Astronomy 126 - Interstellar Medium
Swarthmore College
Fall 2008
Thursday, 1:15 - 4:15
Cornell 110
Prof. David Cohen

More than perhaps any other topic in astrophysics, studies of the interstellar medium (ISM) require us to marshal our basic physical understanding of gravity, plasma and radiation processes, different types of equilibria, spectral line formation and analysis, and gas dynamics in order to understand astrophysical phenomena. Furthermore, although the interstellar medium makes up only a fraction of the total mass of the galaxy, it is a very important component of the galaxy:

- It is the matrix in which star formation and star death occur.
- Its chemical abundances provide clues about past stellar evolution and even the formation of the galaxy.
- Its structure and dynamics provide information about past violent events (e.g. supernovae).
- The ISM affects observations of almost every distant astrophysical object.
- Accretion of interstellar gas powers the central engines of AGN.
- In the early universe, gas played an even more important role, relative to stars and galaxies; and intergalactic gas—which can be studied using many of the same techniques as interstellar gas—makes up a significant fraction of the baryonic mass of the universe at high red shift.

Our seminar will have two themes this semester. The first is the use of the ISM as a test-bed for understanding and applying basic physical processes. The second is the *multi-component* picture of the ISM (see problem #3 on the first week's assignment).

We will be using Dyson and Williams The Physics of the Interstellar Medium as our main text. The book is available in the bookstore and

should cost about $50. It's paperback and small. We will supplement this text quite extensively with other readings, including articles as well as textbooks. Two classic texts we'll use are Osterbrock's The Astrophysics of Gaseous Nebulae and Active Galactic Nuclei and Spitzer's Physical Processes in the Interstellar Medium. These two books are written for graduate students, but we can use them if we're careful. These books and others are on the class honors reserve shelf in Cornell (not behind the desk, but near the windows and over a low shelf on your right as you walk in the front door of the library).

Some of the **topics** we'll be studying this semester will include:

1. The very local ISM
2. ISM abundances and dust
3. H II regions (Stromgren Spheres; ionized nebula surrounding hot stars)
4. Molecular clouds and star formation
5. Supernovae explosions
6. The three-phase (McKee-Ostriker) picture of the interstellar medium

A detailed syllabus will be handed out at the beginning of the semester.

These are subject to change, and may be combined in various ways. For each topic, there are theoretical and observational issues which we must cover first (or concurrently). Thus, I envision pairing readings in the text (usually Dyson and Williams, but sometimes supplemented with sections of chapters from the other two books) with more topical articles.

In fact, we will read a fair number of research and review articles. These will give you a much better sense of open questions and controversy in the field than any textbook can.

In the first two class meetings, we'll cover the material in chapters 1 and the first half of 2 of Dyson and Williams, with an emphasis on using absorption lines to study gas clouds in the ISM. We'll then apply these physical techniques to the study of the local ISM – using real data – specifically to the study of absorption line diagnostics of the local interstellar medium.

We will come back to the local ISM repeatedly, since issues of abundances, photoionization, supernovae impacts on the ISM, and the multi-phase picture of the ISM are all relevant here, and because it's easier to study in many ways due to its proximity and relative simplicity, and also because we have extra information about the local ISM from measurements made of material right her in the solar system (and from clues based on how the solar wind interacts with the very local ISM).

Procedures and Policies:

Your grade will depend on your preparation and participation in class, as well as the midterm and final. Most of our assignments will include a list of comments and questions that you should look over before you do the reading, and in response to which you should jot down notes as you read. The purpose of these is to help you figure out what the most important points in the reading are and to prepare you for topics we're likely to discuss in our seminar meetings. You generally will *not* have to hand in your notes written in response to these questions and comments. (Though I may change this practice, depending on how our seminar discussions go.) There will be more standard, generally quantitative problems too, and also small presentations on specific topics. These will be numbered, and you will write up solutions to these problems by the *morning of the Wednesday before our Thursday seminar* meeting. They will be handed in the mailbox outside my office door (SC 125) by 9:30 on Wednesday morning in order for you to get full credit.

I will look over your solutions (or presentation notes, as the case may be), give you some feedback/comments, and hand them back to you by Wednesday at 5:30 PM. This way, you can refresh your memory, see what items you might need to brush up on before our seminar meeting the following afternoon, and see if you've got any new questions you'd like to see addressed in seminar. If I tell you in my written comments that your answer to a question is wrong or inadequate or that your presentation looks thin or poorly focused, I will expect you to correct these problems prior to the seminar meeting (but not hand in any new written work; just be prepared to do a better job when/if you present the material in seminar).

I will grade your solutions, but relatively leniently – on a A, B, C… scale. You will get an A if you make a decent attempt to thoroughly answer each question and have the right answer or something close for most of them. But I do expect you to hand in work of the quality, neatness, and completeness that you'd demonstrate for a regular problem set. My goal here is to have a system that rewards you for doing a careful job of preparing, with the bulk of the work done well

before we meet (so I can give you feedback and to keep you from doing all the work in the last minute, the night before seminar), and to encourage you to plan for our discussions in seminar (which will follow the comments and questions I mentioned above), not just focus on the algebra, etc. that's required to solve the problems. I will *not* be collecting assignments in the seminar or giving you post-seminar assignments. I don't really want students engrossed in copying down algebra/numbers from the board while we're going over problems in class. However, there will be motivation to make sure you can correctly solve all the problems on a given assignment by the time that week's seminar meeting is over, because similar problems will appear on our midterm and final. I will *not* be handing out my own solutions to the problems.

If your assignment is late, but handed in prior to seminar, you will get at most a B. Assignments handed in after seminar (begins) will get no credit. These assignments will be worth 30% of your grade, with the midterm also being worth 30% and the final 40%. Good class participation is expected, and will boost your final grade modestly. In my experience, though, it's hard to participate well in seminar if your assignment hasn't been done well. Remember: your fellow students are counting on you to do a good job since they will be relying on you to learn how to do the problems they struggled with and to give clear presentations on material for which you are the "local expert" (by virtue of being assigned a presentation on a particular topic).

If you are sick, have a family or personal emergency, or some similar situation, let me know as soon as possible if you think it will prevent you from getting the week's assignment done. We'll see what we can do, in that case, but it is imperative that you contact me as soon as possible and certainly before the assignment is due.

At the beginning of the semester (like, *NOW*), you should **review** what you learned in Astronomy 16 about the ISM, using your notes and old textbooks. You can also check out some of the resources at hven.swarthmore.edu/resources.html, such as the *Encyclopedia of Astronomy and Astrophysics*.

You should review enough to be able to answer and discuss – prior to our fist seminar meeting – the following questions:

How do we know that there's dust in interstellar space?

How about neutral gas? Ionized gas? Molecules? Magnetic fields? Cosmic rays?

What determines the size of an H II region? Why should an (idealized) H II region have a relatively sharp boundary?

How does the measurement of the amount of extinction per unit distance tell us the average density of dust particles in space?

What physical properties can be learned from a spectrum?

What's the physical process by which hydrogen emits 21 cm radiation?

What's the virial theorem?

What do the following terms mean?

- Radiative recombination
- Free-free emission
- Synchrotron radiation
- Molecular cloud