

# HETDEX: AGN-galaxy clustering at $2 < z < 3.5$

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## Hobby-Eberly Telescope Dark Energy Experiment

- ⇒ blind, large-scale spectroscopic survey with VIRUS at HET
- ⇒ 300 square degrees (60 square degrees with spectra) over 3 years
- ⇒ about 0.75 million redshifts from  $1.9 < z < 3.5$  ( $\text{Ly}\alpha$  emitters)
- ⇒ about 1 million redshifts from  $0 < z < 0.5$  (OII emitters)
- ⇒ **Timeline: 2015-2017**



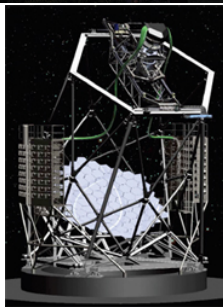
# Hobby-Eberly Telescope (HET)

- McDonald Observatory, Texas
- fixed elevation-axis design
- segmented primary mirror  
11.1 x 9.8 m (9.2 m effective aperture)



## HETDEX

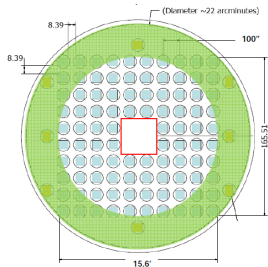
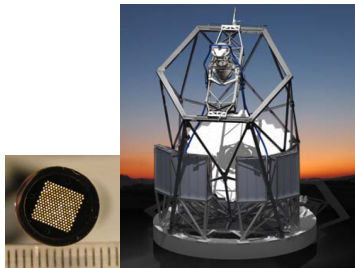
- ⇒ HET upgraded to 22 arcmin field of view
  - ⇒ in progress
- ⇒ new instrument VIRUS
  - ⇒ construction complete by end of 2014



# VIRUS instrument

## Visible Integral-Field Replicable Unit Spectrograph (VIRUS)

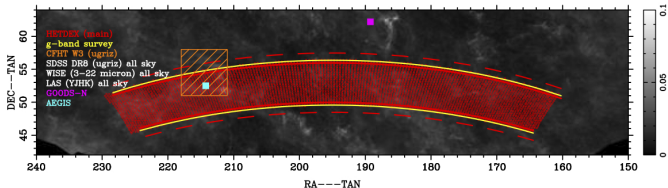
- 75 IFUs feeding 150 spectrographs
- each IFU contains 448 fibers (33 600 spectra per shot)
- 3500 – 5500 Å at  $R \sim 750$
- Line flux limit:  
 $3.5 \times 10^{-17}$  erg/cm<sup>2</sup>/s  
and  $m_{AB} \sim 22$



# Survey Design

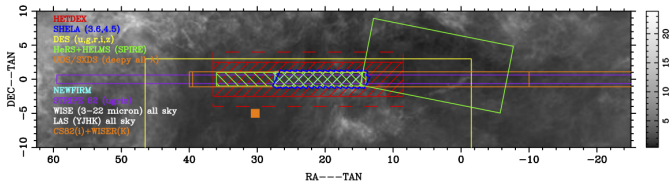
## ⇒ Spring field:

- 42x7 deg<sup>2</sup> with 1/4.5 fill factor
- centered on 13hr, +53deg



## ⇒ Fall field:

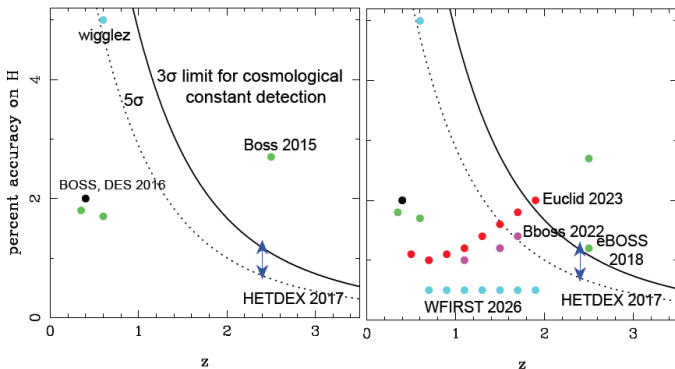
- 28x5 deg<sup>2</sup>
- centered on 1.5hr, 0deg



⇒ Fall field with ancillary data in optical (grizy, DES), near-IR (K, NEWFIRM), mid-IR (Spitzer-SHELA), far-IR (Herschel-HeRS)

