VENUS EXPLORATION WITH INFRASOUND TECHNIQUES

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Overview

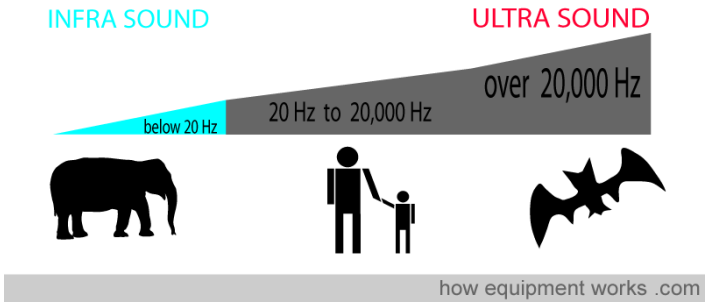
- The formation, evolution and structure of Venus remain a puzzle more than fifty years after the first visit by a robotic spacecraft.

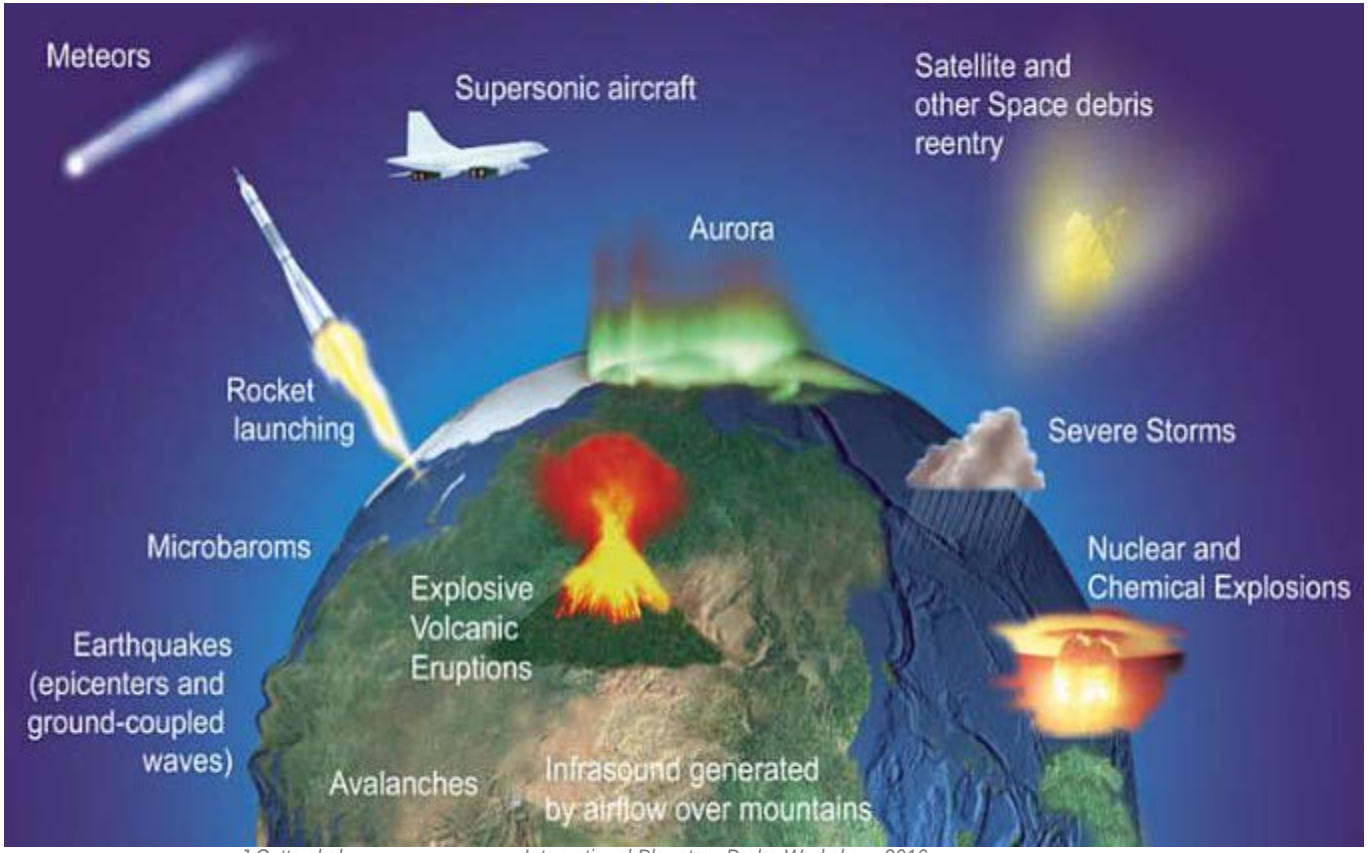
- To understand how Venus works as a planet it is necessary to understand if it is still active and, if so, to use Venus quakes to probe its interior.

