KWFC

Kiso Wide Field Camera

Kiso Observatory, The Univ. of Tokyo

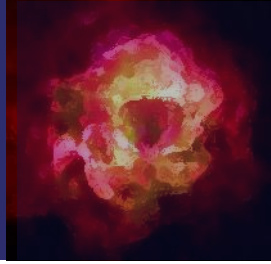
KWFCの現状

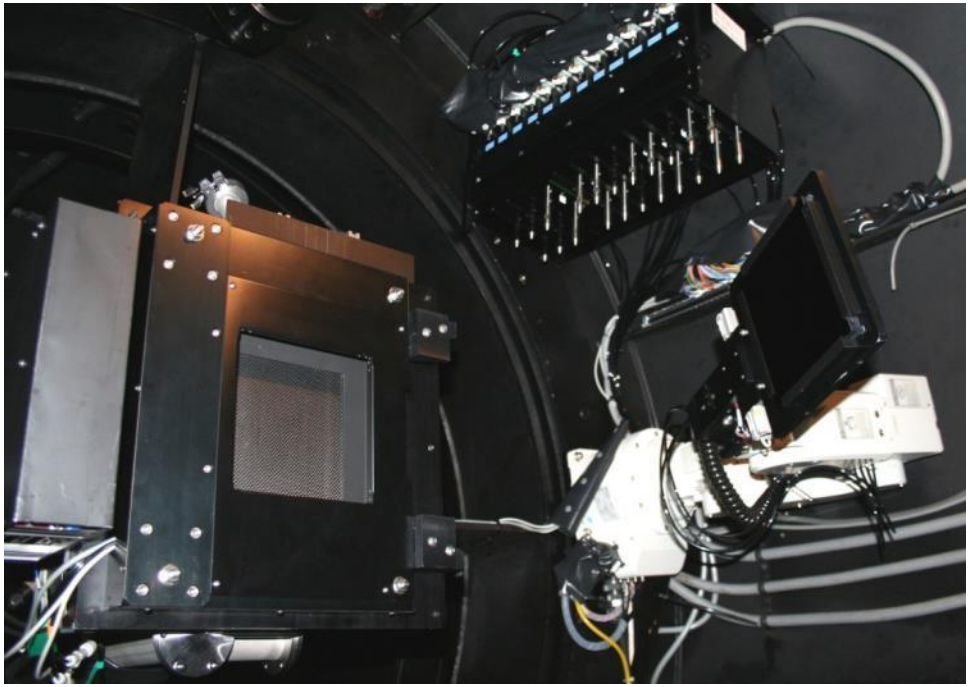
酒向重行, KWFC開発チーム (東京大学 木曽観測所)

KWFC

Kiso Wide Field Camera

Kiso Observatory, The Univ. of Tokyo





- 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

Ongoing wide-field projects

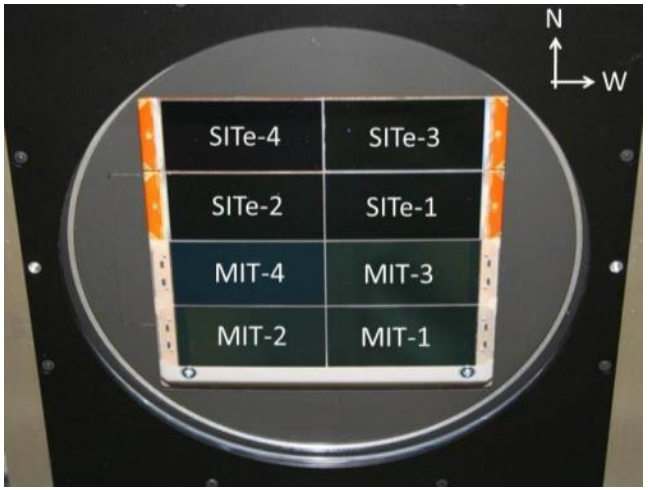
D>1m, FoV>1deg^2, ground based camera

Telescope/Camera	Diameter (m)	FoV (deg^2)	AΩ
Kiso Schmidt /KWFC	**1.0**	**4.8**	**3.8**
MOA II/MOA-cam3	1.8	2.2	4.4
Sloan Digital Sky Survey II	2.5	1.5	7.4
Palomar Transient Factory(PTF)	1.2	7.8	8.8
Skymapper	1.4	5.7	8.8
CFHT/MegaPrime	3.6	1.0	10
Pan-STARRS (x4)	1.8	9	15
Subaru/Suprime-Cam†	8.2	0.3	16
Subaru/Hyper Suprime-Cam	8.2	1.8	91

Future wide-field projects

WIYN/ODI	3.5	1.0	10
Kiso/ Extremely Wide-field camera	**1.0**	**36**	**28**
Palomar Transient Factory(ZTF)	1.2	35	40
Blanco/DEcam	4.0	3	37
LSST	8	9.6	319

CCDs



Read mode

mode	bin	Generated FITS	Read time
18	1x1	MIT x 4 files SITe x 4 files	125 sec
28	2x2	MIT x 4 files SITe x 4 files	85 sec
14	1x1	MIT x 4 files	63 sec
24	2x2	MIT x 4 files	30 sec

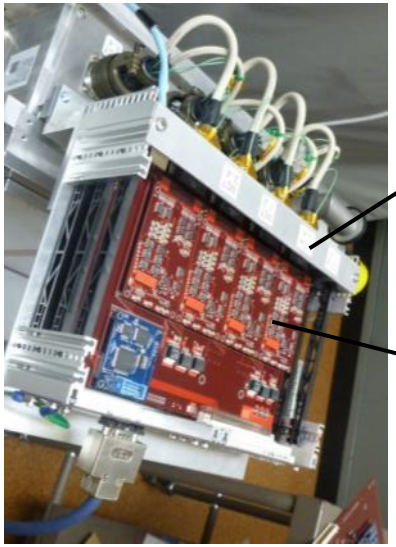
Specification of CCDs

	MIT-CCD	SITe-CCD (ST-002A)
Number of CCDs	4 pcs	4 pcs
Number of pixels†	2k x 4k pixels	2k x 4k pixels
Readout noise††	~10 e^-	~ 30 e^-
Well††	~ 8 x 10^4 e^-	~ 8 x 10^4 e^-
Pixel size	15 μm/pix	
Gain	~2.2 e^- ADU^{-1}	
Dark current††	< 5 e^- $hour^{-1}$ $pixel^{-1}$	
Readout Time†† including overheads	All-CCD read: 120 sec MIT-CCD only read: 60 sec	
Interval space between CCDs††	~ 90 arcsec in the N-S ~ 60 arcsec in the W-E	
Operation temp.	168 K	

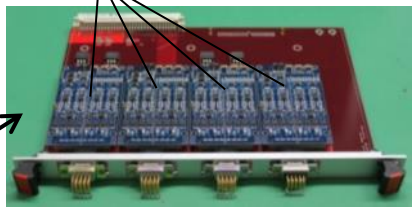
† 2 x 2 binning available.
†† w/o binning, All-CCD read-mode

KAC (Kiso Array Controller)

KAC analog part

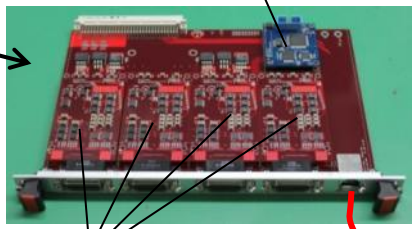


ADC daughter boards



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

IF board



generates bias voltages & clock voltages

DRV daughter boards

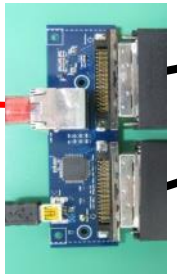
Ethernet cable

LVDS

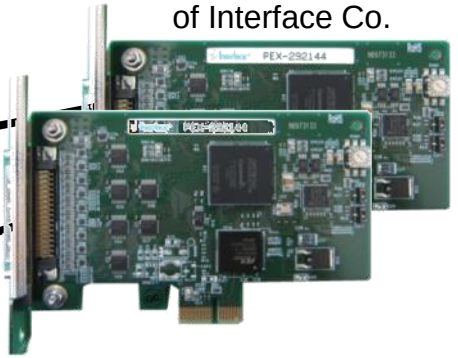
KAC digital part

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.

