Introduction to WFU, VIRUS, & DEX

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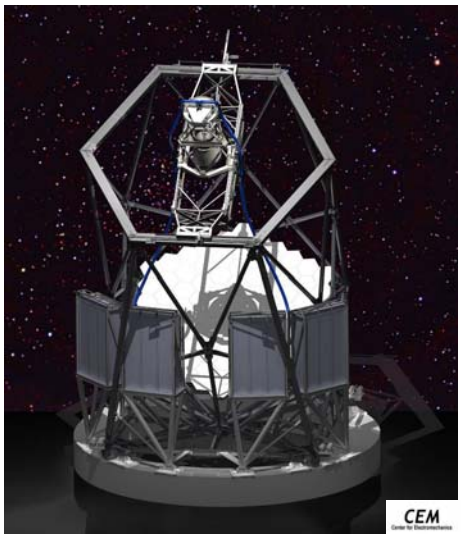
HETDEX Science Workshop Feb 09

Scope

- What HETDEX is
- WFU
- VIRUS
- DEX survey parameters

Hobby Eberly Telescope Dark Energy Experiment

- HETDEX is:
  - Upgrade of HET to have a new 22 arcmin wide field of view
  - Deployment of the hugely replicated integral field spectrograph, VIRUS
  - Execution of a very large blind spectroscopic survey
  - Measuremnt of expansion rate and angular diameter distance at z~2.4 to determine if there is any evolution of dark energy
- HETDEX enables a lot of ancillary science
  - Which is why we're here today



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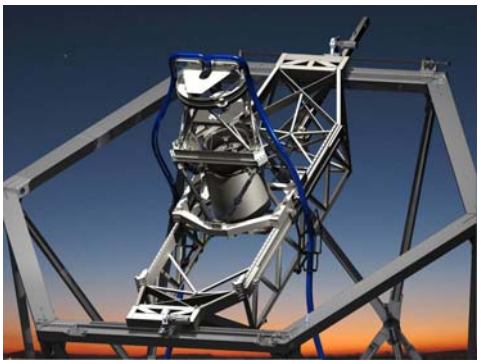
HETDEX Overview

- 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}~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
  - Finding low metallicity stars
  - Identifying sub-mm galaxies
  - Surveying clusters for gravitationally lensed LAEs

Upgrade of HET

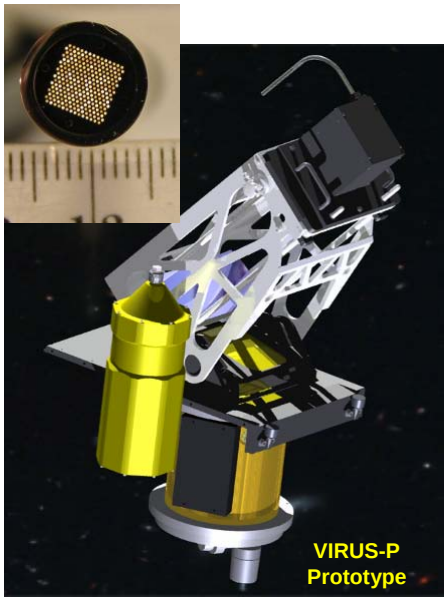
- HET is a very cost effective telescope but only views a small patch of sky at once
- New wide field corrector and tracker along with some modifications to the structure will upgrade HET to view 22 arcmin diameter field of view
- Integrated control system for rapid setup and high efficiency



- Key aspect of upgrade is the provision of closed-loop metrology on all axes and primary mirror radius of curvature to maintain image quality and plate scale
  - Guiders, wavefront sensors
  - DMIs, tip-tilt sensors

