The Martian Dayglow

Comparing Mars Express SPICAM UV data with kinetic transport simulations

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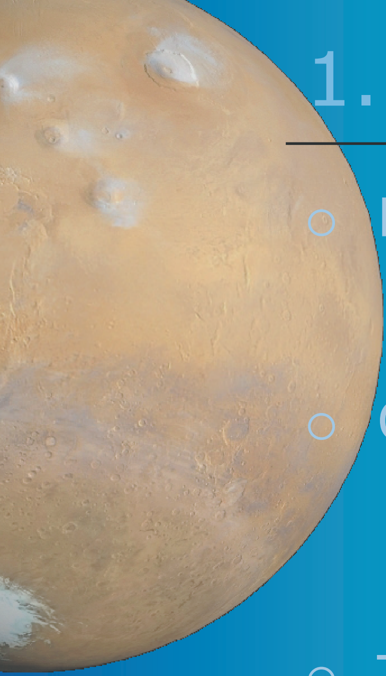
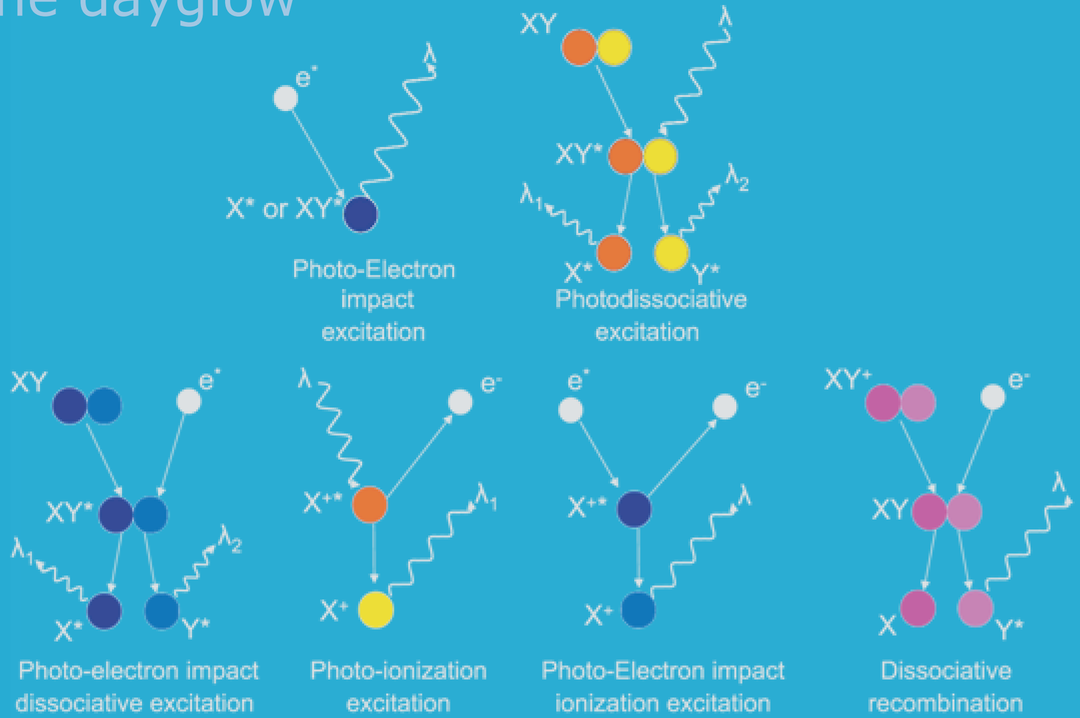
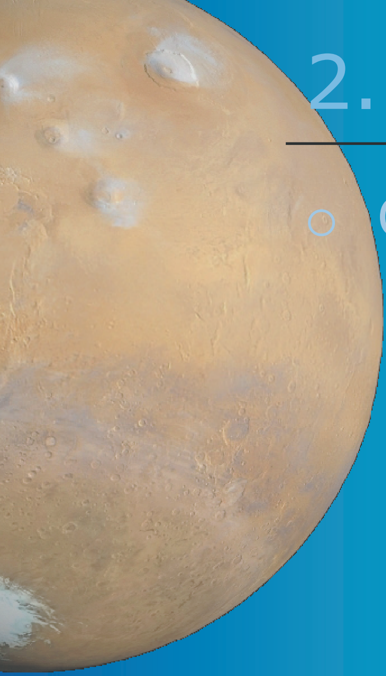


1. Mars' dayglow

- Dayglow
  - Atmospheric emission of excited states of molecules and atoms
- On Mars – processes of CO_2, CO and O with:
  - Photons
  - Electrons
  - Dissociative recombination
  - + resonant scattering
- Tools to study the dayglow
  - Observations
  - Modelling



Leblanc *et al.* (2006)

