XRISM Lab Astro Working group

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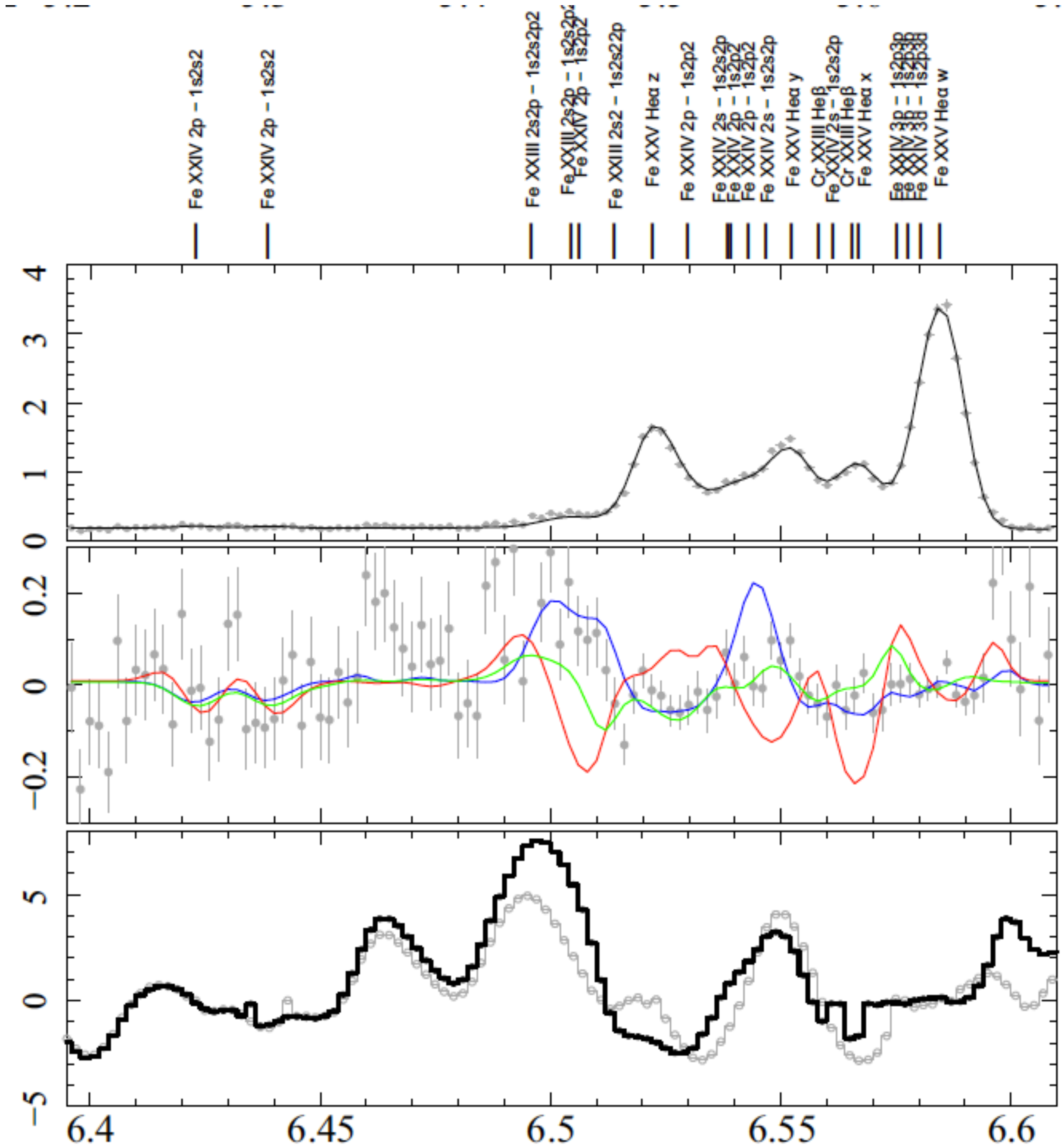
Background

