in #9.

Here is a more detailed description of the elements of the course:

Three take-home writing assignments that happen at the beginning/end of the semester:
1) I give you a popular science article and you write a 2-page papers about (a) why the work is important, (b) what its main conclusions are (c) how it makes an advance based on previous
research (d) what you would do differently if you were doing the work (i.e. criticize their methods and/or their writing). You will need to find the scientific article to which it refers and also read that. You may consult any other articles you want, and any reference books, but no people. The second of the two would definitely be an EXTREMELY recently published paper on gravitational waves, thereby assessing whether they have expanded their knowledge to the edge of human understanding in the field.

Two take-home papers about gravity. One at the beginning and one at the end. The first one is a brief paper with no citations and no references and you're not allowed to look anything up because I really just want to hear what you remember. I'll hand you that assignment shortly. The second one will be more formal, and will require citations.

Two take-home group problem tests. These are done in groups of 3 and 4 and you are not allowed to talk with people outside your group. You are allowed to consult books and internet and articles. You are required to add two pages to the back of your solution describing the wrong-turns you made in devising your solution and what you learned from them. You should add one page describing the tests you made on your solution to determine if it is correct. It would be good if at least one of these tested the notion of Curvature of spacetime, since that is one of the goals. These take-home group problem tests would also incorporate (a) making profitable wrong turns, (b) breaking down a complex problem into doable parts and (c) determining whether the answer was correct or not.

Presentation on one area: assessed whether they've become an expert in their area.

Regular Homework: Finally there will be 6 relatively traditional homework assignments, with math, and right answers, and you showing your work.

Here is how I put everything together into a grade which is meant to measure your achievement of the course goals. When you turn in your final gravity paper, I'd also like you to turn in a binder that organizes all your work in the class as a portfolio of your participation. Please add at the front a two-page paper summarizing your sense of your progress through the course.

**Feedback Mechanisms and how they contribute to final grade**

<table>
<thead>
<tr>
<th>Feedback Mechanism</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Exhilaration Interview and Check-In</td>
<td>0%</td>
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<tr>
<td>Homework Assignments (6 solo HWs, first draft)</td>
<td>15%</td>
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<tr>
<td>Homework Revisions</td>
<td>5%</td>
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<tr>
<td>Group HW take-home assessments (2, HW3 and HW8)</td>
<td>10%</td>
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<tr>
<td>Press Release/Scientific Paper Writing Assignments (3)</td>
<td>15%</td>
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<tr>
<td>Paper on your mode in group work and learning style</td>
<td>15%</td>
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<tr>
<td>Project (15% paper, 10% presentation, 5% on class involvement)</td>
<td>30%</td>
</tr>
<tr>
<td>Gravity papers (before and after)</td>
<td>10%</td>
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**ACCOMMODATIONS**

Haverford College is committed to supporting the learning process for all students. Please contact me as soon as possible if you are having difficulties in the course. There are also many resources on campus available to you as a student, including the Office of Academic Resources.
and the Office of Access and Disabilities Services. If you think you may need accommodations because of a disability, please contact Sherrie Borowsky, Coordinator of Accommodations, Office of Access and Disability Services at hc-ads@haverford.edu. If you have already been approved to receive academic accommodations and would like to request accommodations in this course because of a disability, please meet with me privately at the beginning of the semester (within the first two weeks if possible) with your verification letter.