P2-157

The Circumpolar Stratospheric Telescope – FUJIN – for Observations of Planets

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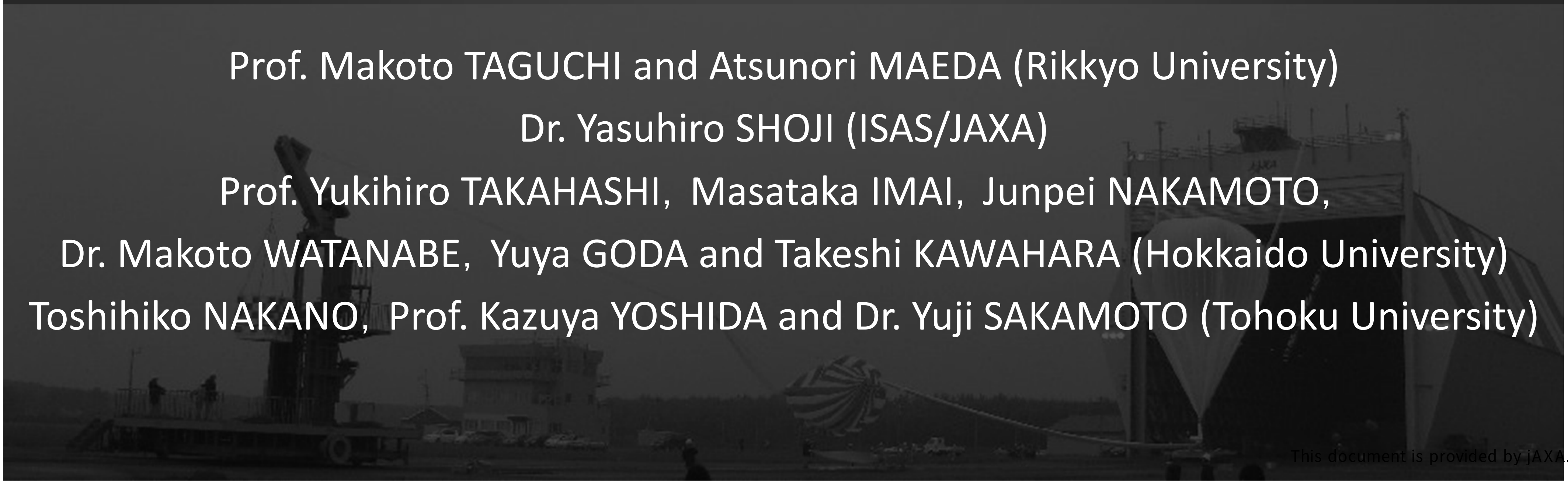


Purpose

Venus (Dayside)
Circulation
Temperature
Chemistry

Venus (Nightside)
Lightning
Airglow

Mercury
Na Atmosphere
And Tail

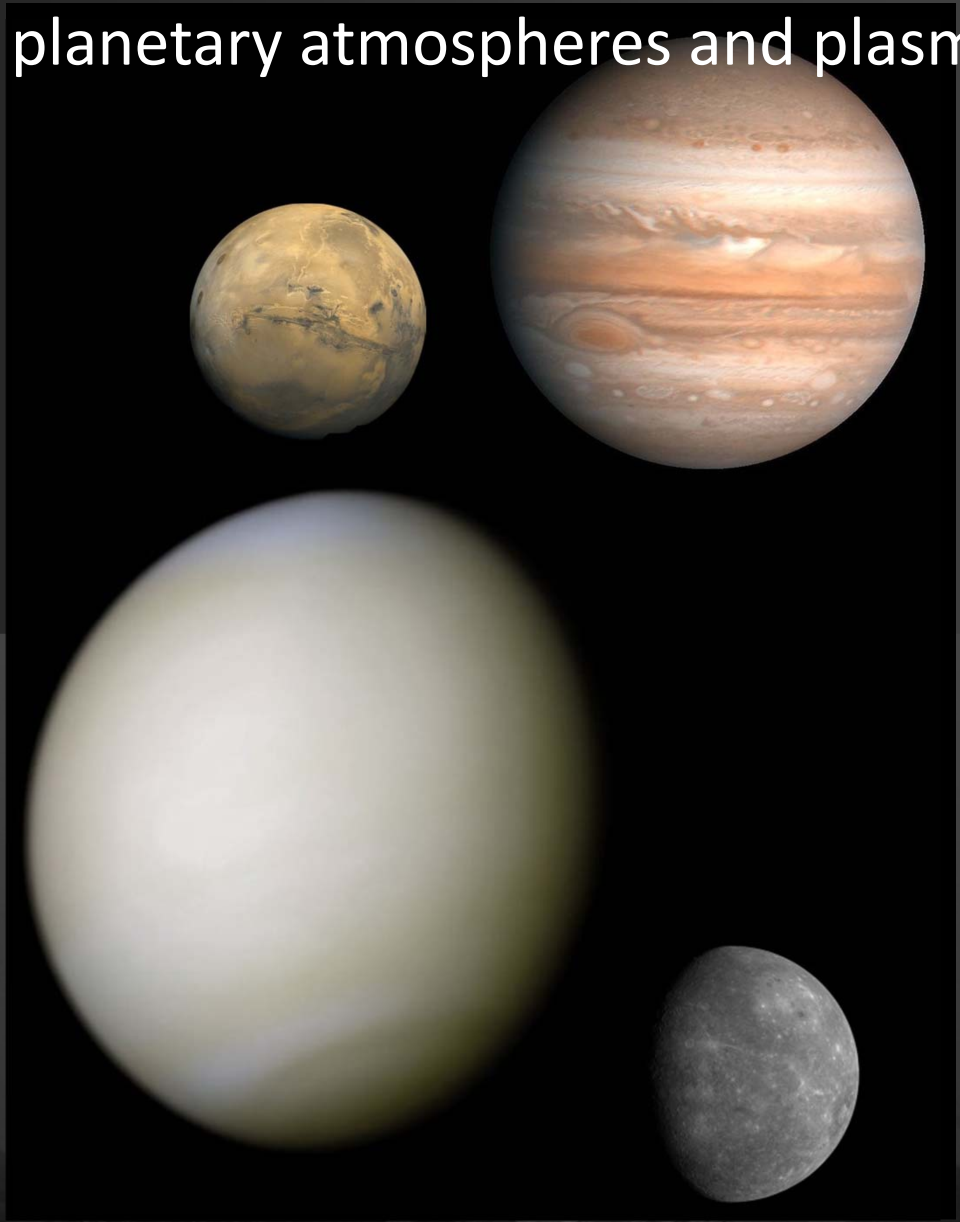
Jupiter
Aurora
Satellites
Io Torus
Magnetosphere
Cloud Physics
Circulation
Lightning

