100 AU in diameter.

We now have a second set of HST observations made immediately after the refurbishment mission that provides even greater detail and reveals even more of these objects. About half of all the low-luminosity stars are proplyds. The poster paper describes quantitative tests about their fundamental structure and addresses the question of whether the circumstellar material is a disk or shell. One object (HST16) is seen only in silhouette against the nebula and is easily resolved into an elliptical form of optical depth monotonically increasing toward the central star.

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p1

A STUDY OF ANGULAR MOMENTUM LOSS IN BINARIES USING THE FREE LAGRANGE METHOD.

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The evolution of a binary star system depends greatly on the angular momentum losses in the system brought about by gravitational radiation and mass outflow (e.g., evaporating winds and magnetic braking) from the secondary component of the binary. Using a three-dimensional hydrodynamic fluid code based on the free Lagrange method, we study the loss of specific angular momentum from a binary system due to an evaporative wind from the companion of a millisecond pulsar. We consider binaries of different mass ratios and winds of different initial velocities and in particular attempt to model the system PSR 1957+20. We are in the process of incorporating the effect of the radiation force from the pulsar and the magnetic field of the companion on the mass outflow. The latter effect would also enable us to study magnetic braking in cataclysmic variables and low-mass X-ray binaries.

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p2

EVOLUTION OF PROTOPLANETARY DISKS WITH DYNAMO MAGNETIC FIELDS.

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The notion that planetary systems are formed within dusty disks is certainly not a new one; the modern planet formation paradigm is based on suggestions made by Laplace more than 200 years ago. More recently, the foundations of accretion disk theory where initially developed with this problem in mind by von Weizsäcker [1], and in the last decade astronomical observations have indicated that many young stars have disks around them. Such observations support the generally accepted model of a viscous Keplerian accretion disk for the early stages of planetary system formation. However, one of the major uncertainties remaining in understanding the dynamical evolution of protoplanetary disks is the mechanism, or mechanisms, responsible for the transport of angular momentum and subsequent mass accretion through the disk. This is a fundamental piece of the planetary system genesis problem since such mechanisms will determine the environment in which planets are formed.

Among the mechanisms suggested for this effect is the Maxwell stress associated with a magnetic field treading the disk. Due to the low internal temperatures, and resulting low degree of thermal ionization, through most of the disk, even the question of the existence of a magnetic field must be seriously studied before including magnetic effects in the disk dynamics. On the other hand, from meteoritic evidence it is believed that magnetic fields of significant magnitude existed in the earliest, PP-disk-like, stage of our own solar system's evolution. Hence, the hypothesis that PP disks are magnetized is not made solely on the basis of theory. Previous studies have addressed the problem of the existence of a magnetic field in a steady-state disk and have found that the low conductivity results in a fast diffusion of the magnetic field on timescales much shorter than the evolutionary timescale (~3×10^6–10^7 yr from astronomical observations). Hence the only way for a magnetic field to exist in PP disks for a considerable portion of their lifetimes is for it to be continuously regenerated. Levy [2] has suggested this could be accomplished by an α–ω dynamo mechanism working within the disk. Stepinski and Levy [3] derived a criterion to determine the ability of the dynamo to regenerate the magnetic field, and Stepinski et al. [4] have shown that a magnetic field may exist in certain parts of the disk depending on the disk properties. Because the dynamo mechanism depends on the turbulence for its excitation, the generated magnetic field will supplement, rather than replace, the turbulent viscosity in transporting angular momentum. In the present work, we present results on the self-consistent evolution of a turbulent PP disk, including the effects of a dynamo-generated magnetic field.

For our calculations, to include the effects of the large-scale dynamo magnetic field, we redefine the Shakura and Sunyaev dimensionless turbulence parameter, α_{ss}, to

$$\alpha_{eff} = \alpha_{ss}\left(1 + \frac{6}{\beta\alpha_{ss}^{1/2}}\right)$$

where β is the ratio of gas to magnetic pressure and we have assumed that $B \sim B_\phi$ and $B_r \approx \alpha^{1/2} B_\phi$. The magnetic pressure is also taken into account by writing

$$P = P_{gas}\left(1 + \frac{1}{\beta}\right)$$

With these we solve the standard set of time-dependent α disk equations. The opacity of nebular material is considered to be given by the piecewise continuous power laws used by Ruden and Pollack [5]. The self-consistent solution of disk structure in the presence of a magnetic field is calculated as follows. At each timestep, we compute the structure of a uniform α_{ss} nonmagnetic disk. The ionization degree profiles of such disks are calculated from equilibrium between thermal plus nonthermal sources (cosmic rays and radioactive isotopes) and sinks (recombination onto grains or ions). In the present work it is assumed that all grains are the same size, equal to 50 μm. We determine those places in the disk where the dynamo can operate, estimate its magnitude, and compute a new structure using α_{eff}. Such a structure is then evolved to the next timestep using a finite-difference scheme and the operation is repeated.

