Millimeter observations of Mars with the IRAM 30-m antenna : Constraints on CO, T(P), and zonal winds

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Introduction:

Observations of Mars in the submillimeter range have been performed for almost 30 years (Kakar et al, 1977). CO (1-0) and (2-1) transitions (at 115 and 230 GHz respectively) have been used, together with the ^{13}CO (1-0) and (2-1) transitions (at 110 and 220 GHz respectively), to constrain the CO mixing ratio and the temperature profile (Clancy et al., 1983, 1990). In addition, a CO mapping of the martian disk has been made in the (1-0) and (2-1) lines of ^{12}CO (Lellouch et al., 1991a). No variations higher than 40% were recorded over the martian disk, and a mean CO mixing ratio of 8+/- 2 10^{-4} was inferred. Observations made in the IR range during 1988-89 and 1990-91 in the (1-0) and (2-0) vibrational bands (Billebaud et al., 1992, 1998) led to mean values of CO of 6.2 +/2 10^{-4} and 8.5 +/- 3 10^{-4} respectively. Later, from the reduction of an ISO-SWS averaged spectrum of Mars, a mixing ratio of 7 10^{-4} was inferred (Lellouch etal., 2001). Later on, the CO millimeter transitions were used to constrain the thermal profile (in addition to the GCM model), assuming a constant CO mixing ratio of 7 10^{-4} , in order to determine the water vapor vertical profile from HDO and $H_2{}^{18}O$ millimeter transitions (Encrenaz et al., 2001), or from the H_2O submillimeter transition at 557 GHz (Biver et al., 2005).

However, new observations acquired from the Mars Express instruments should now have the capability of accurately monitoring CO as a function of location and season. Since CO_2 is subject to condensation in the martian atmosphere while CO is not, one should expect variations of the CO mixing ratio by quantities as large as about 30% ; in addition, these variations should be modulated by dynamical effects, as observed on the Ar/CO_2 ratio measured by the GRS instrument aboard MGS (Sprague et al., 2004). Krasnopolsky, from high-resolution near-IR spectroscopy, reported variations of the CO mixing ratio from 8 10^{-4} north of 23N latitude up to 12 10^{-3} at 50S latitude during early nortern summer (Ls = 112°). In parallel, improvements in the GCM models (Forget et al., 1999) now allow to predic thermal profiles as a function of location and season with a very good precision. For these reasons, we have pursued our program of CO millimeter observations at the IRAM 30-m antenna with an new approach : instead of using a mean CO mixing ratio to determine the thermal profile, we will now use the thermal profile as predicted by the GCM and we will search for possible variations of CO in time and space. In addition, we will continue our study of the zonal winds (Lellouch et al., 1991b),by coupling our observations with the maps obtained with the IRAM interferometer at Plateau de Bure (Moreno et al., 2001).

The observations:

Observations have been performed during two runs : June 13-17, 2001 (Ls = 179°) and Nov. 1 , 2005 (Ls = 320°). In both cases, the 4 CO transitions (^{13}CO(1-0) at 110 GHz, ^{12}CO (1-0) at 115 GHz, $^{13}C0$(2-1) at 220 GHz, ^{12}CO(2-1) at 230 GHz) have been observed in 13 positionsover the martian disk (center C, N/S/E/W limbs, NE/NW/SE/SW limbs, CN/CS/CE/CW intermediate positions). In addition to the study of CO and T(P), the spectra, recorded at maximum spectral resolution (20 kHz) will be used to retrieve a map of the zonal winds. These data, together with those of the IRAM interferometer at Plateau de Bure, will be compared to the GCM predictions.

Figures 1 to 4 show examples of the 4 CO lines at the disk center. All four transitions will be used to constrain the CO vertical distribution. It can be seen that the ^{13}CO(1-0) transition is very weak and appears in emission.. The 3 other transitions will be used for measuring the winds.

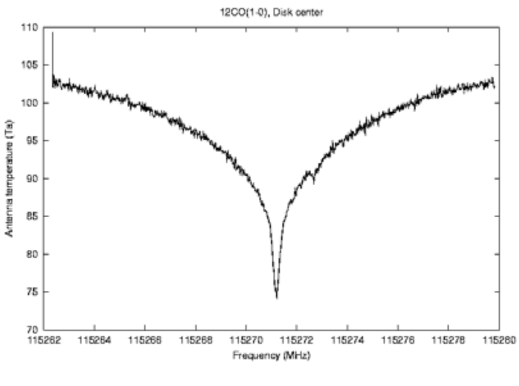

Fig. 1. The ^{12}CO(1-0) transition at the disk center.

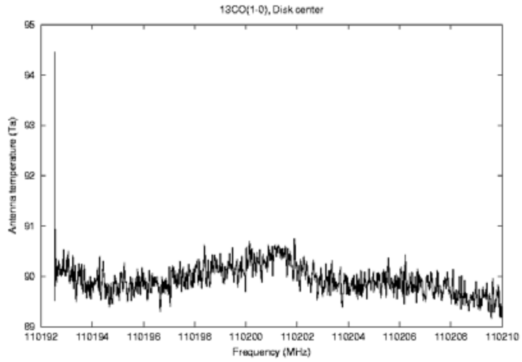

Fig. 2. The ^{13}CO(1-0) transition at the disk center.

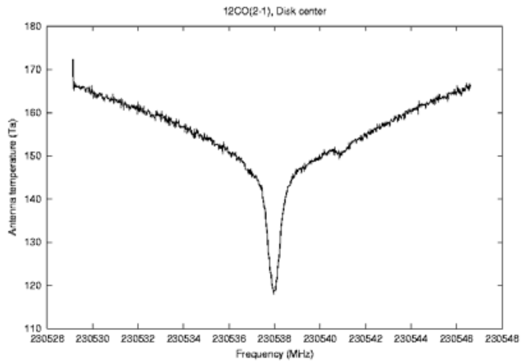

Fig. 3. The ^{12}CO(2-1) transition at the disk center.

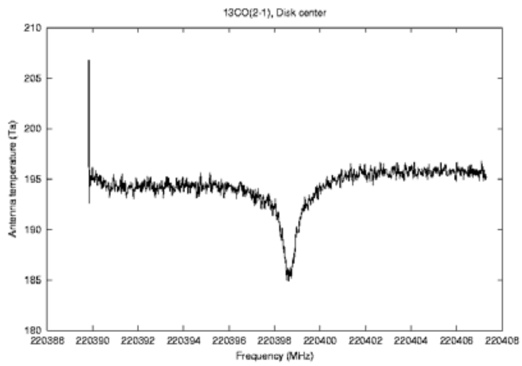

Fig. 4. The 13CO(2-1) transition at the disk center.

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