Effect of dark matter fluids on gravitational constant measurements

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Abstract

This paper explores the possibility of experimentally testing the viscosity of dark matter fluids in laboratories on Earth's surface. From the theoretical calculation results, the viscous force of dark matter fluid and gravity are basically the same order of magnitude as the gravitational force. At the same time, because the experimental devices for measuring the gravitational constant are very precise and can accurately sense changes in gravity, we believe that the existing experimental devices for measuring the gravitational constant can be used to measure the viscosity of dark matter fluids. Since the experiment is carried out on the ground, it is convenient to control various parameters artificially. In this paper, the influence of the viscous force of dark matter fluid on the measurement results of gravitational constant is discussed by analyzing the existing experimental device for measuring the gravitational constant by the angular acceleration feedback (AAF) method. This paper argues that in some current experiments on measuring the gravitational constant by angular acceleration feedback methods, the influence of the viscous force of dark matter fluids has been ignored. If the influence of the viscous force of dark matter fluid is taken into account, the problem of inconsistent results of different experiments can be better solved. After the introduction of the viscosity of dark matter fluids, the upper and lower limits of the gravitational constant (HUST-19) measured by the angular acceleration feedback method of Huazhong University of Science and Technology can be extended to $6.674351 \times 10^{-11} m^3 \cdot kg^{-1} \cdot s^{-2}$ and $6.674551 \times 10^{-11} (m^3 \cdot kg^{-1} \cdot s^{-2})$, which can improve the inconsistency with the time-of-swing method results to a certain extent.

1 Introduction

If there is a large amount of dark matter fluid in the space-time of the universe, and this dark matter fluid is disturbed during the flow process, elementary particles of visible matter can be produced. Examples include electrons, protons, and neutrons [1]. These elementary particles formed by the turbulence generated by dark matter fluids are also affected by the viscous force of dark matter fluids [2].

From the observation facts, if this dark matter fluid exists, then their viscous force on visible matter will produce some observable cosmic scale effects. For example, the incline of the rotation axis of a star or planet that occurs during the movement of a galaxy. From the calculation results, this dark matter fluid model can predict the rotation axis tilt of stars or planets in the movement of galaxies [2]. After all, it is still difficult to solve the problem of the rotation axis of stars or planets from the current physical theories.

So can the viscous force of this dark matter fluid on visible matter produce observable effects on the scale of ground laboratories? After analysis, this paper believes that because the viscosity of dark matter on visible matter is equal to the effect of gravity in magnitude, the various experimental devices that can be used to measure the gravitational constant on Earth should be used to measure the viscosity of dark matter fluids. This also provides us with a very effective way to conduct dark matter fluid experiments on the scale of ground laboratories. At the same time, the results of this paper also provide a new perspective to explain how different the various measurements of gravitational constants currently being made can be.

The reason for these different measurement results of the gravitational constant is that dark matter fluids are not taken into account for experiments. For example, the impact of the Earth's rotation. Since the Earth is constantly rotating, the direction of the force of the dark matter fluid on the attraction ball also changes from time to time. If very effective measures are not taken into account to reduce this error, the effect of the viscous force of dark matter fluid will lead to a relatively large error in the results of the experiment. According to some important experimental results, these laboratories are located in cities at different latitudes. For example, the Gravity Experiment Center of Huazhong University of Science and Technology is located in Wuhan, 30 degrees north latitude. The gravitational experiment in Seattle, Washington, was conducted at 47 degrees north latitude. Experiments at these two different latitudes will cause the effect of dark matter fluids on the mass of the attraction ball in the laboratory to become very different. This may also be an important reason for the large difference in the values of gravitational constants obtained by the two laboratories.

2 Differences between the two methods of gravitational constant measurement

At present, there are two main methods for measuring the gravitational constant [3]. The first is the time-of-swing method (TOC). Since the attraction ball in the time-of-swing method does not move, the viscosity of the dark matter fluid will be relatively small. An important error that this method is easy to cause is that the elastic coefficient of the fiber is difficult to ensure that it is linear. Because when measuring the effect of gravity on the torsion, the twist angle of the fiber must be taken into account. This torsion’s twist angle is mainly influenced by the fiber material. Especially in laboratory measurement processes, if more accurate data is required, a larger twist angle of the fiber is required. A large fiber twist angle means that the fiber twists into a nonlinear region. This in turn creates greater system error. Therefore, although this measurement method has been improved over the decades, its accuracy is still very limited. After all, the improvement of the accuracy of the entire experiment depends on the development of materials science.

