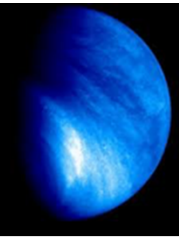
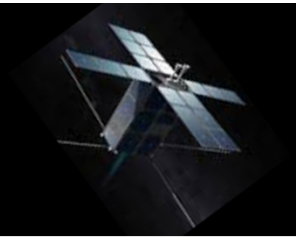


CubeSat UV Experiment (CUVE)



Unveil Venus' UV Absorber with CubeSat UV Mapping Spectrometer

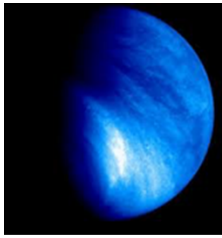
Funded through the NASA Planetary Science Deep Space Smallsats Program (PSDS3)

V. Cottini (UMD)
S. Aslam (NASA/GSFC)
N. Gorius (CUA)
T. Hewagama (UMD)
L. Glaze (NASA/GSFC)
N. Ignatiev (IKI RAN)
G. Piccioni (INAF-IAPS)
E. D' Aversa (INAF-IAPS)

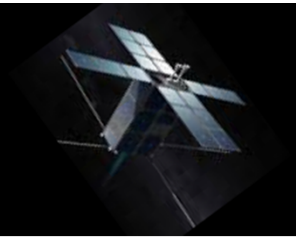
Characterize Venus' unknown UV absorber(s) to understand the planet's radiative and thermal balance, and its upper clouds dynamics and chemistry

CUVE

CubeSat UV Experiment



CubeSat UV Experiment (CUVE)



CUVE TEAM

PI: ***Valeria Cottini*** (UMCP, NASA-GSFC)

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

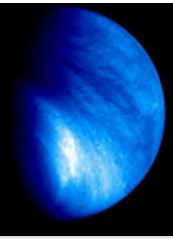
Coll.: ***Lori Glaze*** (NASA-GSFC), ***Nikolay Ignatiev*** (IKI RAN, Russia), ***Emiliano D'Aversa*** (INAF-IAPS, Italy)

Design, fabrication and operation of spectrometers for remote sensing:
Aslam and ***Gorius***

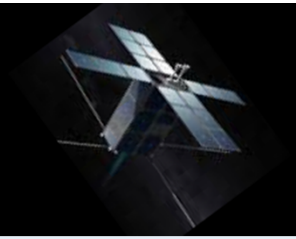
Venus mission concept formulation studies:
Cottini, Glaze, Piccioni, Ignatiev

Mission and Instrument Design:
Mission Planning Lab (MPL) of the NASA Wallops Flight Facility, Instrument Design Center (IDC) at Goddard, Aslam, Gorius, Hewagama, Piccioni

Venus' atmospheric composition, chemistry, dynamics and radiative transfer modeling:
Cottini (Cottini et al. 2008, 2009, 2012, 2016), ***Piccioni*** - PI of ESA/VenusExpress VIRTIS instrument, ***Ignatiev*** - CoI of ESA/VenusExpress VMC instrument, ***Hewagama***, ***D'Aversa***)



CubeSat UV Experiment (CUVE)



Venus

Venus is an ideal target for SmallSats deep space exploration:

- Reachable by an independent small spacecraft
- ~1/3 of low-mass stars have planets in the Venus-zone (interior to HZ)
- Still open compelling questions that needs to be addressed

Credit: JAXA Akatsuky

- UV measurements must be acquired from space
- Venus science achievable with cost efficient compact spacecraft
- Public is very interested (CUVE > 70 articles in few months from more than 10 countries in the world)

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NASA CubeSat Mission Receives Funding to Solve Venusian Mystery

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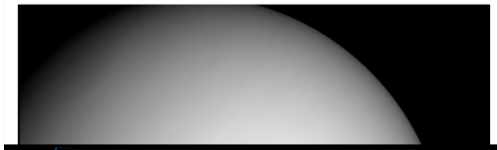

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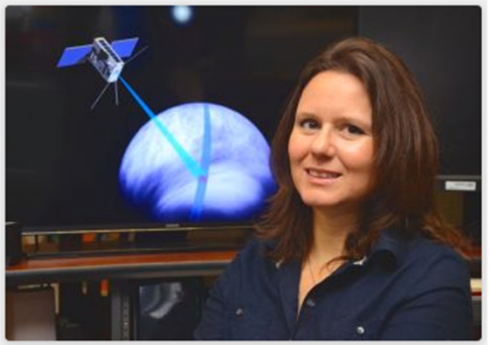
What Are Those Weird Dark Streaks on Venus? NASA CubeSat Mission Could Find Out

