# Fundamental parameters of massive stars: the super-computer era

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Massive stars :
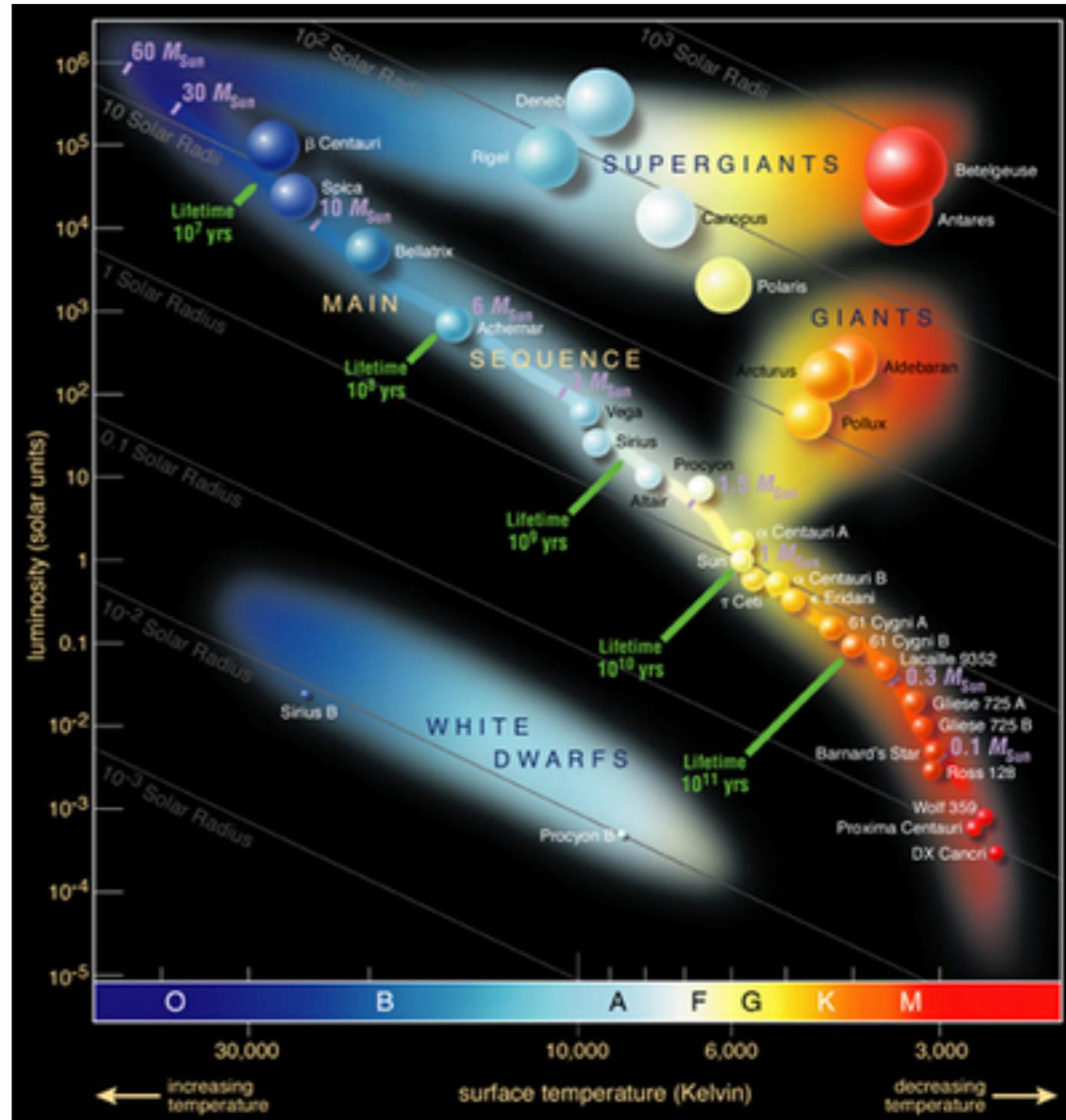
