

Ly- α emitters from the Hobby-Eberly Telescope Dark Energy Experiment

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(on behalf of the HETDEX Consortium)



Ly- α Universe Paris July 2009



HETDEX collaboration



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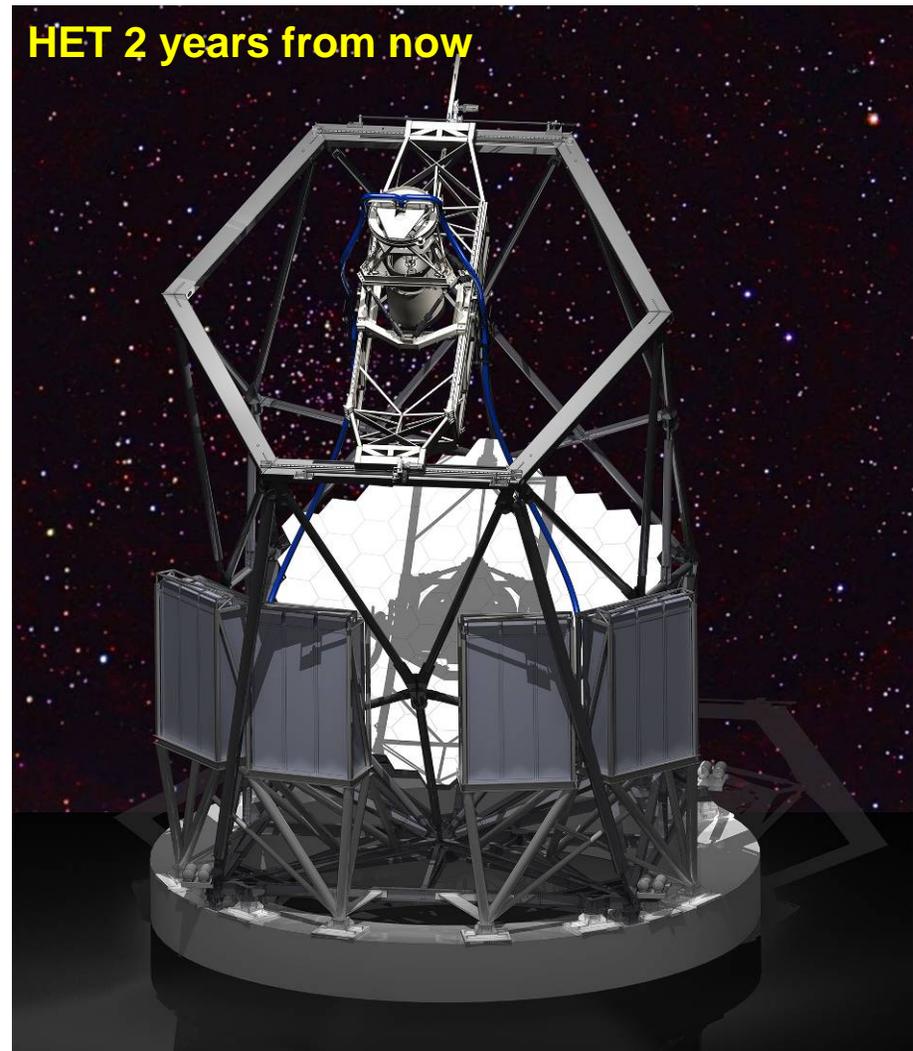
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- HETDEX is:
 - Wide Field Upgrade of HET to have 22- arcmin diameter field
 - Deployment of the hugely replicated IF spectrograph, VIRUS
 - Execution of a huge blind spectroscopic survey containing 0.8M LAEs with $1.9 < z < 3.5$
 - Aim to constrain the evolution of dark energy via the power spectrum of LAEs
 - Realizes promise of HET as a premier survey facility
- HETDEX has been in development since 2007
 - First light for wide field upgrade projected for mid 2011
 - First observations in Fall 2011

