STARS - S01

Wladimir (Wlad) Lyra
Brian Levine

AMNH After-School Program

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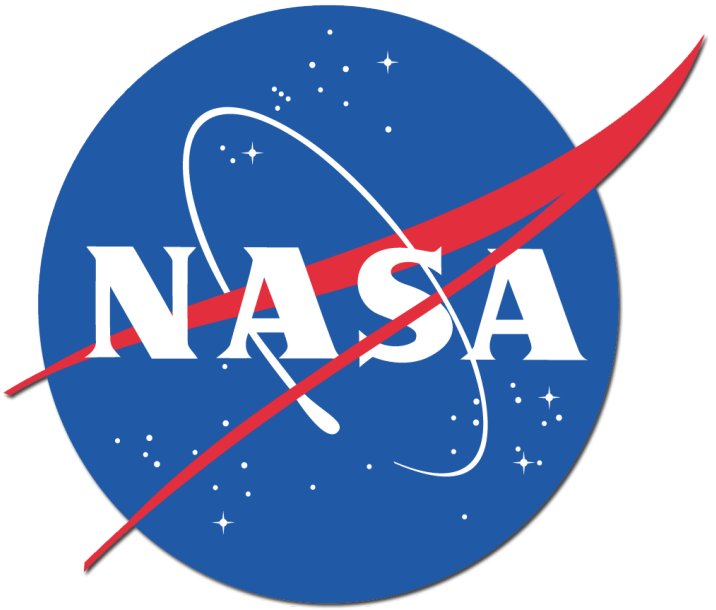

Quick Bio

Wladimir (Wlad) Lyra

Ph.D. in Astronomy, 2009

Stellar Astrophysics
Planetary Sciences

Solar-type stars, extrasolar planets,
star and ***planet formation***, hydrodynamics.

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Wladimir (Wlad) Lyra

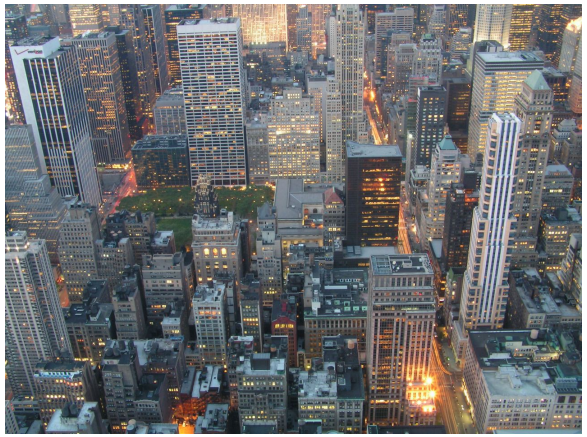
Rio de Janeiro, Brazil

Ph.D. in Astronomy

Stellar Astrophysics
Planetary Sciences

Solar-type stars, extrasolar planets,
star and planet formation, turbulence.

Moved around a lot. Lived in **6 countries**
and I'm not even 30 yet...



New York, USA

Heidelberg, Germany

Rio de Janeiro, Brazil

Uppsala, Sweden

Stockholm, Sweden

La Serena, Chile

Baltimore, USA

Lisbon, Portugal

Munich, Germany

Quick Bio

Brian Levine

Astrophysics Educator

Brooklyn

Bronx Science

Stony Brook

MS 821

AMNH

Outline

What is a star?

Principles of Stellar Astrophysics
- Nuclear Fusion
- Stellar temperatures, colors, sizes, masses
- Spectral sequence
- Hertzsprung-Russell (HR) diagram

Groups of stars
- Open clusters
- Globular clusters
- Galaxies

The Milky Way and the night sky

What is a star?

What is a star?

Hard to define.....

What is a star?

"The Sun is a mass of incandescent gas
A gigantic nuclear furnace
Where Hydrogen is built into Helium
At a temperature of millions of degrees"

Why Does The Sun Shine
-Tom Glazer – later covered by They Might Be Giants

"The Sun is a miasma of incandescent plasma"

Why Does The Sun Really Shine
-They Might Be Giants

"A star is a massive, luminous ball of plasma that is held together by gravity"

-Some luminary wikier

What is a star?

What is plasma?

Plasma is ionized gas

Being ionized, it responds to electromagnetic fields

What is a star?

What is plasma?

Plasma is ionized gas

Being ionized, it responds to electromagnetic fields

Plasma is just gas

No need for a fancy word here.

Stars are balls of gas.

What is a star?

“A star is a fusor in hydrostatic equilibrium”

-Me

“To the Universe what a brick is to a house:
Its smallest building unit”

-Also me

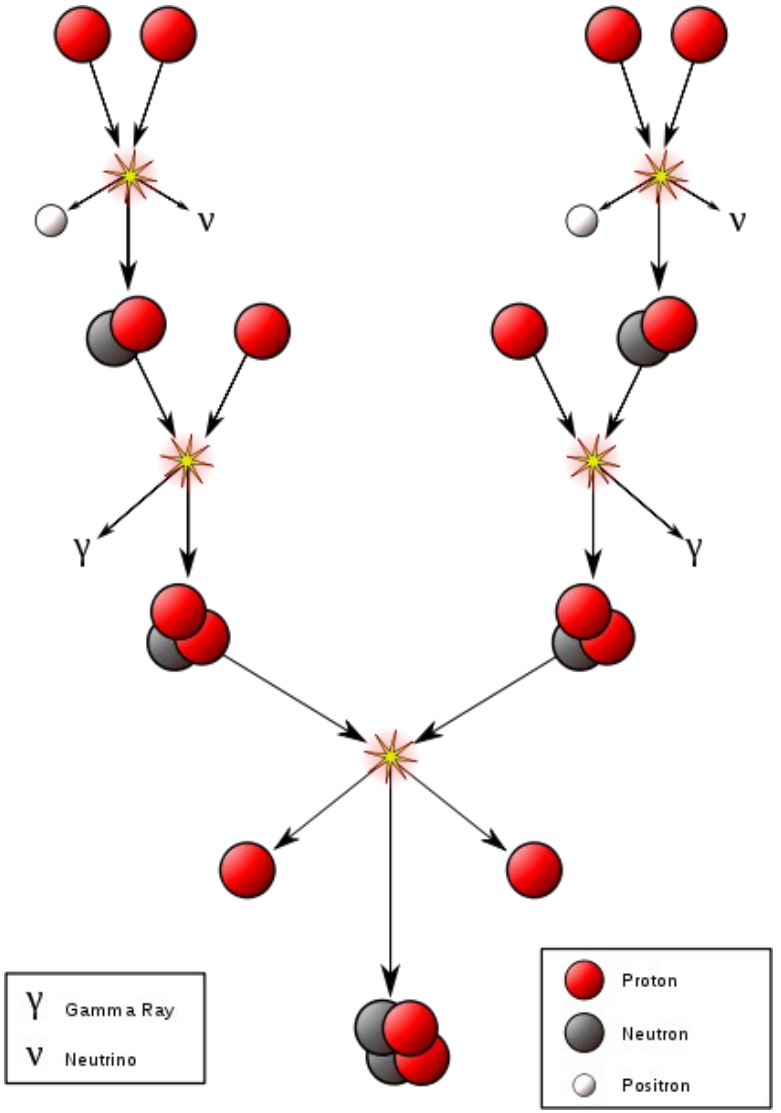
All men have the stars, but they are not the same things for different people. For some, who are travelers, the stars are guides. For others they are no more than little lights in the sky. For others, who are scholars, they are problems [to solve].

All men have the stars, but they are not the same things for different people. For some, who are travelers, the stars are guides. For others they are no more than little lights in the sky. For others, who are scholars, they are problems [to solve].

And solve it we did!

A fusor in hydrostatic equilibrium

Nuclear fusion: The proton – proton chain



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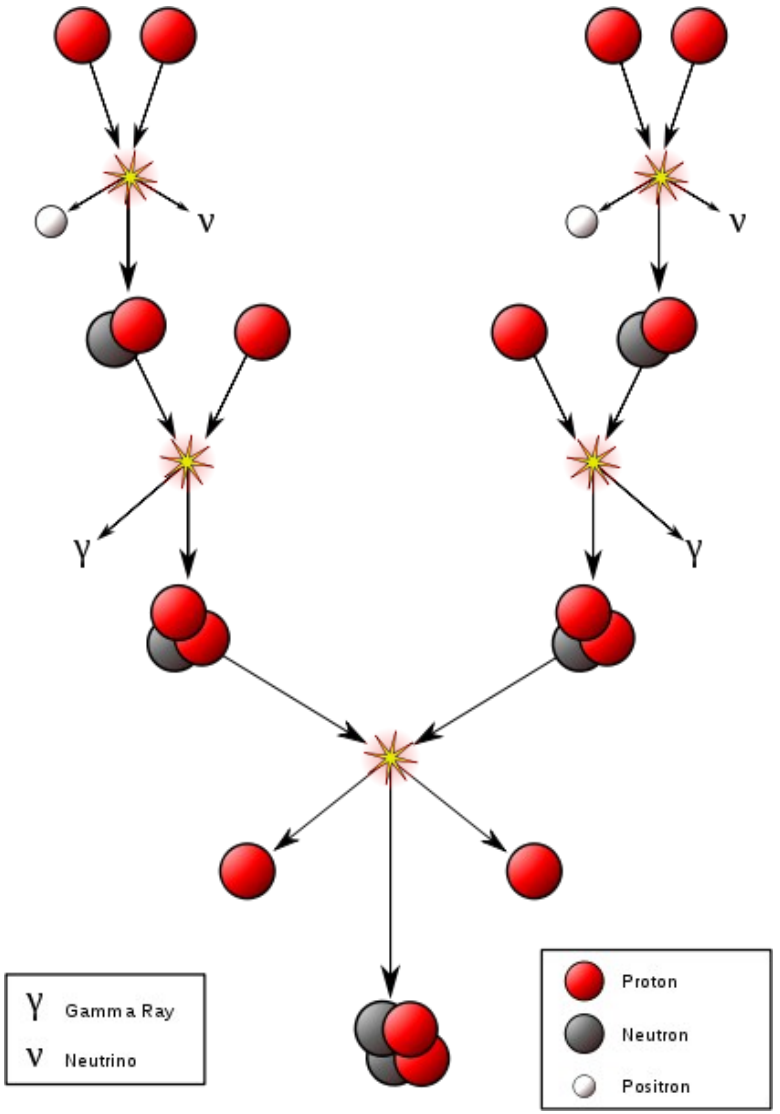


A little fact....

