Polarized signatures of a Venus-type exoplanet

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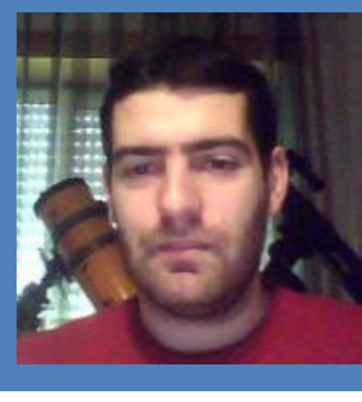


Abstract

Polarimetry is a technique that may provide crucial information about the conditions for habitability of an exoplanet. Through polarized signals it is possible to characterize an extrasolar planet atmosphere, by characterizing its nature, properties and distributions of the scattering particles. This technique can also be used to complement other techniques, such as spectroscopy or photometry.

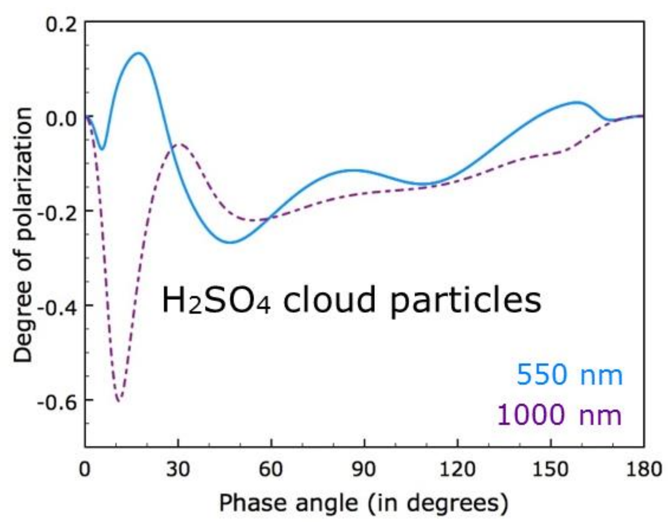
We report typical polarized signals of a Venus-type atmosphere at different stages of its evolution and discuss its observed features. We show the results for $\lambda = 0.55\ \mu\text{m}$.

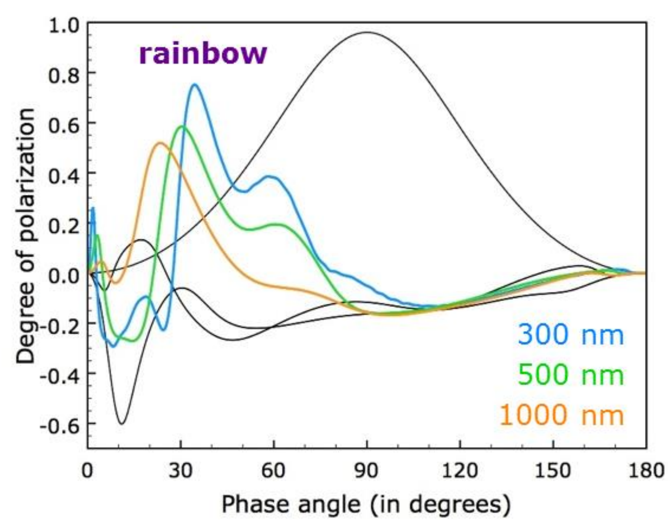
Polarization

Venus-type atmosphere?

Earth-type atmosphere?

