Vibrational excitation and dissociation of deuterium molecule by electron impact

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The results of this presentation are in collaboration with:

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$\mathbf{D_2}$ $= \{\mathrm{X}\,^1\Sigma_g^+, \mathrm{b}\,^3\Sigma_u^+, \mathrm{B}\,^1\Sigma_u^+\} = \{\mathrm{X}, \mathrm{b}, \mathrm{B}\}$

$\mathbf{D_2^-}$ $= \{\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+\} = \{\mathrm{X}^-, \mathrm{B}^-, \mathrm{C}^-\}$

Local Complex Potential Model

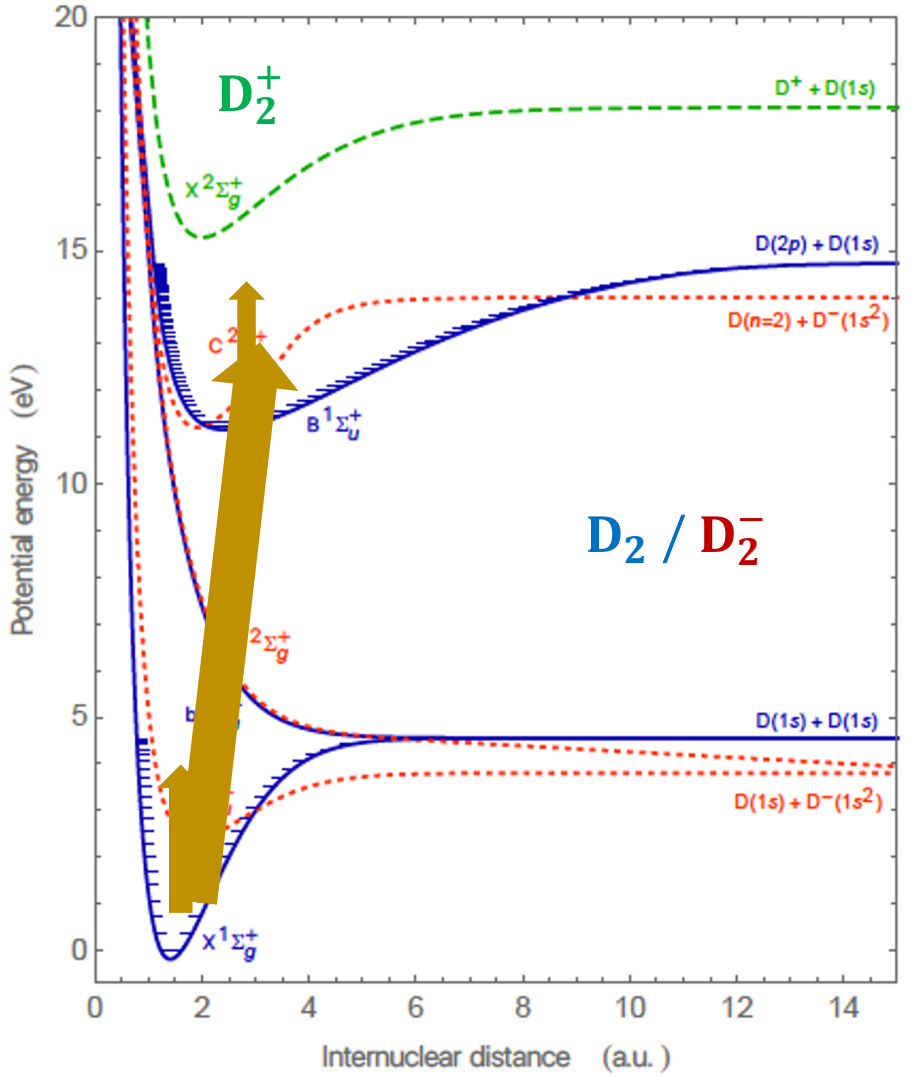
First time (in my knowledge) of using this approach to calculate vibrationally-electronically-excited collisions

Electron-D_2^+ results will be presented by Ioan Schneider

V. Laporta, R. Agnello, G. Fubiani, I. Furno, C. Hill, D. Reiter, and F. Taccogna, *Submitted* (2021)

$$\mathbf{D_2} = \{\mathrm{X}\,^1\Sigma_g^+, \mathrm{b}\,^3\Sigma_u^+, \mathrm{B}\,^1\Sigma_u^+\} = \{\mathrm{X}, \mathrm{b}, \mathrm{B}\}$$

$$\mathbf{D_2^-} = \{\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+\} = \{\mathrm{X}^-, \mathrm{B}^-, \mathrm{C}^-\}$$



Label	Reaction
	Vibrational excitation
VE1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v')$
VE2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v')$
VE3	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v')$
	Dissociative electron attachment
DA1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(1s) + \mathrm{D}^-(1s^2)$
DA2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(n=2) + \mathrm{D}^-(1s^2)$
DA3	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(n=2) + \mathrm{D}^-(1s^2)$
	Dissociative excitation
DE1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$
DE2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{b}\,^3\Sigma_u^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$
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DE6	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$

$$\mathbf{D_2} = \{\mathrm{X}\,^1\Sigma_g^+, \mathrm{b}\,^3\Sigma_u^+, \mathrm{B}\,^1\Sigma_u^+\} = \{\mathrm{X}, \mathrm{b}, \mathrm{B}\}$$

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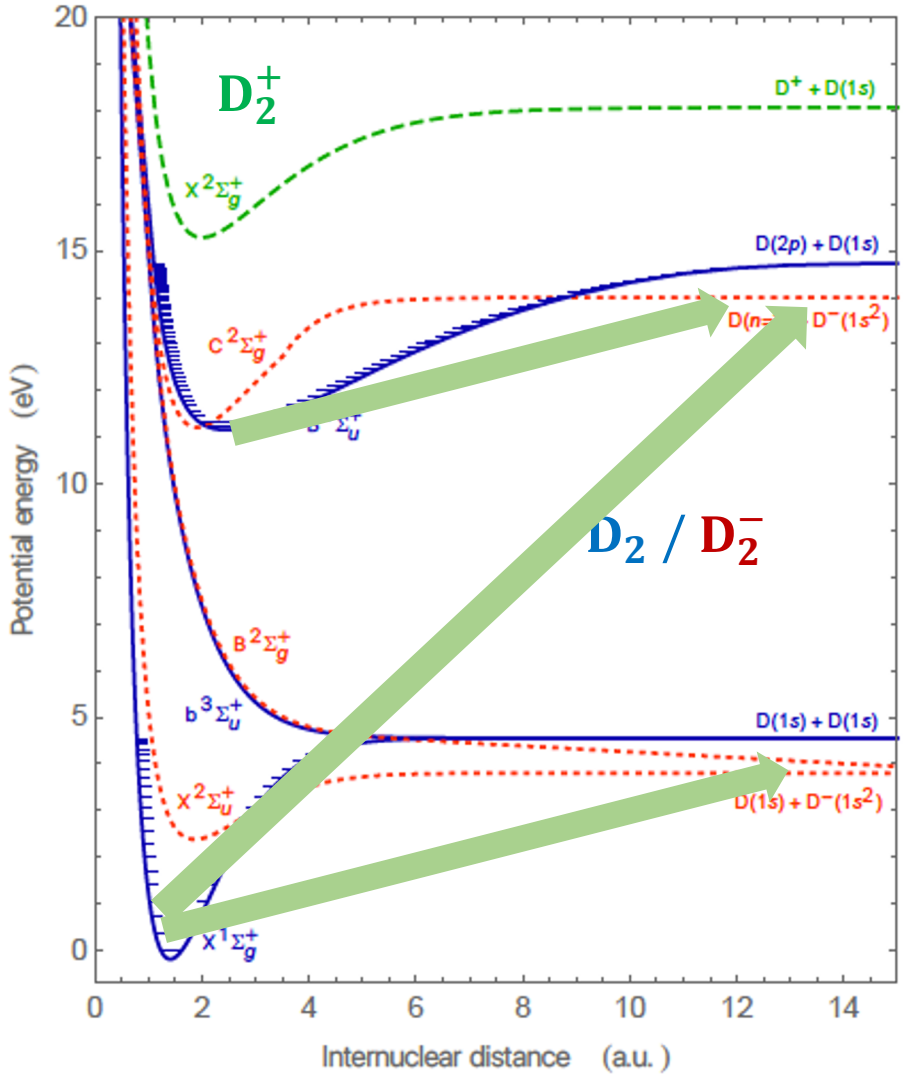

Label	Reaction
	Vibrational excitation
VE1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v')$
VE2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v')$
VE3	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v')$
	Dissociative electron attachment
DA1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(1s) + \mathrm{D}^-(1s^2)$
DA2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(n=2) + \mathrm{D}^-(1s^2)$
DA3	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(n=2) + \mathrm{D}^-(1s^2)$
	Dissociative excitation
DE1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$
DE2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{b}\,^3\Sigma_u^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$
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DE4	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(2p) + \mathrm{D}(1s)$
DE5	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{b}\,^3\Sigma_u^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$
DE6	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$

$$\mathbf{D_2} = \{\mathrm{X}\,^1\Sigma_g^+, \mathrm{b}\,^3\Sigma_u^+, \mathrm{B}\,^1\Sigma_u^+\} = \{\mathrm{X}, \mathrm{b}, \mathrm{B}\}$$

