Search of SO_2 in the Martian atmosphere by ground-based submillimeter observation

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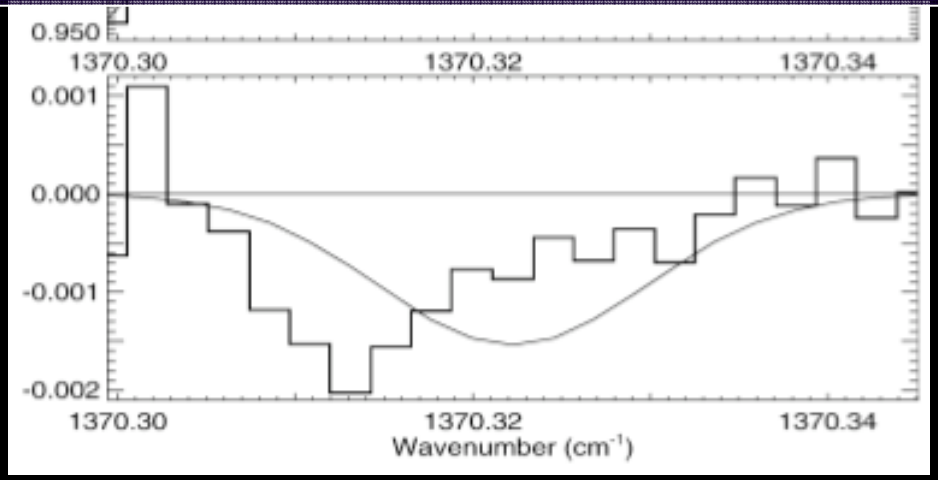
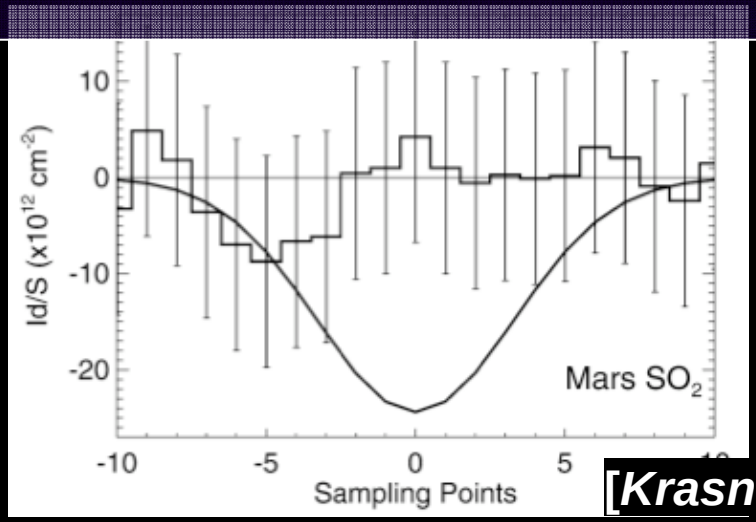
- **Volcanism** had occurred throughout much of history of Mars [Neukum et al., 2004], and the release of gases into the atmosphere, due to volcanism, may have had significant **climatic effects** [Levine and Summers, 2008].
- SO2 could have played a significant role in episodic warming of Mars [Halevy et al., 2007].

Open question & Purpose of this study

- **No sign of the atmospheric components**
- Encrenaz et al. [1991] ; SO2 < 30 ppb
- Krasnopolsky [2005] ; SO2 < 1 ppb ; *This value is based on the intensity summed over multiple unresolved lines at several frequencies or the intensity summed the values at several undetected individual lines.





[*Krasnopolsky, 2005*]

- A firm understanding for their activities is essentially indispensable. In this study, we focus on a sensitive search for Martian sulfur oxide (SO and SO2) with the higher-dispersion spectroscopic observation in submillimeter range.

ASTE Observation

- Observation for Martian SO2 with a higher spectral-resolution than previous studies.

