

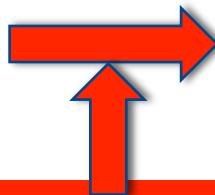


Disk-integrated reflection light curves of planets

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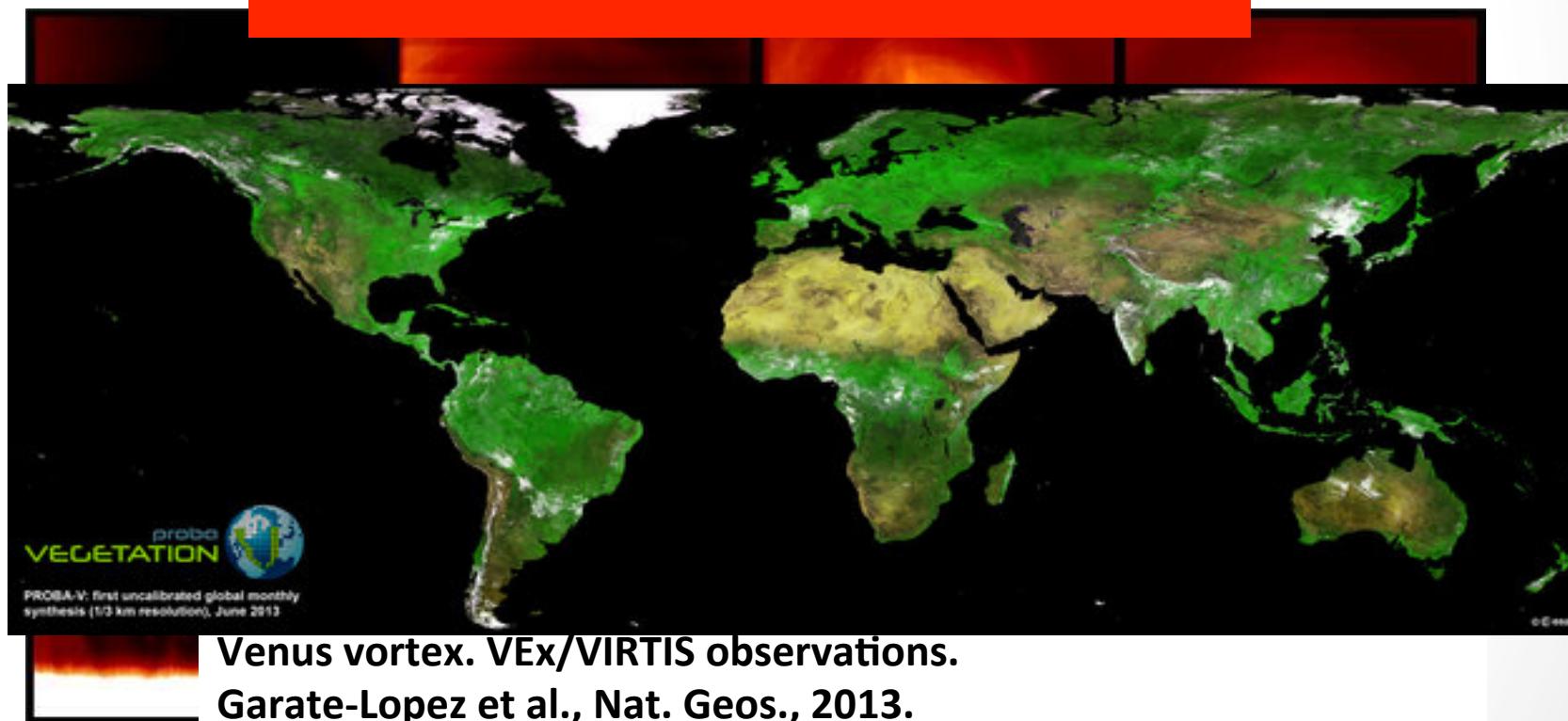
Remote sensing of planets

From observables...



*...to atmospheric magnitudes
(albedos, temperatures, ...)*

Radiative transport models (RTM)



[2]

Wish list for our RTM

Fast →

Forward exploration, inversion

Accurate →

Minimal simplifying assumptions

Flexible →

Viewing/illumination geometries

Clouds, hazes, non-uniform surfaces, ...

Integrate locally/globally

Thermal emission/reflection

Add new physics, i.e. polarization

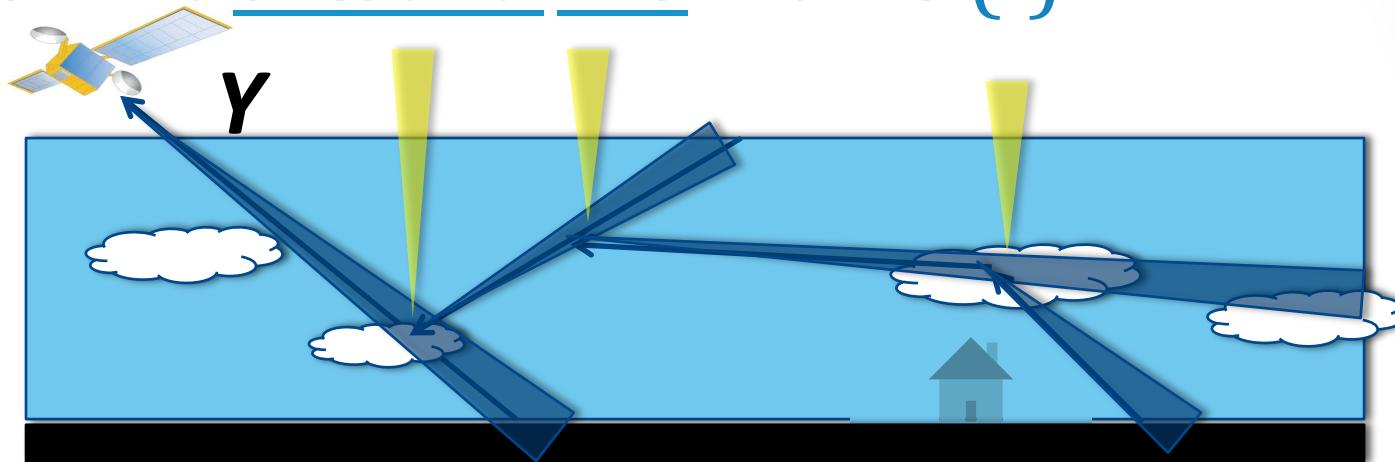
Tentative solution:

Backward Monte Carlo algorithms

[3]

García Muñoz & Mills, *under review*

How Backward MC works (I)



B:
$$Y = \iiint d\Omega d\tau [A] + \iiint d\Omega d\tau \iiint d\Omega d\tau [B] + \iiint d\Omega d\tau \iiint d\Omega d\tau \iiint d\Omega d\tau [C] + \dots$$

MC:

$$\langle Y' \rangle = [A] + [B] + [C] + \dots$$

$$\langle Y'' \rangle = [A] + [B] + [C] + \dots$$

$$\langle Y''' \rangle = [A] + [B] + [C] + \dots$$

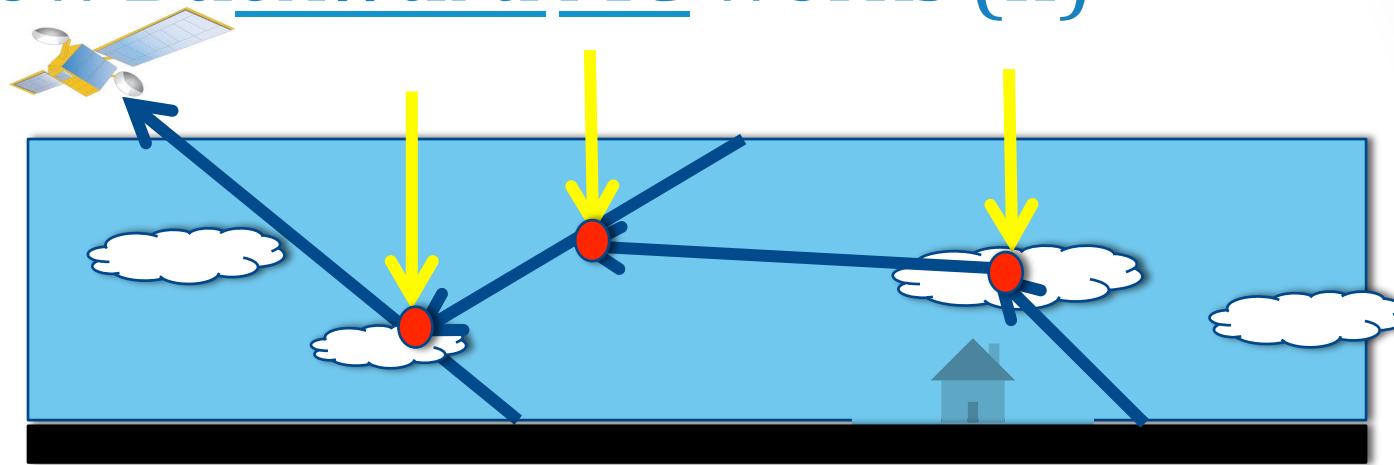
$$\langle Y^{'''} \rangle = [A] + [B] + [C] + \dots$$

$$\langle Y \rangle = Y + O(N^{-1/2})$$

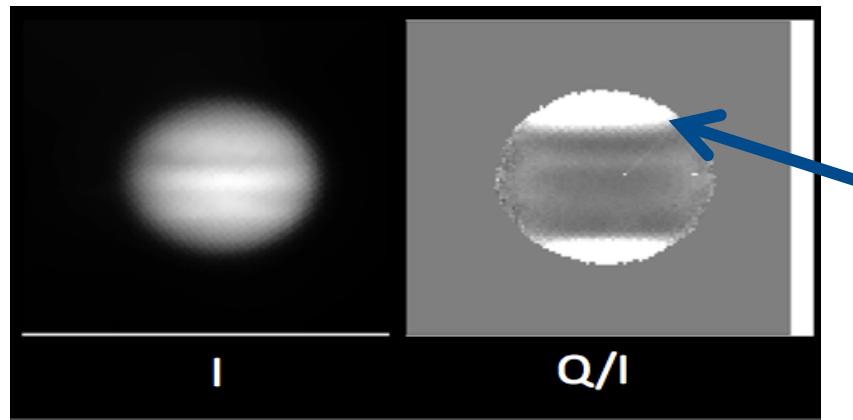
Σ *N = # realizations*

(4)

How Backward MC works (II)



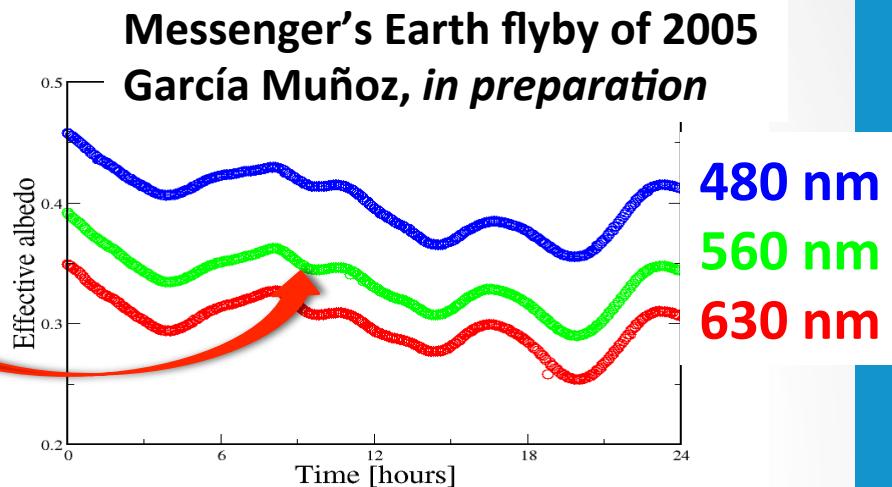
BMC can readily account for polarization



Jupiter's Polar haze
(Schmid et al., 2011)

[5]

