Effective range of gravitation

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Abstract: It is generally believed that both gravitational and electromagnetic forces belong to macroscopic interactions. However, since the smallest unit of matter is impossible to be infinitely small, the gravity or electromagnetic force cannot be infinitely small too. When these two macroscopic interactions are less than a certain value, it can be considered that there is no longer any interaction. How to determine the interaction range of gravitation, this article mainly analyzes by using the Planck length as the smallest unit of spacetime. It is assumed that if the gravitational potential changes across spacetime of Planck length less than a certain energy value, it indicates that gravitational potential cannot cross the Planck length. The gravitation will disappear as a result. From this, it is inferred that the effective interaction range of the gravitational force is related to the size of the mass. According to the gravitational effective range of the sun, the gravitational effective range of the huge mass of the galaxy's center can be calculated, and then the diameter of the galaxy's core can be calculated.

Keywords: Universal gravitation; Interaction; Milky Way

1 Introduction

There are two main theories about gravitation, which are Newton's gravity theory and general relativity. Newton's theory of gravity is an approximation of general relativity in flat spacetime. The general theory of relativity is mainly applied near very large masses. If you stay away from large masses, the spacetime becomes flat, and general relativity can be approximated as Newton's theory of gravity.

However, there is a problem with this approximation. According to Newton's gravitational theory or general theory of relativity, the interaction distance of gravitation should be infinite, even though the gravity is very, very small at infinite distance. This is in contradiction with the laws of physics. After all, if the structure of matter is small enough, it will face the limitations of quantum laws.

Another problem is the speed of gravity. Since an observing system can always be found to observe that the mass is in a moving state, the main form of gravitation that can separate from the mass of the object and interact with distant mass is gravitational waves. It's just that the frequency of this gravitational wave is relatively low compared to ordinary mass motion.

Since it is the propagation of gravitational waves, it must carry energy. When this energy encounters other masses, it may be absorbed by these masses. This causes energy of gravitational waves to experience the attenuation in the mass during propagation. In this case, when the gravitational wave is relatively weak, this attenuation will cause the range of the gravitational force to become limited.

Combining the above two situations, we can see that the scope of gravity is not able to affect infinitely distant spacetime, as predicted by existing gravitational theories. There is a relatively limited range of gravity. Of course, from the perspective of human observation, this limited range of action may be as long as several light years. So relative to humans, this is still a very long distance. However, relative to the entire spacetime, this limited range of influence will have a very large impact on the composition of matter in the universe.

2 Estimating the lower energy limit using solar system data

First, let's determine the minimum scale of space-time. As for the minimum scale of space-time, from the perspective of virtual space-time physics [1], when the space-time scale is smaller than a Planck length, it will enter virtual space-time. So we can use Planck length as the smallest unit of scale in space-time. In other words, the continuous space-time we are seeing is actually discontinuous, or jumping, from a very small scale. It's like an image is made up of the smallest pixels. It's just that the pixel dimension of space-time is very small, about the length of a Planck.

After determining the minimum scale of space-time, we can make the following assumptions:

If the gravitational potential energy per unit mass across the smallest dimension of space-time (Planck length) changes less than a certain value, the gravitational force will not be able to propagate to the space-time beyond this Planck length.

Of course, gravity meets the requirements of the superposition principle. Therefore, although the gravitational force generated by a certain mass cannot cross a certain Planck length, if other masses provide a new gravitational gravity at this position, and the superimposed gravitational gravity exceeds the minimum gravitational potential, the overall effect of the gravitational force can still travel through the Planck length.

This can be expressed by the following formula:

First the gravitational potential difference:

$$\Delta V = \frac{GM}{r} - \frac{GM}{r + l_p} \approx \frac{GMl_p}{r^2}$$

If

$$\Delta V < \varepsilon$$

Then

$$\frac{GMl_p}{r^2} < \varepsilon \qquad (1)$$

Or

$$r > \sqrt{\frac{GMl_p}{\varepsilon}} \qquad (2)$$

Among them, it is difficult to determine the minimum energy ε in theory. It is because this energy is affected by many factors. This may include various quantum effects, as well as the effects of various masses on the propagation of gravitational waves. In order to obtain a more accurate minimum energy value, we can use the gravitational range of the solar system to determine. At present, our research on the solar system still has some relatively direct observation data. These figures are relatively accurate.

