Introduction to Astrophysics

PHYS 4330

Fall 2022: offered in English
Course webpage: http://orion.astr.nthu.edu.tw/ita/

Instructor & GSI

- **Instructor: Huei-Ru Vivien Chen 陳惠茹**
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- **Graduate Student Instructor: Jane Yap 葉於瑄**
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  - **Office hour:**
  - **Email: yapyeexuan@gapp.nthu.edu.tw**

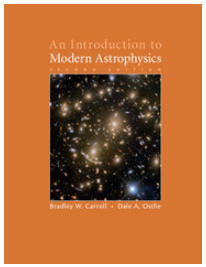
Course Information

- **This course is aimed at building a solid foundation for science majors inclined to pursue research in astronomy related fields. Lectures in the first semester cover broad, considerable knowledge of modern astrophysics, including astronomical measurements, physical processes in celestial objects, dynamics in stellar systems, (the Solar system objects if time allows), etc. Students must have prerequisite skills in physics at undergraduate level unless otherwise approved by the instructor.**

- 這門課是針對可能從事天文物理研究，或對天文物理有興趣的同學而設計。目的在於為將來可能進行的天文研究計畫作合理的準備。第一學期的課程包含基本的天文現象、座標系統的介紹及深入地探討部份的天文物理系統，如恆星天體內的物理狀態及輻射機制、恆星演化、系統動力學、（太陽系）等。 除非經任課教師同意，修課學生必須具備等同於物理系學士班三年級以上的物理及數學訓練。

Textbook & Reference

- **Textbook**
  - **An Introduction to Modern Astrophysics (2ed)**
    - Bradley W. Carroll & Dale A. Ostile 2017
      (Cambridge University Press)
      ISBN: 9781108422161
    - Textbook website



- **Reference**
  - **The Physical Universe**
    - by Frank H. Shu 1982 (University Science Books)

More on Your Textbooks

- An Introduction to Modern Astrophysics (1st edition)
  - 1996, Addison-Wesley
  - cgs units
  - Match research better, but
  - Some chapters need further editing
- An Introduction to Modern Astrophysics (2nd edition)
  - 2017, Cambridge University Press (2007, Addison-Wesley)
  - MKS units
  - Match general public better, but bad for future reading of professional astronomy journals or articles
  - Improved content arrangement with better figures

Lectures and Grading Policy

- Time and Venue
  - Tuesdays 14:20 - 17:20, 521 2nd General Building
- Lecture arrangement
  - Offered in, but not limited to, English
  - 17 lectures in total
  - Final examination on January 10th, 2023
- Grading Policy
  - 60% problem sets (due 5PM of the following Thursday)
  - 30% final exam
  - 10% attendance

Course Coverage I

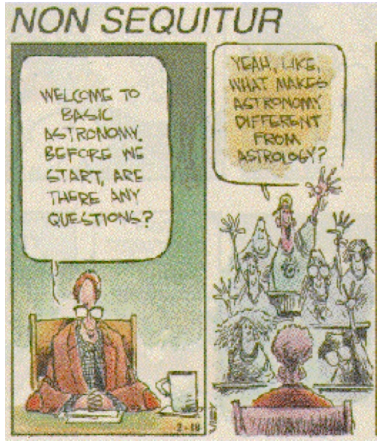
- Tools of Astrophysics
  - Overview
  - Celestial sphere and celestial mechanism
  - Telescopes
  - Basic measurements and nature of light
  - Interaction of light and matter
- Stars and Interstellar Medium
  - Binary systems
  - The classification of stellar spectra
  - Stellar atmospheres
  - Main-sequence stars & their interior structures

Course Coverage II

- Stellar evolution
  - Interstellar medium & star formation
  - Main sequence and post-main-sequence stars
  - Pulsating stars
  - The fate of massive stars

But before we start, let's have a chat.

Astronomy? Astrology?

