Australian Government
Australian Research Council

OzGrav

ARC Centre of Excellence for Gravitational Wave Discovery

Mission Gravity – Outreach PD

OzGrav Retreat 2018

Swinburne University of Technology · Australian National University · Monash University · The University of Adelaide · The University of Melbourne · The University of Western Australia · AAO · CSIRO

Mission Roles

Each member of the team will have a specific role to study one aspect of the star

Each team will travel to a different star to develop its evolutionary model

- Teams will use multiple representation to share their models
- The class will come together to generalize their models to create a broader view

Mission Review

This part is very important to understanding your class!
Don't short-change it!

- Why is it important to understand stars?
- What do you know (or think you know) about stars? Talk with your team!
- How can we describe stars' properties?
- How can we measure these? What are our barriers to measuring these?

Mission Training: Science Manual

Goal: To measure how a star's…

Temperature

Size (Diameter)

Mass

Composition

… change over its lifetime

To do this, you will measure the star's…

Peak Wavelength

Angular Diameter

Gravitational acceleration (of a probe)

Metallicity

… over its lifetime

Using Wavelength of Light to Find Temperature

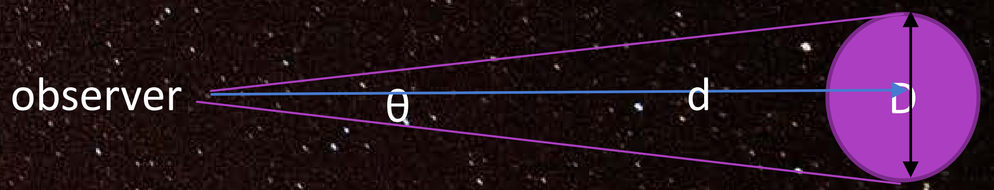
- Hot objects such as stars radiate energy in the form of light and heat
- Light is a wave. The colour of the light depends on the wavelength of the light wave.
  - Red light has a long wavelength compared to blue light
- The wavelength of the light can provide the temperature of the star.
  - Shorter wavelength light waves are more energetic and indicate hotter stars

- Include a diagram of wave / EM spectrum
- The VR Spectrometer will provide the measure of the most dominant (peak) wavelength in the star
- The following relation (Wien's displacement law) relates the peak wavelength (in nanometers) and the temperature (in degrees Kelvin)
  - $Temperature\ (K) = \frac{2{,}900{,}000\ K \cdot nm}{Wavelength\ (nm)}$
  - Example if the peak wavelength is 500 nm
    - $T(K) = \frac{2{,}900{,}000\ K \cdot nm}{500\ nm} = 5{,}800\ K$

This part can be varied according to the time of the lesson and level of students! Additional info is in the manual!

Use Angle to Find the Diameter of a Star

- Geometric relationships are used to find the size of objects in the universe
- The size of the star will change depending on how far away the observer is
- The VR device will measure apparent angular size (θ in radians) and the distance to the star (d in meters)



- To find the diameter of the star, use the following trigonometric relation for small angles
- $D = d \times \theta$

Use Orbital Motion to Measure the Mass of the Star

- The motion of an orbiting object provides information about the object being orbited.
  - The motion of planets orbiting the Sun provides information about the size of the Sun
  - The motion of satellites orbiting the Earth provides information about the size of the Earth.
- Newton's Law of Gravitation models the motion of orbiting objects.
  - The gravitational force between two objects depends on the masses of the objects and how far apart they are.
  - The gravitational force determines the motion of the object (how fast it moves, how it changes motion along the curving path of orbit, etc.)

The VR accelerometer and VR range finder provide data about how the motion of the cannon changes as it orbits (acceleration) and the distance at which it orbits (distance in solar radii).

These and Newton's Law of motion provide the following relationship to determine the mass of the star in Solar Mass Units. G is a constant of proportionality which is here scaled to 1.

