TRACE CONSTITUENTS IN THE MIDDLE ATMOSPHERE BY HIGH RESOLUTION UV SPECTROSCOPY

SUBMITTED BY:

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THE IMAGING SPECTROMETRIC OBSERVATORY - ISO

BUILT FOR SPACELAB I

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(RESPONSIBILITY FOR INSTRUMENT REMAINS WITH M.R.TORR)

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ISO SCIENCE

ISO IS A GENERAL PURPOSE INSTRUMENT WHICH CAN BE USED TO STUDY NUMEROUS ATMOSPHERIC PROBLEMS.

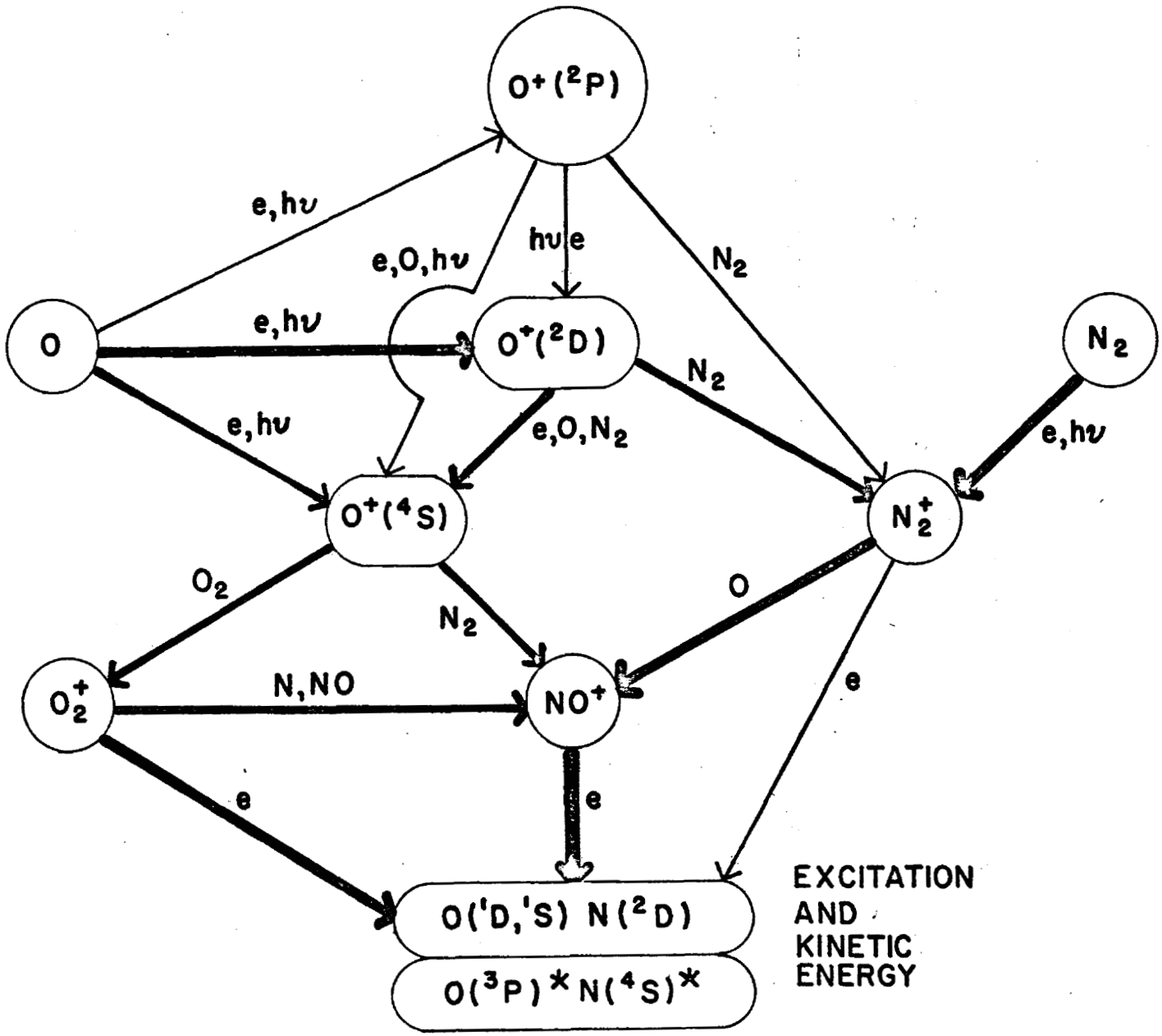
SPACELAB 1 WILL BE USED TO OPERATE MAINLY IN A SURVEY MODE.

