HETDEX collaboration

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HETDEX is:

→ blind spectrographic survey on 9.2m Hobby-Eberly Telescope

→ At least 420 square degrees, which is 1200 hours (140 nights)

→ about 1 million redshifts from $1.9<z<3.8$ (Ly-alpha emitters)

→ about 1 million redshifts from $0<z<0.5$ (OII emitters)

→ upgraded HET with new top-end, including 22' field

→ new instrument VIRUS which is 150 spectrographs (R=800 from 350nm – 580nm)

→ one unit spectrograph has been in use for over 2 years

TIMELINE: 2011-2013

HETDEX will provide:

→ direct detection of DE at z=2.5 (for a Λ model)

→ curvature measure to about 10^{-3} (>10x better than present)

→ modest improvement on zeropoint (e.g., w_0)

→ significant improvement on evolution (e.g., w_a)

→ H(z=2.8) to 0.9% (in 140 nights)

→ D_A(z=2.8) to 0.9%

→ Amplitude of power spectrum to 1.5% (structure growth)

→ HETDEX+ (VIRUS in parallel mode) can obtain 10x the area over 10 years, with no new hardware.

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 nearby clusters
- Galactic structure from stellar kinematics
- Low metallicity stars

Expected Numbers

Continuum and line sensitivity from baseline:

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

- **0.8 million LAEs at 1.9<z<3.5**
- **1.0 million [OII] emitters at z<0.5**
- **0.4 million other galaxies**
- **0.25 million stars with spectra**
- **2000 Abel galaxy clusters**
- **10,000-50,000 AGNs at z<3.5**

Above numbers will increase by about 10x for parallel observations.

What HETDEX needs from ODI:

→ Imaging over the full fields

→ g and r, at a minimum, and B is very useful

→ Depth to AB=25 at 10-sigma

→ 2 fields:

  → 11h, 58d (footprint of 42d x 10d)

  → 2h, 0d (footprint of 50d x 5d)

Data Management:

→ Munich (Drory as lead) is lead for the data and software for HETDEX. They are also doing the same for PanSTARRS.

→ The data storage needs are not extreme (100 Tb reduced data over the full survey), but the software needs are large.

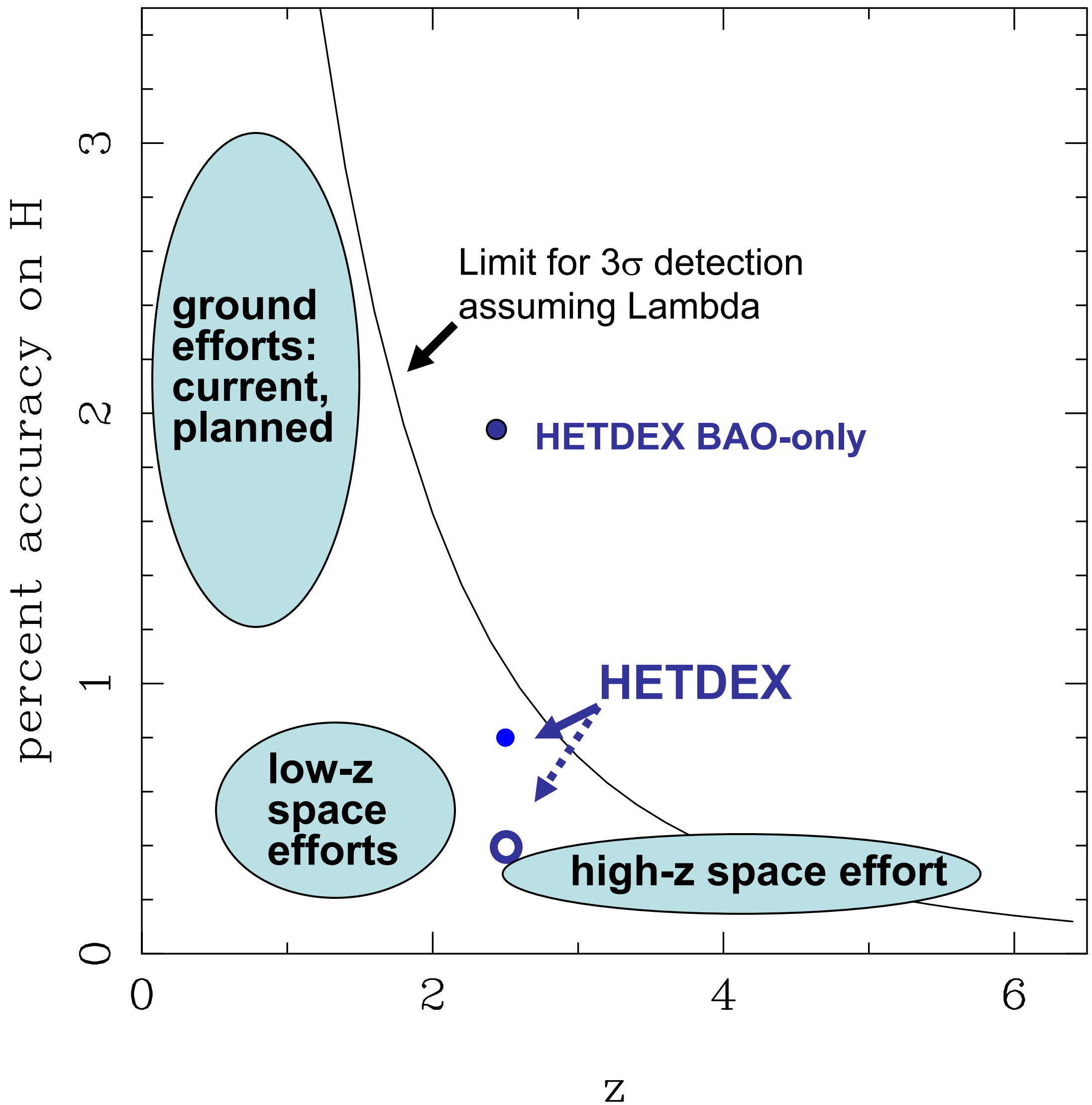
→ The pilot survey provides data in nearly the same form that we will get from HETDEX. There are two software codes (one in C and one in Fortran) that are being run, and emission line detections from both provides excellent cross-checks on robustness. We are debating as to whether to maintain two codes during the main survey.

→ Code to detect emission lines is well tested on real data.

→ A major issue though is how to optimize reductions for the plenty of other science, especially that which will come from the parallel observations (10x the data volume)!

→ There is a large meeting on this issue in the Spring. A set of white papers exists which forms the base for this meeting.

