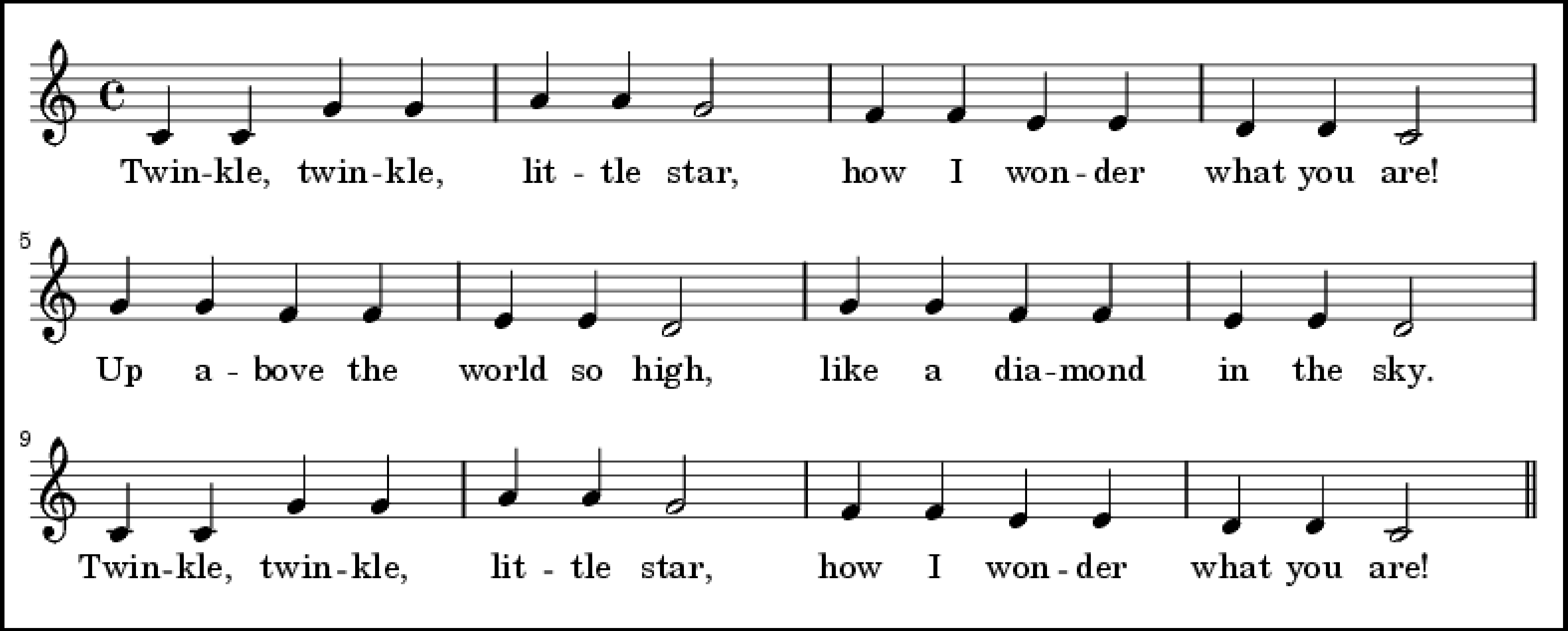
Twinkle twinkle little star

The life and times of stars

or

Understanding stellar types with the Hertsprung Russell diagram



Some basics on the nature of light

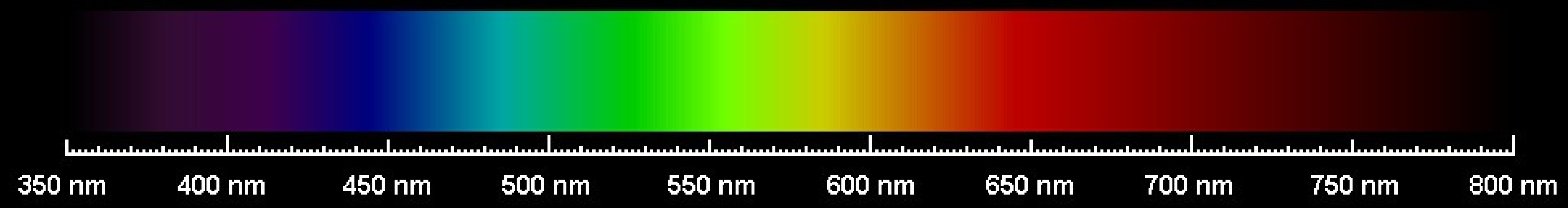
White light is made up from light of many colours – a rainbow

Light can be thought of a made of particles called photons, but also as waves!

The different colours represent different energy levels of the photons – e.g. a blue photon is more energetic than a red photon

A blue photon has a shorter wavelength than a red photon, so the shorter the wavelength the more energetic the photon

Hot objects give out a light with a continuous range of colours – but the peak colour is determined by the temperature of the object, *a white hot object is hotter than something that is red hot*



Visible Continuous Spectrum 2

(Perceived Brightness Partially to Scale)

Some basics on the nature of light

The colour of the light coming from an object can therefore be used to measure its temperature.

A blue star is much hotter than a red star

Matter is comprised of atoms – they have a nucleus surrounded by electrons

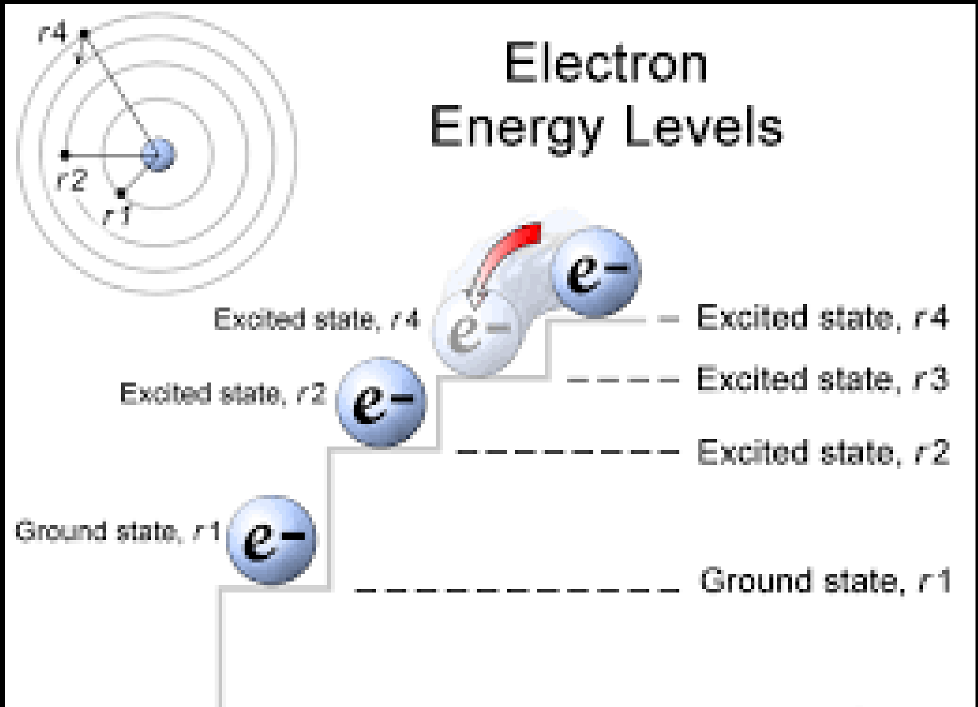
The electrons orbit the nucleus with very specific energy levels, they can move from one energy level to another (if energised by radiation for example) but cannot sit a random level in between

If an electron moves to a higher energy level it will absorb energy.

If it falls to a lower energy level it will radiate energy as a photon

The energy contained in an absorbed or radiated photon totally depends on the change in levels – as does the colour

The levels are specific and characteristic of different elements

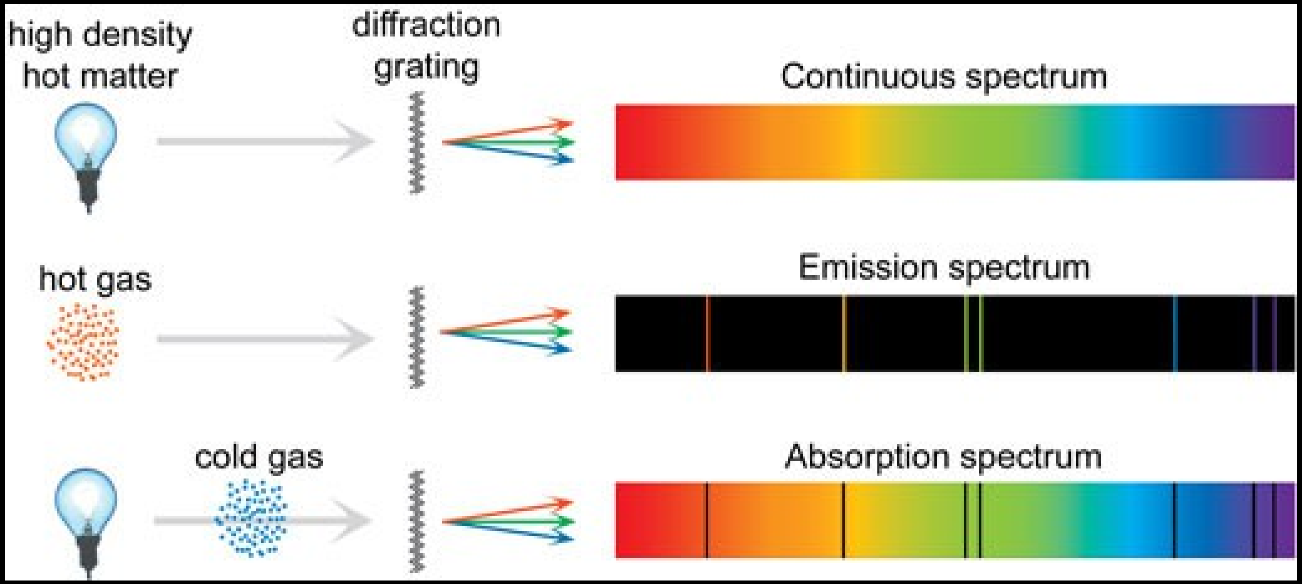


Spectra

A simple hot object e.g. an incandescent light bulb will give out a “continuous spectrum

Very hot gas will give out an emission spectrum

A continuous spectrum passing through gas will have certain colours absorbed



Examples

A galaxy will give out a continuous spectrum as it has billions of different sources

The surface of the Sun gives out a continuous spectrum – it is an incandescent body

The Sun's atmosphere will produce an absorption spectrum as it is a gas that the Sun's light is shining through

Most nebula will produce emission spectra when suitably energised, they are essentially gas clouds

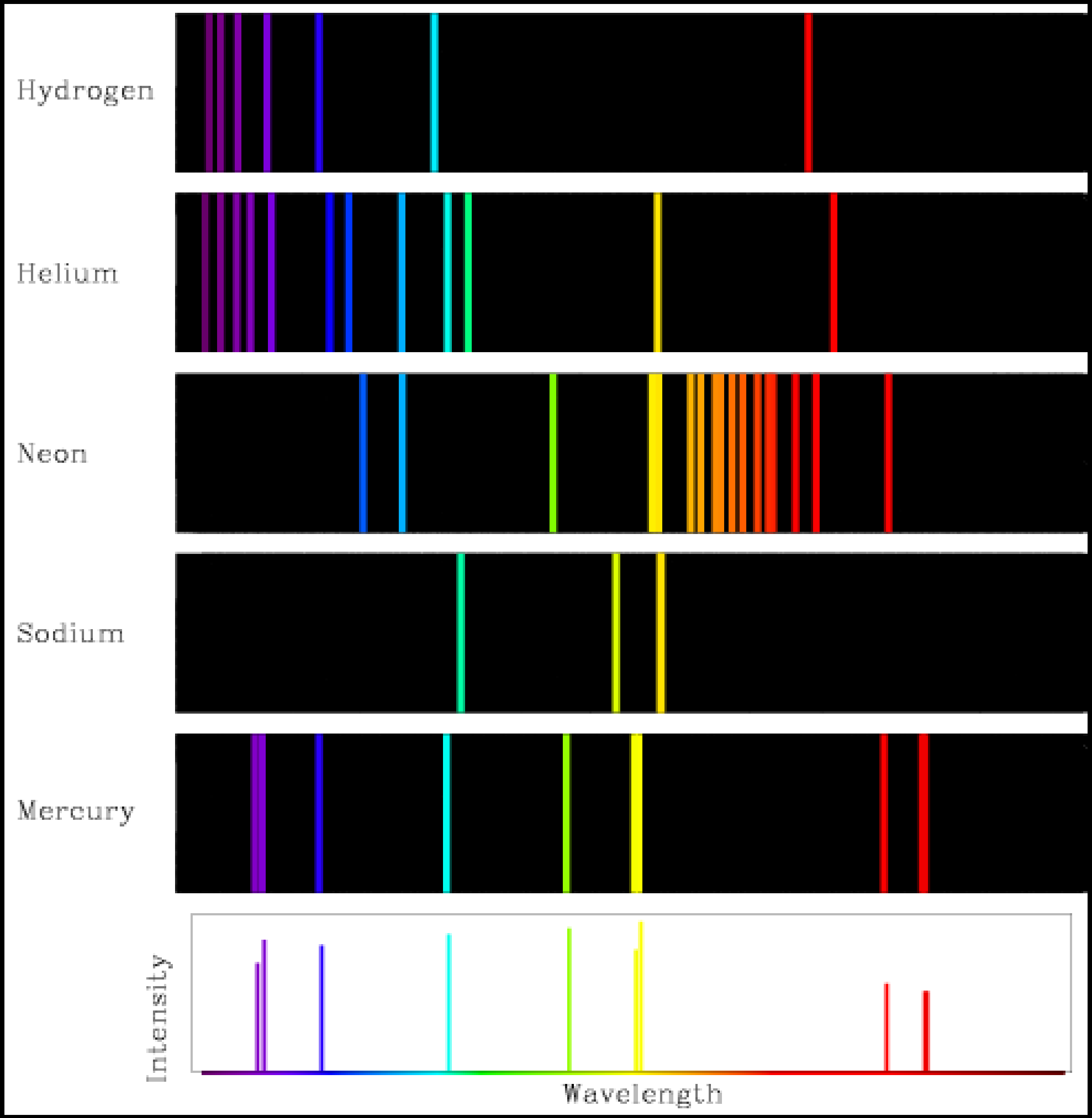
Summary

Light can be considered to be particles (photons) or waves

The colour of a photon represents its energy

Analysing the colours coming from objects in space can give information on their temperature and what they are made of

