



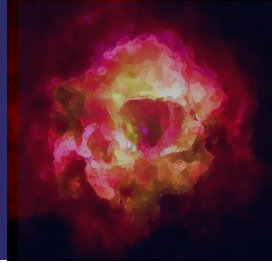
# KWFC



**KISO WIDE FIELD CAMERA**  
KISO OBSERVATORY, THE UNIV. OF TOKYO

KWFCの開発・運用

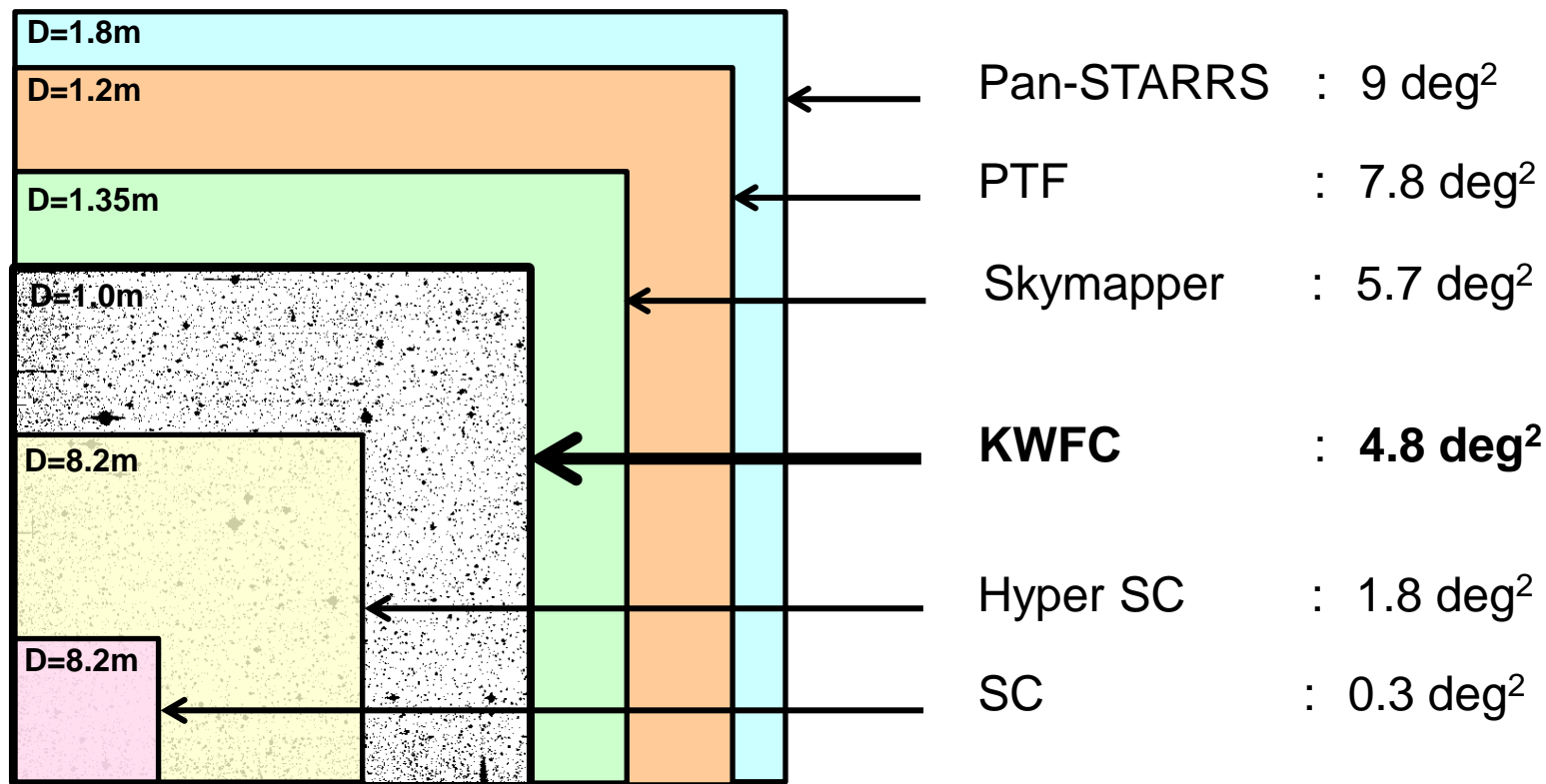
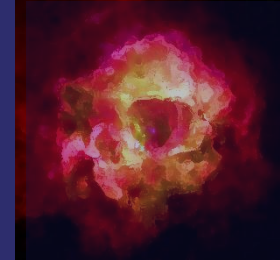
酒向重行 (東京大学 木曾観測所)



- A facility instrument for the Kiso 105-cm Schmidt telescope
- 8 CCD chips with a total of 8k x 8k pixels
- F.O.V of 2.2 deg. x 2.2 deg.
- Filter exchanger with a robotic arm capable of storing 12 filters
- Automatic observation system

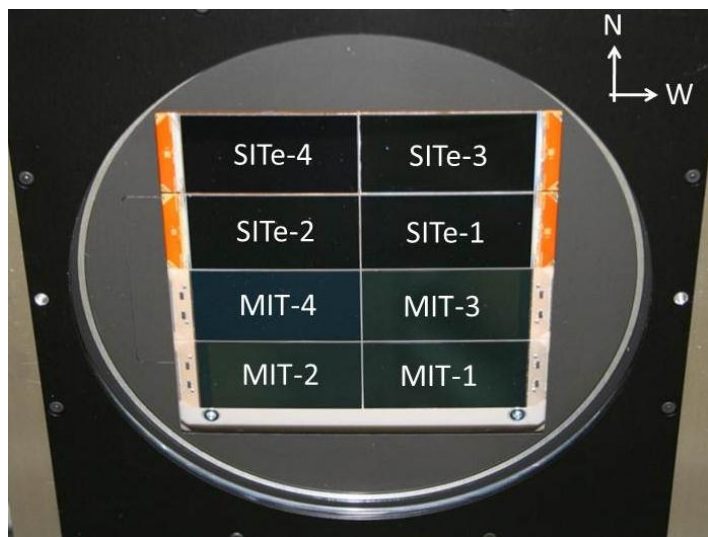
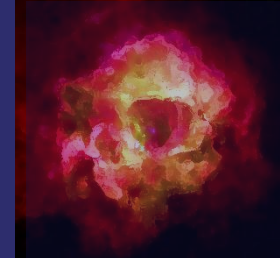
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# CCDs

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	MIT-CCD	SITe-CCD (ST-002A)
Number of CCDs	4 pcs	4 pcs
Number of pixels <sup>†</sup>	2k x 4k pixels	2k x 4k pixels
Readout noise <sup>††</sup>	5 - 10 e <sup>-</sup>	~ 20 e <sup>-</sup>
Well <sup>††</sup>	~ 1 x 10 <sup>5</sup> e <sup>-</sup>	~ 8 x 10 <sup>4</sup> e <sup>-</sup>
Pixel size	15 μm/pix	
Gain	~2.0 e <sup>-</sup> ADU <sup>-1</sup>	
Dark current <sup>††</sup>	< 5 e <sup>-</sup> hour <sup>-1</sup> pixel <sup>-1</sup>	
Readout Time <sup>††</sup> including overheads	All-CCD read: 120 sec MIT-CCD only read: 60 sec	
Interval space between CCDs <sup>††</sup>	~ 90 arcsec in the N-S ~ 60 arcsec in the W-E	
Operation temp.	168 K	

† 2 x 2 binning is available.