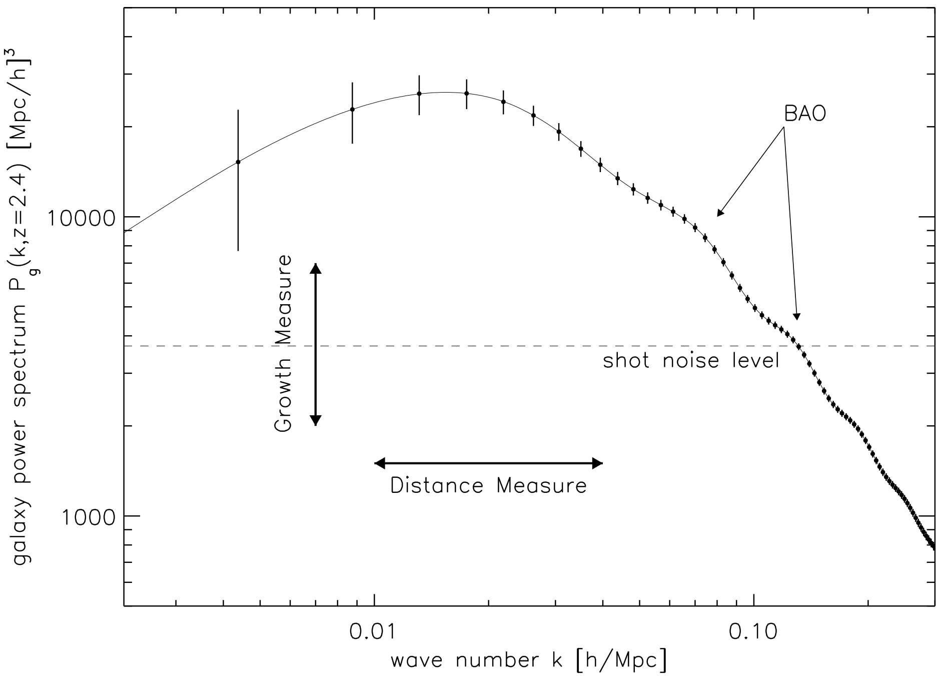
Planned Effort on Expansion Rate

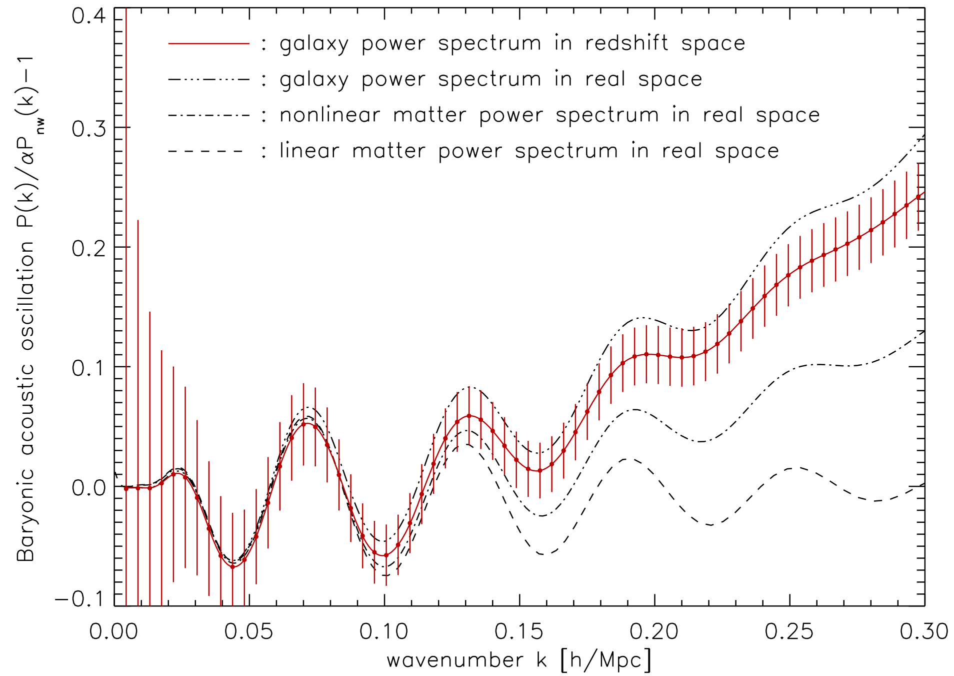


Distance from the lambda line is closely related to standard figure-of-merits

Low-z understanding of dark energy should be covered well. The next logical step is z>2.

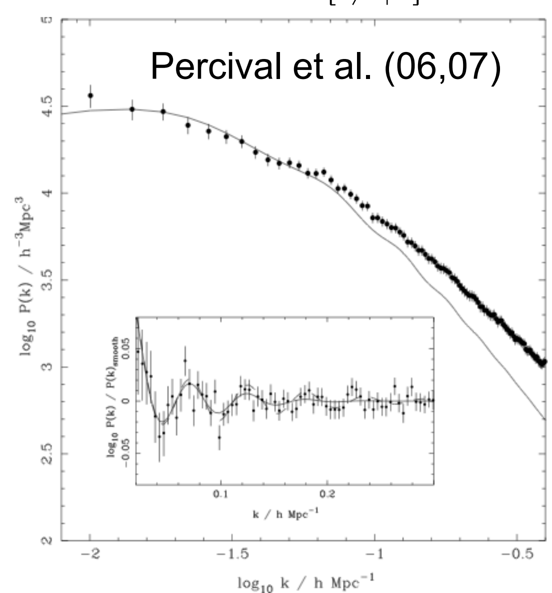
Power of the Power Spectrum





P(k) has 5 measures to exploit:

1. **Phase of the oscillations: geometric**
2. **Amplitude of oscillations: structure growth**
3. **Amplitude of P(k): structure growth**
4. **Linear/non-linear transition: geometric**
5. **General shape (e.g., turn-over): geometric**



Contamination in the Power Spectrum

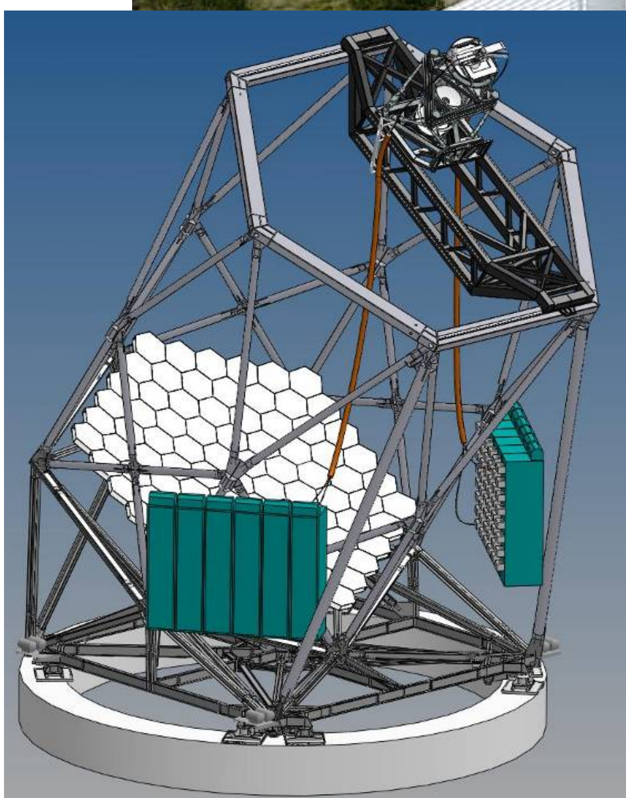
→ Since HETDEX relies on the power spectrum, we need to have as pristine a sample of tracers as we can get.

→ For the dark energy constraints, we can tolerate around 15% contamination in the LAE sample.

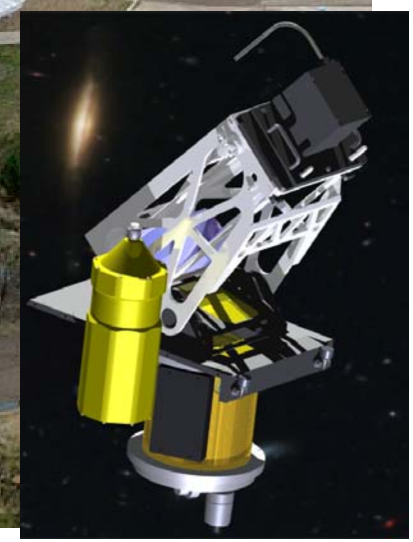
→ For nearly all other science goals, the contamination should be much lower.

→ With AB=25 imaging, we expect to reach the magic 20AA cut that provides a clean separation between high-z LAE and low-z [OII] emitters.

