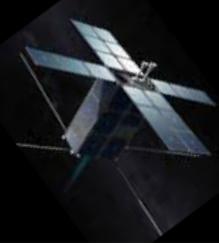


CubeSat UV Experiment (CUVE)

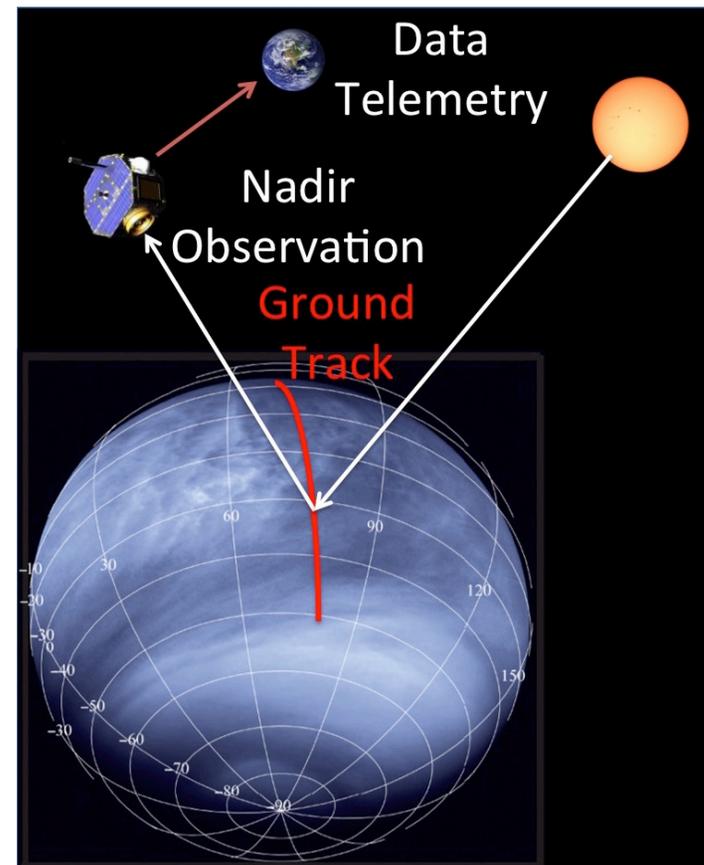


CUVE – CubeSat UV Experiment: Unveil Venus ‘ UV Absorber with CubeSat UV Mapping Spectrometer

Characterize Venus’ unknown UV absorber(s)
to understand the planet’s radiative and thermal
balance, atmospheric dynamics, and chemistry of
its upper clouds

