HETDEX
Hobby-Eberly Telescope Dark Energy Experiment

OVERVIEW

McDonald Observatory
THE UNIVERSITY OF TEXAS AT AUSTIN

1. Total HETDEX time: Board allocated 1100 hours, and we come back once we know more after commissioning. Our expectation remains that we need 1500 hours for spring field and 750 for fall, for a total of 2250 hours.

2. These numbers assume a full suite of 78 good units.

3. Requests for Board
   - What does the Board want to see from hetdex or do we get free reign to observe with the 1100 hours?
   - Can you send money to TACC, maybe 10k?

4. Issues
   - We can eat through the 1100 hours with a small number of units, and will just have to take that into account in observing decision and future requests.
   - Collaborators requesting the 10% time.

Data Requirements on TACC

After 10 years (at 200 Gb/night for 365*.65 nights/yr), we will generate 3 Pb of data. This includes calibration (2x) and data analysis (3x). Some of this can be scratch, so 3 Pb is probably a safe number. It is linear with year, so 0.3 Pb/yr.

Year	Raw	Proc	Sraw	Sproc
2017	100	300	100	300
2018	100	300	200	600
2019	100	300	300	900
2020	100	300	400	1200
2021	100	300	500	1500
2022	100	300	600	1800

TACC currently charges $100/Tb/yr. It will probably be down to $50 in 2 years.

$ in thousand per year:

Year	Raw	Proc	Sraw	Sproc	rate	$raw	$proc
2017	100	300	100	300	100	10	30
2018	100	300	200	600	75	15	45
2019	100	300	300	900	75	23	68
2020	100	300	400	1200	50	23	70
2021	100	300	500	1500	50	25	75
2022	100	300	600	1800	50	30	90

Data Management

- Discuss money to TACC
- Need HET to monitor data storage on TACC (close to limit of number of files currently)
- Need HET to control permissions for PI-led data on TACC
- Need to understand reduction (cpu) needs for LRS2 on TACC

Data Management

1. HETDEX will be using TACC/Munich for all data needs. We will not rely on HET to preserve raw data. There is a need to have adequate storage at HET for some to-be-determined period. This is probably a month of continuous VIRUS data. At 100 Gb/night, that is only 3Tb at HET.

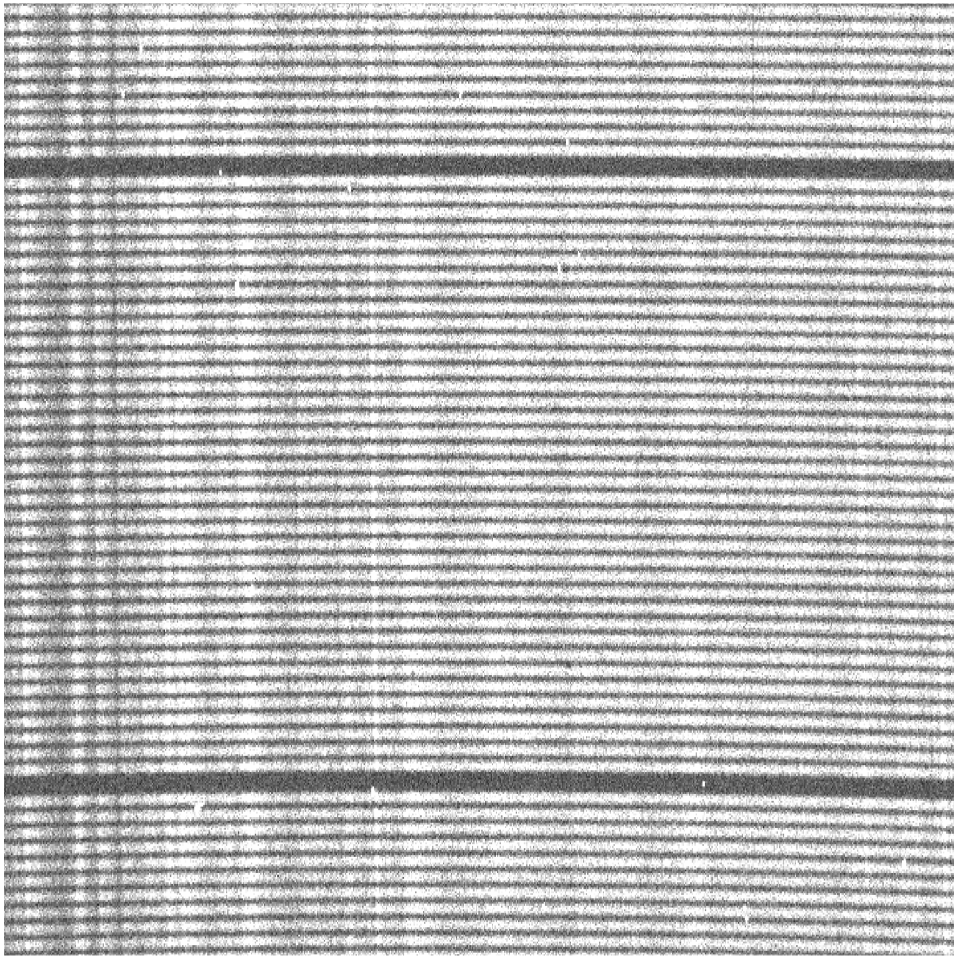
2. TACC willing to provide storage and access for all HET data. This includes replication, redundancy, long-term storage, and access.

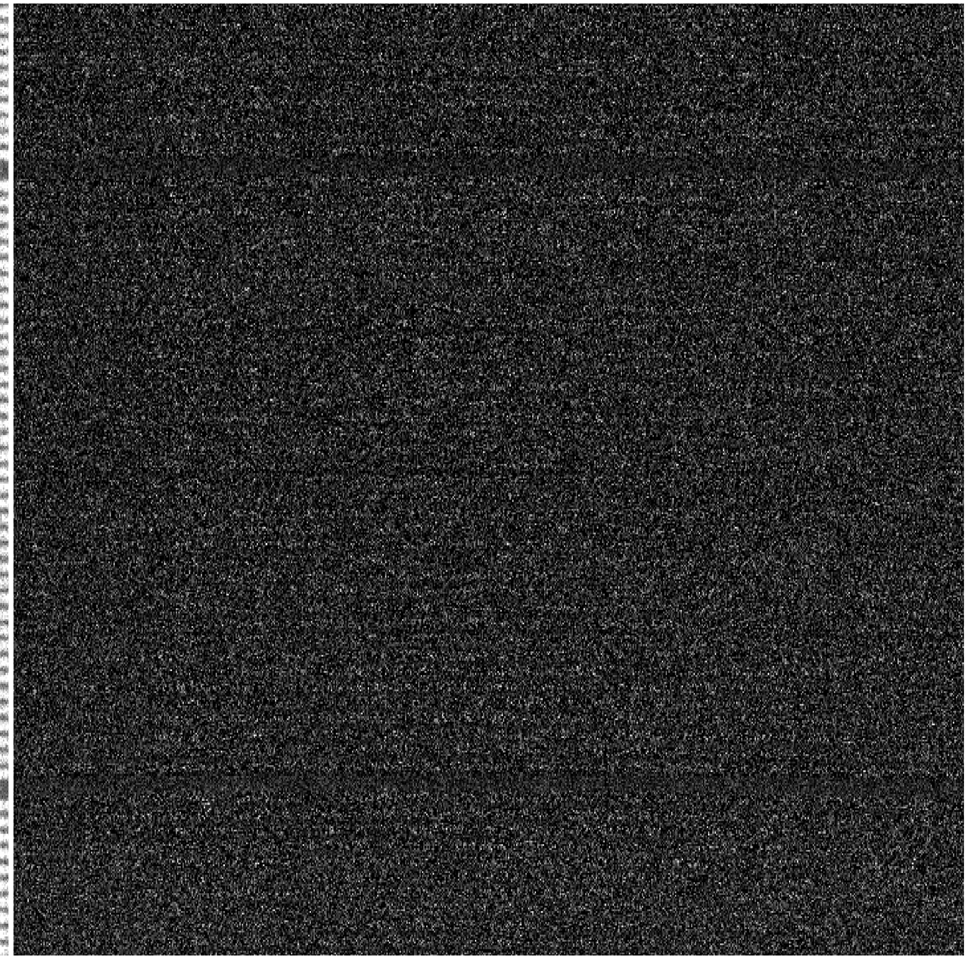
3. Data ingestion and access through HET-wise (same as cure-wise, adaption of astro-wise).

