TIMESCALE FOR THE DECAY OF MAGNETIC FIELDS OF PULSARS

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ABSTRACT. It is generally agreed that the magnetic fields of pulsars decay with the time. The previous estimates for the decay timescale range from 2Myr to < 10Myr based on the evolutionary tracks in the $(P,\dot{P})$ diagram and the kinematics of pulsars. We make a new estimate, by using the 'measured fields' themselves, to be about 20Myr and show that the z-distribution of pulsars is consistent with the new estimate if the known dependence of velocities of pulsars on the magnetic moment is taken into account.

If the magnetic moment decays exponentially the initial and the present magnetic moments M and m are related by $M^2 = m^2(1+\tau/\tau_B)$, where τ is the characteristic time and τ_B is the field decay time. It is unlikely that all the pulsars decay with the same τ_B. When a single τ_B is assumed for the whole pulsar population two types of errors occur : i) deviation of the assumed τ_B from the mean value for the population and ii) deviation of τ_B of the individual pulsars from the mean of the population. Our aim is to find out the correct mean value of τ_B for the population by minimising the error due to the first cause. The error due to the second cause cannot be reduced anyway by assuming a single τ_B. The r.m.s. error in the initial fields calculated by assuming a single τ_B is given by,

$$\sigma_M = \frac{1}{2}\,\frac{1}{\tau_B^2}\,\left\langle \frac{m_j^2\,\tau_j^2}{1+\tau_j/\tau_B} \right\rangle \sigma_{\tau_B} ,$$

where the suffix j indicates the jth pulsar. The value of τ_B which minimises σ_{τ_B} is the correct mean value.

σ_{τ_B} is computed by using all the 293 pulsars for which magnetic field strengths are listed in the pulsar table by Manchester & Taylor (1981). The results are presented in Figure 1. σ_{τ_B} decreases rapidly as τ_B is increased from 1Myr to ~20Myr and thereafter it goes into a shallow minimum at 33 Myr, suggesting that τ_B is about 20Myr.

Now, one may ask whether such a large value for τ_B is reasonable ? In particular, is it consistent with the observed z-distribution of pulsars ? To check this we computed the expected z-distribution as

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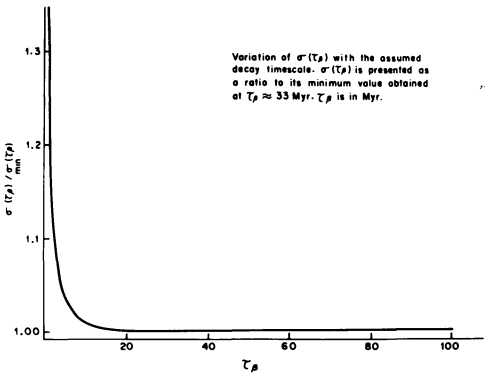

Figure 1

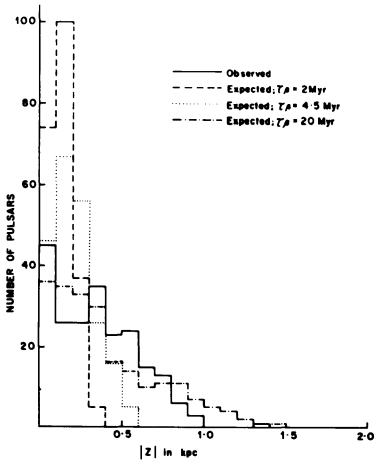

Figure 2

follows. Anderson & Lyne (1983) have pointed out a correlation between the measured transverse velocities of 26 pulsars and their magnetic moments. There is a spread of nearly a factor of 30 in velocities such that higher the magnetic moment, higher the velocity. The correlation has been confirmed by using a sample of 59 pulsars for which the speeds have been obtained through interstellar scintillation measurements (Cordes, 1987). This coupled with the fact that pulsars with larger magnetic moments have smaller ages helps in containing pulsars to smaller z values than are possible otherwise. To demonstrate this, we have restricted ourselves to the second Molonglo sample (Manchester et.al.,1978) to minimise selection effects. For each pulsar, an age is calculated, from the observed characteristic age, by assuming a τ_B . We get a z height for the pulsar by multiplying the age with a mean z-velocity appropriate for its magnetic moment. The z-velocities are computed by using the relationship between the transverse velocities and the magnetic moments observed by Anderson & Lyne. The expected z-distributions obtained by using different τ_B are shown in Figure 2. A comparison with the observed z-distribution, shows that a τ_B of 20Myr is consistent with the observations. While comparing, one should remember that if proper allowance is given for projection of velocities the calculated distributions would become more concentrated towards low z values.

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