RETRIEVAL OF UPPER HAZE AEROSOL PROPERTIES FROM SPICAV-UV AND -IR DATA

M. Luginin[(1)],D. Belyaev[(1)], A. Fedorova[(1)],

F. Montmessin[(2)], O. Korablev[(1)], J.-L. Bertaux[(2),(1)]

(1) Space Research Institute (IKI), Russia

(2) LATMOS, CNRS, France

LATMOS

ИКИ
ИНСТИТУТ
КОСМИЧЕСКИХ
ИССЛЕДОВАНИЙ
РАН

International Venus Conference 2019
Niseko, Hokkaido, Japan
May 31 - June 3 2019

UPPER HAZE STUDY OVERVIEW

- Submicron particles (r <= 0.3 µm)
  - Polarimetery from Pioneer Venus Orbiter (12 years of observations)
    - Kawabata et al., 1980; Esposito and Travis, 1982; Sato et al., 1996; Braak et al., 2002
  - Day-side limb scans from Pioneer Venus Orbiter
    - Lane and Opstbaum, 1983 (12 orbits analyzed)
  - Day-side limb scans from Venera 9, 10
    - Krasnopolsky, 1983 (2 orbits)
- 1-µm particles
  - Solar occultations from SPICAV/SOIR onboard VEx
    - Montmessin et al., 2008 (joint analysis of 3 channels for data set of 3 orbits)
    - Wilquet et al., 2009 (independent analysis of 3 channels for data set of 3 orbits)
    - Luginin et al., 2016 (single SPICAV IR channel analysis of full 8 year dataset)
  - Nightside limb observations performed by VIRTIS onboard Vex
    - De Kok et al., 2011 (4 observations)

SPICAV-UV AND IR SPECTROMETERS

	UV	IR	
Spectral range	118–320 nm	0.65-1.05 µm	1.05-1.7 µm
Resolution	1.5 nm	7.8 cm^{-1}	5.2 cm^{-1}

Single pixel FOV = 40''×40''
Off-axis parabolic mirror + concave UV grating + CCD matrix with 384×288 exposed elements
1 measurement – 5 bins containing 1, 2, 4, 8, 16, or 32 lines in spatial direction

Combination of AOTF and 2 photodiodes
Consecutive scan of a spectrum
FOV = 0.07° at solar occultation mode

METHODOLOGY OF SOLAR OCCULTATION

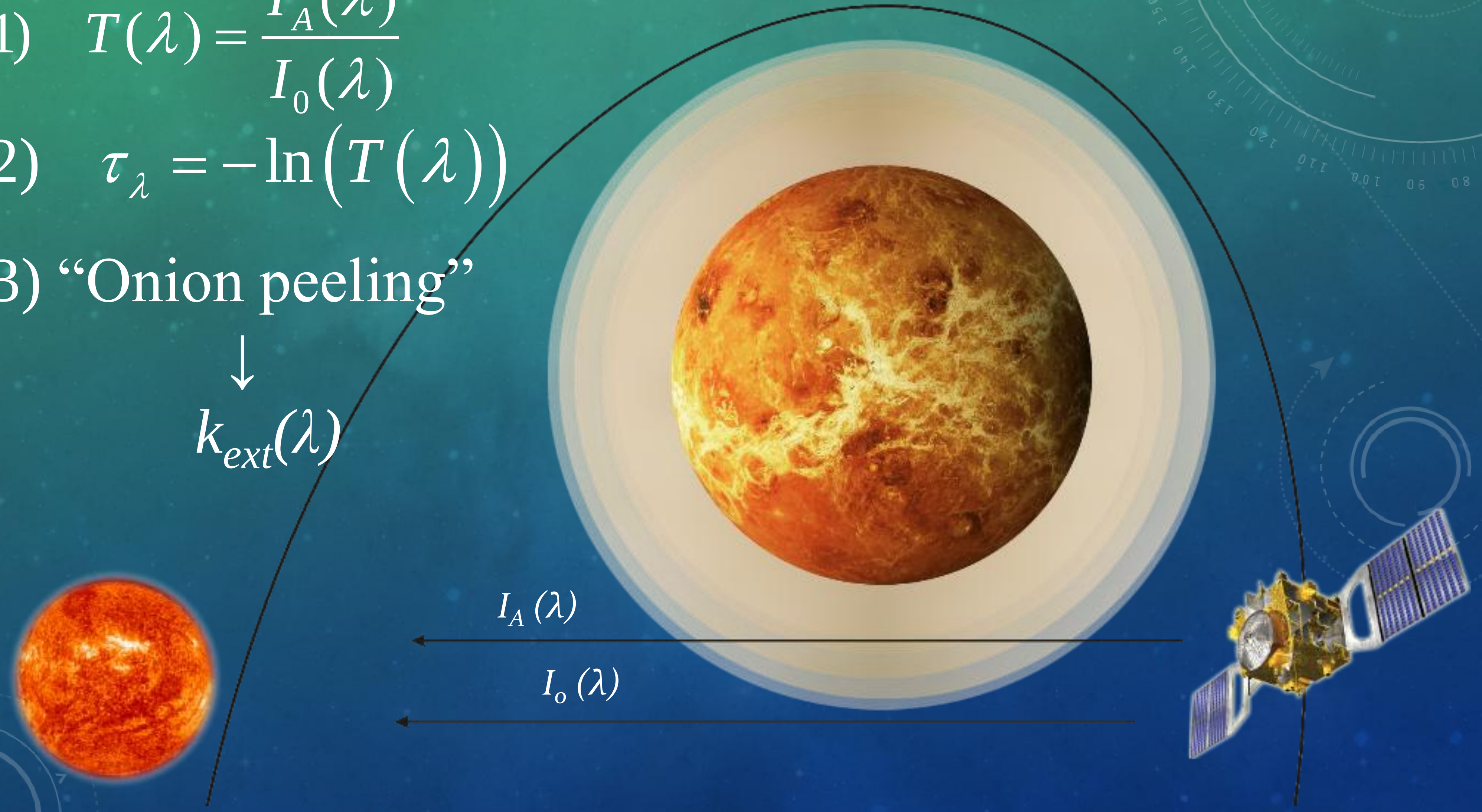
1) $$T(\lambda) = \frac{I_A(\lambda)}{I_0(\lambda)}$$

