Venus Airglow Measurements and Orbiter for Seismicity (VAMOS): A Mission Concept Study

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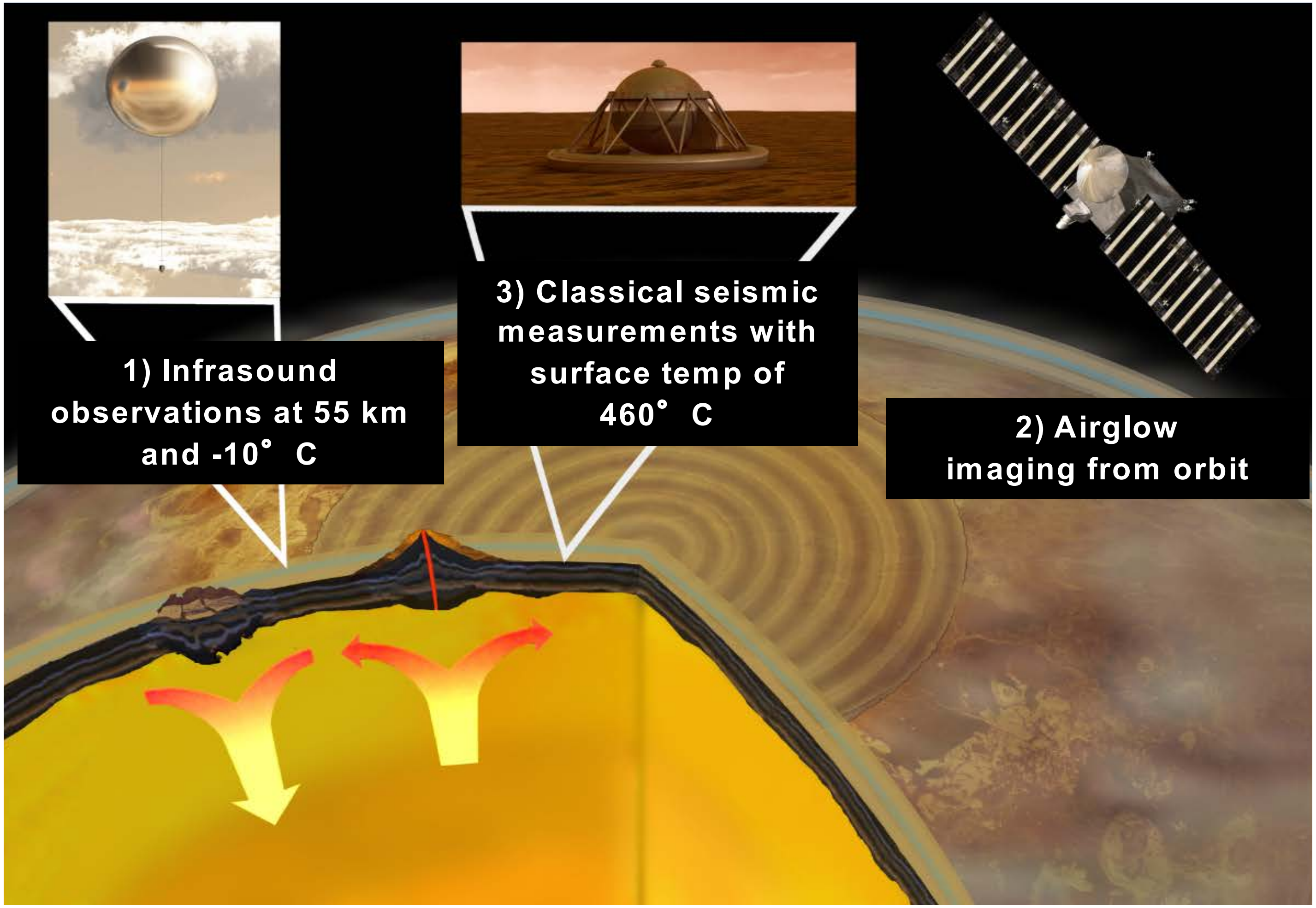
Outline

