

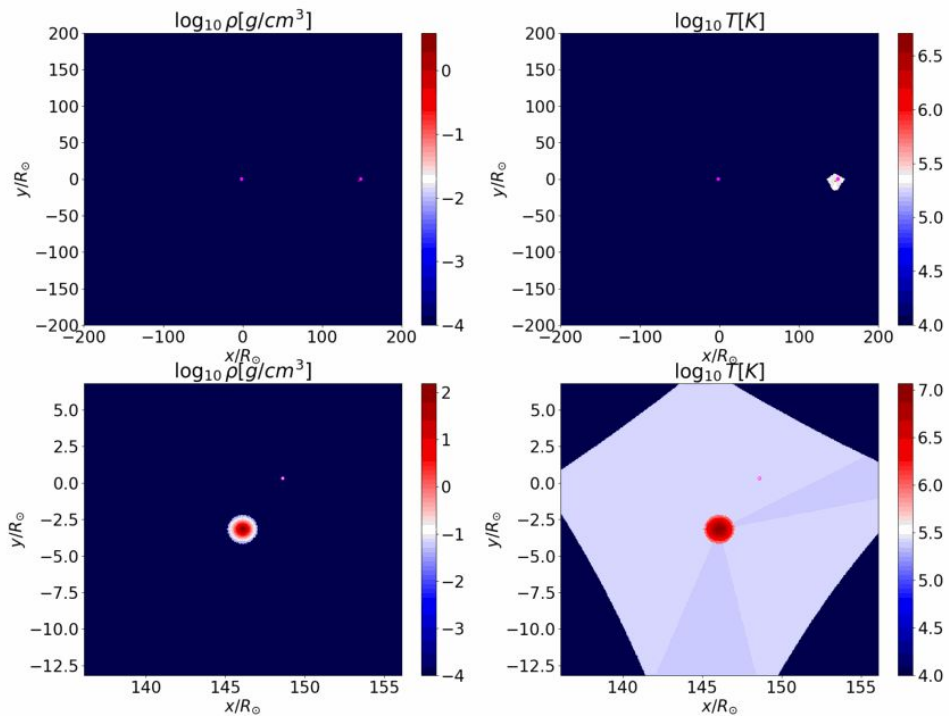
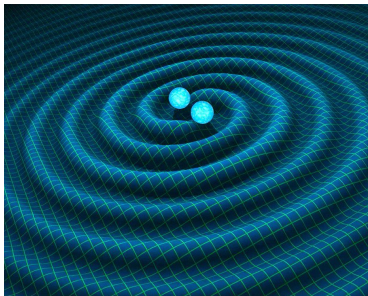
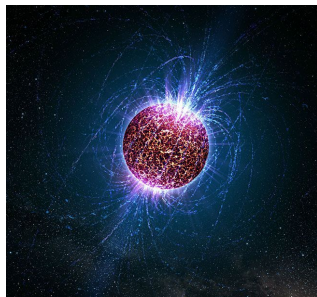
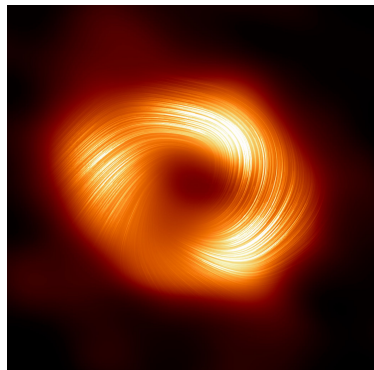
# Computing the Heavens: An Introduction to Computational Astrophysics

