HETDEX
Hobby-Eberly Telescope Dark Energy Experiment

McDONALD OBSERVATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

The Hobby-Eberly Telescope Dark Energy Experiment

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(on behalf of the HETDEX Consortium)

Hobby-Eberly Telescope Dark Energy Experiment

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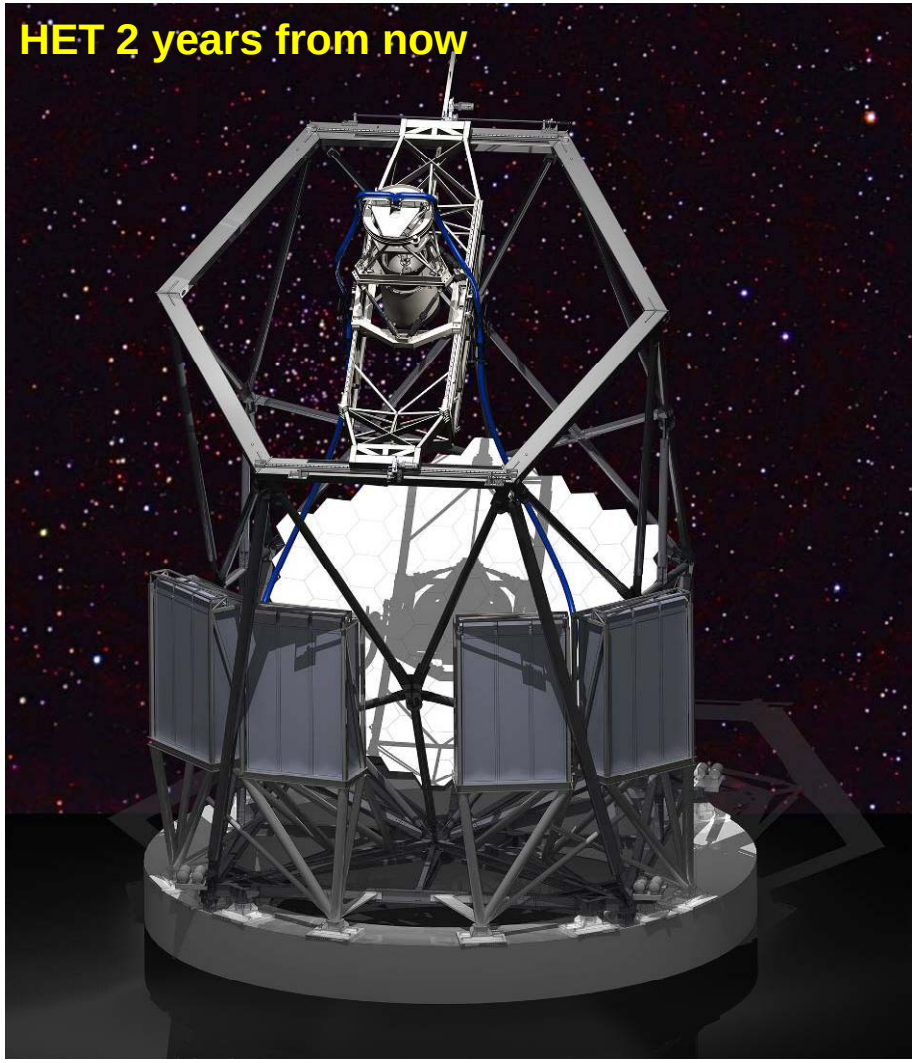
Hobby-Eberly Telescope Dark Energy Experiment

- HETDEX is:
  - Wide Field Upgrade of HET to have 22- arcmin diameter field
  - Deployment of the hugely replicated integral field spectrograph, VIRUS with 33k fibers on the sky
  - Execution of a huge blind spectroscopic survey containing 0.8M Ly-a emitting galaxies (LAEs) with $1.9 < z < 3.5$
  - Aim to constrain the evolution of dark energy via the power spectrum of LAEs
- HETDEX has been in development since 2007
  - First light for wide field upgrade projected for Q3 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
  - Complement low z experiments (DES and BOSS)
- 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}~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 also superb for
  - Tracing DM in galaxies
  - Identifying sub-mm galaxies
  - Surveying for gravitationally lensed LAEs

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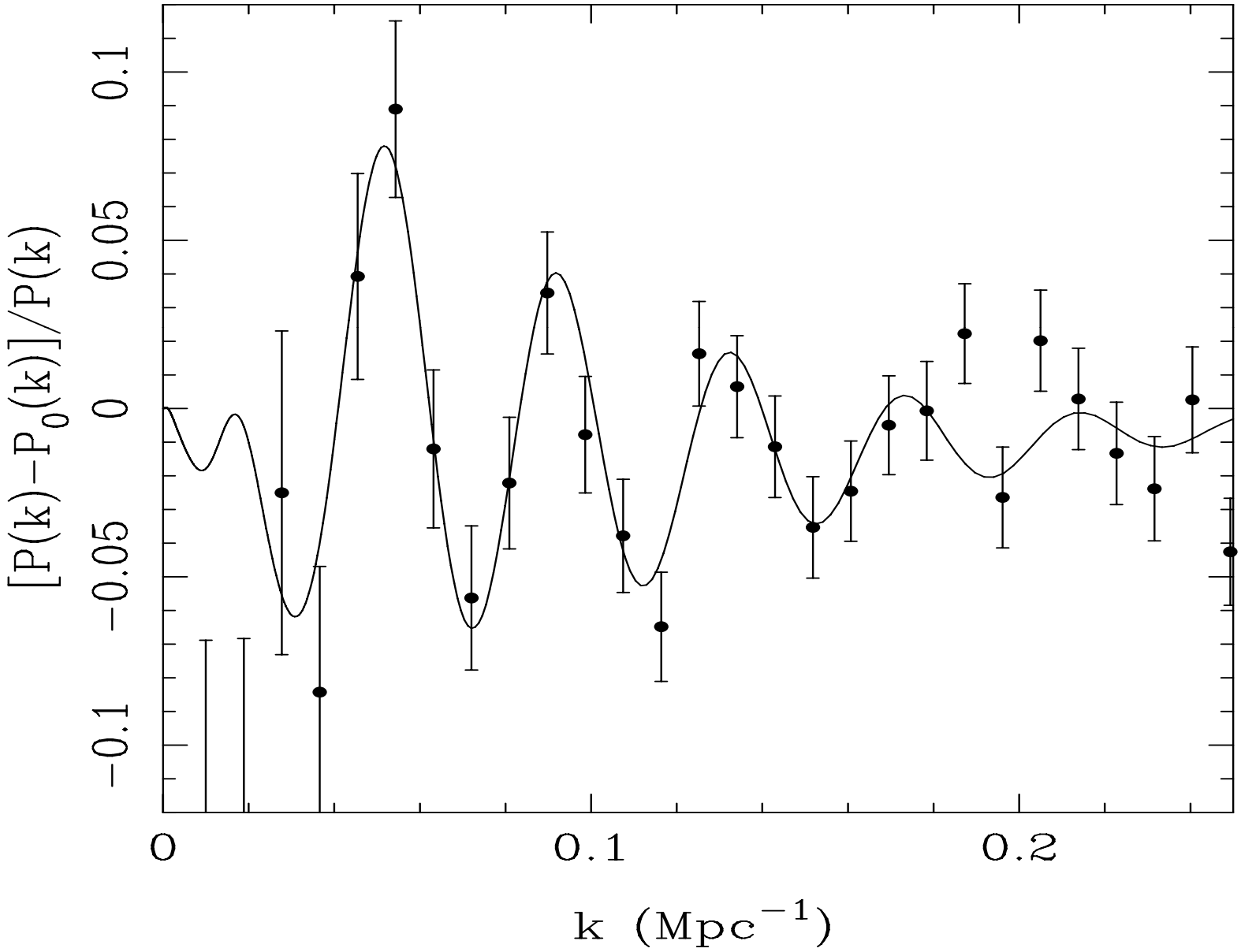
Realization of BAO in HETDEX



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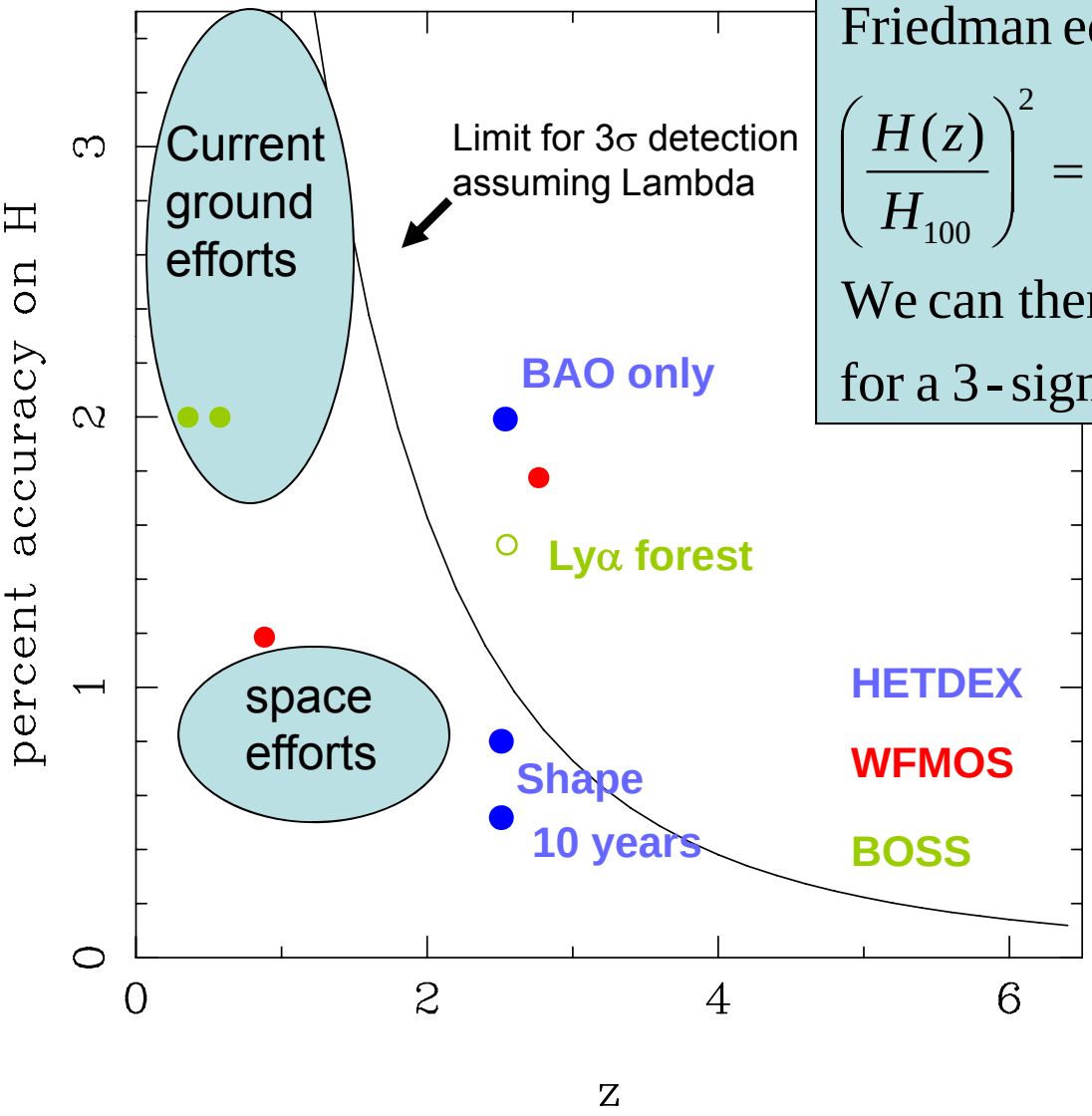
Current and Planned Effort on Expansion Rate