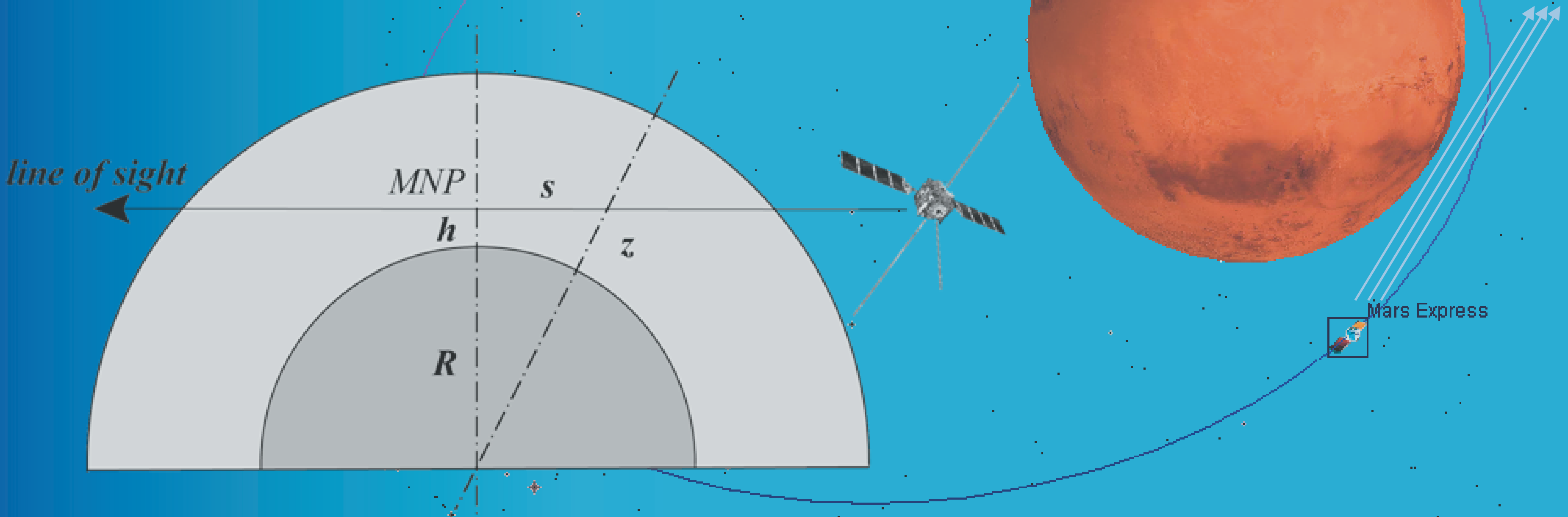


2. SPICAM Data analysis

- Observations of SPICAM in a limb configuration
  - Dayglow
  - For the modelling: photoionisation is dominant
  - Integration along the line of sight to get the intensity I in Rayleigh, altitude z by altitude z

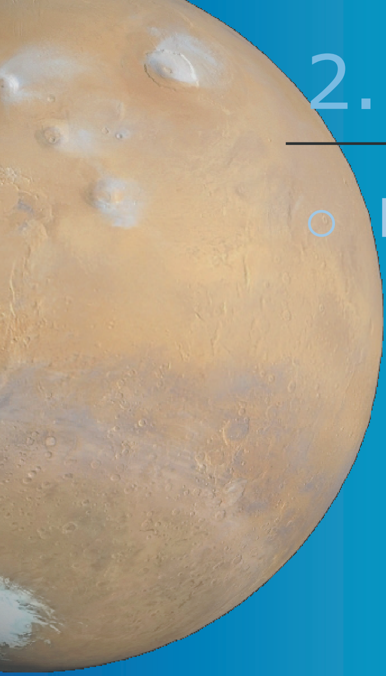
$$s^2 = (R + z)^2 - (R + h)^2$$

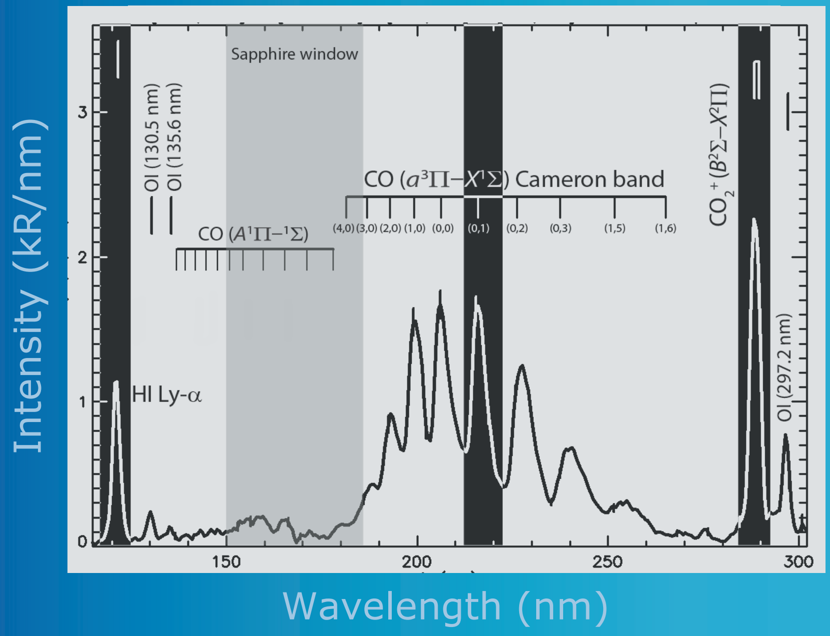
$$I = \int \eta(s)\, ds$$

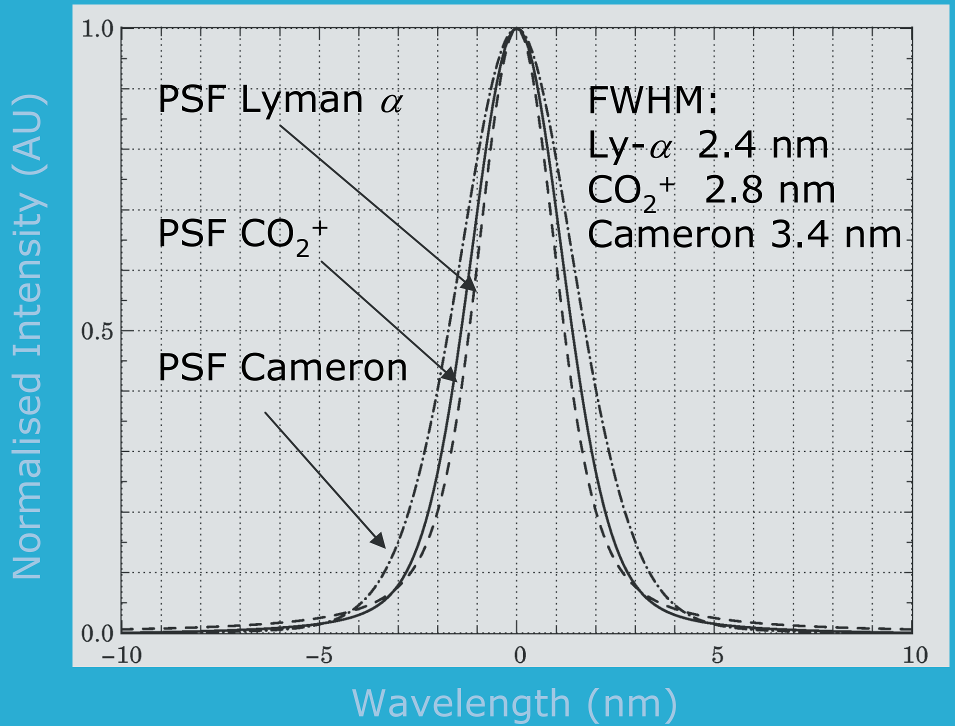


2. SPICAM Data analysis

- Retrieving line intensity altitude profiles
  - PSF determination
    - 3 PSF are now used to cover the full spectral range
    - Voigt fits on Cameron CO(0,1), Ly-α and CO_2^+ done on 150,000 dayglow spectra (90 orbits)
  - Convolution with an emission line model (Conway, 1981)
  - Integration of the fitted spectrum

