Early Science Results from CQUEAN Commissioning Observation

– Unique Views on Gamma Ray Bursts to High Redshift Quasars –

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CQUEAN

• Camera for Quasars in EArly uNiverse

• Fast (~1+ year) development, low cost
  (0.12 billion won) proto-type instrument for CEOU
## Basic Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science Camera CCD</strong></td>
<td>E2V Deep Depletion Chip</td>
</tr>
<tr>
<td><strong>Format and pixel size</strong></td>
<td>1024 x 1024, 0.276” (13 micron)</td>
</tr>
<tr>
<td><strong>FOV</strong></td>
<td>4.7’ x 4.7’ (with focal reducer)</td>
</tr>
<tr>
<td><strong>QE</strong></td>
<td>90% at 0.8 μm, 25% at 1 μm</td>
</tr>
<tr>
<td><strong>Readout time</strong></td>
<td>1 sec</td>
</tr>
<tr>
<td><strong>Readout noise</strong></td>
<td>8.2 DN</td>
</tr>
<tr>
<td><strong>Dark Current (@-70)</strong></td>
<td>0.1 - 0.2 e-/sec</td>
</tr>
<tr>
<td><strong>Gain</strong></td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Fringe</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Filters</strong></td>
<td>SDSS g,r,i, LSST z,Y, ts, tz</td>
</tr>
<tr>
<td><strong>Linearity</strong></td>
<td>&lt; 35,000 DN</td>
</tr>
</tbody>
</table>
Q.E.

CQUEAN Filters

- SDSS g, r, i, LSST z, Y, and custom \(i_s\) and \(i_z\) filters
- 28mm diameter, circular filters
How did SMBHs grow?

Shen et al. (2007) suggested that the fast growth of SMBHs occurred at z ~ 5.5, while the slow growth with heavy BH seeds occurred at z > 6.4.

SDSS (Shen et al. 2008) and AKARI (Im et al. 2010) data support these findings.

Basic Strategy

- Select r-band dropouts from SDSS (300,000 candidates over 3,000 deg² area)

- Cross-match with Y/J-band data from UKIDSS/LAS (3,000 candidates)

- Follow-up imaging with CQUEAN: 30-50 best candidates

Follow-up spectroscopy
High redshift quasar selection (@ z ~ 5.5, and @ z ~ 6.5)

CQUEAN@2.1-m Struve Telescope
Commissioning run  
(August 10 – 17, 2010)

- Installation of CQUEAN
- Engineering test of CQUEAN operation (modification of software, etc)
- Test observations
  - Pretty pictures
  - High redshift quasar candidates
  - Gamma Ray Bursts (GRBs)
  - Standard stars

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Stephen’s Quintet (Arp 319)
M15

M77
감마선 폭발천체 GRB 100814A (z=1.44) 
과거사진과 CQUEAN사진 비교

과거 탐사관측자료 사진 
GRB 100814A의 모습이 보이지 않음.

사전이 포착한 감마선 폭발천체의 모습.
과거에 볼 수 없었던 새로운 천체.
GRB 100814A의 영상이 선명하게 보임.

GRB 100814A Light Curve

De Pascuale, M., Im, M., Pak, S., W. Park, Y. Jeon, et al. (2010, in prep.)
Im, M., Pak, S., Park, W., Jeon, H., Kim, E., & Kim, J. (2010, GCN Circular,11093)
GRB 100816A, Short GRB at z=0.80

Im, M., Park, W., Pak, S., Jeong, H., Kim, E., & Kim, J. (2010, GCN Circular 11108)

High redshift quasar selection (@ z ~ 5.5, and @ z ~ 6.5)
Selection of Quasars at $5.3 < z < 6.2$

Limiting Magnitude, etc

<table>
<thead>
<tr>
<th>Filter</th>
<th>$\lambda_{50}$ (μm)</th>
<th>Sky Count (DN/sec)</th>
<th>Sky Brightness (mag/arcsec²)</th>
<th>Magnitude Limit (mag at 5σ, 1hr integration)</th>
<th>$T_{eq}$ (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>0.623</td>
<td>1.2</td>
<td>21.3</td>
<td>24.1</td>
<td>56.0</td>
</tr>
<tr>
<td>i</td>
<td>0.768</td>
<td>4.6</td>
<td>20.6</td>
<td>24.3</td>
<td>14.6</td>
</tr>
<tr>
<td>is</td>
<td>0.739</td>
<td>5.0</td>
<td>20.3</td>
<td>24.0</td>
<td>13.4</td>
</tr>
<tr>
<td>iz</td>
<td>0.849</td>
<td>8.0</td>
<td>19.8</td>
<td>23.8</td>
<td>8.4</td>
</tr>
<tr>
<td>z</td>
<td>0.877</td>
<td>5.2</td>
<td>19.6</td>
<td>23.4</td>
<td>12.9</td>
</tr>
<tr>
<td>Y</td>
<td>0.991</td>
<td>3.8</td>
<td>18.5</td>
<td>22.1</td>
<td>17.7</td>
</tr>
</tbody>
</table>

Numbers are for a dark night
$T_{eq}$: time when RN = Sky noise
Future plan

- 60 nights per year on 2.1m
- Observe ~4000 targets over 4000 deg$^2$
  ~30-50 Quasars at z ~ 5.5
  ~ 5 Quasars at z > 6.5
- ~10 - 15 GRBs per year
- Open for UT astronomers