**The INAF Campo Imperatore Observatory in Abruzzo (Italy) as an Earth observation facility for the study of Venus night airglows (VNAs).**
P. D'Incecco[1], D. A. Gorinov[2], M. Dolci[1], L. Tartaglia[1], F. De Luise[1], G. Valentini[1], M. Cantiello[1], J. Filiberto[3], S. S. Bhiravarasu [4], E. Brocato[1], G. Rodeghiero[1,5], A. Valentini[1], S. Benedetti[1], M. Di Carlo[1], A. Di Cianno[1], S. Di Frischia[1], N. Napoleone[1], A. Piersimoni[1], E. Portaluri[1], G. Raimondo[1], P. Spanò[1], and G. Di Achille[1].
[1]National Institute for Astrophysics (INAF) - Astronomical Observatory of Abruzzo, Teramo, Italy (piero.dincecco@inaf.it); [2]Space Research Institute of the Russian Academy of Sciences, Moscow, Russia; [3]Astromaterials Research and Exploration Science (ARES) Division, NASA Johnson Space Center, Houston, TX, 77058, USA; [4]Space Applications Centre, Indian Space Research Organization, Ahmedabad, India; [5]National Institute for Astrophysics (INAF) - Astrophysics and Space Science Observatory of Bologna (OAS), Italy.

**Introduction:** The National Institute for Astrophysics (INAF) Campo Imperatore Observatory is located in the Gran Sasso mountains in Abruzzo, Italy, at an altitude of 2150 m above the sea level. The atmospheric transparency, along with the climatic conditions - especially in winter - have always made it a suitable site for observations in the near infrared (1 - 2 micron) [i.e., 1].

The Campo Imperatore Observatory is equipped with the AZT-24 reflecting telescope, Ritchey-Chrétien configuration, with an aperture of 1.1 m. The new motorization system – currently in the commissioning phase - will allow great pointing and tracking accuracy (<0.1 arcsec), as well as an uncommonly fast-tracking speed (the mechanics is designed to reach 3 degrees/second). With this facility we are starting the ADvanced VENus' Night Airglows Near-infrared Telescope (ADVENANT) project, which aims to observe and study Venus' nightside airglows (VNAs).

**Implementation of the Near-Infrared detector for the AZT-24 telescope:** The AZT-24 is going to be equipped with a camera based on a commercial InGaAs sensor, sensitive in the entire band from 450 nm to 1.78 micron (Johnson photometric bands: V, R, I, J, H_short), even if for Venus specific measurements, we will focus on infrared only. The Quantum Efficiency in the J and H bands is around 90%. It will be equipped with a forefront optics with a tip-tilt corrector, in order to work in seeing-enhanced mode (it will likely be possible to reach a seeing of 1.5 arcsec, from the starting >2.5 arcsec). The pixel scale would be between 0.4 and 0.6 arcsec/pixel. The camera formats available (between 640x480 to 960x1200) will allow for Field-of-Views of approximately 6x8 arcmin, or even larger. In addition to the broad-band filters (I, J, H_short) appropriate narrow-band filters will be foreseeable, selected on the basis of the scientific programs that will potentially have the greatest impact.

**Venus' Nightside Airglows (VNAs):** The thick atmosphere of Venus presents a puzzling and complex dynamic structure. While the cloud layer (approximately from 50 to 70 km altitude) can be thoroughly studied using cloud images in UV, visible, and IR [2]. The region from 80 to 120 km largely remains a mystery, as it lacks clouds that allow motion tracking studies and thus it is impossible to measure winds using remote sensing [3]. Yet this altitude range is important for Venus atmospheric dynamics as it is a region of transition between the global retrograde zonal super rotation (RZS) mode below to the subsolar-antisolar (SS-AS) cell circulation above [4].

Interestingly, this transition region can be studied using VNAs — NO and $O_2$, which peak at 110 and 97 km, and can be observed in UV and near-IR (Figure 1), respectively [5,6]. In this proposal, we focus on the infrared observations of the $O_2$ ($a^1\Delta_g$) emission at 1.27 µm (Table 1). The atomic oxygen forms on the dayside from the dissociation of $CO_2$ and then travels to the nightside with the SS-AS circulation where it recombines in the downwelling flow and emits around midnight [7]. However, the maximum of the emission is not found directly at the antisolar point, but shifted towards 22 h of local time [6]. Therefore, other dynamic mechanisms, such as thermal tides and stationary gravity waves, are suspected to play a role at these altitudes [8].

Overall there is a scarcity of experimental data about VNAs. Indeed, only the Venus Express mission studied this phenomenon, as well as a few short ground-based observations. Our presentation aims at addressing this issue and proposing a new series of ground-based observations of the oxygen nightglow on Venus using the AZT-24 telescope at the INAF Campo Imperatore Observatory.

**The Campo Imperatore Observatory as a Earth observation facility for future missions to Venus:** Orbital data about VNAs may be provided by the VIKA instrument on the Venera-D mission. However, the $O_2$ monitoring capabilities of the VIKA instrument are much lower than those of VIRTIS/VEx, due to different principle of operation. For this reason, the dataset and observation time to be provided from the future Near-Infrared detector of the AZT-24 telescope will provide a unique tool for Earth observations of Venus, anticipating and complementing the wealth of orbital data coming from the forthcoming missions to Venus

[9-14]. Thorough monitoring of the $O_2$ airglow distribution across the nightside can offer new information on the mechanisms that influence the dynamics of the upper mesosphere of Venus. Emergence and decay of nightglow emission areas, their local time and latitude distribution, provide clues on the up- and downwelling motions and the dynamics in general. In turn, this data is crucial for the ongoing effort to characterize the atmosphere of Venus using global circulation models. For this reason, we propose the Campo Imperatore ADVENANT project as a ground segment for the future missions to Venus.

