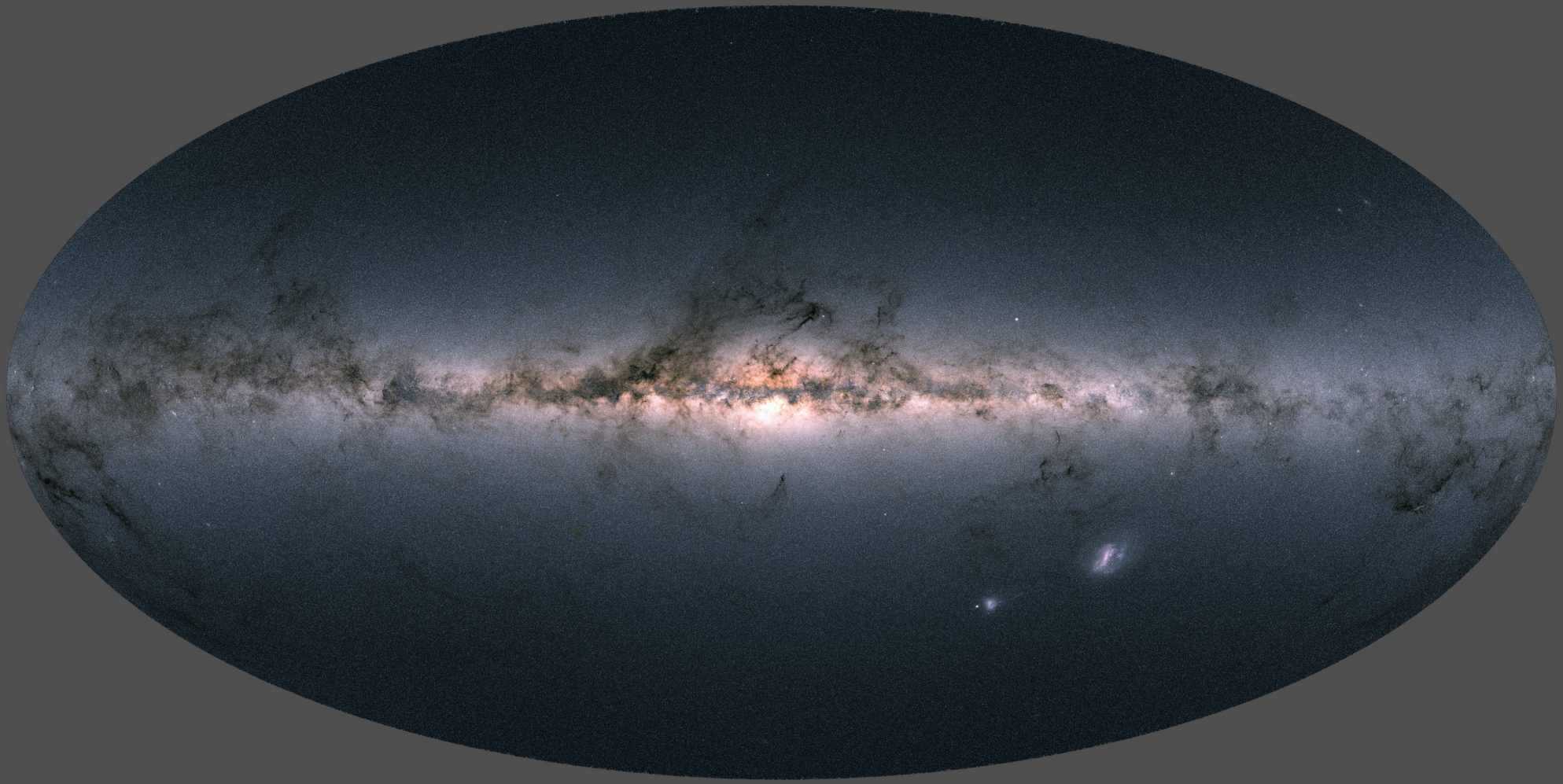
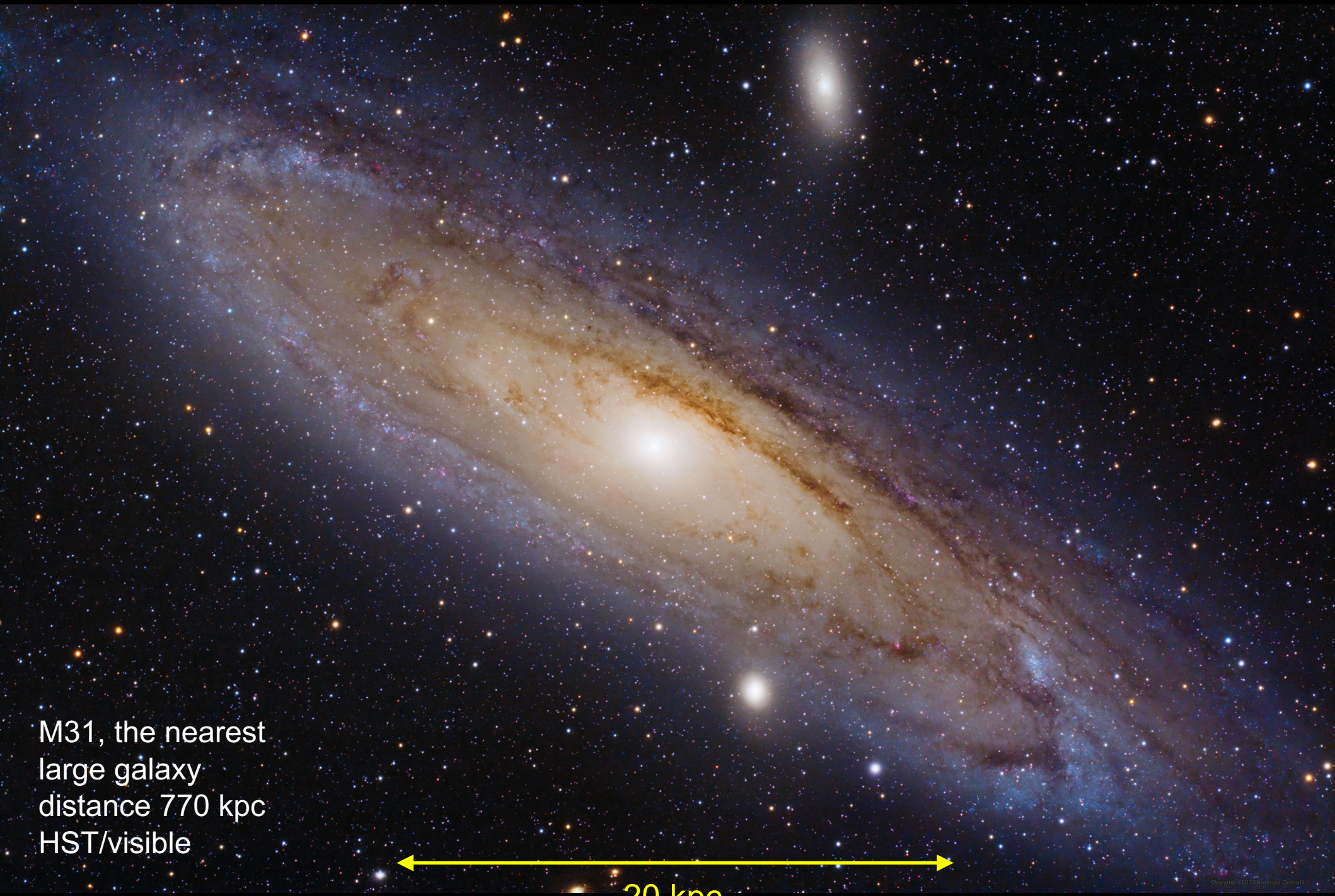
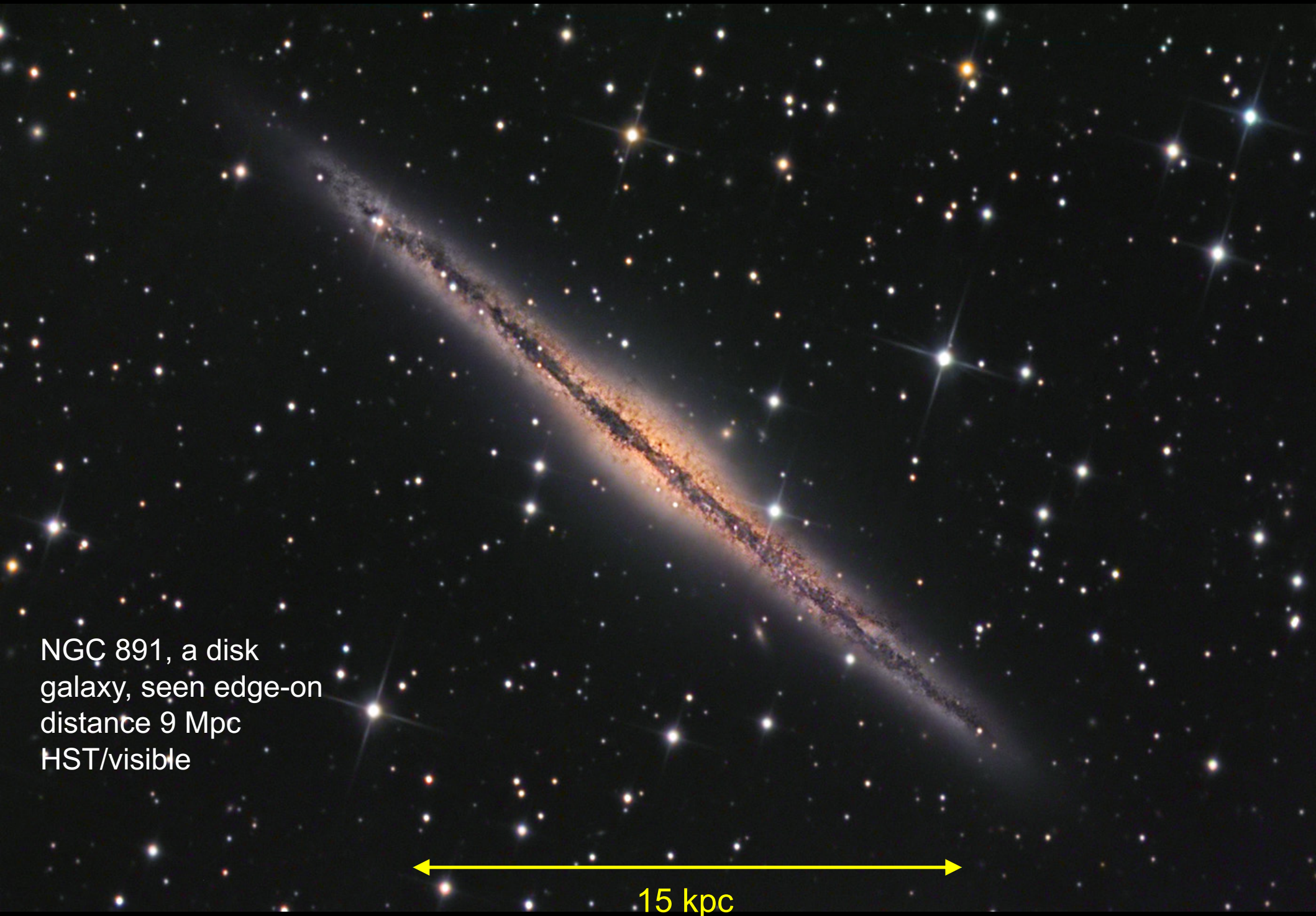
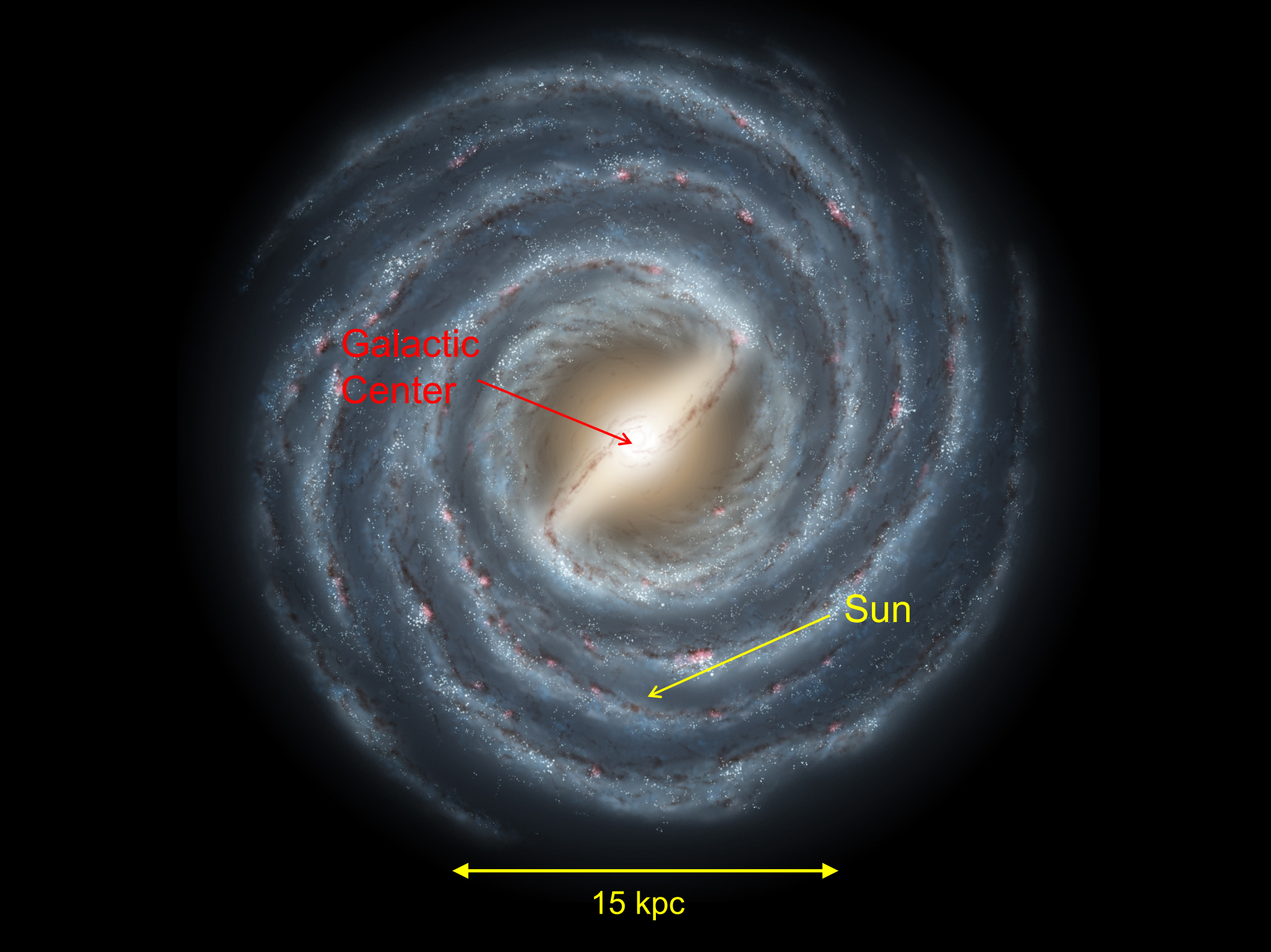


