Mars photometry with OMEGA observations

S. Erard, P. Pinet, Y. Daydou, P. Drossart, R. Melchiorri,
Th. Fouchet, O. Forni, G. Bellucci, F. Altieri, J.-P. Bibring, Y. Langevin
and the OMEGA team

Spectral variations in OMEGA data set

- Compositional variations
- Albedo variations

\+ Variations related to:

viewing geometry <= surface physical properties
aerosols scattering <= aerosols density,
composition,
size distribution
surface temperature <= emissivity vs reflectance

Spectral variations in OMEGA data set

Variability is explored through signal modeling in a number of situations

Expected outcome:

- Signal prediction for observations
- Understanding the crucial parameters
- Defining a valid range for these parameters
- Deriving physical information

Mars spectral modeling

Computes:

I/F = f(Ls, local time, location, viewing geometry, surface tilt)

Based on previous simulations (Erard 2001, GRL), improved

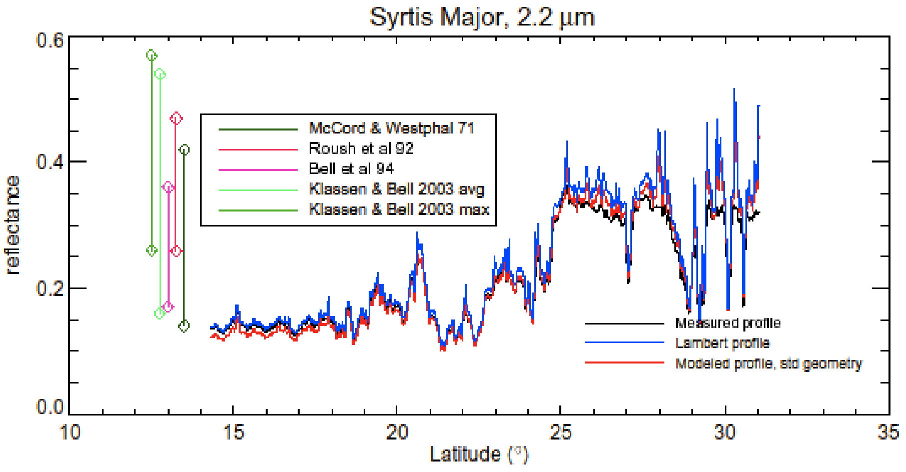
Uses new reference data:

- Complete interface to European Mars Climate Database
  (v. 3.1, MGS scenario - Lewis et al 2001)
  => T, P = f(L_s, local time, Long, Lat, z)
- Interface to TES albedo map
  => surface albedo / spectral type in a 1° box
- Absolute solar spectrum (from Colina et al 1996 + Kurutz 1997)
- Sun distance and L_s (from Allison & McEwen 2000)

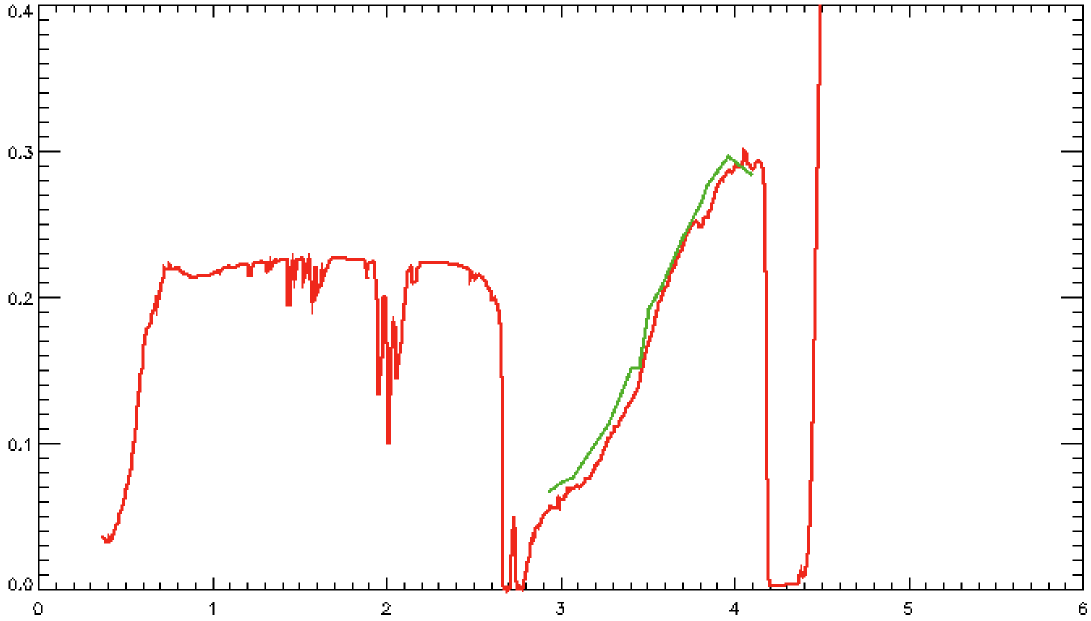
Model output

1) Spectra (here compared with Klassen & Bell 2003, IRTF)
2) Monochromatic profiles (modeling of OMEGA session)

Syrtis Major
Dark regions



Arabia Terra φ = 9.3°, e = 25°, i = 34°
Ls = 53°



Mars spectral modeling - arguments

Prime arguments:

Ls
local time
longitude / latitude
viewing geometry (e, i, φ)

From Ω observations
(Spice routines)

Optional:

surface orientation (i, e)

included in the Ω data base
(computed from MOLA)

