

**LASER PROBING of  
TRANSPORT PROPERTIES and  
ROTATIONAL ALIGNMENT of  
 $\text{N}_2^+$  DRIFTED in He**

by

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Laser Probing of Transport Properties and Rotational Alignment of  $N_2^+$  Drifted in He

Thesis directed by Professor Adjoint Stephen R. Leone  
and Research Professor Veronica M. Bierbaum

Results of transport property and rotational alignment experiments of the atmospherically important molecule  $N_2^+$  are presented, as measured in a flow-drift apparatus using the technique of single-frequency laser-induced fluorescence (LIF). A trace amount of  $N_2^+$  is drifted in helium as a buffer gas; the external axial electric field of the drift tube varies the center-of-mass collision energy of the ion-neutral pair. The net effect over hundreds of buffer gas collisions is to establish a steady-state anisotropic ion velocity distribution, the precise character of which is determined by the ion-neutral interaction potential, mass ratio, and field strength. A single-frequency ring dye laser is used to probe Doppler profiles of various rotational lines of the  $(v', v'') = (0, 0)$  band in the  $B \ ^2\Sigma_u^+ - X \ ^2\Sigma_g^+$  system at 390 nm. The single-frequency cw laser technique allows one to measure the velocity component distribution function (VCDF) along the laser propagation direction  $\mathbf{k}$ ; the VCDF is a projection of the *complete* ion velocity distribution function. Additionally, the rotational alignment of the ions as a function of one component of sub-Doppler laboratory velocity is probed by polarized LIF.

Drift velocities and ion mobilities are determined from the shift of the first moments of the coaxial LIF Doppler profiles, while perpendicular and parallel translational temperatures are determined from the widths or second central moments of the profiles in the direction probed. Drift velocities measured up to a field strength

of 16 Td appear to be in good agreement with data derived from earlier arrival-time measurements. A small but definite increase in mobility with increasing rotational state from  $J=13.5$  to  $J=22.5$  is observed. A significant difference of over 100 K between the parallel and perpendicular temperatures is measured at the highest field strength employed (16 Td). A small degree of positive skewness or third central moment is observed as well in the parallel VCDF's, which is of particular interest since a high-velocity tail has not been previously reported for any molecular ion system. Additionally, by probing with linearly polarized light and measuring the degree of polarization of the resultant LIF, the collision-induced quadrupole rotational alignment parameter  $A_0^{(2)}$  is determined as a function of field strength and velocity subgroup. A strong correlation is found between the degree of rotational alignment and the velocity subgroup when probed parallel to the field direction, with the alignment parameters generally increasing monotonically across the distribution. A dramatic difference in velocity-selected alignment as a function of rotational state is observed as well, for experiments conducted on various rotational lines at a fixed field strength of 12 Td. For sufficiently low rotational state ( $J$  about 9), it appears that  $A_0^{(2)}$  changes sign across the Doppler profile.

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## TABLE OF CONTENTS

<b>Chapter</b>	<b>Page</b>
I. INTRODUCTION.....	1
A. General motivation.....	1
B. Interaction potential.....	6
C. Ion transport properties.....	9
D. Collision-induced rotational alignment.....	10
References for Chapter I.....	12
II. GENERAL EXPERIMENTAL TECHNIQUES .....	14
A. Introduction .....	14
B. Ion source & flow-drift region.....	14
1. Ion source & production conditions .....	16
2. Flow tube considerations.....	23
3. Drift & charge separation regions .....	25
C. Ring dye laser system & diagnostic tools.....	29
1. General description .....	30
2. Diagnostic tools.....	34
3. Beam transport & polarization control.....	43
D. Laser-induced fluorescence detection techniques .....	46
1. Unpolarized detection .....	46
2. Polarized detection .....	50
E. Electronics and data acquisition programming.....	55
F. General data analysis considerations.....	59



G. Spectroscopy of the $N_2^+ B^2\Sigma_u^+ - X^2\Sigma_g^+$ system .....	61
1. General spectroscopic structure.....	61
2. Hyperfine spectroscopy .....	67
References for Chapter II .....	69
III. ROTATIONALLY-RESOLVED TRANSPORT PROPERTIES OF $N_2^+$ IN He ..	71
A. Introduction .....	71
B. Descriptive theory.....	71
C. Measurement & analysis techniques.....	77
1. Measurement details.....	77
2. Velocity component distribution functional forms .....	84
3. Line shape analysis.....	90
D. Results .....	95
1. First moments: drift velocities & mobilities .....	96
2. Second central moments: translational temperatures .....	104
3. Third central moments: direct measure of skewness.....	109
E. Possible systematics.....	111
1. Axial ion flow-velocity experiments.....	113
2. LIF intensity vs. tube voltage experiments.....	122
F. Discussion & theory.....	125
1. First moments.....	127
2. Second central moments.....	135
G. Conclusions .....	136
References for Chapter III.....	138