The second is the angular acceleration feedback method (AAF). This angular acceleration feedback method was proposed in the 50s of the last century [4]. However, due to the complexity of the experimental setup, there are currently only two laboratories in the world that can complete this experiment better. The two laboratories are the laboratory in Seattle, Washington [5] and the laboratory of Huazhong University of Science and Technology [6]. The angular acceleration feedback method mainly uses two different turntables to ensure that the gravitational moment and the moment of inertia of the torsion pendulum are equal by adjusting the angular acceleration of the torsional pendulum. In this case, the torsion does not produce a torsion angle. The torsional angle is zero, which ensures that the measurement results do not cause serious systematic errors due to nonlinear problems with the torsional suspension fiber.

Therefore, in principle, the angular acceleration feedback method should be able to obtain more accurate gravitational constant results. However, due to the complexity of the device, there are not many laboratories in the world that can carry out this experiment. However, it is believed that with the increasing requirements for the measurement accuracy of gravitational constants in the future, the use of angular acceleration feedback to measure gravitational constants will become a mainstream.

At present, the angular acceleration feedback method has two turntables, including a turntable for placing the attraction ball and a turntable for suspension of the torsion, and the two move relative to each other at the same time. At the same time, the entire measurement process lasts a relatively long time, generally lasting about three to six days. In such a long time, the Earth also rotated three to six times. This means that the direction of the viscous force of the dark matter fluid changes by three to six cycles. Therefore, the uncertainty of the influence of the viscous force of dark matter fluid on the measurement results becomes relatively large.

Of course, in the angular acceleration feedback method, four to eight attraction balls placed symmetrically are used. These symmetrically placed attraction balls are subject to the same direction of the viscous force of the dark matter fluid, so the effect of the viscous force of the dark matter fluid they produce can cancel each other. However, when we delved deeper into the angular acceleration feedback method, we found that although these attraction balls are very symmetrical, their masses will be slightly different. For example, in the experimental setup of Huazhong University of Science and Technology, the mass difference between the two pairs of corresponding attraction balls reached $1g$. Considering that the viscous force of dark matter fluids is about the same as gravity in order of magnitude, although the mass of these four balls reaches $32kg$, their mass difference is only $1g$, and the error can still rreach1/30,000. This error may not seem large, but for the current gravitational constant experimental results can reach 10 ppm, this error must be reduced to 1/100,000 to obtain more ideal results. The calculation results also prove that the difference between the results measured by the current angular acceleration feedback method and the results measured by the time-of-swing method has indeed reached an error of 10ppm.

In order to more accurately analyze the systematic errors caused by the viscous force of dark matter fluids in the angular acceleration feedback method, and understand the causes of these systematic errors, we make a more detailed calculation here.

First of all, we summarize the parameters of some equipment used by Huazhong University of Science and Technology in the experimental process. Among them, the mass of AAF's Pendulum is 40g, the mass of AAF's suction ball is: $m \approx m_A \approx m_B \approx m_C \approx m_D \approx 8.54kg$, the diameter of the four suction balls is 0.127m. and the rotation speed of the suction ball is ω=2.79$mrad/s$, corresponding to the period

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{2.79 \times 10^{-3}} = 2250(s)$$

The distance from the center of mass of the ball to the center of torsional pendulum is $R = 0.17m$.

According to the results of paper [2], the velocity of dark matter relative to the attraction sphere is $8 \times \frac{10^7 m}{s}$, and $\mu = 10^{-31} Pa \cdot s$, so that the viscosity of the dark matter fluid subjected to the four attraction balls is

$$f_T = m_T f_{1kg} \approx 2.67 \times 10^{12} m_T \pi \mu v \approx 6.71 \times 10^{-11} m_T$$

Where

$$m_T = m_A + m_B + m_C + m_D \approx 4m$$

Figure 1 shows the force on a single attraction ball. The angle 23.4° is the inclination of the Earth's axis. 60° is the angle between the position of the laboratory of Huazhong University of Science and Technology and the axis of the earth.