The Sun's luminosity

3.86×10^{33} ergs/s (1 erg=10^{-7} J)

As you know, $E=mc^2$

Every second the Sun converts

4 million tons

of matter into energy

The Sun's mass

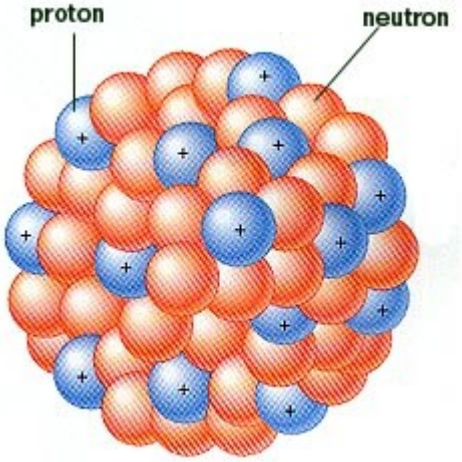
1.99×10^{33} g

Over 10 billion years, the Sun will have converted only

a thousandth

of its mass into energy.

How is an atomic nucleus bound together if the protons are like-charged?



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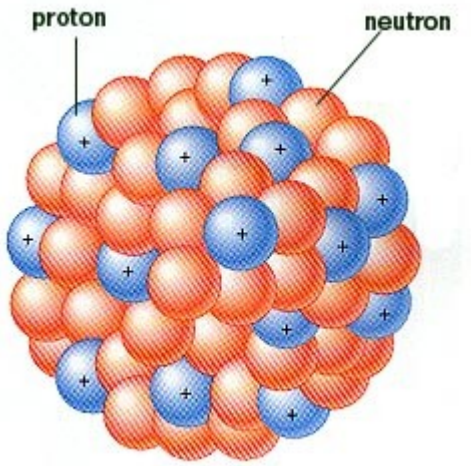


Another force of nature exists at nuclear distances
Not Gravity. Not Electromagnetism.

Strong Force

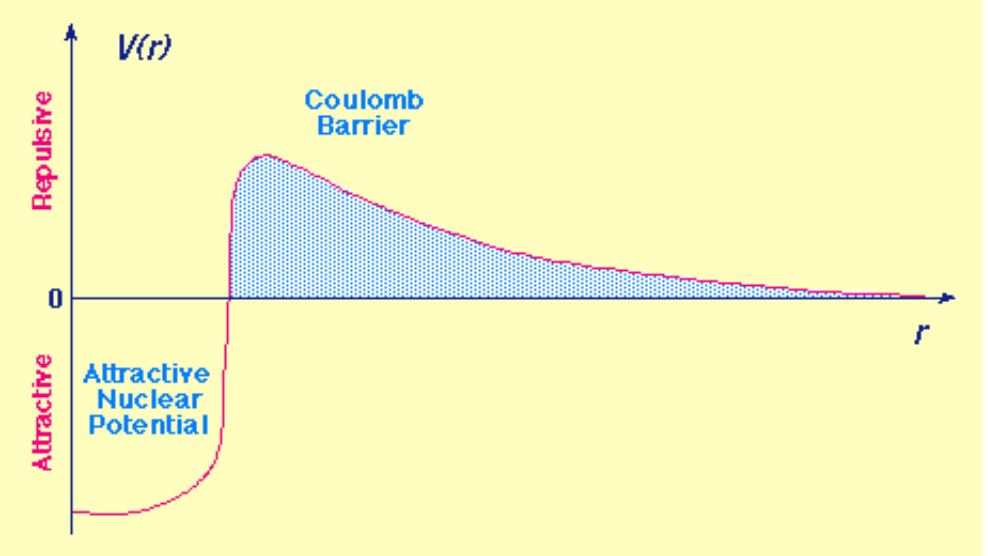
The Coulomb force (EM) between protons is repulsive,
but the strong force between protons is attractive!

A fusor in hydrostatic equilibrium

The Coulomb Barrier

Protons are like-charged and thus repel each other

You need to get them really close so that nuclear forces start to operate

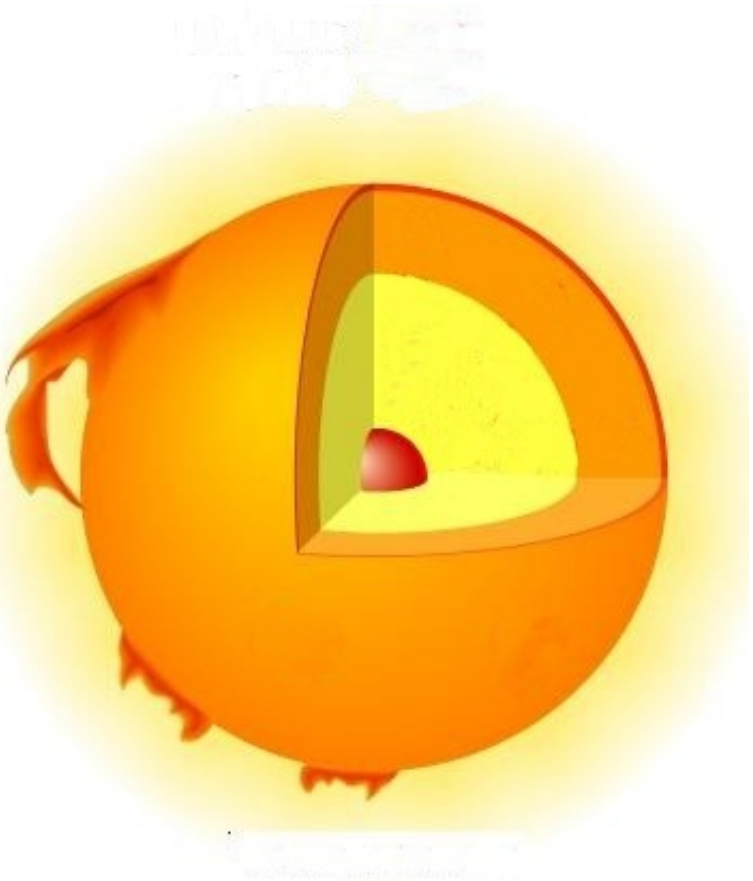


Really close means: packed together - HIGH DENSITY

fast speeds - HIGH TEMPERATURE

A fusor in hydrostatic equilibrium

The Sun's core



HIGH DENSITY
HIGH TEMPERATURE

The core's fact sheet

Temperature :	15 million K
(Sun's surface:	~6000 K)
Density :	150 g/cm^3
(Density of Iron:	7 g/cm^3)
Radius:	0.2 $R_\odot$

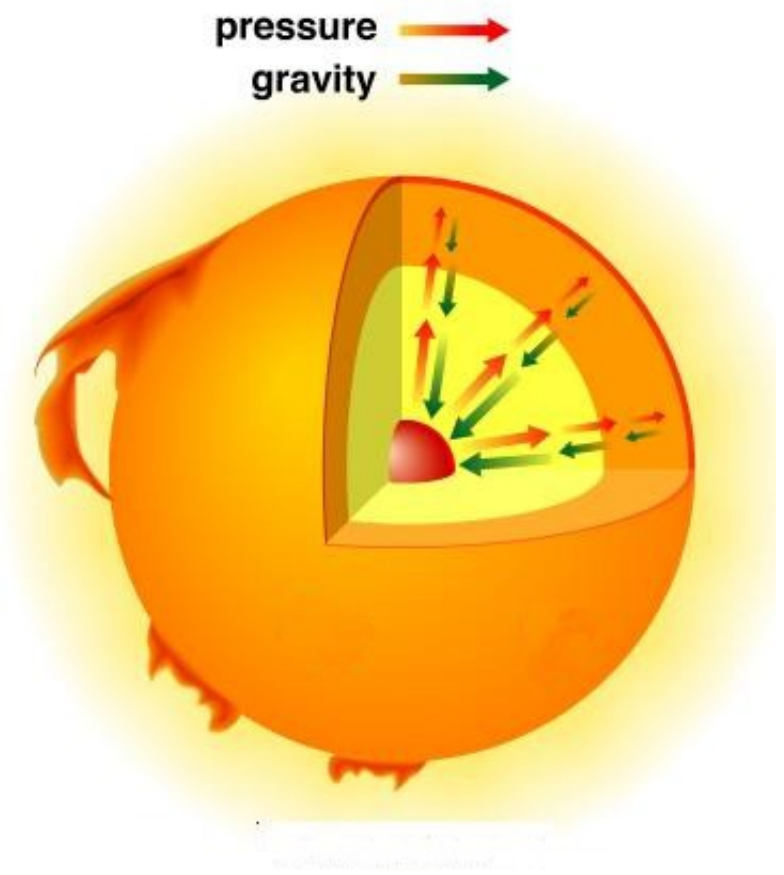
A fusor in hydrostatic equilibrium

Hydrostatic equilibrium

A tug of war between

(outwards) PRESSURE

(inwards) GRAVITY



Are all stars like the Sun?

A fusor in hydrostatic equilibrium

The range of stellar masses

120 $M_\odot$

Too much mass.

