

Study of Venus' cloud layers by polarimetry with SPICAV/VEx

Loïc Rossi¹, Emmanuel Marcq¹, Franck Montmessin²,
Jean-Loup Bertaux², Anna Fedorova^{3 4}, Oleg Korablev^{3 4},
Daphne Stam⁵

¹*LATMOS/UVSQ, Guyancourt, France*

²*LATMOS/CNRS, Guyancourt, France*

³*Space Research Institute/IKI, Russia*

⁴*Moscow Institute of Physics and Technology, Dolgoprudny, Russia*

⁵*Technische Universiteit Delft, Delft, The Netherlands*

EGU GA 2014-04-30

Polarization studies of Venus

Ground-based observations 1920s-1970s (Lyot, Coffeen, Dollfus...)

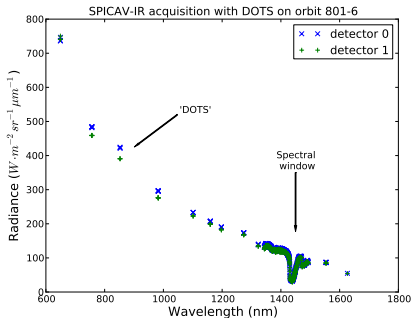
- ▶ Hansen and Hovenier (1974) used a polarized radiative transfer code to retrieve the parameters of the cloud layers
- ▶ Pioneer Venus OCPP: polarimetric measurements analyzed by Kawabata (1980), Sato (1996) to retrieve parameters of the haze layer

Main results

Shape	spherical droplets
Hazes	$r_{\text{eff}}^h \sim 0.25 \mu\text{m}$ $\nu_{\text{eff}}^h \sim 0.25$
Cloud	$r_{\text{eff}}^c \sim 1 \mu\text{m}$ $\nu_{\text{eff}}^c \sim 0.07$
Composition	concentrated $\text{H}_2\text{SO}_4\text{-H}_2\text{O}$ solution

Principle of measurement

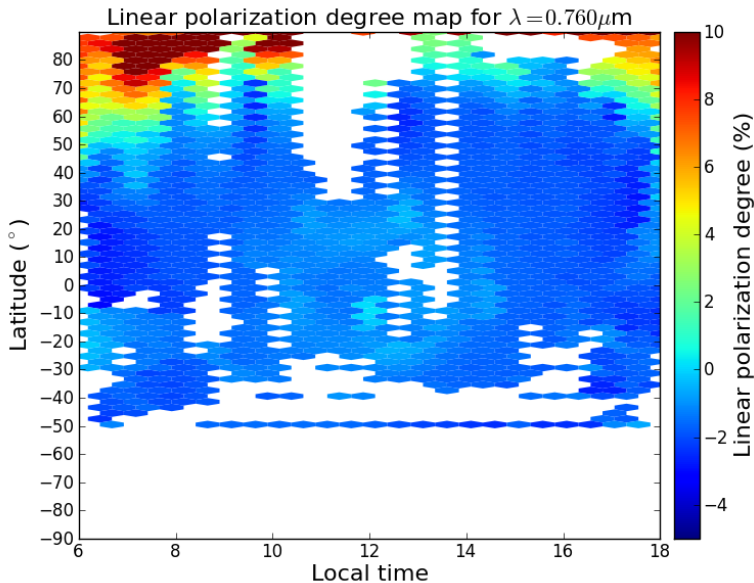
SPICAV-IR is an infrared spectrometer onboard ESA's Venus Express spacecraft, working in the 0.65 – 1.7 μm range.

