Electron-impact vibrational excitation of carbon monoxide in planetary atmospheres

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Outline

- Introduction
  - Electron cooling
  - Method of calculation
- CO cross sections

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  - Carbon Monoxide densities
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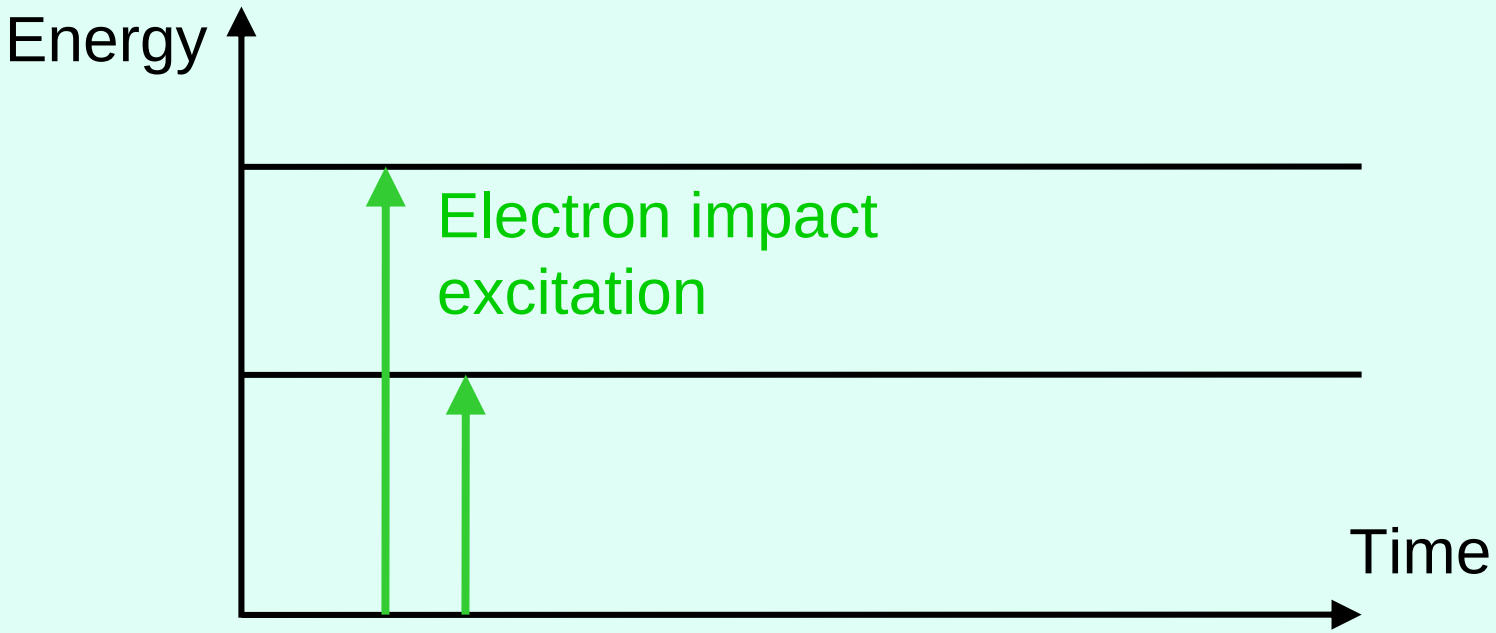
- Conclusions
  - Are refined measurements of CO ICS required?

Introduction - Electron cooling

- Electrons lose energy by impact on gases, producing vibrational excitation.



Introduction - Electron cooling

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- The energy is then transferred by
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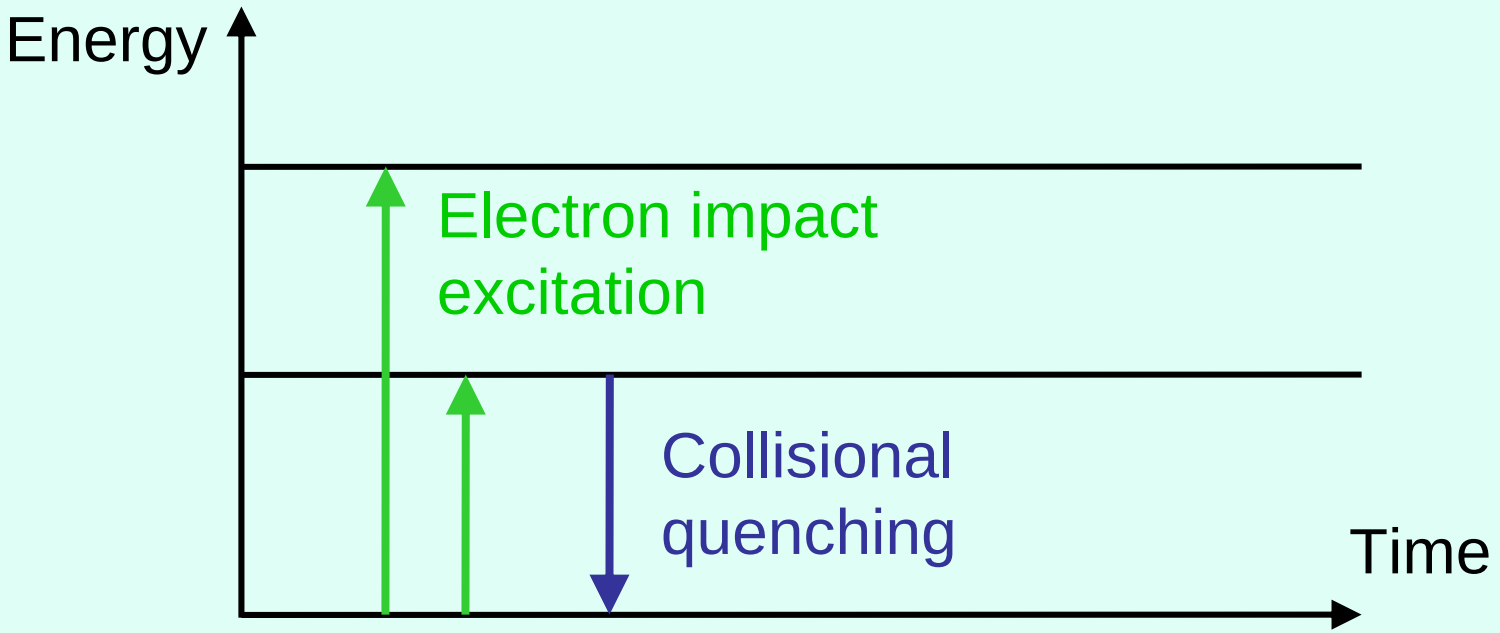
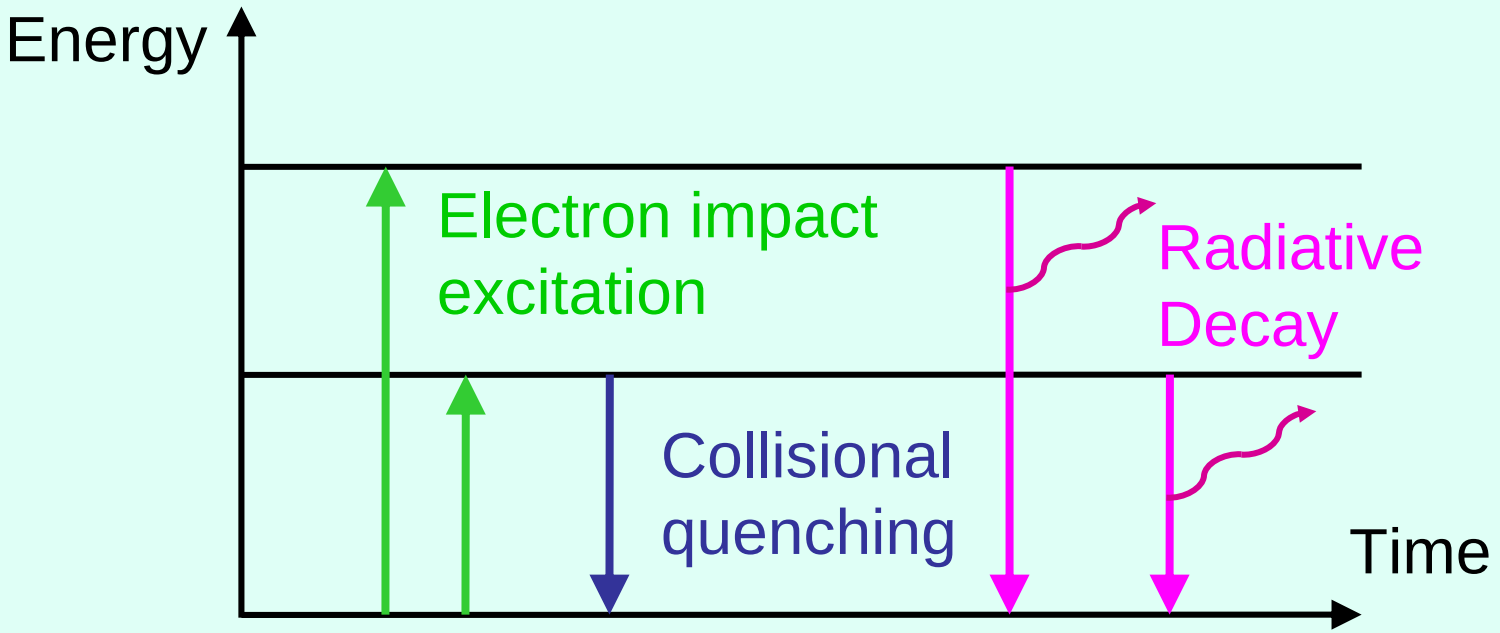


