“Life’s a journey, not a destination.”

Aerosmith

HW3 is due in class on Monday.

Group Project 1 is due on April 1.

Test 2: two weeks from today!

About stars:

- How hot are stars? ✓ $T = 2.9x10^6/\lambda$
- How BIG are stars (size)? ✓ Eclipsing binaries/parallax
- How massive are stars? ✓ Binaries
- What are stars made of? ✓ Spectral lines: H, He
- How much energy do stars emit? ✓ Luminosity
- Where does that energy come from? ✓ H Fusion: $E=mc^2$
- How far away are stars? ✓ Parallax, eclipsing binaries.

Holy cow, that's everything!

Plus spin, the structure of the Sun, neutrinos, etc.

Reminder: How to make a star brighter: $L_{ap}=R^2\sigma T^4/d^2$

- Make it hotter: $E \sim T^4$
- Make it bigger: $E \sim R^2$
- Make it closer: $E \sim 1/d^2$

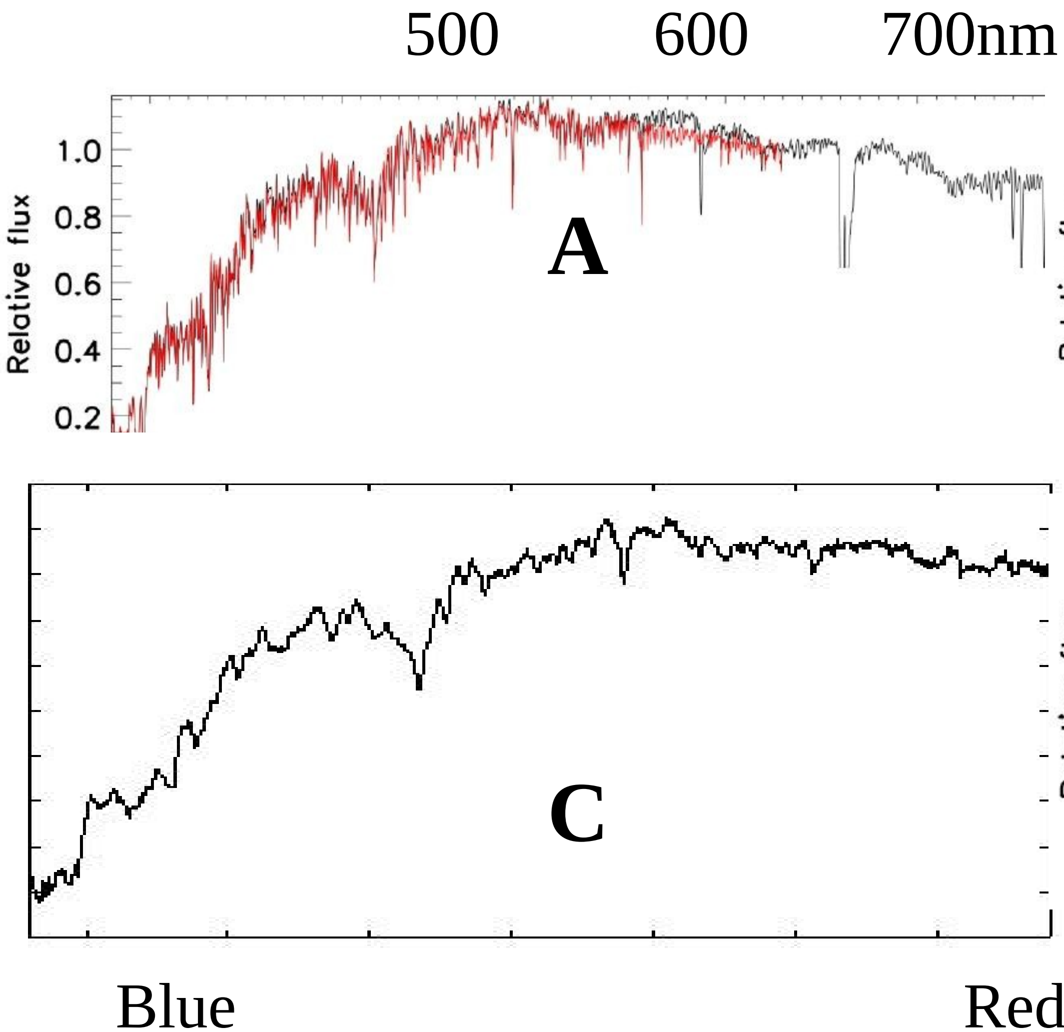
Hotter is most powerful.

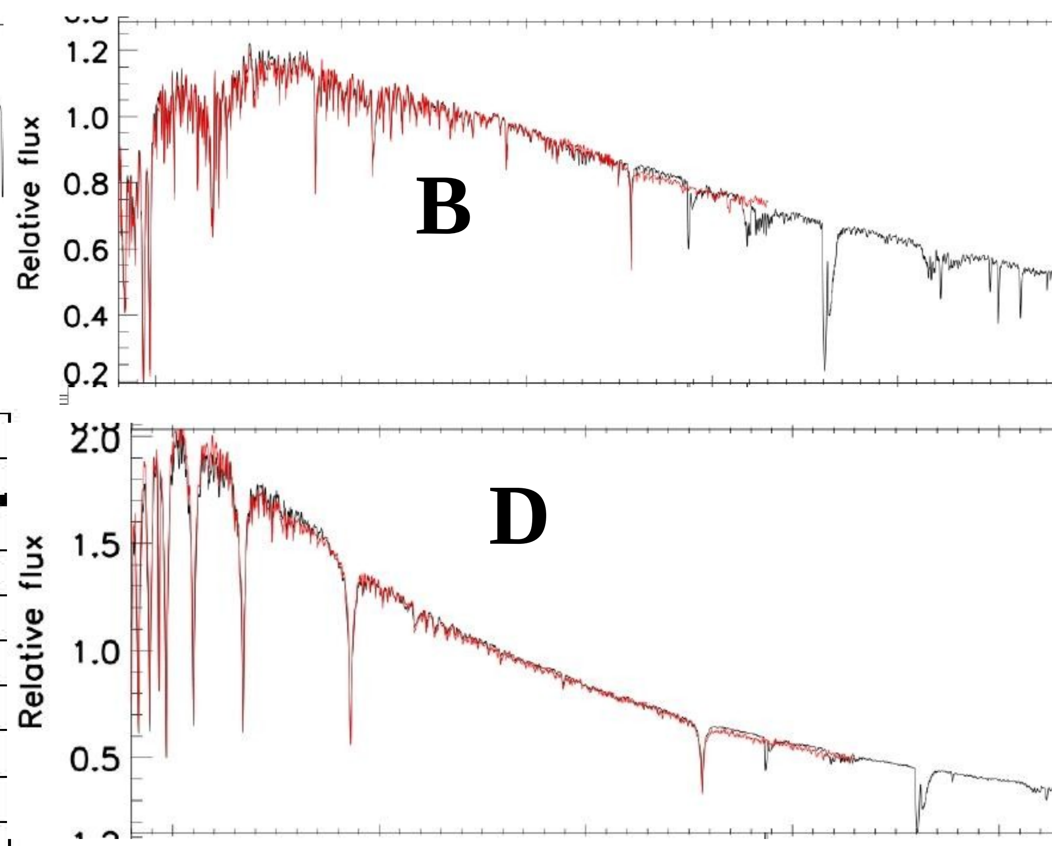
In-class Group Time

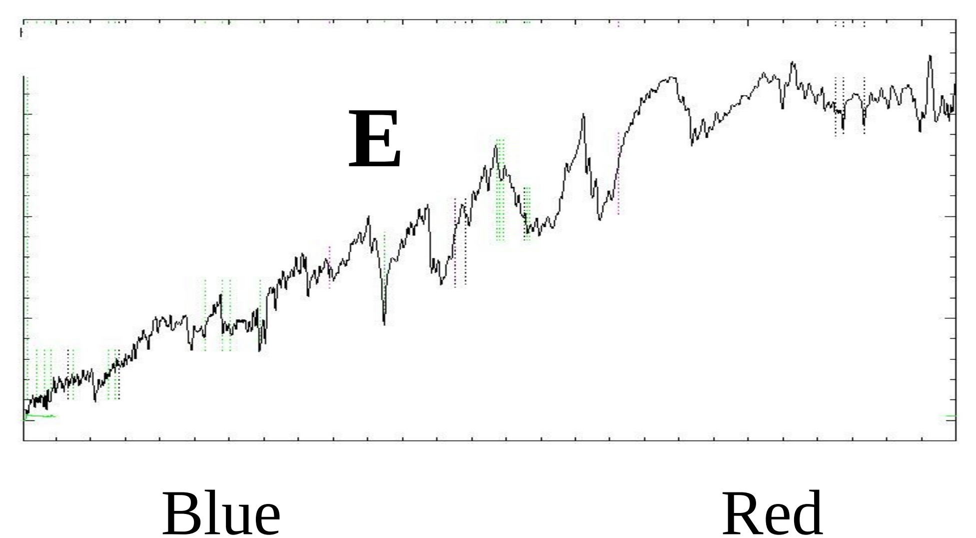
On the top of the group answer sheet,
write all your names.

Groups of no fewer than 3 and no more than 5.

No individual papers.







