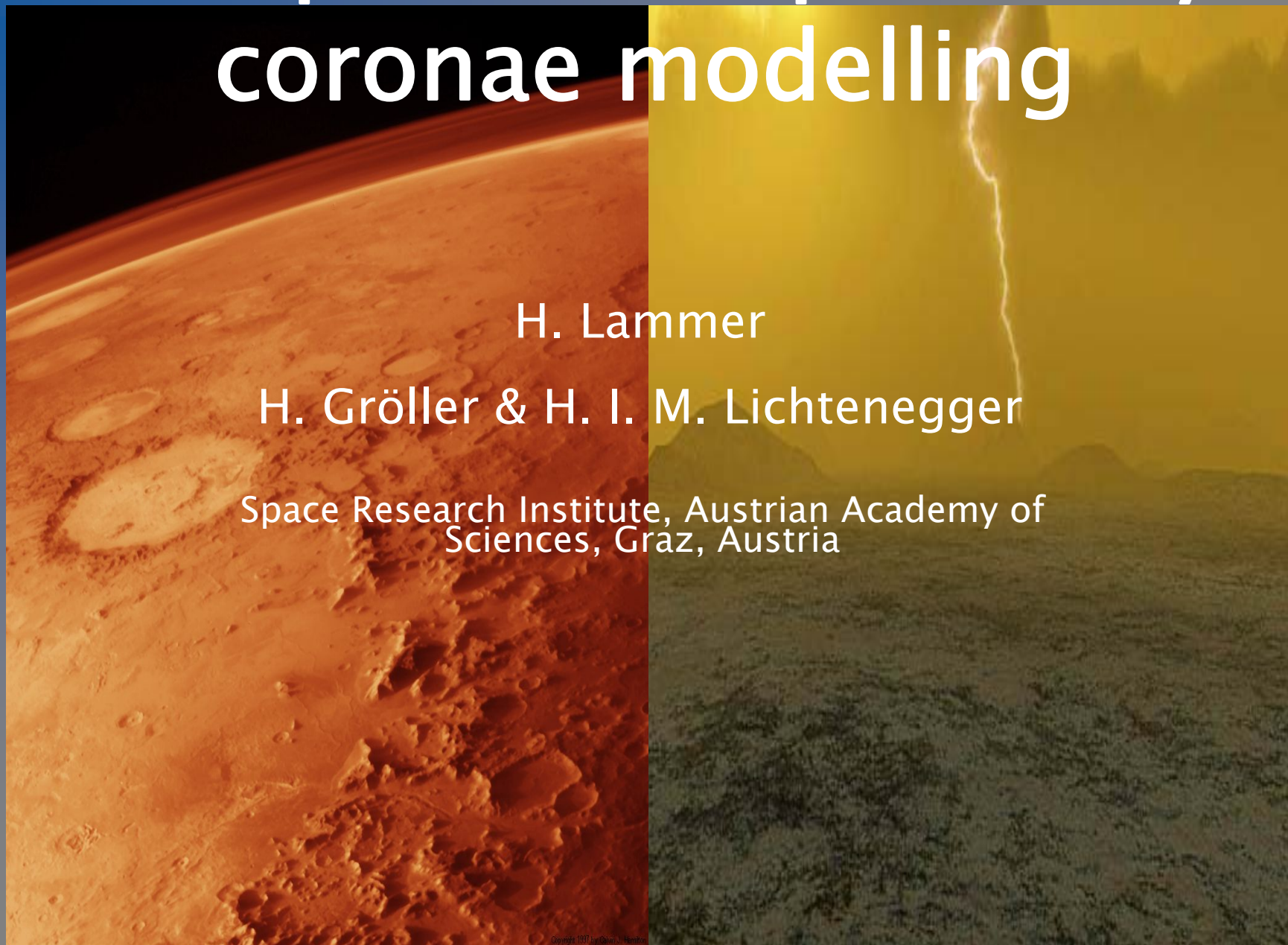
Exosphere and planetary coronae modelling



H. Lammer

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Thermosphere- hot particle - exosphere modelling

Scientific drivers and goals

- 3D Monte Carlo model for the calculation of non-Maxwellian energy density functions (EDFs) above the exobase for hot neutral particles
- Studying the response of hot EDFs to solar activity conditions
- Coupling of 3D EDFs above the exobase with the “cooler” background gas and 3D exosphere models for delivering accurate inputs for MHD and hybrid models

Photochemical production of hot neutrals

Neutral Atmosphere

CO_2, O, O_2, N_2 …

Ions + Electrons

CO_2^+, O^+, O_2^+, N_2^+, … e^-…

Example: „hot O atoms“

Major Source of suprathermal atoms in upper atmosphere: dissociative recombination of molecular ions

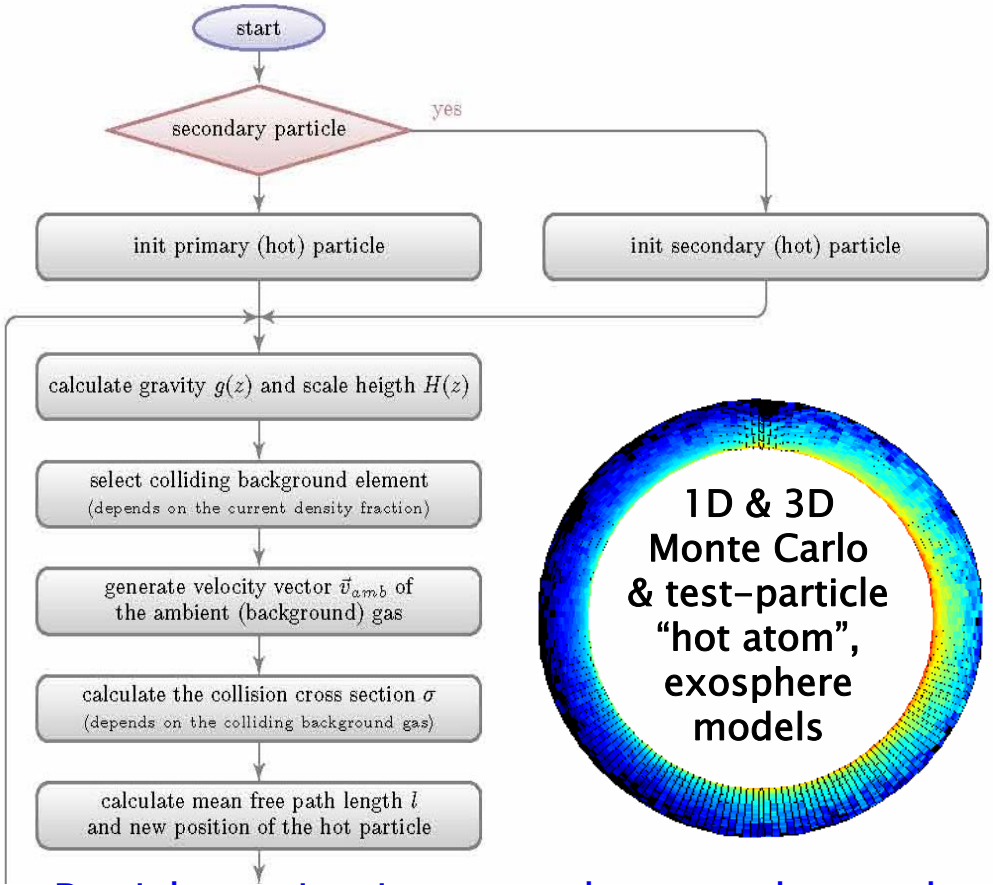
$O_2^+ + e \rightarrow O(^3P) + O(^3P) + 6.96$ eV	Br = 0.22
$O_2^+ + e \rightarrow O(^3P) + O(^1D) + 5.00$ eV	Br = 0.42
$O_2^+ + e \rightarrow O(^1D) + O(^1D) + 3.02$ eV	Br = 0.31
$O_2^+ + e \rightarrow O(^1D) + O(^1S) + 0.80$ eV	Br = 0.05

