Ultra Violet Imager on Venus Climate Orbiter

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Summary

JAXA/ISAS plans to launch a mission called "Venus Climate Orbiter (VCO)" in 2008 to study the atmosphere of the Venus and to understand the origins of the atmosphere of the Earth. The scientific objectives are outlined below.

To understand the mechanism of the revolution of the atmosphere
To understand the structure of meridional circulation
To survey the mesoscale phenomenon
To understand the mechanism of cloud formation and lightning descharge
To measure the ground surface radiant emittance and exploration of active volcanoes.

To achieve these objectves, five cameras which are designed for differant wave length will be installed on the orbiter and visualize the atmospheric motion on Venus with respect to the ground surface in full circumference and in three dimensions.

Ultra Violet Imager (UVI), one of VCO cameras, measures SO2 (280nm) and unknown absorber (365nm) distribution on dayside cloud top by using SiCCD to estimate Cloud-tracked winds. We have designed UVI taking account of best imaging, radiation dose, weight/power limit etc., and will make preflight model since april 2005.

Science Objectives

Cloud/Haze Physics

Largescale(10^3〜10^5km) - Mesoscale(1〜10^3km) Structures.
Interaction between Lower and Middle Atmospheres

Atmosphere Dynamics

Super-rotation
Largescale/Mesoscale Wind Distribution
Planetary Waves/Gravity Waves

Distribution of Unknown Ultraviolet Absorber

Photochemical Processes of SO_2 and H_2SO_4

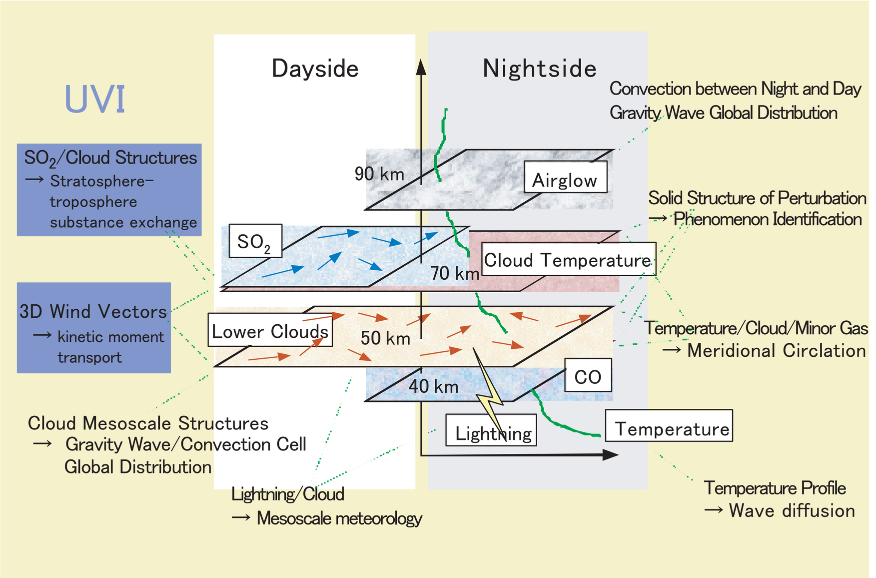
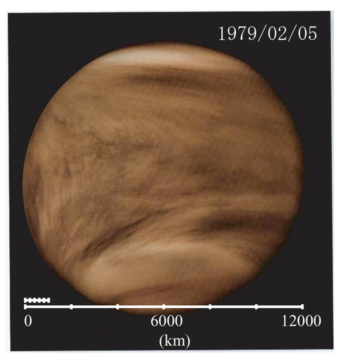


Fig.1.1: Concept of the three-dimensional visualization of Venus meteorology in the proposed mission (From Japanese Venus Mission Proposal,Fig:1.3-8).

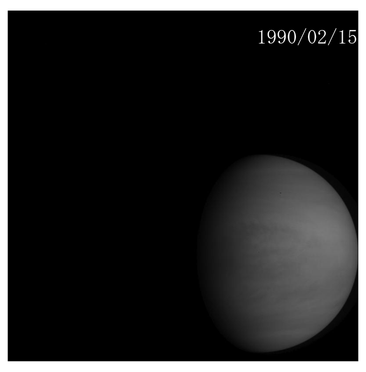
UVI Observation Outline

By using the knowledge of the past satellite observation, in order to attain the science purpose, it optimizes so that efficient observation can be performed. Global data is obtained in short exposure time by the two-dimensional solid state imager.