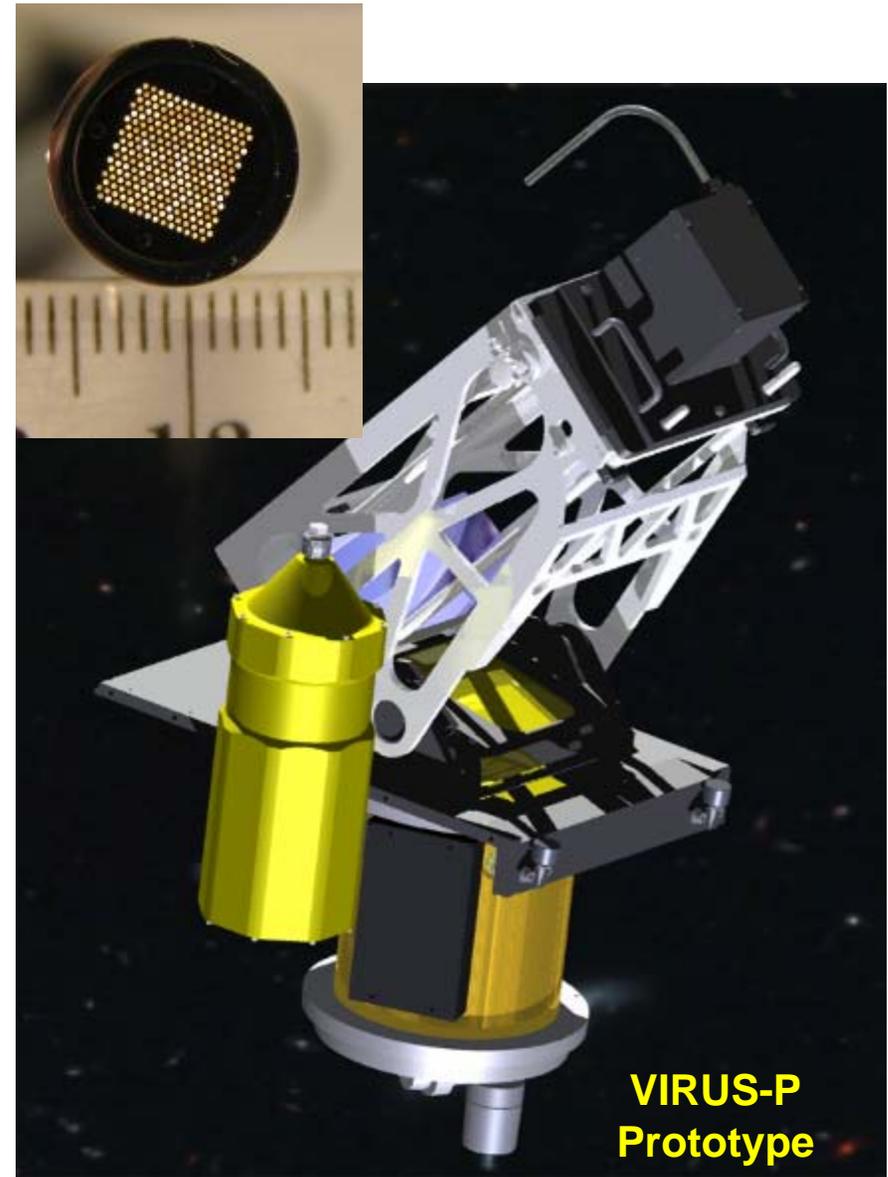


HETDEX Overview

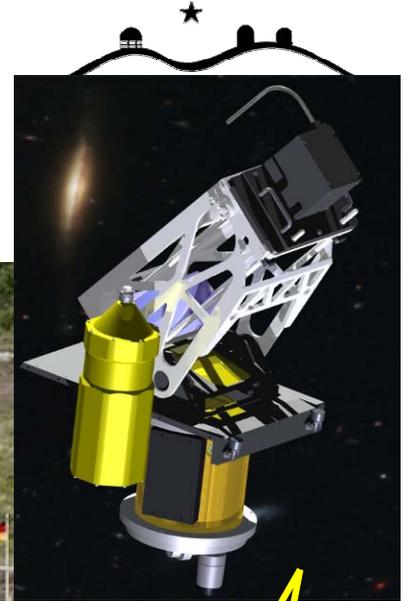
- Two observational approaches to make progress on DE
 - Get the tightest possible constraints at low redshift where effect of DE is stronger
 - Go to higher redshift where we can measure the evolution
 - Both approaches are needed
- Almost all projects are focused at $z < 1.5$
 - Due to observational constraints
- Aims of HETDEX
 - Measure the expansion rate to percent accuracy at $z > 2$
 - Provide a direct constraint on the density of DE at $z > 2$
 - Provide the best measure of curvature
- Tracers are Ly- α emitting galaxies
 - Numerous, easily detected with integral field spectrograph
- 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 $m_{AB} \sim 22$
- 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
- VIRUS is very complementary to MUSE
- VIRUS is also superb for
 - Tracing DM in galaxies
 - Identifying sub-mm galaxies
 - Surveying for gravitationally lensed LAEs

VIRUS

- Replicated integral field spectrographs (VIRUS)
 - Inexpensive fiber-fed unit IFS copied 150 times; deployed as 75 pairs
 - Each pair fed by 50x50 arcsec² IFU with 448 fibers of 1.5" diameter
 - 33,600 spectra per exposure
 - Three exposures fill area of IFU and observe 54 sq. arcmin total area
 - 350-550 nm coverage, R~700
- VIRUS prototype deployed in 2006



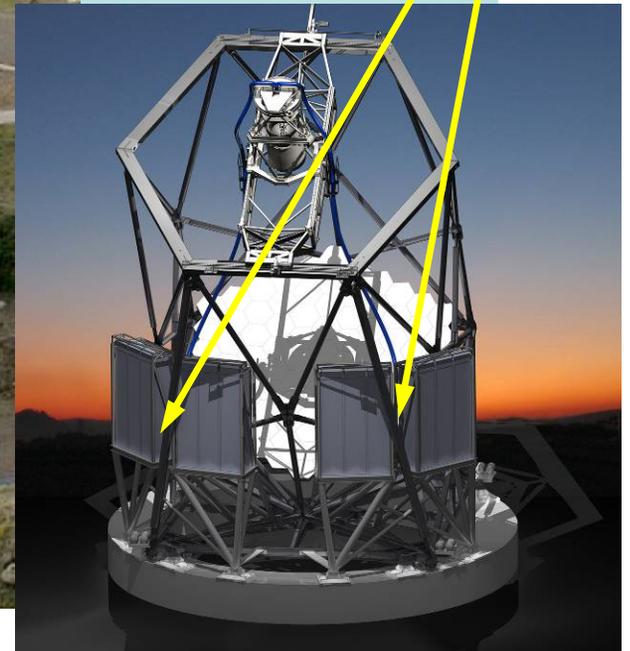
VIRUS on HET



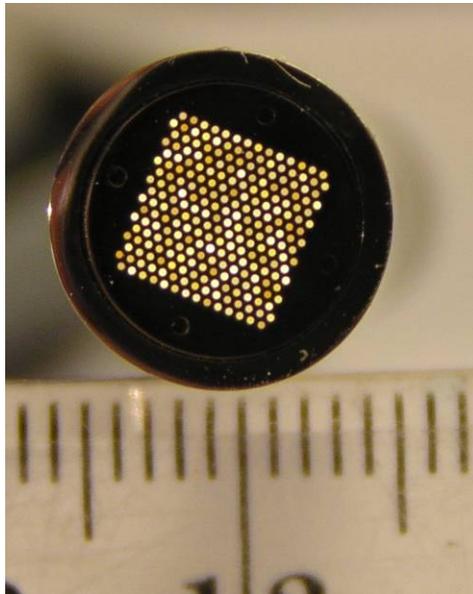
VIRUS consists of 150 units mounted on HET