Excessive energy production blows atmosphere away and prevents further mass accretion.

NO HYDROSTATIC EQUILIBRIUM

0.08 $M_\odot$

Too little mass.

Not enough compression to ignite fusion.

NO FUSION

A fusor in hydrostatic equilibrium

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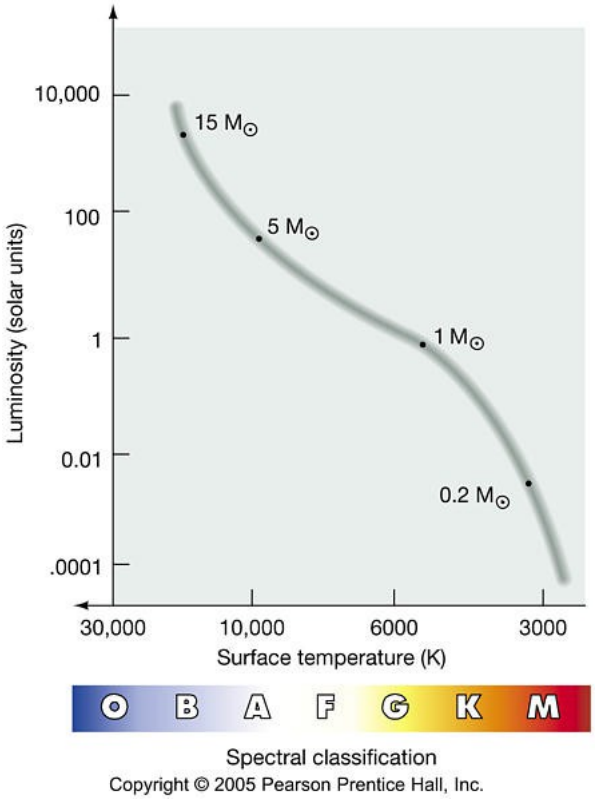

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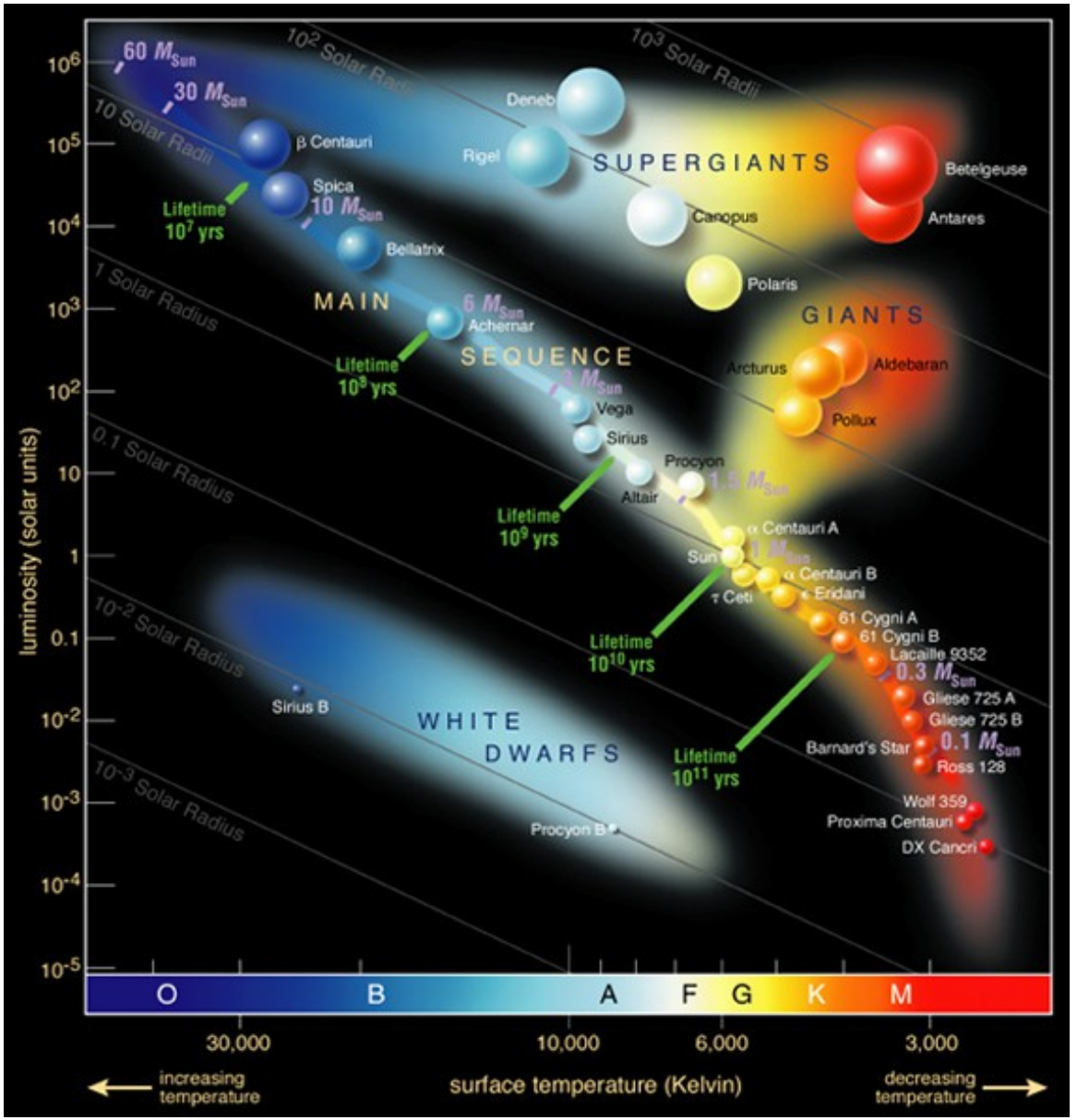
Types of stars – The HR diagram



HR stands for “Hertzsprung-Russel”

Temperature x Luminosity

Spectral Types

OBAFGKM

“Oh be a fine girl/guy, kiss me”

Each type is subdivided into ten numbered subtypes (eg, K8, B6)

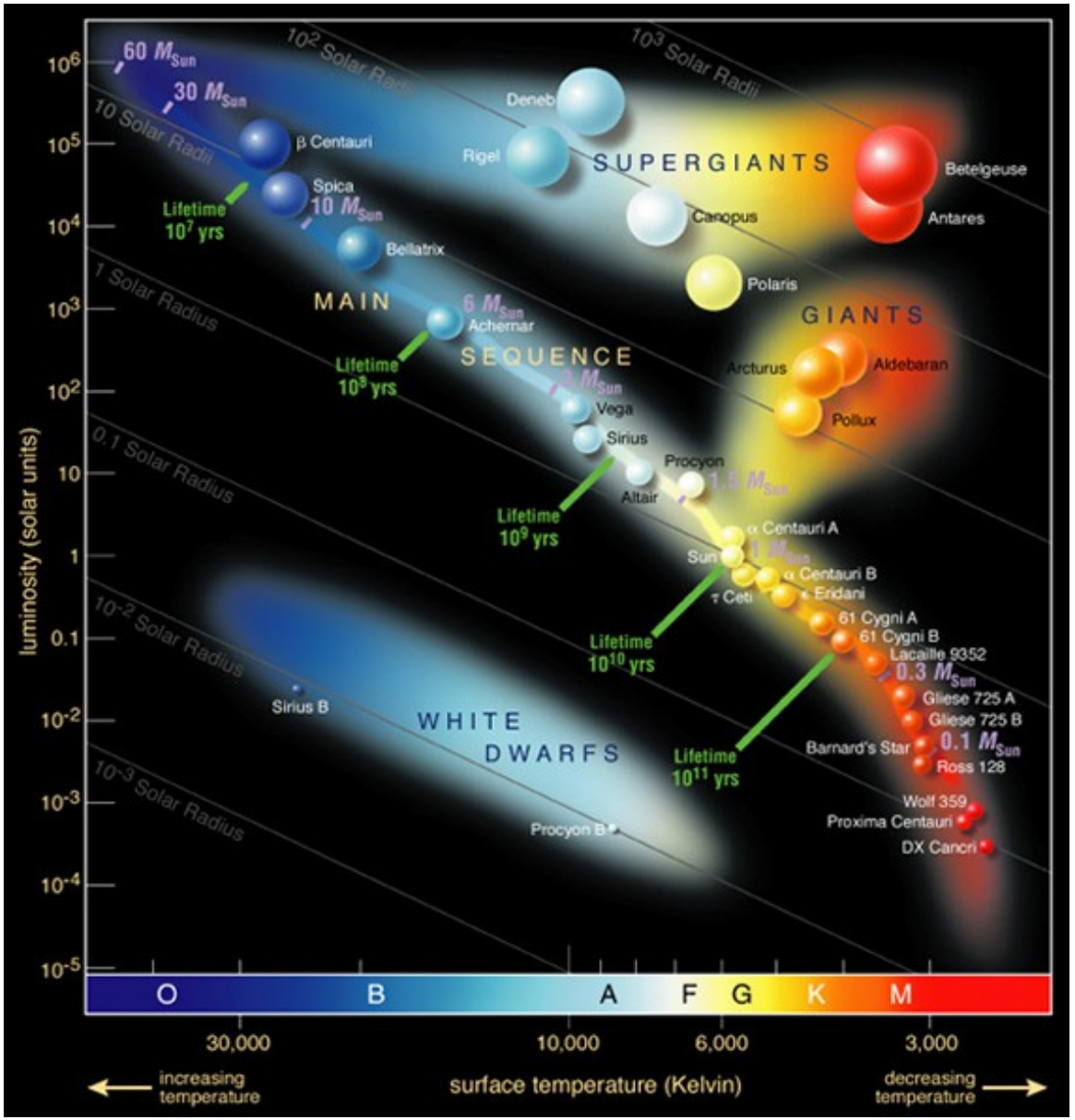
One of the most famous sentences in Astronomy

