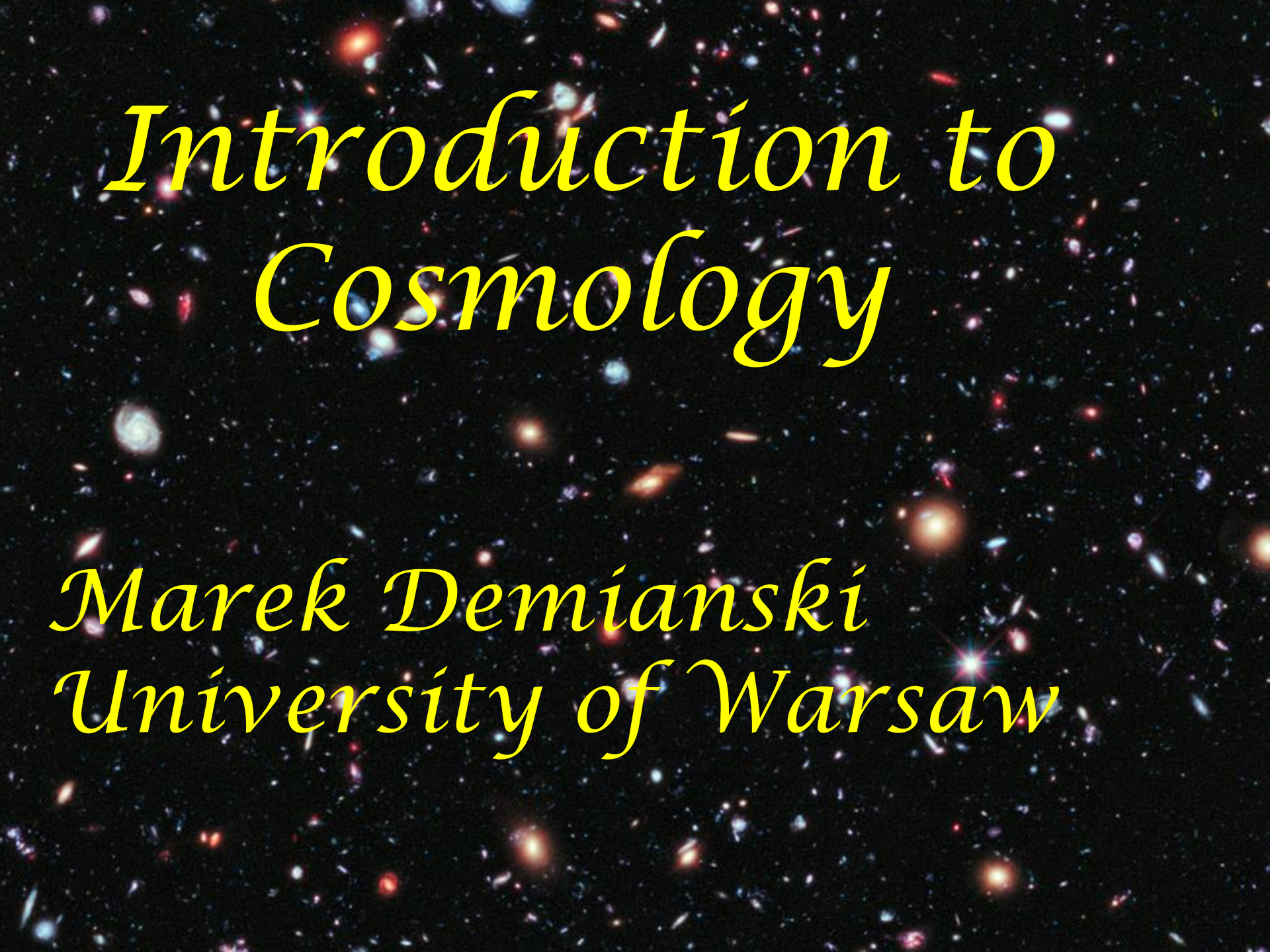
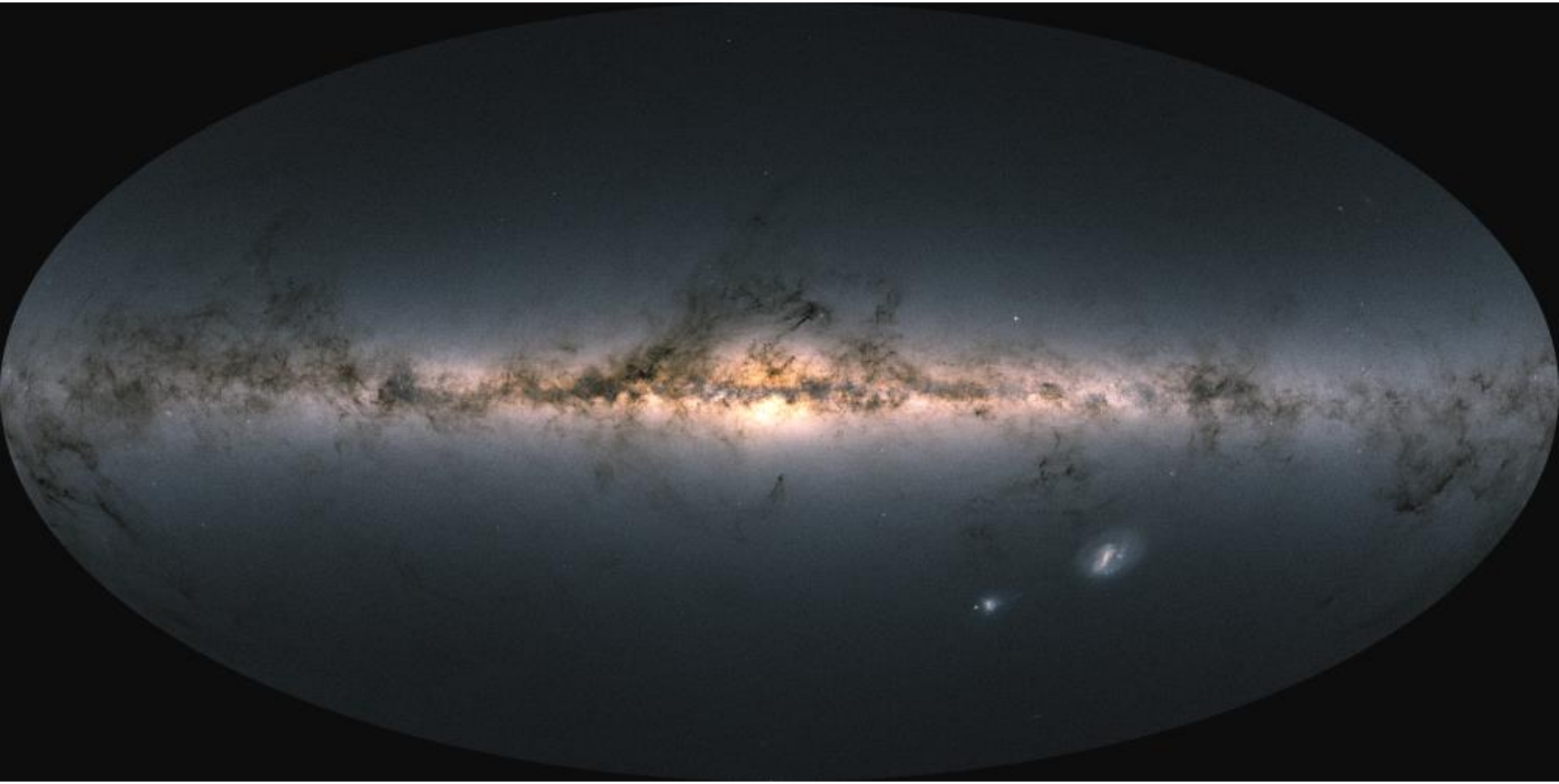
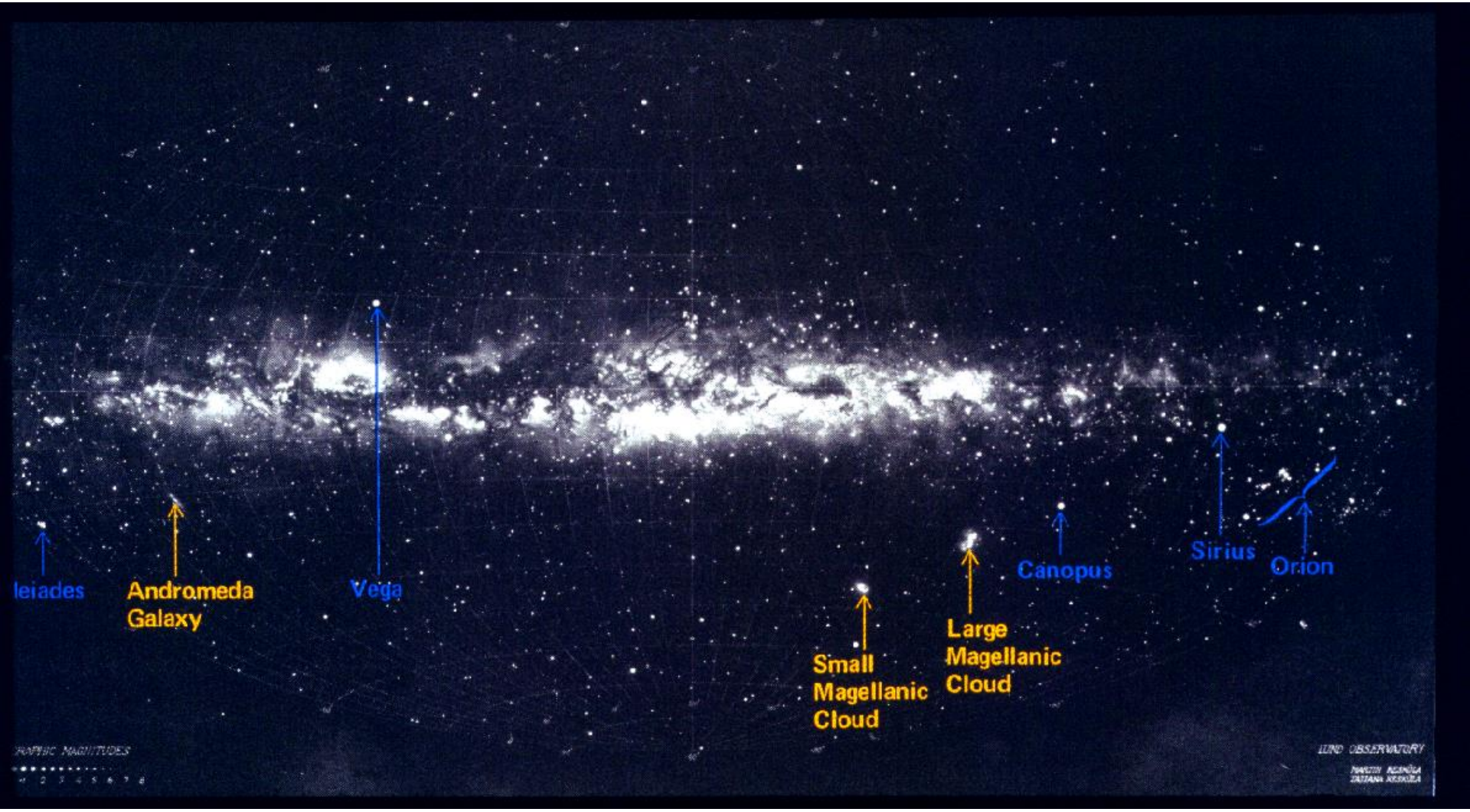
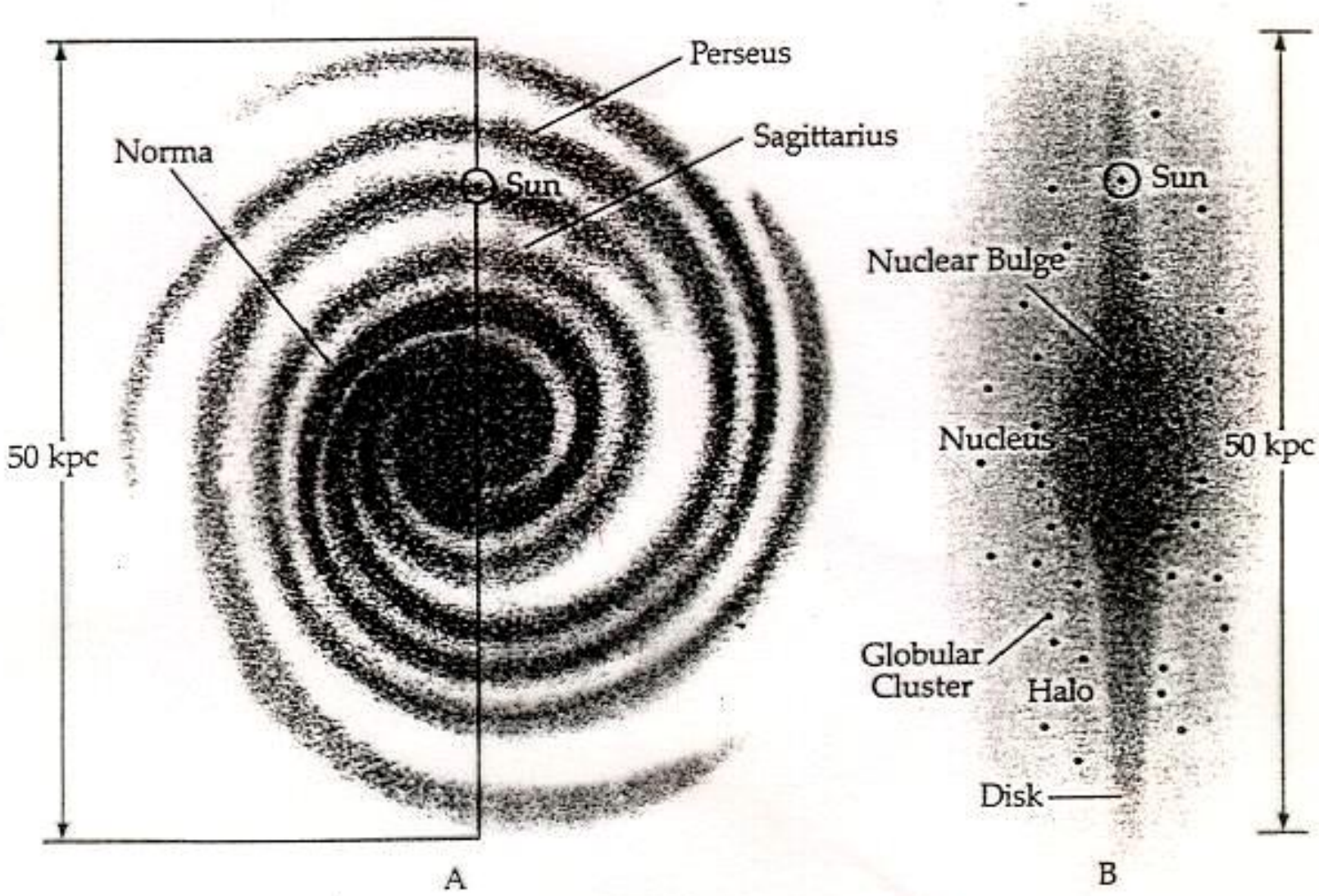

