Summary of whether the gravitational constant is a variable

Zhi Cheng

gzchengzhi@hotmail.com

Abstract: During this time, I have been thinking about whether the space-time structure and gravitational constant are variables. Because many mistakes are unavoidable in the thinking process, the conclusions often change. In addition, in the process of thinking, I also discussed with some scholars and kept getting new ideas. Relevant theories and models are gradually determined. So, I wrote this paper to make a summary. I feel that what is relatively certain at present is the new space-time structure. This can be confirmed by correcting the change of the gravitational constant for the precession of Mercury's perihelion and the three-layer structure of the Milky Way. Although not strong, it is logically self-consistent. This article re-analyzes the data with specific time records such as BIPM-01, BIPM-14, JILA-10, UCI-14, HUST-09, HUST-18. The analysis results show that the experimental results have improved to a certain extent after considering the influence of the earth's orbit and Jupiter.

Keywords: gravitational constant; measurement of gravitational constant; Jupiter

1 Introduction

What is space-time? This is a basic question in physics. But what is the matter composition of space-time? Physics seems to be difficult to answer. The "ether" hypothesis a hundred years ago believed that space-time is an elastic substance. However, because it could not meet the covariance requirements of the theory of relativity, it was finally abandoned by people.

The article inferred in the paper [11] that in fact the energy distribution range of the electrostatic field of this electron and proton is what we usually call "space-time".

The measurement of the gravitational constant is very difficult. Nevertheless, with the development of various related technologies since 2000, the measurement accuracy of the gravitational constant has been significantly improved. Therefore, some systematic errors that could not be considered in the past can also be taken into consideration, thereby effectively improving data consistency.

In order to explore the influence of various factors on the gravitational constant, a basic assumption is needed, that is, space-time compression will change the gravitational constant. The specific analysis is explained in detail in one of my papers [1]. The basic idea is to assume that space-time compression will result in a shortening of the spatial measurement scale. However, it is observed in the distant flat space-time observation system that the mass should not be changed, otherwise the law of conservation of energy is violated. In this way, the Schwarzschild radius of the mass measured in the flat space-time reference frame should also remain unchanged. Now switch to the compressed space-time reference system. As the space measurement unit is reduced, the measured Schwarzschild radius should become longer. Regardless of the frame of reference, the mass cannot be changed. The speed of light is constant and cannot be changed. Therefore, what can be changed when space-time is compressed is the gravitational constant. The scale of the space-time compression is related to the position of the space-time structure of all masses at that point [11].

With the assumption that space-time compression will increase the gravitational constant, we can specifically calculate the Earth's perihelion and aphelion, as well as the influence of Jupiter's position on the gravitational constant measured on the earth.

2 The influence of the change of space-time structure on the gravitational constant

Taking into account the conclusion of the paper [11], the relationship between the changes in the space-time structure of the solar system and the changes in the gravitational constant measured on the earth can be summarized as the following two situations:

2.1 The influence of the Earth's perihelion and aphelion on the gravitational constant

The calculation formula can be expressed as:

$$G' \approx G\left(1+\frac{\Delta b}{r}\right) = G(1+\alpha)$$

Where r is approximately the space-time radius of the solar system

$$r \approx 10^{14} m$$

And Δb is the semi-major axis of the earth's orbit minus the distance between the earth and the sun. G is the gravitational constant of the aphelion position of the earth. G' is the gravitational constant measured at any position in the earth's orbit.

According to the data of the change in the distance between the earth and the sun in a one-year time span, the changes in the gravitational constant shown in Table 1 can be obtained.

In Table 1, the following formula is used to approximate the calculation [12]

$$d = 1 - 0.01672\cos\left[0.9856(day - 4)\right]$$

Table 1: The influence of the change of the earth's orbit on the gravitational constant

Time (Month)	***d*(AU)**	***1+α***	**Errors ($\times 10^{-11} m^3 kg^{-1} s^{-2}$)**
0.5	0.983578436	1.000049417	0.00032982
1	0.98492459	1.000047403	0.000316379
1.5	0.987268895	1.000043896	0.000292972
2	0.990456135	1.000039128	0.000261149
2.5	0.994275281	1.000033415	0.000223017
3	0.998473463	1.000027134	0.000181099
3.5	1.002772719	1.000020703	0.000138173
4	1.006888391	1.000014546	9.708E-05
4.5	1.010547979	1.000009071	6.05405E-05
5	1.013509178	1.000004641	3.09742E-05
5.5	1.015575926	1.000001549	1.03386E-05
6	1.016611382	1	6.43173E-13
6.5	1.016546988	1.000000096	6.42946E-07
7	1.015387008	1.000001832	1.22249E-05
7.5	1.013208244	1.000005091	3.39789E-05
8	1.010154954	1.000009659	6.44647E-05
8.5	1.006429298	1.000015232	0.000101664
9	1.002277955	1.000021443	0.000143113
9.5	0.997975786	1.000027879	0.000186069
10	0.993807642	1.000034114	0.000227686
10.5	0.990049498	1.000039737	0.000265209
11	0.986950183	1.000044373	0.000296155
11.5	0.984714904	1.000047717	0.000318473
12	0.983491662	1.000049547	0.000330686
12.5	0.983361446	1.000049742	0.000331987

2.2 The influence of Jupiter's position on the gravitational constant measured on Earth

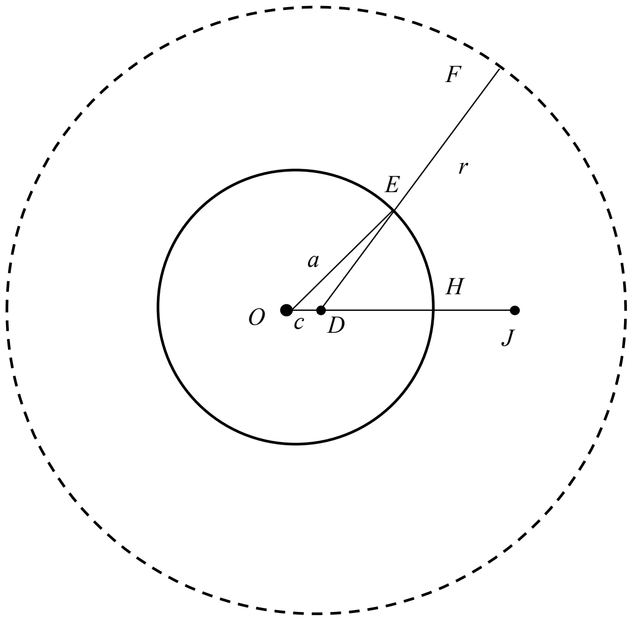

Figure 1. The position between the earth, Jupiter and the sun

In Figure 1, *O* is the position of the sun, *E* is the position of the earth, *J* is the position of Jupiter, and *D* is the position of the center of mass between Jupiter and the sun. Since Jupiter's orbital period reaches 11.8 years, Jupiter and the sun can be regarded as stationary.

