Exploring the Use of Airglow Measurements for Detecting Seismicity on Venus

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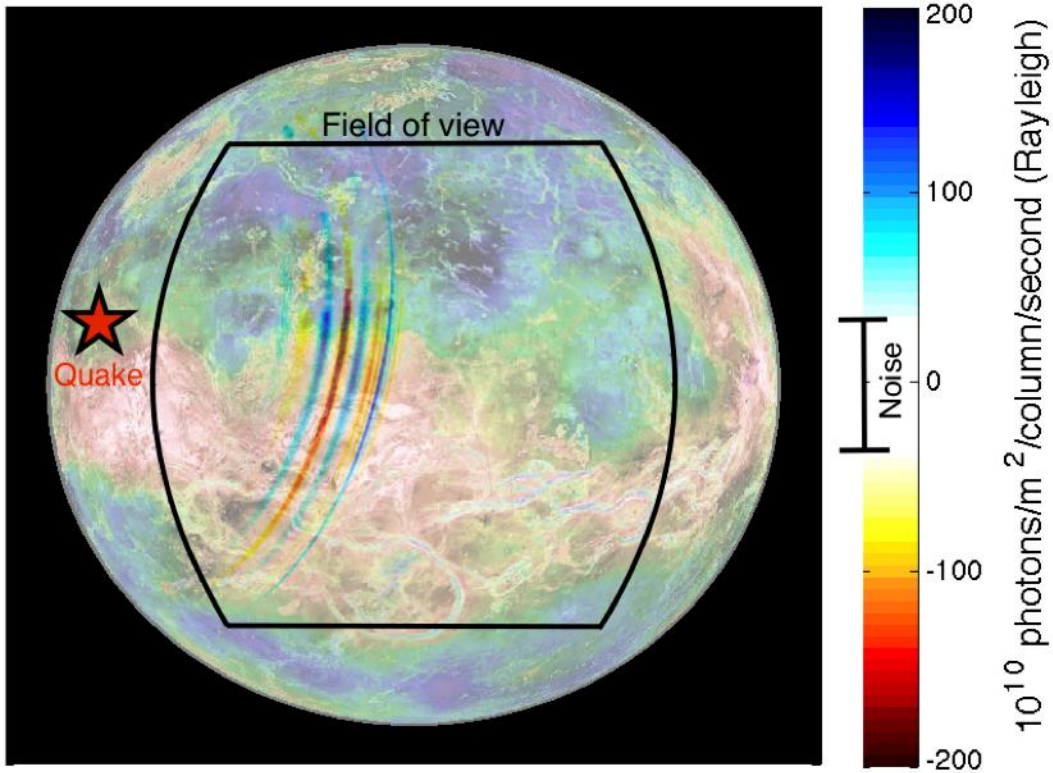

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Venus: A poorly known planet

Despite similarities with the Earth, Venus evolved differently and very little is known about:

- Interior structure (core, mantle, crust)
- Long-term evolution
- Present-day geologic activity

Seismology would help answering these questions and improve our understanding of the planet

Seismicity of Venus

In the lack of plate tectonics, the potential seismic activity of Venus is debated:

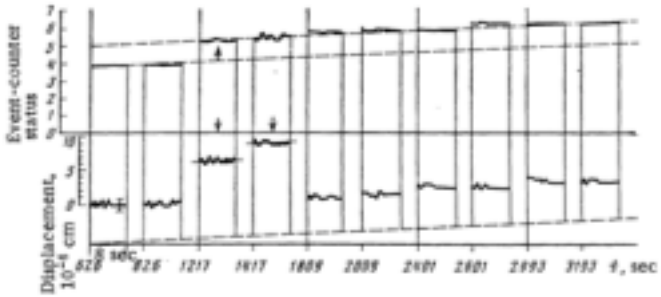
- High temperature → aseismic deformation
- No continents, no conclusive evidence of subduction

- Low water content
- Possible local subduction (Davaille and Smrekar, 2017)
- Presence of surface faults (active?)
- Phase transitions
- Other sources (e.g. volcanic eruptions)