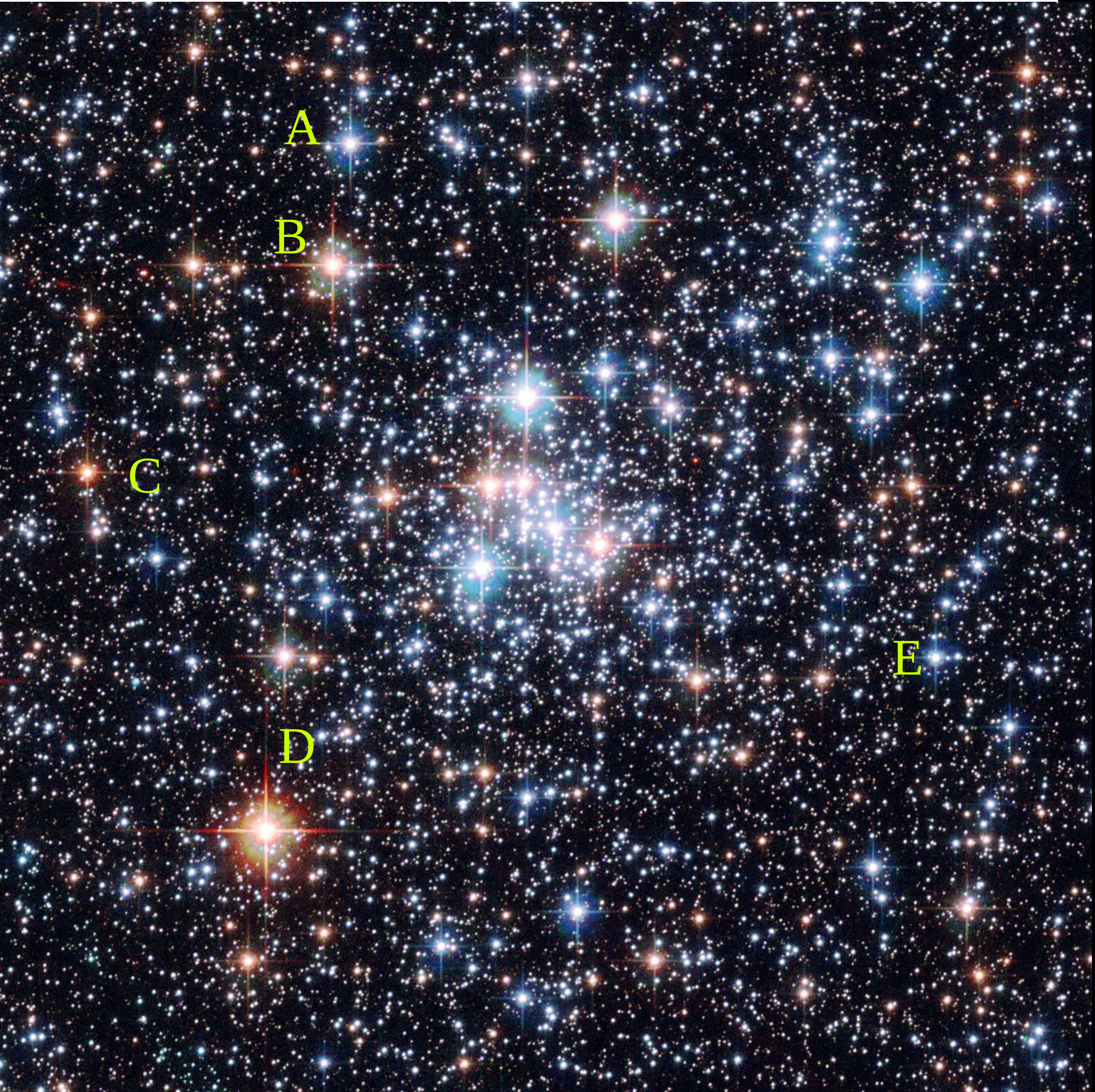
1) Which star is the hottest?

2) Which star is the coolest?

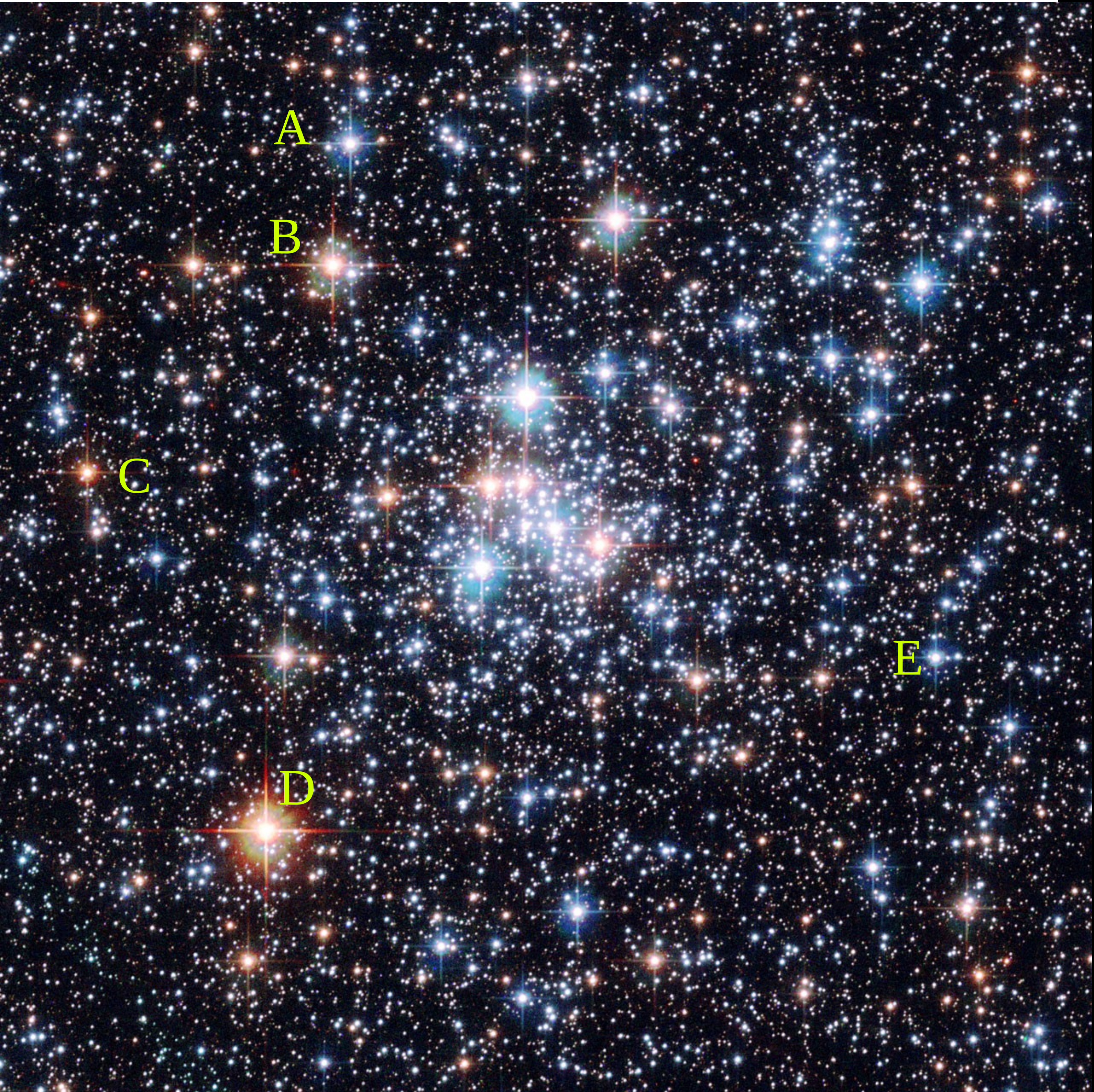
3) What does the size of the dot represent in a picture like this?

4) What does the color represent?

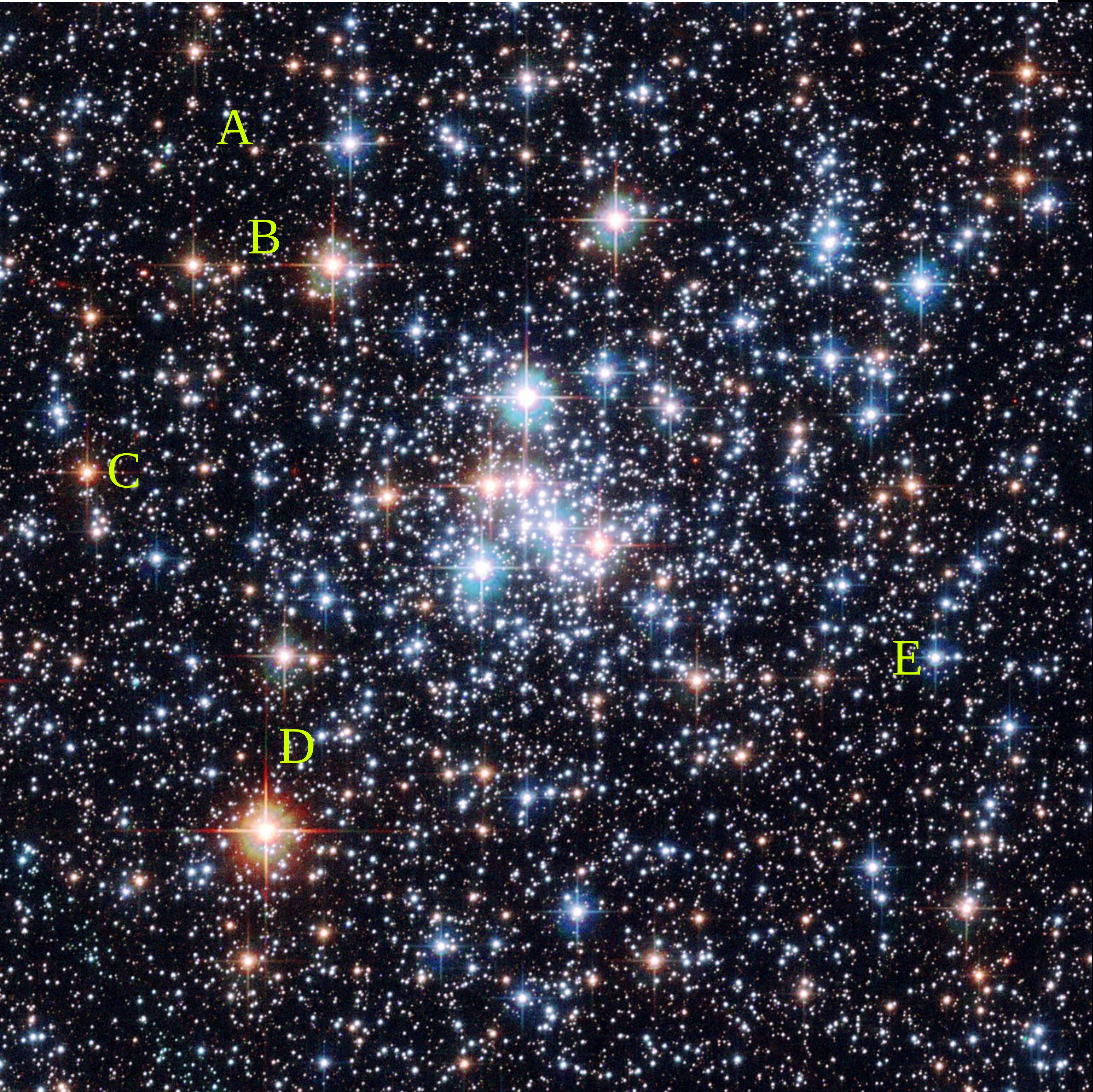
This is a cluster. Compared to how far away this is from us, the distance across the cluster is tiny. The estimate that the stars in this cluster are all at the same distance from us is good.



5) What is the difference between Star A and Star B? (Other than temperature or color and assuming the dots are the same size.)



6) What is the difference between Star B and Star D? (Assuming they are the same temperature.)



7) What is the difference between Star C and Star E? (Other than temperature and assuming the dots are the same size.)