4. Users will have to get an account on TACC (which is trivial) or use a web interface to pull their data.

5. TACC has signed up for data storage. We also expect reduction and analysis to all be on TACC/Munich for HETDEX.

Example Data

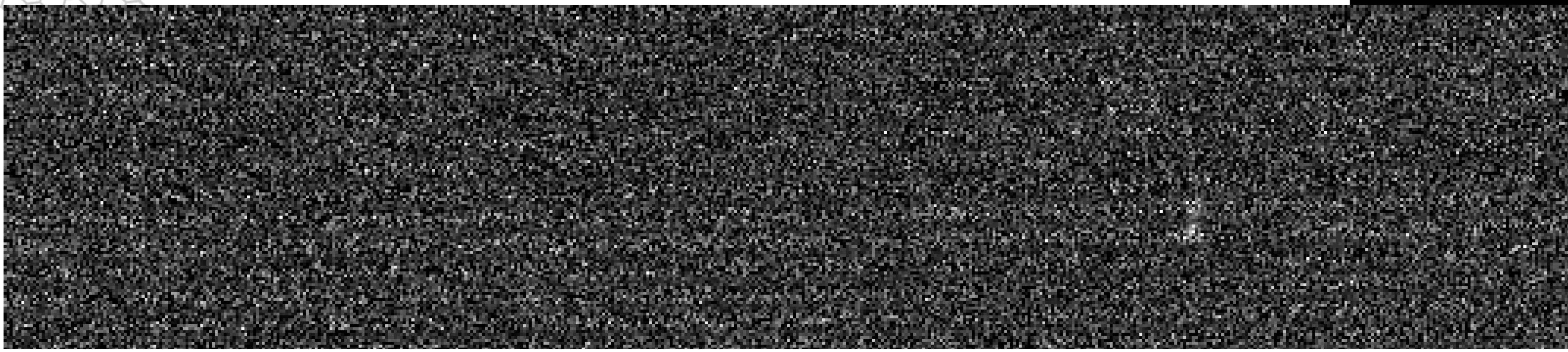


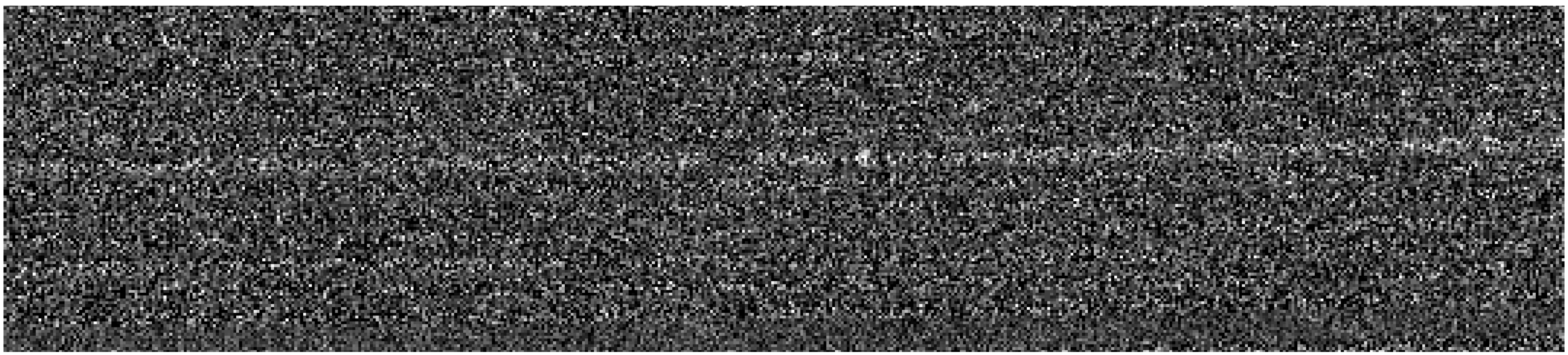


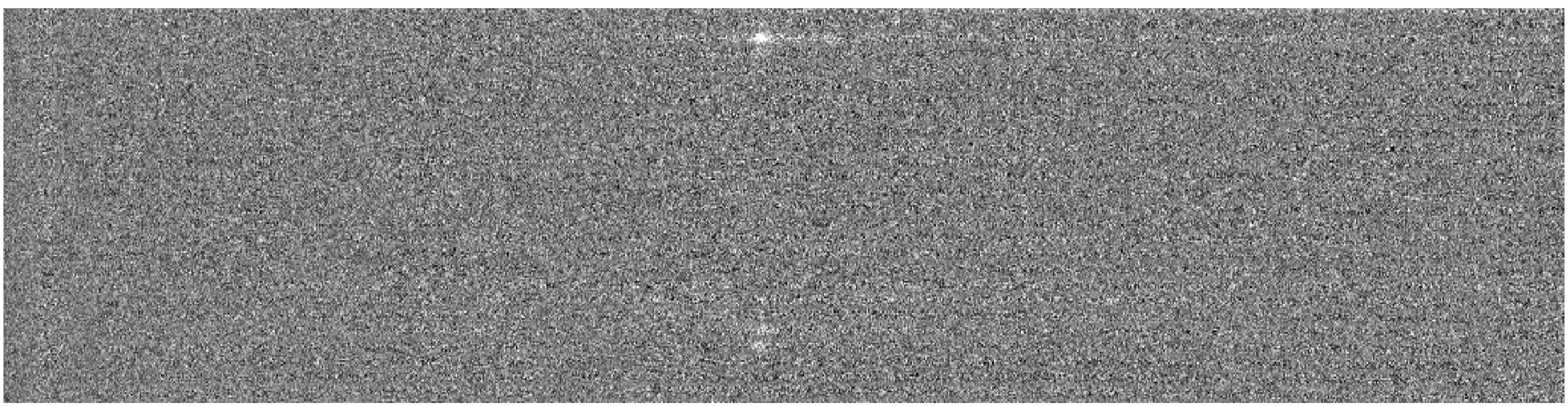
Dark skies, as good as it will ever get

Processed to detector noise

Random interesting objects







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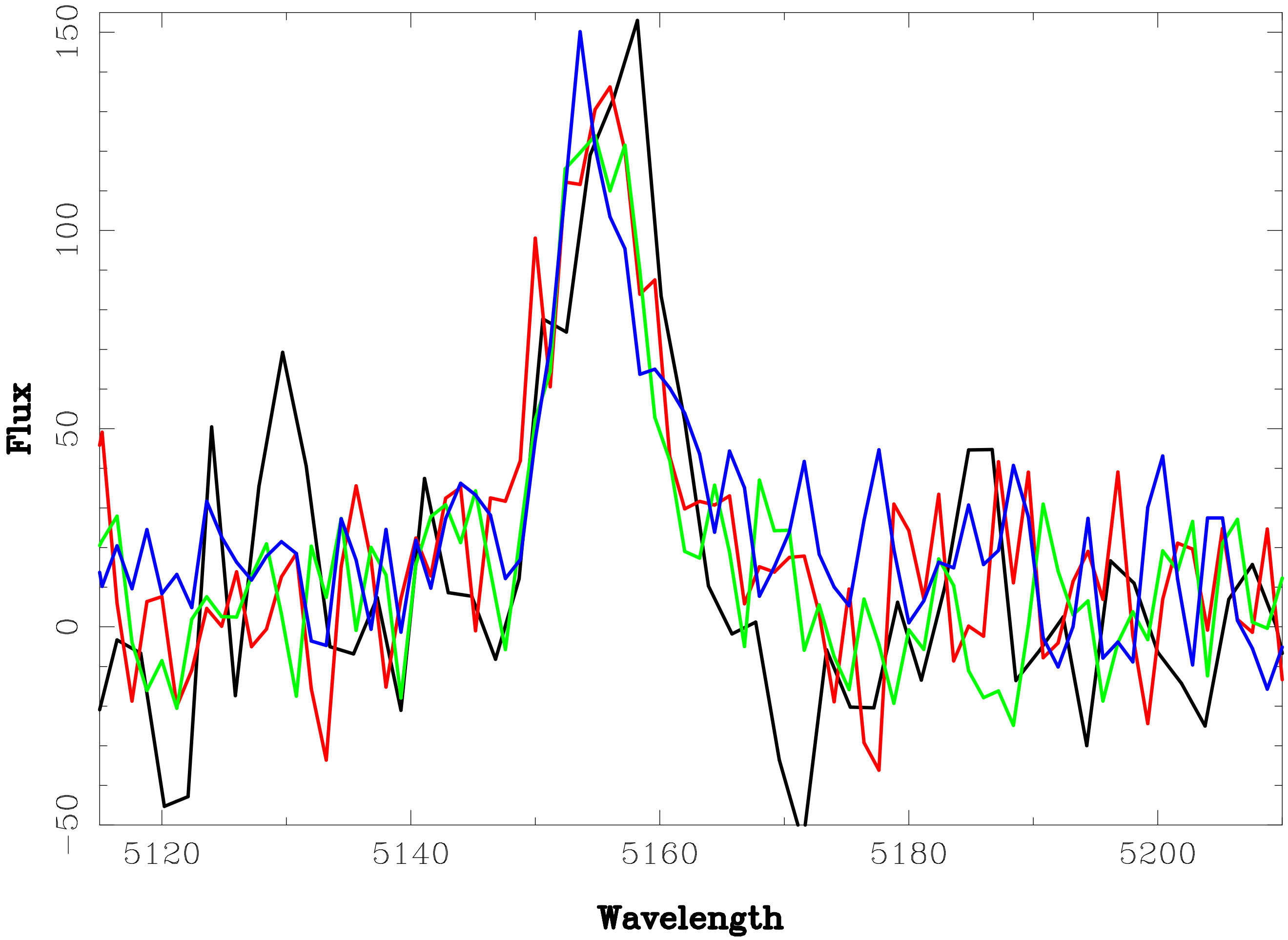
Confirmation of a VIRUS LAE (in black) with spectra from LRS (in colors)



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HETDEX is:

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→ **blind spectrographic survey on the Hobby-Eberly Telescope**

→ **300 square degrees in 1400 hours (140 nights) over 3 years (taken in 4000 shots of 20 minutes each); at 1/5 fill, this provides 60 sq deg of sky with spectra**

→ **about 0.7 million redshifts from $1.9<z<3.5$ (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=750 from 350nm – 550nm), covering 1/5th of the focal plane with 34,000 fibers**