Mars
Dust Storm
Chemistry

Saturn
Aurora
Titan

Purpose

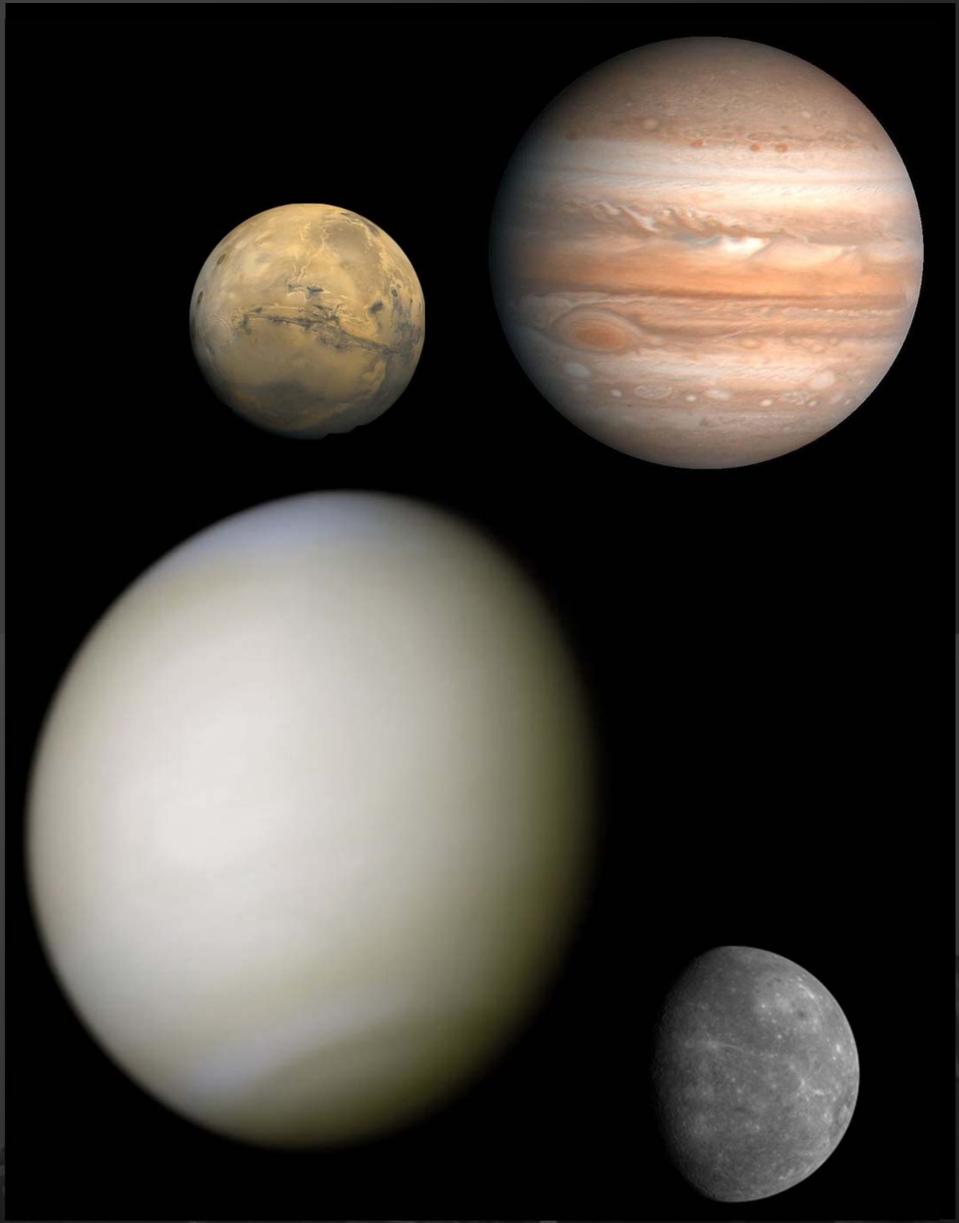
In order to understand time-dependent phenomena in the planetary atmospheres and plasmas,



- Long-term observation
  - 1 week ～ several months
  - Continuous for 24 hours
- High spatial resolution
- Monochromatic and multi-color
- Multi-purpose telescope

Advantages of planetary observations by a circumpolar stratospheric telescope

- Stable atmospheric condition
  - Good seeing
  - Fine weather
- Small absorption and scattering
  - UV (O_3)
  - IR (H_2O, CO_2, etc.)
  - Daytime observation
- Long-term observation from the polar stratosphere
- Multi-purpose
- Recoverable
  - Reusable
  - Improvement and upgrade
  - Low cost



History of FUJIN Project

2002 Start of project

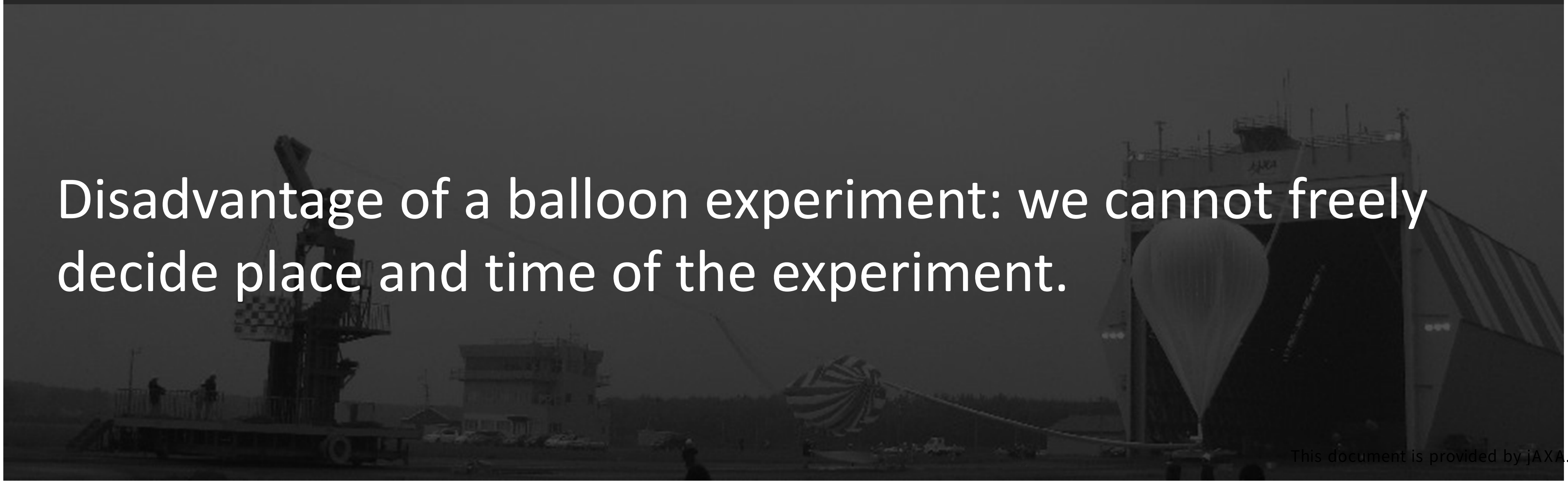
2009 1st experiment, failed due to failure in the onboard CPU

2010 Improvement

2011 Experiment cancelled due to delay of development

2012 Cancelled due to bad wind condition

2013 Cancelled due to malfunction in the bus system



Disadvantage of a balloon experiment: we cannot freely decide place and time of the experiment.

