

The Hertzsprung-Russell Diagram

VIREO – Virtual Educational Observatory

Aims



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



Ejnar Hertzsprung



Henry Norris Russell

Hertzsprung-Russell diagram (HRD)
1910

evolution of stars

surface temperature
+ luminosity

or...

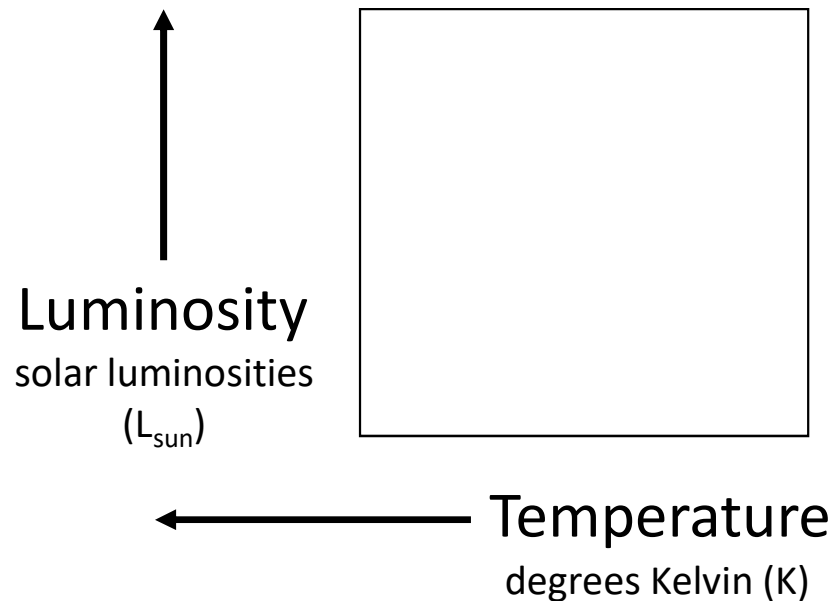
colour index
+ absolute magnitude



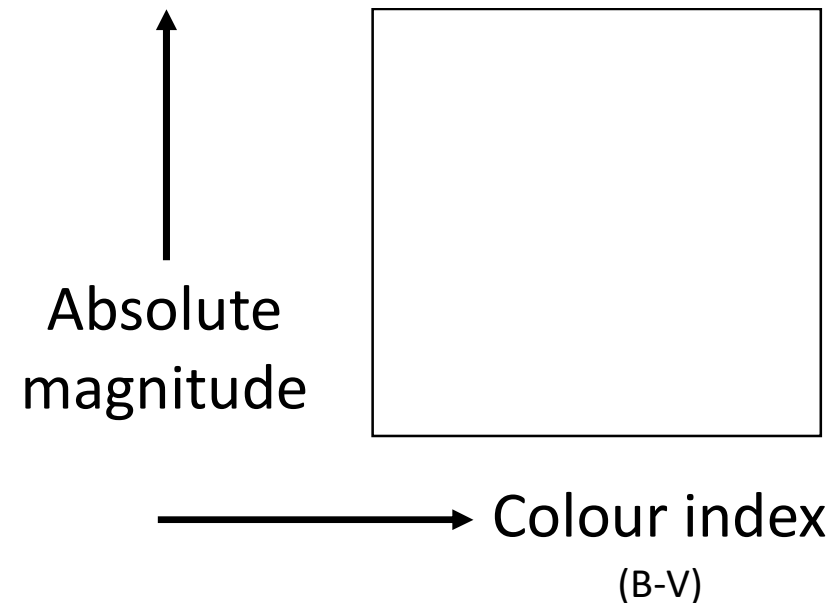
colour-magnitude
diagram (CMD)

HRD or CMD

Hertzsprung-Russell
diagram (HRD)

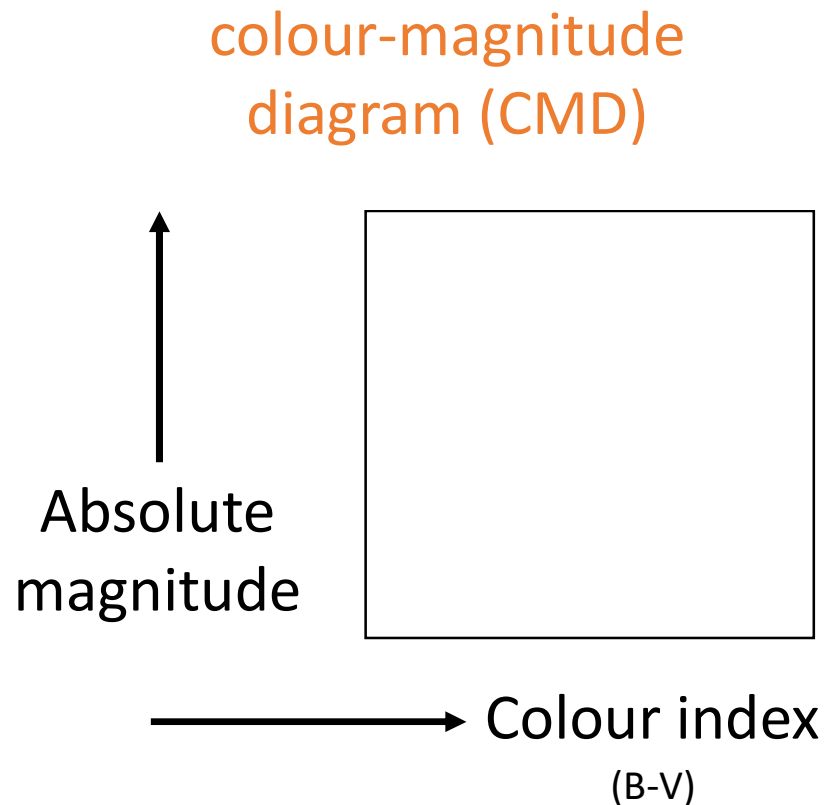


colour-magnitude
diagram (CMD)