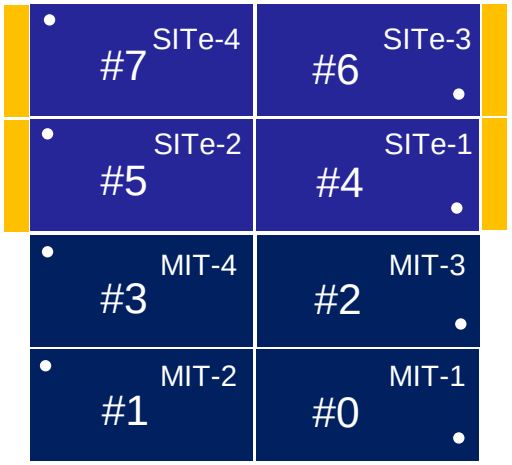
The KAC is a data acquisition system newly developed based on the TAC system (Sako et al. 2008) of the TAO project.
The clock-timing-signals are generated in real-time by software in a manner similar to the TAC system.
The frame data is transferred to a memory space in the PC and then written (appended) 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

RAW image file

KWFC*xxxxxxx*#.fits x 8 files

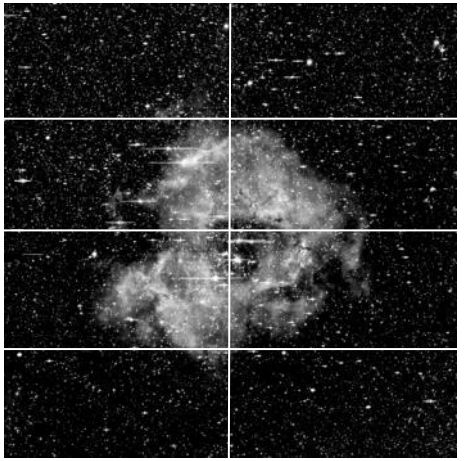
- 2048 x 4100 pix
- 16 bit unsigned integer FITS
- 16 Mbytes/file x 8 files = 128 Mbytes

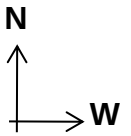


QL image file

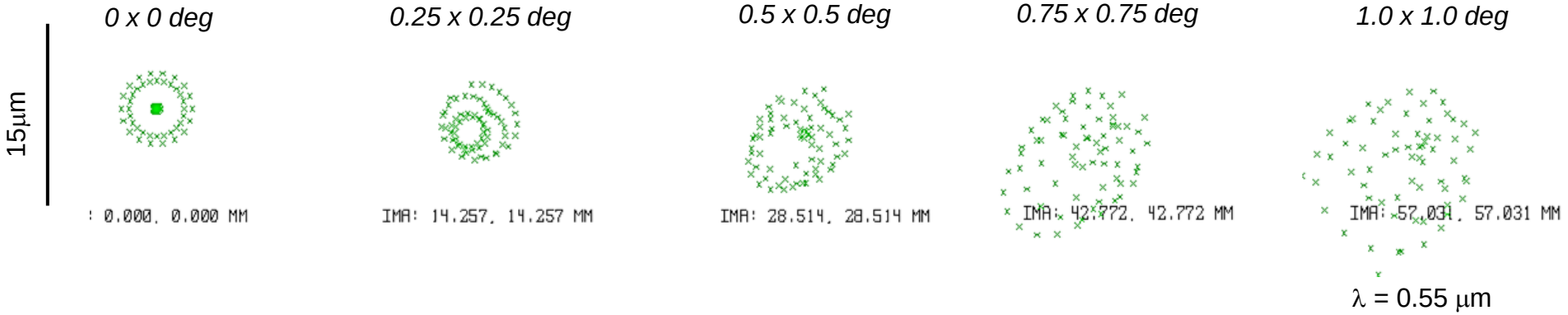
KWFC*xxxxxxx*Q.fits x 1 file

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



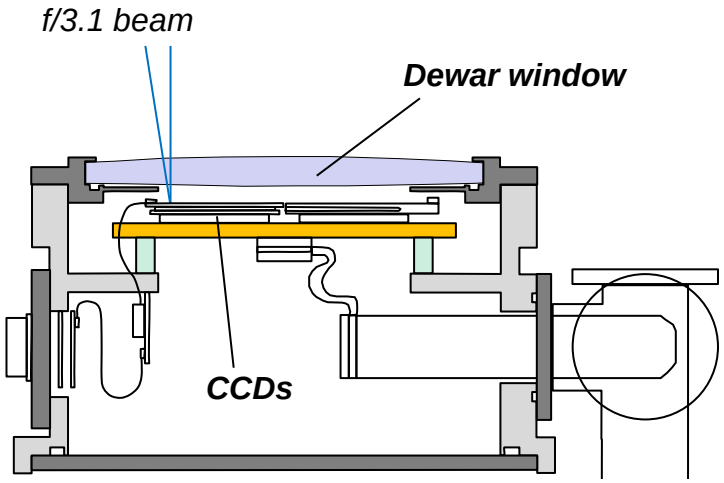


Optics



λ = 0.55 μm

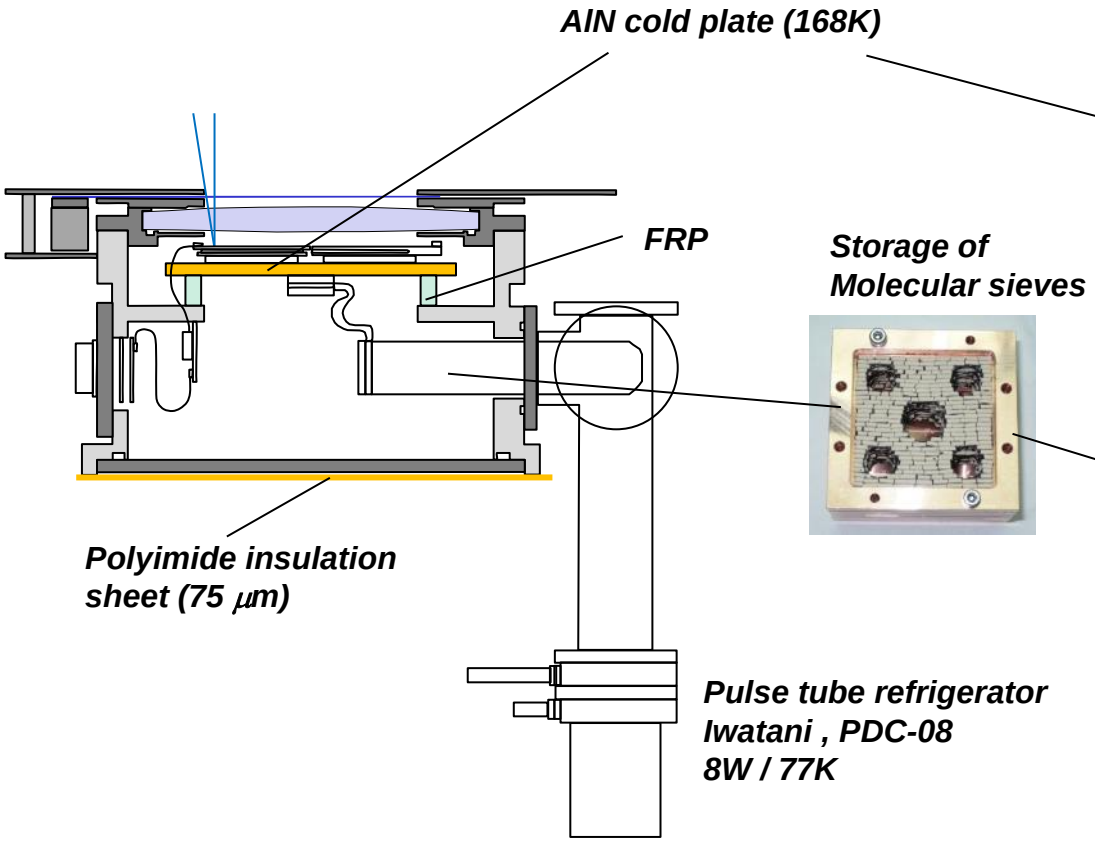
Dewar window works as a field flattener.

