Radio Physcics and Radio Astronomy, 2001, v. 6, No. 2, pp. S89–S92

SUPERMASSIVE COMPACT OBJECT WITHOUT EVENTS HORIZON IN GAS ENVIRONMENT

E. Yu. Bannikova [1] **and L. V. Verozub** [2]

Kharkov National University,
Svobody Sq.4, Kharkov 61077, Ukraine

A simplest model of a supermassive object without event horizon in a gas environment, that are similar to the ones in the Galaxy center, is considered. It is shown that at the spherically symmetric accretion onto such an object the luminosity is about $10^{37} erg/s$ which agrees with low luminosity of the Galactic center.

1. Introduction

An analysis of the observation data gives evidence for the existence of a massive (about $2.6 \cdot 10^6 M_\odot$) compact object in the Galactic center [1-4] The observation data do not allow to make a definite conclusion about the nature of the object. For this reason it is identified, as a rule, with a supermassive black hole [5-7].Another possibility is considered in the present paper.

Bimetric gravitation equations, the spherically symmetric solution of which have no the events horizon and physical singularity in flat space-time from the viewpoint of a remote observer were proposed in paper [8]. The radial component of the gravity force F affecting a test particle with mass m in the spherical coordinate system in flat space-time is given by

$$F = -m \left[c^2 B^1_{00} + (2B^0_{01} - B^1_{11})v^2\right]. \quad (1.1)$$

Here B^1_{00}, B^0_{01} and B^1_{11} are the nonzero components of the strength tensor $B^\gamma_{\alpha\beta}$ of gravity field in flat space-time:

$$B^1_{00} = \frac{C'}{2A},\ B^0_{01} = \frac{C'}{2C},\ B^1_{11} = \frac{A'}{2A}, \quad (1.2)$$

where $f = (r_g^3 + r^3)^{1/3}$, $r_g = 2GM/c^2$ is the Schwarzschild radius, v is the radial component of a particle velocity and

$$C = 1 - \frac{r_g}{f},\ A = \frac{r^4}{f^4 C}.$$

Fig 1 shows the function F (in arbitrary units) of the distance r/r_g.

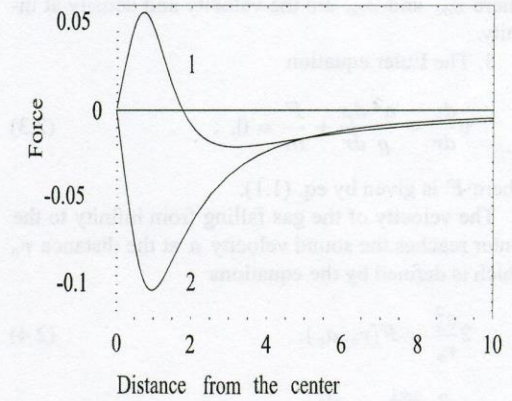

Fig. 1. *The gravitational force F (in arbitrary units) as the function of r/r_g acting on free falling particles (the curve 1) and particles at rest (the curve 2).*

It is shown in the paper [9] that equilibrium stable configurations of the degenerated Fermi - gas with masses up to $10^9 M_\odot$ or more than that can exist in the above theory. So, we can suppose that such a kind of the object can be found in the Galaxy center.

2. Peculiarity of accretion onto the massive objects without events horizon

Consider the object without the events horizon with the mass $2.6 \cdot 10^6 M_\odot$ in the center of a spherically symmetric gas medium. Let us assume that the gas density is sufficient to describe the gas motion by using the hydrodynamics equations and the state equation is $P = K\rho^\gamma$ where P is the gas pressure, ρ is

[1] e-mail: bannikova@astron.kharkov.ua
[2] e-mail: verozub@gravit.kharkov.ua

the density, K and γ are constants. For numerical estimates we assume in this paper that $\gamma = 4/3$.

The following equations are used here for describing the system [10].

1. The integral of the continuity equation

$$4\pi r^2 v\rho = \dot{M}, \tag{2.1}$$

where v is the radial gas velocity at the distance r from the center, $\dot{M} \equiv dM/dt$ is the mass rate of accretion.

2. The adiabatic relationship between the sound velocity a and the density ρ

$$\rho = \rho_\infty \left(\frac{a}{a_\infty}\right)^{2/(\gamma-1)}, \tag{2.2}$$

where v_∞ and ρ_∞ are the velocity and density at infinity.

3. The Euler equation

$$v\frac{dv}{dr} + \frac{a^2}{\rho}\frac{d\rho}{dr} + \frac{F}{m} = 0, \tag{2.3}$$

where F is given by eq. (1.1).