Disk integration

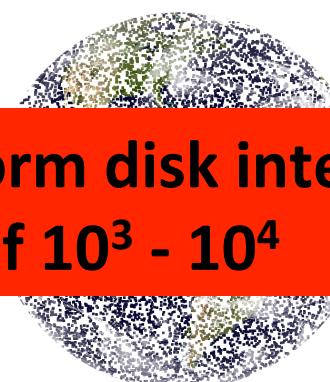


Useful in Solar System (e.g. Venus) & Exoplanets

Non-MC approach



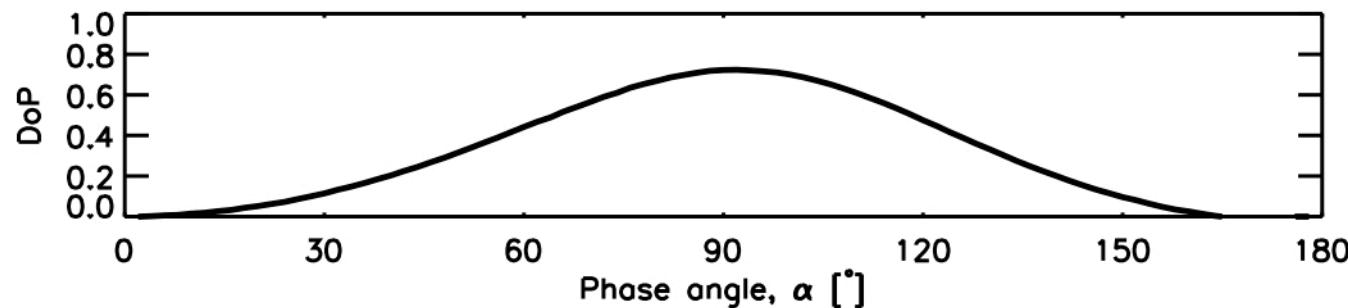
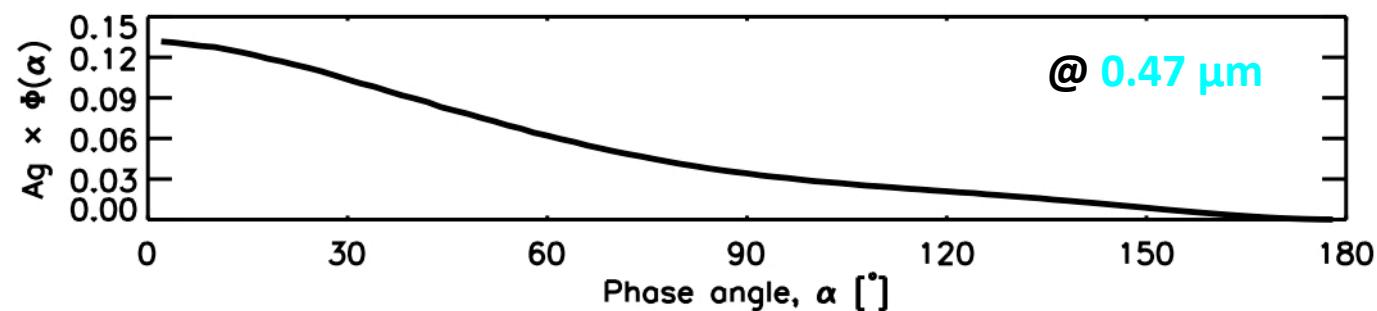
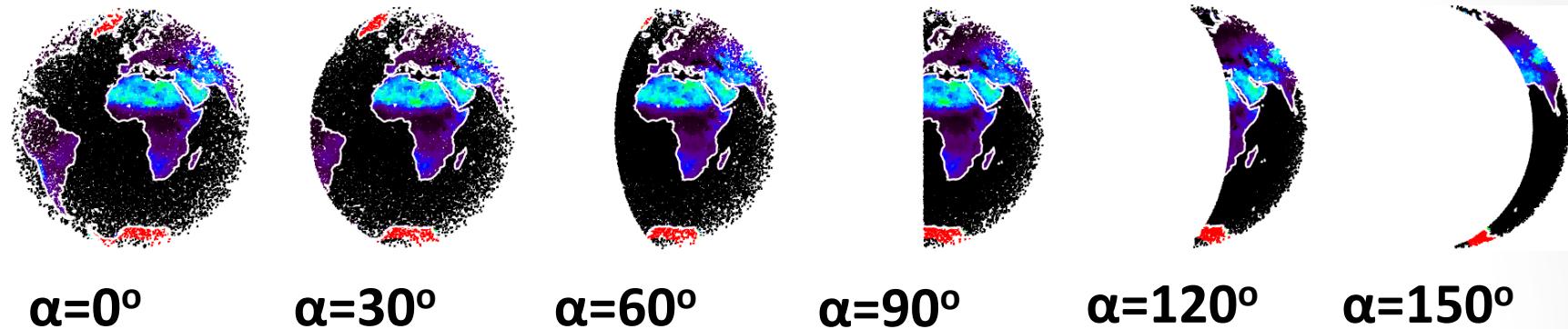
MC approach



**MC vs. Non-MC for non-uniform disk integration:
Gain in computational time of 10^3 - 10^4**

[6]

