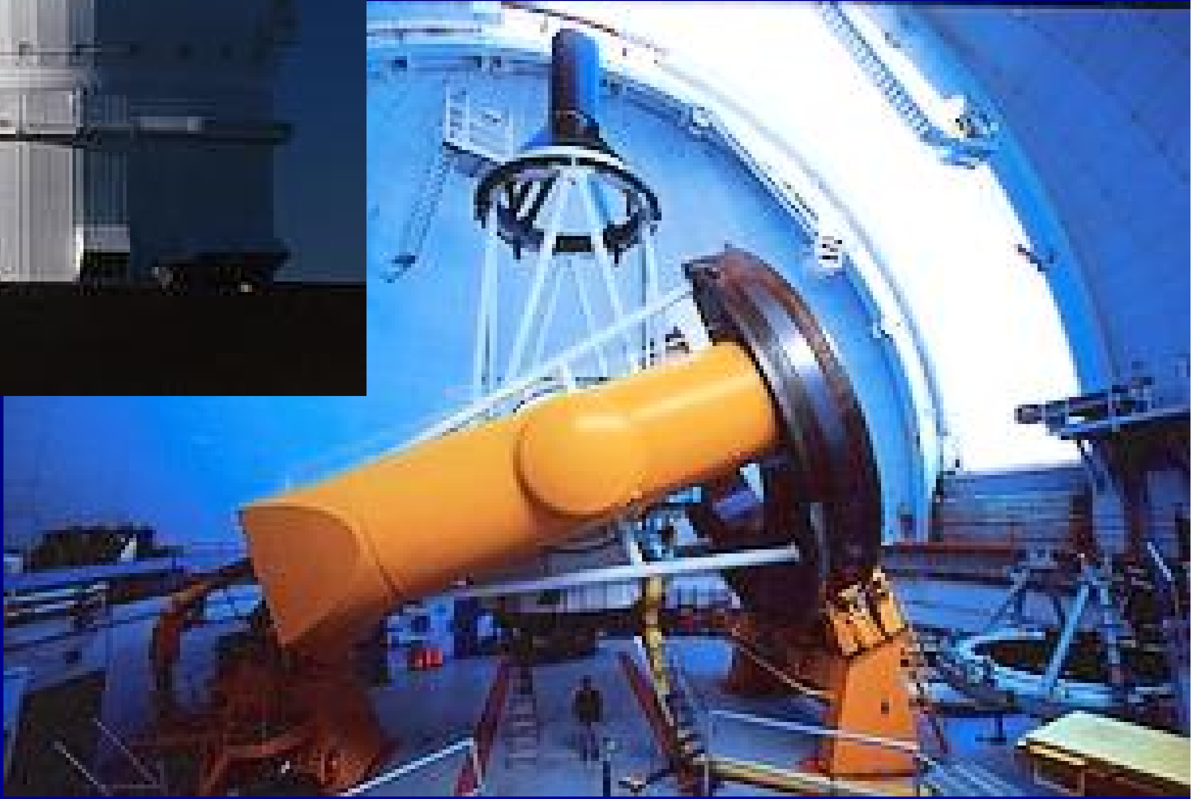
CFHT and Subaru Wide Field Camera

WIRCam and Beyond: OIR instrumentation plan of ASIAA

Chi-Hung Yan

Institute of Astronomy and Astrophysics, Academia Sinica

Canada France Hawaii Telescope



3.6 m telescope

F/3.8 prime focus

Terms of Collaboration

- 68 nights of CFHT observation (2001-2007)
- Taiwanese involvement in WIRCam development
- Cospa contributes USD 2M (40% of WIRCam)
- WIRCam development started from late 2001.

WIRCam

- A wide field IR camera needed to complete the wide field imaging capability and keep CFHT competitive in the 10 meter era.
- Fits Taiwanese needs to get access to world class telescope and develop the instrumentation capability
- The project officially started in Oct 2001 with the financial support from Taiwan and Korea.

The largest format working infrared camera in the world. (c.f. WFCam in UKIRT)

The first camera has the on-chip infrared guide stars.

Quick Facts

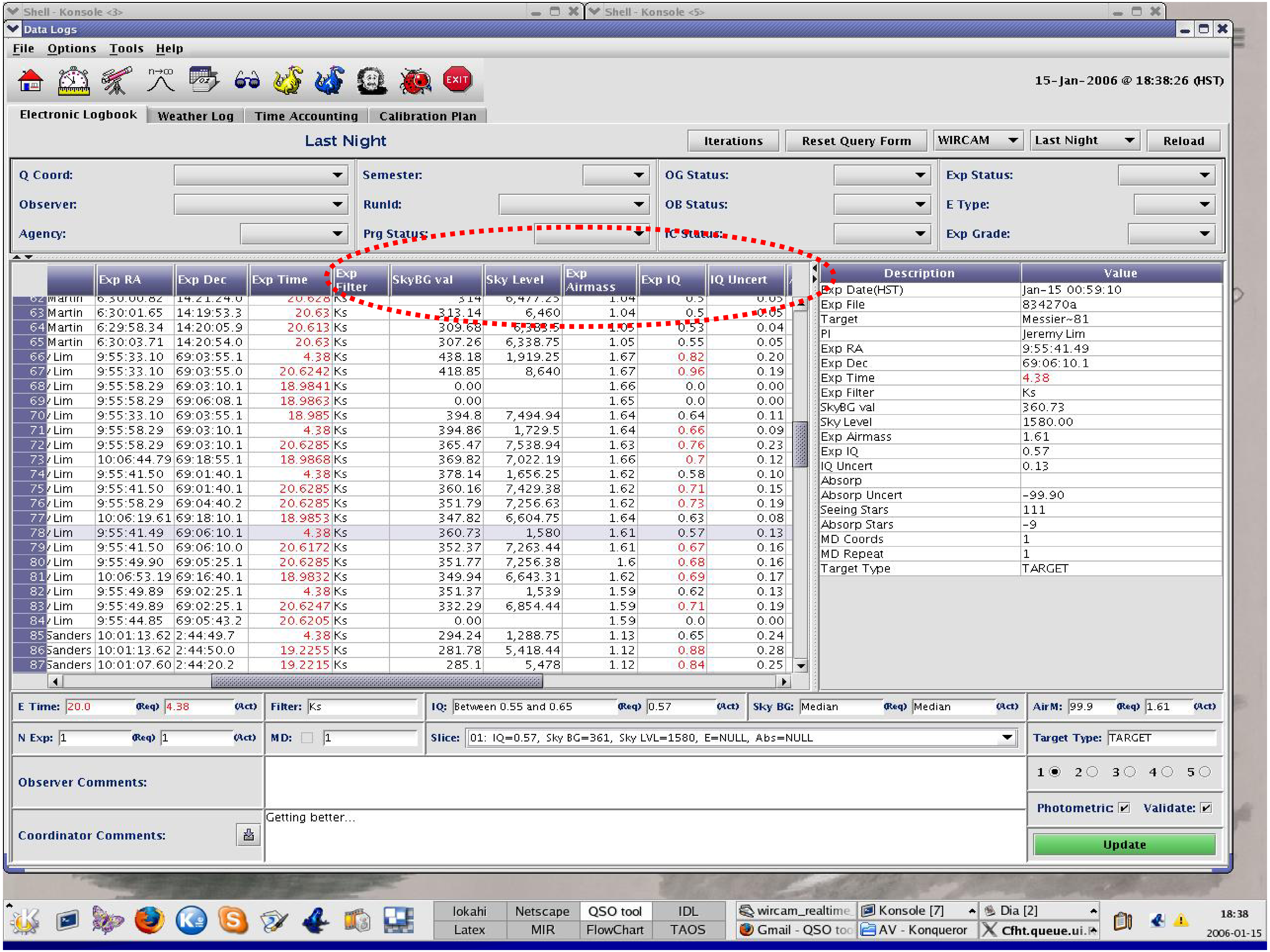
- Environment: Prime focus CHFT12K upper end
- 4 2k-by-2k pixel Hawaii2-RG arrays. FoV is 20x20 arcmin with resolution 0.3 arcsec per pixel.
- Filters
  - Broad-band filters: Y, J, H, Ks
  - Narrow band filters: Low OH-1 Low OH-2, CH_4 On, CH_4 Off, H_2, K continuum.
- Cooling system: close cycled refrigerator at 80K
- Most different features
  - On-chip guiding
  - Sub-pixel dithering
- Image stabilizer Unit: 50 Hz tip-tilt correction
- Array controller: SDSU III system 128 outputs
- Readout out time: 2 sec (CDS)
- The measured optical distortion of WIRCam is <0.8% (maximal in the corners of the field) or ~20 pixels

Our Contribution

Four engineers from ASIAA have joined the development in the past four years on

- The system specifications
  - Subsystem requirements and contracts
- Array controller electronics and testing
  - Controller design, DSP code, cabling
  - Gain calibration, noise reduction, guide window calibration
- Real time data pipeline
  - IQ, sky level, air mass analysis
- Guider signal simulation
  - Guider correction capability analysis

We still participate the development of image process pipeline with CFHT astronomers.


Shell - Konsole <3>
Shell - Konsole <5>
Data Logs
File Options Tools Help
15-Jan-2006 @ 18:38:26 (HST)
Electronic Logbook
Weather Log
Time Accounting
Calibration Plan
Last Night
Iterations
Reset Query Form
WIRCAM
Last Night
Reload
Q Coord:
Observer:
Agency:
Semester:
RunId:
Prg Status:
OG Status:
OB Status:
IC Status:
Exp Status:
E Type:
Exp Grade:
Exp RA | Exp Dec | Exp Time | Exp Filter | SkyBG val | Sky Level | Exp Airmass | Exp IQ | IQ Uncert
63 Martin 6:30:01.65 14:19:53.3 20.63 Ks 313.14 6,460 1.04 0.5 0.05
64 Martin 6:29:58.34 14:20:05.9 20.613 Ks 309.68 6,383.5 1.05 0.53 0.04
65 Martin 6:30:03.71 14:20:54.0 20.63 Ks 307.26 6,338.75 1.05 0.55 0.05
66 Lim 9:55:33.10 69:03:55.1 4.38 Ks 438.18 1,919.25 1.67 0.82 0.20
67 Lim 9:55:33.10 69:03:55.0 20.6242 Ks 418.85 8,640 1.67 0.96 0.19
68 Lim 9:55:58.29 69:03:10.1 18.9841 Ks 0.00 1.66 0.0 0.00
69 Lim 9:55:58.29 69:06:08.1 18.9863 Ks 0.00 1.65 0.0 0.00
70 Lim 9:55:33.10 69:03:55.1 18.985 Ks 394.8 7,494.94 1.64 0.64 0.11
71 Lim 9:55:58.29 69:03:10.1 4.38 Ks 394.86 1,729.5 1.64 0.66 0.09
72 Lim 9:55:58.29 69:03:10.1 20.6285 Ks 365.47 7,538.94 1.63 0.76 0.23
73 Lim 10:06:44.79 69:18:55.1 18.9868 Ks 369.82 7,022.19 1.66 0.7 0.12
74 Lim 9:55:41.50 69:01:40.1 4.38 Ks 378.14 1,656.25 1.62 0.58 0.10
75 Lim 9:55:41.50 69:01:40.1 20.6285 Ks 360.16 7,429.38 1.62 0.71 0.15
76 Lim 9:55:58.29 69:04:40.2 20.6285 Ks 351.79 7,256.63 1.62 0.73 0.19
77 Lim 10:06:19.61 69:18:10.1 18.9853 Ks 347.82 6,604.75 1.64 0.63 0.08
78 Lim 9:55:41.49 69:06:10.1 4.38 Ks 360.73 1,580 1.61 0.57 0.13
79 Lim 9:55:41.50 69:06:10.0 20.6172 Ks 352.37 7,263.44 1.61 0.67 0.16
80 Lim 9:55:49.90 69:05:25.1 20.6285 Ks 351.77 7,256.38 1.6 0.68 0.16
81 Lim 10:06:53.19 69:16:40.1 18.9832 Ks 349.94 6,643.31 1.62 0.69 0.17
82 Lim 9:55:49.89 69:02:25.1 4.38 Ks 351.37 1,539 1.59 0.62 0.13
83 Lim 9:55:49.89 69:02:25.1 20.6247 Ks 332.29 6,854.44 1.59 0.71 0.19
84 Lim 9:55:44.85 69:05:43.2 20.6205 Ks 0.00 1.59 0.0 0.00
85 Sanders 10:01:13.62 2:44:49.7 4.38 Ks 294.24 1,288.75 1.13 0.65 0.24
86 Sanders 10:01:13.62 2:44:50.0 19.2255 Ks 281.78 5,418.44 1.12 0.88 0.28
87 Sanders 10:01:07.60 2:44:20.2 19.2215 Ks 285.1 5,478 1.12 0.84 0.25
Description | Value
Exp Date(HST) Jan-15 00:59:10
Exp File 834270a
Target Messier~81
PI Jeremy Lim
Exp RA 9:55:41.49
Exp Dec 69:06:10.1
Exp Time 4.38
Exp Filter Ks
SkyBG val 360.73
Sky Level 1580.00
Exp Airmass 1.61
Exp IQ 0.57
IQ Uncert 0.13
Absorp
Absorp Uncert -99.90
Seeing Stars 111
Absorp Stars -9
MD Coords 1
MD Repeat 1
Target Type TARGET
E Time: 20.0 (Req) 4.38 (Act)
Filter: Ks
IQ: Between 0.55 and 0.65 (Req) 0.57 (Act)
Sky BG: Median (Req) Median (Act)
AirM: 99.9 (Req) 1.61 (Act)
N Exp: 1 (Req) 1 (Act)
MD: 1
Slice: 01: IQ=0.57, Sky BG=361, Sky LVL=1580, E=NULL, Abs=NULL
Target Type: TARGET
1 2 3 4 5
Observer Comments:
Coordinator Comments:
Getting better...
Photometric
Validate:
Update
Iokahi Netscape QSO tool IDL
Latex MIR FlowChart TAOS
wircam_realtime
Konsole [7]
Dia [2]
Gmail - QSO too
AV - Konqueror
Cfht.queue.ui.
18:38
2006-01-15