→ **VIRUS-P has been in use since 2006**

TIMELINE: 2017-2020

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HETDEX will provide:

→ **direct detection of DE density at z=2.3 (for a Λ model)**

→ **curvature measure to about 10^{-3} (>5x better than present)**

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

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

→ **H(z=2.3) to 1% (in 140 nights)**

→ **D_A(z=2.3) to 1%**

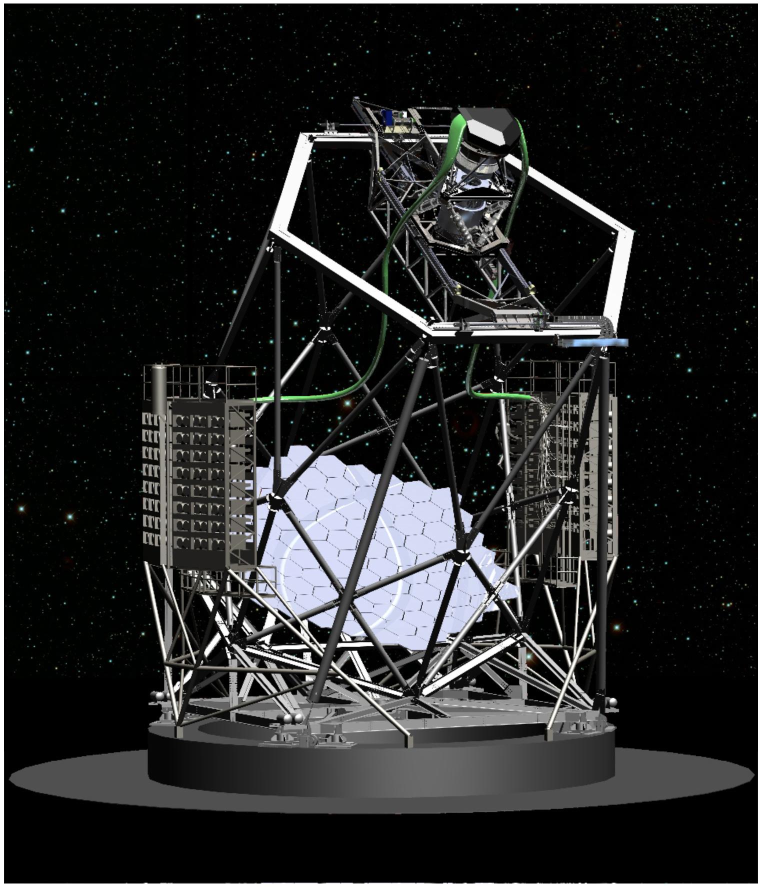
→ **Amplitude of power spectrum to 2% (structure growth)**

→ **H and D_A provide a JDEM FoMSWG figure-of-merit of 170-250**

→ **HETDEX+ (spring and fall fields) can obtain 3-4x the area in 5-6 years, providing up to 2x better uncertainties**

Dark Energy Observational Landscape

- HETDEX: 2017-2020, 1.9<z<3.5
- BOSS: 2009-2014, z=0.35,0.6,2.5
- eBOSS: 2015-2018, z=2
- WIGGLEZ: done, 0.5<z<0.8
- DES: 2012-2016, 0.3<z<1.0
- MS-DESI: 2020-2025, 0.6<z<2.5
- EUCLID: 2019-2025, 0.8<z<2.0
- WFIRST: >2020
- CHIME: 0.8<z<2.2



