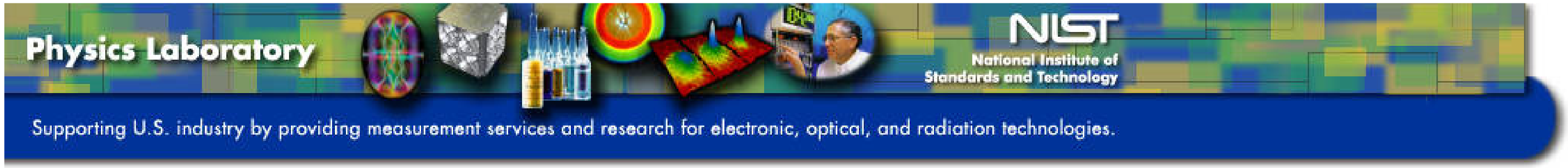

Spectroscopic Research Projects at NIST on Light Elements

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NIST Atomic Spectra Database

physics.nist.gov

Participants

Experimental Research:	J. Reader, J. Tan, G. Nave, J. Gillaspy, C. Sansonetti, J. J. Curry, A. Tauheed*
Theoretical Approaches:	Ch. Froese-Fischer*, Y. Ralchenko*, M. Ali*, O. Zatsarrinny*, J.-F. Wyart*,
Data Assessment and Compilations:	J. Reader, E. Saloman*, J. Fuhr*, D. Kelleher*, L. Podobedova*, J. Sansonetti*, A. Kramida*, W. Wiese*, C. Sansonetti, J. J. Curry, G. Nave
Database Development:	Y. Ralchenko*, A. Kramida*, R. Ibacache, A. Jackson, A. Zimmermann

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Projects on Light Elements

A. Atomic Spectra Database

B. H,D, and T

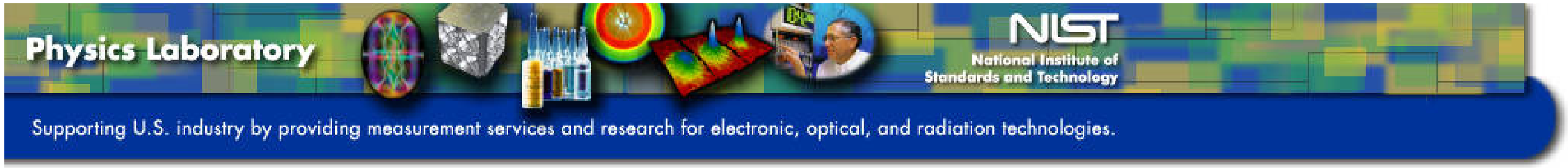
C. He and Li

D. Be and B

E. Other Light Elements

F. W

G. Future Plans



A. ASD and Associated Databases

Atomic Spectra Database –

Version 3.15 (4.0 coming)
950 spectra
144,000 transition wavelengths
77,000 energy levels
Auxiliary tools
- Grotrian diagram
- Saha-equil. radiation plot for arbitrary plasma parameters
- Line ID plot
- FLYCHK spectral modelling

<u>50,000 queries per month</u>

Bibliographic Databases

EL and Wavelengths
Atomic transition probabilities
Line shapes and shifts

NIST Atomic Spectra Database

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C. H, He, and Li

- **'Accurate atomic transition probabilities for hydrogen, helium, and lithium,'** Wiese and Fuhr, JPCRD 2009.

- **'Relativistic all-order and multi-configuration Hartree-Fock calculations of the 4d-4f energy separation in Li I,'** Safronova, Fischer, and Ralchenko, PRA 2007.

- **'Electron-impact excitation and ionization cross sections for ground state and excited state helium atoms,'** Ralchenko et al., At. Data and Nucl. Data Tables 2008.