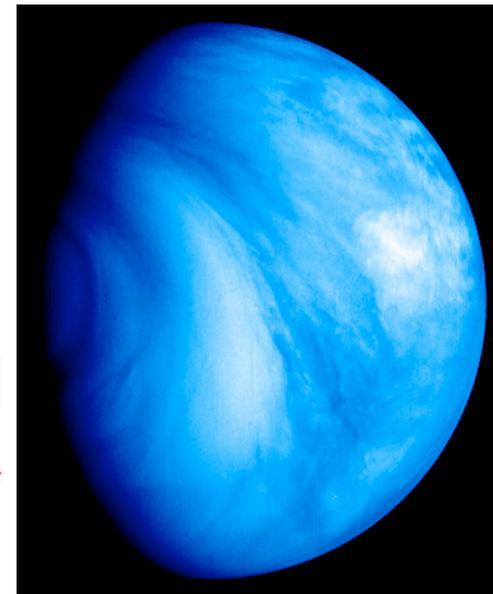
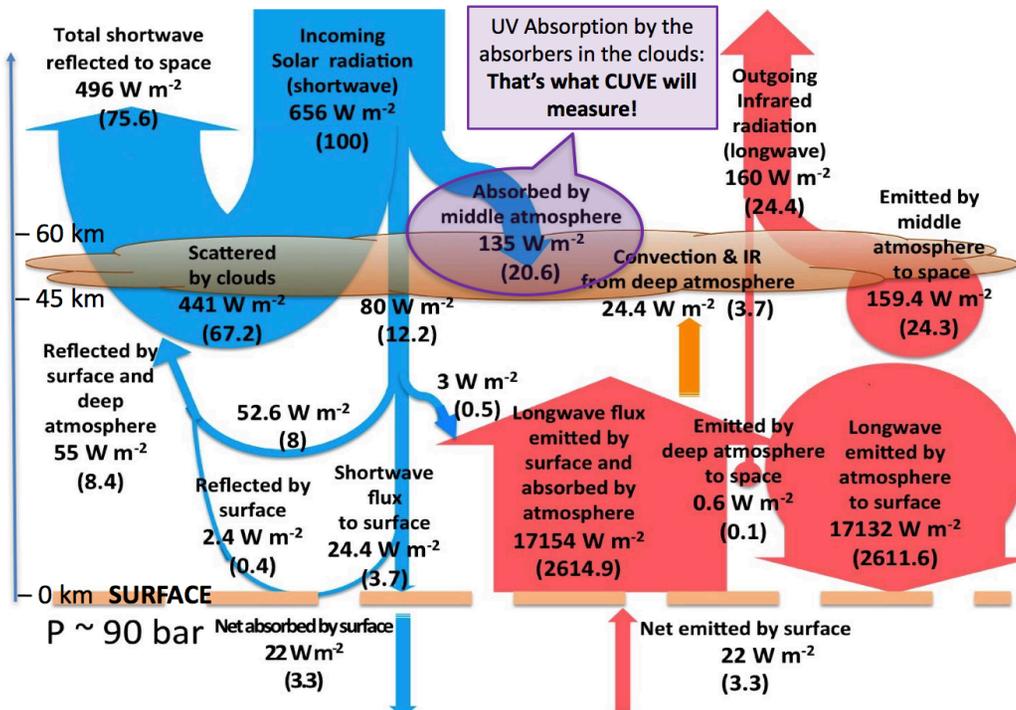
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Funded through the NASA NASA Planetary Science
Deep Space Smallsats Program



CubeSat UV Experiment (CUVE)

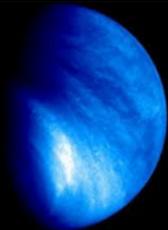
- Venus clouds reflect in the visible most of the incoming solar radiation (albedo ~75–90%)
- The bulk of down-welling SW solar radiation absorption occurs in the UV
- ⇒ A still unknown absorber in Venus clouds absorbs in the UV ~50% of the incoming solar radiation
- ⇒ Clouds and absorber determine Venus' atmospheric equilibrium
- This absorbed energy is the primary atmospheric engine of Venus



What is the nature of this absorber?

⇒ Venus UV spectrum!

Detailed radiative energy balance in the atmosphere of Venus (Read et al., 2016).



CubeSat UV Experiment (CUVE)



Venus in the **visible** is quite **featureless**, in the **UV** we observe **dark and bright regions**.

- Dark regions: half of the solar energy received by Venus is absorbed in the UV by a still **unknown absorber situated at the top of the planet clouds layer**.

- **What is the nature of this absorber and why does it absorb so much?**

- **This is still one of the most important but unanswered questions about our twin planet!**

▶ We need to determine the nature, concentration and distribution of UV absorbers to understand the **overall radiative and thermal balance of the planet, atmospheric dynamics and the chemistry of the upper clouds**.

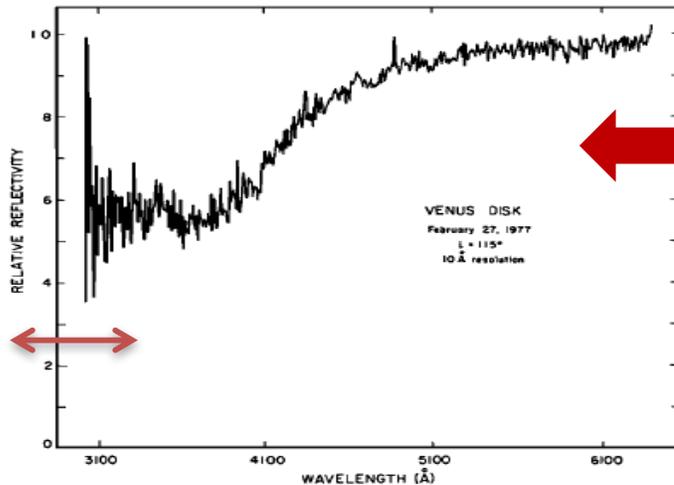
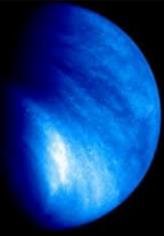
An Unsolved Problem