Colour-Magnitude Diagram

- ◇ 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

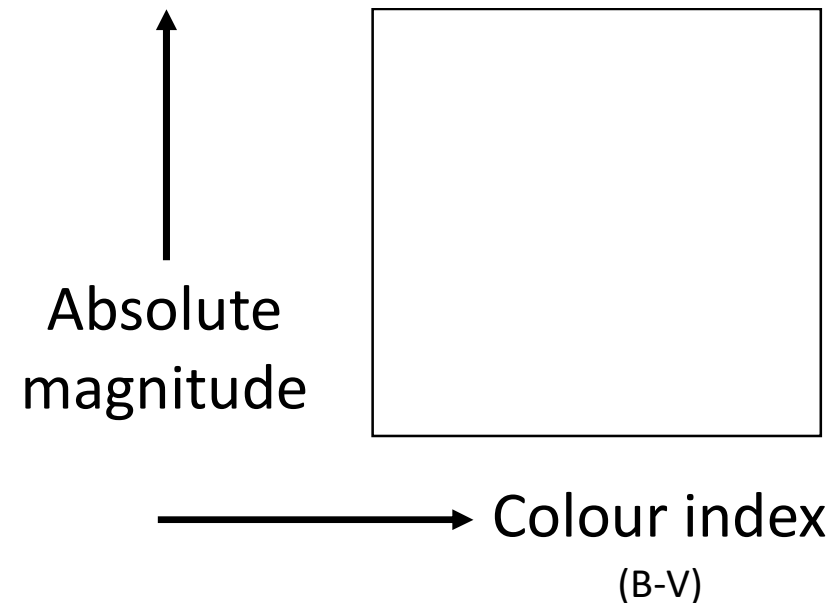
◇ Colour index ($B-V$)
*the magnitude through the B filter minus
the magnitude through the V filter*

◇ Filter
*device placed in front of a telescope,
only allows certain wavelengths to pass
through and be recorded*

