

# The Hertzsprung-Russell Diagram

VIREO – Virtual Educational Observatory

# Aims



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Alice Perry, Ogden Student Intern, July 2017

- ◊ To use the observational + analysis tools of modern astronomy
- ◊ To use the setup that professional astronomers use at large telescopes
- ◊ To produce and compare Hertzsprung-Russell diagrams of star clusters
- ◊ To estimate the distance + age of star clusters
- ◊ To conduct independent scientific research

# Hertzsprung-Russell Diagram



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Ejnar Hertzsprung



Henry Norris Russell

↓  
Hertzsprung-Russell diagram (HRD)  
1910

evolution of stars

surface temperature  
+ luminosity

or...

colour index  
+ absolute magnitude

↓  
colour-magnitude  
diagram (CMD)

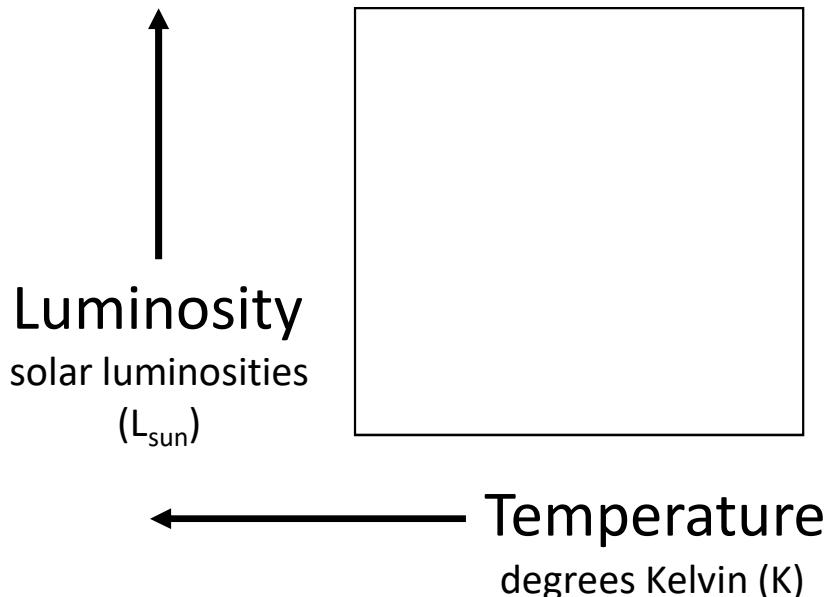
# HRD or CMD



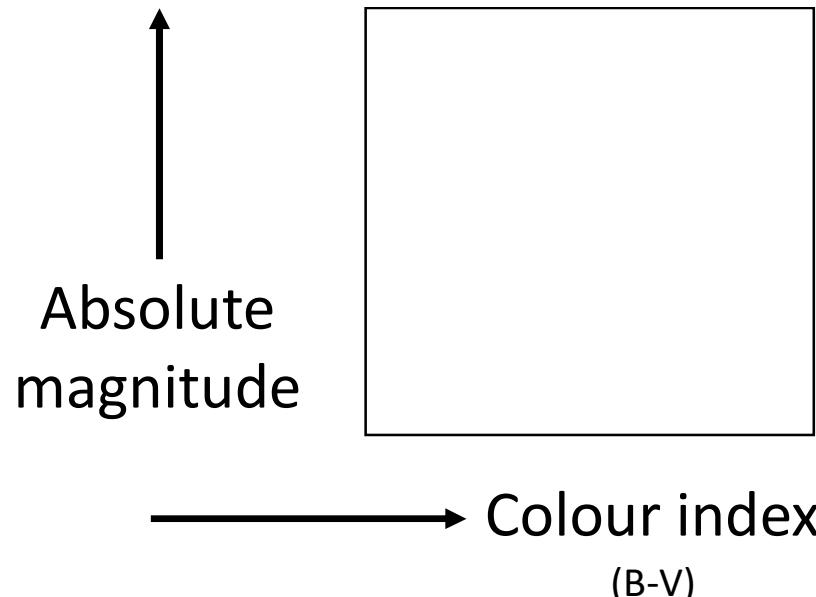
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Hertzsprung-Russell  
diagram (HRD)



colour-magnitude  
diagram (CMD)



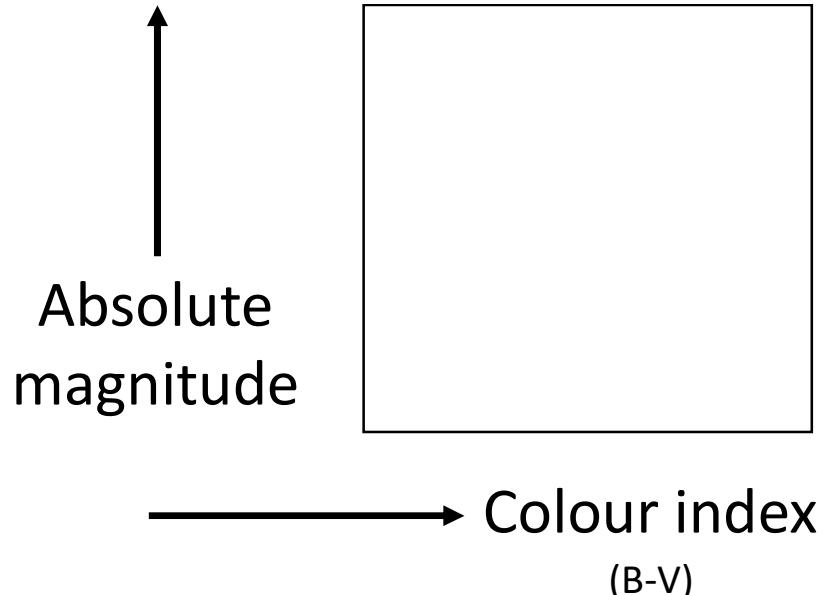
# Colour-Magnitude Diagram



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- ◊ Magnitude  
*measure of the brightness of an object. The brighter the object, the more negative its magnitude*
- ◊ Apparent magnitude ( $m$  or  $V$ )  
*the object's magnitude as seen by the telescope on Earth*
- ◊ Absolute magnitude ( $M$  or  $M_V$ )  
*the object's apparent magnitude if it was at a distance of 10 parsecs away from Earth*

colour-magnitude  
diagram (CMD)



