Formation of Circumstellar Disks and Non-ideal Magnetohydrodynamic Effects

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Circumstellar disks are supposed to form as natural by-products of star formation processes due to large angular momenta in natal molecular cloud cores. As the initial angular momentum typically observed is much larger than that of a formed star, efficient mechanisms of angular momentum transport are required in star and disk formation processes. Gravitational torque is important when magnetic fields are weak, but typically magnetic fields observed in molecular clouds are strong enough to remove angular momenta efficiently and overcome the centrifugal barrier. In fact, it was pointed out that magnetic fields transport angular momentum too efficiently and it is difficult to form a circumstellar disk in the early phase of star formation. Obviously this problem cannot be that serious in reality because many protoplanetary disks and extra-solar planets have been observed, and because the fraction of binaries or multiples is known to be high. In order to circumvent this magnetic braking catastrophe, many solutions have been proposed recently.

Because of the high density and low temperature, the ionizing degree in star forming clouds is so low that non-ideal magnetohydrodynamic effects such as Ohmic dissipation and ambipolar diffusion work effectively. These effects extract magnetic flux from the dense region and suppress angular momentum transport. Using non-ideal MHD simulations, we demonstrate that these effects can resolve the so-called magnetic braking catastrophe in the early phase of star formation and enable disk formation. We also perform synthetic observations using post-processing radiation transfer calculations and the ALMA simulator. We compare our results with a recent ALMA observation of a young circumstellar disk around Elias 2-27 and find good agreement.