

# Computing the Heavens: An Introduction to Computational Astrophysics

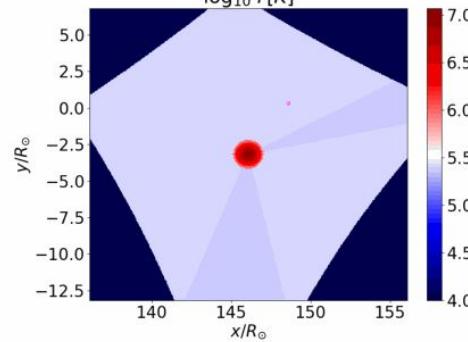
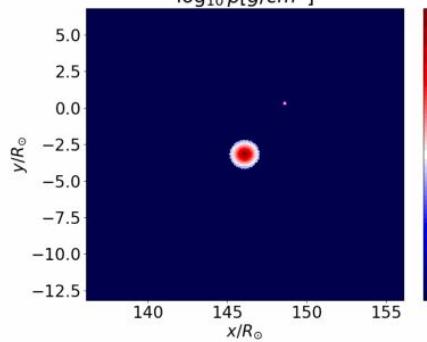
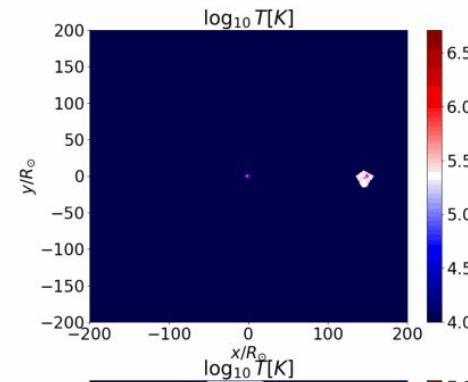
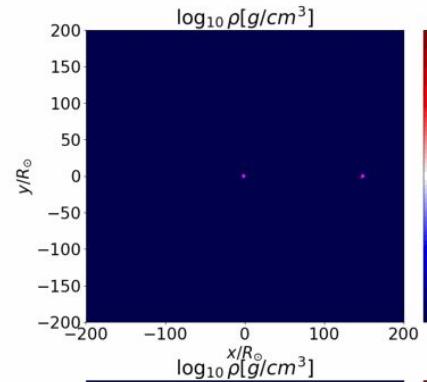
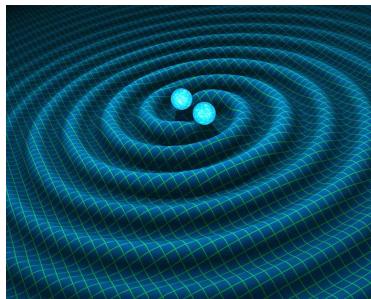
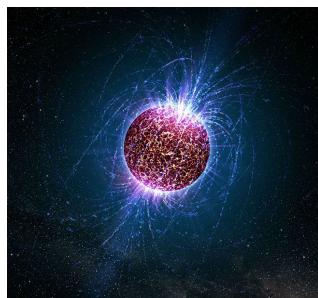
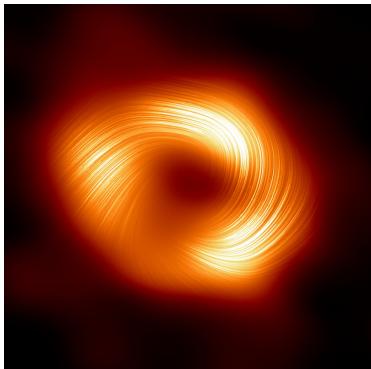
Instructor:  
Ian Johnson

# Recap of Last Week (with slides)

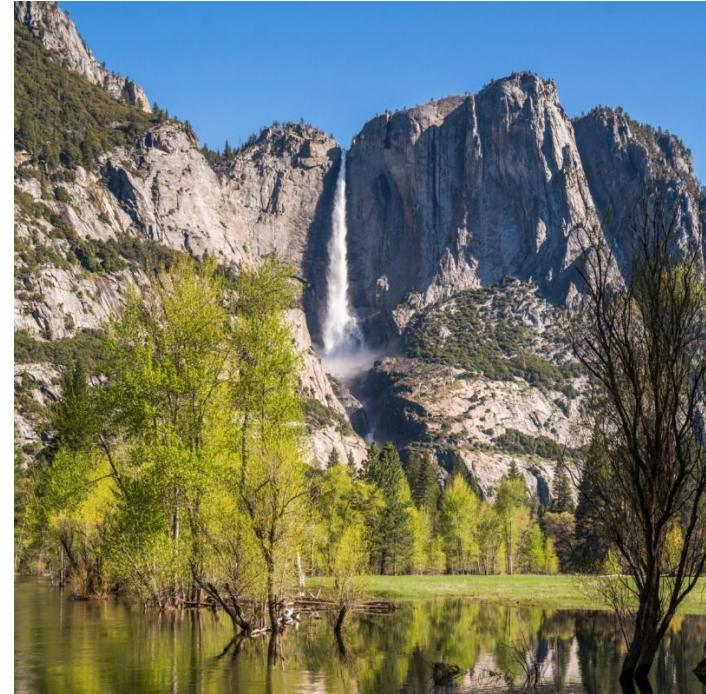
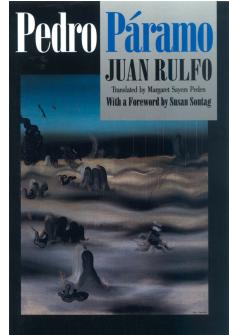
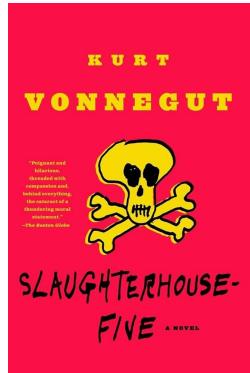
# Who am I?



# What Do I Study?



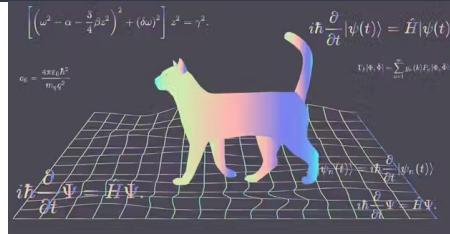
# Outside of Work...



# What is Computational Astrophysics?

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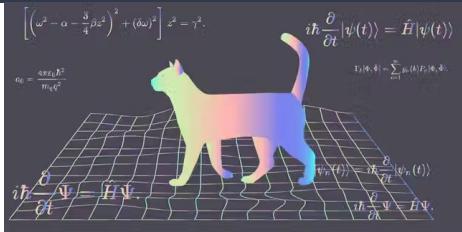
- Physics
- Astronomy
- Software



```
31     self.file = None
32     self.fingerprints = []
33     self.settings = {}
34     self.debug = False
35     self.logger = logging.getLogger(__name__)
36     if path:
37         self.file = os.path.expanduser(path)
38         self.file = os.path.abspath(self.file)
39         self.file = os.path.normpath(self.file)
40         self.fingerprints = []
41
42     @classmethod
43     def from_settings(cls, settings):
44         debug = settings.get('debug', False)
45         return cls(debug=debug, config=settings)
46
47     def request_seen(self, request):
48         fp = self.request_fingerprint(request)
49         if fp in self.fingerprints:
50             return True
51         self.fingerprints.append(fp)
52         if self.file:
53             self.file.write(fp + os.linesep)
54
55     def request_fingerprint(self, request):
56         return request.fingerprint(request)
```

# What is Computational Astrophysics?

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



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

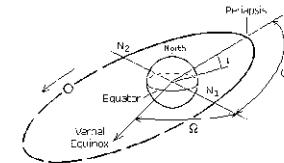
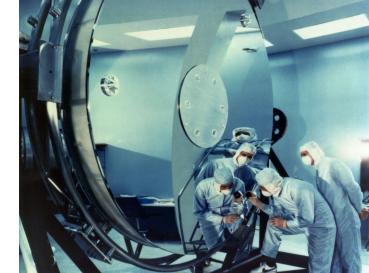


Figure 4

Periodic table of the elements																		
	Groups		Groups		Groups		Groups		Groups		Groups		Groups		Groups			
	Alkali metals		Halogens		Alkaline earth metals		Noble gases		Transition metals		Post-transition metals		Metalloids		Non-metals		Metal hydrides	
	Li Be		F Cl Br		B C N O F		He Ne Ar		Sc Ti V Cr Mn Fe Co Ni Cu Zn		Ga Ge As Sb Te Po At		Ge Si P S Cl Br		S Se Br I At Po At		H Li Be	
1	H	Li	Be	B	C	N	O	F	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	H	
2		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
3		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
4		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
5		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
6		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
7		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
8		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
9		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
10		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
11		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
12		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
13		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
14		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
15		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
16		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	
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71		Mg	Al	Si	P	S	Cl	Ar	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	He	



And More!