B. H, D, and T

Transition		Hydrogen			Deuterium		Tritium	
		λ (nm)	$A_{\text{non-rel.}}$	$A_{\text{relativ.}}$	λ	$A_{\text{relativistic}}$	λ	$A_{\text{relativistic}}$
L_α	1 – 2	121.567	4.699	4.6986	121.533	4.6999	121.523	4.7004
L_β	1 – 3	102.572	5.575e–1	5.5751e–1	102.544	5.5766e–1	102.535	5.5771e–1
H_α	2 – 3	656.464	4.410e–1	4.4101e–1	656.29	4.4113e–1	656.23	4.4117e–1
H_β	2 – 4	486.270	8.419e–2	8.4193e–1	486.14	8.4216e–2	486.09	8.4224e–2

B. H, D, and T

Hydrogen

Transition	Non-relativistic value	Relativistic values		
	Green et al. 1957	Baker 2008	Jitrik & Bunge 2004	Pal'chikov 1998
$1s - 2p$	6.265	6.2649		
$1s - 2p_{1/2}$		6.2649	6.2649	6.2649
$1s - 2p_{3/2}$		6.2648	6.2648	6.2648
$1s - 3p$	1.672	1.6725		
$1s - 3p_{1/2}$		1.6725	1.6725	1.6725
$1s - 3p_{3/2}$		1.6725	1.6725	1.6725
$1s - 4p$	0.6818	0.68186		
$1s - 4p_{1/2}$		0.68186	0.68186	0.68186
$1s - 4p_{3/2}$		0.68186	0.68186	0.68186

C. Helium and Lithium

He I, 128 lines → 2243 lines

Li I, 57 lines → 152 lines

Li II, 52 lines → 475 lines

C. Helium and Lithium

Lithium

	Line Strengths	
	2s ^2S – 2p $^2P^o$	2p $^2P^o$ – 3d ^2D
THEORY:		
Yan and Drake	32.9990726 (length) 32.9990681 (velocity)	77.00916742
Fischer et al.	33.0027	77.0068
Pestka and Woznicki	33.0093	76.9775
Qu et al.	33.0076	—
Peach et al.	33.023	—
LIFETIME EXPTS.:		
Schmitt et al.	33.02	76.99*
McAlexander et al.	33.005	—
Martin et al.	32.97	—

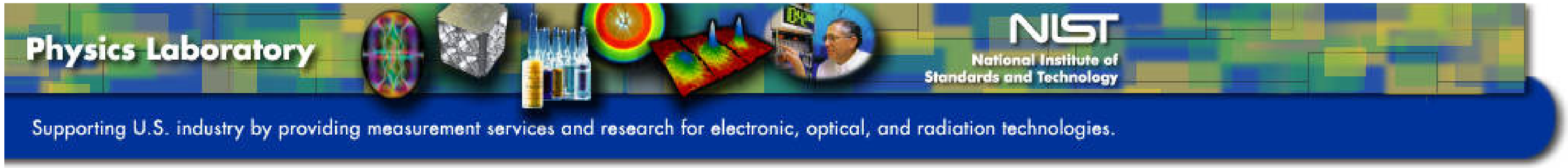
D. Beryllium and Boron

- **'Tables of Atomic Transition Probabilities for Be and B,'** Wiese and Fuhr, in progress.

- **'A critical compilation of energy levels and spectral lines of neutral boron,'** Kramida and Ryabtsev, Phys. Scripta 2008.

- **'Additions to the spectrum and energy levels and critical compilation of doubly-ionized boron, B II,'** Kramida, Ryabtsev, Ekberg, Kink, Mannervik, and Martinson, Phys. Scripta 2008.

- **'Additions to the spectrum and energy levels and a critical compilation of helium-like and hydrogen-like boron, B IV and B V,'** Kramida, Ryabtsev, Ekberg, Kink, Mannervik, and Martinson, Phys. Scripta 2008.