By Paul Scott Anderson

Il secondo ha invece un cuore italiano. Si tratta di **Cuve** (CubeSat UV Experiment), ed è proposto da **Valeria Cottini**, ora all'University of Maryland dopo una carriera all'Inaf di Roma. «Cuve è un progetto di missione per lo studio di Ve- a Media Inaf, «che ho pro- eam interdisciplinare di netarie, modelli atmosferi- er telerilevamento e, ovvia- rget Venere. Il core team è americane (Università del Space Flight Center della tolica d'America) e italiane



Valeria Cottini

Il nostro progetto di missione prevede che il satellite venga messo in orbita attor- core payload composto di uno spettrometro ad alta risoluzione e una camera

PHYS.ORG Nanotechnology | Physics | Earth | Astronomy & Space | Technology | Chemistry | Biology

Home » Astronomy & Space » Space Exploration » April 10, 2017

Proposed CubeSat mission to study atmospheric processes on Venus

April 10, 2017 by Tomasz Nowakowski, Astrowatch.net, Astrowatch.net

A small CubeSat designed to investigate atmospheric processes on for further development. The spacecraft, known as the CubeSat UV study solar system planets and asteroids, selected by the agency u SmallSat Studies (PSDS3) program.

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Science Instruments

Aug. 15, 2017

NASA Studies CubeSat Mission to Solve Venusian Mystery

Venus looks bland and featureless in visible light, but change the filter to ultraviolet, and Earth's twin suddenly looks like a different planet. Dark and light areas stripe the sphere, indicating that something is absorbing ultraviolet wavelengths in the planet's cloud tops.

A team of scientists and engineers working at NASA's Goddard Space Flight Center in Greenbelt, Maryland, has received funding from the agency's Planetary Science Deep Space SmallSat Studies, or PSDS3, program to advance a CubeSat mission concept revealing the nature of this mysterious absorber situated within the planet's uppermost cloud layer.

Called the CubeSat UV Experiment, or CUVE, the mission would investigate Venus' atmosphere using ultraviolet-sensitive instruments and a novel, carbon-nanotube light-gathering mirror.

Similar in structure and size to Earth, Venus spins slowly in the opposite direction of most planets. Its thick atmosphere, consisting mainly of carbon dioxide, with clouds of sulfuric acid droplets, traps heat in a runaway greenhouse effect, making it the hottest planet in our solar system with surface temperatures hot enough to melt lead.

Although NASA and other international space programs have dispatched "the exact nature of the cloud top absorber has not been established," s Investigator Valeria Cottini, a researcher at the University of Maryland wh experts in the composition, chemistry, dynamics, and radiative transfer c "This is one of the unanswered questions and it's an important one," she

Past observations of Venus show that half of the solar energy is absorbe upper layer of the sulfuric-acid clouds, giving the planet its striped dark wavelengths are scattered or reflected into space, which explains why th featureless, yellowish-white sphere in the optical — wavelengths visible

Theories abound as to what causes these streaked, contrasting features explanation is that convective processes dredge the absorber from deep cover, transporting the substance to the cloud tops. Local winds disperse of the wind, creating the long streaks. Scientists theorize the bright areas ultraviolet are probably stable against convection and do not contain the areas do.

"Since the maximum absorption of solar energy by Venus occurs in the nature, concentration, and distribution of the unknown absorber is funda a highly-focused mission — perfect for a CubeSat application."

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Piccoli satelliti Nasa crescono

C'è anche l'italiana Valeria Cottini, già all'Inaf di Roma e ora all'University of Maryland, tra i responsabili dei progetti premiati dalla Nasa per sviluppare una flottiglia di mini satelliti all'arrembaggio del Sistema solare, lune e asteroidi compresi

di Stefano Parisini | Segui @StefanoParisini | venerdì 31 marzo 2017 @ 19:49

And the winner is... Durante la conferenza della Lunar and Planetary Society statunitense, svoltasi la scorsa settimana in Texas, sono stati nominati i vincitori dei complessivi **3.6 milioni di dollari** che la Nasa ha messo in palio **per sviluppare missioni scientifiche spaziali** utiliz- Luna, ianeti quelli In que-

Il Sistema solare. Crediti: Nasa

IFLSCIENCE!