Introduction to
Cosmology
Marek Demianski
University of Warsaw

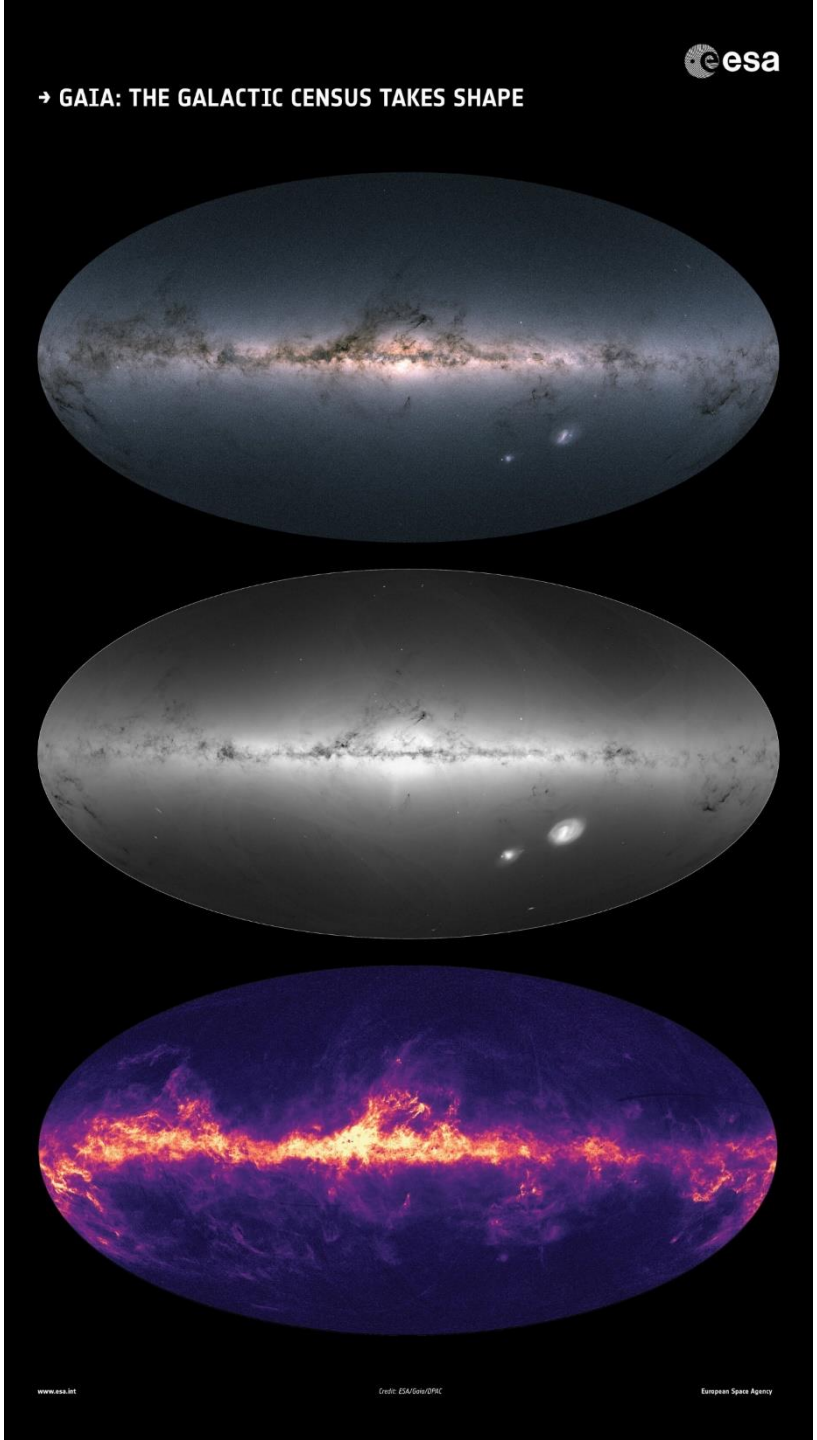



Pleiades
Andromeda Galaxy
Vega
Small Magellanic Cloud
Large Magellanic Cloud
Canopus
Sirius
Orion
PHOTOGRAPHIC MAGNITUDES
LUND OBSERVATORY


Perseus
Sagittarius
Norma
Sun
50 kpc
A
Sun
Nuclear Bulge
Nucleus
50 kpc
Globular
Cluster
Halo
Disk
B

Size of the Milky Way

- Diameter of the disk 120000 ly
- Thickness of the disk 1000 ly
- Diameter of the galactic halo 300000 ly
- Distance of the Sun from the galactic center ~ 25000 ly
- Mass ~ $120 \times 10^9 M_\odot$
- Number of stars ~ 200×10^9