D. Beryllium and Boron

Be I

	gf-values			
	$2s^2\ ^1S - 2s2p\ ^1P^o$	$2s2p\ ^3P^o - 2p^2\ ^3P$	$2s2p\ ^1P^o - 2s3s\ ^1S$	$2s2p\ ^1P^o - 2s3d\ ^1D$
CALCULATIONS:				
Tachiev and Froese Fischer	1.380 (D=0.1 %)	4.005 (D=0.3 %)	0.3452 (D=2.6 %)	1.1934 (D=4.5 %)
Nam	1.383 (D=1.0 %)	4.047 (D=1.4 %)	0.3633 (D=0.8 %)	1.2306 (D=0.0 %)
Weiss	1.3755 (D=0.14 %)	4.0232 (D=0.15 %)	0.3559 (D=1.57 %)	1.2011 (D=1.89 %)
Jönsson et al.	1.3711 (D=0.12 %)	4.0178 (D=0.07 %)	—	—
Fleming et al.	1.375 (D=0.23 %)	—	—	—
LIFETIME EXPTS.:				
Irving et al.	1.40 ± 0.04	—	—	—
Schnabel and Kock	1.34 ± 0.03	—	—	—

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D. Beryllium and Boron

B I

	Experiments			Calculations	
Atomic Level	**Lundberg *et al.***	**O'Brian and Lawler**		**Tachiev and Froese Fischer**	**Fernley *et al.***
$2s2p^2\ ^2\mathrm{D}$	—	23.1±1.2		22.9	—
$2s^2 3s\ ^2\mathrm{S}$	—	4.0±0.2		4.00	—
$2s^2 3d\ ^2\mathrm{D}$	—	4.7±0.2		4.63	—
$2s^2 4s\ ^2\mathrm{S}$	—	8.7±0.4		—	9.09
$2s^2 4d\ ^2\mathrm{D}$	10.3±0.5	10.0±0.5		—	9.39
$2s^2 5s\ ^2\mathrm{S}$	11.0±0.6	—		—	14.66

E. Other Light Elements

- **Improved critical compilations of selected transition probabilities for neutral and singly-ionized carbon and nitrogen,'** Wiese and Fuhr, JPCRD 2007.

- **'MCDHF energies and transition probabilities for … transitions in Ne II,'** Fisher and Ralchenko, Int. J. Mass Spec. 2008.

- **'Experimental study of weak intersystem lines and related strong persistent lines of Ne II,'** Bridges and Wiese, PRA 2007.

- **'Extended EUV and UV spectrum of Ne II,'** Kramida, Brown, Feldman, and Reader, Phys. Scripta 2006.

- **'The Ne II spectrum,'** Kramida and Nave, Eur. Phys. J. D 2006.

- **'New FTS measurements, optimized energy levels and refined VUV standards in the Ne III spectrum,'** Kramida and Nave, Eur. Phys. J. D 2006.

- **'Energy levels and spectral lines of Ne VIII,'** Kramida and Buchet-Poulizac 2006.

- **'Energy levels and spectral lines of Ne VII,'** Kramida and Buchet-Poulizac, Eur. Phys. J. D 2006.

E. Other Light Elements (Na → Ar)

- **'Atomic transition probabilities of sodium and magnesium: A critical compilation,'** Kelleher and Podobedova, JPCRD 2008.

- **'Atomic transition probabilities of aluminum: A critical compilation,'** Kelleher and Podobedova, JPCRD 2008.

- **'Atomic transition probabilities of silicon: A critical compilation,'** Kelleher and Podobedova, JPCRD 2008.

