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Yuri Dunaev
Ukraine, Kyiv
(dunaev.levitski@gmail.com)

GRAVITATIONAL CONTRACTION OF CELESTIAL BODIES' ATMOSPHERES AND ITS IMPACT ON THEIR TEMPERATURES

Key words:

Ideal gas law, terrestrial atmosphere, atmosphere of Venus, solar atmosphere, diesel engine, gravitational contraction, adiabatic compression, molar volume of gas, gas temperature, atmospheric pressure, solar surface

The Summary

Celestial bodies heating particularly planets, brown dwarfs and Sun is mainly due to the gravitational contraction of their atmospheres. Gravitational contraction of the solar atmosphere is the Sun's source of heating, which opinion at the end of the 19th century was proposed by Kelvin and Helmholtz. The solar heating occurs without any participation of nuclear fusion reactions.

About adiabatic air contraction in diesel engine cylinders

In modern science, particularly physics there exist a lot of as if long ago resolved problems, to revise which does not make sense. Specialists know that ignition of fuel in diesel engine working cylinder occurs while its injection therein full with previously compressively heated air. Air heating inside diesel engine cylinder occurs without any substantial heat exchange with the environment i.e. as it is conveniently named "adiabatically".

Gravitational compression of the Earth's atmosphere as well as those of other planets and Sun if only to ignore the influence of weather and climate factors can also be considered as adiabatic and examining these adiabatic processes makes up the object of the proposed study that might be considered as a continuation of my 2011 article [1].

In order to adiabatically compress in a closed volume a volume of gas v_0 to that of $v_1 < v_0$ one needs to fulfill a certain work that has to equal the product of a volume lost during the compression $v_0 - v_1$ and a certain averaged pressure p_m that might be represented as arithmetic mean of the initial pressure p_0 and final pressure p_1. Such work may also be presented as a difference between the final and initial energies. Then:

$$p_1 v_1 - p_0 v_0 = p_m (v_0 - v_1) = \frac{p_1 + p_0}{2}(v_0 - v_1), \qquad (1)$$

From here one might find out the final pressure p_1

$$p_1 = p_0 \frac{3v_0 - v_1}{3v_1 - v_0}, \qquad (2).$$

If to try to calculate the final pressurep_1, if e.g. $v_1 = 0.1v_0$, the equation (2) will give a pointless result because the compression is not fulfilled one-time but continuously, which can be easily imagined if to divide the process in a series of stages during each of which the contraction would be made by a quite insignificant value. Then if for instance the contraction is made in n = 10 consecutive stages in each of which $v_1^* = 0.9v_0^*$ (here and later index $*$ will signify that the indexed values refer only to one of the stages), the final volume will make$v_1 = 0.9^{10}v_0 = 0.3487v_0$.

Having composed an equation

$0.9^n = 0.1$, and transformed it to $nlg0.9 = lg0.1$, we might calculate the number of stages necessary to contract an initial volume v_0 to the final volume $v_1 = 0.1v_0$.

$n = \frac{lg0.1}{lg0.9} = \frac{-1}{-0.0457575}$ =21.8543.   And indeed, $0.9^{21.8543} = 0.1$.

In order to find out the pressure that has to be obtained at the end of a stage one use the equation (2)

$p_1^* = p_0^* \frac{3v_0^* - 0.9v_0^*}{2.7v_0^* - v_0^*} = 1.2353p_0^*$.

At the end of all 21.8543 stages the final pressure will equal

$p_1 = 1.2353^{21.8543}p_0 = 101.3p_0$

The compressed gas energy will make

$p_1v_1 = 101.3x0.1p_0v_0 = 10.13p_0v_0$, and as its mass remains unchanged it will mean that its temperature will increase more than 10folds.

We might increase the calculation accuracy by decreasing the effectiveness of each stage and increasing their number, e.g. if we take $v_1^* = 0.99v_0^*$

Then $v_1 = 0.99^n v_0 = 0.1v_0$. $n = \frac{lg0.1}{lg0.99} = \frac{-1}{-0.0043648} = 229.1$, $v_1 = 0.99^{229.1}v_0 = 0.1v_0$,

$p_1^* = p_0^* \frac{3v_0^* - 0.99v_0^*}{2.97v_0^* - v_0^*} = 1.0203p_0^*$, $p_1 = 1.0203^{229.1}p_0 = 100p_0$.

The last means that resulting 10fold compression of the air with room temperature of 293K (as in diesel engines) its temperature will also grow 10fold achieving ca. 3000K.

The last points that at the end of an adiabatic m-fold compression of gas its temperature will grow m-fold and its pressure m^2-fold.

We can check up the drawn conclusions using one more example.

Admitting that$v_1 = 0.2v_0$, we can compose the equation$0.99^n = 0.2$. Transforming it to $n\,lg0.99 = lg0.2$ we can calculate the number of stages necessary to compress the initial volume v_0 to the final volume$v_1 = 0.2v_0$.

