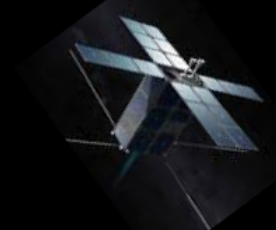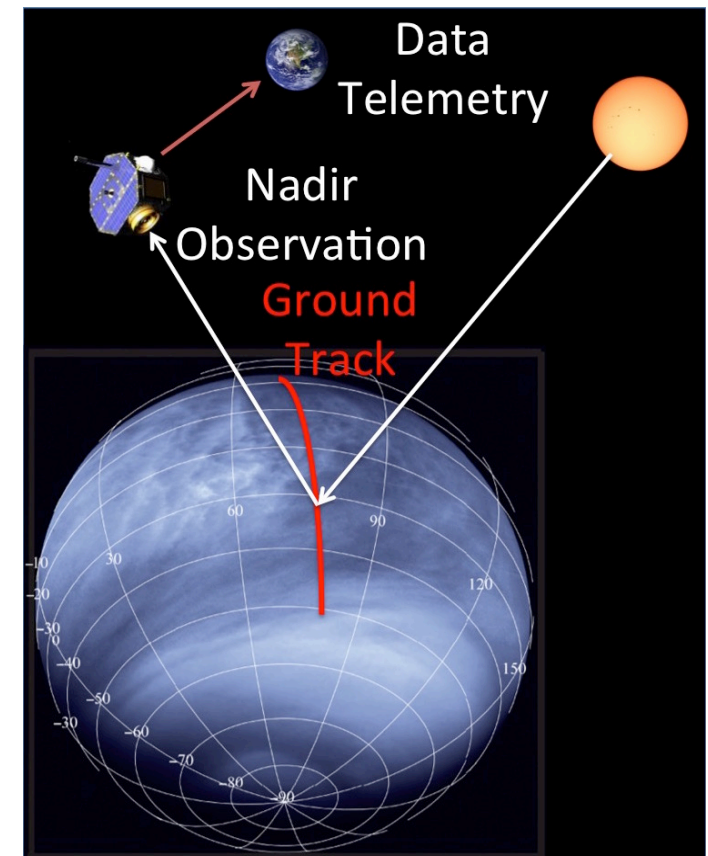# CUVE – CubeSat UV Experiment:
Unveil Venus ' UV Absorber with CubeSat UV Mapping Spectrometer

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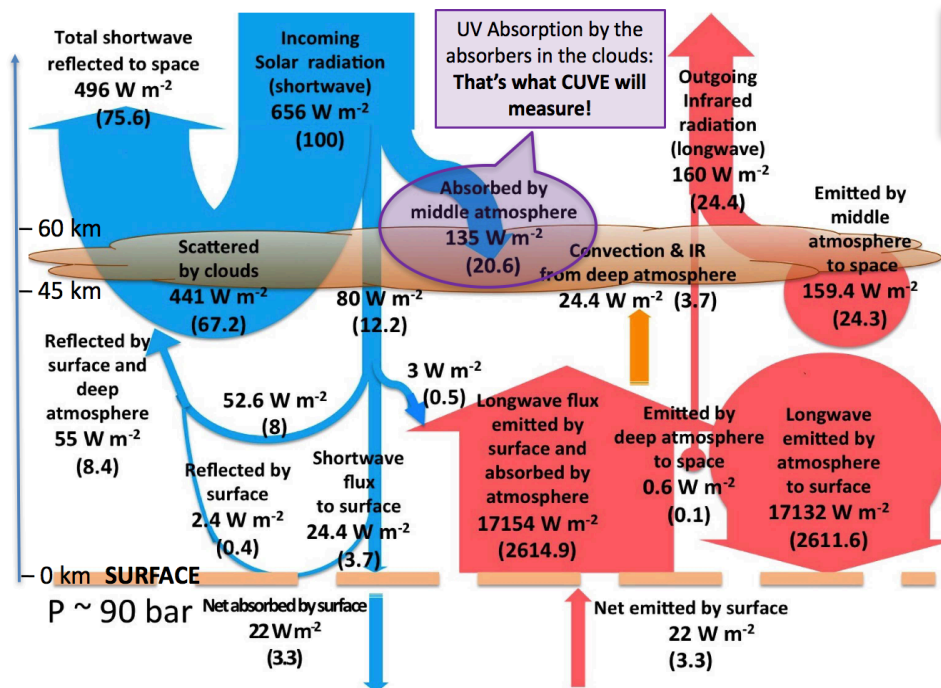