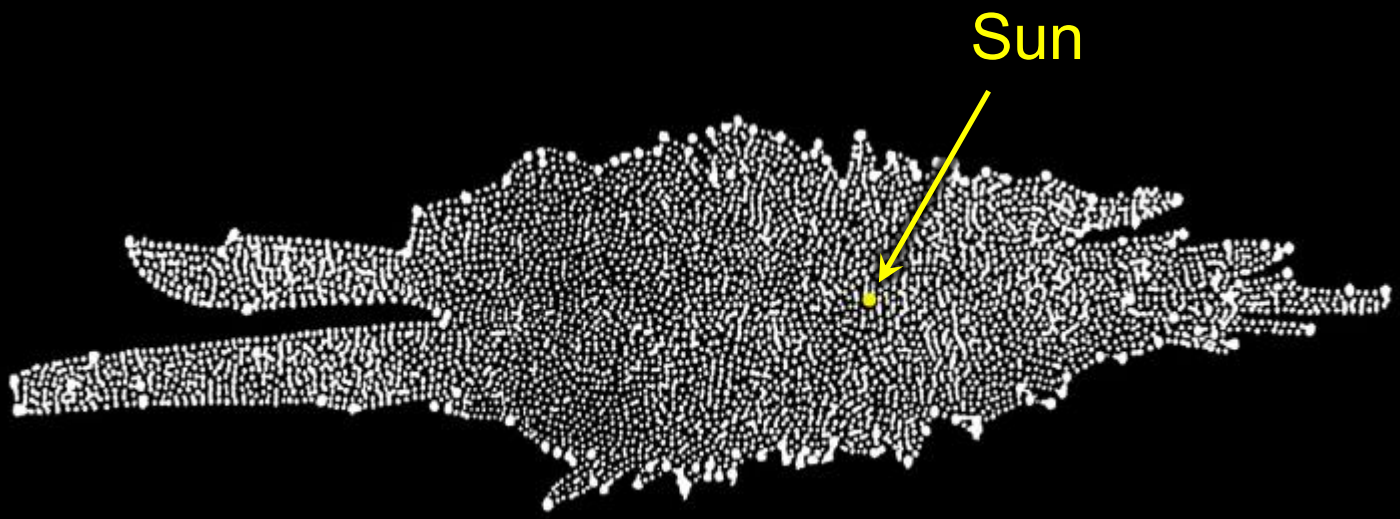

M31, the nearest
large galaxy
distance 770 kpc
HST/visible
20 kpc


25 kpc

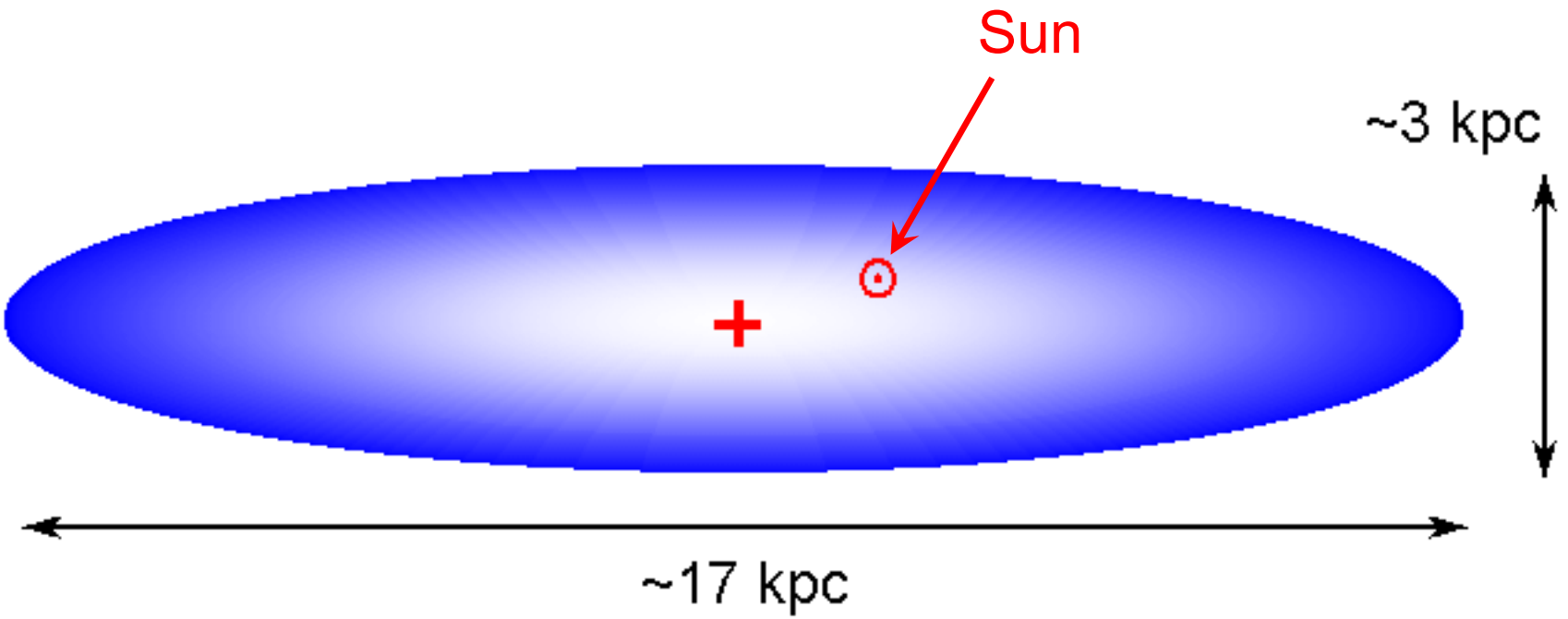

NGC 891, a disk
galaxy, seen edge-on
distance 9 Mpc
HST/visible
15 kpc

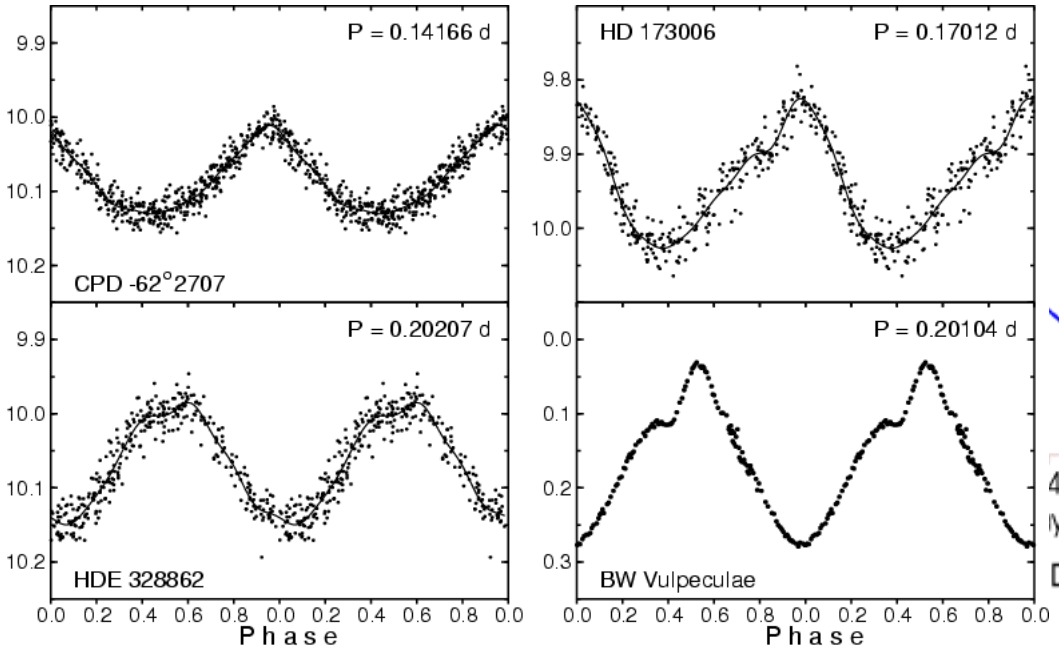

Galactic
Center
Sun
15 kpc

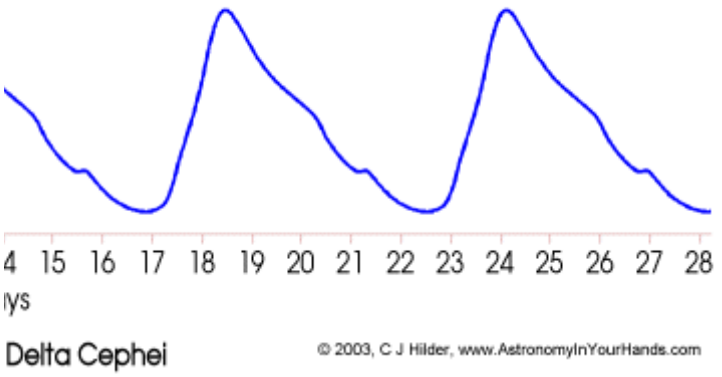
