VIRUS: Replication as an upgrade path

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Hobby-Eberly Telescope (HET)

* 9.2m effective aperture
* Fixed elevation axis at 55° (think Arecibo)
  access to ~81% of the local visible sky
* Segmented Mirror (91 segments, 1m diameter)
* Limited tracks (~2-3 hrs per night per source)
* Queue observing
* Use Lyman alpha emitters (LAEs) to place a direct constraint on the density of dark energy at $z > 2$

* Measure the expansion rate to percent accuracy at $z > 2$

* .1% constraint on curvature

60 sq deg in 420
(Net fill factor in survey is 1/7)
Wide-Field Upgrade
VIRUS

A replicated spectrograph for HETDEX

* 150 identical channels
* 33,600 fibers
* 22 arcminute field
* 350–550nm
HETDEX

Observations and Data
3 years survey duration starting in 2014

* 700,000 LAEs in 9 cubic Gpc volume $1.9 < z < 3.5$
* 600,000 [OII] emitters $z < 0.48$
* 400,000 other galaxies, 7000 QSOs $z < 3$
* 250,000 stars, 20,000 NVSS radio sources
* 2000 galaxy groups and clusters
* 5000 galaxies w/resolved kinematics
Why Replication?

Increased technical difficulty, cost and risk associated with larger optics

Scalability - Small number for smaller telescope, larger number for upcoming 30m class telescopes

33,600 fibers * .250mm = 8.4m slit
VIRUS-P(prototype)

(now the Mitchell Spectrograph)

* 246 fibers with 1/3 fill factor
  (3 dithers for full coverage)
* 100 x 102 arcsecond FOV
* 4.16 arcsecond per fiber
* 4 grating options (340-685 nm)
* HET or 2.7m
* Test platform for replicated design

Hill, McQueen 2008
## VIRUS & LRS 2

<table>
<thead>
<tr>
<th></th>
<th>VIRUS</th>
<th>LRS2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength Range</td>
<td>350-550nm</td>
<td>350-1000nm</td>
</tr>
<tr>
<td>Resolution</td>
<td>~700</td>
<td>~1800 (varies by channel)</td>
</tr>
<tr>
<td>Fiber size</td>
<td>1.5 arcsec</td>
<td>&lt; 1 arcsec</td>
</tr>
<tr>
<td>Speed</td>
<td>f/3.65</td>
<td>f/3.65</td>
</tr>
<tr>
<td>Dispersion</td>
<td>VPH gratings</td>
<td>Grisms</td>
</tr>
<tr>
<td>Input Head Design</td>
<td>Dither to Fill IFU (1/3 FF)</td>
<td>Lenslet coupled IFU</td>
</tr>
<tr>
<td>Field Size</td>
<td>22 arcmin diameter</td>
<td>7&quot;x12&quot;</td>
</tr>
<tr>
<td># of Fibers</td>
<td>33,600</td>
<td>287 (total)</td>
</tr>
<tr>
<td></td>
<td>(224 per channel)</td>
<td></td>
</tr>
<tr>
<td>Beam size</td>
<td>115mm</td>
<td>115mm</td>
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</table>

Monday, April 1, 13
Spectrograph (Unit) Components

We are building 75
Challenges of Replication

Repeatability, record keeping, "industrialization", repetition
VIRUS

Assembly & Alignment

Monday, April 1, 13
## Detectors - Testing & Multiplexing

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter</th>
<th>Value</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>1</td>
<td>Number of Pixels</td>
<td>2064 x 2064</td>
<td>3.1</td>
</tr>
<tr>
<td>2</td>
<td>Pixel Size</td>
<td>15 μm x 15 μm</td>
<td>3.1</td>
</tr>
<tr>
<td>3</td>
<td>Fill Factor</td>
<td>100%</td>
<td>3.1</td>
</tr>
<tr>
<td>4</td>
<td>Image Area</td>
<td>30.72 mm x 30.72 mm</td>
<td>3.1</td>
</tr>
<tr>
<td>5</td>
<td>Device Type</td>
<td>Thinned backside illuminated</td>
<td>3.3</td>
</tr>
<tr>
<td>6</td>
<td>Quantum Efficiency</td>
<td>≥ 50% (wavelength dependent between 350 nm and 650 nm)</td>
<td>3.5</td>
</tr>
<tr>
<td>7</td>
<td>Anti-reflection Coating</td>
<td>Yes</td>
<td>3.7</td>
</tr>
<tr>
<td>8</td>
<td>Full Well Capacity</td>
<td>≥ 65,536 electrons</td>
<td>3.8</td>
</tr>
<tr>
<td>9</td>
<td>Dark Count</td>
<td>&lt; 1 electron per pixel within a 600 second integration time</td>
<td>3.10</td>
</tr>
<tr>
<td>10</td>
<td>Charge Transfer Efficiency</td>
<td>&gt; 0.99999</td>
<td>3.12</td>
</tr>
<tr>
<td>11</td>
<td>Readout Noise</td>
<td>≤ 4.2 electrons for any set of CCD and readout electronics</td>
<td>3.5 &amp; 3.18</td>
</tr>
<tr>
<td>12</td>
<td>Flatness</td>
<td>Active area surface shall be flat to within ±10 μm with respect to the best fit plane that passes through this surface</td>
<td>4.1</td>
</tr>
<tr>
<td>13</td>
<td>Operating Temperature</td>
<td>Between -110°C and -90°C</td>
<td>6.1</td>
</tr>
</tbody>
</table>
Ensemble Results

First 16 Detectors
Image quality meets specifications and provides clear separation of spectra

Working with MPE to generate more data as input for refinement in CURE data reduction pipeline
Camera Mirror Glue up

Detector Assembly Jig

Camera Mirror Assemblies + Installed Spider (Cryostat Base)
Invar “spider” support with CCD and field flattener installed

Field flattener being aligned during glue-up

Flex circuit and other electronics parts
VIXENS (VIRUS–P Investigation of the Extreme Environments of Starbursts)

Heiderman et al.

Star Formation Rate (M_☉ yr⁻¹)

10 50 100 300

Early Interaction Phase

ARP 105
ARP 104
VV 769
ARP 298
ARP 240

Mid-Interaction Phase

ARP 91
ARP 242
VV 219
VV 253
VV 731

Late Interaction Phase

ARP 157
ARP 81
ARP 220
ARP 299

log Gas Surface Density (M_☉ pc⁻²)

2 3 4 5

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VIRUS Support Structure

Cryogenic System
Measure BAO on galaxy power spectrum

Constrain dark energy equation of state