A CubeSat Mission To Venus Might Finally Unlock The Mystery Of Its Atmosphere

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Venus - High resolution beautiful art presents planet of the solar system. This image elements furnished by NASA (Shutterstock/Vadim Sadovski)

NASA Is Planning A Big Mission To Venus


2018년 02월 15일 목요일
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최종수정 2017.08.17 04:00 기사입력 2017.08.16 08:03
나사, 'CUVE' 임무 시작
• (Mercury)
• (Venus)
• (Earth)
• (Mars)
• (Jupiter)
• (Saturn)
• (Uranus)
• (Neptune)
Space 24
Defence 24 Energetyka 24 Cyberdefence
POLITYKA KOSMICZNA PRZEMYSŁ BEZPIECZEŃSTWO SATELITY POJAZDY KOSMICZNE NAUKA I EDUKA
NASA wyśle CubeSata by przyjrzał się atmosferze Wenus
18 sierpnia 2017, 16:48
International Business Times
TECHNOLOGY
NASA Mission To Venus Looks To Pierce Thick Atmosphere
BY ELANA GLOWATZ ON 08/15/17 AT 5:52 PM
NASA is on a mission to unlock the mysteries of the Venus atmosphere, sending a tiny satellite to Earth's inward neighbor to investigate its clouds.
UKŁAD SŁONECZNY, WENUS
NASA rozważa wysłanie cubesatów w kierunku Wenus
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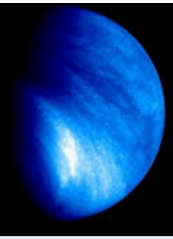
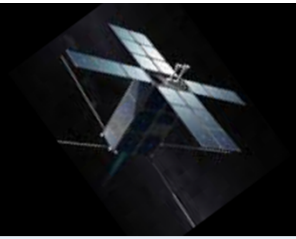
MARTES, 5 DE SEPTIEMBRE DE 2017
La NASA estudia una misión a Venus con un CubeSat
Missão CubeSat volta-se para resolução do mistério de Vênus VIDEO
Chamado de CubeSat UV Experiment, ou Cuve, a missão tem como objetivo investigar a atmosfera de Vênus.
CLIQUE PARA ASSISTIR : Missão CubeSat volta-se para resolução do mistério d...
Ingrid Gehlen Felkl
Autor do artigo
(Revisado por Edimarcio Augusto Monteiro)
Notica 2
Vídeo editado por
O segundo planeta do Sistema Solar parece sem graça e sem nenhuma peculiaridade atmosférica
BOOK SMART AND SLEEP WELL IN CHICAGO
VENUS IS HIDING A SECRET WE COULD FINALLY FIND OUT
Contributed by
Elizabeth Rayne
Aug 21, 2017
Venus has managed to hide many secrets in its tc on the verge of revealing one of them.
NASA's Planetary Science Deep Space SmallSat Stud a team of scientists and engineers at its Goddard Space Flight Center to advance a CubeSat concept for a mission to investigate what is absorbing so many UV rays in the uppermost layer of its clouds.
wavelengths in the planet's cloud tops."
The really strange part is that visible light is reflected by Venus' atmosphere, not absorbed by it. Venus is choked by extremely dense clouds of gaseous sulfuric acid that reflect visible light, which makes the planet difficult to observe with conventional telescopes. Amateur astronomers who find Venus in the night sky are often disappointed to learn that the planet appears as a featureless white dot to the naked eye.



CubeSat UV Experiment (CUVE)



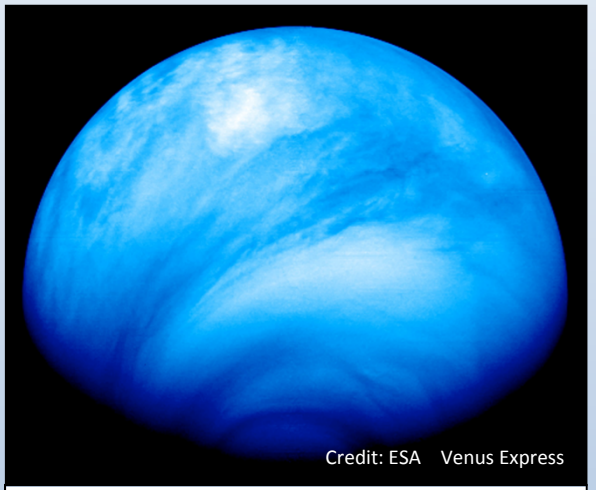
Venus cloud top science

• Venus is almost **featureless** in the **visible**

• Venus clouds reflect in the visible most of the incoming solar radiation (albedo ~75–90%)