Herschel model (1785)

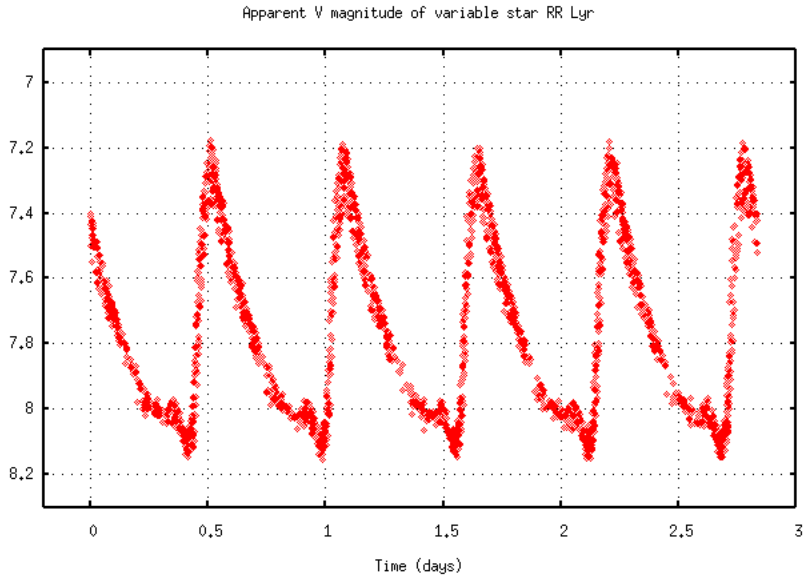


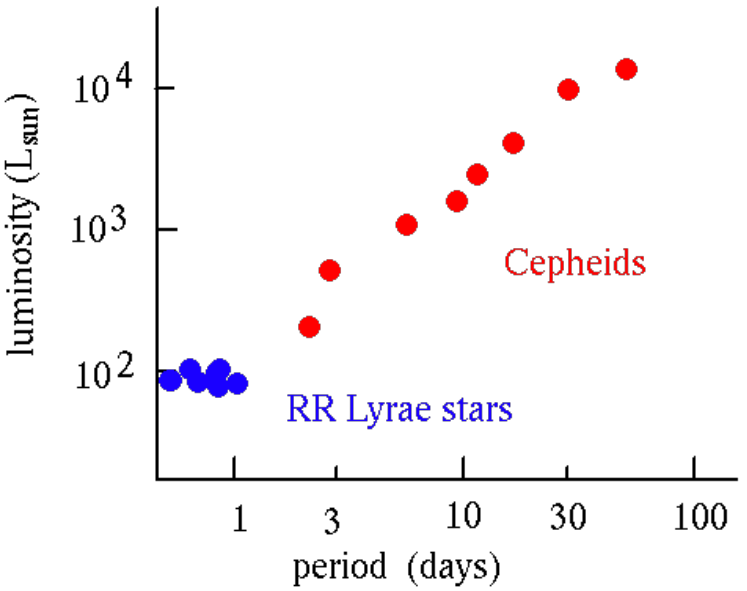
Kapteyn Model (1922)

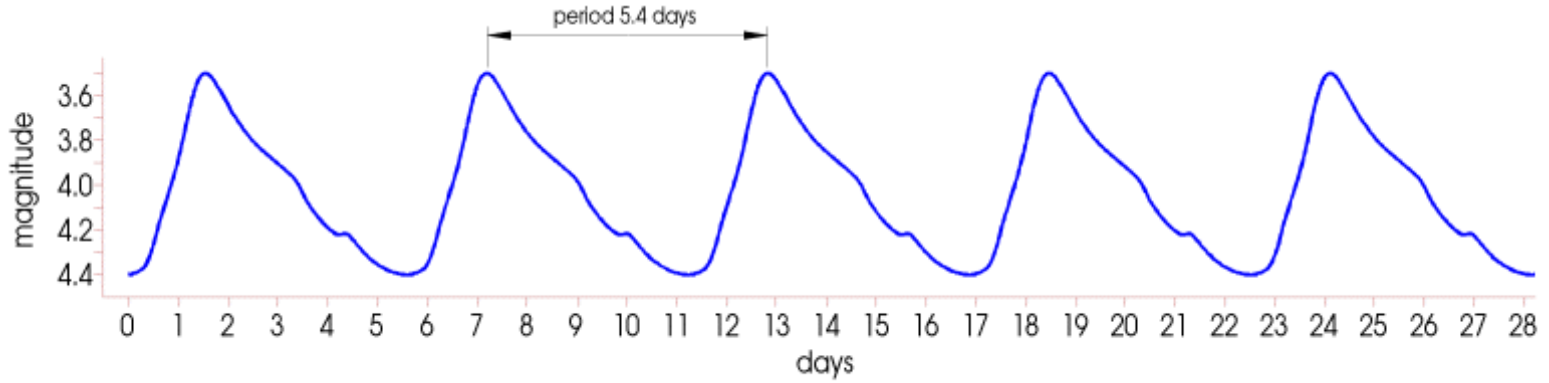


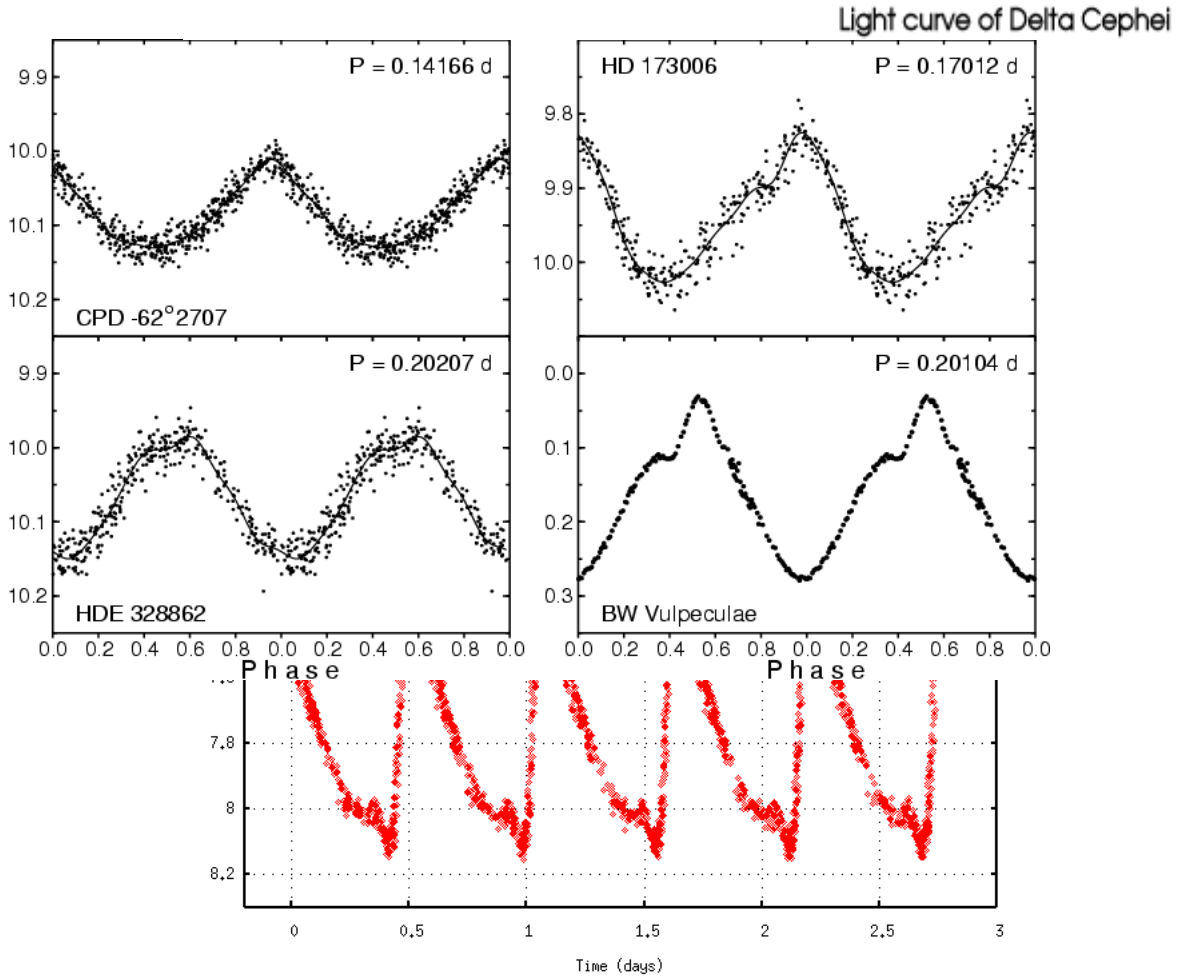

P = 0.14166 d
CPD -62°2707
HD 173006
P = 0.17012 d
P = 0.20207 d
HDE 328862
P = 0.20104 d
BW Vulpeculae
Phase
Phase