- Motivation
- Science background
- Mission concept overview
- Summary

Motivation

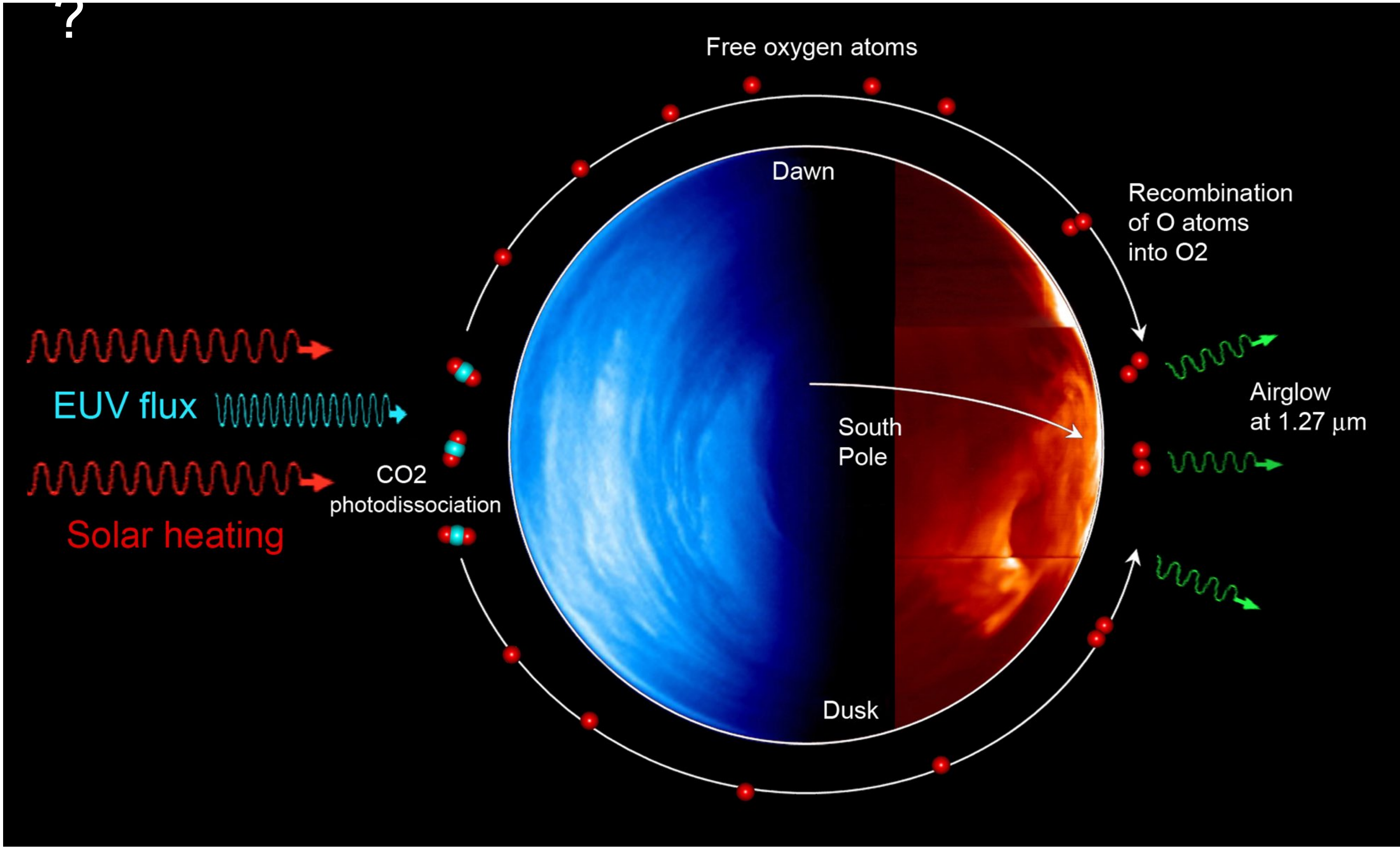
- The planetary evolution and structure of Venus *remain uncertain* more than half a century after the first visit by a robotic spacecraft. Why has Venus become so inhabitable planet? We don't know.
- To understand how Venus evolved it is necessary to *detect signs of seismic activity*.
  - Due to the adverse surface conditions on Venus, it is infeasible to place seismometers on the surface for an extended period of time.
- Due to *dynamic coupling between the solid planet and the atmosphere*, the waves generated by quakes propagate and may be detected in the atmosphere itself.
- Our main threshold objectives are:
  - Determine the *global seismic activity* of Venus; determine *crustal thickness* and *lithospheric structure*
  - Determine the dominant source regions for *gravity waves* and assess any possible connection to topography
  - Determine *ionospheric instabilities* for Venus

Techniques Defined to Detect Seismicity on Venus



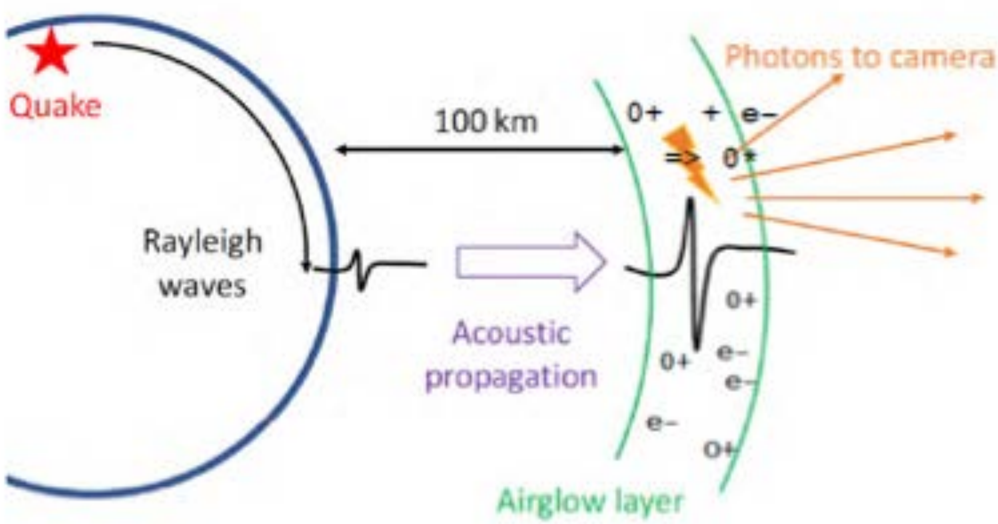
Cutts et al. (2015)