For the present computations we begin with a disk of mass 0.245 $M_\odot$ and angular momentum 5.6×10^{52} g cm^2 s^{-1}. Such initial conditions may represent a disk coming out of its earliest evolution stage in which, as has been argued by Shu et al. [6], the disk dynamics are dominated by a fast redistribution of angular momentum driven by gravitational waves. The surface density initially obeys $\Sigma(r) = \Sigma_0 [1 + (r/r_0)^2]^{-15/4}$ (it is zero for $r > r_0$), which, with $\Sigma_0 = 10^4$ g cm^{-2} and $r_0 = 15$ AU, gives the initial disk mass and angular momentum. However, after an initial period of less than 10^4 yr the detailed original mass distribution is forgotten. The turbulence parameter α_{ss} is assumed to be 10^{-2}. This value has been found by assuming the turbulence is driven by convection and has been used as a fiducial value in previous disk evolution calculations. The strength of the magnetic field is taken such that the Lorentz force induced by it on the turbulent motions balances the Coriolis force on them, and at this point the dynamo mechanism would be undercut.

As can be seen in Fig. 1, the magnetized disk evolves faster than the purely turbulent one. The increased efficiency in transferring angular momentum in the presence of a magnetic field results in higher accretion rates and hence a faster reduction of the disk's mass. It also results in faster spreading of the disk. As pointed out by Stepinski et al. [4], depending on the degree of ionization, turbulence strength, and disk local properties, the magnetic field can be sustained in different parts of the disk. In most cases, there will be an intermediate region where the dynamo cannot regenerate a seed magnetic field. We call such region the magnetic gap. In Fig. 2 this region is seen as a bulge in the surface-density profile. The bulge is formed as material is transported more easily in the regions where the magnetic field contributes and gets stuck where the viscosity is purely turbulent. The jump in the surface density from outside the gap to its interior can be by as much as a factor of ~4 for this value of β. This contrast is proportional to the strength of the magnetic field. The position and width of the gap varies with time as disk conditions and ionization levels change. As the disk evolves and cools down, the inner boundary moves inward as its position is controlled mainly by thermal ionization. The outer boundary, whose location is initially determined by the ionization from cosmic rays, moves inward as the surface density blocking its passage to the midplane decreases. However, the cooling of the disk implies a reduction in its half thickness, and, because the dynamo regeneration mechanism depends very strongly on this property, when H decreases below a certain value, the magnetic field can no longer regenerate and the outer boundary moves quickly outward. The dynamo can no longer sustain the magnetic field almost anywhere in the disk. From this point on, the dynamics of the disk are controlled mainly by whatever mechanism is responsible for generating the turbulence. For the present disk parameters and initial conditions this happens after 10^6 yr. The viscosity is proportional to the surface density, hence the disk with a magnetic field, which has evolved faster up to this point, now slows its evolution so that the heavier unmagnetized disk catches up to it and the two surface-density profiles are almost the same. This can also be seen in Fig. 1 where the disappearance of the magnetic field results in a sharp decrease in the accretion rate as the disk readjusts itself to the new, solely turbulent viscosity. The rate of decrease of the disk mass also becomes smaller for the previously magnetized disk as the unmagnetized disk tends to catch up to it.

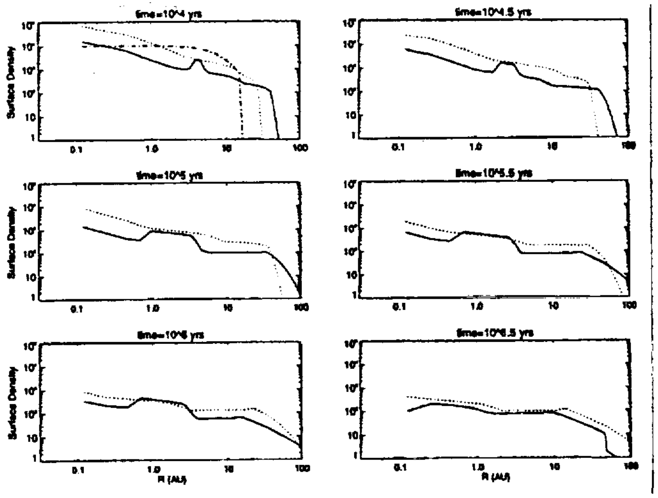

Fig. 1. Time evolution of protoplanetary disk mass, outer radius, and accretion rate onto the protostar for $\alpha_{ss} = 10^{-2}$. The magnetized disk quantities are the solid lines and the dotted lines are for the unmagnetized disk solution.

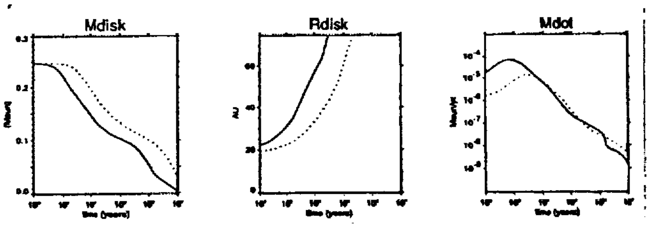

Fig. 2. Radial profiles of the surface density at different times. The solid line corresponds to a magnetized disk with $\alpha_{ss} = 10^{-2}$ and $\beta = 20$. The dotted line is the solution for a solely turbulent disk with the same α_{ss} and the dash-dotted line in the first panel shows the initial condition. The surface density is given in g/cm^2 and the radial distance is in AU.

An additional feature of the magnetized disk, which may have important consequences for the assumed planet formation going on in the disk, is the persistence of the surface density bulge, as planetesimal build-up will be facilitated in such a region as compared to its surroundings.

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