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Anisotropic distribution of space pulsar velocities

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Abstract: On the base of new data it is shown that the observed proper motions and directions of the tangential velocities of pulsars manifest the extremely anisotropic distributions. These anisotropies cannot be explained by the structure of our Galaxy or by various types of solar motions. They can be caused by the cosmological vector potential and the action of the new force. This force must be stronger in higher magnetic fields. The positive correlation between tangential velocities V_t and surface magnetic fields of pulsars B_s is seen indeed. It is shown that the new force can provide pulsar velocities up to several thousands of km/sec.

Keywords: Pulsars, Proper Motions, Magnetic Fields, New Force

1. Introduction

A radio pulsar can be considered as one of the most exciting astrophysical objects. Indeed its central body is a neutron star with radii of order of 10 km and masses of order of the solar mass (2 x 10^{33} g), the nuclear density (10^{14} – 10^{15} g / cm^3), superfluid neutrons and superconducting protons in inner regions and magnetic fields of order of 10^{12} G at the surface.There are relativistic electrons and positrons in magnetospheres of neutron stars.These stars are formed during explosions of supernovae. Many unusual physical processes are realized in radio pulsars, and they can be used to verify some new theories and models. To better understand the origin and evolution of radio pulsars , it is very important to know the space velocities of these objects and the distribution of these velocities. Unfortunately, the absence in pulsars of spectral lines that could be compared to the laboratory standards makes estimation of their radial velocities impossible.Therefore, studies are basically limited to tangential velocities derived from observed proper motions of the pulsars in the plane of the sky. Corresponding values can be found in the pulsar catalogue [1]. This moment it contains parameters of more than 2300 objects, however proper motions have been measured for approximately 200 pulsars only.

The velocities of pulsars were found to be very high, in some cases, exceeding 1000 km/s (see, e.g., [2] and references therein). Several mechanisms have been proposed to explain such high velocities, and are reviewed, for example, by Lai [3].

2. Proper Motions of Radio Pulsars

First of all we shall analyse measured proper motions from the catalogue [1]. Using the angle between the motions in right ascension $\mu_\alpha = (d\alpha/dt) \cos\delta$ and declination $\mu_\delta = d\delta/dt$:

$$\xi = \text{atn} (\mu_\alpha / \mu_\delta) \qquad (1)$$

we obtain the distribution of the directions of such motions in the plane of the sky.

Here α is the right ascension and δ the declination of the pulsar considerd. Maximal values of μ_α and μ_δ are of order of 100 marcsec, therefore we can use the plane trigonometry to calculate ξ (Fig.1)[4]

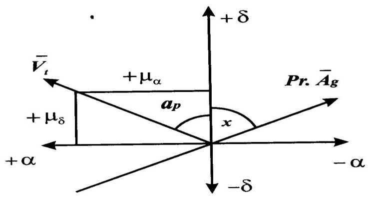

Fig 1. *Direction of a pulsar motion (V_t) on the plane of the sky, vector A_g (cosmological vector potential) will be described further.*

Apriori we must expect that the space velocities of pulsars when they are formed are randomly directed. Therefore, the distribution of the directions of pulsar motions should be isotropic. However Fig.2-3 show that directions of pulsar motions are distributed very ununiformly.

The structure of the Galaxy and the pattern of its magnetic fields cannot cause this anisotropy. It can likewise not be explained by the acceleration of binary systems due to asymmetric X-ray radiation because of deviations of the neutron-star magnetic field from a dipolar field [5].