- Created to avoid problems similar to what happened with analysis of Hitomi Perseus spectrum
- Prepare for xrism by starting efforts to accumulate likely atomic data and modeling constants and tools before launch
- Start with the science in the hitomi white papers. Flow the science goals down to what atomic data or quantities are needed
- Determine the observation science driven accuracy we need from laboratory measurements or calculations, and compare to what's already been published or measured
- Estimate scope and size of the effort to fill the gaps, and prioritize the list



SPEX V 3.03

Relative residuals:
APEC V3.0.8
Chianti V 3.0
SPEX V2

Nominal significance any additional line for **baseline model** and **improved 3T model**

Requirements flowdown traceability matrix

Case #	Topic	Science Goal	Physical quantity	Required Precision	Spectral Models	Spectral Measurement	Required Precision	Line or feature	Approximate energy (keV)	Specific line	Requireme on...
Astro-H White paper + XRISM Science Team inputs											
1	**Galactic Center**	Determine the fraction of diffuse Galactic center X-ray emission from gas and unresolved stellar sources	Thermal broadening	100 km/s	Collisional plasma	Fe XXV Ka line width	2.2 eV	Fe XXV Ka	6.70	resonance	emissivity
								Fe XXIV	6.65	DRsat	transition energy
								Fe XXIII	6.64	DRsat	transition energy
								Fe XXII	6.62	DRsat	transition energy
2	**Galactic Center**	Measure the scattering angle between the Sgr A*-Radio Arc and our line of sight to get accurate distances, and thus timing of light echoes. Two methods: (1) The low-energy cutoff of the Compton shoulder	Scattering angle	10 deg	MCRT	Low energy cutoff of Fe I Ka Compton shoulder	5 eV	Fe I (+near neutral) Ka	6.40		transition energy

Status of science traceability matrix development

- Mostly complete
- 81 science investigations
- >500 atomic data requirements flowing from science
- many overlaps, only ~ 150 distinct ones
  - 30 transition energies
  - 29 charge transfer
  - 4 absorption depth
  - 62 'emissivity'
  - 7 Fluorescence yield
  - 7 oscillator strength
  - ~few others: edge depths, rrc emissivity…
- We focus first on transition energies
- simpler to interpret than requirements on code quantities