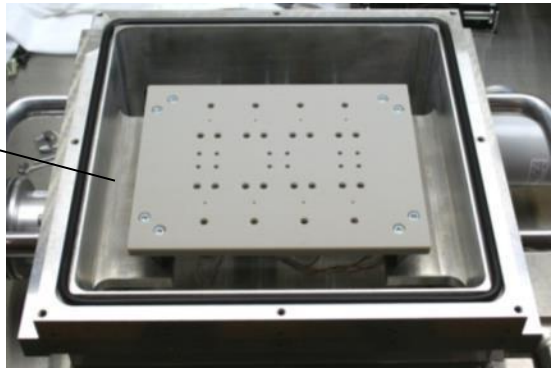


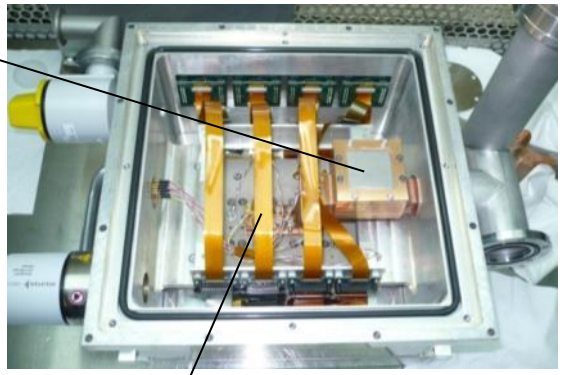
Field of View	2.2 deg. x 2.2 deg.
Pixel scale	0.946 arcsec pixel^{-1}
PSF image quality	Seeing limited (the best seeing size is 2.5 arcsec)
Image distortion	< 0.2 arcsec at all image area

Objective spectroscopy (R~100) is available.

Cryogenics







FPC cables for CCDs

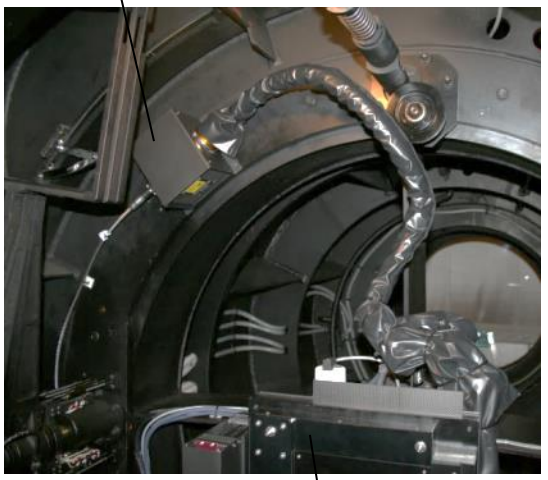
The molecular sieve 13X 1/16 of Nacalai Tesque used.

Vacuum system

Updated in 2012

Auxiliary vacuuming by Ion pump enables continuous operation through the year without additional vacuuming.

Ion pump, VacIon Plus-20

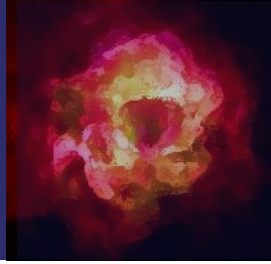


KWFC dewar

Ion pump

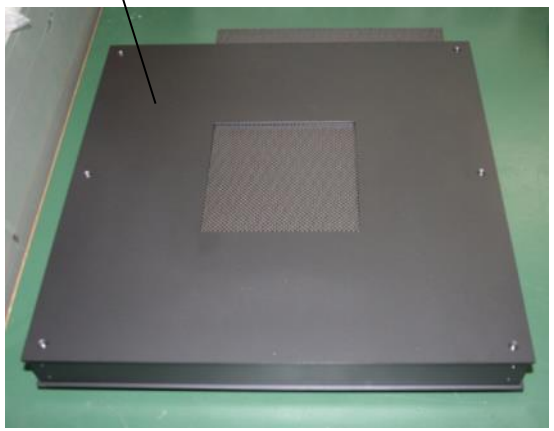
Model	Varian, VacIon Plus-20, Diode type
Pumping speed	27 l/s
Max starting pressure	< 0.75 x 10^{-3} torr
Operating life	5.7 years
Weight	7kg
Controller	Varian, MiniVac, Model 929-0191

Shutter Unit

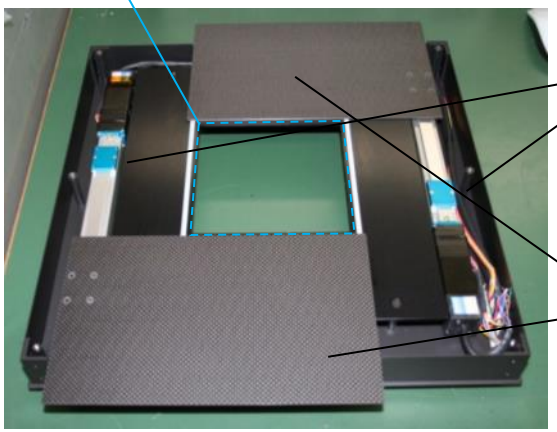


Achieves uniform exposures on all the CCD pixels.

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.

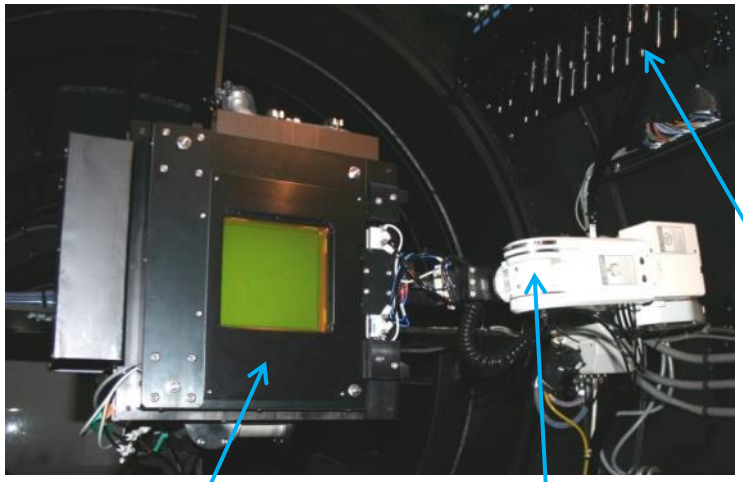


Linear actuators
KUMISA-160-PB-R of KSS

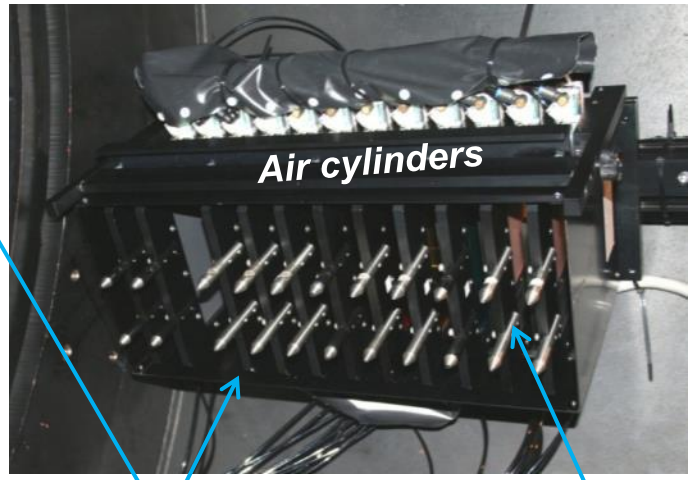
Shutter plates (CFRP)
255 x 160 x 1.5 mm

The accuracy of an open time is approximately 3 msec.