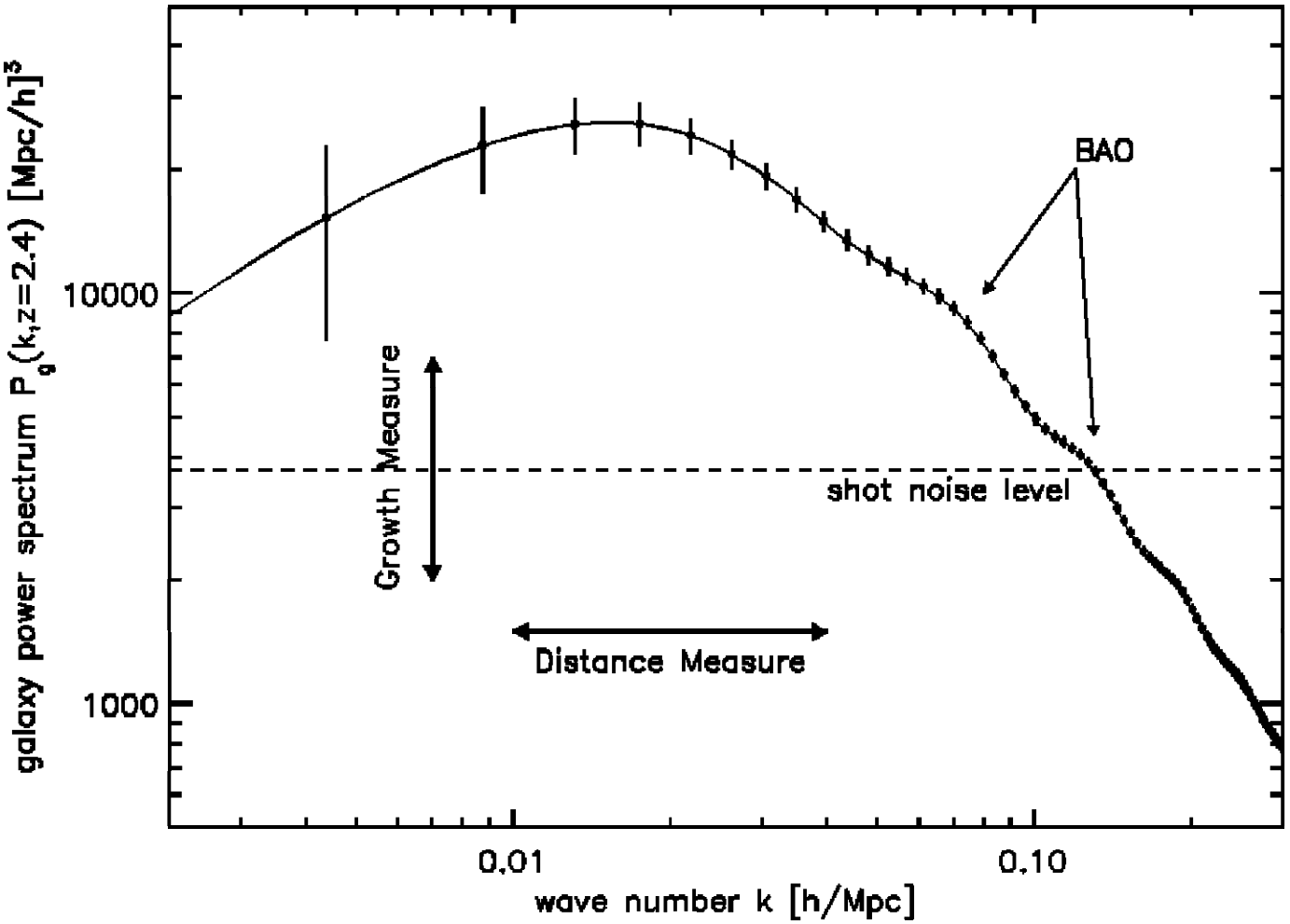
Friedman equation gives:

$$\left(\frac{H(z)}{H_{100}}\right)^2 = \omega_m(1+z)^3 + \omega_k(1+z)^2 + \omega_\Lambda(z)$$

We can then calculate the $H(z)$ accuracy for a 3-sigma detection of ω_Λ.

Constraints at low-z should be covered well. The next logical step is z>2.

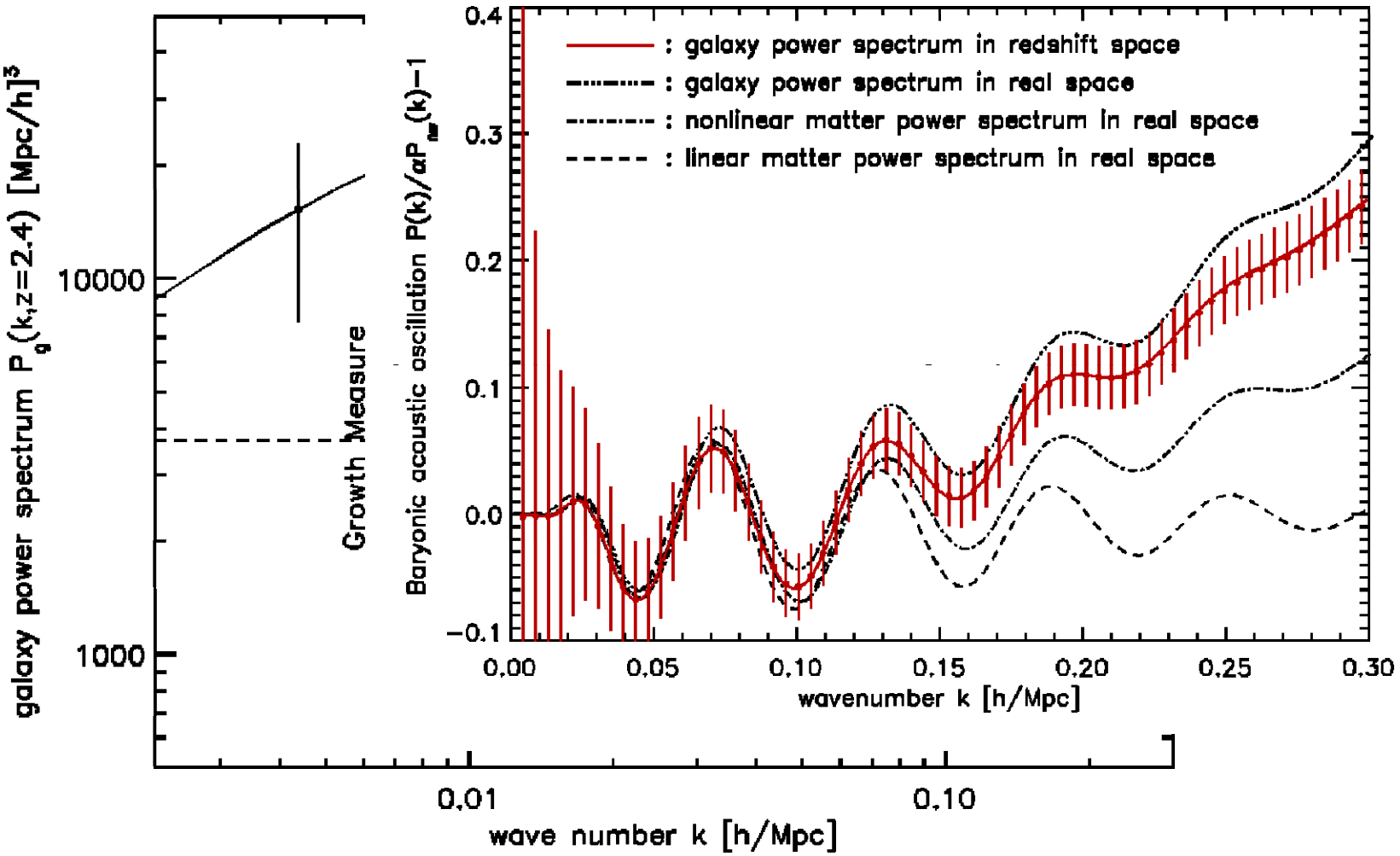
The power of the power



Entire shape of power spectrum can constrain distance and contains information about structure growth – if non-linear growth can be understood

(Shoji, Jeong & Komatsu, 2009, ApJ, 693, 1404)

