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OKAYAMA ASTROPHYSICAL OBSERVATORY WIDE-FIELD CAMERA

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ABSTRACT

We present the design, expected performance, and current status of the wide field near-infrared camera (OAOWFC) now being developed at Okayama Astrophysical Observatory, NAOJ, NINS. OAOWFC is a near-infrared survey telescope whose effective aperture is 91cm. It works at Y, J, H, and K_s bands and is dedicated to the survey of long period variable stars in the Galactic plane. The field of view is 0.95×0.95 deg^2 which is covered by one HAWAII-2 RG detector of 2048×2048 pixels with the pixel size of 18.5 μm × 18.5 μm, that results in the sampling pitch of 1.6 arcsec/pixel. OAOWFC can sweep the area of 840 deg^2 every 3 weeks, attaining a limiting magnitude of 13 in K_s band. It allows us to observe long period variables embedded in the Galactic plane where interstellar extinction is severe in optical.

Key words : instrumentation: infrared — stars: AGB — Galaxy: structure

I. INTRODUCTION

It has been thought that short-period Miras are an ideal probe to investigate the Galactic structure. First, they are old enough, with an age of 5 to 10 Gyr, to be classified as the old population. Hence, their distribution reflects the mass distribution of the Galaxy. Second, they are very bright in the near-infrared. For example, K-band magnitude of a Mira located at the distance of the Galactic center is 7.6 and the one located at the disk edge beyond the Galactic Center is 9.5. Thus, we can detect them throughout the Galaxy even with a small telescope. Third, their distances can be derived via a period-luminosity relation (Glass and Evans 1981, Feast *et al.* 1989). Using the de-reddened apparent magnitudes and observed periods, we can derive their distances. The interstellar reddening to the Miras can be corrected using their near infrared colors, because the dust shell surrounding short-period Miras are usually optically thin in the near-infrared.

In spite of these ideal characteristics, massive surveys that search for short-period Miras have never been carried out so far. There are two major reasons. First, from an astronomical point of view, short-period Mira have been unnoticed objects. Astronomers' interest has been focused on the violent mass-loss phenomena found in long-period Miras, since the discovery of stellar masers. Second, from a technical point of view, there has long been a lack of large format infrared arrays as opposed to the optical CCDs. The first astronomical application of IR array was reported in 1985 (Forrest *et al.* 1985), and the appearance of 1K × 1K array is 1995 (Kozlowski *et al.* 1995), only 10 years before.

In this work, we make a wide-field infrared camera with a field of view up to 1 deg^2 using a large near infrared array, and monitor the Galactic plane to search for long-period variables, mainly focusing on the short-period Miras. The monitoring survey will be carried out in two bands to discriminate variable type (Ita *et al.* 2004) and to evaluate the interstellar reddening.

In this paper, we present the design, expected performance, and current status of OAOWFC.

II. DESIGN

Okayama Astrophysical Observatory Wide-Field Camera(OAOWFC) is being constructed as a renewal of the 91cm telescope. The telescope was manufactured in 1959, as the first domestic 1-m class telescope in Japan. The mount is fork-equatorial with a maximum slew speed of 1.5 deg/s. Almost all the parts except for the top-ring and the secondary mirror are used in the new camera.

The total F-ratio of OAOWFC is F/2.5, which is one of the fastest optics in the near-infrared. The resultant pixel resolution is 1.6 arcsec/pix and the field of view is 0.95×0.95 deg^2. The overview of the OAOWFC is shown in Fig. 1 and the major specification is shown in Table 1.

(a) Optics

Fig. 2 shows the optical layout of OAOWFC. It is designed referring to UKIRT WFCAM (Henry *et al.* 2000), which is the most successful design attained so far to get a field of view up to 1×1 deg^2 in the thermal infrared. The design consists of two major parts,