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VE2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v')$
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	Dissociative electron attachment
DA1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(1s) + \mathrm{D}^-(1s^2)$
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	Dissociative excitation
DE1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$
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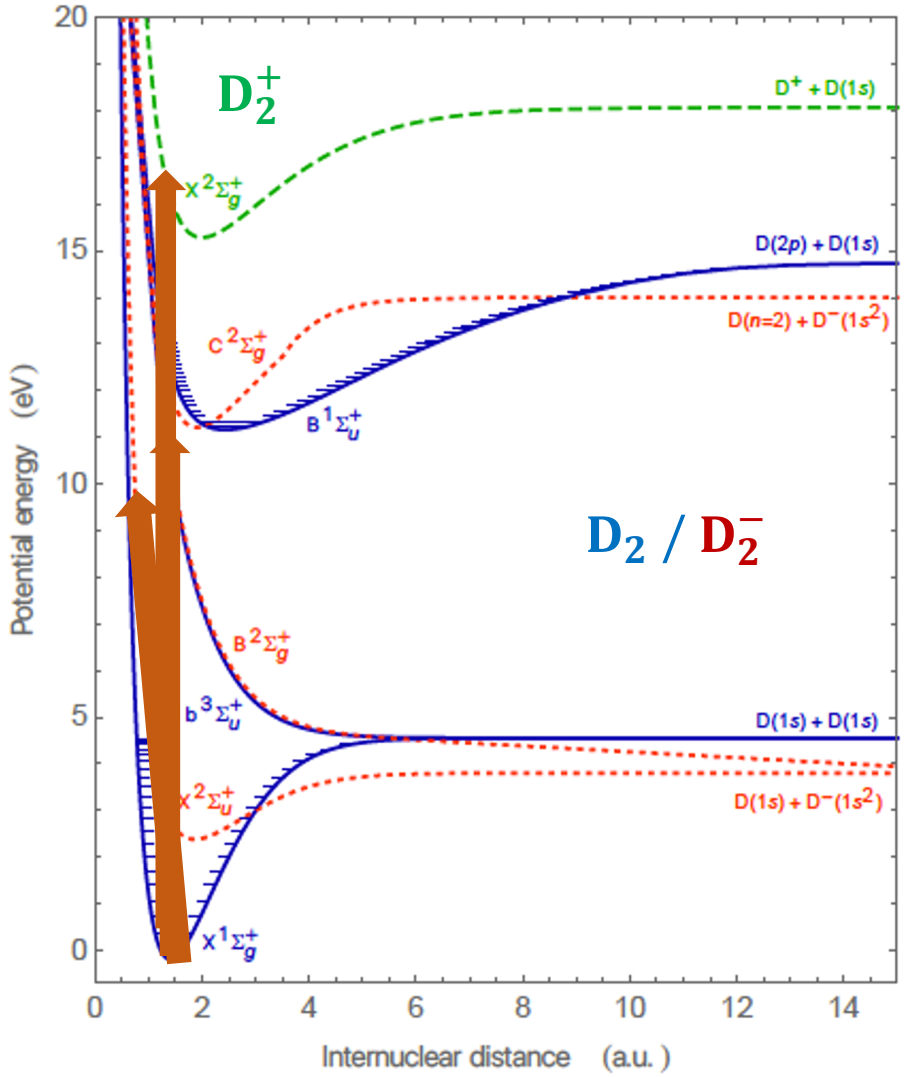
DE6	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$



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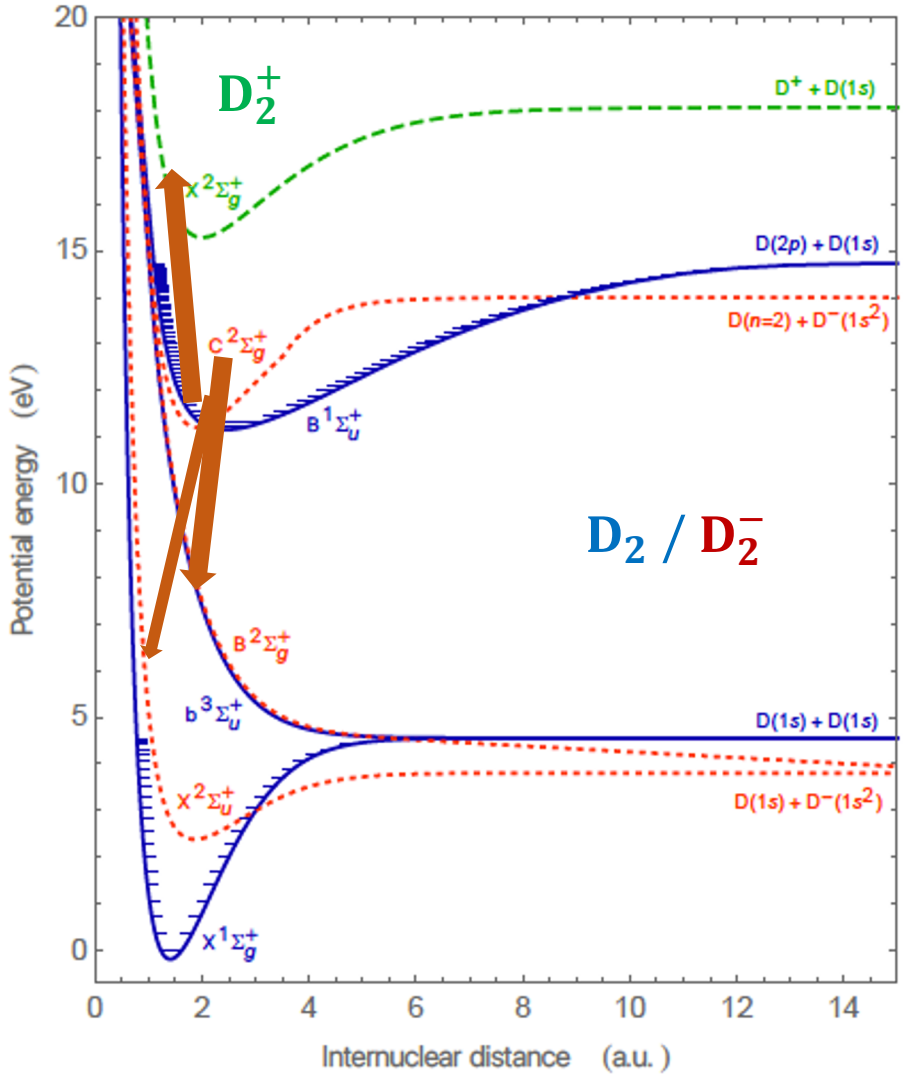

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	Vibrational excitation
VE1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v')$
VE2	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v')$
VE3	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v')$
	Dissociative electron attachment
DA1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+) \rightarrow \mathrm{D}(1s) + \mathrm{D}^-(1s^2)$
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	Dissociative excitation
DE1	$e(\epsilon) + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$
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DE4	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(2p) + \mathrm{D}(1s)$
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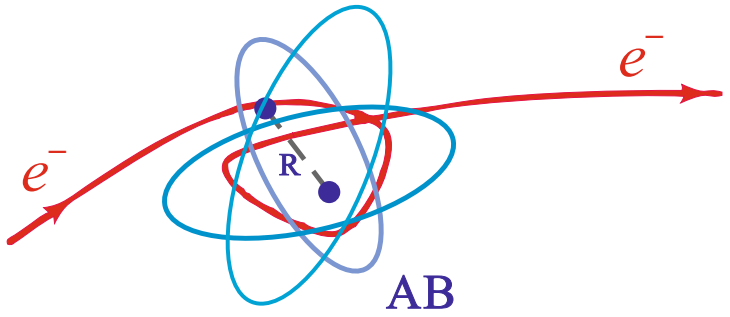
DE6	$e(\epsilon) + \mathrm{D}_2(\mathrm{B}\,^1\Sigma_u^+; v) \rightarrow \mathrm{D}_2^-(\mathrm{C}\,^2\Sigma_g^+) \rightarrow e(\epsilon') + \mathrm{D}_2(\mathrm{X}\,^1\Sigma_g^+; \epsilon_c) \rightarrow e(\epsilon') + \mathrm{D}(1s) + \mathrm{D}(1s)$

Local Complex Potential model for electron-molecule scattering

Processes occurring for resonant electron-molecule scattering:

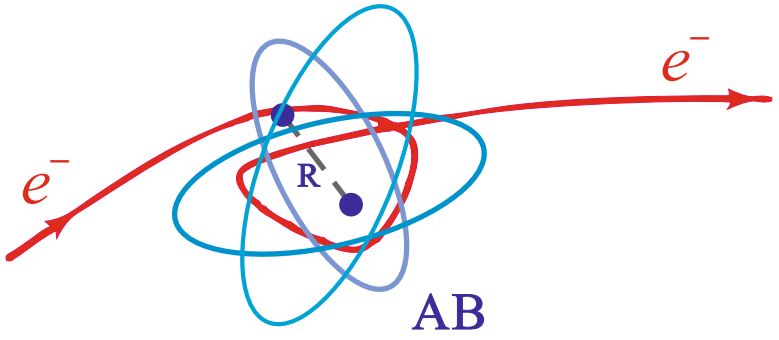
$$e^- + AB(v) \rightarrow AB^- \rightarrow AB\,(w) + e^- \qquad Vibrational\ Excitation$$
$$\rightarrow A^- + B \qquad Dissociative\ Attachment$$
$$\rightarrow A\ + B + e^- \qquad Dissociative\ Excitation$$
$$e^- + AB^+(v) \rightarrow AB^* \rightarrow A\ + B \qquad Dissociative\ Recombination$$

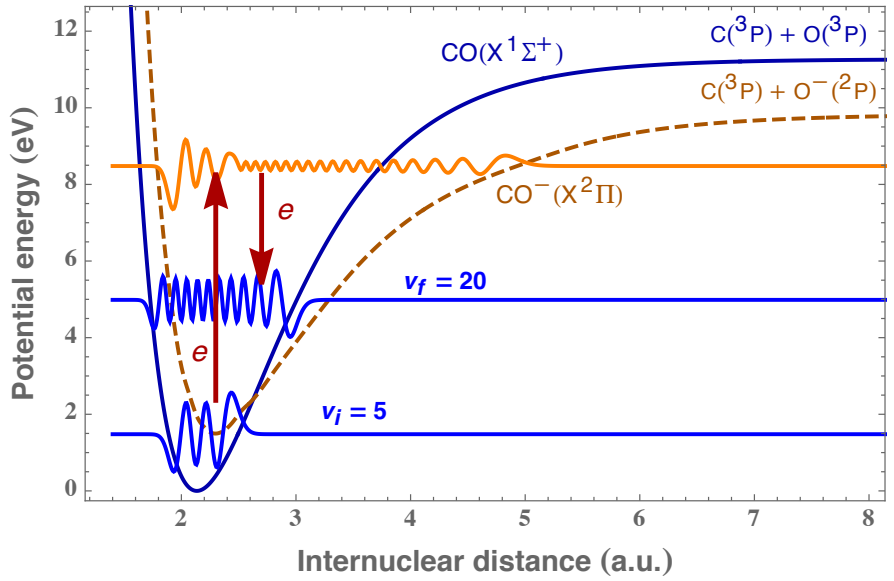


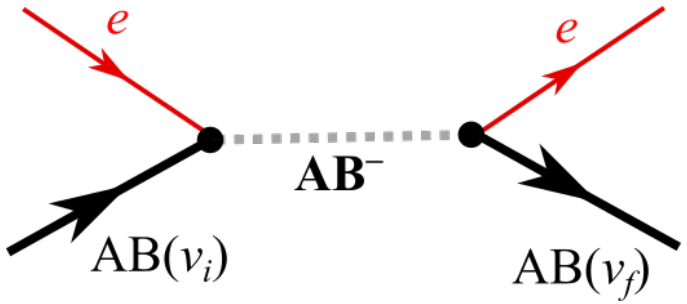
MQDT approach for electron-D_2^+ will be presented by Ioan Schneider