OE is the orbital radius of earth, *DF* is the radius of the solar system's space-time structure *r*. Here, Jupiter's orbit is approximately regarded as a circle. then

$$\angle EOD = \theta = \frac{x}{6}\pi$$

Where *x* is the time when the earth leaves Jupiter’s opposition position, the unit is "month"

And

$$OD = c$$

Here

$$DE = \sqrt{a^2 + c^2 - 2ac \cdot cos\theta}$$

And

$$DH = a - c$$

Then

$$\Delta b = DE - DH$$

Where

$$a = 1.5 \times 10^{11} m$$

$$c = 1.5 \times 10^{9} m$$

So

$$\alpha \approx \frac{\Delta b}{r} = \frac{DE - DH}{r}$$

Then according to the paper [11], the change in the gravitational constant caused by the deviation from Jupiter's opposition point every half month is calculated, namely

$$G' = (1 + \alpha)G$$

Where *G* is the value of the gravitational constant measured at the position of the earth when Jupiter's opposition to the sun. *G'* is the value of the gravitational constant measured at other locations.

The results are shown in Table 2

Table 2 The errors of the gravitational constant caused by the time deviation from Jupiter opposition

Time (month)	**1+α**	**Errors (×$10^{-11}m^3kg^{-1}s^{-2}$)**
0.5	1.000001	3.44512E-06
1	1.000002	1.35388E-05
1.5	1.000004	2.95744E-05
2	1.000008	5.04337E-05
2.5	1.000011	7.46699E-05
3	1.000015	0.000100613
3.5	1.000019	0.00012649
4	1.000023	0.000150543
4.5	1.000026	0.000171152
5	1.000028	0.000186937
5.5	1.000029	0.000196847
6	1.000030	0.000200226

3 Analysis of some time-recorded measurement values of gravitational constant

Since Cavendish measured the gravitational constant, humans have measured the gravitational constant many times. However, considering that the relative error of the measurement of the gravitational constant before 2000 is close to 150ppm. Such a relative error exceeds the estimation results of this article and my previous days, so these data are not suitable for analyzing the gravitational measurement data of Jupiter's orbit on the earth. influences. For example, for the measurement result of TR&D-96 [2], the accuracy is too low, about 6.6730 (90), it can be seen that the gravitational constant measured before 2000 has no obvious correlation with the specific month. Therefore, below this accuracy, the changes in the positions of Jupiter and the Earth have little effect on the results.

Since 2000, the accuracy of the measurement of the gravitational constant has been improved to a certain extent. By 2018, the accuracy of the measurement of the gravitational constant has been increased to 12ppm [3]. Such a relative error exceeds the influence of Jupiter on the measurement of the gravitational constant. Therefore, some common changing laws should be found from these data and considered as systematic errors.

In addition, at present, the systematic error caused by different measuring devices is indeed relatively large. For example, the measurement accuracy of BIPM-01[4] and BIPM-14[5,6] are very high, but their results are very different from the measurement results of the HUST series, which is difficult to explain by the influence of Jupiter. Therefore, it can be determined that the difference of the measuring device will cause a large systematic error. Therefore, to compare the data and understand the influence of Jupiter on the measurement of gravitational constant on the earth, the same device should be mainly used.

3.1 BIPM-01 和 BIPM-14

The first measurement by Quinn et al. was from October 1 to October 30, 2000 [4]. The result of the measurement is $6.67559 \times 10^{-11} m^3 kg^{-1} s^{-2}$. In 2000, Jupiter's opposition time was November 28, 2000, and there was a **one-month** difference between the two. It shows that the earth and Jupiter are basically on the same side.

The second measurement was from August 7th to September 7th, 2007 [5,6]. The result of the measurement is $6.67545 \times 10^{-11} m^3 kg^{-1} s^{-2}$. Jupiter will oppose the sun in 2007 on June 5, 2007. There is a difference of **two months** between the two, and the earth has already begun to leave Jupiter. The measured result is slightly smaller.

The relative position between the Earth and Jupiter during these two measurements can be shown in Figure 2. Since the A position measured for the first time is closer to Jupiter, the measured gravitational constant will be larger.。

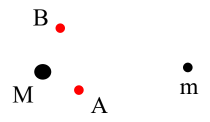

Figure 2. A: BIPM-01; B: BIPM-14

According to Table 2, the first measurement is 0.000002G smaller than Jupiter's opposition point. Now add 0.000002G to the first measurement result to get

$$6.67560 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

The second measurement is 0.000008G smaller than Jupiter's opposition. Now add 0.000008G to the result of the second measurement, we can get:

$$6.67550 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

It can be seen that after considering the influence of Jupiter, the results of the two experiments have improved to a certain extent.

Considering the influence of the earth's orbit again, the first measurement was in 10.5 months, which was relatively close to the perihelion, so from Table 1, you can see that the measured value of the gravitational constant at this time is relatively large, so the influence of about 0.000040G needs to be subtracted. The value of the gravitational constant after such correction is:

$$6.67533 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

The second measurement was about 8.5 months, and the influence of the Earth's orbit was slightly smaller than that of 10.5 months. From Table 1, it can be seen that about 0.000015G can be subtracted, so that the corrected gravitational constant value is:

$$6.67540 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

This data is significantly better than the original data.

Table 3 lists the corrected results for easy comparison.

Table 3. The corrections to BIPM data

Time	**J. oppsition**	**Experiment**	**Jupiter**	**Earth**
Oct. 1 – Oct. 30, 2000	Nov. 28, 2000	6.67559	6.67560	6.67533

Aug.7 – Sept.7, 2007	Jun. 5, 2007	6.67545	6.67550	6.67540

Where, the unit of gravitational constant is ($\times 10^{-11} m^3 kg^{-1} s^{-2}$).
"Jupiter" means that considering the influence of the Jupiter's position.
"Earth" means that considering the influence of the earth's orbital position.
"J. opposition" means the time of Jupiter opposition.