HET
Mt. Fowlkes west Texas

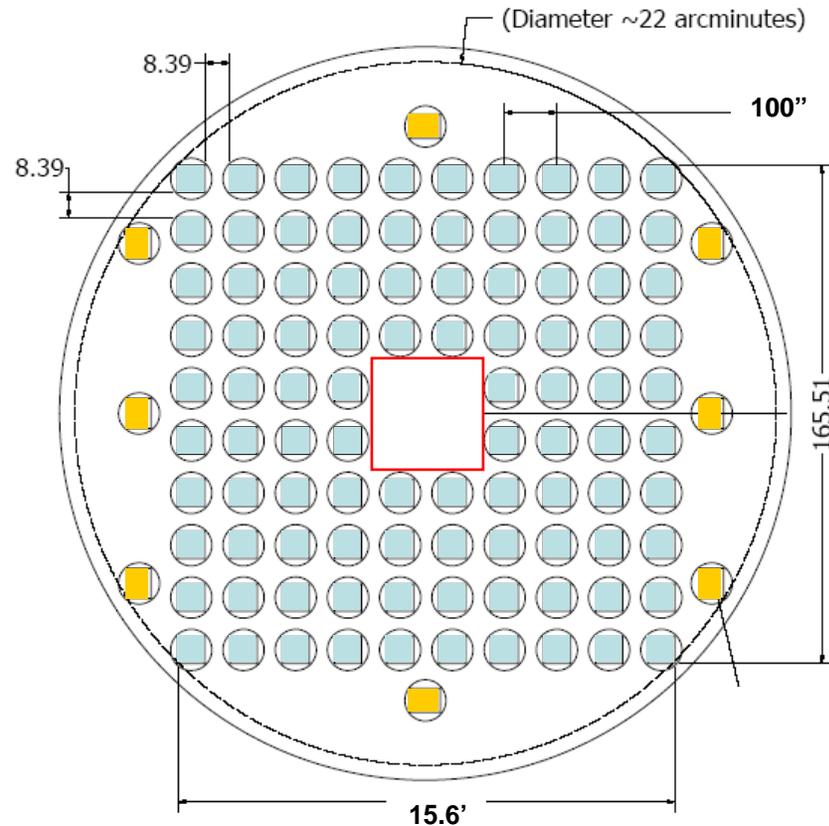
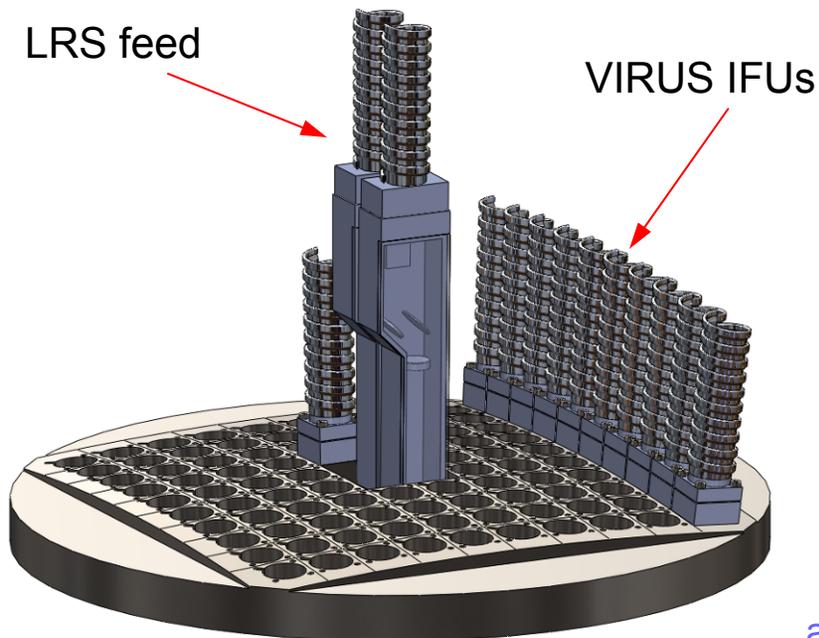


- Bundles of fibers totaling 33,600 enable the weight of VIRUS to be mounted low
 - Each IFU is a bundle of 448 fibers split into two slits to feed a spectrograph pair
 - Simple design maximizes throughput and minimizes cost
- Development in collaboration with AIP
 - nine already delivered



VIRUS field layout

- Grid layout of IFUs with $\frac{1}{4}$ fill factor
 - feeds for other instruments at the middle of the field
 - Allows parallel observations with VIRUS
- Baseline 75 IFUs will leave some gaps, but goal is to fill the matrix

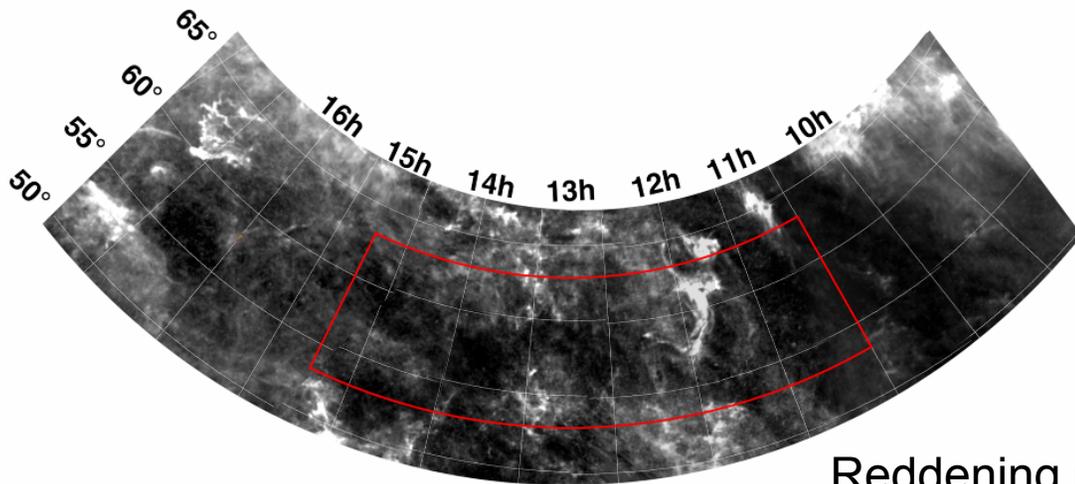


Survey Areas & Supporting Data

- HET is most efficient observing in the north
 - Primary 420 sq. degree Spring survey area will be located in north galactic cap
 - Fill-factor of observed area within this field will be 1/7, so 60 sq. deg. Observed in total
 - Will cover this area with a survey in g,r with the WIYN ODI to AB~25.5 to provide continuum observations
- A second equatorial Fall field will provide overlap with surveys in other wavebands and will provide access from southern hemisphere telescopes
 - Most likely field is XMM-LSS
 - 60 sq. deg. area of low extinction
 - Expect to cover some part of this area more densely
 - Will start observing in Fall 2011 to provide a first rapid survey for early characterization and science results
 - Overlap with Spitzer Warm surveys and coverage from KMOS on VLT will be particularly interesting for characterizing the LAE population

