Raumfahrttechnik und Extraterrestrik

Advances in Space Technology and Exploration

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Clemens Riegler,
Hakan Kayal

VELEX:
Venus Lightning Experiment

Nr. 3

VELEX: Venus Lightning Experiment

Clemens Riegler[1]*, Hakan Kayal[1]

Abstract
Lightning has fascinated humanity since the beginning of our existence. Different types of lightning like sprites and blue jets were discovered, and many more are theorized. However, it is very likely that these phenomena are not exclusive to our home planet. Venus's dense and active atmosphere is a place where lightning is to be expected. Missions like Venera, Pioneer, and Galileo have carried instruments to measure electromagnetic activity. These measurements have indeed delivered results. However, these results are not clear. They could be explained by other effects like cosmic rays, plasma noise, or spacecraft noise. Furthermore, these lightning seem different from those we know from our home planet. In order to tackle these issues, a different approach to measurement is proposed. When multiple devices in different spacecraft or locations can measure the same atmospheric discharge, most other explanations become increasingly less likely. Thus, the suggested instrument and method of VELEX incorporates multiple spacecraft. With this approach, the question about the existence of lightning on Venus could be settled.

Keywords
Venus, Lightning, Descent, Rotorcraft, Autorotation

[1] *Deparment of Aerospace Computer Science, JMU Würzburg, Germany*
***Corresponding author**: clemens.riegler@uni-wuerzburg.de

Contents

Introduction

Lightning on Earth are a somewhat mysterious occurrence. While some types can be explained already, others are not fully understood yet. High altitude lightning such as sprites are even discovered as late as in the 90s [1, 2]. This is why we observe these phenomena closely. On Earth, there are several lightning detection and observation systems [3, 4, 5]. Even Cubesats, such as SONATE or SONATE-2 [6, 7] can detect lightning from space using very small components. Lightning are not limited to our planet. Venus is also supposed to have lightning. Past measurements over a multitude of missions were summarized by Lorenz in 2018 [8]. He concluded that there is still much ambiguity in lightning detections on our sister planet.

During the presentation of a seminar work on missions to Venus, mentioning that lightning on Venus are still somehow not fully explained, H. Kayal proposed to study a dedicated mission for exploration of lightning on Venus using autorotating vehicle [H. Kayal, personal communication, June 29th, 2022]. A subsequent analysis showed that several questions regarding lightning on Venus are still unanswered [8].

In the following sections, the challenges of Lightning detections on Venus will be explained in short. The VELEX mission setup and measurement philosophy will be explained. Followed by a conclusion and future work.

1. Challenges

As explained by Lorenz [8], these lightning are somewhat of a mystery on Venus. He identified several issues that can lead to erroneous measurements that, up until now, could not have been ruled out by any mission. In the following paragraphs, the most pressing issues are discussed. This includes a short explanation of how VELEX plans to solve these issues by design. The following issues are taken from Lorenz's work, which is very well compiled in their Table 2 [8][p.8].

Debris from Spacecraft Debris from spacecraft was one possible explanation for detecting Venera 9 and 10 orbiters. The reflection of heat shields, jettisoned stages, or other smaller parts can indeed appear as a flash of lightning in a visible Spectrometer. Multiple spacecraft will be used, this will reduce the likely hood of debris causing a detection. Thus, one has to be aware that the other spacecraft might also cause detections. VELEX will subsequently not use a visible Spectrometer to avoid this problem in the first place.

Spacecraft Noise The noise of the spacecraft can be an issue for any measurement. Especially when magnetic and electronic fields are involved, just like with lightning. VELEX will use multiple spacecraft. This will reduce the likely hood of extraordinary spacecraft interactions causing false detections. However, the problem could be in the design. Thus, two different types of spacecraft will be used for measurements. This will reduce the likely hood of spacecraft noise being a problem significantly.

Cosmic Rays These radiation effects are a typical issue with spacecraft. Especially cameras suffer from issues with Cosmic rays. VELEX will not utilize Cameras. The flight through the cloud layer of Venus is not expected to be of significant visual interest. H-Field and E-Field measurements are expected to be more reliable. On earth, these technologies are well known to detect lightning over hundreds of kilometers.