Gondola Ready for Launch in 2013

- Size and weight:
  - 1.0 (W) x 1.0 (D) x 3.6 (H) m
  - 790kg (300 kg ballast incl.)
- Telescope:
  - Schmidt-Cassegrain type
  - ϕ300 mm, f=6000 mm
  - Az-El mount
- Power Supply:
  - Li-ion battery (25.9 V 50 Ah)
  - Solar Cell Panel (240 Wmax)
- Telemetry:
  - Serial comm. 2400 bps（data down link and command uplink)
  - Double-tone command
  - NTSC analog composite video downlink

Long hoods, second star sensor, functional heaters have been added.

Attitude Control and Pointing System

- Requirement:

Pointing error
1/30 sec (video frame)

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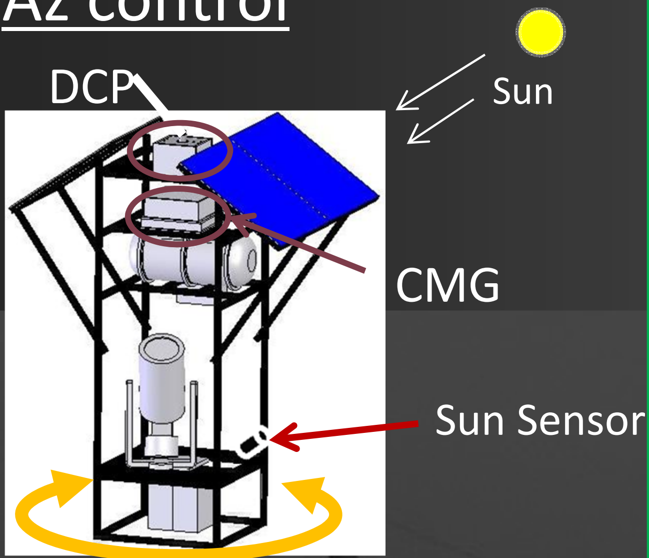
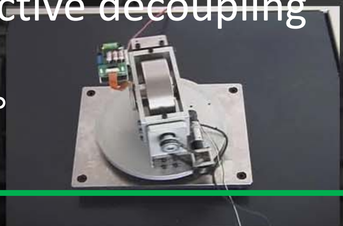
Diffraction limit (ϕ=300mm)
= 0.34 arcsec (λ=400nm)
0.75 arcsec (λ=700nm)

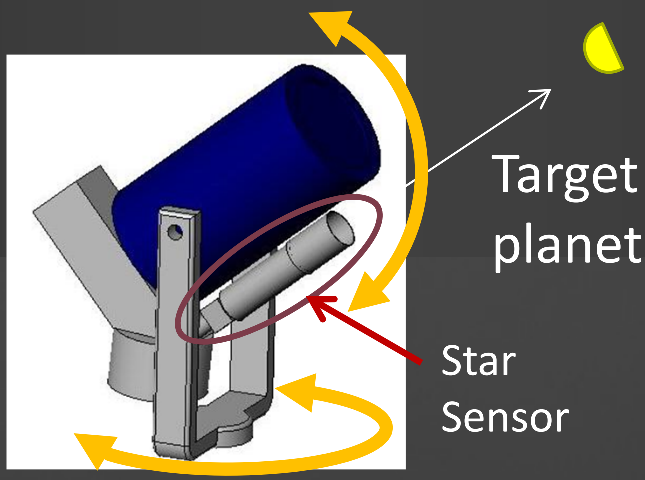
Az control



Sun-oriented attitude
Actuators: Control moment gyro (CMG)+Active decoupling motor (DCP)
Accuracy: 0.5 °