# Colour-Magnitude Diagram



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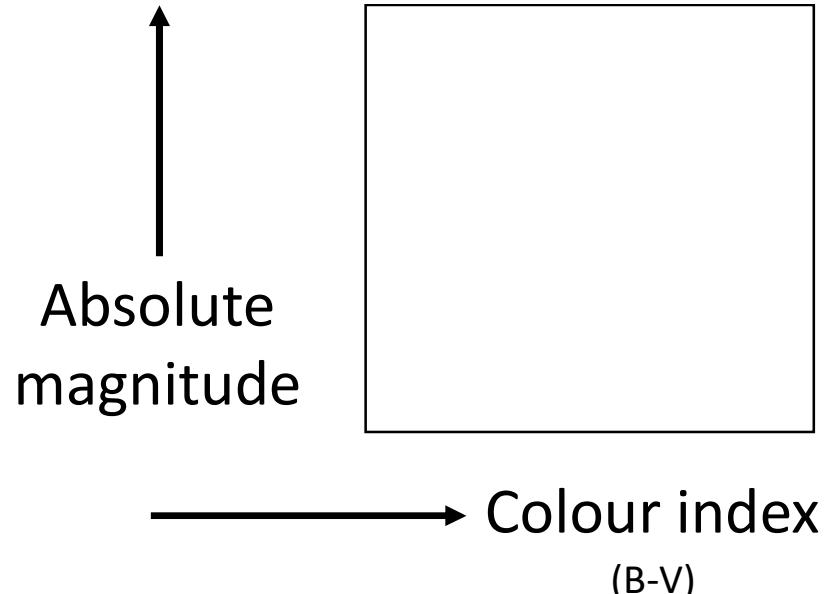
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- ◊ Colour index ( $B-V$ )  
*the magnitude through the B filter minus the magnitude through the V filter*
- ◊ Filter  
*device placed in front of a telescope, only allows certain wavelengths to pass through and be recorded*

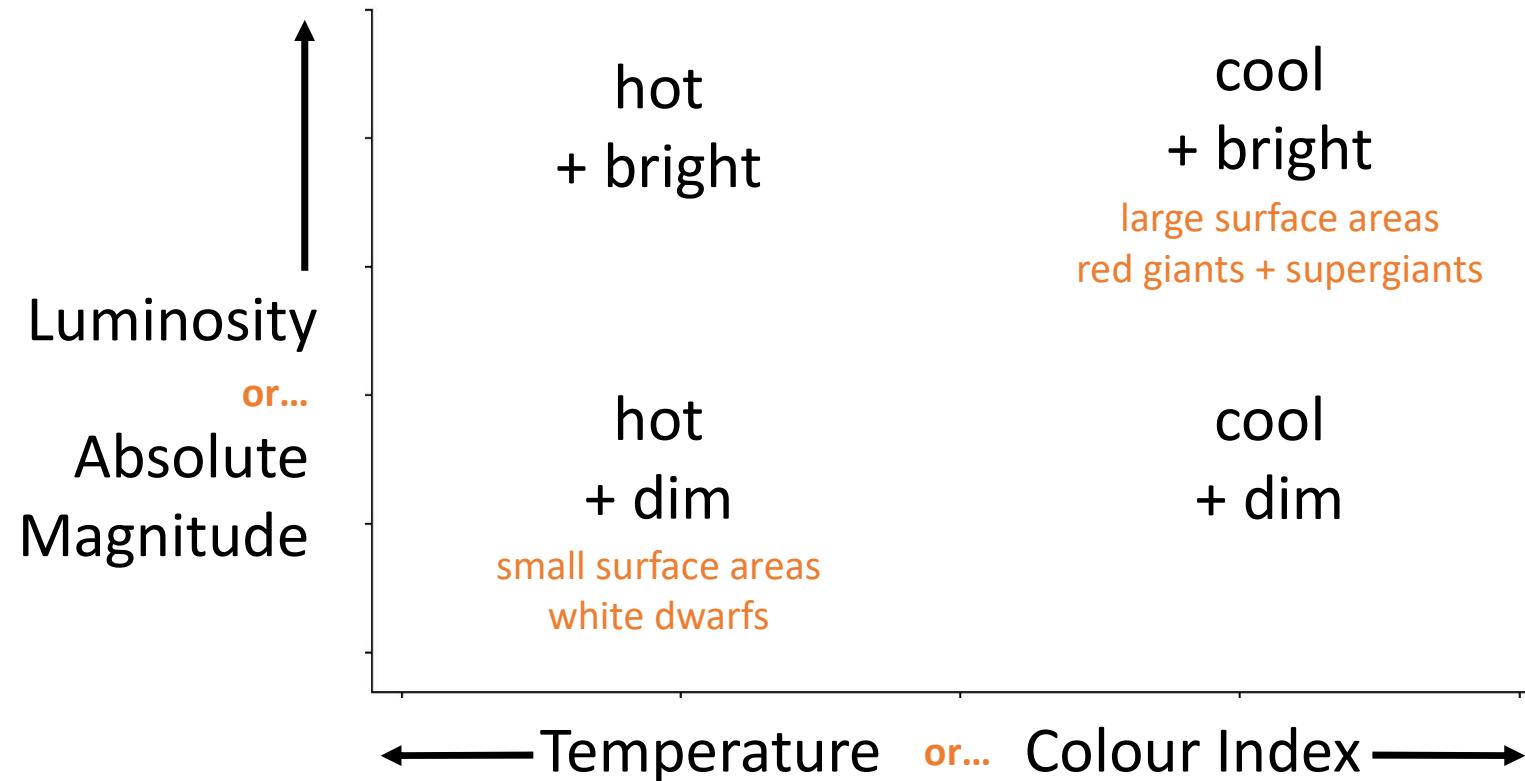


B = blue filter (360nm-520nm), V = yellow filter (450nm-650nm)