Spectral Types

O B A F G K M

Oh Be A Fine Girl Kiss Me

Types of stars – The HR diagram



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"Oh be a fine girl/guy, kiss me"

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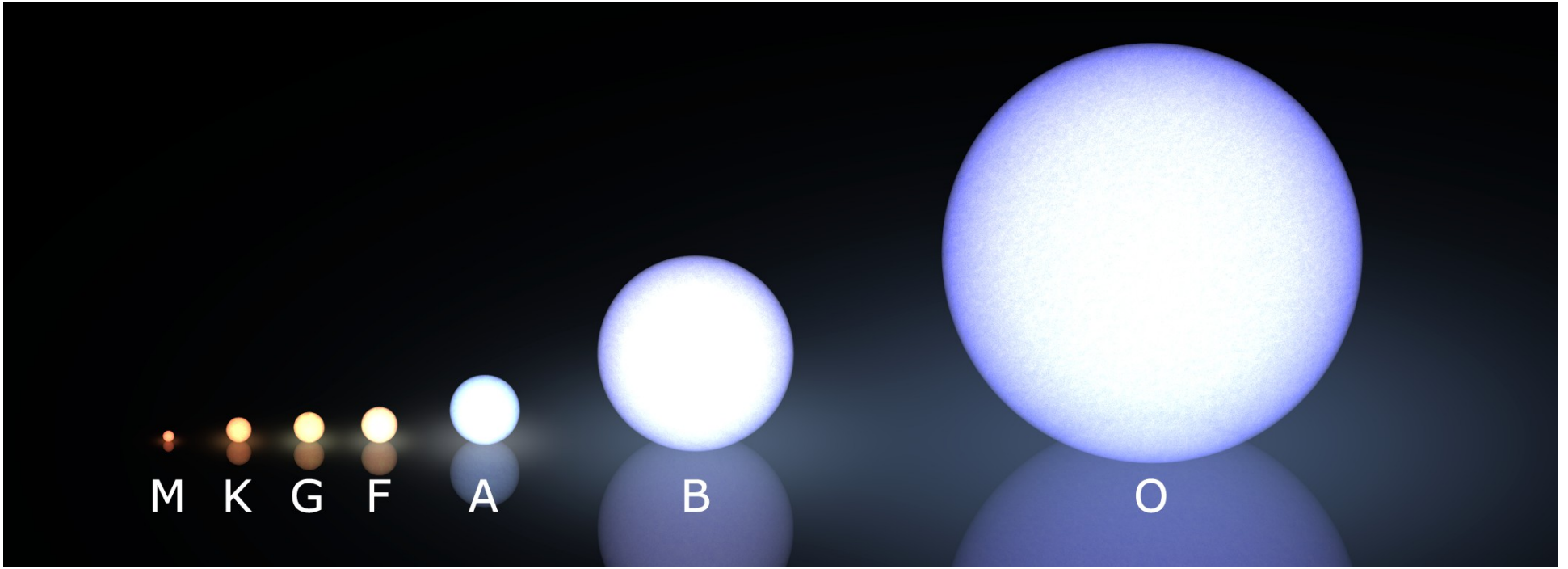
Luminosity classes

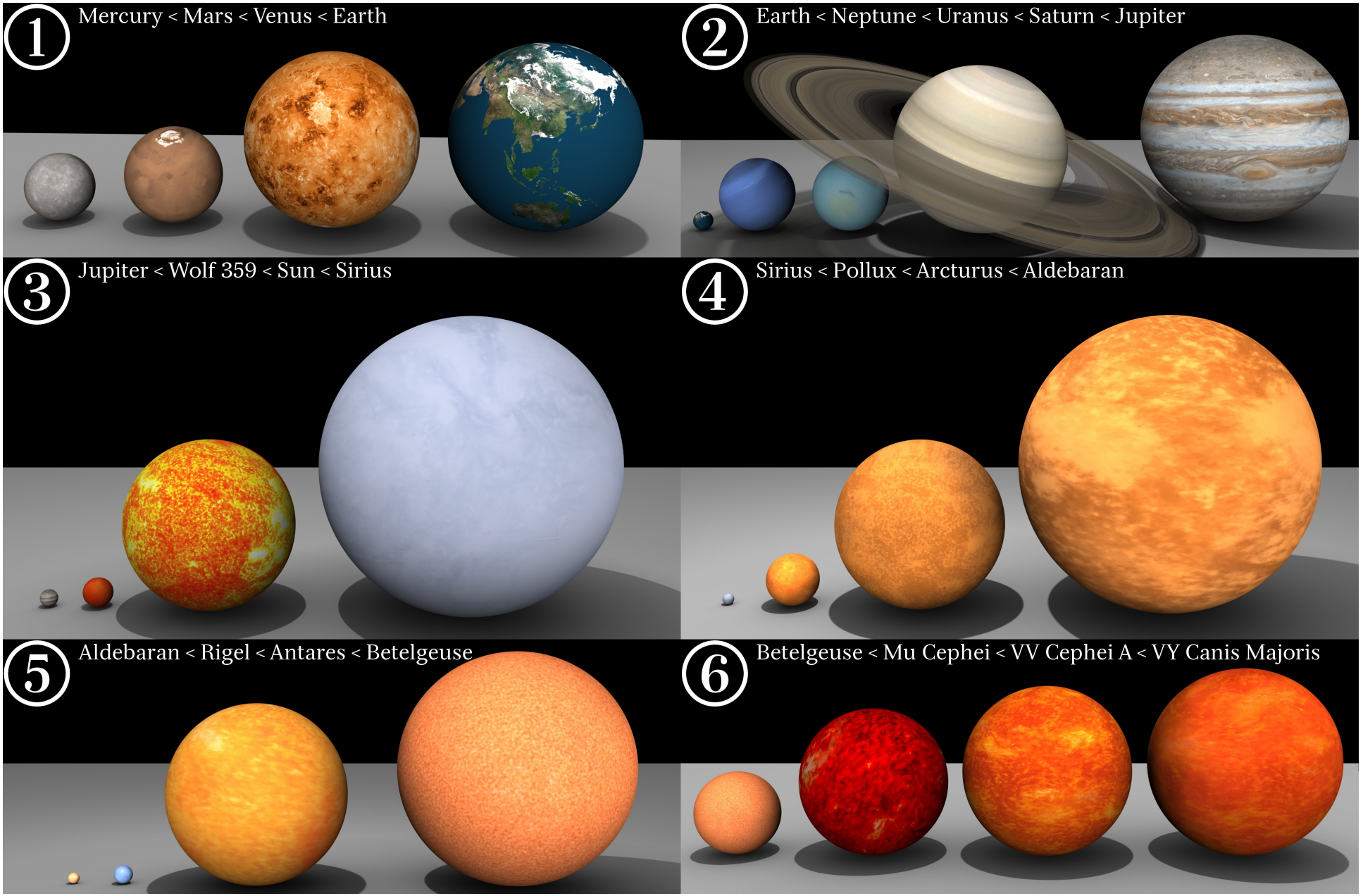
I - Supergiants
II - Bright giants
III - Giants
IV - Subgiants
V - Dwarfs
VI - Subdwarfs
VII - White Dwarfs

The **Sun** is a **G2V** star
Sirius is a **A1V** star
Betelgeuse is a **M2I** star
Pollux is a **K2III** star

