the general science journal

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Swivelling time of spherical galaxies towards disk galaxies

by using Gravitomagnetism.

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Abstract

This is the second paper dedicated to detailed calculations of disk galaxies. The first is "*On orbital velocities in disk galaxies : "Dark Matter", a myth?*" [2] wherein I explain how to calculate the mass distribution of a disk galaxy and the orbital velocities of the stars, starting from a mass distribution of the originally spherical galaxy. This is based on the extended gravitation theory, called "Gyro-Gravitation" or gravitomagnetism. No existence of Dark Matter nor any other fancy supposition is needed at all in these calculations.
The objective of this paper is to find the mathematical equations related to the time which is needed for the star's orbit to swivel down to the equator. The total diameter-change of the disk galaxy in the time can be found as well. Yet, these deductions are simplified by keeping constant the bulge's gyrogravitational properties during the process. I leave to the reader to experiment with time-dependent models of gyrogravitational fields in the bulge.
An explanation for the very limited windings of our Milky Way's spirals is a direct consequence of this paper.

1. From a spherical to a disk galaxy.

Let us consider a spherical galaxy with a diameter $\mathcal{R}_e$. Because the centre contains massive spinning stars or spinning black holes, a gyrotation field will start to make the stars' orbit swivel, as shown in [2] and [3].
After a time t , the radius of the disk galaxy is $\mathcal{R}_e$. The stars beyond $\mathcal{R}_e$ did only swivel partly, and are not part of the disk itself.
Consider fig.1.1 wherein the spherical galaxy's bulge is shown. The bulge is the group of fast spinning stars that has a global spin. However, the spin-vectors of the individual fast spinning stars are oriented variously. The considered star with mass m orbits at a distance $\boldsymbol{r}$ from the galaxy's centre.

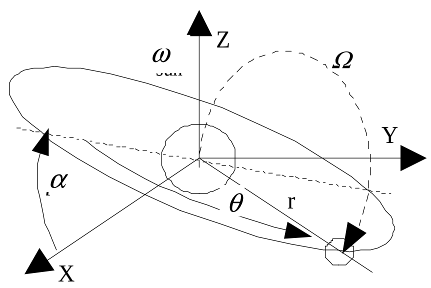

Fig. 1.1 : Definition of the angle α and θ. The orbital plane is defined by the orbital inclination α in relation to the axis X .

The location of the orbiting star inside the orbit is defined by the angle θ . The equipotential line of the gyrotation Ω through the orbiting star has been shown as well.

From a former paper[1] we know that the tangential gyrotational acceleration of a star's orbit is given by:

$$a_{t,\Omega} = -\frac{G\,I\,\omega\omega'}{2\,r^2c^2}\left(\sin\alpha\cos 2\alpha\left(1-3\sin^2\alpha\right)-\frac{3}{4}\sin 4\alpha\cos\alpha\right) \tag{1.1}$$

at the place $\theta = 0$.
Herein, I is the inertial moment of the bulge, ω its angular velocity, α the orbit's inclination angle of the considered orbiting star, and ω' its orbital angular velocity, which follows the Kepler law:

$$\left(\omega'\right)_{\text{sphere}} = \frac{\mathrm{d}\theta}{\mathrm{d}t} = \frac{v_{\text{star}}}{r} = \frac{1}{r}\sqrt{\frac{G\,M_0}{r}} \tag{1.2}$$

wherein M_0 is the bulge's mass.

The swivelling equation (1.1) can be represented in a graph, as in fig.1.2.

This means that for prograde orbits, the states of rest are given for an orbital inclination of α = 0 and π/4. For retrograde orbits, they are α = 0 and 3π/4.

