



HAL
open science

Study of Venus cloud layers by polarimetry using SPICAV/VE_x

Loïc Rossi, Emmanuel Marcq, Franck Montmessin, Anna Fedorova, Daphne Stam, Jean-Loup Bertaux, Oleg Korablev

► **To cite this version:**

Loïc Rossi, Emmanuel Marcq, Franck Montmessin, Anna Fedorova, Daphne Stam, et al.. Study of Venus cloud layers by polarimetry using SPICAV/VE_x. EGU General Assembly 2015, Apr 2015, Vienna, Austria. pp. EGU2015-1656. insu-01144092

HAL Id: insu-01144092

<https://insu.hal.science/insu-01144092v1>

Submitted on 15 Sep 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Study of Venus cloud layers by polarimetry using SPICAV/Vex

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

¹Université Versailles St-Quentin-en-Yvelines, LATMOS-IPSL, Guyancourt, France. ²CNRS/INSU, LATMOS-IPSL, Guyancourt, France. ³Space Research Institute (IKI), Moscow, Russia. ⁴Moscow Institute of Physics and Technology (MIPT), Dolgoprudny, Russia. ⁵Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands.

1. CONTEXT

- Since 1929, polarization has been used to characterize Venus' clouds and hazes refractive index, radius and particle size distribution;
- Most of our knowledge is based on measurements and modeling made by Lyot[4], Hansen and Hovenier[1], Kawabata[2] and Sato[8] with ground and space observation;
- Our goal here is to make new measurements using the polarimetric data provided by the instrument SPICAV-IR on Venus Express, in orbit since 2006.

