Investigating the role of diffusion effects in the fractionation of minor elements in solar loops…

…using a high-order & multi-specie 1-D model

$n_s, u_s, T_s^{\parallel}, T_s^{\perp}$, $\mathbf{q_s^{\parallel}, q_s^{\perp}}$ solved for **Neutrals**, **Charged particles**, **Electrons**

For all these quantities we determine a comprehensive set of collision terms, e.g. for velocity:

$$\frac{\delta u_s}{\delta t} = \frac{1}{n_s m_s}\left[\underbrace{\sum_{t\neq s} n_s m_s \nu_{st}(u_t - u_s)}_{\text{Friction}} + \underbrace{\sum_{t\neq s} \nu_{st}\frac{z_{st}\mu_{st}}{k_b T_{st}}\left(q_s - q_t\frac{n_s m_s}{n_t m_t}\right)}_{\text{Thermal effects}}\right] \quad \textit{(compact formulation)}$$

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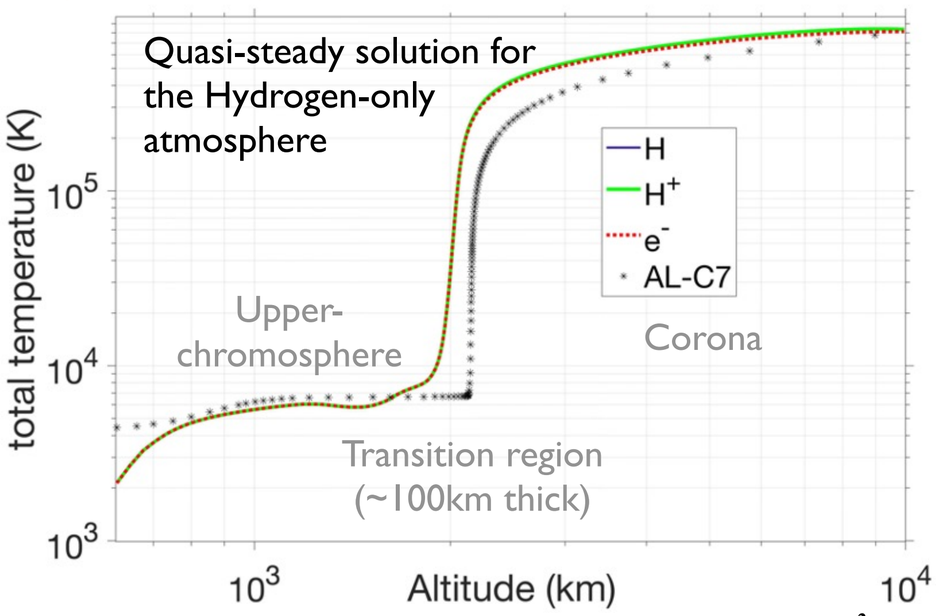
The thin transition from upper-chromosphere to corona is computed self-consistently & dynamically



- Radiative cooling $\mathbf{\Lambda(T) = 10^{-21} 10^{[\log_{10}(T/T_2)]^2} \chi(T)}$

A) Optically thin(/thick) empirical law:

B) *Carlsson & Leenaarts (2012)* semi-empirical approx

- Heating $\mathbf{Q(z) = (F_0/H)(A(z)/A_0)e^{-(z-z_0)/H}}$

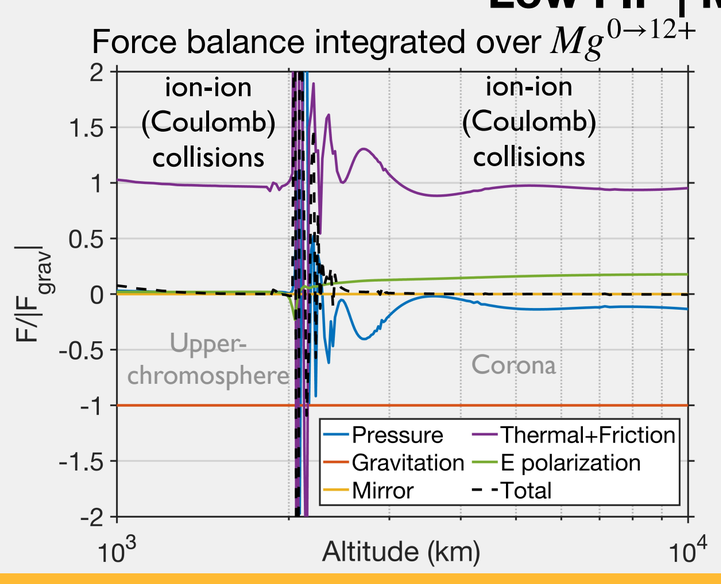
C) Empirical law (mechanical flux):