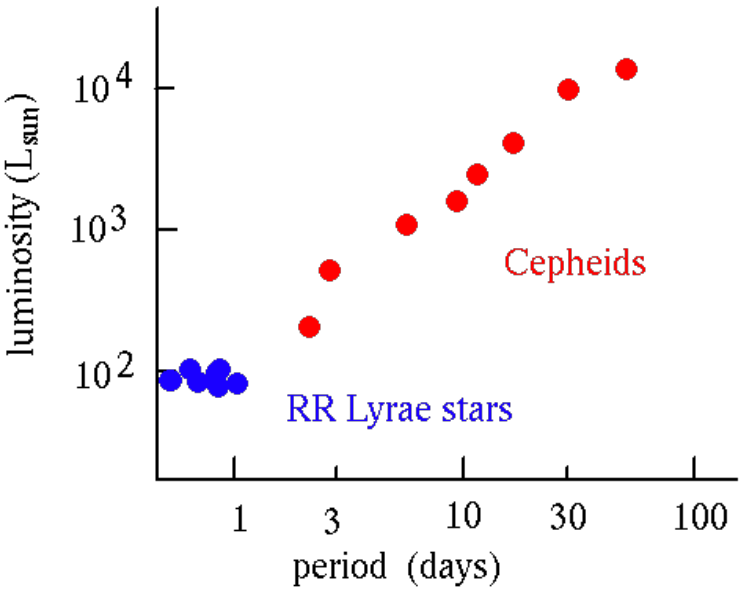

Delta Cephei
© 2003, C J Hilder, www.AstronomyInYourHands.com

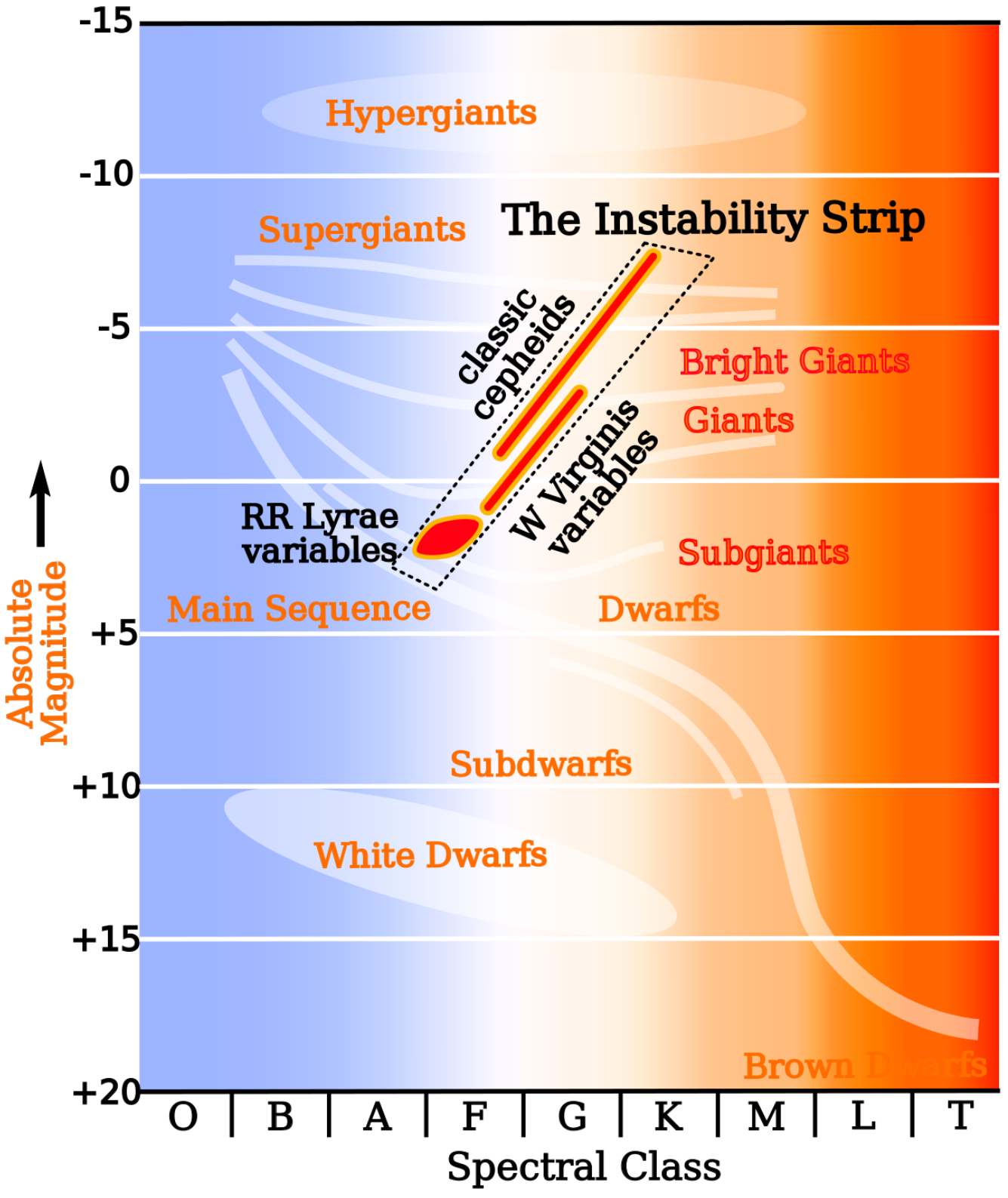

Apparent V magnitude of variable star RR Lyr
Time (days)


luminosity (Lsun)
Cepheids
RR Lyrae stars
period (days)

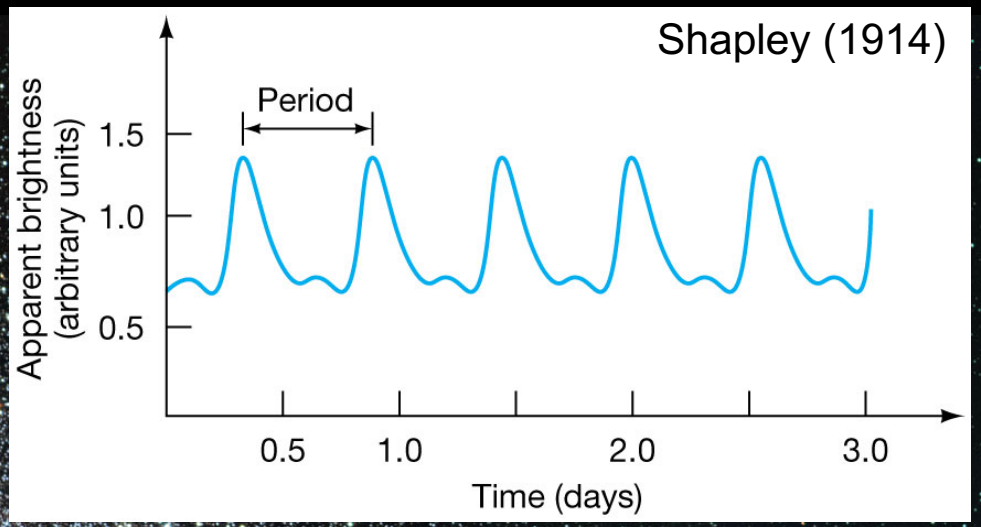

period 5.4 days
magnitude
3.6
3.8
4.0
4.2
4.4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
days

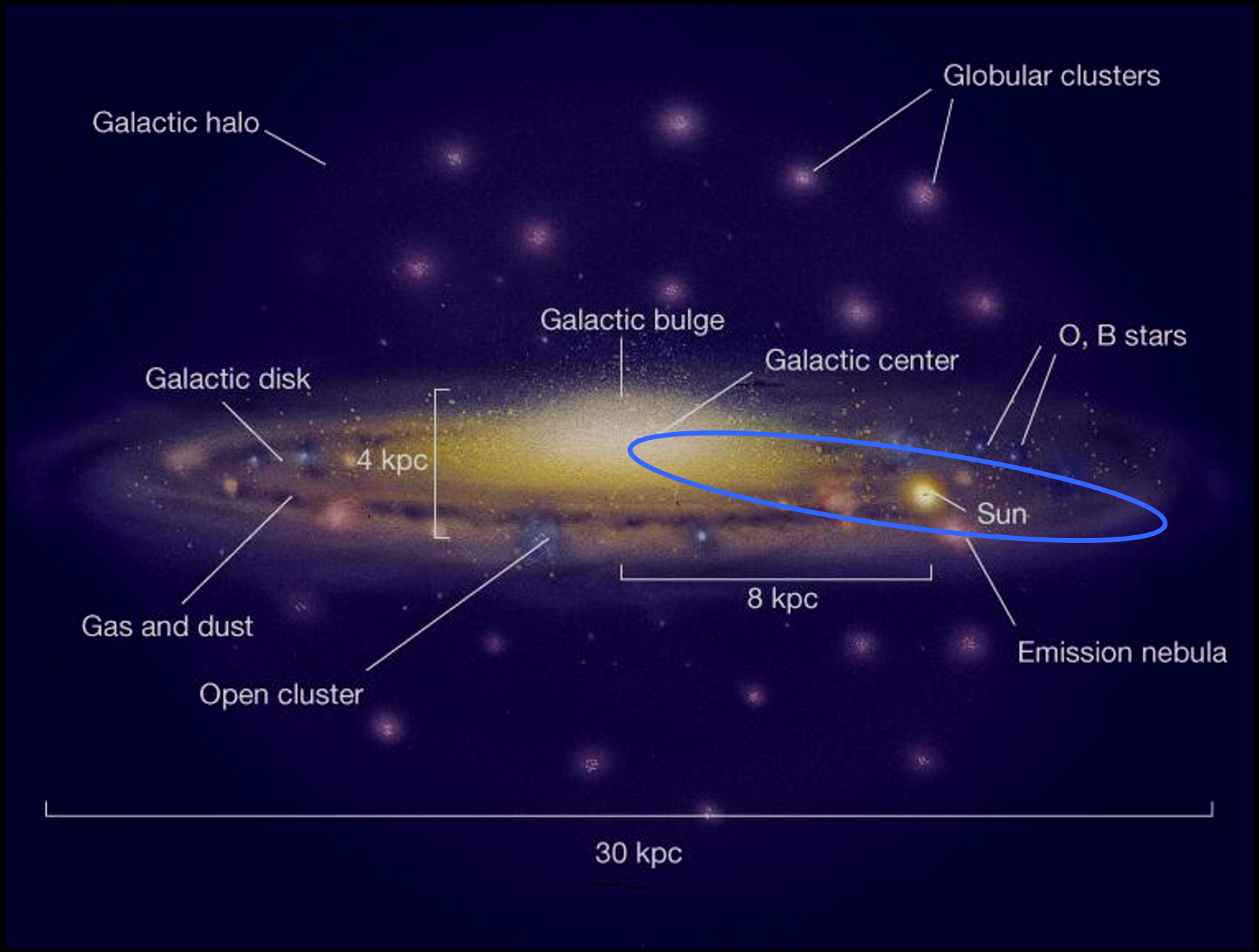

Light curve of Delta Cephei
© 2003, C J Hilder, www.AstronomyInYourHands.com
P = 0.14166 d
CPD -62°2707
HD 173006
P = 0.17012 d
P = 0.20207 d
HDE 328862
P = 0.20104 d
BW Vulpeculae
Phase
Phase
Time (days)

