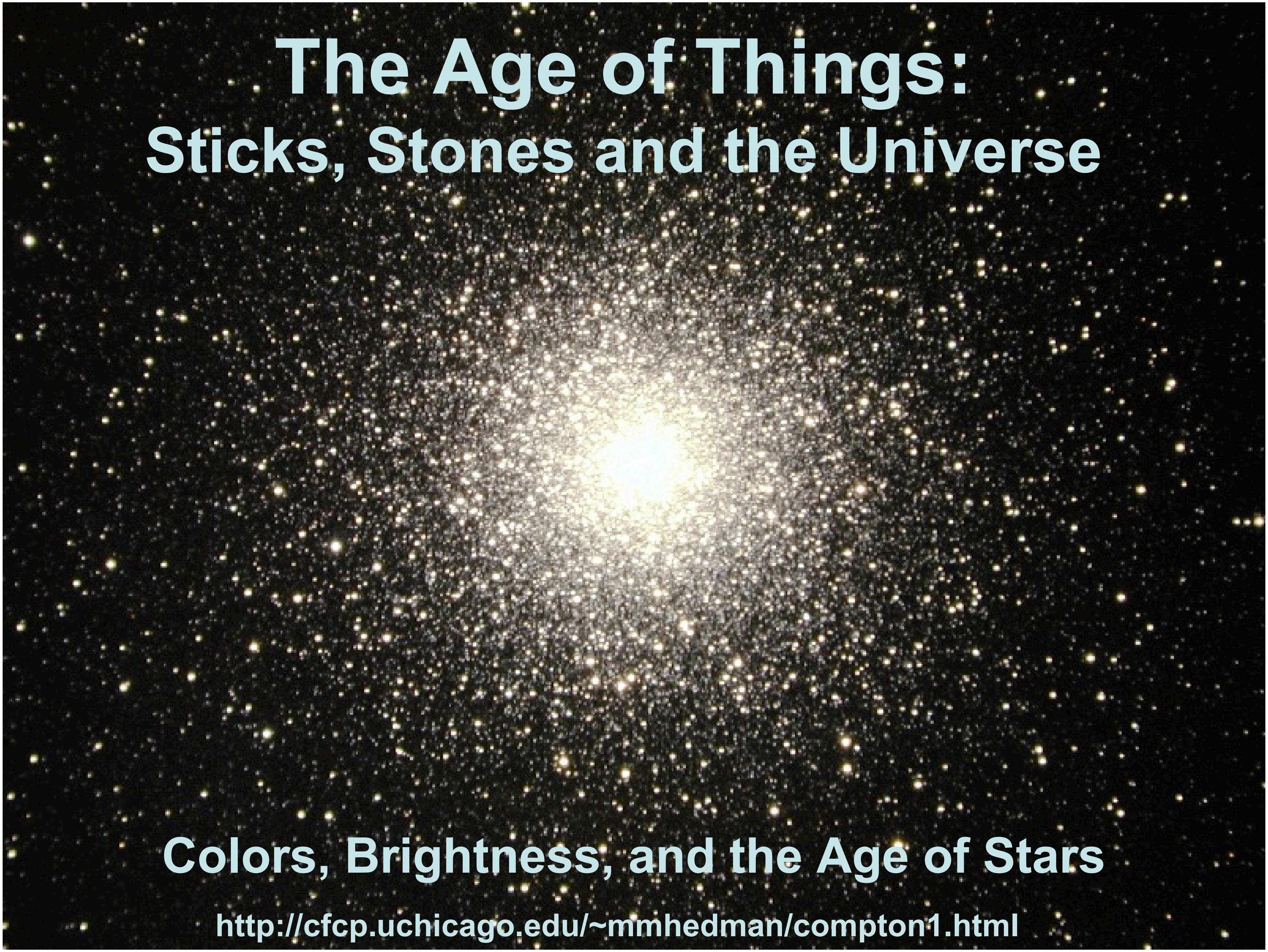
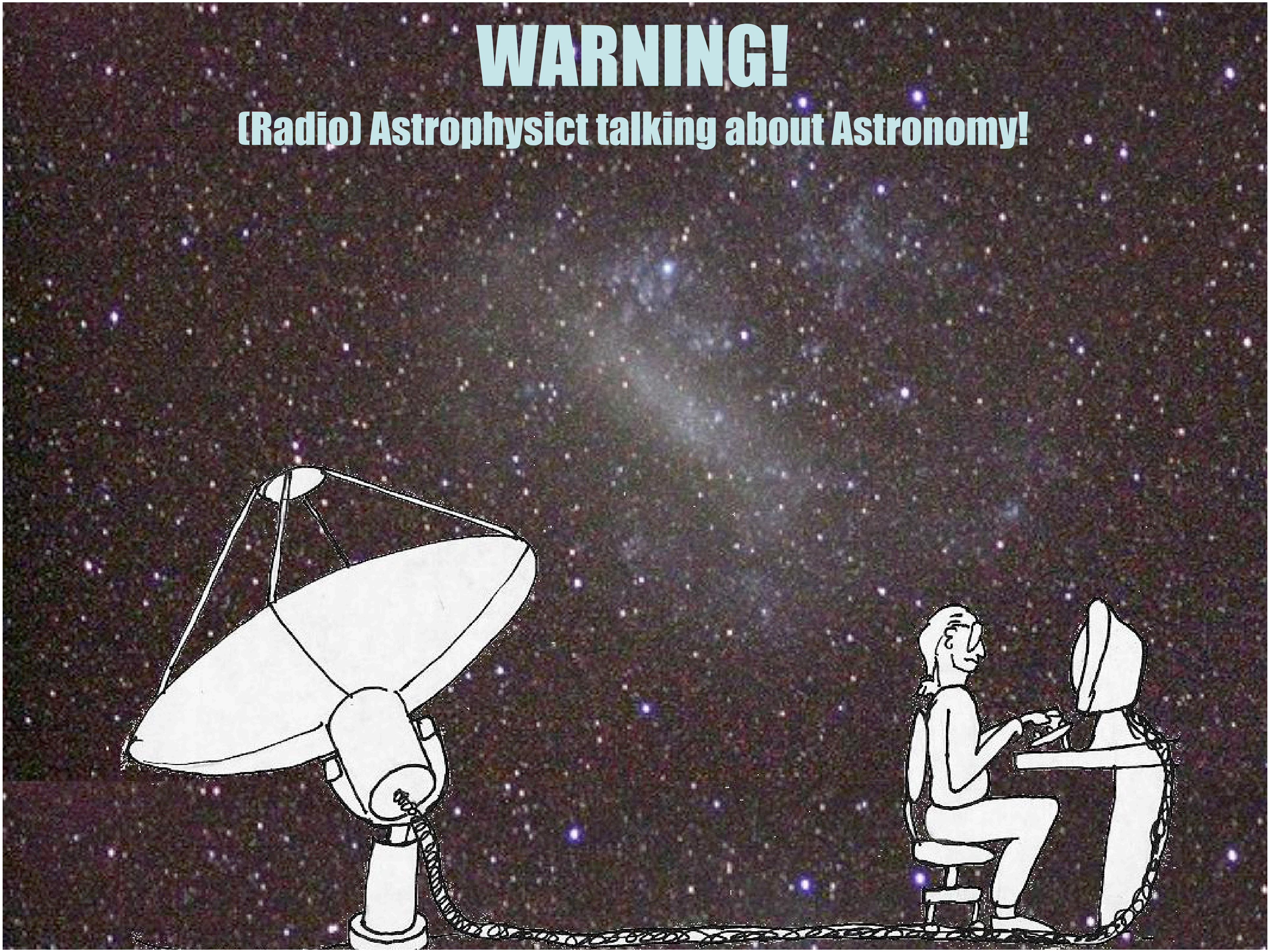
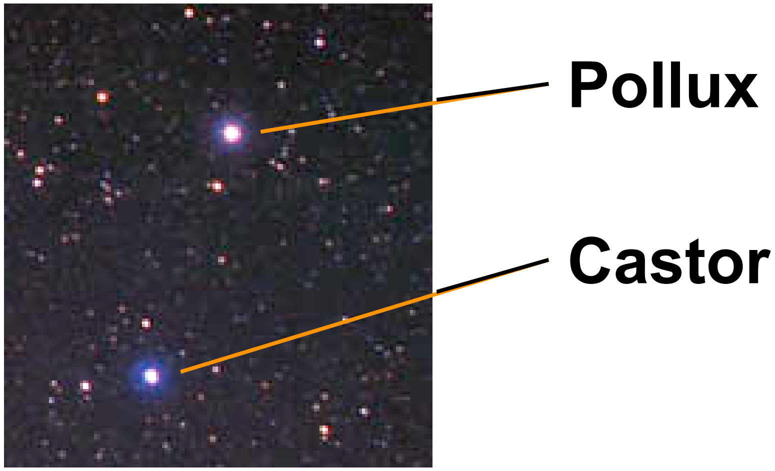
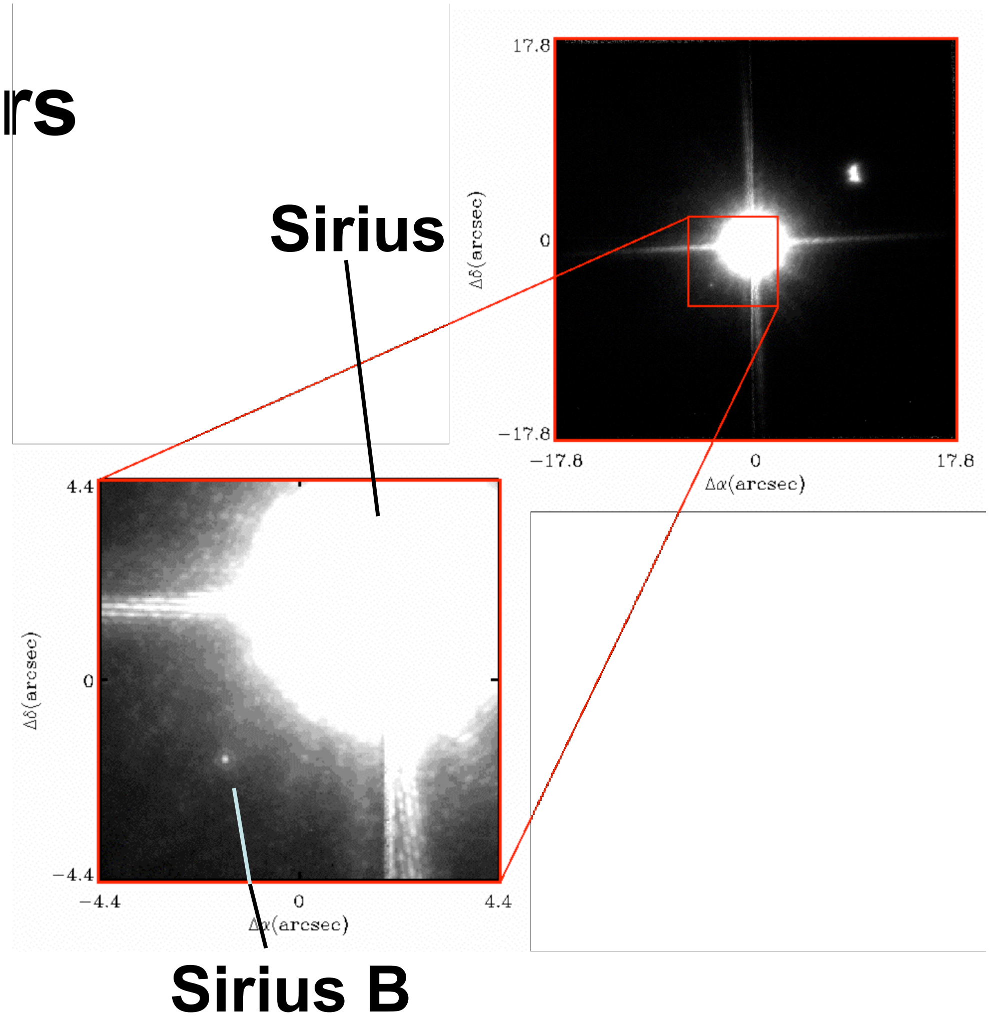

The Age of Things:
Sticks, Stones and the Universe
Colors, Brightness, and the Age of Stars
http://cfcp.uchicago.edu/~mmhedman/compton1.html


WARNING!
(Radio) Astrophysict talking about Astronomy!

The Brightness of Stars



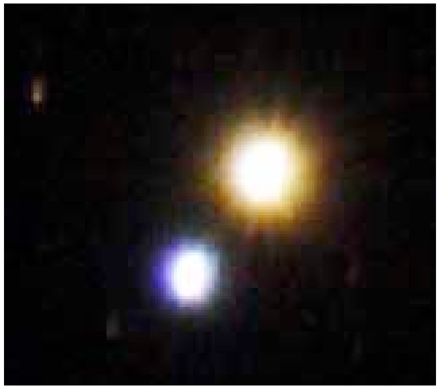
The Pleades

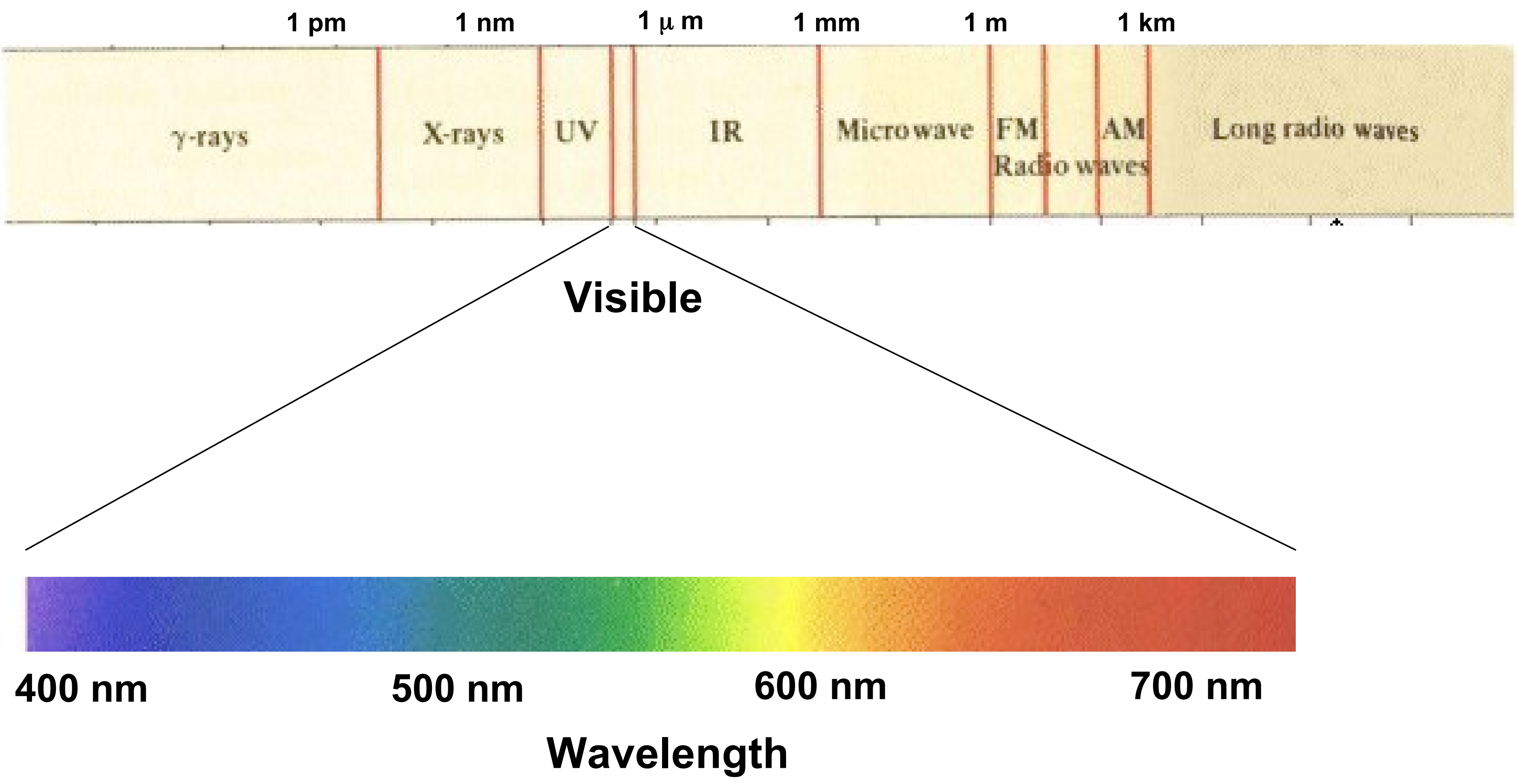


Luminosity = Total power emitted by star in the form of light.