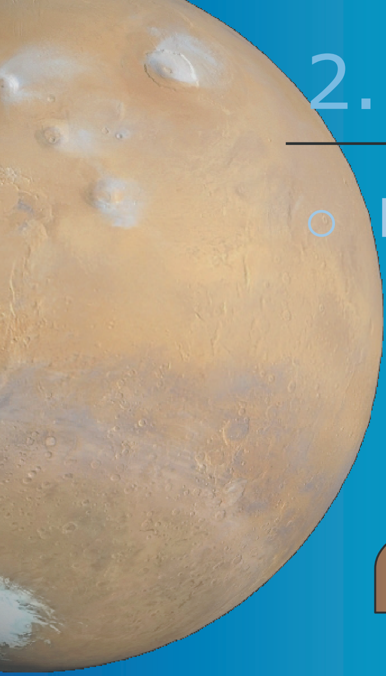


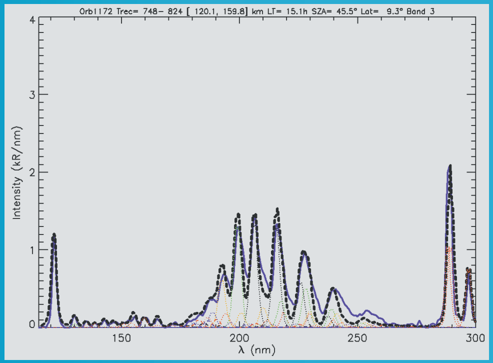




2. SPICAM Data analysis

Retrieving line intensity altitude profiles: summary

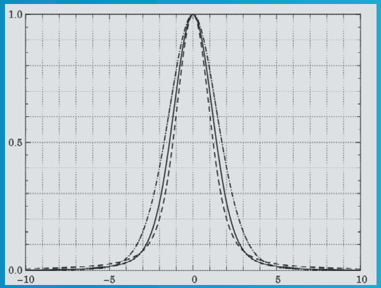




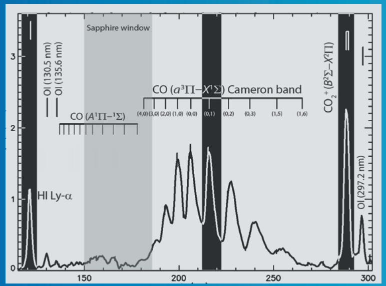
Building of a theoretical spectrum

Groups	Number of orbits	Orbits No.	# Spectra	$f_{10.7,Mars}$ ($f_{10.7,Earth}$)
Group 1	7	947-983	11484	33 (90)
Group 2	8	1234-1285, 1349-1371	18384	36 (88)
Group 3	6	2231-2342	11726	38 (80)
Group 4	11	1036, 1039, 1298, 1321, 1413, 1414, 1426, 2022, 2137, 2151, 2166	22664	~ 54 (125)
Group 5	2	2966, 2967	2636	30 (77)

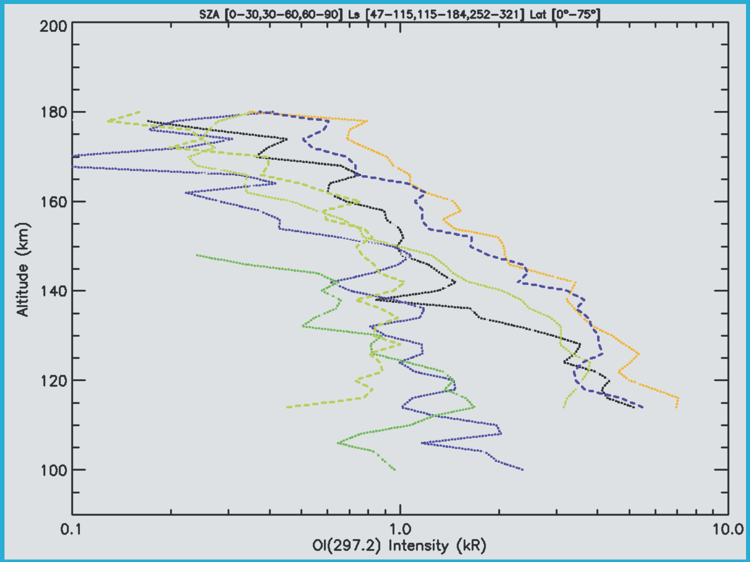
Binning of 70,000 spectra



PSF determination



Choice of emission lines



Altitude emission line profiles. Ex. OI297

3. Modelling Mars' airglow

- Physical summary: *Trans*-Mars
  - Evolution from TRANSCAR (Earth): Lilensten et al. (2002)
  - Coupled kinetic-fluid model

    Kinetic: suprathermal electrons

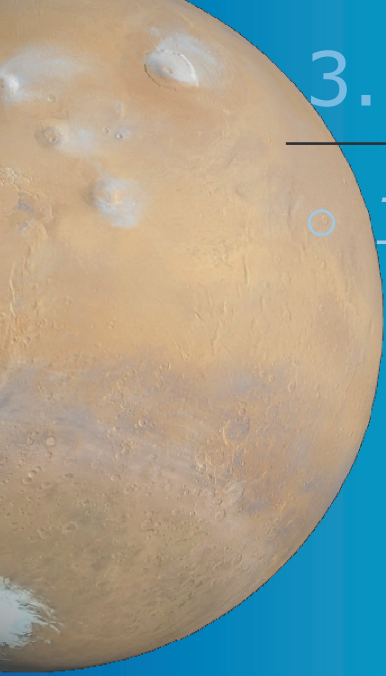
    Fluid: thermal ions and temperatures

    Airglow: CO Cameron and $CO(4^+)$, CO_2^+, OI(297.2), OI(135.6)