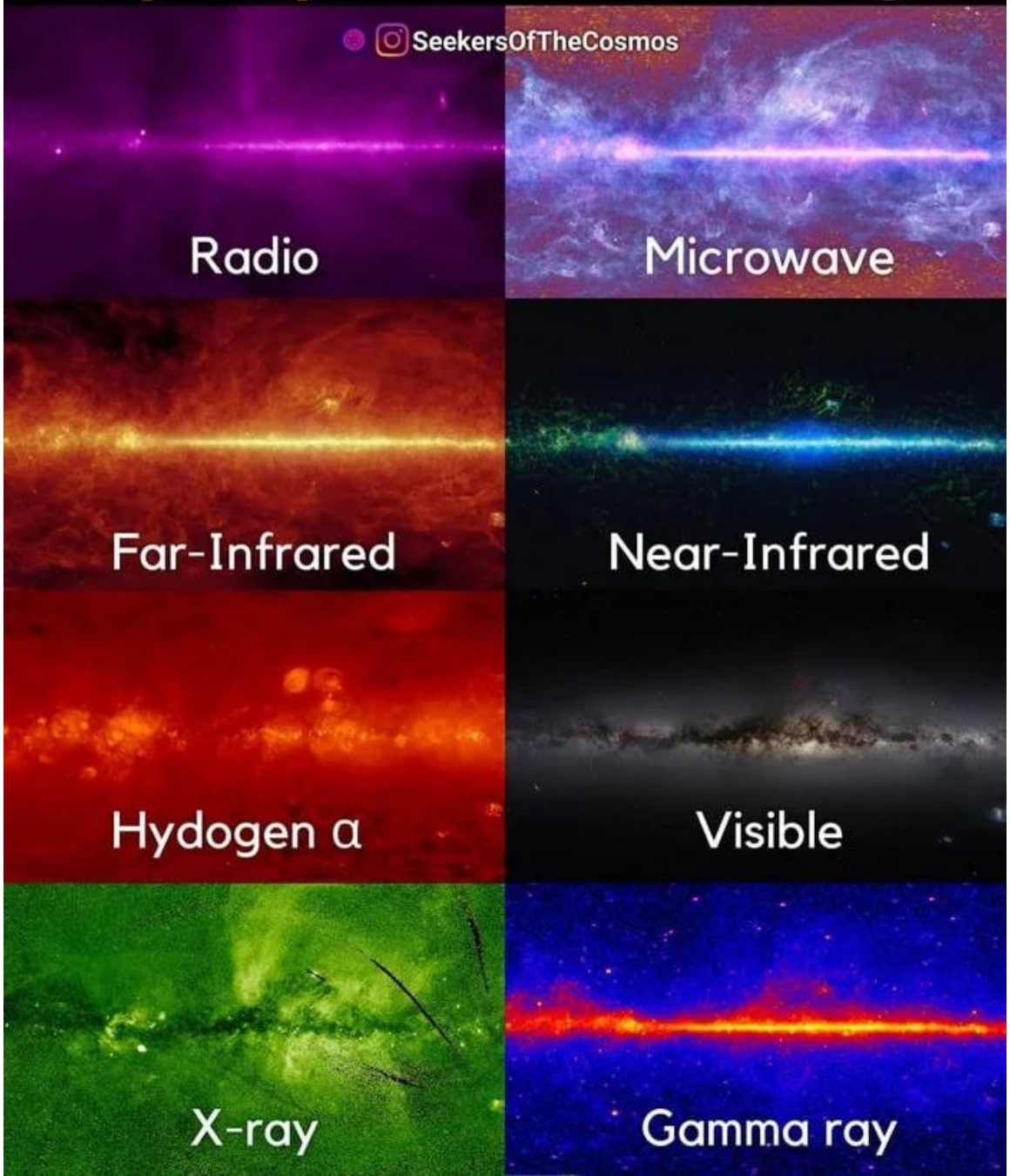


Total brightness

Density of stars

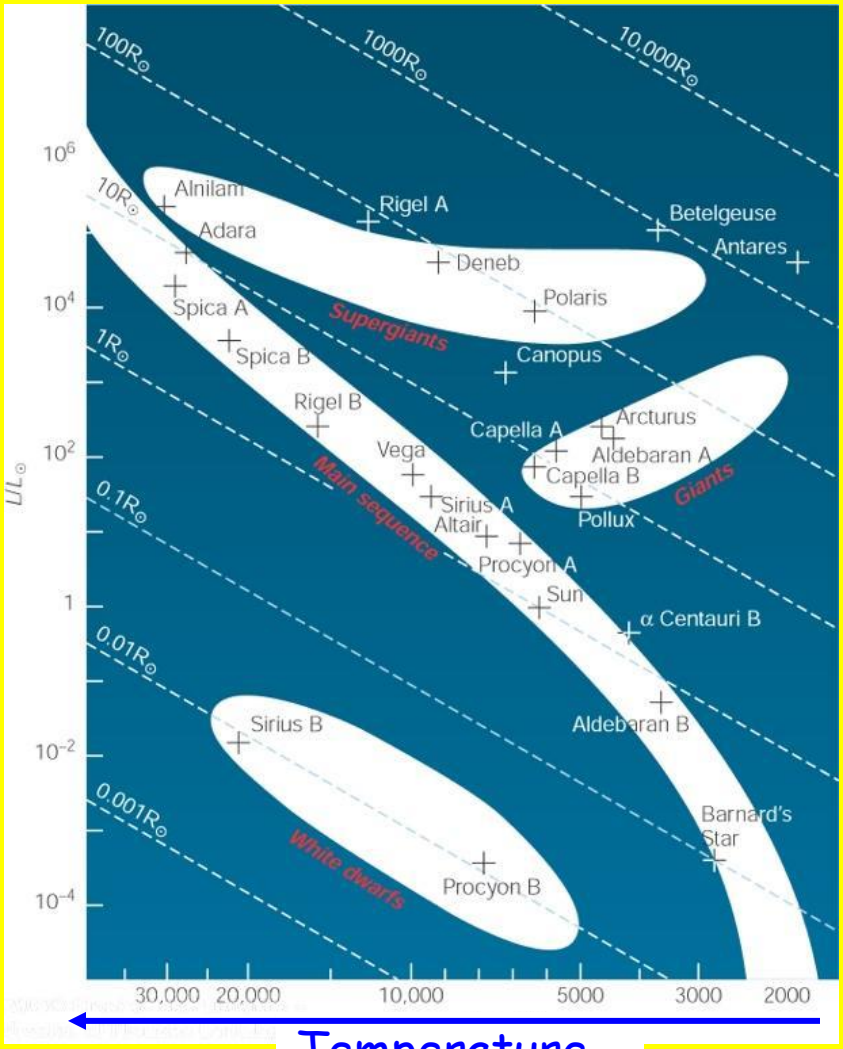
Interstellar dust

Milky Way in different wavelengths



http://www.chromoscope.net/

Hertzsprung-Russell Diagram

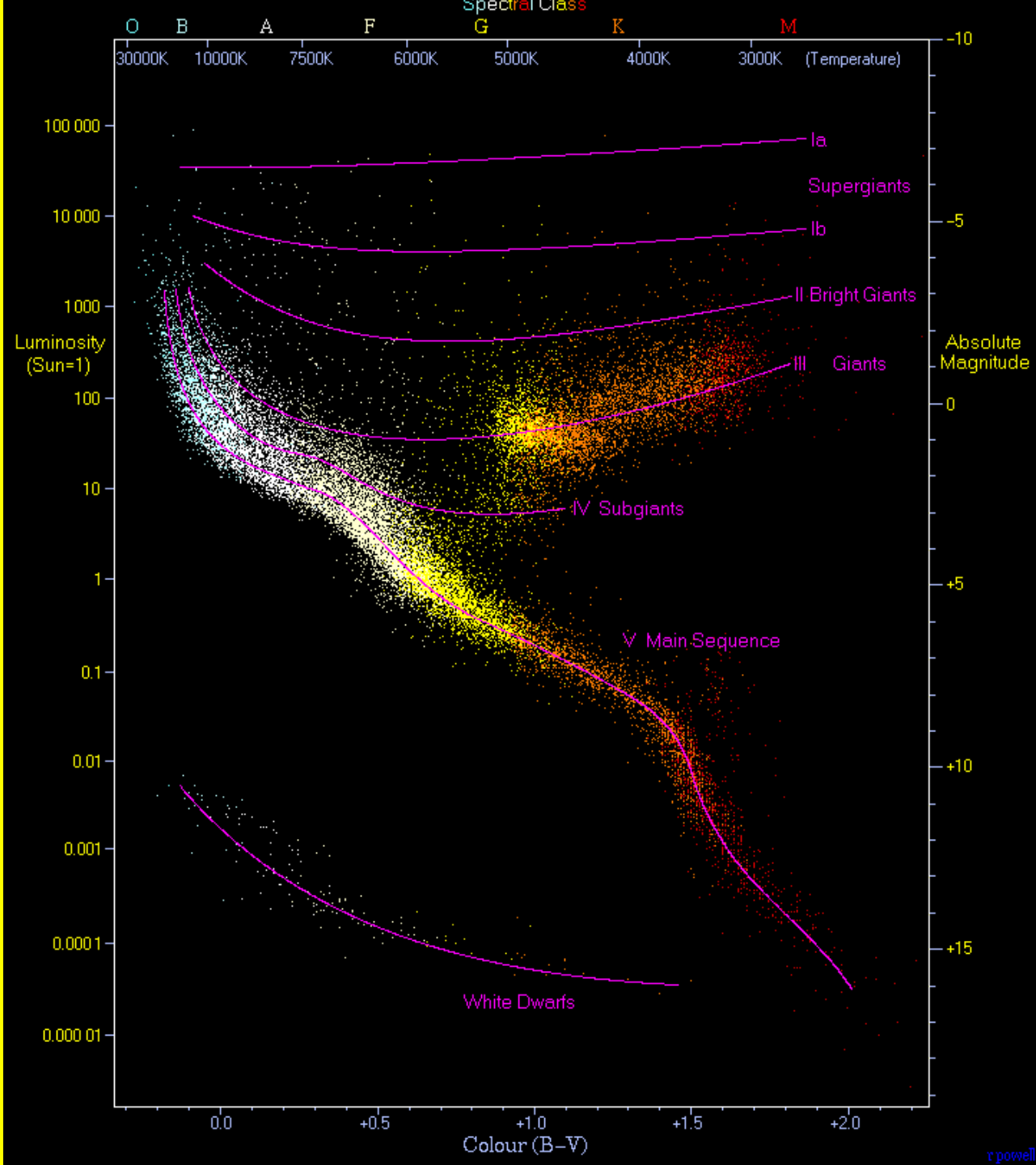


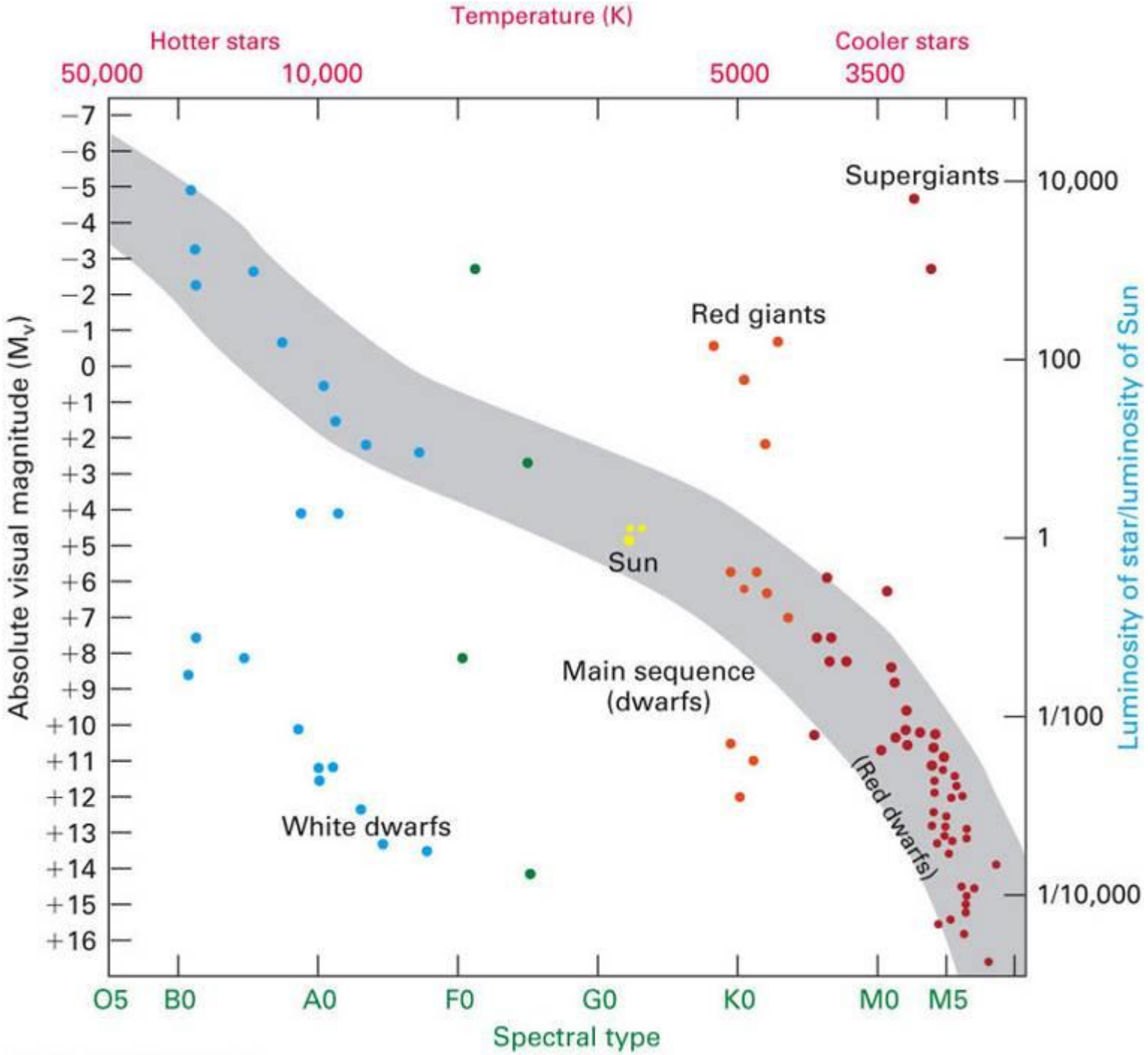
Absolute mag. or Luminosity

or Spectral type: **O B A F G K M**

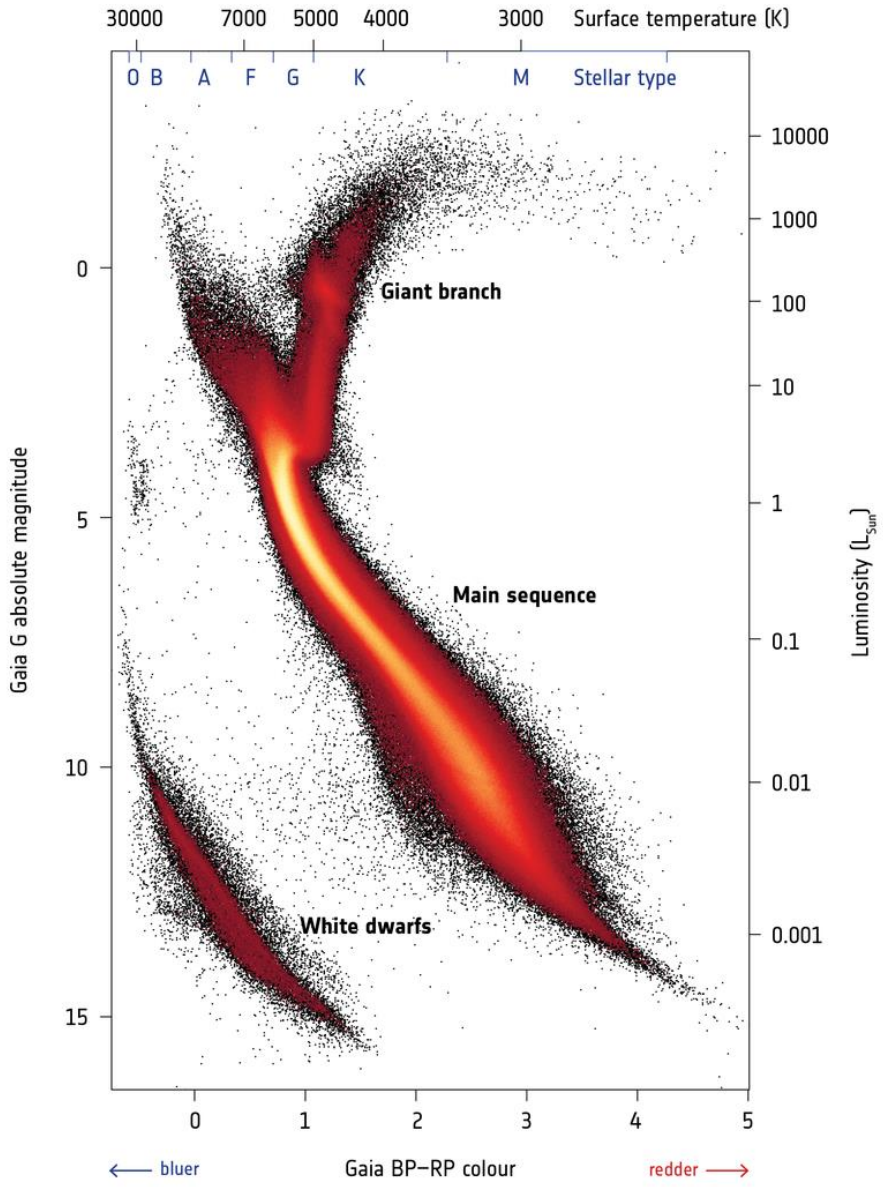
or B-V: **-0.4 0.0 +0.6 +1.6**

Hertzsprung - Russell diagram



