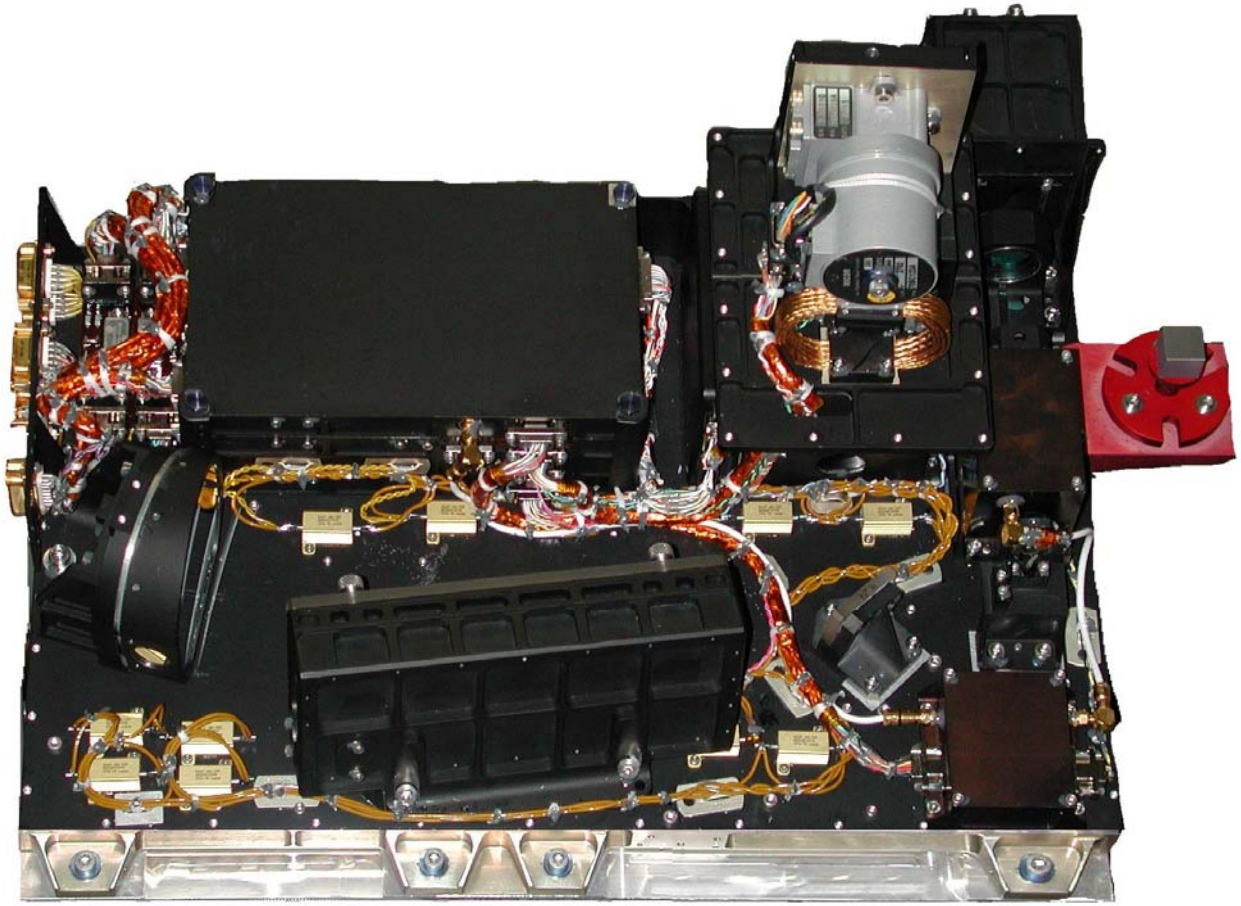
Studying methane and other trace species in the Mars atmosphere using a SOIR instrument



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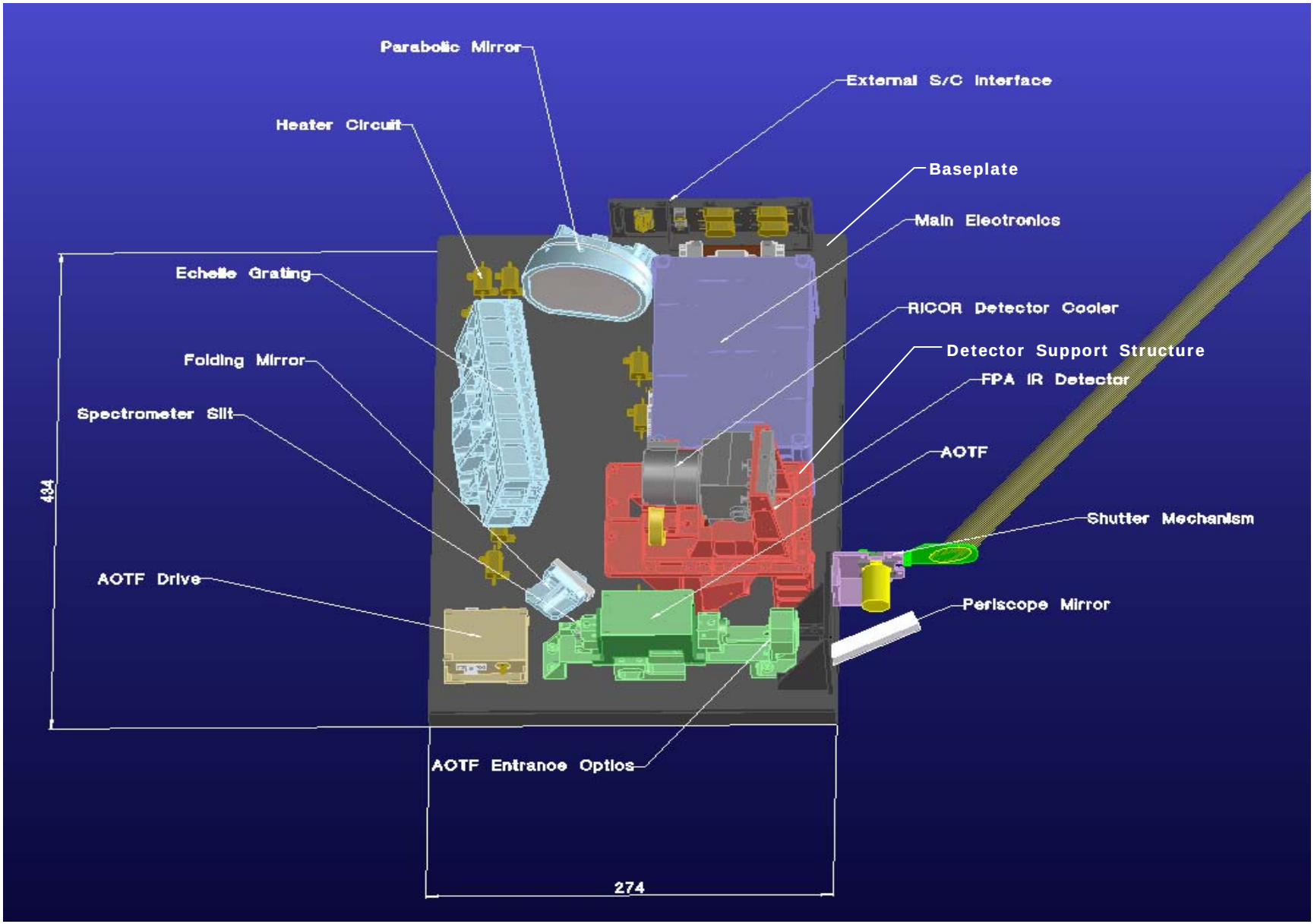
Talk outline