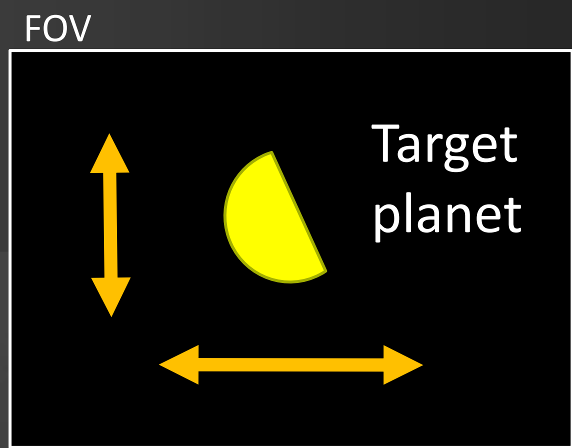


Coarse guiding

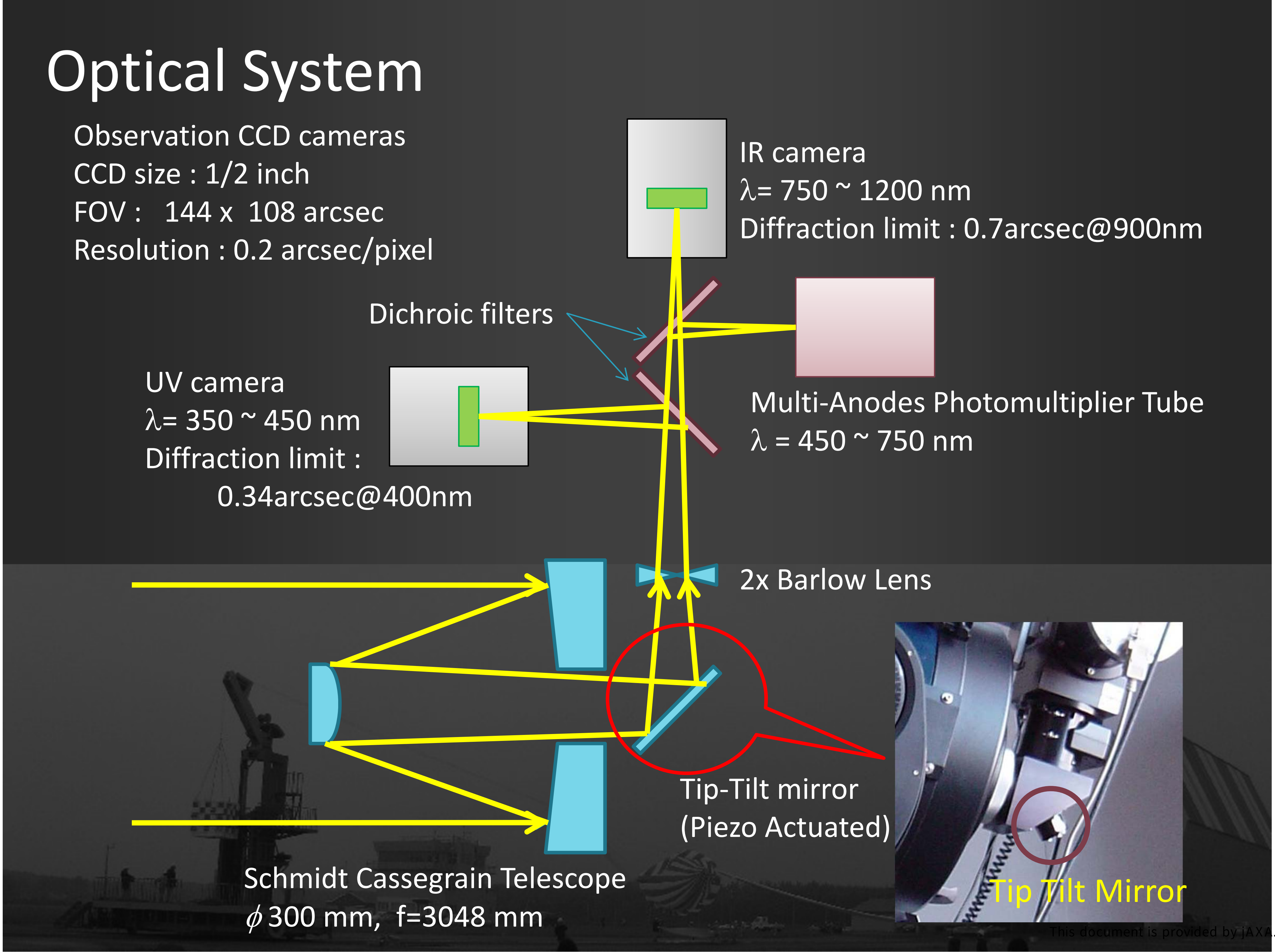


Target-oriented
Mount: Az-El gimbals
Accuracy: 1’

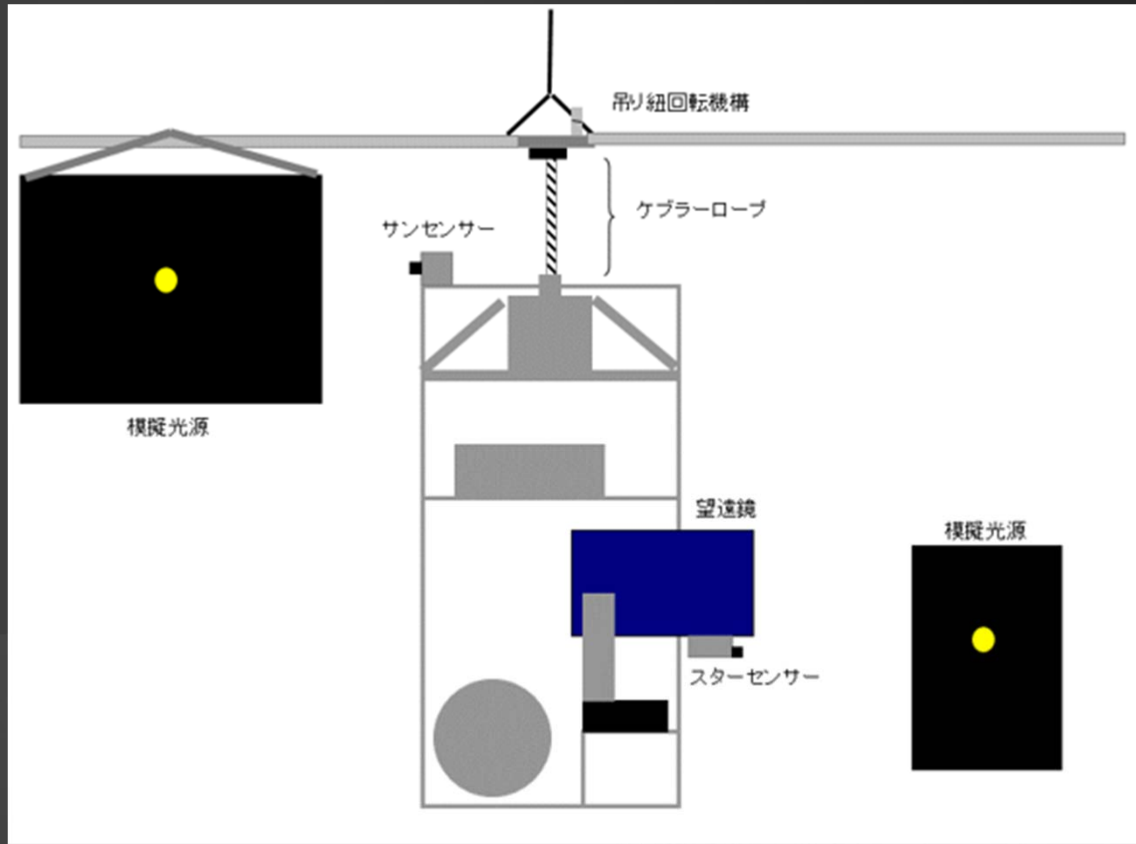
Fine guiding



Error correction
Actuator: Tip-tilt mirror
Accuracy: 0.1”