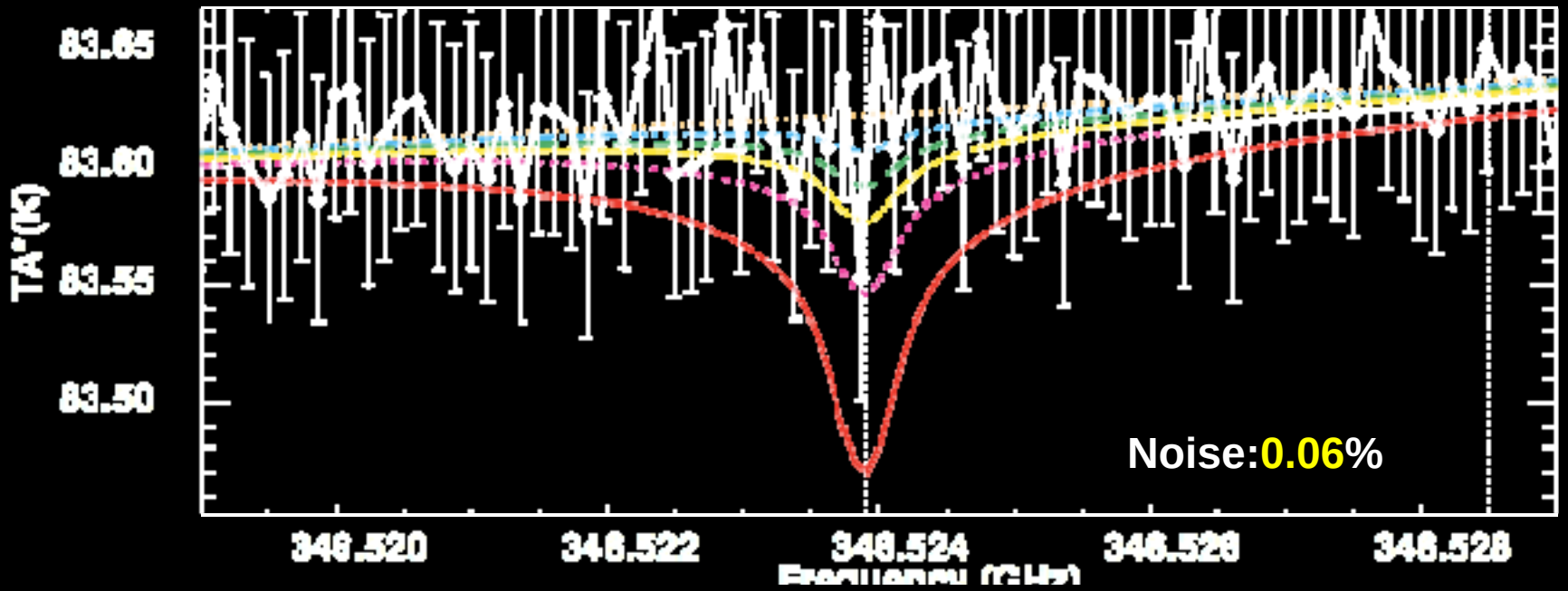
* cf. IRTF: 77,000 in Krasnopolsky [2005]

ASTE (Atacama Submillimeter Telescope Experiment)	
Elevation	4800 m
Diameter	10 m
Bean size	22”
Frequency range	324-366 GHz (925-820 um, 10.8-12.2 /cm)
Period	2007/Dec./26 (UT 0-5) Ls = 8.1
Mars Diameter	12” (210-299°W)
Rel. Velocity	7.7 km/s (0.03 /cm, 0.01 GHz)
Target	SO, SO2(346.5285, 346.5285 GHz)
Integration time	67m24s (cf. 2003/Jun. Ls = 195 at Krasnopolsky 2005)

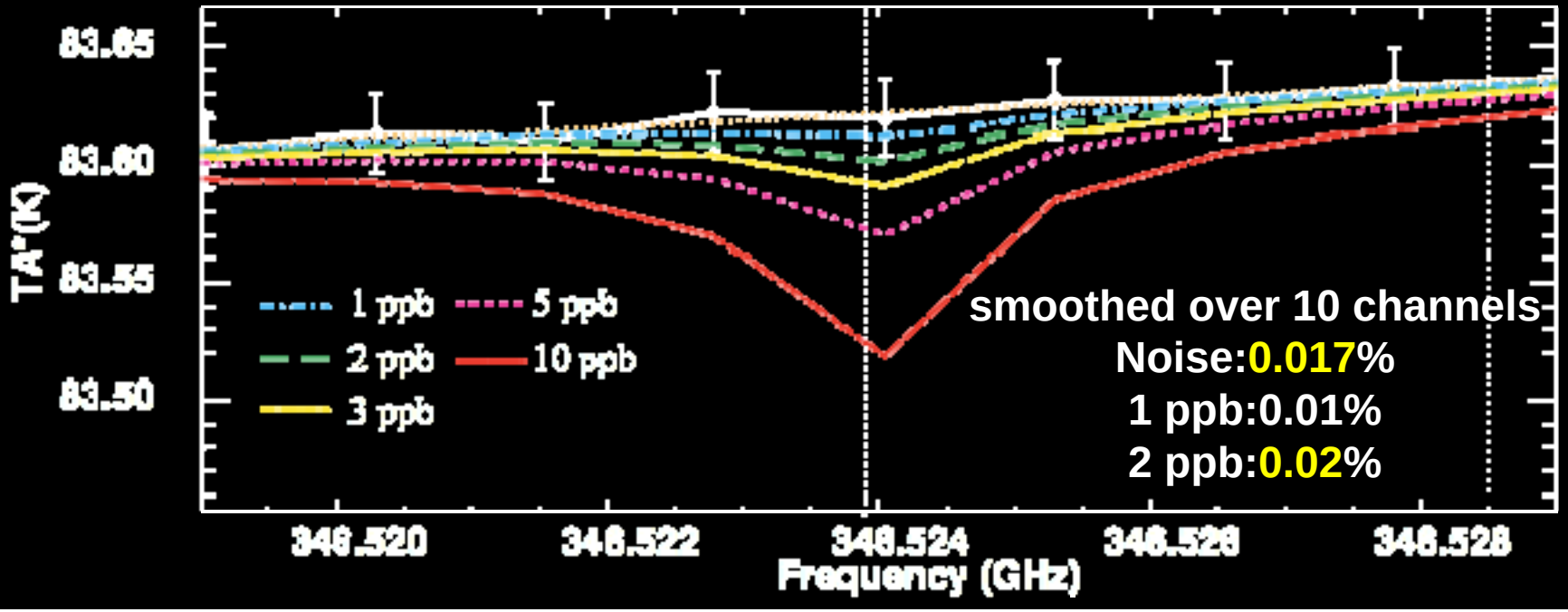
XF Digital Spectrometer (MAC)				
Bandwidh	Channels	Freq. Resolution	Vel. Resolution	Resolving Power
128 MHz	1024	0.125 MHz	0.11 km/s	2,768,000 *

