Revisiting Venus Doppler-wind maps obtained by ALMA: Impact of missing short-baseline data and uncertainty in the flux calibration

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Venus atmospheric dynamics is well known with its super-rotating circulation in the troposphere (below the cloud layer). A different circulation regime, that is, subsolar-to-antisolar (day-to-night) flow is considered to be dominant in the upper thermosphere. The dynamics in the intermediate region, i.e., middle/upper atmosphere above the cloud layer, is an important topic to understand how the global circulation changes from the super-rotation to the subsolar-to-antisolar flow. Although the observational constraints of the middle/upper atmospheric dynamics are still limited, the most widely employed observation technique is to measure a Doppler-shift of carbon monoxide (CO) absorption line at millimeter and sub-millimeter wavelengths. The derived Doppler-shift tells us a wind velocity projected along the line-of-sight of observation (a.k.a. “Doppler-wind”) at altitudes of ~95-110 km [e.g., 1-3]. ALMA (Atacama Large Millimeter/submillimeter Array) is undoubtedly one of the most essential and attractive observational facilities to obtain spatial distribution of such Doppler-winds on Venus disk. On the other hand, interferometric observations of Solar system planets, which are very bright and large, often encounter several technical problems compared to other astronomical observations. One of the shortcomings of interferometric observations of Solar system planets is the lack of short-baseline visibilities, i.e., lack of the sensitivity to large-spatial scale brightness distribution. This is known as a “resolve-out” problem and is unavoidable when observing Venus near the inferior conjunction (apparent disk diameter is ~40-60 arcsec). Another caveat of ALMA Venus CO observation is the effect of uncertainty in the flux calibration. Recently, it is reported that the current flux calibration (including the raw data acquisition) scheme in the ALMA data can introduce significant errors in the absolute flux and also in the spectral line shape for any very bright objects [4]. In fact, the presence of such errors has been confirmed with other ALMA data of Mars [5]. The unwilling (and without knowing) distortion of the spectral line shape becomes a critical issue when interpreting the Doppler-wind maps.
This presentation reviews the technical issues of observing Venus with ALMA, and evaluate the impact of those technical issues on the Doppler-wind maps by running radiative transfer and ALMA observation simulations.

[1] Lellouch et al. (2008), PSS 56, 1355–1367.
[2] Clancy et al. (2012), Icarus 217, 794–812.
[3] Moullet et al. (2012), A&A 546, id.A102, 12 pp.
[4] ALMA knowledge base:
https://help.almascience.org/kb/articles/what-errors-could-originate-from-the-correlator-spectral-normalization-and-tsys-calibration
[5] ALMA Mars data are being analyzed in collaborations with Shohei Aoki (University of Liège, Belgium), Kazi Rygl (INAF, Italy), and Eric Villard (European Southern Observatory).

Keywords: Venus atmosphere, ALMA