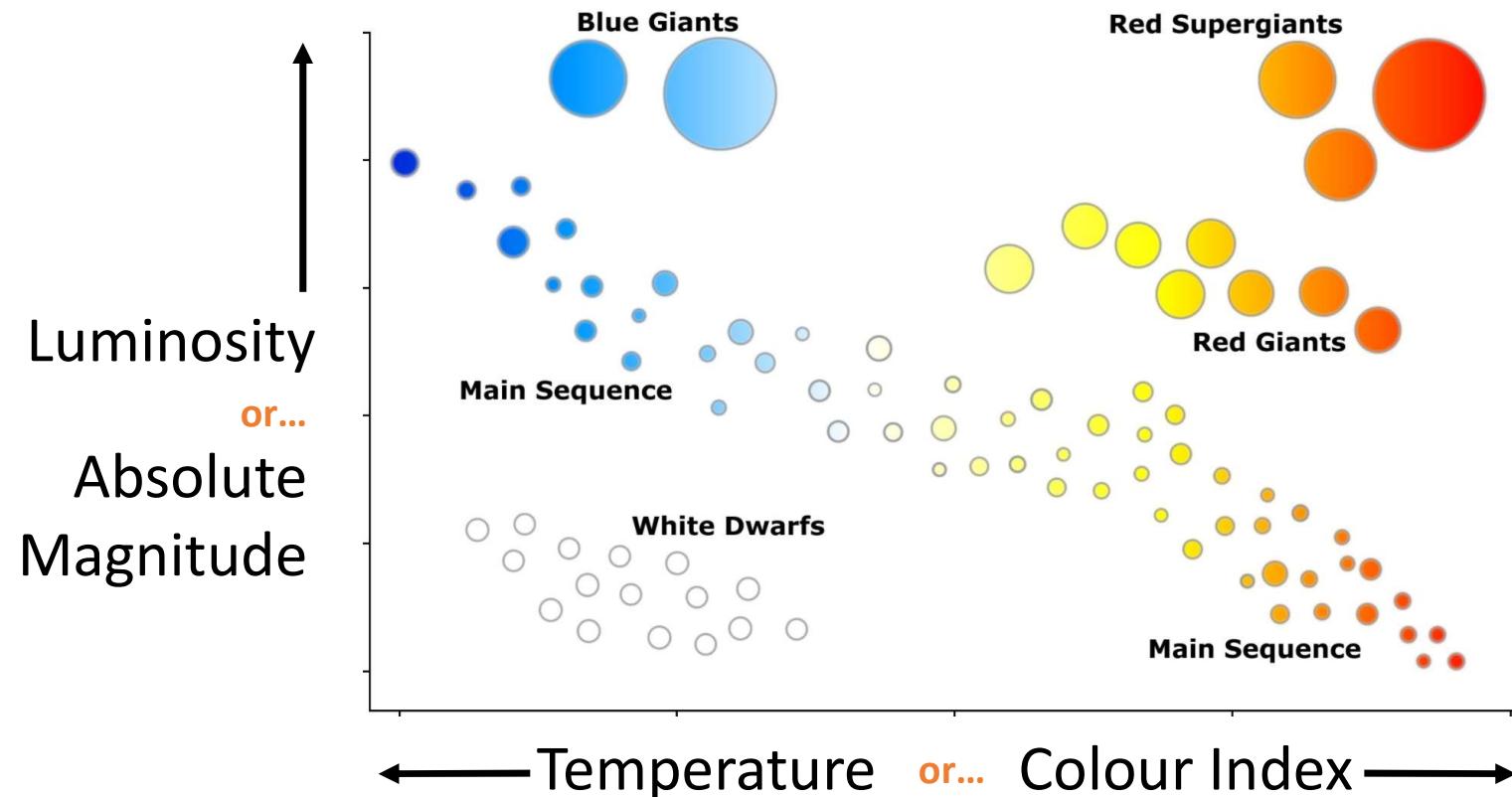
colour-magnitude  
diagram (CMD)



