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PHYSICAL PARAMETERS AND ORBITAL CHARACTERISTICS OF MARS AND THEIR COMPARISON WITH EARTH

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Abstract. Mars is almost half the size of Earth. Its equatorial radius is 3396.2 km; this is about 53% of the Earth's radius (6371 km). The average density of Mars is 3.93 g/cm³, which is significantly less than the average density of Earth (5.513 g/cm³). Its less dense, light-element-rich core has a lower melting point. This may explain why the core of Mars remains completely molten, despite significant cooling since its formation. Mars orbits the Sun in an orbit more elliptical than Earth's orbit, with an eccentricity close to 0.0934, with a year twice as long as the Earth's year (365.25 days). The reduced surface gravity has affected the volcanic morphology of the surface and the atmospheric evolution of Mars. This explains the colossal scale of Martian volcanoes, which are much more powerful than the largest mountains on Earth. Volcanism on Mars is one of the main factors controlling the geological evolution of Mars, which has profoundly influenced the formations on the planet's surface, the internal thermal dynamics and the past conditions in its atmosphere.

Keywords. Terrestrial planets, physical parameters, internal structure, volcanic surface morphology.

Physical and orbital characteristics.

Mars is a much smaller planet compared to Earth. Its equatorial radius is 3396.2 km, and its polar radius is 3376.2 km. On average, this is only about 53% of the Earth's radius (6371 km). Due to its smaller size, the surface area of Mars is approximately equal to the land area of Earth. The mass of Mars is 6.4169×10^{23} kg, which is almost 11% of the mass of Earth (5.9722×10^{24} kg). This much lower mass also results in weaker gravity. The acceleration due to gravity at the equator of Mars is about 3.72 m/s², which is about 38% of the Earth's value. The average density of Mars is 3.93 g/cm³, which is noticeably less than the average density of Earth (5.513 g/cm³). The lower density indicates a number of differences in the internal composition compared to Earth. In particular, it indicates a less dense core and a different ratio of the volume of the core to the mantle.

That is, it is a critical parameter that directly constrains models of its internal composition and thermal evolution. This lower density indicates that the inner layers of Mars, especially its core, contain a higher proportion of light elements mixed with iron than in the Earth's core. This difference in composition has profound consequences: the less dense, lighter-element-rich core has a lower melting point. This may explain why the Martian core remains completely molten despite significant cooling since its formation. It also affects the planet's ability to maintain a long-term magnetic field [15], directly linking such a fundamental physical characteristic as density to the history of its geodynamo and to the retention of an atmosphere.

Observational data obtained by various spacecraft have shown that Mars has a weak magnetic field with a strength of up to 2% of that of the Earth; and it has the opposite polarity to that of the Earth [6]. According to the results obtained, in the equatorial region the magnetic field strength is less than 45 nT with a magnetic moment in the range (2.5-3.1)□10^{18} T/cm^3; This value is almost three orders of magnitude less than the Earth's, which is 8□10^{21} T/cm^3. This difference in the magnetic field of Mars is explained by the compression of the interplanetary magnetic field in this place, which flows around an almost non-magnetic planet.

Another explanation is the hypothesis that the magnetic field is insignificant due to the fact that the current studies coincided with the moment of inversion, at which the poles of the Mars magnetic field are changing right now. Measurements of the magnetic field by the equipment of the Mars Global Surveyor spacecraft (SC) [1, 16] also showed that Mars still has its own magnetic field, but it lacks a global structure. It consists of magnetic mascons, the intensity of which does not exceed 750 nT. And they are mainly located in the southern hemisphere (Fig. 1) [2].