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Near-Term DE Experiments

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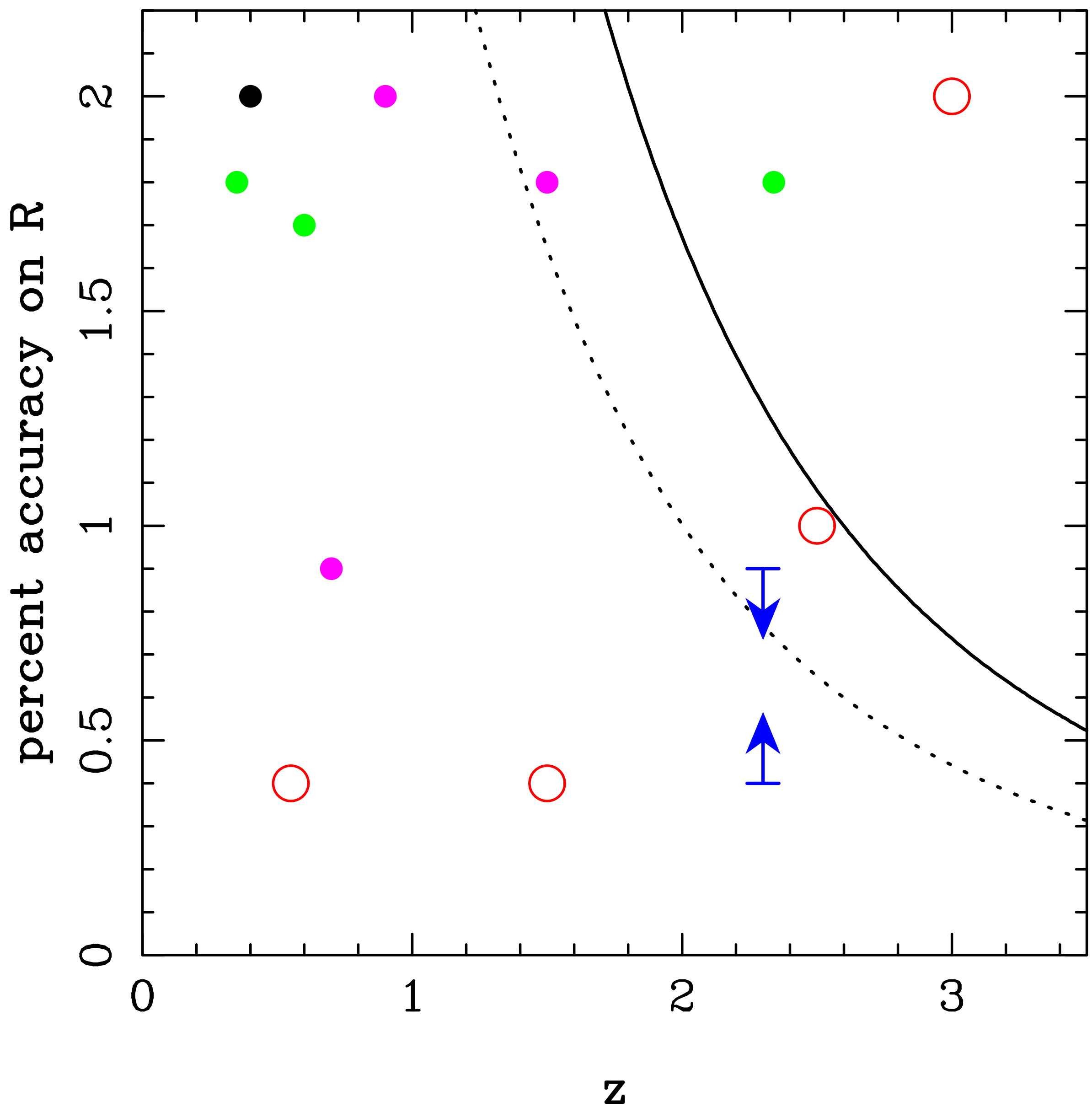
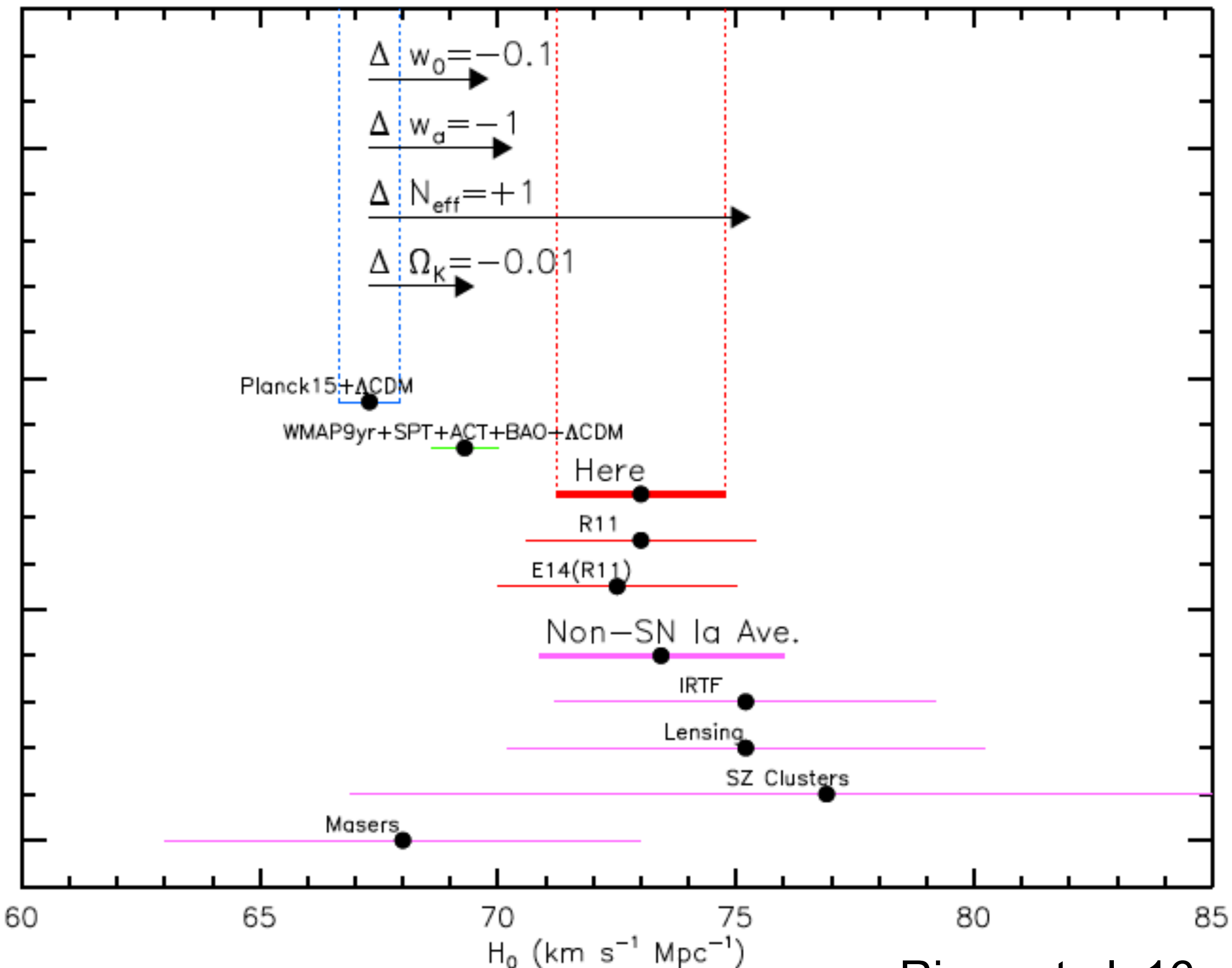
DES
BOSS
eBOSS
HETDEX
MS-DESI



Measurements of H0



Riess et al. 16

Fig. 12.— Local measurements of H_0 compared to values predicted by CMB data in conjunction with ΛCDM. We show 4 SN Ia-independent values selected for comparison by Planck Collaboration et al. (2014) and their average, the primary fit from R11, its reanalysis by Efstathiou (2014) and the results presented here. The 3.0σ difference between *Planck*+ΛCDM and our result motivates the exploration of extensions to ΛCDM.

