THEORETICAL AND OBSERVATIONAL INVESTIGATIONS OF PULSAR PROPERTIES

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BANGALORE UNIVERSITY
for the degree of

Doctor of Philosophy

By

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DECLARATION

I declare that the work presented in this thesis has been conducted by me in the **Raman** Research Institute, Bangalore, India. No part of this work has been submitted for the award of any other degree, diploma, associateship, fellowship or any such title.
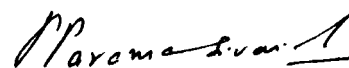
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SYNOPSIS

Pulsars are highly magnetised, rotating neutron stars* They emit energy in a wide band of radio frequencies, at the expense of their rotational energy* The intensity and polarisation of the radio luminosity implies that it is caused by a coherent, non-thermal process* It is believed that neutron stars are born in explosions of massive stars (an event known as a "supernova"), which also leaves behind a shell of luminous material known as a "supernova remnant". However, only a minute fraction of the pulsars and supernova remnants known are found to be physically associated in the sky. Moreover, the birthrates of the two species appear to be at variance with each other* In this thesis we start with an attempt to compute a reliable birthrate for pulsars by means of statistical analysis of pulsar data.

We restricted ourselves to the pulsars observed by the Second Molonglo Survey for the sake of uniformity of the sample* We studied the observational limitations tor "selection effects") of this survey and found an important selection effect which was hitherto neglected, as well as a new selection effect which is peculiar to this survey, Using the same survey, we studied the variation of the interstetlar eletron density n_e in the Galaxy under the constraint that the pulsar distribution be cylindrically symmetric with respect to the galactic centre, We combined results from various independent sources (including ours) and arrived at a reliable formula for

n_e as a function of the height $\mathbb{Z}$ above the galactic plane*

$$n_e(\mathbb{Z}) = 0.03 + 0.02 \, EXP-(|\mathbb{Z}|/70)$$

We then used a Monte Carlo scheme tocompute a weighting factor for each pulsar. This accounts for the incompleteness of the pulsar survey with respect to each pulsar* Using these weights we computed the birthrate of pulsars in a novel manner* We used the concept of "pulsar current" J_p (number $sec.^{-1}$ Galaxy^{-1}) which is the movement of pulsars along the period (P) axis in a plot of the period vs the period derivative. J_p is always a rigorous lower bound on the birthrate of pulsars; but in a certain segment of the J_p vs P curve we may actually compute the birthrate itself. This was done incorporating the various selection effects. Our calculation is the first to have accounted for these selection effects; in addition, our calculation is entirely model independent*

Our calculation further showed that a large fraction of pulsars are born at large periods (P >0.5 s.), contrary to the conventional belief that pulsars are born with very small periods ($\sim$ milliseconds). We have called this phenomenon "injection" of pulsars, and offered two possible explanations for it.

An important input into our birthrate calculation is f , the fraction of pulsars that are seen by us. This arises necessarily because pulsars do not emit radiation isotropically but in the form of a rotating beam* Conventionally was taken to be 0.2, but it depends critically upon the size and shape of the pulsar beam. We studied the recent polarisation

data on some pulsars and conluded that pulsar beams can be much larger than generally assumed, thus increasing the effective value of f to 0.5. In addition we found that the pulsar beam size decreases as the pulsar ages. Incorporating all these new results we computed the birth rate of pulsars to be once every 28^{+40}_{-14} years in the Galaxy. As this is not too different from estimates of supernova remnant birthrates, we conclude that no significant discrepancy exists between the birthrates of pulsars and supernova remnants.

In this thesis we also present the results of our observations of pulsars using the Ooty Radio Telescope. Improved declinations have been measured for 40 weak pulsars. Flux densities at 327 MHz are also presented for these pulsars* For 32 of these pulsars, improved periods have been derived using the improved positions,

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CHAPTER 1

INTRODUCTION

1.1 THE PULSAR OBJECT

The term PULSAR (in short PSR) refers to stellar objects emitting periodic radio pulses discovered by Jocelyn Bell (Hewish et. al. 1968). The few notions about these objects which have retained their wide acceptance to this day were established very soon after the discovery of pulsars by Hewish et. al. in 1968. These are:

(a) A ROTATING NEUTRON STAR (a compact star of radius $\sim$10 Km. consisting mainly of degenerate neutrons) is the only known stellar configuration capable of producing the observed periodicities (periods P in the range milliseconds to seconds)+ In the first few pulsars discovered the periods ranged from 0.25 s. to 1.5 s. This' led to the speculation that the plusar object may be a WHITE DWARF, either rotating (Ostriker 1968) or vibrating (Skilling 1969). However, the discovery of the Crab pulsar (Staelin and Reifenstein 1968) and the Vela pulsar (Large, Vaughan and Rills 1968) with perids of 0.033 s. and 0.089 s. respectively, laid to rest such speculations and pointed to a rotating neutron star (Gold 1968; Pacini and Salpeter 1968; Pacini 1968) which is the only stable

stellar   configuration   capable   of   producing   such   short
periodicities.