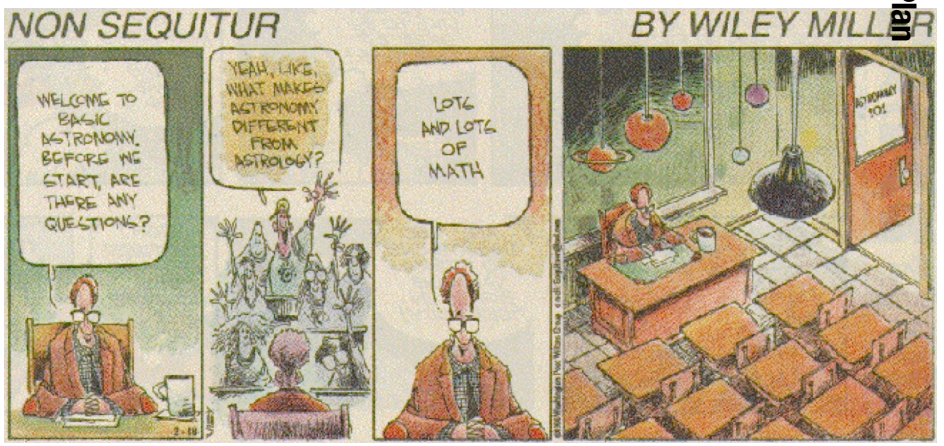


- Welcome to Introduction to Astrophysics. Before we start, are there any questions?
- Yeah, like, what makes astronomy different from astrology?

(And your thoughts?)

Lots and Lots of Math...

(Oh, yeah, we mean it.)



Credit: Evad Damast

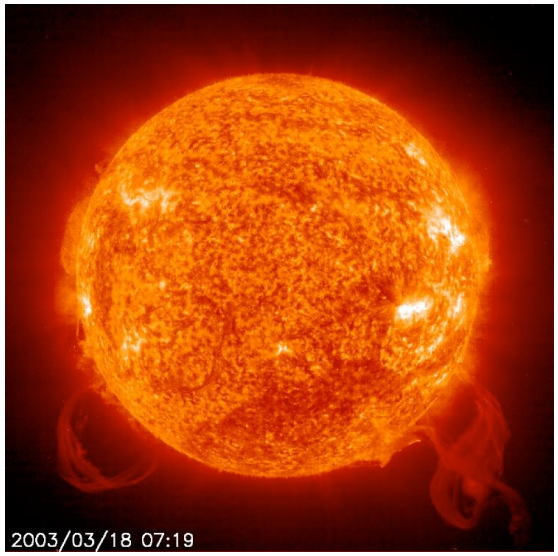
But not just math, Astronomy is Art!

Astronomy is Passive Science

We observe, observe, and observe.

Then we come to understand what it is all about in Nature.

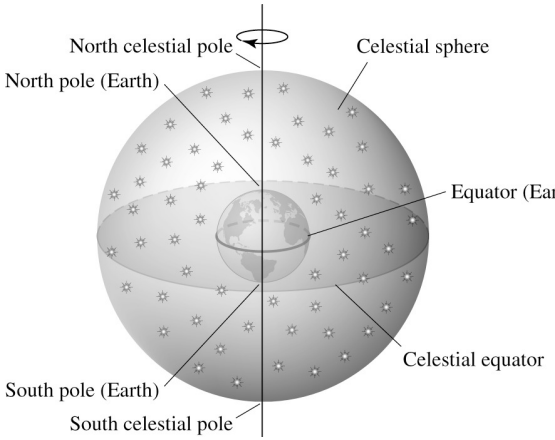
Sometimes, exciting predictions are also out there.



