The Balloon Infrared Spectrograph for Surface Thermal Emission (BIRSTE)

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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 nightside surface. A balloon gondola would serve as a convenient platform to carry this instrument within the benign environment characteristic of ~55 km altitude.

Background

Low-absorption atmospheric "windows" have been found to exist at Venus (e.g. Fig 1) [1-5]. The band centered at ~1 μm is dominated by emission from the surface [6], allowing remote sensing applications. Silicate minerals containing FeO exhibit an absorption in reflectance, also at ~1 μm. Thus, iron-rich (basaltic) and iron-poor (felsic) mineralogies could be distinguished [7].

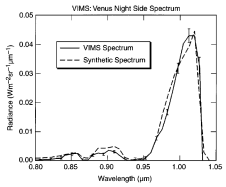

Figure 1: Nightside emission from Venus measured by Cassini VIMS [4].

Analysis Approach

The data reduction technique for BIRSTE is similar to that used by VIRTIS on VEX [5]. The brightness of the emission at ~1 μm (Fig 1) is a function of: 1) surface temperature, 2) cloud opacity, and 3) emissivity. For studies of the surface, we seek to derive 3) while correcting for 1) and 2).

The surface of Venus exists in thermal equilibrium with the atmosphere. Variations in thermal emission from the surface due to temperature therefore depend on elevation. This effect can be corrected using the topographic map from Magellan, the average surface temperature, and the lapse rate of the atmosphere near the surface.

The observed radiance of the features at 0.85 and 0.9 μm is dominated by the transmission of the clouds. Variations seen in these windows provides a correction to the cloud transmission at 1 μm.

References and Acknowledgement

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Objective

Relatively little is known about the composition of the Venus surface. By measuring the variation in surface emissivity at 1 μm, broad mineralogic categories will be correlated with established geologic units. This will assist in the understanding the origin of volcanic materials and the timing of processes.

Platform

BIRSTE could be carried by a range of platforms (orbiter, plane, descent probe) but here we focus on a balloon gondola (Fig. 2), similar to that used by the Soviet VEGA mission [8].

The environment at ~55 km is relatively benign [9]: ~0.5 atm, ~30°C (Fig. 2). Zonal winds carry the balloon at a ground speed of ~300 km hr^{-1} (80 m s^{-1}) allowing observations across all nightside longitudes in 2.6 days. Non-rechargeable batteries impose severe mass and power constraints [11].

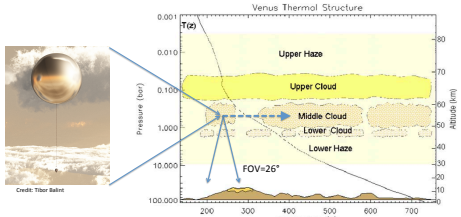

Figure 2: Illustration of balloon platform and nominal environment at altitude. Graphics from [11].

Instrument Design

BIRSTE is a point (non-imaging) Rowland circle spectrograph (see Table 1 and Fig. 3). A single concave grating disperses and reimages the 26° FOV onto a detector array.

A 1024×122 pixel full-frame Silicon CCD was selected due to its low dark current, enhanced long-wavelength sensitivity (QE of 40% at 1 μm), and charge-summing capability prior to readout. No active detector cooling is required. A shutter mechanism allows the background signal to be measured.

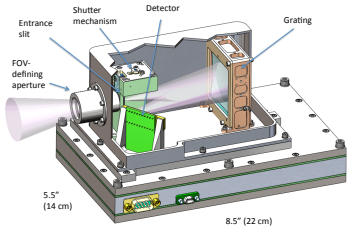

Figure 3: BIRSTE mechanical model with light path.

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
Estimated spatial resolution (with clouds)	50 – 100 km
Estimated spatial resolution (no clouds)	~40 km
Mass	2 kg
Power	3 W
Volume	22×14×10 cm
Data production rate	14.4 bits per second

Figure 4 shows an estimate of the signal to noise ratio for a single observation. Details: one second integration time, brightness from Fig 1, background subtracted, 10 rows of binning.

Compared to VEX VIRTIS-M, BIRSTE provides: up to ~3x improvement in spatial resolution, full spectral coverage across 1 μm feature, >100x larger SNR, no solar-scattered light.

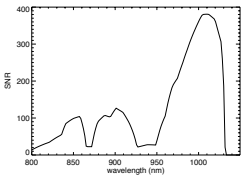

Figure 4: Estimate of the SNR for a single observation of the Venus nightside with BIRSTE.