- Infrasonic techniques can be implemented from balloon platforms using existing technologies and take advantage of Venus' dense atmosphere to achieve high sensitivity

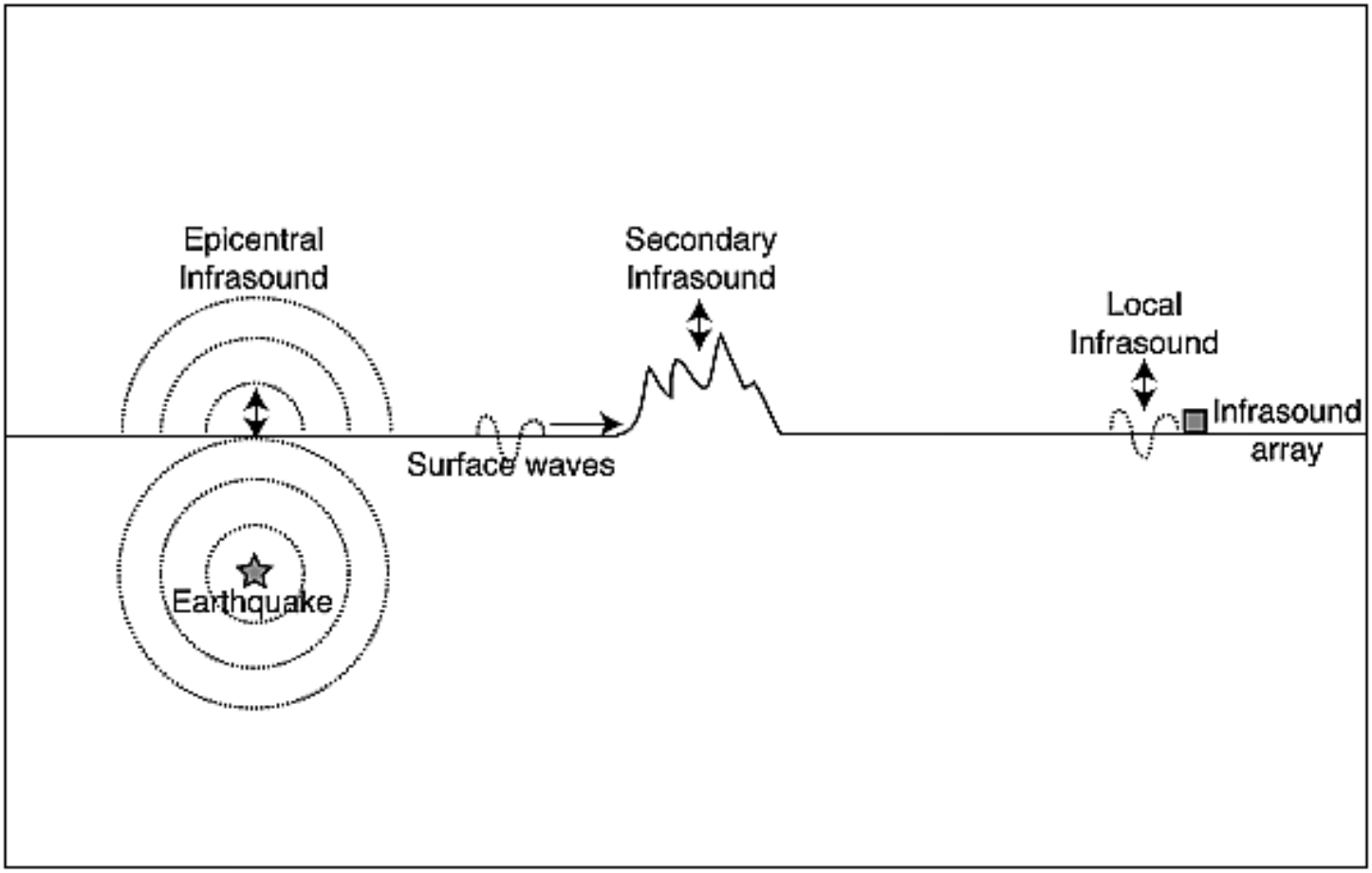
- Infrasound techniques can also tell us about how energy is transferred in the atmosphere and potentially help unravel the mystery of the Venus superrotation

What is infrasound?