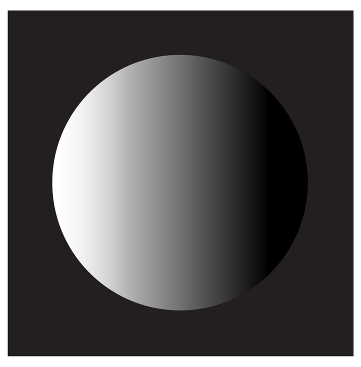
Characteristic	Explanation
High spatial/temporal resolution	To mesure mesoscale structures.
Pair Obserbation (separated from 2-4hour)	To estimate wind vector distribution
Long term observation	To estimate meridional circulation



Vehicle: Pioneer Venus Orbiter
Instrument
Imaging method: Spin-scan mapping by Photodiode
Exposure Time: 3.5 hour
Imaging Interval
Spatial Resolution: 〜500km, 〜30km
Filter Center: 300〜390nm
S/N: 〜100
※Only wind velocity long-term observation



Vehicle: Galileo
Instrument: Solid-State Imaging
Imaging method: two-dimensional CCD 800x800, 8bit
Exposure Time: 25 msec
Imaging Interval: indefinite
Spatial Resolution
Filter Center
S/N
※65 images was taken in UV.



Vehicle: Venus Climate Orbiter
Instrument: Ultra Violet Imager
Imaging method: two-dimensional CCD 1024x1024 12bit
Exposure Time: under 1sec
Imaging Interval: 2〜4 hours
Spatial Resolution: 10km (@3.7Rv)
Filter Center: 280nm, 365nm (FWHM30nm)
S/N: 100 (targeted value)

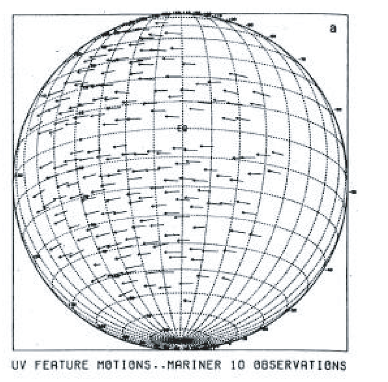


Fig.2.1: The wind distribution that was calculated by an image out of purple of Mariner 10 (Limaye and Suomi, 1981). Such wind distribution will be estimated continually using data by UVI.

UVI Performance

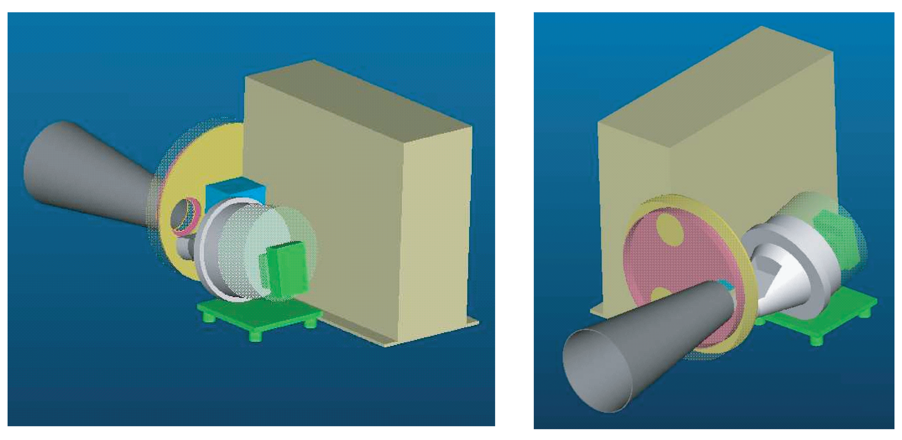
observation method	dayside	obserbation of the scatterd solar light by clouds top
Sensor Type		The imager using the reflective refraction optical system
Obserbation Wave length		280nm , 365nm
Wavelength Resolution		30nm
FOV		12°
Angler Resolution		0.015° (@13Rv)
S/N		100 (Target Value)
Sensor Temperature		23±3℃
Optics	Total F Number	16
	Synthetic Focal Length	63.3 mm
	Aperture	Effective aperture 3.96mm
	MTF	the Center of the Field: 0.82 the edge of the field: 0.80
	Spot size	the Center of the Field: 1 μm the edge of the field: 1 μm
	Glass material	Zero-dur (board)+Al+MgF2(coat)
Detector	Type	Si -CCD(The number of elements: 1024×1024)
	Cooler	None
	Temperature	0℃
	Exposure Time	1sec
	Quantum bit Number	12bit
Filter	Filter Wheel	Position: front of lens
	Wave Center	280nm/365nm 38.5φ
	Width	30nm
Shutter		Mechanical (T. B. D)
Hood	Type	Single Cone
	Size	T.B.D
	Hood Temperature	No Control
Mass		3.2kg
Electric Power	Measure	9.4W
	Stand-by	4.4W
Data rate under AD convert		T.B.D