Physical Mechanism for Airglow on Venus

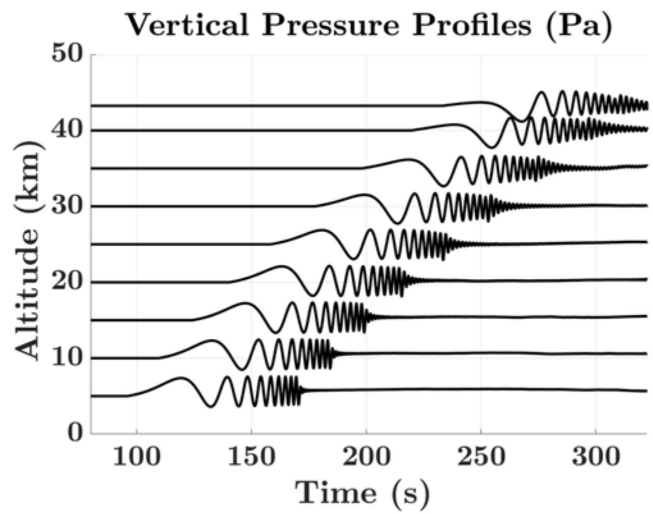


http://www.esa.int/spaceinimages/Images/2007/04/Airglow_production_schematic

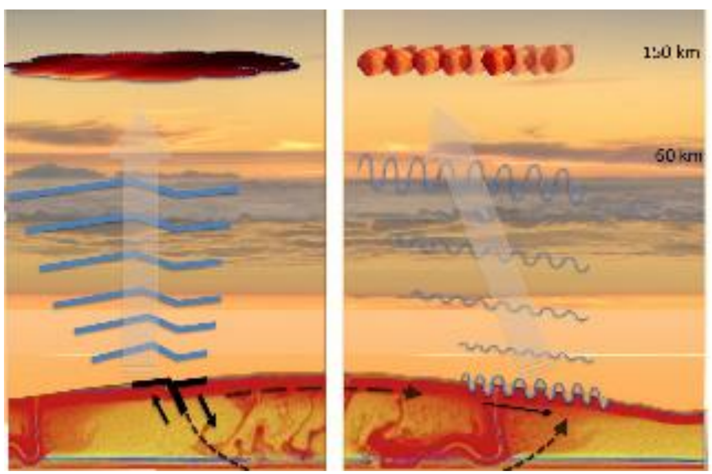
Planetary Quakes Observable in the Atmosphere?



