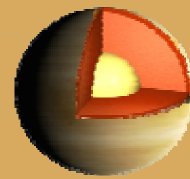

Venus Smallsat and Cubesat Missions

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Topics

- Opportunity
- Challenges
- Rideshare options to Venus
- Infrared monitoring of Venus from circular orbit
- Detecting transient events
- Issues

Objectives

- Examine the feasibility of sending Cubesats or Smallsats to Venus to perform scientific missions
- Determine the primary technical challenges to be addressed
- Describe significant science that can be accomplished with the resources available for a Venus Smallsat

Challenges

- Lifetime and reliability
  - Cubesats have limited lifetime and this will need to be extended if they are to be capable of reaching and operating at planetary targets
  - Smallsats are more robust but still pose reliability questions
- Launch vehicles
  - Dedicated planetary launches are unaffordable because they do not scale well to small sizes.
  - Some form of ride share option will be needed
- Communications
  - Cubesats have a very limited data return capability because of limited antenna aperture size and power
  - Smallsats have more capabilities but the cost of tracking support will become a major factor for a small mission

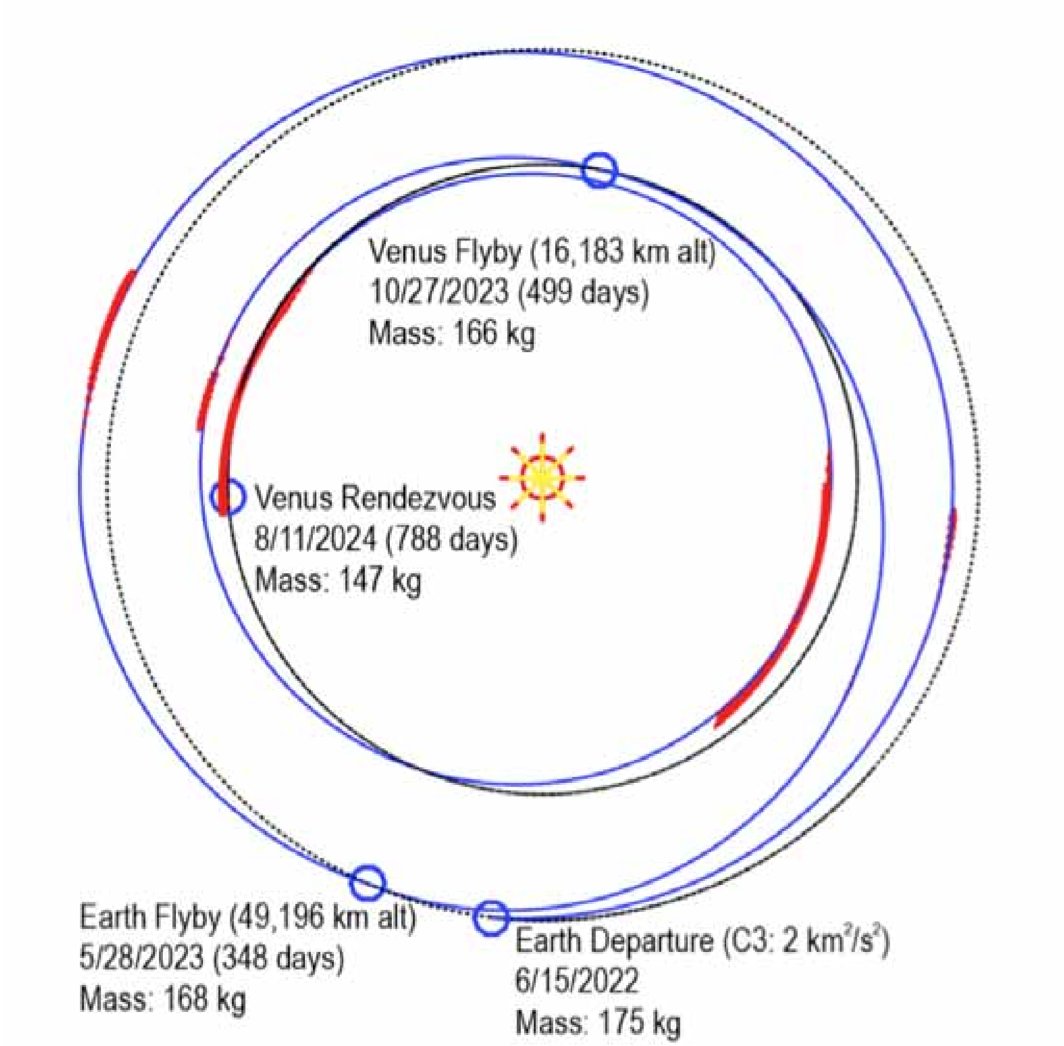
Rideshare Options for Getting to Venus

- Venus Rideshare
  - Venus science mission (orbiter, probe or lander)
  - Venus gravity assist (Sun or outer planet)
- Mars Rideshare
  - Mars Orbiter
  - Mars Lander
- High Earth Orbit/ Lunar Rideshare
  - GEO/GTO
  - Lunar (e.g. EM2)

Launch Options Constrain Venus Mission Architectures

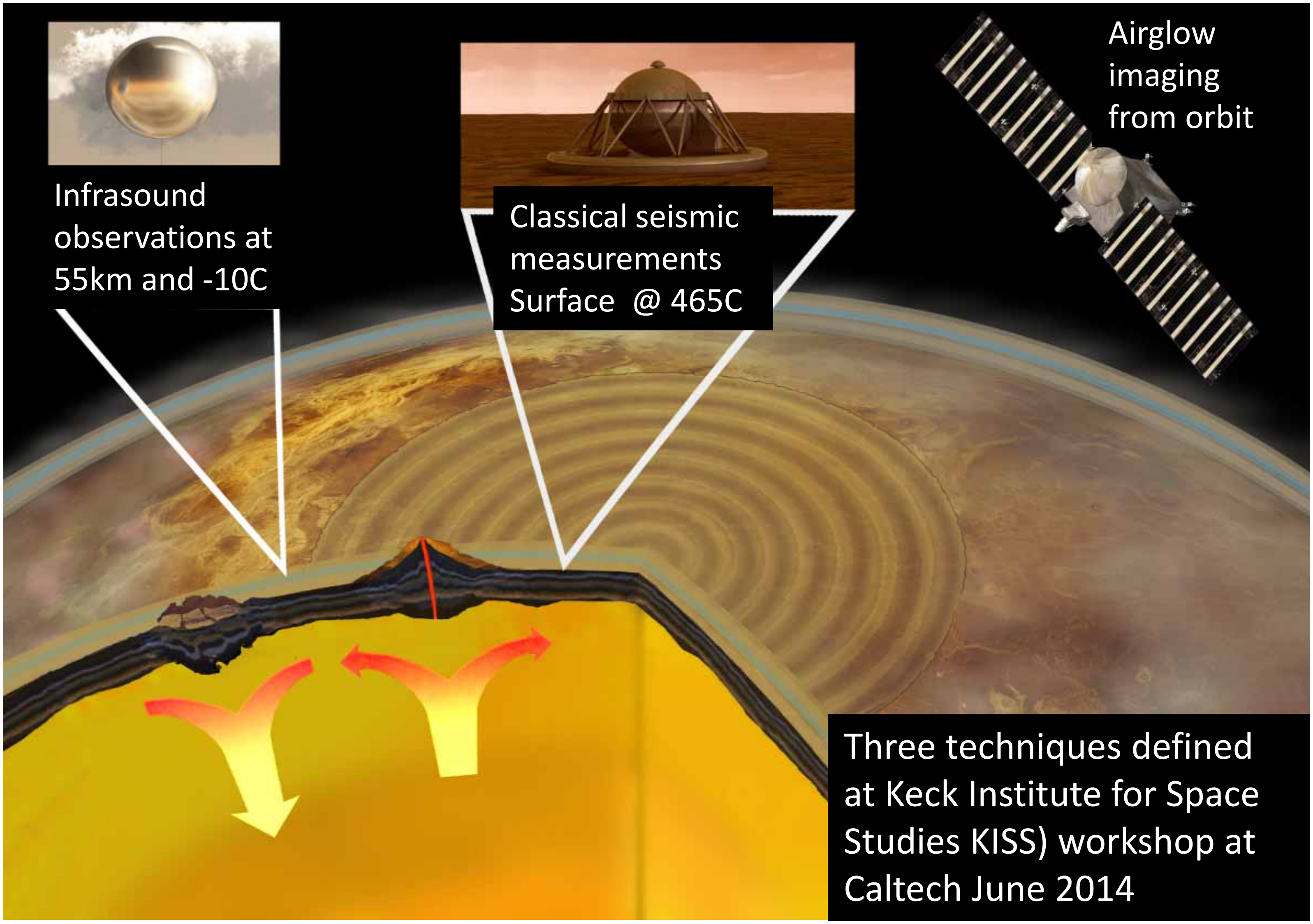
	Ride-Share Option (Venus Hohmann transfer orbits occur every 19 months)		
	Venus (opt 1)	**HEO/Lunar (opt 2)**	**Mars (opt 3)**
Candidate launches			
Frequency	Every few years	Several per year	Every two years
Candidate missions	Discovery/NF-4 Europa	Orion(EM-1 or EM-2) Comsat	Mars 2020 or Mars 2022
Propulsion	Chemical	SEP	SEP
Trip Time (months)	4+	24+	36+
Spacecraft	Cubesat or Smallsat	Smallsat only	Smallsat only
Most accessible Venus orbits	Highly elliptical	Circular or L2	Circular or L2
Needed investigations	Characterizing dependence on approach direction & velocity	Trajectory variability with Earth departure date; Earth escape costs	Further exploration of interplanetary trajectories.

