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

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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

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HETDEX observing plan

- Blind survey with 150+ integral field spectrographs, known as VIRUS
  - 33,600 spectra per exposure
  - 350 – 550 nm
  - Line flux limit 3.5e-17 and m_{AB}~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

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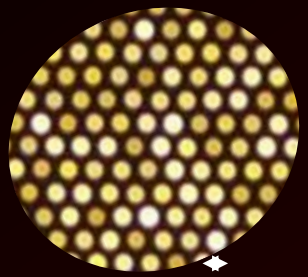
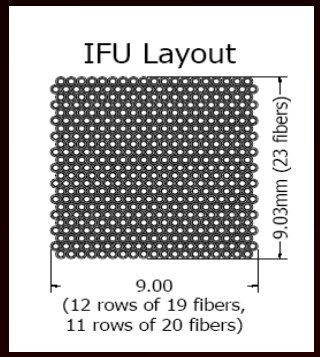
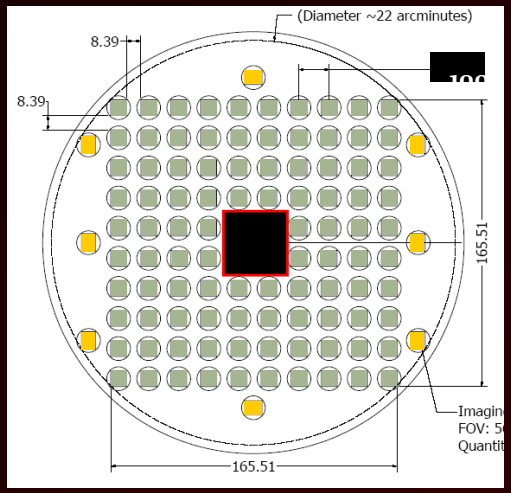
HETDEX observing plan



1.5” fiber dia

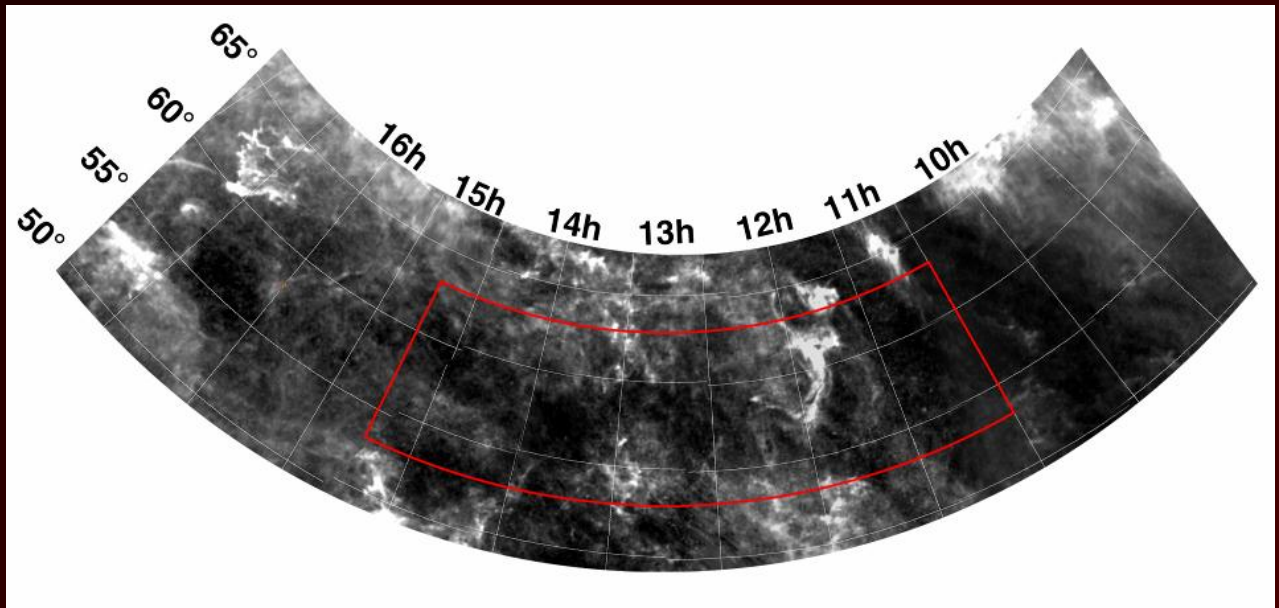


IFU 448 fibers
50 x 50 arcsec



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

HETDEX Survey covers 420 square degrees



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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

