CUVE – Cubesat UV Experiment

Unveil Venus' UV Absorber with CubeSat UV Mapping Spectrometer

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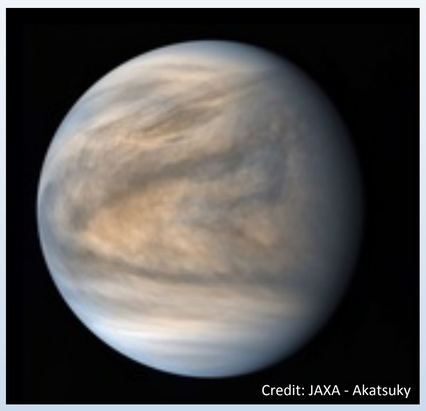
CUVE TEAM includes experts in: Venus' atmospheric composition, chemistry, dynamics and radiative transfer; Mission and Instrument Design; Venus mission concept formulation studies; Design, fabrication and operation of spectrometers for remote sensing

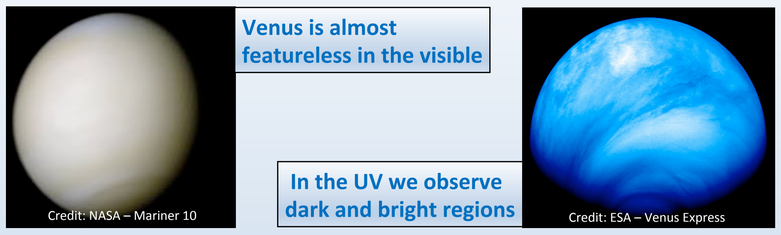
WHY VENUS?



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

VENUS CLOUD TOP SCIENCE



- 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
- Clouds top structure and UV absorbers nature are key parameters for understanding Venus' atmospheric dynamics and energy balance
- Venus science is achievable with **cost efficient compact spacecraft**
- Public is very interested on Venus (> 70 articles on CUVE in few months from more than 10 countries in the world) – see bottom page – and see Jessup, K.-L. *et al. Motivations for a Detailed In-Situ Investigation of Venus' UV Absorber. VEXAG* 2017- LPI contribution and EPSC 2018.

We need a Venus UV spectrum

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: Sn, 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)

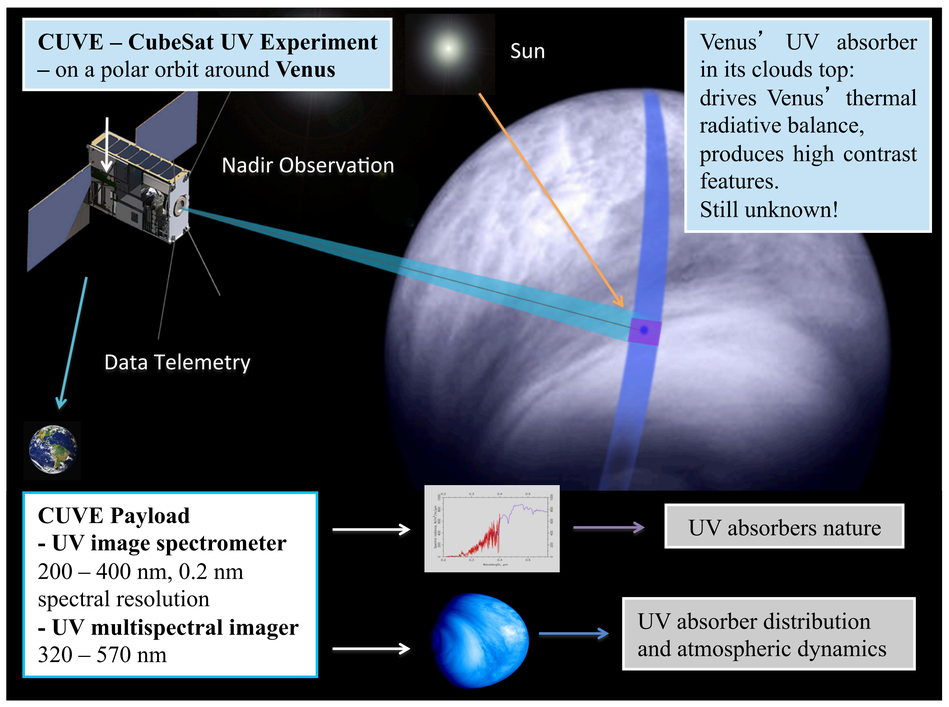
PREVIOUS UV OBSERVATIONS

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

- Difficult to investigate the UV absorber from Earth's surface due to strong UV absorption in Earth's atmosphere
- Pioneer Venus -> not high spectral resolution and some noise (*e.g.,* Stewart *et al*, 1979)
- VMC on Venus Express and Akatsuki gave us amazing UV images but 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
- 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 to derive the science objectives:
1) Nature of the UV-absorbers; 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

Acknowledgements: We acknowledge the support of NASA Planetary Science Deep Space SmallSat Studies (PSDS3) program and NASA/GSFC



MISSION OVERVIEW

- 1 unique **12U spacecraft**
- Can be deployed from Geostationary Transfer Orbit (GTO)
- Other possible rideshare opportunities: LEO missions, Heliophysics, Discovery, New Frontiers
- 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)

CUVE VENUS SIMULATED DATA

Nadir UV dayside spectrum is mostly composed of solar light back-scattered by atmospheric cloud particles.

=> From the spectrum we can derive 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.

Venus UV spectrum