Monte-Carlo modeling of the electron aurora.

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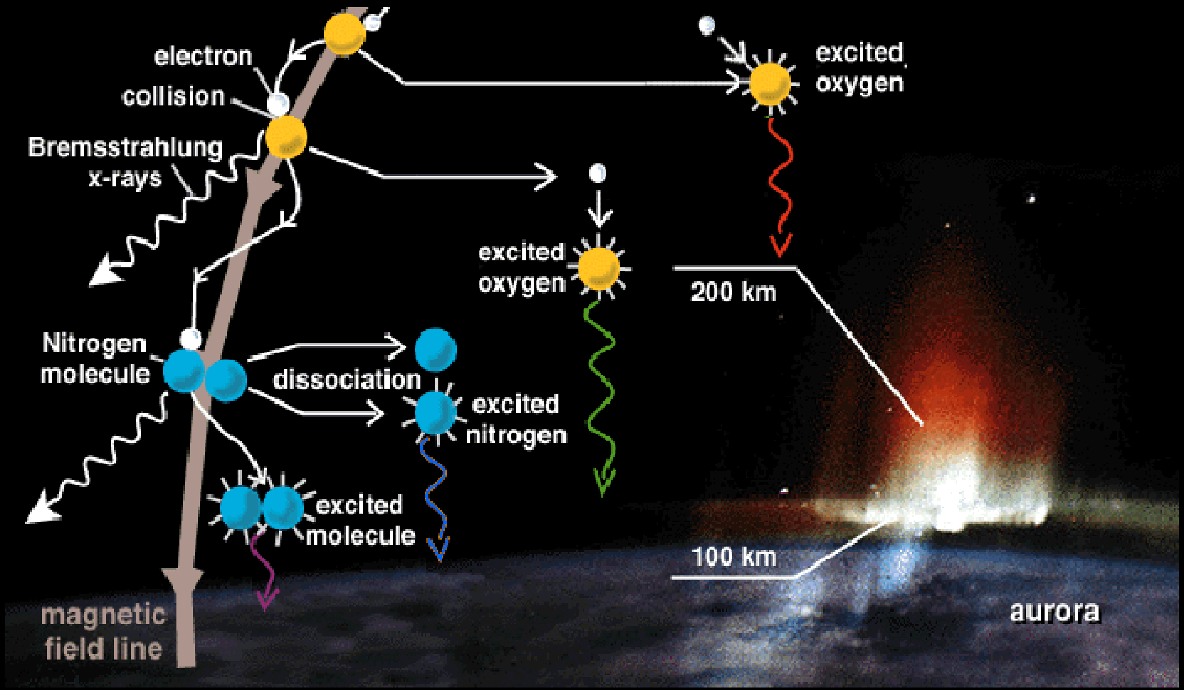
Context

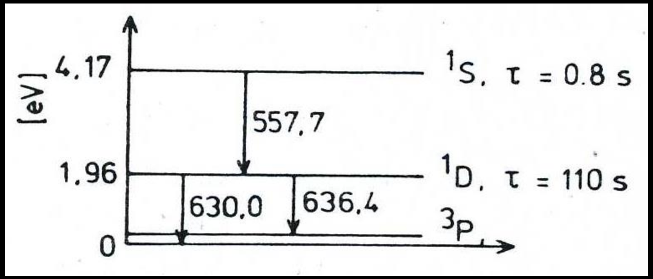
- Auroral emissions result from the precipitation of charged particles from the Earth magnetosphere into the ionosphere.
- Precipitating particles (electrons and protons) collide with the ambient gas constituents causing
  - Ionization that produces secondary electrons
  - Excitation and emission of light (mostly due to the secondaries)
  - An upward return flux of charged particles (the ionosphere remains neutral)