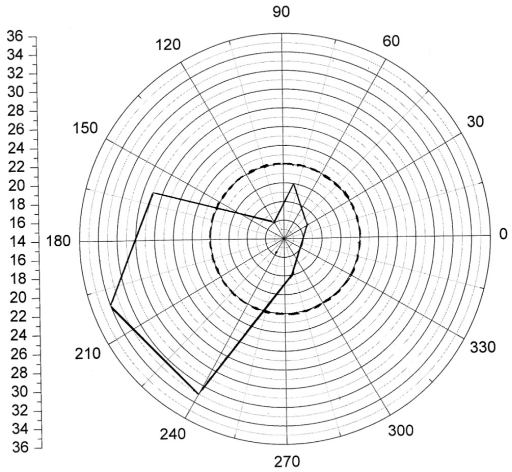

Fig 2. *Distribution of observed angles ξ (solid line). Dashed line shows the expected uniform distribution.*

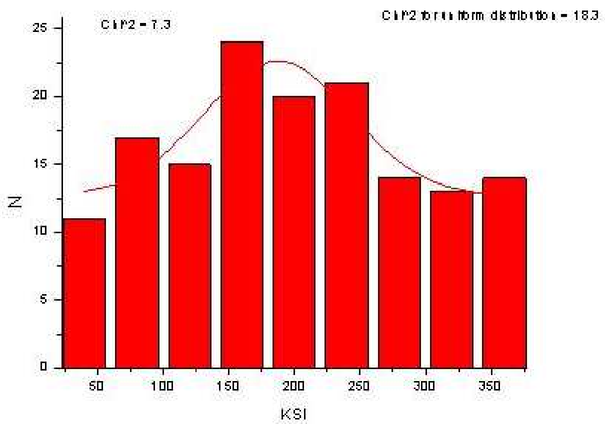

Fig 3. *Histogram representing the distribution of angles ξ.*

3. Distribution of Pulsar Velocities

It is quite interesting to determine the main direction of pulsar motions. We estimated angles between transverse velocities of pulsars V_t and «the cosmological» vector potential A_g [6]. For this aim we must use spherical trigonometry (Fig.4) [4].

We need to calculate the angle ε. The system of equations for our problem has the following form [7]:

$$\mathrm{Cos}\, z = \mathrm{Sin}\delta_{PSR}\, \mathrm{Sin}\delta_{Ag} + \mathrm{Cos}\delta_{PSR}\, \mathrm{Cos}\delta_{Ag}\, \mathrm{Cos}\,(\alpha_{Ag} - \alpha_{PSR}) \quad (2)$$

$$\mathrm{Sin}\, x = \mathrm{Cos}\delta_{Ag}\, \mathrm{Sin}\,(\alpha_{Ag} - \alpha_{PSR}) / \mathrm{Sin}\, z \quad (3)$$

$$\mathrm{Cos}\, \varepsilon = \mathrm{Sin}\, z\, \mathrm{Cos}\,(x + \xi) \quad (4)$$

The distribution of angles ε between V_t and A_g is shown in Fig.5.and 6 As we can see there is the preferable direction of pulsar motion near 120^0 from the direction of A_g. In any case the uniform distribution is very bad approximation of the observed picture.

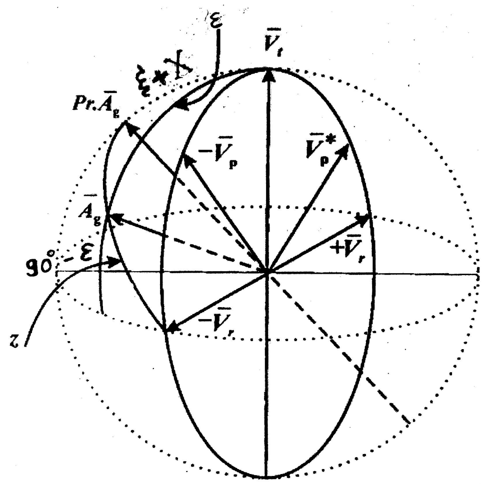

Fig 4. *Distribution of different angles on the celestial sphere.*

4. Pulsar Velocities and the New Force

We use the formula (2) from [4]:

$$V = (2\, m_\nu c^2 / m_n)\, \lambda_1^2\, \Delta A\, (\Delta A/\Delta X)\, T \quad (5)$$

where T is time of action of the new force, $2\, m_\nu c^2 = 33$ eV, .the coefficient $\lambda_1 = 10^{-12}$ (G cm)$^{-1}$ [2], $\Delta A = 10^{11}$ G cm [2], $\Delta A/\Delta X$ is the magnetic field at the surface of the pulsar, . m_n is the mass of neutron. This expression means that V is proportional to magnetic field B. Fig 7 shows that such a tendensy is observed indeed.