More on the Class Contents

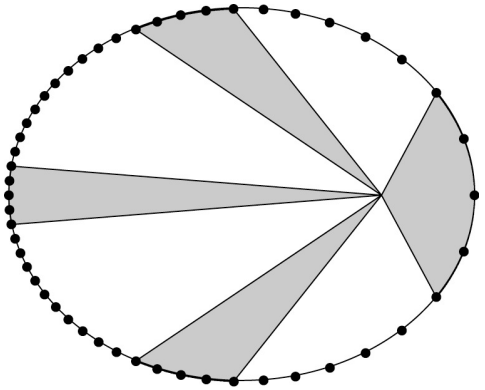
Tools of Astrophysics
Stars and Interstellar Medium
Stellar Evolution

Coordinate Systems



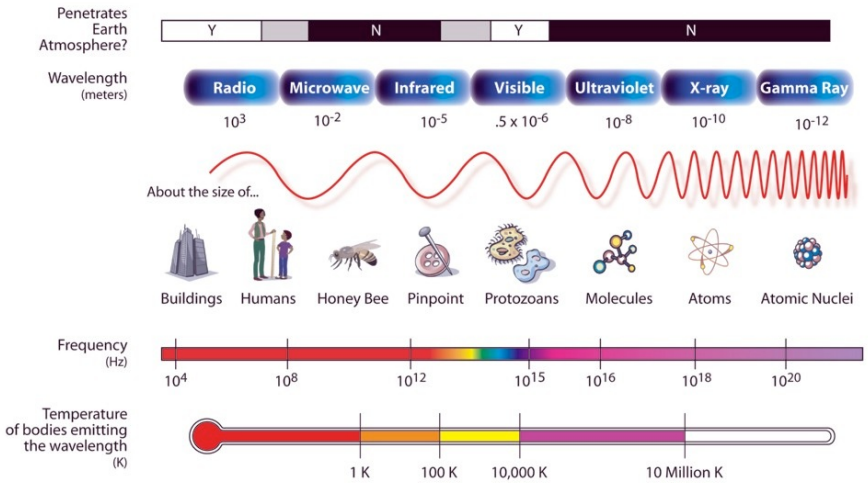
- How to register stars on the sky?
- How do we know where to find what?
- How do we register ourselves in the Universe?

Celestial Mechanics

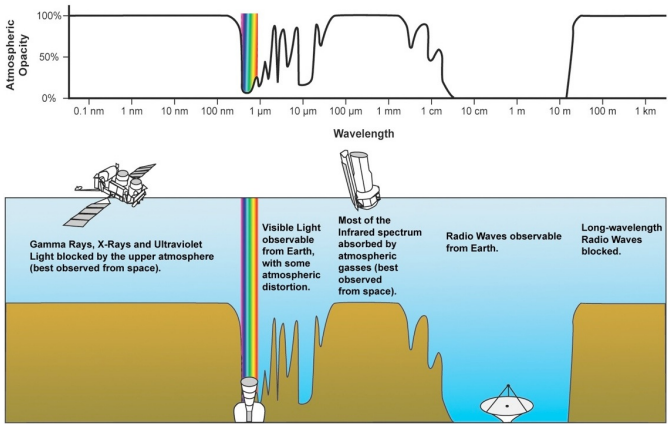


- Kepler's laws (1609)
- Gelilo (1610, 1632)
  - Father of modern observational astronomy
- Newton's laws of motion (1687)
- The Virial theorem: dynamics in a relaxed system

Spectrum of Light



Seeing through the Atmosphere



Wavebands that are unaccessible on the ground

Far-infrared (FIR)