†† w/o binning, All-CCD read-mode



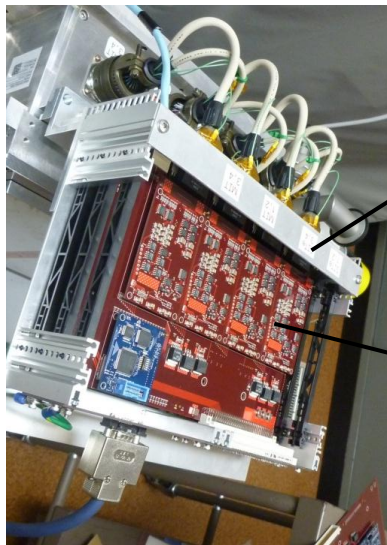
# CCD Readout

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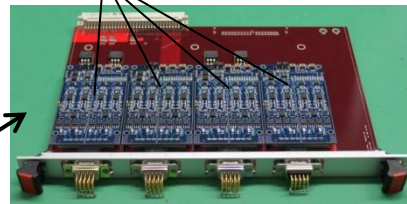


## KAC (Kiso Array Controller)

### KAC analog part

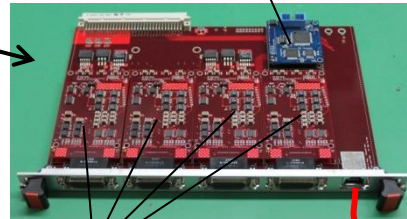


ADC daughter boards



- clamp circuits
- pre-amplifiers
- low-pass filters
- 16-bit ADC for 4ch

IF board



generates bias voltages & clock voltages

DRV daughter boards

Ethernet cable

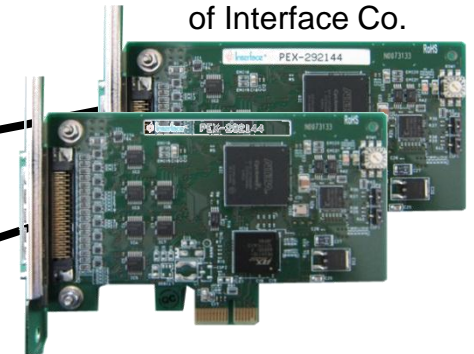
### KAC digital part

non-real-time Linux-OS

LVDS board



PEX-292144 of Interface Co.

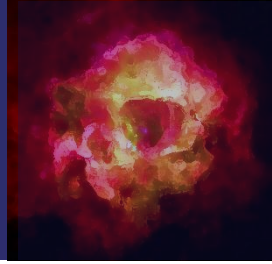


PEX-292144 is capable to handle I/O signals with minimum loads of CPUs in synchronization with an internal timing clock.

The KAC is a data acquisition system newly developed based on the TAC system (Sako et al. 2008) of the TAO project. The clock-timing-signals are generated in real-time by software in a manner similar to the TAC system. The frame data is transferred to a memory space in the PC and then written (appended) at the end of a raw-data file. The generated raw-data file is converted to FITS-image files for each of the CCDs with subtracting the correlated double sampling data.

# Image Files

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## RAW image file

**KWFCxxxxxxx#.fits** x 8 files

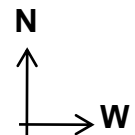
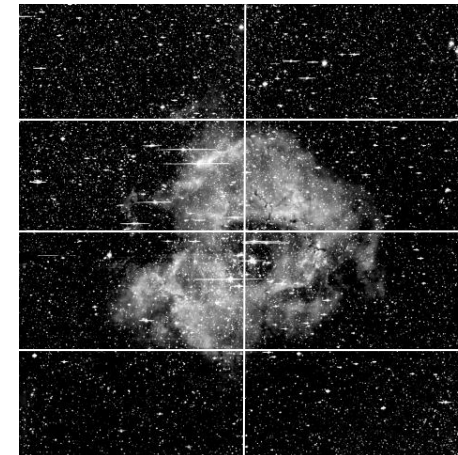
- 2048 x 4100 pix
- 16 bit unsigned integer FITS
- 16 Mbytes/file x 8 files = 128 Mbytes



## QL image file

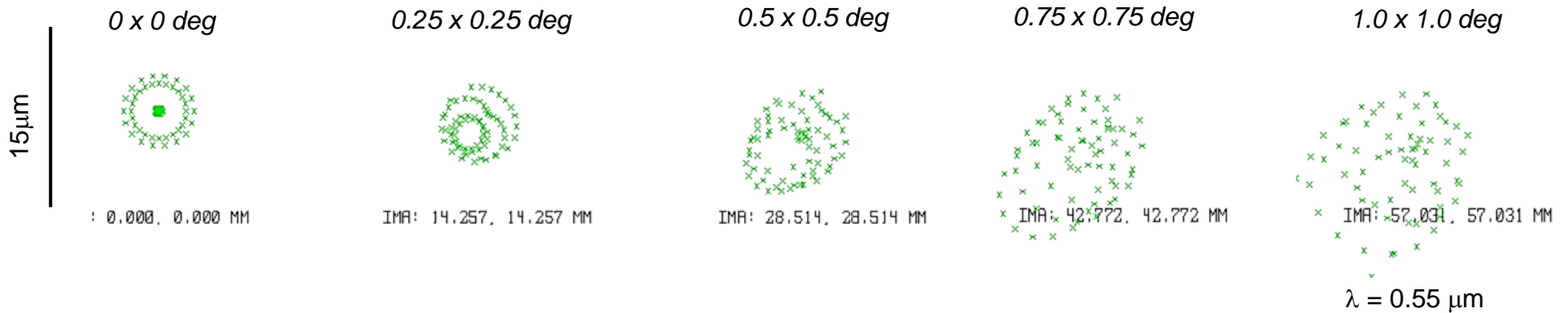
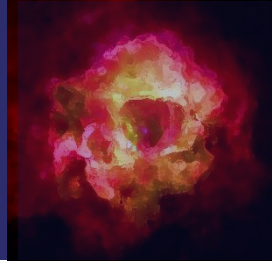
**KWFCxxxxxxxQ.fits** x 1 file

- Automatically generated for each exposure
- Eight combined image
- 8k x 8k pixel, 128 Mbytes

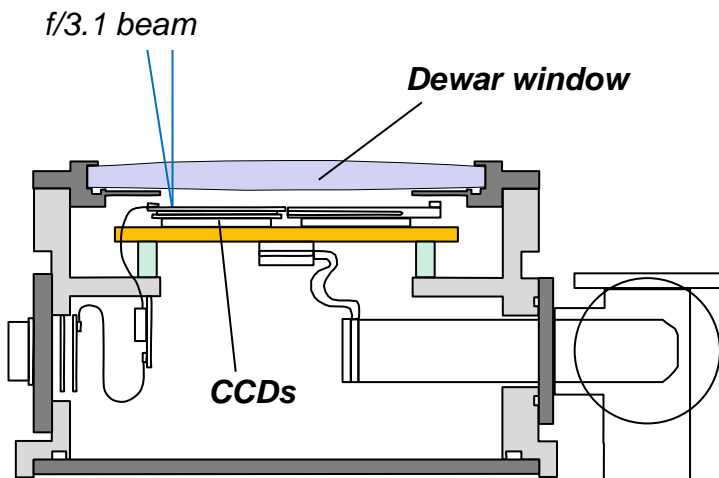


# Optics

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Dewar window works as a field flattener.



