# Four Possible Ways to Model Rotating Universe

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**ABSTRACT**

It is known that most existing cosmology models do not include rotation, with few exceptions such as rotating Bianchi and rotating Godel metrics. Therefore in this paper we aim to discuss four possible ways to model rotating universe, including Nurgaliev's Ermakov-type equation. It is our hope that the new proposed method can be verified with observations, in order to open new possibilities of more realistic nonlinear cosmology models.

Keywords: Ermakov-type equation, nonlinear cosmology, Newtonian cosmology, vortex dynamics, turbulence

## 1. Introduction

Some years ago, Matt Visser asked the following interesting questions: How much of modern cosmology is really cosmography? How much of modern cosmology is independent of the Einstein equations? [3]

Local rotations (vortices) play a role in radical stabilization of the cosmological singularity in the retrospective extrapolation, making possible a static or steady-state (on the average) Universe or local region. Therefore Einstein could "permit" the galaxies to rotate instead of postulating a cosmological constant *ad hoc* in his general-relativistic consideration of a static Universe. Though, it does not necessarily mean that the cosmological constant is not necessary for other arguments.[1]

In this paper we will discuss four possible ways to model the rotating Universe. While in the last section more realistic one is suggested, based on Newtonian cosmology model but here we include the vortical-rotational effect of the whole Universe. We review an Ermakov-type equation obtained by Nurgaliev [1][2], and solve the equation numerically with Mathematica.

It is our hope that the new proposed method can be verified with observation data.

## 2. Rotating Godel Universe

In this section, we will review Rotating Godel Universe. The 3-space has a cylindrical symmetry. The kinematic properties of this universe have recently been vividly illustrated by Buser, Karjari and Schleich. They employed the technique of ray tracing and visualized various scenarios to bring out the optical effects experienced by an observer located in this universe. Braeck, Gron & Farup have shown that it yields a simple expression of angular velocity of the Universe: [8]

$$\Omega = \frac{1}{\sqrt{2}a} \tag{1}$$

Hence, the local angular velocity in a plane orthogonal to the symmetry axis of the 'river of space' in the Gödel spacetime has a constant value. This means that the swinging plane of a Foucault pendulum rotates with this angular velocity with respect to the reference particles defining the space of the Gödel universe. It should be noted that, in this universe, the cosmic mass does not cause perfect inertial dragging.[8]

The swinging plane of a Foucault pendulum is not rotating together with the cosmic masses in this universe.

Ozsváth and Schücking have discussed Mach's principle in connection with a finite rotating universe model. This solution was said to have a non-Machian character. However, the phenomenon of inertial dragging was not mentioned. Thus, it was not noted that the rotation of the universe means that there is not perfect inertial dragging in such a universe.[8]

The connection between the perfect inertial dragging and vanishing rotation of the universe means that the existence of rotating universe models need not be anti-Machan after all. It only means that there is not a sufficiently large causal mass in the universe to drag the swinging plane of a pendulum around together with the cosmic mass.[8]

## 3. Post-Newtonian model

In this section, we will review a Lagrangian expression for vorticity in Newtonian cosmology. The Lambda-CDM model provides today the accepted standard concordance description of our Universe. Its late dynamics is dominated by a collisionless cold dark matter (CDM) component and a cosmological constant. [9]

This concordance model is based on general relativity (GR) as the theory of gravity and on assuming homogeneity and isotropy on very large scales, so that the Universe as a whole is described as a Friedman-Lemaıtre-Robertson-Walker (FLRW) space-time and its overall expansion is parametrized by the cosmic scale factor a(t), governed by the Friedmann equations. However, on small enough scales the Newtonian treatment of structure formation is usually assumed to be a good approximation.[9]

Then, assuming a pressureless fluid (dust) description that is valid at sufficiently early times (before shell crossing), the evolution of the CDM component is given by the Euler–Poisson equations.[9]

In Newtonian theory the vorticity is defined as the curl of the velocity, which is vanishing if the velocity is exactly of the scalar type. Furthermore, as it follows from the Kelvin circulation theorem, a pressureless fluid which is initially curl free remains curl free. Of course, a fluid which is initially curl free will generate vorticities when it enters into the multistream regime. This regime is accompanied with multivalued velocities, and this is also one reason why the single-stream fluid description breaks down.[9]