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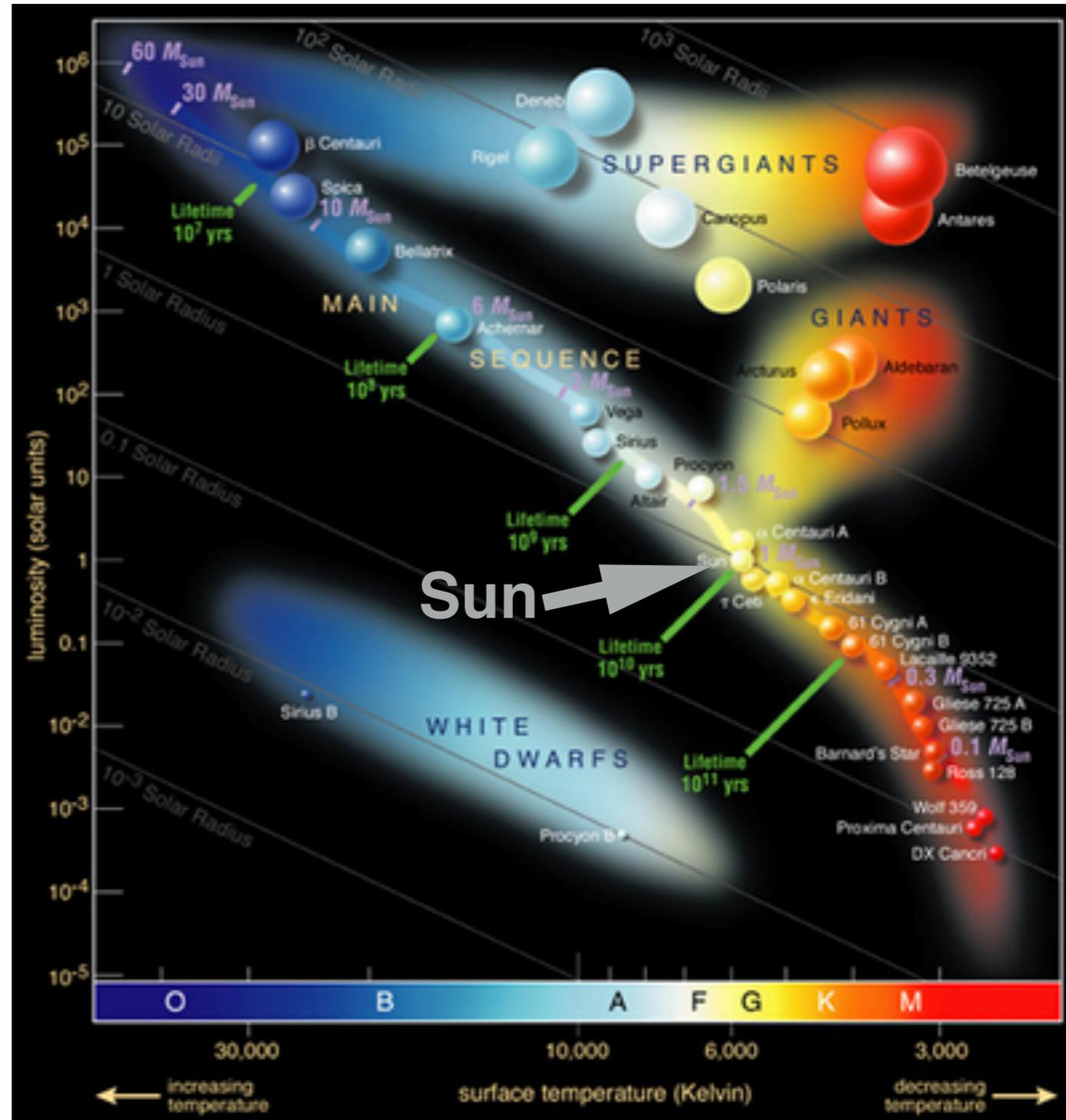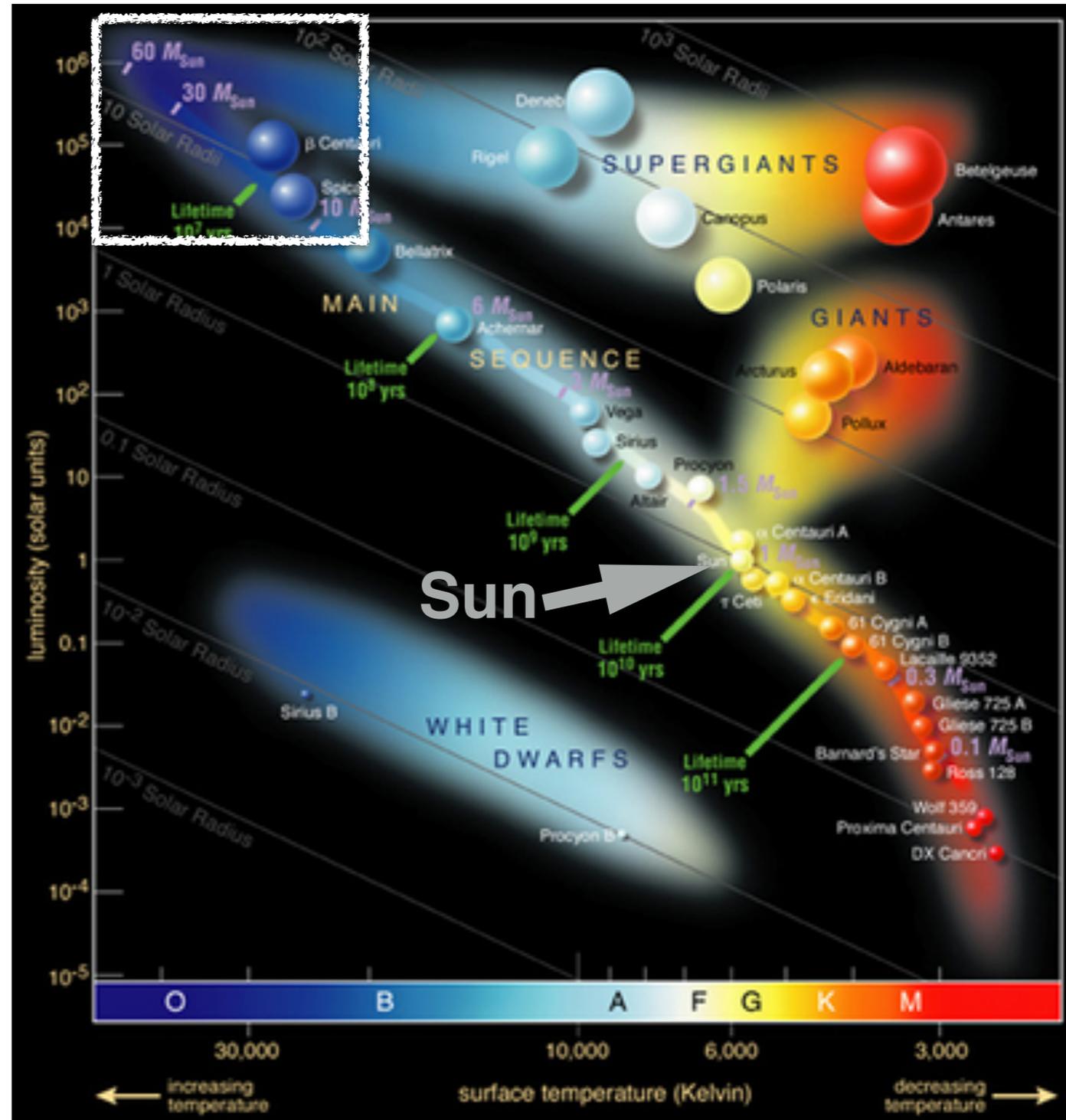
# Massive stars :