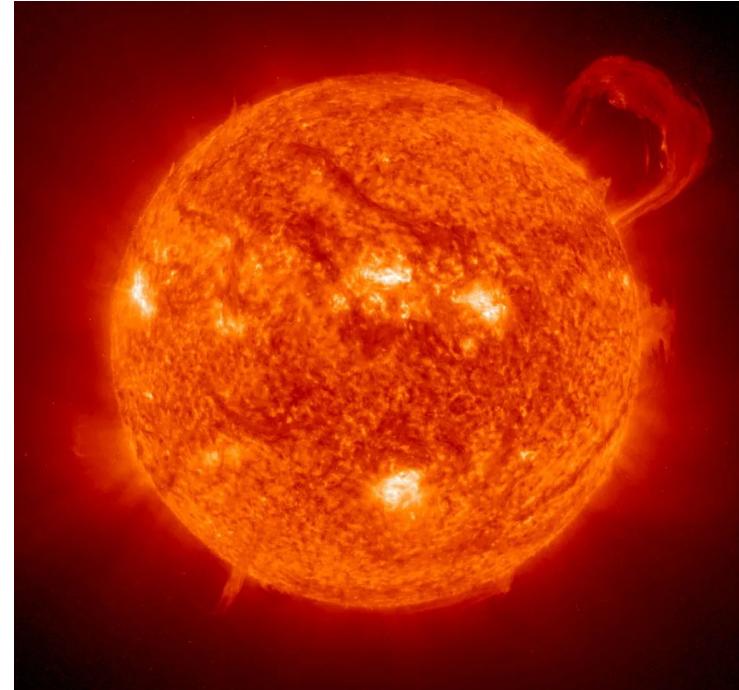
# An Astronomy Overview: Basics of Astronomy

# Stars: The Building Blocks of Astronomy

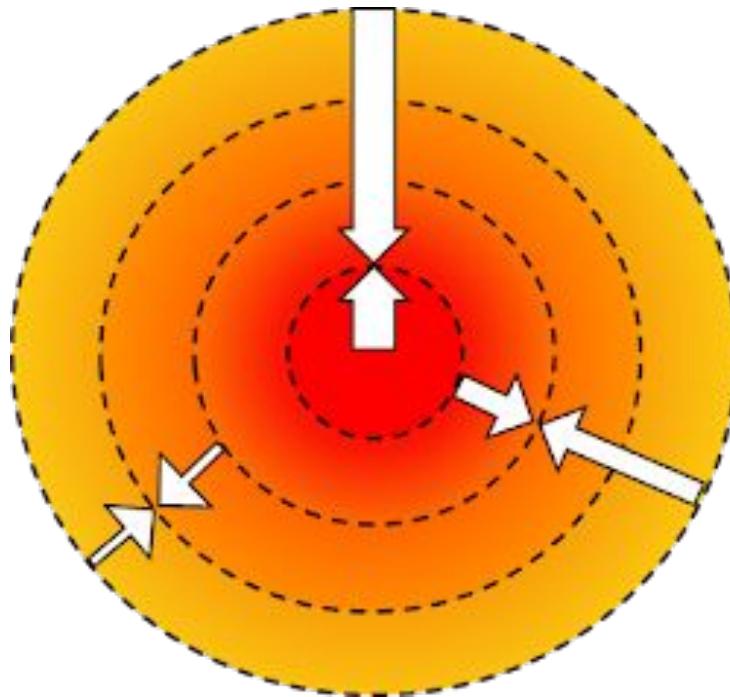
# What Are Stars Made of?

- 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

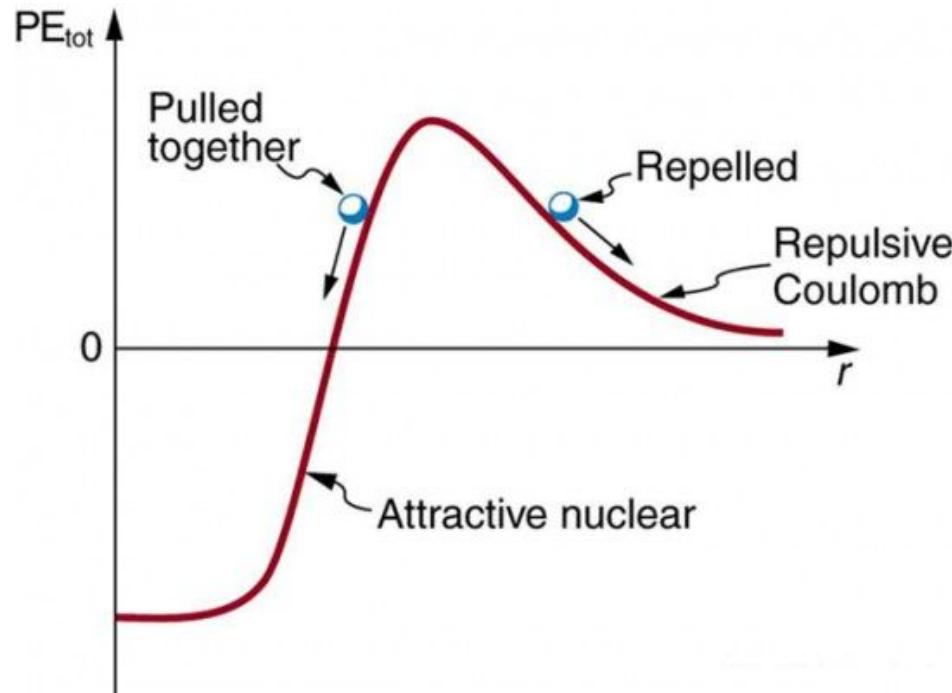
$$\rho_r \frac{d^2r}{dt^2} = -\frac{dP_r}{dr} - G \frac{M_r \rho_r}{r^2}$$

Hydrostatic equilibrium

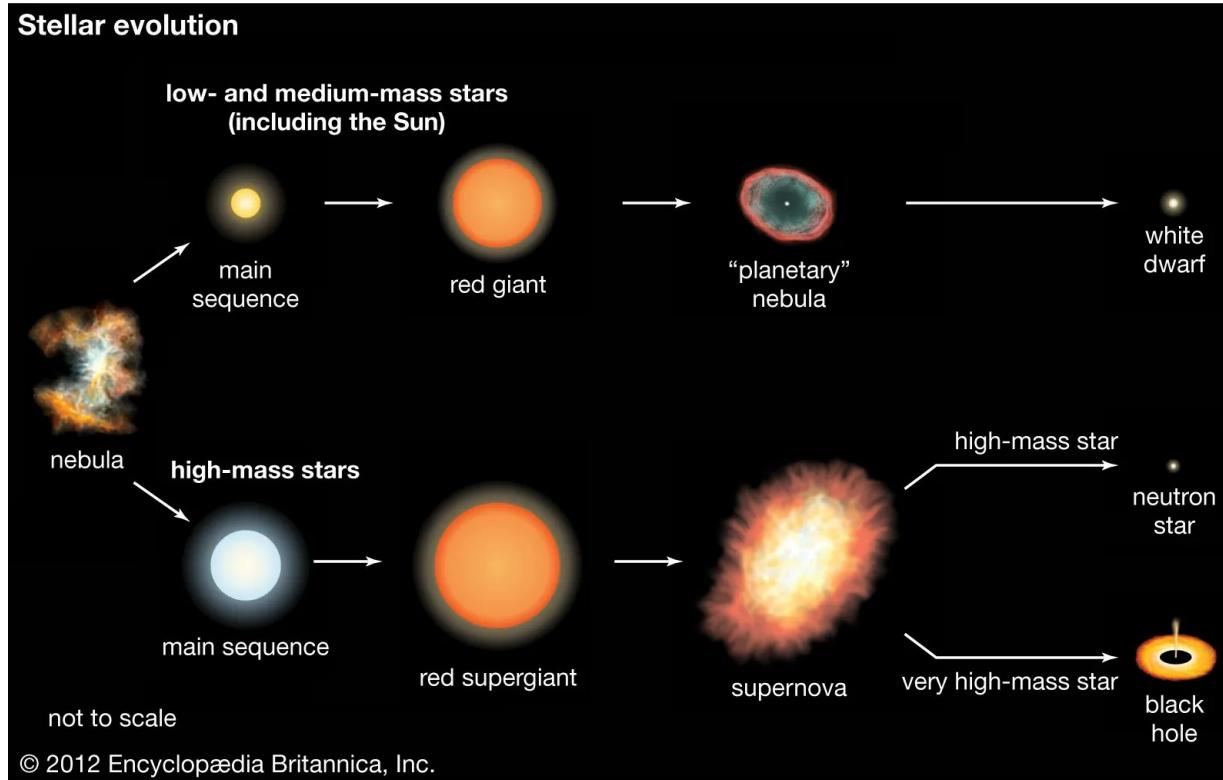
$$\frac{dP_r}{dr} = -G \frac{M_r \rho_r}{r^2}$$

