Astrophysical Phenomena Revealed by Space VLBI
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VSOP Observations of PSR B0329+54

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1 Introduction

The pulsar B0329+54 was observed on 22 August 1998 using the HALCA satellite, the VLBA, the 140 foot telescope in Green Bank and the DSN's 70 meter telescopes in Goldstone and Madrid. The observations where at 1634 to 1666 MHz with 64 channels in two IFs resulting in a spectral resolution of 0.5 MHz. The VSOP observations were performed from 06:00 to 18:00 UT on August 22, 1998. These observations used the Green Bank, Goldstone, Madrid and Usuda tracking stations and the NRAO's VLBA correlator.

The IF at the 140 foot telescope was split with one output going to the VLBA recorder and with the other going to the spectrum analyzer. The spectrum analyzer was used to produce a dynamic spectrum of the pulsar in the frequency range 1600 to 1670 MHz. The data were integrated for 90 seconds with a frequency resolution of 0.078125 MHz and 128 phase bins across the full pulsar cycle.

2 Correlation

The data were correlated using the VLBA correlator. Two passes of the data were made. The first pass correlated the data in the standard fashion while the second made use of pulsar gating. The gate was centered on the main pulse of 0329+54 and had a total passband of 15% of the pulse cycle. The timing information obtained from the 140 foot telescope spectrum analyzer observations during the VSOP observations of 0329+54 was used to determine the exact time that the pulsar gate was turned on and off.

Fringes for 0329+54 were found at all times on ground to space baselines for both the standard correlation and the gated correlations. Only the gated data will be discussed here. Figure 1 shows the (u, v) coverage obtained for this observation.

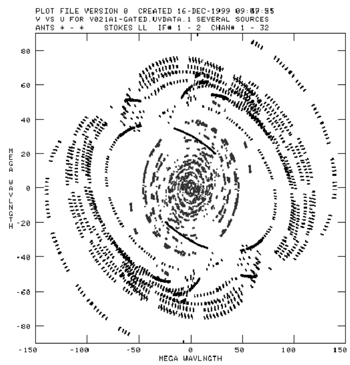

Figure 1: (u, v) plot of valid data from VSOP observations of PSR B0329+54 (V021a1). The black (outer) points indicate space-ground baselines and the grey (inner) points indicate ground-ground baselines. The u axis range is ± 150 Mλ and the v axis range is ± 90 Mλ.

3 Dynamic Spectra

The dynamic spectrum of 0329+54 from the 140 foot data is shown in Figure 2. The dynamic spectrum plots the flux versus time and frequency. This conveniently displays the "twinkling" of the pulsars signal due to the turbulent plasma located between the pulsar and the observer. The data shown in Figure 2 represent a preliminary calibration of the data and the uncalibrated bandpass edges of the 4 IFs can easily be seen. The data were integrated over the entire pulse to produce the dynamic spectra shown in Figure 2.

In the dynamic spectrum shown in Figure 2 there are several interesting features that should be noted. The first is that the flux rises by about a factor of ten at certain frequencies and times. Secondly, the flux brightenings are periodic both in frequency and in time, with the lower frequencies leading the higher frequencies. This is indicative of the turbulent plasma creating two (or more) dominate paths over which the pulsar emission can reach the Earth. The light along these multiple paths produce interference fringes at the Earth resulting in the features seen in Figure 2. This will be referred to as a multiple imaging event for the remainder of the paper.

In Figure 2 we also show a dynamic spectrum produced using the correlated flux from the HALCA to 140 foot telescope baseline data.

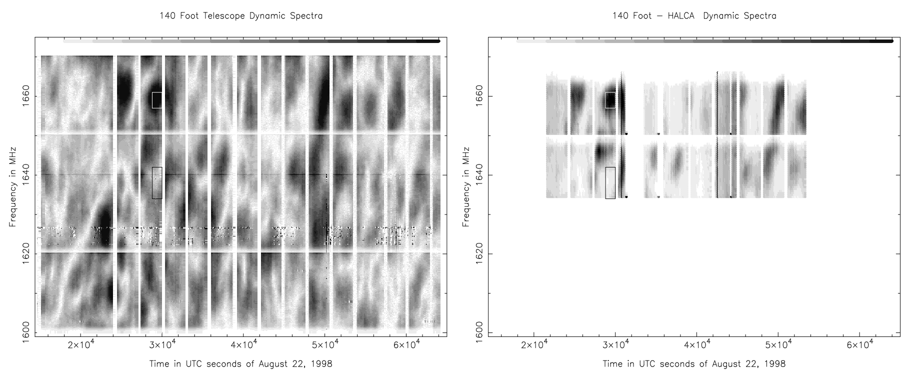

Figure 2: Dynamic spectrum of PSR B0329+54 using the 140 foot telescope on August 22, 1998 (left) and using the correlated flux on the HALCA to 140 foot baseline (right). The "bar" at the top of the images indicates the flux level with white being the lowest flux and black being the largest. Interference from the Iridium satellites can be seen from 1620 to 1627 MHz. The two boxes in each dynamic spectra indicate the data used for producing the images in Figure 3.

Roughly the same features are seen in this dynamic spectrum and in the one produced using only the 140 foot telescope data. The subtle differences can provide information on the size scale, distance or velocity of the turbulent plasma creating the multiple imaging events.

3.1 Multiple Imaging Event

In Figure 2 two boxes are shown for each dynamic spectra. The data within these boxes were used to produce the images shown in Figure 3. One data set was chosen such that it was during a multiple imaging event and could display multiple images of the pulsar and possibly image wander. The other data set was chosen at a time where multiple images would not be expected.

In Figure 3 the grey scale represents the multiple image data set (upper box in Figure 2) and the contours represent the single image data set (lower box in Figure 2). The total flux in the multiple imaging event is approximately 290 mJy while it is approximately 30 mJy in the "normal" image. These fluxes are the average pulsar flux integrated over the full pulse cycle. The total flux of the brightest component during the multiple imaging event is approximately 250 mJy while the secondary

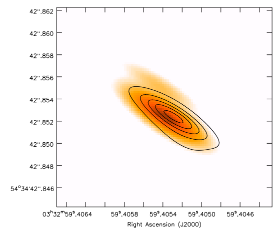

Figure 3: The contours show an image of 0329+54 produced during a period of low flux. The contours are derived from the data shown in the lower box in Figure 2. The grey scale image shows another image of 0329+54 derived from a period of high flux. This image is derived from the data in the upper box in Figure 2.

image is approximately 40 mJy. The two images of the pulsar during the multiple imaging event are separated by about 2.9 mas ($\sim$ 3.5 A.U. at 1 kpc). Also it can be seen that the images have been shifted by about 1.5 mas as would be expected from this type of phenomena (Gupta, Rickett and Lyne 1988). However, this data is not phase referenced. It is fortunate that these observations involved HALCA since the multiple images would not have been resolved from ground only VLBI experiments.

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References

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