Earth: Generation of Infrasound by Quakes

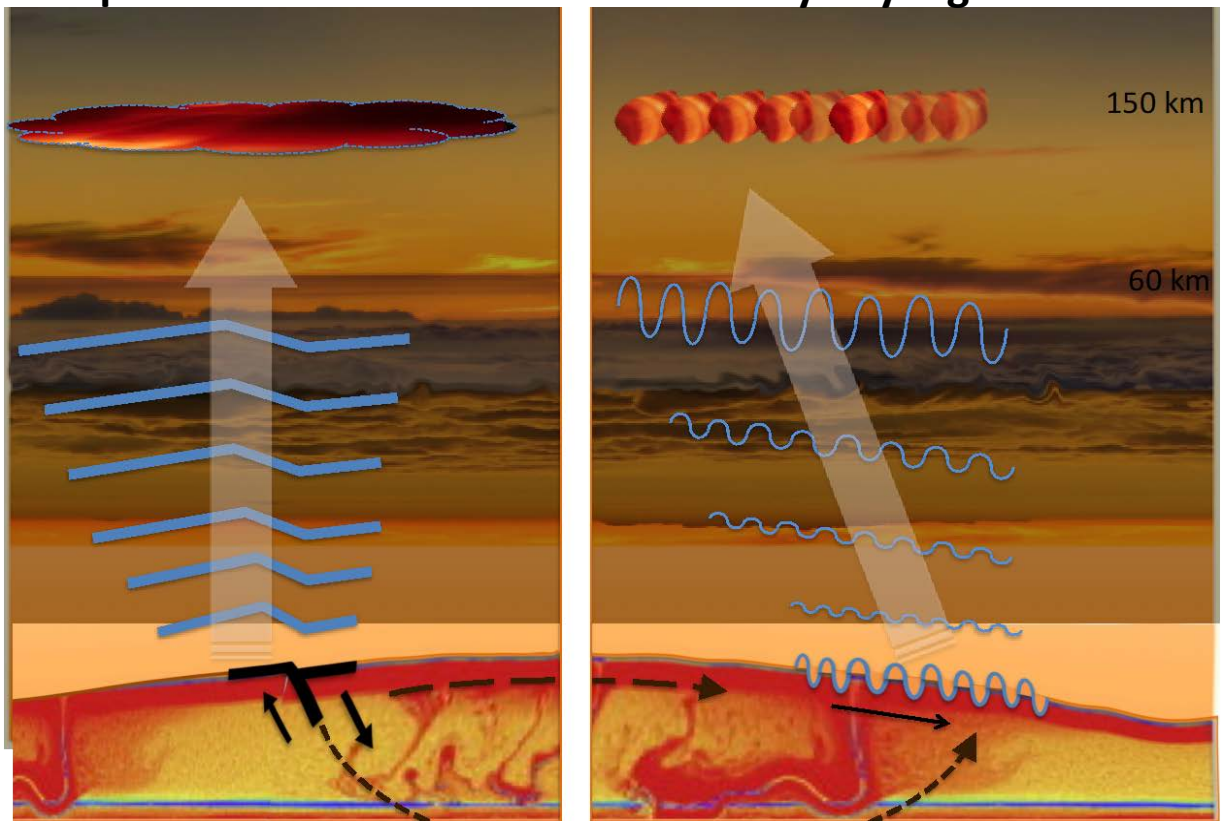


Epicentral infrasound originates from directly above the epicenter and propagates to the infrasound array through the atmosphere

Secondary and local infrasound is generated by surface waves coupling with the atmosphere at a distance from the epicenter

