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*Article*

# A New Frame Work of Thermodynamics: An Artificial Energy Cycle and the Big Energy Cycle in the Universe

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**Abstract**

This new frame work of thermodynamics consists of three parts: （1） **The traditional thermodynamics**, relating to all the ordinary thermodynamical processes we meet in our life，work, and ordinary research, covering an extremely immense scope. Numerous human practices confirm that all these processes are irreversible, and entropy tends to increase, never decreases. (2） **The thermodynamics of thermal electrons in a magnetic field**: Some new experiments each about thermal electrons emitted from two identical and parallel Ag-O-Cs emitters in a vacuum tube. The tube is applied by a static magnetic field that bends the trajectories of the electrons, resulting in a weak asymmetry in the motion of the thermal electrons (to left or to right). The tube can output a weak but macroscope electric current and a power. Thus, the internal energy of the tube decreases slightly, and the temperature of the tube follows to drop down slightly. So, the tube automatically attracts waste heat from ambient air to compensate its output power. The magnetic field here is a nice Maxwell's demon. An experiment video is included in this article. (3） **Cosmic thermodynamics**: The universe is closed, and there is naturally an extremely immense intrinsic ocean of thermal radiation in the central part of the closed universe. The temperature of the heat ocean is 2.73K. Black holes are natural demons in the universe. A big band followed by a big assemble forms a big cycle. All the matter and energy in the universe are involved in the big cycle. Clausius' Heat Death is an excessive anxiety.

**Keywords:** traditional thermodynamics; thermodynamics of thermal electrons in a magnetic field; a closed universe; the 2.73K heat ocean; matter shuttling; radiation shuttling; black holes are natural demons; big band and big assemble form a big cycle

## 1. Traditional Thermodynamics (a Brief Description)

At present time，we spend electric energy every day. One joule **electric energy**, as we use it, converts to one joule **waste heat**. There are numerous similar processes that convert work to waste heat, such as various frictions, a basketball fall onto the ground, wind or water whirling, air leakage of a car tire, even metal rusting，and so on, covering an extraordinarily immense scope.

One joule electric energy converts to one joule waste heat exactly. Energy is conserved wherever and whenever. That is the first law of thermodynamics. It is a law of the universe.

Electric energy is **useful energy**, that means, it can be used to do work. Waste heat is **useless energy**, that means, **it can never be used to do work again**. All the **energy source** are useful energy that the nature grants us. **Every piece of the energy source can be used do work once only.**

That is the second law of thermodynamics. According to this law, all the practical thermodynamical processes are irreversible, resulting in the monotonical increase of the entropy of the universe.

The second law of thermodynamics is always valid for almost all the artificial and natural processes known by mankind. The final fate of the universe is, as predicted by Clausius, all the energy

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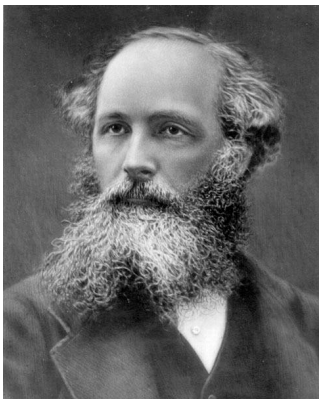
in the universe changes to waste heat, and radiates to the infinitive vast cosmic space, leading to the Heat Death.[1,2]

## 2. Thermodynamics of the Thermal Electrons in a Magnetic Field

However, in the history of physics there were a few outstanding people who doubted sharply and profoundly **the absolute single-direction of all the physical processes described by the second law of thermodynamics**. Among them, James Clerk Maxwell was the most genius and brave one.

From 1866 to 1871, Maxwell immersed himself in the search for a way of how to



James Clerk Maxwell 1831-1879

convert waste heat back to useful energy again. Limited by the historic level of science and technology of his era, he has not successfully designed or executed such an experiment. Nevertheless, he wrote down his thoughts and experiences of his exploration into his famous textbook *Theory of Heat* published in 1871. He hoped that in some future days this cherished wish of mankind would be realized by some inheritors. [4,5]

In his exploration, Maxwell imagined to use a closed container filled up with air molecules. The container is divided by a separator into two parts, A and B, as shown in Figure 1. At the middle on the separator, there is a small door, which is controlled by an **intellectual being**. (Kelvin called Maxwell's "intellectual being" jokingly a **demon**.)

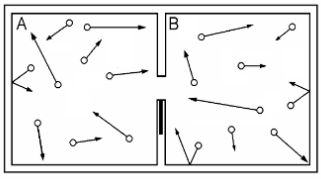



**Figure 1.** An air container of two parts, A and B. There is a small door at the middle of the separator, which is controlled by a small intellectual being.

At the beginning, the air in the container is at a thermal equilibrium state. The temperature and pressure of the air are uniform everywhere in the container.

The demon has two typical work modes, described respectively as follows.

In the first mode, the demon permits the faster molecules to pass the door from A to B, and the slower molecules to pass the door from B to A, as shown in Figure 2. Gradually, the temperature in A drops down and the temperature in B rises up. A temperature difference between A and B emerges, enabling a part of the internal energy of the air in the container to be used to do work.

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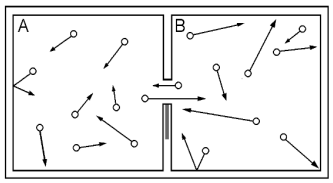



**Figure 2.** A temperature demon.

In the second work mode, the demon permits only the molecules of A to pass the door to B, and does not permit the molecules of B to pass the door to A, as shown in Figure 3. Gradually, the pressure in A drops down and the pressure in B rises up. A pressure difference between A and B emerges, also enabling a part of the internal energy of the air in the container to be used to do work.

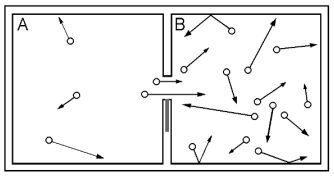



**Figure 3.** A pressure demon.

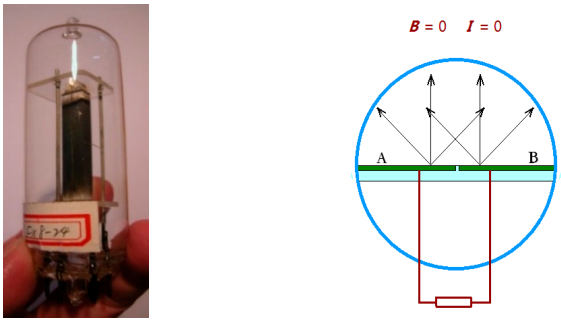
In the past about 150 years, many physicists and inventors, have made numerous efforts to design and execute various experiments, hoping to find such a demon.

However, they all failed.

The two authors of this paper, in the past several decades (X. Y. Fu since 1960, 65 years; Z. T. Fu since 2000, 25 years), following Maxwell's steps, insisted on searching for such an entropy reducing experiment. They replaced Maxwell's gas molecules in the container by the thermal electrons in a vacuum tube, which contains two identical and paralelll Ag-O-Cs thermal electron emitters. Figure 4 (1) and (2) show such an electron tube, FX8-24, used in one of the experments. The work function of Ag-O-Cs surface is only 0.8 eV, the least one among all known thermal electron emitters. They eject thermal electrons ceaselessly at room temperature (the so called "dark current" in the photomultipliers or night vision devices). The experiment can be performed with the whole closed circuit at a same room temperater, that is a great advantage. [6–13]

Of course, the anticipated output current and power are very tiny. However, they are already macroscopic ones.

When no magnetic field is applied on the tube, there is no output current, as shown in Figure 4 (2).




(1) a photo of electron tube FX8-24（2）the cross section and the circuit

**Figure 4.** The electron tube FX8-24. Two identical and paralelll Ag-O-Cs thermal electron emitters A and B are settled in a vacuum tube.

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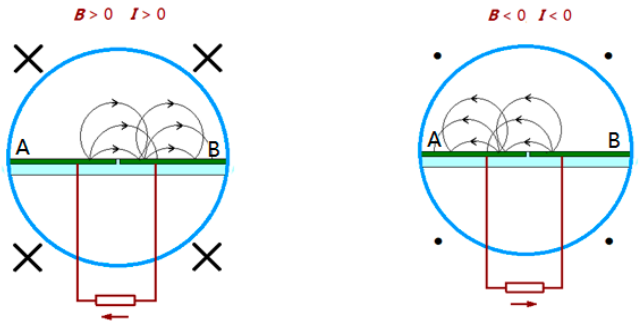


(1) （2）

**Figure 5.** (1) If the direction of the magnetic field is positive, the output current is positive. (2) If the direction of the magnetic field is negative, the output current is ngative.