Data Telemetry

Nadir Observation

Ground Track

Venus Cloud Properties and Radiative Balance
- Upper cloud desk is a mix of 80% H_2SO_4 and H_2O
- Venus receives double of solar energy than Earth
- Venus and Earth systems absorb comparable SW power
- Clouds have high albedo in visible (~75–90%)
- About 50% of solar SW absorption is in the UV
- This absorbed energy is the primary atmospheric engine of Venus
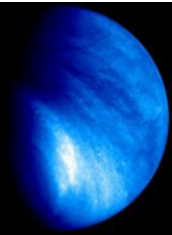- Clouds and absorber determine Venus' atmospheric equilibrium

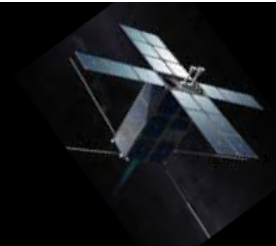*What is the nature of this absorber?*

	~2.5 kW/m²	~1.3 kW/m²
Solar constant		
Full disc avg	656 W/m²	341 W/m²

For Venus
- bulk of down-welling SW absorption is in the UV
- Clouds reflect 75-90% of SW

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!
This has implications for the **energy balance and dynamics of the whole atmosphere**.

▶ Determining the nature, concentration and distribution of the unknown UV absorber is fundamental to understanding the **overall radiative and thermal balance of the planet**, in particular the **atmospheric dynamics and the chemistry of the upper clouds**.
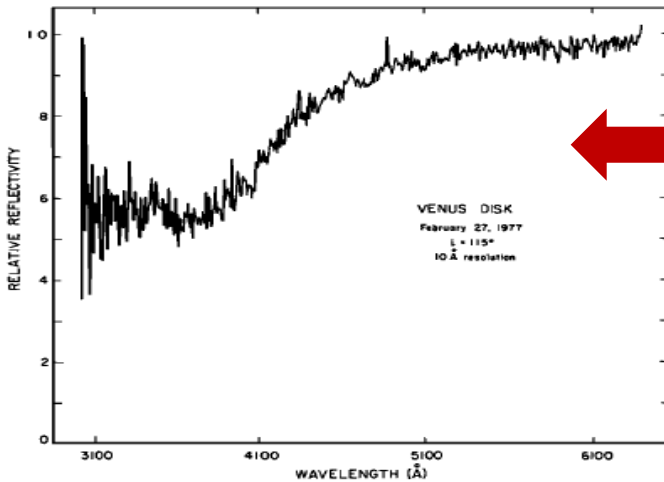
An Unsolved Problem
• Some possible species have been proposed to explain the nature of the contrast features in the UV:
S_x, SO_2, Sn, SCl_2, S_2O, $FeCl_3$, Cl_2 and many others (C_3O_2, CH_2O, $NOHSO_4$, NO_2 , N_2O_4, NH_3NO_2, $(NH_4)_2SO_4$, $(NH_4)S_2O_5$, NH_4Cl, Cl_2, SCl_2, $HClO_4$) (*e.g.,* 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)

Fig. 2. Venus/Sun ratio spectrum.

Left: Venus spectrum (Barker et al., 1979) – Pioneer Venus

Right: synthetic spectrum (from Zazova et al.)
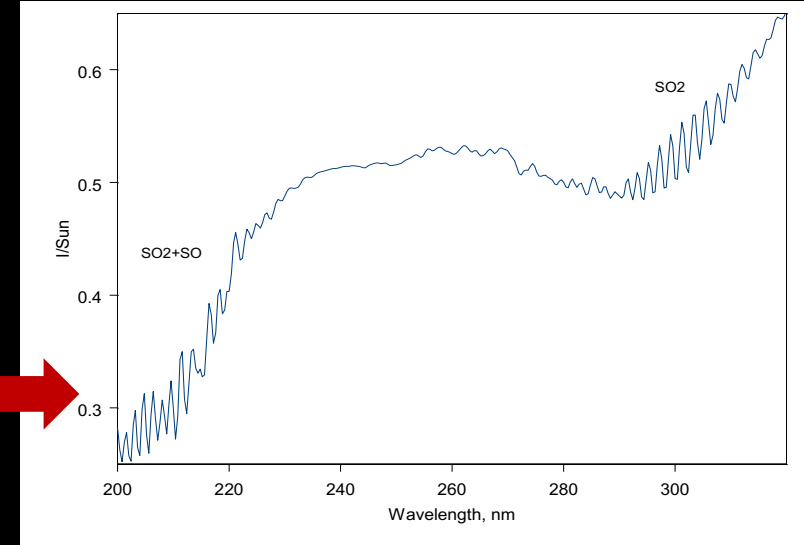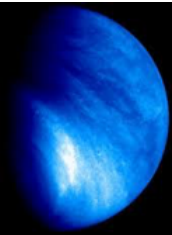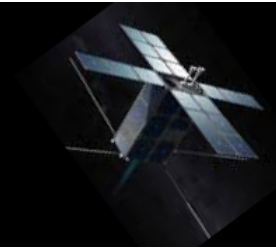