(b) A HIGHLY MAGNETISED, ROTATING NEUTRON STAR can   explain
the observed rate of decrease in the period (Gold 1968) which is
observed to be typically $\sim 10^{-15}$ sec./sec. (Radhakrishnan et al.
1969; Cole 1969; Davies et al 1969; Richards and Comella
1969), since a rotating magnetic dipole would radiate energy in
the   form   of   electromegnetic   waves   at   the   expense   of   the
rotational energy* Pacini (1967) suggested the scheme as the
energy source in the. Crab nebula even before the discovry of
pulsars. The observed P and $\dot{P}$ suggest that the dipole
magnetic field strength B is typically $\sim 10^{12}$ gauss at the
stellar surface*

(c) The observed radio luminosities coupled with the
compactness of the pulsar suggest that the equivalent black-body
brightness temperature T_B must be $\sim 10^{a1}$ °K. As this is a
physically unrealistic temperature, the radio luminosity must
result from a coherent radiation process (Craft   et   al.   1968;
Lyne and Ricket 1968; also see Manchester and Taylor 1977).

(d) The large bandwidth of the radio radiation, ranging
from 10 MHz to 10 GHz (Davies et al. 1968; Robinson et al.
1968; Radhakrishnan et al. 1968), its spectrum, and the
polarised nature of the radiation (Lyne and Smith 1968)
indicate a non-thermal type of radio emission (e.g., synchrotron
radiation), In this case the polarisation of the radiation will
reflect   the   orientation   of   the   magnetic   field*   Early
polarisation   observations   (Radhakrishnan   and   Cooke   1969)

suggested that the magnetic field configuration must be similar
to that near the axial regions of a dipole.

Thus the early consensus was that pulsars are highly
magnetized, rotating neutron stars from which radio radiation is
coherently emitted close to the axis of the magnetic dipole*
Provided that the line of sight to an observer lay within the
cone of radiation emanating from the magnetic axis, he would see
a pulse every time the rotation of the neutron star sweeps the
beam past him (Radhakrishnan and Cooke 1969;   Kornesaroff 1970;
Radhakrishnan et al. 1969).

1.2 SOME OUTSTANDING PROBLEMS

Almost everything else concerning pulsars is enmeshed in
some sort of controversy, The foremost problem in pulsars
concerns the exact mechanism of radio radiation and its
coherence, Currently one school of thought (consisting of the
POLAR CAP MODELS based on the work of Radhakrishnan and Cooke
(1969), and pioneered by Sturrock (1971), Ruderman and
Sutherland (1975), Arons (1979), and Cheng and Ruderman (1980))
has achieved partial success in interpreting phenomenologically
the vast pool of observational data.   There are now 330 observed
pulsars (Manchester and Taylor 1981) each displaying a variety
of behaviour regarding (1) the morphology of the pulse, (2)
polarisation, (3) radio luminosity and its variation, (4)
drifting subpulses, (5) pulse structure on a variety of time
scales down to micro-seconds, etc. (an excellent compilation of
these properties can be obtained in Manchester and Taylor

(1977), who give copious references to the original contributors). However, theorists are facing immense difficulties in using basic physics (essentially electrostatics and electrodynamics) to establish the "foundations" of these models (again Manchester and Taylor (1977) is a good reference though a recent review by Nichel (1982) may be more appropriate; however see Goldreich and Julian (1969), Flowers et al. (1977), Cheng and Ruderman (1980), and Melrose (1981) for some of the difficulties with these models). Another school of thought, consisting of the LIGHT-CYLINDER MODELS (Smith 1970 and 1973, Zheleznyakov 1971), has even greater difficulty in making a plausible model (however, see Ferguson (1983) for a dissenting opinion)+ Thus the mechanism of radio radiation remains a major problem to this day.