Kenda et al., 2018



Garcia at al., 2016

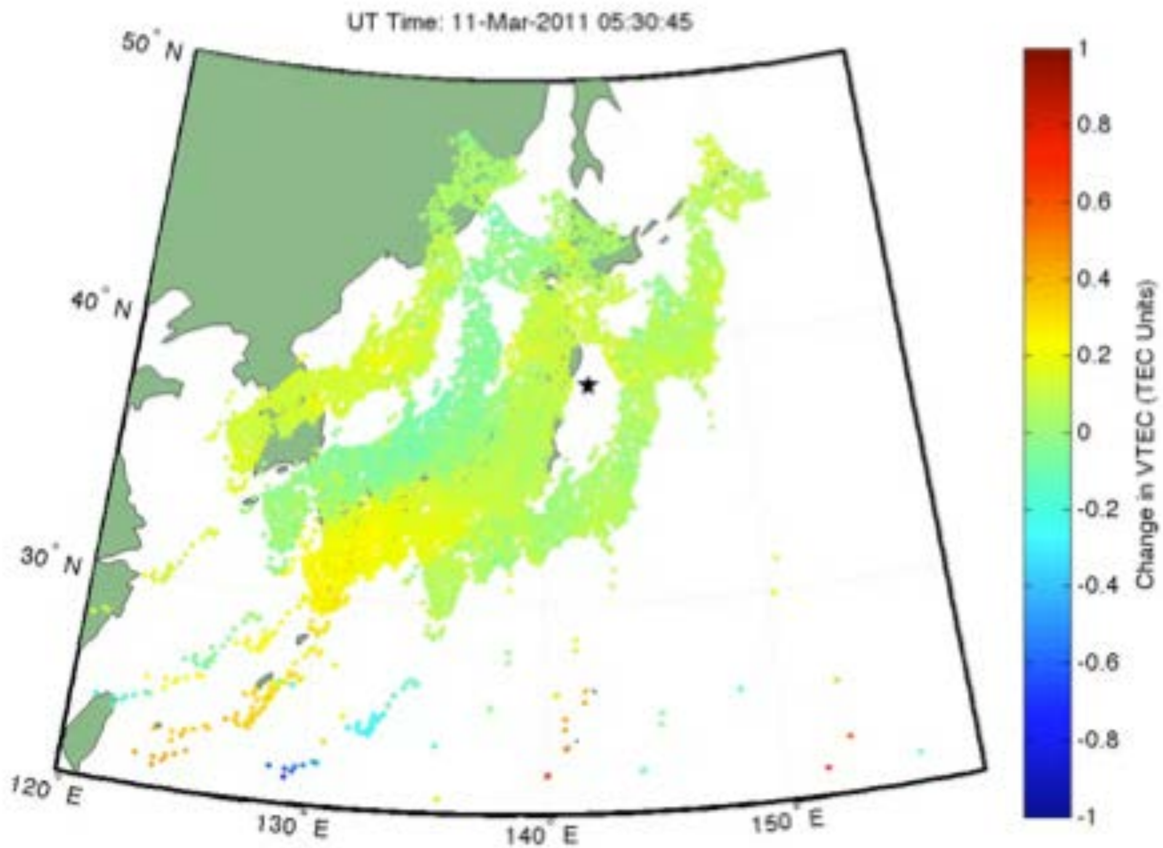


Cutts et al., 2015

- Synthetic seismograms at different altitudes in the atmosphere are shown
- Ground motion from quakes produces infrasonic pressure signals (frequency< 20 Hz) at the epicenter and far away (due to Rayleigh waves)
- Venus' thick atmosphere couples with ground motion 60x better than Earth

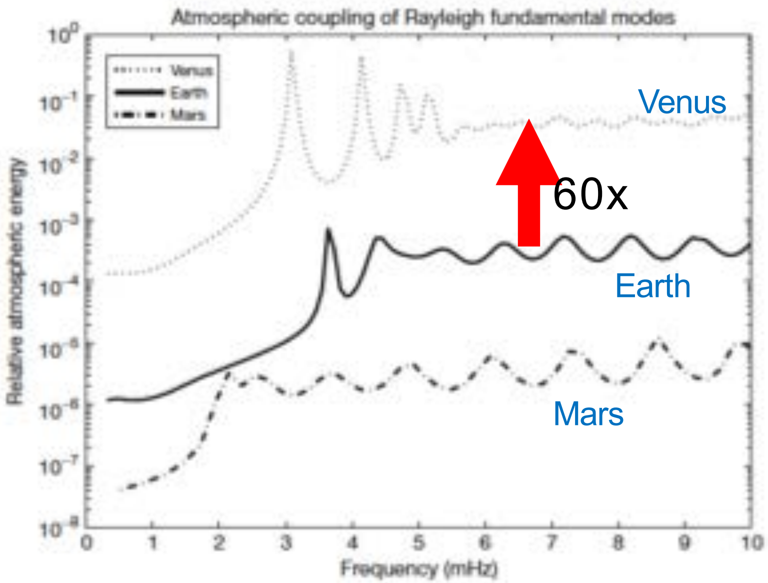
Seismic Wave Generated Ionospheric Disturbances on Earth

