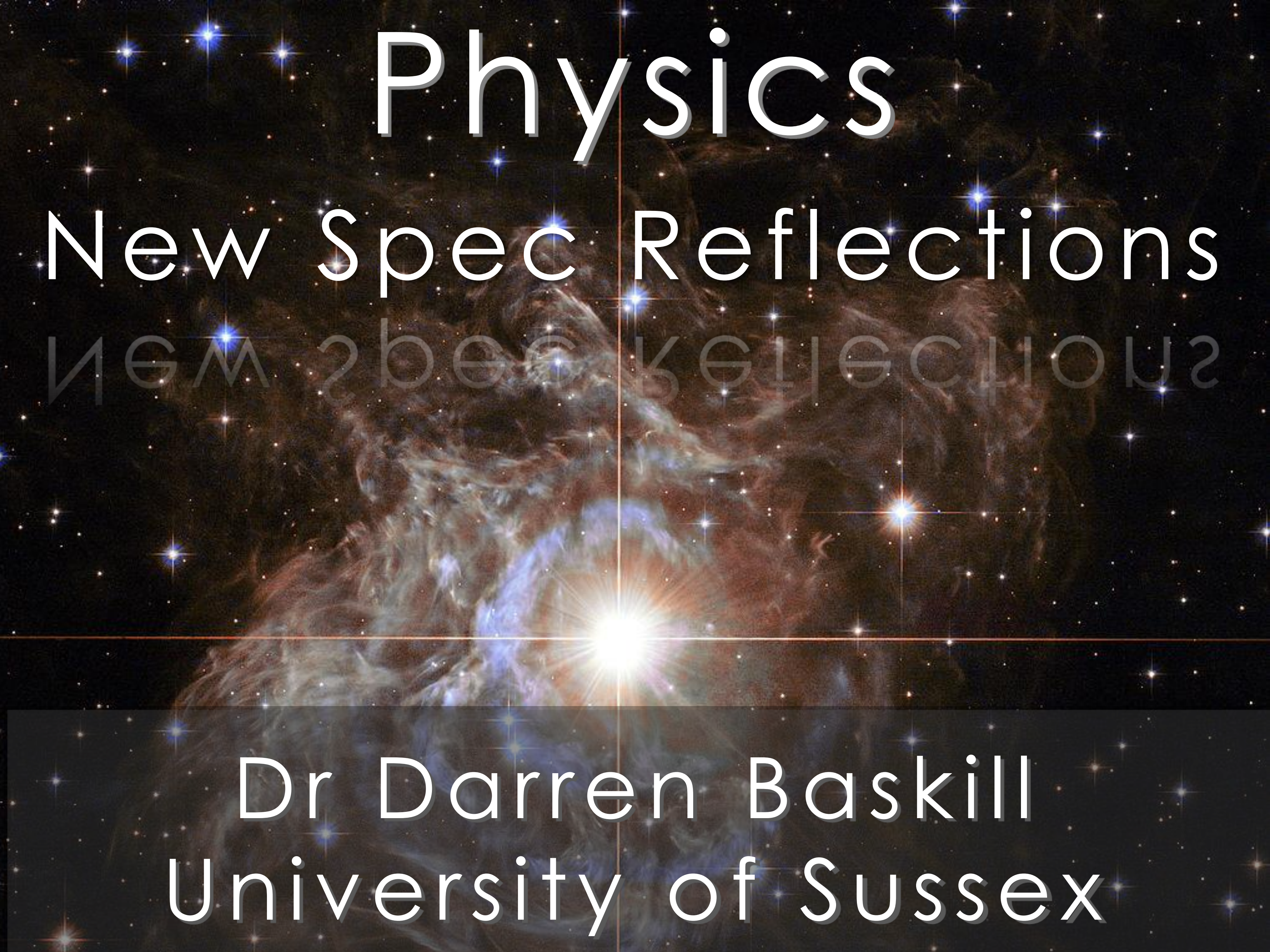

Physics
New Spec Reflections
Dr Darren Baskill
University of Sussex

A bit about me

Dr Darren Baskill

- Manages the outreach programme in Physics, Astronomy & Maths at the University of Sussex.
- Lectures undergraduate students (data analysis for 1st year physicists & astronomy for art students)
- Part of SEPnet, the South-East Physics Network of 9 universities working together
- Committee member for the Institute of Physics (South-Central)
- Occasionally still does science.

My Job: Doing outreach in schools & elsewhere

Our Outreach Programme

In 2017/8…

17,000 people at 115 events

~ 6,600 general public

~ 5,300 students at fairs

~ 4,900 School/college students in classrooms

- 30% (34) events are with WP partner schools

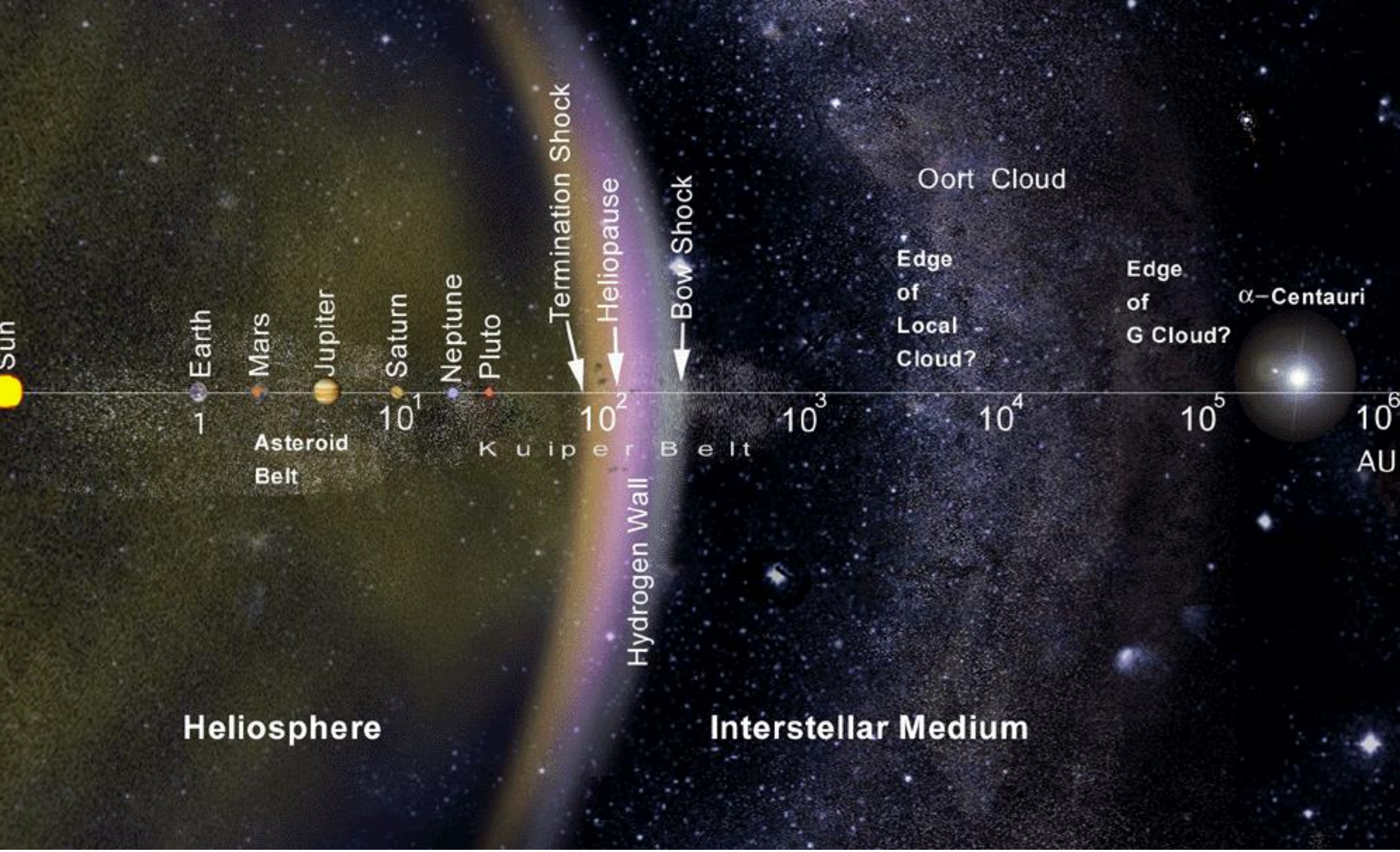
Also days like today!

UNIVERSITY OF SUSSEX

Outreach @ Sussex

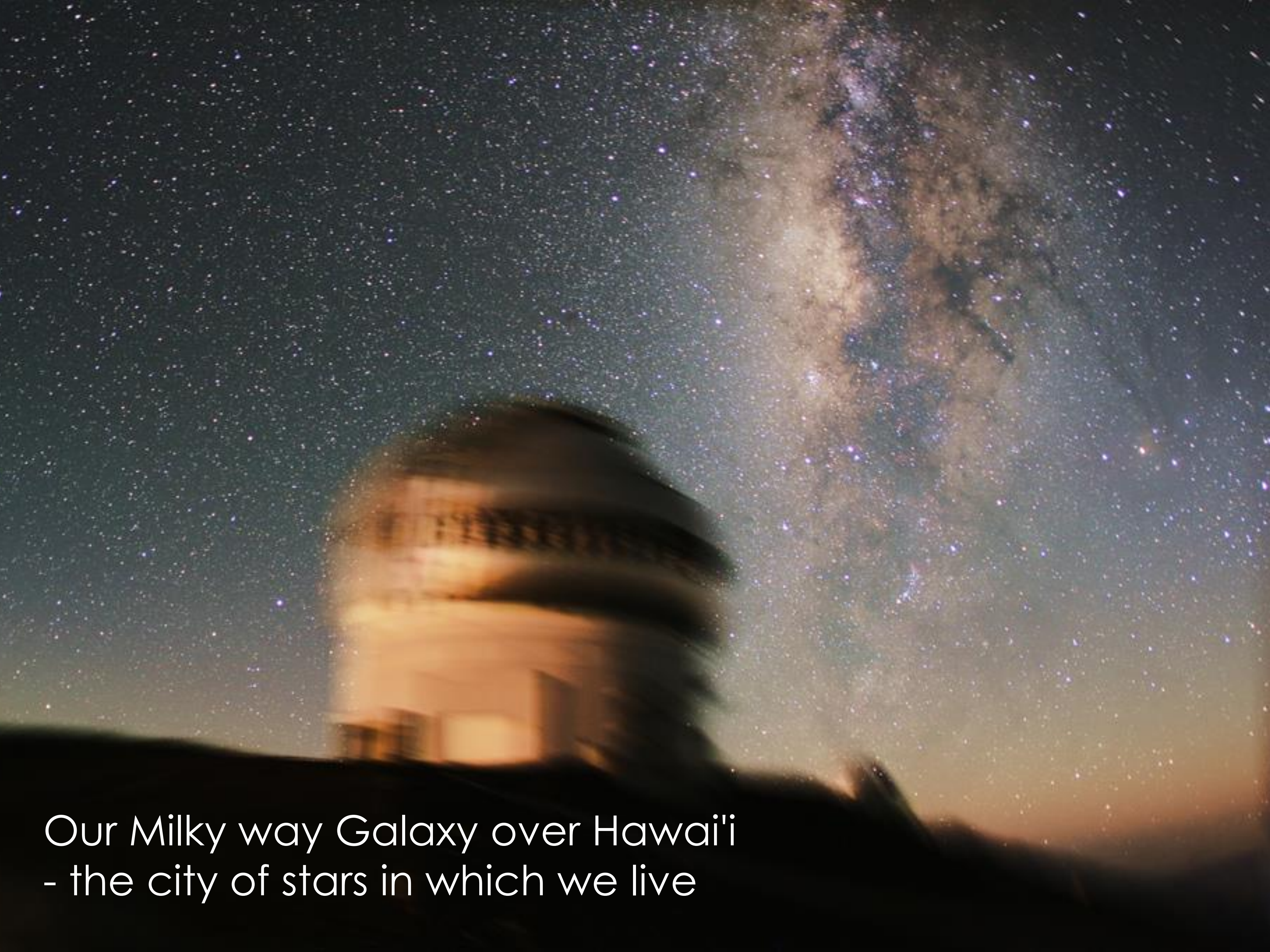
- We employ our university students to deliver the activities – they are wonderful role models!
- We visit schools, or schools visit us
- “Experiments in a suitcase”

Stars, planets, dwarf planets, asteroids/minor planets, comets & exo*s

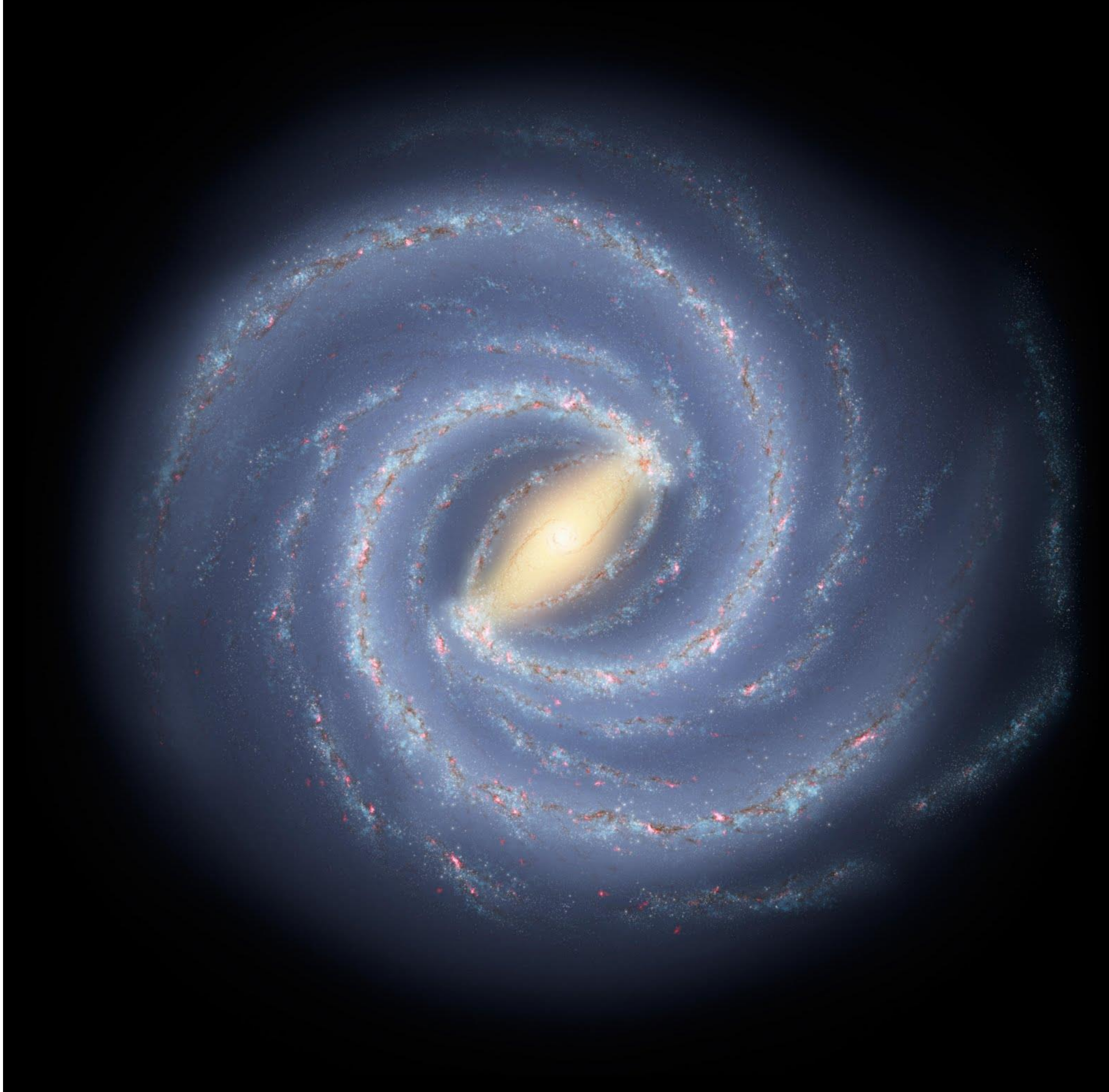


Logarithmic scale: Beyond the Oort cloud,
the interstellar medium and stars

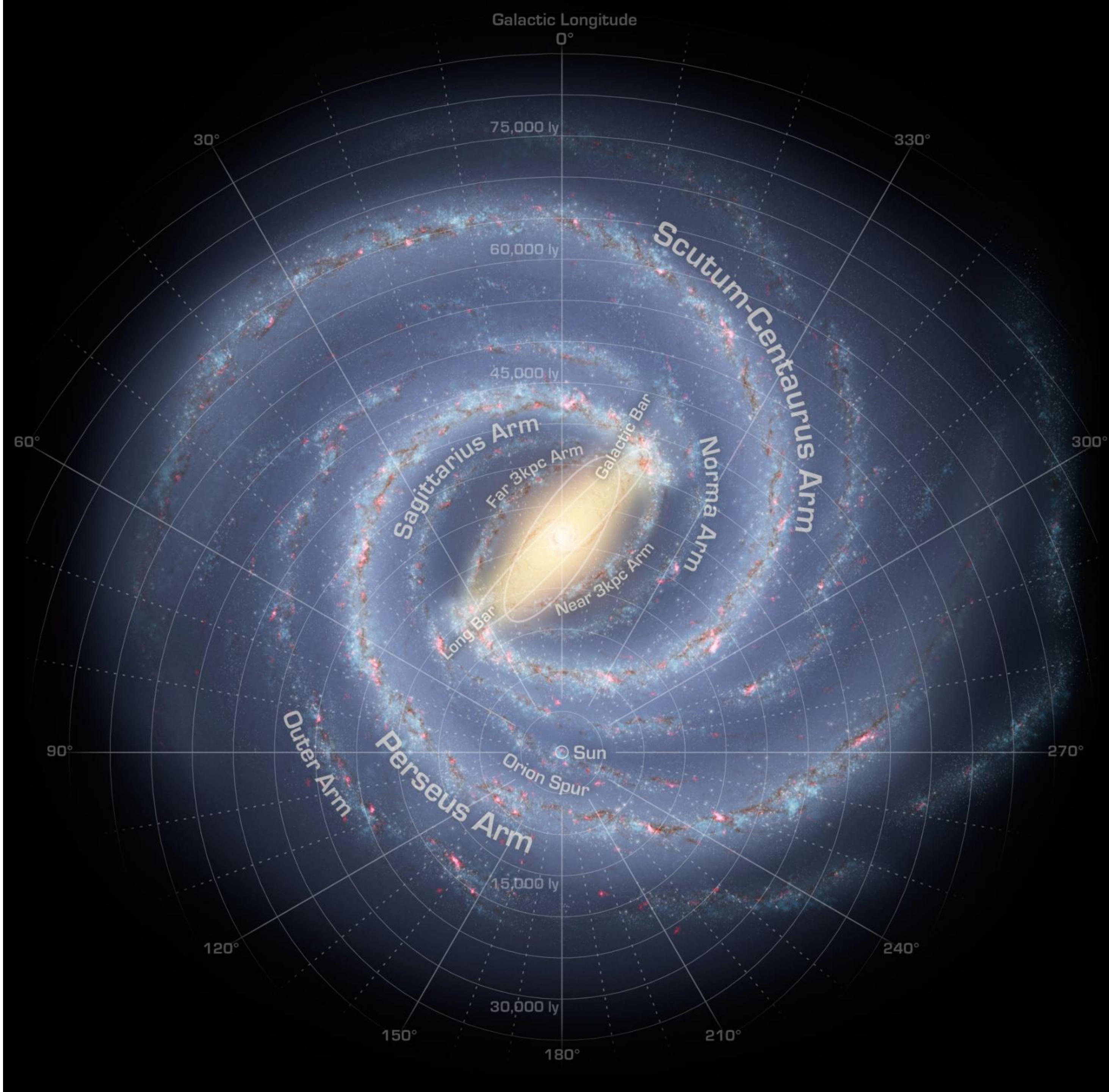
The Milky-way


Our Milky way Galaxy over Hawai'i
- the city of stars in which we live

The Milky-way

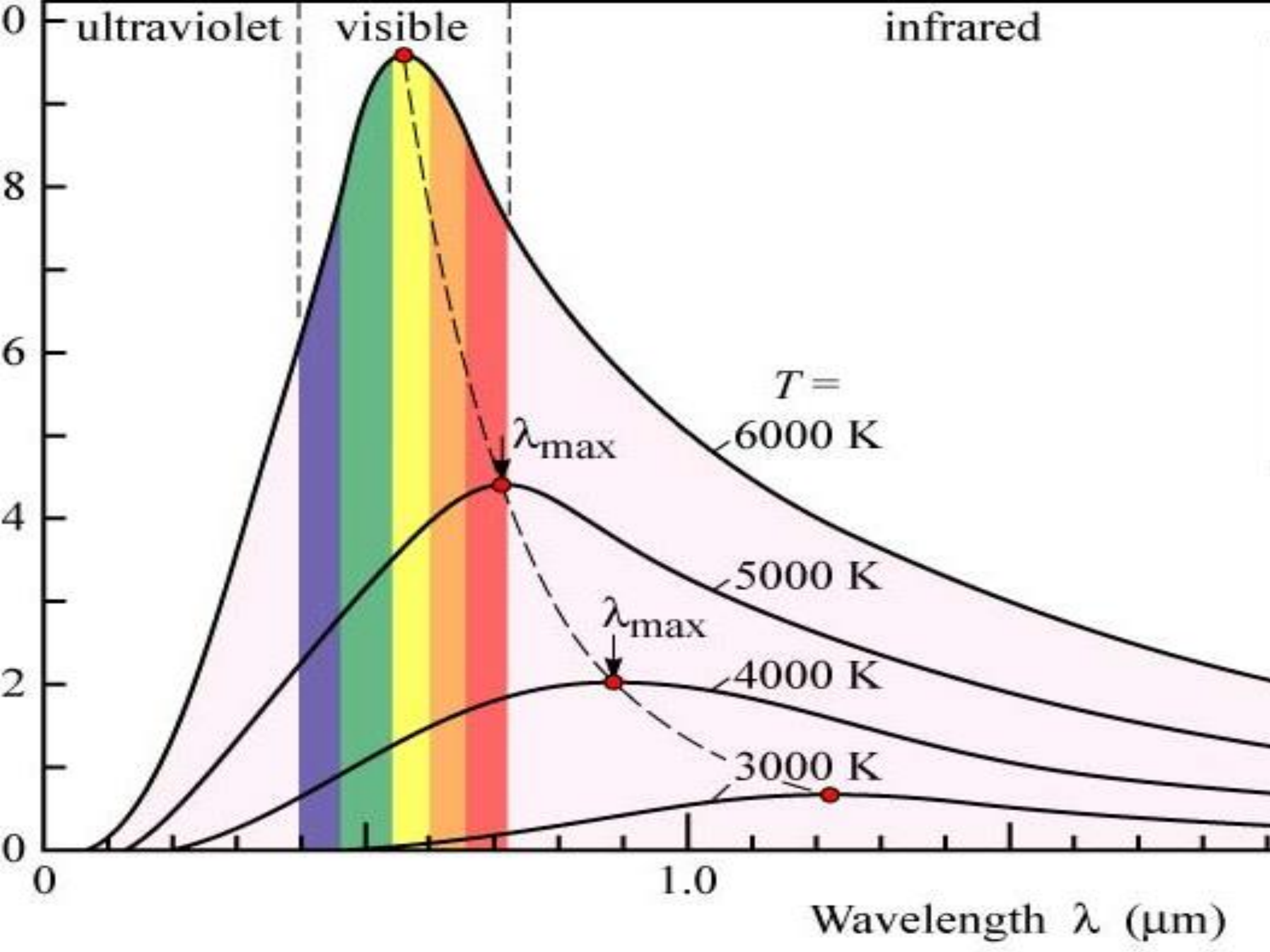


The Milky-way



Artist impression from the side – showing dust lanes.