# Fusion

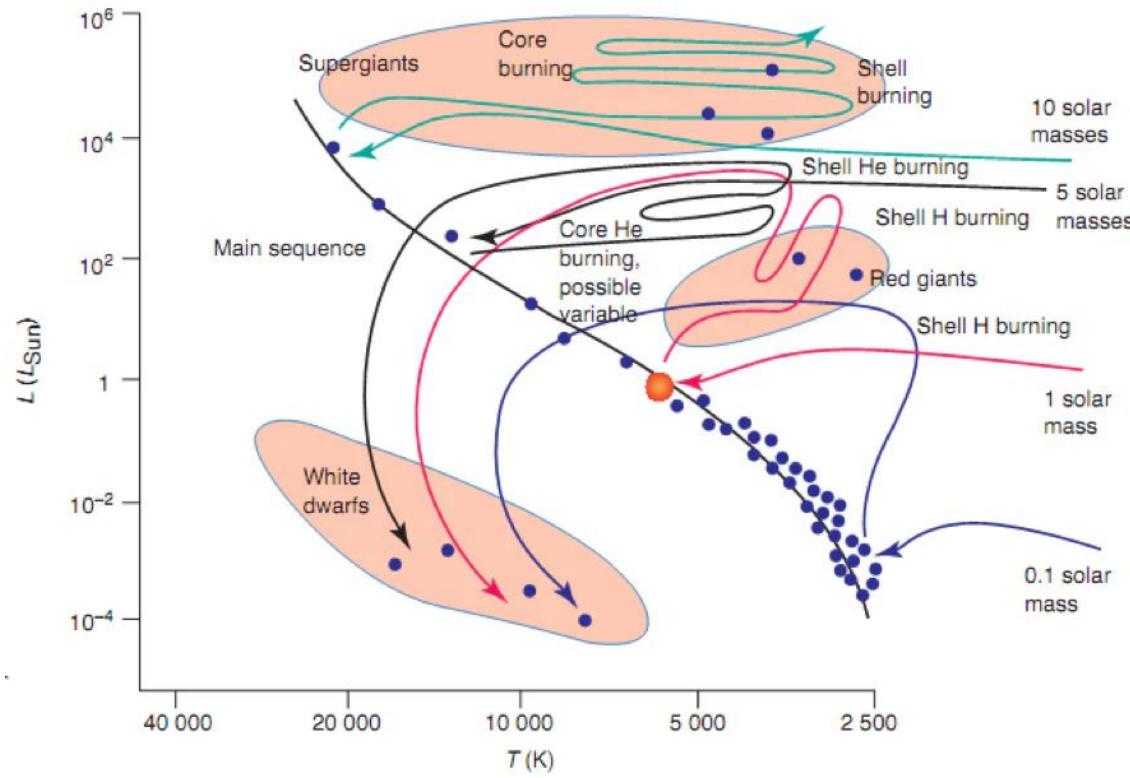
- Fusion Burns Up to Iron
- Fusion releases heat which builds pressure
- Stars are the creators of almost all elements



# Stellar Evolution



# Main Sequence



# Galaxies: The size of the universe

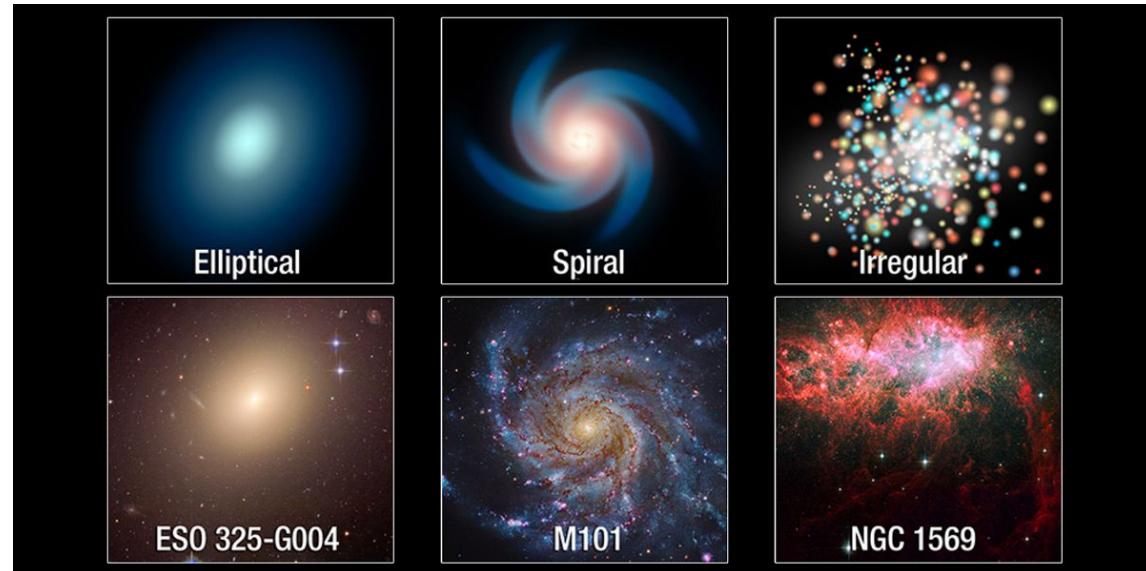
# Galaxies are Star Groups

- $10^5$  to  $10^{13}$  solar masses of stars
- Most of the mass is dark matter
- $\sim 100,000$  light years across ( $\sim 10$  kpc)
- Have dwarf galaxies
- Centered on a supermassive black hole



# Types of Galaxies

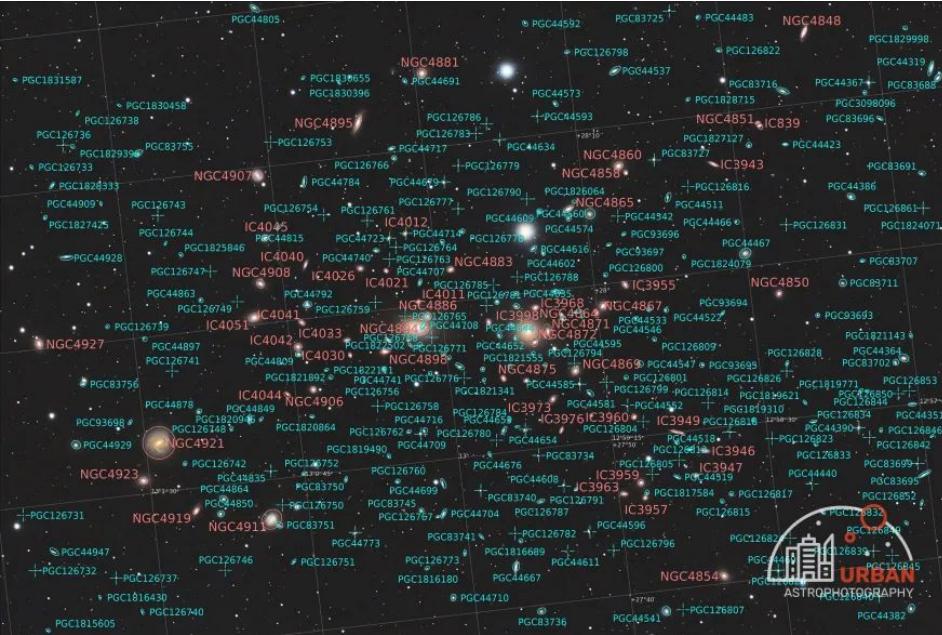
- Types:
  - Spiral
  - Elliptical
  - Irregular
  - S0
- Spirals:
  - Star Forming
  - Young + Brighter
  - Disk structure
- Ellipticals:
  - Old + Dimmer
  - Spherical



*What causes the difference?*

# Things Can Get Bigger

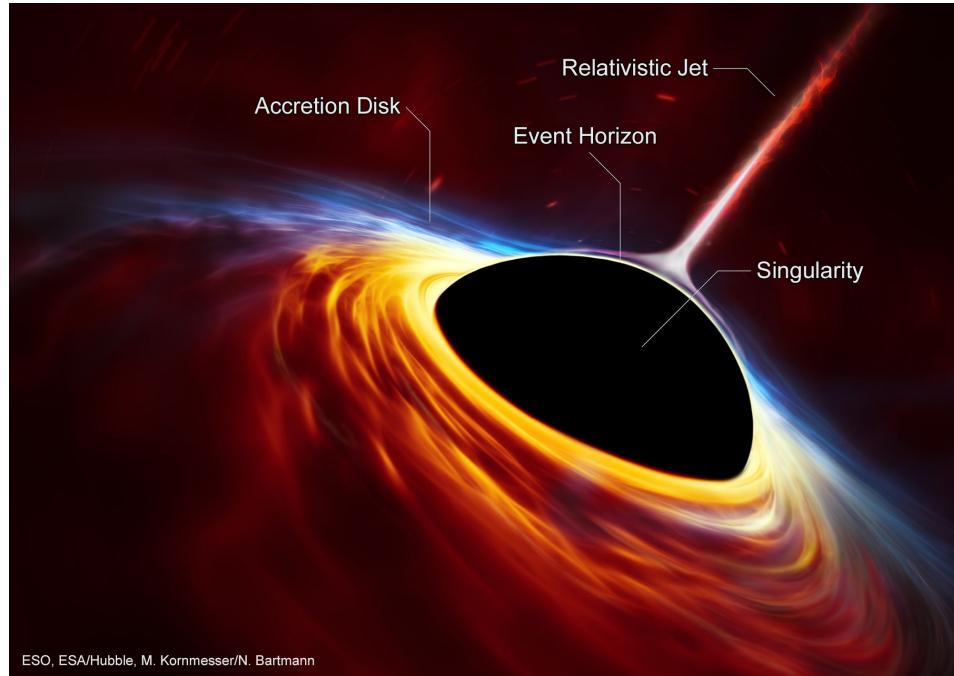
- Groups have a few galaxies
  - Galaxy clusters have 1000s of galaxies
  - In between is made of very hot gas (ten million Kelvin!)
  - But mostly dark matter...