~50% of the solar energy received by Venus is **absorbed in the UV** by a **unidentified absorbers** in its top cloud layer

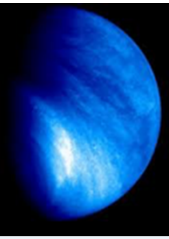
• This absorbed energy is the primary atmospheric engine of Venus - superrotation



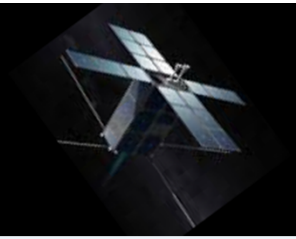
• In the **UV** we observe **dark and bright** regions

• Clouds top structure and UV absorbers nature are key parameters for understanding Venus' atmospheric dynamics and energy balance

We need a Venus UV spectrum!



CubeSat UV Experiment (CUVE)



Previous UV observations

Mission	Instrument Channel	Spectral Range	Resolution
Pioneer Venus	OUVS	110-340 nm	1.3 nm
Venus Express	VIRTIS (M Visible)	290-1100 nm	2 nm
Venus Express	SPICAV (SUV)	110-310 nm	1-1.5 nm
Venus Express	VMC (UV)	345-384 nm	40 nm
Akatsuki	UVI	293-365 nm	72 nm
HST	STIS (low/med Res)	115-555 nm	var. 0.27 nm
Messenger	MASCS VIS	300-1000 nm	4.7 nm
CUVE	Spectrometer	200-400 nm	0.2 nm
CUVE	Imager	320-570 nm	4 nm

Pioneer Venus not high spectral resolution and noisy (*e.g.,* Stewart *et al*, 1979)

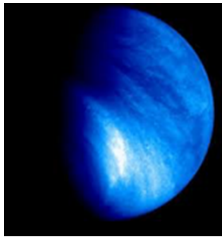
VMC on Venus Express and Akatsuki gave us amazing data/UV images, not spectra

Hubble Space Telescope acquired few UV spectra (Jessup et al. 2015), but might not be able to acquire many more due to Sun-avoidance requirements. Good spectra but **limited dataset/spatial coverage**

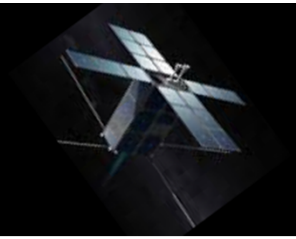
Difficult to investigate the UV absorber from Earth's surface due to strong UV absorption in Earth's atmosphere

Venus Express bands not resolved both in VIRTIS and SPICAV spectrometers

CUVE can provide high resolution UV spectrum of Venus, with large coverage and imaging of cloud top structure



CubeSat UV Experiment (CUVE)



Known and Potential UV Absorbers

Known absorbers:

- SO_2 varies from 0.1 to 1 ppm at the cloud top (Barker 1979, Conway *et al*. 1979, Stewart *et al.* 1979, Esposito *et al*. 1988, Bertaux *et al*. 1996 Marcq *et al*. 2011)
- SO about 30% of SO_2 (Na *et al*., 1990)

Other candidate species for the observed UV contrast features:

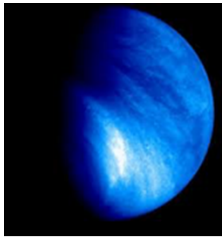
- Sulfur-bearing species - sulfur S_x, S_8, S_2O, OSSO – $FeCl_3$:

- Zasova 1981 proposes 1 % $FeCl_3$ in 80% H_2SO_4 and Krasnopolsky (1986) favored it

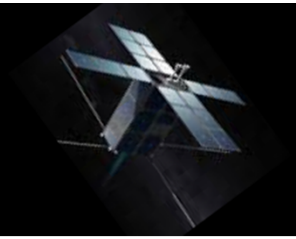
Recently:

- Petrova, 2018, support ferried chloride through analysis of glory on Venus
- Messenger MASCS found best fit for S_2O and OSSO (Perez-Hoyos et al. 2018)
- Lab results fit Pioneer Venus data with OSSO (Wu et al. 2018)
- Carlson 2016 suggests cyclo-octal S_8 and polymeric sulfur S_x (>500 nm we can discriminate it from $FeCl_3$)

Other proposed absorbers: SCl_2, 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)