2) $$\tau_\lambda = -\ln\big(T(\lambda)\big)$$

3) "Onion peeling"

$$\downarrow$$

$$k_{ext}(\lambda)$$



RETRIEVAL OF AEROSOL EXTINCTION

UV

Belyaev et al. 2017. Night side distribution of SO 2 content in Venus' upper mesosphere. *Icarus*, *294*, 58–71.

Fit of the transmission spectra in 180- 300 nm

- CO_2, SO_2, SO absorption
- CO_2 Rayleigh scattering
- Aerosol parameterization: "α-model"

τ_0 and α are free parameters

$$\tau_{aer}(\lambda) = \tau_0 \times (\lambda_0/\lambda)^{\alpha}$$

$$\lambda_0 = 235 \text{ nm}$$

- 'Onion peeling' method with Tikhonov's regularization to retrieve aerosol extinction

- 6 UV wavelengths to maintain the "density" of IR wavelengths
- 200, 220, 236, 260, 280, 300 nm

- Interpolation to IR altitude mesh

IR

Luginin et al. 2016. Aerosol properties in the upper haze of Venus from SPICAV IR data. Icarus, 277, 154–170.

- Transmission at 10 wavelengths outside of gaseous absorption bands
- 'Onion peeling' method to retrieved extinction
- Subtraction of CO_2 Rayleigh scattering gives aerosol extinction

