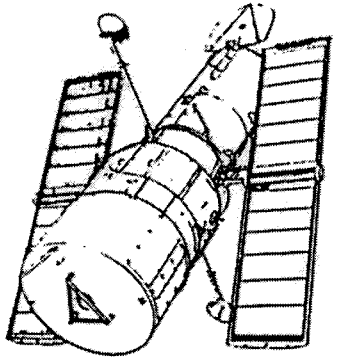
Solar System Aeronomy by Electron Impact with Application to UV Observations by Satellites

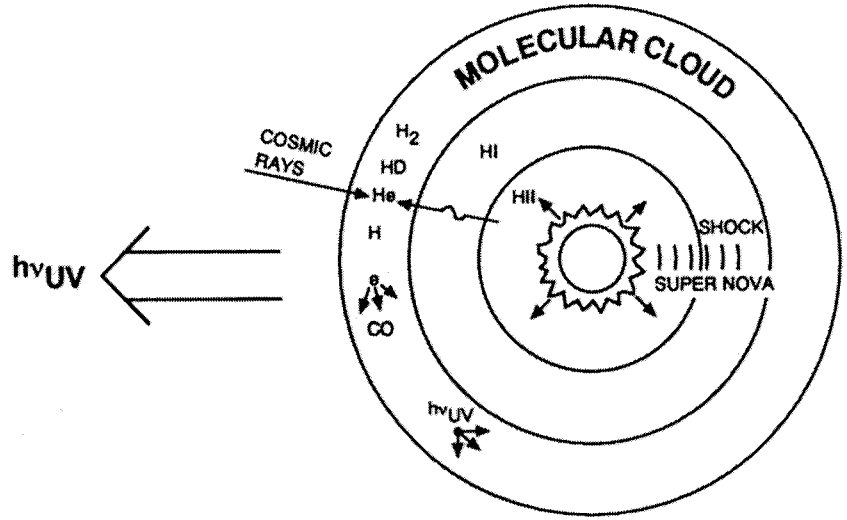
Joseph Ajello

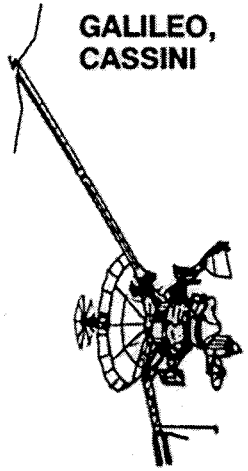
Dr. Ajello will give an invited presentation at the Chemistry summer school at the University of San Carlos, Brazil. This talk will discuss the UV observations of the solar system by NASA spacecraft: Galileo, Voyager and HST. High resolution imaging UV spectrometers with array detectors can now measure global properties of the upper atmospheres of the planets. The energetics of solar UV deposition or magnetosphere particle precipitation can only be modeled with accurate cross sections of the major species of the upper atmosphere: N_2, H_2, O_2, CO, CO_2, O and H. The JPL Ultraviolet Emission Laboratory provides the emission cross sections that allow aeronomers to estimate planetary composition and energy flux into the upper atmosphere.

SOLAR SYSTEM AERONOMY BY ELECTRON IMPACT WITH APPLICATION TO UV OBSERVATIONS BY SPACECRAFT

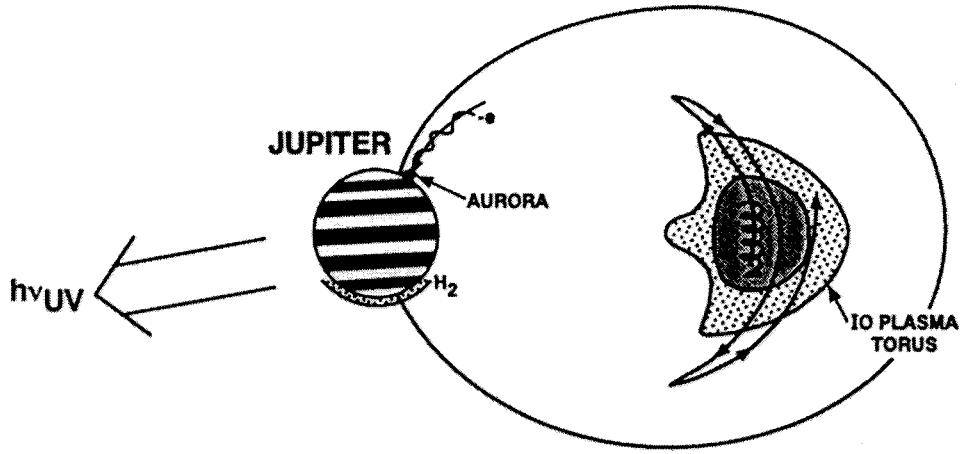


HST, FUSE





GALILEO, CASSINI



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Processes: $N_2 + e \xrightarrow{Q}$ LBH, NI, II lines, $c' \rightarrow X$

$O + e \longrightarrow$ OI (1304, 1356 Å)

$H + e \xrightarrow{Q}$ H Lα, Lyman Series

$H_2 + e \longrightarrow H_2$(B, C), Rydberg Series

Missions:

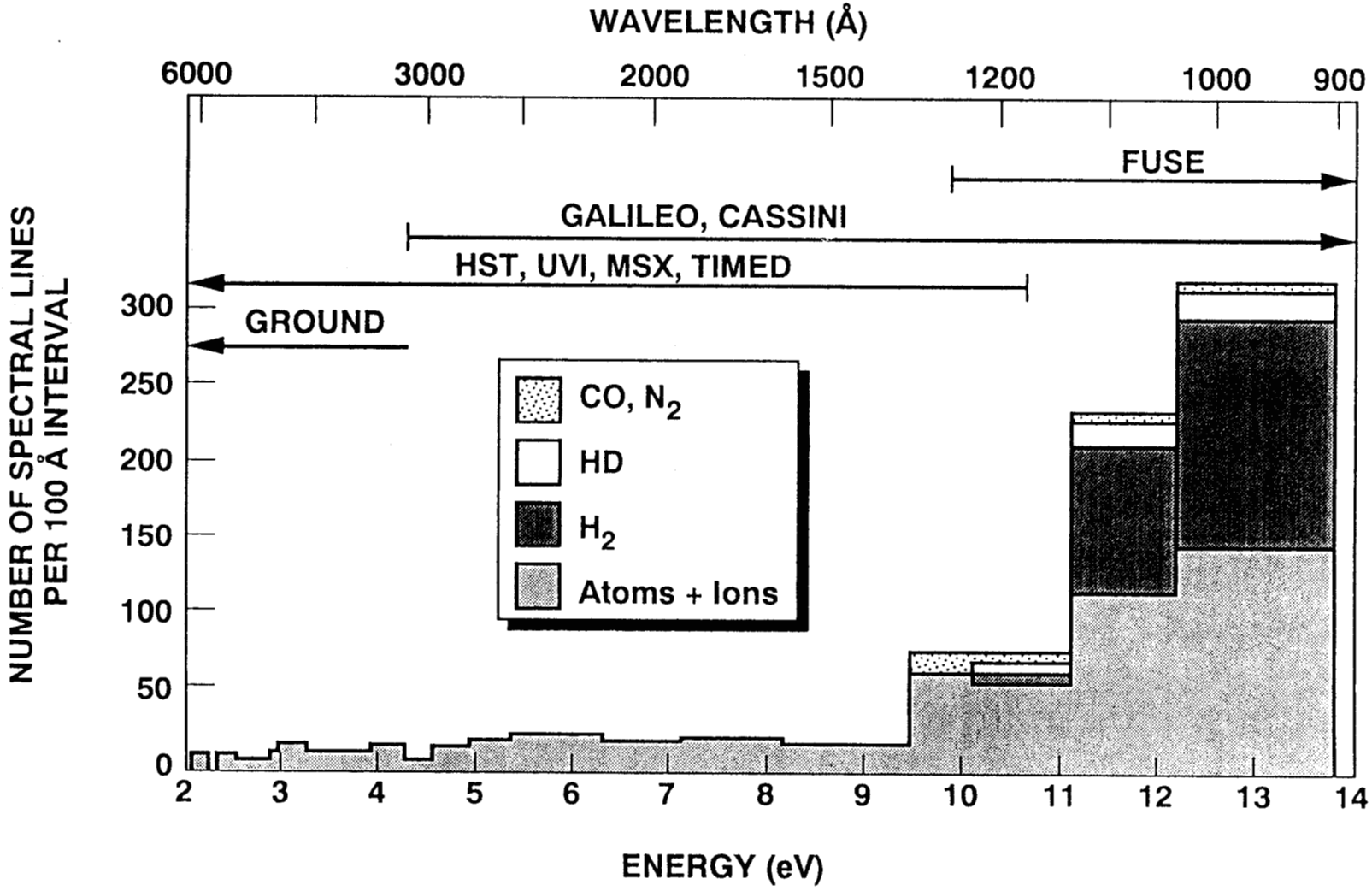
Earth

UVI
MSX
TIMED
DMSP
RAIDS

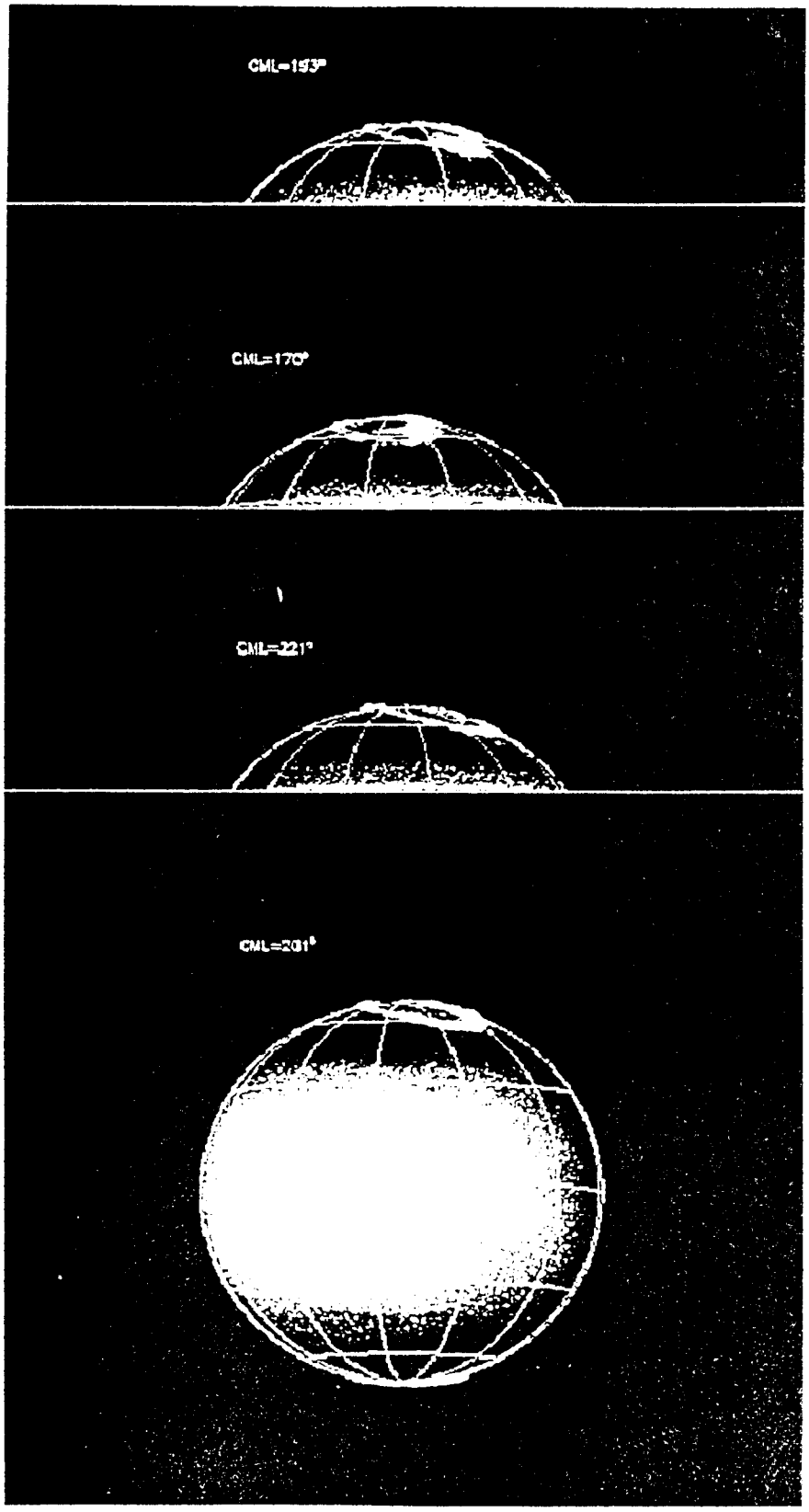
Outer Planets

Galileo
Cassini
HST
HUT
EUVE

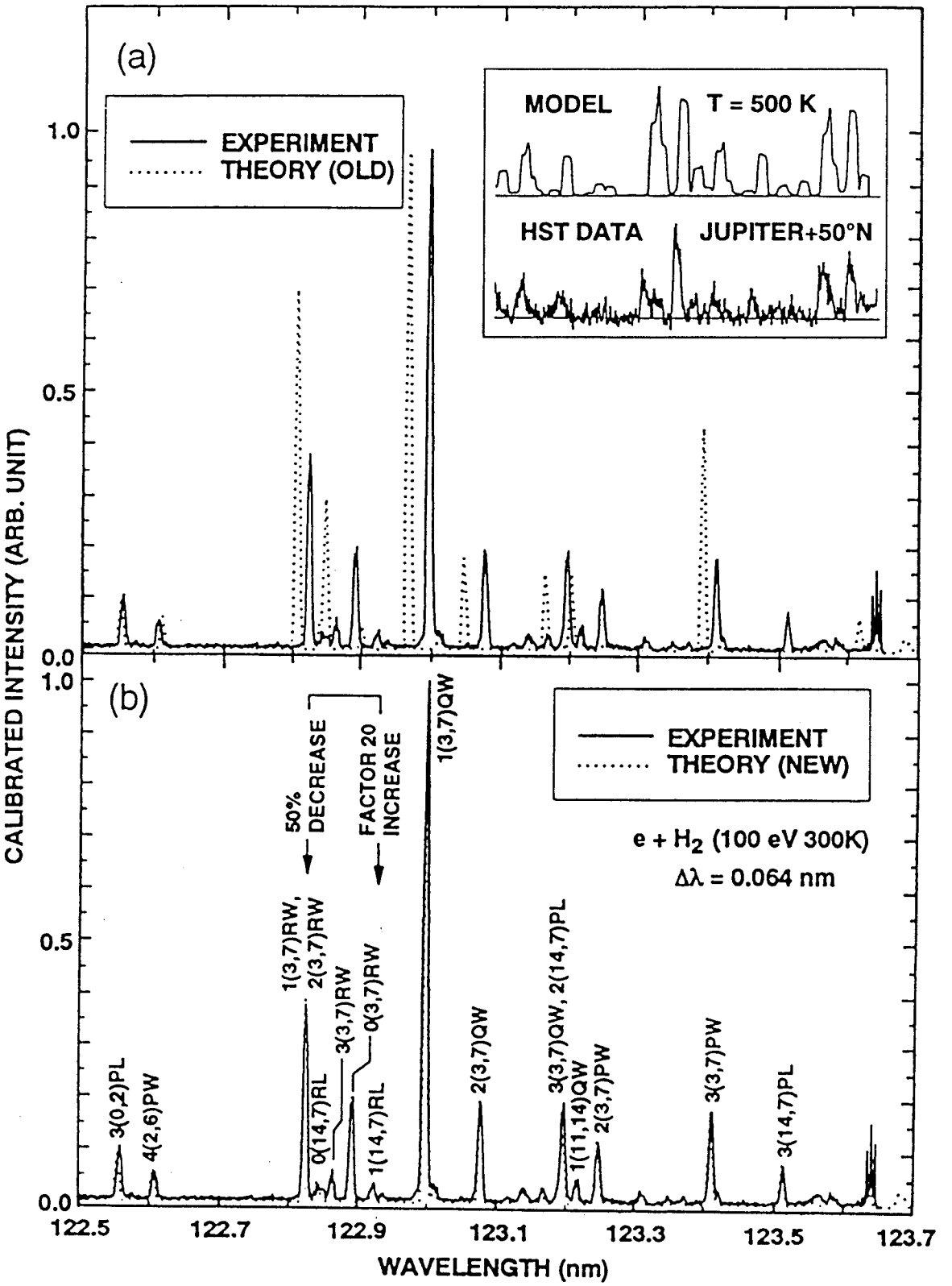
MANY ABSORPTION AND EMISSION LINES IN THE EUV



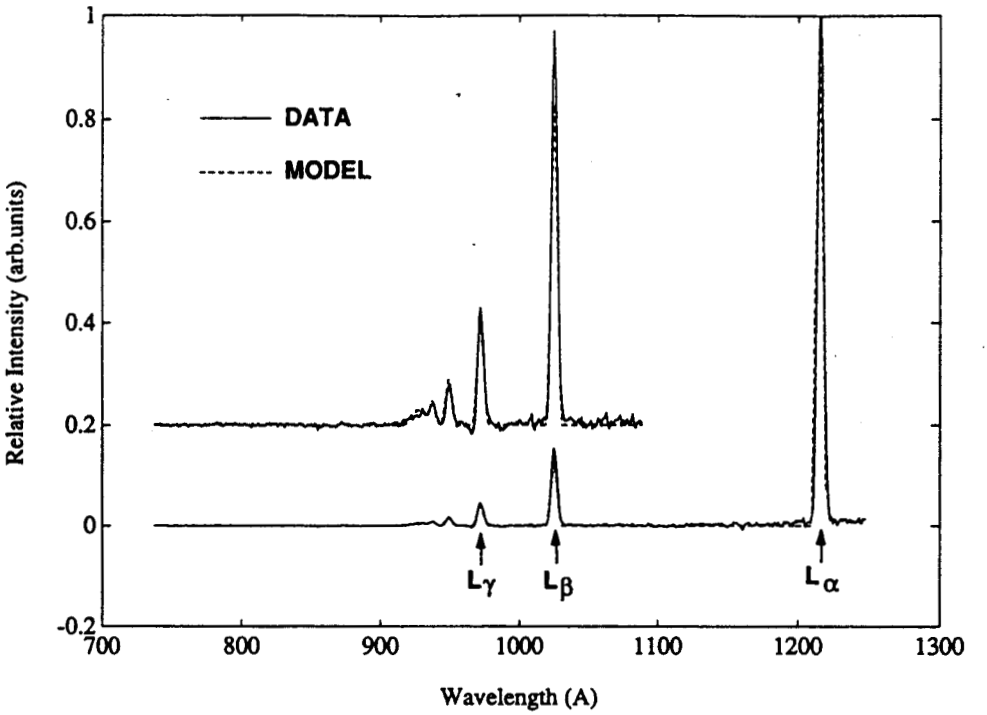
WFPC II FUV LYMAN BAND IMAGE OF JUPITER AURORA

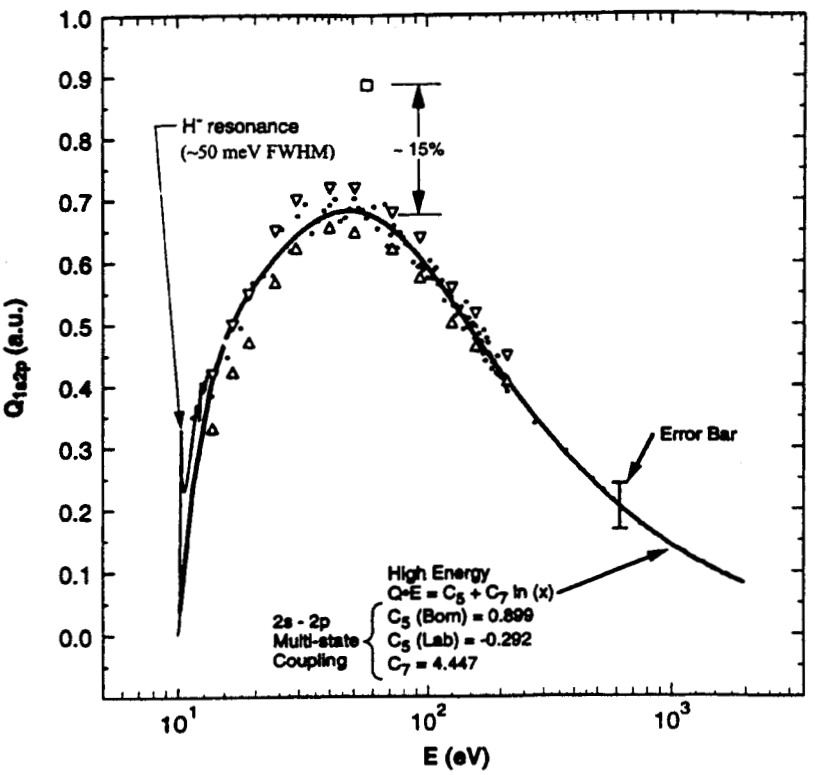


3M HIGH RESOLUTION STUDY OF H_2: APPLICATION OUTER PLANETS



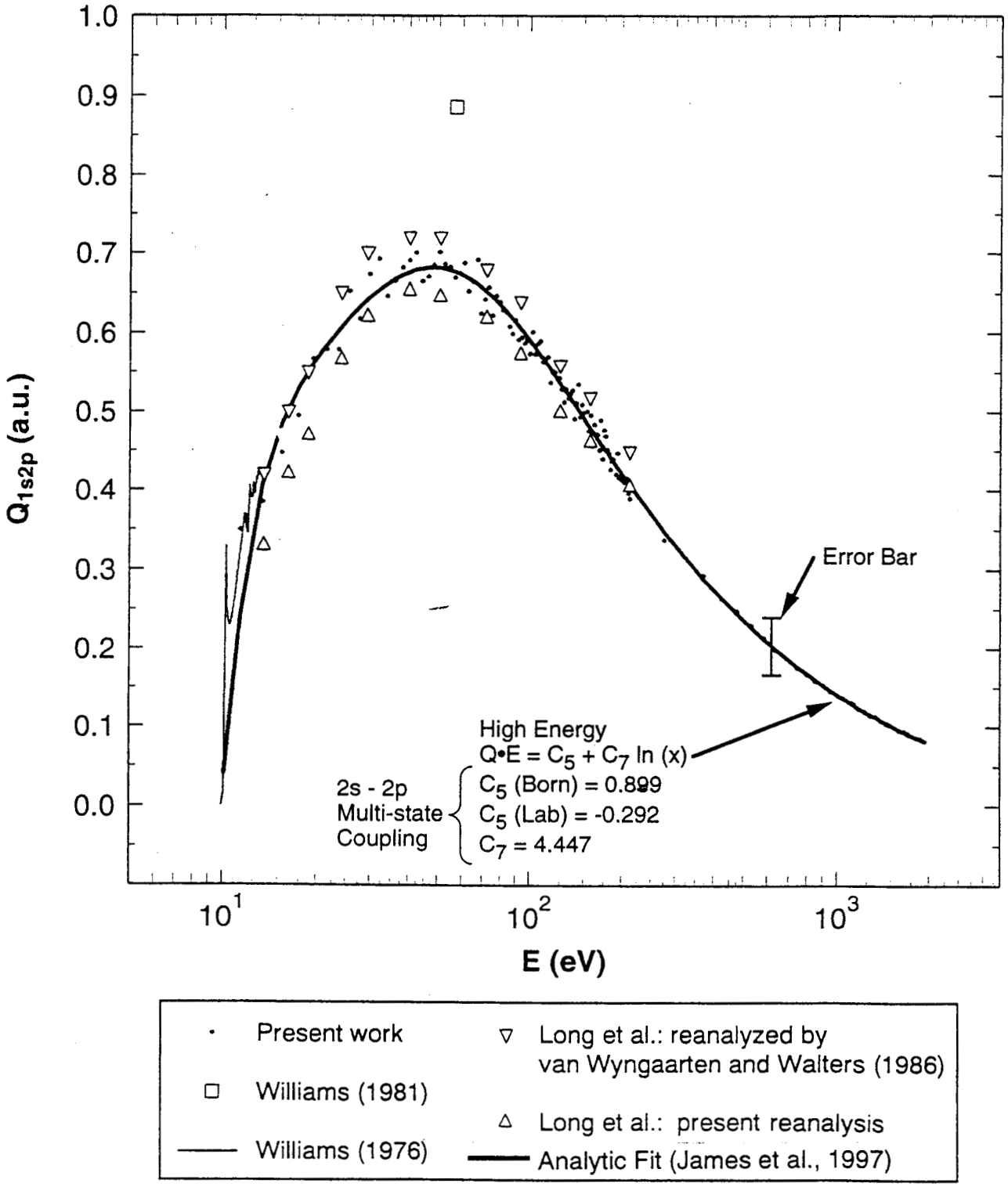
EXPERIMENTAL H (1s - 2p) CROSS SECTIONS FOR e + H $\xrightarrow{Q}$ Lα





