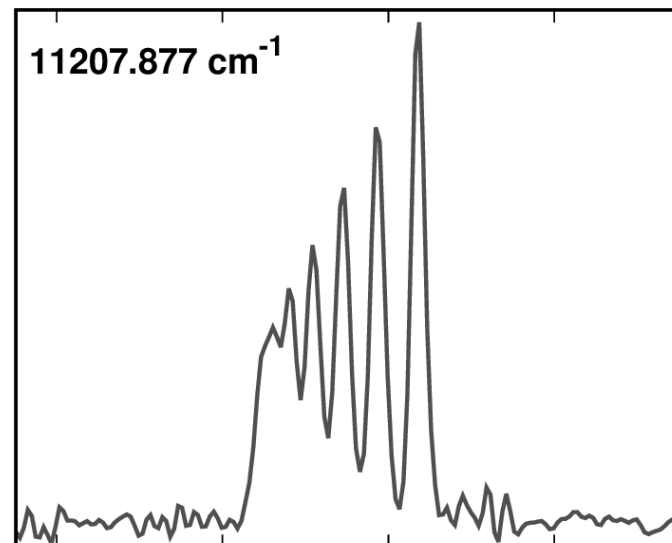
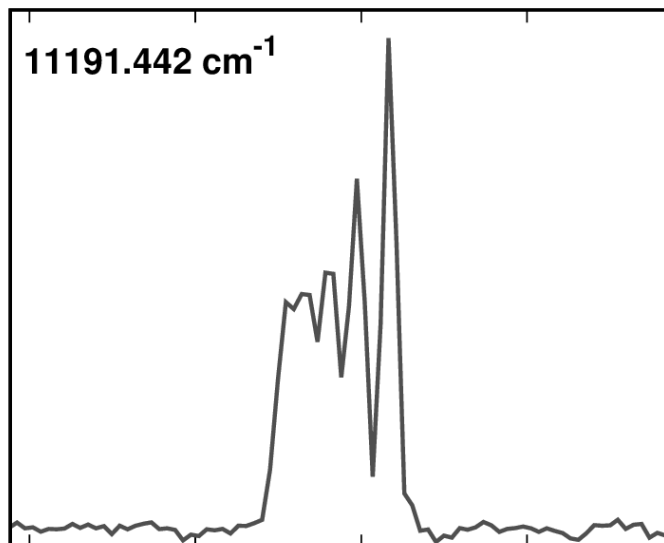
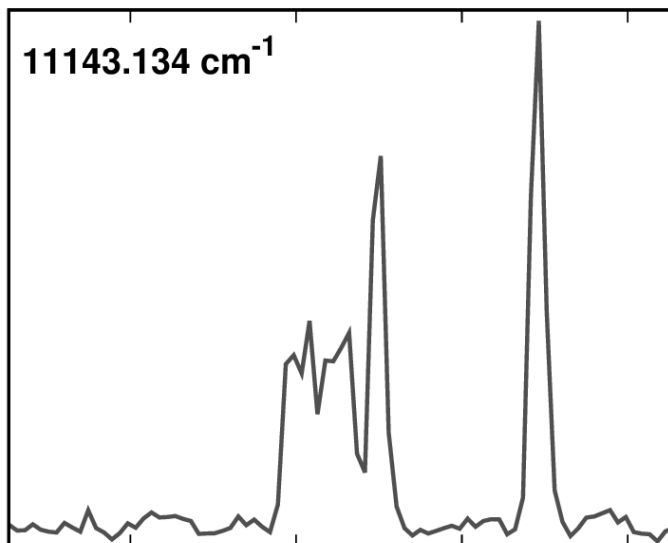
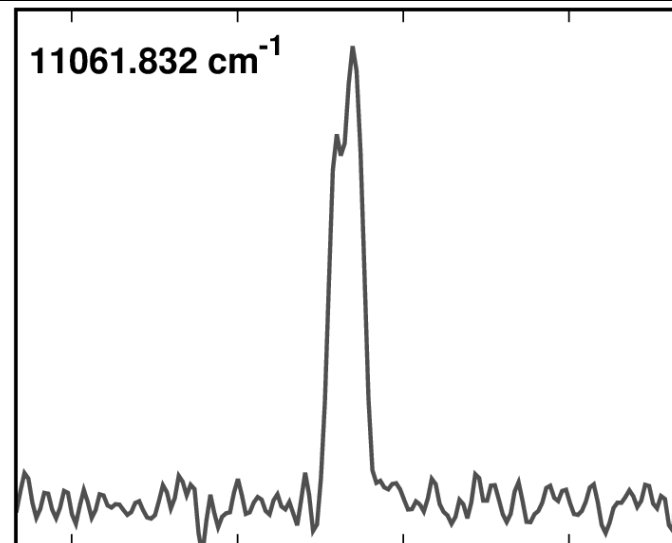
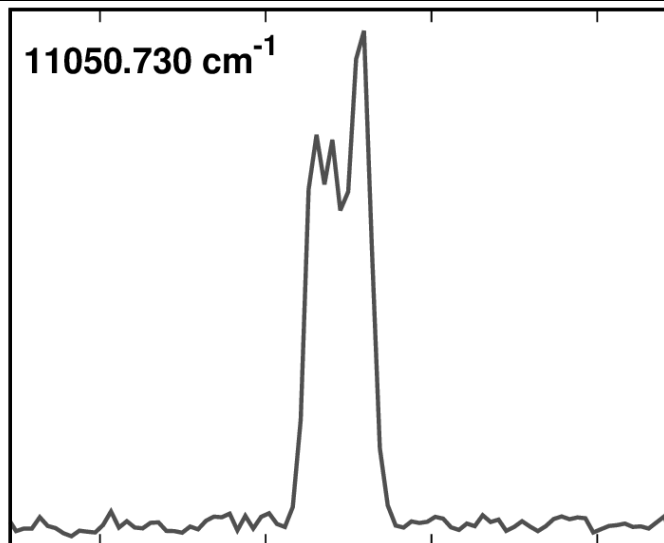
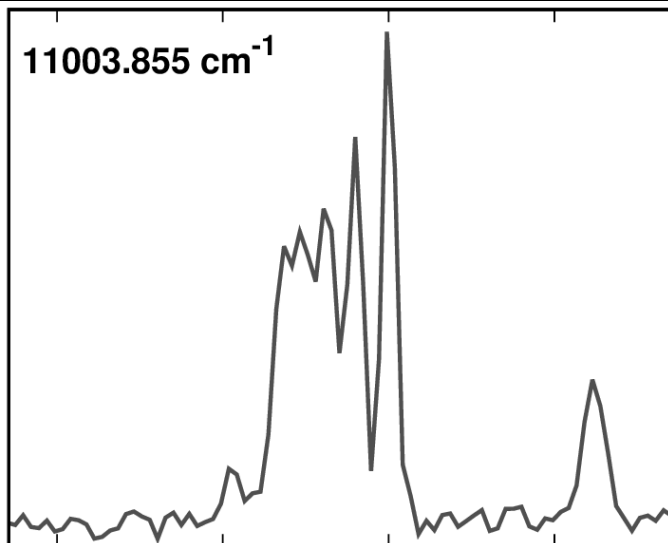


Six Lines to Tell a Story

Michael P. Wood - University of St. Thomas, St. Paul, MN



2 cm^{-1} ←————→

Earlier Vanadium Results

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 215:20 (13pp), 2014 December

doi:[10.1088/0067-0049/215/2/20](https://doi.org/10.1088/0067-0049/215/2/20)

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IMPROVED $V\text{ I } \log(gf)$ VALUES AND ABUNDANCE DETERMINATIONS IN THE PHOTOSPHERES OF THE SUN AND METAL-POOR STAR HD 84937

J. E. LAWLER¹, M. P. WOOD¹, E. A. DEN HARTOG¹, T. FEIGENSON¹, C. SNEDEN², AND J. J. COWAN³

¹ Department of Physics, University of Wisconsin, Madison, WI 53706, USA; jelawler@wisc.edu, mpwood@wisc.edu, eadenhar@wisc.edu, tfeigenson@wisc.edu

² Department of Astronomy and McDonald Observatory, University of Texas, Austin, TX 78712, USA; chris@verdi.as.utexas.edu

³ Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA; cowan@nhn.ou.edu

Received 2014 August 28; accepted 2014 October 13; published 2014 December 2

- echelle and FTS spectra
- 836 transition probabilities
- covers 238 – 916 nm
- FTS hyperfine constants for 26 levels
- hyperfine patterns for hundreds of stellar lines
- V abundance of Sun and HD 84937

Recent Vanadium Results

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 224:35 (13pp), 2016 June

doi:10.3847/0067-0049/224/2/35

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EXPERIMENTALLY MEASURED RADIATIVE LIFETIMES AND OSCILLATOR STRENGTHS IN NEUTRAL VANADIUM

C. E. HOLMES¹, J. C. PICKERING¹, M. P. RUFFONI¹, R. BLACKWELL-WHITEHEAD², H. NILSSON², L. ENGSTRÖM³, H. HARTMAN²,
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Received 2015 July 6; accepted 2016 March 24; published 2016 June 14

ABSTRACT

We report a new study of the V I atom using a combination of time-resolved laser-induced fluorescence and Fourier transform spectroscopy that contains newly measured radiative lifetimes for 25 levels between $24,648\text{ cm}^{-1}$ and $37,518\text{ cm}^{-1}$ and oscillator strengths for 208 lines between 3040 and 20000 Å from 39 upper energy levels. Thirteen of these oscillator strengths have not been reported previously. This work was conducted independently of the recent studies of neutral vanadium lifetimes and oscillator strengths carried out by Den Hartog et al. and Lawler et al., and thus serves as a means to verify those measurements. Where our data overlap with their data, we generally find extremely good agreement in both level lifetimes and oscillator strengths. However, we also find evidence that Lawler et al. have systematically underestimated oscillator strengths for lines in the region of $9000 \pm 100\text{ Å}$. We suggest a correction of 0.18 ± 0.03 dex for these values to bring them into agreement with our results and those of Whaling et al. We also report new measurements of hyperfine structure splitting factors for three odd levels of V I lying between $24,700$ and $28,400\text{ cm}^{-1}$.

Recent Vanadium Results

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Recent Vanadium ~~Results~~ Challenge

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 224:35 (13pp), 2016 June

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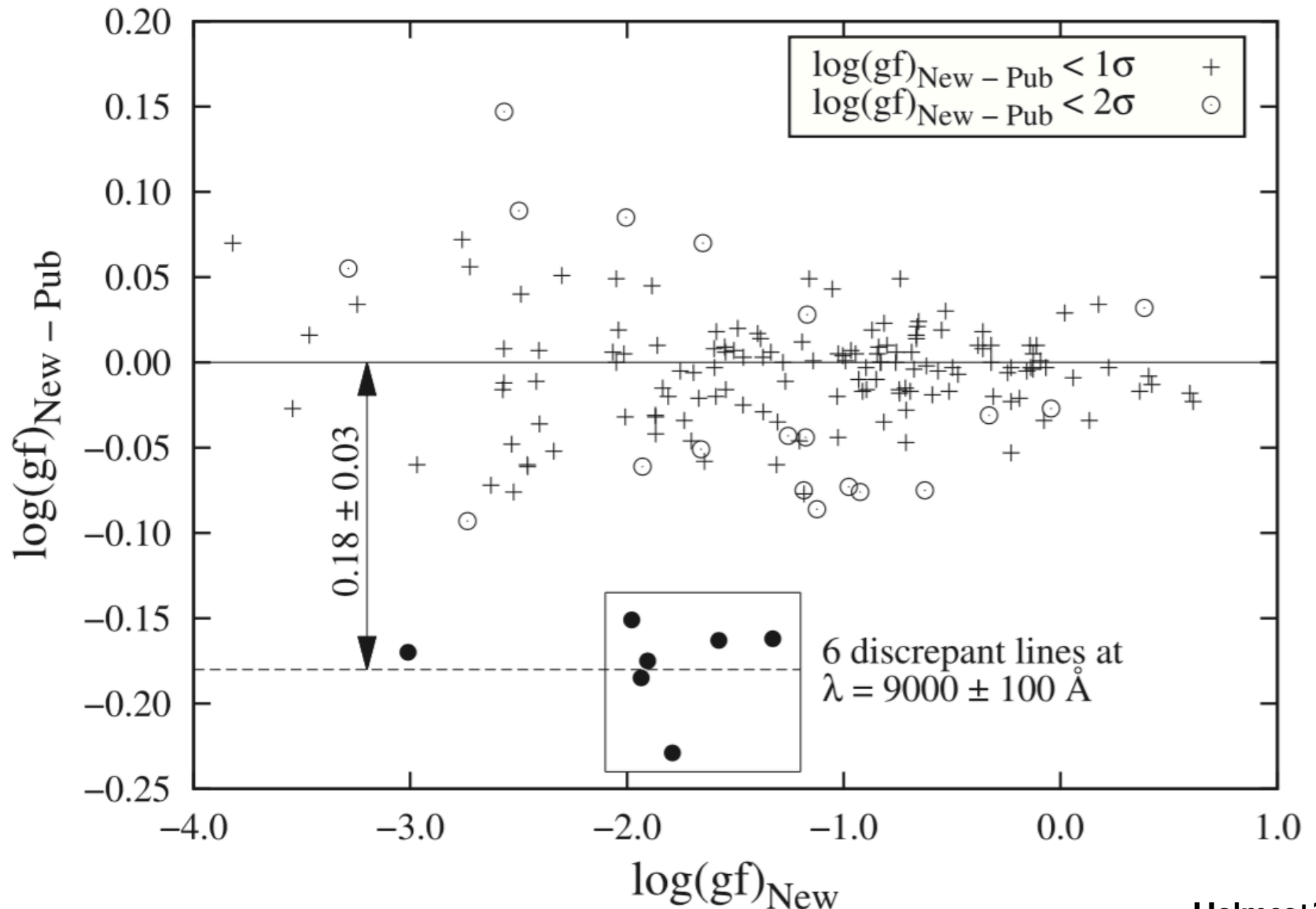
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Recent Vanadium Challenge



Vanadium Reanalysis

$$A_{ul} = \frac{BF_{ul}}{\tau_u}$$

The Reliability of Lifetimes

1 H Hydrogen																	2 He Helium	
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon	
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon	
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton	
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon	
55 Cs Cesium	56 Ba Barium			72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium																	
		57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium		
		89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium											

The Reliability of Lifetimes

> 40% of all elements!