Although the relationship between pulsars and their environment is understood better, there are still many problems waiting to be solved* It is believed, for example, that massive stars explode towards the end of their lives (an event known as a SUPERNOVA), leaving behind a shell of stellar material known as a SUPERNOVA REMNANT (SNR) and a NEUTRON STAR (Baade and Zwicky 1934). This picture gained immense credibility with the dicovery of a young pulsar each in the Crab SNR as well as in the Vela SNR. However there are two types of supernova events (Minkowski 1942), and it is not fully established that only one type leaves behind a neutron star and not the other, as speculated by Shklovskii (1982). It is also not clear whether such a neutron star immediately becomes a pulsar or has a duration of dormancy when it does not put out any radio pulses* If pulsars are indeed born in such a scenario, then we should

find a pulsar within or near each SNR. But only three pulsars (PSR 0531+21, PSR 0833-45 and PSR 1509-58) are believed to be associated with an SNR each, out of the 330 pulsars and 120 SNRs known to this date. Furthermore, the presently computed birthrates of pulsars and SNRs appear to be significantly different (Trimble (1983), Manchester and Taylor (1977) and the references therein).

Finally the internal structure of neutron stars is a subject of much theoretical study and is of great importance even in understanding their external behaviour. For example the internal structure will ultimately determine whether the pulsar magnetic field decays within its lifetime or not (Chanmugan 1973; Ewart et al. 1975). Again it is not known with certainity whether ions can be pulled out of the surface of a neutron star as easily as electrons (Chen et al. 1974). The validity of the Ruderman and Sutherland model is critically dependent upon the answer to this question.See Ruderman (1972) and Baym and Pethik (1975) for reviews on the internal structure of neutron stars.

1.3 PREVIOUS ESTIMATES OF THE PULSAR BIRTHRATE

In this thesis we attempt to answer some of the above questions by analysing statistically the vast amount of observational data which has accumulated in the last ten years or so. We start with an attempt to obtain a reliable birthrate for pulsars.

Usually the birthrate of pulsars is computed by the simple argument that, in steady state conditions, the total number of pulsars N_G in our Galaxy should be equal to the birthrate b multiplied by the mean lifetime of pulsars τ_m. N_G is obtained by using the inferred space density of potentially observable pulsars in our Galaxy, and dividing it by a beaming fraction f which accounts for those pulsars which are not beamed towards the Earth. In order to study the distribution of pulsars in the Galaxy it is necessary to know their distances. For about 30 pulsars distances have been measured by means of HI absorption. For the majority of pulsars, however, the observed dispersion measure, together with the galactic thermal electron density model, is the only means of estimating distances,

To obtain the true distribution of pulsars with respect to the radio luminosity L , galactocentric radius R_G and the height z above the galactic plane, the various selection effects due to the inverse square law, the sky coverage, system sensitivity, etc., must be taken into account. This exercise was first done by Large (1971), and later by Davies et al. (1977), Taylor and Manchester (1977), and Manchester (1979), each on an increasing size of data sample. The consensus now is that there are $\sim 10^5$ pulsars in the Galaxy beamed towards us. All these authors assume that the fraction of pulsars beamed towards us is 0.2. Therefore N_G was estimated to be $\sim 5 \times 10^5$ pulsars. We mention in passing that somewhat lower estimates of N_G ($\sim 1 \times 10^5$) have been obtained by Guseinov and Kasumov (1979) and Arnaud and Rothenflug (1980); and Gailly et al. (1978) obtain N_G to be in the range 0.4×10^5 to 13×10^5 . However, these lower estimates are most likely due to the higher

choice of L_{min}, the limiting radio luminosity in the L distribution, made by these authors*

τ_m can beestimated by two methods* By assuming the dipole model for pulsar braking (Ostriker and Gunn 1969), the age τ of a pulsar can be estimated by the relation $\tau \approx \frac{1}{2} P/\dot{P}$, where P is the period and $\dot{P}$ is the period derivative* However, τ is not a true estimate at ages larger than a few million years (Lyne et al. 1975, Taylor and Manchester 1977), either due to magnetic field decay (Ostriker and Gunn 1969), or alignment of the magnetic axis with the rotation axis (Goldreich 1970; Michel and Goldwire 1970; Davis and Goldstein 1970). The discrepancy between τ and the true age at large τ appears to be confirmed by the proper motion measurements of Lyne et al. (1982). Following the method of Davies et al. (1977), Manchester and Taylor (1977) obtain an estimate of τ_{min} as follows* Of the 87 pulsars with known characteristic ages at that time (just before the Second Molonglo Survey almost doubled the total number of pulsars), about 20 have ages less than one million years* Then the upper limit on the "equivalent" lifetime is approximately $87/20$ or 4.5 million years, which implies that the mean lifetime is around 2 million years* However, these authors did not take into account the selection effect depending on period or radio luminosity*