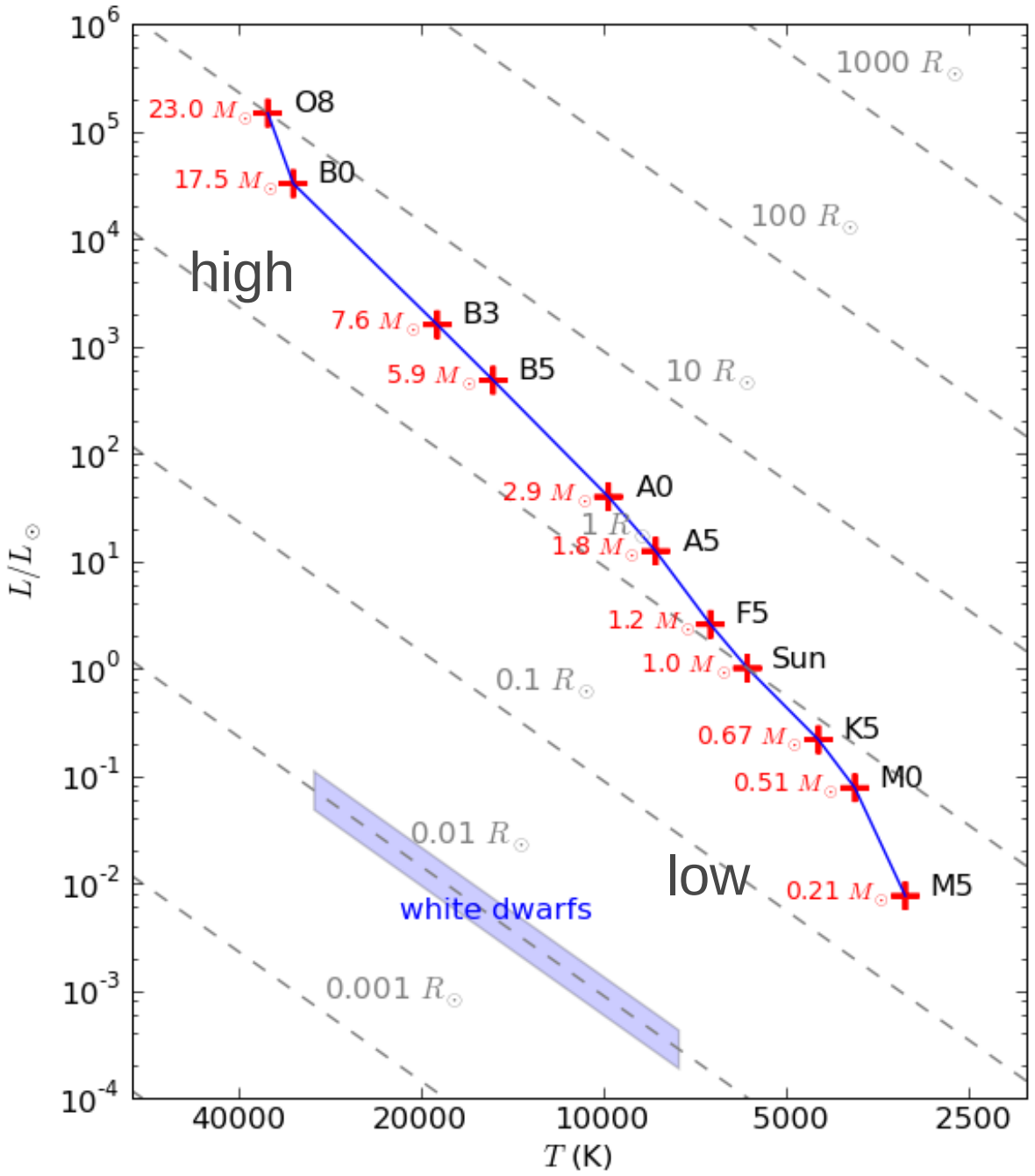


→ GAIA'S HERTZSPRUNG-RUSSELL DIAGRAM



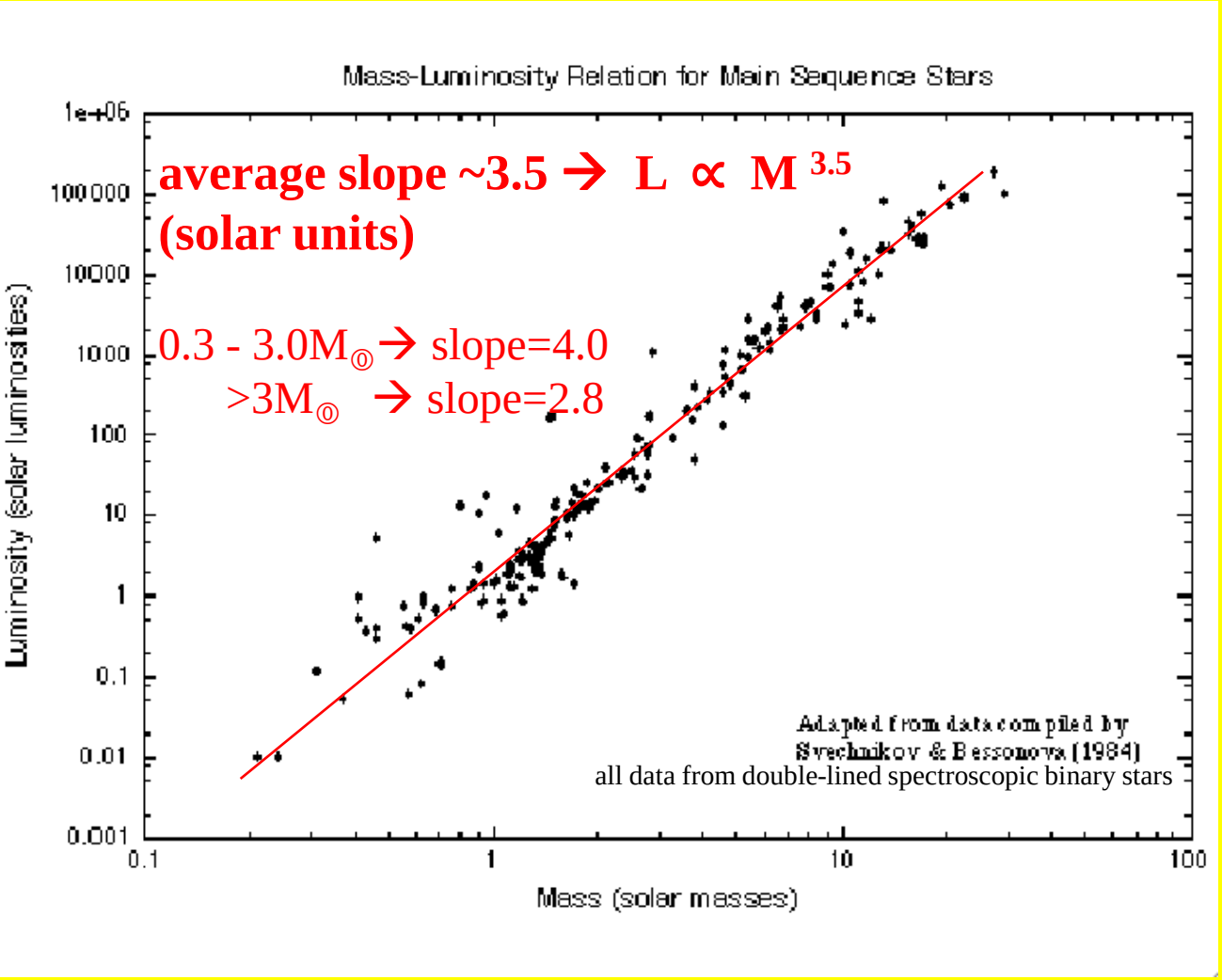
Gaia H-R Diagram

Stellar Masses on the HR Diagram



www.astro.sunysb.edu/mzingale/software/astro/HR_radius_wd.png

Mass-Luminosity Relation



The Milky Way galaxy contains about 200×10^9 stars

The Gaia satellite measured properties of about 1.8×10^9 stars

Statistical approach

The mass function ξ(m)

dN – the numer of stars with masses in the range (m, m + dm)