The velocity of the gas falling from infinity to the center reaches the sound velocity a at the distance r_s which is defined by the equations

$$2\frac{a_s^2}{r_s} = F(r_s, a_s), \tag{2.4}$$

$$r_s^2 a^{\frac{\gamma+1}{\gamma-1}} = \frac{\dot{M}}{4\pi Q},$$

where a_s is the value of a at $r = r_s$,

$$Q = \frac{\rho_\infty}{a_\infty^{2/(\gamma-1)}}.$$

In contrast to the Newtonian gravity law, equations (2.5) may have two solutions. For example, at $a_\infty = 10^7 cm/s$, at the density of the particles number $n_\infty = 10^3 cm^{-3}$ and at $\dot{M} = 10^{-6} M_\odot/year$, the numerical solution of eqs. (2.5) yields

$$r_{s1} = 5.3 \cdot 10^{15} cm \qquad a_{s1} = 1.7 \cdot 10^8 cm/s$$
$$r_{s2} = 5 \cdot 10^{10} cm \qquad a_{s2} = 6.5 \cdot 10^8 cm/s.$$

The radius R of the central object can be found by a numerical solution of the equation of the hydrodynamical equilibrium and is equal to $0.04 r_g$ ($3 \cdot 10^{10} cm$).

The reason of the appearance of the second solution is that the gas velocity of a particle falling from infinity increases up to the distances of the order of the Schwarzschild radius and after that decreases according to the peculiarity of the gravity force.

Eqs. (2.1), (2.2) and (2.3) can be written in the form

$$v' - \frac{2K}{D} r^{1-2\gamma} v^{1-\gamma} + \frac{F}{D} = 0, \tag{2.5}$$

where

$$D = v - K r^{-2(\gamma-1)} v^{-\gamma},$$
$$K = a_\infty^2 (A/\rho_\infty)^{\gamma-1}$$

and

$$A = \dot{M}/4\pi.$$

We find the function $v(r)$ as a result of the numerical solution of eq. (2.5). Fig. 2 shows v as the function of r in the range from $1.4 \cdot 10^{11} cm$ up to the surface of the central object.

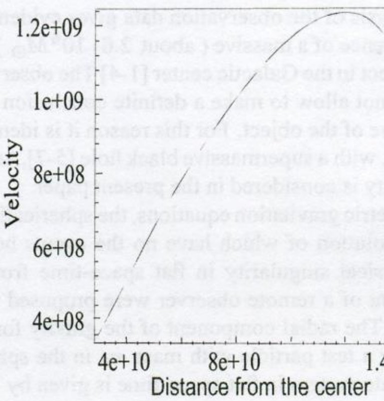

Fig. 2. *The velocity v (cm/s) as the function of r (cm) from $1.4 \cdot 10^{11} cm$ to the surface of the central object.*

3. Luminosity

The force of the radiation pressure at the radial distance r from the center is given by

$$F_{rad} = \frac{L\sigma_T}{4\pi r^2 c}, \tag{3.1}$$

where L is the luminosity and $\sigma_T = 0.66 \cdot 10^{-24} cm^2$. The Eddington's limit of the luminosity

$$L_{Ed} = \frac{4\pi r^2 c}{\sigma_T} F, \tag{3.2}$$

where F is given by eq. (1.1), is a function of r, and is equal to $10^{38} erg/s$ at the $r = R$.

The "impact" luminosity is

$$L_{im} \approx v^2(R)\, \dot{M}, \tag{3.3}$$

where $v(R)$ is defined by eq.(2.5) at $r = R$. For the object under consideration $v(R) = 2.3 \cdot 10^8 cm/s$ and at $\dot{M} = 10^{-6} M_\odot/year$ we obtain $L_{im} \approx 10^{37} erg/s$, that is observed luminosity of Sgr A*. This fact is noteworthy because the explanation of the low luminosity of the Galaxy center at the spherically symmetric accretion is a central problem [5, 6, 7]

4. Ionization Radius

There must be an ionization zone around the central object without events horizon (the same as around neutron stars [11]) which depends on the temperature of the central object and the physical conditions in the gas environment.

An effective temperature of the object is given by

$$T_* = \left(\frac{L}{4\pi\sigma_T R^2}\right)^{1/4} \tag{4.1}$$

where L is the luminosity of the object and σ is the Stephan-Boltzmann constant. For example, at $L = 10^{37} erg/s$ the temperature $T_* = 5.4 \cdot 10^4 K$. The maximum of the radiation corresponds to the wavelength about 560 $\AA$

Let us assume that the number of neutral atoms, ions and electrons per unit volume is n_1, n_+ and n_e, respectively. We shall assume that $n_e = n_+$. At these conditions $n_1 = (1 - X)n$, where $n = n_1 + n_+$ is the total number density and $X = n_+/(n_1 + n_+)$ is the degree of the ionization at the distance r from the center.