FOR THE FIRST REFLIGHT WE PLAN TO SELECT A FEW SPECIFIC QUESTIONS TO ADDRESS. THESE MAY BE CHANGED LATER DEPENDING ON DEVELOPMENTS IN THE FIELD. ISO IS DESIGNED TO SELECT EXPERIMENT MEASUREMENT SEQUENCES BY SOFTWARE CONTROL.

WE HAVE CHOSEN TO CONCENTRATE ON THE CHEMISTRY OF SEVERAL METASTABLE AND VIBRATIONALLY EXCITED SPECIES, SINCE THESE ARE DIFFICULT TO STUDY IN THE LAB.

ISO WILL ALSO BE CAPABLE OF PROVIDING A DATABASE OF BASIC PARAMETERS TO USE IN MODELLING. THESE WILL BE DERIVED FROM THE INTENSITIES OF EMISSIONS WHOSE SOURCES AND SINKS ARE WELL KNOWN.

THERMOSPHERIC IONIC PROCESSES



THE N_2^+ PROBLEM

PROBLEM: CURRENT MODELS PRODUCE TOO MUCH N_2^+ IONZATION

SOLUTION 1 : INCREASE THE RECOMBINATION RATE, BECAUSE N_2^+ IS VIBRATIONALLY EXCITED IN THE THERMOSPHERE

LAB RESULT: NO DEPENDENCE ON VIBRATIONAL EXCITATION - E. ZIPF

SOLUTION 2 : DECREASE CHARGE EXCHANGE OF $O^+(^2D)$ WITH N_2

LAB RESULT: NO. THE RATE COEFFICIENT IS LARGE 10^{-9} cm s^{-1} - BIONDI'S GROUP, CONFIRMED BY NOAA GROUP.

CONCLUSION : THE REACTION OF N_2^{+*} WITH O MUST BE LARGER THAN N_2^+ WITH O

USE ISO TO CHECK THESE LAB RESULTS AND THE ABOVE HYPOTHESIS.

EXPERIMENT : DETERMINE WHETHER THE CHARGE EXCHANGE OF $O^+(^2D)$ WITH N_2 PROCEEDS RAPIDLY ($K=10^{-9}$) OR SLOWLY ($K=10^{-10}$)

METHOD: MEASURE THE $O^+(^2D)$ CONCENTRATION. THE TWO RATES WILL YIELD CONCENTRATIONS WHICH DIFFER BY NEARLY AN ORDER OF MAGNITUDE.

PARAMETER: EMISSION AT 3728.9A DUE TO THE TRANSITION $O^+(^4S - ^2D)$

THE MEASUREMENT WILL BE MADE IN A LIMBSCAN MODE WHERE THE SURFACE BRIGHTNESS WILL BE SEVERAL RAYLEIGHS TO TENS OF RAYLEIGHS DEPENDING ON K.

EXPERIMENT: MEASURE THE PRODUCTION OF N_2^+ DUE TO CHARGE EXCHANGE OF $O^+(^2D)$ WITH N_2

THE REACTION IS RESONANT IF N_2^+ IS FORMED IN THE V=2 LEVEL OF THE A STATE.

METHOD: OBSERVE PERMITTED TRASITIONS OF N_2^+ ORIGINATING IN THE V=1 LEVEL OF THE A STATE, E.G.

1-0 AT 9212A

ISOLATE CHARGE EXCHANGE SOURCE BY MONITORING RESONANCE FLUORESCENCE PRODUCTION VIA:

2-0 AT 7874A, 2-1 AT 9502A, 3-1 AT 8105A

MEASURE THE ROTATIONAL TEMPERATURE.

RESONANCE FLUORESENCE GIVES A KINETIC THERMAL DISTRIBUTION CHARGE EXCHANGE WILL GIVE A NON EQUILIBRIUM TEMPERATURE.

EXPERIMENT: INVESTIGATE THE DESTRUCTION OF N_2^+ BY REACTIONS WITH O

REACTIONS OF VIBRATIONALLY EXCITED N_2^+ WITH O HAVE NEVER BEEN STUDIED IN THE LAB. POSSIBLE CHANNELS INCLUDE:

$$N_2^{+*} + O \rightarrow NO^{+*} + N \qquad (1)$$

$$N_2^{+*} + O \rightarrow O^+ + N_2 \qquad (2)$$

REACTION (1) WILL PRODUCE VIBRATIONALLY EXCITED NO^+ IN $V>2$.