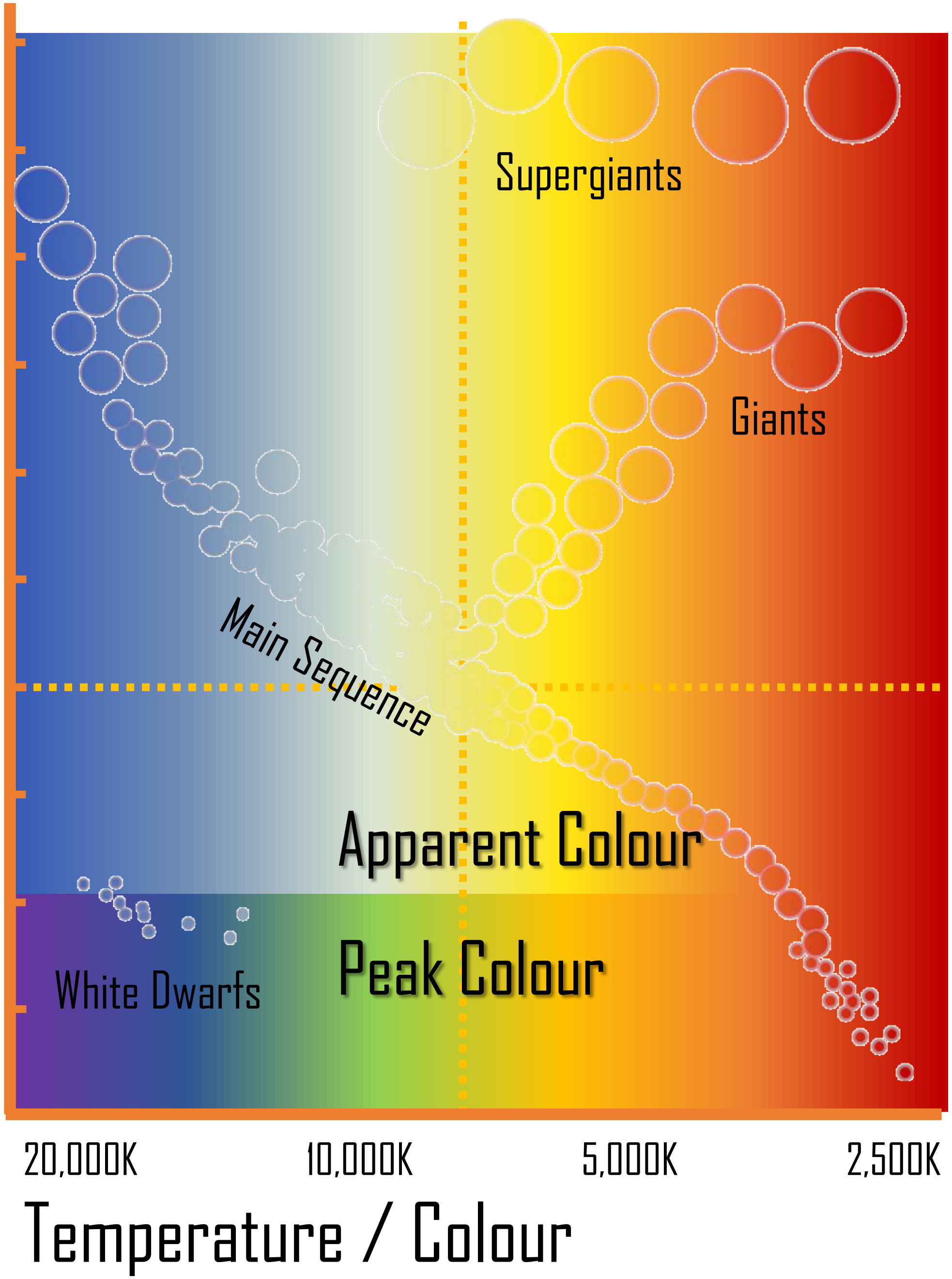
We know this by comparing with other, distant galaxies.



ultraviolet
visible
infrared
T =
6000 K
5000 K
4000 K
3000 K
λmax
λmax
0
8
6
4
2
0
0
1.0
Wavelength λ (μm)

A note about the colours of stars…

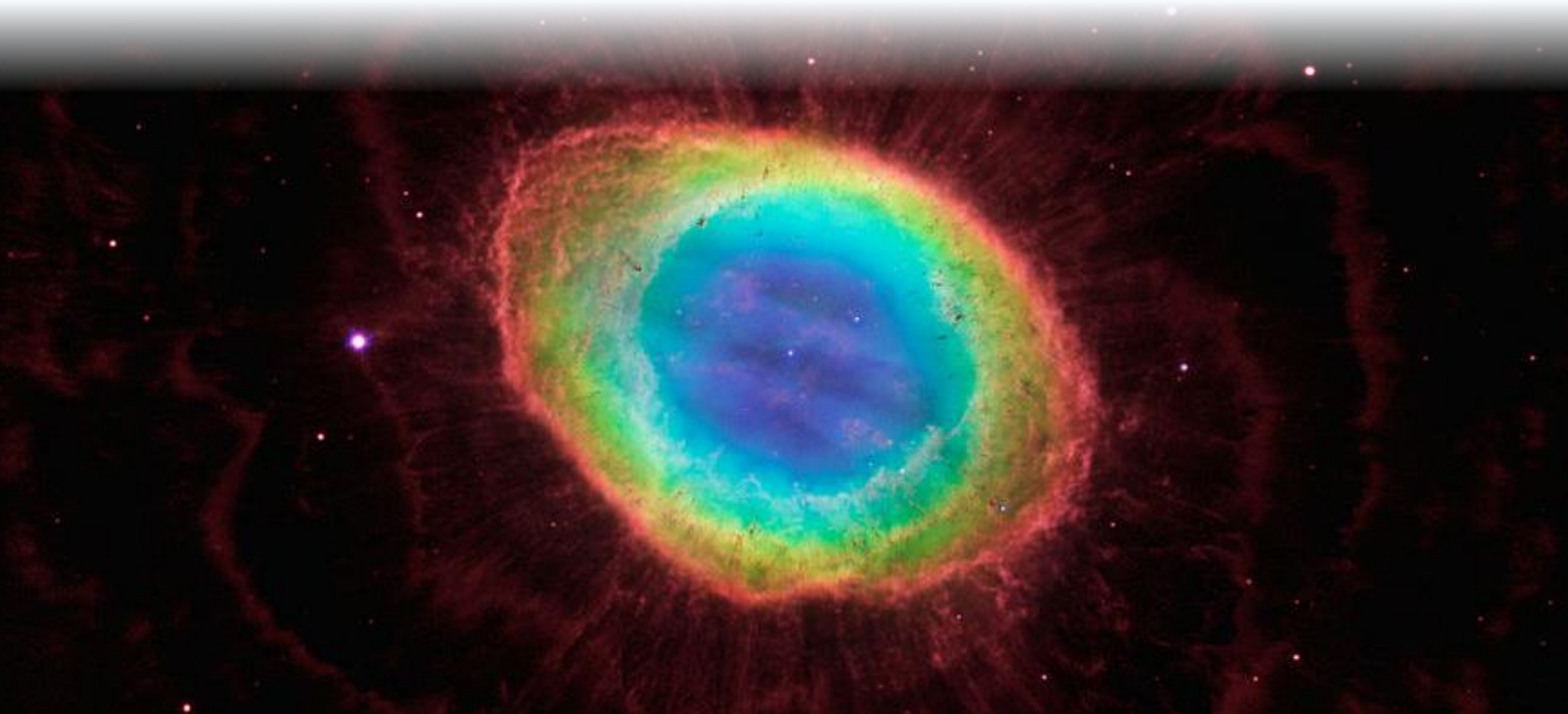
The colour of stars depend on their temperature – blue stars are hotter then red.



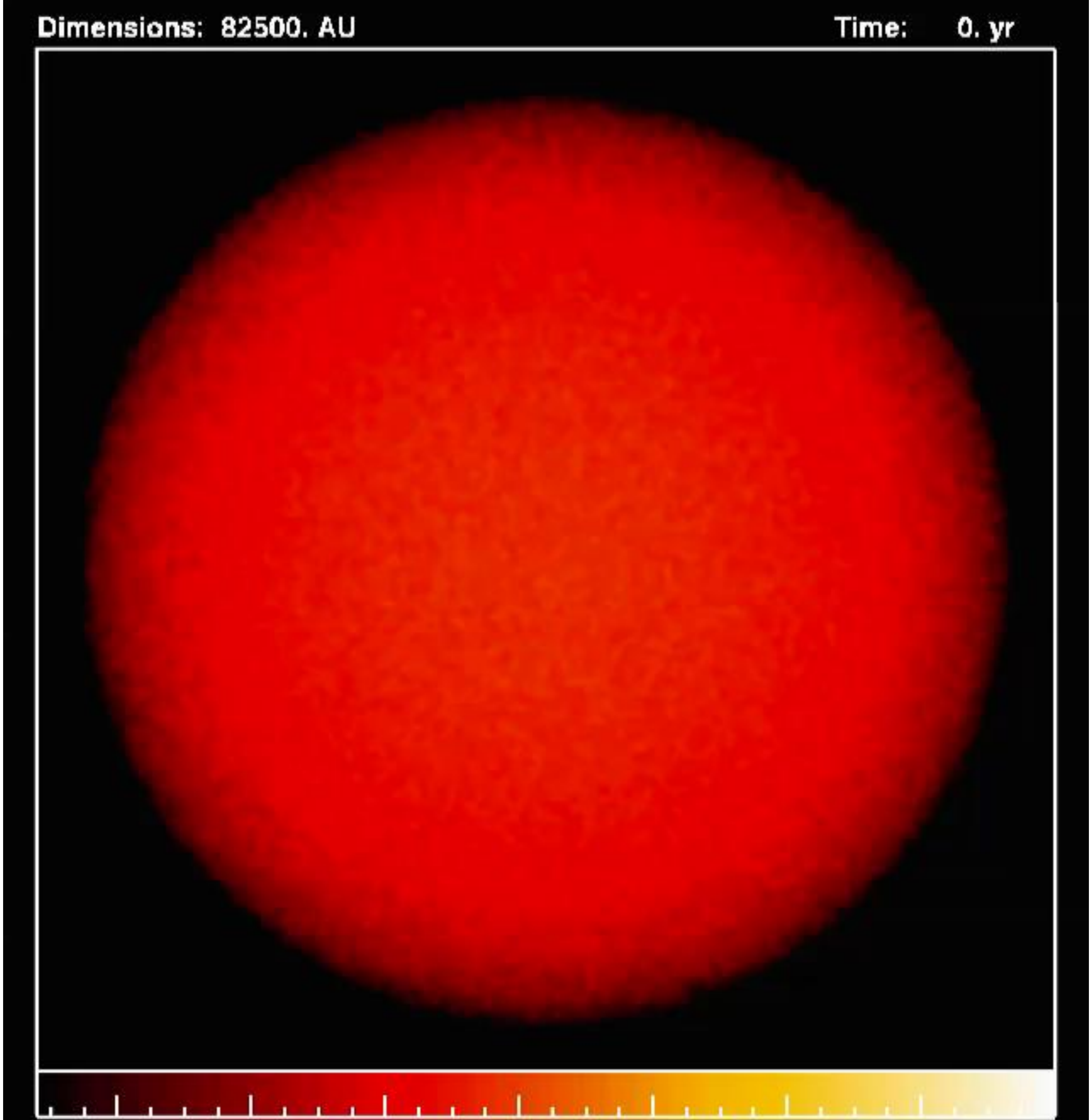
Stars don't emit a single, colour but a broad range.

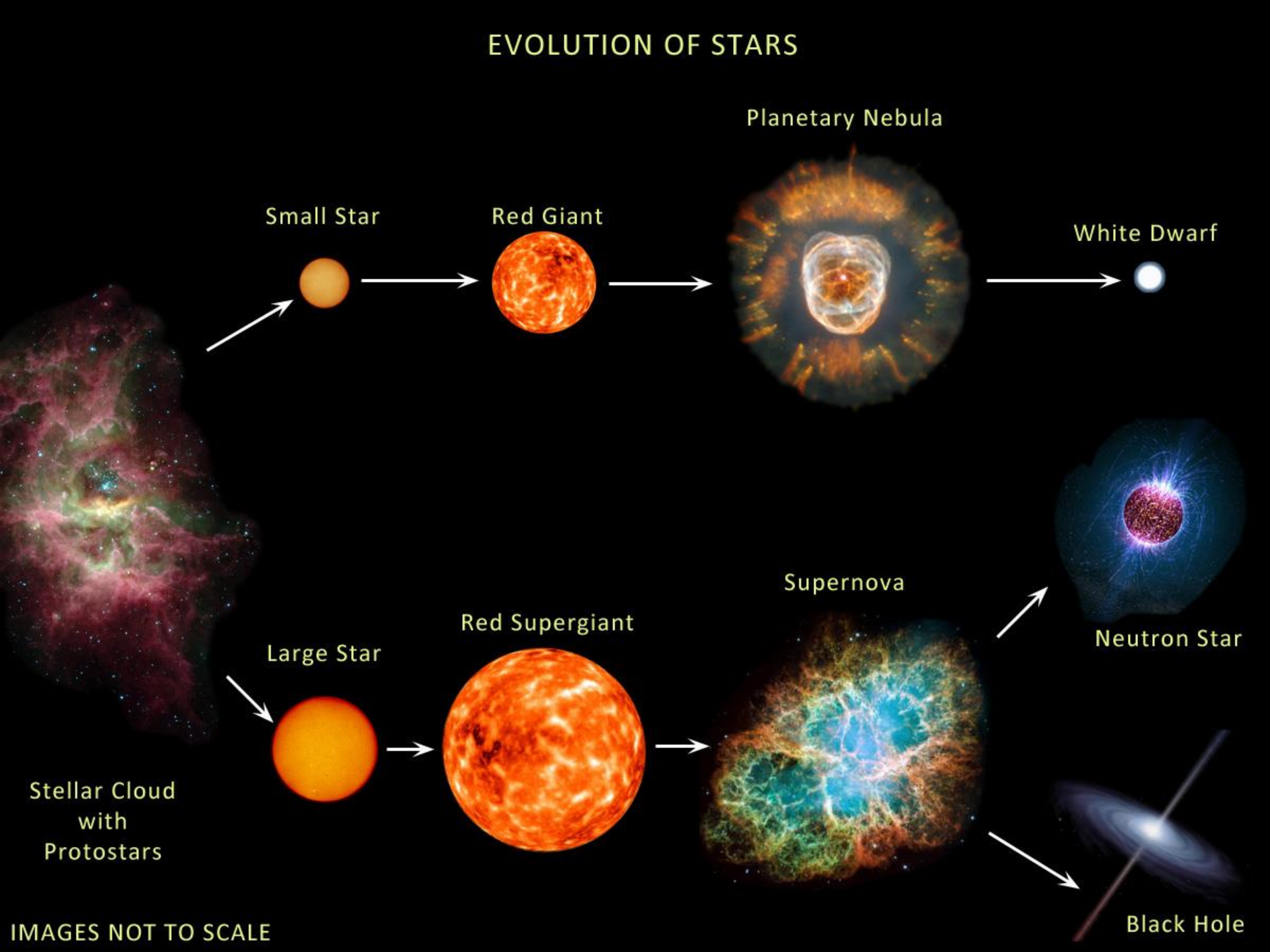
We don't see green stars as they also emit blue and red light, and so appear white

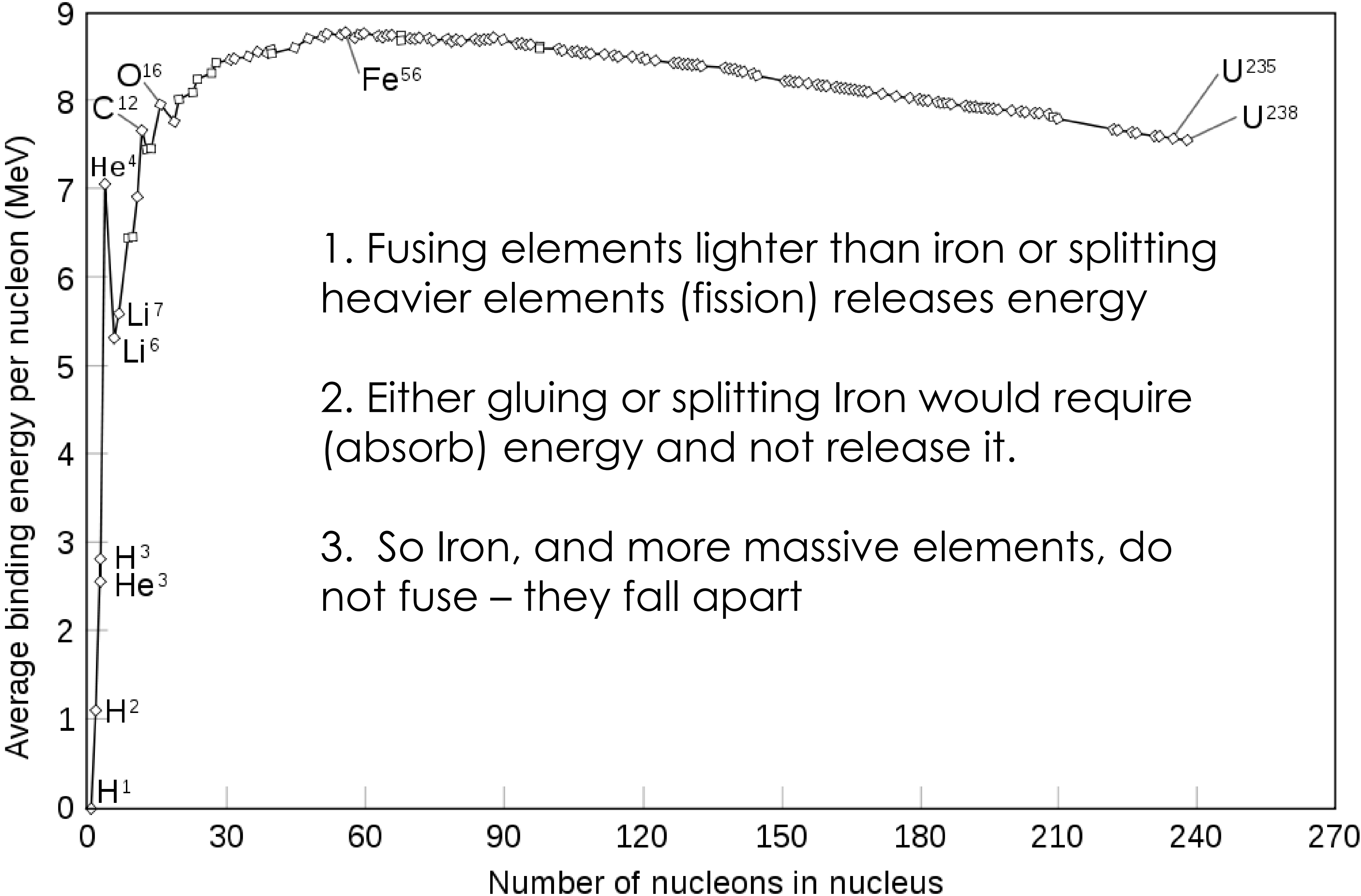
The Evolution of Stars



Computer Simulations




EVOLUTION OF STARS
Small Star
Red Giant
Planetary Nebula
White Dwarf
Stellar Cloud with Protostars
Large Star
Red Supergiant
Supernova
Neutron Star
Black Hole
IMAGES NOT TO SCALE