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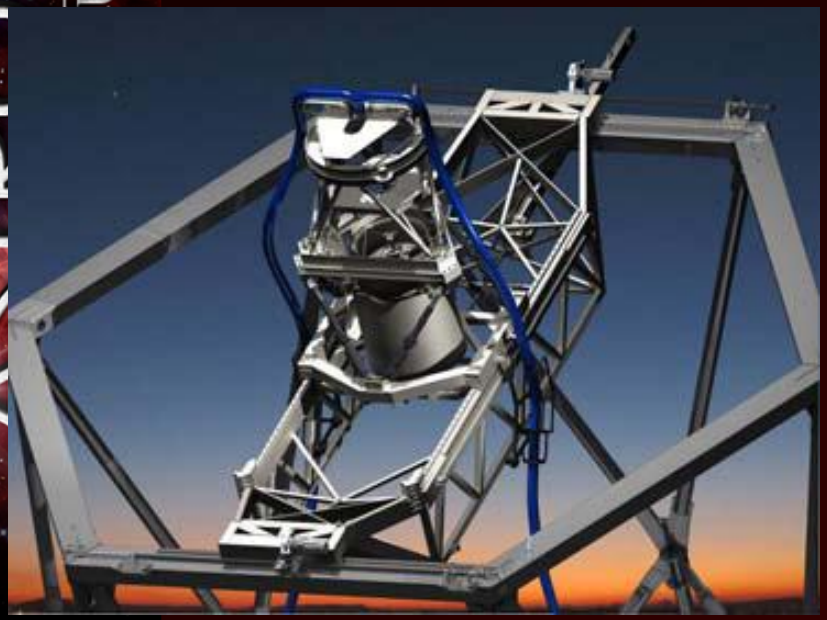
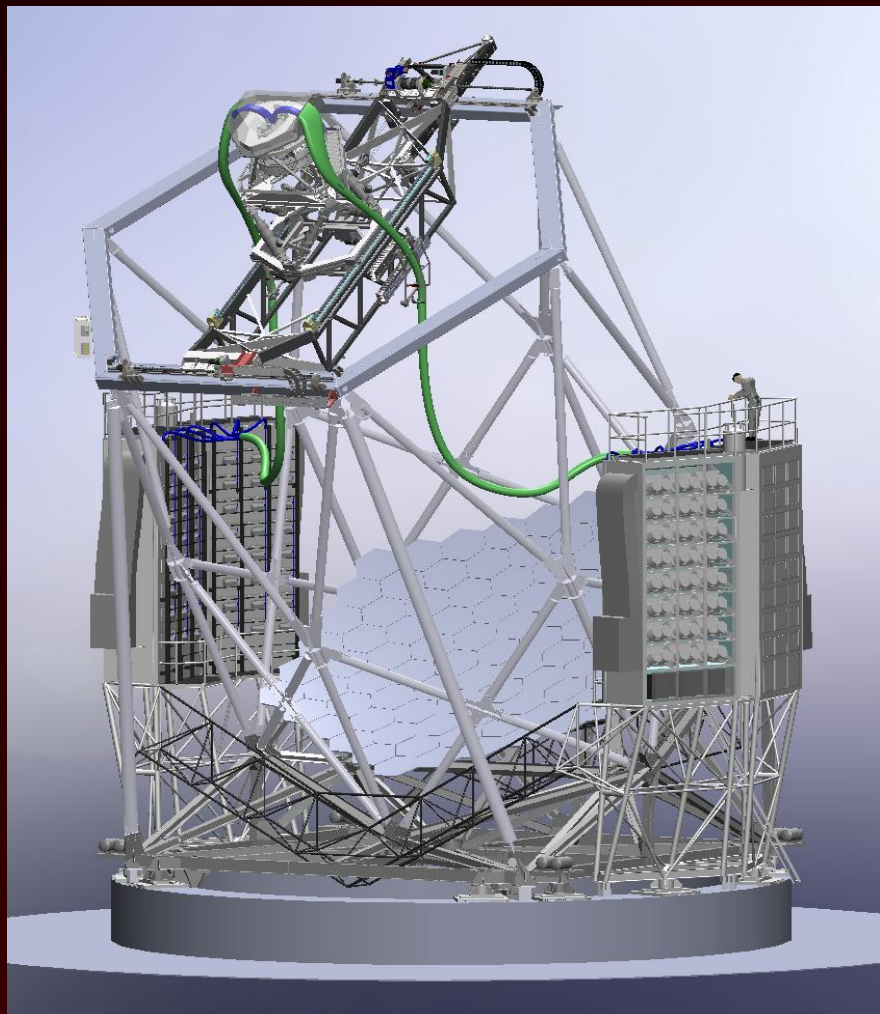
Telescope upgrade

