A NEW JAPANESE INFRARED BALLOON TELESCOPE

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ABSTRACT

We have developed a new 50 cm infrared balloon-borne telescope. The first flight of this telescope system is scheduled in this September.

We adopted an offset paraboloidal mirror and use its primary focus, so that we can reduce significantly the amount of background emission from the telescope itself. The structure of the telescope is made of CFRP so as to reduce weight as well as to make the optics free from thermal contraction due to low temperature during observational flights.

For the detector, we apply our newly developed 4×8 stressed Ge:Ga array and make 150–180 μm photometry. The detector is installed in a cryostat and is cooled by liquid He down to 2 K. Because of the large detector format, the observational efficiency will become higher: we can survey a wide area of the sky (up to $10^\circ \times 10^\circ$) with a high spatial resolution of $1.5'$ in one flight.

We plan to survey the Orion region, W51, etc. and to map some external galaxies in the first flight.

FAR-INFRARED ARRAY DETECTOR

Ge:Ga photoconductors are at present the most sensitive detector for far-infrared radiation in the wavelengths of 50–200 μm (see Hiromoto *et al.*, 1989). The cutoff wavelength is about 100 μm in unstressed condition, while we can extend the wavelength to longerword by applying mechanical stress onto a detector chip.

We have developed a 4×8 array of stressed Ge:Ga detectors (Makiuti *et al.*, 1998). The cutoff wavelength of this detector array is 170 μm. Owing to the large format of the array, we can efficiently map wide area of far-infrared sky.

This detector array is a prototype of the array that will be used for the Astro-F (IRIS) satellite, which is to be launched in 2003. We will test performance of the detector by using the detector to

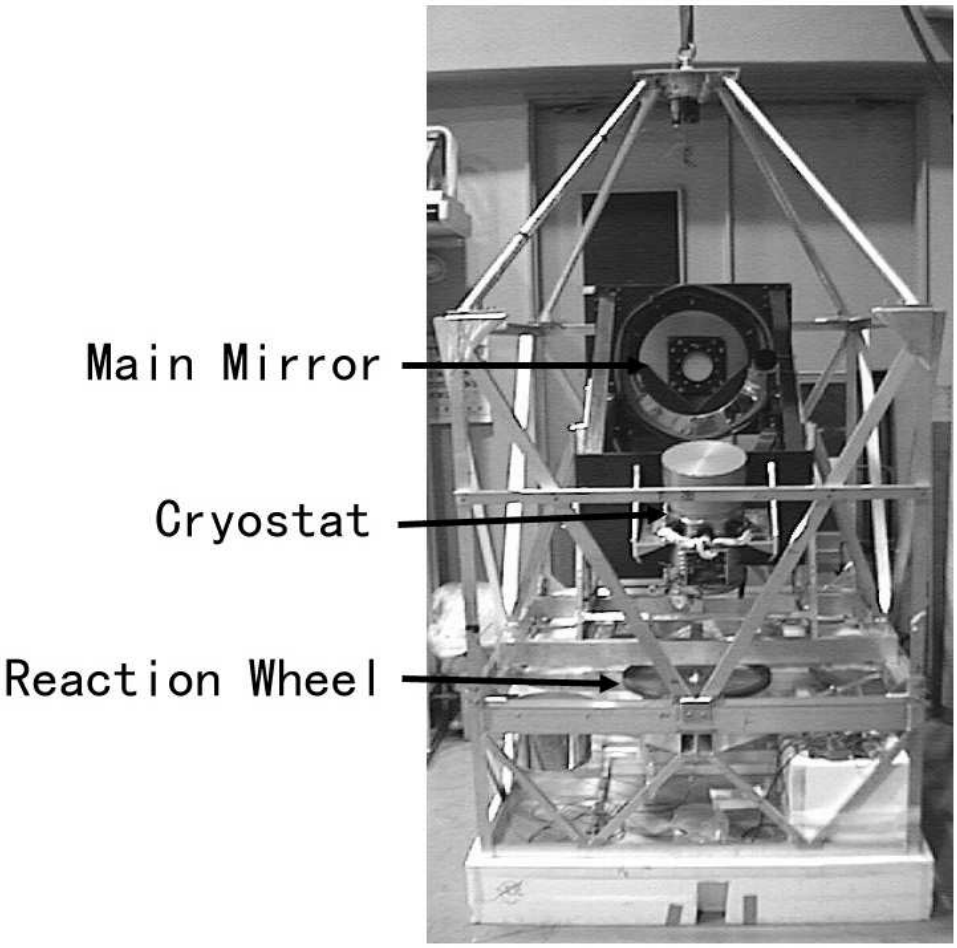

Fig. 1. A photograph of our telescope system

the balloon observations.

TELESCOPE

A photograph of the telescope is shown in Figure 3. The primary mirror is an offset paraboloid with a diameter of 50 cm. The focused light is lead into a cryostat. The infrared detector is installed in the cryostat, and is cooled down to 2 K by liquid Helium.

For infrared telescopes, one of the main noise sources is background radiation. Since the telescope itself is one of main sources of the background radiation, we need to reduce this background radiation.

