STIMULATED RADIO EMISSION OF THE INTERSTELLAR MEDIUM

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1. A number of anomalies were recently observed in the radio emission of the OH molecule in the interstellar medium (anomalous line-intensity ratio [1-3], strong circular polarization of the radiation in the absence of absorption polarization [4], very small width of the spectrum [1-4]). The temperature of the emission from the W3 source as obtained in the latest measurements [5] at 1665 MHz exceeds 2×10^6 °K. Naturally, the main mechanism proposed to explain these anomalies was coherent amplification of the radio emission due to the population inversion of the hfs levels of the OH molecule [2-4], wherein the total gain may reach, say, 10^7 [4]. The possibility of coherent amplification in the interstellar medium under the influence of optical pumping was considered also in [6].

The purpose of this letter is to demonstrate that radio emission can be generated in an amplifying interstellar medium as a result of the feedback produced in scattering by free electrons or cosmic-dust particles 1). The properties of the "cosmic maser" differ appreciably from the properties of the "cosmic maser amplifier," and this explains the observed anomalies.

2. The sources of anomalous radio emission of OH lie in regions where the hydrogen is highly ionized [1-4]. These regions have high densities of electrons and interstellar dust, which are capable of scattering the radio emission. The back-scattered radiation can cause self-excitation and generation by the amplifying region of the interstellar medium. The condition for self-excitation is:

$$\exp(\alpha L) = \alpha/\kappa, \tag{1}$$

where α and κ are the gain and back-scattering coefficients of the medium per unit length and L is the dimension of the generating region.

3. Thomson scattering by electrons. The coefficient of back-scattering by electrons is given by

$$\kappa \simeq N_e\Omega_{gen}(e^2/mc^2)^2[\Delta\omega_a/(\Delta\omega_s + \Delta\omega_a)], \tag{2}$$

where N_e is the electron density, Ω_{gen} the generation solid angle, determined by the shape of the generation region, and the last factor takes into account the broadening of the emission spectrum due to back-scattering by the electrons. For the Doppler broadening $\Delta\omega_a$ of the amplification line and $\Delta\omega_s$ of the scattered-radiation spectrum we can assume that $\Delta\omega_s \gg \Delta\omega_a$ (the mass of the amplifying molecule is $M \gg m$) and

$$[\Delta\omega_a/(\Delta\omega_s + \Delta\omega_a)] \simeq \tfrac{1}{2}(mT_M/MT_e)^{1/2},$$

where T_M and T_e are the kinetic temperatures of the amplifying molecules and of the electrons, respectively. For example, for OH molecules and for $T_e \simeq 10T_M$ we obtain

$$\kappa \simeq 0.5 \times 10^{-9} N_e \Omega_{gen} \text{ psec}^{-1}. \tag{3}$$

For $N_e = 10^3$ cm^{-3} and $\Omega_{gen} \simeq 1$ sr, according to (1), for self-excitation of a region with dimension L = 1 psec, a total gain $\exp(\alpha L) \simeq 3 \times 10^7$ is sufficient.

4. Scattering by cosmic dust. The data on dust particles in cosmic clouds are highly approximate [8]. For an estimate, we consider cosmic dust in the form of spherical dielectric particles of diameter D and dielectric constant ϵ and concentration N_d. The back-scattering coefficient is

$$\kappa = N_d \Omega_{gen} (\pi^5/3)(D^6/\lambda^4)[(\epsilon - 1)/(\epsilon + 2)]^2, \tag{4}$$

and in this case $\Delta\omega_s \ll \Delta\omega_a$, since the dust-particle mass is $M_d \gg M$. Assuming that regions with abundant dust exist, say regions with dust concentration three orders of magnitude higher than the average concentration near the galactic plane, $\langle N_d \rangle \simeq 4 \times 10^{-14}$ cm^3 [8], and with particle diameter $D \simeq 10^{-3}$ cm, then self excitation of a region with dimension L = 1 psec is possible in principle only if the total gain is $\exp(\alpha L) \simeq 3 \times 10^{15}$ ($\Omega_{gen} = 1$ sr, $\lambda = 18.5$ cm, $\epsilon \simeq 2$). Feedback by dust particles is less effective than by free electrons, but the existence of dense regions with larger particles may greatly facilitate the self excitation.

5. There is an essential difference between feedback by electrons and by cosmic dust. In the former case, strong broadening of the emission spectrum takes place in back scattering ($\Delta\omega_s \gg \Delta\omega_a$) and therefore the spectrum narrowing takes place in only one passage through the amplification region: the width of the emission spectrum is $\Delta\omega_{em} \simeq \Delta\omega_a/\sqrt{\alpha L}$. In the second case, in the absence of turbulence of the scattering particles, $\Delta\omega_s \ll \Delta\omega_a$ and continuous narrowing of the spectrum takes place after many passages through the generation region ($\Delta\omega_{em} \simeq \Delta\omega_a/\sqrt{\alpha ct}$, where t is the time) [9], down to the limiting width $\Delta\omega_{em} \simeq \Delta\omega_s/\sqrt{\alpha L}$. In the case when the scattering particles undergo turbulent motion and $\Delta\omega_s > \Delta\omega_a$, the width of the emission spectrum is the same in both cases.

6. The foregoing estimates show that the sources of the anomalous radio emission of OH can operate in the generation mode. The presence of a threshold in the generation mode, unlike the amplification mode, can greatly alter the properties of the radiation, such as the spectrum, directivity, polarization, and time dependence of the intensity. For example, a slight dependence of the back-scattering or absorption coefficient of the interstellar medium on the polarization can greatly change the polarization of the generated radiation. If the threshold is suddenly exceeded (by a pulsed increase of the gain or decrease of the loss), an exponential growth of the emission intensity is possible, followed by emission of a "giant" pulse.

7. The role of the proposed mechanism in the anomalous radio emission from the interstellar medium can also be assessed by observing the electron and cosmic-dust density in the anomalous-emission sources, the time dependence of the emission intensity, etc.

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1) A laser using feedback by scattering particles was proposed and constructed in [7].

INFLUENCE OF THE MEAN FIELD ON THE CHARACTER OF VARIATION OF THE NUCLEAR SHAPE

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The shape of the nuclei of the transition regions is determined by competition between numerous factors such as the properties of the self-consistent field and also pairing and quadrupole forces. An exact account of all these factors is a complicated problem [1]. Some peculiarities, however, can be qualitatively explained by starting from the properties of the levels of the self-consistent field. Thus, for example, the observed jumplike change of the nuclear shape from spherical to prolate in the region of 88 - 90 neutrons is apparently a manifestation of the realignment of the proton levels near the Fermi surface, due to the inclusion of descending Nilsson orbitals $1/2^-$ [550], $3/2^-$ [541], and $5/2^-$ [532] emerging from the $h_{11/2}$ node. All the neutron orbitals near N = 90 are descending and therefore addition of any pair of neutrons contributes to the shift of the minimum of the total energy toward larger deformations. However, the pairing forces (especially in the case of even-even nuclei) can offset this effect and the nucleus remains spherical until the number of neutrons reaches a critical value corresponding to a shift of the minimum such that the descending proton orbitals in question are included. Since the addition of the last pair of neutrons is simultaneously accompanied by a large increase in the number of the nucleons on the descending orbitals (2 neutrons and 6 protons), the resultant shift in the energy minimum should also be appreciable, and this indeed corresponds to a jumplike increase in the deformation.