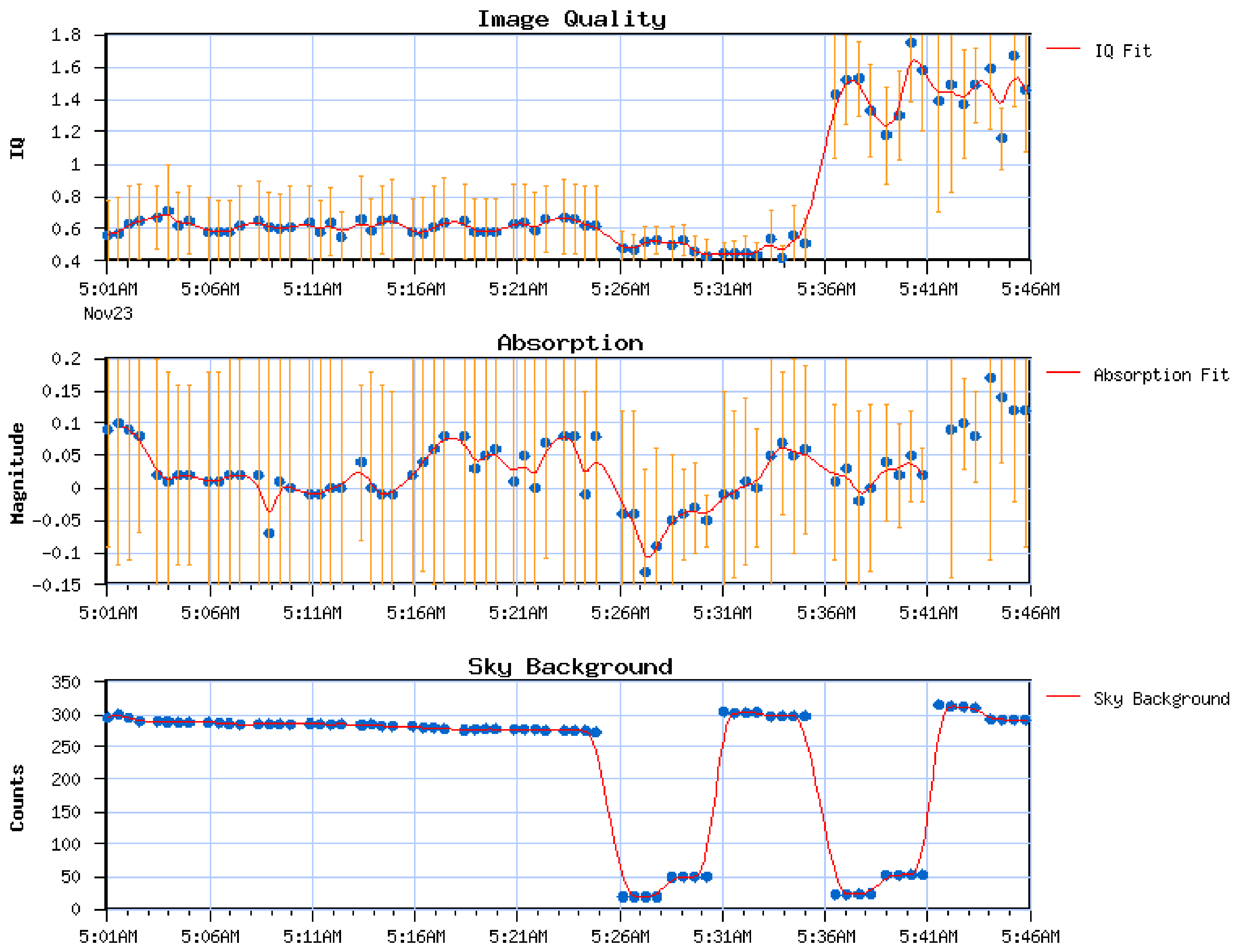
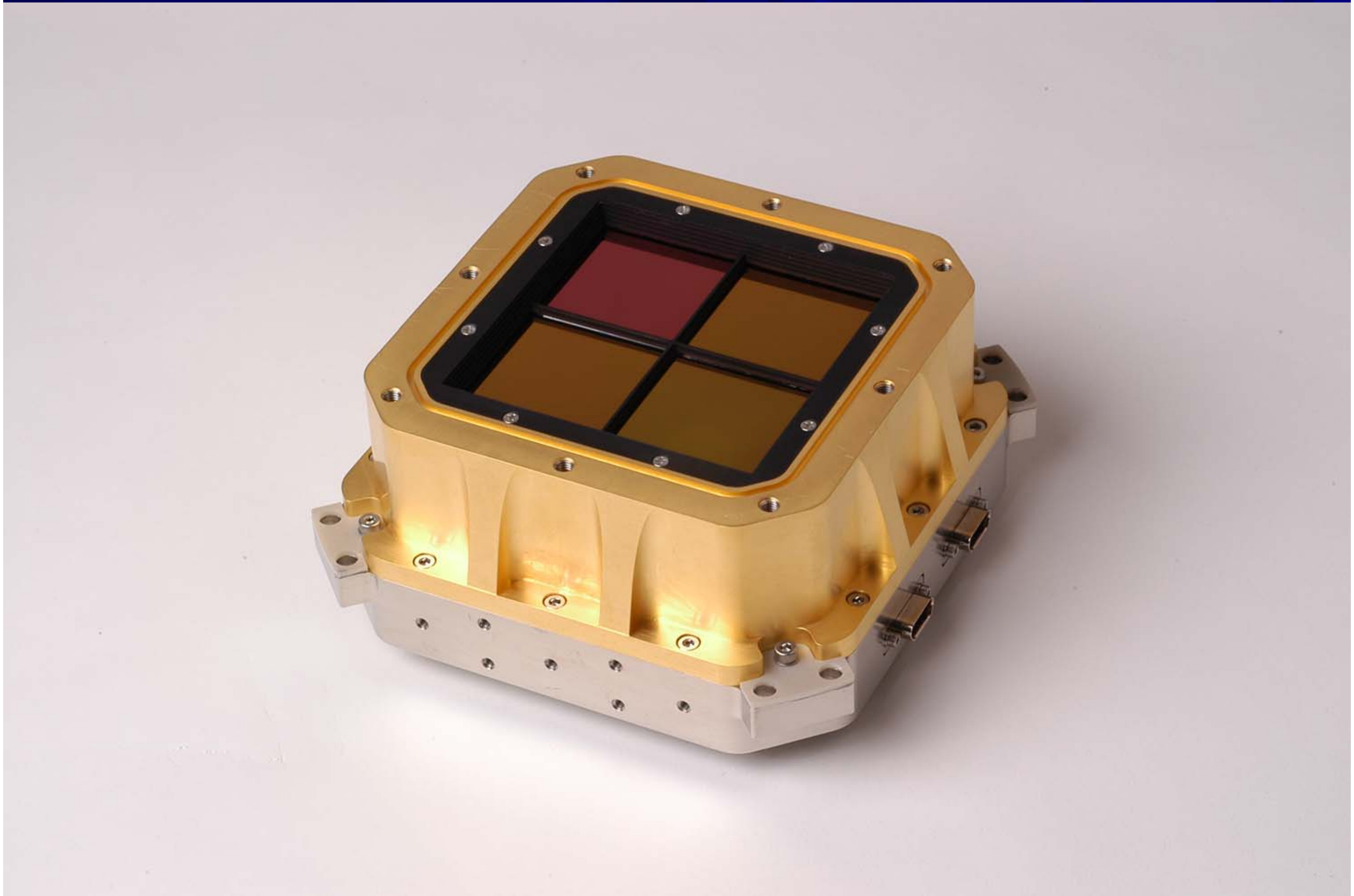


Image Quality
IQ
IQ Fit
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
5:01AM
Nov23
5:06AM
5:11AM
5:16AM
5:21AM
5:26AM
5:31AM
5:36AM
5:41AM
5:46AM
Absorption
Magnitude
Absorption Fit
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
Sky Background
Counts
Sky Background
350
300
250
200
150
100
50
0