Component	Module	Element	Component [kg]	Module [kg]	Element [kg]
UVI-S	Hood	Hood	1.71	0.09	0.09
		Hood Bracket			0.00
	Sensor	Lens		0.76	0.10
		Detector			0.10
		Filter			0.10
		Thermal Strap			0.20
		Insulator			0.02
		Case			0.24
	Filter Wheel	Filter Wheel		0.85	0.52
		Motor+Bracket			0.33
UVI-AE		Circuit PWB+E (x3)	1.50		0.60
		Circuit shackle			0.05
		bolt			0.135
		Case			0.71
Total			3.21		

UVI Weight Detail

Component	Module	Element	Observation(W)		Standby (W)	
UVI	Hood		.0.0		0.0	
	Sensor	Detector		3.00		1.10
		Filter Wheel	3.0		1.1	
		Preamp				
	Sensor Controller	ADC Board	2.0	6.4	1.0	3.3
		TMG Board	1.5		0.8	
		Power Supply Board	2.9		1.5	
合計				9.37		4.35

UVI Electric Power Detail



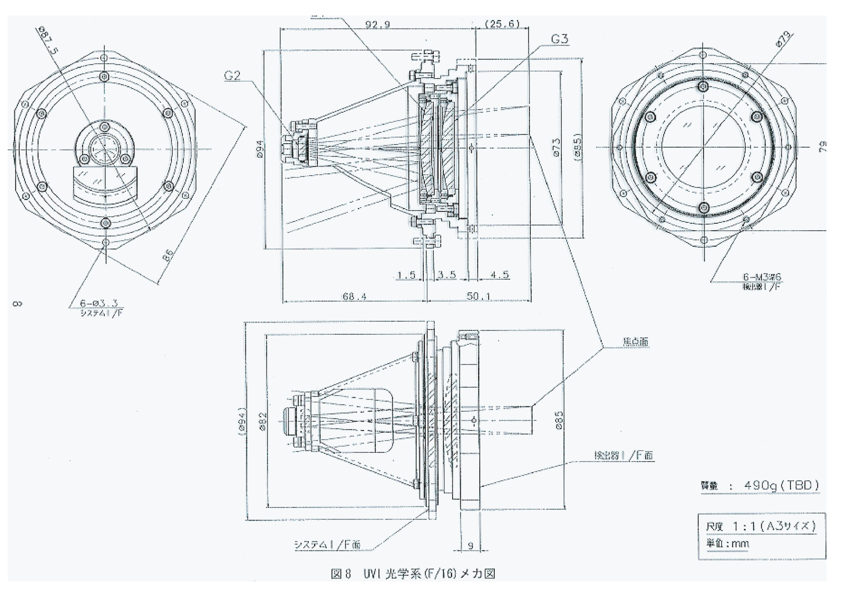


Fig.3.1: Above) Ultra Violet Imager. Below) UVI Optical system.

