Propagation of uncertainty through population models

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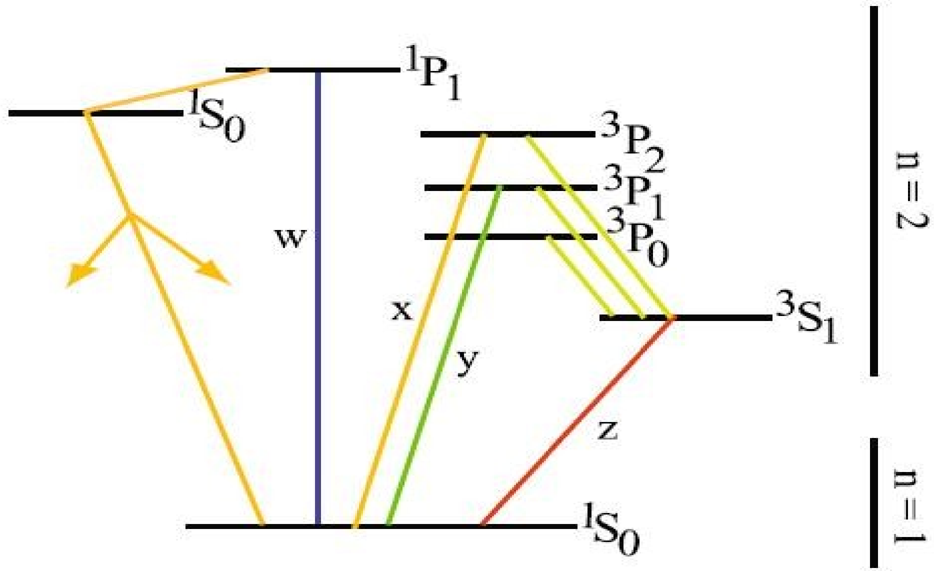
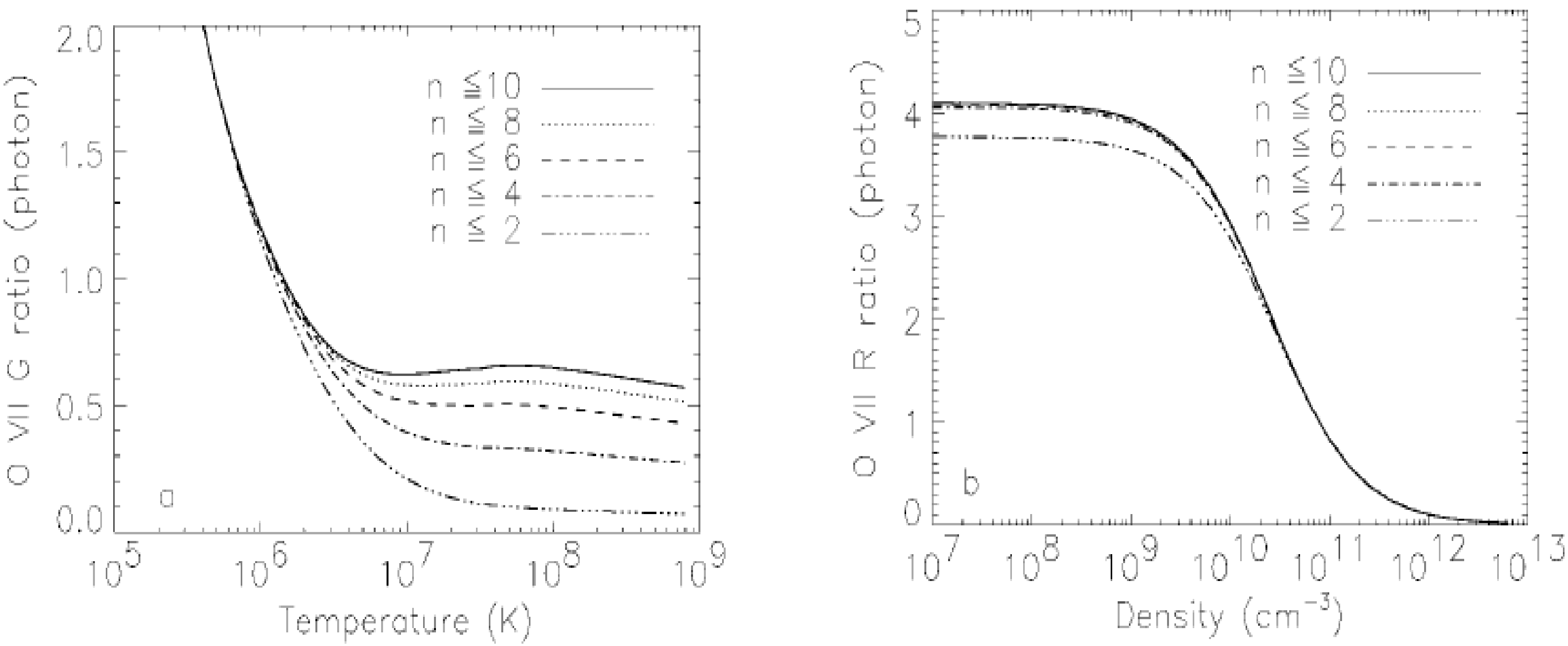