Then a static and uniform magnetic field (that is provided by one or a pair of stationary permanent 2kg magnets) is applied to the tube. For the first time, the magnetic field is in the direction pointing into the paper, and it bends the trajectories of the thermal electrons as shown briefly in Figure 5 (1). A slight asymmetry in the electrons' thermal motion emerges. The number of electrons emitted from emitter A and fall down into B in each second is slightly greater than the number of the electrons emitted from B and fall into A. A net transfer of electrons from A to B happens. Emiter A losing some net electrons continuously, charges positively; and emitter B, receiving some net electrons continuously, charges negatively. A potential difference between A and B emerges, enabling the electron tube to output a current and an electric power to an exterior load, a resistor *R*, or, a storage battery.

For the second time, the direction of the static magnetic field is opposite, pointing out from the paper. The direction of the output current is also opposite, as shown in Figure 5 (2).

If the magnetic field keeps constant for a long duration (that is easy, just keep the permanent magnet stationary), the electron tube can output a stable electric current and a stable electric power in the whole duration. For examples, 30 seconds, 3 minutes, 1 hour, 3 hours, and so on, as long as the performers wish.

As the electron tube ceaselessly outputs electric energy to do work on the exterior resistor with a power $P = I^2R$, according to the first law of thermodynamics, the internal energy of the tube tends to decrease, though very slightly. And **the temperature of the tube follows to drop down**, also very slightly.

Thus, the tube can spontaneously attract the waste heat from the ambient air to compensate its energy loss due to the output of electric energy.

The experiment verifies that **1 joule waste heat is possible to convert back to 1 joule electric energy, without producing other effects**, violating the Kelvin-Planck statement of the second law of thermodynamics, realizing Maxwell's splendid hypothesis.

The following is an experiment video of the vacuum tube FX8-24, lasting for 100 seconds:

20100802 FX8-24 100s.mp4

In this experiment, the whole closed circuit is desired to be kept at a same room temperature, say, $t = 20^oC$. However, the room the authors used to perform the experiment is not a fine thermostatic laboratory. It is just a common dwelling room. There are usually some $3^oC$ ~ $7^oC$ changes in

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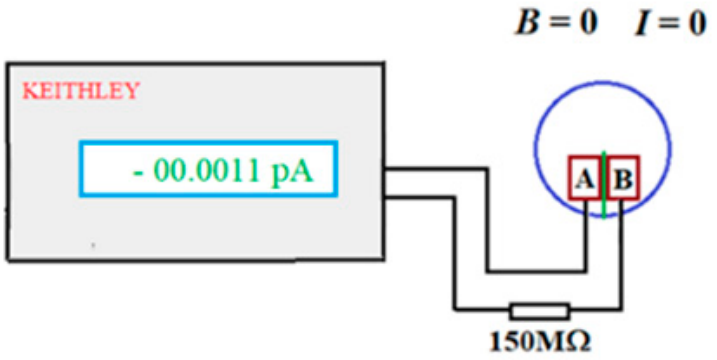
temperature every day (24 hours). So, the temperature of the room is actually always changing, very slowly. And there is temperature difference distributed along the closed circuit, of the magnitude of several 0.1°C. The temperatures at all the connections of two different metals along the closed circuit are usually not exactly equal each other. The general Peltier-Seeback effect along the whole closed circuit is usually not zero, though very small, fluctuating ceaselessly. That results in a background fluctuating current in the circuit.

The whole video lasts for 100 seconds.

(1) From $t = 0$ to $t = 10$ seconds

No magnetic field is applied to the vacuum tube in this duration. So, no real output current exists in the circuit, only a small fluctuating background current as shown in the video, (see the simple circuit drawing below).

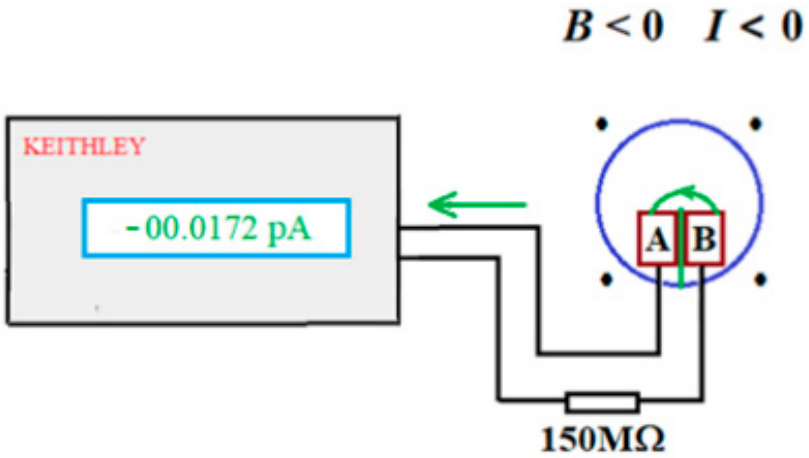
$$I_o \approx (-7 \sim -15) \times 10^{-16} \text{ A} = (-0.7 \sim -1.5) \text{ fA}.$$




(2) From $t = 10$ to $t = 40$ seconds

Move in a permanent magnet of 2 kg at $t = 10$ seconds, as shown in the video. There appears a fundamental negative output current in the circuit (see the simple drawing below), fluctuating slightly.

$$I \approx (-140 \sim -200) \times 10^{-16} \text{ A} = (-14.0 \sim -20.0) \text{ fA},$$




(3) From $t = 40$ to $t = 70$ seconds

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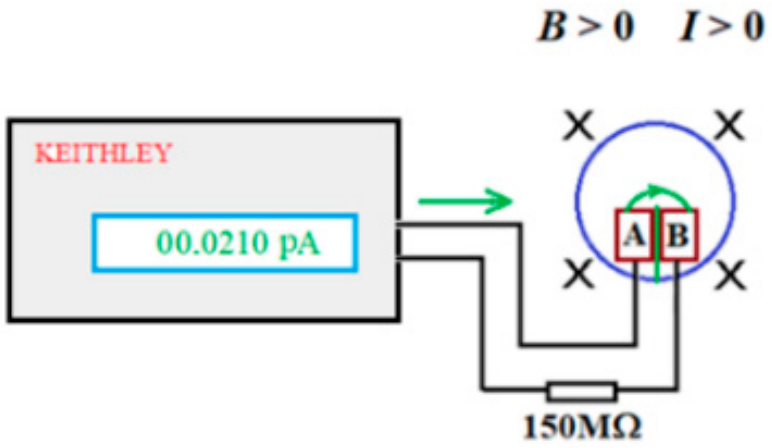
Reverse the direction of the magnetic field at $t = 40$ seconds, as shown in the video. The direction of the output current is also reversed, the output current becomes positive (see the simple drawing below),

$$I \approx (+200 \sim +230) \times 10^{-16} \text{ A} = (+20.0 \sim +23.0) \text{ fA},$$




And so on. [14–20]

**Two clear photoes of the set up of the experiment**

(1) The general set up of the experiment

Keithley 6514（$10^{-16}$A） a copper shielding box a magnet

(There is a box compass on the top of copper box showing the direction of the magnetic field.)

(2) The arrangement within the copper shielding box

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An electron vacuum tube, a resistor $R$ = 150 MΩ (red), a metal tube containing a thermometer probe, some connection lines, etc.

## 3. Cosmos Thermodynamics

All the natural energy source are originated from the big bang. Now, let us have a discussion about the big bang.

Most astrophysicists today believe that the present universe was produced by a big bang [21–24].

The authors of this article regard that a big bang followed by a big assemble forms a big cycle. All the matter and energy in the universe are involved in such a big cycle.

It is essentially a thermodynamic exploration.

The authors approve of the idea that the space of the universe is gravitationally closed, and all the matter and radiations are impossible to fly off the closed universe.

Within the closed universe，naturally, there is an immense intrinsic heat ocean. It is just the microwave background radiation discovered in 1965. This 2.73K heat ocean is not produced by the big bang. [25]

### *3.1. Assemble of all the Matter that Scattered into the Cosmic Space by the Big Band*

The authors, like most of today's astrophysicists, approve of the theory of the
big bang established by Lemaitre, Hubble, Gamow, et al [22–25].

However, there is a major deficiency in the present theories of cosmology: Where did **the primitive atom** of the big bang, come from?

Most people just avoid this problem.

The authors assert that this problem is a crucial one in cosmology. It should not be avoided, absolutely.

The authors approve of the idea that the universe is gravitationally closed. All the matter, the electromagnetic radiations and so on are impossible to fly off the closed universe. They are involved in an extremely immense cycle in the closed universe.

However, for the first step, let us look back the current theory about the fundamental characteristics of the cosmic space.