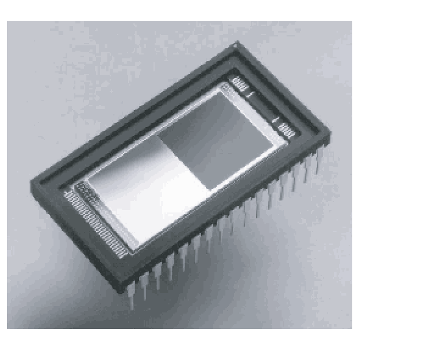


Fig.3.2: E2V CCD47-20NIMO

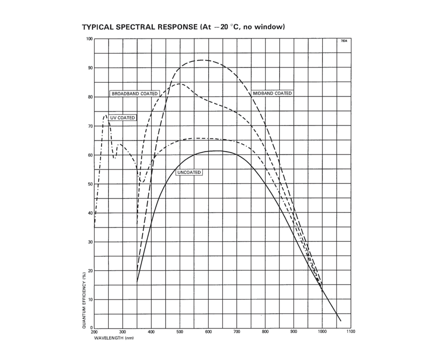


Fig.3.3: CCD47-20 quantum efficiency

Optimal wavelength

Using observation of the scatterd solar ultraviolet light by topside clouds, we know distribution of unknown absorber and SO_2. The filter center is chosen as following:

For unknown absorber:

365nm is chosen because it is same wave length as PVO observation.

For SO_2 distribution:

Advantageous wavelength is calculated in consideration of the absorption characteristic of SO_2.
The contrast maximum is near **280 nm** (It is a low wavelength side from an absorption belt peak). (Fig.4.2)

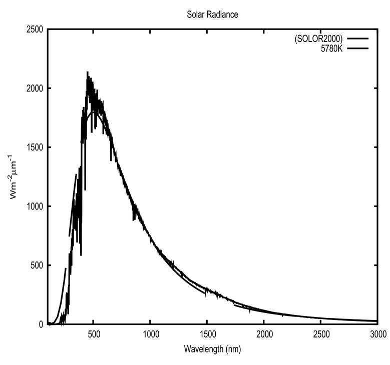


Fig.4.1: Spectrum of SOLAR2000 model and 5780K black body radiation in the Venus distance. Since solar radiation spectrum has the gap from that of black body radiation around ultra violet, the estimation is archieved using both 5780K black body radiation and SOLAR2000 model.

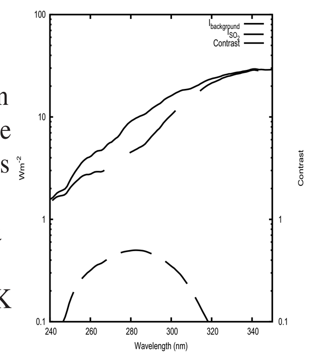
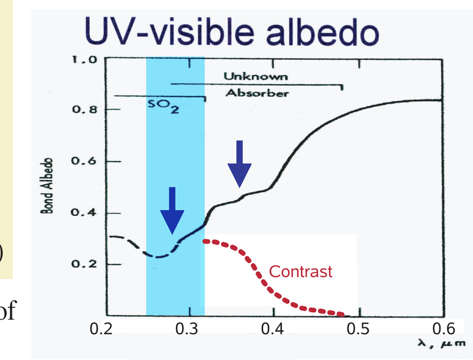


Fig.4.2: Presumption of the contrast by SO_2 absorption. The result about the case of dl=15nm. It becomes the contrast maximum when it is made the main wavelength of 282nm. The contrast maximum approaches 284nm of an absorption belt peak as dl becomes small.



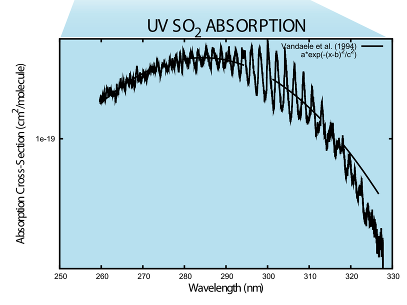


Fig.4.3: Above: The Venus albedo in 200 to 600 nm presumed from the past observation, and contrast of the absorption pattern in near ultra violet wave length (Moroz et al.,1985). Below: Near 300nm Absorption cross-section area of SO_2 (Vandaele et al., 1994). It was used when estimating the contrast maximum center wavelength.

