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Monte-Carlo modeling of hot O, C, and H particles in Venus upper atmosphere

H. Gröller (1), V. I. Shematovich (2), H. I. M. Lichtenegger (1), H. Lammer (1), M. Pfleger (1), Yu. N. Kulikov (3), W. Macher (1), U. V. Amerstorfer (1), and H. K. Biernat (1)
(1) Space Research Institute, Austrian Academy of Sciences, Graz, Austria, (2) Institute of Astronomy, Russian Academy of Sciences, Moscow, Russian Federation, (3) Polar Geophysical Institute, Russian Academy of Sciences, Murmansk, Russian Federation

Abstract

Suprathermal O, C, and H atoms produced by means of photochemical reactions in planetary thermospheres can play an important role for the escape of atmospheric species by direct or indirect processes. In either case the non-thermal energy distribution functions at the exobase must be known in order to estimate the hot exosphere density profiles. For this purpose hot particles generated via photochemical processes are traced along their stochastic way through the thermosphere of Venus by using a 3D Monte-Carlo model and the kinetics and transport characteristics of these particles are determined. The simulation includes the collision of the suprathermal particles with the background gas, the energy transfer, and the tracing of secondary and cascaded hot atoms, which are generated in collisions of the hot particles with ambient constituents. A non-linear electron dissociative recombination coefficient as well as energy and mass dependent collision cross sections and their corresponding scattering angles are also taken into account. The exosphere density is obtained from the corresponding energy density and angular distribution at the exobase altitude by using a test particle model which traces the ballistic trajectories of hot O, C, and H atoms in the exosphere.

In this model we consider inelastic and quenching collisions between the traced hot particle and the ambient neutral atmosphere as well as differential cross sections to determine the scattering angle in the collisions. We also include rotational and vibrational excitation energies for the calculation of the initial energy of the produced hot oxygen atoms. Our results indicate that the differential cross sections and the fraction between elastic, inelastic and quenching collisions are the most sensitive parameters which effect the corona density. We found that the hot O densities inferred from PVO observations can be reproduced based on a forward scattering model but without a significant contribution of inelastic and quenching collisions.

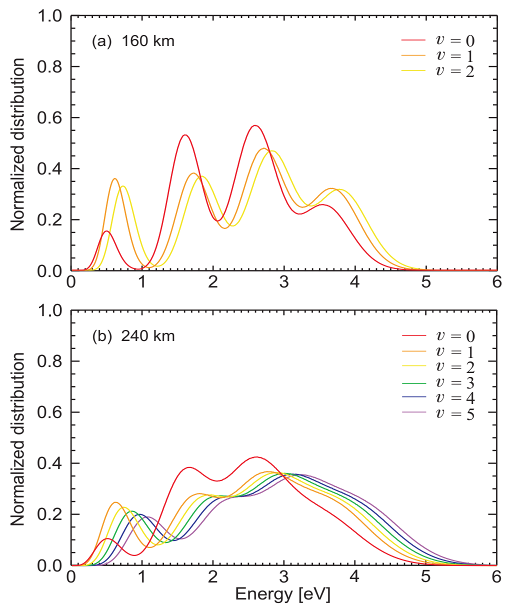

Figure 1: Normalized velocity distributions for hot O atoms produced by DR of O_2^+ in (a) the first three vib. states at 160 km altitude and (b) for $v = 0 - 5$ at 240 km altitude. Only three curves are shown in panel (a), because $> 80\%$ of O_2^+ are in the $v = 0 - 2$ states [1].

The atmospheric and ionospheric density profiles as well as the ion and electron temperatures were taken from [2]. Figure 1 shows the normalized velocity distribution of the start velocities of the newly produced hot O atoms. The EDF of hot O atoms is calculated at an altitude of 240 km. Above, collisions between hot and thermal particles become rare, and the EDFs are

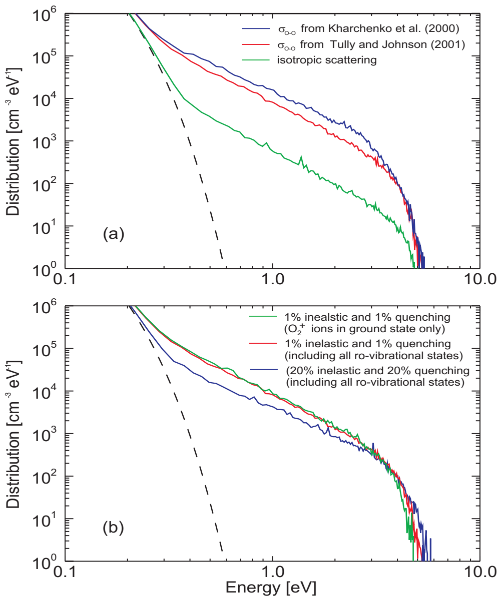

Figure 2: Panel (a): energy distribution function based on isotropic scattering, and on scattering angles according to [3] and [6] at 240 km altitude for 1% inelastic and 1% quenching collisions. Panel (b) shows the influence of the fraction of elastic, inelastic and quenching collisions and the ro-vibrational states with the cross sections taken from [6]. The dashed lines equal the Maxwell distribution of the O background.

not significantly affected by collisions any more. By using the EDF and the corresponding angular distribution of the hot O atoms, a large set of ballistic trajectories is calculated in order to obtain the hot O density in the exosphere. The calculated EDFs in Figure 2a show the effects of the forward scattering for two different cross sections for O-O collisions (taken from [3] and [6]) compared to isotropic scattering. Figure 2b illustrates how a higher fraction of inelastic and quenching collisions shifts the EDF to lower densities and to higher energies, respectively. The exosphere density profiles are displayed in Figure 3. For reference, the result of a pure isotropic scattering model [4] (green line) as well as the PVO observations of [5] (dots) are also included in Figure 3.

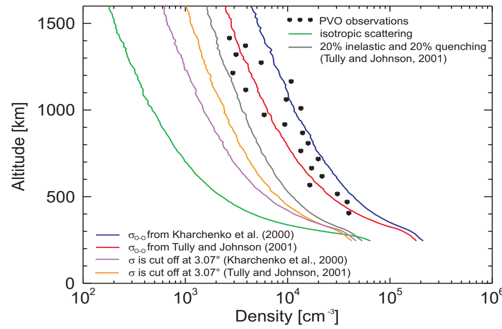

Figure 3: Hot O corona density as function of altitude for various scattering angle distributions. Dots correspond to the early PVO observations.

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