Radiative processes, stellar atmospheres and winds (WS 2021/2022)

Problem set 1

Before you start to work on this problem set, recapitulate the definition and meaning of important astronomical quantities: Stellar parallaxes, apparent and absolute magnitude, distance modulus, Planck function,

$$
\begin{aligned}
B(\nu, T) &= \frac{2h\nu^3}{c^2} \frac{1}{\exp(h\nu/(kT)) - 1}, \\
B(\lambda, T) &= \frac{c}{\lambda^2} B(\nu, T) = \frac{2hc^2}{\lambda^5} \frac{1}{\exp(hc/(\lambda kT)) - 1},
\end{aligned}
$$

and color index.

Note: The 'points' assigned to each problem denote its (relative) difficulty. For each problem sheet, a maximum value of 12 points is foreseen.

Problem 1 [4 points] *Stellar parallaxes*

a) The parallax angle for Sirius is 0.379". Determine the distance to Sirius in units of (i) parsecs, (ii) light years, and (iii) km. Determine also the distance modulus.

b) HIPPARCOS was able to measure parallaxes down to almost 0.001". To get a sense of that level of resolution, determine how far from a one-Euro coin (diameter $\approx$ 2.3 cm) you would need to be to observe it subtending an angle of 0.001".

c) Repeat problem 1b), assuming now a resolution of 25 microarcsecond. 25 microarcsecond is the typical resolution (at 15 mag) of the present GAIA (Global Astrometric Interferometer for Astrophysics) ESA space mission, the successor to HIPPARCOS.

Problem 2 [5 points] *Barnard's star*

Barnard's star (in Ophiuchus) has the largest known proper motion (10.3577" yr^{-1}), and the fourth-largest parallax angle, 0.54901". The center of its H_α line (in air) is observed at 6560.34 Å.

a) At which wavelength would this line be observed from a satellite?

b) Calculate the radial and transverse velocity of Barnards's star, and determine its speed through space.

Problem 3 [3 points] *Spectra and fluxes*

The left-hand figure on page 35 of the lecture script displays digitized spectra from O to A stars, where all fluxes have been arbitrarily normalized to a value of '100' at 5450 A. Thus, and except for arbitrary shifts, the *relative* fluxes of the different stars are easily comparable.

a) Identify the most important Hydrogen features in the spectra.

b) Obviously, the relative fluxes on the long-wavelength side have a rather similar shape. Assume that the stars are black-body radiators, and determine the temperature dependence of the flux ratio ($\rightarrow$ ratio of Planck-functions) for two arbitrary wavelengths, λ_1 and λ_2, in the Rayleigh-Jeans approximation, i.e., $hc/(\lambda kT) \ll 1$. Note that such a flux ratio corresponds to a certain *color index*. What do you conclude? From which wavelengths on might the Rayleigh-Jeans approximation be justified for A-stars and for O-stars, with surface temperatures of 10,000 K and 40,000 K, respectively?

Have fun, and much success!