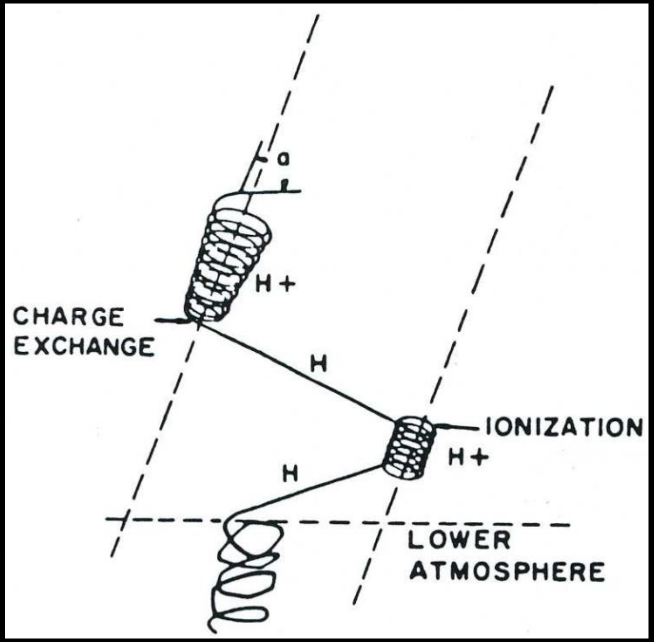
Context

- Excitation of atoms and molecules (O and N_2 for example) produce emission of light that can be detected to remotely sense the auroral activity
- The return flow of particles produces a feedback on the acceleration region where auroral particles gain energy
- The ionosphere and magnetosphere are therefor coupled
- This coupling can be studied by measuring the particles flux (in situ) and by remotely sensing the auroral emissions (up to the global scale).

Context







$$e(E) + X \rightarrow \begin{cases} e(E') + X \\ e(E') + X^* \\ e(E') + X^+ + e(E_s) \end{cases}$$

Monte-Carlo modeling

- A Monte-Carlo modelling of the aurora, or any other phenomenon related to gas kinetics, is a numerical analog describing the microscopic physics in a stochastic manner.
- A Markov chain is used to evolve the numerical sample representation of the modeled gas
- Statistical properties of the modeled gas are accumulated as the Markov chain is ran.

Monte-Carlo modeling

- The MC model produces a stochastic solution of the steady state Boltzmann equation:

$$\mathbf{v}\frac{\partial}{\partial \mathbf{r}} f_e + \mathbf{s}\frac{\partial}{\partial \mathbf{v}} f_e = Q_{e,photo}(\mathbf{v}) + Q_{e,secondary}(\mathbf{v}) + \sum_{M=O,CO,N_2,CO_2} J(f_e, f_M),$$

Advection/ acceleration in phase space

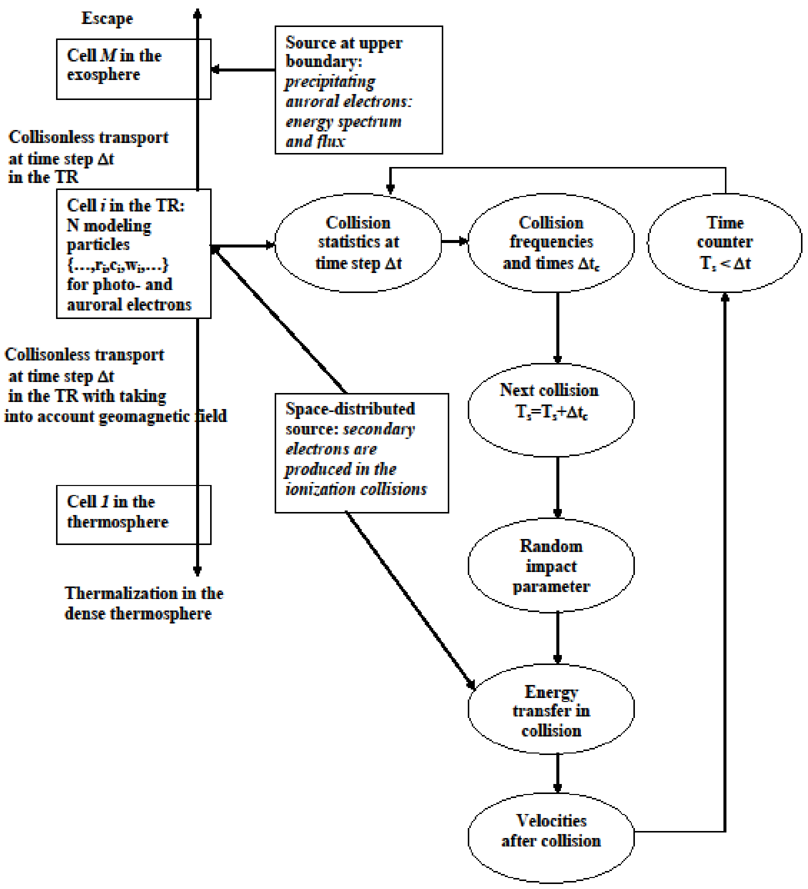
Photoionization when needed

Production of secondary electrons

Elastic and inelastic scattering due to collision with the constituents of the ambient gas