Surface pressure
Opacity
Surface reflectance

Default values from GCM + TES,
can be changed

Mars spectral modeling - surface

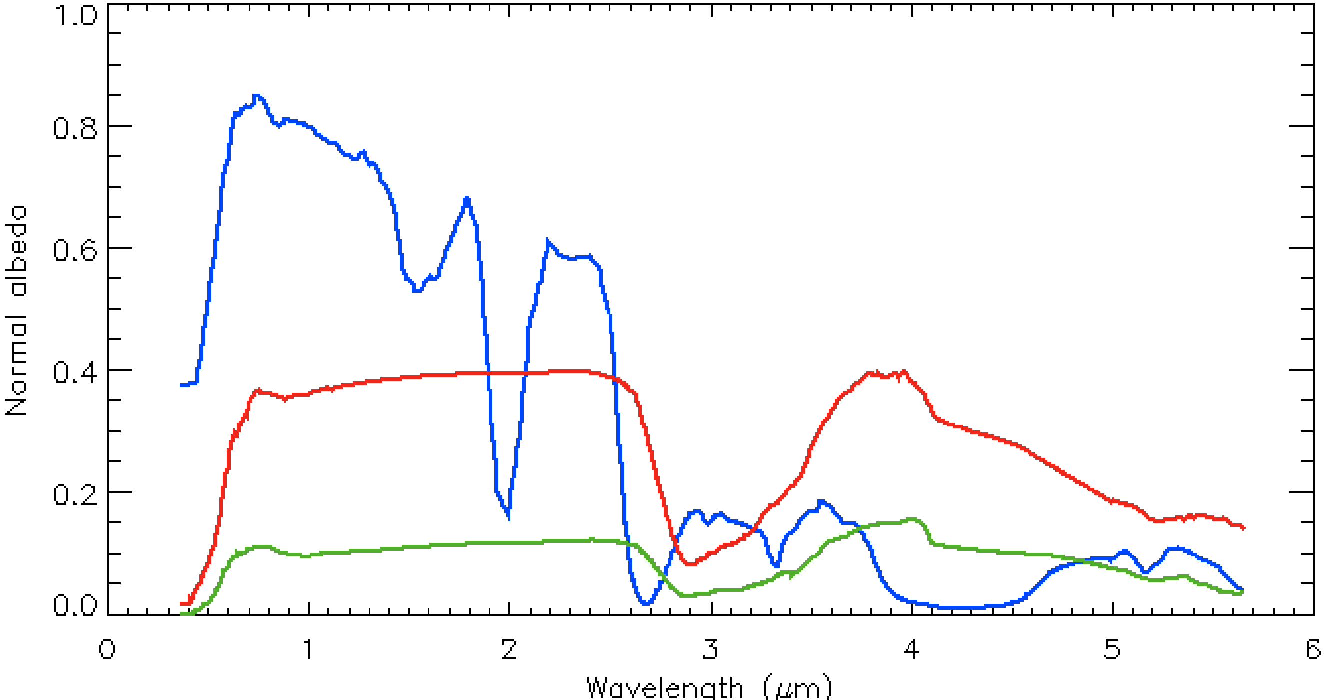
Surface reflectance: linear combinations of 3 spectral types

0.3-5.7 µm composites (modified from Erard & Calvin 1997)

Bright & dark soils from thermal modeling of IRS at longer λ

(derived under Lambertian assumption)

Polar caps spectra poorly known before OMEGA



⇒ Check absolute levels

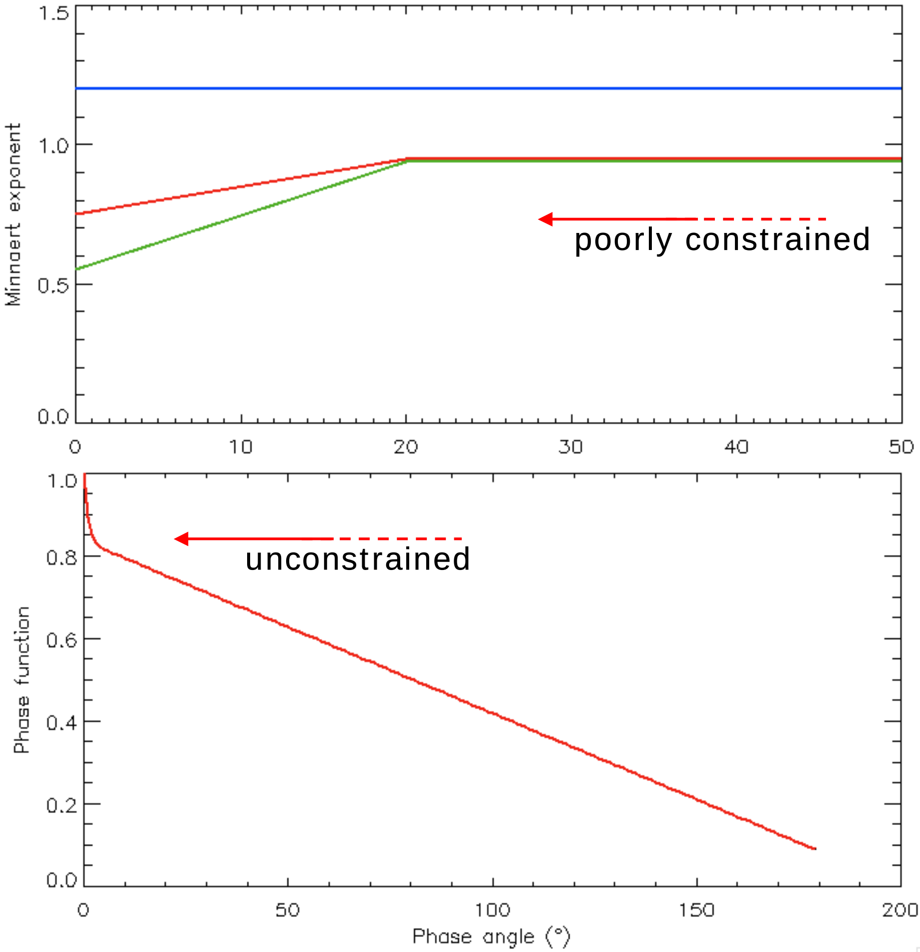
⇒ Check cap spectrum

Mars spectral modeling - surface

Surface photometry
1) Minnaert + phase function

Minnaert exponent from a synthesis of observations:
Binder & Jones, 1972, Thorpe 1973,
Pleskot & Kieffer 1977,
de Grenier & Pinet 1995, Erard 2000