Venus Orbiter - Candidate Trajectory with SEP

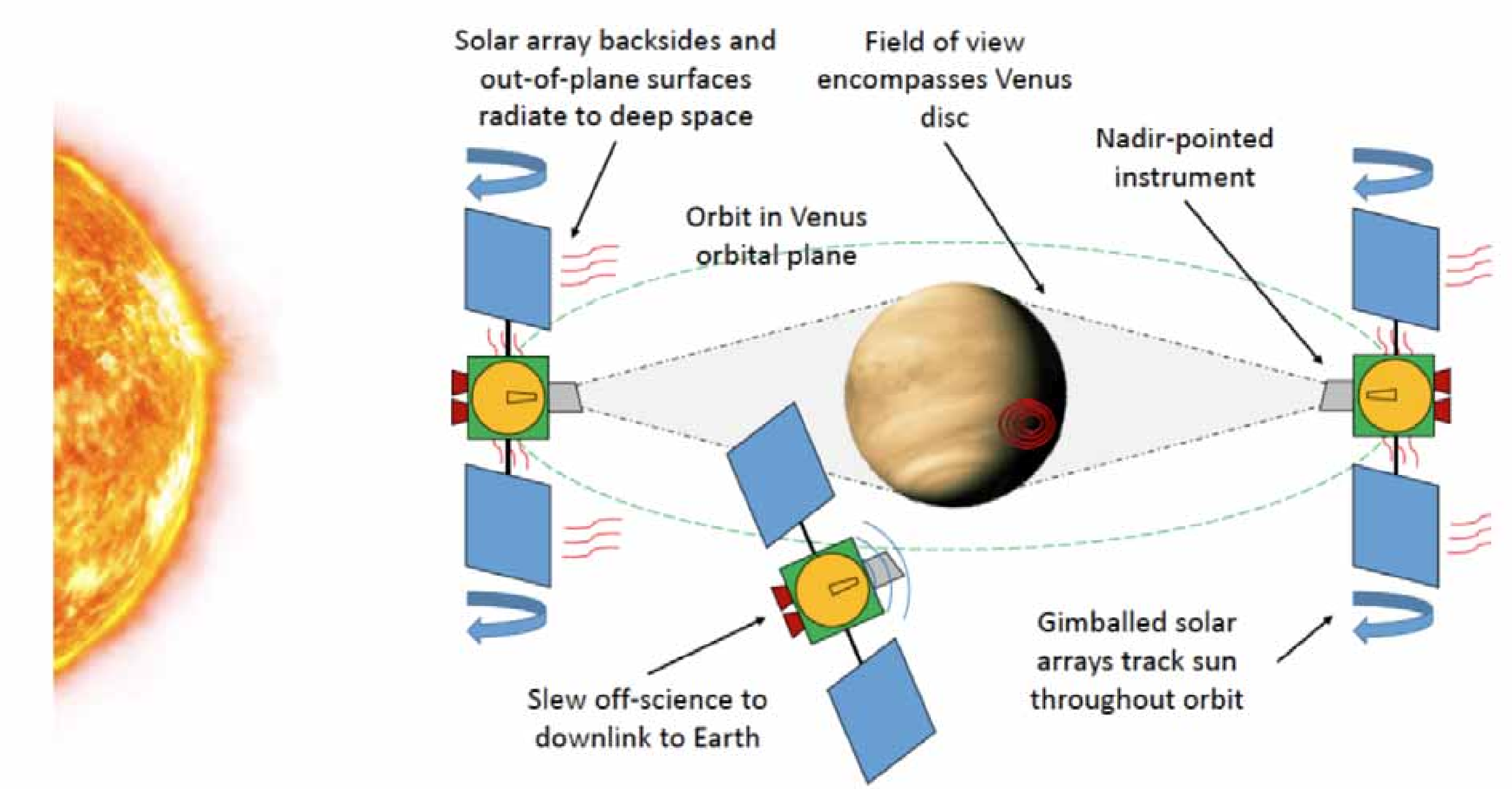


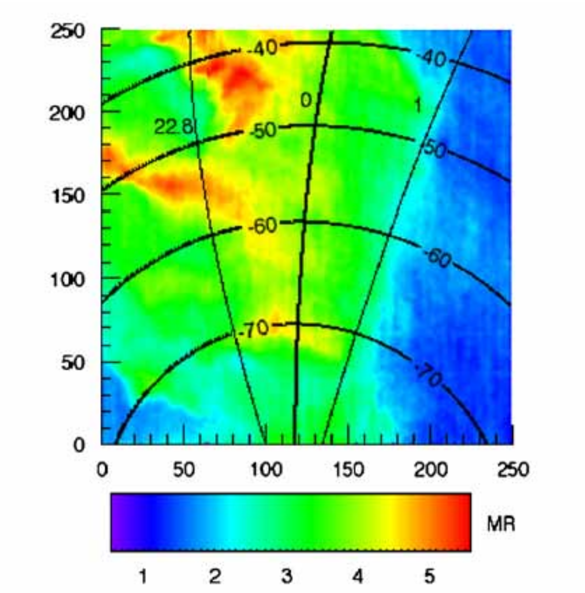