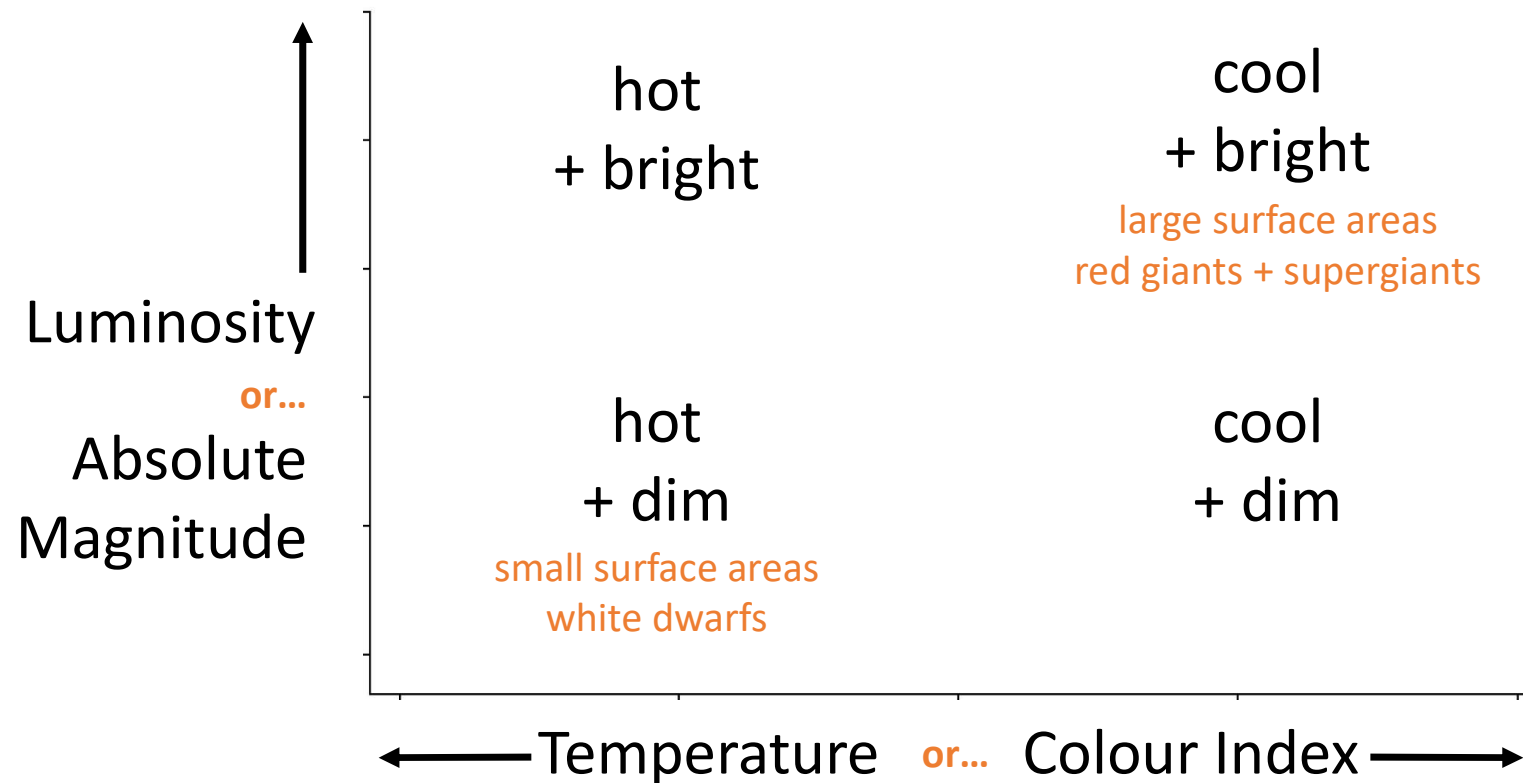


B = blue filter (360nm-520nm), V = yellow filter (450nm-650nm)

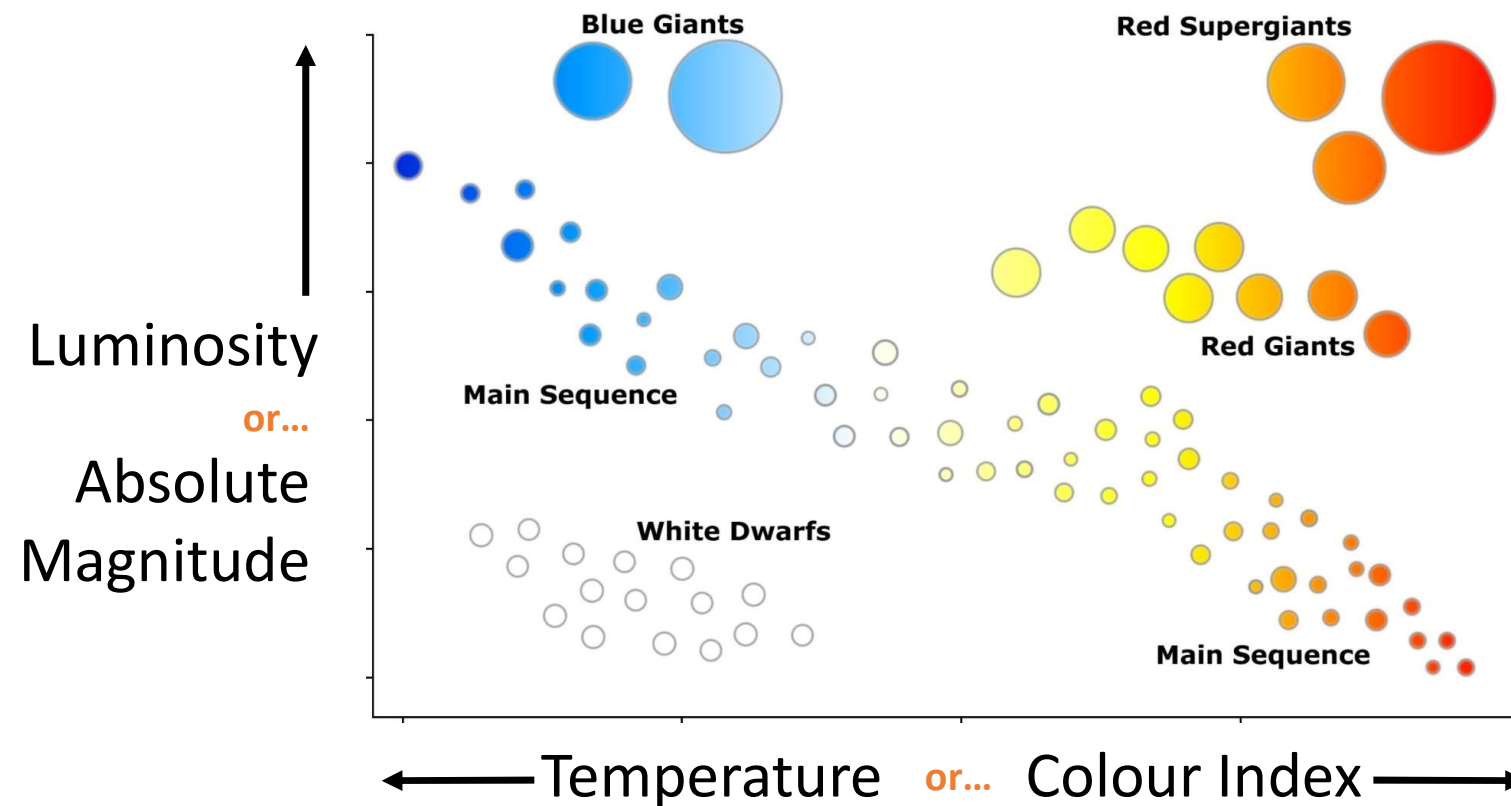
colour-magnitude
diagram (CMD)



