INFLUENCE OF SOLAR RADIATION ON TEMPERATURE CONDITIONS IN THE SOLAR NEBULA; A.B.Makalkin, Schmidt Institute of Earth Physics, USSR Academy of Sciences, 123810 Moscow, and V.A.Dorofeyeva, Vernadsky Institute of Geochemistry and Analytical Chemistry, USSR Academy of Sciences, 117334 Moscow; USSR

Irradiation of the solar nebula (preplanetary disk) by the protosun and young sun decreases the vertical temperature gradient within the disk and can suppress convection /1-3/.

We have constructed the model of the solar nebula for the evolution phase next to the phase of collapse and accretion of the envelope onto the protosun's core and the disk. At the phase considered the disk surrounds the young sun, and solar radiation is incident at a low angle upon the surface of the disk. The model includes this external heat source for the nebula (irradiation by the young sun) in addition to the internal one (viscous energy dissipation).We have computed distribution of P-T parameters within the nebula and estimated variations of these parameters during its evolution /2/.

The nebula is considered in quasi-steady state as the viscous α-disk /3/ with $\alpha = 0.001$. This low value of α is in concordance with lifetimes of observed protostellar disks of the order of 10 Myr /4/. In a case of $\alpha < 0.01$ the vertical energy flux in the disk due to turbulence is much lower than that due to radiation. For radiative energy transport in z-direction the temperature profile and gradient in the viscous accretion disk with the temperature-dependent opacity have been estimated /6/.

The model reported here, includes the effect of phase transitions: condensation of silicates and condensation of water. Solar radiation flux absorbed by the nebula depends on the shape of its optical surface, and this shape depends on the internal thermal and phase structure of the nebula.

The heat flux emitted by the disk at radial distance R is equal to σT_{ph}^4, where T_{ph} is the temperature at the photosphere (optical surface) of the disk and σ is Stefan-Bolzmann constant. We have the following balance of energy fluxes in the steady state: $\sigma T_{ph}^4 = F_s + D_1$, where F_s is the flux of solar radiation, absorbed by the disk at this R; D_1 is the viscous energy dissipation inside the disk per unit area of one surface.

The results of our calculations are shown in the Figure. The solid curves represent the temperatures at the photosphere (T_{ph}) and equatorial plane (T_o) calculated for the following set of parameters:mass transfer rate in the nebula $\dot{M} = 1.5 \cdot 10^{18}$ g s^{-1}, protostellar luminosity and radius $L = 6.2\ L_\odot$, $r = 4.7\ r_\odot$ (which correspond to the time 0.1 Myr). The dotted curves show T_{ph} and T_o calculated for $\dot{M} = 1.5 \cdot 10^{18}$ g s^{-1}, $L = 1.3\ L_\odot$, $r = 2.2 r_\odot$ (at the time $\simeq$1.5 Myr.). The dashed curves z_{ph} and z_c represent respectively heights of photosphere and of condensation of silicats for the first of the two sets of parameters. At heights lower than z_c silicates are partly evaporated and the two-phase solid-gas silicate region exists. From our calculations we found that in this region (at $R < 0.5$ AU) the shape of the photosphere allows solar radiation to heat the disk (F_s/D_1= 1-1.5 AU). In the

TEMPERATURE IN THE NEBULA: Makalkin A.B., Dorofeyeva V.A.

range of R from 0.5 to 0.6 AU F_s decreases, and in the range from 0.6 to 1 AU $F_s = 0$. The situation changes at R >1 AU, where water ice begins to condense at photosphere of the nebula. Here we obtained an extended (from 1 to 4 AU at 0.1 Myr) two-phase region at the photospheric level with coexisting water vapor and ice and nearly constant temperature ≃140 K. Presence of this region results from the following: 1) With ice condensation opacity increases and the photospheric level becomes higher. Hence the nebula becomes again exposed to solar radiation. 2) Due to solar irradiation thickening of the disk cannot be sharp. The balance of solar heating and radiative cooling of the nebula leads to rather high (and increasing with R) curvature of its surface in the radial range where the two-phase region exists. This effect implies an increase of F_s with R: near the outer limit of this range (which for the first set of parameters is near 5 AU) we get $F_s/D_1 \simeq 100$. Convection is suppressed in the outer part of this range of R. The position of the outer edge of the two-phase region is determined by the condition that water vapor at the photosphere is exhausted by condensation, and there is no possibility to increase the photospheric opacity and height any more. Hence solar irradiation drops drastically. This implies the drop of z_{ph} and T_{ph}. The outer part of the nebula is heated by viscous dissipation only ($F_s = 0$), and conditions for convection are satisfied. The boundary near 5 AU can be related to the interface of formation regions of terrestrial and jiant planets.

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