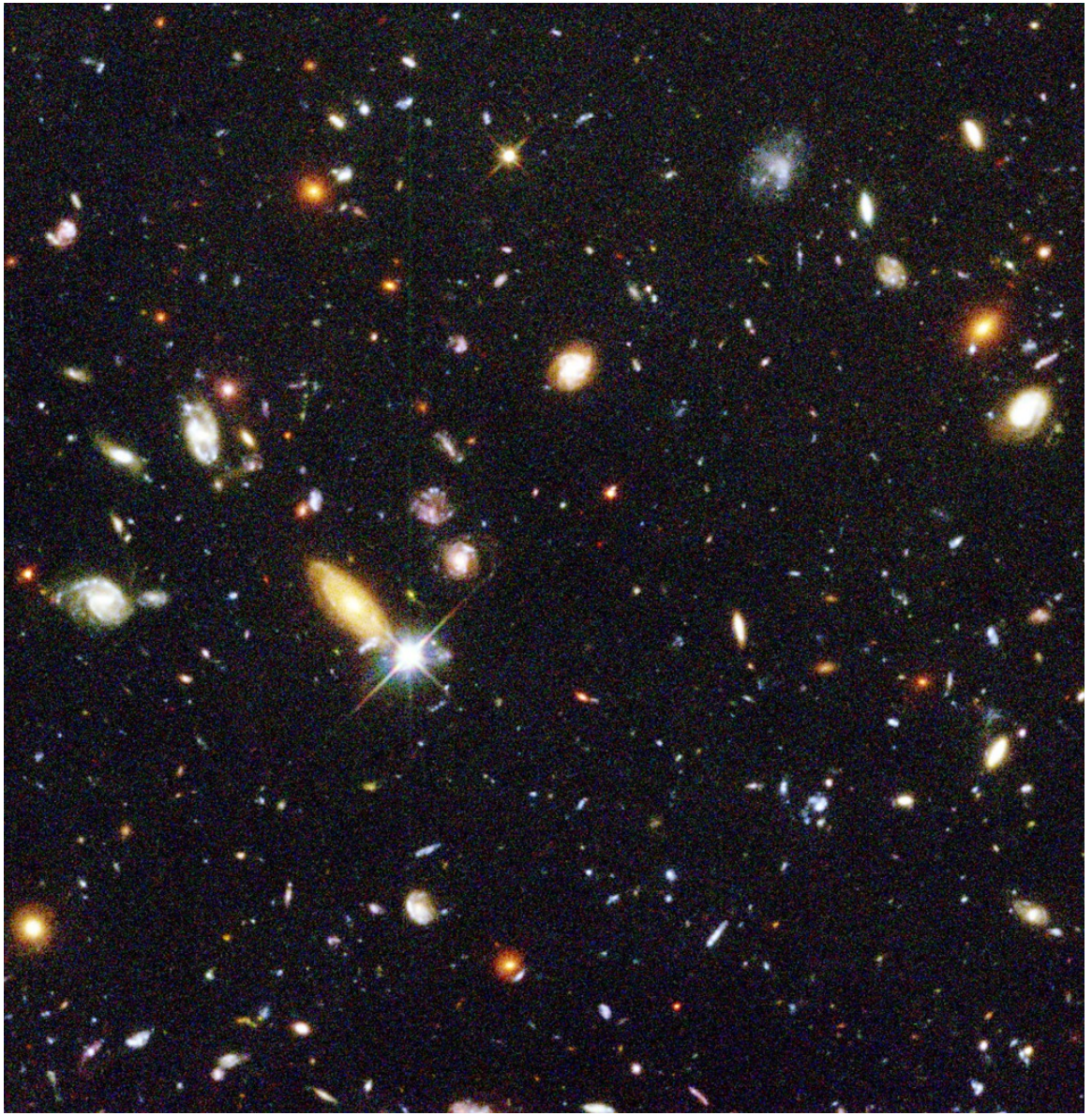
Sizes and colors of Main Sequence stars



Giant stars can be A LOT BIGGER



To the Universe what a brick is to a house:
its smallest building unit.



What structures do stars make?

Globular clusters

Open clusters

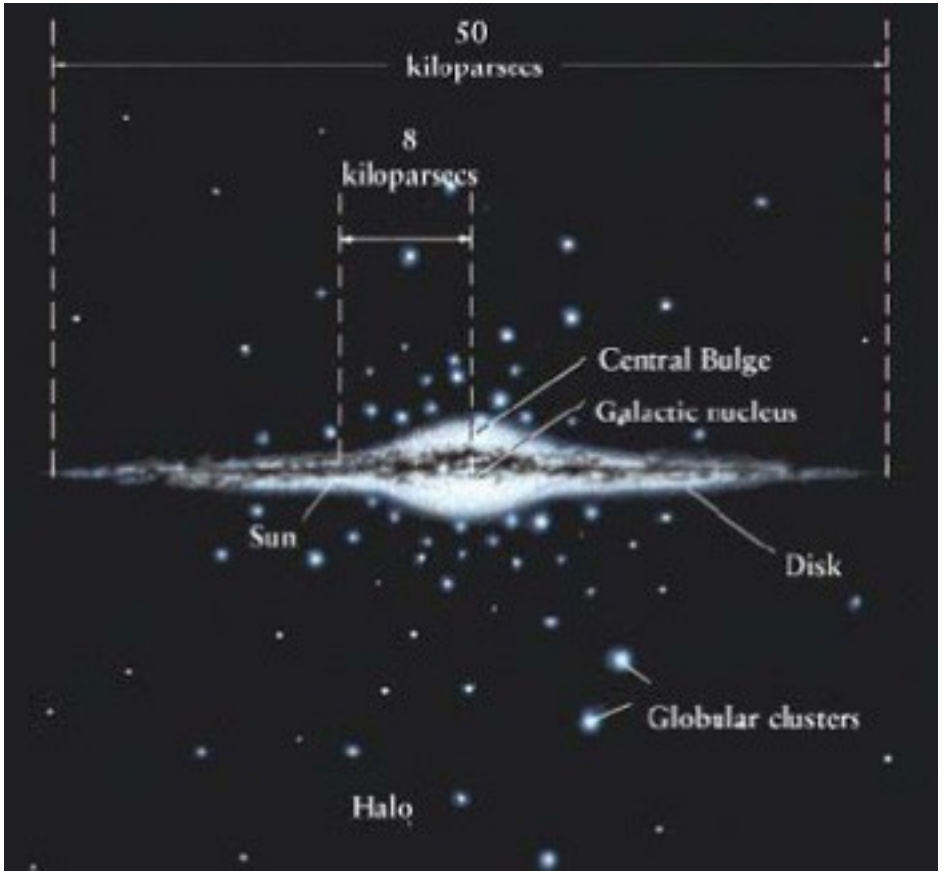
Binary and multiple systems

And all of these combine to form.... ?

And all of these combine to form.... ?

Galaxies!

Globular Clusters



-First structures to form, during the
formation of the galaxy itself

- Spherically distributed around the galaxy, in the halo

- Very massive, millions of stars

- ~200 orbit the Milky Way

Open Clusters

- Disk stars

- Young, newly formed stars
  < 1 Gyr

- Nearly all stars are formed in open clusters

- Trace the spiral arms

- 10^4 stars

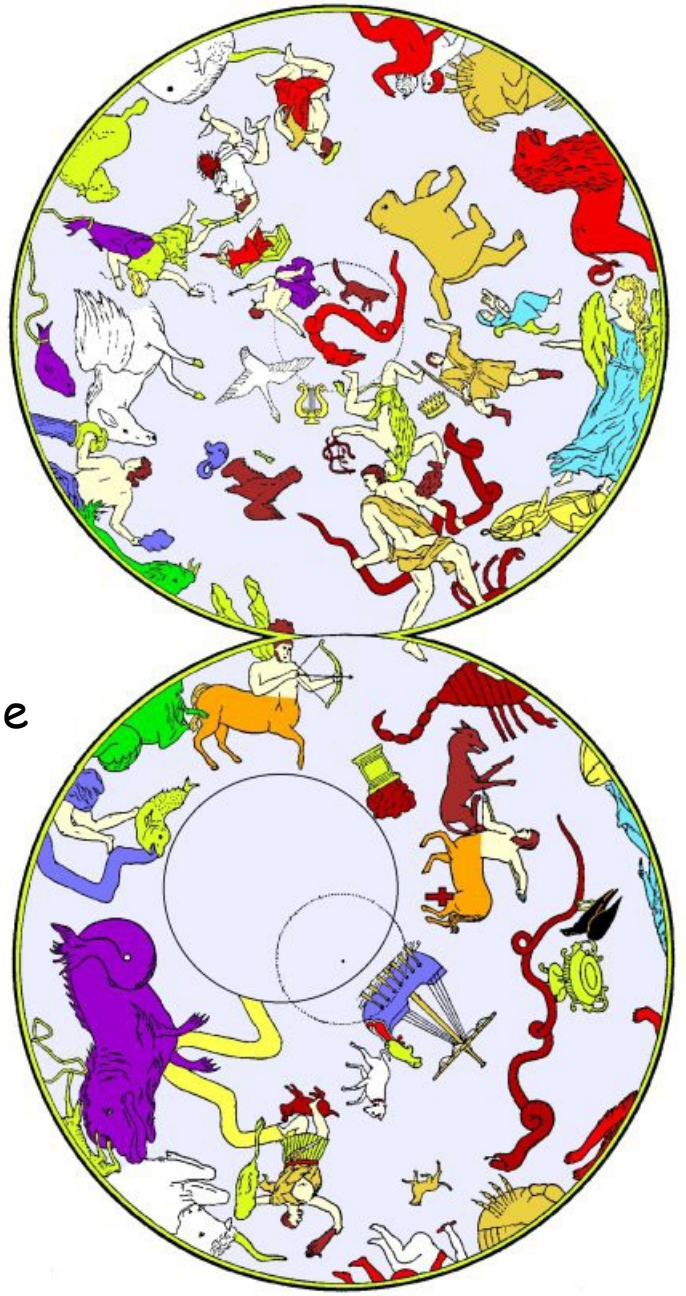
- Thousands are known in the Milky Way

How about constellations?

