ACCUMULATION OF A RAPIDLY ROTATING PROTOSTAR AND THE FORMATION OF AN ASSOCIATED NEBULA AS A RESULT OF ANGULAR MOMENTUM TRANSPORT BY TURBULENT FRICTION

W M Tscharnuter
MPI für Astrophysik, Garching b. München, W-Germany

The influence of angular momentum transport by turbulent friction on the structure of a rotating protostar has been investigated. Turbulence is characterized by a simple viscosity parameter $\eta = \xi \cdot c_s \cdot l$, where c_s denotes the local speed of sound, l the typical length scale of the largest eddies (thickness of the nebula) and ξ the "efficiency" parameter (= 1/10 in our model).

In modelling the solar nebula we started out from a 3 $M_\odot$-cloud of density 10^{-20} g/cm^3 for which the ratios thermal/gravitational and rotational/gravitational energy are about 1 and 1.2 10^{-4}, respectively, i.e. the cloud is assumed to be marginally unstable according to the Jeans criterion and to rotate with an angular velocity inferred from the galactic rotation. During about 3 10^4 yr after the formation of a stellar core containing initially only a few 10^{-3} $M_\odot$ the central condensation has accreted 0.5 $M_\odot$. At the same time an almost stationary disk-like nebula has taken shape whose densities and temperatures range from 10^{-11} to 10^{-13} g/cm^3 (the surface densities are 10-30 g/cm^2) and from 10^3 to 10^2K, respectively, within a distance of 5 10^{12} up to 2 10^{14} cm. Its rotation is very nearly Keplerian. We have thus covered the collapse and accretion phases up to the point where the further evolution is dominated by a quasi-stationary accretion flow due to turbulent friction. From our numerical model we may estimate this evolutionary timescale to be of the order of 10^7 yr.

DISCUSSION

Bodenheimer: Could you comment on the stability of the core? Is it likely to fission?

Tscharnuter: Unfortunately, at present it is not possible to study the internal structure of a rapidly rotating protstar consistently with the accretion flow. Estimates for the ratio $|E_{tot}/E_{grav}|$ yield numbers in the range 0.27 - 0.28, so that fission cannot be excluded.

Unno: In your formula for turbulent friction, why do you use the sound

D. Sugimoto, D. Q. Lamb, and D. N. Schramm (eds.), Fundamental Problems in the Theory of Stellar Evolution, 105–106

speed instead of the characteristic speed in the system?

Tscharnuter: Since the driving mechanism for turbulence is unknown, the speed of sound, as an upper limit for the turbulent velocity, is at least reasonable. Of course, typical velocities generated by differential rotation, as long as they are smaller than the speed of sound, ought to be considered too.