Results

[*Nakagawa et al., 2009*]



- The spectrum does **NOT** show the SO2 absorption.



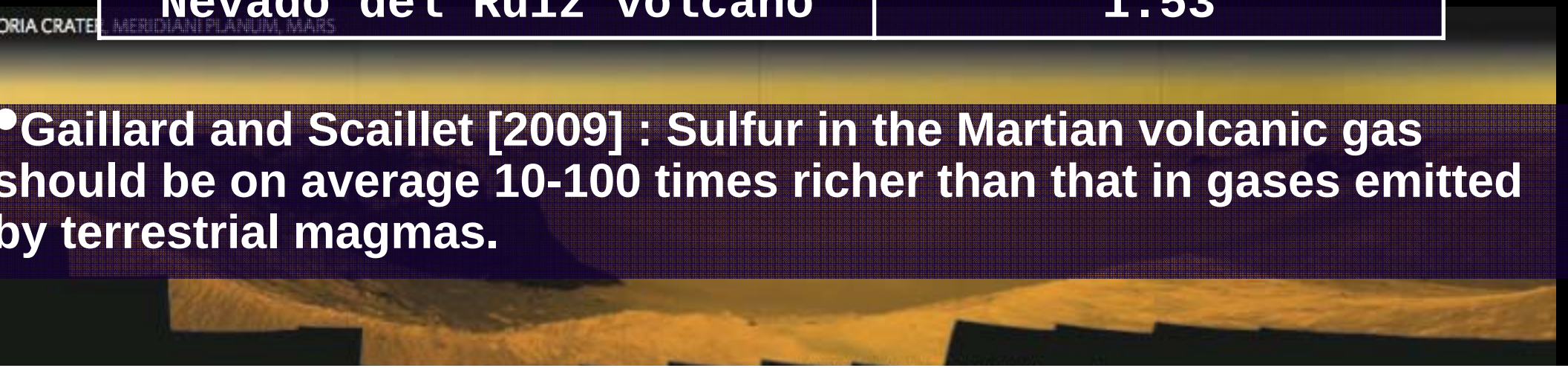
Discussions

- The spectrum does **NOT** show the SO2 absorption.
- The current global average upper limit of **2 ppb** to SO2.
- **The Martian volcanic and crustal activities are very tenuous on northern winter.**

- The evidence for SO2 could not be found in the atmosphere in **the area of CH4 accretion**.

[*Delmelle and Stix, 2000*]

NAME	CH4/SO2
Usu volcano	0.04
Kudriavy volcano	3x10^-6
Galeras volcano	2x10^-5
Nevado del Ruiz volcano	1.53



- Gaillard and Scaillet [2009] : Sulfur in the Martian volcanic gas should be on average 10-100 times richer than that in gases emitted by terrestrial magmas.

Conclusion & Future work

- Our result **strongly restricts** the production of **volcanic gases** from the Martian surface into the atmosphere.
- Our result is against the source of CH4 from volcanic and crustal gas.
- Some kind of non-volcanic **carbon hydride source** shall possibly b under the Martian surface which may induce the degassing of CH4.

- Short lifetime of SO2 ;
- Continuous monitoring of magmatic volatile is significantly indispensable (**APEX observation in Nov. 2009.**)
- Large ground-based single-dish antennas which could benefit from longer integration times and ALMA can be expected to constrain minor species such as sulfur species (**SO2, SO, H2S, and OCS**), and other outgassing species (**CH2O, PH3, and HCl**).