3.2 JILA-10

The experiment of JILA-10 was mainly completed from May to June 2004 [7], and their measurement results are $(6.67234 \pm 0.00014) \times 10^{-11} m^3 kg^{-1} s^{-2}$. Considering that Jupiter's opposition in 2004 is March 4th. Therefore, during the measurement process from May to June, the earth is gradually moving away from Jupiter, so the measured value will gradually decrease. In the paper by Parks et al., Figure 2 shows the series of data measured during this time [7]. It can be seen that the value of the gravitational constant measured in June has dropped significantly.

Although there is no specific data, it can be roughly seen from the figure that the average difference between the data in May and the data measured in June is about $0.00001G$.

3.3 UCI-14

The measurement time of UCI-14 is 9-11/2000, 12/2000, 3-5/2002, 3-5/2006[8]. Among them, the measurement in 2004 was discarded due to too much noise signal. Newman et al. used three types of fibres. Among them, 9-11/2000 used the first fibre, 12/2000, 3-5/2002 used the second fibre, and 3-5/2006 used the third fibre.

Although the second fibre was used in 12/2000, the number of experiments was only more than one hundred, so the second fibre was mainly used in 3-5/2002.

In 2000, Jupiter opposed the sun on November 28. Therefore, the 9-11/2000 experiment differs from Jupiter's opposition time by about **2 months**. The 12/2000 experiment coincided with Jupiter's opposition to the sun. The opposition of Jupiter in 2002 was January 1st. Thus, the time difference between the 3-5/2002 experiment and Jupiter's opposition is about **4 months**. Jupiter's opposition in 2006 was May 4th. It can be seen that in 3-5/2006, the Earth was closest to Jupiter, a difference of about **half a month**. At this time, the maximum gravitational constant value should be measured. Although the earth was very close to Jupiter at the time of 12/2000, considering that the data measured in this month was relatively small and averaged by the data of 3-5/2002, the measurement result of fibre 2 was mainly affected by the measurement data of 3-5/2002. Considering that the earth began to move away from Jupiter in 3-5/2002, the value of the gravitational constant measured during this period should be relatively small.

Through the above analysis, we can conclude that the order of the experimental measurement results is:

$$\text{Fibre 3} > \text{Fibre 1} > \text{Fibre 2}$$

The actual measurement result is

Fibre 1: $6.67435(10) \times 10^{-11} m^3 kg^{-1} s^{-2}$.

Fibre 2: $6.67408(15) \times 10^{-11} m^3 kg^{-1} s^{-2}$

Fibre 3: $6.67455(13) \times 10^{-11} m^3 kg^{-1} s^{-2}$

It can be seen from the results of UCI-14 that the first result in 2000 was greater than that in 2002, and 2006 was closer to Jupiter, and the result was the largest.

Therefore, according to Table 2, adding the data of Fibre1 to the effect of **two months**, that is, the difference of 0.000008G, you can get

$$6.67440(10) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

Add the data of Fibre2 to the impact of **four months**, that is, the difference of 0.000023G, you can get

$$6.67423(15) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

Adding the Fibre3 data to the impact of **half a month**, a difference of about 0.000001G, you can get

$$6.67455(13) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

It can be seen that the three sets of data have improved to a certain extent.

Consider the influence of the earth's orbit.

The measurement time of Fibre1 is about October. As can be seen from Table 1, the influence of about 0.000034G needs to be subtracted, so that the corrected gravitational constant value is

$$6.67417(10) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

The measurement time of Fibre2 is about 4 months. As can be seen from Table 1, the influence of about 0.000015G needs to be subtracted, so that the corrected gravitational constant value is:

$$6.67413(15) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

The measurement time of Fibre3 is also about 4 months. As can be seen from Table 1, the influence of about 0.000015G needs to be subtracted, so that the corrected gravitational constant value is:

$$6.67445(13) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

It can be seen that the values of the above three gravitational constants have also been significantly improved. All results are listed in Table 4, which can be used for comparison.

Table 4. The corrections of UCI-14

Time	**Method**	**J. oppsition**	**Experiment**	**Jupiter**	**Earth**
9-11/2000	Fibre1	28/11/2000	6.67435	6.67440	6.67417
12/2000, 3-5/2002	Fibre2	1/1/2002	6.67408	6.67423	6.67413
3-5/2006	Fibre3	4/5/2007	6.67455	6.67455	6.67445

Where, the unit of gravitational constant is ($\times 10^{-11} m^3 kg^{-1} s^{-2}$).
"Jupiter" means that considering the influence of the Jupiter's position.
"Earth" means that considering the influence of the earth's orbital position.
"J. opposition" means the time of Jupiter opposition.

3.4 HUST-09

The first experiment of HUST-09 was from March 21, 2007 to May 20, 2007, and from April 19, 2008 to May 10, 2008 [9, 10]. The time of Jupiter's opposition in 2007 and 2008 are June 5, 2007 and July 9, 2008.

The second experiment was from August 25, 2008 to September 28, 2008, and from October 8, 2008 to November 16, 2008.

It can be seen that the first experiment is closer to the time of Jupiter opposition. The time interval is about **2 months**. The second experiment was a little farther away from Jupiter's opposition, about **two and a half months** on average. Therefore, theoretically, the result of the first experiment measurement will be larger than the result of the second experiment.

The reality is that the gravitational constant measured by Luo's team in the first experiment is：

$$(6.67352 \pm 0.00019) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

The gravitational constant measured in the second experiment is:

$$(6.67346 \pm 0.00021) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

According to the calculation in Table 2, if the data of the first experiment plus the influence of $0.000008G$ of Jupiter, the result of the first experiment is

$$(6.67357 \pm 0.00019) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

The second experiment took **two and a half months** longer than Jupiter's opposition to the sun. According to Table 2, it can be seen that the result of the second experiment is $0.000011G$ less than the gravitational constant of Jupiter's opposition point. So, the second experiment data plus the Jupiter influence of $0.000011G$, the second data will become

$$(6.67354 \pm 0.00021) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

It can be seen that the experimental data has been significantly improved.

If you consider the influence of the earth's orbit, the average measurement time for the first experiment is about April, and the average measurement time for the second experiment is about October.

According to Table 1, the corrected value after the first experiment is

$$(6.67347 \pm 0.00019) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

The corrected value for the second experiment is:

$$(6.67331 \pm 0.00021) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

Table 5. The corrections to HUST-09

Time	J. oppsition	Experiment	Jupiter	Earth
21/3 – 20/5/2007	5/6/2007	6.67352	6.67357	6.67347
19/4 – 10/5/2008	9/7/2008			
25/8 – 28/9/2008	9/7/2008	6.67346	6.67354	6.67331
8/10 – 16/11/2008	9/7/2008			

Where, the unit of gravitational constant is ($\times 10^{-11} \mathrm{m}^3 \mathrm{kg}^{-1} \mathrm{s}^{-2}$).
"Jupiter" means that considering the influence of the Jupiter's position.
"Earth" means that considering the influence of the earth's orbital position.
"J. opposition" means the time of Jupiter opposition.