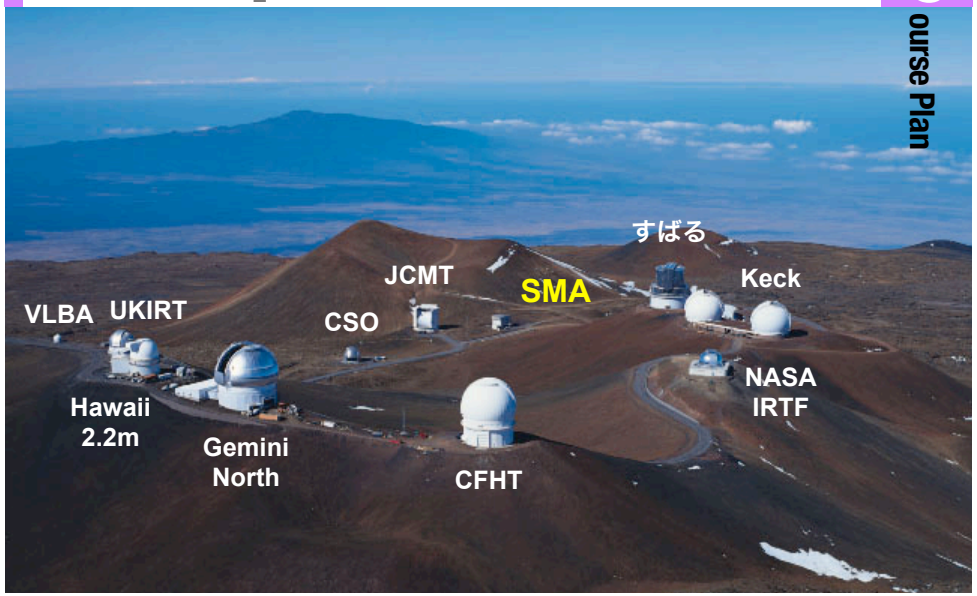
Mid-infrared (MIR)

Ultraviolet (UV)