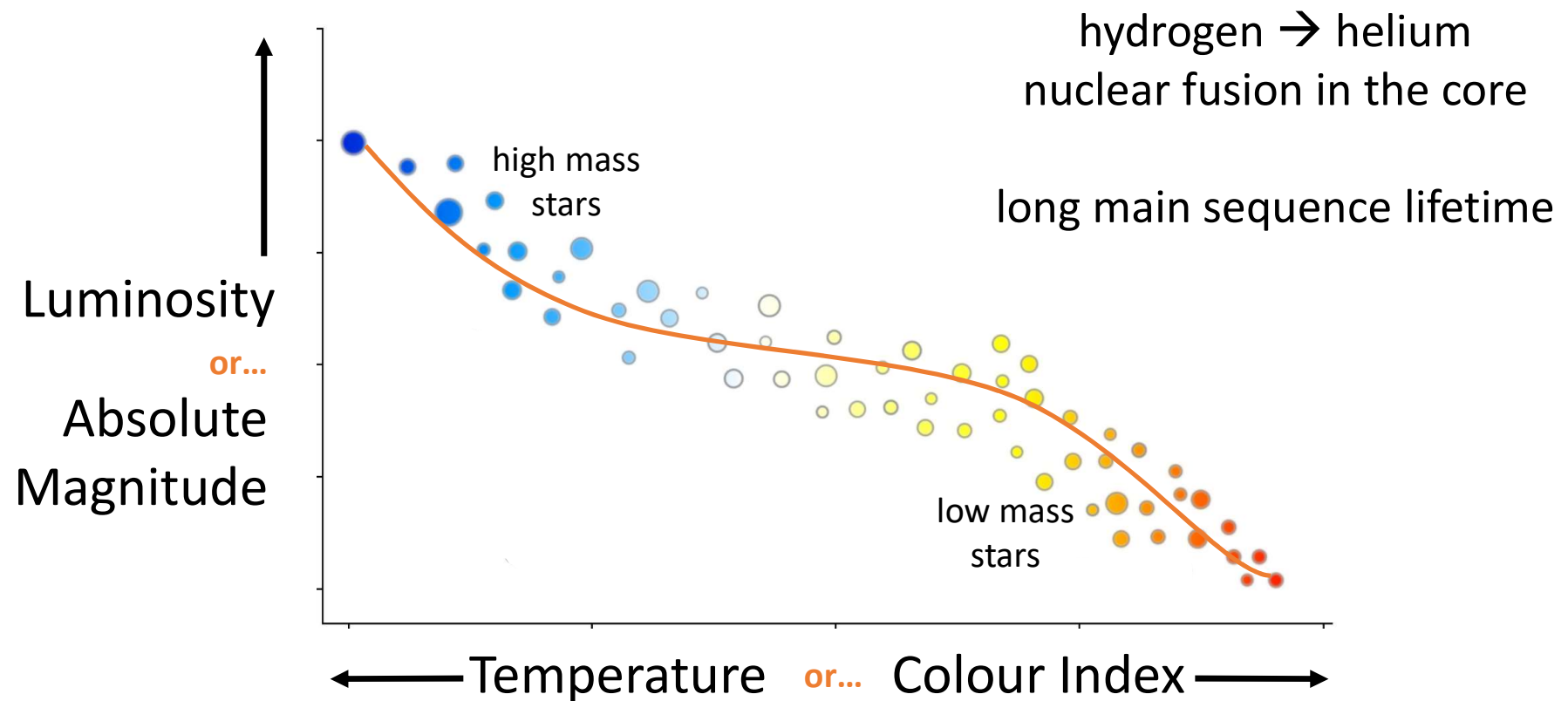
HRD or CMD



HRD or CMD



Main Sequence



Star Clusters

- ◇ 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

- ◇ 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

- ◇ 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

$$m-M$$

apparent magnitude
from the CMD

in the V filter, the distance
modulus is written as

$$V-M_V$$

absolute magnitude
from the ZAMS

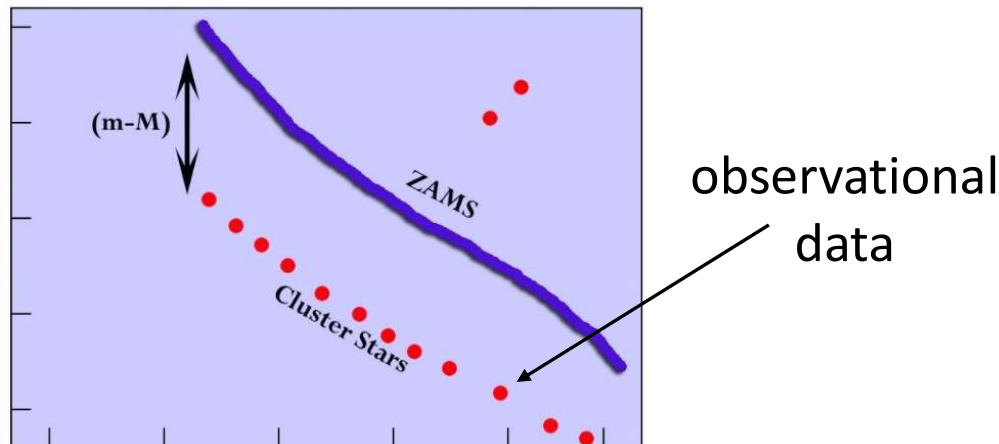
Distance to the Star Cluster

◇ The distance to the cluster can be calculated using the formula:

distance (parsecs) $\log_{10} D = \frac{m - M}{5} + 1$ distance modulus

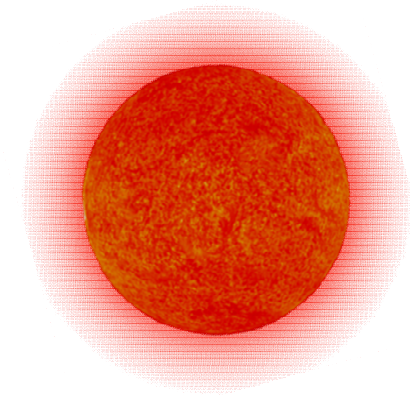
logarithm (base 10)