Local Complex Potential model

$$e + AB(v_i) \rightarrow AB^- \rightarrow e + AB(v_f)$$







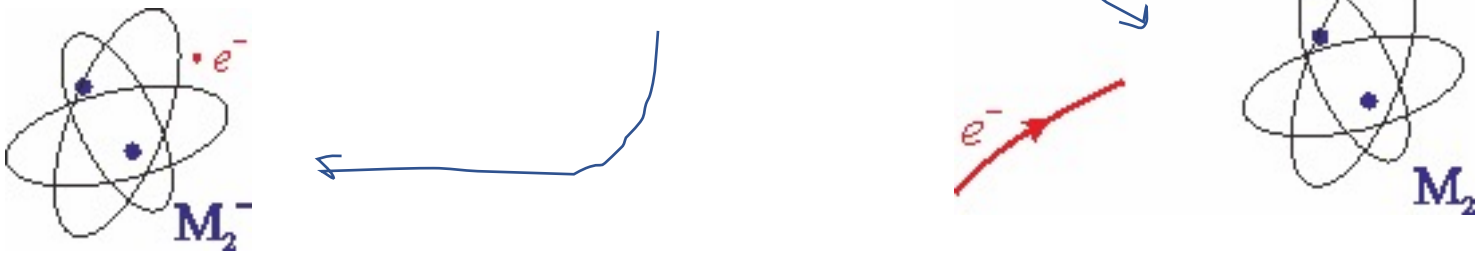
Some theoretical details

Let's consider electron-molecule scattering with the presence of two interacting resonances:

$$e^- + M \rightarrow {M_1}^-, {M_2}^- \rightarrow e^- + M^*$$

The process can be described by two discrete electronic states, $|d_1\rangle$ and $|d_2\rangle$, *embedded-in* and *interacting-with* a single electronic continuum $|\vec{k}\rangle$

$$|\Psi\rangle \sim |d_1\rangle + |d_2\rangle + |\vec{k}\rangle$$



Resonant bound state

Interaction between
electron and neutral molecule

The electron-molecule effective Hamiltonian

$$\boldsymbol{H = H_0 + U + V}$$

$$H_0 = \left|d_1\right\rangle(T_N + V_0 + \epsilon_1)\left\langle d_1\right| + \left|d_2\right\rangle(T_N + V_0 + \epsilon_2)\left\langle d_2\right| + \int d\vec{k}\ \left|\vec{k}\right\rangle(T_N + V_0 + \epsilon_{\vec{k}})\left\langle\vec{k}\right|$$

$$U = \cancel{\left|d_1\right\rangle U_{12}\left\langle d_2\right|} + \text{h. c.}$$

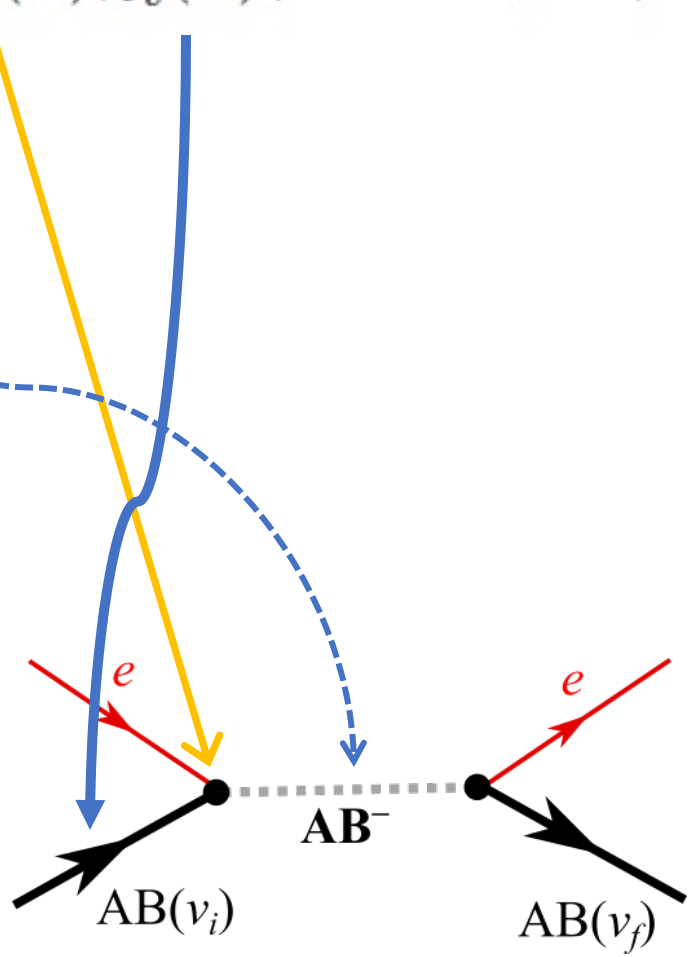
$$V = \int d\vec{k}\ \left|d_1\right\rangle V_{1k}\left\langle\vec{k}\right| + \left|d_2\right\rangle V_{2k}\left\langle\vec{k}\right| + \text{h. c.}$$

- V_0 is the neutral molecule potential
- $\epsilon_{1,2}$ are the resonance energies respect to V_0
- *U* describes the coupling between the discrete states
- *V* couples the discrete states with the continuum states

$$\left[-\frac{\hbar^2}{2\mu}\frac{d^2}{dR^2} + V_r^-(R) - \frac{i}{2}\Gamma_r(R) - E\right]\xi_{s,v}^r(R) = -\mathcal{V}_r^s(R)\,\chi_v^s(R)\,, \qquad r \in \mathcal{R}\,,$$

$$\mathcal{V}_r^{s2} = \frac{\hbar}{2\pi}\frac{\Gamma_r^s}{k}\,, \qquad \Gamma_r = \sum_{s\in\mathcal{S}}\Gamma_r^s\,, \qquad r \in \mathcal{R}\,.$$

$$\mathcal{S} = \{\mathrm{X}\,^1\Sigma_g^+, \mathrm{b}\,^3\Sigma_u^+, \mathrm{B}\,^1\Sigma_u^+\} = \{\mathrm{X}, \mathrm{b}, \mathrm{B}\}$$
$$\mathcal{R} = \{\mathrm{X}\,^2\Sigma_u^+, \mathrm{B}\,^2\Sigma_g^+, \mathrm{C}\,^2\Sigma_g^+\} = \{\mathrm{X}^-, \mathrm{B}^-, \mathrm{C}^-\}$$



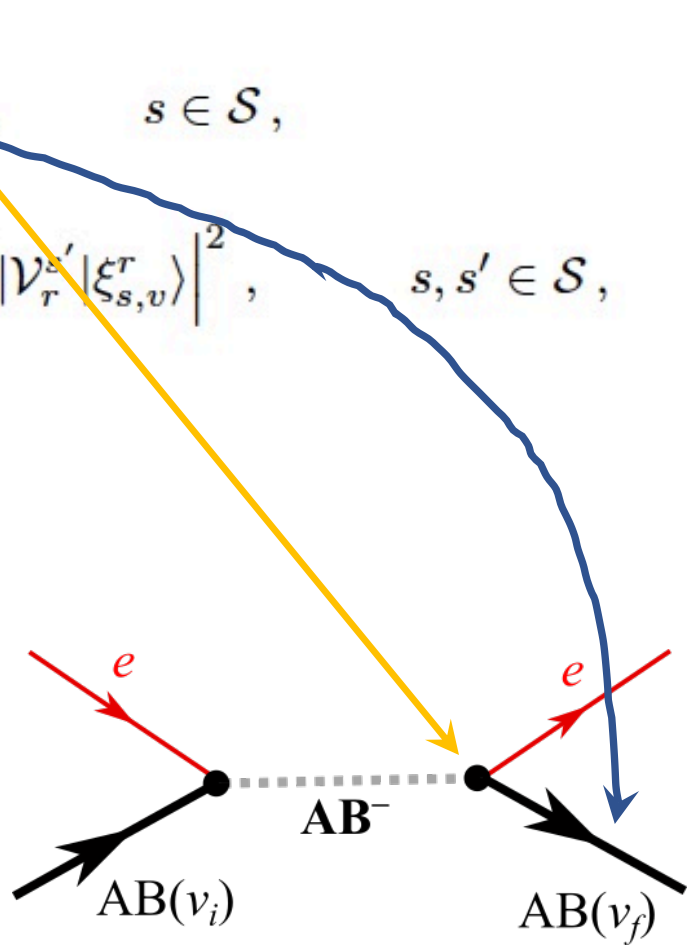
$$\sigma^{\mathrm{VE}}_{s,v\to s',v'}(\epsilon) = \sum_{r\in\mathcal{R}} \frac{2S_r+1}{(2S_s+1)\,2}\frac{g_r}{g_s\,2}\frac{64\,\pi^5\,m^2}{\hbar^4}\frac{k'}{k}\left|\langle\chi^{s'}_{v'}|\mathcal{V}^{s'}_{r}|\xi^{r}_{s,v}\rangle\right|^2, \qquad s,s'\in\mathcal{S},$$