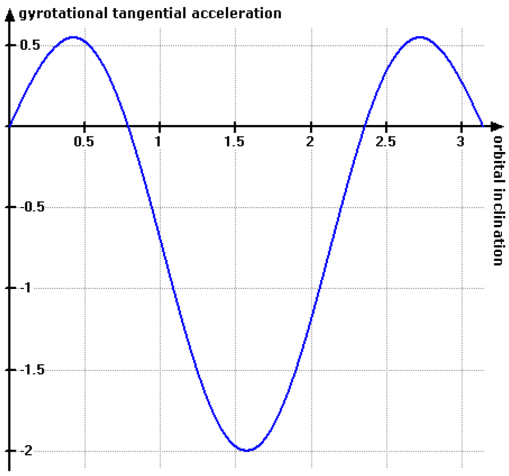

Fig. 1.2. Tangential gyrotational orbit acceleration for $\theta = 0$.

For inclinations between $\alpha = 0$ and $\pi/4$ (prograde), and for $\alpha = 3\pi/4$ and 2π (retrograde), the acceleration tends towards positive values, resulting in a rotational drift towards the rotational axis of the Earth.
For inclinations between $\alpha = \pi/4$ and $\pi/2$ (prograde), and for $\alpha = \pi/2$ and $3\pi/4$ (retrograde), the acceleration will much more strongly tend towards negative values, resulting in a rotational drift towards the equatorial axis of the Earth, and retrograde orbits are strongly pushed back into prograde orbits.

We saw in [2] that the -simplified- value of the stars' velocity in disk galaxies has become :

$$v_{\text{star}} = \sqrt{\frac{G\,M_0}{R_0}} \tag{1.3}$$

wherein M_0 is the mass and R_0 the radius of the bulge (fig.1.3) We have not taken into account the gyrotational forces of the bulge as a part of the attraction force, just for simplicity of the calculations. These forces are to be considered as of secondary order.

This means that (1.2) will become, after the swivelling:

$$(\omega')_{\text{disk}} = \frac{\mathrm{d}\theta}{\mathrm{d}t} = \frac{v_{\text{star}}}{r} = \frac{1}{r}\sqrt{\frac{G\,M_0}{R_0}} \tag{1.4}$$

When comparing both equations, the factor $r^{-1/2}$ becomes $R_0^{-1/2}$ after time.

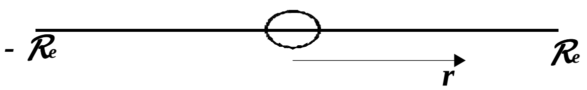

Fig. 1.3: The schematic view of a disk galaxy with a radius $\mathcal{R}_e$. The bulge is nearly a sphere or an ellipsoid. The bulge area, the disk and the fuzzy ends are studied separately. And r is the considered place.

Below, I now will study the swivelling time for the stars' orbits in a simplified form. Consequently, we will replace some values by approximations or by their average value.

2. The swivelling time from a spherical galaxy to a disk galaxy.

The transformation from a spherical galaxy to a disk galaxy is quite clear. We have seen that randomly inclined orbits of planets about the Sun have swivelled until they arrived to the Sun's equatorial plane. Also most of the stars outside the galaxy's bulge swivel to the bulge's equator plane.
Out of fig.1.2. follows that at a certain distance r , the path length between the random inclination angle α of an orbit lays between zero and $\pi\, r$. The average path length is then $\pi\, r/2$ until the equator. And this is also the average path length until the swivelling star passes at the disk's equator for the first time (remember that the motion is an exponential decreasing oscillation). Remark that the complete swivelling will not occur nearby the bulge, due to the fuzzy and strongly variable gyrotation fields in that region.

Integrating (1.2) twice over time gives the time which the average star need to reach the disk region.

Hence, $$\pi r/2 = \int_0^t \left(\int_0^t a_{t,\Omega}\,\mathrm{d}t \right) \mathrm{d}t \tag{2.1}$$

To get rid of α in (1.1), let us replace the geometric function in α of (1.1) by its average value between $\alpha =$ 0 and $\alpha = \pi/2$.