H0 derived from Planck compared to local measures could signify noise or non-standard cosmology (e.g., extra neutrino species, curvature, evolving dark energy).

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HETDEX Dark Energy Constraints

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- Our baseline spring survey provides constraints on H and Da each to 0.9%.
- Fall survey adds about a 25% improvement. Combined this will get to about 0.8% on both. The combined accuracy on R is then below this.
- We correlate known LAEs with all fibers, picking up faint emission lines. OII will not be detected since there is no correlation (hopefully!); faint LAEs will be detected. Hard to predict increase accuracy in H and Da, but maybe up to 50%.
- As a conservative estimate, we should get R to 0.5%-0.8%.

HETDEX Commissioning

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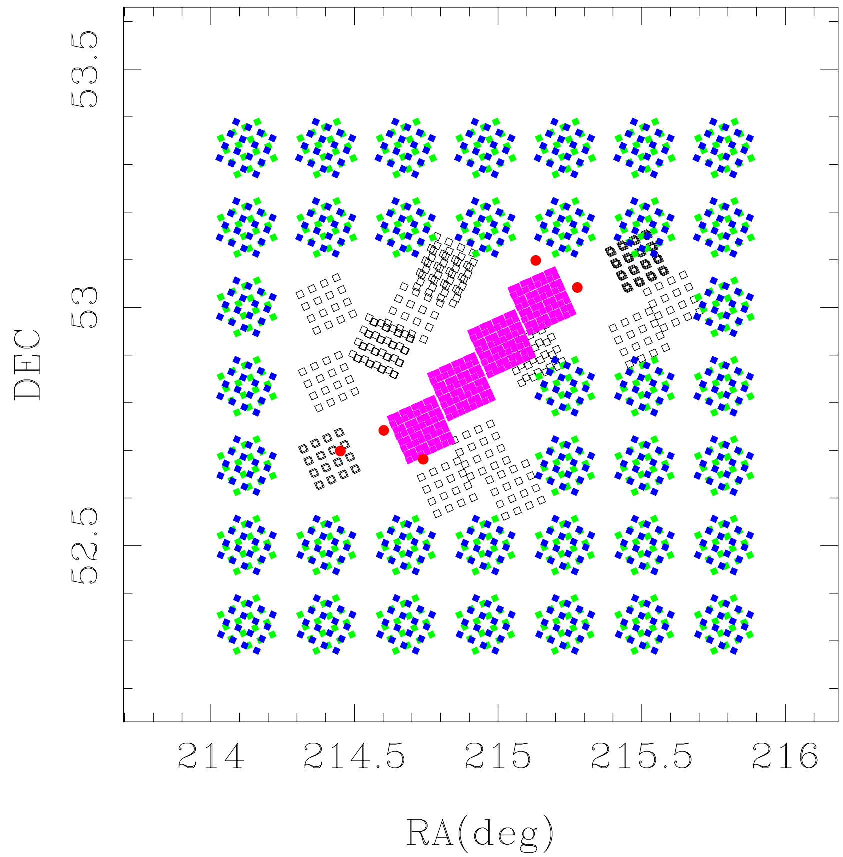
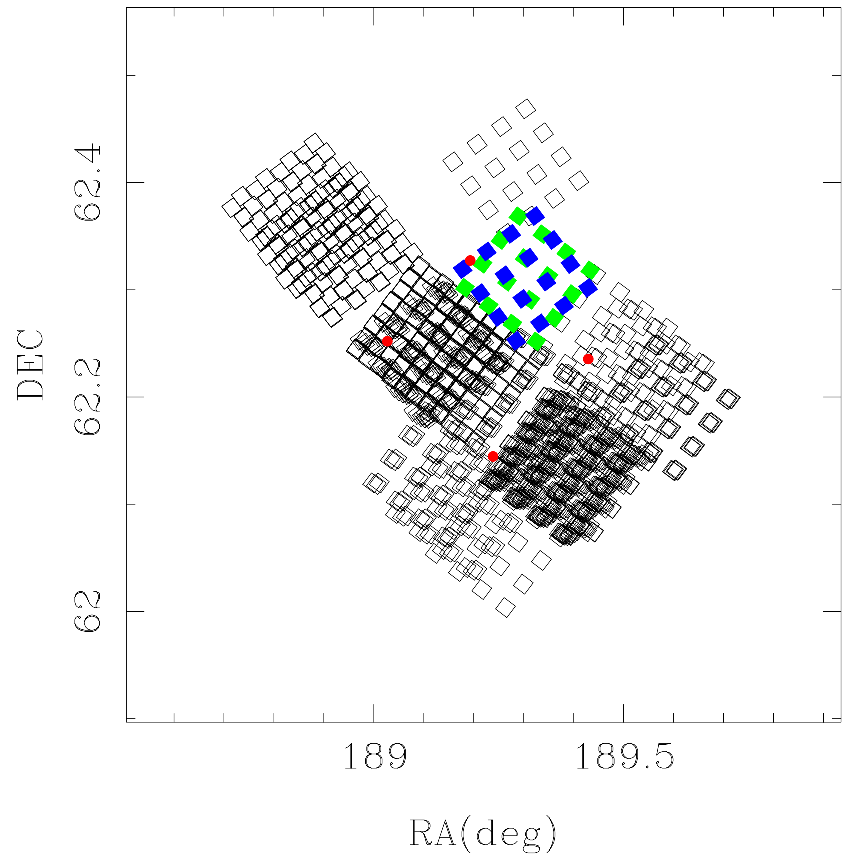
EGS field coverage to get bias



Goods-N field to go deep



Data Reductions and Analysis

- Have about 100 20-min shots
- All data reduced with panacea. Not using hetwise yet, so doing it with easy to use scripts.
- Reductions currently includes sky-subtracted, fiber-extracted, astrometric correction (to within 1” for all 7000+ fibers), relative dithers to 0.05”.
- Flux calibration has been automated, and almost implemented.
- Analysis to the point of emission-line detection is automated and needs significant additional effort. Most work is going into this stage.

Data Reductions and Analysis (how it works)

- Use Greg Zeimann's reduction package (very robust)
- KG reduces all virus data with scripts. Takes about a few minutes of time to set it up for the previous night, including all parallel. Routinely re-reduce months of data in a few hours.
- Hand-off to PSU (Robin and Derek) for detection.

