# Advanced population modelling

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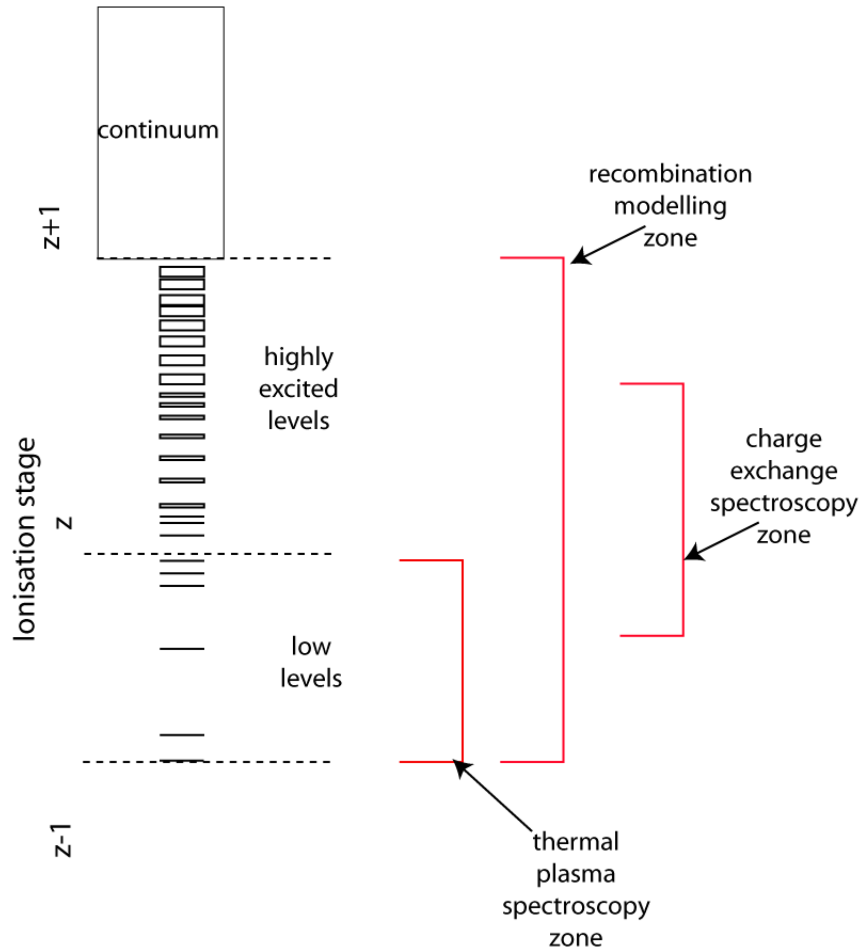
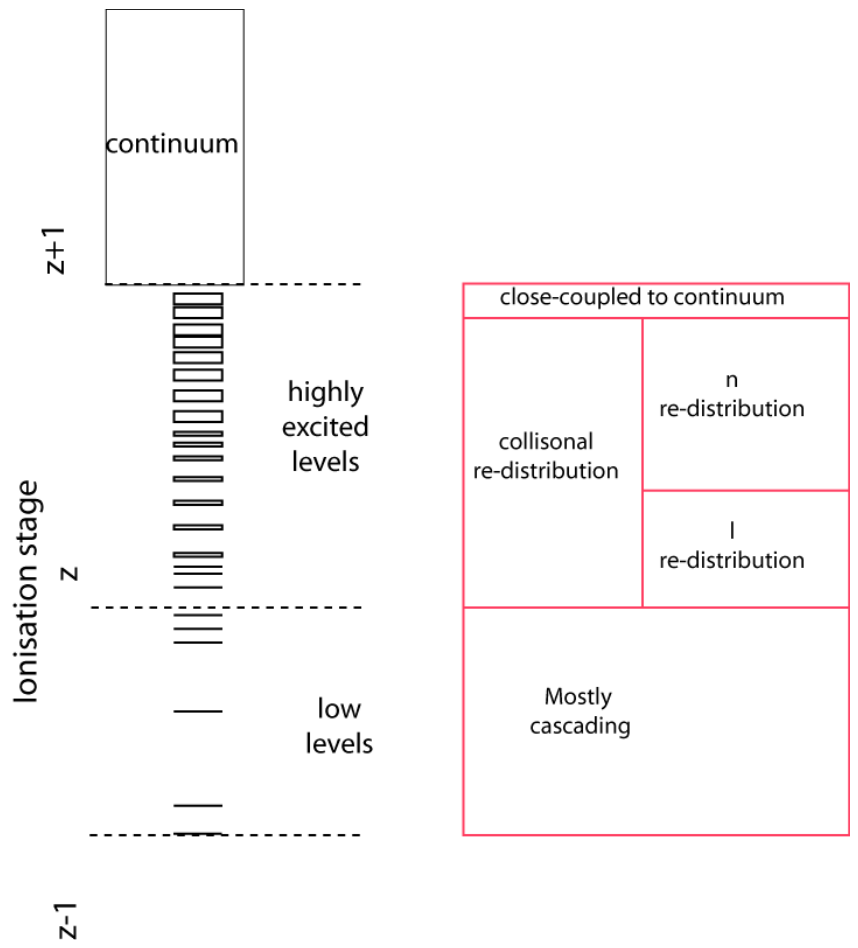
- Overview of atomic level structure, zones and nomenclatures
- Techniques – representative levels, condensation, projection
- ADAS population models
- A universal baseline of charge exchange data for heavy species