1 H Hydrogen																	2 He Helium	
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11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon	
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37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon	
55 Cs Cesium	56 Ba Barium			72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium																	
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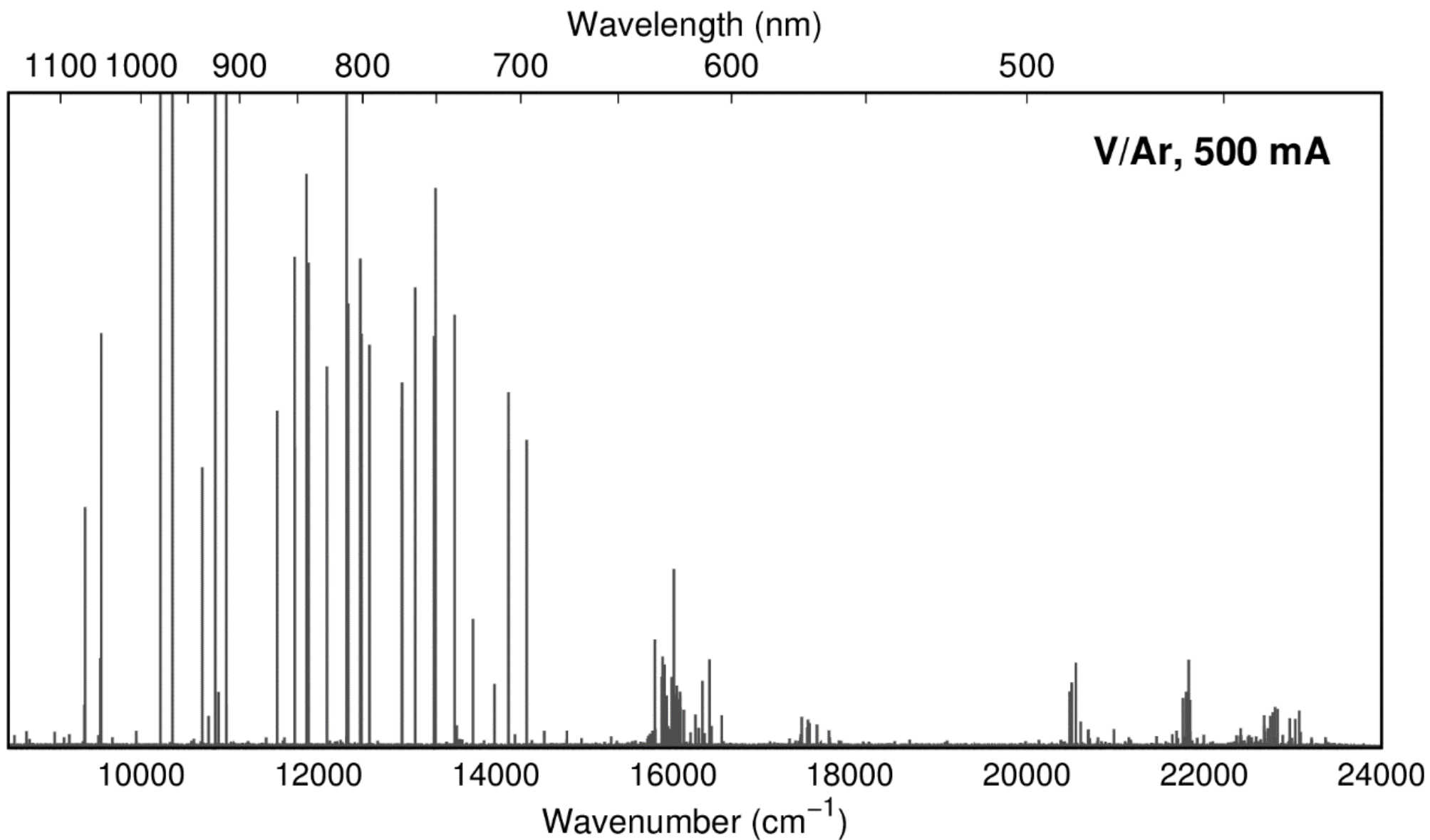
The Reliability of Lifetimes

DenHartog+2014

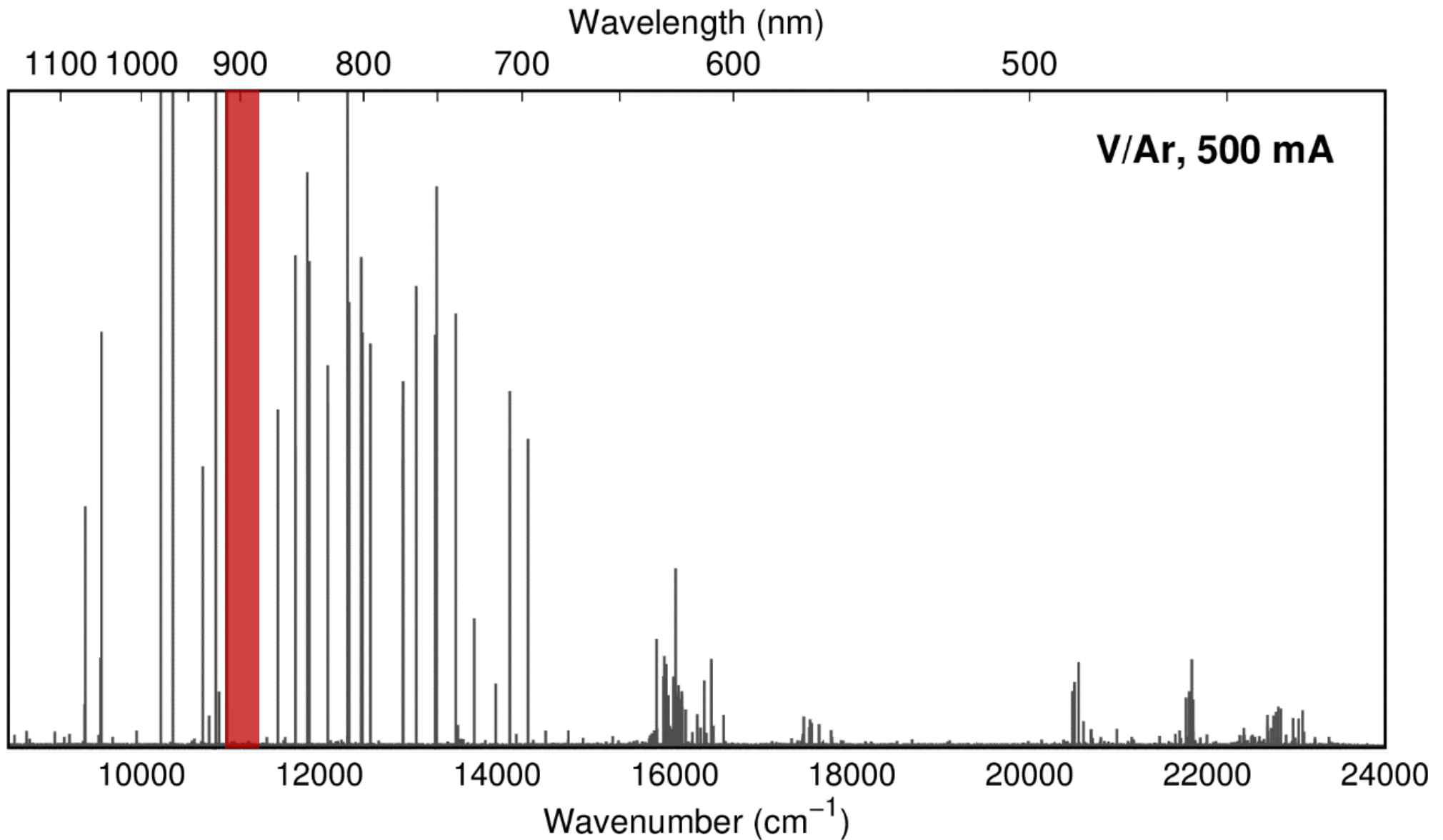
The image shows a periodic table of elements with a color gradient from red to purple. The element Vanadium (V) is highlighted with a white border. The text 'DenHartog+2014' is centered over the table.

1 H Hydrogen																	2 He Helium	
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon	
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The Difficulty of BFs