# Compact Objects: The Oddballs of Astronomy

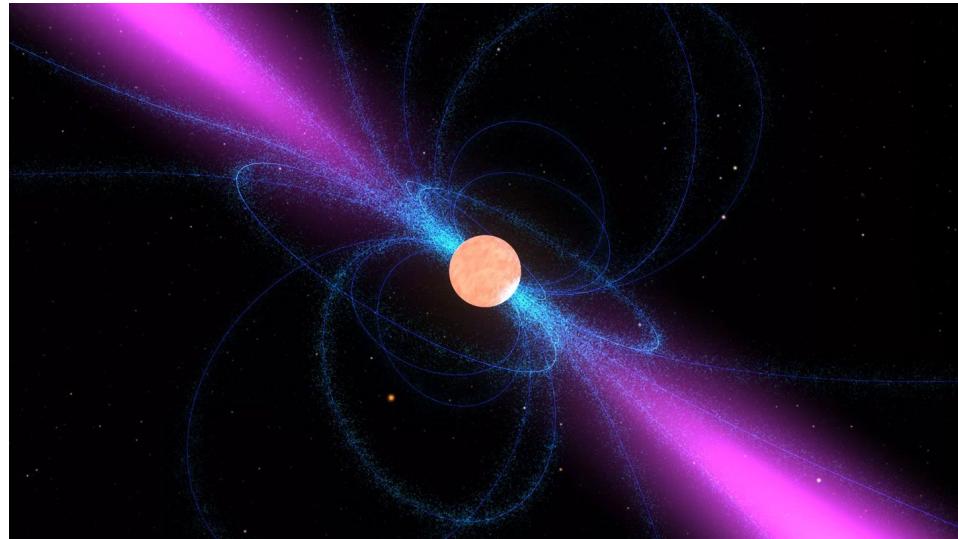
# Black Holes

- Relativity says nothing can exceed the speed of light
- Black holes formed via star death
  - Or during the early universe
- We can only see their accretion
- Can be observed by gravitational effects



# Neutron Stars

- Just shy of being a black hole
- The whole star is like an atom
- Hosts up to 1.6 billion Tesla magnetic fields
- Used as “standard clocks” (error of  $1.7 \times 10^{-17}$  s)



# Cosmology: The History of the Universe

# Exoplanets: And the search for life

# Presentations!

# Presentations

- Introduce yourselves again
- Make 3-5 slides to speak for 5-10 minutes
- Teach me about either:
  - The basics of your topic
  - The specifics of a part of your topic
- Compile work on one computer using other computers to do background research
- We will work for ~30 minutes
- Don't worry about knowing everything and please ask me clarifying questions

Group	Member A	Member B	Member C	Member D
# 1	Isabella	Thalia	Tiana	Olivia
# 2	Samantha	Hirushi	Katerina	Jadyn
# 3	Ella	Maddy	Ava	



Stony Brook  
University



## Women in Science & Engineering (WISE)

We are offering CPR Training from the University Police Department!

**When?** 4-5 PM on Thursday, Nov 21st, 2024

**Where?** Stony Brook Main Campus Student Union Building Multipurpose Room

**Cost?** Class is free, but certification is \$20.00 payable by check at the class

**There are 20 spaces available, so first-come first-serve. We will contact you regarding your status.**

Register via the QR code or this link:  
<https://forms.gle/CXGnE6dgQiCS8wSF6>

Group Picture!  
(Now or Later?)

# How to Read Plots in Astro

# Anatomy of a Plot

## Common features of a graph

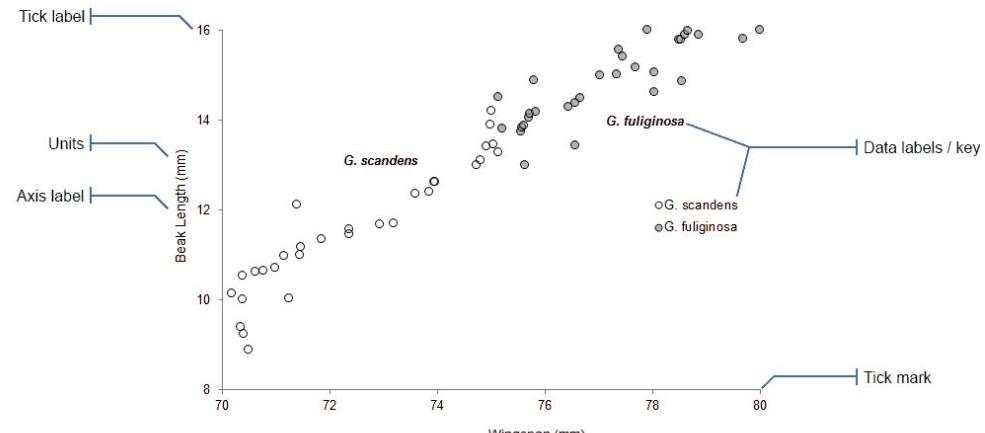


Figure 2. Correlation between wingspan and beak length for *Geospiza scandens* and *Geospiza fuliginosa*.