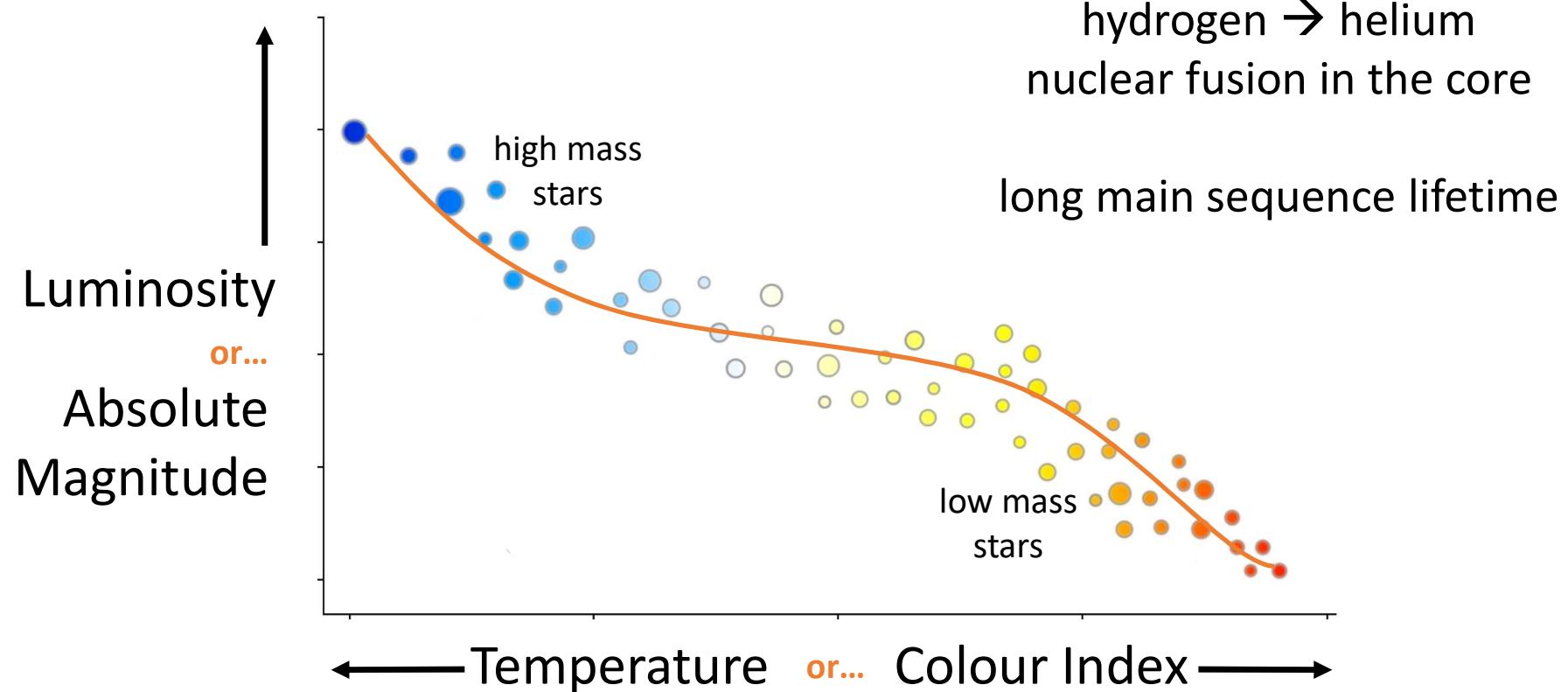
# HRD or CMD



# HRD or CMD



# Main Sequence



# Star Clusters



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- ◊ Globular clusters
  - tight groups of ancient stars*
  - poorly understood*



- ◊ Open clusters
  - stars formed from the same collapsing cloud of gas*
  - stars are roughly the same age + distance*
  - smaller + younger than globular clusters*



# Zero-Age Main Sequence



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- ◊ Star clusters contain stars of many different masses
- ◊ When the cluster is young, the stars all lie along the main sequence
  - this is the zero-age main sequence (**ZAMS**)
  - plotted using the *absolute magnitudes* of the stars



their position on the  
main sequence  
depends on their mass

- ◊ All stars in the cluster are roughly the same distance from Earth
- ◊ Their light is dimmed according to that distance

# Distance Modulus



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- ◊ Plot the colour index of the stars against the *apparent* magnitude
  - this is the magnitude as observed from Earth
  - typically, the apparent magnitude through the V filter is used
  - the colour index is  $B-V$
- ◊ Compare this observational main sequence to the ZAMS

calculate the  
distance modulus

in the V filter, the distance  
modulus is written as



# Distance to the Star Cluster

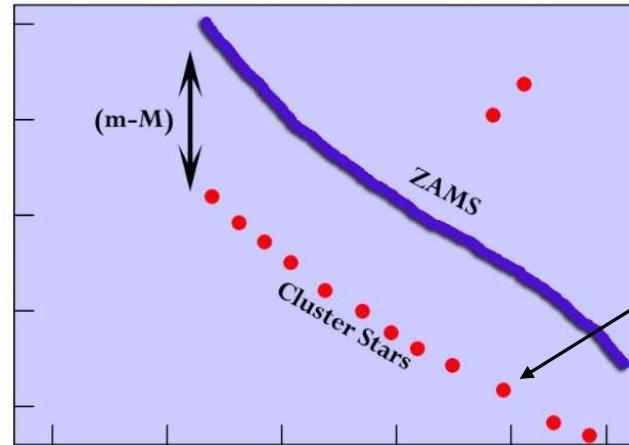
- ◊ The distance to the cluster can be calculated using the formula:

$$\log_{10} D = \frac{m - M}{5} + 1$$

distance (parsecs)      distance modulus

logarithm (base 10)

$10^0 = 1$	$\log_{10} 1 = 0$
$10^1 = 10$	$\log_{10} 10 = 1$
$10^2 = 100$	$\log_{10} 100 = 2$
...	



observational  
data

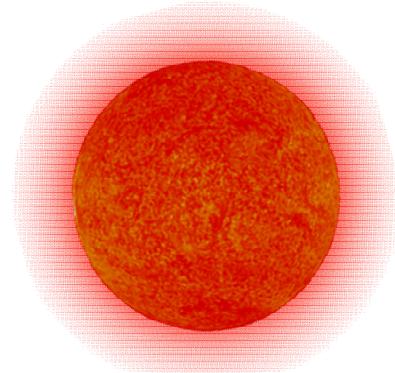
# Age of the Star Cluster



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- ◊ As a star ages, it starts to run out of hydrogen fuel in its core
- ◊ Hydrogen begins to burn in a shell around the core
- ◊ The star expands and cools → red giant
- ◊ The first stars to become red giants are the most massive stars  
→ followed by the less massive stars
- ◊ As a cluster ages, its main sequence gets shorter  
+ the red giant region becomes increasingly populated