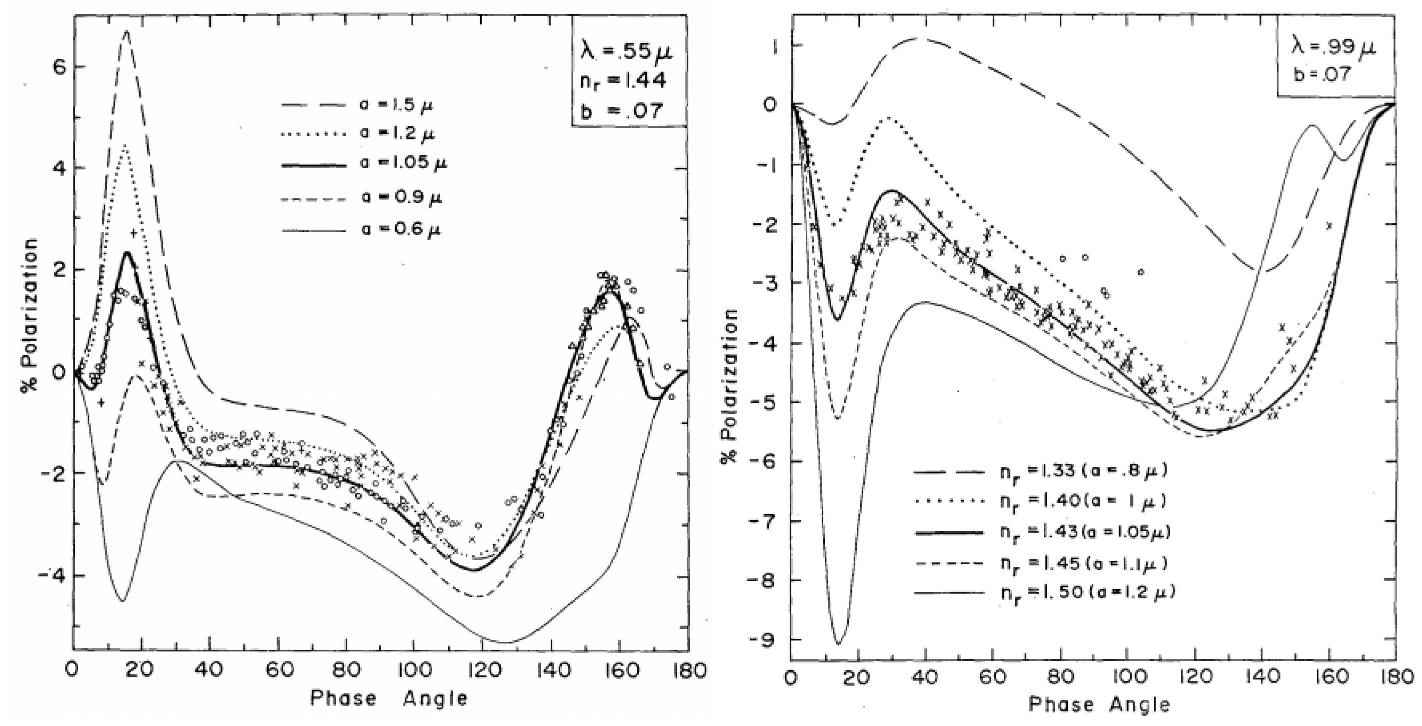
Degree of polarization P is very sensitive to particle properties (size, shape, composition):





Polarimetry of Venus

Ground based polarimetry of Venus clouds [Hansen and Hovenier, 1974]:

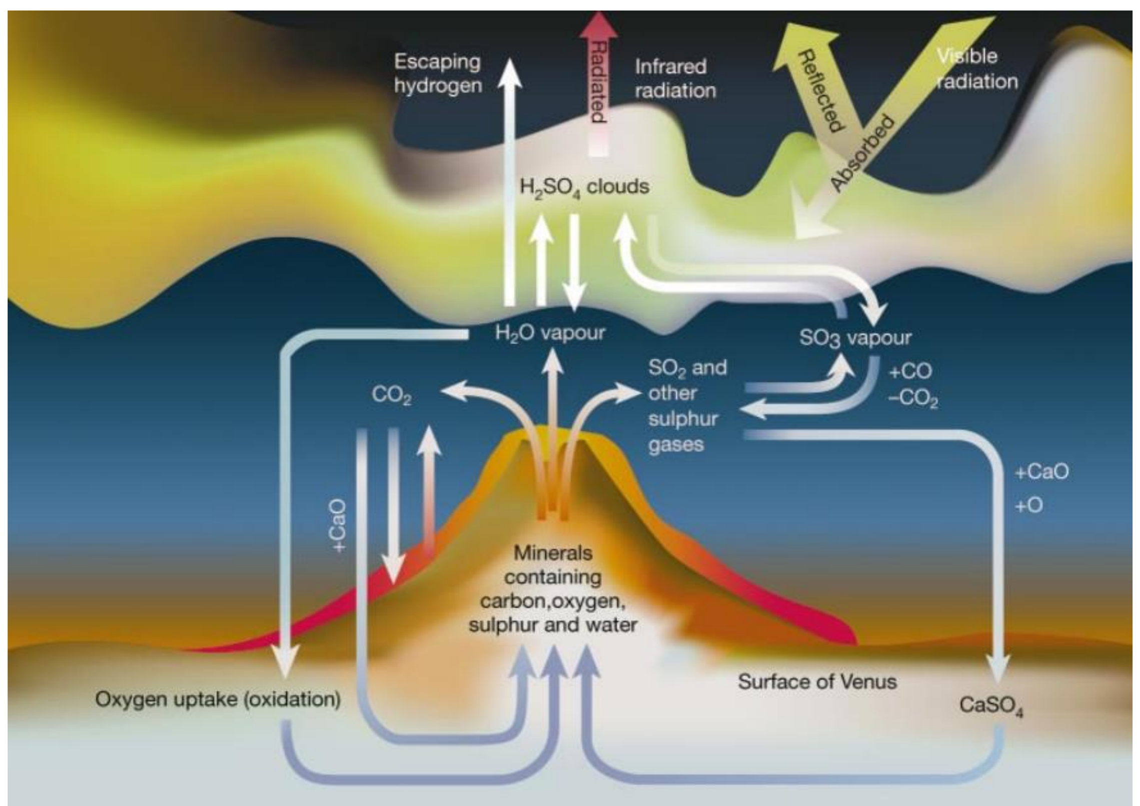


Hansen and Hovenier derived the cloud properties:

- $n_r = 1.44 \pm 0.015\ \mu\text{m}$ (at 0.55 μm)
- $r_{eff} = 1.05 \pm 0.10\ \mu\text{m}$
- $\sigma_r = 0.07 \pm 0.02\ \mu\text{m}$

Climate model evolution

[Bullock and Grinspoon 2001]

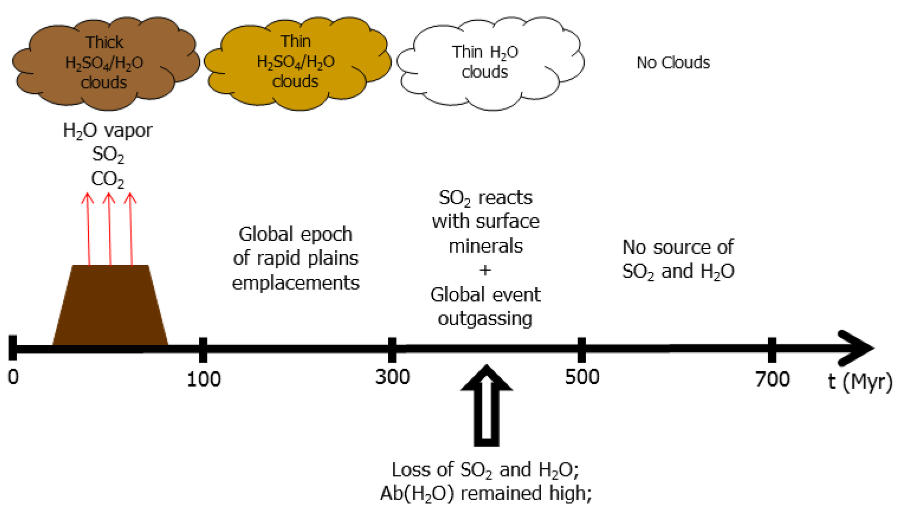


- Venus experienced [Bullock and Grinspoon 2001] events of rapid cooling and warming triggered by volcanic activity, over the past 1 Gyr.
- Volcanic activity released large amounts of sulphur dioxide (SO_2) and water vapor (H_2O) into the atmosphere.

Image credits: Prinn (2001).

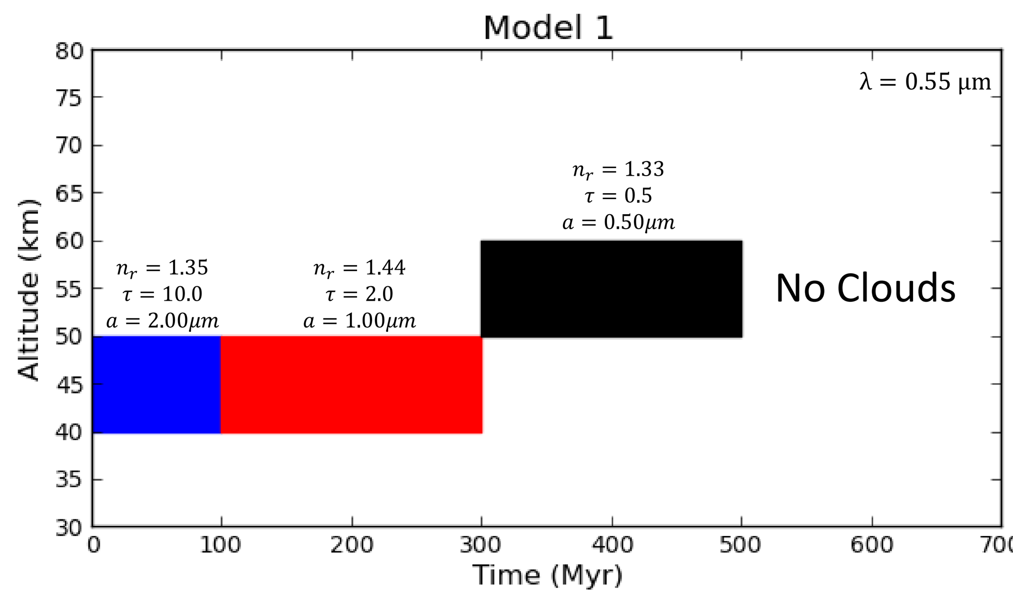
Initial conditions:

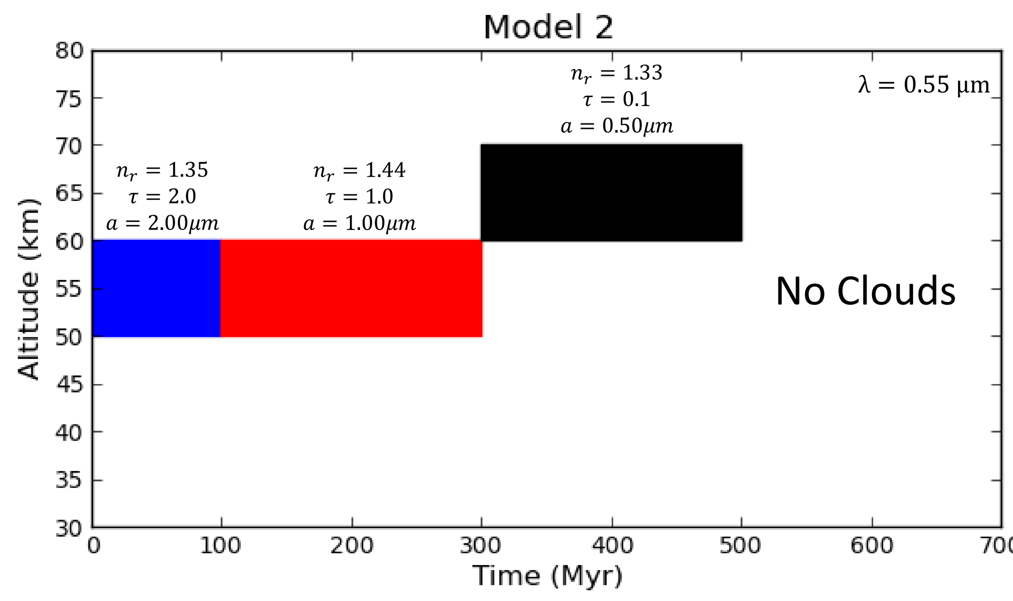
- Model 1: $[H_2O]_i \approx 100 \times [H_2O]_{today}$; $[S_2O]_i \approx [S_2O]_{today}$; amount of lava expelled was sufficient to cover the whole surface with a layer of 10 km of thickness.
- Model 2: $[H_2O]_i \approx [H_2O]_{today}$; $[S_2O]_i \approx 0.01 \times [S_2O]_{today}$; amount of lava expelled was sufficient to cover the whole surface with a layer of 1 km of thickness.



Input values for our simulations

To perform our simulations, we used the anisotropic Rayleigh scattering theory as described by Hansen and Travis (1974) and the double adding code described by Stam et al. (2006).

