Uncertainties in the Ne V infrared diagnostics

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Uncertainties in atomic data and how they propagate in chemical abundances

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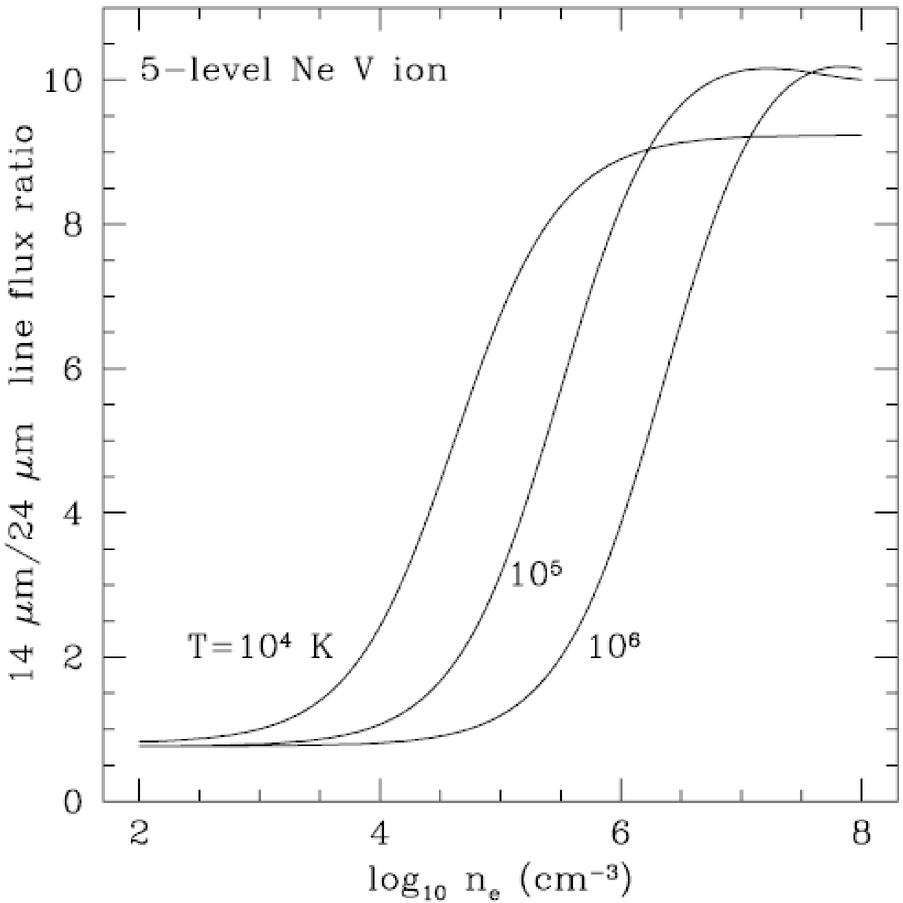
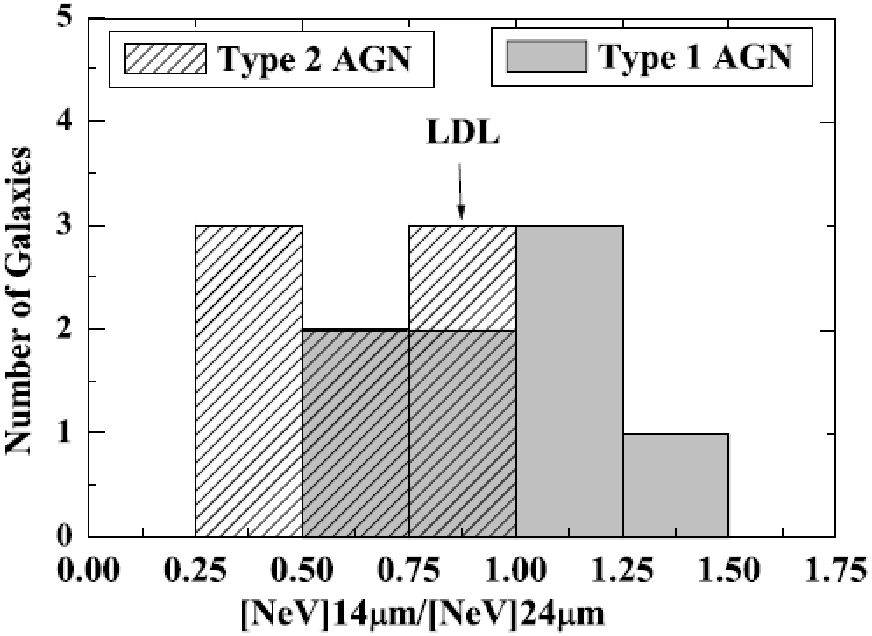
Systematic study of [Ne V] (14 μm/24 μm) in AGNs indicates that those below the LDL are type 2