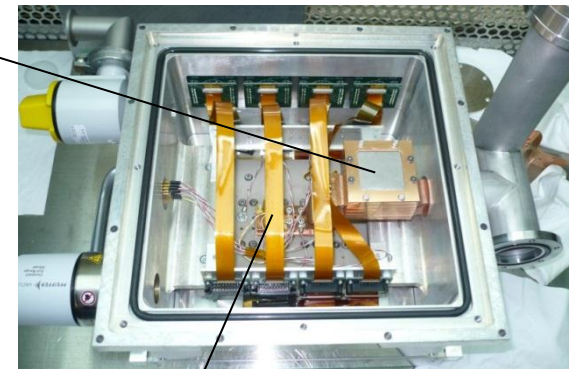
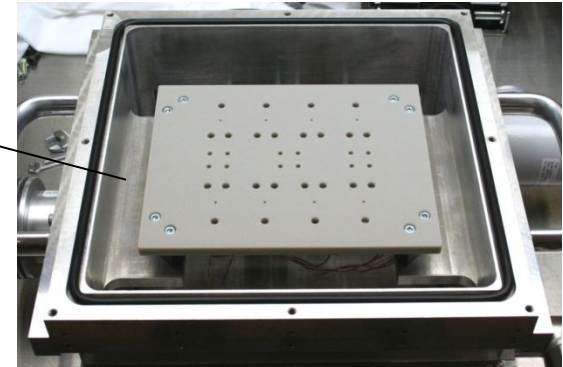
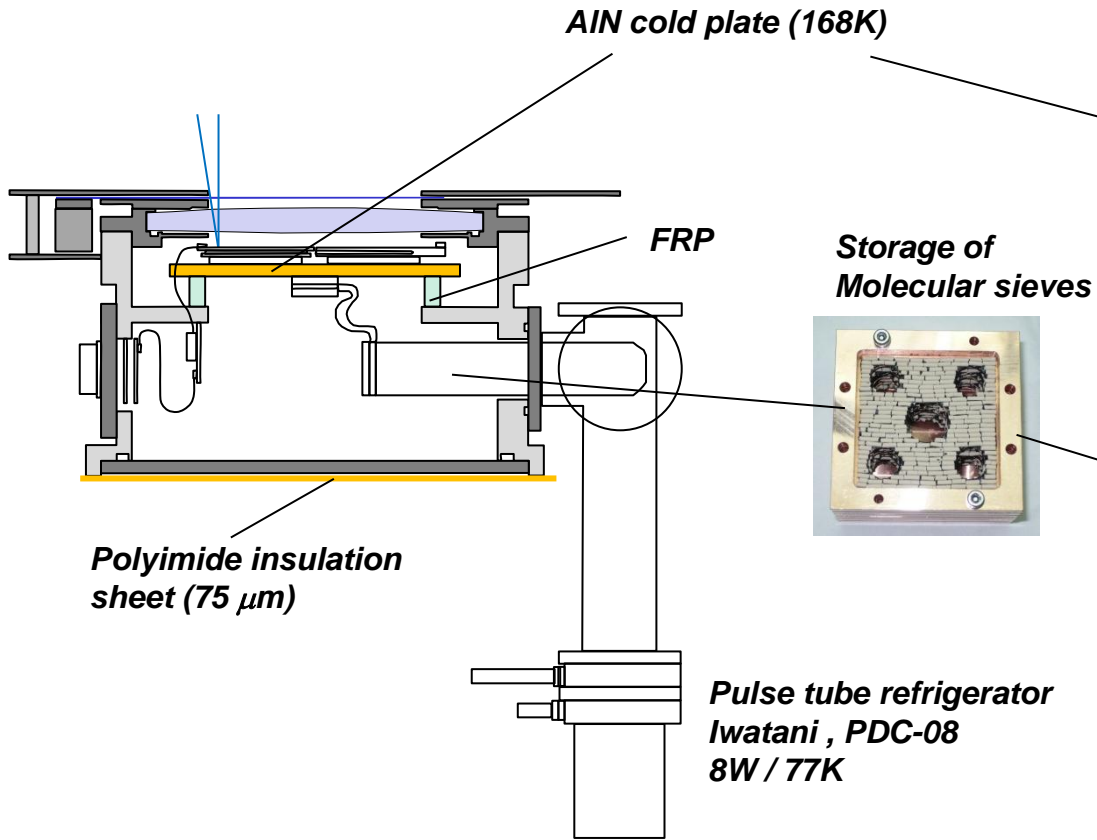
<b>Field of View</b>	2.2 deg. x 2.2 deg.
<b>Pixel scale</b>	0.946 arcsec pixel <sup>-1</sup>
<b>PSF image quality</b>	Seeing limited ( the best seeing size is 2.5 arcsec)
<b>Image distortion</b>	< 0.2 arcsec at all image area

Objective spectroscopy (R~100) is available.



# Cryogenics

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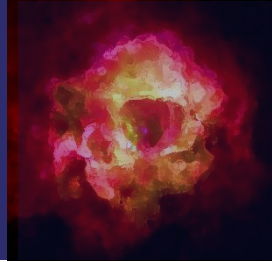
*FPC cables for CCDs*

The molecular sieve 13X 1/16 of Nacalai Tesque is used.  
The Vaclon Plus-20 ion pump of Varian Inc. will be adopted.



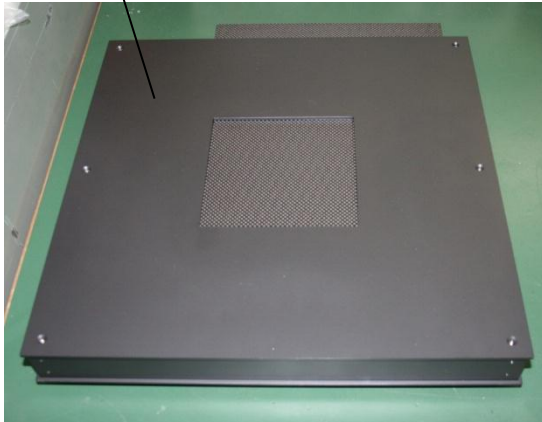
# Shutter Unit

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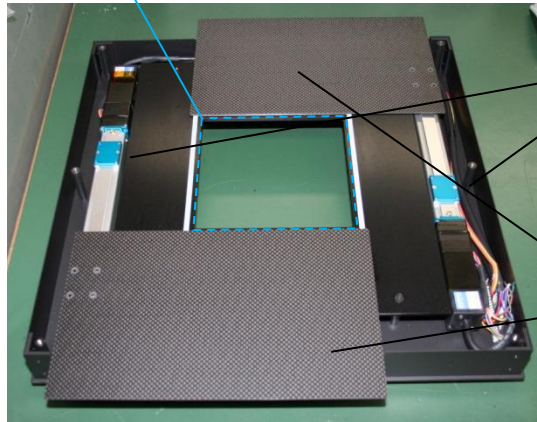


**Achieves uniform exposures on all the CCD pixels.**

*400 x 400 x 47 mm.*



*Air tube with several dozen holes working as exhaust nozzles of dry air to prevent the flattener lens from fogging.*