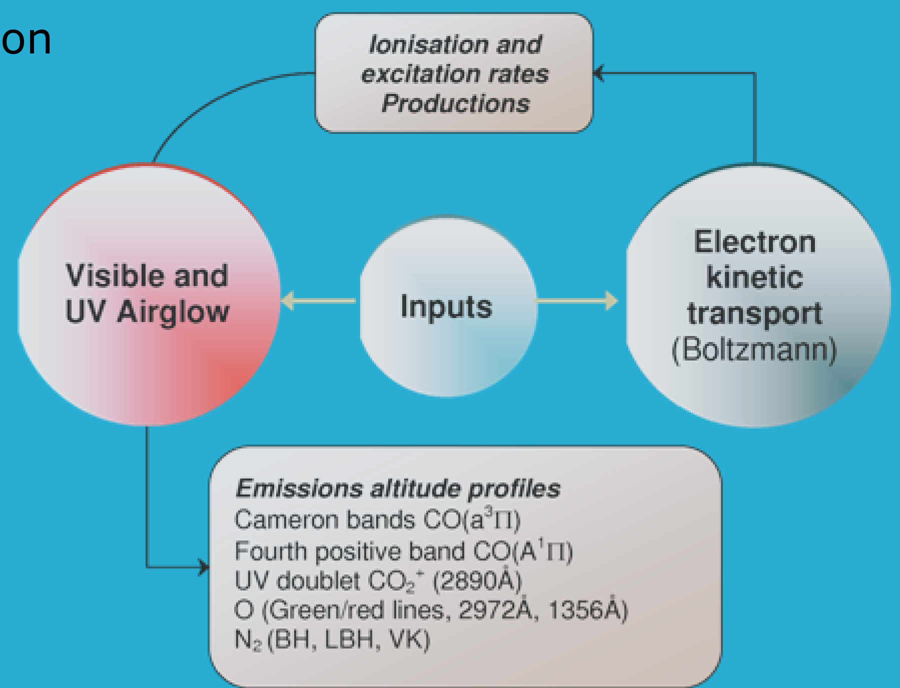
  → For the airglow, only the kinetic part is presented here

- Domain of validity
  - Dayside ionosphere of Mars but possibility of including electron precipitation
  - Altitudes: 80-500 km

3. Modelling Mars' airglow



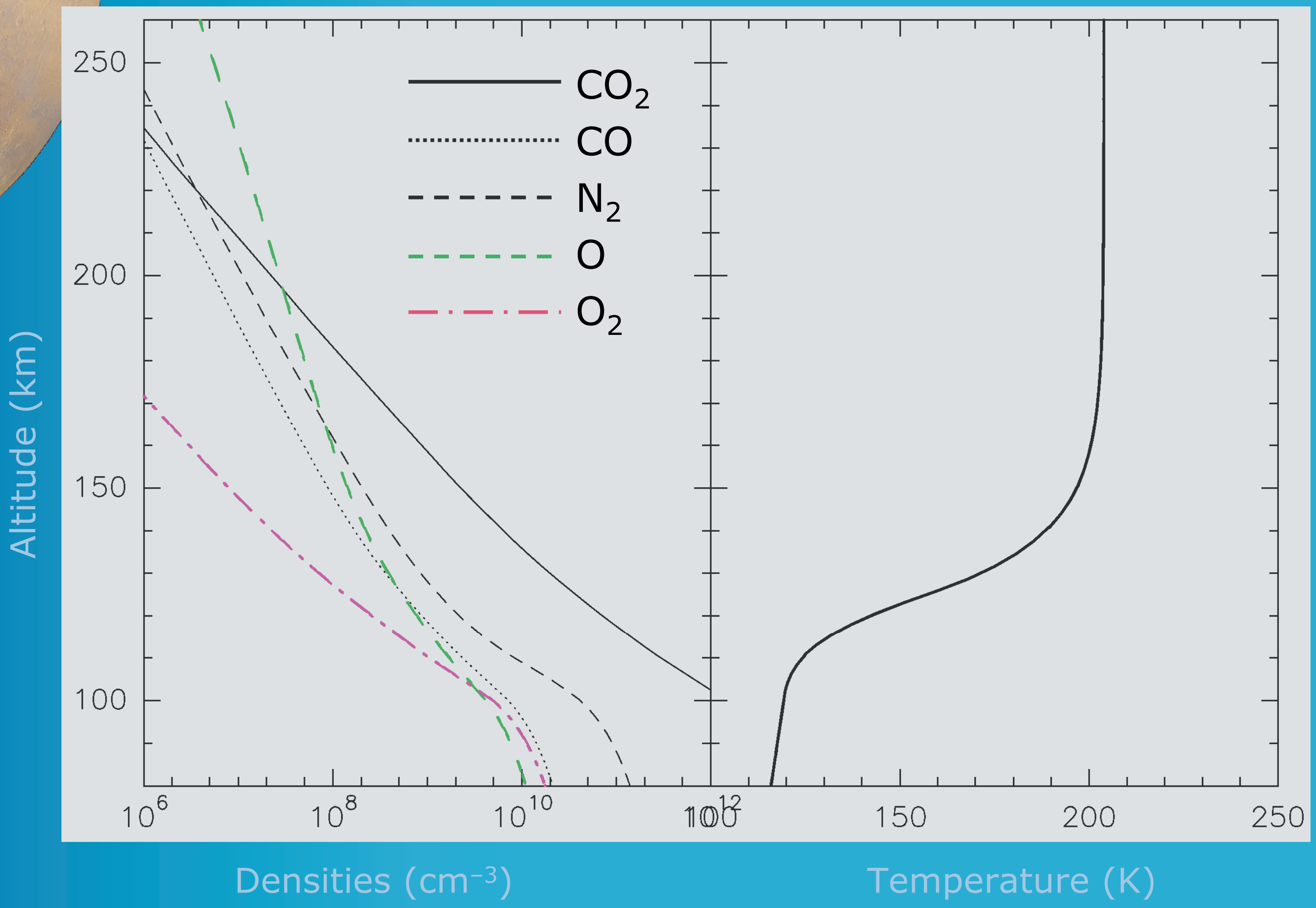
- *Trans*-Mars: Inputs of the model
  - EUV flux depending on solar proxies
    - EUVAC model (Richards et al., 1994)
  - Neutral atmosphere
    - Mars Thermosphere GCM (Bougher *et al.*, 1999) for Viking 1 and Mariner 6 conditions
  - Cross sections on CO_2, O_2, O
    - Photoionisation
    - Electron impact ionisation
  - Chemical reactions
    - Ion-neutral
    - Ion-ion