According to the cosmology principle, adopt the Robertson Walker metric, Einstein's field equation and the equation of state, one can finally derive the relation between the **cosmos scale factor** ***R*** and **time** ***t***, $R = R(t)$, as shown by equation (1) and Figure 1.

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$$t - t_1 = \int_{R(t_1)}^{R(t)} \frac{dR}{\sqrt{\Lambda(R)}} \tag{1}$$

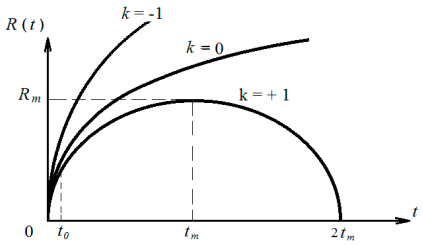


**Figure 1.** Different space curve sign *k* result in different $R = R(t)$: $k = +1$, $k = 0$ and $k = -1$,.

$R = R(t)$ has three different situations, depending on the values of the **space curve sign *k***.

(1) ***k* = + 1，the cosmic space is closed**. All the matter and radiations that scattered into the cosmic space by the big bang, may fly outward, getting farther and father. However, after reaching their individual far-most positions, all of them will fly back one after another towards the central region of the closed universe again, passing through the central region, and begin shuttling in the closed universe ceaselessly.

(2) ***k* = 0，the cosmic space is flat.** In this situation, all the matter, radiations and so on that scattered into the cosmic space by the big bang can fly outward to the infinitely remote space, however, with a lower and lower kinetic energy, gradually approaching zero. They can never return back.

**(3) *k* = -1，the cosmic space is open.** In this situation, all the matter, radiations and so on that scattered into the cosmic space by the big bang just fly quickly outward to the infinitely remote space. They will never return back.

The above descriptions of equation (1) and Figure 1 are correct, strict and profound, well recognized by most astrophysicists today. However, the theory is really abstract and not easy to perceive and put into use. The authors think that this extremely profound and mysterious theory might be enriched by a brief and intuitional explanation as follows.

Whether the universe is closed is determined by two factors:

**(1) The total amount of the mass of the universe. That is the attractive factor**. The mass mentioned here, consists of common visible matter, dark matter, various electromagnetic radiations, neutrinos, and so on, some kinds of the matter are totally unknown to mankind today. According to the present knowledge, the dark matter is 5 times of the visible matter, seems very important.

**(2) The total amount of the energy of the big bang. That is the repulsive factor.**

If the first factor prevails over the second one, the universe is closed.

If the two factors are “equivalent” or “balanced”, the universe is flat.

If the second factor prevails over the first one, the universe is open.

As have mentioned above, the authors approve of the first situation, $k = +1$.

The authors also believe that in the middle of the closed and extraordinary immense universe, naturally, there should be an extremely immense ocean of equilibrium thermal radiation at some essentially stable temperature. The microwave background radiation at 2.73K discovered in 1965 should just be this extremely immense heat ocean. It is not produced by the big bang [25].

More than $2 \times 10^{12}$ galaxies produced by the big bang are now flying fiercely outward. Their individual immense kinetic energies derived from the big bang are converting to their individual potential energies. When the galaxies reach their individual far-most positions in the close universe, they will return back one after another, and fly towards the central region of the closed universe again. It is of course impossible for them to return back to the start point of the big bang at a same

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time. All these galaxies will rush through the central region with different tremendous kinetic energies and fly towards their individual far-most positions on the other sides of the central region. Then, because of the gravitational attraction, they will slow down, and finally return back once again to the central region. In such a way, they keep shuttling through the central region of the universe repeatedly and ceaselessly.

In every galaxy, there are numerous stars and also many black holes. Every black hole, once formed, takes in all the matter and electromagnetic radiations that approach it, and gets larger. A black hole even annexes any celestial body that approach it (including annex another black hole).

The directions of the shuttling of the numerous galaxies are various in the $4\pi$ solid angle. Hence, the ceaseless shuttling offers numerous opportunities for the $2 \times 10^{12}$ galaxies to meet each other in the central region. And, the numerous and numerous various celestial bodies in all these galaxies (about $2\times10^{23}$ stars, and so on) will also have numerous chances to approach even meet each other.

Annexation happens whenever a black hole meets another celestial body in the shuttling. Especially, the black holes of all the galaxy cores are extremely greater than the black holes of the star-magnitude, they are extremely important in the general annexation processes in the universe.

After an extremely long period of shuttling and annexations, finally, the total number of the black holes and other celestial bodies in the universe will begin to decrease. The masses of the survived black holes will become larger and larger, meanwhile, their shuttling amplitudes become shorter and shorter. These two factors will greatly increase the chances of the survived black holes to encounter with the other shuttling celestial bodies. The general annexation processes in the whole universe will thus become faster and faster.

After an extremely long, long duration, eventually, **all the matter within the closed universe will inevitably be assembled together to form an extraordinary immense central black hole**.

In this assembling process, most of the kinetic and potential energy of all the celestial bodies in the $2 \times 10^{12}$ galaxies are eventually assembled indirectly or directly into the central black hole, preserving a great amount of precious energy for the next big bang, without undergoing the process of entropy increase.

At that time, the picture of the universe will become very simple: In the extraordinary immense central part of the closed universe, there is an immense and very dilute heat ocean at a temperature of about 2.73K; and at the center of the heat ocean, there is an extraordinary massive central black hole, which has an even more massive core containing all the real matter of the universe. The whole geometric picture of the universe at that time is rather similar to the one of a hydrogen atom.

**The formation of the central black hole accomplishes the first preparation for the next big bang: the reassemble of all the real matter.**

The next problem is, how to overcome **the deadly obstruction of the second law of thermodynamics** to collect and assemble again the great amount of energy that has scattered in the form of light and heat into the vast 2.73K heat ocean due to all the irreversible processes of the big bang and all its subsequent processes, to **accomplish the second necessary preparation** for the next big bang: **the reassemble of the lost energy.** In other words, **the reduction of the entropy that was produced during the big bang and all its subsequent processes.**

Fortunately, the black holes have a second important assembling function: they can collect and assemble spontaneously an extraordinary immense amount of energy in the form of thermal radiation from the extraordinarily immense 2.73K heat ocean. How much energy in the form of light and thermal radiation a big bang and all its subsequent processes have scattered into the vast 2.73K heat ocean, how much energy in the form of 2.73K thermal radiation, will all the black holes, especially the extremely immense central black hole, collect and assemble back from the heat ocean again, leading to a new big bang.

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*3.2. The 2.73K Heat Ocean Is an Intrinsic Existence in the Closed Universe*

3.2.1. The 2.73K Background Radiation Was Not Produced by the Big Bang

As is well known, in 1965, Penzias and Wilson unexpectedly discovered the 2.73K microwave background radiation coming from the remote space in all the directions. The microwave background radiation shows three fundamental characteristics: (1) uniform and stable, (2) excellent isotropic in the space, (3) its spectrum coincides with Planck's formula for the black body radiation at a temperature of about 3K (later, measured more accurately, 2.73K). They are actually the same fundamental characteristics of the equilibrium thermal radiation in the cavity within a solid at the same temperature. Accordingly, what Penzias and Wilson discovered is an extremely immense and stable ocean of equilibrium thermal radiation at a temperature of 2.73K. The authors believe that it is just the intrinsic extremely immense heat ocean in the central part of the closed universe. [25]

The meaning of **isotropic** here is, at any point in the 2.73K heat ocean (and also at any point in the cavity within a solid at the same temperature), in any direction in the 4π solid angle, the intensity and spectrum of the thermal radiations are identical.

How deep is the 2.73K heat ocean? How immense is its total volume?

The background microwave radiation is an equilibrium thermal one, it is impossible to measure its depth and volume by any direct astronomic observation.

A certain part of the researchers had different opinion from ours. They believed that the microwave background radiation at 2.73K was produced by the big bang, which happened $1.37\times10^{10}$ years ago.

The authors, like almost all the astrophysicists today, accepted the theory that about 380,000 years after the big bang, when the interior temperature of the expanding primitive fire ball dropped down to about 3000K, the electrons and protons in the plasma within the expanding primitive fire ball combined to become hydrogen atoms. The neutral hydrogen atoms no longer exchanged heat with the thermal radiation. The fireball decoupled. The interior of the fireball became transparent for the thermal radiation. All the thermal radiation within the decoupled fire ball got free, and started immediately to fly off the fire ball at light speed in all the directions to the exterior extremely vast space. That is a free ejection.