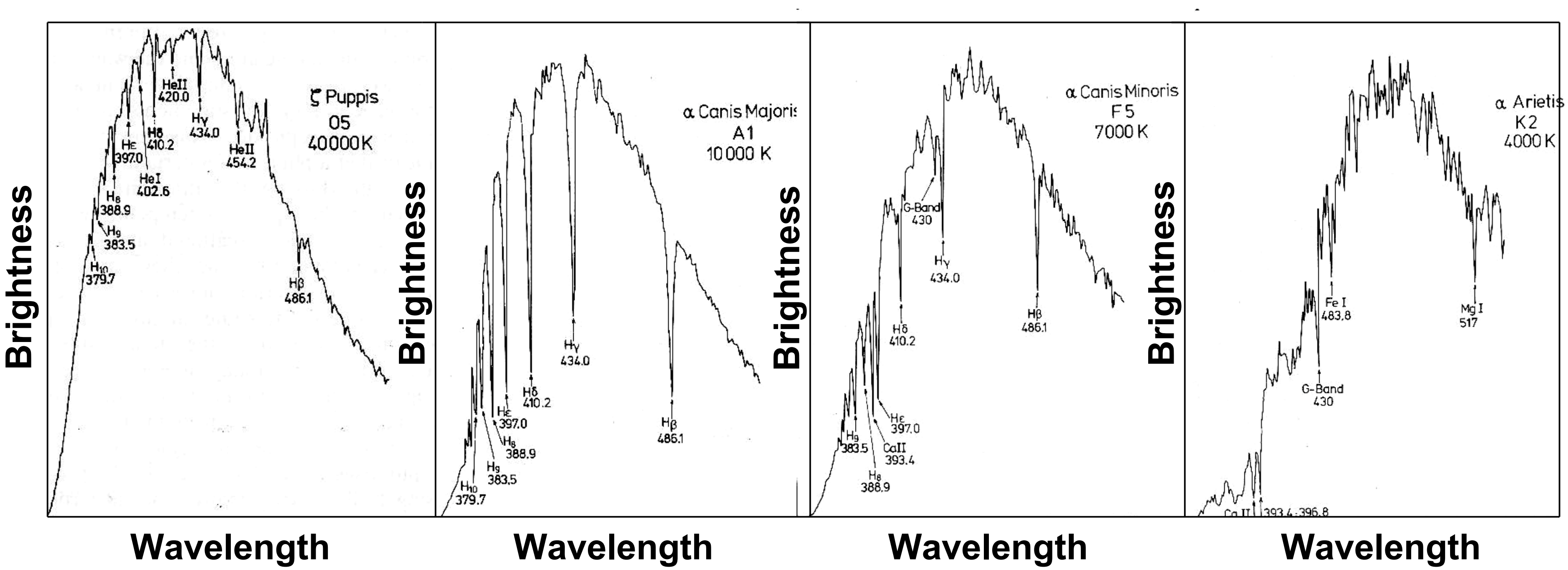
Colors and Spectra

Alberio

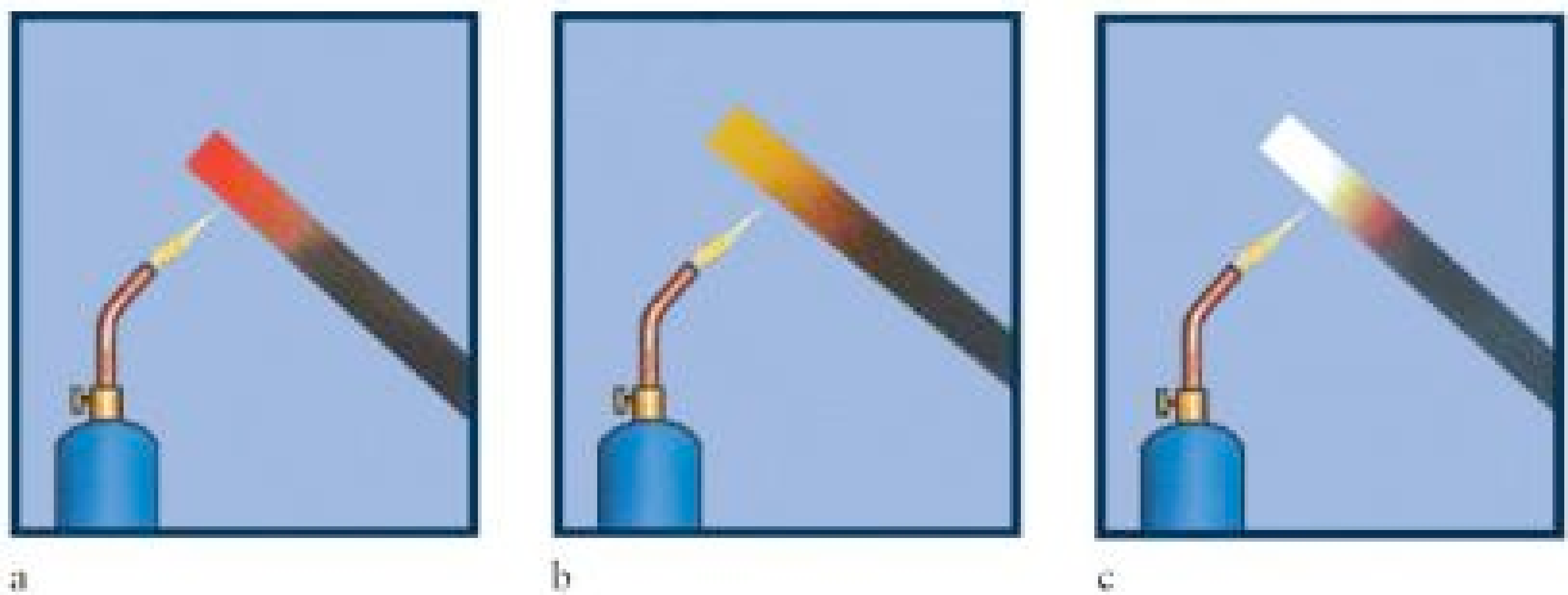




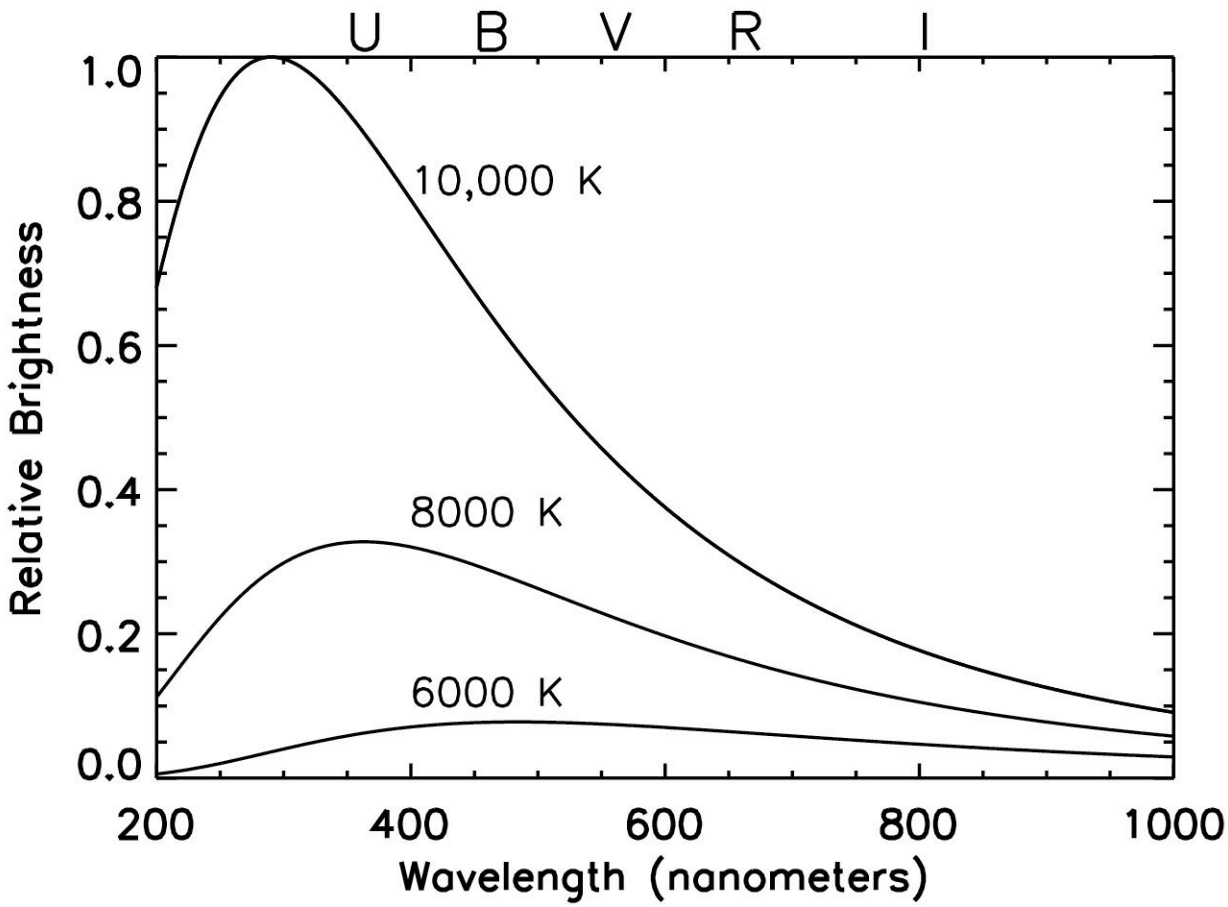
The Spectra of Stars



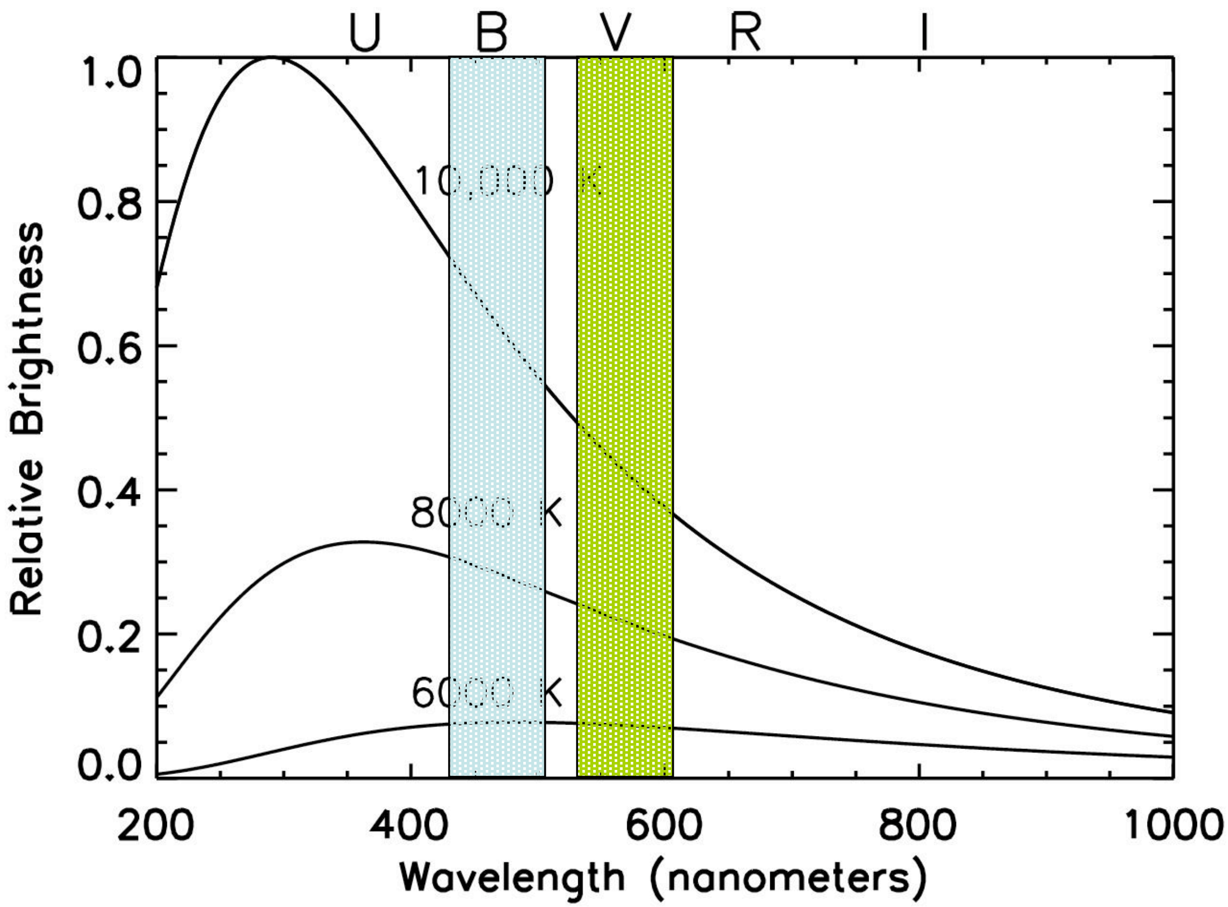
Thermal Radiation



Thermal Spectrum



Astronomical Filters



Magnitudes

Arcturus

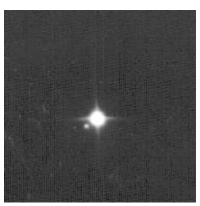
Magnitude 0

↓ 2.5 times brighter

Spica

Magnitude 1

↓ 2.5 times brighter



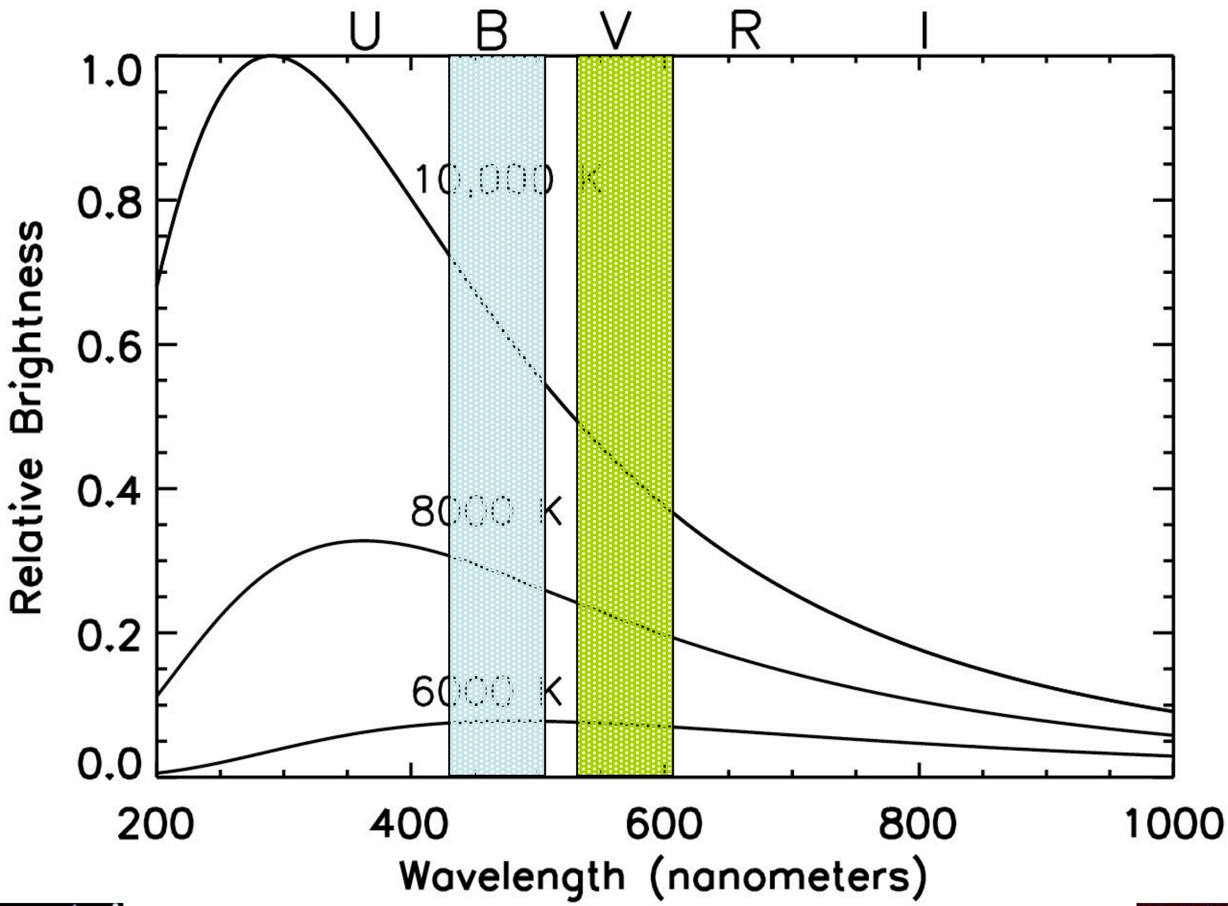
Polaris

Magnitude 2

↓ 2.5 times brighter

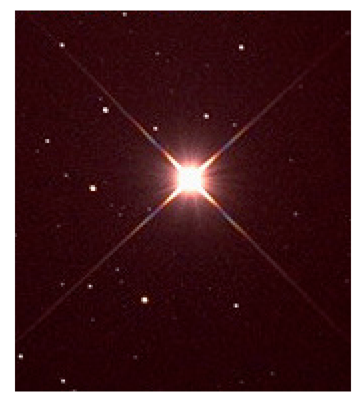
Magnitude 3

Colors

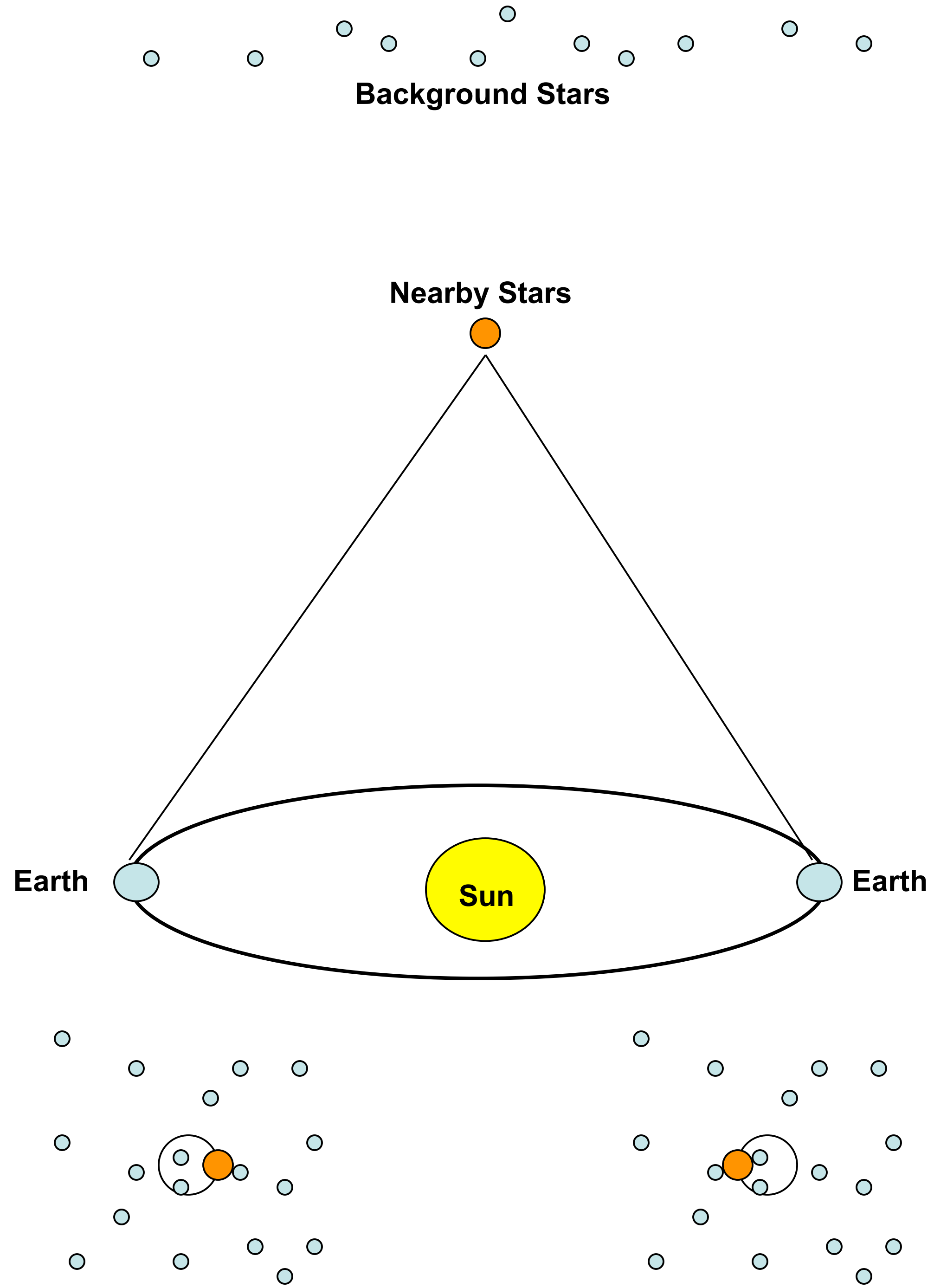


Rigel,
B-V = - 0.03

Betelgeuse,
B-V = 1.85



Measuring Distance to the stars using Parallax



Magnitudes

Arcturus

