Exam Stars – Monday, May 28, 2018 – 10.00am -13.00pm

Leiden University

Welcome to the Stars 2018 exam. It contains **FIVE** questions.

→ You have 3 hours to complete this exam
→ Please write your answers for the five questions on **five separate sheets**
→ Use of a simple calculator (non-graphical) is allowed
→ List with formulae and physical constants is provided

[In this exam you can score 80 pnts in total]

Question 1: [17 pnts]

1a) Would you expect to see O-stars in open clusters, in globular clusters, or in both? Why? **[3 pnts]**

1b) Procyon is of stellar type F5V. Explain what the 'F', '5', and 'V' stand for. Can you qualitatively describe its spectrum? How does Procyon compare (qualitatively) to the Sun in mass, radius, and effective temperature? **[3 pnts]**

1c) Procyon has a faint companion with the same effective temperature as the main star, but it has a luminosity which is 2000x lower. How much smaller is the radius of the companion? What kind of star is this? **[3 pnts]**

1d) A star identical to the Sun has an observed V-band magnitude of m_v=8.5. What is its distance? **[3pnts]**

1e) The Saha equation has a dependency on the *density of free electrons*. Explain what this dependency is, and its physical reason. **[5 pnts]**

Question 2: [17 pnts]

2a) Briefly name/explain the four different stages of the birth of a star. **[4 pnts]**

2b) Explain the *virial theorem.* **[3 pnts]**

2c) Use the *Jeans' criterion* to explain why often multiple stars are formed from one collapsing cloud. **[5 pnts]**

2d) Consider two spherical hydrogen clouds named A and B have the same temperature. Cloud A has a mass that is 1.5x larger and a radius that is 1.2x larger than cloud B. Which of the two clouds is more likely to form stars? **[5 pnts]**

Question 3: [14 pnts]

3a) Explain limb darkening **[3 pnts]**

3b) Explain the physical origin of natural broadening, Doppler broadening, and pressure broadening of stellar absorption lines. **[3 pnts]**

3c) a stellar absorption line is box-shaped with a depth of 50% of the surrounding continuum, and a width of 5 nm. What is its equivalent width? **[3 pnts]**

3d) An interstellar cloud with a known thickness of z_0 and constant density ρ, has an opacity of κ_ν at frequency ν. A beam of light with intensity I_ν shines through the cloud and exits the cloud with an intensity of 0.01 I_ν. Express z_0 in terms of the other parameters. **[5 pnts]**

Question 4: [15 pnts]

4a) Star A has a significantly shallower radiative temperature gradient than star B, with all other parameters equal. Which of the stars is more likely to exhibit convection, and why? **[3 pnts]**

4b) Briefly explain the term *mixing length theory* **[3 pnts]**

4c) Briefly explain the kappa mechanism in Cepheids. **[4 pnts]**

4d) In the core of a star, hydrogen is fused in to helium. Explain, using the ideal gas law, the equation for hydrostatic equilibrium, and the virial theorem, how this affects the core temperature. **[5 pnts]**

Question 5: [17 pnts]

5a) Sketch the evolution of a sun-like star through the Hertzsprung-Russel diagram. Indicate the Zero-Age Main Sequence (ZAMS), the Red Giant Branch (RGB), the Asymptotic Giant Branch, and the stage in which a Planetary Nebula is formed. **[4 pnts]**

5b) Qualitatively describe the processes occurring in the star during the ZAMS, RGB, and AGB stages. **[4 pnts]**

5c) Given the luminosity of our Sun of 3.8×10^{26} W, how much hydrogen does it fuse into helium per second? The mass of a helium atom is 6.6465×10^{-24} g. **[3 pnts]**

5d) Explain how the terms *Chandrasekar limit*, *electron degeneracy*, *white dwarfs*, and *supernovae Ia* are linked. **[3 pnts]**

5e) Why can elements more massive than *lead* only be produced by *rapid neutron capture*, and not by *slow neutron capture*? **[3 pnts]**