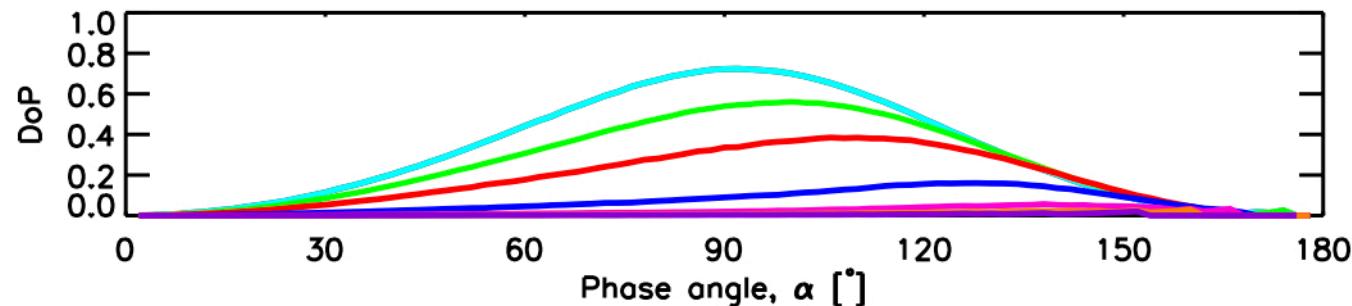
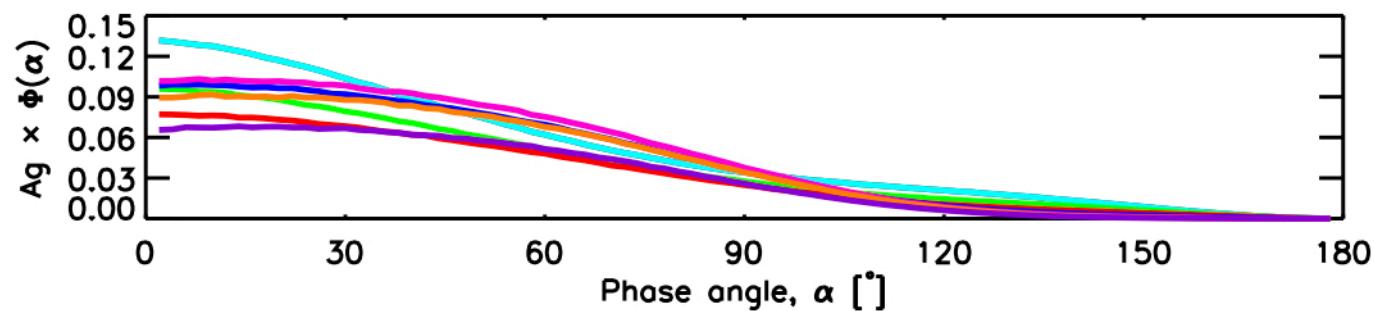
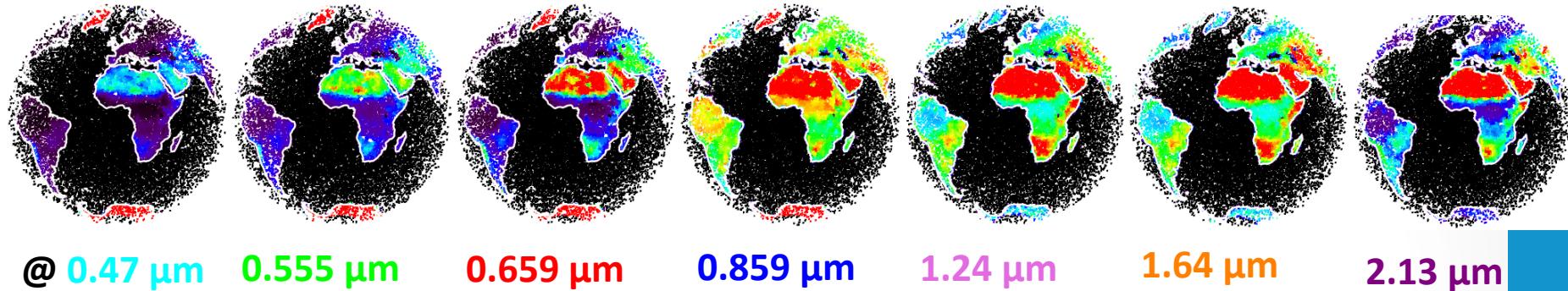
Phase curves of a cloudless Earth



[7]

Phase curves of a cloudless Earth

Albedos: MODIS

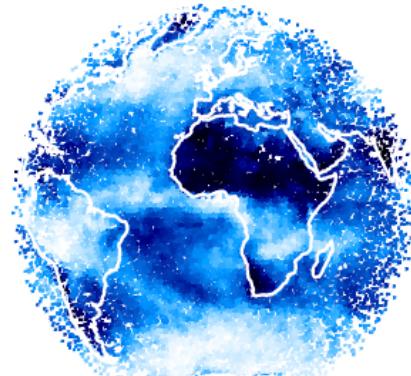


[8]

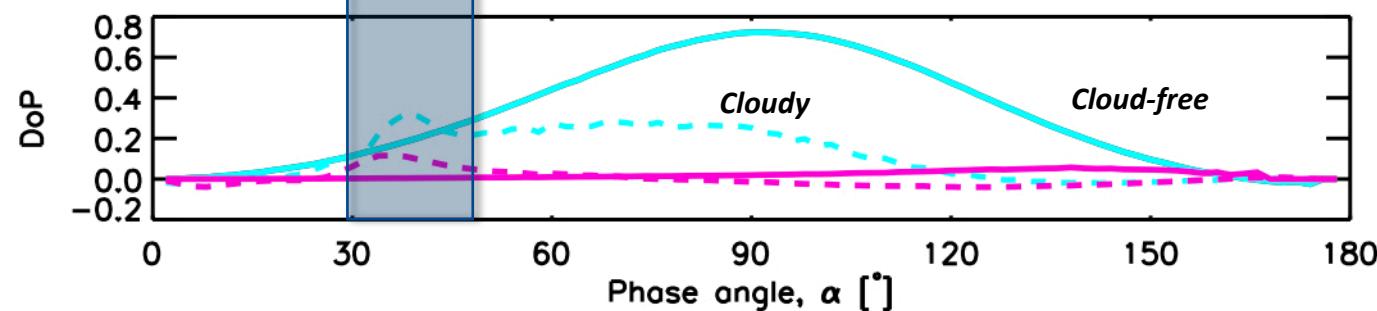
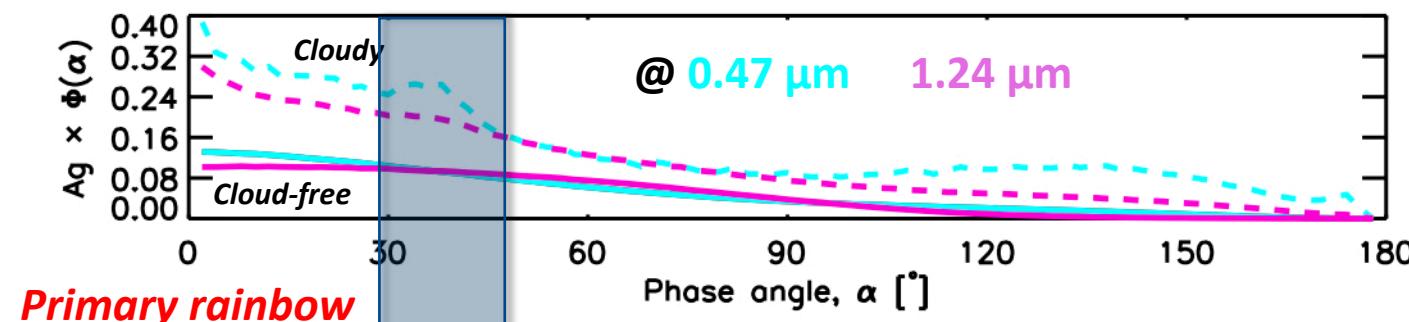
Phase curves of a cloudy Earth