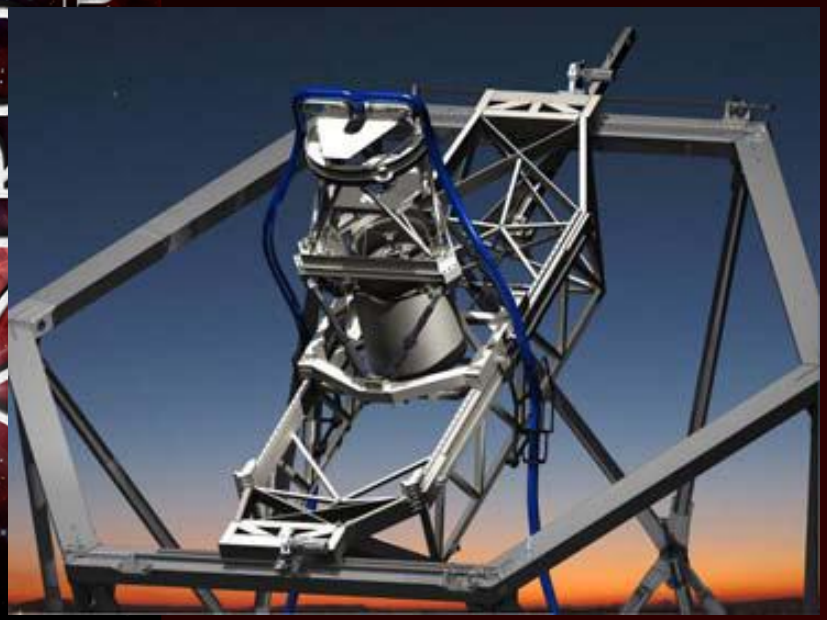
- Wide Field Upgrade of HET to 22 arcmin FoV and 10 m pupil

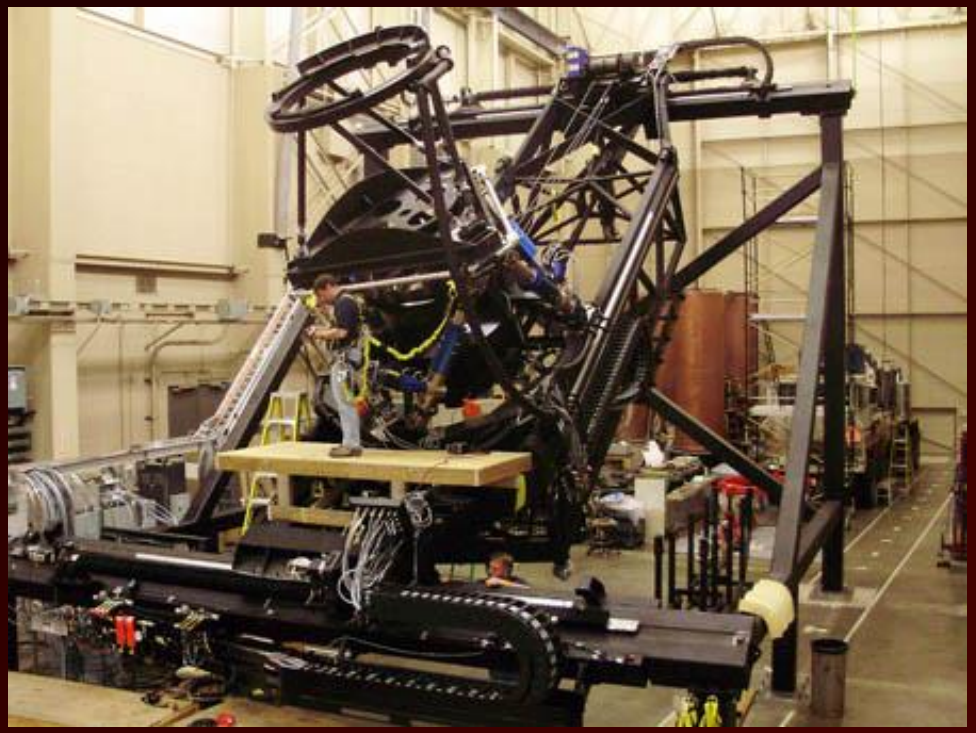




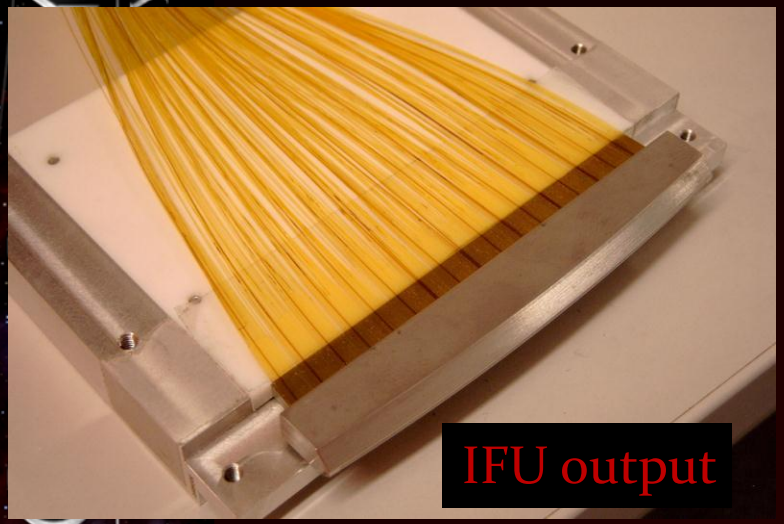
Telescope upgrade

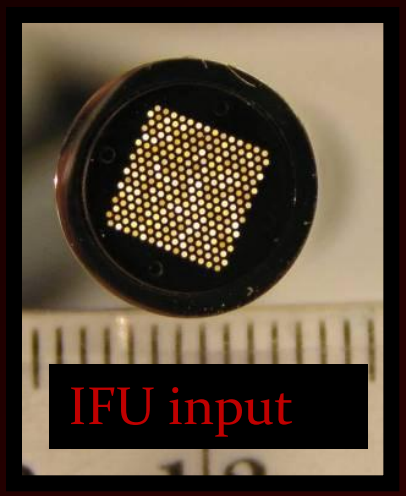
- Wide Field Upgrade of HET to 22 arcmin FoV and 10 m pupil