- Some **possible species have been proposed to explain the nature of the contrast features in the UV**:

S_x , SO_2 , Sn , SCl_2 , S_2O , $FeCl_3$, Cl_2 and many others (C_3O_2 , CH_2O , $NOHSO_4$, NO_2 , N_2O_4 , NH_3NO_2 , $(NH_4)_2SO_4$, $(NH_4)_2S_2O_5$, NH_4Cl , Cl_2 , SCl_2 , $HClO_4$) (*e.g.*, Pollack *et al.*, 1980; Zasova *et al.*, 1981; Toon *et al.*, 1982; Na and Esposito, 1997; Krasnopolsky 2006),

- **Thus far, the origin has not been established**

CubeSat UV Experiment (CUVE)



Left: Venus spectrum
(Barker et al., 1979) –
Ground-based
observations

Right: synthetic spectrum
(from Zasova et al.)

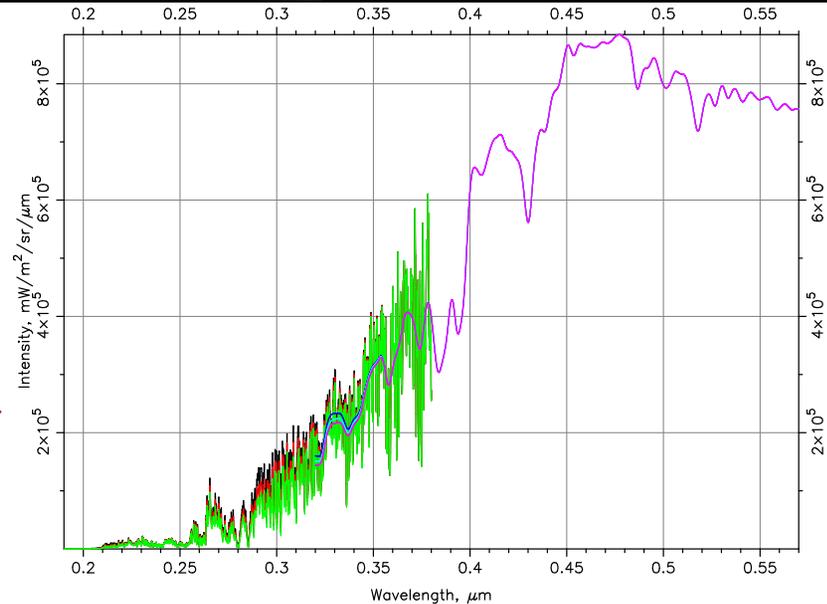


Fig. 2. Venus/Sun ratio spectrum.

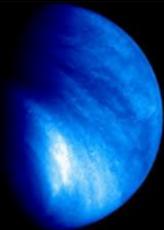
Venus UV spectrum

▶ UV dayside nadir is mostly solar light back-scattered by atmospheric cloud particles
=> information about scattering particles and gases encountered in the atmosphere by the scattered solar radiation.

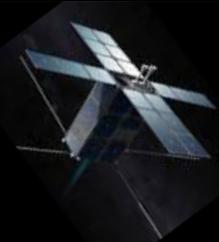
▶ The spectrum has multiple absorption features between 200 and 500 nm:

- SO₂ and also SO bands between 200 and 320 nm
- An other absorber above 320 nm.

Inhomogeneity in spatial and/or vertical distribution of the **unknown absorber** produces the famous **UV features** [used to study the **dynamics of the clouds**]



CubeSat UV Experiment (CUVE)



Previous UV observations

Pioneer Venus low spectra resolution (1.3 nm) and spectra too noisy (*e.g.*, Stewart *et al*, 1979)

VMC on Venus Express and Akatsuki gave us great data/UV images, not spectra!

