Level 2 Stars, Workshop 7

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Star Formation

a) What is the Jeans Mass?

b) Show that the Jeans Mass (M_J) for a spherically symmetric gas cloud satisfies the relation

$$M_J = \left(\frac{5kT}{G\mu m_p}\right)^{3/2}\left(\frac{3}{4\pi\rho}\right)^{1/2} \quad ,$$

where T is the temperature of the cloud, μ is the (dimensionless) mean molecular mass, and ρ is the average density of the cloud.

[Recall that $U = -\frac{3}{5}\frac{GM^2}{R}$]

c) In which regions of the interstellar medium would you expect an object to have a low Jeans mass? What would you expect the mean-molecular mass to be in that region?

d) Hayashi tracks trace the paths that protostars take on the Hertzsprung-Russell diagram before joining the main sequence. Draw a Hertzsprung-Russell diagram highlighting the main sequence and the Hayashi tracks for both a low-mass (1 $M_\odot$) and high-mass (25 $M_\odot$) protostar. On the basis of these Hayashi tracks, briefly explain the evolution of both the low-mass and high-mass protostar.

e) What is the Kelvin-Helmholtz time? Why is it relevant for the evolution of protostars?

f) Calculate the Kelvin-Helmholtz time for a 1 $M_\odot$ protostar with the following properties: an effective temperature of 4,000 K, an initial luminosity of 100 $L_\odot$, a final luminosity of 0.5 $L_\odot$, and an average luminosity of 1 $L_\odot$.

[$L_\odot = 3.84 \times 10^{26}$ W; $m_H = 1.67 \times 10^{-27}$ kg; $M_\odot = 1.99 \times 10^{30}$ kg; $k = 1.38 \times 10^{-23}$ J K^{-1}; $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}]