Among the three data, if only the influence of Jupiter is considered, the data has improved significantly. But if the influence of the earth's orbit is taken into consideration, the data deteriorates.

3.5 HUST-18

HUST-18 is the latest measurement result. Among them, the angular acceleration feedback method (AAF) is divided into three years for measurement, and the measurement time is

Table 6. The time and data of HUST-18 (Estimated from the Fig. 2 of paper [3])

Time	Method	Value ($\times 10^{-11} \mathrm{m}^3 \mathrm{kg}^{-1} \mathrm{s}^{-2}$) (Estimated)
12/2014 – 01/2015	AAF-I	6.67452
04/2016 – 06/2016	AAF-II	6.67438
09/2017 – 11/2017	AAF-III	6.67455

Considering the influence of Jupiter, AAF-I is one and a half months away from Jupiter's opposition time on February 6, 2015, and the *G* measurement value is the largest.

AAF-II is two months away from Jupiter's opposition on March 8, 2016, and the measured value of

G is slightly smaller.

AAF-III is six months away from Jupiter's opposition time on April 7, 2017, and G is the smallest.

Table 7. The corrections to HUST-18

Time	Method	J. oppsition	Experiment	Earth	Jupiter
12/2014 – 01/2015	AAF-I	06/02/2015	6.67452	6.67419	6.67422
04/2016 – 06/2016	AAF-II	08/03/2016	6.67438	6.67435	6.67440
09/2017 – 11/2017	AAF-III	07/04/2017	6.67455	6.67422	6.67442

Where, the unit of gravitational constant is ($\times 10^{-11} m^3 kg^{-1} s^{-2}$).
“Jupiter” means that considering the influence of the Jupiter’s position.
“Earth” means that considering the influence of the earth's orbital position.
“J. opposition” means the time of Jupiter opposition.

It can be seen that considering the influence of the orbital position of Jupiter and the earth, the improvement is not very obvious, mainly because the data after AAF-I correction is obviously smaller. But its advantage is that it can better explain why the measured value of AAF-II is the smallest. Because during this period the position of the earth's orbit is the farthest from the sun. It is shown in Figure 3.

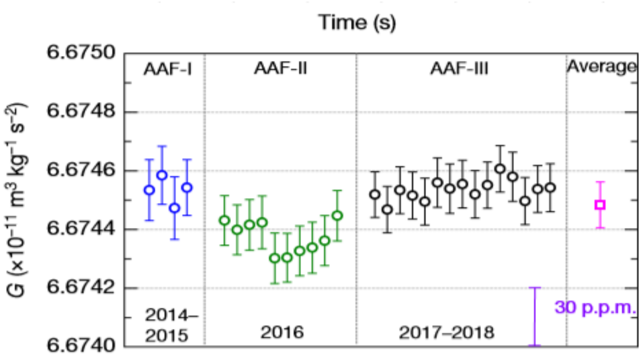

Figure 3. The AAF results of HUST-18 [3]

4 The influence of the change of gravitational constant on the perihelion of Mercury

From the calculation in the paper [13], it can be seen that considering the influence of parameterized post-Newtonian parameters, the theoretical calculation has a certain error range, so the theoretical value calculated according to the general relativity is in the range: (42.9779±0.0009)” [14]

The results currently extracted by Pireaux from the EPM2001 star map are now more accurate [15, 16], and the range of observation values reaches 43.0005”-43.0200”.

It can be seen from the above that there is still a certain error between the very high-precision theoretical calculation and the observed value.

If the influence of the change of the gravitational constant is taken into account, the corrected data is 43.0174”, which is exactly the same as the observed value. Of course, the introduction of EPM2017 has greatly improved the accuracy of the observed value of Mercury's perihelion precession, from the original ±0.0085" to ±0.008" [17], that is, the latest observation range is 43.0010"-43.0195 ". It is still consistent with theoretical calculations.

5 The movement of dwarf galaxies outside the Milky Way

Clark M. Thomas pointed out that there are many ancient dwarf galaxies outside of large galaxies. If it is considered that these dwarf galaxies will be attracted by the gravity of large galaxies, the motion of these dwarf galaxies will be random [18]. However, this is not the case. For example, the dwarf galaxies that have been observed on the periphery of the Milky Way galaxy have basically the same motion modes as other stars inside the Milky Way, and their speeds are about 204*km/s*.

Therefore, the motion of these dwarf galaxies cannot be explained by the gravity vortex model based on Newton or general relativity [18]. However, if we analyze the three-layer structure of the Milky Way proposed in the paper [19], we can find that the status of these dwarf galaxies on the periphery of the Milky Way is the same as that of other stellar systems inside the Milky Way, and their movement should be the same.

6 Conclusion

What exactly is "space-time" is a basic physics question. The new model will help us understand some problems and phenomena that were difficult to explain in the past.

One problem that has been ignored for a long time in the past is the electrostatic field energy of electrons and protons. Although the field strength of the positive and negative electrostatic fields can cancel each other, the energy of the electrostatic field seems unable to cancel each other. After all, the radius of the electron is much smaller than the radius of the proton. As a result, the electrostatic field energy possessed by electrons exceeds the electrostatic field energy possessed by protons. So where does the electrostatic field energy go? The new space-time structure model believes that these electrostatic field energies have not disappeared, but have become the "space-time" on which various substances need to depend on their existence.

With this new "space-time" model, some problems become easier to understand, that is, space-time, like mass, is also a form of energy. Space-time itself can also be squeezed by mass, forming gravity.

If we can learn more about the nature of space-time in this new model, it may be used to uncover the relationship between gravity and electromagnetic interaction.

Another conclusion brought by the new space-time model is that the gravitational constant may not be a constant, but constantly changes with the degree of space-time compression.

There are two main factors in the solar system that affect the gravitational constant measured on the earth. One is the influence of the distance between the earth and the sun. The other is the influence of Jupiter. The distance between the earth and the sun has a greater influence. If some of the measured values of the gravitational constant in the past take these two factors into account, the accuracy of the measured values can be improved to a certain extent. Of course, we have also noticed that there are some situations that have not improved and even worsened the results. The existing problems are worthy of in-depth discussion, and may help to improve the new space-time model.