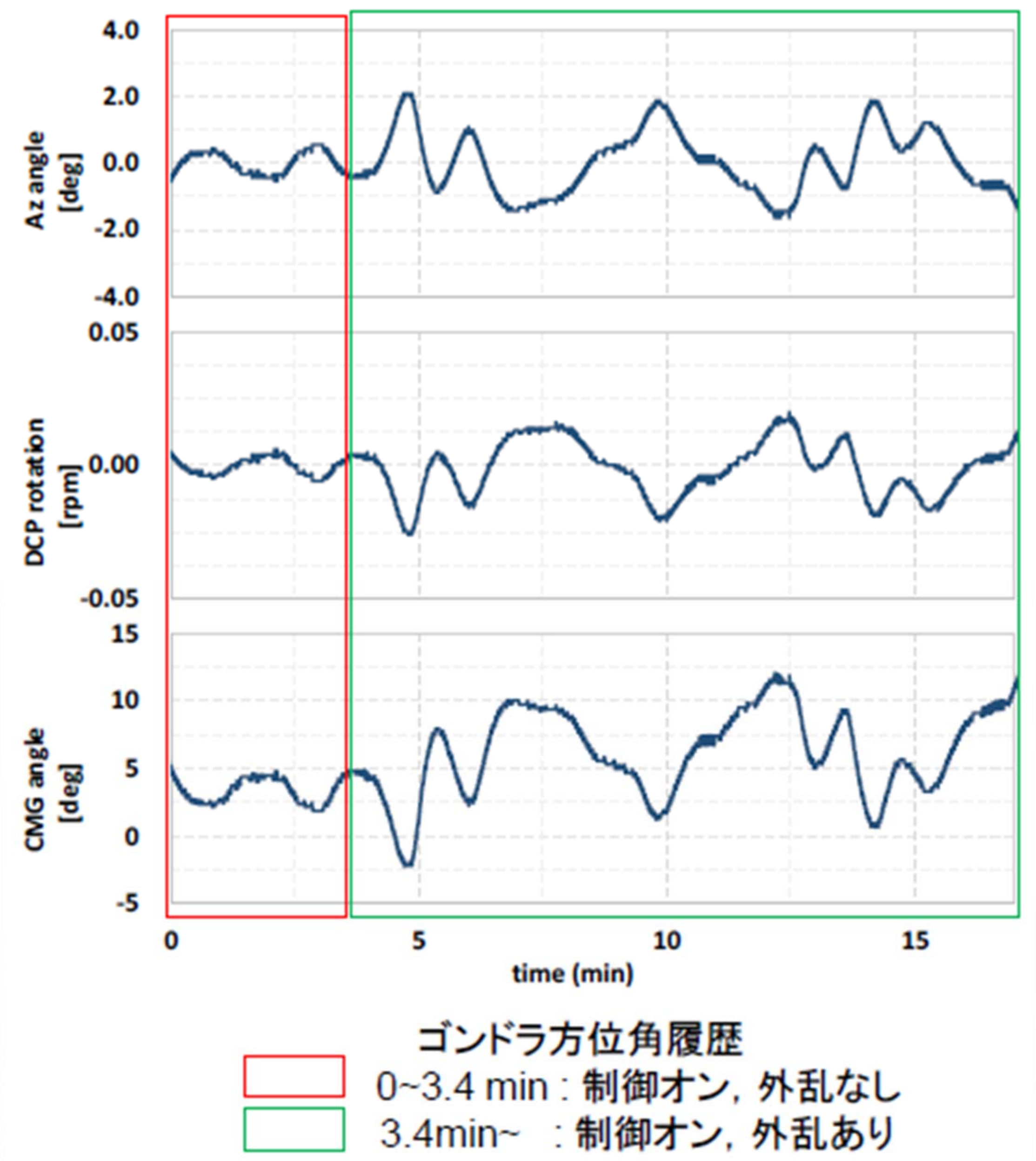

Optical System
Observation CCD cameras
CCD size : 1/2 inch
FOV : 144 x 108 arcsec
Resolution : 0.2 arcsec/pixel
IR camera
λ= 750 ~ 1200 nm
Diffraction limit : 0.7arcsec@900nm
Dichroic filters
UV camera
λ= 350 ~ 450 nm
Diffraction limit :
0.34arcsec@400nm
Multi-Anodes Photomultiplier Tube
λ = 450 ~ 750 nm
2x Barlow Lens
Tip-Tilt mirror
(Piezo Actuated)
Tip Tilt Mirror
Schmidt Cassegrain Telescope
φ300 mm, f=3048 mm

Performance test of the attitude control and coarse guiding system — experimental setup



The gondola was hanged by a rope, and rotated by a rotator as a perturbation generator which simulates the flight condition.