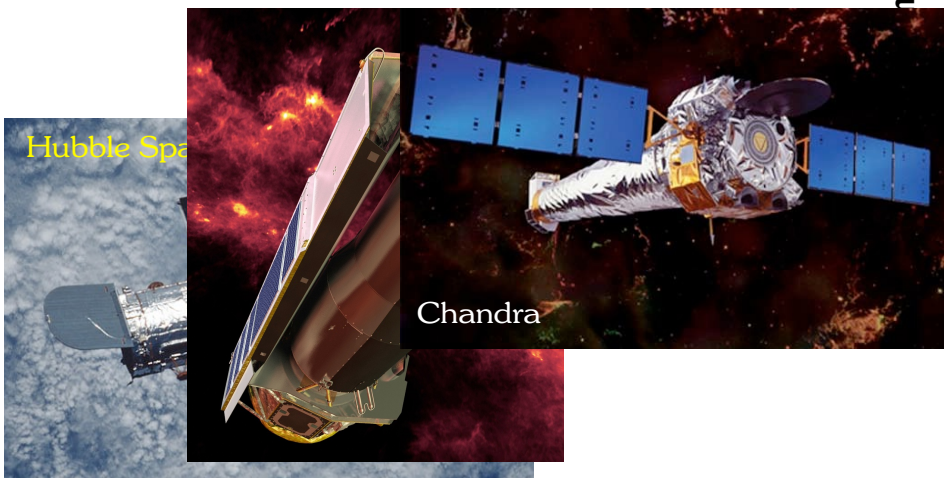
X-ray

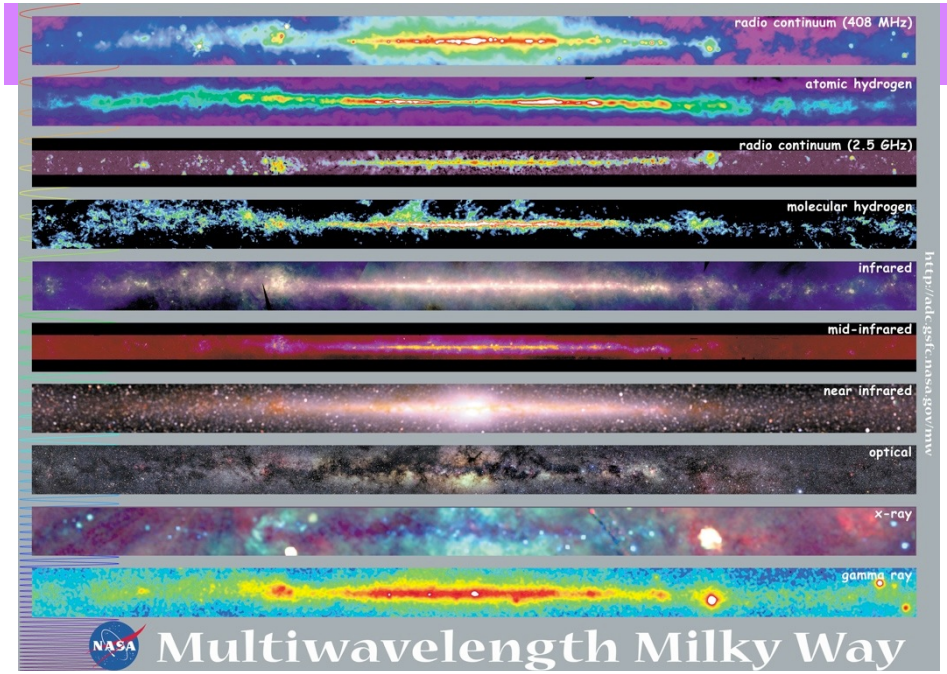
Gamma-ray

Telescopes



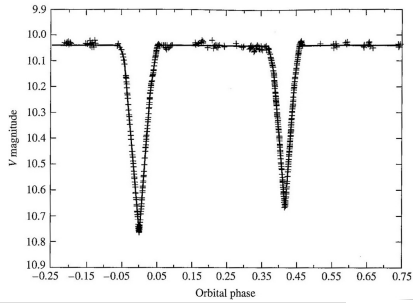
Space Observatories

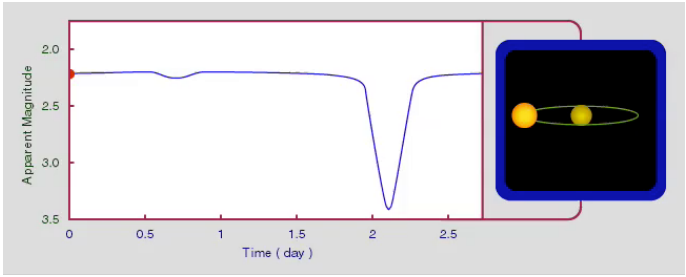




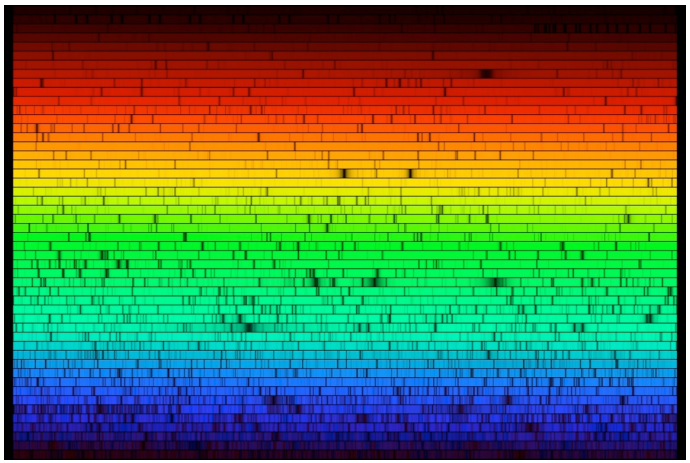
Binary Systems

- Important for deriving stellar parameters





Interaction of Light & Matter



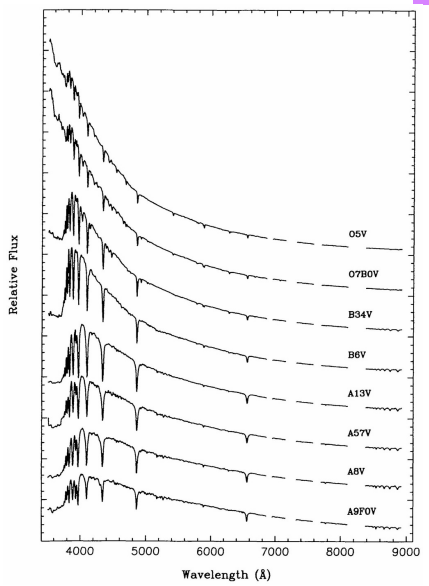