Phase function from ISM bright regions (Kirkland et al 1997)
+ other solutions (Heynyey-Greenstein)
No spectral dependency
Pb: Minnaert breaks down at phase > 60°



Mars spectral modeling - surface

Surface photometry
2) Hapke model

Parameters from visible measurements:
Arvidson et al 1989 (Viking lander red filter)
Johnson et al 1999 (Pathfinder bright soils)

w = 0.7 Θ =5°
(but isotropic particles)

=> 5 parameters per surface type
No observational constraint on dark regions

Mars spectral modeling - atmosphere

Model atmosphere

Very simple modeling, but not required to be very accurate here.
Two options:

1) 6 mbar CO_2 (downsampled from MODTRAN band model)
   \+ simple log scaling with path length
2) OMEGA a posteriori simulations (Melchiorri et al 2004)

- Exact geometrical path length computed for high angles
  <= Neglects refraction

- Rayleigh scattering added
- Atmospheric emission added (single isothermal layer)

Mars spectral modeling - aerosols

Aerosols scattering / emission

Used mainly for continuum shape (spectral slope):

- Decoupled from gaseous absorption, single scattering

- Q_{back}, Q_{ext} and phase function from Mie theory:
  ~ neutral dust (mineralogical) n = 1.55 k = 0.01
  Modified-gamma size distribution (Drossart et al 1991)

- Scaled with opacity from GCM [f(L_s, Lat, Pressure)]

- Backscattered and emitted light added to surface reflectance, filtered by upper atmospheric layers => reasonable approximation at low phase / i, e angles

Mars spectral modeling - assessment

Validity domain:

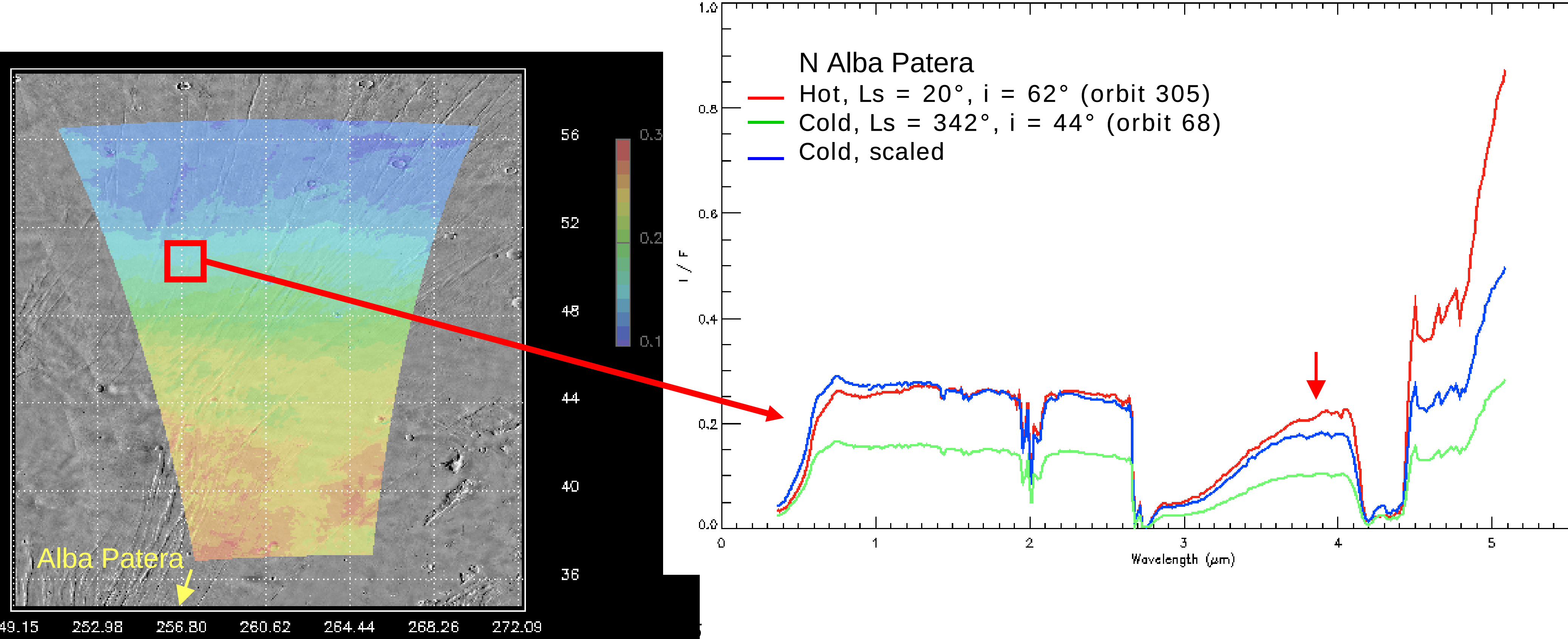
- 0.3-3 µm range
- Moderate phases (<30°) / near-normal geometry (<40°)

What needs to be better constrained:

- Surface reflectance at long wavelengths
- Surface phase function at large phase
- Aerosol phase function at large phase
- Aerosol scattering at large angles / large opacity