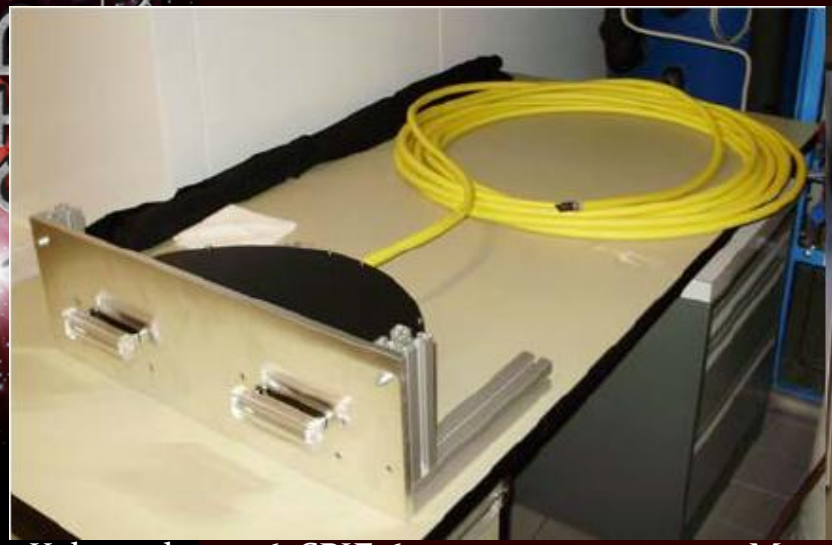


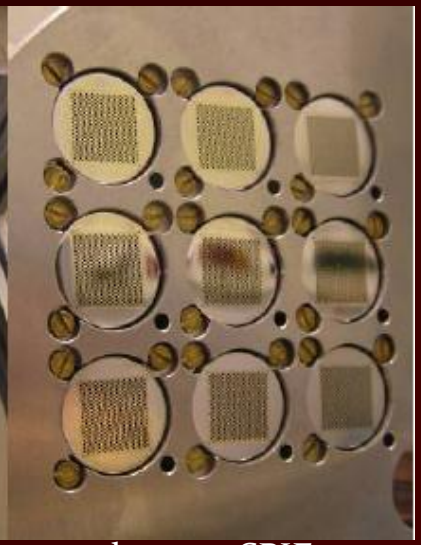
Fiber bundles





Nine IFUs have been built by AIP and delivered to UT for testing

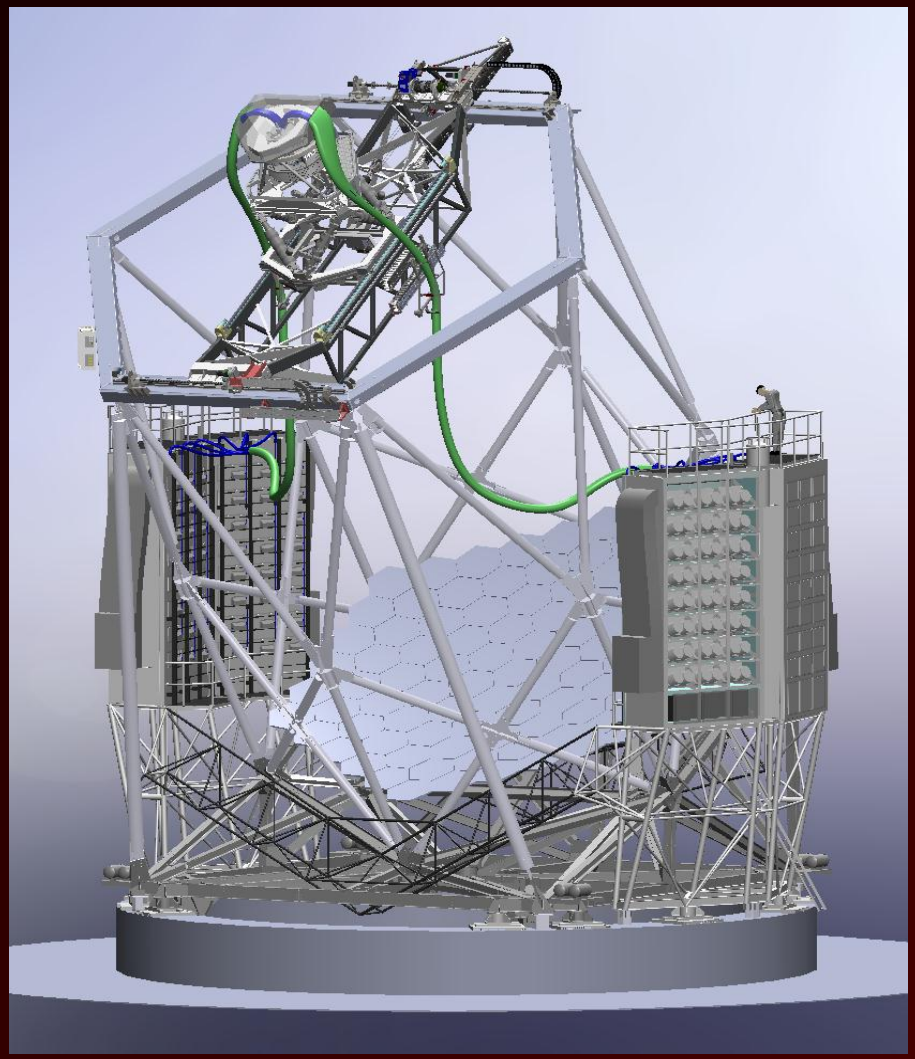




Kelz et al., 2006, SPIE 6273-121; Murphy et al., 2008, SPIE 7018-104; Soukup et al., 2010, SPIE 7735-180

VIRUS