This result generalizes to GR where, however, vorticity is a four-vector and is defined as the antisymmetric part of the covariant derivative of the four-velocity of matter. In addition, the gravitational field (i.e., the space-time metric) in general also contains a vector part, leading to the relativistic effect of frame dragging. It follows that, although related, the Newtonian and GR vorticity fields are different, in subtle ways.[9]

After some initial definitions and calculations, Rampf obtained the Cauchy invariants:[9]

$$\frac{1}{2}\varepsilon^{ijk}\dot{J}^{l}_{j}J_{lk}=\frac{a_{ini}}{a}\omega^{i}_{ini}. \qquad (2)$$

which shows that the vorticity decays away with the Hubble expansion. Equation (2) is a result for the so-called Cauchy invariants for cosmological fluids, which have not yet been reported in the literature.[9]

## 4. Modified FRW Metric to explain the Cosmological Constant

One of the most outstanding problems of the standard model of cosmology today is the problem of cosmological constant/dark energy. It corresponds to about 73 per cent of the energy content of the universe gone missing. It has been shown by Zorba that it is possible to postulate a modified FRW metric for our universe, which animates a universe spinning rigidly but very slowly with an angular frequency that is equal to the Hubble constant. It is shown by a simple argument that in such a universe there will be an overlooked rotational energy whose average value is identically equal to the matter-energy content of this universe as observed by a coordinate observer.[10]

After some initial assumptions, Zorba obtained a spinning FRW-universe Friedmann equation as follows:[10]

$$\frac{\dot{R}^2}{R^2}=\frac{8\pi G}{3}\rho+H_0^2-\frac{kc^2}{R^2}. \tag{3}$$

Meanwhile, the standard Friedmann equation for a non-spinning FRW universe with an artificially added cosmological constant term is given by (Hobson et al. 2006):

$$\frac{\dot{R}^2}{R^2}=\frac{8\pi G}{3}\rho+\frac{\Lambda c^2}{3}-\frac{kc^2}{R^2}. \tag{4}$$

We therefore see that the herein proposed spinning-universe model reproduces exactly the result obtained from the FRW metric as used in the Einstein equation with an artificially added cosmological constant.

## 5. Deriving Ermakov-type equation for Newtonian Universe with vortex

It has been known for long time that most of the existing cosmology models have singularity problem. Cosmological singularity has been a consequence of excessive symmetry of flow, such as “Hubble’s law”. More realistic one is suggested, based on Newtonian cosmology model but here we include the vortical-rotational effect of the whole Universe.

In this section, we will derive an Ermakov-type equation following Nurgaliev [1]. Then we will solve it numerically using Mathematica 11.

After he proceeds with some initial assumptions, Nurgaliev obtained a new simple local cosmological equation:[2]

$$\dot{H} + H^2 = \omega^2 + \frac{4\pi G}{3}\rho, \qquad (5)$$

Where $\dot{H} = dH / dt$.

The angular momentum conservation law $\omega R^2$ = const = K and the mass conservation law $(4\pi/3)\rho R^3$ = const = M makes equation (5) solvable:[2]

$$\dot{\mathrm{H}} + \mathrm{H}^2 = \frac{K^2}{R^4} - \frac{\mathrm{GM}}{\mathrm{R}^3}, \qquad (6)$$

Or

$$\ddot{R} = \frac{K^2}{R^3} - \frac{GM}{R^2}. \qquad (7)$$

Equation (7) may be written as Ermakov-type nonlinear equation as follows;

$$\ddot{R} + \frac{GM}{R^2} = \frac{K^2}{R^3}. \qquad (8)$$

Nurgaliev tried to integrate equation (7), but now we will solve the above equation with Mathematica 11. First, we will rewrite this equation by replacing GM=A, K^2=B, so we get:

$$\ddot{R} + \frac{A}{R^2} = \frac{B}{R^3}. \qquad (9)$$

As with what Nurgaliev did in [1][2], we also tried different sets of A and B values, as follows:

a. A and B < 0

```
A=-10;
B=-10;
ODE=x''[t]+A/x[t]^2-B/x[t]^3==0;
```

```
sol=NDSolve[{ODE,x[0]==1,x'[0]==1},x[t],{t,-10,10}]
Plot[x[t]/.sol,{t,-10,10}]
```