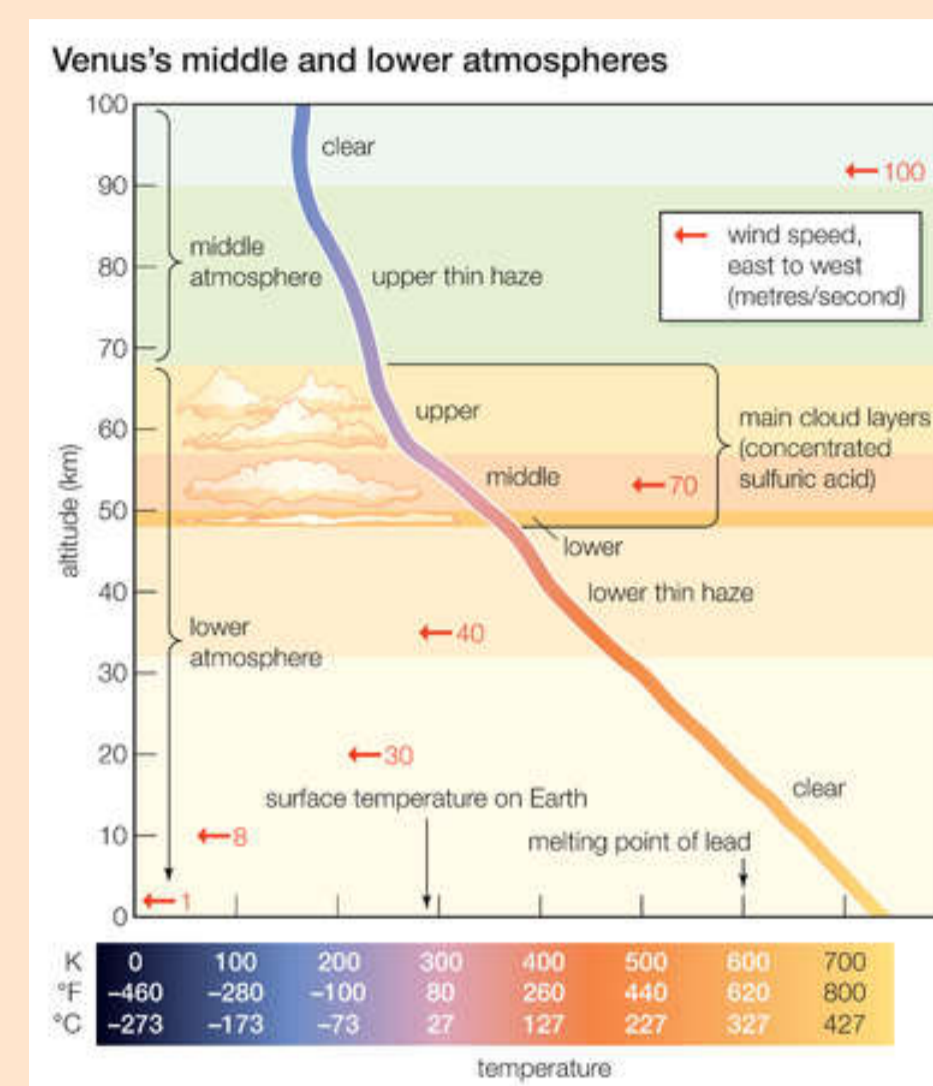


Figure: Structure of Venus clouds

	Main cloud layer	Hazes
Altitude	50 to 75 km	30 to 90 km
Composition	H ₂ SO ₄ -H ₂ O	H ₂ SO ₄ -H ₂ O
Radius	r ~ 1 μm	r ~ 0.25 μm

Table: Current knowledge of Venus clouds.

2. SPICAV-IR