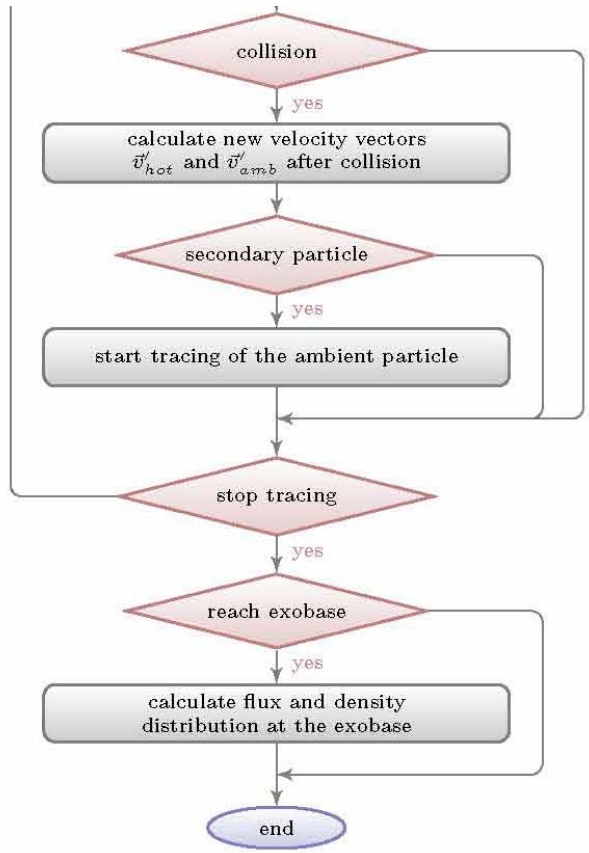
[Kella et al., Science 276, 1530, 1997]

Flux of hot oxygen at the exobase

→ Oxygen exosphere above exobase → ion pick up & loss

Planetary coronae, exosphere, photochemical and sputter loss Monte Carlo & test-particle modelling





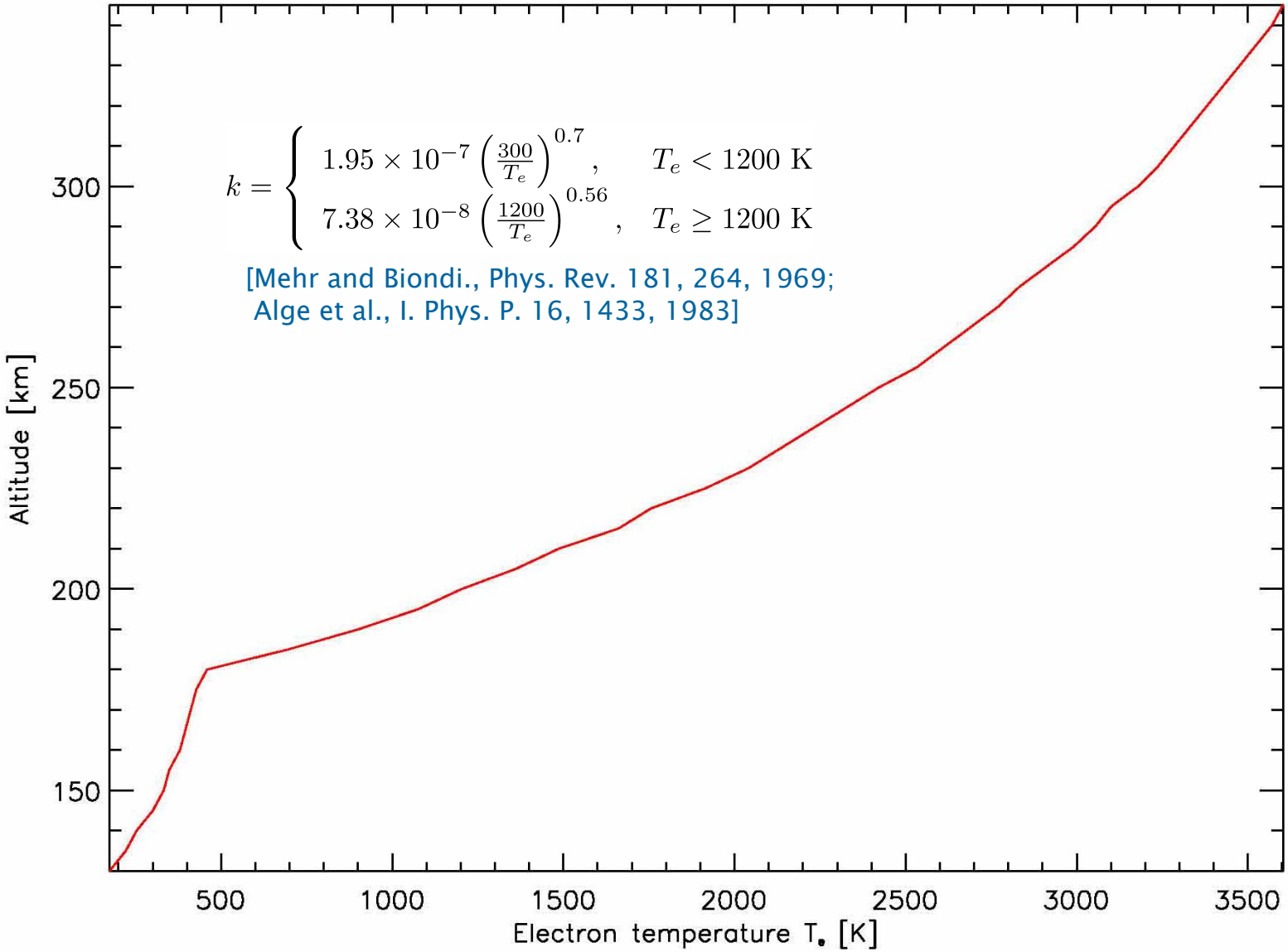
- Particle tracing in atmospheres and exospheres → to obtain accurate and more realistic neutral particle populations in planetary environments which will be used for MHD and hybrid (kinetic) solar/stellar wind – exosphere interaction modelling → total non-thermal neutral and ion losses

- Non-linear collision (energy, mass, etc.), photo-dissociation (T_e, etc.) cross-sections and coefficients, etc.

