Interpretation of Brightness Contrast of Venus in 5μm

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Final target
Comprehending Super-rotation

・The generation mechanism of the super rotation remains unclear.

→Hypothesis：The super rotation is caused by equatorial Kelvin wave and/or the thermal tides.

(Yamamoto & Tanaka 1997, Takagi & Matsuda 2007)

→We should Investigate atmospheric wave structures.

Prior research

- Most studies have used the ultraviolet(**UV**) wavelengths to image atmospheric waves at **70km**(Venus cloud top).
- Some studies have used the infrared wavelengths(**2.3μm**) and to image atmospheric waves at **50km**.
- By observation of the dayside **1.7μm** reflected sunlight to quantify carbon dioxide absorption, we succeeded to detect the atmospheric waves at **60km**. (Hosouchi,2012)

観測	高度 [km]
紫外(昼面)	70
1.7 μm 分光	58-64
赤外(夜面)	50

Table. Observed height In each wavelength (Seiff et.al.,1985,Hosouchi,2012)

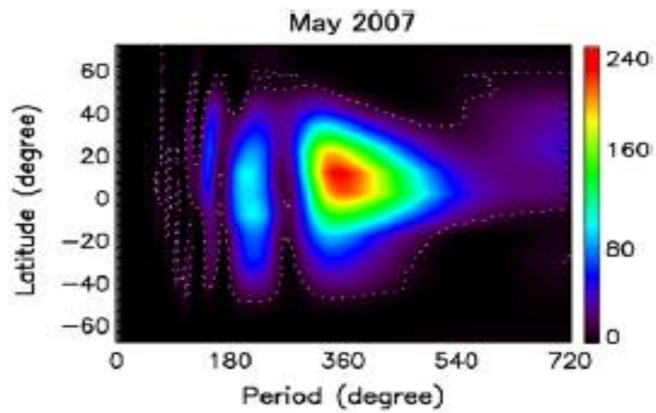


Fig.Atmospheric wave at 60km
(Hosouchi, 2012)

Observation

・We once planed to compare waves at 60km with waves at **70km** by VEX ultraviolet observation.
（Not realize!）
・To detect waves at 70km, we observe **5.04μm** wavelengths because in this wavelengths the cloud particle are black.

・Observation
IRTF (at Mauna Kea)
3m telescope, CSHELL spectrometer
2014 May 14-23(HST)

→Contrast of brightness is found.

