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On the orbital velocities nearby rotary stars and black holes

T. De Mees - thierrydemees@pandora.be

Abstract

Observation of some huge spinning black holes in the centre of galaxies, and surrounded by orbiting stars, shows that stars close-by the black hole orbit at much higher speeds than normally expected, whereas the velocity of stars at higher distances suddenly falls down to normal values.
In a former paper "On the shape of rotary stars and black holes" I found the analytic expressions for the forces on rotary stars and black holes, due to the *gyrotation* forces. These forces are generated by the second field of gravitation, based on the Maxwell Analogy for Gravitation[5,6,7,8] (or historically more correctly: the Heaviside[2] Analogy for Gravitation). In earlier papers, I showed the great workability of this analytical method, at the condition that the "local absolute velocity" is defined in relation to a major gravitational field instead of the "observer system" as with GRT. I found so the detailed explanation for the double-lobes explosions of supernova, and for the equator explosions.
Here, I deduct the velocity distribution of orbital objects nearby or farther away from rotary stars or black holes.

Keywords. Maxwell Analogy – gravitation – star: rotary – black hole – torus – gravitomagnetism – methods : analytical
Photographs : ESA / NASA

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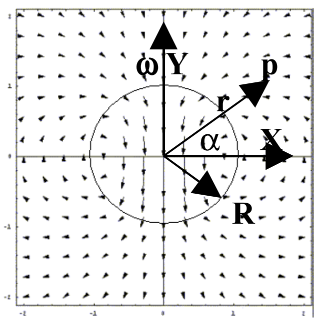
1. Introduction : the Maxwell analogy for gravitation (gravitomagnetism).

The Maxwell Analogy for gravitation can be put in compact equations, originally given by Heaviside[2, 3, 5]. Electrical charge is then substituted by mass, magnetic field by gyrotation, and the respective constants as well are substituted (the gravitation acceleration is written as $\mathbf{g}$, the so-called "*gyrotation field*" as $\mathbf{\Omega}$, and the universal gravitation constant as $G = (4\pi\ \zeta)^{-1}$. I use sign $\Leftarrow$ instead of $=$ because the right hand of the equation induces the left hand. This sign $\Leftarrow$ will be used when we want to insist on the induction property in the equation. $\mathbf{F}$ is the induced force, $\mathbf{v}$ the velocity of mass m with density ρ. Operator $\times$ is used as a cross product of vectors. Vectors are written in bold.
All applications of the electromagnetism can from then on be applied on *gravitomagnetism* with caution. Also it is possible to speak of gravitomagnetism waves. Please read my earlier papers for a better comprehension[5, 6, 7, 8].

2. Gyrotation of spherical rotating bodies in a gravitational field.

For a spinning sphere with rotation velocity ω , the results for gyrotation are given by equations inside the sphere (2.1) and outside the sphere (2.2) [5]:



$$\Omega_{\text{int}} \Leftarrow \frac{-4\pi G\rho}{c^2}\left[\omega\left(\frac{2}{5}r^2-\frac{1}{3}R^2\right)-\frac{r(r\bullet\omega)}{5}\right] \tag{2.1}$$

$$\Omega_{ext} \Leftarrow \frac{-4\pi G\rho R^5}{5r^3c^2}\left(\frac{\omega}{3}-\frac{r(\omega\bullet r)}{r^2}\right) \tag{2.2}$$

fig. 2.1

(Reference: adapted from Eugen Negut, www.freephysics.org) The drawing shows equipotentials of $-\Omega$.

wherein $\bullet$ means the scalar product of vectors. For homogeny rigid masses the following equation can be written :

$$\Omega_{ext} \Leftarrow \frac{-G\,m\,R^2}{5r^3c^2}\left(\omega-\frac{3r(\omega\bullet r)}{r^2}\right) \tag{2.3}$$

When this way of thinking is used, it should be kept in mind that the sphere is supposed to be immersed in a steady reference gravitation field, namely the gravitation field of the sphere itself.

3. Orbital velocity nearby fast spinning stars.

Total orbital acceleration in the equatorial plane.

Let us call the circular orbital velocity $\mathbf{v}$. By the action of gyrotation, I proved[5] that the orbits must lay in the equator plane of the rotary star. The accelerations due to gyrotation are then given by the Analogue Lorentz Law[5]. On top of this gyrotation term, the gravitation term (Newton) must be added.

$$a_x \Leftarrow v\ \Omega_y - \frac{G\,m}{r^2} \tag{3.1}$$

Using (2.3), I find at the level of the equatorial plane:

$$\Omega_y \Leftarrow \frac{-G\,m\,R^2}{5r^3c^2}\,\omega \tag{3.2}$$

and combined with (3.1) this gives:

$$a_x \Leftarrow -\frac{G\,m\,R^2\omega\,v}{5\,r^3c^2} - \frac{G\;m}{r^2} \tag{3.3}$$

Now, using the geometrical law

$$a_x \Leftarrow \frac{v^2}{r} \tag{3.4}$$

(3.3) and (3.4) must be equal to in order to get an equilibrium.

Total orbital velocity in the equatorial plane for spherical and toric fast spinning stars.

