

# On the Temperature of the Exospheres of the Earth, Mercury, Venus, Mars, Jupiter, and of the Solar Corona

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**Abstract**

**Full Text**

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*Astronomy*

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**On the Temperature of the Exospheres of the Earth, Mercury, Venus, Mars, Jupiter, and of the Solar Corona**

*(Presented by Academician I. M. Frank on 1 VII 1969)*

Let us compare the known values of the absolute temperatures of the upper layers: the Earth' s exosphere ( $T_E$ ) and the upper solar corona ( $T_S$ ), with the corresponding values of the gravitational potentials  $U_E$  and  $U_S$ , while neglecting the influence of the Sun' s gravity in the Earth' s atmosphere.

Celestial body	Temperature of corona and exosphere, °K	$U$ , cm <sup>2</sup> /sec <sup>2</sup>	$^{3/2}kT/m_H U^*$
Sun	$2 \cdot 10^6$	$6.3 \cdot 10^{14}$	0.40
Earth	$1.5 \cdot 10^3$ (1)	$5.6 \cdot 10^{11}$	0.34

\*  $m_H$  is the mass of a hydrogen atom (proton).

Although the results of the comparison depend only weakly on the choice of heights above the surfaces of the Earth and the Sun for which the comparison is made, for definiteness we shall take as the corresponding heights those minimum values at which practically collisionless orbital motion of hydrogen atoms around these celestial bodies becomes possible. For the Earth such a height is approximately 800 km, and for the Sun about  $1.4 \cdot 10^6$  km. The data given above refer to these heights.

The good agreement of the ratios  $^{3/2}kT_S/m_H U_S$  and  $^{3/2}kT_E/m_H U_E$  is striking, as is the closeness of both these ratios to 0.5. The latter circumstance indicates the closeness of the root-mean-square velocities of hydrogen atoms (protons) to the first cosmic velocity both in the upper corona and in the Earth' s upper exosphere.

S. B. Pikel' ner (2) showed that the upper limit of possible temperatures of the outer atmospheres of many stars is determined by their gravitational potential.

From this point of view, the exospheres of the Earth and the Sun, as we have seen, have limiting temperatures; moreover, in them the state of dissipation occurs for particles with the mass of a hydrogen atom. What is unexpected is that neither the radical differences in the magnetic fields of the Earth and the Sun, nor the composition and degree of ionization of the particles in their exospheres, nor other differences in conditions have disrupted the determining influence on the temperature of the terrestrial and solar exospheres exerted by the proper gravitational fields of these celestial bodies. This, as well as the fact that interplanetary gas consists mainly of hydrogen (atomic and ionized) and in the vicinity of the orbits of other planets (apart from the Earth), suggests that the ratio  $^{3/2}kT/m_{\text{H}}U$  differs little from its values for the Earth and the Sun also in the exospheres of Mercury, Venus, Mars, and Jupiter. It is possible that here, too, the mean kinetic energy of the particles inhabiting the exospheres is close to the kinetic energy of a hydrogen atom (proton) having the first cosmic velocity for these planets.

Using this, one can estimate the temperatures of the exospheres of Mercury, Venus, Mars, and Jupiter as follows:

Celestial body	Mercury	Venus	Mars	Jupiter
Temp., °K	400	800	300	25 000

As for the extent of the upper exospheres, other conditions being equal it is proportional to the ratio of the temperature  $T$  to the mass  $m$  of the particles populating the given exosphere. As is known, Jupiter's atmosphere consists mainly of hydrogen. This means that the extent of its exosphere, if its kinetic temperature is close to 25 000°K, is uniquely large. Like the solar corona, it probably extends over many radii from the planet's surface; accordingly, in estimating its temperature the corresponding height was taken to be equal to Jupiter's radius.

For Venus, the Mariner 5 measurements<sup>(3, 4)</sup> were taken into account; from them it follows that the point of comparison should be taken at an altitude of  $\sim 5000$  km above the planet's surface. It should be emphasized that the measured<sup>(3, 4)</sup> temperature of Venus's exosphere (650–700°K) is close to the maximum possible value.

In conclusion I express my sincere gratitude to Academician S. N. Vernov, Prof. K. I. Gringauz, and Prof. S. B. Pikelner for valuable discussion and advice.

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*Note: Figure translations are in progress. See original paper for figures.*

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