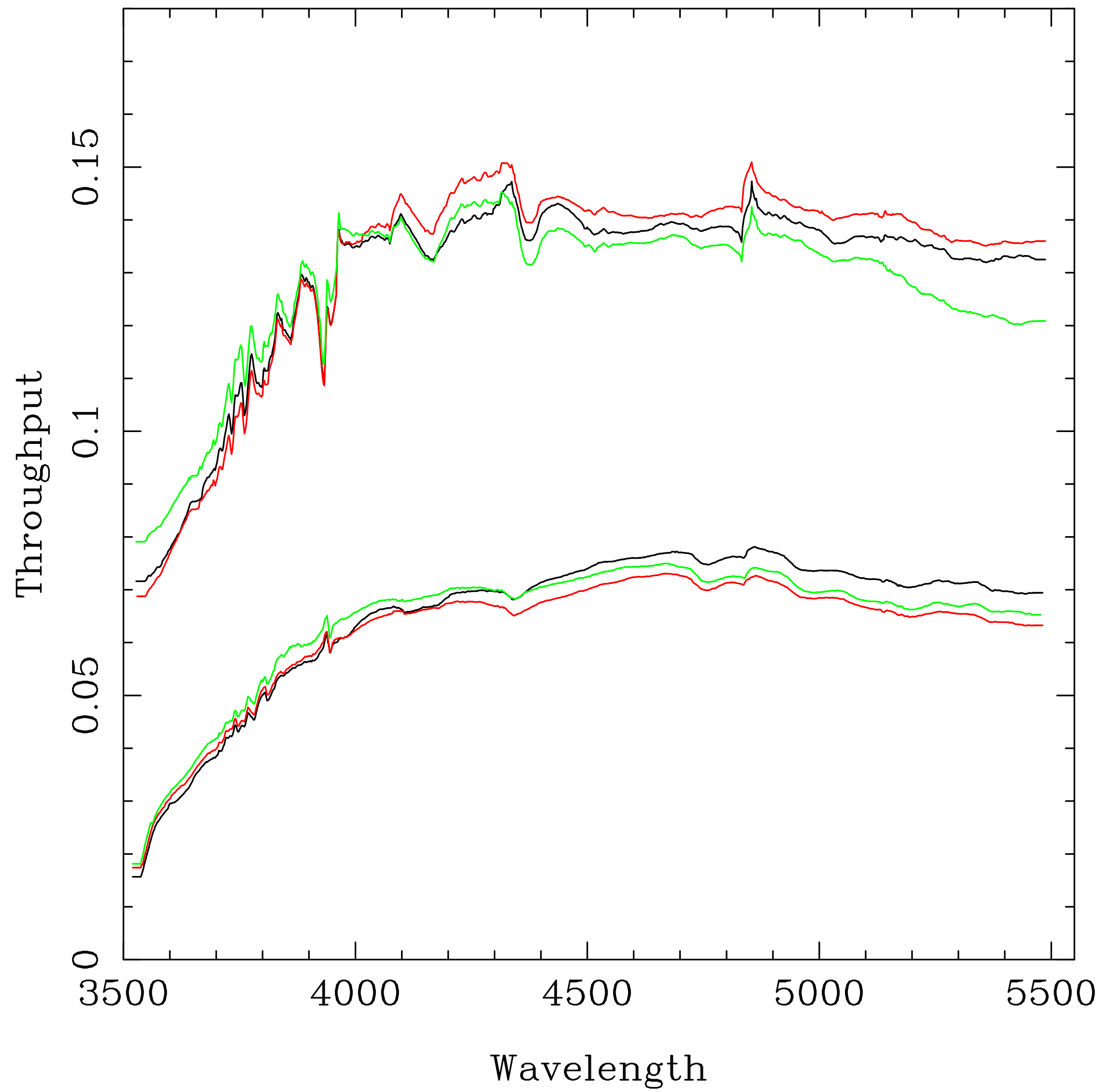
Throughput and Flux Limit

Slides to come….

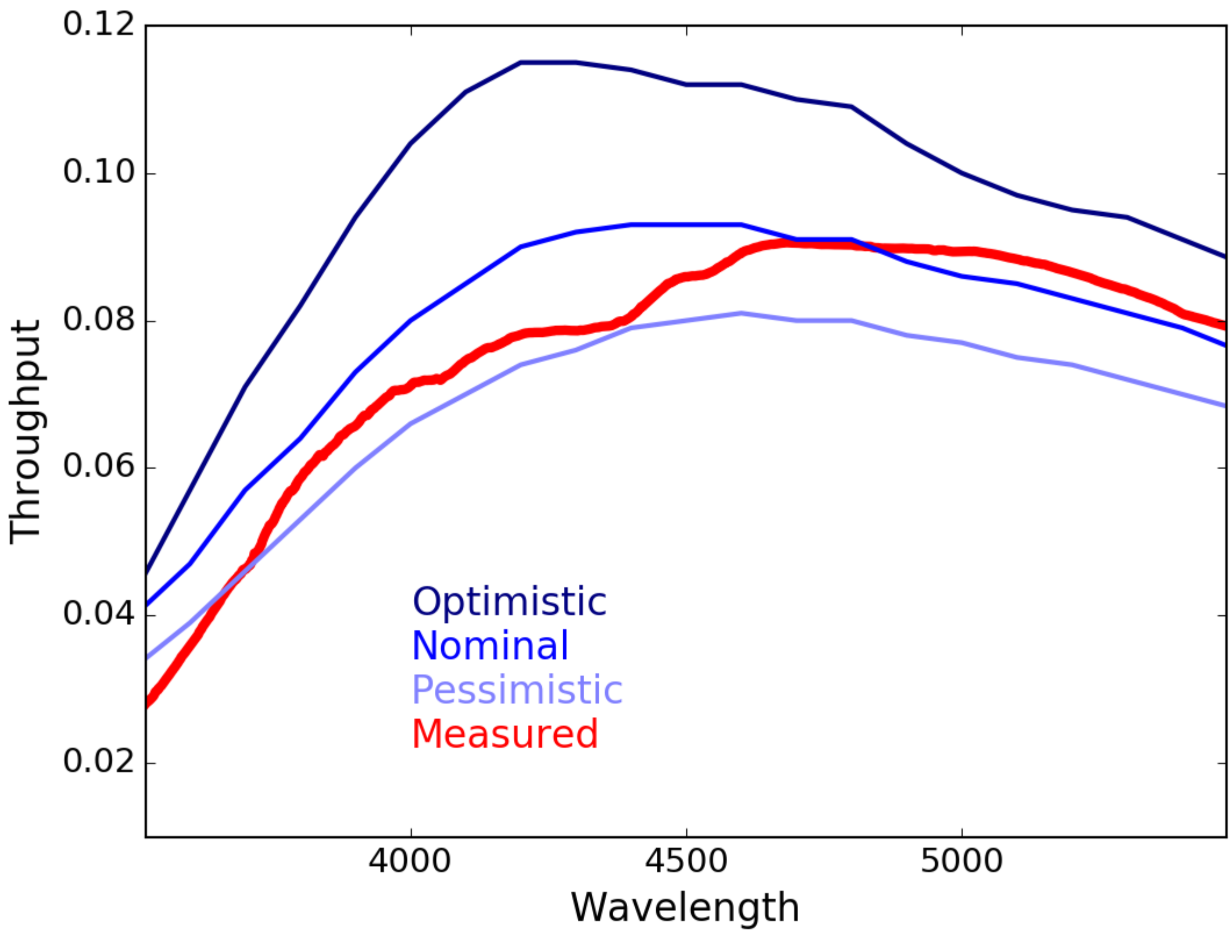
Total time request

Slides to come (but nothing has changed from before)