VIRUS

- 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
- 6



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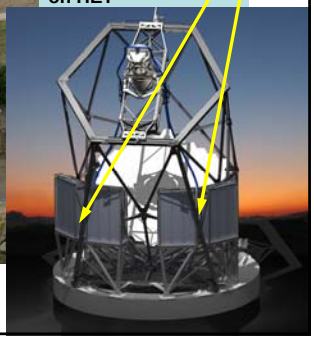
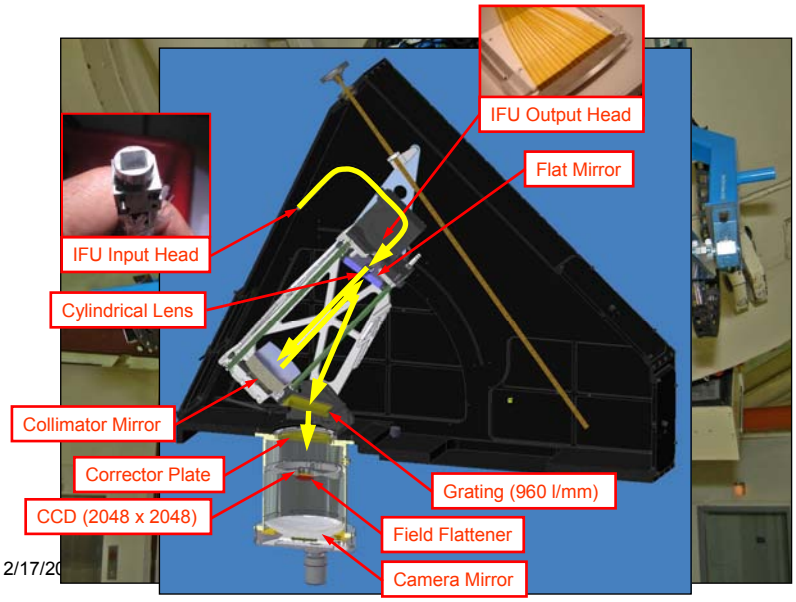
VIRUS on HET

HET
Mt. Fowlkes west Texas

VIRUS consists of 150 units mounted on HET

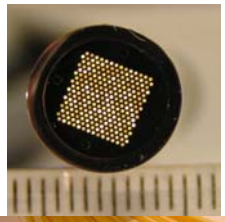
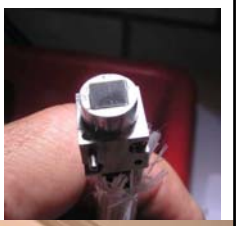


VIRUS Prototype Spectrograph



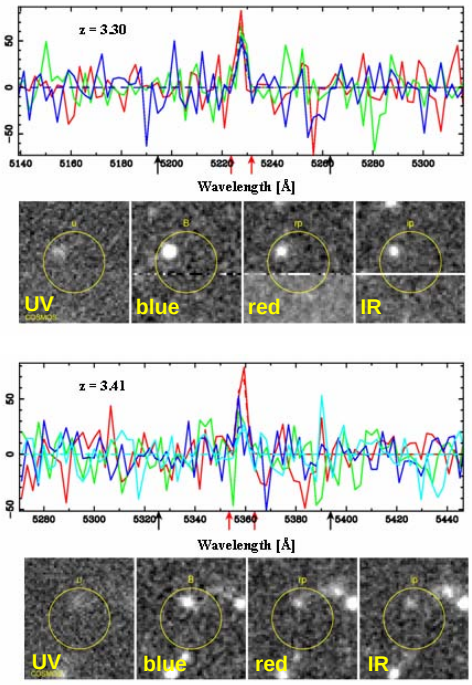
IFU development

- IFU design is a simple fiber 'densepak' configuration where the fiber cores are in a hexagonal close pack with 1/3 fill factor
  - More efficient than lenslet coupled IFU and cheaper
  - Dither pattern of three exposures fills in field area
  - High efficiency confirmed with test bundles
  - Fed at f/3.65 for low FRD
- Constructed by AIP (Potsdam)
  - 9 IFUs already funded by AIP and MPE

Results from the HETDEX Pilot Survey

- Proven the design
  - Meets the requirements for HETDEX
  - Very stable instrument
  - Test bed for software
- Measured the performance
  - Detected LAEs and [OII] emitters
- Provided the cost basis for replicating the instrument
- VIRUS-P is a powerful instrument in its own right
  - Being used for many other projects