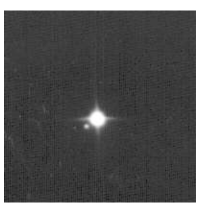
Magnitude 0

37 Light years Away

Spica

Magnitude 1

262 Light Years Away



Polaris

Magnitude 2

431 Light Years Away

Magnitude 3

Magnitudes


Arcturus

Magnitude 0

37 Light years Away

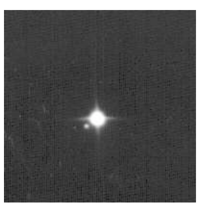
Absolute Magnitude - 0.30


Spica

Magnitude 1

262 Light Years Away

Absolute Magnitude - 3.55


Polaris

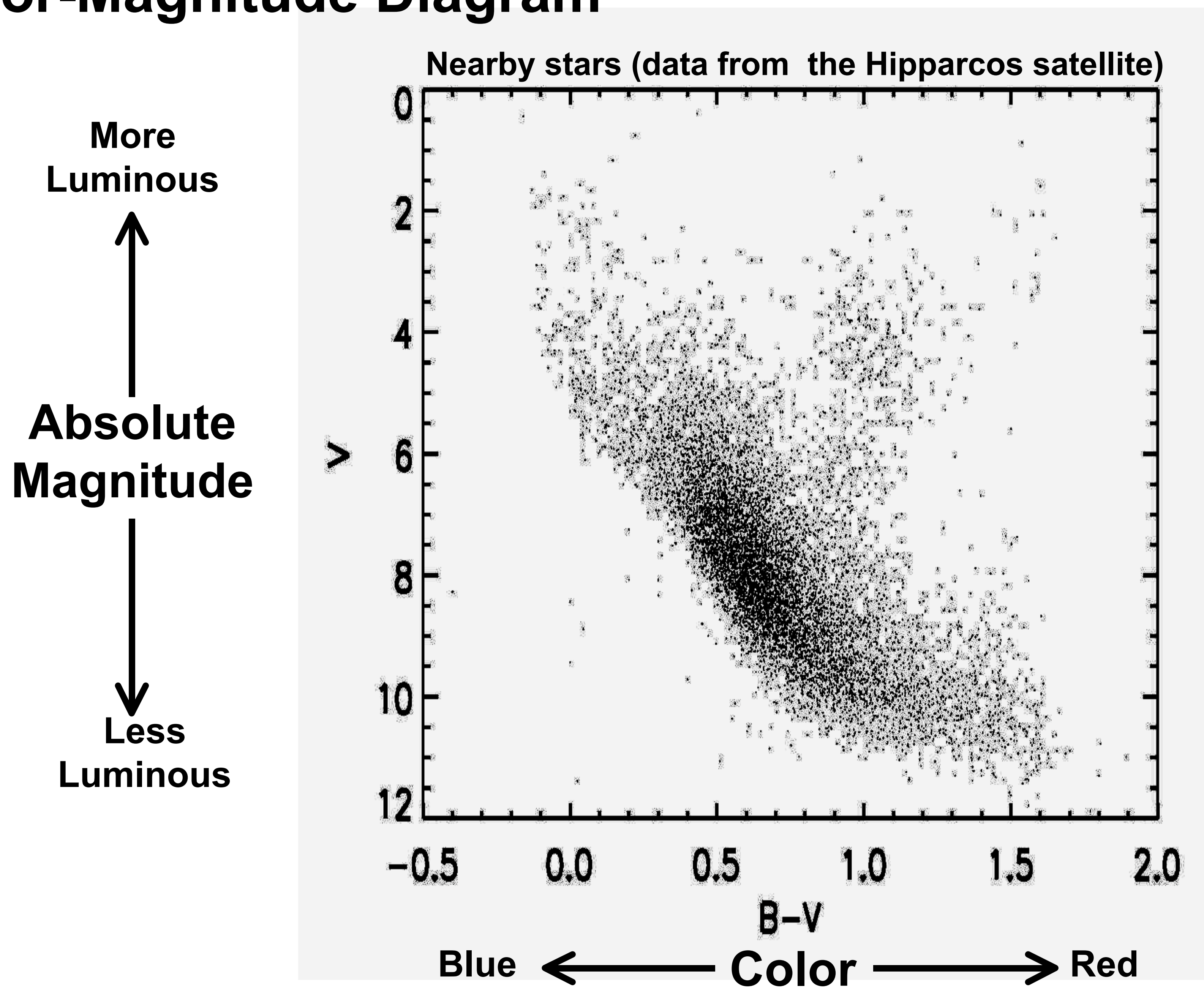
Magnitude 2

431 Light Years Away

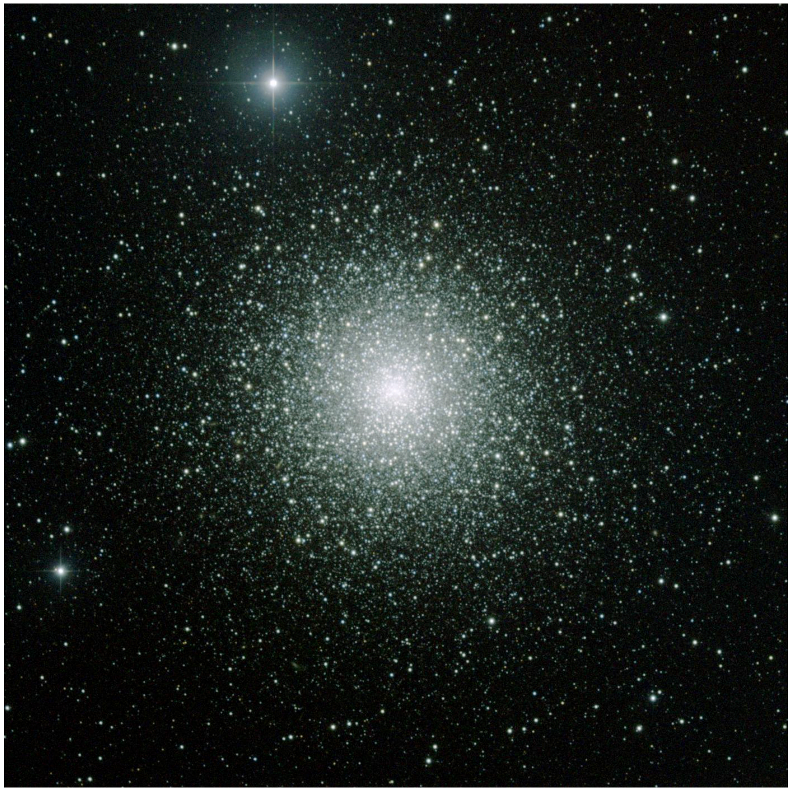
Absolute Magnitude - 3.59

Magnitude 3

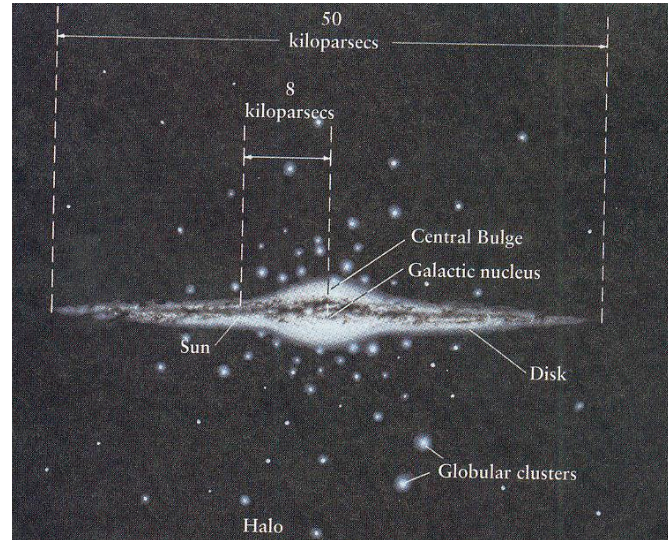
Color-Magnitude Diagram



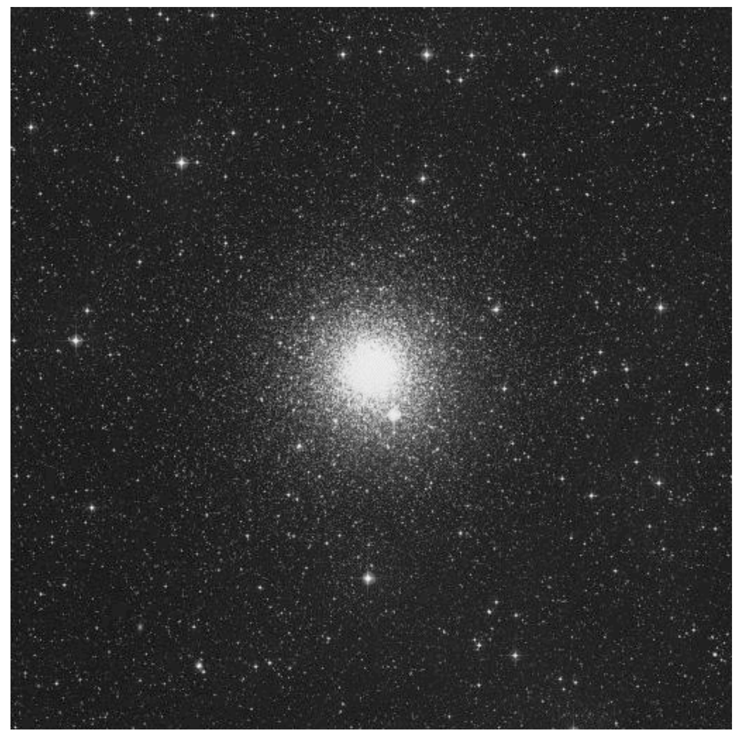
Globular Clusters



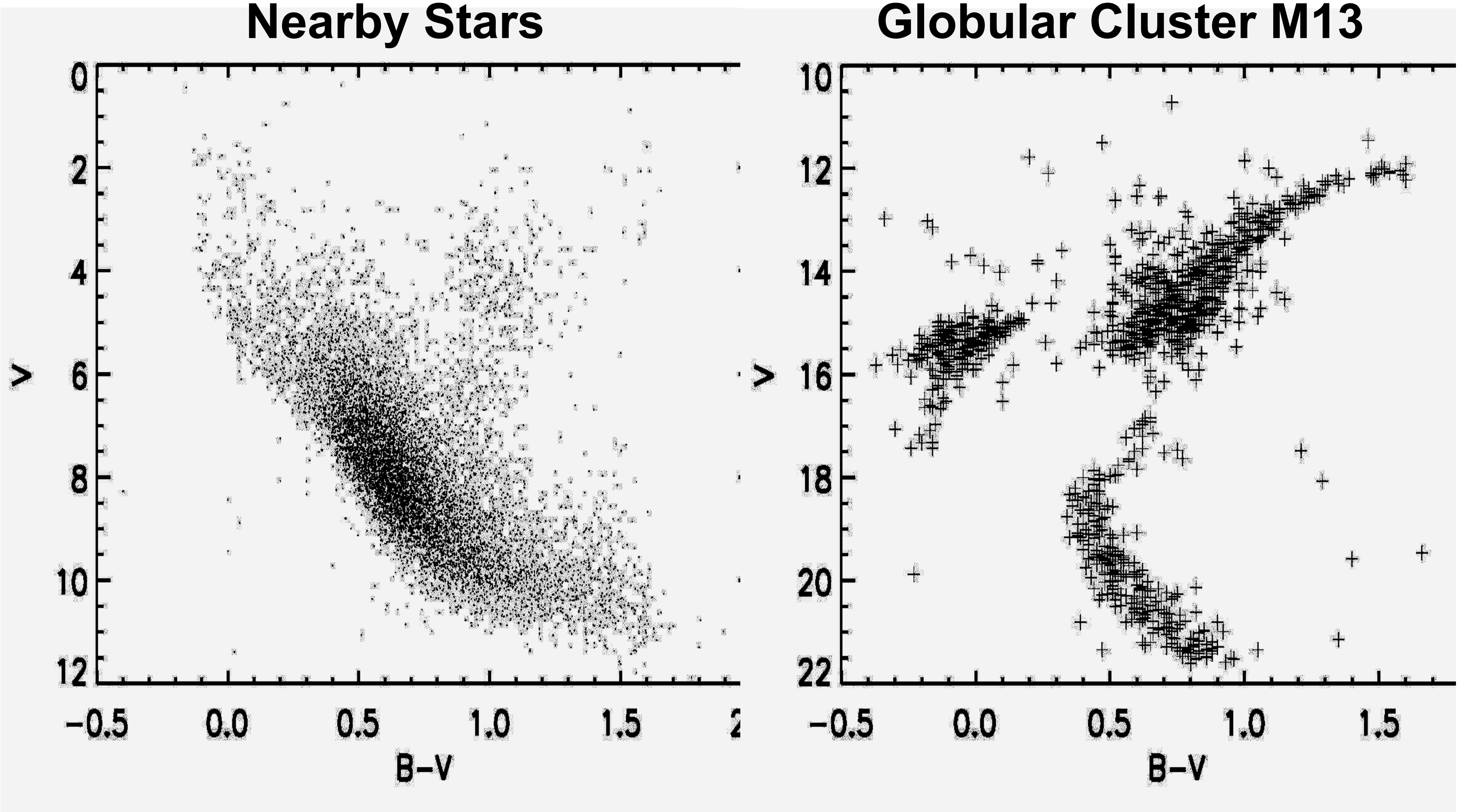
M15



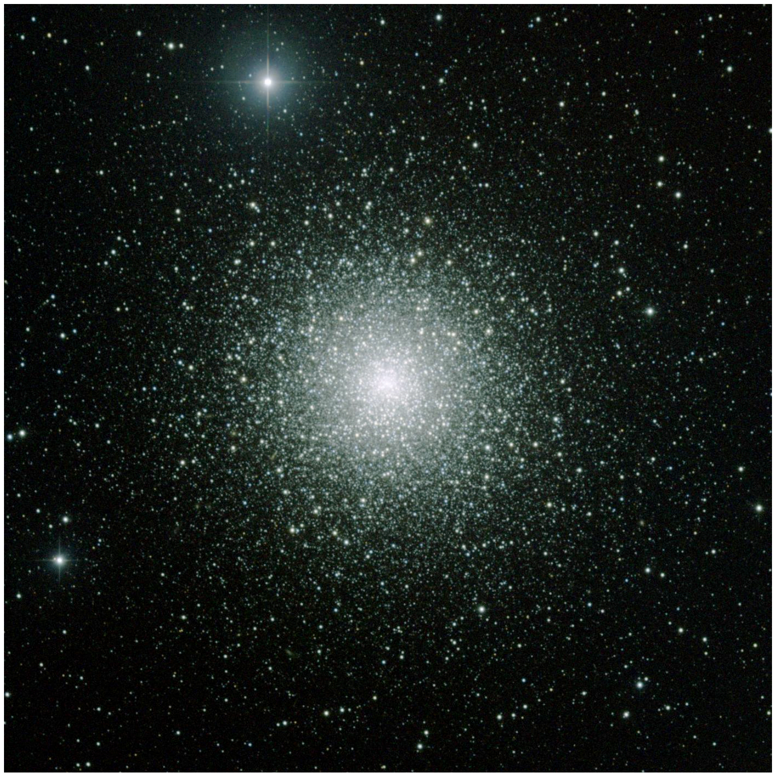
