Observation of planets by a circumpolar stratospheric telescope

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Phenomena in the planetary atmospheres and plasmaspheres have been studied by various methods using emissions emitted from there in the spectral regions from radio wave to X-ray. Optical observation of a planet has been performed by a ground-based telescope, a satellite telescope and an orbiter. A balloon-borne telescope is proposed as another platform for optical remote sensing of planets. Since it is floated in the stratosphere at an altitude of about 32 km, fine weather condition, excellent seeing and high transmittance of the atmosphere in the near ultraviolet and infrared regions are expected. Especially a planet can be continuously monitored by a long-period circumpolar flight. For these reasons we have been developing a balloon-borne telescope system FUJIN for planetary observations from the polar stratosphere.

In the FUJIN-1 system a Schmidt-Cassegrain telescope with a 300-mm clear aperture is mounted on a gondola whose attitude is controlled by control moment gyros, an active decoupling motor, and attitude sensors. The gondola can float in the stratosphere for periods longer than 1 week. Pointing stability of 0.1"rms will be achieved by the cooperative operation of the following three-stage pointing mechanisms: a gondola-attitude control system, two axis telescope gimbals for coarse guiding, and a tip/tilt mirror mount for guiding error correction. The optical path is divided to three paths to an ultraviolet camera, an infrared camera and a position-sensitive photomultiplier tube for detection of guiding error. The size of gondola is 1 m by 1 m by 3 m high, and the weight is 784 kg including the weight of ballast of 300 kg.

The first experiment of the balloon-borne telescope system was conducted on June 3, 2009 at Taikicho, Hokkaido targeting Venus. However, it failed due to a trouble in an onboard computer. The gondola was redesigned to be FUJIN-1 for the second experiment in August in 2012, when the target planet was also Venus. Unfortunately the experiment was canceled, because the stratospheric wind condition was not suitable for retrograde flight. The prelaunch ground-test results showed the high attitude control and pointing performance enough for achieving the requirements under low temperature and pressure condition.

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1. Science Objective of FUJIN

For studies on planetary atmospheres and plasmas it is essential to observe both spatial and temporal variations.
Project “a balloon-borne telescope for planetary observations” is given name to “FUJIN”.

2. Advantages of a Balloon-borne Telescope

∗ Stable atmospheric condition

・Good seeing

Since atmospheric density at the balloon altitude is 1/100 of that at the ground, a 100 times better seeing is expected. Diffraction limited spatial resolution can be achieved.

・Fine weather

∗ Wide spectral window

・Near-ultraviolet light

There is UV absorber such as ozone in the lower atmosphere. So the spectral region which can be observed on the ground is mainly restricted to visible region. But at a balloon altitude, the spectral region which can be observed is expanded to near ultraviolet region.

・Infrared light

There isn’t IR absorber such as water vapor and carbon dioxide. So Infrared region can be observed.

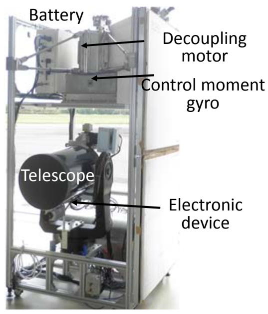
∗ Continuous observation in the polar region

A ground-based telescope in the middle and low latitudes can not perform a continuous observation of a planet.
On the other hand a balloon-borne telescope in the polar region can observe a planet all day long. Furthermore, altitude change of a planet according to the diurnal motion is small in the polar region.