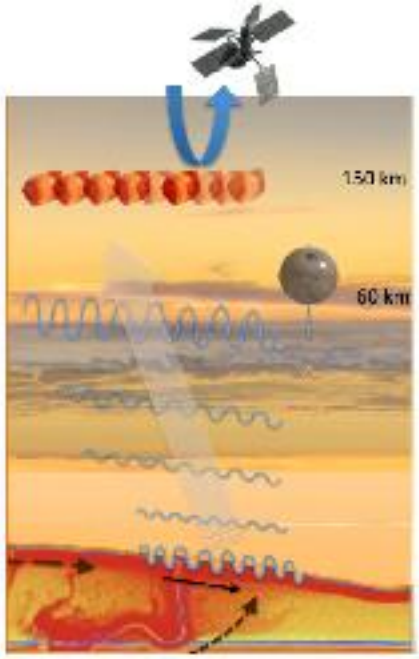
Current estimates and analogies with the Earth (intra-plate seismicity) suggest possible quakes of magnitude up to 6.5. M=5 quake would occur over days/weeks intervals.

Seismology on Venus

- Venera 13 and 14 short-lived seismometers (1982)
- Difficulties for surface seismology
- Strong atmospheric coupling: balloons and remote-sensing seismology
- Here we focus on possible future detection of seismicity via observations of the IR airglow fluctuations



Ksanfomaliti et al., 1982



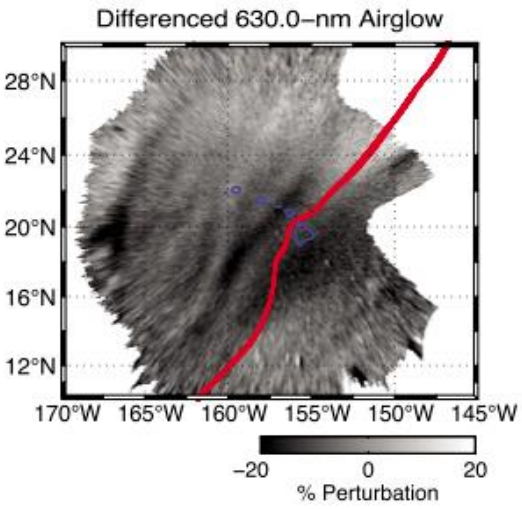
Cutts et al., 2015

Airglow observations on the Earth: Tsunamis

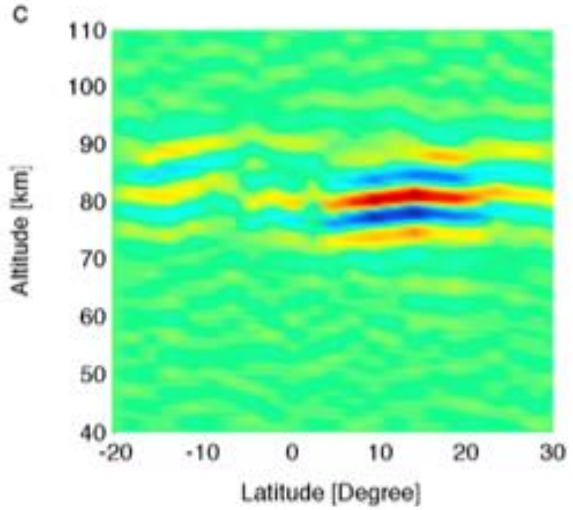
Various observations of airglow response to tsunamis:

- Visible
- Ground-based (Hawaii)
- Tohoku-Oki 2011

- Infrared
- Satellite-based (SABER)
- Chile 2015



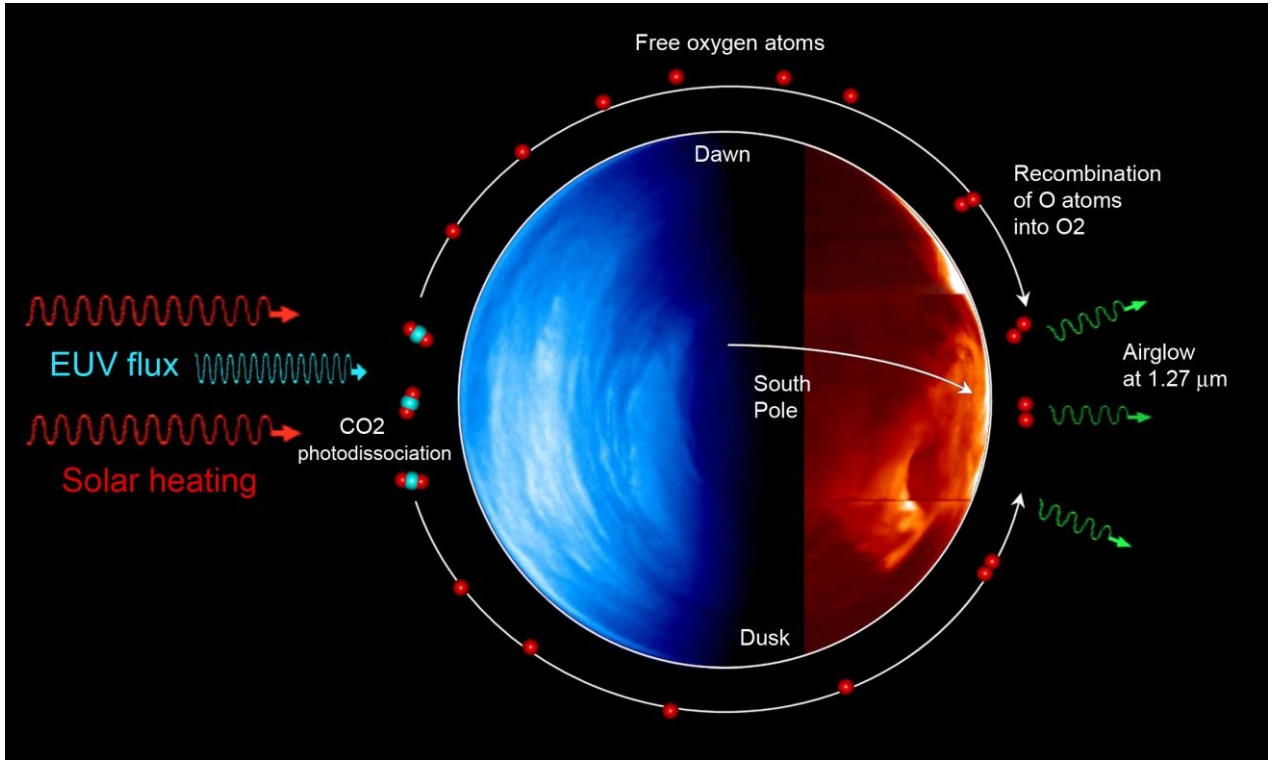
Makela et al., 2011



Yang et al., 2016

Near-Infrared Airglow on Venus

- Bright airglow at 1.27 micron on the Nightside of Venus
- VIRTIS measurements (on Venus Express) give the 2D distribution of the Volumetric Emission rates
- Vertical profile from measurements and modelling