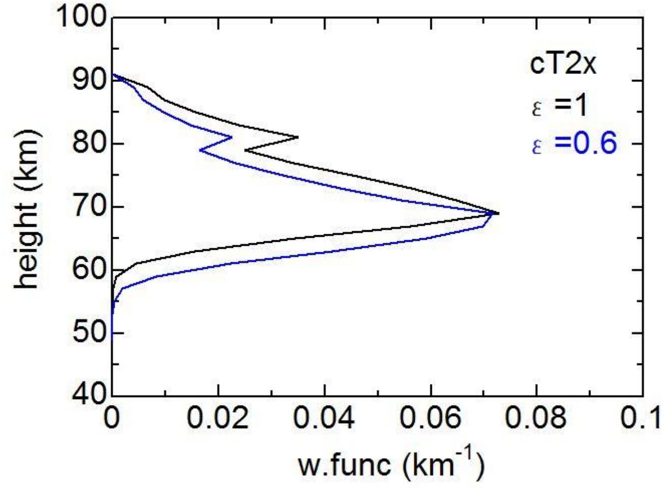


Fig. Weight function

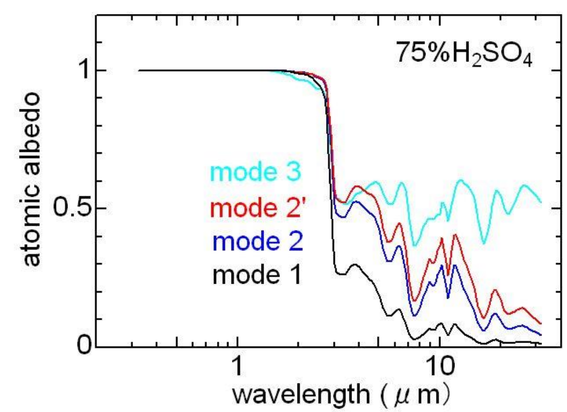
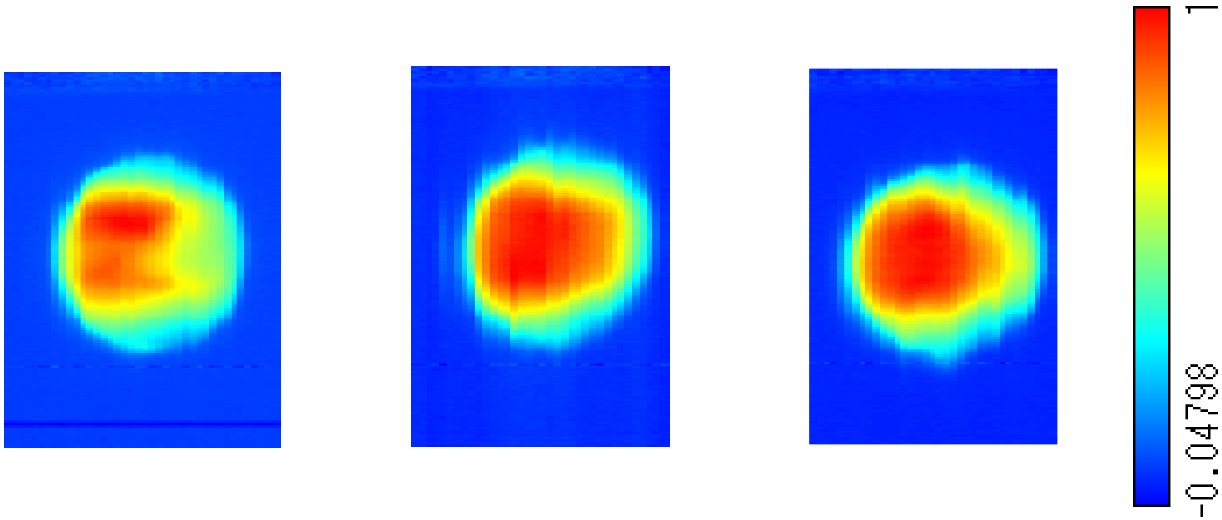
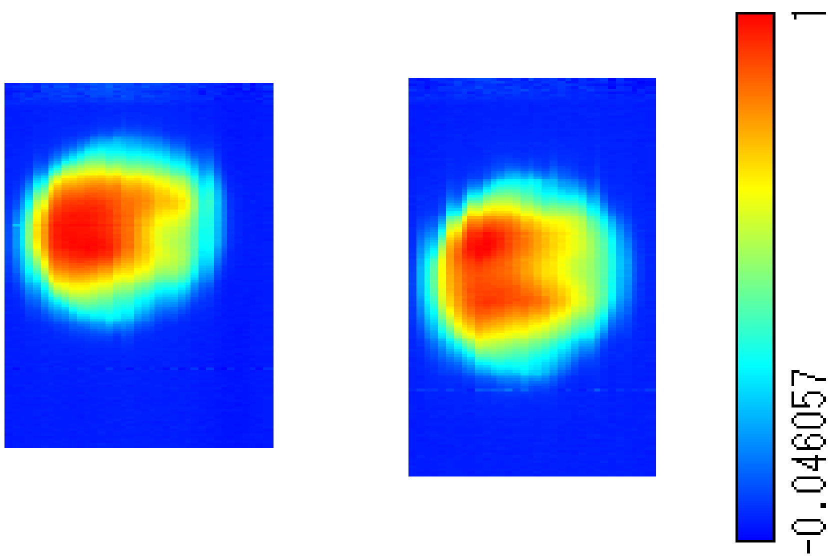