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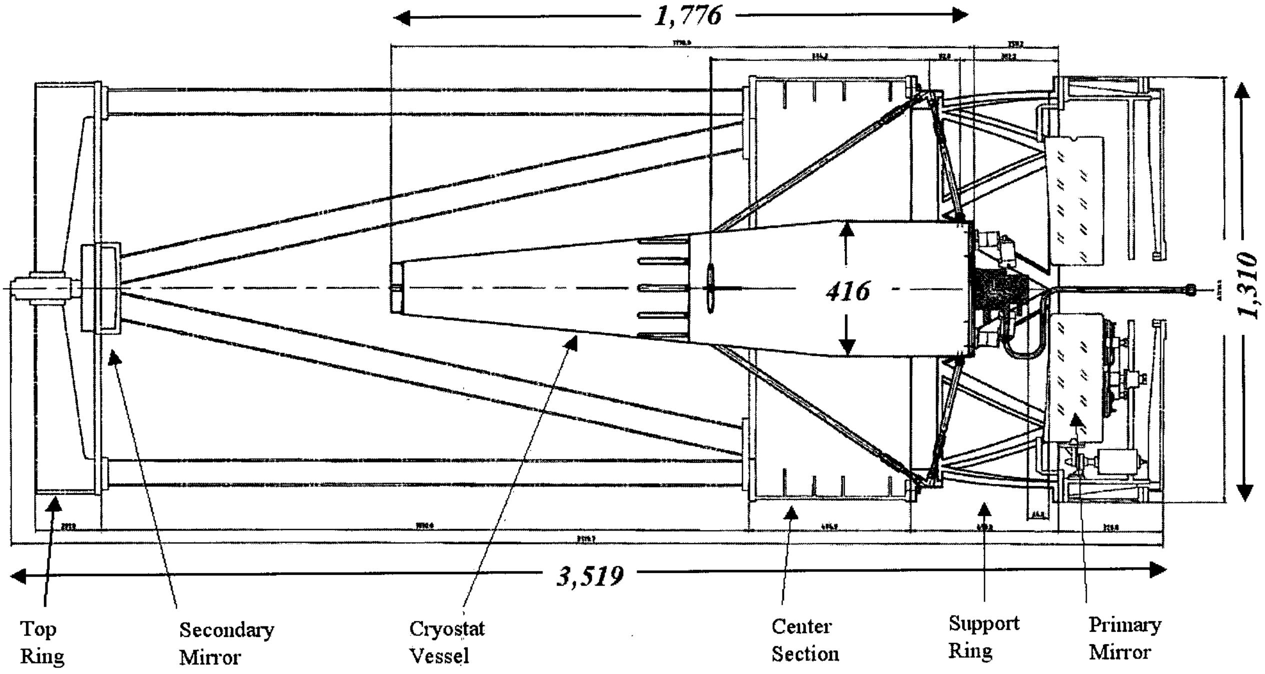

Fig. 1.— Overview of OAOWFC

the forward Cassegrain optics and the quasi-Schmidt optics. Once the forward Cassegrain optics makes an image after the secondary mirror, it is relayed by a field lens, and re-imaged by the quasi-Schmidt optics. A clear pupil is formed just behind the collimator, so that we can take a deep K-band image by placing the quasi-Schmidt optics into a cryostat and cool them down.

There are some differences between our design and the WFCAM. We employed spherical doublet for the collimator instead of the Schmidt aspheric corrector. This replacement leads to the reduction of chromatic aberration at the focus. Accordingly, the focal adjustment of OAOWFC can be made only by adjusting the distance between primary and secondary mirror. Further, all the optical components have a spherical surface, except for the primary mirror. It contributes to reducing the cost and the difficulties in lens fabrication.

(b) Cryostat

Fig. 3 shows the cross sectional view of the quasi-Schmidt cryostat. All the inner components are housed in a radiation shield, and it is supported by 8 thin plate made of glass fiber to thermally isolate it from cryostat vessel. A two-stage closed-cycle refrigerator resided at the bottom cools all the inner components. The first stage cools the radiation shield to 100K, and the second stage cools the detector to 60K via a dedicated heat path made of copper.

There is a major difference in heat design with WFCAM. OAOWFC has a cooled radiation shield tube extended to the cryostat window. The inner surface of the tube is threaded and coated with infrared black paint. The design is rather efficient in absorbing unwanted thermal radiation through window, and diminishing stray light, compared with the un-cooled reflecting baffle design employed in WFCAM(Henry *et al.* 2002).

There is a filter-exchanger in front of the detector. It holds six filters in total; four broad-band filters, one ND filter, and one light shield. A selected filter holder is actuated by a cryogenic motor and rolled over in front of the detector. The ND filter is placed to broaden the detection limit toward the brighter end, since nearby Miras are too bright for OAOWFC. Therefore, the ND filter and the broad-band filter can be used simultaneously.

The cryostat is mounted on the upper part of the support ring, and 8 rods made of stainless steel with geared turnbuckle support the cryostat (Fig. 1). A tension of 5 kN will be given to each rod to support the cryostat rigidly.