Credit: ESA

Near-Infrared Airglow on Venus

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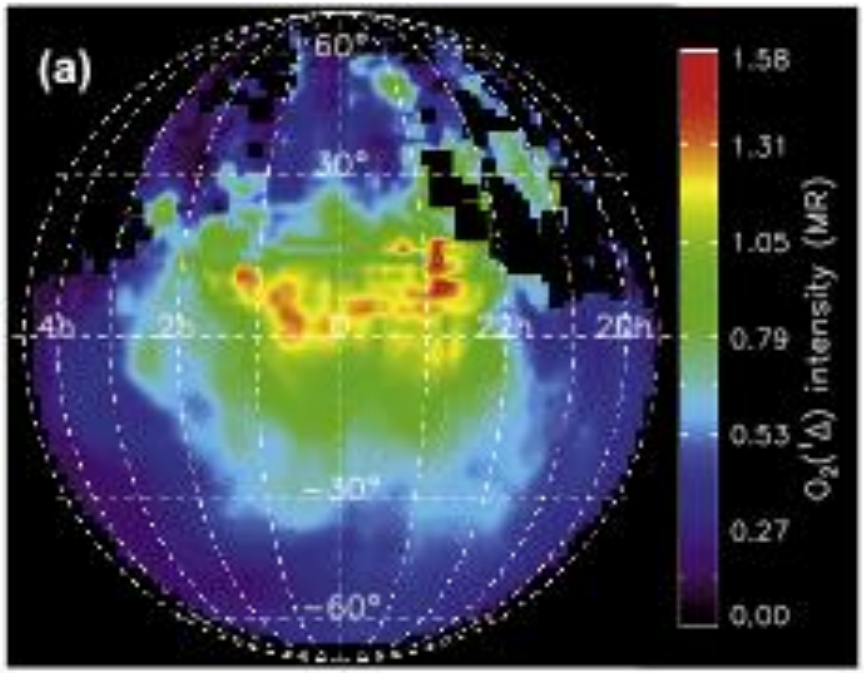
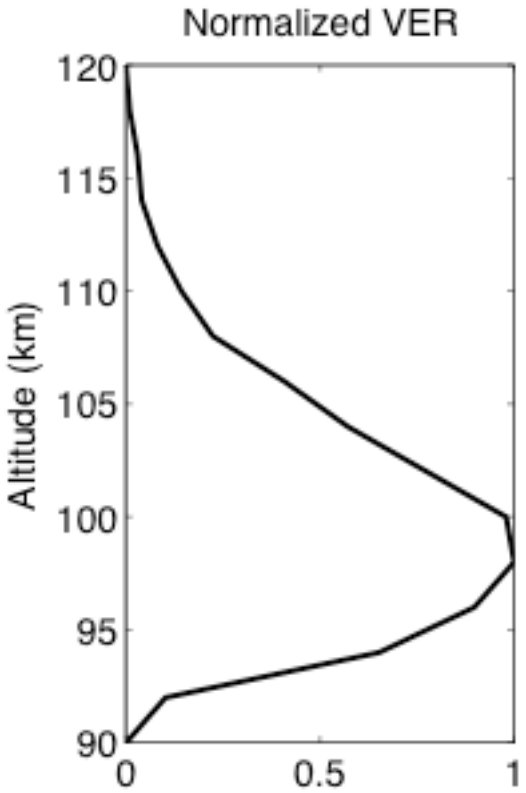


Soret et al., 2012



Krasnopolsky, 2011

Principle

Would a dedicated airglow camera, orbiting Venus, be able to detect seismic activity?