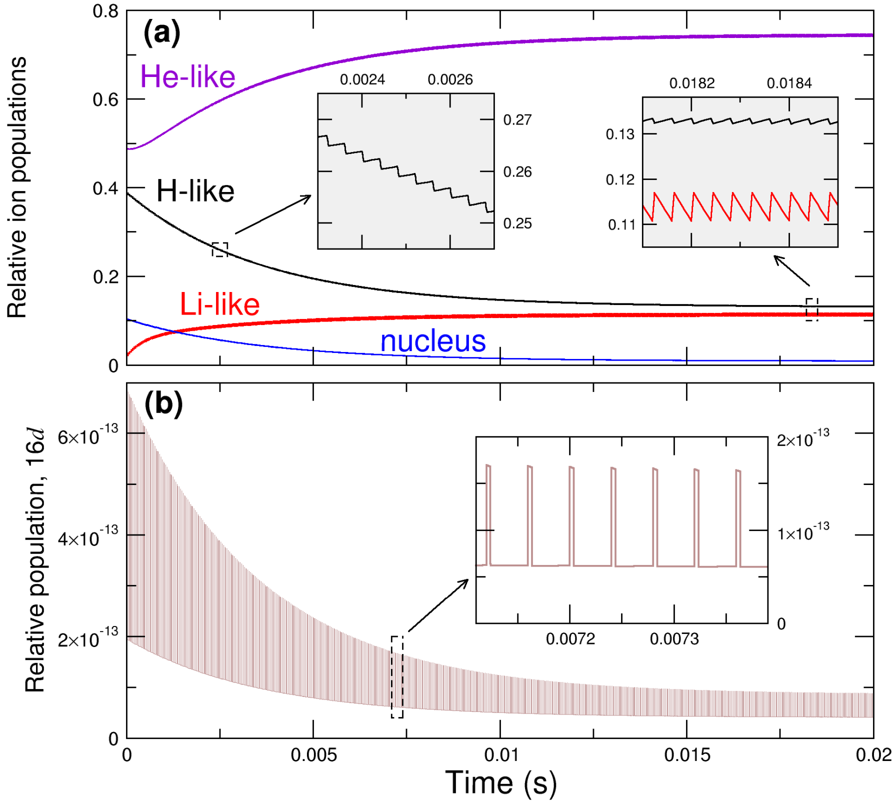
- **'Critically evaluated atomic transition probabilities for sulfur S I-XV,'** Podobedova, Kelleher, and Wiese, JPCRD 2009.

- **'Experimental transition probabilities for infrared lines of Cl I,'** Bridges and Wiese, PRA 2008.

- **'Kinetics of highly-excited states in Ar17+ charge-exchange recombination fusion plasma spectroscopy,'** Marchuk, Ralchenko, et al., J. Phys. B 2009.

- **'Kinetics of highly-excited states in Ar17+ charge-exchange recombination fusion plasma spectroscopy,'** Marchuk, Ralchenko, et al., J. Phys. B 2009.

E. Ar



Charge-exchange recombination spectroscopy with heavy impurities (Ar)

F. Tungsten

- **'Energy levels and spectral lines of tungsten, W III through W LXXIV,'** Kramida and Shirai, At. Data and Nuc. Data Tables 2009.

- **'Ionization energies of tungsten ions: W^{2+} through W^{71+},'** Kramida and Reader, At. Data and Nuc. Data Tables 2006.

- **'Compilation of wavelengths, energy levels, and transition probabilities for W I and W II,'** Kramida and Shirai, JPCRD 2006.

- **'Measurement of the D-line doublet in high-Z highly-charged sodium-like ions,'** Gillaspy et al., PRA 2009.

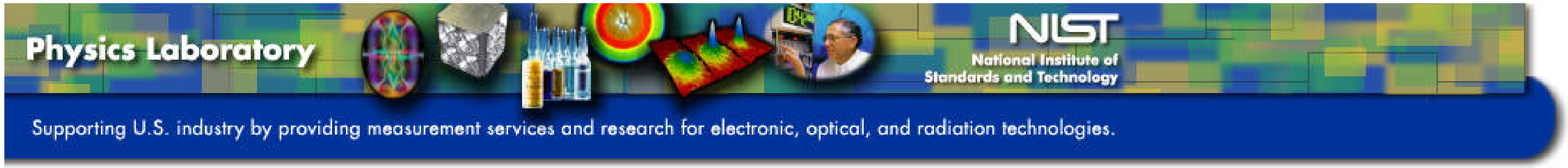
- **'Bright EUV lines emitted by highly-ionized tungsten ions as diagnostic indicators of the tungsten transport in ITER core plasmas,'** Feldman et al., Nuc. Fus. 2008.