Monte-Carlo modeling

Kinetic Monte Carlo model of electron transport:

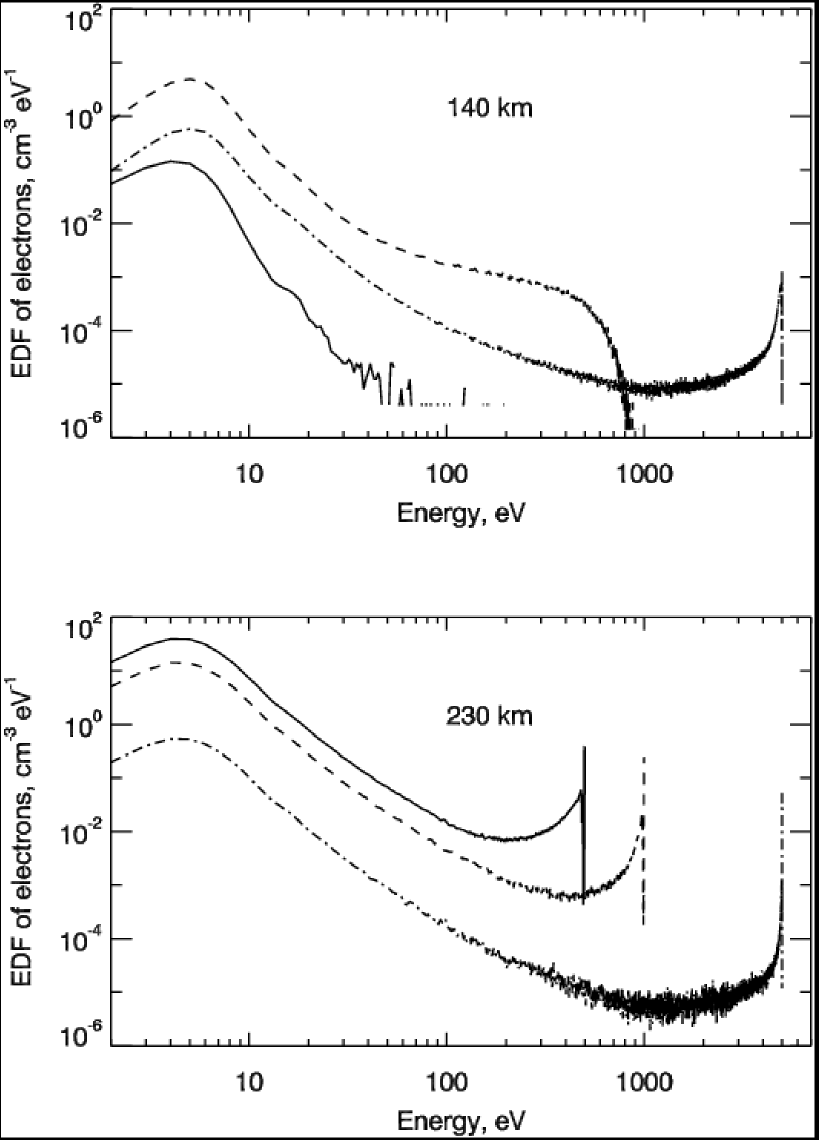


Preliminary results

- The model produces runs for
  - Mono-energetic electron flux input at the top of the model (E_0 at choice of the user)
  - Mono-directional pitch angle distribution
  - Isotropic pitch angle distribution
- The MC code calls MSIS to obtain its atmospheric composition.
- CPU time: ~40 h (AMD opteron 6282 SE 2.6 - 3 Ghz)
- New machine with appropriate computing power ordered recently (2x Xeon E5 2640 v4 2.4 - 3.4 Ghz)

