The Circumpolar Stratospheric Telescope FUJIN for Observations of Planets

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Introduction

It is important to conduct long-term continuous observations for studies of time-dependent phenomena in the planetary atmospheres and plasmas. A balloon-borne telescope "FUJIN" or the god of wind has been developed for the purpose of promoting these studies by observing them from the polar stratosphere where atmospheric transmittance and seeing greatly surpass those on the ground. FUJIN can be a low-cost space platform for optical observation of planets. "FUJIN-2" is the second generation system aiming spectroscopic and imaging observations of Venus during a westward circumpolar flight from ESRANGE in Kiruna, Sweden in 2021.

Science Objective

Characteristic markings on a Venus disk have been identified when it is observed in the ultraviolet and blue spectral regions as shown in Fig.1. These markings are thought to be caused by gaseous absorbers in the Venusian atmosphere (Fig.2). The absorption in the spectral region with wavelengths shorter than 320 nm is identified as SO_2 above the cloud-tops. However, an absorber which is responsible for absorption longer than 320 nm has not yet been identified. Recently, Perez-Hoyos et al. [2018] shows that OSSO and/or S_2O can be the absorber in the Venusian atmosphere (Fig.3) and that higher resolution spectroscopy can quantitatively evaluate contributions by these candidate absorbers. The science objective of FUJIN-2 is to identify the absorbers by spectroscopic and imaging observations in the ultraviolet and blue regions.

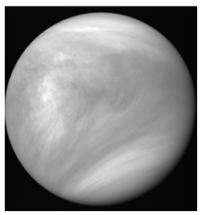

Fig.1. A Venus image acquired by Akatsuki/UVI at a wavelength of 365 nm where contrast of the Venus disk is the highest.

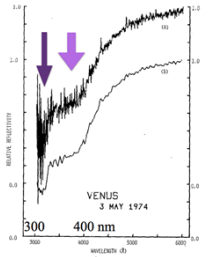

Fig.2. Reflectivity spectra of Venus obtained by Pioneer Venus Orbiter.

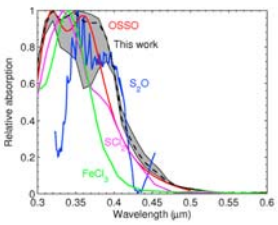

Fig.3. Absorption spectra of Venus observed by Messenger (dashed line) and candidate absorbers (colored lines) [Perez-Hoyos et al., 2018].

Outline of FUJIN-2

A conceptual illustration of the FUJIN-2 gondola is shown in Fig.4. FUJIN-2 is equipped with a 406 mm Cassegrain telescope with a Nasmyth focus, and lifted by a scientific balloon up to an altitude of 32 km. Attitude of the gondola is controlled so that a solar cell panel always faces the sun. Electrical power larger than 300 W is supplied by the solar cell panel and charged to or discharged from a Li-ion battery with a capacity of 100 Ah. The approximate total weight is 1000 kg including ballast.

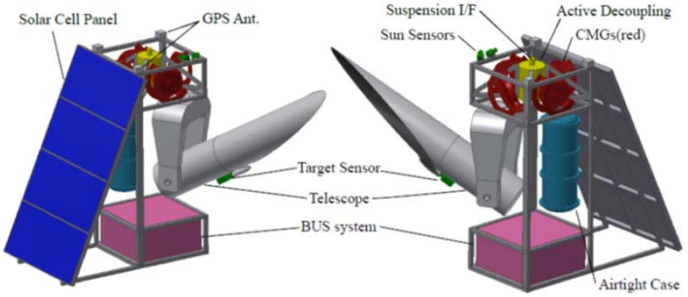

Fig.4. A conceptual illustration of the FUJIN-2 gondola.

風神 FUJIN

Attitude Control and Pointing System

To realize a diffraction limited spatial resolution a pointing error should be less than 0.1" rms. The attitude control system of FUJIN-2 has been improved from that of the FUJIN-1 system which controls only an azimuthal angle of the gondola to a three-axis stabilizing system, but the strategy is inherited as shown in Fig.5.

Control stage 1: Attitude of the FUJIN-2 gondola is controlled by a three-axis stabilizing system with an active decoupling mechanism, a pair of control moment gyros and sun sensors.

Control stage 2: A target is captured by the telescope using two star sensors which have wide and narrow field-of-views, respectively.

Control stage 3: The target is stabilized at the center of the field-of-view of the telescope by a closed-loop control with a tip/tilt mirror and a position sensitive photomultiplier tube (PMT).

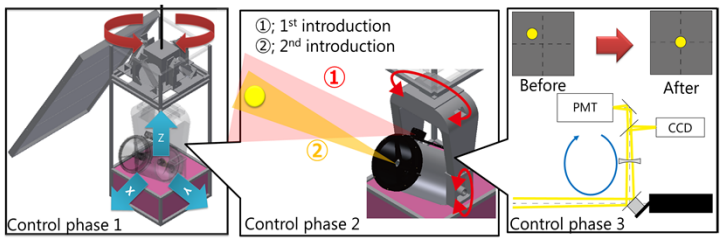

Fig. 5. Attitude control and pointing system of FUJIN-2.

Optical System

Specifications of the telescope is listed in Table 1. The optical path of the telescope is divided into three paths which go to the PMT for the pointing, a CCD camera with bandpass filters for monochromatic imaging and a spectrometer. 8 bandpass filters are mounted on a turret wheel, and one of them is selected for a specific observation purpose. The spectrometer covers a wavelength region from 200 nm to 550 nm with a spectral resolution of 0.5 nm. A CCD line sensor captures a spectrum. The CCD camera for imaging and the spectrometer can be synchronously operated. An image of Venus at 365 nm will be obtained every 10 min, and a spectrum will be obtained every 2 hours. Fig.6 shows an example of reflectivity spectrum of Venus obtained by the spectrometer installed on the Pirka telescope of Hokkaido University in Nayoro on March 7, 2019.

Table 1. Specifications of the FUJIN-2 telescope

Telescope type	Cassegrain with a Nasmyth focus
Clear aperture	406 mm
Focal length	~6000 mm
Band-pass filter	8
Detector	CCD
Mount	Altazimuth mount

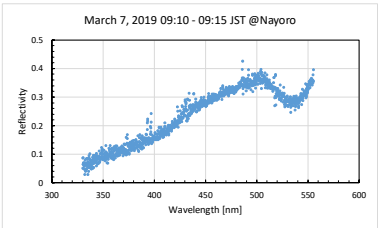

Fig. 6. Reflectivity of Venus observed by the Pirka telescope of Hokkaido Univ with the spectrometer for FUJIN-2.

Experiment Plan

A ground-based experiment at Taiki Aerospace Research Field in Hokkaido, Japan is planned in 2019 to demonstrate the performance of the attitude control system. An engineering model of the gondola will be used in this experiment. Then, a scientific balloon experiment in which Venus will be observed with FUJIN-2 will be conducted in the summer season in 2021. A westward circumpolar flight pass shown in Fig.7 is expected. The gondola will be back to the launch site in a several weeks.

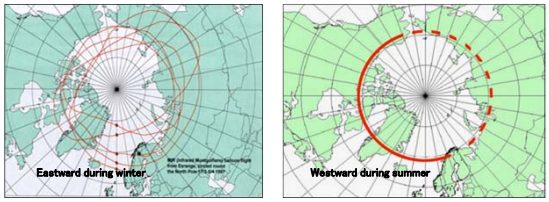

Fig.7. Expected circumpolar flight paths of FUJIN-2 (left) for the winter season and (right) for the summer season. [provided by ESRANGE]