→ **Modeling:**

1. Signature of a quake in the atmosphere
2. Induced airglow fluctuations
3. ‘Maps’ of the quake

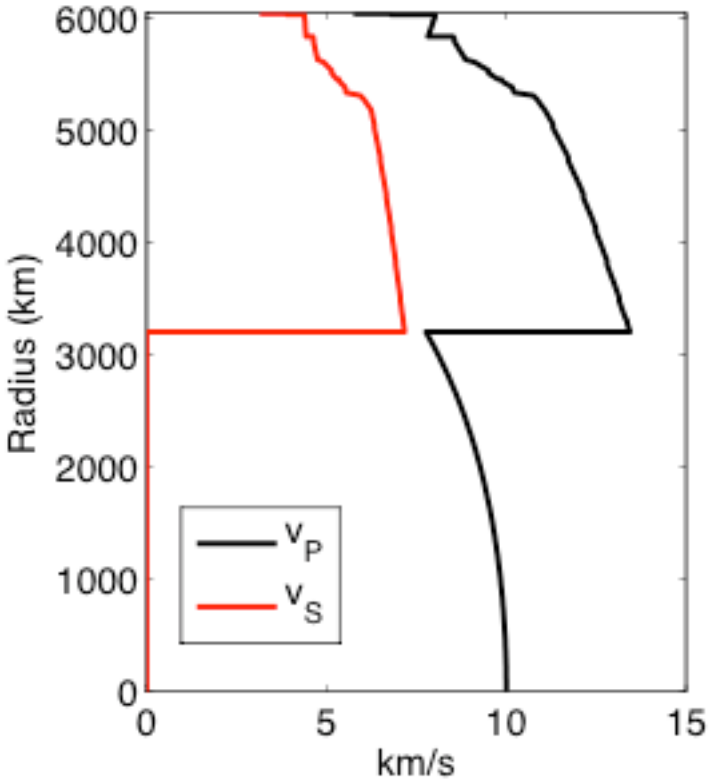
Normal Modes and Synthetics

Structure

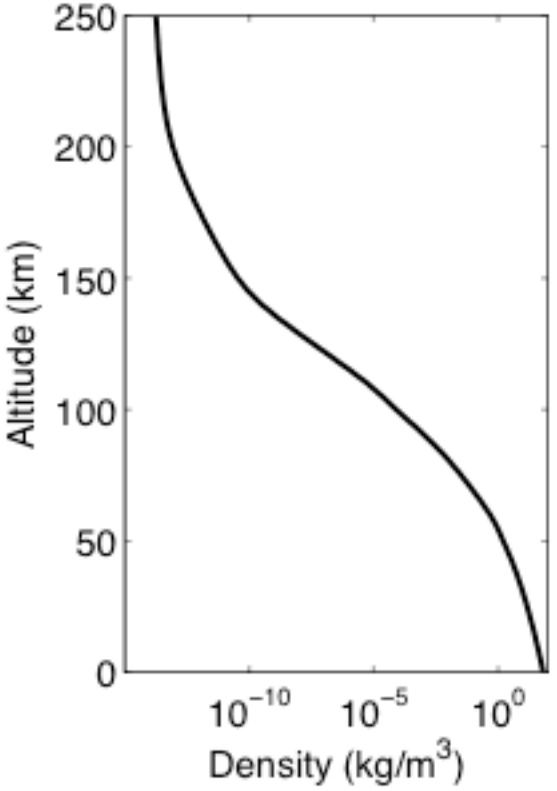
Modes

Synthetics

Solid part: PREM-like interior model



Atmosphere: Venus GRAM



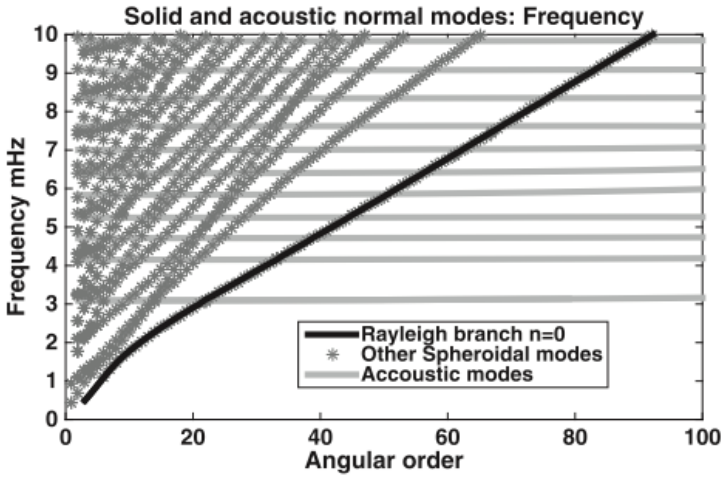
Normal Modes and Synthetics

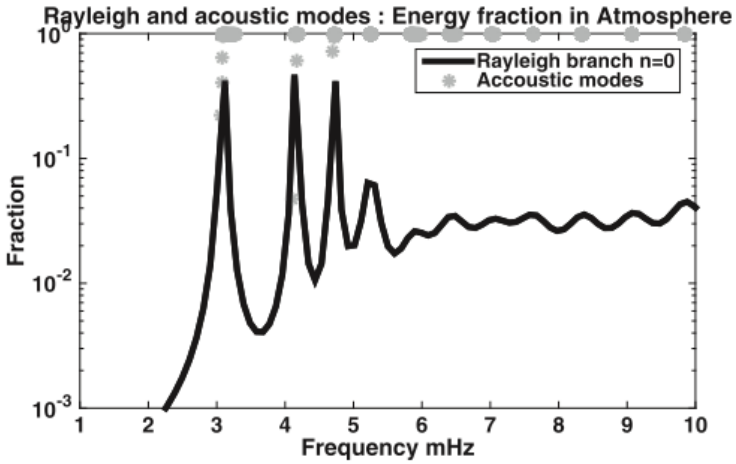
Structure

Modes

Synthetics

- Rayleigh modes up to 50 mHz
- Viscous and molecular relaxation
- Radiative top-boundary condition
- Strong coupling between solid planet and atmosphere





