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THE IMPACT OF GIANT PLANETS' INTERNAL ENERGY ON THE EVOLUTION OF THEIR ATMOSPHERES.

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The internal energy of the giant planets of the solar system has not yet been determined. Determination of internal energy by various space missions and observations from Earth gives different results. The article discusses the internal energy of giant planets and the sources of this energy. The effect of internal energy on the atmospheres of giant planets is also emphasized.
Key words: planets:solar system planets – giant planets- – planet atmospheres – internal energy sources

1. INTERNAL ENERGY SOURCES OF GİANT PLANETS

The specific radiation emanating from the surfaces of planets is thermal in nature, belonging to the infrared and radio spectra, and its spectral density is determined by the Planck law:

$$\mathrm{B}_{v}(\ \mathrm{T}) = \left(2\pi \mathrm{h} v^{3}/\mathrm{c}^{2}\right)\left(\mathrm{e}^{[\mathrm{h}/\mathrm{kT}]} - 1\right)^{-1} \tag{1}$$

where h is the Planck constant, k is the Boltzmann constant, v - the frequency, T - the surface temperature, and c - the speed of light. By integrating formula (1) with respect to frequency, we obtain the Rayleigh-Jeans formula for radiation, which describes thermal cadiation in the radio spectrum for planets when the condition $\mathrm{h}v << \mathrm{kT}$ is satisfied.

All planets in the Solar System processes internal energy: the energy of a planet's matter and any internal processes or motion represents its internal en-

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ergy. Various factors, including mass, temperature, and composition, influence a planet's internal energy. For instance, Earth possesses significant internal energy due to the heat generated by the decay of radioactive elements and the friction of moving tectonic plates. The Earth's internal energy also includes the energy accumulated from the movement of molten rock and magma within the mantle and the motion of oceans and the atmosphere. Other planets in the Solar System also have internal energy, although the sources and amounts of energy may vary. The internal energy of the giant planets, which are larger in size and mass than Earth, depends on:

- Heat generated from gravitational compression,
- Energy released during phase transitions,
- Conversion of hydrogen molecules in the planet's atmosphere,
- Tidal heating from their moons,
- Heat flow from the planet's core,
- Natural convection,
- Radioactive decay in the planet's core,
- Seismic energy dissipation during exothermic phase transitions,
- Energy released during gravitational differentiation processes as heavy metals "sink" from the mantle to the core.

The energy of matter is generated when it collapses under its own gravity. The internal energy of a planet plays a critical role in its structure and behavior, generally in its geology, climate, and other environmental aspects. [1, 3, 4, 8]

2. THE ENERGY BUDGET OF GIANT PLANETS

For the planets of the Solar System, the primary source of energy is the Sun, which provides heat and light in the form of electromagnetic radiation. For the giant planets in our Solar System (Jupiter, Saturn, Uranus, Neptune), the energy budget is the balance of energy entering and leaving the planet.

The energy budget of the giant planets is influenced by internal processes such as the generation of heat through the reduction of size under their own gravity, changes in the planet's matter distribution known as gravitational contraction, and the conversion of rotational energy. Additionally, the internal energy of giant planets includes spontaneous internal processes and motions like the circulation of their atmospheres and the movement of their moons. The energy budget of the giant planets is further affected by the composition of their atmospheres, thickness, the presence of dynamic weather patterns (variations in the disk), and the characteristics of other derivatives. Giant planets have larger and more massive atmospheres than the terrestrial planets and are subject to complex weather patterns and other phenomena that contribute to their energy budgets.

In summary, the energy budget of giant planets depends on a combination of solar energy, internal processes, and the characteristics of the planet's atmosphere. This balance plays a specific role in the planet's behavior and structure and affects the formation and evolution of its atmosphere and moons. [2]

3. GRAVITATIONAL ENERGY AS A SOURCE OF ENERGY ON JUPITER

Gravitational energy is a form of potential energy related to the position of objects within a gravitational field. On Jupiter, gravitational energy results from the process of gravitational contraction (compression). It is the energy associated with the collapse of planetary matter within its own gravitational field in space. During compression, the planet undergoes a process of combining gas and dust, which results in exposure to higher temperatures and pressures. This causes a reduction in the geometric size of the matter under its own gravity and leads to the release of energy. This energy ultimately represents Jupiter's internal energy and heat. In addition to gravitational compression, Jupiter's gravitational energy enhances the influence of its gravitational field on the motion of its moons and other objects. The gravitational energy of these objects, affected by their velocities and positions within the field, can be converted and released as they move and interact with other objects. Overall, gravitational energy is an important source of energy for Jupiter and plays a role in the structure and behavior of the planet. The study of interactions between objects in the gravitational field and gravitational forces is a fundamental concept. [8]