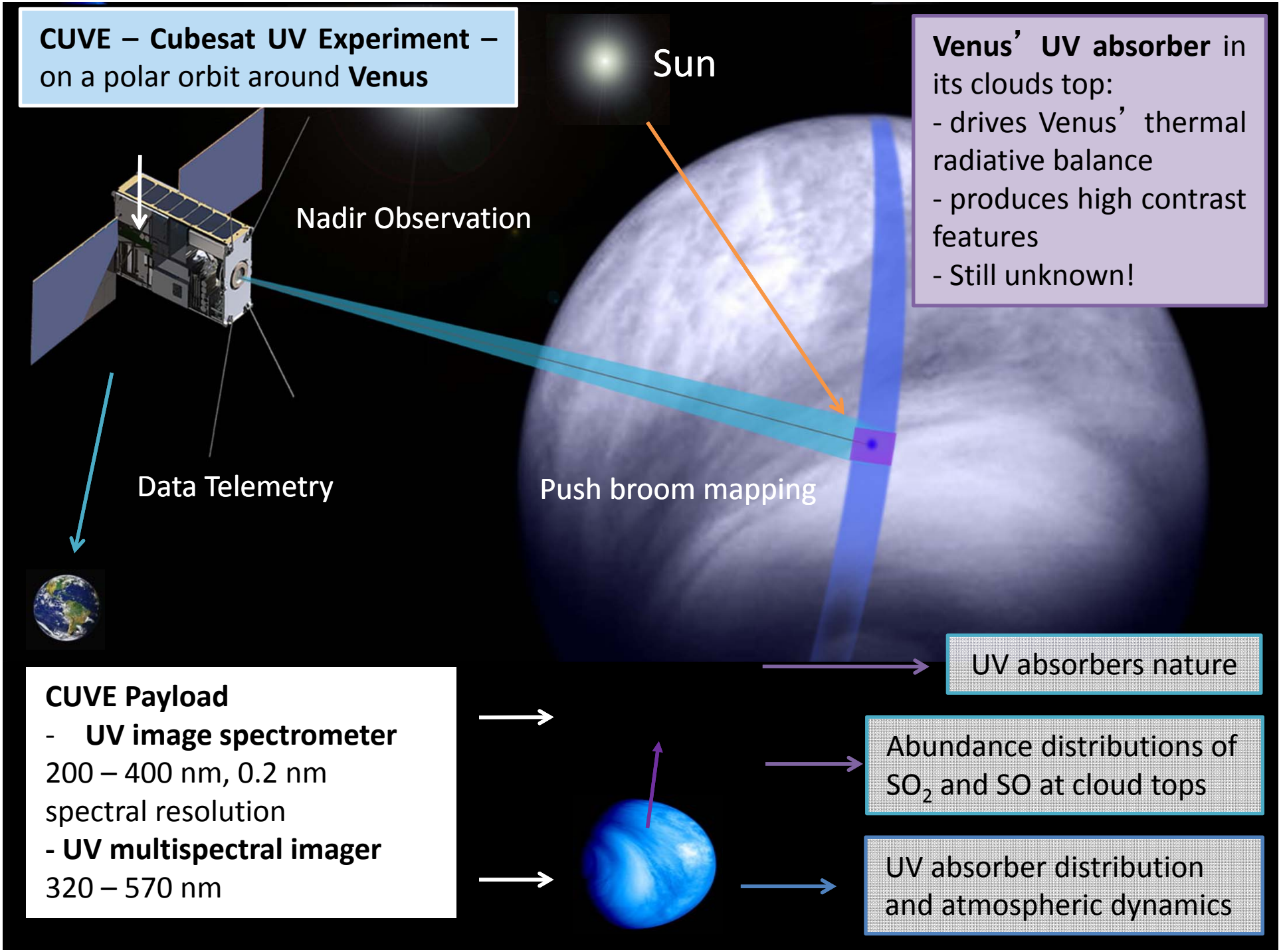


CubeSat UV Experiment (CUVE)