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- Luminosity > 10^{4-5} L$_\odot$

- Temperature > 25000K
  (Sun ~5700K)

- Powerful stellar winds
  Mass loss ~10^{-5} M$_\odot$/year
  Winds can reach 3000 km/s

- Short lifetime < 10^7 yrs while Sun
 ~ 10^{10} yrs **Rare**
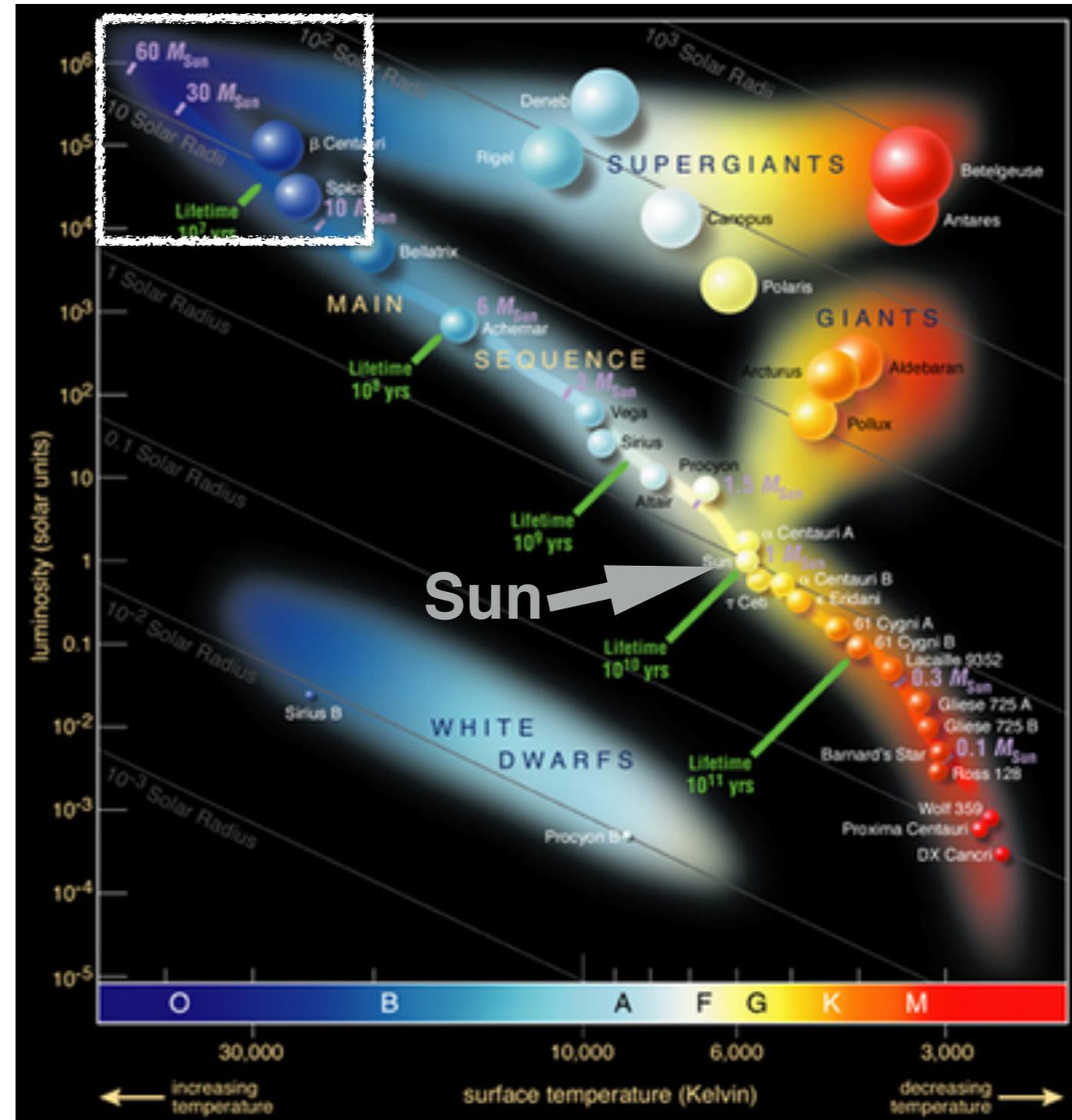
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They play a crucial role into the
ecology (evolution and
dynamic) of the galaxies