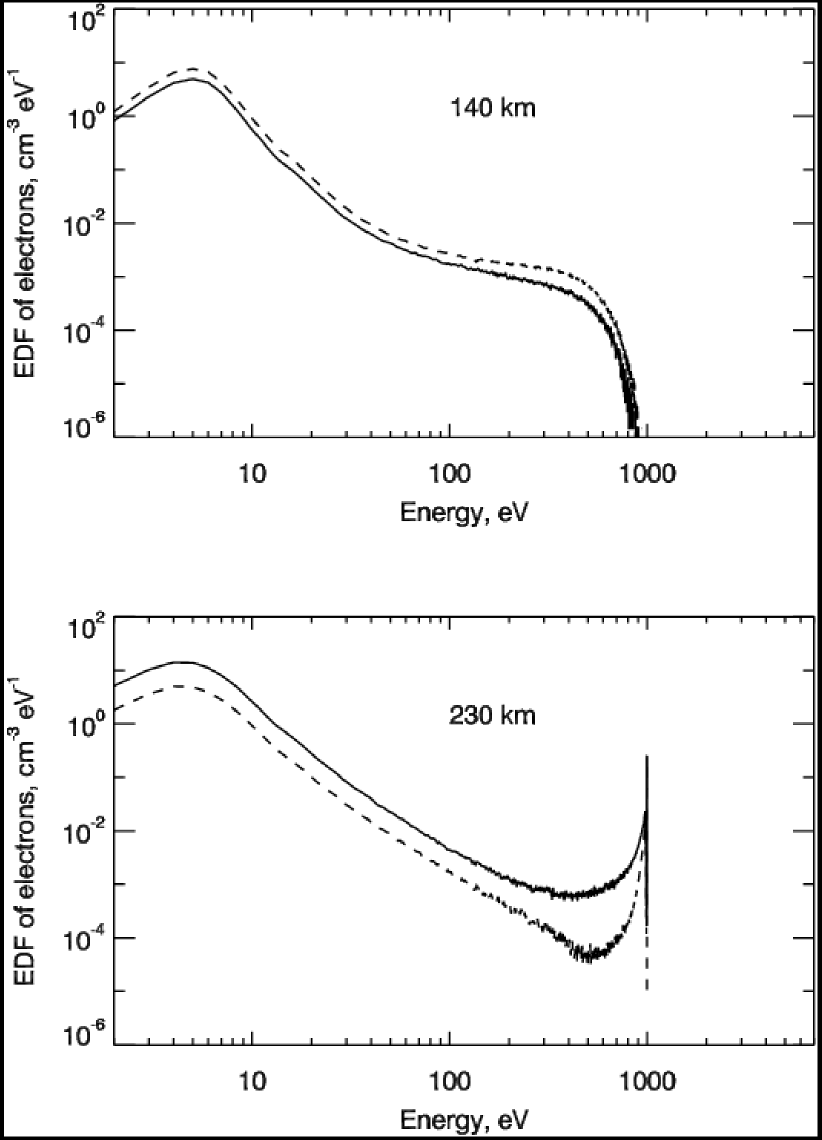
Energy distribution function

- Simulation for isotropic injection,
  - E_0= 0.5 keV (solid),
  - 1 keV (dashes),
  - 5 keV (dash-dot)