Cloud fraction:

MODIS

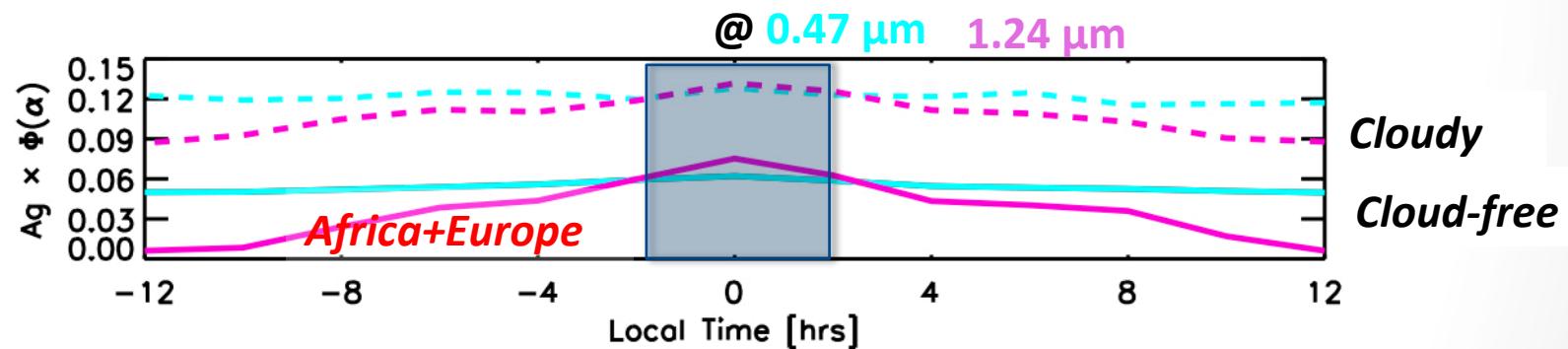
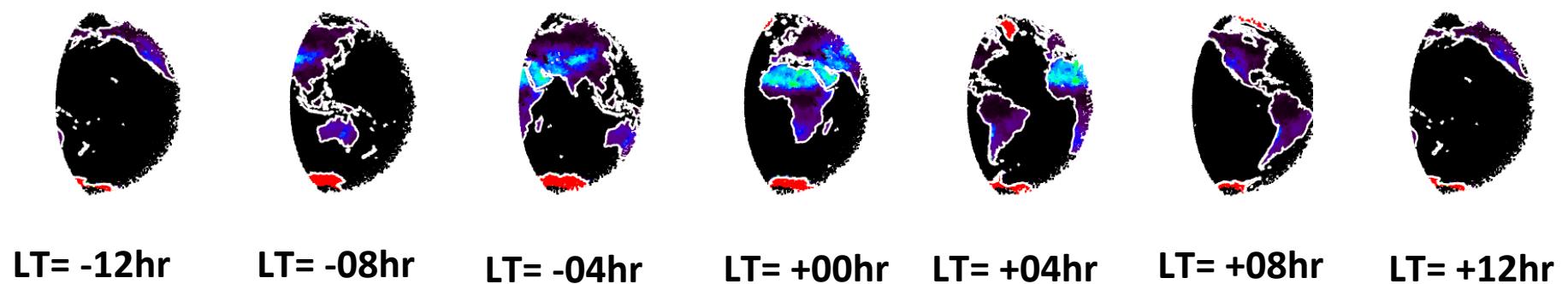


$$r_{\text{eff}} = 7.33 \mu\text{m}; v_{\text{eff}} = 0.4; n_r = 1.336 - 1.299$$



[9]