Science Grade Arrays

#54

J-QE=0.756

K-QE=0.81

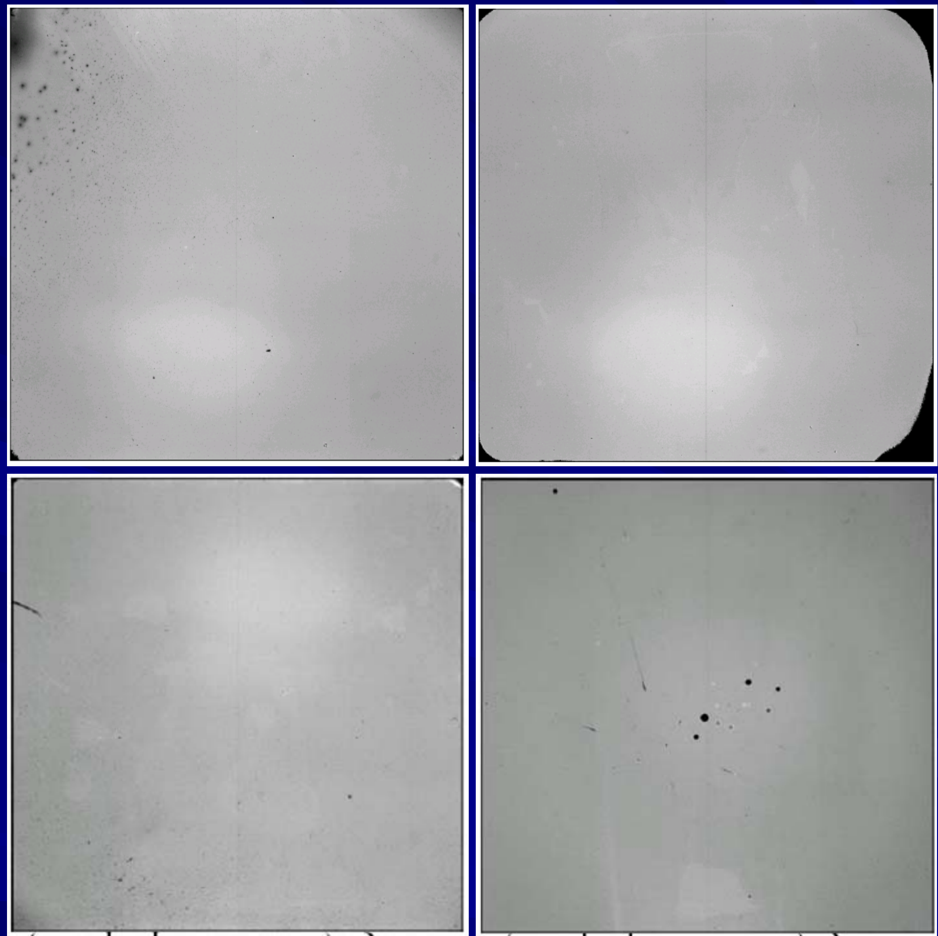
Noise=19.3e^-

#52

J-QE=0.739

K-QE=0.813

Noise=22.0e^-



#60

J-QE=0.889

K-QE=0.832

Noise=24.5e^-

#77

J-QE=0.71

K-QE=0.747

Noise=19.3e^-

2.5mm gaps between the arrays

Controller for WIRCam

- 2 x SDSU III system with 1 timing board, 8 video board and 1 clock board are used.

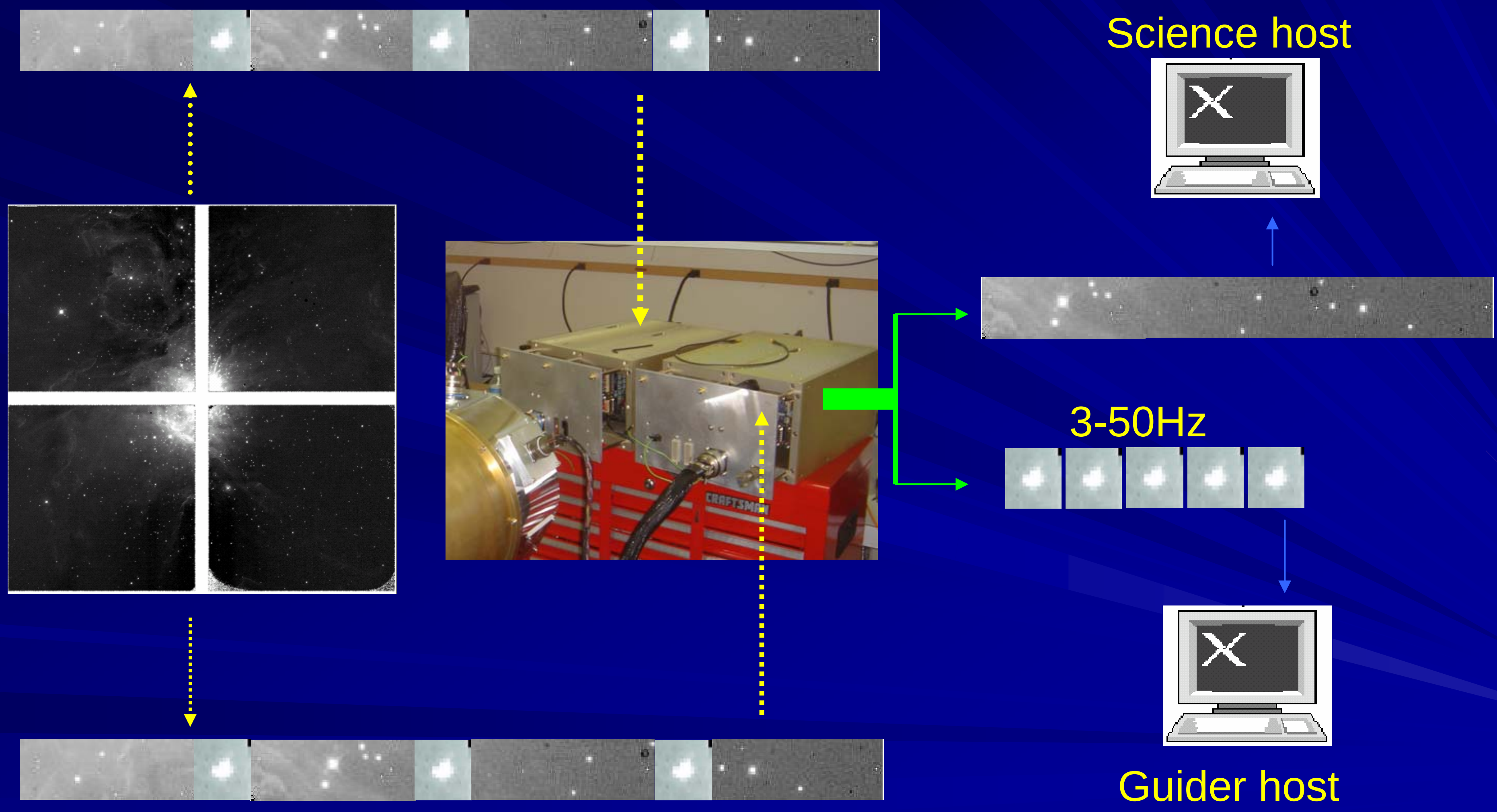
4s readout with

< 20e$^-$ readout is achieved.

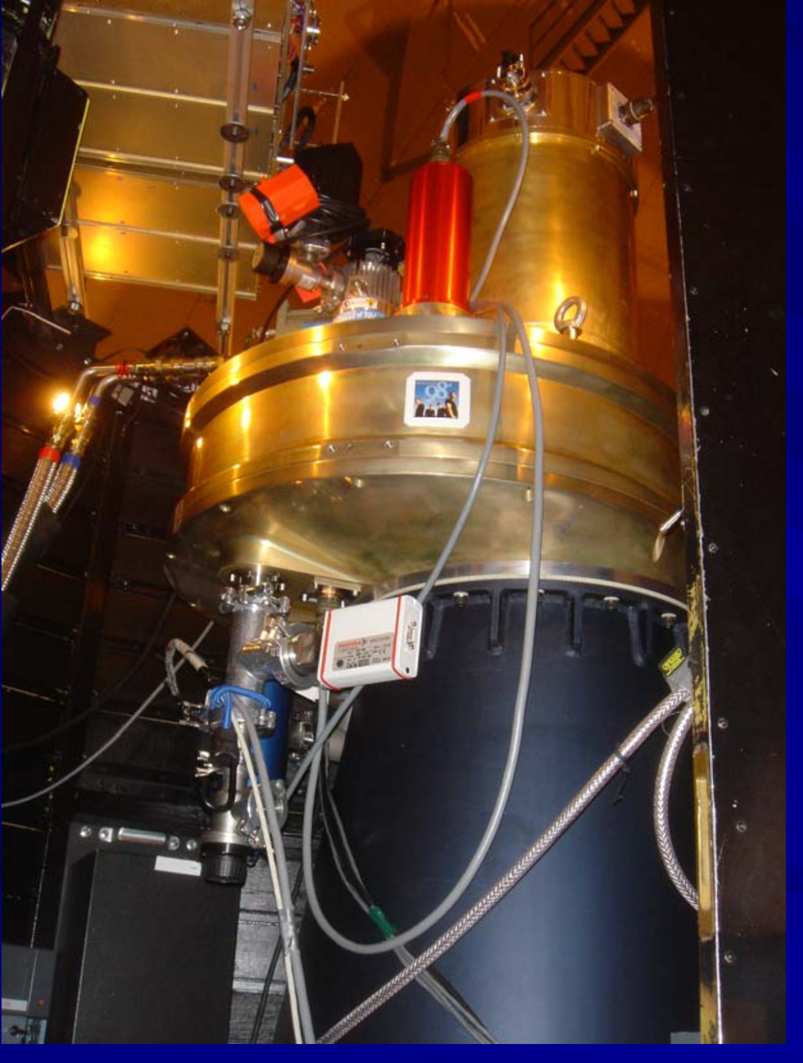
1s readout under testing now.

