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Short Communication

Calculation of the influence of the entropy of stars on the Earth's exosphere and the theory of entropic gravity

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Abstract

In the first part of this study, the entropic contribution of star objects, observable during the night between November 13 and 14, 2021, in the sky above Belgrade (Lat. 44° 49' 04" N, Long. 20° 27' 25" E, mean Elev. 117 m), Serbia, to the thermodynamic equilibrium of the Earth's exosphere, was determined. In the second part of the study, the force of gravitational attraction between the considered star objects and the Earth was calculated, by applying entropic gravity theory. The obtained results shed new light on the importance of star objects for sustaining the Earth's thermodynamic system.

Abbreviations

Lat.: Latitude; Long.: Longitude; Elev.: Elevation; MEP: Maximum Entropy Production

Introduction

Star objects in the night sky attract the attention of the scientific community nowadays [1-3], as well as in ancient times. To investigate the impact of the stars on the thermodynamic state of the Earth's system, it is the most convenient to consider that part of the Earth's atmosphere, which is the most distant from the surface and the closest to the Universe, i.e., the Earth exosphere.

In the frame of this study, the calculation of the entropy contribution of 2798 star objects was recognized as a suitable tool, which could facilitate the understanding of the maintenance of the thermodynamic system of the complex Earth system. The calculations, based on two different physical pictures, enabled the discussion of the contribution of the entropy of the stars to the entropy of the exosphere, as well as the calculation of the gravitational attraction between stellar objects and the Earth system.

In order to determine the influence of the entropy contribution of the considered stellar objects, on the thermodynamic local equilibrium of Earth's exosphere, let us recall that the Prigogine theorem [4] introduced the thermodynamic principle of MEP, discussing non-equilibrium thermodynamic of the investigated system. MEP is proportional to the entropy production (σ_{ab}) value (contribution of increased entropy, appeared in a system as a result of the heat exchange). Prigogine theorem claims that the system in a non-equilibrium thermodynamic state will experience changes, until the rate of σ_{ab} do not approach to the smallest value (σ_{ab} tends to minimum value). On the other hand, if it is considered an open system, very far from thermodynamic equilibrium (such as the Earth's exosphere), in the parts of the system that are closer to reaching local thermodynamic equilibrium, entropy tends to its maximum value. The distance of given parts of the exosphere

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from the local thermodynamic equilibrium will be discussed in the first part of this study.

Further, recall that entropy is recognized as the origin of gravity within the scope of entropic gravity theory [5]. In order to gain a deeper insight into the influence of stars on the Earth system, the second part of the study will calculate the force of gravitational attraction between the observed stellar objects and the Earth.

It is important to note that two different physical pictures are considered in this paper. In order to consider the entropy contribution of different stellar objects (commented within star constellations, due to the large number of considered stars - 2798) and their influence on the thermodynamic state of the Earth's exosphere, the presence of a significant thermal energy exchange in the exosphere was assumed. Accordingly, the Earth's thermodynamic system is treated as an open system. On the contrary, the calculation of the gravitational force of attraction between the considered star objects and the Earth, based on Verlinde's model, required the proposal of a different physical picture and the consideration of the Earth as a closed system.

Materials and methods

Star constellations were monitored in the night sky above Belgrade, Serbia (Lat. 44° 49' 04'' N, Long. 20° 27' 25'' E, mean Elev. 117 m), on the night of 13/14. November 2021, in the period from 6:30 p.m. until 06:30 a.m. To collect data of significance for the research, a Java web sky browser was used [6,7]. Changes in the star constellations and their observable objects were recorded every 15 minutes. The total number of star objects considered was 2798. The data analysis method was performed, considering the distance of each stellar object from Earth, and its effective temperature, T_{eff}. For the calculations, an expression that describes the intensity of solar radiation falling on the object was used: $H_0 = \frac{R^2}{D^2} \cdot H_{Sun}$, where is H_o - the intensity of the solar radiation, incident on the object, H_{Sun} - the power density at the Sun's surface (as determined by Stefan Boltzmann's blackbody equation): $H_{Sun} = 64 \cdot 10^6 \frac{W}{m^2}$, D – distance of the star object from the Sun, and R – the radius of the Sun ($R = 695 \cdot 10^6 m$).

