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Planetary formation through a gravitational instability

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Planets form in disks of gas and dust. There is a general consensus that during the early evolution of these disks mass must be transported inward while angular momentum must be transferred outward, a situation anticipated by consideration of the solar system. In this work, the position is adopted that involve a simultaneous formation of a star and planets around it through a gravitational Jeans-type instability in a protostellar disk of gas and dust. The possibility that protostellar disks are dynamically unstable to nonaxisymmetric gravity disturbances with characteristic scales much larger than the vertical scale height is discussed, using a local WKB approach. It is shown analytically that in gravitationally unstable, spatially inhomogeneous, differentially rotating disks gravity perturbations can effectively transfer angular momentum outward to the outer parts of the system, as mass flows inward to the growing star through gravitational torques. It is proposed that the spontaneous generation of such Jeans-unstable linear modes of collective oscillations is the source of turbulence in protostellar disks. An expression is derived for the viscosity coefficient due to disk turbulence. The value of the α parameter of the Shakura & Sunyaev (1973) disk accretion model is estimated. Three-dimensional N-body experiments that simulate the nonlinear development of gravitational instabilities are also used to test the validities of the theory.

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