Main Survey on sky

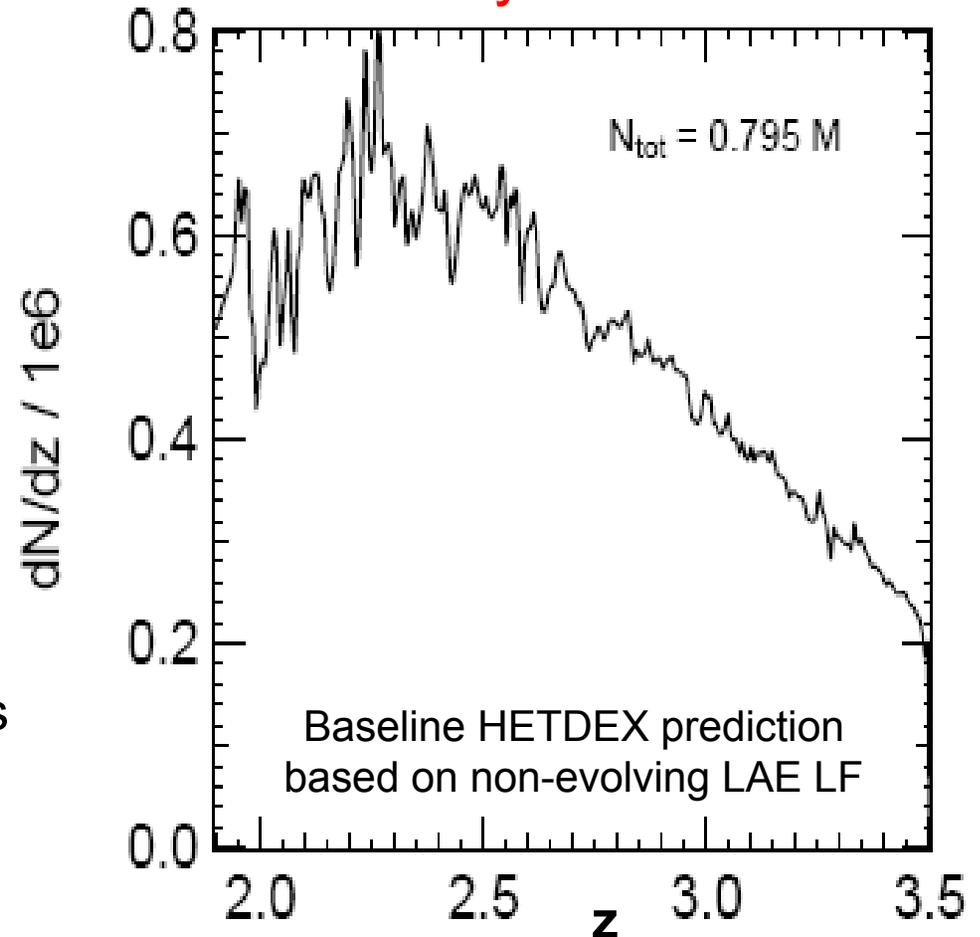
- Dec $\delta = 53-63^\circ$ optimal for HET
- 420 sq. degrees covered
 - 60 sq. deg observed
 - 20 minutes per observation
- 4000 observations in 3 years
- Can be extended to earlier and later RA for more efficient observing before galactic extinction is greater than $A_U=0.1$ mag



Reddening map with baseline survey limits

Expected content of the survey

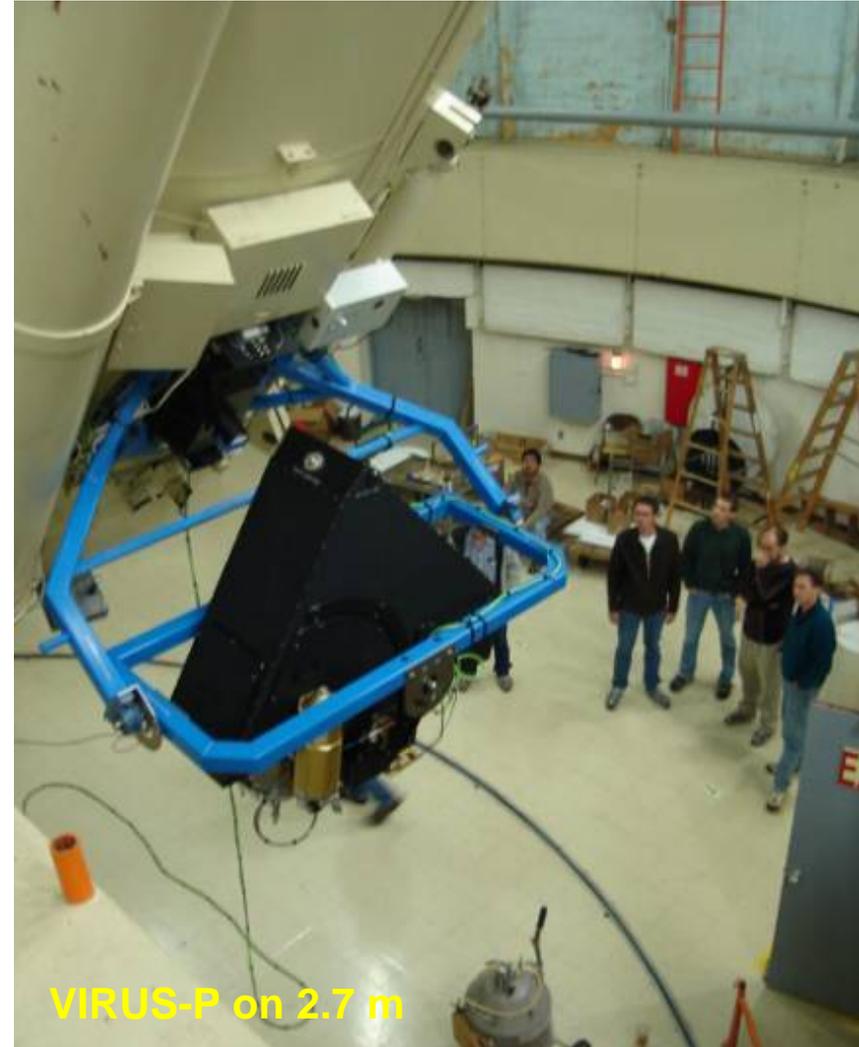
- Main aim is a large sample of LAEs and other line emitting galaxies
 - 0.8M LAEs ($1.9 < z < 3.5$), 1M [OII] emitters ($0 < z < 0.5$)
 - Discriminated to 10% level with an equivalent width cut via a wide field imaging survey with WIYN ODI
- Blind spectroscopy will cover a wide range of interesting objects
 - AGN, clusters, metal-poor stars

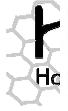


| Redshift | 1.9 | 2.5 | 3.0 | 3.5 |
|---|------|------|------|------|
| Wavelength (nm) | 350 | 425 | 485 | 550 |
| Line Sensitivity (10^{-17} erg/cm ² /s) for 0.8M galaxies | 9.5 | 3.9 | 3.4 | 3.5 |
| Continuum Sensitivity of baseline (AB mag) | 21.5 | 22.0 | 21.9 | 21.6 |