# Constraining Dark Energy with HETDEX

⇒ measure power spectrum of  $\sim 800,000$  LAEs



⇒ measure  $H(z = 2.3)$  and  $D_A(z = 2.3)$  to 0.9%

⇒ **constrain evolution of dark energy ( $w_a$ )**

⇒ **most precise measurements at  $z > 2$**

# AGN in HETDEX

fully blind IFU spectroscopic survey data from HETDEX enables multitude of ancillary science, including AGN

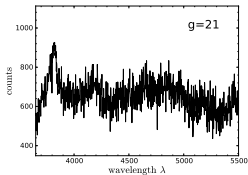
⇒ no preselection required

⇒ detection through characteristic emission lines in spectra

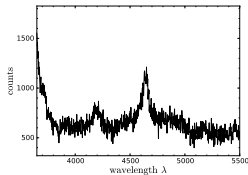
- type-2 AGN hard to identify  
([Ne V]3426 line, X-ray, mid-IR, ...)
- type-1 (broad line) AGN easy to distinguish from LAEs and [OII] emitters
  - ⇒ several lines detectable (MgII, CIII], CIV, Ly $\alpha$ ) up to  $z = 3.5$
  - ⇒ unambiguous redshift identification at  $z > 1.3$

# simulated type 1 AGN spectra

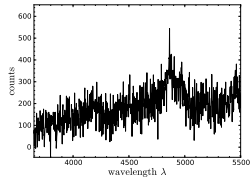
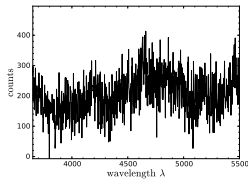
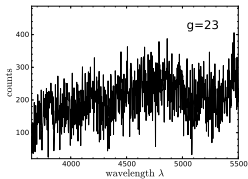
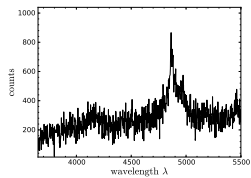
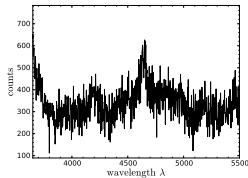
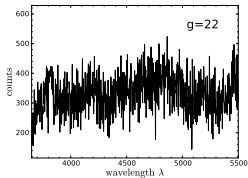
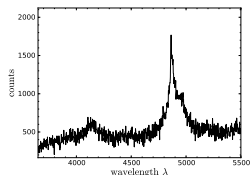
⇒  $z = 1$



⇒  $z = 2$

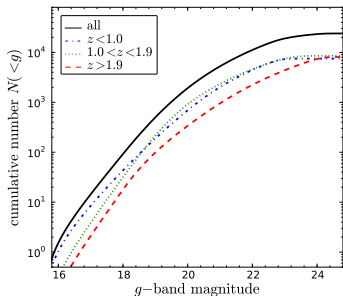


⇒  $z = 3$





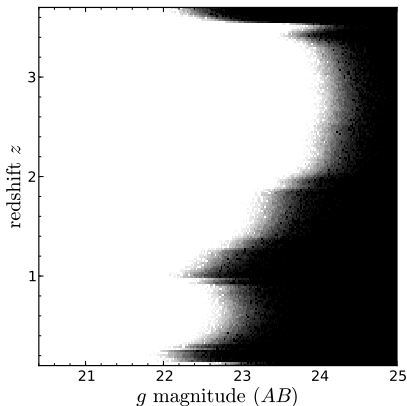
# HETDEX AGN selection



predicted number  
counts

main field:  $\sim 20\,000$  AGN  
 $> 10\,000$  AGN at  $z > 1$   
no preselection

Predicted HETDEX AGN  
selection function

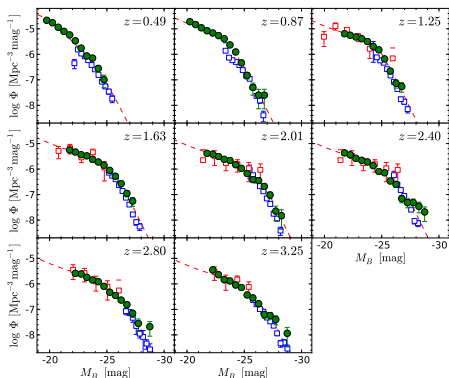


# AGN demographics

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- ⇒ excellent sample for statistical studies of type 1 AGN
- AGN luminosity function and evolution from  $0 < z < 3.5$
  - Evolution of active BH mass function and Eddington ratio distribution function
  - AGN-Galaxy clustering