Venus: Seismo acoustic waves at balloon altitudes

Epicentral infrasound **Secondary Rayleigh infrasound**

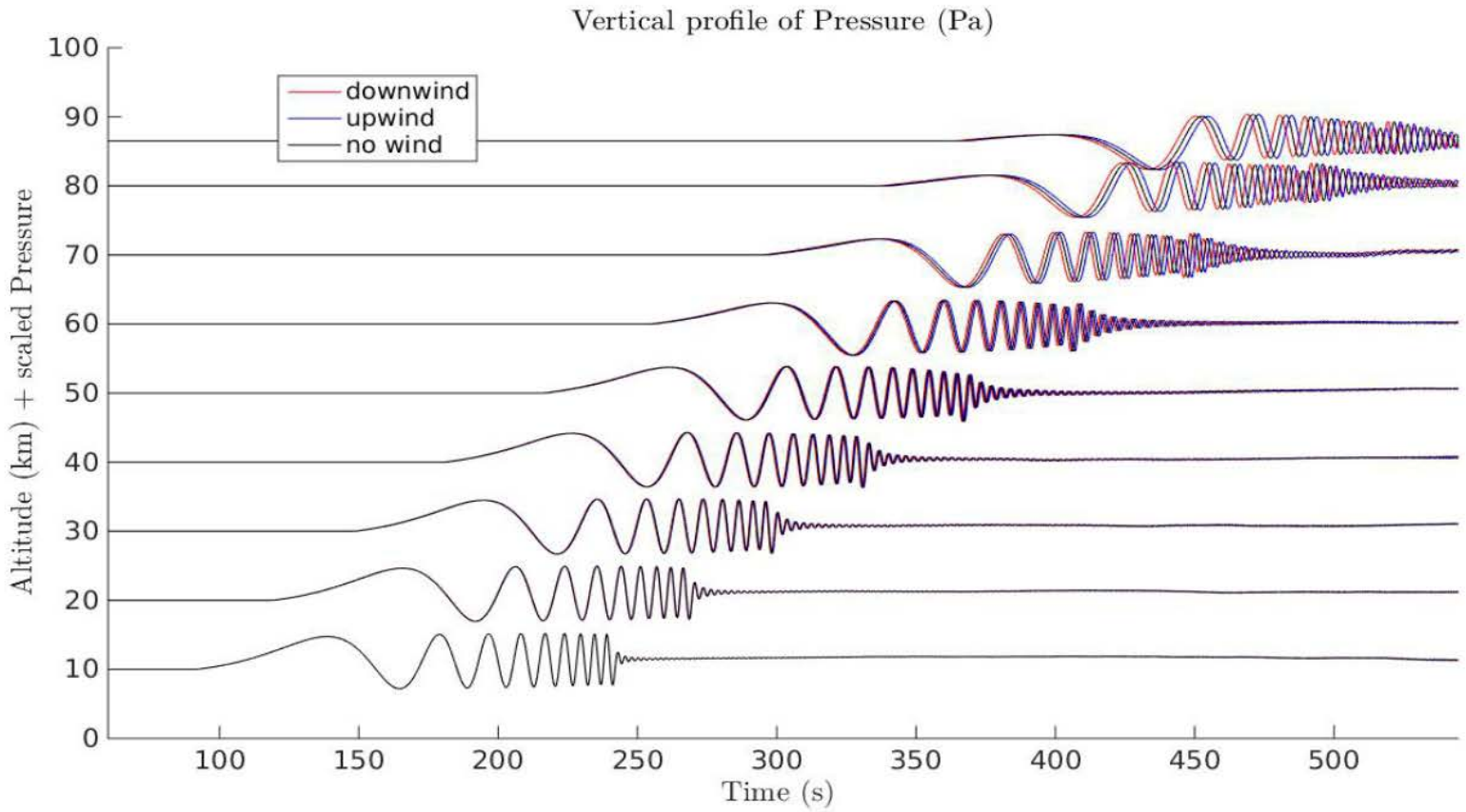


Seismic signals couple 60X more efficiently into the atmosphere than on earth/ The amplitude of the pressure wave relative to ambient increases with height

Epicentral wave from M 3 quake yields a 50 Pa pressure delta at 60 km
Rayleigh waves from larger earthquakes will be detectable to large distances

Wavelength shape insensitive to wind duct

- Almost no attenuation below 80km for frequency <1Hz
- Negligible effect of wind duct on wavefront shape in same altitude range because of vertical wave propagation
- Infrasound wave is a faithful replica of seismic wave



Earth: Balloon Detection of Infrasound –NASA-HASP

Day

Night

Ocean Microbarom

High Altitude Student Platform (HASP)

HASP 2015

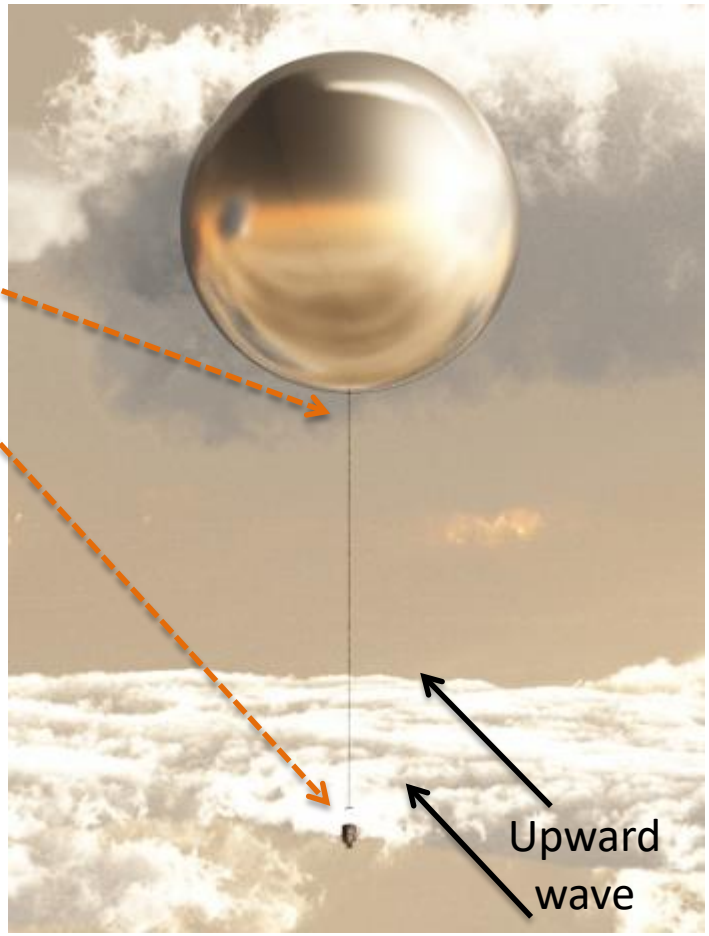
FL1 FL3 FL5 SNAK

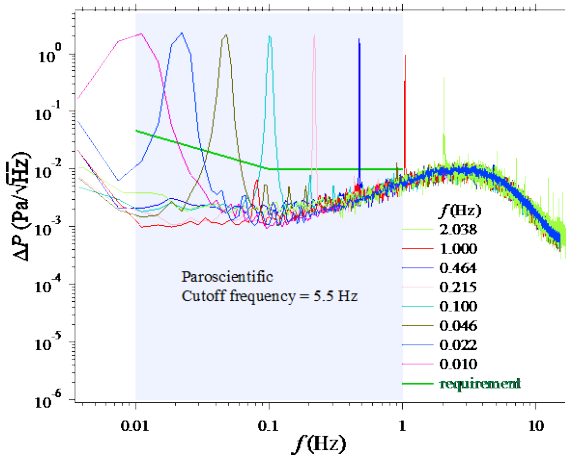
Notes: FL1, FL2, FL3 are sensors on the balloon train. SNAK is a ground station