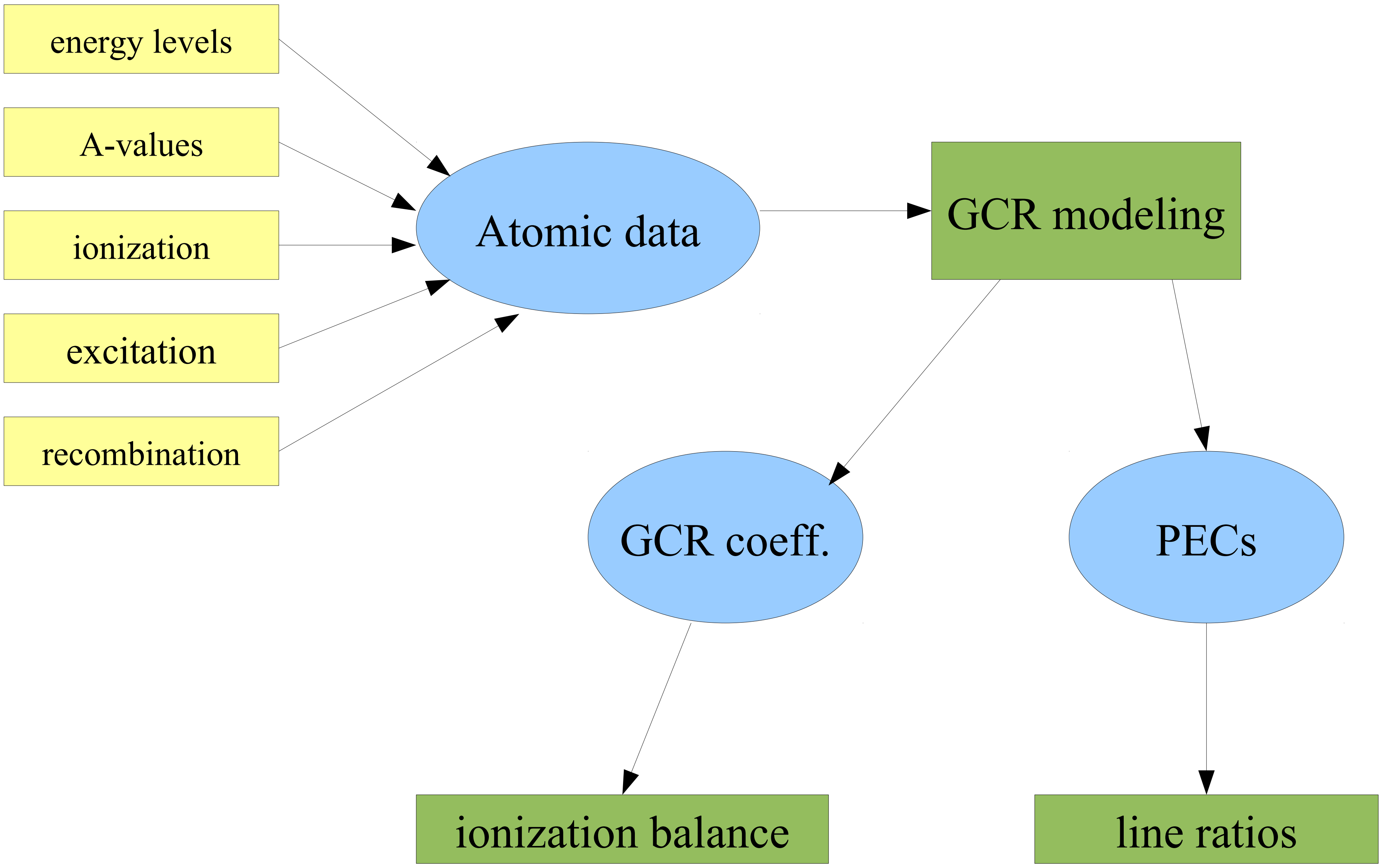
$$\text{G-ratio} = \frac{x + y + z}{w}$$

$$\text{R-ratio} = \frac{z}{x + y}$$



Smith et al (2001)

Modeling calculations



Baseline uncertainties

- are calculated by looking at the difference between a state-of-the-art calculation and a more approximate method
- represent a generous estimate of our current confidence in a data set
- have the correct temperature and density trends (e.g. excitation resonances become less important at high temperatures)
- do not truly represent the uncertainty of the state-of-the-art calculation
- are uncorrelated