Some examples of spectra



August Comte 1835

"On the subject of stars, all investigations which are not ultimately reducible to simple visual observations are necessarily denied to us. We shall never be able by any means to study their chemical composition"

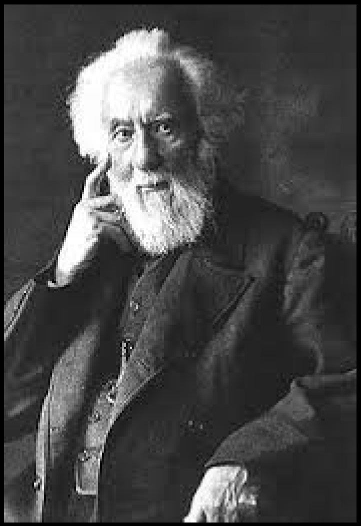
1860 Gustav Kirchhoff and Robert Bunsen discover that Fraunhofer lines are produced by elements in the Sun's atmosphere, *spectroscopy was born*

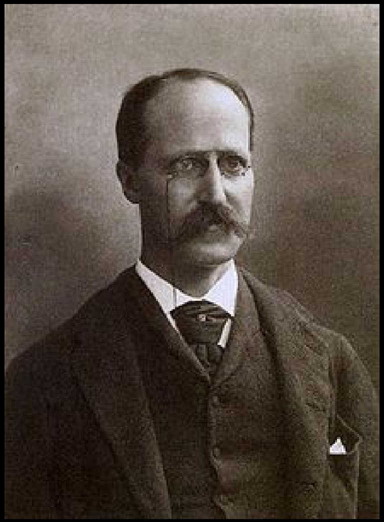
A brief history

1817 Joseph von Fraunhofer observes solar spectra and observes over 500 lines

The cause of the lines is not understood until Kirchoff and Bunsen explain them in 1860

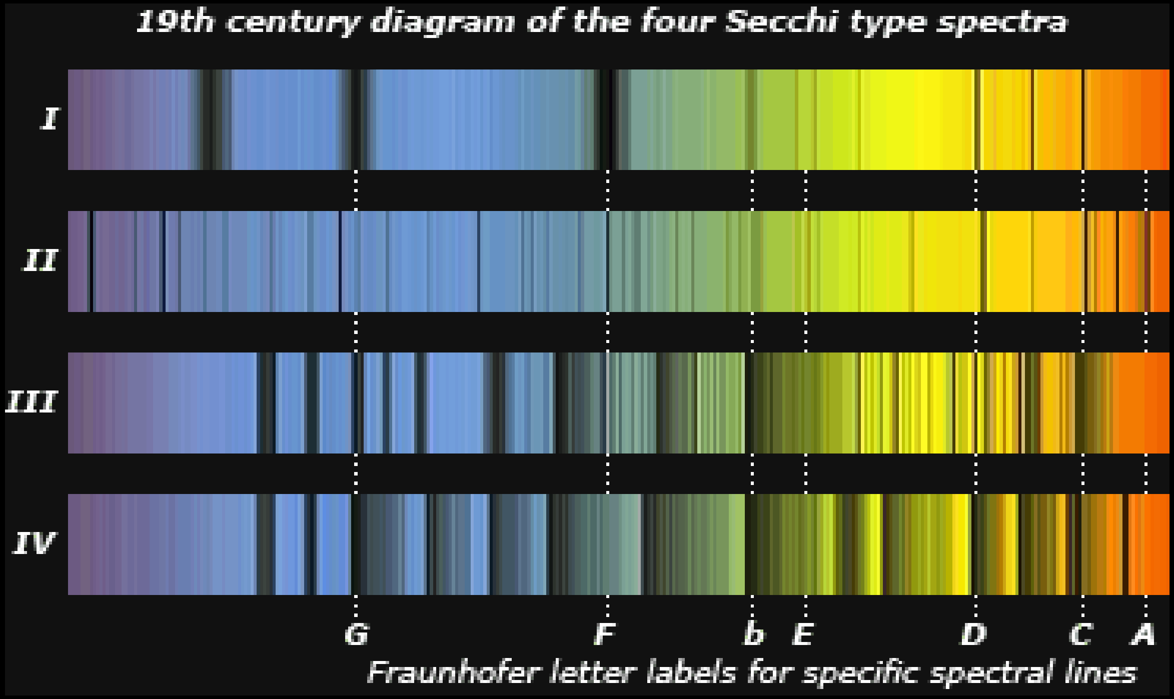
1864 William Huggins identifies chemical elements in solar spectra





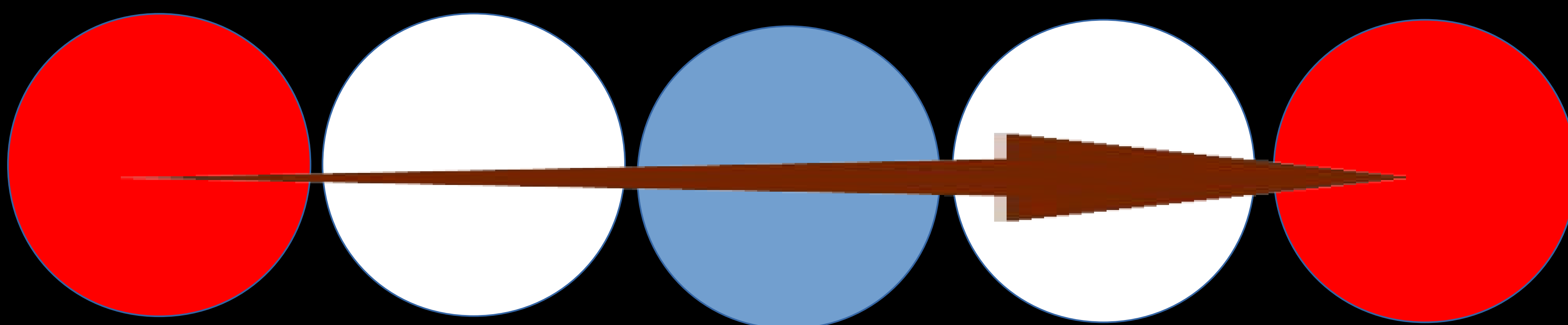
1887 Henry Rowland produces the first solar atlas with over 20,000 spectral lines

1863 to 1870 Father Angelo Secchi classifies stars into four categories based on their colours and the strength and width of the spectral lines



Early theories

Hermann von Helmholtz (1863) & James Homer Lane (1871) – contraction of nebulae & gravitational heating

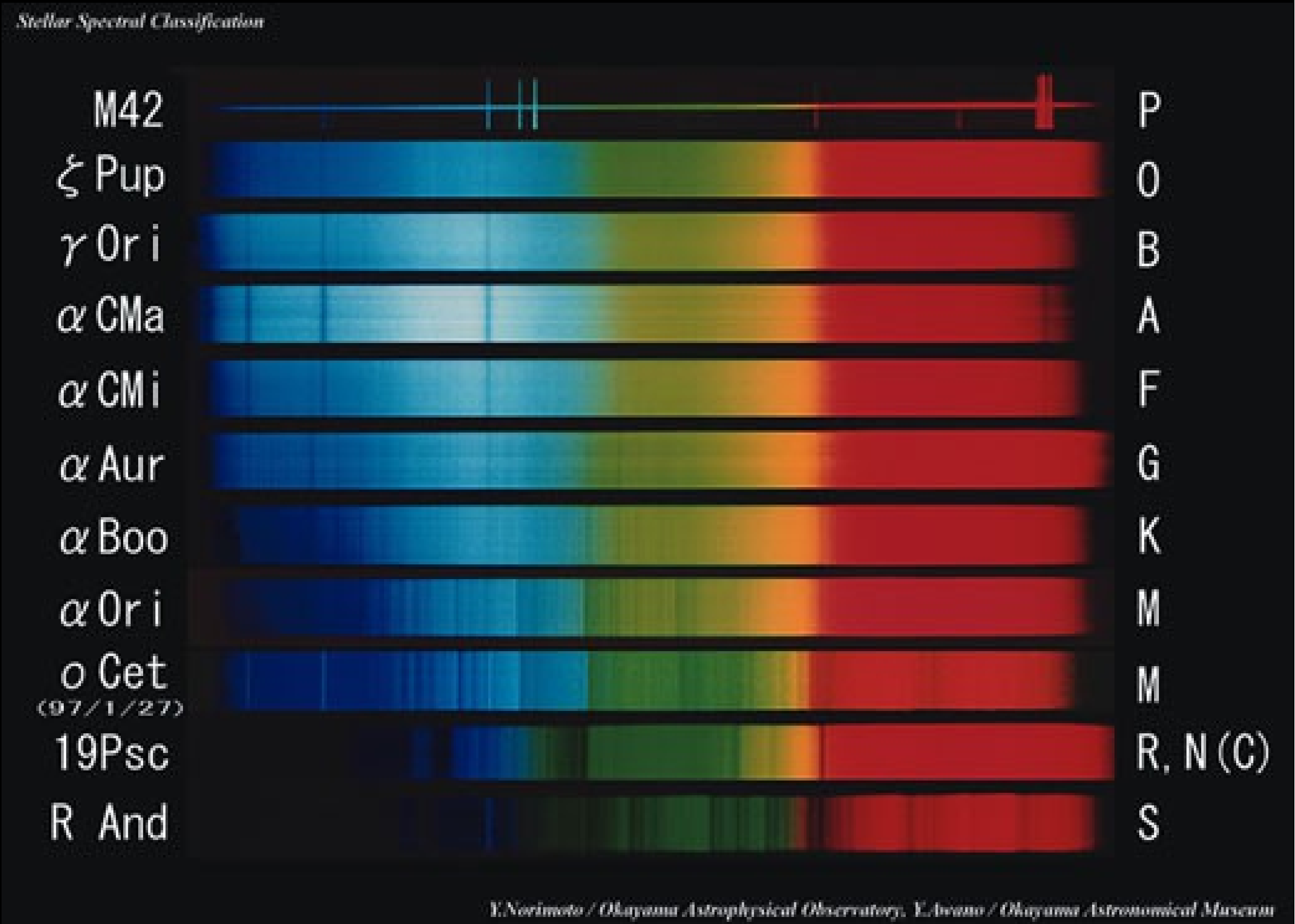


Herman Vogel and Norman Lockyer proposed schemes based on this theory (1890)

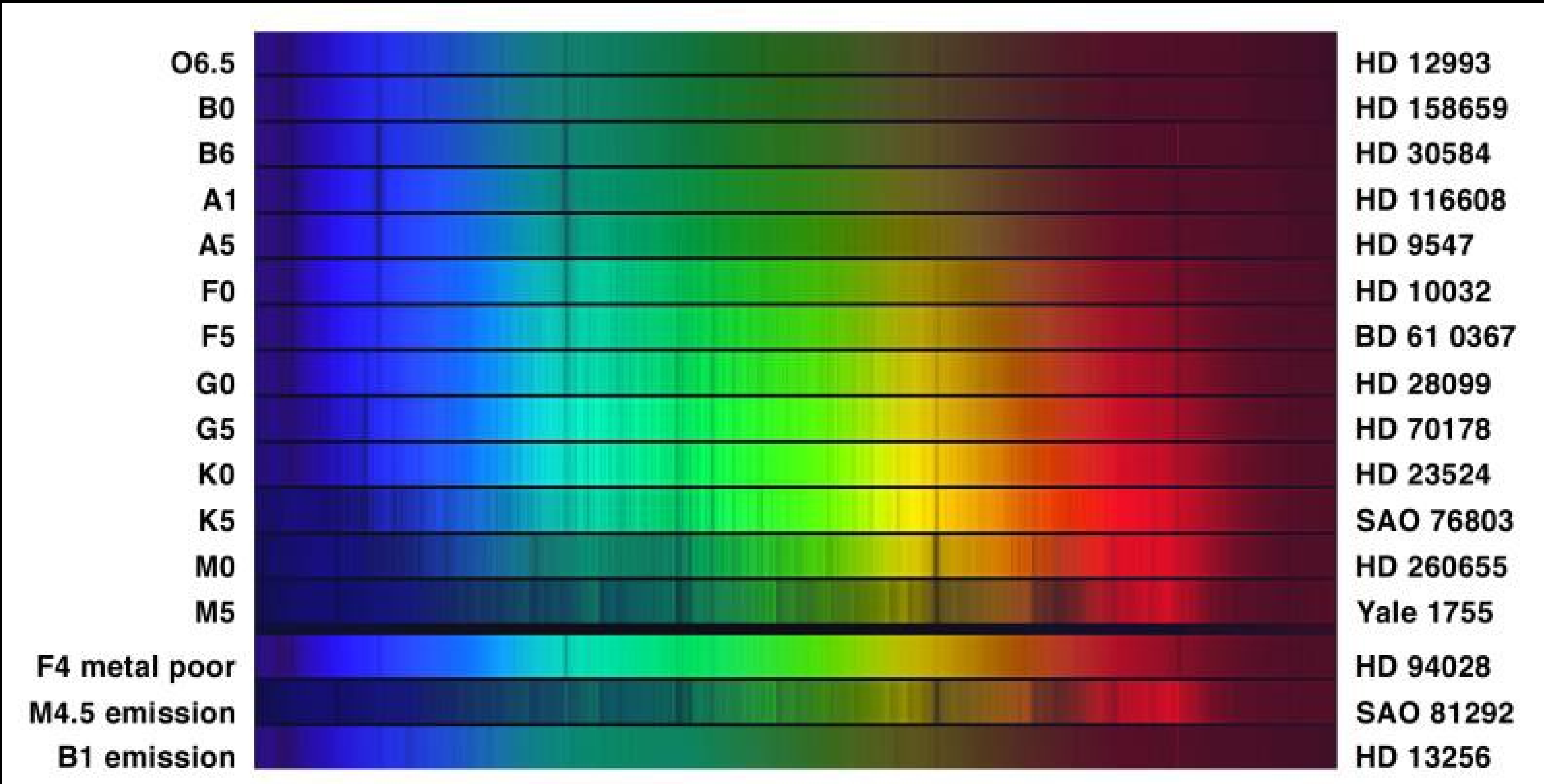
Henry Draper catalogue 1890

Supervised by E C Pickering, Williamina Fleming and her team of “computers” combined the letter system of Draper and Secchi's system