Example SEP trajectory requires 33 kg of Xe + 26 months to rendezvous with Venus.

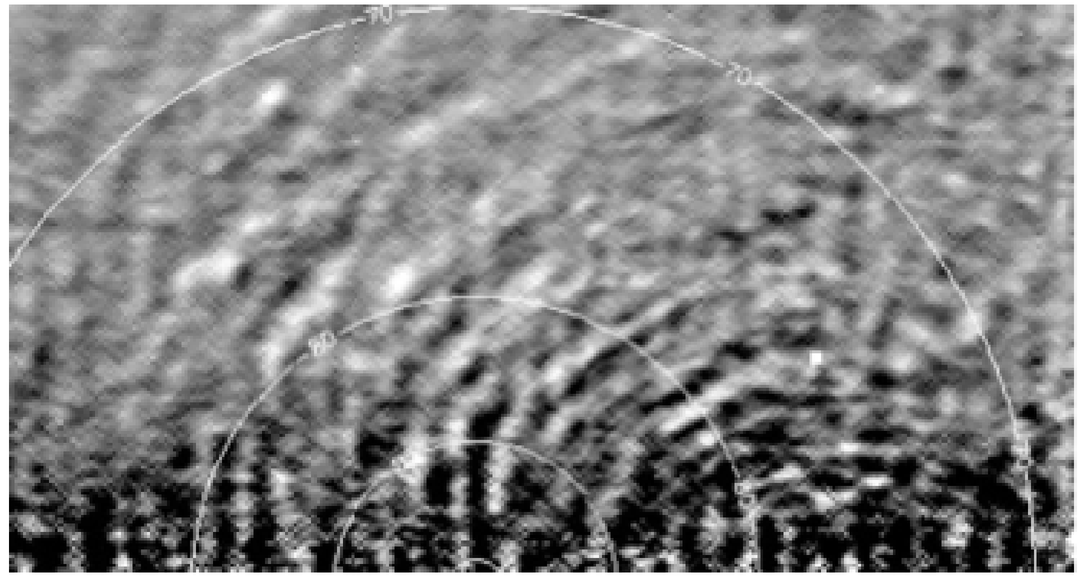
Probing the Venus Interior with Seismic Waves