Constellations are *NOT* physical

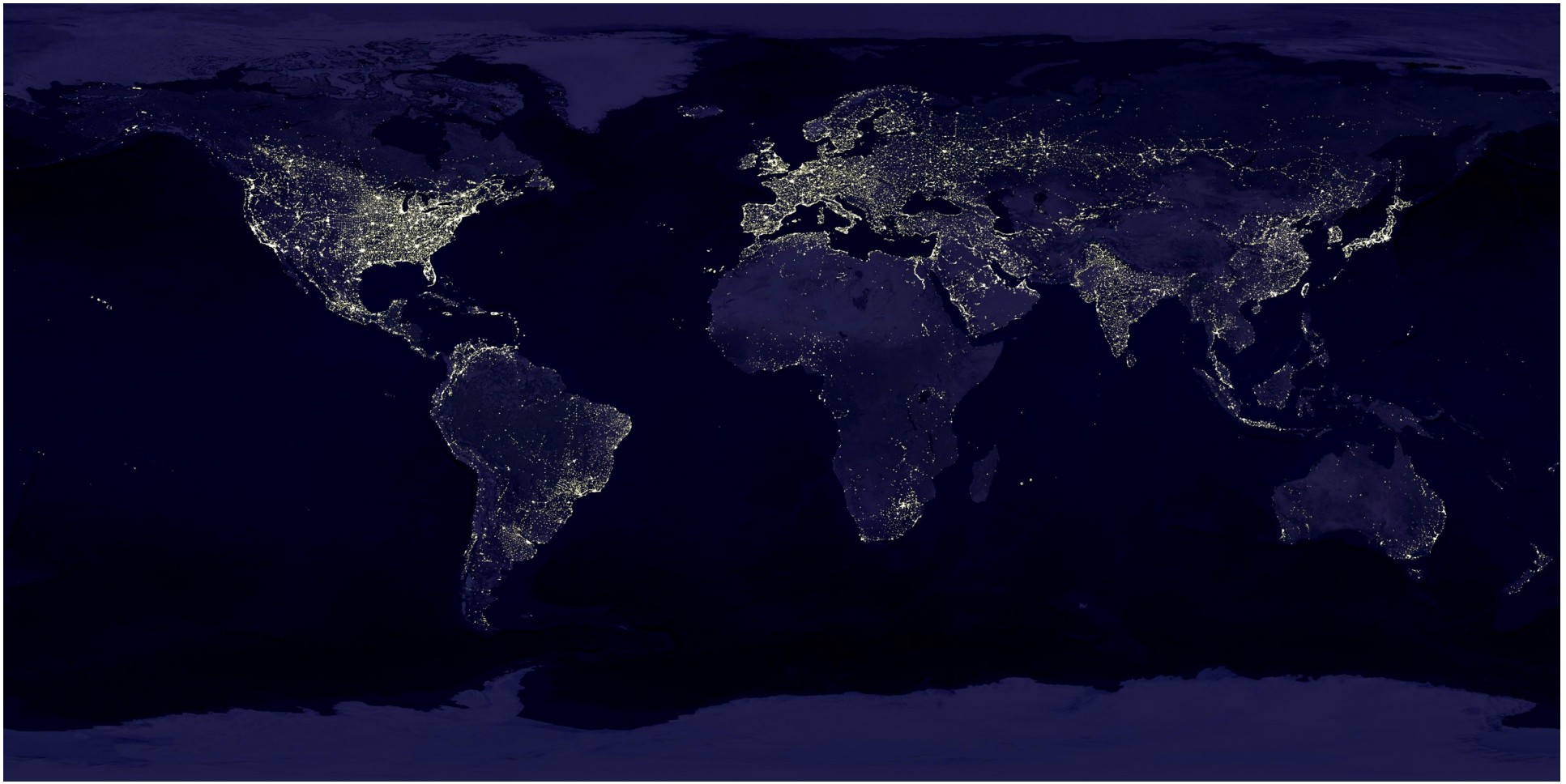
- They are human invention, a useful way to map the sky **as seen from Earth**

We divided the stars visible with the naked eye into 88 constellations.



How many stars can one see from NYC?

Where can we better see stars?



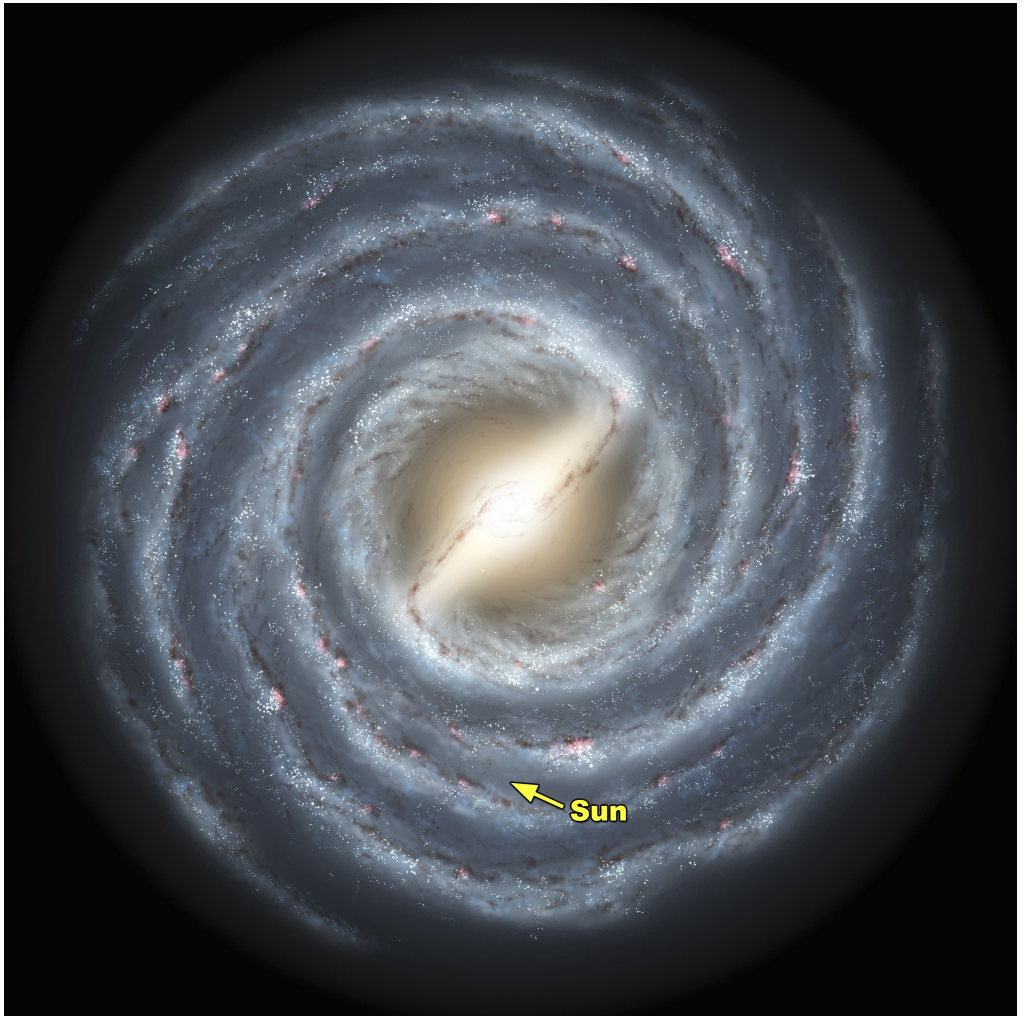
Only 6000 stars?

YES! We only see a tiny fraction of our galactic neighbourhood!