**Observation plan:** The observability window is the period during which at least a defined percentage of the night side of Venus is visible, and it roughly corresponds to the time span between the maximum elongations of Venus, including the lower conjunction.

Within the observability window, we will daily monitor the planet disk. When a VNA is detected, the observation will be continued in follow-up mode with high-cadence (an image being acquired every few minutes) to study the evolution of this phenomenon.

The spatial resolution will depend on the seeing of the site, taking into account that image reconstruction techniques (i.e., lack imaging) will be applied and are expected to produce sub-arcsecond imaging.

Within the above-mentioned observational constrains, the expected spatial resolution will range between 300 km and 700 km at the center of the disk. This spatial resolution is sufficient to detect and track VNAs. Indeed, VNAs can reach sizes of several degrees in latitude and longitude (Figure 1) [6].

The observation campaign will cover several Venus years to allow us to assess if there is any long-term trend and/or correlation with regional surface features, such as highlands and volcano-tectonic regions.

**References:** [1] Del Principe, M. et al. (2005) AJ 129 2714. [2] Peralta, J. et al. (2017) Icarus 288 235-239. [3] Royer et al. (2021) Whitepaper #015 submitted to the Planetary Science and Astrobiology Decadal Survey 2023-2032 [4] Bougher, S.W. et al. (1997) U. of Arizona Press 259-292. [5] Stiepen, A. et al. (2012) Icarus 220 2 981-989. [6] Shakun, A. et al. (2023) Solar Sys. Res. 57 3 200-213. [7] Gérard, J.-C. et al. (2008) Geophys. Res. Lett. 35 L02207. [8] Gorinov, D. et al. (2018) Geophys. Res. Lett. 45. [9] Garvin, J. B., et al. 2022, Planet Sci J, 117. [9] Zasova, L. V., et al. 2019, Solar System Research, 53, 506. [11] Senske, D., et al. 2017, Report of the Venera-D Joint Science Definition Team. [12] Ghail, R., et al. 2021, EnVision Assessment Study Report, Yellow Book. [13] Haider, S. A., et al. 2018, cosp, 42, B4.1 [14] Smrekar, S., et al. 2020, EPSC2020 (Copernicus Meetings).

**Table 1** - Mean O2 (a1 Δg) emission intensities from Earth-based observations and from previous VIRTIS-M measurements that were not accounting for surface influence.

| *Author(s)* | Year(s) of observation | Instrument | Mean 02 emission intensity (MR) | Peak 02 emission intensity (MR) |
|---|---|---|---|---|
| Crisp et al. (1996) | 1991-1994 | Canada-France Hawaii Telescope | 1 | 6 |
| Ohtsuki et al. (2008) | 2002-2007 | CSHELL | 0.28 | 5 |
| Krasnopolsky (2010) | 2009 | CSHELL | 0.52 | 1.2 |
| Piccioni et al. (2009) | 2006-2009 | VIRTIS-M | 0.52 ± 0.4 | 1.2 |

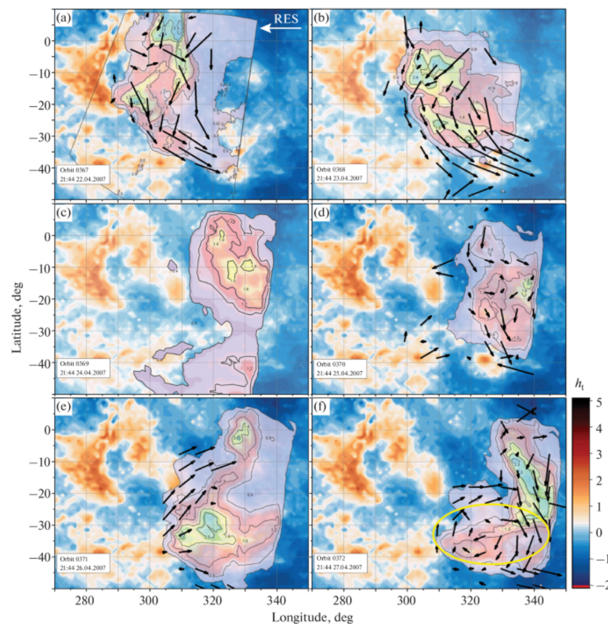


**Figure 1:** Sequence of orbits from the Venus Express VIRTIS-M dataset. Orbit-to-orbit changes in intensity of a localized bright structure and in atmospheric dynamics from orbit 367 to 372. Date and time are shown on each panel. (a) Orbit 367: emission intensity (MR, contours) and velocity vectors (arrows) on top of surface topography (background color); (b) orbit 368: displacement of the bright structure towards southeast, maximum intensity decreased from 4.5 to 2.5 MR; (c) orbit 369: displacement towards northeast, decrease of the maximum intensity to 1.5 MR. Wind velocity data is unavailable due to the absence of image pairs; (d) orbit 370: southward displacement and decrease of wind magnitude compared to orbits 367–368 down to 0–15 m/s, which can indirectly indicate increased vertical transport; (e) orbit 371: westward displacement, meanwhile the wind is eastward, and the peak intensity increases to 2 MR; (f) orbit 372: eastward displacement and emergence of closed circular motion with a diameter around 1500 km, centered at 30° S; 330° E (1 h local time) [6].