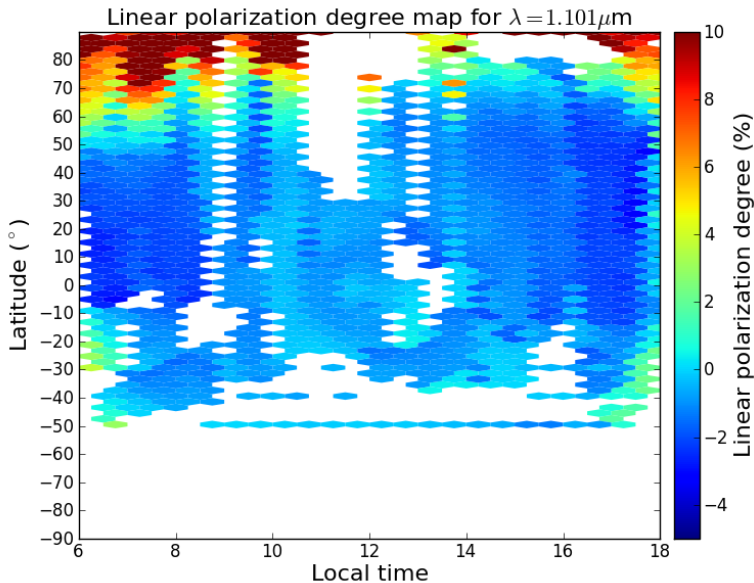


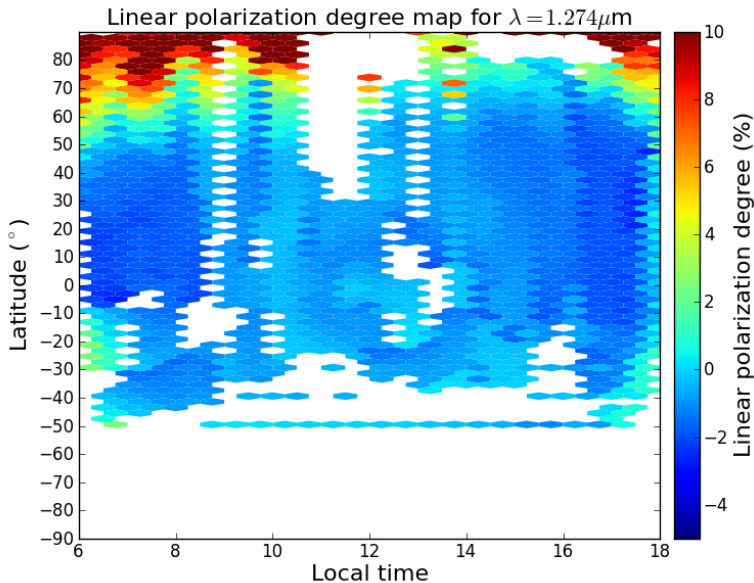
- ▶ spectral window and continuum measurement
- ▶ based on an acousto-optic tunable filter (AOTF)
- ▶ produces two beams polarized in perpendicular directions