Lognonné et al., 2016

Normal Modes and Synthetics

Structure

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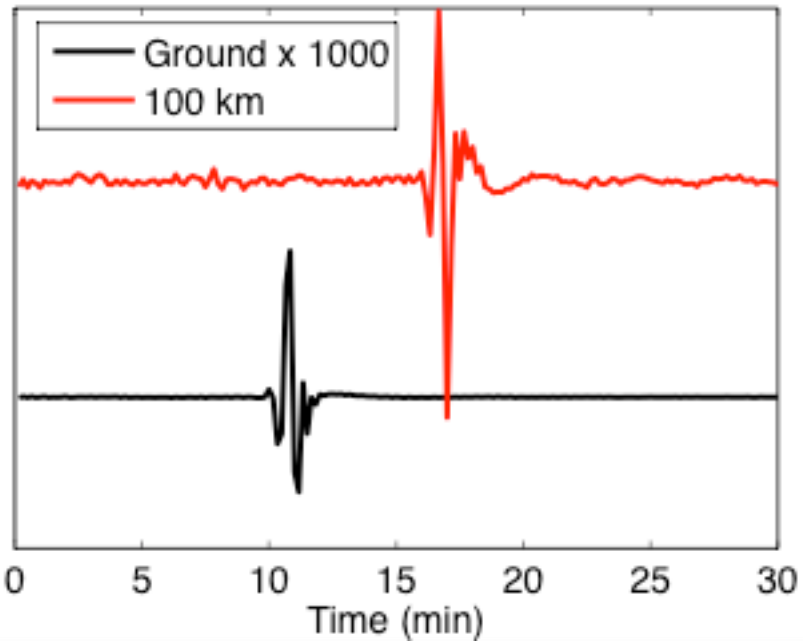
The atmosphere acts as an amplificator due to the exponential decrease of the density:



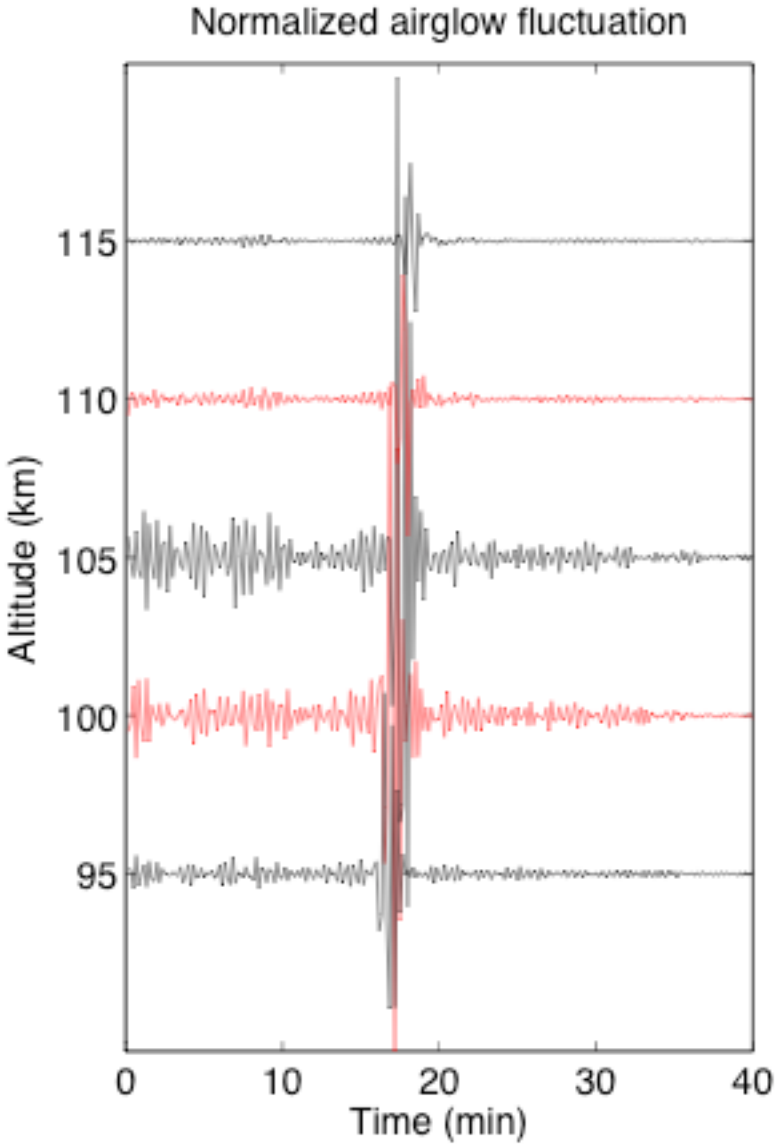
Airglow Fluctuations

The fluctuation of the Volumetric Emission Rate (VER) of O_2 is computed following *Lognonné et al. (2016)* at different altitudes in the airglow layer (90 to 120 km):