→ At this magnitude, the contamination should be less than a few percent.



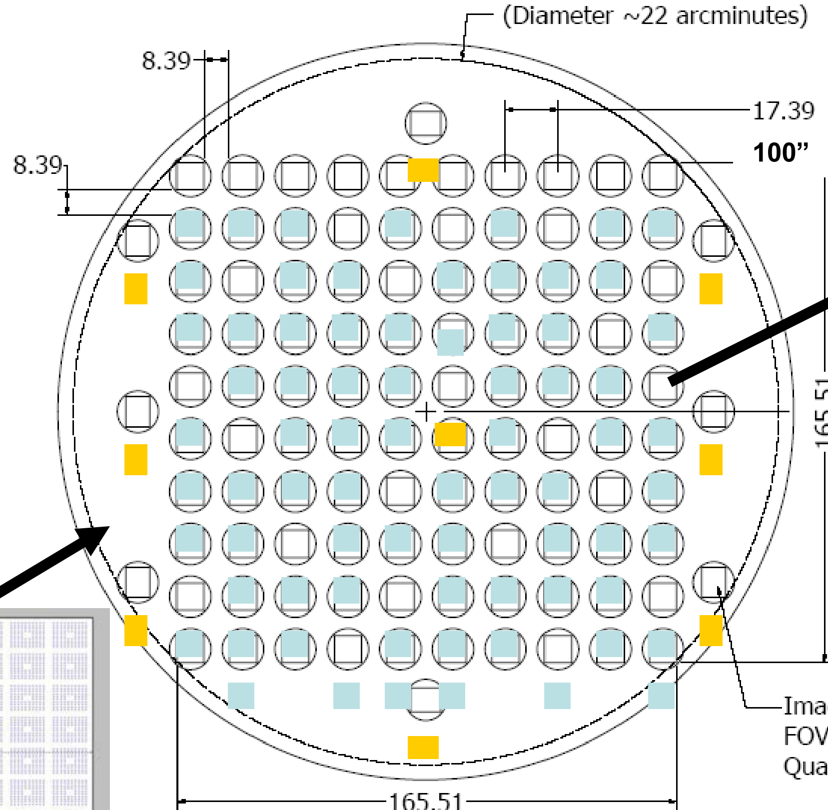
HET is the world's third largest telescope. It will be upgraded with a uniquely powerful new instrument called VIRUS

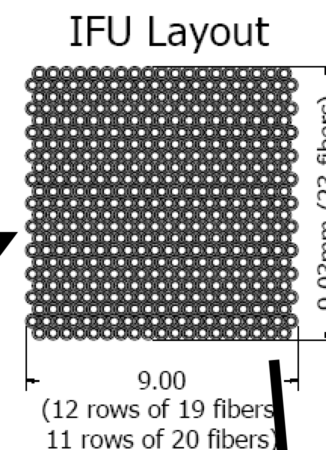


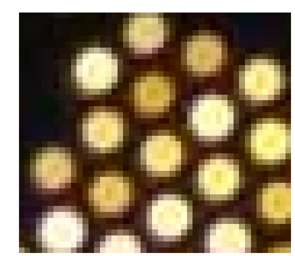
VIRUS consists of 150 units mounted on HET

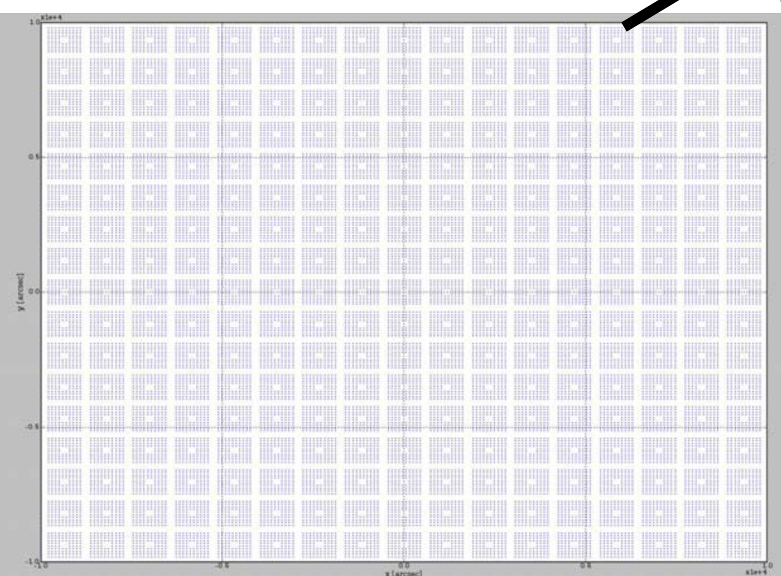
IFU layout on sky

- 75 IFUs feed 150 spectrographs (max 192)
- Focal plane is shared with other instruments, allowing parallel mode
- 1/7th fill over the full 22' diameter field





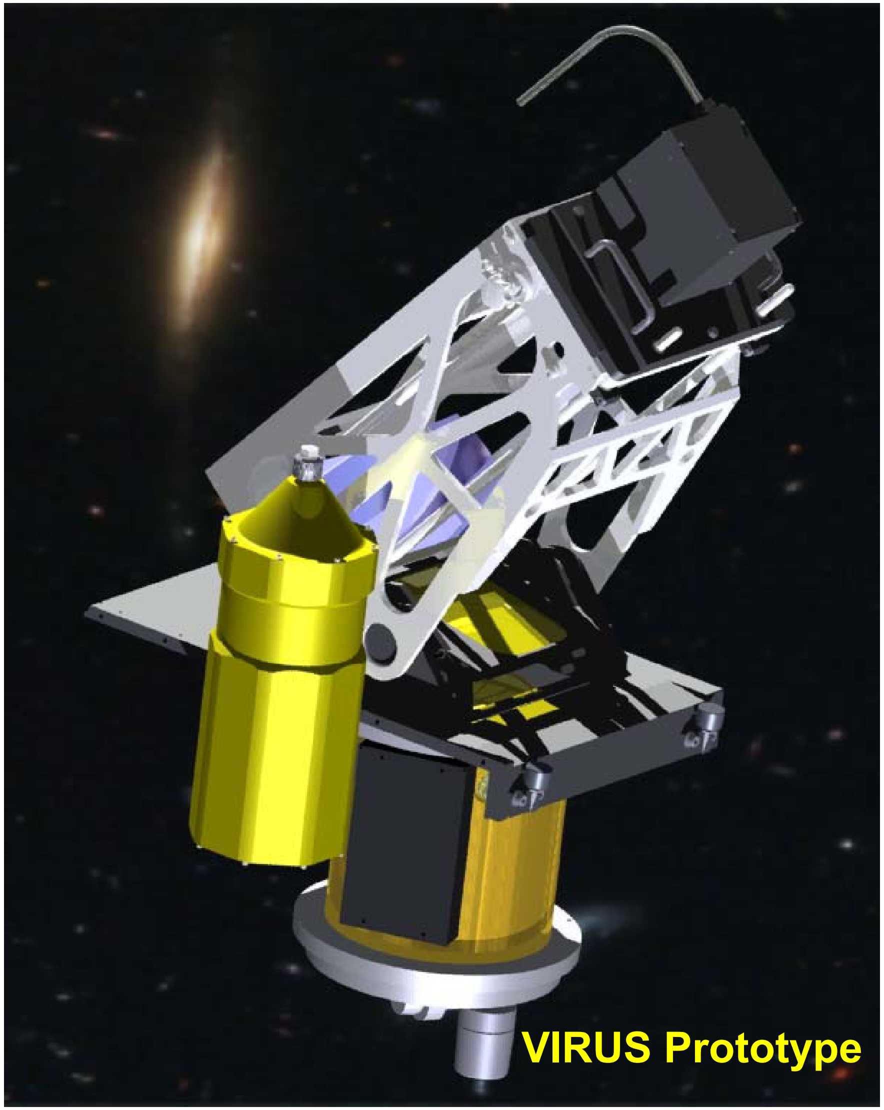




VIRUS-P, the first unit spectrograph

Funded by the George & Cynthia Mitchell Foundation, NESSI, McDonald Observatory, MPE, and AIP

