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Mesoscale stationary waves on Venus' dayside clouds

José Silva¹, Javier Peralta², Takeshi Imamura³, Ricardo Hueso⁴, Alejandro Cardesin-Moinelo^{5,6,7}, Maxence Lefevre⁸, Yeon Joo Lee¹, and Daniela Espadinha⁷

¹Planetary Atmospheres Group, Institute for Basic Science, Daejeon, South Korea

²Departamento de Física Atomica, Molecular y Nuclear, Facultad de Física, Universidad de Sevilla, Sevilla, Spain

³Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Japan

⁴Departamento de Física Aplicada, Escuela de Ingeniería de Bilbao, Universidad del País Vasco/Euskal Herriko Unibertsitate, Universidad del País Vasco/Euskal Herriko Unibertsitatea, Bilbao, Spain

⁵European Space Astronomy Centre, Madrid, Spain

⁶Institute of Astrophysics of Andalucía, Glorieta de la Astronomía, Granada, Spain

⁷Institute of Astrophysics and Space Sciences, University of Lisbon, Astronomical Observatory of Lisbon, Lisbon, Portugal

⁸LATMOS-IPSL, Paris, France

Venus' atmosphere remains a dynamic and enigmatic engine which not only completely covers the surface of the planet but is believed to have had a dramatic impact on how the planet evolved. The current mechanisms that drive its behaviour and its interactions with both external forces and the surface of the planet have continuously been pieced together for decades, from remote observations to climate modelling, in an attempt to coalesce into a uniform picture of atmospheric circulation.

Atmospheric gravity waves on Venus have garnered increasing attention in the past decade, sparked by the first observation of a planetary scale bow-shape by the Japanese space mission Akatsuki in December 2015. The still ongoing mission has thus far provided a continuous cover of the planet's cloud layer, including further detection and characterization of stationary waves on the top of the clouds with the Ultraviolet Imager (UVI) which is sensitive to ultraviolet reflected solar radiation, and at slightly lower levels thanks to the capabilities of the Longwave Infrared Camera (LIR) which uses thermal imaging in the mid-infrared.

For the past decade, most efforts to study gravity waves on Venus have been directed towards understanding both their forcing mechanisms and their influence on atmospheric circulation. Because these waves are driven by such a fundamental force as gravity and also since they can transport energy and momentum across several atmospheric layers, finding these structures on the atmospheres of other planets becomes another tool in understanding their behaviour and contribution to their planets' energy budget in the atmosphere. Gravity waves can be generated through multiple means, the most common being flow over mountains and convection, which can produce different characteristics on the generated waves. Gravity waves with orographic origins have been widely studied on Earth and a similar mechanism has been proposed for Venus, supported by the presence of the aforementioned stationary waves, which are fixed relative to topography and are commonly associated with prominent mountains on Venus. However, these waves are detected near 60-70 km above the surface and require a positive statically stable environment to be able to propagate, a condition which seems to not always be verified between the

surface and the cloud layer. Modelling efforts have been able to reproduce the largest of these structures and how they may propagate from the surface to the top of the clouds where we observe them, but such efforts for smaller-scale features are still ongoing. Since gravity waves feature a wide range of scales and characteristics, other generating sources like convection or shear instability have been proposed. Knowledge of the origin of these waves would also aid in the understanding of their role in the larger picture of Venus' atmosphere dynamics and quantify their influence at various scales.

Ongoing work for the detection of these waves has already provided some headway with a broadening coverage of past and emerging data sets at 0.283, 3.8, 5 and 10 μm wavelengths [Fukuhara et al. 2017; Fukuya et al. 2022; Kitahara et al. 2019; Kouyama et al. 2017; Peralta et al. 2017], focusing on waves propagating at seemingly different altitudes. The higher spatial resolution of images gathered from several spacecraft allows the identification and characterization of progressively smaller and more varied wave shapes. Such data sets include instruments from Venus Express, namely the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) and from Akatsuki including UVI and the 2 μm Camera (IR2), targeting the upper clouds on the dayside with ~ 20 km/pixel resolution, covering the low latitudes with Akatsuki and high southern latitudes with VEx.

By using these data sets, we hope to expand the current base sample of stationary features detected on Venus and also combine observations at several wavelengths to infer on possible three-dimensional properties of these features and their influence on the atmospheric flow. Additionally, with a larger coverage from several instruments, we will broaden the possible distribution of stationary features to a wider latitudinal coverage and time period, which enables a comparison of the behaviour of these mesoscale structures at different latitudes and possible influence of both the underlying topography and local wind flow regime on the morphology and dynamics of these waves.

References

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