Venus UV spectrum

The dayside nadir looking UV spectrum of Venus is mostly composed of solar light back-scattered by atmospheric cloud particles => information about both scattering particles and gases encountered in the atmosphere by the scattered solar radiation.

▸ The spectrum has multiple absorption features between 190 and 500 μm:
• Pure absorption of CO_2 below 200 nm.
• In the region between 200 and 320 nm, at the cloud tops, are present SO_2 and also SO bands.
• The spectrum above 320 nm implies the presence of another absorber that has not been identified so far. Inhomogeneity in spatial and/or vertical distribution of the **unknown absorber** produces the famous **UV features** on the Venusian's disc. Tracking their motions has been usually used to study the **dynamics of the clouds**.
• Looking at the nightside at limb we can also observe **nightglow emissions** by NO, CO, and O_2.

Previous UV observations

- Pioneer Venus resolution was 1.3 nm and spectra were very noisy (*e.g.,* Stewart *et al,* 1979).
- Venus Express bands not resolved both in VIRTIS and SPICAV spectrometers: VIRTIS-M VIS channel had limited spectral range and resolution to resolve the 1 nm spaced lines of SO and SO_2 bands (spectral range 283.85 - 1098.98 nm, ~ 2 nm spectral resolution and stray light contamination of the spectrum) and the absorption at 365 nm it is not clear; SPICAV best resolution is ~ 1 nm and with more data binning and better S/N the resolution was even lower - 1.5 nm and the signal-to-noise ratio (SNR) in nadir ~ 10-100.
- VMC on Venus Express and Akatsuki gave us great data/UV images, not spectra.
- In fact, there are no any high resolution and high SNR UV spectra of Venus acquired from space in the spectral range 190 – 570 nm.
- Hubble Space Telescope acquired two UV spectra, but will not be able to acquire more due to Sun-avoidance requirements
- It is hard to investigate the UV absorber from Earth's surface due to strong UV absorption in Earth's atmosphere
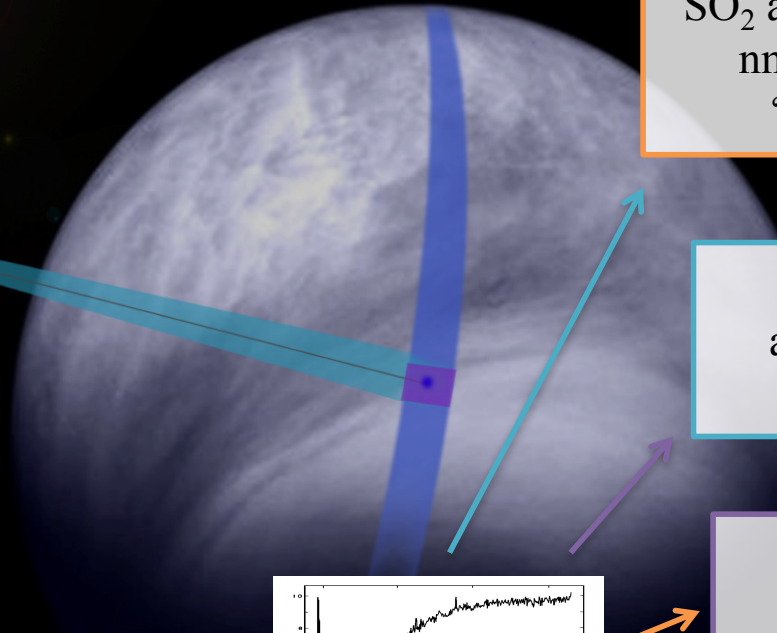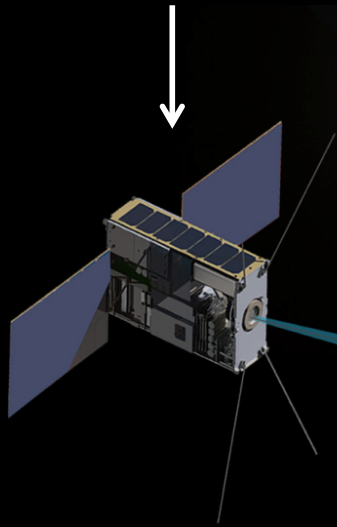
▶ We want a better UV spectrum

-> **CUVE will provide high resolution spectrum of Venus in the UV**

Cubesat UV Experiment (CUVE) will investigate Venus' atmosphere with two on-board science payloads.