IV. COLLISION-INDUCED ROTATIONAL ALIGNMENT OF $N_2^+$ IN He .....	141
A. Introduction .....	141
B. Descriptive theory.....	144
1. Qualitative & heuristic arguments.....	144
2. Simple classical theory.....	150
3. Quantum theory.....	157
4. Extensions to quantum theory.....	160
C. Experimental & analysis techniques.....	165
D. Results .....	175
1. Field dependence of alignment for single rotational line.....	176
2. Rotational quantum state dependence of alignment.....	182
E. Possible systematics.....	188
F. Discussion & dynamics theory.....	192
1. Steady-state fully-velocity averaged theory.....	195
2. Partial velocity selection .....	200
G. Conclusions .....	205
References for Chapter IV.....	206
BIBLIOGRAPHY .....	208
APPENDIXES .....	218
A. Relevant circuit diagrams .....	218
B. <i>Eta-Spex</i> program listing .....	(on diskette)
C. <i>AMCalc</i> angular momentum calculator program .....	(on diskette)

## LIST OF TABLES

<b>Table</b>	<b>Page</b>
2.1 Relevant transition frequencies for (0,0) band of $N_2^+ B^2\Sigma_u^+ - X^2\Sigma_g^+$ system ..	66
3.1 Tabulated results of first moment experiments .....	99
3.2 Tabulated results of second central moment experiments.....	108
4.1 Example of data collection sequence for sub-Doppler alignment experiment...	169
4.2 Example of program data output .....	172
4.3 Example of program data analysis output .....	174
4.4 Tabulated results of rotational state alignment experiment.....	190

## LIST OF FIGURES

<b>Figure</b>	<b>Page</b>
1.1 $N_2^+$ -He interaction potential in Jacobi coordinates .....	8
2.1 Overall schematic of experimental apparatus .....	15
2.2 To-scale diagram of ion source region .....	17
2.3 Representative mass spectra for Fall '95 experiments .....	20
2.4 Representative mass spectra for Fall '97 & Spring '98 experiments .....	21
2.5 Schematic of drift tube electrical connections .....	26
2.6 Ring dye laser optical and electronic schematic.....	31
2.7 Optics table components schematic .....	35
2.8 Construction diagram of 20 cm long ULE Fabry-Perot cavity.....	38
2.9 Scope trace of Fabry-Perot transmission peaks.....	39
2.10 Perspective view of apparatus and PMT stack.....	47
2.11 To-scale plan view of stepper-motor driven PMT stack .....	53
2.12 Block schematic of counter portion of acquisition system.....	58
2.13 Typical LIF spectra of single spin-rotation line .....	62
2.14 Pump-fluoresce diagram for $R_1(15)$ transition .....	64
2.15 LIF survey spectra of five rotational lines.....	65
3.1 Representative first-moment LIF data.....	78
3.2 Representative second central moment LIF data.....	83
3.3 Whealton-Woo functional form for various skewness parameters .....	88

3.4 Simulated spectra of underlying hyperfine structure.....	91
3.5 $R_1(15)$ drift velocities .....	97
3.6 $R_1(15)$ mobilities .....	98
3.7 Drift velocities and mobilities for various rotational lines at 12 Td .....	102
3.8 J-dependent mobilities at 12 Td, broken down by day of observation.....	103
3.9 Second and third central moment data on $R_1(15)$ , Fall '95 .....	105
3.10 Translational temperatures for $R_1(15)$ .....	107
3.11 Evidence of positive skewness in coaxial probe data.....	110
3.12 Field off/field on line centers as function of charge separation voltage.....	115
3.13 Diagnostic data on axial ion flow velocity systematic .....	118
3.14 Axial ion flow velocity experiments with different source aperture sizes .....	120
3.15 Results of charge-separation voltage scanning experiments .....	123
3.16 Results of drift voltage scanning experiments .....	124
3.17 Summary plot of $\text{CO}^+$ -He LIF and arrival time mobilities .....	126
3.18 Literature values of $\text{N}_2^+$ and $\text{CO}^+$ mobilities .....	129
4.1 Cartoon diagram of LIF probe-detection scheme.....	145
4.2 Cartoon $m_j$ distribution picture .....	148
4.3 Schematic of “two-angle” LIF geometry for alignment experiment .....	152
4.4 Isotropic and aligned fluorescence intensities for the two probe directions.....	156
4.5a) Perpendicular probe polarization results for $R_1(15)$ .....	177
4.5b) Coaxial probe polarization results for $R_1(15)$ .....	178

4.6 Corresponding $m_j$ distributions for $R_1(15)$ at 16 Td .....	183
4.7 Raw polarization data from rotational state alignment experiment .....	185
4.8 Systematic plasma polarization checks .....	187
4.9 Polarization data of Fig. 4.7 with simple subtractive correction.....	189
A.1 Simple analog divider circuit .....	219
A.2 Simple window detector circuit.....	220
A.3 Stepper motor driver circuit for rotation stage .....	221