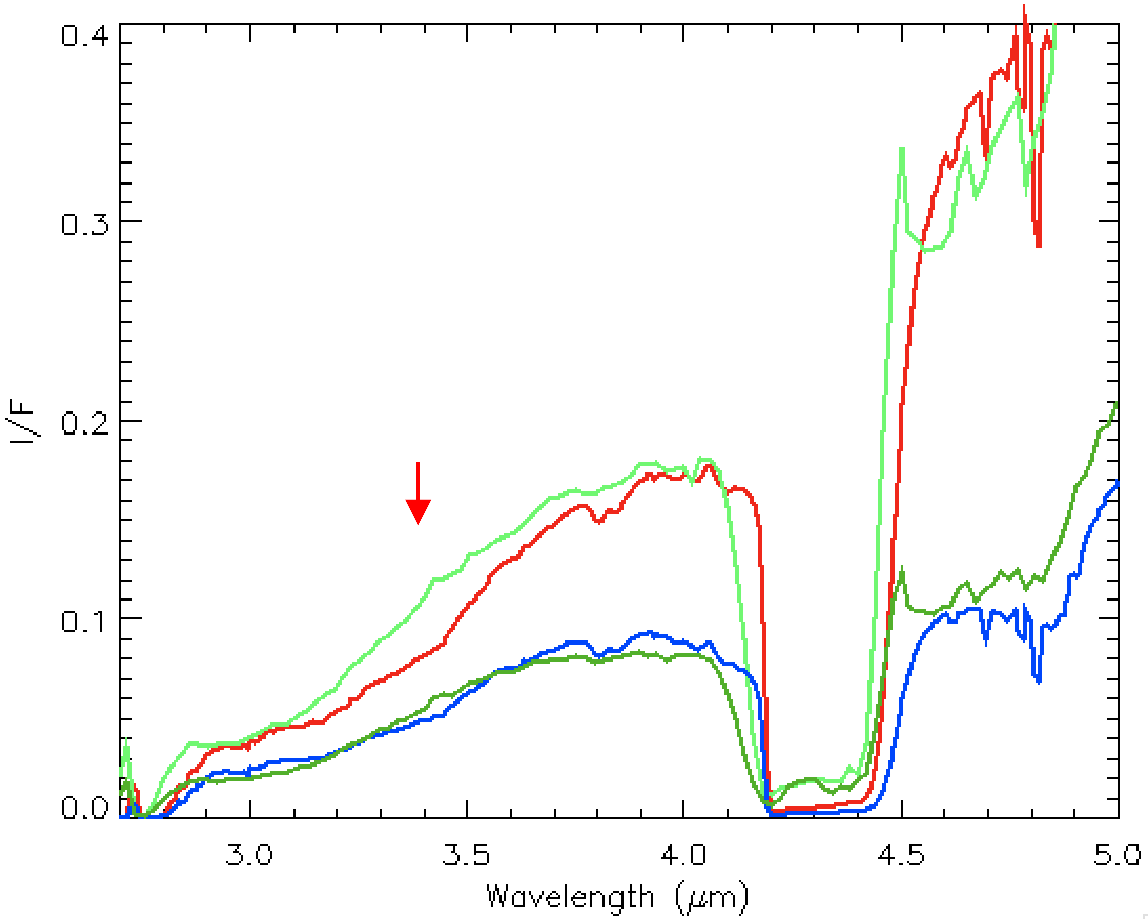
Reflectance at longer wavelengths

OMEGA: allows observation of reflectance at long wavelength
Cold terrains (winter, early morning): low thermal contribution



Reflectance at longer wavelengths

Observations vs simulations



~ correct fit of level and shape

⇒ reflectance estimates ~OK at long wavelengths ? (slightly overestimated 3.2-3.6 µm range?)

Angular variations

Pb: Surface photometry & aerosols scattering always express together (at least in the 0.7-2.7 μm range)

Methods:

- EPF sequences
  Pb: very limited coverage with OMEGA so far
- Observations of same areas under different opacities
- Observations of same areas under different geometries
  - Overlapping observations
    (e.g. presentation by Baratoux yesterday with HRSC)
  - Several instruments
    Pb: Amplifies remaining calibration issues

OMEGA EPFS

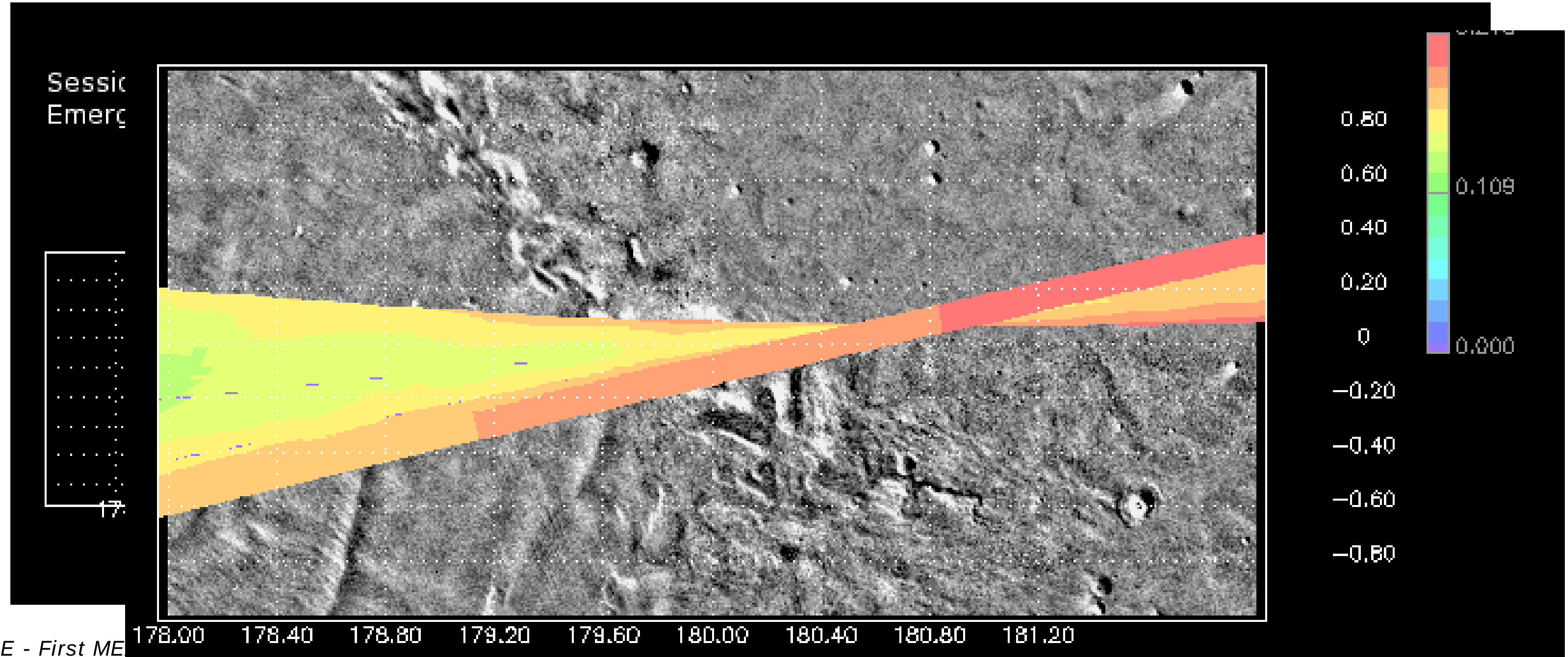
Bright uniform region (Lucus Planum, lat= 0°, long ~ 180°)