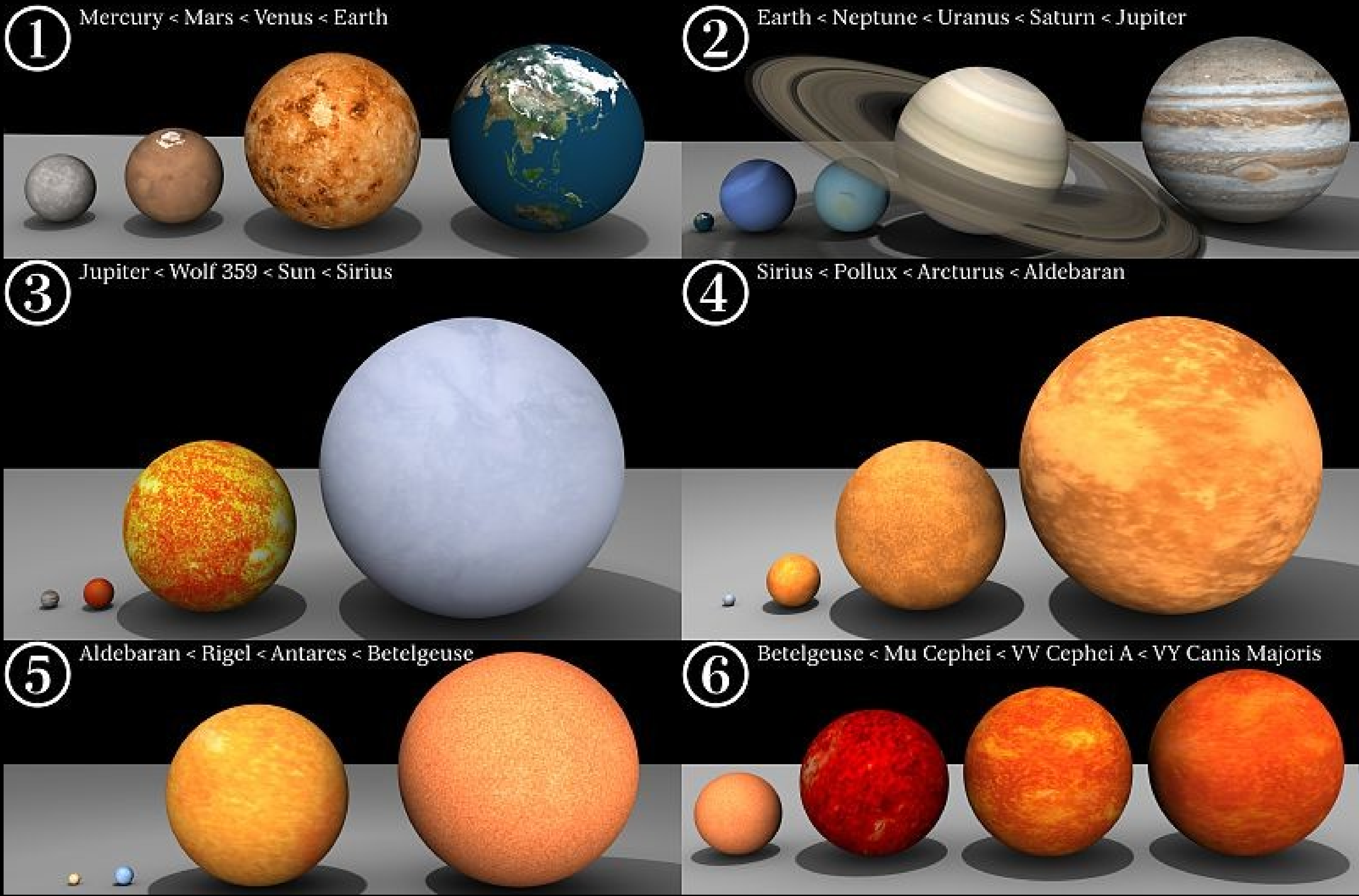
O B A F G K M



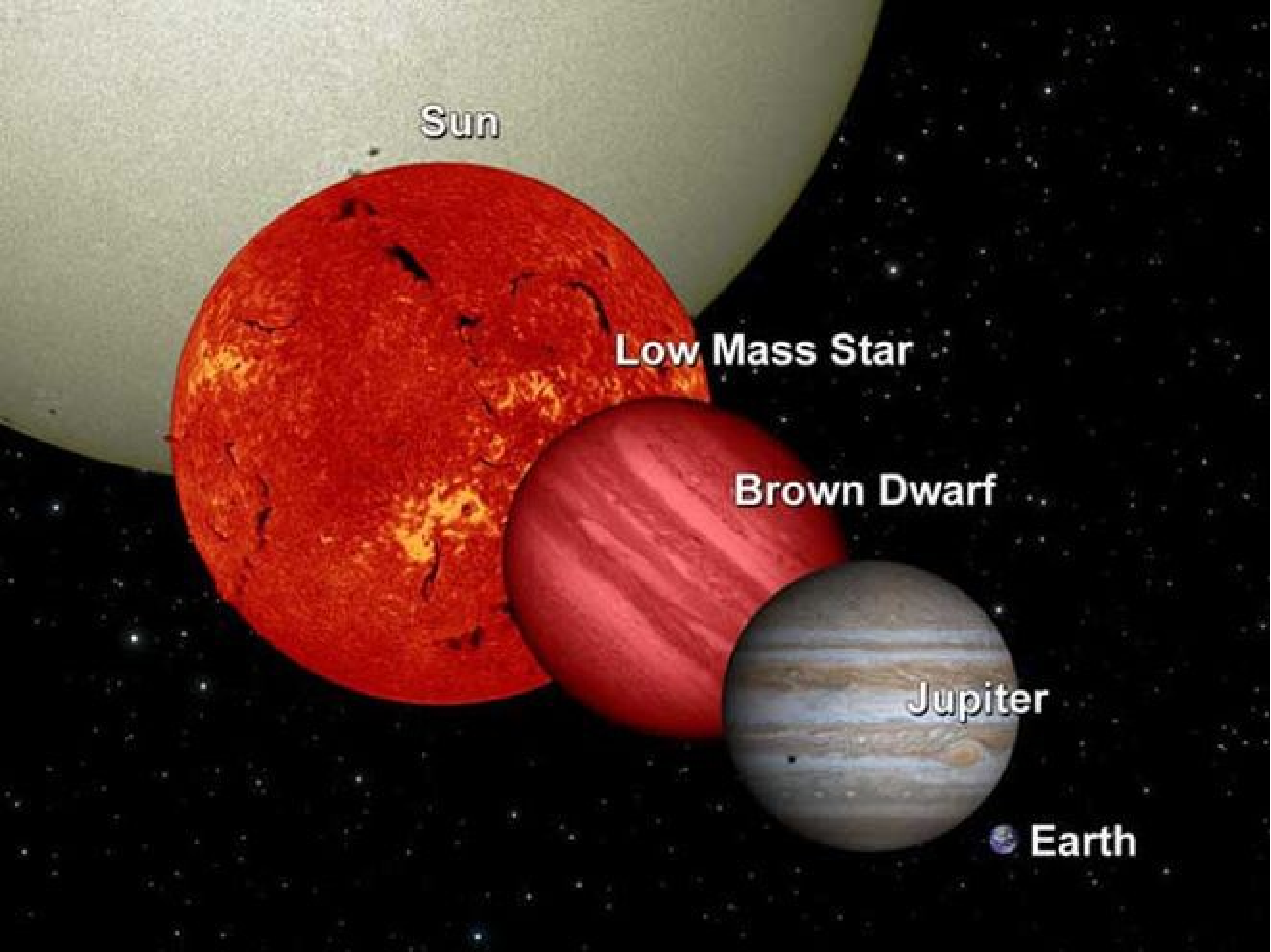
Stellar Spectral Classification
M42
ξ Pup
γ Ori
α CMa
α CMi
α Aur
α Boo
α Ori
ο Cet
(97/1/27)
19Psc
R And
P
O
B
A
F
G
K
M
M
R, N (C)
S
Y.Norimoto / Okayama Astrophysical Observatory, Y.Awano / Okayama Astronomical Museum


O6.5
B0
B6
A1
A5
F0
F5
G0
G5
K0
K5
M0
M5
F4 metal poor
M4.5 emission
B1 emission
HD 12993
HD 158659
HD 30584
HD 116608
HD 9547
HD 10032
BD 61 0367
HD 28099
HD 70178
HD 23524
SAO 76803
HD 260655
Yale 1755
HD 94028
SAO 81292
HD 13256