- SOIR instrument description
- Results from VEX-SOIR in orbit around Venus
- Possible observations from a representative Mars orbit
- Martian atmospheric constituents within the SOIR spectral range
  - Detection limits
- Ongoing improvements to SOIR
- Nadir capabilities
- Conclusion

SOIR Instrument Characteristics

SOIR characteristics	Value or range
Wavelength range	2.29 to 4.43 µm
Wavenumber range	2353 to 4310 cm^{-1}
Spectral sampling interval	1 pixel = 0.1 cm^{-1}
Resolving power [$\lambda/\Delta\lambda=\upsilon/\Delta\upsilon$]	23200 to 43100
FOV	2' x 30'
Spectral resolution Spatial resolution (Δz at limb)	0.12 – 0.18cm^{-1} < 1 km
Detector	2D HgCdTe, 320x256 pixel matrix
Power	17.8 W
Mass	< 8 kg
Size	414 x 254 x 210 mm^3

SOIR instrument description



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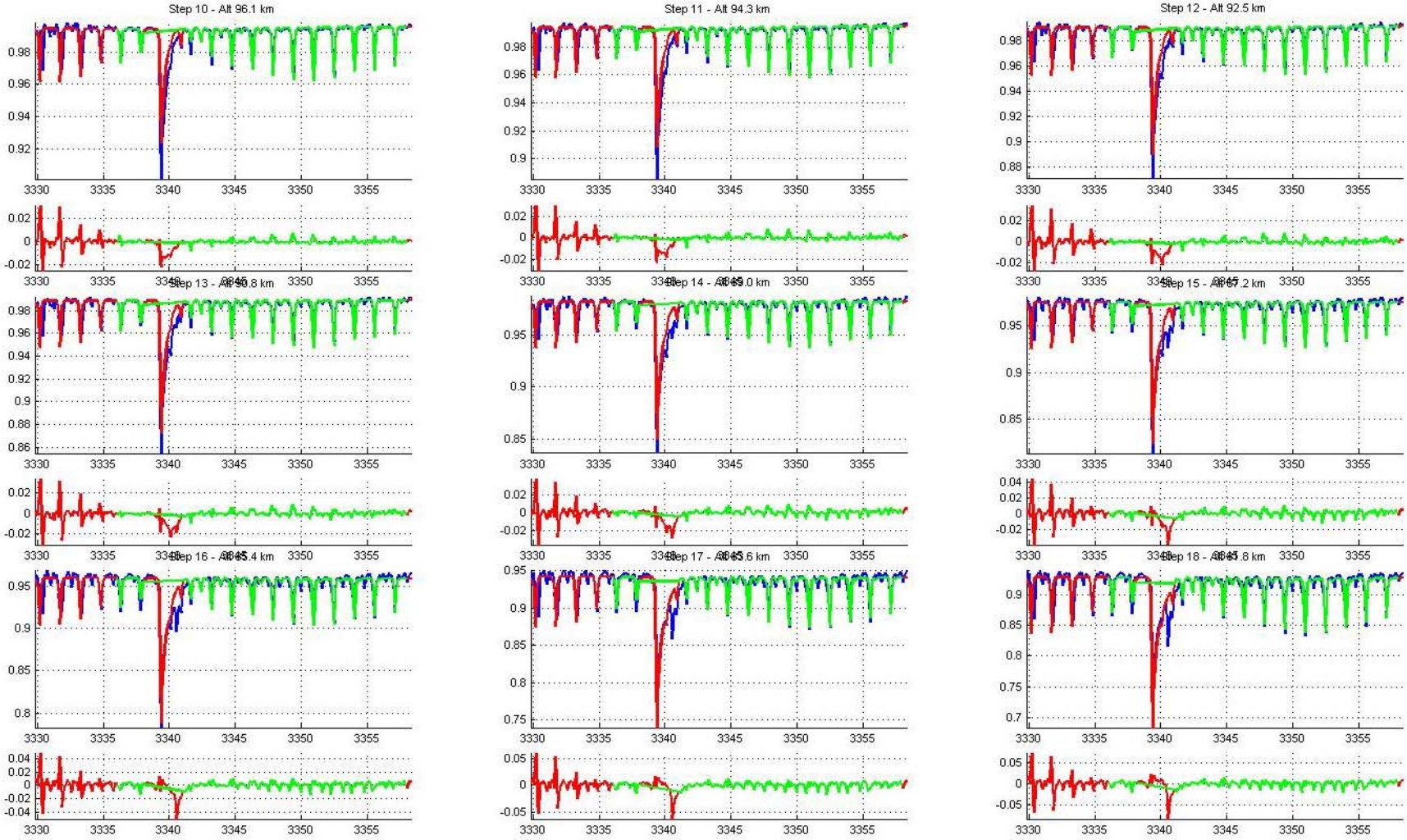
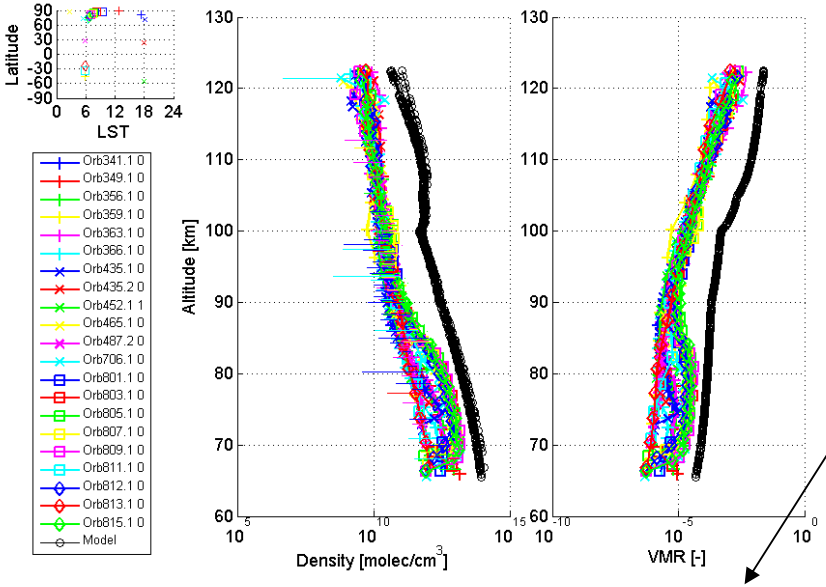
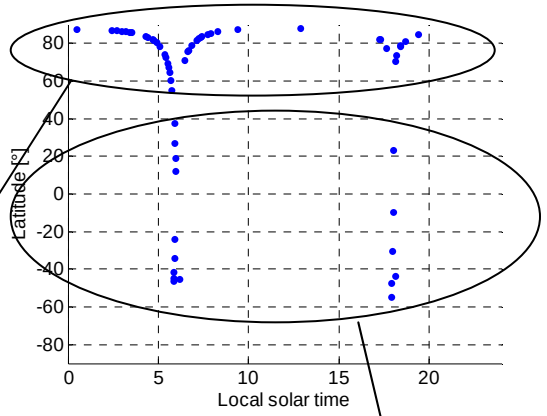
Example of results: orbit 341.1 order 149 (2/4)

