Contrast sources for the infrared images taken by the Venus mission AKATSUKI

Seiko Takagi [1], Naomoto Iwagami [1] (seiko@eps.s.u-tokyo.ac.jp)

[1] Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

This poster participates in OSP

Outstanding Student Poster Contest

1. Introduction

AKATSUKI's main aim is to elucidate the Venus meteorology. For such purpose, five cameras and a radio occultation instrument are on board. Since each cameras uses different wavelength, they may observe targets at various altitudes at the same time. The strategy of the AKATSUKI mission is to understand the acceleration mechanism by measuring various meteorological parameters in the acceleration region by using the cloud tracking and the radio occultation techniques at various altitudes.

The present work discusses the contrast sources for the 0.90 $\pm$0.05 µm dayside image of the 1 µm camera (IR1), the 2.26 $\pm$0.03 µm nightside image and the 2.02 $\pm$0.02 µm dayside image of the 2 µm camera (IR2), the 10 $\pm$2 µm image of the 10 µm camera (LIR) and their representative altitude.

2. Target

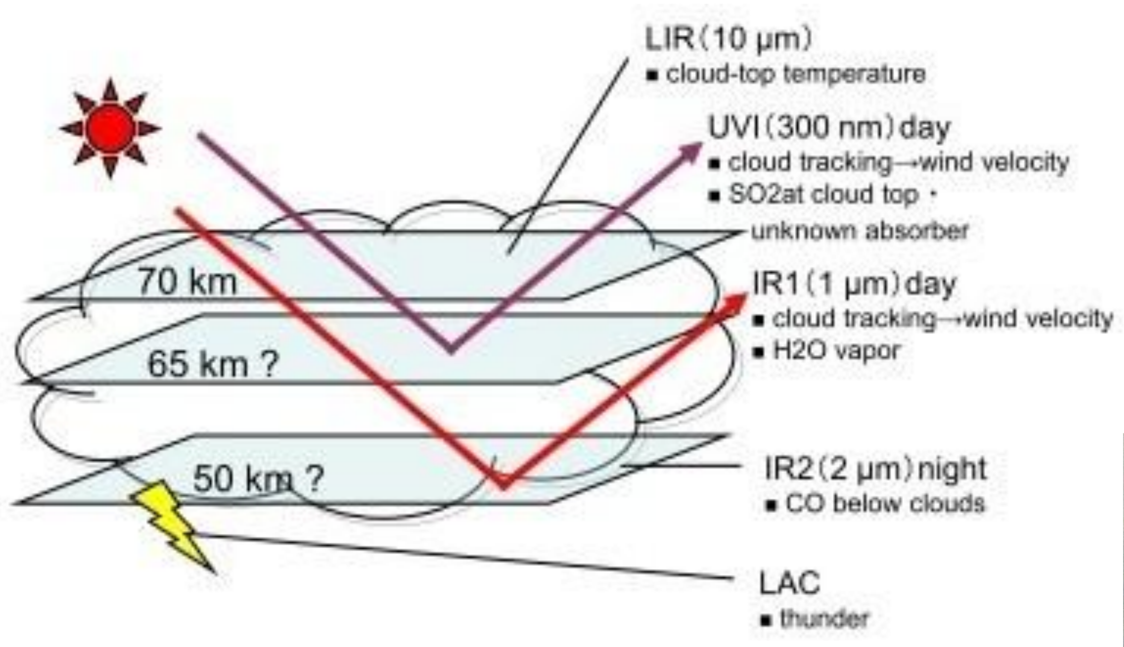

Fig. 1 Schematic of the three-dimensional observation by AKATSUKI.

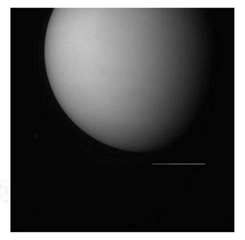

Fig. 2 A 0.986 µm image of Venus dayside taken by SSI on board Galileo (from NASA website) Contrast of brightness 3 %

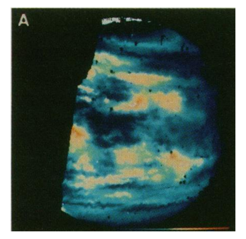

Fig. 3 A 2.3 µm nightside image of Venus taken by NIMS on board Galileo (from NASA website). Contrast of brightness 100 %

- **In Fig.2,** there are some small-scale (～ 300 km) features with contrast of 3 % (Belton et al., 1991).
- Such faint feature in the 0.90 µm image taken by IR1 camera must be tracked to determine the meteorological parameters.
- Knowledge about the contrast source and representative altitude is important.