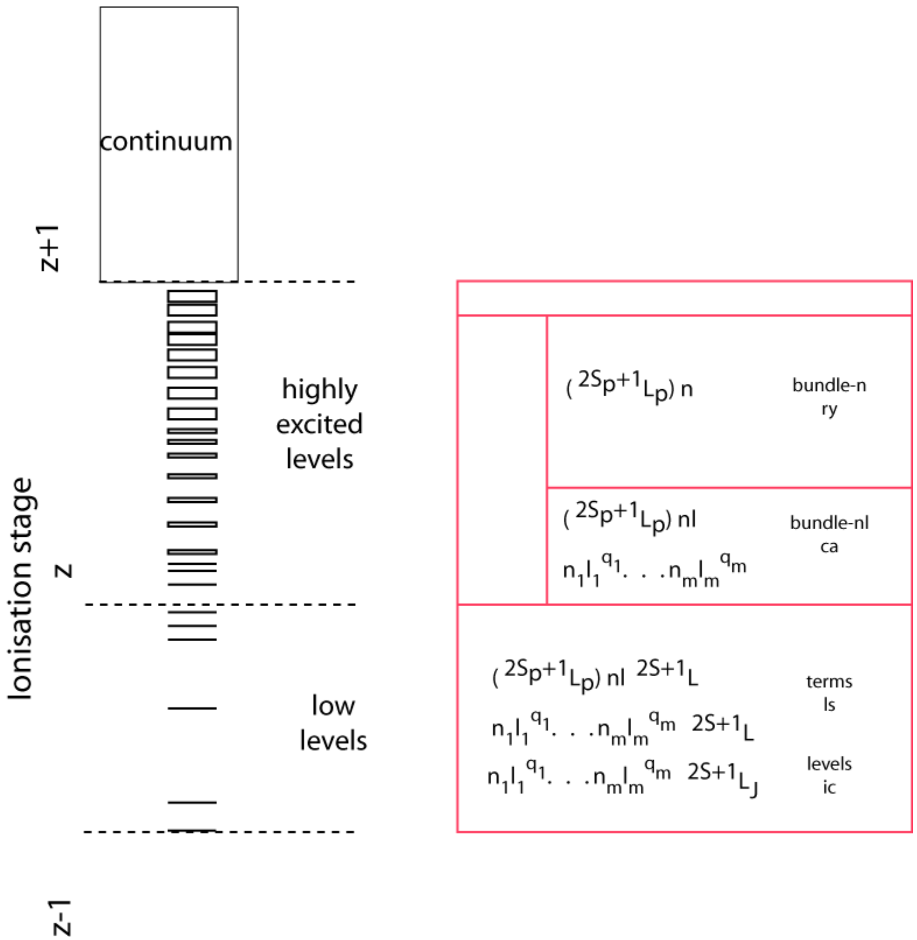
# Level zones and relevance



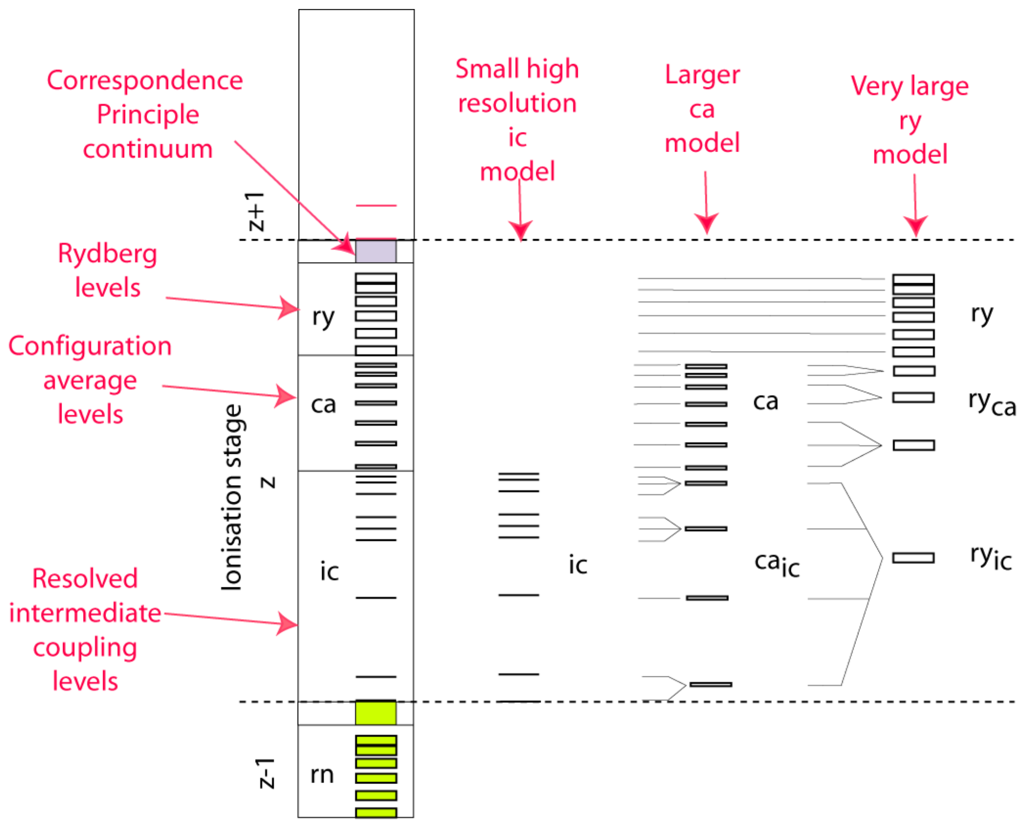
# Collisionality regimes



# Level nomenclatures and nmemonics



# Collisional-radiative models




Yields a series of population calculations of varying resolution and span

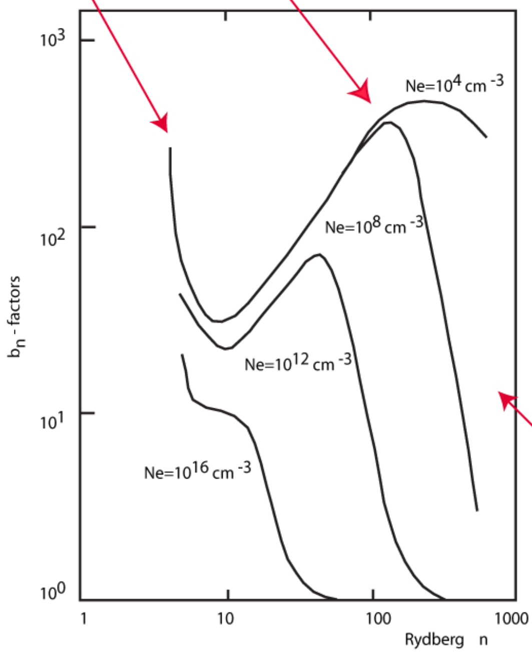
# Bundle-n (ry) and bundle-nl (ca) populations

$b_i$ - factor defined in term of population $N_i = N_i^{(Saha)}\, b_i = 8\,(\pi a_0^2 I_H/kT_e)^{3/2}\,(\omega_\iota/2\omega_+)\,\exp(I_i/kT_e)\, b_i$

$c_i = b_i - 1$ , $\mathrm{exp}b_i = \exp(I_i/kT_e)\, b_i$ $\longrightarrow$ $b_i$ , $c_i$ , $\mathrm{exp}b_i$ representations