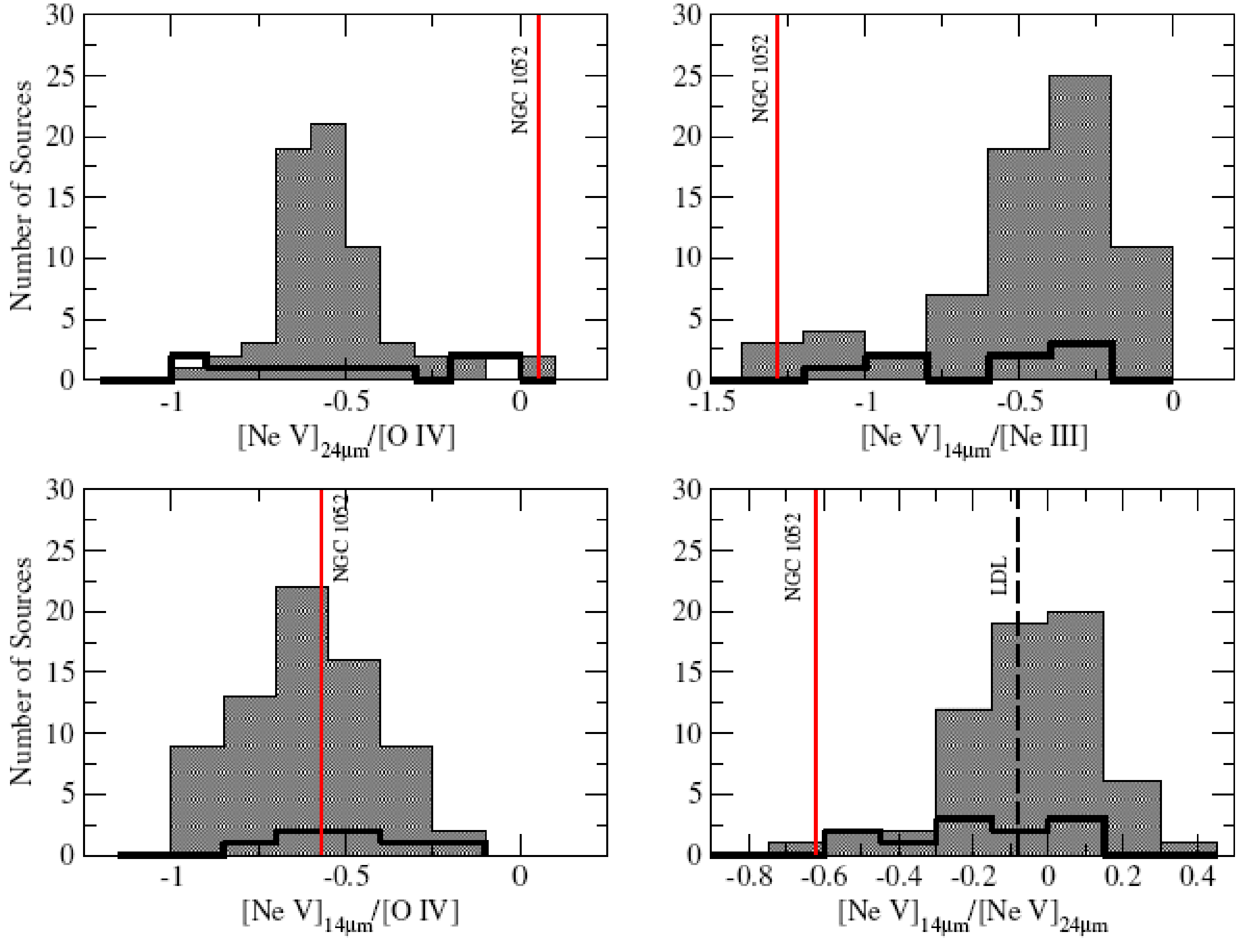


Figures from Dudik et al. 2007, ApJ, 664, 71

In Weaver et al., 40% of the AGNs sampled displayed a [Ne V] (14 μm/24 μm) below the LDL

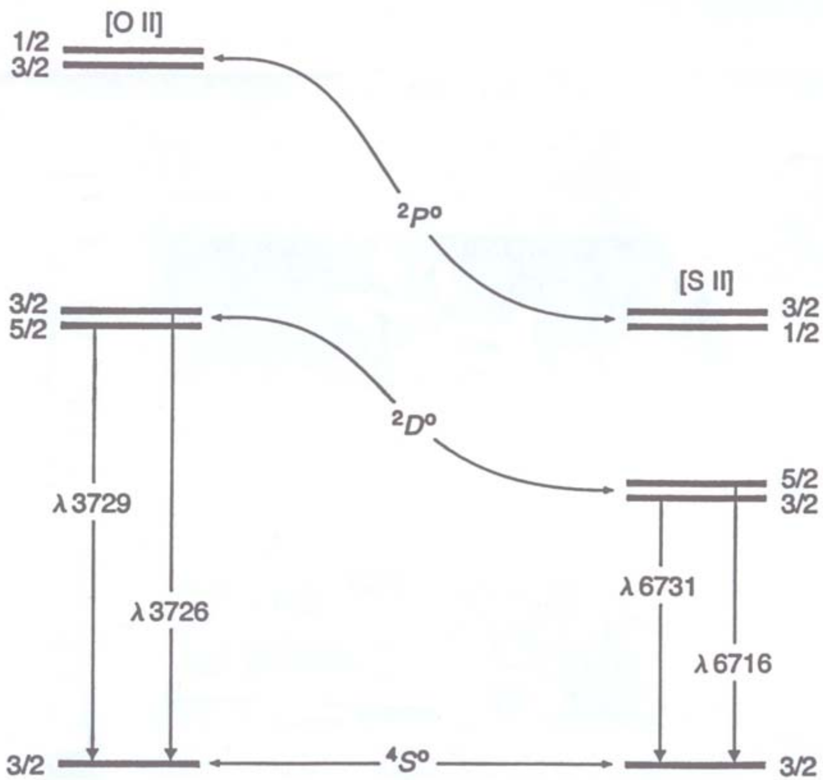
[O IV] 25.89 μm

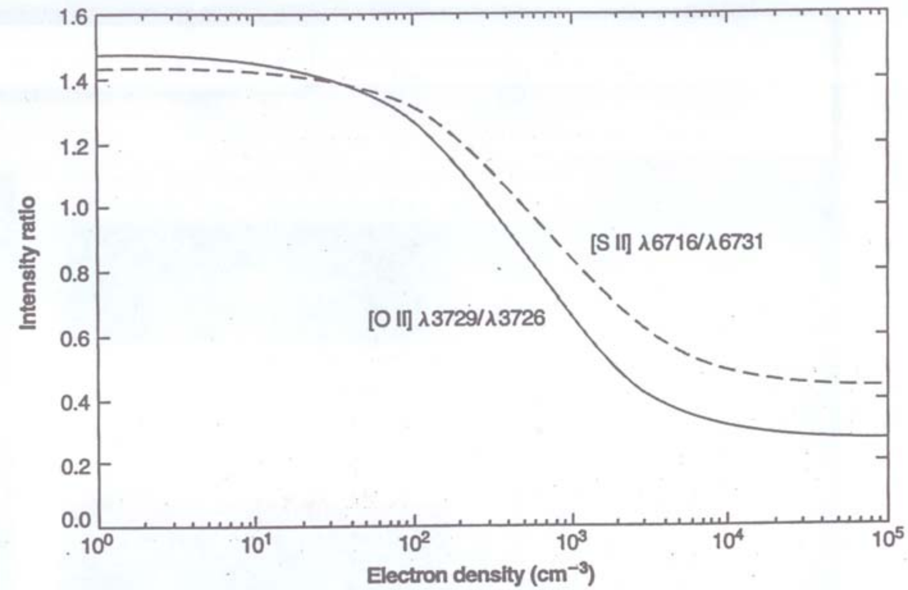
[Ne III] 15.51 μm



Plots from Weaver, Meléndez & et al. 2010, ApJ. 716, 1151

The high-density limit of [O II] (3729 Å / 3726 Å) is sensitive to the M1 A-value





Original images from Osterbrock & Ferland (2005)

As shown by Eissner & Zeippen (1981), the M1 A-value in N-like ions is sensitive to high-order relativistic corrections

The magnetic dipole transition probability is given by (Drake 1971)

$$A_{ij}(\mathrm{M1}) = 3.5644 \times 10^4\ \mathrm{s}^{-1} \times (E_i - E_j)^3 \frac{1}{g_i} S_{ij}^{\mathrm{M1}}$$

$$S_{ij}^{\mathrm{M1}} = |\langle i | \mathbf{Q} | j \rangle|^2$$

$$\mathbf{Q} = \sum_{m=1}^{N} \mathbf{Q}(m) + \sum_{n=1}^{N} \sum_{m<n} \mathbf{Q}(nm), \quad (2.14)$$

where

$$\mathbf{Q}(m) = [\mathbf{l}(m) + \boldsymbol{\sigma}_m] \left\{1 + \frac{\alpha^2}{2} \left[\!\left[\left(\frac{\partial^2}{\partial r^2} - \frac{l(l+1)}{r_m^2}\right) - \frac{E^2}{20} r_m^2\right]\!\right]\right\} + \frac{\alpha^2}{4} \mathbf{p}_m \times (\mathbf{p}_m \times \boldsymbol{\sigma}_m)$$
$$+ \frac{\alpha^2}{2} [\mathbf{r}_m \times (\mathbf{r}_m \times \boldsymbol{\sigma}_m)] \left\{\frac{E^2}{20} - \frac{Z}{r_m^3}\right\} + \frac{\alpha^2}{8} E \boldsymbol{\sigma}_m \quad (2.15)$$