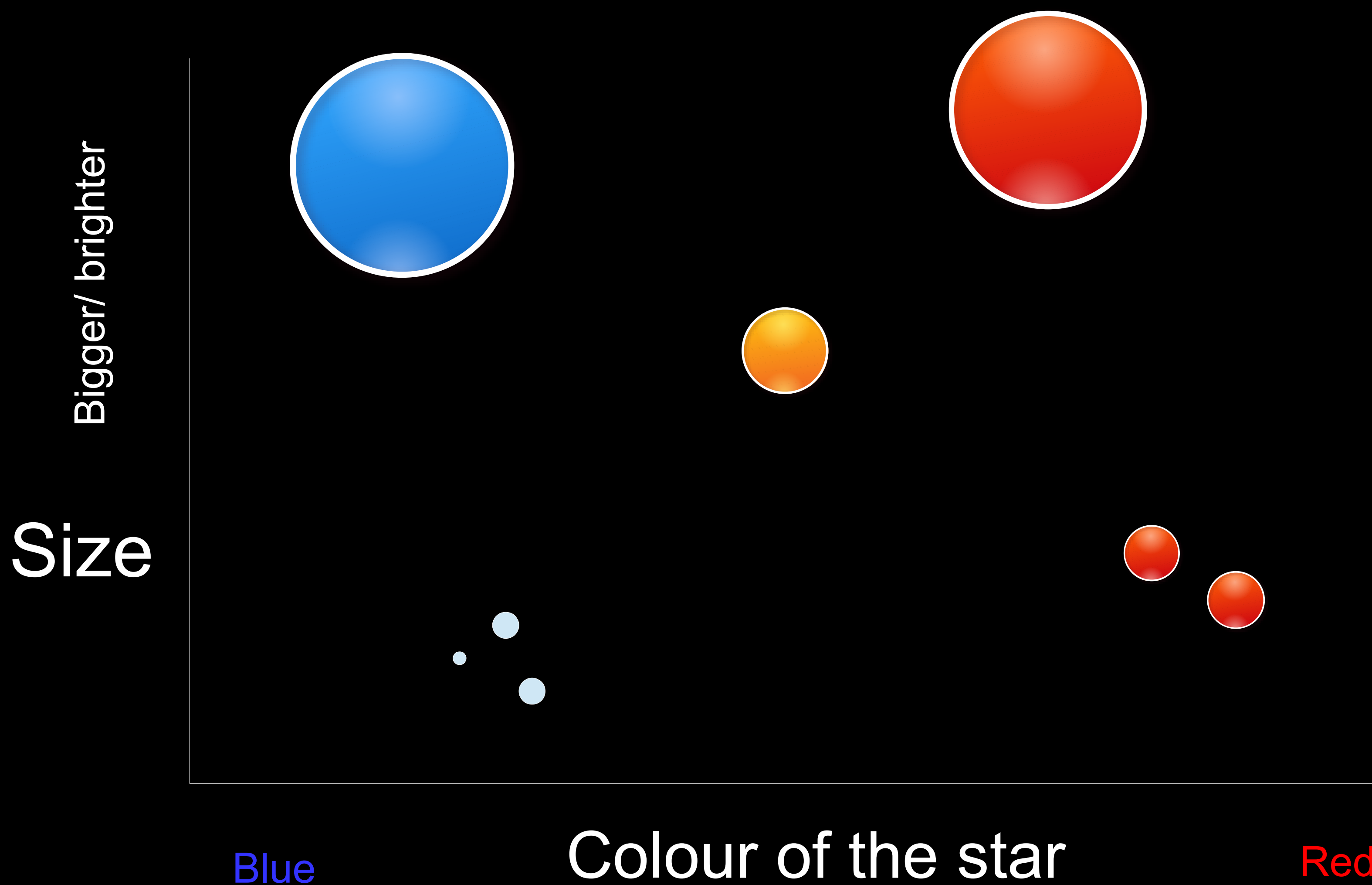
Sizes of stars



Relative sizes of stars and planets in the solar system


Sun
Low Mass Star
Brown Dwarf
Jupiter
Earth

Plot a graph of size versus colour



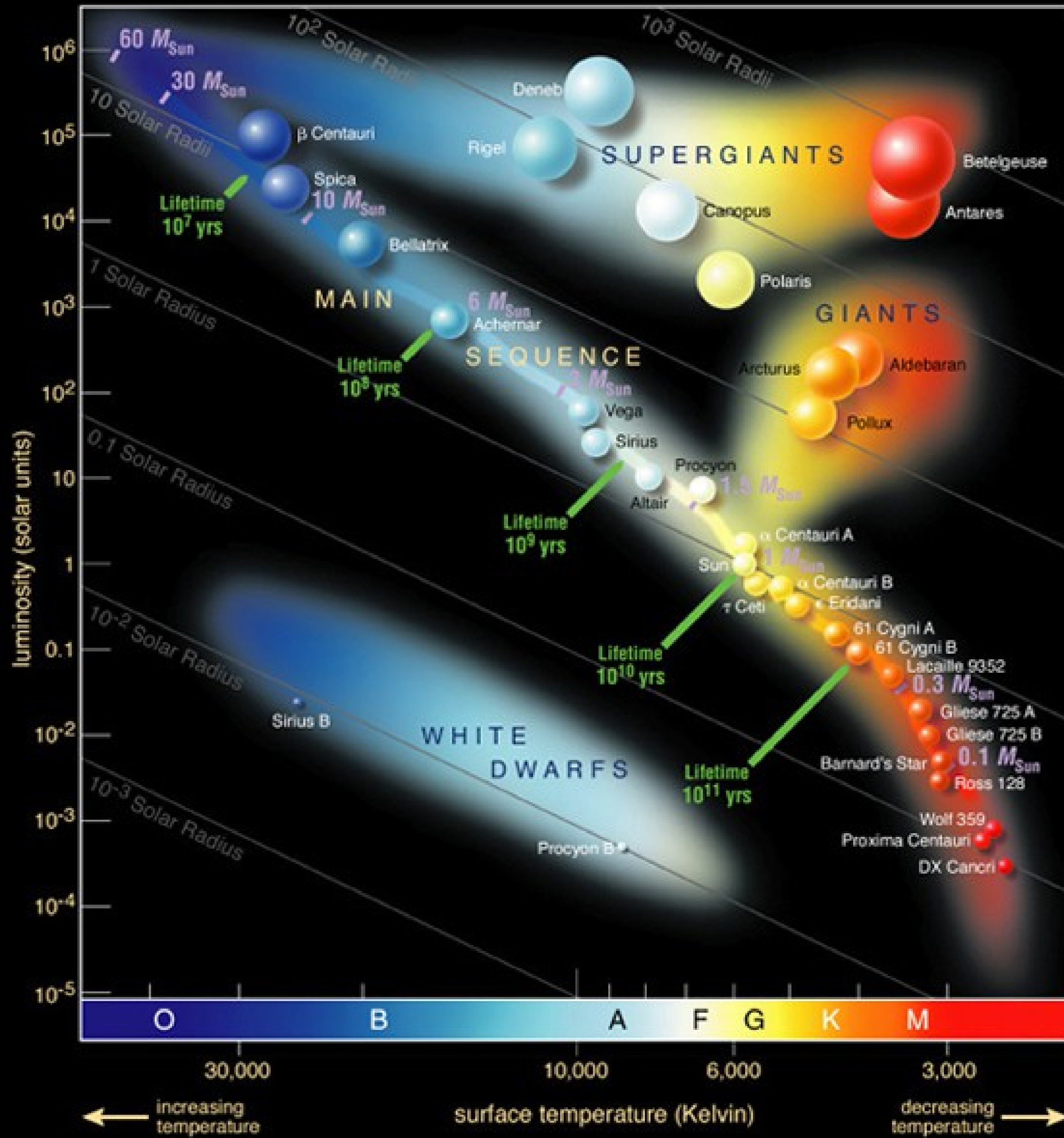
Hertsprung and Russell

1911 Danish astronomer, Ejnar Hertzsprung, plots the absolute magnitude of stars against their colour (effective temperature)

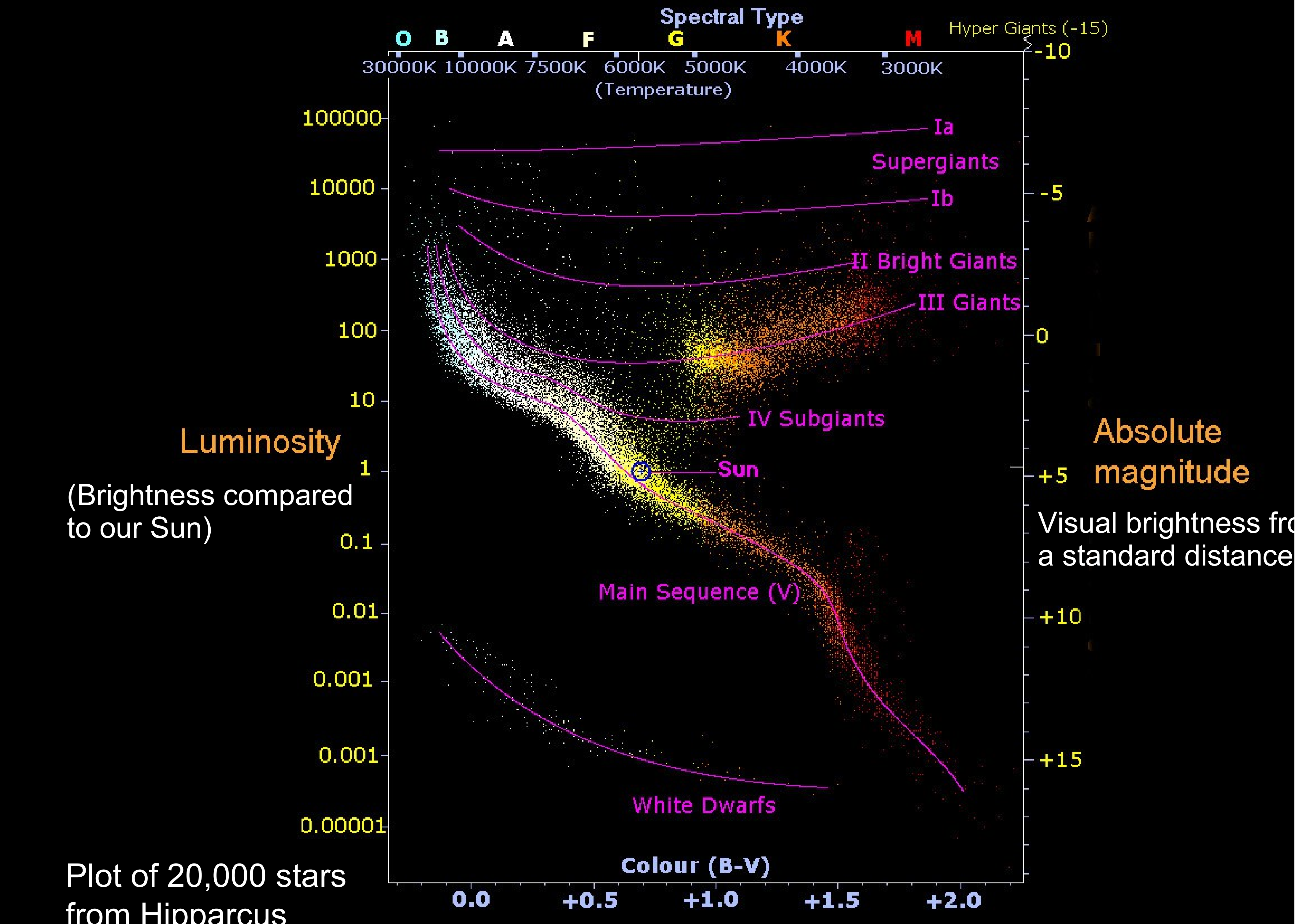
1913 American astronomer Henry Norris Russell used spectral class against absolute magnitude

The relationship between temperature and luminosity of a star is not random but falls into distinct groups

The Hertzsprung – Russell diagram is born



luminosity (solar units)
surface temperature (Kelvin)
increasing temperature
decreasing temperature
30,000
10,000
6,000
3,000
O
B
A
F
G
K
M
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
SUPERGIANTS
GIANTS
MAIN SEQUENCE
WHITE DWARFS
Deneb
Rigel
Betelgeuse
Antares
Canopus
Polaris
β Centauri
Spica
Bellatrix
Achernar
Arcturus
Aldebaran
Pollux
Vega
Sirius
Procyon
Altair
α Centauri A
Sun
α Centauri B
τ Ceti
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
Procyon B



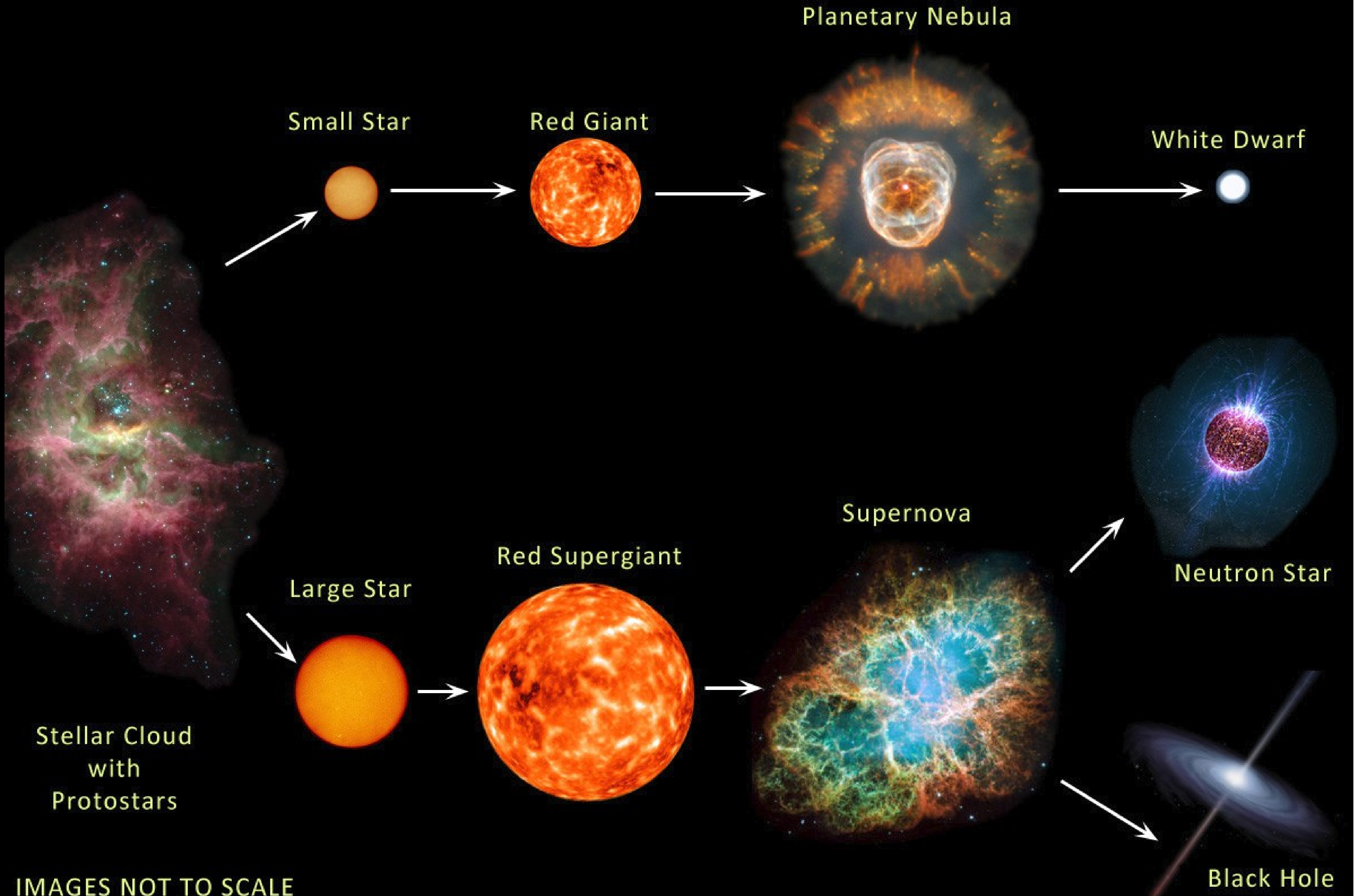
Plot of 20,000 stars from Hipparcus

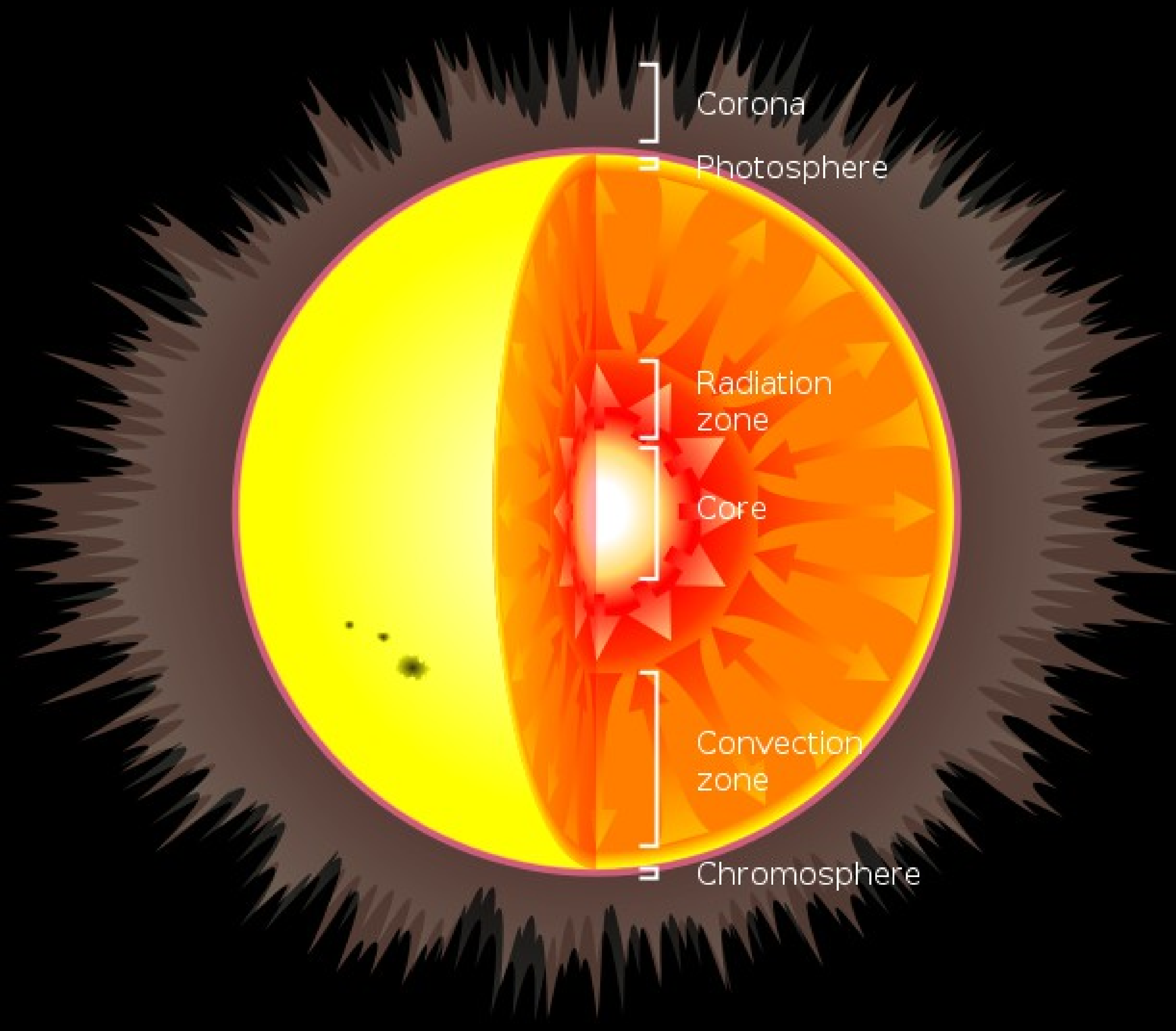
	Temp (K)	Class	Mass*	Radius*	Luminosity*	Hydrogen lines	Fraction of all main-sequence stars
O	≥ 30k	blue	≥ 16	≥ 6.6	≥ 30,000	Weak	~0.00003%
B	10k–30k	blue white	2.1–16	1.8–6.6	25–30,000	Medium	0.0013
A	7.5k–10k	white	1.4–2.1	1.4–1.8	5–25	Strong	0.006
F	6k–7.5k	yellow white	1.04–1.4	1.15–1.4	1.5–5	Medium	0.03
G	5.2k–6k	yellow	0.8–1.04	0.96–1.15	0.6–1.5	Weak	0.076
K	3.7k–5.2k	orange	0.45–0.8	0.7–0.96	0.08–0.6	Very weak	0.121
M	2.4k–3.7k	red	0.08–0.45	≤ 0.7	≤ 0.08	Very weak	0.7645
L	1.3k–2.4k	red brown	0.005–0.08	0.08–0.15	0.000,05–0.001	Ext. weak	
T	0.5k–1.3k	brown	0.001–0.07	0.08–0.14	0.000,001–0.000,05	Ext. weak	
Y	≤ 0.5k	dark brown	0.0005–0.02	0.08–0.14	0.000,000,1–0.000,001	Ext. weak	