THROUGHPUT

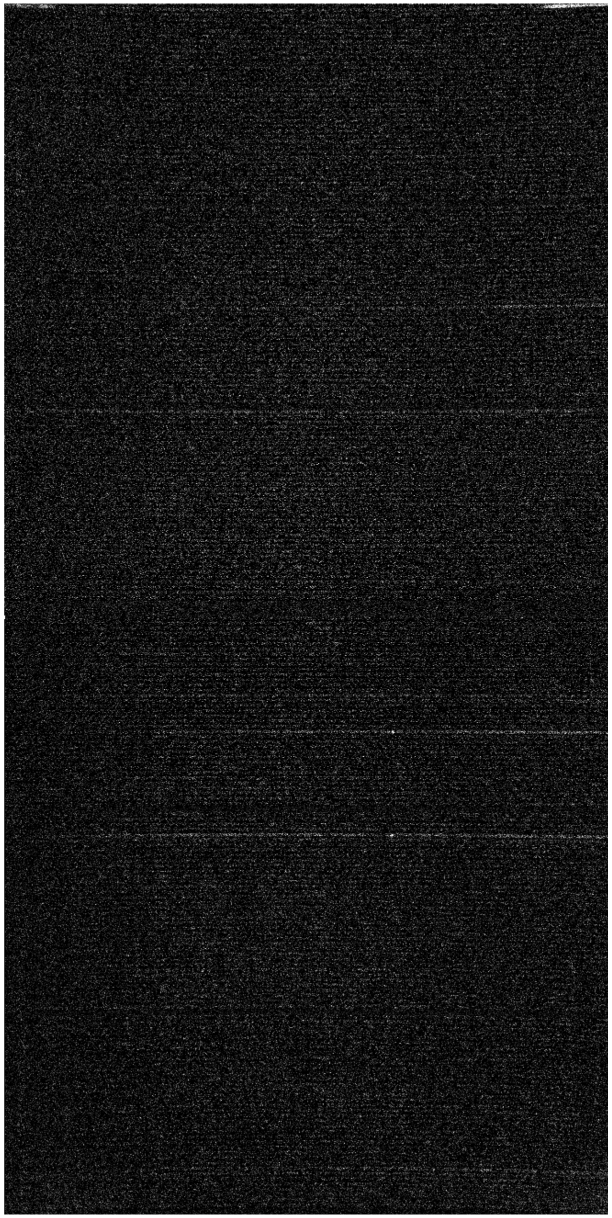


THROUGHPUT

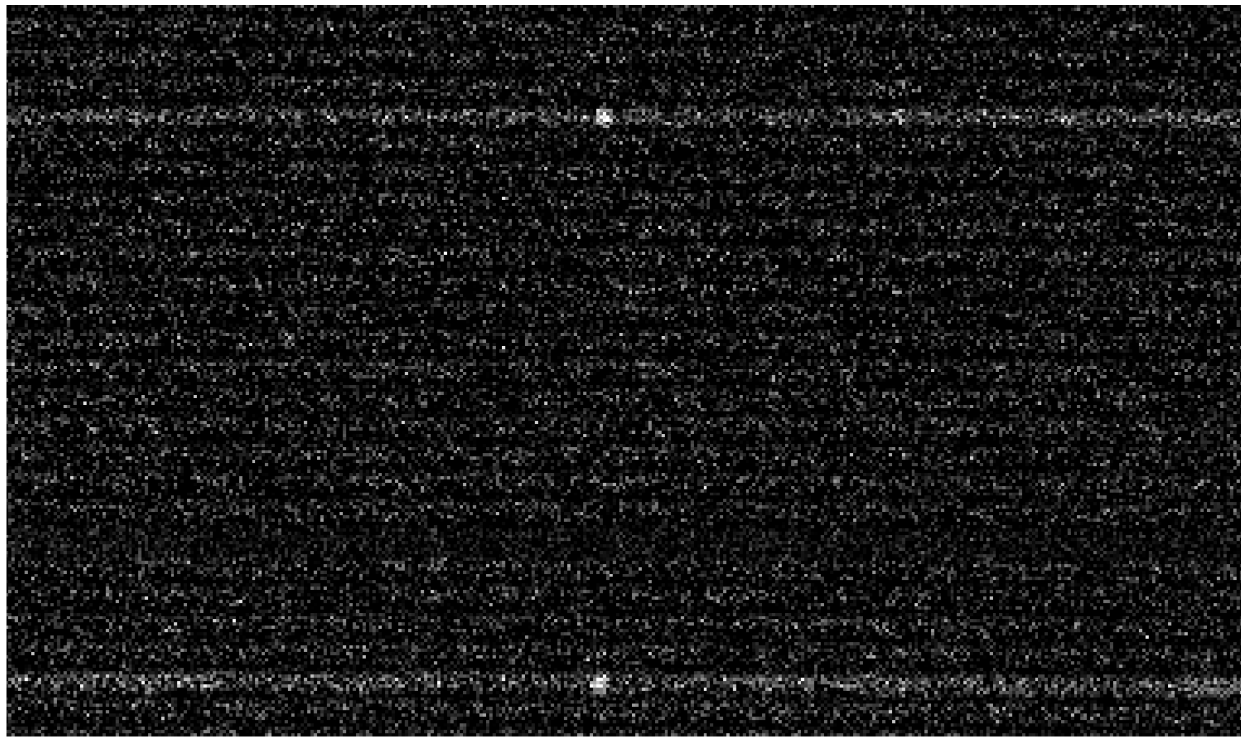


We have gone through about 7 calibration stars and the average throughput is just above our nominal expectation. We have another 30+ stars to include and will provide statistics as well.

