



Solar XUV and ENA-driven water loss from early Venus' steam atmosphere

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What makes a planet to evolve into a potential habitat? Why are Venus and Earth so different?

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(IWF Early Sun: radiation and particle environment



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(IWF Energetic neutral atoms (ENAs)





Chassefière, 1996, JGR

ENAs or energetic neutral atoms were observed everywhere around the Solar system planets where the corresponding equipment was available $\Box \rightarrow \langle \overline{\Box} \rangle + \langle \overline{\Box} \rangle +$

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<u>Aims</u>: to study the influence of ENAs on the atmospheric escape from early Venus assuming realistic conditions of early Sun (inspired by the study of Chassefière, 1996, JGR).

- 1D hydrodynamic code to model the inner atmosphere structure
- Direct Simulation Monte Carlo (DSMC) for modelling of the hydrogen corona and ENAs
- DSMC code to model the collisions of ENAs with deep atmospheric layers and their influence on atmospheric temperature and escape profiles
- Simplified formulas to model dragging of other atmospheric species by escaping hydrogen

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(IWF Simulation domain geometry





The coordinate system used is centered at the planet and has its x-axis toward the star, the y-axis opposite the orbital velocity, and the z-axis completes the right-handed coordinate system. The assumed magnetospheric obstacle

$$X = R_s \left(1 - \frac{x^2 + y^2}{R_t^2} \right)$$

where R_s and R_t define the location of the substellar point and the based width respectively. K.G. Kislyakova (IWF) (IWF) ENA driven loss from Venus' atmosphere February 10, 2016 6 / 11

(IWF Cross section problem





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(IWF Atmospheric escape: ENAs heating







Young Sun	$I_{\rm XUV} \ [{\rm erg} \ {\rm cm}^{-2} \ {\rm s}^{-1}]$	$L_{\rm th} [{\rm s}^{-1}]$	C: $L_{\rm th, ENA} [{\rm s}^{-1}]$	A: $L_{\rm th, ENA} [{\rm s}^{-1}]$	B: $L_{\rm th, ENA} [{\rm s}^{-1}]$
30 XUV	280	8.6×10^{31}	8.6×10^{31}	8.7×10^{31}	9.5×10^{31}
100 XUV	930	1.66×10^{32}	1.68×10^{32}	1.72×10^{32}	1.82×10^{32}



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The flux of escaping hydrogen is dragging other atmospheric species and removing them from the atmosphere.

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- ENAs influence on the atmosphere heating/escape budget is much lower than the one estimated by Chassefière due to a lower solar wind flux
- However, ENAs change the temperature and velocity profiles of Venus' primordial atmosphere
- Influence of ENAs on the hydrogen escape is close to negligible, because heating mostly occurs above the sonic point
- Strong flux of escaping hydrogen can drag other species and increase the atmosphere mass loss

Results of the study can be found in Lichtenegger, Kislyakova et al., GRL, submitted

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