How to form spectrum?

What can we learn in the Solar spectrum?

How about stellar spectra?

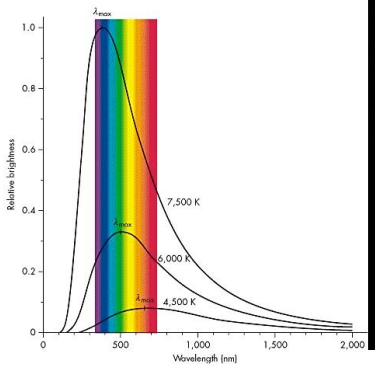
Main-Sequence Stars

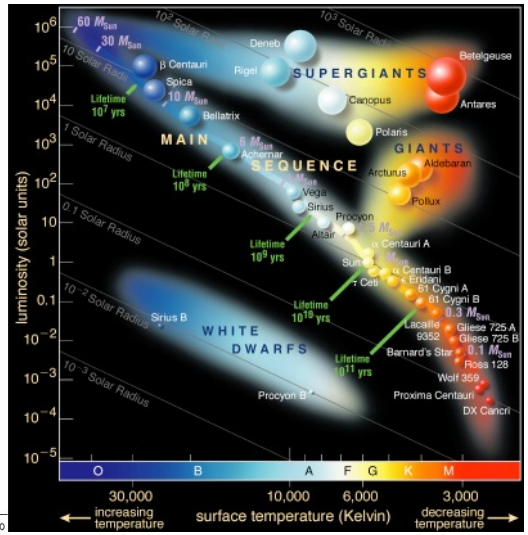
- Classification of stellar spectra
- Stellar atmosphere & radiative transfer
- Interiors of stars
- The Sun



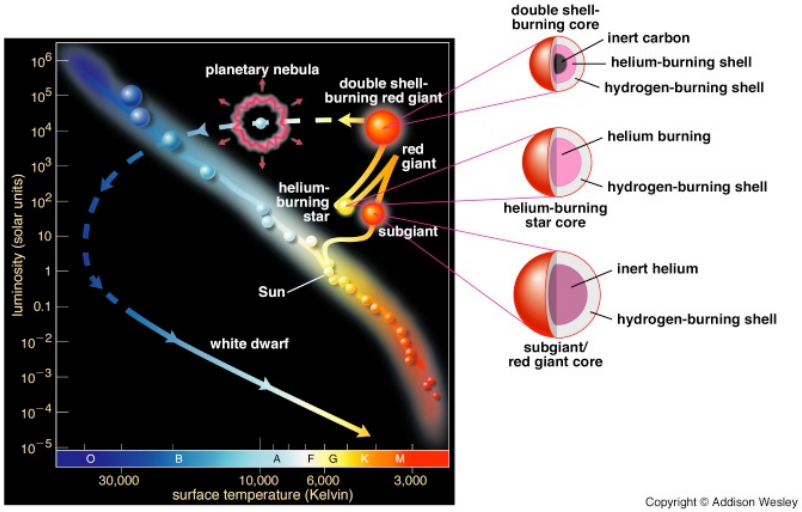
Classification of Stars

- Hertzsprung-Russell Diagram (HR Diagram)