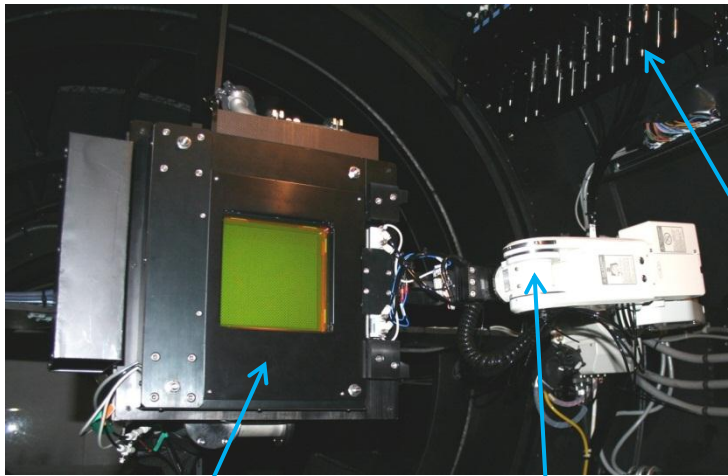
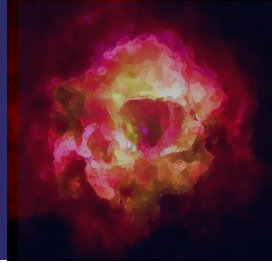
*Linear actuators  
KUMISA-160-PB-R of KSS*

*Shutter plates (CFRP)  
255 x 160 x 1.5 mm*

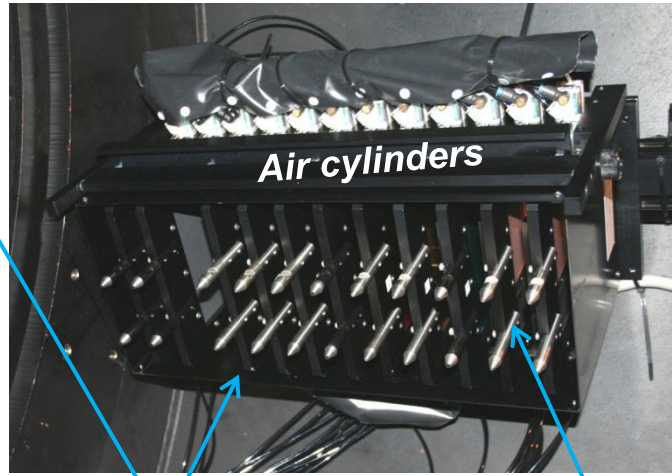
The accuracy of an open time is approximately 3 msec.

# Filter exchanger

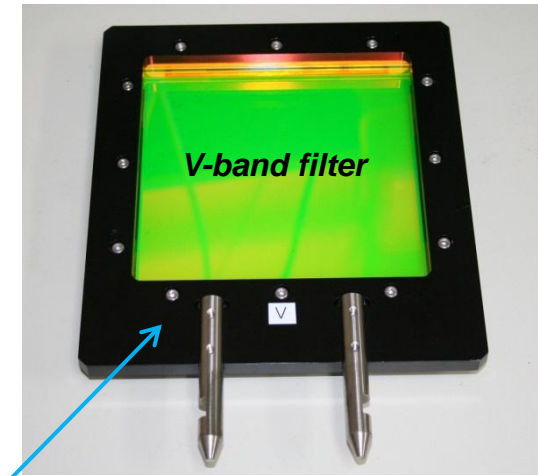
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**Focal plane unit**



**Filter Magazine  
with 12-slots**



**Filter holders**

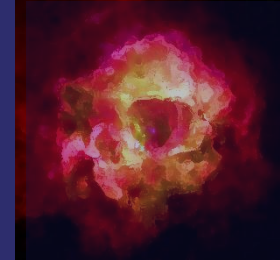
**Robotic arm**

MELFA RV-2SQ  
- Mitsubishi Electric Co.  
- 6-axis arm, payload of 2 kg,  
- compliance control function  
- collision detection function

- Exchange time of filters is about 45 sec.
- For safety reasons, the cover of the primary mirror is temporary closed during exchanging filters.
- For safety reasons, filter exchange is prohibited in Elv > 60 degrees.

# Filters

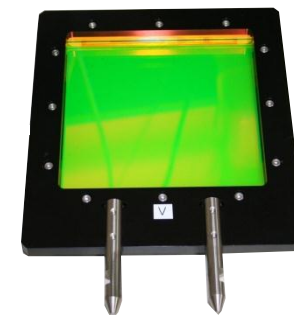
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## Broad band filters

	$\lambda_o$ (nm)	$\Delta\lambda$ (nm)
B	445	122
V	551	109
R	659	125
I	809	153

	$\lambda_o$ (nm)	$\Delta\lambda$ (nm)
SDSS-u	353	56
SDSS-g	467	131
SDSS-r <sup>†</sup>	(613)	(123)
SDSS-i <sup>†</sup>	(756)	(120)
SDSS-z <sup>††</sup>	---	---



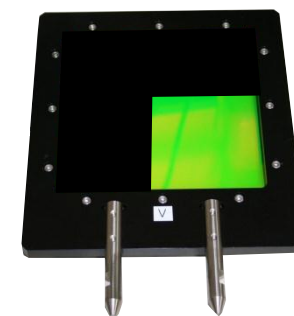
158 x 158 x 15 mm

<sup>†</sup> Design values for a beam of f/3.1.

<sup>††</sup> Long-wavelength-pass characteristic of 826 nm cut-off  
The effective bandwidths depend on QE of the CCDs.

## Narrow band filters

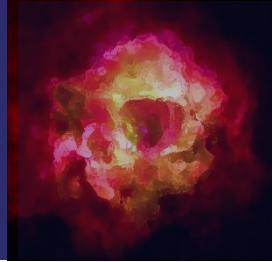
- Now, only 100 x 100 mm filters developed for 2kCCD are available. F.O.V. is limited to be 50' square.
- Future plans of 158 x 158 mm filters → Nishiura-san's presentation.



100 x 100 mm

# Limiting Mag.

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## Estimated Limiting Magnitude<sup>†</sup>

	<b>B</b>	<b>V</b>	<b>R</b>	<b>I</b>
<b>MIT-CCD</b>	21.9	21.3	20.9	20.2
<b>SITe-CCD</b>	22.2	21.2	20.9	20.1

<sup>†</sup> Estimated from the measured values of 2kCCD assuming S/N=10, exposure time of 15 min, seeing size of 3 arcsec

## Measured Limiting Magnitude<sup>†</sup>

	<b>SDSS-u</b>	<b>SDSS-g</b>	<b>SDSS-i</b>
<b>Chip 0, 2-7</b>	20.5 <sup>‡</sup>	20.9	20.3
<b>Chip 1 (MIT)</b>	18.8 <sup>‡</sup>	20.9	20.3