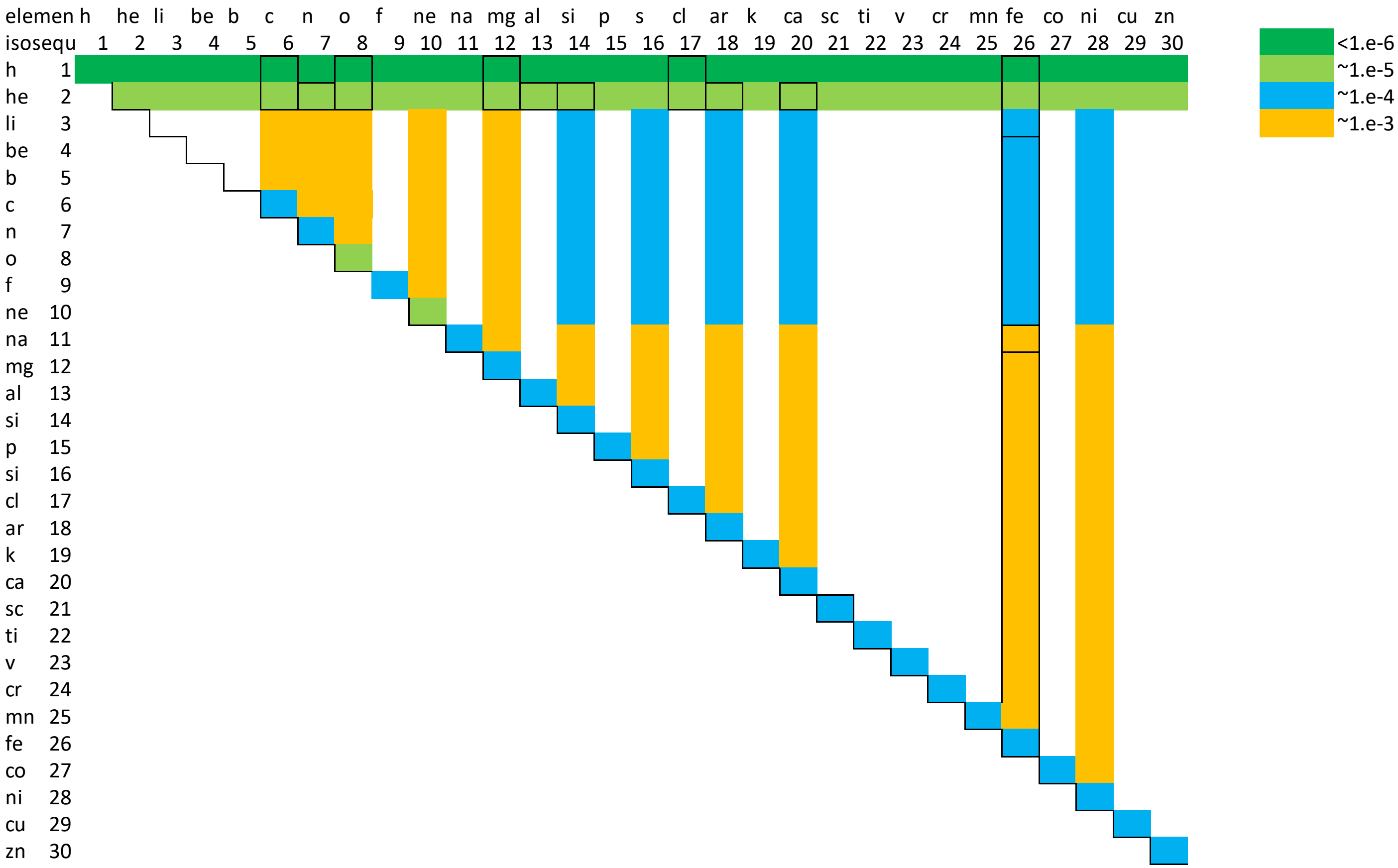
Transition energies required vs. status

case	Topic	Science Goal	Physical quantity	Required accuracy	spectrum quantity	Required accuracy	Line or feature	E (keV)	Specific line	Requirement on...	Required accuracy (eV)	best measurement	Reference(s) for measurement
71	High-z chemical evolution	Measure the redshift and ejecta mass from a GRB progenitor	Column density	NH < ?? to >4 sigma	RRC Edge energy	100 eV	Fe XXVI RRC edge	9.28		transition energy	50	0.039	nist
32	Black Hole XRBs	Determine the collimation length scale of the SS433 jet (by measuring the radial velocity and widths of emission lines as a	Line-of-sight velocity	50 km/s	Fe XXV Ka, Kb, Fe XXVI	1 eV	Fe XXVI Kb	8.25		transition energy	0.5	0.039	nist
32	Black Hole XRBs	Determine the collimation length scale of the SS433 jet (by measuring the radial velocity and widths of emission lines as a	Line-of-sight velocity	50 km/s	Fe XXV Ka, Kb, Fe XXVI	1 eV	Fe XXV Kb	7.88		transition energy	0	7.800	nist
5	Galactic Center	Measure the rotation curve/dynamics of hot gas near Sgr A* (is it outflowing?)	Line-of-sight velocity	50 km/s	Fe XXVI Ka, Fe XXV Ka	1 eV	Fe XXVI Ka	6.96		transition energy	0.5	0.039	nist
12	Active and Massive	Measure the velocity of coronal plasma during flares to test chromospheric evaporation theory	Line-of-sight velocity	50 km/s	Fe XXV Ka centroid	1 eV	Fe XXV Ka	6.7	resonance	transition energy	0.5	0.335	1989PhRvA..40..150B
53	Clusters	Map velocity fields in clusters to measure turbulence, identify sloshing motion, etc.	Velocity dispersion	50 km/s	Line width in Fe XXV	1 eV	Fe XXIV	6.65	Inner-shell satellites	transition energy	0.1	1.330	1993ApJ...409..846B
42	Young SNR	Determine how shock energy is turned into cosmic rays by measuring the energy	Shock thermaliz	0.2	Line ratios	0.1	Fe XXIII	6.64	Inner-shell	transition energy	0.1	1.500	1986ApJ...304..838S

