generally speaking, differs from the slowing down due to the magnetic-dipole radiation in vacuum [11]. If the escape of ions from the surface of a given neutron star is impossible, it can be a pulsar only under far reaching additional assumptions. Thus, worthy of special attention in this case is the "volcanism" hypothesis, namely the ejection of matter from within the star [12]. Another possibility is radiation of electromagnetic waves in the magnetosphere of a slowly rotating pulsar as a result of accretion [13]. The possibility of heating the surfaces of the observed pulsars by accretion (if the field is estimated from the vacuum approximation) is not realistic. To be sure, it is worth while to consider a related possibility, that of heating the surface by particles ejected by a given pulsar and accelerated in its own magnetosphere.

It seems to us that the problem touched upon in the present article should be taken to account in any consistent and self-consistent pulsar theory.

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HIGHLY EXCITED ELECTRONIC LEVELS OF THE H_2 MOLECULE IN ASTROPHYSICS

Ya. B. Zel'dovich and T.V. Ruzmaikina
Institute of Applied Mathematics, USSR Academy of Sciences

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The H_2 molecule is of great interest in astrophysics. Numerous theoretical investigations (see, for example, [1, 2]) and the first successful measurements outside the atmosphere [3] point to large content of the molecules in certain clouds of interstellar hydrogen (up to equality of the concentrations of H_2 and H). The fact that these molecules were not observed until recently is due to the peculiarity of the H_2 spectrum. All the lines from the ground state are in the ultraviolet or in the far infrared regions of the spectrum, to which the earth's atmosphere is opaque (see the table).

Electronic transitions	Terms	$^1\Sigma_u^+ \to {}^1\Sigma_g^+$	$^1\Pi_u \to {}^1\Sigma_g^+$
	$\lambda(v = J = 0)$	1008 Å	1108 Å
Vibrational transitions	v	0 - 1	
	λ	2.2 μ	
Rotational transitions	J	0 - 2	1 - 3
	λ	28 μ	16 μ

The purpose of the present article is to call attention to highly excited molecules, in which the transitions between close electronic levels fall in the radio band. The exposition that follows is a development of an idea by Kardashev [4], that it is possible to observe under astrophysical conditions radio lines of atomic hydrogen with tremendous numbers of levels, up to several hundred.

The electronic spectrum of an H_2 molecule in which one electron is strongly excited is similar in first approximation to the spectrum of the hydrogen atom. The far electron is in the field of the central H_2^+; this field is close to a Coulomb field at large distances. To estimate the probabilities of the transitions between levels with large n we shall therefore use the probabilities calculated for H. We recall that for highly excited atomic hydrogen the most probable transitions between levels with large n are those to the neighboring level ($A_{n,n-1} = 6 \times 10^9 n^5$ sec^{-1}) [5]. The highly excited molecule H_2 is capable of dissociating into the atoms H(1S) or H(1S) and H(2S, 2P). The probability of such a transition, however, is very small for a molecule whose excited electron is in a state with large orbital angular momentum. Its ψ function is vanishingly small at the center, where the ψ functions of the nuclei and of the second electron differ from zero.

In analogy with the case of atomic hydrogen [5], the population of the molecular levels for which the ionization potential is much smaller than kT is close (at any rate when $l \gg 1$) to the population obtained at kinetic equilibrium between the highly-excited H_2 levels, the H_2^+ molecular ions, and the free electrons. The ratio of the optical thickness τ, summed over l, of a cloud with dimension R along the line of sight in the radio line, $\tau(\nu_{n,n-1}) = (2 \times 10^{-5} T^3 \nu_{n,n-1}) R_e N_{H_2^+}$, to the optical thickness in the continuous spectrum for close values of ν, due to the absorption in free-free transitions, is equal to (see [4]):

$$\frac{\tau(\nu_{n,n-1})}{\tau(\nu)} \sim \frac{2 \cdot 10^{10}}{T^{3/2} n^3} \frac{N_{H_2^+}}{N_e} .$$

Assuming that H_2^+ is produced only when H_2 molecules are ionized from high ($\nu \geq 5$) vibrational ground-state levels by radiation with $\lambda \sim 1000$ Å, and using the customarily assumed radiation field intensity [2], the H_2 ionization cross section [6], the population of the excited vibrational levels [1], and the rate of disintegration of H_2^+ taken from [7], we obtain $N_{H_2^+} \gtrsim 3 \times 10^{-6} (N_{H_2}/N_e)$, which yields $\tau(\nu_{n,n-1})/\tau(\nu) \gtrsim 1$ for $T \sim 50°K$, $n \sim 100$ ($\lambda \sim 40$ cm), $N_{H_2}/N \sim 0.1$, $N_e \sim 0.01$ cm^{-3}, and $N \sim 10$ cm^{-3}.

Thus, preliminarily estimates favor the possibility of observing highly excited molecules. The practical realization of this idea must apparently be proceeded by a solution of a number of theoretical problems, primarily the problem of the excited-level spectrum.

The levels of the excited electron in the H_2 molecule are split as a result of the non-Coulomb terms of the potential produced by the H_2^+ located at the center. This splitting is different for molecules of ortho- and para-hydrogen in the lowest rotational state $j_{H_2^+} = 3/2$ and 1/2 for ortho- and para-H_2^+, respectively. In the case of ortho-hydrogen (and para-H_2 in excited rotational states), the non-Coulomb correction V is determined by the interaction of the quadrupole moment of the central H_2^+ with the external electron, $V \sim (10^{-11}/n^3 l) \times [(J - 1/2)/(J + 1)]$ erg for $l \gg 1$, and in para-hydrogen by the interaction of the magnetic moments of the internal and excited electrons, $V \sim 10^{-15}/n^3 l$ erg ($l \gg 1$).

The energy of the high electronic levels of a molecule in which vibration or rotation is excited exceeds the ionization threshold. As a result, autoionization is possible with simultaneous transitions of the molecule into a lower rotational-vibrational state[1)] or inversion from the ortho- into the para-state. However, as shown by calculation, the probability of this process is extremely small for molecules whose excited electron has a large orbital angular momentum ℓ.

Notice should be taken of the difference between the highly-excited H_2 and H_2^+. Whereas the excitation of one electron in H_2 leaves at the center the stable system H_2^+, the highly-excited molecular ion dissociates within a time $10^{-14}n^2$ sec which is much shorter than the characteristic time of spontaneous transitions between levels. Therefore observation of the radial lines of excited H_2^+ has extremely low probability. Only the lowest excited state has a shallow (1.65×10^{-3} eV) minimum in which two bound states are contained [8]. Among the radio transitions in H_2^+, worthy of attention are the transitions between the hyperfine-splitting levels of the ground state of H_2^+ [1]. An attempt to use them to observe H_2^+ has so far not been successful [9]. Substantially different from H_2 and H_2^+ are the HD and HD^+. Not being symmetrical, they have a dipole moment. In HD, the dipole moment has a smallness m_e/m_p (the electron structure is symmetrical in the approximation of infinitely heavy nuclei). In the ground electronic state, $d \sim \hbar^2/m_p e$. In HD^+, the charge is likewise almost symmetrical with respect to the nuclei, and the center of gravity is shifted towards the deuteron, so that $d \sim er/6$ relative to the center of gravity (r is the distance between nuclei). The presence of a dipole moment in HD and HD^+ activates the 0 - 1 rotational transition corresponding to absorption with $\lambda \sim 112$ μ. It also gives rise to specific corrections to the high electronic levels of HD, owing to the interaction of the electron with the HD^+ remainder.

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