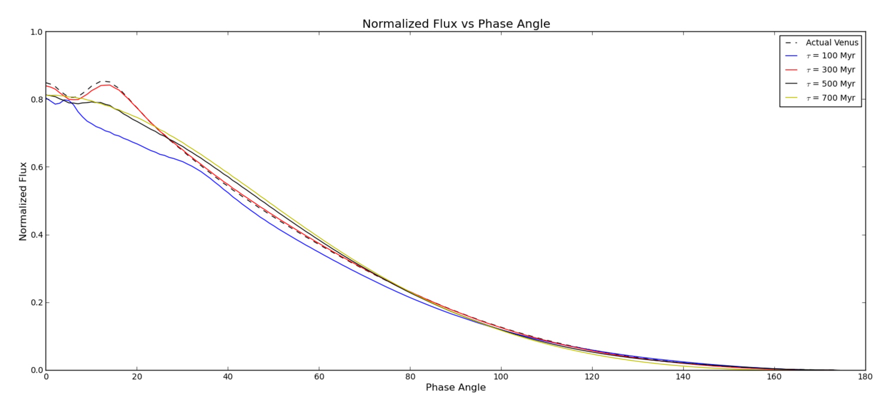


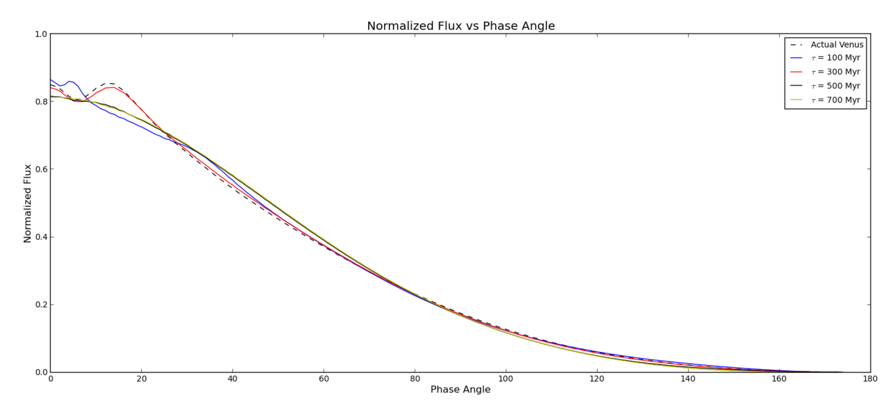


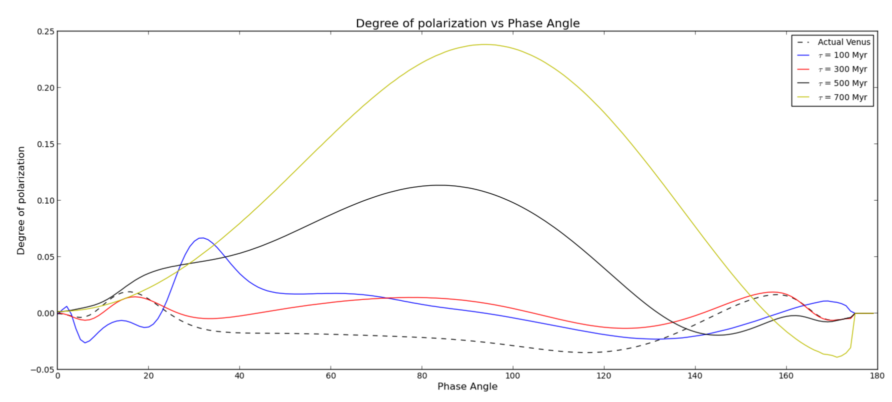
Results of our simulations

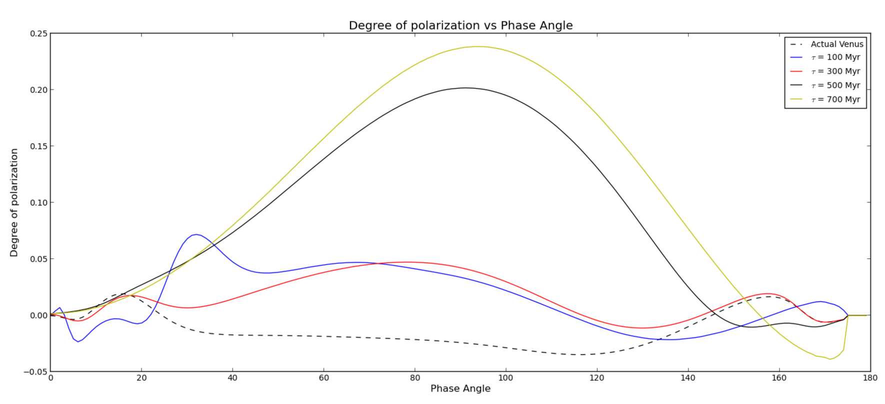
Model 1

Model 2









Summary

- Clouds give information about the composition of the atmosphere and the radiative balance of the planet.
- Clouds may give information about the habitability of the planet.
- If we detect an exoplanet in polarization, we may identify its evolutionary state by comparing the polarized signals against simulated ones.

Future work

- Connect a more detailed cloud formation model with the prediction of polarized signals.
- Extend this work to other planetary atmospheres: Earth (N_2); Mars (CO_2); Jupiter (H_2);

References:

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[3] Hansen, J. E and Travis, L. D., *Light scattering in planetary atmospheres*, Space Science Review, 16, 527-610, 1974.
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