Reproduced from Bowman and Lees 2016)

Venus: Concept for infrasonic detection of quakes

Paroscientific 213B microbarometer

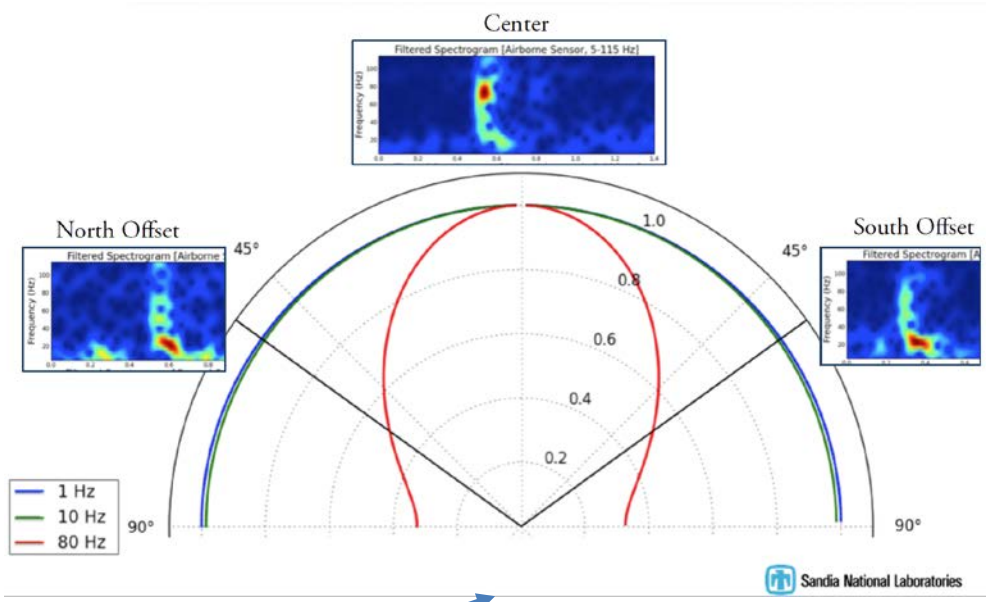




Venus-Analog Infrasound Studies – Phase 1

Platform for Infrasonic sensor validation

Seismic Hammer 0.19Mega-joules, 3 times per minute



Directivity of infrasonic radiation from the seismic hammer

Venus Analog Infrasound Studies – Phase 2 and 3

Phase 2 Dedicated Small Superpressure balloon flight

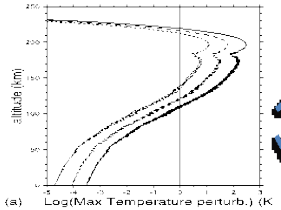
Location: Eastern Oregon
Duration: 1 to 2 days