For that purpose, we use an offset mirror so that no warm structures such as stay would interfere the optical path and minimize the background radiation from such structures.

The second point is that the reflected light from the primary mirror is directly lead to the cryostat and we use no warm secondary mirror. Thus we can minimize the background radiation from warm mirror surfaces.

Finally, we encircle the primary mirror by thin aluminium plate ("skirt" in Figure 3) to reduce leakage of the background radiation from around the mirror due to diffraction.

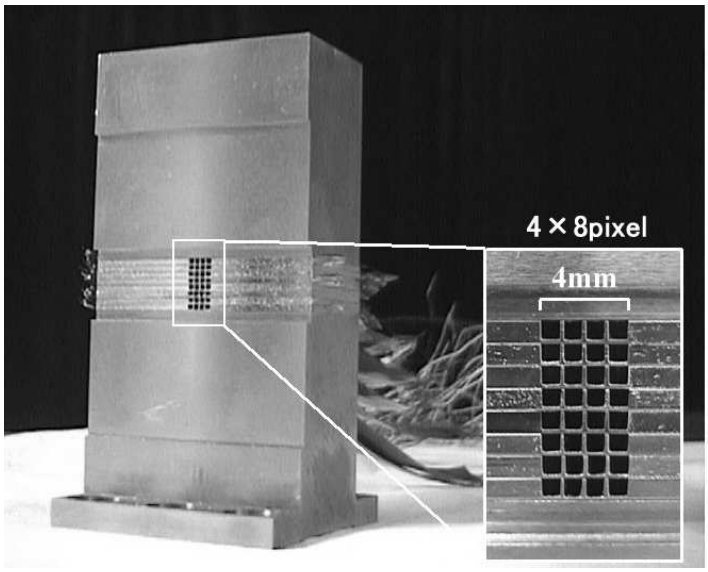

Fig. 2. The stressed Ge:Ga 4×8 array far-infrared detector

Owing to these configurations, we expect the emissivity of this telescope less than 10 %.

As for structural material of the telescope, we use CFRP to avoid thermal contraction of the telescope during a flight to retain good focusing. CFRP is also useful to reduce weight of the telescope.

ATTITUDE CONTROL SYSTEM

We summarize the attitude control system as the following.

- Alt-Azimuthal control

  Azimuthal angle: rotate the whole gondola

  Elevation angle: move telescope in the gondola

- Attitude Sensors
  - 3-axis optical fiber gyrometer
  - Star camera
  - Potentiometer (elevation axis)

- Driver

  Elevation Axis
  DC servomotor

  Azimuthal Axis
  Reaction wheel + unloader

- Controller

  Onboard CPU (digital base control)
  - High flexibility — applicable for various observations

We control the direction of the telescope by alt-azimuth control. The azimuthal angle is controlled by rotating the whole gondola, and the elevation angle is controlled by rotating the telescope in the gondola.

In the determination of the attitude of the gondola, we use 3-axis gyrometer to determine the rotation angles of the gondola. In addition to this, we use CCD star camera to calibrate and correct the determination by the gyrometer. Potentiometer is also used to determine the elevation angle of

Table 1: An Outline of the Balloon-borne Telescope System

Item	Description
Dimension	1.8 m × 1.6 m × 3.0 m (W×D×H)
Total weight	400 kg (without ballast)
Mirror diameter	50 cm (offset paraboloid)
Detector	4×8 Array
	(cooled down to 2 K by liquid Helium)
Spatial resolution	$1.5' \times 1.5'$ (1 pix)
Detection limit	10 Jy or 10^{-8} W m^{-2} sr^{-1} (1 sec. integration)
Objects	survey of galactic interstellar matter
	extragalactic star-forming activities
	160 μm photometry: temperature and mass of interstellar grain
	$\rightarrow$ first flight in this September

the telescope in the gondola.

The determined attitude is compared with a target attitude by an onboard CPU, and requisite motions of drivers on both azimuth and elevation axes are calculated. The results are D/A converted to move the drivers.

Since the control is done by digital base, the control system is flexible because we can simply rewrite the program to adjust *e.g.* a change of angular momentum of the gondola and we can apply some new observational modes such as pointings and microscans easily. That is to say, this control system has a high generality, and it can be applied to various telescope systems.

We tested this attitude control system. A result is shown in Figure 4. In this example, we achieve a stable control with a stability of about $1'$.

OBSERVATION PLAN

The first flight of this telescope system is scheduled in this September. In the first flight, we survey 160 μm continuum in various regions to determine temperature and mass of interstellar grains, whose temperature is less than 30 K. We plan to observe the Orion region and the W51 region, etc.. The total area of the observation will be about 100 square-degrees. We will also carry out mapping observations of some near-by active galaxies.

In the first flight, we will fly the telescope from Sanriku, Japan. After the first flight, we plan to fly the telescope several times from India in a few years.

REFERENCES

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Makiuti, S., et al., *Infrared Astronomical Instrumentation*, ed. A. M. Fowler, Proc. SPIE, 3354 (1998).