The same may be applicable to the 2.02 µm dayside, 2.26 µm nightside and 10 µm day and nightside images.

- **In Fig.3,** there are a lot of features showing contrast of almost 100 % (Tsang et al., 2009).
- It is also interesting whether the source of such large contrast in nightside seen in Fig.2 is consistent with the source of small contrast seen in the dayside as seen in Fig.1 or not.

3. Simulation

3.1 Radiative transfer calculation

Calculation：Adding & Doubling method
Atmospheric absorption：line-by-line method
Atmospheric model：VIRA 1985
(Keating et al., 1985)
Absorption line data：HITRAN 2004 & HITEMP
(Rothman et al.,2005,
Wattson & Rothman, 1992;
Pollack et al., 1993)

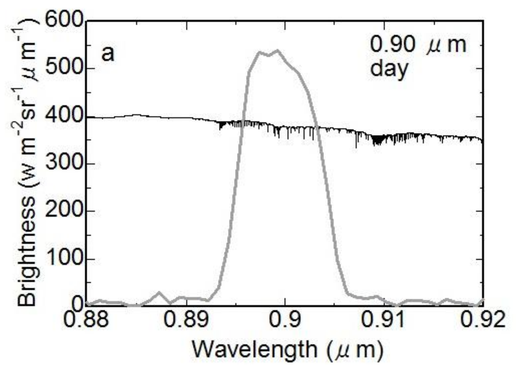

Fig. 4 The example of calculated brightness (this solid curve) and the transmission profiles of the filter (thick solid curve). The maximum transmission of the filter is 0.27 %.

3.2 New Cloud model 'Cloud T2x' [Takagi & Iwagami, 2011]

To calculate the brightness distribution on the Venus disk, a Venus atmosphere model, molecular line database, a cloud model and a radiative transfer calculation are necessary.

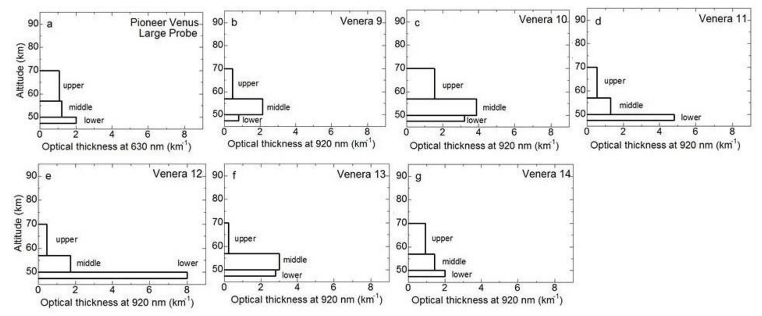

Fig. 5a-g Optical thickness of three layers measured by the entry probes summarized by James et al.(1997). a: Pioneer Venus Large Probe; b-g; Veneras.

A mean cloud model (Fig.3h) and deviations (Tab.1) from the mean are calculated from the measured data by previous entry probes (Figs. 3a-g).

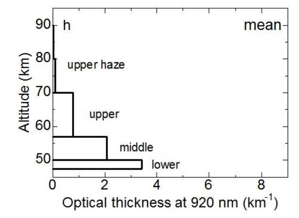

Fig. 6 Mean of 7 profiles Fig.5a-g. The upper haze layer is added to the mean following Crisp (1986).

Optical thickness of each mean cloud layer are redistributed to 2 km thick layers so as to keep constant mixing ratio of cloud particles within each (middle, upper, and upper haze) layer.

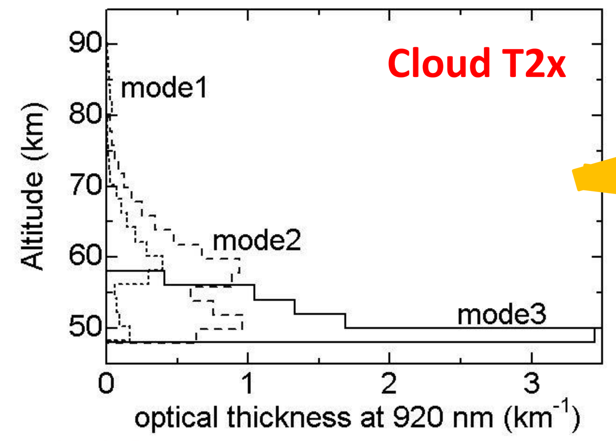

Fig. 7 cloud T2x. The cloud model used for the present calculation made from the mean profile shown in Fig.3h by adjusting it to 2 km thickness and constant mixing ratio of particles in each layer.