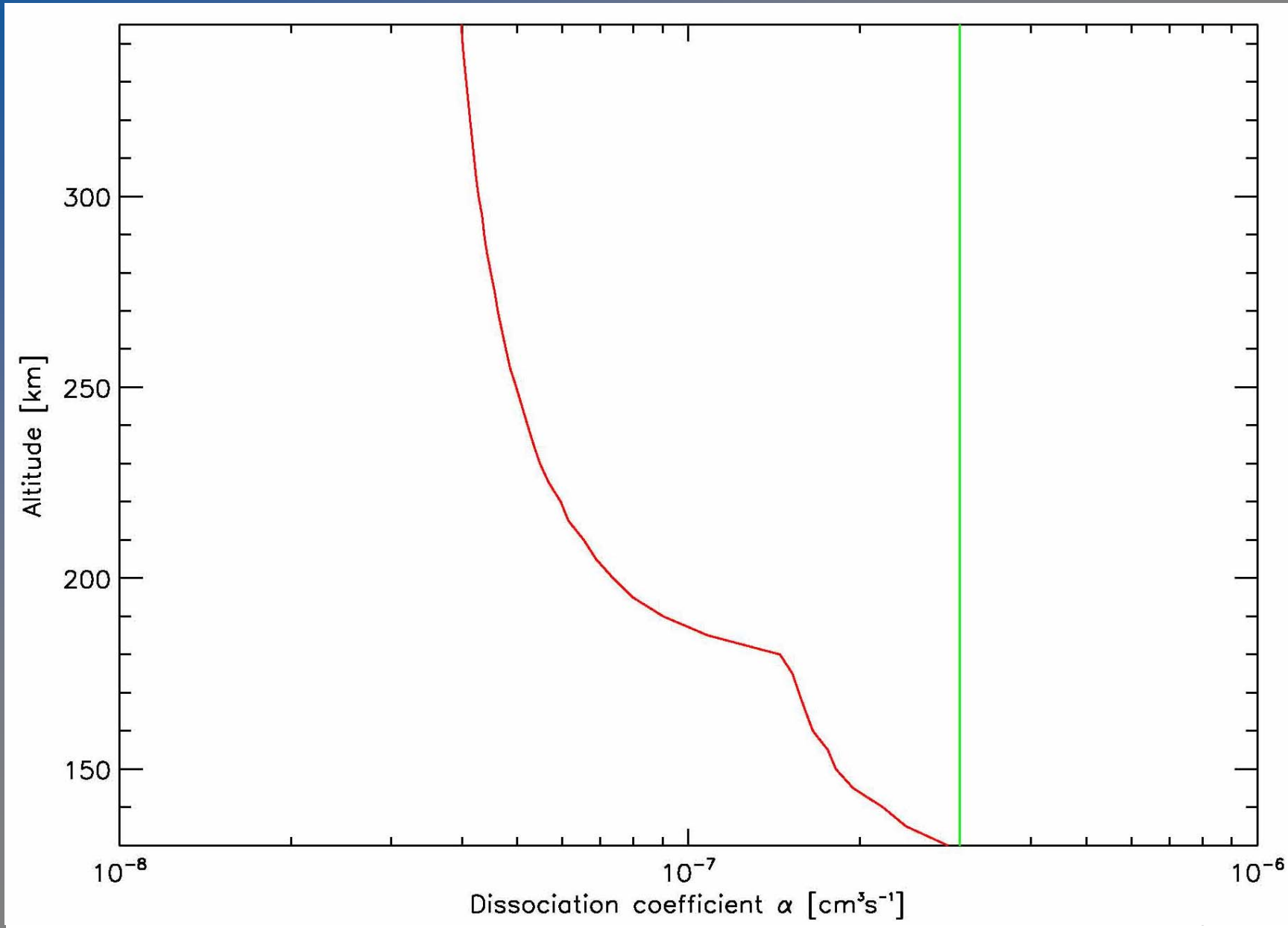
Non-linear dissociation coefficient: f(T_e)

$$k = \begin{cases} 1.95 \times 10^{-7} \left(\frac{300}{T_e}\right)^{0.7}, & T_e < 1200 \text{ K} \\ 7.38 \times 10^{-8} \left(\frac{1200}{T_e}\right)^{0.56}, & T_e \geq 1200 \text{ K} \end{cases}$$

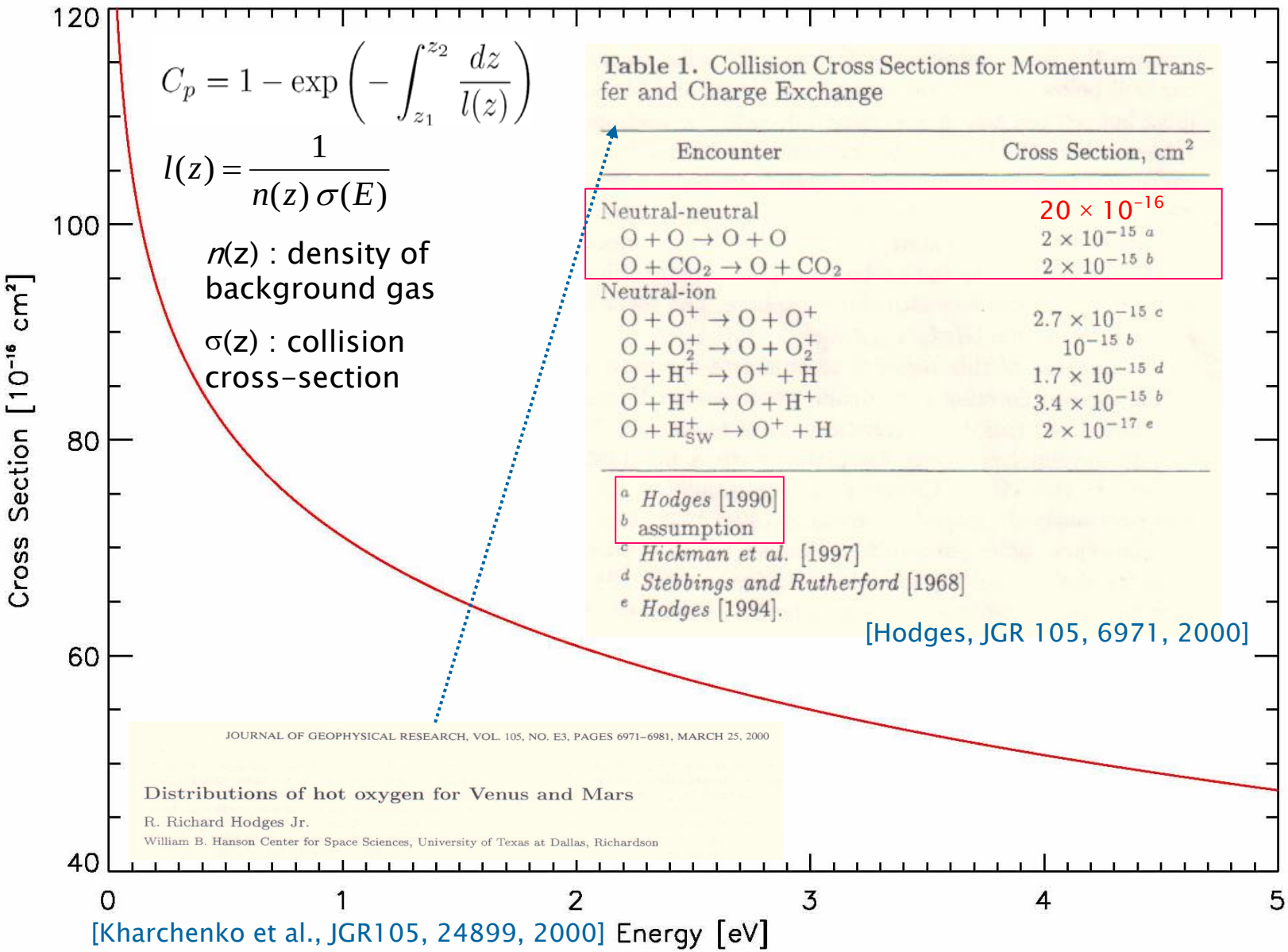
[Mehr and Biondi., Phys. Rev. 181, 264, 1969;
Alge et al., I. Phys. P. 16, 1433, 1983]