= COSMIC ENGINES
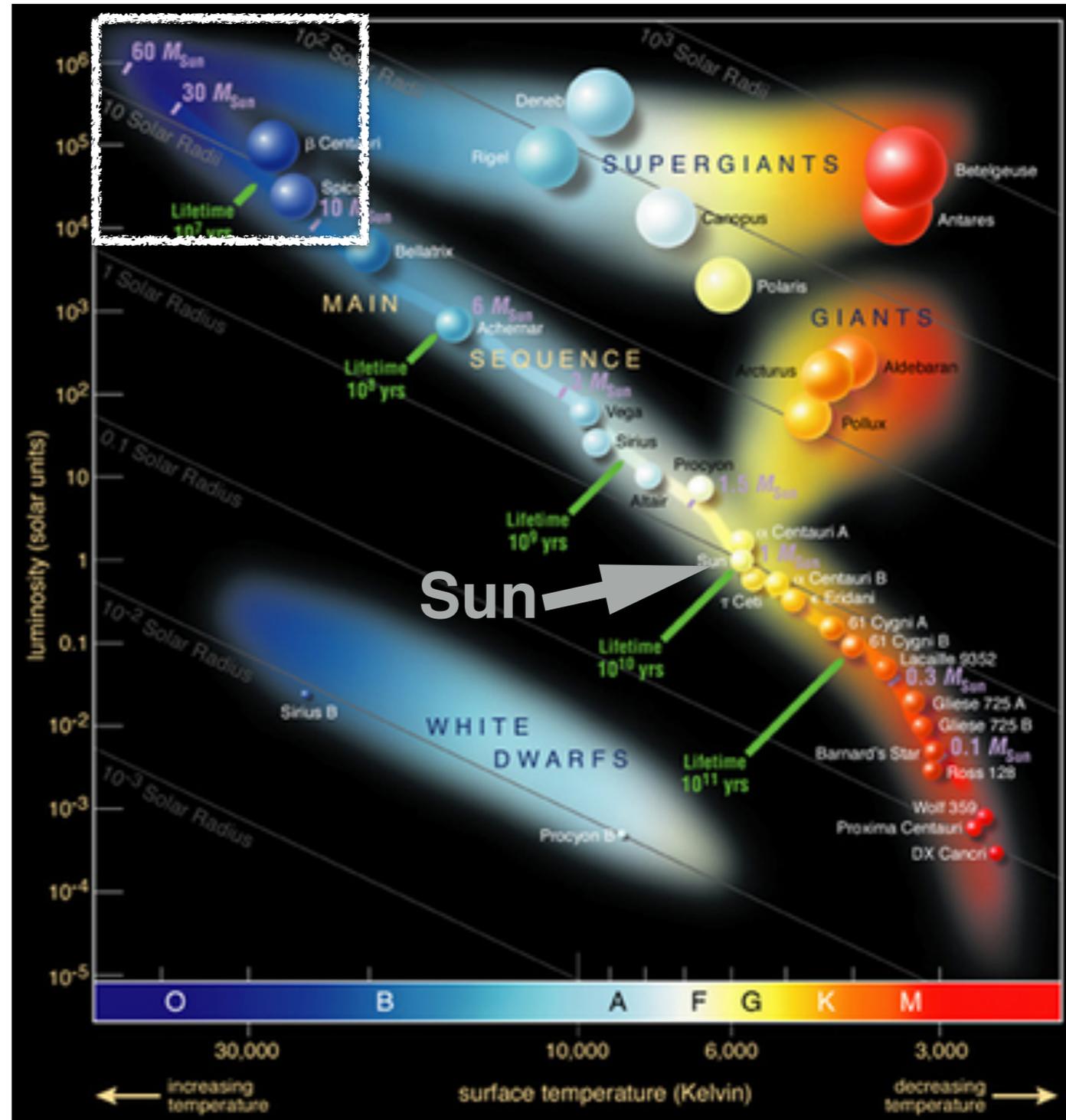
Open questions: Binary interactions

