AST 4930: Star Formation

Spring 2021

Instructor:	Prof. Adam Ginsburg	**Time:**	M,W,F — Period 9 (16:05 - 16:55)
Email:	adamginsburg@ufl.edu	**Place:**	FLG 0245
		Office Hours:	Friday 1pm-2pm and by appointment

Timing / Structure:
The course will be taught primarily in person. Class periods will consist of lectures. The course will be taught largely as a classic lecture course so that we can cover a wide range of material. Active learning will be employed when possible.

Active Learning is when the learner is engaged directly by solving problems and discussing or presenting material - i.e., not just listening and taking notes. There is extensive evidence that active learning is more effective than passive learning, but it only works when the student buys in to the process.

The primary assessment method in the course is via homeworks. Homework is a form of asynchronous active learning. The homeworks are set up as a combination of derivations, numerical problems, and discussion problems. They are intended to provide practice with the methods discussed in class and to stimulate understanding of the science of star formation.

Course Pages:

1. https://ufl.instructure.com/courses/526135
2. https://github.com/keflavich/StarFormationClass

Communication:
Communication will be via e-mail, Canvas, & Zoom.

Office Hours:
Office hours will be held in person, though zoom meetings can be scheduled as an alternative.

Main References:

- Star Formation Notes by Mark Krumholz https://github.com/Open-Astrophysics-Bookshelf/star_formation_notes, https://open-astrophysics-bookshelf.github.io/
- The Formation of Stars by Steven Stahler and Francesco Palla https://ui.adsabs.harvard.edu/abs/2004fost.book.....S/abstract
- Accretion Processes in Star Formation by Lee Hartmann https://ui.adsabs.harvard.edu/abs/1998apsf.book.....H/abstract
- Tom Megeath's "The Secret Lives of Stars" http://astro1.physics.utoledo.edu/~megeath/ph6820/ph6820.html

Objectives: You will learn the fundamentals of star formation, from gravitational collapse of a molecular cloud to formation of a nuclear burning core.

You will gain experience solving physical problems and developing physical insights. You will learn about physical processes and order-of-magnitude estimation techniques.

This class will fill in the size scales between ISM and stars, and will have some overlap with each.

Course Outline:

Learning goals of the course:

1. Understand the fundamentals of star formation theory and observables
2. Practice formulating, and answering, questions for research
3. Learn key concepts and practice working with them to develop a vocabulary for discussing star formation

Grading Policy:

- Class Assignments and participation, homework (65%)
- Project (35%)

The late policy is 10% credit lost per day. However, I generally will give extensions if late assignments are well-justified and excused in advance. If you request an extension after the deadline, a doctor's note or equivalent is required. No credit will be given for the final project if it is late.

More information on UF grading policies is here: https://gradcatalog.ufl.edu/graduate/regulations/#text

Letter grades are:

Letter	Minimum %
A	93
A-	90
B+	87
B	84
B-	80
C+	77
C	74
C-	70
D+	67
D	64
D-	60

I reserve the right to curve the class such that your scores improve if the final score distribution is lower than I expect. This can only help your grades; I will not apply a curve to reduce your score below the raw score.

Attendance

Attendance is required in class. Part of your grade for the semester is based upon class participation during the class sessions. If you feel that you have a situation that may allow for a make-up, contact the professor immediately via email.

Excused absences are consistent with university policies in the graduate catalog (https://catalog.ufl.edu/graduate/regulations/#text) and require appropriate documentation.

Course Communication Policy:

- We will use Canvas for announcements and other digital communication, so you are expected to regularly check Canvas.
- The instructor can be contacted via e-mail at adamginsburg@ufl.edu
- Zoom will be used for remote meetings and/or recordings.
- Regular attendance in person is essential and expected.

Students Requiring Accommodations

Students with disabilities requesting accommodations should first register with the UF Disability Resource Center (352.392.8565) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodations. Students with disabilities should follow this procedure as early as possible in the semester

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

Health absence policies

We will have face-to-face instructional sessions to accomplish the student learning objectives of this course.

- If you are experiencing any symptoms of respiratory disease (cold, flu, covid), please do not attend class.
- You are requested to wear approved face coverings when appropriate.
- If you are sick, course materials will be provided to you with an excused absence, and you will be given a reasonable amount of time to make up work. Find more information in the university attendance policies.

Online Teaching Policy (applies only to Zoom class sessions)

Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or

video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

Students are requested, but not required, to keep their video on during Zoom meetings. During breakout sessions and interactive work sessions held on zoom, both audio and video participation will be required. Students must have a functional webcam and microphone.

