WHITE PAPER

EXPLORING ASTRONOMICAL SPECTROSCOPY WITH THE NEXOS™ SPECTROMETER: FROM BACKYARD TO SPACE APPLICATIONS

EXECUTIVE SUMMARY

Spectroscopy is one of the most powerful tools in modern astronomy, enabling scientists to determine the physical and chemical properties of celestial bodies through light analysis. In preparation for the upcoming Mauve mission, a scientific satellite by Blue Sky Space carrying two Avantes NEXOS™ spectrometers into orbit, an experimental ground-based setup was developed. This setup was designed to simulate similar measurements under terrestrial conditions.

Using a Newtonian telescope and an unmodified NEXOS™ spectrometer, valuable spectral data of bright stars were collected from a suburban backyard. The results demonstrate that the NEXOS™, though compact and lightweight, provides high-quality, reliable spectral data even in non-ideal observing conditions. This reinforces its suitability for both ground-based and space-borne spectroscopy applications.

1. INTRODUCTION

Spectroscopy lies at the heart of astronomical research. By decomposing starlight into its constituent wavelengths, astronomers can extract information about the chemical composition, temperature, motion, and structure of celestial objects. From nearby stars and nebulae to distant galaxies, much of our understanding of the universe is derived from spectroscopic data.

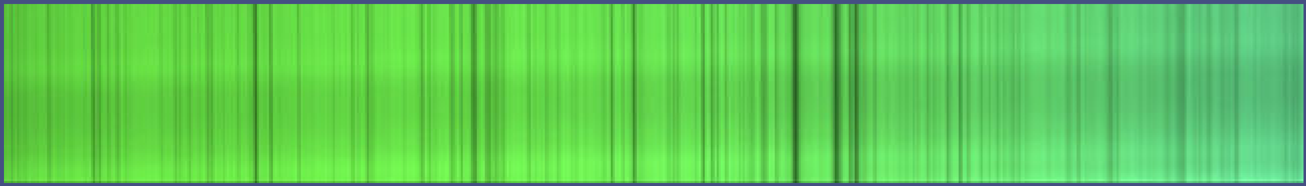

Figure 1: Each element in a star's atmosphere absorbs light at specific wavelengths, creating a unique spectral 'barcode'. By analyzing these patterns, astronomers can identify the chemical composition and conditions of stars and planets. This image shows the spectrum of the sun.

Spectroscopy enables researchers to uncover a wide range of information from a single spectrum, including:

- Chemical composition of stars and nebulae
- Temperature, density, and pressure of stellar atmospheres
- Rotation, velocity, and radial motion of stars
- Stellar age, size, and luminosity
- Presence of flares, turbulence, or accretion disks
- Orbital characteristics of binary systems and exoplanets
- Absorption effects from interstellar dust & gas

These fundamental measurements are usually performed with large, professional observatories or even space telescopes. However, advances in compact instrumentation now make it possible to perform meaningful astronomical spectroscopy using smaller, commercially available equipment.

The Avantes NEXOS™ is an example of such innovation. Designed for versatility and robustness, NEXOS™ combines compact form with high optical performance, making it ideal for both research laboratories and challenging field environments.

2. THE CHALLENGES BEHIND INNOVATION

The Mauve satellite is scheduled for launch in November 2025 into a low Earth orbit. Mauve is a UV-Visible observatory designed to study stars across our galaxy, with a particular focus on their magnetic activity, powerful flares, and the effects on the habitability of nearby exoplanets.

The mission will deliver data through a multi-year collaborative science program, enabling thousands of hours of observations on hundreds of stars. By capturing these long-term variations, Mauve will open new possibilities in time-domain stellar spectroscopy.

Two unmodified, commercial-off-the-shelf Avantes NEXOS™ spectrometers on board Mauve will record ultraviolet and visible light spectra, helping to reveal the dynamic processes driving stellar flares and variability. The decision to use standard instruments highlights the reliability of Avantes technology. NEXOS™ combines mechanical stability, compact design, thermal robustness and resistance to vibration and electromagnetic interference, making it ideal for space conditions.