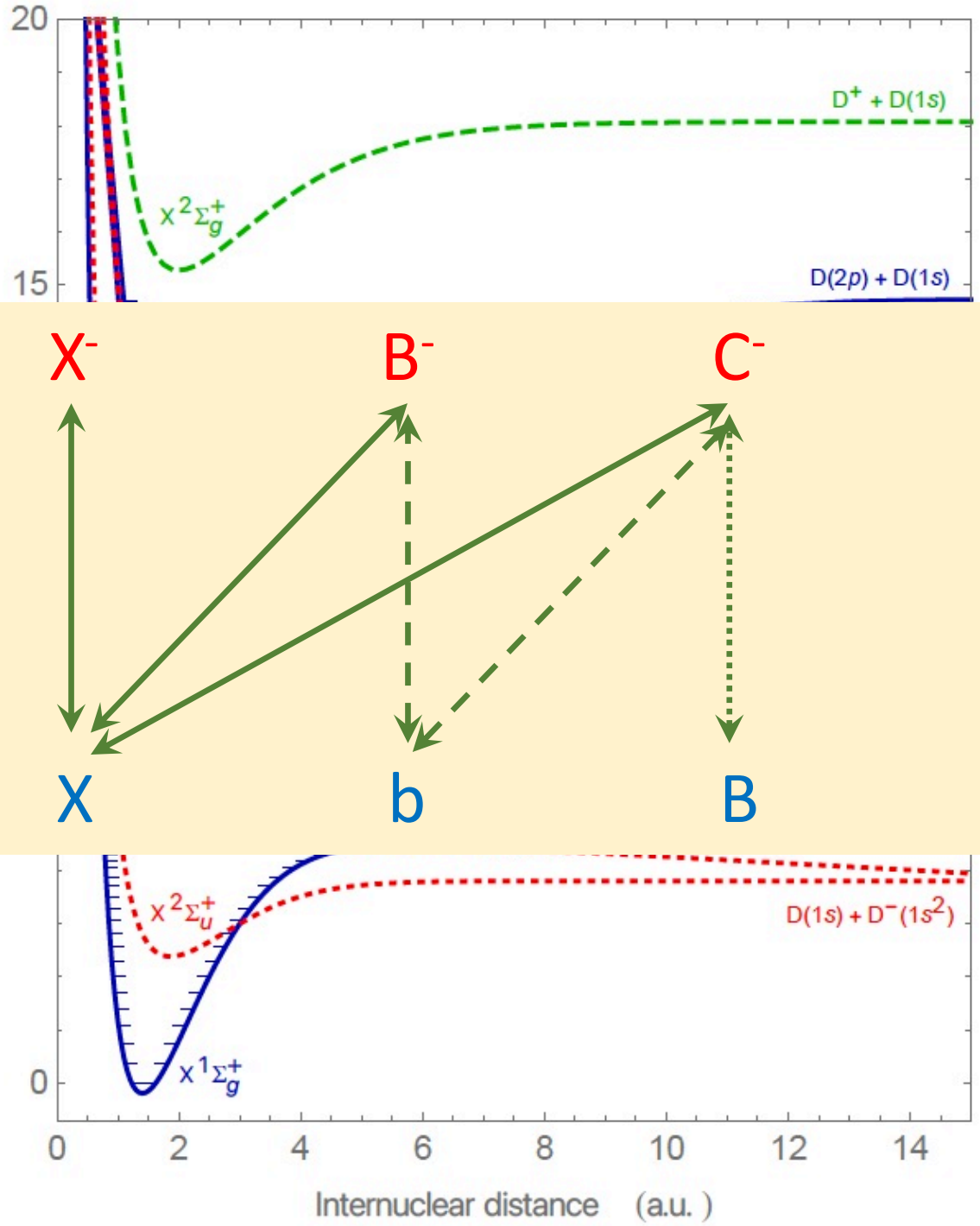
$$\sigma^{\mathrm{DA}}_{s,v}(\epsilon) = \sum_{r\in\mathcal{R}} \frac{2S_r+1}{(2S_s+1)\,2}\frac{g_r}{g_s\,2}2\pi^2\,\frac{K}{\mu}\,\frac{m}{k}\lim_{R\to\infty}\left|\xi^{r}_{s,v}(R)\right|^2, \qquad s\in\mathcal{S},$$

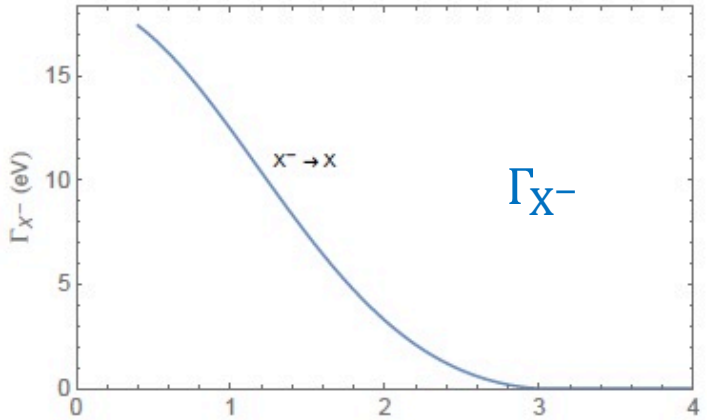
$$\sigma^{\mathrm{DE}}_{s,v}(\epsilon) = \sum_{r\in\mathcal{R}} \frac{2S_r+1}{(2S_s+1)\,2}\frac{g_r}{g_s\,2}\frac{64\,\pi^5\,m^2}{\hbar^4}\int_{\epsilon^{th}}^{\epsilon^{max}} d\epsilon_c\,\frac{k'}{k}\left|\langle\chi^{s'}_{c}|\mathcal{V}^{s'}_{r}|\xi^{r}_{s,v}\rangle\right|^2, \qquad s,s'\in\mathcal{S},$$

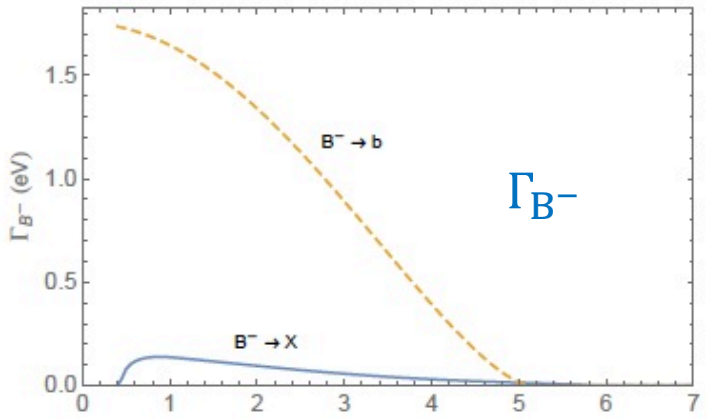
$$\mathcal{S} = \{\mathrm{X}\,^1\Sigma^+_g, \mathrm{b}\,^3\Sigma^+_u, \mathrm{B}\,^1\Sigma^+_u\} = \{\mathrm{X},\mathrm{b},\mathrm{B}\}$$

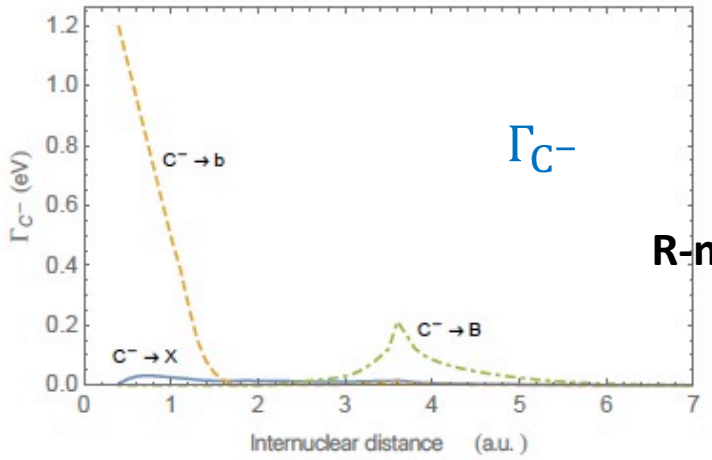
$$\mathcal{R} = \{\mathrm{X}\,^2\Sigma^+_u, \mathrm{B}\,^2\Sigma^+_g, \mathrm{C}\,^2\Sigma^+_g\} = \{\mathrm{X}^-,\mathrm{B}^-,\mathrm{C}^-\}$$





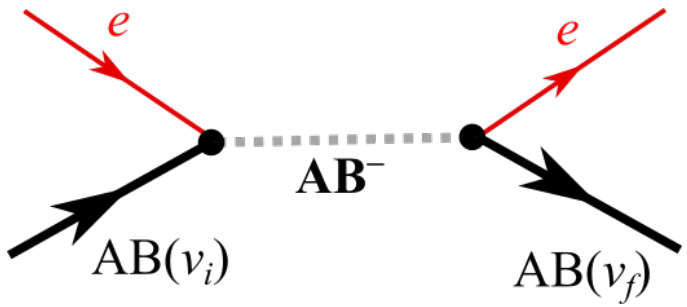
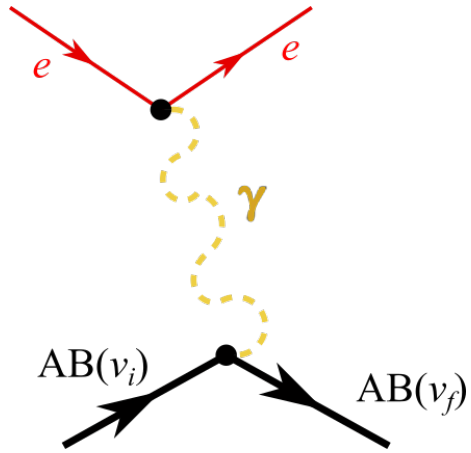






R-matrix calculations

Beyond LCP model...

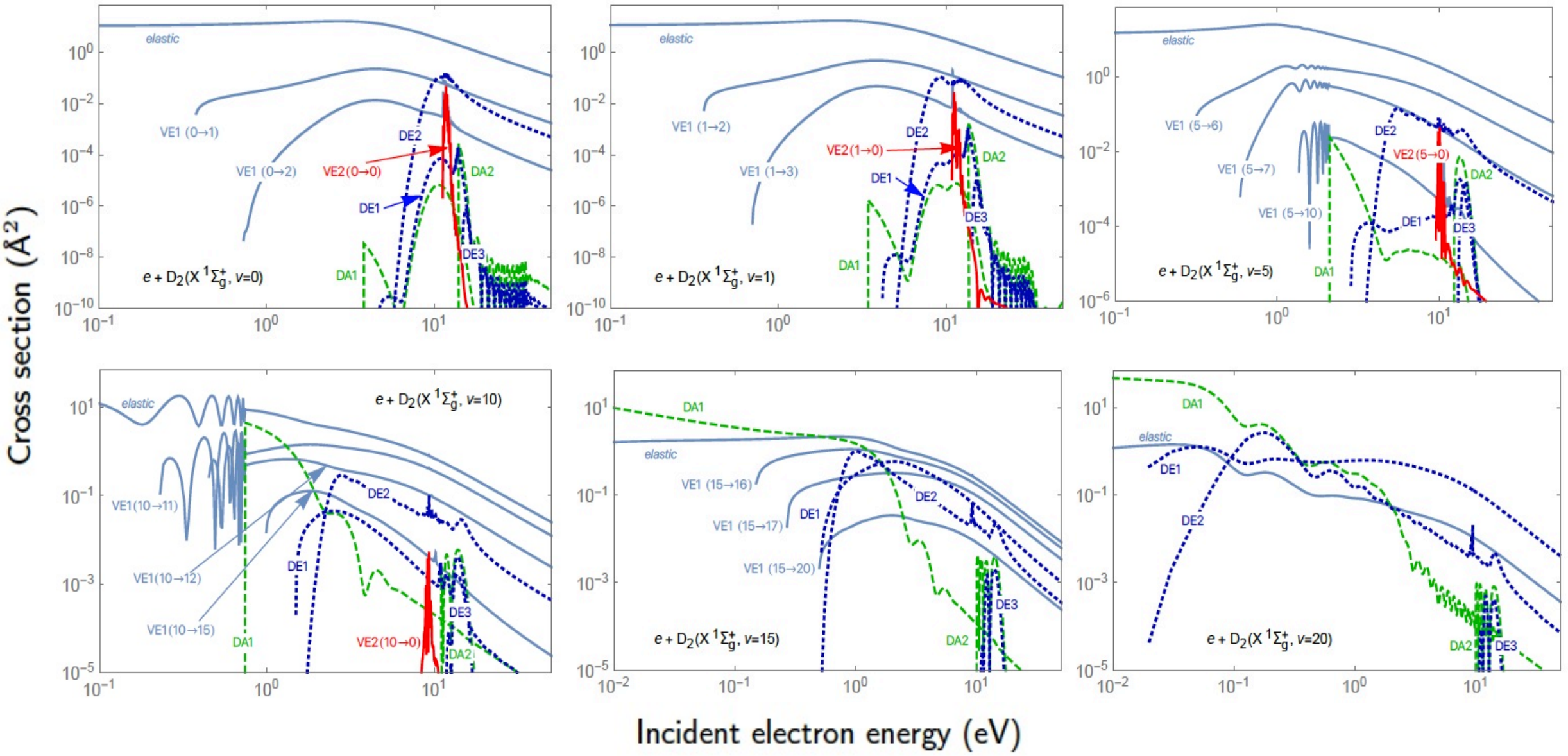
$$\sigma(\epsilon) \propto \left| \text{  } + \text{  } \right|^2$$