Alternatively, can also be estimated by dividing the mean height $\langle z \rangle$ of pulsars above the galactic plane by their mean z-velocity, $\langle V_z \rangle$, which can be obtained indirectly from the proper motions which have been measured for a few pulsars (Anderson et al 1975; Backer and Sramek 1976; Manchester et

al, 1974; and Lyne et al. 1982). These "kinematic" ages have the advantage of being independent of errors in pulsar distances. On this basis Manchester and Taylor (1977) obtain the mean lifetime of pulsars to be 2×10^6 yrs, which is in good agreement with the above estimate. Thus using 4 million years for the mean equivalent lifetime, Manchester and Taylor (1977) obtain the birthrate to be once every 6 years in our Galaxy. In this calculation they neglect a very important selection effect, viz., the radio luminosity selection effect, which biases the observed sample towards bright, and consequently young, pulsars. Lyne (1981a) obtained τ_m to be 5 million years after analysing a much larger sample of 278 pulsars with known characteristic ages, as well as an enlarged sample of 26 pulsars with improved proper motion measurements (Lyne et al. 1982). He obtains a birthrate of one pulsar born every 10 years. Howver, he too neglected the radio luminosity selection effect. More recently, Lyne (1981b) took the radio luminosity selection effect into *account* and obtained a *birthrate* of one every 30 years in our Galaxy,

Thus most previous computations of the birthrate suffer from two major uncertainities, viz., the neglect of the radio luminosity selection effect in computing pulsar ages, and the assumption that the fraction of pulsars beamed towards the Earth is only 0.2. A somewhat less serious, but nevertheless significant, uncertainity is the conventionally adopted model for the thermal electron density in the Galaxy, which establishes the distance scale to pulsars*

1.4 THE PRESENT WORK

Our first exercise is to extract a "uniform" and "complete" working sample of pulsars from the presently available data. Most of the 330 pulsars known to this date have been detected by four surveys, viz., the FIRST MOLONCLO SURVEY (IMS, Large and Vaughan 1971), the JODRELL BANK SURVEY (Davies et al. 1972, 1973), the ARECIBO SURVEY (Hulse and Taylor 1974, 1975), and the SECOND MOLONGLO SURVEY (IIMS, Manchester et al. 1978). Each survey has its own limitations in terms of telescope sensitivity to any pulsar parameter; for example, the Arecibo survey could detect pulsars whose radio flux S was as weak as 1.4 mJy (1 milli Jansky (mJy) = 10^{-29} watts/m^2/Hz), while the Jodrell Bank survey could not go below 15 mJy; the Arecibo syrvey could detect pulsars right down to 0.4 seconds in period while the Jodrell Bank survey could not go below 0.3 s; etc. Because of this we firstly restricted ourselves to the IIMS for the sake of uniformity of the sample. Moreover the IIMS detected 224 pulsars, which is a significant fraction of the total number of pulsars detected so far. We made a thorough study of the observational limitations (known as "selection" effects) for the IIMS and derived the following formula ,for the minimum detectable flux S_{min} for a pulsar

$$S_{min} = S_0 (1 + T_{sky}/T_R)(1 + K.DM./p)^{1/2} (\cos \delta)^{1/2} \qquad (1.1)$$

where T_{sky} and T_R are the receiver and sky noise temperatures, DM is the dispersion measure of the pulsar, K is a constant depending upon the minimum bandwidth of the receiver? and is the declination. We have confirmed from the IIMS data that this formula is an improved representation of

the selection effects in this survey as compared to the conventionally used formula (Taylor and Manchester (1977), eq. (8-5)). The new features of this formula are firstly the period dependence of S_{min} which has so far received very scanty attention (Large and Vaughan 1971, and Huguenin 1976), and secondly the declination dependence which is peculiar to IIMS and has not been mentioned so far.