- \> 70% are binary or multiple systems

Binary fraction
Number of companions
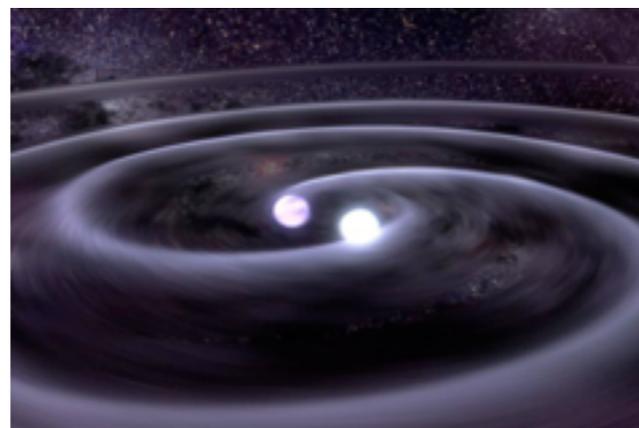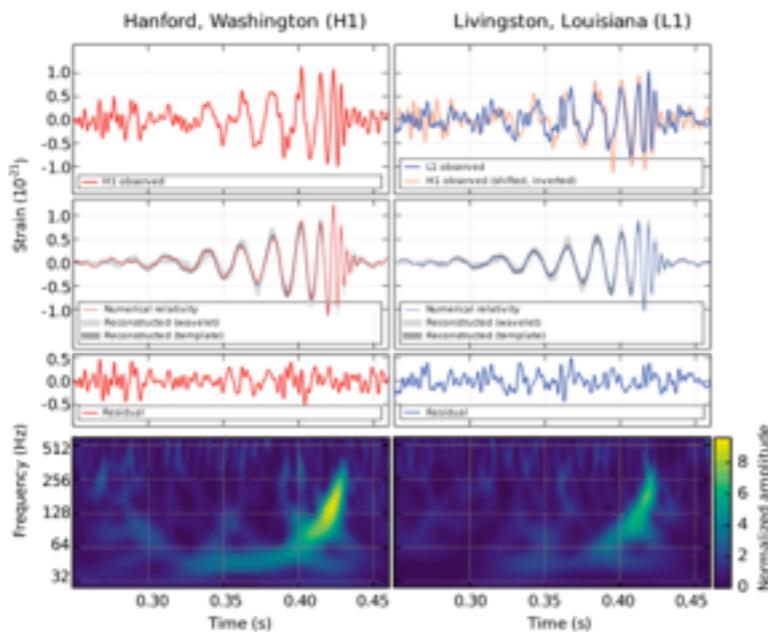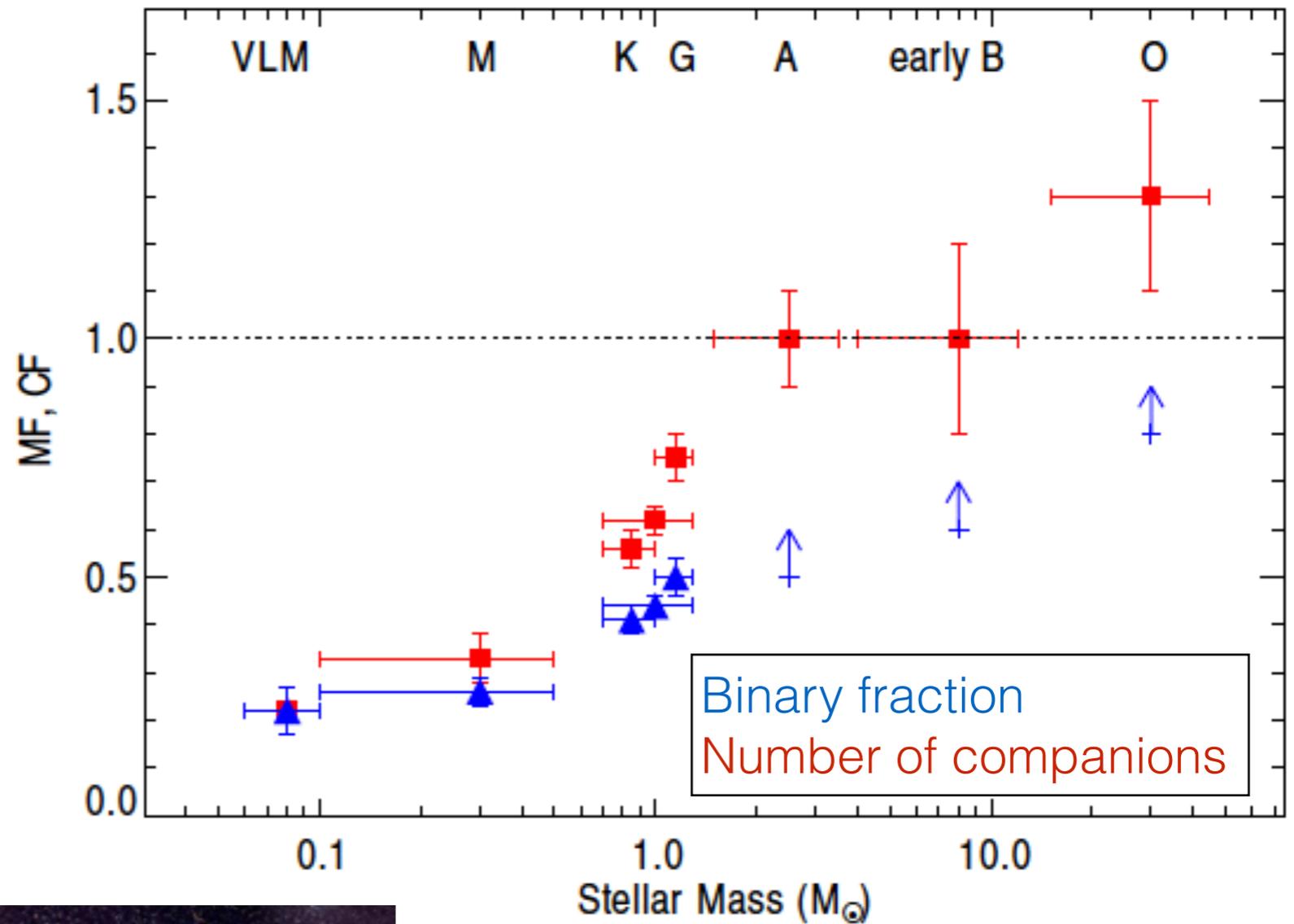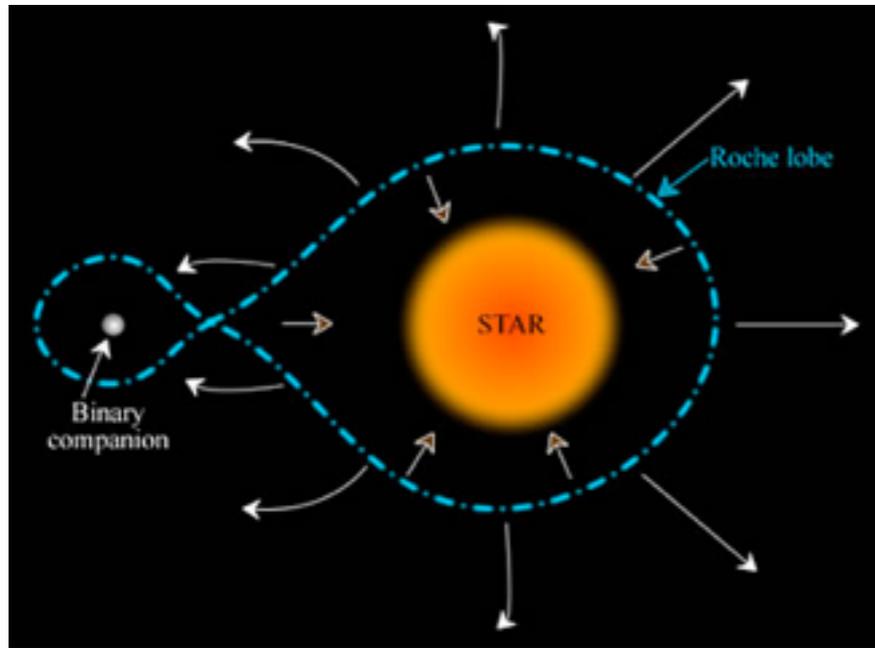
Open questions: Nature of the stellar winds

- Stellar winds are not homogeneous but composed of clumps.