*Relative to the Sun

Birth

EVOLUTION OF STARS

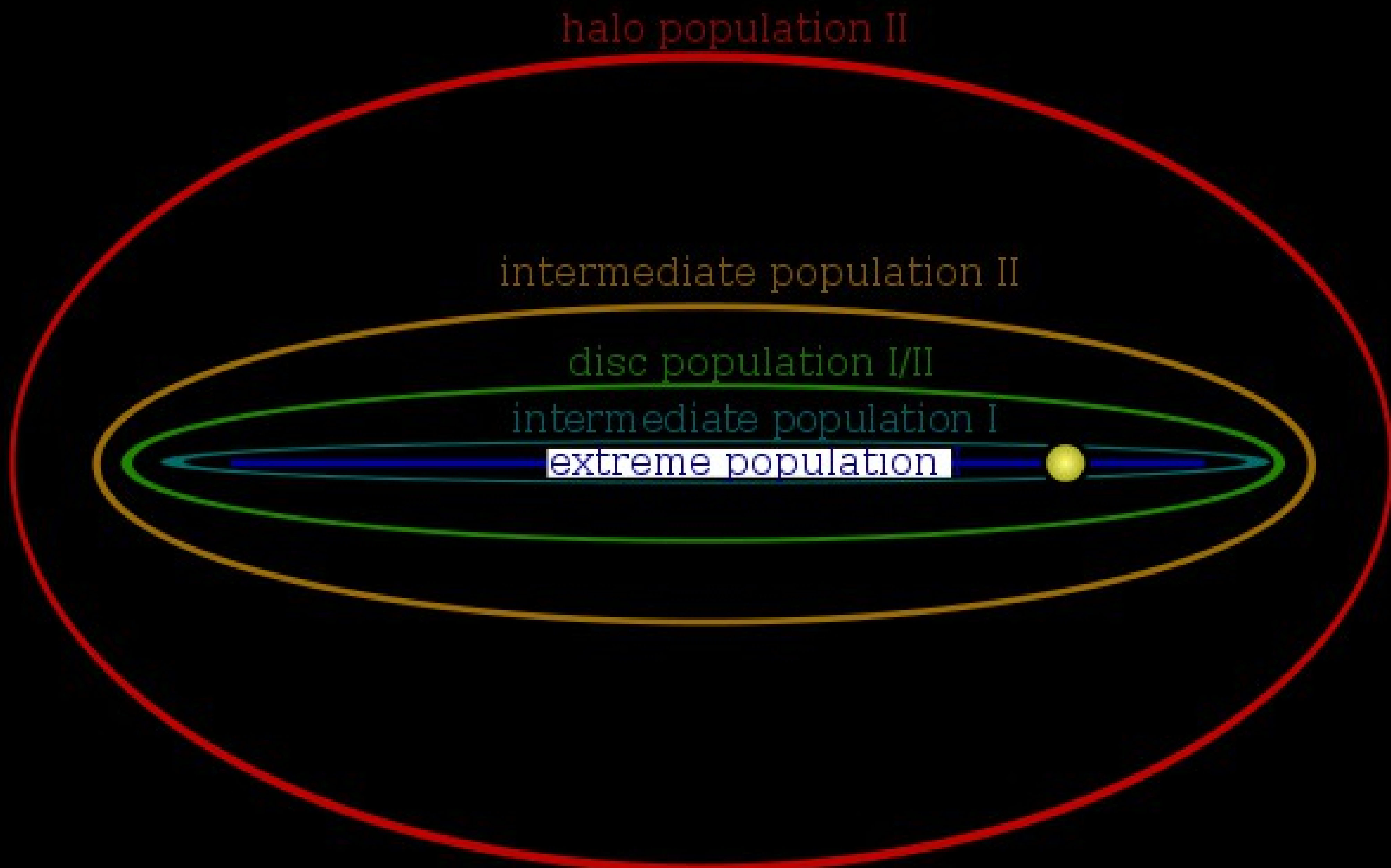



Corona
Photosphere
Radiation zone
Core
Convection zone
Chromosphere

Stephan's Quintet, interacting galaxies showing waves of star formation

M82

NASA, ESA and the Hubble Heritage Team STScI/AURA). Acknowledgment: J. Gallagher (University of Wisconsin), M. Mountain (STScI) and P. Puxley (NSF).



Distribution of star populations in the Milky Way

Young stars in NGC 602a – part of the Small Magallanic Cloud

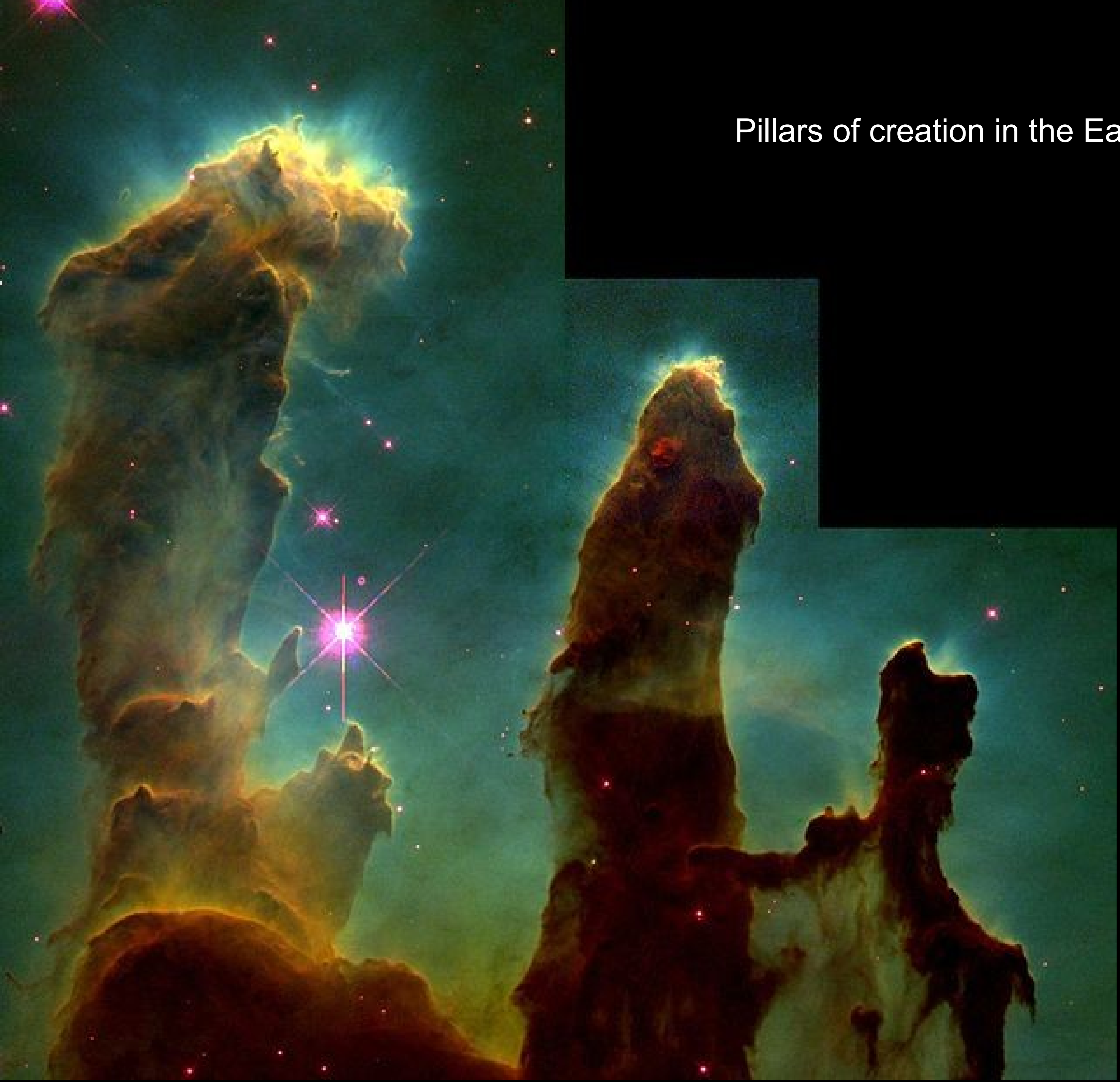
Birth of a new star in the Circinus molecular cloud

ESA/Hubble & NASA
Acknowledgements: R. Sahai (Jet Propulsion Laboratory), Serge Meunier

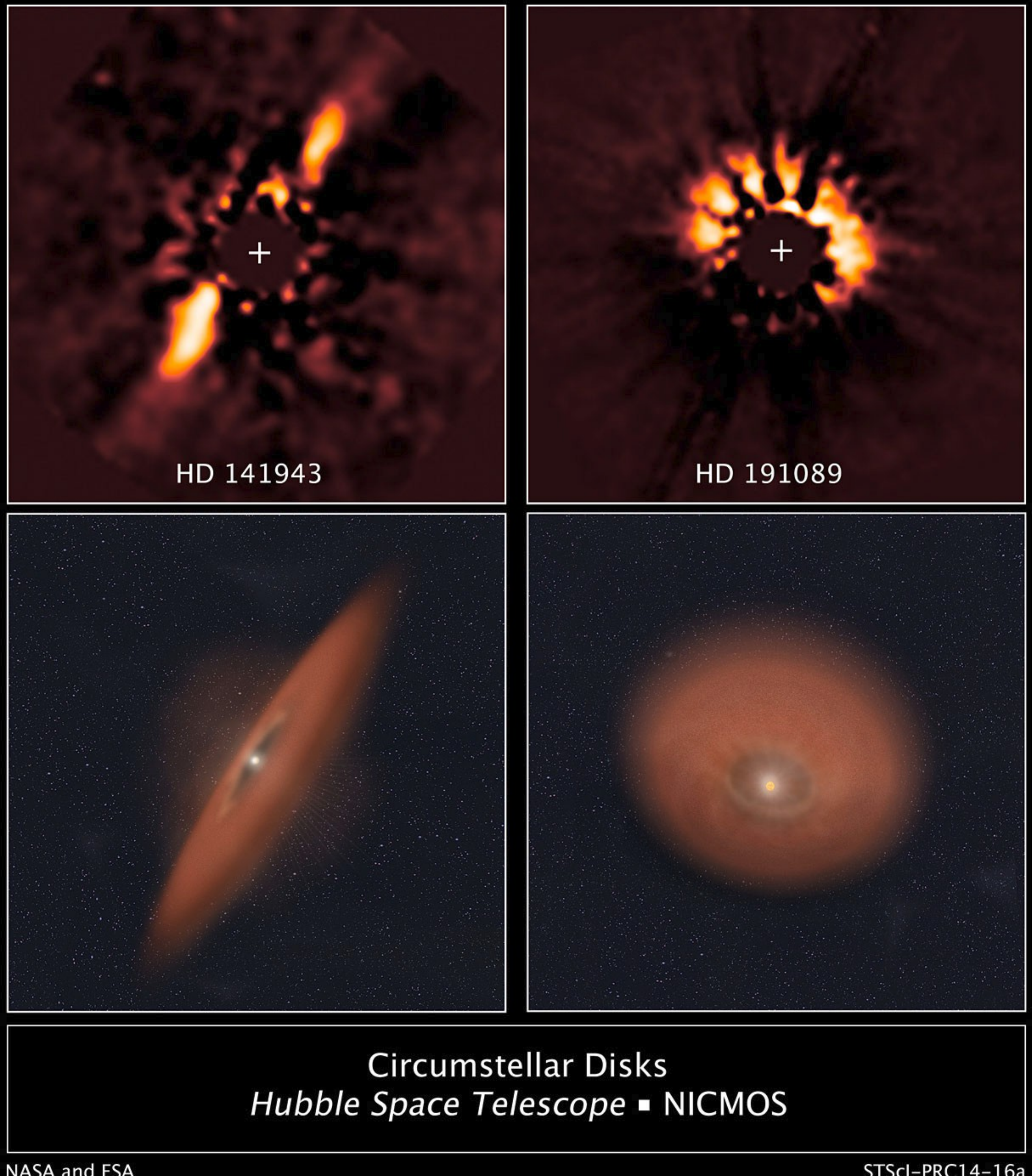

NASA & ESA


NASA, ESA, and M. Livio and the Hubble 20th Anniversary Team (STScI)