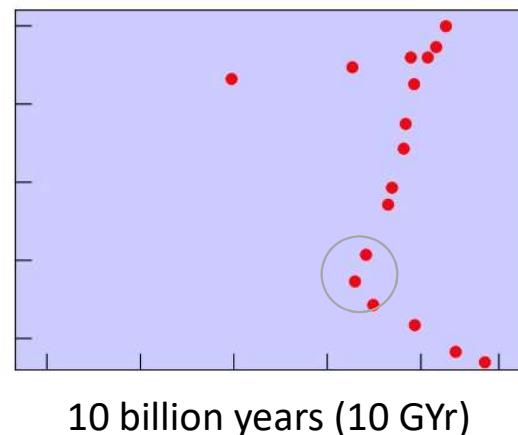
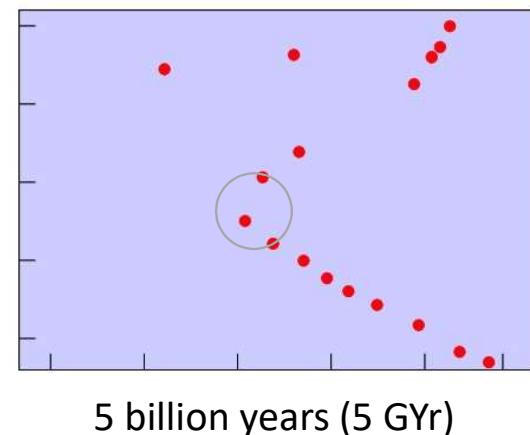
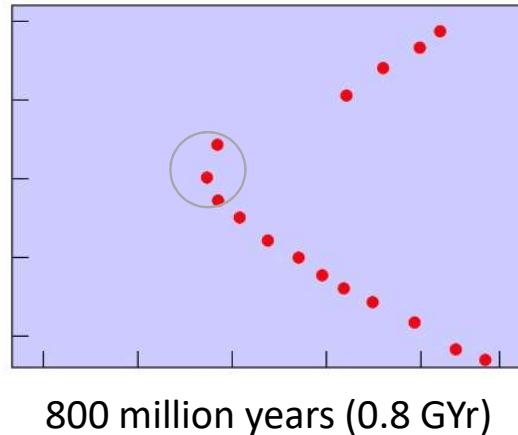
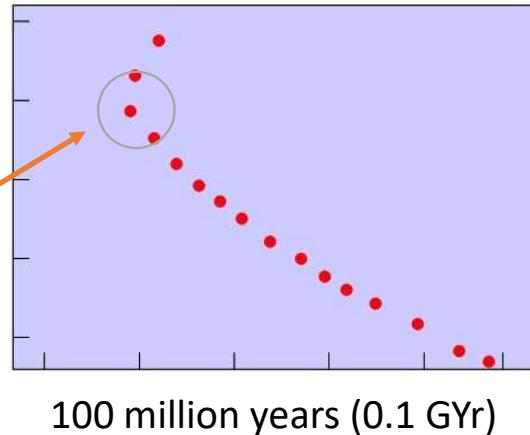
# Age of the Star Cluster



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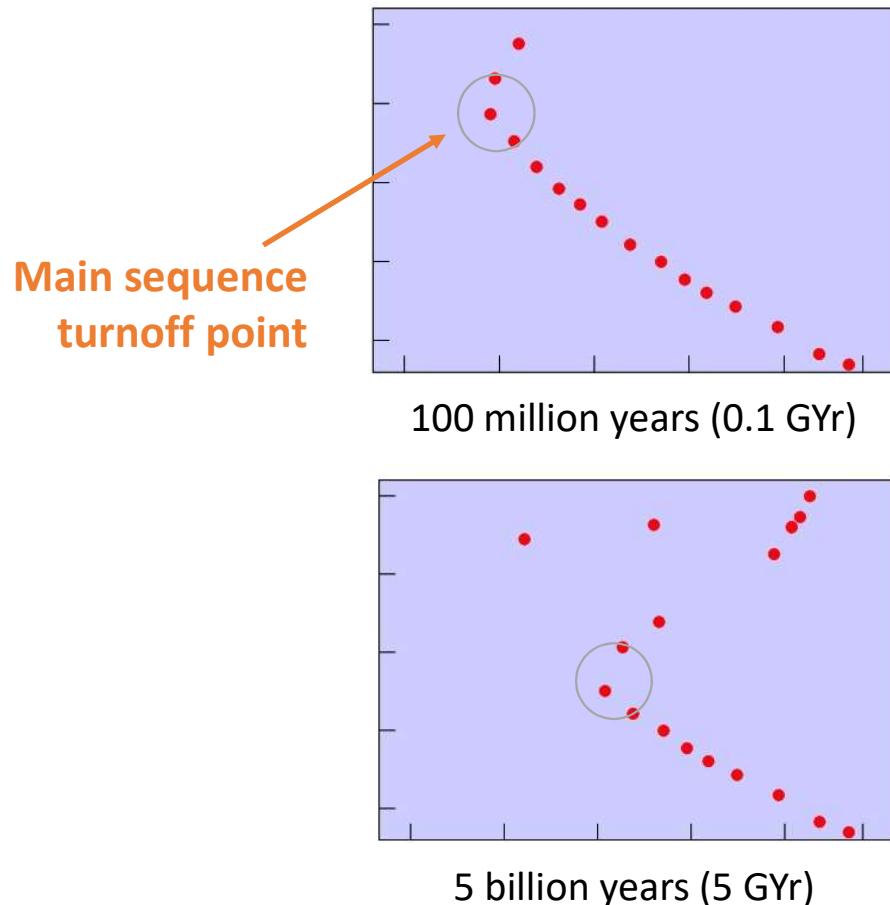
Main sequence  
turnoff point