Another evidence that can be used to prove that the gravitational constant may be constantly changing is the correction of Mercury's perihelion precession. If it is considered that the gravitational constant of Mercury's orbital position may be different from the gravitational constant of Earth's position, some relatively minor corrections will be brought to the theoretical analysis value of Mercury's perihelion precession. So that the theoretical calculation and the actual observation value are in good agreement.

Thanks

During my period of thinking about the change of the gravitational constant and the new space-time model, I had a very useful discussion with Dr. Rupert Sheldrake on this topic. Under his prompt, I reconsidered other factors that affect the change of the gravitational constant. In addition, we also discussed that more precise and original data may be needed to obtain strong evidence to support the change of the gravitational constant. I also want to thank Lev Verkhovsky from Russia. I discussed with him about the change of the frame of reference and found that some of his ideas are closer to mine. The discussion with Mr. Lev Verkhovsky was very pleasant. After these days of thinking, I think his use of the Doppler effect to explain the changes in the frame of reference of the special theory of relativity is also very creative. In addition, I think some of the literary content discussed on his website is also very enlightening.

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引力常数是否为变量的总结

Zhi Cheng

gzchengzhi@hotmail.com

摘要：这段时间我一直在思考时空结构和引力常数是否为变量的问题。由于思考过程中不免出现许多错误，因此结论也经常改变。另外在思考过程中，我还跟一些人士进行了讨论，不断获得了新的想法。有关理论和模型也逐渐确定下来。因此写了这篇论文做一个总结。我感到目前比较确定的是新的时空结构覆盖的范围。这可以从给水星近日点进动做引力常数变化的修正，银河系的三层结构等获得证实。虽然还算不上强有力，但逻辑上能够保持自洽性。本文重新对 BIPM-01, BIPM-14, JILA-10, UCI-14, HUST-09，HUST-18 等有具体时间记录的数据进行了分析。分析结果表明，考虑了地球轨道和木星的影响之后，实验结果都有一定程度改善。

关键词：引力常数；引力常数测量；木星

1 引言

什么是时空？这是一个物理学的基本问题。但是要涉及到时空究竟是什么材料构成的？物理学似乎就很难回答。一百多年前的“以太”假设认为时空是一种弹性物质。但是由于无法满足相对论协变性要求，最终被人们抛弃。

文在文献[11]中推断实际上这种电子和质子的静电场能量分布范围就是我们平时所说的“时空”。

引力常数的测量是一件很困难的事情。尽管如此，自 2000 年以来随着各种相关技术的发展，引力常数的测量精度还是有很明显的提高。因此一些过去无法考虑的系统误差也可以被考虑进来，从而有效提升数据的一致性。

为了探讨各种因素对引力常数的影响，需要一个基本假设，就是时空压缩会改变引力常数。具体的分析在我的一篇论文中有详细的解释[1]。其基本思路就是假设时空压缩将导致空间的度量尺度缩短。然而在远处平坦时空观察系观察到该时空中的质量不应该改变，否则违背能量守恒定律。这样在平坦时空参照系测量到的该质量的史瓦西半径也应该保持不变。现在切换到被压缩的时空参照系中，由于空间的度量单位缩小了，所测量到的史瓦西半径应该变长。而无论在哪个参照系，质量不能改变，这是能量守恒定律的要求。光速则是常数，也不能够改变。因此时空被压缩能够被改变的就是引力常数。时空被压缩的尺度和所有质量在该点的时空结构位置有关系[11]。

有了时空压缩将使引力常数增大的假设之后，我们就可以具体计算地球近日点和远日点，以及木星位置不同对地球上测量到的引力常数的影响。

2 时空结构变化对引力常数的影响

考虑到文献[11]的结论，太阳系中，时空结构的变化对地球上测量到的引力常数的变化关系可以总结为如下两种情况：

2.1 地球近日点和远日点对引力常数的影响

计算公式可以表示为：

$$G' \approx G\left(1+\frac{\Delta b}{b}\right)=G(1+\alpha)$$

其中 b 近似为太阳系的时空半径

$$b \approx 10^{14}m$$

而Δb为地球轨道长半轴减去地球太阳之间的距离。G 为地球远日点位置的引力常数。G'为地球轨道任意位置测量到的引力常数。

按照一年时间跨度，地球与太阳之间距离的变化的数据，可以获得表 1 显示的引力常数变化的情况。

表 1 中，采用下面的公式近似进行计算[12]

$$d=1-0.01672\cos[0.9856(day-4)]$$

Table 1: The influence of the change of the earth's orbit on the gravitational constant

Time (Month)	d(AU)	**1+α**	**Errors (×$10^{-11}m^3kg^{-1}s^{-2}$)**
0.5	0.983578436	1.000049417	0.00032982
1	0.98492459	1.000047403	0.000316379
1.5	0.987268895	1.000043896	0.000292972
2	0.990456135	1.000039128	0.000261149
2.5	0.994275281	1.000033415	0.000223017
3	0.998473463	1.000027134	0.000181099
3.5	1.002772719	1.000020703	0.000138173
4	1.006888391	1.000014546	9.708E-05
4.5	1.010547979	1.000009071	6.05405E-05
5	1.013509178	1.000004641	3.09742E-05
5.5	1.015575926	1.000001549	1.03386E-05
6	1.016611382	1	6.43173E-13
6.5	1.016546988	1.000000096	6.42946E-07
7	1.015387008	1.000001832	1.22249E-05

7.5	1.013208244	1.000005091	3.39789E-05
8	1.010154954	1.000009659	6.44647E-05
8.5	1.006429298	1.000015232	0.000101664
9	1.002277955	1.000021443	0.000143113
9.5	0.997975786	1.000027879	0.000186069
10	0.993807642	1.000034114	0.000227686
10.5	0.990049498	1.000039737	0.000265209
11	0.986950183	1.000044373	0.000296155
11.5	0.984714904	1.000047717	0.000318473
12	0.983491662	1.000049547	0.000330686
12.5	0.983361446	1.000049742	0.000331987