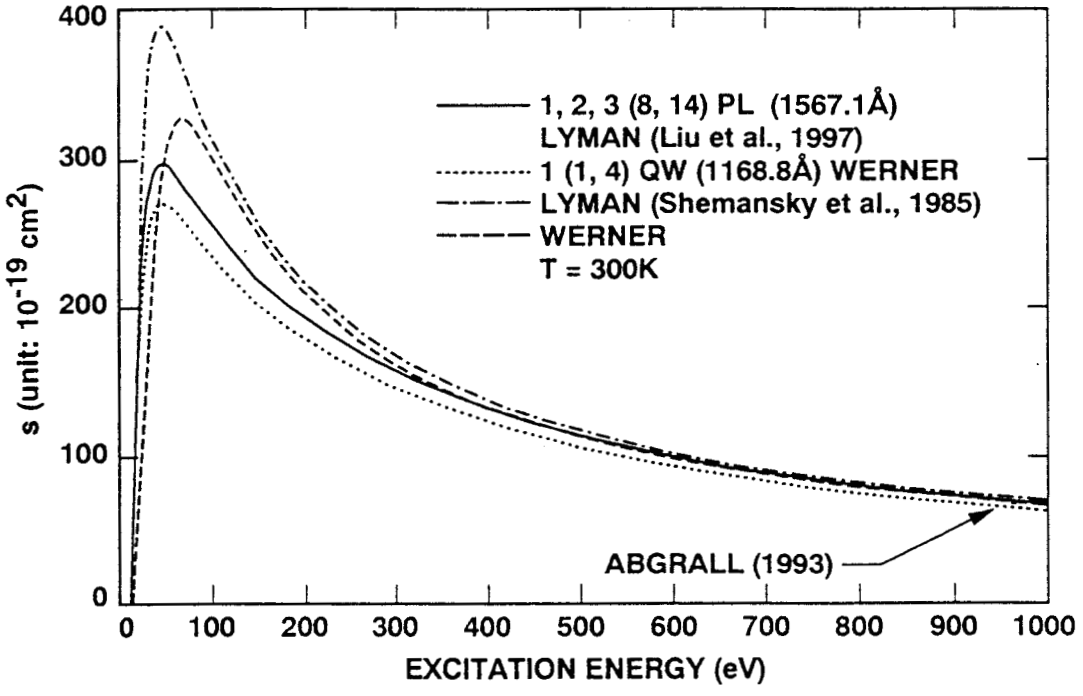
• Present work	▽ Long et al.: reanalyzed by van Wyngaarten and Walters (1986)
□ Williams (1981)	△ Long et al.: present reanalysis
—— Williams (1976)	—— Analytic Fit (James et al., 1997)

