Physics 172

Stellar Astronomy & Cosmology

Spring 2025
William & Mary

[Peter Komka, MTI, AP]

Instructors

Prof. Seth Aubin

Office: room 255, Small Hall, tel: 1-3545
Lab: room 069, Small Hall (new wing), tel: 1-3532

e-mail: saaubi@wm.edu
web: http://www.physics.wm.edu/~saubin/index.html

Noah Donald

Office: room 220, Small Hall
e-mail: nldonald@wm.edu

Office hours:

Aubin: T & Th noon - 1 pm, or anytime (open office hours)
Donald: Th 4-5 pm

Course Objectives

Introduce **stellar** astronomy and **cosmology**

→ Concepts, Methods, and Science.

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- Spectroscopy: identifying atom & molecules from their light.
- Astronomy instruments: optical, radio, x-ray telescopes & LIGO.

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- Spectroscopy: identifying atom & molecules from their light.
- Astronomy instruments: optical, radio, x-ray telescopes & LIGO.
- Solar systems: Sun, solar system, stars, and exo-planets.
- Main sequence stars, stellar evolution.
- Special stars: dwarfs, Cepheids, neutron stars, black holes.
- Exploding stars: novae, supernovae, mergers.
- Einstein's relativity: Special & General Relativity.

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- The Milky Way galaxy, galaxy types, **dark matter.**
- Galaxy clusters, the expanding universe, **dark energy.**
- Big Bang, inflation, the cosmic microwave background.
- Future of the universe, multiverses.

Course Materials

Text: A significant fraction of the course materials and problem sets will be taken from the following required texts for the course:

Astronomy (2nd Ed.) by A. Fraknoi, D. Morisson, and S. C. Wolff [OpenStax (Rice U.), 2022]

→ Download for free at:
https://openstax.org/details/books/astronomy-2e/

Note: Swem Library has 2 hardcopies.

Course materials will be posted on:

- Blackboard course site
- Prof. Aubin website:
https://saaubi.people.wm.edu/TeachingWebPages/Physics172_Spring2025/Physics172_Spring2025.html

Course Delivery Structure

Primarily Remote Asynchronous

All of the lectures will be delivered remotely via short videos posted on the course site.

Synchronous sessions: MWF 9:00-9:15 am

- At the start of each official class period, there will be a short **synchronous problem solving session** (or class announcement/discussion).
- You are expected to have **already viewed the video lecture** for that day.
- **Attendance** is expected.
- Opportunity for **Q&A**.
- These sessions will be recorded and posted on the course site.
- **Official office hours** begin immediately after this problem solving session.

Extra course time

Due to the shortened semester, each “lecture” will be approximately 54 minutes long on average (videos + problem session).

Course Work

- **Problem sets:** roughly every week.
- **Participation:** attendance, questions/discussion, quizzes.
- **Papers** for the 2 interludes.
- **Midterm:** 2 midterm tests.
- **Final** covers all course material with emphasis on end of semester.

Participation:	10%
Problem sets:	20%
Interlude Papers (2):	25%
Midterms (2):	25%
Final Exam:	20%
Total =	100%

PollEv

Usage

- Class discussion questions (ungraded).
- Participation gauge.
- In-class quizzes.
- Starts next week (January 27-31).

Sign-up

- Free
- Use mobile device (tablet, phone) or laptop.
- Sign-up instructions (see syllabus for details): https://polleverywhere.com/login
- Upon entering a W&M email address, you will be prompted to sign in via Single-Sign On (SSO) with you W&M credentials.

Problem Sets (I)

- Important for verifying and deepening understanding of **text chapters** and **lectures**.
- Typically, one week to complete and due on **Fridays**.
- 3-5 problems, mostly quantitative, some qualitative.
- Turn in on **ExpertTA** … sometimes hard copy (in-class).
- A random sample of 1-5 problems will be graded for hard copies.
- Source for some midterm test problems (and final exam).

Problem Sets (II)

You should complete the problem sets on your own.

Allowed

- "Verbal" discussion of problems between students.
- Ask for assistance during office hours.
- TBD: Physics SPS tutoring (free): Thursdays 6-8 pm.
- Consultation of written references (and internet).