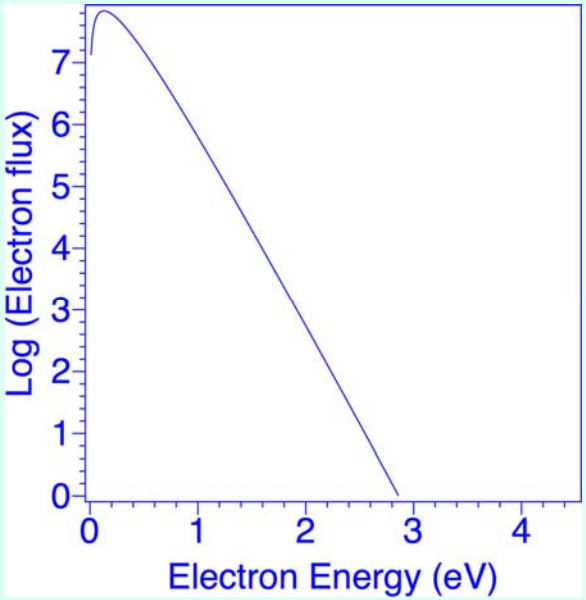
Introduction - Electron cooling

- Electrons lose energy by impact on gases, producing vibrational excitation.
- The energy is then transferred by
  - quenching in collisions, or by
  - radiative decay.



Introduction - Method of calculation

It is assumed that the free electrons in the atmosphere have a Maxwellian distribution at a specific electron temperature T_e.



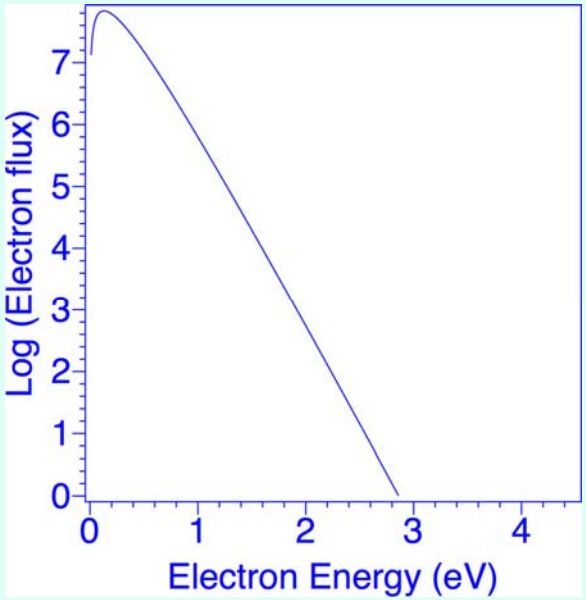
Introduction - Method of calculation

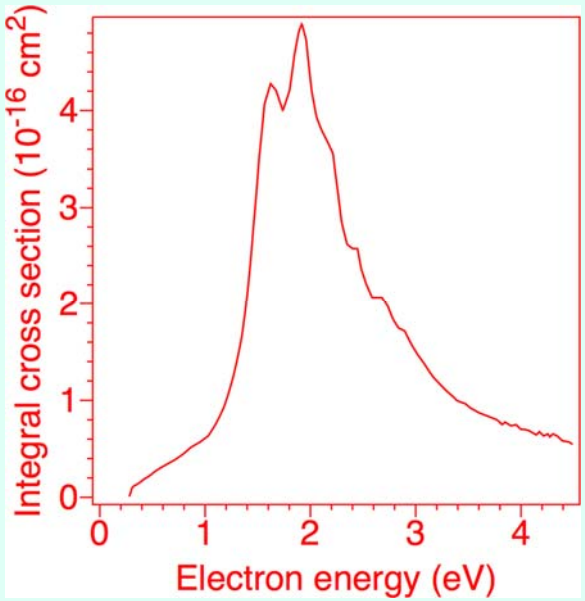
It is assumed that the free electrons in the atmosphere have a Maxwellian distribution at a specific electron temperature T_e.

The electron distribution is folded with the Integral Cross Section for vibrational excitation to give the electron energy transfer rate $Q_{0\nu}(T_e)$ at electron temperature T_e.

$$Q_{0\nu} = E_{0\nu}\sqrt{\frac{8kTe}{\pi m_e}}\int_0^\infty x\,\sigma_{0\nu}(E)\exp(-x)dx$$