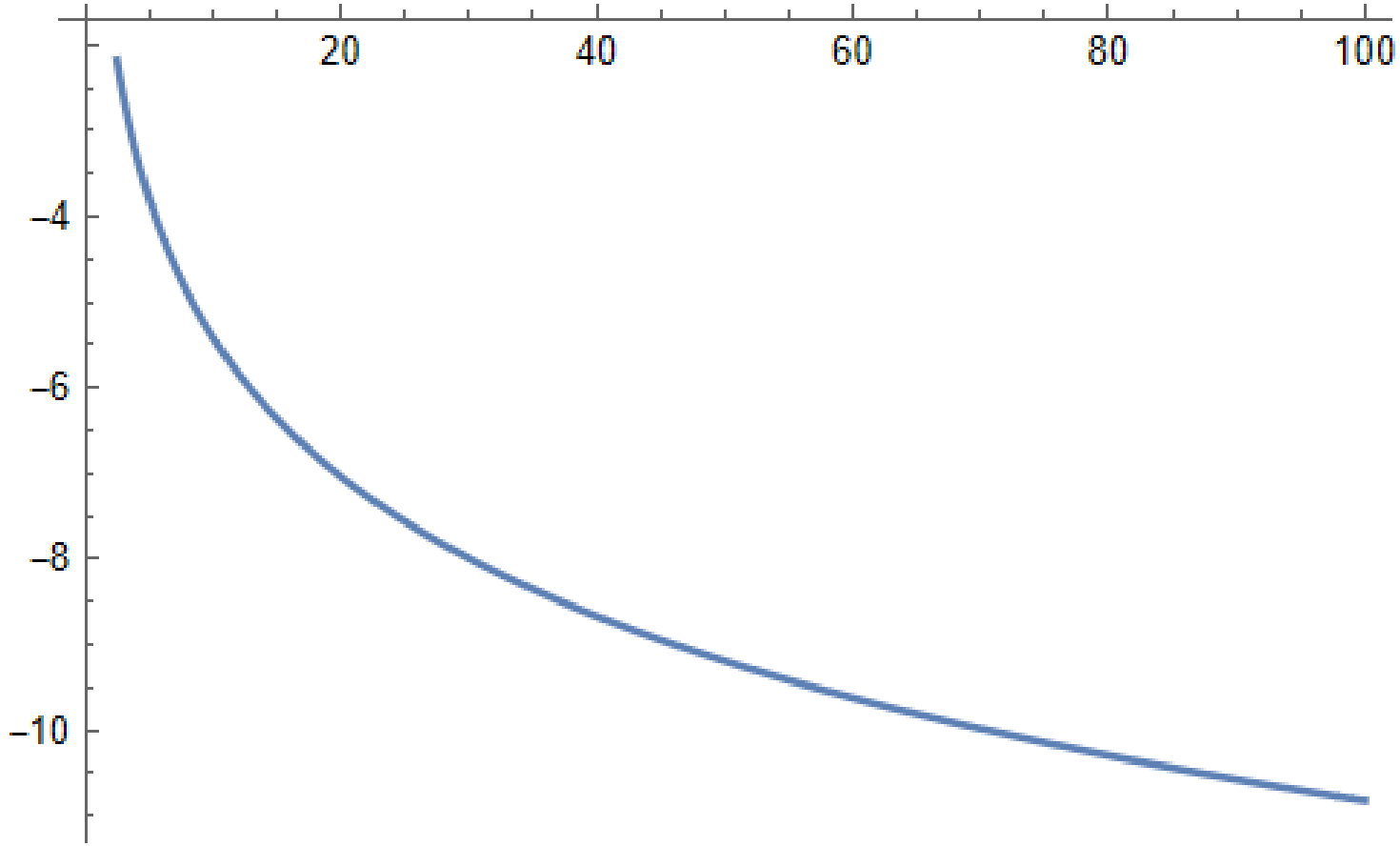
$$dN = \xi(m/M_\odot)\, d(m/M_\odot)$$

Edwin Salpeter, 1955

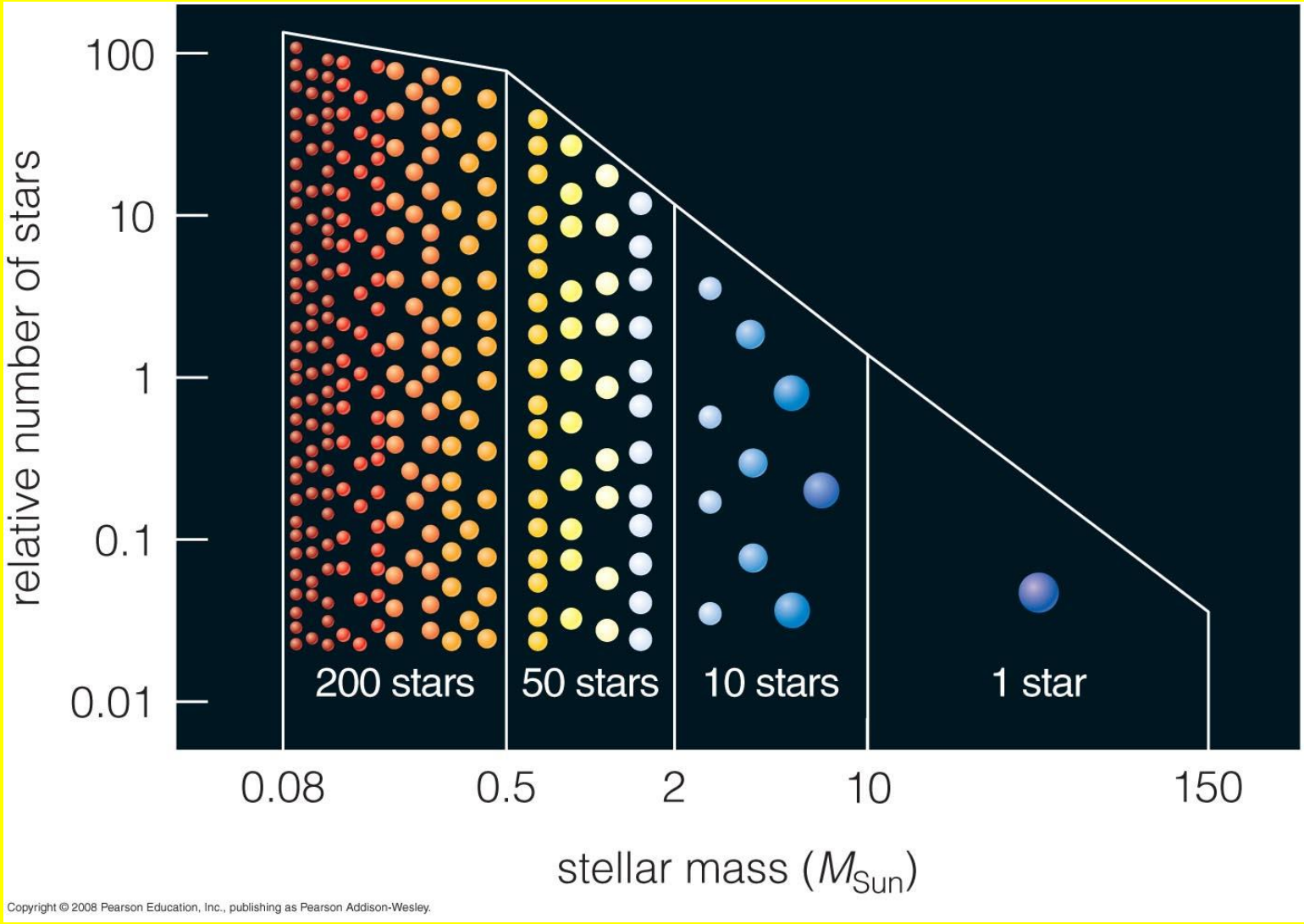
$$\xi(m/M_\odot) \sim (m/M_\odot)^{-2.35}$$

In[4]:= `Plot[-2.35 Log[x], {x, 0.08, 100}]`

Out[4]=



Massive Stars Are RARE!



Stellar Properties Review

Distance: from parallax (limited!!)

1.3 pc – 200 pc

Luminosity: from brightness and distance

$10^{-4}\ L_\odot$ – $10^{6}\ L_\odot$

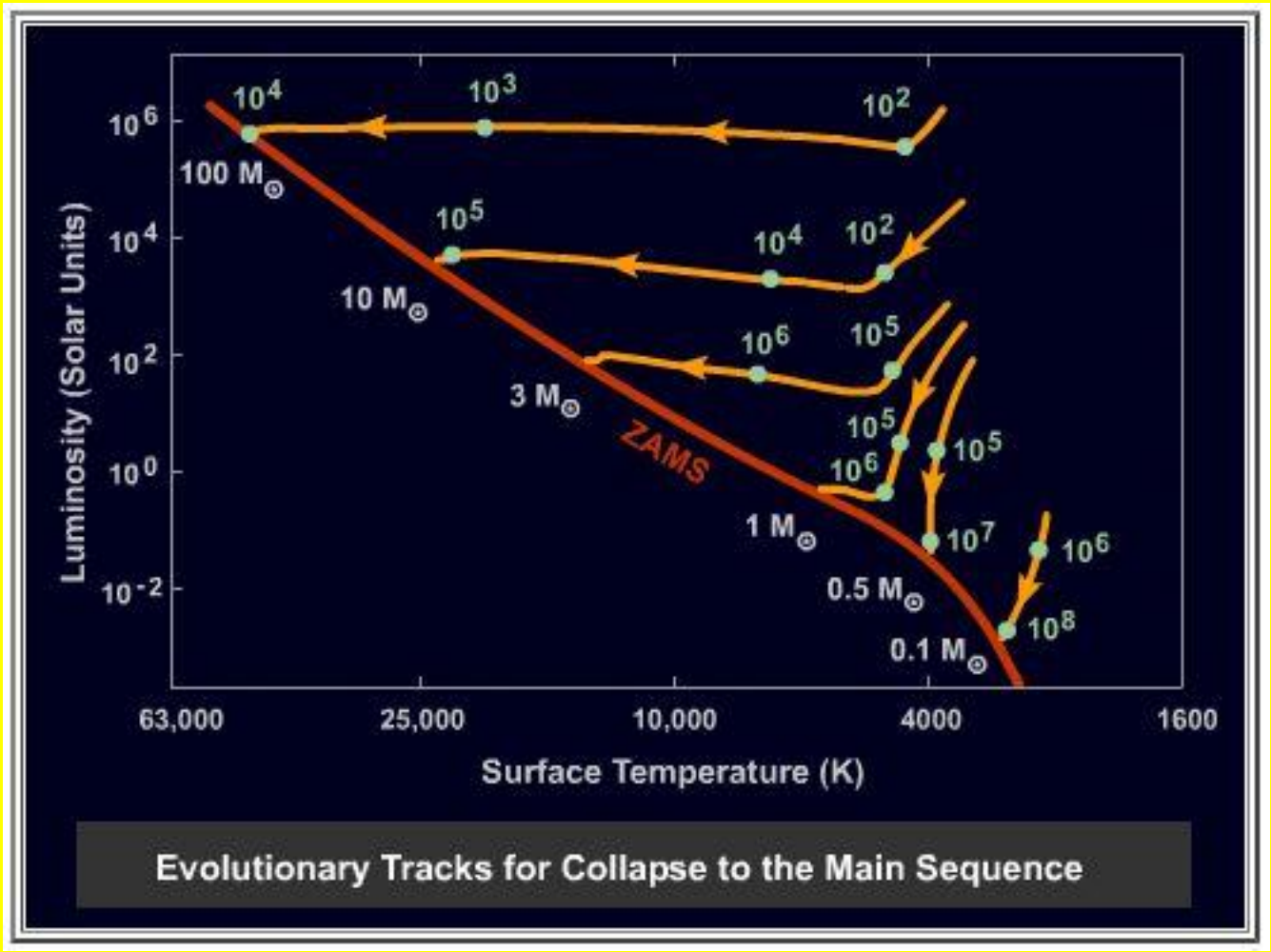
Temperature: from color (better: spectral type)

3,000 K – 50,000 K

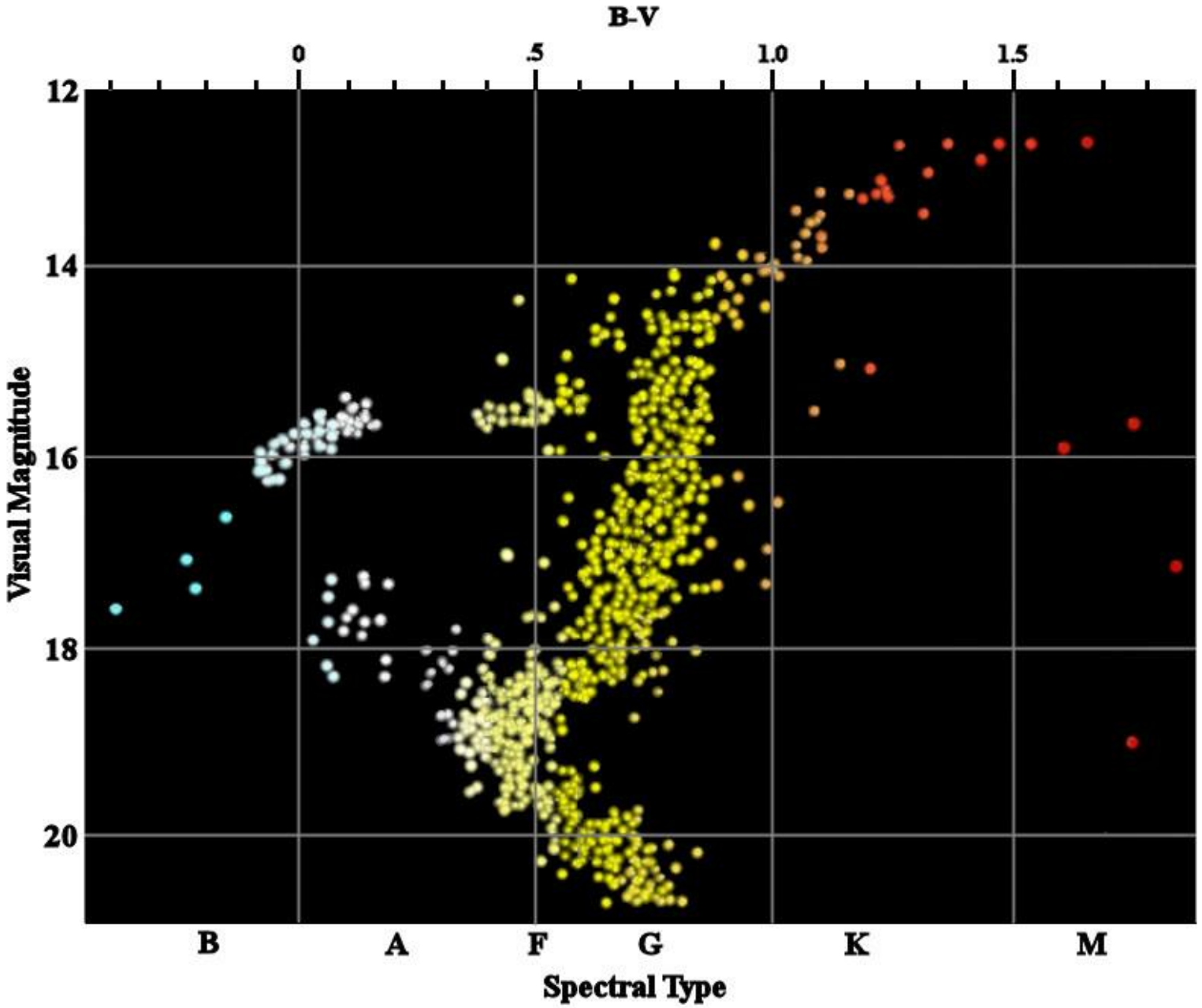
Mass: from period (P) and average separation (R) of binary star orbit