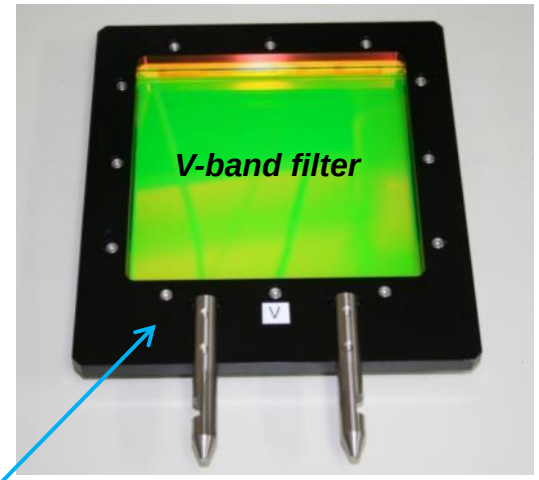
Filter exchanger



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.
- Maintenance works for stable operation scheduled next Autumn.

Safety-net system

In development phase

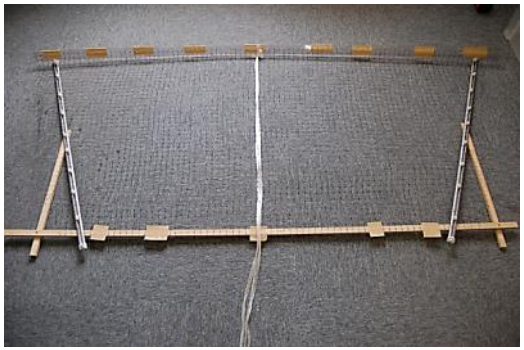
Quick movable safety-net system

- Installed just below the prime focal plane
- Closed / opened in < 2 sec

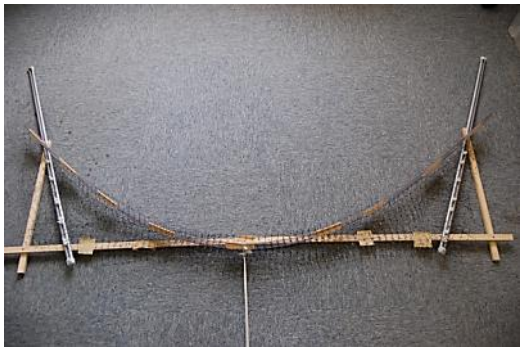
→ Remove the elevation limit for exchanging filters

Rough design and verification tests with an actual model completed.

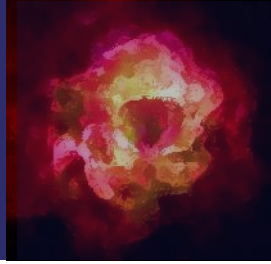
Closed (during exchanging filters)



Opened (during exposure)



Large-format filters



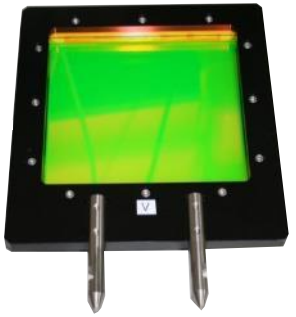
Updated in 2012

Broad-band filters

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

	λ_o (nm)	$\Delta\lambda$ (nm)
SDSS-u	353	56
SDSS-g	467	131
SDSS-r	613	123
SDSS-i	756	120
SDSS-z†	---	---

† Long-pass characteristic of 826 nm cut-off
The effective bandwidth depends on QE of CCDs.



158 x 158 x 15 mm

Narrow-band filters

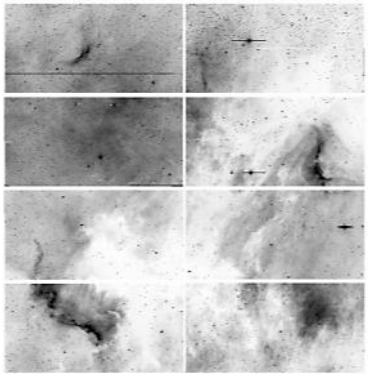
	λ_o (nm)	$\Delta\lambda$ (nm)	
Hα (N6590)	659	16	Designed by Nishiura-san

Future plans → Nishiura-san's presentation.

Medium-band filters

	λ_o (nm)	$\Delta\lambda$ (nm)	
xxx	xxx	xx	Designed by Kawara-san

under manufacture now



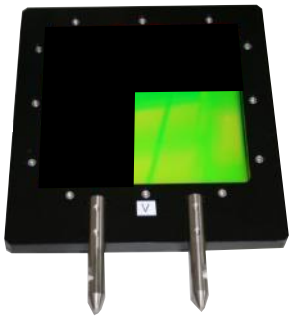
NGC7000 obtained with Hα(N6590) filter

Small-format filters

Updated in 2012

Single-filter holder

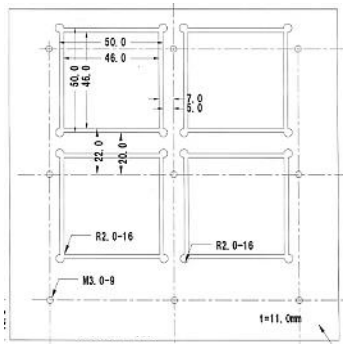
- 100 mm x 100 mm filters developed for 2kCCD available.
- F.O.V. limited to be 50’ square.

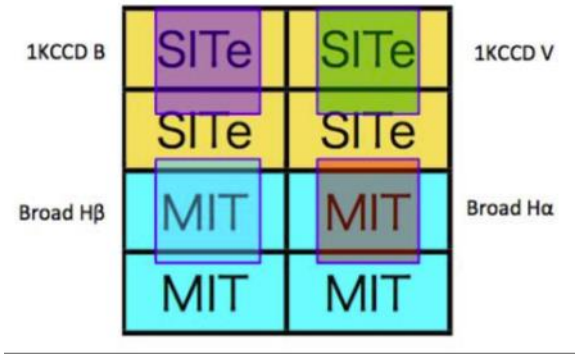


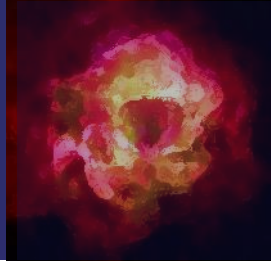
100 x 100 mm

Multiple-filter holder

- 4 pieces of 50 mm x 50 mm filters developed for 1kCCD available.
- F.O.V. limited to be 30’ square.
- Developed for Minezaki-san’s observations (P0009)







Estimated Limiting Magnitude†

	B	V	R	I
MIT-CCD	21.9	21.3	20.9	20.2
SITe-CCD	22.2	21.2	20.9	20.1

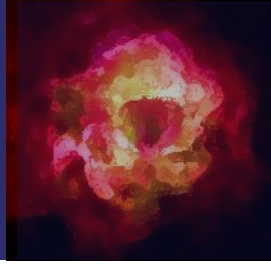
† Estimated from the measured values of 2kCCD assuming S/N=10, exposure time of 15 min, seeing size of 3 arcsec