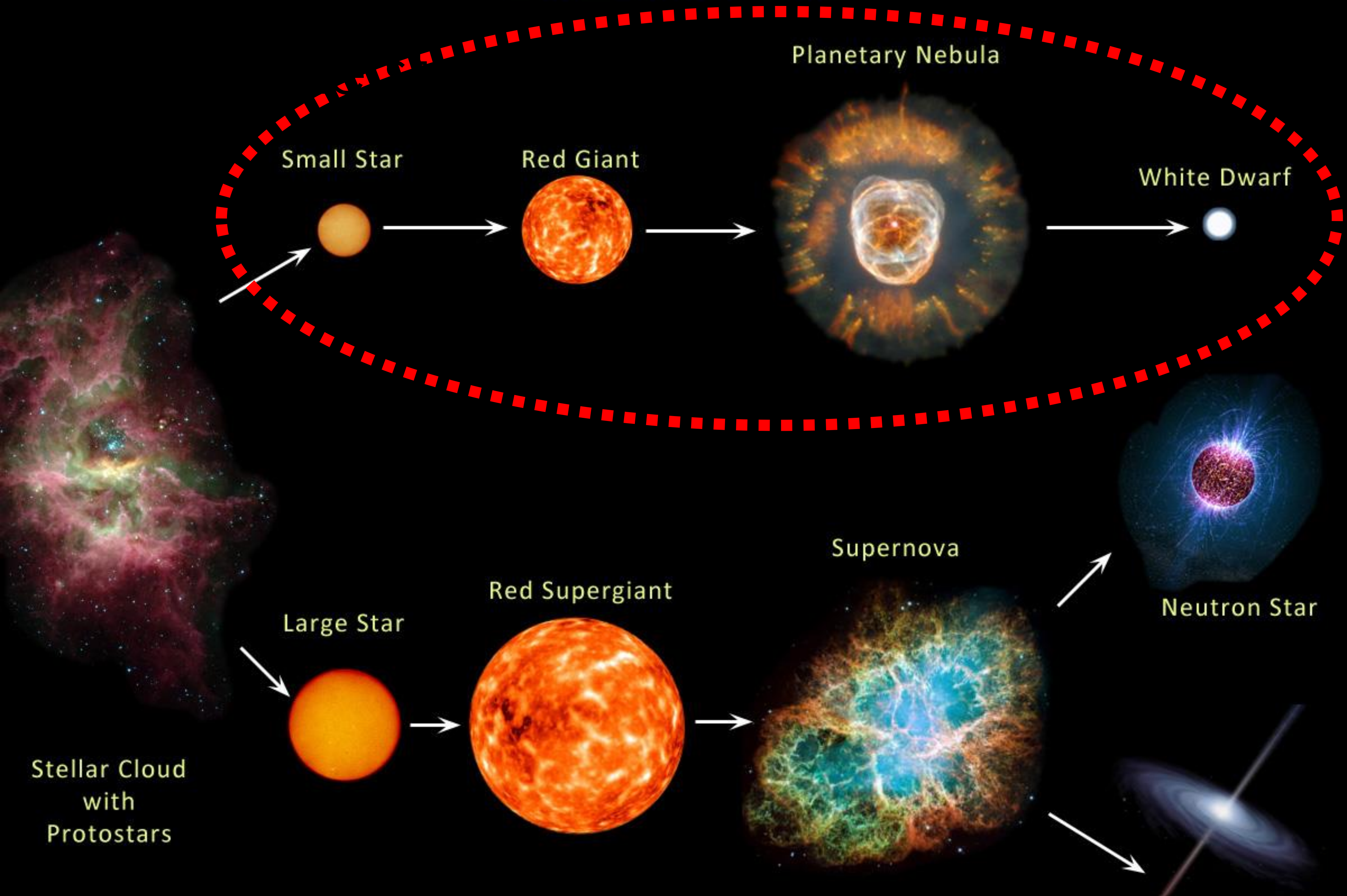


1. Fusing elements lighter than iron or splitting heavier elements (fission) releases energy

2. Either gluing or splitting Iron would require (absorb) energy and not release it.

3. So Iron, and more massive elements, do not fuse – they fall apart

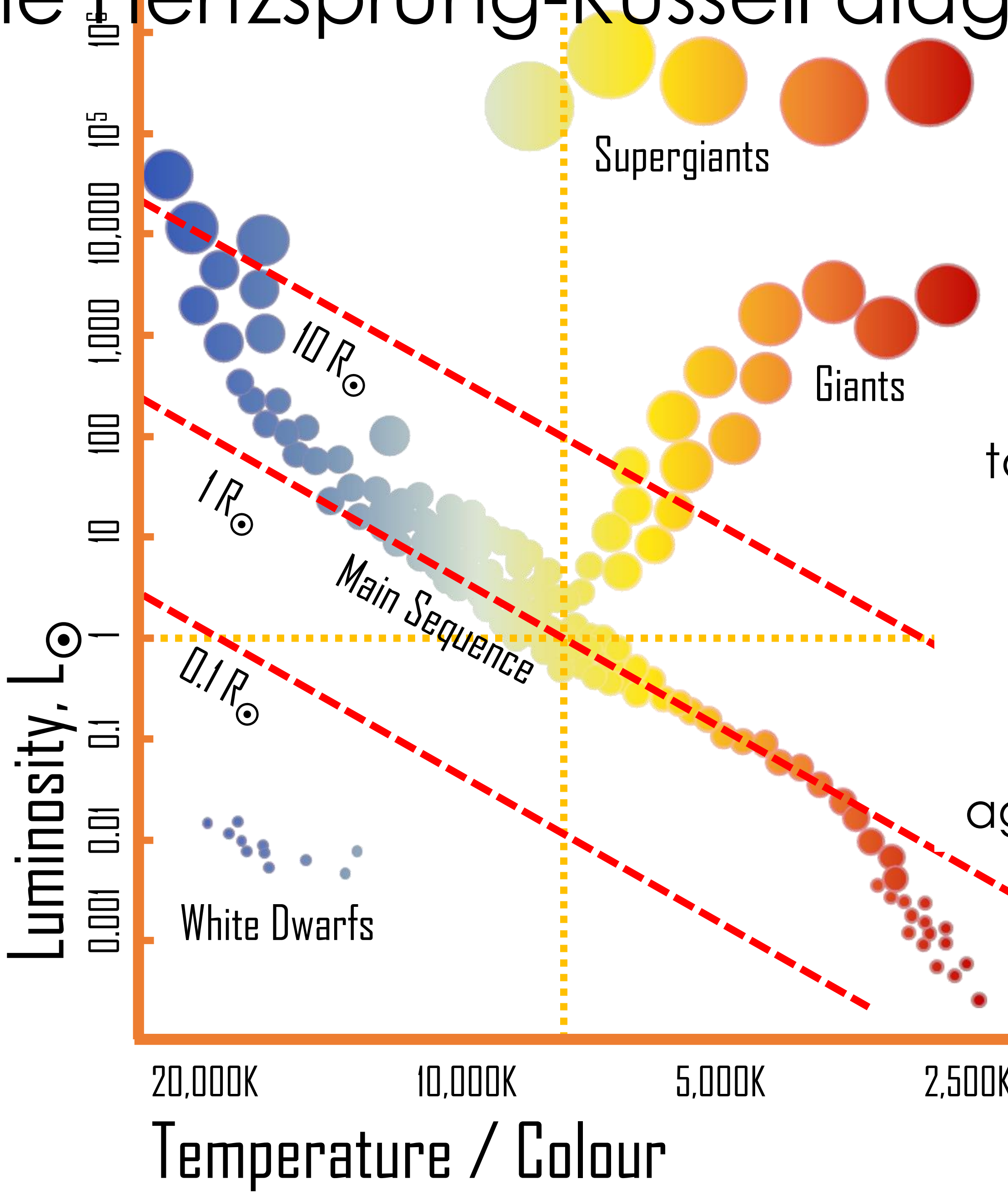
EVOLUTION OF STARS



IMAGES NOT TO SCALE

The Hertzsprung-Russell diagram

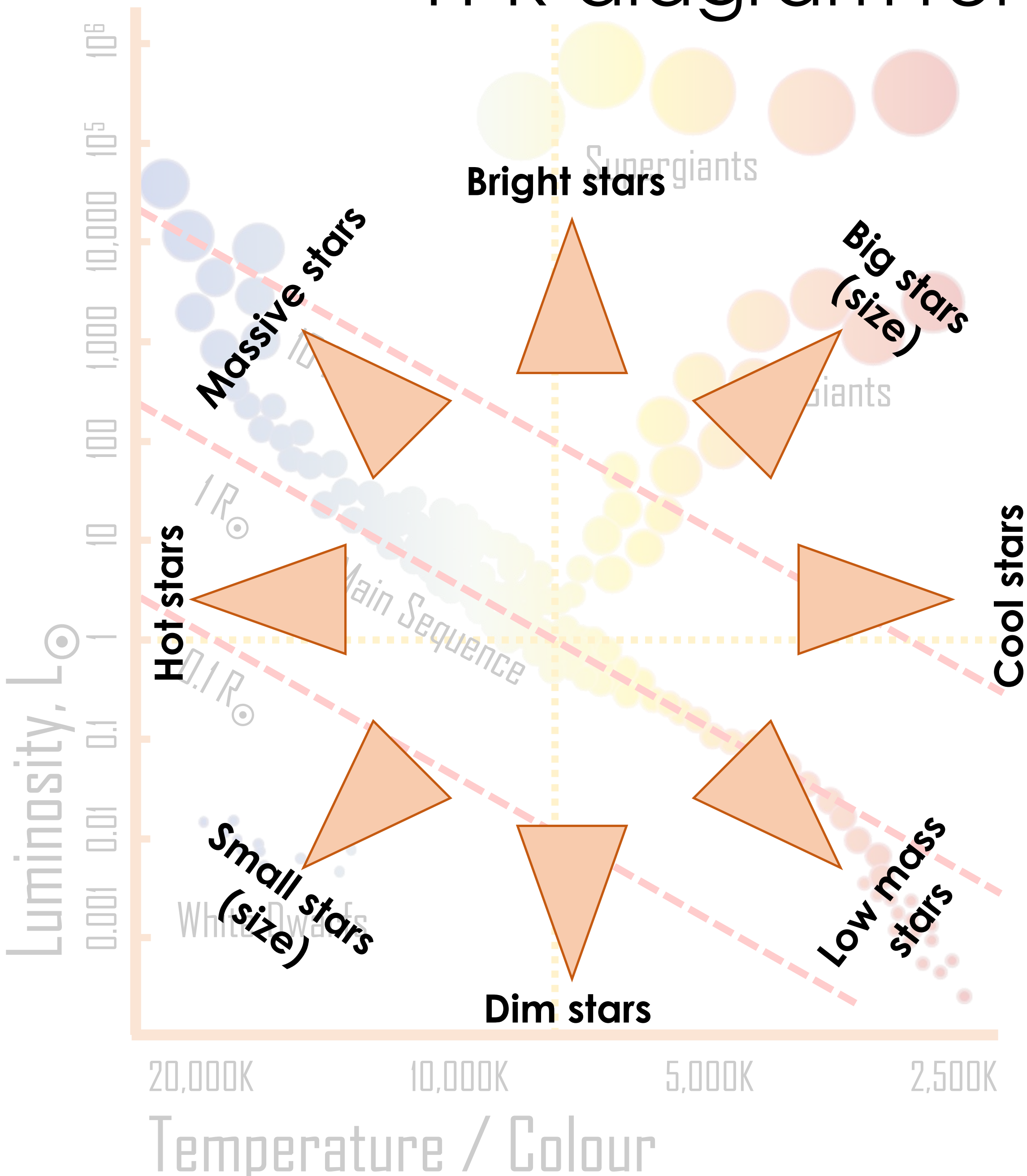
Stellar Evolution



They were trying to find patterns in the properties of stars - and stumbled into patterns when colour is plotted against luminosity!