Not Allowed (i.e., honor code violation)

- Equation-based numerical discussions.
- Collaborative effort with other students.
- Consultation of solution manual.
- Artificial intelligence generated solutions (e.g., ChatGPT).

Problem Sets (III)

You must setup an **ExpertTA** account ($35 USD) by going to the website:

https://reg.theexpertta.com/USA48VA-465B21-3NZ

[Please use your **W&M username**]

Most of the problem sets will be submitted on ExpertTA

- ExpertTA will provide results on which questions were answered correctly and which were not.
- Hints and feedback will usually be provided for incorrect answers.
- For most questions (except true/false questions), multiple attempts will be allowed.
- Points will be deducted for multiple submissions, and the use of hints and feedback.

Interludes (COLL 200)

Interlude I: Humanity and the stars.

→ reaches out to CSI & ALV domains.

CSI = Cultures, Societies, & Individuals

ALV = Arts, Letters, and Values

Interlude II: Humanity and the universe.

→ reaches out to CSI & ALV domains.

Interlude Structure

Readings, discussions, short papers.

Course work

2 papers: one for each interlude, 4-5 pages.

Schedule (I)

Week 0: 1/22-24 **Intro to Astronomy [Ch. 1, 2]**
Overview, units, distance scales, time, atoms to galaxies, radius of the Earth.

Week 1: 1/27-31* **Basic Physics I: Motion and Orbits [Ch. 3]**
Constellations, gravity, orbits, Kepler' laws, seasons, precession, parallax.

Week 2: 2/3-7 **Basic Physics II: Newton and Gravity [Ch. 3]**
Kepler's laws, Galileo, Newton's laws, conservation laws, gravity, circular motion, tides.

Week 3: 2/10-14 **Basic Physics III: Light and Matter [Ch. 5, 16.1-2]**
Electromagnetic waves, blackbody radiation, photons, atoms, fusion, Doppler effect.

Week 4: 2/17-21 **Astronomy Instruments [Ch. 6]**
MIDTERM #1. Telescopes, resolution, adaptive optics, interferometry, space telescopes.

***Add/drop deadline: Friday, January 31, 2025**

Schedule (II)

Week 5: 2/24-28 **Stars I: Our Sun & Main Sequence Stars [Ch. 15, 16, 17]**
Structure, solar wind, sunspots, fusion, star brightness and temperature.

Week 6: 3/3-7 **Stars II: Stellar Evolution [Ch. 17, 18, 19, 22]**
Luminosity vs mass, H-R diagram, spectroscopy, star types, stellar birth & exo-planets.

---------- Spring Break ----------

Week 7: 3/17-21 **Stars III: Stellar Death [Ch. 22, 23]**
Helium fusion and beyond, red giants, white dwarfs, novae, supernovae, neutron stars.

Interlude I paper: Humanity and the stars.
Week 8: 3/24-28** **Black Holes & Einstein's Relativity [Ch. 24]**
Special & general relativity, spacetime, gravitational redshift, black holes.

Week 9: 3/31-4/4 **Galaxies I: Milky Way and Galaxy Types [Ch. 25, 26]**
MIDTERM #2. The Milky Way galaxy, Shapley-Curtis debate, galaxy types, dark matter.

****Withdraw deadline: Monday, March 24, 2025**

Schedule (III)

Week 10: 4/7-11 **Galaxies II: Galaxy Structures [Ch. 26, 27]**
Galaxy types, distance ladder, expanding universe, quasars, supermassive black holes.

Week 11: 4/14-18 **Galaxies III: Galaxy Clusters and Evolution [Ch. 28]**
Galaxy mergers, distribution of galaxies in space, dark matter again, dark energy.

Week 12: 4/21-25 **The Big Bang Theory [Ch. 29]**
Birth and age of the universe, cosmic microwave background, inflation hypothesis.

Interlude II paper: Humanity and the universe.
Week 13: 4/28-5/2 **The Universe [Ch. 29]**
Future of the universe, multiverses, limits of science, philosophy, and religion.

---------- Classes Finish ----------

May 8, 2025, 9am-noon **Final Exam**

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- **Testable** facts and model (hypothesis).