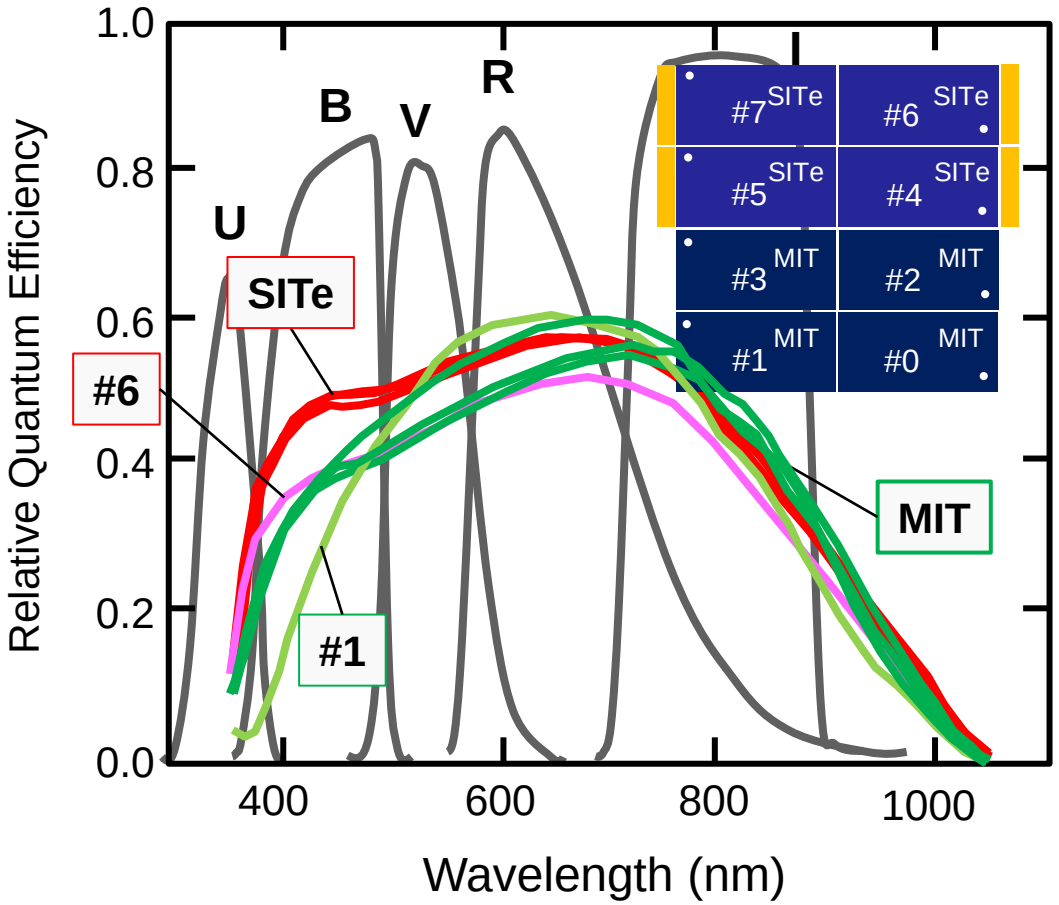
Measured Limiting Magnitude†

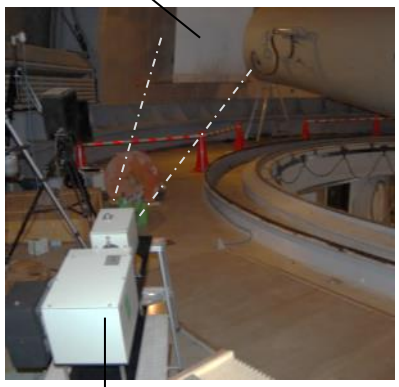
	SDSS-u	SDSS-g	SDSS-i
Chip 0, 2-7	20.5‡	20.9	20.3
Chip 1 (MIT)	18.8‡	20.9	20.3

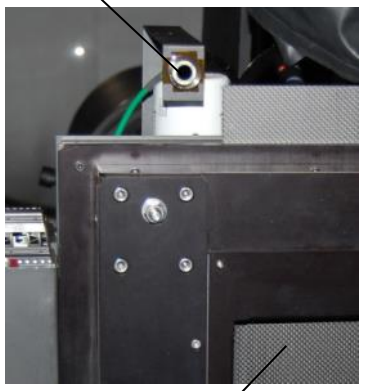
† S/N=5, exposure time of 3 min
‡ 2x2 binning

QEs of CCDs









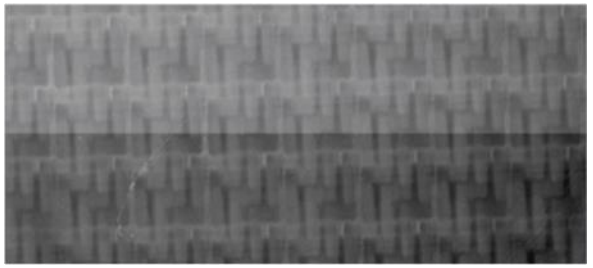
- Relative spectral responses of QE measured with spectrophotometer and PD.
- Absolute QE will be calibrated with caribrated PD.

Flat Images

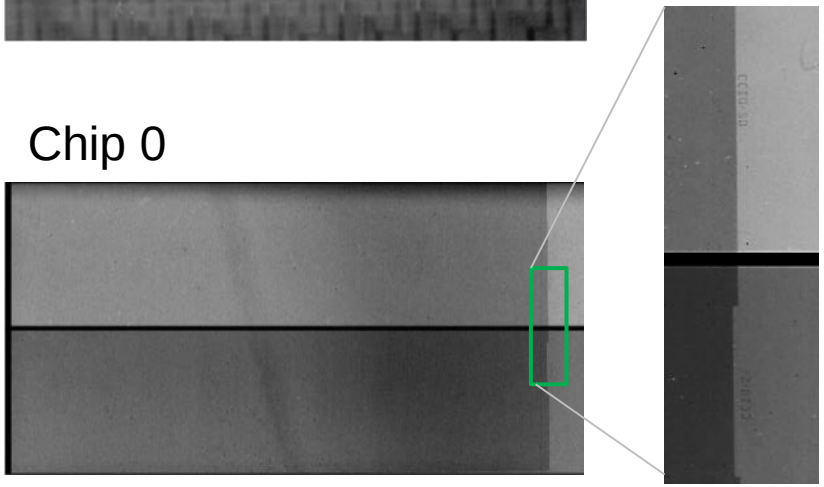
Flat pattern varies with the filter band.

examples

- Chip 1, SDSS-g band



- Chip 0

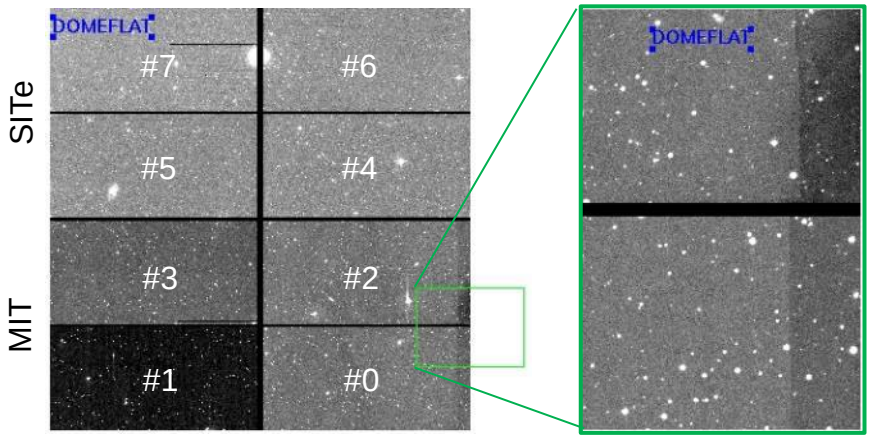


FILTER	ND	mode =18	mode =28	mode =14	mode =24
u	NO	240	60	240	60
B	1.0	40	10	40	10
g	1.0	28	7	10	7
V	1.0	10	3	10	3
R	1.4	15	4	15	4
R	1.0	6	1.5	6	1.5
I	1.0	28	7	28	7

