

EXPLORING THE VARIABILITY OF THE METEORIC METAL LAYERS IN THE VENUSIAN ATMOSPHERE

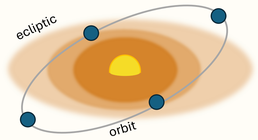


Bianca Ceragioli[1] (hkgm2062@leeds.ac.uk), John Plane[1], Daniel Marsh[1,2], Wuhu Feng[3], Dwayne Heard[1], Joanna Egan[4], Juan Diego Carrillo-Sánchez[5], Diego Janches[5], Aurélien Stolzenbach[6], Sébastien Lebonnois[7], Franck Lefèvre[8]

[1] School of Chemistry, University of Leeds, Leeds, UK; [2] School of Physics and Astronomy, University of Leeds, Leeds, UK; [3] National Centre for Atmospheric Science (NCAS), Leeds, UK; [3] National Centre for Atmospheric Science (NCAS), Leeds, UK; [4]Open University, Milton Keynes, UK; [5]NASA, Goddard Space Flight Centre, US; [6]Instituto de Astrofisica de Andalucia, Granada, Spain; [7]Laboratoire de Météorologie Dynamique (LMD), Paris, France; [8]Laboratory for Atmospheres, Observations, and Space (LATMOS), Paris, France;

Cosmic dust and the metal layers

As they orbit, planets collide with **interplanetary dust** around the plane of the **ecliptic**.



In the presence of an atmosphere, cosmic dust melts and ablates at **~1 μbar**, forming layers of neutral and ion metals.

	Venus	Earth	Mars
Dust input (t d^{-1})	31.0 ± 15.5	27.9 ± 8.1	2.1 ± 1.0
Orbital variability sources	inclination	eccentricity tilt	eccentricity inclination tilt
Metal layers	not observed yet	metal layers at 80-105 km	Mg^+ layer at 90 km

Table 1: Dust mass input, orbital variability and presence of metal layers on Venus, the Earth and Mars

→ What could the metal layers look like on Venus?

The meteoroid input function

The metal layers on Venus are modelled using the **meteoroid input function.**

Zodiacal Cloud Model (**ZoDy**) → Meteoroid Input Function (**MIF**)

Leeds Chemical ABlation MODel (**CABMOD**) → Meteoroid Input Function (**MIF**)

The MIF assigns a cosmic dust input to each atmospheric layer, distributed across **Fe, Na, Mg, Si** and their ions.

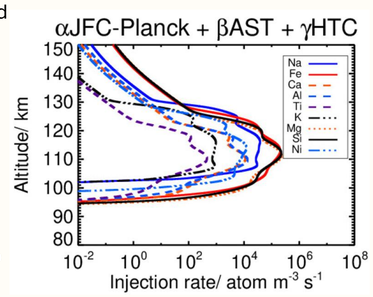


Figure 1: Metal injection rate for Venus[1].

The MIF and the Venus PCM

The MIF is injected in the atmosphere using the **Venus PCM** (1D/3D), a GCM model with complex photochemistry and dynamics[2]. The injected metals experience:

- **a chemical network;** the species react with the other components of the atmosphere of Venus
- **dynamics and transport;** including winds and molecular and ambipolar ion diffusion, particularly important around and above the turbopause

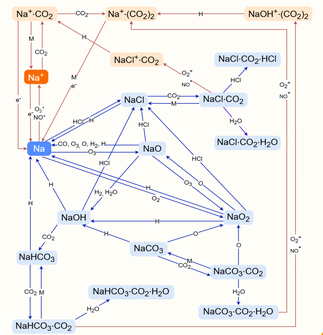


Figure 2: Na chemical network

Results: variability of the sodium layer

Latitudinal variability

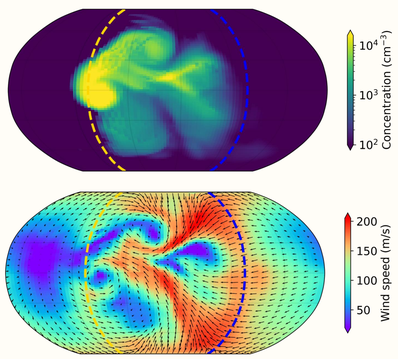


Figure 7: Comparison of Na density (7a) and winds (7b) at 115 km of altitude.

Winds introduce latitudinal variability; this is an area of transition between the superrotation and subsolar to antisolar regimes, generating highly variable wind patterns.

Day-night variability

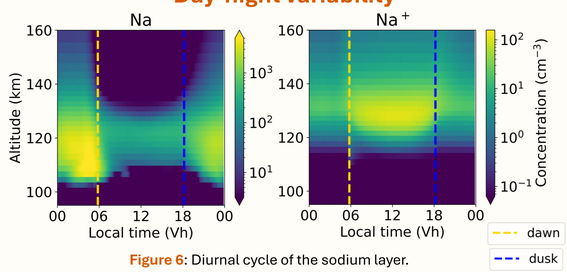
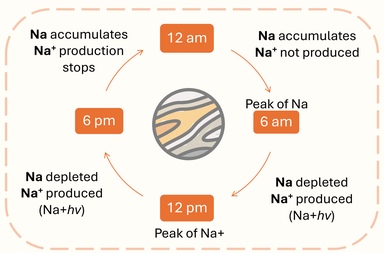
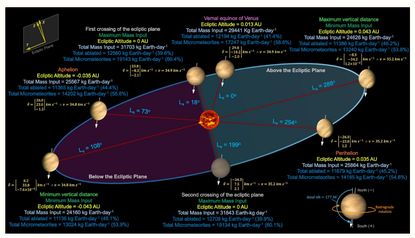


Figure 6: Diurnal cycle of the sodium layer.