Venus Express bands not resolved both in VIRTIS and SPICAV spectrometers:

- VIRTIS-M VIS channel insufficient spectral range and resolution to resolve the 1 nm spaced lines of SO and SO₂ bands (spectral range 283.85 - 1098.98 nm, ~ 2 nm spectral resolution), stray light contamination of the spectrum, not clear absorption at 365 nm;
- SPICAV best resolution is ~ 1 nm or lower (1.5 nm with more data binning and better S/N - in nadir ~ 10-100)

Hubble Space Telescope acquired UV spectra (Jessup *et al.* 2015), but will not be able to acquire more due to Sun-avoidance requirements

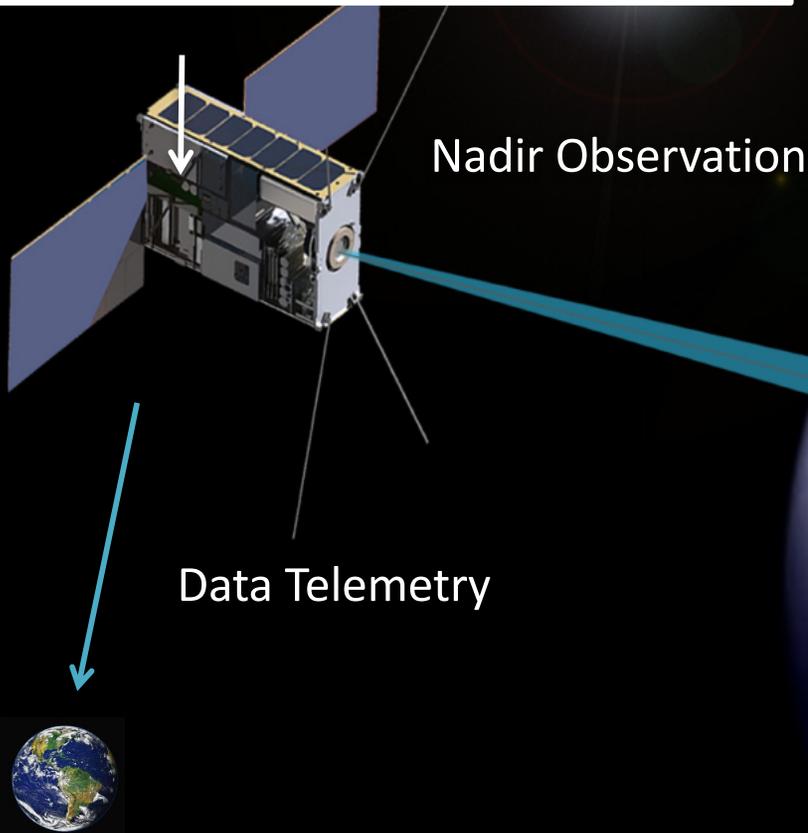
There are no any high resolution and high SNR UV spectra of Venus acquired from space in the spectral range 200 – 570 nm

Difficult to investigate the UV absorber from Earth's surface due to strong UV absorption in Earth's atmosphere

We need a good UV spectrum!

CUVE will provide high resolution UV spectrum of Venus

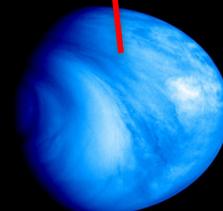
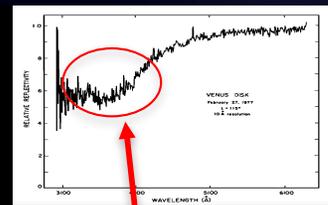
CUVE – Cubesat UV Experiment
– on a polar orbit around **Venus**



Venus' UV absorber in its clouds top:
-drives Venus' thermal radiative balance
-produces high contrast features
-Still unknown!

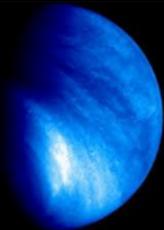
CUVE Payload

- **UV image spectrometer**
200 – 570 nm, 0.2 nm spectral resolution
- **UV multispectral imager**
320 – 570 nm



