Basic information

Title	ASTR 670 • Interstellar medium and gas dynamics
Website	ELMS/Canvas
Location	Computer Science Instructional Center (CSI), Room 1122
Lecture times	Tue/Thu 2:00 – 3:15pm
Instructor	Benedikt Diemer (he/him)
Email	diemer@umd.edu
Office	PSC 1107
Office hours (on zoom)	Monday 3-4pm, or by appointment

Description

The effects of hydrodynamics are ubiquitous in the Universe, from the large-scale distribution of hydrogen to the atmospheres of planets. We will understand the equations of hydrodynamics and their basic consequences, such as waves, instabilities, and shocks. Rather than deriving the equations in detail, we will focus on hands-on exercises to solve them numerically. One particularly important gas system is the interstellar medium (ISM), the gas in galaxies. The ISM is composed of numerous phases that exhibit different temperatures and thus experience numerous different, complex physical processes; we will survey the most important ones.

By the end of the course, you will be able to…

- describe the physics of gas and fluids via the equations of hydrodynamics
- use numerical codes to solve and visualize complex hydrodynamic problems
- appreciate the numerous applications of hydrodynamics in astrophysics
- apply your knowledge to the specific problem of the interstellar medium
- understand the microscopic processes that determine the state of the ISM

General expectations

Given that this is a graduate course, I will not spell out detailed expectations and course policies in this syllabus. Most importantly, please bring your own initiative and curiosity! The goal is not to get a good grade but to develop a deep understanding of the subject that will serve you throughout graduate school and beyond.

Attending the lectures is key, of course. I ask that you put your phones away during class and actively participate; I will try to make the lectures as interactive as possible. The idea is to learn together, rather than for me to hold a monologue. Please feel free to reach out if you need help with the course material or with any other issue that might be preventing you from staying on top of the course.

This course contains a significant computing component, building on ASTR 615. I will expect a foundation in python and general computing, such as consoles and Unix. While I am happy to discuss algorithmic and numerical issues, I hope you understand that I will not debug your code for you.

Course policies

Grading: Your grade will be composed of 5 homework sets, a hands-on numerical project, and two exams. Late homework will only be accepted for excused, documented absences. While you are encouraged to discuss with your peers, your homework and project need to be the result of your own work, thinking, and understanding. Please see shc.umd.edu for information on academic integrity and ugst.umd.edu/courserelatedpolicies.html for general UMD course policies.

Type of grade	Weight
Homework	35%
Semester project	15%
Midterm exam	20%
Final exam	30%

Learning environment: This course encourages scientific discussion and collaboration as a means of learning. Thus, we will find ourselves in disagreement or debate at times. It is important that we agree to conduct our conversations in a professional manner and to foster an environment in which everyone feels included and respected. I will make every reasonable attempt to create an atmosphere in which every student feels comfortable voicing their argument without fear of being personally attacked, mocked, demeaned, or devalued. Any behavior that threatens this atmosphere will not be tolerated, including harassment, sexual harassment, and derogatory language with respect to race, gender, nationality, or any other personal characteristic. Please let everyone speak and respect each other's point of view. Please alert me immediately if you feel threatened, dismissed, or silenced at any point during the semester or if your engagement in our discussions has been hindered by the learning environment in any way.

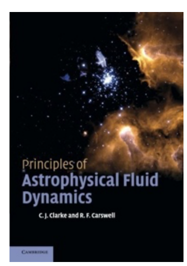
Possible changes due to COVID

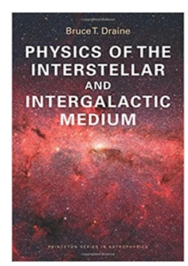
I have made my best effort to adjust the course to the current environment, but we live in quickly changing times! Our course might need to adapt, including the schedule and grading scheme. If the University closes the campus, we might need to switch to an online format on short notice.