Because the universe is closed, the ejected 3000K decoupled thermal radiation could not fly to the infinitively far space. Like the galaxies' shuttling, after reaching their far most positions in the closed universe, the outward flying decoupled thermal radiation should turn back to the central part of the universe, and then kept shuttling in the closed universe with extraordinarily great amplitudes, meanwhile, becoming more and more dispersive. Then, after an extremely long relaxation time, through exchange heat with the cosmic atoms, molecules, dusts and rocks (they are all at the temperature of 2.73K) in the metagalaxy region, the shuttling thermal radiation should finally mingle into the extremely vast 2.73K heat ocean, that is the final destination of the decoupled thermal radiation.

However, there are a part of the researchers who alleged that, after flied off the decoupled fire ball, the thermal radiation kept "**expanding adiabatically**" for an extremely long time, and expanded finally to the 2.73K background equilibrium thermal radiation of today. They believe, it is still expanding today.

They speak of an "adiabatic expansion". What do they mean by this terminology here?

The initial state of the "adiabatic expansion" was an equilibrium thermal radiation at 3000K in the decoupled fire ball, and the final state of it is an equilibrium thermal radiation at 2.73K, occupying an extraordinarily immense cosmic space. Then, how about the numerous intermediate states? Were they all at thermal equilibrium states?

If they were, the expanding process should have been a quasistatic process. That is obviously irrational. All the 3000K decoupled photons are travelling outward freely at light speed. There is no anything like the cylinder piston system or something else to control or limit the outward ejection at

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the light speed of the decoupled photons. It is just a free ejection at light speed of the 3000K decoupled photons, not an "expansion" of the thermal radiation in any container.

If all the intermediate states were not equilibrium states, how could the scattering decoupled thermal radiation that flied outward at light speed finally change suddenly to a 2.73K equilibrium state?

Hence the authors claim here again，the 2.73K microwave background radiation is not the afterglow of the decoupled fire ball, that means, it is not produced by the big bang.

The 2.73K background radiation itself is an intrinsic existence in the closed universe, an extremely immense and stable heat ocean. It existed before the big bang. It exists now. It will exit in the future. persistence

(For more details about this topic, read the appendix of this article, please.)

3.2.2. The Extraordinarily Immense 2.73 K Heat Ocean Itself

Now, let us surmise briefly the structure and picture of the 2.73K heat ocean itself.

As a preparation, let us first make a calculation of the mass density of the 2.73K equilibrium thermal radiation.

From Stefan-Boltzmann's law, the radiation intensity from the surface of a black body (the energy emitted in unit time from unit area of a black body surface at a given temperature) at $T = 2.73K$ is

$$J = \sigma T^4 = 3.15\times10^{-6}\, js^{-1}m^{-2}. \tag{2}$$

As is well known, the relation between the radiation intensity from the surface of a black body $j$ and the energy density of the equilibrium thermal radiation in a solid cavity at the same temperature $u$ is

$$J = \frac{1}{4}cu, \tag{3}$$

Hence, at $T = 2.73K$, the energy density of the immense heat ocean is

$$u = \frac{4}{c}J = 4.26\times10^{-14}\, Jm^{-3}. \tag{4}$$

And，the mass density of the thermal radiation in the heat ocean is，

$$\rho = \frac{u}{c^2} = 4.73\times10^{-31}\, kg/m^3 \tag{5}$$

Let us imagine to have a look at the picture of the 2.73K heat ocean. The whole heat ocean should be a very large sphere, as shown in Figure 2. Our metagalactic region is located at the central part of the vast heat ocean, represented by a very small circle.

Containing the metagalactic region and within the radius of $R_1$, is the $T = 2.73K$ region, as shown by the blue part in Figure 2.

Then, from $R_1$ to $R_2$, is the thermal radiation decaying region, as roughly and briefly shown by the light-blue part in Figure 2; the corresponding temperature falls down gradually from 2.73K to 0K,

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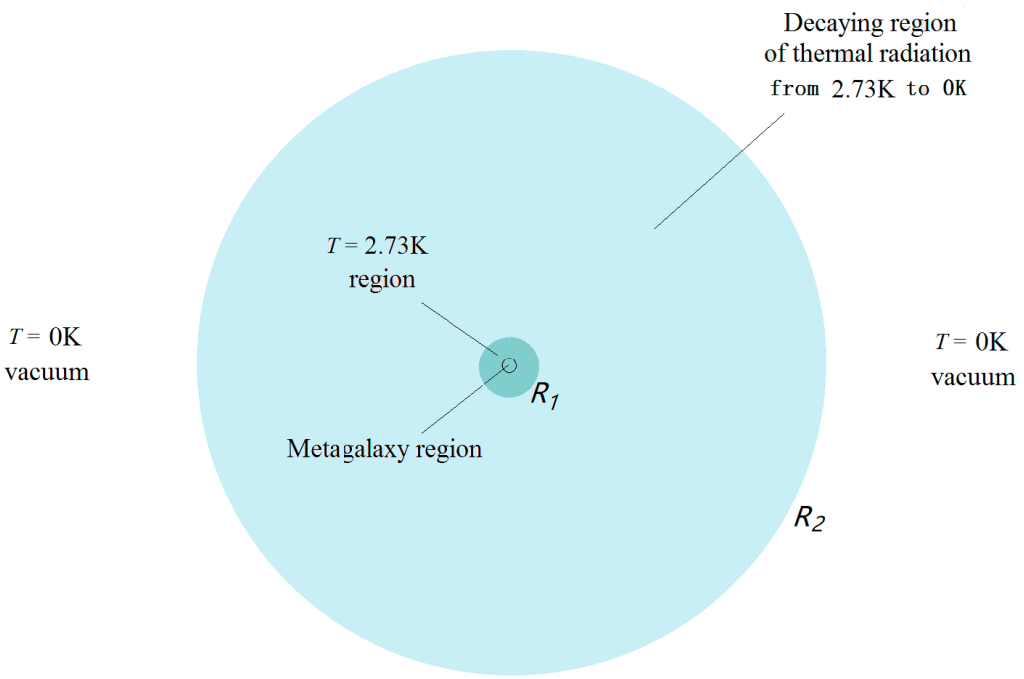


**Figure 2.** A heat ocean model. The central small circle is the metagalaxy region. The bigger blue circle with a radius $R_1$ is the 2.73 K region. Then, from $R_1$ to $R_2$, the thermal radiation decaying region, , with the temperature drops down from 3K to 0K, as shown by a light blue color. Out of $R_2$, is the infinitively vast cosmic vacuum, $T$ = 0, $\rho$ =0.

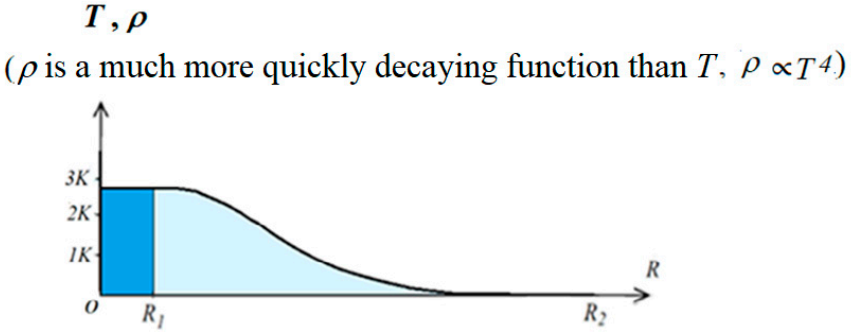


**Figure 3.** We suppose the central part of the heat ocean is a spherical region of radius $R_1$, filled up with 2.73K thermal radiation. Stretched outward from $R_1$ to $R_2$, the temperature of the thermal radiation decreases gradually from 2.73K to 0K, while the density of the thermal radiation decreases much more quickly to zero. Beyond $R_2$ is the infinitively vast cosmic empty space.

$$T = T(R) \tag{6}$$

which corresponding to a roughly similar but much more fast decaying mass density,

$$\rho = \rho(R) \tag{7}$$

$\rho$ is essentially proportional to $T^4$ , as shown by (2), (3) and (5)

Finally, out of $R_2$, is the infinitively vast empty cosmic space, the absolute vacuum.

In the 2.73K region, and, also in the thermal radiation decaying region, all the outward flying photons undergo red shift. Strictly to say, few of the outward flying photon is precisely along the radius of the closed heat ocean. So, guided by their tangential kinetic energy (may be very tiny), all

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the outward flying photons will eventually turn back and fly towards the central region of the heat ocean again, undergoing blue shift.

Passing through the central region, the blue shifted photons will fly to their individual far most sites on the other side of the central region, undergoing red shift again.

In such a way, all the photons will keep shuttling ceaselessly in the various directions in the $4\pi$ solid angle, all with extraordinarily great shuttling amplitudes, and the whole closed heat ocean keeps fundamentally stable and equilibrium.

The heat ocean is extraordinary immense, and its mass may be extraordinary great, which might also contribute considerably to the gravitational close of the universe.