- 649.4, 756.6, 852.5, 982.4, 1101.1, 1159.6, 1197.3, 1273.4, 1323.0, 1553.7 nm

LATITUDE COVERAGE OF OBSERVATIONS

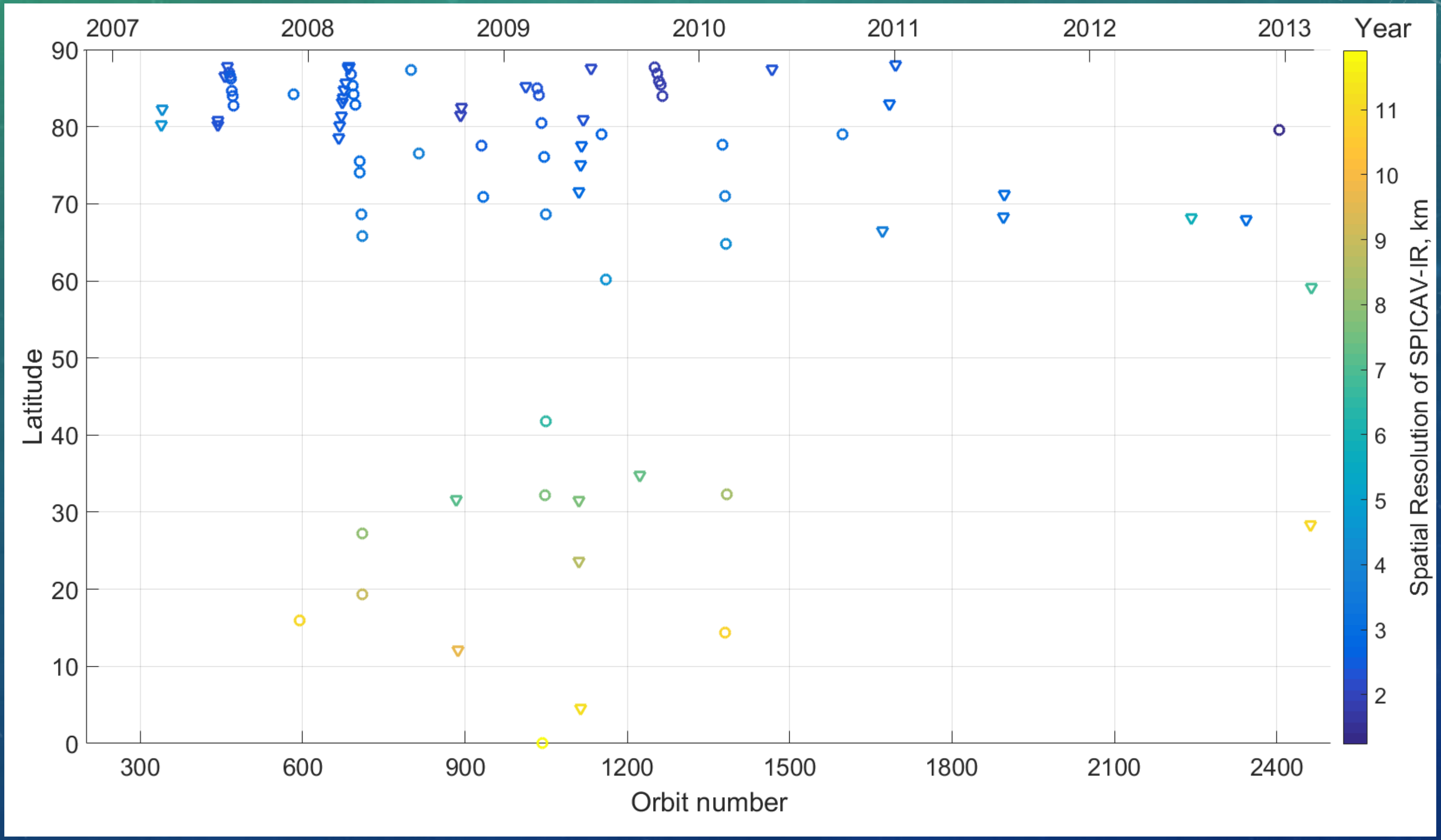
UV

402 solar occultation sessions