From the results of some observations or theoretical calculations, if the position of Neptune is used as a standard, the radius of the solar system can stably bind the planet to 40AU. If the boundary radius of the interaction between solar wind and interstellar wind is viewed, this radius is about 120AU. If the calculation is based on the farthest Oort Cloud, the gravitational range of the solar system is about 100,000AU, which is about

$$r \approx 1.5 \times 10^{16} m$$

In this way, we can determine that the minimum energy is approximately:

$$\varepsilon = \frac{GMl_p}{r^2} = \frac{6.67 \times 10^{-11} \times 2 \times 10^{30} \times 1.6 \times 10^{-35}}{2.25 \times 10^{32}}$$

The *M* is the mass of the sun. This can be calculated:

$$\varepsilon = 9.5 \times 10^{-48} J/kg$$

This is a very small amount of energy. Such as 1*eV*= 1.6021766208(98)$\times 10^{-19}$ *J*

Also note that the minimum energy solved here has taken into account all factors, including the effects of quantum effects and galaxy mass on gravitational waves. Therefore, the data can be used to estimate the gravitational range of a larger range of mass galaxies and even super clusters.

3 Estimation of core radius of spiral galaxy

For example, for the Milky Way, the core part reflects the radius of the core mass that can stably bind the stars. This is similar to the planetary system of the solar system. Considering that the mass of the galaxy's core is about 4 million solar masses, That is $4 \times 10^6 M_{\odot}$

If calculated according to formula (2), its radius is approximately

$$r = 3 \times 10^{19}\text{m}$$

This distance is in the range of approximately 3,000 light-years.

Of course, this is calculated based on the Oort Cloud that exists around the solar system. The reality is that with such weak gravity, the solar system cannot bind large planets. Therefore, in order to effectively bind the large mass in the spiral galaxy, it can be calculated by referring to the farthest planet restrained by the solar system. This distance is about 100AU, That is 1.5×10^{13}m.

According to the galaxy center's $4 \times 10^6 M_{\odot}$ mass, it can be estimated that the radius of the galaxy core is approximately

$$r = 3 \times 10^{16}\text{m}$$

That is about 3 light years. It is now known that the Milky Way’s core mass accumulation range is about 10 light years. This reflects that the above estimation of about 3 light years is basically applicable. The mass beyond the core of the Milky Way is mainly due to the vortex movement around the core caused by each galaxy being pulled by nearby masses. It's like a whirlpool of liquid.

