INVESTIGATIONS OF THE MARTIAN NEUTRAL ATMOSPHERE DURING THE POLAR NIGHT AND IN THE EARLY MORNING WITH THE MARS EXPRESS RADIO SCIENCE EXPERIMENT MaRS.

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Introduction:

The Radio Science experiment MaRS on Mars Express is sounding the Martian ionosphere and neutral atmosphere in Earth occultation geometry.

Experiment description: MaRS observes the phase, amplitude, polarisation and propagation times of radio signals transmitted from the spacecraft and received on Earth. The signals are affected by the propagation through dispersive media (atmospheres, ionospheres, interplanetary medium, solar corona), by the gravitational influences of the planets and by the relative motion of spacecraft, Earth and Mars resulting in the Doppler shift of the carrier frequency.

A simultaneous and coherent dual-frequency downlink at X-band (8.4 MHz) and S-band (2.3 MHz) via the Spacecraft's High Gain Antenna (HGA) is required to separate effects from the dispersive media from the classical Doppler shift (s. Fig. 1).

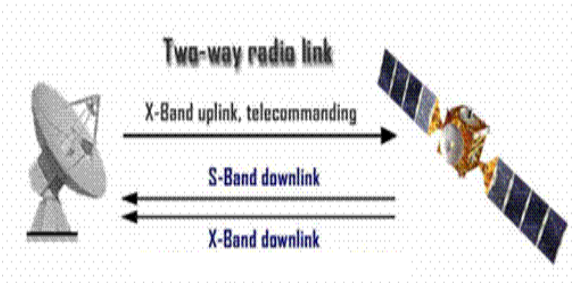

Fig. 1: Two-way radio link used by MaRS

Different measurement geometries allow to investigate the gravitional field of Mars, the dielectric properties of the surface and the atmosphere and ionosphere of the planet. Ionospheric electron density profiles between 80 km and 400 km and neutral atmosphere profiles in the altitude range from the surface to about 50 km can be retrieved.

Sounding of the Martian atmosphere: The bending of the radio carrier ray paths in the Martian ionosphere and neutral atmosphere prior to the occultation of the spacecraft by the planetary disc as seen from the Earth is used to derive vertical profiles of electron density in the ionosphere and density, pressure and temperature profiles in the neutral atmosphere (s. Fig. 2).

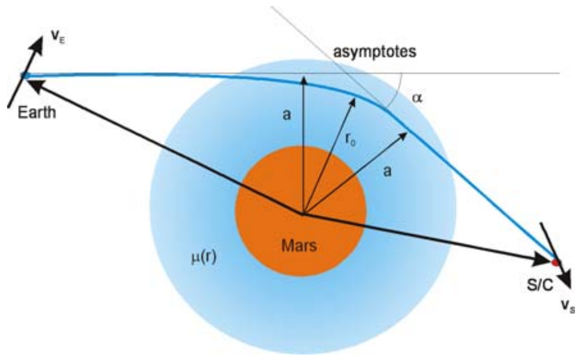

Fig. 2: Geometry of Radio Ray Bending in the Martian Atmosphere. The bending can be analysed by the total bending angle α, and the distance of the ray asymptotes a from the center of planet. r0 defines the closest approach of the bended ray.

The bending of the ray path is caused by the atmospheric refractivity. 'Geometric' optics is applied to describe the ray path in the atmosphere by the total bending angle α and the ray asymptotes a (s. Fig. 2). The variation of the bending angle, ray asymptote and refractivity μ are linked through an Abel transform [Fjeldbo et al., 1971]:

$$\mu(r) = \exp\left\{ \frac{1}{\pi} \int_{a_1}^{\infty} \ln\left[\frac{a}{a_1} + \sqrt{\left(\frac{a}{a_1}\right)^2 - 1} \right] \frac{d\alpha}{da} \, da \right\}$$

The analysis of the two-way radio link requires modifications of the well established Fjeldbo method. An explicit calculation of the uplink and downlink ray paths is necessary to separate atmospheric effects affecting the different carrier frequencies used for uplink and downlink. [Lipa and Tyler, 1979].

