ASTR 405
Planetary Systems
Introduction

Fall 2025

Prof. Jiayin Dong

Modules

- Part I: Exoplanet Detection Methods
  - Explore the techniques astronomers use to discover planets beyond our solar system
- Part II: Exoplanet Demographics and Planet Formation
  - Investigate the statistical properties of exoplanets and theories of how planetary systems form
- Part III: Exoplanet Atmospheres, Interiors, and Characterization
  - Examine methods for studying the physical properties and compositions of distant worlds

Prerequisites

- Introductory classical mechanics (PHYS 212)
- Introductory astrophysics (ASTR 210)
- Calculus and differential equations (MATH 241 and MATH 285 or equivalent)
- Background in scientific computing in Python (ASTR 310 or equivalent)

Exams

- You will have three midterms. Each module will conclude with a midterm examination.
  - Tentative dates are 9/29, 11/3, 12/3.
- There is no final exam. In lieu of a final exam, you will work on a mini-project and turn it into a written report due on 12/17.

Grading

Component	**Weight**	**Description**
Problem Sets	40%	Nine assignments; lowest grade dropped (5% each)
Midterm Exams	30%	Three exams (10% each) following each module
Mini-Project	20%	Written report
Class Participation	10%	Regular attendance and engagement

Grading Scale

A+: 97–100%

A: 93–96%

A-: 90–92%

B+: 87–89%

B: 83–86%

B-: 80–82%

C+: 77–79%

C: 73–76%

C-: 70–72%

D+: 67–69%

D: 63–66%

D-: 60–62%

F: Below 60%

Class Policies

- Ask questions: Feel free to ask questions anytime–chances are others are wondering the same thing.

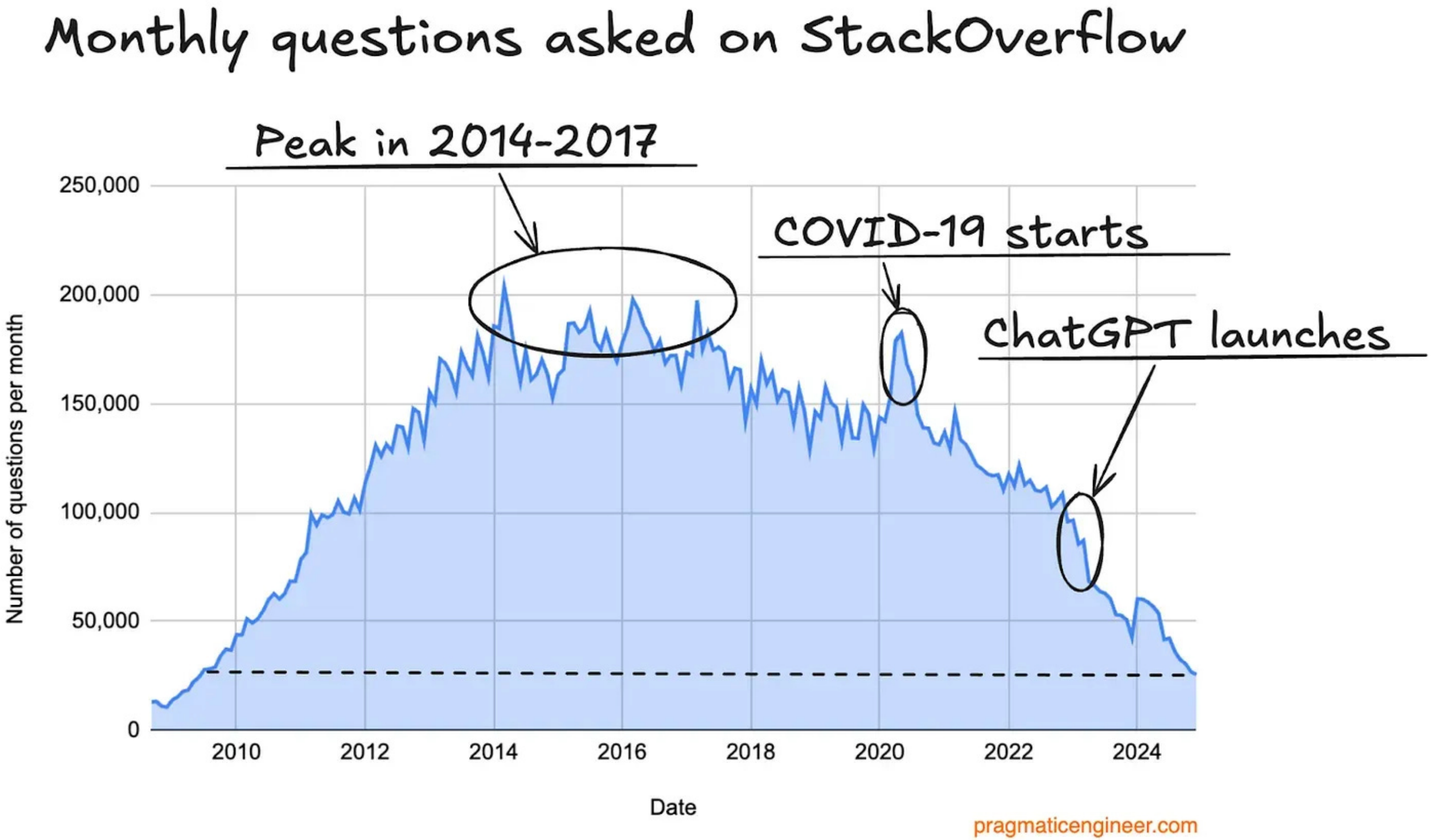
- Respect others: Listen to your classmates, value different ideas, and keep our classroom welcoming for everyone.