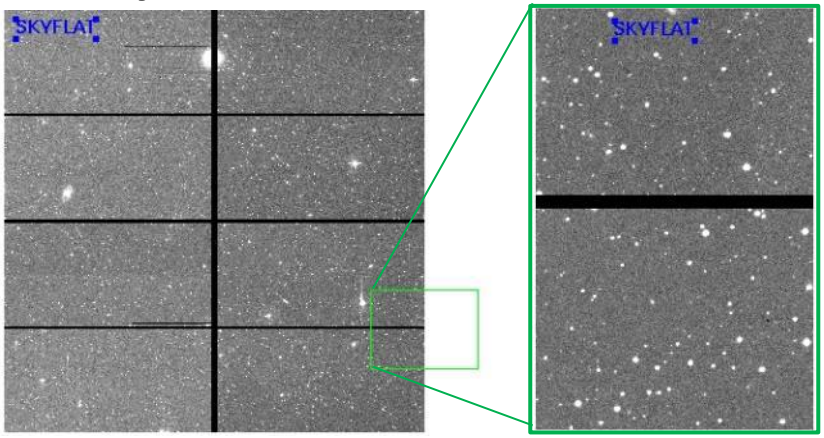
Recommended dome-flat setting and exposure time in sec

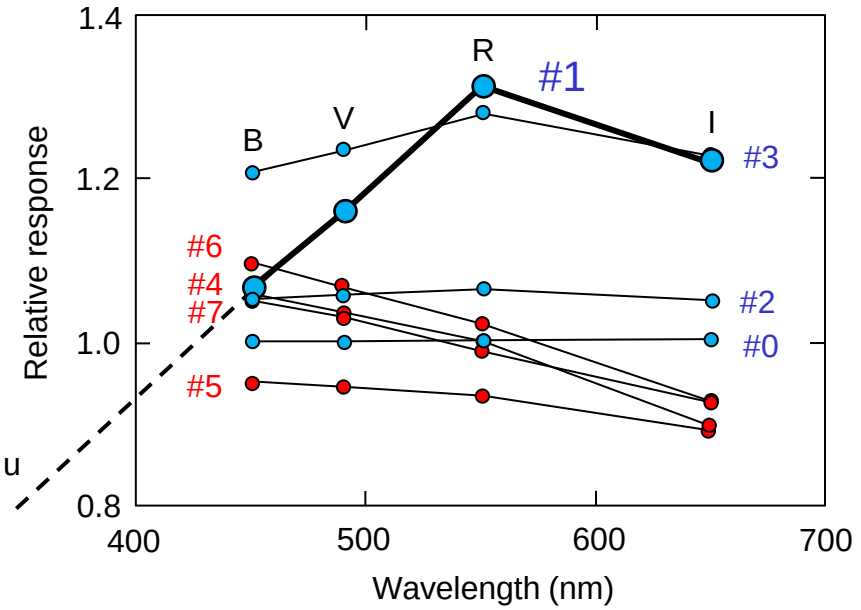
Flat fielding

with Dome Flat



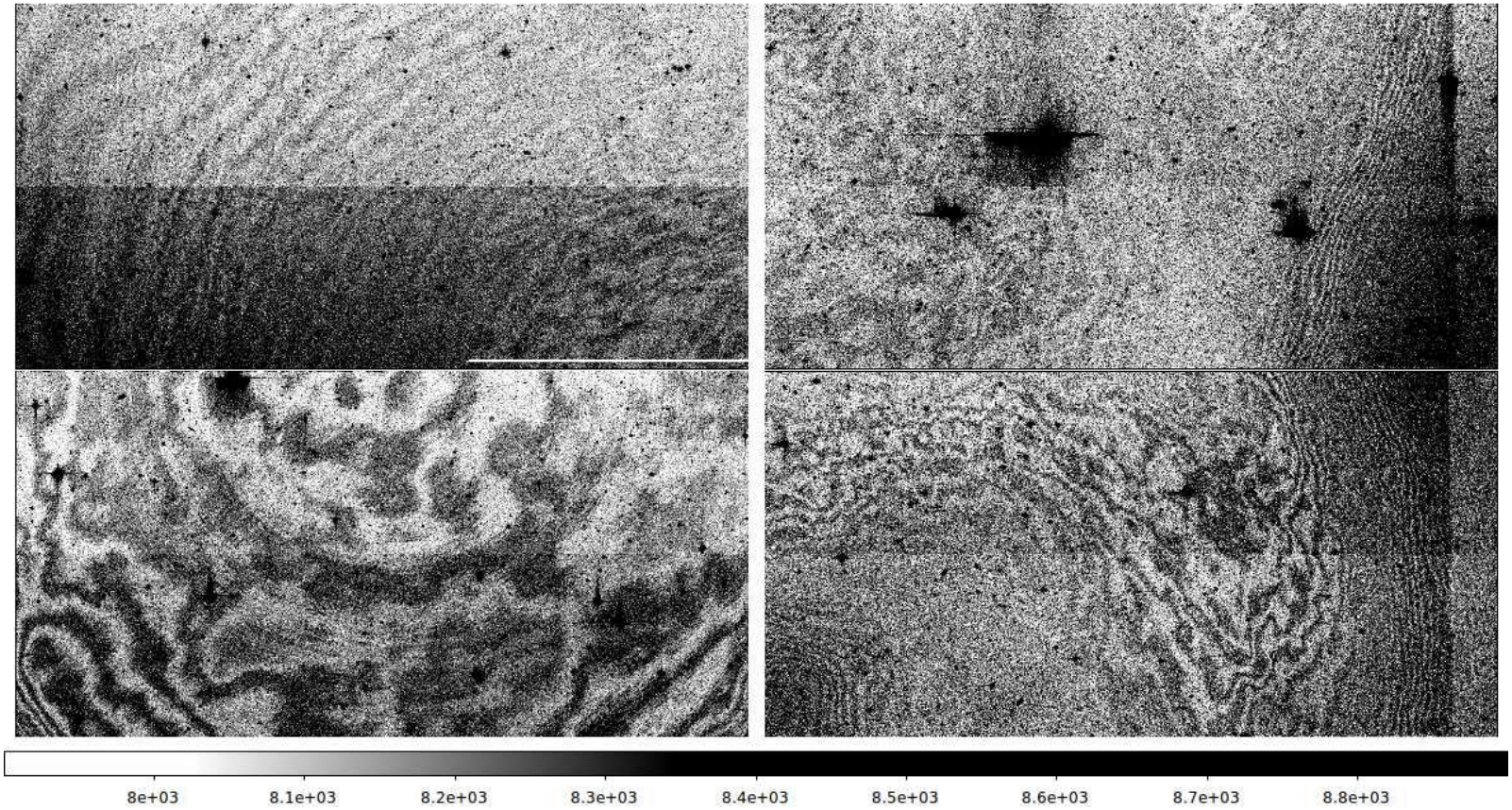
with Sky Flat





- 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.