Goal 0.75s readout

Signal Flow



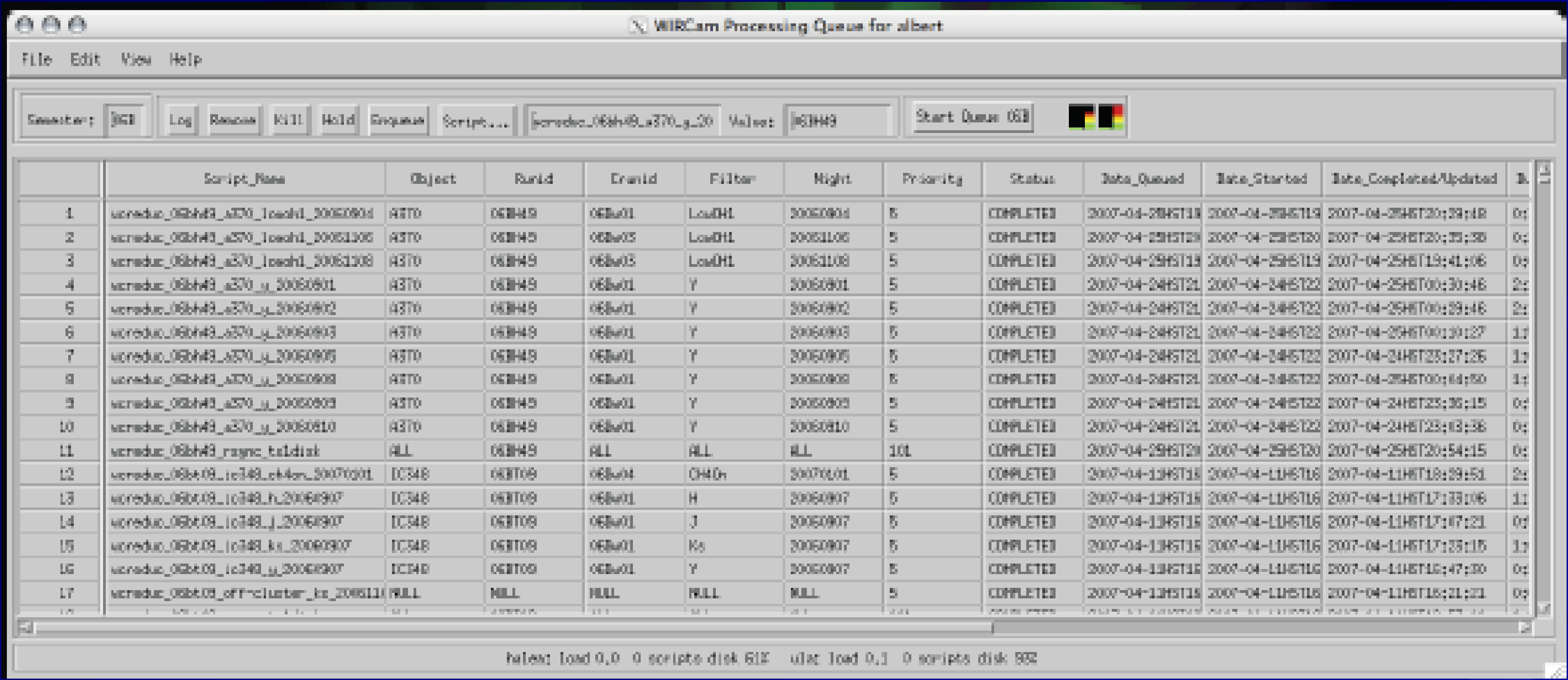
Full Mosaic Operation in Jun. 2005

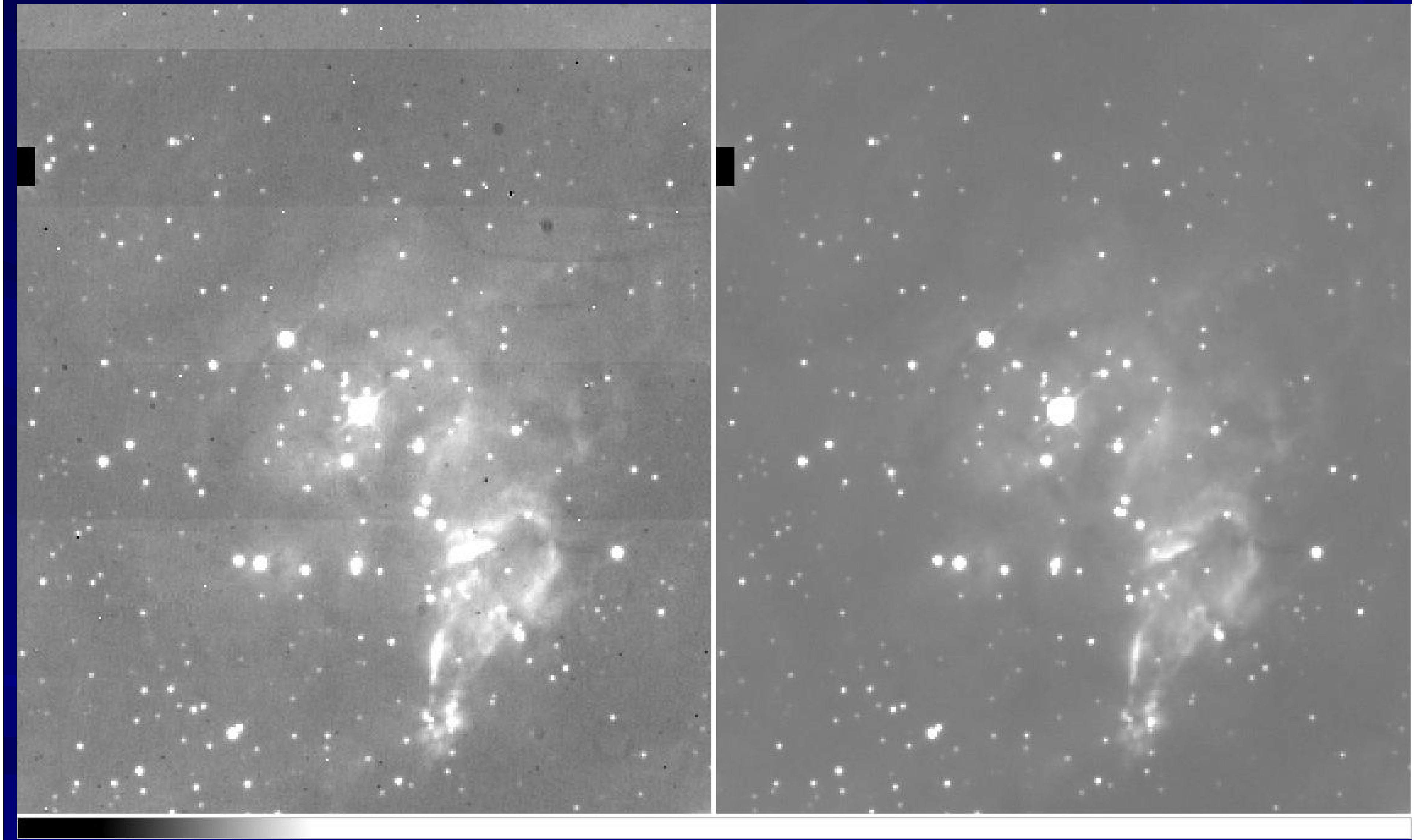


Performance

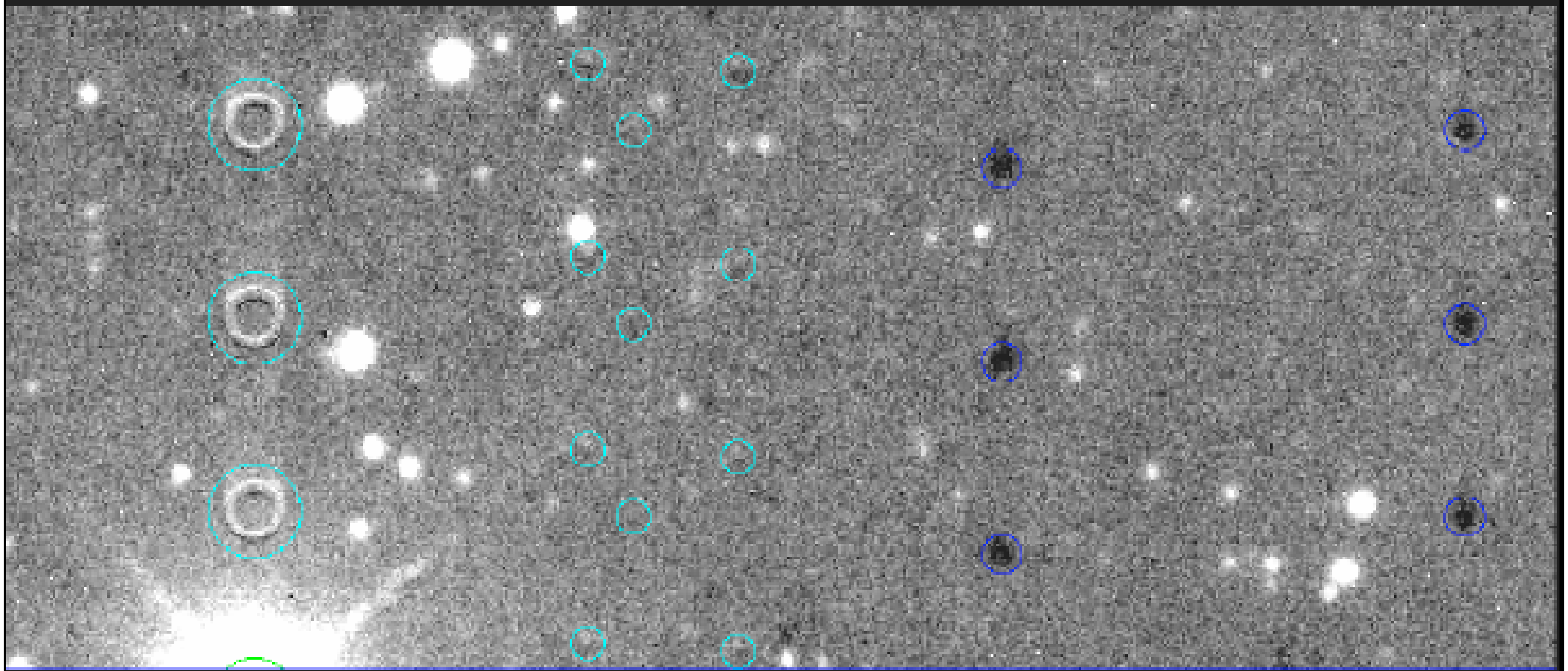
Filter	Array QE	Optics Transmission	Overall throughput	Expected Zero-point (Vega)	Measured Zero-point (Vega)
Y	50%?	80%	27%	24.58	24.65
J	75%	75%	39%	24.96	25.02
H	75%	70%	48%	25.12	25.18
Ks	80%	69%	49%	24.37	24.43

Software Developments





Negative and Edge Crosstalks



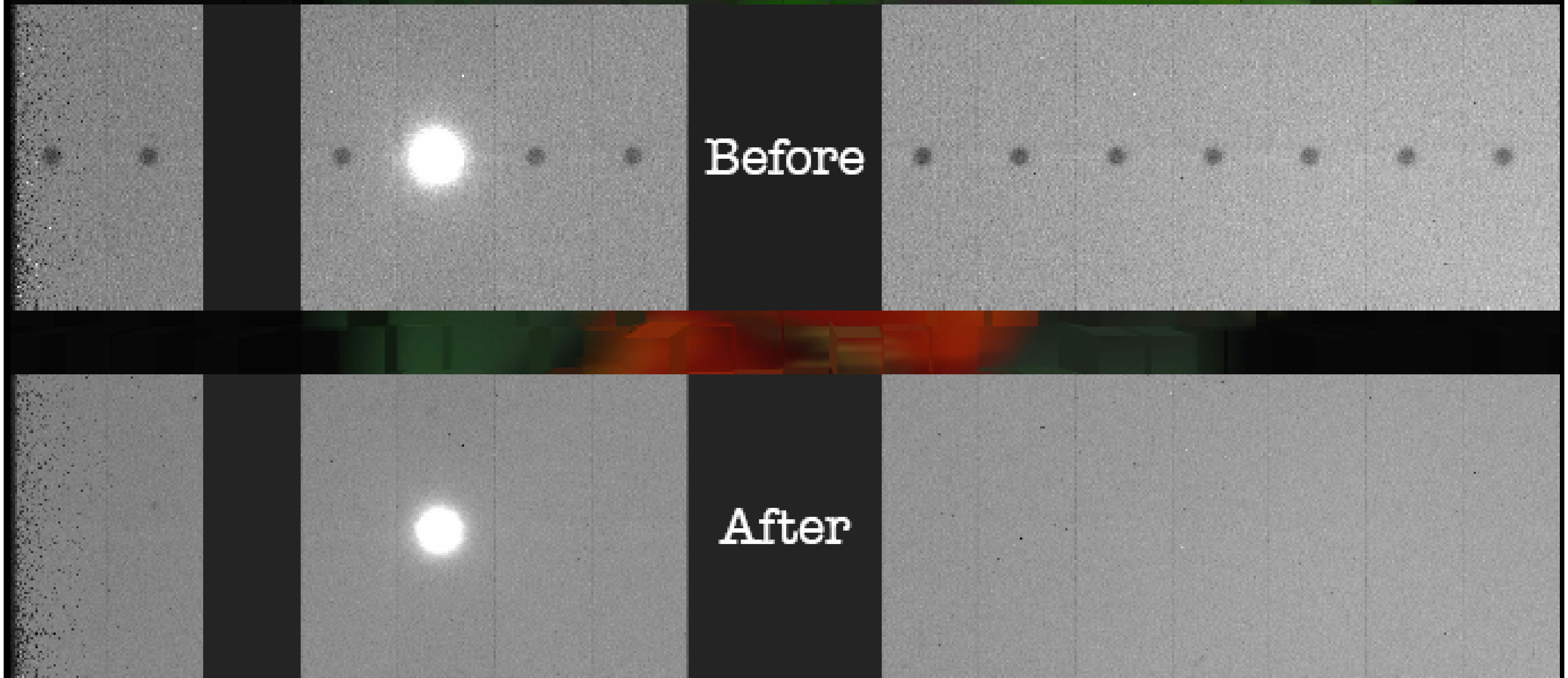
Median of the 32 amplifiers isolates commonalities