In Fig.7 pulsars in binary systems were excluded, because some uninvestigated processes could play a role in a distortion of the dependence (5).

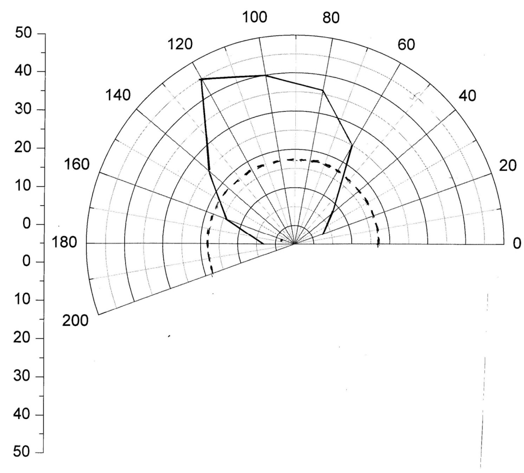

Fig 5. *Distribution of angles between V_t and A_g (solid line). Dashed line is the iniform distribution.*

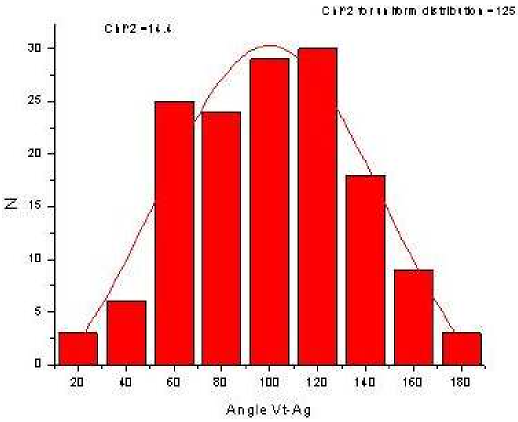

Fig 6. *Alternative presentation of the tistribution of angles ε.*

Magnetic fields at the pulsar surfaces can achieve values more than 10^{12} G. For such fields and the used parameters we can obtain from (5) velocities up to several thousands km/sec.

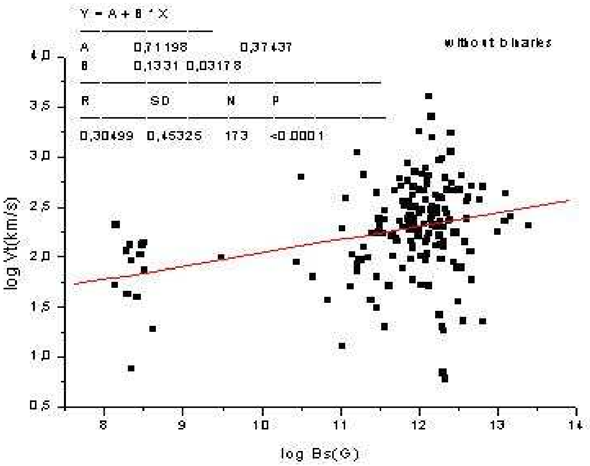

Fig 7. Dependence of the transverse velocities of pulsars on their surface magmetic fields.

5. Conclusions

1. New data confirm the previous conclusion on the extremely anisotropic distributions of the observed proper motions and directions of the tangential velocities of pulsars. Let us emphasize that former results have been obtained on the base of data for several dozens of pulsars (for example, 45 objects in [2]). The confirmation of these results shows that the anisotropy of pulsar velocities is real.
2. The observed anisotropies can be caused by the cosmological vector potential.
3. The new force can provide pulsar velocities up to several thounds km/sec.
4. The action of the new force must be stronger in higher magnetic fields. There is indeed the positive correlation between V_t and B_s.

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