THE RADIATIVE LIFETIME OF NO^{+*} IS OF THE ORDER OF MILLISECONDS

MEASURE: NO^{+*} EMISSIONS FROM $V\geq 4$ (I.E. LESS THAN 11,000A)

DETERMINE WHETHER THESE INTENSITIES ARE CONSISTANT WITH PRODUCTION OF N_2^+ BY CHARGE EXCHANGE WITH O.

EXPERIMENT: STUDY THE CHEMISTRY OF METASTABLE N^+ IONS

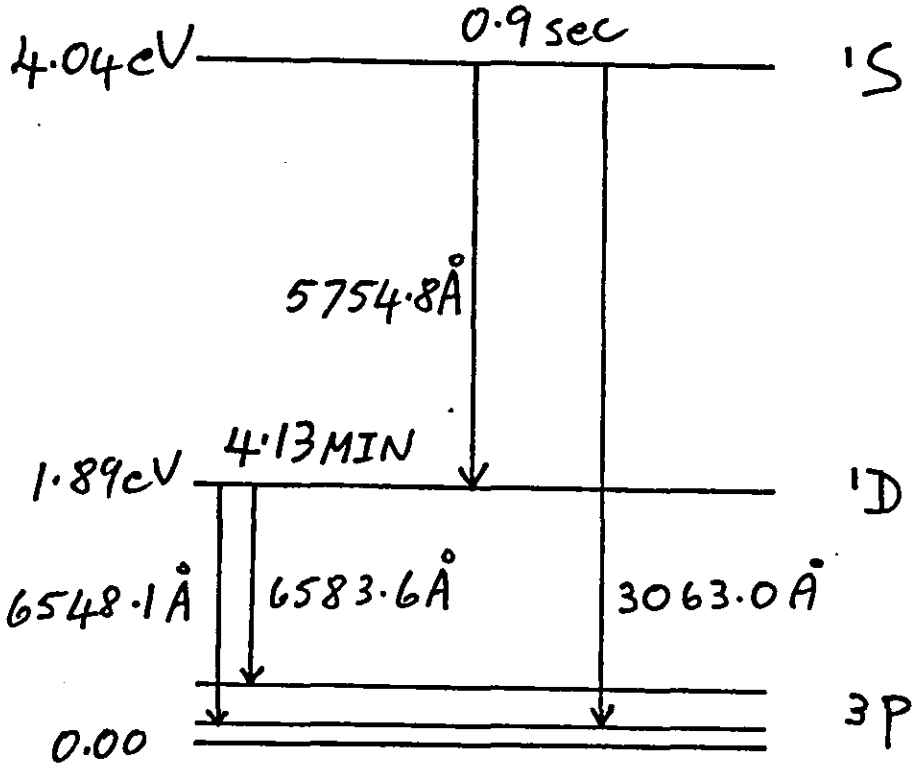
EMISSIONS:

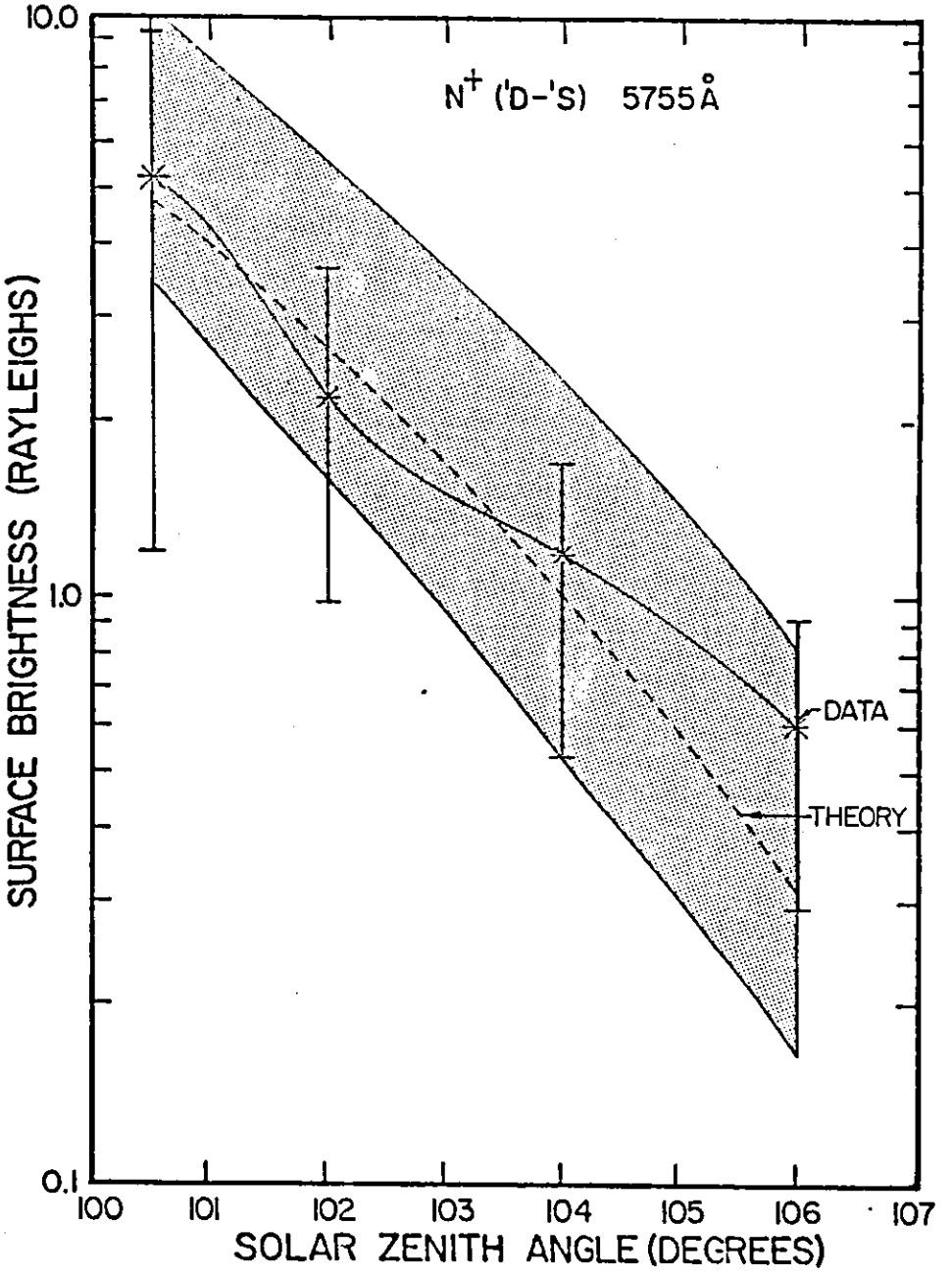
$N^+(^1D - ^1S)$ AT 5755 A	0.9 s
$N^+(^3P - ^1D)$ AT 6548 A AND 6583 A	4.13 MIN

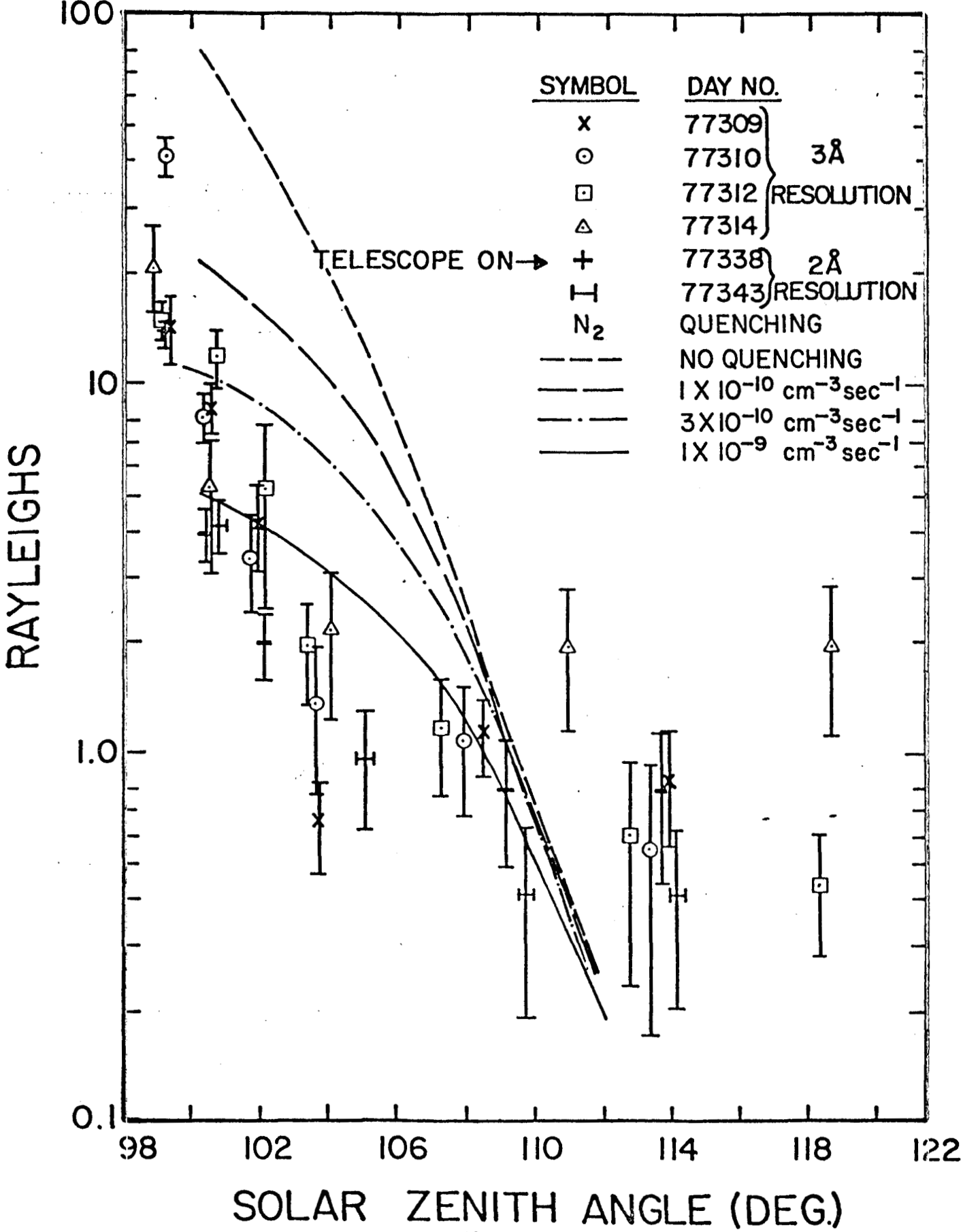
COMMENTS: THESE EMISSIONS HAVE BEEN DETECTED FROM THE GROUND, BUT WEAKLY. LIMBSCAN PLUS THE HIGH SENSITIVITY OF ISO WILL PERMIT US TO STUDY THE SOURCES AND SINKS IN DETAIL.