Venus' strong UV absorber in its clouds top drives Venus' thermal radiative balance, produces high contrast features and its nature is still unknown.

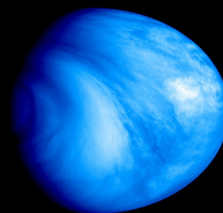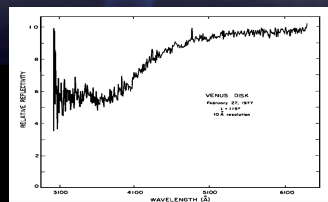SO$_2$ and SO absorption (190 – 320 nm) and correlation with the "unknown" UV absorber

Nature of the "unknown" UV absorber (range 320 – 490 nm) dayside

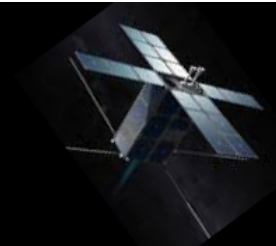UV Nightglow:
NO (190-300nm), CO (205-240nm), O$_2$ (400-500nm)

CUVE
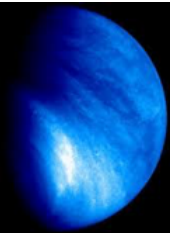-UV spectrometer
-UV multispectral imager

UV absorber distribution

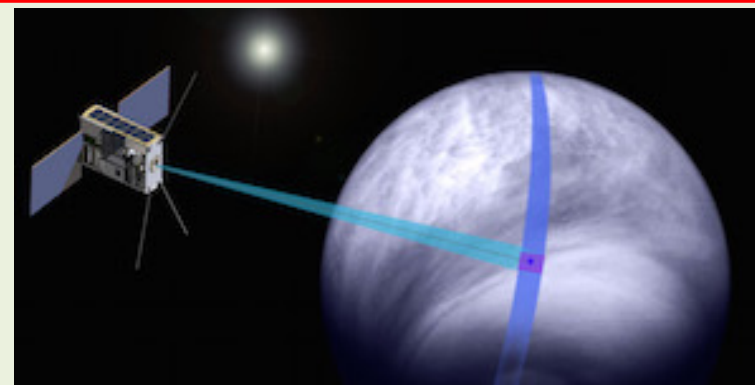Atmospheric dynamics at the cloud tops from wind tracking (190 – 490 nm)
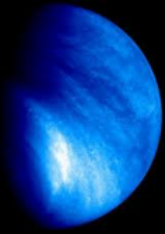
CubeSat UV Experiment (CUVE)

CUVE Payload:

- UV spectrometer 190 – 380 nm, 0.2 nm spectral resolution

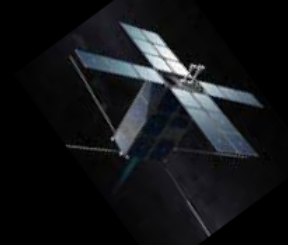**- UV multispectral imager** 320 – 570 nm, 4 nm spectral resolution

Instrument Summary

	Spectrometer	Imager
Telescope diameter (mm)	80	
Total Spectral Range (nm)	190 - 570	
Detectors	CCD (custom coating)	
Type	Low scattering Czerny Turner design	Linear Variable Filter Imager
Spatial Resolution (km) @66000km	3	3
Angular Resolution (arcsec)	10	10
Spectral Range (nm)	190 – 380	320 - 570
Spectral Resolution (nm)	0.2	4

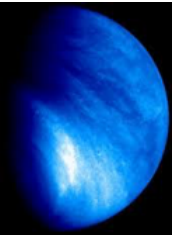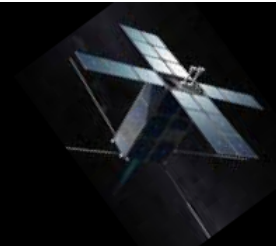**Mission Overview, Schedule and Launch Opportunities**

- **CUVE** is a **12U** high-altitude orbiter on an **elliptical orbit around Venus**
- It will perform mostly nadir dayside observations, and some limb nightside observations

- 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 CUVE technical requirements are based on reaching Venus as **secondary payload of a planetary mission**, including missions that are not targeting Venus or of a LEO/MEO/GEO mission.