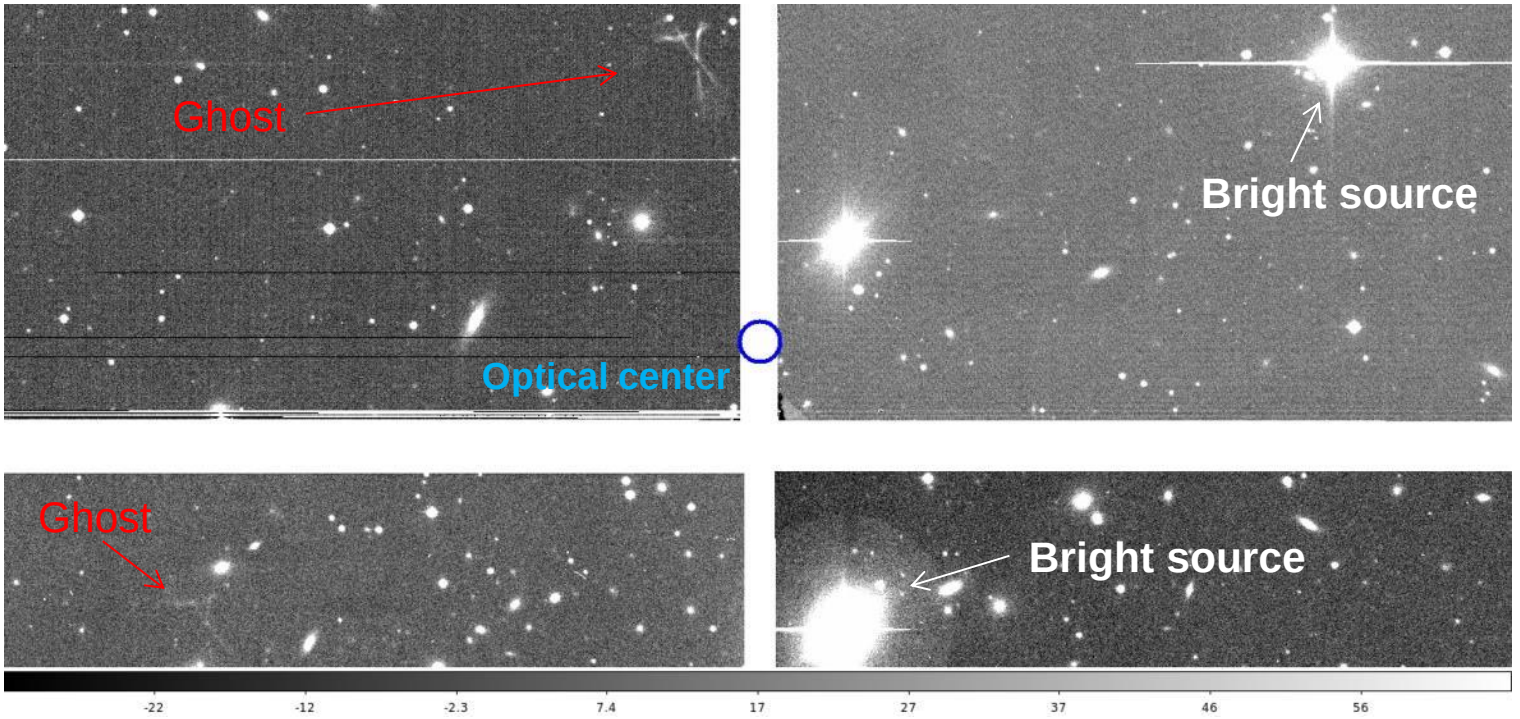
Fringe



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

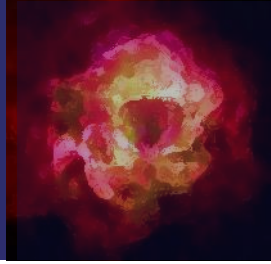
$$\frac{\text{Fringe p-v}}{\text{Sky background}} \sim 1\ \%$$

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



Instruments

Telescope

KWFC

Weather station

Sensors

Observation

observer

log

Real-time transfer

ORIHIME (MySQL, WWW servers)

Current status / Log DB

Instrument Status Viewing

Queue Manager

Emergency Shutdown

Observer Manager

SSL-VPN

Remote Observations via www

Outside of observatory

Data Storage

Pipeline Software

Real-time transfer

PC for Intensive Prog.

DB Server
Data Storage
Reduction Software

Real-time transfer

Data Storage for SMOKA

Real-time transfer

Kiso

Posting

Mitaka

SMOKA

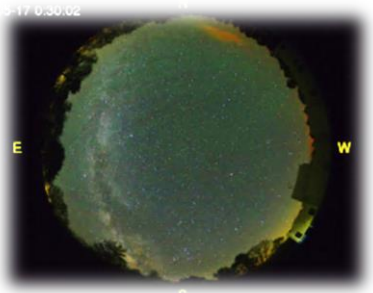
Rental server (KISS)

DB server
WWW server

WWW

To amateur

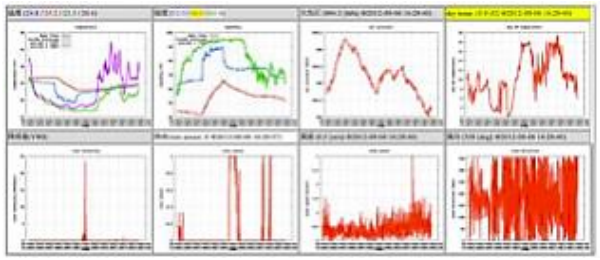
Weather sensors

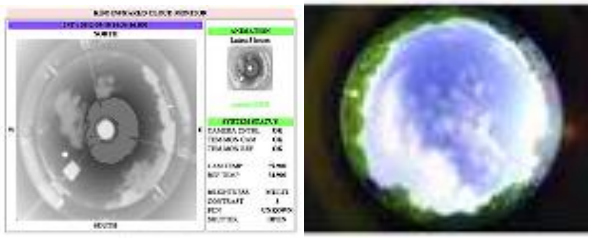


Weather Station on the roof of the main building

- 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 cameras inside dome

New weather sensors





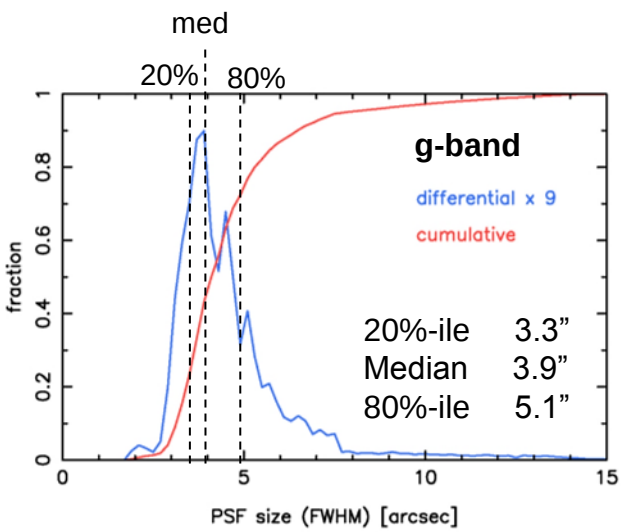
Weather data viewer on web

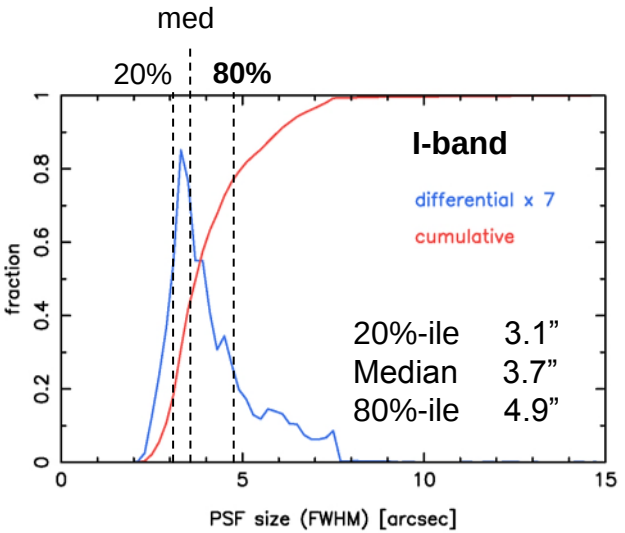
- Fog sensor
- FoV camera
- Measures to snow covering
- Network cameras inside dome and rooms
- Network camera outside dome