Local Complex Potential model

Resonant contribution

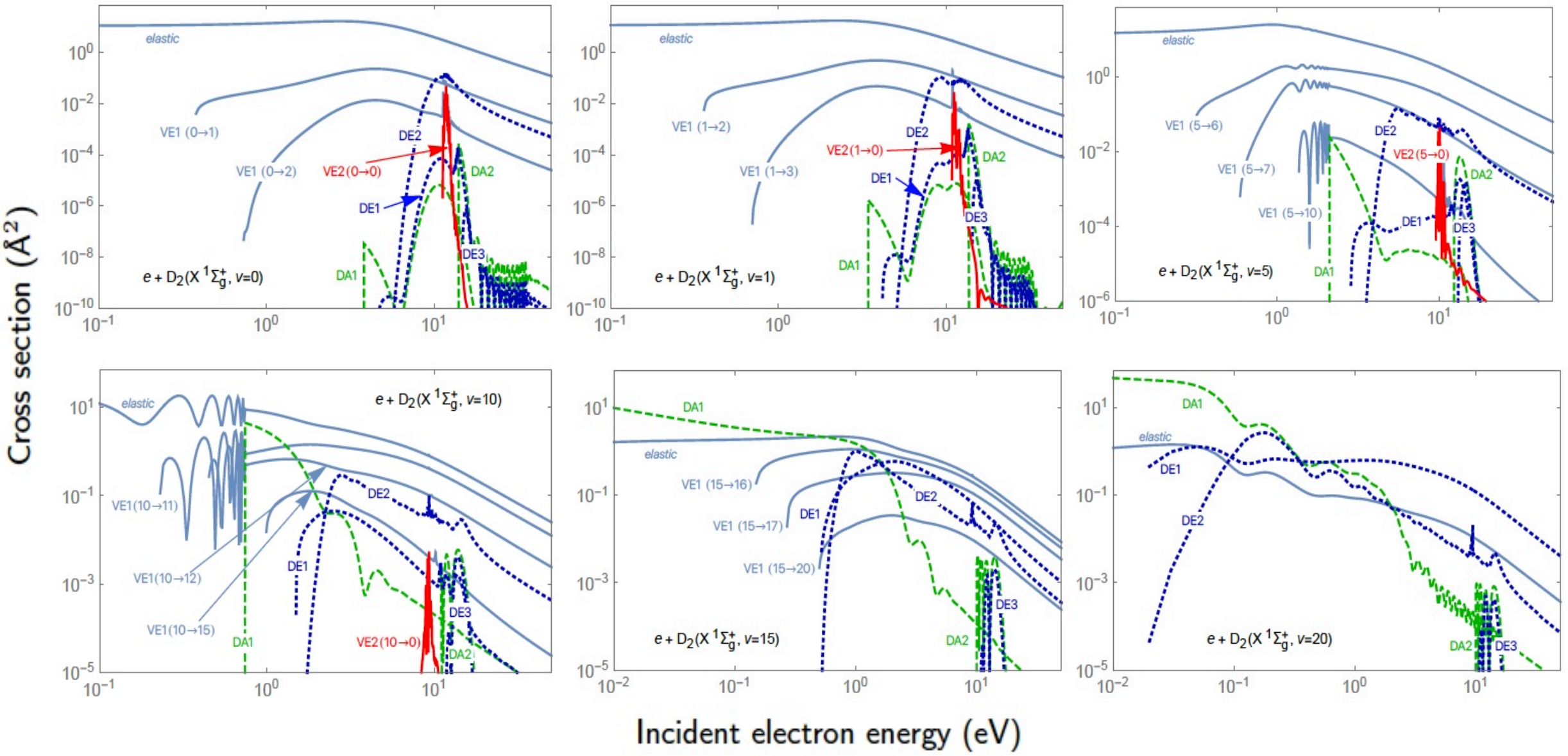
"non-resonant" contribution

$e + D_2(X, v) \rightarrow e + D_2(X, w)$ elastic, VE1

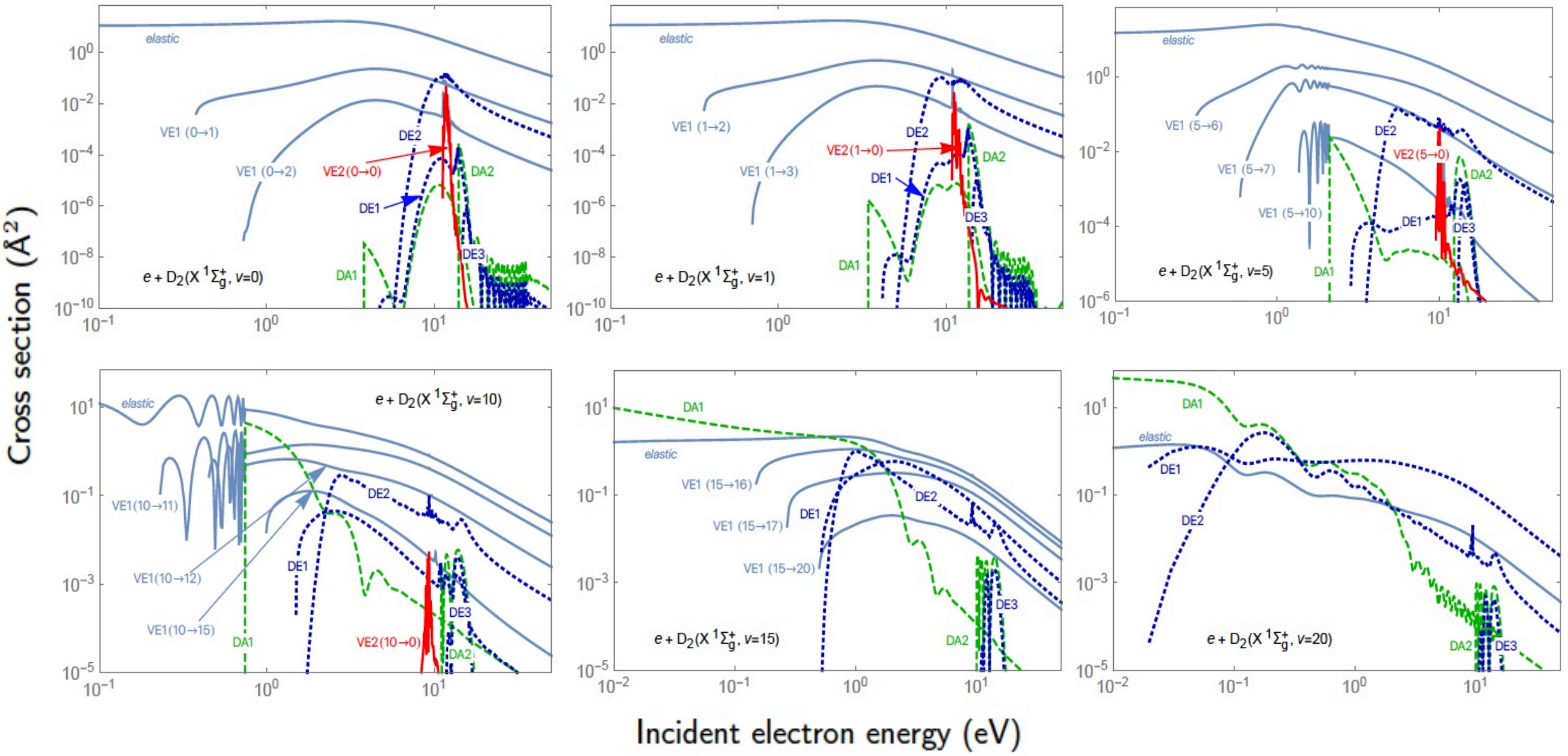


$e + D_2(X, v) \rightarrow D(1s) + D^-(1s^2)$ DA1

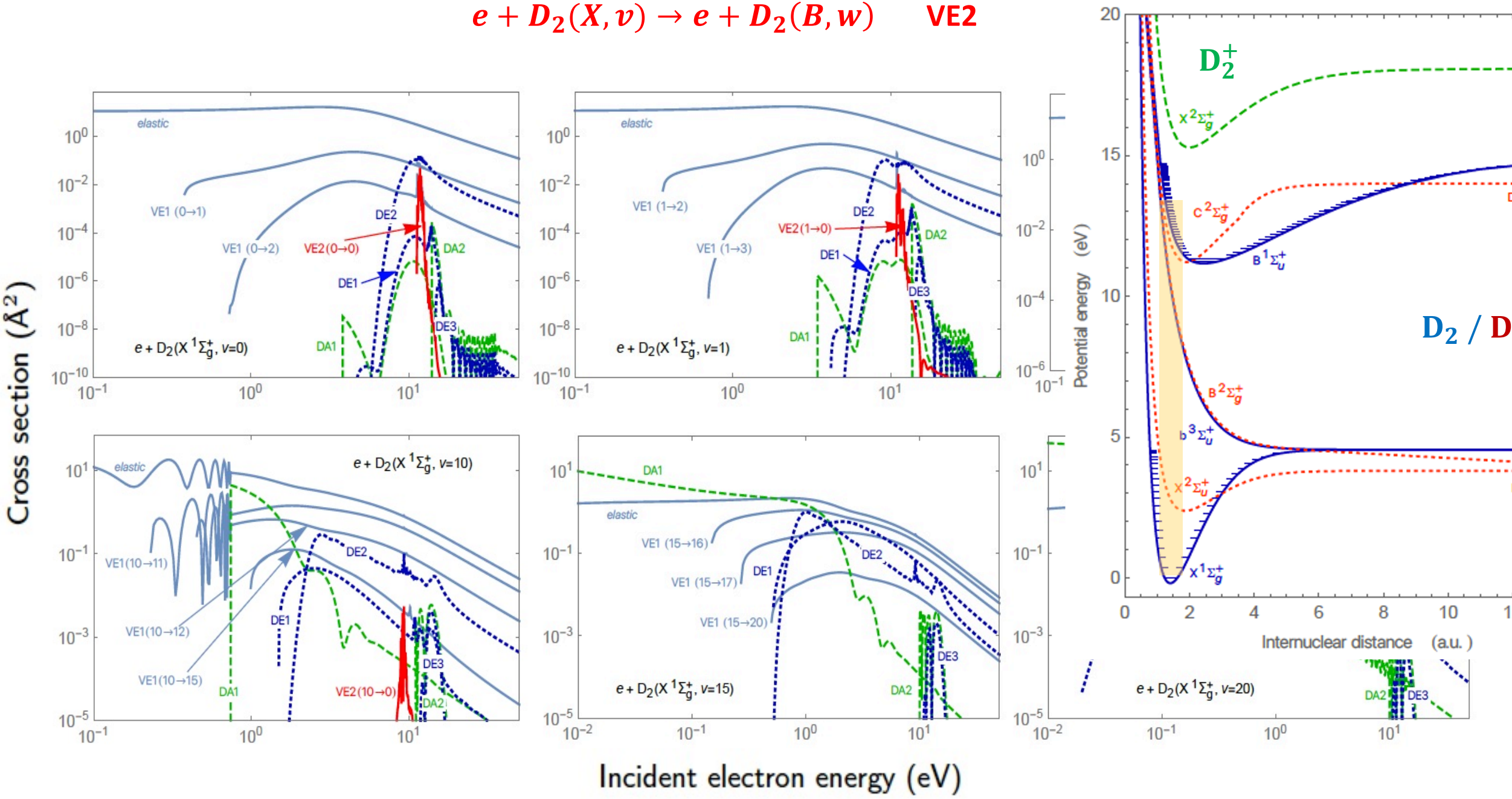
$e + D_2(X, v) \rightarrow D(n = 2) + D^-(1s^2)$ DA2



