THE BALLOON INFRARED SPECTROGRAPH FOR SURFACE THERMAL EMISSION (BIRSTE) OF VENUS.

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Introduction: To address fundamental questions regarding geologic processes on Venus, we propose a simple near-infrared spectrograph with low resource requirements to measure thermal emission originating from the surface. A balloon gondola would serve as a convenient platform to carry this instrument within the benign environment characteristic of ~55 km altitude.

Background: Ground-based observations of the Venus nightside revealed narrow-band spectral features in the near infrared attributed to thermal emission from the lower atmosphere, observable through low-absorption "windows" [1]. Subsequent observations have been made by additional ground-based efforts and interplanetary mission flybys [2-5]. The band centered at ~1 μm is dominated by emission from the surface [6], leading to the suggestion that iron-rich (basaltic) and iron-poor (felsic) mineralogies can be broadly discriminated based on differences in emissivity [7]. Using this technique, analysis of the Venus Express VIRTIS dataset has demonstrated evidence of compositional variations associated with previously identified geologic units in the southern hemisphere [5].

Platform: A balloon gondola, similar to that used by the Soviet VEGA mission [8], provides a convenient platform to conduct remote sensing observations of the surface. The nominal altitude of such a platform is ~55 km [9]; this region of the atmosphere is relatively benign, with an ambient temperature of ~30°C and air pressure of ~0.5 atm. Zonal winds carry the balloon at a ground speed of ~300 km hr^{-1} (80 m s^{-1}) allowing observations across all longitudes in 5.3 days.

Measurement Requirements: We adopt a required geometric spatial footprint of 25 km. At an altitude of 55 km, this sets a relatively large angular resolution requirement of ~26°. In addition to the highly transparent 1 μm band, we require other windows to monitor and correct for cloud opacity variations. Therefore, we require a wavelength range of 800–1050 nm, which also contains two bands centered at 850 and 900 nm [4]. In order to remove the small contribution of emission from the atmosphere, characteristic CO_2 features must be resolved. Therefore, we require a spectral resolution of 5 nm with a sampling of at least 2.5 nm.

Instrument Design: A point (non-imaging) spectrometer is a good match to this application. Given the large angular size of one spatial resolution element, no telescope is required. A Rowland circle spectrograph provides a simple, compact optical design with adequate performance. A stock holographic, aberration-corrected grating with a dispersion of 68 nm mm^{-1} meets our design criteria. We validated the imaging performance of the system using a black-box Zemax model of the grating provided by the vendor.

Based on a trade study of available sensors, we chose a full-frame transfer CCD with a format of 1024×122 and a pixel size of 0.024 mm square (1.6 nm wavelength sampling). The responsivity of this sensor is enhanced relative to the standard response of Si in the near infrared, with a QE of ~40% at 1 μm. Because of the high sensitivity and low dark current, no active cooling is required. A shutter mechanism located at the entrance slit allows the background to be measured.

Table 1: BIRSTE specifications and accommodation.

Wavelength range	800 – 1050 nm
Spectral resolution	5 nm
Spectral sampling	1.6 nm
Field of view	26°
Geometric spatial resolution	25 km from 55 km
Mass	2 kg
Power	3 W
Volume	22×14×10 cm
Data production rate	14.4 bits per second

Performance: Using a radiometric model of the instrument and the nightside source brightness measured by Cassini VIMS [4], we can estimate the signal-to-noise ratio (SNR) of an observation. We find that using a long slit and binning the detector by 10 rows results in a signal production rate of 1.5×10^5 e^- s^{-1} in one spectral channel at 1 μm. Assuming good background subtraction, this results in an SNR of 380 in 1 s. Instrument specifications and accommodation requirements are given in Table 1.

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