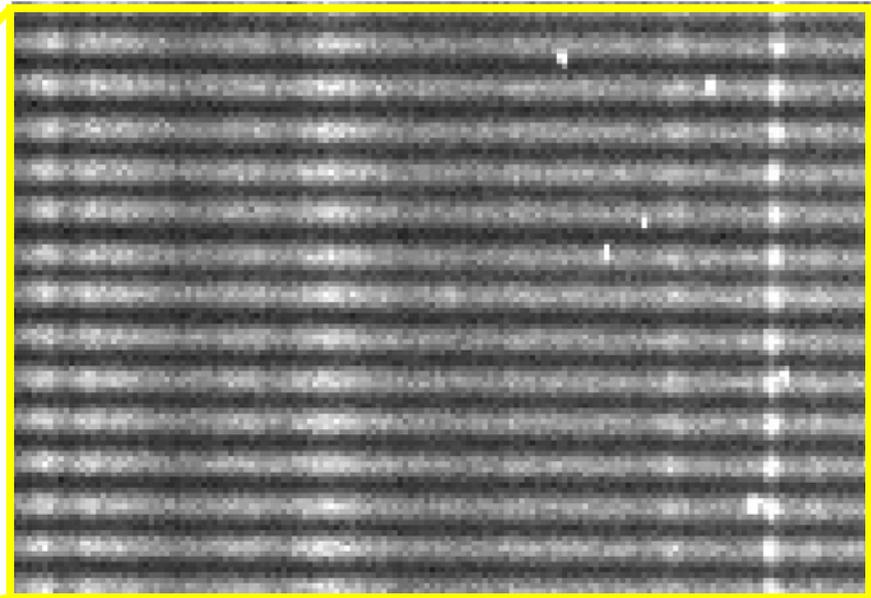
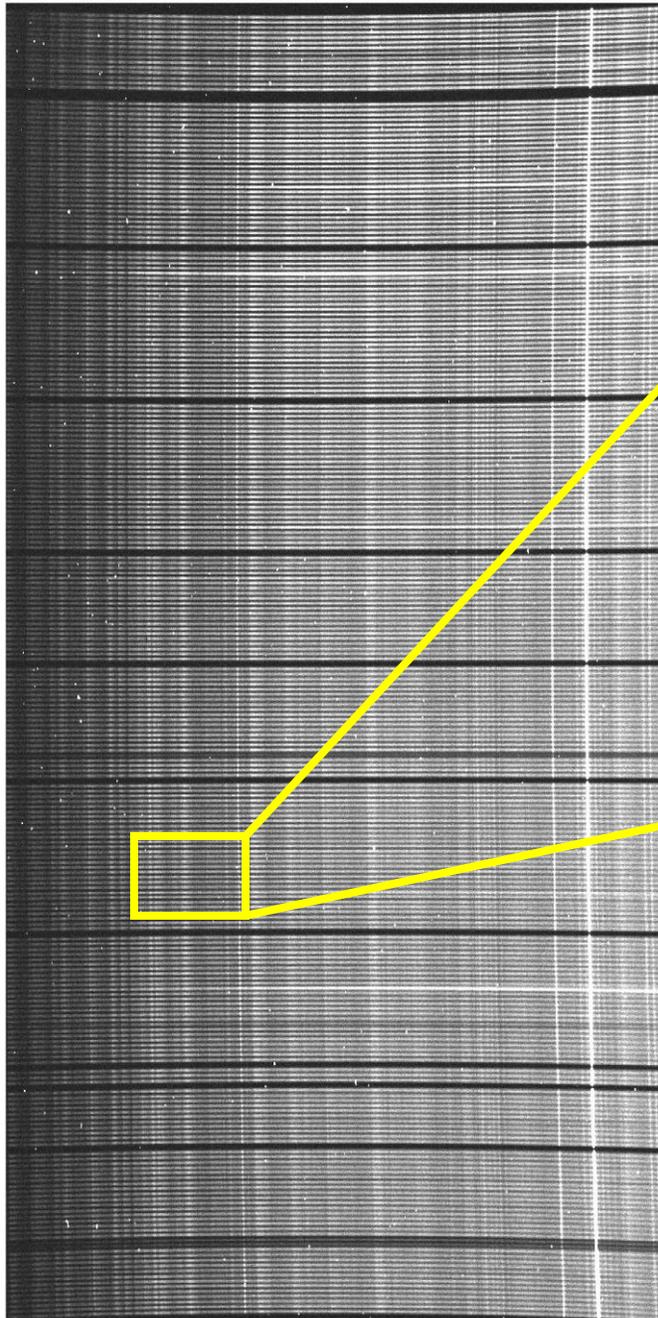
HETDEX Pilot Survey

- Pilot survey using VIRUS-P
 - Demonstrate method and detection limits
 - Develop software
 - Measure LAE evolution and bias
- VIRUS-P prototype unit IFS on McDonald 2.7 m
 - Fed at f/3.65 (4.1 " dia fibers)
 - 3.4 sq. arcmin coverage
 - 340 – 580 nm coverage R~800
 - $1.8 < z < 3.8$ for Ly- α
- COSMOS, GOODS-N, XMM-LSS, and MUNICS-S2 fields
 - Fields selected to have deep multi-wavelength broad-band imaging
- 200 arcmin² surveyed in 2 years
 - expect ~150 LAEs in final catalog
 - 1.3×10^6 cubic Mpc comoving volume
 - 6 hours observation time per field
 - 6×10^{17} erg/cm²/s 5- σ line flux limit