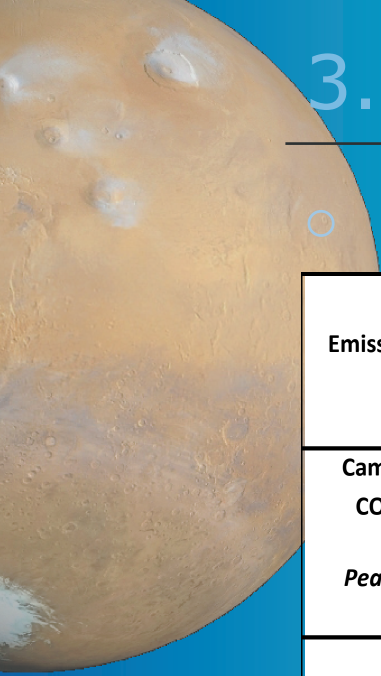


Earth: Lilensten and Blelly (2002)
Simon et al. (2007)
Venus: Gronoff et al. (2008)
Mars: Witasse (2000)
Simon et al. (2008)

3. Modelling Mars' airglow

- Neutral atmosphere
  - Viking conditions, $f_{10.7}$ = 70, χ = 45º, equatorial lat.



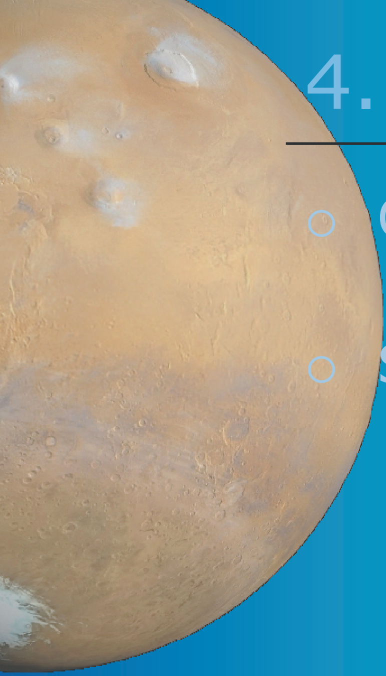


3. Modelling Mars' airglow

Uncertainties on the cross sections

Emission lines and bands	Production/emission process and related cross section references			
	$h\nu + CO_2$	$e + CO_2$	$e + CO$	*Dissociative Recombination of CO_2^+ or O_2^+*
Cameron bands $CO(a^3\Pi - X^1\Sigma)$ *Peak value and energy*	Lawrence (1972) 1.7×10^{-17} cm^2 @ 92 nm	*No recommended value* Avakyan (1998) 2.40×10^{-16} cm^2 @ 80 eV	Furlong & Newell (1996) *$E \leq 70$ eV* 1.89×10^{-16} cm^2 @ 9.7 eV	Fox & Sung (2002) Skrzypkowski *et al.* (1998) –
CO 4+ $(A^1\Pi - X^1\Sigma)$ *Peak value*	Gentieu & Mentall (1972) 3.2×10^{-18} cm^2 @ 90 nm	Ajello (1971) 1.30×10^{-18} cm^2 @ 30 eV	Beegle *et al.* (1999) 6.96×10^{-18} cm^2 @ 26 eV	Fox & Sung (2002) Tsuji *et al.* (1998) –
CO_2^+ UV doublet $(B^2\Sigma_u^+ - X^2\Pi_g)$ *Peak value*	Avakyan (1998) 7.28×10^{-18} cm^2 @ 52 nm	Itikawa (2002) 4.69×10^{-17} cm^2 @ 150 eV		
Green line $O(^1S)$ *Peak value*	Lawrence (1972) 2.5×10^{-17} cm^2 @ 100 nm	Itikawa (2002) LeClair & McConkey (1994) 1.69×10^{-17} cm^2 @ 50 eV		Kella *et al.* (1997) –

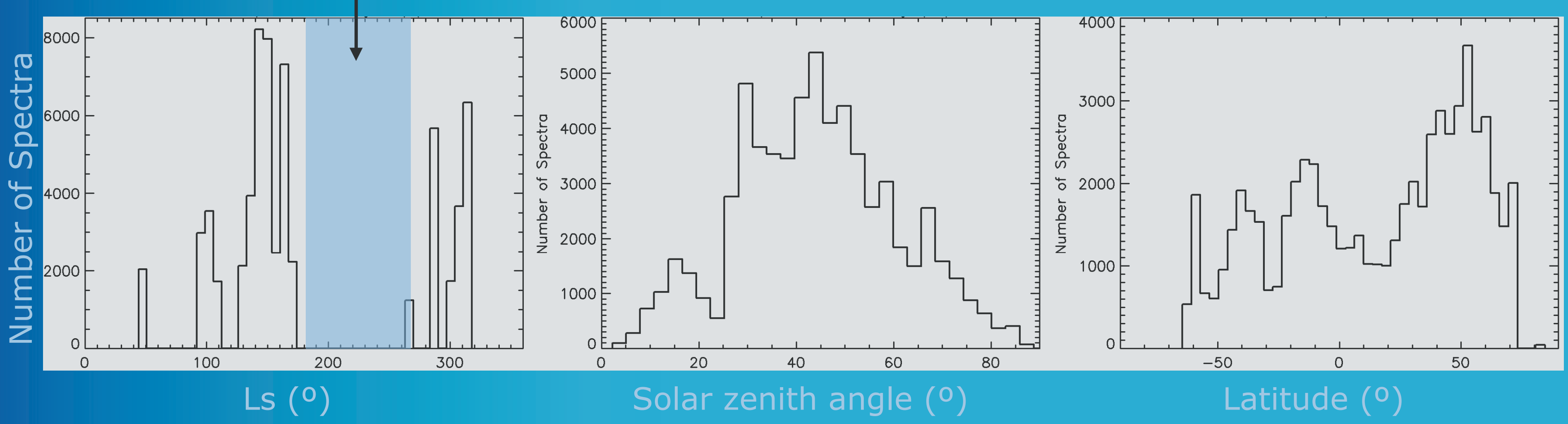
- Uncertainties > 75%
- Uncertainties > 25%
- Uncertainties < 25%