Non-linear vs. linear dissociation coefficients



Elastic collision cross-section I: O → O



$$C_p = 1 - \exp\left(-\int_{z_1}^{z_2} \frac{dz}{l(z)}\right)$$

$$l(z) = \frac{1}{n(z)\,\sigma(E)}$$

n(z) : density of background gas

σ(z) : collision cross-section

Table 1. Collision Cross Sections for Momentum Transfer and Charge Exchange

Encounter	Cross Section, cm²
Neutral-neutral	20×10^{-16}
$O + O \rightarrow O + O$	2×10^{-15} [a]
$O + CO_2 \rightarrow O + CO_2$	2×10^{-15} [b]
Neutral-ion	
$O + O^+ \rightarrow O + O^+$	2.7×10^{-15} [c]
$O + O_2^+ \rightarrow O + O_2^+$	10^{-15} [b]
$O + H^+ \rightarrow O^+ + H$	1.7×10^{-15} [d]
$O + H^+ \rightarrow O + H^+$	3.4×10^{-15} [b]
$O + H^+_{SW} \rightarrow O^+ + H$	2×10^{-17} [e]

[a] *Hodges* [1990]
[b] assumption
[c] *Hickman et al.* [1997]
[d] *Stebbings and Rutherford* [1968]
[e] *Hodges* [1994].

[Hodges, JGR 105, 6971, 2000]

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Distributions of hot oxygen for Venus and Mars

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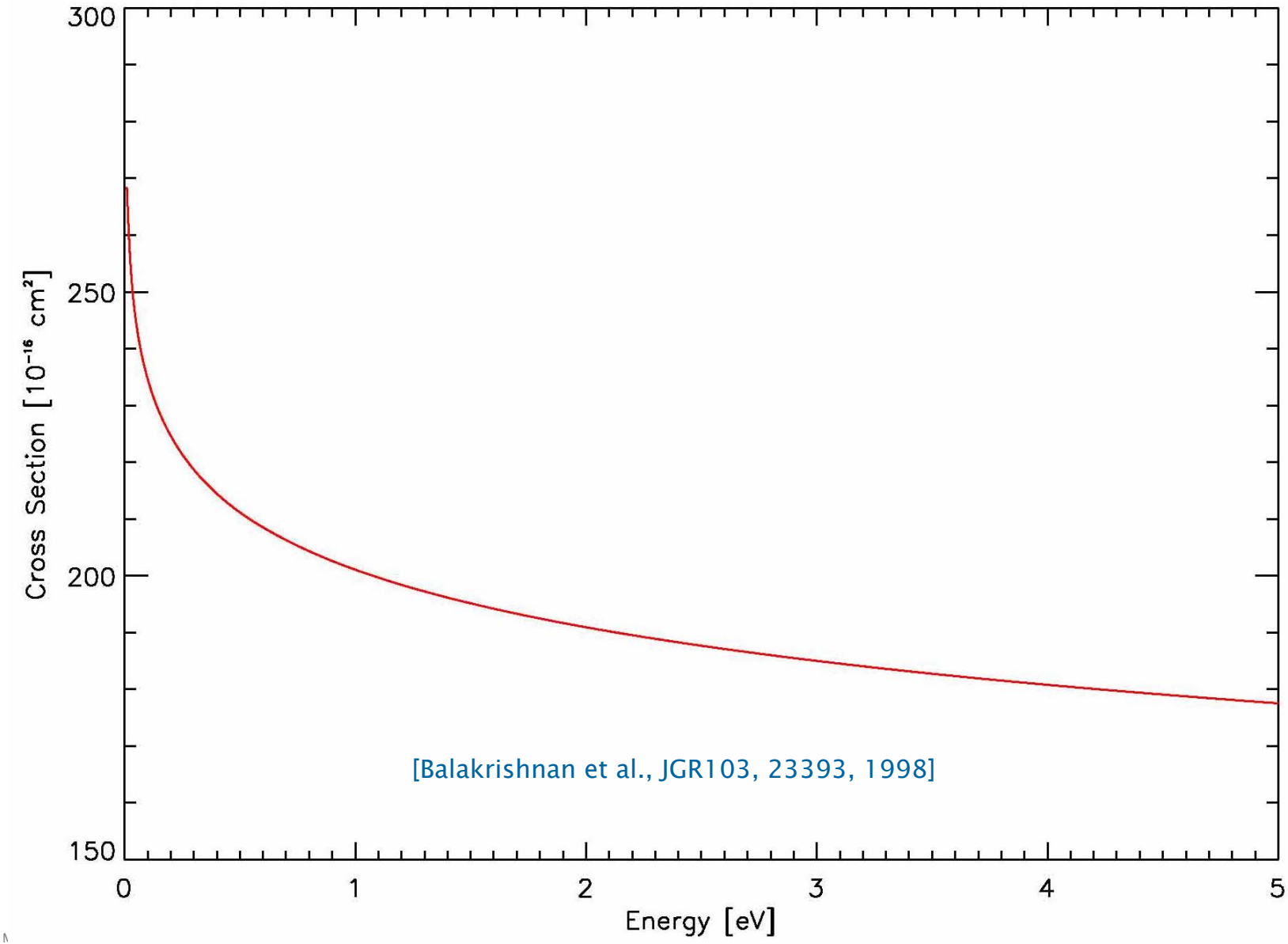
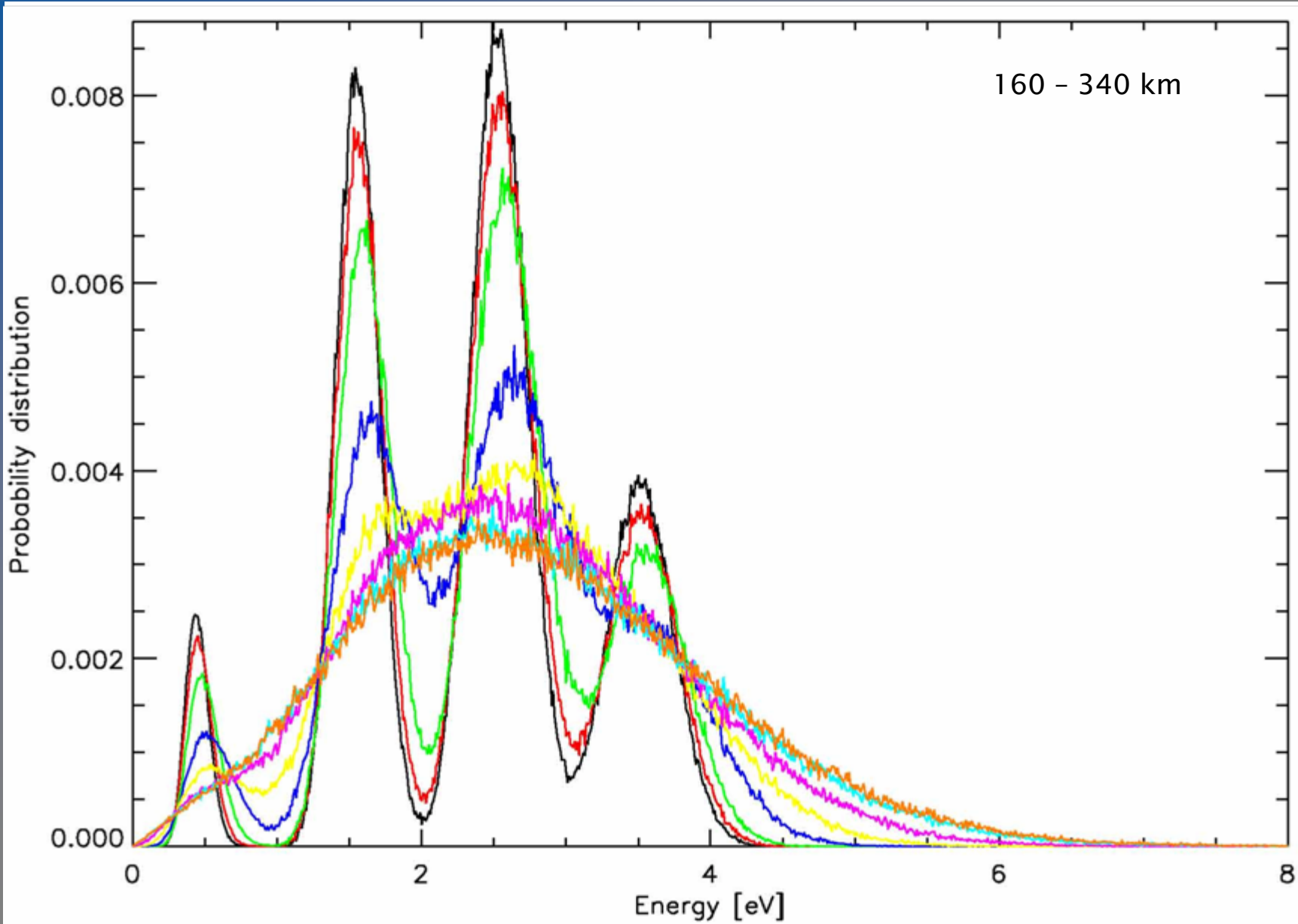
[Kharchenko et al., JGR105, 24899, 2000]