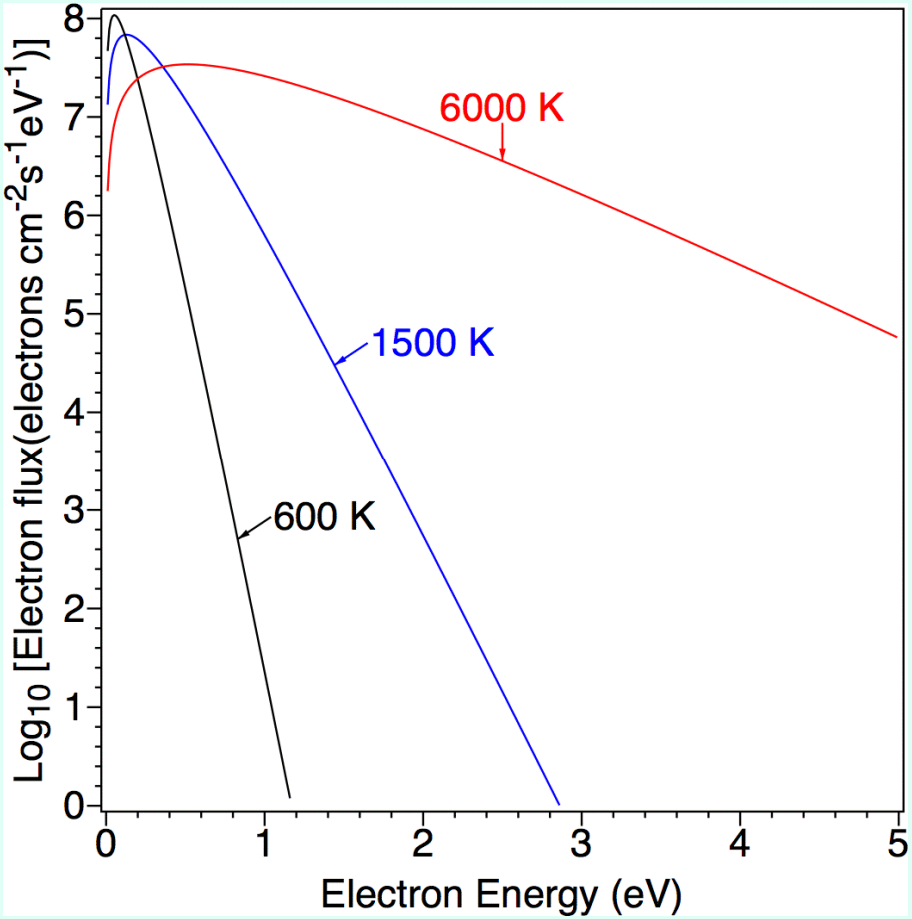
where $x = \frac{E}{kT_e}$

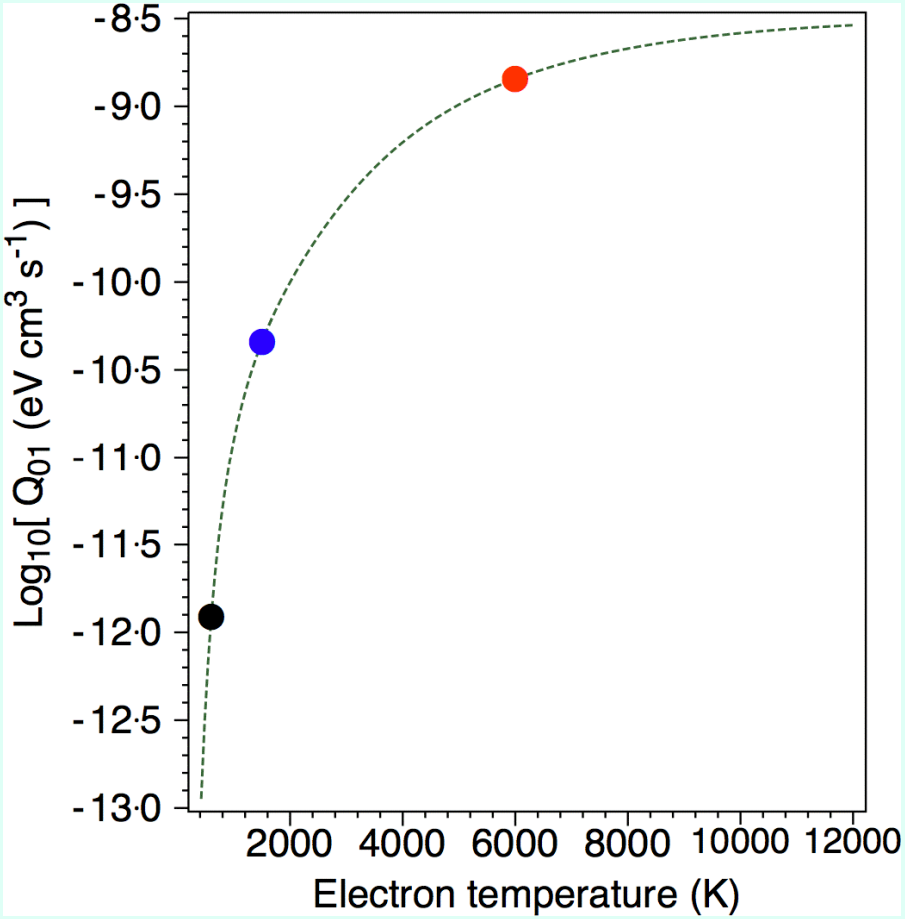




Introduction - Electron cooling rate

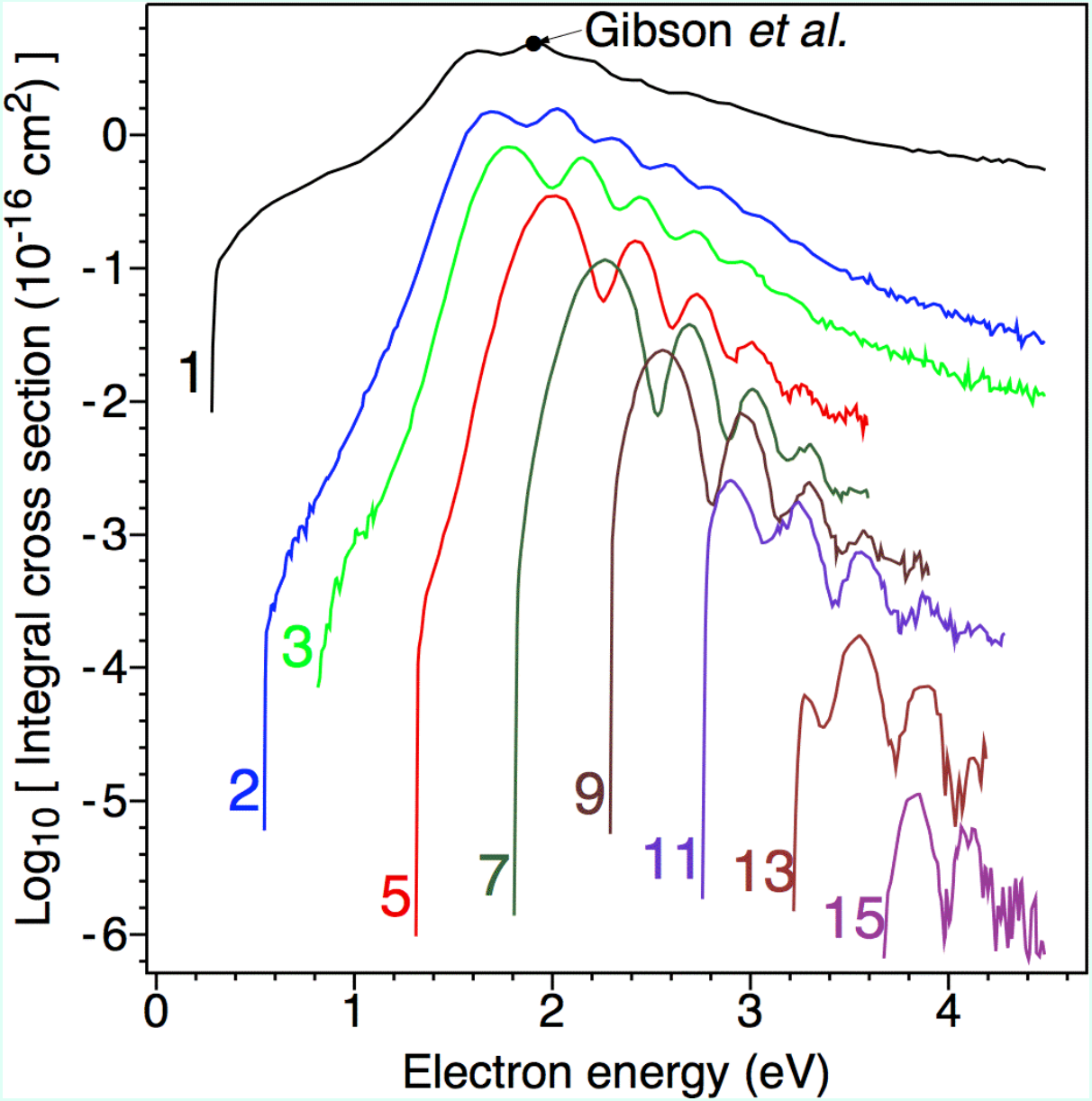
The electron energy transfer rate is calculated as a function of electron temperature.