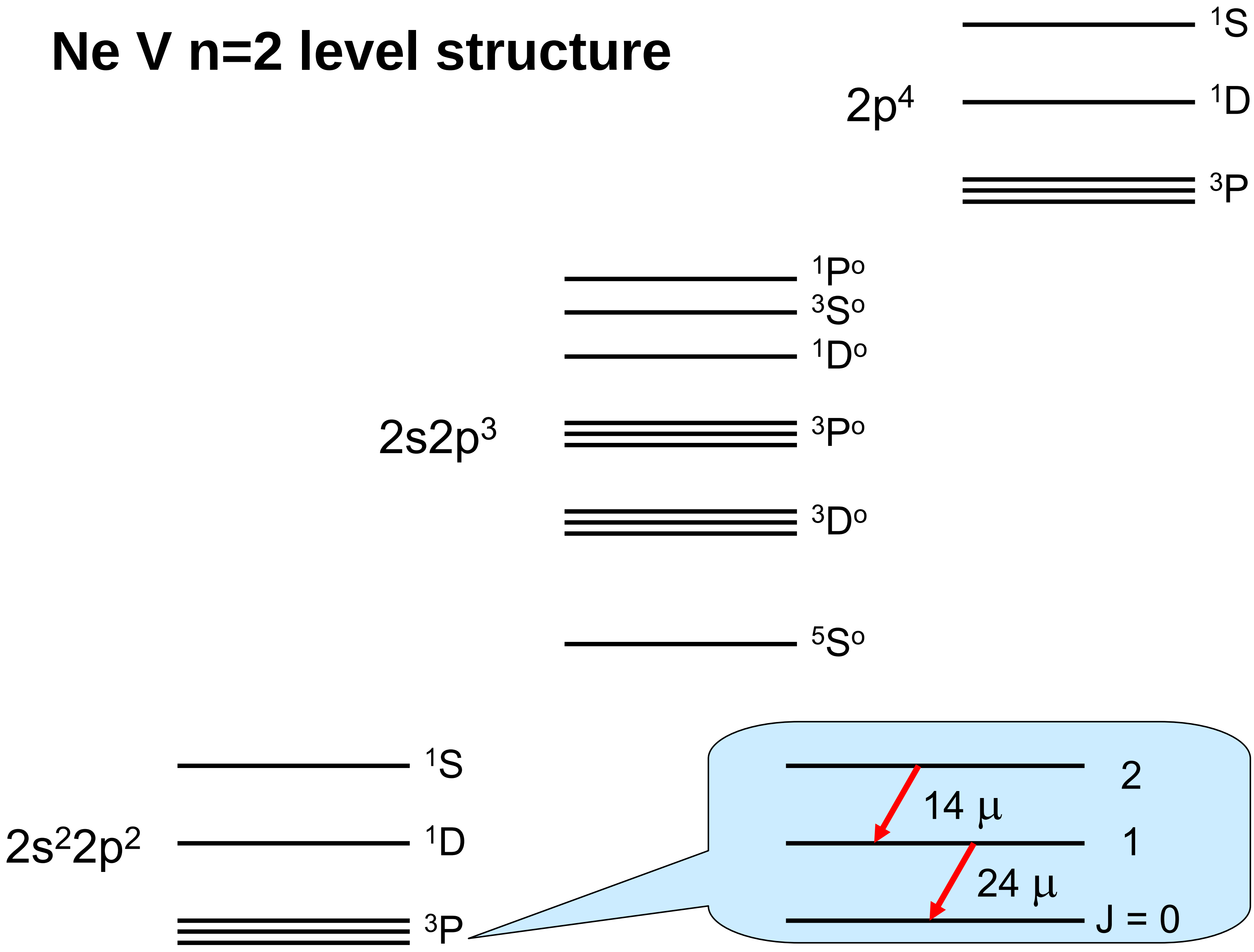
and

$$\mathbf{Q}(nm) = \frac{\alpha^2}{2} \left(\frac{r_{nm} \times [\mathbf{r}_{nm} \times (\boldsymbol{\sigma}_n + \boldsymbol{\sigma}_m)] + (\mathbf{r}_n \times \mathbf{r}_m)\mathbf{r}_{nm} \cdot (\mathbf{p}_n + \mathbf{p}_m)}{r_{nm}^3} - \frac{(\mathbf{r}_n \times \mathbf{p}_m) - (\mathbf{r}_m \times \mathbf{p}_n)}{r_{nm}}\right). \quad (2.16)$$

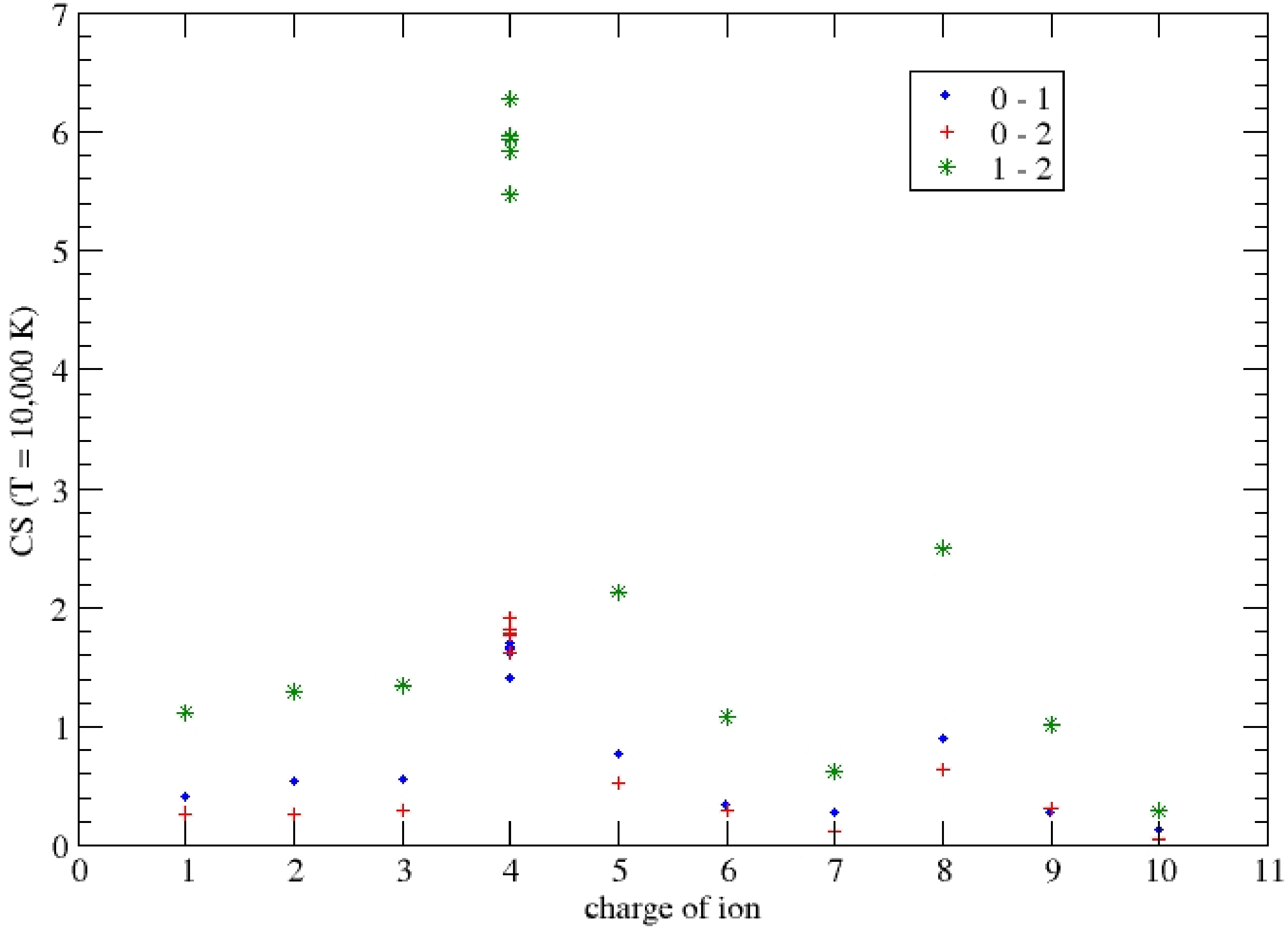
The high-density ratio computed with the corrected M1 A-values is in excellent agreement with observations