Star-forming region in Carina



Pillars of creation in the Eagle nebula



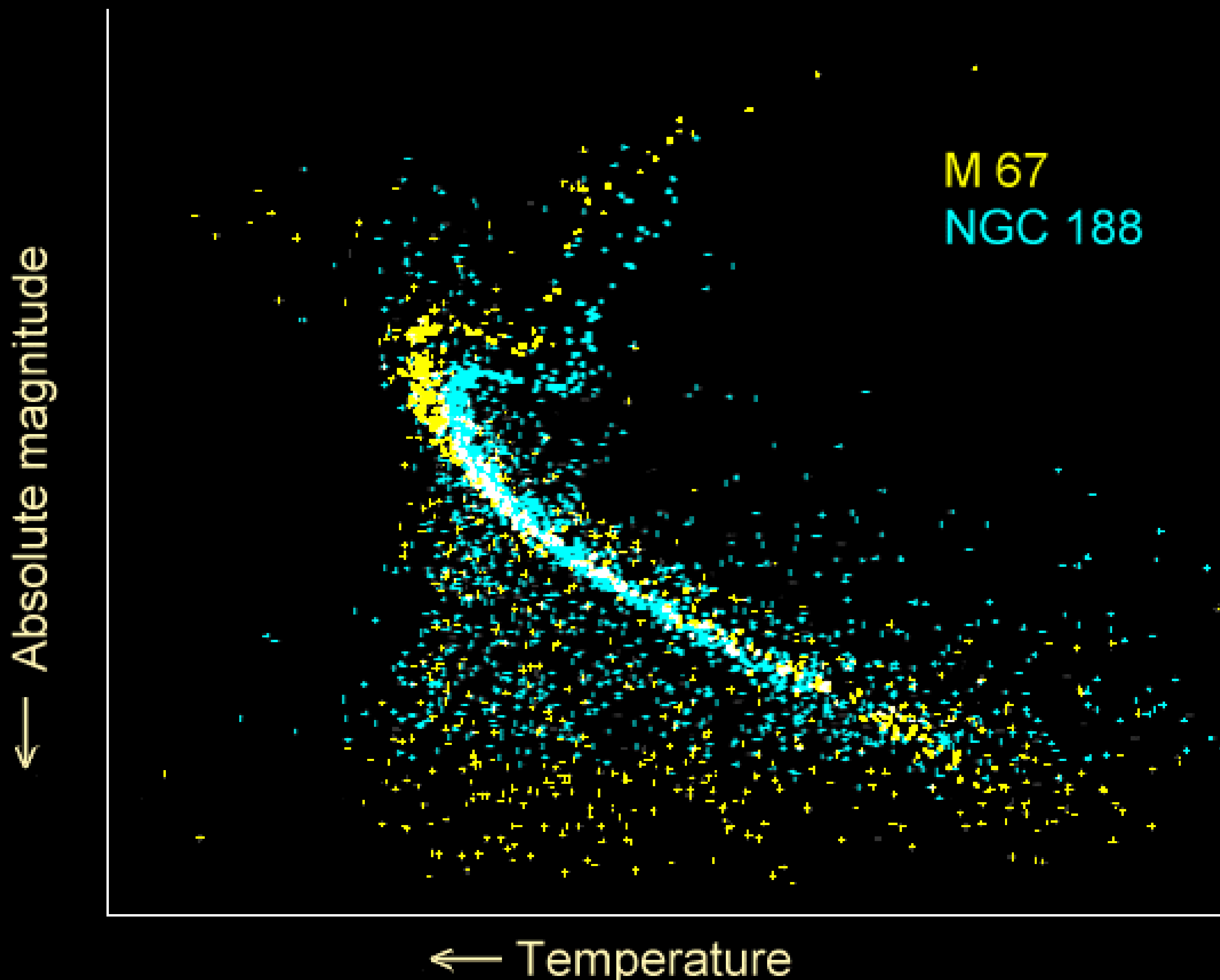
Young Sun-like stars showing accretion discs in near-infrared

NASA, ESA, ESO, D. Lennon and E. Sabbi (ESA/STScI), J. Anderson, S. E. de Mink, R. van der Marel, T. Sohn, and N. Walborn (STScI), N. Bastian (Excellence Cluster, Munich), L. Bedin (INAF, Padua), E. Bressert (ESO), P. Crowther (Sheffield), A. de Koter (Amsterdam), C. Evans (UKATC/STFC, Edinburgh), A. Herrero (IAC, Tenerife), N.

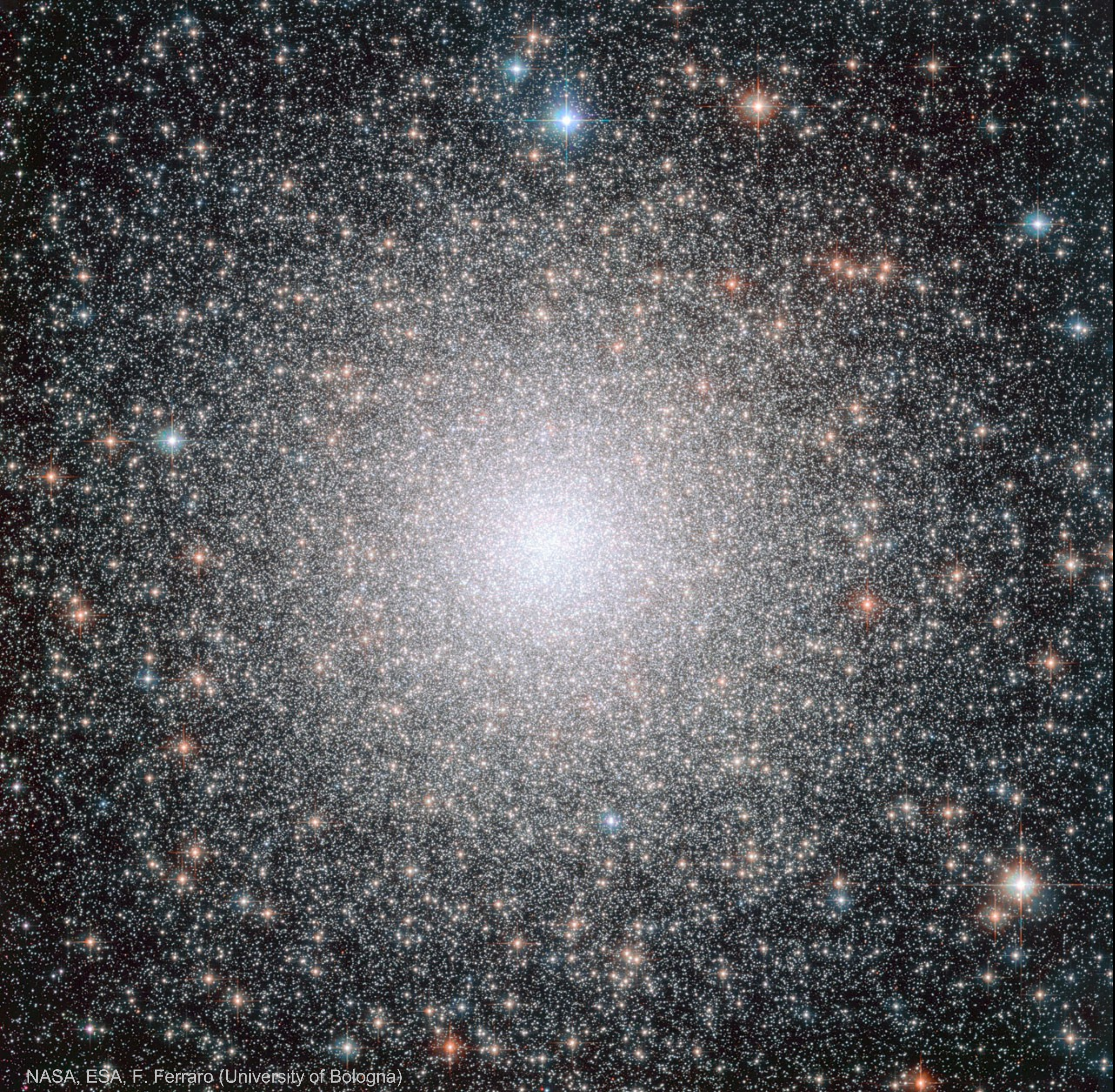
Hot brilliant O type stars in active star forming regions