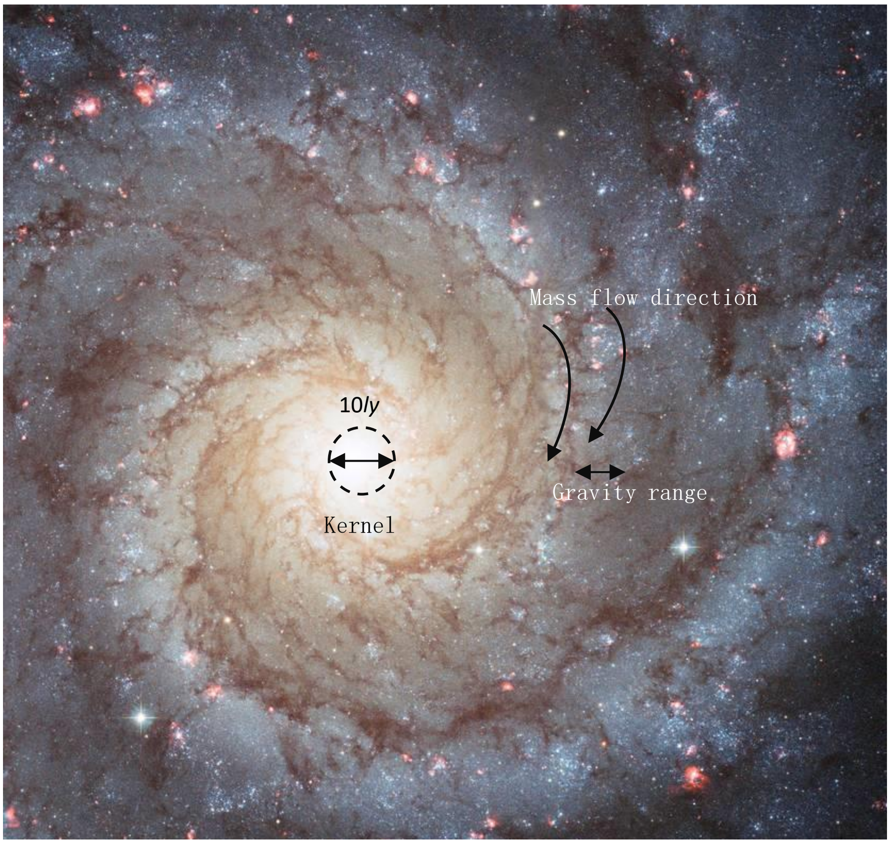

Figure 1 Structure of M74 galaxy

（Source: https://www.nasa.gov/multimedia/imagegallery/image_feature_2132.html）

Figure 1 shows the structure of a galaxy M74 galaxy. In its core part is about 10 light years. The reason why it can show that the core part is significantly different from other parts is that the core area is a region where gravitation can directly interact. The direct action of this gravitational force also causes the core of the spiral galaxy to present a spherical structure, forming a "bulge" at the center of the disc. At the periphery of the core area, because the gravity of the core area cannot reach that far, the material flow in the periphery is actually pulled by the viscosity of the fluid generated by the limited gravitational interaction, and the mass flow is generated. This mass flow conforms to the basic laws of fluid mechanics. Therefore, it also accords with the law of conservation of mass flow and particle flow. Like the following form

$$\frac{\partial}{\partial t}\varphi + \nabla \cdot J = 0$$

Since the mass motion of the galaxy's periphery moves according to the law of fluid, rather than the inverse square relationship of the central force, the speed of the stars' motion at all levels of the galaxy's periphery is basically the same. It also avoids the assumption of dark matter.

4 Summary

From the above analysis, as a kind of macro force, universal gravity has a limited distance of interaction. It does not extend to infinity as we imagined. The reason for this effect is that if gravitation can work at infinity, the entire universe should be a very large structure moving around a center of mass. However, in fact, our existing astronomical observation technology shows that different galaxies and super clusters in the universe are equal to each other. Just like the different molecular structures in a homogeneous liquid. To understand it from the viewpoint that the gravitational action distance is limited. The matter in the entire universe can be understood as the ions in the liquid that can move freely. There is an interaction between these "ions", but the distance between the interactions is very limited, which makes the liquid viscous, which in turn forms various motion structures in the galaxies.

If such a model is correct, it may bring us a new universe view. This new model of the universe is very different from the existing model of the universe. That is, our current universe may be infinite, rather than limited as claimed by old models of the universe. Dark matter may still exist, but since some problems do not require dark matter to explain it now, these "dark matter" may be rare, or it may be a completely different form.

Reference

[1] Cheng, Z (2019). Foundations of Virtual Spacetime Physics. LAP LAMBERT Academic Publishing

万有引力的有效作用范围

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摘要：一般认为万有引力和电磁力都属于宏观相互作用。然而由于构成物质的最小单位是不可能无限小的。故万有引力或者电磁力不可能无限小。当这两种宏观相互作用小于一定的数值的时候，就可以认为已经不再存在任何相互作用了。如何确定万有引力的相互作用范围，本文主要从普朗克长度来进行分析，假设如果在跨越普朗克长度时空的引力势变化小于某个能量数值，则表明引力势无法穿越普朗克长度，引力将因此而消失。由此推算出万有引力的有效作用长度与质量的大小有关系。按照太阳的引力有效作用范围可以推算出银河系中心巨大质量的引力有效作用范围，进而推算出银河系核心的直径。