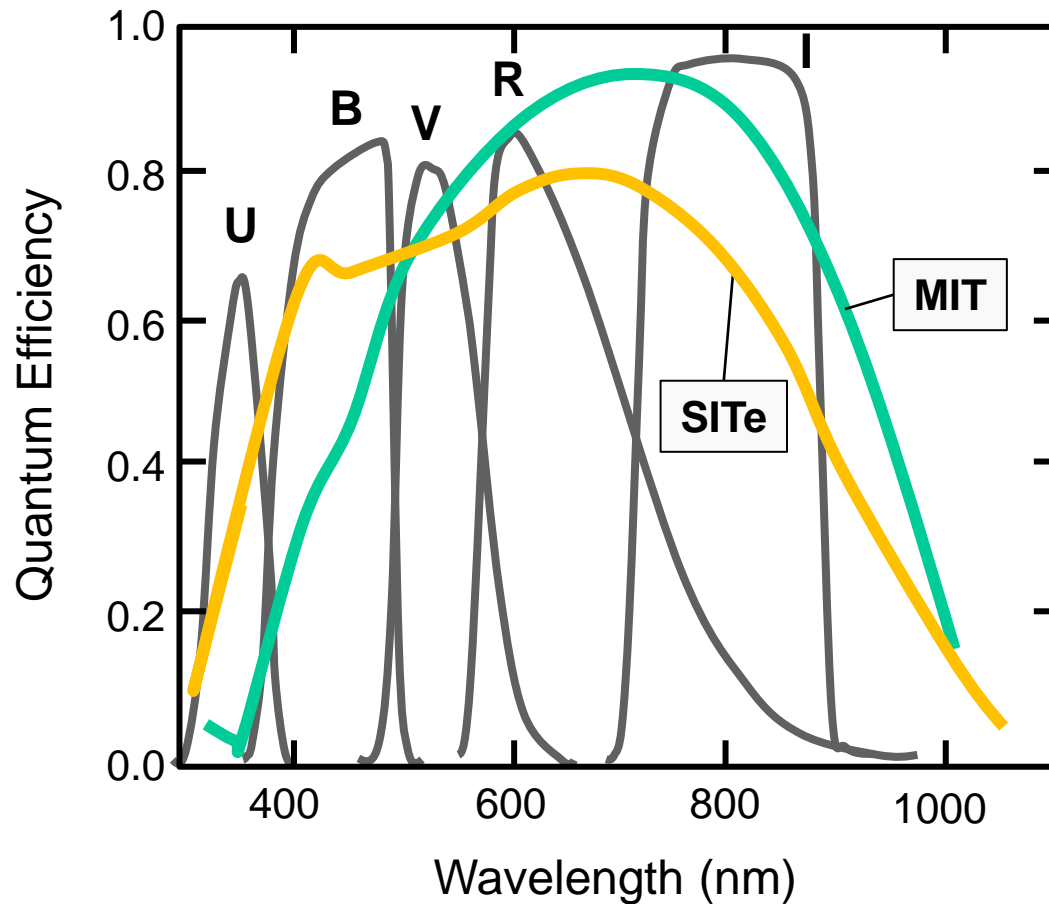
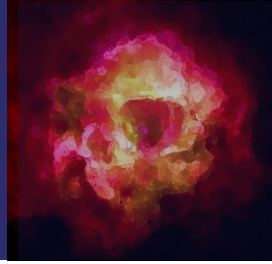
<sup>†</sup> S/N=5, exposure time of 3 min

<sup>‡</sup> 2x2 binning



# QEs of CCDs

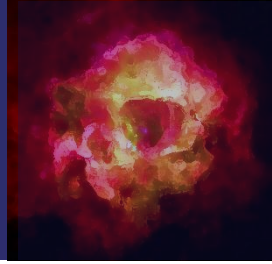
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- Typical spectral responses of the CCDs
- QEs of CCDs onboard KWFC have not yet been measured.

# Flat Images

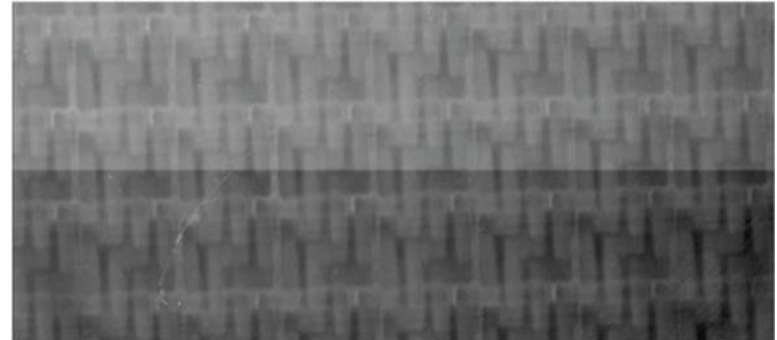
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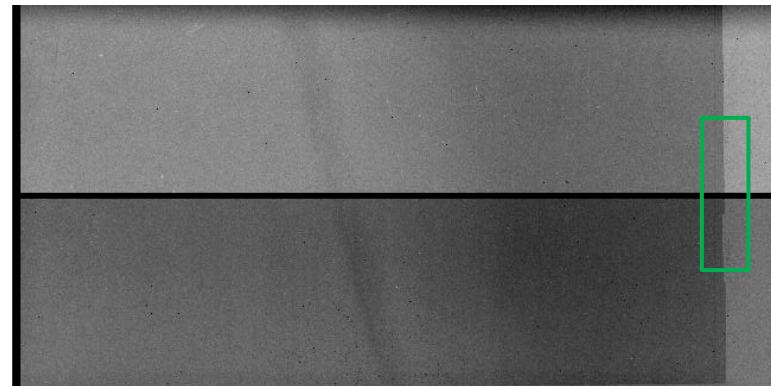
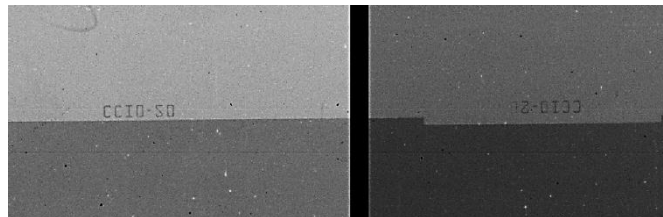
Flat pattern varies with the filter band.