$\mathrm{exp}b_i$ representation required for very low Te

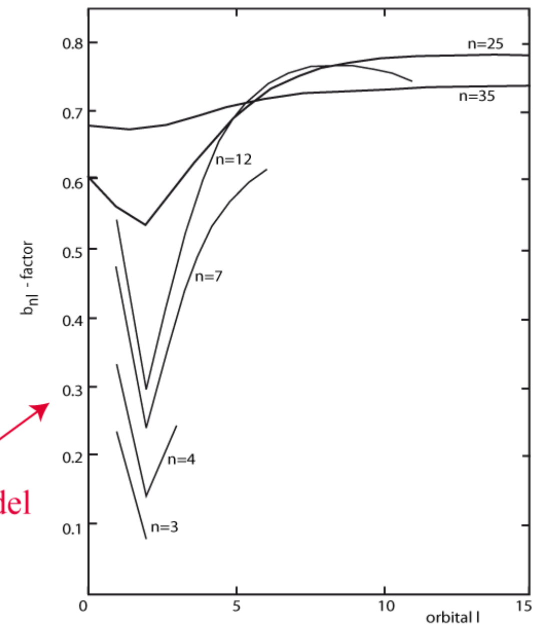
$c_i$ representation required




iron population structure $Fe^{+14}$

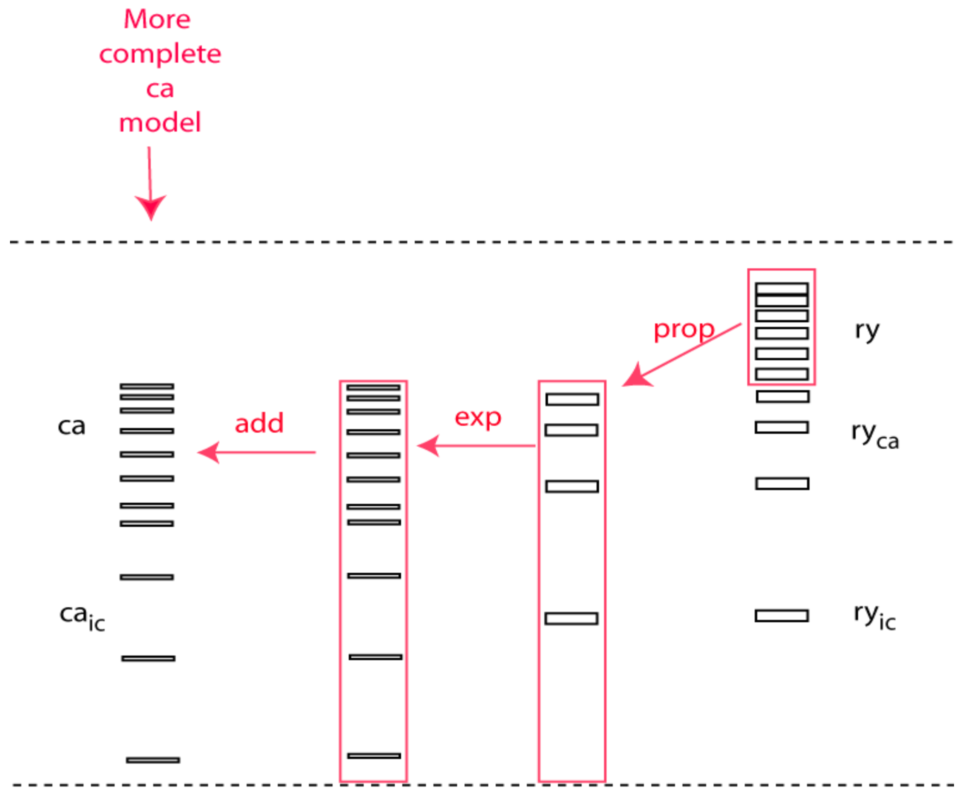
$b_n$ model

$b_{nl}$ model



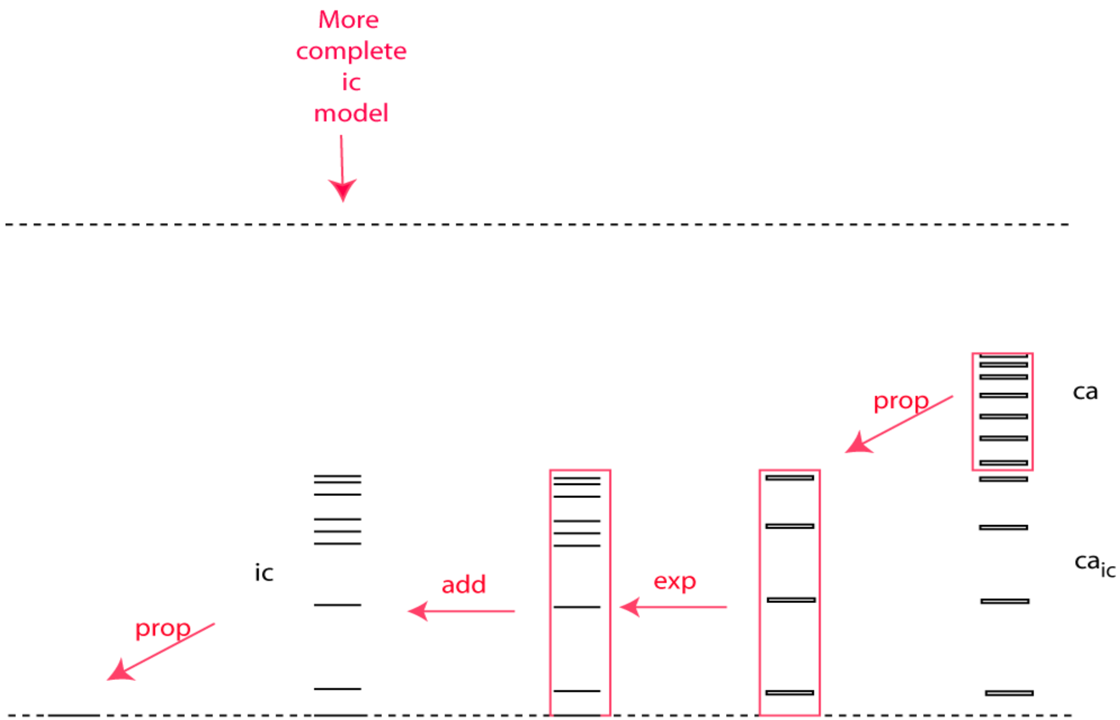

Hydrogen population structure. Case B depopulated, Ne=$10^4$ cm$^{-3}$ Te= 1eV

# Lifting CR models:  propagated top-up




*ry* collisional-radiative matrix propagated onto the $ry_{ca} + ry_{ic}$ manifold, expanded over the higher resolution $ca + ca_{ic}$ manifold and added to the direct $ca + ca_{ic}$ collisional-radiative matrix.

# Lifting CR models:  propagated top-up




*ca* collisional-radiative matrix propagated onto the $ca_{ic}$ manifold, expanded over the higher resolution *ic* manifold and added to the direct *ic* collisional-radiative matrix.

Repeat similar process to obtain $\alpha_{cd}$ and $S_{cd}$ coefficients

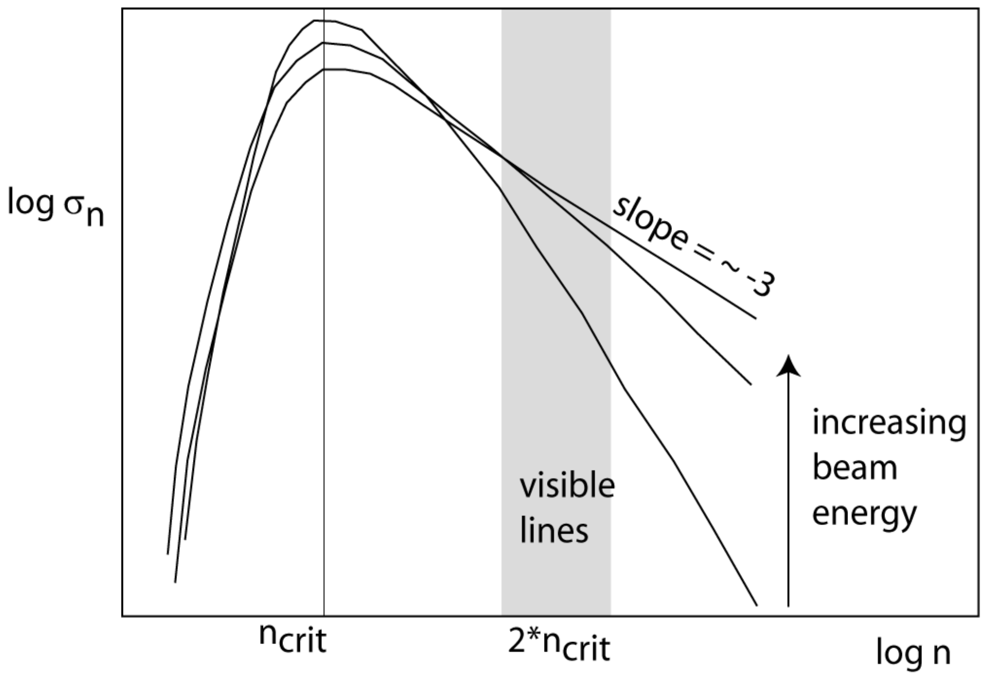
Suitable approach for higher precision spectrsocopy and GCR modelling