– Cooling rate (for excitation from ground) = $\sum_{\nu=1}^{\nu_{\max}} Q_{0\nu}(T_e)[\mathrm{e}^-][\mathrm{Mol}]$

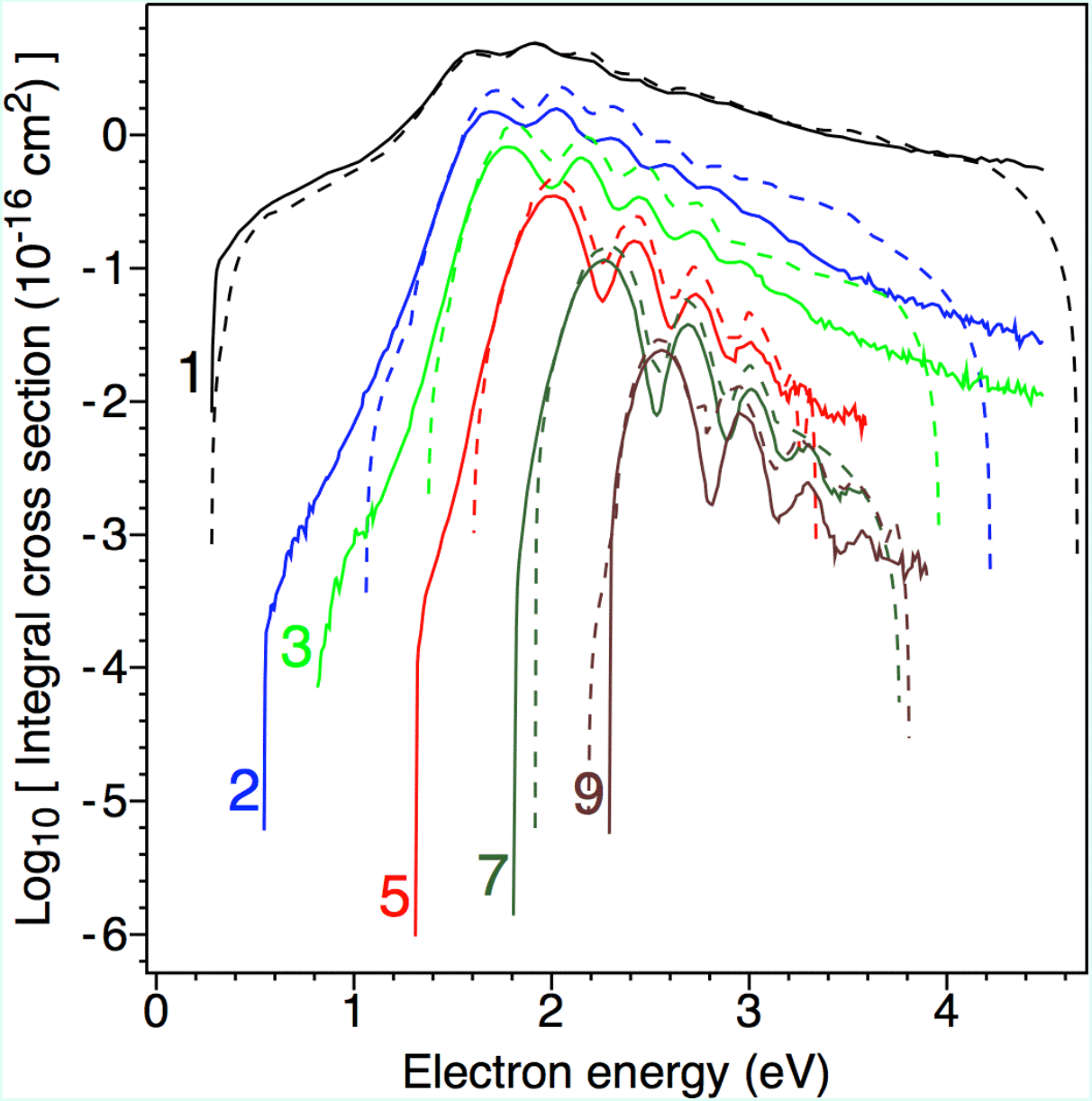
Cross sections for excitation of CO



(——)

Relative cross sections of M. Allan, scaled to an absolute measurement by Gibson *et al.* (1996).

Cross sections for excitation of CO



(——)

Relative cross sections of M. Allan, scaled to an absolute measurement by Gibson *et al.* (1996).

(– – –)

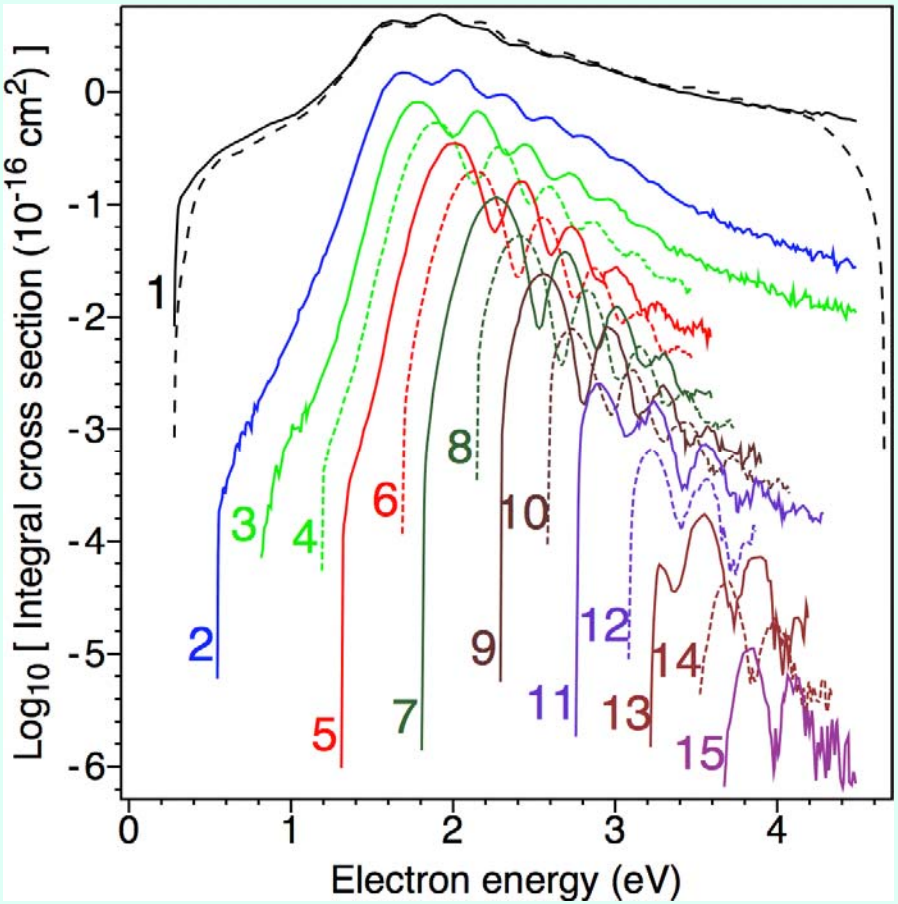
G. Poparić *et al.* (2006), scaled similarly