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

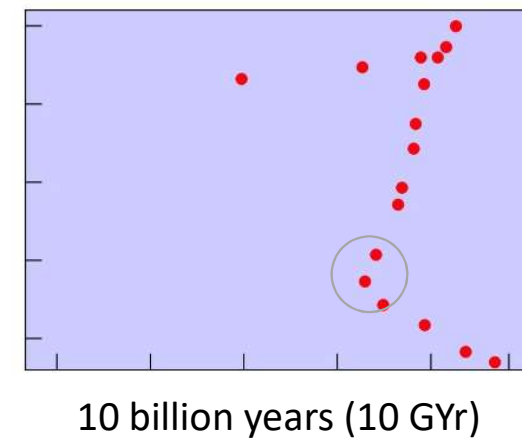
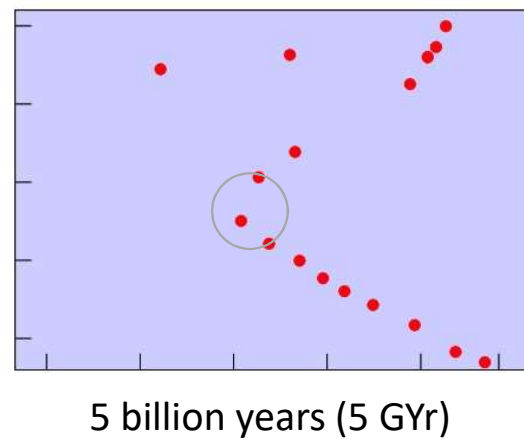
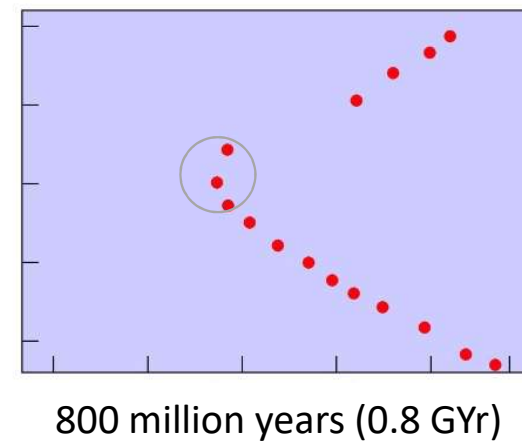
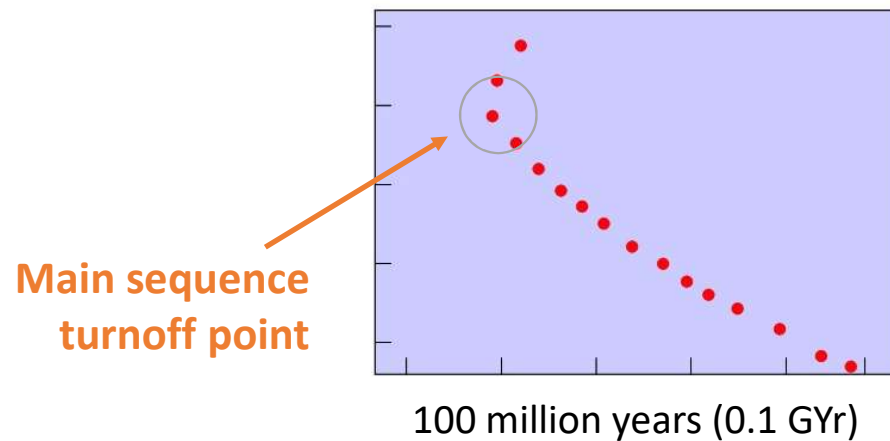