(c) Detector

The array detector selected is HAWAII2-RG PACE (HgCdTe, Loose *et al.* 2003) manufactured by Rockwell Scientific Company LLC. The array is one of the largest NIR detector in the world, which has an active area of 36.9 mm × 36.9 mm, and sensitive from 0.85 μm

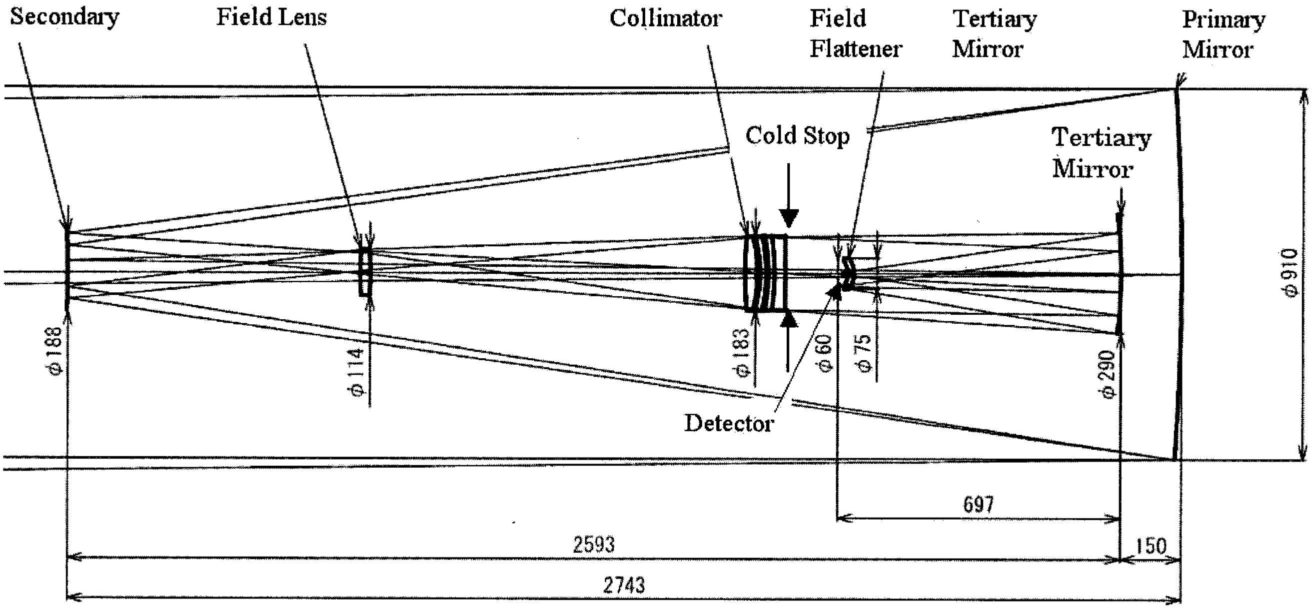

Fig. 2.— Optical Layout of OAOWFC

Table 1.
Specifications of OAOWFC

Telescope	
Effective Diameter	910 mm
Optical Configuration	Forward Cassegrain + quasi-Schmidt
Total F-ratio	F/2.5
Central Obscuration	35%
Detector	HAWAII2-RG(HgCdTe)
Format	2048 × 2048
Pixel Size	18 μm × 18 μm 1.6 arcsec × 1.6 arcsec
Sensitive Area	36.9 mm × 36.9 mm
Field of View	0.95 deg. × 0.95 deg.
Operating Temperature	80 K
Filters	Y,J,H K_s and ND
Typical exposure time	45 s
Survey Efficiency	14 deg^2/hour 108 deg^2/night 840 deg^2/3weeks

to 2.5 μm. We chose 32-output design to minimize the readout time that is expected to be 1.4 s. The array is controlled by dedicated front-end electronics and Messia V controller (Nakaya 2004). The Messia V has been developed by NAOJ as a next generation multi-purpose array controller, and it is already used by 15 Japanese instruments.

III. EXPECTED PERFORMANCE

(a) Detection Limits

To trace the variability of the Miras in the near-infrared, precise photometry of S/N=30 is required, since the typical variation amplitude of Miras is 1 magnitude in the near-infrared. Fig.4 shows the expected detection limits of OAOWFC in three bands with S/N=30. It is expected that OAOWFC can reach K=13 with an exposure of 45 s. The K=13 corresponds to an apparent magnitude of short-period Miras located at 20 kpc away with an absorption of A_K =3.5. Therefore, it will be safe to say that almost all the Miras in the Galaxy observable from Okayama can be seen with OAOWFC.