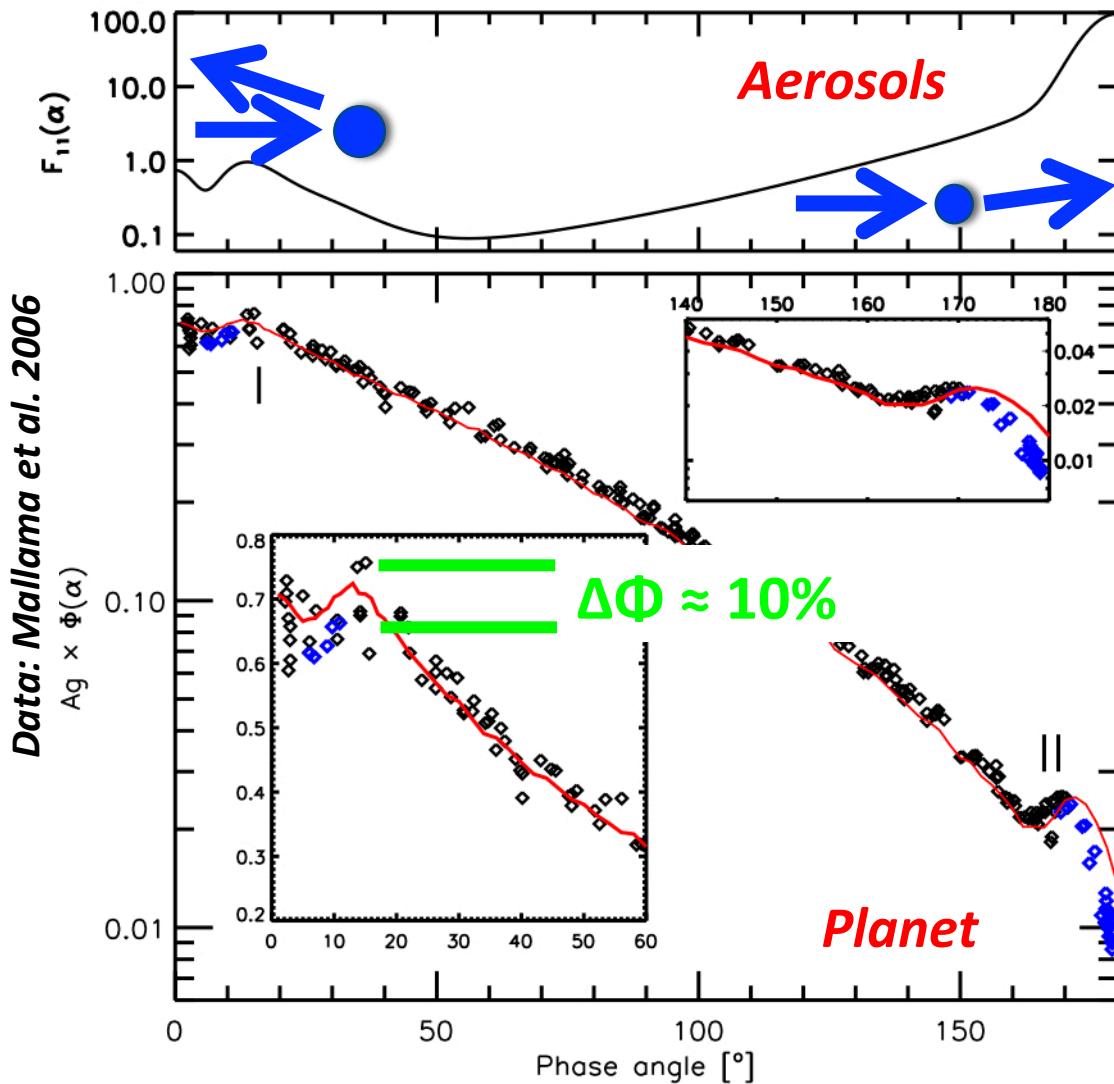
Diurnal variability of Earth



(10)