Example Data

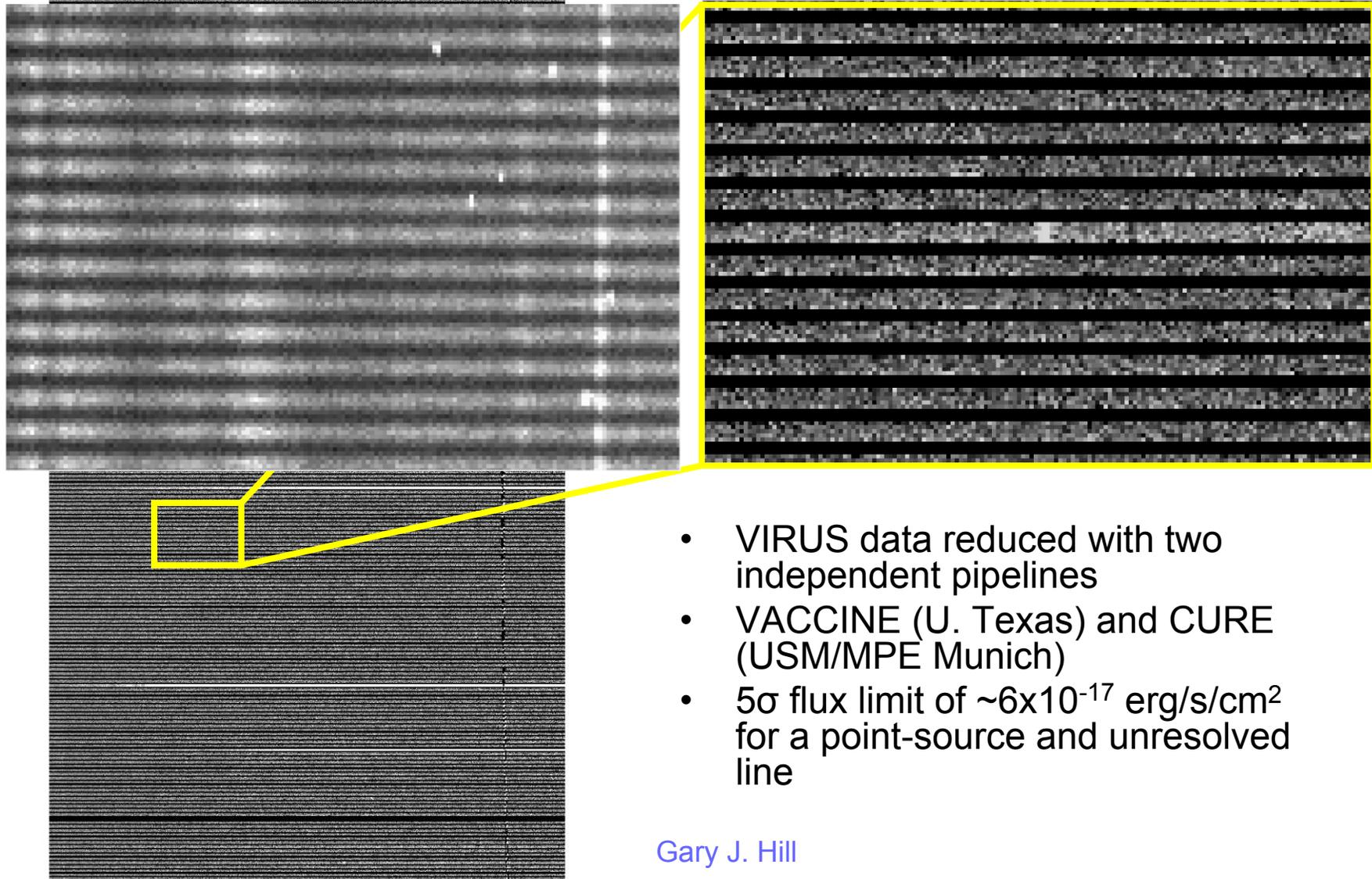


- 6 position dither pattern ensures good field coverage
- Three 20 min exposures at each position
- 2 hr of effective exposure time

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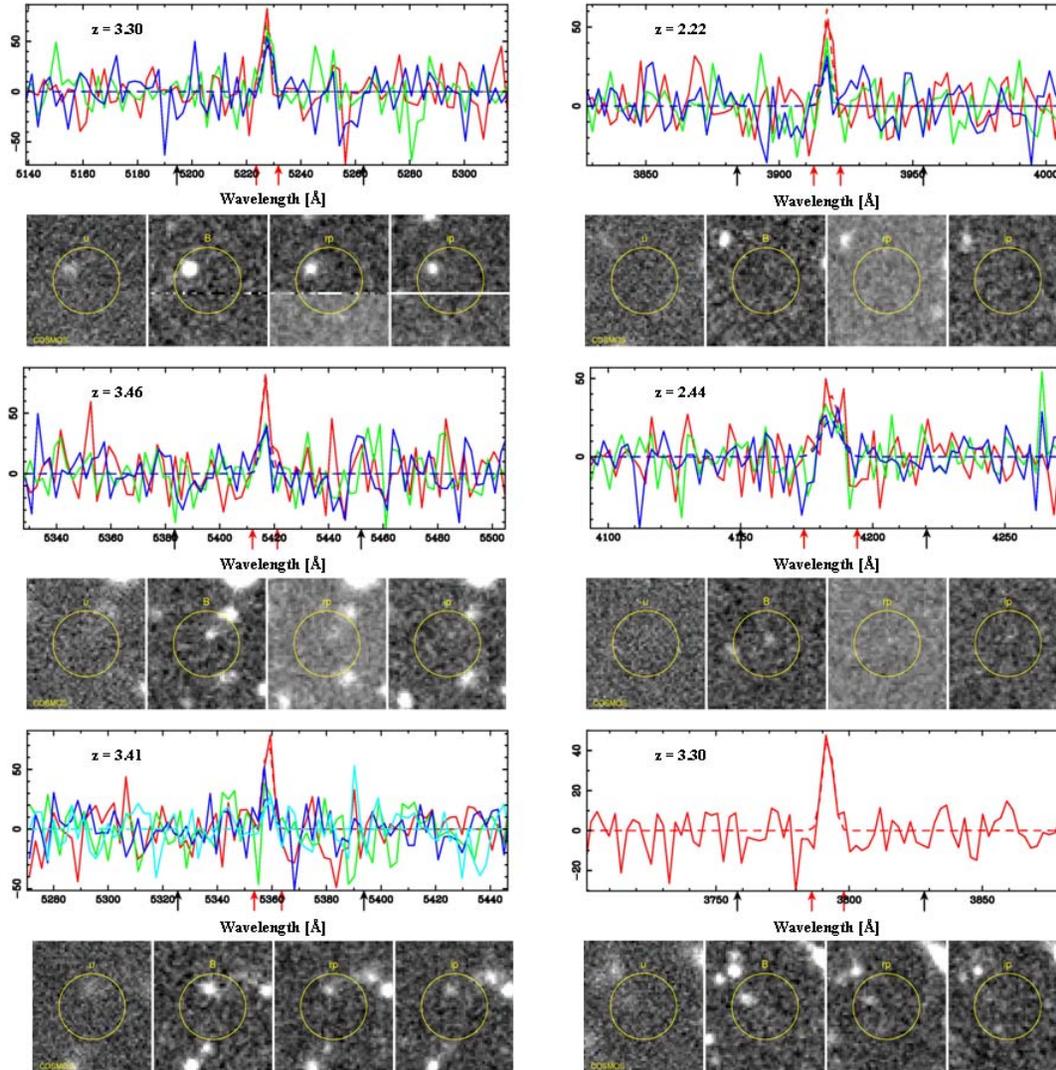