Instructor:  
Ian Johnson

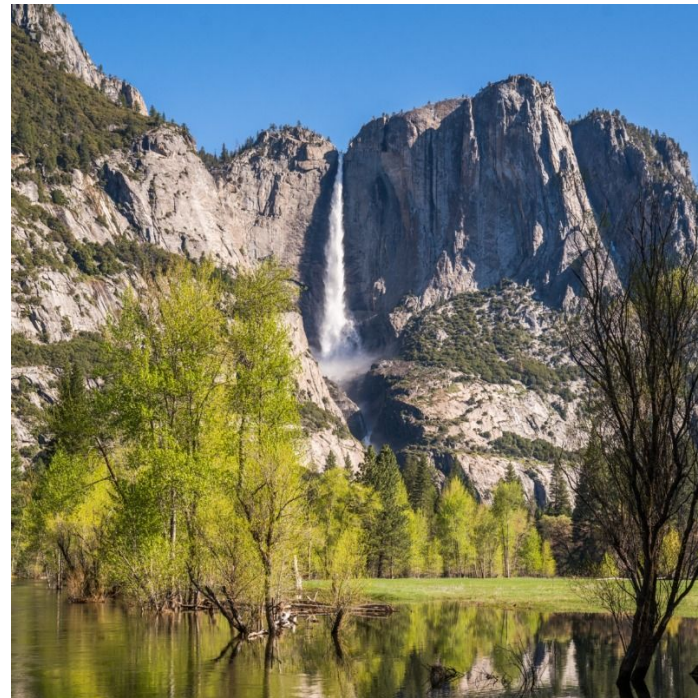
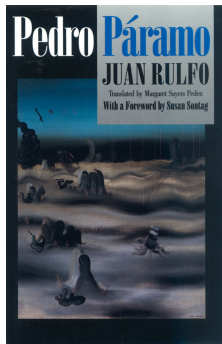
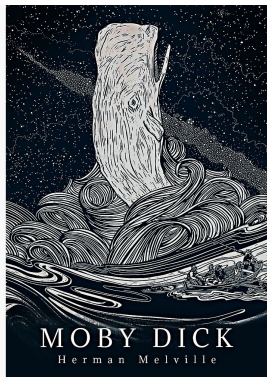
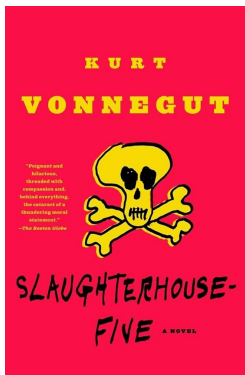
# Who am I?



# What Do I Study?



# Outside of Work...



Now, About You!

Activity: Make a rough circle

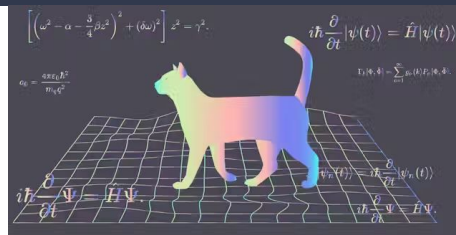
- Name/Pronouns
- School/Year
- Sport/Hobby you do
- Favorite Astro Object
- Name of Previous Students

# What is Computational Astrophysics?



# What is Computational Astrophysics?

- Physics
- Astronomy
- Software

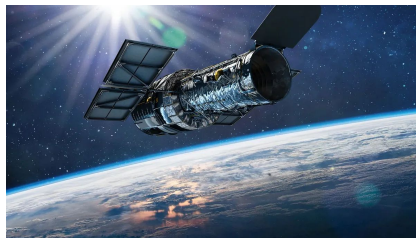


```
31 self.settings = Settings()
32 self.file = None
33 self.fingerprints = {}
34 self.verbose = True
35 self.debug = False
36 self.logger = logging.getLogger(__name__)
37 if path:
38     self.file = os.path.join(path, 'requests.log')
39     self.file_exists()
40     self.fingerprints.setdefault(self.file, 0)
41
42 @classmethod
43 def from_settings(cls, settings):
44     debug = settings.get('debug', False)
45     return cls(job_dir=settings, debug=debug)
46
47 def request_seen(self, request):
48     fp = self.fingerprints.get(request)
49     if fp is None:
50         return True
51     self.fingerprints.add(request)
52     if self.file:
53         self.file.write(fp + os.linesep)
54     self.request_fingerprint(request)
55     return request_fingerprint(request)
```



# What is Computational Astrophysics?

- Physics
  - Math
  - Model Design
- Astronomy
  - Chemistry
  - Optics
- Software
  - Coding
  - Hardware



$$f'(x) = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$$

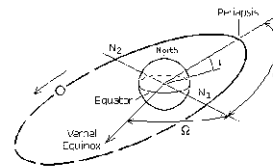


Figure 4.3

- $i$  = Inclination
- $\omega$  = Argument of Perapsis
- $\Omega$  = Longitude of Ascending Node
- $N_1$  = Ascending Node
- $N_2$  = Descending Node