#### 3.2.3. The Big Bang and Its Subsequent Processes Are All Extraordinarily Great Irreversible Processes, Resulting in Immense Increase of Entropy

**(**These processes deliver immense amounts of light and heat (energy) into the 2.73K heat ocean, which is a waste heat reservoir, and actually, can also be regarded as an energy reservoir.)

(1） The big band is a tremendously great explosion. Like a supernova, it directly scattered extraordinarily tremendous amount of light and heat into the space of the closed universe. These light and heat cannot fly off the closed universe. They will keep shuttling in the closed universe ceaselessly with extremely great amplitudes. After an extremely long relaxation time, finally, mingle into the 2.73K heat ocean.

(2） As have discussed above, about 380,000 years after the big bang, the interior temperature of the expanding primitive fire ball dropped down to about 3000K. As the decoupled fire ball has an immense volume similar to the volume of the Milky Way and at a very high temperature 3000K, it should have an extraordinary immense amount of energy of light and thermal radiation. The whole fire ball became transparent. All the thermal radiations in the decoupled fire ball got free, started immediately to fly off the fire ball at the speed of light in all the directions, and travelled also at the speed of light into the farther vast space. Then, they should also keep shuttling in the closed universe, and finally mingle into the 3K heat ocean.

(3) In the further expansion of the fireball, all the real matter of an immense amount within it (mainly hydrogen and helium) changed into numerous nebulae, into galaxies, and into even more numerous stars and other celestial bodies. All these processes are also irreversible, sending immense light and heat into the heat ocean, producing immense entropy.

(4) Then in a very long period, there formed early or late, extremely numerous and numerous stars in all the galaxies. Like the sun, most of these stars have averagely a lifetime of about $10^{10}$ years (actually longer or shorter), ejecting ceaselessly light and heat into the vast space due to the energy produced in their interior nuclear fusions of hydrogen and helium. All these light and heat also scattered into the closed universe, and finally mingle into the 3K heat ocean.

And so on.

All the processes described in the above paragraphs increase the entropy in the closed universe tremendously. In the same time, they deliver immense amount of light and heat into the vast 2.73K heat ocean.

### *3.3. The Collection and Assemble of Energy from the 2.73K Heat Ocean by the Black Holes, Leading to a New Big Bang*

In the heat ocean, the 2.73K thermal equilibrium radiation travels everywhere randomly and ceaselessly at the speed of light. Every black hole in the metagalaxy region is immersed in the vast 2.73K heat ocean, it takes in the 2.73K thermal radiation at the speed of light from all the directions since its birth and throughout its extremely long lifetime. Meanwhile, a black hole never delivers any thermal radiation to its exterior. Such a process is distinctly **a single way collection of the thermal energy** from the extremely cold 2.73K heat ocean to the black hole that is at an extremely high (latent) temperature, as it has an immense amount of internal energy. **The process apparently violates the Clausius's statement of the second law of thermodynamics.**

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**Black holes are natural demons in the closed universe.**

Let us see 3 typical examples of black holes of different grades.

3.3.1. A Black Hole with a Mass 10 Times of the Sun

As shown in Figure 4 (a)，its mass is

$$M_1 = 10\ M_\odot = 10\times(2\times10^{30}) = 2\times10^{31}\ \text{kg}. \tag{8}$$

Its Schwarzschild radius is

$$R_1 = \frac{2GM_1}{c^2} = 2.96\times10^4 \approx 30km. \tag{9}$$

When this $M_1 = 10\ M_\odot$ black hole was formed, most of the matter and energy of its original star collapsed down into the new formed black hole. The great amount of the gravitational potential energy of the matter of the original star first converts to kinetic energy and heat step by step, and finally concentrates into the small new formed black hole. So, there is a great amount of internal energy in the black hole that is now highly concentrated in a very small volume. Hence, the newly formed black hole can be regarded to be equivalent at some extremely high (latent) temperature, see Figure 4 (a).

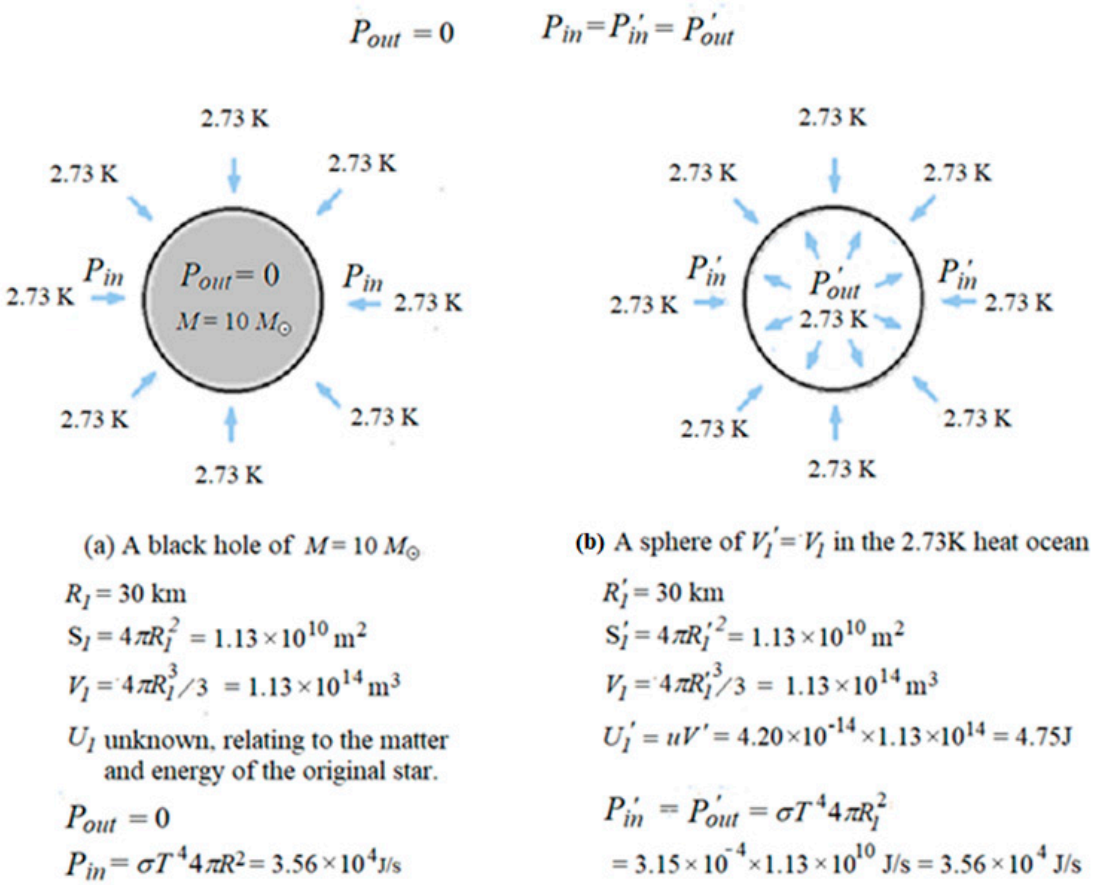


**Figure 4.** (a) A black hole of M = 10$M_\odot$, $R_1$ = 30km, $V_1$ = 1.13×10$^{14}$m$^3$, its internal energy is considerably great; b) In the heat ocean, in a same volume $V_1' = V_1$, the energy of the 2.73K thermal radiation is only $U_1' = 4.75$J.

(A common bomb contains a great amount of chemical energy, that can do a great amount of work. From the point of view of the second law of thermodynamics, the bomb is equivalent to be at a (latent) extremely high temperature.)

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The volume and surface area of the black hole of the $M_1 = 10\ M_\odot$ are

$$V_1 = (4\pi/3)R_1^3 = 1.13\times10^{14}\text{m}^3, \tag{10}$$

$$S_1 = 4\pi R_1^2 = 1.13\times10^{10}\text{m}^2 \tag{11}$$

respectively, as shown in Figure 4 (a).