4. Results

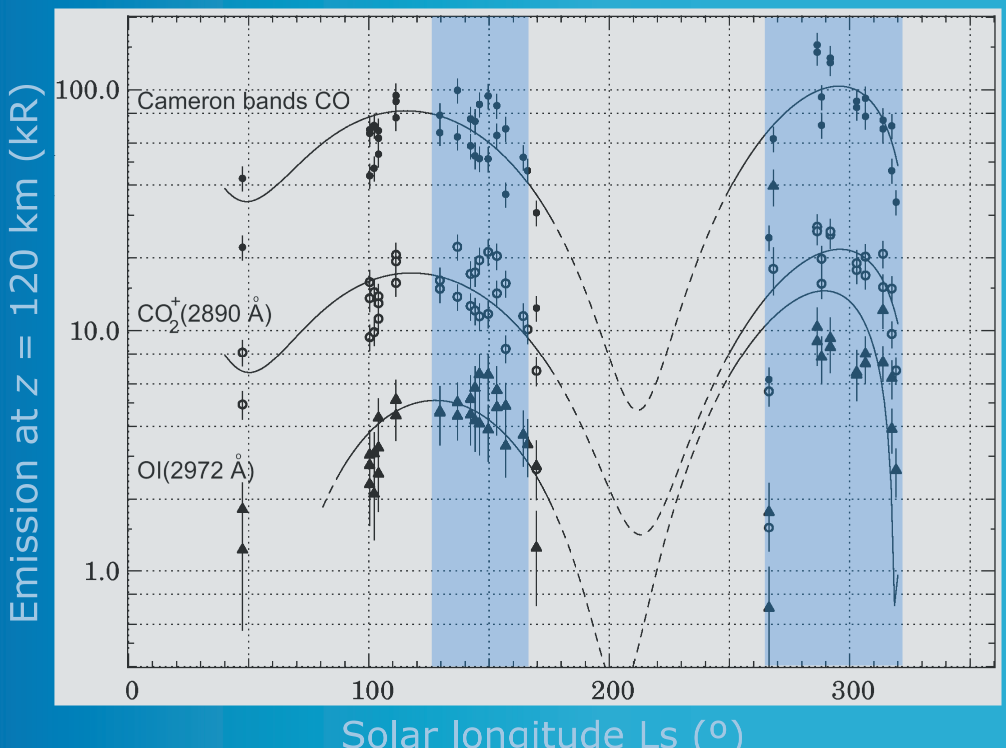
- Observations
  - 70,000 spectra, solar activity low to high
- Statistical distribution of the measurements
  - Solar longitude (Ls) distribution: gap Ls=180-260º
  - Solar zenith angles: very good coverage
  - Latitudes: good coverage

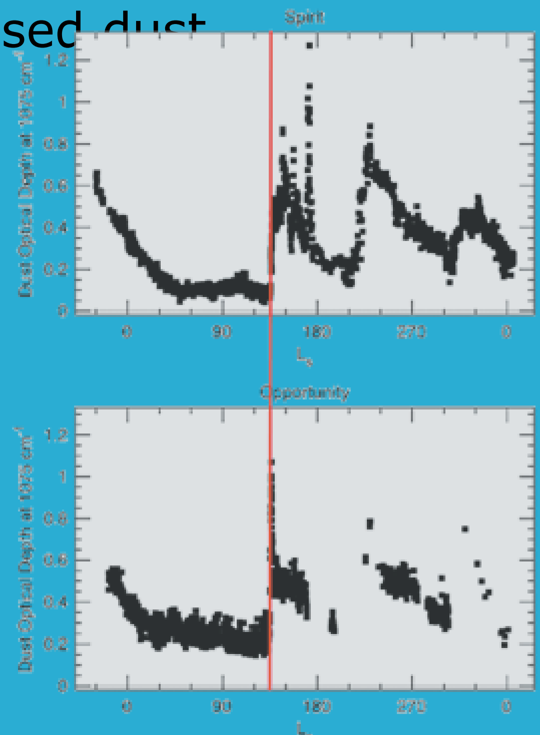
Gap in seasonal coverage Ls=180-260º



4. Results

- Statistical study
  - 37 orbits, ~ 70 000 spectra
- Seasonal variation
  - Cameron, CO_2^+, OI(2972Å) follow the neutral density variations measured by SPICAM (Forget et al., 2007)
  - Correlation at Ls = 140º with increased dust opacities → dust storm?