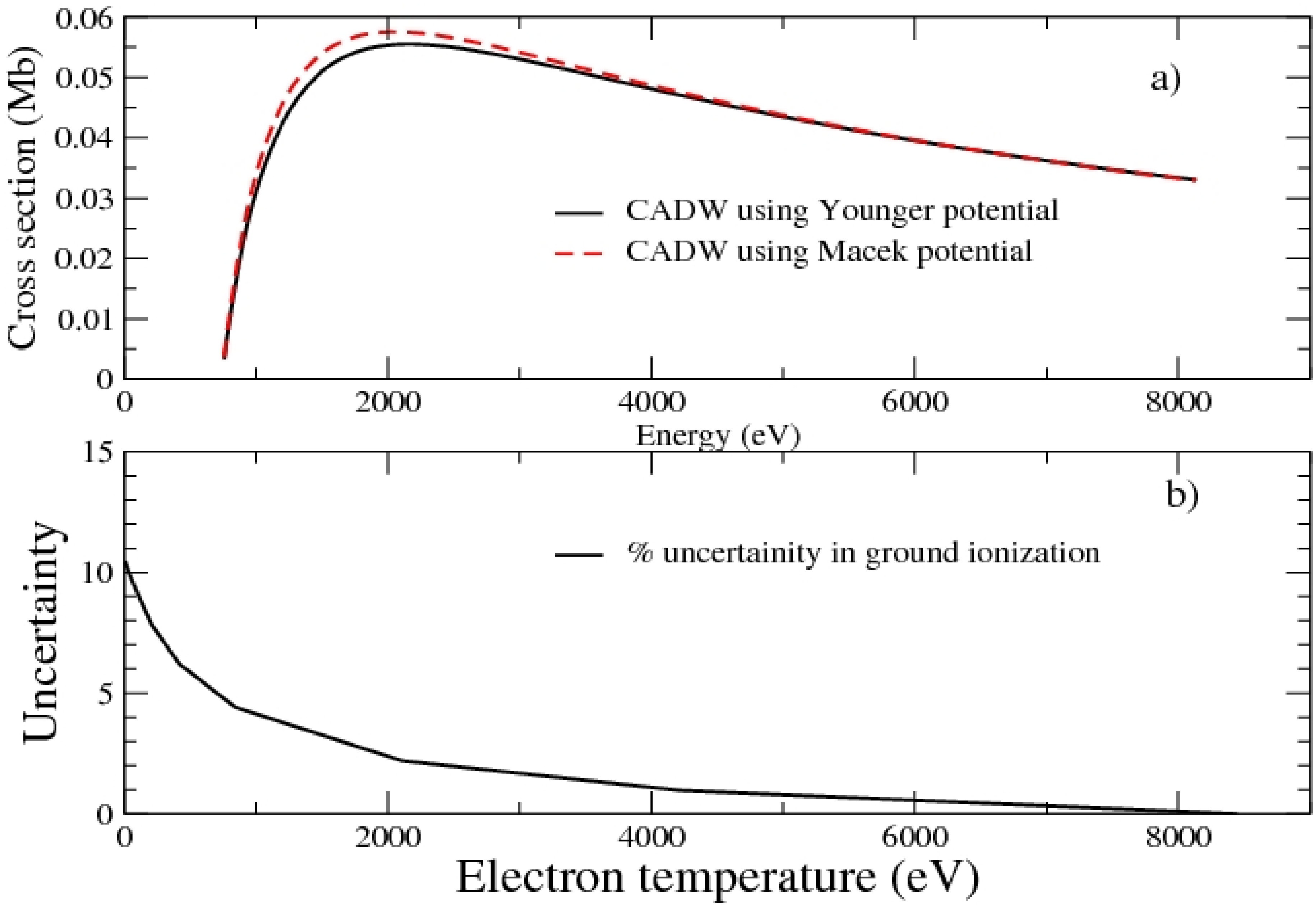
Sensitivity Studies

- measure variations in atomic data to variations in input parameters for a single method
- measure the convergence of data values to calculation size
- can produce fully correlated uncertainties
- do not determine absolute uncertainty between methods
- have difficultly determining the range of input parameters to reflect confidence in output data

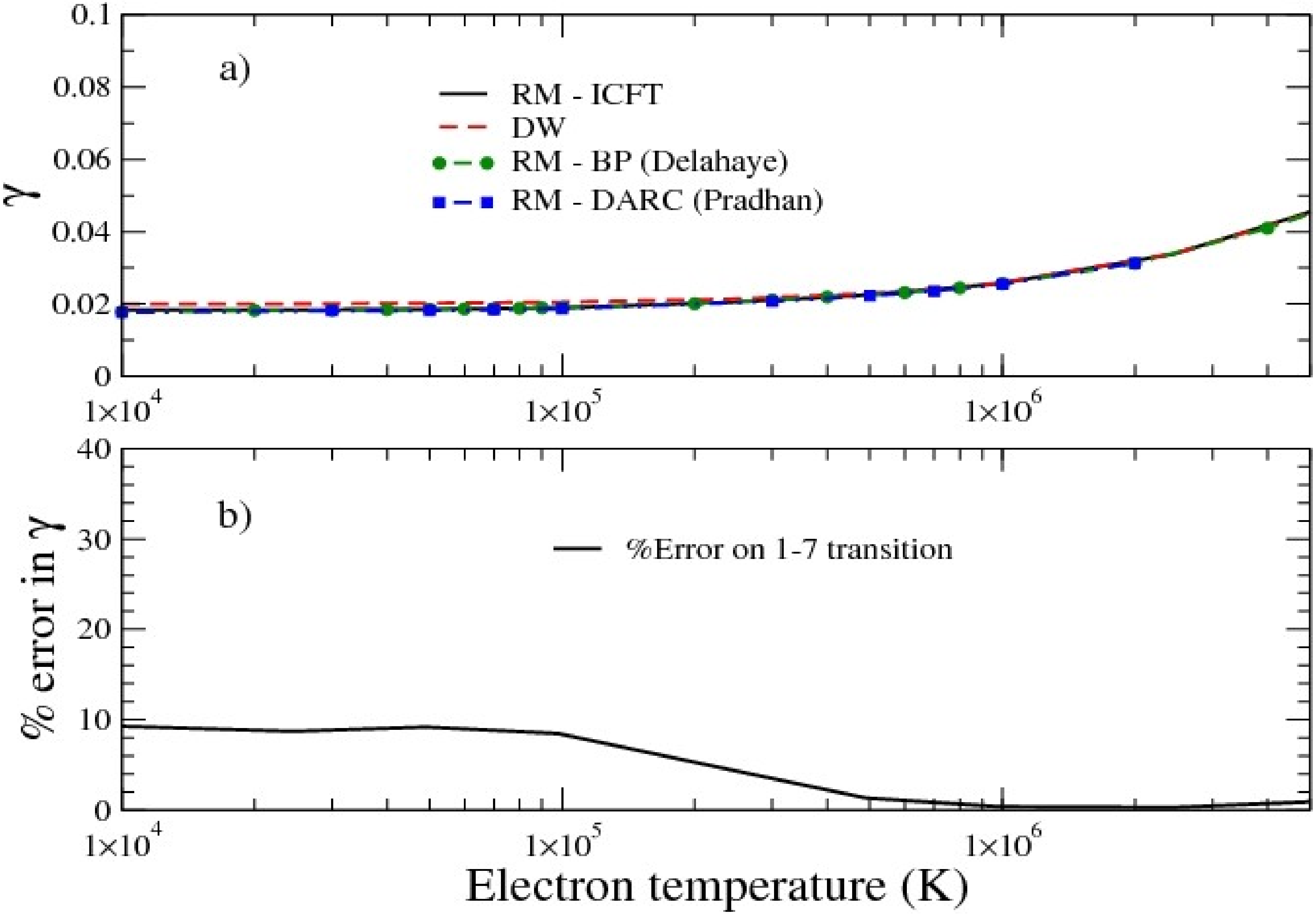
He-like O

- n=4 model
- energies – no uncertainties
- A-values – NIST vs. AUTOS
- ionization
  - low n – DW: Younger vs. Macek
  - high n – ECIP with DW uncertainty trends
- excitation rates
  - low n – R-matrix vs. DW
  - high n – DW vs. PWB
- radiative recombination – AUTOS vs. Gaunt factor
- dielectronic recombination – AUTOS: shifted vs. unshifted