- 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



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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

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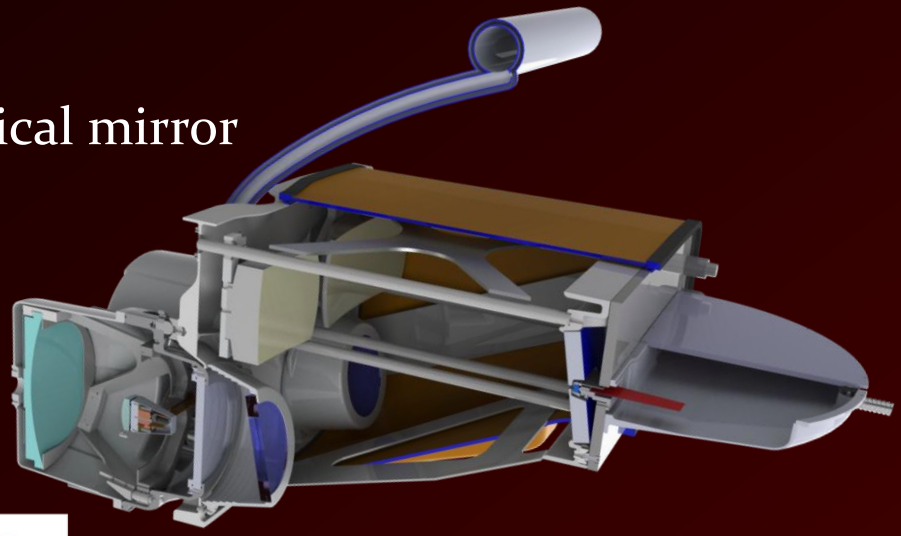
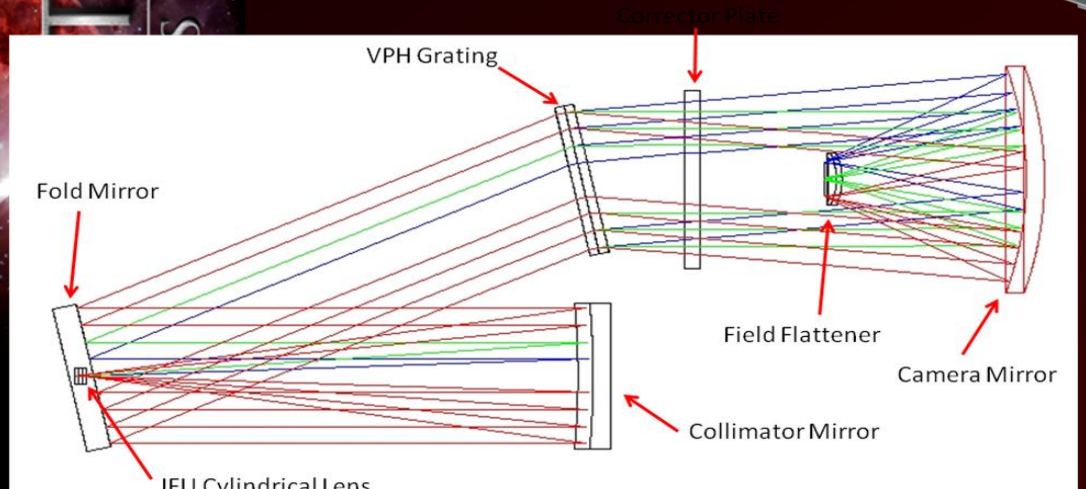
Participate in optical and mechanical design of VIRUS