- **'EUV spectra of highly-charged ions W^{54+} - W^{63+} relevant to ITER diagnostics,'** Ralchenko et al. J Phys. B 2008.

- **'Spectra of W^{39+} - W^{47+} in the 12 – 20 nm region observed with an EBIT light source,'** Ralchenko et al., J. Phys. B 2007.

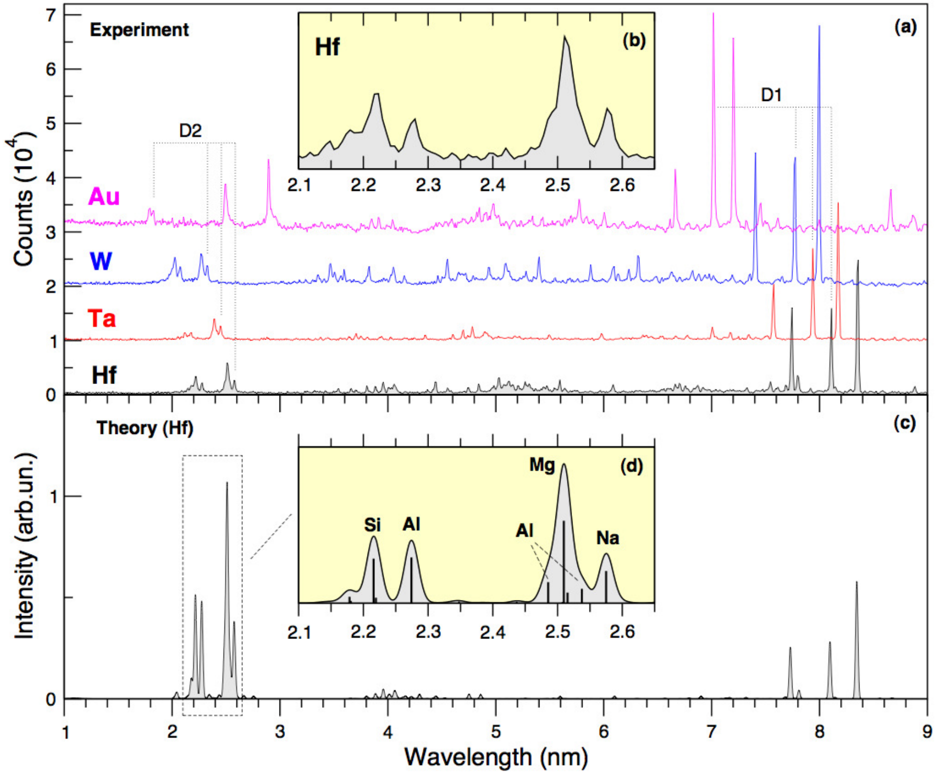
- **'Density dependence of the forbidden lines in Ni-like tungsten,'** Ralchenko, J. Phys. B 2007.

- **'Accurate modeling of benchmark x-ray spectra from highly-charged ions of tungsten,'** Ralchenko et al., PRA 2006.