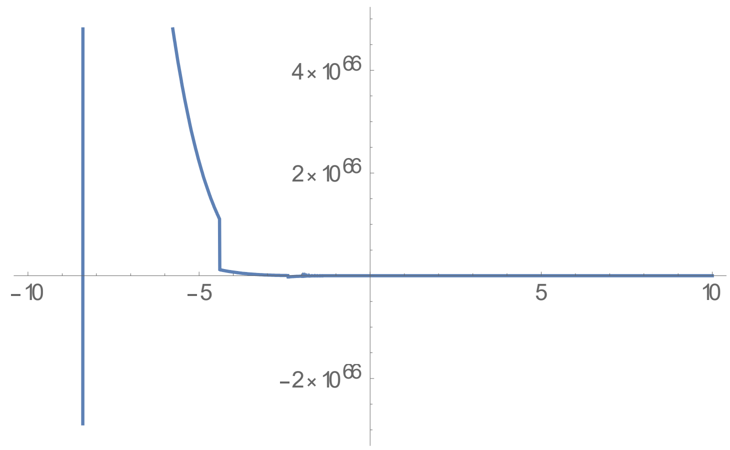


Figure 1. Plot of Ermakov-type solution for A=-10, B=-10

b. A < 0, B > 0

```
A=-10;
B=10;
ODE=x''[t]+A/x[t]^2-B/x[t]^3==0;
sol=NDSolve[{ODE,x[0]==1,x'[0]==1},x[t],{t,-10,10}]
Plot[x[t]/.sol,{t,-10,10}]
```

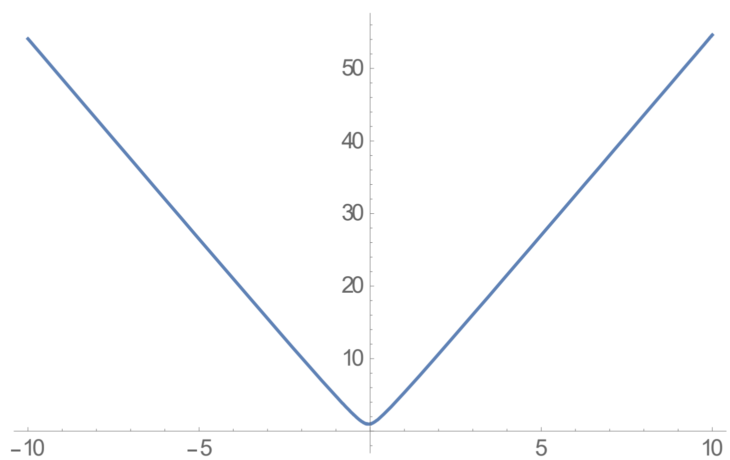


Figure 2. Plot of Ermakov-type solution for A=-10, B=10

c. A > 0, B < 0

```
A=1;
B=-10;
ODE=x''[t]+A/x[t]^2-B/x[t]^3==0;
sol=NDSolve[{ODE,x[0]==1,x'[0]==1},x[t],{t,-10,10}]
Plot[x[t]/.sol,{t,-10,10}]
```

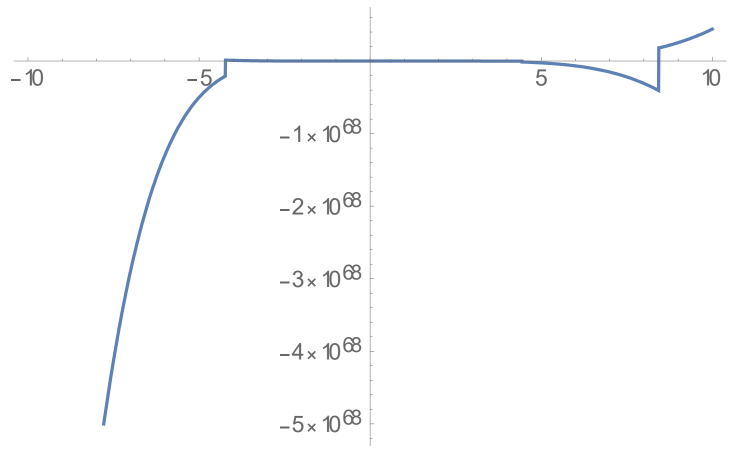


Figure 3. Plot of Ermakov-type solution for A=1, B=-10

d. A >0, B > 0

```
A=1;
B=1;
ODE=x''[t]+A/x[t]^2-B/x[t]^3==0;
sol=NDSolve[{ODE,x[0]==1,x'[0]==1},x[t],{t,-10,10}]
Plot[x[t]/.sol,{t,-10,10}]
```