∗ Other

・reusable
・low cost
・easy to recall

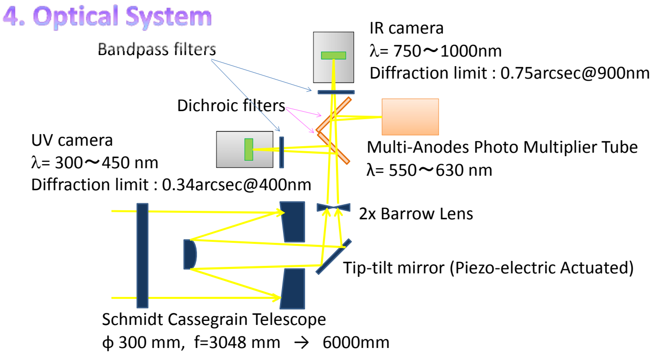
3. FUJIN-1 System



External view of FUJIN-1

Dimension		Unit
Main frame	1.0(W)*1.0(D)*3.3(H)	m
Sun battery panel	2.0(W)*1.0(H)	m
Mass		
Main body/Ballast	520/257	kg
Telescope		
Type	Schmidt Cassegrain	
Effective aperture	305	mm
Focal point distance	6000	mm
Observational wavelength(UV)	400(300~450)	nm
Observational wavelength(IR)	900(750~1000)	nm
Power system		
Maximum power consumption	283	W
Voltage of battery	22.8	V
Battery capacity	50	Ah
Voltage of Solar cell	37	V
Maximum output of Solar cell	240	W

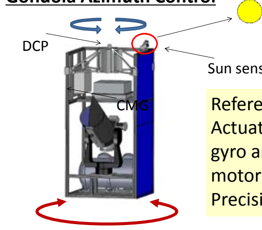
4. Optical System



5. Pointing Control System

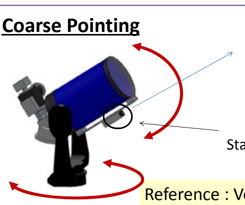
Precision aimed in 0.1 arcsec ≤ Diffraction limit of the telescope(ϕ=300mm) = 0.34 arcsec (λ=400nm) 0.75 arcsec (λ=700nm)

Gondola Azimuth Control



Reference : Sun
Actuator : Control moment gyro and active decoupling motor
Precision : 0.1 deg

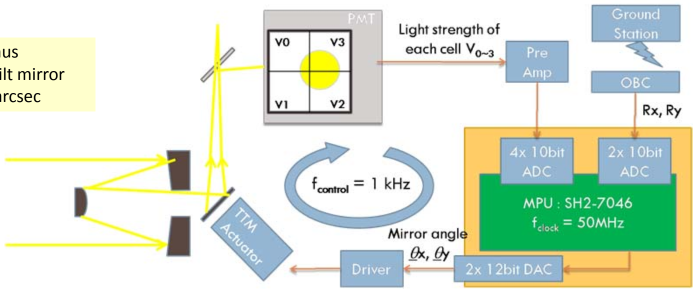
Coarse Pointing



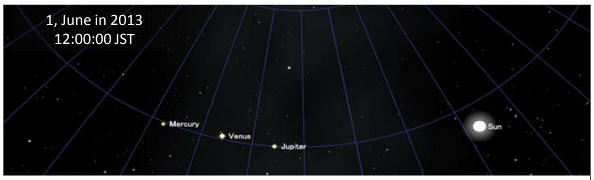
Reference : Venus
Actuator : Az + El drive motor
Precision : 1/60 deg

Fine Pointing

Reference : Venus
Actuator : Tip-tilt mirror
Precision : 0.1 arcsec



6. FUJIN-1 Balloon Experiment in 2013

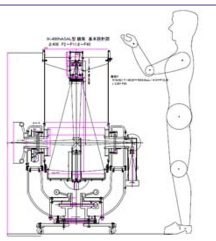


- Flight Window
  - May, June in2013
- Place
  - Taiki-cho, Hokkaido, Japan
- Target of Planet
  - Venus
  - Mercury(option)
  - Jupiter(option)
- Object
  - The system of FUJIN1(Pointing, Power, and communication) will be checked.
  - Operating the predefined performance of pointing stage1,2,and 3 will be checked.
  - Trapping and pointing Venus in the telescope field will be checked.

7. New Telescope for FUJIN-2

A new telescope is under production and will be put into observation in 2014.

∗ ϕ400mm
∗ f=12000~16000mm
∗ Nasmyth Focal point
∗ Cassegrain type



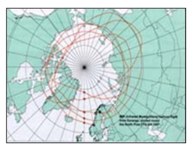
8. Future Plan

∗ A balloon experiment in Kiruna, Sweden will be performed in August 2014 for the earliest case.

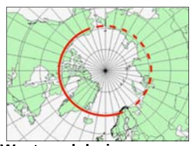
—A continuous observation for two days will be challenged for the first time.

∗ Long-duration observation by the circum polar flight will be the next step.

—The gondola lunched from Kiruna will pass over North America Continent and the northern coast of Russia, returning to Kiruna.



Eastward during winter



Westward during summer