ON SEASONAL GROWTH OF GEYSER ACTIVITY IN THE SOUTH POLAR REGION OF ENCELADUS.

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Features of solar irradiation of planets and their satellites. For the planets Venus, Earth, Mars, Saturn, Uranus and Neptune, we have a significant inclination between the plane of their equators and their orbits. Therefore, during the rotation of these planets around the Sun, we register significant differences in the arrival of solar energy to their different latitude zones. For example, since the equator of Saturn is significantly inclined to the plane of the orbit, we have been studying the changes of seasons in its atmosphere on this planet since 1977. In works [12, 14, 19], we pointed out significant changes in Saturn's atmosphere, which we explained by seasonal variations in the arrival of solar energy to it. For our analysis, we used the results of numerous observational data at the equinoxes in 1966, 1980, 1995 and 2010. Our calculations [6] showed that with the period of rotation of the planet around the Sun in 29.45 years and with an eccentricity of the orbit of 0.06, the southern hemisphere of Saturn receives on average a quarter more energy from the Sun than the northern one. At the equinox, Saturn is at an average distance from the Sun (Fig. 1).

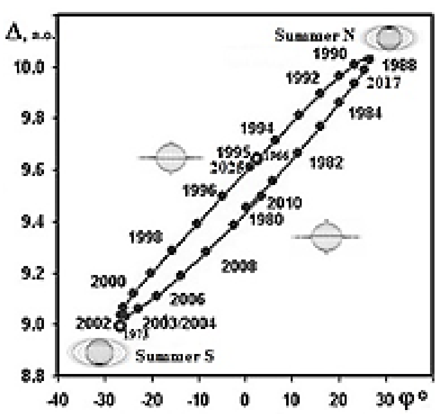

Fig. 1. Changes in the radius-vector (Δ) of Saturn with changes in the saturnocentric inclination (φ) in 1966-2025 [20].

For the analysis, we used the results of our observations [5, 14-18, 21], observations of many amateurs, other scientists [4, 9, 13] and data from spacecraft and space telescopes [7] obtained in 1964-2020. During this time, every ≈14.7 years, there were four consecutive passages of the plane of the planet's rings through the plane of the Earth's orbit at the equinoxes, when Saturn was at the average distance to the Sun, and both hemispheres were irradiated by it equally (Fig. 1). Since Enceladus (like other satellites of Saturn) moves practically in the equatorial plane of the planet, this affects the thermal and other physical characteristics of the upper atmosphere of the planet and the surface of the satellite in almost the same way.

The sea under the southern polar region. In the period 2004-2017, the "Cassini" spacecraft made almost 150 approaches to Enceladus. Using the data collected during the operation of the apparatus, a global infrared map of this satellite was created. On Fig. 2 shows 5 different types of its surface. The 3 images in the top row show the front, trailing and Saturn-facing hemispheres of the satellite; 2 in the bottom row – show the northern and southern polar regions. The colors indicate differences in the properties of the ice on the surface: red – corresponds to fresh and smooth ice, blue – to older ice. The map shows that the polar region around the South Pole is covered with a lot of very fresh ice. Its presence is well explained by geysers, which actively ejected water into the surrounding space from the ocean beneath the surface of Enceladus. There are 4 "tiger" lanes, 130 km long. No impact crater was found near the bands. This indicates the geological youth of these formations. That is, the origin of the bands is related to the processes in the bowels of the satellite.

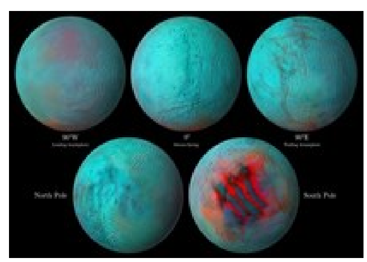

Fig. 2. Maps of different hemispheres of Enceladus (https://universemagazine.com/wp-content/uploads/2020/09/A_new_view_of_Enceladus_annotated_pillars.jpg).