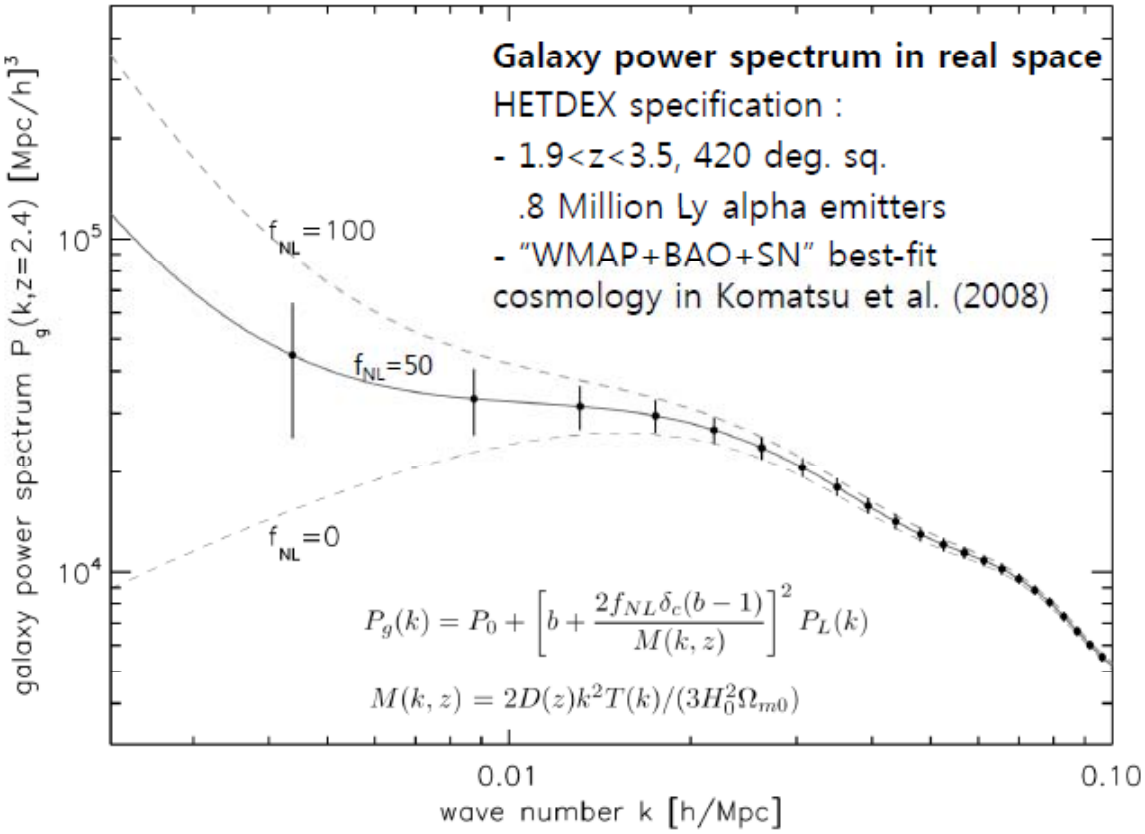
The power of the power



Non-linear growth in real and redshift space can be modelled with 3rd Order Perturbation theory - distinctive shape provides distance measure

Jeong & Komatsu, 2006, ApJ, 651, 619
Jeong & Komatsu, 2009, ApJ, 691,569

The power of the power

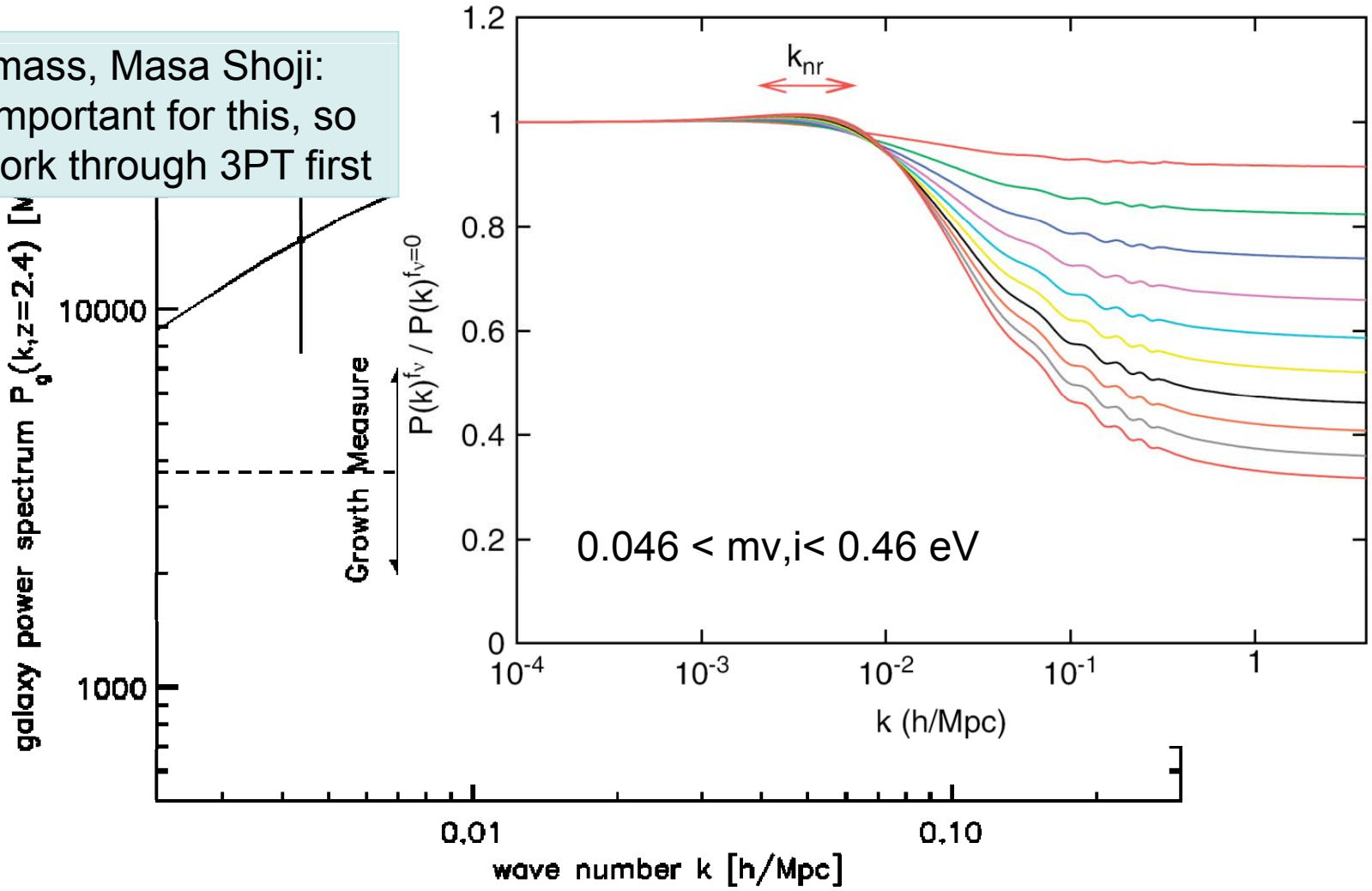


Primordial non-Gaussianity amplitude: get f_{NL} to an accuracy of around 5

Jeong, D., and Komatsu, E., 2010, "Primordial non-Gaussianity, scale-dependent bias, and the bispectrum of galaxies", arXiv:0904.0497

The power of the power

Neutrino mass, Masa Shoji: high k is important for this, so need to work through 3PT first



Talk to Donghui, Masa, and Eiichiro about further applications of the power spectrum!

* Papers can be viewed at **hetdex.org** under “Resources”

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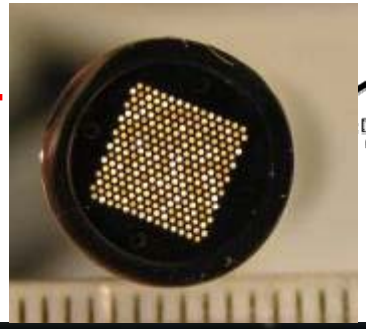
How to do it……
VIRUS