Fig. Atomic Albedo

Data image





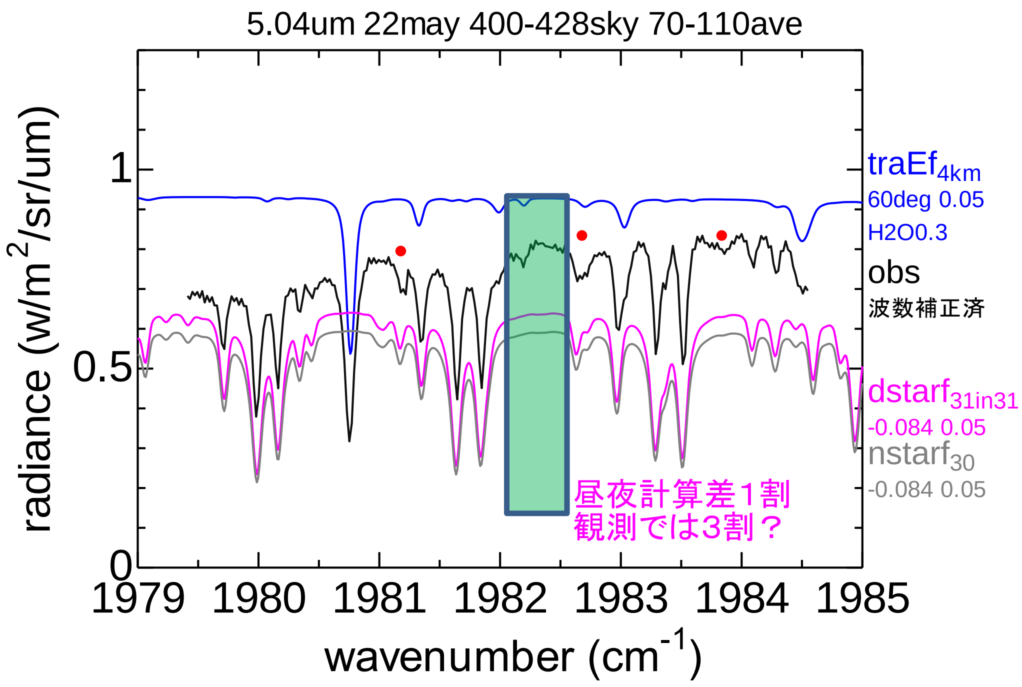
※左上から、
19日、20日、21日
22日、23日
の観測データ

Data Analysis

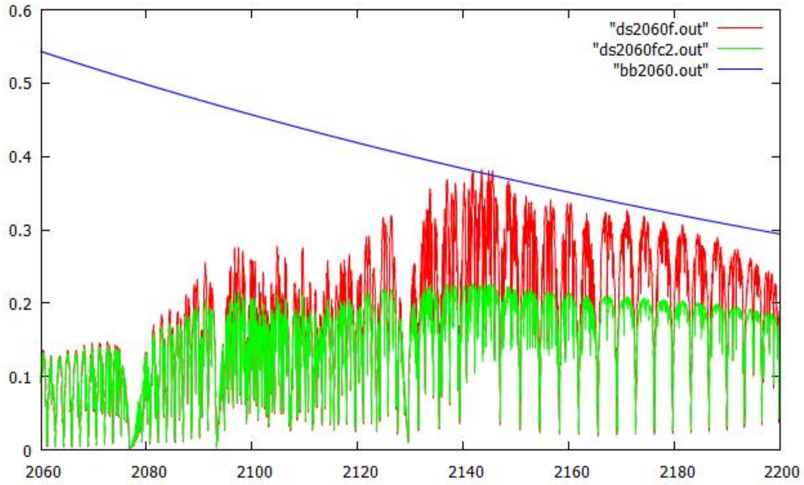
・Brightness at 1982～1982.5cm^{-1} (no gas absorption) is used.

・Hypothesis: This brightness contrast is due to contrast of cloud temperature, because little sunlight reflection should affect in this wavelengths.

・We compare this data with a numerical calculation model of radiative transfer to identify the true primary factor in the contrast.