Scaled TES albedo (1 μm) = 0.31 - 0.34

Ls = 58.8° (approaching aphelion) => low expected opacity ~0.19 in visible

Morning (7:50) — 30 min acquisition => possible dissipating fogs

see poster by Pinet et al.



OMEGA EPFS

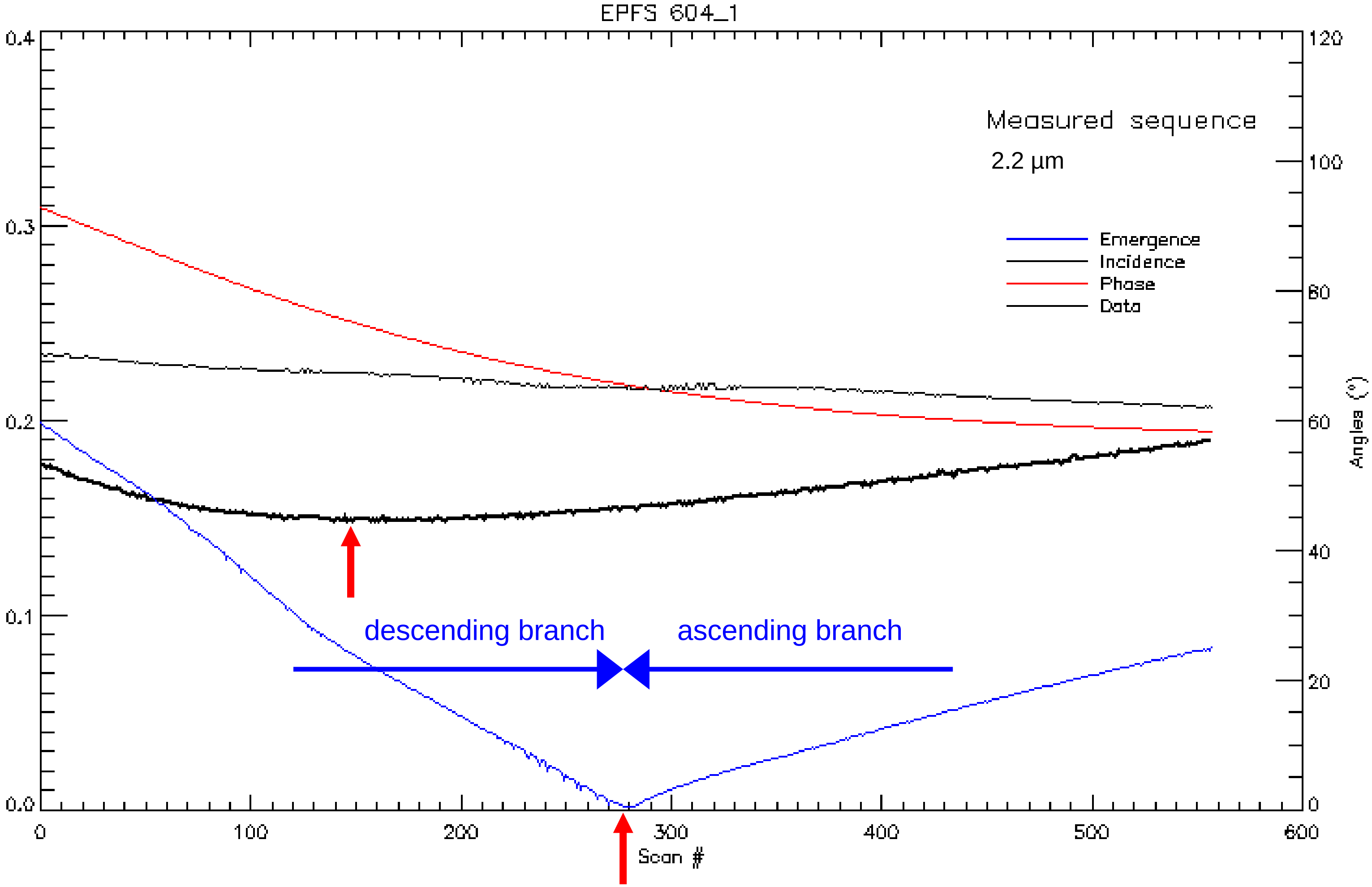
Properties:

Large variations in e (60°-0°-25°)

Slow decrease in incidence (70-62°)

Large phase angles (58°-93°)