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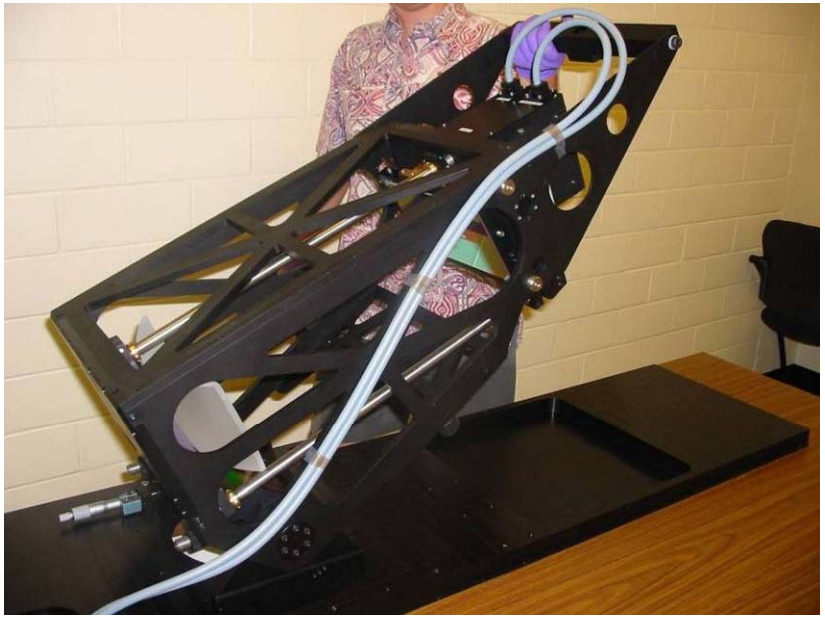
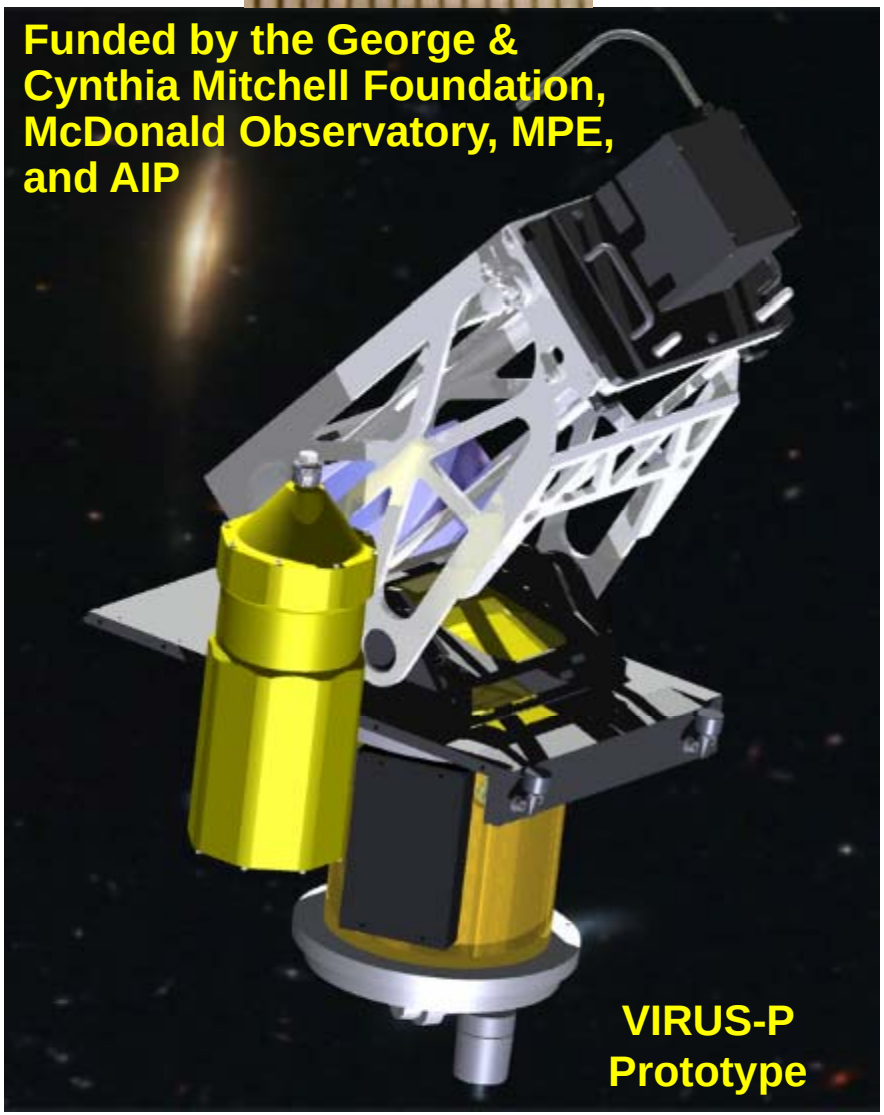
- Replicated integral field spectrographs (VIRUS)
  - Inexpensive fiber-fed unit IFS copied 150 times; deployed as 75 pairs
  - Each pair fed by 50x50 arcsec^2 IFU with 448 fibers of 1.5” diameter
  - 33,600 spectra per exposure
  - Three exposures fill area of IFU and observe 54 sq. arcmin total area
  - 350-550 nm coverage, R~700
- VIRUS prototype deployed in 2006





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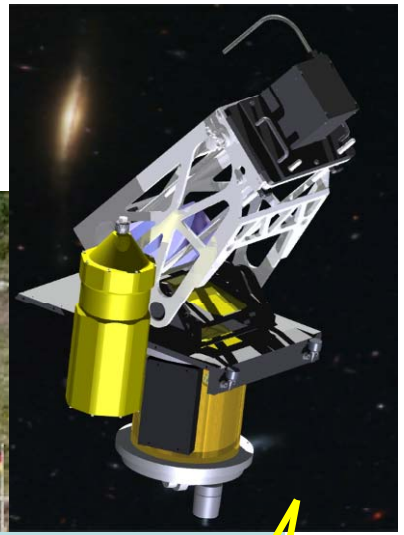
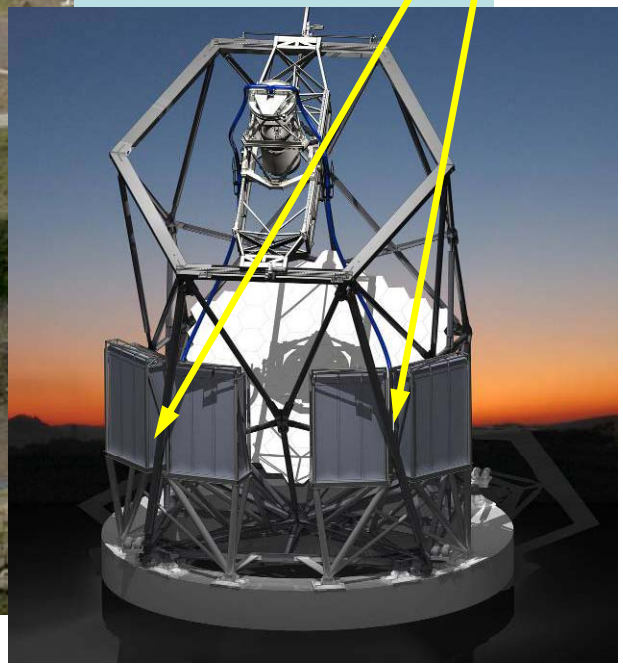
VIRUS on HET



VIRUS consists of 150 units mounted on HET



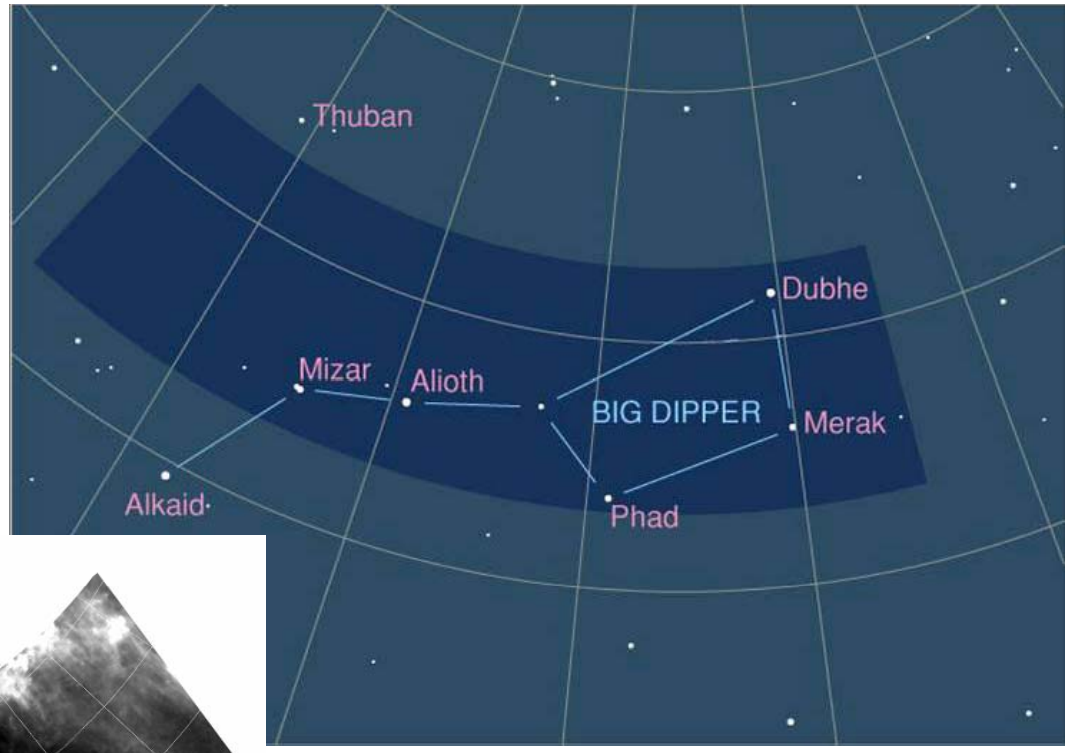
Survey Areas & Supporting Data

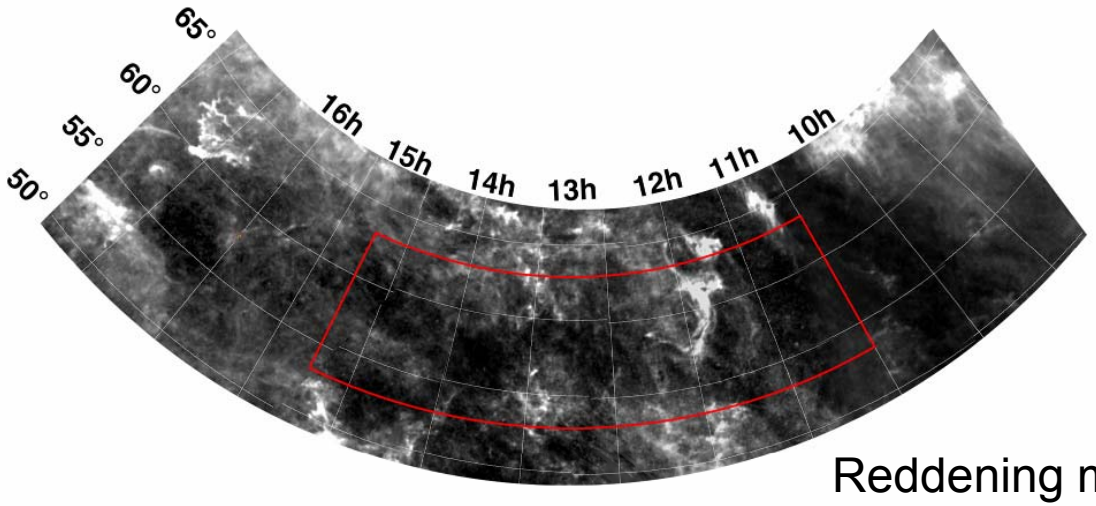
- HET is most efficient observing in the north
  - Primary 420 sq. degree Spring survey area will be located in north galactic cap
  - Fill-factor of observed area within this field will be 1/7, so 60 sq. deg. Observed in total
  - Will cover this area with a survey in g,r with the WIYN ODI to AB~25.5 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 (high k)
  - Hope to 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 δ = 53-63^{O} 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