2.2 木星位置对地球上测量的引力常数的影响

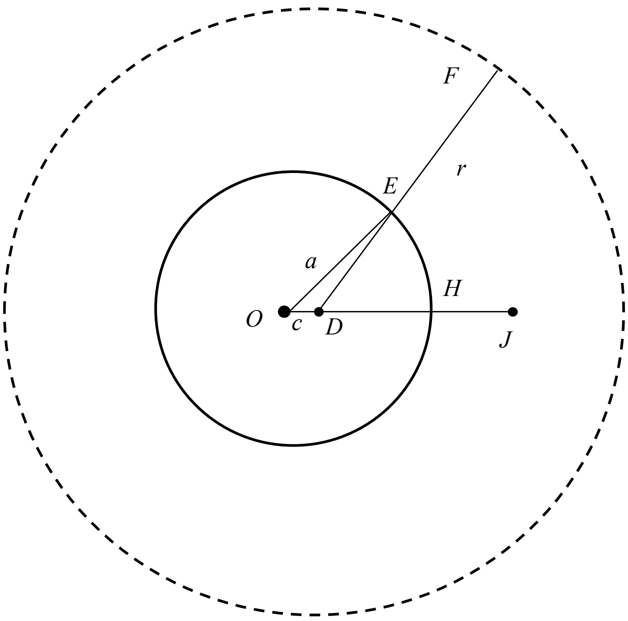

Figure 1. The position between the earth, Jupiter and the sun

在图 1 中，O 为太阳位置，E 为地球位置，J 为木星位置, D 为木星和太阳之间的质心位置。由于木星的轨道周期达到 11.8 年，因此可以近似将木星和太阳看做静止不动。

OE 为木星到太阳的轨道半径， DF 为太阳系时空结构的半径 r. 考虑到 r 远大于地球的轨道半径，因此$r \approx b$. 这里近似将木星的轨道看作是圆形。则

$$\angle EOD = \theta = \frac{x}{6}\pi$$

其中 x 为地球离开木星冲日位置的时间，单位为“月”

而木星和太阳之间的质心位置到地球的距离

$$OD = c$$

这样

$$DE = \sqrt{a^2 + c^2 - 2ac \cdot cos\theta}$$

而

$$DH = a - c$$

这样

$$\Delta b = DE - DH$$

上述参数中

$$a = 1.5 \times 10^{11} m$$

$$c = 1.5 \times 10^9 m$$

因此

$$\alpha \approx \frac{\Delta b}{b} = \frac{DE - DH}{b}$$

然后按照文献[11]计算出偏离木星冲日点之后每半个月造成的引力常数的变化，即：

$$G' = (1 + \alpha)G$$

其中 G 为木星冲日时间，在地球位置测量到的引力常数数值，该数值选择。G’为其他位置测量到的引力常数数值。

结果如表 2 所示：

Table 2 The errors of the gravitational constant caused by the time deviation from Jupiter opposition

Time (month)	**1+α**	**Errors ($\times 10^{-11} m^3 kg^{-1} s^{-2}$)**
0.5	1.000001	3.44512E-06
1	1.000002	1.35388E-05
1.5	1.000004	2.95744E-05
2	1.000008	5.04337E-05
2.5	1.000011	7.46699E-05

3	1.000015	0.000100613
3.5	1.000019	0.00012649
4	1.000023	0.000150543
4.5	1.000026	0.000171152
5	1.000028	0.000186937
5.5	1.000029	0.000196847
6	1.000030	0.000200226

3 一些有时间记录的引力常数测量数值的分析

自卡文迪许测量引力常数以来，人类已经对引力常数进行了非常多次数的测量。不过考虑到 2000 年之前对引力常数的测量其相对误差接近 150ppm. 这样的相对误差超过了本文以及我前几天的估算结果，因此这些数据不适合用来分析木星轨道对地球上引力测量数据的影响。比如对于 TR&D-96 的测量结果[2]，由于精度太低，大约为 6.6730(90)，可以看出 2000 年之前测量出来的引力常数数值跟具体的月份没有什么明显的关联性。因此在这样的精度下面，木星和地球位置的变化对结果的影响不大。

而自 2000 年以来，引力常数测量的精度得到一定程度的提高，到了 2018 年引力常数测量的精度已经提高到了 12ppm[3]. 这样的相对误差超过了木星对引力常数测量数值的影响。因此从这些数据中应该可以发现一些共同的变化规律，并将其作为系统误差来进行考虑。

另外目前来看，因为测量装置不同而造成的系统误差确实比较大。比如 BIPM-01[4]和 BIPM-14[5,6]的测量精度都非常高，但是他们的结果同 HUST 系列的测量结果差距却非常大，难以用木星的影响来解释。因此可以确定测量装置的不同将会造成很大的系统误差。因此要进行数据的对比，了解木星对地球上测量引力常数的影响，应该主要使用同一台装置来进行。

3.1 BIPM-01 和 BIPM-14

Quinn 等人的第一次测量是在 2000 年 10 月 1 日至 10 月 30 日[4]。测量的结果是 $6.67559 \times 10^{-11} m^3 kg^{-1} s^{-2}$. 而在 2000 年木星冲日时间为 2000 年 11 月 28 日，二者相差一个月。说明地球和木星基本位于同一侧位置。

第二次测量是 2007 年 8 月 7 日至 9 月 7 日[5,6]。测量的结果是$6.67545 \times 10^{-11} m^3 kg^{-1} s^{-2}$. 2007 年木星冲日时间为 2007 年 06 月 05 日。二者相差两个月，地球已经开始离开木星。测得的结果略小一些。

这两次测量的时候地球和木星之间的相对位置可以用图 2 来表示。由于第一次测量的 A 位置更靠近木星，因此测量出来的引力常数会更大一些。

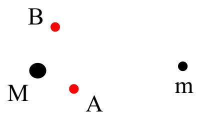

Figure 2. A: BIPM-01; B: BIPM-14

对照表 2，第一次测量比木星冲日点小 0.000002G，现在将第一次测量结果加上 0.000002G, 可以得到:

$$6.67560 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

第二次测量比木星冲日点小 0.000008G。现在将第二次测量的结果加上 0.000008G，可以得到：

$$6.67550 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

可以看出，考虑了木星的影响之后，两次实验的结果有一定程度的改善。

再考虑地球轨道的影响，第一次测量是 10.5 月，这个时候比较接近近日点，因此通过表 1，可以查阅到，此时的引力常数测量值比较大，因此需要减去大约 0.000040G 的影响，这样矫正以后的引力常数数值为：

$$6.67533 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

第二次测量是大约 8.5 月，地球轨道的影响比 10.5 月要偏小一些，则通过表 1 可以查阅到可以减去大约 0.000015G, 这样矫正以后的引力常数数值为：

$$6.67540 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

这个数据比原始数据要有比较明显的改善。

表 3 将矫正的结果列表出来，便于比较。

Table 3.