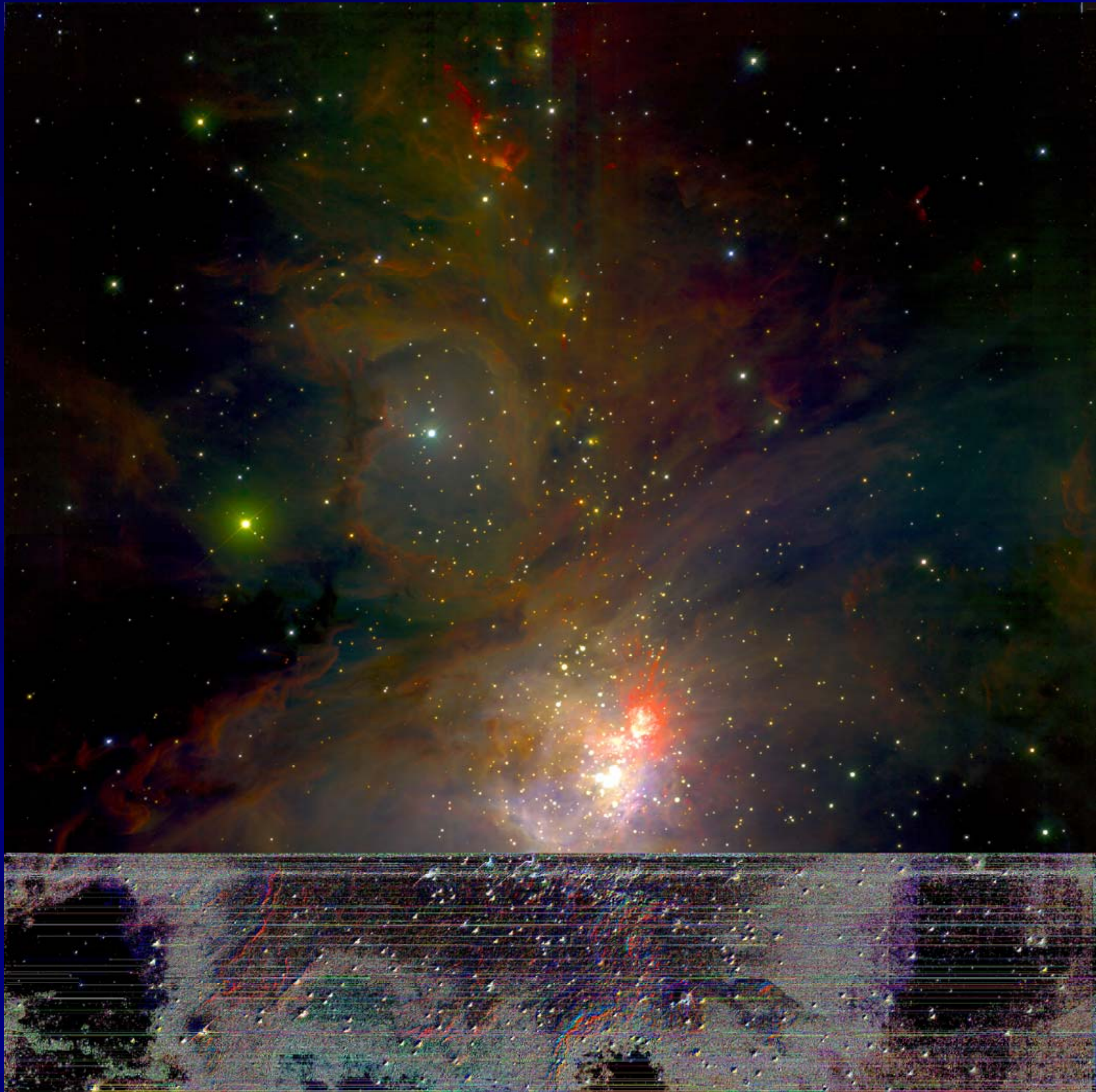
Latest news! Tests in the lab

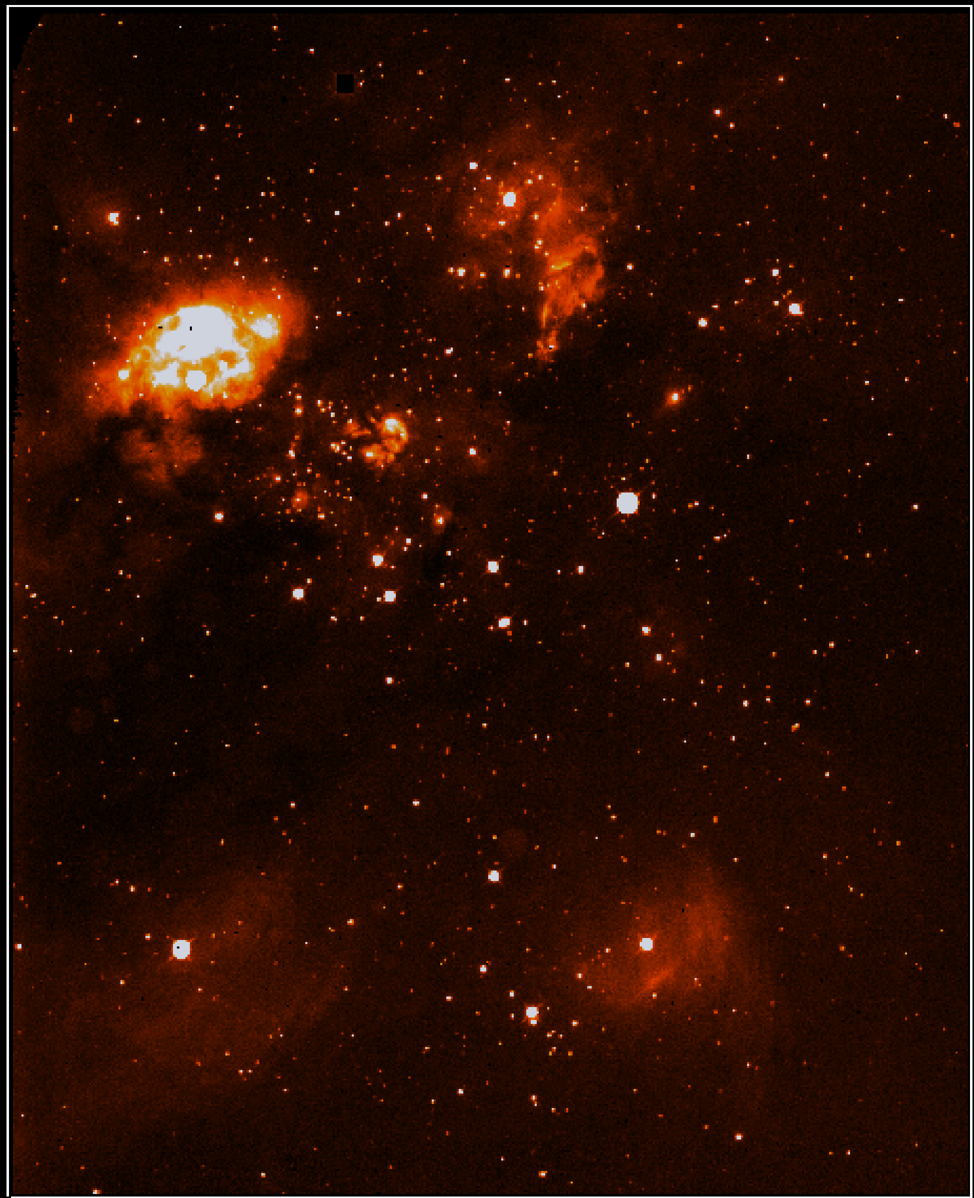
=> Engineering detector

=> 32 amps / 4 video board controller - same clocking

=> Change V_{ref} bias voltage







Star Forming Region W3A

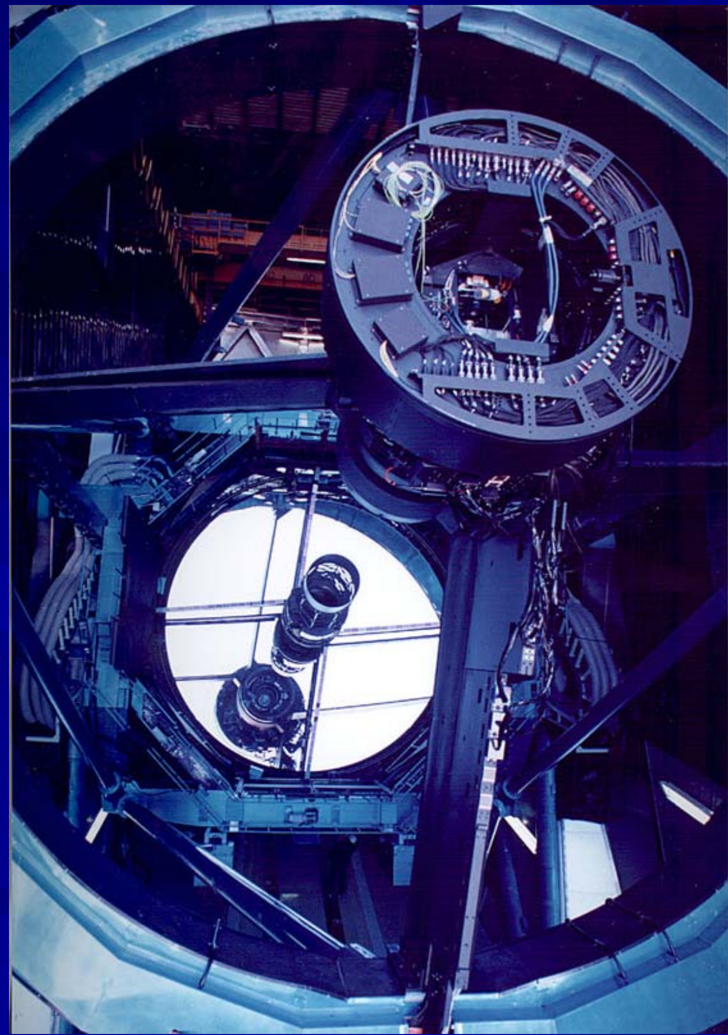
What's next?