The Milky Way has ~200 billion stars

We only see 6000 in the night sky

DUST obscures our vision



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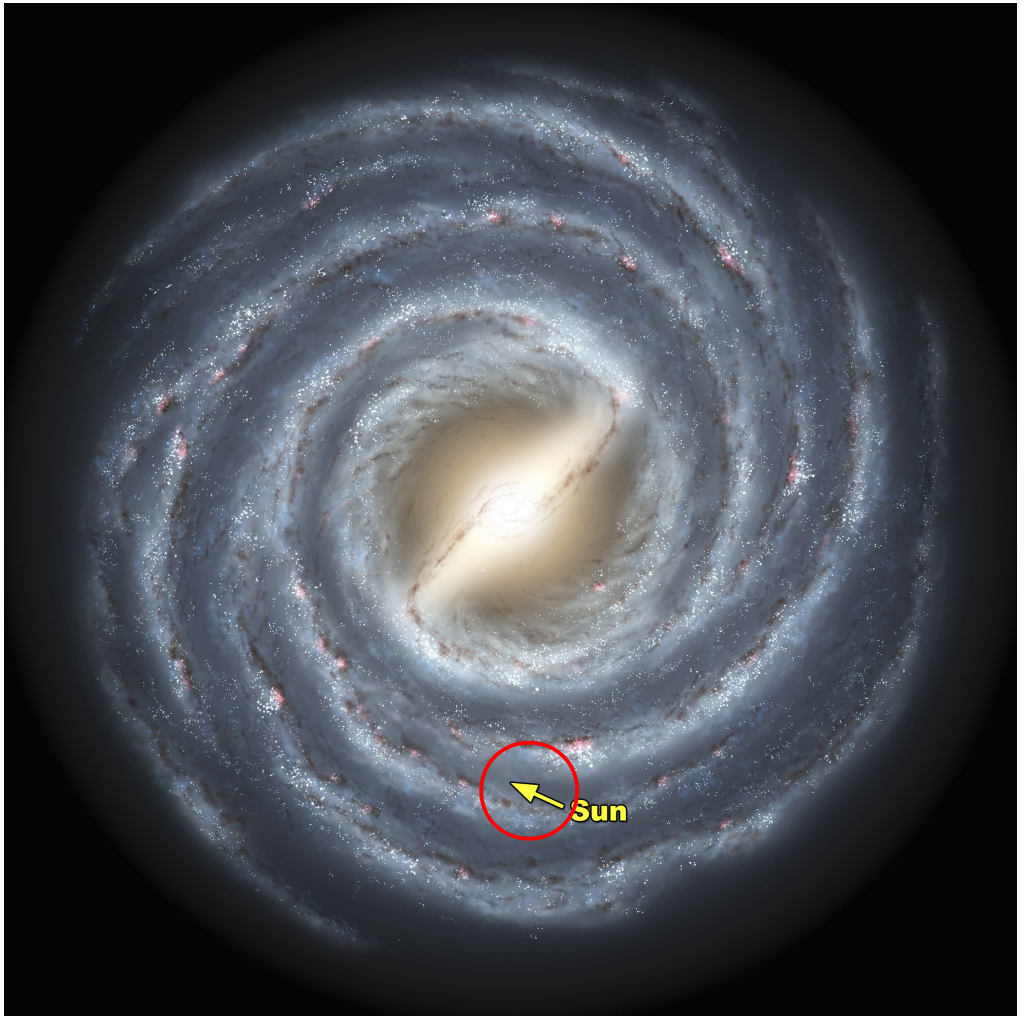
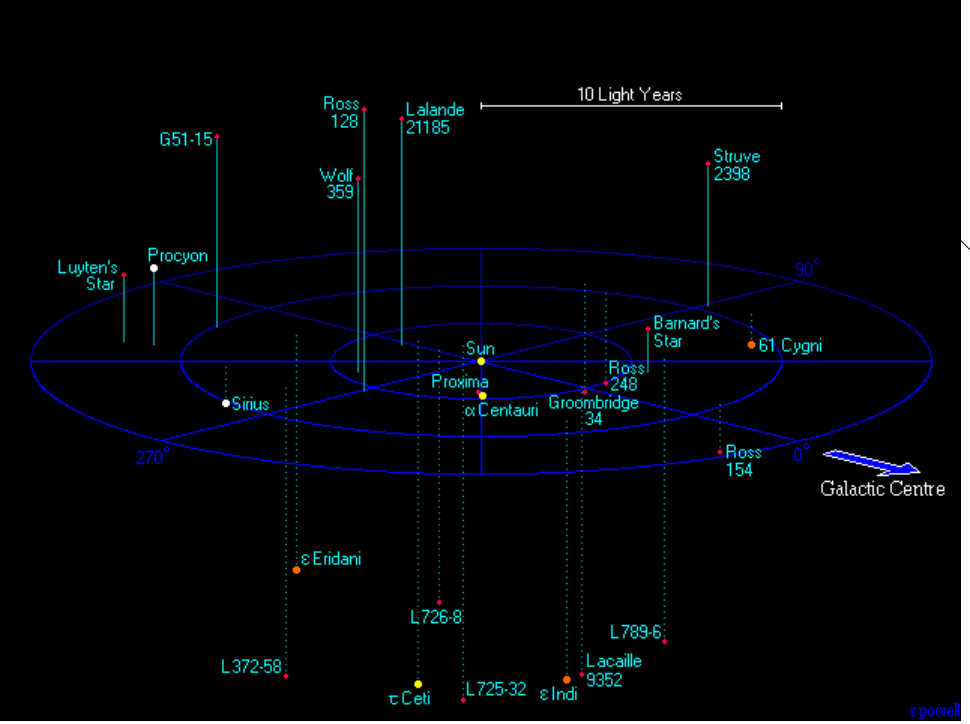
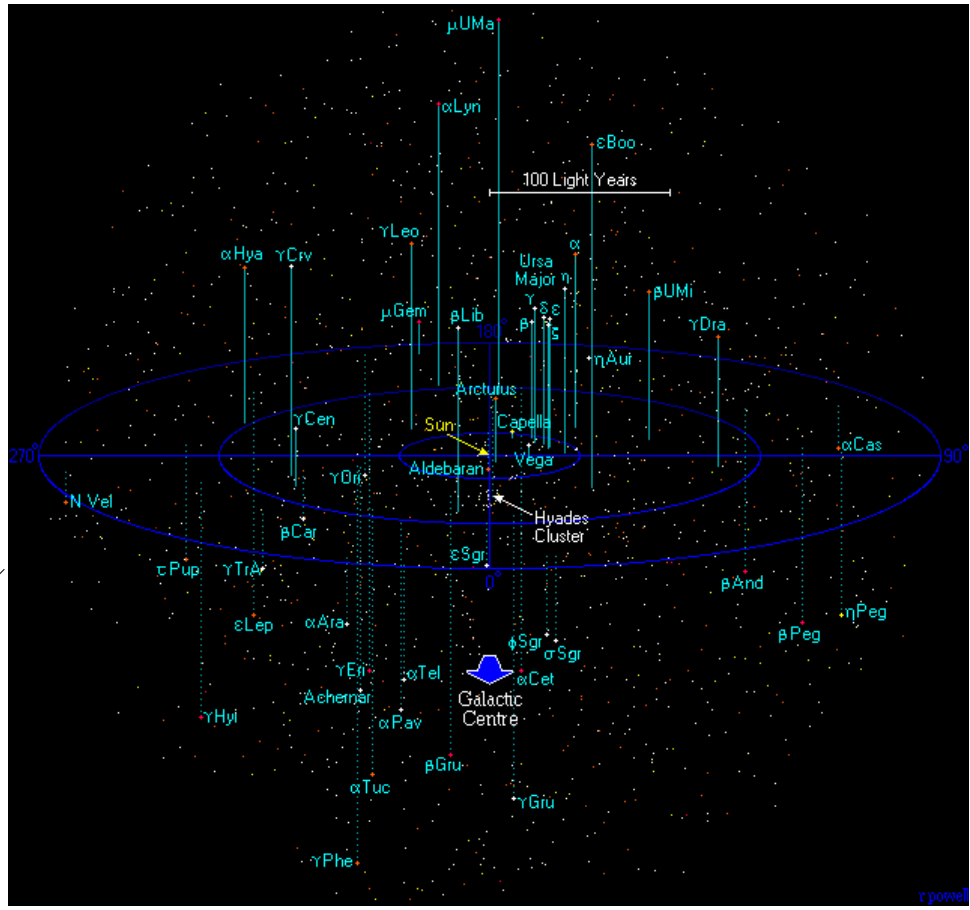



10 Light Years
Ross 128
Lalande 21185
G51-15
Wolf 359
Struve 2398
Luyten's Star
Procyon
Barnard's Star
61 Cygni
Sun
Proxima
Ross 248
Sirius
α Centauri
Groombridge 34
Ross 154
Galactic Centre
ε Eridani
L726-8
L789-6
Lacaille 9352
L372-58
τ Ceti
L725-32
ε Indi

x 10


μUMa
αLyr
εBoo
100 Light Years
γLeo
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γCrv
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γCen
Sun
Capella
αCas
Vega
Aldebaran
γOri
N Vel
Hyades Cluster
βCar
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τPup
γTrA
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αAra
βPeg
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Achernar
Galactic Centre
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αPav
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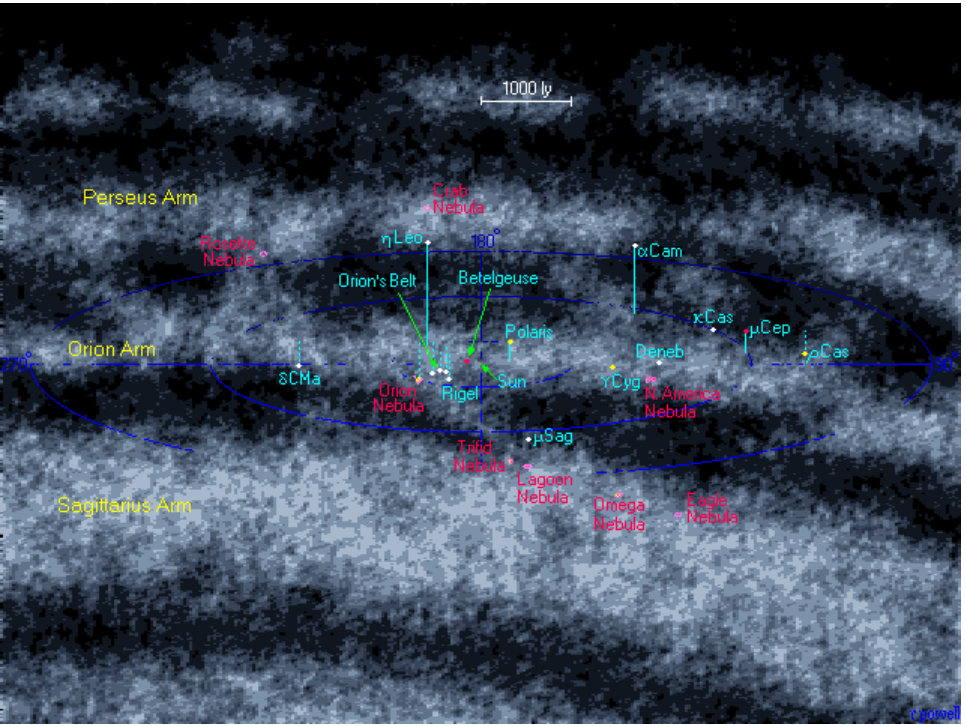
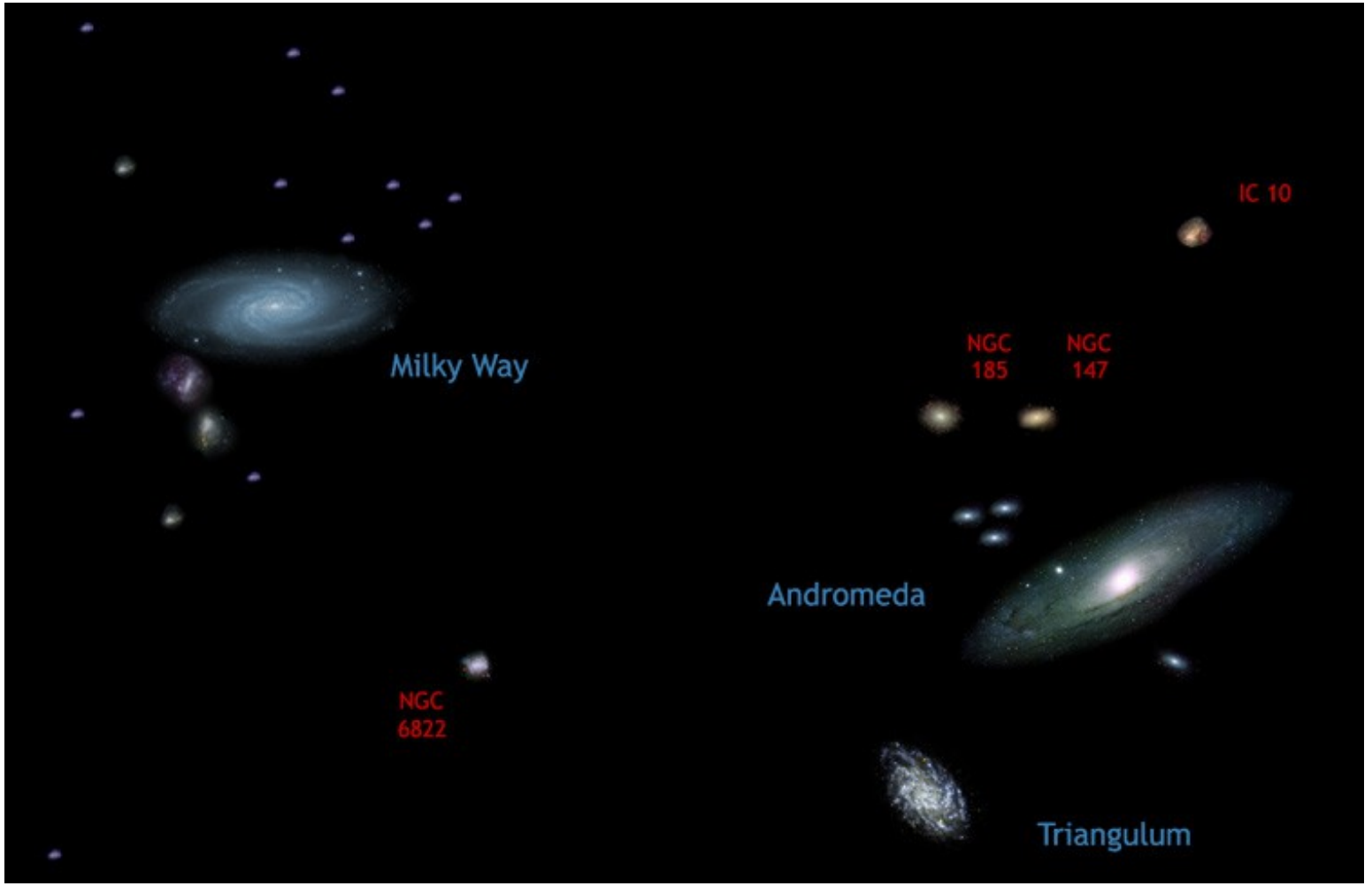
x 10