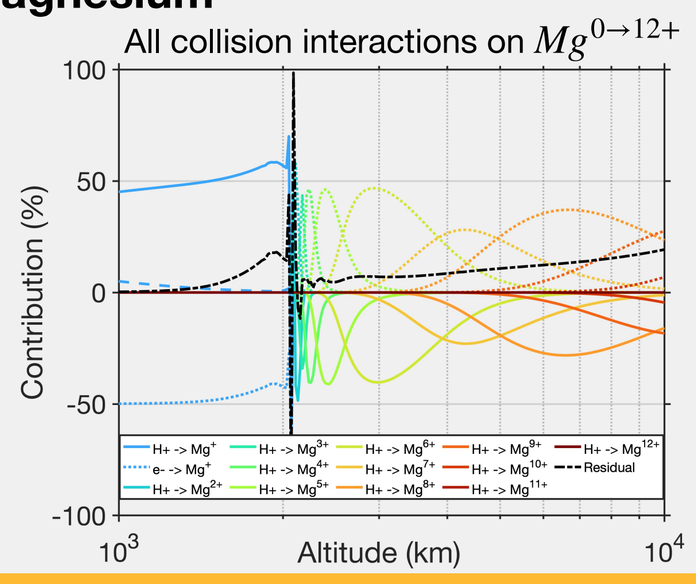
D) (non-)WKB Alfvèn-wave heating

All results shown in this poster include cases A) and C)

The other cases are being tested → stay tuned !