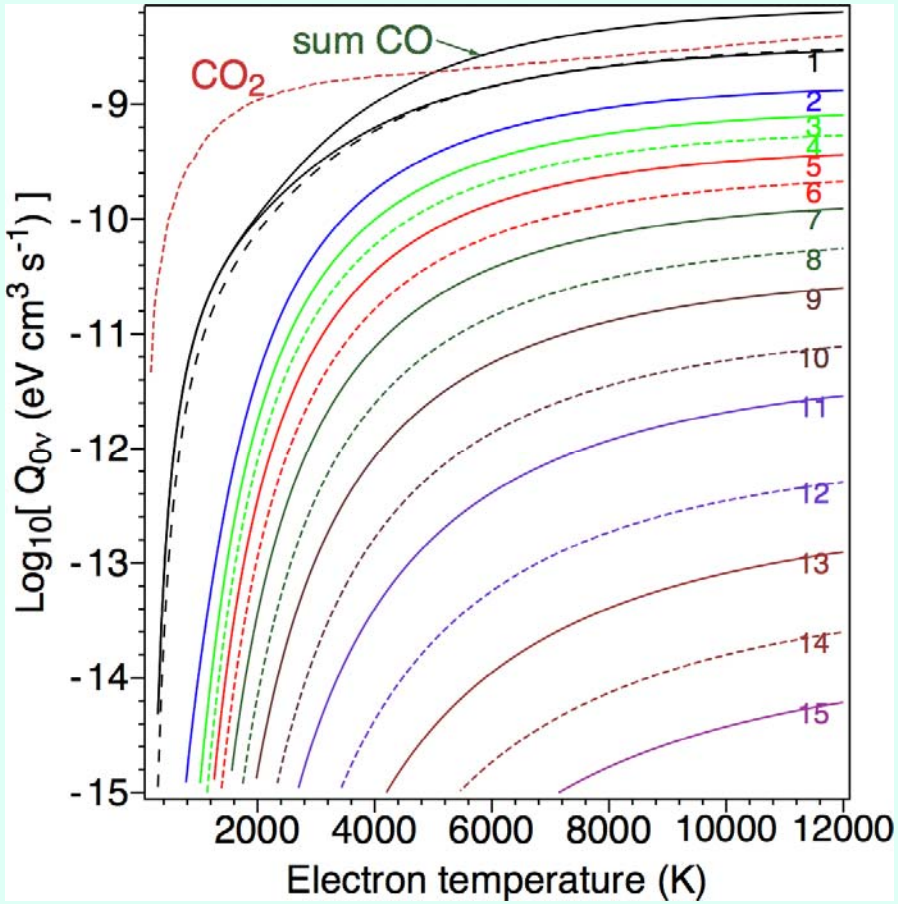
Electron energy transfer rates for CO

(———) Cross sections of M. Allan

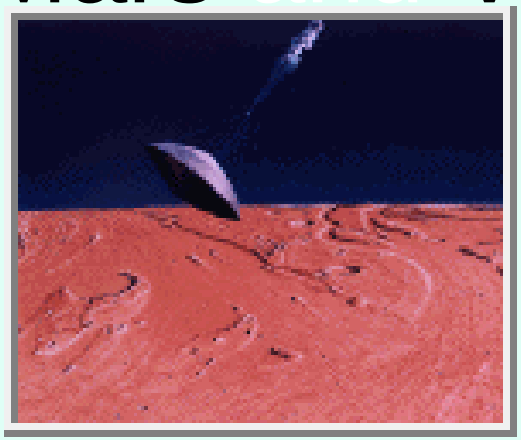
(---------) Interpolation of cross sections of M. Allan

(– – –) Cross sections of G. Poparić *et al*.