examples

- Chip 1, SDSS-g band

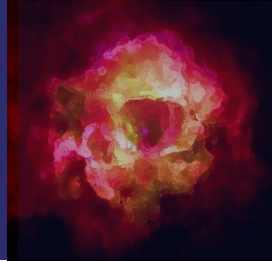


- Chip 0

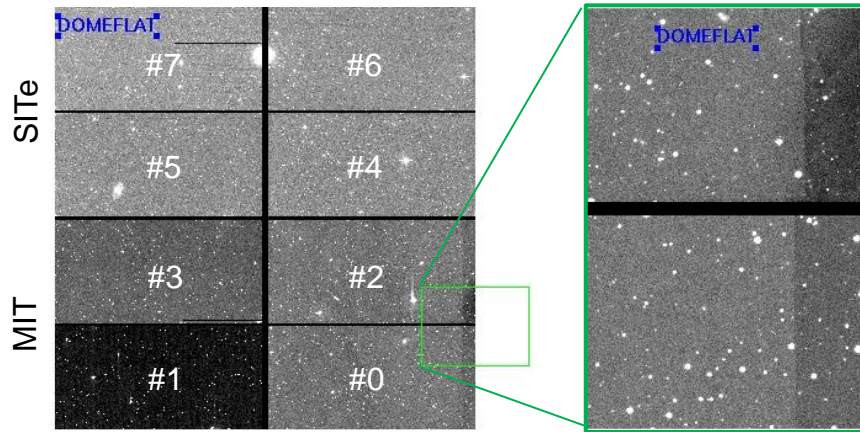


# Flat fielding

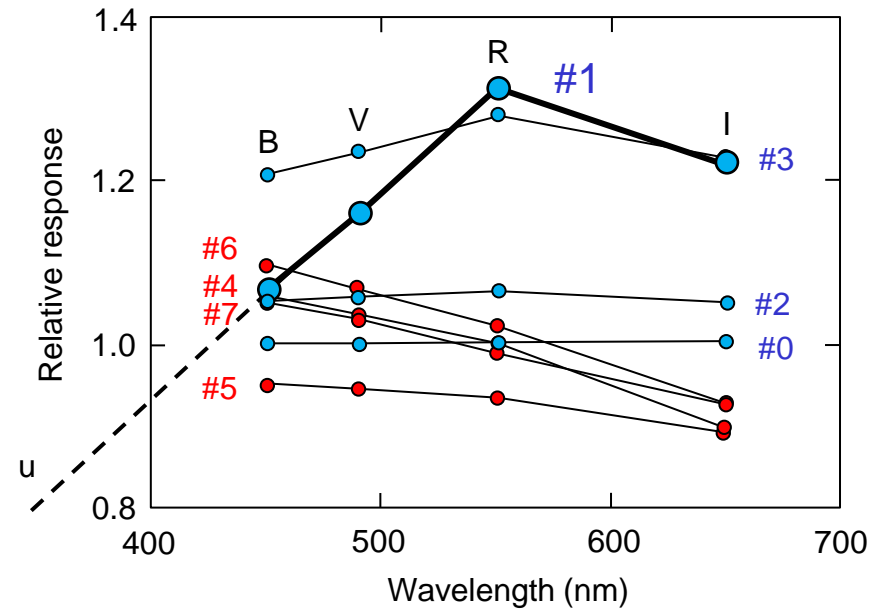
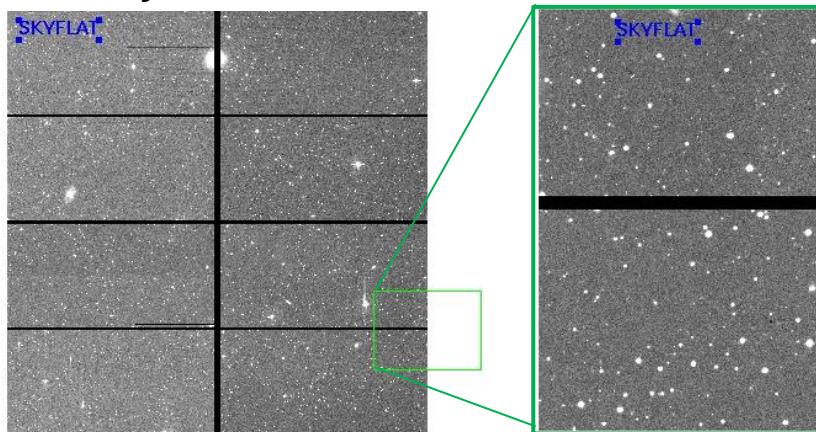
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with Dome Flat



with Sky Flat

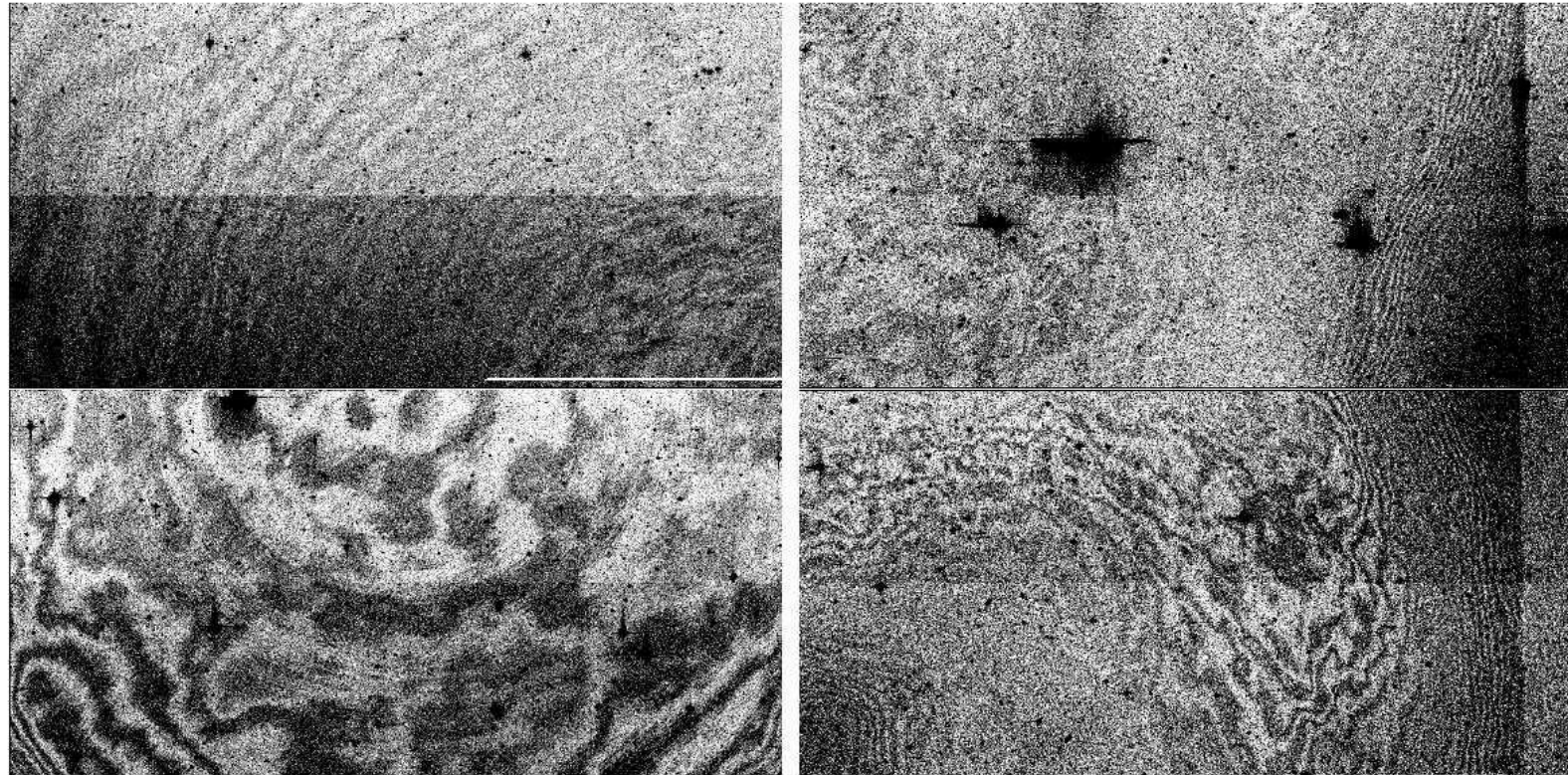
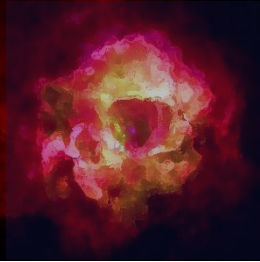


- Chip #1 has a steep spectral response of QE in the shorter wavelength. → mismatching between colors of sky and dome-flat.
- Flat fielding with 'sky frames' is recommended.