# Age of the Star Cluster



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consider the length of  
the main sequence  
(up to the turnoff point)

compare the HRD/CMD to a  
computer model,  
called an isochrone

can estimate the age of  
the cluster

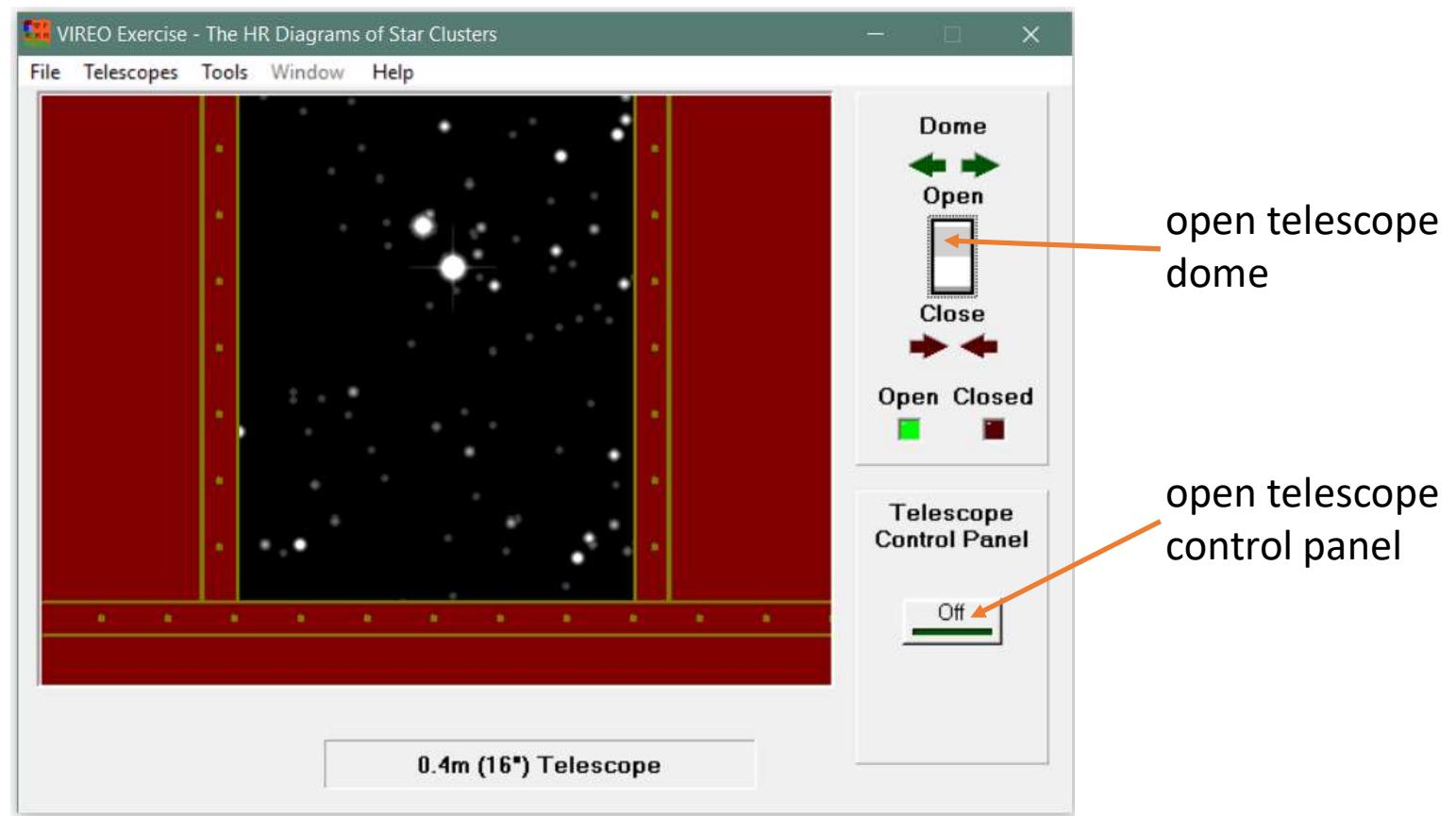
# The Hertzsprung-Russell Diagram

**observing star clusters  
with a telescope  
simulator**

# Setting up the Telescope



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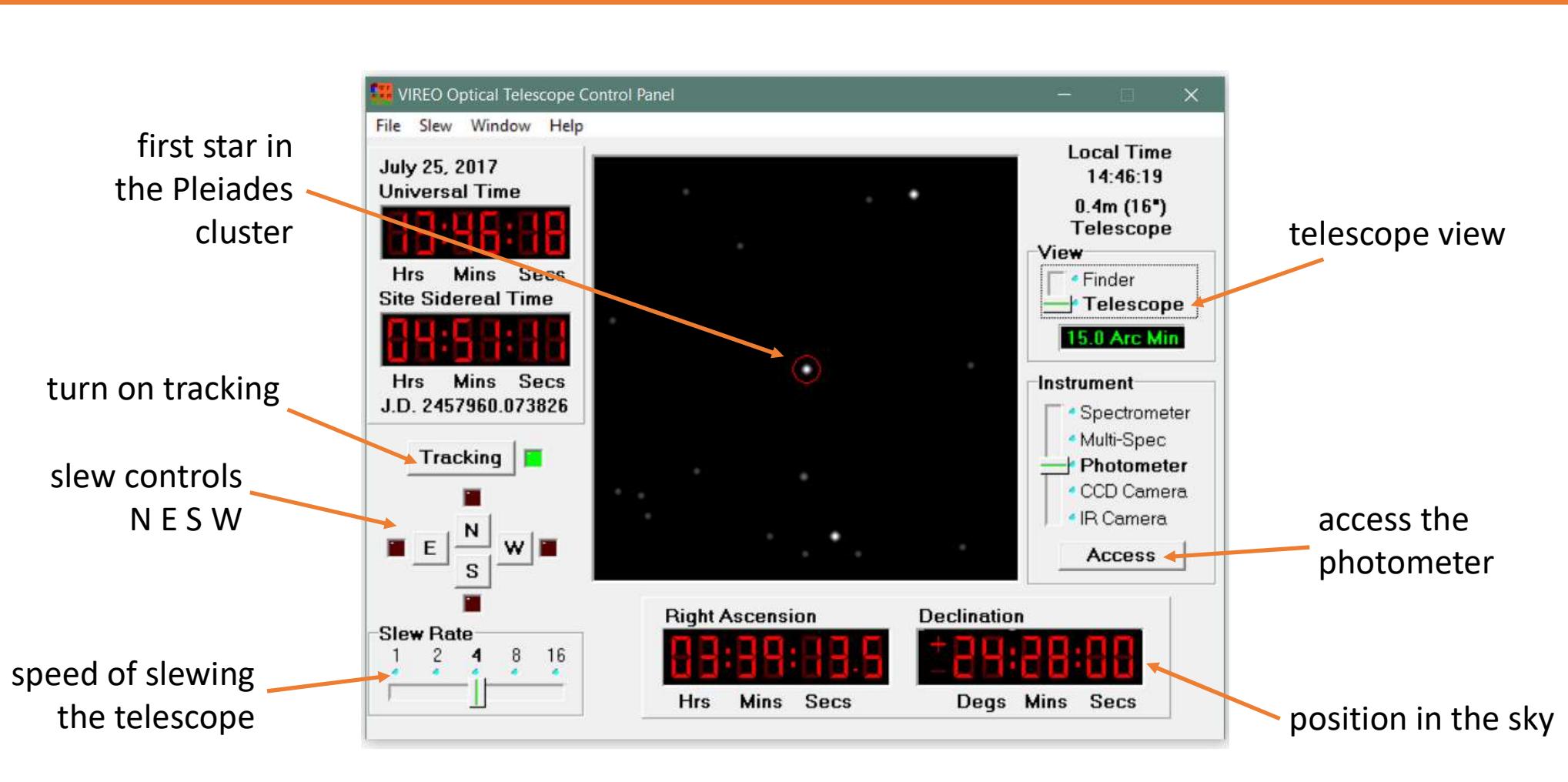