# Anatomy of a Plot

- Title
- Axes
  - Labels
  - Units
  - Scale
- Legend
- Caption

## Common features of a graph

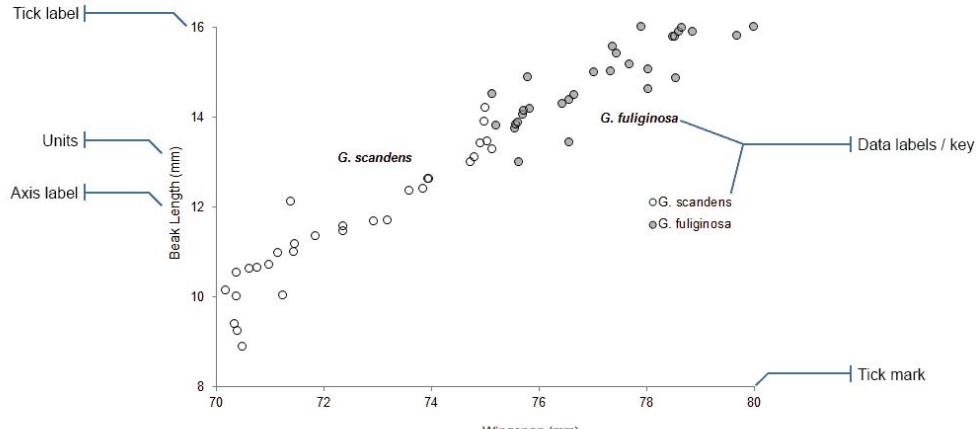


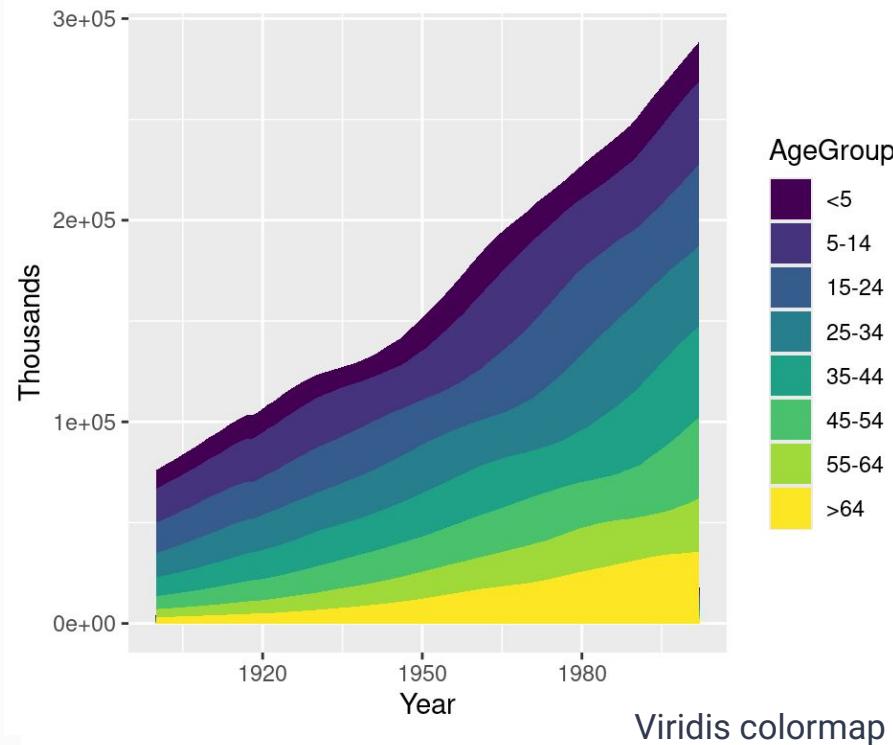
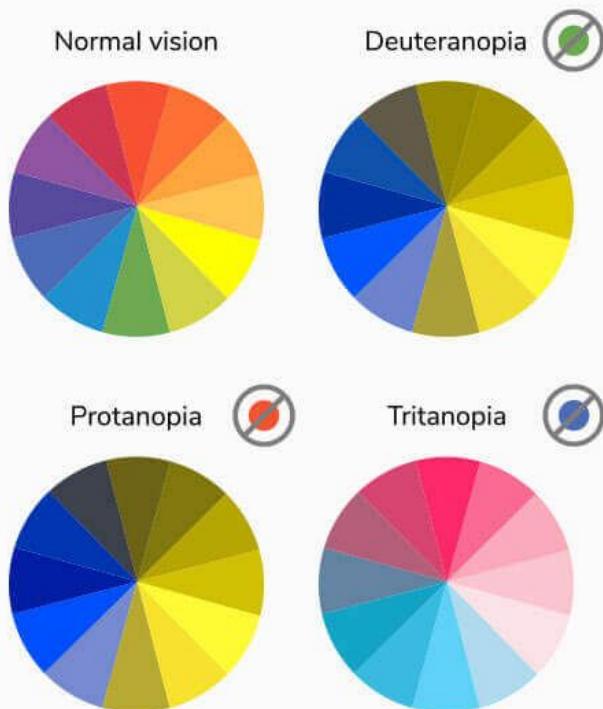
Figure 2. Correlation between wingspan and beak length for *Geospiza scandens* and *Geospiza fuliginosa*.

# Axioms of Plot Design

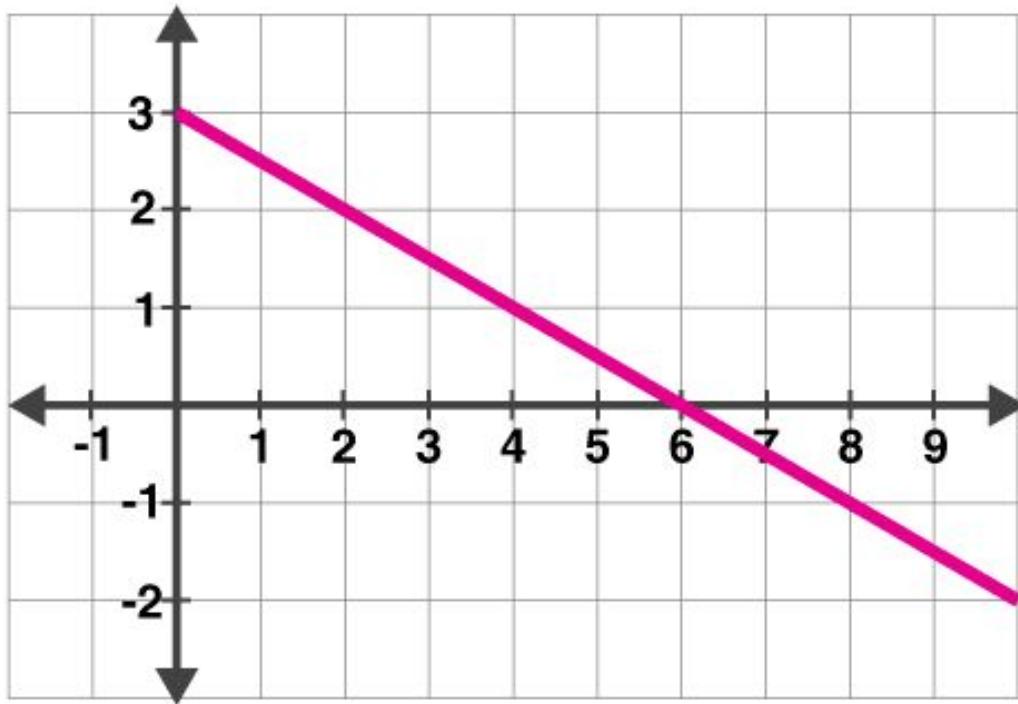
Plots should...

- Speak for themselves
- Be easy to read for everyone
- Maintain scientific rigor

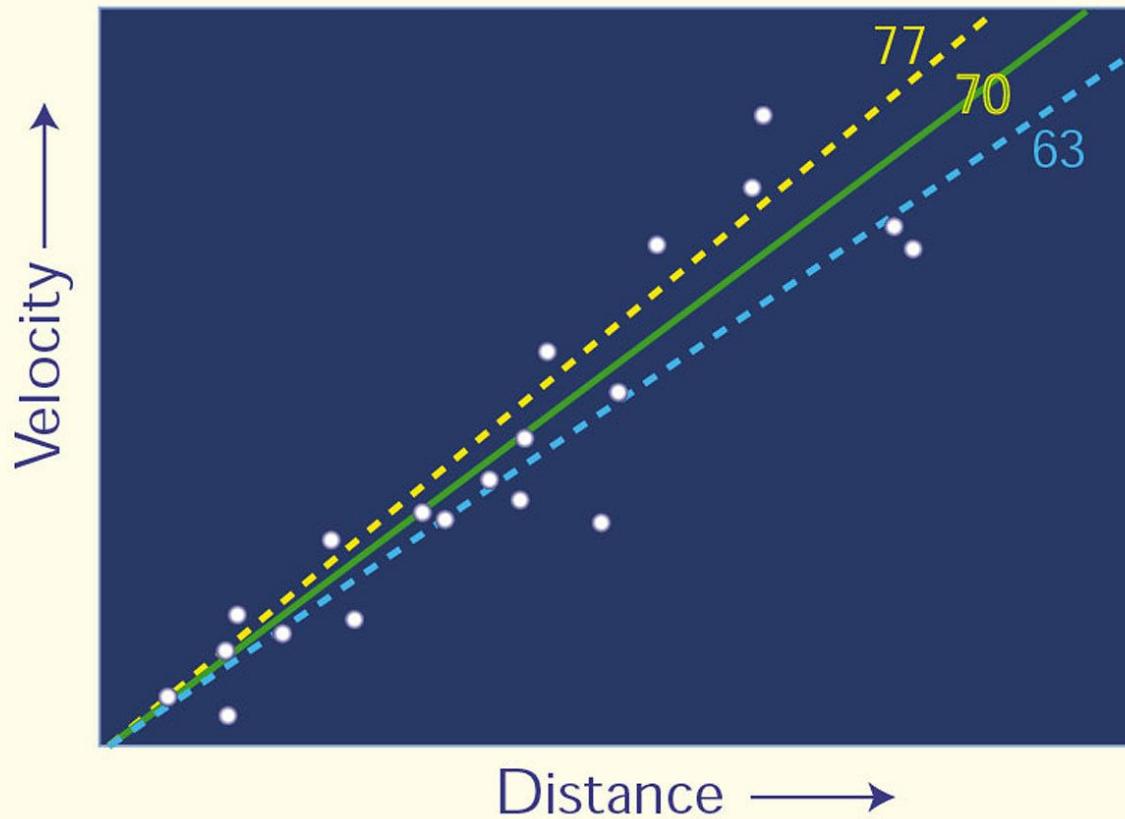
# Color Blindness



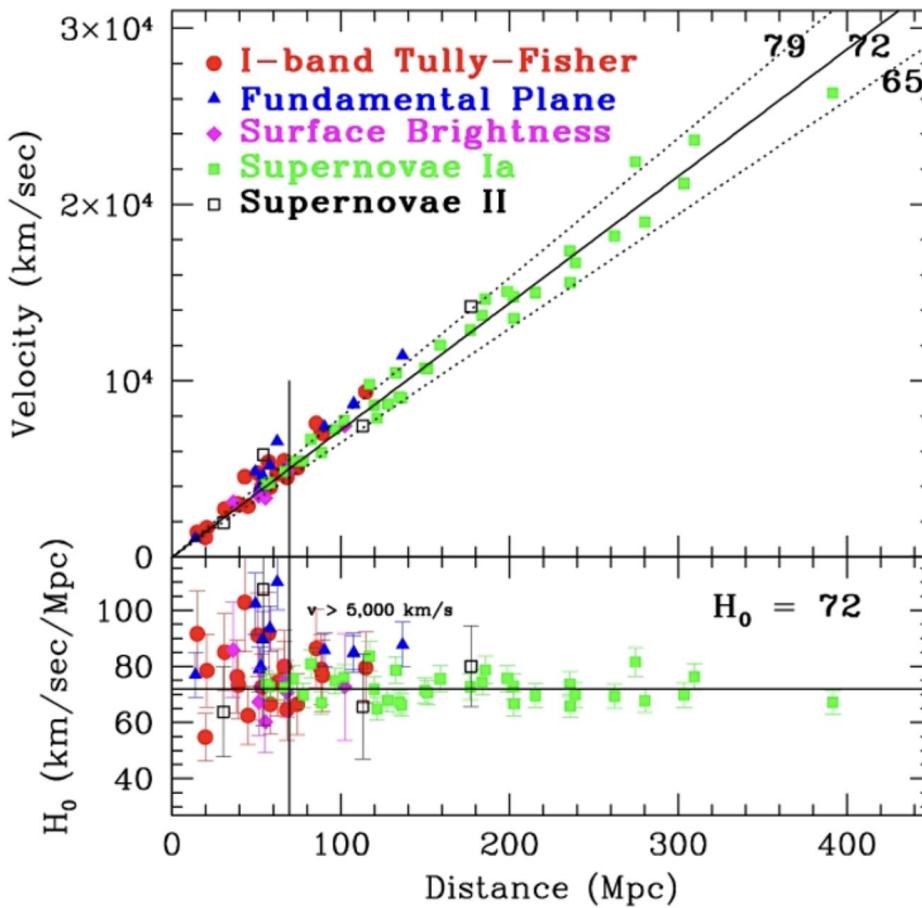
# Let's Judge Some Plots!