IT IS POSSIBLE THAT THESE METASTABLE SPECIES MAY AFFECT THE CONCENTRATIONS OF OTHER CONSTITUENTS SUCH AS $O(^1D)$ AND $O^+(^2P)$.

N^+


4.04eV
0.9 sec
1S
5754.8Å
1.89eV
4.13 MIN
1D
6548.1Å
6583.6Å
3063.0Å
3P
0.00


10.0
1.0
0.1
N^+ (^1D-^1S) 5755Å
SURFACE BRIGHTNESS (RAYLEIGHS)
DATA
THEORY
100
101
102
103
104
105
106
107
SOLAR ZENITH ANGLE (DEGREES)


EVENING TWILIGHT
N+(1D–3P) 6584Å INTENSITY
SYMBOL
DAY NO.
x 77309
⊙ 77310
⊡ 77312
△ 77314
3Å RESOLUTION
TELESCOPE ON→
+ 77338
⊢ 77343
2Å RESOLUTION
N2 QUENCHING
NO QUENCHING
1 X 10-10 cm-3sec-1
3X10-10 cm-3sec-1
1X 10-9 cm-3sec-1
RAYLEIGHS
100
10
1.0
0.1
98
102
106
110
114
118
122
SOLAR ZENITH ANGLE (DEG.)