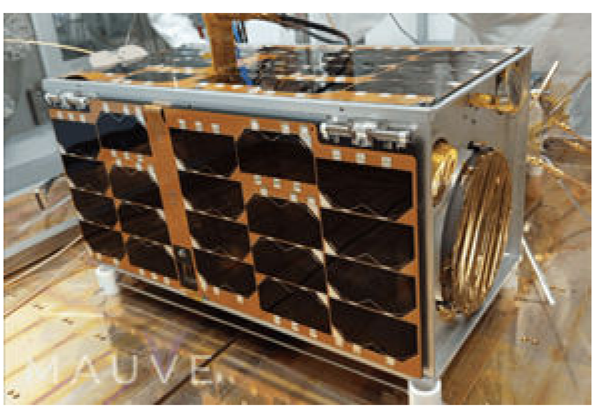

Figure 2: The Mauve satellite, developed by Blue Sky Space, will carry two Avantes standard NEXOS™ spectrometers into low Earth orbit to study ultraviolet emissions from active red dwarf stars.

3. GROUND-BASED VALIDATION EXPERIMENT

To prepare for the Mauve mission, an experimental setup was developed to replicate, as closely as possible, the type of measurements the satellite will perform, this time from Earth. The goal was to evaluate how the NEXOS™ performs when integrated into an amateur-grade telescope system under normal atmospheric conditions.

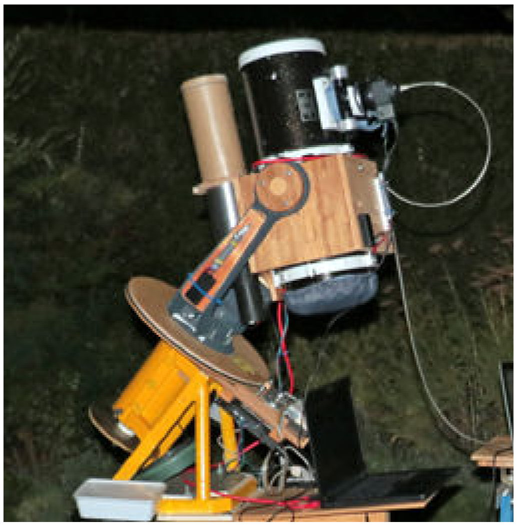

Figure 3: Ground-based setup: a 150 mm Newtonian telescope coupled via optical fiber to an Avantes NEXOS™ spectrometer. The system was mounted on a custom-built equatorial fork mount and aligned using a guiding camera for accurate tracking.

3.1 Telescope and Optical Configuration

The experiment used a SkyWatcher Quattro 150 mm Newtonian telescope mounted on a DIY equatorial fork mount. Tracking was managed with a guiding telescope using PHD2 software, achieving a tracking precision of approximately 0.7 arcseconds RMS under good conditions.

At the focal point, a 3D-printed beam splitter assembly replaced the eyepiece. The beam splitter directed light simultaneously to a guiding camera and a 200 µm optical fiber, which transmitted the starlight to the NEXOS™ spectrometer located several meters away. This setup minimized weight and ensured precise alignment between the star and fiber input.

3.2 Spectrometer and Data Acquisition

The Avantes NEXOS™ spectrometer features a Czerny-Turner optical design with 4096 calibrated pixels and 14-bit dynamic range. Data acquisition was carried out with AvaSoft software, allowing real-time calibration and export of spectra for further analysis.

Unlike traditional astronomical spectrographs that require extensive image processing (flat-fielding, dark-frame subtraction, wavelength calibration), NEXOS™ directly produces a digitally calibrated spectrum, simplifying the workflow.

All observations were conducted from a Bortle 5 suburban location in Waalre, the Netherlands, approximately 23 meters above sea level, shortly after sunset.

4. EXPERIMENTAL RESULTS

The bright star Vega (α Lyrae) was chosen as the primary test target due to its brightness and well-documented spectral profile. Vega is an A0V-type star with a surface temperature of approximately 9600°C, about 1.5 times the size of the Sun, and emits nearly
40 times more energy.

