REMOTE SENSING OF SEISMIC ACTIVITY ON VENUS USING A SMALL SPACECRAFT: INITIAL MODELING RESULTS, A. Komjathy[1], A. Didion[1], B. Sutin[1], B. Nakazono[1], A. Karp[1], M. Wallace[1], G. Lantoine[1], S. Krishnamoorthy[1], M. Rud[1], J. Cutts, J. Makela[2], M. Grawe[2], P. Lognonné[3], B. Kenda[3], M. Drilleau[3] and Jörn Helbert[4]

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Introduction: The planetary evolution and structure of Venus remain uncertain more than half a century after the first visit by a robotic spacecraft. To understand how Venus evolved it is necessary to detect the signs of seismic activity. Due to the adverse surface conditions on Venus, with extremely high temperature and pressure, it is infeasible with current technology, even using flagship missions, 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 can be detected in the atmosphere itself.

The Venus Airglow Measurements and Orbiter for Seismicity (VAMOS) is a mission architecture concept to enable a small spacecraft in Venus orbit to detect and characterize the perturbations of the neutral atmosphere and ionosphere induced by seismic waves. Venus is surrounded by the brightest naturally occurring airglow layer known in the Solar System. Airglow is a result of various atoms, molecules, and ions that get photoionized by ultraviolet radiation from the Sun and then release energy as visible and infrared light when they recombine and return to their normal state. Perturbations in the neutral atmosphere caused by seismicity on Venus leave an imprint in this airglow layer, which spans altitudes from 90-110 km. We use remote optical observations of this layer to study these perturbations, allowing us to infer the currently unknown seismicity and crustal structure of the solid planet below.

Additional perturbations from atmospheric sources (i.e., gravity waves) are also present in this airglow layer and provide insight into Venus' atmospheric dynamics, particularly the variability in the zonal wind on dayside and nightside. The unexplained day-to-day variability in the airglow and hence the oxygen atom abundance is an additional target of investigation.

Science Investigation: Two specific airglow emissions are investigated in the mission concept study, one occurring at 1.27 μm (visible on the night-side) and the other at 4.3 μm (visible on the dayside). The significant advantage of observing nightglow on Venus is that it is much brighter on Venus than on Earth [*2*] and that airglow lifetime (~4,000 sec) is significantly longer than the period of seismic waves (10-30 sec). This makes it very attractive for directly detecting surface waves on Venus. This is in sharp contrast with Earth where the lifetime of airglow is about one order of magnitude smaller (~110 sec) than, e.g., the tsunami waves we routinely observe on Earth with 630 nm airglow instruments [*4*]. We also investigate the use of a 4.3 μm infrared (IR) channel to detect slow moving processes including gravity waves and signals of non-adiabatic heating of the atmosphere generated by the Venus quakes. The 4.3 μm channel complements the 1.27 μm one in possibly sensing epicentral waves generated by quakes at higher altitude of 120 km because energy is dissipated as heat at this altitude.

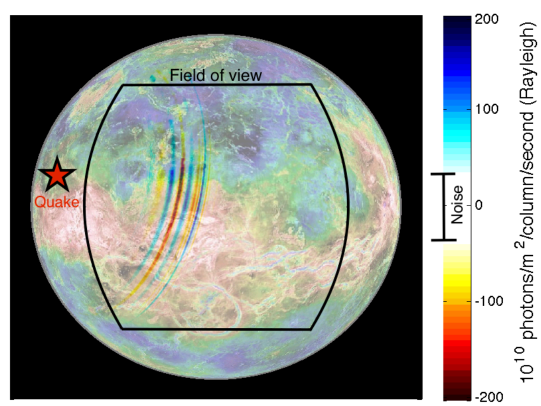

Figure 1. Modeled airglow fluctuations due to 20-sec seismic waves generated by a M_w=5.8 quake. (See Airglow Movie [1] in References). The star is quake location and the colors indicate airglow fluctuations above the conservative ±30 Rayleigh detection noise estimate using 0.3° planetary resolution.

Modeling Results: Physics-based modeling of seismic-wave-generated 1.27 μm airglow intensity variations on Venus demonstrated the possibility of identifying seismic events by remote sensing of planetary airglow signals. The seismic displacements induce a variation in the concentration of the excited O_2, and thus in the volumetric emission rate (VER) [*3*]. This fluctuation can then be computed at every point and radially integrated to give the intensity fluctuation as seen from outside the atmosphere. Normal modes and surface waves can be numerically computed for a fully coupled solid planet/atmosphere system. This technique allows the calculation of the seismic signals within the atmosphere and in the airglow layer in particular.

To obtain realistic fluctuations in the airglow intensity, we used a 3D statistical model of the background VER based on more than two years of Venus Express observations. Seismograms up to 50 mHz (20 sec) were computed for a quake at 20 km depth on Venus occurring outside the FOV. Such quakes may be considered as representative of a quake triggered by lithospheric cooling in the thin brittle layer of Venus. These seismograms included the Rayleigh fundamental modes and the first five overtones of spheroidal surface waves. Analysis by [3] indicate that peak-to-peak variations larger than 3000 Rayleigh are expected up to 60° of epicentral distance for a M_w=6.5 quake. For the sensor investigated, this provides a signal-to-noise ratio of 6 with respect to the 98% peak-to-peak detection threshold of ±250 Rayleigh for 2.5 sec integration time and a single pixel of 5 km x 5 km. A detection threshold of about ±30 Rayleigh is then achieved by stacking 36 pixels using 5 sec integration, which is expected to satisfactorily image a 20 sec half-Rayleigh wavelength squared surface. In *Figure 1* (play Venus Airglow movie: http://goo.gl/j3I1bG) we display our resulting airglow fluctuations for a M_w=5.8 quake calculated on the nightside of Venus using stacked processing. The detection threshold is then about M_w=5.3 [5].

Summary: The VAMOS mission concept is being studied at JPL as part of the NASA Planetary Science Deep Space SmallSat Studies (PSDS3) program, which can not only produce a viable and exciting mission concept for a Venus SmallSat, but will have the opportunity to examine many issues facing the development of SmallSats for planetary exploration. Our mission concept VAMOS would measure atmospheric perturbations from an orbiting platform that could provide a breakthrough in detecting seismicity on Venus and in the monitoring of seismic wave propagation.

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