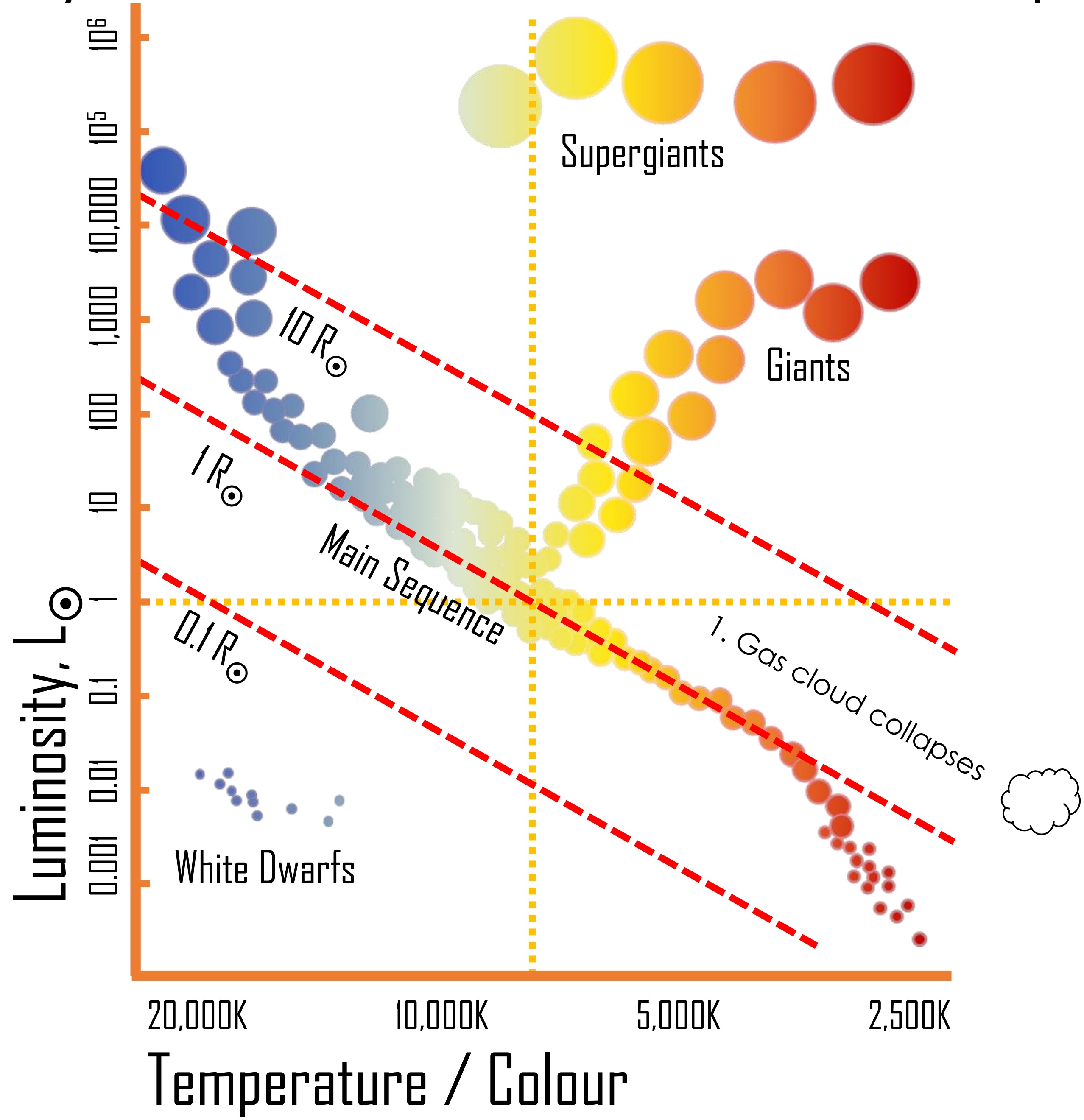
H-R diagram reminder…

H-R Diagram

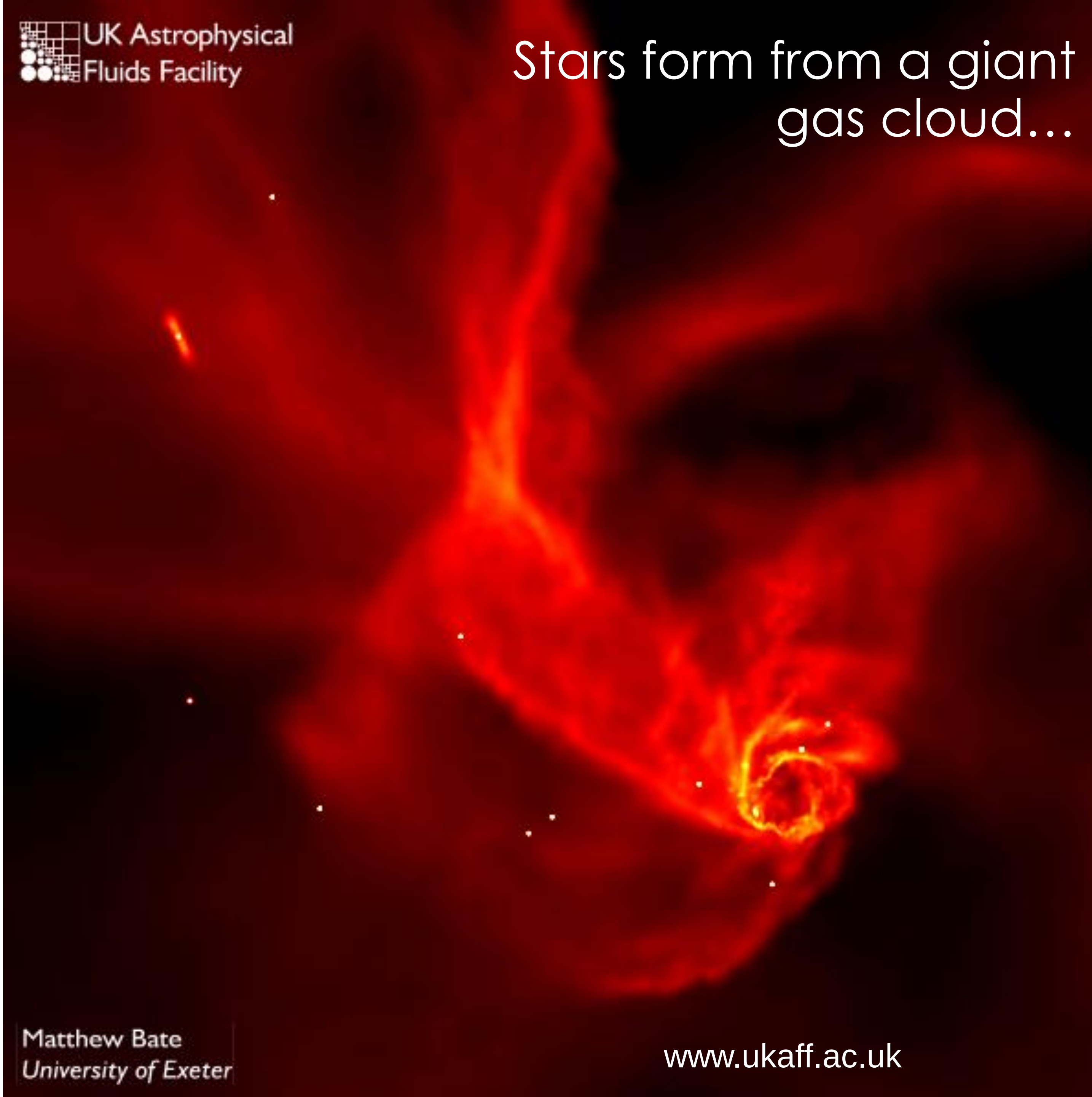


Summary of the Sun's Evolution: Step 1

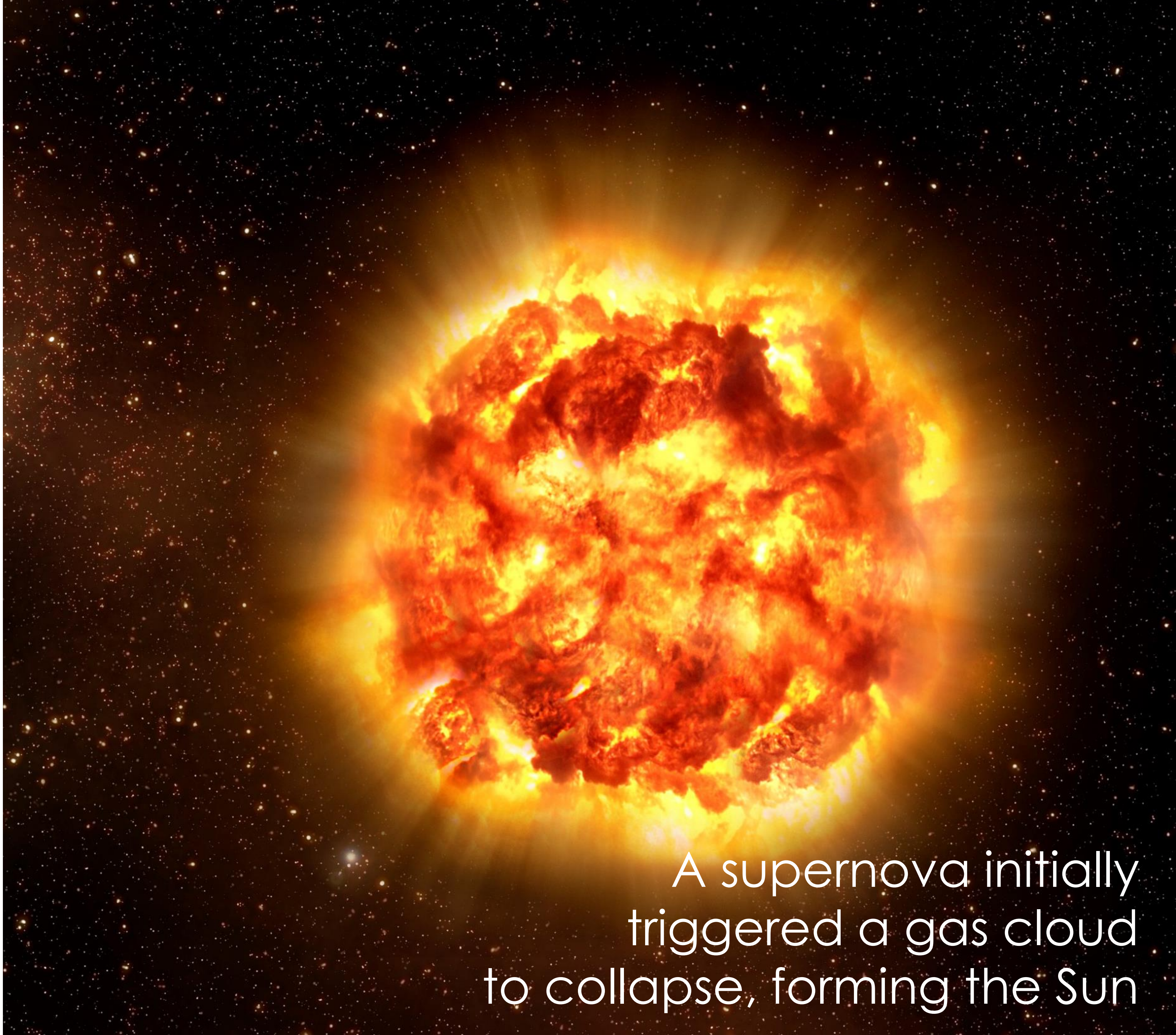
Stellar Evolution



Stellar Evolution

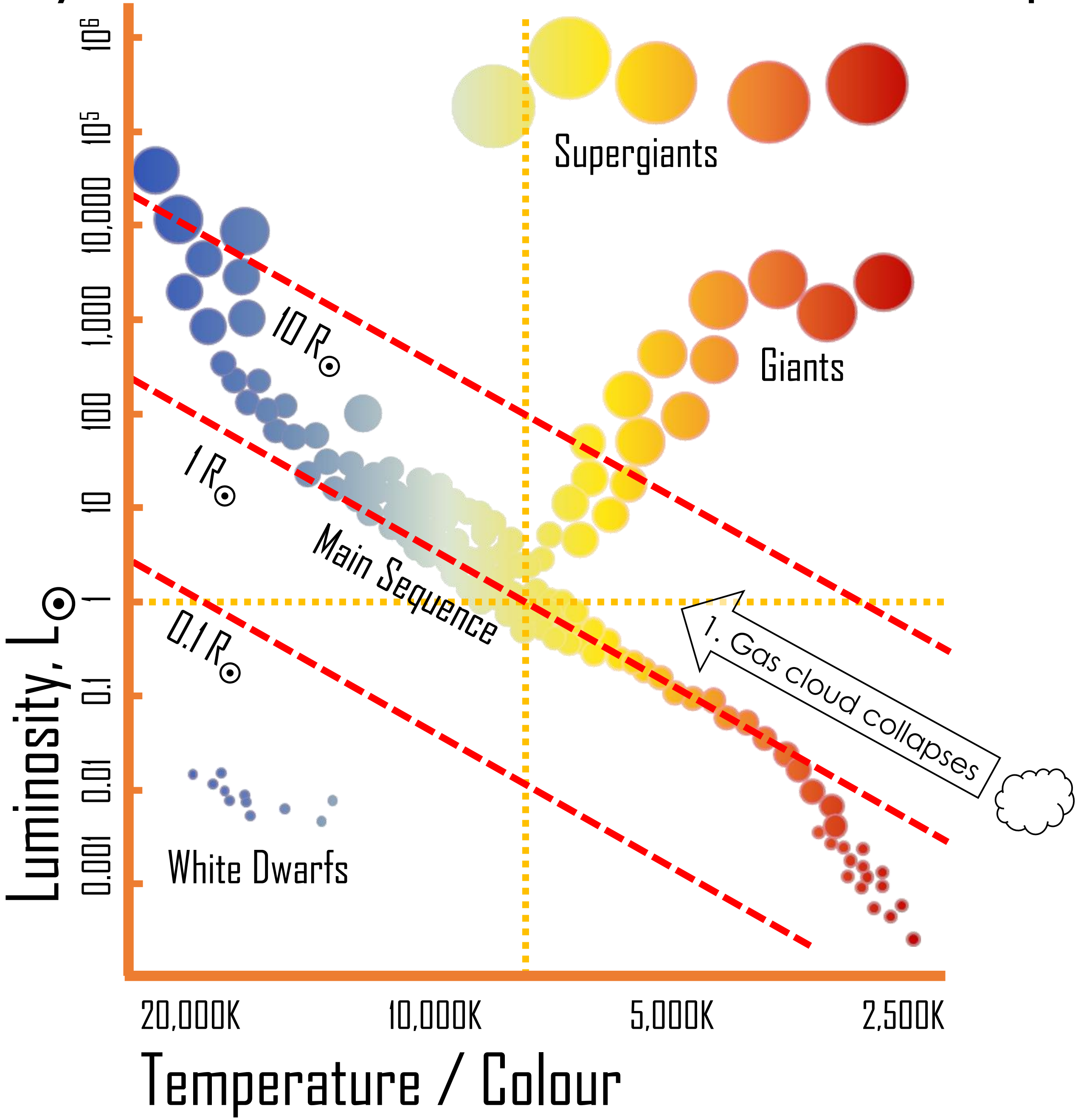


Stellar Evolution



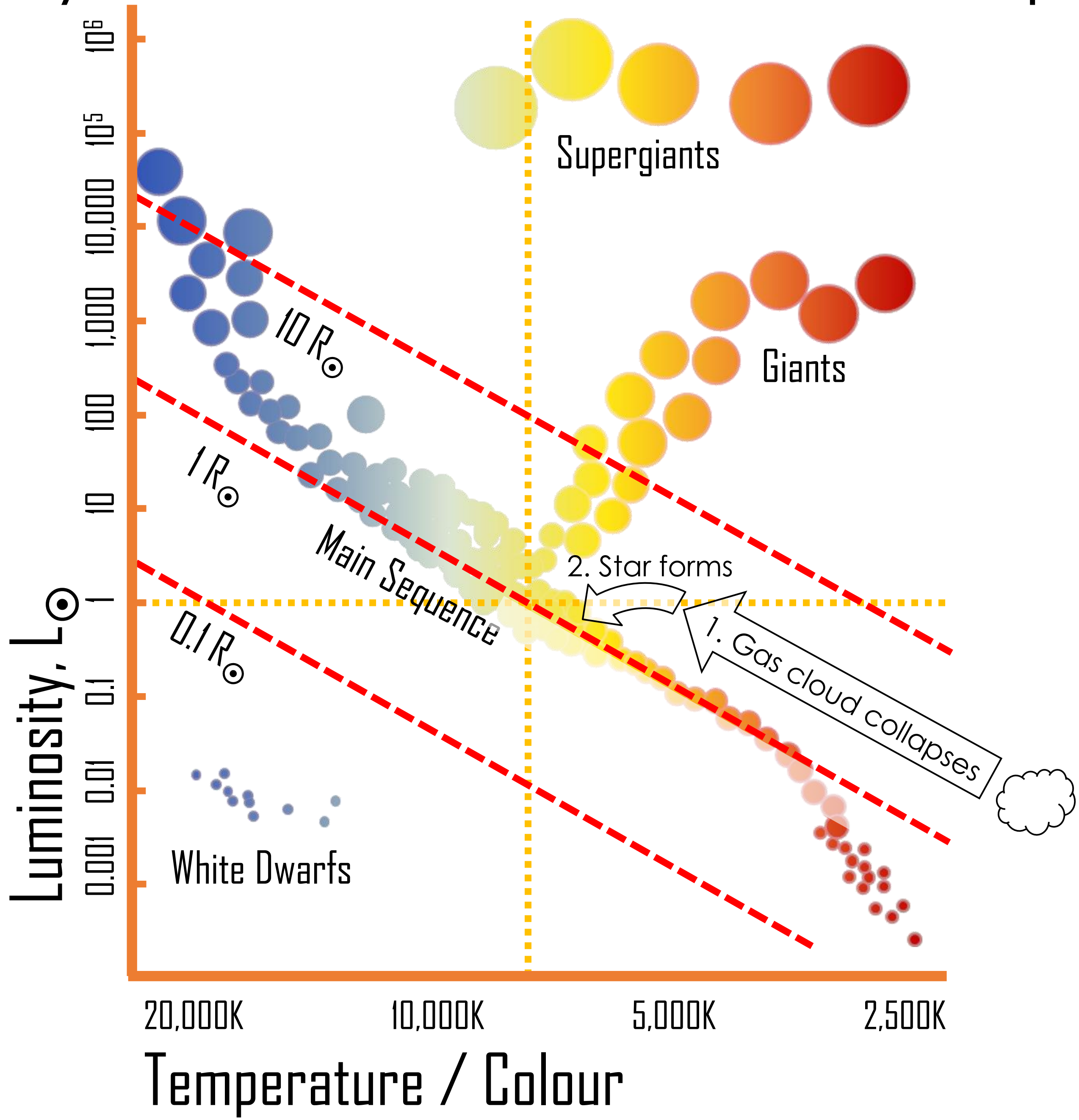
Summary of the Sun's Evolution: Step 1

Stellar Evolution



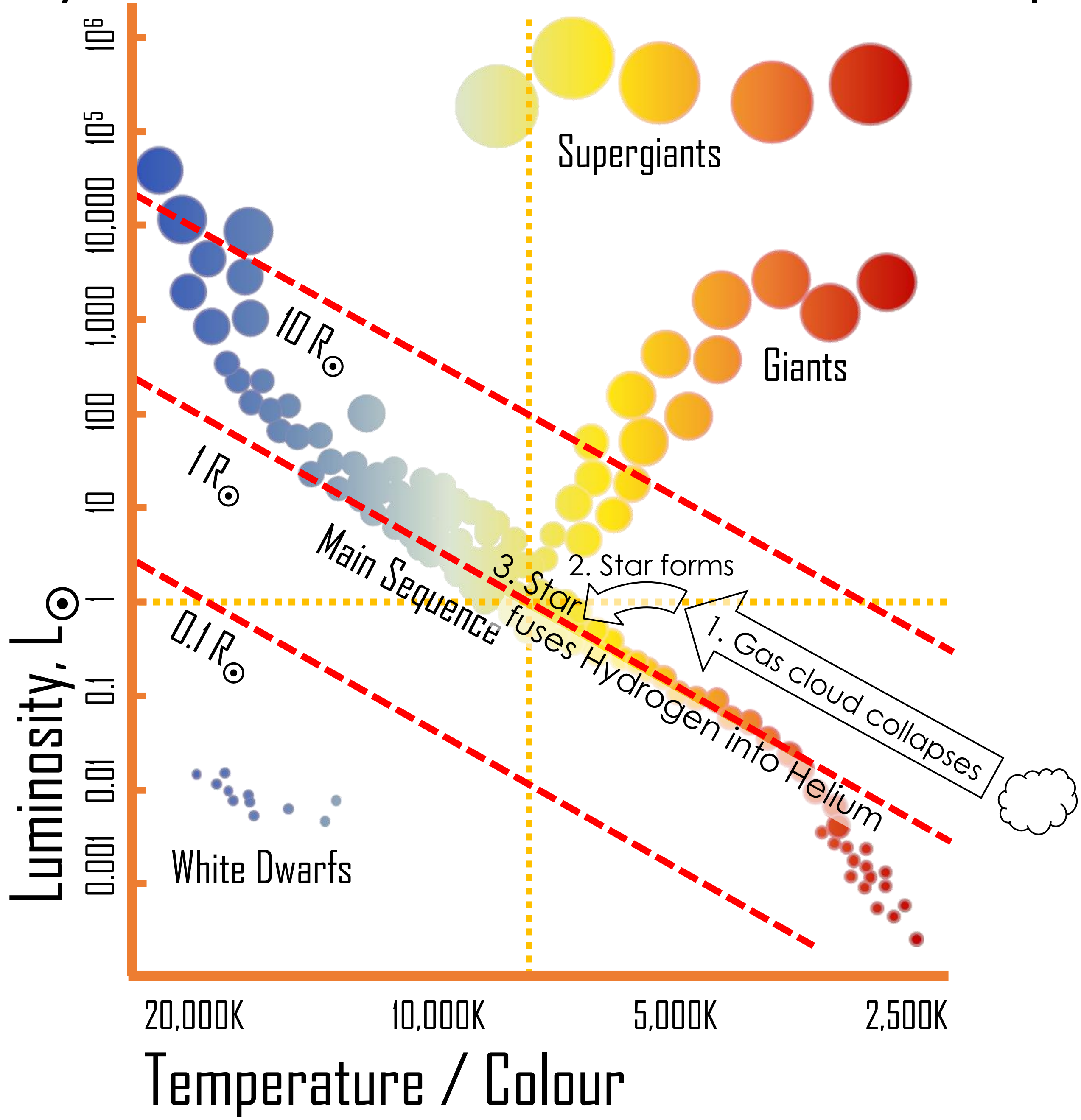
Summary of the Sun's Evolution: Step 2

Stellar Evolution



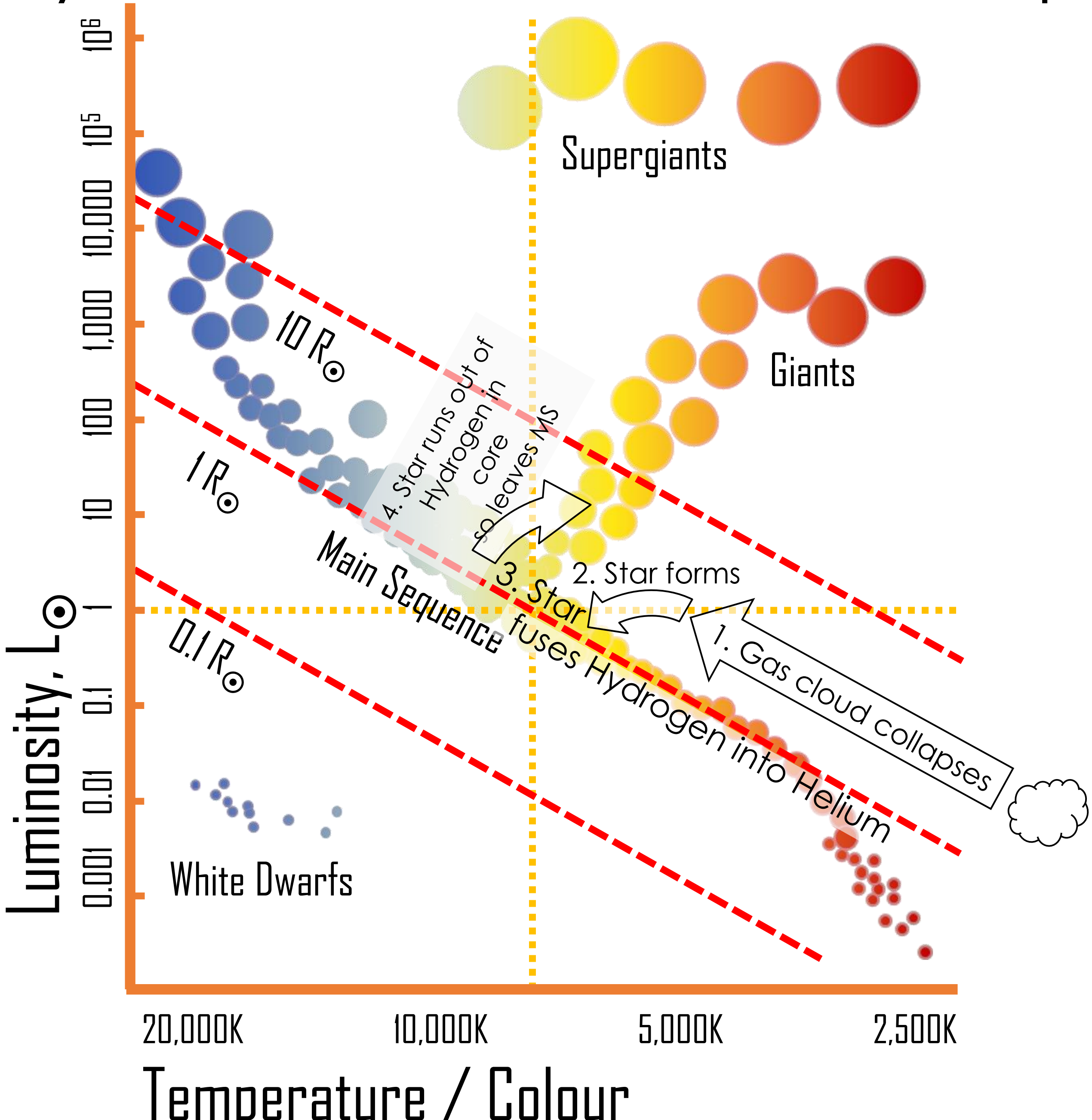
Summary of the Sun's Evolution: Step 3

Stellar Evolution



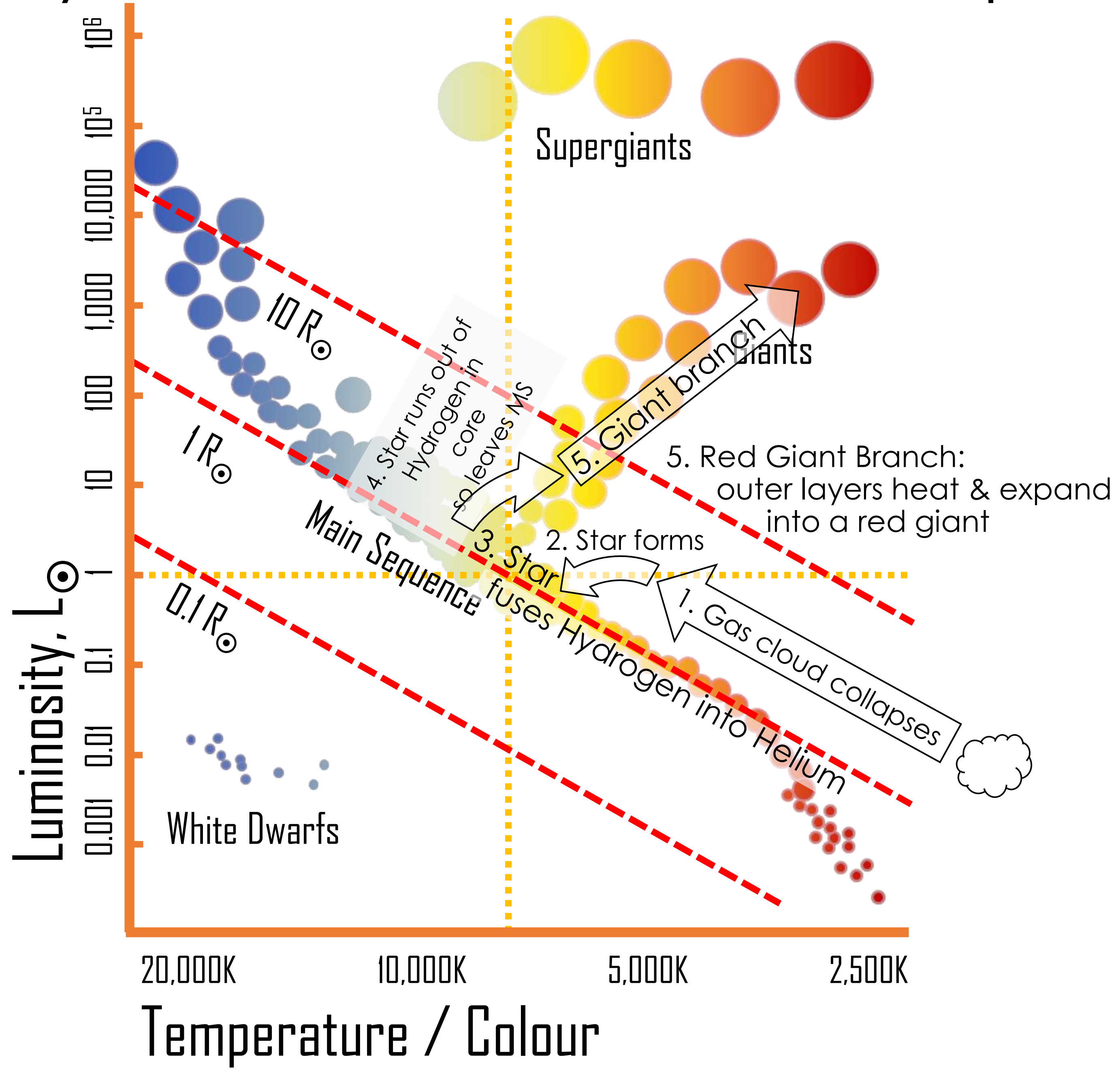
Summary of the Sun's Evolution: Step 4

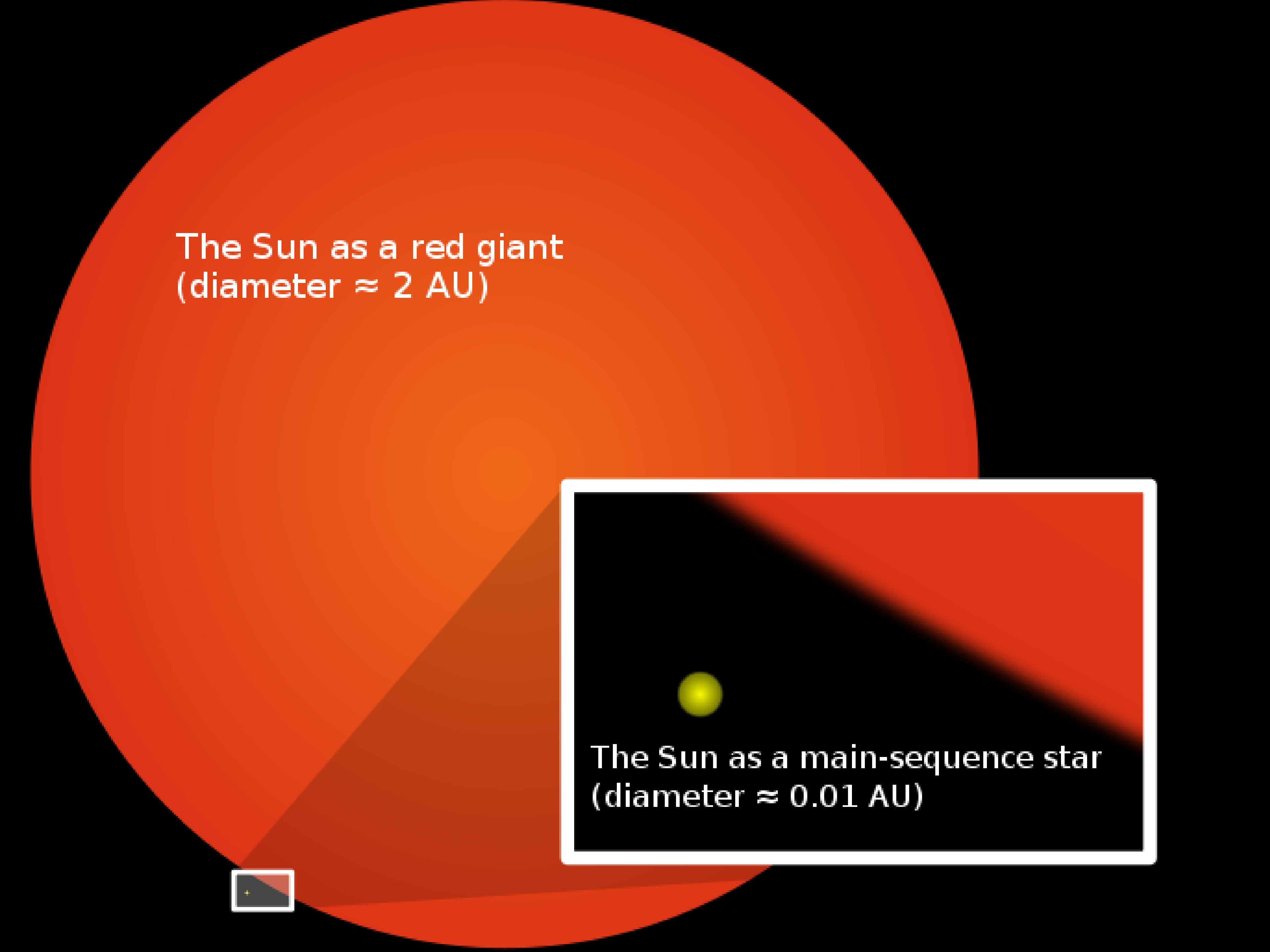
Stellar Evolution



Summary of the Sun's Evolution: Step 5

Stellar Evolution



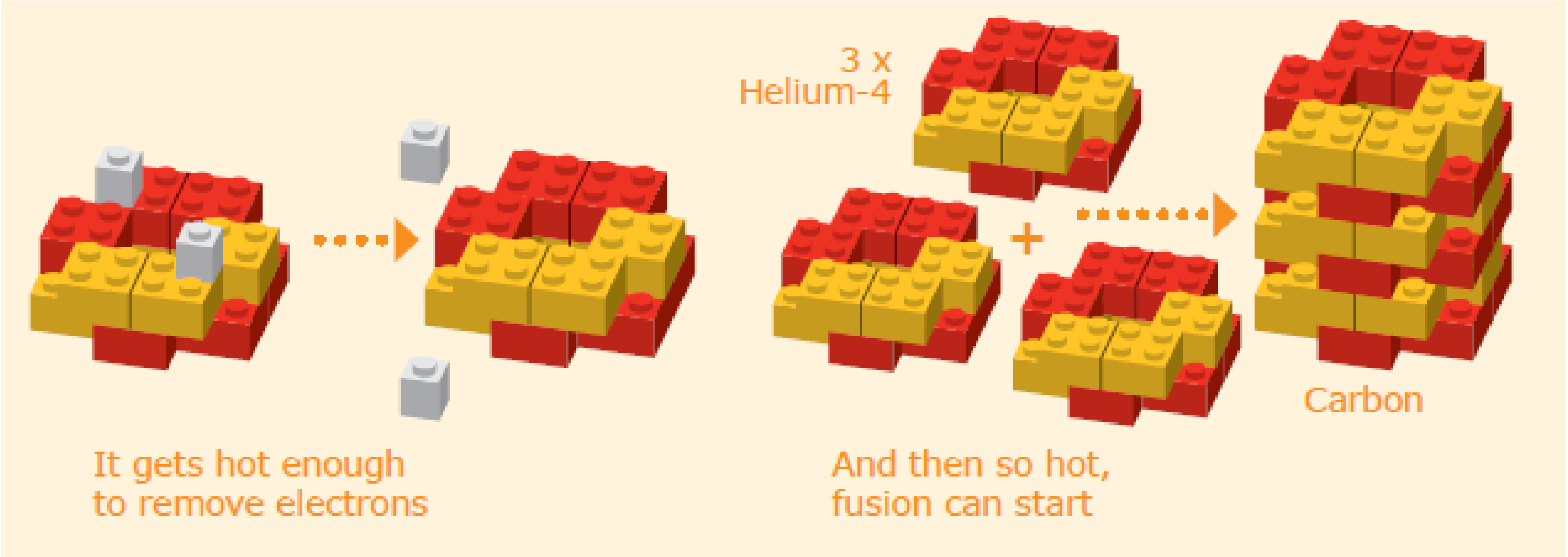

The Sun as a red giant
(diameter ≈ 2 AU)
The Sun as a main-sequence star
(diameter ≈ 0.01 AU)

Core Helium Flash

Eventually, thanks to Hydrogen burning in a shell around the core, the core temperature becomes hot enough for…

Helium to finally fuse into carbon!

This fusion heats the core allowing *even more* helium to fuse – a sudden runaway chain reaction!

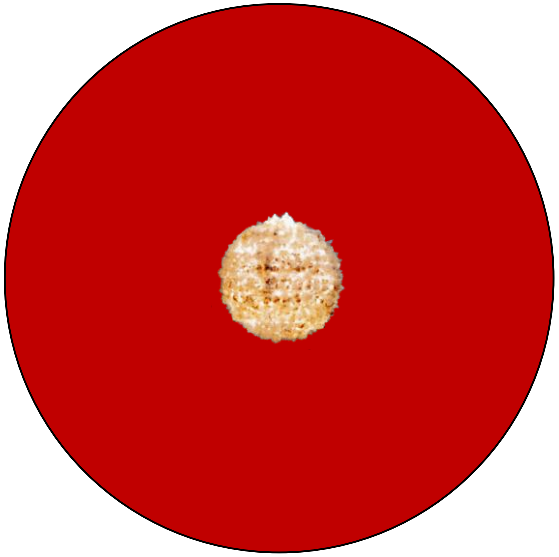


Core Helium Flash

Within *seconds*, temperature is high enough for thermal pressure to overcome gravity.

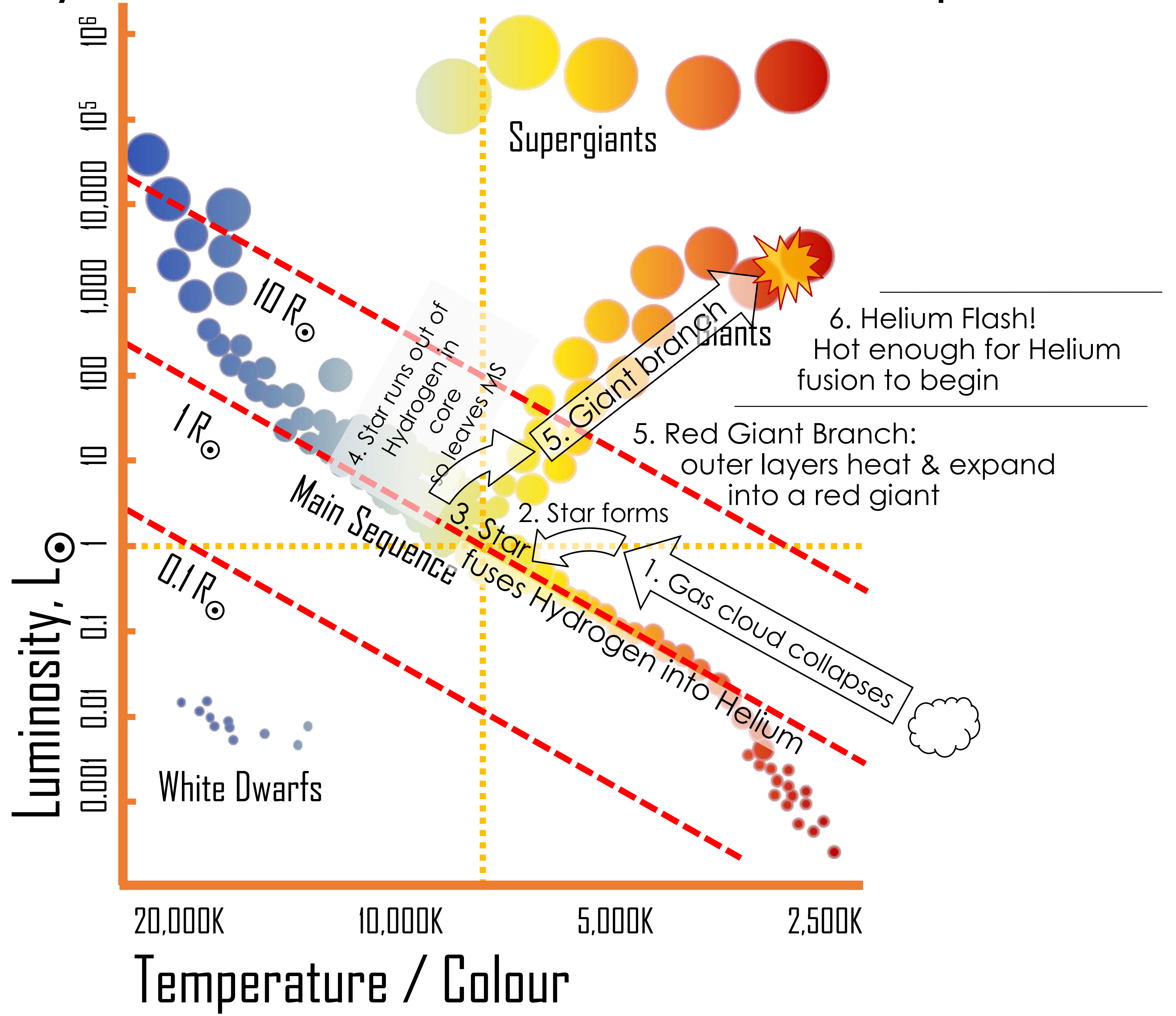
This explosion is called the *Helium flash*.

The inner layers expand, easing the core pressure & causing the nuclear reactions to slow. The star shrinks, its luminosity falls and it stabilises, turning Helium into Carbon.