A related study（Kouyama）
Brightness contrast at 4.7μm wavelength



図：Numelical calculated 4.7μm spectrum
（Blue line is 230K black-body radiation.）

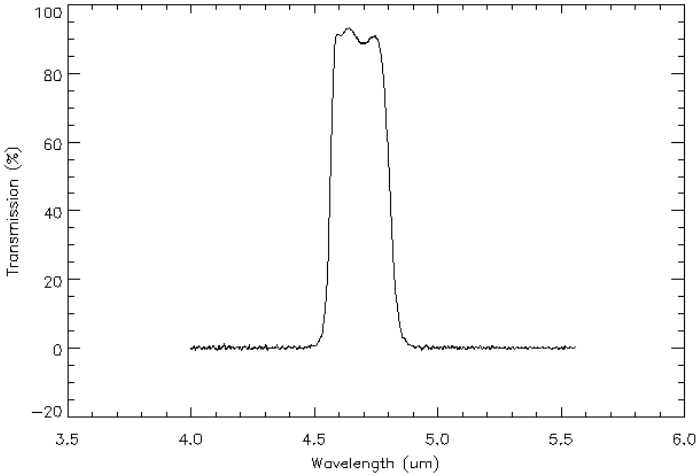


Fig. Instrumental function

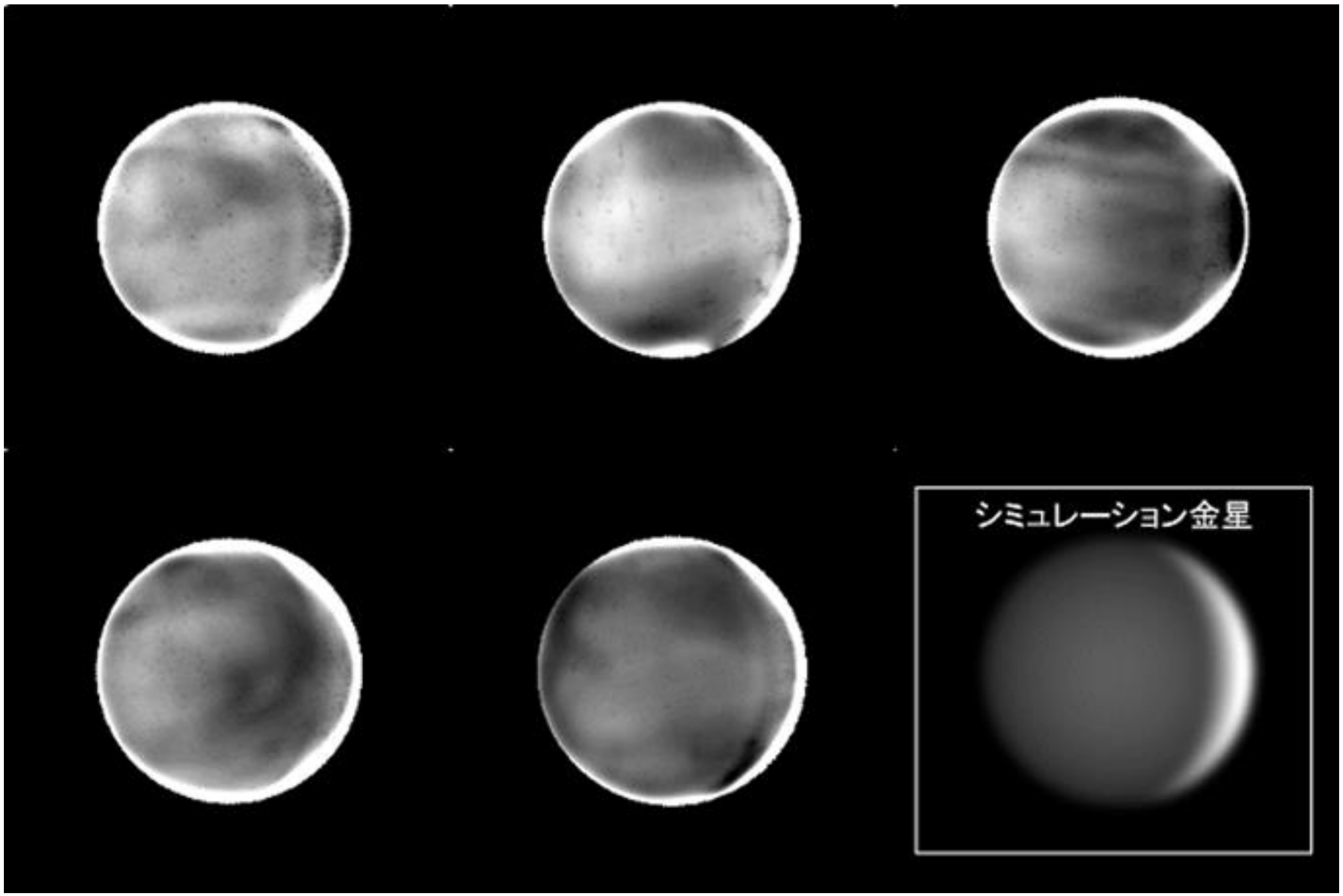
Observation brightness contrast of Venus in 4.7±0.15μm.