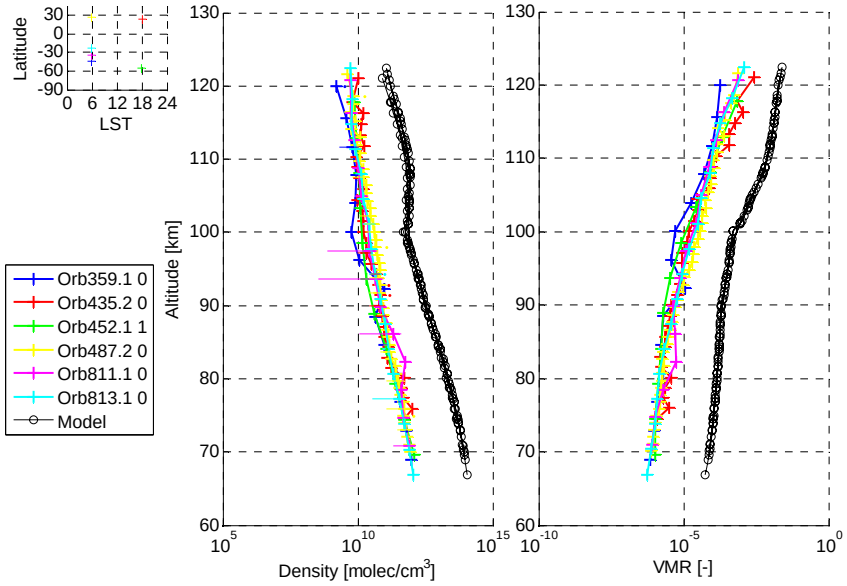


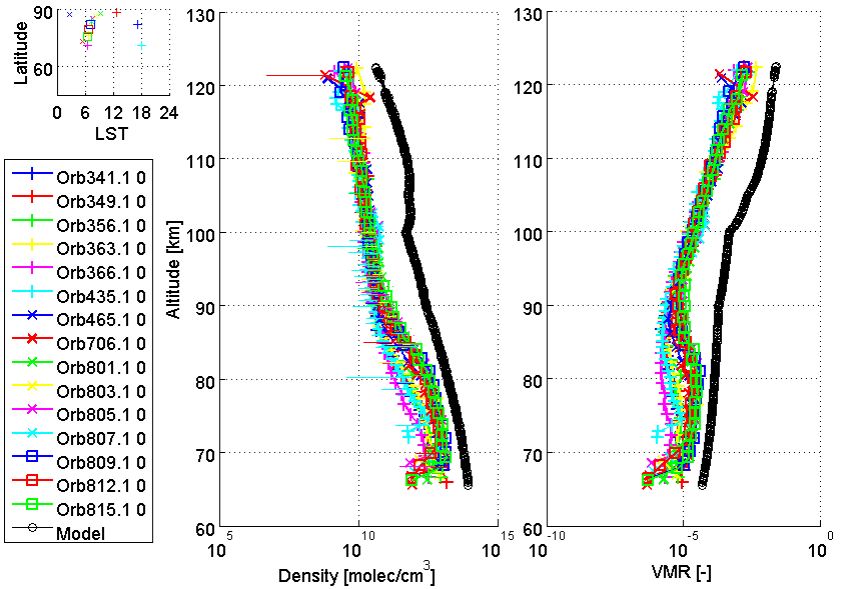
CO vertical profiles





Latitudinal dependency





(VMR obtained from total density of VIRA model)

