NASA-CR-194111

Progress Report

The Physical and Chemical Evolution of Protostellar Disks:

I. The Growth of Protostellar Disks

(a.) Progress to Date

This study constitutes one part of our multi-disciplinary approach to the evolution of planet-forming disks. The goal here is to establish the disks' thermal and mechanical properties as they grow by the infall of their parent interstellar clouds. Thus far, Stahler, with the help of two MIT graduate students, has made significant advances toward establishing the evolving surface density of such disks.

Previous theoretical investigators of circumstellar disks have always assumed that the material in the disk plane travels in circular Keplerian orbits. However, such orbits are *not* a natural state during the earliest phase of disk growth, since the infalling matter from the parent cloud has a large radial component of momentum. Accordingly, Stahler and student Maxwell Brothers investigated the consequences of dropping the restrictive Keplerian assumption. They found that the disk naturally divides into two regions. In the outermost, low-density portion, the matter is directed along curved trajectories pointed toward the central star. Early in the disk evolution, this fast-moving material impacts the star directly.

Once the outer disk radius grows to more than 3.4 times the radius of the star, the high angular momentum of the outer material causes it to miss the star. At this point, a second, inner region forms. Here, the matter is indeed traveling in circular, nearly Keplerian orbits. However, the gas continues to drift inward toward the star because of the drag exerted by

(NASA-CR-194111) THE PHYSICAL AND CHEMICAL EVOLUTION OF PROTOSTELLAR DISKS. THE GROWTH OF PROTOSTELLAR DISKS: PROGRESS TO DATE Final Report (MIT) 3 p

N94-13423

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the infalling material impacting this region. The surface density here is much higher than in the other disks, and we expect this portion to be warmer, as well. Here, the radiation from the inner region will almost certainly dominate the total disk luminosity.

Stahler and Brothers had difficulty establishing the manner in which the inner disk grows following its formation. This problem has been addressed by Stahler and graduate student Charles Collins. Stahler and Collin's derived coupled differential equations that describe the evolution of the two regions. Currently, they are attempting to solve these equations through numerical techniques.

(b) Future Goals

The major goal for the coming year is to establish the basic thermal and radiative properties of the disk. The temperature within the inner disk will be computed by a simple energy budget argument. If, as expected, this region is optically thick, we will be able to calculate the temperature necessary to radiate away all the energy generated. Sources include both the kinetic energy of infall and the gravitational potential energy released by the disk matter as it spirals in toward the star. In addition, the disk is subjected to radiation from the central star.

Once we establish the run of temperature with respect to radius, the spectral energy distribution of the disk's, radiation field can be calculated in a relatively straightforward manner. Each annulus will be assumed to radiate as a blackbody at the local temperature. The total radiation field will then be obtained as an integral over all annuli. Knowledge of the character of the disk radiation is of key importance for the other two parts of our project–the study of the survival of infalling grains from the cloud, and the calculation of processes in the accretion shocks on the disk surfaces.