EXPERIMENTAL H (1s - 2p) CROSS SECTIONS

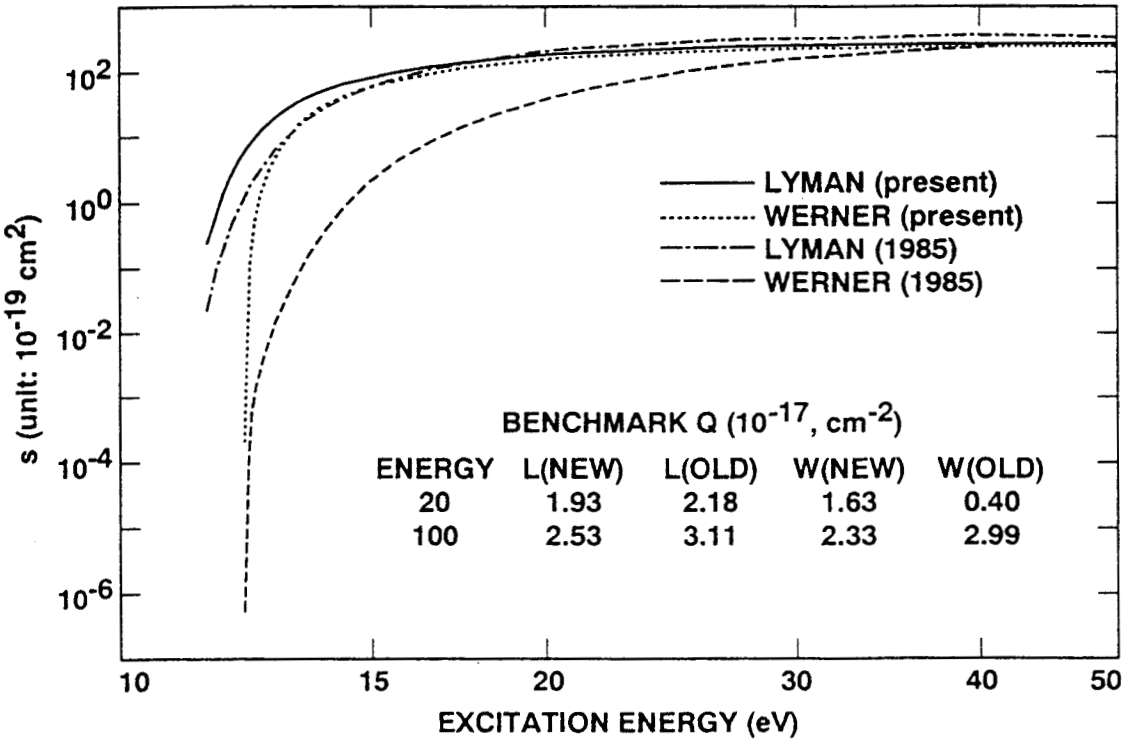


HIGH RESOLUTION STUDY OF LYMAN & WERNER EXCITATION CROSS SECTIONS

NORMALIZATION BORN REGION



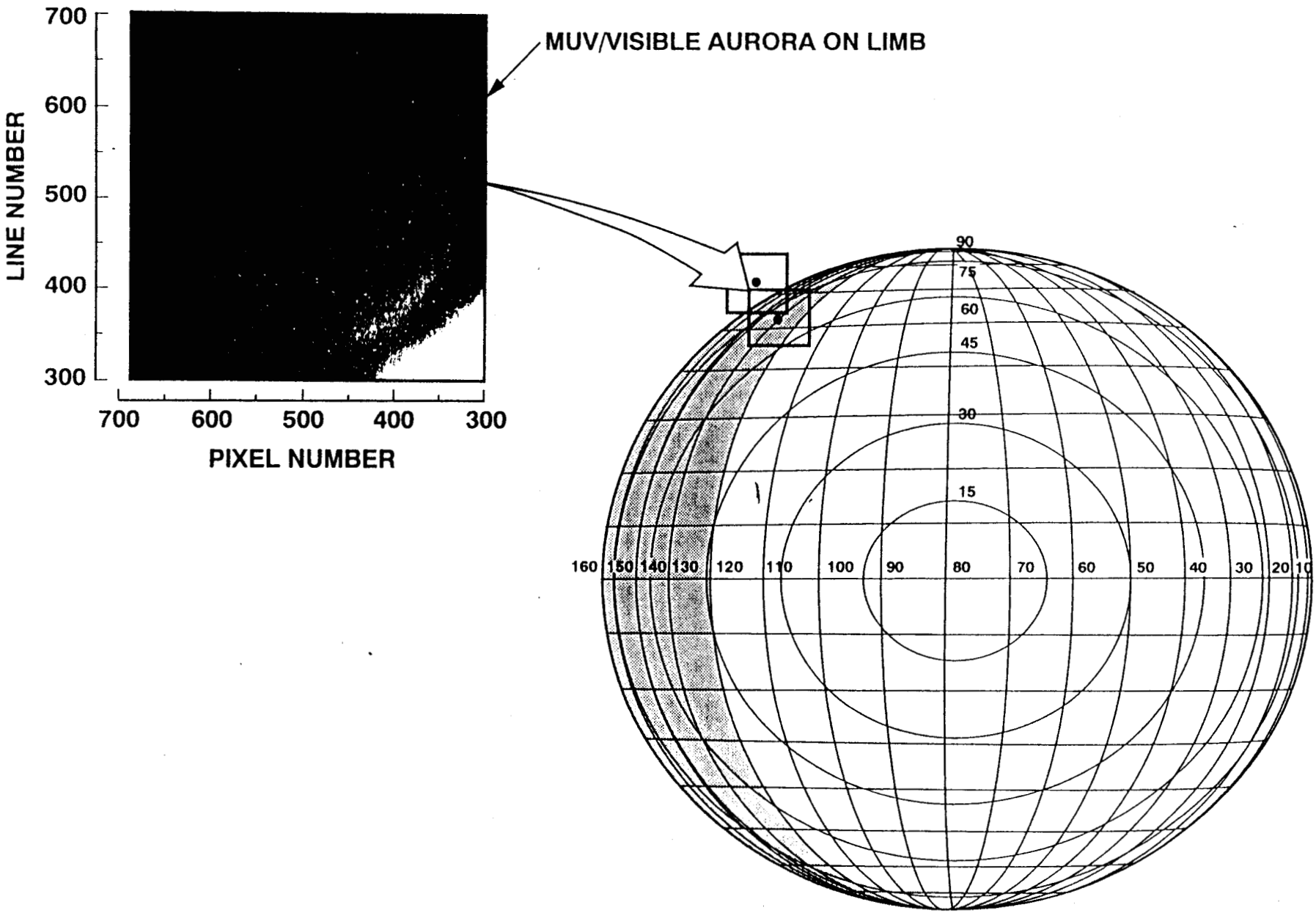
THRESHOLD REGION



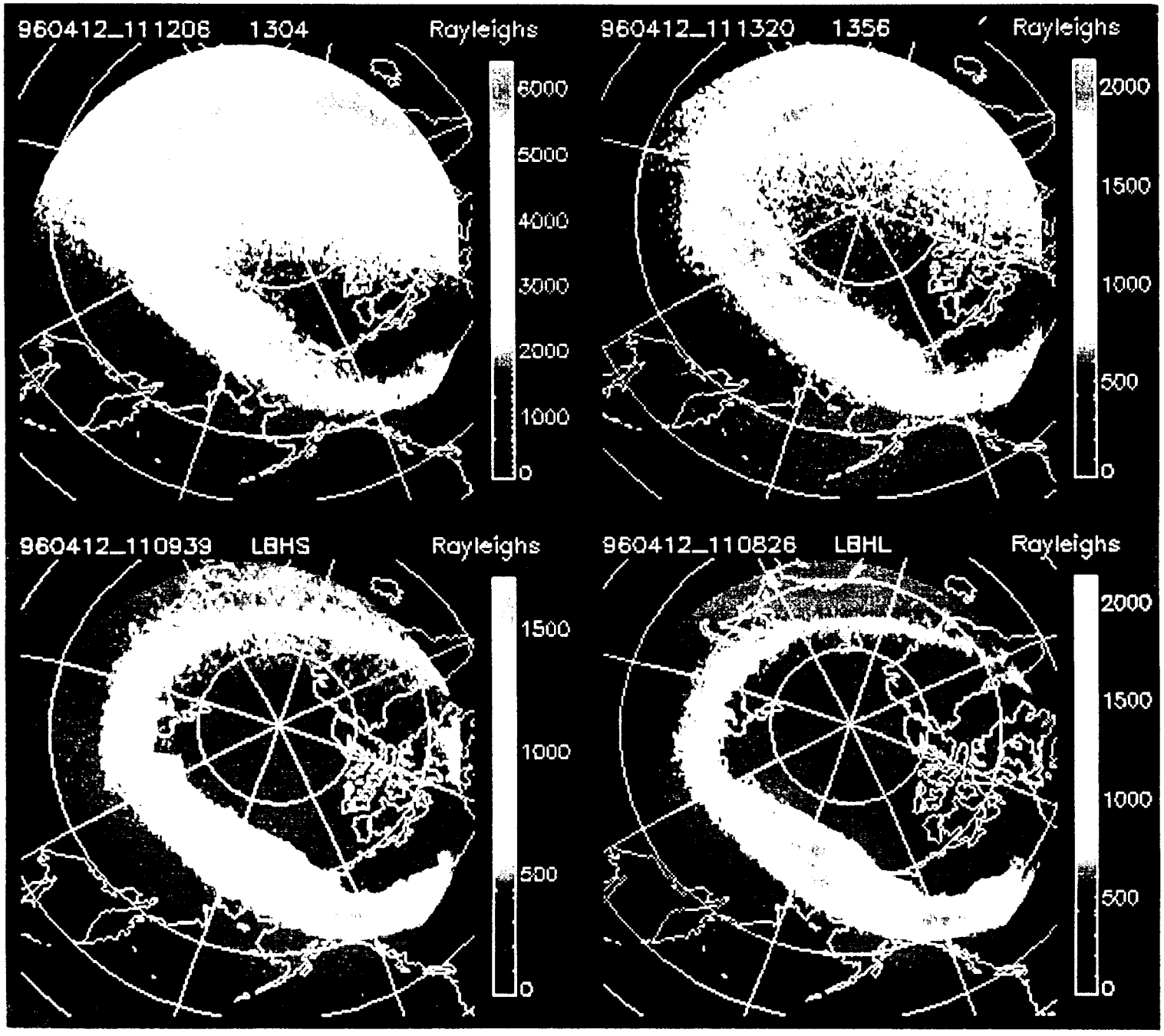
BENCHMARK Q (10^{-17}, cm^{-2})

ENERGY	L(NEW)	L(OLD)	W(NEW)	W(OLD)
20	1.93	2.18	1.63	0.40
100	2.53	3.11	2.33	2.99

C3 SSI CLEAR FILTER (400 – 800 nm) IMAGE OF DARKSIDE JUPITER AURORA

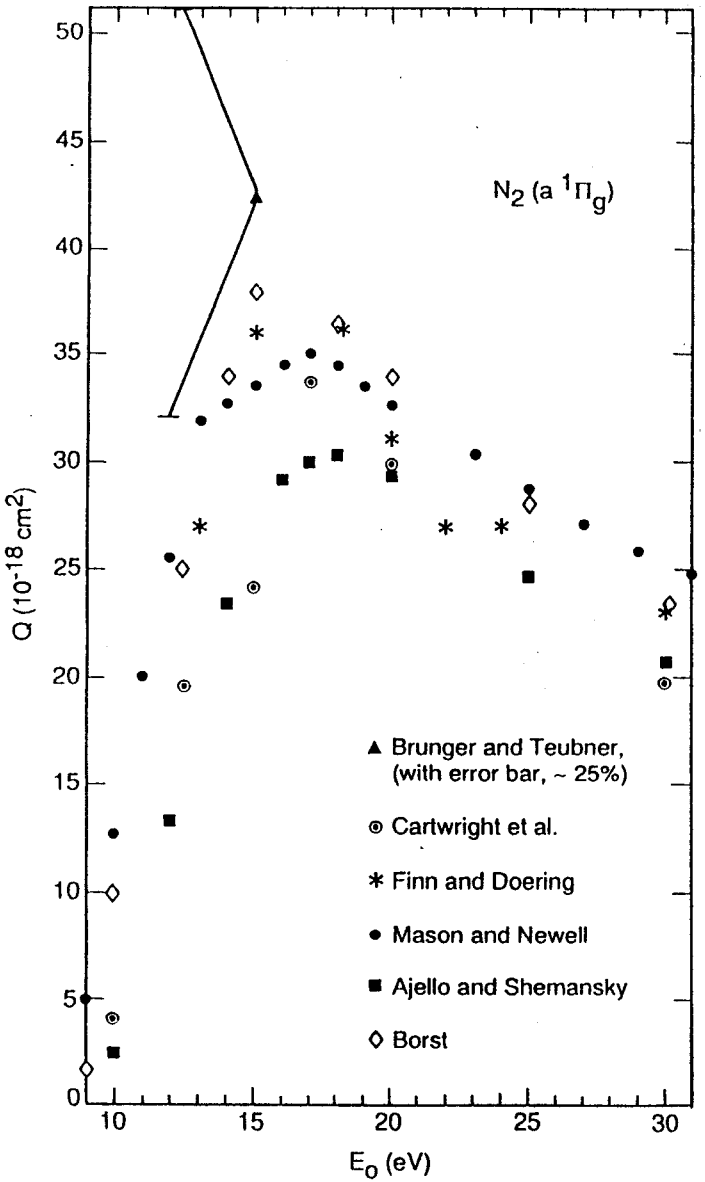


UVI GLOBAL IMAGE AT OI (1304, 1356 Å) & N_2 (LBH)



STATUS OF N_2 (a $^1\Pi_g$) CROSS SECTIONS

EXCITATION CROSS SECTIONS FOR N_2 (a $^1\Pi_g$)



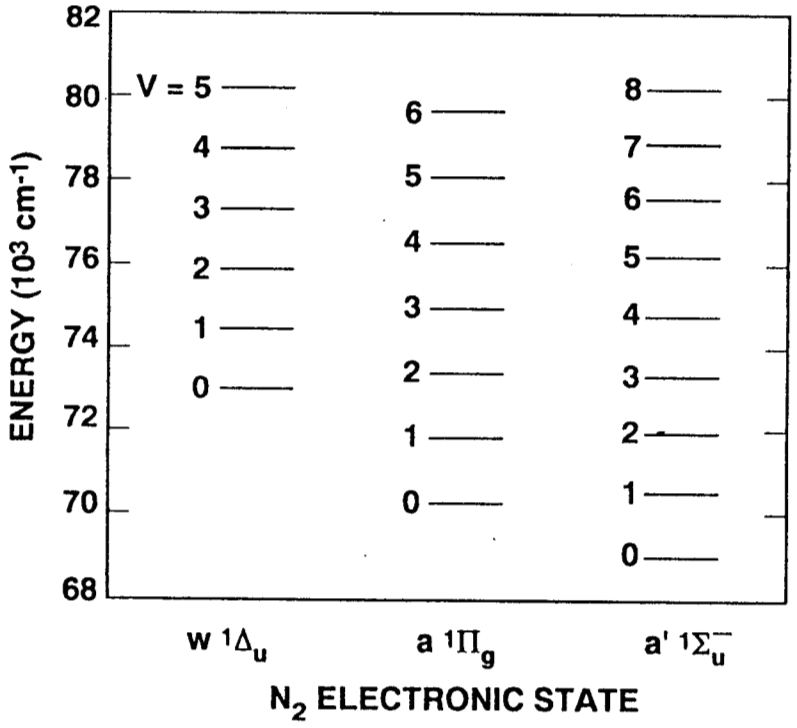
MEASUREMENTS OF THE LBH ELECTRON IMPACT CROSS SECTION

Measurement	Type	Peak Location (eV)	Peak Value (10^{-17} cm^2)
Ajello (1970)	PE	16	3.85
Brinkmann and Trajmar (1970)	ES	17	4.5
Borst (1972)	MP	15.6	3.85
Finn and Doering (1976)	ES	17	3.6
Cartwright *et al* (1977)	ES	17	2.72
Ajello and Shemansky (1985)	PE	17	2.65
Mason and Newell (1987)	MP	17	3.50
Zetner and Trajmar (1987)	ES		4.29
Brunger and Teubner (1990)	ES	17.5	4.24

Zobel, Germany 1996 (In Progress)

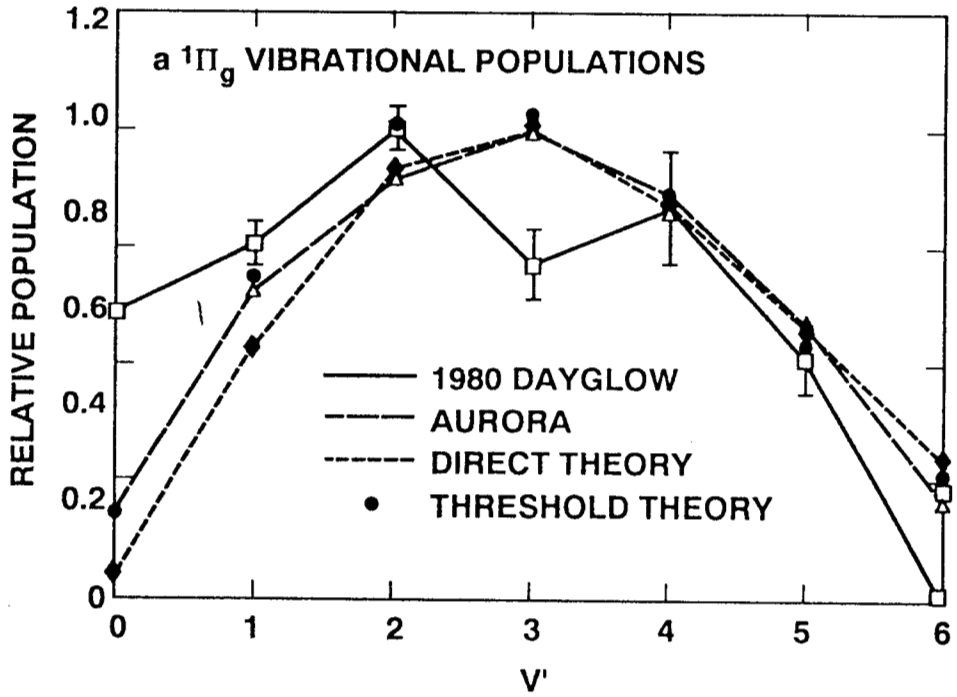
Trajmar, JPL 1996 (In progress)