Phase 3 NASA Superpressure Balloon – payload of opportunity

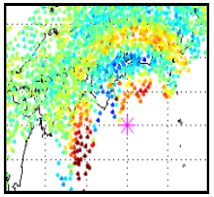
Location: New Zealand
Duration: 30 days

Venus: Detection of seismic infrasonic signature from space

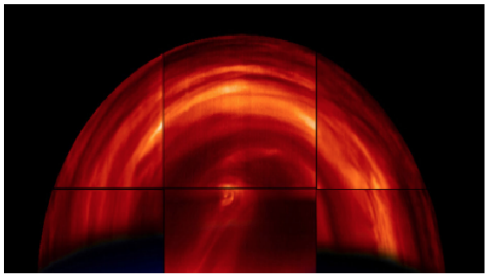
Atmospheric Density Variations



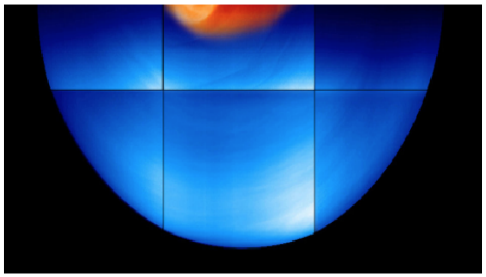
Adiabatic Temperature variations



Total Electron Content (TEC) Variations

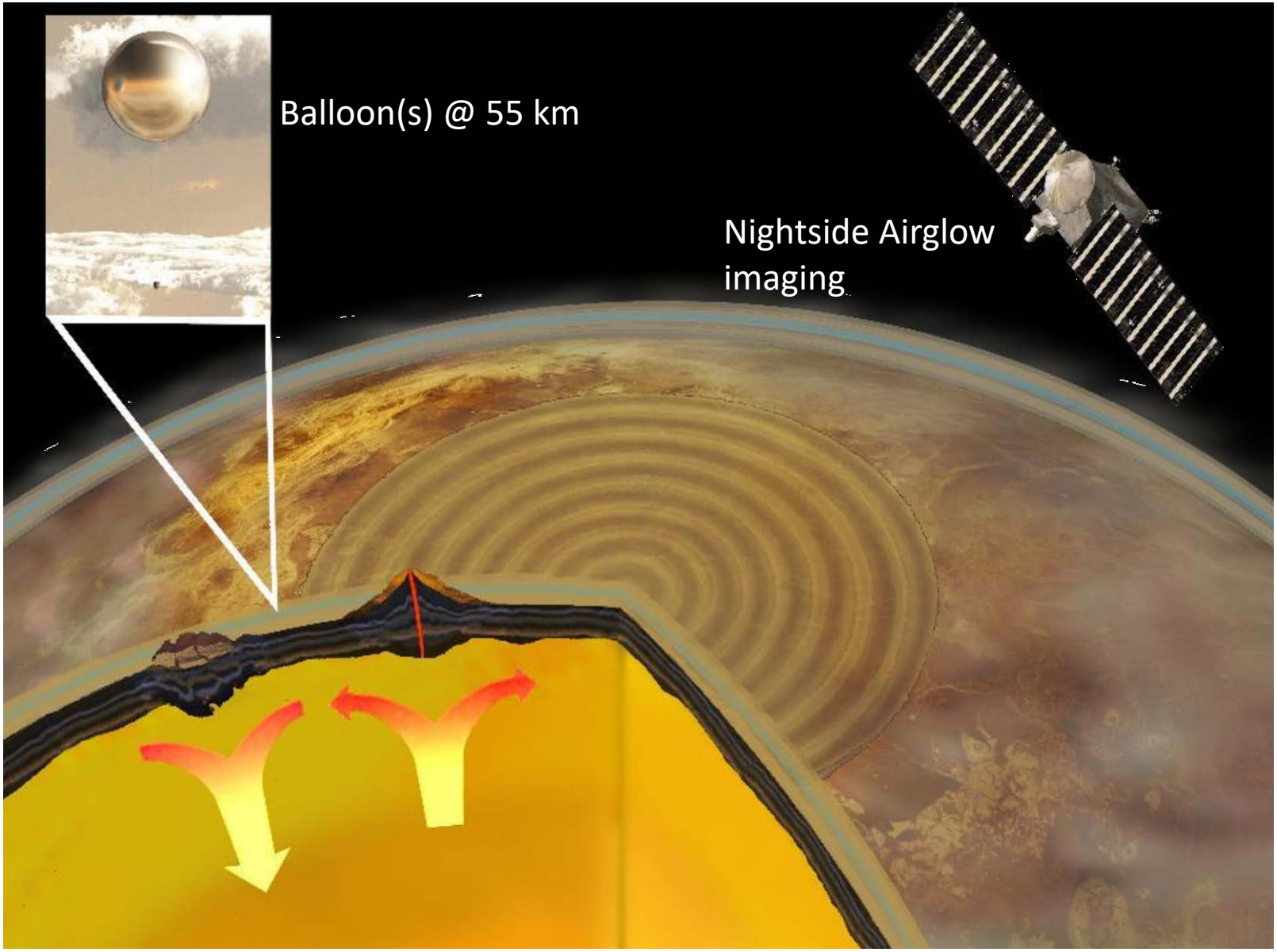


Venus IR airglow (here at 1740nm)



UV airglow (here at 480nm)