EXPERIMENT: STUDIES OF O_2^+ IONS

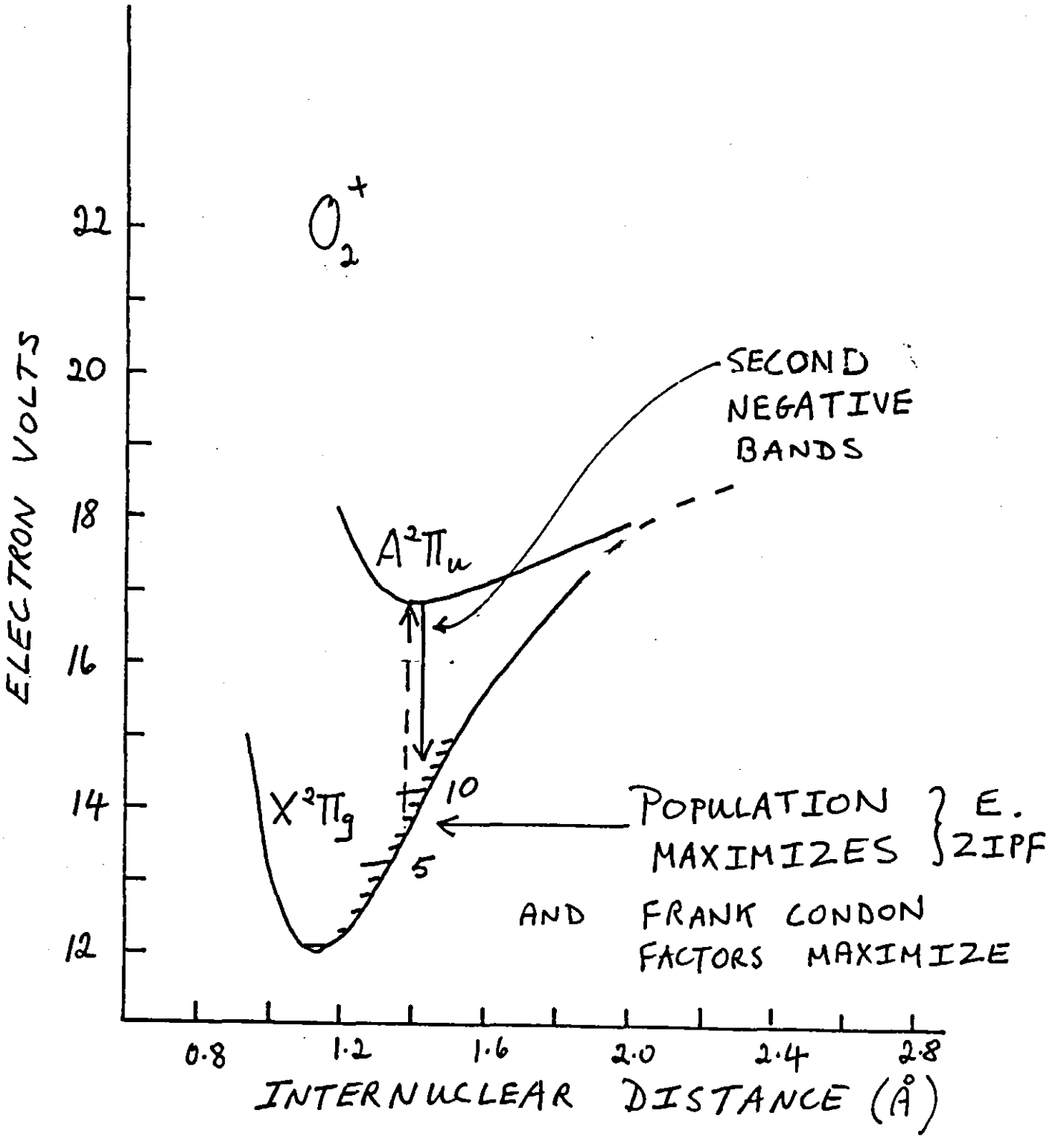
RECENT WORK BY E. ZIPF SUGGESTS THAT THERMOSPHERIC O_2^+ IONS RESIDE MAINLY IN VIBRATIONAL LEVELS BETWEEN 4 AND 16. THIS MEANS THAT THE POPULATION DISTRIBUTION WILL BE MORE CLOSELY ALIGNED WITH THE LEVELS WHERE THE FRANK CONDON FACTORS MAXIMIZE .

CONCLUSION: O_2^+ IS THEREFORE MUCH MORE SIMILAR TO N_2^+ THAN WAS PREVIOUSLY REALIZED. SIGNIFICANT EXCITATION TO THE $A^2\pi_u$ STATE VIA RESONANCE ABSORPTION OF SOLAR RADIATION MAY BE EXPECTED.

THESE EFFECTS MIGHT SIGNIFICANTLY AFFECT THE RECOMBINATION OF O_2^+ IN THE THERMOSPHERE.

MEASUREMENTS OF THE SECOND NEGATIVE BANDS WILL THEREFORE PROVIDE INFORMATION ON THE VIBRATIONAL DISTRIBUTION OF O_2^+

MEASUREMENTS: 0-5 3232,3210 0-6 3421,3397 0-7 3629,3603 ETC.


O_2^+
ELECTRON VOLTS
22
20
18
16
14
12
SECOND NEGATIVE BANDS
$A^2\Pi_u$
$X^2\Pi_g$
I
10
5
POPULATION } E. MAXIMIZES } 2IPF
AND FRANK CONDON FACTORS MAXIMIZE
0.8
1.2
1.6
2.0
2.4
2.8
INTERNUCLEAR DISTANCE (Å)

O_2^+ CONTINUED:

WE ALSO INTEND TO SEARCH FOR EMISSIONS IN THE $O_2^+(a^4\Pi - X^2\Pi_G)$ SYSTEM. THE SOURCE IS VIA CASCADE FROM THE $b^4\Sigma$ STATE VIA THE FIRST NEGATIVE TRANSITIONS.