Class Demeanor (in person)

Students are expected to arrive to class on time and behave in a manner that is respectful to the instructor and to fellow students. Please avoid the use of cell phones and restrict eating to outside of the classroom. Opinions held by other students should be respected in discussion, and conversations that do not contribute to the discussion should be held at minimum, if at all.

Materials and Supplies Fees

There are no additional fees for this course.

University Honesty Policy

UF students are bound by The Honor Pledge which states, '*We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity by abiding by the Student Honor Code. On all work submitted for credit by Students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment."*' The Honor Code specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TA in this class. https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/

Counseling and Wellness Center

Contact information for the Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc/Default.aspx, 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Homework

Submit homeworks via Canvas. Always submit a pdf, and please also submit jupyter notebooks (ipynb) if you used them.

Some of the homeworks have problems tagged with (G). These problems are added for the graduate version of this class. You may attempt these for up to an additional 10% of extra credit (I'm keeping this bonus small, given the amount of work, because I don't want to tempt you to go overboard).

Homework schedule

1. Problem Set 1: Jan 13 - Jan 24
2. Problem Set 2: Jan 24 - Feb 14
3. Problem Set 3: Feb 14 - Feb 28
4. Problem Set 4: Feb 18 - Mar 14
5. Problem Set 5: Mar 24 - Apr 4

Preliminary Schedule

Dates are Monday of the week; we meet M/W/F

- Week 1 (Jan 13, 15, 17): Syllabus, meta-discussion, molecular clouds & gravitational collapse (Krumholz Ch 6)
  Problem Set 1
- Week 2 (Jan 22, 24): Molecular Clouds & Gravitational Collapse: Krumholz Ch 6, Megeath lecture 7
  Problem Set 1 Due
  Problem Set 2
- Week 3 (Jan 27, 29, 31): Cores & Gravitational Collapse
- Week 4 (Feb 3, 5, 7): Protostar Formation: Krumholz ch 16, 17
- Week 5 (Feb 10, 12, 14): Accretion, Core temperature structure
  Problem Set 2 due
  Problem Set 3
- Week 6 (Feb 17, 19, 21): Protostellar evolution tracks
- Week 7 (Feb 24, 26, 28): Disks
  Problem set 3 due
  Problem set 4
- Week 8 (Mar 3, Mar 5, Mar 7): Outflows
- Week 9 (Mar 10, 12, 14): Turbulence
  Reading for Final Project due
  Problem set 4 due
  Problem set 5
- Spring break.
- Week 10 (Mar 24, 26, 28): Shocks [Adam traveling Mar 28: JSTUC]
- Week 11 (Mar 31, Apr 2, 4): Binaries
  Problem set 5 due
- Week 12 (Apr 7, 9, 11): High-mass star formation
- Week 13 (Apr 14, 16, 18): The IMF
- Week 14 (Apr 21, 23): Astrochemistry

- Week 15 (Finals)

General topics covered

Clouds to Stars:

- Pressure support and spherical collapse
- The Hayashi track, Kelvin-Helmholtz contraction
- Bondi-Hoyle accretion
- Turbulence
- The initial mass function
- Star clustering
- Triggered star formation
- Dust

Disks:

- The Toomre instability
- Dust growth, protoplanet formation
- Disk heating, passive disks

Feedback:

- Accretion and outflow shocks
- Photoionization, HII regions

Additional Presentation topics:

- Collisional formation of massive stars
- Fluid instabilities in the ISM (Kelvin-Helmholtz, Rayleigh-Taylor)

- Turbulence: Any subtopic you like. (statistical characteristics, generation, dissipation, observations)
- Shocks (Rankine-Hugoniot Jump Conditions)
- Dust from clouds to cores to disks

Topics from Tom Megeath's class: **Bold** will be covered here. *Italics* are optional.