NGC 362

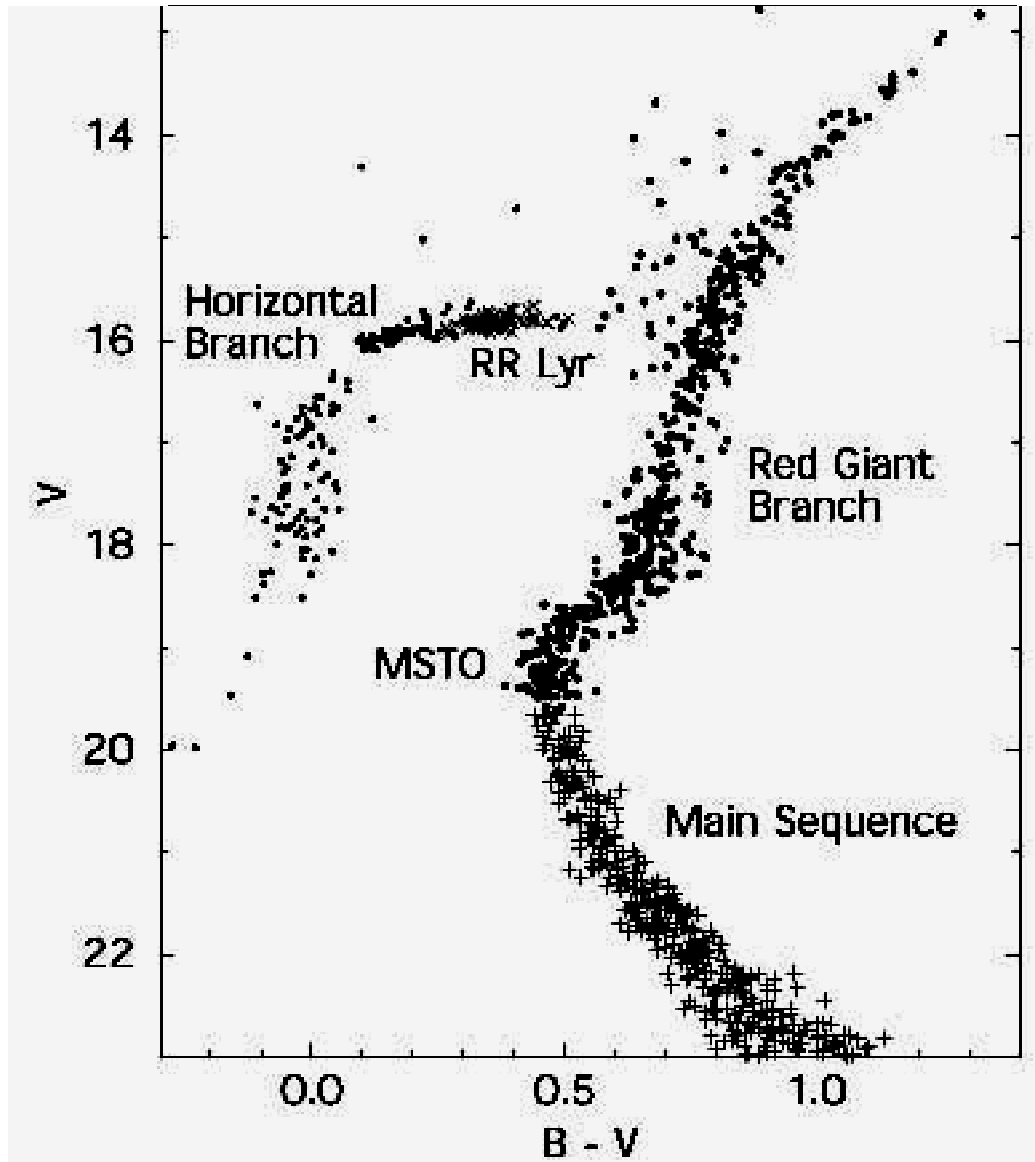


Color-Magnitude Diagrams of Globular Clusters

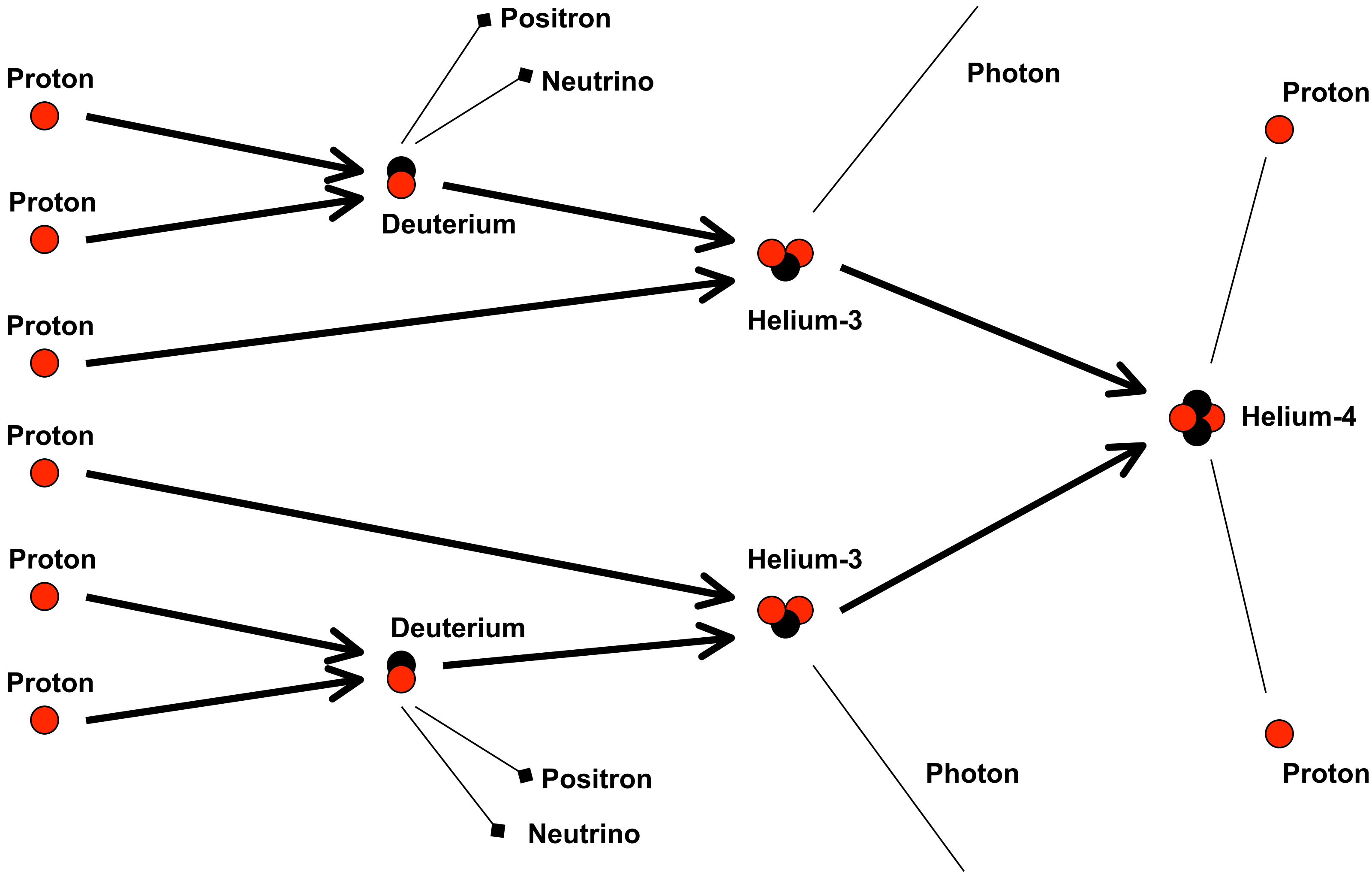


Another Globular Cluster: M15

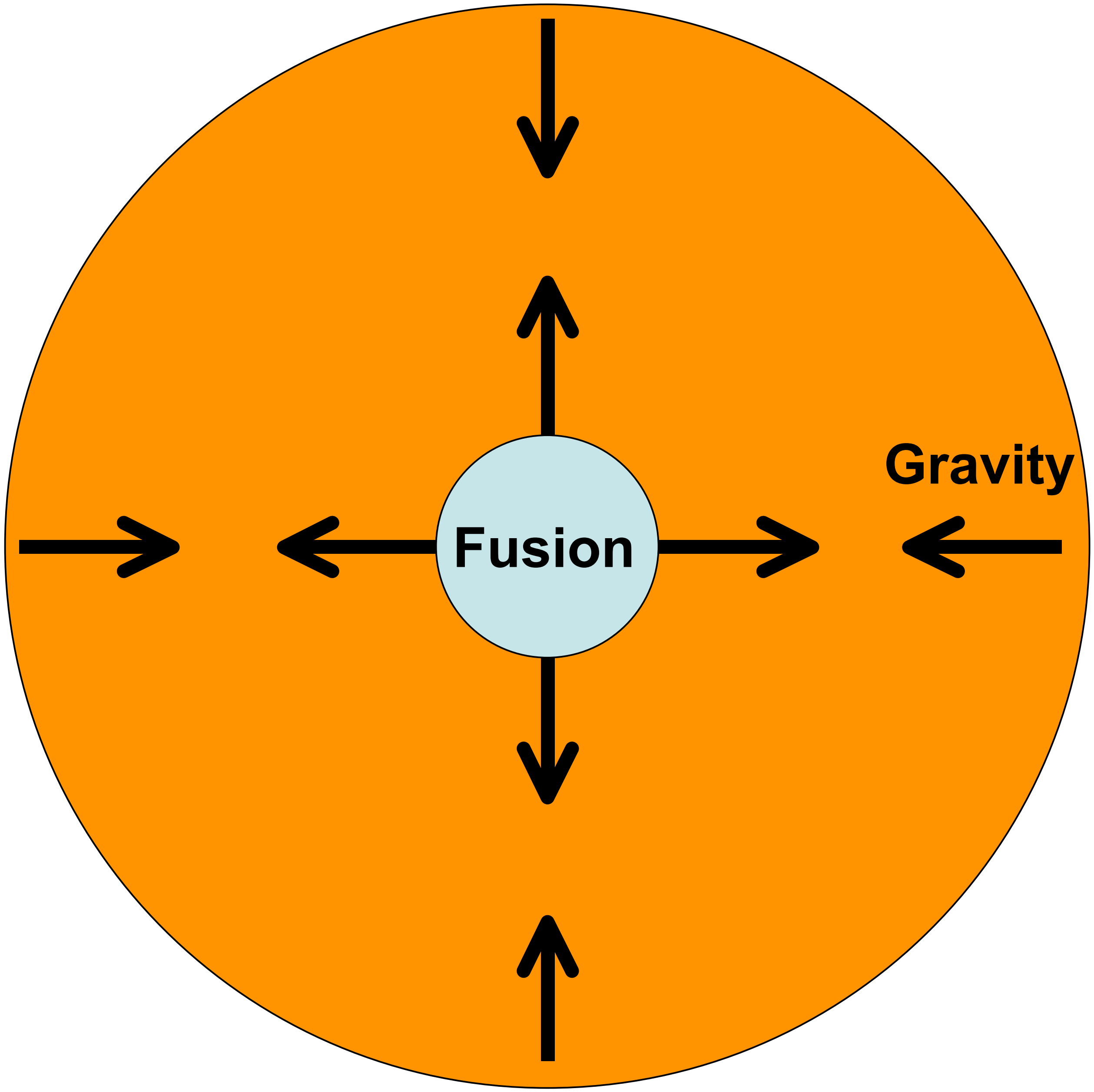




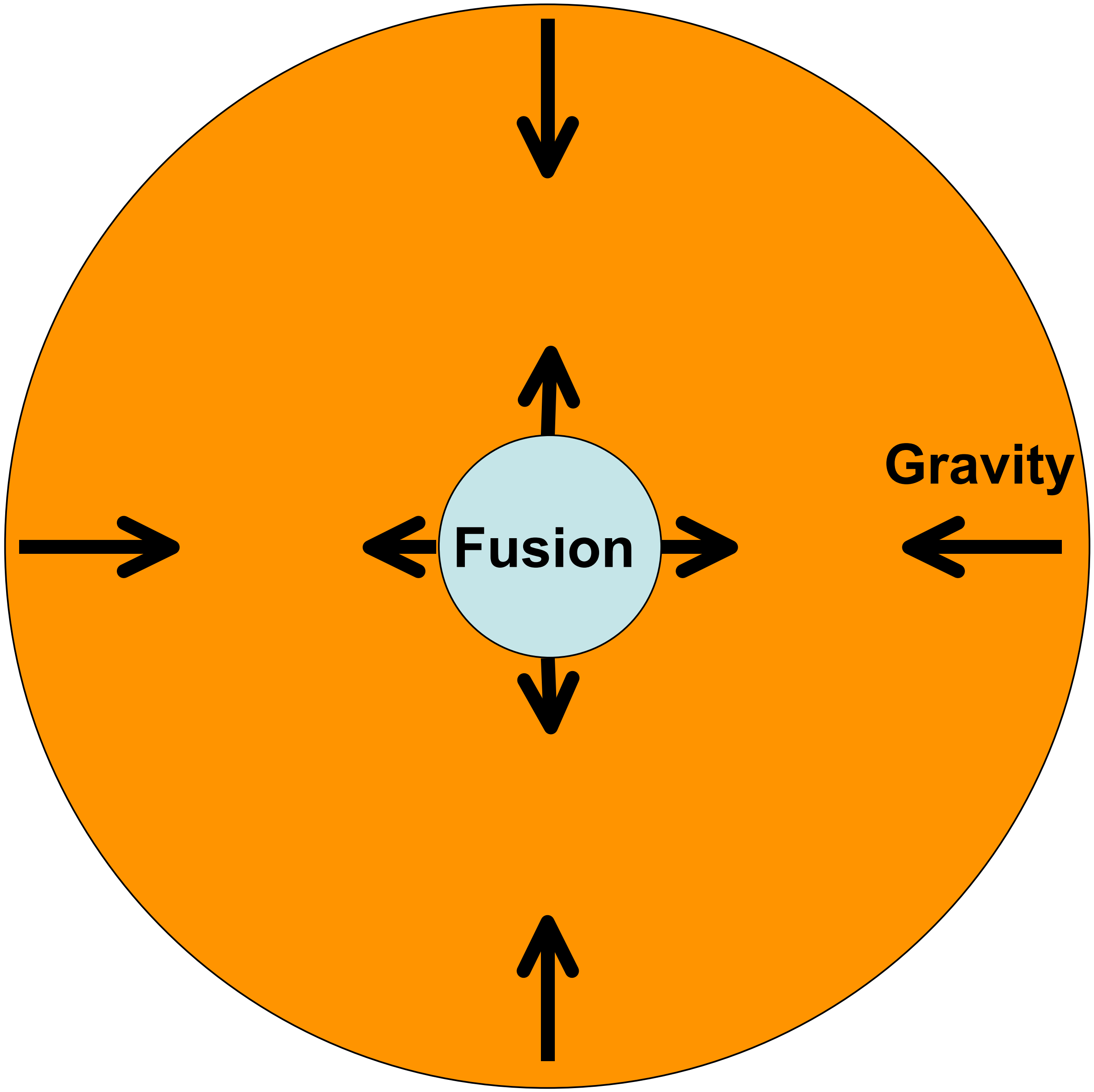
Nuclear Fusion



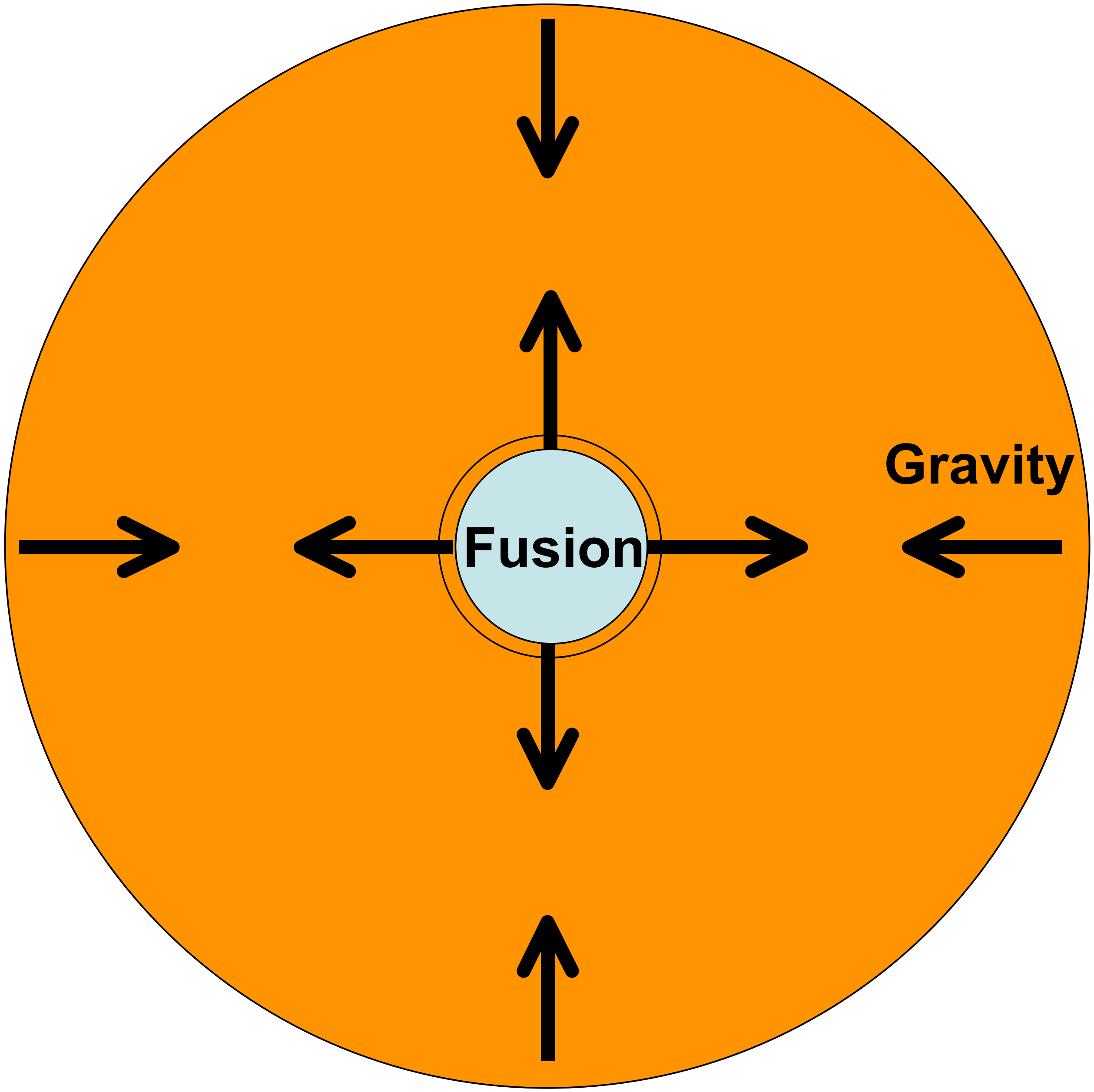
Equilibrium in Main Sequence Stars



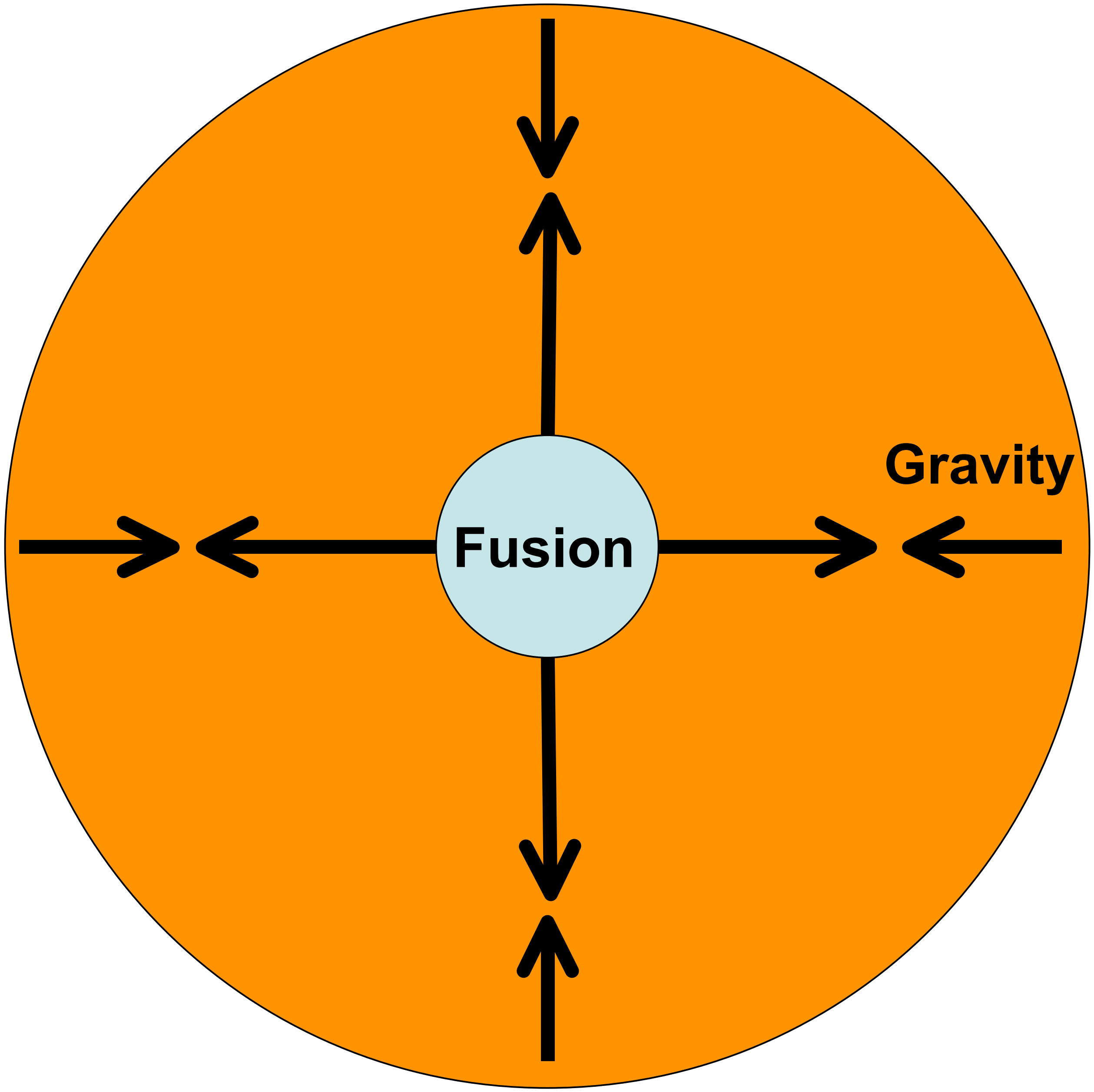
Equilibrium in Main Sequence Stars



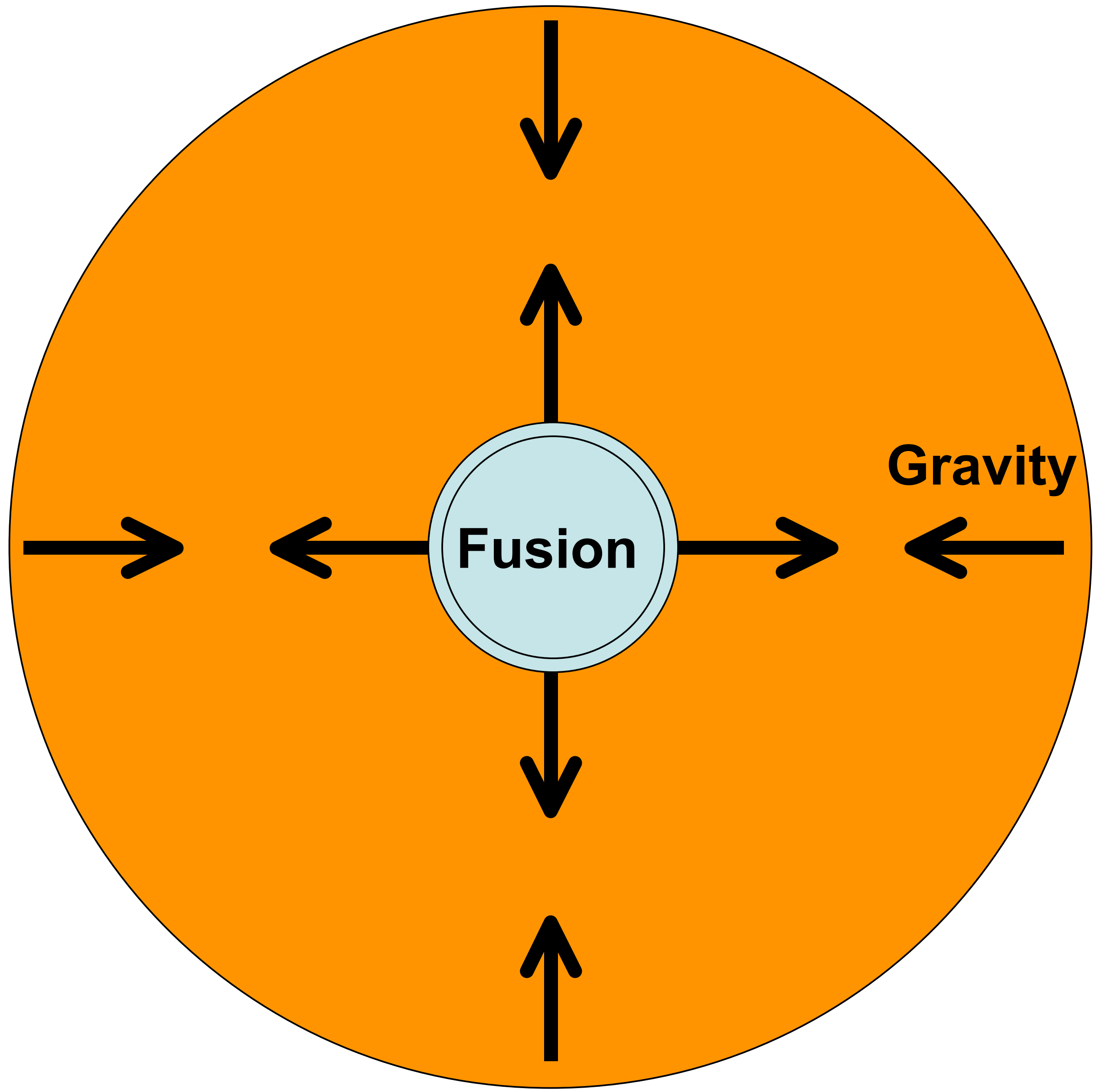
Equilibrium in Main Sequence Stars



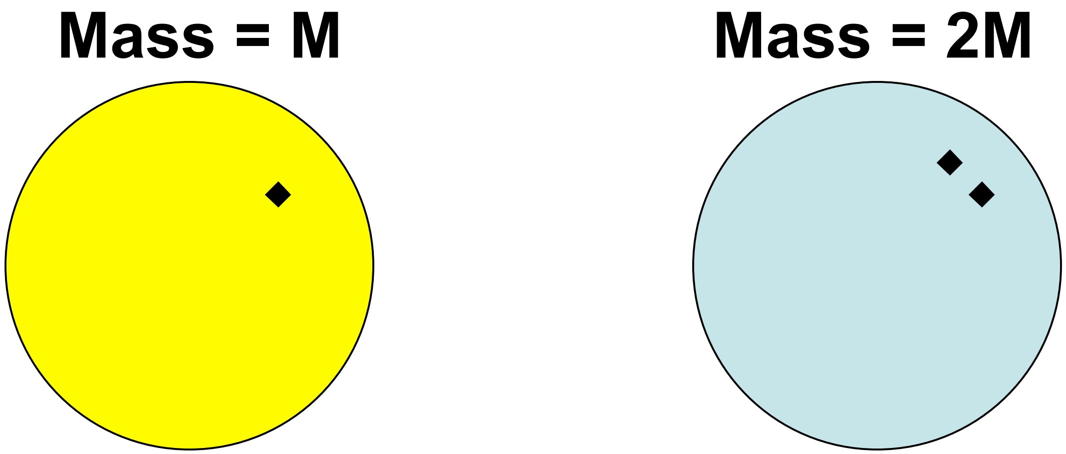
Equilibrium in Main Sequence Stars



Equilibrium in Main Sequence Stars



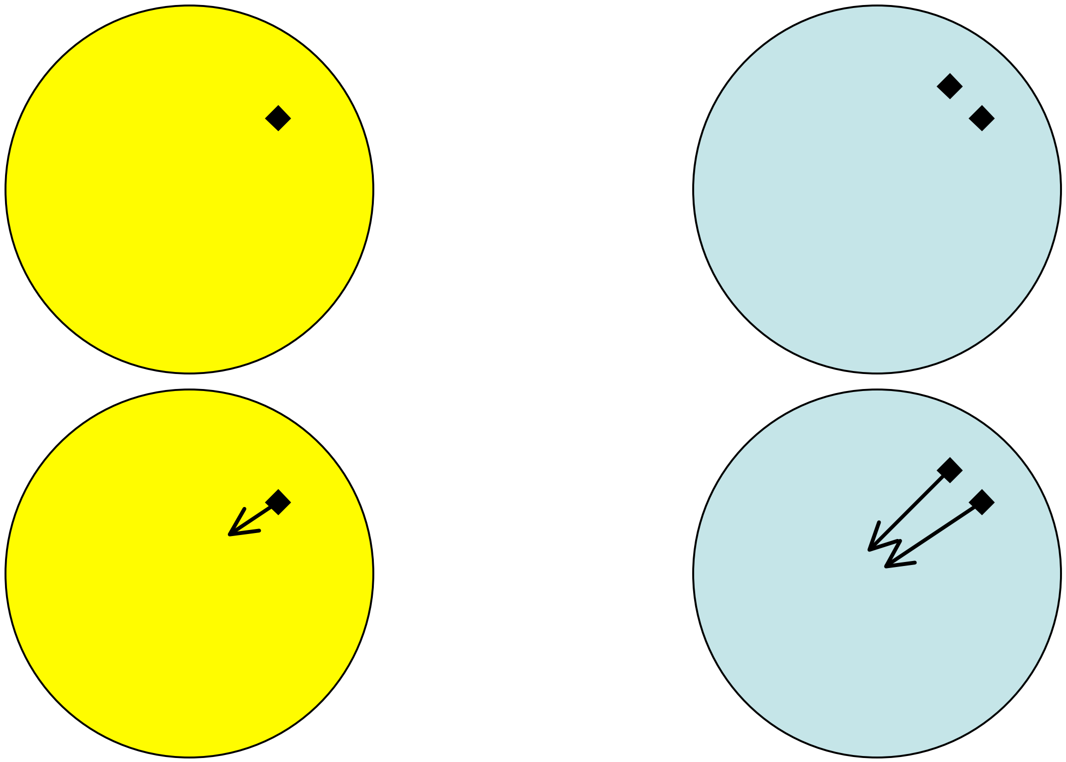
Supporting the Mass of the Star