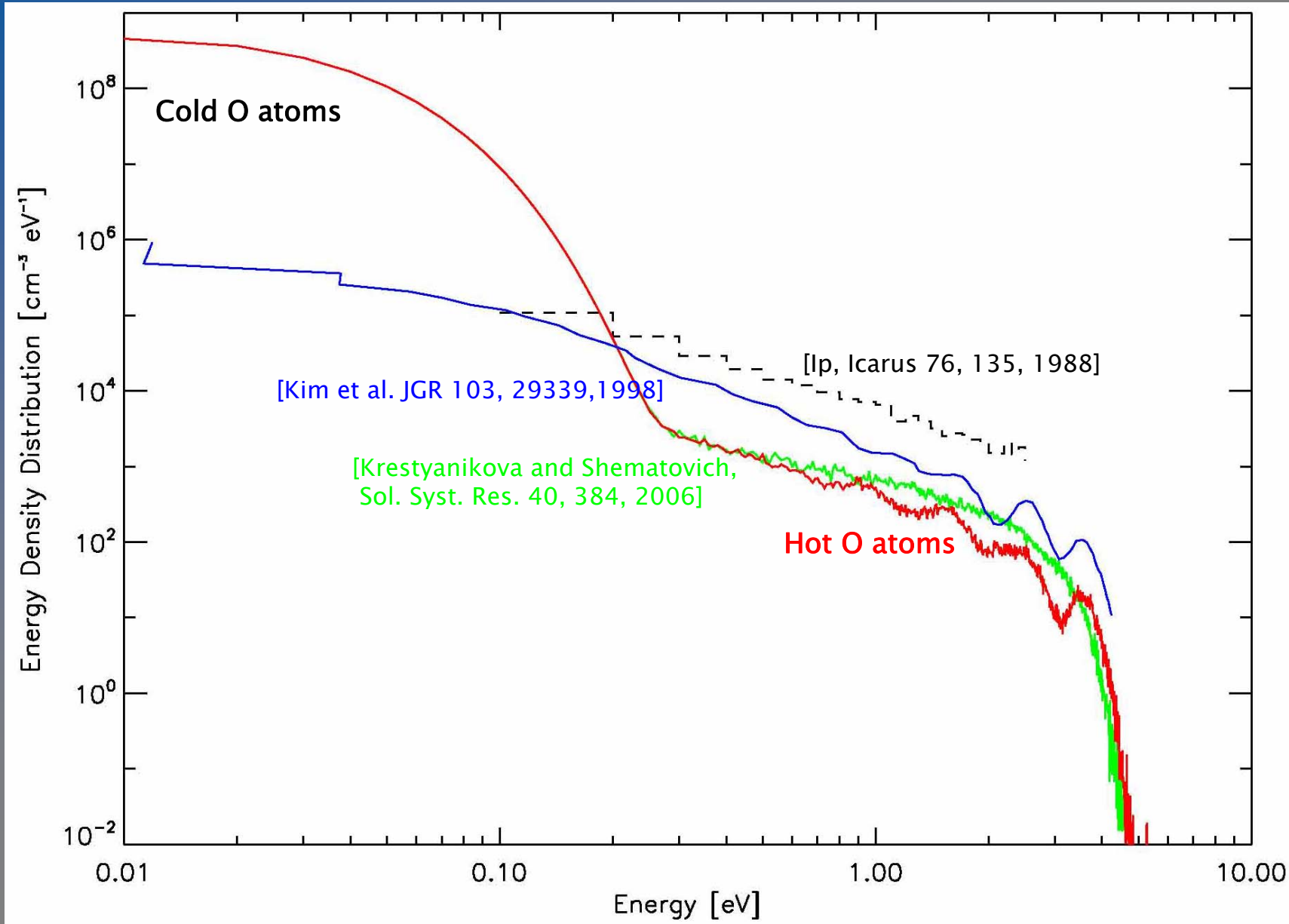
Elastic collision cross-section II: O → N_2 (CO_2)