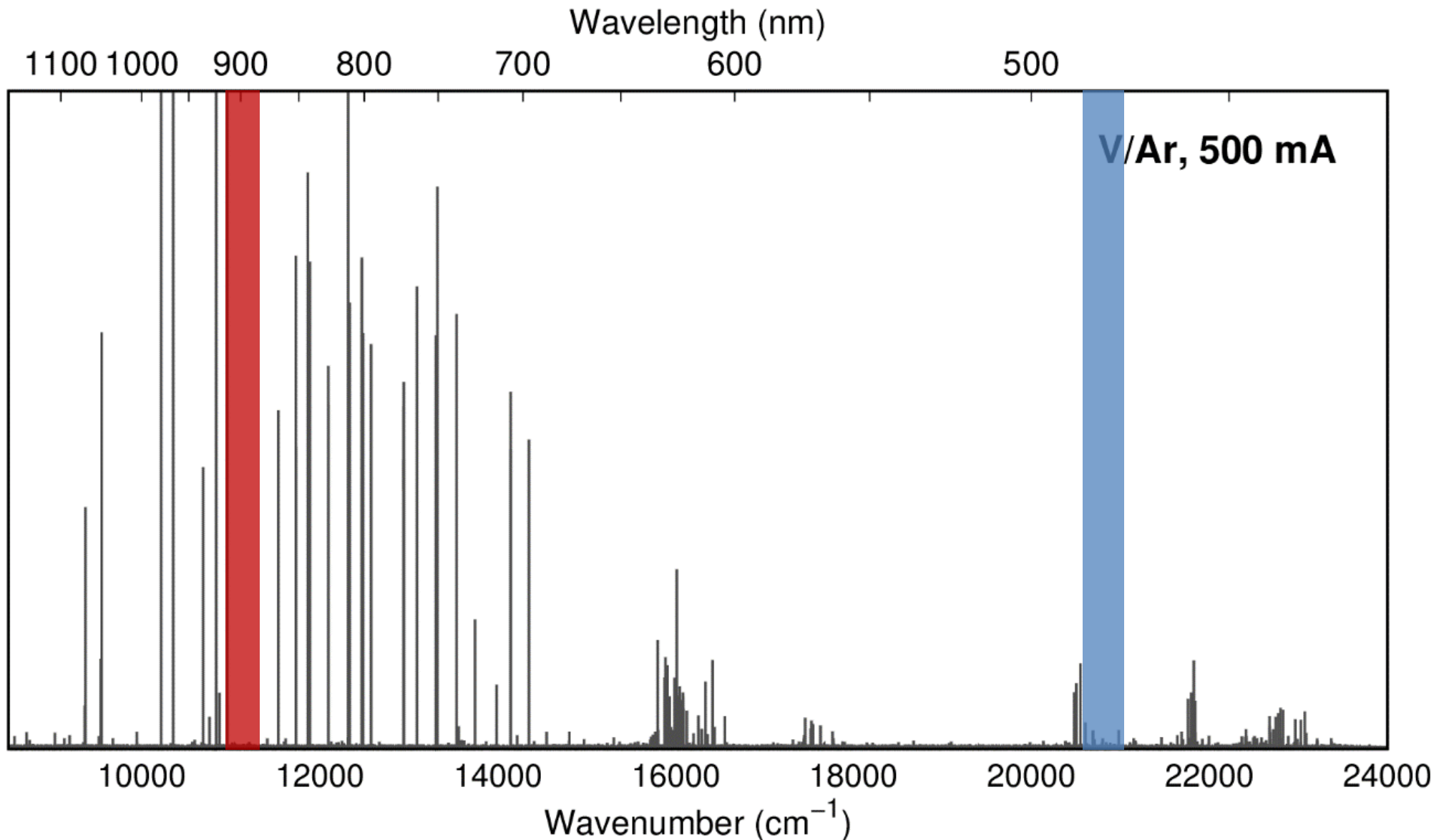


The Difficulty of BFs

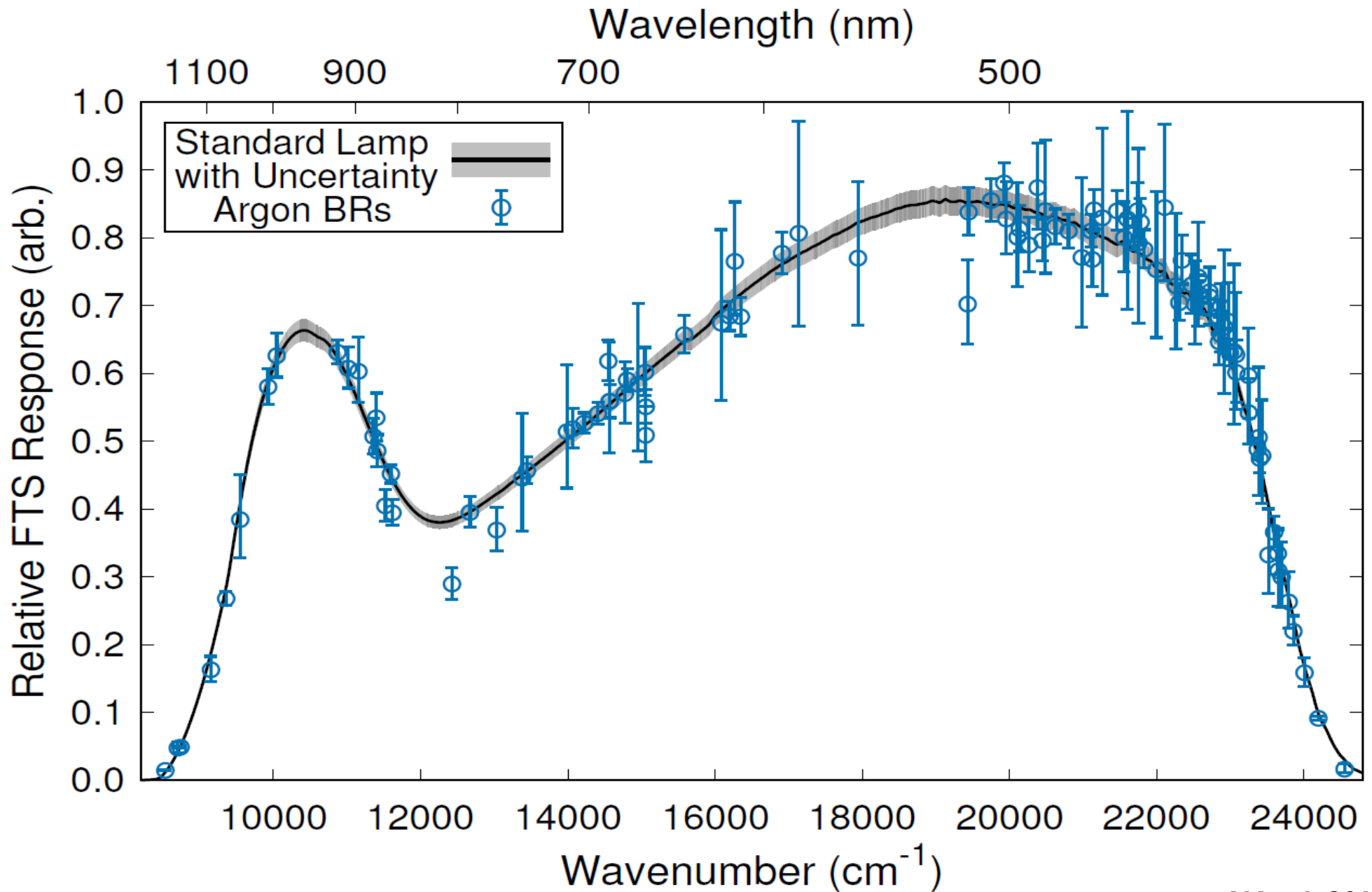


The Difficulty of BFs

$\sim \text{x2 in } \lambda$



The Importance of Calibration



Need for Multiple Calibrations



ELSEVIER

Journal of Quantitative Spectroscopy and Radiative