0.08 $M_\odot$ – ~100 $M_\odot$

Star formation timescale



M-15
Very old –
estimated age
$12 \cdot 10^9$ yrs



The Hertzsprung-Russell diagram of stars in M-3

Globular clusters

Mass $\approx 10^6\, M_\odot$

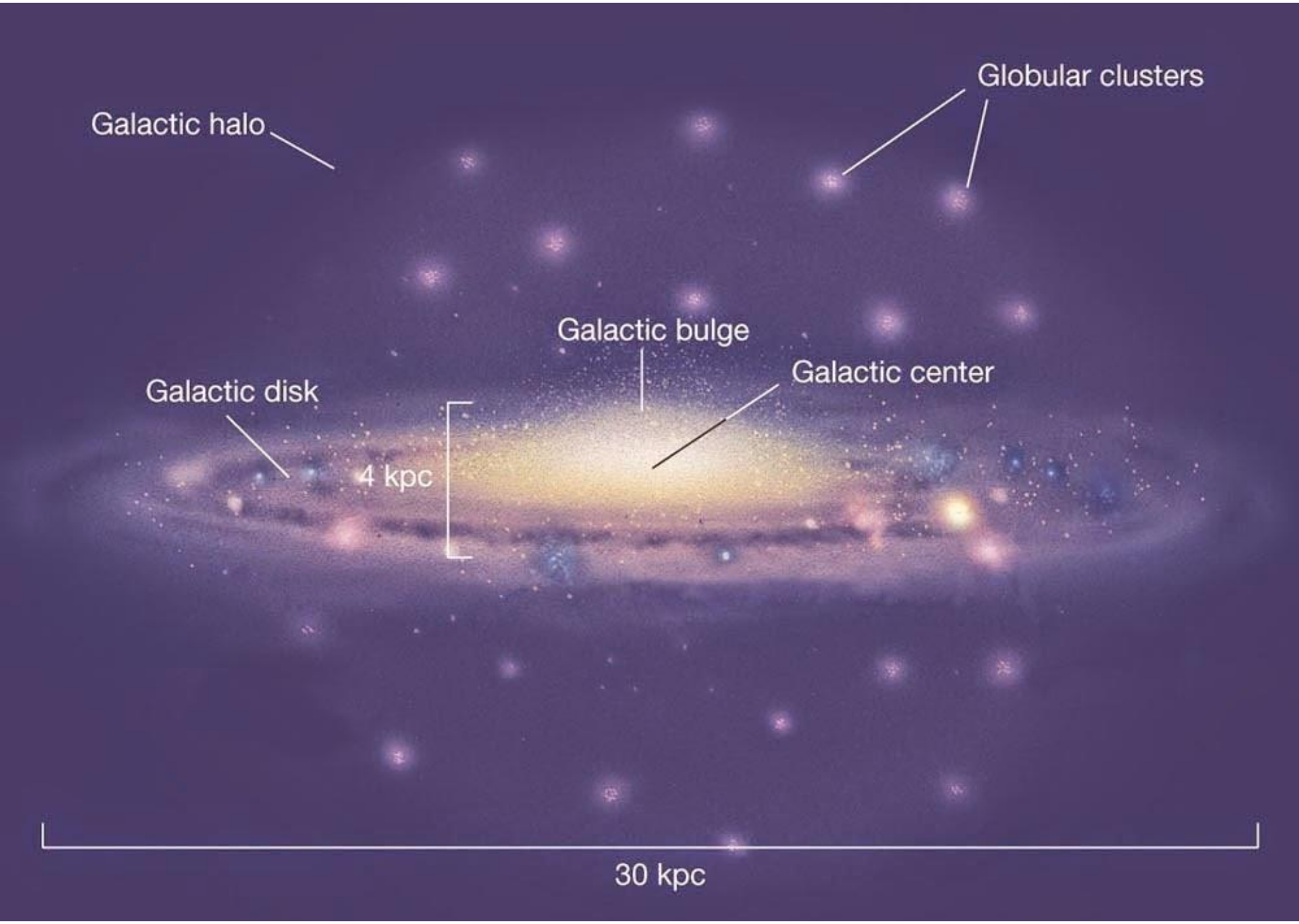
Size $\approx$ 300ly

Contain mostly old stars and no gas or dust

Mostly spherical in shape

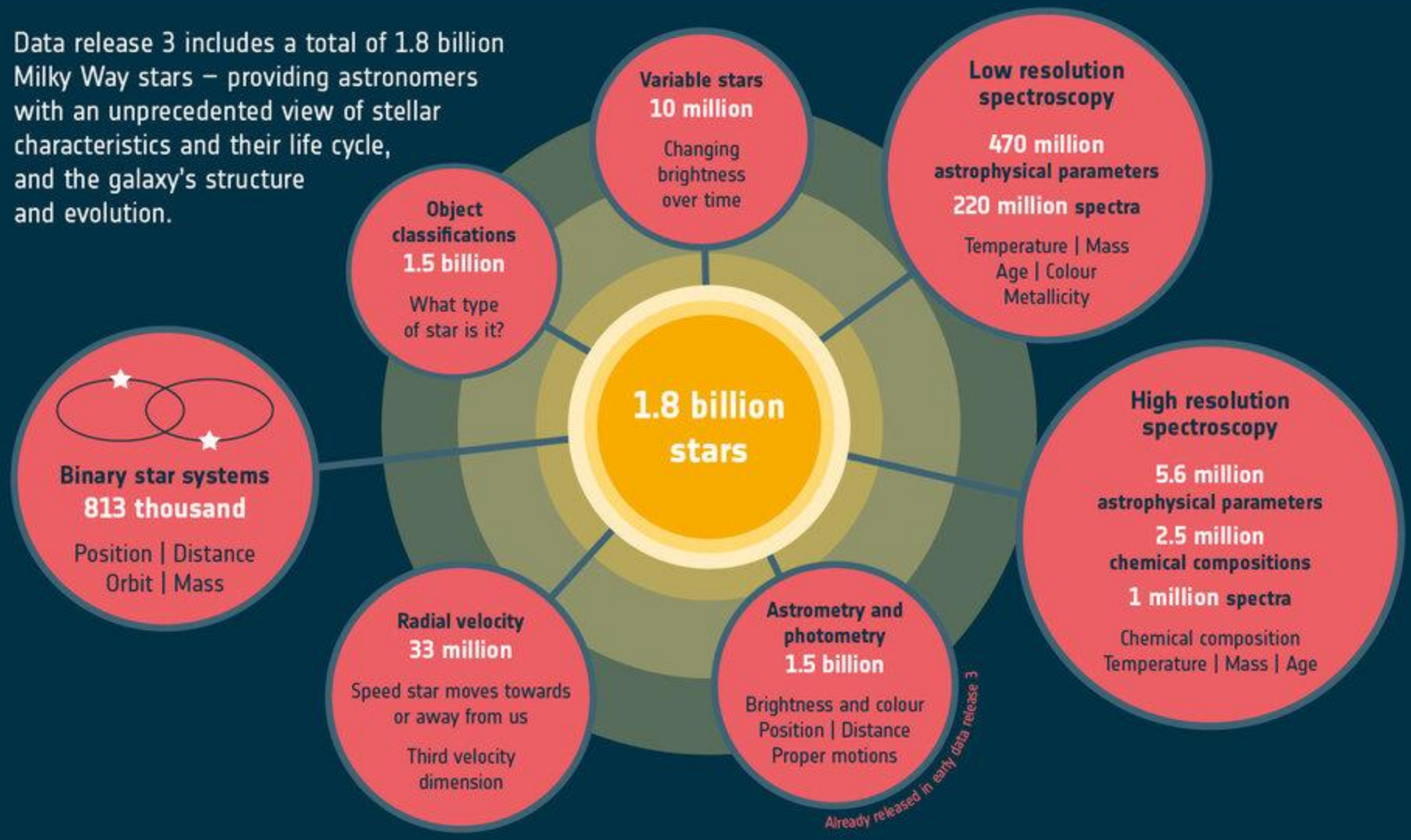
Centers are very dense up to several 10^3 stars per ly^3

Distributed in a spherical halo around the galactic disc


Globular clusters
Galactic halo
Galactic bulge
Galactic center
Galactic disk
4 kpc
30 kpc