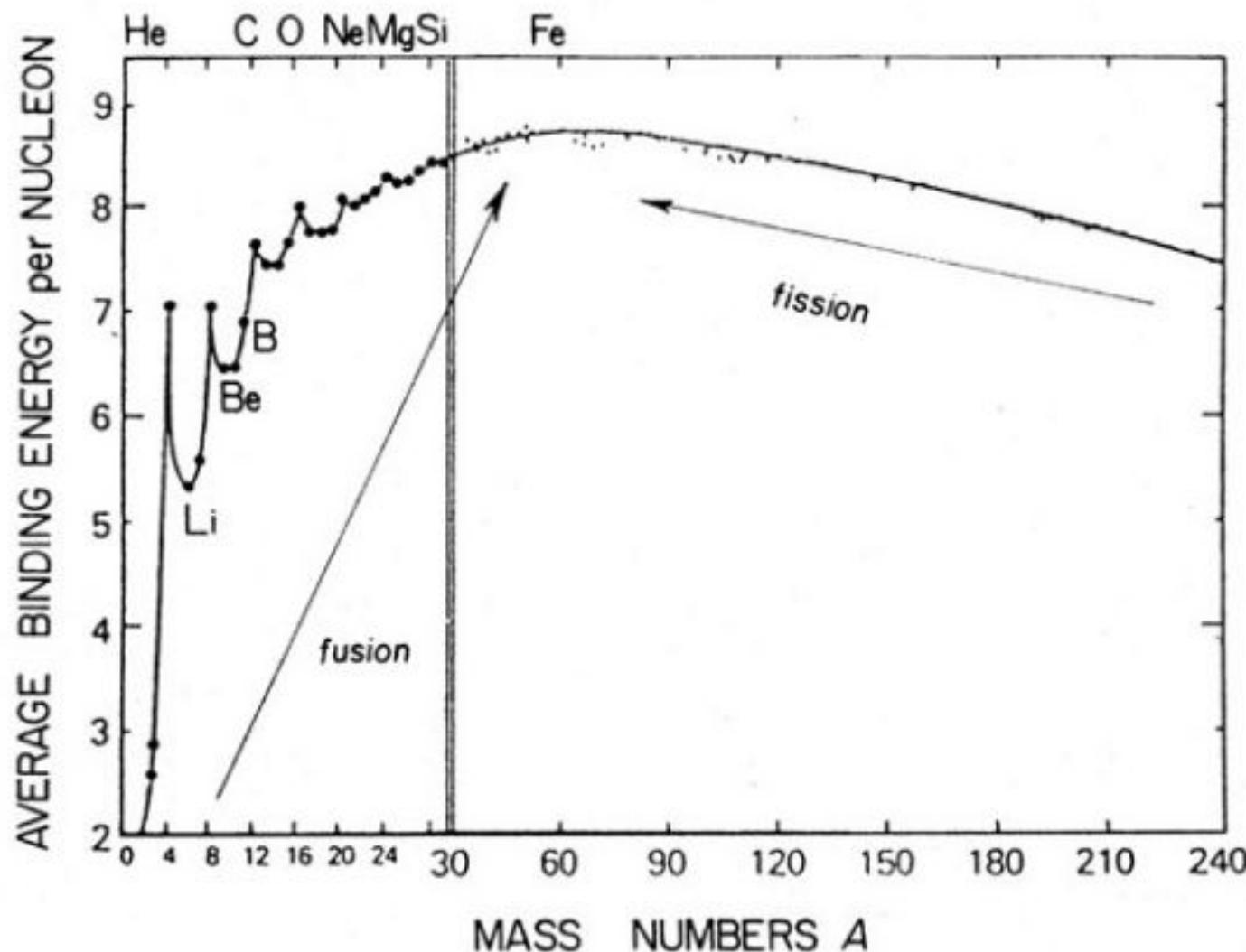
# Hubble Diagram for Cepheids

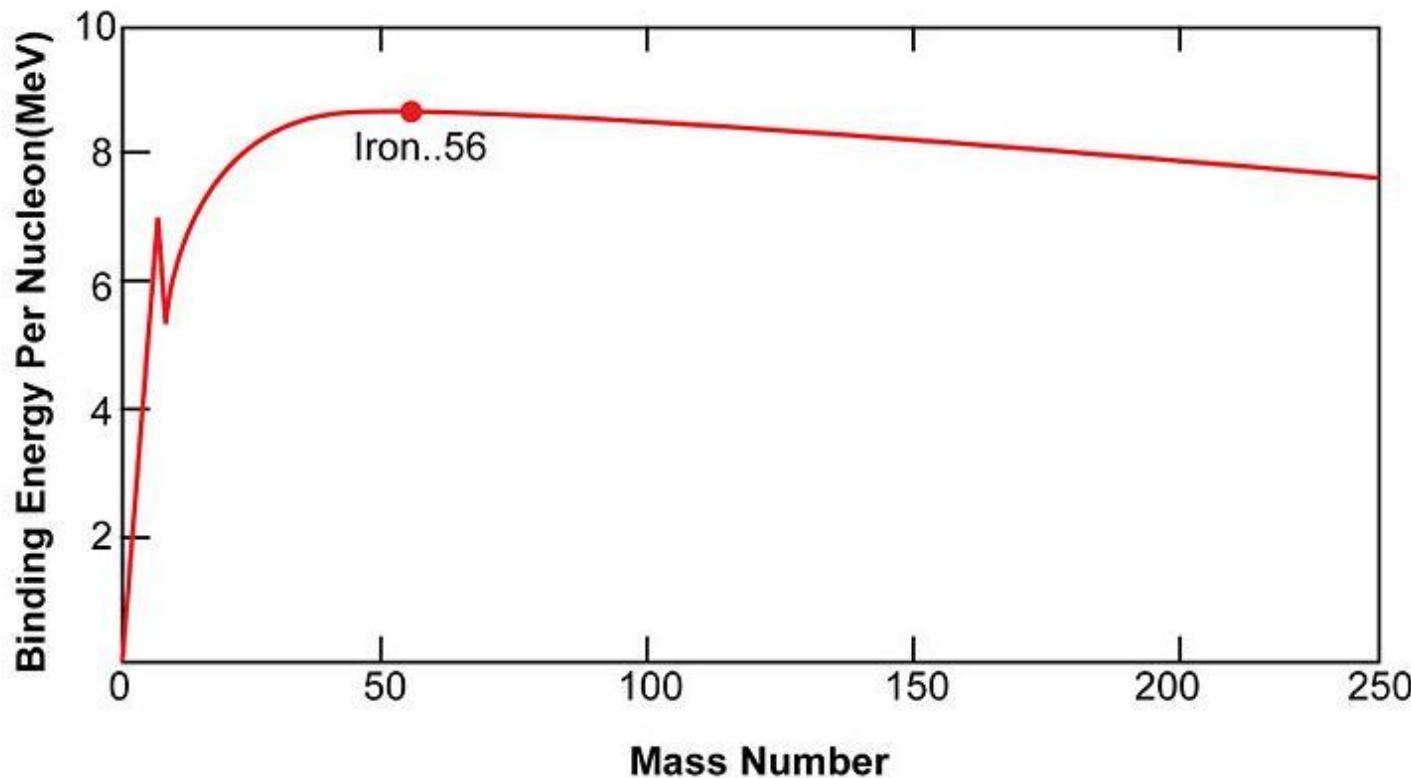


Caption: Hubble diagram showing the final results from the HST Key Project (Freedman et al. 2001) In the top panel velocity is plotted versus distance for the five secondary distance methods labeled in the plot. The solid line is for a slope of 72, flanked by dotted lines indicating a 10% uncertainty. The bottom panel shows the residuals for a value of  $H_0 = 72 \pm 3$  (stat)  $\pm 7$  (sys)  $\text{km s}^{-1} \text{Mpc}^{-1}$ .