4.1 Measurement Conditions

The observations took place under partial cirrus cloud cover and moonlit skies. Despite these non-ideal conditions, the NEXOSTM successfully captured a high-quality spectrum with the following parameters:

- Integration time: 200 seconds
- Averaging: 10 integrations of 20 seconds each
- Signal-to-noise ratio (SNR): 414
- Spectral resolution (FWHM): 4.5 nm at the H-δ line

4.2 Spectrum Analysis

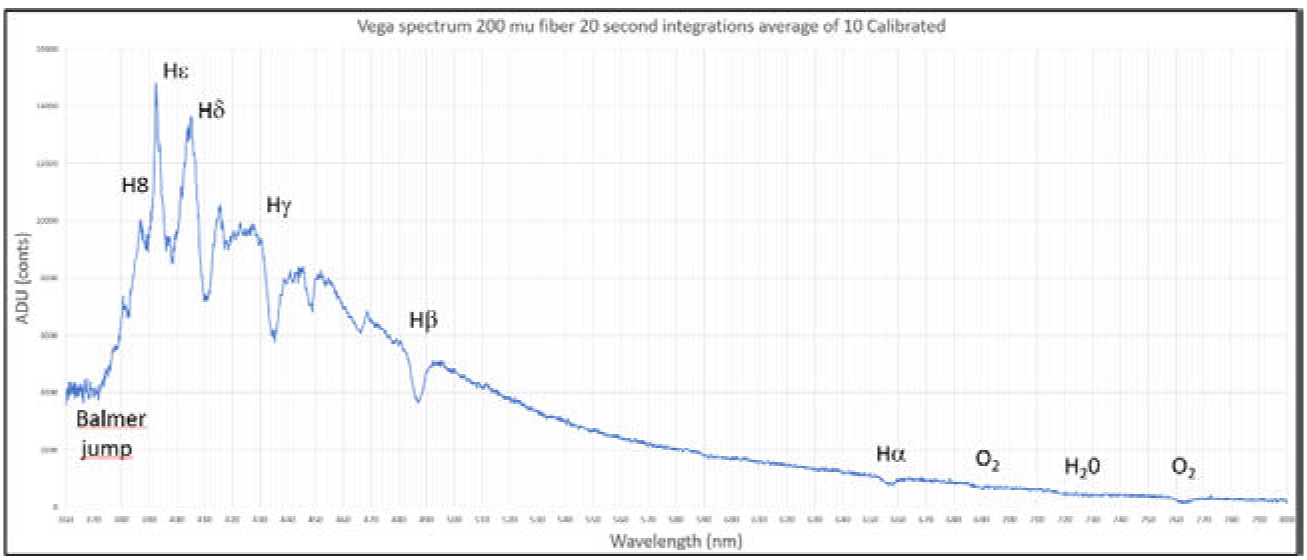

Figure 4: Recorded visible-light spectrum of Vega captured with the NEXOS™ spectrometer. Broad hydrogen Balmer lines are clearly visible, while UV wavelengths below 360 nm are absorbed by Earth's atmosphere.

The recorded spectrum shows a smooth continuum with pronounced Balmer absorption lines (Hα, Hβ, Hγ, etc.) and a visible Balmer jump at 364.5 nm. Wavelengths below 360 nm yielded no signal due to atmospheric absorption, underlining the importance of performing UV spectroscopy in space.

Further comparison between a 200 µm and 600 µm optical fiber revealed that increasing the fiber diameter slightly improved signal intensity but reduced spectral resolution, an important trade-off in system configuration

5. DISCUSSION

The results demonstrate that the Avantes NEXOS™ spectrometer can deliver scientifically valuable, high-SNR data even under non-ideal ground conditions. The achieved resolution of 4.5 nm and signal-to-noise ratio exceeding 400 are remarkable for an instrument of this size and weight.

The experiment clearly shows that a compact, commercially available spectrometer can be successfully applied to stellar spectroscopy from Earth. The data obtained with the backyard setup provides a valuable analog to the type of measurements that will be performed by the Mauve satellite in space, where the NEXOS™ instruments will operate in the ultraviolet range beyond the reach of ground-based telescopes.