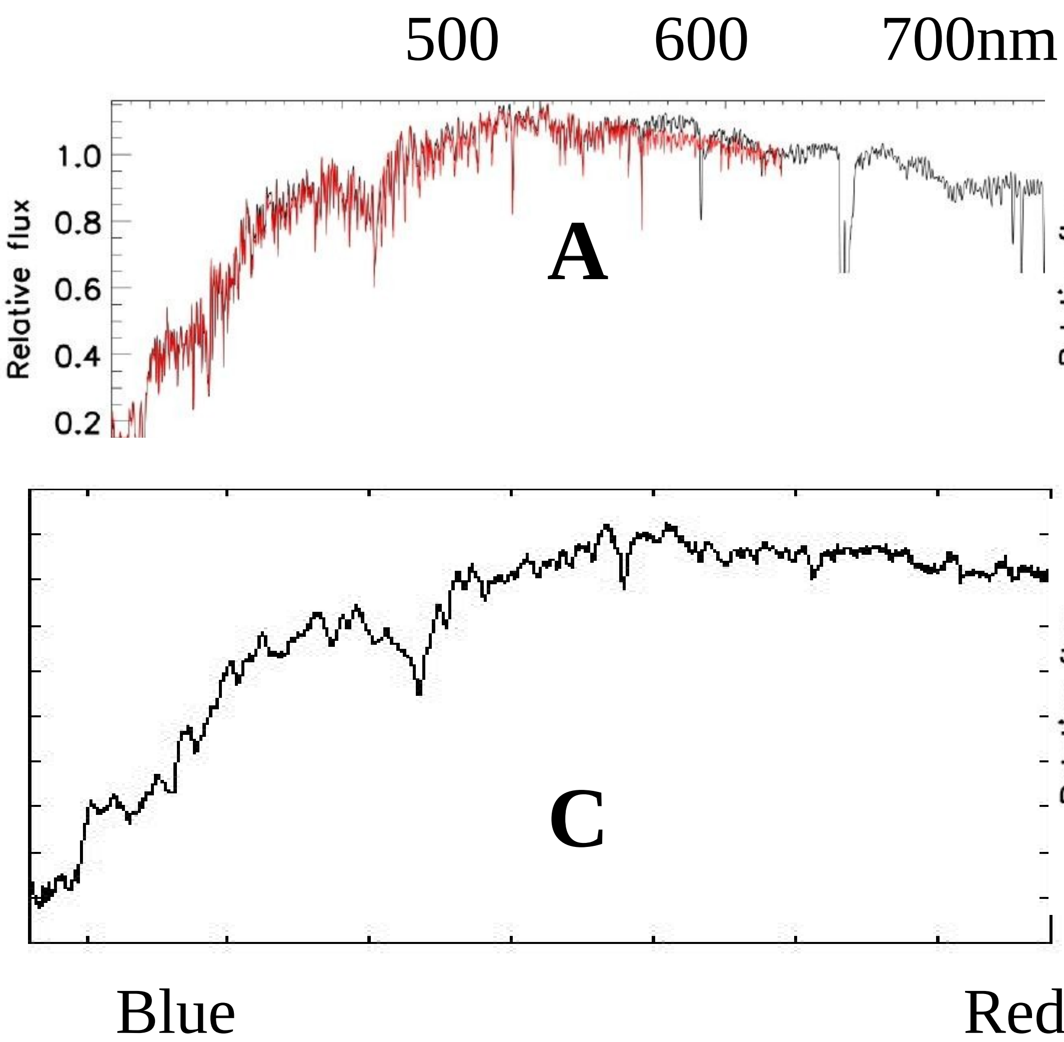
8) Which stars are most common in this image: large dots or small dots (brighter stars or fainter stars)?

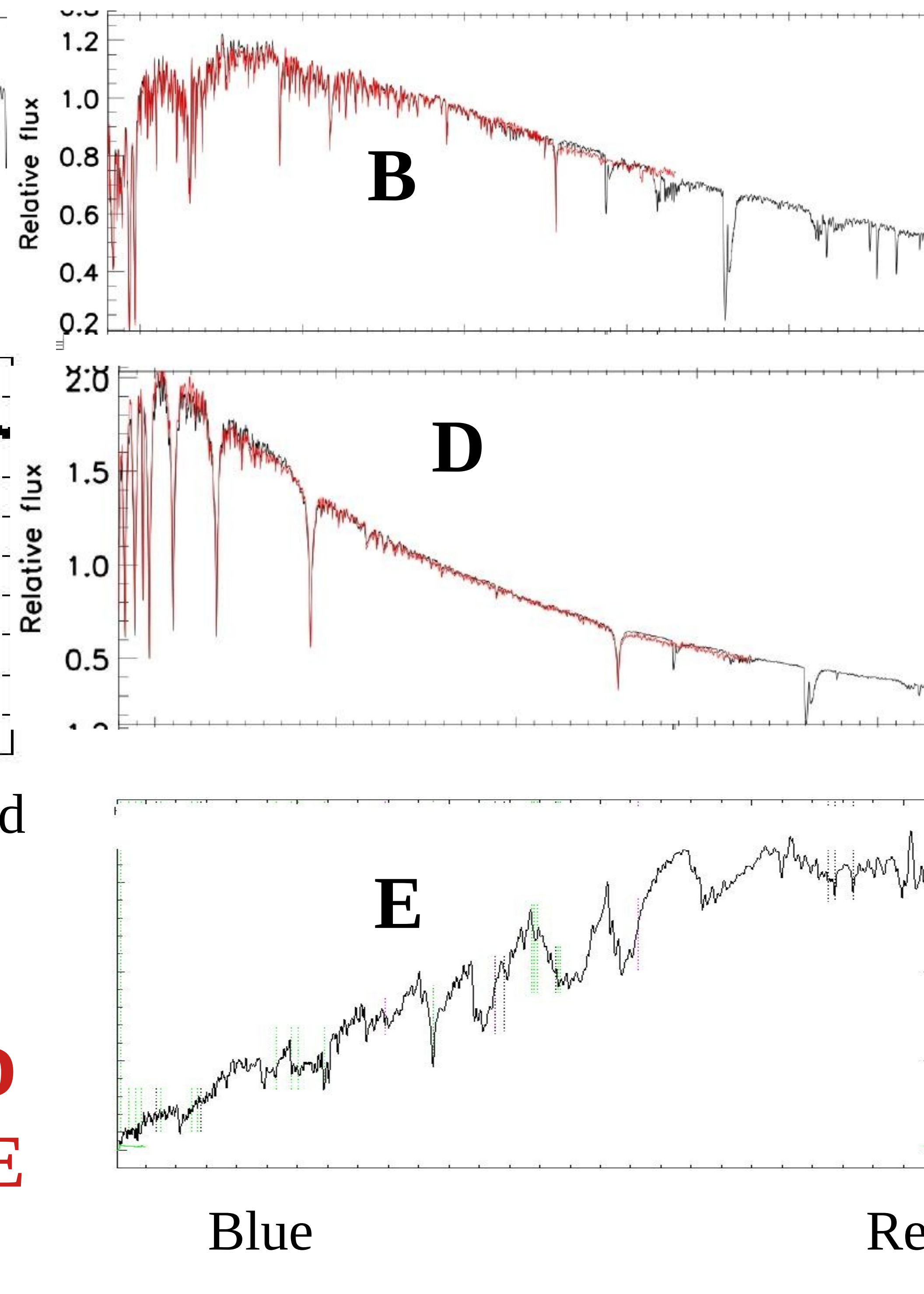
9) Which stars are most common in this image: red, blue, or white stars?

10) Based on your previous 2 answers, which stars are the most common?

11) Describe them in terms of temperature and size.

Turn in your paper.





1) Which star is the hottest? **D**

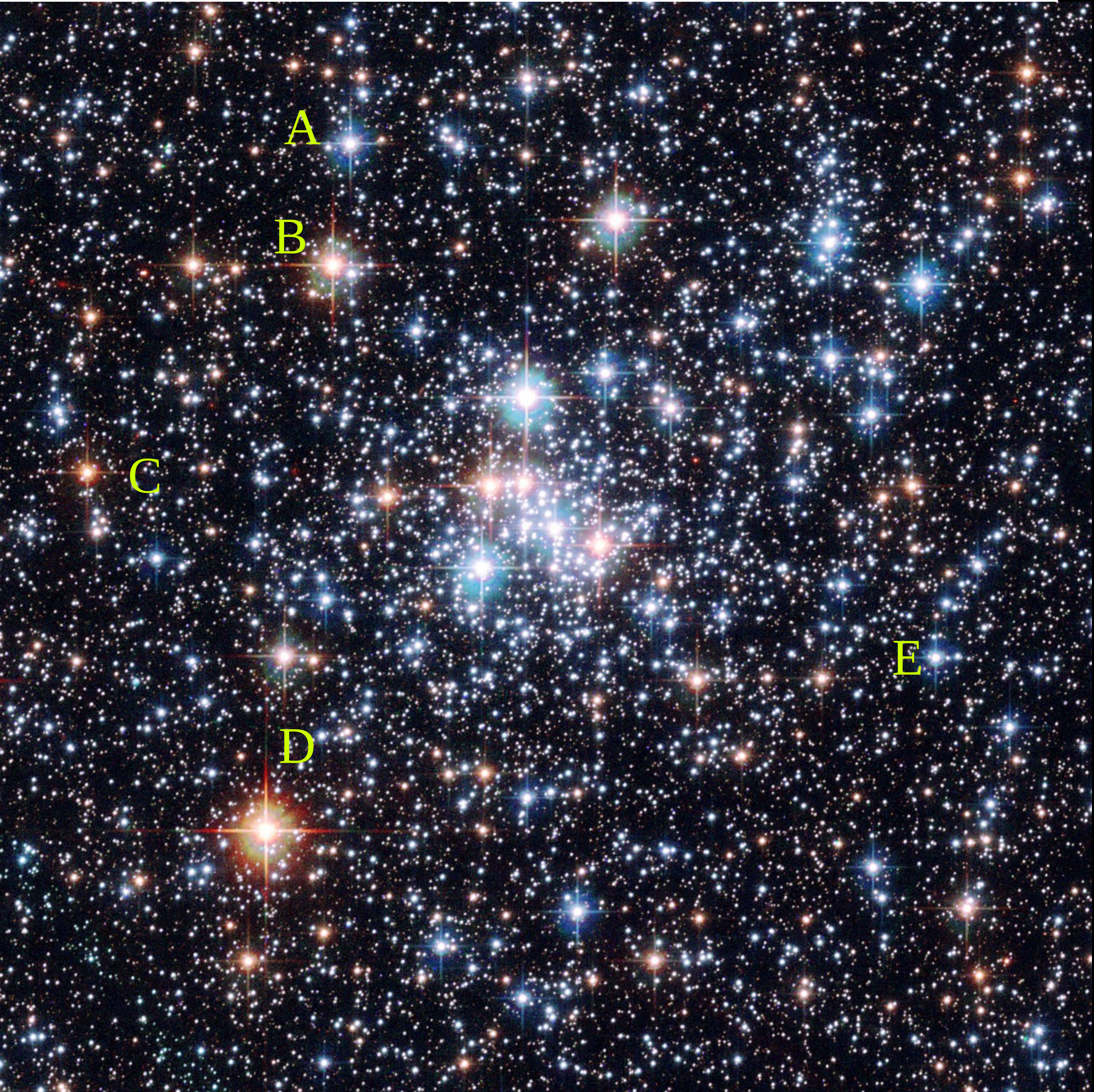
2) Which star is the coolest? **E**

3) What does the size of the dot represent in a picture like this?