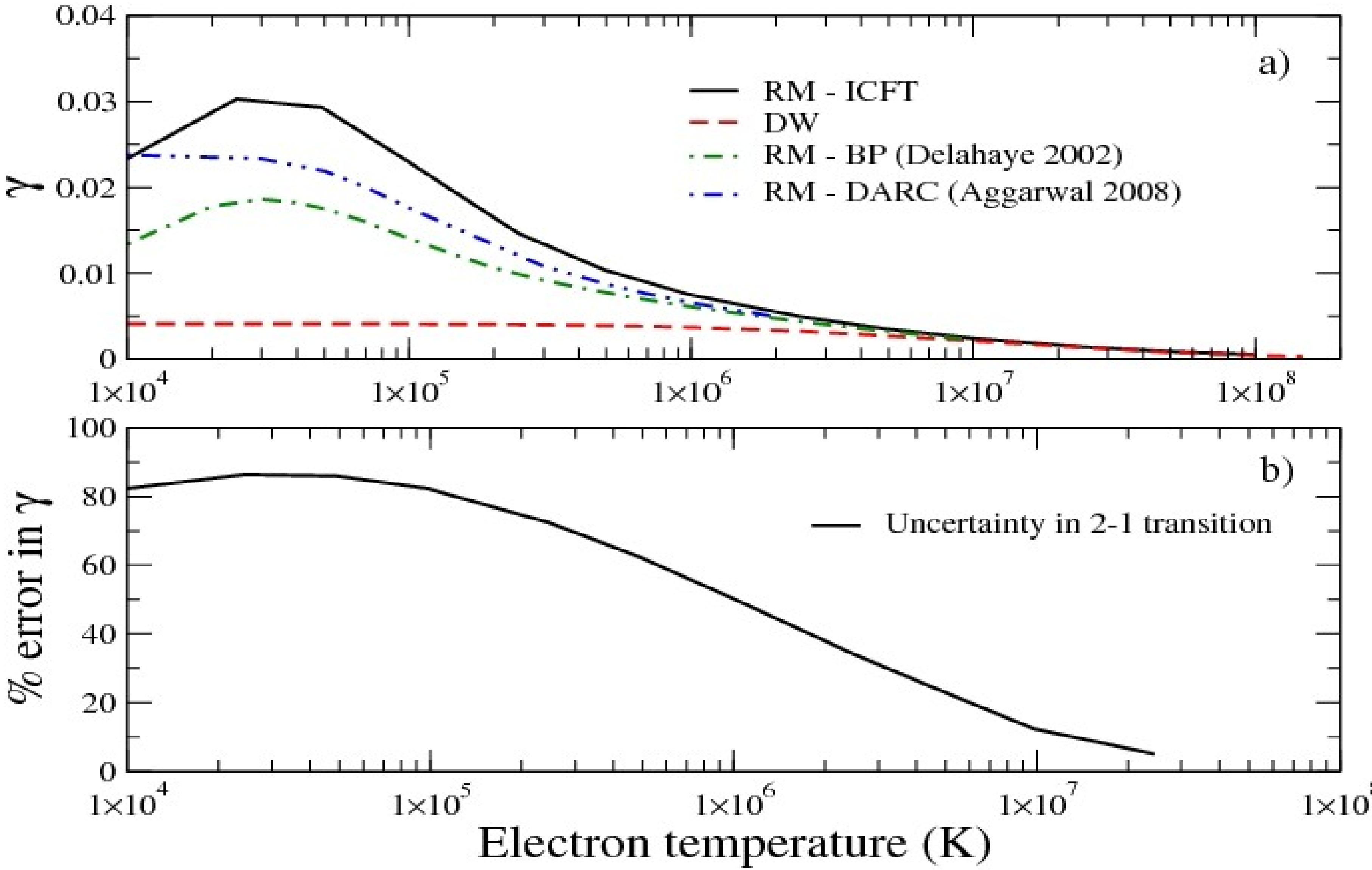
Baseline data – ionization



Baseline data – excitation



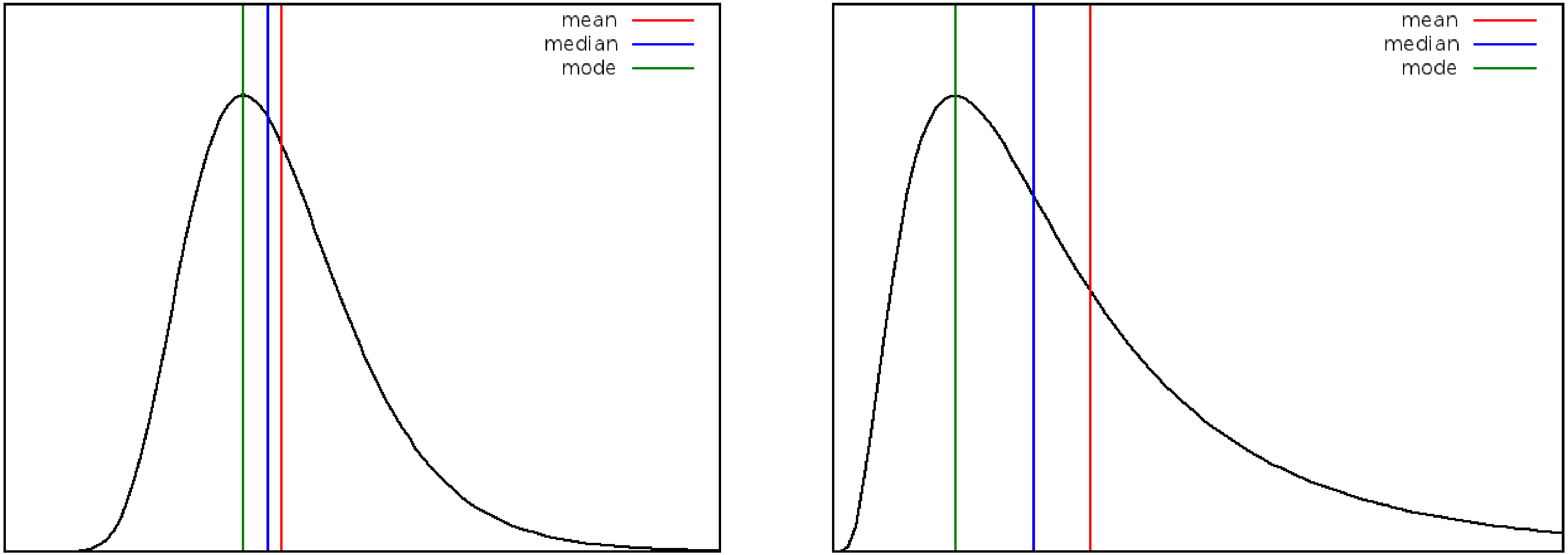
Baseline data – excitation



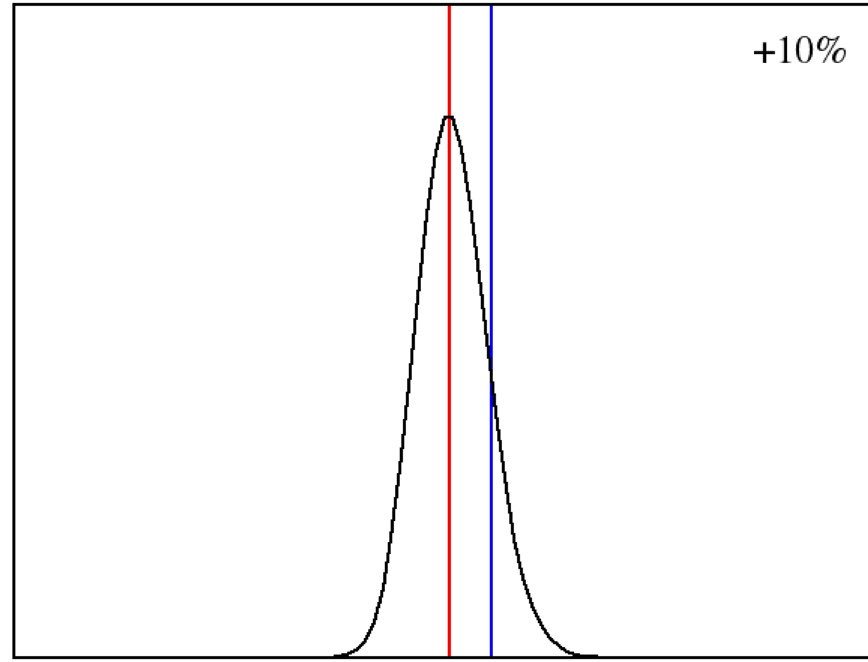
Distributions

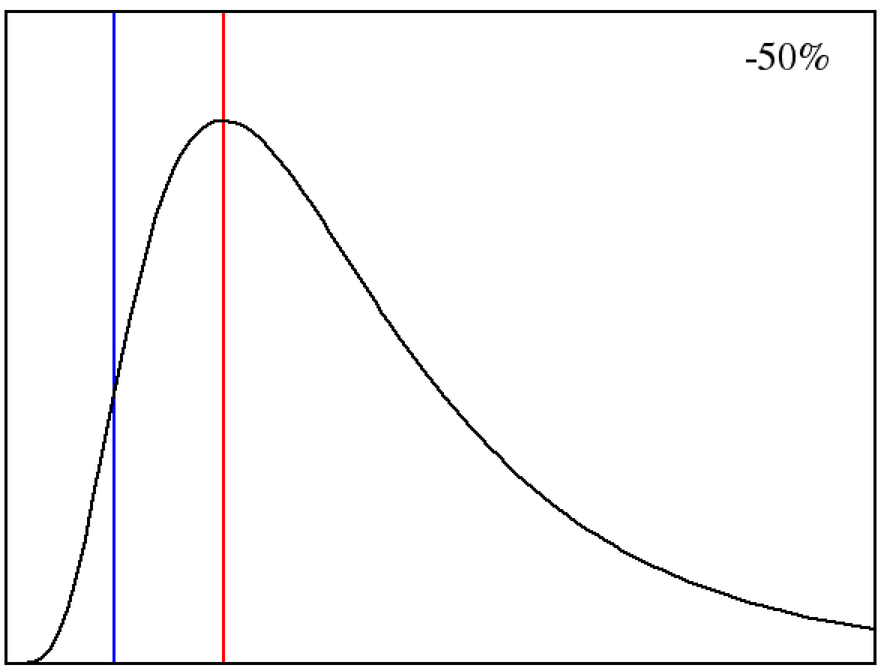
- for baseline data, we need to choose a distribution for the data
- since all of our data are positive-definite, we choose a log-normal distribution
- for small uncertainties, the log-normal distribution approaches a normal distribution
- output GCR coefficients or PEC data is fit using 3 distributions to see which works best (normal, log-normal, shifted log-normal)