The south polar region of Enceladus attracted attention due to the presence of a thermal anomaly inside it [11] and the ejection of water geysers through cracks in its surface [3, 8, 10, 23]. Observational data showed the presence of a thin icy lithosphere there and the presence of liquid close to the surface. In [2], it is proposed to explain the shape of Enceladus by the presence of local heating in the southern polar region, which leads to the melting of ice under the crust and the formation of the polar sea there.

Density estimates (1.609 g/cm^3) indicate that the satellite consists of water ice, with a certain percentage of silicates and iron. Therefore, it is believed that its bowels can heat up due to the decay of radioactive elements. Tidal heating can also help maintain such a high temperature of some areas in the interior of the satellite. The presence of propane and acetylene found in geysers during spectral observations may indicate that water on Enceladus is in contact with the hot silicate layer of the core [9]. That is, in fact, the warming and melting of the ice sheet is quite deep.

Change in the activity of the hemispheres of Saturn's satellite. The maps of the southern polar region obtained by the "Cassini" instrument [1, 11] confirmed the localization of heat along the "tiger" stripes (Fig. 2). They were the source of geysers observed in 2004-2011. Similar features in infrared rays are also visible in the front hemisphere already near the northern polar region of the satellite. This indicates that there are also places covered with fresh ice in the northern polar region. And therefore, similar geological processes occur in both hemispheres of this satellite of Saturn. And the appearance of fresh ice in the northern hemisphere can also be associated with geysers, as in the southern one. Samples of matter taken by "Cassini" in the emissions from the satellite during a close flyby near the surface, showed that they consisted of almost 93% H_2O, up to 4% nitrogen, up to 3% CO_2, up to 1% methane, and traces of ammonia, acetylene, propane, etc. Therefore, the seas on Enceladus are more than 30 km deep and can cover its entire surface.

Research shows that the ice layer is quite uneven in thickness. And near the poles it is much thinner than at the equator. It is clear that areas with thin ice are the result of ice melting, and areas with thicker ice are the result of its freezing. We believe that the reason that the thickness of the ice near the poles is less, is the presence of seasonal changes, and alternate a significant increase in the heating of the opposite polar regions of Enceladus during its rotation with Saturn around the Sun.

After all, the long polar day at the southern polar region takes place at distances of about 9 AU from the Sun. And at the northern polar region, this happens at a distance of more than 10 AU. This excess heat of more than 25% in the southern polar circle may be enough to allow conditions in the southern polar regions to form much more powerful geyser emissions than is the case in the northern polar regions of the satellite. Not only that, but such an excess of thermal energy over the southern polar region most likely led to the formation of the famous four "tiger" lines, 130 km long, up to 2 km wide, and up to 0.5 km deep. For the same reason, the thickness of the ice crust near the South Pole can be only about 2 km; and near the North Pole, the thickness can increase to 10 km. At middle and equatorial latitudes, the thickness of the ice is even greater. Comparison of data from Fig. 2 and changes in Δ of Saturn (Fig. 1), shows that in 2015-2017 we moved to the polar day already beyond the Arctic Circle. And although the distance from the Sun has increased by almost 0.9 AU, and yet the maps in Fig. 2 show new formations of fresh ice (red shade) in the front summer northern hemisphere of the satellite as a result of geyser eruptions.

In 2021 Enceladus, like Saturn, underwent a transition from the polar day in the northern hemisphere, and we are now approaching the equinox in 2024-2025 [22]. After that, the transition to the summer season will take place already in the southern hemisphere of Enceladus. And this will lead to a significant increase in geyser activity already in the southern polar region.

Therefore, it would be very interesting to follow the gradual growth of geyser activity in the "tiger" stripes around the south pole of Enceladus. **A special program of observations in 2023-2030 with the help of infrared equipment on Keck's Telescopes, the Very Large Telescope and space telescopes – could be dedicated to the fact of seasonal growth of geyser activity beyond the southern polar circle of Enceladus.**

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