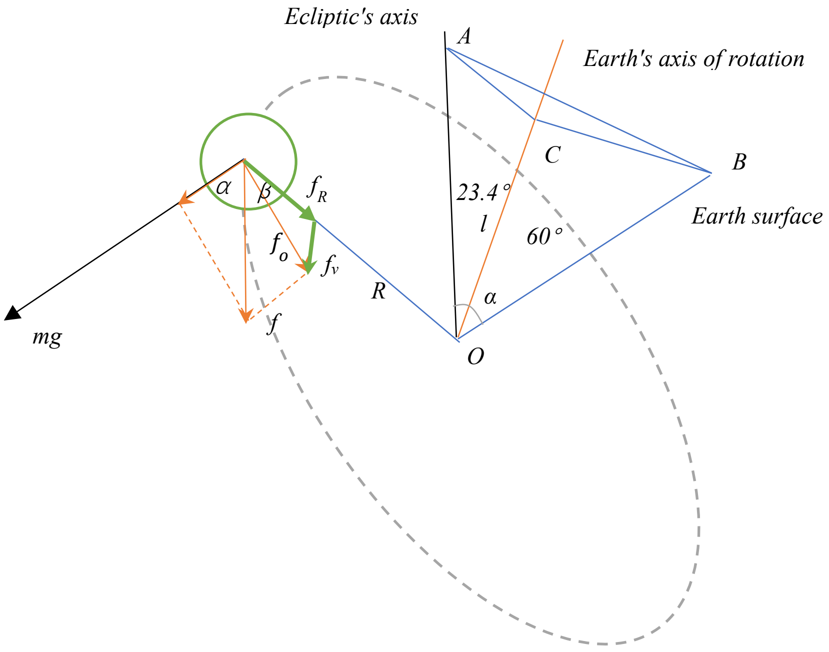

Figure 1. Force analysis of the attraction ball

Figure 1 plots the force of an attraction ball. where mg is the direction of gravity, that is, the direction of the vertical experimental plane in the laboratory. The viscous force of the dark matter fluid produces a direction that is inconsistent with the direction of gravity, because the Earth's axis of rotation is deflected. At the same time, the position of the laboratory is located above the latitude of a certain angle of the earth, which causes the viscosity of the dark matter fluid to form an angle α the direction of gravity.

The viscous force f of the dark matter fluid is projected into the orbital plane of the attraction ball to form a perpendicular force f_o. The force forms the two force components of f_R and f_v in the radius of the attraction ball orbit and the tangent direction of the orbit, respectively. The angle between f_o and f_R is β.

Since f_R is directed towards the center of mass of the torsional pendulum, no torque is generated, which does not affect the rotation of the torsion and attraction ball. Therefore, only the f_v component can affect the acceleration of the attraction ball and the rotation angle of the torsional pendulum.

However, because the entire angular acceleration feedback method measures for a relatively long time, due to the rotation of the earth in the measurement process, it will cause the viscous force of the dark matter fluid to rotate around the direction of gravity during the test of a cycle. The cycle is 24 hours. The angular velocity is $\Omega = 7.27 \times 10^{-5}\, rad/s$

This can be seen from Figure 1

$$\Omega = \frac{d\angle ACB}{dt} = \frac{d\varphi}{dt}$$

This is the angular velocity of the Earth's rotation.

$$cos\varphi = \frac{AC^2 + BC^2 - AB^2}{2AC \cdot BC} = \frac{l^2 \tan^2 23.4° + l^2 \tan^2 60° - AB^2}{2l^2 tan23.4° \cdot tan60°} = b(a - \frac{AB^2}{l^2})$$

And

$$AB^2 = OA^2 + OB^2 - 2OA \cdot OBcos\alpha = l^2 \left(\frac{1}{cos^2 23.4°} + \frac{1}{cos^2 60°} - \frac{2cos\alpha}{cos\, 23.4° \, cos60°} \right)$$

Or

$$AB^2 = l^2(c - dcos\alpha)$$

Then

$$cos\varphi = b[a - (c - dcos\alpha)] = b(a - c + dcos\alpha) = e + hcos\alpha$$

$$hcos\alpha = cos\varphi - e$$

$$cos\alpha = \frac{-e + cos\Omega t}{h}$$

$$sin\alpha = \sqrt{1 - \left(\frac{-e + cos\Omega t}{h}\right)^2}$$

Where a, b, c, d, e, f are the constants.

$$a = \tan^2 23.4° + \tan^2 60°$$

$$b = \frac{1}{2tan23.4° \cdot tan60°}$$

$$c = \frac{1}{cos^2 23.4°} + \frac{1}{cos^2 60°}$$

$$d = \frac{2}{cos\ 23.4°\ cos60°}$$

$$e = b(a - c)$$

$$h = bd$$

Since the viscous force of dark matter fluid is different from the direction of gravity and the normal direction of the attraction ball orbit, the viscous force will form the component of the viscous force of dark matter in different directions for a certain period of time. Among them, the acceptance component perpendicular to the radius of the orbit has an effect on the angular acceleration of the attraction ball f_v. This force is located in the tangent direction of the orbit, so it can be directly accelerated or decelerated by the angular acceleration of the attraction ball. Due to the requirement of conservation of angular momentum, a small acceleration or deceleration of the attraction ball will affect a large change in the angular acceleration of Pendulum, which will cause the measured gravitational constant to deviate from the normal value.