Next we improve the distance scale to pulsars by studying the interstellar electron density* Pulsar distances are generally estimated by means of the formula

$$d = DM / \langle n_e \rangle \qquad (1.2)$$

where $\langle n_e \rangle$ is the mean interstellar electron density, Hall (1980) details a good summary of the various previous attempts to estimate n_e , On account of the large uncertainities associated with the presently used $\langle n_e \rangle$, it is necessary to properly model n_e , For example, n_e is believed to decrease exponentially with increasing height z ; thus the scale height z_0 must be determined* We have tested various models of n_e under the constraint that the resultant galactic distribution of pulsars be cylindrically symmetric about the galactic centre* This is an independent test of n_e and thus helps to reduce the error bars on it. We have also studied the separate n_e of HII regions, which are small regions of (relatively) extremely high electron densities surrounding bright stars. If these are not treated separately, one might lose the proportionality between DM and d that is genarally assumed (eq. (1.2)). We have combined our results with other independent estimates of n_e (see Vivekanand and

Narayan (1982) for references), and have finally chosen the following formula whose form was first established by Lyne (1981a).

$$\eta_e(z) = 0.03 + 0.02 \, \text{EXP} - (|z|/70)$$ (1.3)

Here the first term represents a uniform electron density for the whole galaxy, while the second term represents a separate contribution from HII regions, which have a scale height of 70 pc.

We then use a Monte Carlo scheme to compute for each pulsar a weight, or scaling factor $S(L,P)$, which depends upon its period and radio luminosity L. This is the ratio of the total number of pulsars in the Galaxy to the number detected by the IIMS, with the given P and L. We assumed the galactic distribution of pulsars suggested by Manchester and Taylor (1977), and generated pulsars randomly all over the Galaxy withvariousvaluesof P, L, DM, and S. We kept count of the total number of pulsars generated as well as those which can be seen by the IIMS, using our formula for S_{min} and our model for η_e. The ratio of the two numbers yielded the scale factors. Thus $S(L,P)$ is a measure of the incompleteness of the survey at each P and L. If one were to compute the average of any pulsar parameter, say P, then one must compute the weighted average where the weights are $S(L,P)$.

Finally we compute the birthrate of pulsars in a novel manner. We use the fact that the period of a pulsar is related to its age τ; since $\dot{P}$ is always observed to be

positive (Manchester and Taylor 1981), the period of pulsars always increases with age* We use the concept of pulsar current J_p (= number of pulsars/sec.) which was independently introduced by Phinney and Blandford (1981). This is the number of pulsars at any period, crossing over from lower to higher periods, per unit time* It is identically equal to the birthrate minus the death rate in the period range 0 to P , and is a rigorous lower bound to the birthrate in the same period range, We outline the qualitative features of the J_p vs. P curve, and show that in a certain portion of this curve we may actually expect to measure the complete birthrate, and not just its lower bound. We compute the birthrate by the obvious formula (simplified for our purposes here)

$$J_p (P) = \rho(P) \dot{P} \qquad\qquad (1.4)$$

where $\rho(P)$ is the pulsar density; both $\rho(P)$ and $\dot{P}$ are observed quantities* Thus our calculation is entirely independent of any pulsar model; most previous calculations on the other hand use the age τ , which can only be computed on the basis of a model, In addition, our calculation was the first to incorporate both "radio luminosity" and "period" selection effects (we recall that Lyne (1981b) incorporated the radioluminosity selection effect although he used the model dependent age τ for his calculation)+ We compute the birthrate of'pulsars to be once every 13^{+17}_{-6} years in our Galaxy, assuming a beaming fraction of 0.2 (the error limits represent the 95% confidence limits).

    Our calculation of J_p further showed that the current in

the period range 0.5 s. to 1.0 s. is significantly higher than the current in the period range 0.0 s. to 0.5 s. From our definition of $\mathcal{J}_P$ it is obvious that such a situation can arise only if some pulsars enter the second period bin without flowing through the first* We therefore conclude that pulsars are born in the the second period bin also. This is a surprising result, since it was conventionaly believed that pulsars are born rotating rapidly, with starting periods of the order of a few tens of milliseconds, but never as large as 0.5 seconds, We have named this phenomenon "injection" of pulsars at large periods* The currents in the two period bins are too noisy to allow us to estimate the percentage of pulsars that are injected, but we can state with 80% confidence that it is at least 30%. Now, the noise in our currents is contributed mainly by the spread in scale values $S(L,P)$. We reduced this spread by discarding the observed luminosity L in the computation of $S(L,P)$ and using instead a luminosity L' modelled as a functionof P and $\dot{P}$ following Lyne et al. (1975):

