

LIST OF CONTENTS

	Page
Acknowledgement	iii
Abstracts (In Thai)	iv
Abstract	v
List of Tables	viii
List of Figures	xi
Chapter 1 Introduction	1
1.1 Introduction	1
1.2 Literature Review	2
Chapter 2 Fundamental Theory	4
2.1 The Physics of Star Formation	4
2.1.1 Hydrostatic Equilibrium	4
2.1.2 Collapsing Clouds	7
2.2 Maser Theory	11
2.2.1 radiative transfer	11
2.2.2 Saturation	13
2.2.3 Pumping Mechanism	14
2.2.4 OH Maser Transitions	14
2.3 Effect of magnetic field	18
2.3.1 The spin of the electron	18
2.3.2 The Zeeman Effect	19
2.3.3 Zeeman Splitting in the OH Molecules	20
2.4 Polarization	23
2.4.1 Wave Polarization	23
2.4.2 Faraday Rotation	24
Chapter 3 Observations and Data Reduction	28
3.1 ATNF	28

3.2 Observations	29
3.3 Data Reduction	29
3.4 Image Analysis	31
3.4.1 Flowchart for image analysis	32
3.4.2 Measuring Maser Positions and Intensities	33
Chapter 4 Results	35
4.1 Intensity and spectra	35
4.2 Velocities and Positions	39
4.3 Zeeman Analysis	43
Chapter 5 Discussions	52
5.1 Position and Velocity Distributions	52
5.2 Magnetic Fields in OH330.953-0.182	53
5.3 Suggestion for Future Research	53
Chapter 6 Conclusions	59
Bibliography	61
Curriculum vitae	62

LIST OF TABLES

Table	Page
2.1 Zeeman splitting of the $^2\Pi_{3/2}, J = 3/2$ ground state of OH molecule (σ components); see Davies (1974)	23
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.	30
4.1 The 1665-MHz OH maser features in OH 330.953-0.182 region. The polarizations flux weighted mean velocities and positions are given for each feature. The position offset (0, 0) are given relative R.A.(2000) = $16^h 09^m 53^s.5$ and Dec(2000) = $-51^\circ 54' 54''.0$ respectively.	38
4.2 The 1667-MHz OH maser features in OH 330.953-0.182 region. The polarizations flux weighted mean velocities and positions are given for each feature. The position offset (0, 0) are given relative R.A.(2000) = $16^h 09^m 53^s.5$ and Dec(2000) = $-51^\circ 54' 54''.0$ respectively.	39
4.3 Zeeman Pair Masers in this cluster.	47
4.4 The six possible Zeeman pairs include in Z5. The features L1, L2, R1, R2 and R3 refer to each component in Figure 4.11.	47

LIST OF FIGURES

Figure	Page
2.1 Model spherical gas cloud of mass M and uniform density ρ	5
2.2 Volume Model	6
2.3 Show angle ϕ from the axis to the particle as seen from the center	10
2.4 The rotational energy levels of OH showing Λ -doubling and nuclear hyperfine splitting. F_1 and F_2 corresponding to ${}^2\Pi_{3/2}$ and ${}^2\Pi_{1/2}$ respectively.	16
2.5 The energy levels of OH molecule in the ground state. In the magnetic field, there are four hyperfine transitions at 1612, 1665, 1667 and 1720 MHz.	17
2.6 Zeeman splitting patterns for the ${}^2\Pi_{3/2}$, $J = 3/2$ state of OH molecule. The splitting is plotted in units of velocity (km/sec/mG). Relative intensities of the Zeeman components are shown for each transitions from Davies (1974) and references therein. The patterns in left-hand side of the figure result from observation parallel to the magnetic field and the direction of the magnetic field is pointing towards to the observer. Those on right-hand side are from observations perpendicular to the field.	22
2.7 Relation of instantaneous electric field E to polarization ellipse	25
2.8 Polarization ellipse at tilt angle τ showing instantaneous components E_x and E_y and amplitudes (or peak values) E_1 and E_2	25
2.9 Change in direction of E for left circular polarization	26
4.1 The line shape of feature i (RHCP, 1665 MHz). The upper frames show the contour maps corresponding with the spectra. The contour levels are 0.4, 0.8, 1.6, 3.2 and 6.4 Jy beam ⁻¹	36
4.2 Velocity profiles of the 1665-MHz OH masers in OH330.953-0.182. The peak flux of each feature is plotted against the LSR velocity. The labeled features are listed in Table 4.1.	40

- 4.3 Velocity profiles of the 1667-MHz OH masers in OH330.953-0.182. The peak flux of each feature is plotted against the LSR velocity. The labeled features are listed in Table 4.2. 41
- 4.4 Total intensity spectra of OH masers at 1665- and 1667-MHz transitions. 42
- 4.5 Positions and velocities of the 1665-MHz OH masers in OH 330.953-0.182. The positions are offset from (256,256) at R.A.(2000) = $16^h 09^m 52^s.71$, Dec(2000) = $-51^\circ 54' 54''.58$. The velocity of each feature is given in km s^{-1} . The red, blue and black labels are features of Zeeman pairs, linear polarization pairs and single polarization respectively. 44
- 4.6 The positions are offset from (256,256) at R.A.(2000) = $16^h 09^m 52^s.71$, Dec(2000) = $-51^\circ 54' 54''.58$. The velocity of each feature is given in km s^{-1} . The color labels are coincide with Figure 4.5. 45
- 4.7 Position and velocity profiles of the Zeeman pair Z1. Plus and circle signs indicate RHCP and LHCP respectively. 48
- 4.8 Position and velocity profiles of the Zeeman pair Z2. 48
- 4.9 Position and velocity profiles of the Zeeman pair Z3. 49
- 4.10 Position and velocity profiles of the Zeeman pair Z4 (1665 MHz). 49
- 4.11 Position and velocity profiles of the Zeeman pair Z5. 50
- 4.12 Position and velocity profiles of the Zeeman pair Z4 (1667 MHz). 50
- 4.13 Position and velocity profiles of the Zeeman pair Z6. 51
- 4.14 Position and velocity profiles of the Zeeman pair Z7. 51
- 5.1 Position distribution of OH 330.953-0.182. Symbols are denoted the frequency and the polarization (plus signs for LHCP 1667-MHz, triangles for RHCP 1667-MHz, crosses for LHCP 1665-MHz and circles for RHCP 1665-MHz in this study. Square with the position errors include positions of OH masers and other maser previous observed in the literature. 54
- 5.2 Position distribution of OH 330.953-0.182 maser features after shift (2.05 arc-sec, -2.13 arcsec) offset. Symbols are denoted the frequency and the polariza-

- tion (plus signs for LHCP 1667-MHz, triangles for RHCP 1667-MHz, crosses for LHCP 1665-MHz and circles for RHCP 1665-MHz in this study. Square with the position errors include positions of OH masers and other maser previous observed in the literature. 55
- 5.3 Intensity distribution of the 1665- and 1667-MHz OH maser features. The size of each symbol is proportional to the peak flux density. 56
- 5.4 Plot of radial velocity against RA and declination, for the 1665- and 1667-MHz OH masers in OH330.953-0.182. Symbols are denoted the frequency and the polarization (plus signs for LHCP 1667-MHz, triangles for RHCP 1667-MHz, crosses for LHCP 1665-MHz and circles for RHCP 1665-MHz). The size of each symbol is proportional to the peak flux density. 57