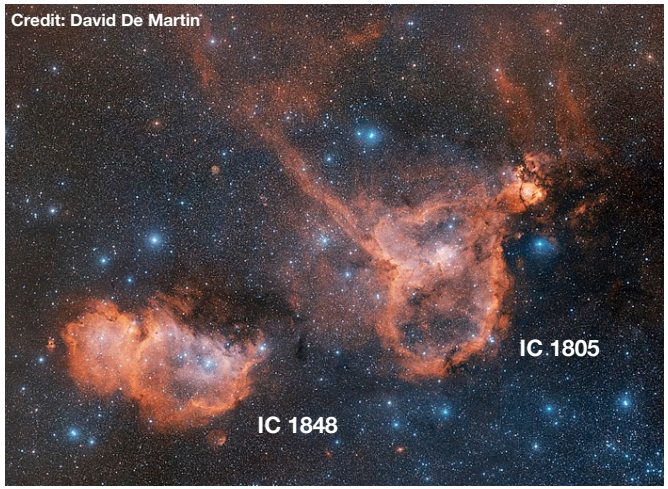




Stellar Evolution



Interstellar Medium

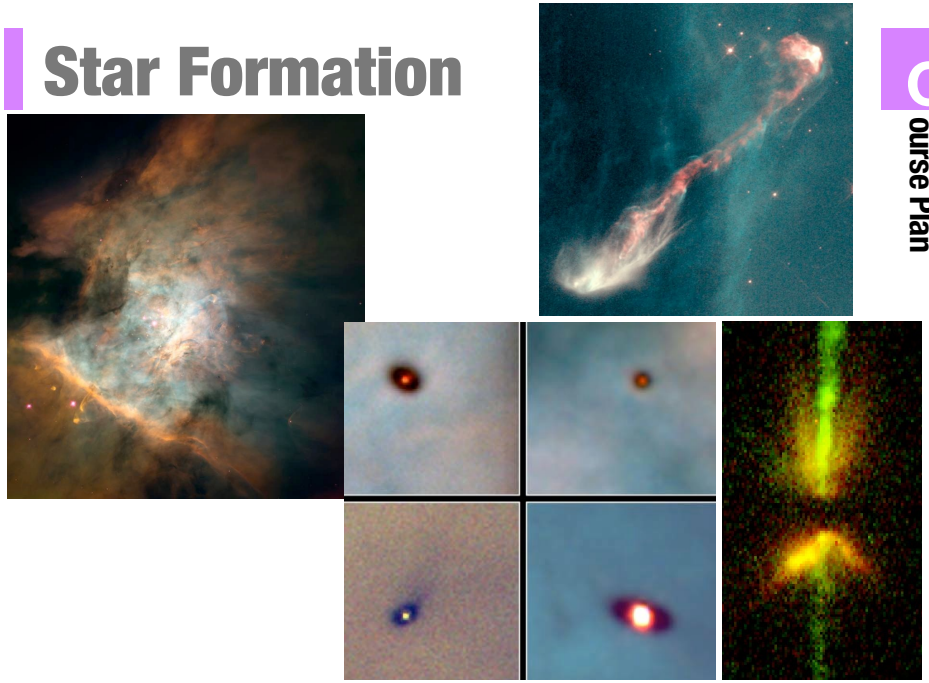


Strong UV radiation creating H II regions filled with ionized gas

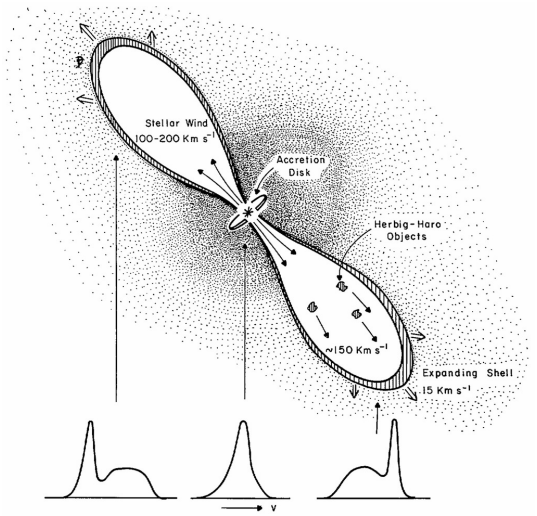
H I = H

H II = $H^+ = p$

Star Formation



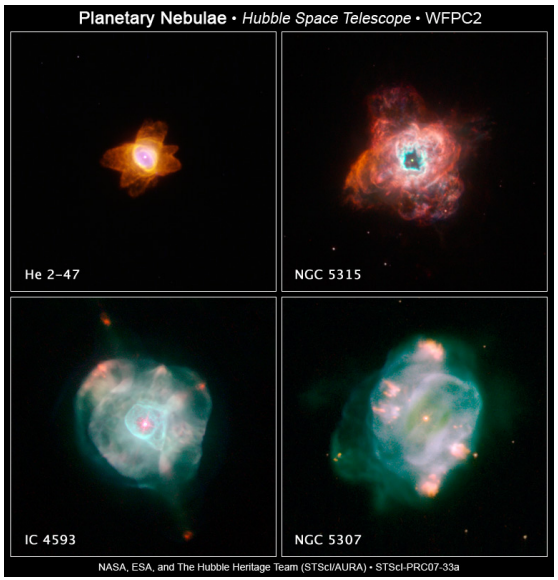
Standard Paradigm



- Infall envelope
- Bipolar jet/outflow
- Accretion disk
- Infall envelope

Planetary Nebulae

- Stellar explosions
  - Planetary nebula
  - Supernova remanent



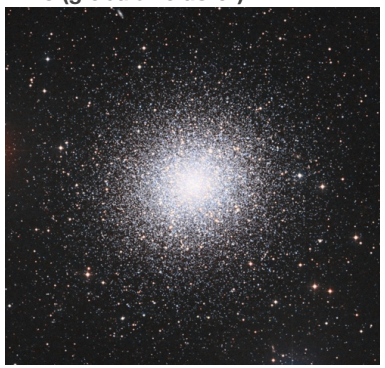