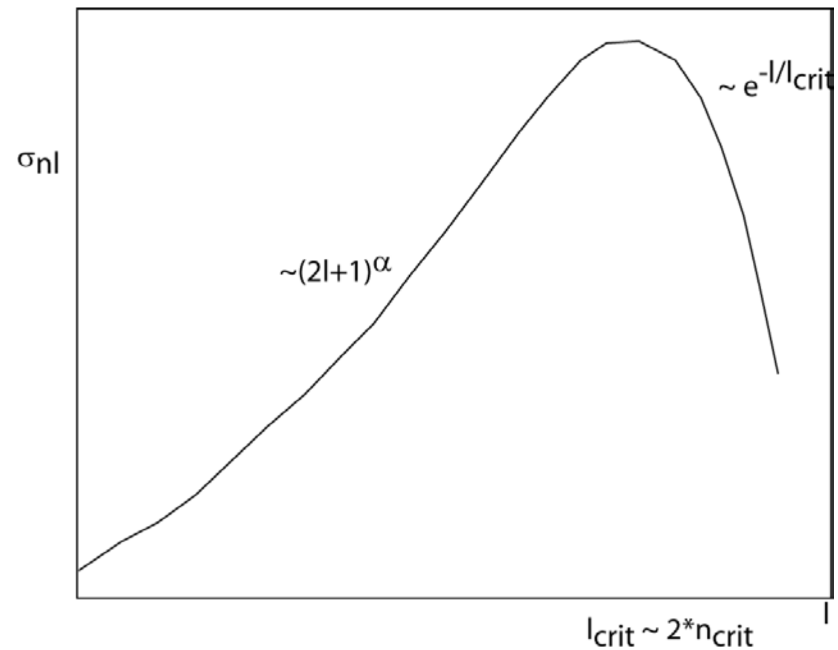
# Population model use in ADAS

| | bundle-n: single system | bundle-n: spin system separated | bundle-nl single and spin separated system | (Jp)nlj-bundled single system | nkm (and mixed fields) | low level balance ic, ls, ca |
|---|---|---|---|---|---|---|
| ADAS use | heavy element $\alpha_{cd}$ , $S_{cd}$ | | | heavy element prop. for full ic-resol. GCR ADAS2XX | | all element ADAS205 ADAS206 |
| | | light element prop. for full ls-resol. GCR ADAS204 | light element prop. for full ls-resol. GCR ADAS2XX | | | all element with proj. ADAS208 ADAS810 |
| | heavy element universal CXS $q_{eff}$ ADAS316 | | light element CXS $q_{eff}$ (l-redist/cascade version) ADAS308 ADAS309 | light element CXS $q_{eff}$ (l-redist/cascade version) ADAS306 ADAS307 | | |
| | | | heavy element CXS $q_{eff}$ ADAS317 | | hydrogen beam emission (restricted level model) ADAS305 | |
| | hydrogen beam stopping and emission ADAS310 | helium beam stopping and emission ADAS311 | helium beam stopping and emission ADAS311 | | hydrogen beam stopping and emission ADAS3XX | |
| | thermal hydrogen emission ADAS310 | thermal helium emission ADAS311 | thermal H and He very low temperature emission ADAS311 | | | |

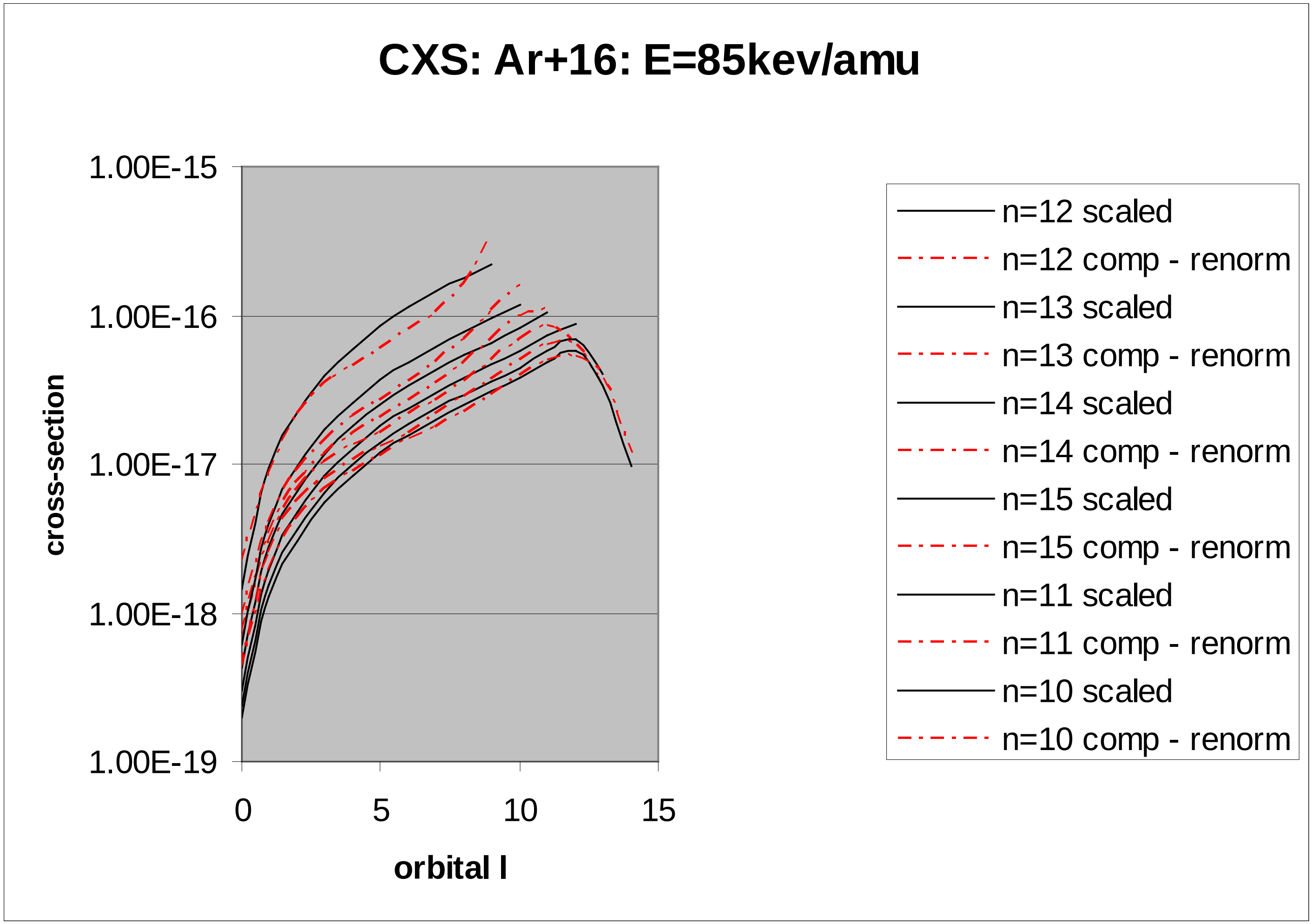
Operational    Final development/test    Development    Rework

