

Chapter 3

Observations and Data Reduction

3.1 ATNF

The Australia Telescope National Facility (ATNF), CSIRO, a set of eight individual radio telescopes, as a national research facility for both Australian and international researchers.

In addition to these, 3 other telescopes located at Tidbinbilla in Victoria, Ceduna in South Australia and Hobart in Tasmania are also to form a Very Long Baseline Interferometry (VLBI) Array known as the Long Baseline Array (LBA). However, the observations described in this thesis only use the telescopes belonging to the ATNF.

Six of these telescopes make up the Australia Telescope Compact Array (ATCA), located at the Paul Wild Observatory near the town of Narrabri. Each of these antennas has a reflecting surface with a diameter of 22 metres. Another similar 22-metre antenna is located at Mopra near Coonabarabran.

The oldest telescope operated by the ATNF is located at Parkes and is 64 m in diameter. It has been operated successfully since 1961. Recent upgrades to accommodate a 13-beam focal plane array have maintained its world-class position as a state-of-the-art instrument.

Using only three stations, the spatial resolution near 1.6 GHz is approximately 0.10 arcsec depending on source declination. This resolution is well suited of observations of masers at distances of a few kpc. Although not matched to the typical maser spotsize (~ 5 mas), the resolution does allow clear position discrimination between the numerous tight clusters of spots (of typical size < 100 mas) that are commonly spread over the total extent of an arcsec.

3.2 Observations

The present observations were made by Caswell and Reynolds using the Long Baseline Array (LBA) telescopes at Parkes, Mopra, and Narrabri on 16-17 August 2000. The signals from the telescopes forming the Compact Array at Narrabri were combined together to form a single telescope with an equivalent size of 64 m diameter. The three stations yield baselines of approximately 119 km, 103 km and 321 km in a predominately north-south direction. The S2 tape system was used to record both right- and left-hand circular polarizations (RHCP, LHCP) simultaneously with a band pass centred at 1667 MHz and limited to 4-MHz bandwidths by digital filters with excellent flat responses in both amplitude and phase. The target source, OH 330.953-0.182 and its associated calibrators, were observed for a total of xx minutes, with the time divided such that each 25 minutes observation of the target was interleaved with five minute periods on a phase and secondary amplitude calibrators, the phase calibrator being 1424-418 and the secondary amplitude calibrator being 1740-517. The flux densities used for these latter two sources, obtained from a comparison of observations of them with those of the absolute flux density calibrator, 1934-638, were 2.83 Jy and 7.21 Jy respectively. 1934-638 was assumed to be unpolarized with a total intensity of 14.157 Jy.

3.3 Data Reduction

Editing, calibration and imaging of the data was carried out by Hutawarakorn Kramer and Caswell at the ATNF in July 2005. The parallel hand (LL & RR) output from correlation of the signals from the two polarization channels was integrated for 5 second periods. One correlation pass for each baseline was required in order to achieve high frequency resolution of 8192 channels across the 4-MHz band, thus enabling both the OH 1665 and OH 1667 lines to be seen with sufficient reduction. In the subsequent processing using the AIPS reduction package, no Hanning smoothing was applied so that the final channel separation remained 0.48828125 kHz ($= 0.088 \text{ kms}^{-1}$), given a final

Table 3.1: Observing parameters for the ATNF spectral-line polarisation observations presented in this thesis. Time on source includes frequent short observations of the phase calibrator sources.

| | |
|---|---|
| Target source name | OH 330.953-0.182 |
| Date of observations | 16 th - 17 th August 2000 |
| Antennas used ¹ (Telescope) | Narrabri, Mopra, Parkes |
| Field centre. (2000) | $\alpha=16^h 09^m 52^s.5$ $\delta=-51^\circ 54' 54'' .0$ |
| Central velocity (km s ⁻¹) | -90.00 |
| Distance (Kpc) | -8.5 |
| Central frequency (MHz) | 1665.402 |
| No. of frequency channels | 8192 |
| Total bandwidth (MHz) | 4 |
| Time on source (hours) | 15 |
| Amplitude calibrator source for the target source | 1740-517 |
| No. of channel used (chan.) | 33-250 |
| Phase calibrator source for the target source | 1424-418 |

velocity spectral resolution is 0.015 km s^{-1} (larger than the final separation by a factor of 1.2 for uniform weighting).