Venus: A mission for studying the Venus interior



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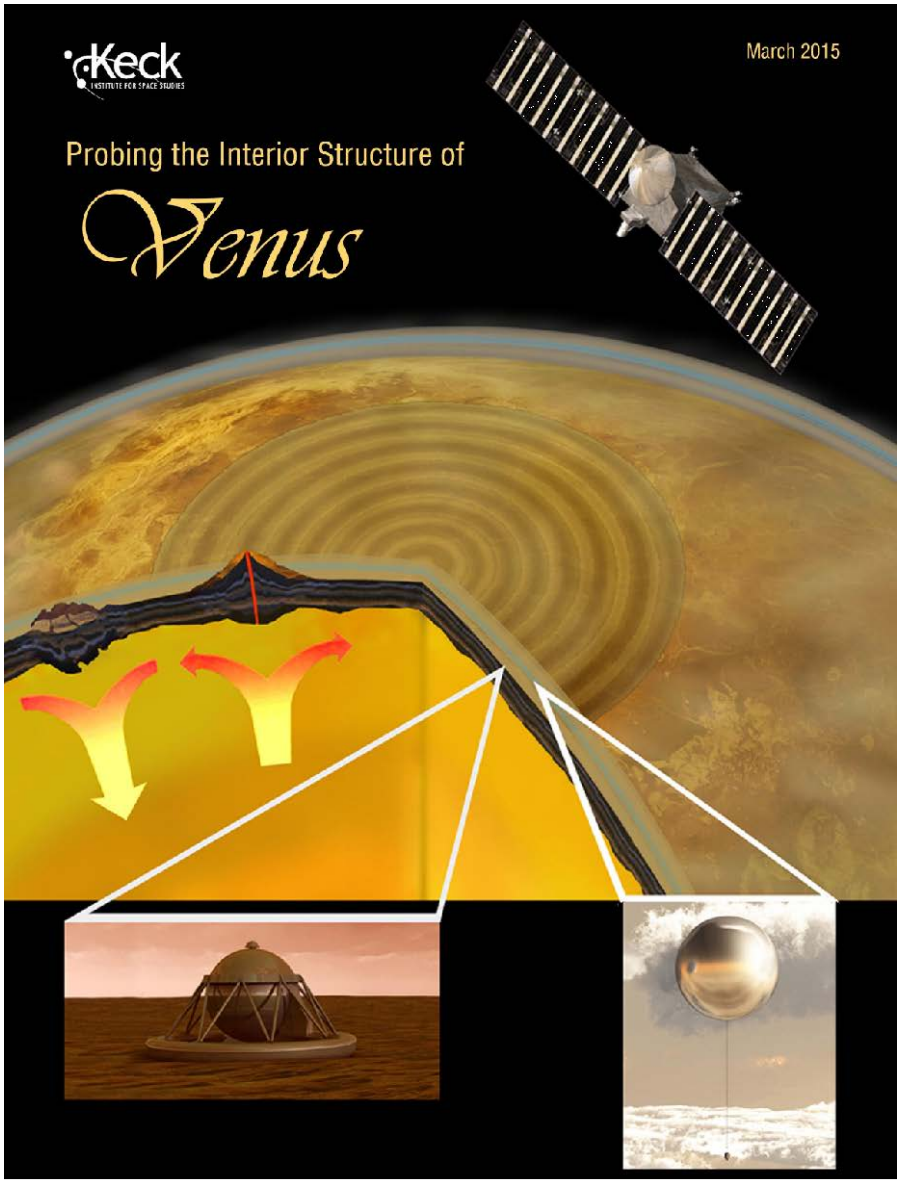
Backup Charts

- KISS Venus Seismology Workshop Report
- The Path Forward – from the 2011 Planetary Science Decadal Survey