$$\delta VER = -\frac{\tau}{1 + i\tau\omega} \nabla \cdot (VER \cdot v_\omega)$$

- τ=4460 is the radiative lifetime
- *v* is the vertical velocity
- ω is the frequency of the mode

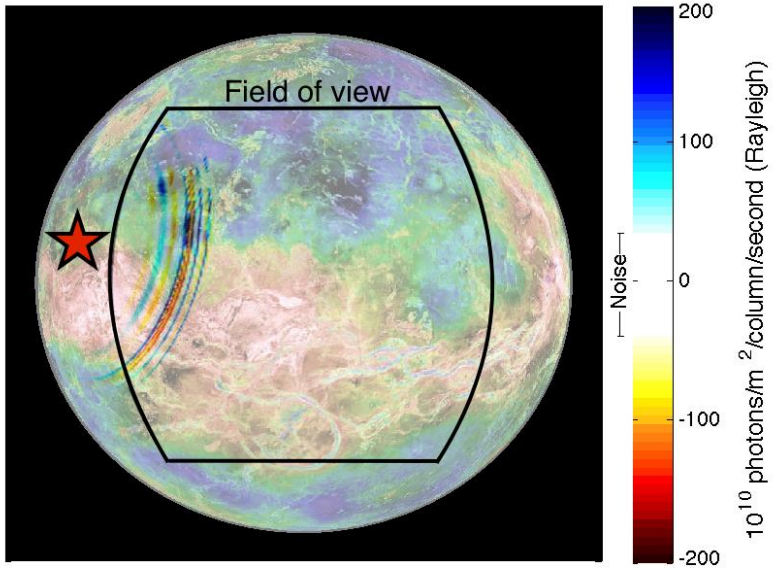
The fluctuation is finally vertically integrated to reproduce the signal as seen from outside the atmosphere.



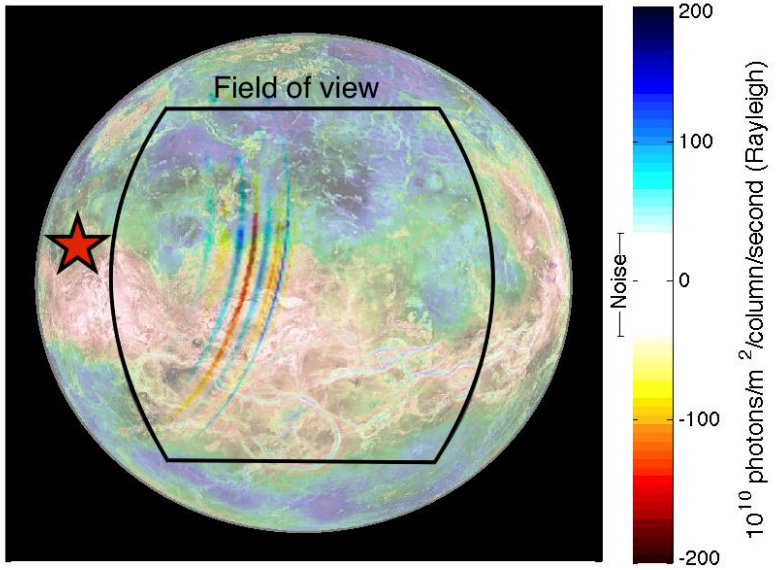
Imaging a Quake

- M_w = 5.8, 20 km depth, isotropic source
- Noise level based on existing cameras
- Camera pointing the antisolar point, field of view 45° by 45°
- Physical pixel size around 20 km by 20 km