# Characteristic behaviour of partial charge exchange cross-sections

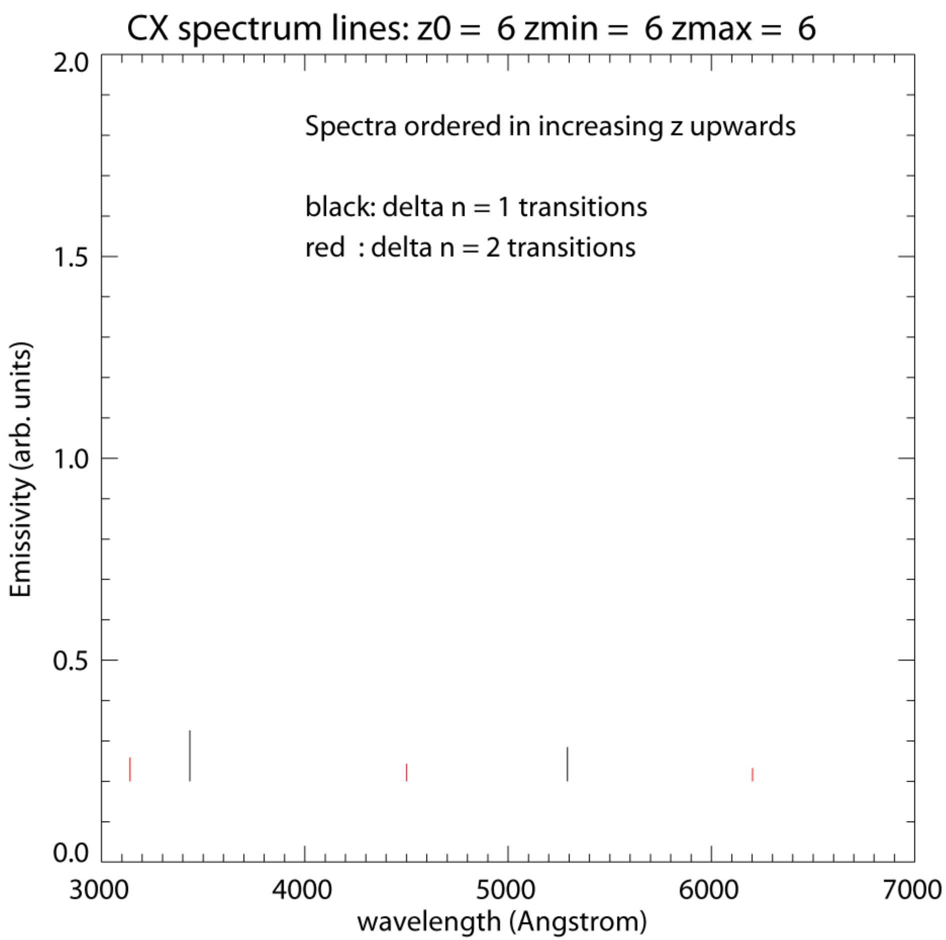


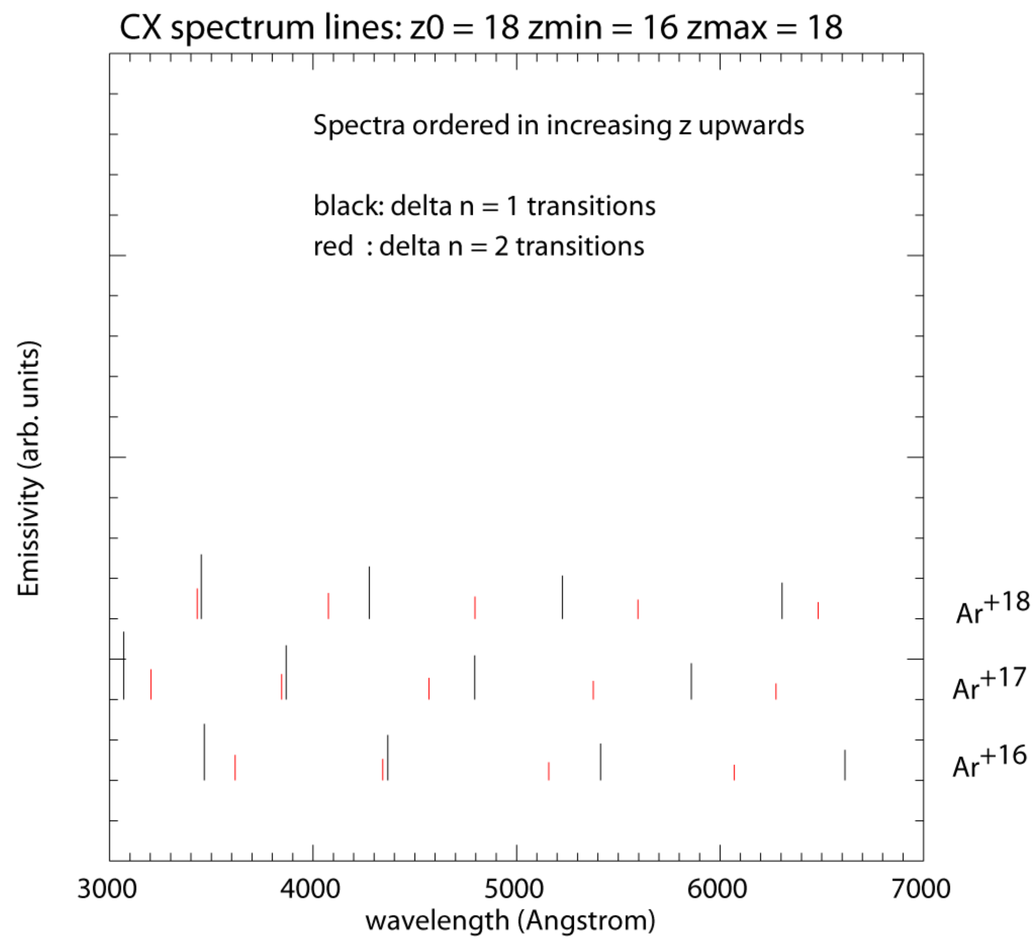



# Comparison of l-subshell cross-sections with light element parametrisation

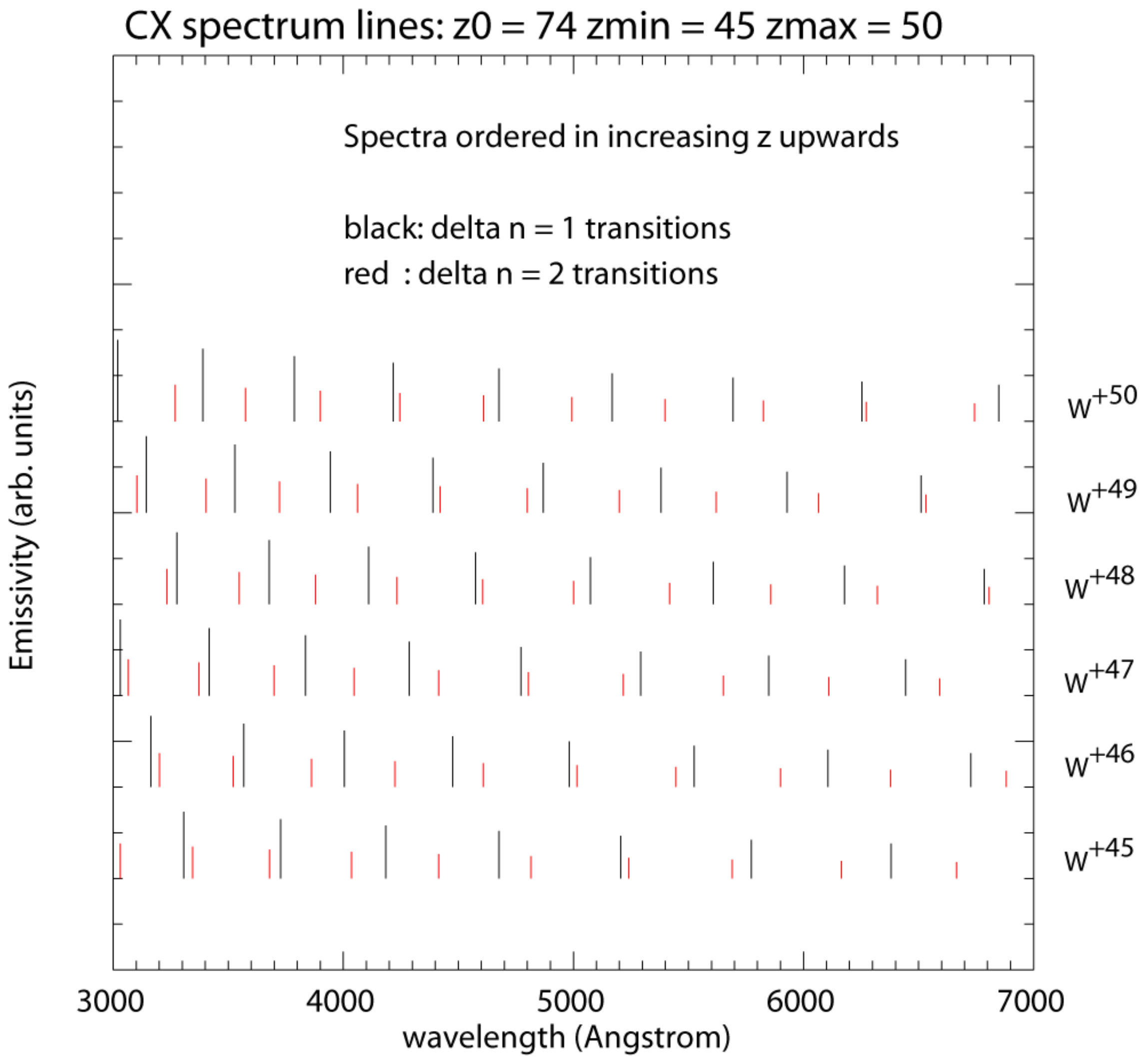