Glory on Venus

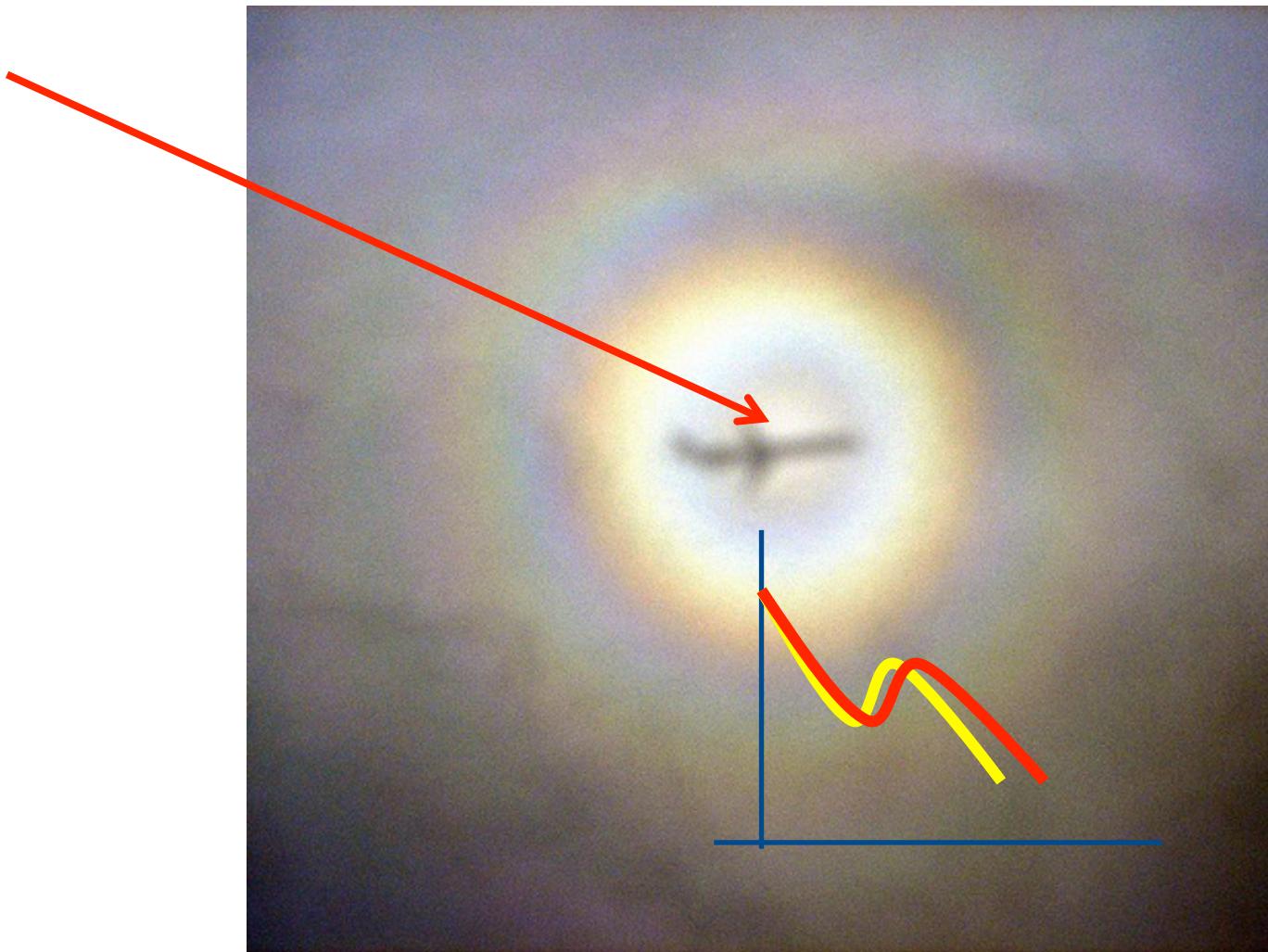
García Muñoz et al.,
in preparation



*Glory is unique to spherical
(liquid?) cloud droplets*

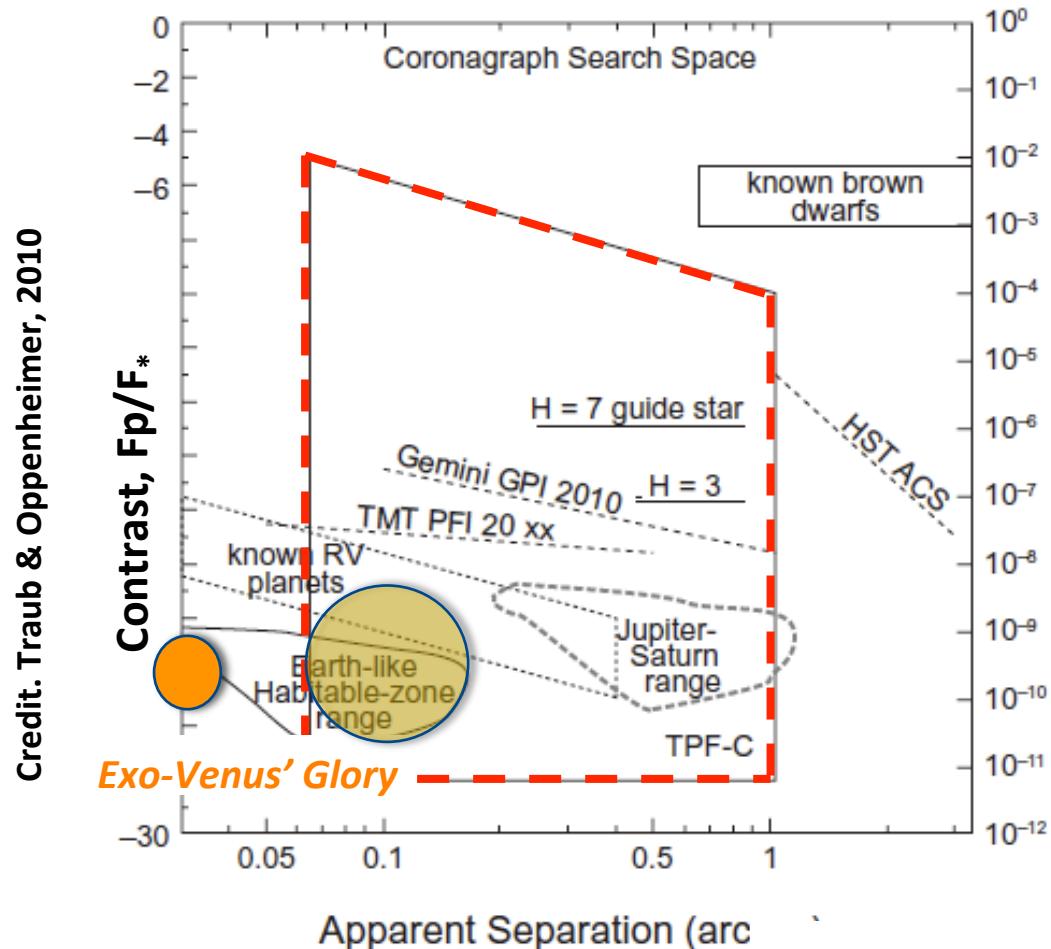
[11]

Something to watch out for



(12)

Reality check



Big Q: When/how do planets
form clouds??? We do ***NOT*** know

(13)



Conclusions

Backward Monte Carlo

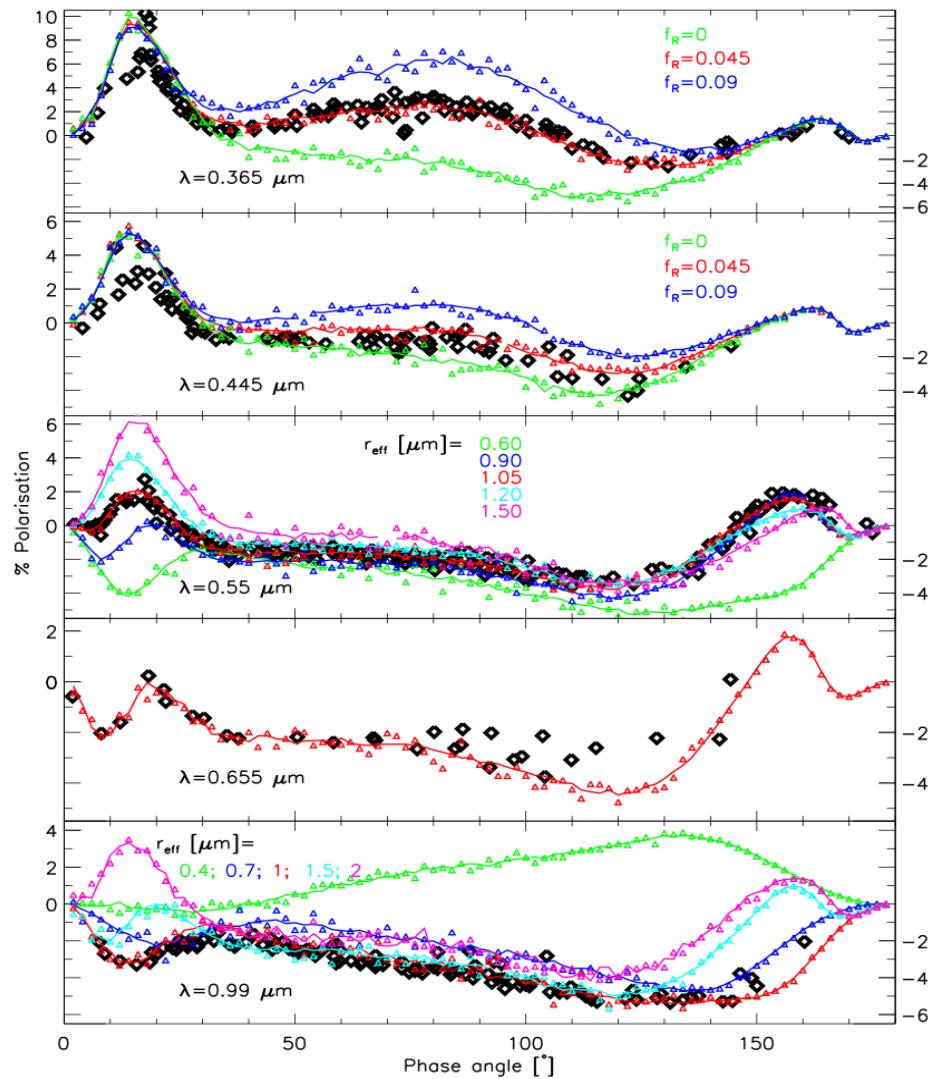
Polarization

(Exoplanet) phase curves

agarcia@rssd.esa.int

[14]