- The mass-loss rates are thus impacted by the clumping which affects the evolutionary theory of massive stars
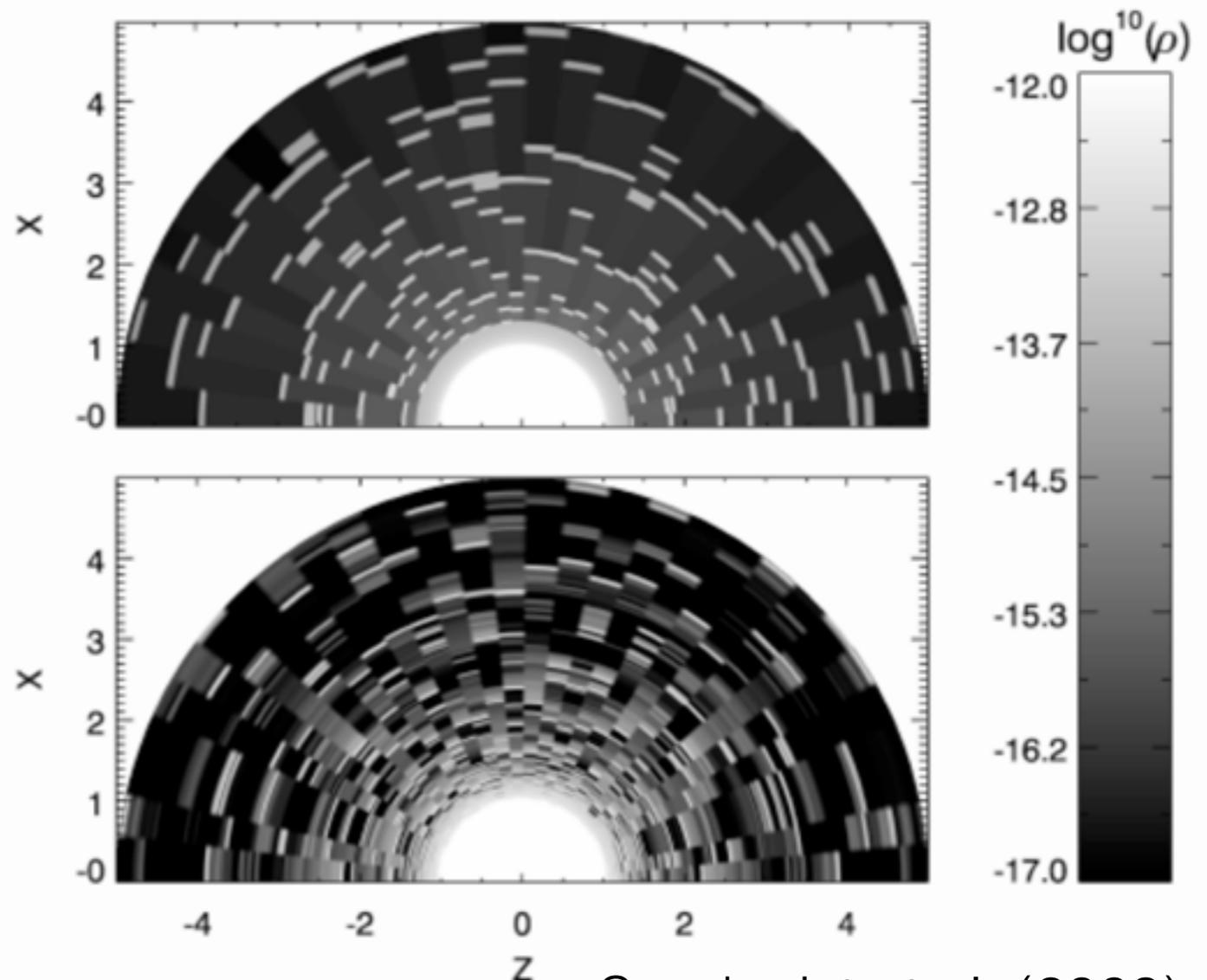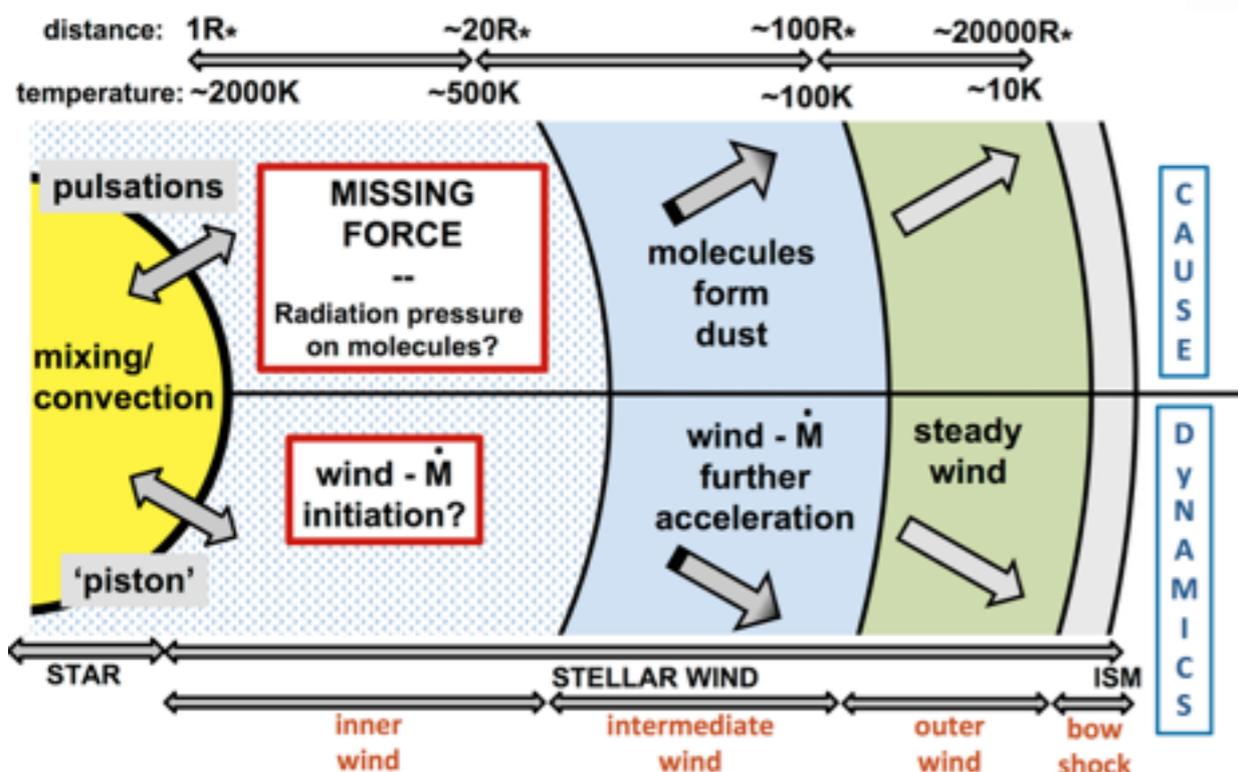
Sundqvist et al. (2009)