THE SOURCE WILL BE MONITORED VIA THE FIRST NEGATIVE BANDS WHICH ARE ALL IN THE VISIBLE.

MEASUREMENTS: O_2^+ FIRST NEGATIVE BANDS (b - a) SEE TABLE
(a - X) TRANSITIONS, E.G.
0,6 4531 A, 0,7 4896 A, 0,8 5316 A,
0,9 5803 A, 0,10 6314 A

A SIMPLE SCALING OF AURORAL INTENSITIES SUGGESTS ABOUT 20R FOR THESE BANDS.

THE MEASUREMENTS SHOULD ALLOW US TO STUDY THE SOURCES AND SINKS OF THE METASTABLE $a^4\Pi$ STATE.

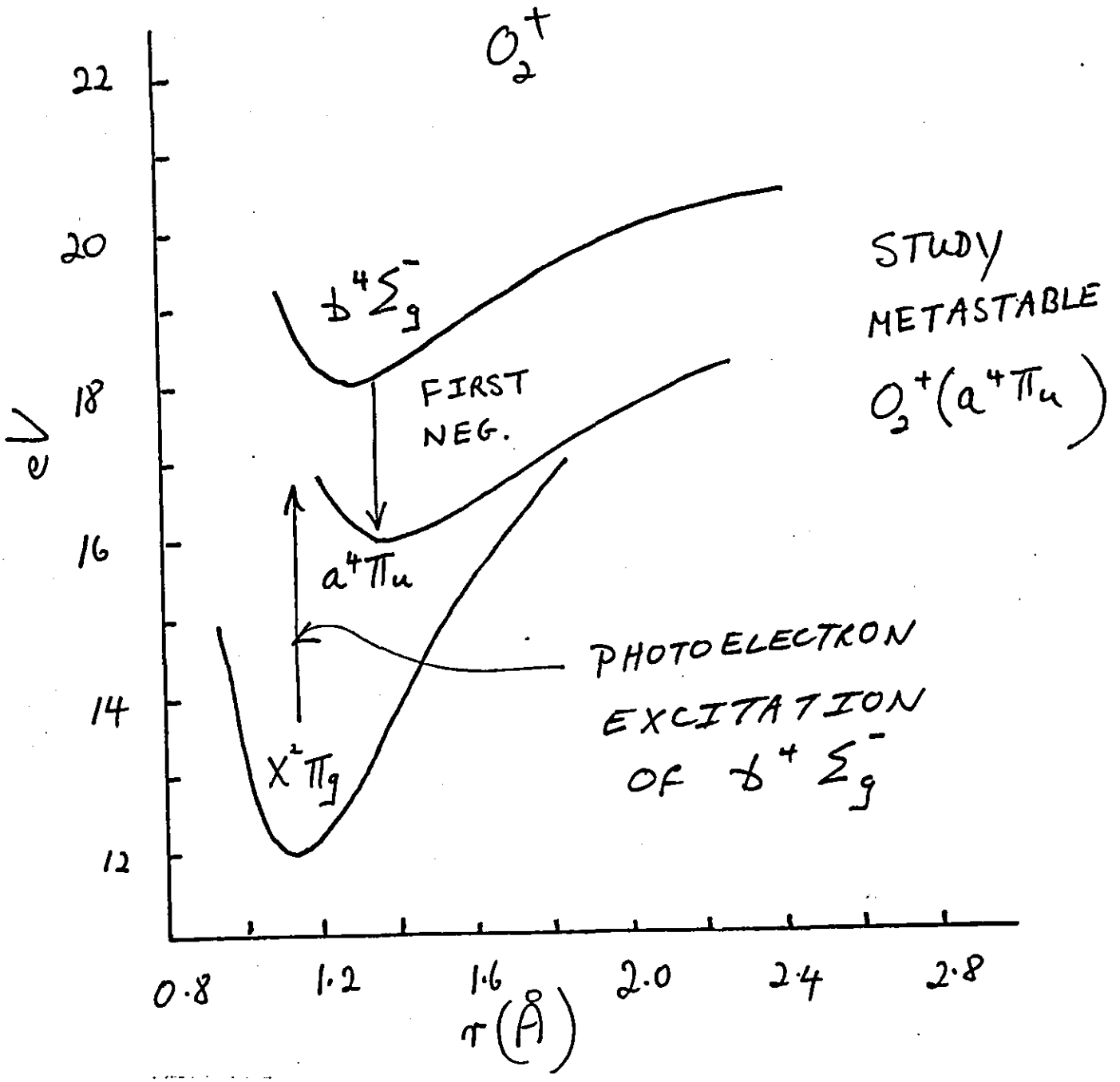

O_2^+
22
20
18
16
14
12
eV
$b^4\Sigma_g^-$
FIRST NEG.
$a^4\Pi_u$
$X^2\Pi_g$
PHOTOELECTRON EXCITATION OF $b^4\Sigma_g^-$
STUDY METASTABLE $O_2^+(a^4\Pi_u)$
0.8
1.2
1.6
2.0
2.4
2.8
r(Å)

TABLE 3.1 O_2^+ 1N (first negative) band intensities

		ν" 0	1	2	3	4	5	6	7	8
	0	5999.9 6.4	6389.0 5.6	6822.3 5.0	7307.6 1.4	7854.4 .6	8474.6 .24			
	1	5608.7 9.4	5947.2 .3	6320.9 .6	6735.3 1.4	7197.2 1.2	7714.5 .7	8297.7 .3		
ν'	2	5274.8 3.0	5573.2 1.8	5900.1 1.0		6656.6 .16	7096.7 .3	7587.3 .3	8136.9 .16	
	3	4987.0 .3	5252.9 1.5							

System intensity - 400R

	ν"
ν'	Wavelength (Å) origin
	Intensity (R) SZA = 90°
	Underlined bands observed

TABLE 3-A

SPECTROMETER UNIT NO.	WAVELENGTH RANGE (Å)	GRATING GROOVES/mm	GRATING BLAZE (Å)	PLATE FACTOR (Å)/mm	APPARENT RESOLUTION(Å) (3 PIXELS-90μ)	SPECTRAL RANGE(Å) PER DETECTOR WIDTH (5.7mm)	MINIMUM DETECTOR POSITIONS PER SCAN	PHOTOCATHODE, WINDOW
1	7500-12,000	400	10,000	50	4.5	285	16	CCD Surface (No image tube)