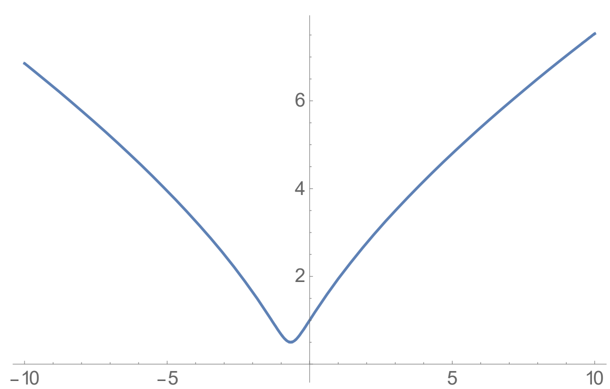


Figure 4. Plot of Ermakov-type solution for A=1, B=1

From the above numerical experiments, we conclude that the evolution of the Universe depends on the constants involved, especially on the rotational-vortex structure of the Universe. This needs to be investigated in more detailed for sure.

As an implication, we may arrive at a precise model of flattening velocity of galaxies without having to invoke ad-hoc assumptions such as dark matter.

Therefore, it is perhaps noteworthy to discuss briefly a simple model of galaxies based on a postulate of turbulence vortices which govern the galaxy dynamics. The result of Vatistas' model equation can yield prediction which is close to observation, as shown in the following diagram:[5]

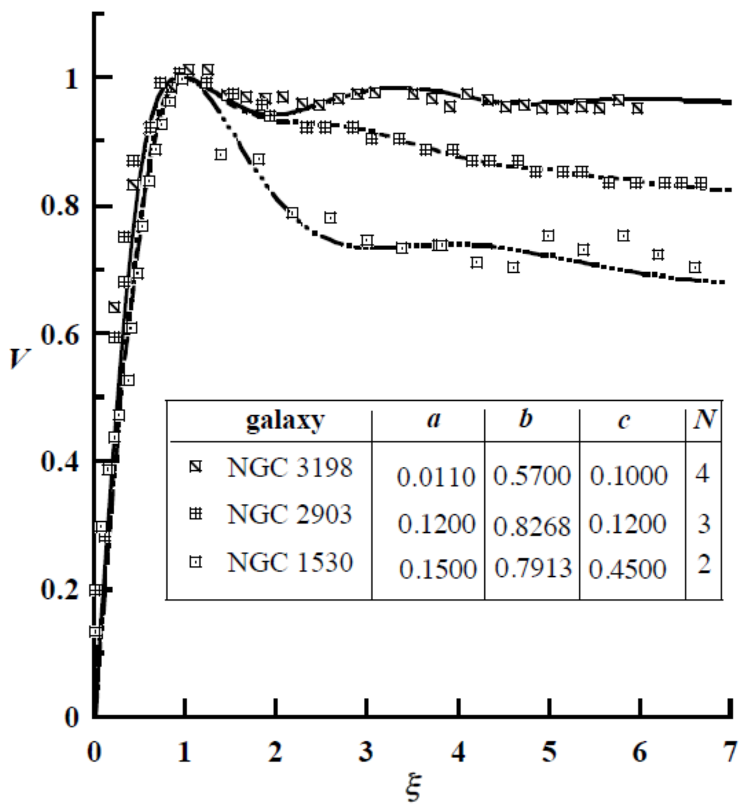


Figure 5. From Vatistas [5]

Therefore it appears possible to model galaxies without invoking numerous *ad hoc* assumptions such as *dark matter*, once we accept the existence of turbulent interstellar medium. The Vatistas model is also governed by Navier-Stokes equations, see for instance [4][5]

**Concluding Remarks**

It has been known for long time that most of the existing cosmology models have singularity problem. Cosmological singularity has been a consequence of excessive symmetry of flow, such as "Hubble's law". More realistic one is suggested, based on Newtonian cosmology model but here we include the vertical-rotational effect of the whole Universe. We review a Riccati-type equation obtained by Nurgaliev, and solve the equation numerically with Mathematica 11. We also discuss a plausible model for flattening velocity observed in numerous galaxies.

We also discuss 3 other ways to model rotating universe, including rotating Godel metric. It is our hope that the new proposed method can be verified with observations, in order to open new possibilities of more realistic nonlinear cosmology models.

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