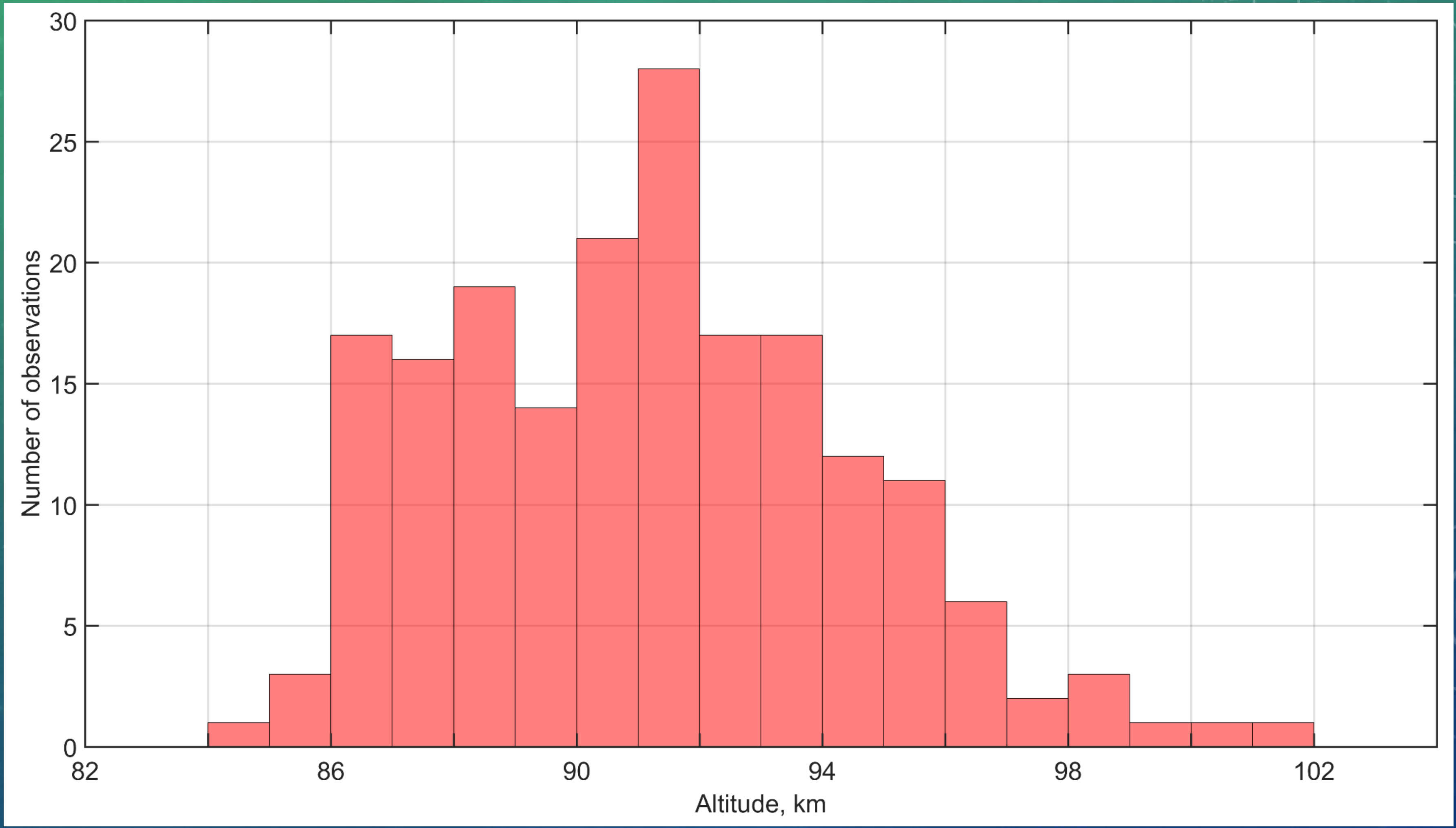
IR

222 solar occultation sessions

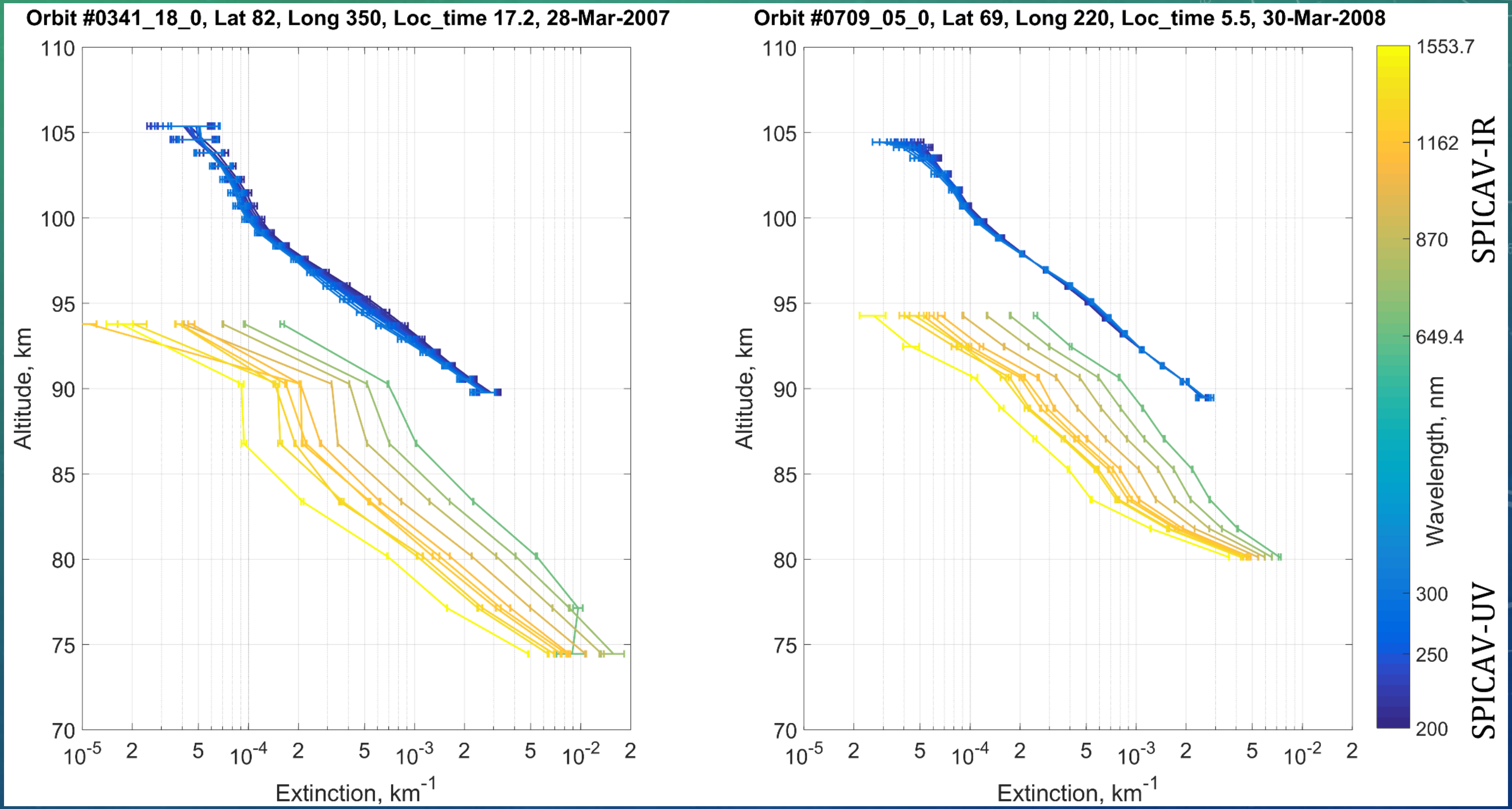
84 solar occultation sessions
186 altitudes



