RADIATION FROM VICINITY OF SUPERMASSIVE OBJECT WITHOUT EVENTS HORIZON

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ABSTRACT. Spectra of the radiation arising at interaction of the spherically symmetric accreting flow with the matter of the atmosphere of the supermassive compact object without events horizon are found.

Key words: Galactic center, Sgr A*.

1. Introduction

The observations of the Galactic center give evidences that a supermassive compact object can be identified with the nonthermal radiosource Sgr A * (Eskart A. and Genzel R., 1996), (Eskart A. and Genzel R., 1997), (Ghez A.M., et al., 1998). The mass of this object is equal to $(2.6 \pm 0.2) \cdot 10^6 M_\odot$. It is supposed that similar supermassive compact objects exist also in the nuclei of other galaxies (Ferrarese F., et al., 1996), (Iyomoto N., et al., 2001), (Miyoshi M., et al., 1995). These objects are usually identified with a supermassive black hole, but there are also other attempts to explain the observation data (Tsiklauri D. and Violler R.D., 1998), (Torres D., et al., 2001). In the paper (Verozub L.V., 1996) another possibility was proposed, which is based on bimetric gravitation equations(Verozub L.V., 1991), the spherically symmetric solution of which has no a physical singularity in flat space-time from the viewpoint of a remote observer. The physical consequences from the equations coincide with the consequences from the Einstein equations at the distances, much larger than the Schwarzshild radius $r_g = 2GM/c^2$, however the ones essentially differ from them at $r \leq r_g$. According to the equations the events horizon is absent in the spherically symmetric solution. The radial component of the gravity force F affecting a test particle with mass m in the spherical coordinates system in flat space-time is given by

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

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

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

$f = (r_g^3 + r^3)^{1/3}$, v is the radial component of the particle velocity, the prime is the derivative on r,

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

It follows from these equations that there can exist

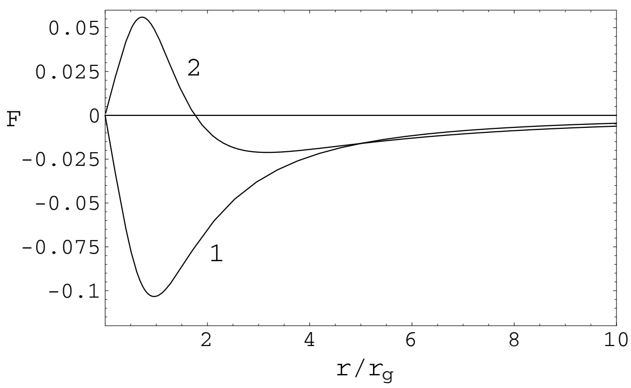

Figure 1: The gravitational force F (in arbitrary units) as the function of r/r_g affecting a particles at rest (the curve 1) and free falling particles (the curve 2).

the equilibrium stable configurations of the degenerated electronic gas with masses up to $10^9 M_\odot$ or more than that and with the radius less than Schwarzshild radius (Verozub and Kochetov, 2001). Such objects are an alternative to black holes.

The object without events horizon, unlike the black hole has a surface and atmosphere, a radiation from which at an accretion can be essential. In this paper a simplified model of the radiation arising at interaction of the spherically symmetric accreting flow with the matter of the atmosphere of such an object is considered without taking into account the magnetic field.

2. The radiation from the vicinity of the object

To find a spectrum of the radiation arising from the atmosphere, we find the profiles of temperature and matter density near to the surface using a method by Zeldovich and Shakura (1969).

Let's introduce parameter $y = \int_{R_0}^{\infty} \rho dR$, where ρ is the matter density, R is the radial coordinate. This parameter characterizes a quantity of the matter which was decelerated. The quantity of the matter of the atmosphere needed to the complete stop, we shall designate through y_0. Similarly (Zeldovich and Shakura, 1969) we will assume that $5 < y_0 < 20$.

The transfer of the radiation in the atmosphere is governed by the equation for the radiation energy density U which, in spherically symmetry and using the Eddington approximation, can be written as:

$$\frac{1}{3}\frac{dU}{dy} = k_1 \frac{L}{4\pi R_*^2 c}, \tag{2}$$

where $L = L_\infty (y_0 - y)/y$, L_∞ is the total radiative luminosity at outer edge of the atmosphere, R_* is the radius of the object. It follows from the solution of the equations of the hydrostatic balance that to the given value of the mass of the central object $M_* = 2.6 \cdot 10^6 M_\odot$ corresponds radius $R_* = 0.04 r_g$ (Verozub and Kochetov, 2001). Taking into account the scattering and bremsstrahlung, the mean opacity it is possible to write down: $k_1 = k_{es} + k_p$, where $k_{es} = 0.4\ cm^2/g$ is the coefficient of the scattering on free electrons, $k_p = 6.4 \cdot 10^{22} \rho T^{-7/2}$ cm^2/g is the Planck mean opacity, T is the gas temperature.