Since the distance between the Sun and the Earth ($0.0000151LY$) is very small, compared to the distances between stellar objects and the Earth, it is approximated that the same radiation intensity of a stellar object, which falls on the surface of the Sun, also reaches the surface of the Earth. Further, having in mind that both radiations (from the Sun to the star object, and the star object to the Sun) travel the same path, the next proportion was used, to understand the intensity of star radiation, approaching the Earth's surface: $T_{eff}(Sun)$: H_{o1} = T_{eff} $(star\ object)$: H_{o2}, H_{o1} - the intensity of the solar radiation, incident on the object, H_{o2} - approximated intensity of the star radiation, incident on the Earth.

In order to find the entropy production (σ_{ab}) of each star object, the next equation was used: $\sigma_{ab} = F_{ab}\left(\frac{1}{T_b} - \frac{1}{T_a}\right)$ (F_{ab} - thermodynamic flux, $T_a - T_b$ - heat flux, $T_a > T_b$). In this equation, the calculated magnitude, H_{o2}, is used as a thermodynamic flux. σ_{ab} is directly proportional to the entropy per area ($\frac{S}{A} = \sigma_{ab} \cdot t$, t - time for which the star constellation is observed in the night sky [8]), which gives the entropic contribution of the examined star object, to the entropy of the Earth's exosphere.

To calculate the gravitational attraction force between stars and Earth, entropic gravity theory was applied.

Results and Discussions

Calculations showed that the highest impact on the local equilibrium of the Earth's exosphere on the given night showed the star constellation Orion ($\left(\frac{S}{A}\right)_{tot} = 1.1 \cdot 10^{-7}\left[Jm^{-2}K^{-1}\right]$), while the lowest entropy contribution arose from the constellation Scutum ($\left(\frac{S}{A}\right)_{tot} = 6.7 \cdot 10^{-12}\left[Jm^{-2}K^{-1}\right]$)). Let us recall the entropic contribution of the celestial bodies of greatest importance for the maintenance of planet Earth: the Sun and the Moon. The calculation shows that $\left(\frac{S}{A}\right)(Sun) = 1.0 \cdot 10^4\left[Jm^{-2}K^{-1}\right]$, and $\left(\frac{S}{A}\right)(Moon) = 7.3 \cdot 10^{-2}\left[Jm^{-2}K^{-1}\right]$(values are calculated for the same time interval considered in the case of star constellations, 12h). Note that the difference between these two values is six orders of magnitude, and despite this, the body with the lower entropy contribution (the Moon) has a very significant impact on the Earth. Since the difference between the entropy contribution of the Moon and the star constellation Orion is five orders of magnitude, it is reasonable to assume that the entropy contribution of the stars is also important for the maintenance of the Earth.

On the other hand, let us recall the direct proportionality between σ_{ab} and $\left(\frac{S}{A}\right)$ values, and that σ_{ab} reaches its lowest value in that physical part of the thermodynamic system of the exosphere, which is closest to equilibrium. Based on the calculations, the part of the exosphere that is closest to thermodynamic equilibrium in the considered night was the part of space in which star objects belonging to the Orion constellation were observed. By the same logic, the physical part of the exosphere that is farthest from equilibrium is that part of space, where stellar objects attributed to the constellation Scutum have been observed.