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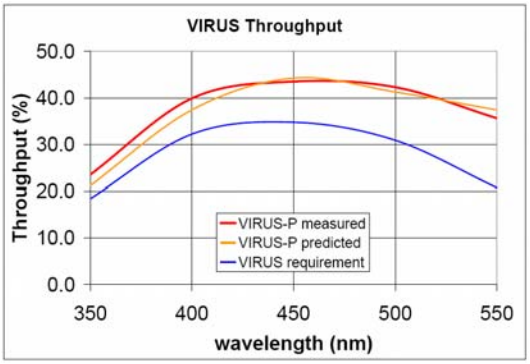
Performance

- Sensitivity of VIRUS-P matches prediction well
  - Exceeds requirement for HETDEX survey
- Predict 0.8 M LAEs on HET for full HETDEX survey, with 20 minutes observation per field
- 10 hours would give ~6e-18 erg/cm^2/s 5-σ line flux limit or AB~24 continuum sensitivity



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

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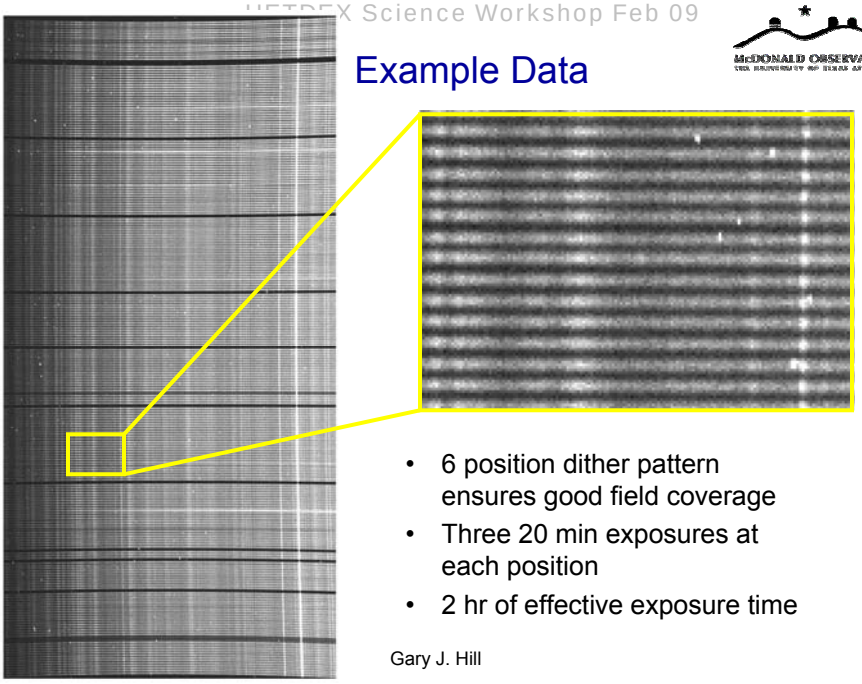
Example Data



- 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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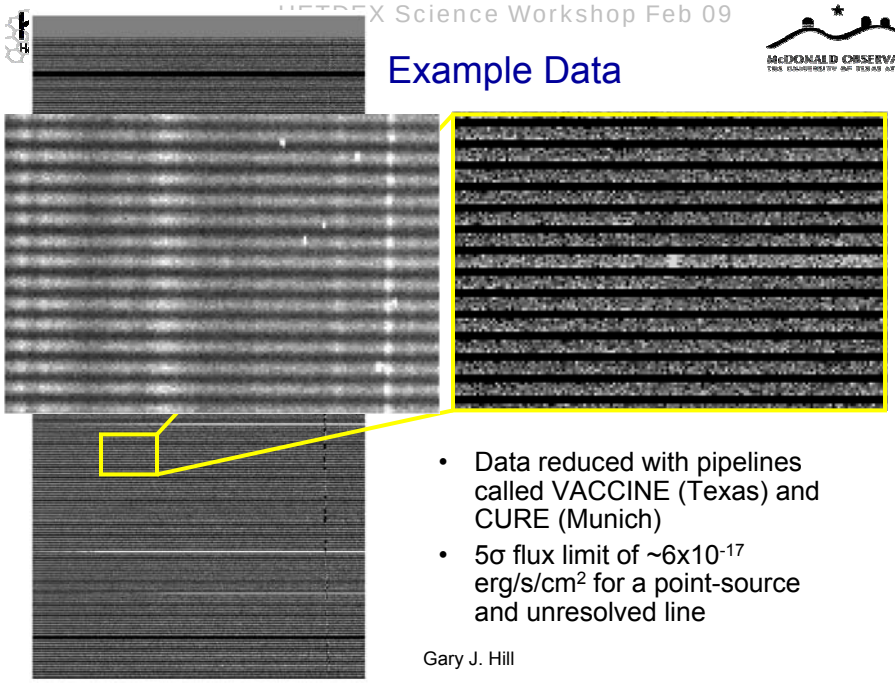
Example Data



