EPSC Abstracts
Vol. 13, EPSC-DPS2019-581-1, 2019
EPSC-DPS Joint Meeting 2019


EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

# Can night-time PFS observations contribute to the measurement of Martian CO?

**Sophie Bauduin**[1], Marco Giuranna[2], Paulina Wolkenberg[2,3], Ann Carine Vandaele[4], Shohei Aoki[4], Séverine Robert[4], Jimmy Bouche[1], Pierre Coheur[1]
(1) Université libre de Bruxelles (ULB), Spectroscopie de l'atmosphère, Service de Chimie Quantique et Photophysique, Brussels, Belgique ; (2) National Institute of Astrophysics INAF-IAPS, Rome, Italy ; (3) Centrum Badan Kosmicznych, Polska Akademia Nauk, Warsaw, Poland; (4) Royal Belgian Institute for Space Aeronomy, Brussels, Belgium

(email : sbauduin@ulb.ac.be)

## Abstract

Because of its important role in the Martian carbon cycle, carbon monoxide (CO) has been the subject of many measurements from ground and from space. From the available observations, daytime measurements have been mostly exploited because of their good signal-to-noise ratio. Night-time observations, on the contrary, have generally been discarded. This work demonstrates the possibility of using PFS [1] night-time observations to measure Martian CO. More particularly, we will show that these observations carry information mostly on the CO column below 9 km and provide a stronger constraint on the near-surface CO abundance compared to daytime observations.

## 1. Introduction

Carbon monoxide (CO) plays a major role in the Martian carbon cycle, notably due to its involvement in the so-called stability problem of carbon dioxide ($CO_2$). Since its first detection in 1969 [1], CO has been largely measured from ground and from space, and the knowledge of its spatial and temporal variations has improved. Nevertheless, measurements of the vertical distribution of CO in the Martian atmosphere remain rare. Very recently, [2] attempted to retrieve CO vertical profiles from PFS daytime observations. They showed that these observations are mainly sensitive to CO below 15 km, but only a total column (0-15 km) is independently retrieved. Night-time PFS spectra could have a better vertical sensitivity. They are indeed generally associated to large thermal inversions, which, on Earth, are known to provide a better decorrelation between the near-surface CO and the rest of the troposphere [3]. Mars night-time measurements are, however, usually discarded in most analyses because of their very poor signal-to-noise ratio (SNR). This is due to a very weak radiation source (thermal infrared) or the lack of Sun radiation (near-infrared), that renders these observations very challenging to analyse. This work has therefore two main objectives: 1) It aims at demonstrating that the exploitation of night-time PFS observations to measure CO is possible, and 2) using these observations, it examines the possibility to gain more information on the vertical distribution of CO than for daytime measurements.

## 2. PFS observations and method

PFS [4] is a double pendulum Fourier transform spectrometer on-board Mars Express. Thanks to two different detectors, the instrument covers a large spectral range going from 250 to 8200 $cm^{-1}$ that is divided in a longwave channel (250-1700 $cm^{-1}$) and a shortwave channel (1700-8200 $cm^{-1}$). For both, the unapodized spectra have a spectral resolution of around 1.3 $cm^{-1}$ and a spectral sampling of about 1 $cm^{-1}$. When apodized by a Hamming function, the spectral resolution decreases to 1.8 $cm^{-1}$.

The main analysis of this work has focused on the 1-0 fundamental band of CO located in shortwave spectra of PFS. One averaged night-time spectrum has been more analysed in depth. It has been built from 24 night-time apodized spectra recorded during the Martian Year (MY) 29 in autumn ($238° \leq L_s$[2] $\leq 253°$) and is presented in Figure 1. It is of good SNR and clearly shows the entire CO band in emission.

The analysis of this averaged spectrum has been made in two steps. The first one has consisted in the

[1]PFS = Planetary Fourier Spectrometer.

[2]$L_s$ stands for Solar Longitude.

retrieval of the associated temperature profile. For this, the $\nu_2$ band of $CO_2$ centered at 667 $cm^{-1}$ in the corresponding averaged longwave spectrum could have been used. However, we will show that the retrieved temperature profile in this case does not lead to a good CO retrieval. The $\nu_3$ band of $CO_2$, centered at 2349 $cm^{-1}$ has therefore been preferred. Once the temperature profile has been obtained, the second step has consisted in the retrieval of the CO profile and its characterization. Both retrievals have been performed using the Optimal Estimation method [5], implemented in the Atmosphit software [2]. This method and the associated required parameters will be fully described.