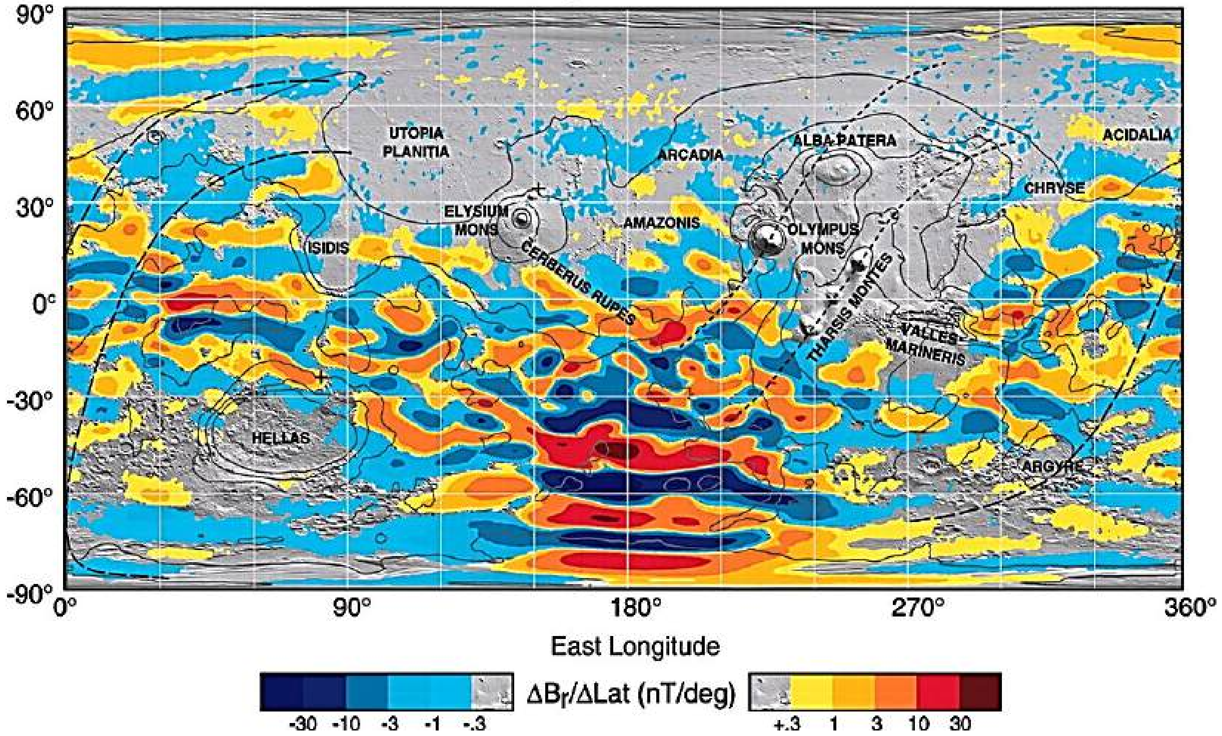

Figure 1. Карта магнітного поля Марса за даними КА «Марс-Глобал-Сервейєр» згідно спостережень за 4 роки. Із сходу на захід пролягають сині та червоні смуги шириною до 160 км та довжиною до 1000 км; вони показують сусідні області кори на Марсі із протилежними напрямками магнітного поля [2].

These magnetic stripes extend from west to east. Moreover, neighboring mascons are almost always magnetized oppositely. It was possible to detect up to 6 such oppositely magnetized pairs. To explain this fact, a hypothesis was proposed that these bands are areas of the crust that solidified at different polarities of the global magnetic field. And its current state is the remains of an ancient magnetic field. The map in Fig. 1 shows characteristic features of the magnetic field similar to those that arise on Earth in places of tectonic faults.

For example, on Earth, the magnetic field changes its direction several times over a million years; therefore, in faults obtained at different times, different directions of magnetic fields are observed. Something similar was observed on the surface of Mars. The orbits of the classical planets are close to circular; and their planes are very slightly inclined to the plane of the ecliptic. Like the vast majority of classical planets, Mars rotates around the central body in a counterclockwise direction when observed from the north pole of the world. Among the terrestrial planets, Mars, the farthest from the Sun, has the slowest speed. Mars orbits the Sun at an average distance of approximately 228 million kilometers (1.52 astronomical units (AU)).

Recall that the average distance from the Earth to the Sun is about 149.6 million km. Mars' orbit is more elongated (elliptical) than the Earth's orbit and has an eccentricity close to 0.0934; this is significantly higher than that of the Earth (0.0167). As a result, Mars' distance from the Sun varies significantly during its year: from approximately 206.6 million km at its closest point to the Sun (at perihelion) to 249.2 million km at its farthest point (at aphelion).

This change in distance has a significant impact on the amount of solar energy received by the planet and on climatic conditions [22, 26], including the duration and intensity of seasonal changes. The significant eccentricity of Mars' orbit is a key factor affecting not only the uneven duration of the seasons, but also the intensity of solar radiation reaching the planet's surface. The difference in insolation between perihelion and aphelion is almost 45%. This value potentially enhances seasonal climatic contrasts, such as the magnitude of temperature gradients and atmospheric dynamics, compared to Earth [24]. This may be one of the main driving factors for the occurrence of powerful global dust storms, which are often observed when Mars approaches perihelion of its orbit [3, 7-9, 27].

The Martian year, or the period of one complete revolution around the Sun, lasts 687 Earth days. This is almost twice as long as the Earth year (365.25 days). The inclination of Mars' orbit to the ecliptic plane is small, at only 1.85°.

One of the most remarkable features of Mars is the length of its day, which is remarkably close to that of Earth. The sidereal period of rotation (relative to the stars) is 24.623 hours. The average solar day is 24 hours and 39 minutes long; this is only 2.7% longer than the Earth day. The axis of rotation of Mars is tilted at an angle of 25.19° to the perpendicular to the plane of its orbit. This tilt is also very close to that of Earth (23.44°) and is the main reason for the presence of well-defined seasons on Mars, similar to those of Earth.

