ON THE CORRESPONDENCE OF OH/H_2O MASER SOURCES TO THE STAGE OF PROTO-STAR FORMATION

Masa-aki Kondo
Dept. of Earth Science and Astronomy, College of General Education, Univ. of Tokyo

VLBI observations have revealed that OH/H_2O maser sources are the aggregations of blobes with the sizes of a few A.U., spreading over the distance of several 10^{17} cm. From the standpoint of masing mechanism, especially for the hydroxyl case, we will argue that the blobes correspond to proto-stars in the stage of forming an opaque core, and the aggregations correspond to proto-clusters.

In the radiative pumping case, the size of maser sources is required to be larger than 10^{16} cm, because they must be tenuous to avoid thermalization. In order to shorten the size, we consider the mechanism of the population inversion in the collision-dominant state, especially in the OH case. Since the collisional cross-section of OH is largest in the ground Λ-doublets, these levels are likely to be firstly thermalized. Then, we consider the chemically open and non-steady state, with regard to the dominant reaction of $H_2O + H \rightleftarrows OH + H_2$, which is realized at the accretion shock boundary of the opaque core. In such a state, the population of OH is affected by the way how the produced OH molecules enter into the rotational and hyper-fine structure levels: In the above cited reaction, the produced OH molecules are situated in high rotational states, and those in the term of $^2\Pi_{3/2}$ selectively enter into the upper levels of the four Λ-doublet levels in each rotational level. Subsequently, the OH molecules in such states are collisionally cascading down through the upper Λ-doublet levels of lower rotational states. Hence, we obtain the population inversion at $J = 3/2$ and $5/2$, which takes on the characteristic of the type I OH-maser sources.

In order to obtain the brightness temperature of $10^{12\sim14}$ K, we need the width of 10^9 cm, in the state where $N_H/10^{14} \sim 6\times10^{-3}\cdot T - 12$ and $N_H > 10^{14}$: Here N_H and T denote the total hydrogen number density (cm^{-3}) and kinetic temperature, respectively. the such state is realized in the accretion shock of the opaque core with the radius of 1 A.U. Concerning the H_2O maser sources, the collisional mechanism in the chemically open and non-steady state is also applicable. However, a detail consideration is necessary for answering the question what stage do H_2O maser sources by the above mechanism correspond to.

D. Sugimoto, D. Q. Lamb, and D. N. Schramm (eds.), Fundamental Problems in the Theory of Stellar Evolution, 66–67.

DISCUSSION

Bodenheimer: During the main accretion phase of a spherically symmetric protostar, the theoretical calculations show that the accretion shock is located only 10^{12} cm from the center or less. Is this small scale consistent with your model?

Kondo: The accretion shock in my model is concerned with the boundary of the opaque core (which some people call the first core). This location depends on the opacity of dust grains. The distance from the center is nearly equal to 1 A.U., under the usual conditions for dust grains, as shown by my calculations (1978, the Moon and the Planets, 19, 245), and those of Larson (1969, M.N.R.A.S., 145, 271).

Mouschovias: You made a point too quickly for me to understand. Do your necessary chemical reactions proceed fast enough compared to the dynamical time scale for contraction of your object, which has $n \sim 10^{16}$ cm^{-3}, to produce an effect?

Kondo: Yes, the reactions of hydroxyl radicals proceed on a time scale of about $10^{-11} n_H$ sec, where n_H is the total hydrogen number density. When $n_H > 10^{14}$ cm^{-3}, this time scale is shorter than the free-fall time scale of $3 \times 10^{14} n_H^{-1/2}$ sec.

https://doi.org/10.1017/S0074180900073630 Published online by Cambridge University Press