20 min after quake



30 min after quake



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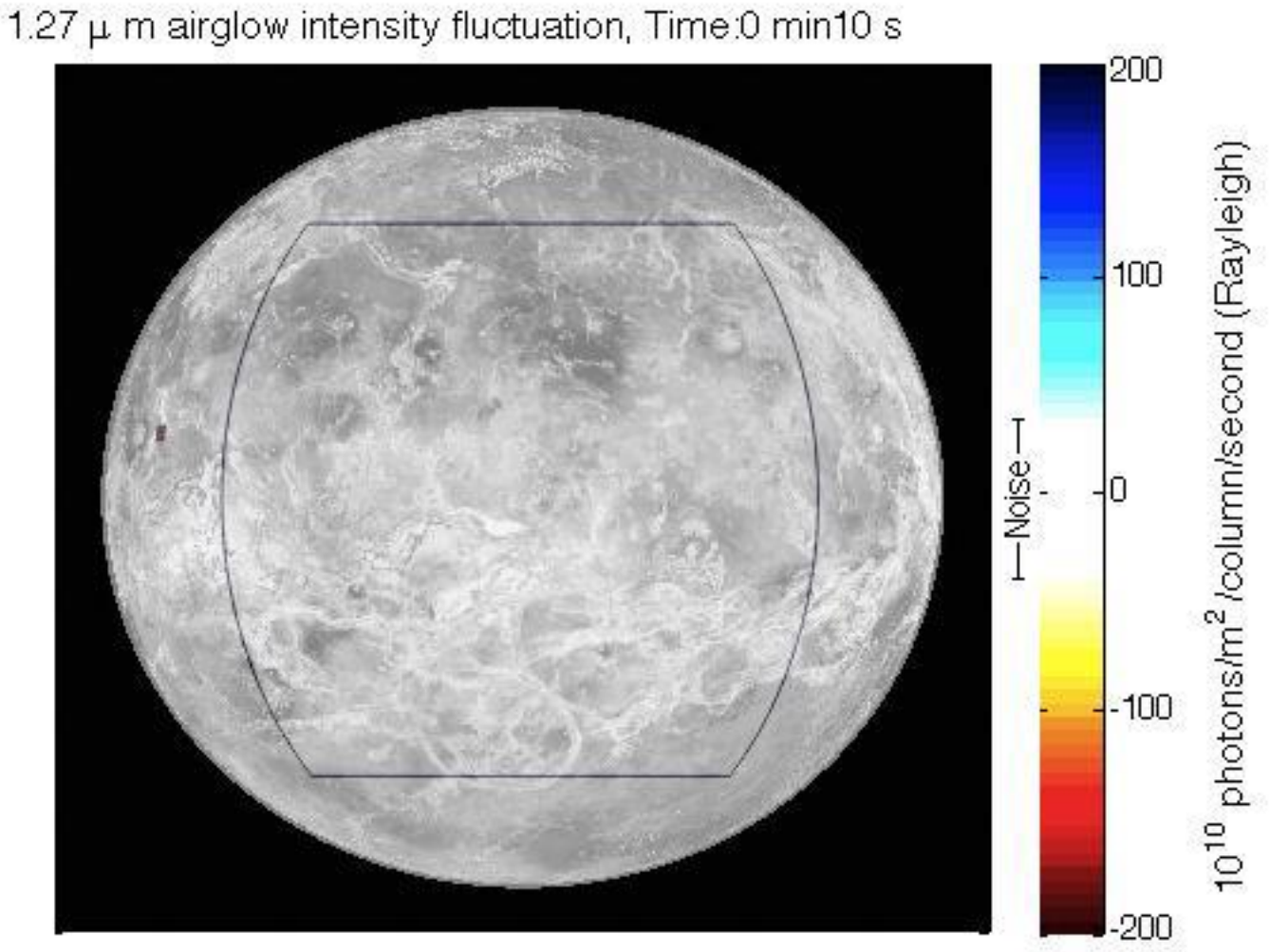

VAMOS and Venus' Seismicity

The ***V**enus **A**irglow **M**easurements and **O**rbiter for **S**eismicity* is a concept study aiming at unveiling Venus' activity and structure:

- A single orbiting camera would serve as a seismic network
- Wave propagation → epicenter location & Rayleigh-wave velocity
- Intensity of the disturbance → magnitude of the quake
- Quakes of magnitude > 5 occurring on the nightside could be detected
- Detection and location of seismic active regions
- Interior structure (crust and upper mantle) through Rayleigh wave dispersion