2	4000-8000	450	5500	44	4	253	16	TRIALKALI Glass
3	2200-4100	900	3000	22	2	127	15	BIALKALI Quartz
4	1100-2300	1200	1500	17	1.5	95	13	CsTe MgF_2
5	300-1200	1200	800	17	9*	95	10	Channel Plate Surface No Window

*18 pixels-540μ
Limited by .045° FOV collimator

PARTICIPATION IN ACTIVE EXPERIMENTS

- PRELIMINARY COORDINATION WITH SEPAC ON SL-1
- TETHERED SATELLITE EXPERIMENTS
- DIAGNOSTIC FOR CHEMICAL RELEASE EXPERIMENTS
- A SUBSTANTIAL ENHANCEMENT IN THIS CAPABILITY WOULD BE REALIZED BY MOUNTING THE INSTRUMENT ON A POINTING SYSTEM

SUMMARY OF RESOURCE PARAMETERS

WEIGHT:	SPECTROMETER ARRAY	239 KGMS
	DEP	18 KGMS
		257 KGMS
POWER:	SPECTROMETER ARRAY	~80 WATTS
	DEP	85 WATTS
		165 WATTS

DIMENSIONS (APPROX.): SPEC. ARRAY: 131 CM X 110 X 74
DEP: 48 CM X 22 X 61

IMAGING SPECTROMETRIC OBSERVATORY

- ARRAY OF 5 IMAGING SPECTROMETERS
- EACH SPECTROMETER AUTONOMOUS
- ISO COVERS BROAD WAVELENGTH RANGE (~200 - 12,000 Å)
- RESOLUTION SELECTABLE DOWN TO ~0.5 Å
- DYNAMIC RANGE: $\sim 10^7$
- SENSITIVITY: MISSION SELECTABLE
  SL-1 - 1R IN 60 SEC. WITH S/N = 5

ASPECTS OF DESIGN

- MODULAR CONSTRUCTION PERMITS FLEXIBILITY FOR REFLIGHTS
- SEQUENCES CAN BE CHANGED IN REAL TIME
- ON-BOARD DISPLAYS CAN BE ADDED

OBJECTIVES

SPACELAB 1

- ATLAS OF THERMOSPHERIC EMISSIONS
- VARIETY OF SPECIFIC STUDIES (DAYSIDE, NIGHTSIDE, TWILIGHT)
- S/C CONTAMINANTS

SPACELAB 6

- FURTHER THERMOSPHERIC AND SOME MESOSPHERIC STUDIES