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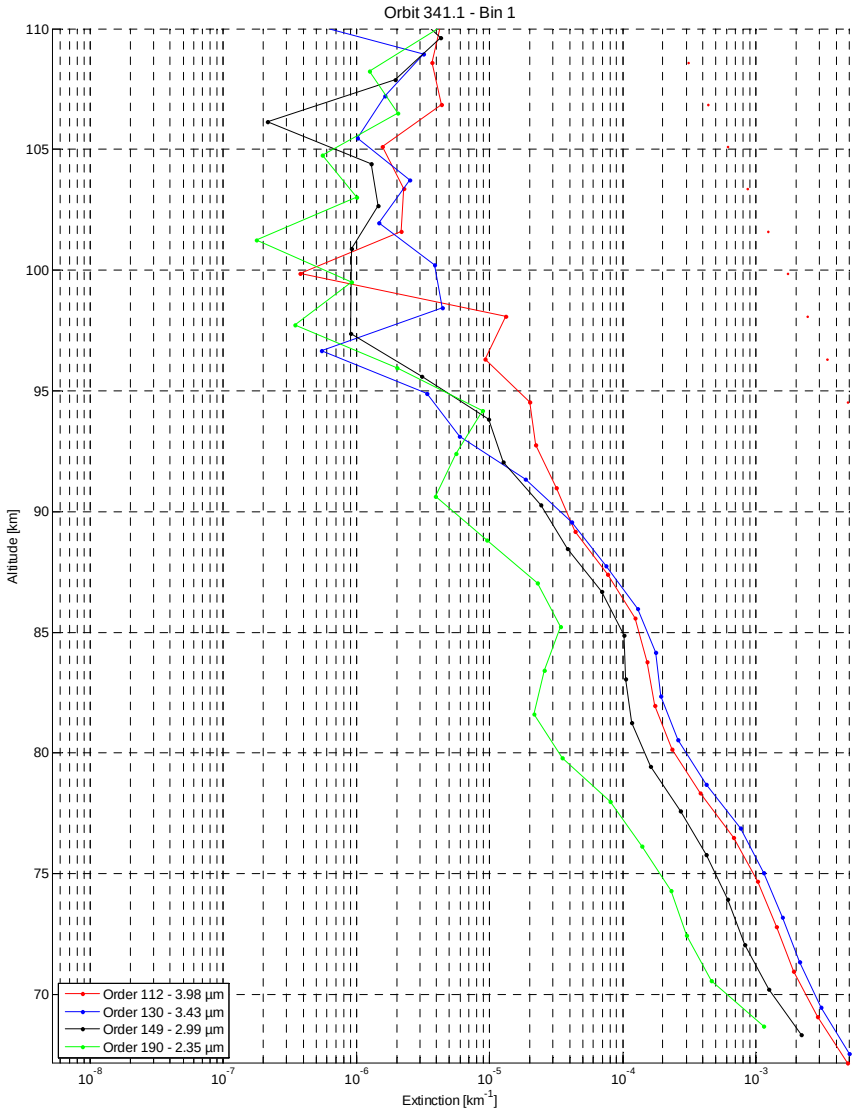
Aerosols:
Retrieval technique – Extinction profiles

- Transmittances ←→ Extinction :

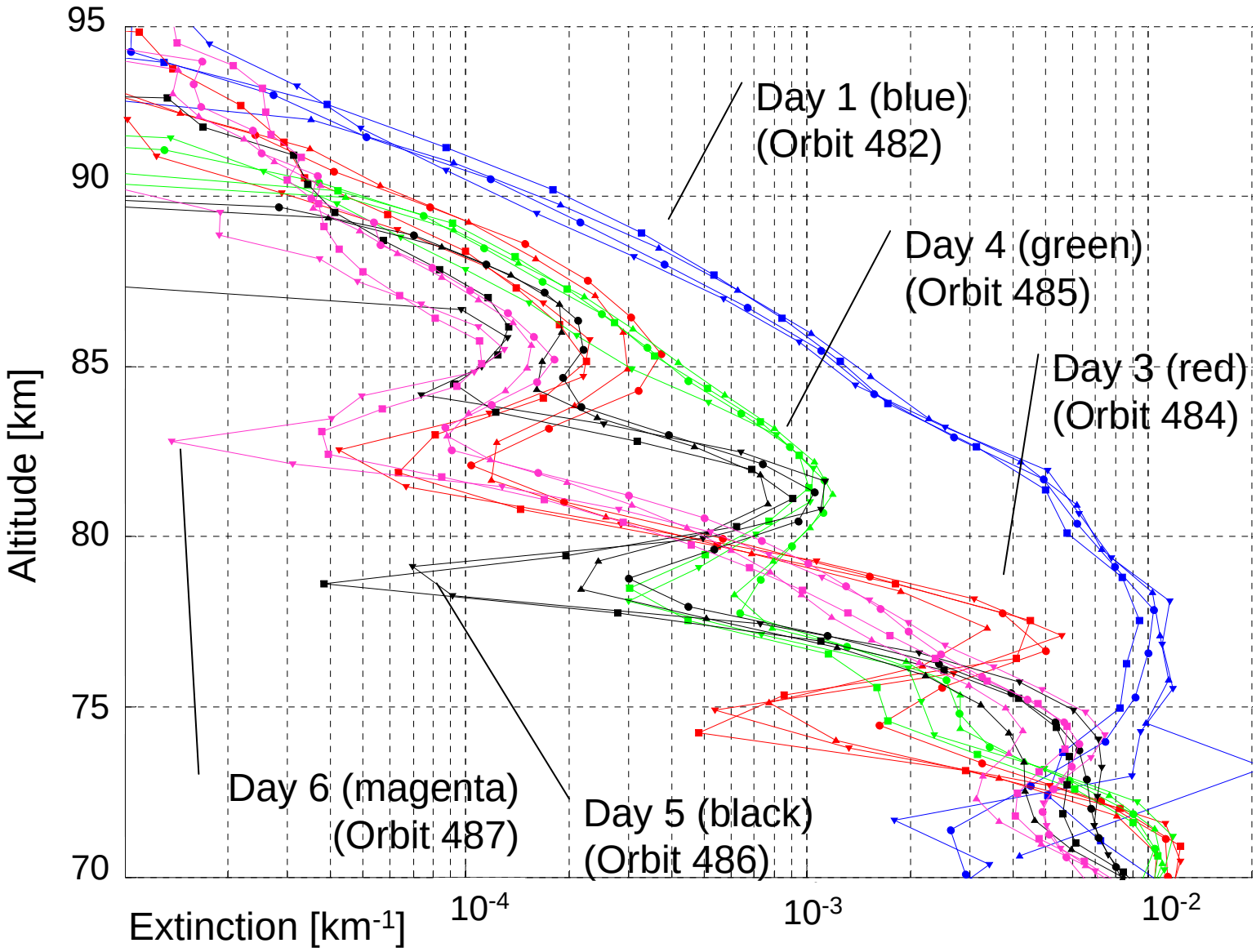
$$\beta_{ext}^{N} = \frac{-\ln\left(\frac{I_N}{I_0}\right) - \sum_{i=1}^{N-1} dz_i \cdot \beta_{ext}^{i}(\lambda, z)}{dz_N}$$