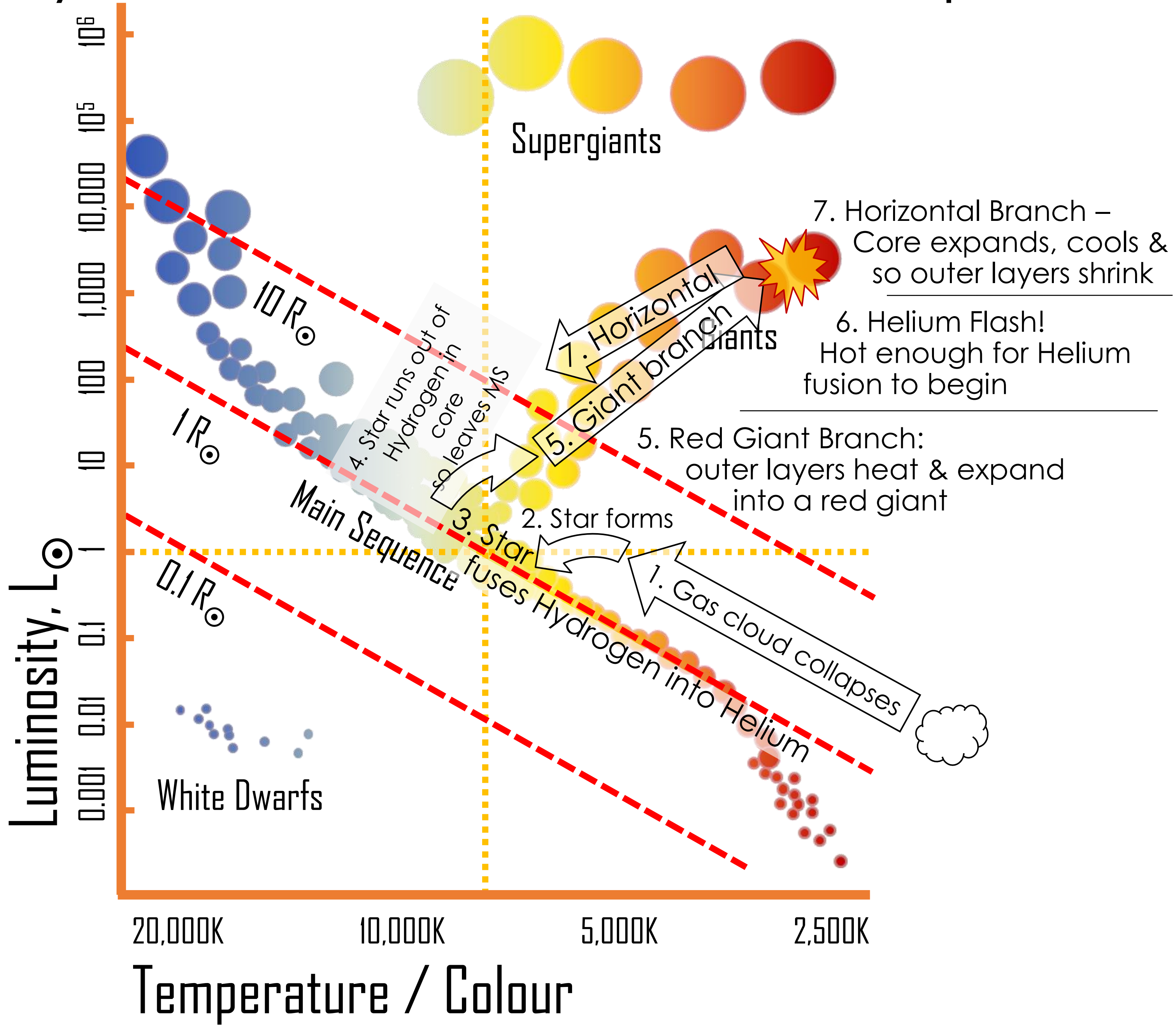
Summary of the Sun's Evolution: Step 6

Stellar Evolution



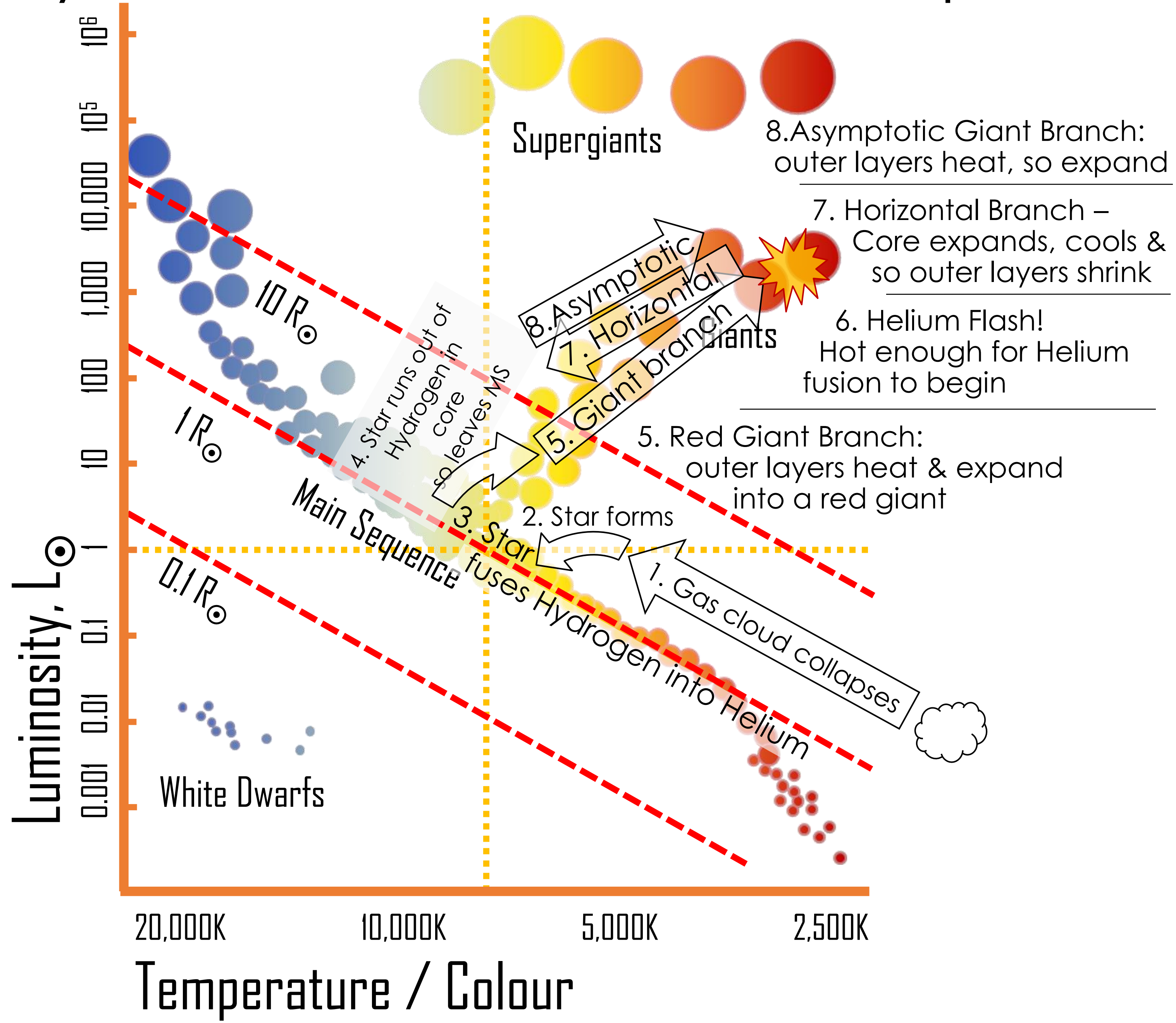
Summary of the Sun's Evolution: Step 7

Stellar Evolution



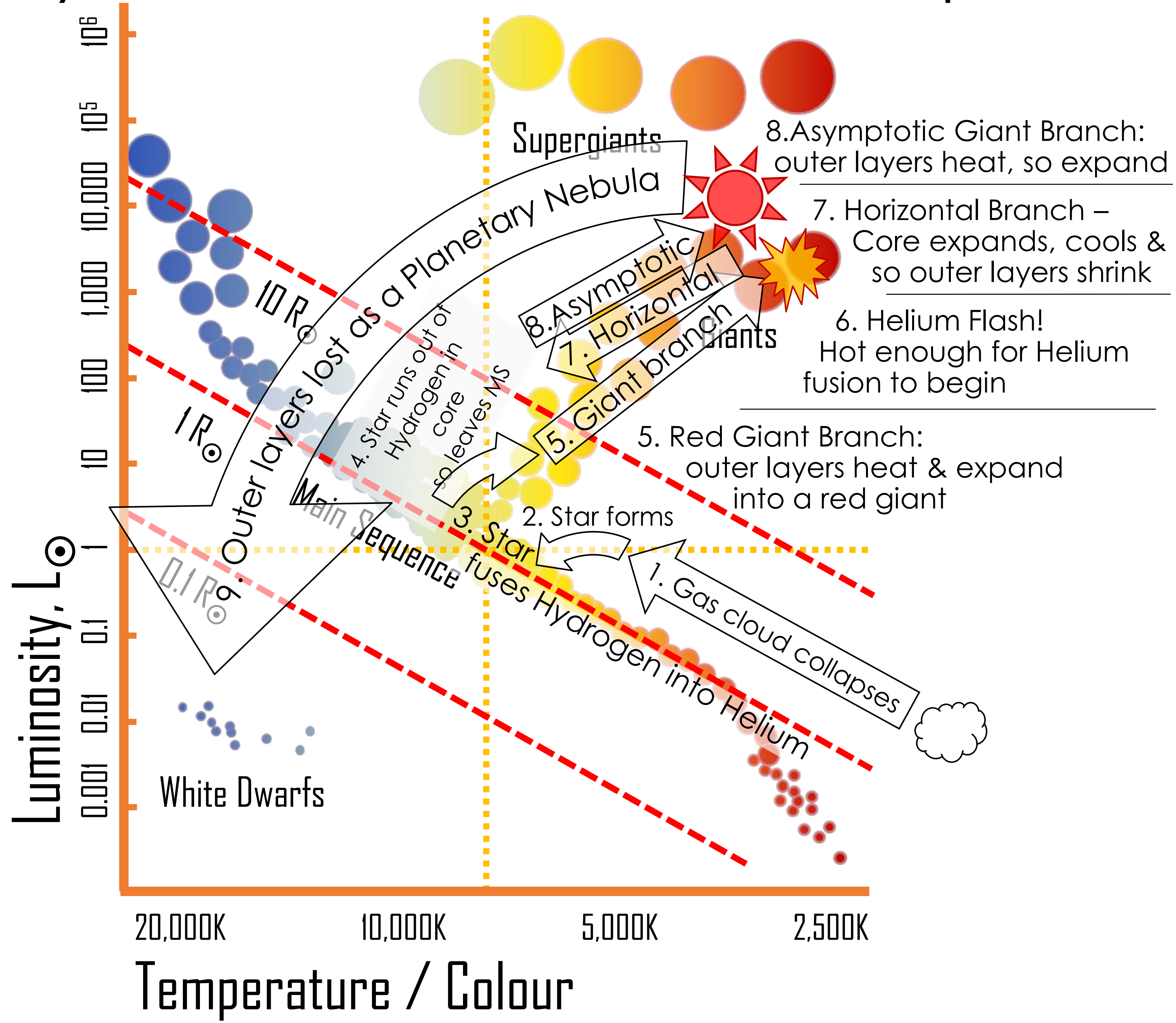
Summary of the Sun's Evolution: Step 8

Stellar Evolution



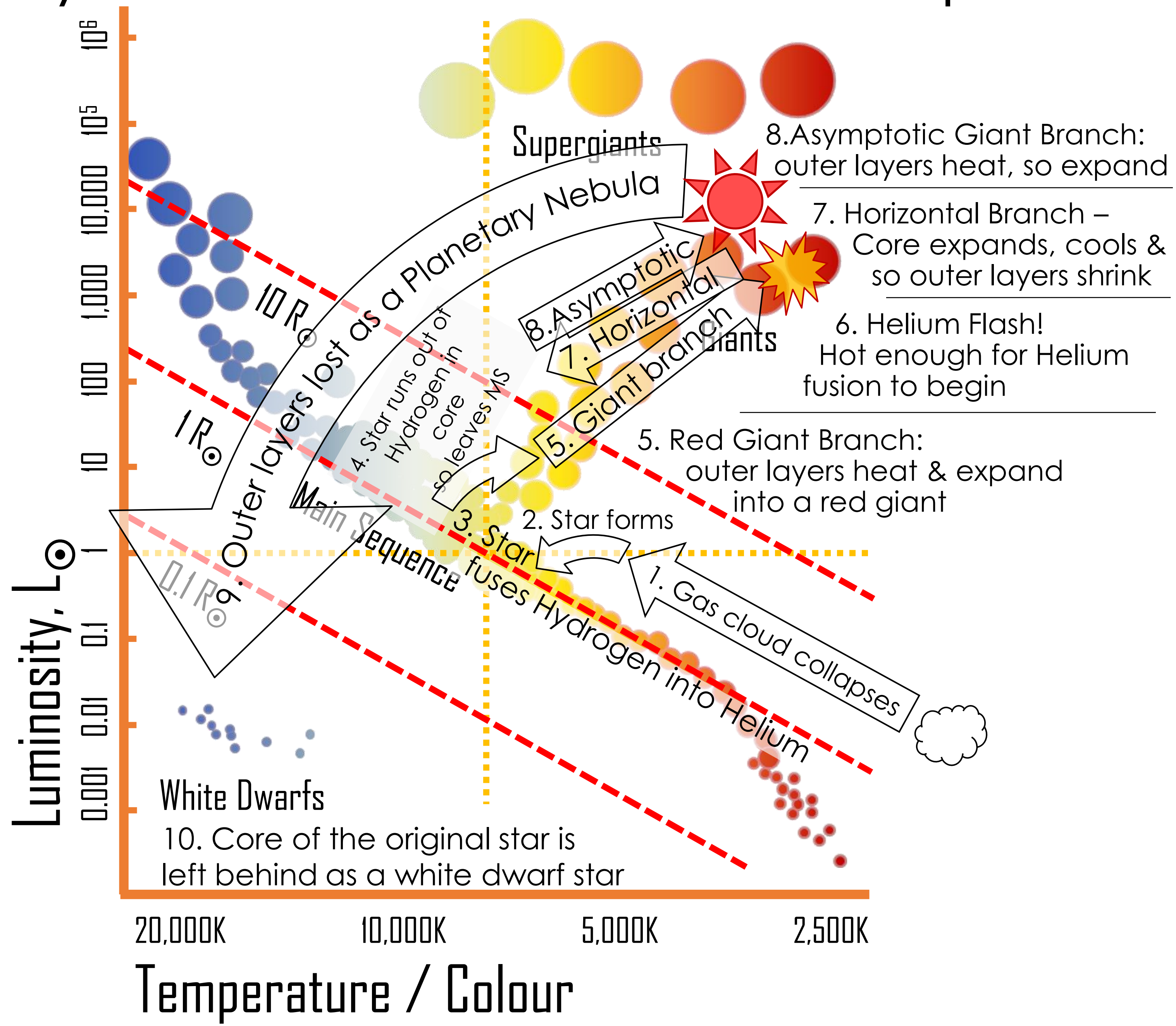
Summary of the Sun's Evolution: Step 9

Stellar Evolution



Summary of the Sun's Evolution: Step 10

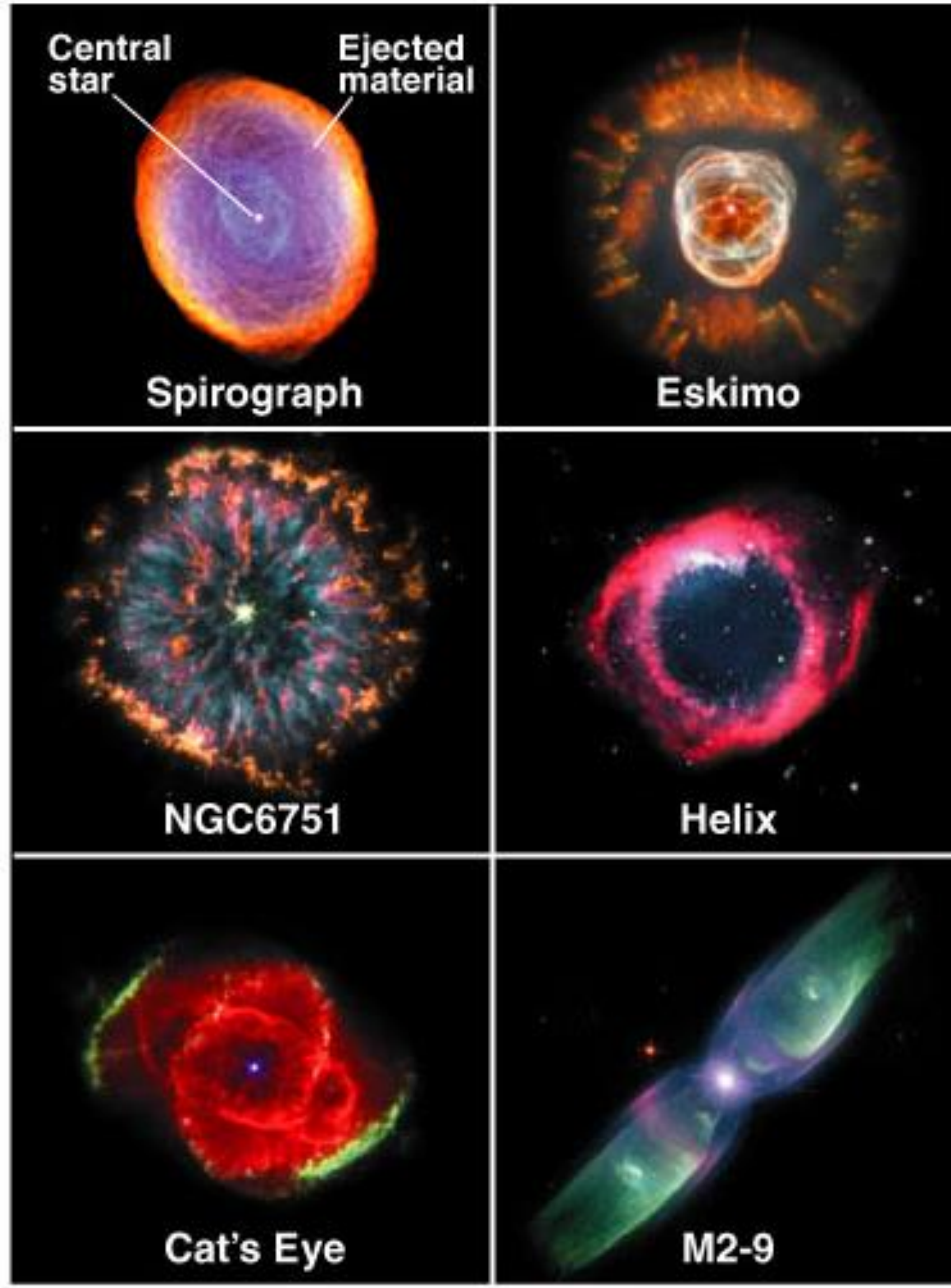
Stellar Evolution



Planetary Nebula

The core temperatures never get hot enough for carbon to fuse, and so AGB stars lose their outer layers as a spectacular planetary nebula.

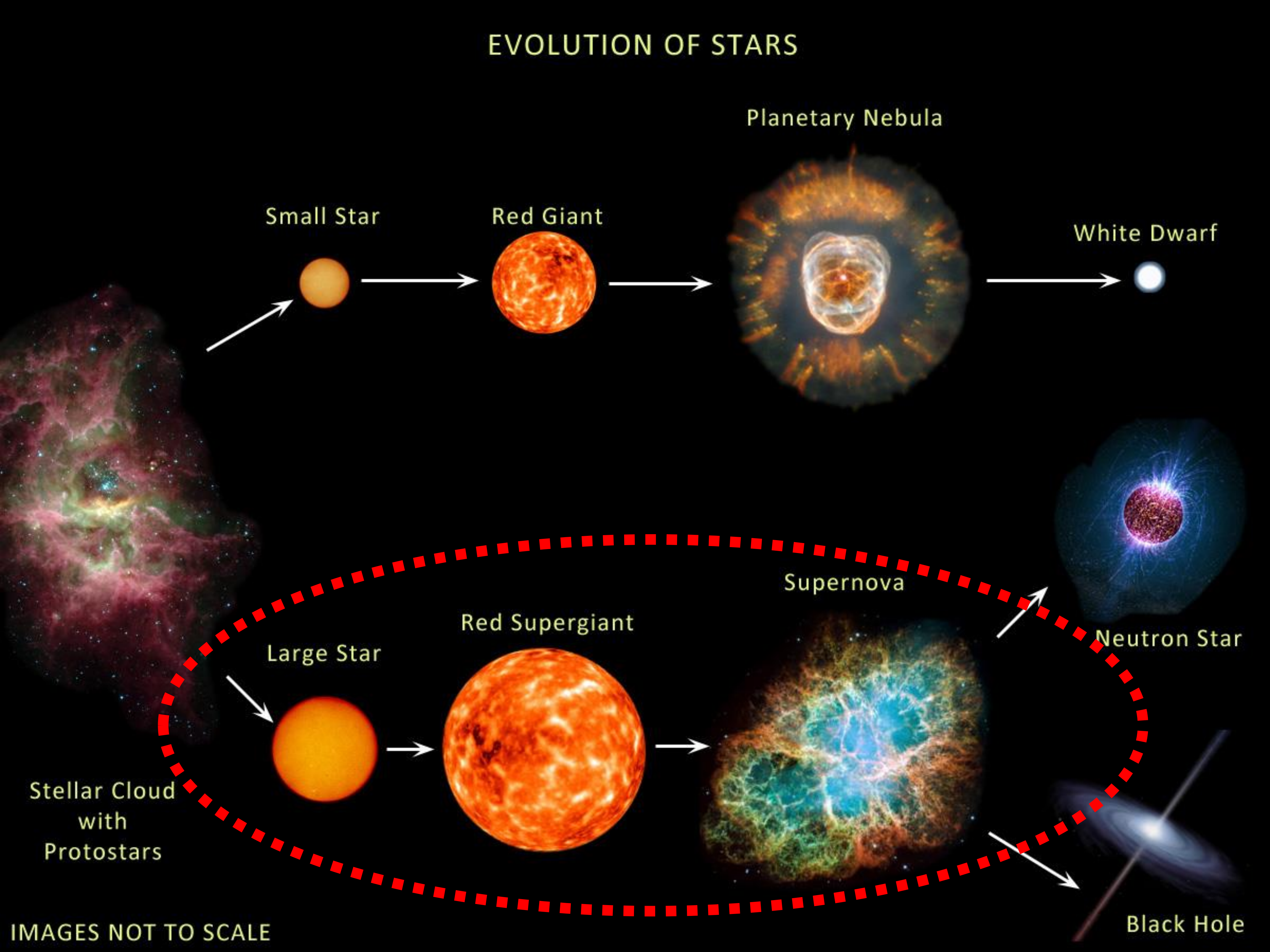
Planetary nebulae are so-called because they look like planets when seen through small telescopes



White Dwarf Stars

The remnant left behind is called a white dwarf star

A white dwarf star typically has about the same mass as our Sun, but packed into a volume no bigger than that of the Earth.


EVOLUTION OF STARS
Planetary Nebula
Small Star
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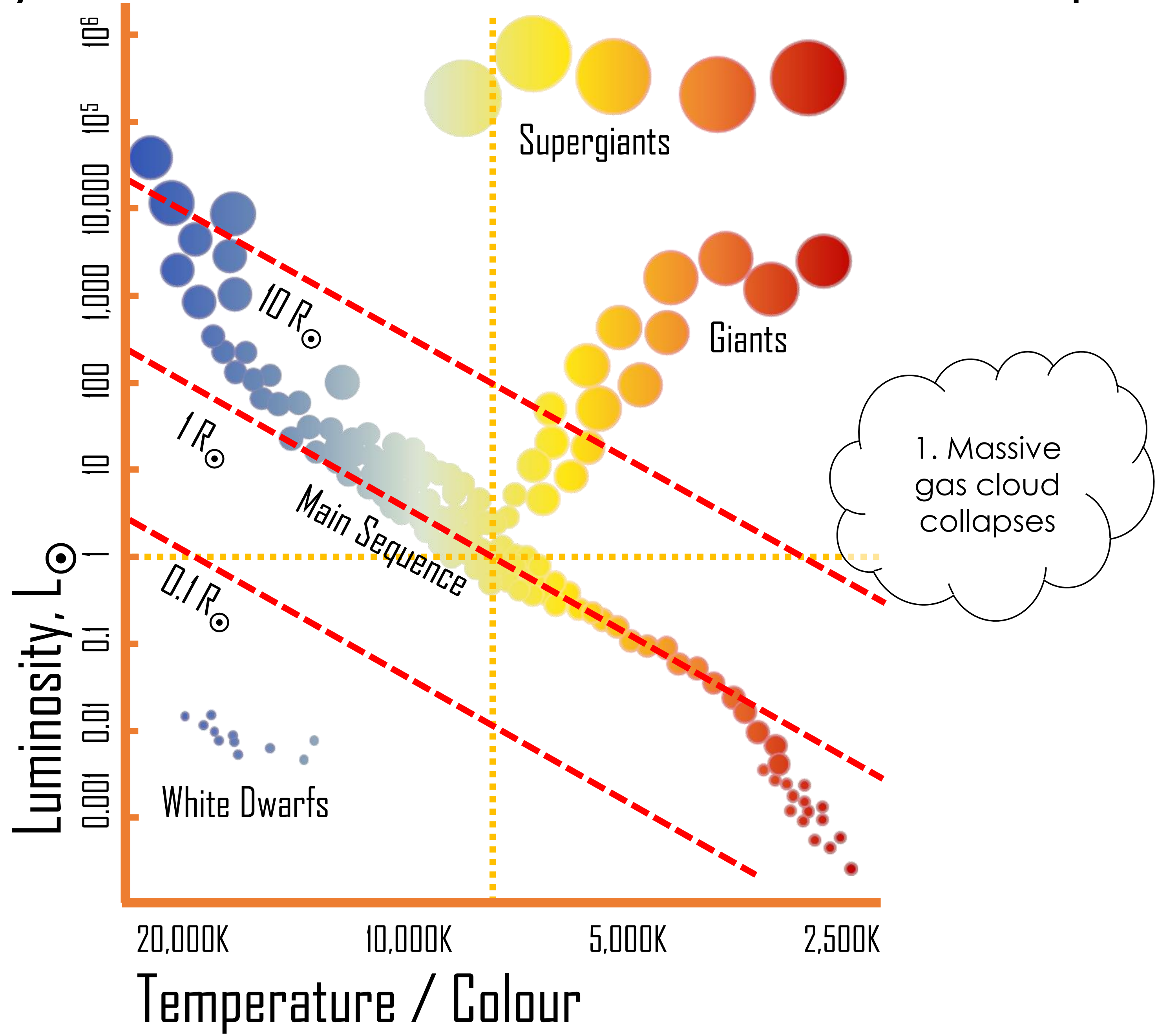
White Dwarf
Supernova
Neutron Star
Red Supergiant
Large Star
Stellar Cloud
with
Protostars
Black Hole
IMAGES NOT TO SCALE

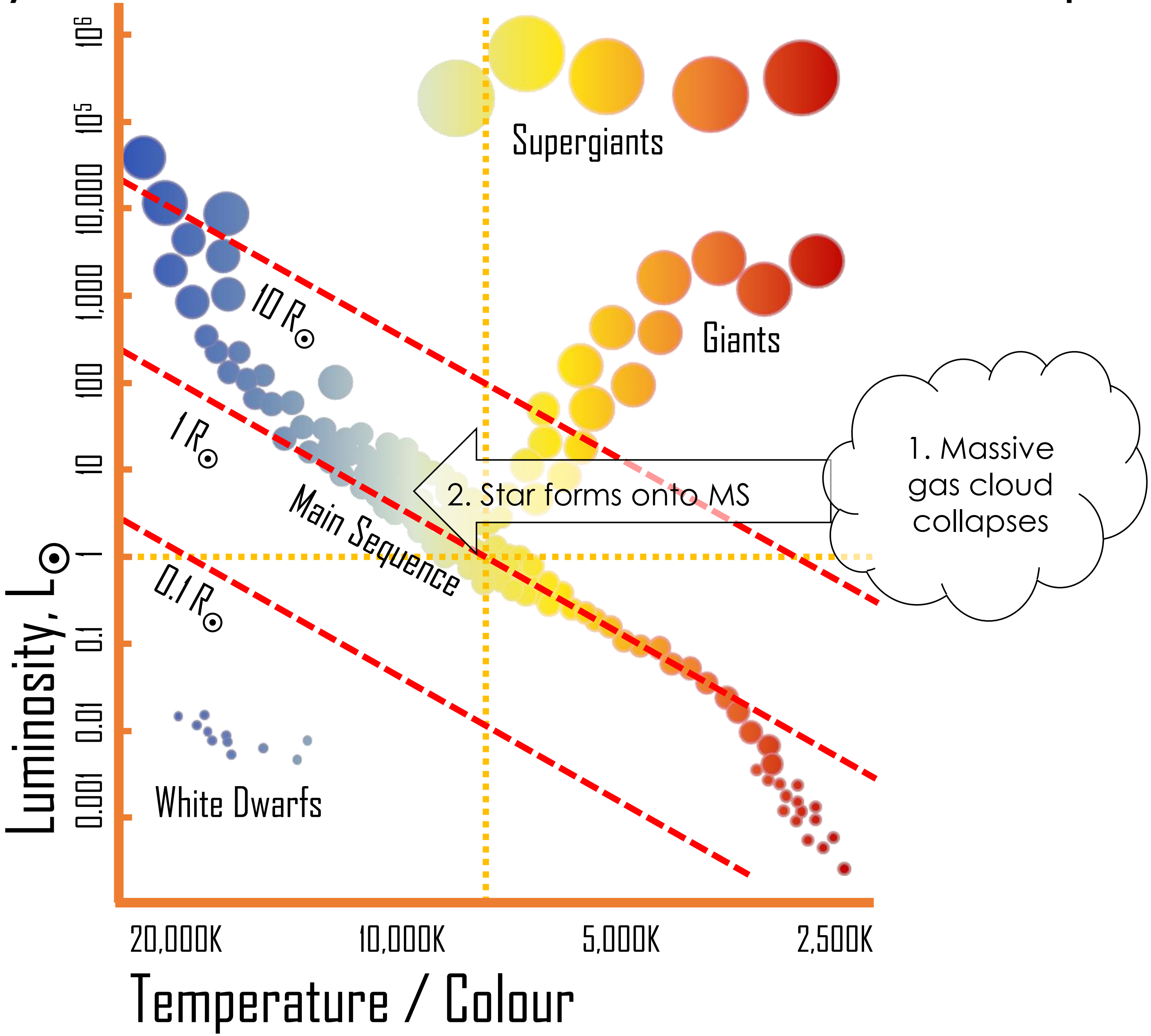
Summary of massive Star's Evolution: Step 1

