EVOLUTION OF MASER SOURCES

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H_2O and OH maser sources are observed in the direction of compact regions of HII and IR stars and molecular complexes. Besides,the maser sources are observed in the direction of star formation regions and are associated with Herbiga-Aro objects and T-Tau stars.

The list of the observed objects, with which in any case H_2O and OH masers are associated, demonstrates that the maser phenomenon accompanies as the star formation as exists in the process of its evolution. H_2O and OH maser sources observed in the direction of compact HII regions and IR stars apparently are clouds formed as a result of thermal instability after the shock wave passage (Burdjuzha, Ruzmaikina 1974). The shock waves are generated either by a stellar wind or are formed before the ionization front of D-type. The maser clouds where the temperature is lower and the density is higher than in the environment, are in hydrostatic equilibrium with it. Usually they are localized to the periphery and near the HII compact region or in the IR-star envelope and are at about $10^{16} \div 10^{17}$ cm from the central star. The cloud masses are about $10^{24} \div 10^{28}$ g. The estimates of OH and H_2O maser cloud mass were obtained from the observed luminosities of maser sources and probable pumping rate with normal concentration of elements and also from their visible dimensions and restrictions on the density. Such masses of the maser clouds suggest an idea that during cooling the maser sources can change either into protoplanets or into comets. The papers (Strelnitsky et al. 1972, Oppenheimer 1975) took notice of the evolutionary connection between the maser sources, the protoplanets and the comets.

H_2O thermal balance of the maser regions (as the hottest and the brightest) in the sources connected with HII compact regions and IR stars was analysed. There are two different regions with maser properties :

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1. Gas-dust envelope of young O-star with $M \sim 30 \div 50$ M. The envelope temperature changes from $T \sim 3 \cdot 10^{3\,o}K$ to $T \sim 300^oK$ depending on the distance to the central star ($10^{15} \div 10^{18}$ cm) and the density changes from $n \sim 10^{10}$ to $n \sim 10^2$ cm^{-3} (Cochran, Ostriker 1977).

2. Gas-dust envelope of M supergiant with $\sim 5\ M_\odot$. The average temperature in the envelope is $T \sim 400^oK$. The envelope dimension is about 10^{16} cm and the density varies from $n \sim 10^{12}$ cm^{-3} on the internal boundary to $n \sim 10^6$ cm^{-3} on the external boundary.

The shock wave passes along the envelope (in IR-stars it passes repeatedly). As a result of the development of the thermal instability behind the shock the gas-dust medium fragmentates and the medium acquires a cloud structure. In such a medium there are conditions for the masers' operation. And in the neighbourhood of HII region and in IR supergiant envelope there is a strong flow of IR quanta, which warms up the medium and any temperature heterogeneities seek to level off.

Can the maser in addition cool the medium? If the pumping mechanism of H_2O masers is near IR-quanta (Litvak 1969, de Joung 1973), hitting the molecular cloud from without, the radioquanta, carrying away the heat, cannot cool the medium as the process "quantum to quantum" takes place. If the pumping mechanism is collisioness (Shmeld et al. 1976), the particle kinetic energy will be worked over into far IR radioquanta and the medium can be cooled (far IR quanta appear with cascade transitions by rotational levels). The average luminosity of molecular H_2O masers is $L_R \sim 10^{31}\ \Omega/4\pi$ erg/sec.