Transition energies required vs. status

42	Young SNR	Determine how shock energy is turned into cosmic rays by measuring the energy spectrum of supra-thermal electrons	Shock thermalization	0.2	Line ratios among	0.1	Fe XXIII	6.64	Inner-shell satellites	transition energy	0.1	1.500	1986ApJ...304..838S
42	Young SNR	Determine how shock energy is turned into cosmic rays by measuring the energy spectrum of supra-thermal electrons	Shock thermalization	0.2	Line ratios among	0.1	Fe XXII	6.62	Inner-shell satellites	transition energy	0.1	1.500	01986ApJ...304..838S
4	Galactic Center	Measure the rotation curve of molecular clouds near Sgr A* from X-ray light echoes and compare to sub-mm data	Line-of-sight velocity	25 km/s	Fe I Ka Doppler shift	0.5 eV	Fe I (+near neutral)	6.4		transition energy	0.25	6.700	2003A&A...410..359P
63	ISM and CGM	Measure the velocity of the super-hot wind in NGC 253 and M82 to determine whether it escapes the galaxy and the	Line-of-sight velocity	50 km/s	Ar XVII (1.34 keV), Ca	1 eV	Ca XIX	3.9		transition energy	1	0.036	2015JPhB...48n4013R
78	Charge Exchange and New	Determine the contribution of CX in clusters (also as a background to the possible 3.5 keV DM line)	??	??	S XVI high-n transition	2-3 eV	Cl XVII	3.51		transition energy	2	8.000	1965JOSA...55..654G
78	Charge Exchange and New	Determine the contribution of CX in clusters (also as a background to the possible 3.5 keV DM line)	??	??	S XVI high-n transition	2-3 eV	Ar XVII	3.5	Inner-shell satellites	transition energy	2	0.002	1995PhRvE..52.1980B
22	NS LMXBs	Determine M/R in Ser X-1 and T5X2 (J17480-2446) from gravitational redshift of Fe K lines from equatorial belt [lower	M/R	0.02	Fe XXV, Fe XXVI, Ar XVII,	>300 km/s [??]	Ar XVII	3.13	resonance	transition energy	5	0.000	nist
39	Young SNR	Detect odd-Z trace elements to measure abundances, charge states and compare	A/H	0.1	Line strengths	0.05	Cl XVI	2.79	resonance	transition energy	5	5.800	Can. J. Phys. 66, 586 (1988).