（Subaru Telescope）

This wavelengths contains CO2 absorption lines.

→We also calculate this spectrum for comparison.

An related study（Kouyama）
Brightness contrast at 4.7μm wavelength



Method

◎：Is cloud temp the primary factor？

We investigate three factors—temperature, summit height, optical thickness.

We change three factors on numerical calculation model and calculate brightness variation in 5.04μm and 4.7μm.

・Numerical calculation model： STAR Code（Nakajima, Tanaka, Hashimoto)

・Cloud model: Takagi Model

・Atomosphere model: VIRA(1985)

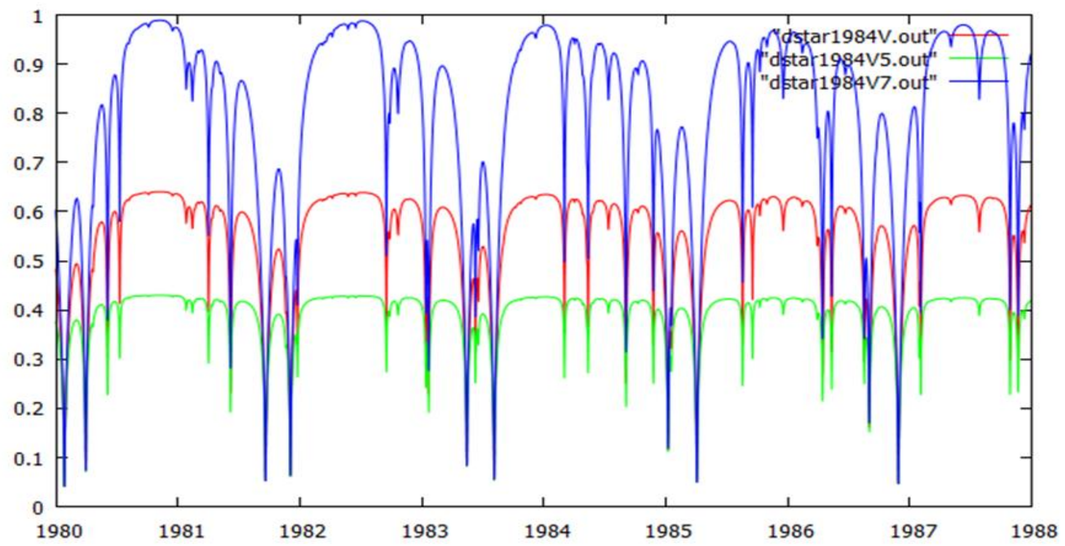


Fig. An example of numerical calculated spectrum
Brightness changes with cloud top height.