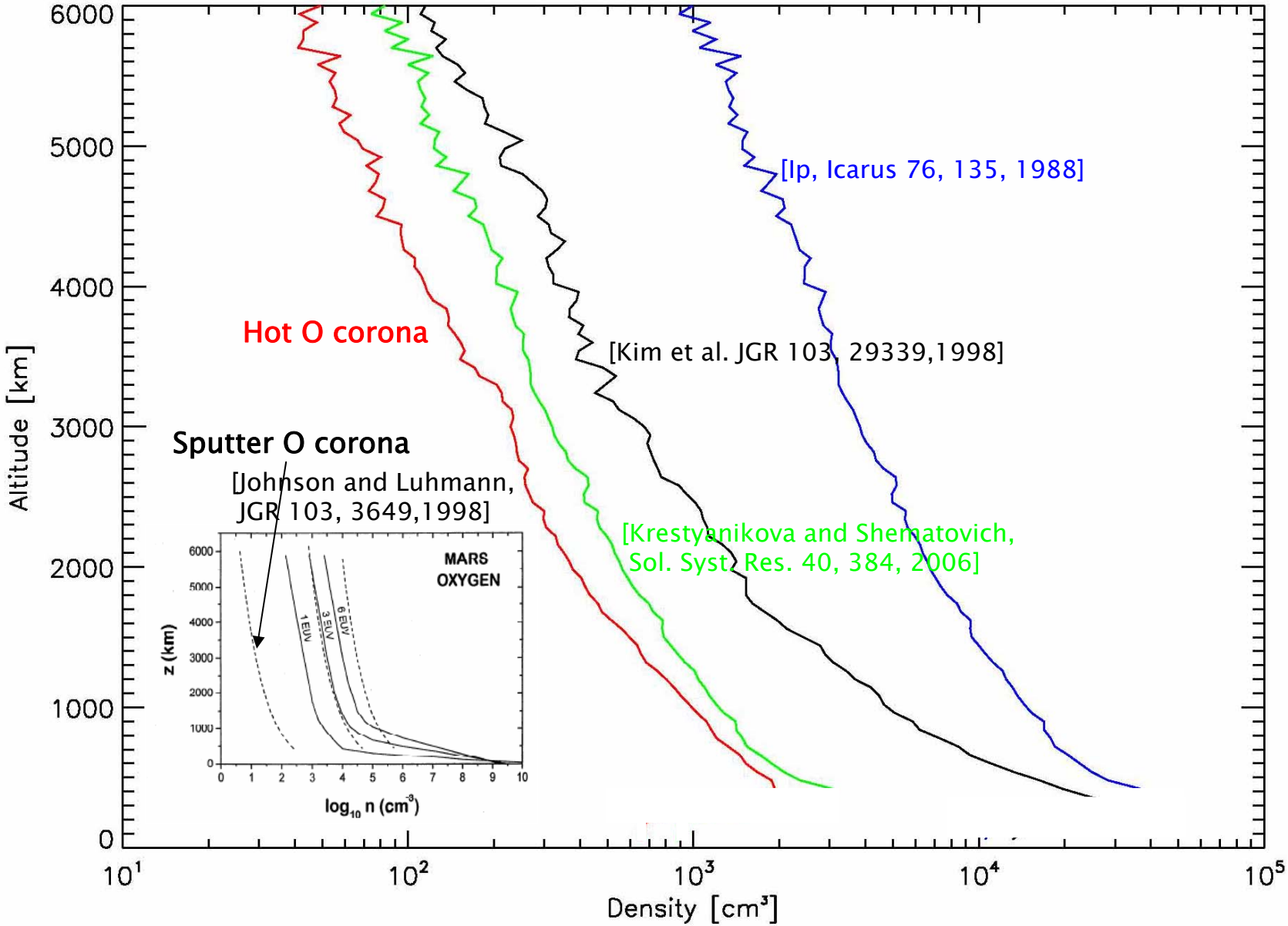
Altitude dependence of initial hot O atom velocity distribution



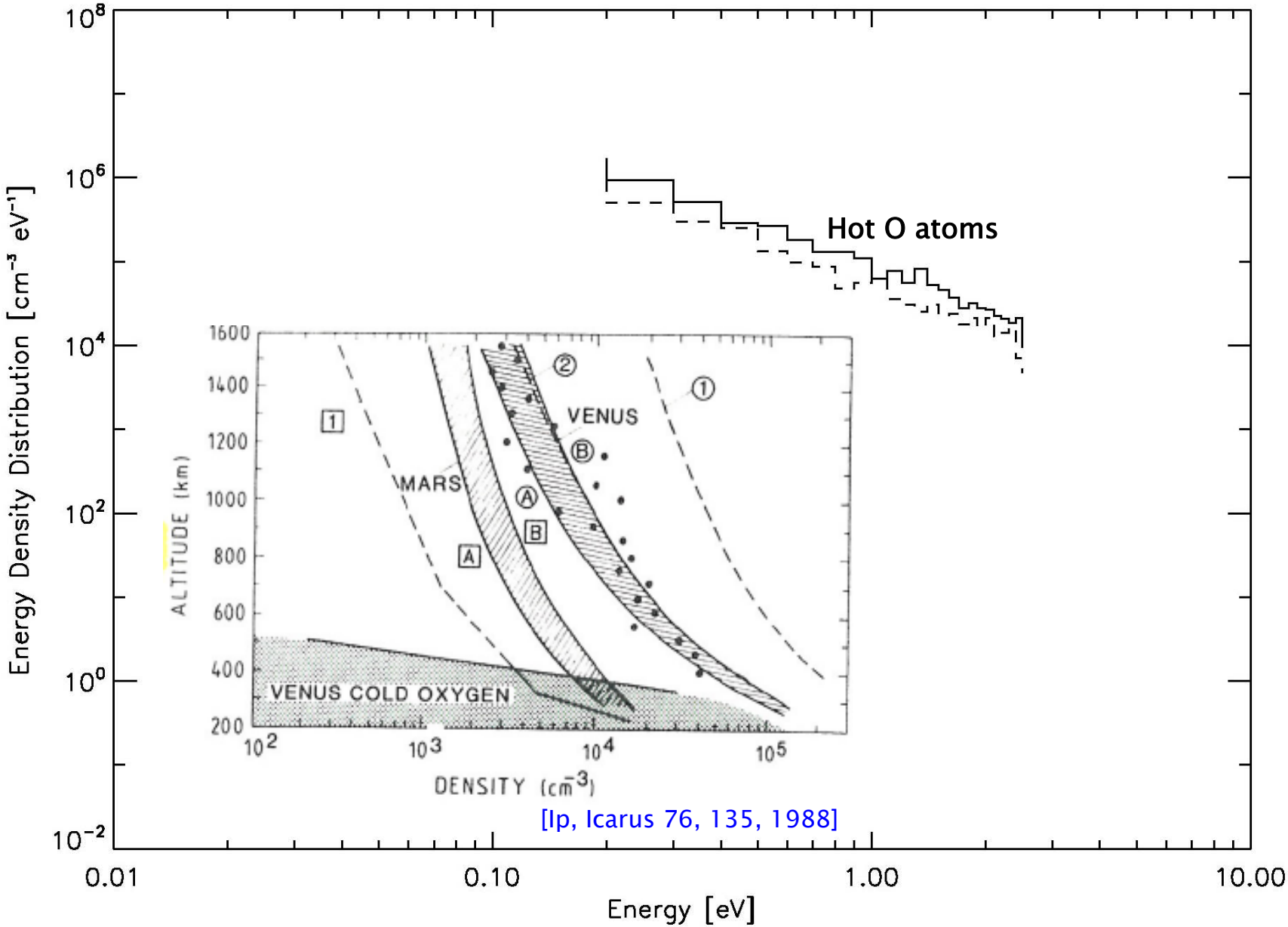
Mars: Comparison of model results (low solar activity Mars Express conditions)