# Telescope Control Panel



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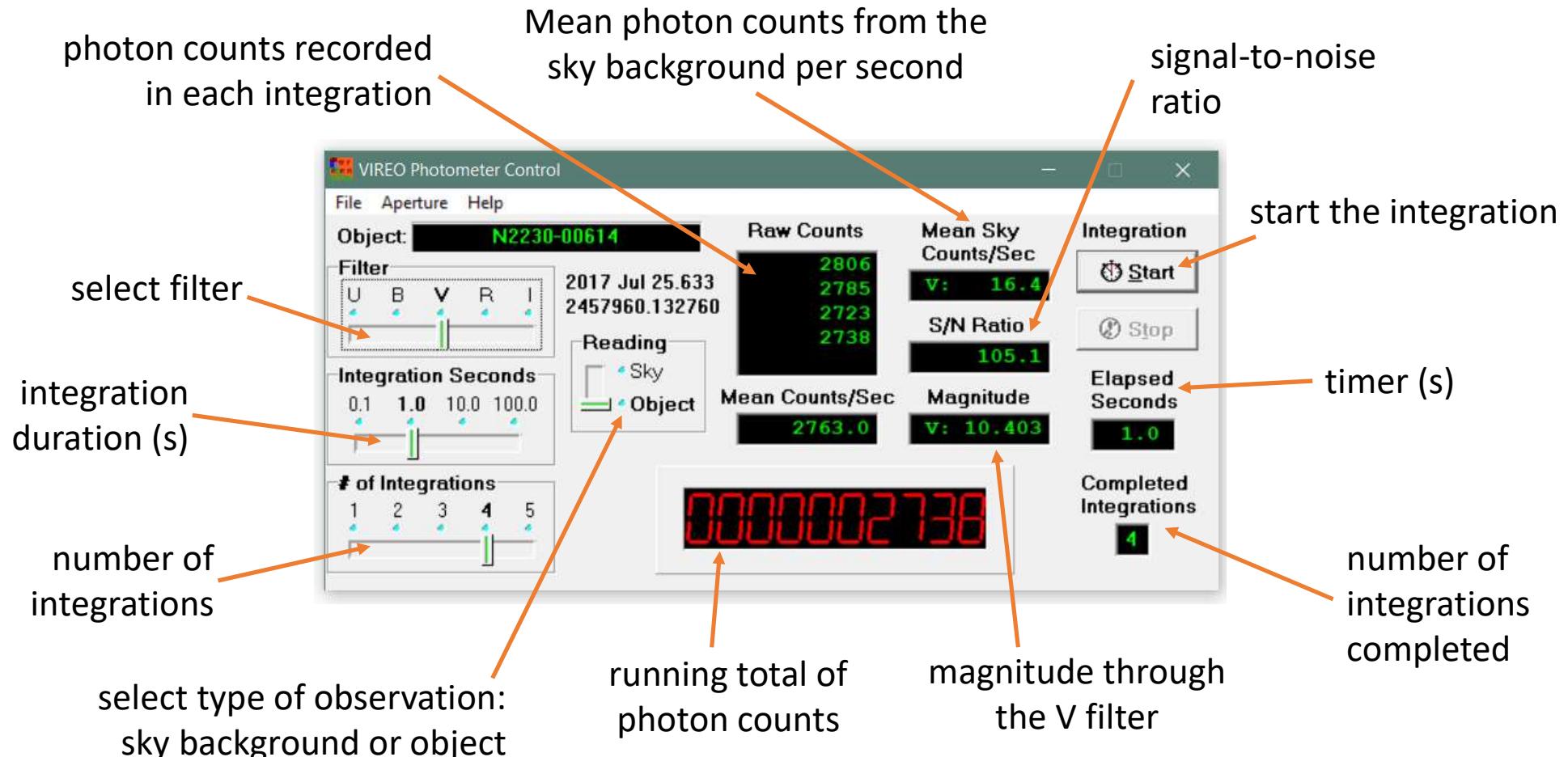
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# Photometer Control Panel