Estimation of possible deviation （Temperature, Cloud height）

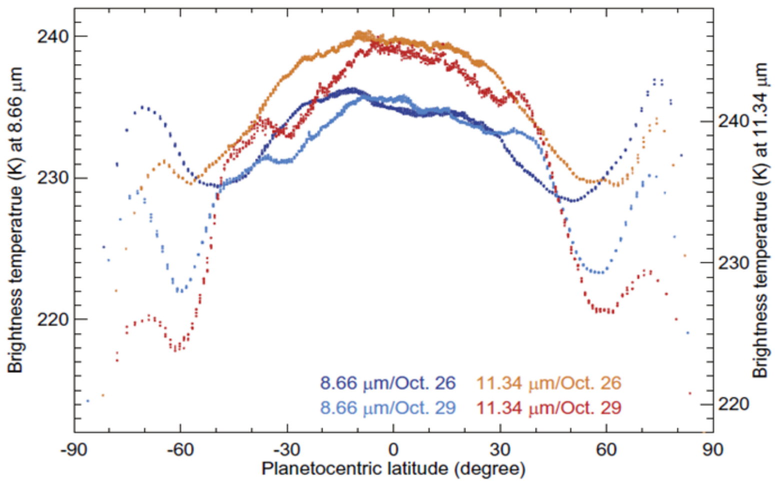


Fig : Recent data of temperature difference due to latitude given by 10µm observation (2014 T.M.Sato
"Cloud Top Structure of Venus revealed by Subaru/COMICS mid-infrated images")

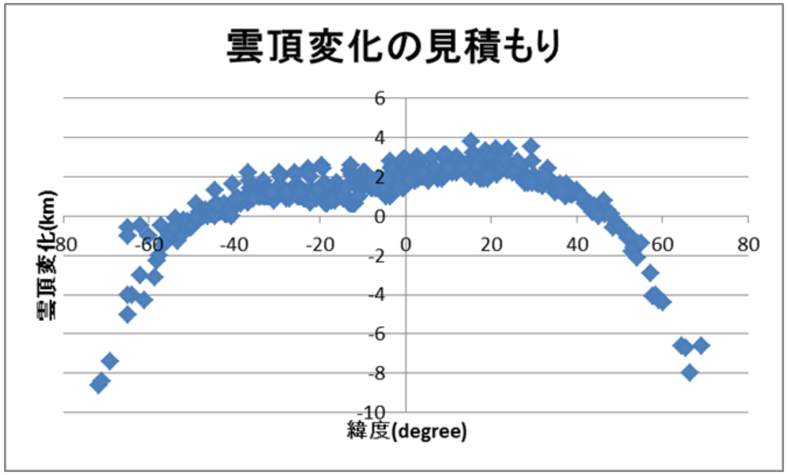


Fig : Recent data of cloud he ight variety given by 1.7µm observation （Iwagami）

At low latitudeds, temperature fractuaation is found to be +/- 3K.(In this study, only low latitude's variety is considered.)

4day-data are used.

At low latitude, cloud top fractuaation is found to be +/-1.23km

Estimation of possible deviation （Optical thickness）

	Attitude(km)	PV	V9	V10	V11	V12	V13	V14	Mean
Upper cloud	70-57	14	6	20	7	6	3	12	10
Middle cloud	57-50	8.4	15	27	9	12	21	10	14.5
Lower cloud	50-47.5	5	2	8	12	20	7	5	8.5
Precloud	48-46	-	-	-	-	-	0.2	0.6	-
Lower haze	48-30	1.4	<3	<3	-	-	-	-	-
Total	27-29	27-29	20-25	50-55	28	38	31	28	33

Table. Observed optical thickness by Pioneer Venus(PV) and Venera(V)（1986 Krasnopolky)

From these data, I calculate unbiased estimation of population variance of optical thickness.

5.04μm and 4.7μm light hardly transmit cloud, so I expect prime layer should be upper cloud. So I calculate variance of each layer, not of the whole cloud.