# Patterns of CXS lines in the visible

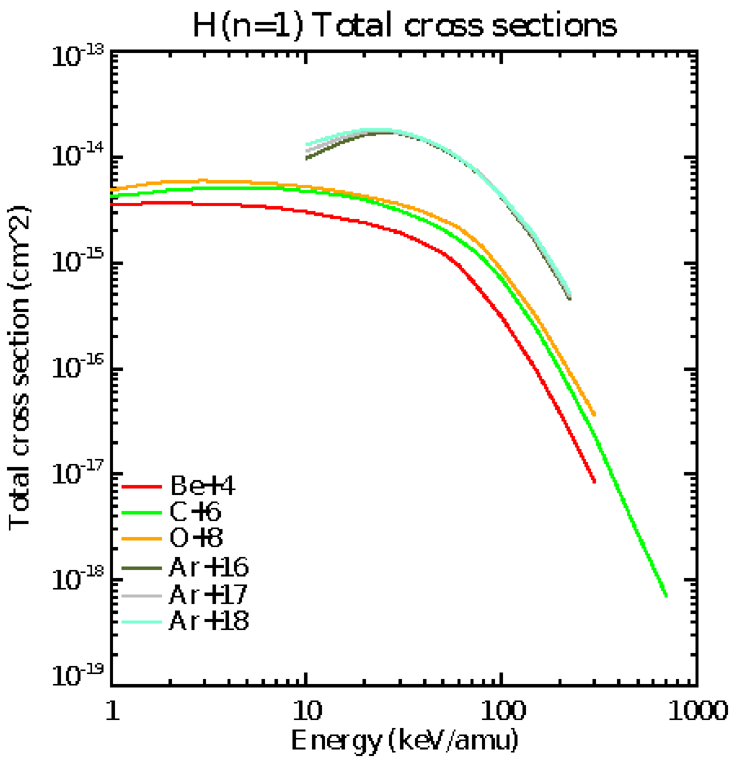


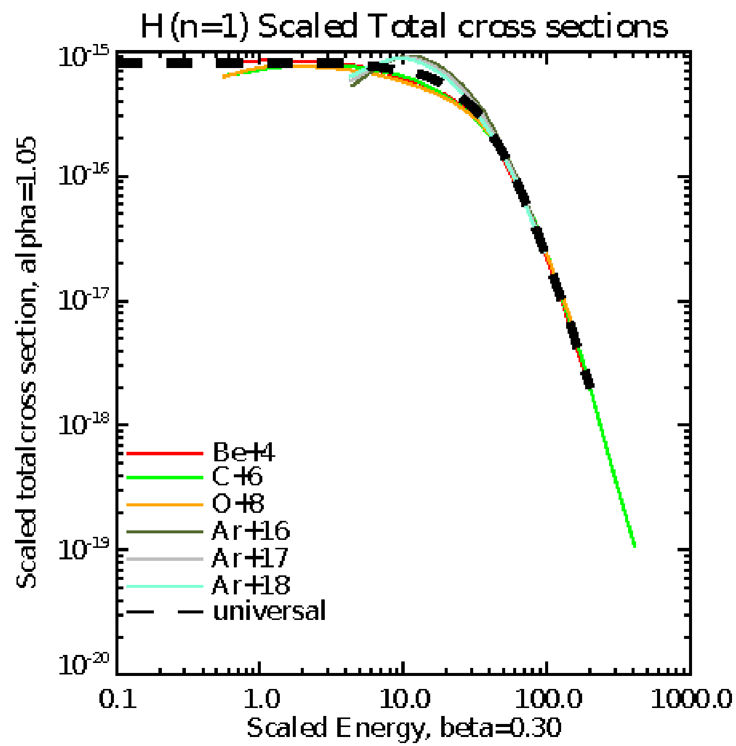



# Patterns of CXS lines in the visible (contd)



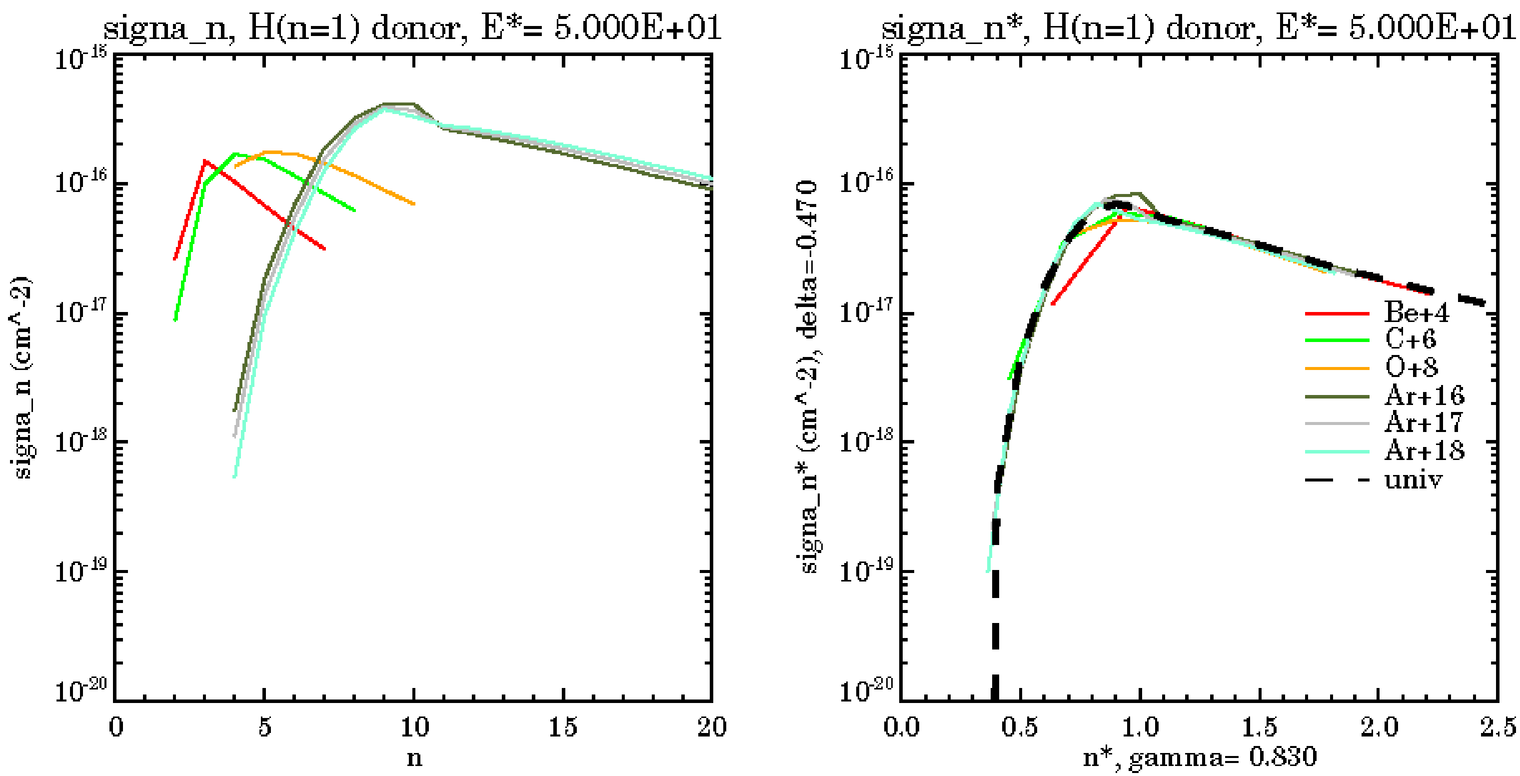
# $z_r$-scaling of total charge exchange cross-sections for H(n=1) donor



