The DESpec spectrographs as an evolution of VIRUS, the HETDEX spectrographs

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May 31, 2012
HETDEX science goals

- Hobby-Eberly Telescope Dark Energy Experiment
  - Constrain expansion history over $1.9 < z < 3.5$
  - Direct detection of dark energy at $z \sim 2.5$ even if it’s a cosmological constant
  - $0.1\%$ constraint on curvature
  - Determine whether dark energy evolves with time
- Tracers are Ly-α emitting galaxies
  - Numerous, easily detected with integral field spectrograph
HETDEX observing plan

- Blind survey with 150+ integral field spectrographs, known as VIRUS
  - 33,600 spectra per exposure
  - 350 – 550 nm
  - Line flux limit $3.5 \times 10^{-17}$ and $m_{AB} \approx 22$
- 420 sq. deg. area survey will contain spectroscopy of:
  - 0.8 million LAEs in 9 cubic Gpc volume $1.9 < z < 3.5$
  - 1 million [OII] emitters $z < 0.48$
  - 0.4 million other galaxies
  - 0.25 million stars
  - 2000 galaxy clusters
  - 7000 QSOs $z < 3.5$
  - 20,000 NVSS radio sources
HETDEX observing plan

1.5” fiber dia

IFU 448 fibers
50 x 50 arcsec

22 arcmin field of view
33,600 spectra at a time

HETDEX Survey
covers 420 square degrees
HETDEX is:

- Major telescope upgrade
  - Replace entire top end of telescope
- New instrument, VIRUS
  - 150+ fiber-fed unit spectrographs
- HETDEX survey observations
  - Software/data analysis
    - Data will be public
Telescope upgrade

- Wide Field Upgrade of HET to 22 arcmin FoV and 10 m pupil
Telescope upgrade

- Wide Field Upgrade of HET to 22 arcmin FoV and 10 m pupil
Nine IFUs have been built by AIP and delivered to UT for testing.
Visible Integral-field Replicable Unit Spectrograph (VIRUS)

- The first highly-replicated instrument in optical astronomy
- 150+ channel fiber-fed Integral Field Spectrograph placing >33,000 1.5” dia fibers on sky
- 350-550 nm coverage and R~700
Texas A&M’s role in HETDEX

- Participate in optical and mechanical design of VIRUS
- Fabrication and procurement of VIRUS components
- Assemble VIRUS unit spectrographs
- Optically align instruments in lab
- Ship to McDonald
Participate in optical and mechanical design of VIRUS

- Simple design
  - Single reflection spherical collimator
  - Schmidt camera
    - Two lenses + one spherical mirror
  - VPH grating
- High throughput

Unit spectrographs packaged in pairs
Fabrication and procurement of VIRUS components
Assemble VIRUS unit spectrographs
Optically align instruments in lab
Ship to McDonald

- Telescope taken down for HETDEX installation January 2013
- First 20 spectrographs completed and shipped to telescope March 2013
Flexibility of VIRUS design

- VIRUS design is adaptable to almost any fiber-fed spectrograph system
  - Easy to change resolution, wavelength range, etc. with simple redesigns
- Has already been used as basis of new spectrograph design
  - LRS$_2$
LRS2 concept

- LRS2 will be the first VIRUS adaptation
  - Consists of two unit pairs, LRS2-B (350 – 650 nm) and LRS2-R (650 – 1100 nm)
  - R~1800
- Work required for LRS2-R:
  - Replace grating with grism dispersers
  - Customize optical coatings
DESpec from VIRUS?

- Same could be done for DESpec
  - Change grating
  - Reoptimize coatings
  - Refractive camera?

Emily Martin’s refractive camera design
DESpec unit spectrograph

- 600-1000nm coverage using DES 2Kx4K CCD
- Roughly 3 pixels per resolution element (R~3334 at 1000nm; 0.1nm/pixel dispersion)
- Refractive camera?
  - Larger detector obscures more light in a reflective design

- Final specs easily changed at this point
  - Depends on the science!
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Single-Arm Spectrograph (A)</th>
<th>Single-Arm Spectrograph (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber Diameter</td>
<td>80 mm (1.4”)</td>
<td>80 mm</td>
</tr>
<tr>
<td>Wavelength Range (nm)</td>
<td>600&lt;l&lt;1000</td>
<td>550&lt;l&lt;950</td>
</tr>
<tr>
<td>CCD</td>
<td>DECam 2kx4k</td>
<td>DECam 2kx4k</td>
</tr>
<tr>
<td>Resolution (Dl nm/pixel) (use 4000 pixels)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td># pixels/fiber</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Camera f/#</td>
<td>f/1.6 = (2.9*45/80)</td>
<td>f/1.6</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>3334 @ 1000 nm</td>
<td>3167 @ 950 nm</td>
</tr>
<tr>
<td>Camera Type</td>
<td>VIRUS</td>
<td>VIRUS</td>
</tr>
</tbody>
</table>

### One-arm DESpec spectrograph specs

### Two-arm DESpec spectrograph specs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Blue Side</th>
<th>Red Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber Diameter</td>
<td>100 mm (1.75&quot;)</td>
<td></td>
</tr>
<tr>
<td>Wavelength Range (nm)</td>
<td>500&lt;l&lt;760</td>
<td>760&lt;l&lt;1050</td>
</tr>
<tr>
<td>CCD</td>
<td>E2V or DECam 2kx4k</td>
<td>DECam 2kx4k</td>
</tr>
<tr>
<td>Resolution (Dl nm/pixel) (use 4000 pixels)</td>
<td>0.065</td>
<td>0.0725</td>
</tr>
<tr>
<td># pixels/fiber</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Camera f/#</td>
<td>f/2.2</td>
<td>f/1.7</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>1923 @ 625 nm</td>
<td>3276 @ 950 nm, 3621 @ 1050 nm</td>
</tr>
<tr>
<td>Camera Type</td>
<td>Reflective or refractive</td>
<td></td>
</tr>
</tbody>
</table>
Estimated cost of DESpec spectrographs

- Need ~10 unit spectrographs
  - ~4000 fibers in focal plane
  - ~400 fibers per unit spectrograph
- VIRUS unit cost is ~$100K
  - Without detector systems
- Total cost for DESpec unit spectrographs after redesign not expected to exceed $200K

- Total cost: $2M
Summary

- VIRUS design could be easily and relatively cheaply adapted to DESpec spectrographs
- Would need ~10 spectrographs
- Cost ~$2M
- 3-4 years of effort in redesign and assembly