The refractivity profiles can be used to derive height resolved density and temperature by assuming hydrostatic equilibrium and validity of the ideal gas law. The different behaviour of the refractivity in the ionosphere and the neutral atmosphere makes it possible to distinguish between the different atmospheric regions (s. Fig. 3).

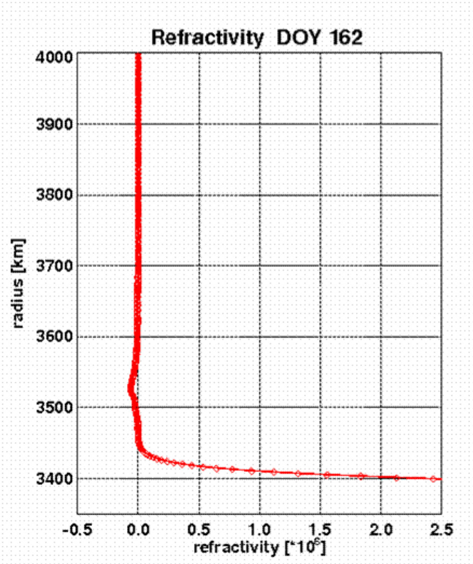

Fig. 3: Refractivity profile. Negative refractivity indicates the ionosphere. A transition region with a refractivity close to zero separates the ionosphere from the neutral atmosphere. The neutral atmosphere can be identified by the positive refractivity.

Since April 2004 several profiles at a height resolution of only a few hundert metres are recorded which cover a large range of surface locations and local times that are different and more diverse than those retrieved by MGS.

Atmosphere during Polar night and sunrise: This presentation will focus on some very special events. Measurements taken during the northern and southern polar night will be presented. These give insight into the still quite unknown temperature variations in the extremely cold high latitudes of the winter hemispheres. Strong variations within the surface boundary layer, significant deviations from atmospheric models due to very sparse a priori knowledge in this latitude range and stable inversion layers even in the upper parts of the atmospheric profiles will be presented. Fig. 4 shows a typical example for the polar night.

In addition, several measurements performed during sunrise will be shown with regard to their latitudinal variation and solar zenith dependency.

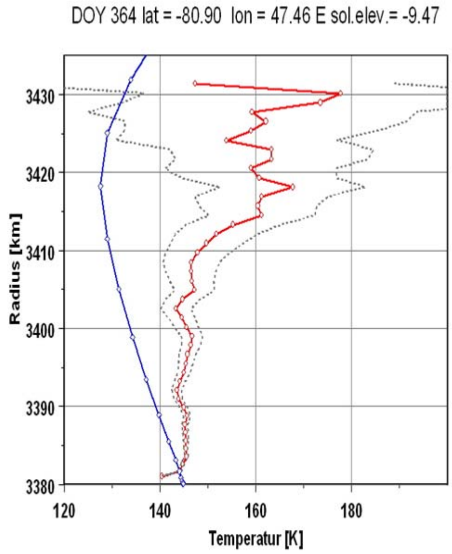

Fig. 4: Temperature profile in southern polar night. The red line shows the measured profile, the 1σ-uncertainty is shown by the dashed lines. The blue line indicates a model calculation.

Model calculations from a Martian General Circulation Model (GCM) developed by the Laboratoire de Météorologie Dynamique de C.N.R.S. (LMD) (*http://www-mars.lmd.jussieu.fr/*) will be compared with the observed atmospheric phenomena and in order to investigate the deviations from the model calculations [Forget et al., 1999].

References:

Fjeldbo, G., Kliore, A.J. and Eshleman, V.R. (1971). The Neutral Atmosphere of Venus as Studied with the Mariner V Radio Occultation Experiments. *The Astronomical Journal,* Volume 76, Number 2.

Forget, F. et al., (1999). Improved General Circulation Models of the Martian Atmosphere from the Surface to Above 80 km. *J. Geophys. Res.,* 104, E10, p. 24155-24176.

Lipa, B. and Tyler, G.L. (1979). Statistical and Computational Uncertainties in Atmospheric Profiles from Radio Occultation: Mariner 10 at Venus. *Icarus,* 39, 192-208.