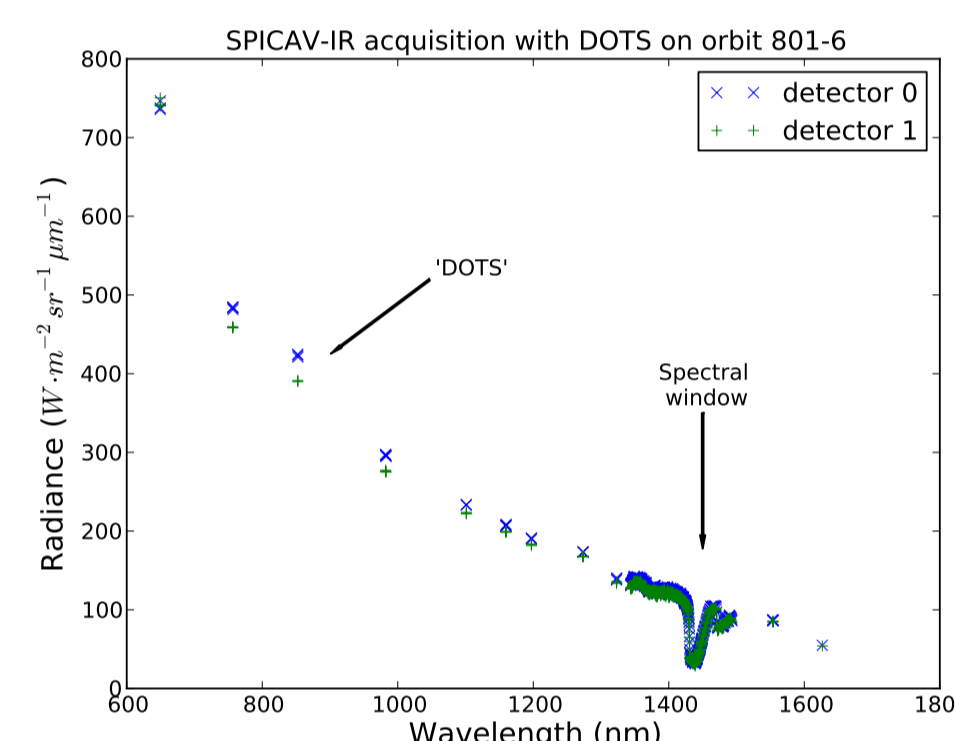


Figure: Example of SPICAV acquisition.

SPICAV-IR is a spectrometer on-board the Venus Express spacecraft[3]. Based on an Acousto-Optical Tunable Filter (AOTF), it produces two beams linearly polarized in perpendicular directions.