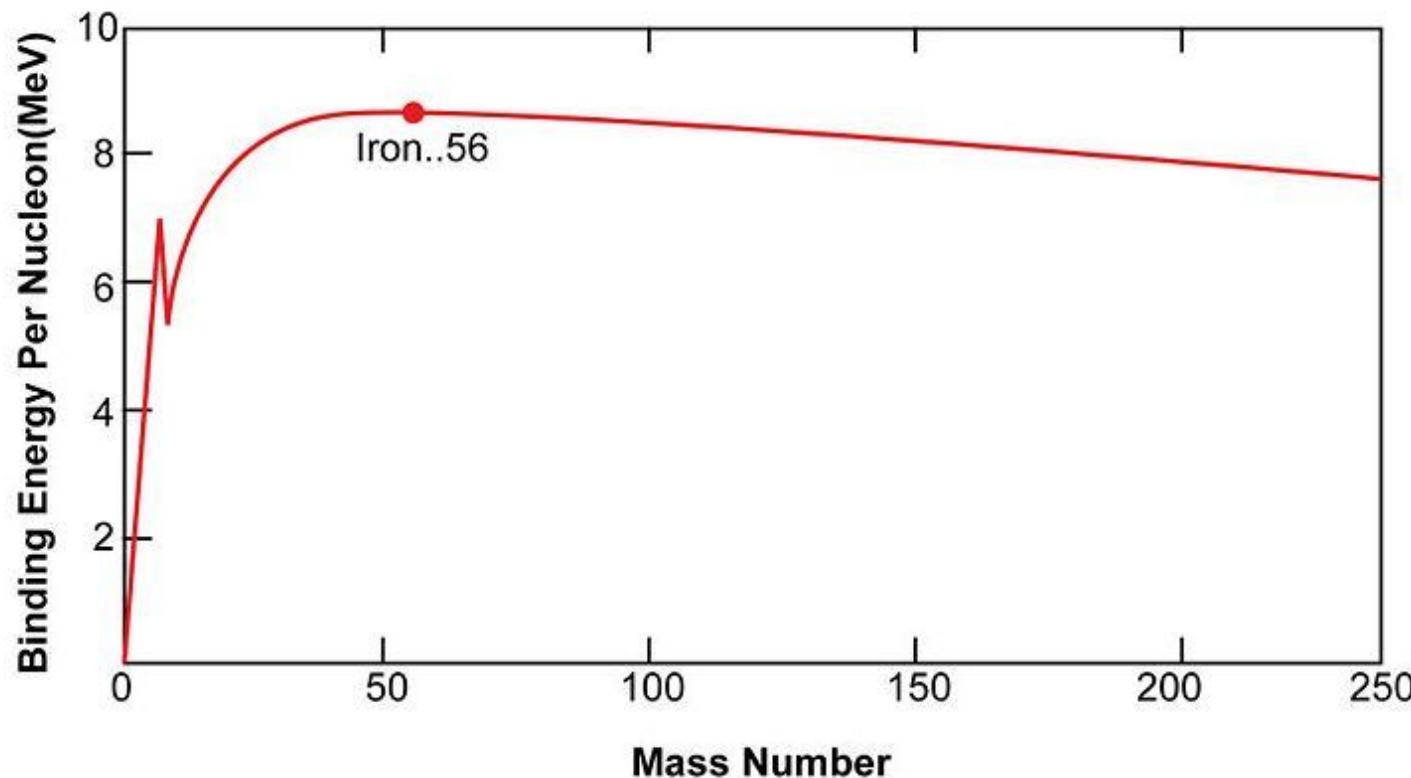


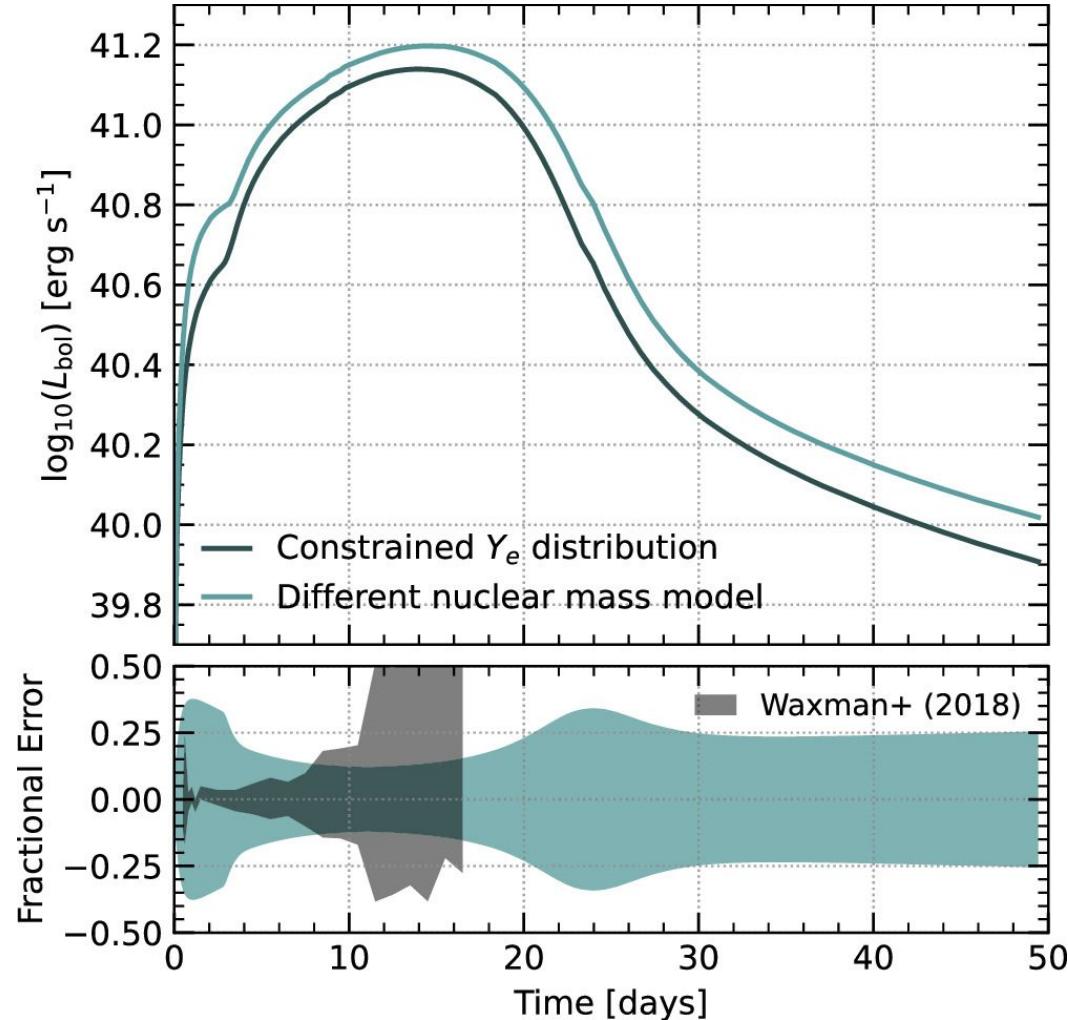
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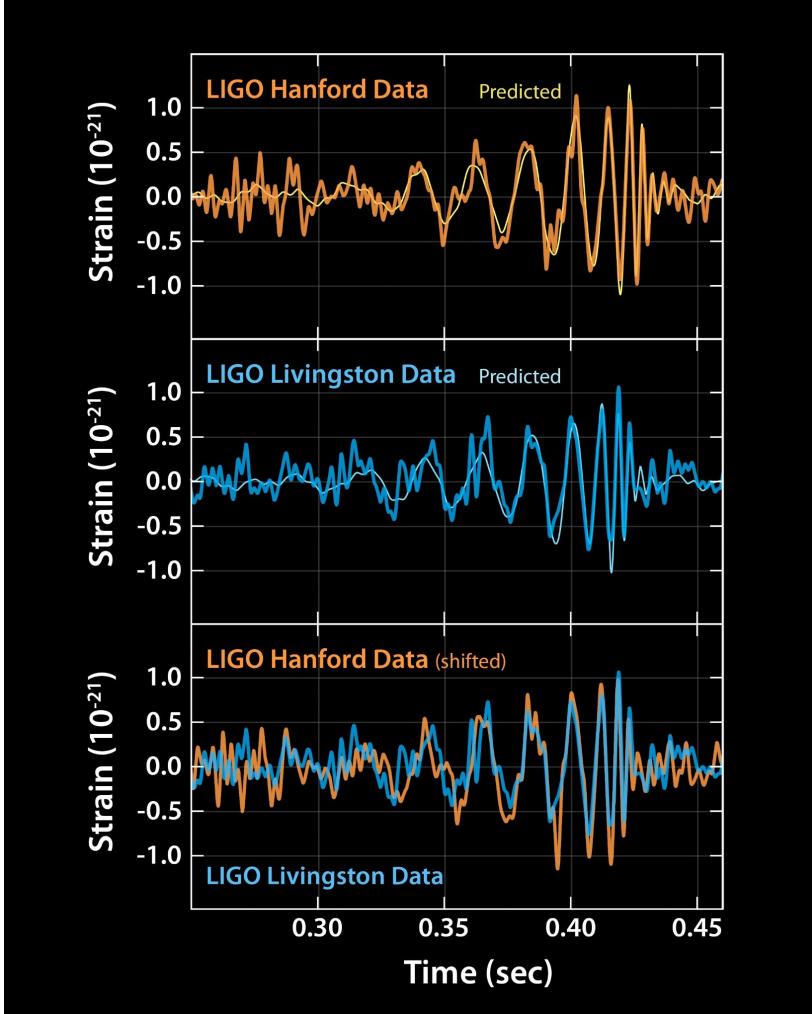