Performance test of the attitude control and coarse guiding system ― result

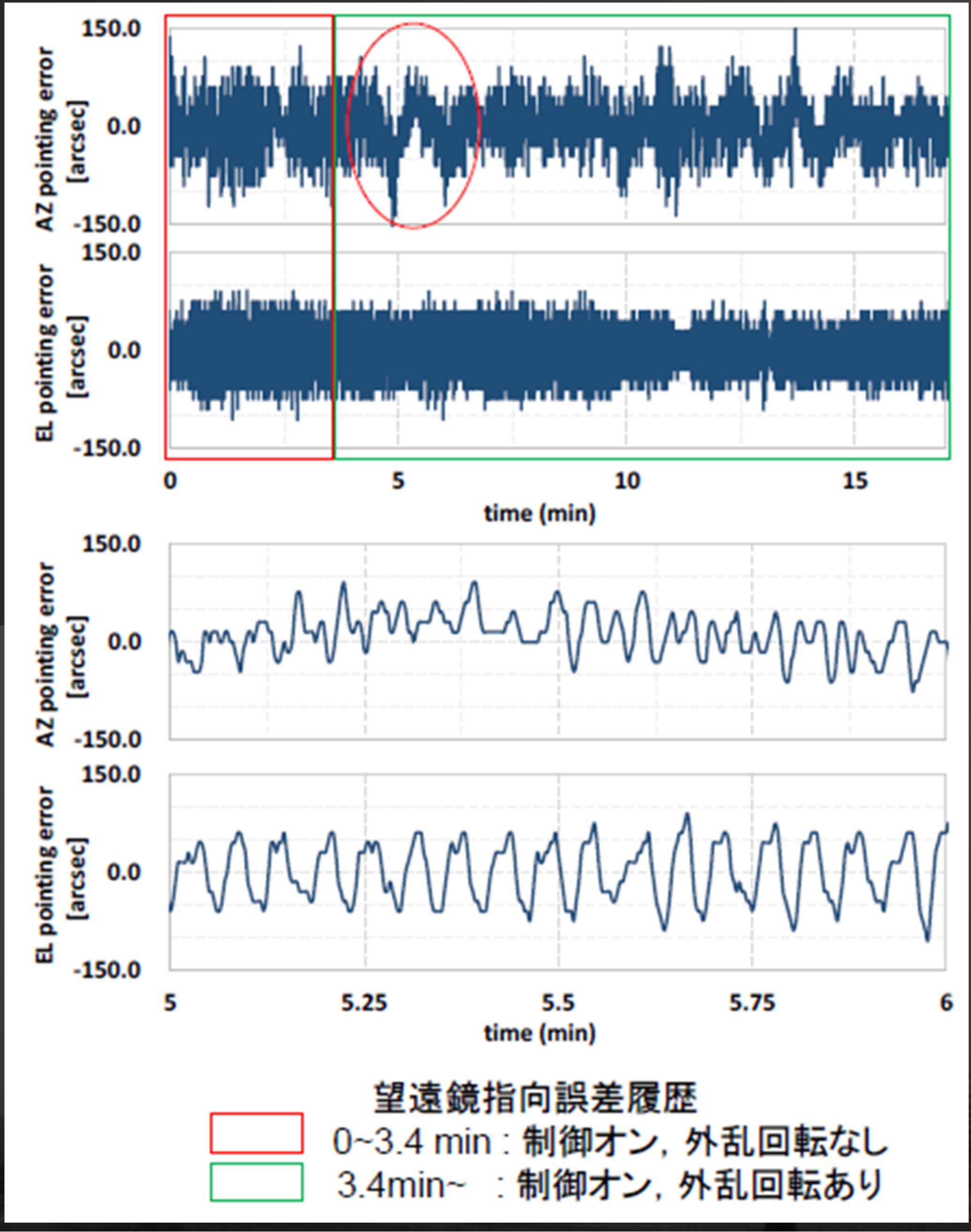


Perturbation: ±1/78 rpm p-p, period 300 sec, added 3.4 min after the start of control.

The Az angle variation was 1.5～2.0° with a period of 300 sec

The star sensor kept locking on the artificial star, though the attitude control error exceeded the target value of 0.5° .

Performance test of the attitude control and coarse guiding system — result



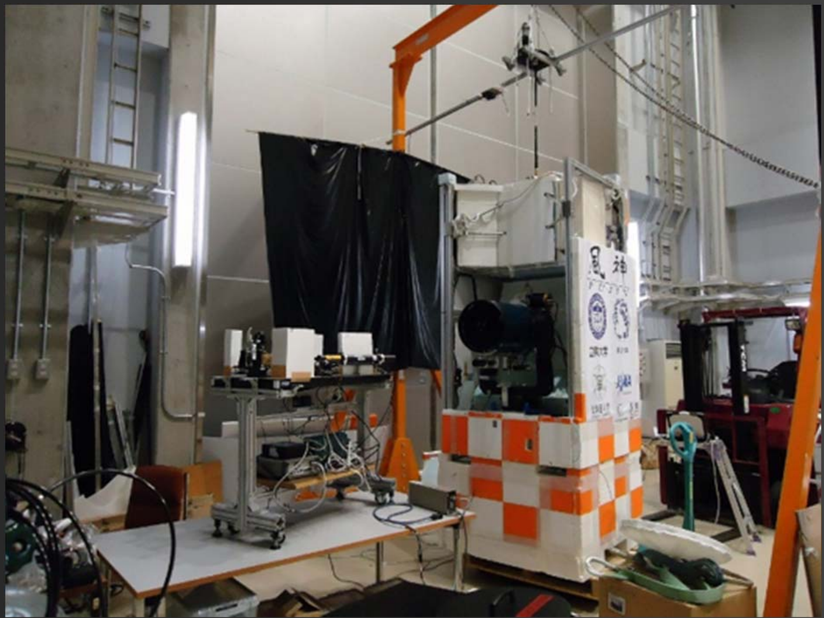
Pointing error:

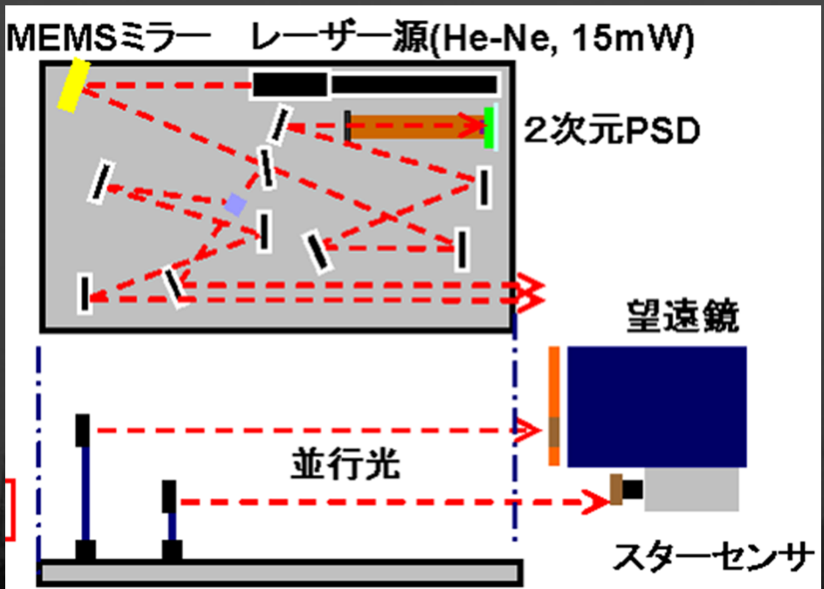
Az: 36” rms

El: 42” rms

The motion of telescope generated an oscillation in the elevation axis with a period of 3~4 sec. This oscillation was generated by reaction of the gondola to the telescope motion, and should be improved in FUJIN-2 by introducing three-axis CMGs.