Measure of the degree of linear polarization:

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

Cross-calibration performed by knowing that for any wavelength $P_{\ell} = 0$ at 0° of phase angle. Acquisition is made with spectral windows and sets of 3, 5 or 10 points for continuum measurement. We use the latter points to measure polarization in up to 14 wavelengths[7].

Channel	Coverage
SW	0.65 μm—1.05 μm
LW	1.05 μm—1.7 μm

Table: SPICAV characteristics

3. SPICAV OBSERVATIONS

- Observations performed in nadir, spot-tracking mode and with zig-zags for SO₂ mapping;
- VEX has a north polar orbit: observations mostly located in northern hemisphere;

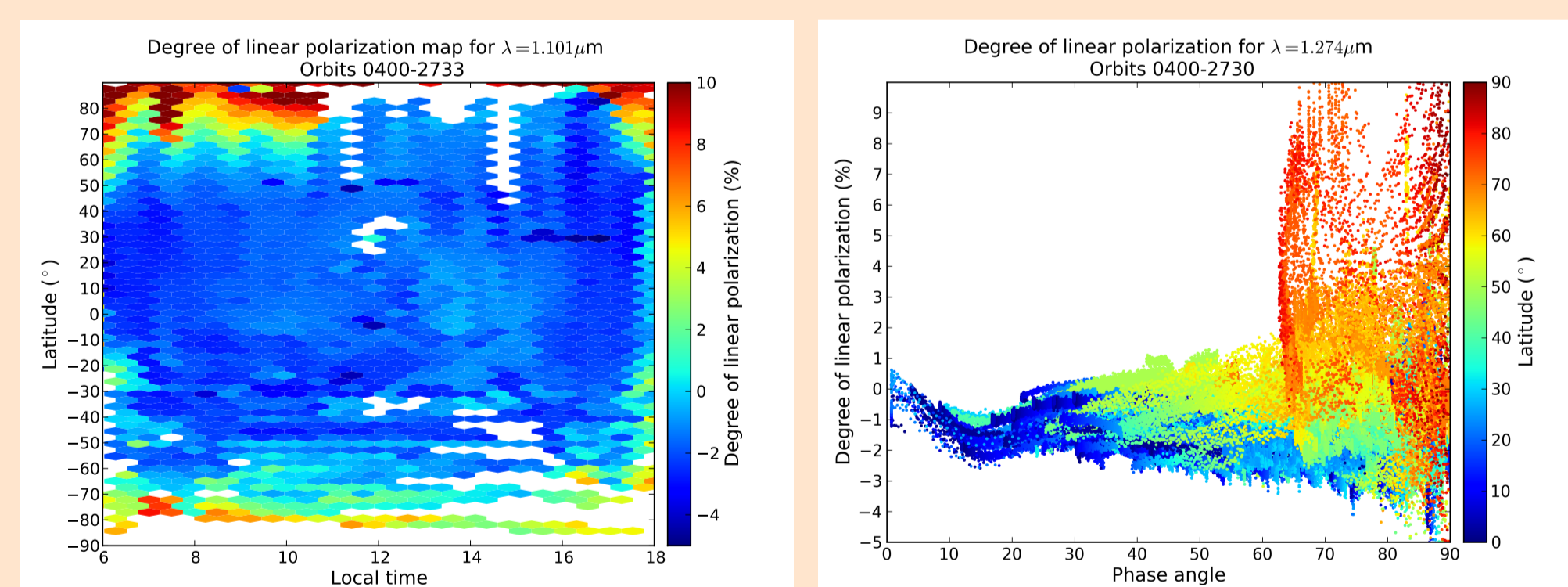


Figure: Left: Average maps from SPICAV polarization observations at 1101 nm for all orbits from 2007-05-26 to 2013-10-16. Right: Polarization nadir observations at $\lambda = 1.274 \mu\text{m}$ for the same period as a function of phase angle and latitude. The glory is visible at $\sim 15^{\circ}$ of phase angle.