For comparison（to compare their temperature）, imagine a sphere in the 2.73K heat ocean of a same volume and a same surface area as shown in Figure 4 (b),

$$V_1' \ (= V_1) = 1.13\times10^{14}\text{m}^3\ , \tag{12}$$

$$S_1' \ (= S_1) = 4\pi R_1'^2 = 1.13\times10^{10}\text{m}^2, \tag{13}$$

The internal energy of the 2.73K thermal radiation in the spherical volume $V_1'$ is

$$U_1' = u\ V_1' = 4.20\times10^{-14}\times1.13\times10^{14} = 4.75\text{J}. \tag{14}$$

The (latent) temperature of the $M_1 = 10\ M_\odot$ black hole ($V_1$) is extremely high. But it does not emit any thermal radiation to the surrounding extremely cold 2.73K heat ocean. Contrarily, it just takes in the thermal radiation at the speed of light in all the directions from the extremely cold 2.73K heat ocean ceaselessly with a power

$$P_{\text{in}}' = \sigma T^4 4\pi R_1'^2 = 3.15\times10^{-6}\times1.13\times10^{10} = 3.56\times10^4\text{J/s}. \tag{15}$$

In each second, suppose the $M_1 = 10\ M_\odot$ black hole takes in the 2.73K thermal radiation of a volume $N_1V_1'$ from the heat ocean, the number $N_1$ should be

$$N_1 = P_1 / U_1' = 3.56\times10^4 \div 4.75 = 7494 \approx 7500. \tag{16}$$

In one day, the corresponding number of the energy $U_1'$ collected from the heat ocean by the $M_1 = 10\ M_\odot$ black hole is

$$N_{day} = 86400\times7500 = 6.5\times10^8. \tag{17}$$

In one year, the corresponding number is

$$N_{year} = 365\times6.5\times10^8 = 2.37\times10^{11}. \tag{18}$$

In one million years, it is

$$N_{10^6\ years} = 2.37\times10^{11}\times10^6 = 2.37\times10^{17}. \tag{19}$$

One million years is a twinkle of an eye in the long, long lifetime of a black hole.

We conclude that, the 2.73K thermal radiation pouring ceaselessly at the speed of light from all the directions into the $M_1 = 10\ M_\odot$ black hole is **a typical new process of spontaneous heat transfer from an extremely low temperature region (at 2.73K) to an extremely high temperature region (a great amount of internal energy concentrated in a small volume, means an extremely high latent temperature)**. Such a process is apparently in contradiction to the Clausius statement of the second law of thermodynamics.

**Black holes are Maxwell's demons in the Nature.**

Numerous and various such black holes of the star magnitude in all the millions over millions of galaxies ceaselessly absorb a very great general amount of thermal radiation from the vast 2.73K heat ocean throughout their individual extremely long, long lifetimes. That is a great process of energy collection.

3.3.2. The Central Black Hole of a Galaxy

Such a black hole usually has approximately a mass of about $10^{10}$ times of the mass of $M_1$, i.e.,

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$$M_2 \approx 10^{10} \times M_1 = 10^{10} \times 10\, M_\odot , \tag{20}$$

The radius of its Schwarzschild sphere is

$$R_2 \approx 10^{10} \times R_1 = 10^{10} \times 30\text{km} \tag{21}$$

and the area of its spherical surface $S_2$ is $10^{20}$ times of the area of $S_1$. It absorbs the 2.73K thermal radiation from the heat ocean at a much greater power,

$$P_{2\text{in}} = \sigma T^4 4\pi R_2^2 = (3.15\times10^{-6}\times1.13\times10^{10}) \times10^{20} = 3.56\times10^{24}\ \text{J/s}. \tag{22}$$

If we still take $U_1' = u\ V_1' = 4.75\text{J}$ as an energy counting unit, the corresponding number $N_2$ of the energy absorbed by $M_2$ in each second is

$$N_2 = P_{2\text{in}} / U_1' = 3.56\times10^{24}\ \text{J} \div 4.75\text{J} = 7.50\times10^{23} \tag{23}$$

The thermal radiation collected by the $M_2$ black hole from the heat ocean is extremely higher than the $M_1 = 10\, M_\odot$ black hole. The process reduces a much greater amount of entropy of the universe in each second.

The total rate of the collections of energy from the heat ocean by all the numerous black holes of galaxy cores in the whole metagalaxy region is of course tremendously greater, and the corresponding decrease of the entropy of the universe is also extraordinarily larger.

As all these above mentioned two kinds of black holes unite step by step (together with all the other celestial bodies in the galaxies) through shuttling and annexations to form eventually the **central black hole**, they should carry all the energy that they have collected from the heat ocean in their individual long, long lifetimes to enter the central black hole.

### 3.3.3. The Central Black Hole of the Universe

The central black hole contains all the real matter of the whole universe, having an extraordinarily immense amount of mass. Its radius is proportional to its mass. The area of its Schwarzschild sphere is proportional to the square of its radius. Hence, it has an extremely and extremely immense spherical area. It will absorb the 2.73K thermal radiation from the extremely vast 2.73K heat ocean ceaselessly from all the directions at the speed of light. Hence, the power of its absorption of the thermal radiation from the immense heat ocean will be extraordinarily great. **The internal energy of the central black hole will rise extraordinarily fast, and, monotonically.**

Notice please, at that time, all the real matter in the universe have already been concentrated into the central black hole. There will be no longer any new mass of real matter to fall into the central black hole. The average energy possessed by per unit mass of the real matter in the central black hole will just rise and rise, quickly and monotonically. **The interior matter should undergo a series of endothermic changes.** By the end of all these endothermic changes, the energy possessed by per unit mass of the interior matter of the central black hole will reach an extremely high level. The authors assert that the matter in such an extreme state is closely identical to the "primitive matter" or "ylem" described by Gamow et al in their theory of **the thermal big bang**.

Nevertheless, the central black hole will continue to absorb energy extremely fast from the heat ocean ceaselessly. Its total internal energy will continue to increase. That means, **its internal repulsive factor will continue to increase**, **extremely fast and monotonically**. Such a unidirectional process should not go on and on without an end, when a threshold value of the repulsive factor is reached and exceeded, a new big bang breaks out!

So far, we have accomplished the description of an extraordinarily big cycle of matter and energy in the universe. A big bang followed by a big assemble forms a big cycle. [26–32]

## 4. Conclusion——A New Frame Work of Thermodynamics

In the above discussions, we have first described and demonstrated by an experiment video of a special test of an artificial entropy reducing process, the experiment of thermal electrons in a

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magnetic field. It is very interesting and enlightening. It means a very tiny cycle of energy in the macroscopic world, challenging the traditional thermodynamics sharply and profoundly.

We also discussed the extraordinarily immense big cycle of matter and energy in the closed universe. A big bang and a big assemble constitute a big cycle. Entropy can either increase, or decrease, both in an extraordinarily immense scale。In general, the increase and decrease of entropy in a big cycle match each other. The entropy of the universe would never reach a Maximum value, Clausius's "Heat Death" is an excessive anxiety.

Hence, the original frame work of thermodynamics needs to be reformed. We put forward **a new theoretical system for thermodynamics** as follows, with the first law keeps unchanged, and the second law changes considerably.

**(1) The first law of thermodynamics is energy conservation.**

Energy is conserved, wherever and whenever. It is a law of the universe.

The total amount of energy of the universe keeps constant (Clausius's word).

And so on.

**(2) The second law of thermodynamics is energy circulation.**

All the matter and energy in the closed universe are involved in a big cycle. Entropy can either increase, or decrease. In general, the increase and the decrease of entropy match each other in a big cycle. The black holes are natural demons in the universe.

Nevertheless, the traditional second law of thermodynamics should not thus be discarded. It is still valid in almost all of the numerous ordinary thermodynamical processes that we meet in our life, work, and ordinary research.

The situation is rather similar to the one in mechanics.

Einstein's special relativity reveals profoundly that Newton's mechanics is no longer valid in some special situations. However, for almost all the practical mechanical problems we meet in our life, work and ordinary research, Newton's mechanics is still valid, it is still accurate to an extremely high extent.

Similarly, for all the numerous ordinary thermodynamical processes we meet in our life, work and ordinary research, the traditional second law of thermodynamics is still valid, covering an extremely wide scope.

**More ever, like energy, entropy is also a real physical quantity.** It has many different forms, for examples, heat temperature quotient entropy, volume expanding entropy, phase change entropy, chemical entropy, and so on.

**Entropy is conserved in all the reversible processes.** This is actually a theorem. The theorem provides a way to find the credible and accurate equivalent relations between the different forms of entropy.

Nevertheless, unlike energy, entropy tends to increase spontaneously in numerous and numerous ordinary processes that we meet wherever and whenever.

Fortunately, entropy can also decrease in the big cycle of matter and energy in the closed universe. We need not to worry about the Heat Death as predicted by Clausius.

The special artificial processes, the experiment of thermal electrons in a magnetic field, results in some very tiny decrease of entropy. Although it is a very tiny process, its output current is already a macroscopic direct current (DC). Such a peculiar and interesting experiment challenges extremely sharply the traditional second law of thermodynamics within the macroscopic world.

**Some adding words**

(1) The universe is extraordinary immense and mysterious. There are so many, many things in the universe still keep totally unknown and totally mysterious to mankind. This article is just a tentative thermodynamical exploration of the cycle of the matter and energy in the closed universe. Mistakes and deficiencies are of course inevitable in such a primary exploration. Any criticism and suggestion to this article are warmly welcome.