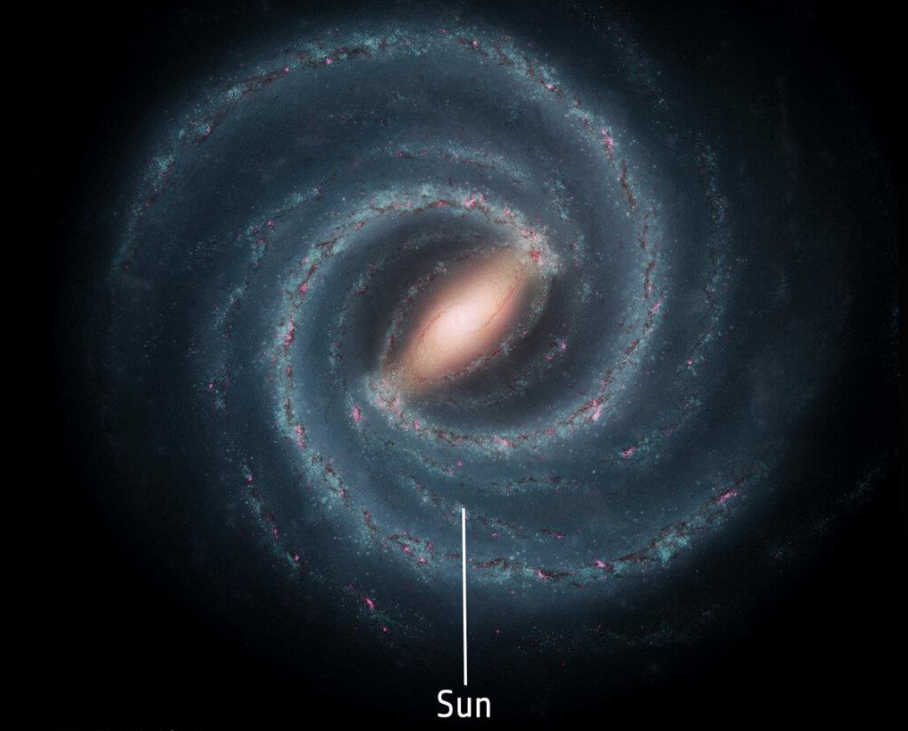
MILKY WAY STARS

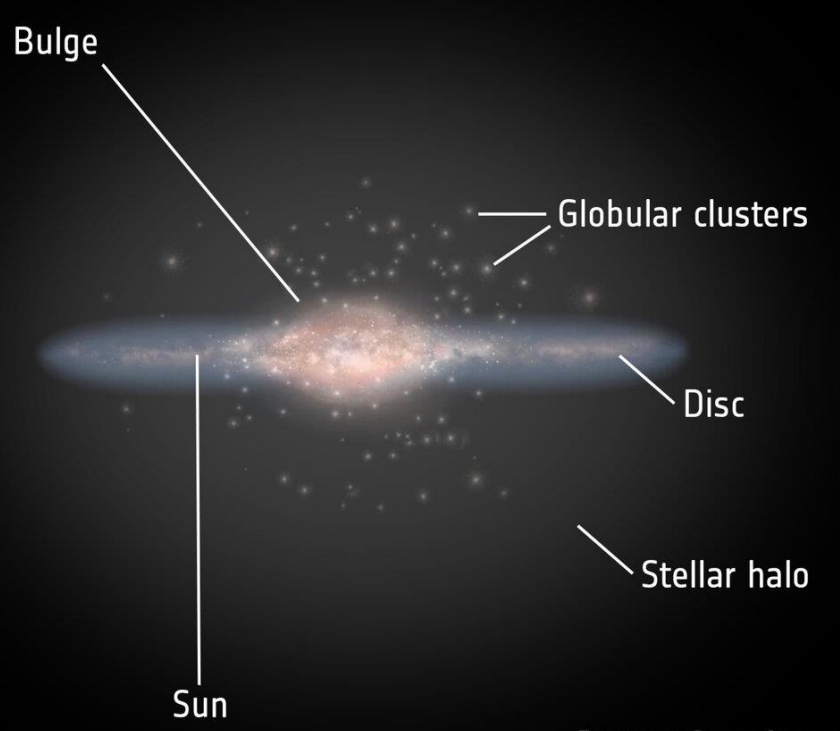
Data release 3 includes a total of 1.8 billion Milky Way stars – providing astronomers with an unprecedented view of stellar characteristics and their life cycle, and the galaxy's structure and evolution.