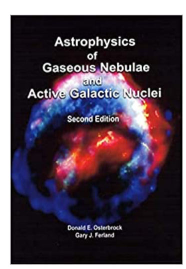
Textbooks

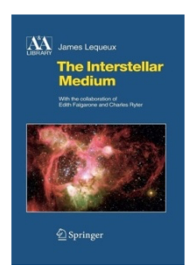
There is no one book that covers the full contents of this course. We will use a number of books; you do not necessarily need to purchase them, although Bruce Draine's text will be essential.

- Cathie **Clarke &** Bob **Carswell**
  Principles of astrophysical fluid dynamics
  Cambridge University Press, ISBN 978-0511813450
- Bruce **Draine**
  Physics of the interstellar and intergalactic medium
  Oxford University Press, ISBN 0-19-853096-X
- Donald **Osterbrock** & Gary **Ferland**
  Astrophysics of Gaseous Nebulae and AGN (2nd ed.)
  University Science Books, ISBN 978-1891389344
- James **Lequeux**
  The interstellar medium
  Springer, ISBN 3540213260









Semester schedule

This schedule is preliminary and likely to evolve during the semester. I will assign the required and recommended readings as we go along. The abbreviations are "CC" for Clarke & Carswell, "D" for Draine, "OF" for Osterbrock & Ferland, and "L" for Lequeux.

Date		#	Topic	Suggested Reading
Part I: Hydrodynamics				
Tue	01/26/2021	1	What is hydrodynamics?	CC §1.1-1.2
Thu	01/28/2021	2	The equations of hydrodynamics	CC §1.3-2.3, 4.3
Tue	02/02/2021	3	Equilibrium and steady flows	CC §5.1-5.3, 9.1
Thu	02/04/2021	4	Waves	CC §6.1
Tue	02/09/2021	5	Numerical hydrodynamics I	---
Thu	02/11/2021	6	Numerical hydrodynamics II	---
Tue	02/16/2021	7	Shocks	CC §7.1
Thu	02/18/2021	---	(Cancelled)	---
Tue	02/23/2021	8	Blast waves	CC §7.2, 8.1-8.3
Thu	02/25/2021	9	Numerical hydrodynamics III	---
Tue	03/02/2021	10	Higher-order schemes & Fluid instabilities	CC §10.1-10.2
Thu	03/04/2021	11	Magneto-hydrodynamics I	CC §13.1-13.2
Tue	03/09/2021	12	Magneto-hydrodynamics II	CC §13.4-13.7
Thu	03/11/2021	---	Midterm exam	---
Part II: The interstellar medium				
Tue	03/23/2021	13	Introduction to the ISM	D §1.1
Thu	03/25/2021	14	The phases of the ISM	D §1.2-3
Tue	03/30/2021	15	Collisional ionization and cooling	D §10.1, §34.1-2
Thu	04/01/2021	16	Supernovae and stellar winds	D §38.1, §39.1-2
Tue	04/06/2021	---	Project presentations I	---
Thu	04/08/2021	---	Project presentations II	---
Tue	04/13/2021	17	Atomic physics I: Photoionization	D §3.1-6, §4.1-5, §13.1, §14.1-2
Thu	04/15/2021	18	H II regions	D §15.1-3, §27.4, OF §2.1-3, §3.1-3
Tue	04/20/2021	19	Atomic physics II: Levels and excitation	D §6.1-2, §6.7, §17.1-2, §18.1-2
Thu	04/22/2021	20	Atomic gas	D §8.1-2, §17.3, §29.1-2
Tue	04/27/2021	21	Atomic physics III: Molecules	D §5.1, §31.1-4, §31.7, §32.1
Thu	04/29/2021	22	Molecular clouds and dust	D §19.1-3, §21.1, §23.1, §32.9
Tue	05/04/2021	23	Star formation	D §41.1, §42.3-5
Thu	05/06/2021	24	Turbulence	L §13.2-3
Tue	05/11/2021	25	Multiphase models of the ISM	D §30.4, §39.4
Mo	05/17/2021	---	Final exam (10:30 – 12:30)	---