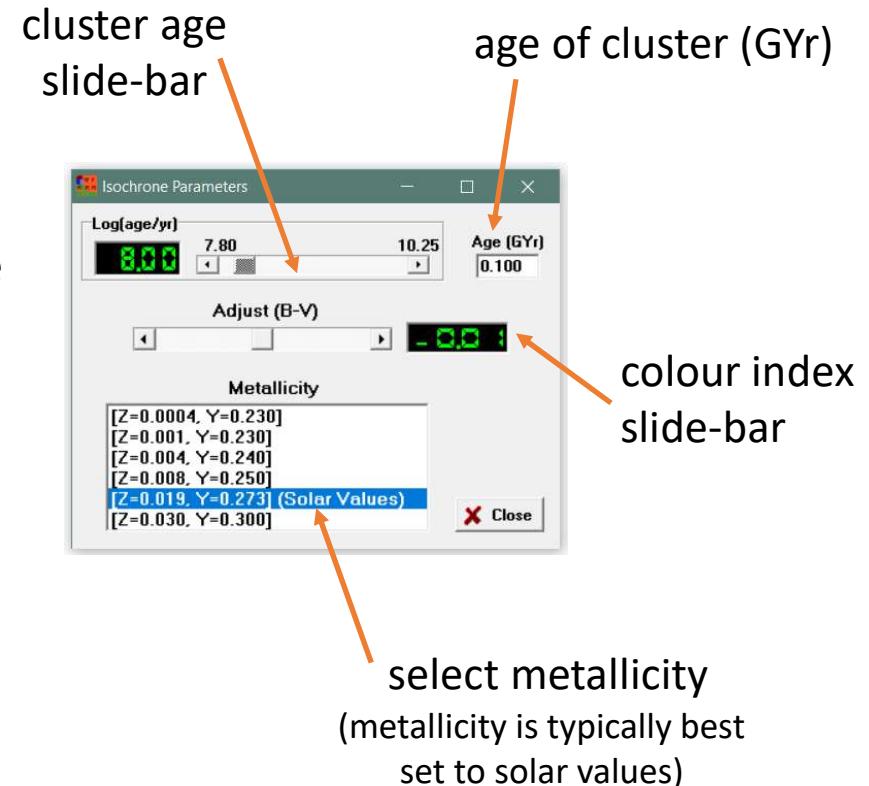
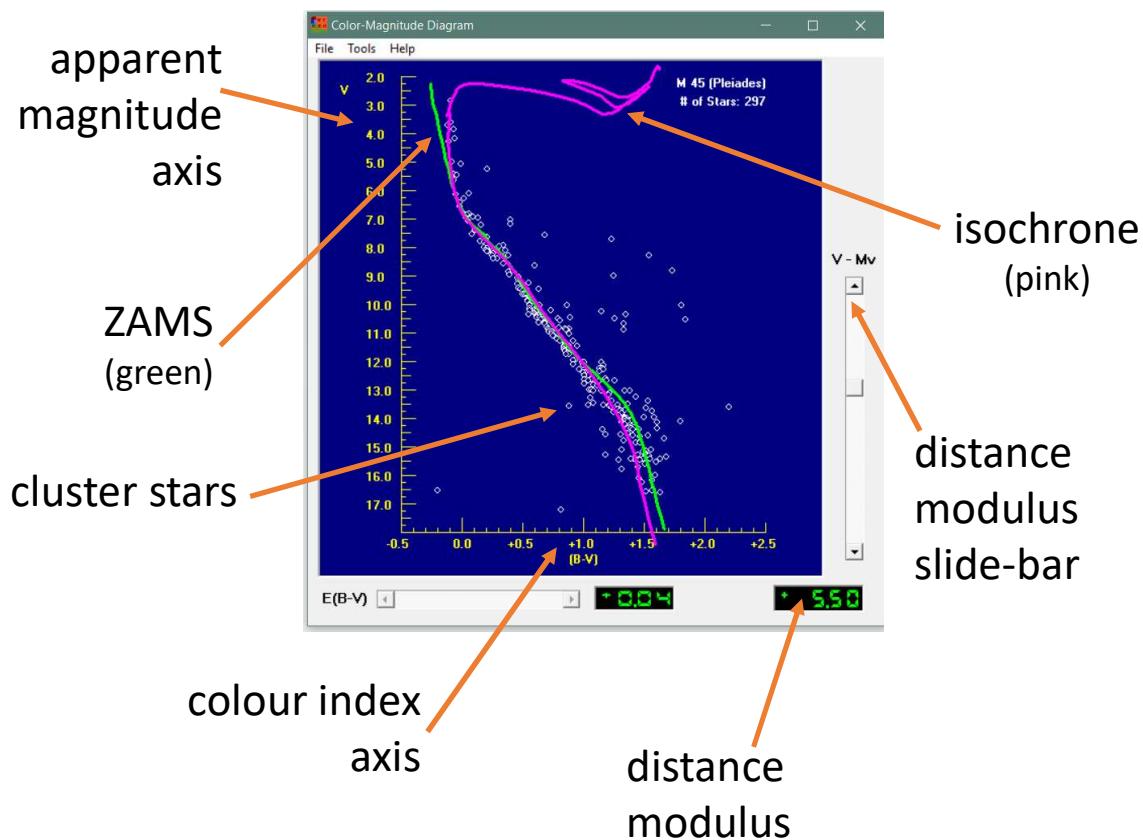
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# Colour-Magnitude Diagram



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# References



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## Photographs + Images:

<http://www.funscience.in/study-zone/Physics/Universe/Sun.php>  
[https://lco.global/files/jbarton/HR%20Diagram\(units\).jpg](https://lco.global/files/jbarton/HR%20Diagram(units).jpg)  
<https://www.britannica.com/biography/Ejnar-Hertzsprung>  
<http://archive.org/stream/worldsworl41gard#page/420/mode/2up>  
<https://apod.nasa.gov/apod/ap100817.html>  
<http://www.atlasoftheuniverse.com/openclus.html>  
<https://www.emaze.com/@AFCLWZWR/I%27universo>  
CLEA manual HRdiag\_sm.doc

## VIREO Software:

<http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html>

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