Example Data

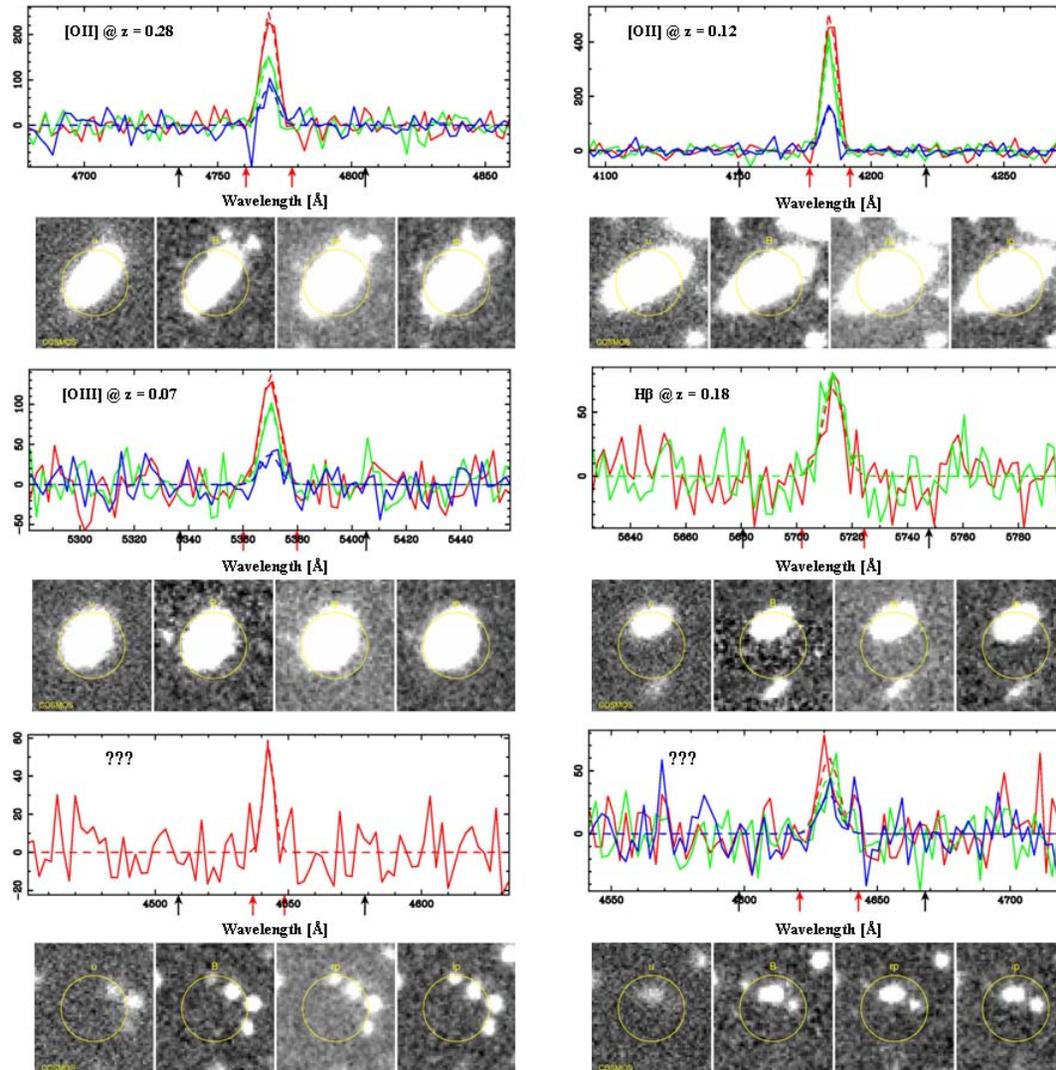


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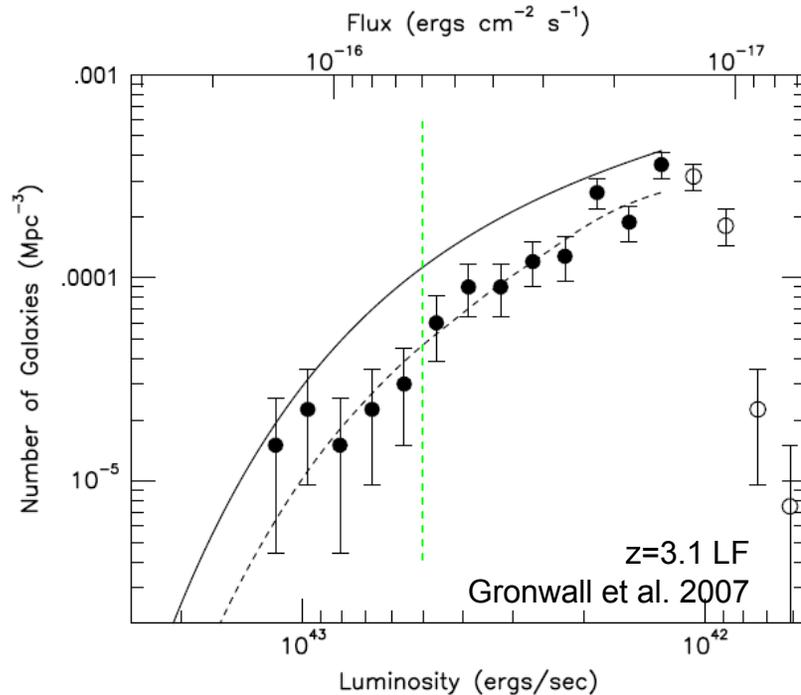
Ly- α Emitters