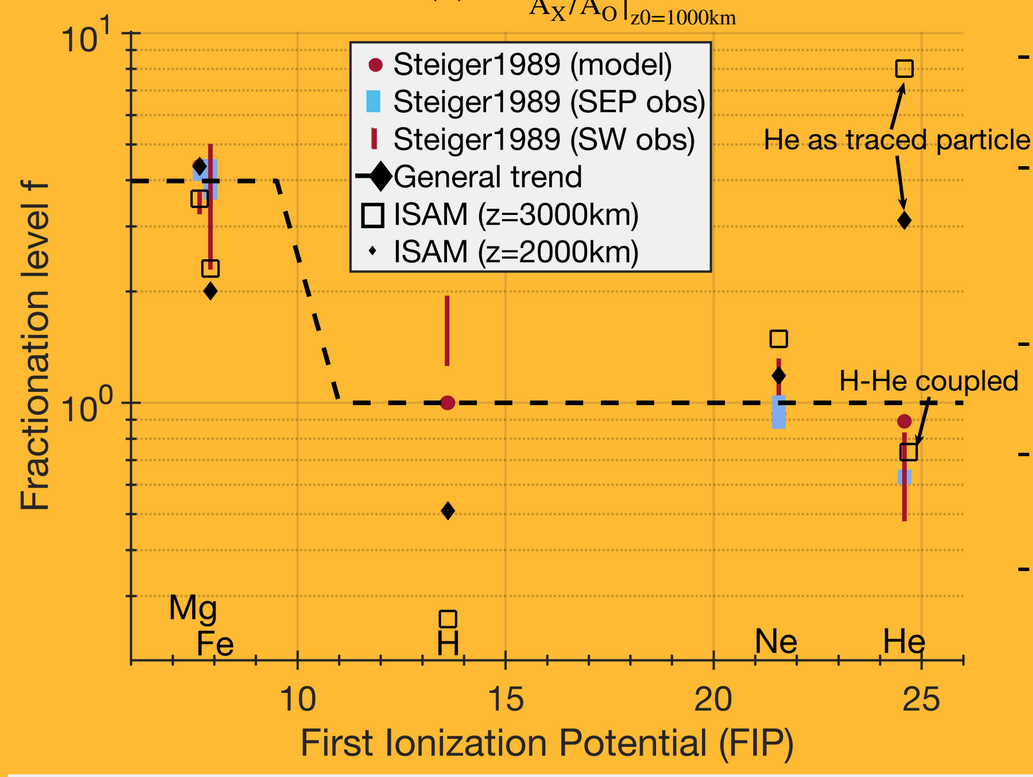
Low FIP | Magnesium





Fractionation in relation to Oxygen

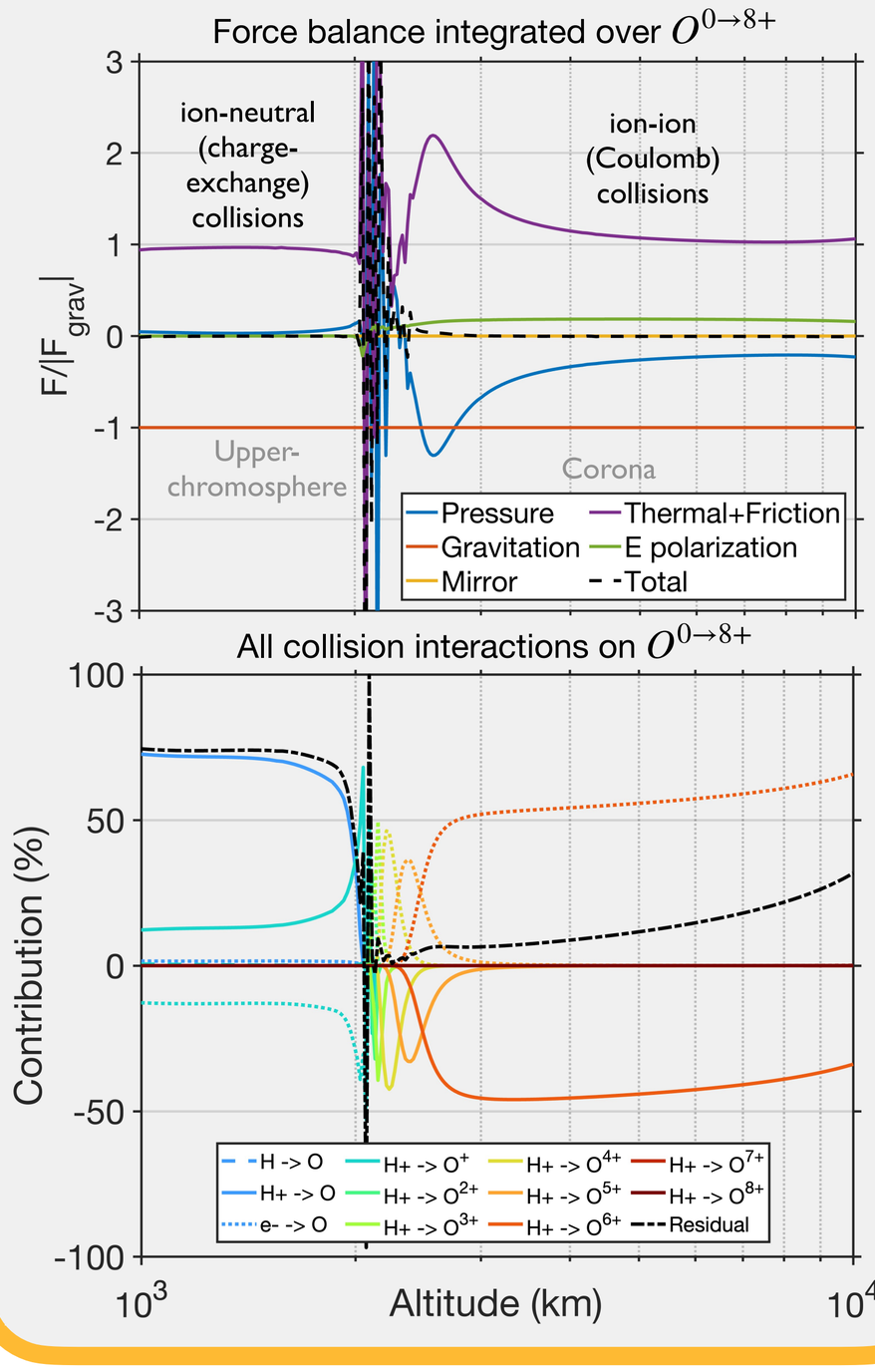
$$f(z) = \frac{A_X/A_O|_{z>z0}}{A_X/A_O|_{z0=1000km}}$$



Main conclusions

- Most of the **fractionation** is already **established at the top of the chromosphere**
- The **type of collision** (ion-ion or ion-neutral) can explain the **low vs high FIP difference**
- **Coulomb collisions with protons are strong** enough to counteract gravity and to push already-ionised low-FIP elements upwards
- **Thermal diffusion effects have a major impact** via Coulomb collisions
- A **pile-up** of plasma **forms in the loop-top** ($z > 10^4$km) over a few days
- **Diffusion alone can explain most of the FIP effect in loops but need additional regulation mechanisms**: e.g. chromospheric mixing, release via reconnection, wave-particle effects

Intermediate FIP | Oxygen



High FIP | Helium *(preliminary results)*

Current status & road map

[Poirier et al. 2023, in prep]