- **1.9’x1.9’ FOV on McDonald 2.7m**
- **4.2” diameter fibers**
- **350-580 nm**
- **R=900**



The VIRUS-P Pilot Survey

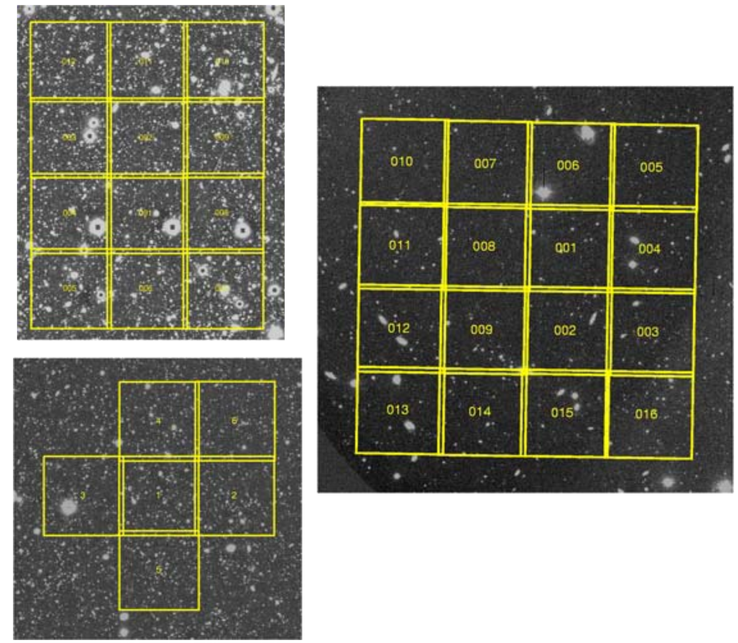
→ 115 $arcmin^2$ surveyed on COSMOS, GOODS-S and MUNICS-S2 fields

→ Fields selected to have deep multi-wavelength broad-band imaging

→ 6 position dither pattern ensures good field coverage (3x20minutes at each position)

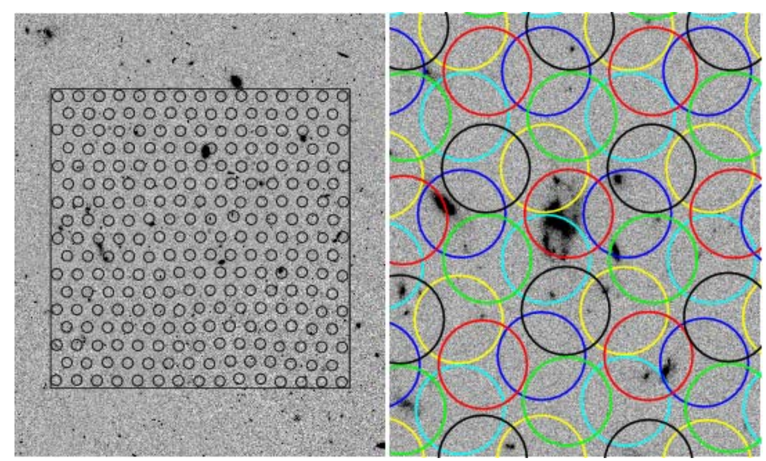
→ 2 hr of effective exposure time

→ 5σ flux limit of ~$6x10^{-17}$ erg/s/cm^2 for a point-source emitting and unresolved line

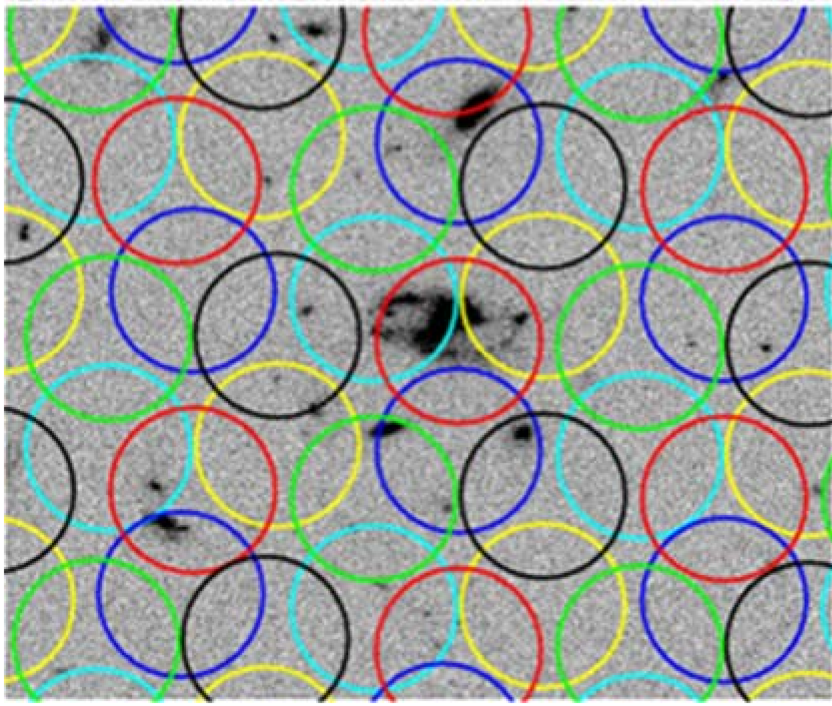


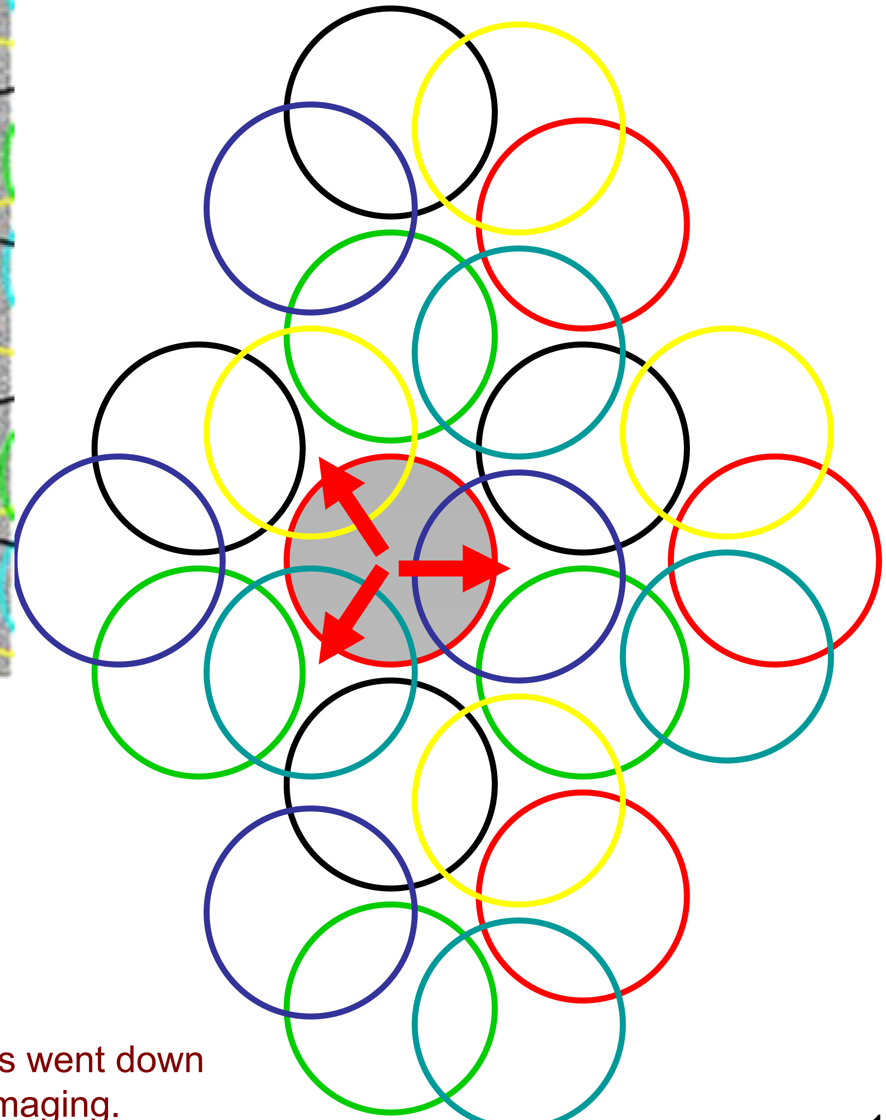
Data Reduction Pipeline:

- **want to get reliable 5-sigma sources**
- **need superb sky subtraction**
- **2 independent pipelines developed:**
  - → **VACCINE out of Texas**
  - → **CURE out of MPE/USM**



DETECTION OF EMISSION LINES



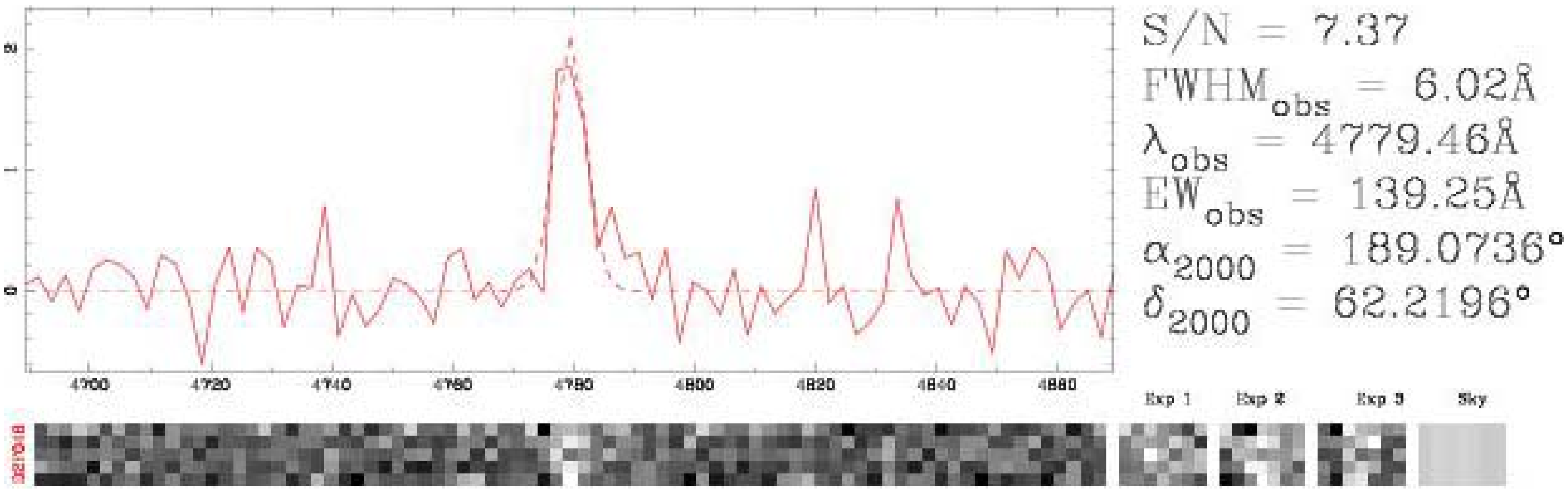


After final classification (in 40 sq arcm):

- → **45 LAEs**
- → **35 [OII]λ3727 Emitters**
- → **5 [OIII]λ5007 Emitters**
- → **3 Hβ Emitters**
- → **1 AGN**
- → **10 ambiguous classifications**

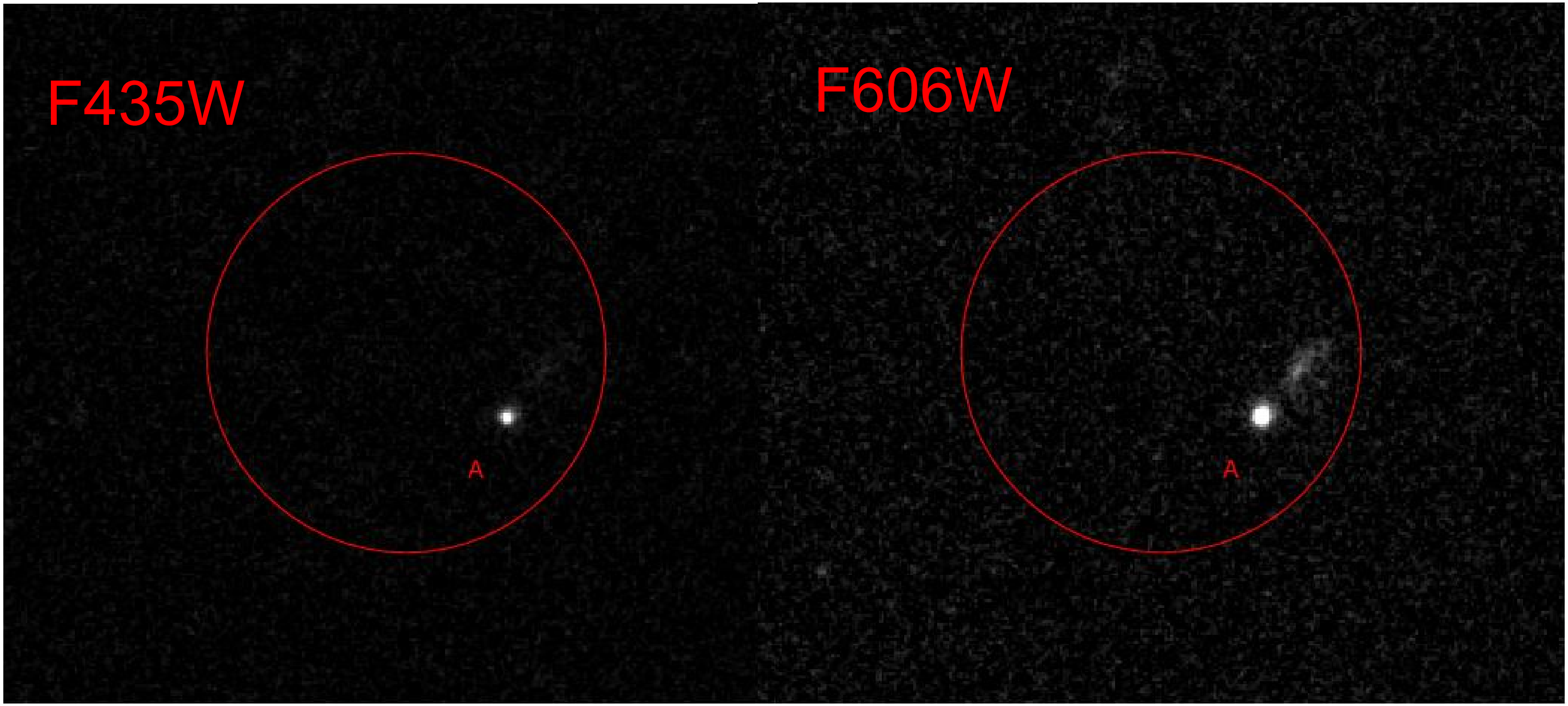
The fraction of ambiguous classifications went down from 50% to 10% by the use of broad-band imaging.