Step 1. Done on Earth: TEC movies of tsunami and seismic waves



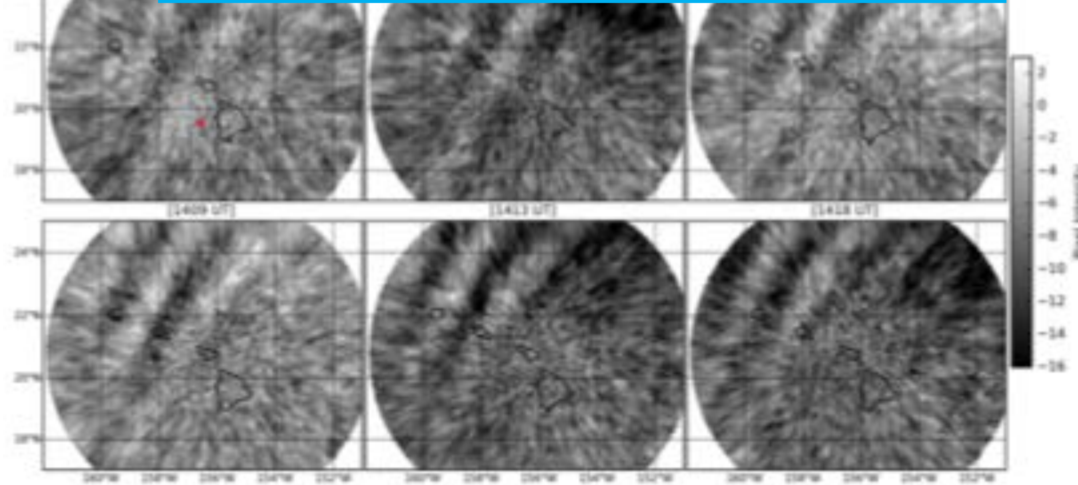
Galvan et al., 2012

Science Background



Lognonne et al., 2016

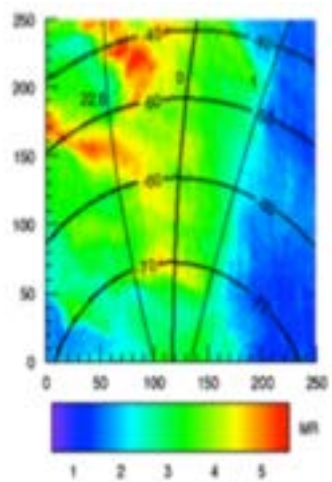
Step 2. Done on Earth: Airglow movies of tsunamis and atmospheric waves



after Grawe and Makela, 2017.

Venus:

- Seismicity on Venus is assumed to be 25x less than that on Earth
- 50 quakes per year with Mw > 5 and 1 to 2 with Mw > 6.5

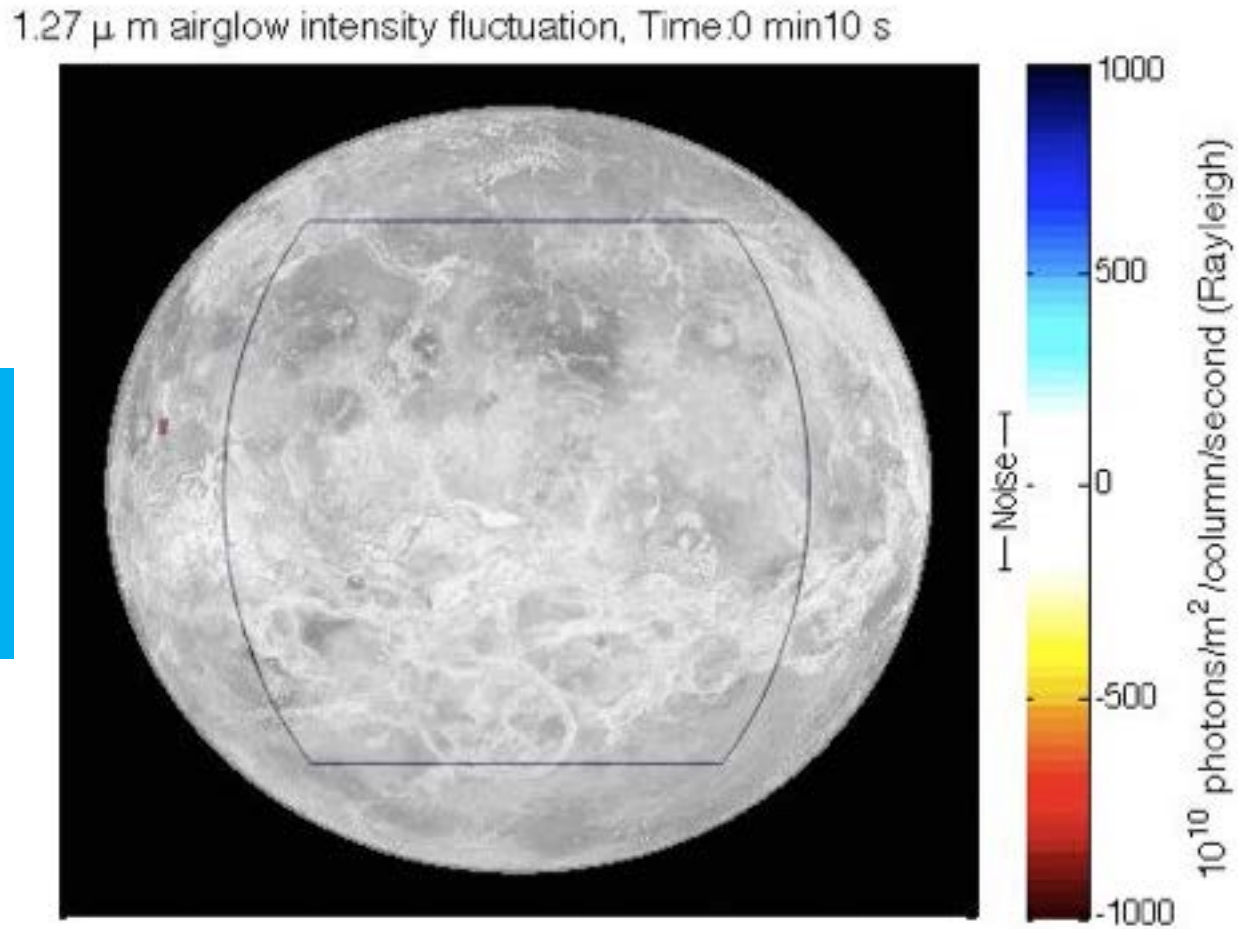


after Garcia et al., 2009

Step 3. Done on Venus by VEX : Airglow image of atmospheric waves

Migliorini et al., 2011; Garcia et al., 2009.