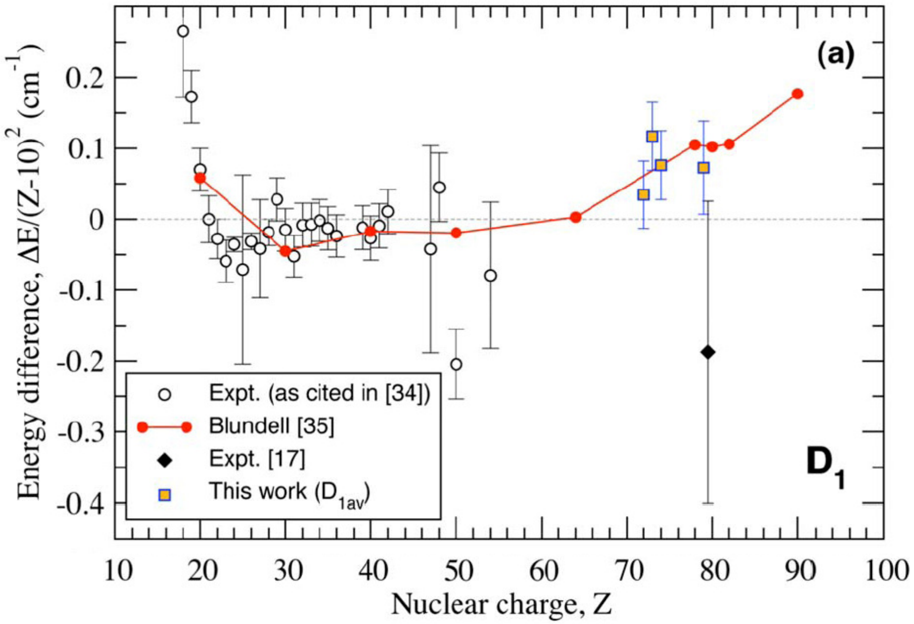


F. Tungsten

Highly-ionized Hf, Ta, W, Au observed in the range of 2-20 nm, for range of electron impact energies



- D-lines of Na-like Tungsten



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F. Tungsten

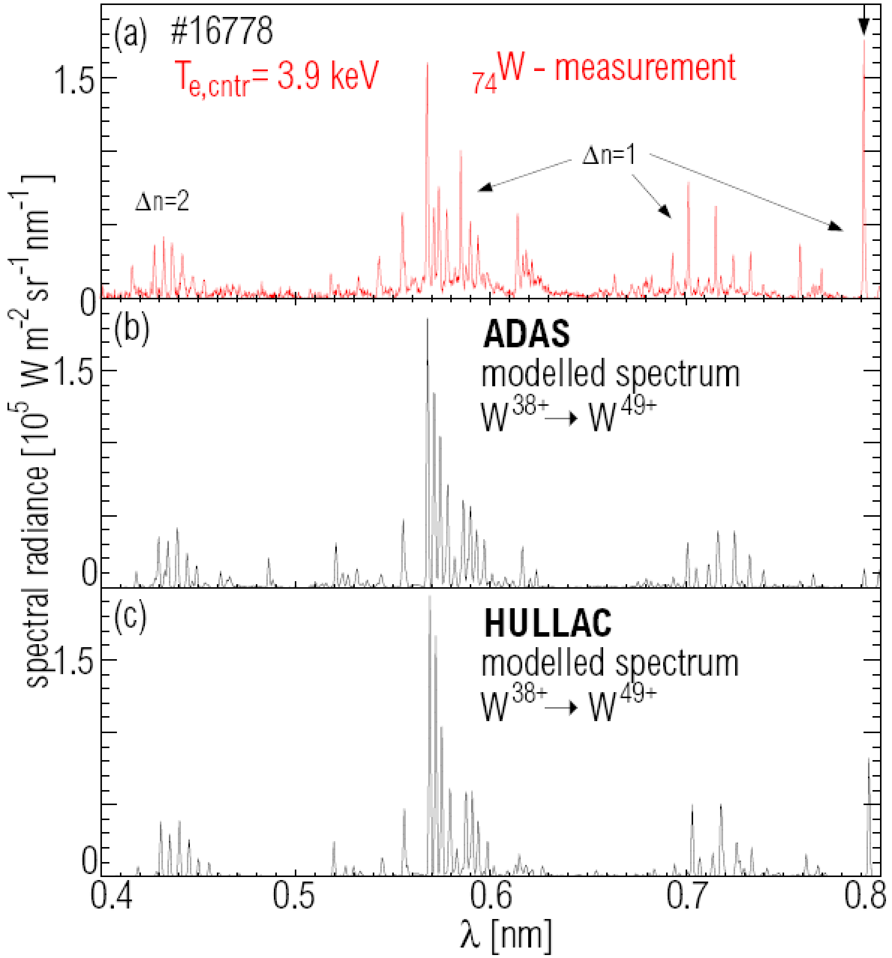
Many lines have been measured and identified for Hf, Ta, W, and Au