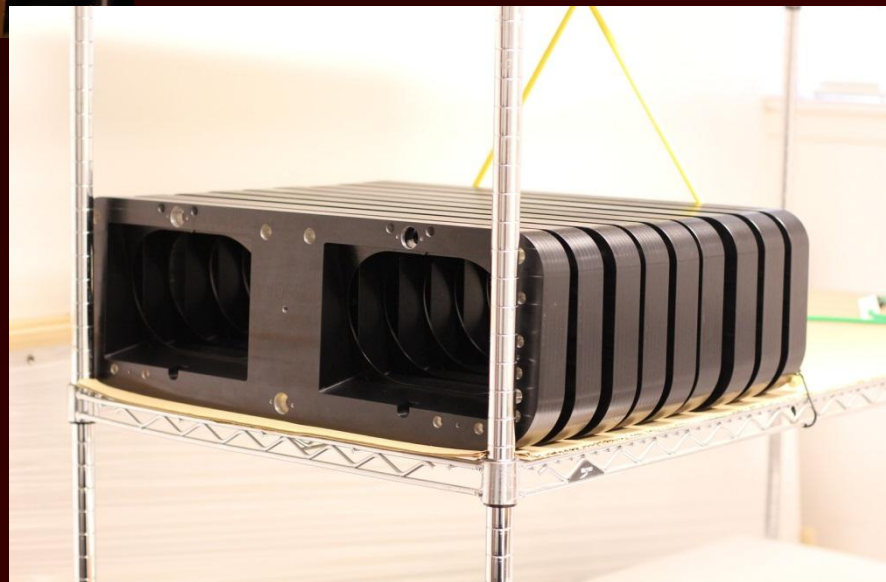
- Simple design
  - Single reflection spherical collimator
  - Schmidt camera
    - Two lenses + one spherical mirror
  - VPH grating
- High throughput