Transfer

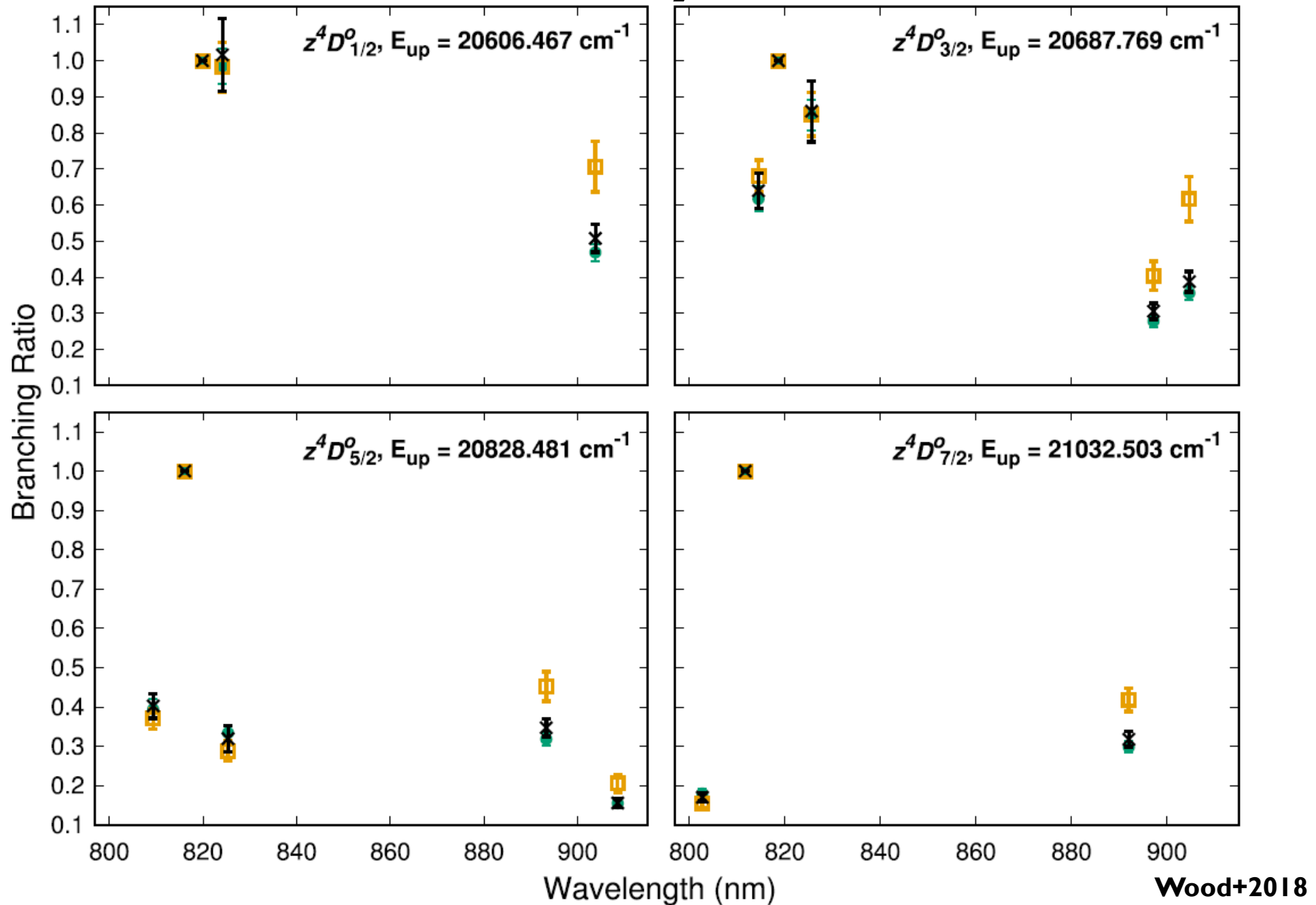


Volume 207, March 2018, Pages 41-47

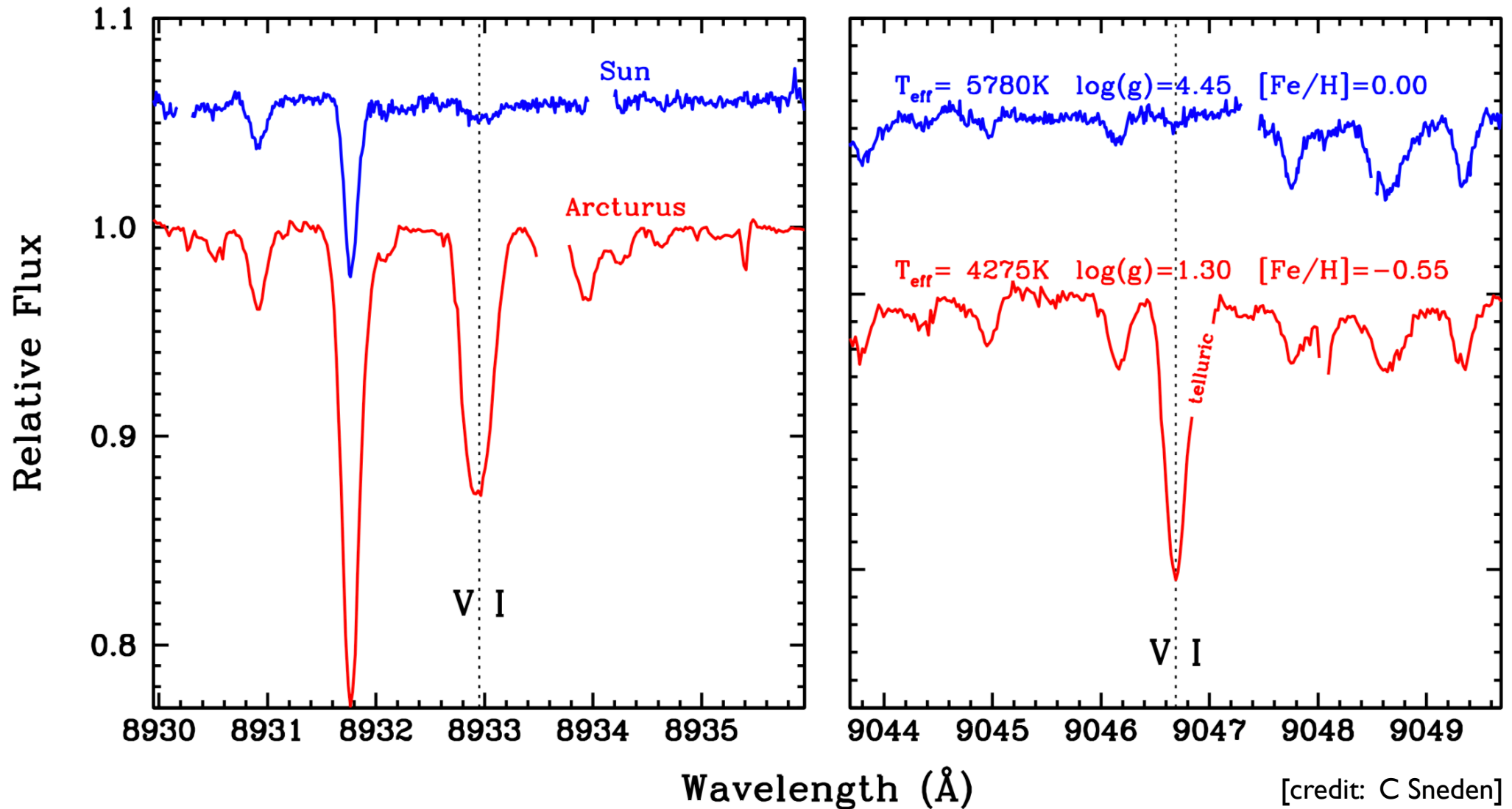
Improving the Ar I and II branching ratio calibration method:
Monte Carlo simulations of effects from photon
scattering/reflecting in hollow cathodes