$n = \frac{lg0.2}{lg0.99} = \frac{-0.69805}{-0.0043648} = 160.138$.

Taking that$v_1^* = 0.99v_{0,}^*$ $p_1^* = 1.0203p_0^*$, $p_1 = 1.0203^{160.138}p_0 = 24.984{\sim}25p_0$.

$p_1v_1 = 24.984x0.2 = {\sim}5p_0v_0$, which testify the correctness of the drawn conclusions.

It would not be of lesser interest to examine the developments occurring to compressed gas if to take off the working pressure p_1 and without heat-exchange with the environment (i.e. once again adiabatically) to permit it to return to the initial pressure p_0.

Then

$p_1 v_1 = p_0 v_2 = RT_1$, where v_2 designates the volume taken by the gas after its adiabatic dilatation.

If as earlier$v_1 = 0.1v_0$,

$v_2 = v_1 \frac{p_1}{p_0} = 0.1v_0 100 = 10v_0$.

Then $p_2 v_2 = p_0 10v_0 = 10p_0 v_0$, which means that the energy as well as the temperature will keep the same values they had obtained after the forced compression. $p_2 v_2 = p_1 v_1 = 10p_0 v_0$. The changes will involve only the relations between pressure and volume.

Having fulfilled the first contraction and first dilatation to the initial volume we could having necessary technical means to make up second and further consecutive contractions and dilatations resulting the temperature and pressure to step up the same m times. So having fulfilled k such cycles the temperature and pressure would increase km times.

Gravitational contraction of the terrestrial atmosphere

If the air is heating inside diesel engine cylinder under the action of mechanic compression why should not the terrestrial atmosphere heat up under the influence of gravitation?

In my opinion the Earth's atmosphere gravitational compression together with solar radiation might be the most important factors influencing its physical state particularly the temperature.

It is known that the coldest place on Earth is Antarctic and the lowest of all there registered temperatures was −89.2 °C (183.8 К), measured July 21, 1983 at the station "Vostok" 3489 m over the sea level, although satellite measurements had registered at East Antarctic plateau even lower temperature of - 93.2 °C (179.8 К).

Average air temperature at sea level is 14°C or 287К, and by elevating similarly to pressure it drops at the rate of 9.8К per each kilometer. Therefore if the station "Vostok" were at sea level the corresponding minimum temperature should have been 183.8 + (9.8 x 3.489) ≈ 218 К (- 55°C). Such should be in my opinion the sea level temperature of the Earth if only there not be the influence of solar radiation, the influence of internal heat and other possible factors, i.e. such as if it were only under the influence of the atmosphere gravitational compression.

Table 1 provides comparative data about minimum and maximum surface temperature of nearest to the Earth bodies of the solar system.

Table 1

Celestial body	Minimum surface temperature in °C/К	Maximum surface temperature in °C/К	Difference between maximum and minimum temperatures
Mercury	-170/103	+449/722	619
Venus	+462/735	+462/735	0

Earth	-55/218	+58/331	113
Moon	-173/100	+127/400	300
Mars	-125/148	+20/293	145

No wonder that Mercury with its very thin atmosphere and minimum proximity to the Sun is characteristic by maximum difference between maximum and minimum temperatures, the first of which might be understood as resulted by solar radiation. For Moon distanced from the Sun much farer such difference is less than half lesser, and for Venus that will be discussed in the next chapter it due to a substantial clouds screening practically does not exist.

Both Mercury and Moon that has no atmosphere have the lowest minimum temperatures apparently neighboring interplanetary one.

Comparing minimum Earth temperatures with analogues ones on Mercury or Moon one come to the conclusion that the difference of approximately 118 K between minimum temperatures on Earth and Moon can be caused exclusively by the gravitational compression of the Earth's atmosphere while the difference of 113 K between maximum and minimum temperatures by solar radiation.

Somewhat similar is situation on Mars where the difference between minimum temperatures on Mars and Moon (48 K) could be explained by compression of Martian atmosphere that is mainly composed with carbon dioxide and has surface pressure of 6.1 millibars and where the difference of 145 K between maximum and minimum temperatures - by the solar radiation.

1. **Gavitational compression of the atmosphere of Venus**

In conformity with [2] conditions on Venus surface are radically distinctive from Earth's. Atmosphere of Venus is the densest of all four small planets. Its density is evaluated as 65 kg/m^3, that is 50 times greater than that of the sea level atmosphere of Earth at 20°C (293 K). 96.5% of Venus atmosphere makes carbon-dioxide and 3.5% - nitrogen with traces of other gases of which the most notable is sulfur-dioxide. The top of the planet is covered with an opaque light reflecting layer of sulfur oxide that prevents visible light examining its surface from space.