Parameter	Ground Experiment	Mauve Mission (Expected)
Environment	Suburban, Bortle 5	Low Earth Orbit
Wavelength range	360–900 nm (visible)	200–400 nm (UV)
SNR (typical)	~400	~300 (UV est.)
Resolution	4.5 nm	9 nm
Instrument	NEXOS™ (COTS)	NEXOS™ (COTS)

Table 1. Comparison of ground-based and expected space-based performance parameters of the NEXOS spectrometer.

These results validate that the same commercial off-the-shelf (COTS) instrument technology used in a small terrestrial telescope can withstand the much more demanding conditions of space operations, an impressive testament to NEXOSTM's robustness and adaptability.

Independent Comparison: UCLO Measurements

To further confirm the accuracy and consistency of the ground-based data, a comparison was made with independent measurements from the University College London Observatory (UCLO). UCLO operates a professional telescope equipped with a different model of Avantes spectrometer, used regularly for student training and research.

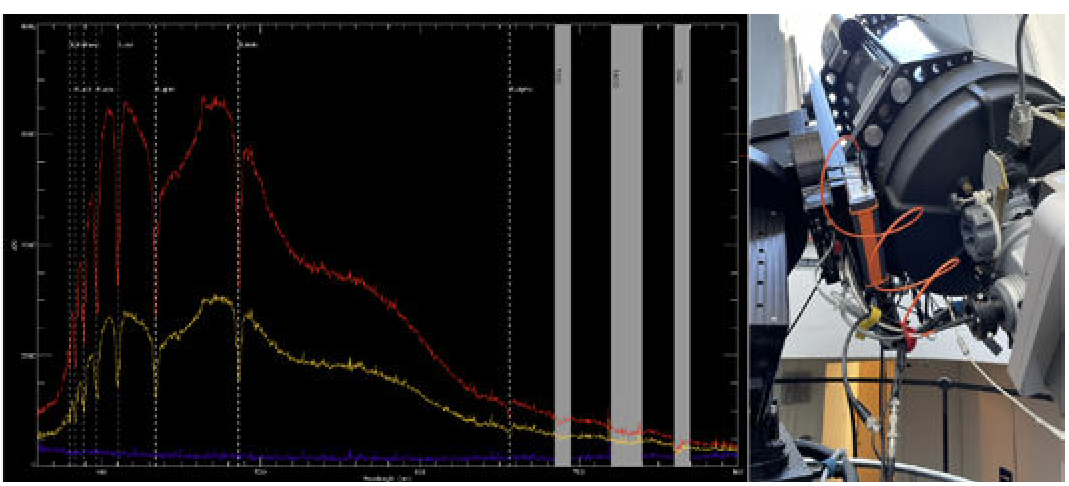

Figure 5. Vega spectrum recorded at the UCLO Observatory using an Avantes spectrometer. The matching Balmer absorption features confirm consistency between independent setups and instruments.

Both the Avantes experiment and the UCLO observatory spectrum show the same broad hydrogen Balmer absorption lines and identical overall continuum shape for Vega. Despite differences in telescope size, location, and spectrometer configuration, the spectral features align remarkably well.

This comparison provides independent verification that Avantes spectrometers deliver consistent, reproducible results across different platforms, ranging from a small backyard telescope to a professional academic observatory. It also reinforces the conclusion that Avantes' optical design and calibration accuracy remain stable under very different environmental and operational conditions.

By including this cross-validation, the study demonstrates not only the performance of the NEXOS™ in a single experiment but also the instrument's broader scientific credibility within the astronomical community.

6. CONCLUSION

This study demonstrates how the Avantes NEXOS™ spectrometer bridges the gap between ground-based experimentation and space-borne research. The instrument's compactness, stability, and optical precision make it an exceptional tool for spectroscopy across diverse environments.

As the Mauve mission commences, two unmodified NEXOS™ spectrometers will soon operate in orbit, continuing Avantes' legacy of enabling scientific discovery from lab to launchpad.

For more information about the experiment, or our products, contact us. We are happy to help you!

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Curious how spectroscopy will help you reveal answers by measuring all kinds of material in-line, at your production facility, in a lab, or in the field? Visit our website or contact one of our technical experts.
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