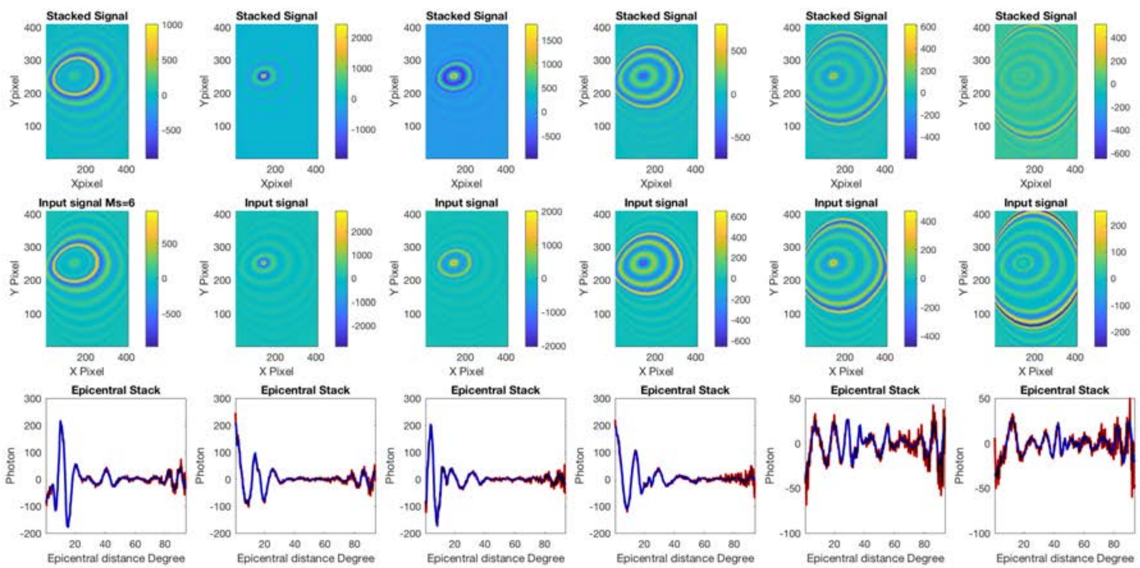
Modeled Airglow Fluctuations Due to Seismic Waves on Venus



Step 4 to come: We will make airglow movies of seismic and atmospheric waves on Venus!

Noise-free simulation

Modeling Airglow Signatures on Venus



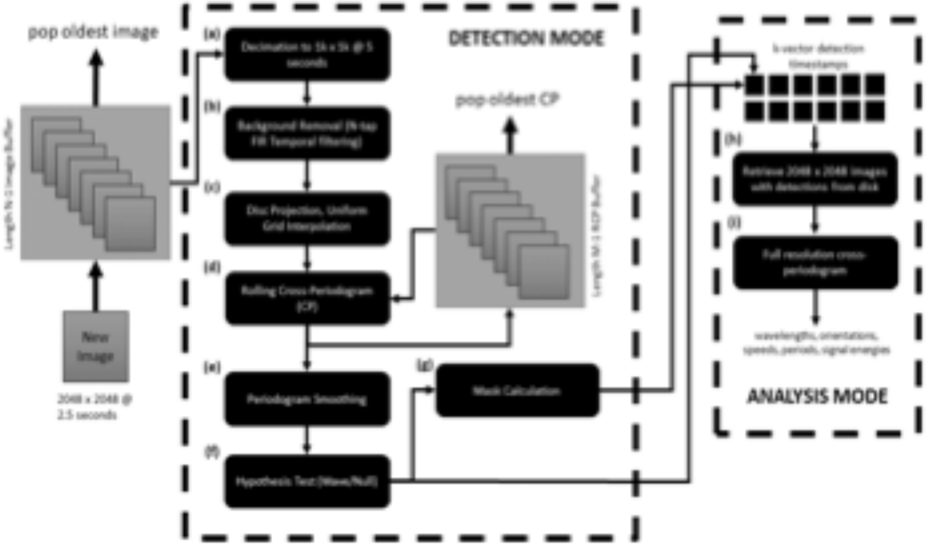
Ms 6.0 quake observed by 4.28 μm

The simulations indicate that the *shot noise* associated with the background is the *most significant source of noise for* 1.27 μm (night-glow) compared to the signal strength. However, 4.28 μm airglow is not affected.