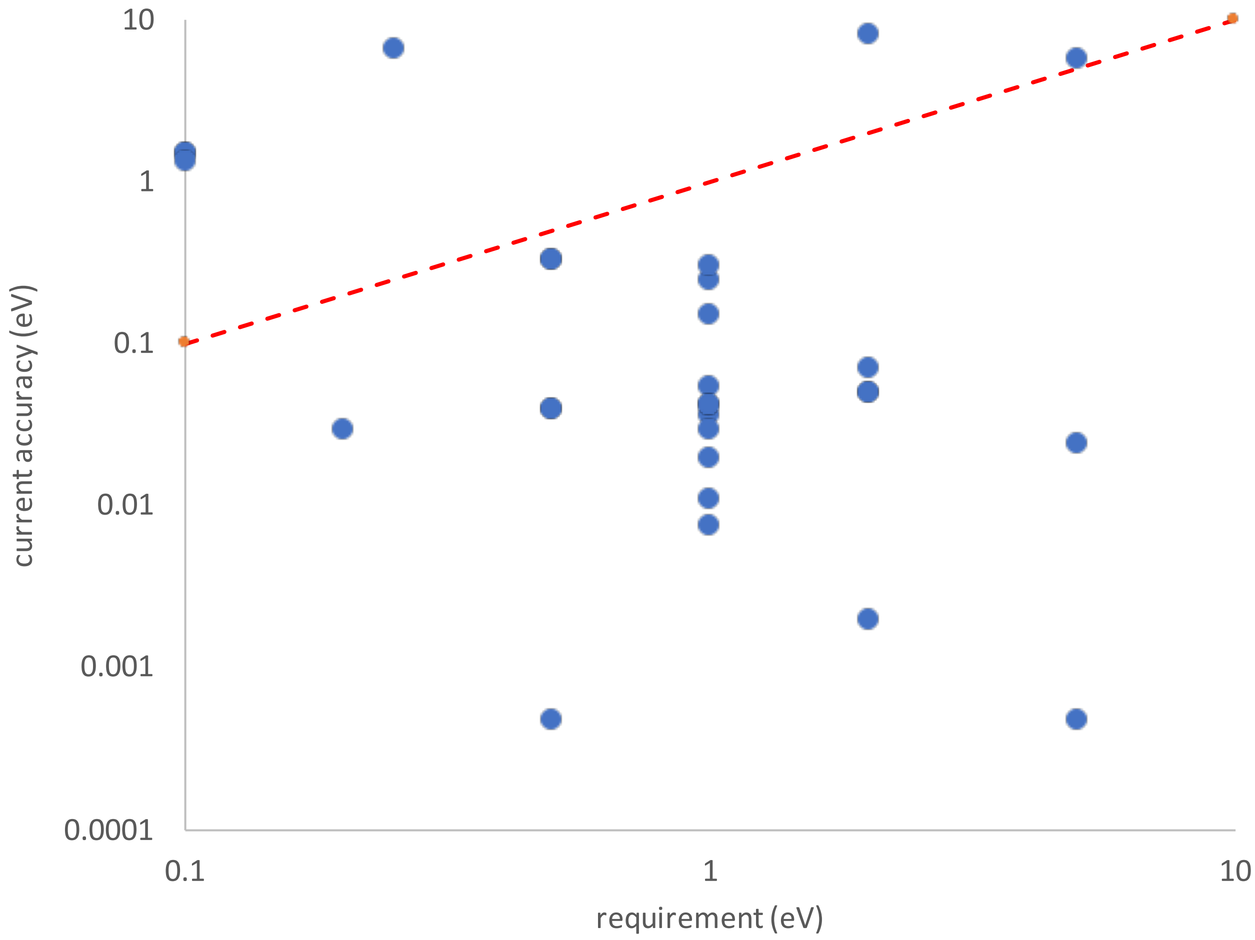
Accuracies of K lines and L lines with E> 1 keV