Identify a strong scientific project with unique instrument

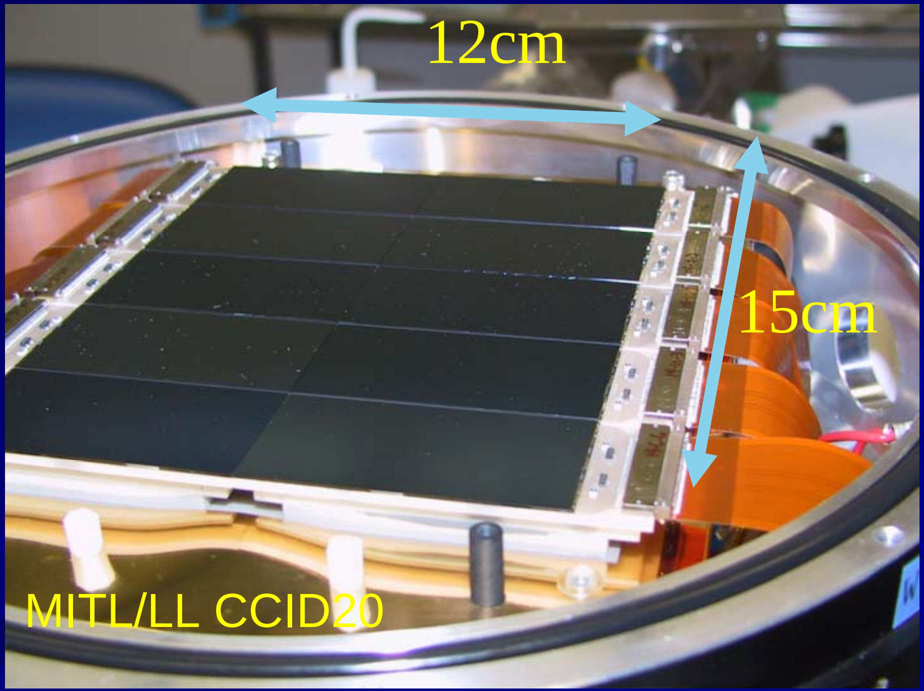
Collaboration with larger telescope

Scientifically attractive

Subaru telescope



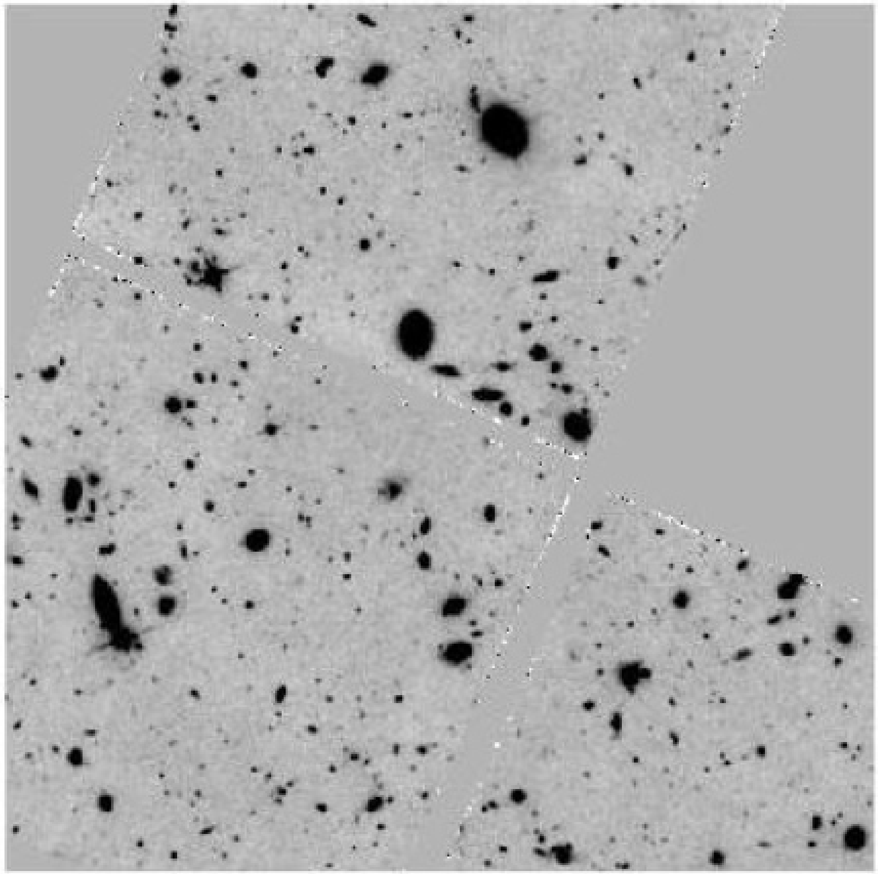
Subaru Prime Focus Camera



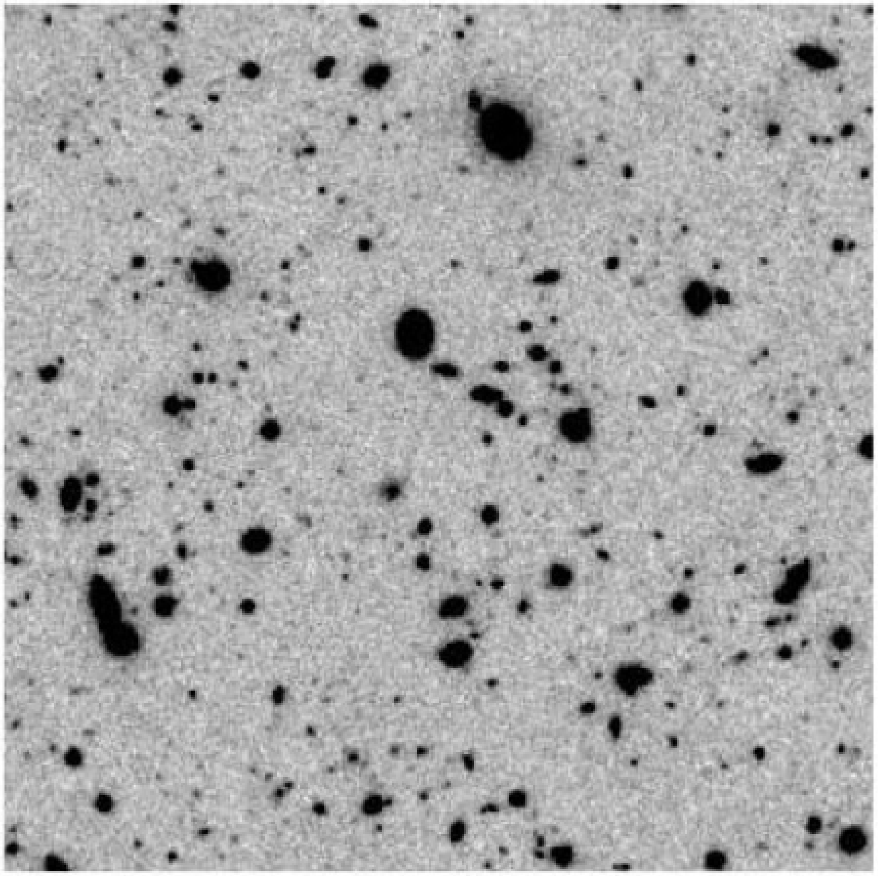
Suprime Camera

Detectors	MIT/LL 2048x4096
Number of CCDs	10 (arranged in 5x2 pattern)
Pixel size	15 um
Pixel scale	0.20"
Field of view	approx 34' x 27'
Read noise	10 e^-
Readout time	60 s
Saturation level	80 000 e^-
Number of filters	maximum of 10

Power of Suprime-Cam



HST 'wide-I' continuum



NB816 narrowband

FOV X100 larger

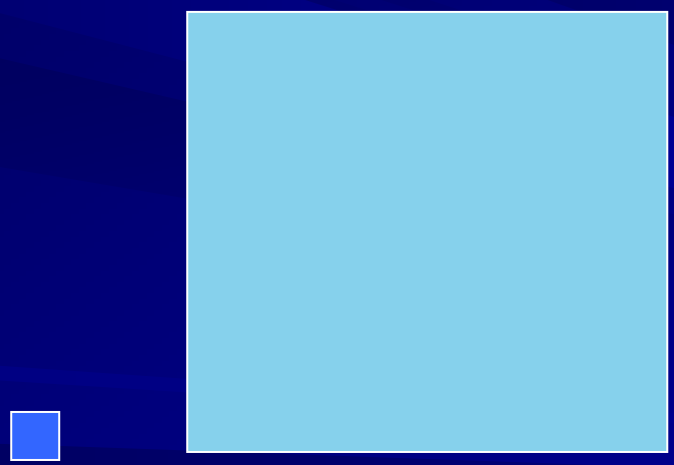
Hu & Cowie 2006 Nature

Demand of Survey Speed

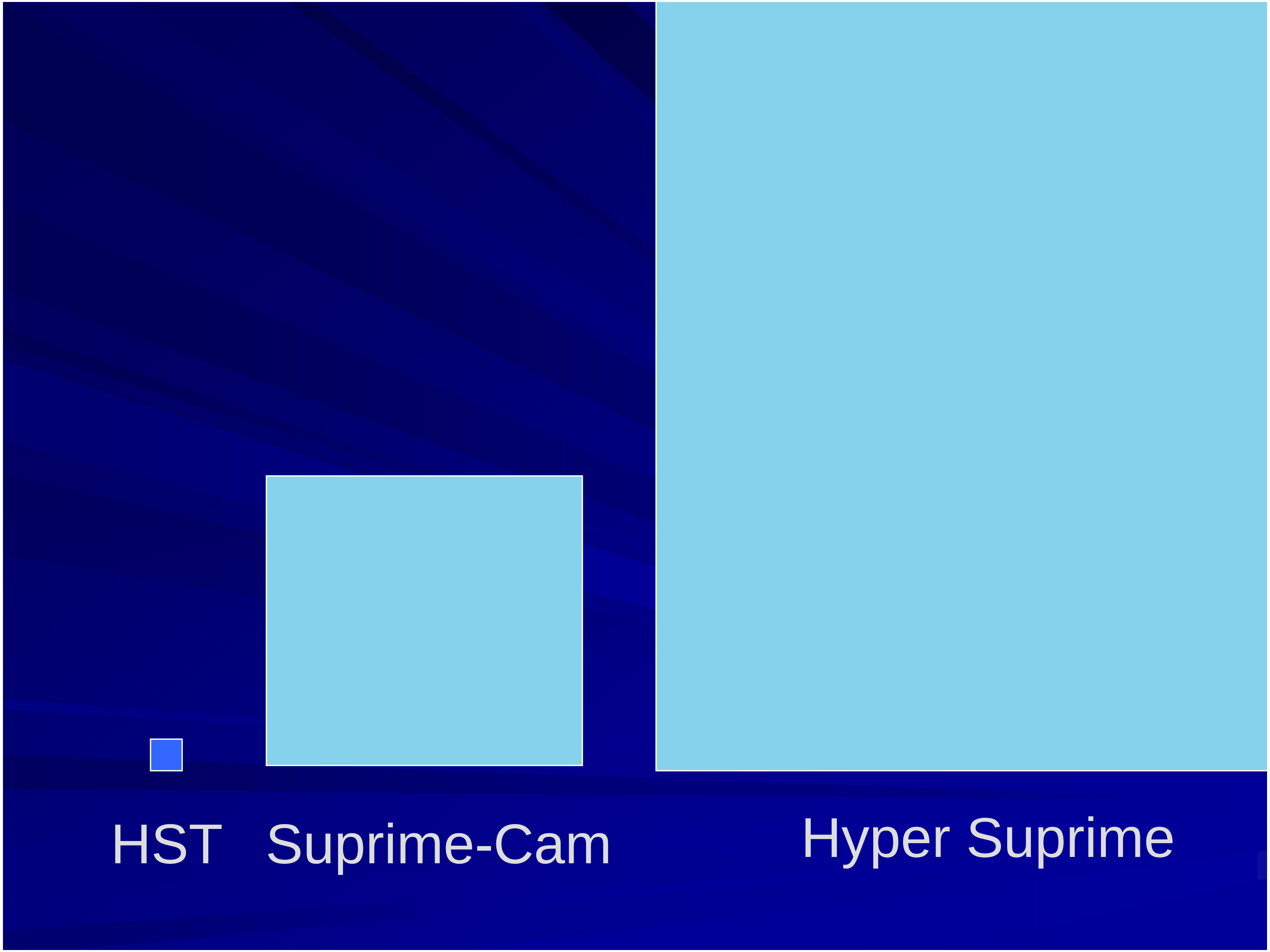
- "Dark Energy" becomes one of the central puzzle in science.
- Because of its tenuous distribution, only astronomical observation could probe its nature.
- But the demand of the survey speed is beyond the capabilities of existing facilities.