Estimated thresholds for reaching the different seismic science goals

Requirements	1.27 µm	4.28 µm
Determine the global seismic activity of Venus (± 1 Moment magnitude unit)	Ms 6.25	Ms 5.5
Determine the mean thickness of the crust	Ms 6.25	Ms 5.5
Determine the regions of seismic/volcanic activity	Ms 6.0	Ms 5.0
Determine the thickness variations of the crust	Ms 6.5	Ms 6.0

Event Detection Algorithm

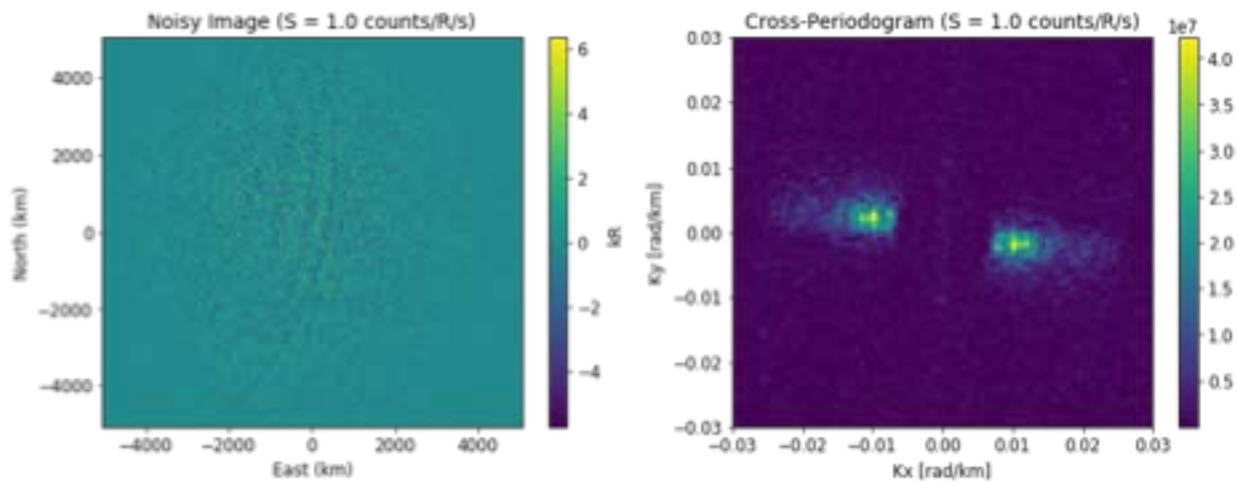


Overview of the wave detection and analysis algorithm.

- Detection mode is designed to run in real time on a decimated version of the image sequence.
- Analysis mode works with the full resolution data and runs on image blocks triggered by detection mode when switched on