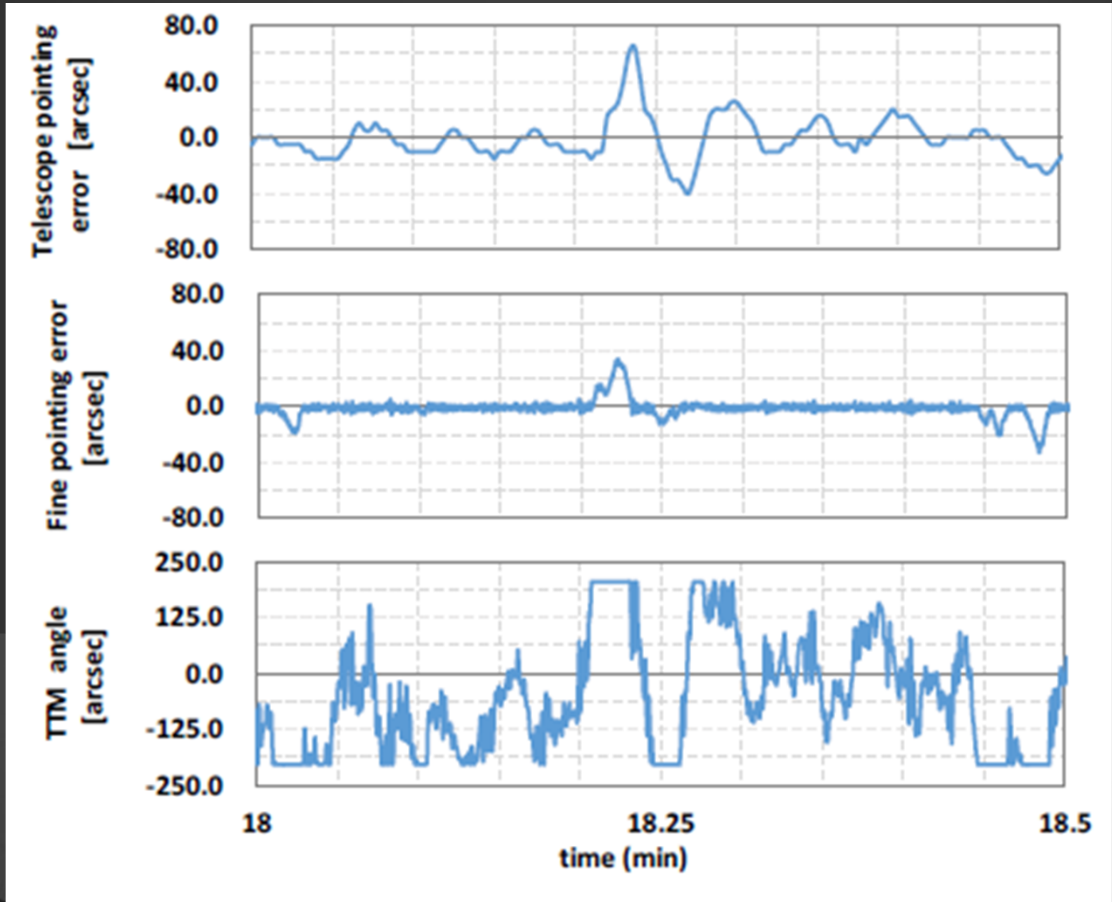
Overall attitude control and guiding performance test using a laser light source





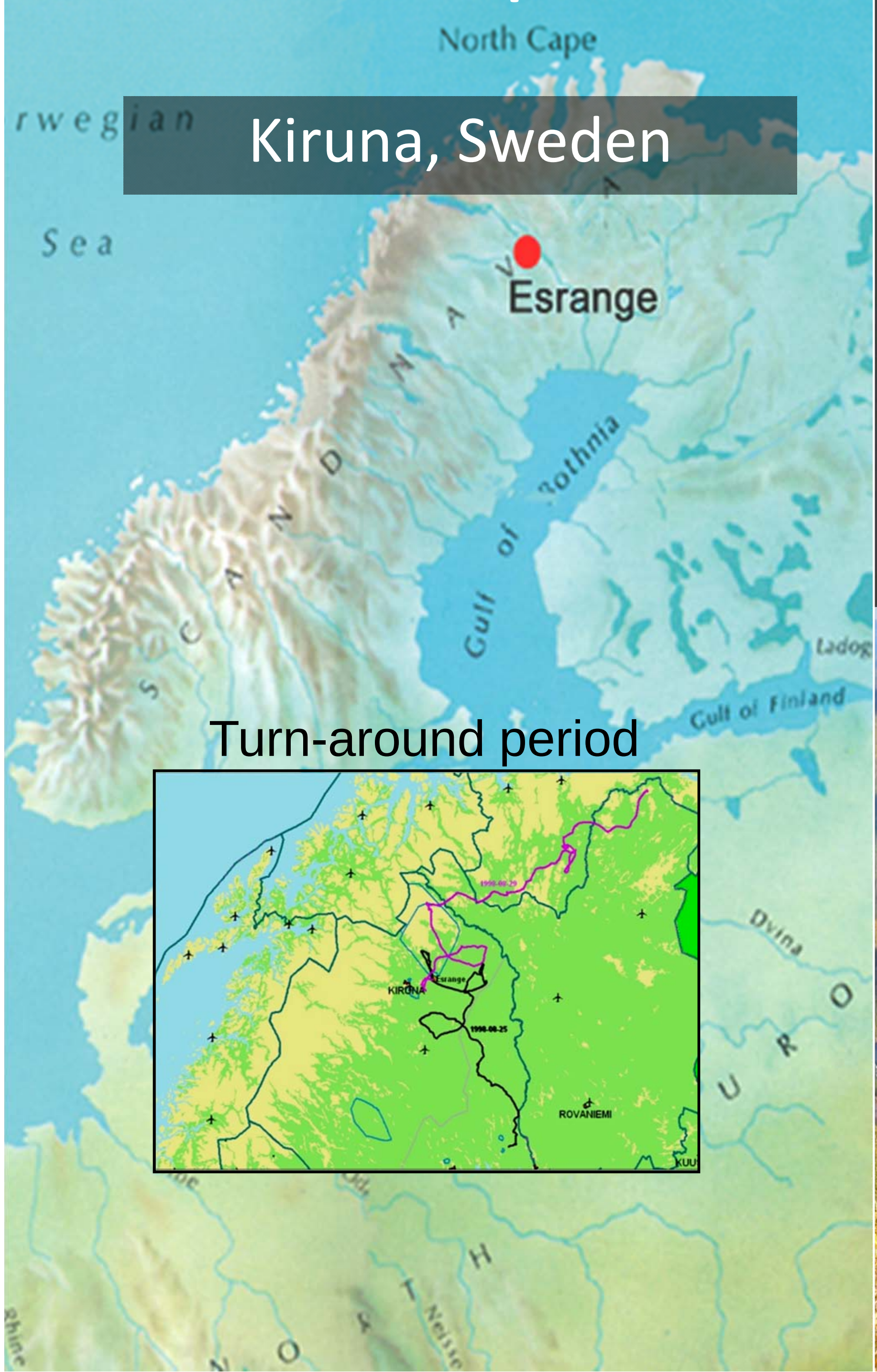
The gondola was hanged by a rope, which was rotated by a rotator as a perturbation generator. A laser was used as an artificial star light source of which the beam direction can be stirred by a vibrating mirror. Two parallel beams were introduced into the apertures of the telescope and star sensor.

Overall attitude control and guiding performance test using a laser light source



For the Az control the fine guiding was effective for 64% of the 2 min period from 17.09 min, and the guiding error was 1.7” rms. This is because the laser image was much larger than an image of a planetary disc, and the sensitivity of position detection became lower. The guiding error will be improved when the telescope looks at an actual planet.