After initial editing of the data quality, the calibrators were used to derive first order phase and amplitude corrections to the target observations and to correct the phases between the RR and LL polarisations. This ensures that the relative positions are correct. The program 'cvel' was used to align channels to the same velocity and to correct for varying Doppler shift arising from the Earth's motion during the observations. Values of 1665.4018 and 1667.3590 MHz for the rest frequencies of the 2 OH lines were adopted.

Initial preliminary maps were made from those channels which contained the strongest spectral features for both polarisations, although the absolute positions of the features in these maps were unknown. However, the position of the strongest (39.12 Jy) spectral feature in the OH 1665-MHz RHCP images at a velocity of -85.5 km s^{-1} had already derived by Caswell (1998) from observations with the ATCA. From this, it was possible to establish absolute positions with an uncertainty of 0.4 arcsec. Thus, channel maps were made from each spectral line channel in the velocity ranging from -84.18 to -99.66 km s^{-1} RHCP feature at a position of RA $16^{\text{h}} 09^{\text{m}} 52^{\text{s}}.5$ and Dec $-51^{\circ} 54' 54'' .0$. The cellsize in each of these maps was 25 mas and the restoring beamwidth was 72×130 mas. These images were written in magnetic tape later analysis, which is the subject of this thesis.

3.4 Image Analysis

This section describes the AIPS tasks which have been used to further analyze the images produced as described above, in particular to measure the number of masers, their positions and intensities in the OH maser source, OH330.953-0.182.

3.4.1 Flowchart for image analysis

The images for all the channels which were expected to show maser position were displayed consecutively for an initial assessment.

1. FITLD

The image files in FITS format were loaded into the AIPS software package from magnetic tape using task FITLD.

2. PCAT

Produces a 'catalogue' list of all the files which have been load into AIPS.

3. TVLOD

Display a particular image on the TV using the parameters, TBLC and TTRC, of TVLOD, an image of a particular channel can be displayed from a multi-channel image file

TBLC 0 0 100 0

TBLC 0 0 100 0

results in the image for channel 100 being displayed on the TV.

4. TVFID

Fiddle with the zoom and enhancement of the currently displayed TV image.

5. TVWIN

A window within an individual channel image on the TV in which OH line emission was present was defined.

6. IMSTAT

The rms noise level within the window in the individual channel map was determined. This was used to define the minimum contour level at which channel containing maser spots would be plotted.

7. KNTR

Produces contour plots of those channels containing maser plots. Several con-

secutive channels could be plotted as part of a single plot. This was done to show more clearly the velocity extent of a particular maser feature.

8. JMFIT

Fit up to four Gaussian components to a portion of an image. It can also solve for a constant, linear, or quadratic two dimensional baseline surface. The program estimates the error in the fits using the image rms and theory.

3.4.2 Measuring Maser Positions and Intensities

From Hutawarakorn (1997), maser emission was seen in the channel maps in discrete spots. The position and intensity of each spot was measured by fitting two dimensional Gaussian components using a least squares technique (the AIPS task JMFIT). The individual components were resolved and usually only one but sometimes up to three were found per channel. The appropriate number of multiple Gaussian components were fitted where they appeared to be blend.

The positional uncertainty of each component is given by half the beam - width in R.A. or Dec. divided by the signal to noise ratio for that component (Condon, 1997). Series of components were found in 3 to 15 successive channels in the same position to within the uncertainty and these were assigned to maser features. Components were rejected unless they were above $3\sigma_{noise}$ in at least three successive channels.