With $\ell_{long} \sim 10^{15}$ cm, $\ell_{transverse} \sim 10^{13}$ cm $\Omega/4\pi \sim 10^{-4}/4$

$$L_R \sim 2.5 \times 10^{26} \text{ erg/sec}$$

From the unit of the cloud volume $\varepsilon^{cool} \sim L_R/v \sim 10^{-15}$ erg/sec cm^{-3} goes away. The luminosity of HII compact zones in far IR $L_{IR} \sim 10^{37} \div 10^{38}$ erg/sec. But only $S/S_o \sim 0.5 \times 10^{-8}$ from the total luminosity, i.e. $\sim 10^{29}$ erg/sec, hits the maser cloud. In the cloud these quanta can be absorbed since collisional de-activation is significant at sufficiently high densities. The probability of de-activation during a collision will be

$$C \sim n\sigma\bar{v} \sim 1.5 \times 10^{-12} \times T_k^{1/2} \times n_{H_2} \text{ sec}^{-1}$$ (Shmeld et al. 1976). With $n \sim 10^7$ cm^{-3}, $T_k \sim 1000^oK$, $C \sim 5 \times 10^{-4}$ sec^{-1}. So, 5×10^{25} erg/sec^{-1} was absorbed by the cloud and per each unit of the volume

$$\varepsilon^{heating} \sim \frac{5x10^{25}}{v} \quad \frac{5x10^{25}}{3x10^{26}x10^{15}} \sim 10^{-16} \text{ erg}\cdot\text{cm}^{-3}\text{sec}^{-1}. \qquad (2)$$

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It is seen that the conditions for cooling in the HII compact zone shell can take place.

The luminosity of the IR supergiant shell is also very high $L_{IR} \sim 2 \times 10^{37}$ erg.sec^{-1}. A part of the total luminosity hitting the maser cloud is

$$S/S_o \sim 2\pi\, \ell_{trans} \cdot \ell_{long} / 4\pi R^2 \sim 0.05$$

i.e. $\sim 10^{36}$ erg/sec^{-1} (here $\ell_{long} \sim 10^{15}$ cm, the value of ℓ_{trans} was taken as equal to $\ell \sim 10^{14}$ cm according to the interferometric results). Since the maser radiation of H_2O from the shells of IR-stars is weaker than from HII-zones, the cloud heating as it is seen ($L_R \sim 10^{25}$ erg$\cdot$sec^{-1}) will prevail and the cloud during collisional pumping will not be cooled (in addition, in the IR-star shell where H_2O maser is located, densities $n \sim 10^9 \div 10^{10}$ and thermalization are essential). The ratio of cooling to heating in the maser cloud of HII-zone with $n \sim 10^7$ cm^{-3} is

$$\frac{\varepsilon^{cool.}_{H_2O}}{\varepsilon^{heat.}_{IR}} \sim 10 \qquad (3)$$

With the density increase this ratio decreases and its general form will be

$$\frac{\varepsilon^{cool.}_{H_2O}}{\varepsilon^{heat.}_{IR}} \sim 10 \times \sqrt{\frac{10^7}{n}} \times f(T) \text{ where } f(T) \sim (T/10^3)^{4/3}$$

is a temperature function.
Since $n_o kT = nkT$, we finally have

$$\frac{\varepsilon^{cool.}_{H_2O}}{\varepsilon^{heat.}_{IR}} \quad 10 \times \left(\frac{10^7}{n}\right)^2$$

Therefore with $\frac{\varepsilon^{cool.}}{\varepsilon^{heat.}} \sim 1 \quad n_{max} \sim 3 \times 10^7$ cm^{-3}$(n/n_o \sim 3)$.

Temperature in the cloud drops from $T_o \sim 10^3$°K to $T \sim 300$°K and, evidently, the molecular maser of H_2O will switch off until the cloud is heated, if there are not the other sources of cooling. The characteristic time of cooling is

$$\tau_{cool.} \sim \frac{nkT}{\varepsilon^{cool.}} \sim 10^{-6} \times \frac{1}{\varepsilon^{cool.}} \text{ sec} \qquad (4)$$

where $\varepsilon^{cool.} \sim 10^{-15} \left(\frac{10^7}{n}\right)^2$ erg$\cdot$cm^{-3} sec^{-1}.

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With $n \sim 10^7\ cm^{-3}$, $\tau_{cool.} \sim 30$ years. Therefore, the radiation of a maser at periphery of a compact zone HII must be an additional source of cooling of the medium and can increase its inhomogeneity.

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