The estimation method of the contrast maximum center wavelength

The following formulas estimate the contrast which the solar radiation absorption by SO_2 makes:

$$Contrast \propto 1-\frac{I_{SO_2}}{I_0}\sim 1-\frac{\int_{-\delta\lambda}^{+\delta\lambda} I_0(\lambda)e^{-\tau(\lambda)}d\lambda}{\int_{-\delta\lambda}^{+\delta\lambda} I_0(\lambda)d\lambda}$$

I0(l): Solar radiant flux density, τ : Optical depth of SO_2 clouds ±dl:Observation wavelength width

A denominator is radiation when all solar radiant flux are scattered ideally. A molecule is a value which estimates radiation of the result which SO_2 absorbed.The following values were used for calculation.

- ・Solar radiant flux: SOLAR2000 model or 5780K black body radiation(Fig.4.1).
- ・Optical depth of SO_2 clouds: The experimental data of Vandaele et al. 1994 (Fig.4.3)
- ・τ = nsl: Assuming that t becomes about one order, the value of n and l is given suitably.
- ・dl: It is regarded as the product of the CCD sensitivity characteristic and the filter transmission characteristic, and a value is given as a parameter..

Radiation Shielding

Comparing with a camera tube or a photodiode, CCDs have many merits of a low noise, low electric power, quantity sensitivity, low cost, etc. However CCDs are easy to be influenced of radiation, and it is needed to consider the measure which protects CCDs. measure which protects CCDs.

Is operation between missions (3 to 4 years) possible?

Worst case total dose: 30〜50Krad.
γ-ray: CCD characteristic is changed when 10Krad are exceeded. (From E2V Data sheet).
proton: CCD has damages to the half of a pixel when 10Krad are exceeded. (The 100MeV proton irradiation experiment result in National Institute of Radiological Sciences: Fig.5.1, Fig.5.2)

→Imaging is possible by using dark image correcting.

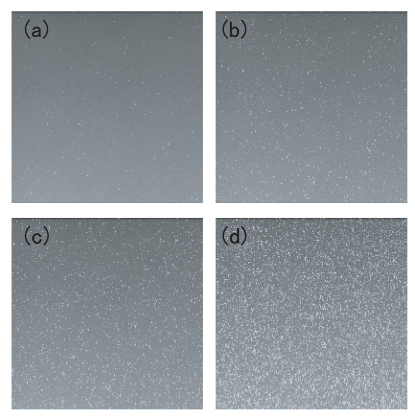


Fig.5.1: A part of CCD dark image (50x50 pixels) after 100MeV proton irradiation at several situation. As the amount of irradiation increases, the number of dark spike also increases. Each estimated total dose: (a): 12.8, (b): 72.8, (c): 322.8, (d): 2332.8 rad.

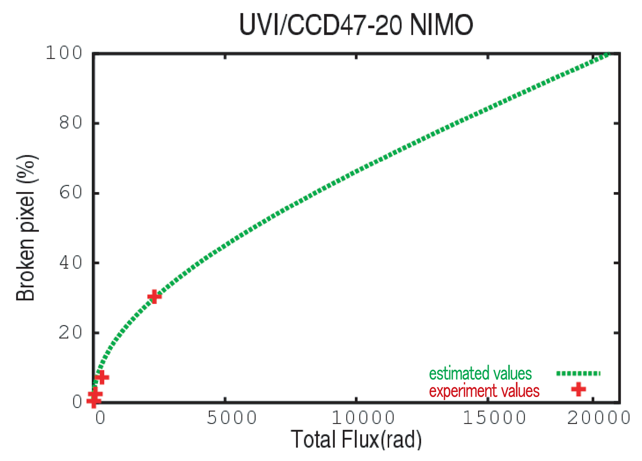


Fig.5.2: Relation between total dose and dark spikes of CCD47-20 NIMO. The presumed curve is estimated by probability calculation, and fitted with experiment values. Under 10 krad(s) total dose, it is expected that the half pixel of CCD receive some damages..

How should CCD be protected?

- Considering the structure of CCD47-20, the proton of several MeV energy gives maximum damage to the CCD (Fig.5.3).
  The CCD should be protected from the proton below this energy.
- The solar proton flux at the quiet time has an extremum near GeV energy (Fig.5.4).
  It is conversely disadvantageous if the proton near an extremum becomes near a number MeV grade as a result of protection.
- The characteristic of the quality of a shield materials (Dale et al., 1993)
  Al:shield is more effective per unit mass.
  Ta:shield is more effective per unit thickness
  Thickness equivalent to aluminum 10mm is an ideal shield.
  When weight-restrictions are also taken into consideration,
  Minimum thickness needed is equivalent to 3mm aluminum(Fig.5.5).

