Basic information

Title	ASTR 670 • Interstellar medium and gas dynamics
Website	ELMS/Canvas
Location	Cambridge Community Center (CCC) 1115
Lecture times	Tue/Thu 2:00 – 3:15pm
Instructor	Benedikt Diemer (he/him)
Email	diemer@umd.edu
Office	PSC 1107
Office hours (on zoom)	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 gaseous system is the interstellar medium (ISM), i.e., the gas between the stars in galaxies. The ISM is composed of numerous phases that exhibit different temperatures and thus experience 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

Your most important contribution to this course will be to actively participate, that is, to attend class in person (zoom will generally *NOT* be an option), ask questions, and stay engaged throughout. Please bring your initiative and curiosity! The main goal is not to satisfy some grading rubric but to develop a deep understanding, as well as skills that will hopefully serve you throughout graduate school and beyond.

Most material will be covered in lectures, but be prepared for some independent study as well. Most notably, you will complete a substantial project over a few months towards the end of the term and present it in class. The projects consist of a mixture of literature review, coding, simulations, and/or math.

This course contains a significant computational component. It is totally fine to start without much foundation in python or coding, but in that case you will need to develop your programming skills rather quickly along the way. While I am happy to discuss algorithmic and numerical issues, I hope you understand that I will not debug your code for you.

One final, important expectation is for you to reach out proactively if you need my help or advice, be it with the course material or with any other issue that may prevent you from staying on top of the course.

Course policies

Type of grade	Weight
Participation	10%
Homework	35%
Term project	20%
Midterm exam	15%
Final exam	20%

Grading: Your grade will be composed of a participation score, about five homework sets, a term project, and two exams. The participation score will be based on in-person attendance and contributions to discussions during lectures. Late homework will only be accepted for excused, documented absences. The final grades will be curved such that an A corresponds to a strong and a B to an acceptable performance.

Collaboration on assignments: While you are encouraged to discuss with your peers, your homework and term project need to be the result of your own work, thinking, and understanding. Please see the UMD sites on academic integrity and general course policies.

Use of AI: You are permitted to use AI tools as a starting point or support for writing and coding. However, the final product (whether writing or code) must be the result of your individual thinking and creativity.

Learning environment: This course encourages scientific discussion as a means of learning, meaning that 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 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 has been hindered by the learning environment in any way.

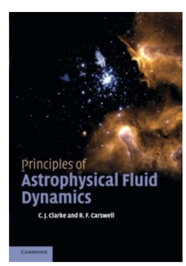
Textbooks

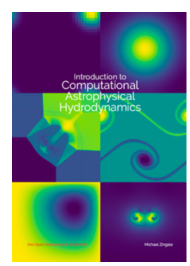
There is no one book that covers the entire content of this course. We will use a number of books, but you do not need to purchase them. The first two books will serve as companions to the hydro part:

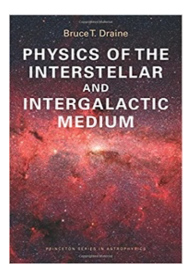
- Cathie **Clarke &** Bob **Carswell**
  Principles of astrophysical fluid dynamics
  Cambridge University Press, ISBN 978-0511813450
- Michael **Zingale**
  Computational astrophysical hydrodynamics
  The astrophysical bookshelf (open-source)

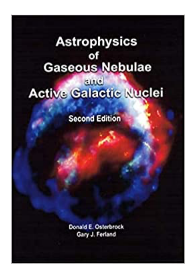
For the ISM part, Bruce Draine's text is "the bible." Especially if you plan to do research in an ISM-related field, this might be the one book to purchase. We will use the other books(s) less frequently:

- 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









Semester schedule

This schedule is preliminary and likely to evolve during the semester. The abbreviations are “CC” for Clarke & Carswell, “Z” for Zingale, “D” for Draine, and “OF” for Osterbrock & Ferland.

Date		#	Topic	Book reading
Part I: Hydrodynamics				
Tue	01/28/2025	1	Ch. 1: From particles to fluids	CC §1.1-2
Thu	01/30/2025	2	Ch. 2: The Euler equations	CC §1.3-5, §2.1-3, §4.1, §4.3
Tue	02/04/2025	3	Ch. 3: Equilibrium and steady flows	CC §4.2, §5.1-3, §9.1
Thu	02/06/2025	4	Ch. 4: Sound waves	CC §6.1
Tue	02/11/2025	5	Ch. 5: Computational hydro I	Z §1-1.2.1, §2, §3.1-2, §7.1
Thu	02/13/2025	6	Ch. 6: Computational hydro II	Z §1.2.2, §1.2.5, §4.1-3
Tue	02/18/2025	7	Ch 7: Shocks	CC §7, §8.1-3, Z §6.1
Thu	02/20/2025	8		
Tue	02/25/2025	9	Ch 8: Computational hydro III	Z §7.2, §8.1-4
Thu	02/27/2025	10		
Tue	03/04/2025	11	Ch 9: Fluid instabilities	CC §10.1-2
Thu	03/06/2025	12	Ch 10: Magnetohydrodynamics	CC §13.1-4
Tue	03/11/2025	---	Midterm exam	---
Part II: The interstellar medium				
Thu	03/13/2025	13	Ch 1: Introduction: What is the ISM?	D §1
Tue	03/25/2025	14	Ch 2: The hot ionized medium	D §10.1, §34.1-2, §38.1, §39.1-2
Thu	03/27/2025	15		
Tue	04/01/2025	16	Ch 3: Atomic physics I	D §3.1-6, §4.1-6, §6.1-2, §6.7
Thu	04/03/2025	17		
Tue	04/08/2025	18	Ch 4: Neutral atomic gas	D §8.1-2, §17.1-3, §29.1-2
Thu	04/10/2025	19	Ch 5: Atomic physics II	D §13.1, §14.1-2, OF §2.1-2
Tue	04/15/2025	20	Ch 6: Photoionized gas and H II regions	D §15.1-3, §18.1-2, §27.4, OF …
Thu	04/17/2025	21	Ch 7: Atomic physics III	D §5.1, §31.1-4, §31.7
Tue	04/22/2025	22	Ch 8: Molecular gas and GMCs	D §19.1-3, §21.1, §23.1, §32.1, §32.9
Thu	04/24/2025	23	Ch 9: Star formation in a turbulent ISM	D §41.1, §42.3-5
Tue	04/29/2025	24		
Thu	05/01/2025	25	Ch 10: Global models of the ISM	D §30.4, §39.4
Project presentations and Final exam				
Tue	05/06/2025	---	Project presentations	---
Thu	05/08/2025	---	Project presentations	---
Tue	05/13/2025	---	Project presentations	---
Mo	05/19/2025	---	Final exam (10:30am – 12:30pm)	---