- Data reduced with pipelines called VACCINE (Texas) and CURE (Munich)
- 5σ flux limit of ~6×10^{-17} erg/s/cm^2 for a point-source and unresolved line

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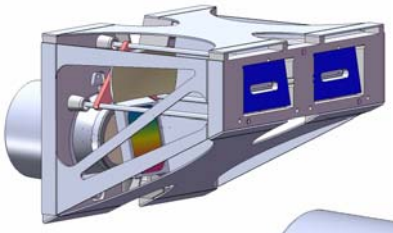
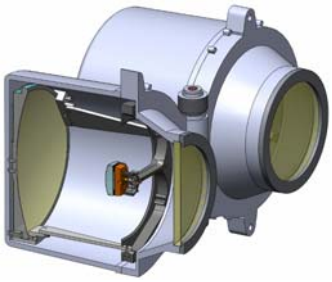
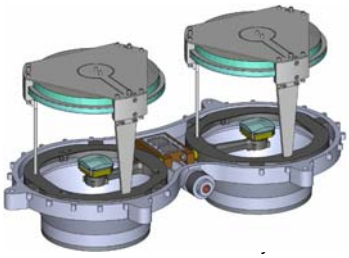
VIRUS Production at UT & TAMU

- Production design of VIRUS is being completed now
  - Key design changes are to fix the format and double the spectrographs
- TAMU will lead the production of VIRUS
  - Large lab space available to set up integration & test line



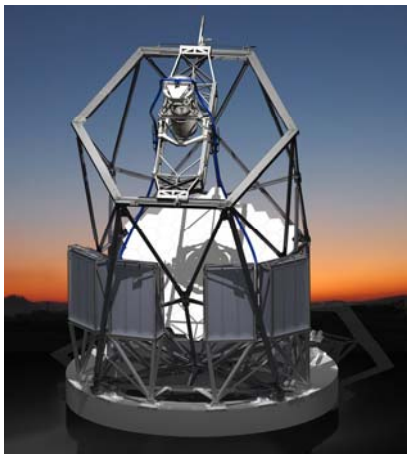




IFU production

- AIP has been leading the IFU development
- 9 IFUs are already delivered
- Will feed 18 spectrographs

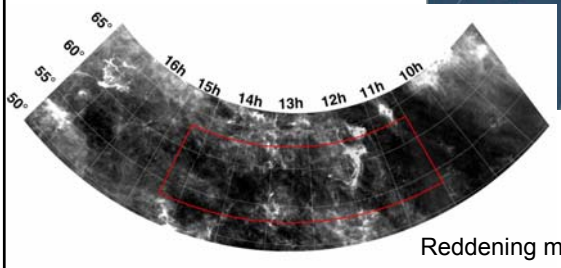
The VIRUS array on HET



- VIRUS detector system will be cooled by a passive LN2 distribution system fed from a large external tank

DEX Survey on sky

- Dec δ = 53-63^{O} optimal for HET
- 420 sq. degrees
  - 2000 x area of moon
- 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

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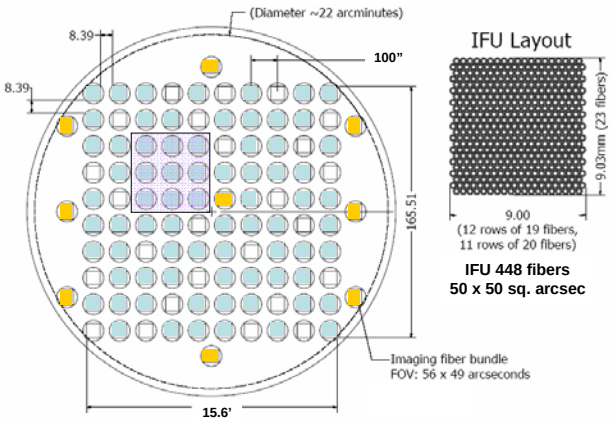
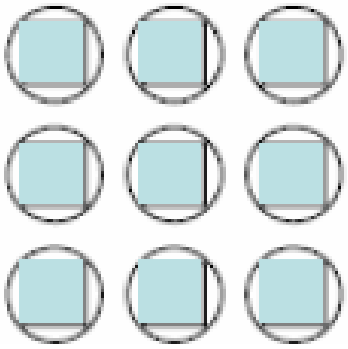
IFU layout on sky