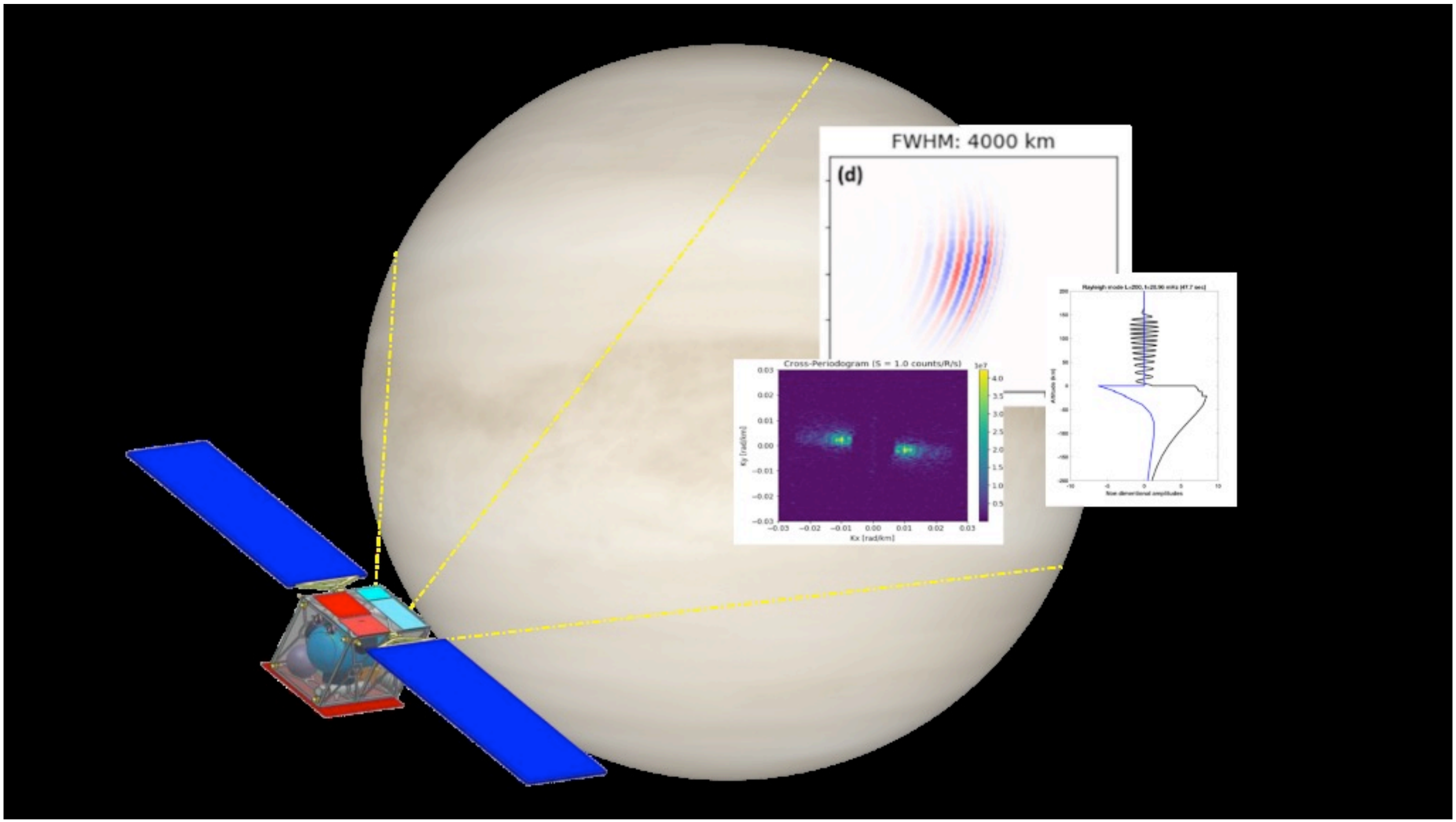
Real-time Wavefront Detection

(left) Simulated image of raw data; (right) two-frame cross-periodogram demonstrating detection feasibility.



Mission Concept Overview

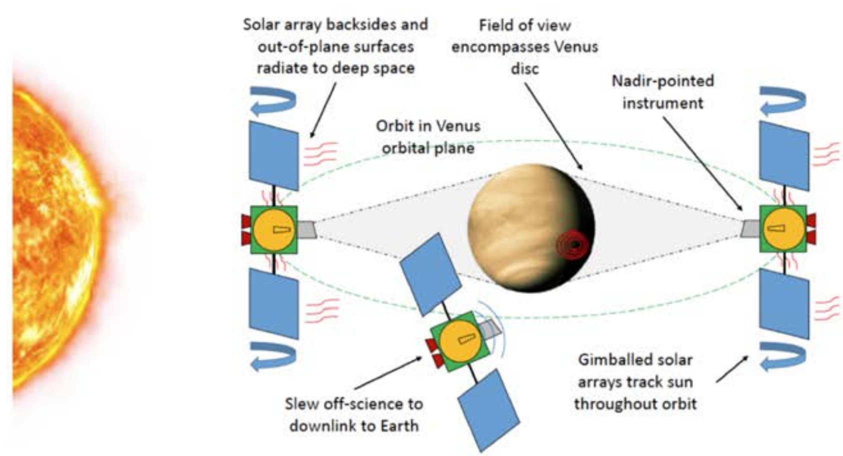
A Continuously Observing Small Spacecraft in High Circular Venusian Orbit

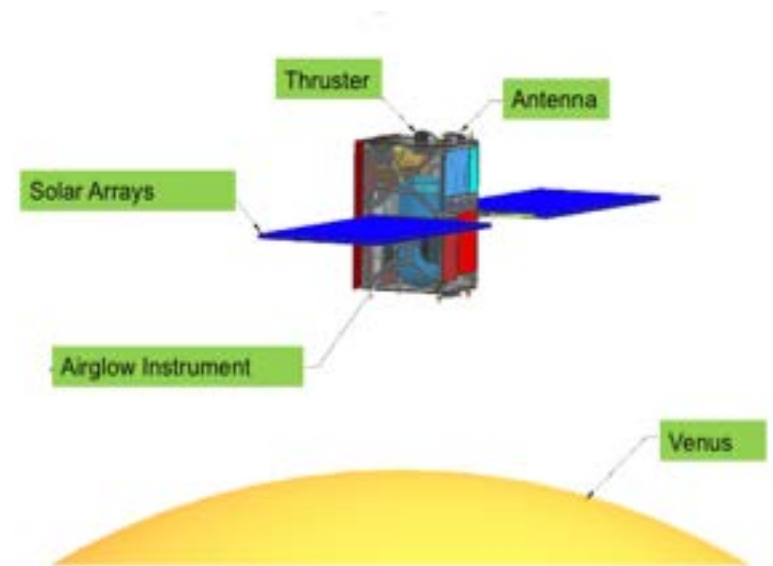


Mission Concept Overview

- Leave Earth as a GTO rideshare – many launches available
- Inject into trajectory to Venus using SEP (one Earth flyby and one Venus flyby);

  Insert into 45000 km Venus circular orbit in the Sun-Venus plane.
- Use 1.27 μm infrared channel for nighttime and 4.3 μm channel for daytime detection.
- Use low-res images for monitoring, send back data only once event is detected
- Determine regions of seismic/volcanic activity, gravity waves and ionospheric instabilities on Venus





Summary

- VAMOS concept study found a feasible way to monitor Venus seismic activity from orbit
- The airglow layer can act as a projection screen for sub-surface activity on Venus
- Seismic events can be distinguished from atmospheric disturbances such as gravity waves, which may also be studied using the same instruments
- Three major challenges found in the study – getting to Venus, shot noise, and data volume
- VAM(on)OS a Venus!

Acknowledgements

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