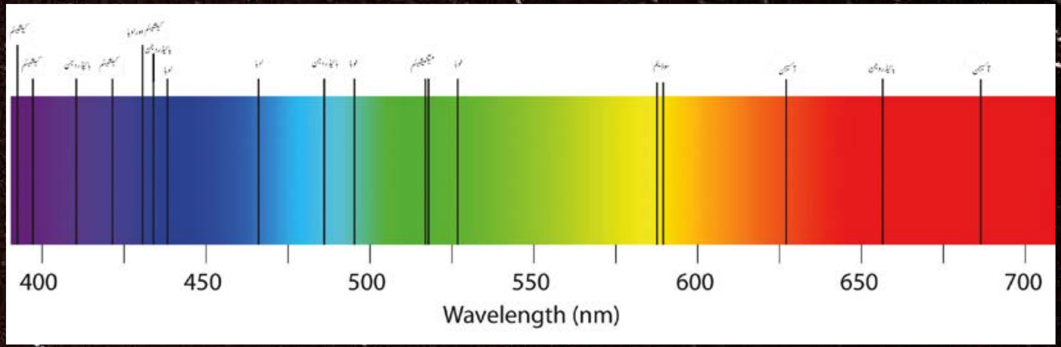
$$Mass = \frac{Acceleration \times (OrbitalRadius^2)}{G}$$

For example, if acceleration=0.04573 and the orbital radius = 4.676, then

$$M = \frac{0.04573 \times (4.676)^2}{1} = 1\ Solar\ mass$$

Using spectra to find the composition of the star

- Light from a star is a combination of many colours (wavelengths) of light
- Light can be passed through devices that spread out the light into its component colours
- When light is spread through a diffraction grating, it shows the colour prism with some conspicuous dark lines
- The location of these bright lines in the spectrum correspond to the dominant elements in the stars



Mission Training: Ground Control Preparation

Experimental Design:

- Identify independent and dependent variables
- Identify experimental pairs and process
- Identify observed vs. calculated parameters

GET READY:

- Data Tables
- Pens
- Roles…

Mission Prep: Roles

- **Science Officer** – leads investigation on temp of star
- **Flight Commander** – leads investigation on the size of star
- **Flight Engineer** – leads investigation on the mass of the star
- ***Mission Specialist*** *– leads investigation on composition of star*

Assigning roles is fun and we plan on adding badges for this. However, you can divide the groups as best suits the class.

Space Safety Rules

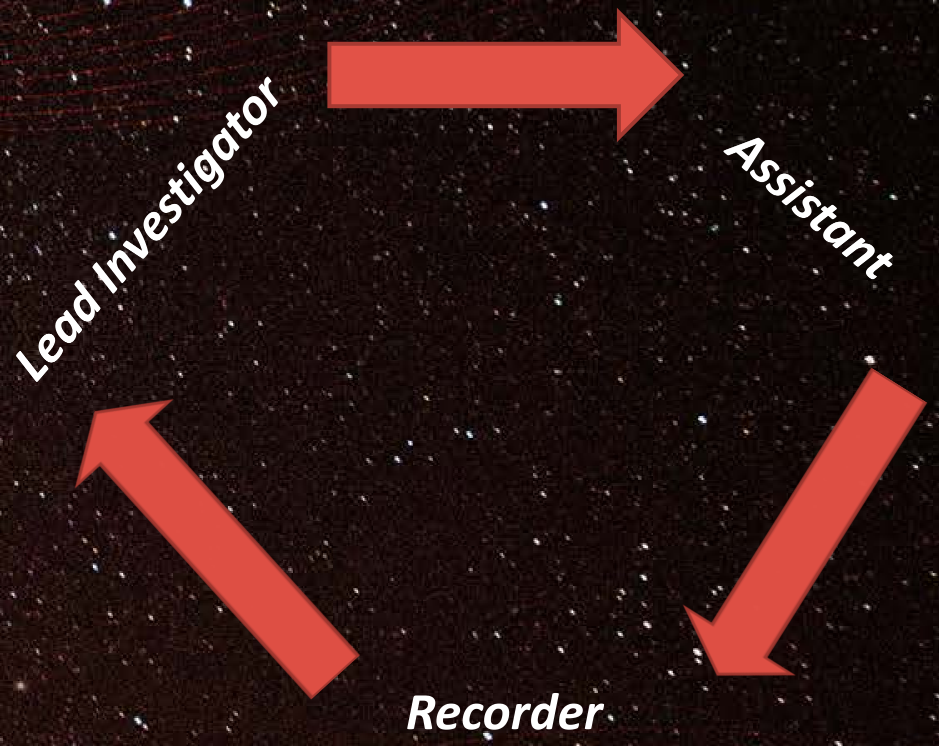
- Listen carefully to all instructions
- Remain seated
- Small motions with controllers
- Ensure equipment remains as you found it
- Don’t harrass the person in VR

Team Roles

Lead Investigator: In the VR, collecting data and reporting it to the team

Assistant: Ensure the person in VR is safe and instructs team on the science background

Recorder: Writes the data reported by the Lead Investigator is properly documented



Mission Training: VR

- Adjusting the headset
- Tools in VR – using the remote… what do the buttons do, etc.
- Navigating in VR – what are the major controls to move through space, time, use tools, etc.