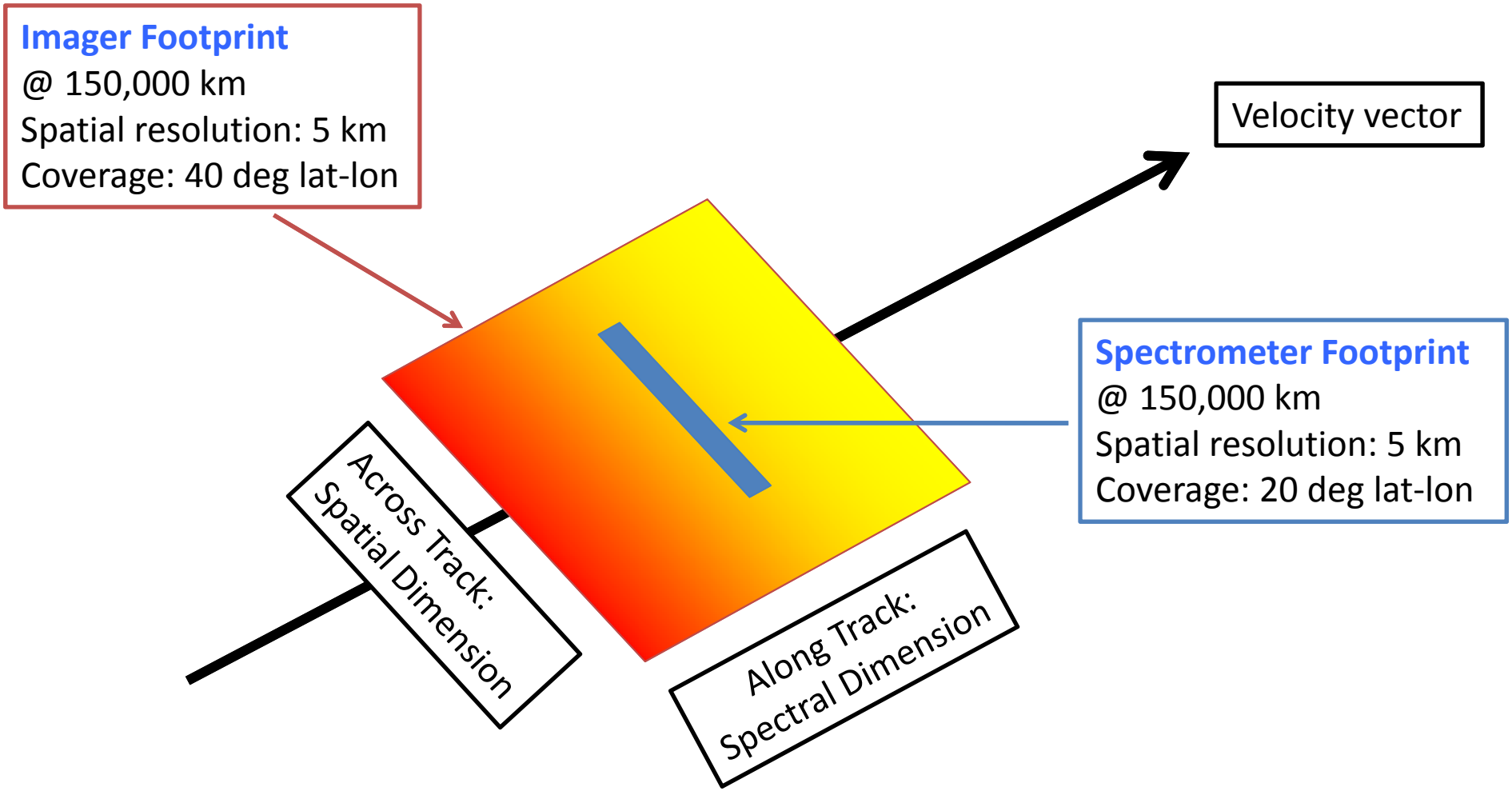


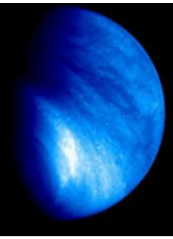
Recent interest on Venus absorbers in the UV

- Belyaev *et al.* are analyzing SPICAV and VIRTIS UV-VIS data
- Petrova, E. *et al*., 2018. *Glory on Venus and selection among the unknown UV absorbers*. Icarus, 306, p. 163-170
- Pérez-Hoyos, S. et al., 2018. *Venus Upper Clouds and the UV Absorber From MESSENGER/MASCS Observations*. JGRE- Planets, 123, 1, pp. 145-162
- Jessup, K.-L. *et al*., 2017. *Motivations for a Detailed In-Situ Investigation of Venus' UV Absorber. VEXAG*. LPI contribution and EPSC 2018.
- Marcq, E. et al., 2017. *Reanalysis of the SPICAV-UV nadir spectra on the day side of Venus: SO_2 , O_3 and other UV absorbers*. EPSC.
- Various papers of Lymaye of *possible microorganism in Venus clouds and UV absorbers*.
- Various papers of Berteaux, Petrova, Lee on *UV albedo and cloud properties from VMC on Venus Express*.
- Markiewicz W. *et al*., 2018. *Aerosol properties in the upper clouds of Venus from glory observations by the Venus Monitoring Camera (Venus Express)*. Icarus, 299, pp. 272-293.
- Frandsen, B. N. *et al*., 2016. *Identification of OSSO as a near-UV absorber in the Venusian atmosphere*. GRL, 43, 21, pp. 11,146-11,155.
- Markiewicz, W. et al., 2014. *Glory on Venus cloud tops and the unknown UV absorber.* Icarus, 234, p. 200-203.