- Polarization is quite uniform across the planet with the exception of the high latitudes:
 - At low latitudes, the polarization is mostly negative;
 - At higher latitudes it becomes positive, reaching values sometimes higher than +10%;
 - A phenomenon known as **glory** is visible nearly every time SPICAV-IR observes at low latitudes;
 - The glory is **also observed in photometry** by the Venus Monitoring Camera (VMC) onboard Venus Express[5, 6].

4. CLOUD MODEL

- The cloud model has a layer of haze above a cloud layer, each homogeneously mixed;
- Polarization retrieved with the doubling-adding method[9];
- Angular position and shape of the glory dependent on the cloud parameters: **the glory is a tool to characterize the cloud layer**;
- Thickening hazes increases the polarization degree near 90° of phase angle: **possible measurement of τ_h at higher phase angles**.

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

Table: Parameters of the cloud model

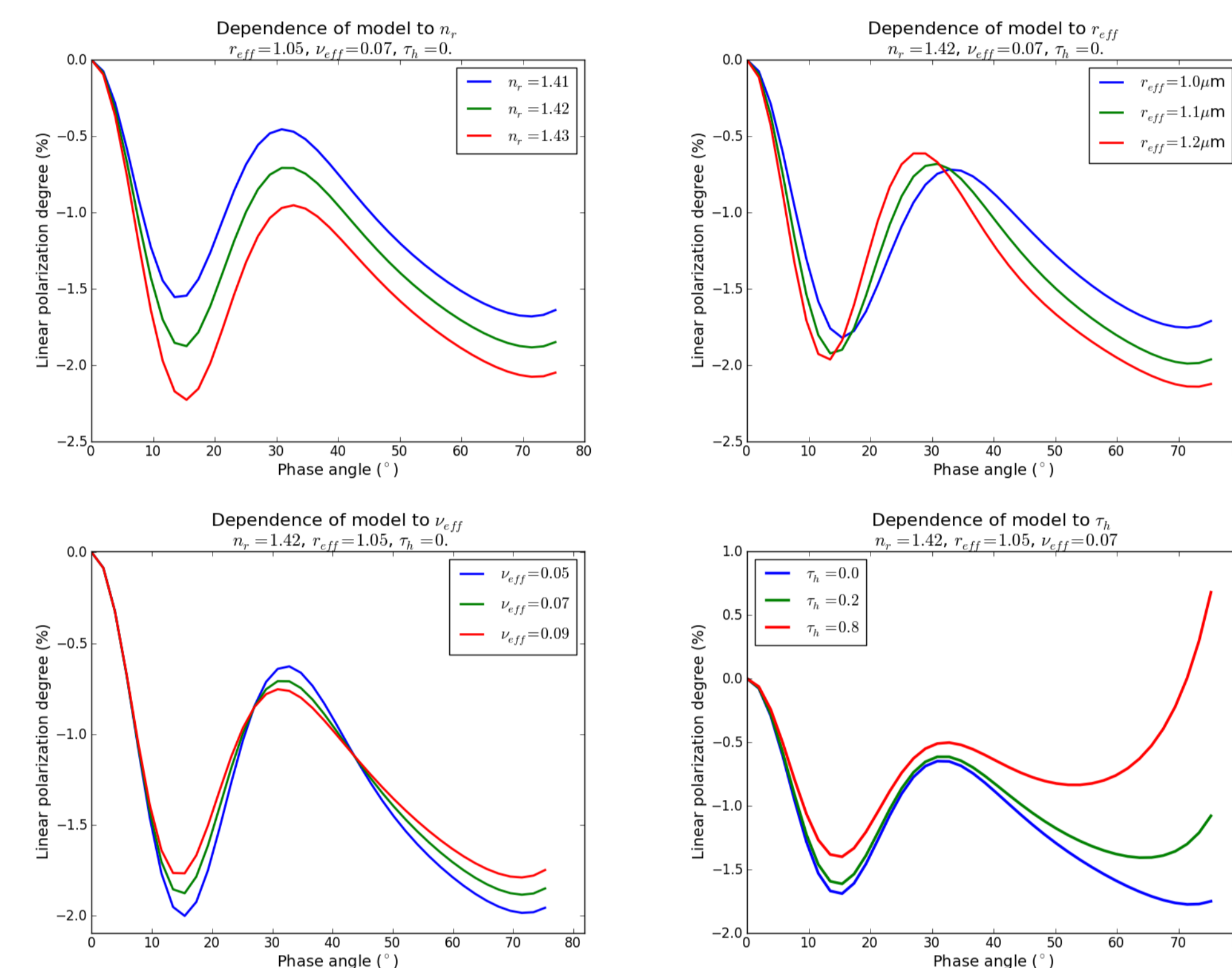


Figure: Illustration of the influence of the cloud parameters n_r , r_{eff} , ν_{eff} and τ_h on the model.

5. GLORY ANALYSIS

Cloud parameters n_r , r_{eff} , ν_{eff} retrieved from 10 selected glories using our model at six wavelengths simultaneously (1.101, 1.16, 1.198, 1.274, 1.324 and 1.553 μm).