# Fringe

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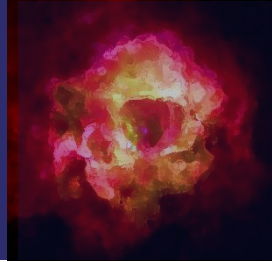


8e+03 8.1e+03 8.2e+03 8.3e+03 8.4e+03 8.5e+03 8.6e+03 8.7e+03 8.8e+03

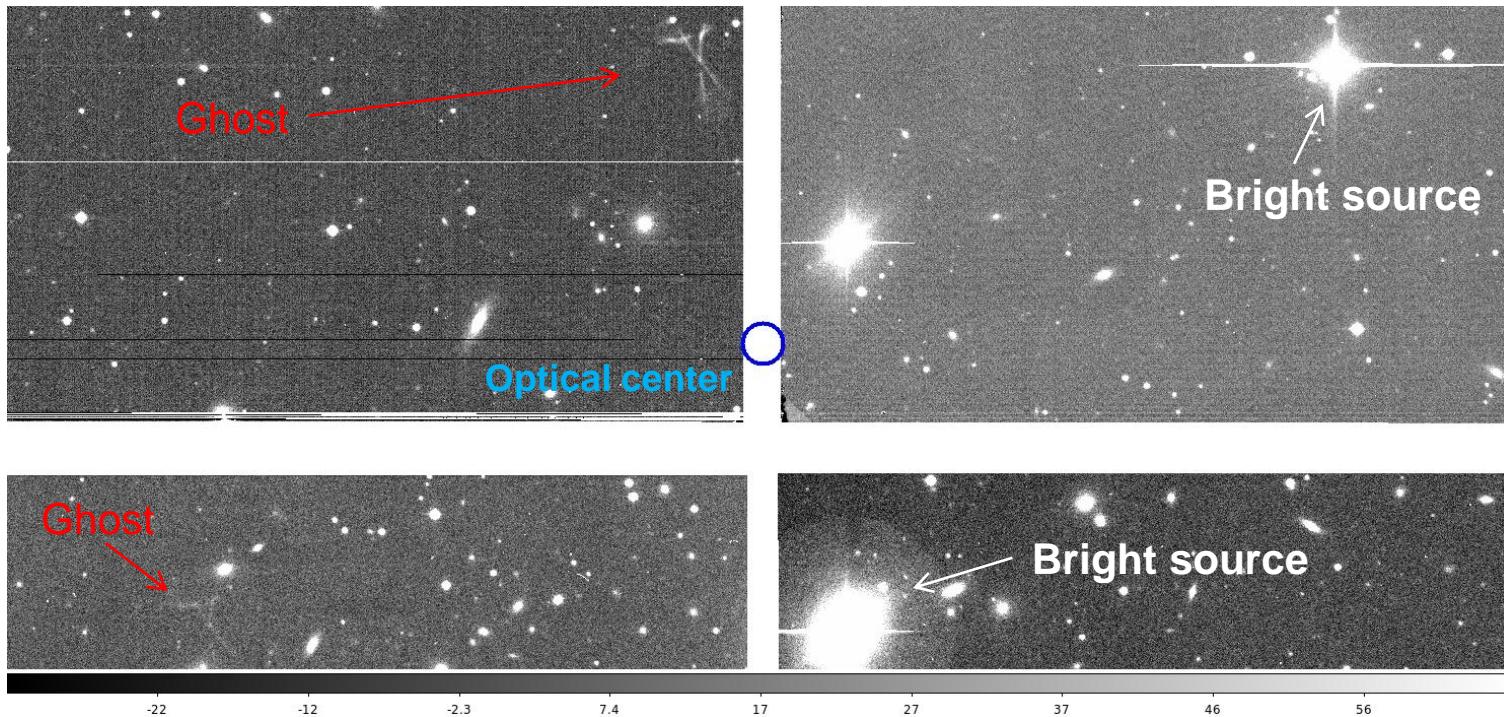
**I band**, 120 sec,  
2x2 binning, MIT-only read  
Reduced image (bias, flat)

$$\frac{\text{Fringe p-v}}{\text{Sky background}} \sim 1\%$$





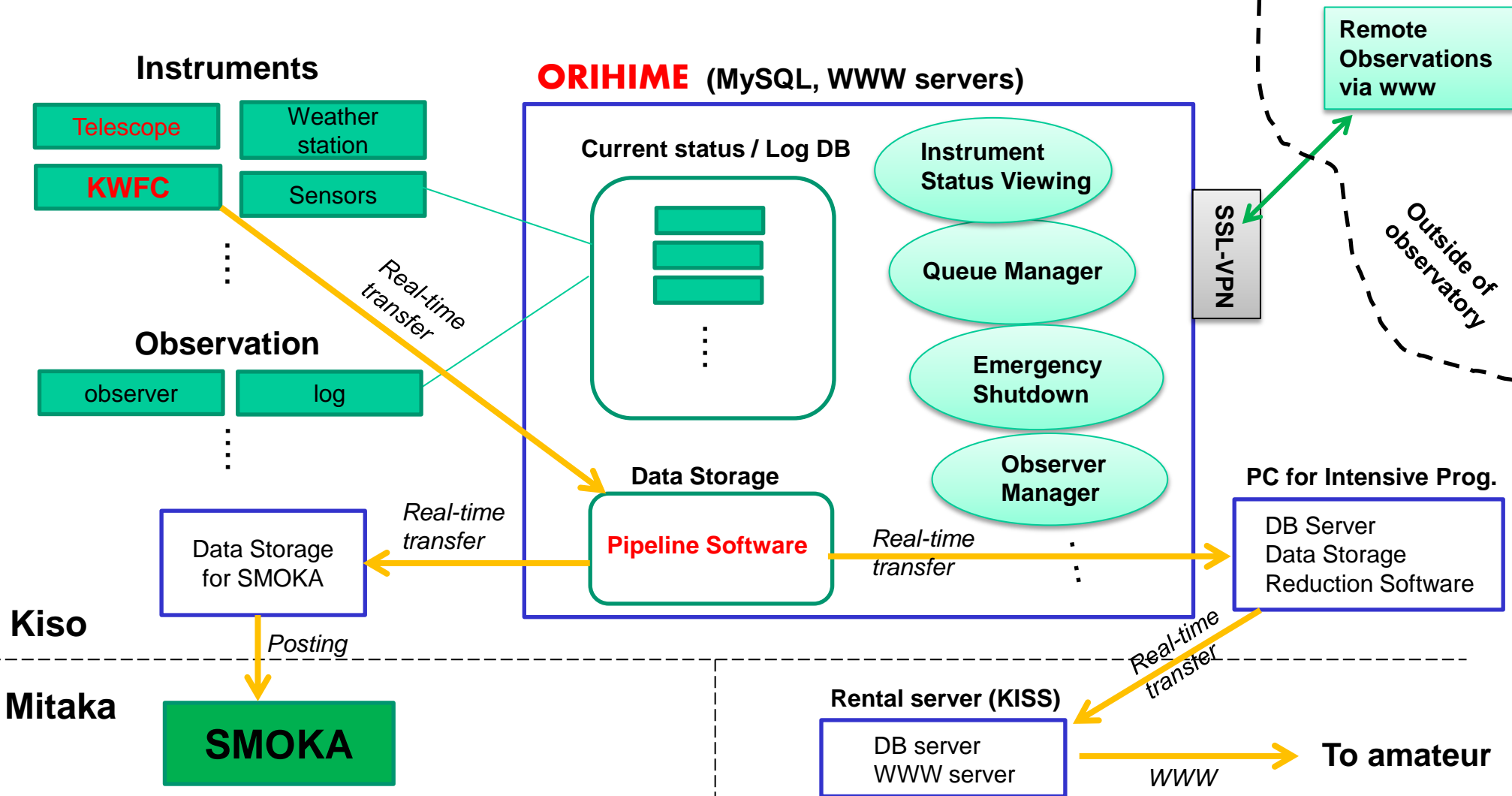
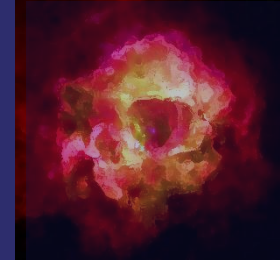
## Jelly-fish shaped ghost



- The jelly-fish shaped ghosts are produced by reflection on the surfaces of the CCDs and the collector lens of the telescope.
- The shape varies with an attitude of the telescope.
- The ghosts can be eliminated by the dithering observation method.

