Stellar Structure and Evolution
—Exercises—
Wolfgang Glatzel
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GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

Part 3

1) Assume that the stellar matter can be described by the equation of state of an ideal gas $p/\rho \propto T/\mu$ (p: pressure, ρ: density, T: temperature, μ: mean molecular weight). Use hydrostatic equilibrium, radiative energy transport and "mass conservation" to derive (by order of magnitude estimates) a relation between luminosity L and mass M of a star. Hint: derivatives of the form $\frac{dy}{dM_r}$ may be estimated by y/M. How does the energy generation influence the luminosity of a star?

In addition, take into account energy conservation (same kind of approximation) with an energy generation rate of the form $\varepsilon \propto \rho T^{\nu}$ and derive a relation between luminosity and effective temperature (use Stefan - Boltzmann's law).

For the pp - chain we have $\nu \approx 5.3$, for the CNO - cycle $\nu \approx 15.6$. Where in the Hertzsprung - Russell - diagram do you expect to find the objects described by the relation derived? For orientation: where are stars that have the same radius?

2) Apart from nuclear reactions accretion is a mechanism by which heat and observable radiation is generated in astrophysics. In this process a gravitating object collects matter on its surface. The gravitational potential energy thereby released is transformed into thermal energy. How big is the maximum radiation energy per accreted mass for an accreting object with given mass and radius, which can be generated in this process?

Express the result in units of c^2 (c: speed of light) for the following accreting objects: a) the earth, b) the sun, c) a giant, d) a white dwarf e) a neutron star, and f) a black hole. Compare with the maximum energy per unit mass that can be generated by nuclear processes.