# AGN Luminosity function



predicted AGN LF for HETDEX main survey (SDSS, VVDS, HETDEX)

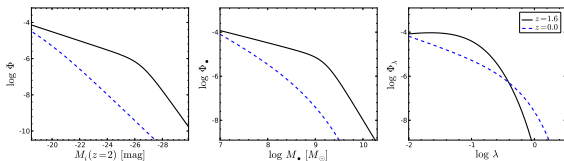
## AGN Luminosity function

constrain faint end of AGN

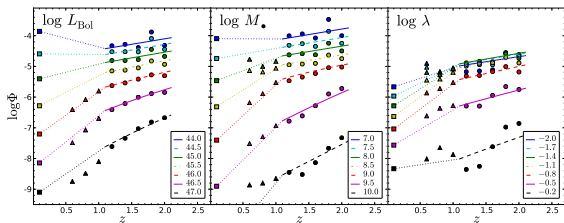
LF between  $z = 2$  and  $z = 3.5$  down to  $g \sim 24$ , without preselection

# Black hole mass and Eddington ratio distribution function

⇒  $M_{\text{BH}}$  estimates from broad lines up to  $z = 2.5$



⇒ determine AGN evolution as function of  $M_{\text{BH}}$  and  $L_{\text{bol}}/L_{\text{Edd}}$

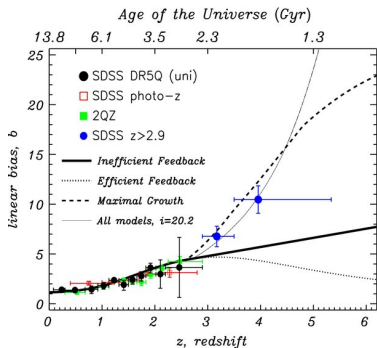


⇒ probe BH mass downsizing between  $0 < z < 2.5$

Schulze+(in prep.)  
based on SDSS+VVDS+zCOSMOS

# AGN-Galaxy clustering

- ⇒ within  $1.9 < z < 3.5$  HETDEX will probe  $10^4$  AGN and  $10^6$  galaxies (LAEs) in the same volume
- ⇒ excellent sample for AGN-galaxy clustering at  $z > 2$
- ⇒ construct AGN-LAE 2-point cross-correlation function (100× increase in power over AGN auto-correlation function)



Ross et al. (2009)

# AGN-Galaxy clustering

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- **large scale clustering:**

- ⇒ AGN bias factor
- ⇒ relation to DM halos (typical DM halo masses)

- **small scale clustering:**

- ⇒ reach below  $1/h$  Mpc separation => nonlinear regime
- ⇒ Halo occupation distribution (HOD) => constrain AGN fueling and feedback

- good statistics to bin in AGN luminosity, BH mass, . . .

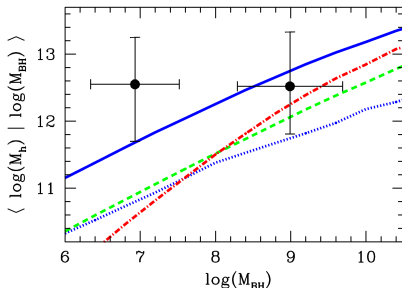
⇒ HETDEX will provide the precise probe of AGN-galaxy clustering at  $z > 2$

# AGN-Galaxy clustering: The $M_{\text{Halo}} - M_{\text{BH}}$ relation

- $M_{\text{Halo}}$  from clustering
- $M_{\text{BH}}$  from spectra

⇒  $M_{\text{Halo}} - M_{\text{BH}}$  relation at  $2 < z < 2.5$

Current estimate at  $1.5 < z < 3$   
based on small samples



Adelberger & Steidel (2005)

# Conclusions

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- HETDEX will start first half 2015
- 3 year, massive, blind spectroscopic survey in two fields over  $300+150 \text{ deg}^2$
- powerful AGN survey (20000 type 1 AGN in main field)
- AGN demographics: AGNLF, BH mass and Eddington ratio distribution function, **AGN-galaxy clustering**
- within  $1.9 < z < 3.5$   $10^4$  AGN and  $10^6$  galaxies in the same volume

⇒ HETDEX will provide unique probe of AGN-galaxy clustering at  $z > 2$