Periodic table of the elements

group

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

1s

2s 2p

3s 3p

4s 4p

5s 5p

6s 6p

7s 7p

8s 8p

9s 9p

10s 10p

11s 11p

12s 12p

13s 13p

14s 14p

15s 15p

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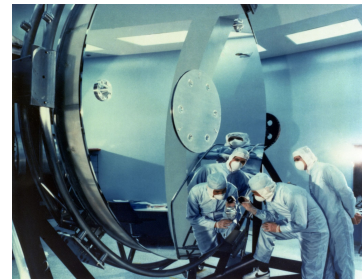
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302s 302p

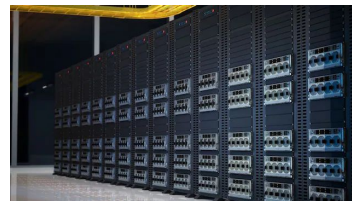
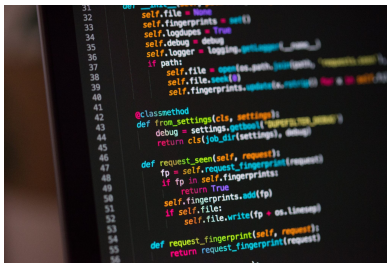
303s 303p

304s

<sup>a</sup>Numbering system adopted by the International Union of Pure and Applied Chemistry (IUPAC). © Encyclopedia Britannica, Inc.



## And More!



# Some Topics

- Simulating the Big Bang
- Simulating black holes merging
- Modeling the chemistry of Exoplanets

Sometimes theory *MUST*  
be tested on computers

Why?

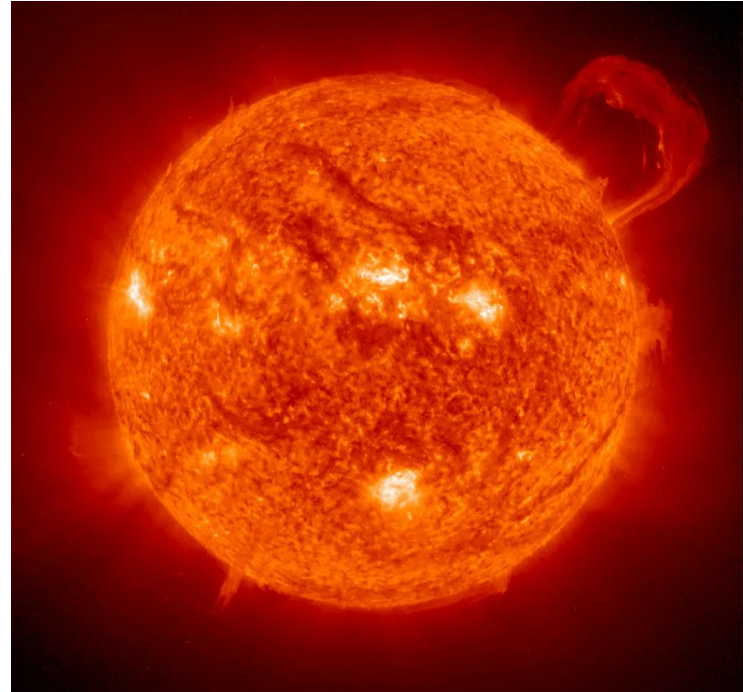
# Stars:

The Building Blocks of  
Astronomy

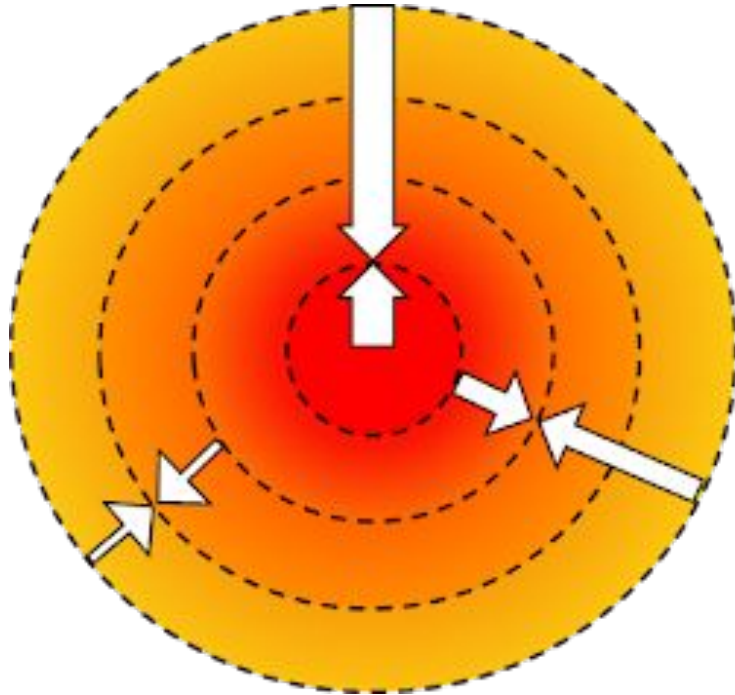
# What Are Stars *Made* of?

- 75% Hydrogen
- 25% Helium
- Trace other elements
- Plasma and a bit of gas

Our Sun—the basis of most  
stellar astrophysics



# Hydrostatic Equilibrium



Hydrostatic equation

$$\rho_r \frac{d^2 r}{dt^2} = -\frac{dP_r}{dr} - G \frac{M_r \rho_r}{r^2}$$

Hydrostatic equilibrium

$$\frac{dP_r}{dr} = -G \frac{M_r \rho_r}{r^2}$$

# Derivatives

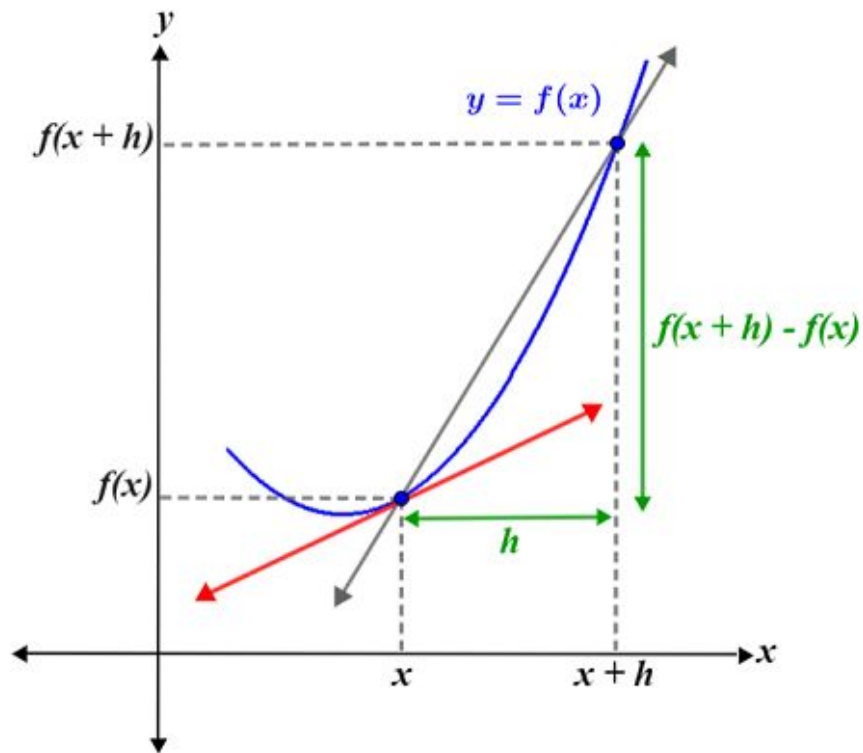
## Notation for the Derivative

$$f'(x)$$

$$y'$$

$$\frac{dy}{dx}$$

$$\lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$$





How Can We Use  
Computers to Calculate a  
Derivative?

Computers *Make* Complex  
Math Trivial

# Topics We (may) Cover

- Stars
- Galaxies
- Cosmology
- Coding Essentials
- Guest Tour + Guest Speaker
- **Main Project: Gravitational Waves of Merging Black Holes**