Аннотация: Принято считать, что гравитационные и электромагнитные силы относятся к макроскопическим взаимодействиям. Однако, поскольку наименьшая единица вещества не может быть бесконечно малой, гравитационная или электромагнитная сила также не может быть бесконечно малой. Когда эти два макроскопических взаимодействия меньше определенного значения, можно считать, что взаимодействия больше нет. Как определить диапазон взаимодействия гравитации, эта статья в основном анализируется с использованием длины Планка как наименьшей единицы пространства-времени. Предполагается, что если гравитационный потенциал изменяется в пространстве-времени длины Планка меньше определенного значения энергии, это указывает на то, что гравитационный потенциал не может пересечь длину Планка. В результате гравитация исчезнет. Из этого следует, что эффективный диапазон взаимодействия гравитационной силы связан с размером массы. В соответствии с эффективным гравитационным диапазоном Солнца, эффективный гравитационный диапазон огромной массы центра галактики может быть рассчитан, а затем может быть рассчитан диаметр ядра галактики.

关键词：万有引力；相互作用；银河系

1 引言

有关万有引力的理论主要有两个，分别是牛顿万有引力理论以及广义相对论。牛顿万有引力理论是广义相对论在平坦时空的近似。而广义相对论则主要应用在非常大的质量附近。如果远离大质量，则这个时候时空变得平坦，广义相对论可以近似为牛顿万有引力理论。

然而这种近似却存在一个问题，就是按照牛顿万有引力或者广义相对论，万有引力的相互作用距离应该是无限远，即便无限远处万有引力已经非常非常小。这跟我们熟知的物理学规律是相矛盾的，毕竟物质结构小到一定的程度之后，就面临量子规律的局限了。

另一个问题就是引力传播的速度影响。由于总是可以找到一个观测系观测到质量是处于运动状态的，而万有引力之所以能够脱离物体质量并对遥远的质量产生相互作用，其主要形式就

是引力波。只是相对于普通质量的运动，这种引力波的频率比较低而已。

既然是引力波的传播，就一定会携带能量。而这种能量遇到其他质量的时候，就有可能会被这些质量所吸收。这导致引力波在传播的时候遇到了物质质量会出现衰减的情况。这样在引力波比较弱的情况下，这种衰减将会导致万有引力的作用范围变得有限。

综合上面的两种情况，可以证明，万有引力的作用范围并非如同已有的引力理论预言的那样，是能够作用于无限遥远的时空的，而是存在一个比较有限的作用范围。当然对于人类的观察视野来看，这种有限的作用范围可能长达几光年。因此相对于人类来说，这还是一个非常长的一个距离。然而相对于整个宇宙时空来说，这种有限作用范围对宇宙中的物质构成就会产生非常大的影响。

2 用太阳系数据估算能量下限

首先我们来确定时空的最小尺度。对于时空的最小尺度是多少，从虚时空物理学[1]的观点来看，在时空尺度小于一个普朗克长度的时候，将进入虚时空。因此我们可以将普朗克长度作为时空最小的尺度单位。也就是说我们现在看到的连续时空实际上从非常微小的尺度来看，是不连续的，或者说是跳跃式的。就像一幅图像是由最小的像素构成的一样。只是时空的像素尺度非常小，大约一个普朗克的长度。

确定了时空的最小尺度之后，我们就可以做下面的假设：

如果跨越时空最小尺度（普朗克长度）的单位质量万有引力势能变化小于某个特定的数值，则万有引力将不能传播到该普朗克长度之后更远的时空。

当然万有引力满足叠加原理的要求。因此虽然某个质量产生的万有引力不能够穿越某个普朗克长度，但是如果有其他的质量在该位置提供了新的万有引力，叠加后的万有引力超过了最小的引力势，则万有引力的整体效应还是可以穿越过去。