Age of the Star Cluster

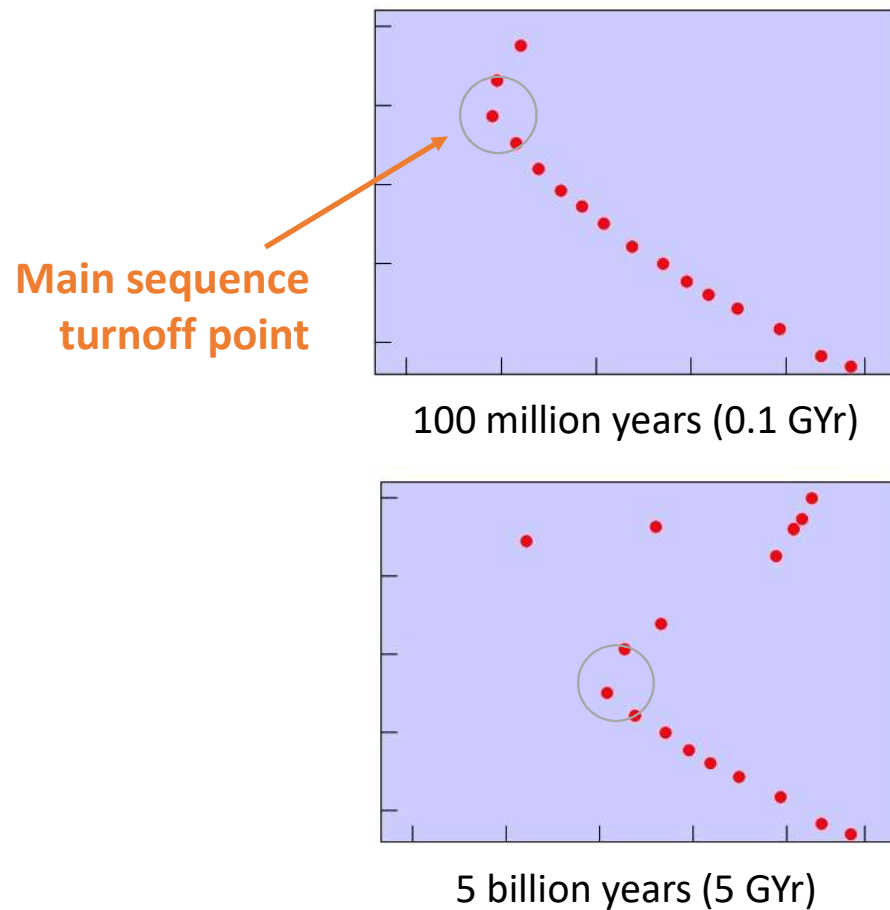
- ◇ As a star ages, it starts to run out of hydrogen fuel in its core
- ◇ Hydrogen begins to burn in a shell around the core
- ◇ The star expands and cools → red giant
- ◇ The first stars to become red giants are the most massive stars
→ followed by the less massive stars
- ◇ As a cluster ages, its main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



Age of the Star Cluster



Age of the Star Cluster



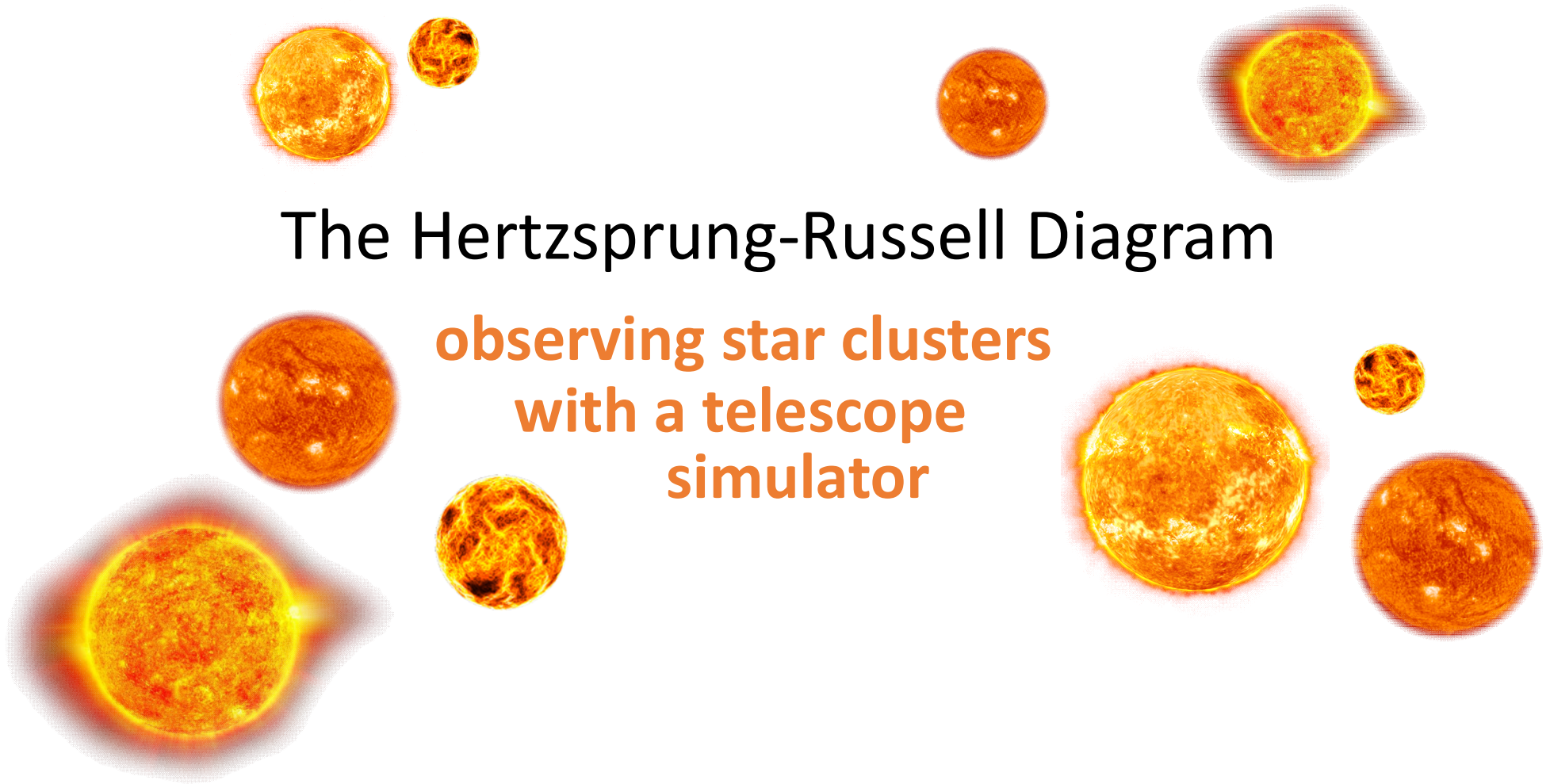
consider the length of
the main sequence
(up to the turnoff point)