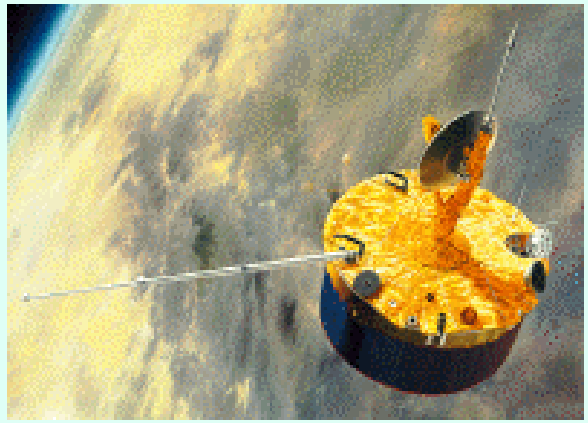


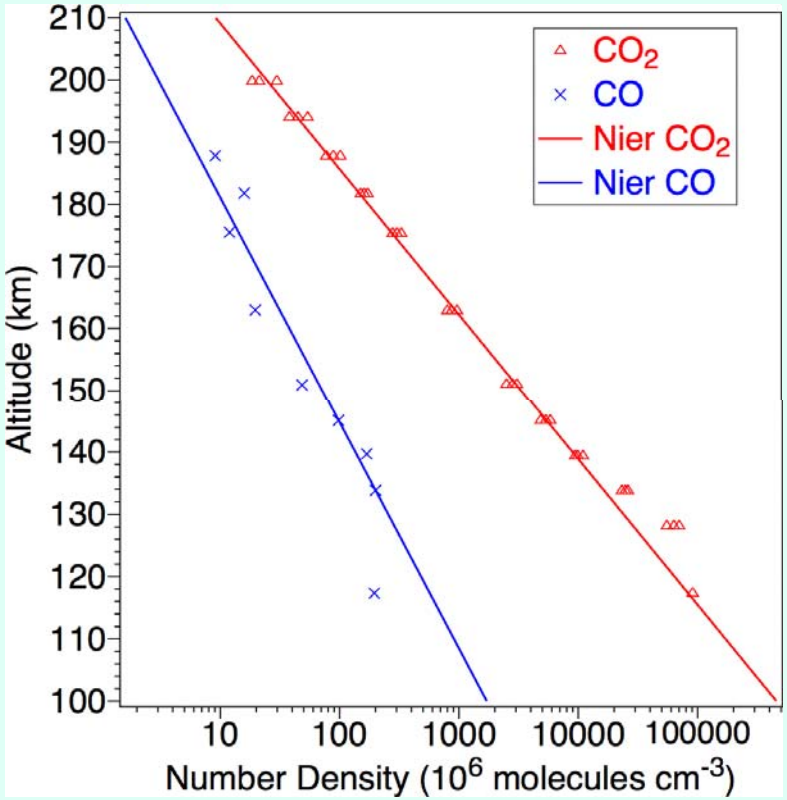
Mars and Venus: Measurements of CO

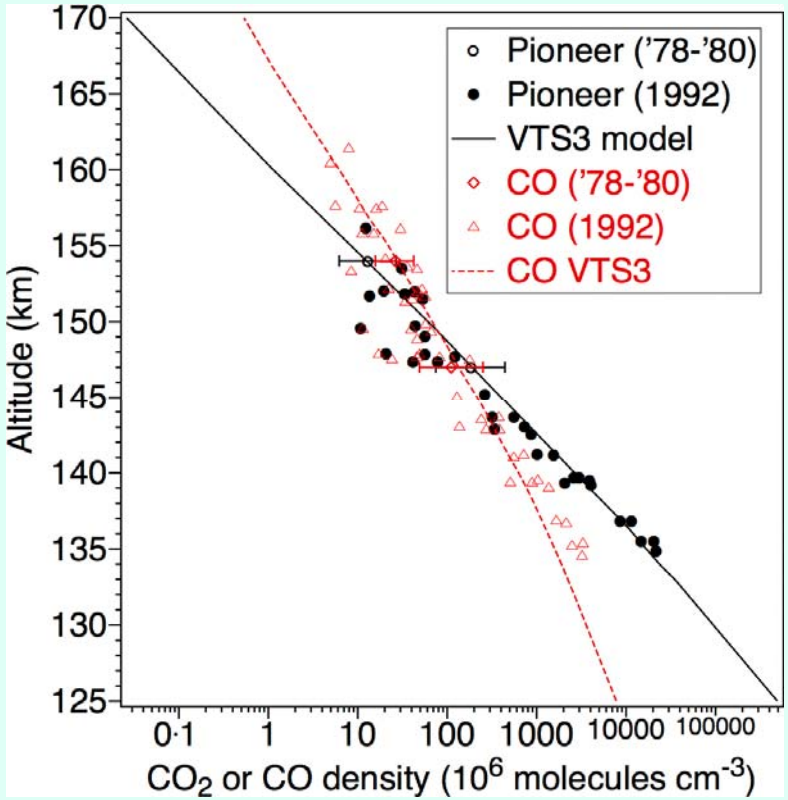


Viking I (1976)

Pioneer Venus (1978–1992)



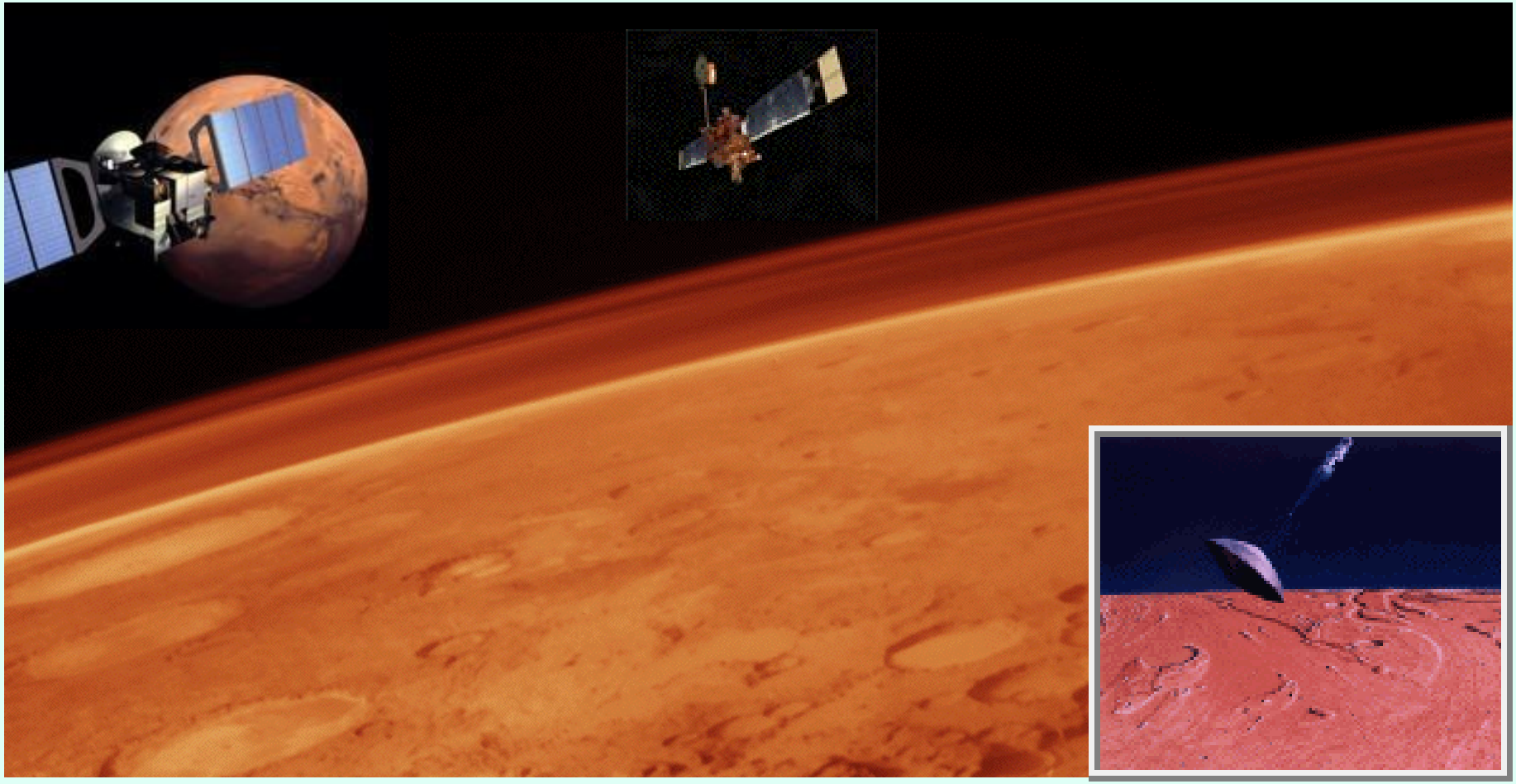




Mars - observing spacecraft

Mars Global Surveyor (1999)

Mars Express (2004)



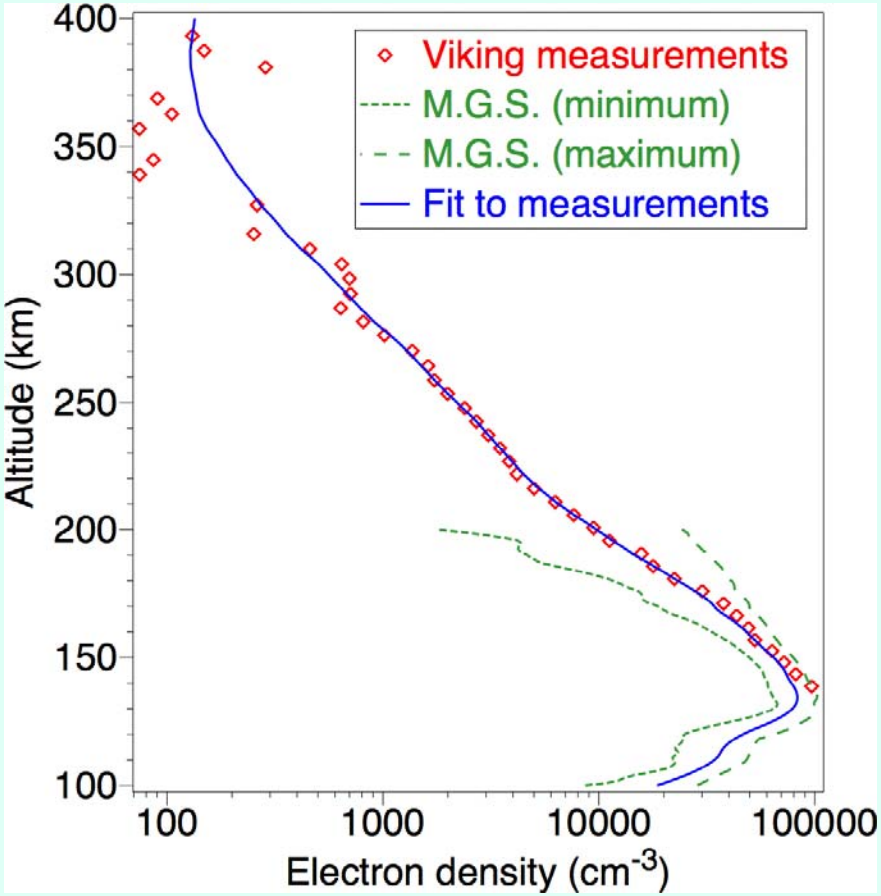
Viking (1976)