Photoionisation drives the diurnal variability, generating a peak in neutral Na just before dawn.

Seasonal variability



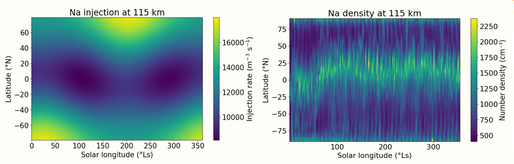


Figure 5: Cosmic dust total mass input[3] (5a). Seasonal variation of Na ablation at 115 km in the MIF (5b) and in the model output (5c).

Orbital variability is minimal; the dynamic atmosphere overrides the variability of the injection.

Results: metal layers

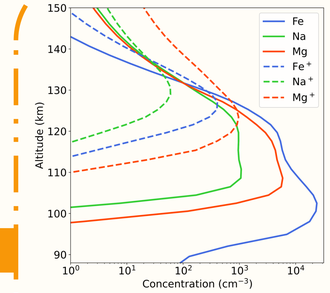


Figure 3: meteoric metal layers on Venus (global average)

As an example, the Na and Fe layers – which peak around 10 km apart – present different column densities and specific patterns.

→ What is the source of this variability, and what shapes the layers?

The injection of MIF metals into the Venus PCM predicts the formation of well-defined meteoric metal layers – **Fe, Na and Mg** are the most prominent.

Highlights:

- The metals separate into **neutral** layers at lower altitudes and **ion** layers at higher altitudes.
- The metal layers peak at **varying altitudes**, and present specific shapes and abundances based on the metal.

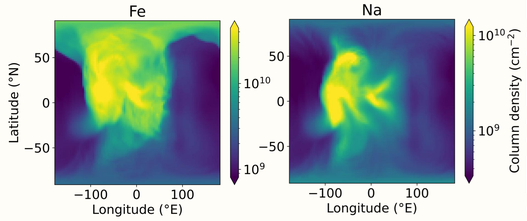


Figure 4: Column density of the Fe and Na layer, presenting different patterns

Conclusions and future work

This work indicates **meteoric metal layers** should form on Venus and peak at between 100 and 130 km.

What shapes the metal layers?

- **Diurnal variability:** driven by photochemistry, due to sunlight-induced ionisation.
- **Latitudinal variability:** driven by dynamics; strong winds cause ablation-dependant patterns.
- **Seasonal variability:** is negligible; Venus's orbital position has a lower impact than the winds.

Where is the Na layer most detectable?

The highest abundance of Na is found at **night**, around the **dawn terminator**.

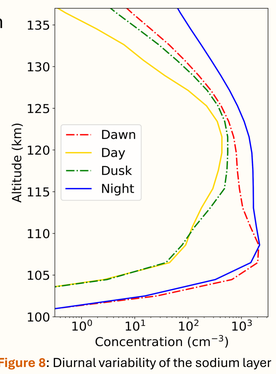


Figure 8: Diurnal variability of the sodium layer

Meteoric metals on Venus

Metals were detected in the **clouds and hazes**:

→ "*Re-Analysis of Pioneer Venus Data: Water, Iron Sulfate, and Sulfuric Acid are Major Components in Venus' Aerosols*" (Mogul et al., 2025)

→ "*A Microphysics Model of Multicomponent Venus' Clouds With a High-Accuracy Condensation Scheme*" (Karyu et al. 2025)

Metals could contribute to the **UV absorber** (e.g. $FeCl_3$) and play a role in the **depletion of SO_2** in the clouds (e.g. Fe^{2+}/Fe^{3+} catalysis).

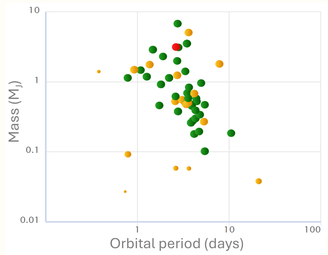


Figure 9: Plot of Na detections (green) and upper limits (yellow) in exoplanets

Meteoric metals in exoplanets

Detecting metals layers on Venus would prove they can form in **CO_2-rich** atmospheres. Na is a good candidate due to its strong signal in the visible, and it has already been detected in 30+ exoplanetary atmospheres[4].

References and acknowledgements

1. J. D. Carrillo-Sánchez, J. C. Gómez-Martín, D. L. Bones, D. Nesvorný, P. Pokorný, M. Benna, G. J. Flynn, and J. M.C. Plane 2020. Cosmic dust fluxes in the atmospheres of Earth, Mars, and Venus. *Icarus, 335*, p.113395.

2. Overview of the Venus PCM. 2025. *Planets*. Retrieved July 2, 2025

3. J. D. Carrillo-Sánchez et al., A comprehensive study of the meteoroid input at Venus, *in preparation*

4. ExoAtmosphere Database (IAC). Retrieved April 28, 2026

This presentation participates in OSPP

EGU

Outstanding Student & PhD candidate Presentation contest

UK Research and Innovation

UNIVERSITY OF LEEDS