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

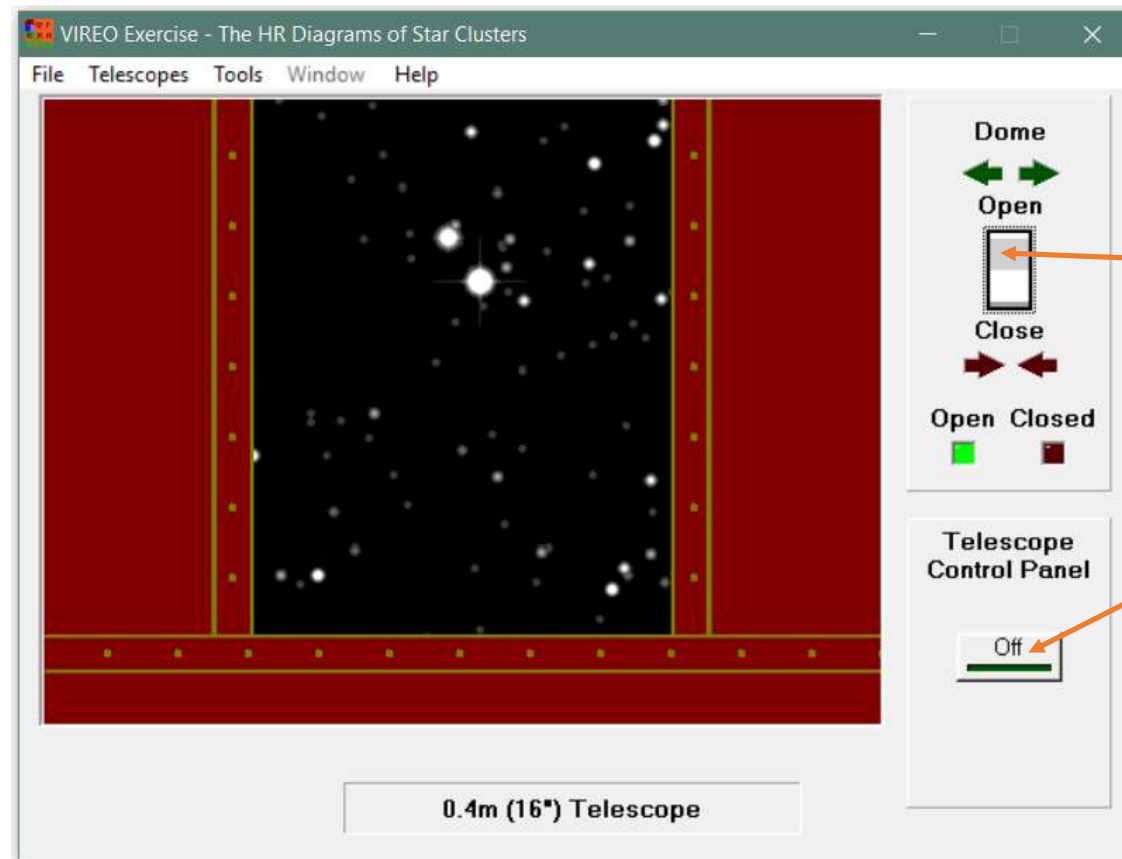
can estimate the age of
the cluster

The Hertzsprung-Russell Diagram

observing star clusters
with a telescope
simulator



Setting up the Telescope



open telescope
dome

open telescope
control panel

Telescope Control Panel

The screenshot shows the VIREO Optical Telescope Control Panel interface. It includes a menu bar (File, Slew, Window, Help), a central telescope view, and various control panels. Annotations with orange arrows point to specific features:

- first star in the Pleiades cluster**: Points to a star in the central telescope view.
- turn on tracking**: Points to the Tracking checkbox, which is currently checked.
- slew controls N E S W**: Points to the directional buttons (N, E, S, W) used for slewing the telescope.
- speed of slewing the telescope**: Points to the Slew Rate slider, which is set to 1.
- telescope view**: Points to the central telescope view window.
- access the photometer**: Points to the Access button under the Instrument section.
- position in the sky**: Points to the Right Ascension and Declination readouts at the bottom.

Panel Details:

- Top Left:** Date: July 25, 2017; Universal Time: 17:46:00; Site Sidereal Time: 04:50:00; J.D. 2457960.073826.
- Top Right:** Local Time: 14:46:19; 0.4m (16") Telescope.
- View Section:** Finder (unchecked), Telescope (checked), 15.0 Arc Min.
- Instrument Section:** Spectrometer (unchecked), Multi-Spec (unchecked), Photometer (checked), CCD Camera (unchecked), IR Camera (unchecked). Access button.
- Bottom:** Right Ascension: 03:09:00.9; Declination: +24:28:00.