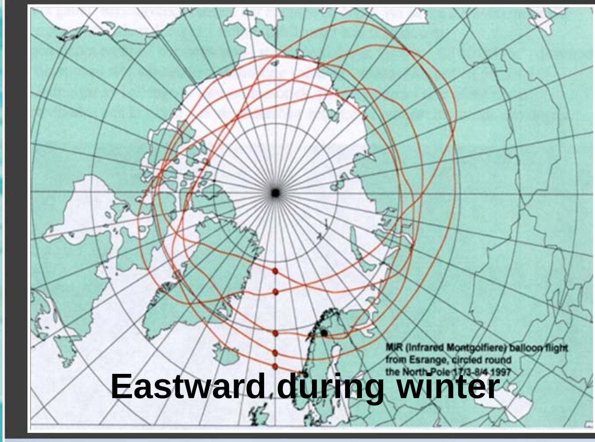
FUJIN-2 Experiment Plan



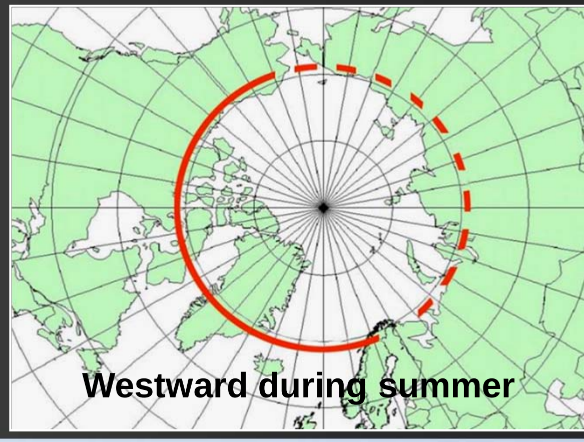
Kiruna, Sweden

Turn-around period

Balloon trajectories



Eastward during winter



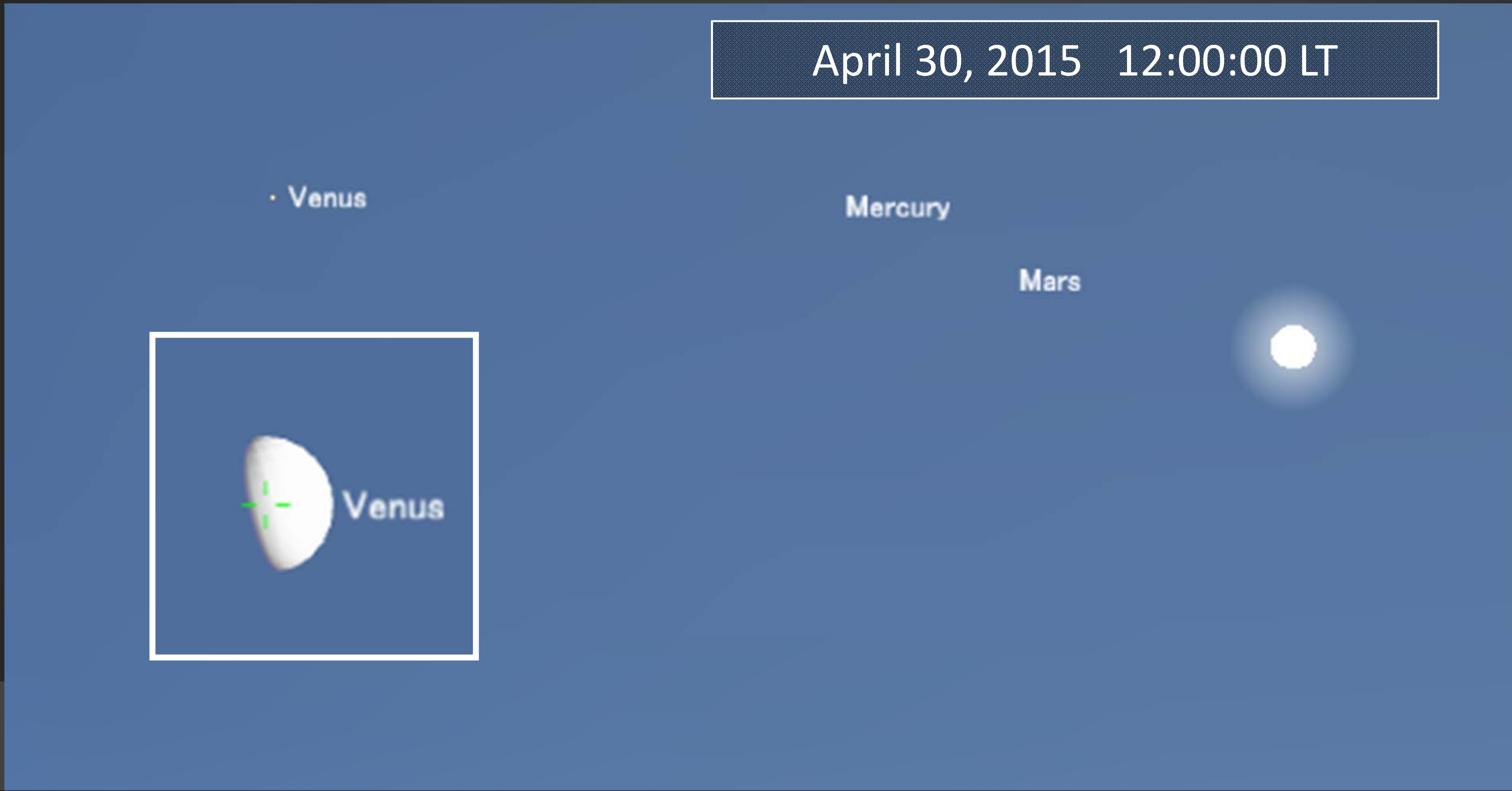
Westward during summer

Flight directions & duration:

Turn-around:	**Sweden (Finland/Norway)** **April/May & Aug/Sept. 1 – 4 days at float**
Winter:	**Northern Finland, Kola Peninsula, ~ 10 h** **Siberia up to 25 h** **Circumpolar flights >14 Days**
Summer:	**North America, 5 – 7 Days** **Circumpolar flights >14 Days**

Polarized Gamma-ray Observer (PoGOLite) has succeeded in a circumpolar flight in the summer in 2013.

FUJIN-2 Experiment Plan



Purpose: Observations of Venus atmosphere

Launch: ESRANGE (Kiruna, Sweden)

Window: April/May, 2015

Flight duration: 24～48 hours

FUJIN-2 Experiment Plan

The new telescope in a test observation. It will be installed in the gondola upside down.

A new telescope

Type: Cassegrain + barlow lens

Focus: Nasmith type

Aperture: 400 mm

F: 30～40 (continuously variable)

Filters: 10 bandpass filters

Improvements after the experiment in 2009

Sub-system	Improvement
Controller	The onboard CPU has been replace by an FPGA.
Electrical I/F	A slip ring has been inserted between the gondola and the balloon.
Power Supply	Main switch, waterproofing, Li-ion battery
Attitude control	Waterproofing of the CMG case
Data storage	SD memory cards
Structure	Reduced weight and height