Other questions: Formation - Evolution - Death

- History of the star-forming region

- Use nebulae around evolved massive stars as tracers for their evolution

- Many more !!!
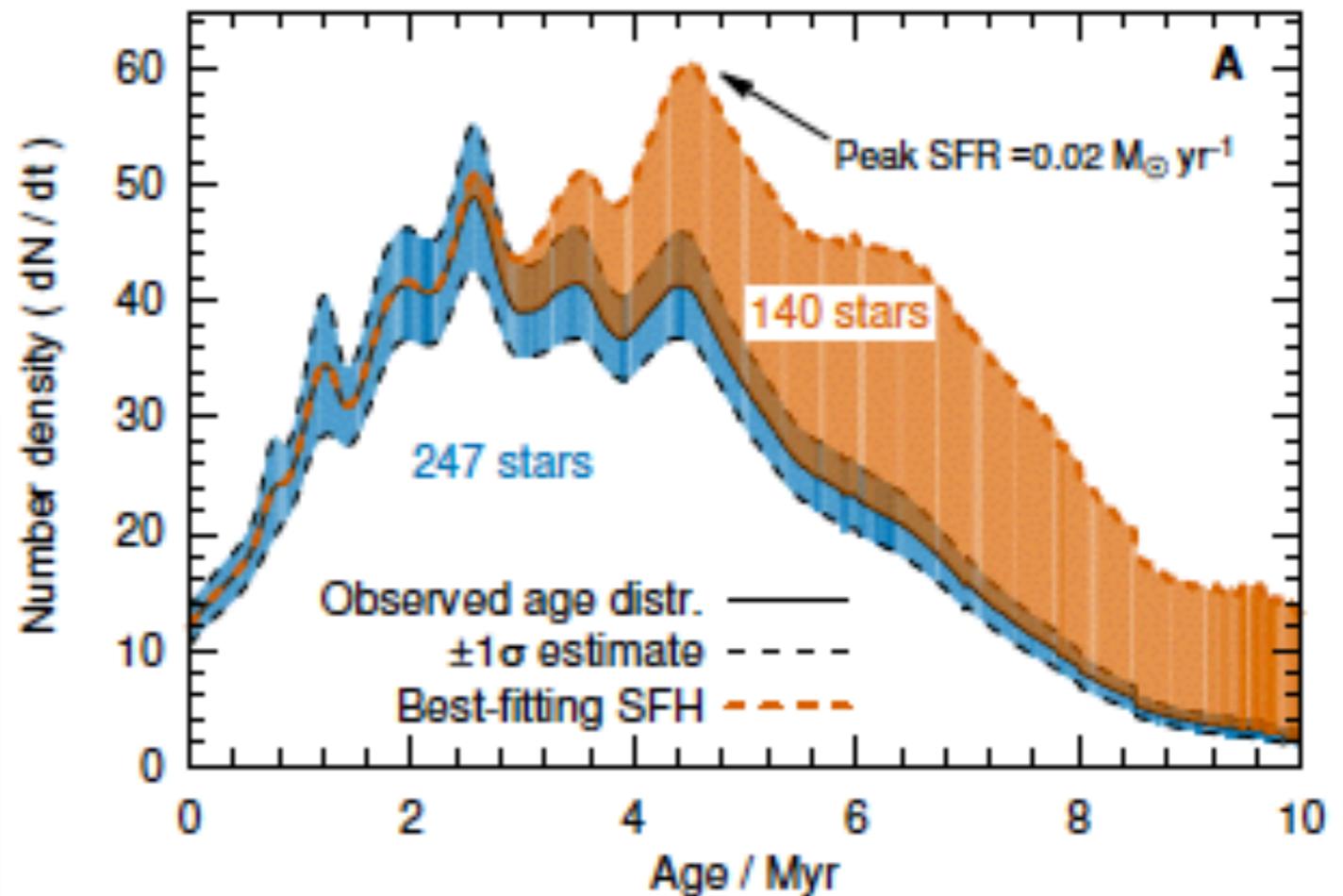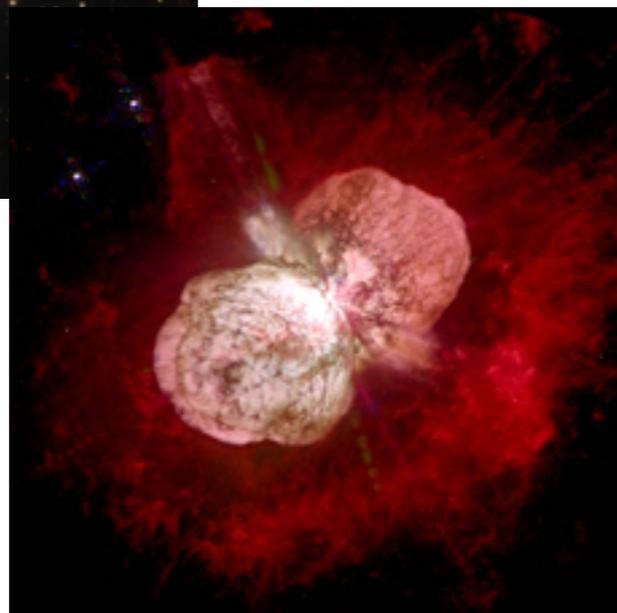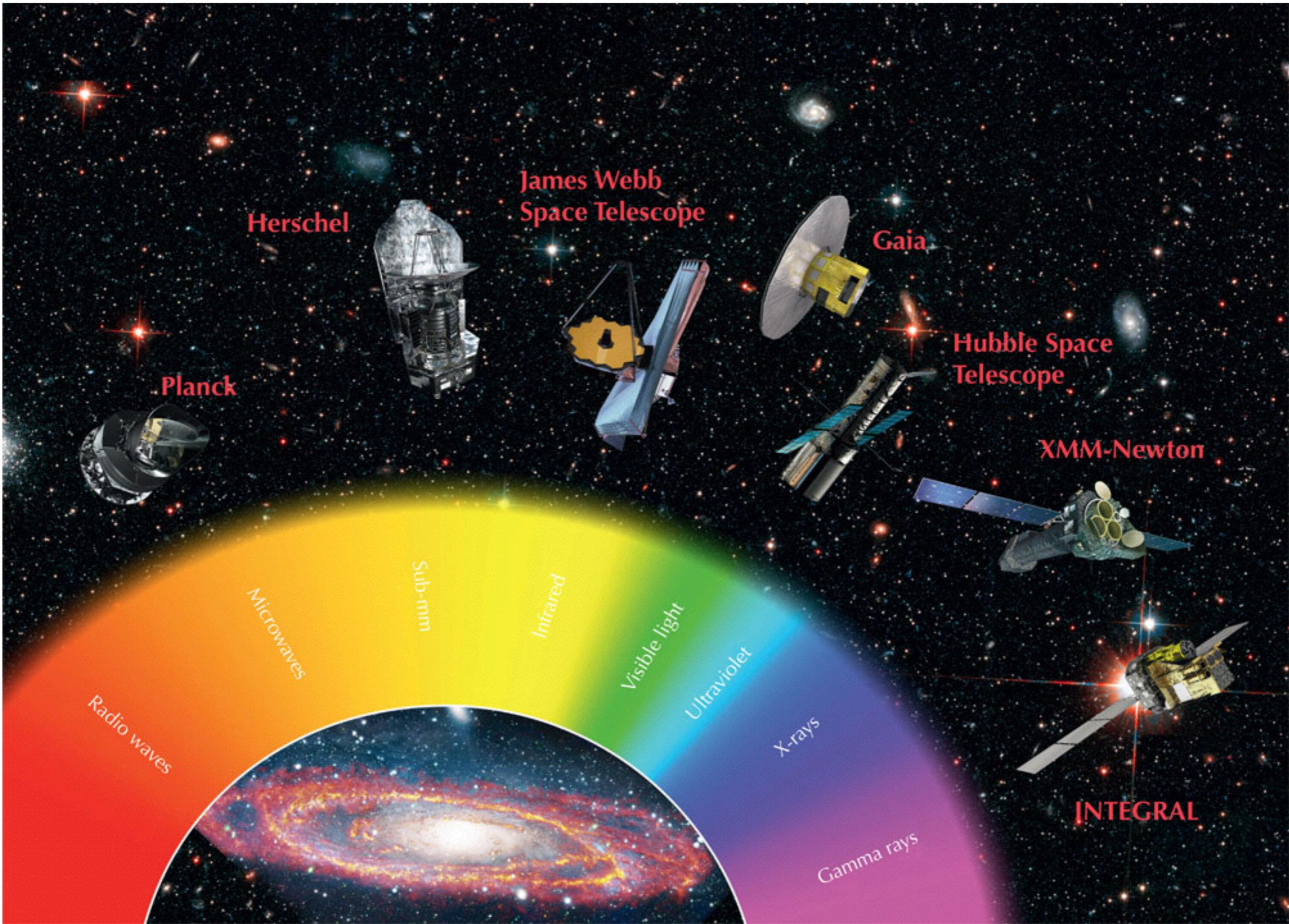
Planck

Herschel

James Webb
Space Telescope

Gaia

Hubble Space
Telescope

XMM-Newton

INTEGRAL

Radio waves

Microwaves

Sub-mm

Infrared

Visible light

Ultraviolet

X-rays

Gamma rays

- One way to provide answers is to use : **ATMOSPHERE CODES** (Radiative transfer)

  Allow to derive the internal structure of the stars
  Allow to determine the stellar and wind parameters
 as well as their surface abundances

- When we want to include the whole physics, very time consuming !

- For one simple star:

  Temperature, gravity, luminosity,
  mass-loss, terminal velocity of the wind, clumping, wind velocity law,
  Helium, Carbon, Nitrogen, Oxygen surface abundances

  ➡ 11 parameters, min. 22 models

  ➡ Each model needs 1 day   **1 Month of calculations**

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Super calculators are required

Thank you