Ion	Observed ratio	Theory (uncorrected)	Theory (corrected)
N I	≤ 0.51	0.64	0.54
O II	0.35	0.43	0.35

Ne V n=2 level structure

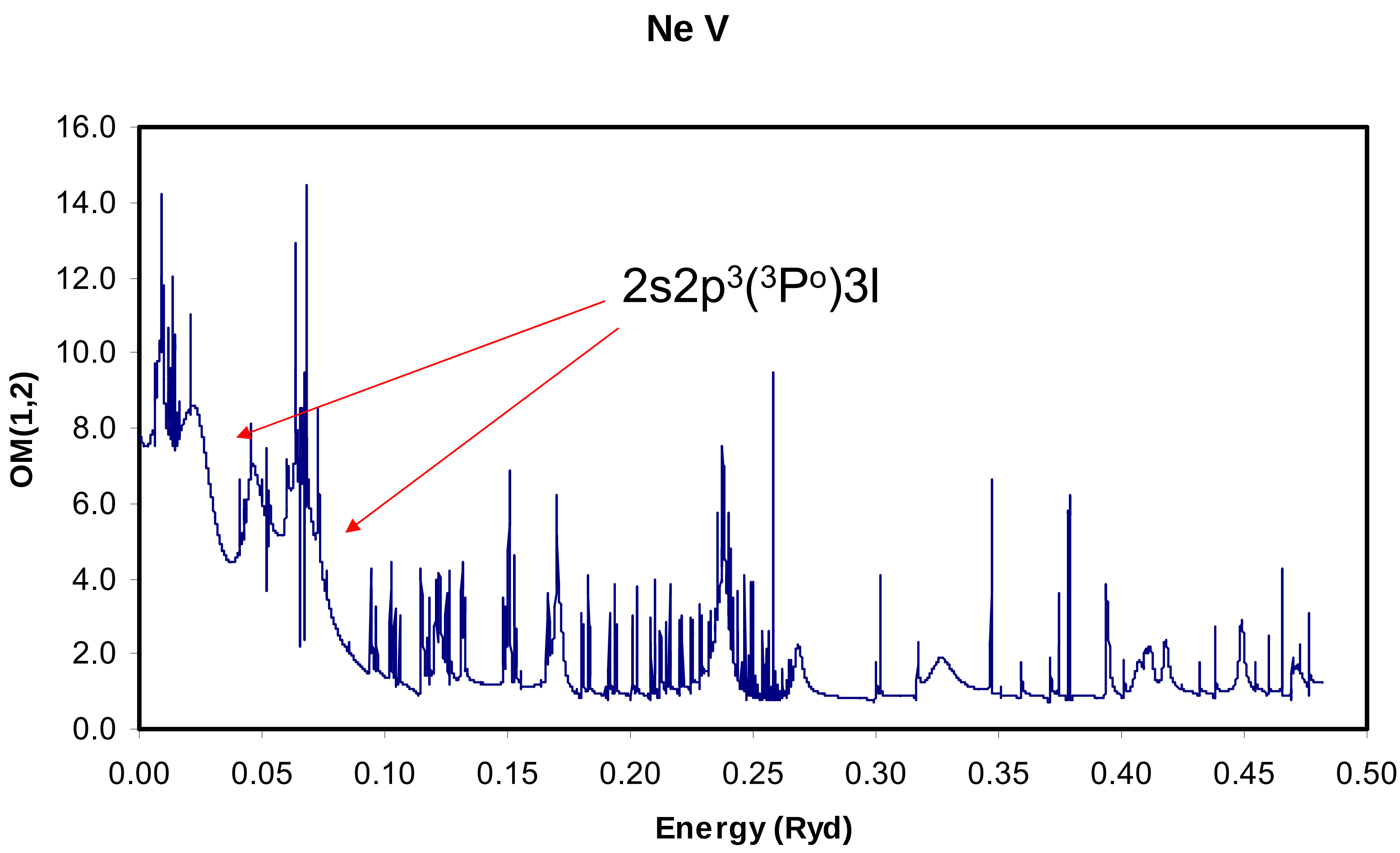


The UPS(1,2) for Ne V is distinctively large in comparison with other C-like ions