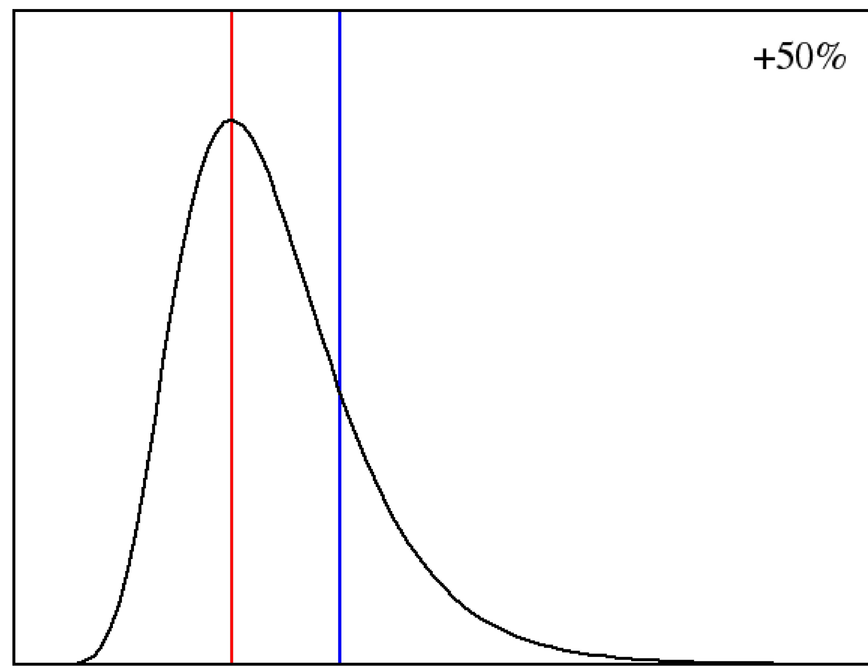
Lognormal distribution



Lognormal distribution

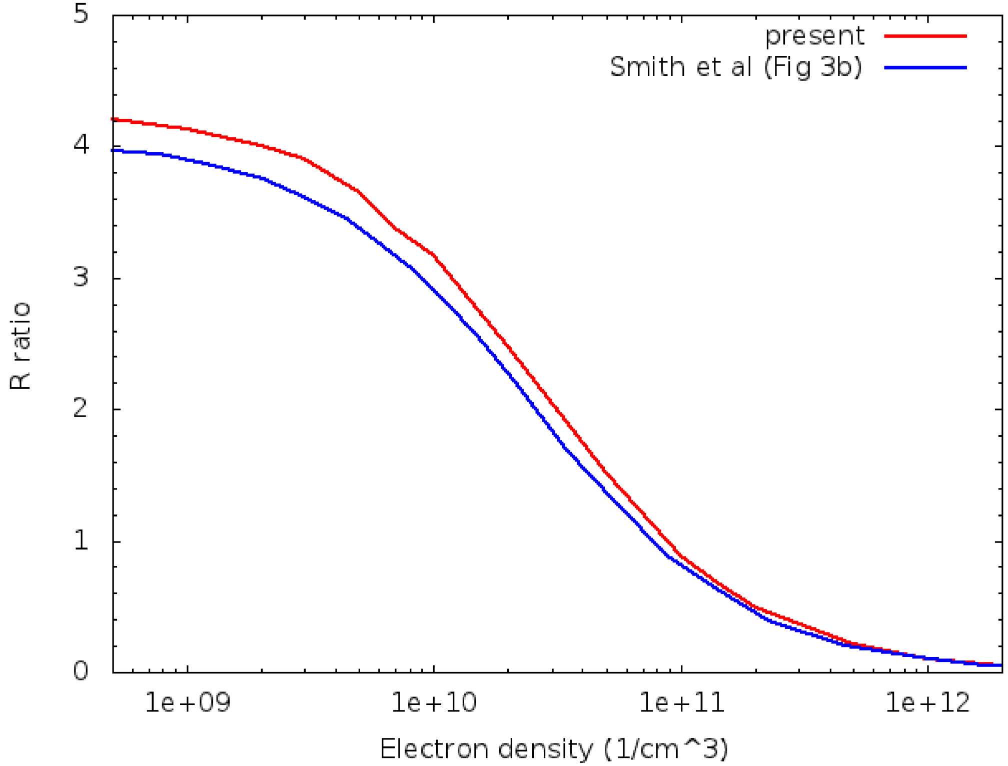




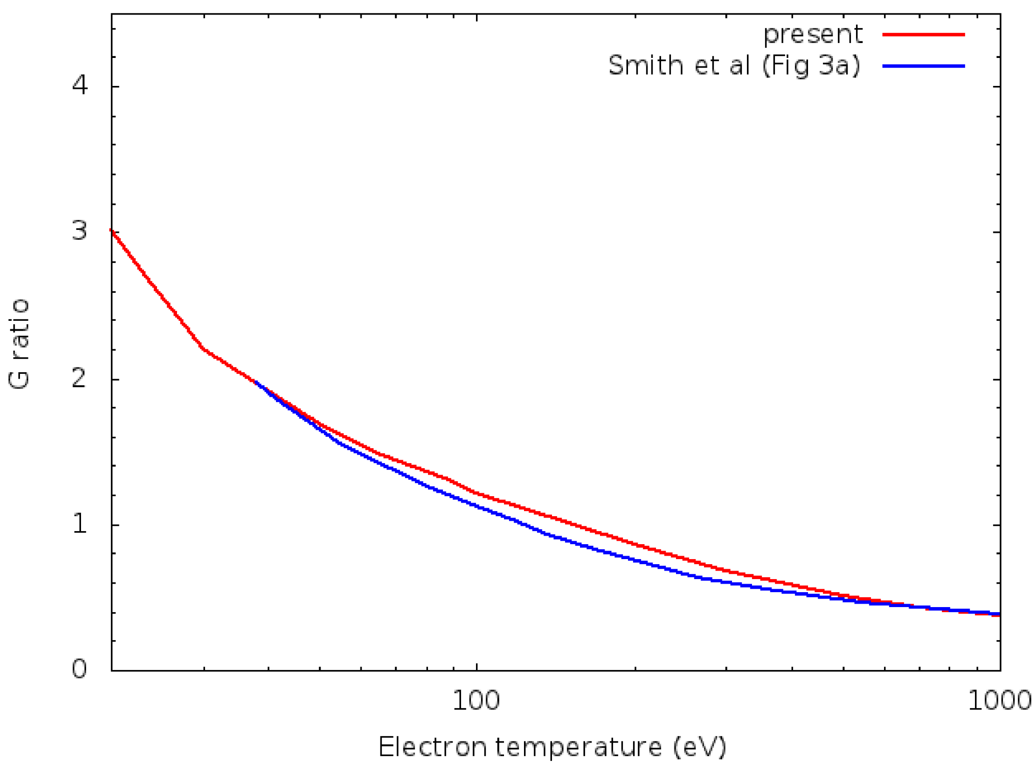


