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Martian CO and wind measurements from ALMA observations

Séverine Robert (1), Hideo Sagawa (2), Ann Carine Vandaele (1) and Shohei Aoki (1, 3, 4)
(1) Royal Belgian Institute for Space Aeronomy, BIRA-IASB, Belgium, (2) Kyoto Sangyo University, Japan, (3) Fonds National de la Recherche Scientifique, FRS-FNRS, Belgium, (4) Tohoku University, Japan, (severine.robert@aeronomie.be)

Abstract

The Earth-based Atacama Large Millimeter/Submillimeter Array (ALMA) telescope is a state-of-the-art interferometer in the sub-mm spectral range, which combines unprecedented spatial resolution and high sensitivity[1]. It is well suited to acquire global measurements of the thermal emission from planetary atmospheres, and its high-spectral resolution allows to measure the Doppler shifts of molecular lines due to wind velocity. Observations of the martian disk were done in May 2014 at the ALMA Observatory. The objective of the observations was to map the full disk at frequencies enabling the detection of CO, HDO and H_2O_2 absorption lines. As CO is optically thick, the temperature profiles may be derived, which is of great interest, as temperature profiles and wind fields in the Martian atmosphere are still incompletely mapped at the planetary scale. To perform this investigation, ASIMUT-ALVL, the BIRA-IASB Radiative Transfer code was used. The reduction and calibration of the interferometric data will be presented. We will also describe the modifications we did to the code and the sensitivity studies we performed beforehand. Hopefully, the global distributions of the thermal and dynamical structure of the atmosphere will be discussed.

1. ALMA observations

As summarized in Table 2, four spectral windows at the frequencies of 335 and 345 GHz (which fall in the ALMA Band-7 receiver) were selected. The heterodyne receivers of ALMA enable the frequency resolution as high as 122 kHz (corresponding to $\sim$ 100 m/s in velocity), which should allow to measure the Doppler - wind shift. An overview of the observations is presented in Table 1 and Table 2. The values given in Table 2 are identical for both observations presented in Table 1.

[1] http://www.almaobservatory.org/en/home/

Table 1: Overview of the observations.

	01 May 2014 4:40	18 May 2014 4:59
MY	32	32
L_S	123.9°	132.1°
Diameter of Mars	14.54"	14.53"
Angular resolution	0.65" (20x20)	1.09" (13x13)
Integration time (min)	44	20
Number of antennas	34	34
Maximum baseline length (m)	558	650

Table 2: Overview of the observations' frequencies

Nb.	Spectral range (GHz)	Resolution (kHz)	Target Species
0	345.31-346.25	969	CO wide range
1	345.67-345.90	122	CO line center
2	335.16-335.63	282	HDO
3	335.08-336.02	969	HDO + H_2O_2

The measured data (i.e. visibilities) were calibrated for the phase fluctuation and flux amplitude. The spectral bandpass characteristics were also corrected. Once the visibilities were calibrated, the radio images (spectral image cubes) were synthesized using the CLEAN procedure. This procedure removes the artefact emission features due to an imperfect visibility sampling on (u,v) spatial frequency domain. Fig. 1 shows the continuum emission image before and after the CLEAN procedure. The image is reconstructed as a 512 x 512 pixel image with a pixel scale of 0.1 arcsec.

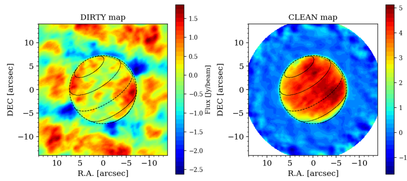

Figure 1: Mars continuum emission map at 335 GHz observed with ALMA. The dirty map (left) is an image which includes a false emission pattern due to imperfect visibility sampling. By applying the CLEAN procedure, the false emission pattern is deconvolved from the image, and finally the clean map is restored (right).

2. ASIMUT-ALVL, the BIRA-IASB Radiative Transfer Model

The BIRA-IASB radiative transfer and retrieval code, ASIMUT-ALVL[1], was used to analyse the data. The ALMA data analysis necessitated some new implementations in the code. In particular the multiple lines of sight (LOS) to be considered due to the size of the beam were not yet considered in ASIMUT. For the data obtained on 1st May, the synthesis beam (i.e. spatial resolution) is an elliptical 2d gaussian function with major and minor axis of 0.65 and 0.42 arcsec respectively. The observed spectral feature is then the result of the incoming radiation from a localized region of the mapped source. This effect is taken into account by considering the weighting function represented on Figure 2.

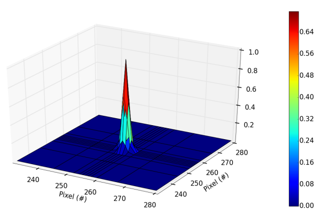

Figure 2: The different contributions are modelled by a two-dimensional gaussian function of Full Width at Half Maximum (FWHM) of the angular resolution and extended on 3 times the FWHM in each direction.

Retrieving the wind velocities implies the retrieval of a spectral shift in the planetary absorption line, here the 3-2 line centered at 345.795 GHz of ^{12}CO in the vibrational ground state. The CO line spectroscopic parameters were extracted from the latest version of HITRAN [2, 3], taking into account that the main buffer gas in the Martian atmosphere is CO_2. The shift retrieval method was modified in ASIMUT. Instead of being done by a simple fit approach, the Jacobians were introduced. This enables us to obtain vertical information, if the information level in the spectrum is sufficient.

3. Current status of the analyis

The update of ASIMUT-ALVL forward model enabled to simulate an appropriate continuum emission brightness temperature map as observed by ALMA. This model map can be used as an input for the "self-calibration" of the measured visibility, which possibly improves the image synthesis quality. After such a reconsideration on the visibility data reduction, the retrieval of wind and temperatures profiles will be tested.

Acknowledgements

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