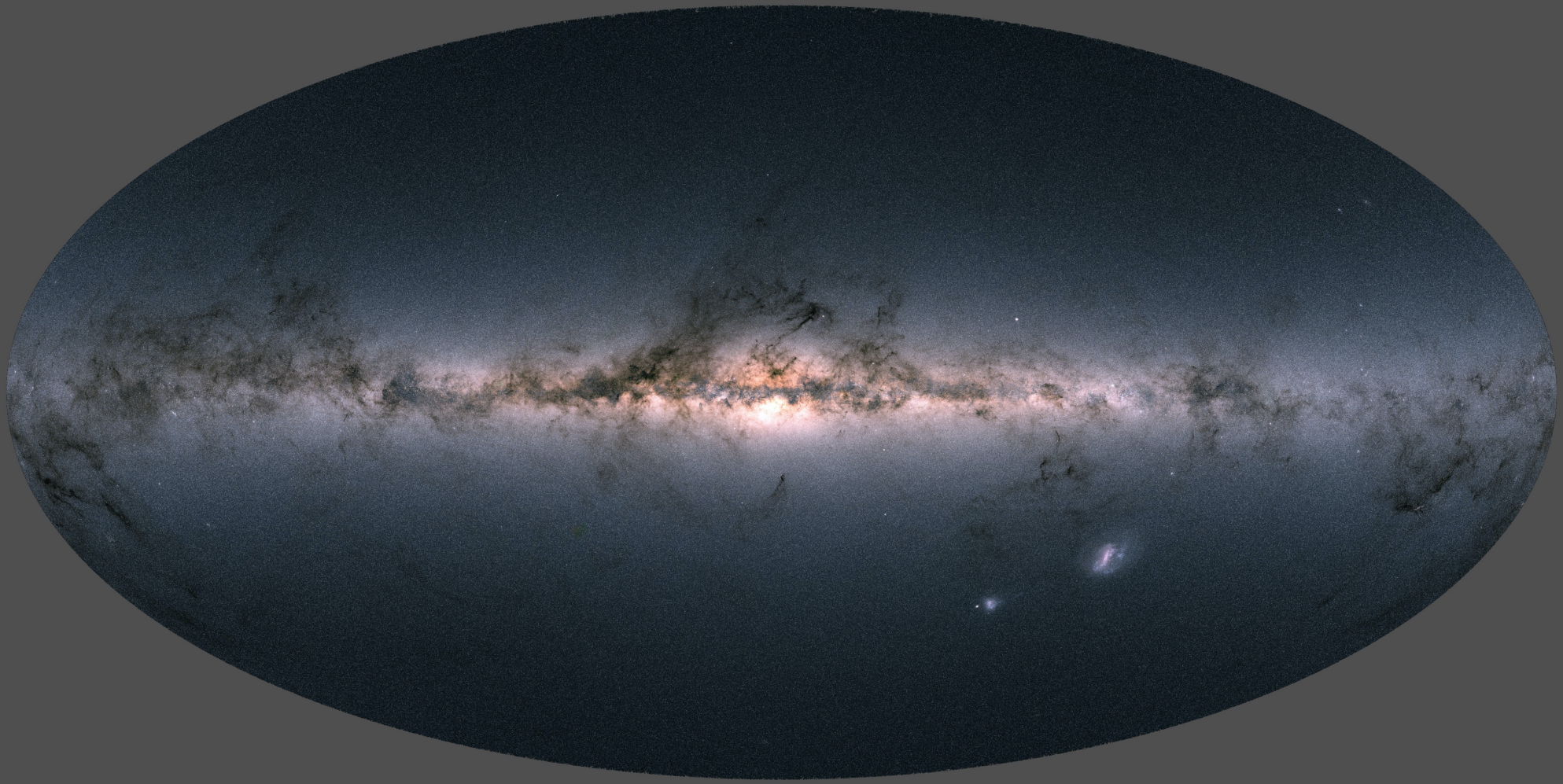

luminosity (L_{sun})
10^4
10^3
10^2
Cepheids
RR Lyrae stars
1 3 10 30 100
period (days)

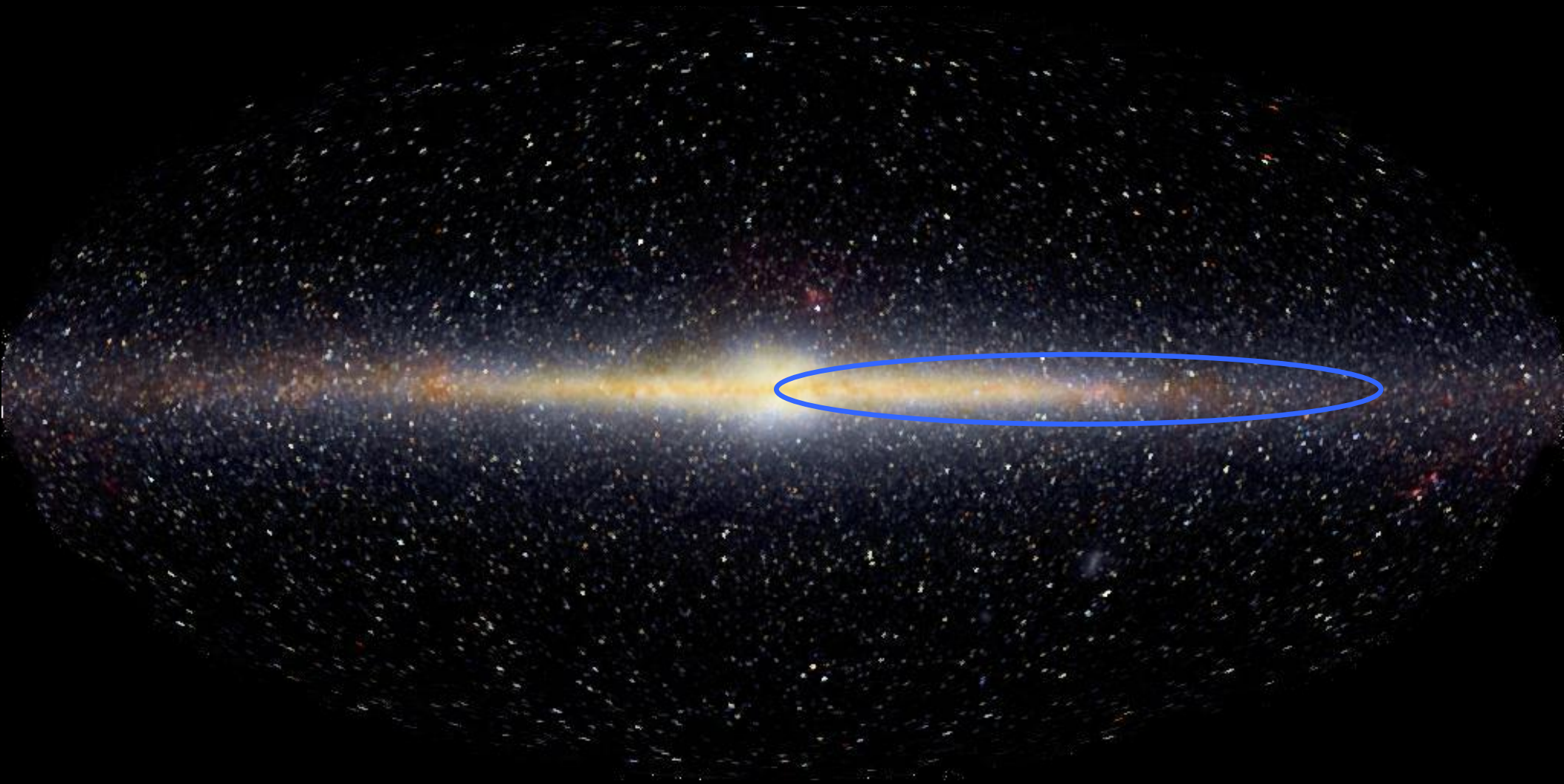

-15
-10
-5
0
+5
+10
+15
+20
Absolute Magnitude
Hypergiants
Supergiants
The Instability Strip
classic cepheids
W Virginis variables
RR Lyrae variables
Bright Giants
Giants
Subgiants
Dwarfs
Main Sequence
Subdwarfs
White Dwarfs
Brown Dwarfs
O
B
A
F
G
K
M
L
T
Spectral Class

globular cluster
47 Tucanae




Globular clusters
Galactic halo
Galactic bulge
O, B stars
Galactic center
Galactic disk
4 kpc
Sun
8 kpc
Gas and dust
Emission nebula
Open cluster
30 kpc