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In order to further discuss the importance of the impact of star entropy contributions, on the Earth system, calculations based on the entropic gravity model were performed. Although the entropic gravity approach is still not entirely established, the literature review shows that researchers discuss various potential applications of entropic gravity theory [9-13]. The application of the entropic gravity theory in the case of the considered star constellations, with the aim of calculating the force of gravity, imposed the following physical picture: according to the holographic principle, the stars could be understood as particles on a holographic screen (each star could have information associated with it, which is duplicated when changing the position of the star, 1star = 1 bit). The part of the exosphere, corresponding to the night sky above Belgrade, visible on the night between November 13 and 14, was considered as a small piece of the holographic screen and was considered as a boundary, around which space-time already emerges. The rest of the planet Earth is imagined as a particle of mass *m*, approaching the holographic screen, from the side of the emerged space-time. Since the mass of a given part of the exosphere is negligible compared to the mass of the rest of the Earth, *m* could be roughly represented as the mass of the planet Earth. Briefly: the observed interacting system consists of a holographic screen (part of the Earth's exosphere), particles on the holographic screen (star objects), and a particle of mass *m* approaching the holographic screen (the rest of the planet Earth). The gravitational attraction between the Earth and the stars is considered by applying Newton's law of gravitation, within the framework of the entropic gravity theory. The area of the holographic screen (*A*) is determined by an equation, considered in geometrized units: $A = \frac{NG\hbar}{c^3}$, where is N - total number of bits (2798). The radius of the holographic screen (exosphere) is determined from the expression: $R = \frac{A}{4\pi} = 14.9$, in order to calculate the value of the gravitational attraction between the Earth and the stars. The mass of stars can be roughly determined, taking into account the expression that describes the equipartition rule: $E = \frac{1}{2} Nk_B T$ (where T could be interpreted as the effective temperature of the star), and the expression: $E = MC^2$. Since it is valid that: $E = \sum_{i=1}^{N} \frac{1}{2} Nk_B T_i$, the calculated mass of all-star objects observable on the holographic screen is: $1.022 \cdot 10^7$. The mass of the Earth ($m(Earth) = 5.972 \cdot 10^{24} kg$) in geometrized units, is: $m(Earth) = 4.4 \cdot 10^{-3}$. Consequently: $F_{gr} = G\frac{mM}{r^2} = \frac{4.4 \cdot 10^{-3} \cdot 1.022 \cdot 10^7}{(14.9)^2} = 2 \cdot 10^5$. Although it is difficult to find the physical meaning of the magnitude expressed in geometrized units, bearing in mind the negative order of the Earth's mass, the obtained result confirms that the gravitational attraction between the Earth and the stars could be not negligible.

According to the theory of entropic gravity, gravity is a consequence of entropic force. Let us recall that the first physical picture in the paper indicated a significant influence of the entropy of the stars, on the entropy of the Earth's exosphere. The application of the entropy theory of gravity represents an additional confirmation of the importance of the stars, presented in the night sky, for the maintenance of the Earth's thermodynamic system.

Although starting from different physical pictures, the results of the conducted research are complementary. The first part of the study is dedicated to researching the influence of 2798 star objects on the thermodynamic state of the Earth's exosphere, while the second part of the study calculated the gravitational attraction between the same star objects and the planet Earth.

Calculation of entropy per area of each star object and application of Prigogine's theorem revealed that the distribution of star objects in space affects the local thermodynamic balance of the Earth's exosphere. Accordingly, the distribution of star objects considered on the night between November 13 and 14, 2021, over Belgrade, Serbia, enabled a discussion of the influence of the entropy contribution of stars on the local thermodynamic balance of a given part of the Earth's exosphere. It was established that the part of space where star objects belonging to the constellation Orion ($\left(\frac{S}{A}\right)_{tot} = 1.1 \cdot 10^{-7} \left[Jm^{-2}K^{-1}\right]$) are observed, was closest to the thermodynamic equilibrium of the Earth's exosphere.