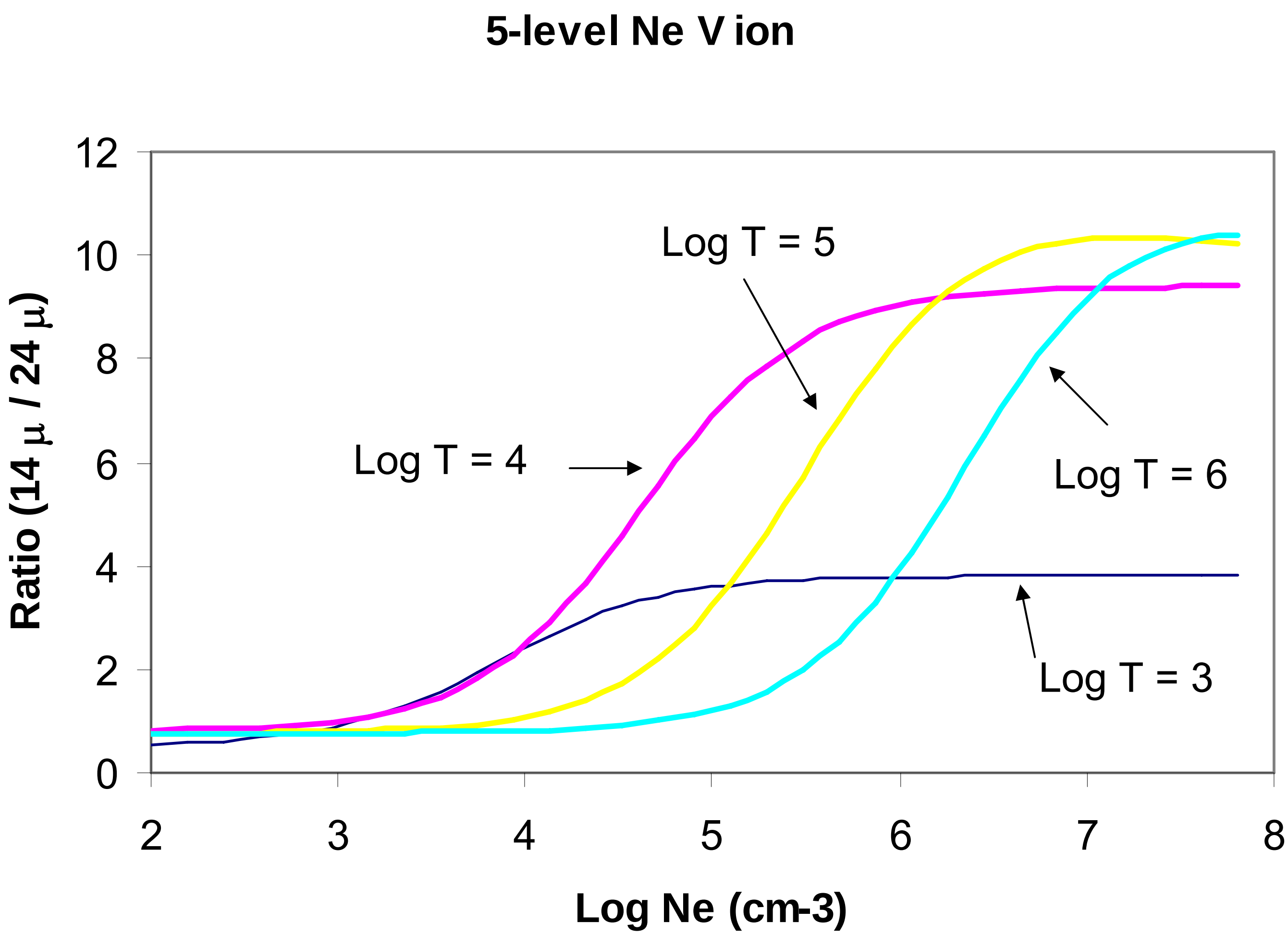
R-matrix calculations for Ne V by Aggarwal (1983), Lennon & Burke (1991, 1994) and Griffin & Badnell (2000)

OM(1,2) is greatly enhanced by $2s2p^3(^3P^o)3l$ resonances sitting right at threshold

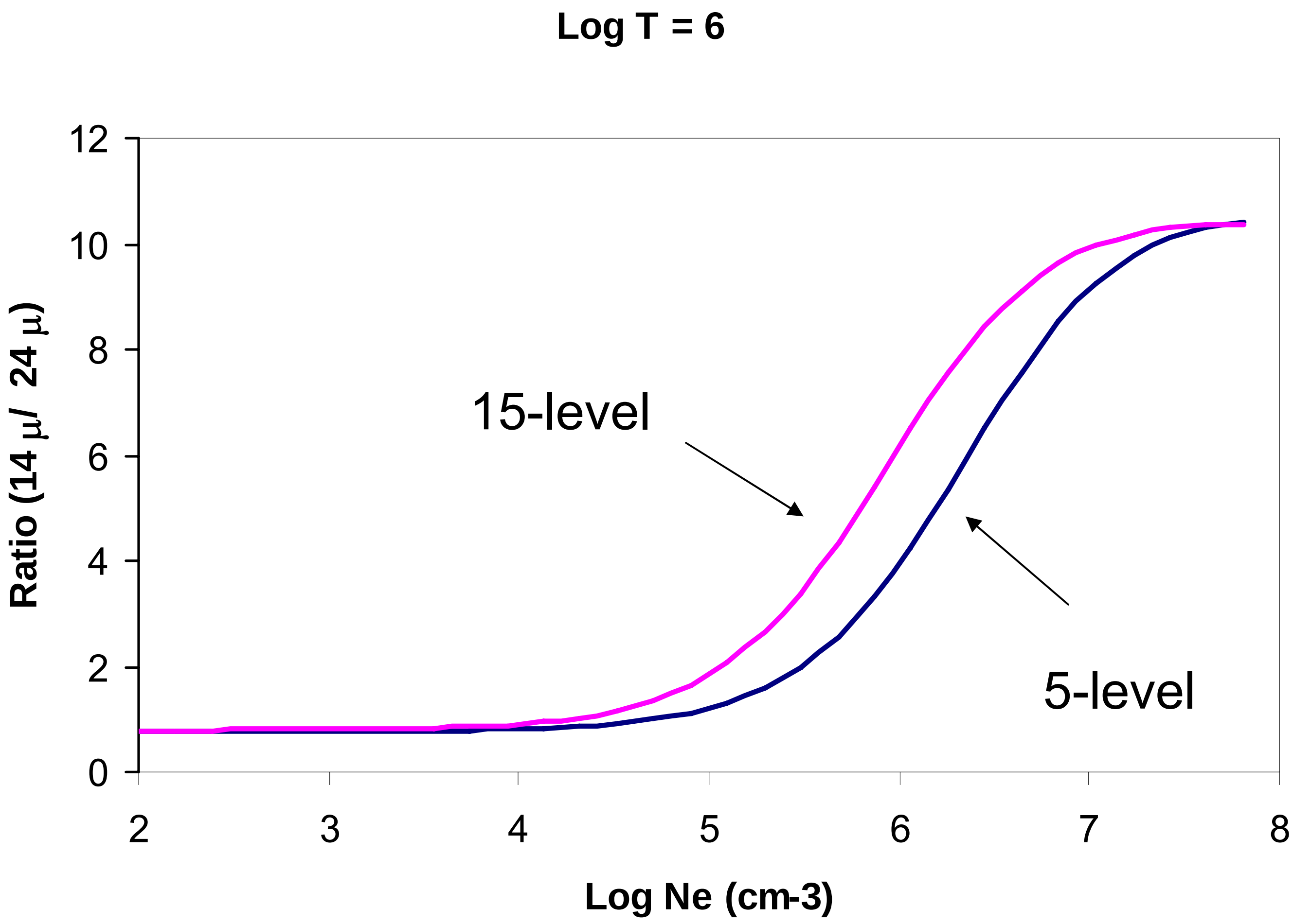


Without corrections: $E_{th}(2s2p^3\ ^3P^o)$ = 1.911 Ryd vs. $E_{expt}(2s2p^3\ ^3P^o)$ = 1.897 Ryd