Brightness

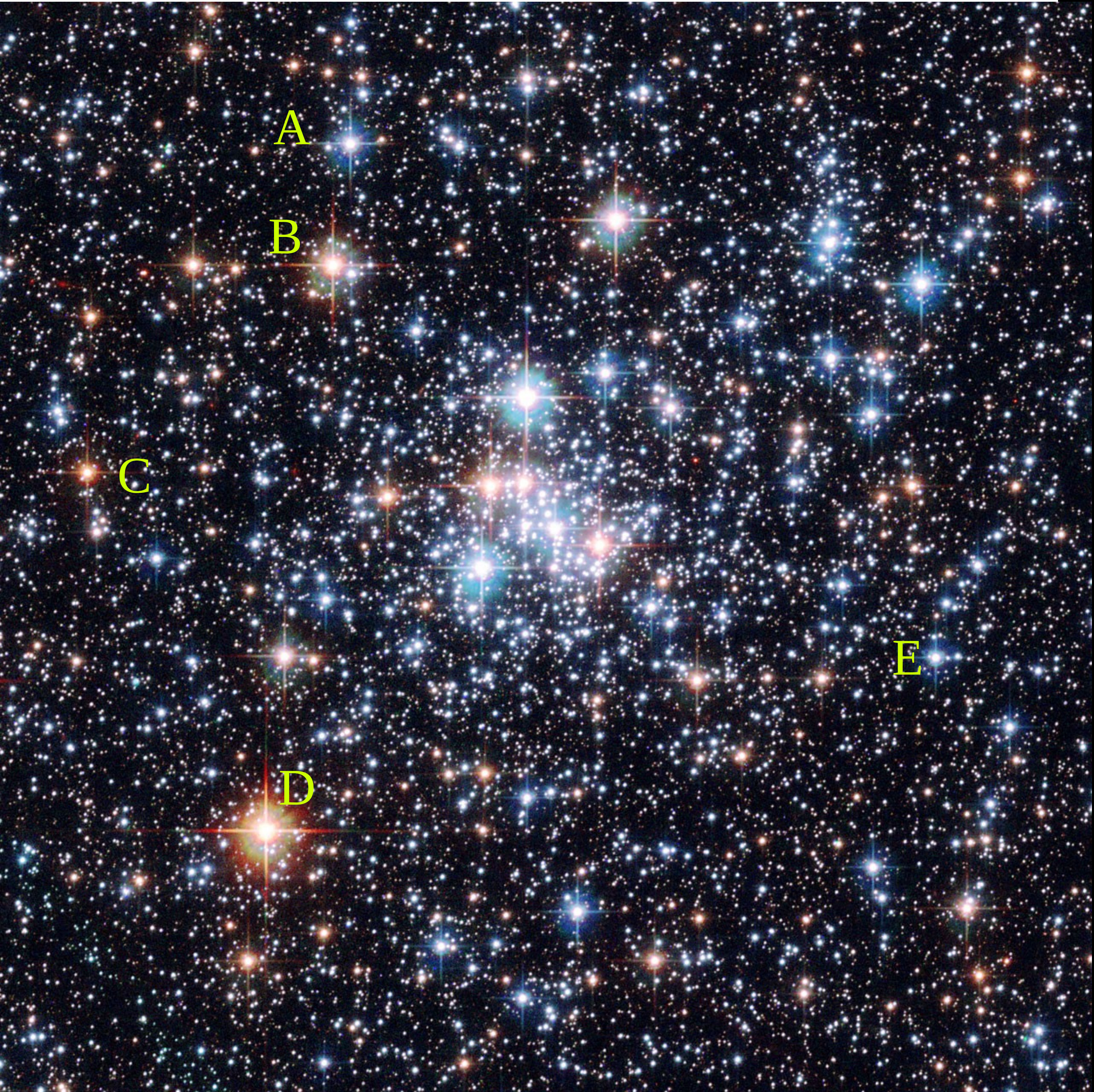
4) What does the color represent?

Temperature



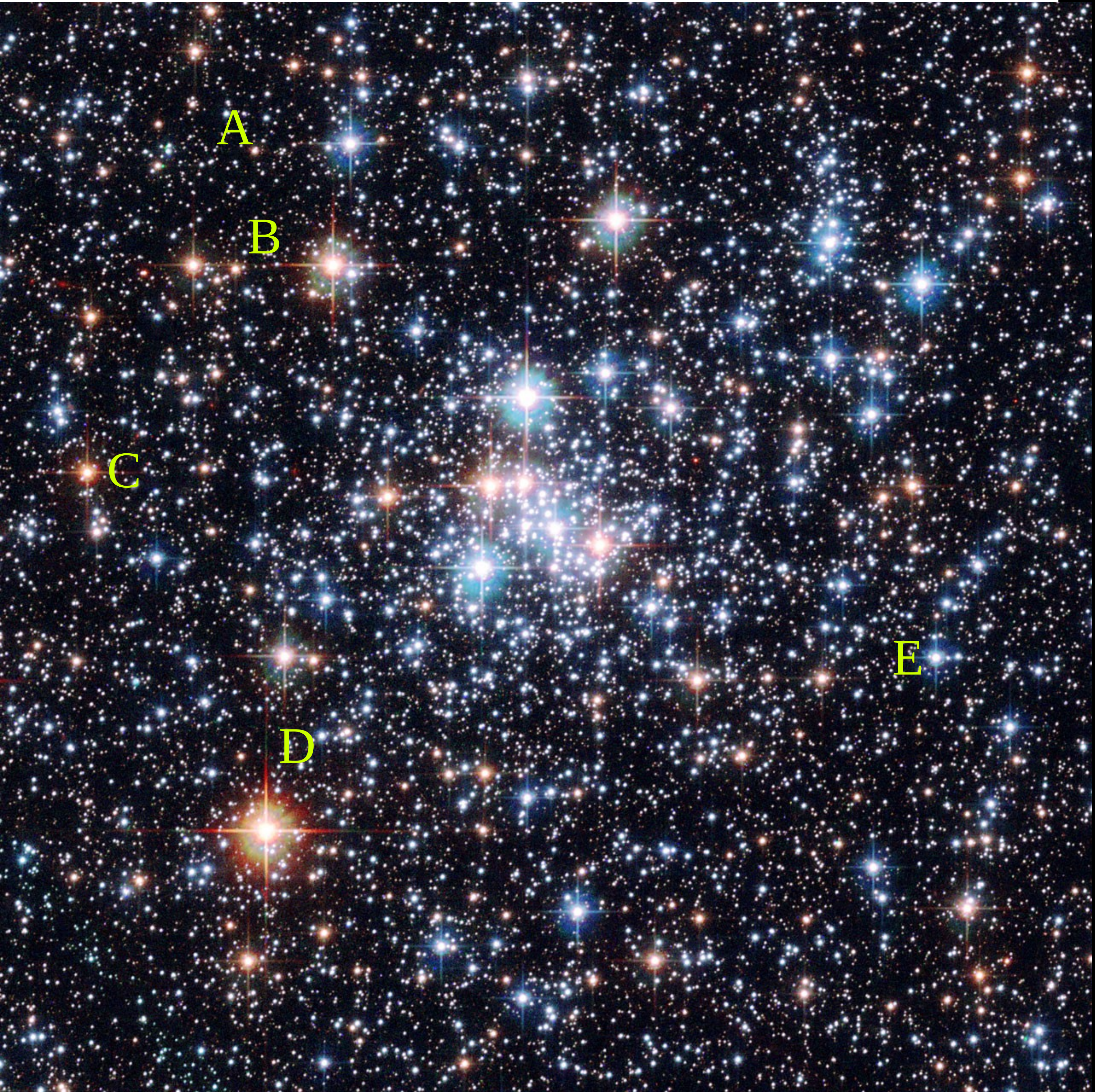
5) What is the difference between Star A and Star B? (Other than temperature or color and assuming the dots are the same size.)

A is smaller than B (or B is larger than A)



6) What is the difference between Star B and Star D? (Assuming they are the same temperature.)

D is larger than B (or B is smaller than D)



7) What is the difference between Star C and Star E? (Other than temperature and assuming the dots are the same size.)

E is smaller than C (or C is larger than E)

8) Which stars are most common in this image: large dots or small dots (brighter stars or fainter stars)?

Small dots

9) Which stars are most common in this image: red, blue, or white stars?