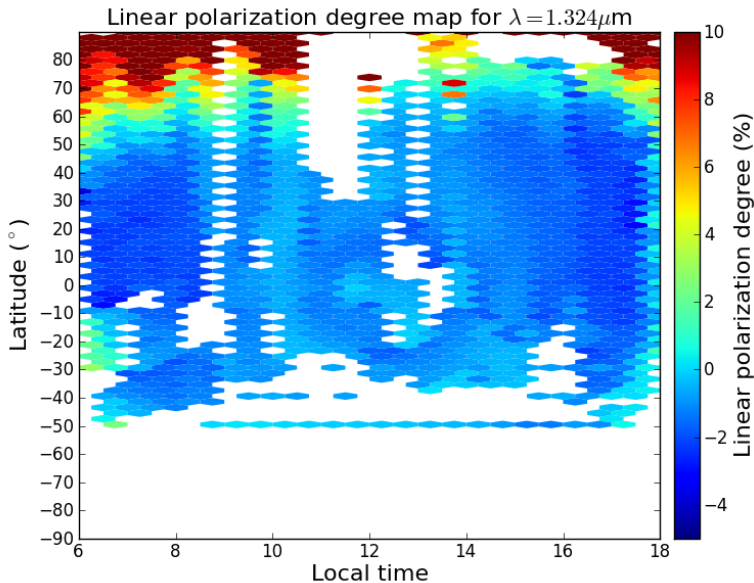
Degree of linear polarization

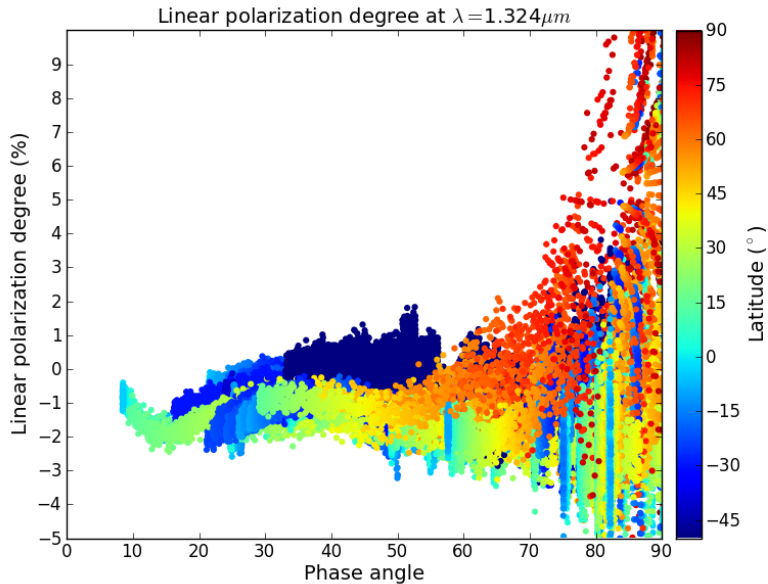
$$P_{\ell} = \frac{P_{\perp} - P_{\parallel}}{P_{\perp} + P_{\parallel}} = \frac{d_1 - d_0}{d_1 + d_0}$$







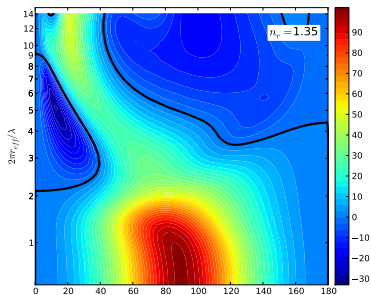




Mie scattering

Polarization patterns produced by Mie scattering on spherical particles depends on the size parameter $x = \frac{2\pi r}{\lambda}$.

- ▶ $x \ll 1$: Rayleigh-like scattering, positive polarization
- ▶ $x > 1$: Mie regime, complex features, in particular **the polarimetric glory**



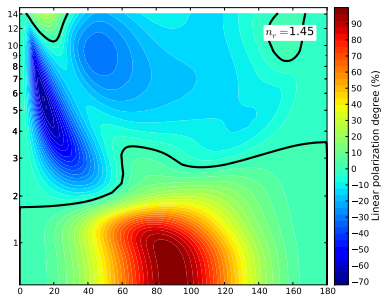
Estimates for cloud particles

- ▶ spherical particles
- ▶ $r \sim 1 \mu\text{m}$
- ▶ $n_r \sim 1.42$ at $\lambda = 1 \mu\text{m}$

Mie scattering

Polarization patterns produced by Mie scattering on spherical particles depends on the size parameter $x = \frac{2\pi r}{\lambda}$.

- ▶ $x \ll 1$: Rayleigh-like scattering, positive polarization
- ▶ $x > 1$: Mie regime, complex features, in particular **the polarimetric glory**



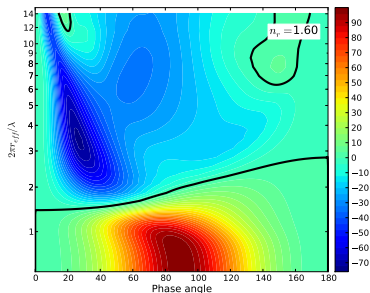
Estimates for cloud particles

- ▶ spherical particles
- ▶ $r \sim 1 \mu\text{m}$
- ▶ $n_r \sim 1.42$ at $\lambda = 1 \mu\text{m}$

Mie scattering

Polarization patterns produced by Mie scattering on spherical particles depends on the size parameter $x = \frac{2\pi r}{\lambda}$.