ESO

Open star clusters NGC 265 and NGC 290 in the Small Magellanic Cloud

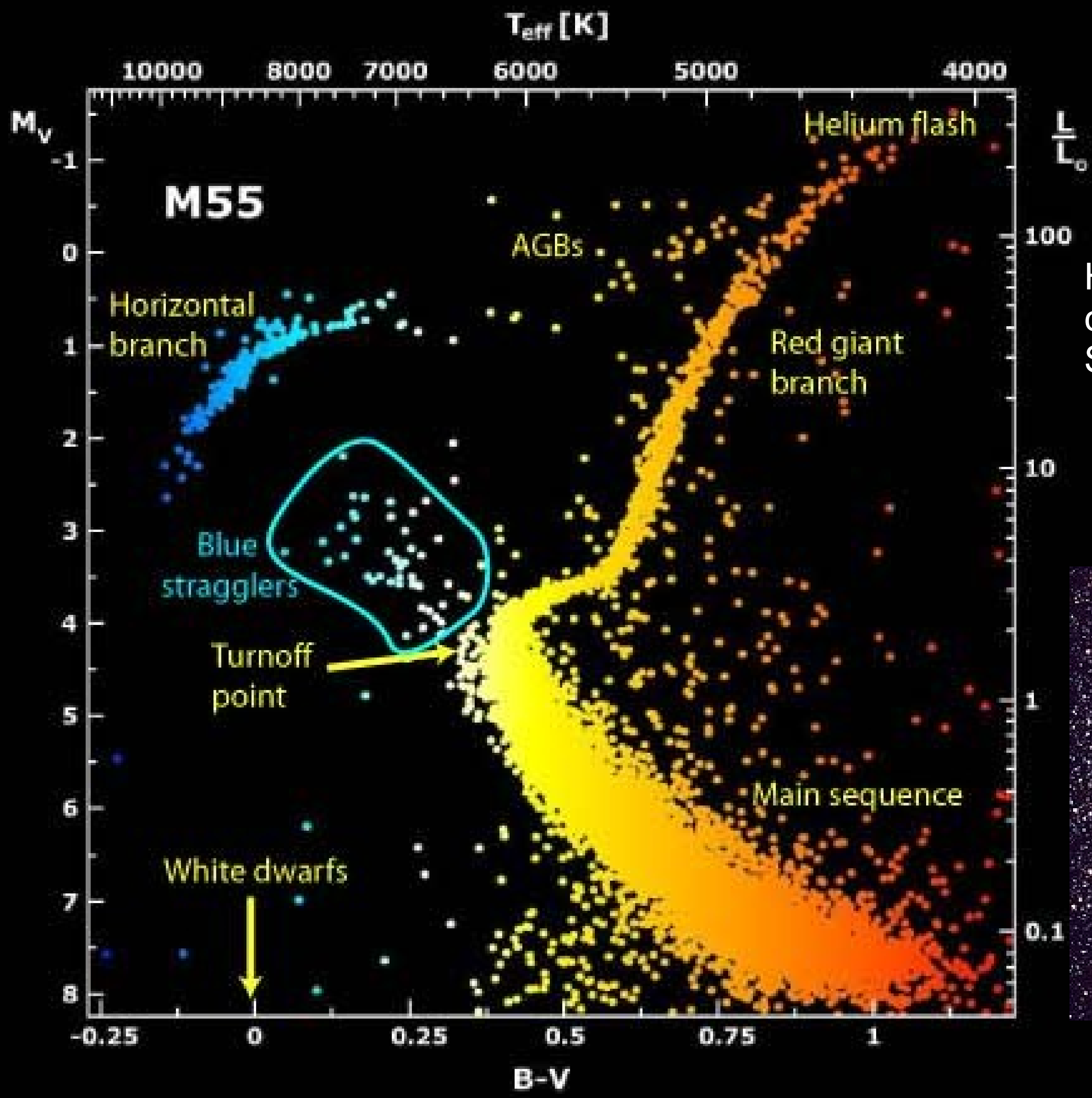


M 67
NGC 188
← Absolute magnitude
← Temperature



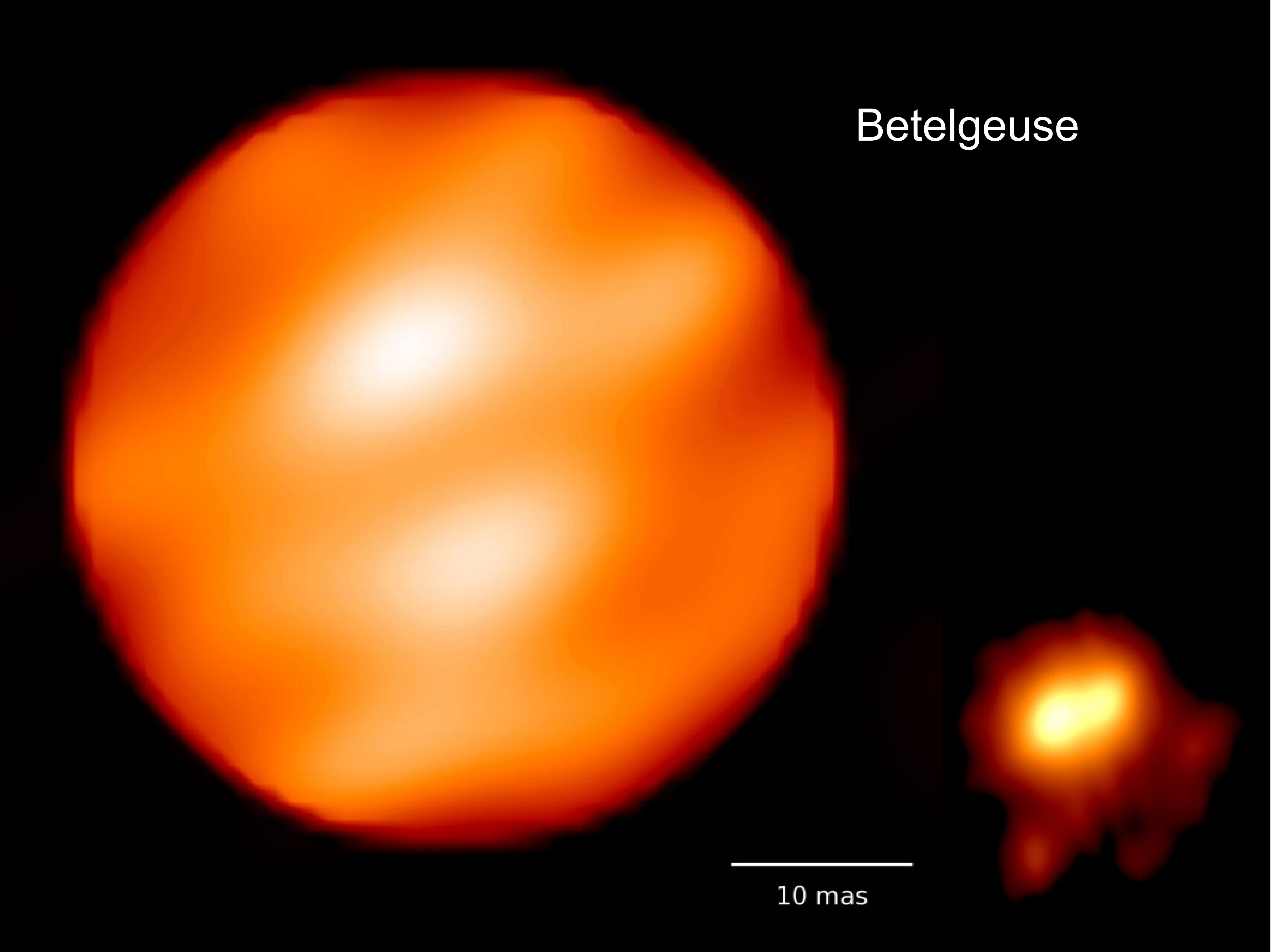
The globular cluster NGC6388

The core of NGC6362 showing stars of an unexpectedly wide age range

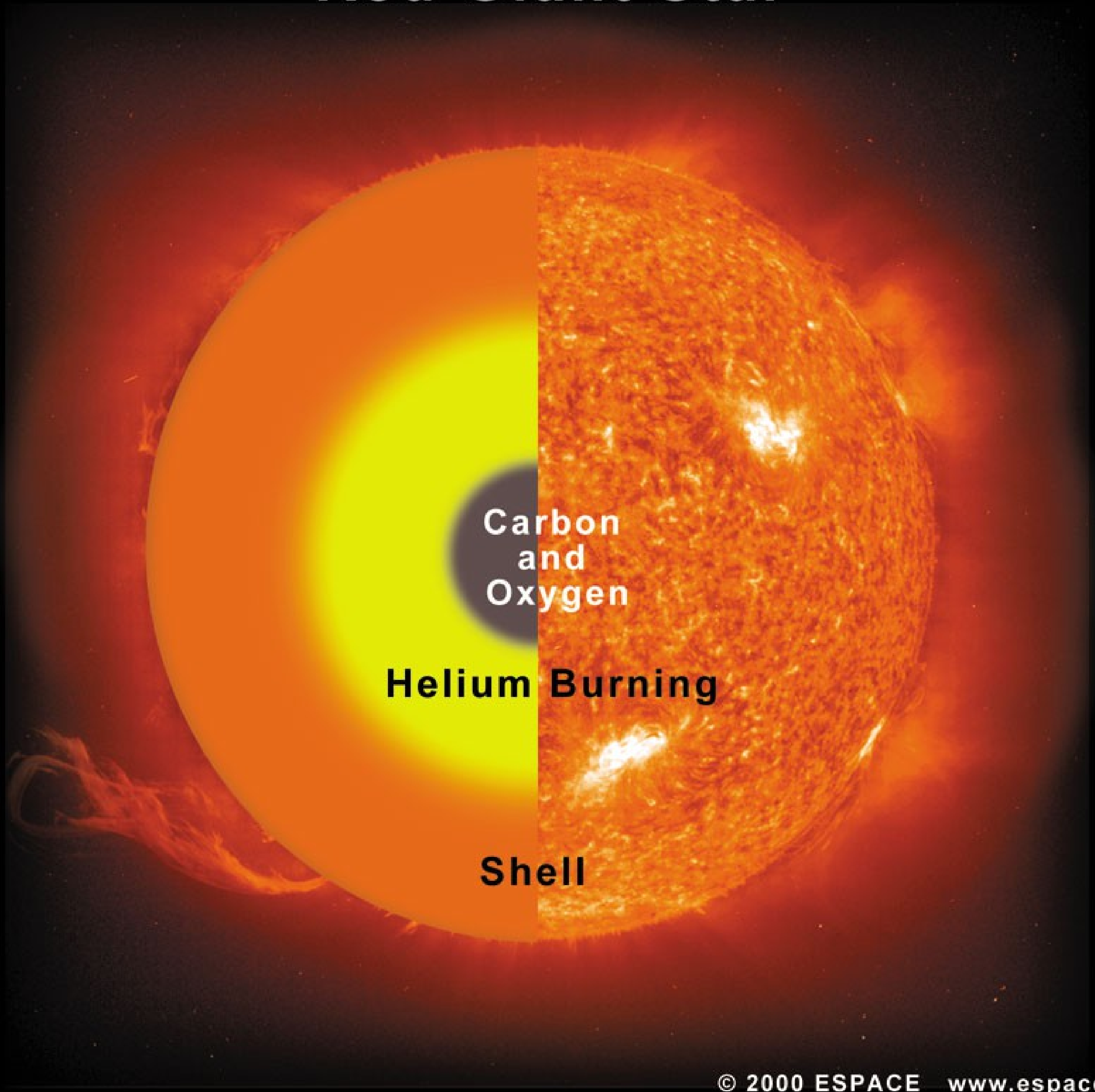


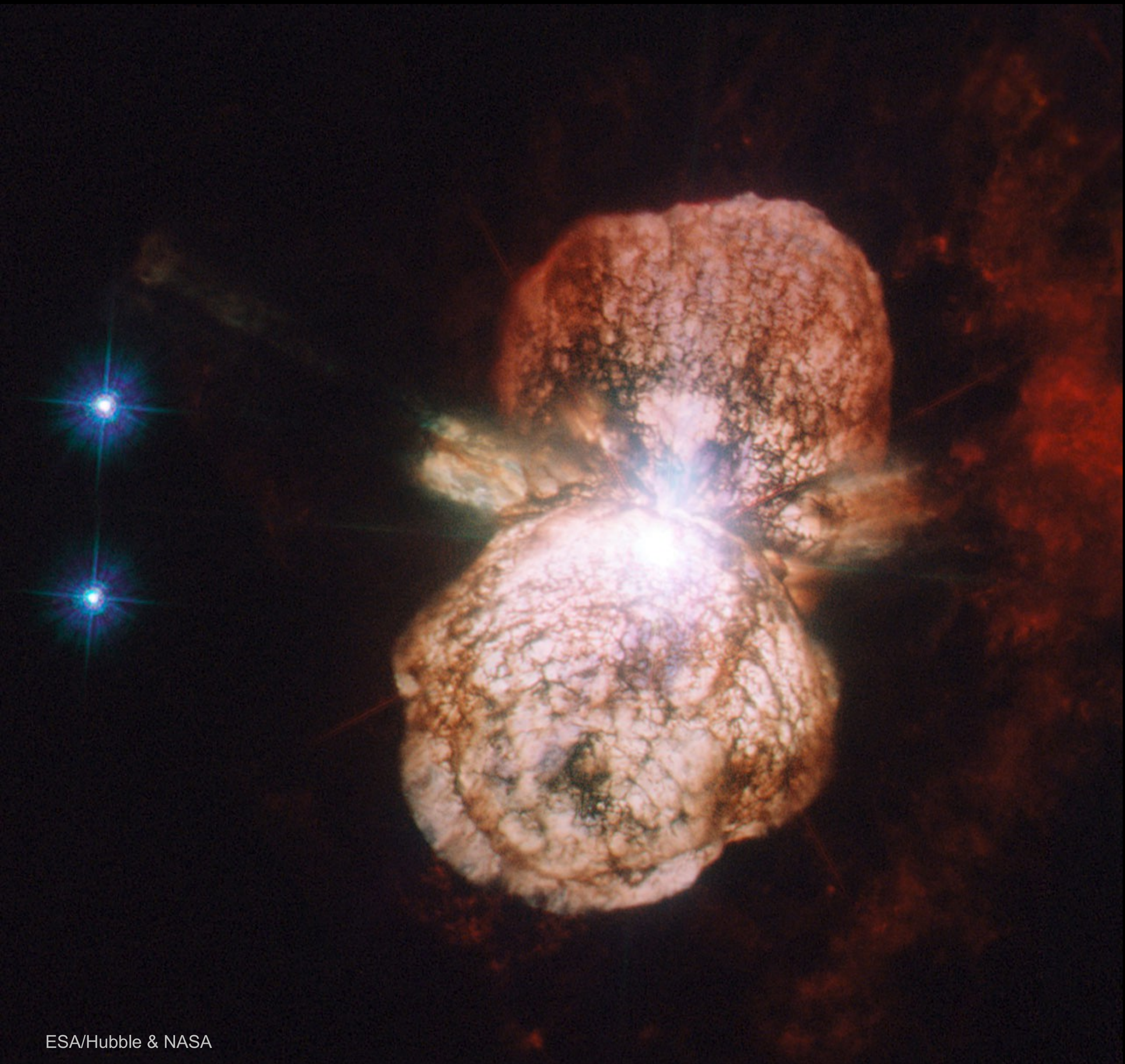
HR diagram for the globular cluster M55 (NGC6809) in Sagittarius

Old age

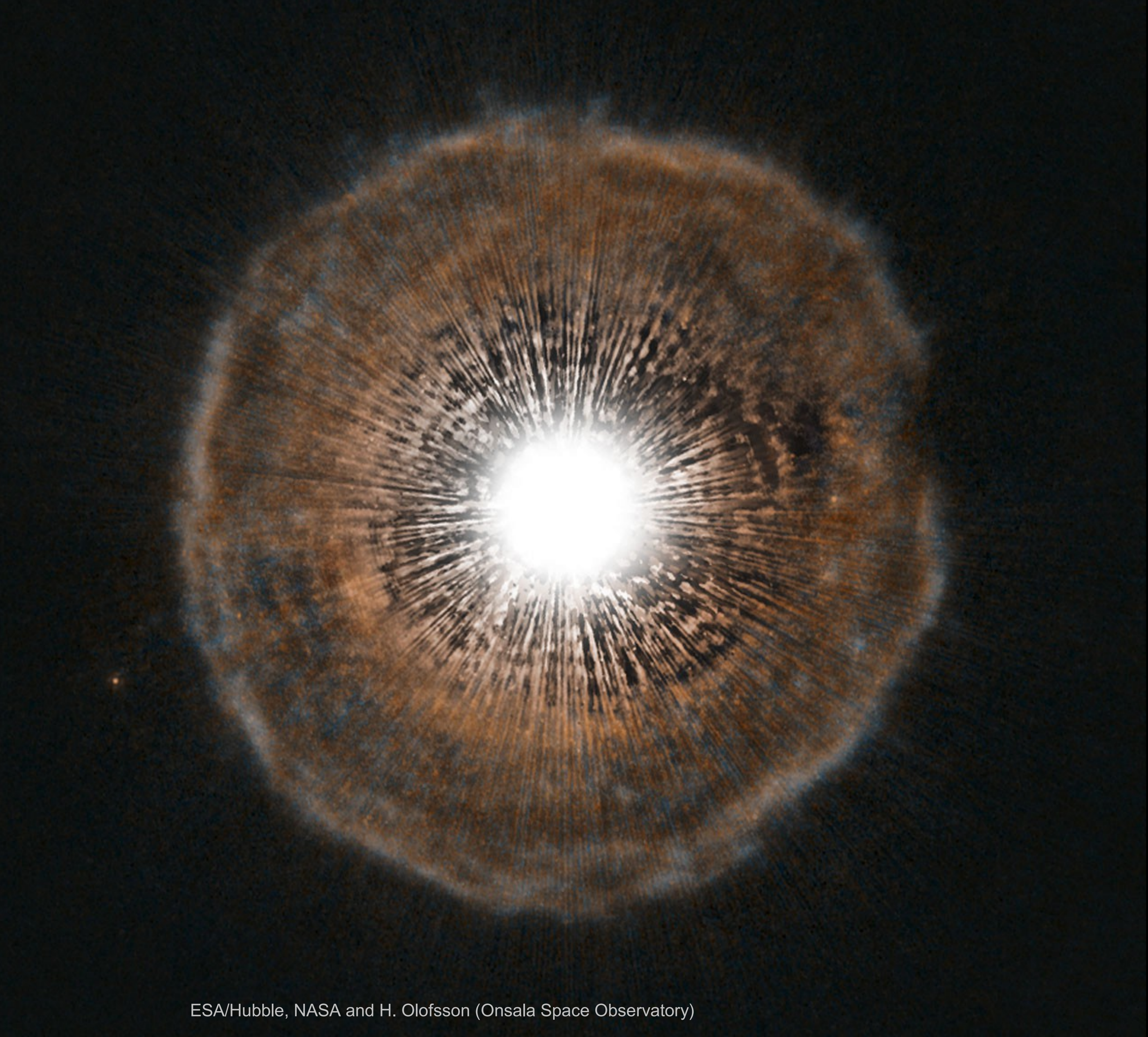

Betelgeuse
10 mas

Red Giant Star





Eta Carinae – a huge star close to the end of its life



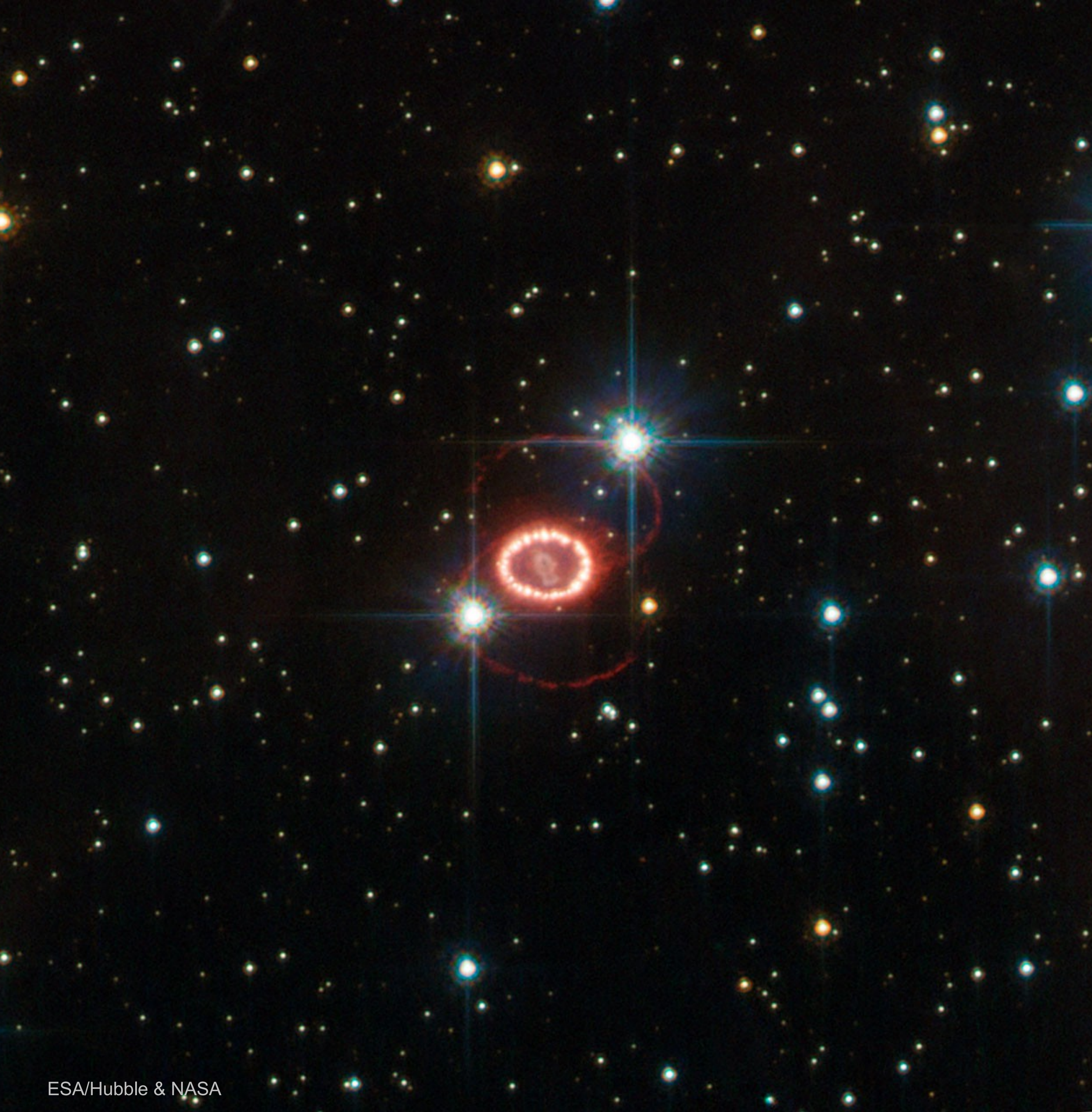
U Cam, an unstable red giant/ carbon star nears the end of its life