The [Ne V] (14 μm/24 μm) ratio is sensitive to temperature but its LDL is approximately constant at ~0.83



At Log T = 6, [Ne V] (14 μm/24 μm) is sensitive to the ion model



We revised the Ne V OMs examining different approximations

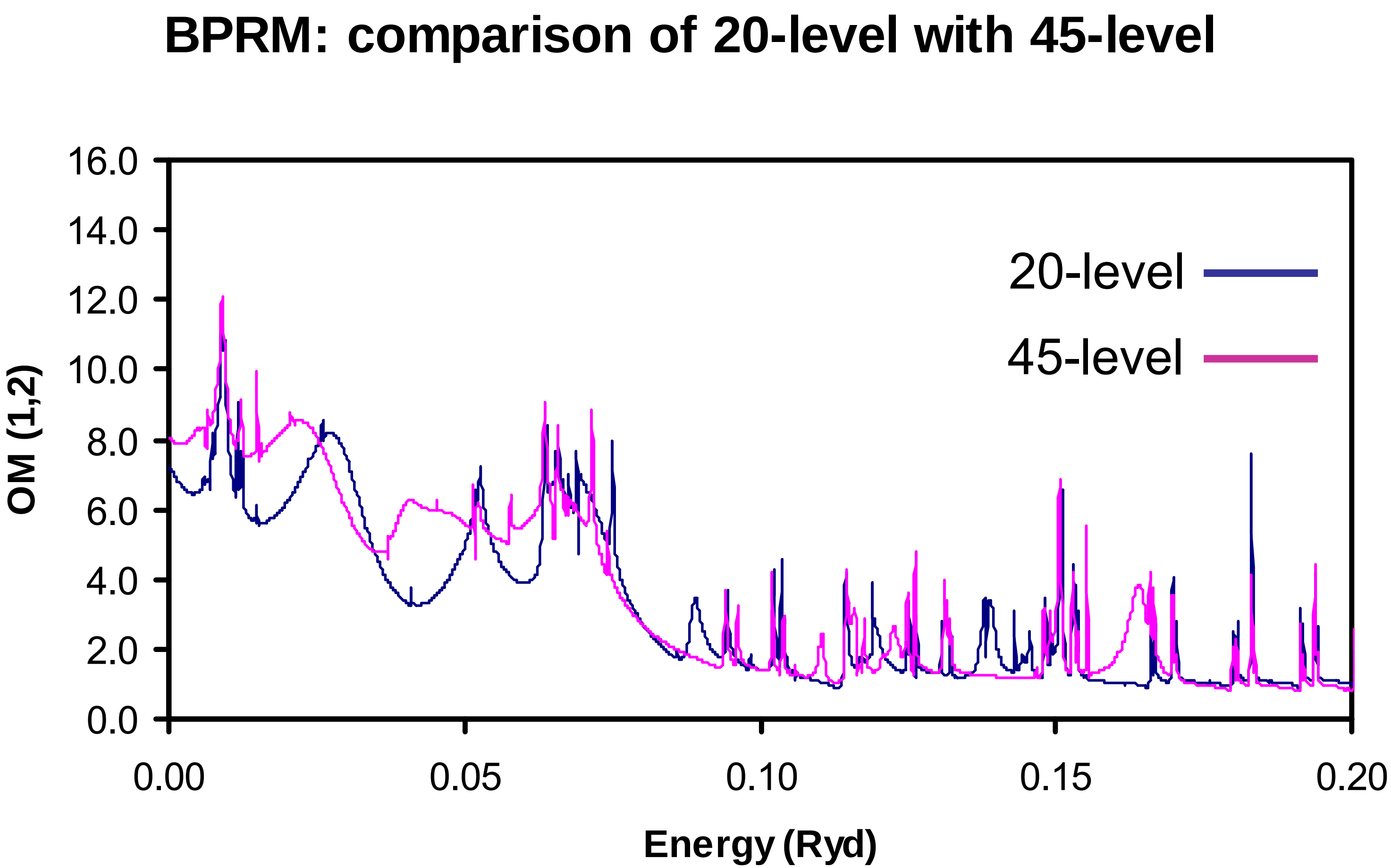
- Target orbitals and representation
  - Fermi-Dirac statistical model (AUTOSTRUCTURE)
  - Relativistic orbitals (GRASP)

- Scattering formalism
  - BPRM
  - DARC

- Term Energy Corrections (BPRM)

$$\psi_i(\mathrm{R}) = \psi_i(\mathrm{NR}) + \sum_{j \neq i} \psi_j(\mathrm{NR}) \times \frac{\langle \psi_j(\mathrm{NR}) \,|\, H(\mathrm{BP}) \,|\, \psi_i(\mathrm{NR}) \rangle}{[E_i(\mathrm{NR}) - E_j(\mathrm{NR})]} + \ldots$$

The near-threshold resonances are sensitive to target representation but do not go below threshold