- Lower level does not correspond anything special



EPFS fit: surface model

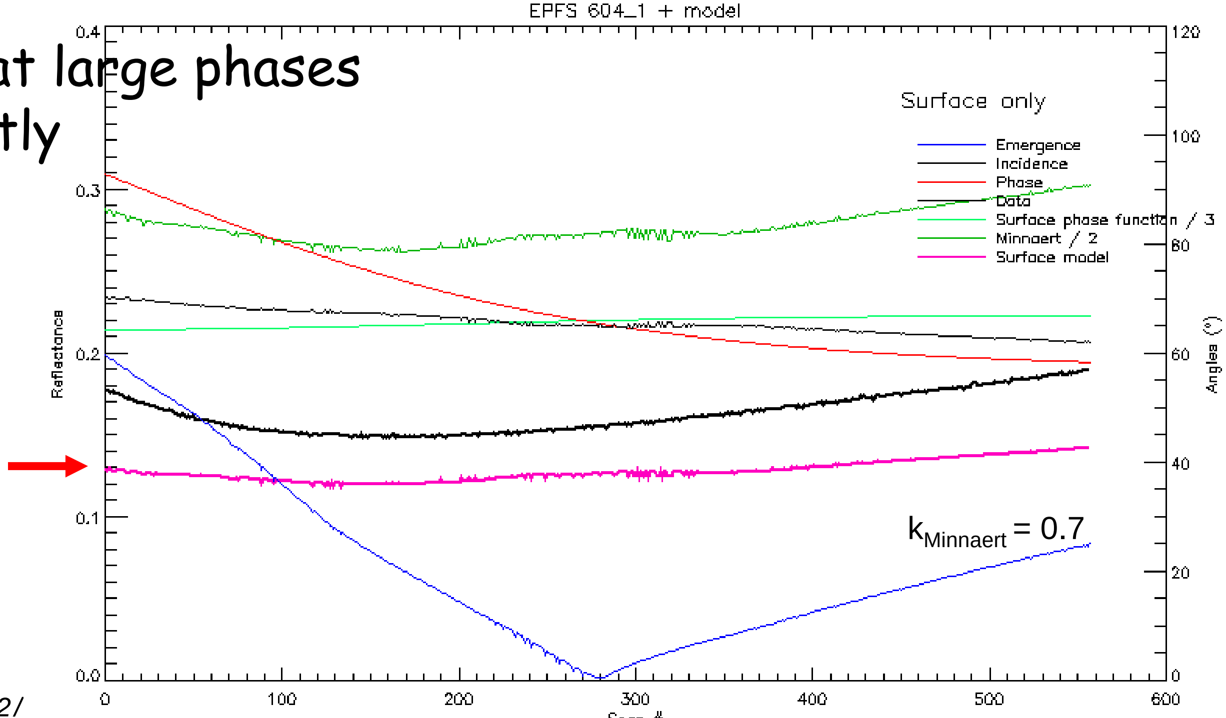
Best fit: $R_{surf} = P_N * \mu_0^k / \mu^{(1-k)} * f(\varphi)$ (Minnaert + phase fct)

Minnaert k=0.7 (value at low phase) + less steep phase function

1) Angular variations ~ follow measurements

2) Measured signal = 1.3 x surface model

- Not Lambertian
- Brighter than expected at large phases
- Visible behaves differently



EPFS fit: aerosols scattering

Previous surface model + Mie scattering

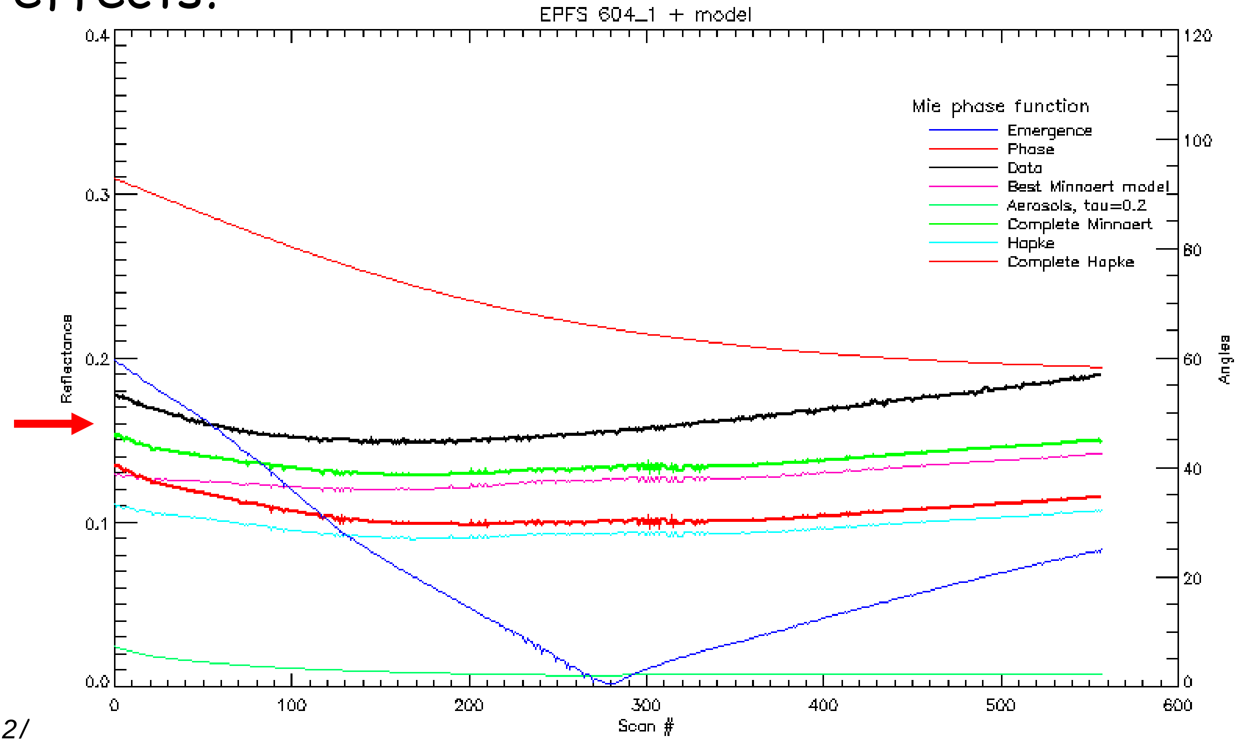
1) ±Correct angular shape in the NIR

Mie phase function too steep - Overestimated at large phases?

Color effects? => Non-spherical particles

2) opacity ~ 0.2 does not brightens spectra

=> Multiple scattering effects?