# Integrated System

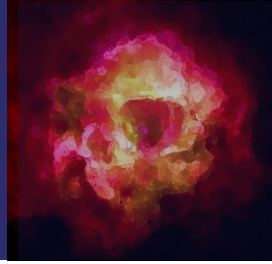
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# Weather Sensor

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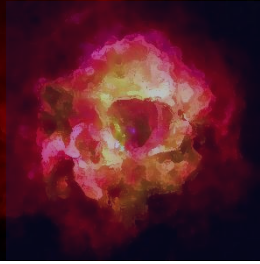


Weather Station on the roof of the main building

- Temperature, Humidity sensors
- Wind direction, velocity sensors
- Rain drop shock sensor
- Rain wet sensor
- All-sky visible camera
- All-sky infrared camera
- Infrared radiation sensor
- Network camera

# Intensive Program

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## Kiso Supernova Survey (KISS)

is a program searching for nearby supernovae in about 100 square degrees in each season. KISS monitors each survey field in the g-band with high cadences, every one hour (five times per night). The main purpose is to catch the earliest optical light of core-collapse supernovae just after explosions (shock breakouts).

*P.I. T. Morokuma (the University of Tokyo)*

## the KWFC Intensive Survey of the Galactic Plane (KISOGP)

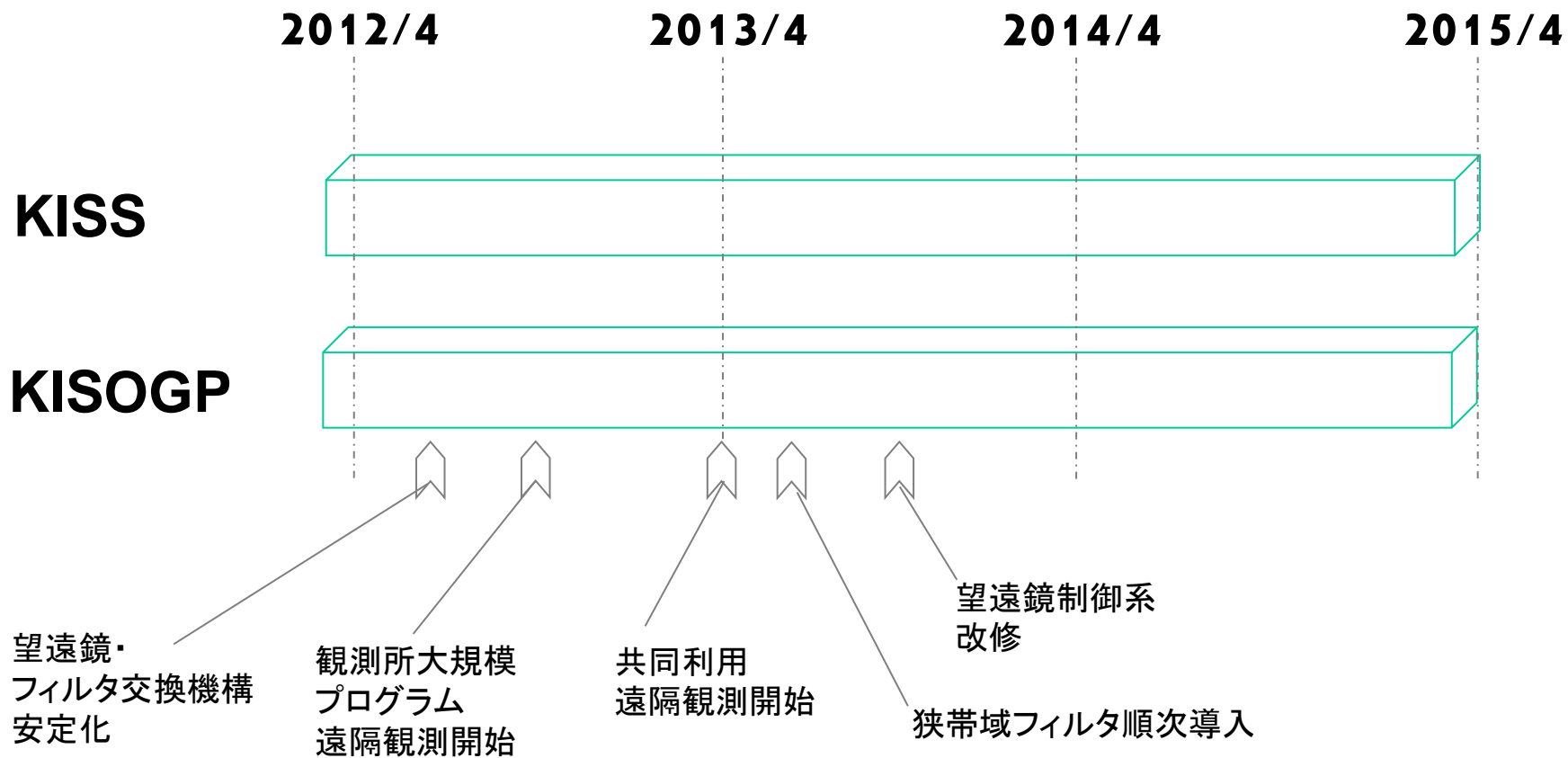
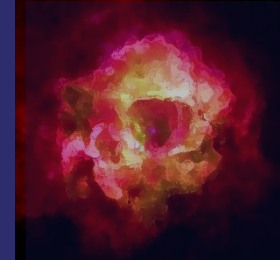
is a monitoring survey program for the northern Galactic plane. The survey field covers 300 square degrees of the Galactic plane between 60 degrees and 210 degrees in the galactic longitude. The plan is to collect roughly 50 time-series images per each region during the three years from 2012. The main goal is to study structure and evolution of the Galaxy based on pulsating stars like Cepheids.

*P.I. N. Matsunaga (the University of Tokyo)*



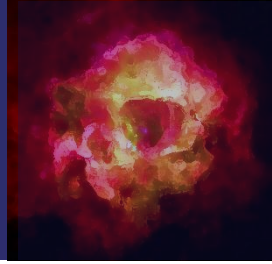
# Time Line

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# Summary

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- A facility instrument for the Kiso 105-cm Schmidt telescope
- 8 CCD chips with a total of 8k x 8k pixels
- F.O.V of 2.2 deg. x 2.2 deg.
- Filter exchanger with a robotic arm capable of storing 12 filters
- Automatic observation system