2. Measurements

Due to the previously explained Challenges, only two measurement options can be utilized. Either H-Field or E-Field measurements. These types of measurements have been used already on Venus, by Venus Express [9], Galileo [10], Pioneer [11] and Venera 11 through 13 [12, 13, 14]. Furthermore, the method is so simple that it is utilized widely by amateurs. The lightningmaps.org project [15], is a good example. They have already developed three versions of their detection system.

3. Experiment Setups

We would argue that such a device, depending on the method, can be built to be relatively small and thus fit on smaller probes that can be dropped from Ballons. This is a common idea for instant brought forward in the Venus Life Finder Proposal [16] and European Venus Explorer Proposals [17, 18].

This can be combined with an autorotation probe that can glide through the atmosphere. Autorotation vehicles allow for better control than parachutes. Furthermore, they can be built small enough for smaller probes to operate on, as typical propulsion systems would be too big for such vehicles. Examples of this have been developed locally at JMU Würzburg with WüSpace as Projects Daedalus 1 [19, 20] and Daedalus 2 [21, 22, 23]. Young et al. [24] also suggested the utilization of such vehicles for Venus. These Autorotation vehicles are called AuroVs.

The AuroVs is planned to be dropped from a balloon. This balloon will also carry a lightning detector to compliment the measurements of the AuroVs. By doing that, spacecraft effects that could obscure measurements are significantly reduced. There are multiple spacecraft in use, but they are also differently built.

AuroVs and the balloon are expected to measure data and send it back to earth (either directly or via a relay). The data can then be analyzed and fused to see whether they align and can pinpoint the existence of lightning and their characteristics. Of these AuroVs, multiple will be utilized to create redundancy during measurements. Figure 1 shows an examplary measurement scenario.

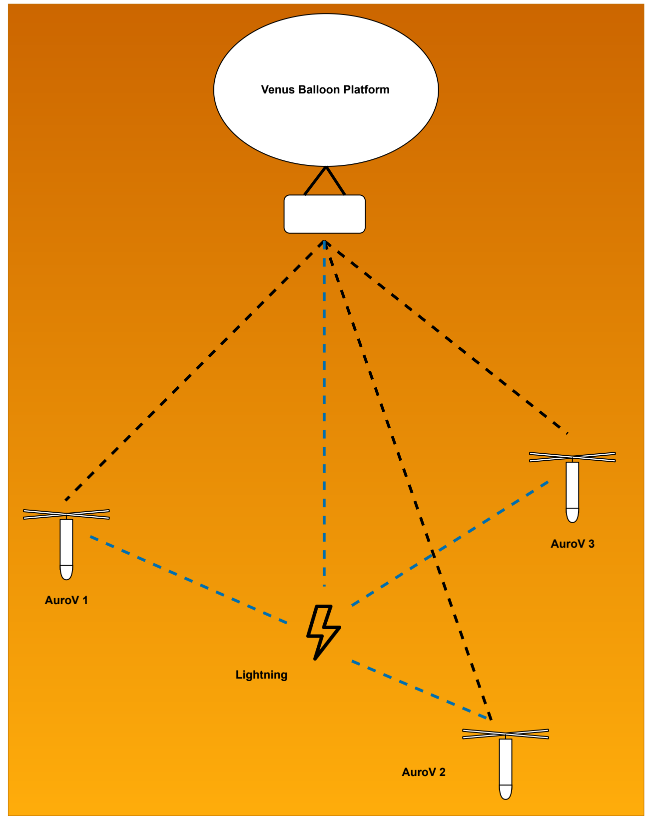

Figure 1. VELEX execution in the clouds of Venus. Black lines are communication lines, blue lines depict lightning detection.

A similar setup can be envisioned with CubeSats, as described by Majid et al. [25]. Magnetic and E-Field measurements have been conducted from orbit in the past [11, 9]. Furthermore, CubeSats can also carry extra optical instrumentation to observe lightning, like the SONATE missions do [6, 7]. The Experiment Setup would be similar to balloon deployed sondes. However, the sondes would enter directly, and one or more CubeSats would replace the balloon as the extra spacecraft. This would allow for a mission that is not reliant on an arguably complex balloon. It could be carried as a secondary Payload to missions like Envision [26], DaVinci [27] or Veritas [28]. An exemplary scenario of this configuration is depicted in Figure 2.