(b) Survey Efficiency

Survey efficiency is estimated with the following assumptions; (1) the time necessary to observe one field is 240 s including the overhead such as telescope pointing and filter exchange, (2) we can observe 8 hours a night, (3) 37% of observable night will be available. The observable fraction was derived based on night weather statistics at Okayama over 11 years. The resultant efficiencies are the followings; 14 deg^2/hour, 108 deg^2/night, and 840 deg^2/3weeks. The sky coverage of 840 deg^2 corresponds to whole Galactic plane observable at Okayama with a width of 3 degrees.

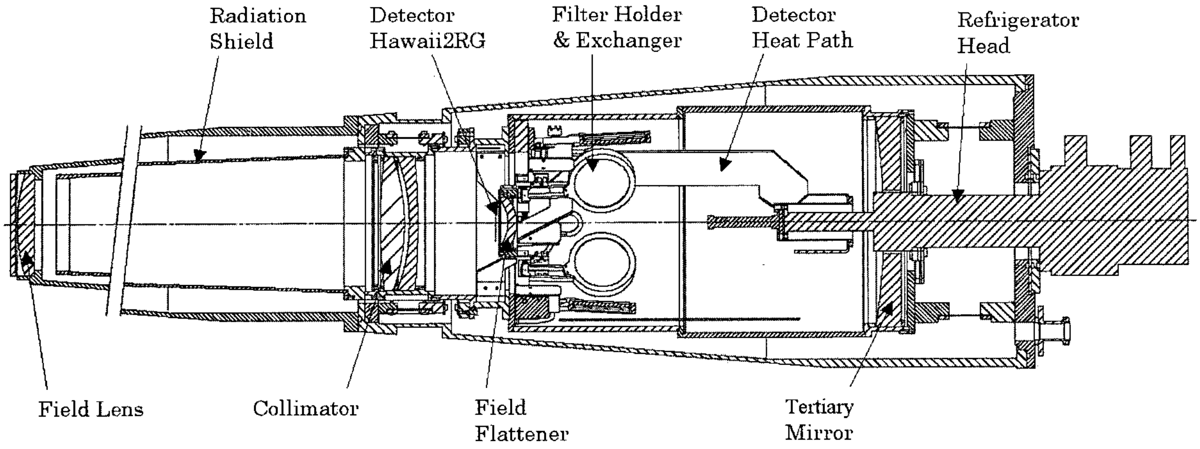

Fig. 3.— Cross section of the OAOWFC cryostat.

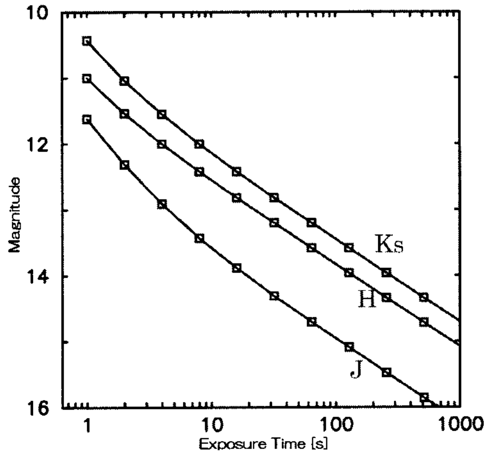

Fig. 4.— Estimated detection limit of OAOWFC (S/N=30)

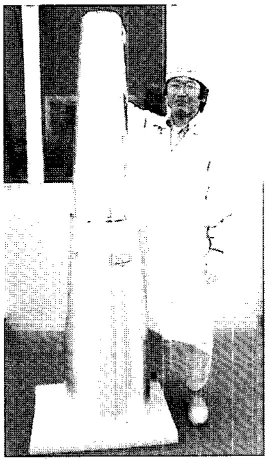

Fig. 5.— Completion of OAOWFC Cryostat Vessel (Sep. 2004).

IV. CURRENT STATUS

All the parts of the cryostat were already manufactured (Fig. 5) at the end of last autumn, and the lens fabrication was completed by the end of last year. Cooling test for the quasi-Schmidt cryostat and optical axis adjustment are under way. If we succeed in making adjustments according to schedule, the cryostat will be mounted on the telescope in March 2005. The arrival of the science grade array is scheduled in April. After operation tests, the science array will be installed in June 2005. We hope to get the first light in summer 2005, and start the survey in early 2006.

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