Infrared Monitoring of Venus with Smallsat





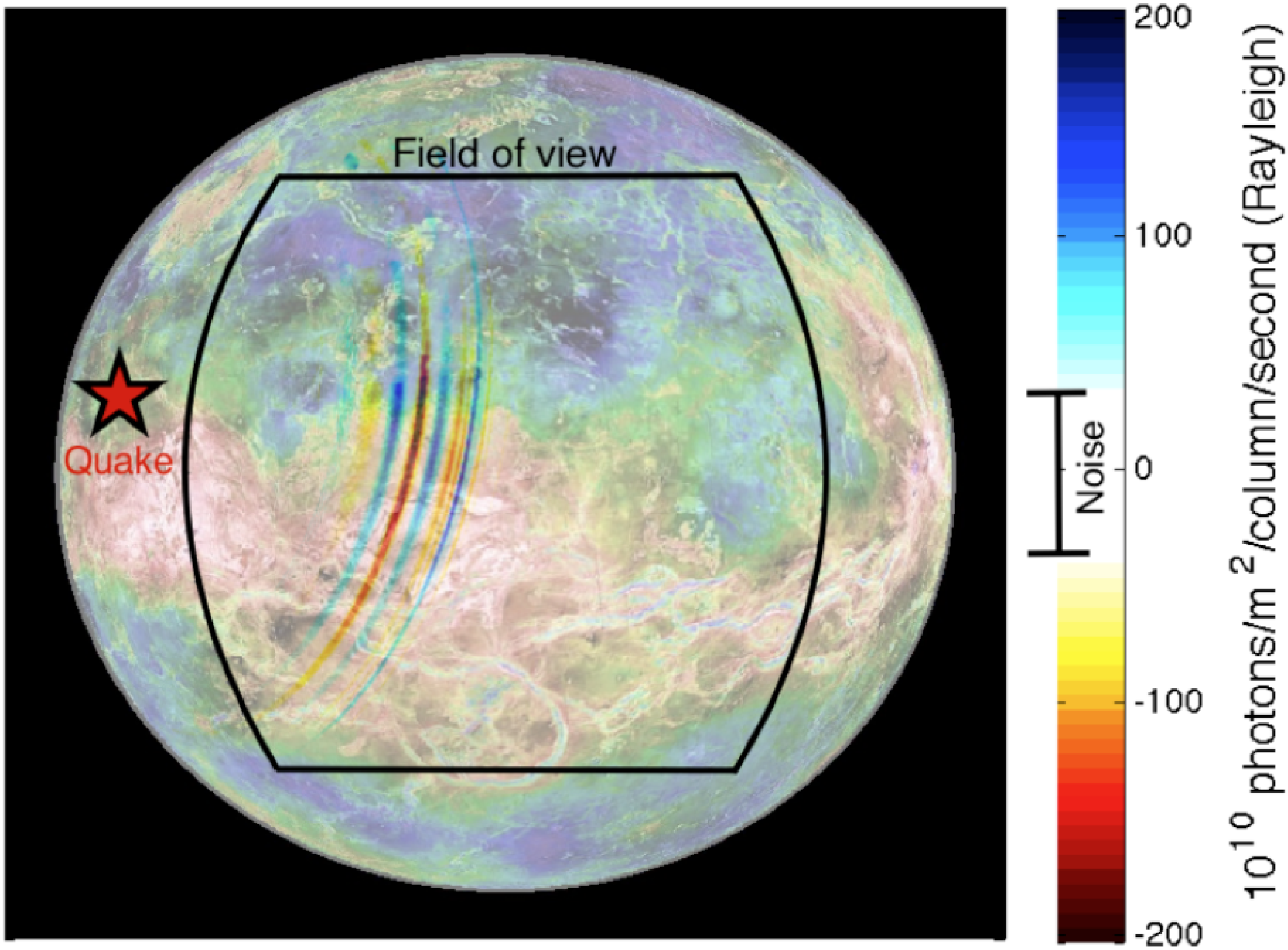


Airglow signal at 1.27 µm from Migliorini, [2011]

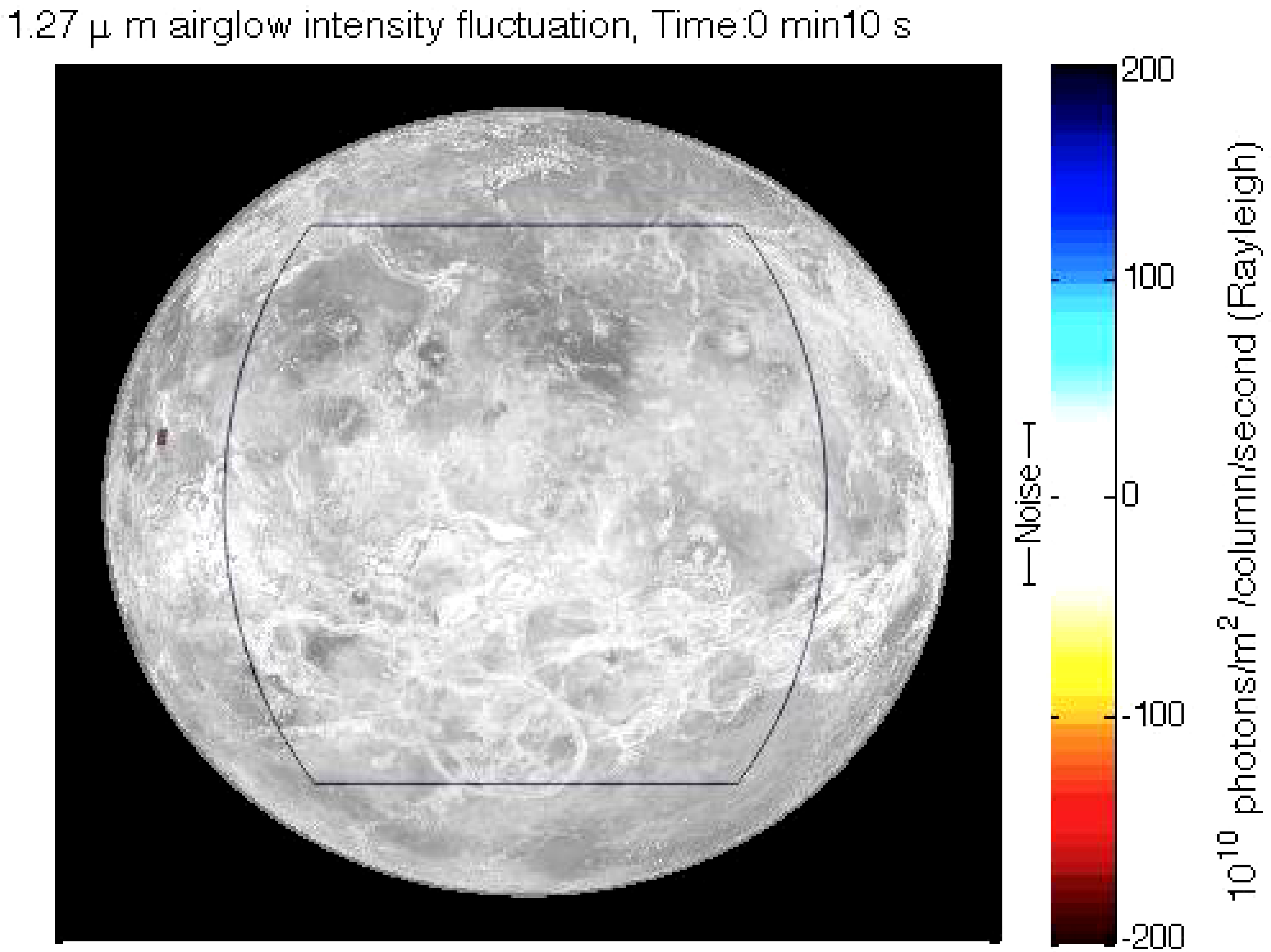
IR emission at 4.3 µm signal from Garcia et al 2009 observed by VIRTIS on Venus Express. The image is contrast enhanced so total modulation is less than 1% Waves are gravity waves emanating from the terminator