Stellar Evolution



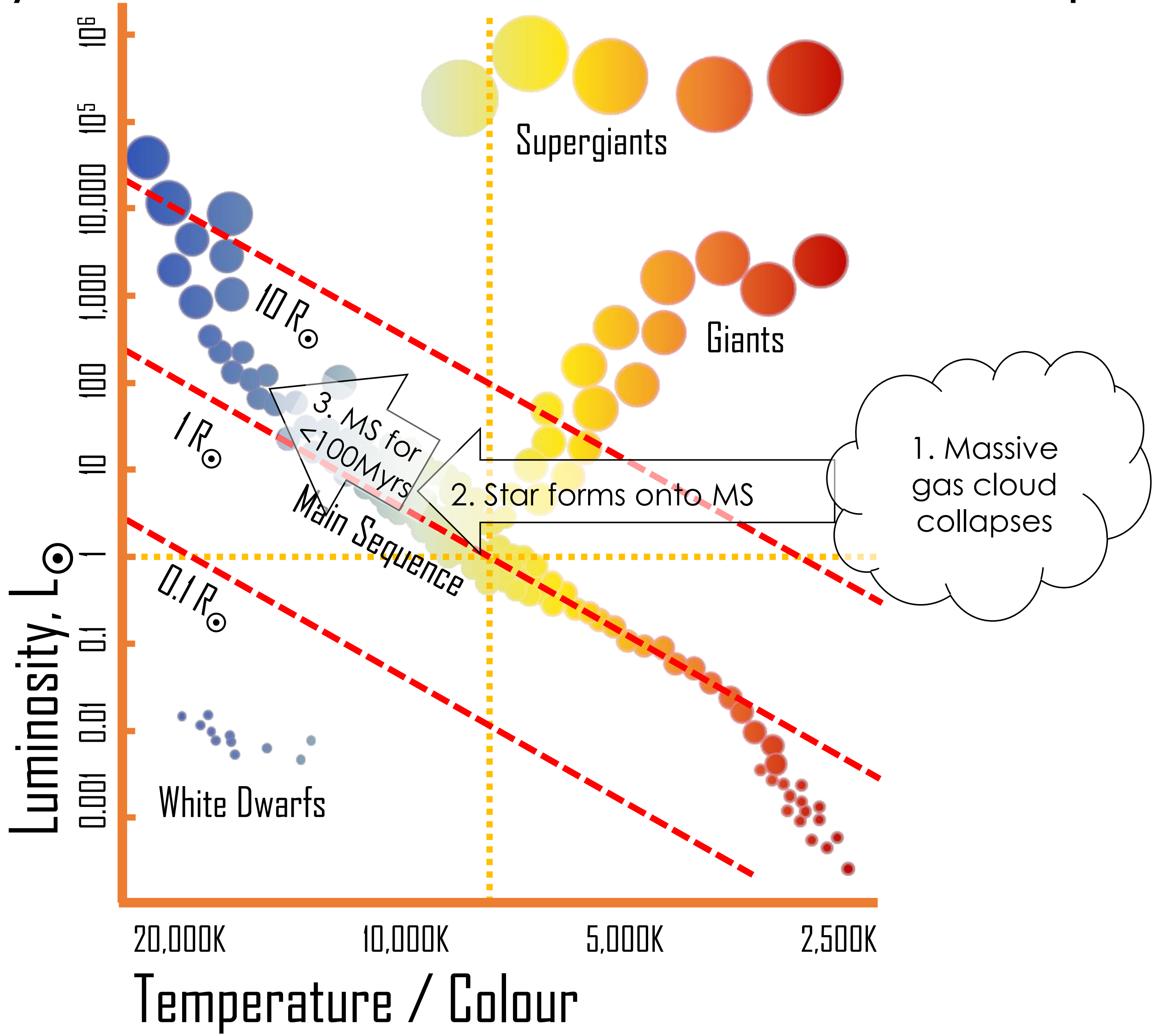
Summary of massive Star's Evolution: Step 2

Stellar Evolution



Summary of massive Star's Evolution: Step 3

Stellar Evolution



Massive main sequence stars evolve differently

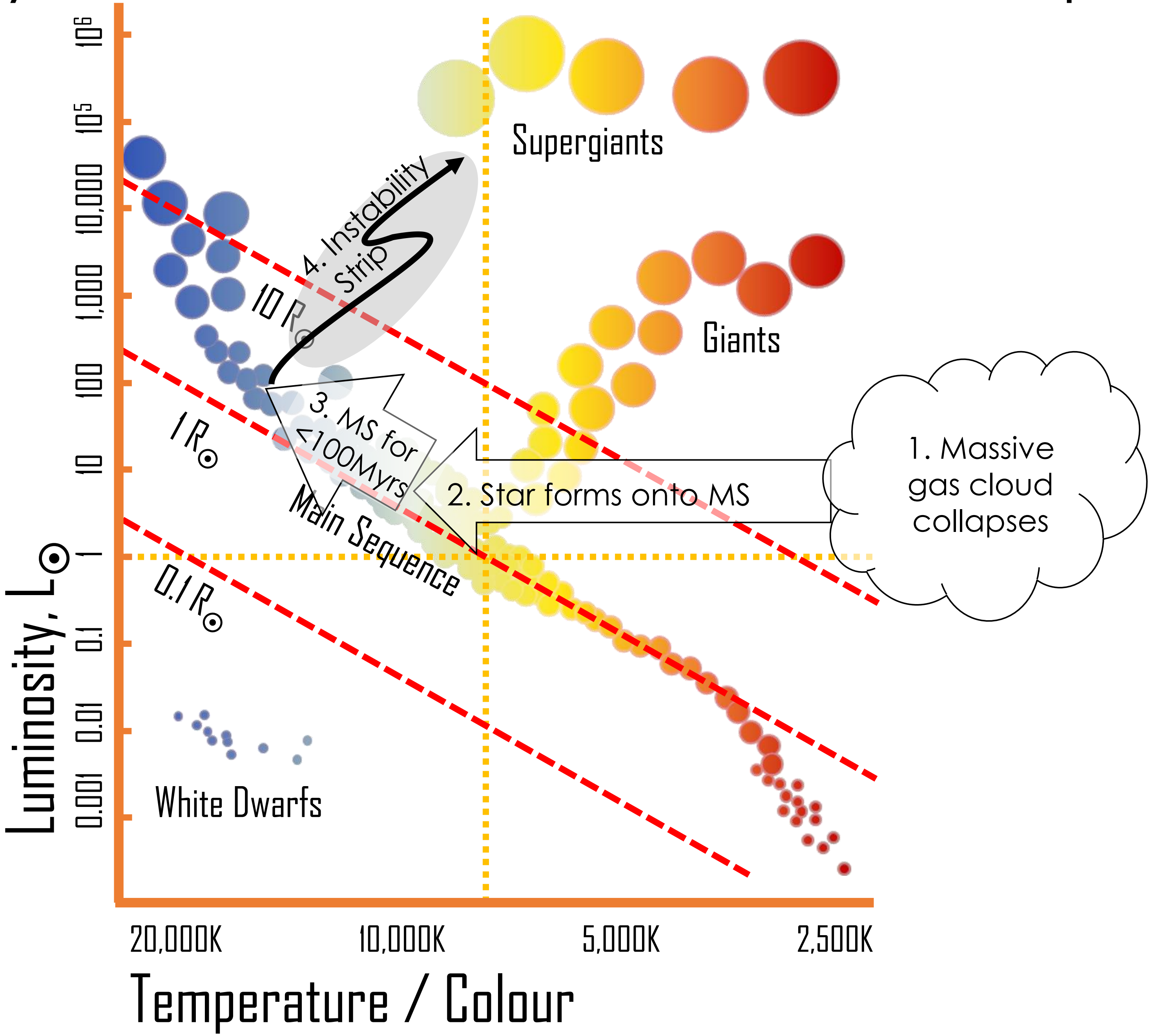
The helium core of a massive star reaches a temperature of 10^8 K *so helium can simply fuse* into Carbon.

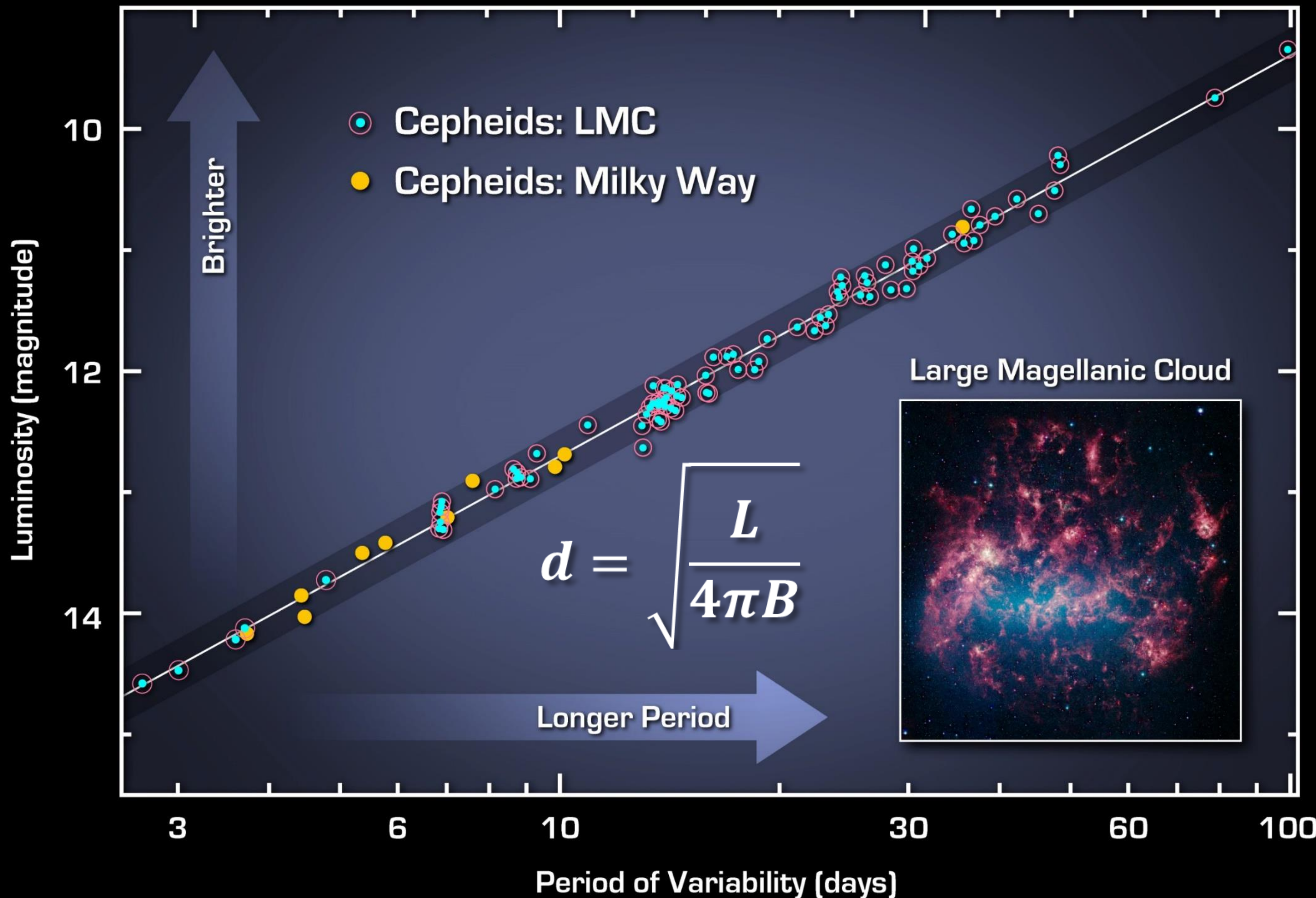
So, unlike smaller stars, there is no Helium flash
- the star's core makes a smooth transition from burning Hydrogen into Helium, to burning Helium into Carbon.

So a massive star does not become a giant star… it becomes a supergiant instead.

Summary of massive Star's Evolution: Step 4

Stellar Evolution

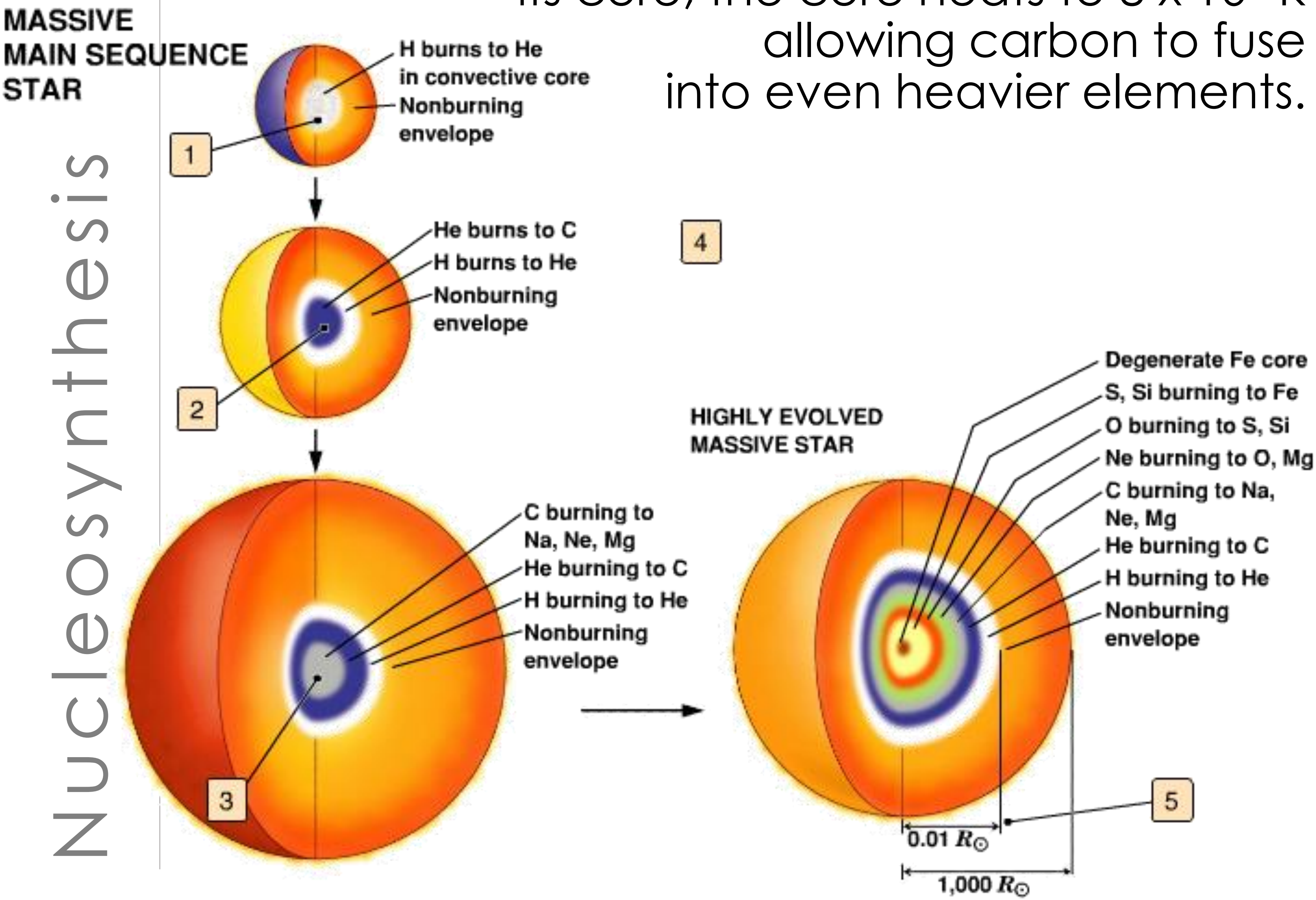




Calibrated Period-luminosity Relationship for Cepheids   Spitzer Space Telescope • IRAC

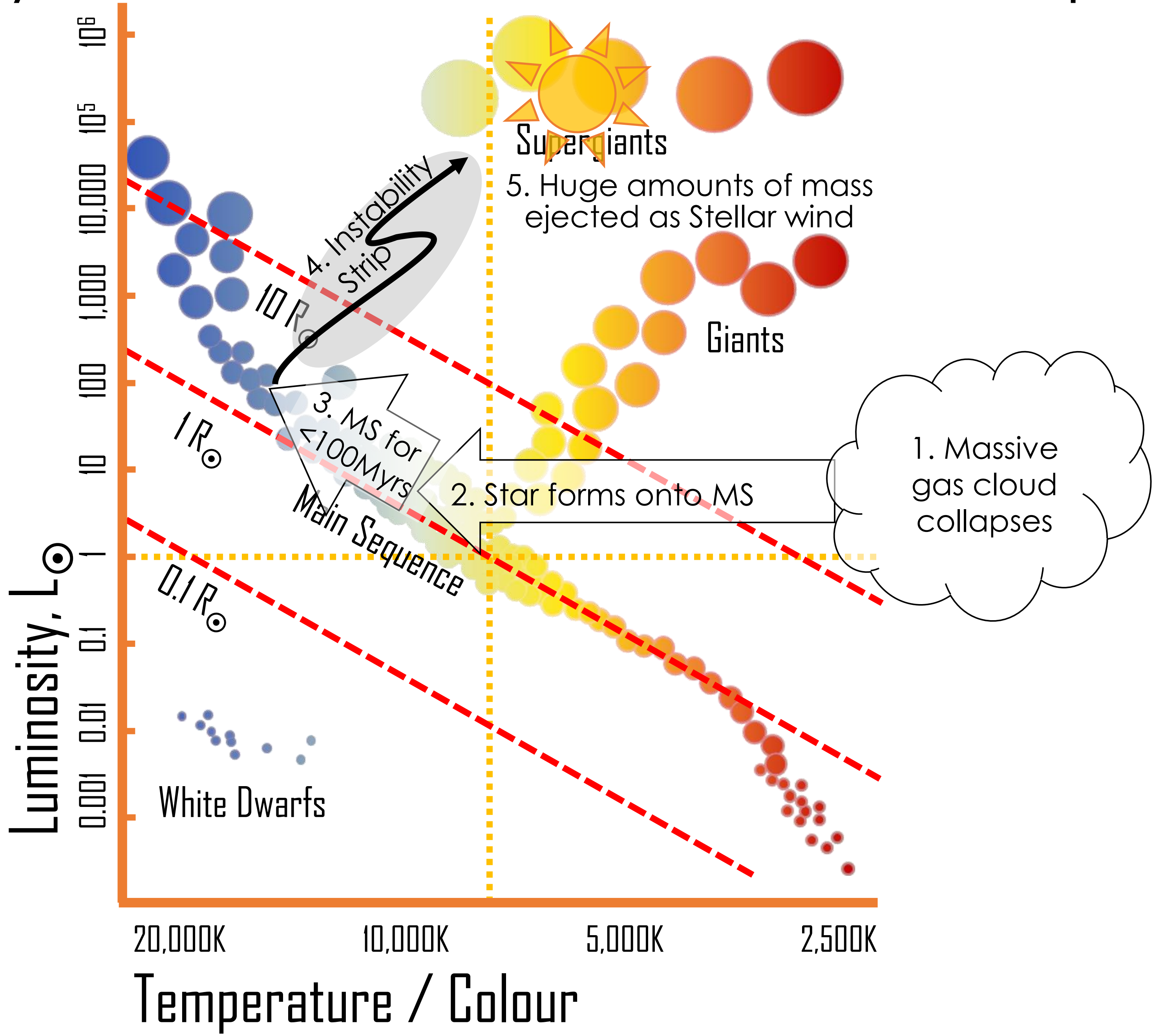
Nucleosynthesis

When a high-mass star runs out of helium in its core, the core heats to 8×10^8 K allowing carbon to fuse into even heavier elements.



Summary of massive Star's Evolution: Step 5

Stellar Evolution



Mass Loss

Massive main sequence stars lose up to $10^{-5}\ M_\odot$ per year

These are Wolf Rayet stars

Very massive stars ($>20\ M_\odot$) may lose 20% of their mass while on the main sequence, & 50% over their entire life

Eta Carinae is $\sim 100\ M_\odot$ but looses $1\ M_\odot$ every 1000 yrs

End of Fusion

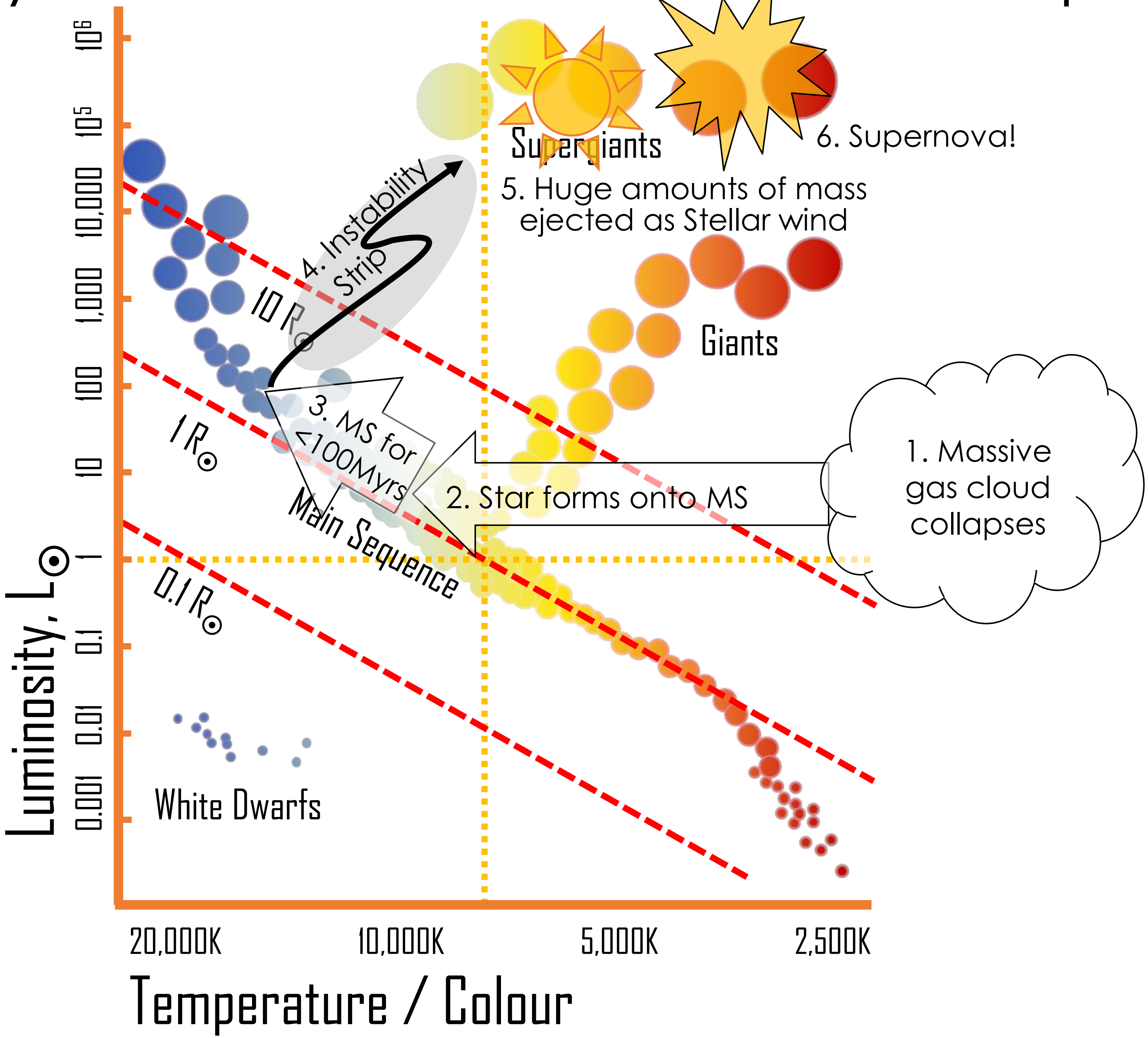
Fusion stops at iron, the most tightly bound atomic nucleus, so no element heavier than iron is fused within stars.