Red or white

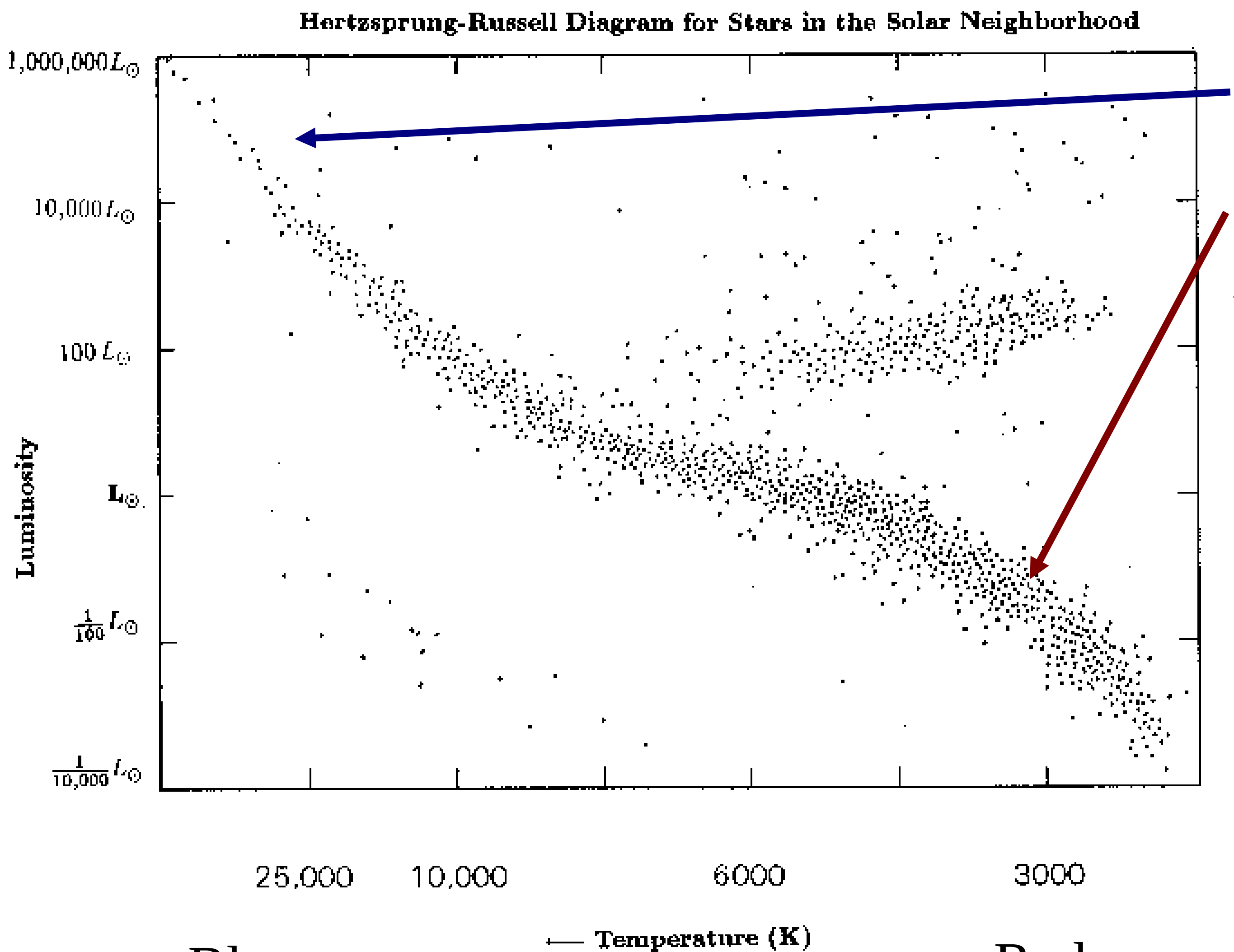
10) Based on your previous 2 answers, which stars are the most common?

Faint, red/white stars.

11) Describe them in terms of temperature and size.

Small, cool

HR Diagram



Blue

Red

The difference between this star and this star is MASS

Relations on the main sequence.

How bright a star is on the main sequence depends on its mass.

$$L = M^{3.5} = \sqrt{M} \times M \times M \times M$$

How long a star is on the main sequence depends on its mass.

$$t_{MS} = \frac{1 \times 10^{10}}{M^{2.5}} = \frac{1 \times 10^{10}}{\sqrt{M} \times M \times M} \, \mathrm{Yrs}$$

These equations use solar units (mass and luminosity)

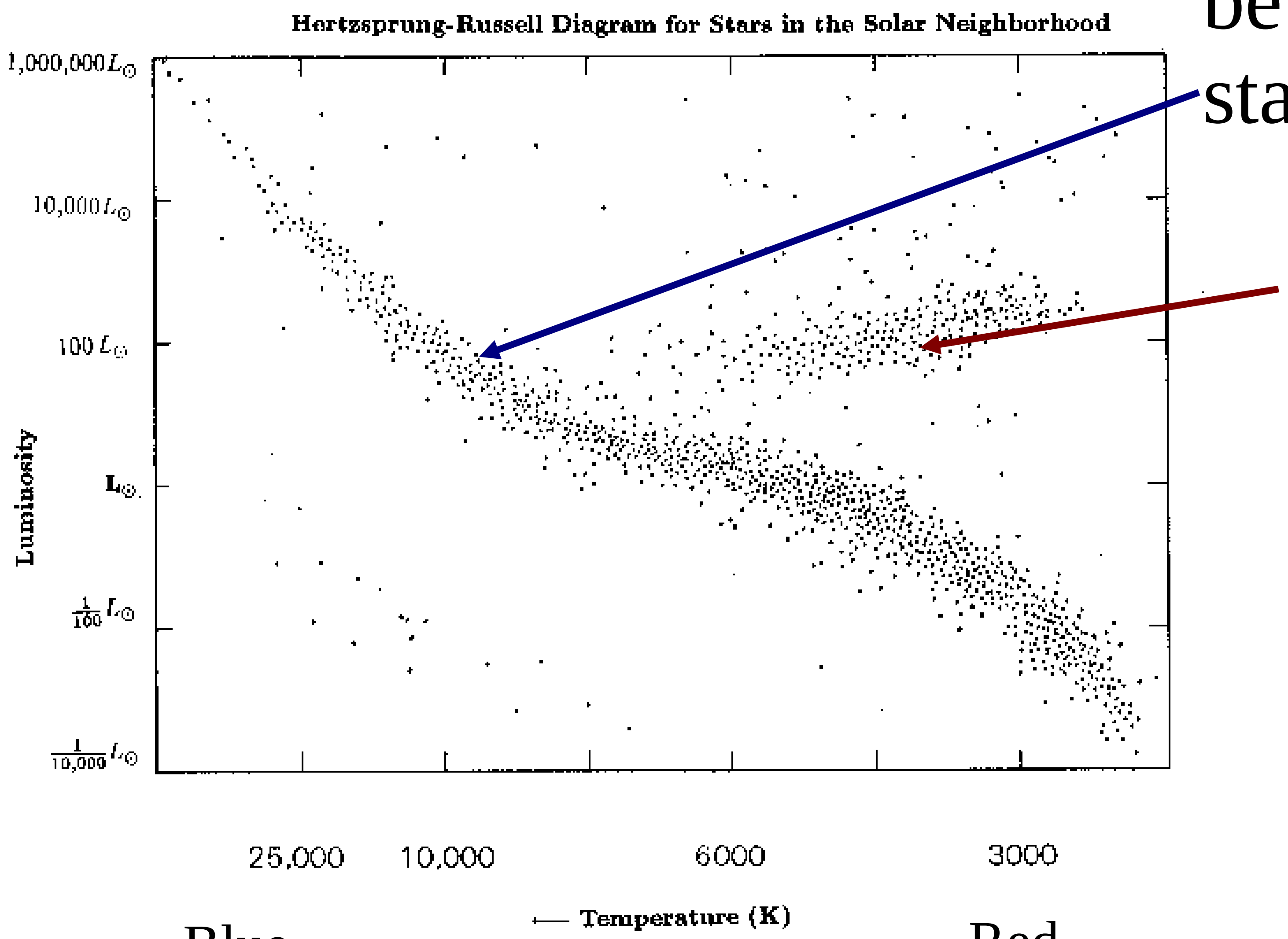
So what about that main sequence?

Stars spend 90% of their lifetime (some kind of generating energy) **on the main sequence.**

That brought us to stellar evolution!

HR Diagram

This difference between these 2 stars is *evolution*



Blue

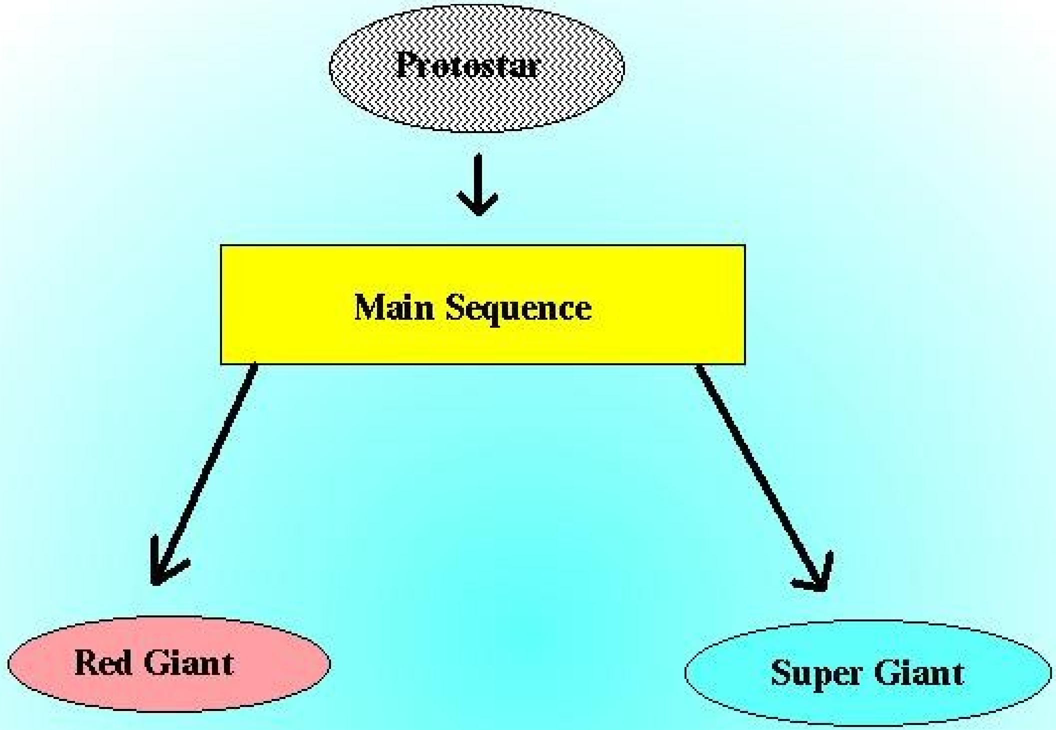
Red

Evolution so far:

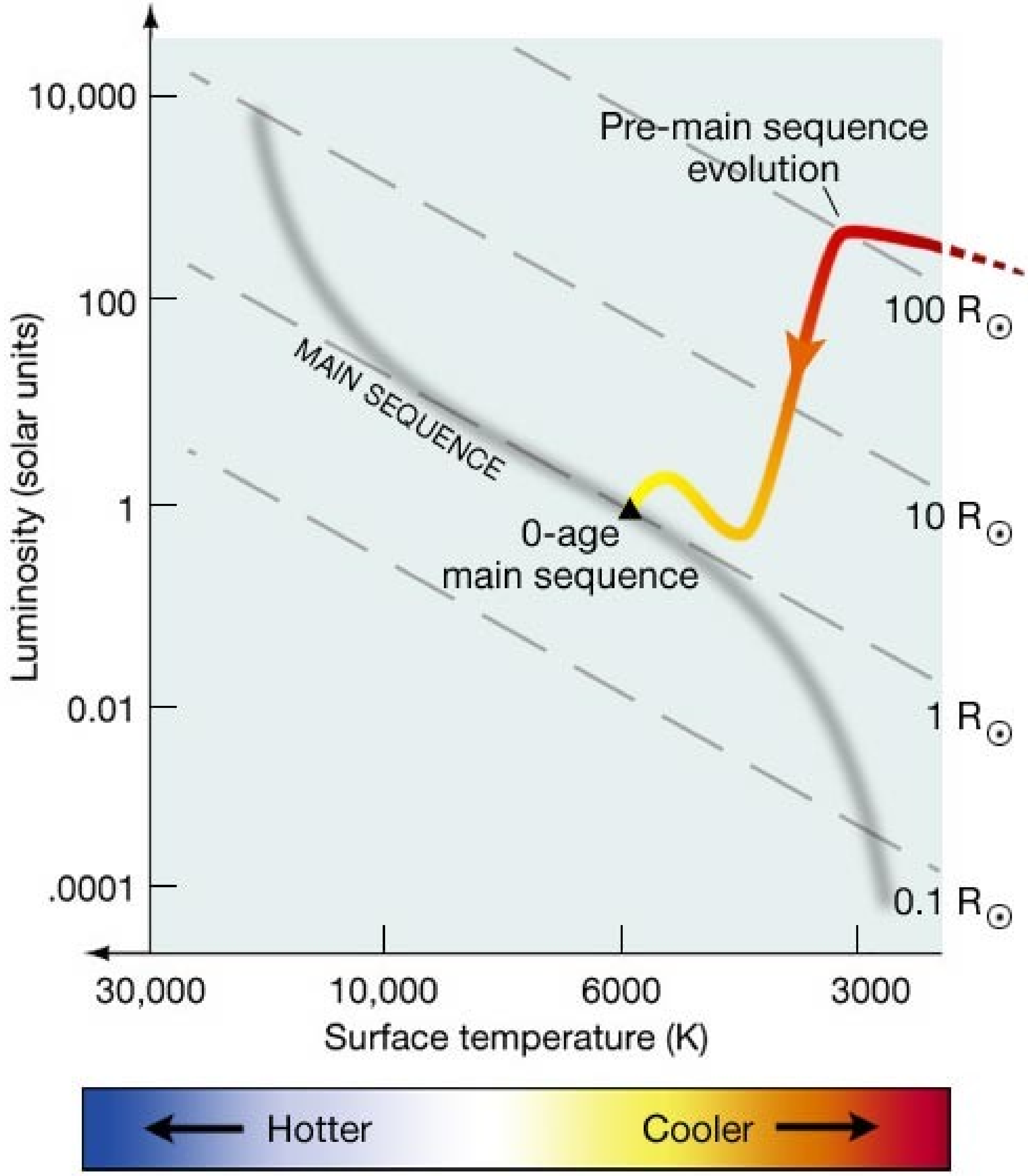
Protostars: get energy from **gravity** (shinking)

Main Sequence: get energy from **fusion**, converting H to He in their cores

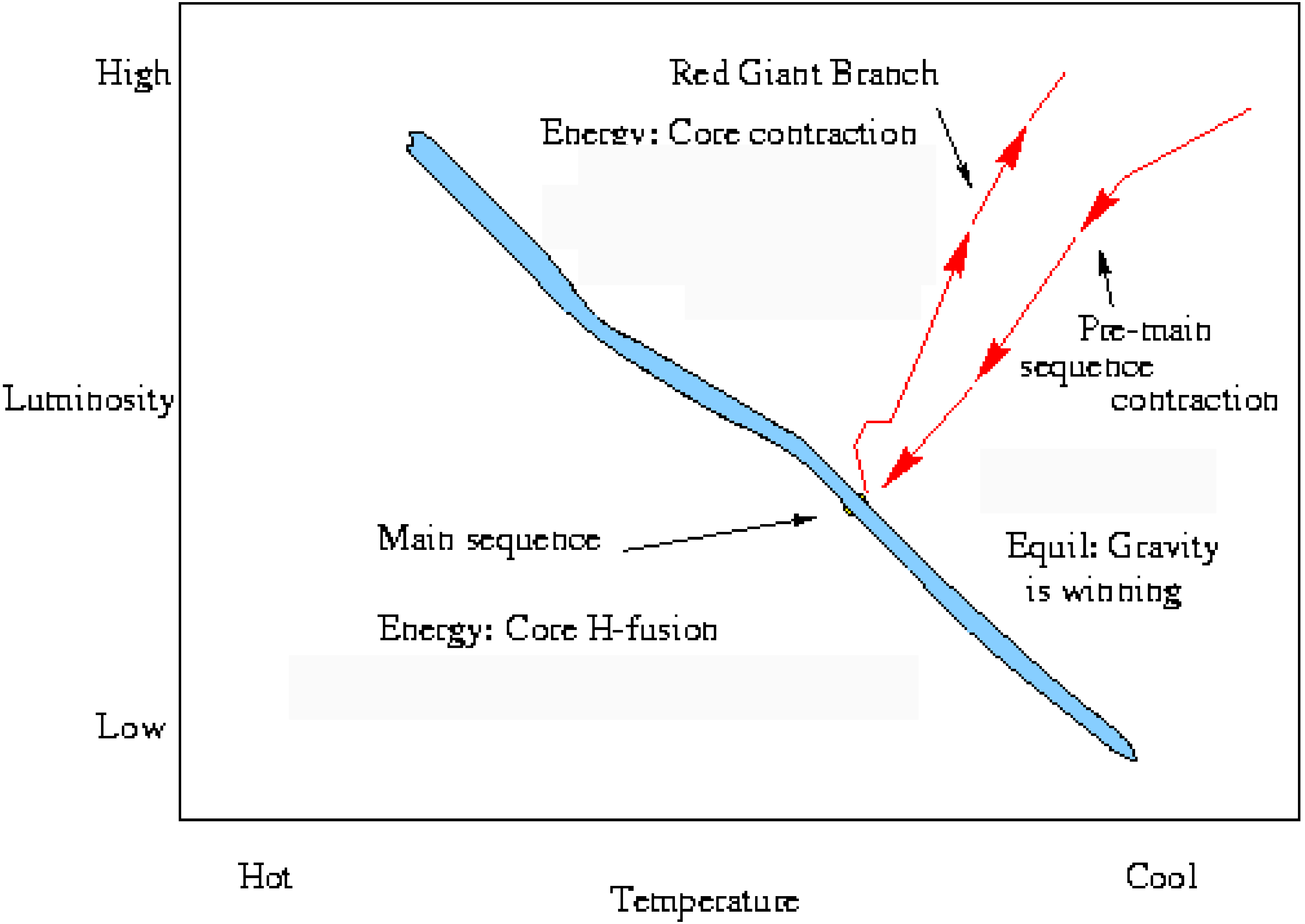
Red giants: get energy from **gravity**, shrinking core and shell H burning. He core shrinks, H shell expands.



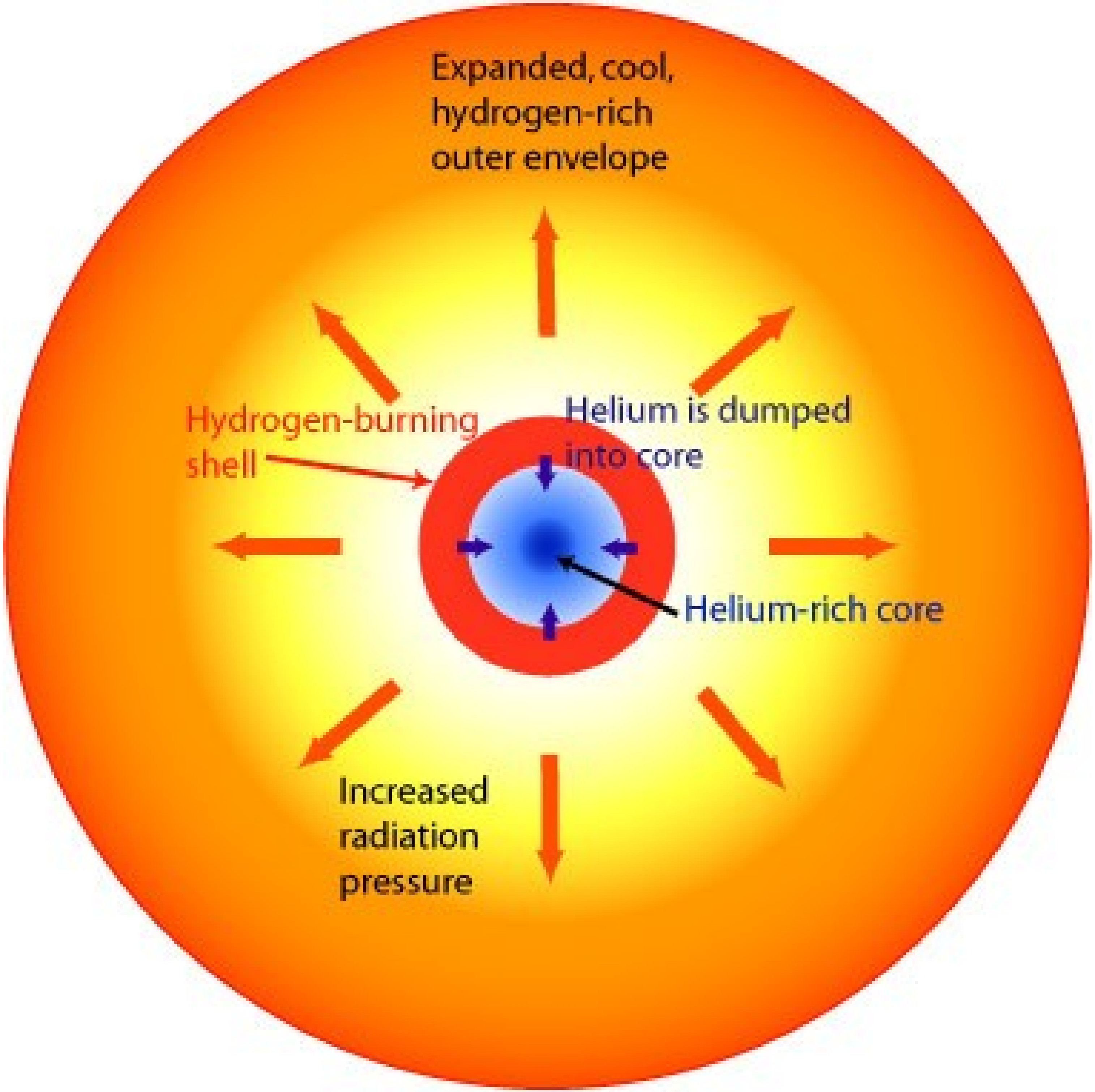
Protostar to main sequence

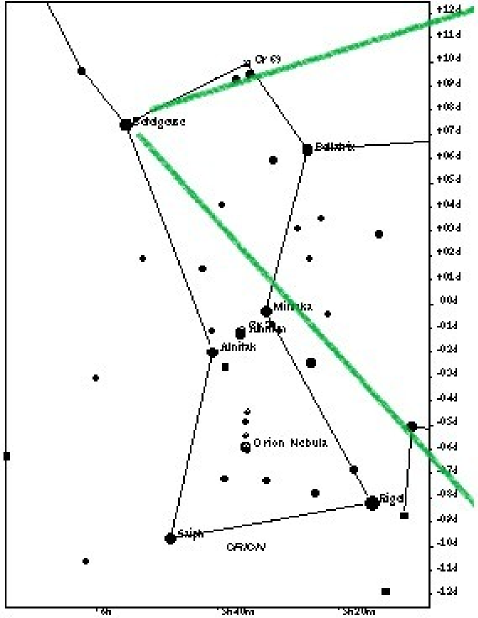


Protostar to main sequence to red giant.