The equations (3.3) and (3.4) bring me to the quadratic equation in v

$$-\frac{v^2}{r} + \frac{G\,m\,R^2\omega}{5r^3c^2}v + \frac{G\;m}{r^2} = 0 \tag{3.5}$$

which can be solved to v :

$$v = v_k\sqrt{1+\left(v_k\frac{\theta}{r}\right)^2} + v_k^2\,\frac{\theta}{r} \tag{3.6}$$

wherein I have named the Kepler velocity as

$$v_k = \sqrt{\frac{G\,m}{r}} \tag{3.7}$$

and wherein I have defined θ as the *"specific angular density"* of the spherical star (dimension of time [s]):

$$\theta_{sphere} = \frac{R^2\,\omega}{10\,c^2} \tag{3.8}$$

At last, I rewrite equation (3.6), just to get a more beautiful equation, by defining the *"angular spread"* s_Ω (dimension of inverse velocity [s/m]) as :

$$s_\Omega = \frac{\theta}{r} \tag{3.9}$$

So, (3.6) becomes:

$$\boxed{v = v_{orbit} = v_k \sqrt{1 + \left(v_k\ s_\Omega\right)^2} + v_k^2\ s_\Omega} \tag{3.10}$$

This general equation describes the orbit velocity for any small object orbiting about the equator of a large mass, whether that large mass is rotating or not. Remark that the generalized orbital velocity is only dependent from the *Kepler velocity* and the *angular spread*.

Discussion

There also exist a second solution of the quadratic equation (3.5). This solution however is physically not probable, because this would lead to a retrograde orbit. I have shown earlier[(5)] that only prograde orbits are stable.

From (3.6), (3.7) and (3.8), it follows that the orbit velocity is inversely proportional to the second power of the orbit radius r , but, for slow spinning stars and for large values of r , the orbit velocity becomes proportional to the inverse square root of r . Even so, the orbit velocity is directly proportional to the spinning star's mass m , but for slow spinning stars, it becomes proportional with the square root of m .

Remark that θ is independent from the star's mass. Equation (3.8) can also be expressed in relation to the inertial moment of the sphere, so that the name *"specific angular density"* becomes more obvious: θ is the angular momentum divided by four times the total energy of the rotary star.

$$I_{sphere} = \frac{2}{5} m\, R^2 \quad \Rightarrow \quad \theta_{sphere} = \frac{I_{sphere}\ \omega}{4\, m\, c^2} \tag{3.11}$$

Although (3.6) is only valid for spinning spheres, the inertial moment of a torus, with a small inner radius compared with the outer radius, is not more than 5 to 10% larger than the inertial moment of a sphere. So, (3.8), which only depends of the stars geometry is reasonably correct for any star in general.

Hence, equation (3.6) can be taken as a good first approach of the orbit velocity of objects near fast spinning stars in general.
For a torus such as a spinning black hole, *specific angular density* θ becomes:

$$\theta_{torus} = \frac{I_{torus}\omega}{4\, m c^2} \tag{3.12}$$

Due to the form of equation (3.6), it is clear that the orbital velocity nearby spinning stars is always larger than the Kepler velocity. Moreover, the decrease of this velocity is approximately directly proportional to $1/r^{3/2}$ for smaller r, and tends to a velocity which becomes Keplerian for larger r.

The equations (3.6) until (3.12) allow astronomers to deduct $G\, m$ and $R^2\, \omega$ in relation to the orbit radius r by observing of the orbits nearby and farther away from the spinning star or black hole.

Validation of the calculus

Figure 3.1 shows the orbital velocities in relation to the orbit radius *r,* for a rotary star with a certain mass and shape and for increasing spin velocities ω . The lowest (blue) curve is Keplerian (ω = 0); the faster the large mass spins, the higher the curve.

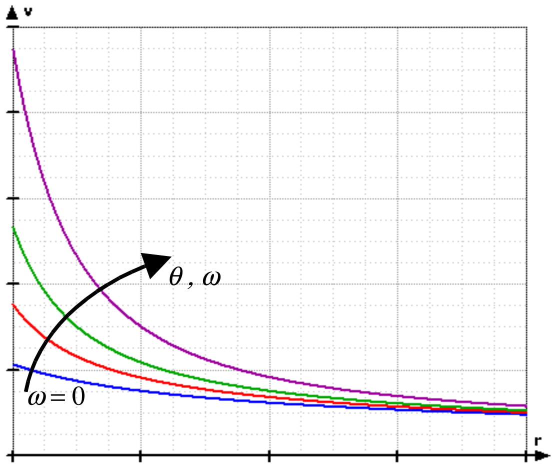


Fig. 3.1

With increasing *specific gyrotation period* θ and thus spin velocity ω, for a same orbit radius r, the velocity rapidly becomes enormous. But at higher distances r, the curve follows quite well the Kepler velocity. Whereas for $\omega = 0$ (Kepler), the orbiting objects at quite large distances r are situated in the smooth part of the curve, the same objects would instead obtain huge velocities when the spin velocity ω is significantly higher. And when looking at orbiting objects at larger distances, the velocity suddenly falls down to nearly the Kepler velocity.

Observation of some huge spinning black holes in the centre of galaxies and surrounded by orbiting stars shows such a behaviour. Stars close-by the black hole effectively do orbit at much higher speeds than expected (based on the Kepler law), whereas the velocity of stars at higher distances suddenly falls down to the expected Kepler values.

4. Conclusion.

The duality of the orbital velocities nearby fast spinning black holes, which is observed in the centre of galaxies, is perfectly described with the Maxwell Analogy for Gravitation. Nearby the spinning black holes, the orbital velocities are very high, but farther away, the orbital velocities suddenly fall to Keplerian values.

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