Observations of the CMB with the Kapteyn Radio telescope

Sander Verdult
Kapteyn Institute Groningen
verdult@fmf.nl

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Abstract

Observations of the the pulsar B0329+54 with the Dwingelo radiotelescope, and using the information found to deterine the period, dispersion measure of the interstellar medium, and with some values from literature things such as the age, the distance to our solar system, the magnetic field strength and more.

I. Introduction

i. Radio Astronomy

Radio astronomy is not a very old field

ii. Cosmic Microwave Background

iii. Atmospheric opacity

iv. Brightness temperature

v. Radiative transfer

II. Observations

i. Telescope

The Dwingeloo Radiotelescope started service in 1956, making it one of the oldest telescopes in the world. Up to 1998 it was used for scientific research by ASTRON. By lack of use it started to decay, but by the help of camras it was restored from 2012 to 2014 as a national monument, and is now once more ready for use by radio astronomers, astronomy students and the likes./citecamras

Table 1: *Kapteyn Radiotelescope Specifications*

Specification	Value
Observing Frequency	11 GHz
Bandwidth	1 GHz
Aperture Diameter	178 mm

ii. Calibrations

iii. Observations

III. Data Reduction

i. Determining the period

Data reduction was done in the web interface of the Astron education website (www.astron.nl/onderwijs), where the data of the observation could be accessed. First we used the dynamical spectrum displayed below to get a rough estimate of the pulse period for our object. This was done by pinning the pulse at a specific wavelength to specific times, and determining the difference. We used the dynamical spectrum between 16 and 18 seconds for our first estimate.

Next we used this estimate of the period to do a fast Fourier transform at 420.07 MHz, resulting in the spectrum shown below in figure 2. The spikes are an intiger multiple of the

Table 2: *Pulse measurements*

Time (s)	Frequency (MHz)
16.348762	417.200781
17.065662	417.200781
17.780409	417.200781

pulse frequency, so by counting the pulses over a larger range, one can make a better a estimate of the pulse time. Dividing 28 pulses over a frequency 39.19 Hz gives us an improved estimate of 0.714444 seconds.

Using this improved estimate still showed an offset between the early and latter pulses, showing us that this estimate was not entirely correct either. We started out with figure 3, where the peaks clearly do not overlap, and it took a series of minor changes to get the peaks of the pulse to overlap exactly such as in figure 4, which gave us a final period estimate of 0.714515 seconds

ii. Determining the dispersion measure

Having found our period, we can now use our data to determine the time difference in arrival of the pulses different frequencies. Plotting a single pulse at different frequencies shows that the lower frequencies have a higher delay then the higher frequencies due to the electron density between our pulsar and the earth. [10]

Measuring these different times at different frequencies, we can use kapteyn-fit to do a least square fitting method on our data, and determine the actual dispersion. With a bit of programming this resulted in a set of data points where the strength of the slope gives us the measured dispersion measure. Adjusting the equation so that we could look for a linear equation, we found a dispersion measure of 26.97

Compensating for this dispersion measure should have given us nicely overlapping peaks. Here however we ran in to a bug on the astron site which could not be avoided, and the

iii. Pulse Profile

Now that determined the dispersion measure and the acurate period, we can calculate the pulse profile of PSR B0329+54. By correcting for the dispersion measure and then adding up the profile of all the frequencies in which the pulse is active, we get a single profile covers the pulse in detail. We do believe that though the previous step had a bug, the final result still got determined properly by the web application.

IV. Results

i. Period

We determined the period to be P = 0.714515 seconds.

ii. dispersion measure

The dispersion measure we found was 26.97.

iii. Period change

We could not determine a change in the time of our measurements. This in term means that there are a lot of other factors we can't determine, but we will discuss these at the discussions.

V. Discussion

Summary of what the results tell you about this pulsar, how does it compare with other pulsars, what does the dispersion measure tell you about the interstellar medium

i. Period

The period we found (P = 0.714515 seconds)is a really common period for a pulsar to have. [2] Literature gives us a frequency of 1.400 per s, which replies to a period of 0.71429, which is similar to what we measured. [6]

ii. Period Change

Though we could not measure the change in period ourself, we have looked this up in the literature, and we found a value of $\dot{P} = 2.048 \cdot 10^{-15} s s^{-1}$ [6]

iii. Age of the pulsar

If we have the period and the pace at which the period changes, we can also determine the age of the pulsar by the following formula: [4]

$$\tau = \frac{1}{2}\frac{P}{\dot{P}} = \frac{1}{2}\frac{0.71415}{2.048 \cdot 10^{-14}} \tag{1}$$

$$= 1.743 \cdot 10^{13} s \quad = \quad 5.528 \cdot 10^{5} year \tag{2}$$

iv. Magnetic field of the pulsar

With the same information we can also determine the minimum strength of the magnetic field around the pulsar.

$$B/tesla \geq 3.3 \cdot 10^{15} \sqrt{P\dot{P}} \tag{3}$$

This results in a magnetic field of atleast $3.99 \cdot 10^{8}$ tesla

v. Dispersion measure

The dispersion measure we found was 26.97.The one we found in literature was 26.84 [5] which is again really close to what we measured.

vi. Distance

With the Dispersion measure and a model for the galactic free electron density we can enter the right ascencion and declination of our pulsar, and tell the model to integrate to a dispersion measure of $26.97 pc/cm^{3}$ at a frequency of 420 Ghz, in which case we find a distance of 1.115 kpc. Literature[5] gives us a paralax distance of $1.06 \pm .12$ kpc so this estimate seems correct aswell.

VI. Conclusions

i. Errors

Important to note is that we have been lax with error margins. Being more precise with these and keeping track of them would have helped us determine how valuable our results are. To properly keep track of the errors in our measurements and calculations, we should have done so from the start.

ii. Comparison with other pulsars

Compared to other pulsars both the magnetic field and the period seem to be part of the norm [9]. Beyond the strong intensity, which is most likely due to it's relative close distance, PSR B0329+54 is an ordinary pulsar.

iii. Future experiments

More observation times are required to calculate the time derivative of the period. Taking into account effects from the motions of our solar system and earth, we should be able to get an accurate estimation of how quickly the period changes over time. This in turn means that information about the size, age, magnetic field and more can be calculated rather precisely.

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