这可以用下面的公式来进行表示：

首先引力势差：

$$\Delta V = \frac{GM}{r} - \frac{GM}{r + l_p} \approx \frac{GMl_p}{r^2}$$

如果：

$$\Delta V < \varepsilon$$

则：

$$\frac{GMl_p}{r^2} < \varepsilon \qquad (1)$$

或者：

$$r > \sqrt{\frac{GMl_p}{\varepsilon}} \qquad (2)$$

其中在理论上确定最小能量ε比较困难。这是因为该能量受到多种因素的影响。其中即可能包括了各种量子效应，也还包括了各种质量对引力波传播的影响。为了获得比较准确的最小能量的数值，我们可以使用太阳系的引力范围来进行确定。目前我们对太阳系的研究还是有一些比较直接的观测数据的。这些数据相对来说比较准确。

从一些观察或者理论计算的结果来看，如果按照海王星的位置作为标准，太阳系能够稳定地束缚行星的半径为 40AU. 如果按照太阳风和星系风相互作用的边界半径来看，这一半径大约 100AU. 而如果按照目前观测到的最远的依奥尔特云来进行计算，太阳系的引力范围大约为 100000AU, 即大约

$$r \approx 1.5 \times 10^{16} m$$

这样我们就可以通过公式（1）确定出最小能量大约为：

$$\varepsilon = \frac{GMl_p}{r^2} = \frac{6.67 \times 10^{-11} \times 2 \times 10^{30} \times 1.6 \times 10^{-35}}{2.25 \times 10^{32}}$$

其中的质量 M 取太阳质量。这样可以求出：

$$\varepsilon = 9.5 \times 10^{-48} J/kg$$

这是一个非常小的能量。比如 1*eV*= 1.6021766208(98) $\times 10^{-19}$ J

另外注意到这里求解出来的最小能量已经考虑到了所有因素，包括量子效应、星系质量对引力波的影响。因此该数据可以用来估算更大范围的质量星系，乃至超级星团的万有引力作用范围。

3 螺旋星系的核心半径估算

比如对于银河系，其核心部分反映出的是核心质量能够稳定束缚恒星的半径范围。这类似于太阳系的行星系统。考虑到银河系核心的质量大约为 400 万太阳质量，即$4 \times 10^6 M_\odot$

如果按照公式（2）的计算，其半径大约为

$$r = 3 \times 10^{19}\text{m}$$

这个距离大约为 3000 光年的范围之内。

当然由于这是按照太阳系周围存在的依奥尔特云来进行计算的。实际情况是，这么弱的引力，

太阳系是无法束缚行星的。因此螺旋星系的核心为了能够有效地束缚住质量，可以参照太阳系束缚住的最远的行星来进行计算。这一距离大约 100AU，即$1.5 \times 10^{13}\mathrm{m}$.

按照银河系中心$4 \times 10^{6} M_{\odot}$质量则可以估算出银河系核心的半径大约为：

$$r = 3 \times 10^{16}\mathrm{m}$$

即大约 3 光年。现在已知其核心的质量聚集范围大约为 10 光年。这反映上述 3 光年左右的估算是基本适用的。而超出了银河系核心范围的质量则主要是由于每个星系受到附近的质量牵引而产生的绕核漩涡运动。这就如同液体的漩涡一样。