LBH CASCADE/CIET ENHANCEMENT BY 1.6



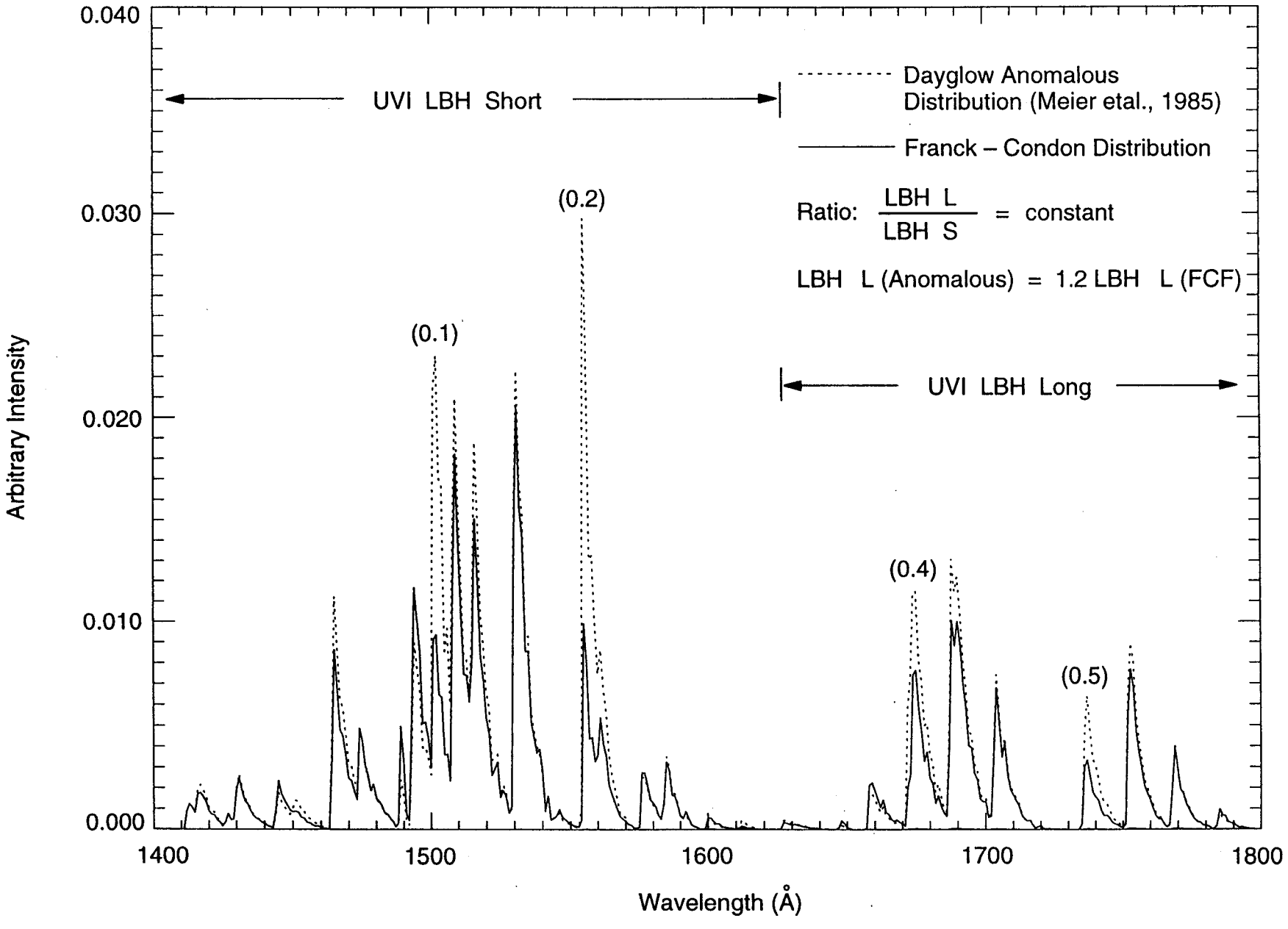
(Eastes et al., 1996)

WHAT IS THE REAL VIBRATIONAL DISTRIBUTION OF THE N_2 (a $^1\Pi_g$) STATE IN LABORATORY, DAYGLOW AND AURORA

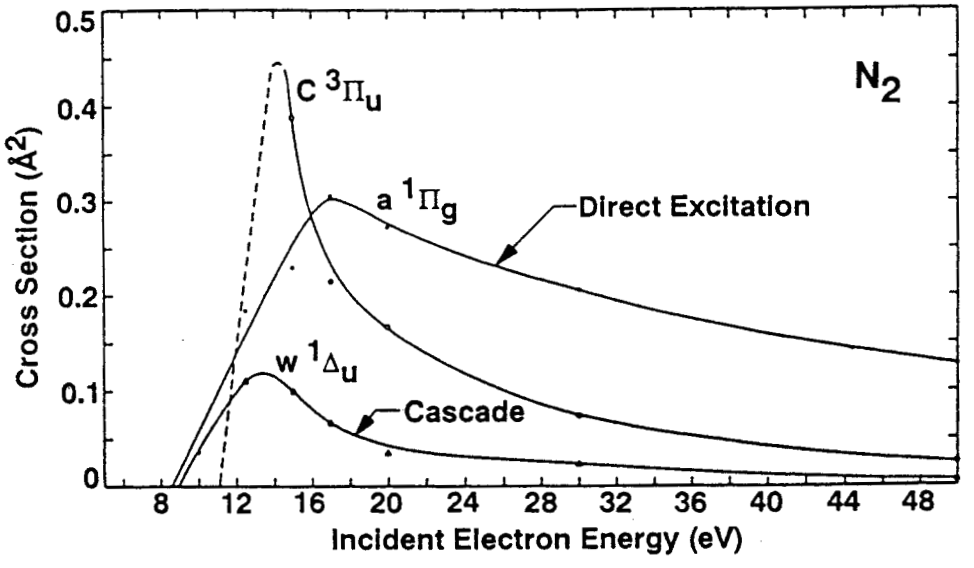


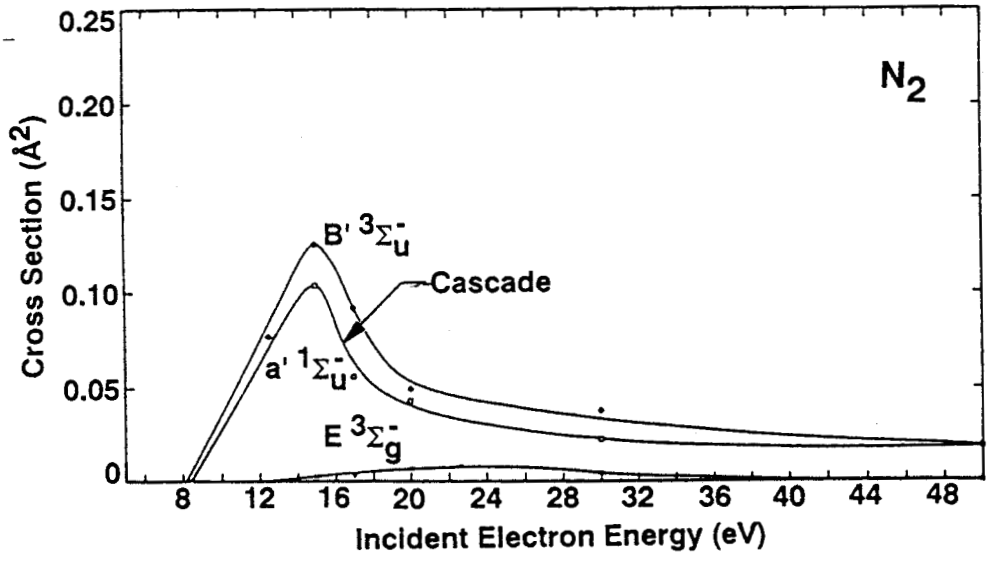
(Meier, 1990)

LBH SPECTRUM THROUGH UVI FILTER



COMPARISON OF LOW-LYING SINGLET STATE EXCITATION CROSS SECTIONS





(Cartwright et al., 1977)

a $^1\Pi_g$ GAIN AND LOSS MECHANISMS

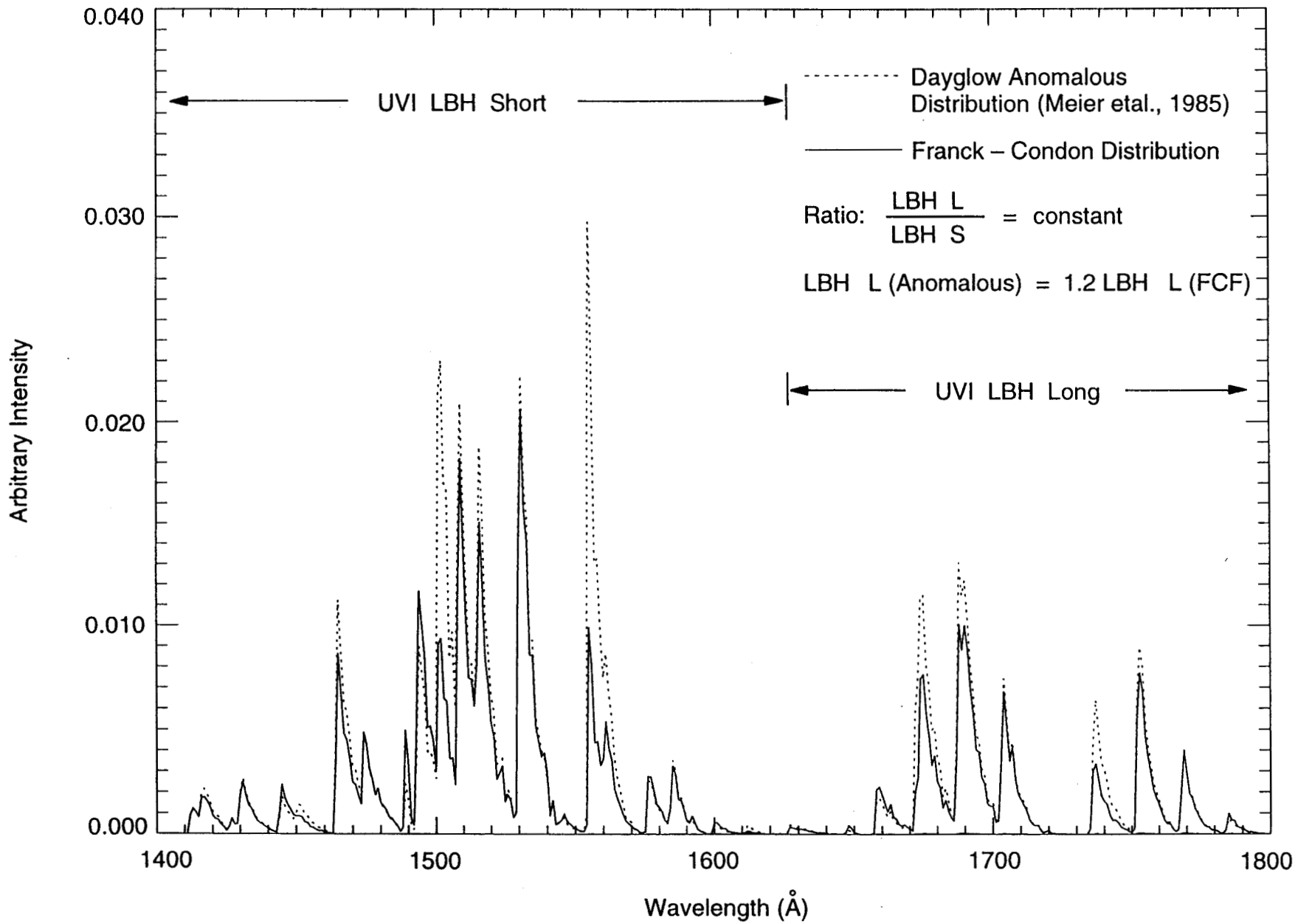
DOMINANT LOSS: $N_2\,(a\,^1\Pi_g) \xrightarrow[\tau \sim 56\ \mu s]{\text{Fluorescence}} N_2\,(X\,^1\Sigma_g^+)$

SECONDARY GAIN & LOSS: $N_2\,(a'\,^1\Sigma_u, w\,^1\Delta_u) + M \xleftrightarrow[\mu s]{\text{CIET}} N_2\,(a\,^1\Pi_g) + M$