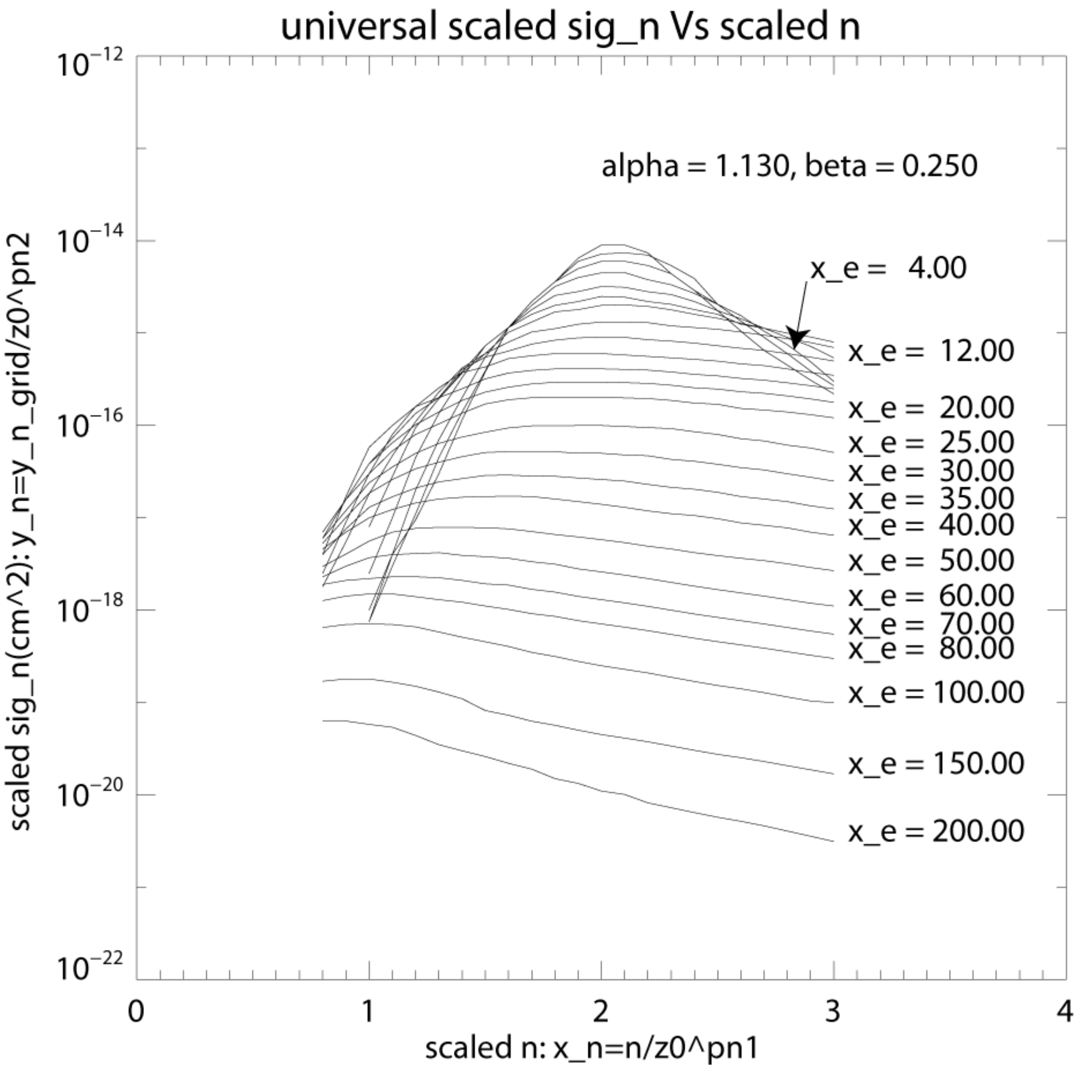

$$\sigma^*_{tot} = \sigma_{tot} z_r^{-\alpha} \qquad E^* = E z_r^{-\beta}$$

# $z_r$-scaling of n-shell charge exchange cross-sections for H(n=1) donor




$$\sigma_n^* = \sigma_n z_r^{-\delta(E^*)} \qquad n^* = n z_r^{-\gamma(E^*)}$$

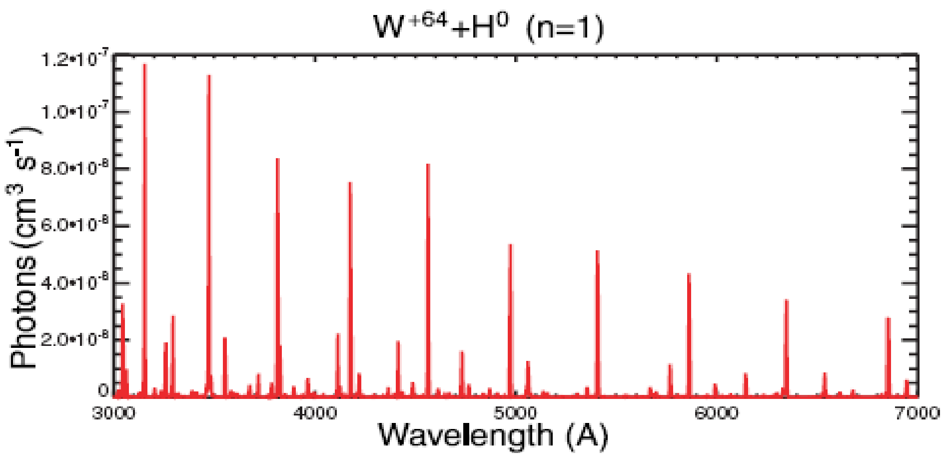
# Universal scaled_sig Vs scaled_n for selected scaled E.

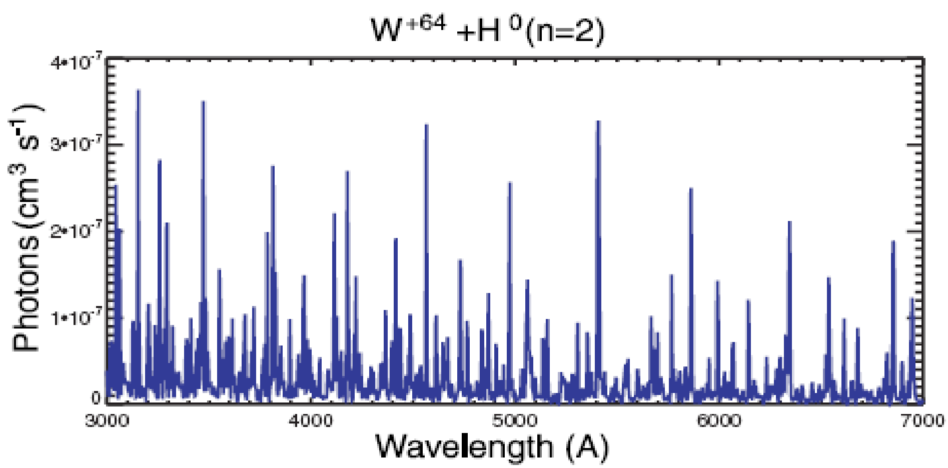


# Extension of the CXS capabilities to heavier species

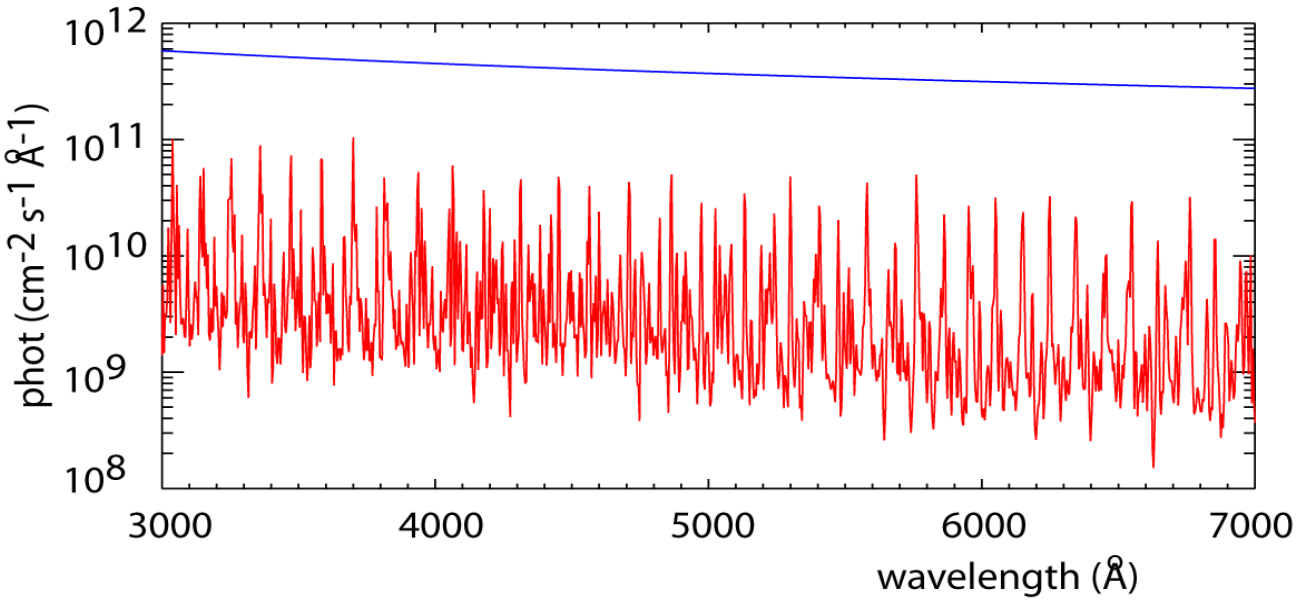
- There are two new codes ADAS315 and ADAS316.
- ADAS315 works on the scale-able universal dataset of format ADF49 to produce an ADF01 data set.
- ADAS316 is a bundle-n population model. It requires a driver data set and, for bundle-n in ADAS, these have historically been archived in ADF25. A new sub-directory /a25_p316 has been assigned and a complete redesign of the driver has been carried out.
- Output ADF26 (the bundle-n population solution), ADF12 (charge exchange effective emission coefficients) and ADF40 (feature emissivity coefficients) may be produced.
- For heavy species CXS, because of the very large number of transitions between highly excited states, the ADF40 format becomes more useful that ADF12.

# Patterns of CXS lines in the visible (contd)



# ITER: tungsten CX compared with Bremsstrahlung




- 50 keV/amu D beam (diagnostic NB), JNBI=300A/m2, INBI=60A
- Using ITER scenario 2 (Te=20keV core, Ne=1x1014cm-3)
- No transport – steady state ionisation balance
- Assume looking vertically down on the beam at the core.
- No beam attenuation effects taken into account.
- W concentration = $1x10^{-6}$ of $N_H$