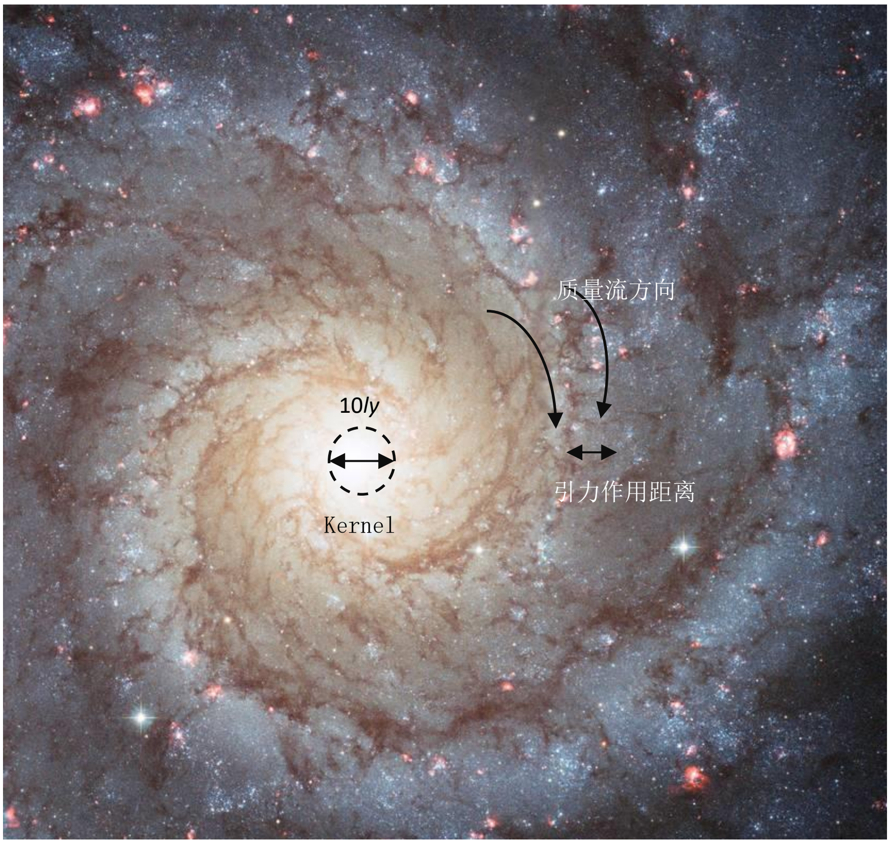

图 1 M74 星系结构图

（Source: https://www.nasa.gov/multimedia/imagegallery/image_feature_2132.html）

图 1 显示了一个类似于银河系的 M74 星系结构图。在其中核心部分大约 10 光年。之所以能够显示出核心部分与其他部分显著不同的原因在于该核心区域是万有引力能够直接相互作用的区域。而这种万有引力的直接作用也导致了螺旋星系核心部分呈现球形的结构，形成一个圆盘中心的“隆起”。在核心区域外围，由于核心区域的万有引力无法达到那么远的距离，因此外围的物质流实际上是依靠有限的万有引力相互作用所产生的流体粘性互相牵引，进而产生的质量流的流动。这种质量流的流动符合流体力学的基本规律。因此也符合质量流和粒子流守恒的规律。比如下面的形式：

$$\frac{\partial}{\partial t}\varphi + \nabla \cdot J = 0$$

由于星系外围质量运动是按照流体的规律来运动，而非有心力的平方反比关系，因此星系外围各层次恒星运动的速度基本是相同的，这与天文学观察结果是一致的。而且还可以避开暗物质的假设。

4 总结

从上面的分析来看，万有引力作为一种宏观力，在宇宙的尺度来看，其相互作用的距离是有限的。而并非我们想象的那样能够延伸到无限远处。之所以出现这样的效果，原因在于如果按照万有引力在无穷远的地方还能够起作用，则整个宇宙的结构应该是一个非常庞大的围绕一个质量中心运动的结构。然而事实上我们现有的天文学观测技术表明，宇宙中不同的星系、超级星团之间是相互平等的。就像一个均匀的液体中的不同的分子结构一样。如果用万有引力作用的有限距离这一观点来进行理解。则可以将整个宇宙中的物质理解成液体中可以自由运动的离子一样，这些"离子"间存在相互作用，但是相互作用的距离非常有限，从而使得液体产生了粘滞性，进而形成星系中物质各种不同的运动结构。

如果这样的模型是正确的，那可能会带来我们一个全新的宇宙观。这种新的宇宙模型与现有的宇宙模型是有很大区别的。即我们现在的宇宙也许将是无限的，而并非过去的宇宙模型所宣称的那样是有限的。暗物质也许仍然存在，但由于一些问题现在已经不需要暗物质来进行解释，故这些"暗物质"也许是极少的，或者是完全不同的另一种形式。

参考文献：

[1] Cheng, Z (2019). Foundations of Virtual Spacetime Physics. LAP LAMBERT Academic Publishing