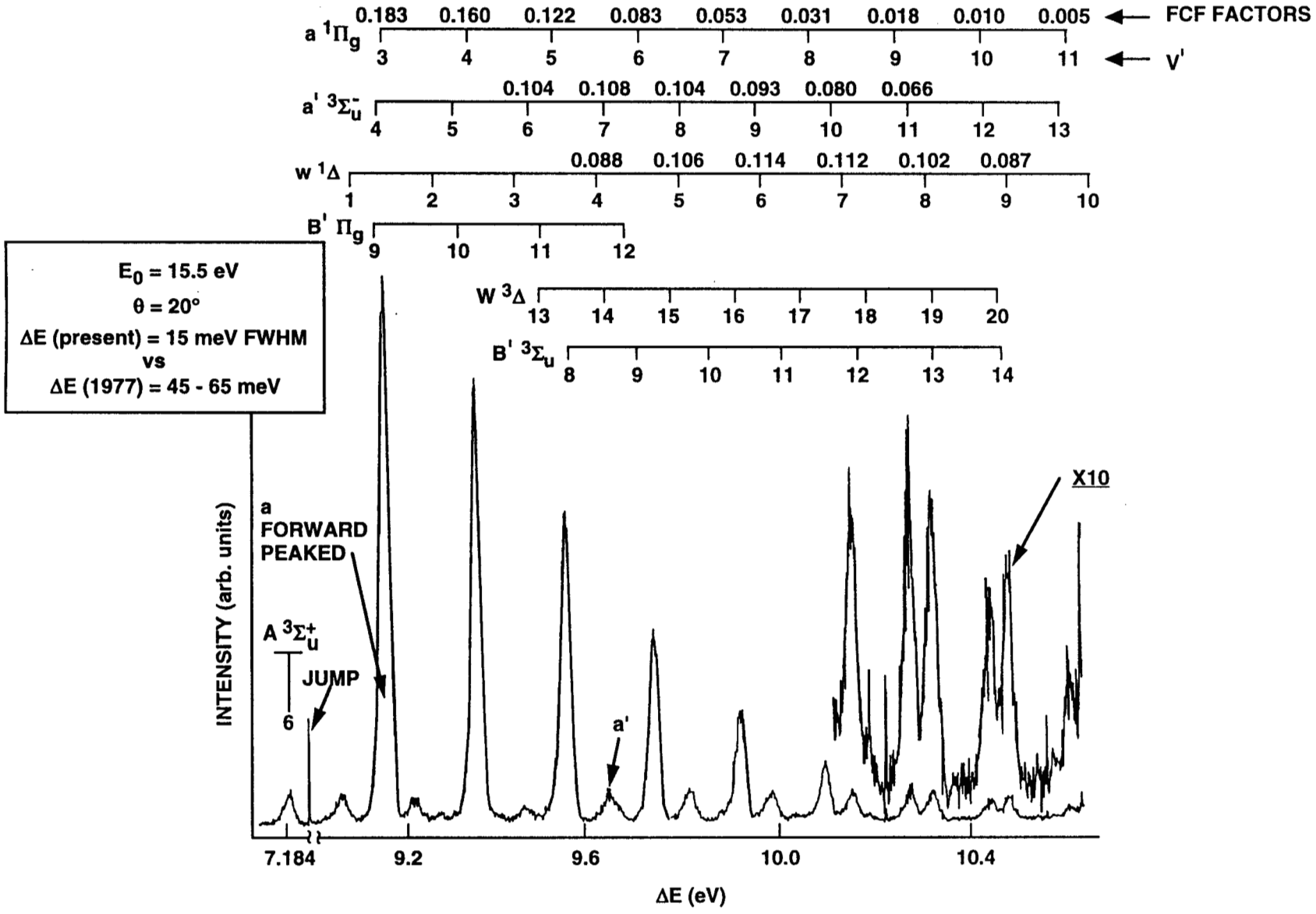
$N_2\,(a'\,^1\Sigma_u, w\,^1\Delta_u) \xrightarrow{\text{Cascade}} N_2\,(a\,^1\Pi_g)$

(Eastes & Dentamaro, 1996)

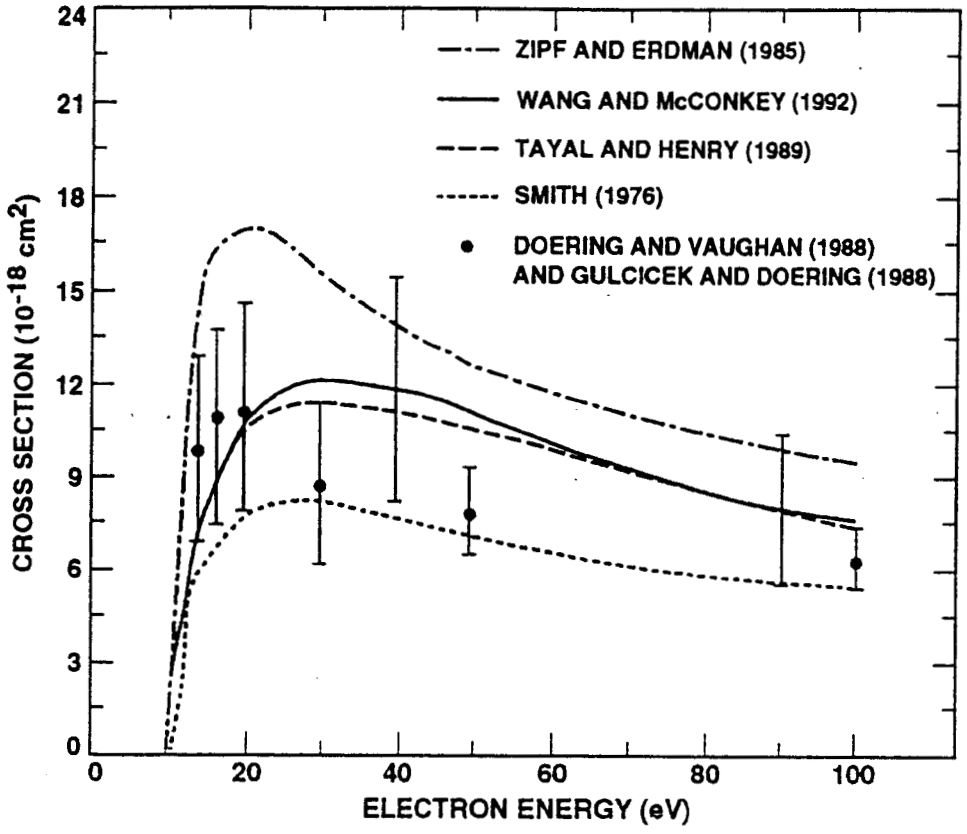
LBH SPECTRUM THROUGH UVI FILTER



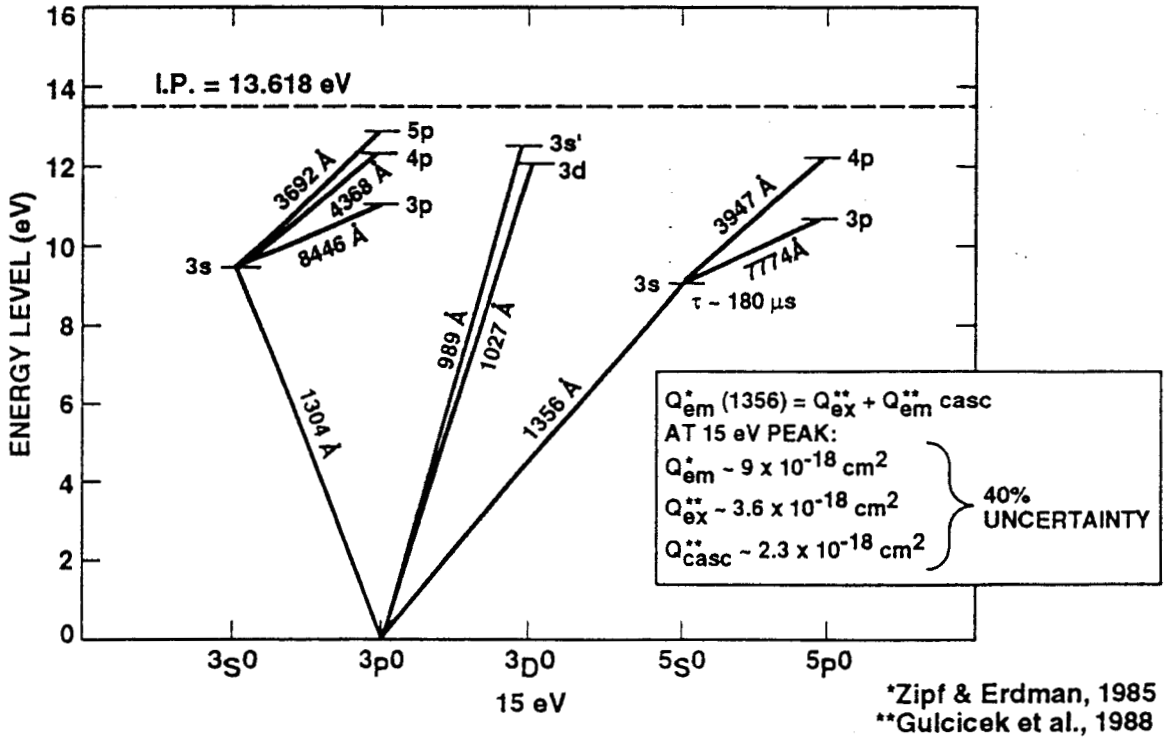
JPL ELECTRON LOSS SPECTRUM OF N_2 IN OPTICALLY FORBIDDEN REGION (7 - 10 eV)