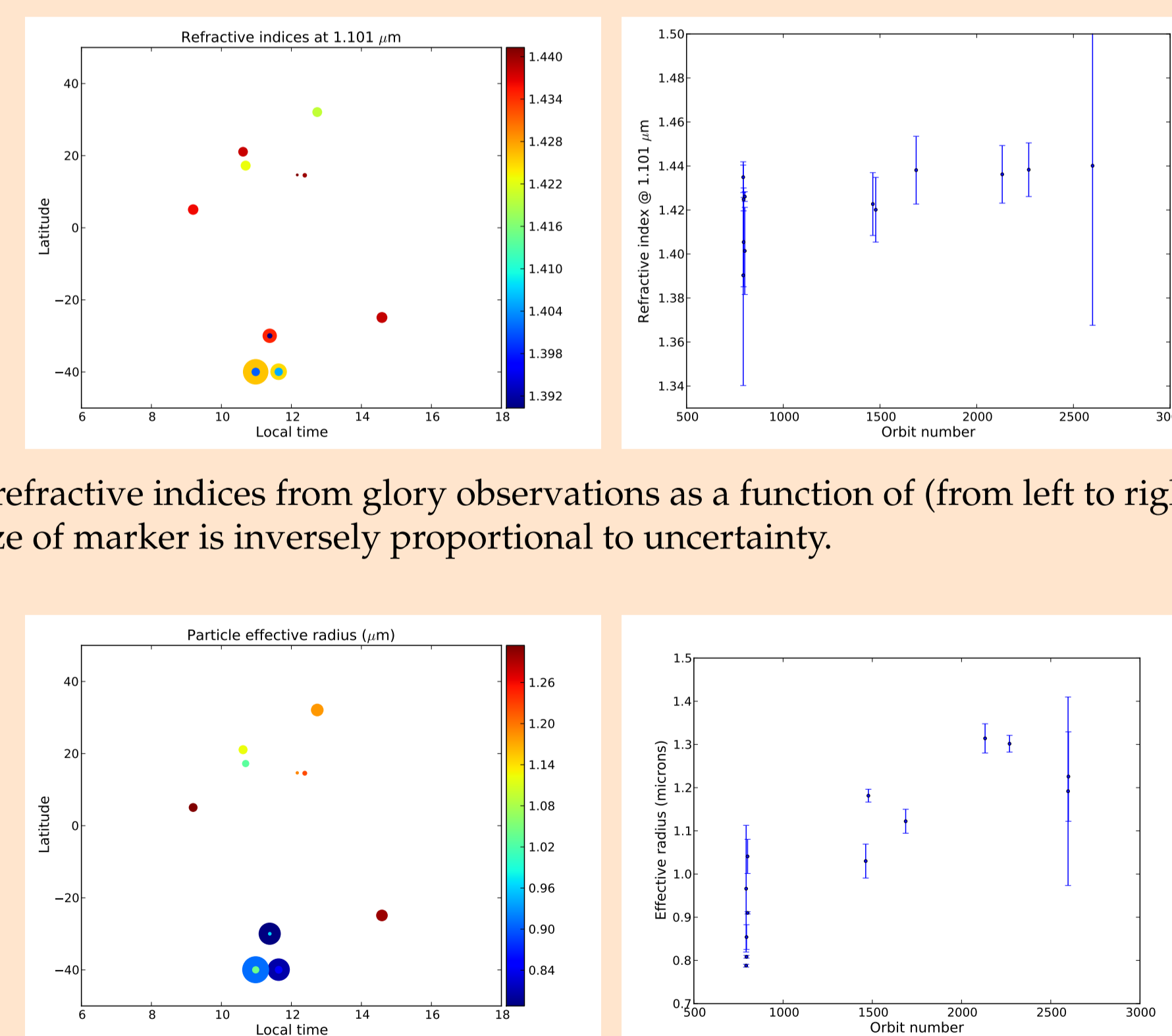


Figure: Retrievals of refractive indices from glory observations as a function of (from left to right) latitude/local time and orbit number. Size of marker is inversely proportional to uncertainty.

- Refractive indices of $n_r \sim 1.44$ at $\lambda = 1.1 \mu\text{m}$, **compatible with concentrated H₂SO₄ solution**;
- Particle effective radius varying in range $0.8 < r_{\text{eff}} < 1.3 \mu\text{m}$;
- Upper limit on variance of the size distribution: $\nu_{\text{eff}} < 0.15$;
- Small haze column densities required $C_h < 1 \mu\text{m}^{-2}$ **at low latitudes**.
- Too few usable glories to make any conclusion regarding latitudinal or local time trends. Possible increase of n_r and r_{eff} with time.

6. HIGHER LATITUDES

- At higher latitudes, thicker haze is required to match observed polarization.
- A fixed composition of the cloud layer is assumed in order to derive the haze column density. For the cloud $r_{\text{eff}} = 1.05 \mu\text{m}$, $\nu_{\text{eff}} = 0.07$ and $n_r = 1.44$ at $1.101 \mu\text{m}$.
- The haze effective radius and variance are set to $r_{\text{eff}} = 0.25 \mu\text{m}$ and $\nu_{\text{eff}} = 0.25$.
- Fits performed at all latitudes in the northern hemisphere;
- The properties of the clouds change with latitude, with increasing haze column density with increasing latitude**. This is in agreement with OCPP measurements.
- A small decrease of C_h occurs between equator and 50° of latitude, followed by a sharp increase towards the pole.
- Kawabata[2], observed an increase in the haze column density with increasing latitude (from $0.23 \mu\text{m}^{-2}$ at low latitudes to $3.1 \mu\text{m}^{-2}$ at high latitudes). Our values fall within this range.