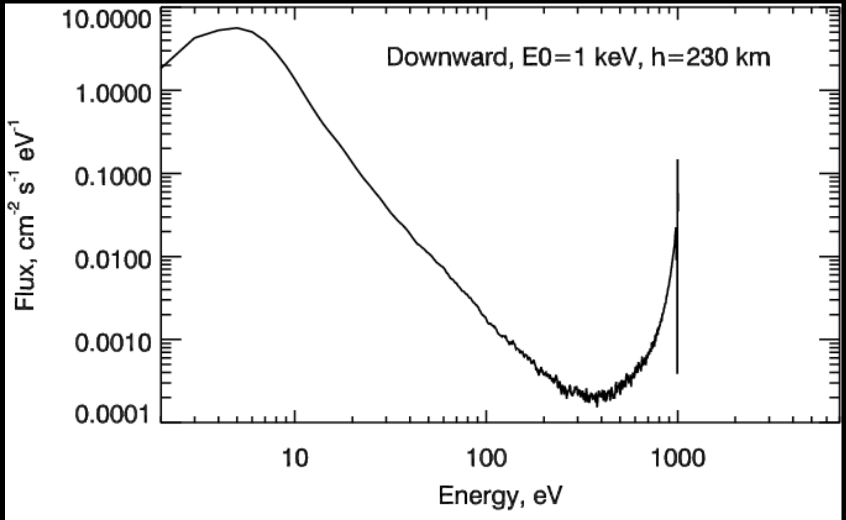
Energy distribution function

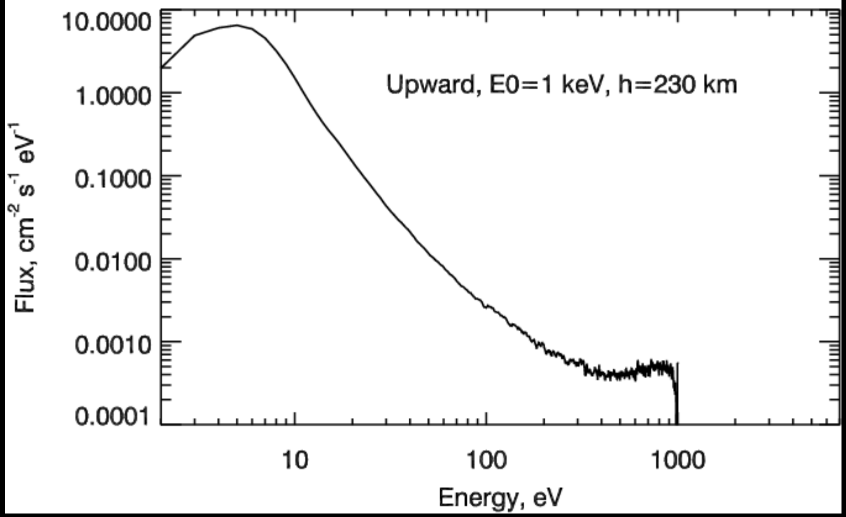
- $E_0 = 1$ keV
  - solid: isotropic
  - dashed: mono-directional