2 times as much material to support

Supporting the Mass of the Star

Mass = M **Mass = 2M**

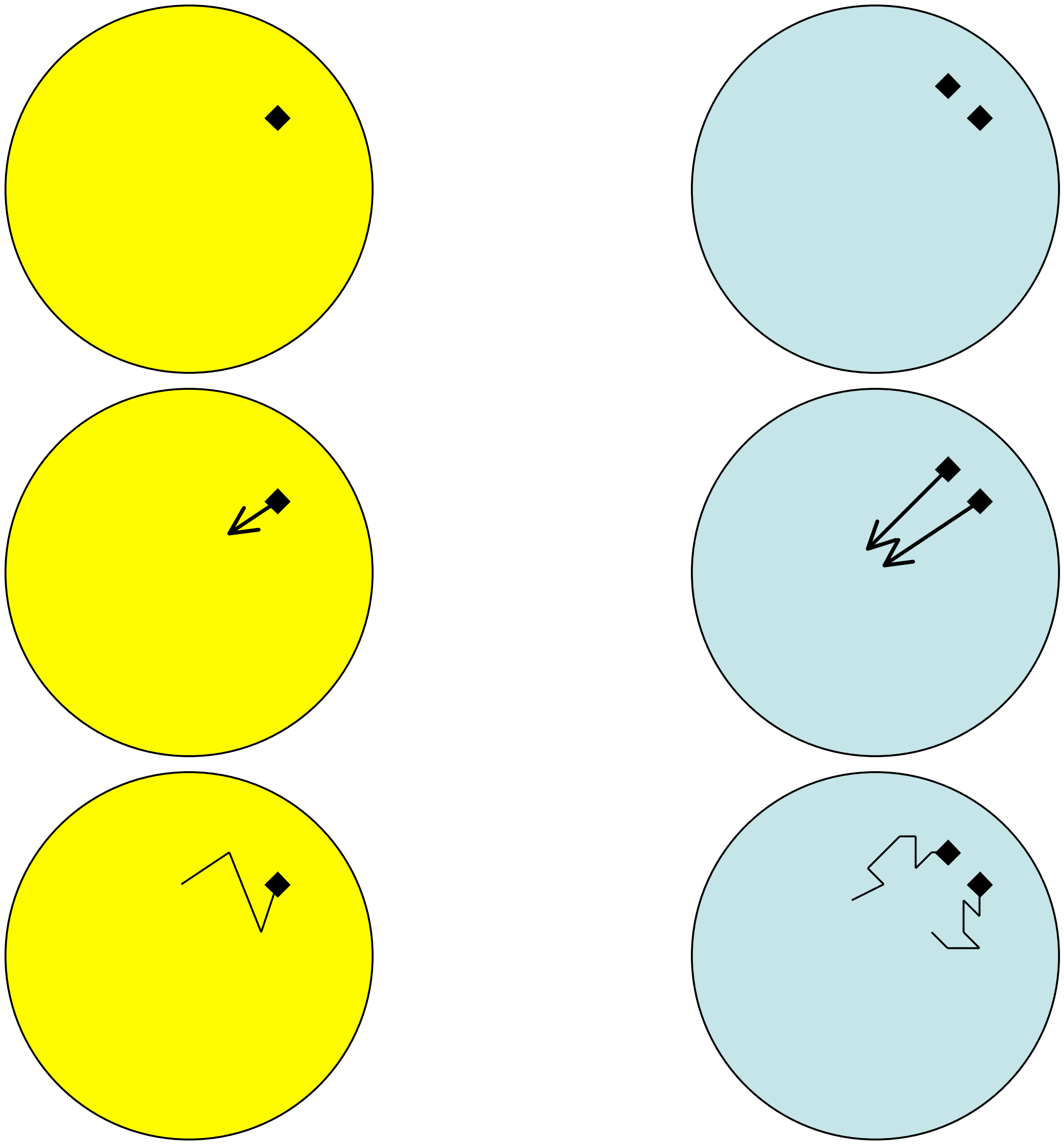


2 times as much material to support

2 times the gravitational force on each particle

Supporting the Mass of the Star

Mass = M **Mass = 2M**

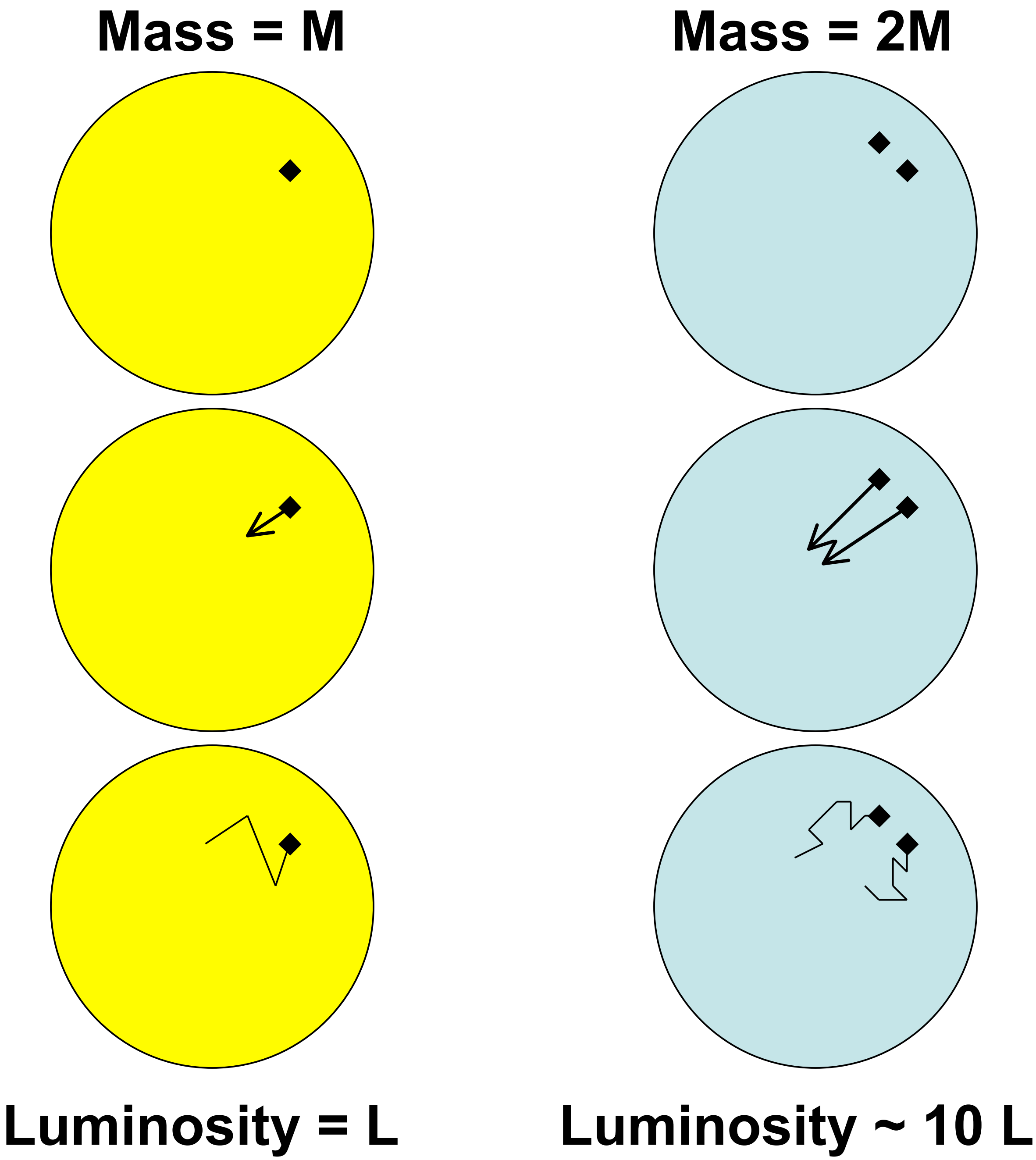


2 times as much material to support

2 times the gravitational force on each particle

2-4 times more rapid rate of energy transport, loss through surface.

Supporting the Mass of the Star



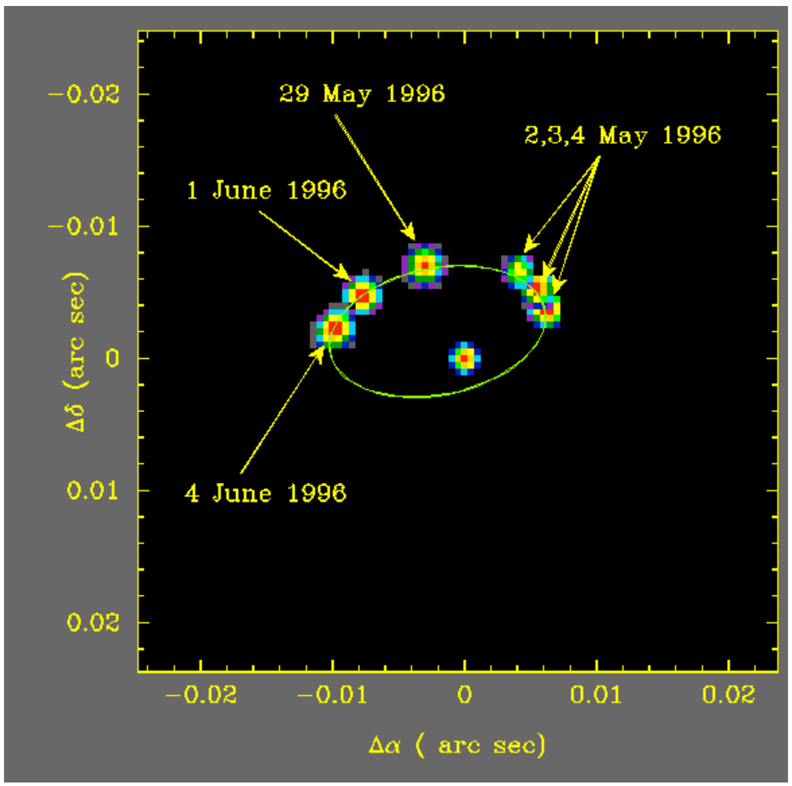
2 times as much material to support

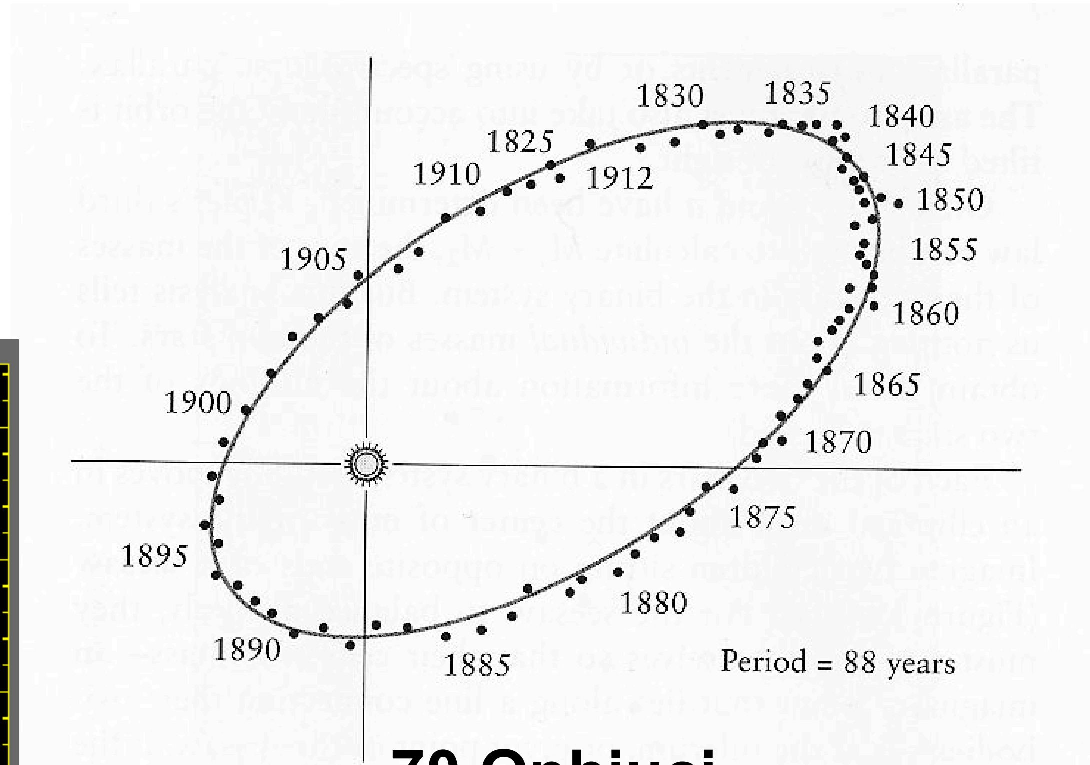
2 times the gravitational force on each particle

2-4 times more rapid rate of energy transport, loss through surface.