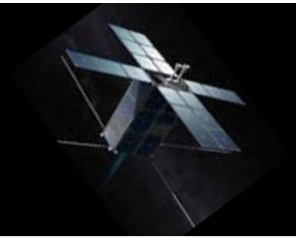

CUVE – Cubesat UV Experiment – on a polar orbit around **Venus**
Sun
Venus' UV absorber in its clouds top:
- drives Venus' thermal radiative balance
- produces high contrast features
- Still unknown!
Nadir Observation
Data Telemetry
Push broom mapping
CUVE Payload
- **UV image spectrometer**
200 – 400 nm, 0.2 nm spectral resolution
- UV multispectral imager
320 – 570 nm
UV absorbers nature
Abundance distributions of SO_2 and SO at cloud tops
UV absorber distribution and atmospheric dynamics

Instrument field of view





CubeSat UV Experiment (CUVE)

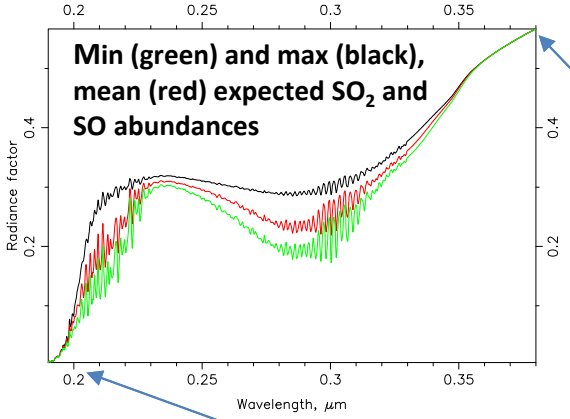


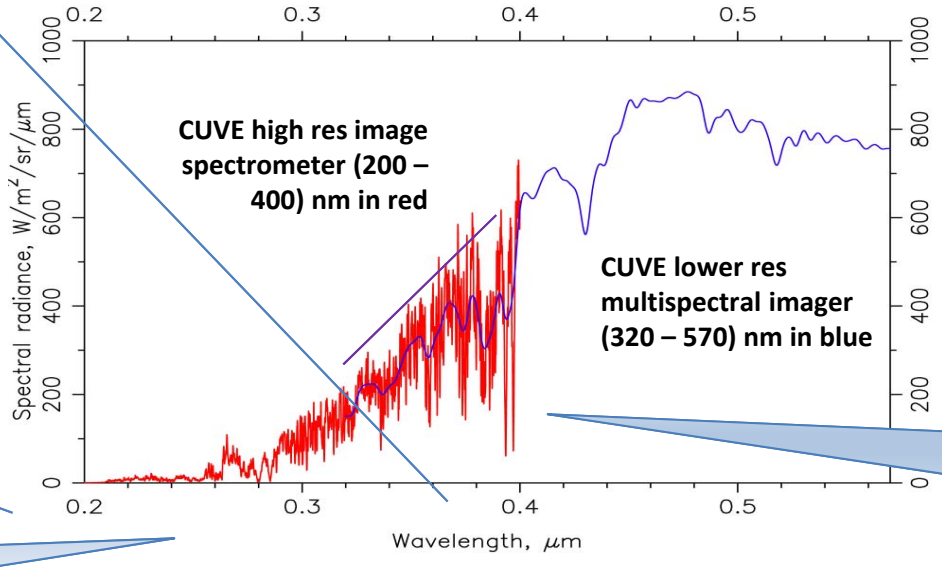
Venus CUVE simulated data products

Nadir UV dayside 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.