The equation of the hydrostatic balance and radiative energy equilibrium is

$$\frac{dP}{dy} = \frac{GM_*}{R_*^2}\left(1 - \frac{r_g}{(r_g^3 + R_*^3)^{1/3}}\right), \tag{3}$$

$$\frac{W}{c} = k_p(aT^4 - U) + 4k_{es}U\frac{kT}{m_e c^2}(1 - \frac{T_\gamma}{T}), \tag{4}$$

where $W \approx L_\infty/(4\pi R_*^2 y_0)$ is the energy, that release on 1g. of the matter at $y \le y_0$. At $y > y_0$, $W = 0$.

We neglect pressure in a layer y_0, which is created by the falling particles since it is much lower than the pressure due to the matter of the atmosphere, and also we use the perfect gas equation of state assuming that the matter is the completely ionized hydrogen. The radiation temperature T_γ is related to U as $U = aT_\gamma^4$, where $a = 7.56 \cdot 10^{-15}$ erg/(cm^{3}grad^4). Thus, we have received the system of differential equations (2), (3), (4), the solutions of which are U, T, ρ as the functions of y. The boundary condition at the outer edge is $U(0) = L_\infty/(4\pi(R_* + H)^2 c) \approx L_\infty/(4\pi R_*^2 c)$, where H is the height of the atmosphere; $\rho(0) = 10^{-12}$g/cm^3 corresponds to the solution of the equations of the spherically symmetric accretion near the surface (Verozub L.V. and Bannikova E.Yu., 1999); $T(0) = 10^5$K (the solution there exists only for $T(0) < 4 \cdot 10^5 K$). L_∞ end y_0 are the parameters. The thermal properties of the atmosphere are illustrated in fig.2 for different luminosities at outer edge of the atmosphere in the case $y_0 = 20$g/cm^2. The solution slightly depends on the boundary conditions. Near the surface $\rho(y_0) \approx 5 \cdot 10^{-6}$g/cm^3. The height of the homogeneous atmosphere is

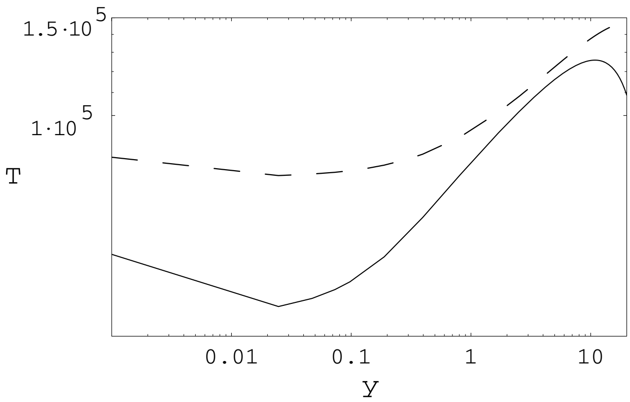

Figure 2: The temperature T as the function of y for $L_\infty = 10^{38}$erg/s (dashed line) and $L_\infty = 10^{37}$erg/s (solid line).

$$H = \frac{kTR_*^2}{\mu m_p GM_*}\left[1 - \frac{r_g}{(r_g^3 + R_*^3)^{1/3}}\right]^{-1} \tag{5}$$

and for the maximum temperature $H \approx 10^6$cm.

To find the spectrum of the radiation, it is necessary to take into account the gravitational redshift and gravitational capture of the radiation by the central object, as in the case for a black hole (Shapiro and Teukolsky, 1985). The light frequency ν measured close the object is related to the light frequency ν_0 as measured at infinity:

$$\nu = \left(1 - \frac{r_g}{(r_g^3 + r^3)}\right)^{-1/2} \nu_0. \tag{6}$$

At $r = R_*$ obtain $\nu = 216.5\nu_0$. The equations of motion of a test particle in the spherically symmetric field is

$$\left(\frac{dr}{dt}\right)^2 = \frac{c^2 C}{A}\cdot\left[1 - \frac{C}{\overline{E}^2}\left(1 + \frac{r_g^2 \overline{J}^2}{B}\right)\right], \tag{7}$$

$$\frac{d\varphi}{dt} = \frac{cC\overline{J}r_g}{B\overline{E}}, \tag{8}$$

where (r, φ, θ) are the spherical coordinates, $B = f^2$, $\overline{E} = E/(mc^2)$, $\overline{J} = J/(r_g mc)$, E is the particle energy, J is the angular momentum. If we through ψ denote the angle between a direction of motion of the photon and the radius, taking into account the equations of motion (7) and (8) we receive

$$\mathrm{tg}\,\psi = \frac{b_{\max} r^2}{f^3}\left(1 - \frac{Cb_{\max}^2}{f^2}\right), \tag{9}$$

where $b_{\max} = 3\sqrt{3}/2$. Fig.3 shows $|\cos\psi|$ as the function r/r_g. Take into account to scattering and gravi-