Unit spectrographs packaged in pairs

Fabrication and procurement of VIRUS components



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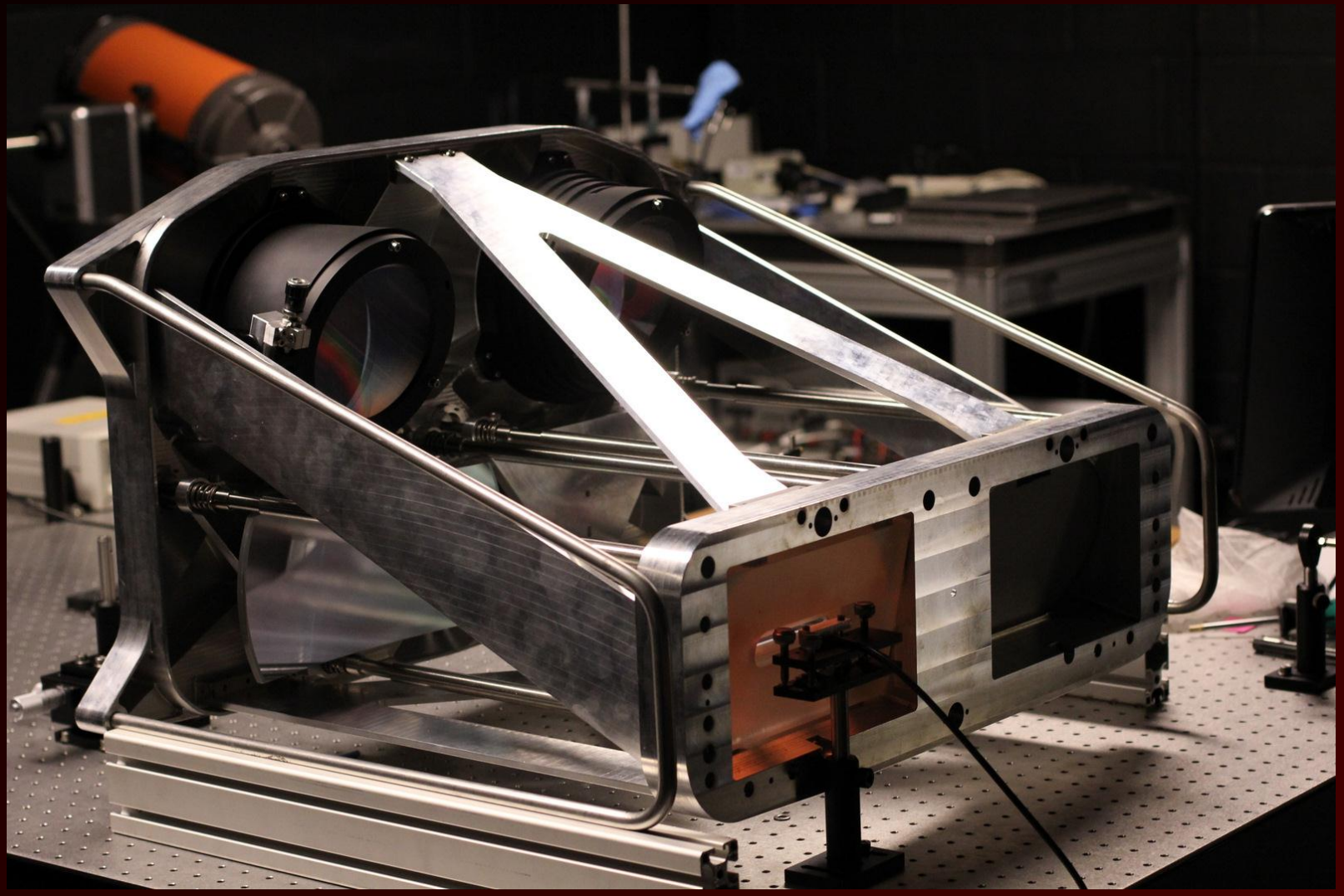
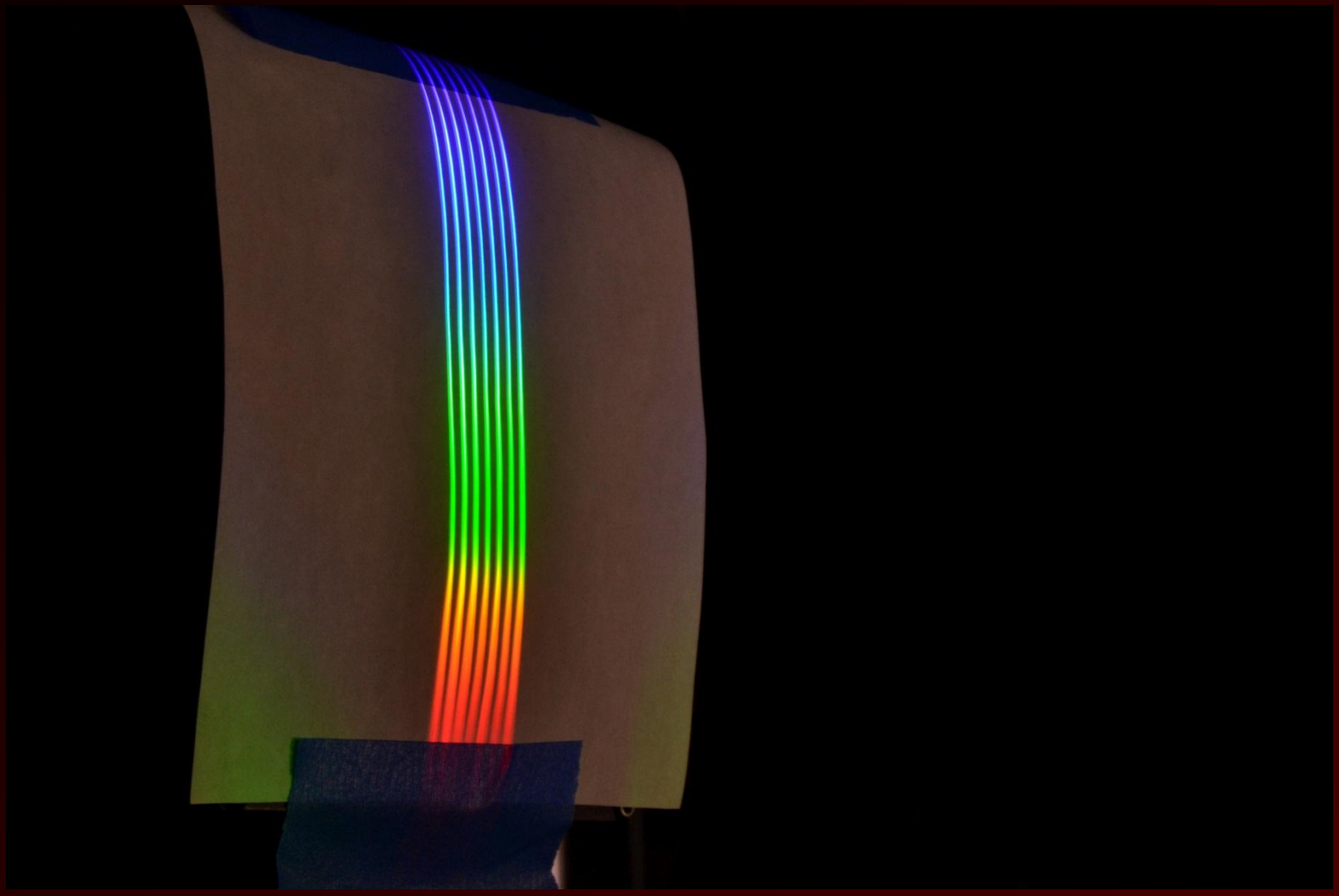
Assemble VIRUS unit spectrographs