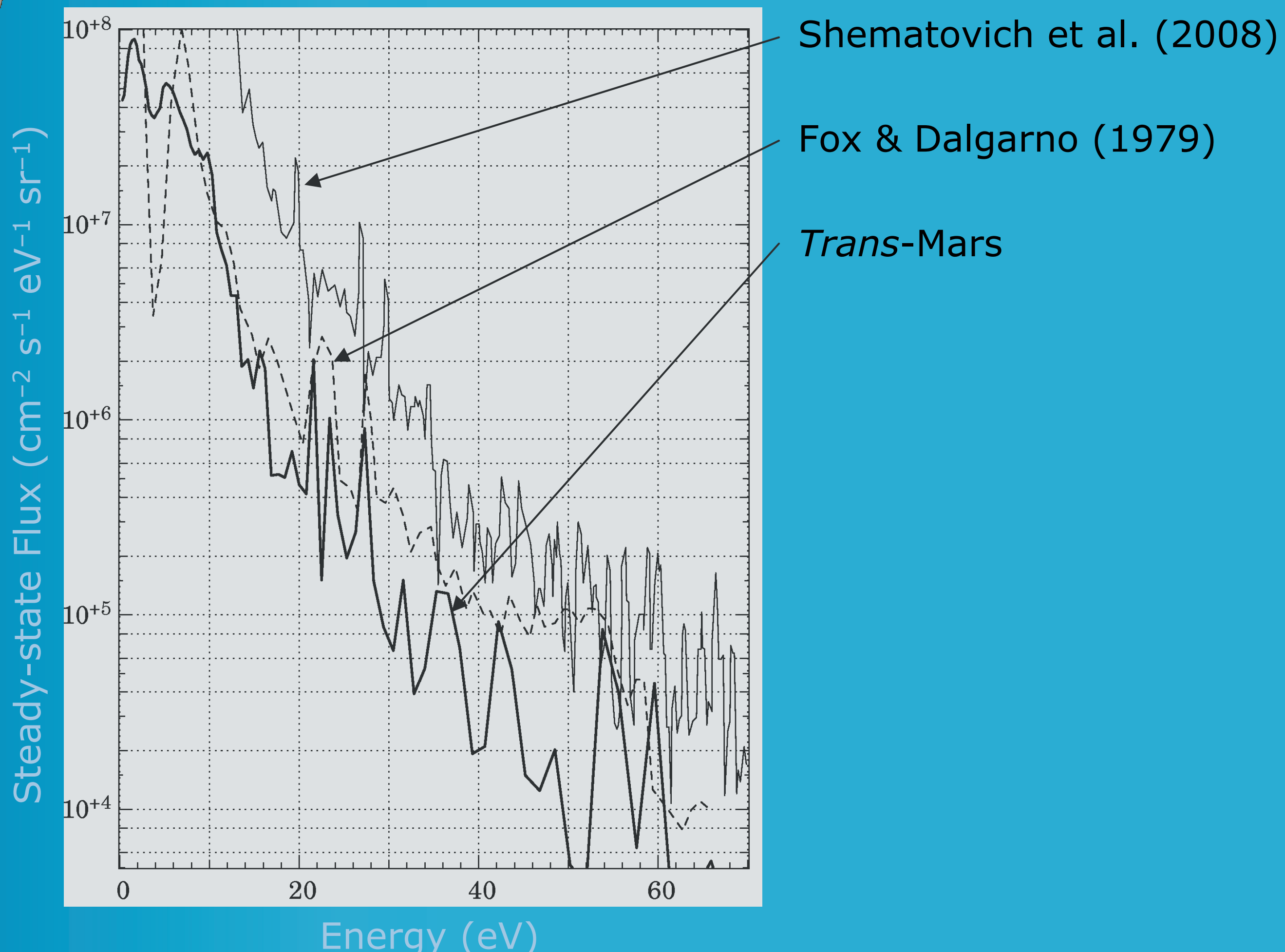


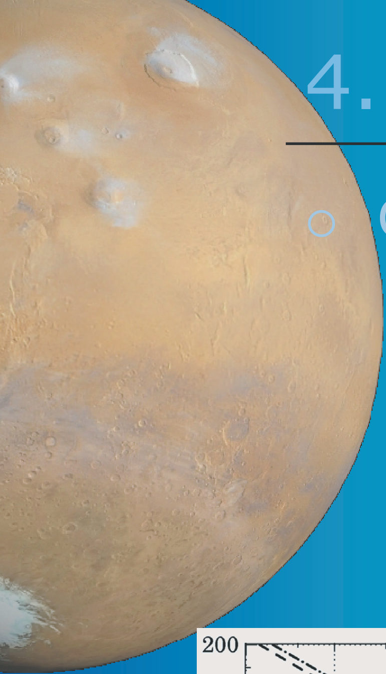
Smith et al. (2006)

Simon et al., submitted to PSS (2008)

4. Results

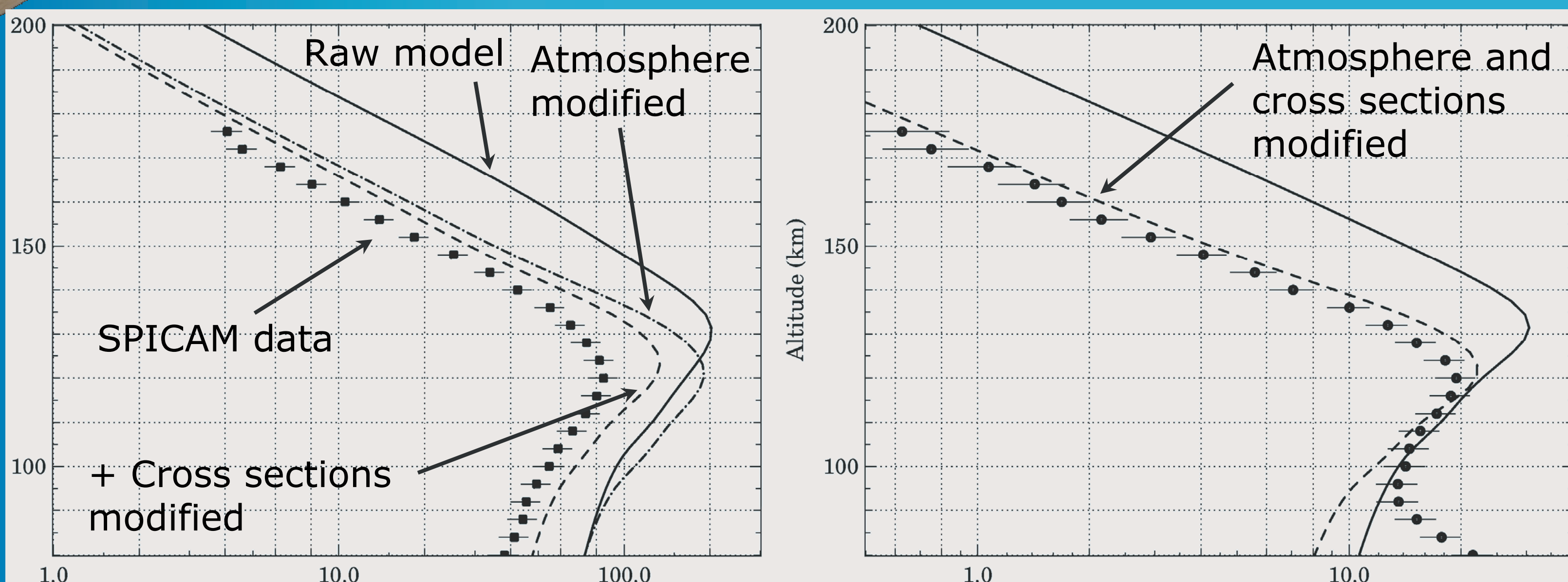
- Steady-state electron fluxes
  - Photoelectron downward fluxes produced at equilibrium for Viking conditions