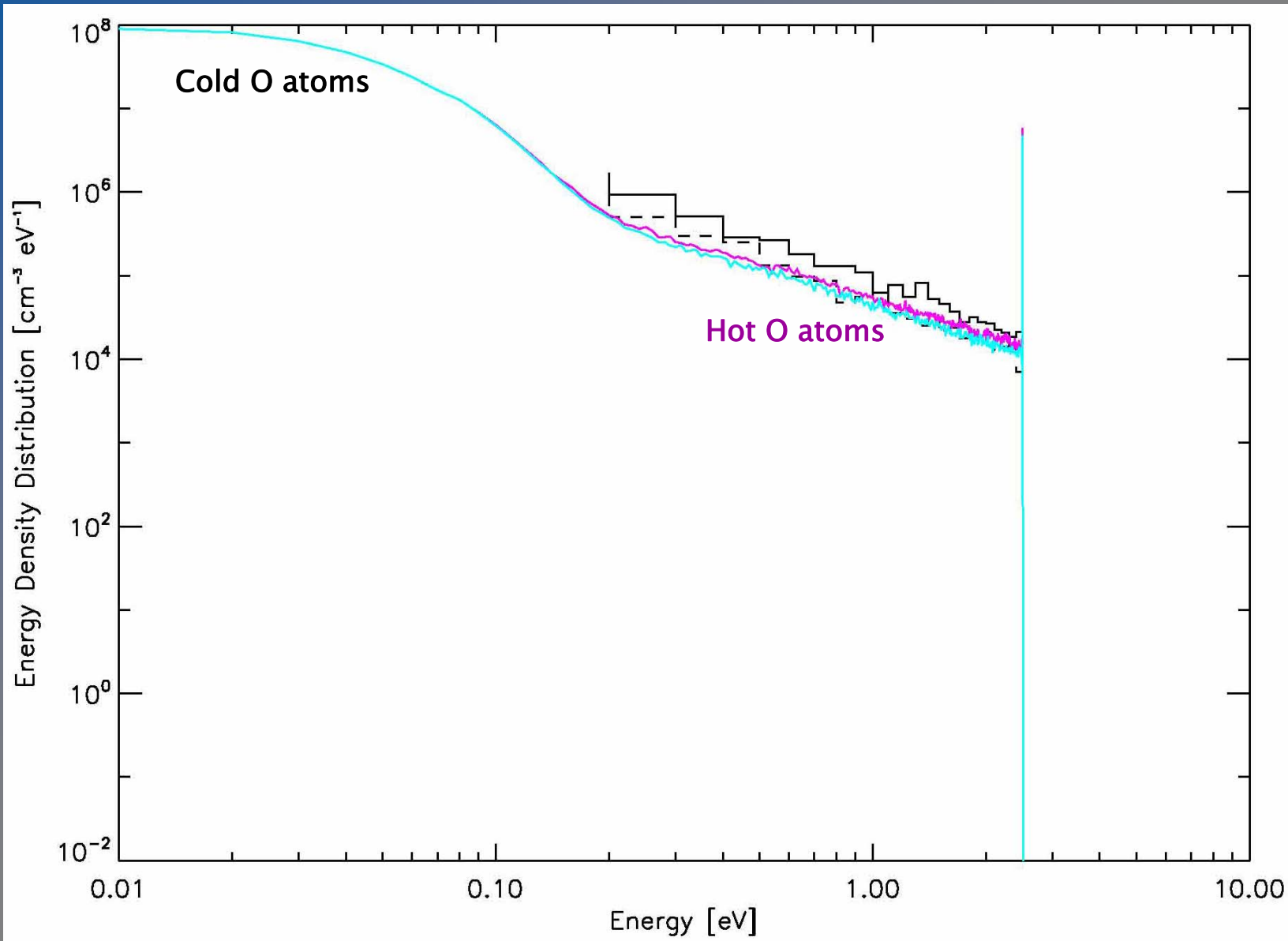
Mars: Hot O corona densities at low solar activity conditions