- **Launch opportunities**: Rideshare/hitchhiker missions associated with NF4, Discovery, Ocean Worlds, VenusBridge, EnVision, Venera-D.
- It will have a minimum science phase of 6 months.
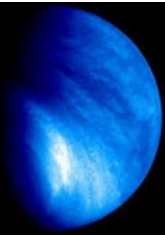
CubeSat UV Experiment (CUVE)

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.
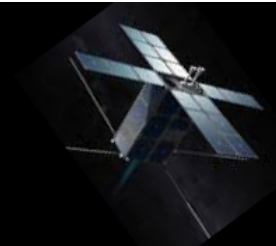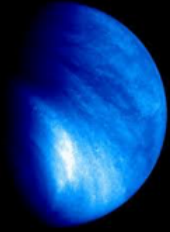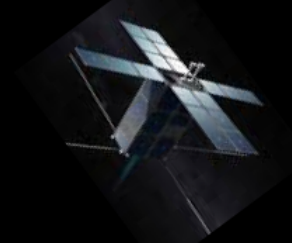
CubeSat UV Experiment (CUVE)

Impact
▶ CUVE will produce the first **broad spectral range** (190 - 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**.
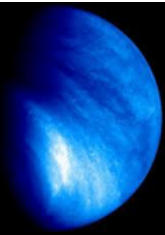
Summary
• Will address a long standing unknown absorber in the atmosphere of Venus.
• Development state - Planetary Science Deep Space SmallSat Studies investigation.
• **CUVE payload is a composite UV-visible spectrometer optimized for CubeSats**.
• Addresses Venus community science: UV investigation is part of the Decadal Survey and the Venus Exploration Analysis Group (VEXAG I.b.1-2, I.c.1-2).
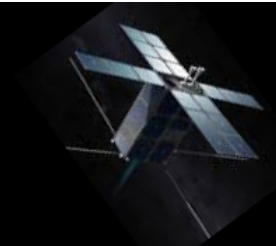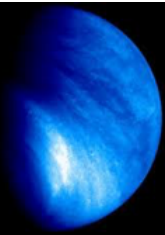
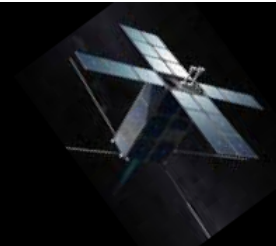# Thank You

Science Instruments

CUVE will investigate Venus' atmosphere with two on-board science payloads (i) a high spectral resolution (0.2 nm) UV spectrometer covering 190-380 nm and (ii) a broadband UV camera (320-520 nm).

CUVE spectrometer will observe Venus' dayside UV albedo spectrum (solar light scattered back from the clouds) to resolve the SO and SO_2 bands and retrieve the composition of the UV-blue absorber and observe Venus' nightside to detect nightglow emissions.

CUVE camera will add contextual information and capture the UV contrast features to derive the absorber distribution and the clouds top structure and dynamics. The analysis, correlation and comparison of measurements with models will determine the origin of the UV absorber and further enhance our understanding of the physics and chemistry of Venus' atmosphere.

Science Objectives

The existence of an "unknown UV absorber" in the upper atmosphere of Venus has been known for decades, since at least Pioneer Venus Orbiter, but it has been difficult to move beyond the label. The UV absorber in the upper clouds absorbs almost half of the solar energy received by the planet. Because of its amazing absorbing power, knowing its nature is very important to understand the overall radiative and thermal balance of the planet and the atmospheric dynamics. CUVE would be able to investigate the UV absorber and its temporal and spatial variations, the atmospheric dynamics and the energy balance, thus complementing current and future Venus missions. It would provide great science return at lower cost, either launched independently or riding along with another Venus's mission or a mission to a different target.

This concept will address the nature of the UV-absorber (range $0.32 - 0.49 \mu m$) and its temporal and spatial variations, abundances and distributions of SO_2 and SO at and above Venus's cloud tops and their correlation with the UV absorber (range $0.19 - 0.32 \mu m$), atmospheric dynamics at the cloud tops using wind tracking ($0.19 - 0.49 \mu m$), structure of upper clouds and night side airglow (NO, CO, O_2).