- ▶ $x \ll 1$: Rayleigh-like scattering, positive polarization
- ▶ $x > 1$: Mie regime, complex features, in particular **the polarimetric glory**



Estimates for cloud particles

- ▶ spherical particles
- ▶ $r \sim 1 \mu\text{m}$
- ▶ $n_r \sim 1.42$ at $\lambda = 1 \mu\text{m}$

Cloud layers

- ▶ Polarized, multiple scattering radiative transfer model based on the doubling-adding method, provided by D. Stam
- ▶ Clouds described by two layers, each homogeneously mixed

- ▶ Observations of glories will yield values for the cloud layer
- ▶ Observations at higher phase angles will provide information about hazes

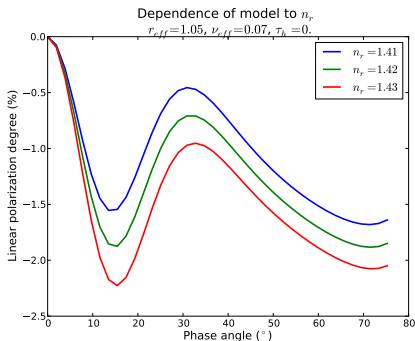
Clouds parameters

	r_{eff}	ν_{eff}	n_r	τ
Haze layer	0.25	0.25	n	τ_h
Cloud layer	r_c	0.07	n	30

Modeling at $\lambda = 1.1 \mu\text{m}$

Parameters retrieval

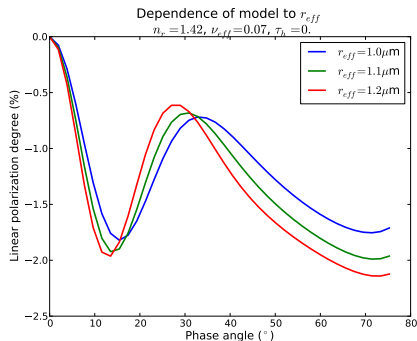
Parameter	Main effect on degree of polarization
n_r	degree of polarization



Modeling at $\lambda = 1.1 \mu\text{m}$

Parameters retrieval

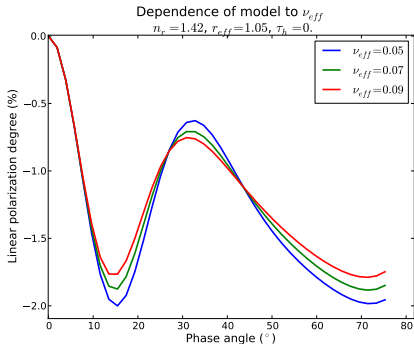
Parameter	Main effect on
n_r	degree of polarization
r_{eff}	position of glory minimum



Modeling at $\lambda = 1.1 \mu\text{m}$

Parameters retrieval

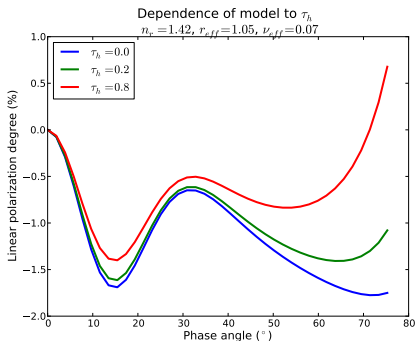
Parameter	Main effect on
n_r	degree of polarization
r_{eff}	position of glory minimum
ν_{eff}	shape of glory