OI (1304 Å) EMISSION CROSS SECTION

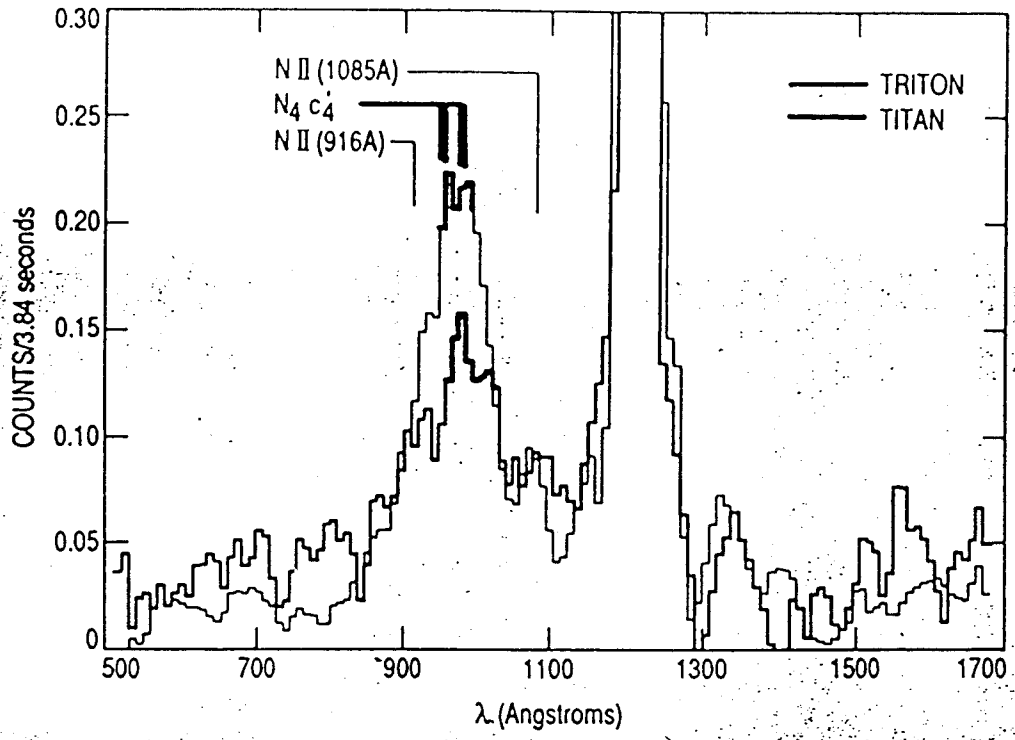


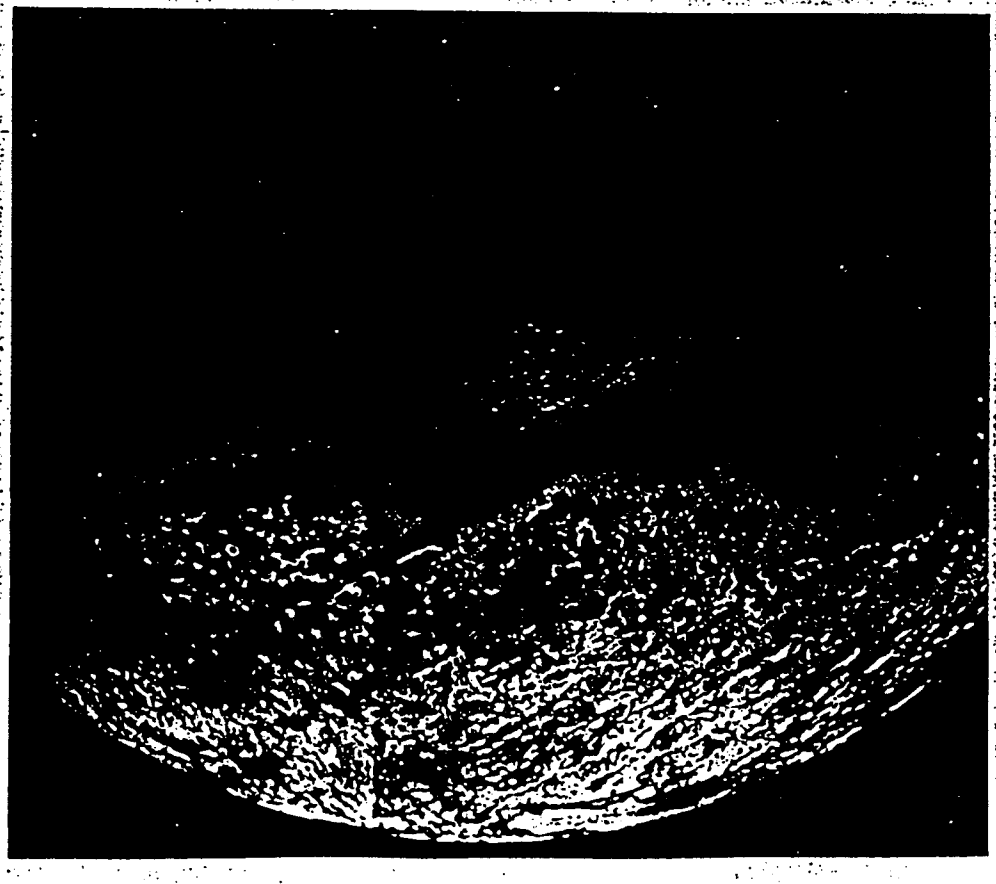
OI PARTIAL GROTRIAN DIAGRAM



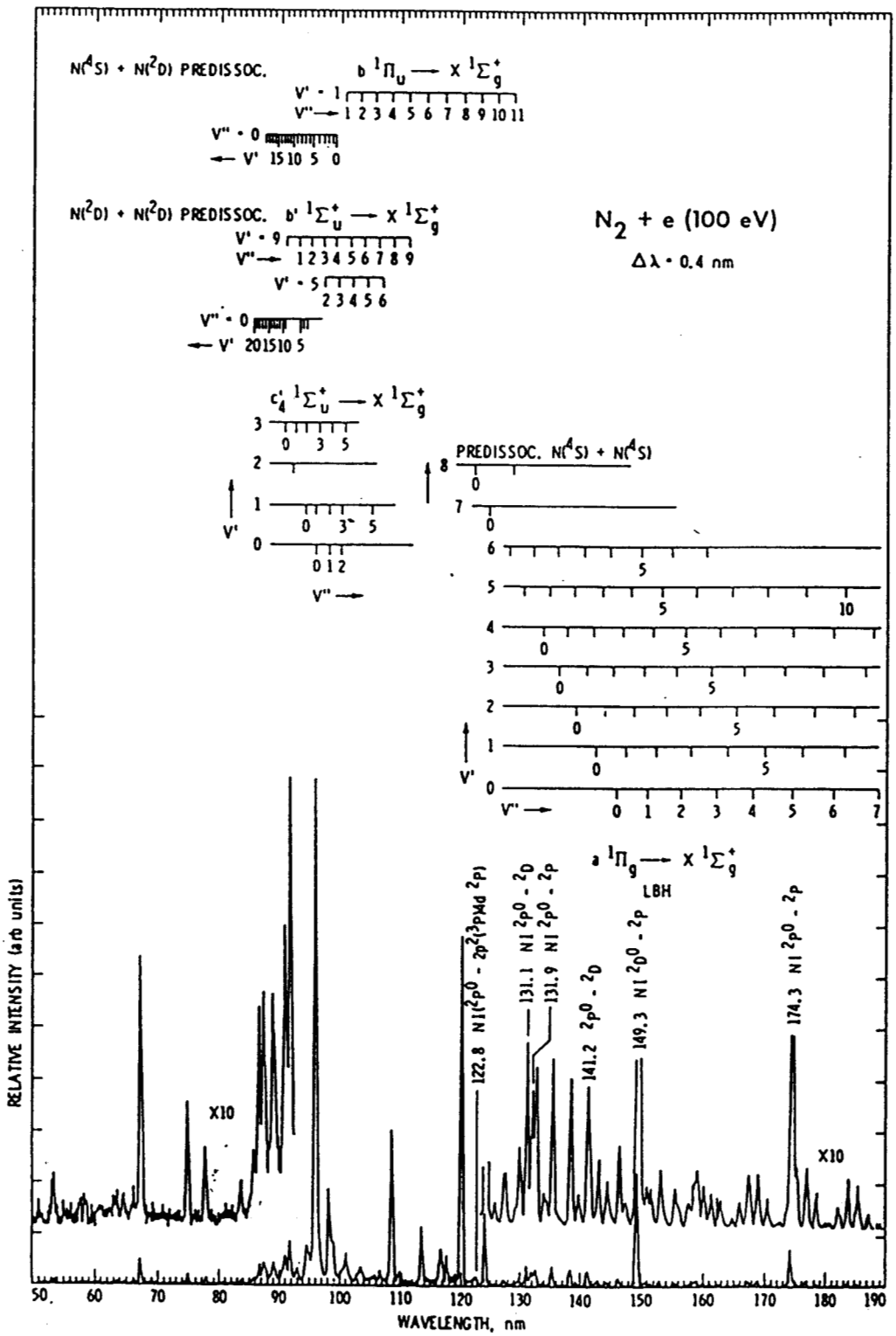
*Zipf & Erdman, 1985
**Gulcicek et al., 1988