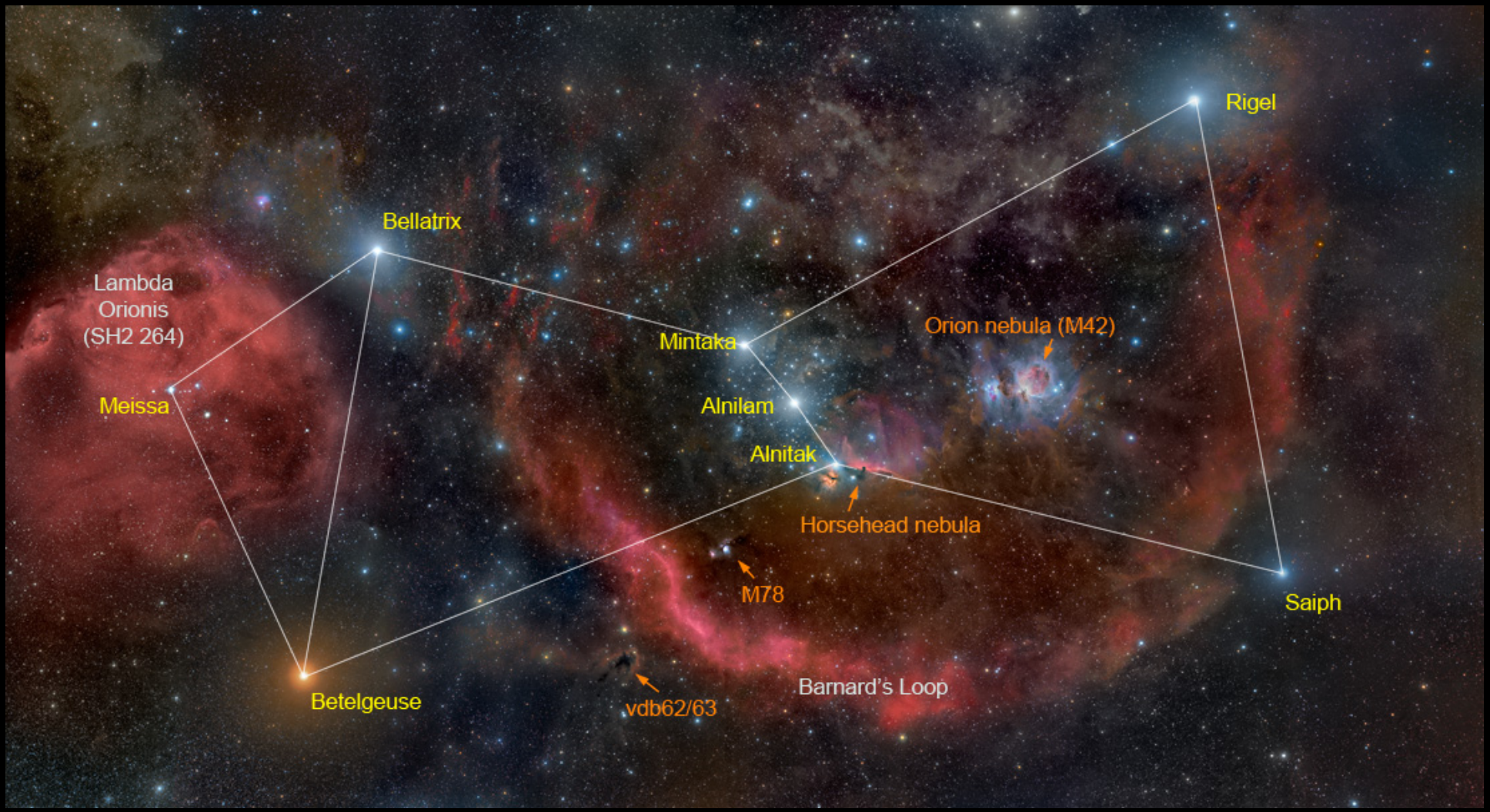
Visible • WFPC2

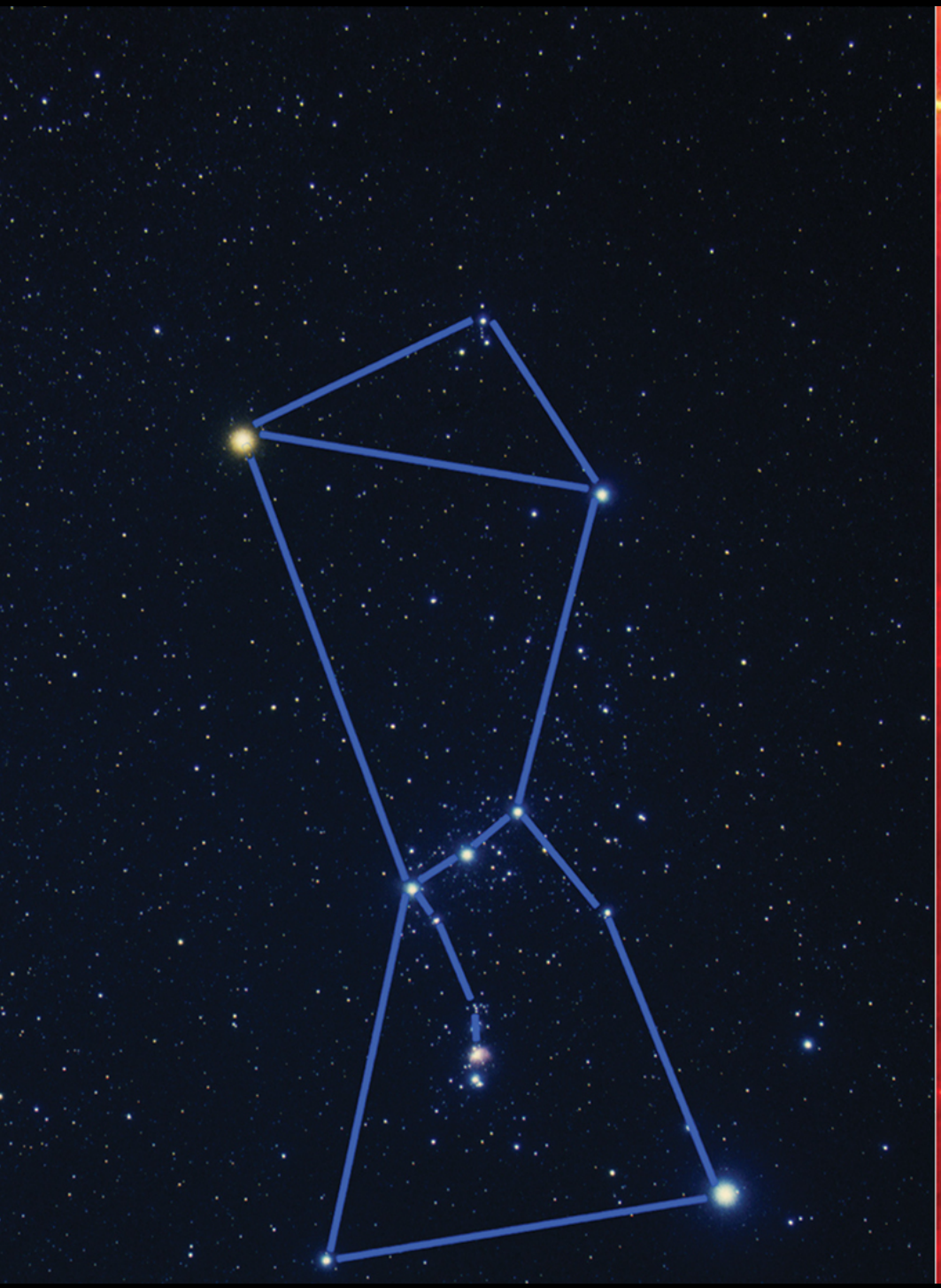
Infrared • NICMOS

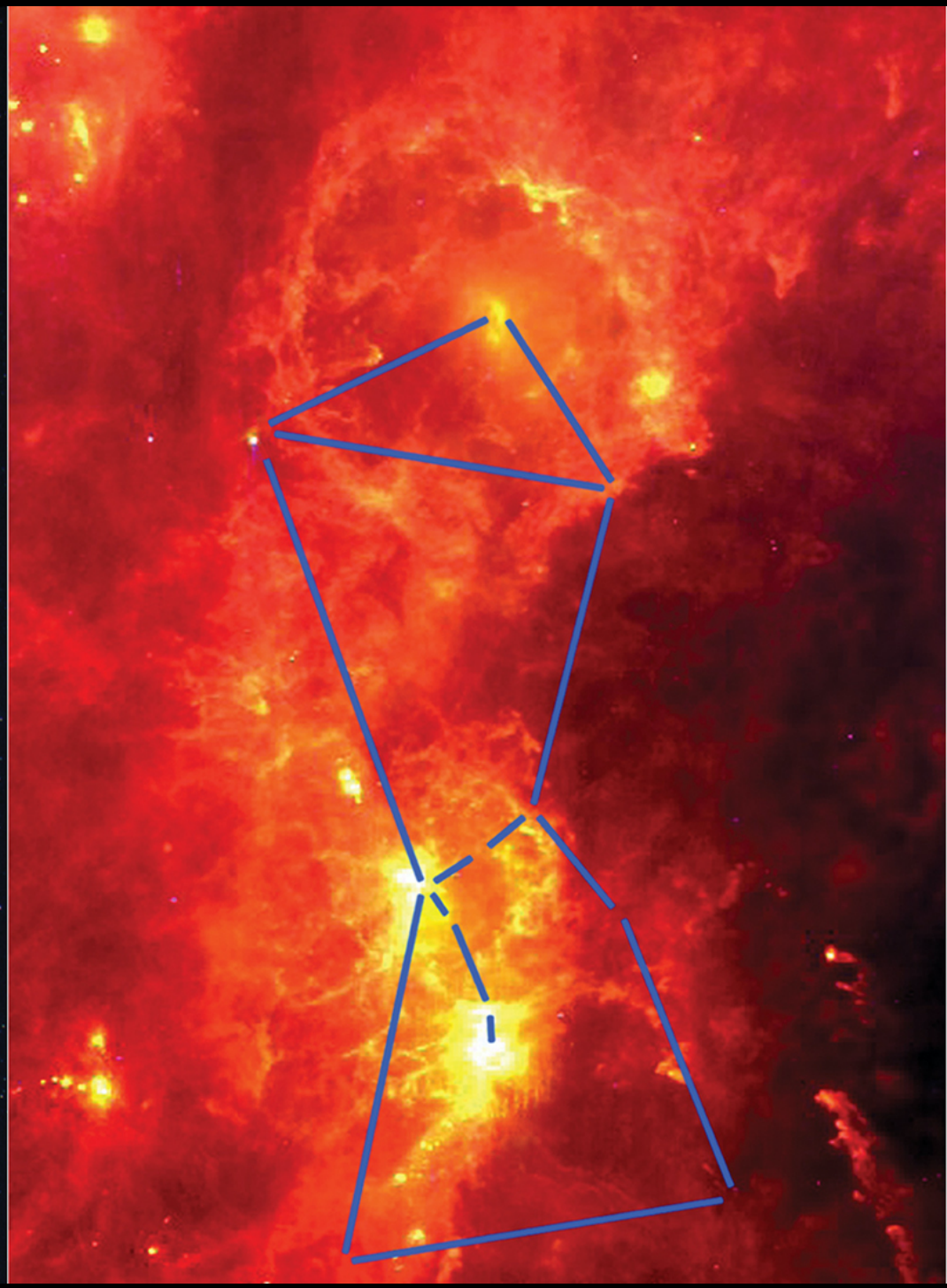
Trapezium Cluster • Orion Nebula

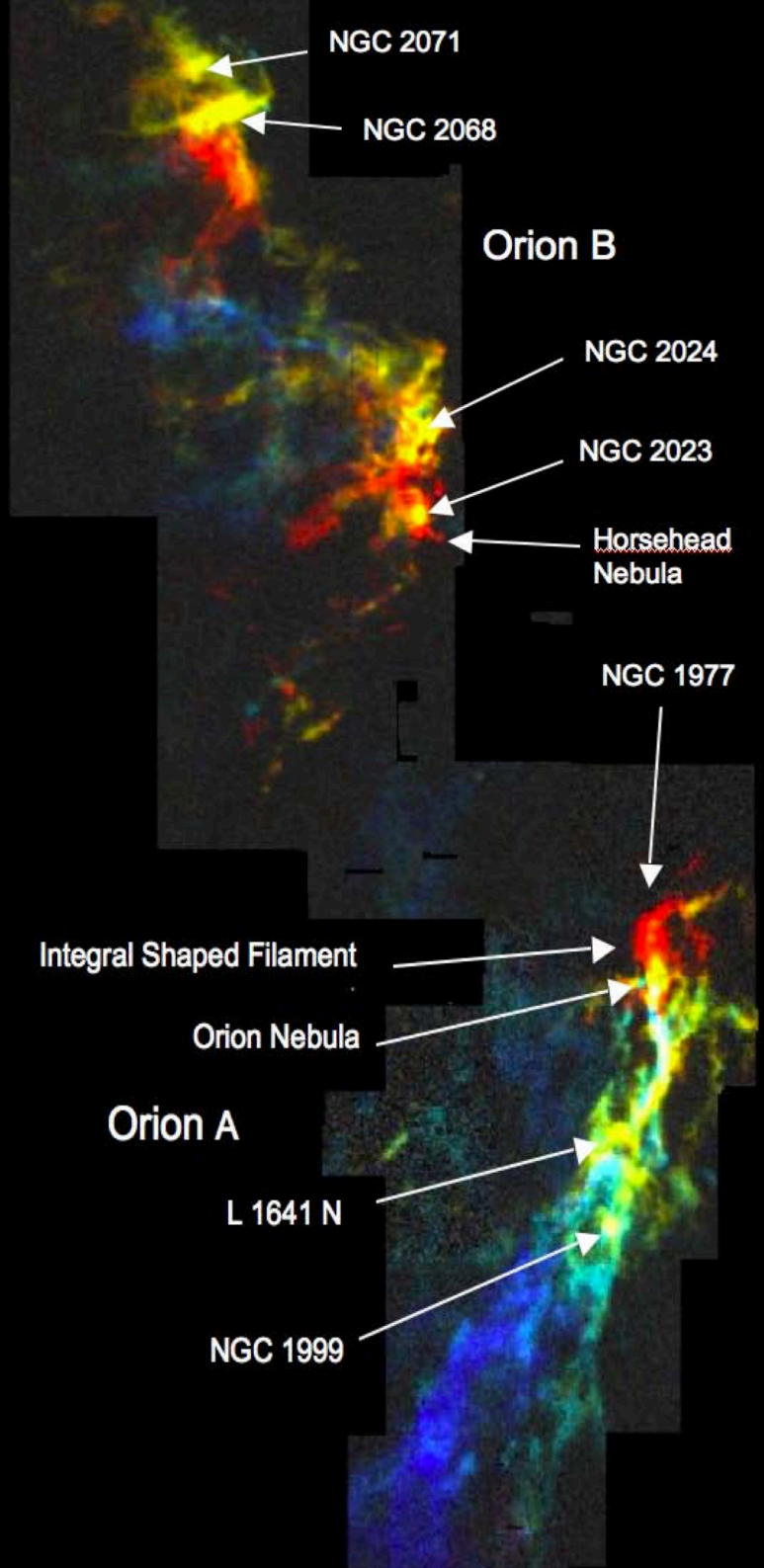
WFPC2 • **Hubble Space Telescope** • NICMOS

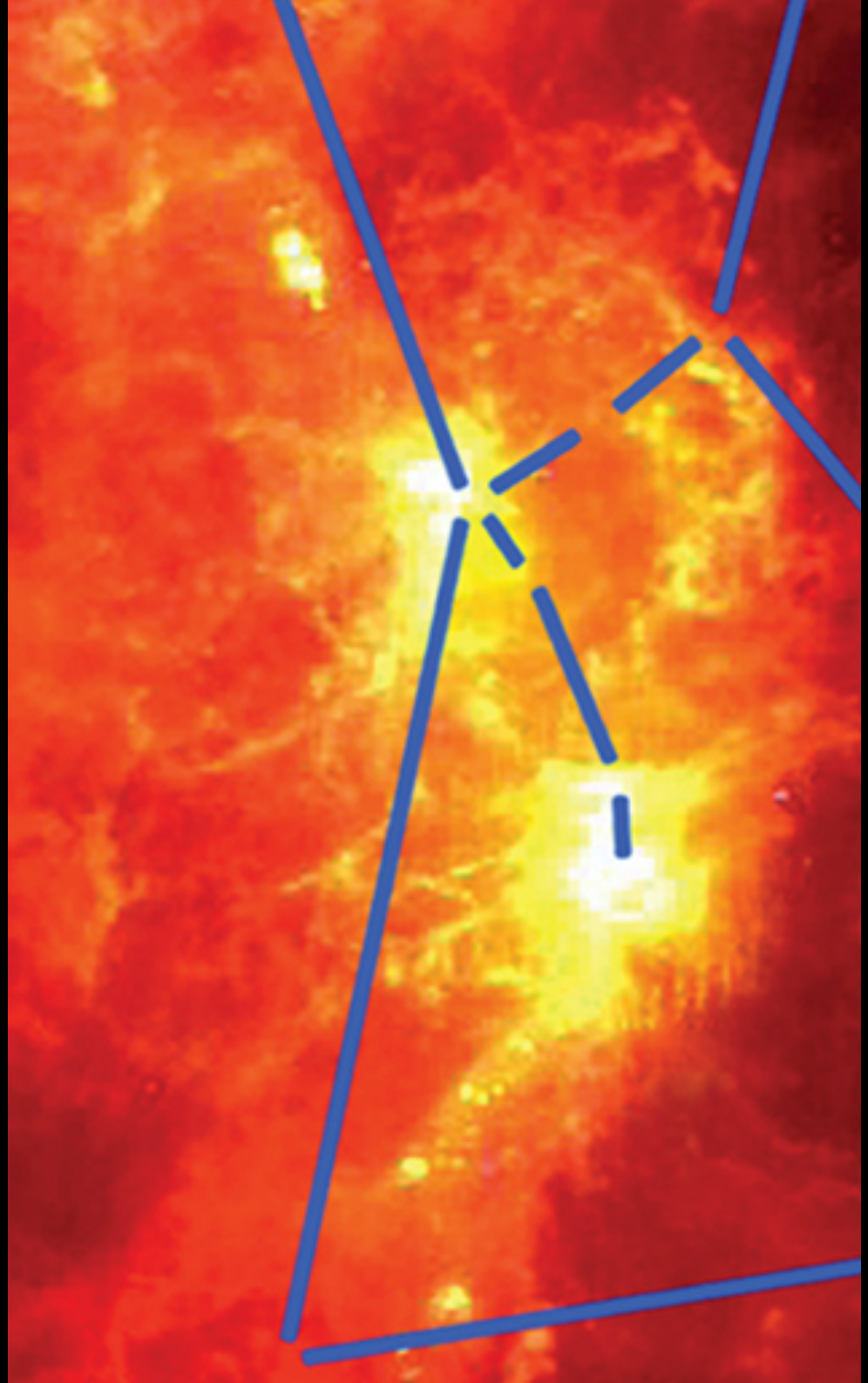