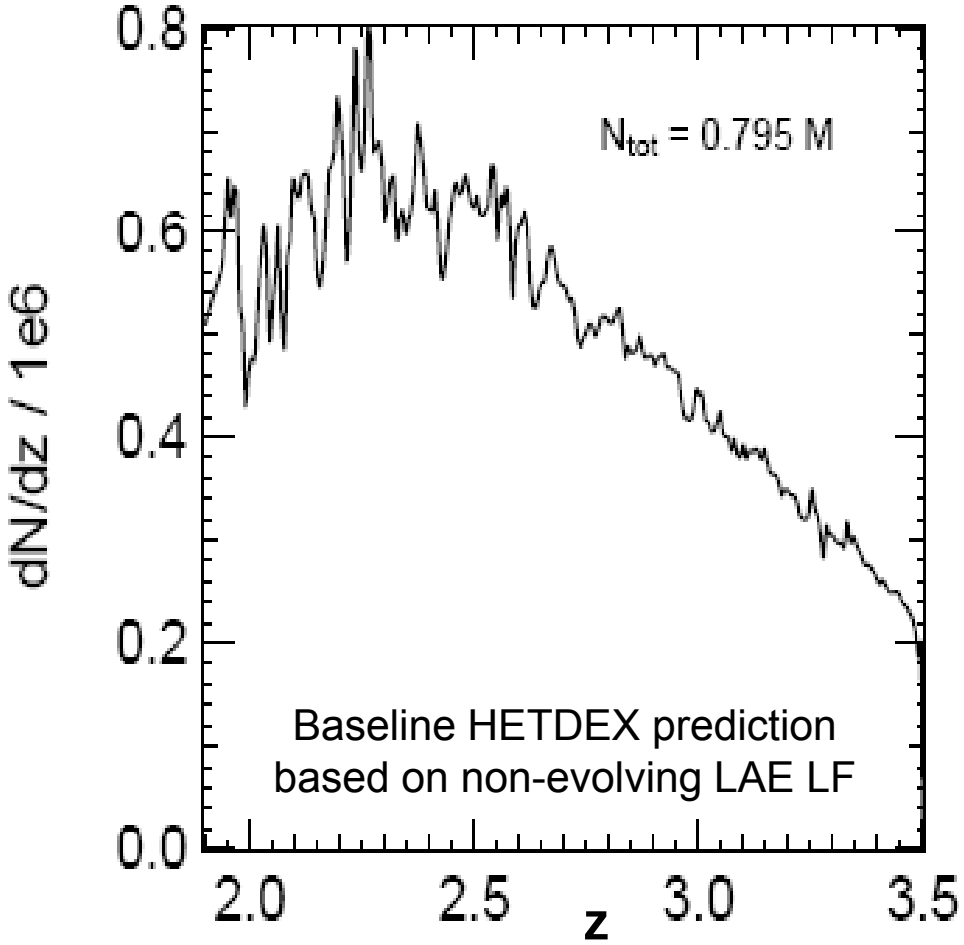




Reddening map with baseline survey limits

Expected content of the survey

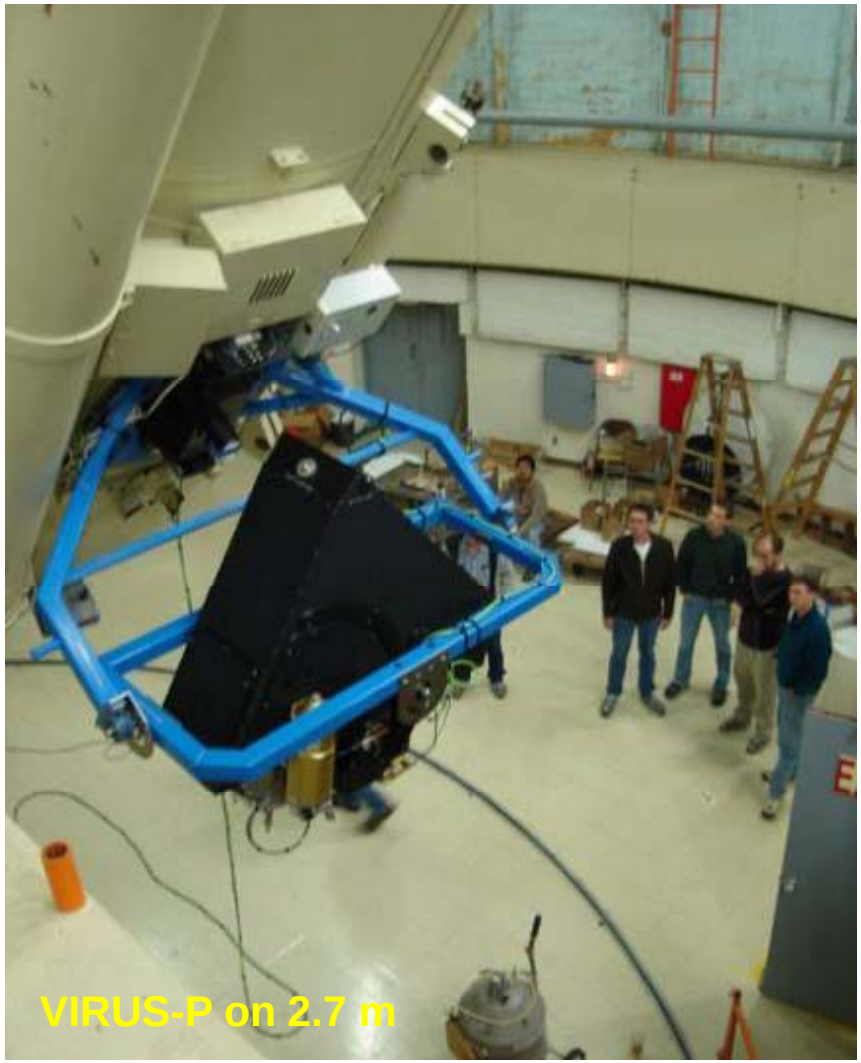
- Main aim is a large sample of LAEs and other line emitting galaxies
  - 0.8M LAEs (1.9 < z < 3.5), 1M [OII] emitters (0 < z < 0.5)
  - Discriminated to 10% level with an equivalent width cut via a wide field imaging survey with WIYN ODI
- Blind spectroscopy will cover a wide range of interesting objects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



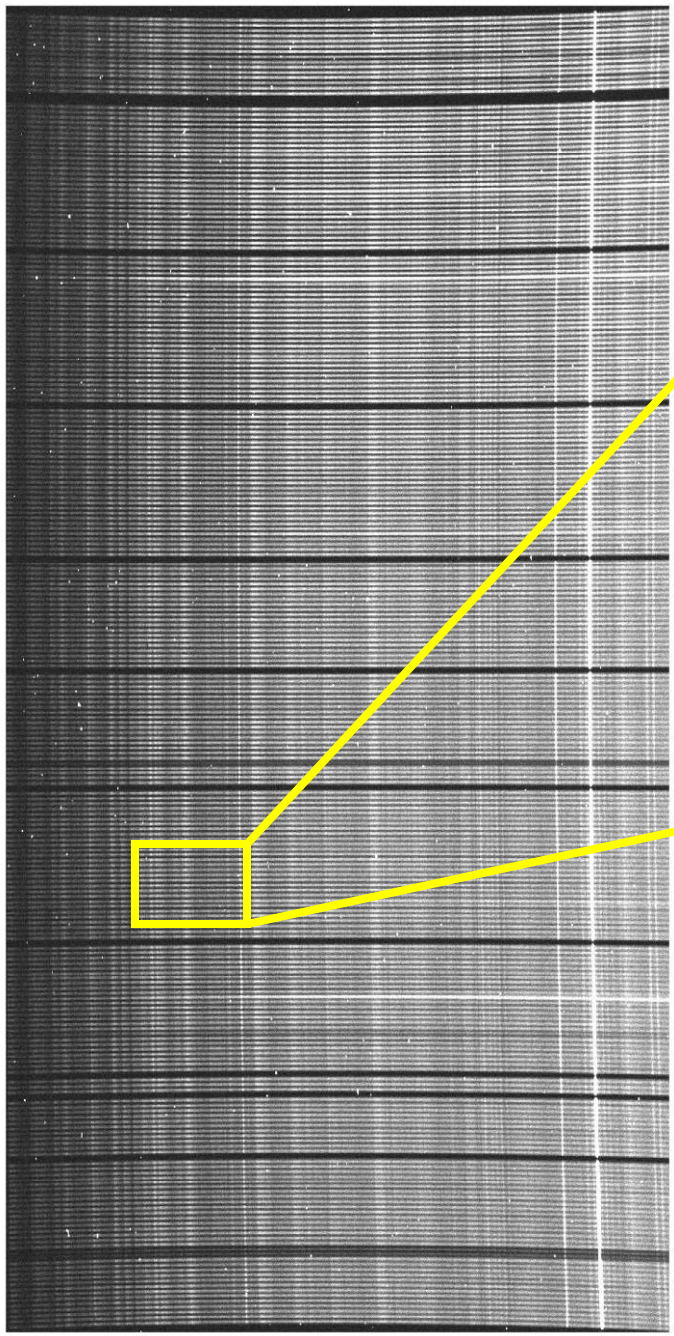
Redshift	1.9	2.5	3.0	3.5
Wavelength (nm)	350	425	485	550
Line Sensitivity (10^{-17} erg/cm^2/s) for 0.8M galaxies	9.5	3.9	3.4	3.5
Continuum Sensitivity of baseline (AB mag)	21.5	22.0	21.9	21.6