- With
  - dz_i the thickness of layer i
  - I_i the atmospheric intensity of layer I
  - I_0 the full sun intensity
  - β_i the extinction of layer i



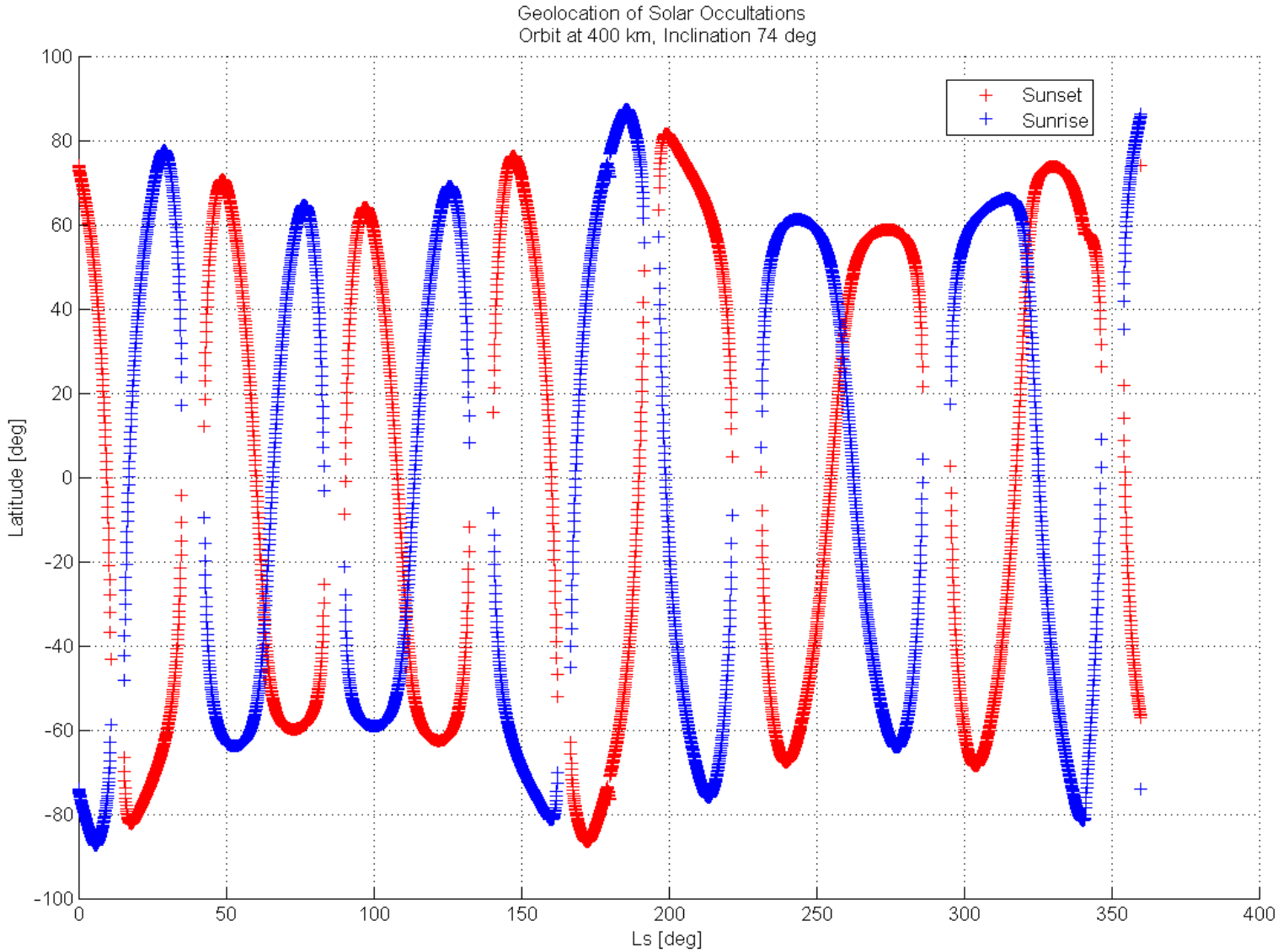
V. Wilquet, et al., "Preliminary characterization of the upper Venusian haze from UV to mid-IR by SPICAV/SOIR on Venus Express", J. Geophys. Research, 2009

Aerosols extinction profiles: Significant variations at high Northern latitudes



V. Wilquet, et al., "Preliminary characterization of the upper Venusian haze from UV to mid-IR by SPICAV/SOIR on Venus Express", J. Geophys. Research, 2009