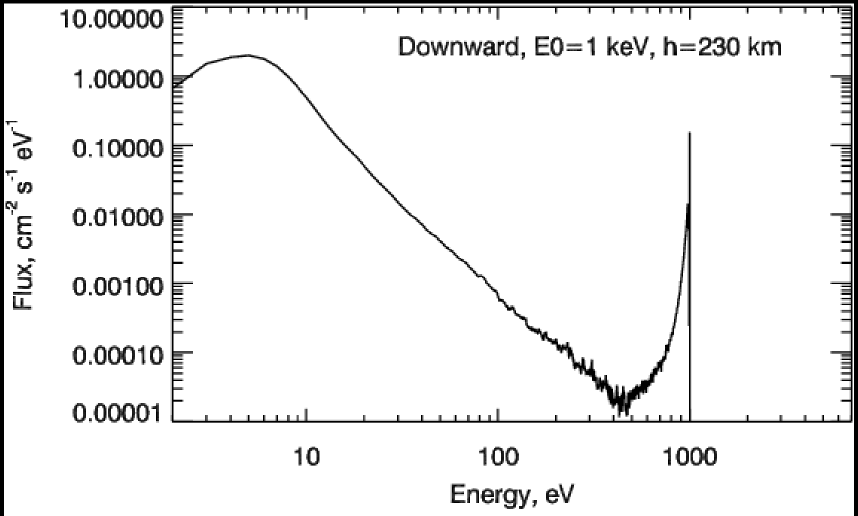
Particles flux at 230 km

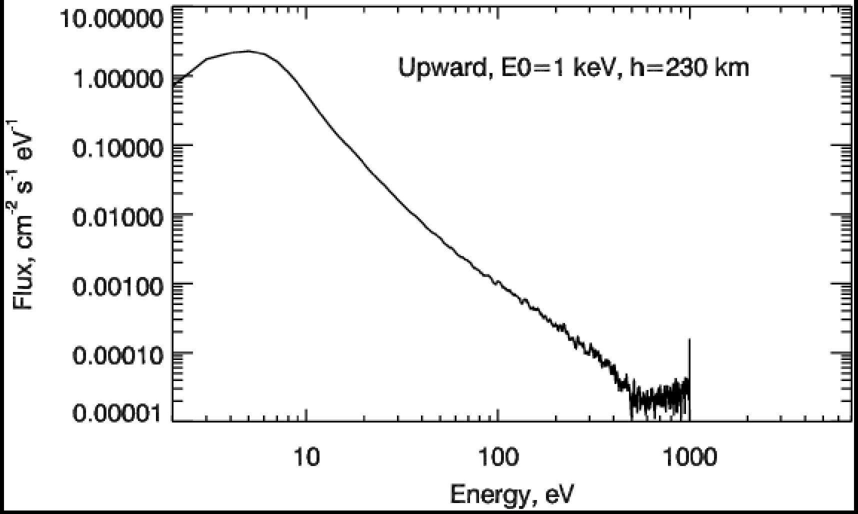
Isotropic





Mono-directional



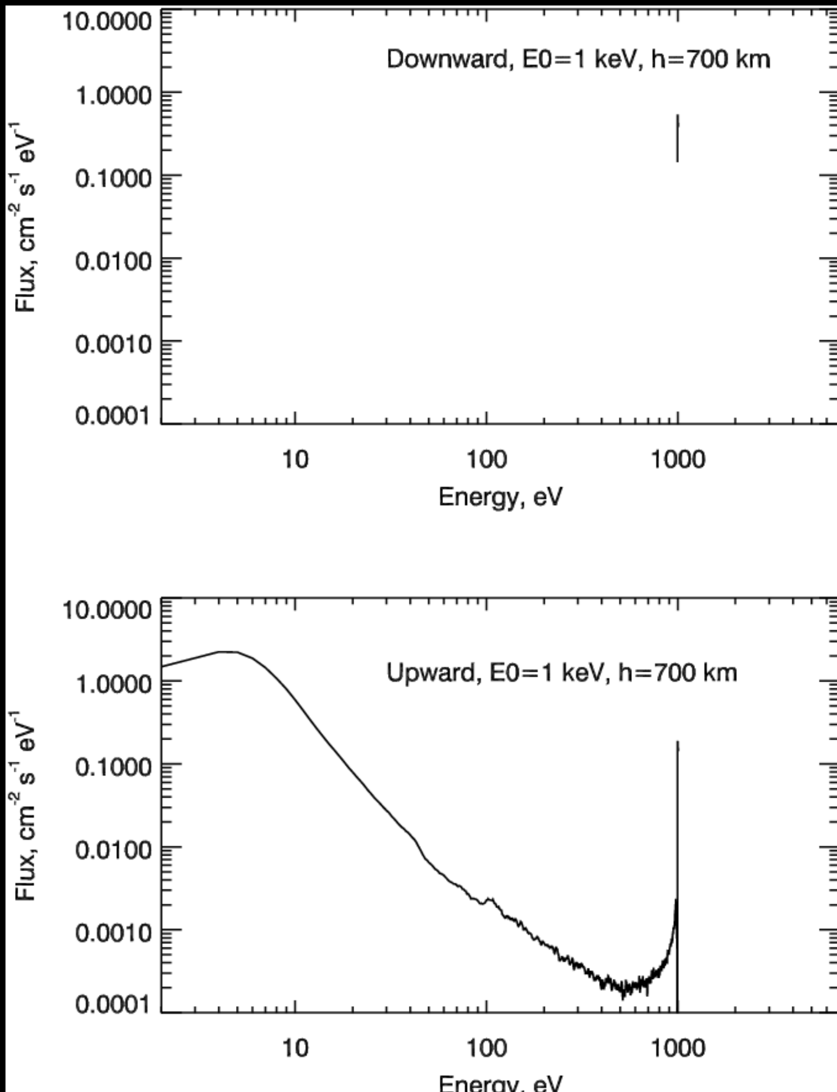


Conclusions

- A Monte-Carlo simulation model of the electron aurora has been developed.
- It computes the electron upward and downward fluxes needed for coupling with other simulation tools
- The effect of magnetic mirroring influences the return flux depending on the initial pitch angle distribution
- Auroral emissions can also be computed as a support to auroral imaging analysis for future space missions.

Particles flux at 700 km

Isotropic



Monodirectional