Optically align instruments in lab



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Ship to McDonald

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

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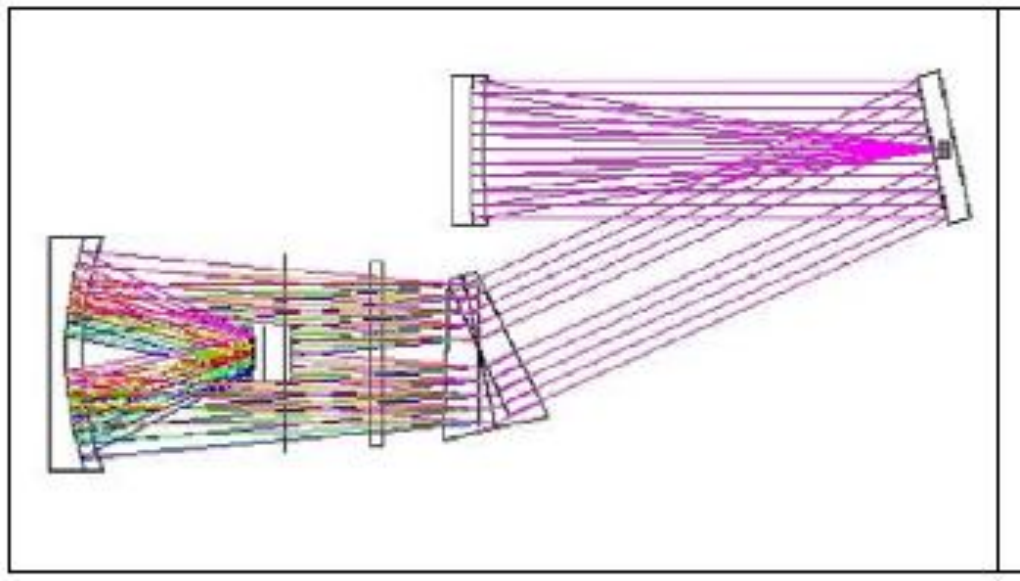
Flexibility of VIRUS design

- 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
  - LRS2

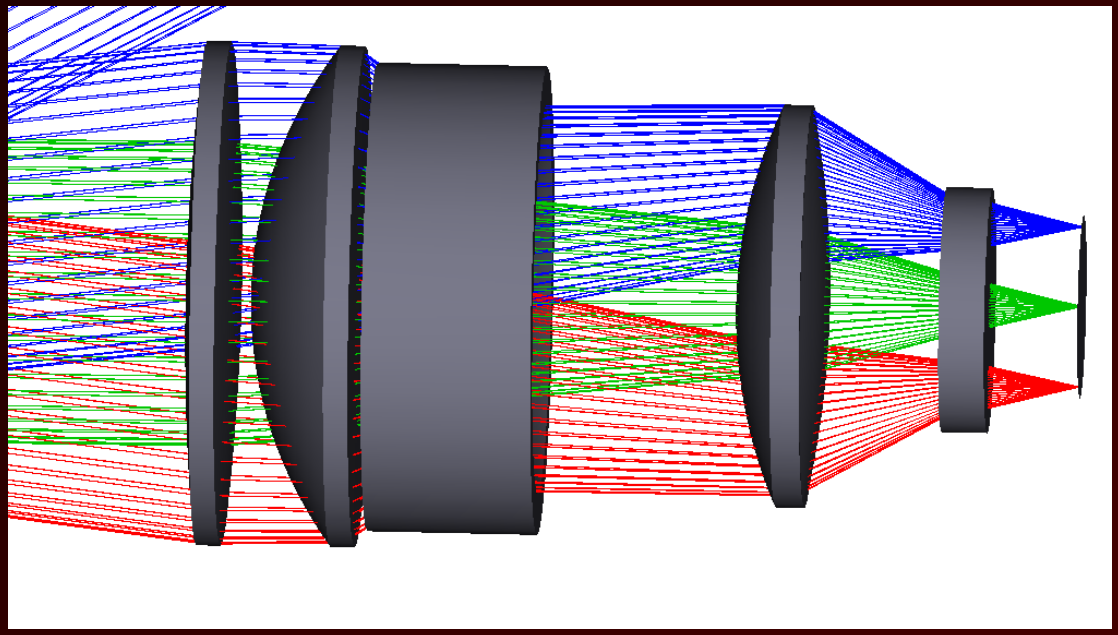
LRS2 concept

- 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!

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One-arm DESpec spectrograph specs

Parameter	Single-Arm Spectrograph (A)	Single-Arm Spectrograph (B)
Fiber Diameter	80 mm (1.4")	80 mm
Wavelength Range (nm)	600<l<1000	550<l<950
CCD	DECam 2kx4k	DECam 2kx4k
Resolution(Dl nm/pixel) (use 4000 pixels)	0.1	0.1
# pixels/fiber	3	3
Camera f/#	f/1.6 = = (2.9*45/80)	f/1.6
Spectral Resolution	3334 @ 1000 nm	3167 @ 950 nm
Camera Type	VIRUS	VIRUS

Two-arm DESpec spectrograph specs

Parameter	Blue Side	Red Side
Fiber Diameter	100 mm (1.75")	
Wavelength Range (nm)	500<l<760	760<l<1050
CCD	E2V or DECam 2kx4k	DECam 2kx4k
Resolution(Dl nm/pixel) (use 4000 pixels)	0.065	0.0725
# pixels/fiber	5	4
Camera f/#	f/2.2	f/1.7
Spectral Resolution	1923 @ 625 nm	3276 @ 950 nm 3621 @ 1050 nm
Camera Type	Reflective or refractive	

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