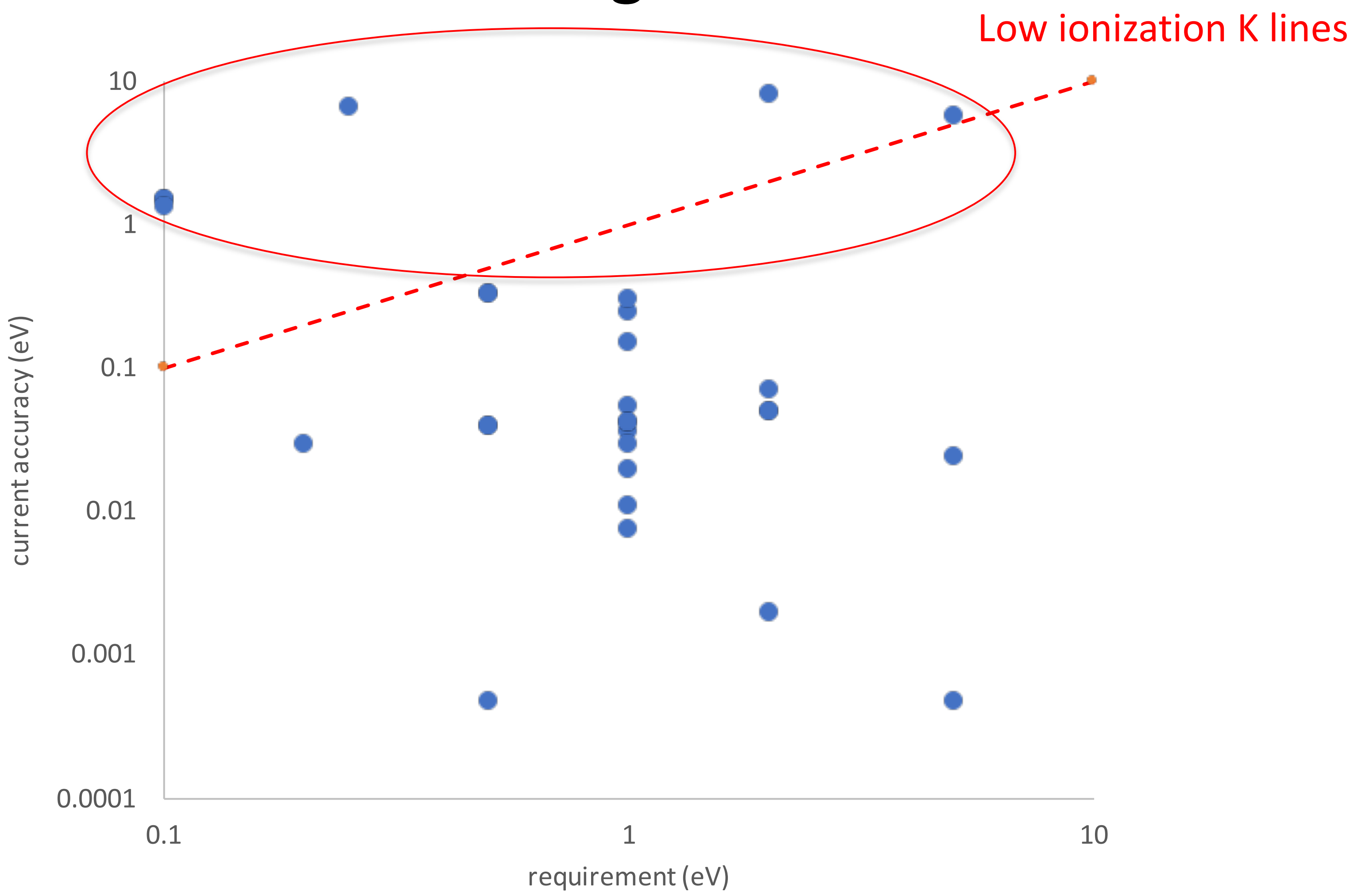
Categories of atomic data requirements

- Line energies
- Oscillator strengths → calculated to ~0.01 – 0.1
- Fluorescence yields → measured neutral ~0.01, calculated ~0.1
- Edge depths → calculated, ~0.01
- ‘Emissivities’ requires modeling to determine most relevant atomic quantities

Required accuracy vs what is available for line energies



Required accuracy vs what is available for line energies



Report on charge transfer

- Document prepared by Renata Cumbee and Maurice Leutenegger
- Charge transfer is least ‘mature’ lab astro topic
  - Processes of interest have ~low energy interaction
  - Likely Involve atomic target
  - ~Few relevant experiments have been done
  - Large scale calculations rely on approximations -> neglect of j
- Identifies key categories of science goals affected by charge transfer
  - Cx as foreground
  - Cx in planets
  - (possible) cx in distant source
- Describes strategy for experiments designed to provide reliable cross sections
  - Start with H target + bare ion, or H-like
  - Observe radiation
  - Benchmark calculations
  - Multielectron targets require apparatus to separate multi-electron events
  - APRA program is under way

Next steps

- Study emissivities: what atomic quantities matter most?
- -Understand whether there's something lacking in the way the laboratory measurements are distributed; propose a solution if need be.
- -Check consistency between spectral models to identify problem areas before launch.
- -Follow up and possibly expand on The Lorentz Test Suite.
- -Compare and consult with work for other applications, eg. fusion.
- -Think about how software (like XSPEC) could and should take into account uncertainties on atomic models and measurements.
- -Discuss avenues for obtaining funding for this work.
- Campaign to simulate all Hitomi PV phase observations and highlight atomic data sensitivity? → invest in better testing capabilities for perturbing atomic data?? Requires money..
- Generate documents (white papers…) to get involvement from the broader lab astro community