a 3D simulation. The array that would be considerably extended is ITPCEL, which would gain one dimension: the necessary memory is multiplied by the number of cells in the grid (here ≈ 20–40), but this array occupied less than $\frac{1}{40}$th of the total, in 2D, with $N \approx 10^4$. One of the biggest array is ITBLOC, which has no reason to vary. Therefore, the memory increase in 3D, due only to physical vectors (like the positions of the particles) is not a major penalizing factor.

5. Isothermal Collapse of an Axially Symmetric Cloud

To compare our method with other hydrodynamic codes we have simulated isothermal collapes of axially symmetric clouds. The calculations are performed in a meridian plane using cylindrical coordinates r, θ, z, where the azimuthal coordinate θ does not appear explicitly because of the assumption of axial symmetry: each particle represents a small toroidal element. Accordingly, the Lagrangian equations are given below in cylindrical coordinates.

$$D\rho/Dt + \rho\, \nabla \cdot \mathbf{v} = 0 \tag{5.1}$$

$$Dv_r/Dt + \nabla_r P/\rho + \nabla_r \phi - A^2/(r^3\rho^2) = 0 \tag{5.2}$$

$$Dv_z/Dt + \nabla_z P/\rho + \nabla_z \phi = 0 \tag{5.3}$$

$$D(\rho A)/Dt + \rho A\, \nabla \cdot \mathbf{v} = 0. \tag{5.4}$$

Where ρ, P, A, ϕ are respectively the density, pressure (thermal and viscous), specific angular momentum, and gravitational potential. The Poisson equation for the gravity is solved by a FFT method. Of course this method is not optimal for variable resolution calculations, since gravity is computed on a grid, which is fixed spatially for all the fluid. In the course of the collapse, however, the total grid has been adjusted to the total extension of the fluid, i.e., the spatial resolution evolves toward smaller grid size with time. We think that the spatially variable resolution is much more important for the fluid hydrodynamics, since it is based on calculations over the sole neighbours, than for the long-range gravitation forces. We use this method as a comparative test of the program, and we confer the reader to gridless methods such as the tree code to solve this problem [9] . The latter, however, consume much more computing time.

More precisely, we solve the N-body interactions in 2D, since the 3D problem is axisymmetric. The particles represent tori all with the same vertical axis Oz, and the same mass. The convolution of density and gravitational potential is transformed in a simple product in the z-direction only. A direct convolution is made in the r-direction.

The potential between particles of coordinates (r, z) and (r', z') is that between two tori of radii r and r' and altitude z and z':

$$\Phi(r, r', z, z') = G \int d\theta/\pi[(z-z')^2 + r^2 + r'^2 - 2rr' \cos\theta + a^2]^{-1/2}, \tag{5.5}$$