Smith et al comparison

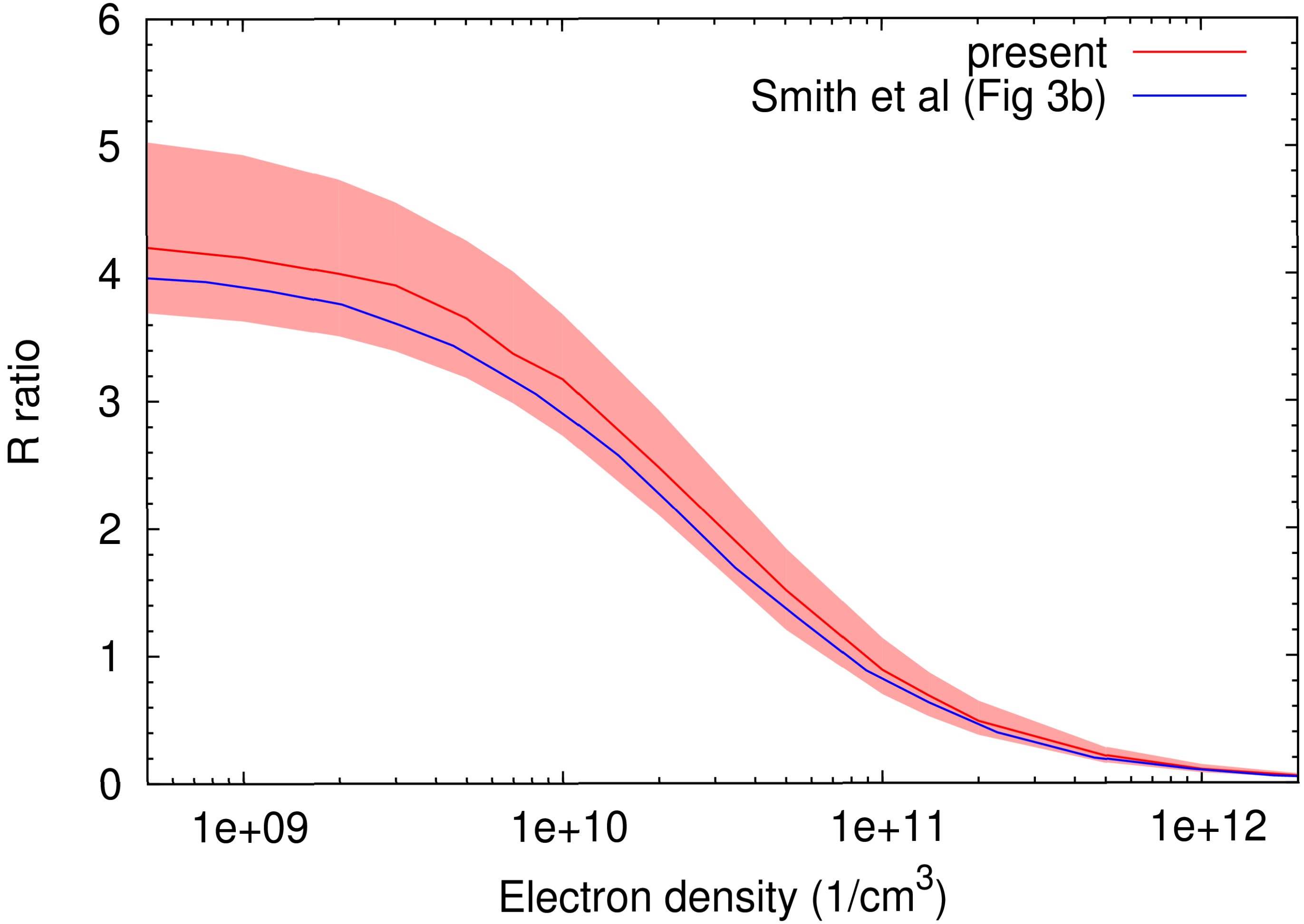
R ratio



G ratio



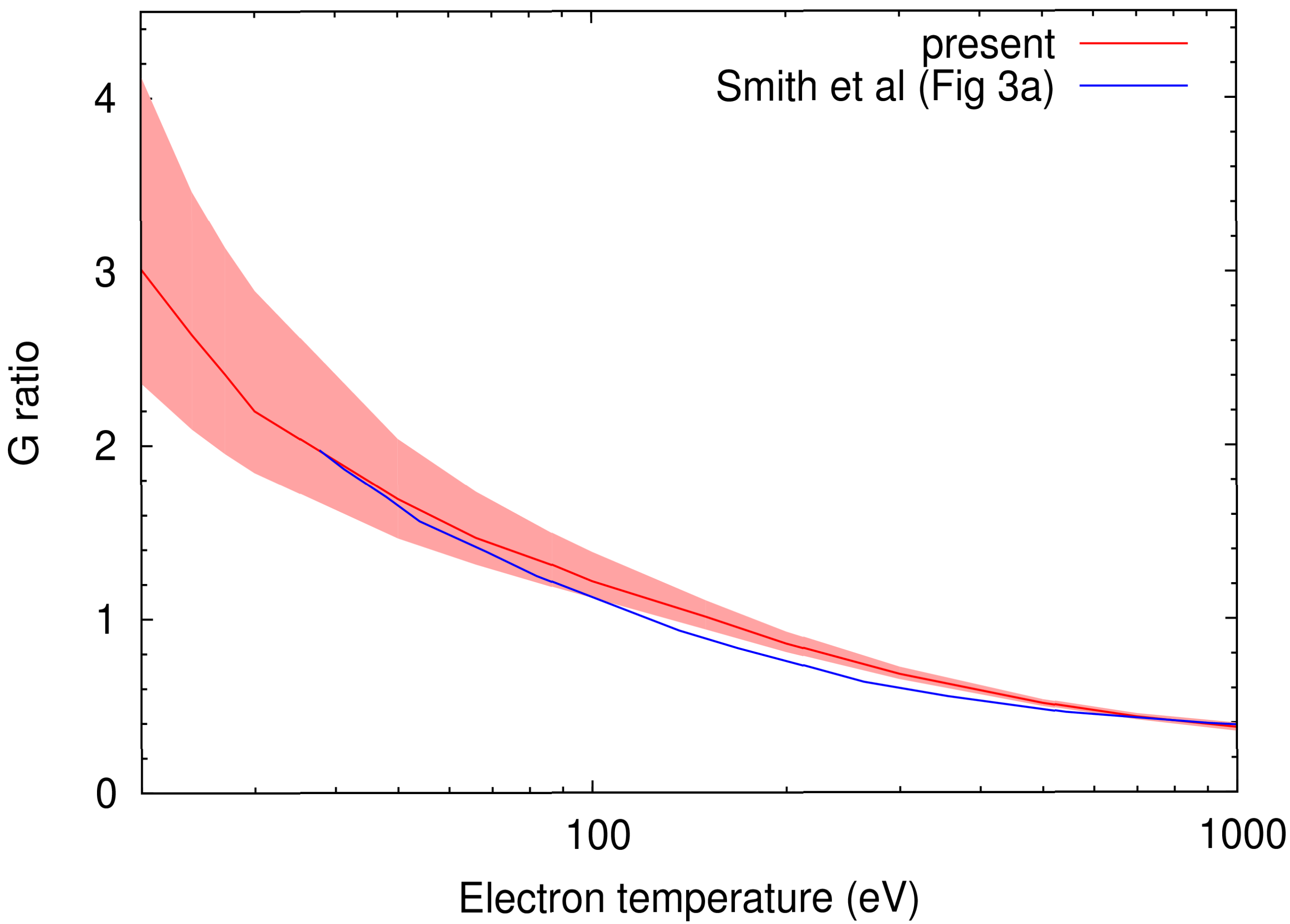
Density diagnostic (R ratio)