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

SO_2 mixing ratio present strong variations of orders of magnitude.
Min and max from Belyaev et al. (2017, Icarus 294, 58), and Vandaele et al. (2017, 295). SO ~ 0.2 of SO_2

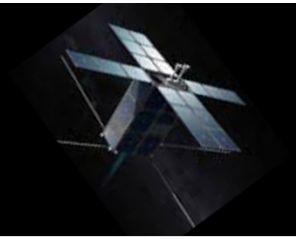




Venus spectrum has multiple absorption features between 200 and 500 nm

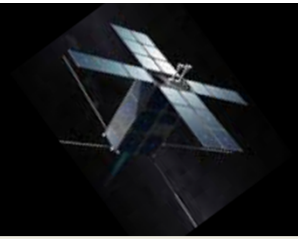
SO_2 and also SO bands between 200 and 320 nm

Unidentified absorbers above 320 nm



Mission overview

- 1 unique **12U** spacecraft
- Can be deployed from Geostationary Transfer Orbit (GTO)
- Other possible rideshare opportunities: LEO missions, Heliophysics, Discovery, New Frontiers
- Flexible launch date
- Spacecraft reach Venus using internal electrical propulsion system
- At Venus, spacecraft will be placed in high altitude polar orbit
- Spacecraft establishes direct communication with DSN during cruise, instrument check-out, insertion, operations
- Mature TRL: Most component have high TRL (6-8).
- Mission end: orbital decay into Venus (no planetary protection concerns)



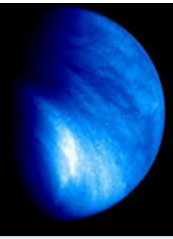
Relevance to NASA

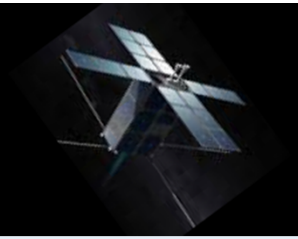
Venus high spectral resolution UV imaging spectroscopy

Broad spectral range (200 - 570 nm) and high spectral resolution (0.2 nm) UV spectrum of Venus

Nature of the UV Absorbers in its Atmosphere,
Venus Atmospheric Composition, Chemistry, Dynamics and Energy Balance

- The study of Venus is part of the three major classes of mission destinations of the *2014 NASA SMD Science Plan – 4.3 Planetary Science Division* Objective "Inner planets: Earth's Moon, Mars and its satellites, Venus, and Mercury" in "Explore and observe the objects in the solar system to understand how they formed and evolve" or *Objective 1.5 of the 2014 NASA Strategic Plan*.
- A UV investigation is also part of the Decadal Survey and the Venus Exploration Analysis Group (VEXAG I.b.1-2, I.c.1-2).





Thank you!

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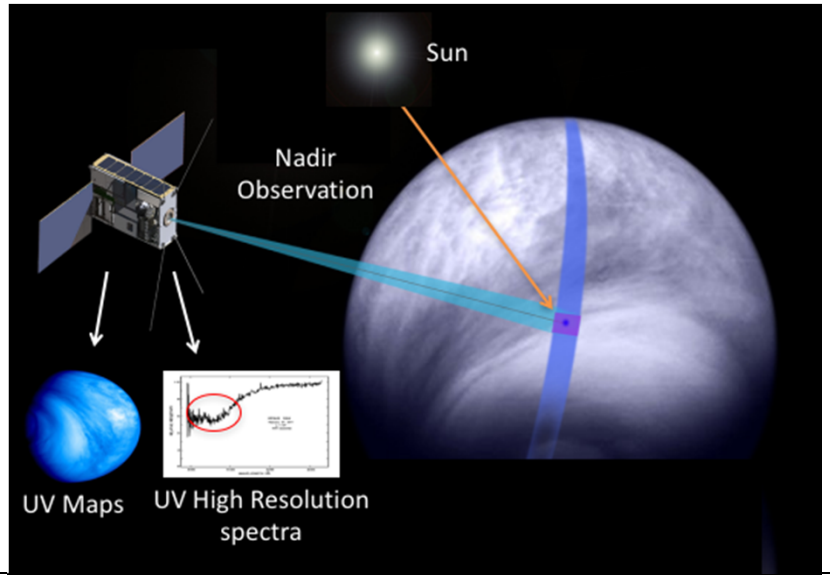
NASA under the NASA Planetary Science Deep Space Smallsats Program (PSDS3) supported the research described in this report.

CubeSat UV Experiment (CUVE)



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SCIENCE OBJECTIVES:

1) Nature of the "Unknown" UV-absorber; 2) Abundances and distributions of SO_2 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)

- 200-400 nm image spectrometer (0.2 nm res)
- 320-600 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 lunch opportunities
- It will perform Nadir dayside observations
- Schedule: early-to-mid 2020s