Under the same conditions, the star objects belonging to the constellation Scutum ($\left(\frac{S}{A}\right)_{tot} = 6.7 \cdot 10^{-12} \left[Jm^{-2}K^{-1}\right]$), marked the area of the exosphere space, which was the furthest from the local equilibrium. The significance of the entropy contribution of stars can be more easily understood, if a comparison is made with the known entropy contribution of other celestial bodies. The entropy contribution of the most influential stellar object, on the Earth's exosphere, is only five orders of magnitude lower than the entropy contribution of the Moon, which confirms the strong influence of stars on the maintenance of the Earth's thermodynamic system (Figure 1).

Noteworthy, the high entropic influence of the stars on the Earth's thermodynamic system can be considered from the point of view of the entropy gravity theory, which recognizes entropy as the origin of gravity. At the moment, the calculated result of the gravitational attraction between the stars and the Earth ($F_{gr} = 2 \cdot 10^5$) is still difficult to use for practical purposes, due to the abstract space in which the discussed problem is considered, and due to the expression of the result in geometrized units. The obtained results open new possibilities for re-examining the question of the role of entropy and its influence on the thermodynamic system of planet Earth, emphasizing the entropic influence of stellar objects.

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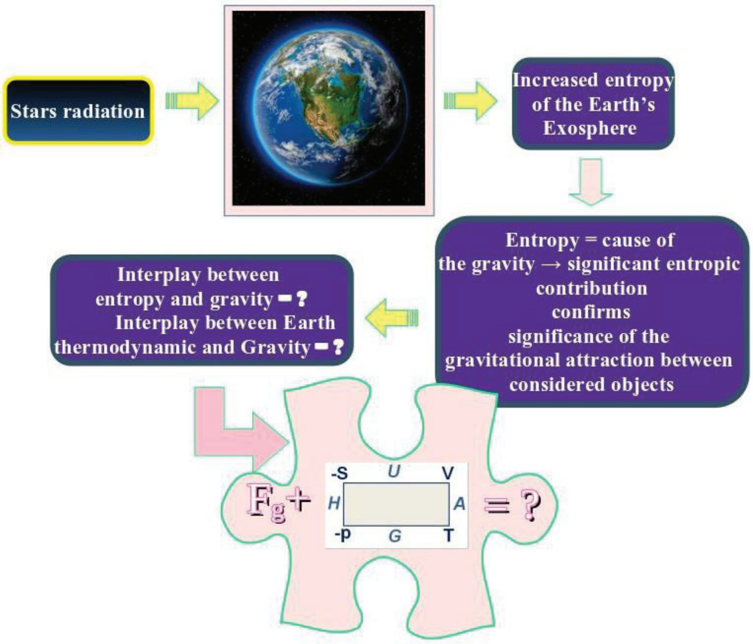

Figure 1: Illustration of the conceptual problem, represented by the data discussed in the study.

Conclusions and Future recommendations

The entropy contribution of each star object, classified within star constellations, can be used to define a distribution map of the distance of different regions of a given part of the exosphere from local equilibrium, under given observation conditions. This map could provide an improved understanding of the complex thermodynamic system of the Earth's exosphere.

On the other hand, the application of the entropic gravity theory resulted in the calculation of the gravitational attraction between the stars and the Earth, which could be observed in a new light. The obtained result confirmed the interplay between entropy, as a thermodynamic parameter, and gravity. This could lead to the investigation of the influence of gravity on the thermodynamic system of the Earth, as well as to the discussion of the behavior of other thermodynamic parameters (which describe the thermodynamic system of the planet Earth), depending on the increase/decrease of entropy, in given parts of the Earth. Since the thermodynamic system of the planet Earth is very complex, research should be divided into examining the thermodynamics of the Earth's atmosphere (which consists of all atmospheric layers) and the thermodynamics of the rest of the Earth (solid and liquid layers). In this way, further studies could allow us to gain a more comprehensive experience of the Earth's thermodynamic system and allow a deeper insight into the complete functioning of the mechanism of the planet Earth.

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