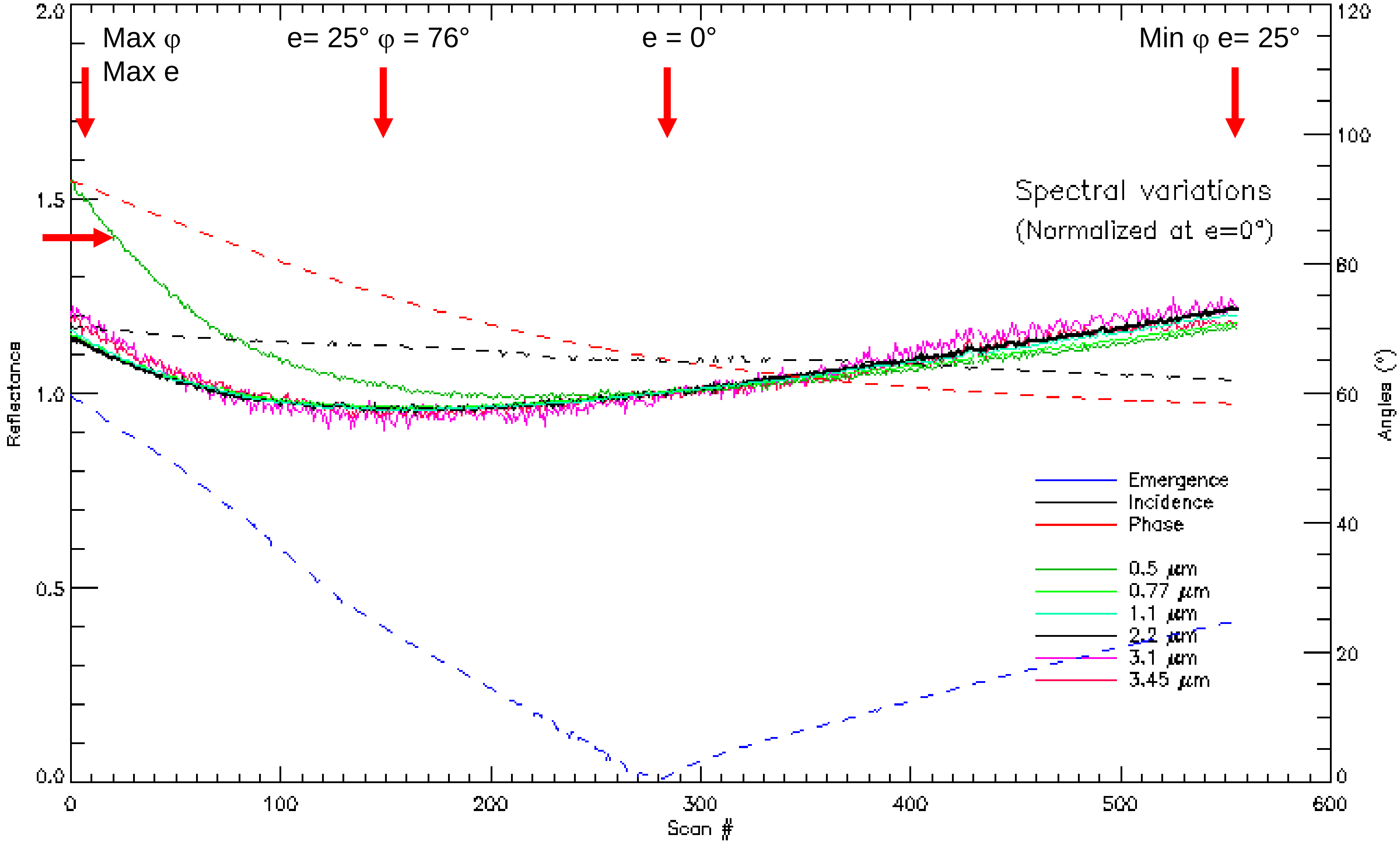


OMEGA EPFS - Spectral variations

Very homogeneous in the NIR (0.7-2.5 µm)

Larger NIR difference occurs at lower phases

Stronger dependency on e or φ in the visible



Aerosols composition?