Solar Occultation Possibilities at Mars



For ascending node starting at vernal equinox

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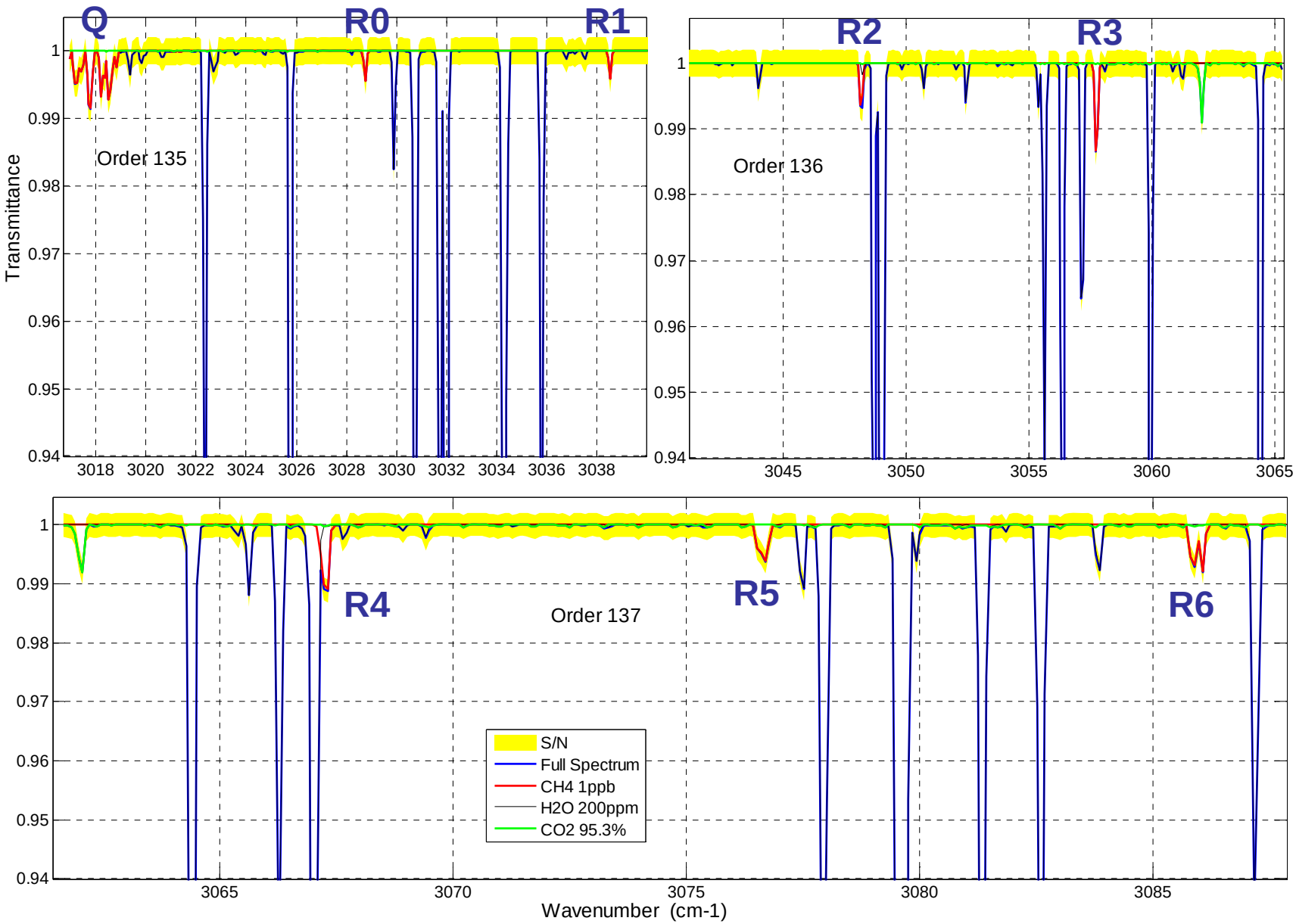
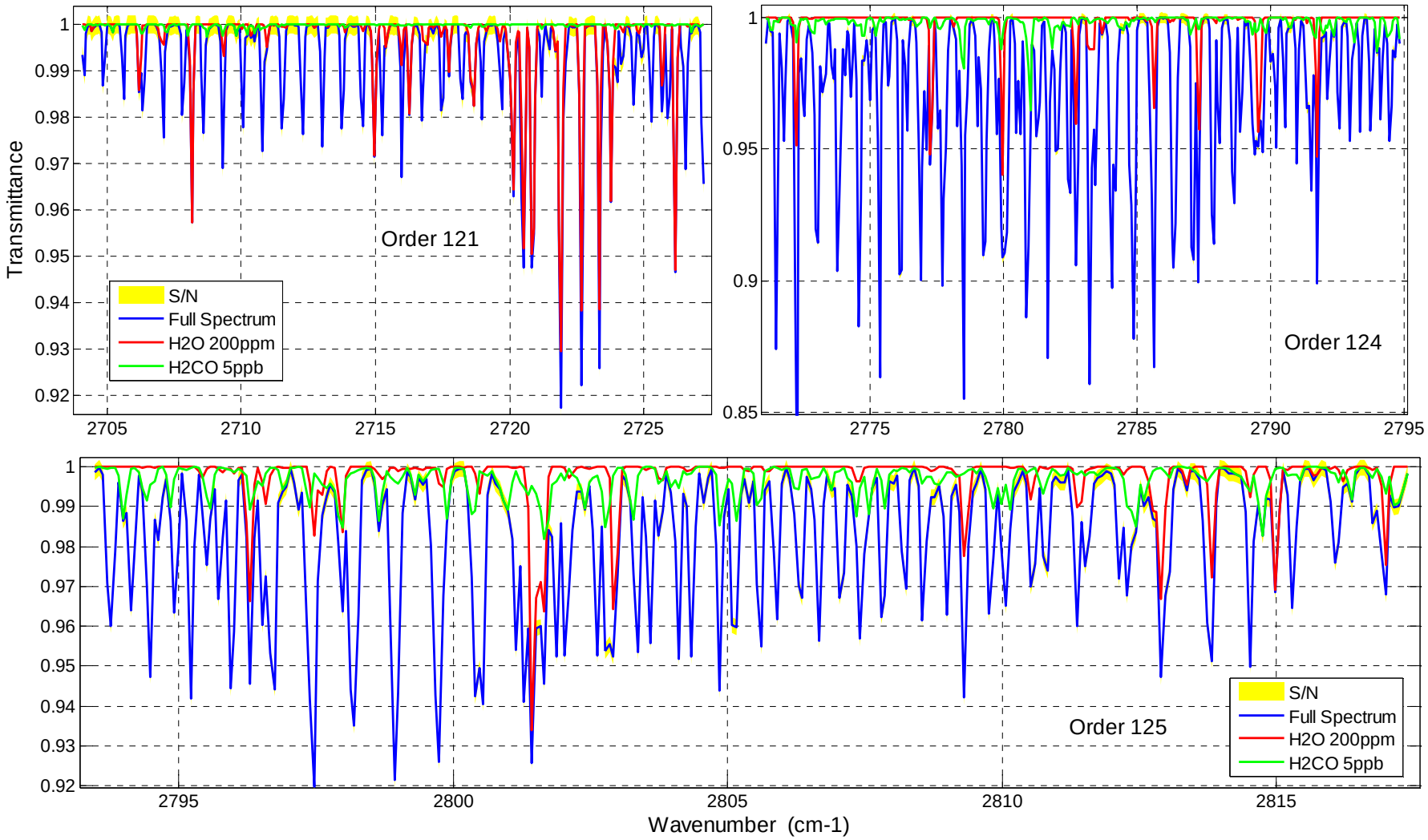
Simulated observations - Methane