Supernova Remanent

- Stellar explosions
  - Planetary nebula
  - Supernova remanent

Star Clusters and Ages

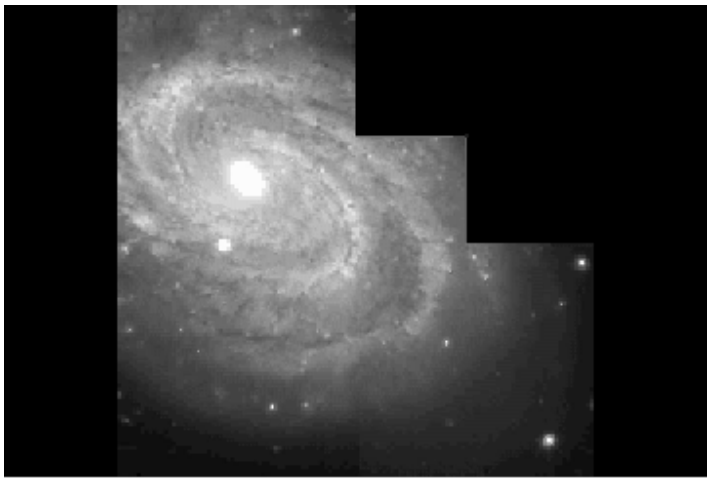
- **Open clusters**
  - Population I, young stars, gravitationally unbound
- **Globular clusters**
  - Population II, old stars, gravitationally bound, virialized

M13 (globular cluster)



Pleiades (open cluster)

Pulsating Stars - Cepheids



Credit: Jeffrey Newman (UC Berkeley) & NASA

Extremely Massive Stars

Eta Carinae

$M \approx 120\ M_\odot$

The only star known to exhibit lasers in the UV