Example LAE detection

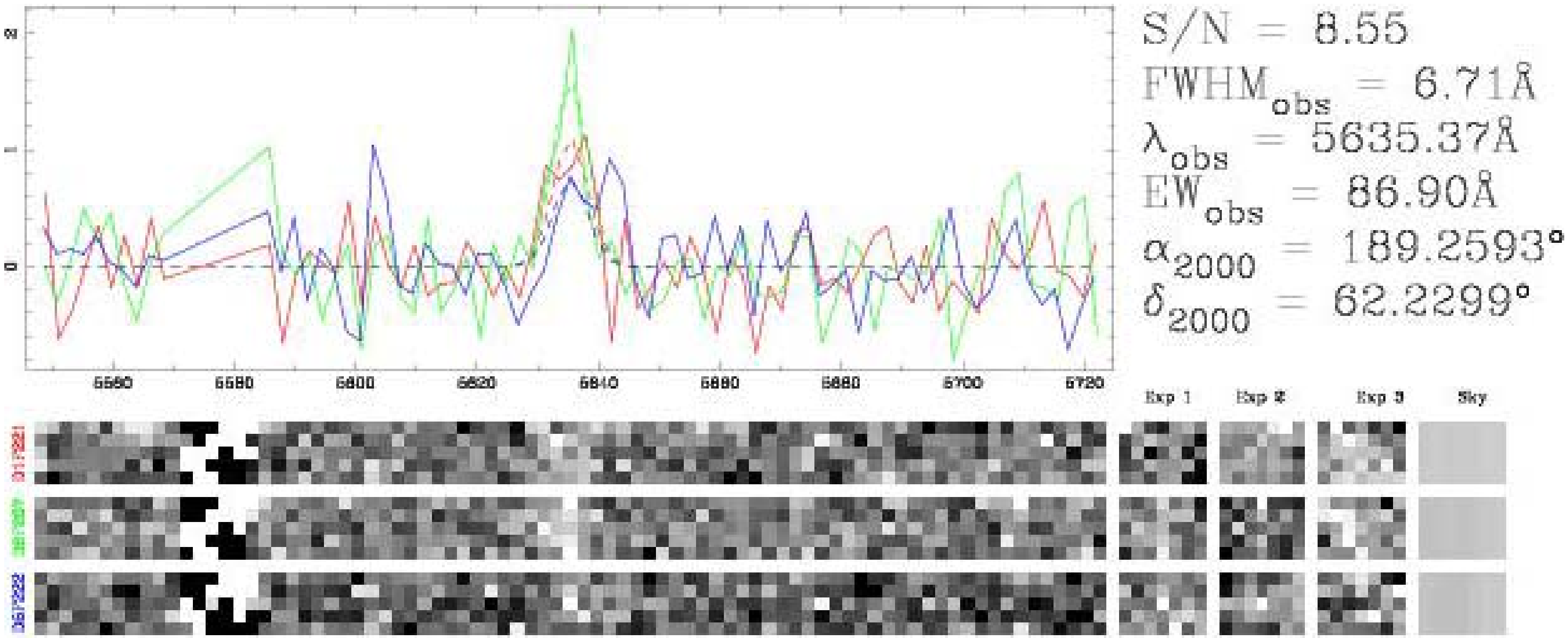


Example LAE images

In the LBG catalog, R_{AB}=25.33, U_{AB}=26.66

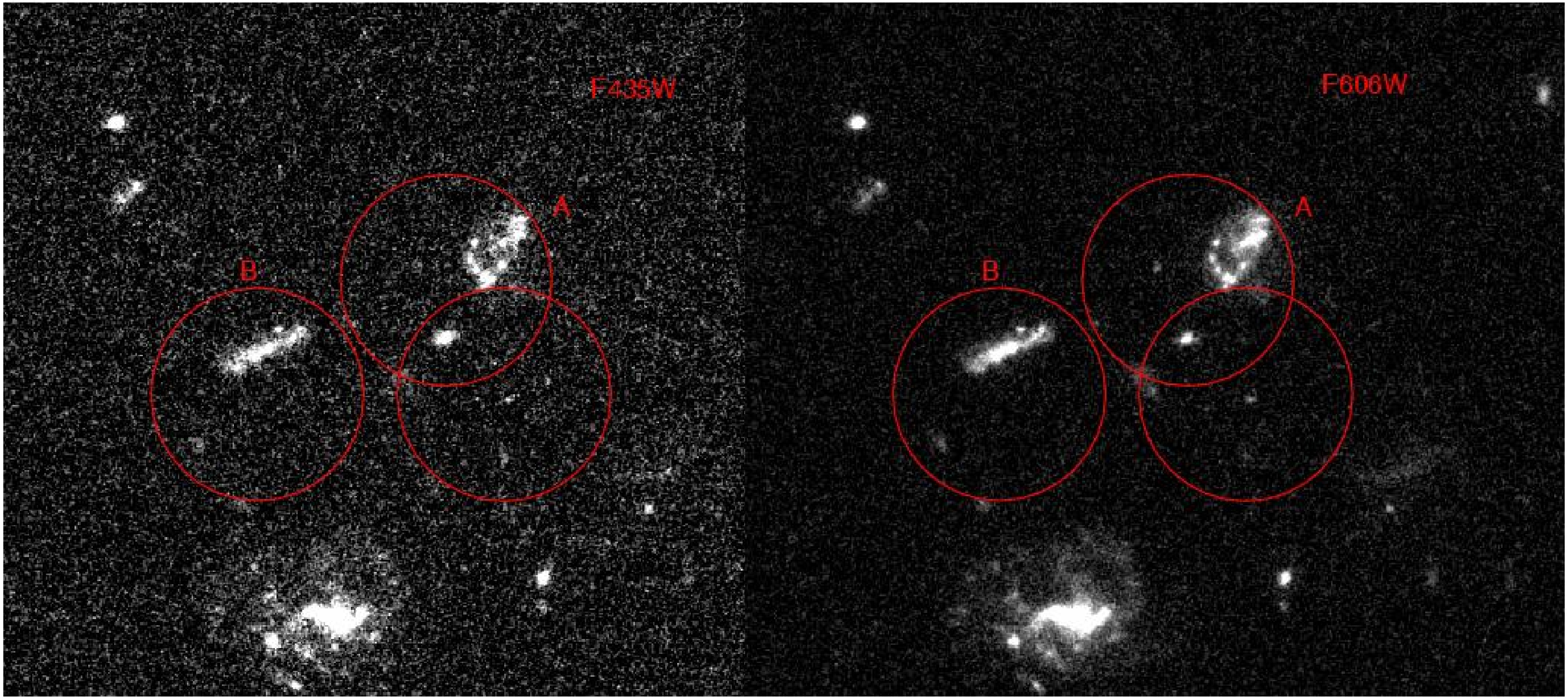


Example [OII] emitter detection



Example [OII] emitter images

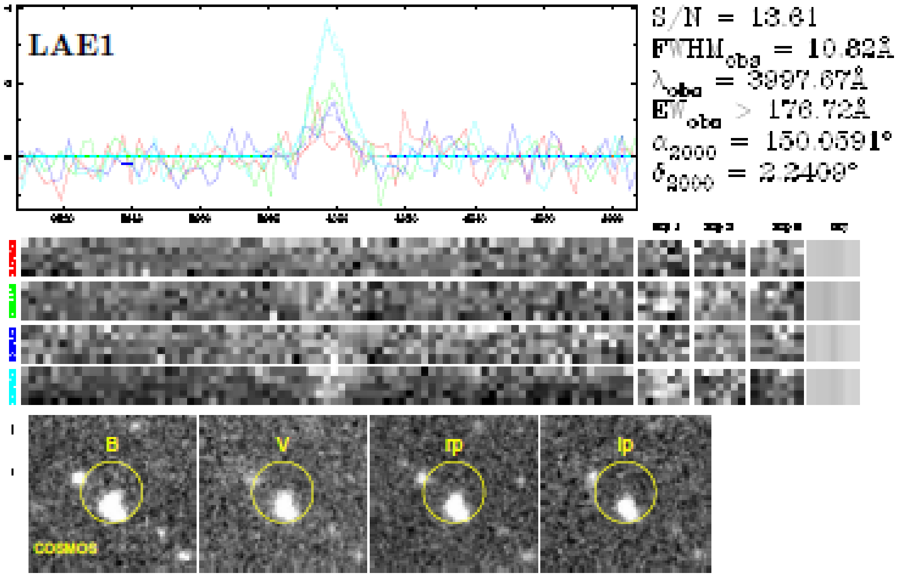