Nebula M1-67 around the Wolf-Rayet star WR124

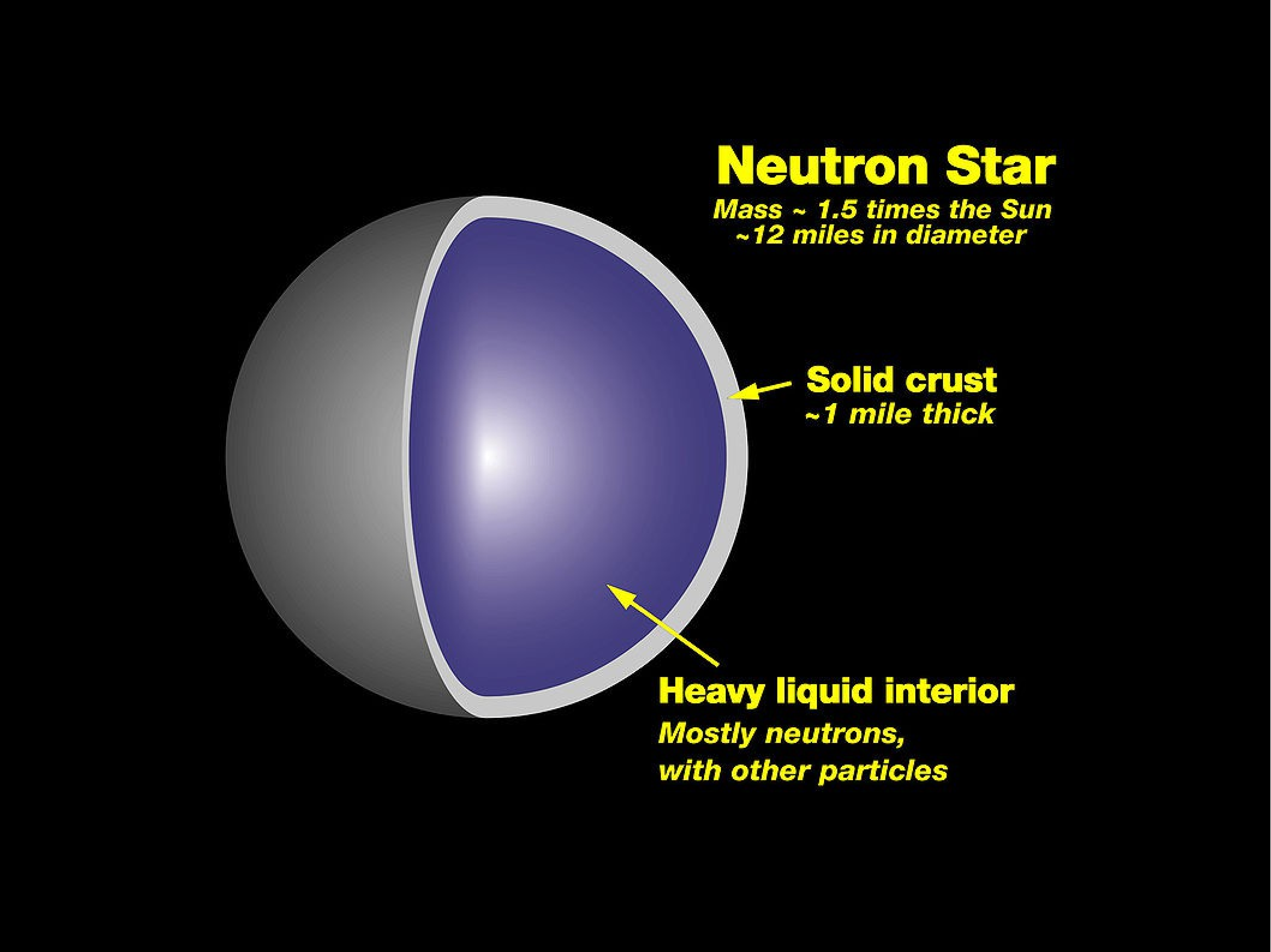
Death

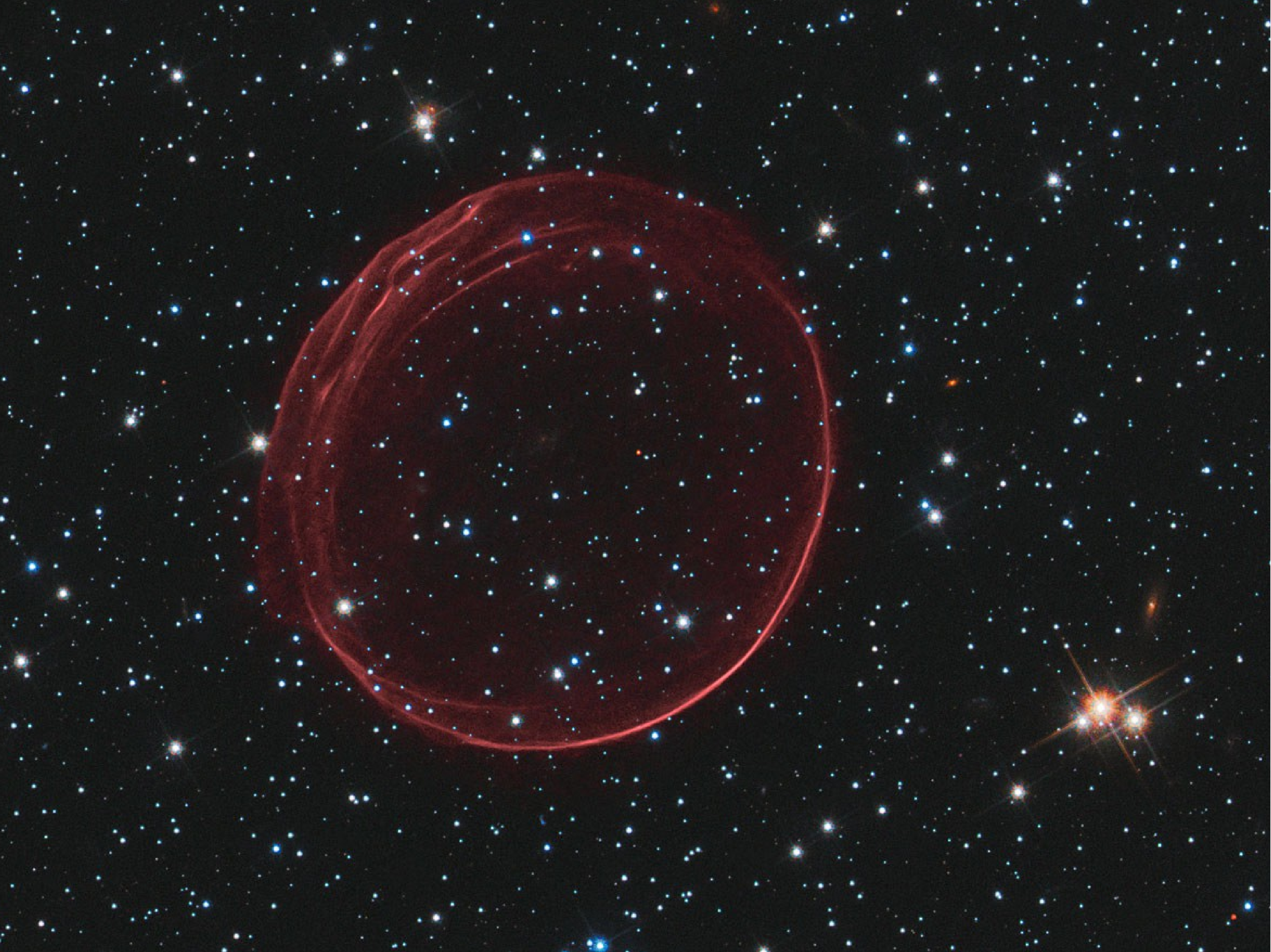
NASA, ESA and the Hubble Heritage Team STScI/AURA). Acknowledgment: J. Gallagher (University of Wisconsin), M. Mountain (STScI) and P. Puxley (NSF).

Super nova in M82 14th January 2014



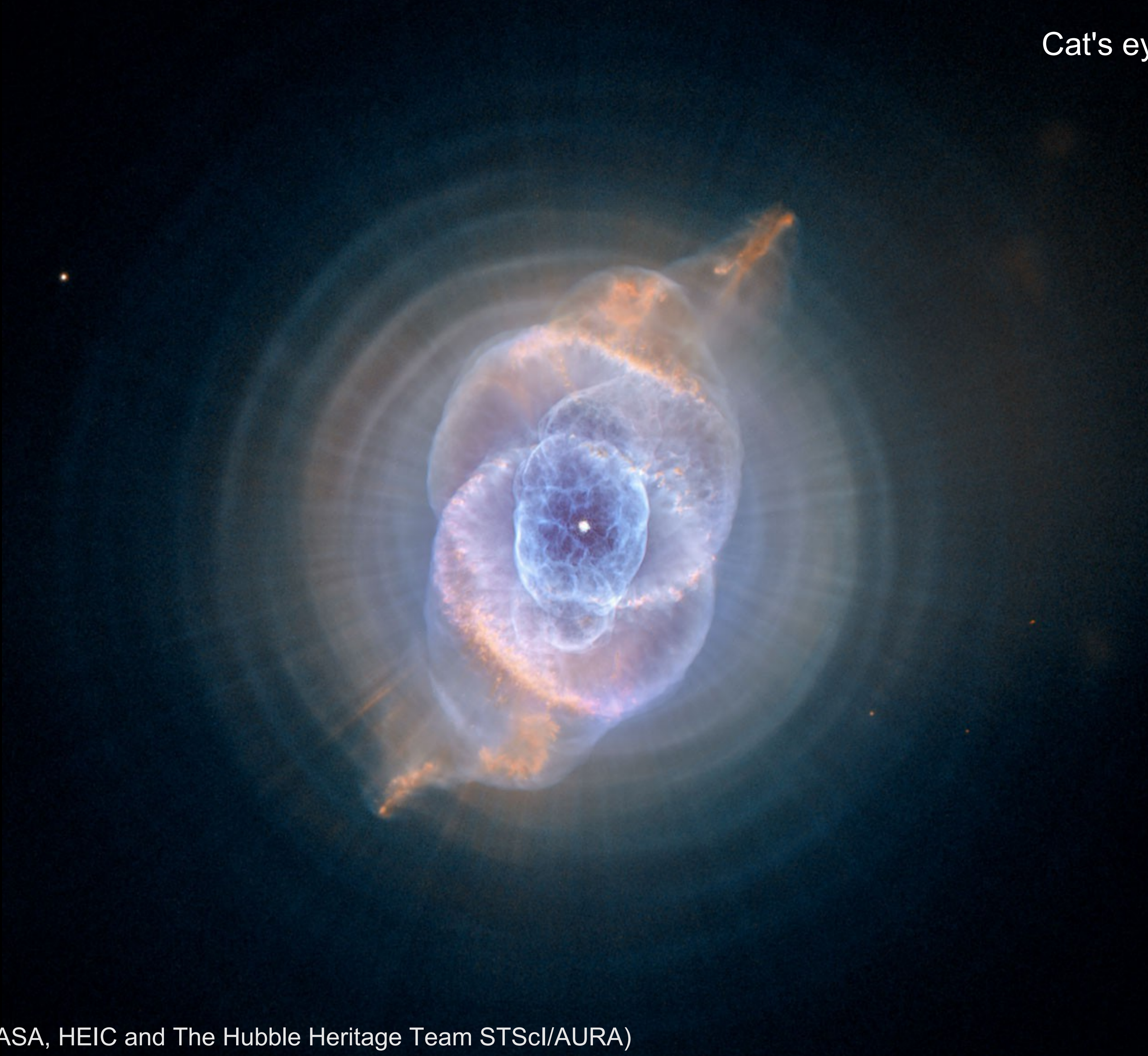
Remains of a supernova SN1987a


Neutron Star
Mass ~ 1.5 times the Sun
~12 miles in diameter
Solid crust
~1 mile thick
Heavy liquid interior
Mostly neutrons,
with other particles



NASA, ESA and Allison Loll/Jeff Hester (Arizona State University). Acknowledgement: Davide De Martin (ESA/Hubble

Cat's eye nebula



ESA, NASA, HEIC and The Hubble Heritage Team STScI/AURA)