(2) In our discussion, we claimed that the black holes are natural Maxwell's demon in the universe. A black hole just ceaselessly takes in the thermal radiation of the 2.73K heat ocean in all the

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directions at the speed of light, reducing the entropy of the heat ocean, i.e., reducing the entropy of the universe ceaselessly. Meanwhile, a black hole can annex any celestial bodies that it encounters, helps the general assemble of matter and energy, leading to a new big bang.

Some people might argue that, according to Bekenstein, the "area entropy" of the event horizon of a black hole should increase when it takes in the 2.73K thermal radiation ceaselessly from the 2.73K heat ocean, and the general change of entropy for the process is still an increasing one, and so on.

The authors claim here that Bekenstein's "area entropy" of a black hole is an incorrect idea. Actually, there are several serious physical mistakes in Bekenstein and Hawking's "black hole thermodynamics". Limited by space, we do not discuss these problems in this article. We have another article *On Bekenstein and Hawking's Black Hole Thermodynamics*, discussing these problems in details. The article can be found through the Preprints ID: preprints-166919.

The pdf file of this article cannot demonstrate our experiment video of tube FX8-24. The readers who are interested in the experiment video can find it through the Reference [15] of this article.

## Appendix A. How Did the Thermal Radiation of the Decoupled Fire Ball Fly Off and Eject Freely into the Vast Cosmic Space, and Their Final Destination

As mentioned above, in our opinion, the 2.73K background radiation is an immense heat ocean, a natural and intrinsic existence in the closed universe.

Some researchers' opinions are different from ours. They believe that the 2.73K background radiation is produced by the big bang. And they believe further that the 2.73K background radiation is the afterglow of the thermal radiation in the decoupled fire ball, 380,000 years after the big bang. From the decoupled thermal radiation to the 2.73K background radiation, there was an "adiabatic expansion" of a long, long duration.

We have explained above that their idea of the "adiabatic expansion" is not correct, the actual process should be a free ejection.

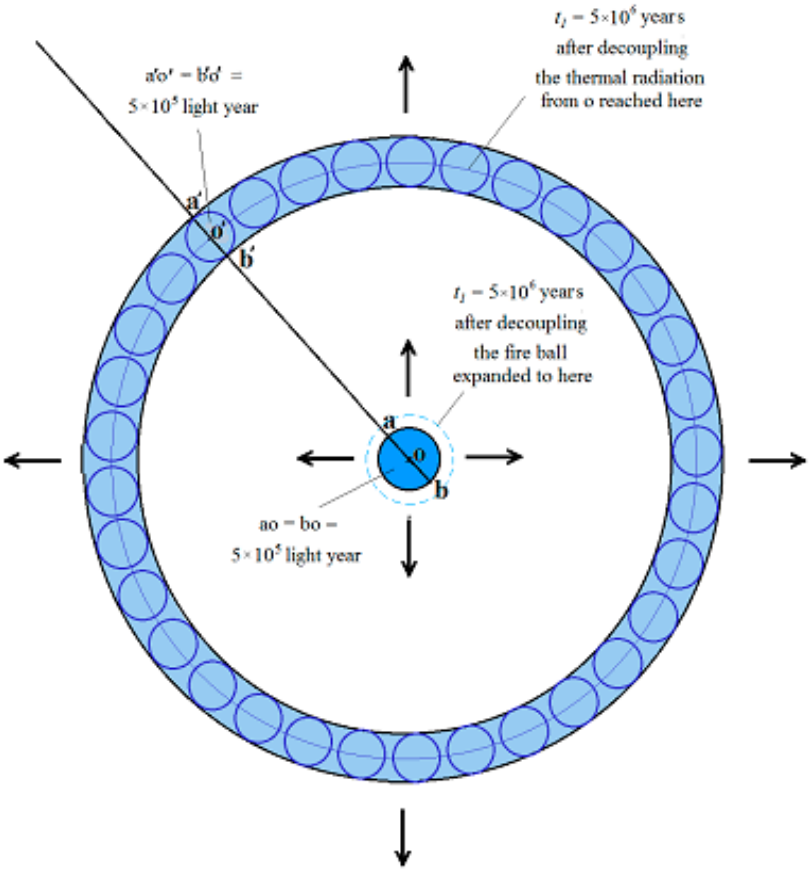


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**Figure 1.** The radius of the decoupled fire ball was about ao ≈ $5\times10^5$ light years, 380,000 years after the big bang. The diameter is ab ≈ $10^6$ light years. once decoupled. all the thermal radiation within the whole decoupled fire ball aob began to fly off at the speed of light to leave it in all the directions. $5\times10^6$ years later, the radiations from the whole sphere aob in the direction of oo′ reached a new place of a sphere a′o′b′, within the spherical layer a′b′ ≈ $10^6$ light years′. And all the thermal radiation from the decoupled fire ball in all the directions in the 4π solid angle all reached the spherical layer a′b′ with a width of a′b′ = $10^6$ light years, the big blue spherical layer in this figure.

Now, let us show how the remnant 3,000K thermal radiation in the decoupled fire ball ejected freely to the exterior vast cosmic space, and their final destination.

First, as shown in Figure 1, the small ball with the diameter ab in the central part of the figure represents the decoupled fireball, 380,000 years after the big bang. Its radius is approximately oa ≈ $10^{22}$ m = $5\times10^5$ light years. (For convenience of discussion, we make up a round number for the radius here, oa ≈ $5\times10^5$ light years, and the diameter is ab ≈ $1\times10^6$ light years.)

When the decouple happened, the fire ball became transparent. All the thermal radiation in the fireball immediately started to fly off in all the directions at the speed of light to the exterior vast cosmic space, and travels straight forward farther and farther. Obviously, it is just a free ejection, not an "adiabatic expansion".

Let us see how the thermal radiation flied freely to the infinitively vast space.

$5\times10^6$ years later, the thermal radiation from point o, and in the direction of oo', reached point o', oo' = 10 oa = $5\times10^6$ light years, as shown in Figure 1. The thermal radiation from point a reached point a', the thermal radiation from point b reached point b'. All the thermal radiations in the direction of oo' from all the points of the decoupled fire ball aob now reached the corresponding points of an equal ball a'o'b', which lay in the spherical layer a'b', obviously a'b' = $10^6$ light years.

And all the thermal radiations ejected from the decoupled fireball aob **in all the different directions** in the 4π solid angle now all reached points within the whole spherical layer a′b′, as shown in Figure 1. The thickness of the spherical layer a′b′ equals the diameter of the small ball ab,

$$a'b' = ab = 10^6 \text{ light years.} \tag{24}$$

$5\times10^7$ years after the decouple, all the thermal radiation from point o arrived at the spherical surface of the radius of oo'' = $5\times10^7$ light years (oo'' = 100 oa), as shown in Figure 2. And in the direction of oo'', the thermal radiation from point a reached point a'', the thermal radiation from point o reached point o'', the thermal radiation from point b reached point b''. All the thermal radiations in the direction of oo'' from all the points of the decoupled fire ball aob now reached the corresponding points of an equal ball a''o''b'', which lay in the spherical layer a''b''. And, all the thermal radiations from all the points of the small ball aob **in all the different directions** in the 4π solid angle now all reached the points within the whole spherical layer a'' b''. Obviously,

$$a'' b'' = a'b' = ab = 10^6 \text{ light years} \tag{25}$$

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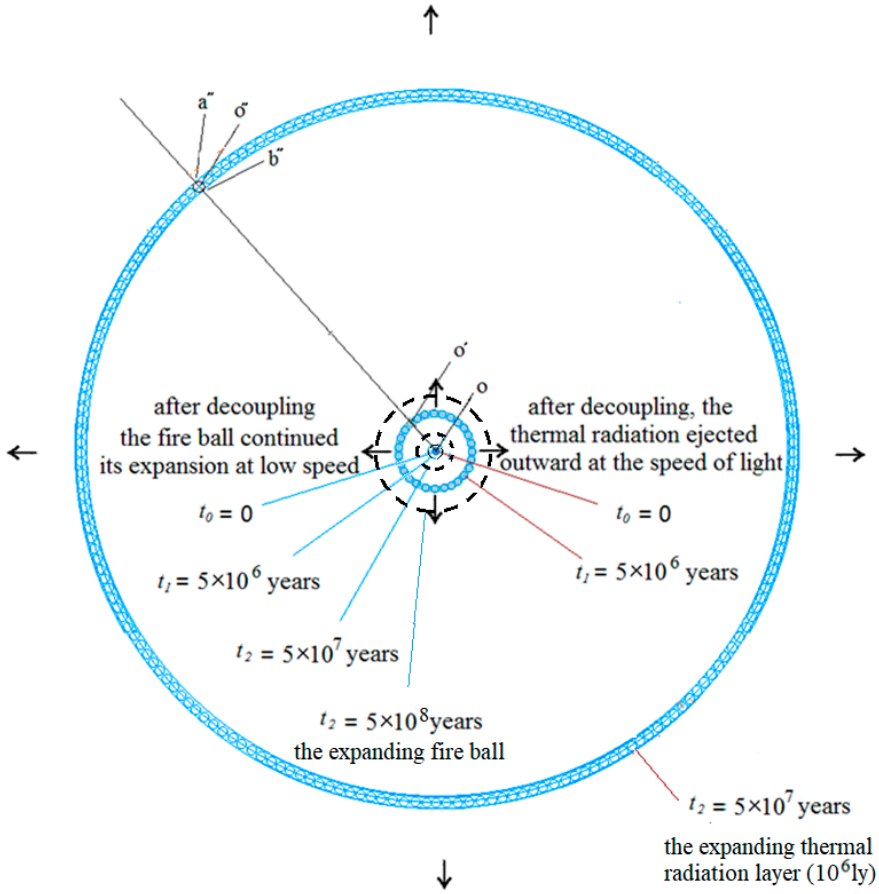