Upper cloud:±59%,Middle cloud:±48%,

Upper+Middle cloud:±42%

Result（Temperature）

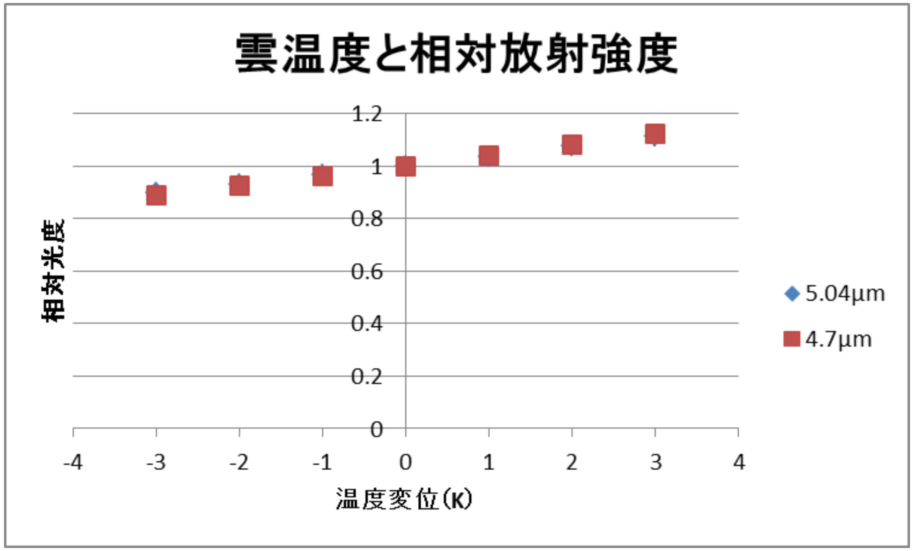


Fig. Brightness variety due to temperature

The whole cloud temperature is changed for the same degree in model.

・Brightness increases with temperature monotonously.The sensitivity difference between 5.04µm and 4.7µm is little.

・As temperature varies 3K, brightness varies about ±10%.