Simulated observations - Formaldehyde



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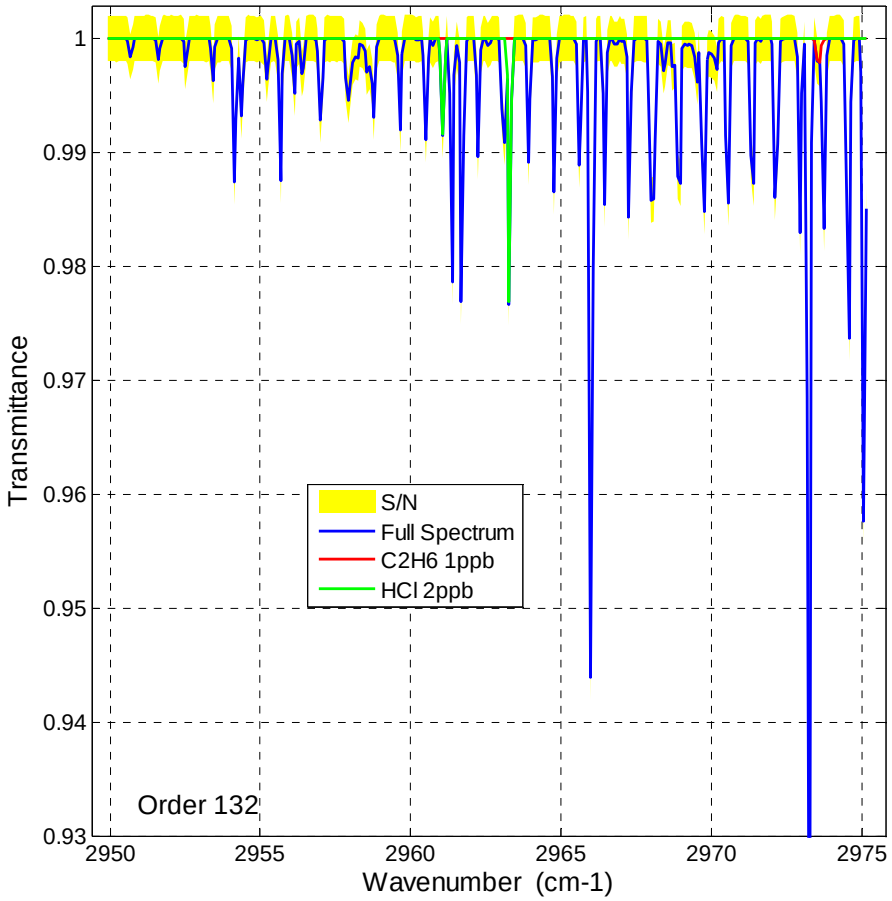
Simulated observations – C_2H_6 and HCl



SOIR Detection Capabilities

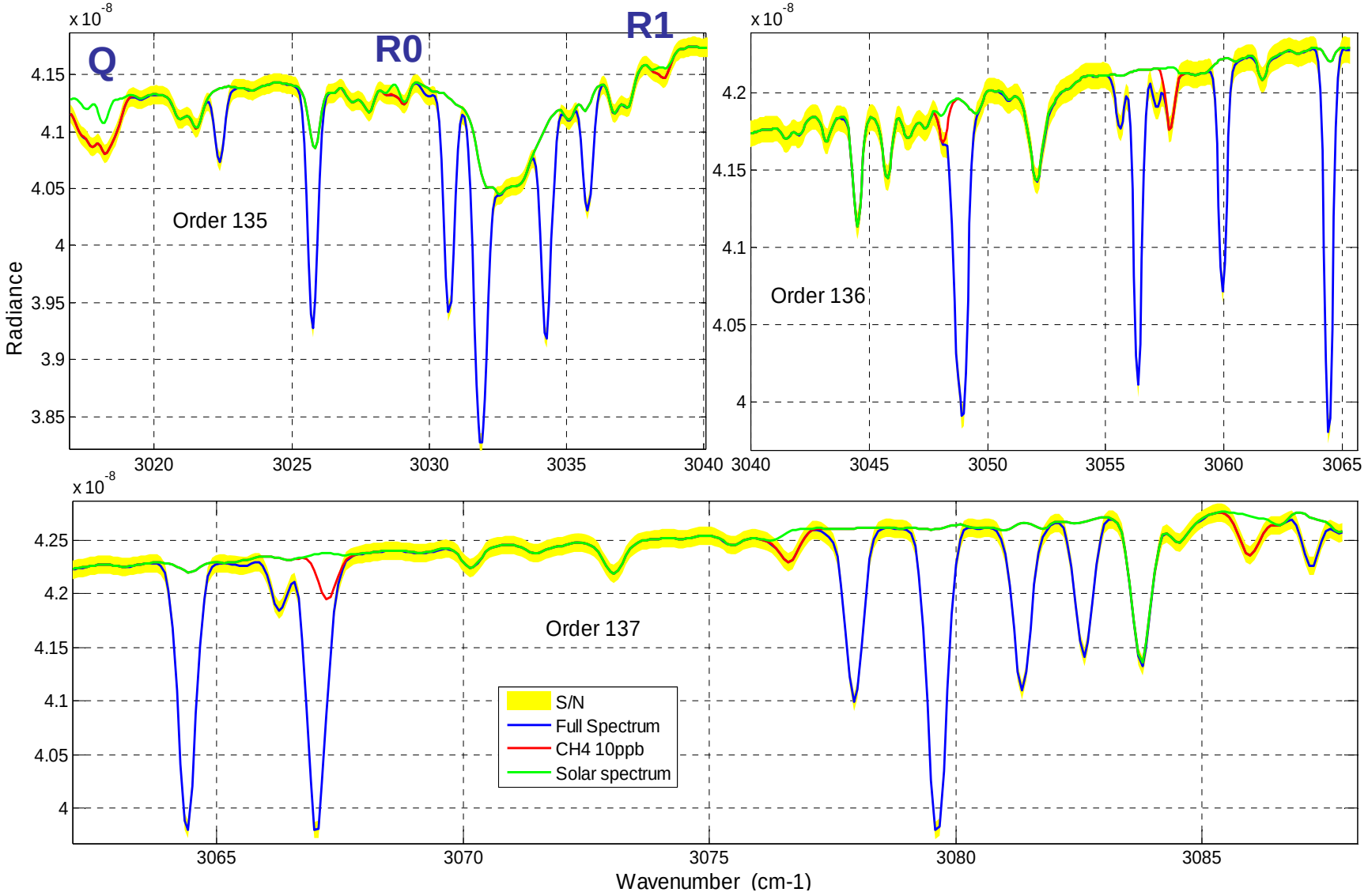
Species	Scientific Objective	Current Knowledge	Detection limit	Expected SOIR Advance
CH_4	Identify sources	0-60ppb	0.1 ppb	CH_4 abundance & improve maps
CO_2	Profile density and T	MGS up to ~50 km	1%, 1K (accuracy)	Model assimilation, P, T profiles
H_2O	Profile	<300 ppm	10 ppb	Photo-chemical loss investigations
CO	Profile	700-800 ppm	1 ppm	Provide GCM model constraints
HDO among others	Profiling isotopic ratios ^{17}OCO; ^{18}OCO $^{13}CO_2$; $C^{18}O_2$	0.85 ppm	1% (accuracy)	Provide profiles
Aerosols	Properties, extinction profiles	TES measurement		Provide profiles, GCM validation
H_2CO C_2H_2 C_2H_6 HCl OCS SO_2	Search for unidentified species	<3.0 ppb <2.0 ppb <400 ppb <2.0 ppb 10 ppb 1.0 ppb	0.1ppb 1 ppb 0.1 ppb 1 ppb 10 ppb 0.1 ppm	Provide profiles and mapping