Optical phenomena on Venus

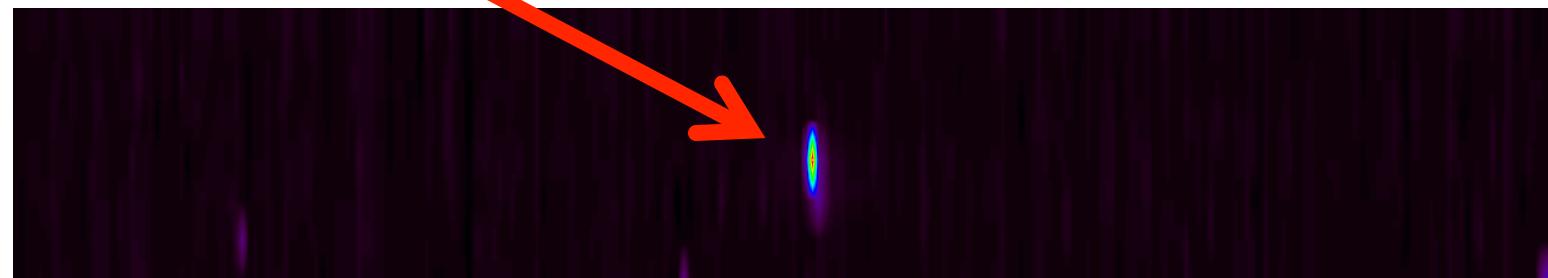


(15)

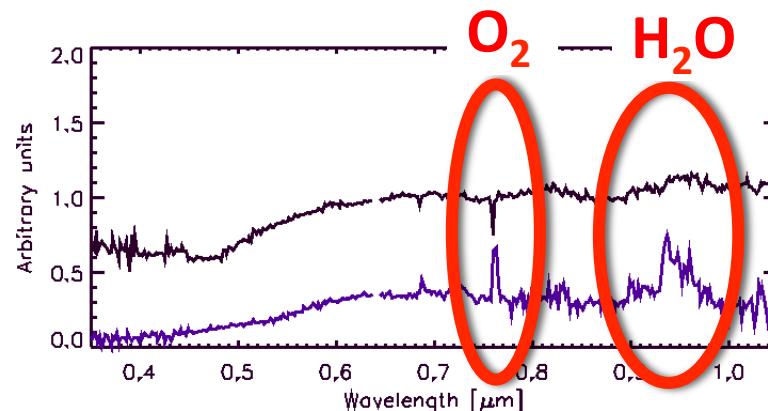
VEx/VIRTIS Earth spectra

You are here

+ A. Cardesín Moinelo



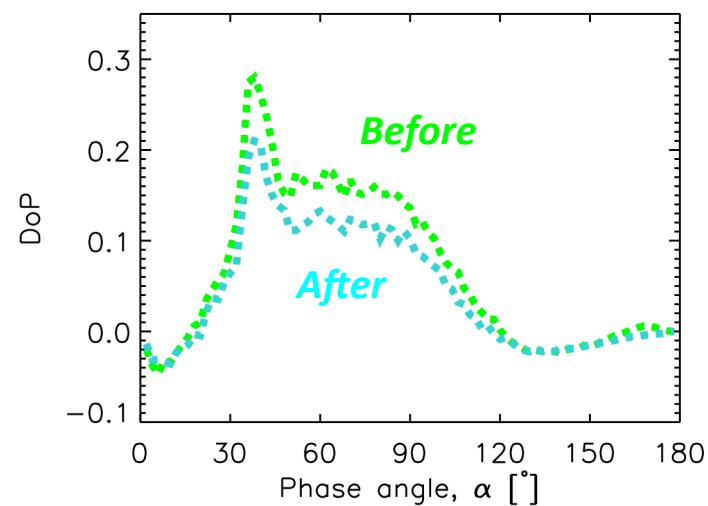
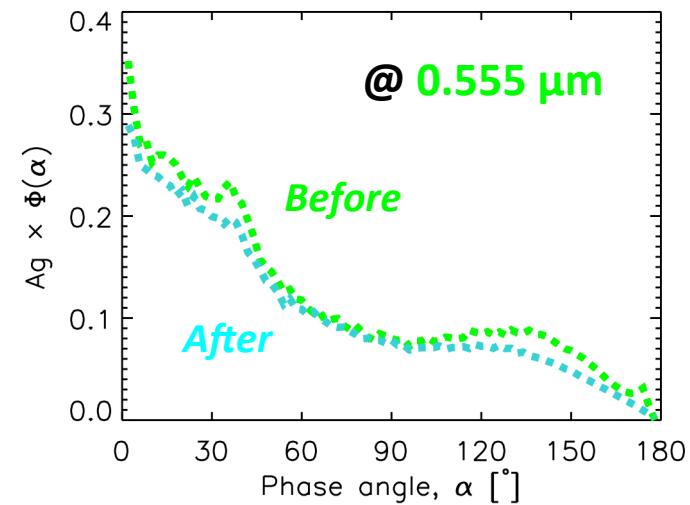
From Venus, Earth is an outer planet $\rightarrow \alpha=0-45^\circ$



Occasionally, look away from mission target!!

(16)

Phase curves of a cloudy+hazy Earth



August 30, 1984



August 8, 1991

After Mt. Pinatubo

Volcanogenic,
aerosols

(17)