All mission controls are driven by the front button: This is a combination touch trackpad and touch-sensitive button

Press and HOLD to re-center (Don't just press)

Practice!
Practice!
Practice!

Training Points

- Charging headsets and remotes
- Charge duration
- Turning Headsets on
- Fit / adjustment of Headsets
- Waking and centring remote
- Choosing app
- Setting up router
- Opening command centre
- Using Command Centre

- Assigning stars
- Turning on sensors
- Travelling to stars
- Using tools
- Aging stars
- Changing distance

Ready – Set – Blast Off!

- Assign roles and confirm what to do!
- Confirm data to be collected!
- Demo manoeuvring with a volunteer (or the teacher)!
- Assign each group a star
- Guide first group through the VR experience together
- Once data is collected, Lead investigator returns home and group confirms they have the data and observations they need
- Rotate roles and confirm what to do!
- Confirm data to be collected!
- Repeat!

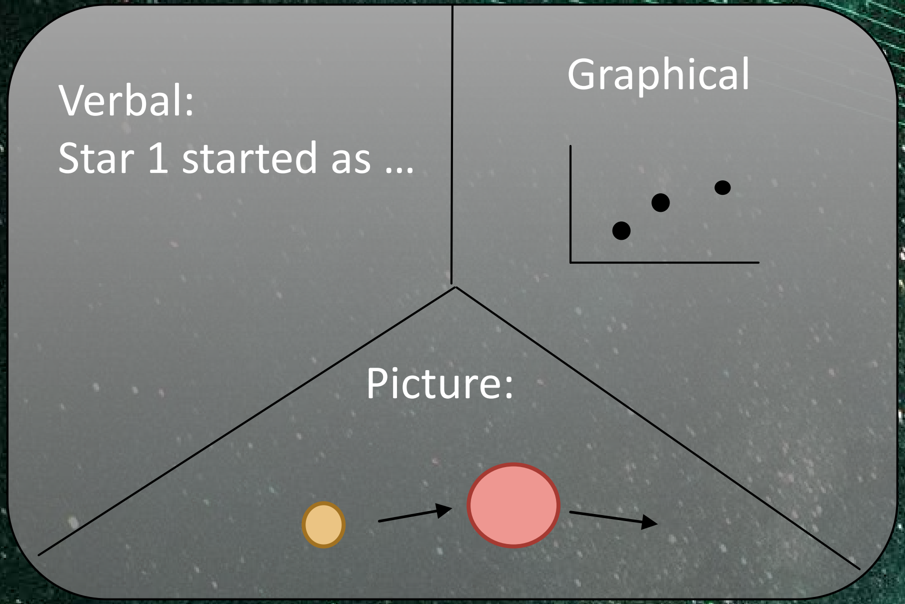
I generally don't show this, at this point switch to command centre view. This is useful to help guide students, though

Results and model to share

This is great to do as time allows, though sometimes a short verbal discussion is OK. Don't hesitate to share the results spreadsheet with teachers so they can use it after the incursion