These values are for solar occultation

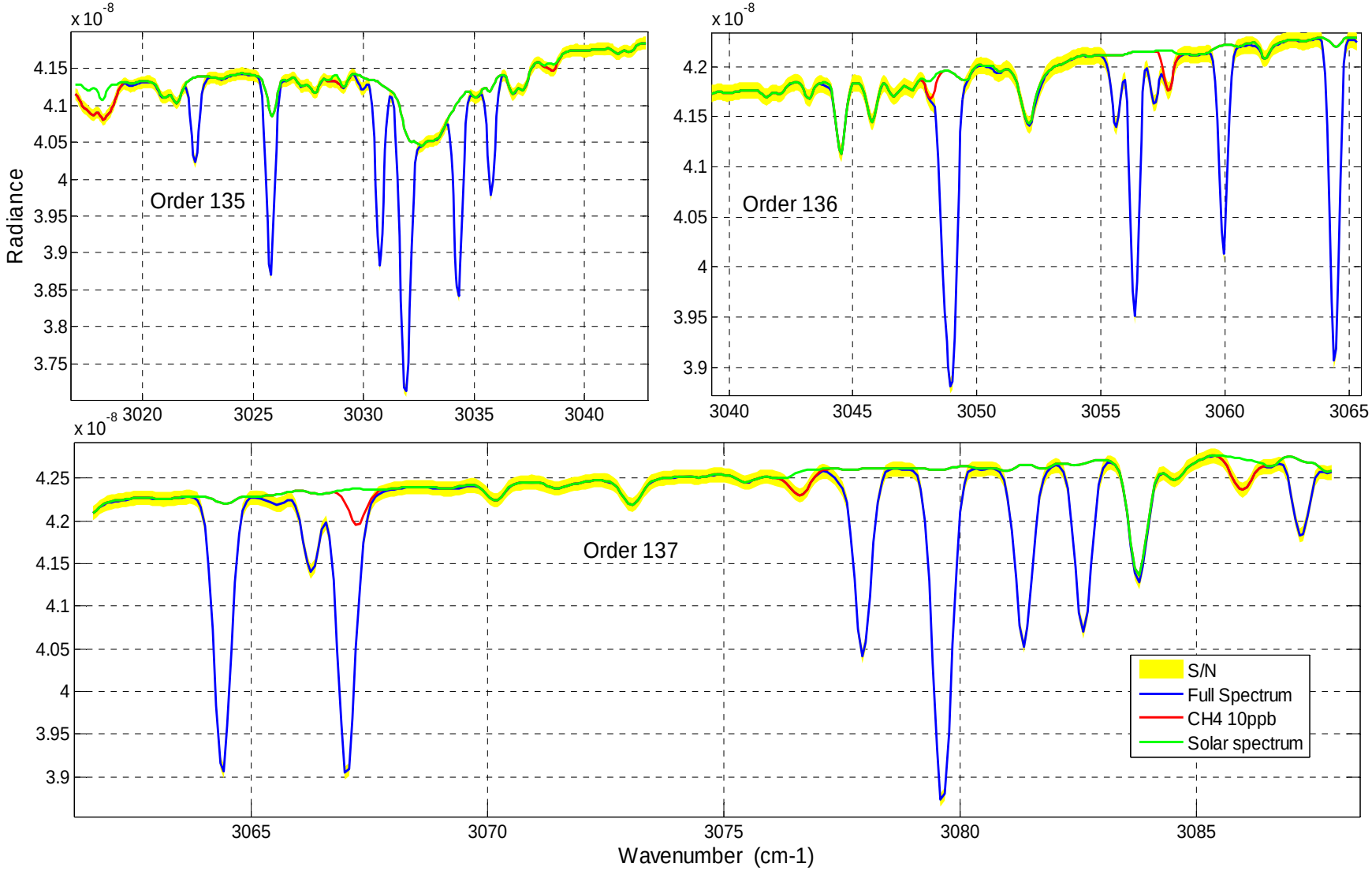
Ongoing Improvements

- Development of an AOTF with side lobe suppression
- New echelle grating using innovative aluminum processing techniques
- Integration of a new generation FPGA to act as interface between the spacecraft telecommand system and the SOIR instrument
- Faster transmission rate and higher data volume
- Optical redesign and signal optimization
- Study on cooling of the resized baseplate and other methods to increase SNR
- Overall increase of Technological Readiness Level (TRL) for future flight opportunities

Nadir simulations



Nadir observations (450 ppm H_2O)



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Conclusions

- SOIR is a spaceflight-proven, easy-to-accommodate instrument that has the full support of Belgian Science Policy
- The SOIR instrument has already proven its capability to monitor routinely key components of the Venus atmosphere
- In the atmosphere of Mars, SOIR could accurately measure CH_4 abundance down to sub-ppb level and retrieve the vertical profile; detect hydrocarbon species and measure the HDO/H_2O isotopic ratio from orbit
- SOIR is evolving towards a versatile version including NADIR. The mapping would be more efficient i.e. not restricted to solar occultation seasons

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