Time	J. oppsition	Experiment	Jupiter	Earth
Oct. 1 – Oct. 30, 2000	Nov. 28, 2000	6.67559	6.67560	6.67533
Aug.7 – Sept.7, 2007	Jun. 5, 2007	6.67545	6.67550	6.67540

3.2 JILA-10

JILA-10 的实验主要在 2004 年五月至六月完成[7]，他们的测量结果为$(6.67234 \pm 0.00014) \times 10^{-11} m^3 kg^{-1} s^{-2}$. 考虑到 2004 年木星冲日时间为 03 月 04 日。因此在五月到六月的测量过程中，地球是逐渐远离木星的，这样测量出来的数值将逐渐减少。在 Parks 等人的论文中，

其中图 2 显示了在这段时间测量的系列数据[7]。可以看出到了六月份所测量出来的引力常数数值明显下降。

虽然没有具体的数据，从图中大致可以看出，五月份的数据和六月份测量的数据平均值大约相差 0.00001G.

3.3 UCI-14

UCI-14 的测量时间分别是 9-11/2000，12/2000,3-5/2002,3-5/2006[8]. 其中 2004 年的测量由于噪音信号太大被舍弃掉了。Newman 等人用了三种扭秤纤维。其中 9-11/2000 用了第一种纤维，12/2000, 3-5/2002 用了第二种纤维，3-5/2006 用了第三种纤维。

12/2000 虽然使用了第二种纤维，但是实验次数只有一百多次，因此第二种纤维主要集中在 3-5/2002 使用。

而 2000 年木星冲日时间为 11 月 28 日。因此 9-11/2000 的实验与木星冲日时间大约相差 2 个月。12/2000 的实验正好与木星冲日时间吻合。2002 年木星冲日时间为 01 月 01 日。这样 3-5/2002 的实验与木星冲日时间相差大约 4 个月。2006 年木星冲日时间为 05 月 04 日。可以看出 3-5/2006 的时候，地球最接近木星，相差大约半个月。这时候应该测量出最大的引力常数数值。虽然 12/2000 的时候地球非常接近木星，但考虑到在这一个月测量的数据比较少，被 3-5/2002 的数据平均，因此纤维 2 的测量结果主要受到 3-5/2002 测量数据的影响。考虑到 3-5/2002 地球开始远离木星，因此这段时间测量的引力常数数值应该比较小。

通过上述分析，我们可以得出实验测量的结果大小顺序为：

$$\text{Fibre 3} > \text{Fibre 1} > \text{Fibre 2}$$

实际的测量结果为：

Fibre 1: $6.67435(10) \times 10^{-11} m^3 kg^{-1} s^{-2}$.

Fibre 2: $6.67408(15) \times 10^{-11} m^3 kg^{-1} s^{-2}$

Fibre 3: $6.67455(13) \times 10^{-11} m^3 kg^{-1} s^{-2}$

从 UCI-14 的结果可以看出，2000 年第一次结果大于 2002 年，2006 年更接近木星，结果最大。

因此对照表 2，将 Fibre1 的数据加上两个月的影响，即 0.000008G 的差异，可以得到

$$6.67440(10) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

将 Fibre2 的数据加上四个月的影响，即 0.000023G 的差异，可以得到

$$6.67423(15) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

将 Fibre3 的数据加上半个月的影响，大约 0.000001G 的差异，可以得到

$$6.67455(13) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

可以看出三组数据有一定程度的改善。

再考虑地球轨道的影响。

Fibre1 的测量时间大约为 10 月，从表 1 可以看出，需要减去大约 0.000034G 的影响，这样矫正以后的引力常数数值为：

$$6.67417(10) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

Fibre2 的测量时间大约为 4 月，从表 1 可以看出，需要减去大约 0.000015G 的影响，这样矫正以后的引力常数数值为：

$$6.67413(15) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

Fibre3 的测量时间大约也为 4 月，从表 1 可以看出，需要减去大约 0.000015G 的影响，这样矫正以后的引力常数数值为：

$$6.67445(13) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

可以看出上述三个引力常数的数值也还是有比较明显的改善。所有结果列表在表 4，可以作为比较。

Table 4.

Time	**Method**	**J. oppsition**	**Experiment**	**Jupiter**	**Earth**
9-11/2000	Fibre1	28/11/2000	6.67435	6.67440	6.67417
12/2000, 3-5/2002	Fibre2	1/1/2002	6.67408	6.67423	6.67413
3-5/2006	Fibre3	4/5/2007	6.67455	6.67455	6.67445

3.4 HUST-09

HUST-09 的第一次实验是在 2007 年 3 月 21 日到 2007 年 5 月 20 日，2008 年 4 月 19 日到 2008 年 5 月 10 日[9, 10]。可以看出，这段时间比较接近地球和木星在同一侧轨道的情况。而 2007 年和 2008 年木星冲日的时间分别是：2007 年 06 月 05 日，2008 年 07 月 09 日

第二次实验是在 2008 年 8 月 25 日到 2008 年 9 月 28 日，2008 年 10 月 8 日到 2008 年 11 月 16 日。

可以看出第一次实验更接近与木星冲日时间。时间大约为 2 个月时间。而第二次实验离木星冲日时间要远一点，平均大约两个半月。两个实验距离木星冲日的时间差距大约为半个月。因此理论上第一次实验测量的结果会比第二次实验的结果要大一些。

实际情况是，第一次实验罗俊小组测量的引力常数数值为：

$$(6.67352 \pm 0.00019) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

第二次实验测得的引力常数为：

$$(6.67346 \pm 0.00021) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

按照表 2 的计算，如果第 1 次实验的数据加上 0.000008G 木星的影响，则第一次实验结果为

$$(6.67357 \pm 0.00019) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

第 2 次实验比木星冲日时间要多两个半月。根据表 2，可以看出第二次实验结果比木星冲日点的引力常数要少 0.000011G. 这样第二次实验数据加上 0.000011G 的木星影响，第二次数据将变成：

$$(6.67354 \pm 0.00021) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

可以看出实验数据有明显改善。

如果再考虑地球轨道的影响，第一次实验平均测量时间大约为 4 月，第二次实验平均测量时间大约为 10 月。

这样按照表 1，第一次实验校正后的数值为：

$$(6.67347 \pm 0.00019) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

第二次实验校正后的数值为：

$$(6.67331 \pm 0.00021) \times 10^{-11} \mathrm{m}^3/\mathrm{kg} \cdot \mathrm{s}^2$$

Table 5.