KISS Venus Seismology Workshop report



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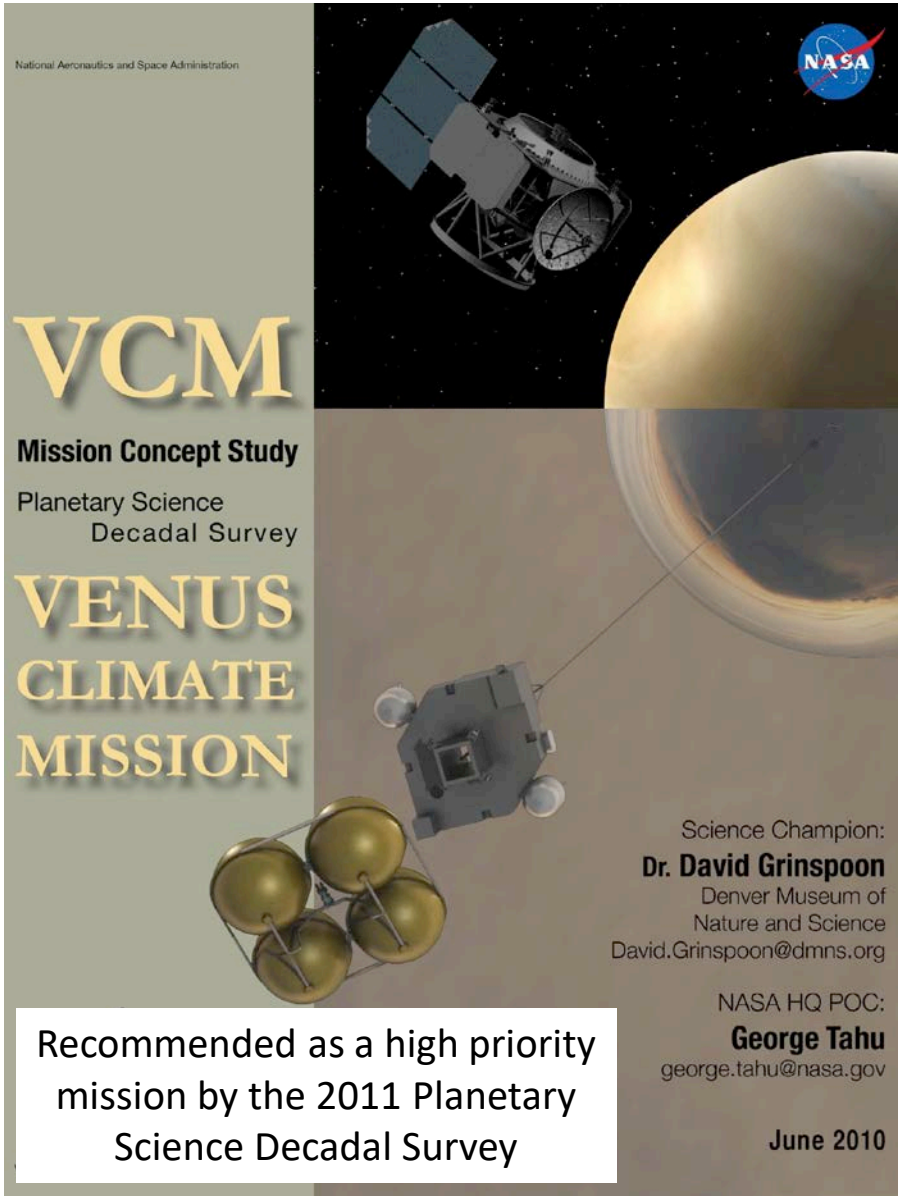
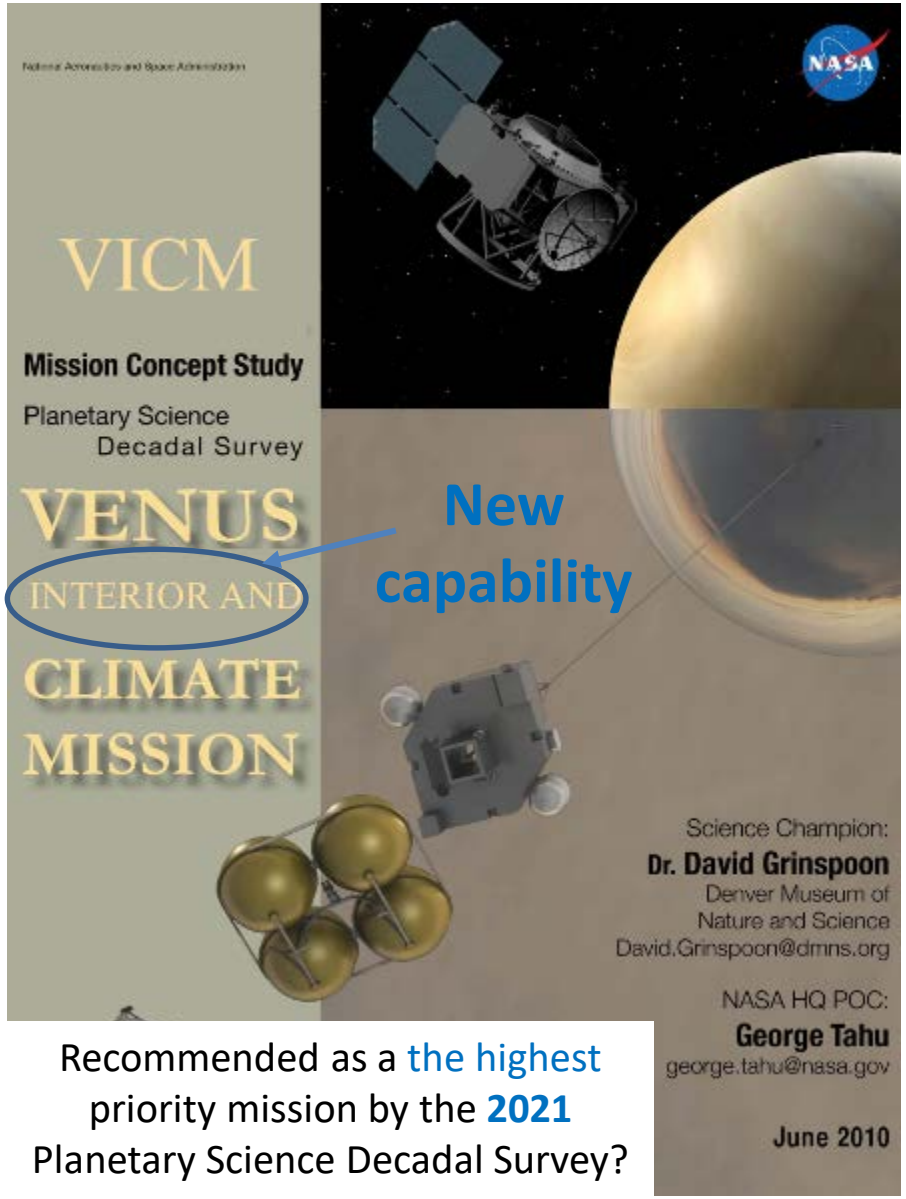
The Path forward – from the 2011 PS Decadal Survey



Recommended as a high priority mission by the 2011 Planetary Science Decadal Survey



Recommended as a the highest priority mission by the **2021** Planetary Science Decadal Survey?