→ ANATOMY OF THE MILKY WAY

esa

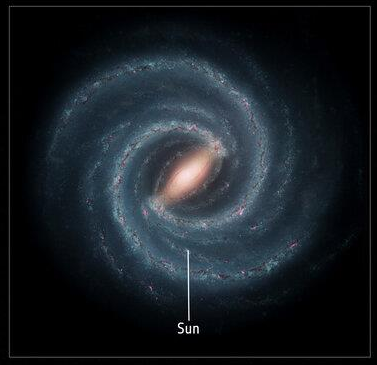




www.esa.int

European Space Agency

THE MILKY WAY'S WARP



Warp

Sun

Bulge

Disk

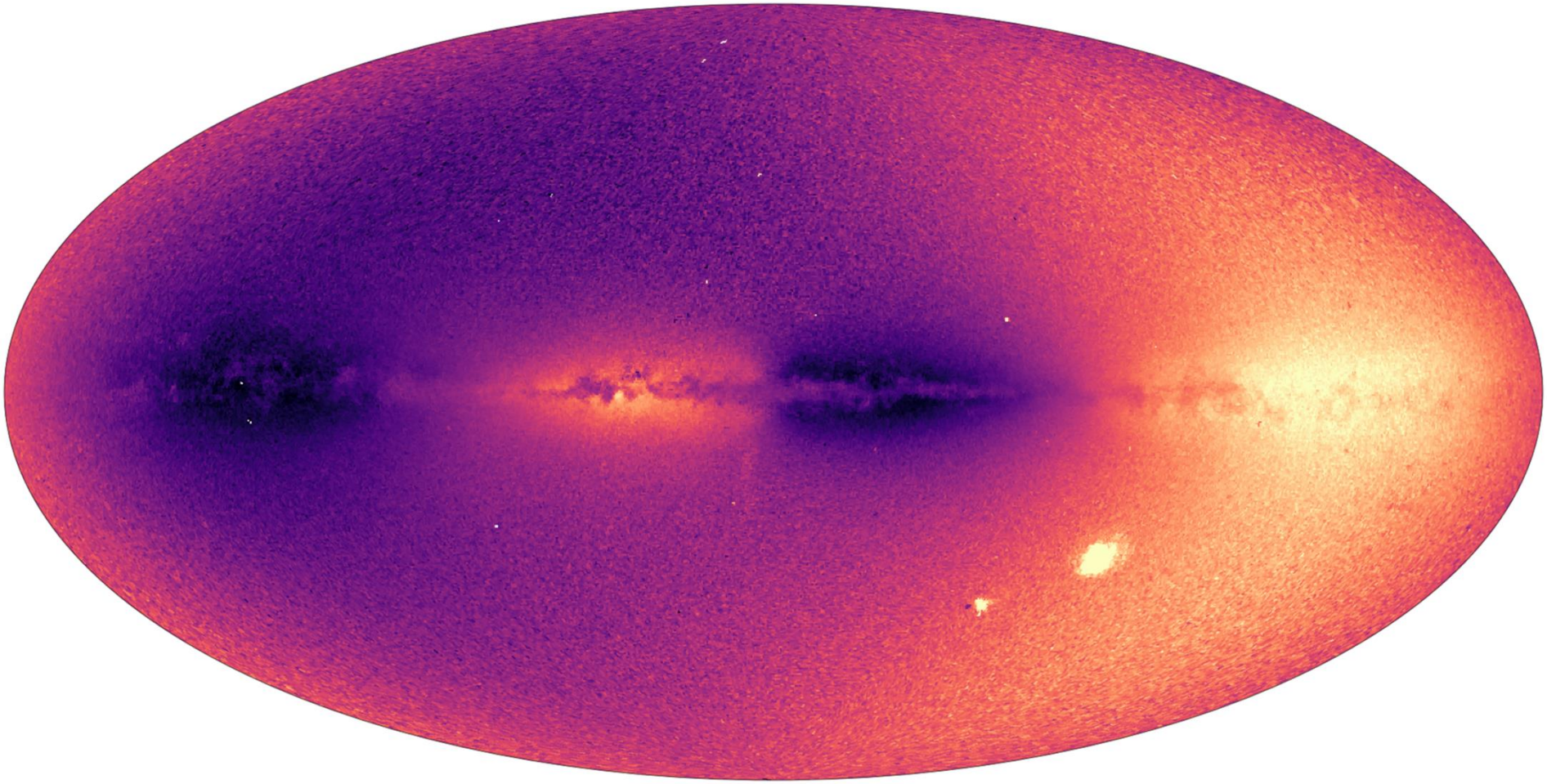
26 000
light years

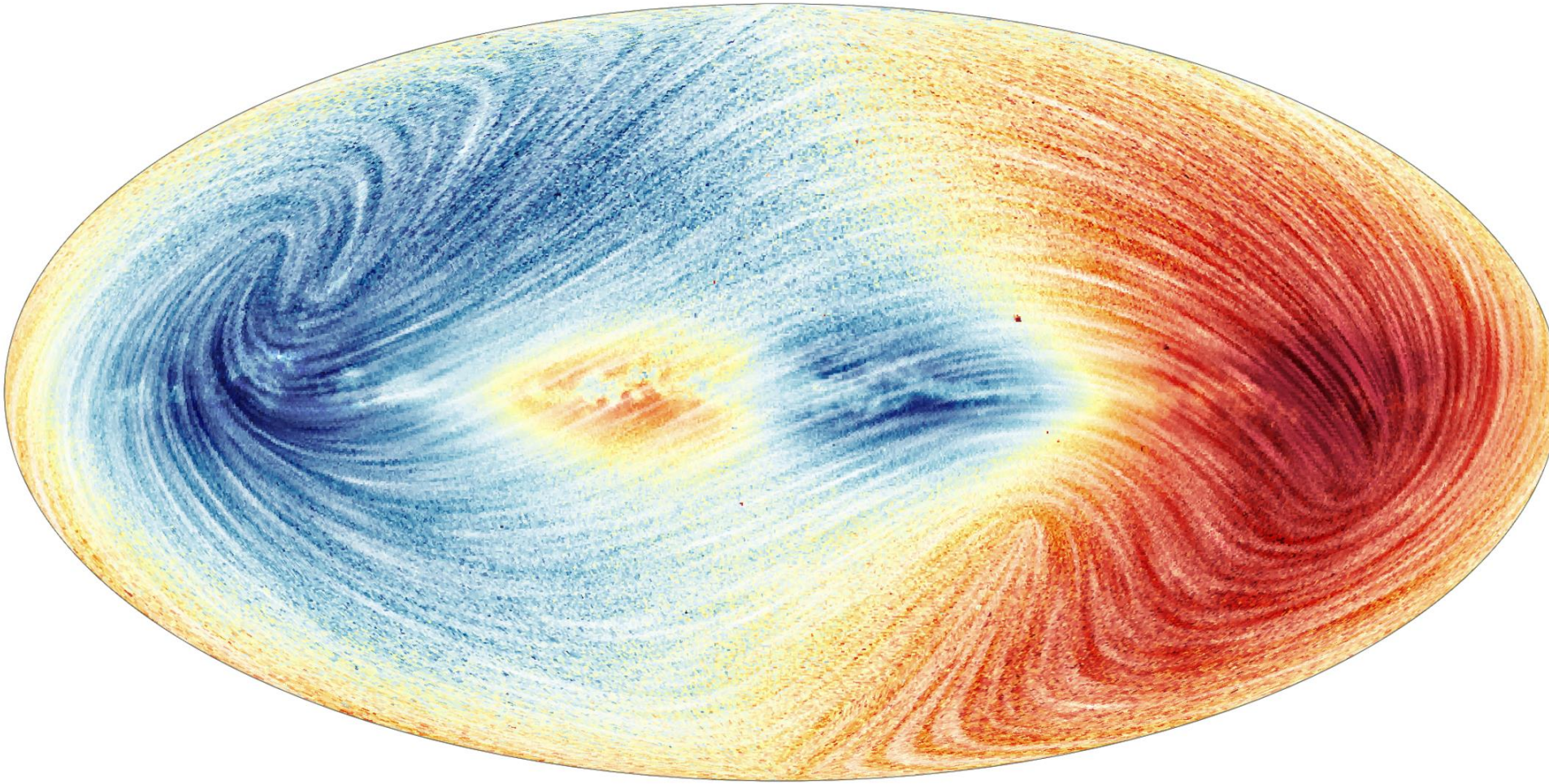
52 000
light years

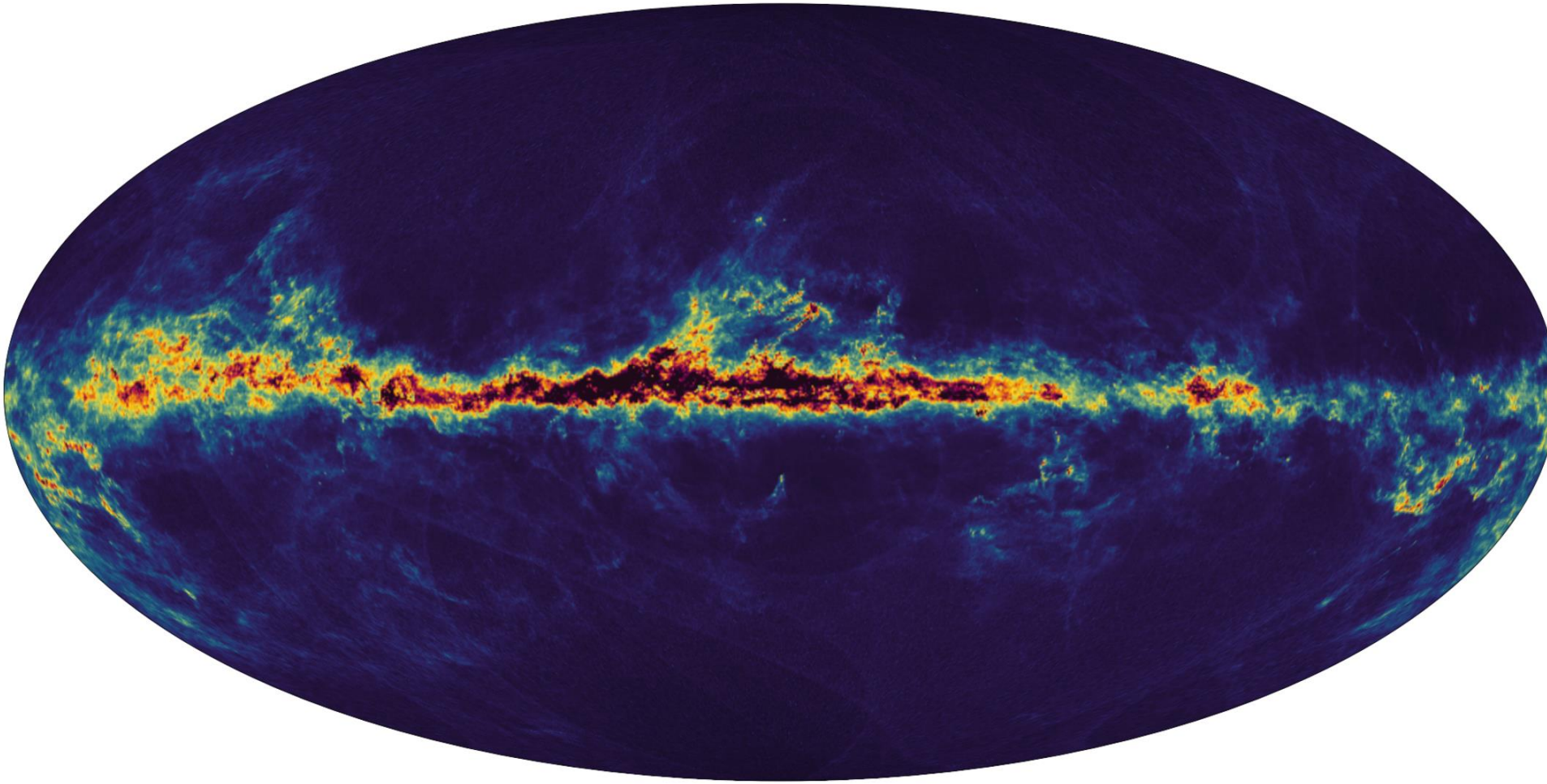
Gaia

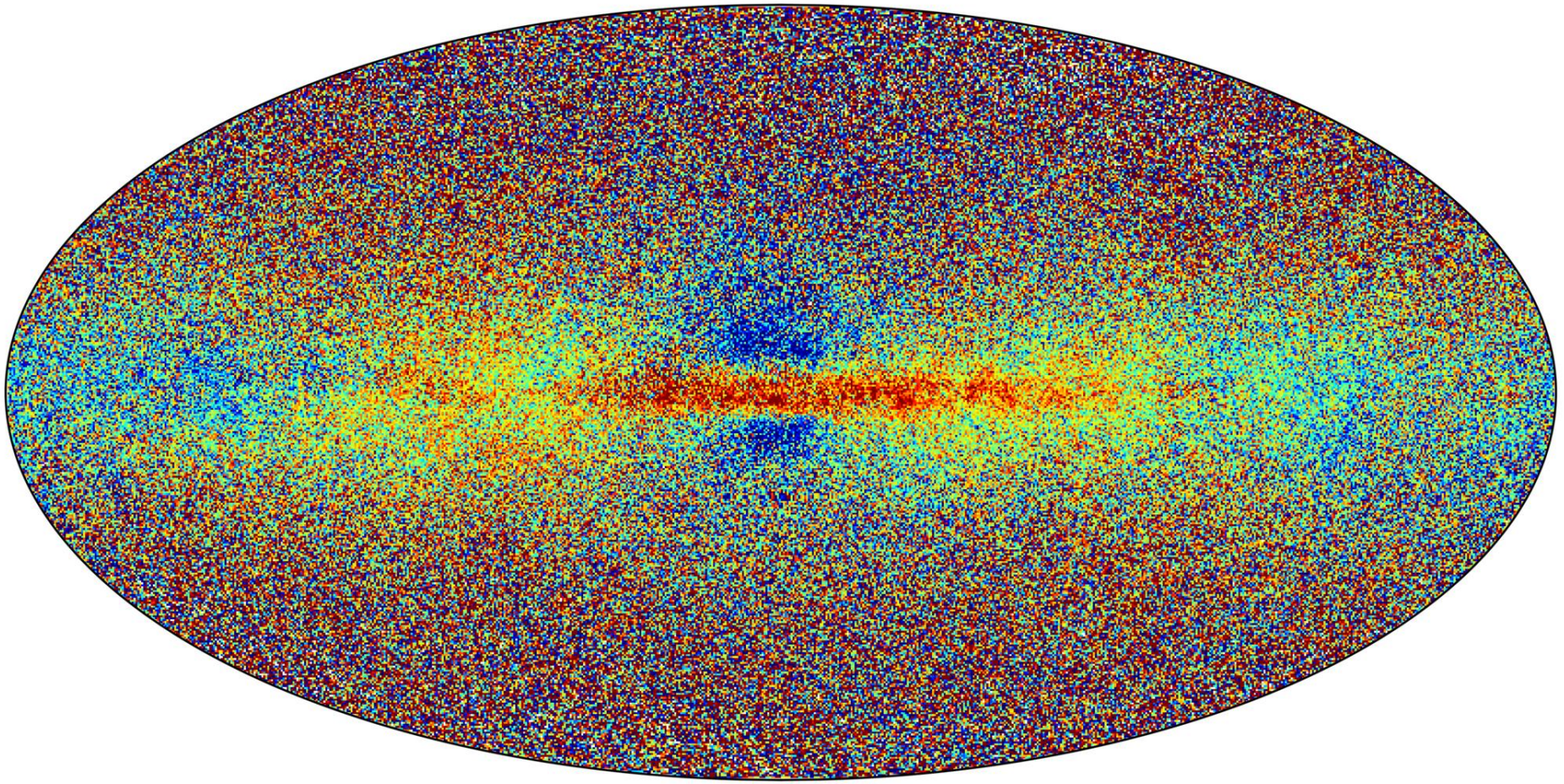
Unraveling the chemical and dynamical history of our Galaxy

Motion of stars in the Milky Way









The Astrophysical Journal Supplement Series, 174:223–260, 2008 January

COMPACT OBJECT MODELING WITH THE STARTRACK POPULATION SYNTHESIS CODE

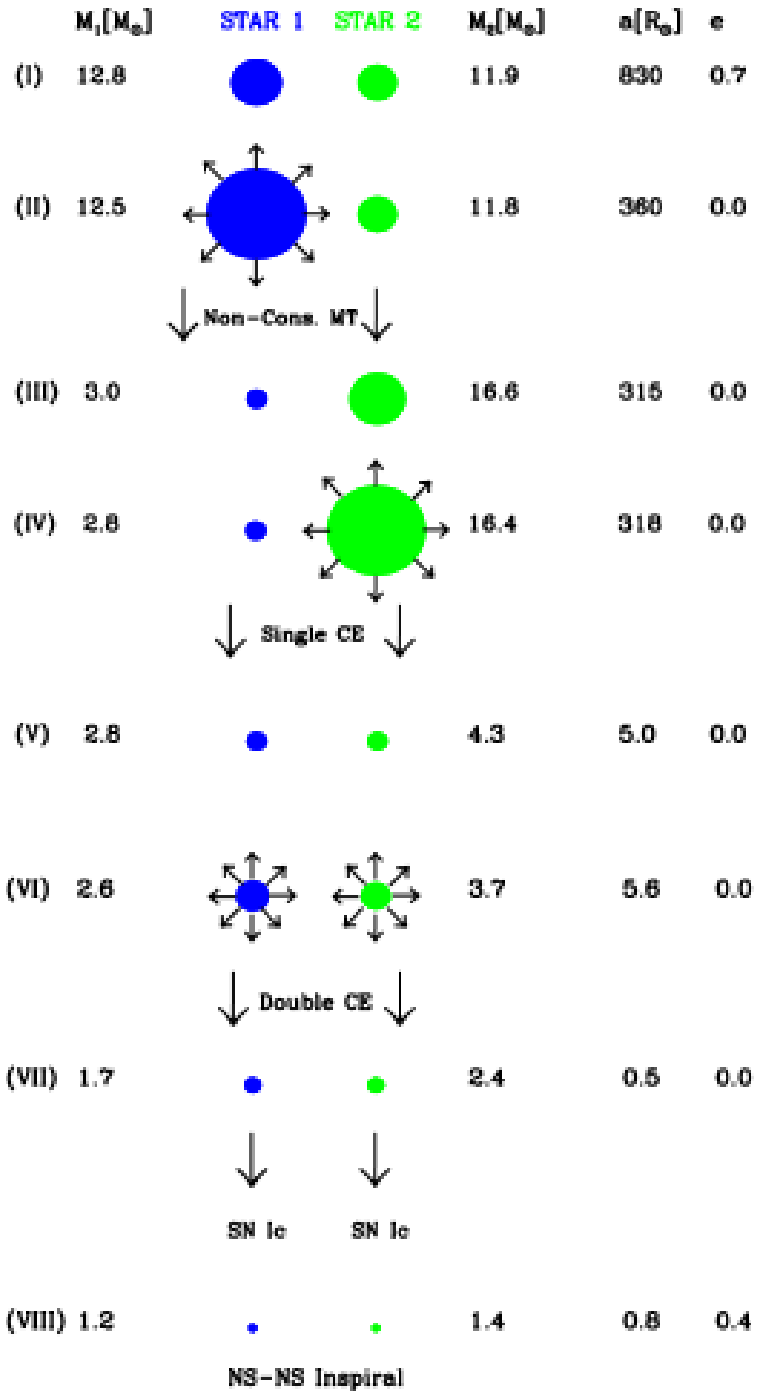
Krzysztof Belczynski,[1,2] Vassiliki Kalogera,[3] Frederic A. Rasio,[3] Ronald E. Taam,[3] Andreas Zezas,[4] Tomasz Bulik,[5] Thomas J. Maccarone,[6,7] and Natalia Ivanova[8]

Received 2005 November 29; accepted 2007 May 28

ABSTRACT

We present a comprehensive description of the population synthesis code StarTrack. The original code has been significantly modified and updated. Special emphasis is placed here on processes leading to the formation and further evolution of compact objects (white dwarfs, neutron stars, and black holes). Both single and binary star populations are considered. The code now incorporates detailed calculations of all mass transfer phases, a full implementation of orbital evolution due to tides, as well as the most recent estimates of magnetic braking. This updated version of StarTrack can be used for a wide variety of problems, with relevance to observations with many current and planned observatories, e.g., studies of X-ray binaries (*Chandra*, *XMM-Newton*), gravitational radiation sources (LIGO, *LISA*), and gamma-ray burst progenitors (*HETE-II*, *Swift*). The code has already been used in studies of Galactic and extragalactic X-ray binary populations, black holes in young star clusters, Type Ia supernova progenitors, and double compact object populations. Here we describe in detail the input physics, we present the code calibration and tests, and we outline our current studies in the context of X-ray binary populations.

Subject headings: binaries: close — black hole physics — stars: evolution — stars: neutron — white dwarfs — X-rays: binaries


M1[M⊙]
STAR 1
STAR 2
M2[M⊙]
a[R⊙]
e
(I) 12.8
11.9
830
0.7
(II) 12.5
11.8
360
0.0
Non-Cons. MT
(III) 3.0
16.6
315
0.0
(IV) 2.8
16.4
318
0.0
Single CE
(V) 2.8
4.3
5.0
0.0
(VI) 2.6
3.7
5.6
0.0
Double CE
(VII) 1.7
2.4
0.5
0.0
SN Ic
SN Ic
(VIII) 1.2
1.4
0.8
0.4
NS-NS Inspiral

1902 Heber Curtis observed novae stars in Andromeda nebula

1920 Curtis – Shapley debate

Curtis – the Andromeda nebula is an extragalactic object

Shapley - Andromeda nebula is part of the Milky Way galaxy

M 31 approaches us at 300 km/s
Vesto Melvin Slipher (1912)

Edwin Hubble