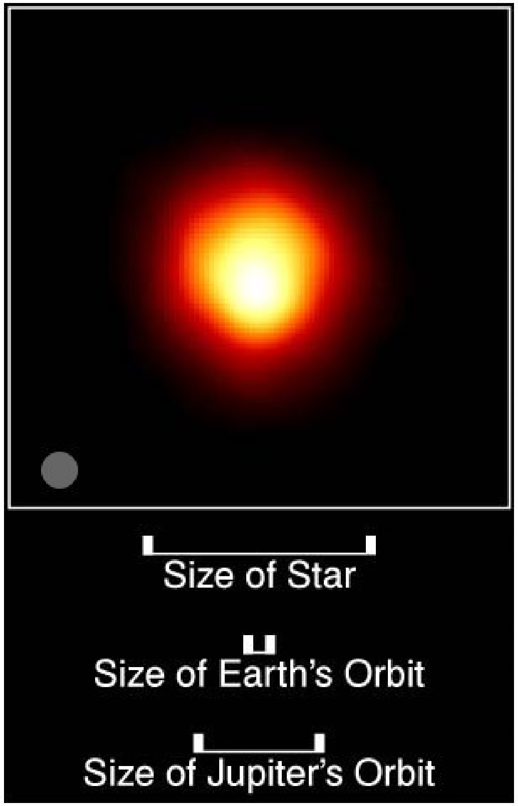


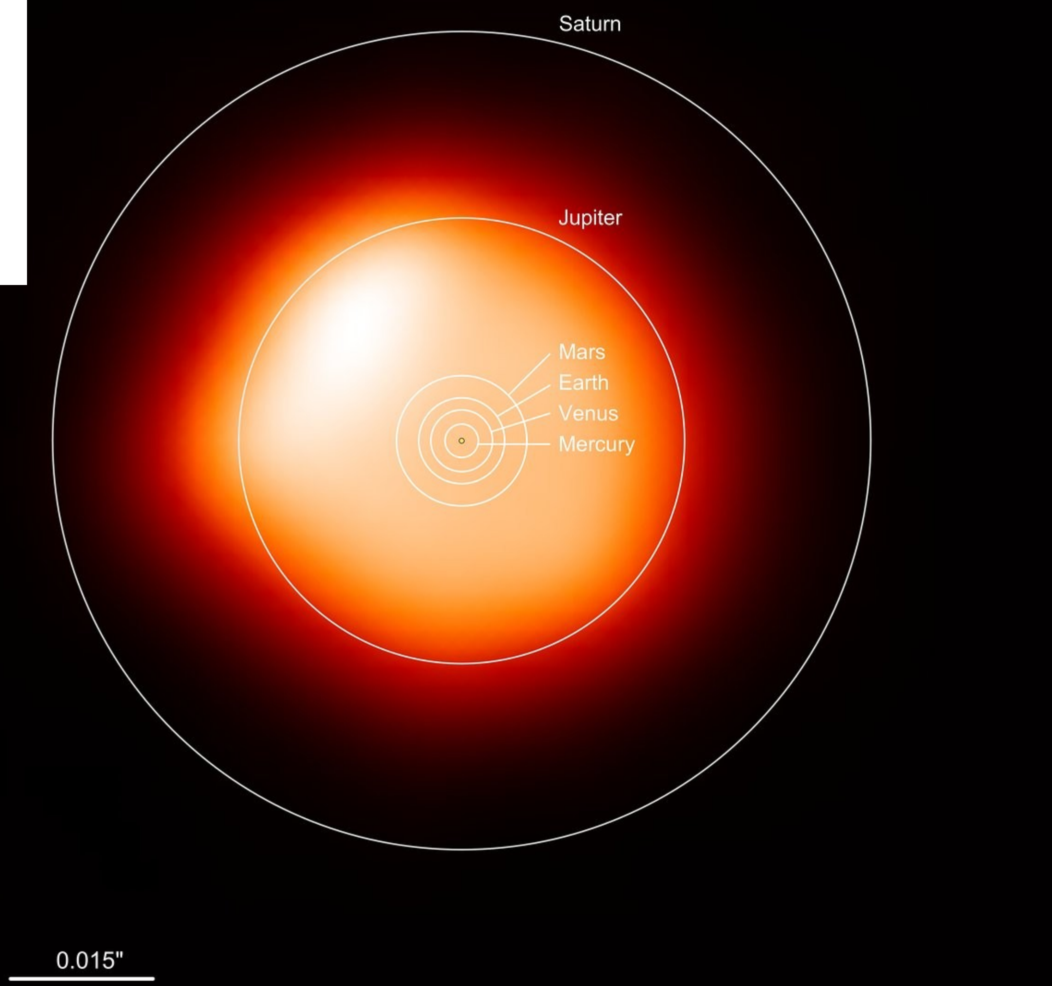
Up the red giant branch: As the core shrinks it gets hotter, the envelope sees a hotter core and expands, getting cooler.

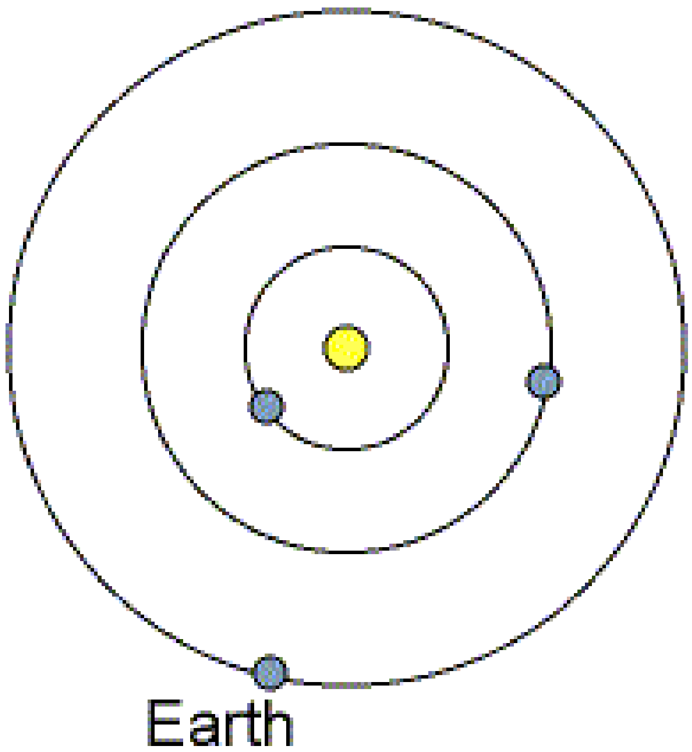




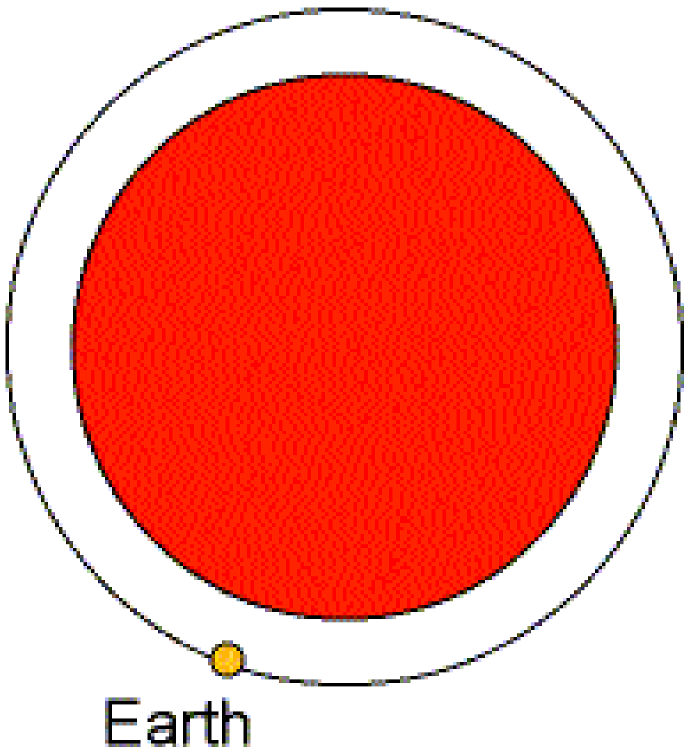
HST view of Betelgeuse in the ultraviolet. Even though Betelgeuse is very large, its distance is too great to resolve details smaller than about 1/4th of its diameter (small gray circle).



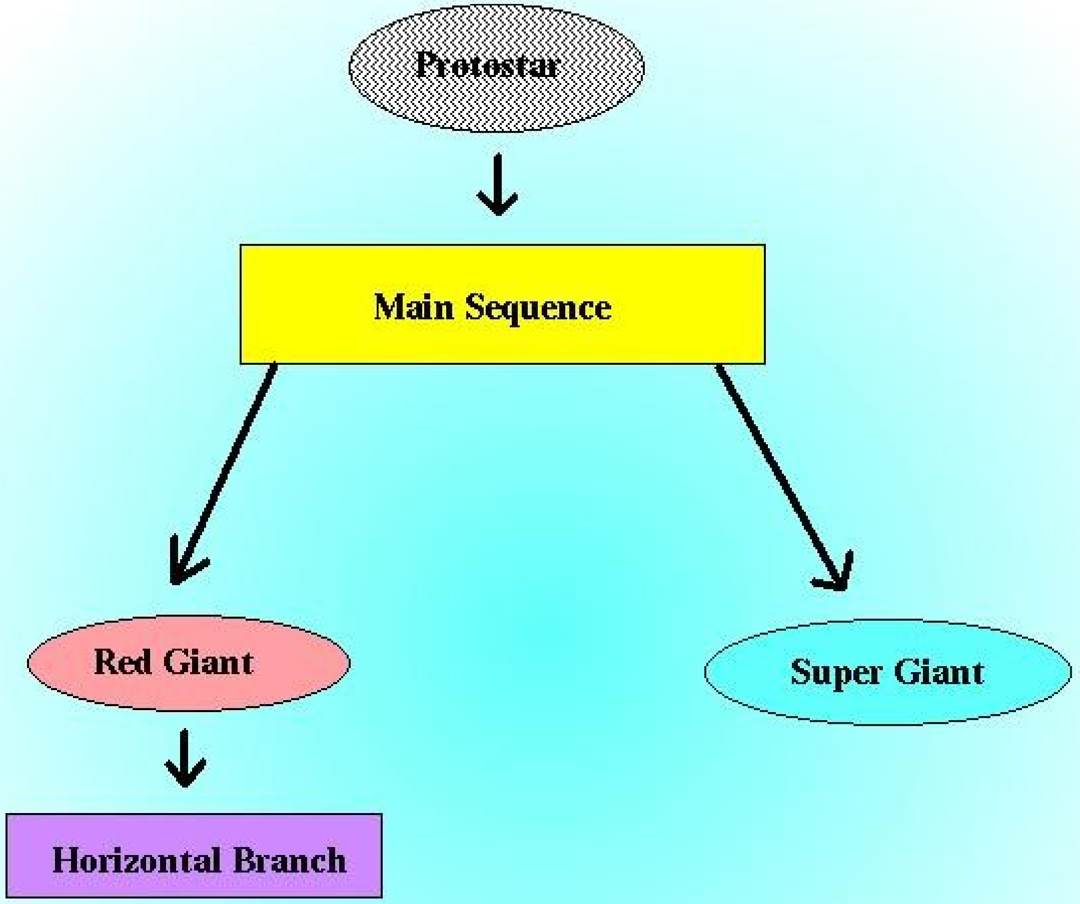




Now: hot core + warm surface; small size.