Mass Estimates from Binary stars

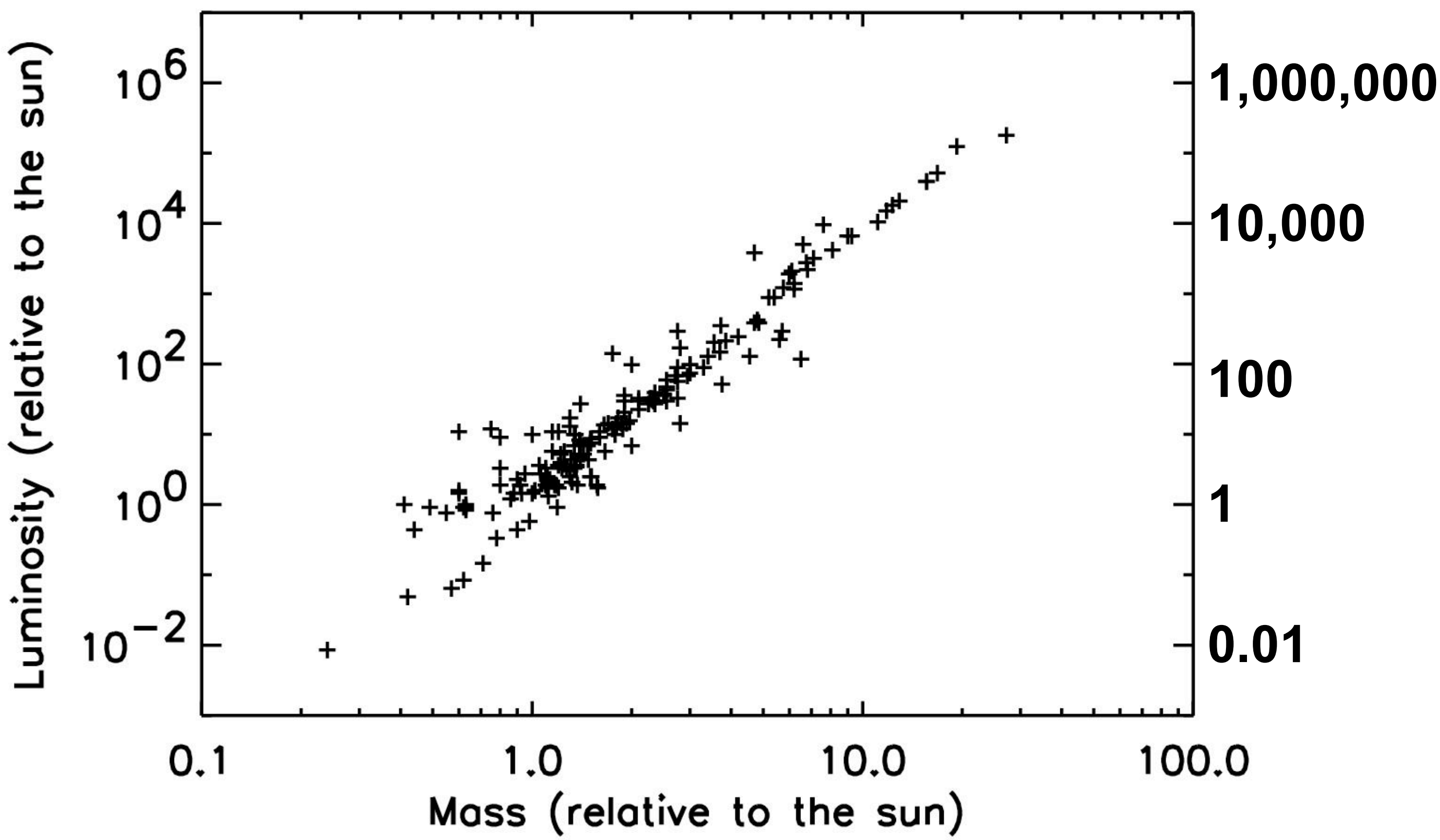
Mizar 1



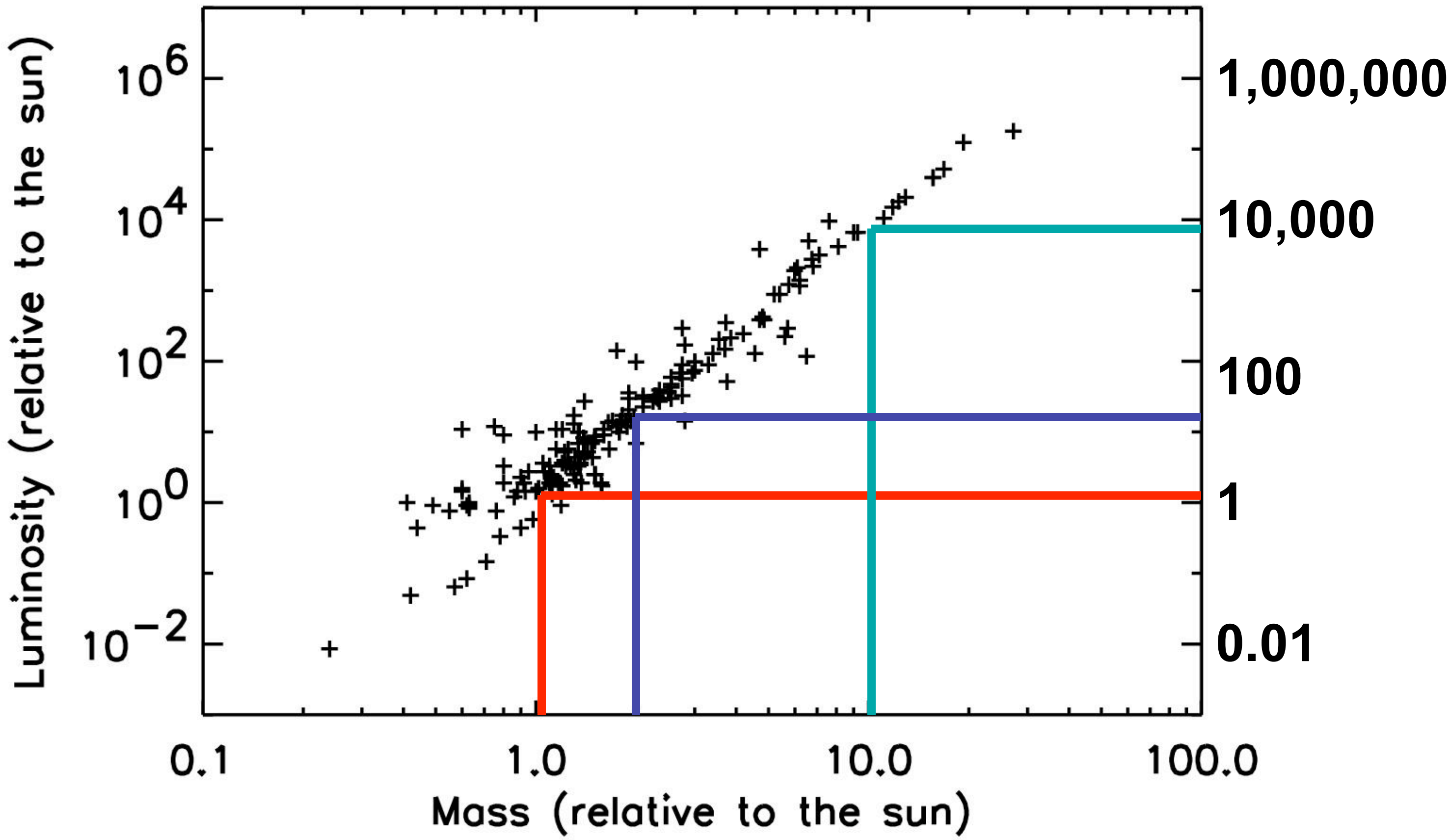


70 Ophiuci

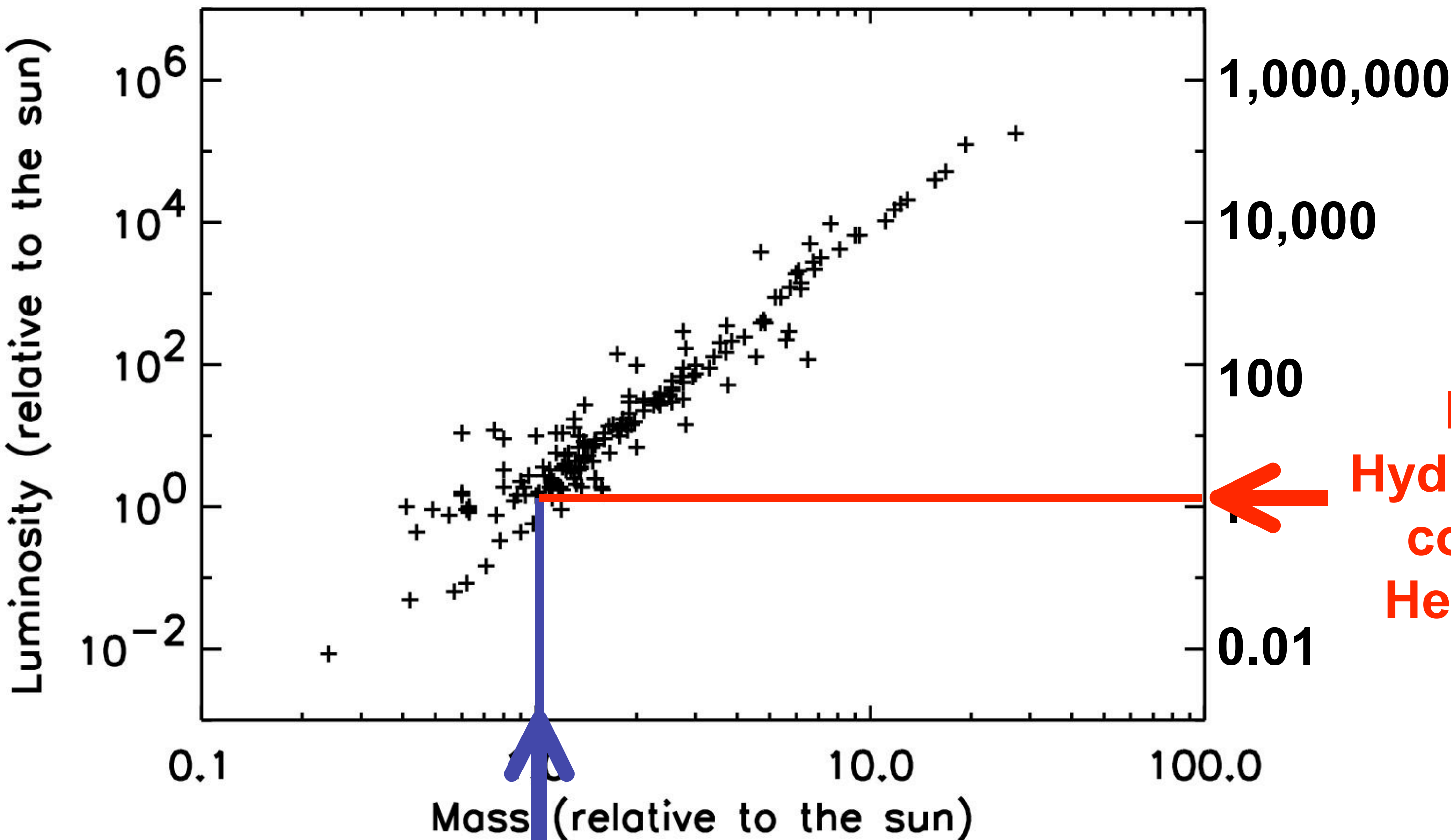
Mass-Luminosity Relation



Mass-Luminosity Relation



Main Sequence Lifetimes



Rate that Hydrogen atoms convert into Helium atoms

Total number of Hydrogen atoms

Time to convert all Hydrogen to Helium 150 billion years

Lifetime of a Main Sequence Star

Luminosity = $4 * 10^{26}$ Watts

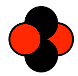
$1.5 * 10^{17}$ kilograms/ Year

Mass = $2 * 10^{30}$ kilogram

All Hydrogen would be converted to Helium in 150 billion years

The Schonberg-Chandrasekhar Limit

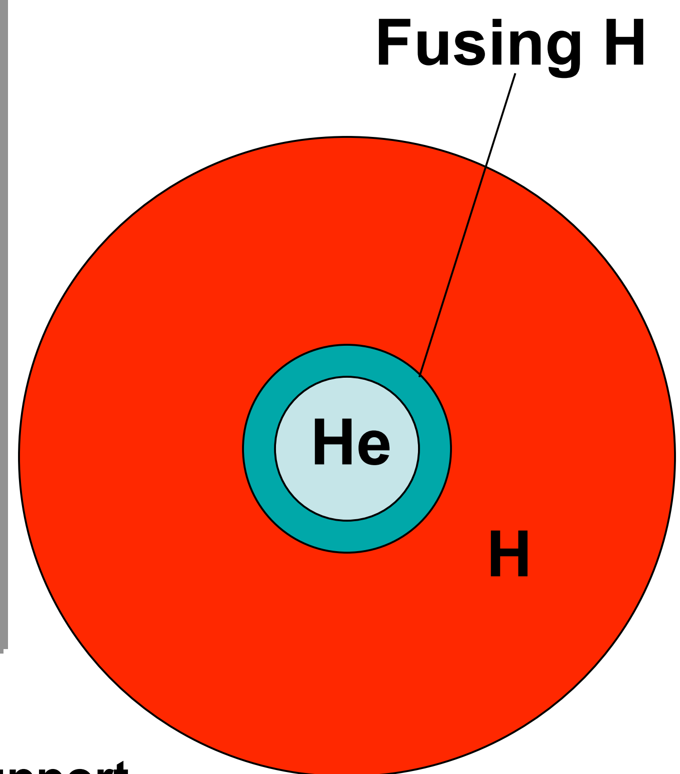
Helium has 4 times more mass than Hydrogen

 **Hydrogen**  **Helium**

Helium undergoes fusion at much higher temperatures than Hydrogen

$H + H \rightarrow D$ $\quad D + H \rightarrow He^3$ $\quad He^3 + He^3 \rightarrow He^4$

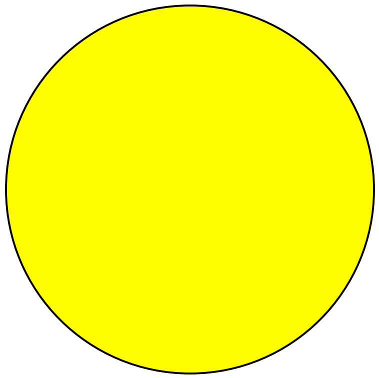
$He + He + He \rightarrow C$



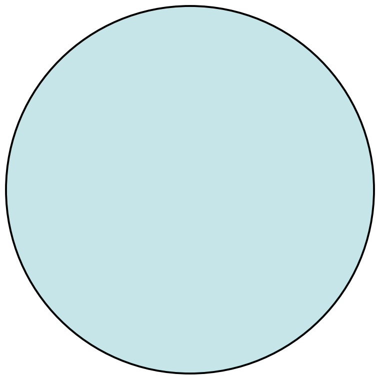
As Helium accumulates in the core, it becomes more and more difficult to support

A main-sequence star cannot maintain equilibrium if more than 10% of its total mass has been converted into Helium