Atmospheric pressure on Venus is 92 times higher than that on Earth and is equal to pressure at 900 m under water. From the same source one can get to know that the Venus surface temperature is 462°C (735 K) high that is higher than that of nearer to the Sun Mercury. Science explains such high Venus surface temperature by greenhouse effect but such explanations raise sound doubts, firstly because of uniformity of diurnal and nocturnal temperatures, because evidently no matter how it would be the greenhouse mechanism its result would depend on solar radiation and therefore might be different for diurnal and nocturnal circumstances. Secondly, once more no matter how it would be the greenhouse mechanism, its effectiveness cannot be higher than that of direct celestial body surface heating by solar radiation as in case of Mercury or Moon.

It would be suitable to make some calculations.

On Earth sea level atmospheric pressure makes 101325 Pa that at temperature of 287 K enables to calculate volume of one Earth atmospheric air mole.

$V_m = \frac{RT}{P} = \frac{8.3144621 \text{ x } 287}{101325} = 0.02355$ m^3/M.

Venus surface atmospheric pressure has to be $101325 \times 92 = 9321200$ Pa. To such pressure has to correspond such molar volume of Venus air

$$V_m = \frac{RT}{P} = \frac{8.3144621 \text{ x } 735}{9321200} = 0.0006556 \text{ m}^3/\text{M}.$$

This means that near the planet surface one mole of the venusian atmosphere occupies a volume 0.02355 : 0.0006556 = 35,92 times lesser than one mole volume of the terrestrial atmosphere.

In average one mole of the terrestrial atmosphere that is composed by 78% of nitrogen, 20% of oxygen, 0.9% of argon, and 1.1% of other gases mainly water has mass 28 x 0.78 + 32 x 0.20 + 39.9 x 0.009 + 18 x 0.011 = 28.7971~ 28.8 g. Terrestrial atmosphere density has to make 28.8 : 0.02355 = 1222.9 г/м^3 = 1.222l9 кг/м^3.

One mole of venusian atmosphere of above mentioned composition has mass 44 x 0.965 + 28 x 0.035 = 43.44g. Venusian atmosphere density on the planet surface has to make 43.44 : 0.0006 = 66260 g/m^3= 66.26 kg/m^3 that only little differ from the above mentioned value of 65 kg/m^3.

In the above example of air heating in diesel motor cylinder all air pressuring work was transformed into its internal energy that is was spent for elevating temperature. In the Venus atmosphere case if for initial state to take the average state of terrestrial atmosphere air at sea level the said mechanism would not correspond to the real state of affairs.

So if while modifying the venusian atmosphere status its pressure elevation totally transformed to heat the temperature would increase $92^{0,5}$ = 9.592 times to 287 x 9.592 = 2752.8 K, which is not the case. In this connection there arises the opinion that in the venusian atmospheric conditions pressure elevation transforms to heat only partially.

Here we can assume that one part of such increase is connected with accomplishing work that totally transforms into heat and provokes 2.561-fold temperature elevation (from 287 K to 735 K) whereas the pressure itself would increase 2.561^2 = 6.559 times (from initial 101325 Pa to 664591 Pa) and molar volume diminishes 2.561 times (from 0.02355 to 0.0090230 m^3/M).

Another part of pressure increase may be not connected with any work, but rather provokes a further 92 : 6.8121= 13.505 times volume increase. Neither work being accomplished the volume increase accompanies by the same increase of molar volume (0.0090230 : 13.505 = 0.0006681 m^3/M) that practically coincides with the above calculated value.

Therefore relation between venusian adiabatic and isothermal pressure increases makes 6.8121 : 13.505 = 0.5044.

2. Other solar system planets heating as result of their atmospheres gravitational pressuring

Great solar system planets heating as well as that of the Sun results as it seems to me from gravitational pressuring of their atmospheres, and here my opinion coincides with those expressed near the end of 19th century by Kelvin and Helmholtz to explain heating of the Sun.

According to [3] the mechanism proposed by Kelvin and Helmholtz is evident if it concerns Jupiter, Saturn and brown dwarfs, which central temperatures seem insufficient for supporting nuclear synthesis. It is estimated that thanks to this mechanism Jupiter radiates more energy than it obtains from the Sun, although Saturn probably not.

Nevertheless contemporary scientists particularly Arthur Eddington affirmed that for maintaining solar temperature during millions and billions years the gravitational pressuring was insufficient, and such a controversy has been resolved in 30th years of the last century by Hans Bette who affirmed that the real source of the solar energy are thermonuclear reactions.

I can't agree with Bette's opinion and my own views on thermonuclear reactions I expressed in the above mentioned article [1].

Conclusions:

1. Celestial bodies heating particularly planets, brown dwarfs and Sun is mainly due to the gravitational contraction of their atmospheres;
2. Gravitational contraction of the solar atmosphere is the Sun's source of heating, which opinion at the end of the 19th century was proposed by Kelvin and Helmholtz;
3. The solar heating occurs without any participation of nuclear fusion reactions.

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