Two objects both at $z=0.512$ via TKRS, A has $R_{AB}=23.11$, B has $R_{AB}=24.02$

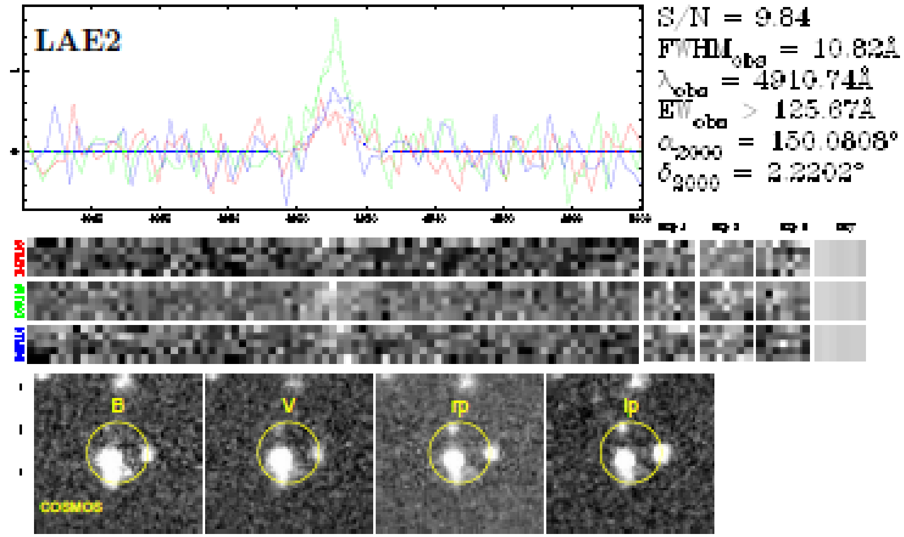


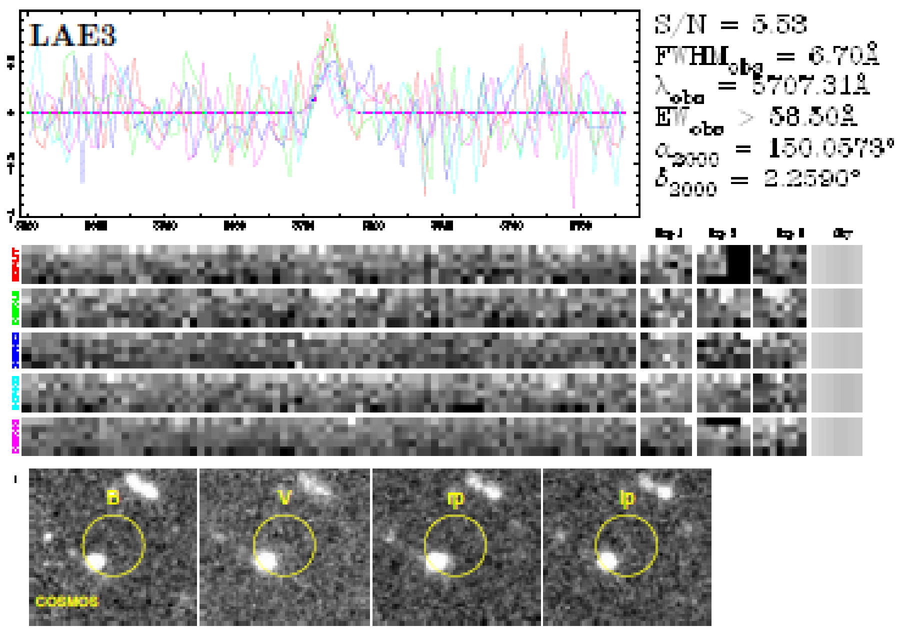
HETDEX
Hobby-Eberly Telescope Dark Energy Experiment

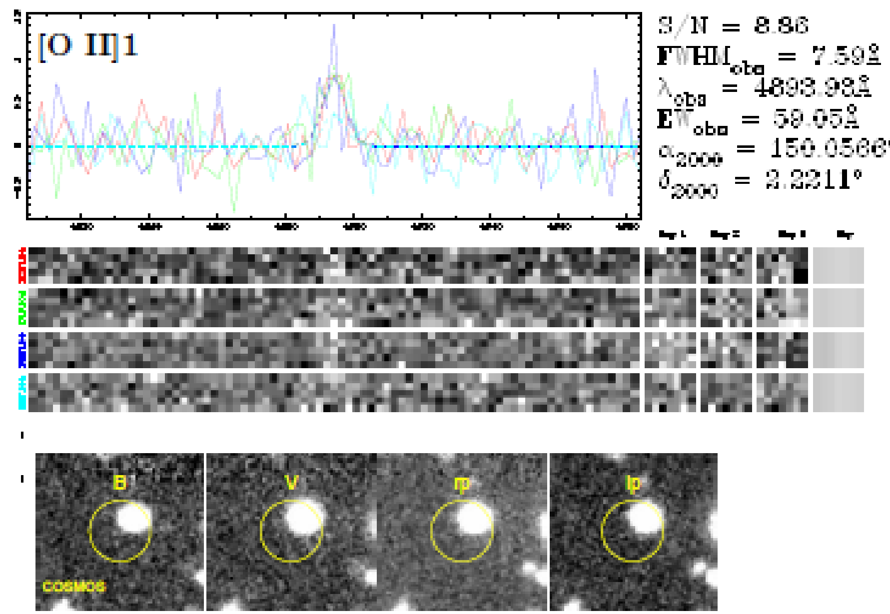
McDONALD OBSERVATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

LAE versus [OII]