UV absorbers nature

UV absorber distribution and atmospheric dynamics

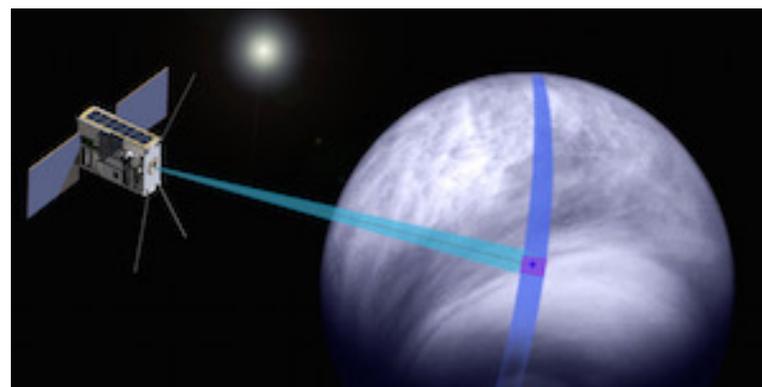


CubeSat UV Experiment (CUVE)



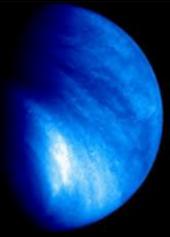
CUVE Payload:

- **UV image spectrometer** 200 – 380 nm, 0.2 nm spectral resolution
- **UV multispectral imager** 320 – 570 nm, 4 nm spectral resolution

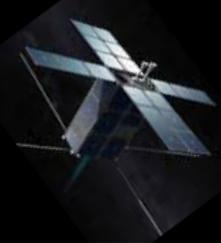


Instrument Summary

Telescope diameter (mm)	80	
Total Spectral Range (nm)	200 - 570	
Detectors	CCD (custom coating)	
	Spectrometer	Imager
Type	Low scattering Czerny Turner design	Linear Variable Filter Imager
Spatial Resolution (km) @66000km	3	3
Angular Resolution (arcsec)	5	5
Spectral Range (nm)	200 – 380	320 - 570
Spectral Resolution (nm)	0.2	4

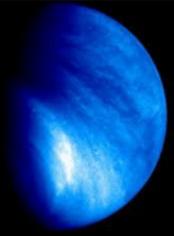


CubeSat UV Experiment (CUVE)



Mission Overview, Schedule and Launch Opportunities

- **CUVE** is a **12U** high-altitude orbiter on an **elliptical orbit around Venus**
- It will perform mostly nadir dayside observations
- **CUVE mission concept was designed to be as compact as possible to increase launch opportunities flying as a CubeSat rideshare reaching Venus as secondary payload of a planetary mission**, including missions that are not targeting Venus or low-Earth orbit (LEO) or a geostationary transfer orbit (GTO), or take advantage of a heliophysics mission launch, an inner solar system mission launch or a Department of Defense launch.
- **Launch opportunities:** Rideshare/hitchhiker missions associated with NF4, Discovery, Ocean Worlds, VenusBridge, EnVision, Venera-D
- **While no Venus mission is currently planned, this versatility greatly increases the chances to conduct the CIUViS science investigation.**
- It will have a minimum science phase of 6 months.



CubeSat UV Experiment (CUVE)



Relevance

- The study of Venus is part of the 2014 NASA Science Plan - Planetary Science Division (Objective 1.5).
- A UV investigation is also part of the Decadal Survey "Visions and Voyages for Planetary Science in the Decade 2013-2022" and the Venus Exploration Analysis Group (VEXAG I.b.1-2, I.c.1-2).
- This is a CubeSat mission with compact technology and highly demanded science return very relevant for the Small Innovative Missions for Planetary Exploration (SIMPLEx) program.

Acknowledgements

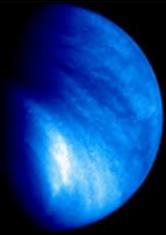
We gratefully acknowledge the support of

- NASA Planetary Science Deep Space SmallSat Studies (PSDS3) program
- NASA/GSFC

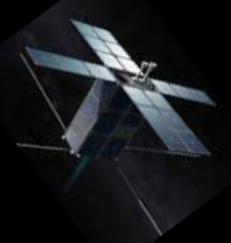
Current Status

We successfully completed our study with NASA/GSFC-WFF Mission Planning Lab.

We are working on our written report to HQ due at the end of November, and in-person debrief first week of December.