Concept of Hyper Suprime

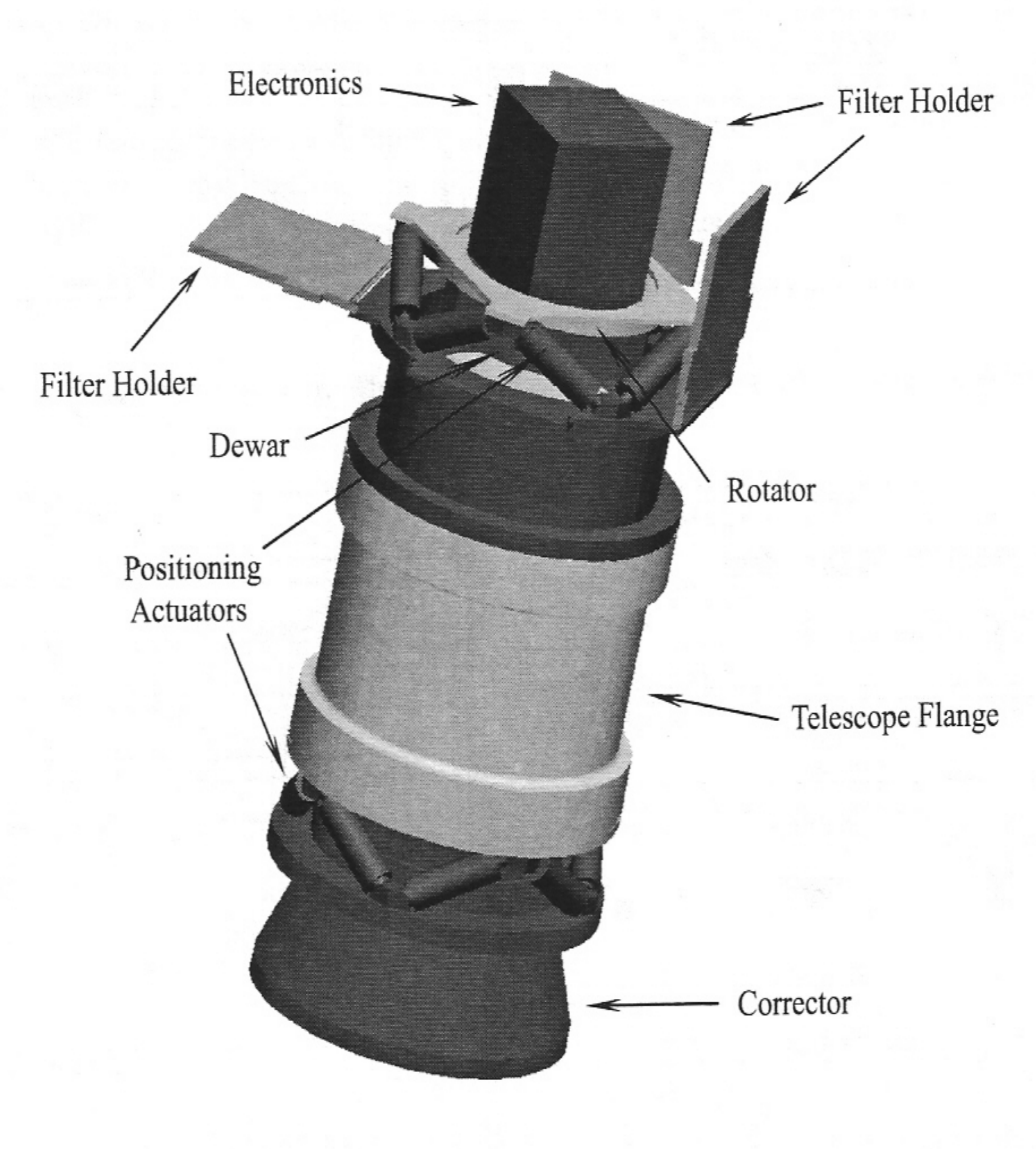
- Expanding the field of view by more than 10 times while keeping the high image quality



HST Suprime-Cam


HST
Suprime-Cam
Hyper Suprime

Hyper SuprimeCam



Detectors	Hamamatsu 2048x4096
Number of CCDs	170
Pixel size	15 um
Pixel scale	0.18"
Field of view	~~2^o~~ Probably 1.5^o
Read noise	$5\ e^-$
Readout time	10 s
Saturation level	$80\ 000\ e^-$
Number of filters	4 exchangeable

Comparison

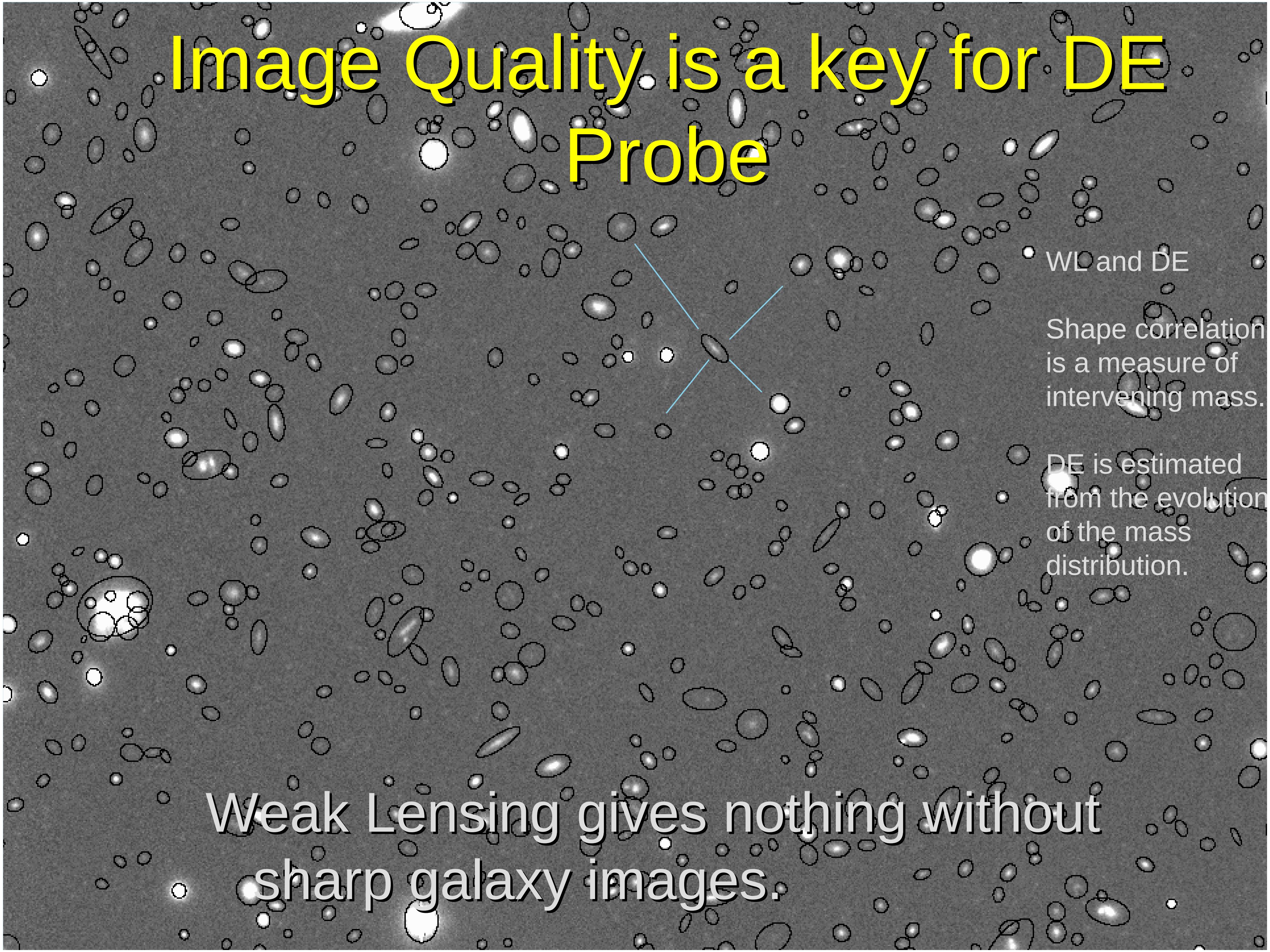
Project	AΩ	$$ [M]	Note
Pan-STARRS	13.4x4	> 50 ?	1.8m x 4 New Tel.
HS	162 (91)	~ 25 ?	8.3 m (Subaru)
LSST	329	~ 300?	6.5 m eq. New Tel.

Pre-cursor of LSST

High image quality is crucial for all the projects.

Only Subaru has a demonstrated performance.

Image Quality is a key for DE Probe



- WL and DE

Shape correlation is a measure of intervening mass.

DE is estimated from the evolution of the mass distribution.

Weak Lensing gives nothing without sharp galaxy images.

HyperSuprime: Specification

- FOV: 2.0 deg (1.4 Gpixel)
  - – 1.5 deg option considered
- Resolution: < 0.3 arcsec (lambda > 600 nm)

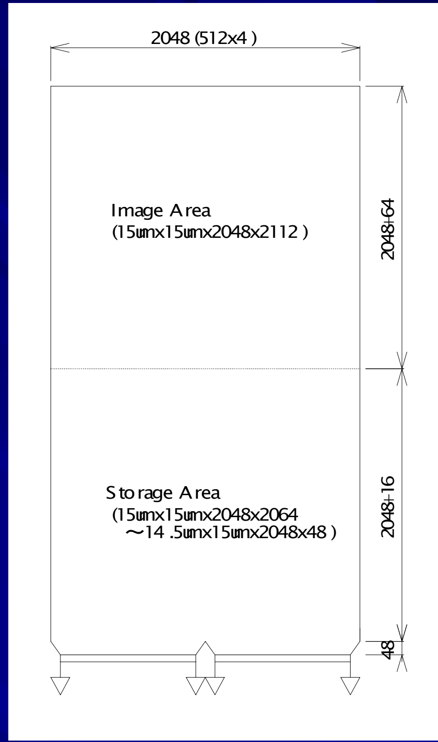
  < 0.4 arcsec (< 600 nm)
- Readout time: < 20 sec
- Weight: < 3 - 3.5 t (including lens)

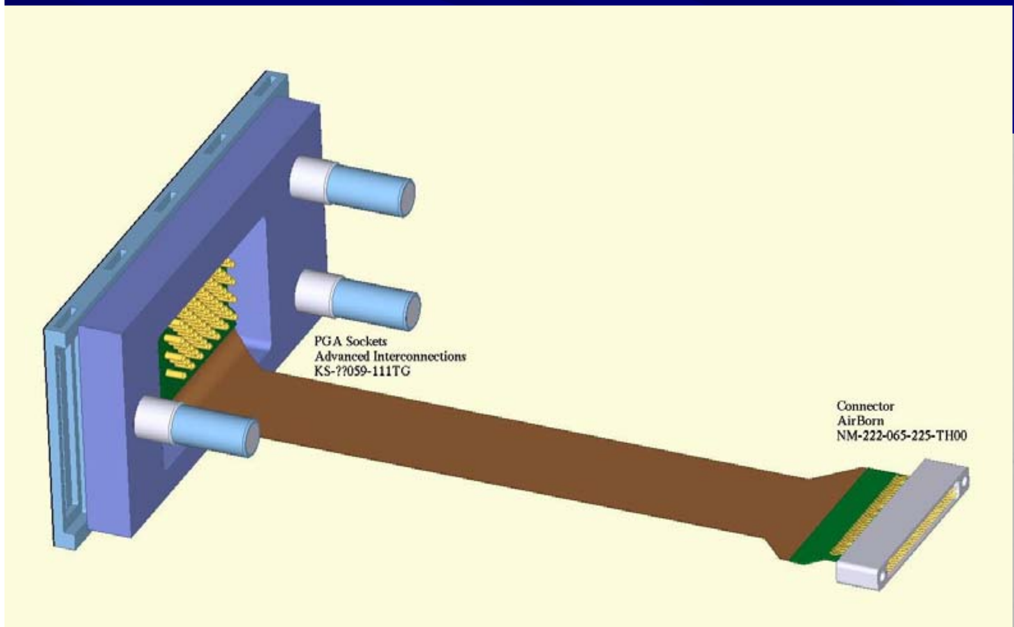
CCD

- Hamamatsu

  2k4k (15μm)