J.E. Lawler  , E.A. Den Hartog 

Vanadium Reanalysis Results

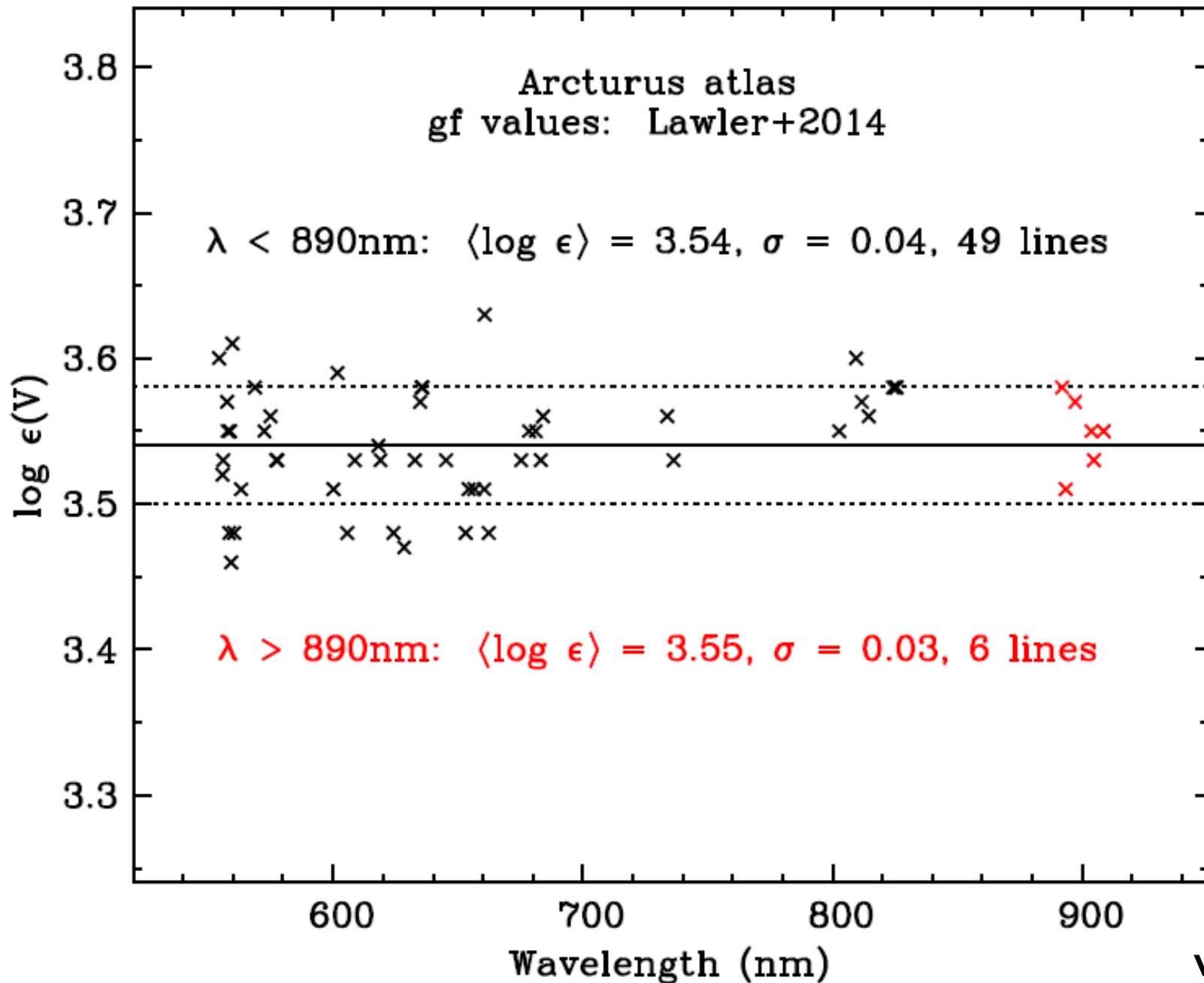


Astrophysical Sanity Check

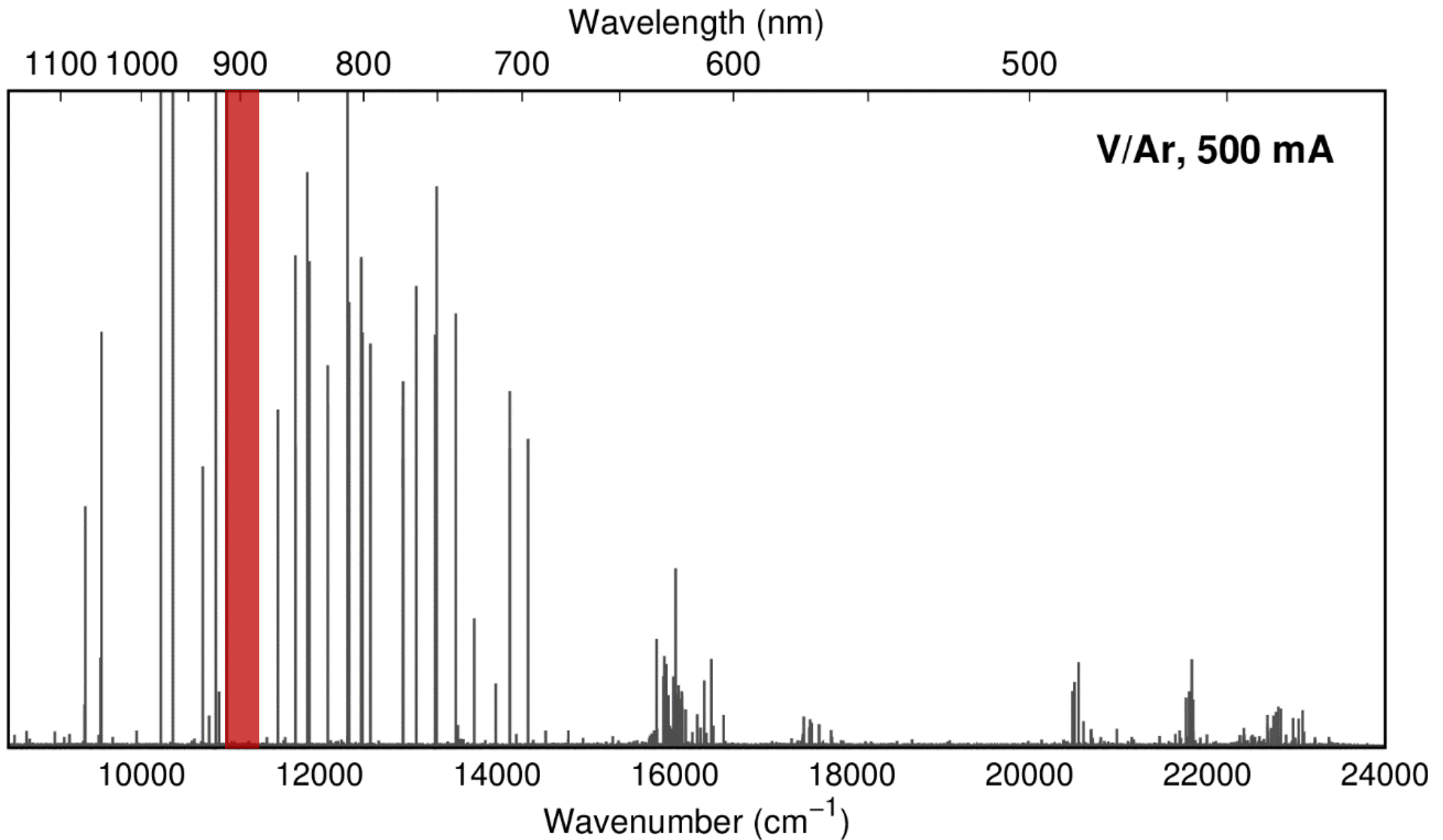


**Lawler+2014 analyzed V I in Sun and metal-poor HD 84937
→ neither has strong neutral V absorption in the red**

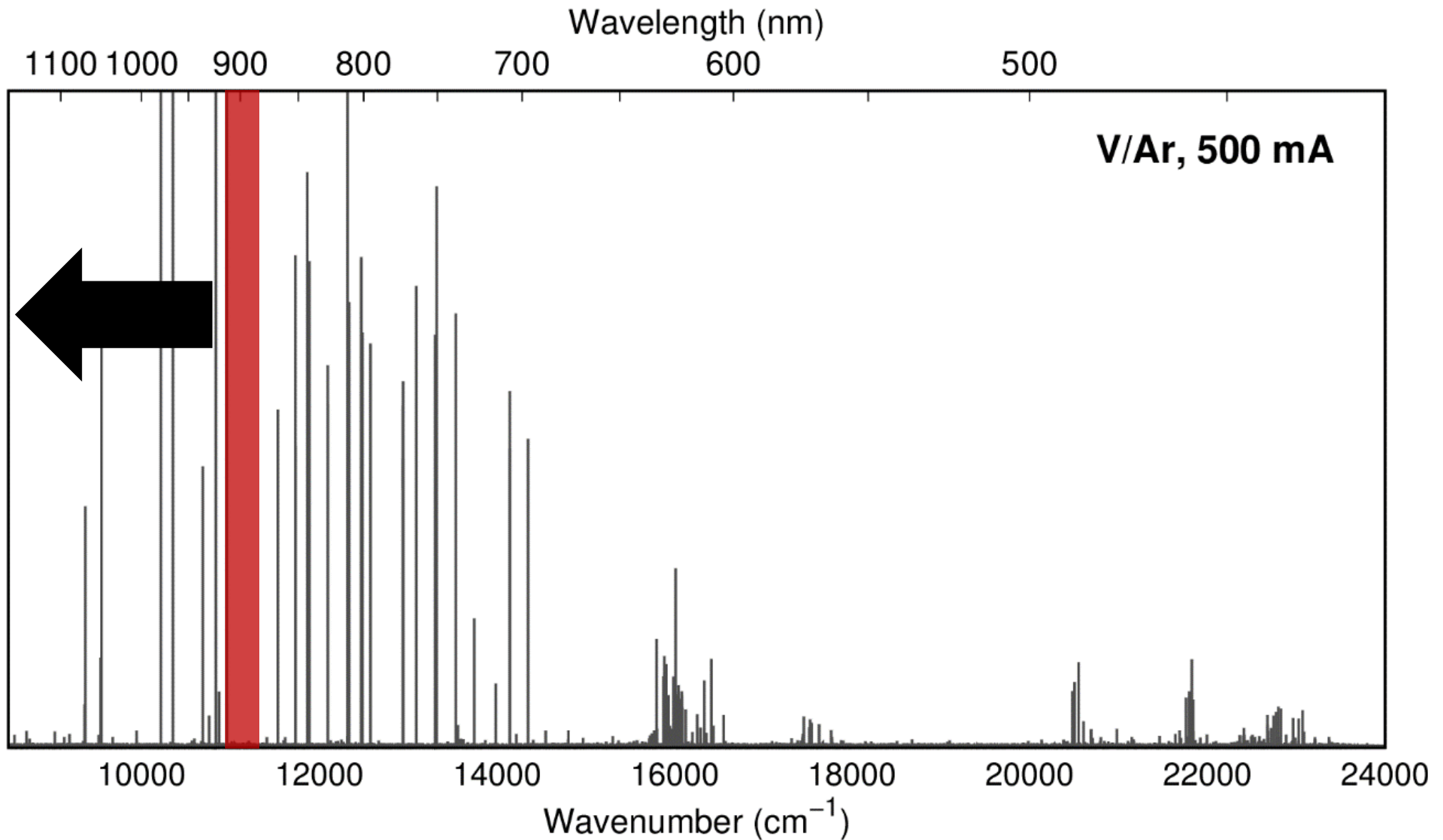
Astrophysical Sanity Check



So...what's the big deal?



So...what's the big deal?



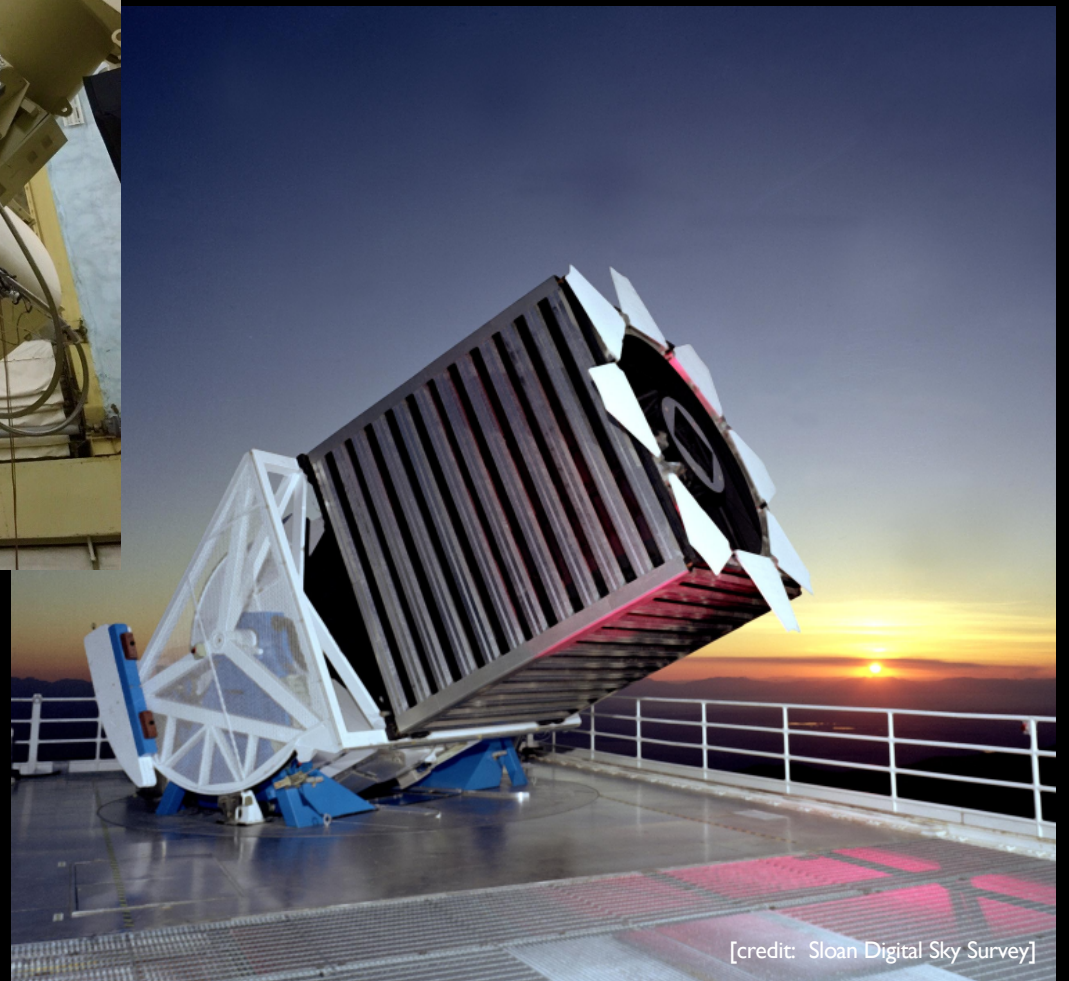
Astronomy's Push to the Infrared



[credit: Random Currents]

**IGRINS: Immersion
Grating Infrared
Spectrograph**

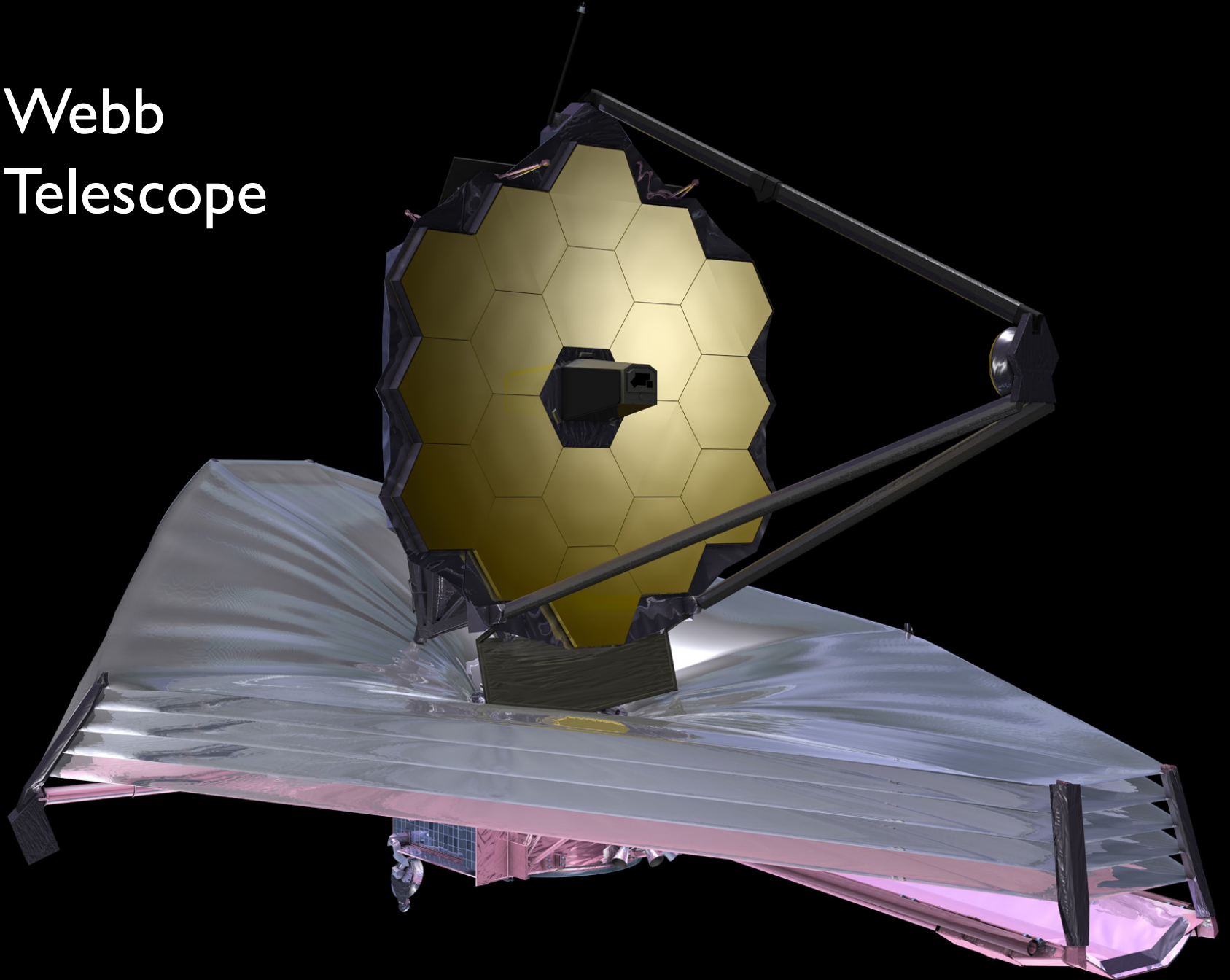
**APOGEE: APO Galactic
Evolution Experiment**



[credit: Sloan Digital Sky Survey]

Astronomy's Push to the Infrared

James Webb Space Telescope



Astronomy's Push to the Infrared

- It's the responsibility of the lab astro community to respond
- Upcoming work
 - Utilize our new V spectra to refine transition probabilities in the IR
 - Study (long overdue) of Ti I IR transition probabilities
 - Submission later this year

Acknowledgements

- Scott Bergeson & Thad Walker

(Pun Intended)

- Stellar Collaborators: Chris Sneden and John Cowan
- Betsy Den Hartog
- Gillian Nave
- Jim Lawler

I've known Jim in many ways...