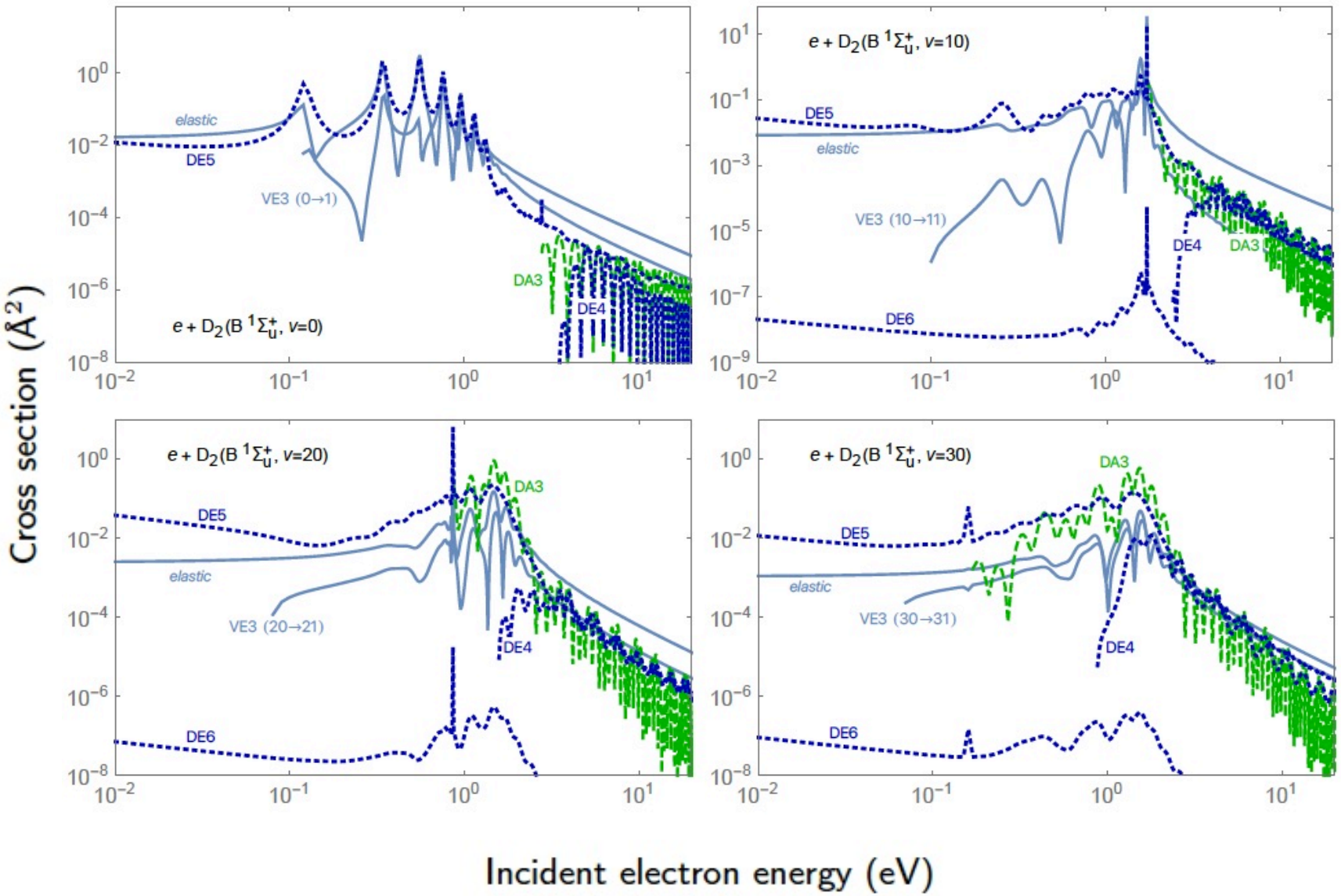
$$e + D_2(X, v) \rightarrow e + D(1s) + D(1s) \quad \textbf{DE1}$$
$$e + D_2(X, v) \rightarrow e + D(1s) + D(1s) \quad \textbf{DE2}$$
$$e + D_2(X, v) \rightarrow e + D(2p) + D(1s) \quad \textbf{DE3}$$



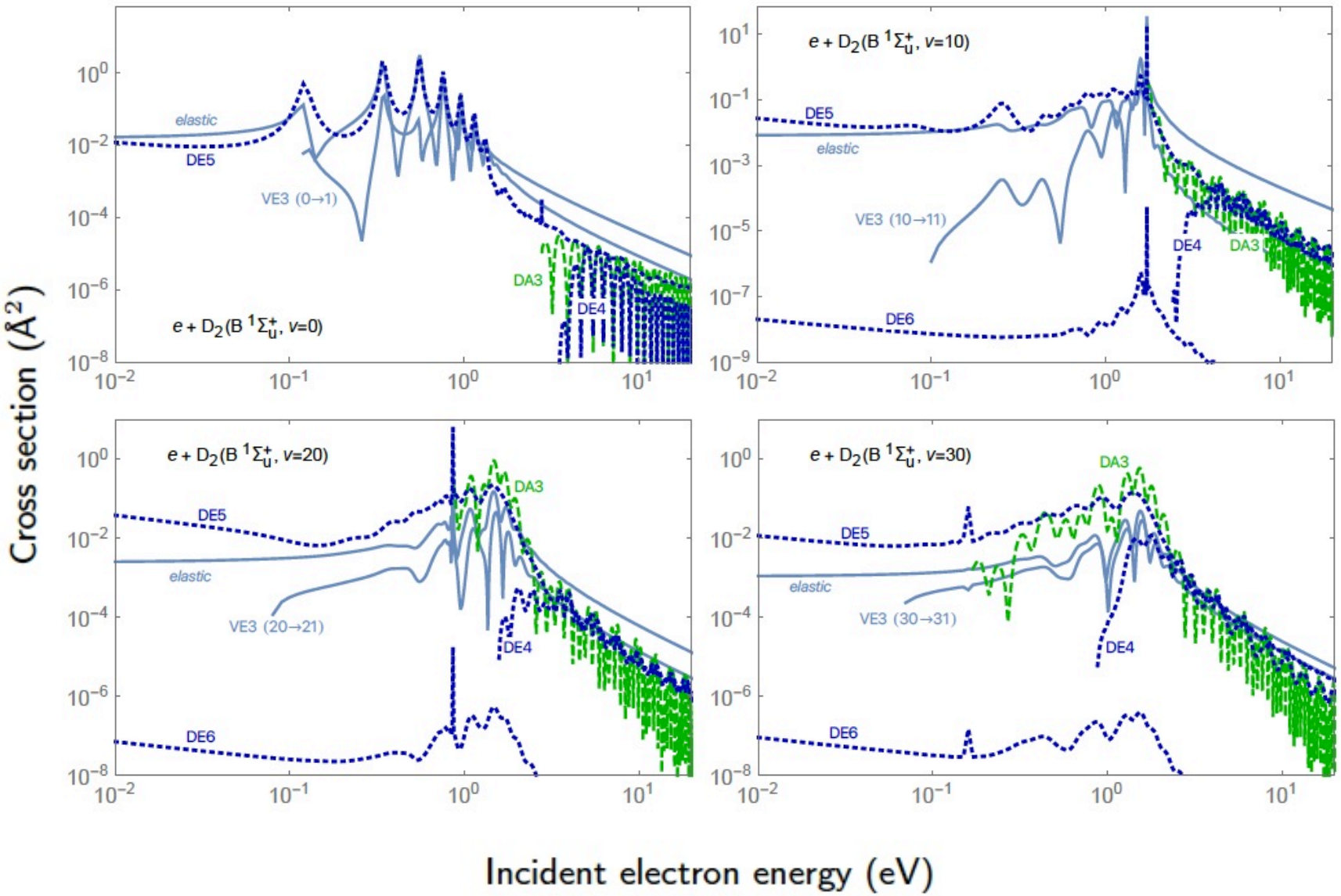
$e + D_2(X, v) \rightarrow e + D_2(B, w)$ **VE2**