The positions and velocities of features quoted in the results table (in Chapter 4) are the flux weighted means of the positions and velocities measured in individual channels;

$$X = \frac{\sum_i X_i S_i^2}{\sum_i S_i^2} \quad (3.1)$$

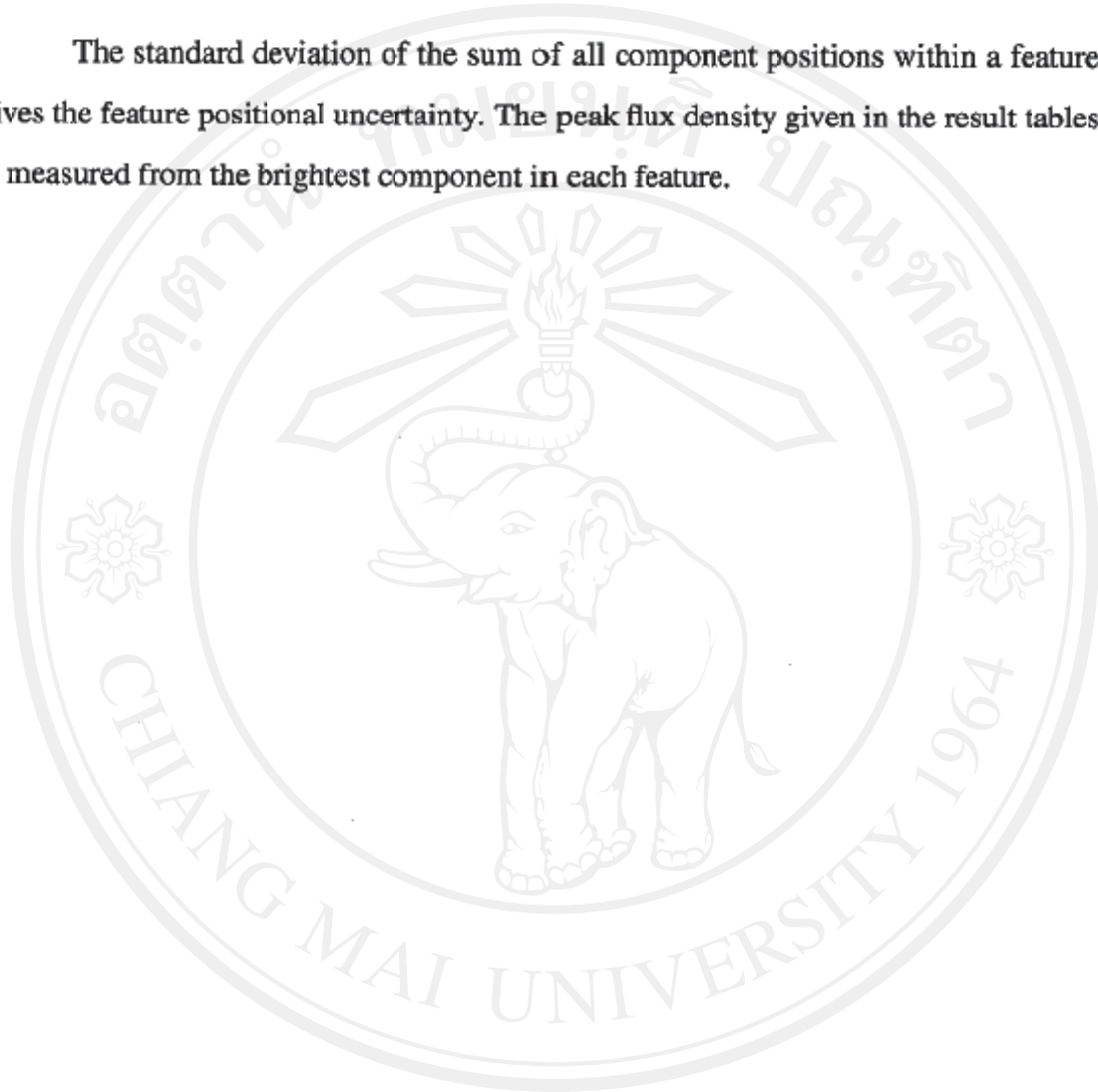
where

X is the mean R.A., Dec. or velocity of a whole feature;

X_i is the R.A., Dec. or velocity of an individual component allocated to that feature;

S_i is the peak flux of an individual component allocated to that feature;
and \sum_i is the sum over the channels containing that feature.

The standard deviation of the sum of all component positions within a feature gives the feature positional uncertainty. The peak flux density given in the result tables is measured from the brightest component in each feature.



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