Weather statistics

Seeing size

using data obtained since 2012/4

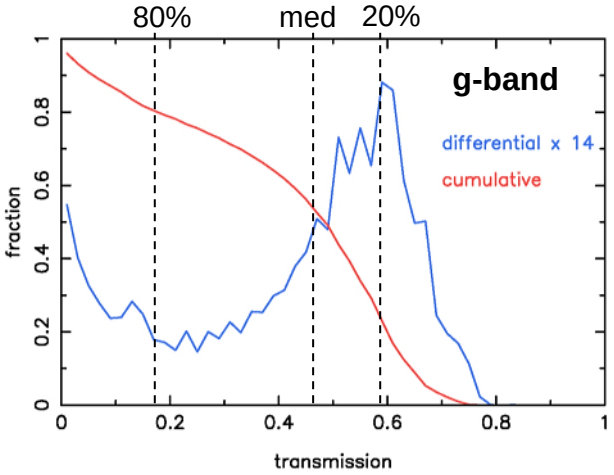




Atmospheric transmission

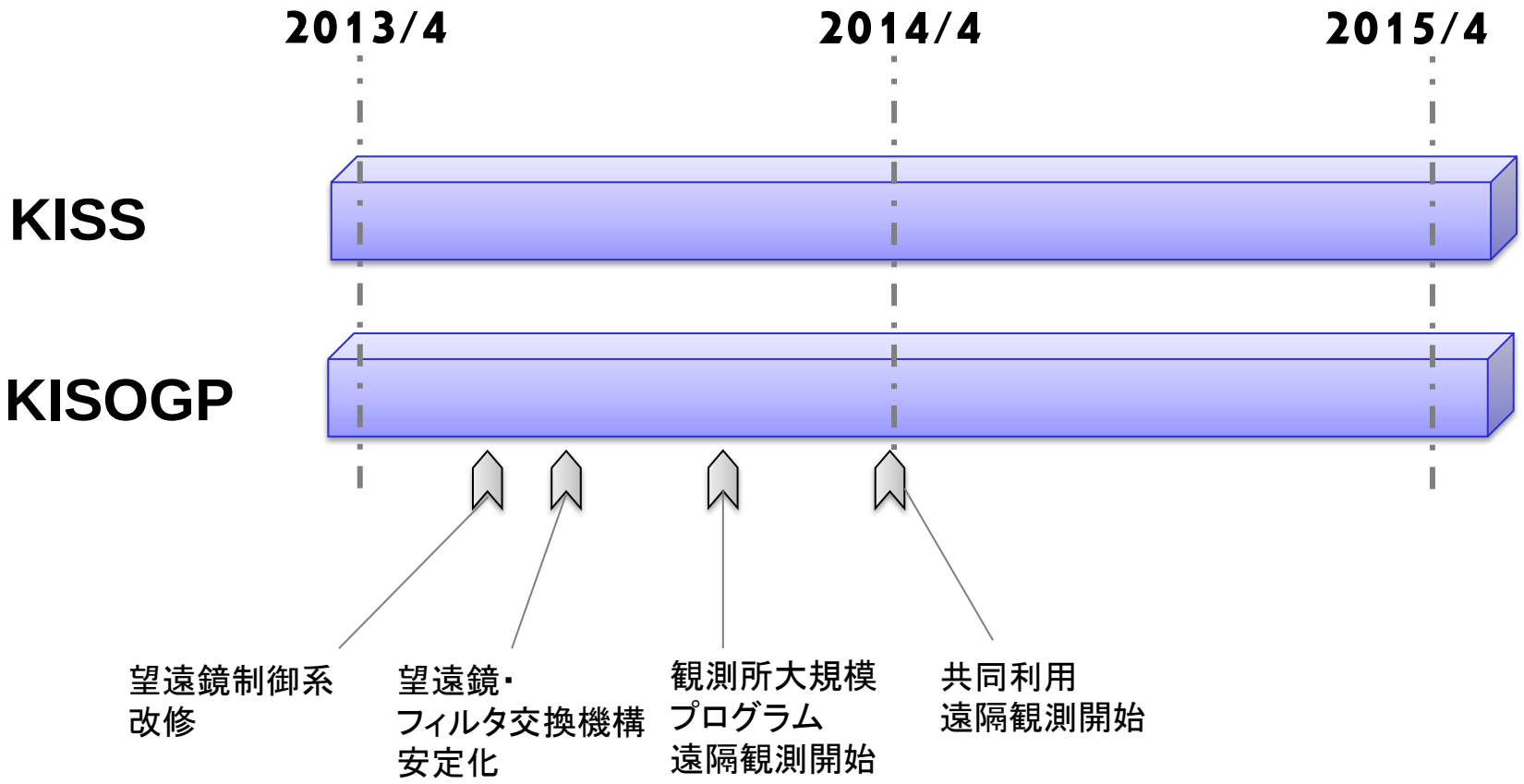
using ‘usable data’ obtained since 2012/4

‘Usable data’ means that a sufficient number of sources to fit with WCS are detected in the image data.

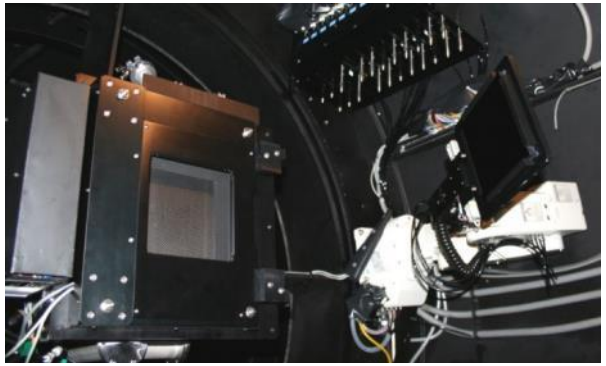


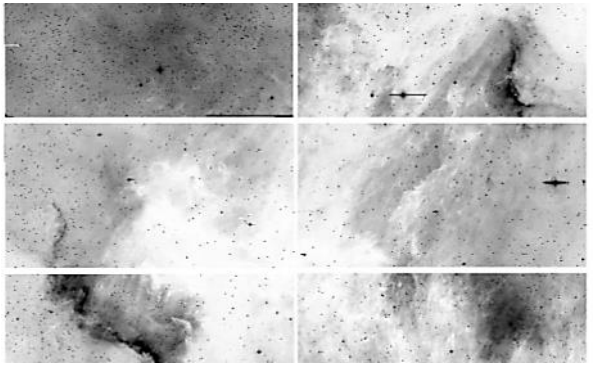
20%-ile 0.59
Median 0.47
80%-ile 0.17

Time Line


2013/4
2014/4
2015/4
KISS
KISOGP
望遠鏡制御系
改修
望遠鏡・
フィルタ交換機構
安定化
観測所大規模
プログラム
遠隔観測開始
共同利用
遠隔観測開始

Summary





- 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

Please cite the following papers when you first refer to the KWFC in a publication.

Sako S. et al., "KWFC: four square degrees camera for the Kiso Schmidt Telescope", in Proc. of SPIE, Vol. 8446, 11 (2012)