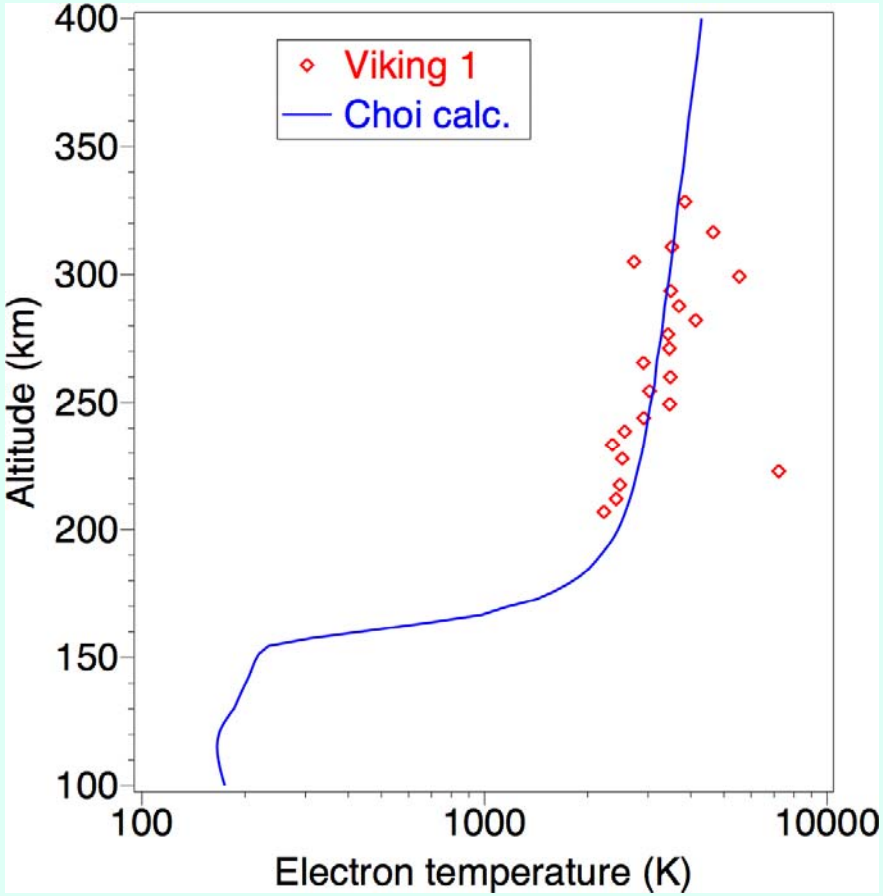
Mars: electron parameters

Electron density:

(——) fit to measurements

Electron temperature: (— –) model consistent with measurements





Mars - electron cooling rates

- Electron cooling rate for molecules in ground state is

$$\sum_{\nu'=1}^{\nu_{\max}} Q_{0\nu'}(T_e)[e^-][Mol]$$

(-----) CO_2

(——) CO(ν'=1, Allan)

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(— -) CO(ν'=2-10, Allan)

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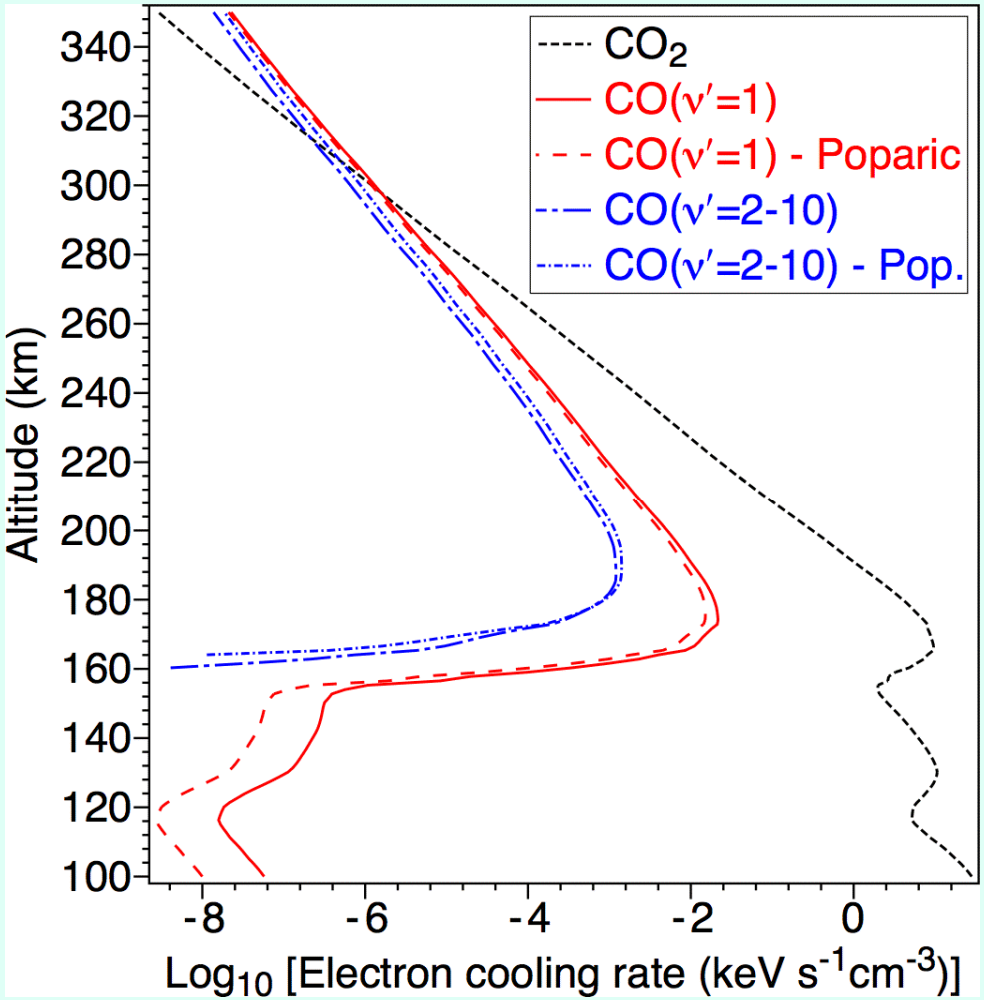
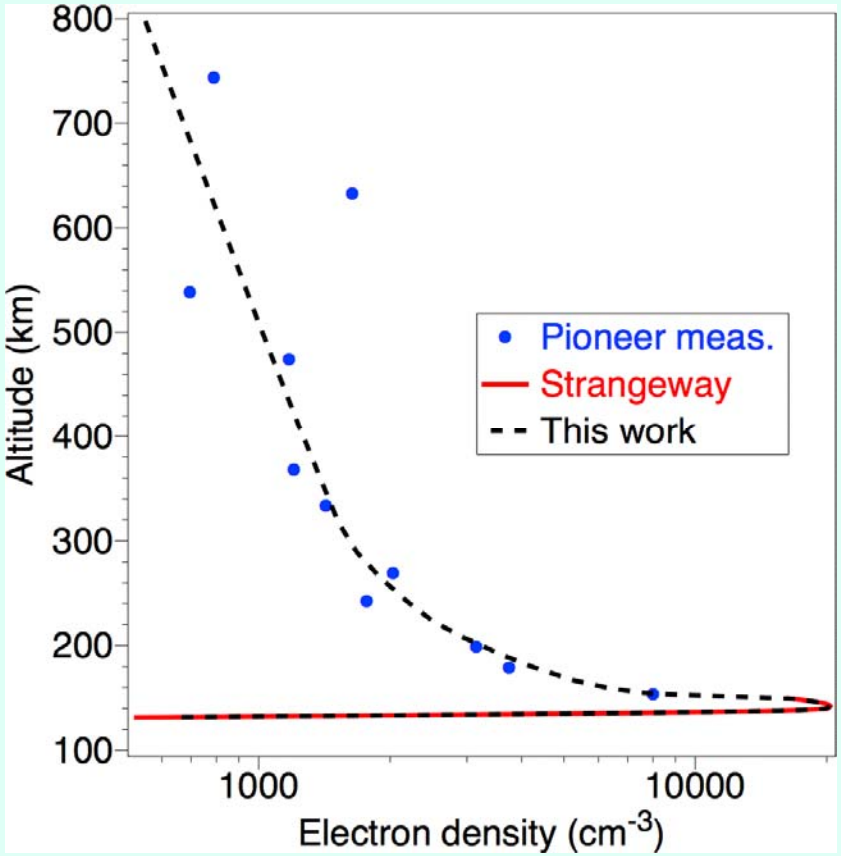
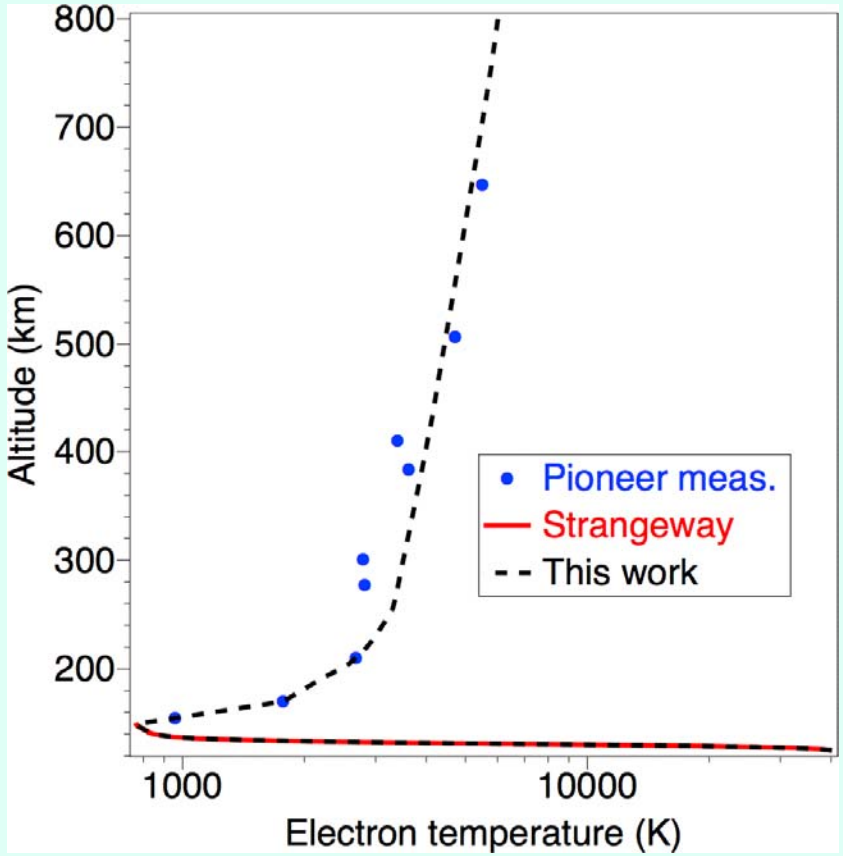