Thus, $$\left(\sin\alpha \cos 2\alpha \left(1 - 3\sin^2\alpha\right) - \frac{3}{4}\sin 4\alpha \cos\alpha \right)_{\text{av}} =$$

$$(\pi/2)\int_0^{\pi/2} \left(\sin\alpha \cos 2\alpha \left(1 - 3\sin^2\alpha\right) - \frac{3}{4}\sin 4\alpha \cos\alpha \right) \mathrm{d}\alpha = \pi/3 \tag{2.2}$$

Hence, $$\left(a_{t,\Omega}\right)_{\text{av}} = -\frac{\pi\, G\,(I\,\omega)_{\text{tot}}\,\omega'}{6\,r^2 c^2} \tag{2.3}$$

Herein, $$(I\,\omega)_{\text{tot}} = \sum_{i=1}^{n} I_i\,\omega_i \tag{2.4}$$

is the total angular momentum for the n stars in the bulge and r is as defined in fig.1.3, as a simplification.

And when applying the equation (2.2) into (2.1) , by assuming that the average tangential gyrotational swivelling acceleration is a constant for each orbit with radius r , it brings me, after integration to:

$$\pi r/2 = \left(a_{t,\Omega}\right)_{\text{av}} \frac{t^2}{2} = -\frac{\pi\, G\,(I\,\omega)_{\text{tot}}\,\omega'}{12\,r^2 c^2} t^2 \tag{2.5}$$

and after rearranging, I get the following result for the swivelling time for a given orbit *r* :

$$t_{(r)} = \sqrt{\frac{6\, r^3 c^2}{G \left(I\, \omega \right)_{\text{tot}} \omega'}} \tag{2.6}$$

For the choice of the value of ω' , I suggest to take the average of equations (1.2) and (1.4), because very probably, the change of angular velocity occurs during the swivelling, while the angular momentum of the bulge is transmitted to the disk.

$$\left(\omega' \right)_{\text{av}} = \frac{1}{r} \frac{\sqrt{G\, M_0}}{\sqrt[4]{r\, R_0}} \tag{2.7}$$

The equation (2.6) can then be rewritten as:

$$t_{(r)} = \frac{6^{1/2}\, r^{17/8} c\, R_0^{1/8}}{G^{3/4} M_0^{1/4} \left(I\, \omega \right)_{\text{tot}}^{1/2}} \tag{2.8}$$

The farther away from the bulge, the longer it takes (nearly quadratically) before the disk takes form. At the extremities $\mathcal{R}_e$ of the disk, there is still a fuzzy zone of stars because only a part of the stars did swivel entirely, namely those who whereof the orbit inclination originally was beyond π/4.

Closer to the bulge, the disk is quickly generated. The growth velocity of the galaxy's disk decreases steadily in time.

3. Discussion.

In the equation (2.8) it is the bulge's angular momentum that is the most difficult to evaluate. Especially because it probably evolved from a low value to a higher value with time, and maybe there occurred a contraction of the central zone.

The time delay which is observed in spirally wound galaxies such as the Milky Way does not correspond at all to the total lifetime of the galaxy. The reason is that there are several phases of time to consider.
The starting point is the spherical galaxy with a spinning center, made of spinning stars and eventually black holes.
Then follows the swivelling of the orbits, by which the disk diameter increases steadily, beginning from the centre and becoming very thin -in cosmic terms- at some places, causing a hyper-density of the disk compared with the original density of the spherical galaxy.
If the original orbit inclination was situated between 0 and π/4, the swivelling was originally pointed towards π/4. Later, when the disk formed, even stars at an orbit inclination till π/4 were attracted by the disk and got swivelled towards the disk. Only at the extremities of the disk, the fuzzy part betrays that the inclination till π/4 is more difficult to swivel down.
The third phase is the formation of the spirals by the contraction of some hyper-dense zones, even yet after a partial formation of the disk. When observing the actual spiral-gradient, it appears as if the delay of time between the formation of the inner and the outer parts of the disk were very short, but in fact this delay is much longer because the stars that are farther away from the bulge can only form spirals at the time that the disk has become hyper-dense enough at that place, while the inner disk zone has its spirals yet formed.
The observed strange form of the spirals, I would rather say: many parts of spirals, correlate quite well with this explanation.

4. Conclusion.

The time for an average orbit-swivelling is proportional to an exponent 17/8 of the star's orbit radius. Although the found time-equation is only a limited part of the formation time of our actual Milky Way, it allows us already to have a clearer view on the formation of disk galaxies.

5. References and interesting lecture.

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