ALTITUDE COVERAGE

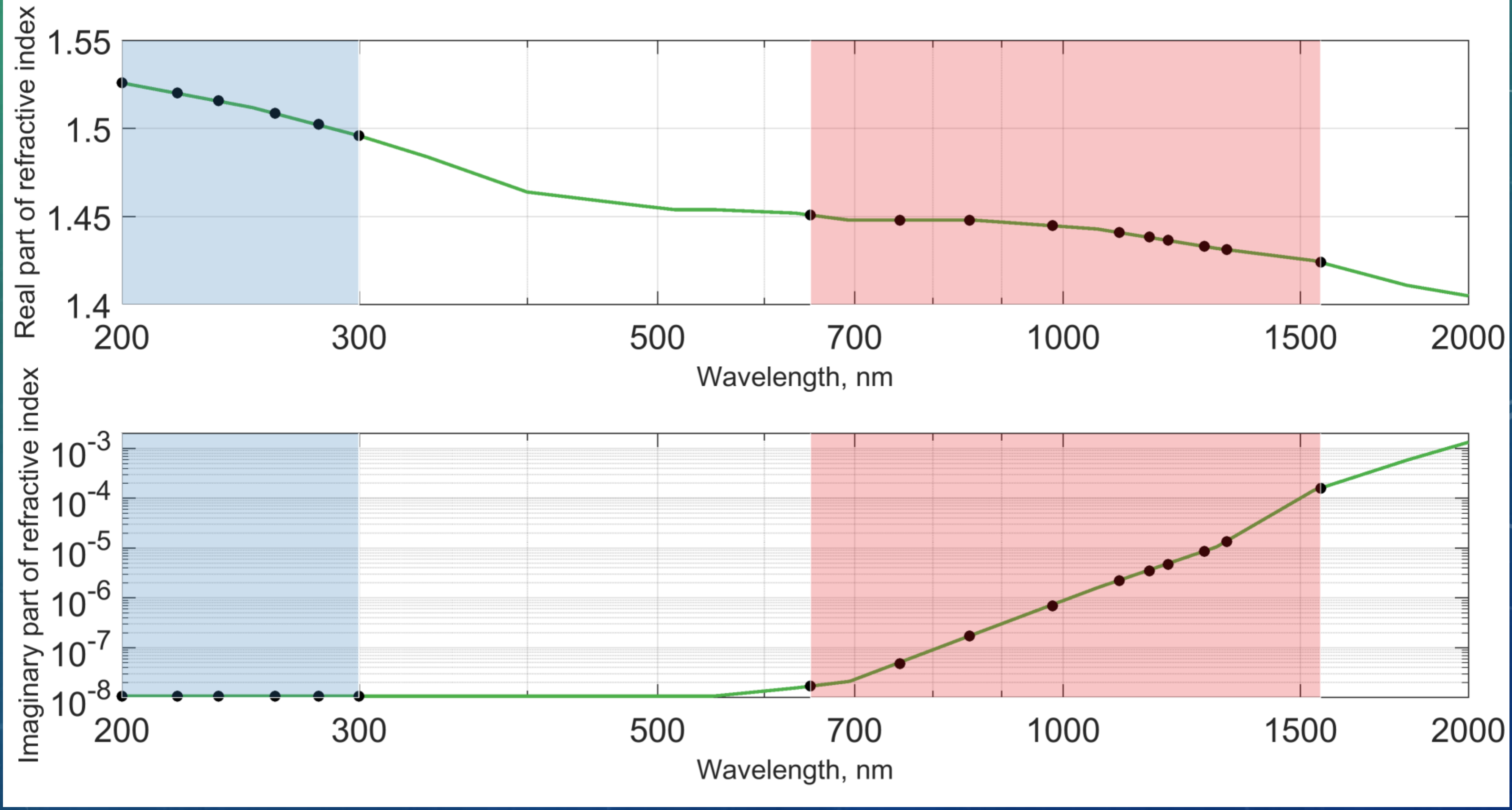


JOINT EXTINCTION PROFILES



H_2SO_4 refractive index

Real and Imaginary indices of refraction for 75 % solution of sulfuric acid at 215 K were taken from Hummel et al. (1988), A new background stratospheric aerosol model for use in atmospheric radiation models, AFGL-TR-88–0166, Air Force Geophys. Lab., Hanscom Air Force Base, Mass



PARTICLE SIZE AND NUMBER DENSITY DETERMINATION

Levenberg-Marquardt fitting procedure to find distribution parameters

$$\chi^2 = \frac{1}{N-k}\sum_{1}^{N}\frac{(k_{exp}-k_{mod})^2}{\delta_{exp}^2}$$

Unimodal lognormal distribution

r_g is fitted

v_{eff} is set to 0.15

$$n(r) = C \times r^{-1}\exp\left(-\frac{(\ln r - \ln r_g)^2}{2\ln^2\sigma_g}\right)$$

$$r_{eff} = r_g \exp\left(\frac{5}{2}\ln^2\sigma_g\right)$$

$$v_{eff} = \exp(\ln^2\sigma_g) - 1$$

Bimodal lognormal distribution

r_{g1}, r_{g2} and γ are fitted

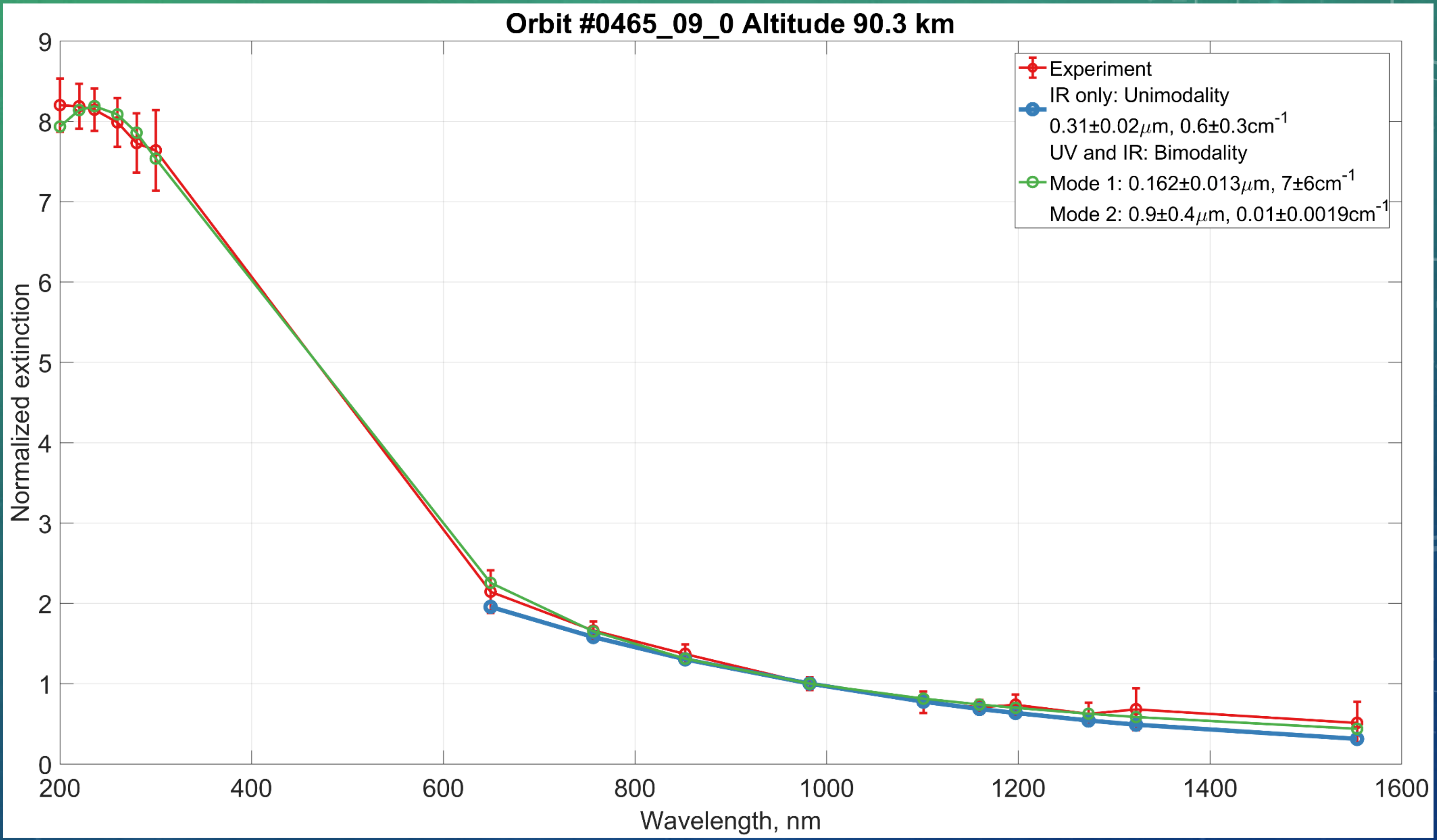
$v_{eff\,1} = 0.15$, $v_{eff\,1} = 0.1$

$$n(r) = \frac{C}{r}\left\{\exp\left[-\frac{(\ln r - \ln r_{g1})^2}{2\ln^2\sigma_{g1}}\right] + \gamma\exp\left[-\frac{(\ln r - \ln r_{g2})^2}{2\ln^2\sigma_{g2}}\right]\right\}$$

$$N(z) = \frac{k_{ext}(z)}{\int_0^\infty \sigma_{ext}(\lambda, z)\, n(r,z)\, dr}$$