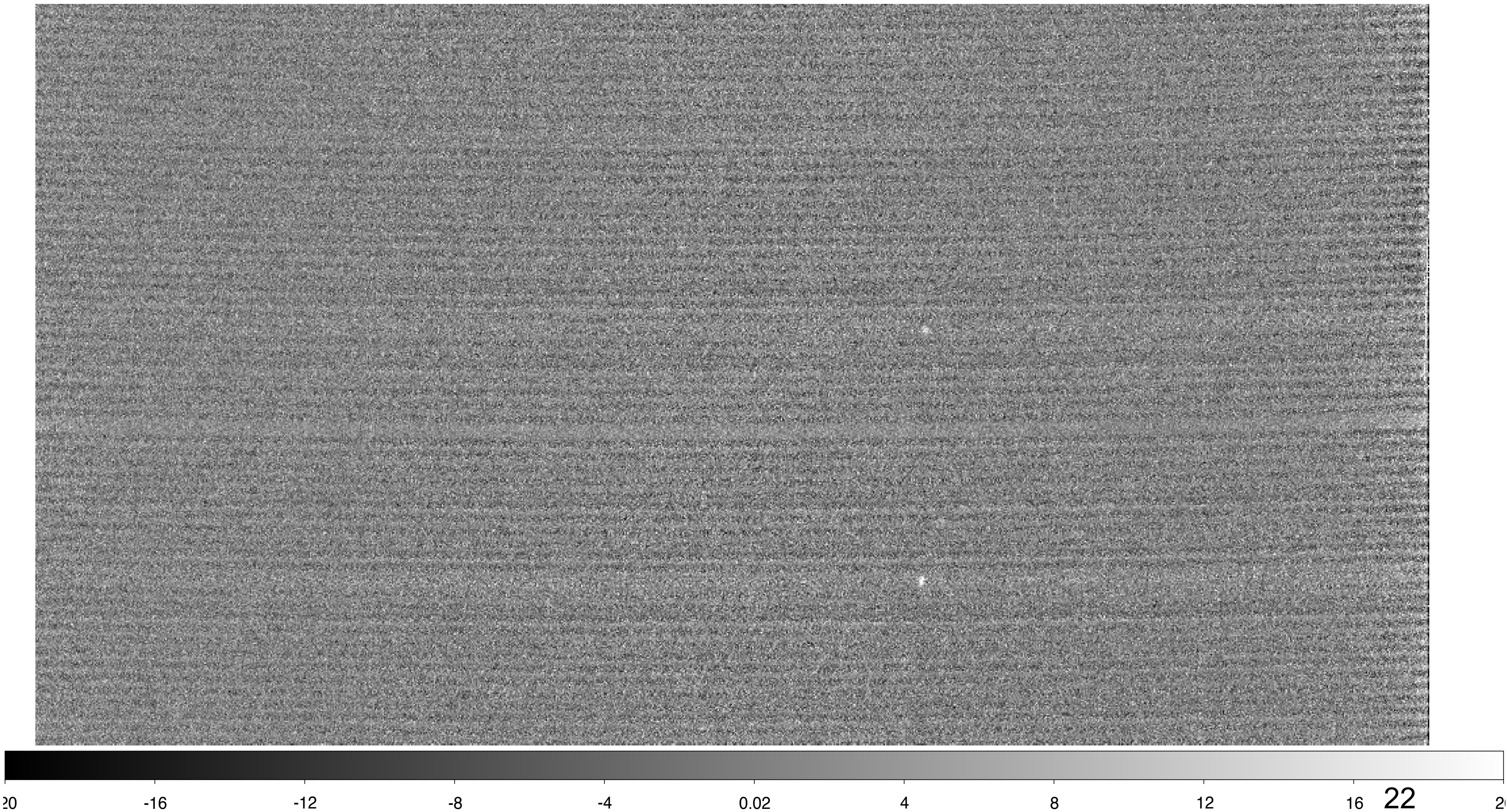
DETECTIONS



Example data frame (2.9 million of these in total)



DETECTIONS



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DETECTIONS

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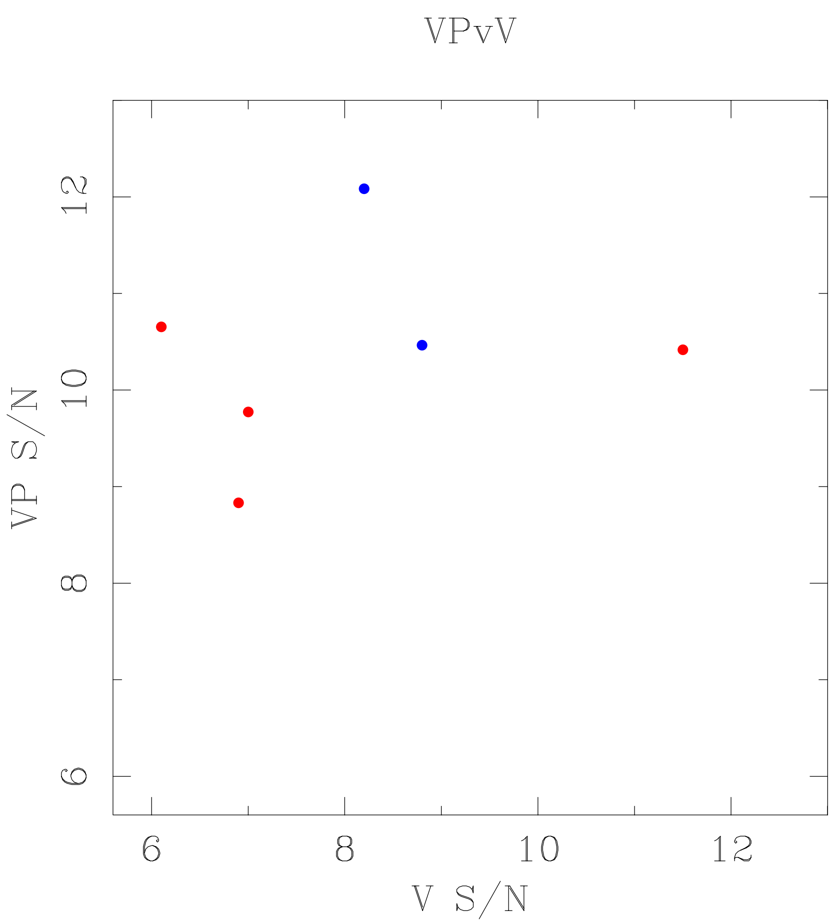
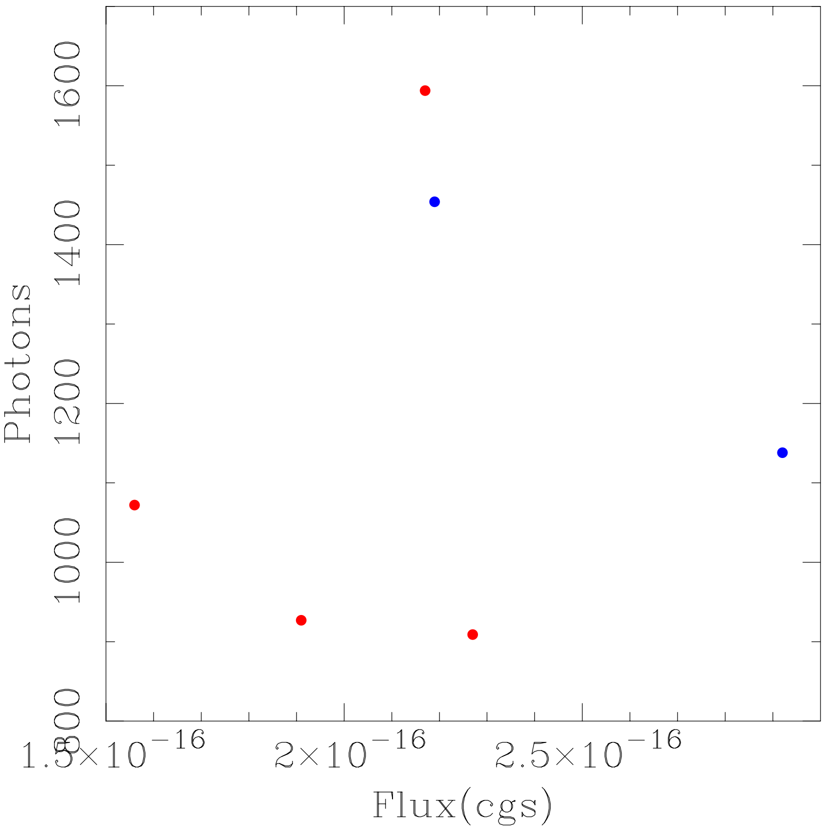
- We are finding about 2 emission lines per good IFU. The expectation is about 3.
- Throughput seems good and the remaining (serious) issue is noise floor.
- We are still struggling with dealing with the various instrumental issues. Signs are the detections will improve in software.
- Current crop of data should provide 100+ LAEs. These will produce publishable results.

FLUX LIMITS


VPvV
VP S/N
V S/N
6
8
10
12
6
8
10
12


Photons
Flux(cgs)
1000
1200
1400
1600
1.5×10^{-16}
2×10^{-16}
2.5×10^{-16}

DEX Commissioning Needs

- Measure detection limit and throughput
- Calibrate false detections
- Calibrate LAE identification
- Measure LAE luminosity function and bias
- Evaluate observing strategy: depth, area, efficiency, based on luminosity function and bias
- Identify fields for commissioning, calibration, repeats
- Integration in HET queue, and quality control
- Plan for monitoring conditions: extinction, window function effects, total field

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VIRUS Commissioning Needs

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- **Measure flux limit and throughput**
- **Measure dither mechanism**
- **Measure location of IFUs in focal plane seats**
- **Determine optimal software calibration (lamp or twilight)**
- **Monitor arc and flat lamps**
- **Monitor dark current, detector temp, pixel flats**

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Latest Dithers

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DEX Commissioning Needs

- LAE luminosity function: need about 2x the current data
- LAE bias: campaign underway, unlikely to complete
- False detection: need a few deep (3x) fields
- LAE/OII discrimination: in progress, just need final astrometric solution
- Total coverage to date is 50 fields with 12 IFUs. This is 16 hours of on sky.