Non-equilibrium synthetic Si IV and O IV spectra formed by the periodic electron beam

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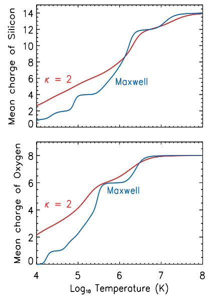
Assumptions

- **Electron beam** is a result of the reconnection and its presence is a common signature e. g. of the coronal heating
- Electron beam travels across the plasma volume for a short time and can be thermalized deeper in the atmosphere
- **Beam + plasma distribution** can be modeled by **the electron distribution with an high energy tail – a κ-distribution**
- The periodic electron beam with plasma is assumed with a **κ-distribution** is during the **first half-period** and **Maxwellian distribution** during **second half-period**. The distributions have **the same low energy part and bulk** and **differ in the high-energy tail** and temperature (the mean energy of distribution) **only**
- The Maxwellian distribution with T=10^4 K is assumed before the interaction. The distribution periodically changes from Maxwellian to κ−distribution. Parameter κ model the magnitude of the electron beam and can be 5 (weak), 3 (middle), and 2 (strong beam, from left to right). The electron beam (tail of the κ−distribution) contains 15%, 25%, and 35 % of the total particle number and carries 30%, 50%, and 75% of energy
- **The beam drivers the plasma out of ionization equilibrium**



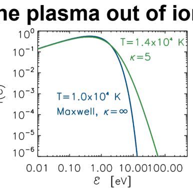
The ion mean charge of ions was used to estimate the effective temperature out of equilibrium