4. Results

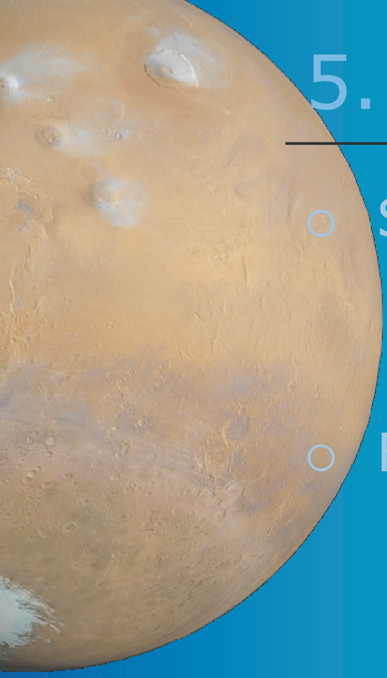
- Comparison with the model
  - Cameron bands of CO, CO_2^+(2890Å), OI(2972Å)
  - Neutral atmosphere (CO_2) divided by 3 with respect to Viking conditions (1976)
  - <u>Need to constrain the model's inputs</u>!



Altitude (km)

Intensity Cameron CO($a^3\Pi$) (kR)

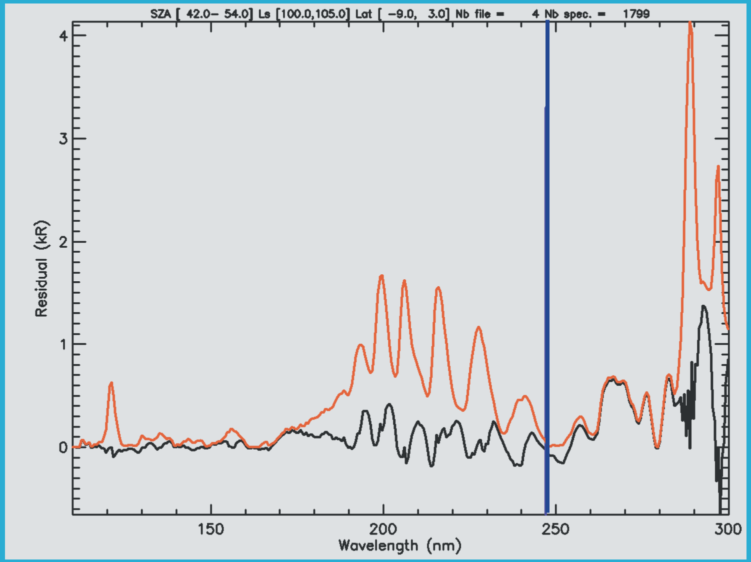
Intensity UV CO_2^+(B-X) (kR)

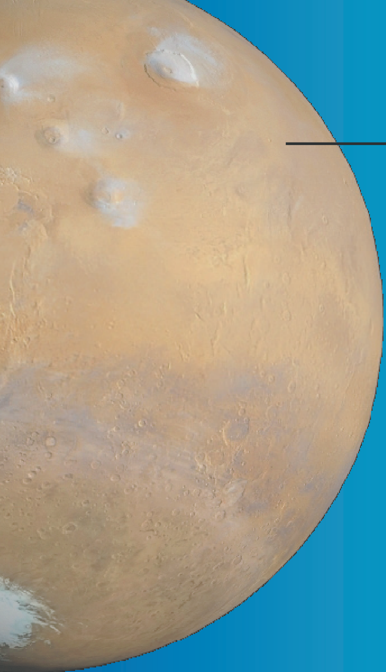


5. Perspectives

- Summary
  - SPICAM's PSF determined on the entire spectral range
  - Variation of the neutral atmosphere up to factor of 3
- Future perspectives
  - Analysis
    - Building of a new synthetic model for the Cameron band system: determination of the relative vibrational populations
    - Subtraction of the Cameron spectrum to access underlying emissions such as O^+ (247 nm)

- Modelling
  - On-going extension to the nightside and the auroral features (Leblanc et al., 2008)
  - Multi-instrument observations of aurorae: radar MARSIS (TEC and electron profiles) coupled with ASPERA (electron fluxes) // SPICAM





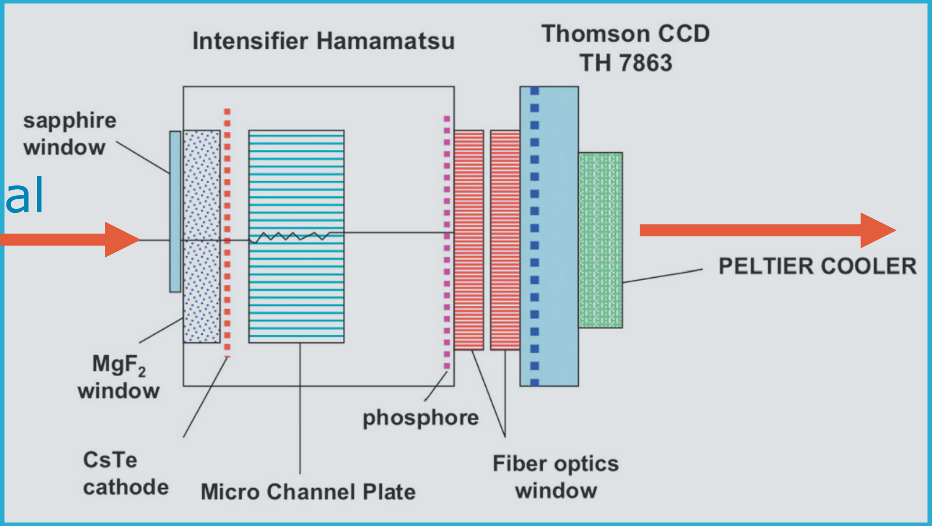
2. SPICAM Data analysis

- The instrument SPICAM onboard MEX:
  - CCD Spectrometer
    - UV channel 118-320 *nm,* 1.5 to 6 *nm* resolution
    - IR channel 1.1-1.7 μm

near IR

UV

Signal



From Bertaux et al., 2006

4. Results

- Data analysis: seasonal variation