However, due to the significant eccentricity of the Martian orbit, the lengths of the seasons in different hemispheres are different. For example, spring in the Northern Hemisphere and autumn in the Southern Hemisphere are the longest seasons, lasting 194 revolutions around the axis; while autumn in the Northern Hemisphere and spring in the Southern Hemisphere are the shortest, lasting 142 revolutions around the axis of Mars. The similarity of the length of the day and the tilt of the axis of Mars and Earth has historically made Mars the most “Earth-like” planet in the Solar System in terms of daily and seasonal cycles. This similarity and the clear analogies with Earth-like conditions have stimulated interest and hypotheses about the possibility of life there [13, 14, 18].

Comparison with Earth.

As follows from the data in Table 1.1, Mars is a smaller, lighter, less dense, and much colder planet than Earth. It is located further from the Sun, which results in a longer year and less solar energy received. Its orbit is more elongated, which causes larger seasonal fluctuations in surface insolation. However, Mars has a remarkably similar day length to Earth and a similar tilt of its axis of rotation. And this determines the presence of daily cycles and seasons similar to those of Earth, although with slightly different durations. Another fundamental difference between the planets is its very thin atmosphere, which is composed mainly of carbon dioxide. The thin atmosphere results in a much larger number of impact craters [4, 5] on the planet's surface.

Table 1. Comparison of physical and orbital characteristics of Mars and Earth

Characteristics	**Mars**	**Earth**	**Ratio (Mars/Earth)**
Equatorial radius (km)	3396.2	6378.1	0.533
Polar radius (km)	3376.2	6356.8 km	0.531 of Earth
Mean radius (km)	3389.5	6371 km	-
Mass (1024 kg)	0.64169	5.9722	0.107
Volume (km3)	1.63118×10^{11}	1.08321×10^{12}	0.151
Surface area (km2)	1.4437×10^{8}	5.10072×10^{8}	0.284
Mean density (kg/m^3)	3934	5513	0.714
Acceleration of gravity (m/s^2)	3.71 (equator)	9.78 (equator)	0.380
Mean distance from the Sun (AU)	1.524	1.000	1.524
Orbital period (Earth days)	686.980	365.256	1.881

Characteristics	Mars	Earth	Ratio (Mars/Earth)
Sidereal period of rotation (h)	24.6229	23.9345	1.029
Inclination of the axis of rotation (°)	25.19	23.44	1.075
Eccentricity of the orbit	0.0935	0.0167	5.599

The following table clearly demonstrates the key parameters that define Mars as a terrestrial planet and its differences from Earth. It emphasizes that Mars is a smaller, lighter, and less dense body located further from the Sun, but with a similar day length and seasonality.

Due to its much lower mass, Mars has a surface gravity that is approximately 38% that of Earth. The reduced surface gravity is a key physical constraint that has profoundly affected two major aspects of Mars: its volcanic morphology and atmospheric evolution. In the smaller gravitational field, volcanic materials can accumulate to much greater heights before succumbing to gravitational collapse. This explains the enormous scale of Martian volcanoes, such as Olympus Mons, which are much more powerful than the largest mountains on Earth. This allowed for the formation of much more massive formations that would be structurally unstable on Earth.

Furthermore, lower gravity means that atmospheric gases are more easily lost to space over geological timescales, contributing to the planet's current thin and rarefied atmosphere [10-12]. Mars' lower gravity is thus a fundamental factor shaping both its unique geological landscapes and its atmospheric history.

The importance of volcanic activity in planetary formation.

Volcanic activity has been a pervasive and fundamental force in shaping the geological evolution of Mars [17, 19-21, 23, 25], with large volcanic formations covering significant parts of its surface. These formations span a vast geological time span, from the ancient Noachian period (over 3.7 billion years ago) to the relatively late Amazonian period (less than 500 million years ago), suggesting that the planet has been volcanically active throughout its history. Indeed, volcanism is recognized as one of the major factors controlling the morphological evolution of Mars, showing parallels with terrestrial volcanic processes.

The available observational data confirm that volcanism on Mars is not simply a geological phenomenon on this planet, but one of the major factors controlling the geological evolution of Mars; it has been an important process throughout the history of Mars. This elevates volcanism to the status of a fundamental, long-term driver that has profoundly influenced the formation of the planet's surface [55], its internal thermal dynamics, and past conditions in its atmosphere. This suggests a deep, interconnected relationship where the internal thermal state of the planet is directly reflected in surface formations and atmospheric chemistry, making volcanism central to understanding the overall planetary evolution of Mars.

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