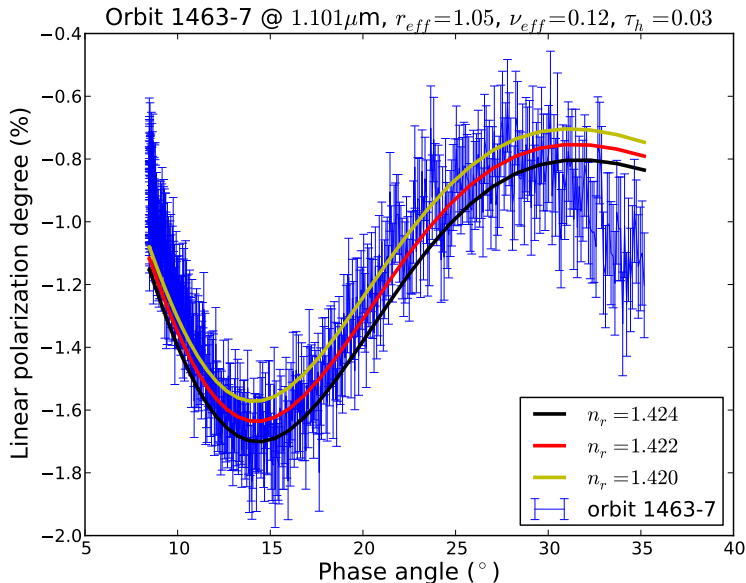


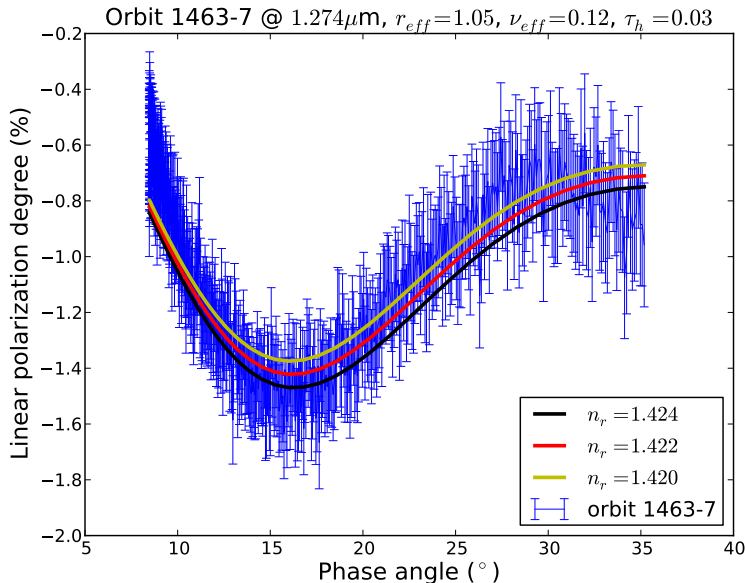
Modeling at $\lambda = 1.1 \mu\text{m}$

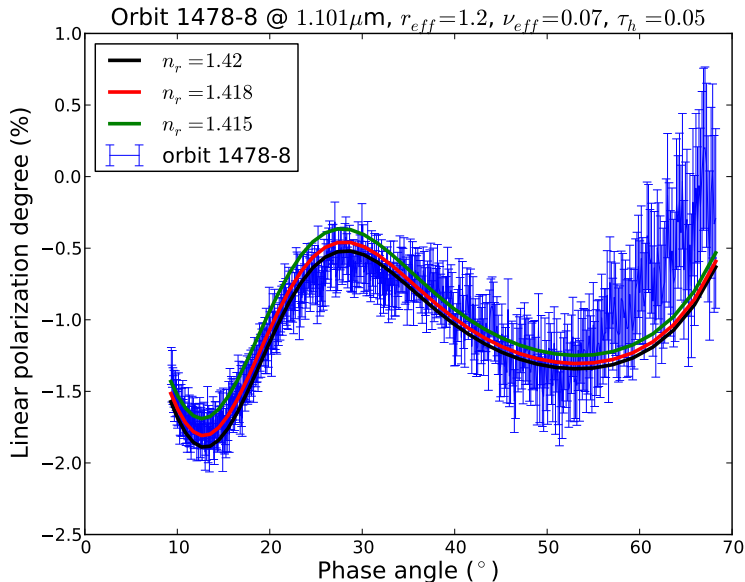
Parameters retrieval

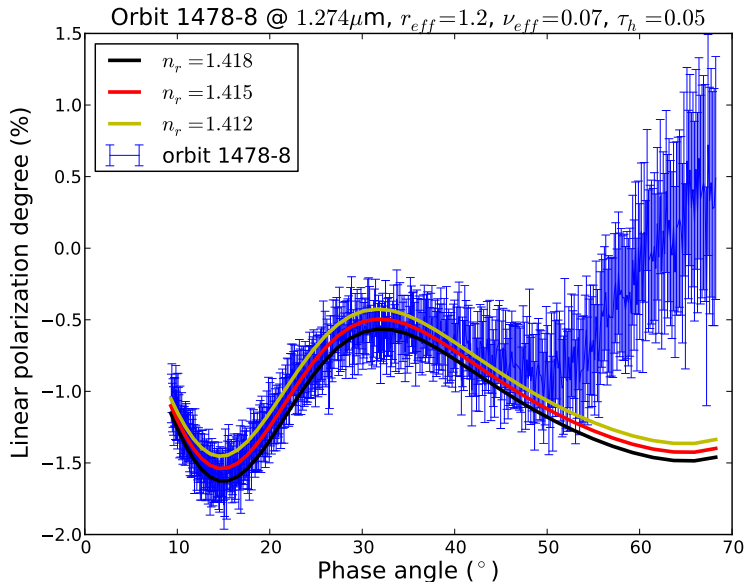
Parameter	Main effect on
n_r	degree of polarization
r_{eff}	position of glory minimum
ν_{eff}	shape of glory
τ_h	positive polarization



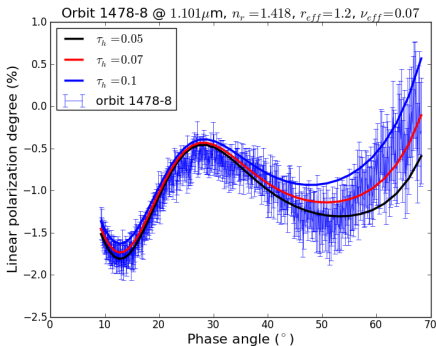




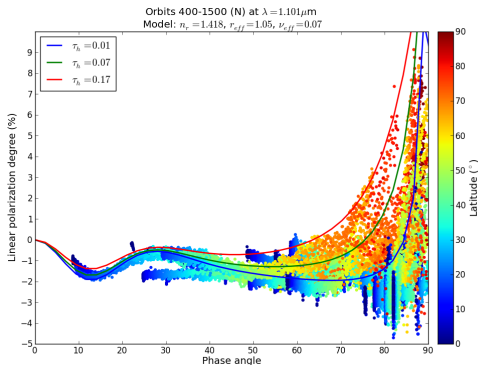




- ▶ At high latitudes, a strong positive polarization is observed
- ▶ Stronger influence of hazes required to match observations
- ▶ Optical depth vary from ~ 0.3 to ~ 0.7
- ▶ Upper limit for τ_h can reach 0.17 at very high latitudes



- ▶ At high latitudes, a strong positive polarization is observed
- ▶ Stronger influence of hazes required to match observations
- ▶ Optical depth vary from ~ 0.3 to ~ 0.7
- ▶ Upper limit for τ_h can reach 0.17 at very high latitudes



Conclusions

- ▶ SPICAV-IR polarization data is in **good agreement** with previous observations, in particular with OCPP
- ▶ Polarization maps confirm values of $r_{\text{eff}} \sim 1 \mu\text{m}$, with **narrow size distribution for cloud particles** at a planetary scale
- ▶ We always observe the glory at low phase angles, as VMC in photometry: **particles are spherical**
- ▶ Retrieved refractive indices are **compatible with sulfuric acid solution**
- ▶ The haze **optical thickness increases towards the poles**

Perspectives

- ▶ Parameters retrieval for each orbit
- ▶ Investigate latitudinal, temporal variability (local time and long term)

Acknowledgments

This PhD thesis is funded by the LabEx “Exploration Spatiale des Environnements Planétaires” (ESEP) N° 2011 LABX-030.

We want to thank the State and the ANR for their support within the programme “Investissements d’Avenir” through the excellence initiative PSL*(ANR-10-IDEX-0001-02).

Contact and presentation download

`http://rossi.page.latmos.ipsl.fr
loic.rossi@latmos.ipsl.fr`