4. VARIATIONS IN THE ABSOLUTE REFLECTIVITY OF JUPITER AND SATURN IN THE SPECTRAL RANGE λ 0.38-1.7 µM OVER TIME AND SPACE

A planet's absolute reflectivity is the measure of the portion of electromagnetic radiation (such as light) that is reflected by its surface or atmosphere. The absolute reflectivity of a planet varies over time and space due to various factors, including the characteristics of the planet's surface and atmosphere, the angle of incidence of solar rays, the presence of clouds, and other atmospheric phenomena. In the spectral range $\lambda 0.38 - 1.7\mu$m, the absolute reflectivity of Jupiter and Saturn is influenced by the properties of the gases in their atmospheres, as well as the presence of clouds and other atmospheric phenomena. In this spectral range, Jupiter's absolute reflectivity generally tends to be lower compared to the λ 0.1-0.4μm range, with varying values. Jupiter's absolute reflectivity is affected by the presence of clouds composed of water, ammonia, and other substances. These clouds can block radiation, leading to a decrease in reflectivity. Saturn's absolute reflectivity in the λ 0.38-1.7 μm spectral range is generally slightly higher than Jupiter's, with values fluctuating around $\lambda 0.2 - 0.5\mu$m. The presence of clouds made of ammonia and other gases affects Saturn's absolute reflectivity. Similar to Jupiter, these clouds can block radiation, which lowers the reflectivity. Overall, the absolute reflectivity of Jupiter and Saturn in the $\lambda 0.38 - 1.7\mu$m spectral range is influenced by atmospheric characteristics, the presence of clouds, as well as by surface properties and the angle of radiation, among other factors.

5. THE ATMOSPHERE OF THE PLANET URANUS

The atmosphere of Uranus is primarily composed of hydrogen and helium, with small amounts of methane, ammonia, and water vapor. The temperature of Uranus's atmosphere is much colder than Earth's, with temperatures around -217 degrees Celsius. Uranus has an active atmosphere with strong winds and other atmospheric phenomena. Winds in the atmosphere of Uranus can reach speeds of up to 900 km/h in the equatorial region, making them among the fastest in the solar system. These winds are driven by the planet's rapid rotation and result in a more active and turbulent atmosphere. The atmosphere of Uranus also features the presence of clouds and hazes made up of substances such as methane, ammonia, and water vapor. These hazes and clouds play a role in the formation of weather phenomena and in the planet's energy balance. Overall, the atmosphere of Uranus is a complex and dynamic system. It is influenced by factors such as the planet's size, composition, and distance from the Sun, which are important in the planet's behavior and structure and play a role in its climate and other environmental aspects.

6. THE ATMOSPHERE OF THE PLANET NEPTUNE

The atmosphere of Neptune is also primarily composed of hydrogen and helium, with small amounts of methane, ammonia, and water vapor. The temperature of Neptune's atmosphere is even colder than that of Uranus, with temperatures around -226 degrees Celsius. Like Uranus, Neptune has an active atmosphere with strong winds and other atmospheric phenomena. Winds in Neptune's atmosphere can reach speeds of up to 960 km/h in the equatorial region, which also ranks them among the fastest in the solar system. These winds are driven by the planet's rapid rotation and contribute to a more active and turbulent atmosphere. Neptune's atmosphere is characterized by the presence of clouds and hazes made up of substances such as methane, ammonia, and water vapor. These hazes and clouds are important in the formation of weather phenomena and in maintaining the planet's energy balance. In general, the atmosphere of Neptune is a complex and dynamic system, affected by the planet's size, composition, and its distance from the Sun. These factors are crucial in shaping the planet's behavior and structure and play a role in its climate and other environmental aspects.

7. EVOLUTION OF PLANETARY ATMOSPHERES.

The study of the evolution of planetary atmospheres involves investigating the characteristics and properties of the gases, particles, and other materials that make up the atmosphere, as well as the events and processes that occur within it. Researchers employ various methods, including the laboratory analysis of atmospheric samples, in-situ measurements using space probes and other instruments, and remote sensing techniques from Earth and space.

In studying planetary atmospheres, scientists rely on several fundamental concepts:

• Composition: Understanding the chemical composition of planetary atmospheres is crucial. It provides insights into a planet's history, evolution, and potential to support life. Researchers examine the quantity and distribution of particles and various gases in a planet's atmosphere to discern its origins and behavior.

• Temperature and Pressure: The atmospheric temperature and pressure on a planet influence its climate, weather phenomena, and other environmental conditions. Scientists investigate how these factors affect atmospheric motion and the planet's overall energy balance.

• Dynamics: The movement of gases and particles within a planet's atmosphere can drive processes such as winds, storms, and other atmospheric events. These processes are studied to understand their effects on the planet's climate and environment.

• Energy Balance: A critical factor in determining a planet's climate and environment is its energy balance. Scientists explore the transfer of heat and energy within the atmosphere, the role of greenhouse gases, and the impact of the planet's distance from the Sun.

Addressing these issues sheds light on the sources of internal energy of planets. The evolution of planetary atmospheres is a complex and multifaceted process that involves studying a broad array of factors and phenomena. This comprehensive approach allows scientists to learn about the characteristics and dynamics of planetary atmospheres, which are essential for understanding their climates and environments. The process of radiating additional internal energy in a planet within the solar system is intrinsically connected to the planet's formation location; hence, studying these aspects in isolation is not sufficient. Previous research indicates that the internal energy change of a planet varies across different wavelengths over time and exhibits different values in various regions of the planet. This uneven distribution and generation of internal energy are manifested in phenomena occurring at different latitudes within the planet's atmosphere. For instance, the Great Storm on Saturn in 2010 provides a compelling example. Data from the Cassini spacecraft revealed that from 2010 to 2011, the great storm altered Saturn's thermal structure in the latitude bands between 20°N and 55°N, markedly increasing the planet's radiated energy. Although the storm lasted only one Saturnian year (until the end of 2011), the resultant increase in Saturn's internal energy was detectable until 2014 [5–7].This suggests that the additional energy radiated by the planet originates not in the atmosphere but from deeper layers, with the atmosphere then responding to this excess energy. Identifying the sources of internal energy in planets is key to understanding the physical conditions of their origins.

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