Photometer Control Panel

photon counts recorded in each integration

Mean photon counts from the sky background per second

signal-to-noise ratio

start the integration

timer (s)

number of integrations completed

magnitude through the V filter

running total of photon counts

select type of observation: sky background or object

number of integrations

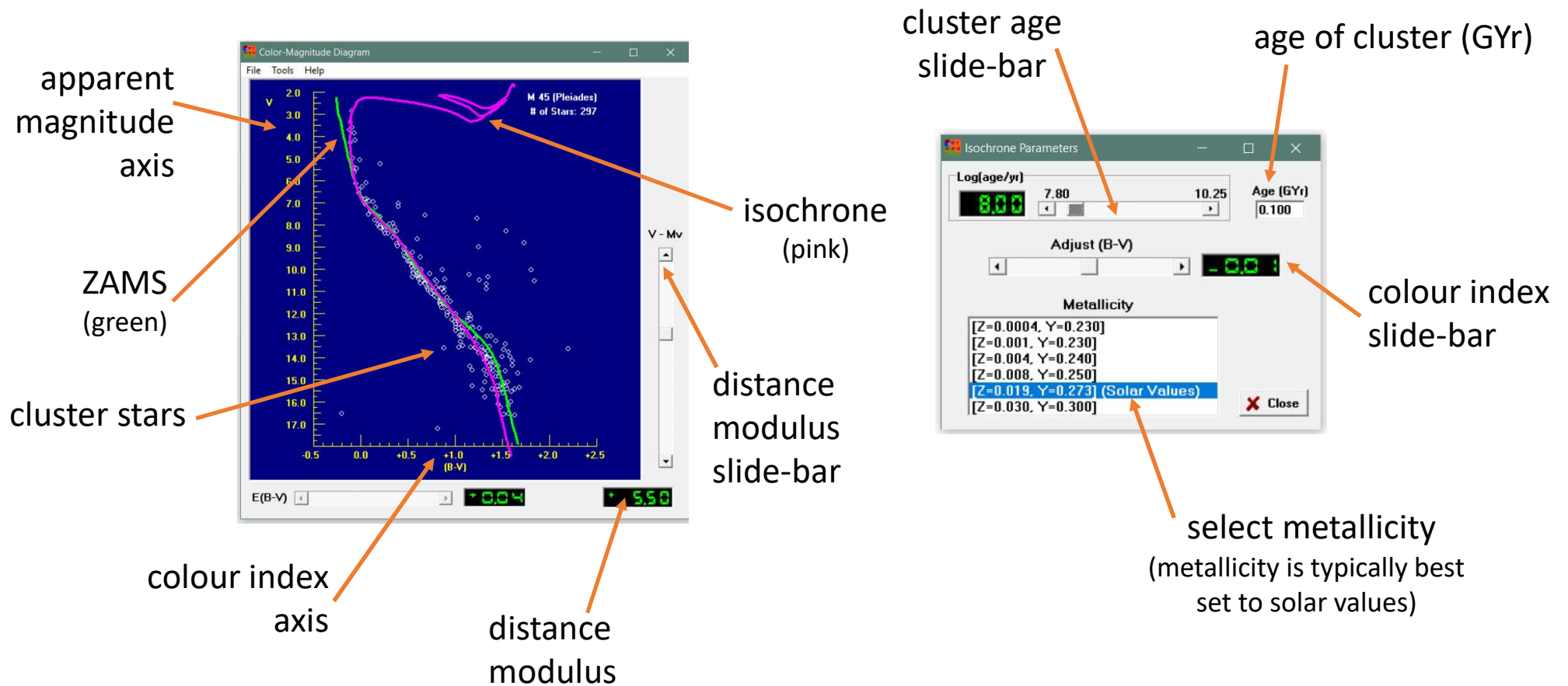
integration duration (s)

select filter

The screenshot shows the VIREO Photometer Control window. At the top, it has a menu bar with 'File', 'Aperture', and 'Help'. The main area is divided into several sections. On the left, there's a 'Filter' section with buttons for U, B, V, R, and I, where 'V' is selected. Below that is 'Integration Seconds' with a slider set to 1.0. Further down is '# of Integrations' with a slider set to 4. In the center, there's a 'Reading' section with radio buttons for 'Sky' and 'Object', where 'Object' is selected. To the right of this is a 'Raw Counts' section showing a list of values: 2806, 2785, 2723, and 2738. Below that is 'Mean Counts/Sec' showing 2763.0. At the bottom center is a large red digital display showing '0000002738'. To the right of the raw counts is a 'Mean Sky Counts/Sec' section showing 'V: 16.4'. Below that is 'S/N Ratio' showing 105.1. Further down is 'Magnitude' showing 'V: 10.403'. On the far right, there's an 'Integration' section with 'Start' and 'Stop' buttons. Below that is 'Elapsed Seconds' showing 1.0. At the bottom right is 'Completed Integrations' showing 4. Arrows from the text labels point to these specific elements in the interface.

Parameter	Value
Object	N2230-00614
Filter	V
Integration Seconds	1.0
# of Integrations	4
Reading	Object
Raw Counts	2806, 2785, 2723, 2738
Mean Counts/Sec	2763.0
Mean Sky Counts/Sec	V: 16.4
S/N Ratio	105.1
Magnitude	V: 10.403
Elapsed Seconds	1.0
Completed Integrations	4

Colour-Magnitude Diagram



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/worldswork41gard#page/420/mode/2up>
<https://apod.nasa.gov/apod/ap100817.html>
<http://www.atlasoftheuniverse.com/openclus.html>
<https://www.emaze.com/@AFCLWZWR/l%27universo>
CLEA manual HRdiag_sm.doc

VIREO Software:

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

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