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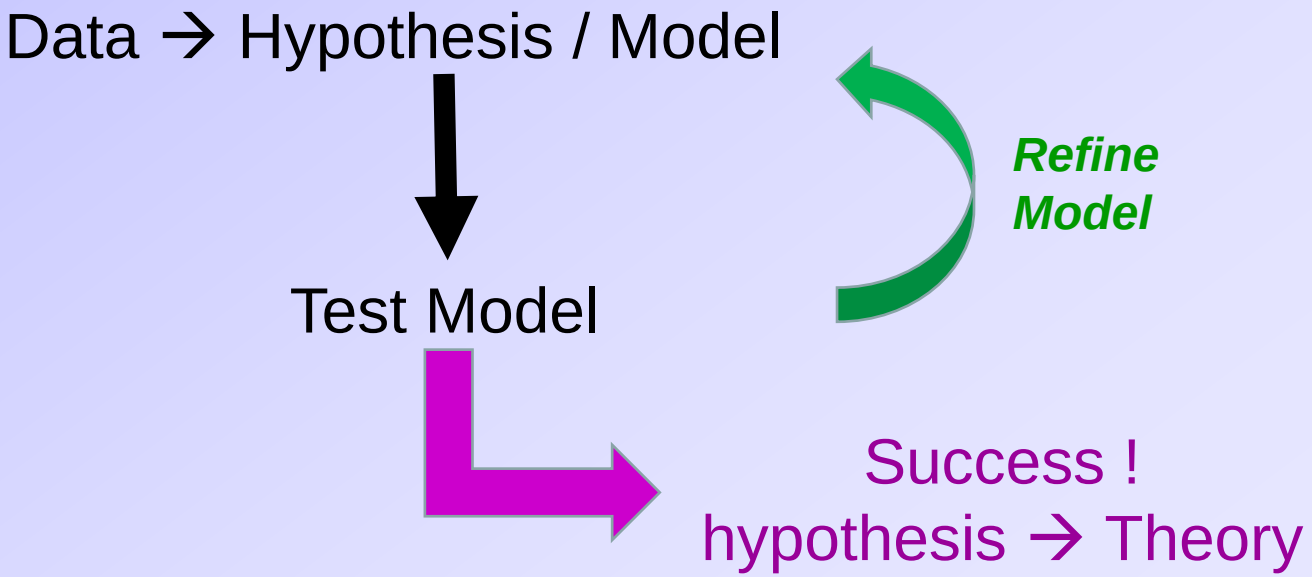
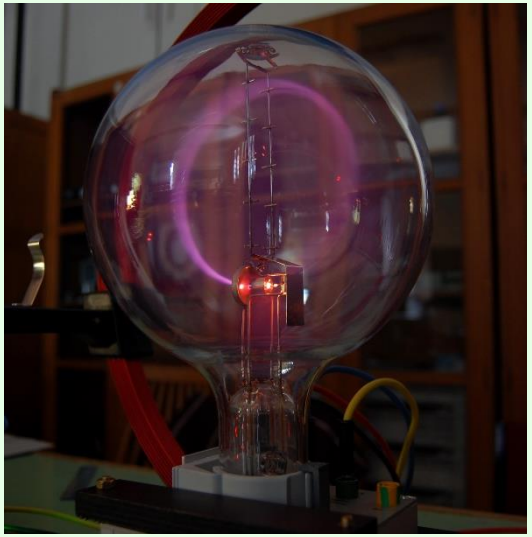
"Scientific method":



How accurate can a Theory be?



[Wikipedia, 2009]

Electron's magnetic "g-factor"

Schrodinger's theory: $g_e = 1.0$

Dirac relativistic theory: $g_e = 2.0$

Present day quantum physics: $g_e = 2.002\ 319\ 304\ 362$

12-digits

Theory and experiment agree to 9 digits !!!

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- Observational science, with physics-based models/theories.

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Answer: As best we can tell, **science/physics** developed from Earth-based experiments **can explain all** observed astronomical phenomena.

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Exceptions:
Big Bang, dark matter, and dark energy (… black holes).

Scientific Units

Scientific Notation


Antares
dust & gas clouds
“Astronomy Picture of the Day”
David McGarvey