Rayleigh waves will move across these scenes at 3.5 km/sec or Mach 15 much faster than any other phenomenon

Prediction of Infrared Signal from Seismic Event



Simulation of Signal from Venus Seismic Event



On Board Data Processing

- Instrumental data rates required for observing these signatures are about 4 Mb/sec
  - Venus Express supported an average rate of 40kb/sec for 8.6 years
  - Cubesat or smallsat would be much smaller

- Returning all this data to Earth is totally impractical

- Need to perform on board event detection and then store possible events followed by returning those to earth in compressed form

- Techniques have already been developed for detection of optical signatures on Earth from tsunamis but we still need to understand how they are best performed on a small spacecraft

Conclusions

- Affordable solutions exist for getting both Cubesats and Smallsats to Venus
  - For Cubesats, the launch and orbital options are more constrained because there are currently no practical solar electric propulsion systems
  - Cubesat scientific payload capability is also limiting for many areas of science particularly with infrared instrumentation requiring cooling

- Detection of Venus quakes appears to be feasible with complementary infrared sensors at 1.27 µm and 4.3 µm with a small mission concept called **VAMOS (Venus Airglow Measurement Orbiter for Seismicity.**

- Other kinds of science can be accomplished with Smallsats where the science can be accomplished with limited data return e.g. **Cupid's Arrow** mission (see Fact Sheet)

- Smallsats in the high circular orbit could also provide a powerful **communications relay capability** for long duration in situ missions such as balloons and surface seismic measurements

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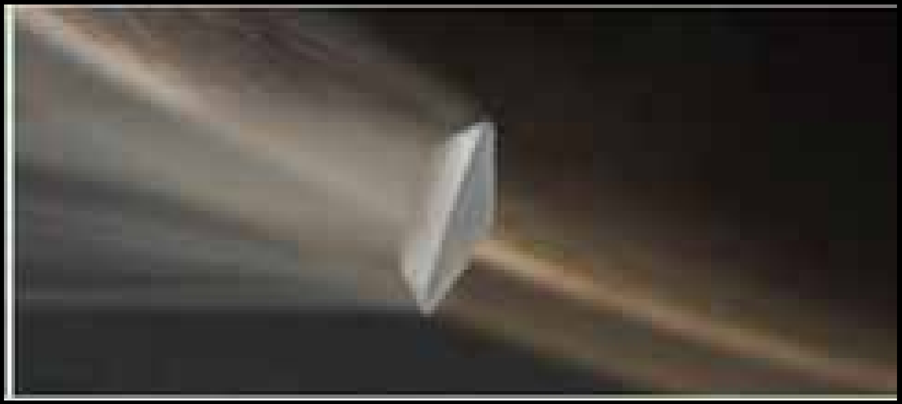
Back Up Slides

- Cupid's Arrow

Cupid's Arrow (PI: C. Sotin, JPL)

Measuring noble gases was rated number 1 investigation of objective A of goal I of the VEXAG "Goals-Objectives-Investigation.

1. Drop-off by a mission flying by Venus



2. …Skims through Venus' atmosphere, below the homopause

3. …samples noble gases

4. … measures the abundance of nobles gases and their isotopic ratios

5. … transmits data to Earth (or to mother spacecraft)