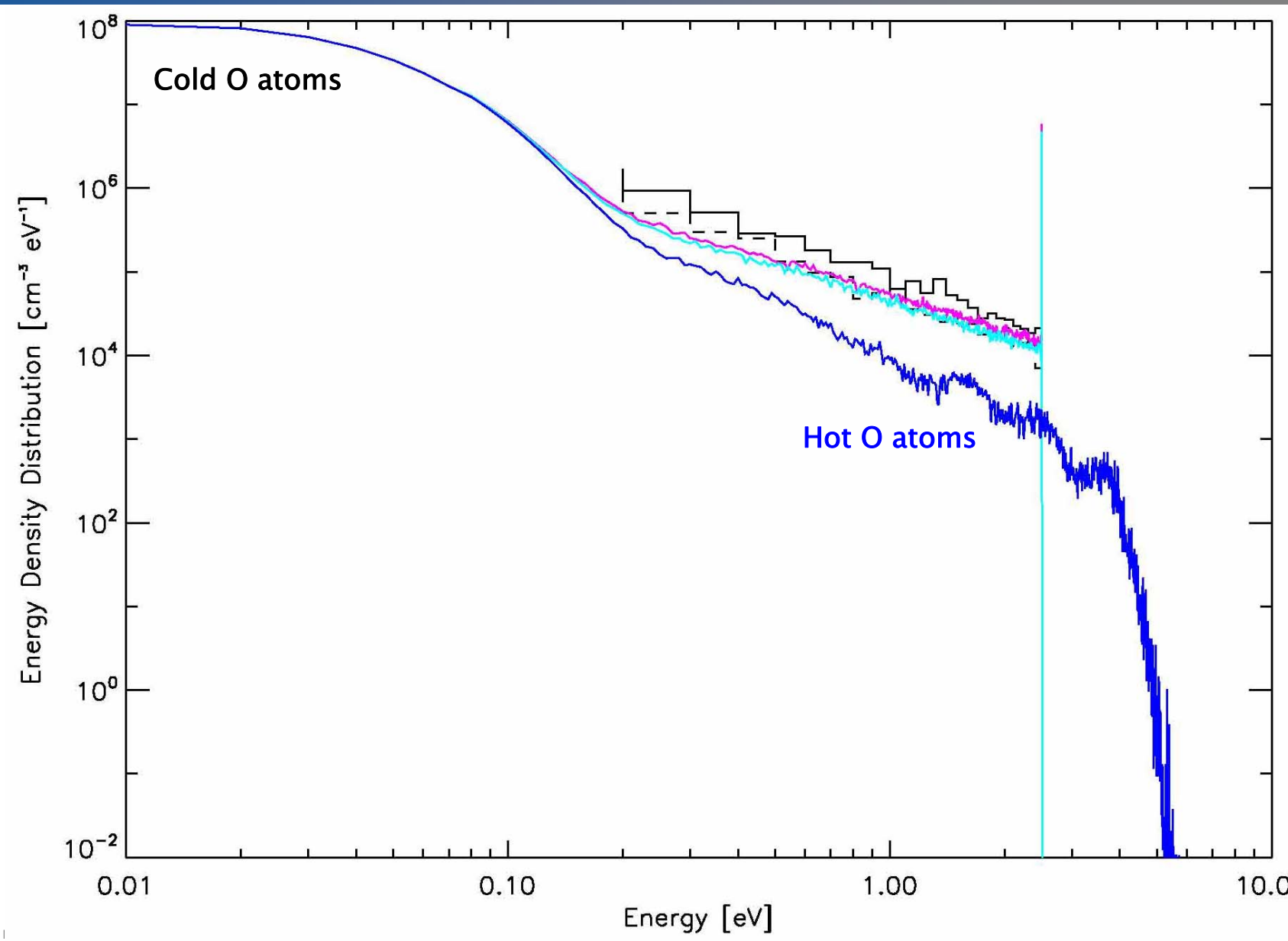
Venus: EDFs → Ip, Nagy and Cravens



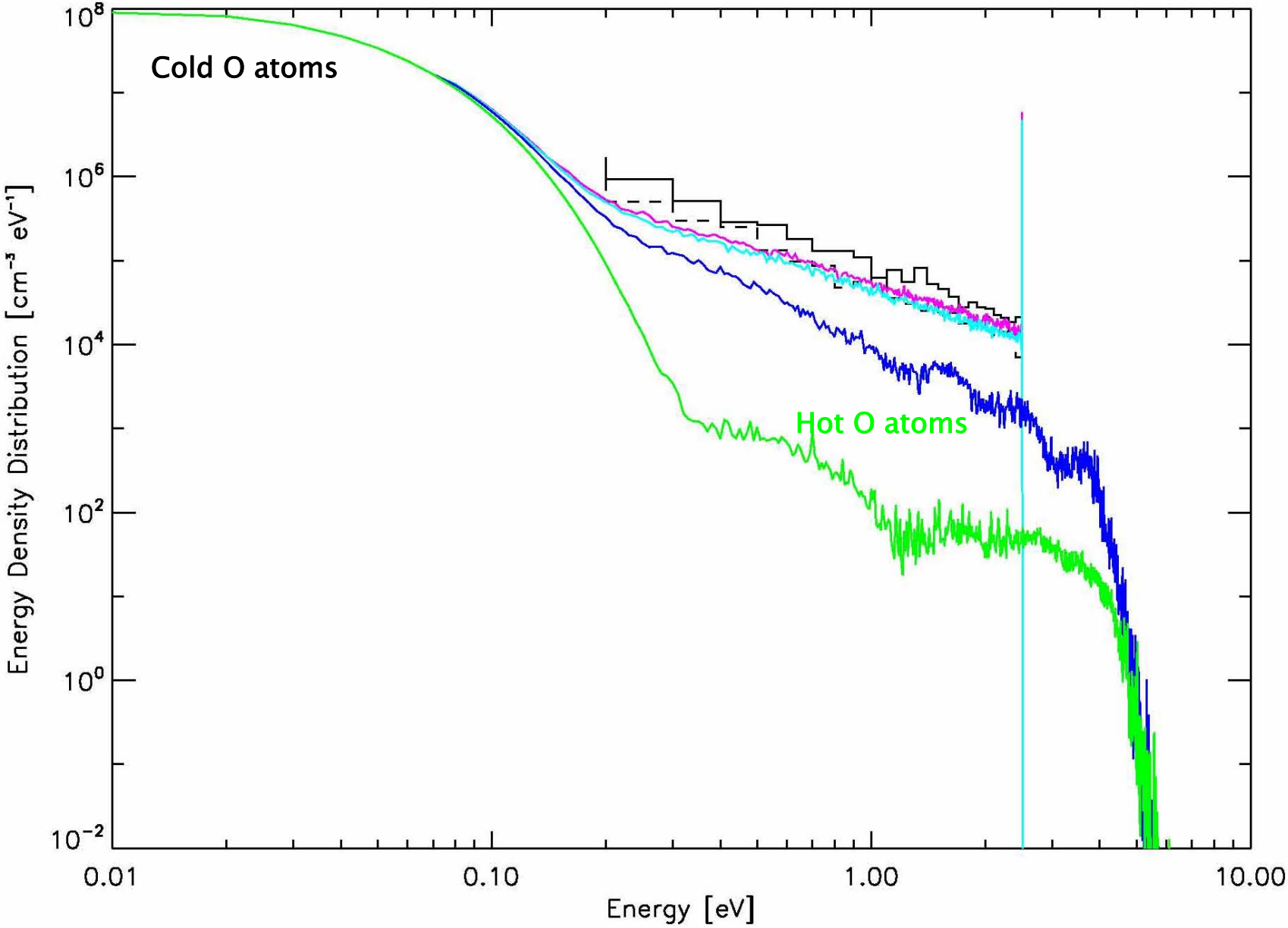
Venus: EDFs (simplified model, σ & α = const.)



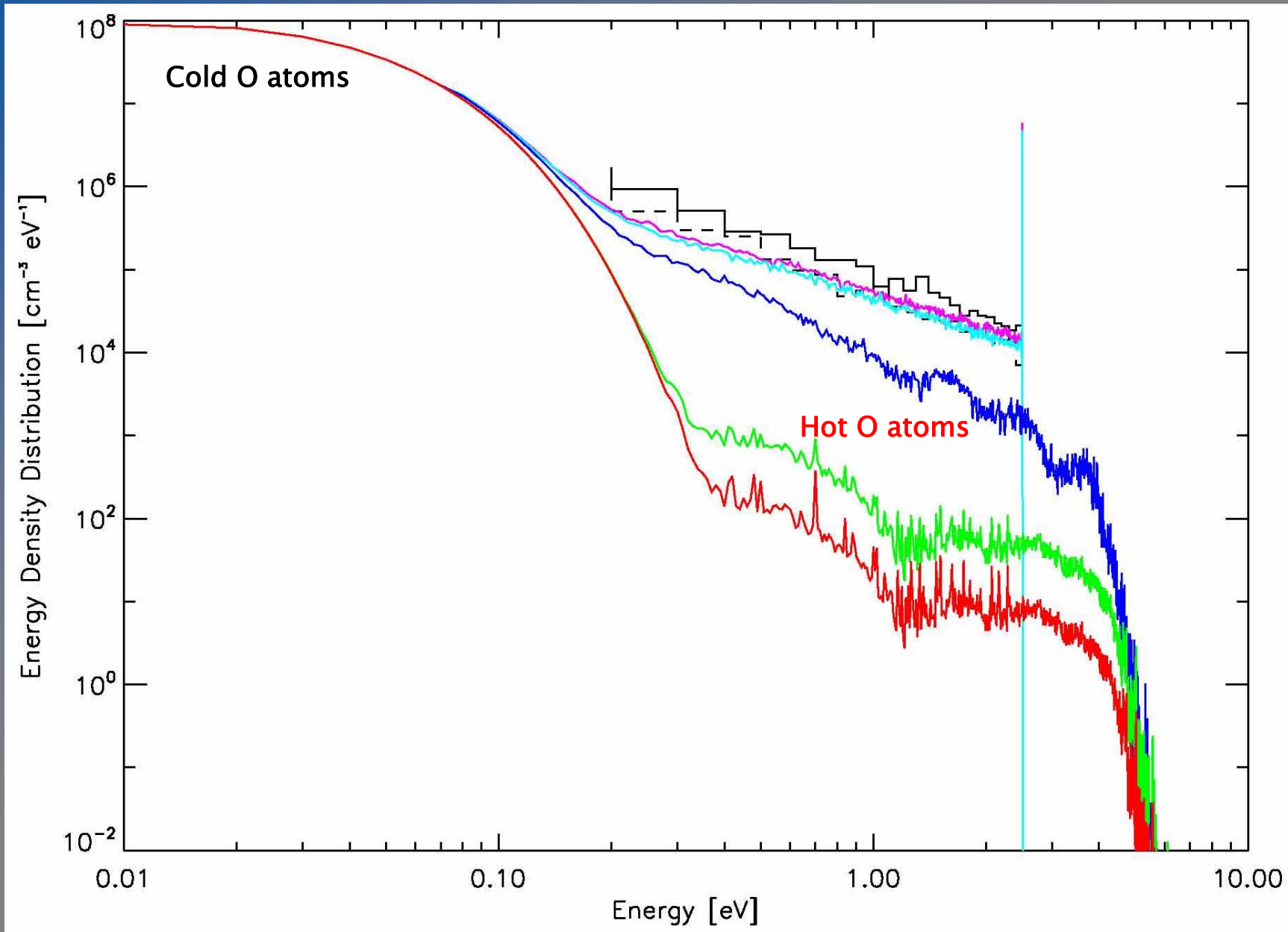
Venus: EDF (σ = const.; α≠ const.)



Venus: EDF (σ ≠ const.; α = const.)



Venus: EDF → 1D (σ ≠ const.; α ≠ const.)



Venus: Hot O corona densities at low solar activity conditions