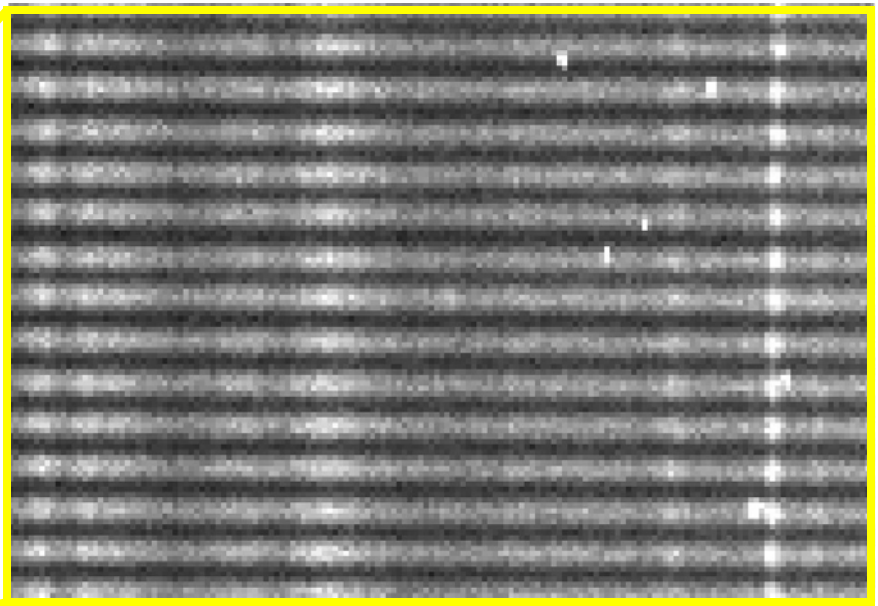
HETDEX Pilot Survey

- Pilot survey using VIRUS-P
  - Demonstrate method and detection limits
  - Develop software
  - Measure LAE evolution and bias
- COSMOS, GOODS-N, XMM-LSS, and MUNICS-S2 fields
  - Fields selected to have deep multi-wavelength broad-band imaging
- 200 arcmin^2 surveyed in 2 years
  - expect ~300 LAEs in final catalog
  - 1.3x10^6 cubic Mpc comoving volume
  - 6 hours observation time per field



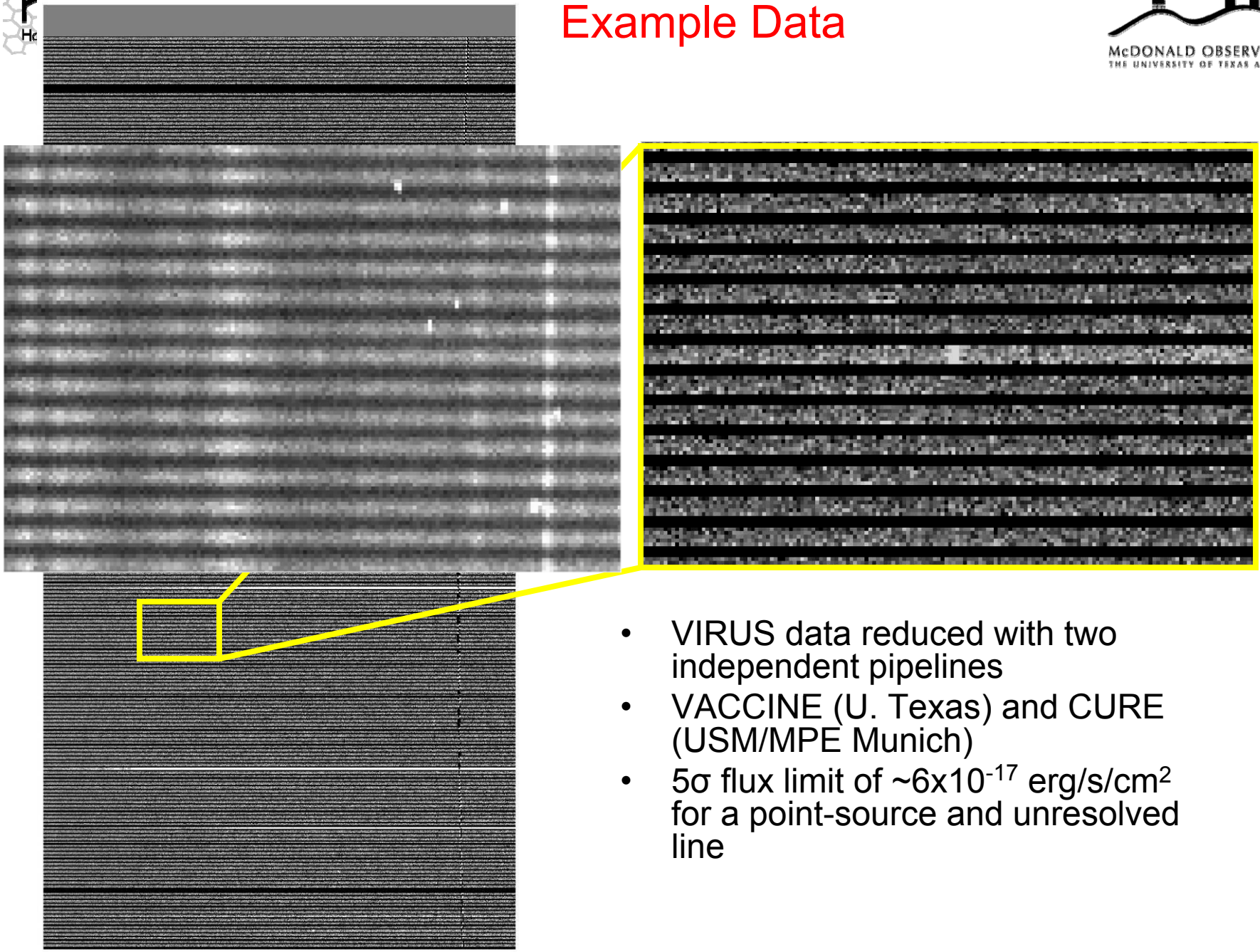
Example Data





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

Example Data



- VIRUS data reduced with two independent pipelines
- VACCINE (U. Texas) and CURE (USM/MPE Munich)
- 5σ flux limit of ~6×10^{-17} erg/s/cm^2 for a point-source and unresolved line

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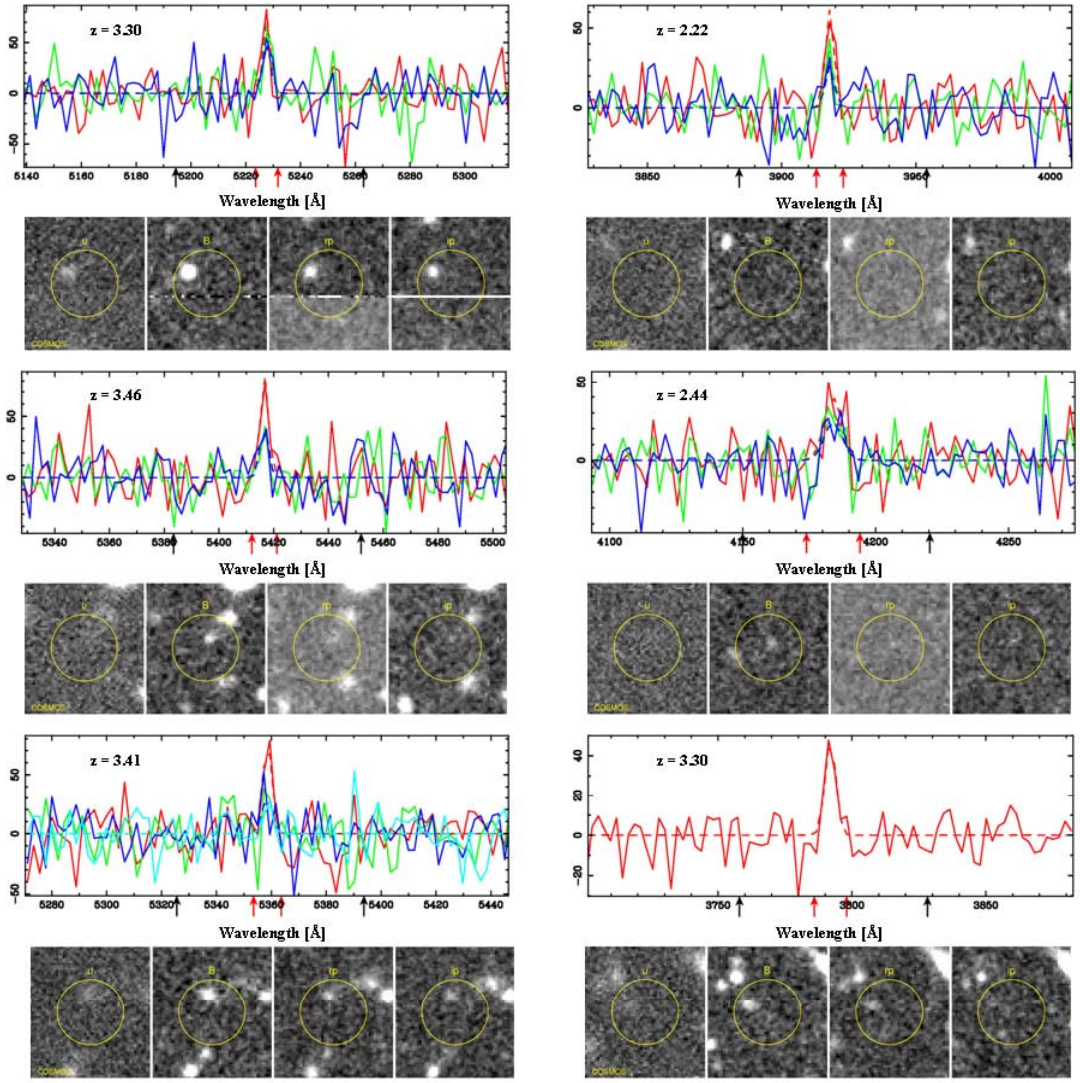
Ly-α Emitters