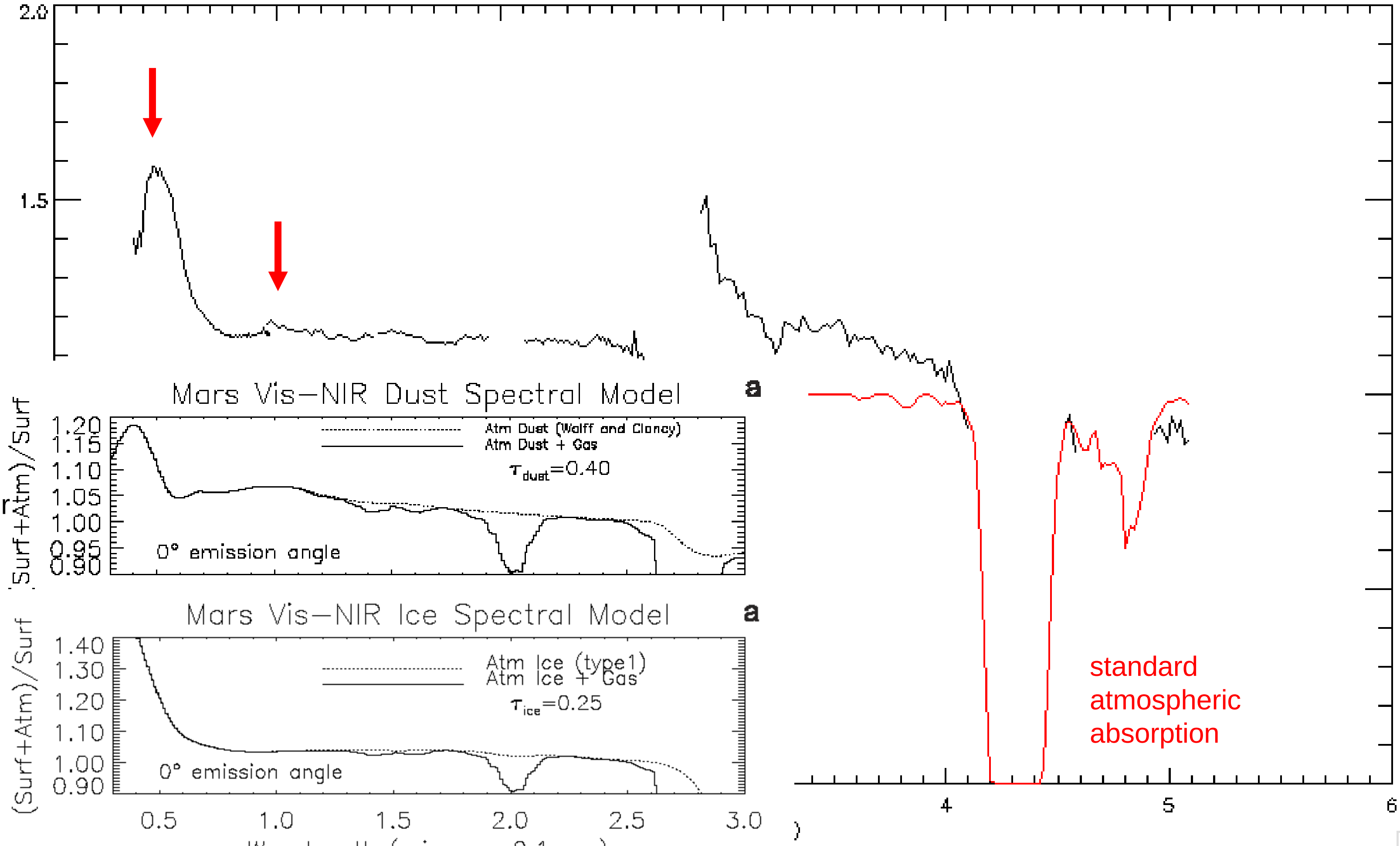
Ratios are similar to Wolfe & Clancy 2003 dust model (not ice)

Broad maximum at ~1 µm associated with 1.5 µm mean particle size

Ratio of
maximum e and φ / e = 0°

Wolfe & Clancy 2003
dust model (palagonite over bright region)

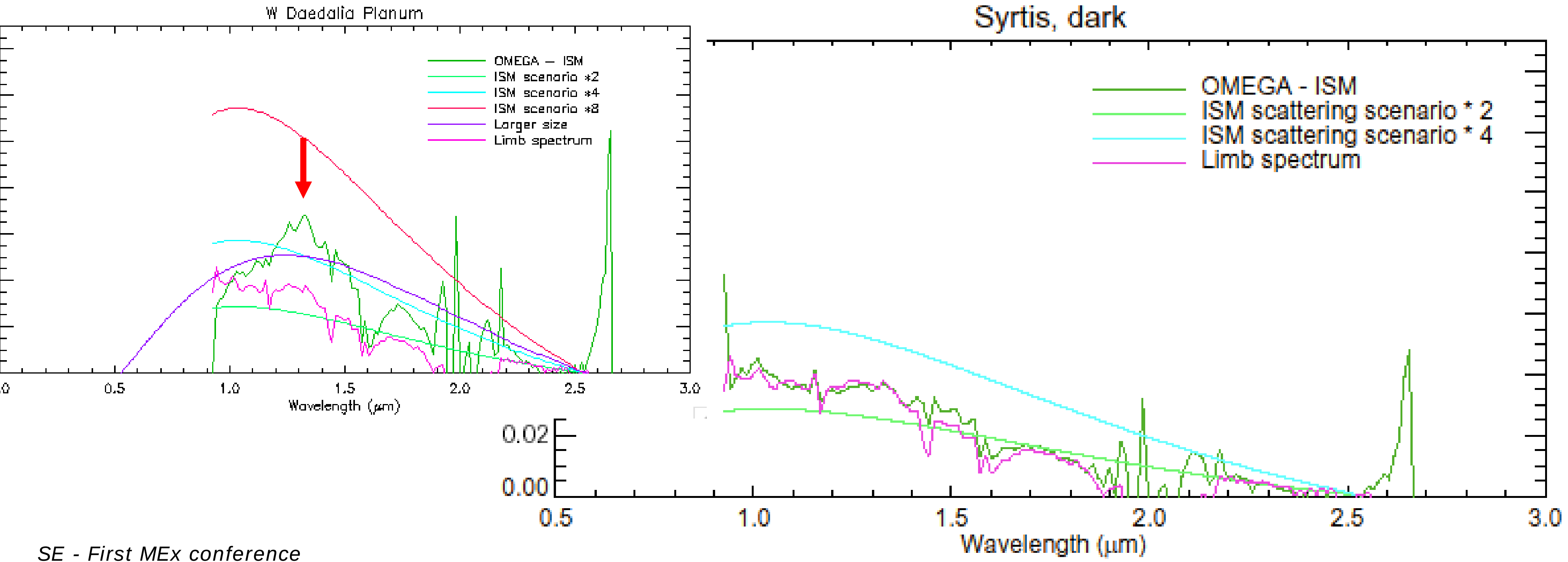
Wolfe & Clancy 2003
ice model



Scattered spectrum

OMEGA-ISM in similar areas + Limb spectra

- Level fit with reasonable opacity ($\tau \sim 0.3$-0.5)
- Occasional maximum at 1.3 μm fit by slightly larger (30%) effective radius



Conclusions

What can be improved from OMEGA analysis:

- Surface phase function at large phases
- Surface phase function in the visible

- Mie phase function for scattering (level, spectral dependency)
- Variations in aerosol size?

Prospects

- More accurate atmospheric/scattering modeling required, in particular at large phase angles
  (e.g. Blecka 2002, Blecka & Erard 2004)

- Systematic study of cold areas to assess surface reflectance in the 3-5 μm range

- More systematic study of aerosol scattering at large phase