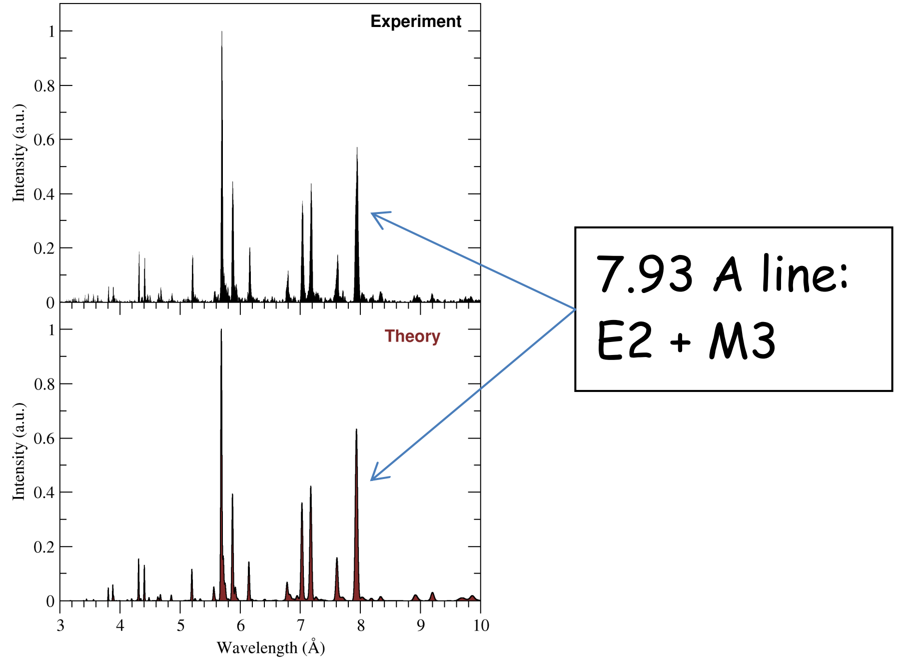
- **Hf, Ta, and Au:** 627 lines measured,
  152 identified,
  115 observed for the first time.

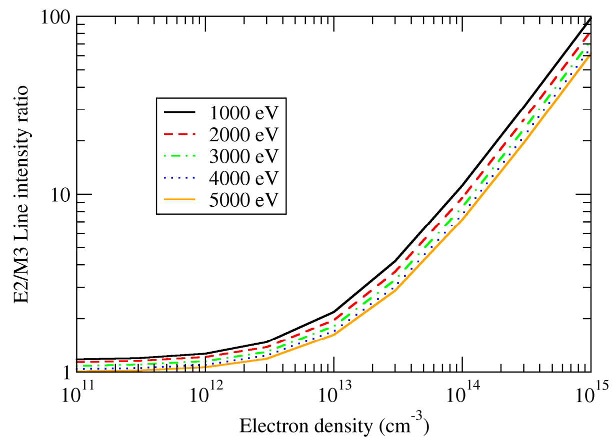
- **W:** several hundred lines are currently under analysis.

F. Tungsten

R. Neu et al, Nuclear Fusion **45**, 209 (2005)







NIST Atomic Spectra Database

G. Future Plans

Compilations

- H, D, T – Energy levels and Wavelengths (Kramida)
- F and Ne – Transition Probabilities (Wiese and Fuhr)
- Ar – Energy levels and Wavelengths (Saloman and Sansonetti)
- Cl – (Podobedova)

Measurements

- Mg (Reader, Feldman, and Brown)

Support

External support

- U.S. Department of Energy, Office of Fusion Energy Sciences
- U.S. National Aeronautics and Space Administration