CubeSat UV Experiment (CUVE)



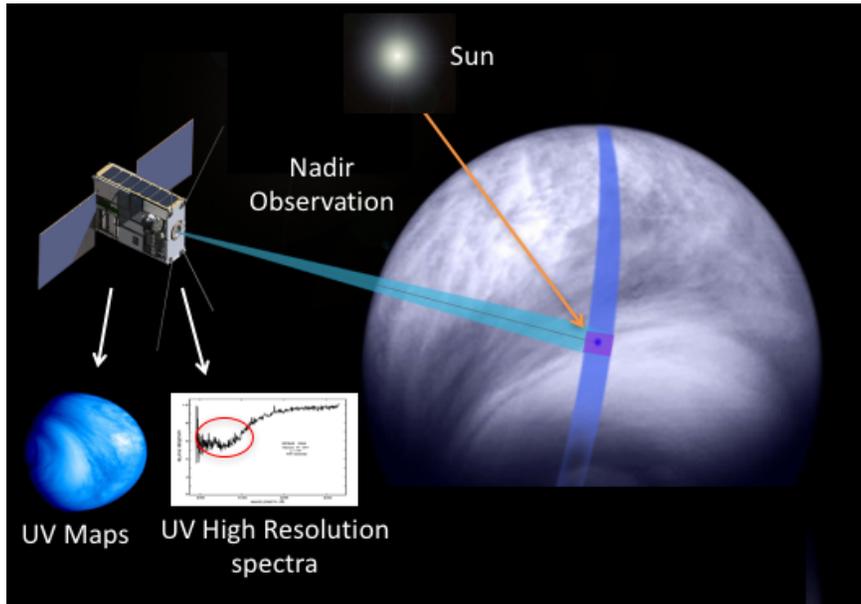
Impact

- ▶ CUVE will produce **broad spectral range** (200 - 570 nm) and **high spectral resolution** (0.2 nm) UV spectrum of Venus from space.
- ▶ CUVE, with its high spectral resolution spectrometer, broad spectral range covering all possible UV absorbers and its contextual imager, will be an **excellent platform to study Venus' atmospheric properties at the top of its clouds** where the UV absorption drives the planet's energy balance.
- ▶ CUVE would complement past, current and future Venus missions, and **provide great science return at lower cost.**

Summary

- Will address a long standing unknown absorber in the atmosphere of Venus.
- **CUVE payload is a composite UV-visible spectrometer optimized for CubeSats.**
- Addresses Venus community science: UV investigation is part of the Decadal Survey and the Venus Exploration Analysis Group (VEXAG I.b.1-2, I.c.1-2).
- Development state: Mission study completed, full report to HQ in preparation.

CubeSat UV Experiment (CUVE)



TEAM MEMBERS/INSTITUTIONS:

Principal Investigator:
Valeria Cottini (UMCP)

Co-Investigators:
Shahid Aslam (NASA-GSFC)
Nicolas Gorius (CUA)
Tilak Hewagama (UMCP)
Giuseppe Piccioni (INAF-IAPS, Italy)

Collaborators:
Lori Glaze (NASA-GSFC)
Nikolay Ignatiev (IKI RAN, Russia)
Emiliano D'Aversa (INAF-IAPS, Italy)

SCIENCE OBJECTIVES:

1) Nature of the "Unknown" UV-absorber; 2) Abundances and distributions of SO₂ and SO at and above Venus's cloud tops and correlation with the UV absorber; 3) Atmospheric dynamics at the cloud tops, structure of upper clouds and wind measurements from cloud-tracking;

PAYLOAD DESCRIPTION:

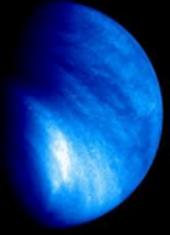
Payload includes (2U, 2kg)

- 200-380 nm image spectrometer (0.2 nm res)
- 320-570 nm multispectral imager (4 nm res)

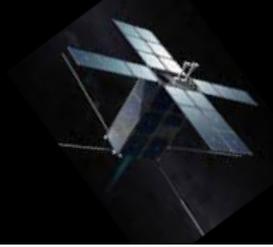
MISSION OVERVIEW:

Baseline Spacecraft Configuration

- CUVE is a 12U high-altitude orbiter in a polar orbit around Venus
- CUVE is a targeted mission, with a dedicated science payload and a compact spacecraft bus capable of interplanetary flight independently or as a ride-share with another mission to Venus or to a different target, in order to increase launch opportunities
- It will perform Nadir dayside observations
- Schedule: early-to-mid 2020s



CubeSat UV Experiment (CUVE)



Thank You