Tell the story of your star using three types of models

- VERBAL
- GRAPHICAL
- PICTORAL



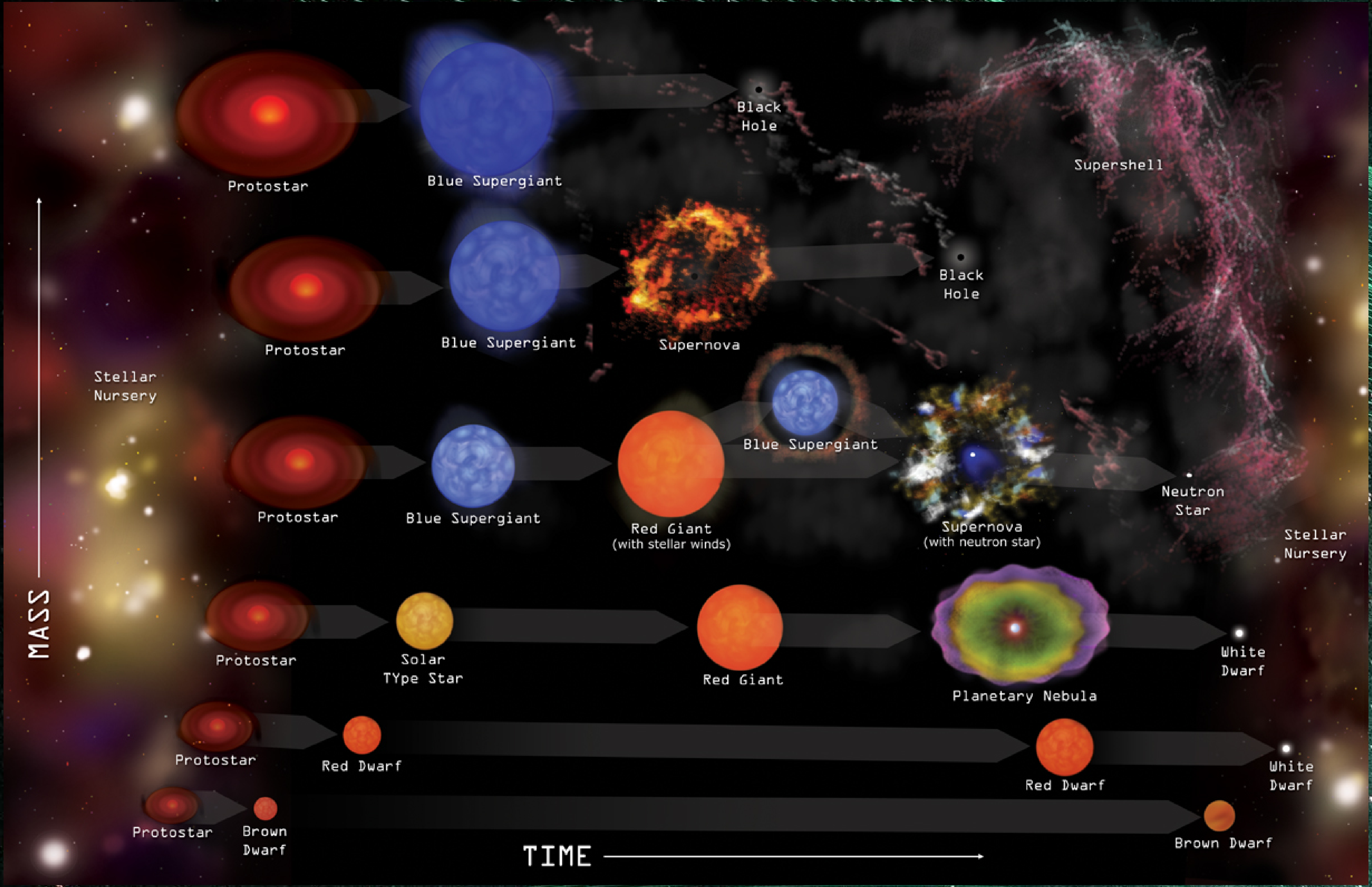
Large Group Model Building

Sharing of models

- Prepare to take ONE minute to share your model with the class!
- Take time to check out the other models
- Focus on the other models and focus on the key similarities and differences.

Consensus Building

- Create consensus statements regarding stellar evolution. Be prepared to share!
- What can we all agree on?
- What can scientists agree on?


Protostar
Blue Supergiant
Black Hole
Supershell
Protostar
Blue Supergiant
Supernova
Black Hole
Stellar Nursery
Protostar
Blue Supergiant
Red Giant
(with stellar winds)
Blue Supergiant
Supernova
(with neutron star)
Neutron Star
Stellar Nursery
MASS
Protostar
Solar Type Star
Red Giant
Planetary Nebula
White Dwarf
Protostar
Red Dwarf
Red Dwarf
White Dwarf
Protostar
Brown Dwarf
Brown Dwarf
TIME

Conclusions

- Feedback about student models vs scientifically accepted models
- What are shortcomings of your model and methodology?
- What about real measurements?
- Final Questions?

OUTREACH

"The **mission** of our centre of excellence is to use the historic first detections of **gravitational waves** to **understand** the extreme physics of **black holes** and **warped spacetime** and to **inspire** the next generation of **Australian scientists and engineers** through this new window on the universe."

Prof Matthew Bailes

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AAO

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THE UNIVERSITY of ADELAIDE

THE UNIVERSITY OF MELBOURNE

CSIRO

Team Roles

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VR Assistant: Ensure the person in VR is safe and provides notes on manoeuvring in VR

Manager: Keeps track of time, ensures the task is completed

Recorder: Writes the data reported by the Lead Investigator is properly documented