Of course, if the masses of all attraction balls are completely equal, and these attraction balls are arranged symmetrically, the direction of f_v is also exactly the same, so that the moment formed by the rotation of all attraction balls around the torsional center of mass is also equal and can cancel each other out. This means that the viscous force of the dark matter fluid does not affect the angular momentum of the attraction ball. However, because the masses of the attraction balls are not exactly equal, there is an imbalance in the torque. The difference in the quality of these attraction balls is

$$\Delta m = 8543.5826 + 8540.5282 - 8541.4167 - 8541.5575 \approx 1.14g \tag{1}$$

As can be seen from Figure 1, the viscous force of dark matter fluid attracting a single ball along the gravitational direction is

$$f_g = fcos\alpha$$

The other two directions are

$$f_v = fsin\alpha sin\beta$$

$$f_R = fsin\alpha cos\beta$$

Of these three force analyses, we only need to consider f_v. Then we find the average over a measurement period

$$\overline{f_v} = \frac{1}{T}\int_0^T fsin\alpha sin\omega tdt = \frac{1}{T}\int_0^T f\sqrt{1-\left(\frac{e-cos\Omega t}{h}\right)^2}\,sin\omega tdt$$

$$= \frac{-1}{T\omega}\int_0^T f\sqrt{1-\left(\frac{e-cos\Omega t}{h}\right)^2}\,dcos\omega t$$

where T is the experimental measurement of one period of rotation of the attraction ball, which is 2250s.

From the numerical calculation results, if the entire experiment is completed in just one day, the moment generated by the viscous force of the dark matter fluid can cancel each other.

However, the reality is that the start time and end time of the experiment may be inconsistent, and there will be a little error. From the situation disclosed in the paper [6], AAF experiments generally last 3 to 6 days, so $216T$ is taken as the upper limit here. From the numerical calculations in Figure 2, the range of change is between [-0.002, 0.004] after about the fifth day. We can take the upper limit of 0.004 and the lower bound of -0.002.

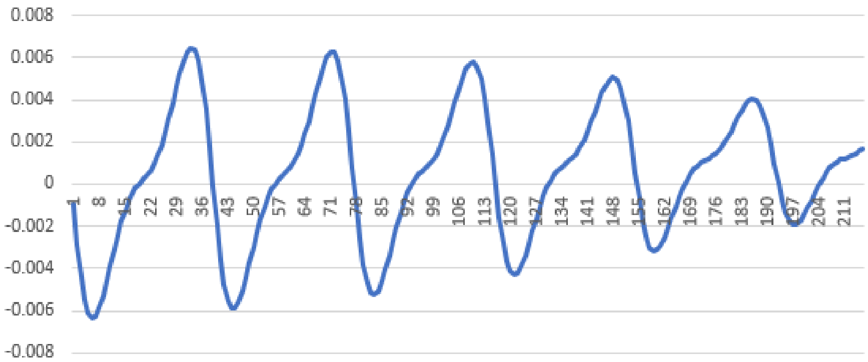

Figure 2. Calculation results of the change in viscosity force of dark matter

Consider the upper limit of the viscosity force of $0.004f$ first, ie

$$\overline{f_v} \approx 0.004 \times 6.71 \times 10^{-11} m \approx 2.68 \times 10^{-13} m$$

The viscous force produced by the mass difference of the four attraction balls is

$$\Delta\overline{f_v} \approx 0.004\Delta f \approx 2.68 \times 10^{-13}\Delta m$$

It can be seen that this resistance force is still relatively large. Even if the actual experimental time is limited, the viscosity of this dark matter fluid will still have a considerable impact. From the calculation results, the shorter the duration of the experiment, the greater the impact of the viscous force of dark matter fluids.

The angular acceleration of the attraction ball produced by this force is

$$\bar{\alpha} = \frac{\Delta\overline{f_r}}{m_T R} = \frac{2.68 \times 10^{-13} \times 1.14 \times 10^{-3}}{34.16 \times 0.17} \approx 5.27 \times 10^{-17}(rad \cdot s^{-2})$$

According to the conservation of angular momentum, the change in the angular momentum of the attraction ball is transferred to the torsion. namely

$$m_T R\bar{\alpha} + \frac{1}{12} m_p (a^2 + b^2)\Delta\alpha_e = 0$$

Therefore, the change in torsional angle acceleration is

$$\Delta\alpha_e = -\frac{12 m_T R\bar{\alpha}}{m_p (a^2 + b^2)} = -174216\bar{\alpha} = -9.18 \times 10^{-12}(rad \cdot s^{-2})$$