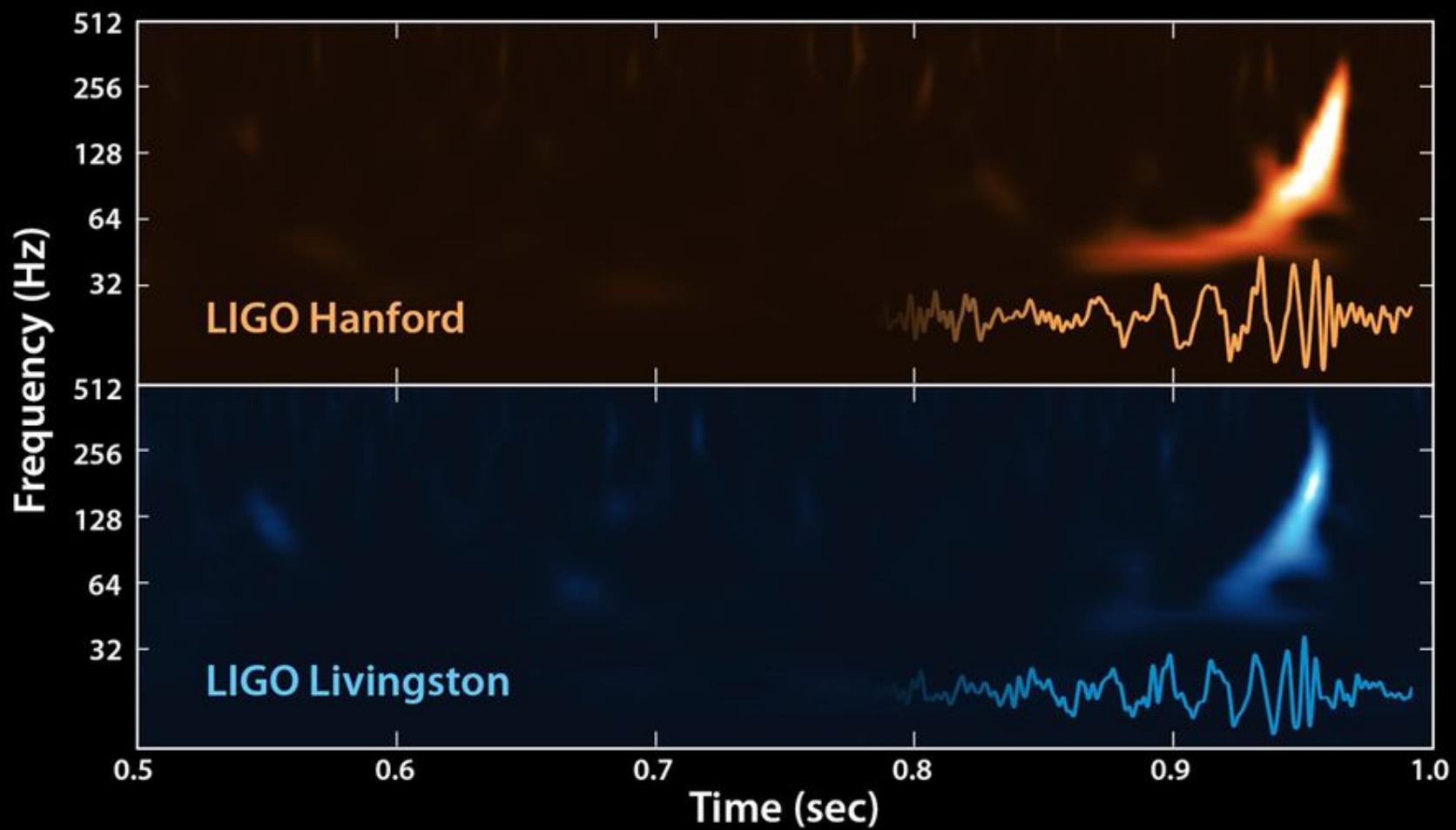


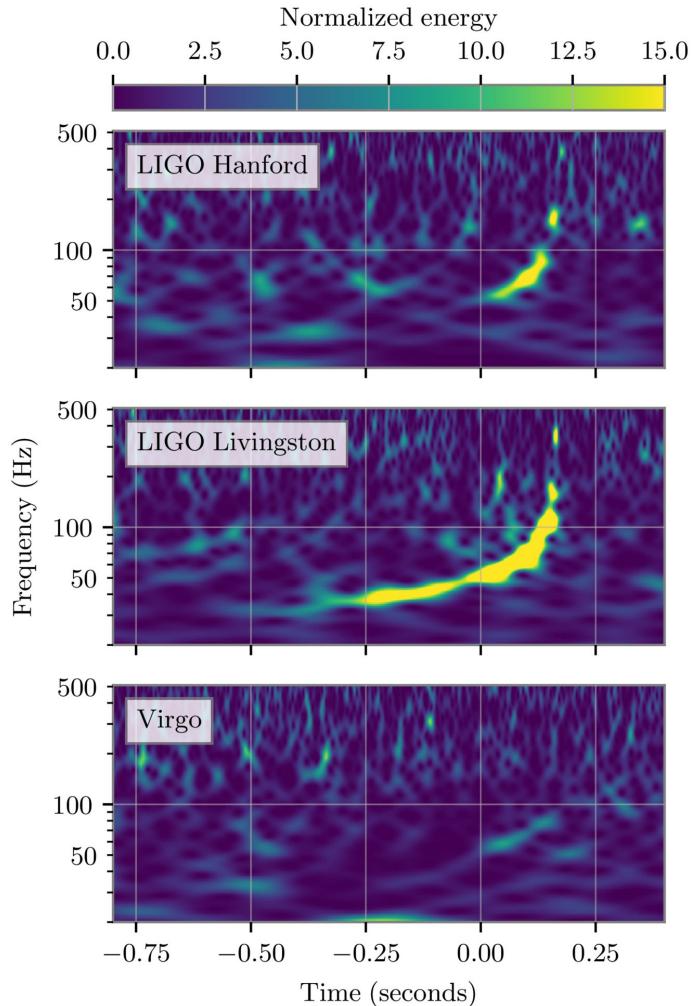
# Is This Data??



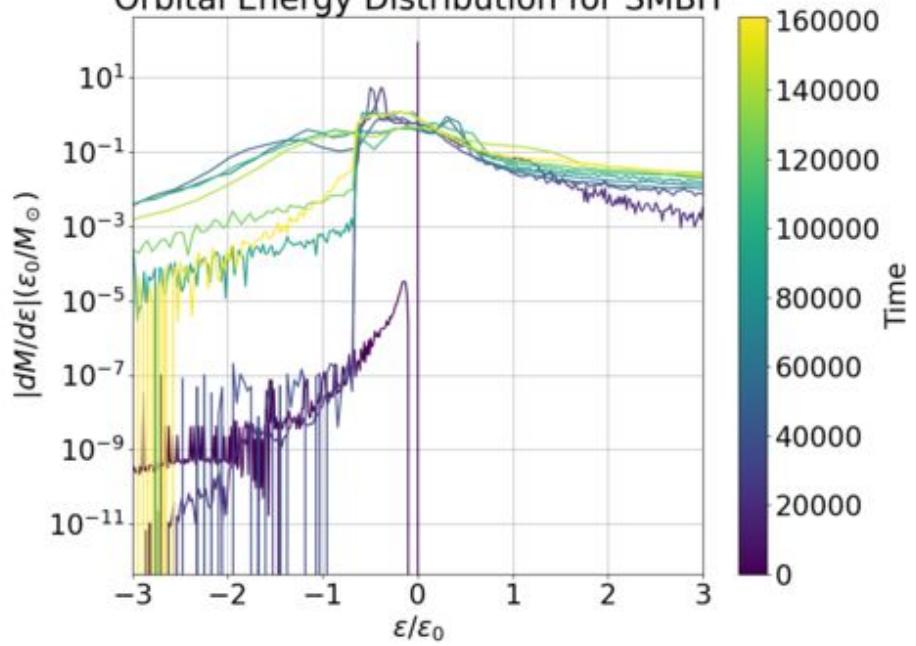








Orbital Energy Distribution for SMBH



Orbital Energy Distribution for sBH