4. Future Work & Conclusion

The first step would be implementing VELEX and incorporating it into a mission. A future perspective can also be the localization of lightning. This can be done if all vehicles have interlink communication and carry sufficiently accurate clocks. This position would be relative to one of the vehicles (the balloon makes the most sense) as no absolute position would be available.

It is interesting to once and for all prove the existence of lightning on Venus. The proposed setup can solve many

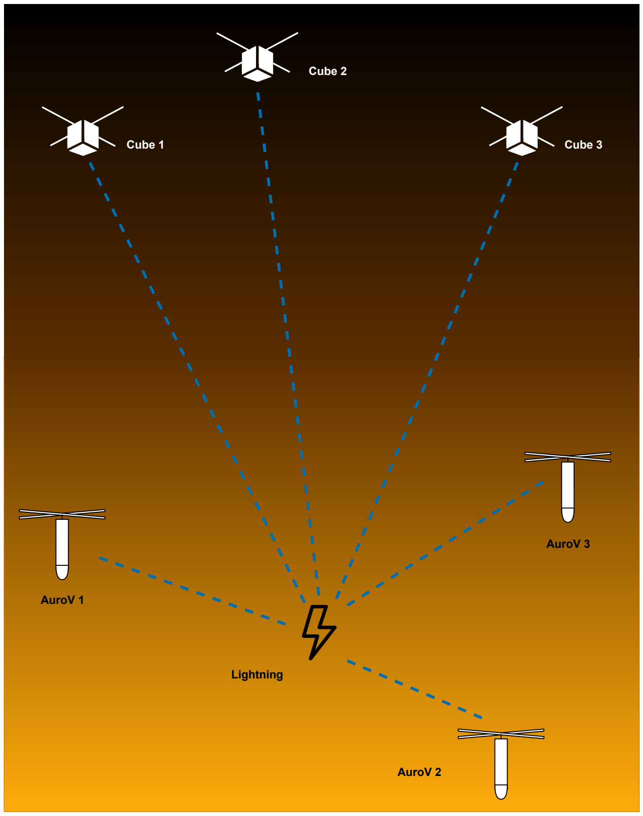

Figure 2. VELEX execution with Cubesats. Blue lines are detection Lines. Communication is envisioned to be direct with a mothership.

problems outlined by Lorenz [8]. Measurements of H- and E-Fields can be built simple and small. This is advantageous for use in smaller drop sondes like AuroVs. It is clear that lightning on Venus needs to be investigated further, and VELEX can be the ideal experiment to do so.

References

[1] JA Valdivia, G Milikh, and K Papadopoulos. Red sprites: Lightning as a fractal antenna. *Geophysical Research Letters*, 24(24):3169–3172, 1997.

[2] Craig J Rodger. Red sprites, upward lightning, and vlf perturbations. *Reviews of Geophysics*, 37(3):317–336, 1999.

[3] Erin H Lay, Robert H Holzworth, Craig J Rodger, Jeremy N Thomas, Osmar Pinto Jr, and Richard L Dowden. Wwll global lightning detection system: Regional validation study in brazil. *Geophysical Research Letters*, 31(3), 2004.

[4] Nicolau Pineda and Joan Montanyà. Lightning detection in spain: The particular case of catalonia. *Lightning: Principles, Instruments and Applications*, pages 161–185, 2009.

[5] A Kh Adzhiev, VN Stasenko, and VO Tapaskhanov. Lightning detection system in the north caucasus. *Russian Meteorology and Hydrology*, 38(1):1–5, 2013.

[6] Hakan Kayal, Oleksii Balagurin, Kirill Djebko, Gerhard Fellinger, Frank Puppe, Dietmar Seipel, Saliha Serdar, Alexander Schneider, Tobias Schwarz, and Harald Wojtkowiak. Next level autonomous nanosatellite operations. In *2018 SpaceOps Conference*, page 2690, 2018.