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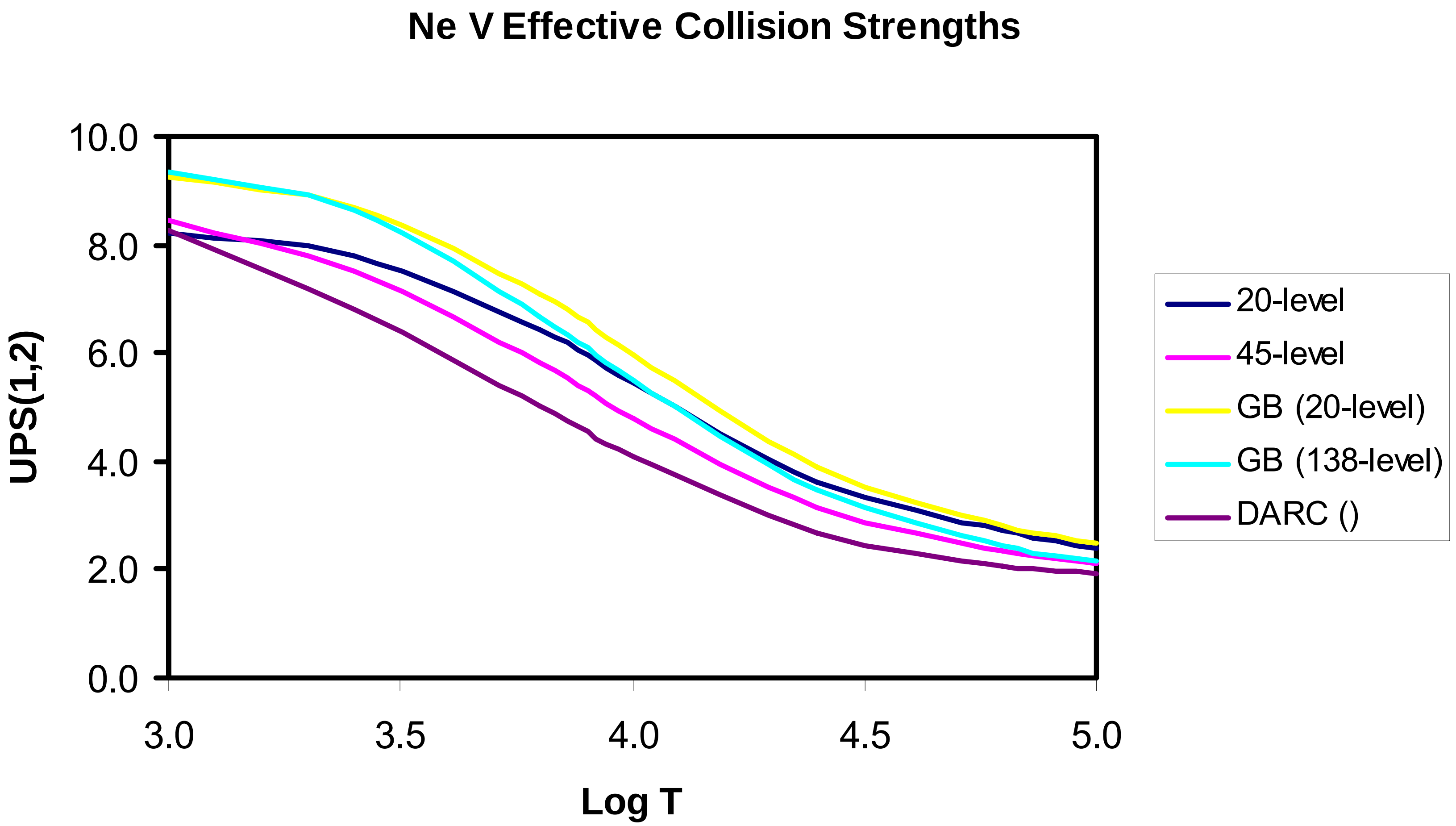
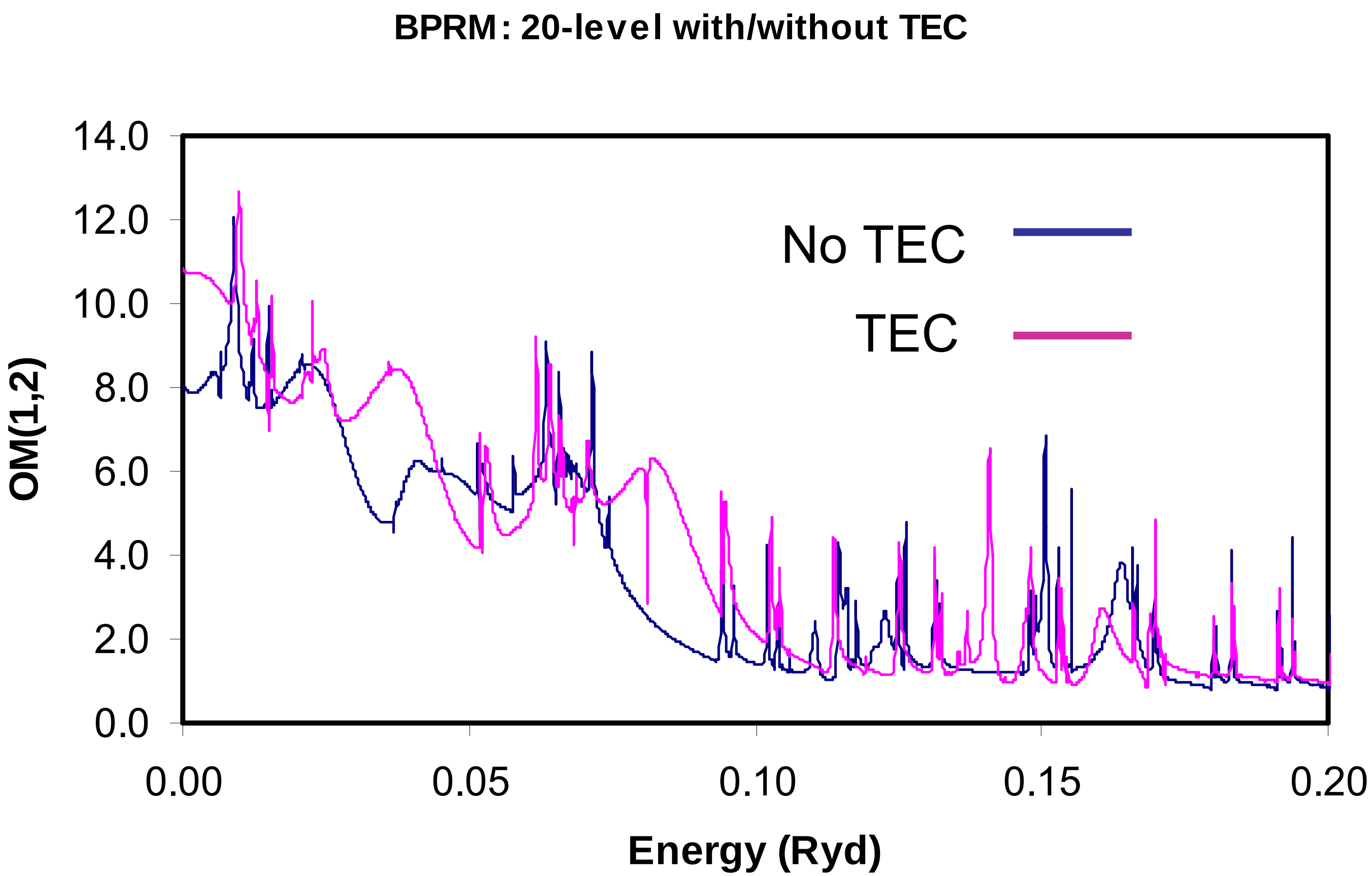
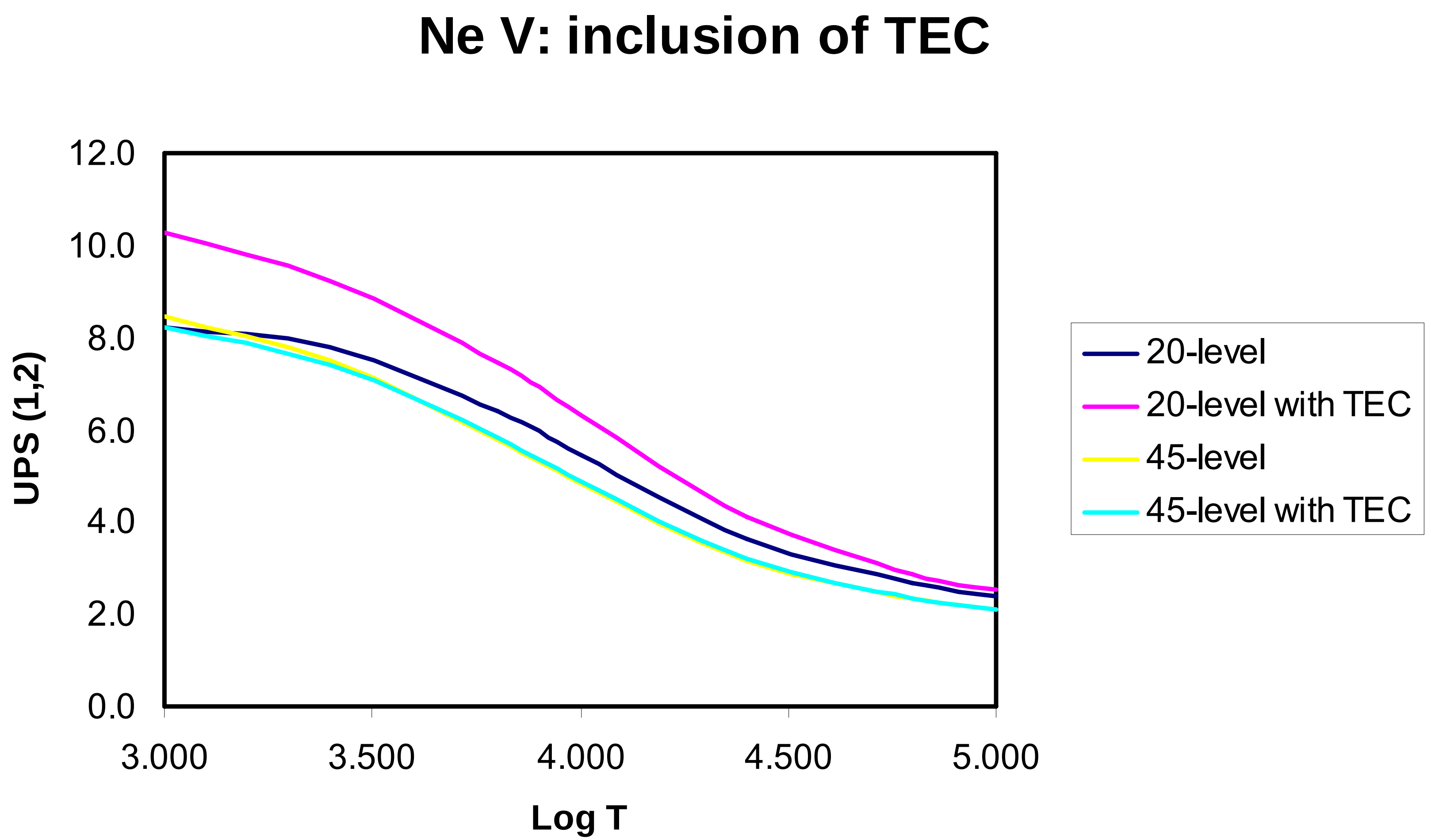