1000 ly
Perseus Arm
Crab Nebula
Rosette Nebula
ηLeo
αCam
Orion's Belt
Betelgeuse
κCas
μCep
Polaris
Orion Arm
Deneb
αCas
εCMa
Orion Nebula
Rigel
Sun
γCyg
N. America Nebula
μSag
Trifid Nebula
Lagoon Nebula
Omega Nebula
Eagle Nebula
Sagittarius Arm

The Local Group

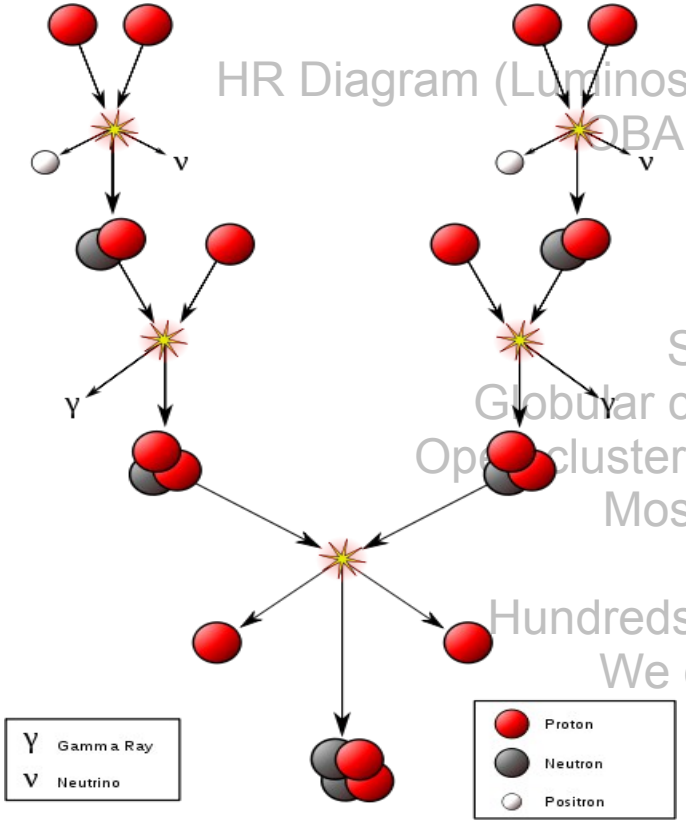


Let's summarize

Stars are fusors in hydrostatic equilibrium

Four Hydrogen nuclei (protons) -> Helium nucleus.
Difference in mass is converted into energy.

Below 0.08 $M_\odot$, no nuclear fusion, above 120 $M_\odot$, no hydrostatic equilibrium



HR Diagram (Luminosity-Temperature) is a powerful tool to study stars
OBAFGKM – the spectral sequence
Hot stars – Blue
Cold stars – Red

Stars *never* form in isolation
Globular clusters form during galaxy formation
Open clusters form continuously in the galaxy's disk
Most stars are in multiple systems

Hundreds of billions of stars in the Milky Way
We only see 6000 in the night sky
Dust obscures our vision

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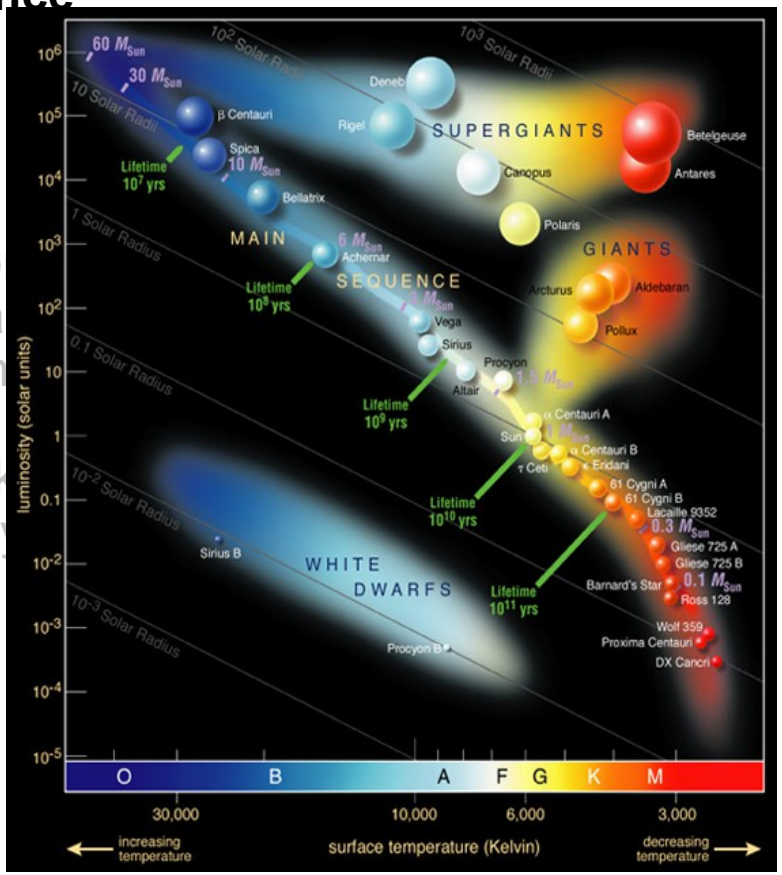

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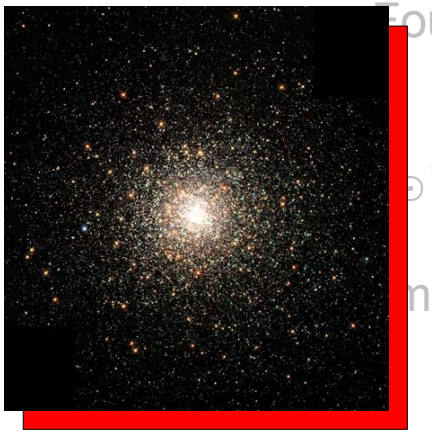

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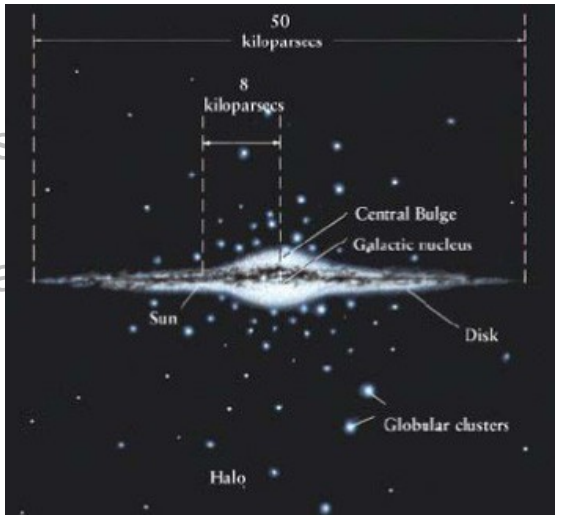

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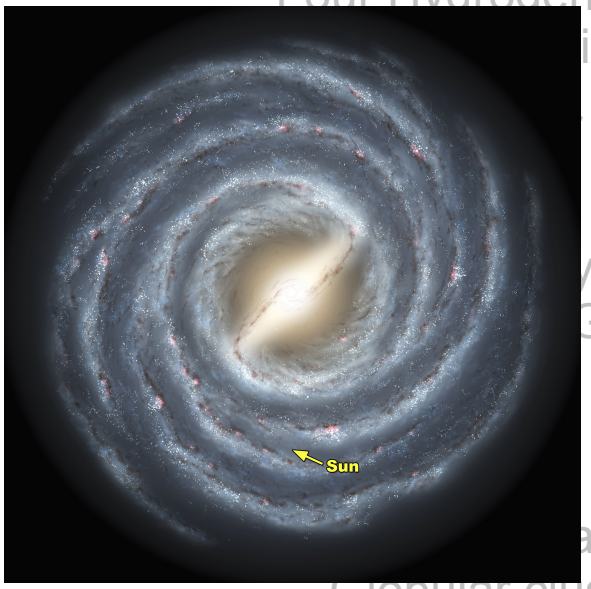

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