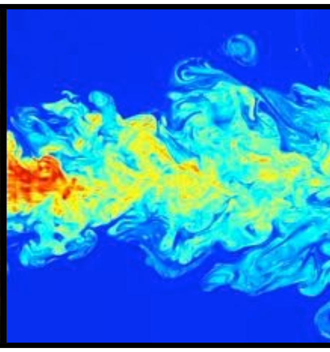
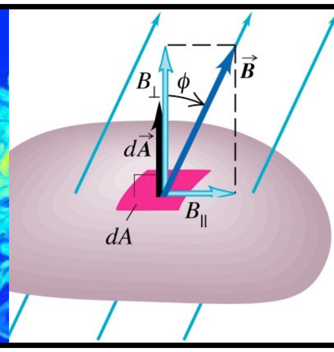
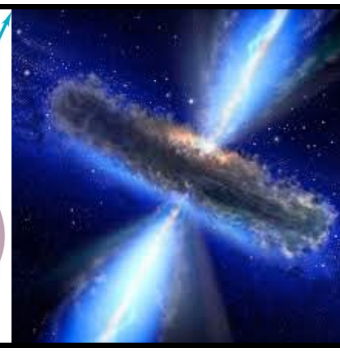
ASTR0 595; Spring Semester 2020

Astrophysical Flows




Course Description

This course presents an in-depth treatment of the dynamics of astrophysical fluids, including both collisional and collisionless fluids, as well as neutral and charged fluids (plasmas). After a first-principles derivation of the various fluid equations (continuity, momentum and energy) linking continuum mechanics to kinetic theory, and a discussion of astrophysical equations of state, we will focus on specific types of flows, including inviscid barotropic flow, turbulent flow, viscous accretion flow, shocks, and spiral density waves. We then study various fluid instabilities (convective instability, thermal instability, interface instabilities, gravitational instability) with applications to astrophysics. Next we discuss numerical hydrodynamics, and end with a treatment of plasma physics, including plasma orbit theory, magneto-hydrodynamics (MHD), magnetic tension and Alfvén waves, the Vlasov equation and the two-fluid model, magnetic reconnection and dynamos, and various astrophysical applications of plasma physics.

Instructor: Prof. Frank van den Bosch (52 Hillhouse, Office: 320)
frank.vandenbosch@yale.edu

Course Website: https://campuspress.yale.edu/astro595/

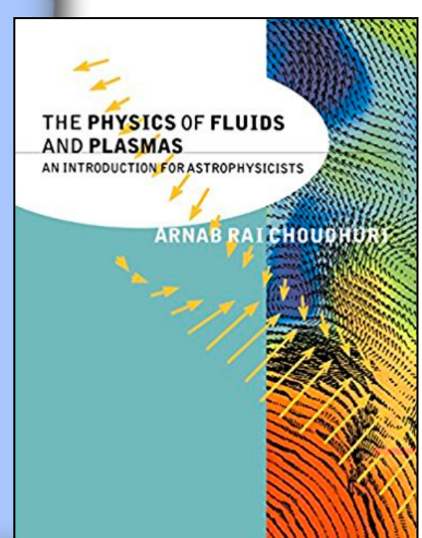
Lecture Hours: MW 9.00 - 10.15am Location WTS A60

Office Hours   : W   4.00 - 5.00pm   Location 52HH#320

Recommended Textbook: The Physics of Fluids and Plasmas: An Introduction for Astrophysicists

Grading: 35% Final Exam
35% Problem Sets
30% Term Paper

Lecture Format: Blackboard presentations
+ detailed lecture notes



Preliminary Schedule

week	Date	Topic
1	Mon 01/13	**Introduction:** Fluids & Plasmas
1	Wed 01/15	**Fluid Dynamics:** the basic equations of fluid dynamics & closure conditions
1	**Fri** 01/17	**Fluid Dynamics:** the stress tensor & viscosity; from Euler to Navier-Stokes
2	Wed 01/22	**Fluid Dynamics:** kinetic theory I; From Liouville to Boltzmann
3	Mon 01/27	**Fluid Dynamics:** kinetic theory II; From Boltzmann to Navier-Stokes
3	Wed 01/29	**Fluid Dynamics:** Vorticity & Kelvin's Circulation Theorem
4	Mon 02/03	**Fluid Dynamics:** Incompressible & Barotropic Flows
4	Wed 02/05	**Fluid Dynamics:** Viscous Flows [incl. accretion disks]
5	Mon 02/10	**Fluid Dynamics:** Turbulence
5	Wed 02/12	**Fluid Dynamics:** Sound waves
6	Mon 02/17	**Fluid Dynamics:** Instabilities
6	Wed 02/19	**Fluid Dynamics:** Shocks
7	Mon 02/24	**Numerical Hydrodynamics:** simulation basics
7	Wed 02/26	**Numerical Hydrodynamics:** solving PDEs and ODEs with Finite Difference Methods
8	Mon 03/02	**Numerical Hydrodynamics:** towards a simple1D hydrodynamics code
8	Wed 03/04	**Numerical Hydrodynamics:** state of the art
9	Mon 03/09	**NO CLASSES [SPRING BREAK]**
9	Wed 03/11	**NO CLASSES [SPRING BREAK]**
10	Mon 03/16	**NO CLASSES [SPRING BREAK]**
10	Wed 03/18	**NO CLASSES [SPRING BREAK]**
11	Mon 03/23	**Collisionless Dynamics:** CBE, Jeans equations & orbit theory
11	Wed 03/25	**Collisionless Dynamics:** impulsive encounters & dynamical friction
12	Mon 03/30	**Plasma Physics:** important length and time scales
12	Wed 04/01	**Plasma Physics:** plasma orbit theory
13	Mon 04/06	**Plasma Physics:** magnetohydrodynamics (MHD)
13	Wed 04/08	**Plasma Physics:** MHD waves
14	Mon 04/13	**Plasma Physics:** Dynamo theory
14	Wed 04/15	**Collisional Dynamics:** Langevin equation & the Fluctuation-Dissipation Theorem
15	Mon 04/20	**Collisional Dynamics:** Markov Processes & the Fokker-Planck equation
15	Wed 04/22	**Q&A and General Review**

The Road To Success

This course will make use of **vector calculus** and **multi-variable calculus**, and the students are expected to be familiar with this. Appendices **A**-**C** in the lecture notes summarize these materials, and the students are strongly encouraged to read these Appendices in detail. Also, Problem Set 1 will test/revive the student's ability with these topics.

➢ Attend **lectures**, and actively participate; ask questions in class!

➢ Carefully read **Lecture Notes** on related material. Study the relevant material using text books, internet etc. (**self-study**)

➢ Seek **help** from instructor
(after class, during office hours, or by arranging for an appointment via e-mail)

➢ **Problem Sets**:

* submit problem sets on time (points will be subtracted for late submissions)
* explain how you came to the solution (derivations), and use words/text to explain your line of thoughts. Failure to do so results in points being subtracted.
* Write clearly and neatly: if I can't read it, I won't give points for it.
* When working on the problem sets, you may consult your fellow students. However, when it comes to writing the solution down, you must do so all by yourself.