  4 output amplifier



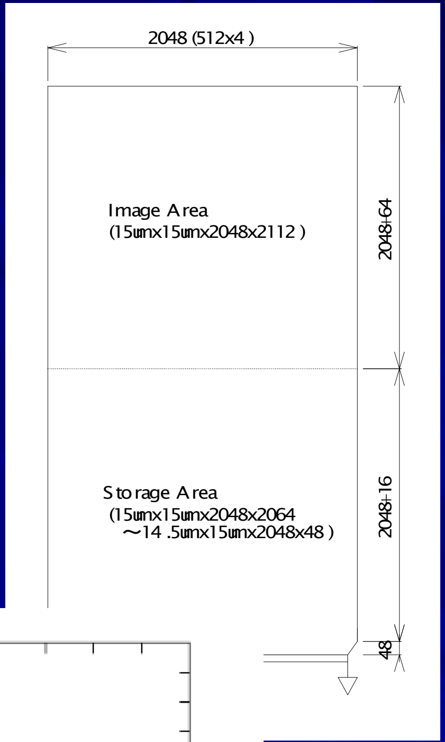


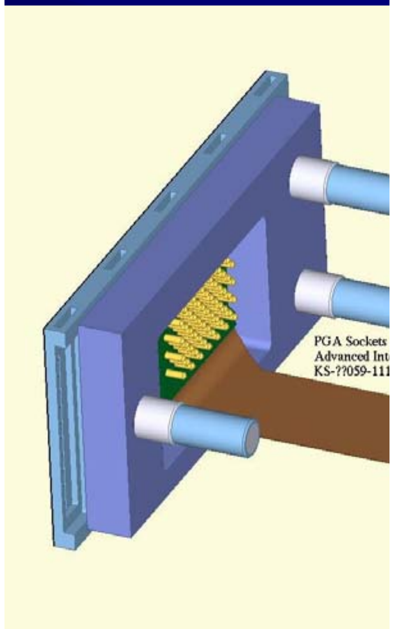
CCD

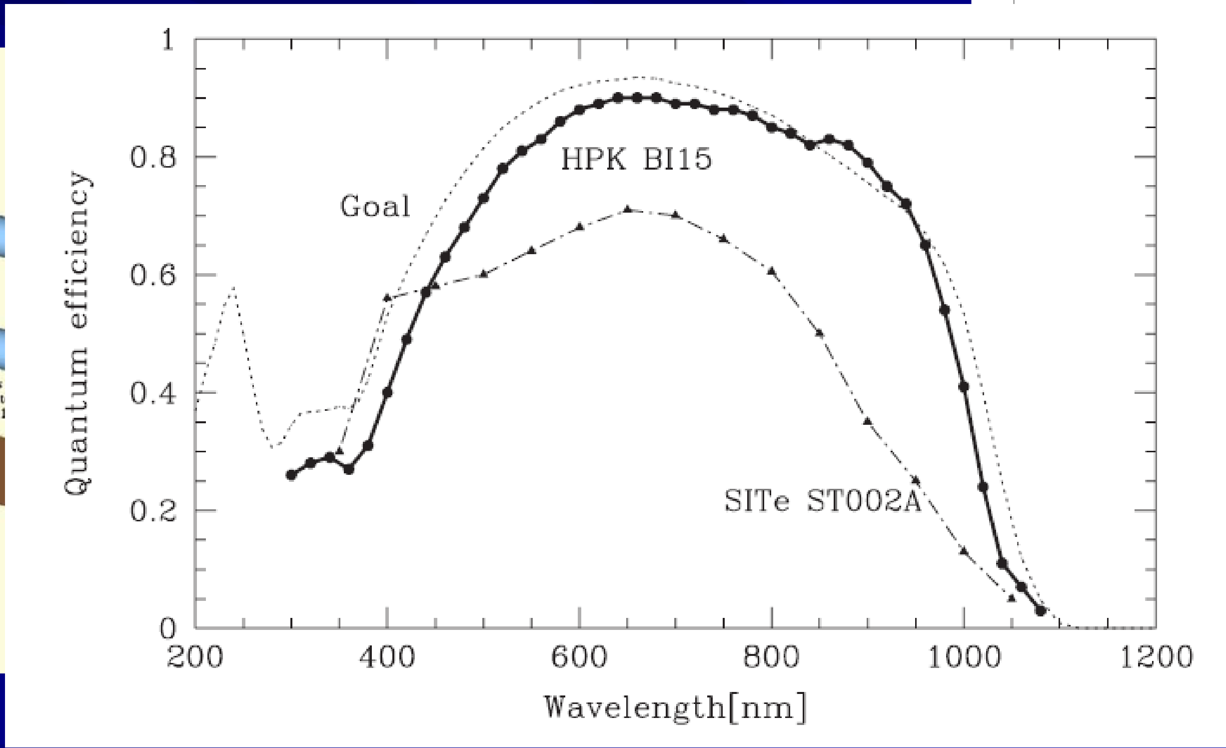
- Hamamatsu

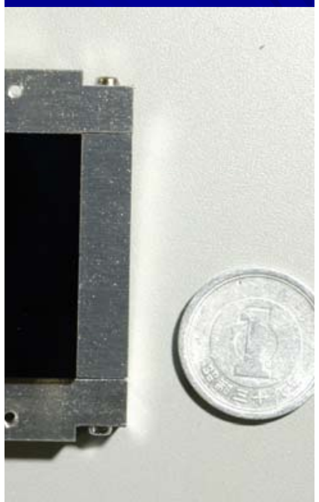
  2k4k (15μm)

  4 output amplifier

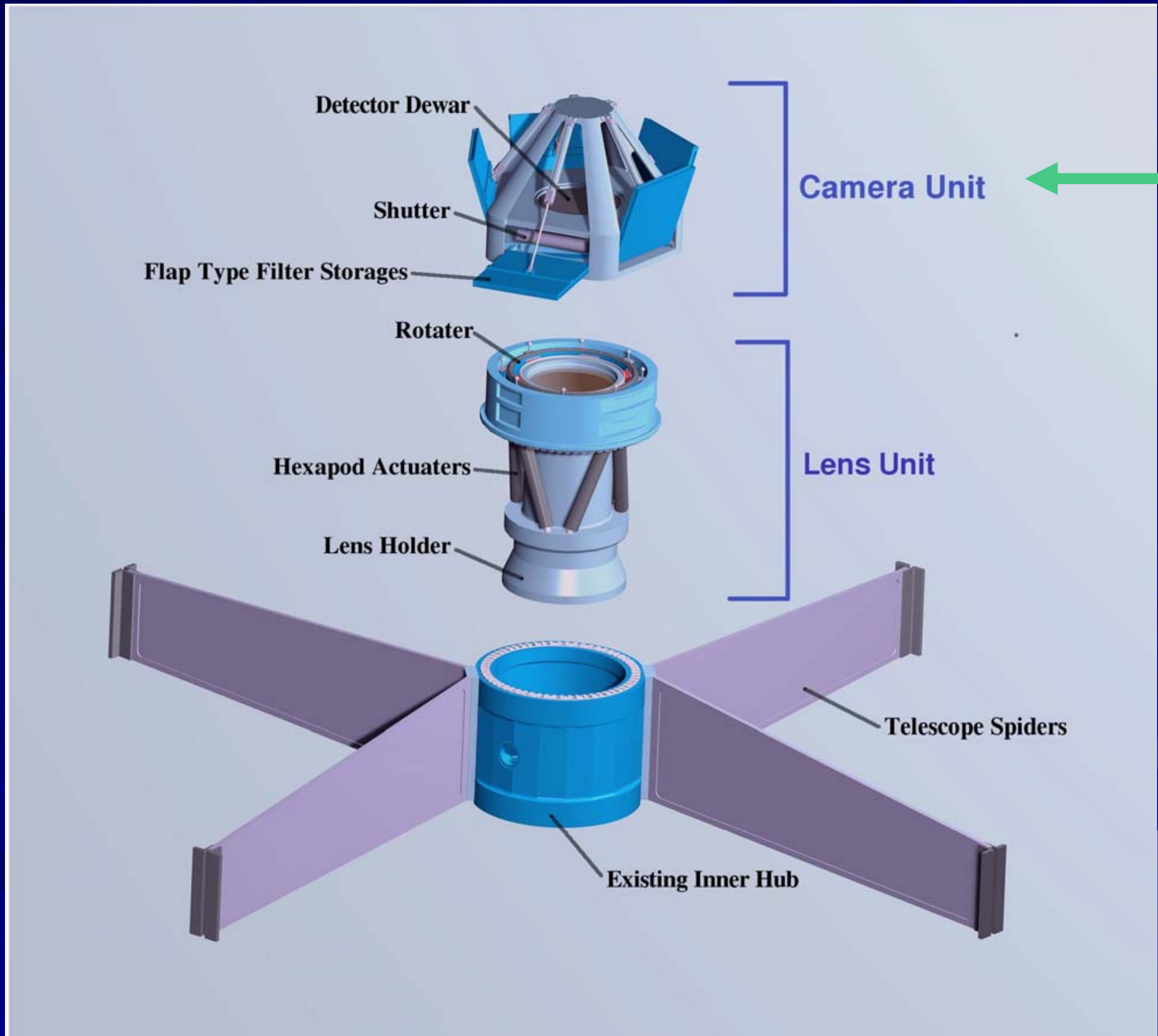








HS: Mechanical Design



Interchan-geable with WFMOS.

1.5 deg option is shown.

Challenges

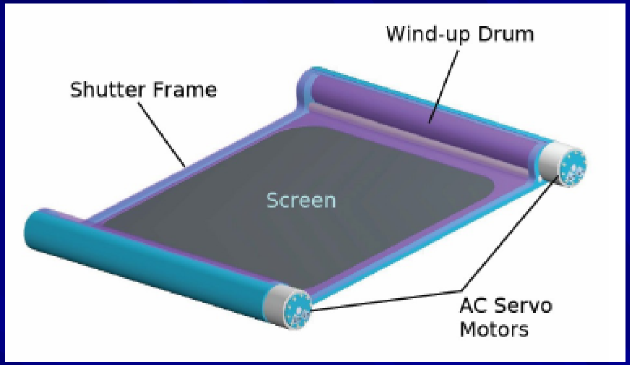
- The wide field corrector
  - Current design 0.8m (1.2m for 2^{o} option)
  - Image quality ~ 80% EE <0.3”
- The large number of CCD chips
  - 612mm focal plane size
- The large size of filters
  - Mosaic filters instead of single large one
- Heavy data flow
  - 100Gb/s data rate while reading
- Budget problem
  - ~30M USD

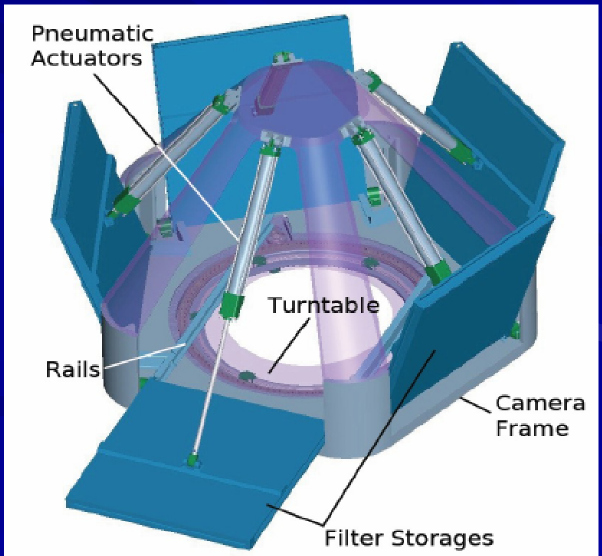
Schedule

- 06/10-07/04 : Tel. Interface Design
- 07/05 : FOV option selected
- 07/06-08/06 : Design Phase
- 08/06-10/06 : Production Phase
- 2011 : First Light

Our participation

- The CCD electronics development
  - FPA prototype
  - CCD emulator and other testing components
- Mechanical part
  - Mechanical Shutter
  - Filter exchanger with S-H testing system
- Optical design and Mechanical components
  - Local companies





AMiBA and HSC

- Synergy with AMiBA ->
  - targeted SZE cluster observations (7-element, summer 2007~)
  - Blind SZE cluster survey (13-element, 120cm,??)
- HSC weak lensing 3000 deg^2 survey
  - Cosmic shear statistic (WL tomography) as a DE probe
  - WL cluster survey as a DM/DE probe

WL (DM) and SZE (hot baryons) observations are complementary to each other!!