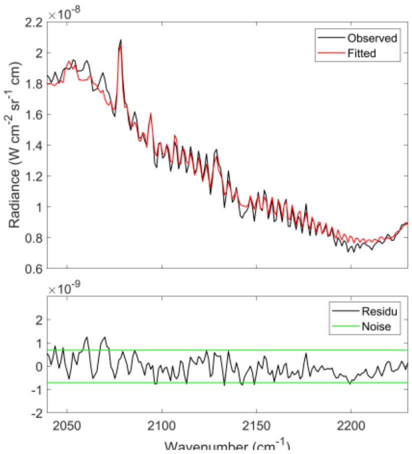


**Figure 1**: Averaged spectrum built for this work. The fitted spectrum resulting from the retrieval is also shown.

# 3. CO profile and characterization

The retrieval of CO from the averaged night-time PFS spectrum using the methodology described above has been successful, and the retrieved CO profile is shown in Figure 2, along with the

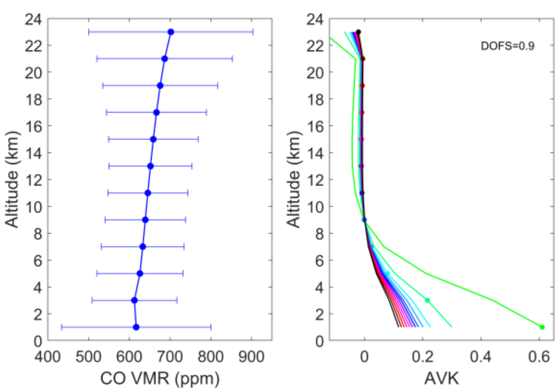


**Figure 2**: Retrieved CO profile (ppm) and its associated averaging kernels.

associated averaging kernels. The fit is shown in Figure 1 and is of very good quality. The important result that comes out the characterization of the retrieved profile is that, even if only the total column is independently retrieved (DOFS[3] of 0.9), night-time measurements of PFS carry information mostly on the CO column below 9 km. They therefore provide a stronger constraint on the near-surface CO abundance compared to daytime observations [2]. The complete characterization and the comparison with daytime observations will be discussed in the presentation.

# 4. Exploitation of night-time measurements

Despite their general low SNR, night-time measurement of PFS can contribute to measure Martian CO and complement daytime observations. As demonstrated in section 3 one added value is the enhanced sensitivity to the near-surface that they allow. By exploiting the entire PFS dataset and performing suitable averages in time and space to increase the SNR, we will try to show in a second step in which regions and periods night-time PFS spectra could be used as a complement of daytime observations to measure the CO abundance.

# Acknowledgements

This work is partly funded by the FNRS CRAMIC project under grant number T.0171.16. S. Bauduin is Chargée de recherches with FRS-FNRS (Belgium). The PFS experiment is funded by the Italian Space Agency (agreement number 2018-2-HH.0).

# References

[1] Kaplan, L. D. et al., Carbon monoxide in the Martian atmosphere, *The Astrophys. J.* **157**, L187-L192, 1969.
[2] Bouche, J. et al., Retrieval and characterization of carbon monoxide (CO) vertical profiles in the Martian atmosphere from observations of PFS/MEX, *JQSRT*, in review.
[3] Bauduin, S. et al., IASI's sensitivity to near-surface carbon monoxide (CO): Theoretical analyses and retrievals on test cases, *JQSRT* **189**, 428-440, 2017.
[4] Formisano, V, et al., The Planetary Fourier Spectrometer (PFS) onboard the European Mars Express mission, *Plan. and Sp. Sci.* **53**, 963-974, 2005.
[5] Rodgers C.D., Inverse methods for atmospheric sounding: theory and practice, Singapore: World Scientific, 2000.

---

[3] DOFS = degrees of freedom for signal (i.e., number of independent pieces of information of the retrieved profile.)