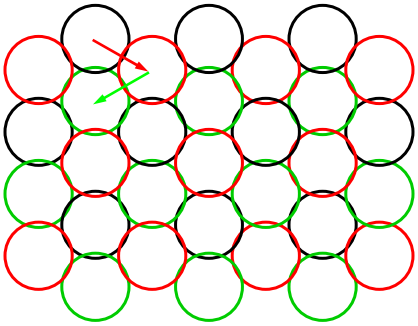
- HETDEX Layout
- 75 IFUs random layout
- 150 spectrographs
- Contiguous 9 IFU block can allow full coverage of 17.4 sq. arcmin area
- Future reconfigurations can fill in a smaller area depending on the total number of spectrographs funded
- Two guide probes and two wavefront sensors range in outer part of the field but do not obstruct the IFUs



Dithering and Offsetting

- An observation of three exposures are needed to fill in the area of each IFU due to the 1/3 fill factor of the fibers





- IFUs are in a matrix with ¼ fill factor, so four offset observations will fill the area, if there are IFUs in all slots

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HETDEX Footprint on Sky

19.5’

- This layout gives the 0.8 M LAEs needed for HETDEX
- Gaps do not effect the accuracy of the power spectrum
- Pointing centers will be randomized naturally by avoiding bright stars on the IFUs

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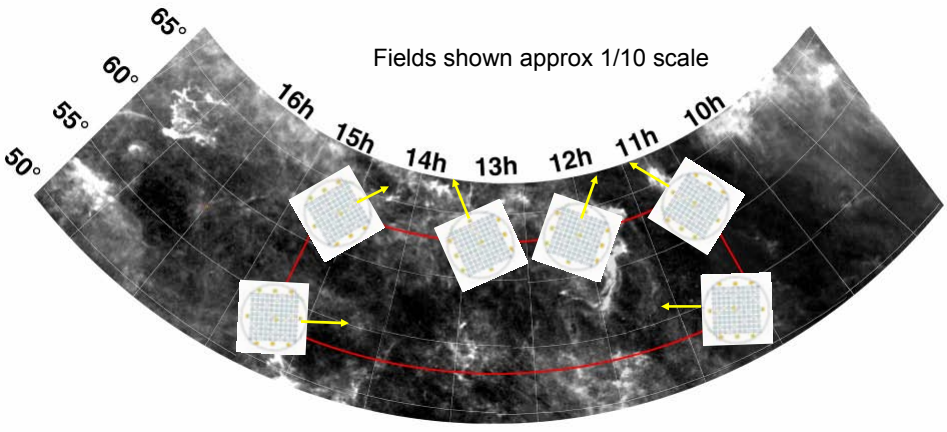
HETDEX Footprint on Sky



Fields shown approx 1/10 scale

- Position angle of field on sky follows parallactic angle through survey

dec	Az(east)	Az(west)	PA(east)	PA(west)
63	16.4	343.6	32.4	327.6
58	29.3	330.7	52.6	307.4
53	39.5	320.5	65.3	294.7

A HETDEX Observation

- An observation for HETDEX lasts 20 minutes, including overhead and 80 sec rewind time to next observation
  - Baseline is to obtain 2 exposures of 170 sec at each dither position with 20 sec readout between each
  - Tests indicate that cosmic ray removal can be achieved without doubling up the exposures, so a more efficient observing strategy will be to obtain a single 360 sec exposure at each dither position
- In the 20 minutes, the tracker moves ~0.7 m
  - The telescope can be parked at a fixed azimuth and fields observed in succession at the same declination
  - Depending on the declination, about every 5th field can be observed in a single declination strip
  - The pupil can be kept well centered on the primary mirror except when chasing the extents of the survey early or late in the observing season
- The survey requires 4000 observations or ~1400 hours
  - A small number of fields distributed through the area will be observed repeatedly to check photometric repeatability; these will go very deep.