Time	J. oppsition	Experiment	Jupiter	Earth
21/3 – 20/5/2007	5/6/2007	6.67352	6.67357	6.67347
19/4 – 10/5/2008	9/7/2008			
25/8 – 28/9/2008	9/7/2008	6.67346	6.67354	6.67331
8/10 – 16/11/2008	9/7/2008			

这三个数据中，如果仅仅考虑木星的影响，数据有明显改善。但是如果考虑到地球轨道的影响，则数据反而恶化了。

3.5 HUST-18

HUST-18 是最新的测量结果。其中的扭称角加速度反馈法(AAF)分成三年来进行测量，测量时间分别是

Time	Method	Value (×10⁻¹¹m³kg⁻¹s⁻²) (Estimated)
12/2014 – 01/2015	AAF-I	6.67452
04/2016 – 06/2016	AAF-II	6.67438
09/2017 – 11/2017	AAF-III	6.67455

考虑木星影响，AAF-I 距离木星冲日时间 2015 年 02 月 06 日差一个半月，G 测量值最大。

AAF-II 距离木星冲日时间 2016 年 03 月 08 日差两个月，G 的测量值略小。

AAF-III 距离木星冲日时间 2017 年 04 月 07 日差六个月，G 最小。

Table

Time	Method	J. oppsition	Experiment	Earth	Jupiter
12/2014 – 01/2015	AAF-I	06/02/2015	6.67452	6.67419	6.67422
04/2016 – 06/2016	AAF-II	08/03/2016	6.67438	6.67435	6.67440
09/2017 – 11/2017	AAF-III	07/04/2017	6.67455	6.67422	6.67442

Where, the unit of gravitational constant is ($\times 10^{-11} m^3 kg^{-1} s^{-2}$).
“Jupiter” means that considering the influence of the Jupiter’s position.
“Earth” means that considering the influence of the earth's orbital position.

可以看出考虑木星和地球轨道位置的影响，改善的不是很明显，主要是 AAF-I 校正后的数据明显偏小。但是它的好处在于能够比较好地解释为什么 AAF-II 的测量数值是最小的。因为在这期间地球轨道的位置离太阳的距离最远。

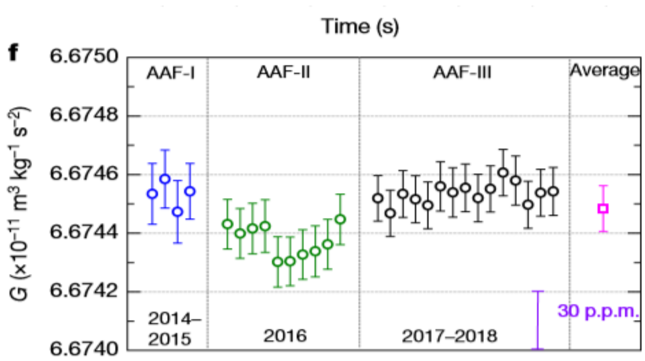

Figure 3. The AAF results of HUST-18 [3]

4 引力常数变化对水星近日点的影响

从论文[13]的计算可以看出，目前考虑到 parameterized post-Newtonian 的参数影响，理论计算存在一定的误差范围，因此按照广义相对论计算出来的理论值范围在：(42.9779±0.0009)”[14]

而目前 Pireaux 从 EPM2001 星图中提取出来的结果是现在精度比较高的[15, 16]，观察值范围

达到 43.0005’’-43.0200’’.

从上面可以看出，在非常高精度的理论计算和观察值之间还是存在一定的误差。

如果考虑到引力常数变化的影响，则矫正以后的数据为 43.0174"，正好跟观察值是一致的。当然 EPM2017 的推出，则使得水星近日点进动的观察值精度有很大的提高，从原来的±0.0085’’提高到了±0.008’’ [17]，即最新的观测值范围为 43.0010’’-43.0195’’，仍然跟理论计算一致。

5 银河系外围小星系的运动方式

Clark M. Thomas 指出，大星系外部存在很多古老的小星系。如果考虑这些小星系会被大星系的引力所吸引，则这些星系的运动将是随机的 [18]。然而实际情况则不是这样。比如在银河系外围的已经被观察到的小星系，它们的运动方式跟银河系内部的其他恒星的运动方式基本上是一样的，速度大约都是 204km/s.

因此这些星系的运动方式无法用基于牛顿或者是广义相对论的星系旋涡理论来进行解释。但是如果考虑到本文所提出的这种银河系三层结构来进行分析，就可以发现这些银河系外围的小星系地位跟银河系内部的其他恒星系地位是一样的，自然其运动方式也应该一样。

6 结论

究竟什么是“时空”，这是一个基本的物理学问题。新的模型的提出，将有助于我们理解一些过去难以解释的问题和现象。

过去长时间被忽略的一个问题就是电子和质子的静电场能量。虽然正负静电场的场强可以相互抵消，但是静电场能量却似乎无法抵消。毕竟电子的半径要远小于质子的半径。因而这也就导致了电子所拥有的静电场能量要超过质子所拥有的静电场能量。那么这些静电场能量到哪里去了？新的时空结构模型认为这些静电场能量并没有消失，而是成为了构成各种物质需要依赖其存在的“时空”。

有了这样的新的“时空”模型之后，一些问题变得更容易理解，就是时空跟质量一样，也是一种能量存在的形式。而时空本身也可以被质量挤压，形成引力。如果我们能够对这种新模型中的时空的性质有更多的了解，或许可以用来揭开引力和电磁相互作用之间的关系。

新的时空模型带来了的另一个结论就是引力常数或许不是一个常量，而是随着时空被压缩程度的不同而不断产生变化的。

在太阳系中对地球上测量到的引力常数产生影响的因素主要包括两个，一个是地日距离的影响。另一个是木星的影响。其中地日距离的影响更大一些。如果过去的一些引力常数测量数值考虑到这两个因素影响之后，都可以在一定程度上改善所测量数值的精度。当然我们也注意到其中存在一些并没有改善，甚至导致结果恶化的情况。这其中存在的问题值得深入探讨，或

许将有助于完善新的时空模型。

另一个可以用来证明引力常数可能会不断变化的证据是水星近日点进动的修正。如果考虑到水星轨道位置的引力常数可能跟地球位置的引力常数有所不同，则将对水星近日点进动的理论分析数值带来一些比较微小的修正。从而使理论计算与实际观测值符合的非常好。

感谢

在我这段时间对引力常数的变化和新的时空模型的思考过程中，我跟 Dr. Rupert Sheldrake 就引力常数变化问题进行了非常有益的讨论。在他的提示下，我重新思考了影响引力常数变化的其他因素。另外也要感谢来自俄罗斯的 Lev Verkhovsky，我跟他探讨了有关参照系尺度的变化问题，发现他的一些想法跟我的想法比较接近。

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