- Lecture 1: Introduction to Young Stellar Objects
- Lecture 2: **Molecular Clouds: Galactic Context and Observational Methods**
- Lecture 3: **Molecular Cloud: Properties and Evolution**
- Lecture 4: **Molecular Cloud: Turbulence and Magnetic Fields**
- Lecture 5: **Dense Cores: Observations**
- Lecture 6: **Isothermal and Bonner Ebert Spheres**
- Lecture 7: **The Collapse of Cores and Infall**
- Lecture 8: **Protostars and the Collapse of Rotating Cores**
- Lecture 9: **The Spectral Energy Distributions of Protostars and Disks**
- Lecture 10: **The Spectral Energy Distributions of Disks**
- Lecture 11: *The Evolution of Disks*
- Lecture 12: **The Initial Mass Function**
- Lecture 13: **Clusters and Associations**
- Lecture 14: *Viscous Accretion Disks*
- Lecture 15: *Magnetospheric Accretion*
- Lecture 16: *Outflows*
- Lecture 17: **High Mass Star Formation**
- Lecture 18: **Pre-main Sequence Stars**
- Lecture 19: *The Stellar Birthline*
- Lecture 20: *Deuterium and Hydrogen Burning*
- Lecture 21: Main Sequence Evolution and Leaving the Main Sequence
- Lecture 22: Why Stars Become Red Giants
- Lecture 23: The Helium Flash and Horizontal Branch
- Lecture 24: AGB Stars and Massive Star Evolution
- Lecture 25: Pulsating Stars, Cepheids & RR Lyrae stars

- Lecture 26: Nucleosynthesis I
- Lecture 27: Nucleosynthesis II
- Lecture 28: From AGB stars to Planetary Nebulae
- Lecture 29: The End Stages of Massive Stars and Supernovae

Topics from Mark Krumholz's "Notes on Star Formation": **Bold** will be covered here. *Italics* are optional.

- 1 **Observing the Cold Interstellar Medium**
- 2 **Observing Young Stars**
- 3 Chemistry and Thermodynamics
- 4 **Gas Flows and Turbulence**
- 5 Magnetic Fields and Magnetized Turbulence
- 6 **Gravitational Instability and Collapse**
- 7 **Stellar Feedback**
- 8 **Giant Molecular Clouds**
- 9 *The Star Formation Rate at Galactic Scales: Observations*
- 10 *The Star Formation Rate at Galactic Scales: Theory*
- 11 **Stellar Clustering**
- 12 **The Initial Mass Function: Observations**
- 13 **The Initial Mass Function: Theory**
- 14 **Protostellar Disks and Outflows: Observations**
- 15 **Protostellar Disks and Outflows: Theory**
- 16 **Protostar Formation**
- 17 **Protostellar Evolution**
- 18 **Massive Star Formation**
- 19 *The First Stars*
- 20 *Late-Stage Stars and Disks*
- 21 *The Transition to Planet Formation*

Topics from PPVII reviews: **Bold** will be covered here. *Italics* are optional.

- The Life and Times of Giant Molecular Clouds
- **The Solar Neighborhood in the Age of Gaia**
- **Star formation in the Central Molecular Zone of the Milky Way**
- **OB Associations**
- **Initial Conditions for Star Formation: A Physical Description of the Filamentary ISM**
- *Magnetic Fields in Star Formation: From Clouds to Cores*
- **From Bubbles and Filaments to Cores and Disks: Gas Gathering and Growth of Structure Leading to the Formation of Solar Systems**
- **The Origin and Evolution of Multiple Star Systems**
- **A Revised Paradigm of the Role of Magnetic Fields for Disk Formation and Outflow Driving towards an Understanding of the First Stage of Planet Formation**
- **Accretion Variability as a Guide to Stellar Mass Assembly**
- *Organic Chemistry in the First Phases of Solar-Like Protostars*
- *A Theoretical Perspective of Structured Distribution of the Gas and Solids in Protoplanetary Disks* [Jaehan's review]
- Hydro-, Magnetohydro-, and Dust-Gas Dynamics of Protoplanetary Disks
- Setting the Stage for Planet Formation: Measurements and Implications of the Fundamental Disk Properties
- *Demographics of Young Stars and Their Protoplanetary Disks: Lessons Learned on Disk Evolution and Its Connection to Planet Formation*
- *The Role of Disk Winds in the Evolution and Dispersal of Protoplanetary Disks*
- Near-Infrared View of Planet-Forming Disks and Protoplanets
- Kinematic Structures in Planet-Forming Disks
- Planet-Disk Interactions and Orbital Evolution
- *Planet Formation Theory in the Era of ALMA and Kepler: From Pebbles to Exoplanets*
- Short-Lived Radionuclides in Meteorites and the Sun's Birth Environment
- Direct Imaging and Spectroscopy of Extrasolar Planets
- Exoplanet Science from the Kepler mission
- Architectures of Compact Multi-Planet Systems
- Geophysical Evolution During Rocky Planet Formation
- Giant Planets from the Inside-Out

- Exploration-Based Reconstruction of Planetesimals
- Chemical Habitability: Supply and Retention of Life's Essential Elements During Planet Formation
- The Isotopic Link from the Planet Forming Region to the Solar System