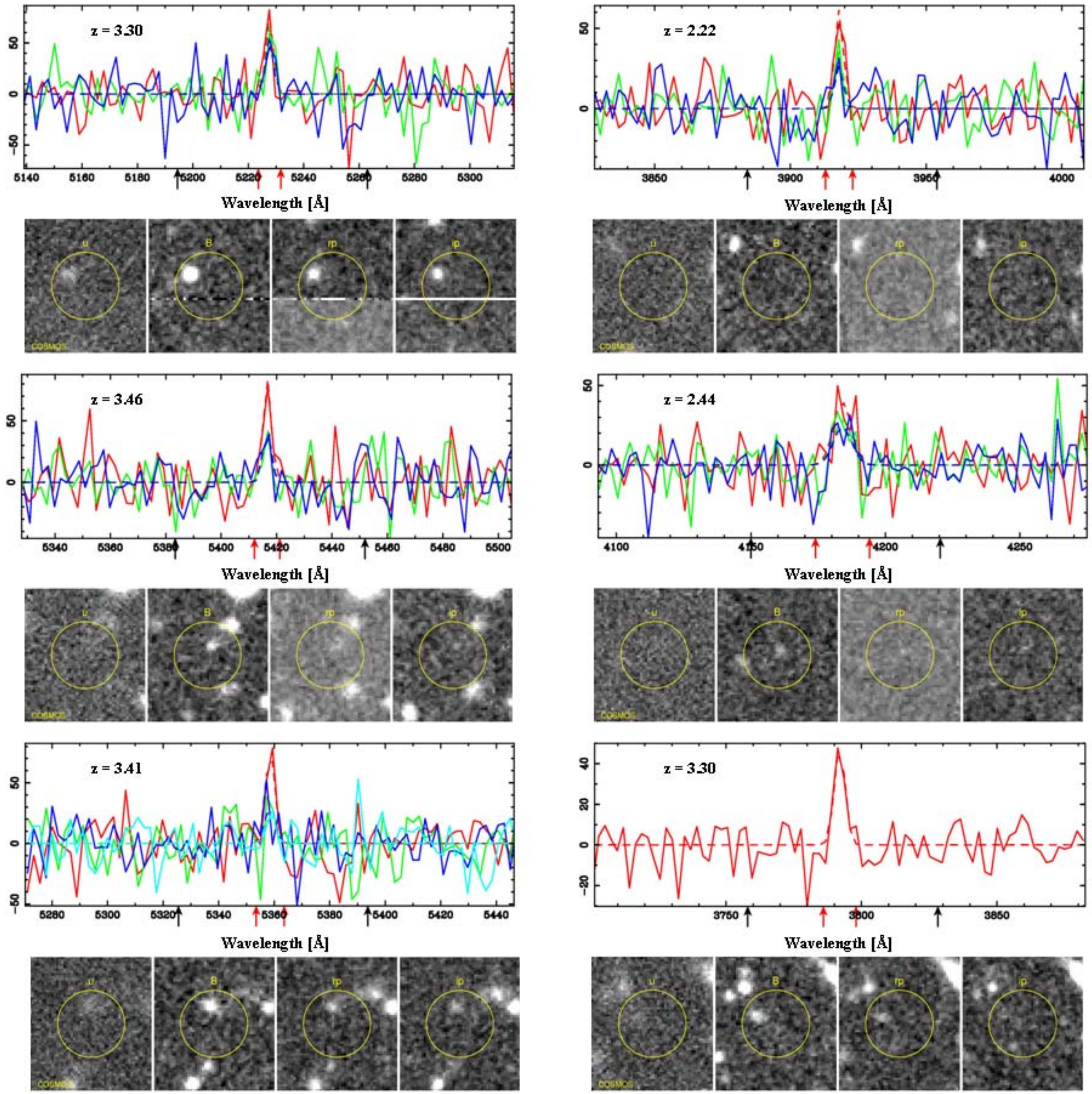




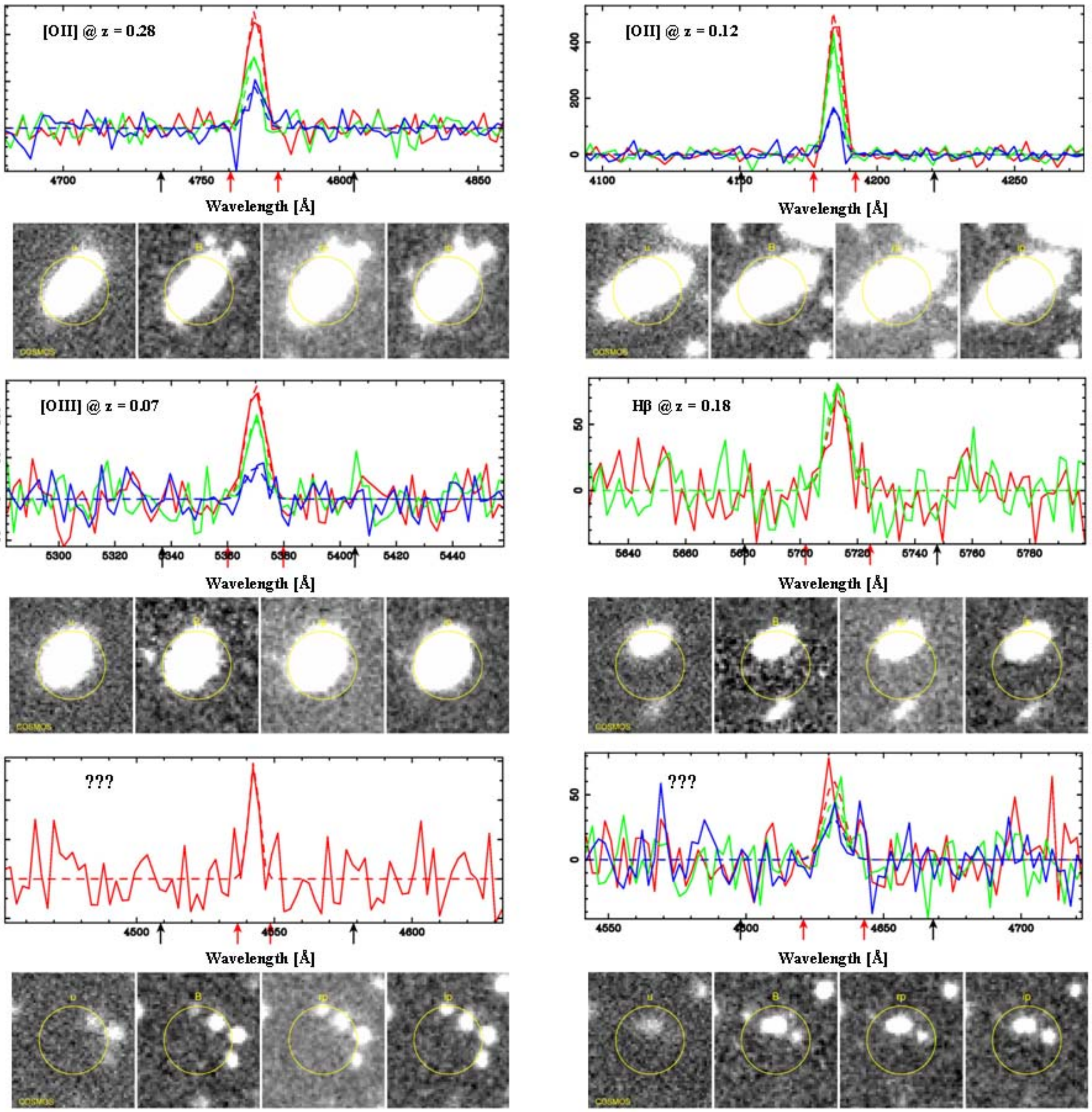




LYMAN ALPHA EMITTERS



LOW REDSHIFT AND UNCLASSIFIED SOURCES



HETDEX and ODI

- **Many aspects of VIRUS and HETDEX are greatly enhanced by an imaging survey**
- **The spring field (11h,58d) is mainly fixed due to HET constraints**
- **The fall field has some flexibility since it will likely be smaller and deeper, focusing on other science (e.g., inflation constraints)**
- **A blind spectroscopic survey with a deep imaging survey will be tremendously useful**