κ = 5 ↔ Maxwell

T: 1.4x10^4 ↔ 1x10^4 K

Tail: ≈ 15% particles

≈ 30% energy

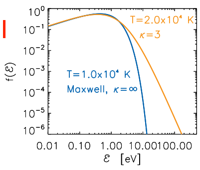


κ = 3 ↔ Maxwell

T: 2x10^4 ↔ 1x10^4 K

Tail: ≈ 25% particles

≈ 50% energy

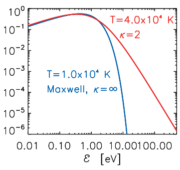


κ = 2 ↔ Maxwell

T: 4x10^4 ↔ 1x10^4 K

Tail: ≈ 35% particles

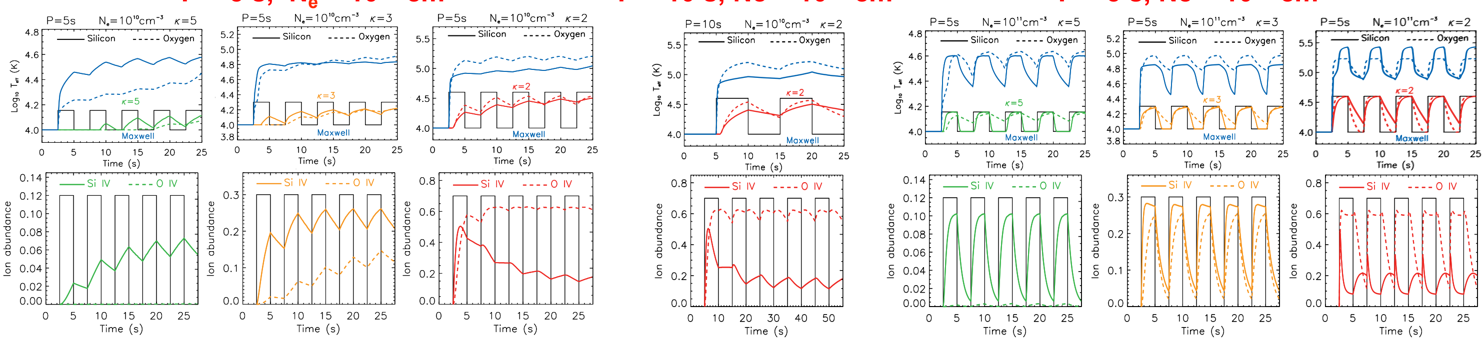
≈ 75% energy



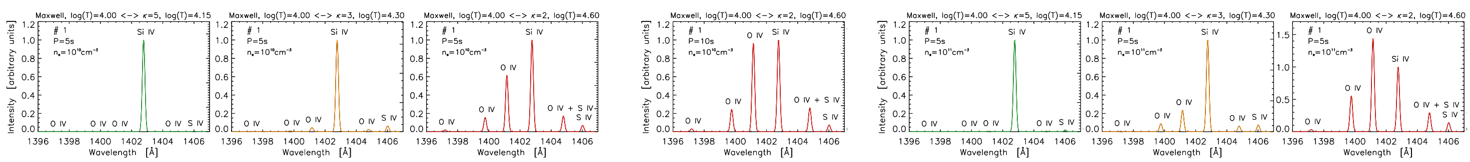
The effective temperatures (T_{eff}) from the mean charge of Silicon and Oxygen (blue lines for the Maxwellian, red lines for κ = 2) are different for the different distributions. **The differences in T_{eff} for the Maxwellian and κ-distribution can be up one order!**

Results

P = 5 s, N_e = 10^{10} cm^{-3} **P = 10 s, Ne = 10^{11} cm^{-3}** **P = 5 s, Ne = 10^{11} cm^{-3}**



The effective temperature and ion abundances for the periodic electron beam with P=5s, N_e=10^{10} cm^{-3}(*left*), P=10s, N_e=10^{10} cm^{-3} (middle), and P=5s, N_e=10^{11} cm^{-3} (left). The time variations for the κ-distribution are shown by green lines (κ=5), orange lines (κ=3), and red lines (κ=2). The effective temperature obtained under assumption of the Maxwell distribution is shown by blue lines.



The synthetic non-equilibrium spectra averaged over the first period for the electron beam described by the κ-distribution with κ=5 (weak beam, green lines), κ=3 (middle beam, orange lines), and κ=2 (strong beam, red lines).

Conclusions

•**Effective temperature** derived from the ionic composition strongly depends on the assumed distribution, **differences** in its estimation can **be one order for κ=2.** The effective temperature is different for different ions

•**Non-equilibrium plasma can form IRIS spectra without oxygen lines.** The relative line intensities depend on the period, electron density and value of κ. Spectra without oxygen lines are formed for a weak electron beam with κ=5 mainly

•Strong electron beam (κ=2) can form peculiar spectra with strong O IV line intensities

•**The energy of electron beam that forms Si IV and O IV spectra is much lower than the thermal energy required for Si IV and O IV ionization**

ACKNOWLEDGEMENTS

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Poster

1. Fundamental physical processes and modeling

Non-equilibrium synthetic Si IV and C IV spectra formed by a periodic electron beam

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Solar transition region is highly dynamic and inhomogeneous. Its heating can be connected with short term particle acceleration processes and formation of the electron distributions with high-energy tails. Such distributions strongly affect the rates of impact ionization, but also recombination and excitation. We study how the plasma can be driven out of ionization equilibrium by a time-dependent presence of high-energy tails. Our model assumes a periodic electron beam passing through the Maxwellian plasma. Ambient plasma during the first half-period has a Maxwellian distribution and the same Maxwellian plasma together with an electron beam during the second half-period is represented by a κ-distribution. The periods 5, 10 seconds and electron densities 10^{10}, 10^{11} cm^{-3} were considered, in addition to different strength of the electron beam indicated by the parameter κ. Transient ionization states and synthetic IRIS spectra of Si IV and O IV were calculated. Naturally, stronger non-equilibrium effects are presented for shorter periods and lower electron densities. Synthetic IRIS spectra show a faster response of silicon ions to the presence of the electron beam in the comparison with the oxygen. This can enhance silicon line intensities in the comparison with an equilibrium state. The line ratio of Si IV to O IV depends on the strength of the electron beam, electron density, and period. For short periods and weak electron beams, the IRIS spectra containing only Si IV lines can be formed. Reversely, strong electron beam and long periods can lead to strong O IV intensities, resembling high-temperature equilibrium spectra. Our results show that the electron beam can drive the plasma out of ionization equilibrium, creating a variety of departures from the equilibrium ones.