Result（Cloud height）

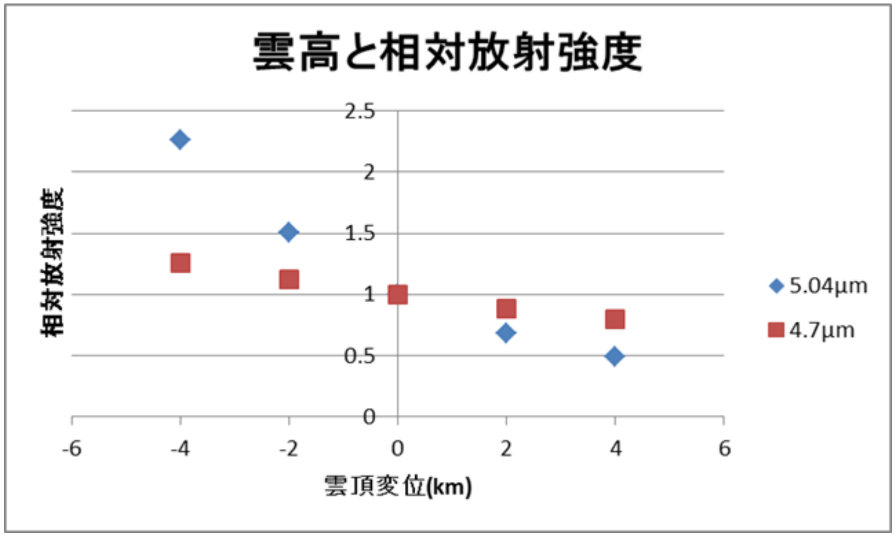


Fig. Brightness variety due to cloud height

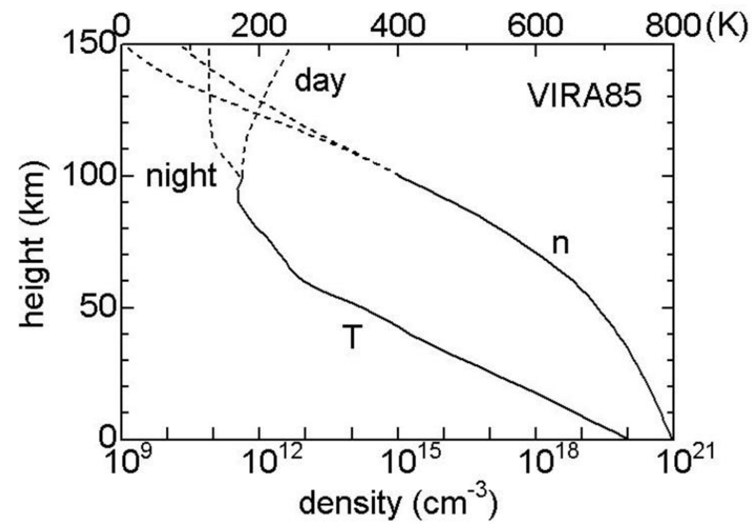


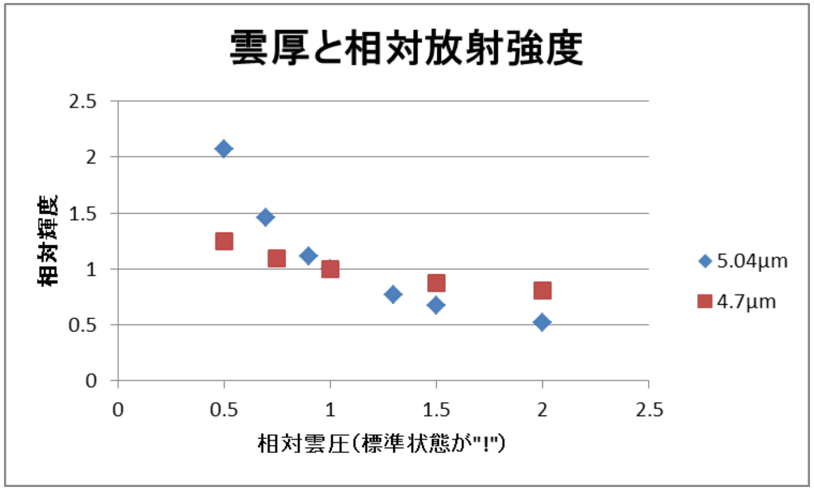
Fig. VIRA model

The cloud is shifted upward or downward in model.

・Brightness falls with cloud height monotously. The sensitivity in 4.7µm is about 1/6 smaller than that in 5.04µm.

・In atmosphere model, since 2km upward shift causes 7K increae in temperature, so the result is caused by not only temperature variety caused by height variety.

Result（Optical thickness）



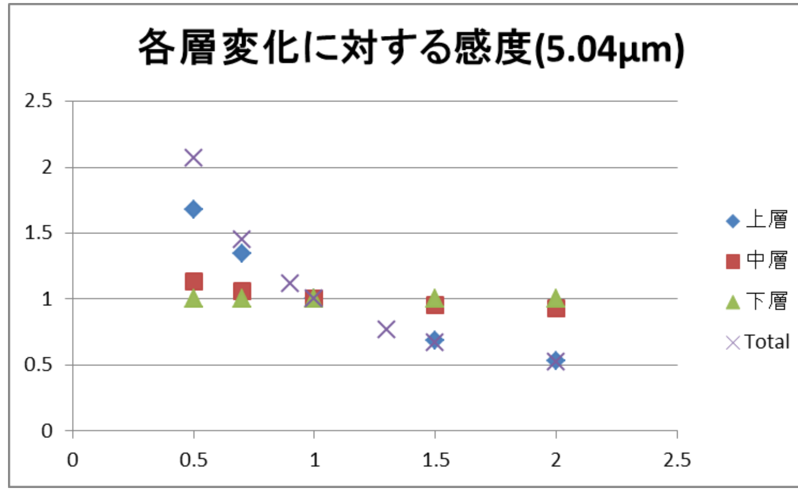


Fig.　Brightness variety due to optical thickness

Optical thickness of cloud model is changed in model.

・Brightness changes nearly inversely proportional to the thickness in 5.04μm.

・Twice optical thickness gives -4km variety of weight function peak, so the two factors correspond.

・Upper cloud is the prime factor of this variety.

Summary

5.04μm	4.7μm
Cloud height……±15%	Cloud height……±5%
Optical thickness……+100～-50%	Optical thickness……+24～-13%
Temperature……±10%	Temperature……±10%

Table. Possible variety due to each factors

・The primary factor is optical thickness,(not temperature).

・Interpreting 5.04μm and 4.7μm image, we should pay attention to this point.