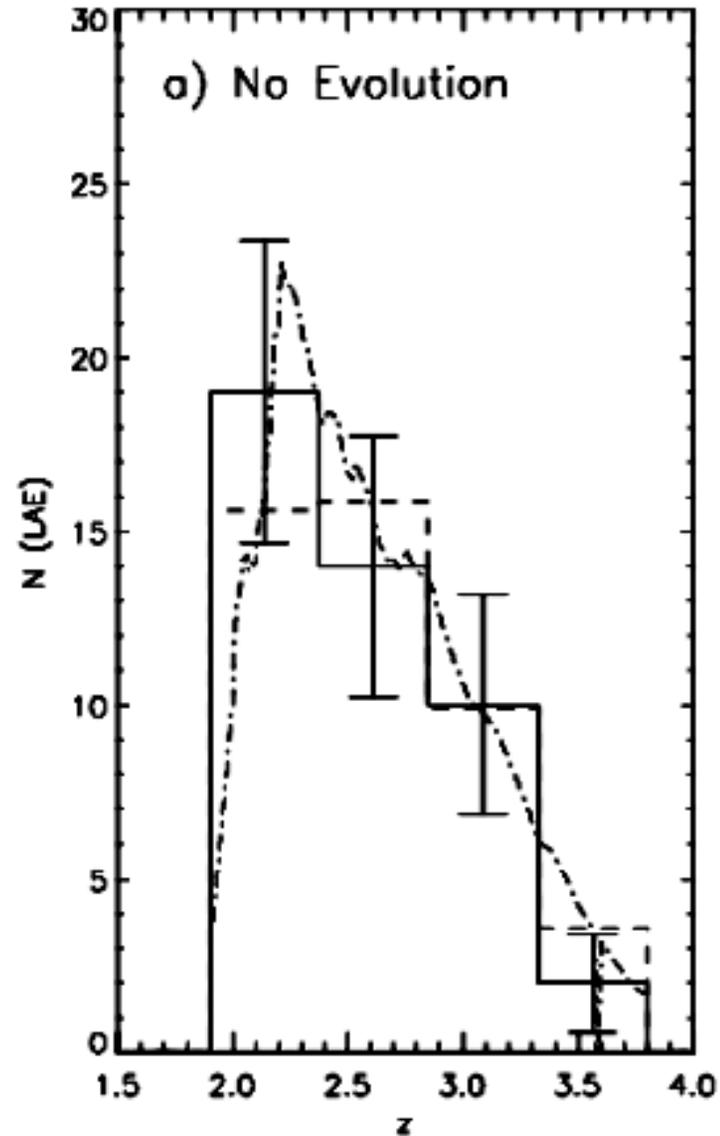
Low redshift and unclassified objects



Preliminary redshift distribution

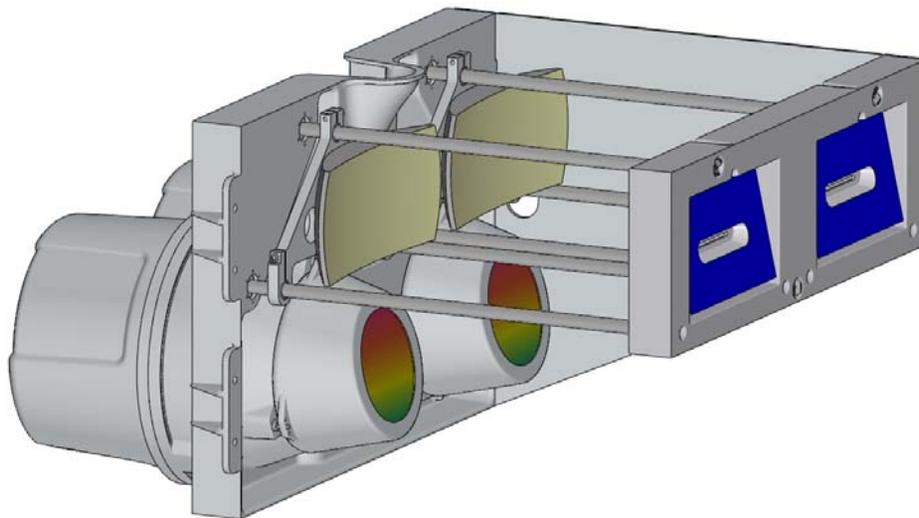


- 45 LAEs in COSMOS field
 - Follow-up spectroscopy with HET LRS is confirming those at $z > 2.5$
- Prediction based on non-evolving LF and measured instrument sensitivity
- Preliminary result consistent with no evolution
- Reanalysis of full dataset is underway



VIRUS Production design

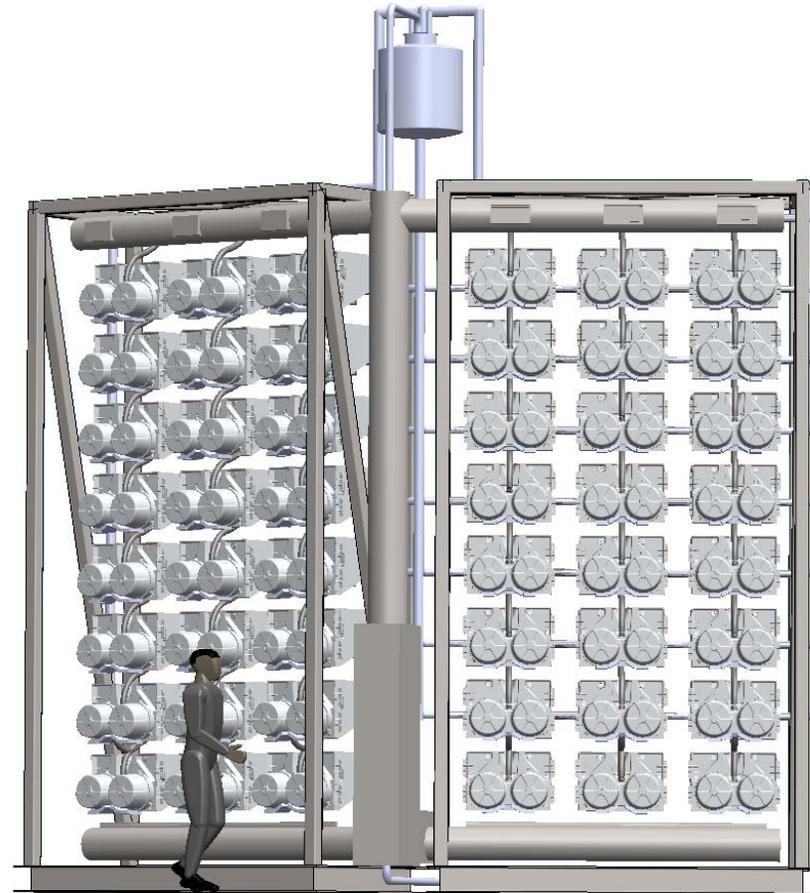
- Production design is complete and we are manufacturing several copies of the production prototype
- Detector system contract will be awarded soon
- Design makes extensive use of castings in both the collimator and camera
- We expect small modifications before full production, based on experience with the production prototypes



VIRUS grating cell blanks

Summary

- The HETDEX project will produce the largest catalog of 0.8M LAEs and another million line emitting objects over a huge volume of space (9 cubic Gpc)
- In addition to providing constraints on dark energy through the LAE power spectrum, the catalog will be *the* source for putting LAEs and other objects in the context of large-scale structure at $z \sim 2-4$
- It will provide the first large-scale 3-D view of the high redshift cosmic web
- The survey will begin in fall 2011
 - Data in the form of line-emitter catalogs and individual spectra will become public after a proprietary period



One of the two banks of VIRUS spectrographs