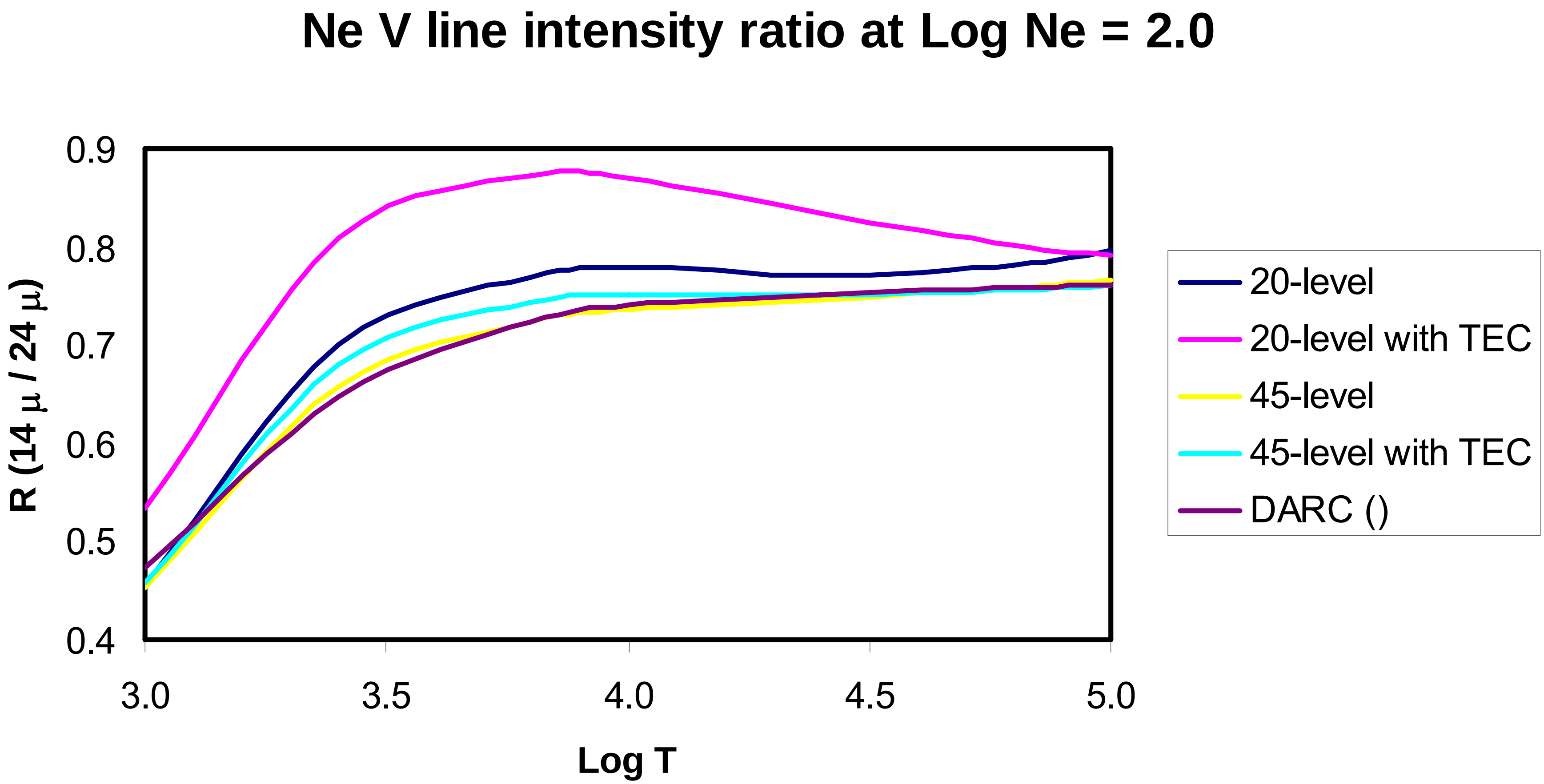
The near-threshold resonances are sensitive to TEC but do not go below threshold



The near-threshold resonances are sensitive to TEC but do not go below threshold



[Ne V] (14 μm/24 μm) at Log Ne ≤ 2 and Log T ≥ 4 is constant at ~0.74



Conclusions

- We agree with van Hoof et al. (2000) that the electron impact effective collision strengths for Ne V $2s^2 2p^2$ are accurate to better than 30% for Log T $\geq$ 4
- We find the low-density limit of [Ne V] (14 μm/24 μm) somewhat lower (0.74) than that (0.83) obtained by Griffin & Badnell (2000)
- The problems with the observed [Ne V] (14 μm/24 μm) low-density limit are not due to inaccuracies in the atomic data
- We recommend similar benchmarking procedures to sort out problems in nebular plasma diagnostics (see presentation by Giulio del Zanna)