[7] Hakan Kayal. Sonate-2 - lehrstuhl für informatik viii - informationstechnik für luft- und raumfahrt. `https://www.informatik.uni-wuerzburg.de/aerospaceinfo/wissenschaft-forschung/sonate-2/`, Mar 2022. Accessed: 2022-05-27.

[8] Ralph D. Lorenz. Lightning detection on venus: a critical review. *Progress in Earth and Planetary Science*, 5(1), jun 2018.

[9] CT Russell, JG Luhmann, TE Cravens, AF Nagy, and RJ Strangeway. Venus upper atmosphere and plasma environment: Critical issues for future exploration. *GEOPHYSICAL MONOGRAPH-AMERICAN GEOPHYSICAL UNION*, 176:139, 2007.

[10] DA Gurnett, WS Kurth, A Roux, R Gendrin, CF Kennel, and SJ Bolton. Lightning and plasma wave observations from the galileo flyby of venus. *Science*, 253(5027):1522–1525, 1991.

[11] FL Scarf, WWL Taylor, CT Russell, and LH Brace. Lightning on venus: Orbiter detection of whistler signals. *Journal of Geophysical Research: Space Physics*, 85(A13):8158–8166, 1980.

[12] LV Ksanfomaliti, NM Vasilchikov, OF Ganpantserova, EV Petrova, AP Suvorov, GF Filippov, OV Iablonskaia, and LV Iabrova. Electrical discharges in the atmosphere of venus. *Soviet Astronomy Letters*, 5:122–126, 1979.

[13] LV Ksanfomaliti. Discovery of frequent lightning discharges in clouds on venus. *Nature*, 284(5753):244–246, 1980.

[14] LV Ksanfomaliti, FL Scarf, and WWL Taylor. The electrical activity of the atmosphere of venus. *Venus*, pages 565–603, 1983.

[15] Blitzortung.rog. Project description of blitzortung.org. `https://www.blitzortung.org/en/cover_your_area.php`. Accessed: 2022-08-11.

[16] Sara Seager and Janusz J. Petkowski. Venus life finder mission study. Technical report, 2021.

[17] Andy Phipps, Adrian Woodroffe, Dave Gibbon, Alex Cropp, Mukesh Joshi, Peter Alcindor, Nadeem Ghafoor, Alex Da, Silva Curiel, Jeff Ward, Martin Sweeting, John Underwood, Steve Lingard, Marcel Van Den Berg, Peter Falkner, and A Phipps@sstl Co Uk. Venus orbiter and entry probe: An esa technology reference study. Technical report.

[18] Andy Phipps, Adrian Woodroffe, Dave Gibbon, Peter Alcindor, Mukesh Joshi, Alex Da, Silva Curiel, Jeff Ward, Martin Sweeting, John Underwood, Steve Lingard, Marcel Van Den Berg, and Peter Falkner. Ssc05-v-4 mission and system design of a venus entry probe and aerobot. Technical report.

[19] Clemens Riegler, Ivaylo Angelov, Florian Kohmann, Tobias Neumann, Abdurrahman Bilican, Kai Hofmann, Jessica Pielucha, Alexander Böhm, Barbara Fischbach, Tim Appelt, Lisa Willand, Oliver Wizemann, Sarah Menninger, Jan von Pichowski, Jonas Staus, Erik Hemmelmann, Sebastian Seisl, Christoph Fröhlich, Christian Plausonig, and Reinhard Rath. Project daedalus, rotor controlled descent and landing on rexus23. 06 2019.

[20] Clemens Riegler, Ivaylo Angelov, Tim Appelt, Abdurrahman Bilican, Alexander Böhm, Babara Fischbach, Christoph Fröhlich, Jessica Gutierrez Pielucha, Alexander Hartl, Erik Hemmelmann, Kai Hofmann, Patrick Kappl, Florian Kohman, Sarah Menninger, Tobias Neumann, Jan von Pichowski, Chrsitian Plausonig, Reinhard Rath, Sebastian Seisl, Jonas Staus, Lisa Willand, Oliver Wizemann, Phillip Bergmann, Frederik Dunschen, Paul Holzer, Ulla Wagner, and Lennart Werner. Project Daedalus: Towards Autorotation based Landing and Descent. In *71st IAC Proceedings*, 2020.