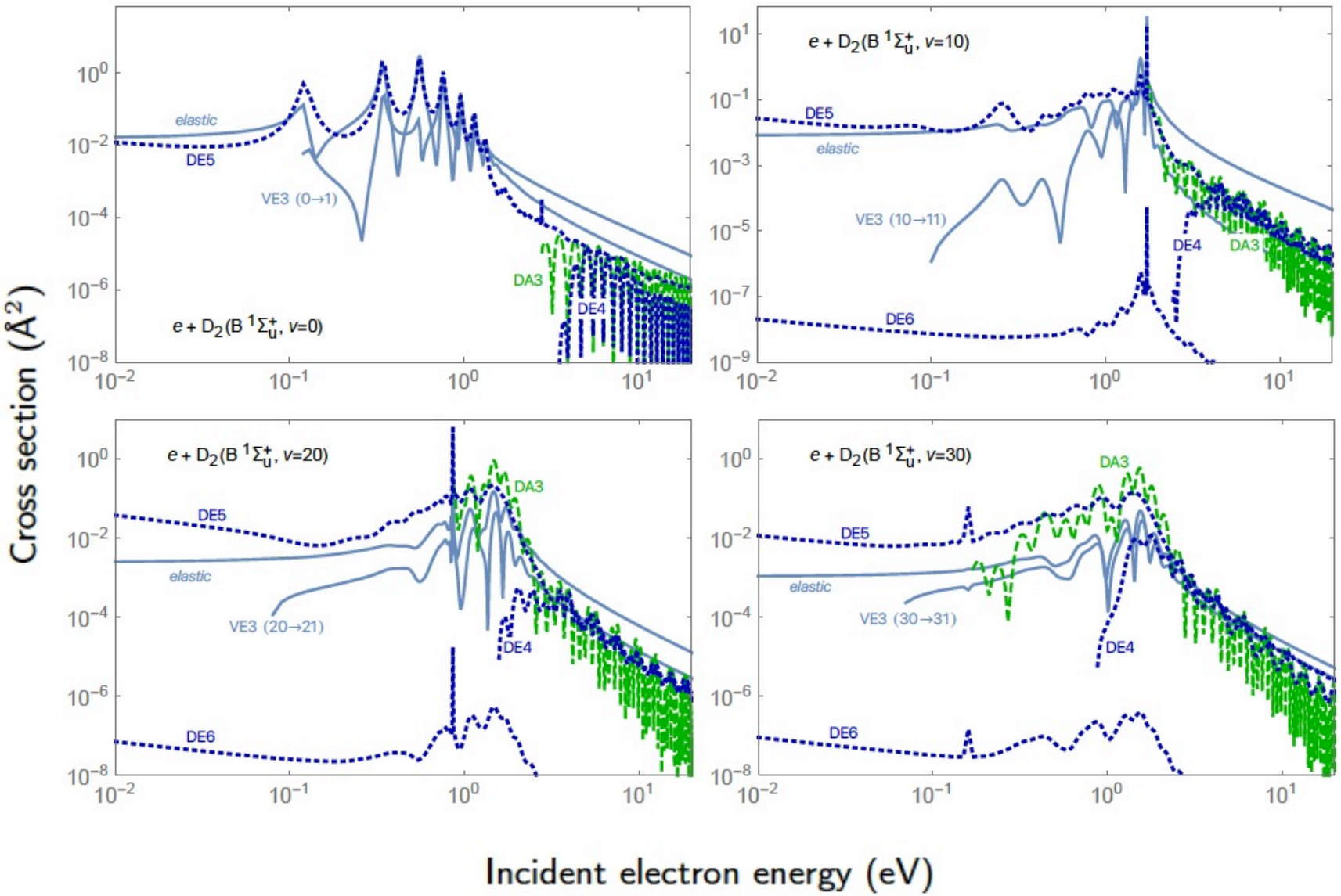
$e + D_2(B, v) \rightarrow e + D_2(B, w)$ elastic, VE3



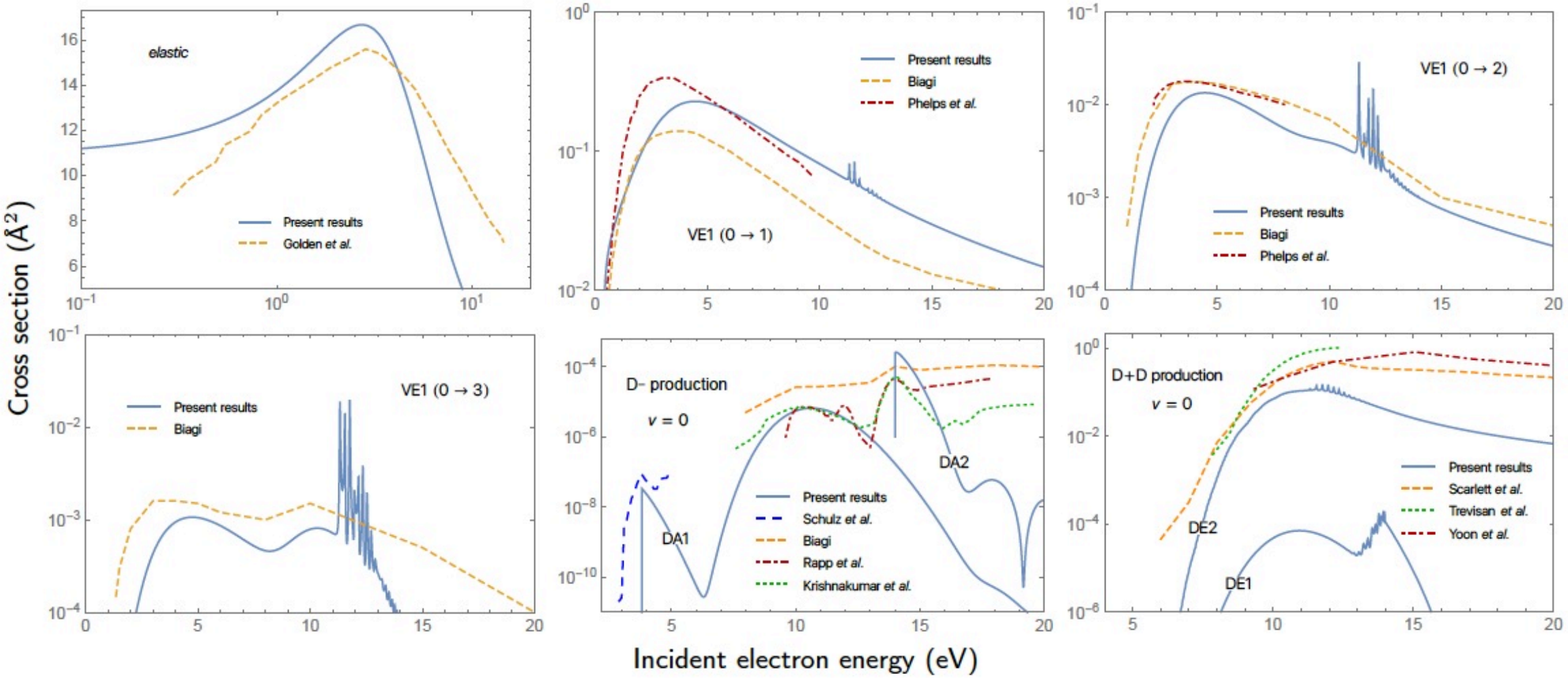
$$e + D_2(B, v) \rightarrow D(n = 2) + D^-(1s^2) \qquad \textbf{DA3}$$



$$e + D_2(B, v) \rightarrow e + D(2p) + D(1s) \qquad \textbf{DE4}$$
$$e + D_2(B, v) \rightarrow e + D(1s) + D(1s) \qquad \textbf{DE5}$$
$$e + D_2(B, v) \rightarrow e + D(1s) + D(1s) \qquad \textbf{DE6}$$