- Homework: Deadlines are firm; no late work accepted.

- AI tools: AI can be a great helper for brainstorming ideas. <u>But your submitted work must be your own.</u> If you use AI, mention how you used it.

Class Participation Grading Policy (Amended 9/3/2025)

- Class participation counts for 10% of your total grade and is based on completing in-class activities. There will be 25+ activities this semester, and you only need to complete 20 to earn full credit. This gives you flexibility if you miss a few classes (due to illness, interviews, or other conflicts), but the best way to reach the 20 – and to get the most out of the course – is to come to class regularly and engage. I have updated the introduction slides to include this policy.



Monthly questions asked on StackOverflow
Peak in 2014-2017
COVID-19 starts
ChatGPT launches
250,000
200,000
150,000
100,000
50,000
0
Number of questions per month
2010
2012
2014
2016
2018
2020
2022
2024
Date
pragmaticengineer.com

Office Hours

- Lectures: MWF 1–1:50 pm @ Astronomy 134
- Teaching Assistant: Spencer Hulsey (sbh2@illinois.edu)
- Office hours
  - Wednesday 2–3 pm @ Astronomy 216
  - Thursday 3–4pm @ Astronomy library

What is a planet?

https://dps.aas.org/education/what_is_a_planet/

IAU Resolution 5A: Definition of a Planet in the Solar System

Contemporary observations are changing our understanding of planetary systems, and it is important that our nomenclature for objects reflect our current understanding. This applies, in particular, to the designation “planets.” The word “planet” originally described “wanderers” that were known only as moving lights in the sky. Recent discoveries led us to create a new definition, which we can make using currently available scientific information.

The IAU therefore resolves that “planets” and other bodies in our Solar System, except satellites, be defined into three distinct categories in the following way:

1. A “planet”[1] is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighborhood around its orbit.
While planets have to be nearly spherical, they usually bulge at the equator, thanks to the fact that planets rotate. The Earth’s diameter at the equator is about 12,760 km (7,925 miles), while from pole to pole it is about 12,720 km (7,900 miles). Scientists estimate that for a rocky body, hydrostatic equilibrium will happen for an object that is about 800 km (500 miles) and has a mass about 1/12,000 that of the Earth (Ceres is about 950 km and has a mass about 1/7000 that of Earth).

Part “a” eliminates satellites of the planets as potential planets even if they are “round.” Part “c” is the major difference between the original draft resolution and the one that passed. This eliminated the Main Belt asteroid Ceres (only one of many asteroids) and Pluto and 2003 UB313 (two of many Trans-Neptunian Objects) and eliminated the possibility of there being dozens of other planets in the near future.

2. A “dwarf planet” is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape[2] , (c) has not cleared the neighborhood around its orbit, and (d) is not a satellite.
In the original resolution, “dwarf planet” was not an official IAU term. The terms “terrestrial” and “gas giant” (or jovian) are not official IAU terms. This resolution then creates a new class of objects that includes Ceres (and possibly a few other Main Belt asteroids), as well as Pluto and other large Tran-Neptunian Objects.

3. All other objects[3] except satellites orbiting the Sun shall be referred to collectively as “Small Solar-System Bodies”.
The term “minor planet” will no longer be used. Small Solar System Bodies include asteroids and comets. While most known asteroids have orbits between Mars and Jupiter in the Asteroid Belt, there are groups of objects that orbit in other parts of the solar system: Near-Earth Asteroids (NEOs), many of whose orbits cross the orbit of the Earth; Trojan Asteroids that share the orbits of several of the planets (Mars, Jupiter, and Neptune); Centaurs, whose highly elliptical orbits cross the orbits of the outer planets; Kuiper Belt Objects, objects in orbits beyond Neptune’s orbit and that orbit in a relatively flat disk between 30 and 50 AU (30 to 50 times Earth’s distance from the Sun); and Trans-Neptunian Objects (TNOs), objects that have orbits beyond the orbit of Neptune (KBOs are a subset of the TNOs).

[1]The eight “planets” are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.
[2]An IAU process will be established to assign borderline objects into either dwarf planet and other categories.
[3]These currently include most of the Solar System asteroids, most Trans-Neptunian Objects (TNOs), comets, and other small bodies.

Derive the Minimum Planet Size

Find the minimum size (order of magnitude) at which a rocky body relaxes to a nearly spherical (hydrostatic) shape.

Assume a non-rotating, uniform density (rocky: $\rho \sim 3\,\mathrm{g\,cm^{-3}}$) planet.

Hint: Compare with yield strength (σ_y).

- The stress beyond which rock fails (brittle/frictional) or flows (ductile creep) over geological time.
- Gravity must generate stresses that meet or exceed σ_y to crush large bumps and let the body round out.
- Typical values for cold to moderate crustal rock: $\sigma_y = 100\ \mathrm{MPa}$, where $1\ \mathrm{Pa} = 1\ \mathrm{N\,m^{-2}} = 1\ \mathrm{kg/(m \cdot s^2)}$.

What is an exoplanet?