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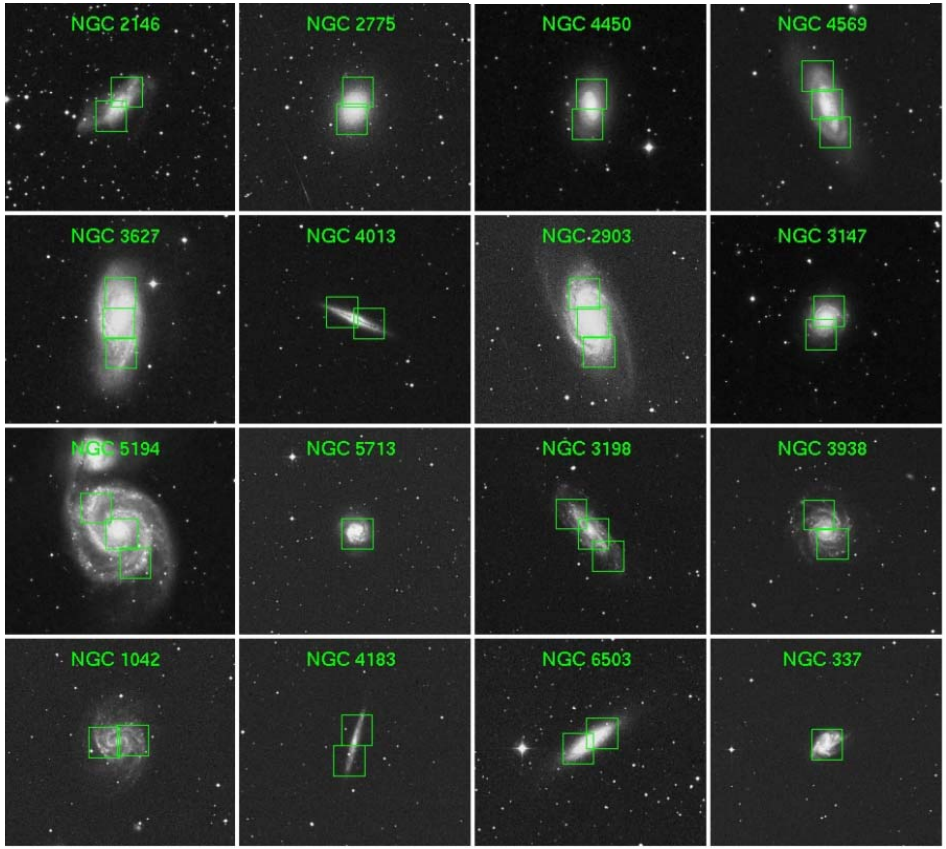
Science from HETDEX and VIRUS

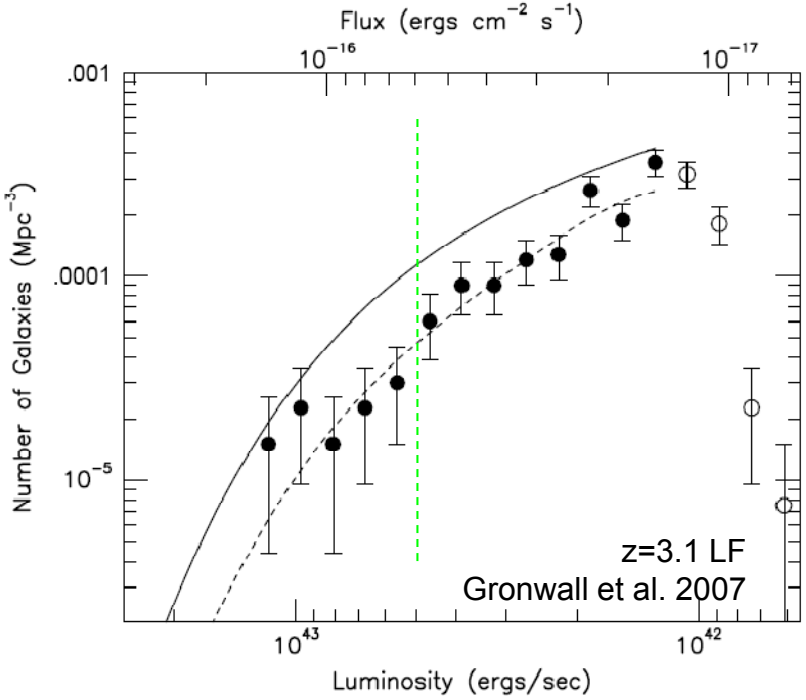
- Detection of dark energy at z>2
- Curvature to 0.1%
- Non-gaussianity measure as good as Planck
- Best measure of total neutrino mass
- Detection of cosmic web in emission
- Nature of LAE
- AGN-Galaxy correlations
- SFR at z<0.4
- Dark matter in nearby galaxies
- Stellar populations at large radii
- Map 2000 clusters kinematically
- Galactic structure from stellar kinematics
- Low metallicity stars

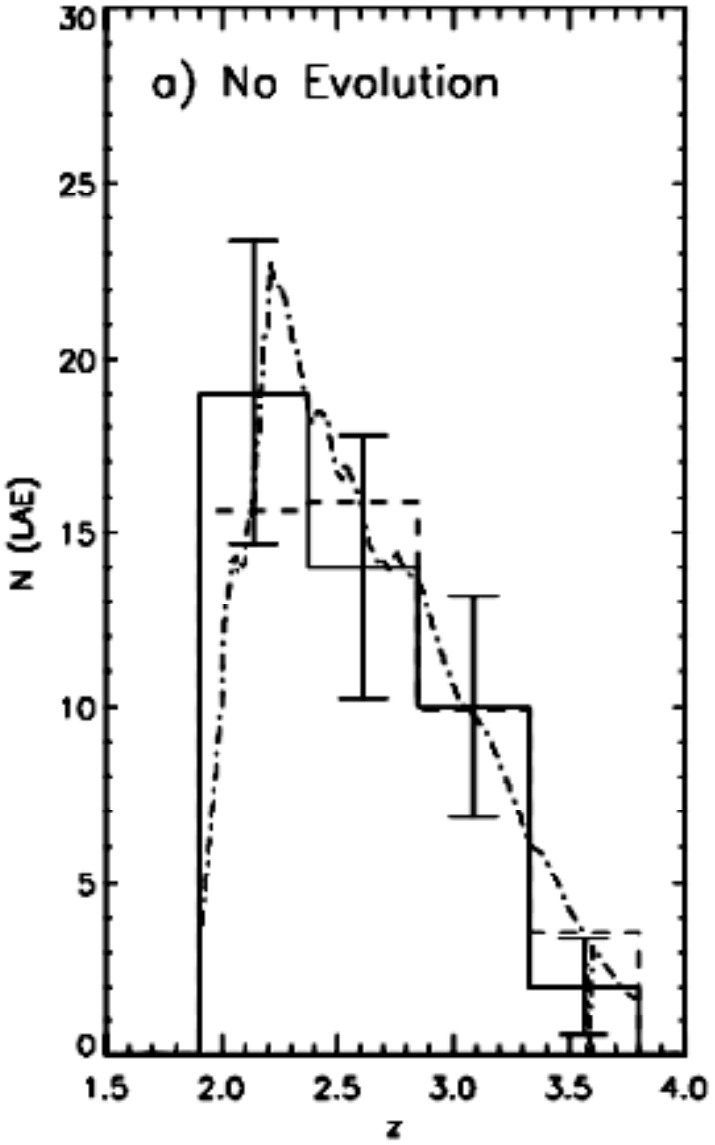
VENGA
VIRUS-P EXPLORATION OF NEARBY GALAXIES



Guillermo Blanc et al.

Preliminary redshift distribution

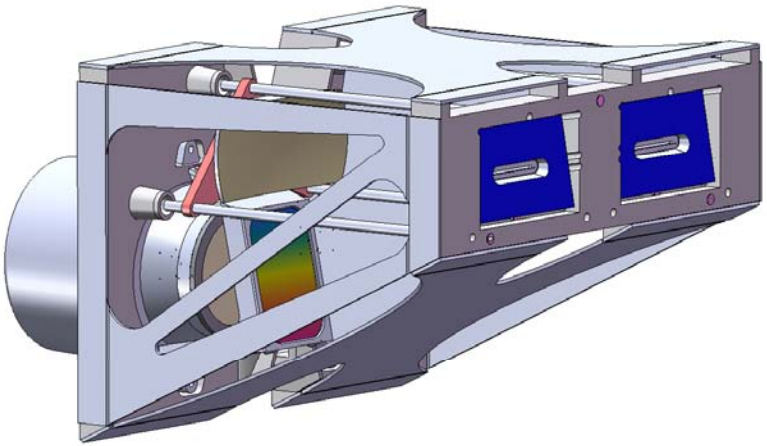




- 45 LAEs in COSMOS field
  - Follow-up spectroscopy with HET LRS is confirming those at z>2.5
- Prediction based on non-evolving LF and measured instrument sensitivity

VIRUS Production at UT & TAMU

- Production design of VIRUS is complete and prototypes are manufactured
- TAMU will lead the assembly of VIRUS
  - Ideal project to jump-start nascent instrument group
  - Large lab space available to set up integration & test line
- This project is cementing the strong ties that are developing in astronomy between UT Austin and TAMU



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VIRUS Production Castings

- Design makes extensive use of castings in both the collimator and camera
  - Even in small quantities the castings are proving very cost-effective (and coming in less expensive than budgeted)