Then at the distance r from the center the Saha formula can be written as:

$$n\frac{X^2}{X-1} = B\,\exp(-\tau), \tag{4.2}$$

where

$$B = \frac{g_+}{g_1} W \left(\frac{T_e}{T_*}\right)^{1/2} \frac{2(2\pi m k T_*)^{3/2}}{h^3} \times \ln\left[1 - \exp(\frac{-h\nu_1}{kT_*})\right]^{-1}, \tag{4.3}$$

T_e is the electronic temperature, g_+ and g_1 are the statistical weights of the ions and the atoms of the ground state, respectively, ν_1 is the ionization frequency,

$$W = \frac{1}{2}\left[1 - \sqrt{1 - \left(\frac{R}{r}\right)^2}\right] \tag{4.4}$$

is the dilution factor, τ is the optical thickness that we define as

$$\tau = [1 - X(r)]\, k_\nu \int_R^r n(r')dr', \tag{4.5}$$

where the function $X(r)$ is the solution of eqs. (4.2) and (4.5). The constant k_ν is the averaged absorption coefficient.

The function $n(r)$ can be found as

$$n(r) = \frac{\dot{M}}{4\pi r^2 m_p v(r)}. \tag{4.6}$$

For numerical estimates we assume that T_e as the function of the distance r is given by

$$T_e = T_{e\infty}\,(\rho/\rho_\infty)^{\gamma-1}. \tag{4.7}$$

Setting, for example, $T_* = 6 \cdot 10^4\ K$ (which corresponds to $L = 10^{37}\ erg/s$) and $T_{e\infty} = 220\ K$ (which corresponds to $v_\infty = 10^7\ cm/s$) we obtain by a numerical solution of eq. (4.2) the function X of r. The function $X(r)$ decreases from 1 to 0.1 when r increases from R to $10^{14} cm$. Fig. 3 shows the ionization degree X as the function of $z = \log(r)$ inside the interval from R to $10^{14}\ cm$.

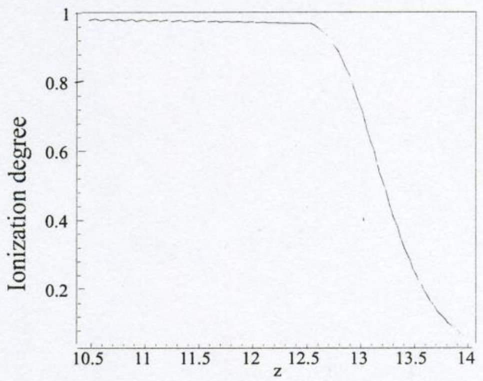

Fig. 3. *The ionization degree* X *as the function of* $z = \log(r)$ *from the radius* R *to* 10^{14} cm.

5. Conclusion

The above a simple model is an alternative to the supermassive black hole in the Galaxy center hypothesis. We hope that a more detailed consideration of the problem and a detailed analysis of the observations will lead to more definite conclusions.

References

[1] A. Eckart and R. Genzel *MNRAS*, **284**, 576 (1997)

[2] A. M. Ghez, M. Morris et al. *Nature*, **407**, 349 (2000)

[3] K. M. Menten, M. J. Reid et al. *ApJ*, **475**, 111 (1997)

[4] F. Yusef-Zadeh, F. Melia et al. *Science*, bf 287, 85 (2000)

[5] H. Falcke and P.L. Biermann *A&A*, **342**, 49 (1999)

[6] F. Melia *ApJ*, **426**, 577 (1994)

[7] R. Yi. I Narayan and R. Mahadevan *Nature*, **374**, 623 (1995)

[8] L. V. Verozub *Phys. Lett. A*, **156**, 404 (1991)

[9] L. V. Verozub *Astr. Nach.*, **317**, 107 (1996)

[10] S. L. Shapiro and S. A. Teukolski, Black Holes, White Dvarfs, and Neutron Stars. Jon Wiley & Sons (1983)

[11] В. Ф. Шварцман *Астрон.ж.*, **47**, 824 (1970)

СУПЕРМАССИВНЫЕ КОМПАКТНЫЕ ОБЪЕКТЫ БЕЗ ГОРИЗОНТА СОБЫТИЙ В ГАЗОВОЙ СРЕДЕ

Е. Ю. Банникова, Л. В. Верозуб

Ранее было показано, что уравнения тяготения, предложенные одним из авторов, допускают существование устойчивых супермассивных конфигураций вырожденного Ферми-газа без горизонта событий. В настоящей работе рассматривается простейшая модель такого объекта в газовой среде с характеристиками, близкими к существующим в центре Галактики. Показано, что светимость за счет столкновения газа с поверхностью составляет около 10^{37}эрг/с, что согласуется с наблюдаемой низкой светимостью Sgr A*.

НАДМАСИВНІ КОМПАКТНІ ОБ'ЄКТИ БЕЗ ГОРИЗОНТУ ПОДІЙ В ГАЗОВОМУ СЕРЕДОВИЩІ

О. Ю. Баннікова, Л. В. Верозуб

Раніше було показано, що рівняння тяжіння, які були запропоновані одним із авторів, дозволяють існування стійких надмасивних конфігурацій виродженого Фермі-газу без горизонту подій. В даній праці розглядається найпростіша модель такого об'єкта в газовому середовищі з характеристиками, які близькі до існуючих в центрі Галактики. Показано, що світність за рахунок зіткнення газу з поверхнею складає близько 10^{37} ерг/с, що узгоджується зі спостереженою низькою світністю Sgr A*.