- Te: 86.7 eV
- Ne from 10^7 to 10^{13}/cm^3
- million Monte Carlo trials per density

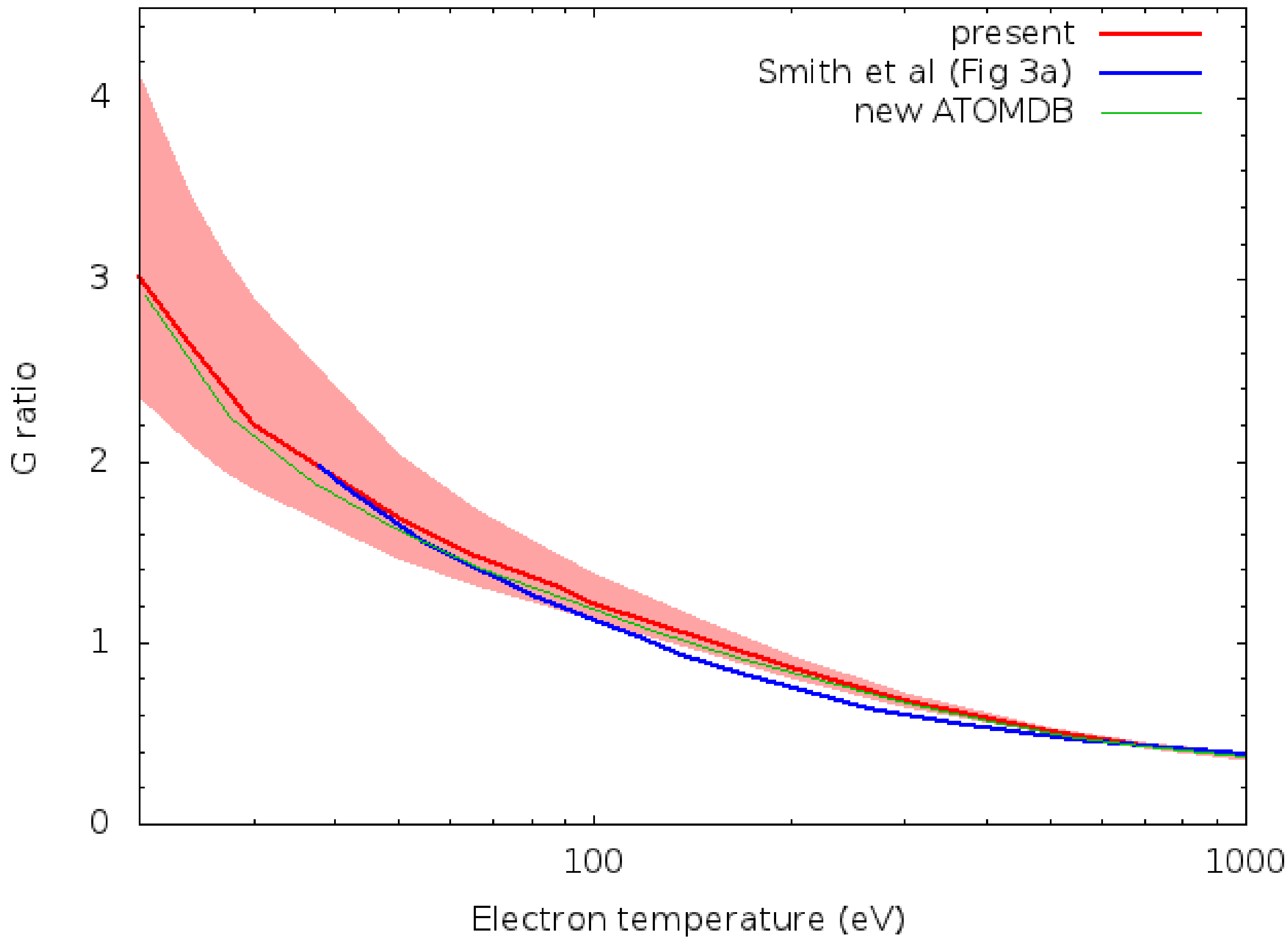
Smith et al (2001)

Temperature diagnostic (G ratio)



- Ne: 10^7 1/cm^3
- Te from 20 – 1500 eV
- million Monte Carlo trials per density

Temperature diagnostic (G ratio)



Conclusions

- Systematically assign uncertainties to all types of atomic data
- Carry the uncertainties through CR modeling using a Monte Carlo approach
- Get usable uncertainties on diagnostics
- Identify differences in CR methods
- Prioritize which atomic data to improve