Hydrogen burning lasts for billions of years
Helium burning lasts for ~ 100,000 years
Carbon burning lasts for ~ 1000 years
Neon burning lasts for ~ 1 year
Oxygen burning lasts for ~ 6 months
Silicon burning in Iron lasts for days

Massive stars end their lives in a spectacular *Supernovae* explosions

Summary of massive Star's Evolution: Step 6

Stellar Evolution



Supernova 1987A in the Large Magellanic Cloud nearby galaxy, was visible to the naked eye in the Southern Hemisphere.

Previous one was in 1604.

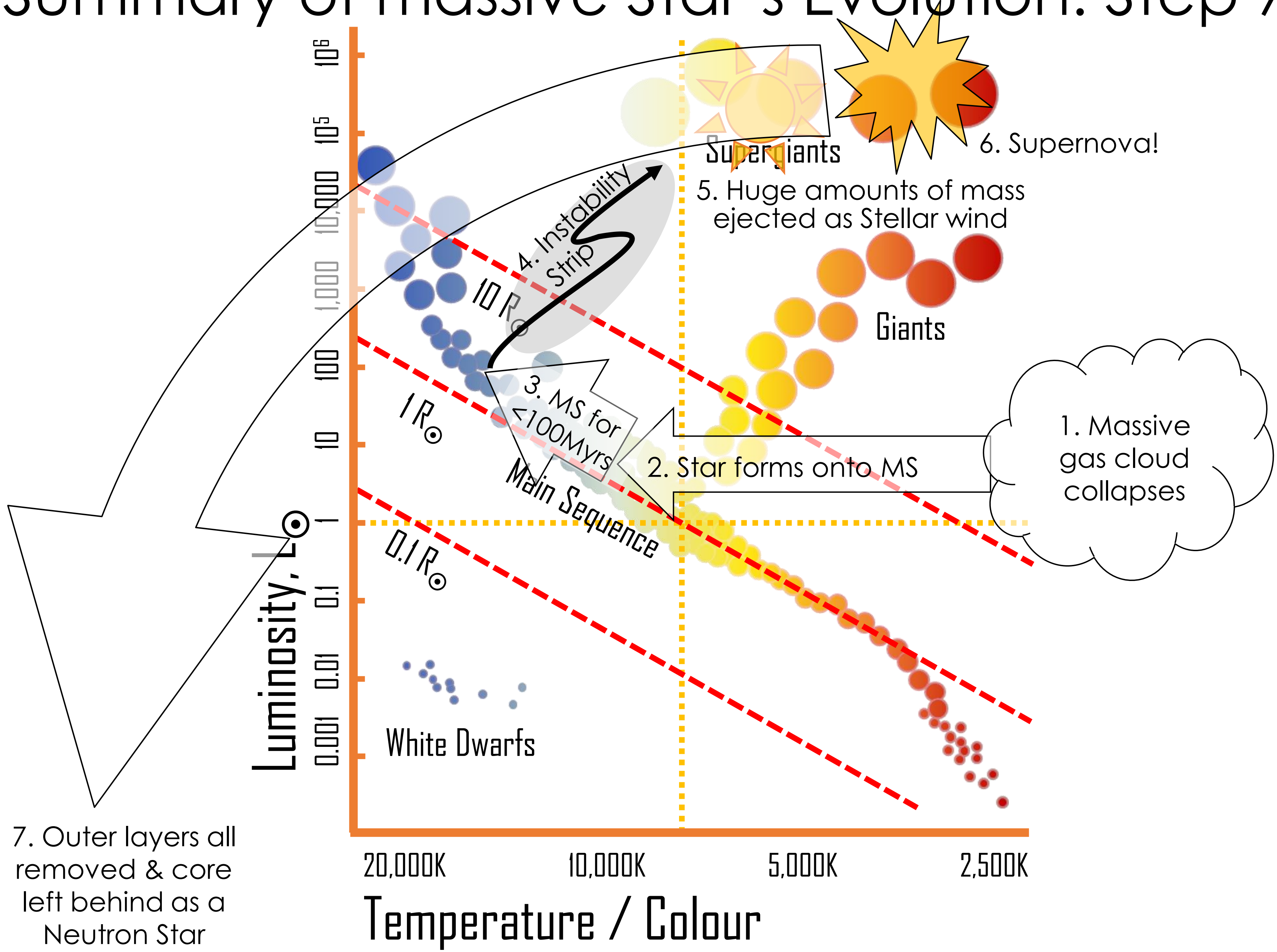
Spreading it around

Supernovae make heavier elements in the violent explosion, and spread these elements into interstellar space.

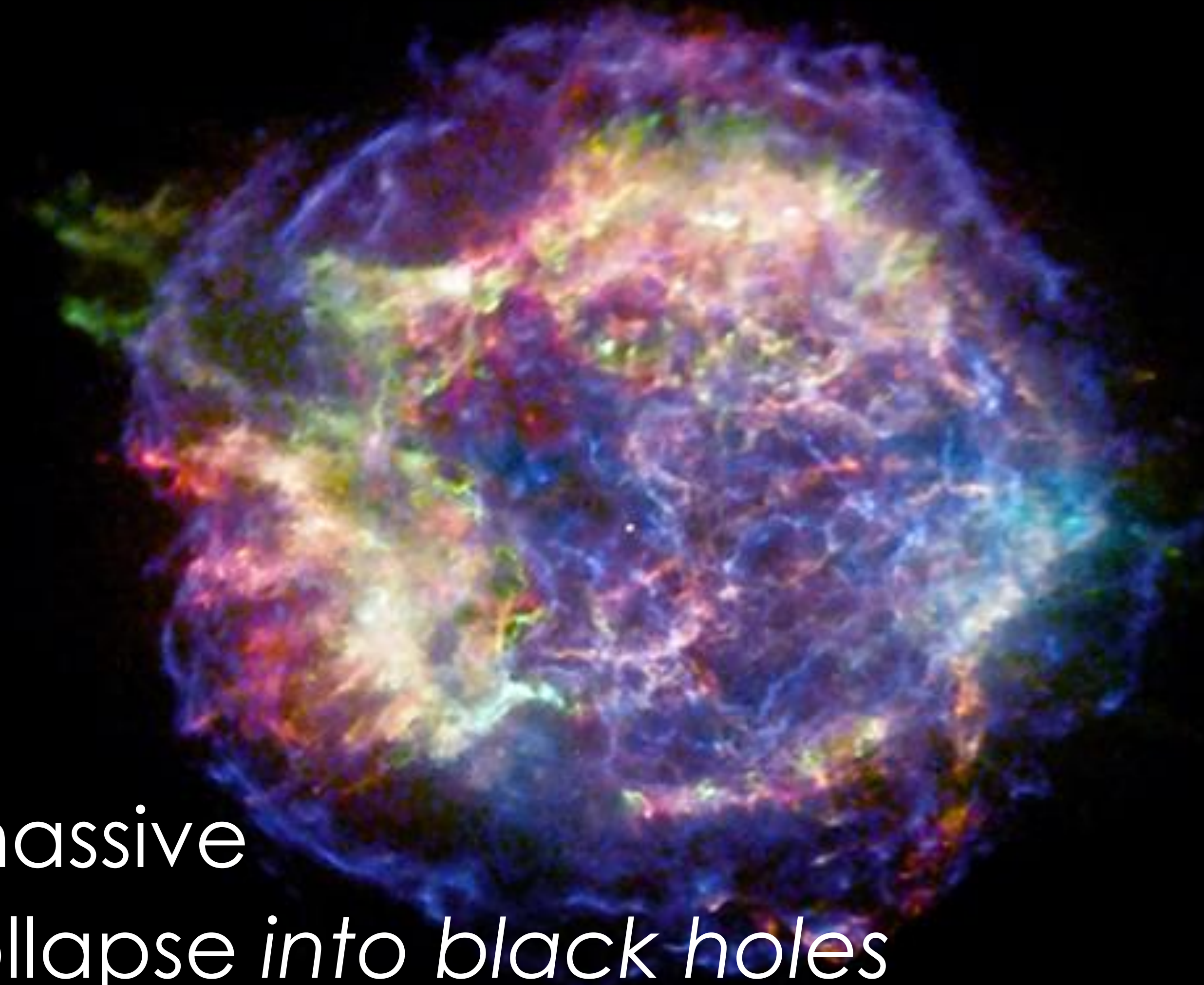
Supernovae are thus essential for life.

We are literally made up of the material from exploding stars.

Summary of massive Star's Evolution: Step 7



If the remaining core is less than 3 $M_{\odot}$ it becomes a *neutron star*.



More massive stars collapse *into black holes*

(*Dark star* would be a much better name!)

Neutron Stars V Pulsars

All neutron stars are pulsars when they are first born, spinning extremely rapidly with strong magnetic fields.

Pulsars only pulse for the first 10M yrs – 99% of neutron stars are no longer pulsars.

Also, we only see them as pulsars if the its beam crosses over the Earth while the pulsar rotates.

Black dwarfs

Do not confuse **black holes** with **black dwarf** stars.

Black dwarfs don't exist (yet)

Black holes are everywhere (where a massive star has died)…

As **white dwarfs** cool, they could (theoretically) cool until they emit no light – a **black dwarf**.

This could take 10^{15-25} years… (the current age of the universe is 13.8×10^{9} years).

Summaries!

What follows is a…

Summary of the Sun's Evolution

&

Summary of the Evolution of Massive stars

Main Sequence Evolution

Summary of the Sun's Evolution

1 & 2. Gas cloud collapse and a star forms

3. Star evolves on the Main Sequence

4. H is turned into He, until core is pure He (that's too cool to fuse)

5. H turns to He (and so heats) in the outer layers only

   - So star expands to sub-giant then red-giant (Red Giant Branch)

6. Core temperature increases until Helium fuses into Be & C

   This suddenly allows energy to be released, temperature increases rapidly, causing rapid expansion - the He Flash

7. Core expands, so cools, fusion slows and outer layers shrink

   Now He becomes C in core (Horizontal Branch star)

8. Slowly heats and expands again (Asymptotic Giant Branch)

9. This time, outer layers are blown away as Planetary Nebula

10. Core shrinks and fades as a White Dwarf star

Summary of Massive star Evolution

- Massive stars "live fast & die young"
- They are responsible for making all elements heavier than carbon, many of which are essential for life
- *Supernovae* spread these heavy elements throughout space - they will be incorporated into future generations of stars and humans!
- The remnant cores are either *neutron stars* (below about $3M_{\odot}$) or *black holes* ($> 3M_{\odot}$)

See also http://www.wimp.com/sizestar/

Summary of Massive star Evolution

1 & 2. A gas cloud collapses and a star forms

3. H is turned into He, until core is pure He

4. H turns to He the outer layers, & the core becomes hot enough for He to fuse into C
   - The star expands into a pulsating variable star

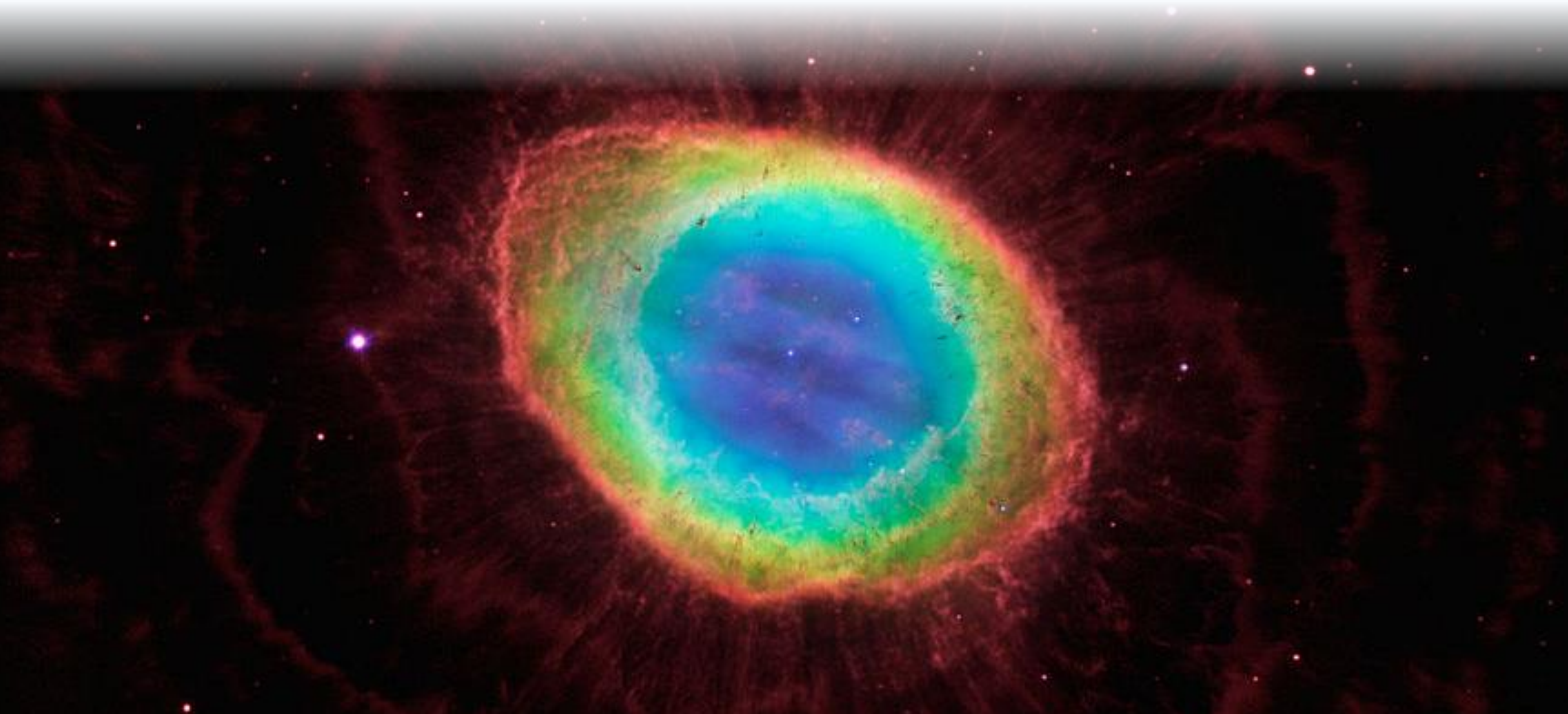
5. It becomes a red supergiant star and then a Wolf-Rayet star

   Heavier elements are made as the core of the star gets hot enough to do so

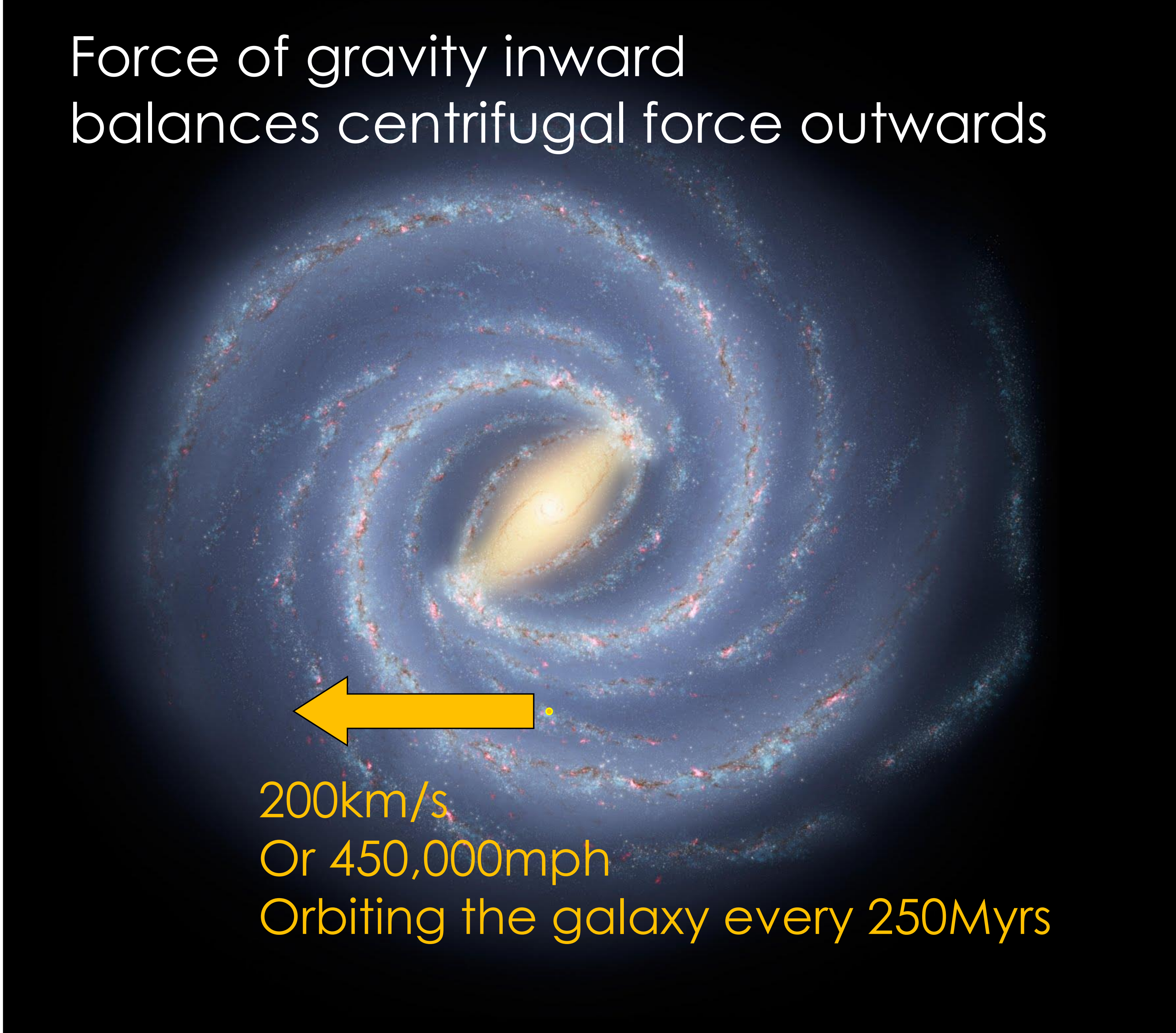
6. Fusion ends as it runs out of fuel - supernova!

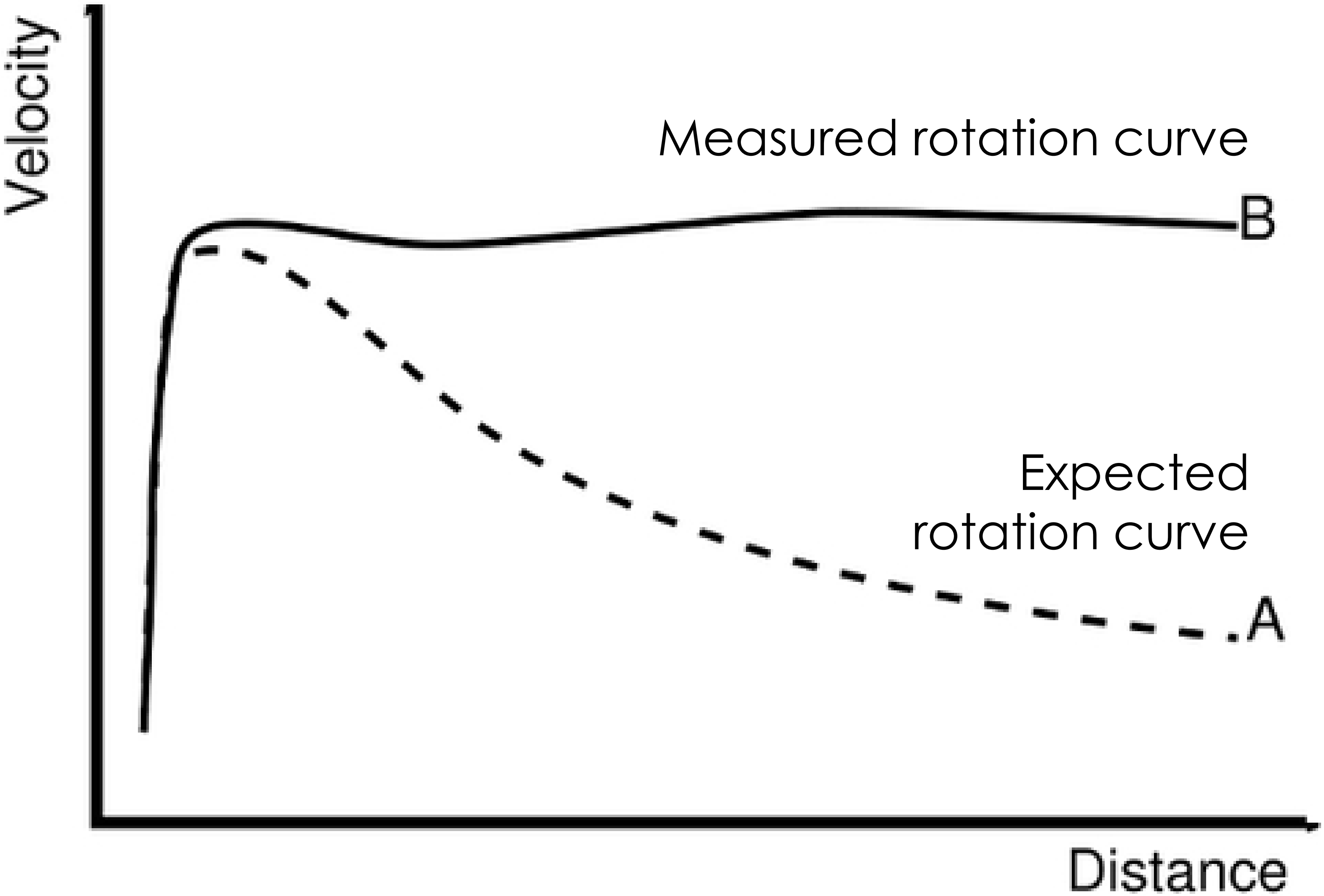
7. Centre collapses to form either a neutron star or black hole