Different Stars, Different Lifetimes

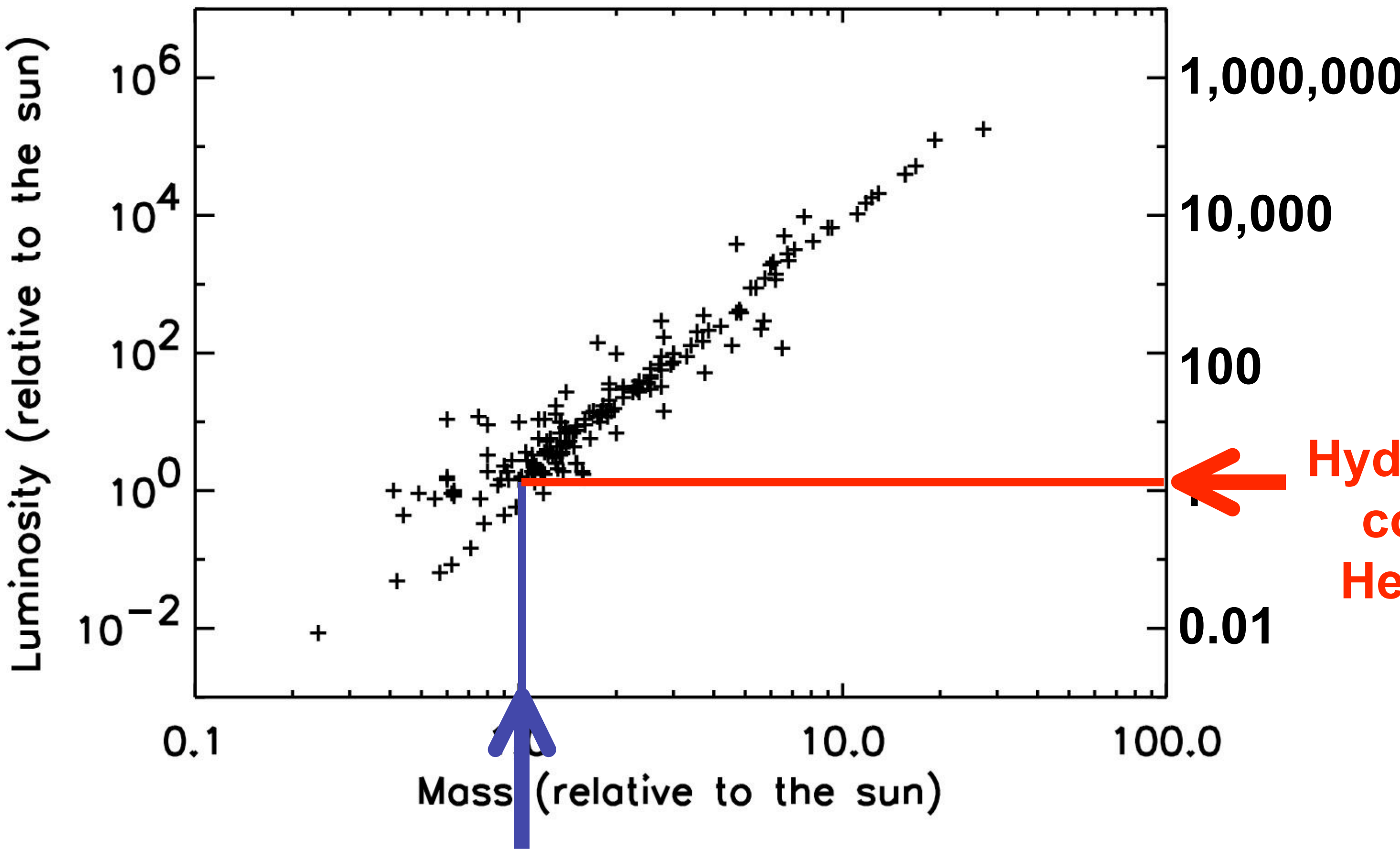


Mass = M
Luminosity = L
Lifetime = 10 Billion Years



Mass = 2M
Luminosity ~ 10 L
Lifetime = 2 Billion Years

Main Sequence Lifetimes

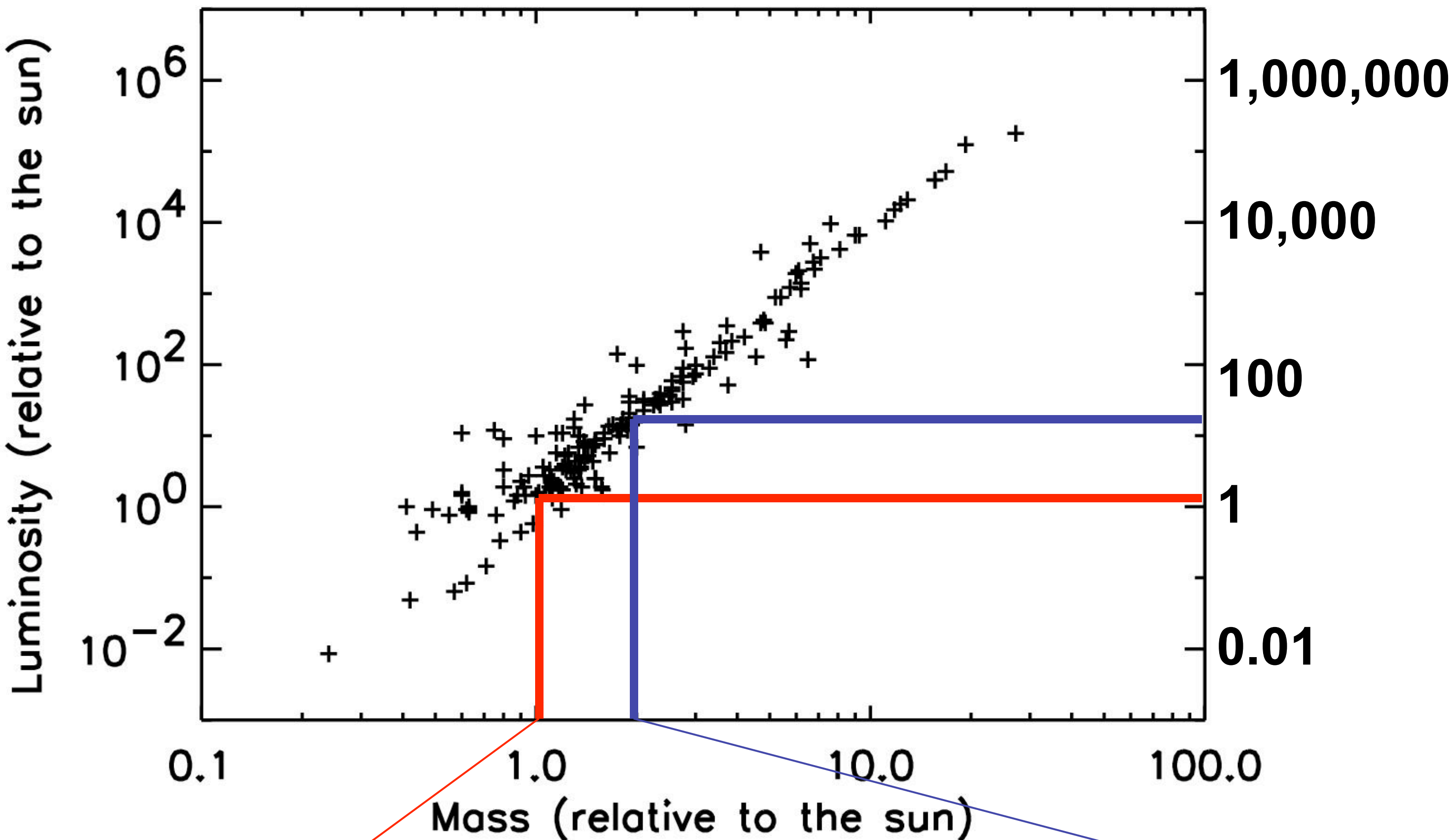


Rate that Hydrogen atoms convert into Helium atoms

Total number of Hydrogen atoms

Time to convert 10% of the Hydrogen to Helium 10 billion years

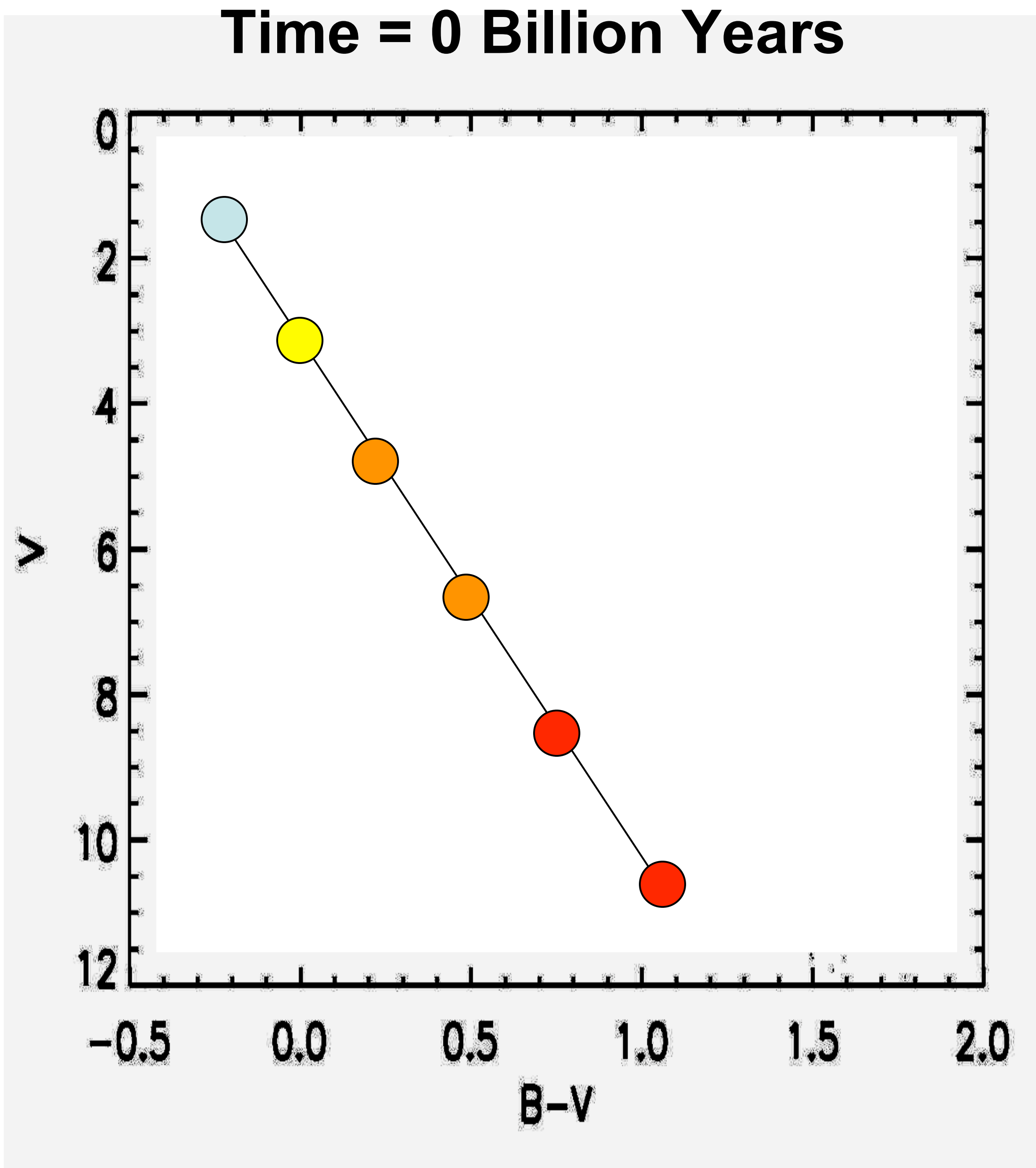
Main Sequence Lifetimes



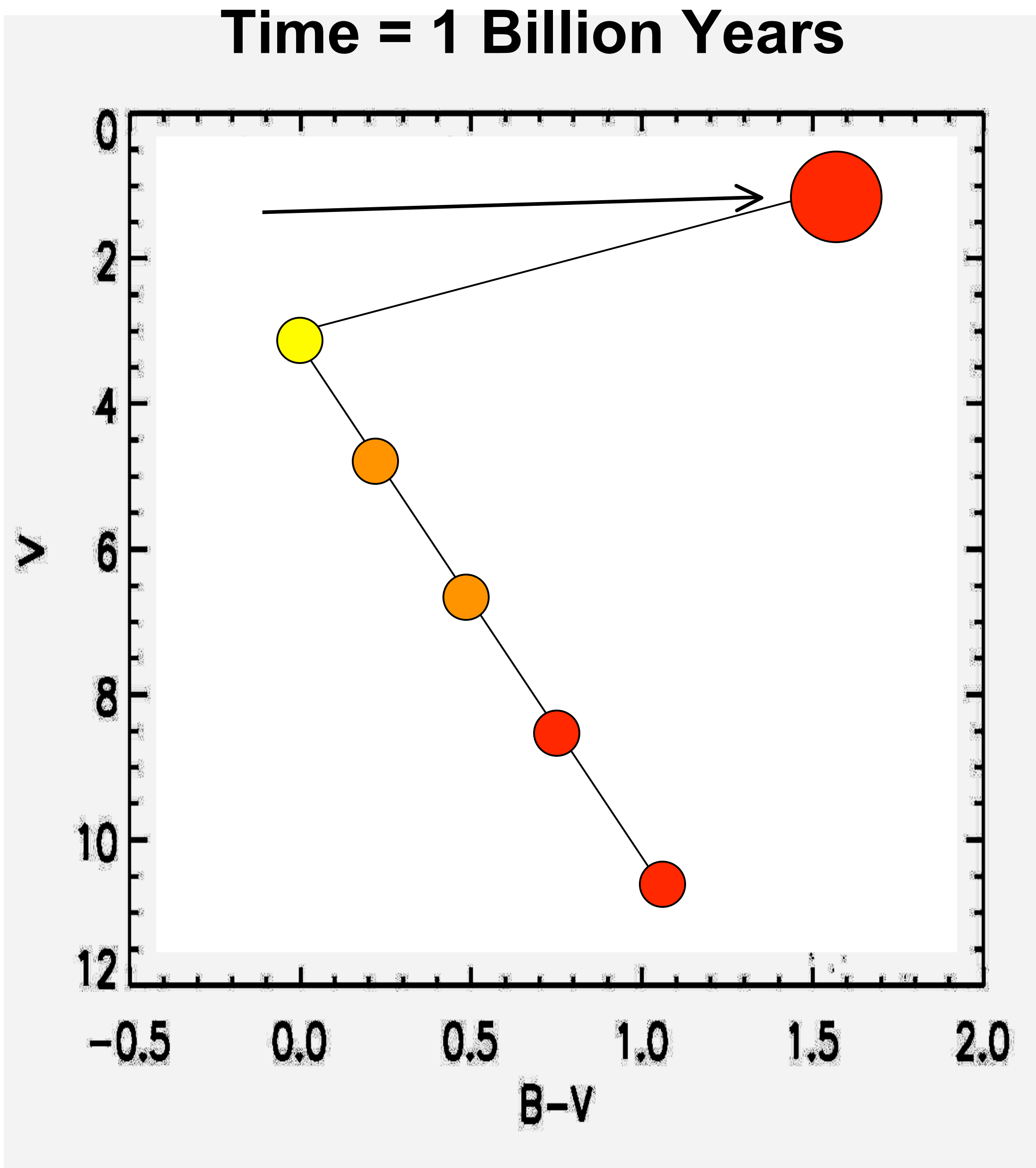
Time to convert 10% of the Hydrogen to Helium
10 billion years