[21] Clemens Riegler. Entry, descent and landing control of an autorotating spacecraft. Master's thesis, JMU Würzburg, 10 2020. UNPUBLISHED.

[22] C Riegler, A Adler, T Appelt, B Bartho, P Bergmann, E Borschinsky, C Bös, F Dunschen, A Ettinger, L Franssen, M Gellerman, P Klaschka, N Koch, J Mehringer, J Mutter, T Neumann, J von Pichowski, M Reigl, L Richter, P Stöferle, L Werner, and J Wolf. Modeling and validation of an autorotation landing controller for reentry and descent applications. In *FAR 2022 Proceedings*, 2022.

[23] Johanna Mehringer, Lennart Werner, Clemens Riegler, and Frederik Dunschen. Suborbital autorotation landing demonstrator on rexus 29. In *4th Symposium on Space Educational Activities*. Universitat Politècnica de Catalunya, 2022.

[24] Larry A Young, Geoffrey Briggs, Edwin Aiken, and Greg Pisanich. Rotary-wing decelerators for probe descent through the atmosphere of venus. Technical report, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MOFFETT FIELD CA ROTORCRAFT ..., 2004.

[25] W Majid, C Duncan, T Kuiper, CT Russell, RA Hart, and E Lightsey. A cubesat mission to venus: A low-cost approach to the investigation of venus lightning. In *AGU Fall Meeting Abstracts*, volume 2013, pages P41D–1946, 2013.

[26] Thomas Widemann, Richard Ghail, Colin F Wilson, and Dmitri V Titov. Envision: Europe's proposed mission to venus. In *Agu fall meeting abstracts*, volume 2020, pages P022–02, 2020.

[27] Lori S Glaze, James B Garvin, Brent Robertson, Natasha M Johnson, Michael J Amato, Jessica Thompson, Colby Goodloe, and Dave Everett. Davinci: Deep atmosphere venus investigation of noble gases, chemistry, and imaging. In *2017 IEEE Aerospace Conference*, pages 1–5. IEEE, 2017.

[28] Suzanne E Smrekar, Scott Hensley, MD Dyar, Jörn Helbert, Jeff Andrews-Hanna, Doris Breuer, Debra Buczkowski, Bruce Campbell, Ann Davaille, G Di-Achille, et al. Veritas (venus emissivity, radio science, insar, topography, and spectroscopy): A proposed discovery mission. 2020.

Raumfahrttechnik und Extraterrestrik

Advances in Space Technology and Exploration

In der Schriftenreihe „Raumfahrttechnik und Extraterrestrik“ erscheinen Beiträge zu neuen Entwicklungen aus dem Bereich der Raumfahrttechnik sowie der Erforschung und Nutzung des Weltraums. Diese können sehr gute studentische Arbeiten, Dissertationen, Aufsätze zu relevanten Themen oder Ergebnisse von Projektarbeiten beinhalten.

Herausgeber:
Prof. Dr.-Ing. Hakan Kayal

Prof. Dr.-Ing. Hakan Kayal
Professur für Raumfahrttechnik
Informatik VIII
Universität Würzburg
Emil-Fischer-Str. 32
D-97074 Würzburg
Tel.: +49-931-31-86649
Fax: +49-931-31-81368
hakan.kayal@uni-wuerzburg.de

Universitätsbibliothek Würzburg
Am Hubland
D-97074 Würzburg
Tel.: +49-931-31-85906
opus@bibliothek.uni-wuerzburg.de
https://opus.bibliothek.uni-wuerzburg.de
Titelblattgestaltung: UB Würzburg

ISSN: 2747-9374

Zitiervorschlag:

Riegler, Clemens; Kayal, Hakan: VELEX: Venus Lightning Experiment, Raumfahrttechnik und Extraterrestrik, Nr. 3 (2022). DOI: 10.25972/OPUS-28248