Venus: electron parameters

Fit (– –) to combination of Pioneer Venus measurements (•) above 150 km and model (——) of R. Strangeway (1996) below 150 km.





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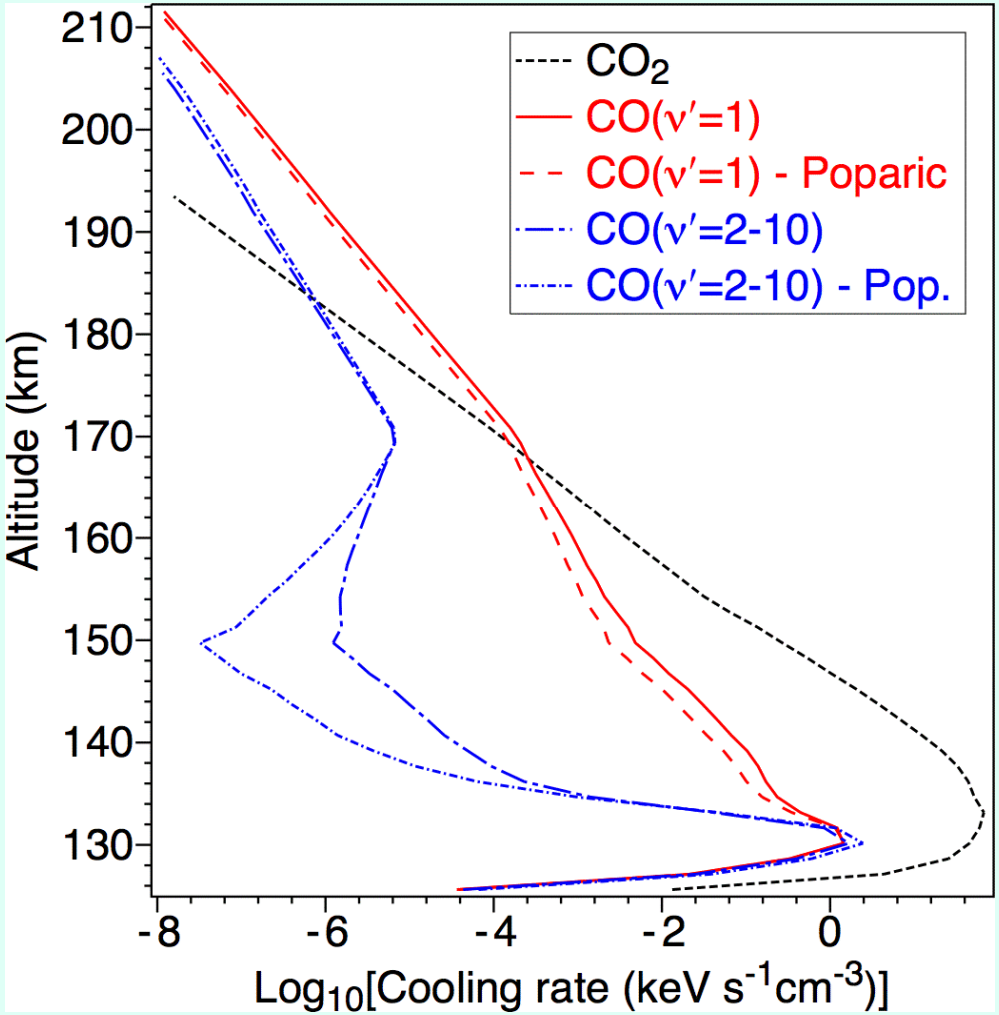

Conclusions

- There has only been one absolute measurement of the cross sections of CO in recent times.
- There are differences of up to 40% in the cross sections for higher vibrational levels, relative to the first level.
- There are significant differences between different measurements at very low energies.
- Electron cooling by CO is significant (relative to that due to CO_2) in the atmospheres of Mars and Venus
- Thus there is a need for new absolute and relative measurements of CO cross sections.