$$L' \propto P^\alpha \dot{P}^\beta \tag{1.5}$$

We recomputed $S(L,P)$ using L' insteadof L , and found that in fact a major fraction of pulsars are injected* We further computed $\mathcal{J}_P$ in various bins of the $P-\dot{P}$ diagram and found that injection occurs at high values of $\dot{P}$ We offer two possible explanations for injection and show that one of them could explain naturally the observed lack of association between pulsars and SNRs. We conclude that injection is a genuine pulsar phenomenon which awaits explanation, and not an artifact of any selection effect or method of analysis.

Since a pulsar does not radiate isotropically but in the form of a beam, we would see only a fraction f of all pulsars in the Galaxy* This is the major uncertainity in our birthrate calculations, since the observed number of pulsars has to be scaled up by $1/f$ to obtain the total number in the Galaxy. f depends upon the shape and size of the pulsar beam, which is conventionally assumed to be circular in cross-section for want of any evidence to the contrary (Manchester and Taylor 1977). In other words, if we characterise the beam cross-section by means of the "North-South" dimension β_m (which is along the projection of the rotation axis on the plane of the sky) and the "East-West" dimension γ_m (along the direction of rotation), it was conventionally assumed that $\gamma_m \cdot \beta_m \sim \langle w \rangle$; which is the mean observed pulse width. The corresponding value of f turns out to be 0.2.

We have investigated the beam shapes by studying the linear polarisation data of some pulsars* In the framework of the widely acccepted Radhakrishnan and Cooke (1969) model for pulsar polarisation, the total change in the orientation θ of the linear polarisation vector across a pulse indicates the relative off-set β of the magnetic pole and the line of sight along the β -axis; i.e., θ tells us how far North (or South) we are relative to the beam centre, By analysinq θ for 16 pulsars we find the ratio β_m/γ_m is on the average 3.0 ± 0.4. We therefore conclude that pulsar beams are highly elongated in the North-South direction* By analysing an enlarged sample of 30 pulsars we find that this ratio varies with period as $P^{-0.65}$ It thus appears that short period pulsars have

highly elongated beams, and that the elongation decreases with increasing period. We have confirmed these results by an independent analysis of the maximum gradient of θ in the pulse, taking into account the spherical nature of 'the pulsar beam geometry* For the mean elongation of 3.0, the value of f is 0.5, which is much larger than the conventional value. Consequently the pulsar birth rate scales accordingly*

As the polarisation data cannot distinguish between the north half of the beam and the south half of the beam, there could still be a factor of 2 uncertainity in f if, for example, pulsar beams were "one-sided" only (Arons 1979). We have analysed the polarisation data to determine the relative orientations of the rotation axis, magnetic axis and the line of sight* We analyse three essentially independent data: (a) the shape of the polarisation angle θ vs the pulse longitude φ curve, (b) the magnitude of the maximum gradient $|d\theta/d\varphi|_{max}$ in the main pulse, and (c) the magnitude and sign of the gradient in the interpulse. We find that the line of sight can lie on either side of the magnetic axis (relative to the rotation axis). In other words, pulsar beams extend both north and south of the magnetic axis, and are not "one-sided"*

The final computation of f for each pulsar was made under the following assumptions: (1) the mean beam width at 10% of peak intensity is 17^0 of longitude, (2) the beam elongation evolves with period as mentioned above, and (3) the relative orientations of the magnetic axis and the line of sight (with respect to the rotation axis) are uniform in the solid angle. Using this we compute that pulsars are born once every

28^{+40}_{-14} years in our Galaxy. We therefore conclude that there is no significant discrepancy between the birthrates of pulsars and SNRs. Towards the end of the thesis we discuss the various implications of our analysis*

Towards the end of this thesis we reproduce the pulblished version of a manuscript concerning our observations on pulsars using the OOTY RADIO TELESCOPE. Improved declinations are presented for 40 weak pulsars. Flux densities at 327 MHz are also presented for these objects* For 32 of these pulsars improved periods are derived using our improved positions* Our work has enabled us to demonstrate that PSR 1922+20 is highly unlikely to be associated with the radio continuum source 4C20.48.

Finally we reproduce published versions of two more manuscripts dealing with work on pulsars done by us which, however have no direct bearing on the contents of this thesis.