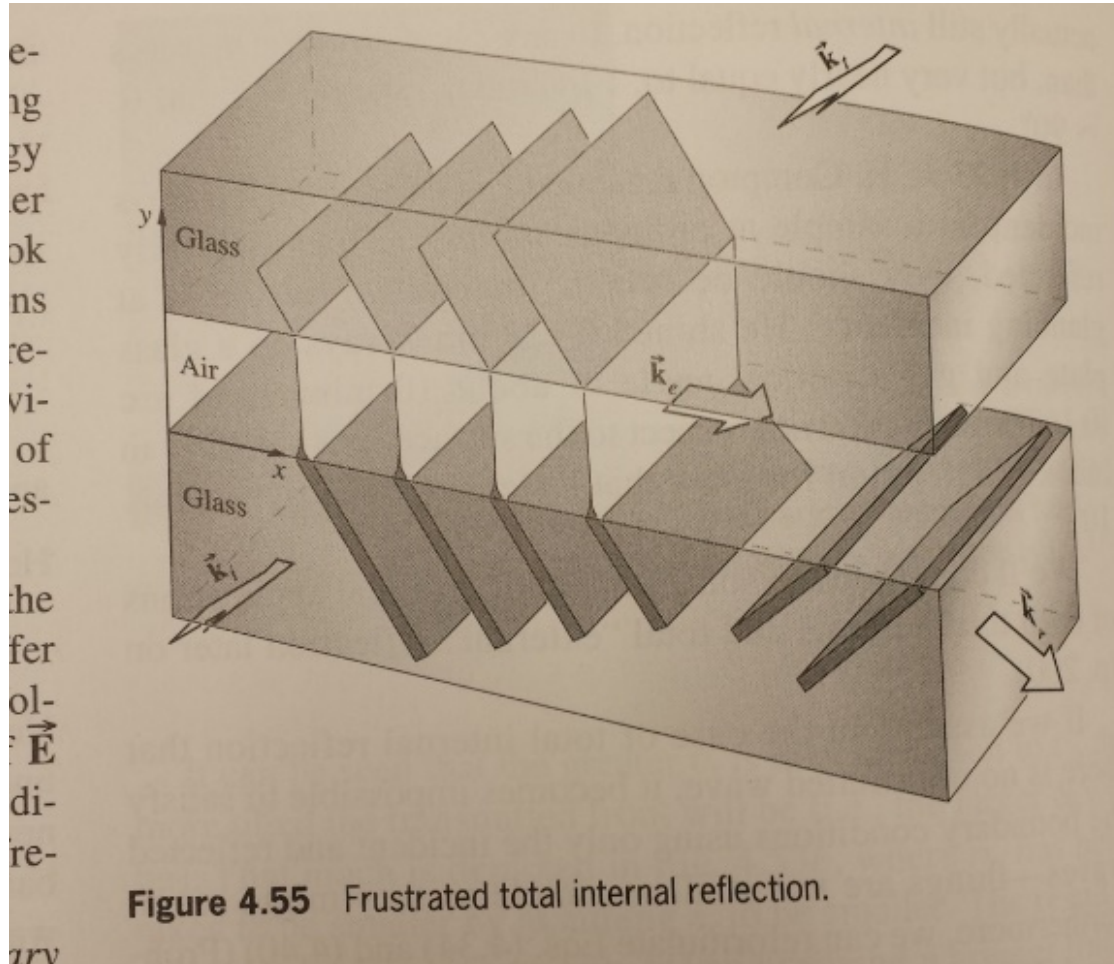
- Undergraduate Professor
 - 307: Intermediate Laboratory
- Undergraduate Research Advisor
- Graduate Professor
 - 545: Atomic Structure
- Graduate Research Advisor
- Collaborator

I've known Jim in many ways...

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 - 307: Intermediate Laboratory
- Undergraduate Research Advisor
- Graduate Professor
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- Graduate Research Advisor
- Collaborator
- Mentor

Parting Thoughts

Parting Thoughts



Parting Thoughts

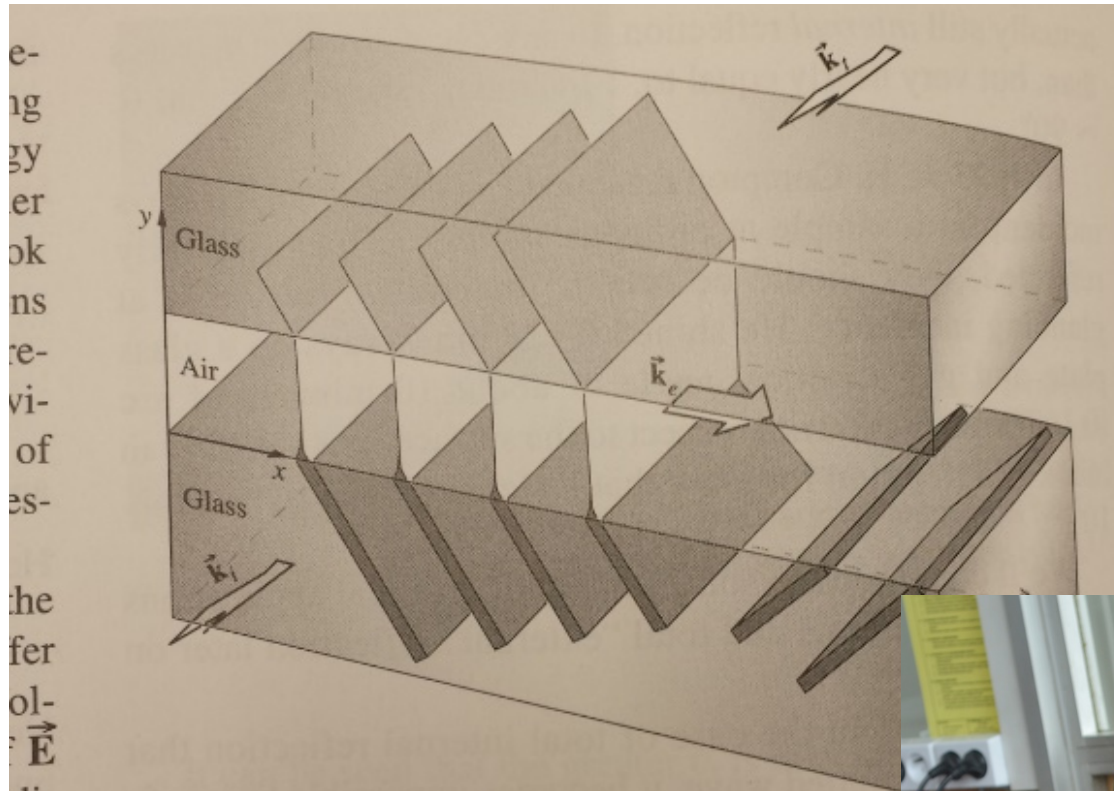


Figure 4.55 Frustrated total internal reflection.

Fourier transform infrared (IR) spectrometer



“To be a good researcher,
you don’t have to know
everything. You just have
to know one thing better
than anyone else.”

– Jim Lawler

Resolution of the Discrepancy?