**Figure 2.** 5 ×$10^7$ years after the decoupling, in the direction of oo'', the radiation from o reached point o'',and the radiation from a reached a'', the radiation from b reached b''. The radiation from all the points of the decoupling ball aob reached the corresponding points of ball a''o''b'', laying in the spherical layer a''b''. And, the radiation from all the points of the ball aob in all the directions in the 4π solid angle reached the spherical layer a''b'',.

$$a''b'' = a'b' = ab = 10^6 \text{ light years.} \quad (26)$$

Similarly, 5 ×$10^8$ years later， all the radiations from all the points of the small ball aob (i.e., from the whole decoupled fire ball at $t$ = 380,000 years) and **in all the different directions** in the 4π solid angle, all reached the correspondent points within the whole spherical layer a'''b''',

$$a'''b''' = a''\ b'' = a'b' = ab = 10^6 \text{ light years.} \quad (27)$$

And, 5 ×$10^9$ years later, 5 ×$10^{10}$ years later， and so on, as the thermal radiation ejected freely from the decoupled fireball aob, flied outward continuously at the speed of light, it always keeps within a spherical layer with a thickness of $10^6$ light years,

$$\cdots = a''''b'''' = a'''b''' = a''b'' = a'b' = ab = 10^6 \text{ light years} \quad (28)$$

The expanding of this spherical layer of the thermal radiation of a thickness of $10^6$ light years, (ab), a'b', a''b'', a'''b''', a''''b'''', a'''''b''''' ……, and so on, should not go on and on at the light speed to the farther and farther space without an end. Because the space of the universe is closed, when some utmost possible position is reached, the thermal radiation layer of a thickness of $10^6$ light years will no longer fly away further. It will return back to the central region of the universe, and passing through the central region, travel to their far most positions on the other side of the central region. In such away, the layer of the $10^6$ light years will keep shuttling in the closed universe ceaselessly, meanwhile, getting more and more dispersive.

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Finally, after an extremely long relaxation time, by interactions (exchange heat) with the cosmic atoms, molecules, dusts or rocks (these matter are all at 2.73K) and so on in the metagalaxy region. And all the thermal radiation from the decoupled fire ball will eventually mingle into the 3K heat ocean, That is their final destination.

So, the authors behold that, the 2.73K background radiation discovered by Penzias and Wilson in 1965 is not the afterglow of the decoupled fire ball. It is not produced by the big bang. It itself is just an extremely immense intrinsic 3K vast heat ocean in the closed universe. It existed before the big bang, it exists now, and it will exist in the future.

In the above discussion, for the sake of concise, we postponed a detail about the process of the light and heat ejected from the surface of the expanding fireball from the time of the big bang to the decouple time, i.e., from $t_1 = 0$ to $t_2 = 380{,}000$ years. Now we make it up as follows.

Please have a look at Figure 3.

After the big bang, the expanding fireball was initially at an extremely high temperature. The temperature descended very rapidly as it expanded. In this process, the whole interior of the fireball was plasma at extremely high temperature, which was totally opaque for the interior thermal radiation. So, the thermal radiation within the expanding fireball could not eject outward freely to leave the fireball.

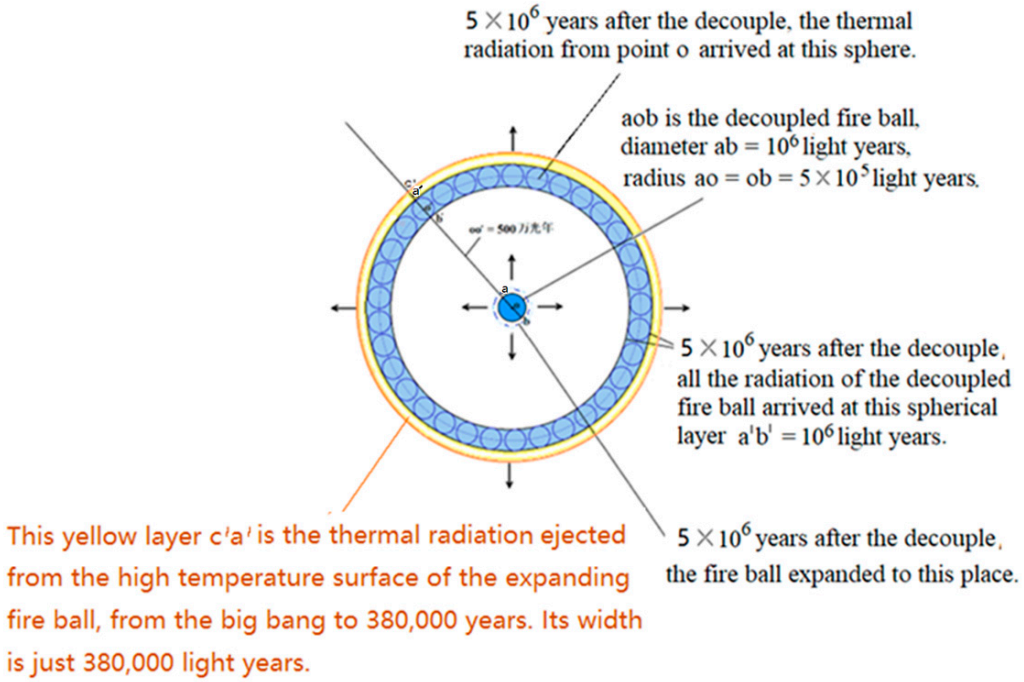


**Figure 3.** Another spherical layer with a width of c'a' = 380,000 light years (shown as a "yellow" one in the figure) just out the spherical layer of $10^6$ light years (the "blue" ones a′b′, a''b'', a'''b''', ……).

However, in the same duration, the surface of the expanding fire ball was also plasma at a lower and also descending temperature, but its temperature still kept very high. This surface of the expanding fire ball should eject thermal radiation ceaselessly, from $t_1 = 0$ to $t_2 = 380{,}000$ years.

Let us make a compare: as is well known, the temperature at the central part of the sun is about 15000K, and the temperature at the surface of the sun is about 6000K. The interior thermal radiation of the sun cannot fly off the sun, because the interior plasma is totally opaque for the thermal radiation. Only the surface of the sun, which is exposed to the exterior space, would eject light and heat ceaselessly. And the temperature of the ejected light and heat is about 6000K.

Similarly, the descending temperature at the surface of the expanding fire ball in the duration from the big bang to the decouple time was also still be extremely high. The surface kept being plasma until the decouple happened, and it was exposed to the vast exterior space. Like the surface of the sun, the surface of the expanding primitive fire ball should eject thermal radiation continuously, from

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$t_1 = 0$ to $t_2 = 380{,}000$ years. Hence, just out the expanding spherical layer with a width of $10^6$ light years (the expanding "blue" spherical layer as shown in Figures 1 and 2),

$$\ldots\ldots\ a''''b'''' = a'''b''' = a'''b''' = a''b'' = a'b' = ab = 10^6 \text{ light years} \quad (29)$$

there is another spherical layer of a width of 380,000 light years, the "yellow" one spherical layer in Figure 3.

$$\cdots\cdots\ c''''a'''' \ c'''a''' = c'''a''' = c''a'' = c'a' = 380{,}000 \text{ light years} \quad (28)$$

The two layers both ejected outward at light speed, one after the other, the yellow one progresses ahead and the blue one follows. After reaching their far-most positions in the closed universe, they will both return back, still one after the other.

Then they will keep shuttering in the closed universe, becoming more and more dispersive. After a long, long relaxation time, finally, both the "blue" and "yellow" thermal radiations should mingle into the stable immense 2.73K heat ocean.

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