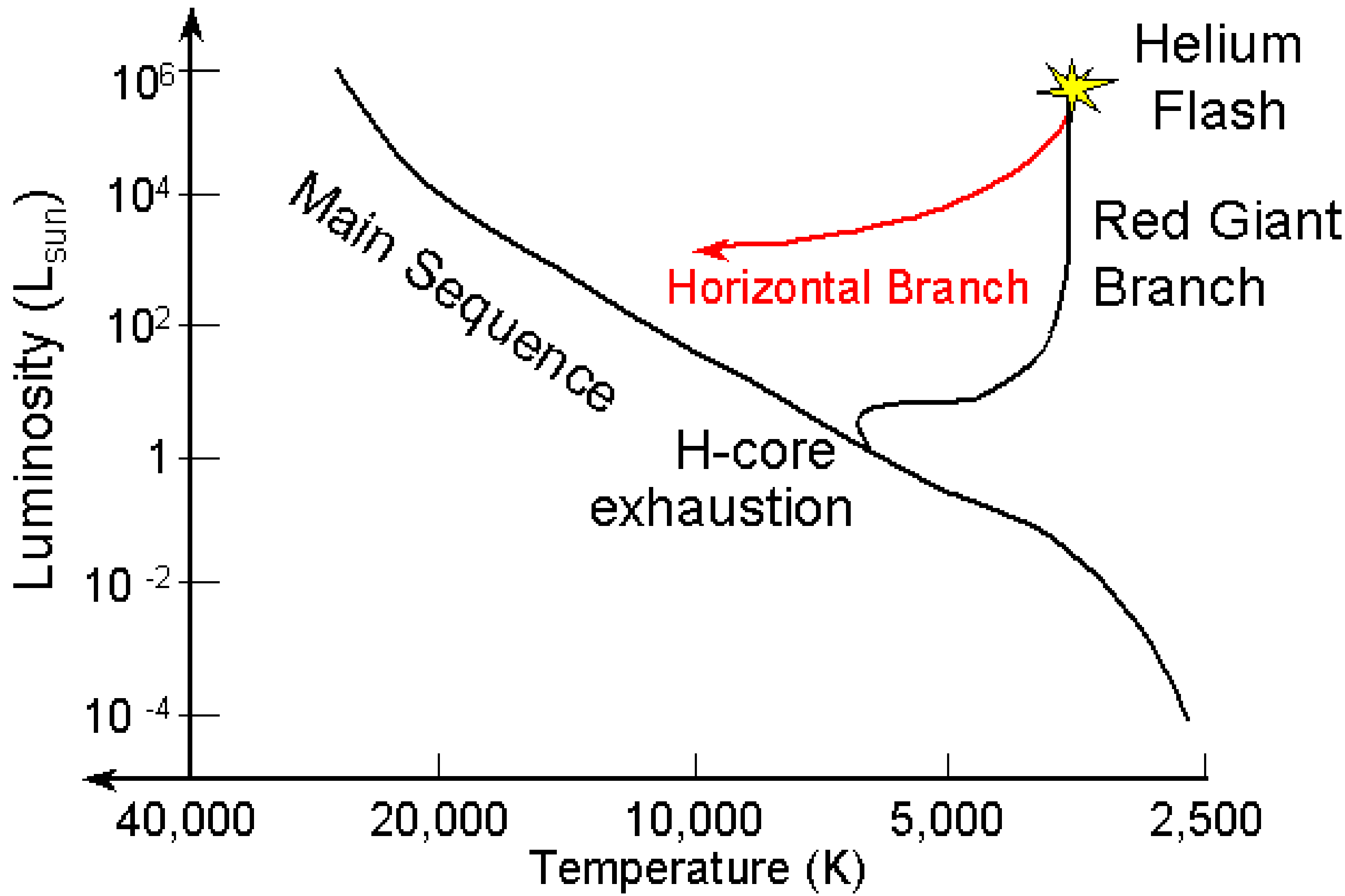


Future: very hot core + cool surface. Large size but less mass; very bright.



Stage 4a: Once stars begin to convert helium to carbon in the core, they become Horizontal Branch stars.

Stars on the horizontal branch are **fusing He to C** in their cores, and H to He in a shell surrounding the core.
Core He burning can go on for about 100 million years (for a star like our Sun).

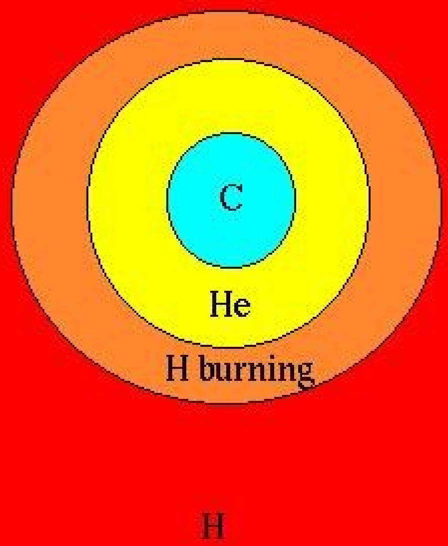


From what you know about stellar evolution, why do you think a star would leave the horizontal branch?

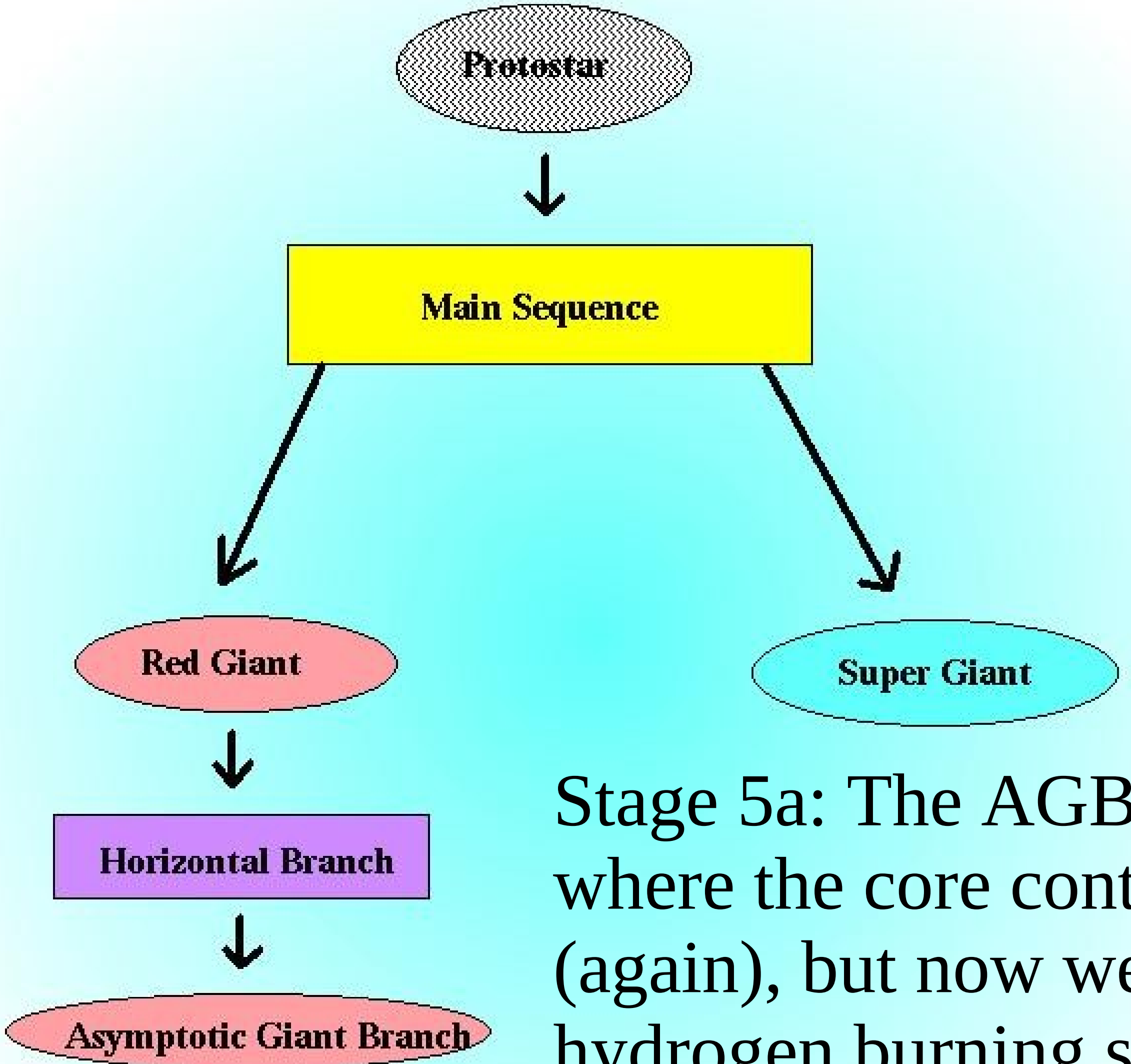
Stars leave the Horizontal Branch when they've used up the He in the core.

This is the structure of the core when a star leaves the Horizontal Branch.

It has a carbon core, surrounded by a layer of helium, which is surrounded by a burning



A Shell of hydrogen (+He + ‘metals’). Surrounding this is the rest of the star, that is getting bigger all the time.



Stage 5a: The AGB. This is where the core contracts (again), but now we have a hydrogen burning shell, and a helium burning shell.

AGB stars are very similar to Red Giants, just bigger (and with a He burning shell).