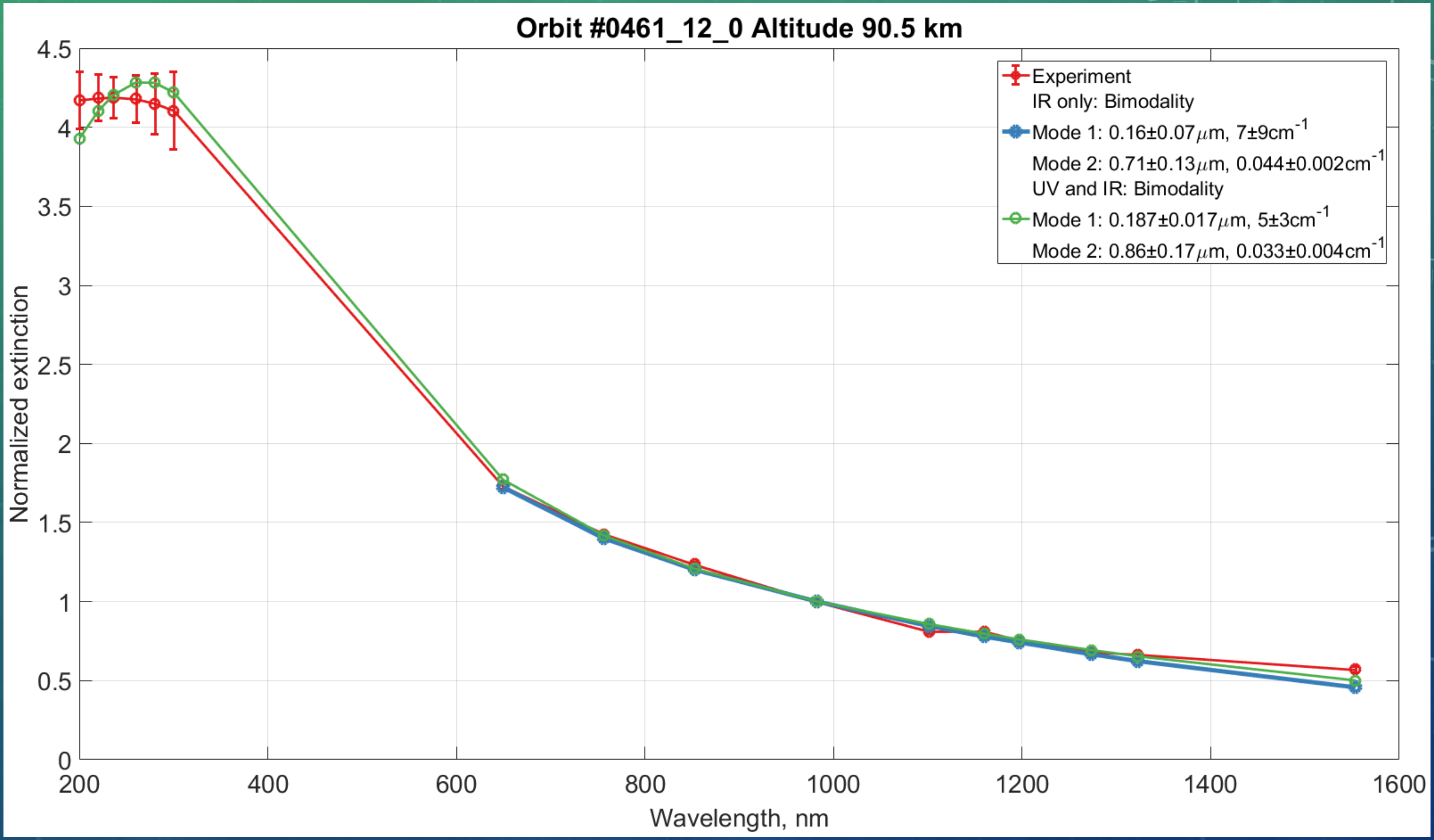
RESULTS:

unimodal distribution → bimodal distribution



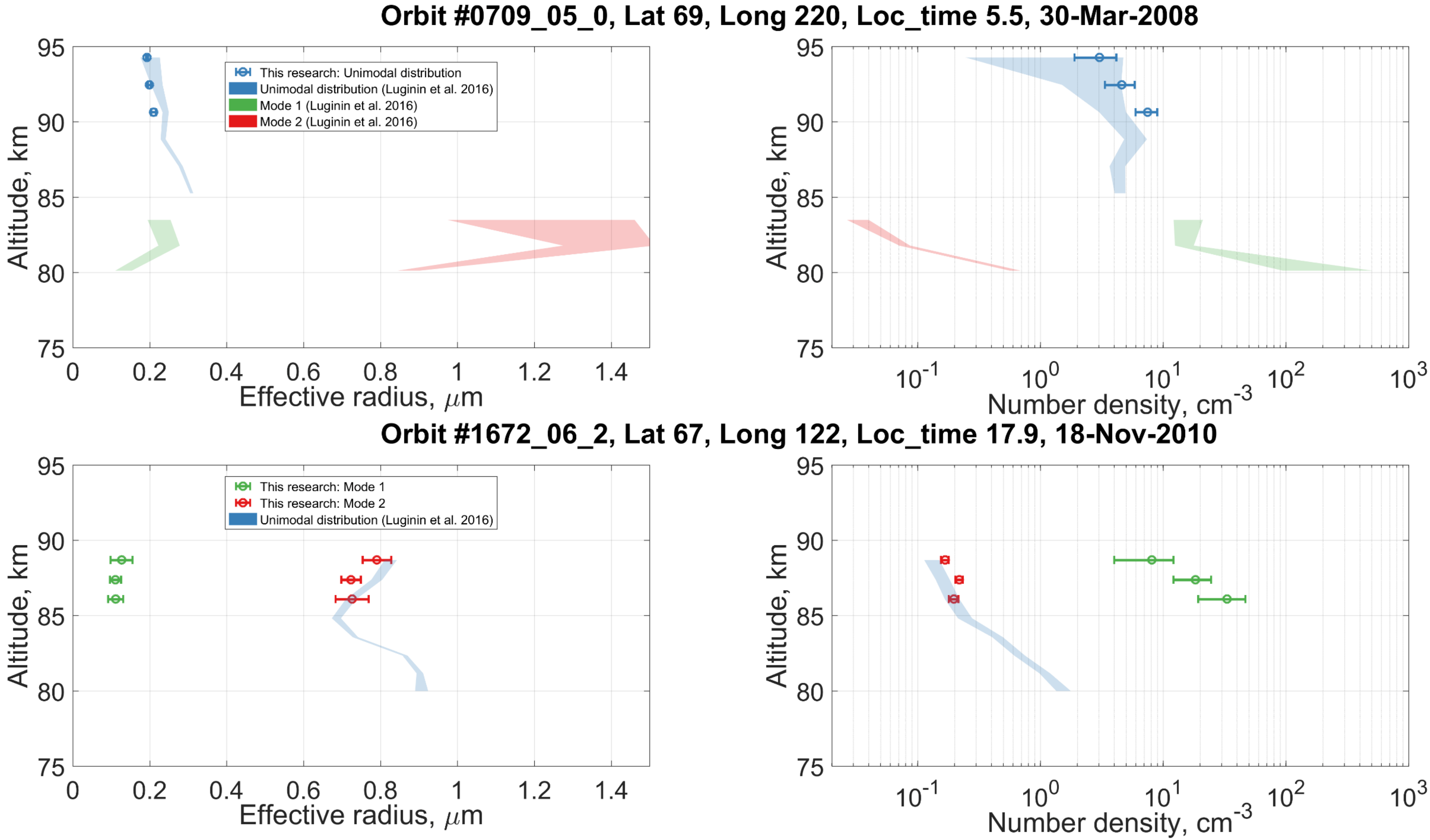
RESULTS:

bimodal distribution → bimodal distribution



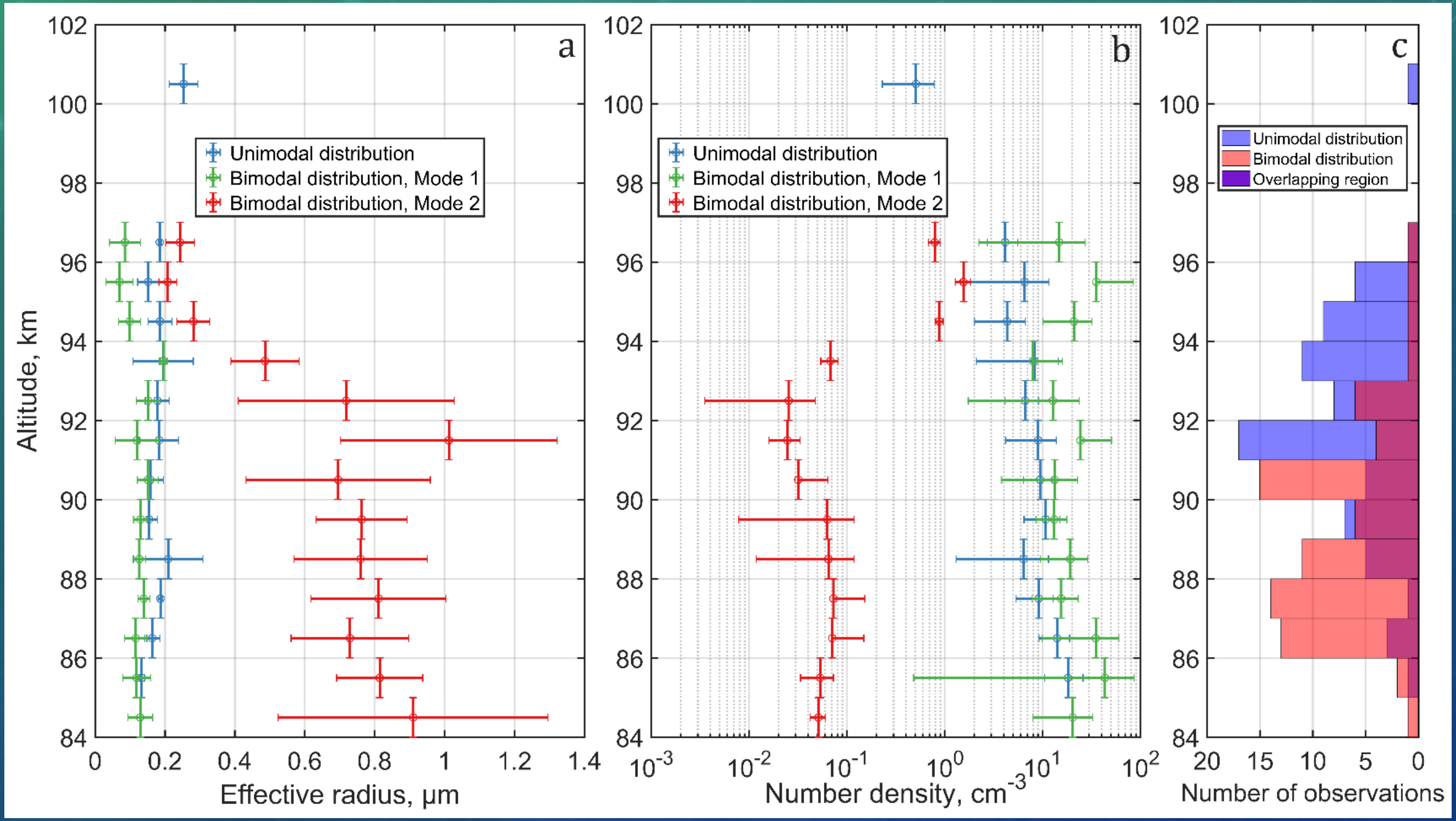
RESULTS:

comparison of IR only and joint UV and IR data

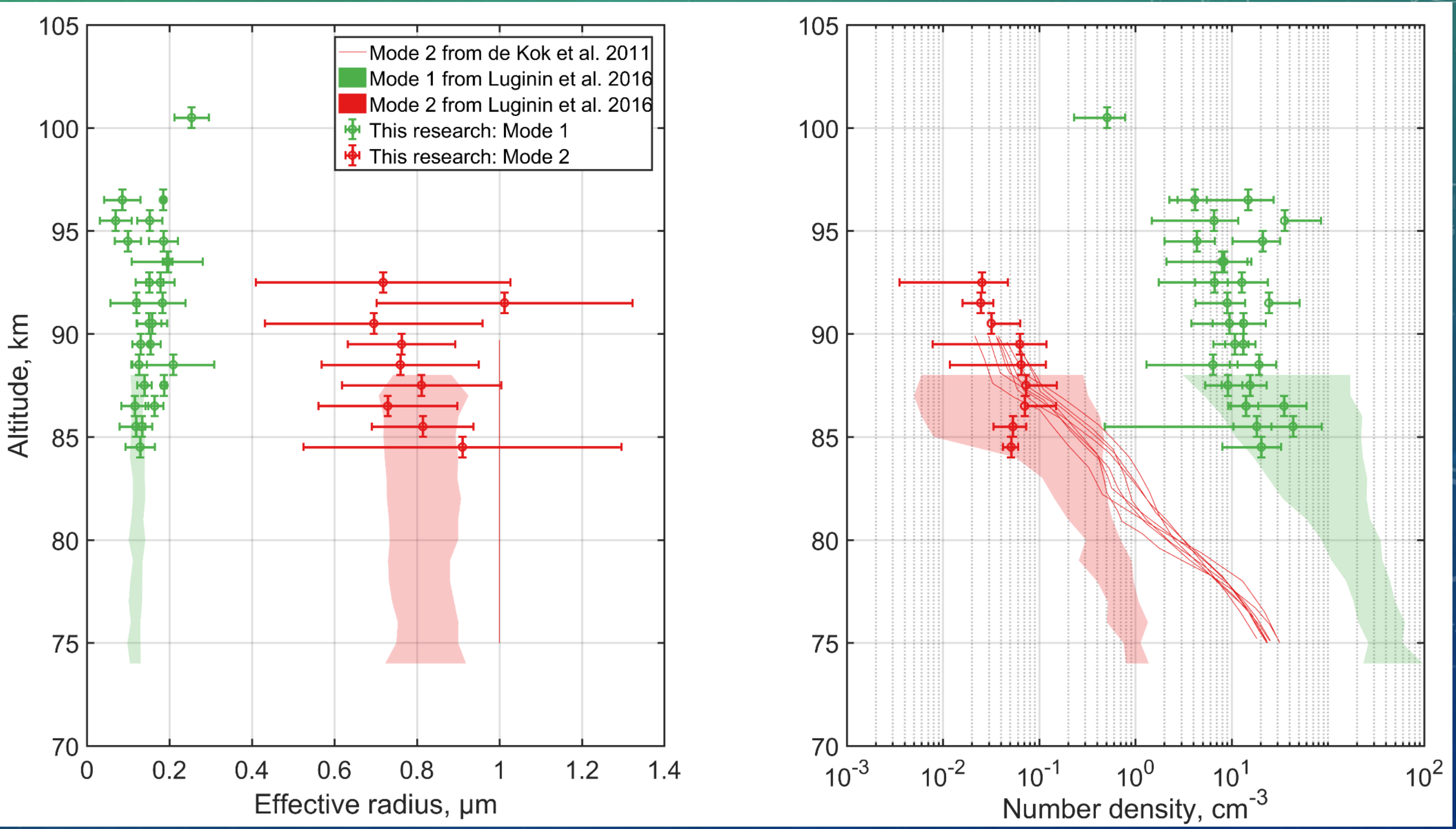


MEAN PROFILES

- Unimodal case: 0.18±0.05 μm and 8±5 cm^{-3}
- Bimodal case averaged in 86–92 km altitude range
- Mode 1: 0.13 ± 0.03 μm and 20 ± 14 cm^{-3}
- Mode 2: 0.8±0.2 μm and 0.05±0.04 cm^{-3}



COMPARING WITH PREVIOUS RESULTS



MAIN RESULTS

- We prove that SPICAV-IR is capable to detect bimodal size distribution of aerosols
- We confirm results obtained from single SPICAV-IR channel. Luginin et al. 2016. Aerosol properties in the upper haze of Venus from SPICAV IR data. Icarus, 277, 154–170.
- Upper haze extends up to 95+ km at high latitudes
- Mode 2 particles are observed up to 91 km at high latitudes