The average amplitude of the angular acceleration of the torsional pendulum measured experimentally is

$$\alpha_e = 462 \times 10^{-9}(rad \cdot s^{-2})$$

It can be seen that the effect of the angular acceleration generated by the viscous force of the dark matter fluid on the angular acceleration of the pendulum is

$$p = -\frac{9.18 \times 10^{-12}}{462 \times 10^{-9}} = -2.0 \times 10^{-5}$$

Considering that the acceleration of the torsional angle velocity is proportional to the gravitational constant, the experimental measured value of the gravitational constant change is

$$\triangle G = pG = -2.0 \times 10^{-5} G = -1.33 \times 10^{-15}\, m^3 \cdot kg^{-1} \cdot s^{-2}$$

$$G_c = G + \triangle G = 6.674484 \times 10^{-11} - 1.33 \times 10^{-15}\, m^3 \cdot kg^{-1} \cdot s^{-2}$$

$$G_c = 6.674351 \times 10^{-11}\, m^3 \cdot kg^{-1} \cdot s^{-2}$$

For the lower bound of -0.002*f*, the corresponding change in gravitational constant is

$$G_c = 6.674551 \times 10^{-11}\, m^3 \cdot kg^{-1} \cdot s^{-2}$$

The average value measured by the TOC method is

$$G_c = 6.674184 \times 10^{-11}\, m^3 \cdot kg^{-1} \cdot s^{-2}$$

Therefore, if the influence of dark matter viscosity is considered, the problem of inconsistency between the two experimental measurements should be solved to a certain extent. Of course, because this is the systematic error that may be caused by the viscous force of the dark matter fluid, as long as some factors in the experimental process are effectively controlled, such as the start measurement time and the end measurement time, if it can be accurate to an integer multiple of 24 hours, this systematic error should be eliminated to a certain extent.

4 Conclusions

Through the analysis of this paper, it is proved that the influence of the viscous force of dark matter fluid on the measurement of gravitational constant is very obvious. The influence of the viscous force of dark matter fluid on the measurement of gravitational constant is mainly manifested in the fact that the attraction ball of relatively large mass motion is affected by the viscous force of dark matter and produces additional torque. This additional moment can cause these attraction balls to generate angular acceleration, and then transfer this angular acceleration to the torsion pendulum by conserving angular momentum, which in turn causes a change in the angular acceleration of the torsional pendulum, and then the sensor measures a changed angular acceleration. The value of the gravitational constant calculated from this changing angular acceleration will be larger or smaller than the true gravitational constant.

In this paper, the experiments of angular acceleration feedback method to measure the gravitational constant conducted by Huazhong University of Science and Technology are analyzed. It is pointed out that because the entire experimental process lasts relatively long, it is not necessarily an integer multiple of 24 hours, which leads to the moment generated by the viscous force of dark matter cannot be canceled out during the entire experimental period. The results of the measurement may depend on how long the experiment continues after the end of the experimental cycle. If the experiment were to end immediately after the full 24-hour cycle, the effect of dark matter viscosity might not be too obvious. However, if it is completed in the subsequent measurement cycles, it may have a large impact on the measured gravitational constant. Of course, as the subsequent extended measurement time becomes longer and longer, this effect may begin to gradually weaken.

The effect of the viscous force of dark matter fluid on the measurement results of the gravitational constant is also related to the latitude of the laboratory where the measurement is located. Theoretically, laboratories with low latitudes, because the angle between the laboratory plane and the Earth's axis of rotation is relatively large, resulting in a larger angle between the direction of the viscous force of the dark matter fluid and the direction of gravity, which should cause a greater impact on the viscosity force of the dark matter fluid, and the measurement in the area with a relatively high latitude The resistance of the dark matter fluid and the angle between the direction of gravity are relatively small, and the results measured at this time should be affected by the viscosity force of the dark matter fluid should be relatively small.

Of course, the influence of the viscous force of dark matter fluid on the experimental measurements of the gravitational constant can be eliminated by dealing with the symmetry of the attraction ball and the torsion. For example, if the masses of all four or eight attraction balls are exactly equal, then the effects of this viscous force of the dark matter fluid can cancel each other out without additional effect on the experimental results.

Of course, from the analysis of this paper, it can also be seen that the viscous force of dark matter fluid is comparable to gravity in orders of magnitude. This also shows that in fact, the effect of the viscous force of dark matter fluids is also very obvious. If we rationally arrange the various factors in the experiment to eliminate these symmetries, then the viscosity of dark matter fluids will be more obvious and easier to measure. This also provides a breakthrough for measuring the viscosity of dark matter fluids and various other parameters of the dark matter fluids in the ground laboratory in the future.

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