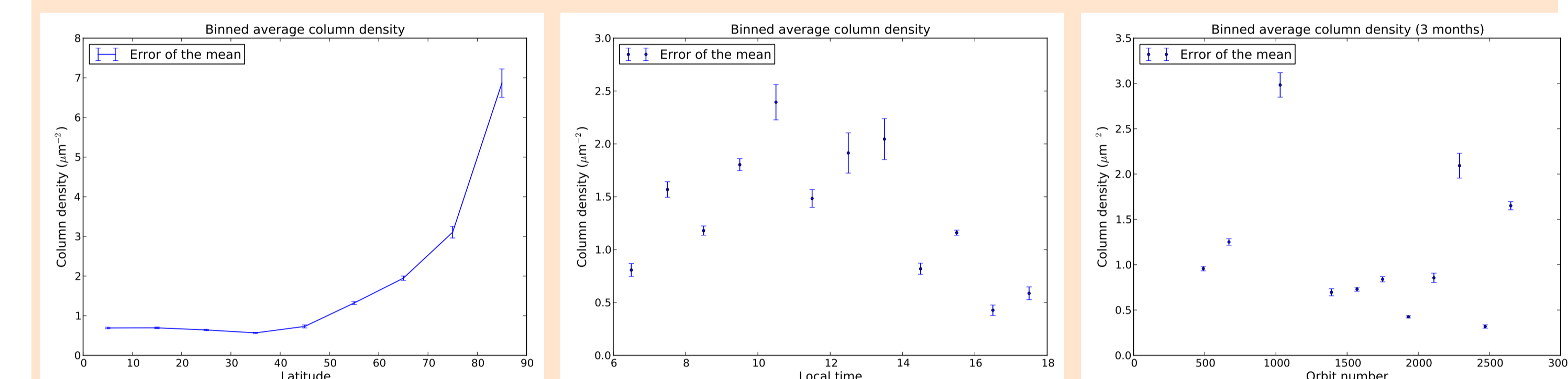


Figure: Binned averaged values of haze column density as a function of (from left to right) latitude, local time and orbit number.

7. CONCLUSION AND PERSPECTIVES

Conclusion

- SPICAV polarization data is fully exploitable with a **large spatial and temporal coverage**;
- Consistent with previous observations** : same features and order of magnitude;
- The glory is observed every time at phase angles $\sim 15^{\circ}$: spherical micrometric particles constitute most of the clouds of Venus;
- Refractives indices retrieved are **compatible with sulfuric acid solution**;
- An **increase of the haze column density is observed with increasing latitude**.

Perspectives

- Investigate further the temporal and spatial variability, in particular for the haze column density;
- Possible information on vertical structure of the clouds from polarimetry in the CO₂ absorption band.
- For further information on the instrument and/or method, please refer to **Rossi et al. 2014** (in press) [7].

REFERENCES

- J. E. Hansen and L. D. Travis. Light scattering in planetary atmospheres. *Space Sci. Rev.*, 16:527–610, Oct. 1974.
- K. Kawabata, D. Coffeen, J. Hansen, W. Lane, M. Sato, and L. Travis. Cloud and haze properties from Pioneer Venus polarimetry. *J. Geophys. Res.*, 85:8129–8140, dec 1980.
- O. Korablev, A. Fedorova, J.-L. Bertaux, A. Stepanov, A. Kiselev, Y. Kalinnikov, A. Titov, F. Montmessin, J. Dubois, E. Villard, V. Sarago, D. Belyaev, A. Reberac, and E. Neefs. SPICAV IR acousto-optic spectrometer experiment on Venus Express. *Planet. Space Sci.*, 65:38–57, may 2012.
- B. Lyot. *Recherches sur la polarisation de la lumière des planètes et de quelques substances terrestres*. PhD thesis, Université de Paris, 1929.
- W. Markiewicz, E. Petrova, O. Shalygina, M. Almeida, D. Titov, S. Limaye, N. Ignatiev, T. Roatsch, and K. Matz. Glory on venus cloud tops and the unknown uv absorber. *Icarus*, 234:200–203, 2014.
- E. V. Petrova, O. S. Shalygina, and W. J. Markiewicz. The vmc/vex photometry at small phase angles: Glory and the physical properties of particles in the upper cloud layer of venus. *Planetary and Space Science*, (0):–, 2014.
- L. Rossi, E. Marcq, F. Montmessin, A. Fedorova, D. Stam, J.-L. Bertaux, and O. Korablev. Preliminary study of venus cloud layers with polarimetric data from spicav/vex. *Planetary and Space Science*, (0):–, 2014.
- M. Sato, L. Travis, and K. Kawabata. Photopolarimetry Analysis of the Venus Atmosphere in Polar Regions. *Icarus*, 124:569–585, dec 1996.
- D. M. Stam, J. F. De Haan, J. W. Hovenier, and P. Stammes. Degree of linear polarization of light emerging from the cloudless atmosphere in the oxygen A band. *J. Geophys. Res.*, 104:16843–16858, 1999.

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). Part of this work was also supported by the COST action MP1104 “Polarization as a tool to study the Solar System and Beyond”.



Loïc Rossi
LATMOS/UVSQ

Web: <http://rossi.page.latmos.ipsl.fr>
E-mail: loic.rossi@latmos.ipsl.fr
Twitter: @AstroLR