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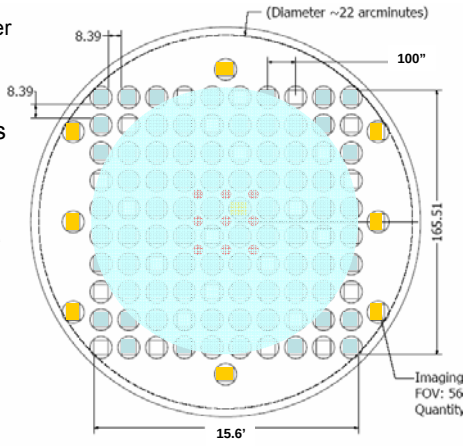
Calibration Strategy

- VIRUS data will be largely self-calibrating
  - Most fibers are looking at sky so excellent sky subtraction
  - ~10 blue stars will fall on IFUs for any exposure, providing a good flux calibration (against the SDSS)
  - Monitoring of guidestar brightness and image size is used in the co-addition of the three exposures that make up a dithered observation
  - This strategy has been tested on pilot survey data and borne out
- Calibration facility provides flat field and emission line lamps with accurate illumination over the field of view
  - Ability to obtain a flat field exposure while rewinding tracker for next observation
  - Ability to illuminate individual fibers isolated from neighbors using masks to periodically record profiles of spectra for deconvolution
- Imaging survey with WIYN ODI in g,r to m~25 will discriminate [OII] emitters and provide additional calibration information

Parallel Mode

- VIRUS can observe in parallel mode when HRS or MRS feeds are being used for the primary science exposure
  - The HRS and MRS fiber feeds are located in front of the VIRUS shutter and do not dither with the VIRUS input
- The feed for the future LRS may use one of the VIRUS IFU positions
  - Which would present problems for dithering and shuttering
- Or it may be integrated with the acquisition camera to provide more capability
  - In that case most of the VIRUS IFUs would be obstructed and parallel observations with LRS would not be possible



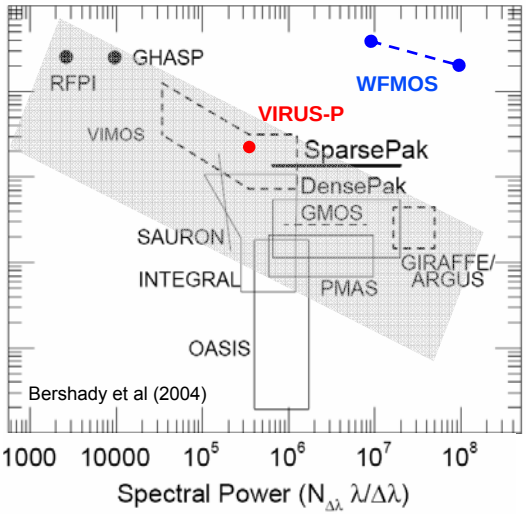
Project Status

- International panels have given the project a strong endorsement on both science and technical sides
  - Science Requirements Review passed in June 2007
  - Preliminary Design Review passed in April 2008
- Funding is in hand for the HET wide field upgrade
  - $23.4M raised or committed (2/3 of total)
  - Now at the point where key long-lead-time items are in manufacture – specifically the wide field corrector and tracker
- VIRUS production is starting
  - We are on schedule to deploy in early 2011
  - Production design and prototyping will be complete mid-year
  - Detector system is being procured
  - First IFUs are delivered
  - Funds in hand for the first 10 spectrographs

VIRUS compared to WFMOS

- WFMOS and VIRUS each achieve a factor of 100 increase in grasp over current instruments
  - WFMOS is sensitive to the stars
  - VIRUS is sensitive to the star formation
- Also very complementary to MUSE
- VIRUS on the upgraded HET will be an unrivalled survey facility

- Now let's hear what we're all planning to do with it!



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