Tab.1 The detail of cloud T2x and deviations.

Layer center altitude (km)	Optical thickness per 2 km mode1	mode2	mode3	total	total	Maximum negative deviation	Maximum positive deviation
89	0.013	0.0	0.0	0.013			
87	0.020	0.0	0.0	0.020			
85	0.033	0.0	0.0	0.033	0.2	- 50 %	+ 50 %
83	0.052	0.0	0.0	0.052			
81	0.082	0.0	0.0	0.082			
79	0.011	0.052	0.0	0.063			
77	0.015	0.077	0.0	0.093			
75	0.024	0.114	0.0	0.138	0.8	- 50 %	+ 50 %
73	0.036	0.168	0.0	0.204			
71	0.053	0.249	0.0	0.302			
69	0.149	0.355	0.0	0.504			
67	0.208	0.495	0.0	0.703			
65	0.290	0.691	0.0	0.981	10.0	- 70 %	+ 100 %
63	0.405	0.946	0.0	1.369			
61	0.565	1.346	0.0	1.911			
59	0.789	1.878	0.0	2.667			
57	0.596	1.777	0.819	3.192			
55	0.114	1.186	2.084	3.384			
53	0.146	1.509	2.652	4.307	14.5	- 42 %	+ 86 %
51	0.186	1.920	3.374	5.480			
49	0.334	1.268	6.898	8.500	8.5	- 76 %	+ 135 %
total				34.0			

4. Results・Discussion

4.1 Source for the contrast in the 0.90 µm dayside image

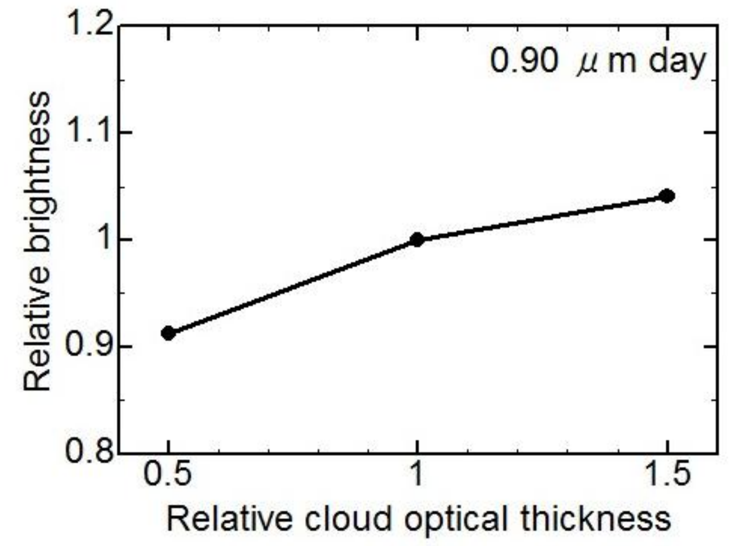

Fig. 8 Calculated and normalized 0.90 µm integrated brightness as a function of the normalized total cloud optical thickness.

Cloud Parameters		Brightness
Alt.	$\pm$4 km	$\pm$ 0.2 %
Optical thickness	- 50 ～ + 50 %	- 8.7 % ～ + 4.1 %
Temp.	$\pm$ 10 K	$\pm$ 0.02 %

The source for the contrast of the order 3 % expected in the 0.90 µm image is due to variation in the **cloud optical thickness**.