The Evolution of Stars



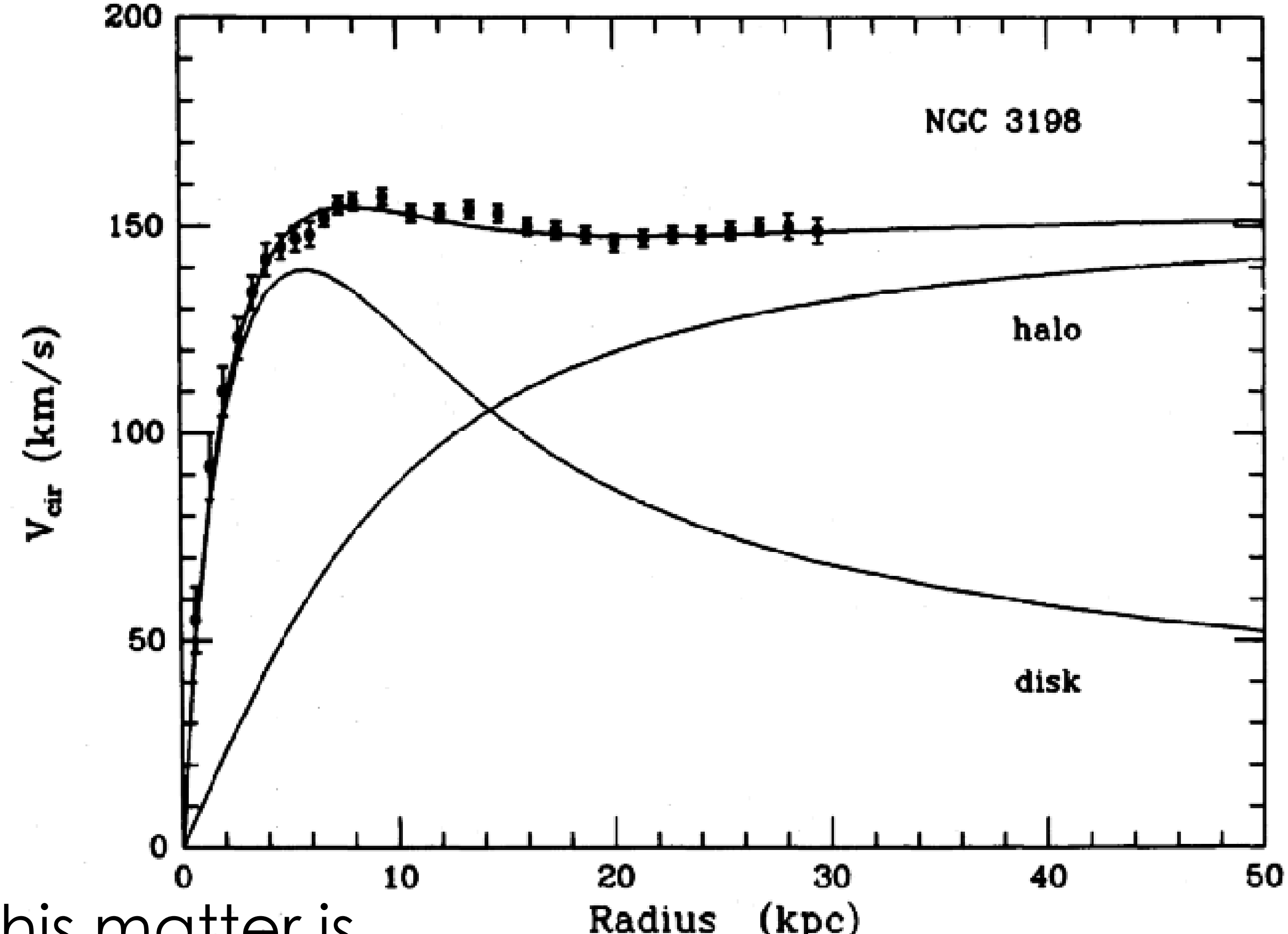
Rotating galaxies




Velocity
Measured rotation curve
B
Expected
rotation curve
A
Distance

Dark Matter

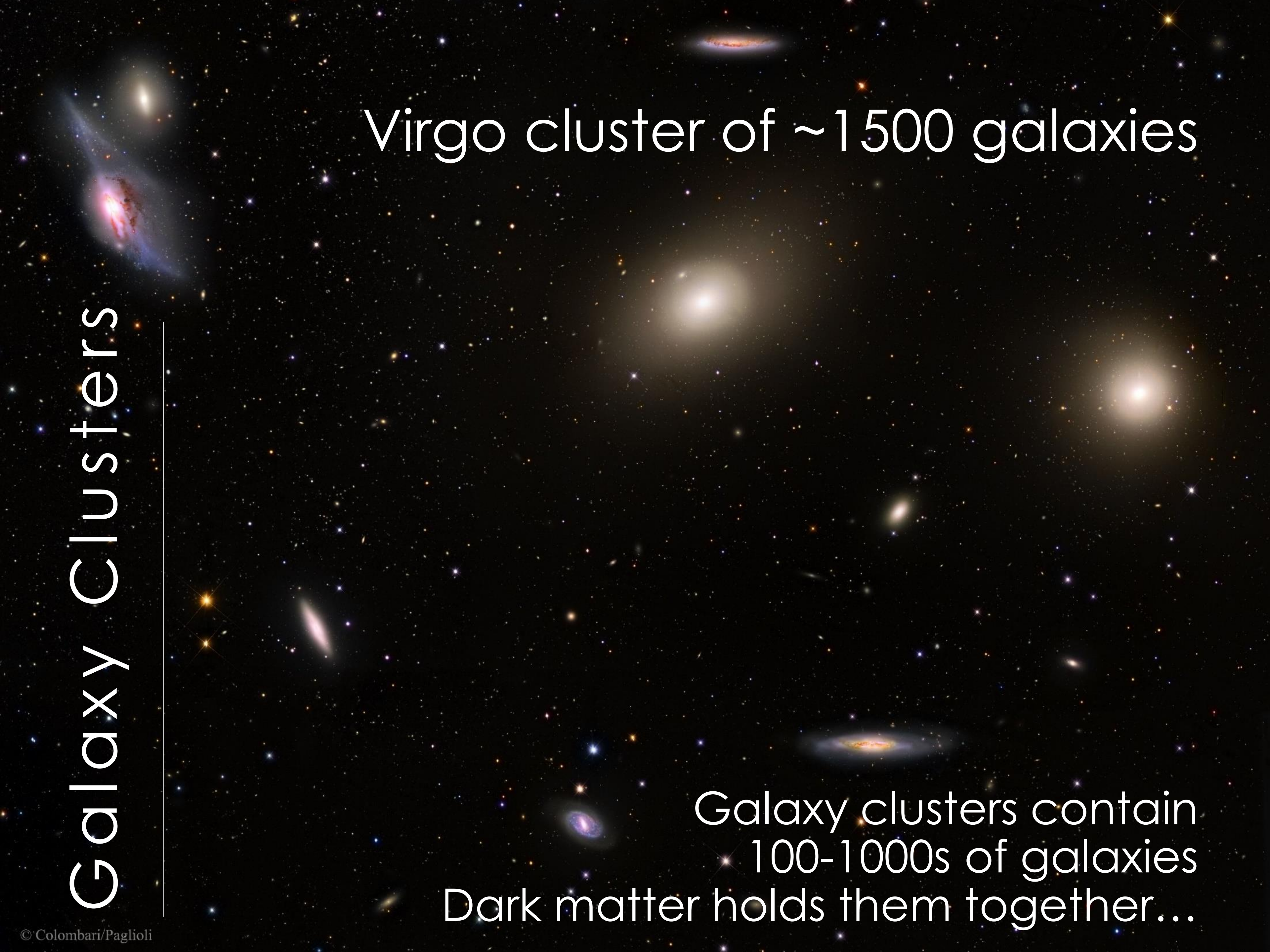
The "flatness" of the observed rotation curves implies that most of the mass (~95%) in a galaxy is in a "halo" surrounding the luminous material



Since this matter is not luminous it is known as dark matter

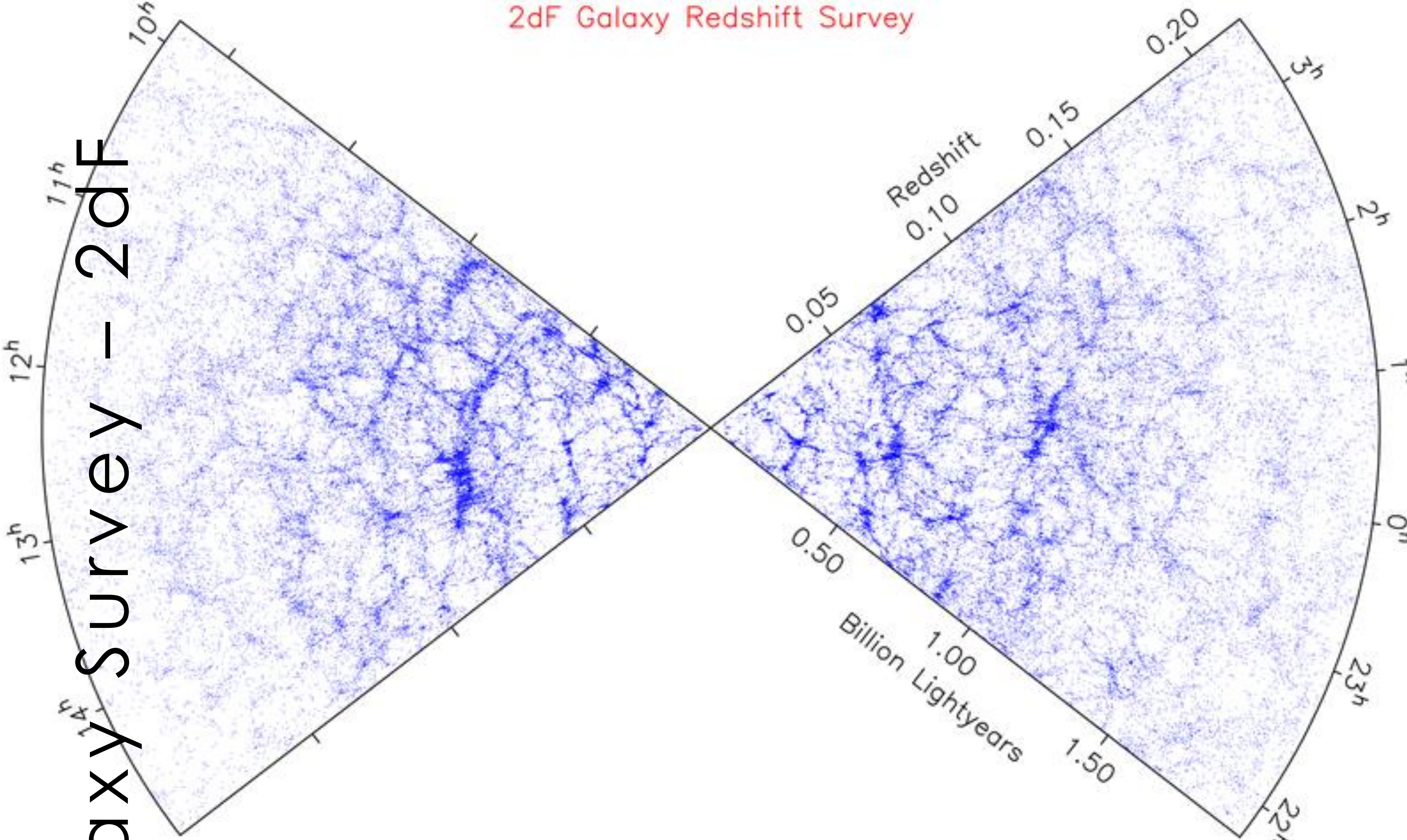
Galaxy Clusters

Virgo cluster of ~1500 galaxies



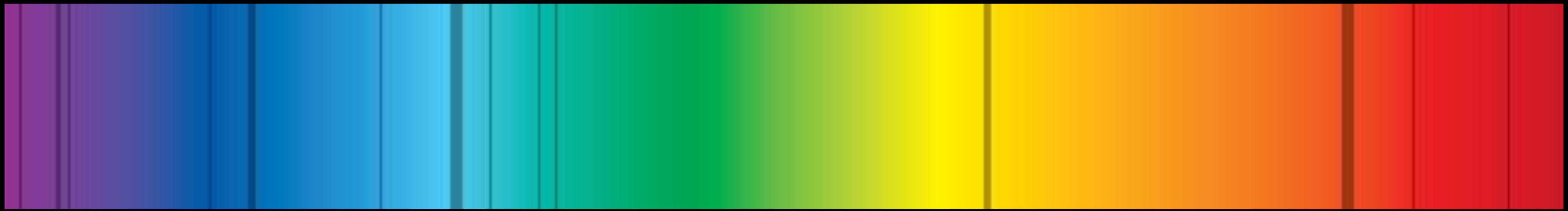
Galaxy clusters contain
100-1000s of galaxies
Dark matter holds them together…

Galaxy Survey – 2dF

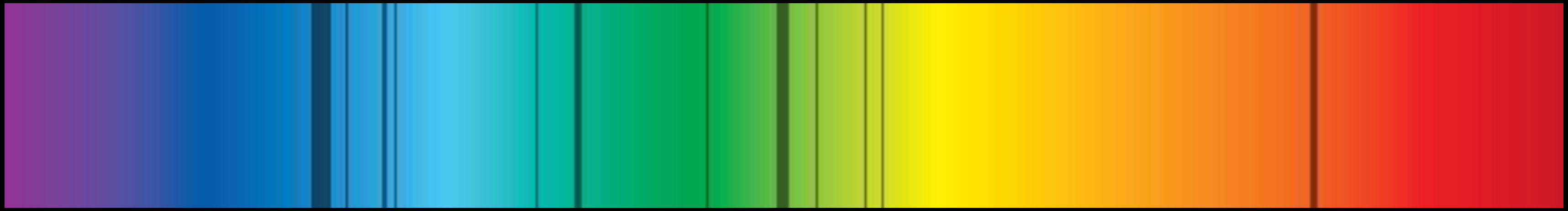


Every single dot here is a galaxy

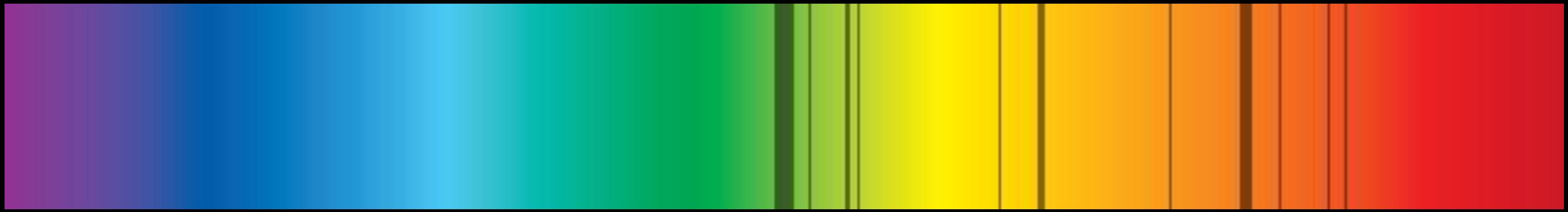
They cluster on huge scales – super clusters



Stationary H & He spectra



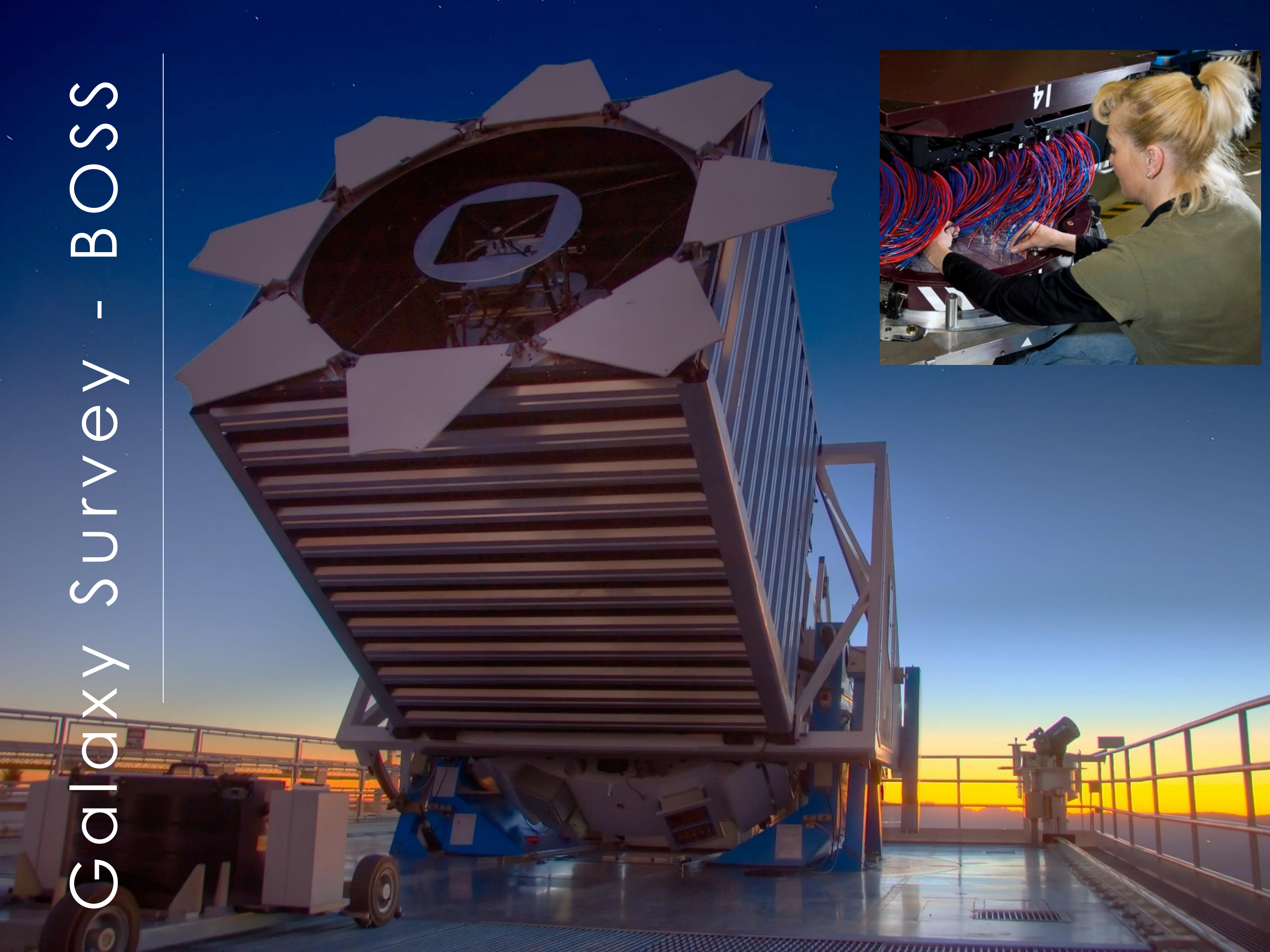
Distant galaxy (z=0.15)



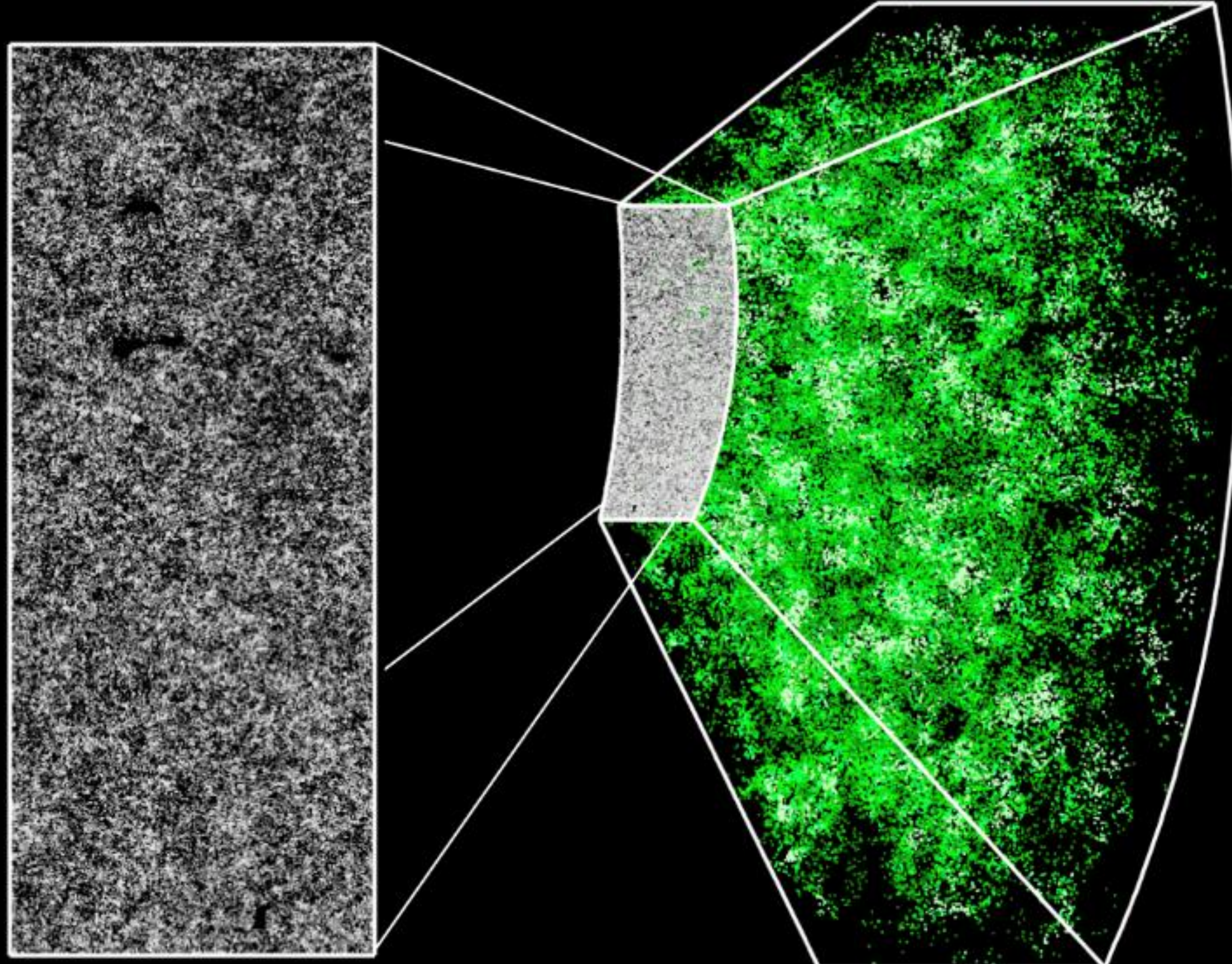
Even more distant galaxy (z=0.4)

The spectral lines are, literally, shifted to the red and so called… Red Shift

Galaxy Survey - BOSS



Galaxy Survey - BOSS



There are 2 trillion (10^{12}) galaxies in the observable universe

The Dark stuff

Dark Matter

- Holds galaxies (and galaxy clusters) together

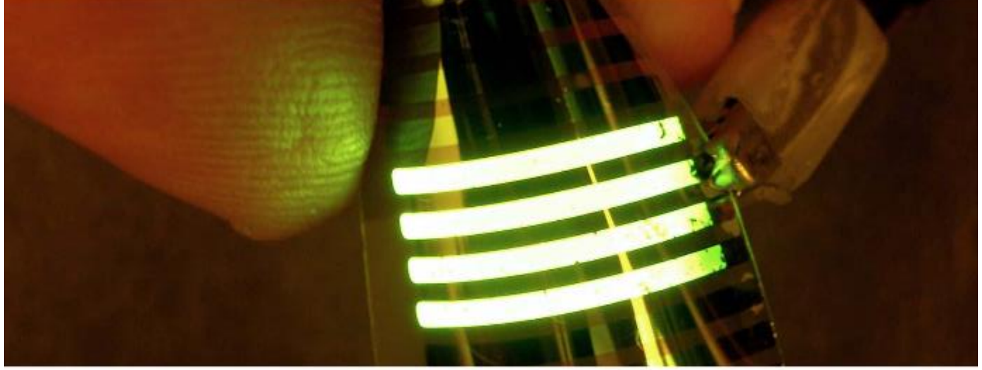
Dark Energy

- Pushes galaxies apart

Think of galaxies as cities (of stars rather than people!), galaxy clusters as countries (a collection of cities), and the expanding Universe like continental drift!

Outreach @ Sussex

Tuesday’s evening lecture



Can plastic still be fantastic?

Dr. Jessica Wade
Department of Physics
and Centre for Plastic Electronics,
Imperial College London

Tuesday 12th February 2019, 7pm - 8pm
Fulton B Lecture Theatre,
University of Sussex

Plastics aren’t always bad news. From stretchable screens to conductive thread and stick-on glucose sensors, new materials are allowing scientists and engineers to get creative with technology. At Imperial College London we custom design plastics that have the electronic properties we need for particular devices. Our conductive plastics can be printed onto flexible electrodes surfaces and used in television displays, solar panels and for regenerative medicine. We will explore what these materials are, how they work, and how they will change the world.

UNIVERSITY OF SUSSEX

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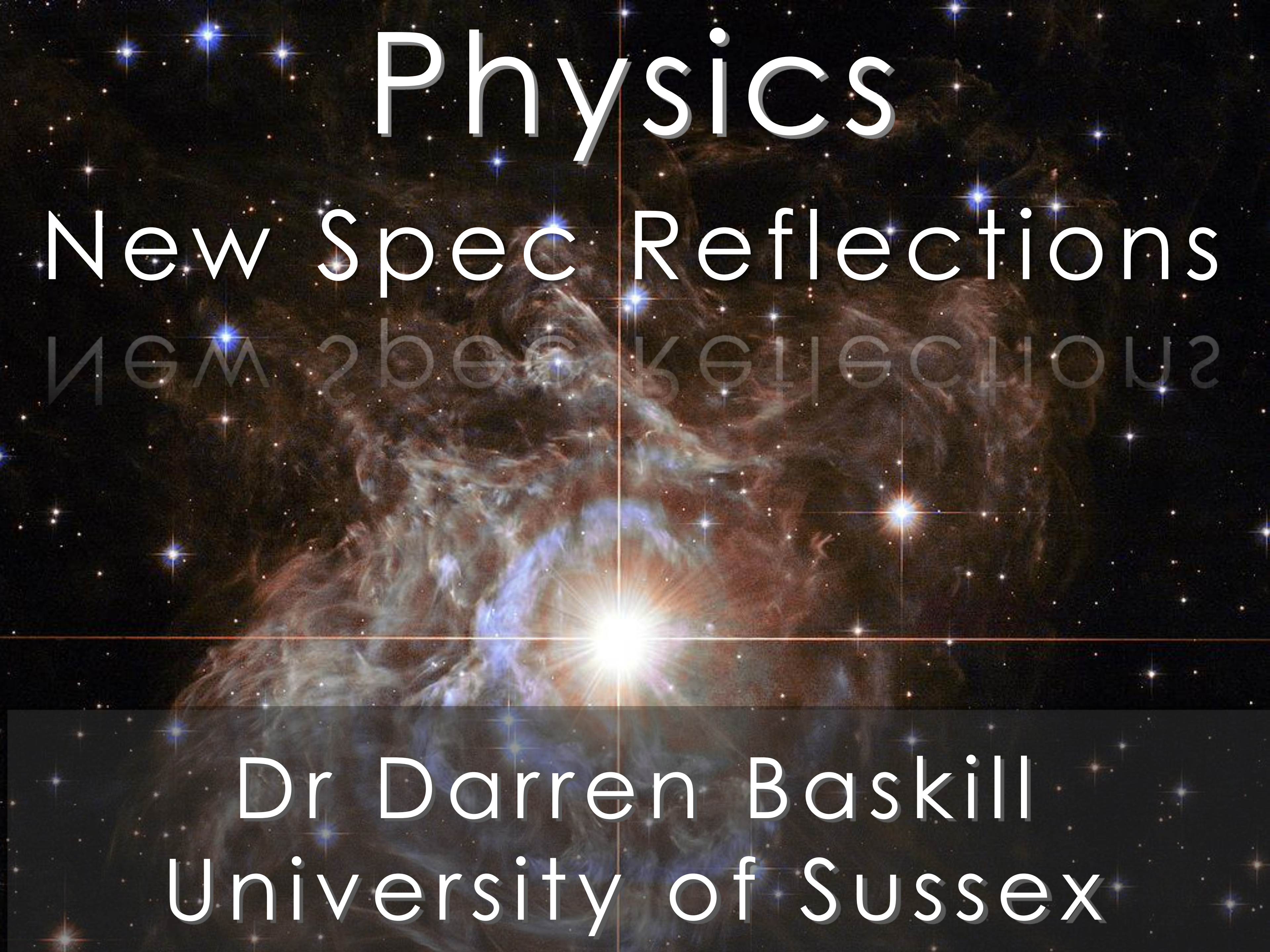
Thank you


Physics
New Spec Reflections
Dr Darren Baskill
University of Sussex