Time to convert 10% of the Hydrogen to Helium
2 billion years

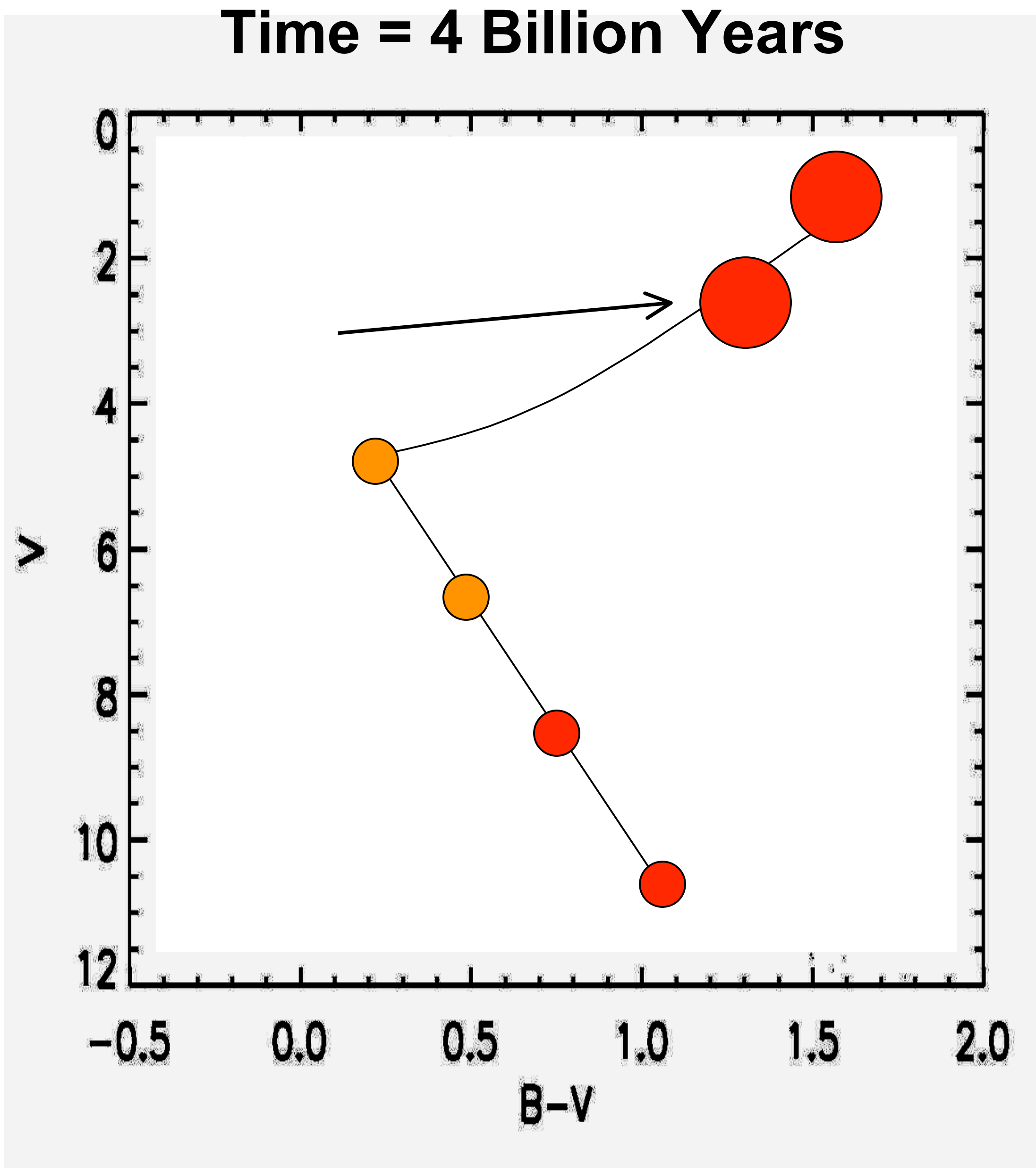
The Changing Main Sequence



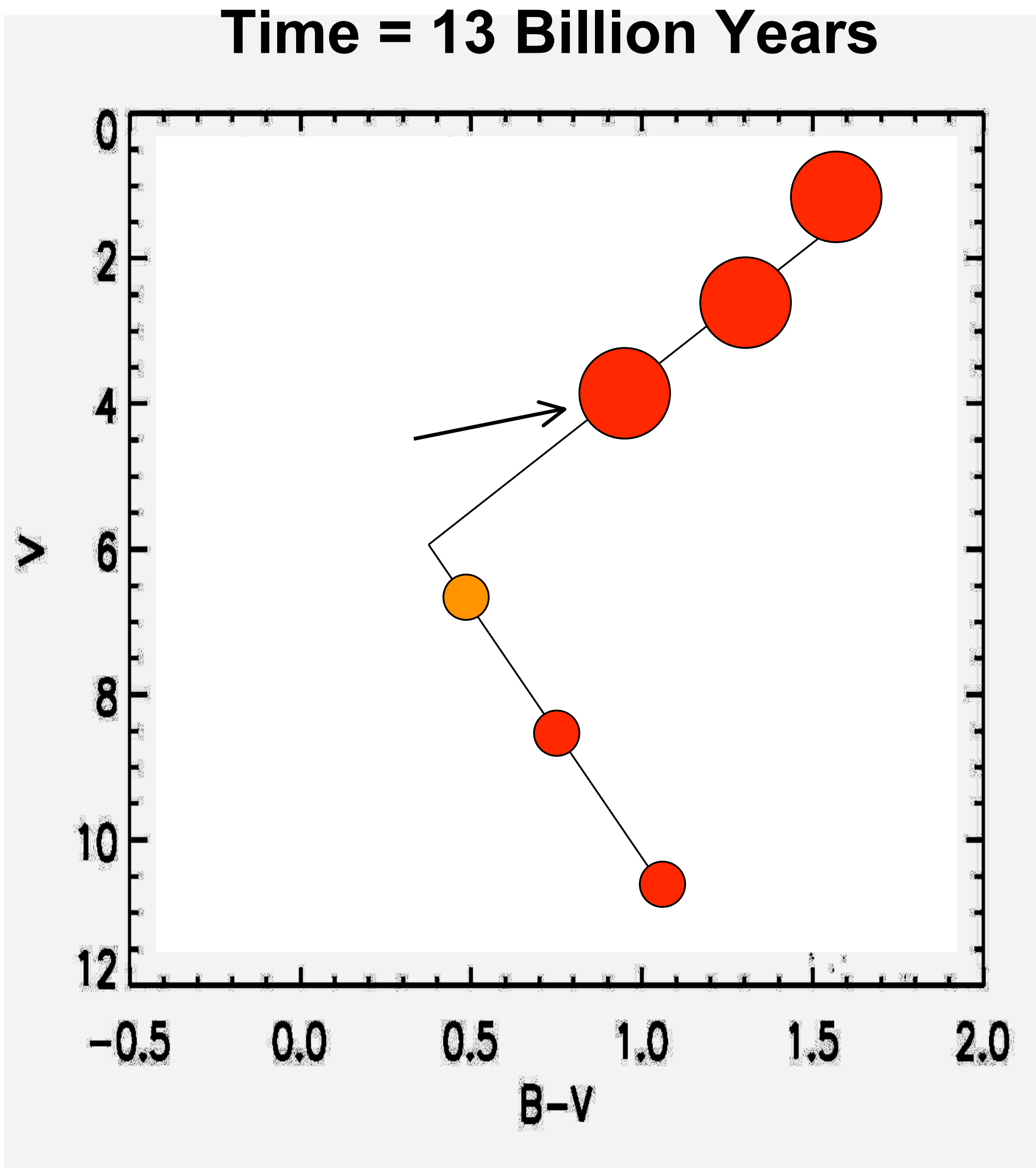
The Changing Main Sequence



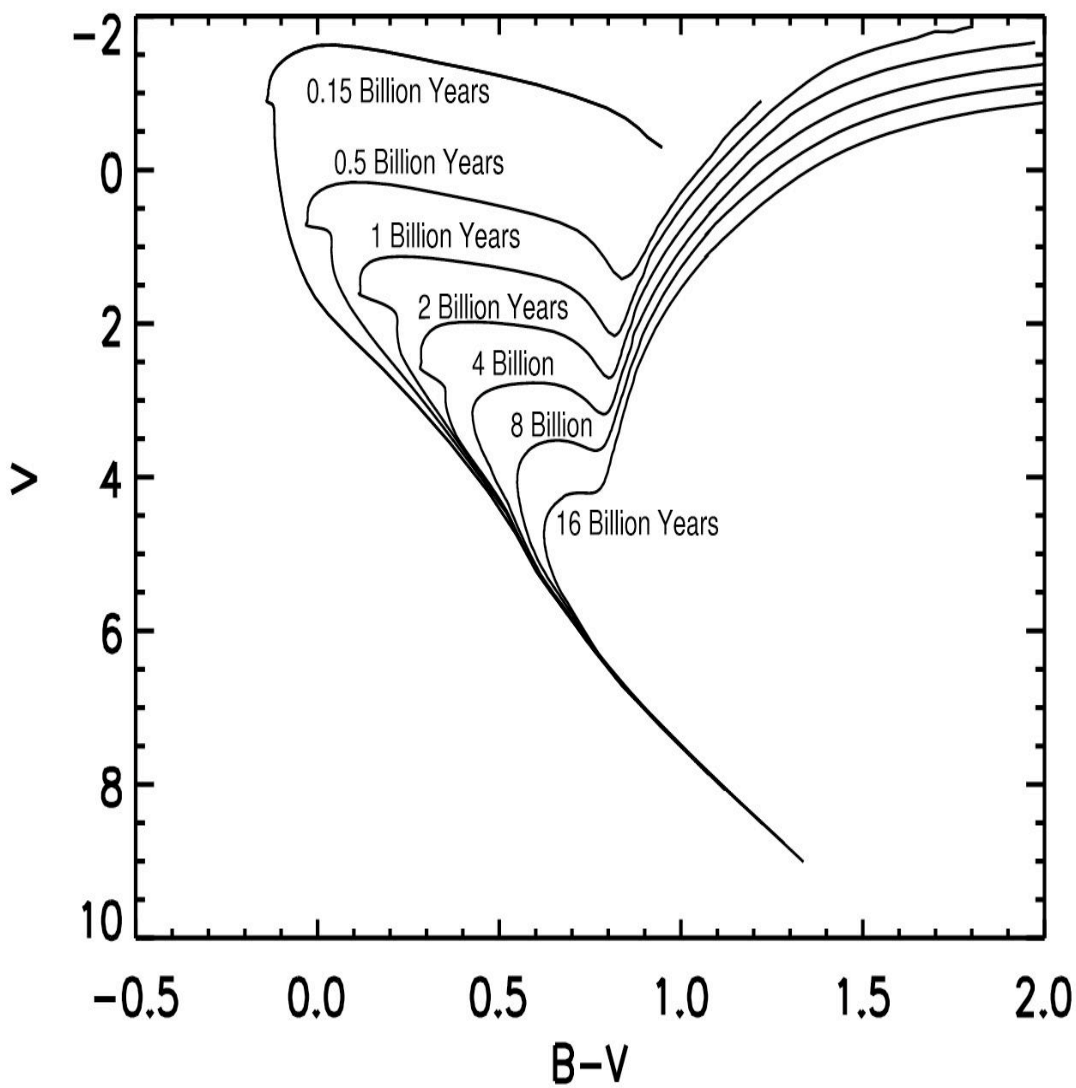
The Changing Main Sequence



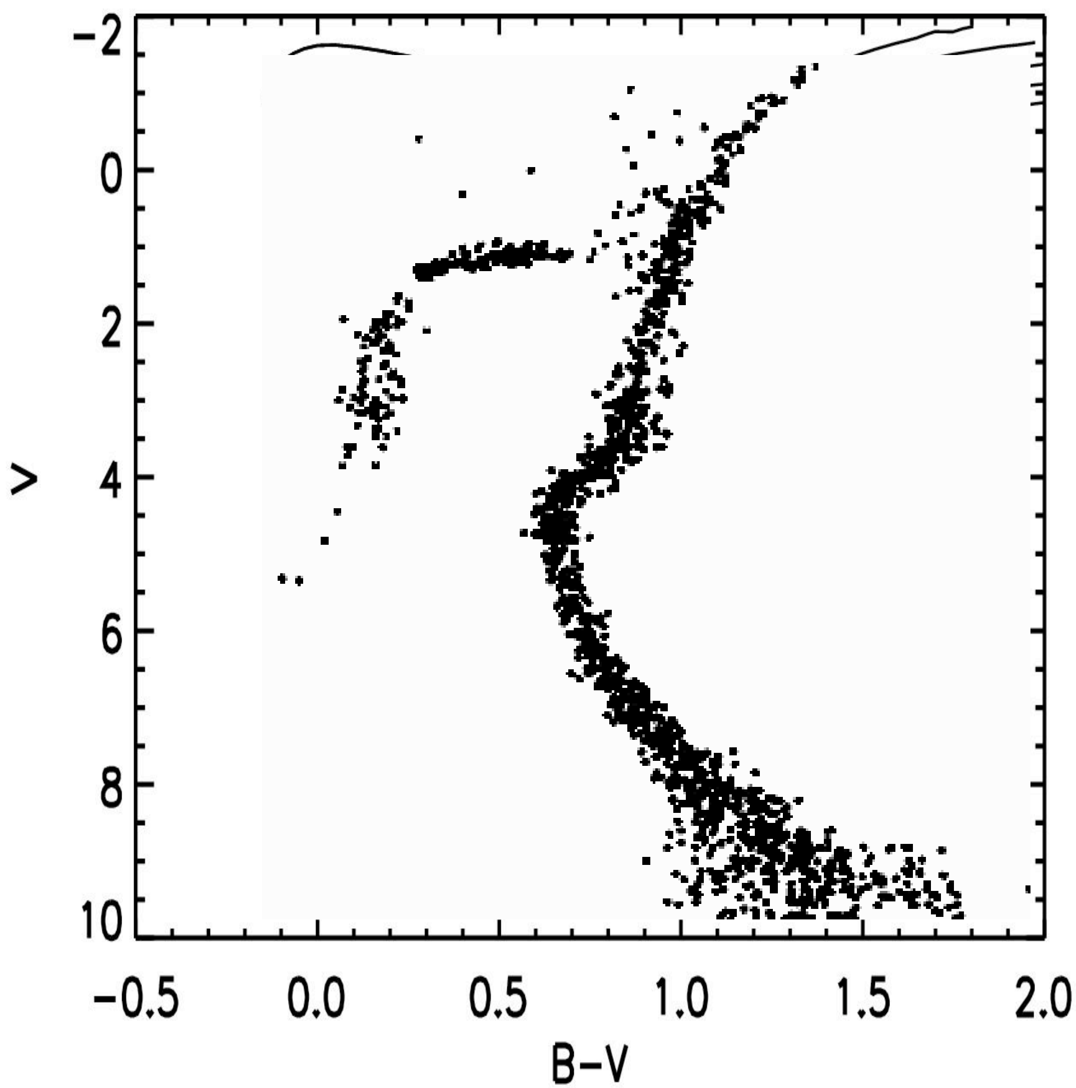
The Changing Main Sequence



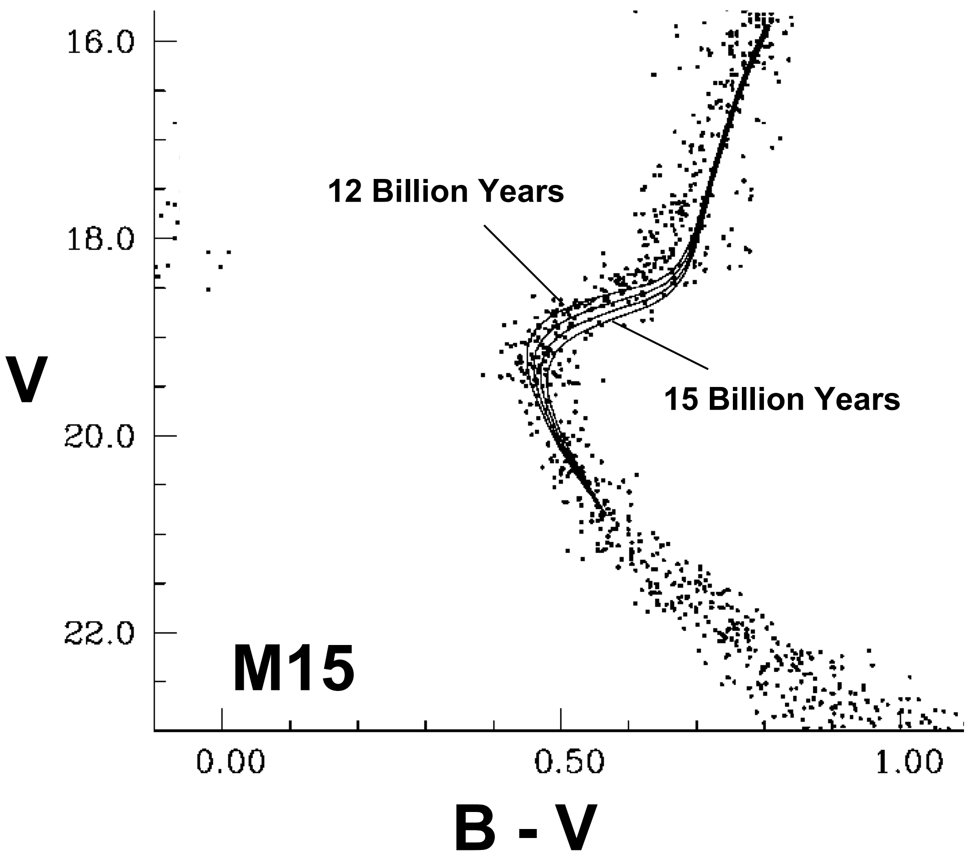
Measuring the Age of Globular Clusters

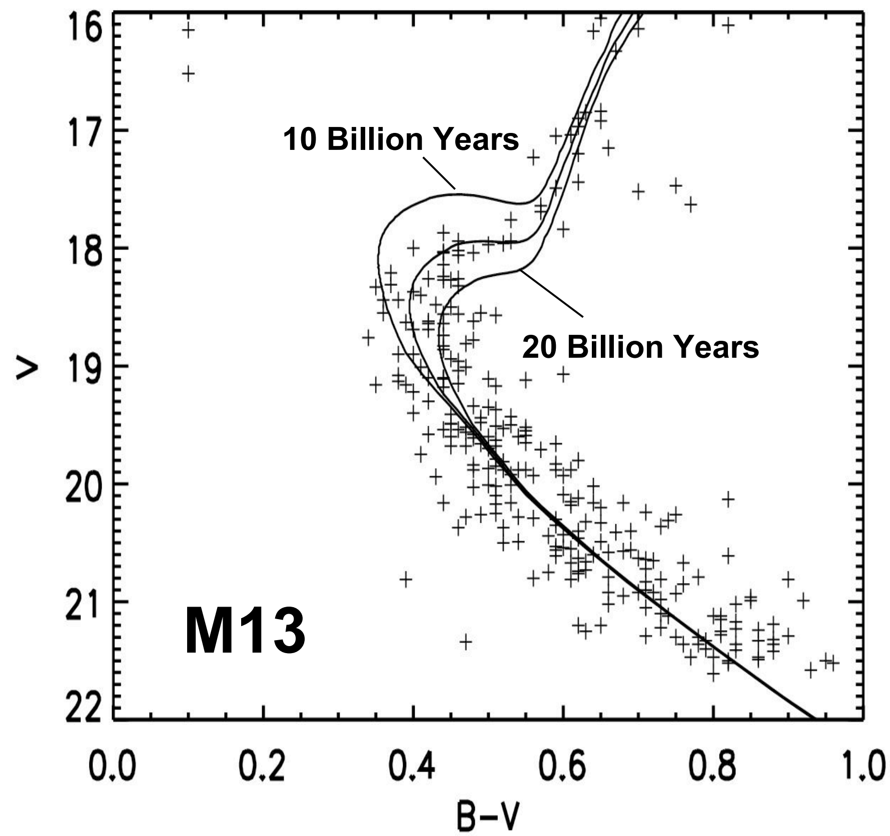


Measuring the Age of Globular Clusters



The Challenge of Measuring Globular Cluster Ages



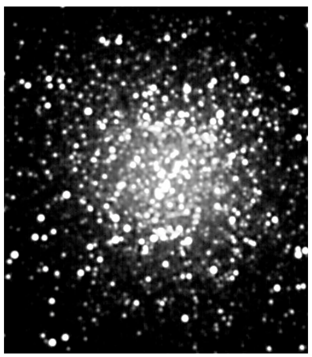


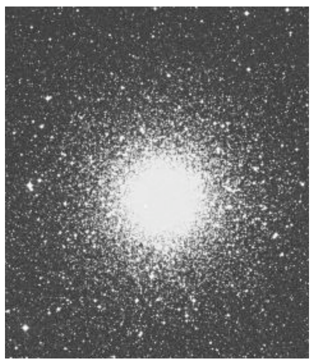
The Oldest Globular Clusters

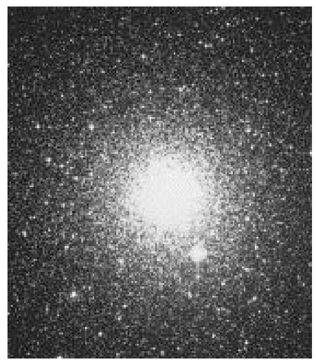

M92


M68


M30


M13

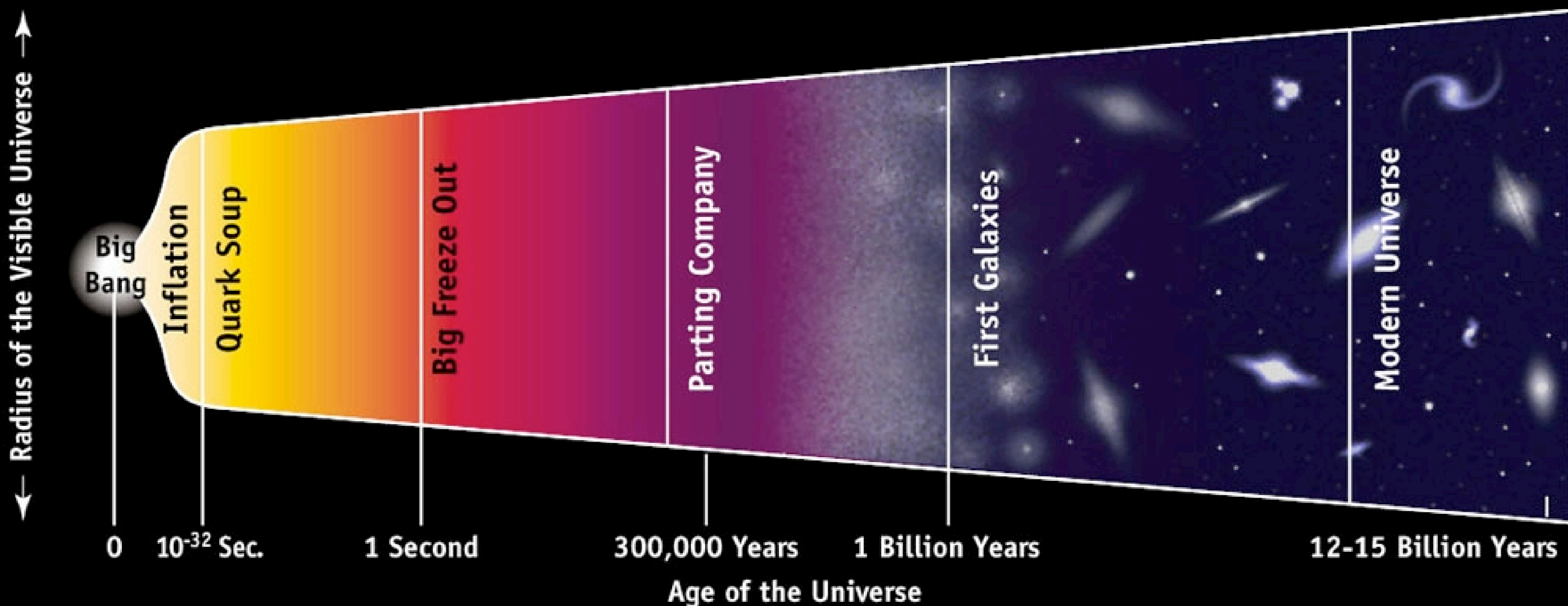

NGC362


NGC6752

Multiple analyses yield ages of 12 billion years, and an uncertainty of about 1 or 2 billion years

Other methods yield similar ages

Next Time



The Age of the Universe