4.2 Source for the contrast in the 2.26 µm nightside image

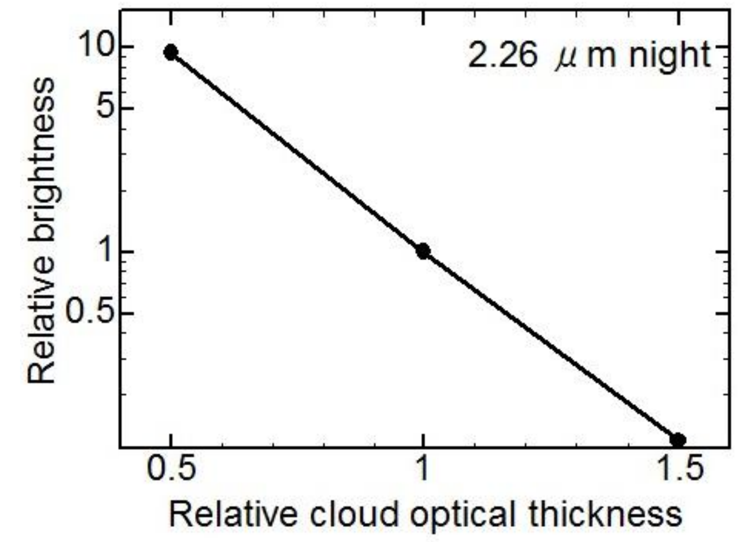

Fig. 9 Calculated and normalized 2.26 µm nightside brightness as a function of the normalized total cloud optical thickness.

Cloud Parameters		Brightness
Alt.	- 4 ～ + 4 km	+ 11.6 % ～ - 1.5 %
Optical thickness	+ 50 ～ - 50 %	- 88 % ～ + 830 %
Temp.	- 10 ～ + 10 K	- 22 ～ + 27 %

The source of the 100 % contrast expected to be seen in the 2.26 µm image is found to be mostly due to variation in the **cloud optical thickness**.

4.3 Representative altitude for the 0.90 µm dayside contrast and the 2.26 µm nightside contrast

How to calculate・・・

For example in 0.90 µm・・・
A 70 %decrease in the optical thickness
($10.0\times(1-0.7)=3$)
Is found to cause 3.010 % decrease in brightness.

A 100 % increase in the optical thickness
($10.0\times(1+1)=20.0$)
Is found to cause 2.771 % increase in brightness.

Tab. 2 Maximum contrast expected for the 0.90 µm dayside and 2.26 µm nightside images calculated for the maximum positive and negative deviations in each layer shown in Tab.1.

	Maximum contrast at 0.9 µm(%)	Maximum contrast at 2.26 µm(%)
Upper haze	1.0	7
Upper	5.8	117
Middle	5.5	255
Lower	4.3	289

over 3 % !!

- **All cloud layers except for the upper haze** have possibility to cause contrast of **3 %** or more in the 0.90 µm dayside image (Tab.2).
- **All cloud layers except for the upper haze** layer may contrast of **100 %** or more in the 2.26 µm image (Tab.2).

4.4 The contrast sources for the 2.26 µm dayside image and the 10 µm image

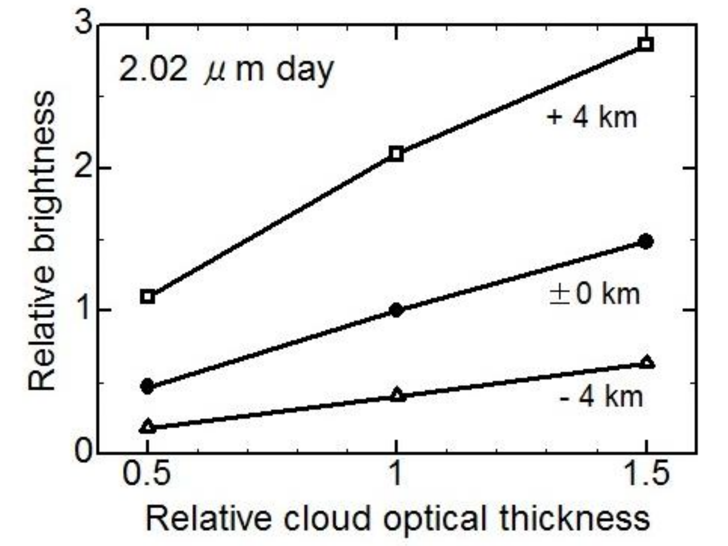

Fig. 10 Calculated and normalized 2.02 µm dayside brightness as a function of the normalized total cloud optical thickness and cloud altitude deviation.