VIRUS grating cell blanks

VIRUS Collimator and camera parts

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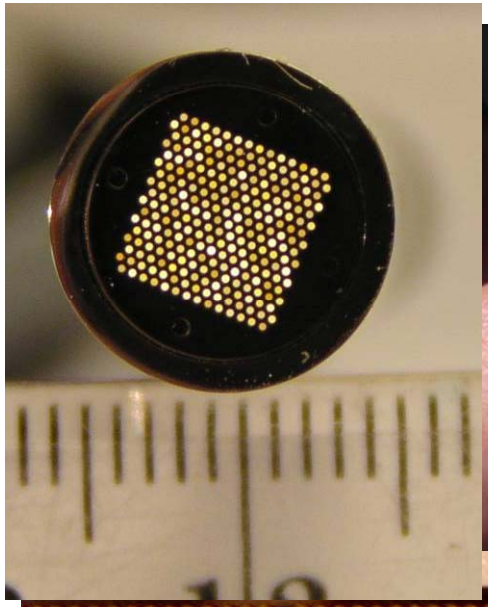
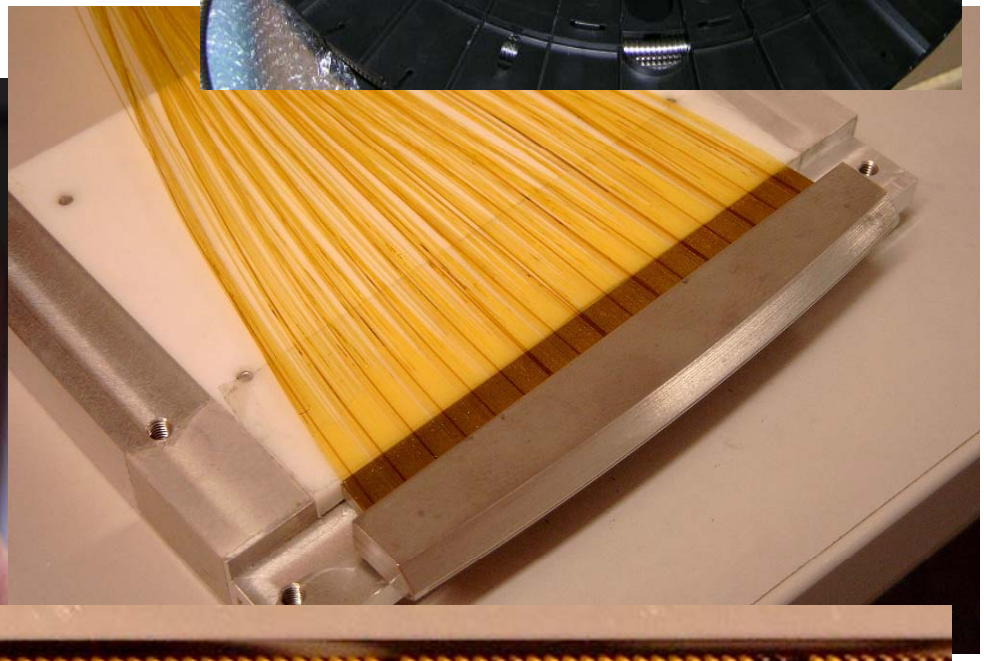
VIRUS Integral Field Unit

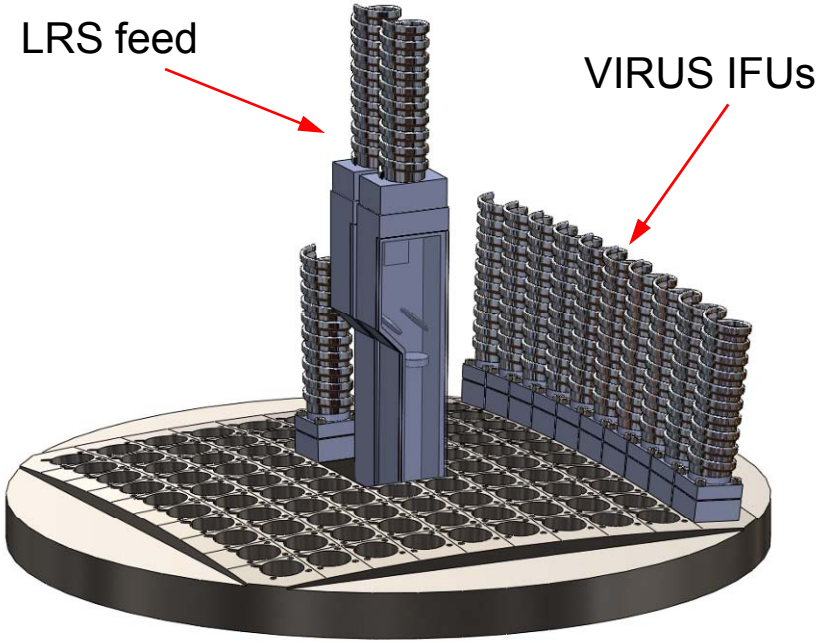
- Bundles of fibers totaling 33,600 enable the weight of VIRUS to be mounted low
  - Each IFU is a bundle of 448 fibers split into two slits to feed a spectrograph pair
  - Simple design maximizes throughput and minimizes cost
- Development in collaboration with AIP
  - nine already delivered

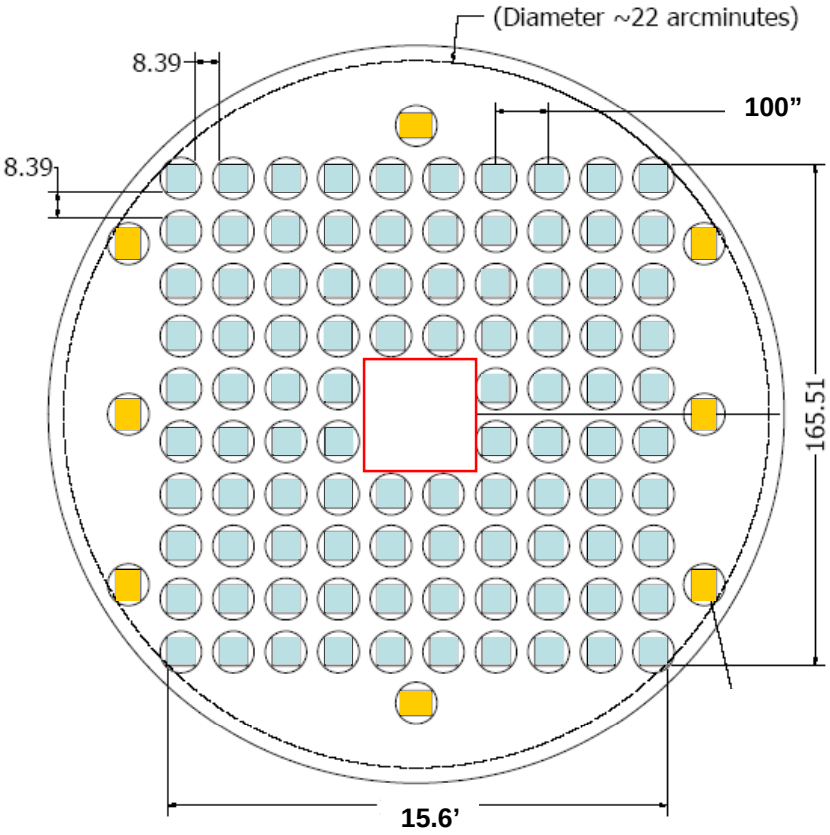




VIRUS field layout

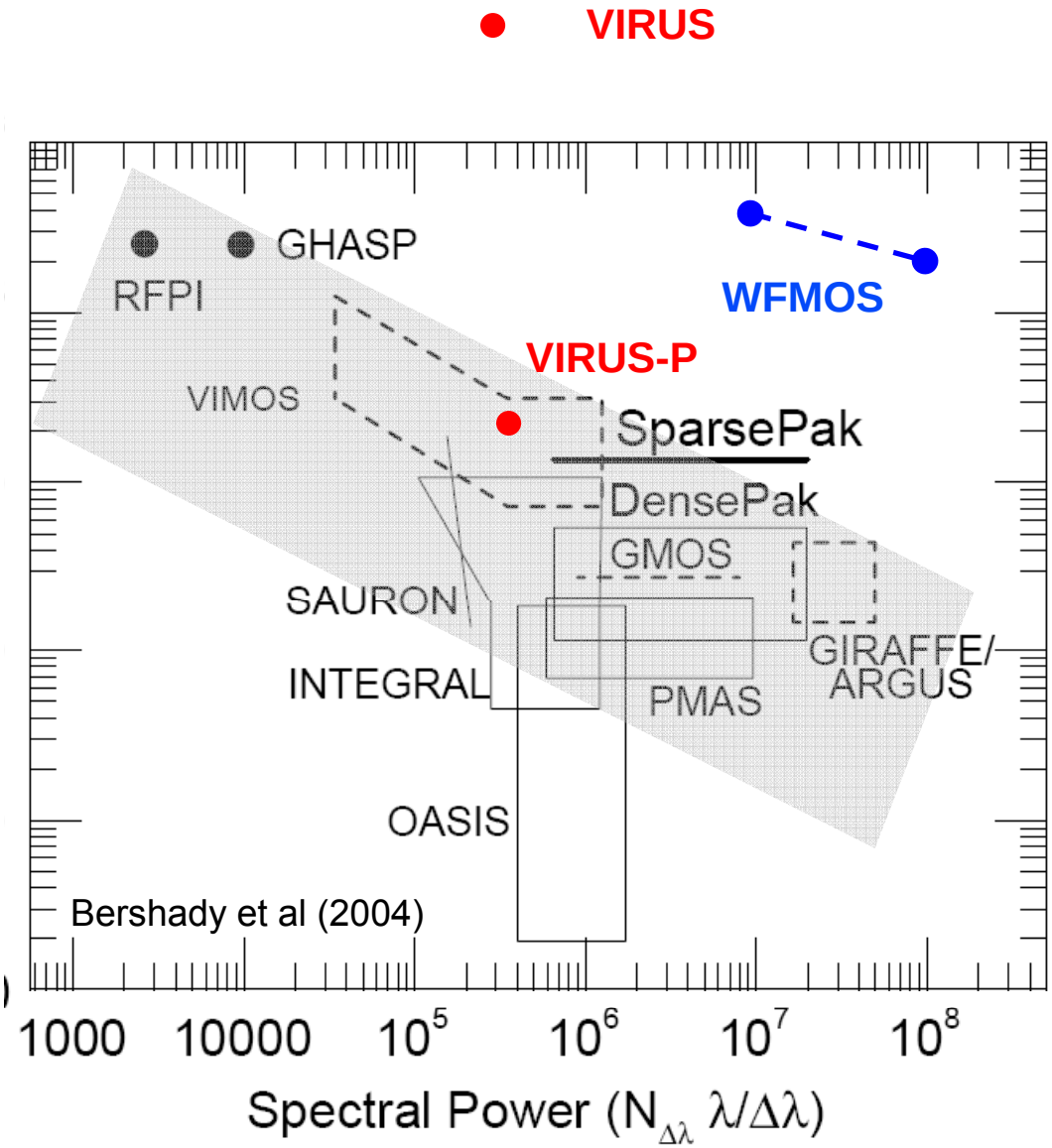
- Grid layout of IFUs with ¼ fill factor
  - feeds for other instruments at the middle of the field
- Allows parallel observations with VIRUS
- Baseline 75 IFUs will leave some gaps, but goal is to fill the matrix





Summary

- The HETDEX project will detect the effect of DE on expansion at z~2 even if it is a cosmological constant
- It will provide the first large-scale 3-D view of the high redshift cosmic web
- The survey will contain a huge range of interesting objects
- $25.5M raised of the required $34M
- The survey will begin in fall 2011

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