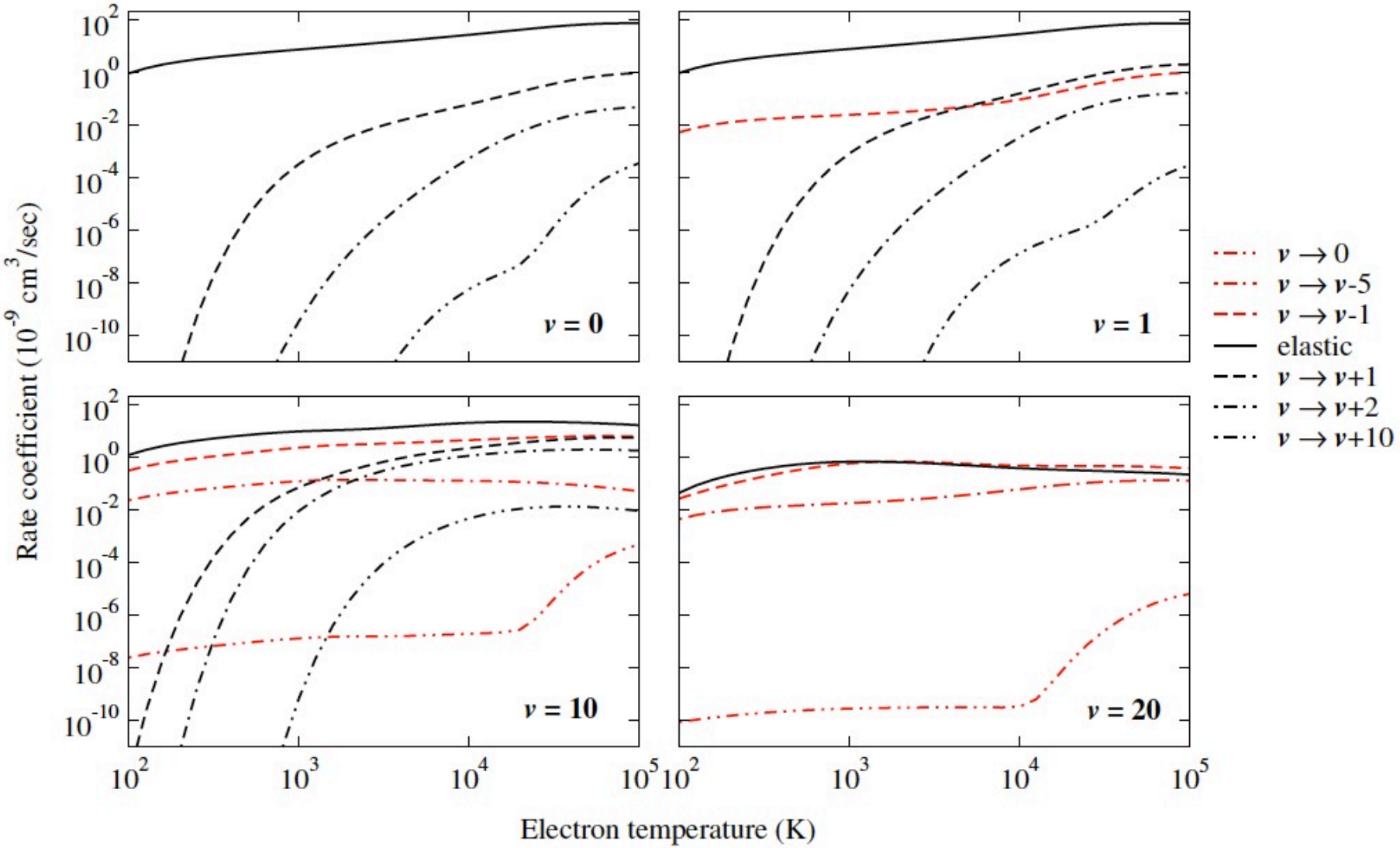


Comparison with data in literature

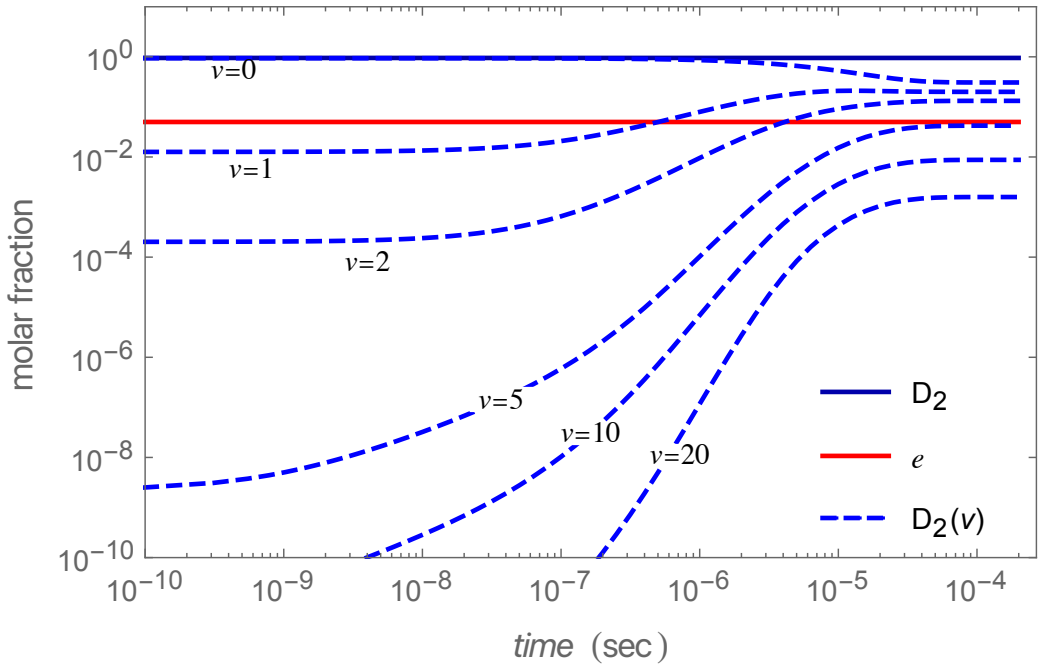


Vibrational relaxation of $D_2(X)$

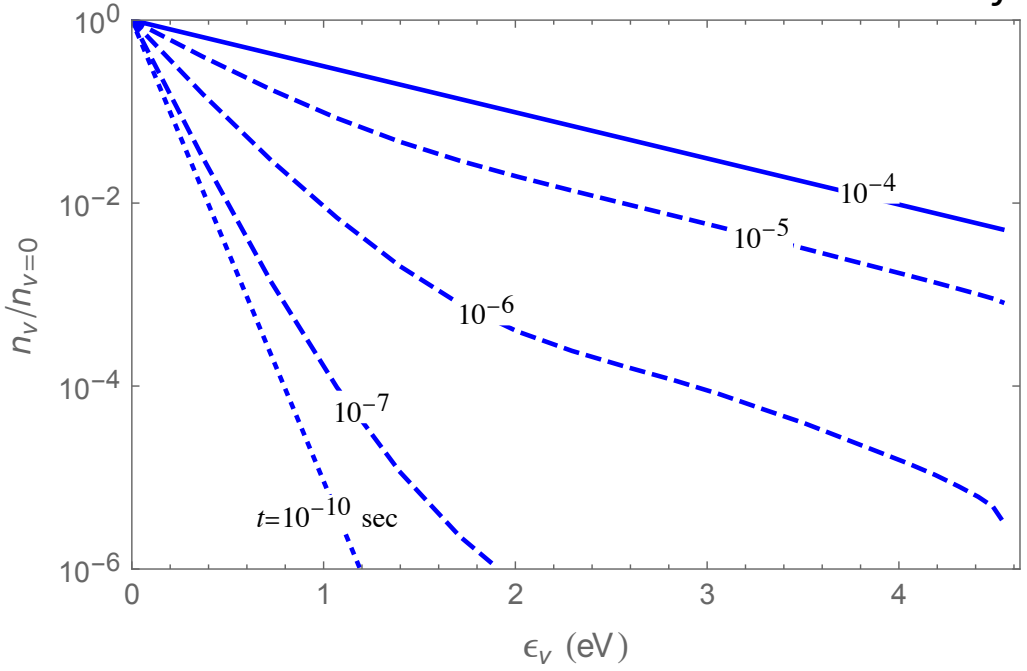
$$e + D_2(X, v) \rightarrow e + D_2(X, w)$$



Vibrational relaxation of $D_2(X)$



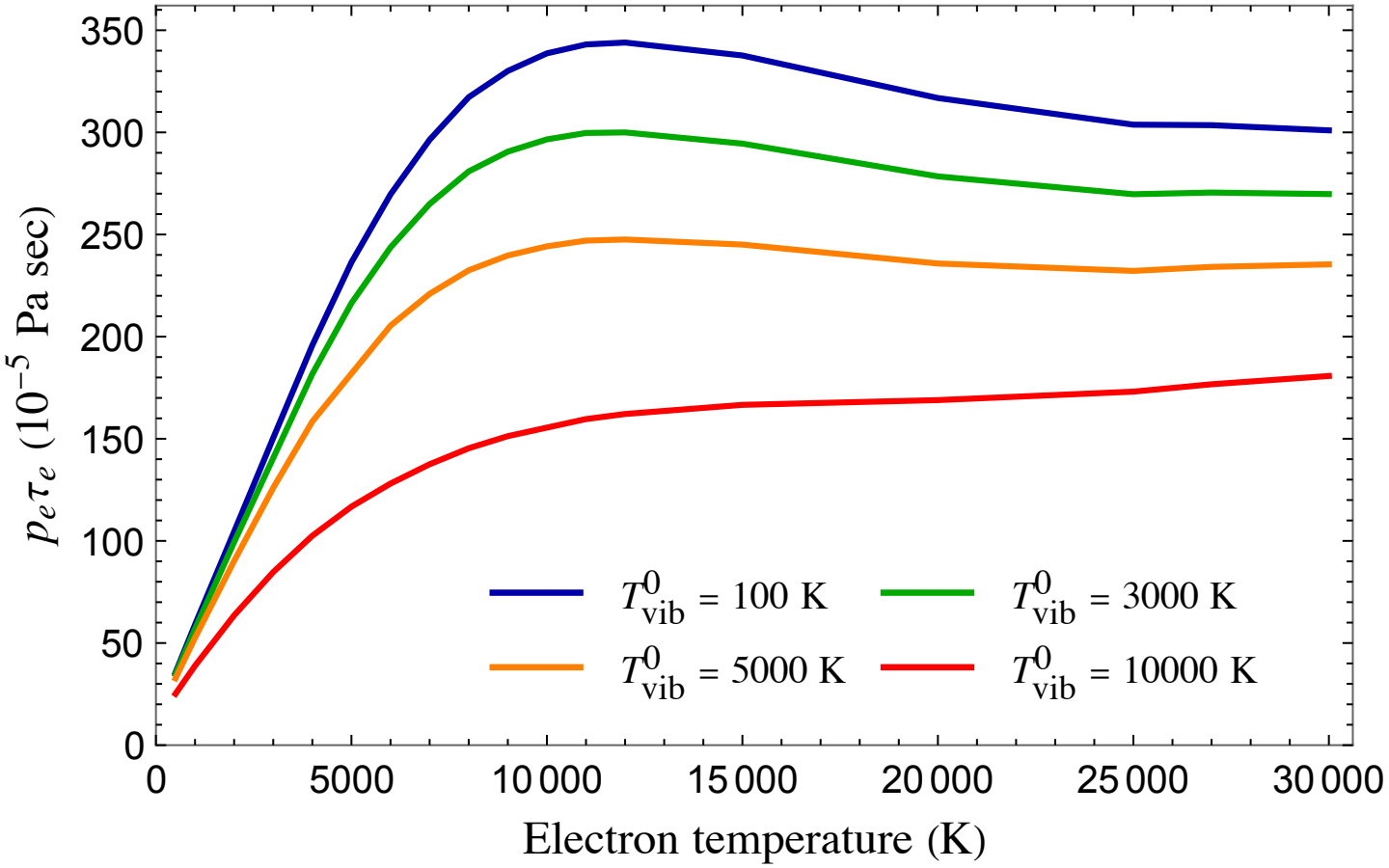
Vibrational distribution function



$$\frac{dn_v}{dt} = n_e \sum_{w=0}^{20} \left[k_{w,v}\, n_w - k_{v,w}\, n_v \right] , \qquad v = 0, \ldots 20 ,$$

n_{tot} = 10^{22} part/m^3
95% of D_2 5% of *e*
T_{gas} = 10000 K
T^0_{vib} = 1000 K

Vibrational relaxation of $D_2(X)$



Conclusions

LCP (this presentation) and MQDT (Ioan Schneider's presentation) models are the only serious theoretical frameworks - **completely ab initio** - to describe state-resolved electron-molecule collisions which are able to take into account correctly **nuclear vibrations (and rotations)**.

I showed the LCP extension to calculate the vibrationally and electronically excited cross sections.

LCP and MQDT models are the only approaches able to calculate **Dissociative Attachment** and **Dissociative Recombination** processes.

Molecular input data come from ab initio quantum chemistry approaches, *e.g.* **R-Matrix.**

Outlook…

Inclusion of the other electronically excited states

H_2 cross sections and isotopic effects (work in progress…)

Including rotational motion

Inclusion of ‘non-resonant’ contributions

Extension of the LCP model for ionization cross sections

Thank you for your attention