Cloud Parameters		Brightness
Alt.	- 4 ～ + 4 km	- 60 % ～ + 109 %
Optical thickness	- 50 % ～ + 50 %	- 50 % ～ + 50 %
Temp.	$\pm$ 10 K	$\pm$ 0.0035 %

The contrast in the 2.02 µm image is found to come from **cloud altitude** change as well as from change in the **cloud optical thickness**.

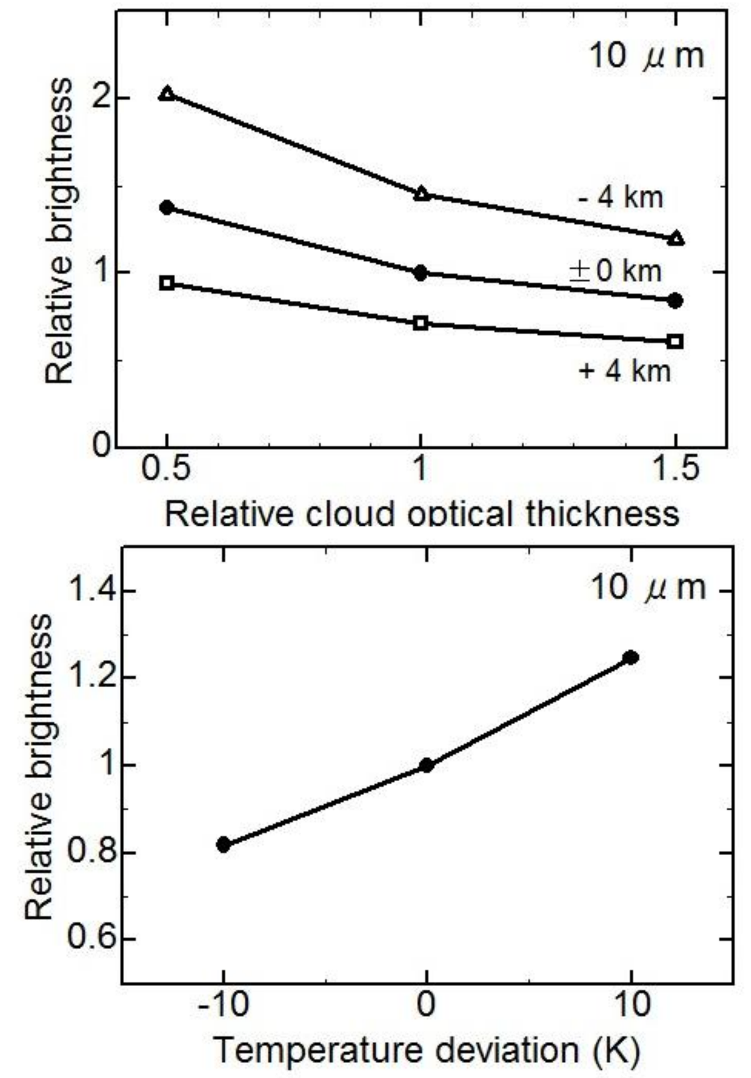

Fig. 11 Calculated and normalized 10 µm brightness as a function of the normalized total cloud optical thickness and cloud altitude deviation (upper figure) and cloud temperature deviation (lower figure).

Cloud Parameters		Brightness
Alt.	- 4 ～ + 4 km	+ 45 % ～ - 29 %
Optical thickness	- 50 ～ + 50 %	+ 37 % ～ - 16 %
Temp.	$\pm$ 10 K	$\pm$ 20 %

The contrast in the 10 µm image is due not only to **temperature** change but also to both the **cloud optical thickness** and the **cloud altitude** deviation as well.

5. Summary

- It is shown that the source of the small contrast expected in the 0.90 µm image is mostly caused by inhomogeneity in the optical thickness.
- It is shown that the source of the large contrast expected in the 2.26 µm image is mostly caused by inhomogeneity in the optical thickness.
- We attempted to determine their representative altitudes.
  - It was found that this spectral band is sensitive to any cloud region (upper, middle and lower), but not sensitive to the upper haze region.
  - The result is not consistent with the previous discussions (Belton et al., 1991; Carlson et al., 1991)
- It is found that the cloud altitude deviation determined from the 2.02 µm brightness may be affected by inhomogeneity in the cloud optical thickness.
- The temperature deviation determined from the 10 µm brightness is found to be affected by the deviations of the cloud optical thickness and the cloud altitude.

Don't give up AKATSUKI!!