CORRELATION BETWEEN WHISTLER WAVE OCCURENCES IN THE VENUSIAN IONOSPHERE AND NUMBER OF SUN SPOTS. K. Shrivastava[1,2] and J. P. Pabari[2], [1]Institute for Excellence in Higher Education, Kaliyasot Dam, Bhopal-462016 (shrivastava123kriti@gmail.com), [2]Physical Research Laboratory Ahmedabad, India-380009 (jayesh@prl.res.in).

Introduction: The Sun is the primary source of all the activity in our solar system including the planetary environments. Among the various solar phenomena, the number of sunspots serves as an indicator of solar activity within the 11-year solar cycle [1]. This can significantly impact planetary magnetospheres and ionospheres [2], leading to various electromagnetic phenomena, including whistler waves [3].

Whistler waves are VLF electromagnetic waves that are generated in a planet's atmosphere due to lightning or non-lightning phenomena. On Venus, Parker Solar Probe suspected whistler wave generation due to disturbance in the magnetic field surrounding the planet [4]. This work aims to understand possible correlation between solar activities (Sun Spot Number) and the whistler wave occurrences for the Venusian atmosphere.

Methodology: The datasets of whistler wave detections observed by Venus Express in the ionosphere of Venus, and Sunspot numbers are analyzed for over five months, from May to September of the year 2012.

A correlation study may be carried out using Pearson formula [5]:

$$\rho(A,B) = \frac{1}{N-1}\sum_{i=1}^{N}\left(\frac{A_i-\mu_A}{\sigma_A}\right)\left(\frac{B_i-\mu_B}{\sigma_B}\right)$$

where A and B are variables (here, A is the number of sunspots and B is the whistler waves occurrence), N is the number of observations, μ_A and σ_A are the mean and standard deviations of A, respectively, and μ_B and σ_B are the mean and standard deviations of B, respectively.

Results and Discussion: A scatter plot based on the Pearson correlation coefficient has been obtained and it is shown in Figure 1. We used the aggregated wave amplitude values of the whistler waves in the Venusian ionosphere and the measured number of sunspots for the analysis. The deviation from the linearity is also depicted in Figure 1. The results show partial dependence of whistler waves on the sun activity.

The correlation can be attributed to several factors related to solar-terrestrial interactions. Increased sunspot numbers often correspond to enhanced solar wind streams, which can interact directly with Venus's ionosphere and weak magnetic field. This interaction could lead to magnetospheric and ionospheric disturbances as well as the generation of electromagnetic disturbances such as whistler waves [6], which might have been observed.

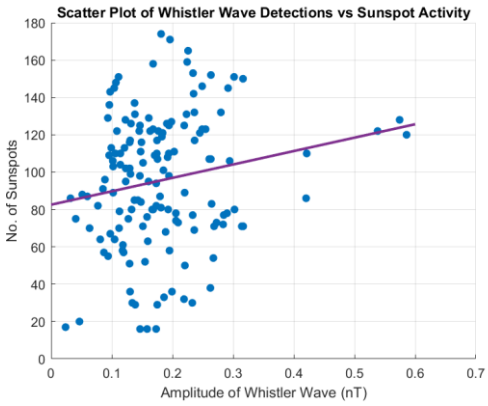

Figure 1. Results of correlation analysis for the number of Sunspots and amplitude of whistler wave for May to September 2012. The Pearson correlation coefficient (ρ) is found to be 0.1818, indicating a weak positive linear relationship between the two variables.

Conclusion: This study, though weak, provides statistical evidence of the dependence of the occurrence of whistler waves and solar activity (indicated by sunspot numbers) in Venus's ionosphere. Further investigation may be necessary.

Data Availability: 1. Whistler waves data: Hart, Richard; Russell, Christopher (2022), "Data table of whistler-mode waves observed by Venus Express in the ionosphere of Venus", Mendeley Data, V2, doi: 10.17632/jst48fbvvw.2.
2. Sun Spot number: WDC-SILSO, Royal Observatory of Belgium, Brussels, https://www.sidc.be/SILSO/datafiles.

References: [1] Dobrijevic, D. (Online, 2022), https://www.space.com/. [2] Liu, L., et al. (2011), *Chin. Sci. Bull.* 56, 1202–1211. [3] Yuguang, T. et al. (2019), *ApJ*, 878(1):41. [4] George, H., et al. (2023). *GRL*, 50, e2023GL105426. [5] Fisher, R. A. (1958), 13th Edition, Hafner. [6] Futaana, Y. et al. (2017), SSR, 212(3-4), 1453-1509.

[1] Last Attended