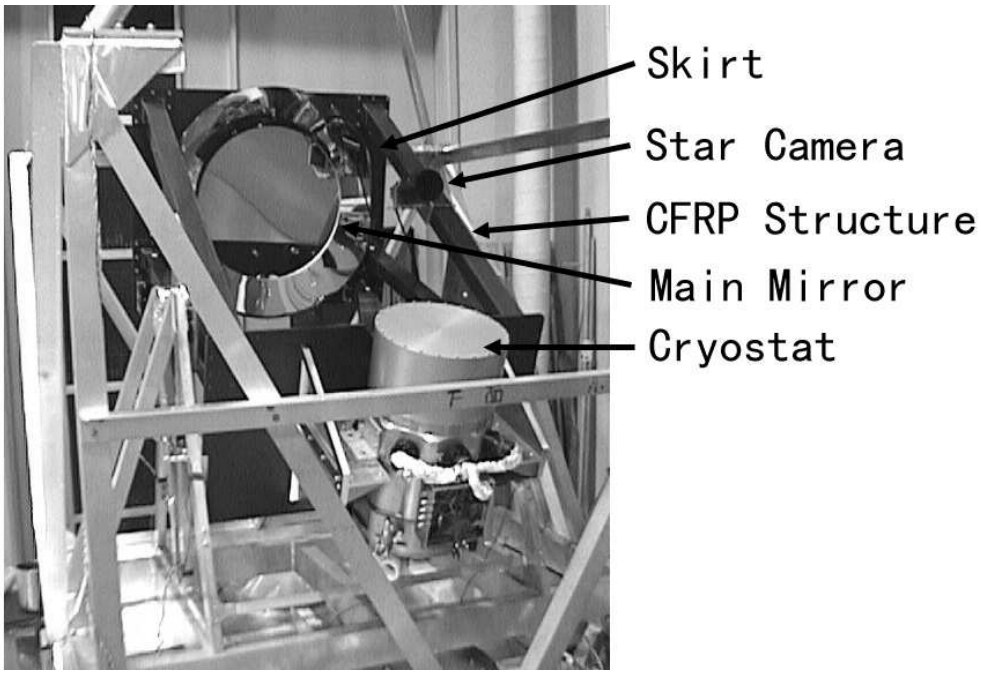

Fig. 3. A photograph of the telescope optics. An offset paraboloidal mirror with a 50 cm diameter (upper left in the figure) reflects infrared light and leads to the infrared detector installed in the cryostat (lower right in the figure). Note that no warm structures are in the optical path.

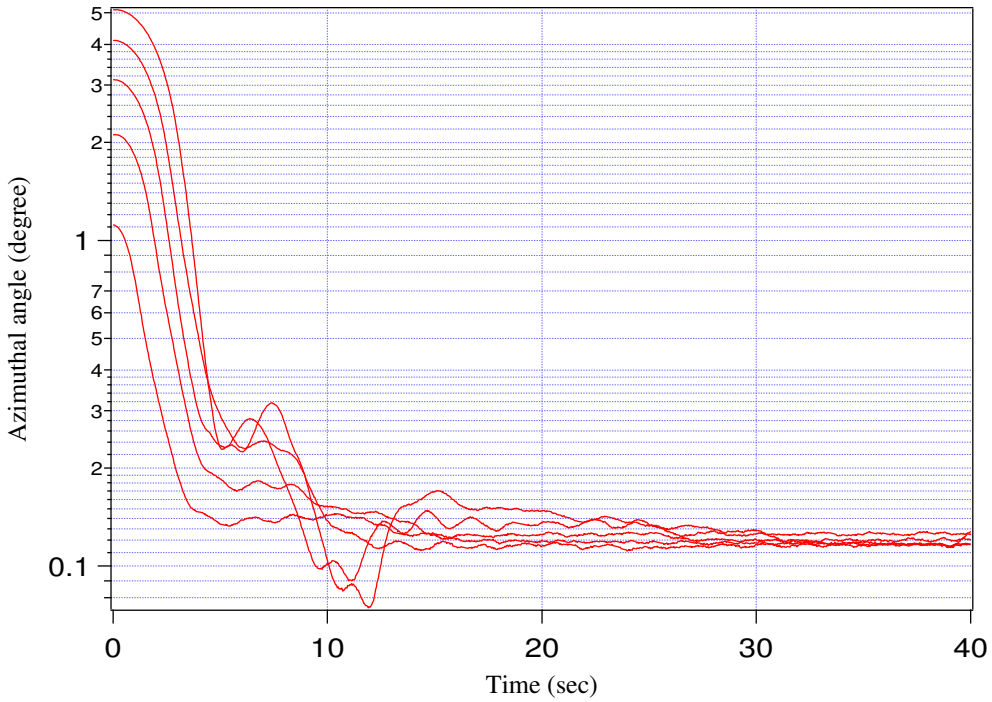

Fig. 4. A test result of the attitude control of the gondola. Transition motions of the gondola when we shift the target angle by 1–5 degree are shown. The vertical axis stands for relative azimuthal angles measured by the onboard gyrometer (see text). In these examples, we achieve a stable control with a stability of about $1'$. Note that the final angle is non-zero, since we apply a bias momentum control by offsetting the gyrometer signal.