CFHT and Subaru Wide Field Camera

WIRCam and Beyond: OIR instrumentation plan of ASIAA

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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, CH₄ On, CH₄ Off, H₂, 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.
Science Grade Arrays

2.5mm gaps between the arrays

#54
J-QE=0.756
K-QE=0.81
Noise=19.3e⁻

#60
J-QE=0.889
K-QE=0.832
Noise=24.5e⁻

#52
J-QE=0.739
K-QE=0.813
Noise=22.0e⁻

#77
J-QE=0.71
K-QE=0.747
Noise=19.3e⁻
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

Science host

3-50Hz

Guider host
Full Mosaic Operation in Jun. 2005
## Performance

<table>
<thead>
<tr>
<th>Filter</th>
<th>Array QE</th>
<th>Optics Transmission</th>
<th>Overall throughput</th>
<th>Expected Zero-point (Vega)</th>
<th>Measured Zero-point (Vega)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>50%?</td>
<td>80%</td>
<td>27%</td>
<td>24.58</td>
<td>24.65</td>
</tr>
<tr>
<td>J</td>
<td>75%</td>
<td>75%</td>
<td>39%</td>
<td>24.96</td>
<td>25.02</td>
</tr>
<tr>
<td>H</td>
<td>75%</td>
<td>70%</td>
<td>48%</td>
<td>25.12</td>
<td>25.18</td>
</tr>
<tr>
<td>Ks</td>
<td>80%</td>
<td>69%</td>
<td>49%</td>
<td>24.37</td>
<td>24.43</td>
</tr>
</tbody>
</table>
Software Developments

![Software Development Image]
Negative and Edge Crosstalks

Median of the 32 amplifiers isolates commonalities

Edge Crosstalk

Negative Crosstalk
Latest news! Tests in the lab

=> Engineering detector

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

=> Change $V_{\text{ref}}$ 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

12cm

15cm

MITL/LL CCID20

Mitsubishi

Canon
## Suprime Camera

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detectors</td>
<td>MIT/LL 2048x4096</td>
</tr>
<tr>
<td>Number of CCDs</td>
<td>10 (arranged in 5x2 pattern)</td>
</tr>
<tr>
<td>Pixel size</td>
<td>15 um</td>
</tr>
<tr>
<td>Pixel scale</td>
<td>0.20&quot;</td>
</tr>
<tr>
<td>Field of view</td>
<td>approx 34' x 27'</td>
</tr>
<tr>
<td>Read noise</td>
<td>10 e⁻</td>
</tr>
<tr>
<td>Readout time</td>
<td>60 s</td>
</tr>
<tr>
<td>Saturation level</td>
<td>80 000 e⁻</td>
</tr>
<tr>
<td>Number of filters</td>
<td>maximum of 10</td>
</tr>
</tbody>
</table>
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
Hyper SuprimeCam

<table>
<thead>
<tr>
<th>Detectors</th>
<th>Hamamatsu 2048x4096</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of CCDs</td>
<td>170</td>
</tr>
<tr>
<td>Pixel size</td>
<td>15 um</td>
</tr>
<tr>
<td>Pixel scale</td>
<td>0.18''</td>
</tr>
<tr>
<td>Field of view</td>
<td>2° Probably 1.5°</td>
</tr>
<tr>
<td>Read noise</td>
<td>5 e⁻</td>
</tr>
<tr>
<td>Readout time</td>
<td>10 s</td>
</tr>
<tr>
<td>Saturation level</td>
<td>80 000 e⁻</td>
</tr>
<tr>
<td>Number of filters</td>
<td>4 exchangeable</td>
</tr>
</tbody>
</table>
## Comparison

<table>
<thead>
<tr>
<th>Project</th>
<th>AΩ</th>
<th>$$ [M]$$</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pan-STARRS</td>
<td>13.4x4</td>
<td>&gt; 50 ?</td>
<td>1.8m x 4 New Tel.</td>
</tr>
<tr>
<td>HS</td>
<td>162 (91)</td>
<td>~ 25 ?</td>
<td>8.3 m (Subaru)</td>
</tr>
<tr>
<td>LSST</td>
<td>329</td>
<td>~ 300?</td>
<td>6.5 m eq. New Tel.</td>
</tr>
</tbody>
</table>

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

Weak Lensing gives nothing without sharp galaxy images.

WL and DE

Shape correlation is a measure of intervening mass.

DE is estimated from the evolution of the mass distribution.
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

Interchangeable with WFMOS.

1.5 deg option is shown.
Challenges

- The wide field corrector
  - Current design 0.8m (1.2m for 2° 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!!