VOYAGER EUV SPECTRUM OF TRITON

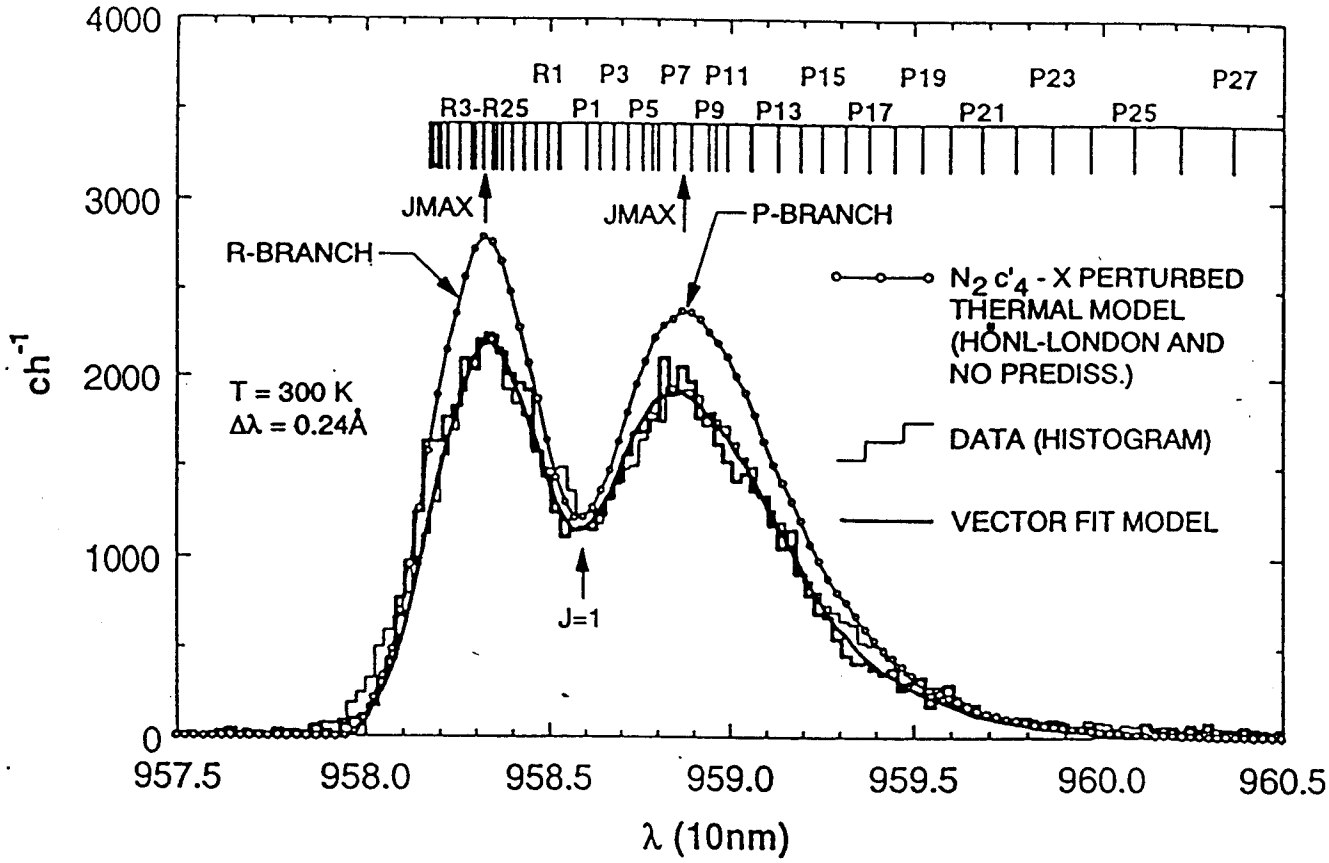


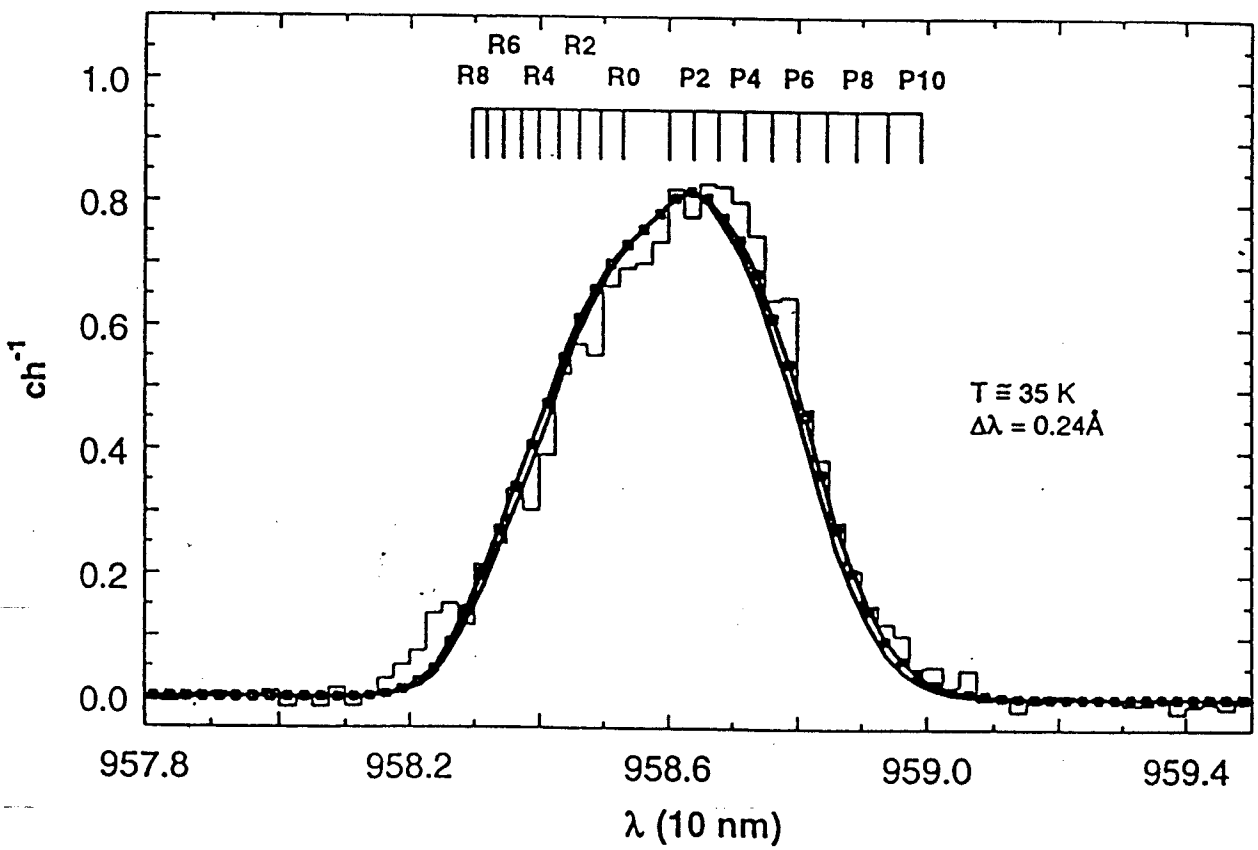


N_2 VUV SPECTRUM AT 100 eV

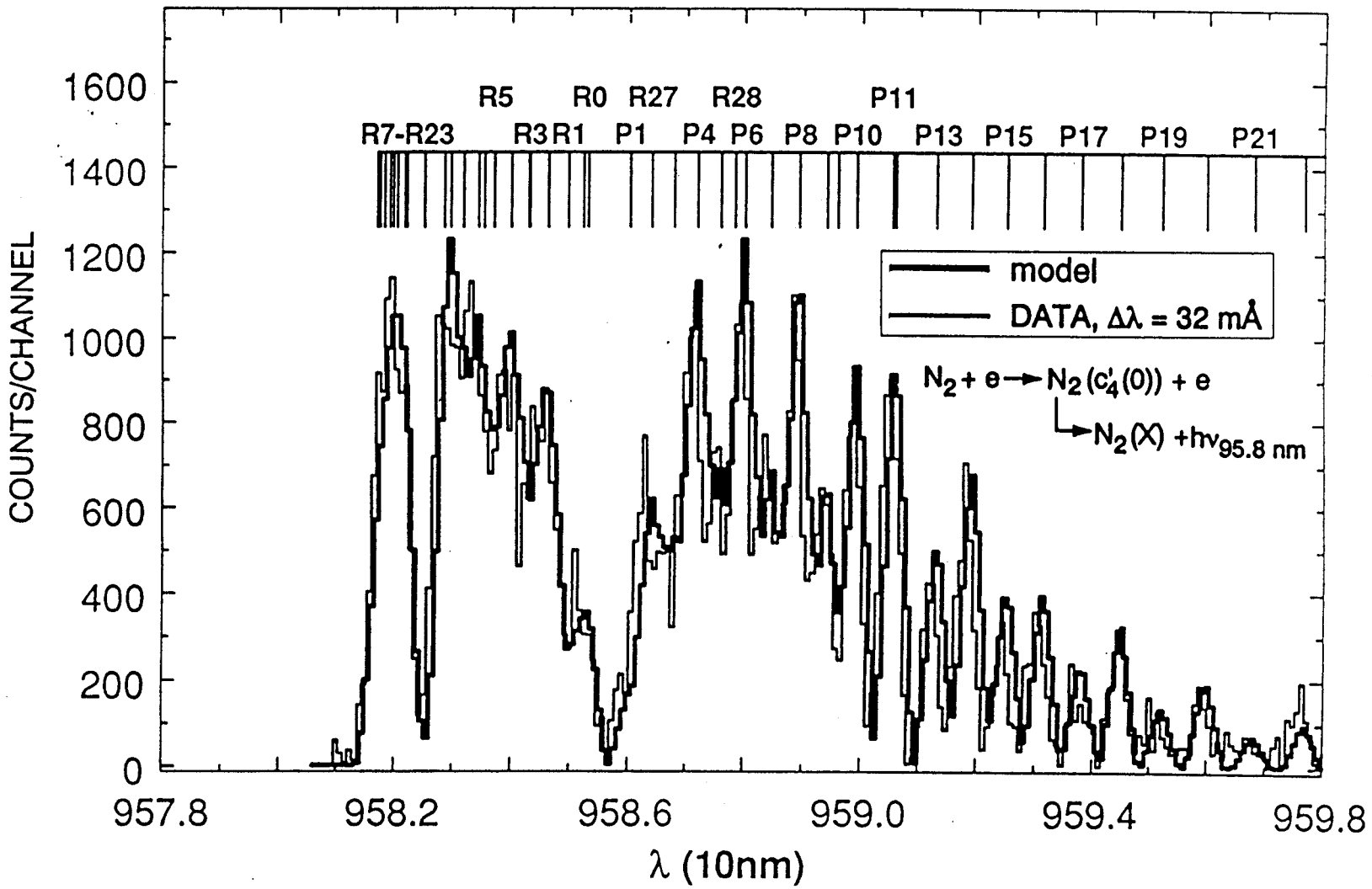


MEDIUM RESOLUTION STUDIES OF N_2 (c'_4 - X) (0,0) BAND ROTATIONAL ENVELOPE AT 100 eV

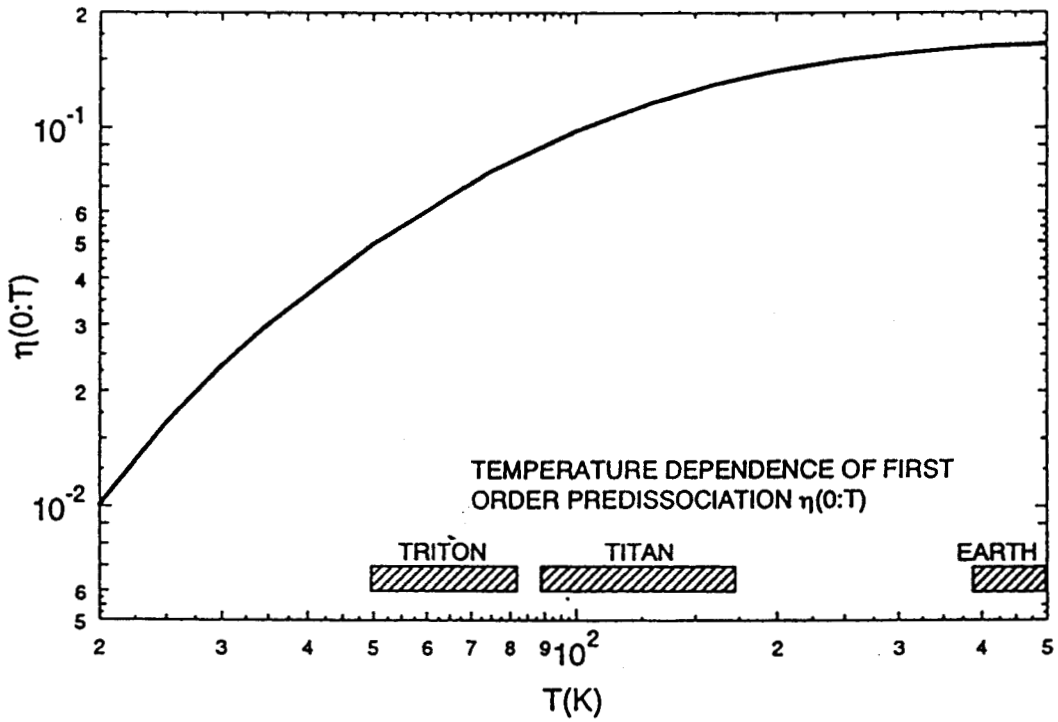


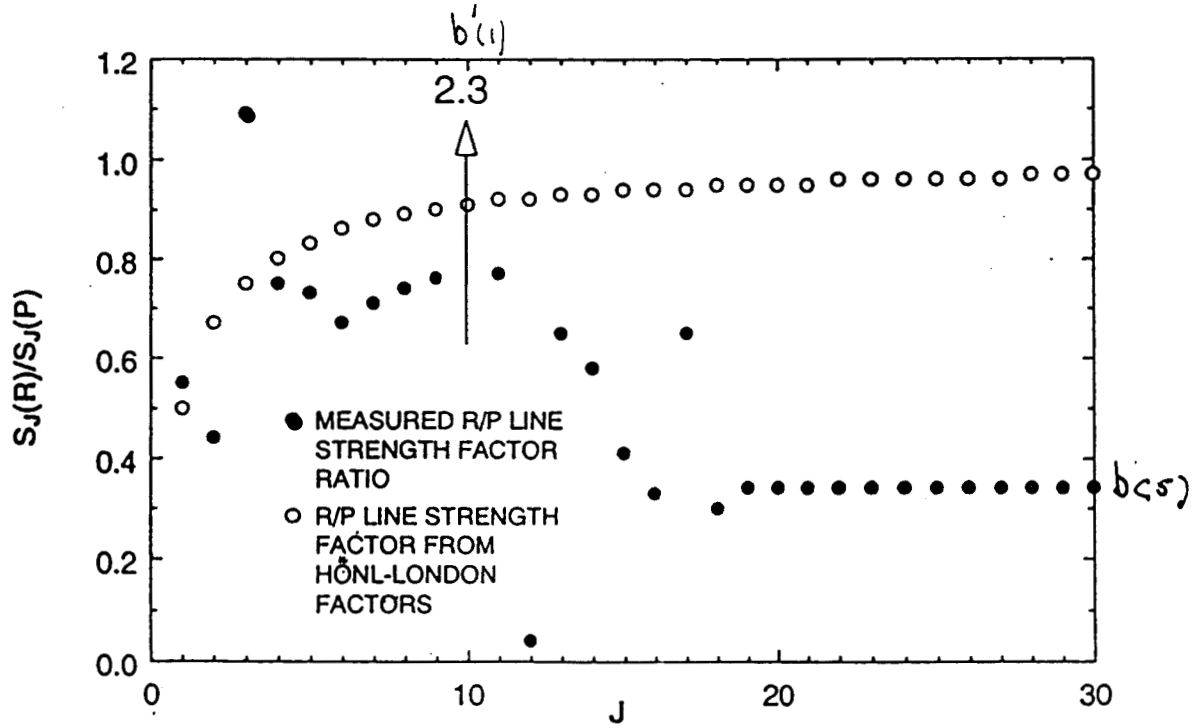


HIGH RESOLUTION ROTATIONAL LINE STRUCTURE N_2 c_4' (0,0) BAND AND MODEL



PREDISSOCIATION YIELD AND PERTURBED LINE STRENGTH FACTOR FOR (c'_4 - X) 0,0 BAND AT 95.8 nm





HIGHLIGHTS OF VUV e-IMPACT PROGRAM

- REVISED BENCHMARK LYMAN-α UV CALIBRATION STANDARD
  - $e + H_2 \xrightarrow{\sigma\ (100\ eV)} H\ (2p) + H + e$
  - $\sigma\ (2p) = 7.3 \times 10^{-18}\ cm^2$ = DECREASE UV σ 15 YEARS 38% ↓:
  - CHANGED Q ACCURACIES 100% → 20%
- DEVELOP e-IMPACT UV CALIBRATION SOURCE (40-300 nm)
  – GALILEO UVS, EUV, POLAR UVI, CASSINI
- HIGHEST RESOLUTION SINGLE SCATTERING UV EMISSION SPECTROSCOPY
  - ATOMS (H, O, ...)
- OVER 40 PAPERS FOR THE FOLLOWING SPECIES:
  - H_2
  - He
  - Ar
  - O_2
  - N_2
  - H_2O
  - Ne
  - C_2H_2 AND CH_2
  - NO
  - NII
  - CO
  - SO_2
  - CO_2
  - H
- LAB $\xrightleftharpoons{\text{SYNERGISM}}$ S/C OBSERVATIONS