NASA and K. Luhman (Harvard-Smithsonian Center for Astrophysics) • STScI-PRC00-19

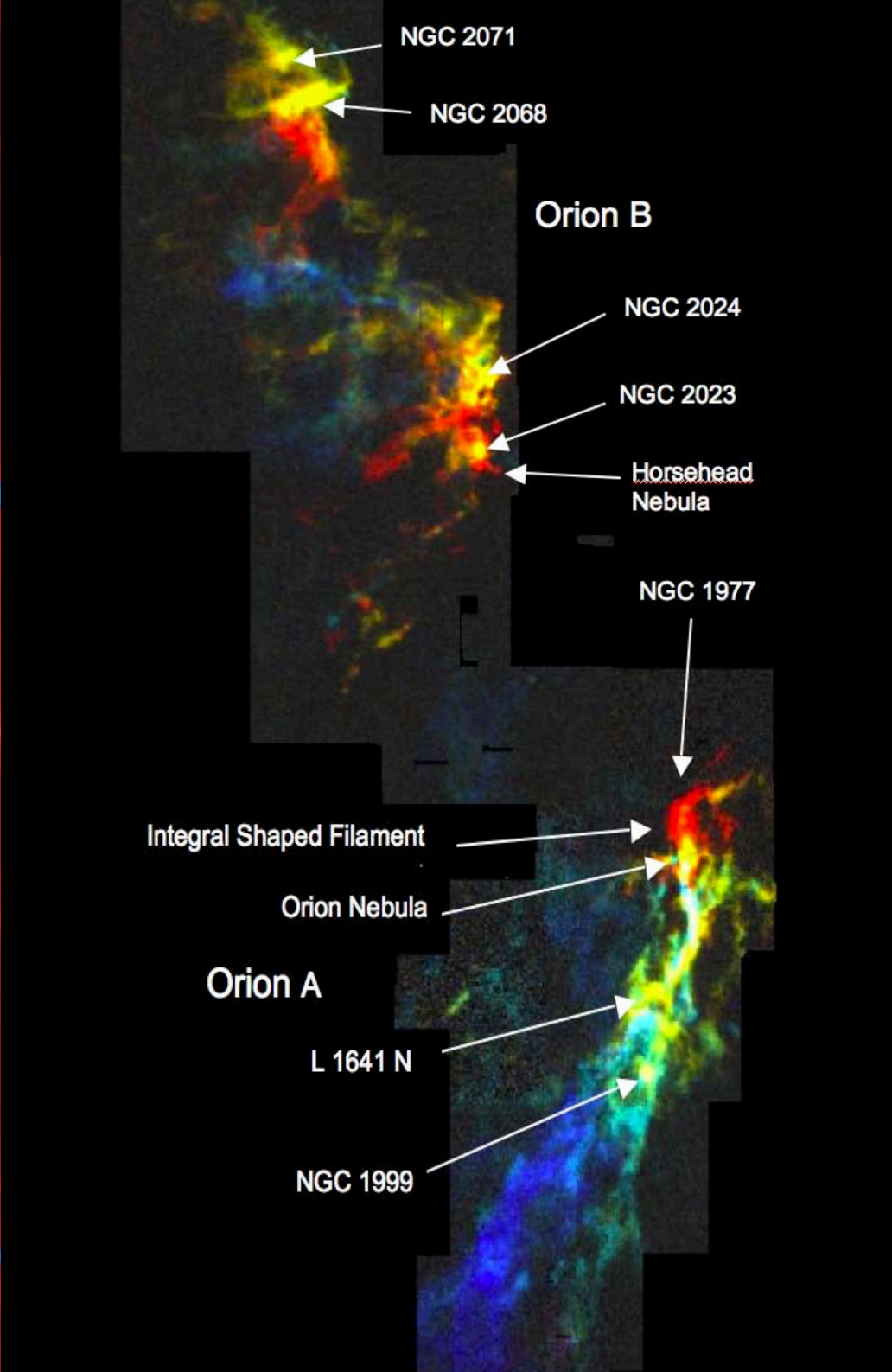

Rigel
Bellatrix
Lambda
Orionis
(SH2 264)
Mintaka
Orion nebula (M42)
Meissa
Alnilam
Alnitak
Horsehead nebula
M78
Saiph
Barnard's Loop
Betelgeuse
vdb62/63