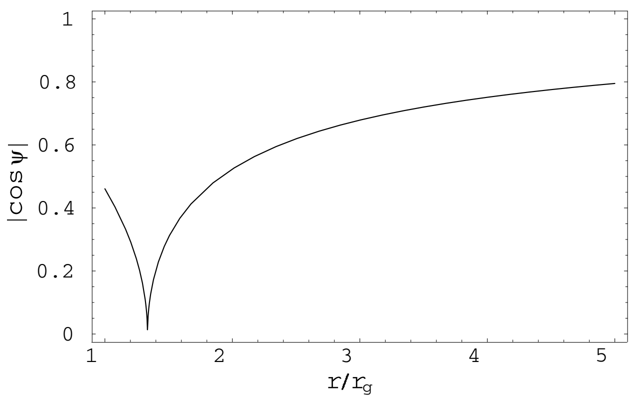

Figure 3: The plot $|\cos\psi|$ versus r/r_g.

tational effects we found that the flow of the radiation is

$$F_{\nu_0} \approx (1 - \cos\psi(R_*))\,\pi B_{\nu_0}\sqrt{\frac{\chi}{k_{es}+\chi}}, \qquad (10)$$

where $\chi = 1.14\cdot 10^{56}T^{-1/2}\nu^{-3}\,(1-\exp(-h\nu/(kT)))\,\varrho$, ν is determined by expression (6) at $r = R_*$. The values of T and ρ correspond to the solution of the system (2), (3), (4) at $y = y_0$. Thus we obtain the following results.

a) Let $L_\infty = 10^{37}$erg/s. Thus $k_{es} < \chi$ at the frequency interval $\nu_0 < 10^{14}$Hz and the atmosphere radiates as a black body; at $\nu_0 > 10^{14}$Hz ($k_{es} > \chi$) and taking into account that the atmosphere of the object is not homogeneous (density grows very quickly with depth), the flow of the radiation (Zeldovich and Shakura, 1969)

$$F_{\nu_0} \approx (1 - \cos\psi(R_*))\left(\frac{3\chi}{\rho k_{es}^2 H}\right)^{1/2}\pi B_{\nu_0}, \qquad (11)$$

where B_{ν_0} is the Planck function. The maximum of the frequency spectrum is at $\nu_0 \approx 5\cdot 10^{13}$Hz and corresponds the luminosity $L_{\nu_0} \approx 10^{19}$erg/(s· Hz).

b) For $L_\infty = 10^{38}$erg/s the radiation is a black body at the frequency interval $\nu_0 < 3\cdot 10^{13}$ ($k_{es} < \chi$); at $\nu_0 > 3\cdot 10^{13}$Hz the flow of the radiation is according to (11). Here the maximum of the frequency spectrum is at $\nu_0 \approx 10^{13}$Hz with the appropriate value of the luminosity $L_{\nu_0} \approx 10^{22}$ erg/(s·Hz). In figures 4 and 5 the frequency spectra in the vicinity of the maximums for the various luminosities is shown. Both cases are considered at $y_0 = 20$g/cm^2. Thus the spectrum 5) are in accordance with the observation data of the Galactic center.

3. Conclusion

It follows from the above results that the our hypothesis that Sgr A* is a supermassive compact object without events horizon does not contradict the observation results and required further deeper investigation.

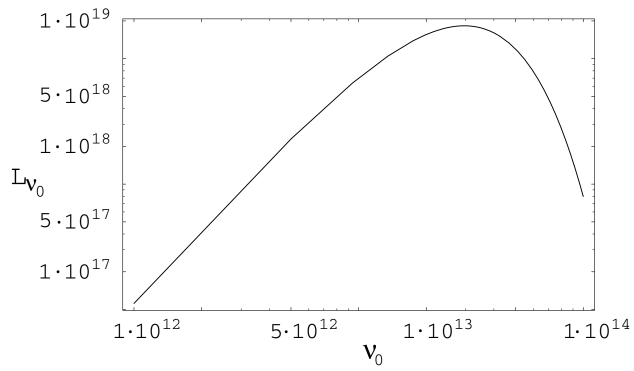

Figure 4: The frequency spectrum for $L_\infty = 10^{37}$erg/s.

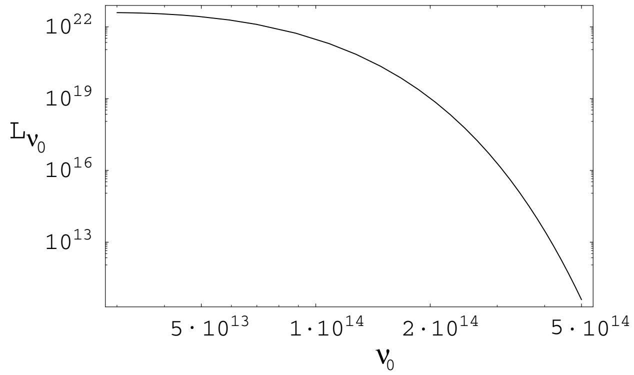

Figure 5: The spectrum for $L_\infty = 10^{38}$erg/s.

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