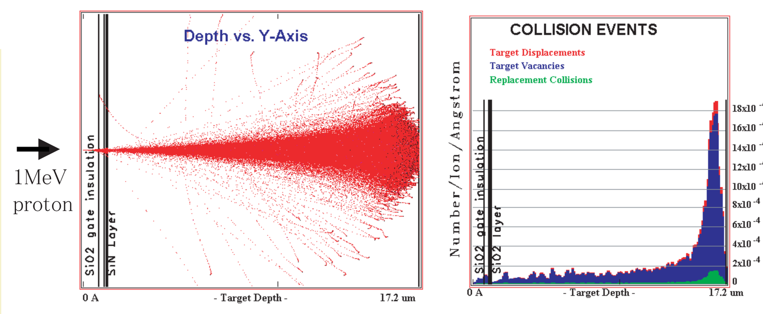


Fig.5.3: The Monte Carlo simulation result by TRIM. CCD47-20 is calculated as a target which consists of substances of six layers. The proton energy which gives the maximum damage is about 1 MeV. Left: Ranges at the simulation of irradiating 10000 1MeV protons perpendicularly from the front of CCD, Right: The situation of the damage caused to CCD.

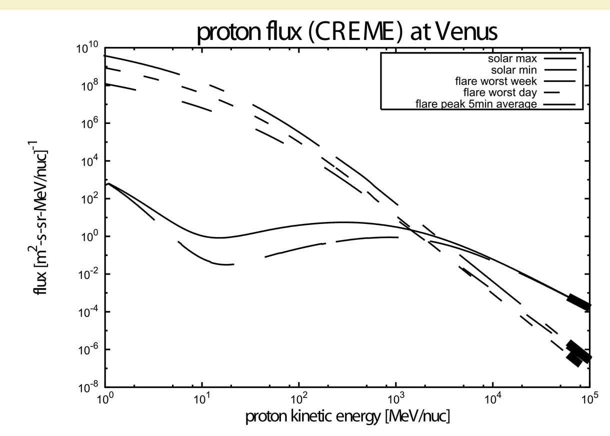
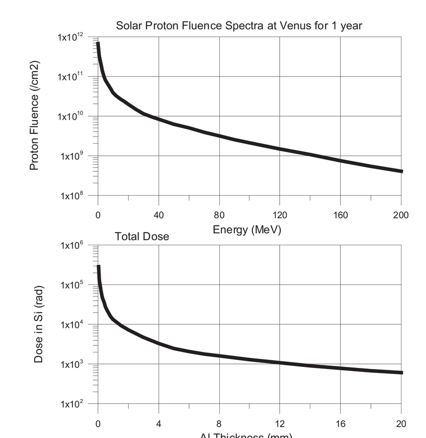


Fig.5.4:The proton flux around Venus which is estimated using the CREME model. At the time of a flare event, it is monotonous reduction as it becomes high energy. At the time of quiet time, it has an extremum near GeV energy.



Space EnvironmentInformation System

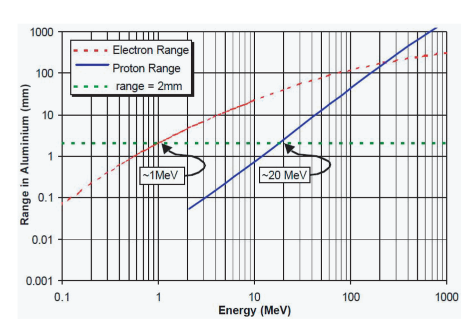


Fig.5.5: Ranges of electron and proton in aluminum. With about 3mm aluminum, CCD can be shielded from the proton of 25MeV.

Future schedule

○ It will be a start schedule about creation of an engineering model from April, 2005. Development of a driver is needed.

○From the thermal demand of a satellite system, it became clear recently that a radiator may be needed for UVI. In this case, certain kind of lightweightizeing is required.

○Examination of the calculation algorithm of a wind vector distribution, and program creation will be needed.

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