NGC 2071
NGC 2068
Orion B
NGC 2024
NGC 2023
Horsehead Nebula
NGC 1977
Integral Shaped Filament
Orion Nebula
Orion A
L 1641 N
NGC 1999




NGC 2071
NGC 2068
Orion B
NGC 2024
NGC 2023
Horsehead Nebula
NGC 1977
Integral Shaped Filament
Orion Nebula
Orion A
L 1641 N
NGC 1999

Composition of the Interstellar Medium

- mirrors stellar composition
  - ~ 70 percent hydrogen
  - few percent “metals”
  - rest helium
- interstellar gas mass ~ 5% of the total mass in stars
- gas may be molecular, atomic, or ionized, depending on local heating and cooling processes
- most of the gas mass is in atomic form; most of the volume is hot ionized gas

Components of the Interstellar Medium

- molecular gas
  - molecular cloud complexes
  - mostly H_2, but also CO, NH_3, H_2CO, ...
  - also contains atomic gas and dust
  - cold and "dense"
    - $T \sim 20 - 50\ K,\ \ n > 10^3\ \mathrm{cm}^{-3}\ (= 10^9\ \mathrm{m}^{-3})$
  - turbulent gas flow
  - gravitational collapse

Components of the Interstellar Medium

- atomic gas
  - cold neutral medium
    - $T \sim 100\ K,\ \ n \sim 1 - 10^3\ \mathrm{cm}^{-3}$
  - warm neutral medium
    - $T \sim 10^3 - 10^4\ K,\ \ n \sim 0.1 - 1\ \mathrm{cm}^{-3}$

Components of the Interstellar Medium

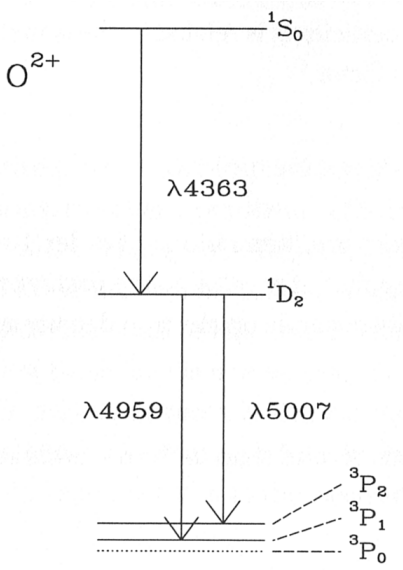
- ionized gas
  - warm ionized medium
    - $T \sim 10^4\ K,\ \ n \sim 10^{-3} - 0.1\ \mathrm{cm}^{-3}$
  - hot ionized medium (“corona”)
    - $T \sim 10^6\ K,\ \ n <\ 10^{-3}\ \mathrm{cm}^{-3}$

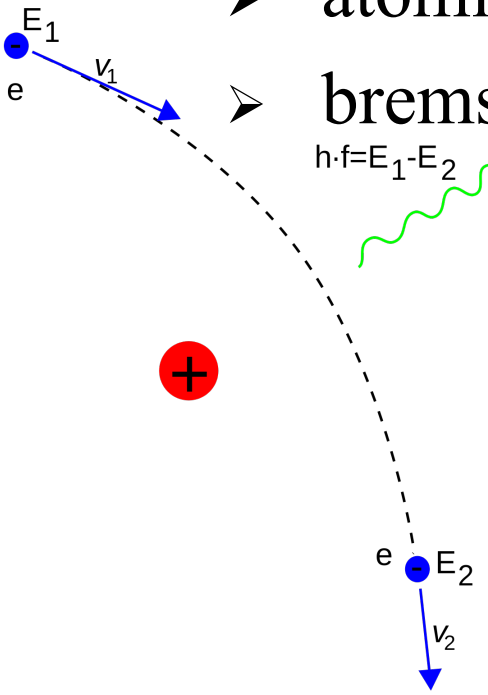
Heating and Cooling

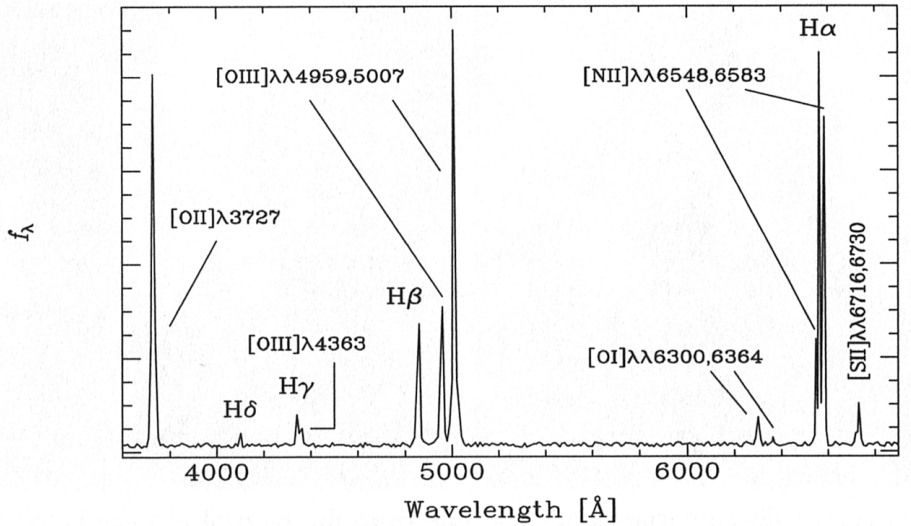
- heating processes
  - cosmic rays
  - ultraviolet radiation background
  - winds and ionizing radiation from massive stars
  - photoelectric heating on dust
  - supernovae

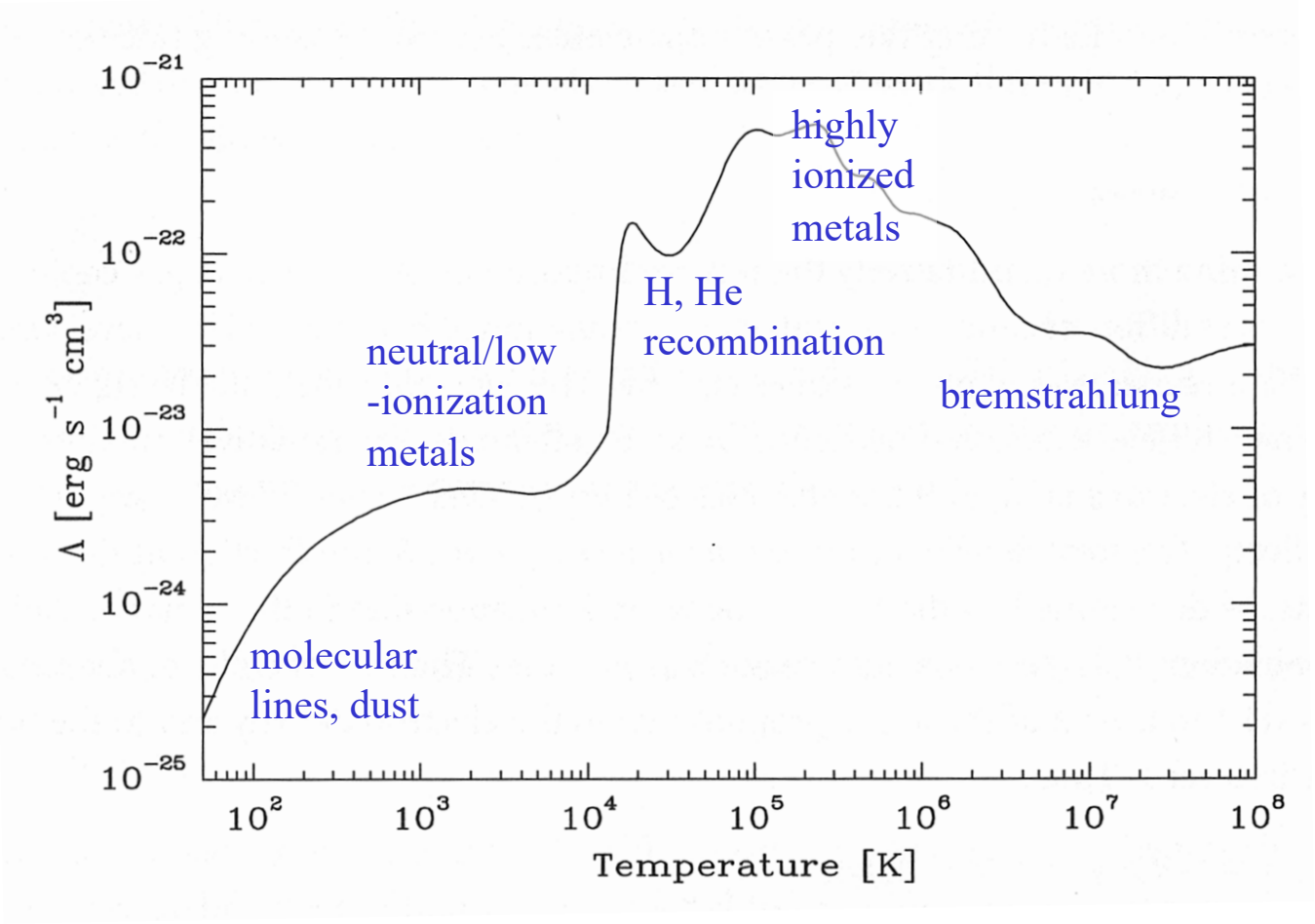
Heating and Cooling

- cooling processes
  - molecular line emission
  - dust emission
  - fine structure line emission
  - atomic/ionic line emission
  - bremstrahlung








10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
Λ [erg s^{-1} cm^{3}]
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
Temperature [K]
molecular
lines, dust
neutral/low
-ionization
metals
H, He
recombination
highly
ionized
metals
bremstrahlung