PULSARS AND INTERSTELLAR MEDIUM: MULTIPLE REGRESSION ANALYSIS OF RELATED PARAMETERS

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(Received 4 July, 1984)

Abstract. An empirical relation which relates the 408 MHz galactic continuum background temperature (408GCBT) to dispersion measures, position and radio-luminosity of 325 pulsars is obtained by means of multiple stepwise regression analysis. This relation shows that pulsars may be considered as galactic probes for the distribution of 408GCBT and interstellar electron density (IED) in interstellar medium (ISM). Peculiar pulsars (O-C $\geq 2.5\sigma$) point out galactic regions where the observed $T_{408}$ are higher (or lower) and $n_e$ lower (or higher) than the averaged ones. Normal pulsars ($-2.5\sigma < O-C < 2.5\sigma$) show galactic regions where observed and computed $T_{408}$ and $n_e$ are in agreement, on the average. Standard pulsars (O-C $\leq 0.05$) show galactic regions where observed and computed $T_{408}$ and $n_e$ are in good agreement. Recent models of pulsar disk systems, suggested by Michel and Dessler (1981) could justify the conclusions drawn for peculiar pulsars having O-C $> 2.5\sigma$.

1. Introduction

In a preceding paper (Fracassini et al., 1983, hereafter referred to as Paper I) multivariate analysis was applied to the parameters of 330 pulsars published by Manchester and Taylor (1981). In this analysis linear correlations (with $R \geq 0.5$) between $T_{408}$ (408GCBT) and $DM$ (dispersion measure), $L$ (radio-luminosity), $d$ (heliocentric distance), $R$ (galactocentric radius) were found. In a recent paper regarding pulsar statistics and their interpretations, Arnett and Lerche (1981) emphasize that one of the causes of the uncertainties that arise in making interpretations of pulsar’s data is our inadequate knowledge about the ISM and IED.

In the present paper, we have performed a multiple stepwise regression analysis of the parameters reported above with the aim to probe and explain the connections between pulsars and ISM.

2. Statistical Analysis

We have used the method of the multiple stepwise regression analysis. This method allows us to obtain a statistical relation between the ‘dependent’ variable (log $T_{408}$ in our case) and some significant ‘independent’ variables selected from a large set of variables. The statistical importance of each variable has been checked by an F-test and, by this way, only the most significant variables enter the relation.
The method cannot give the 'best' relation (in the sense of least-squares), but gives a 'good' one (or some statistically equivalent relations; see below). We have used a program by Buzzi-Ferraris (1975), which is more general than the original program by Efroymson (1964; see also Antonello, 1983). The application of the method has given the following good relation

\[
\log T_{408} = + 0.266 \log DM - 0.605 |Z| - 1.388 \log R + 0.060 \log L + 1.120,
\]

\[+ 0.151 \pm 0.036 \pm 0.038 \pm 0.099 \pm 0.014, \tag{1}\]

for 300 pulsars with known \(T_{408}, |Z|, R, DM, \) and \(L\); the multiple correlation coefficient is \(r = 0.89\). Twelve pulsars (given in Table I) were excluded because they deviate more than about \(2.5\sigma\) (see Figure 1). An equivalent good relation, with \(r = 0.89\), is obtained with \(\log d\) and \(\log W_{50}\) (or \(W_e\)) instead of \(\log DM\) and \(\log L\). The introduction of the significant variables, step by step, is the following: first \(\log DM\) (\(r = 0.67\)), second \(|Z|\) (\(r = 0.78\), third \(\log R\) (\(r = 0.88\)), and finally \(\log L\) (\(r = 0.89\)).

The variable \(\log T_{408}\) is related mainly to \(\log DM, |Z|, \log R\) (or \(\log d, |Z|\) and \(\log R\)) and depends only weakly on \(\log L\) (or \(W_{50}\)); that is, the intrinsic pulsar parameters have only a weak (if any) importance for the value of \(T_{408}\).

3. Discussion of the Results

The parameters contained in relation (1) are \(DM, |Z|, R, \) and \(L\); the first three are contained also in the most complete relations for the IED (Manchester and Taylor, 1981; Guseinov et al., 1981a; Harding and Harding, 1982; Lyne, 1982), the last one, although still related to \(DM\), could show also a weak correlation between the intrinsic radio-luminosity of pulsars and the 408GCBT in the direction of them.

It is worthwhile to compare some peculiar and normal pulsars which scatter from \((O-C) > + 2.5\sigma\) and follow \((O-C) < + 2.5\sigma\), on the average, the relation (1), respectively (the peculiar pulsars are numbered from 1 to 12 in Table I and signed by triangles in Figure 1). If we take into account that:

- the 408GCBT reported by Manchester and Taylor (1981) are taken from the 408-MHz survey of Haslam et al. (1982),
- this survey provides an accurate and complete data base for large scale comparisons with other observations (Haslam et al., 1981; Phillipps et al., 1981),
- the main selection effects at play in the distribution of pulsars in \(Z\) distance, galactocentric radius \(R\) and luminosity \(L\) are due to inverse square law, the areas of sky surveyed and the changing receiver sensitivity due to galactic background noise variations across the Galaxy (Lyne, 1982).

Then we can emphasize the following remarks:

1. The observed \(T_{408}\) values of normal pulsars, averaged by the relation (1), follow the behaviour of the contour maps of the atlas by Haslam et al. (1982). The clear dependence of these temperatures from \(R, Z, \) and \(DM\) shows that these pulsars may be considered as observational tests for 408GCBT and the general relations for the IED found by several authors (see related quotations in this section).