CYCLOPS fibre feed to UCLES at the AAT

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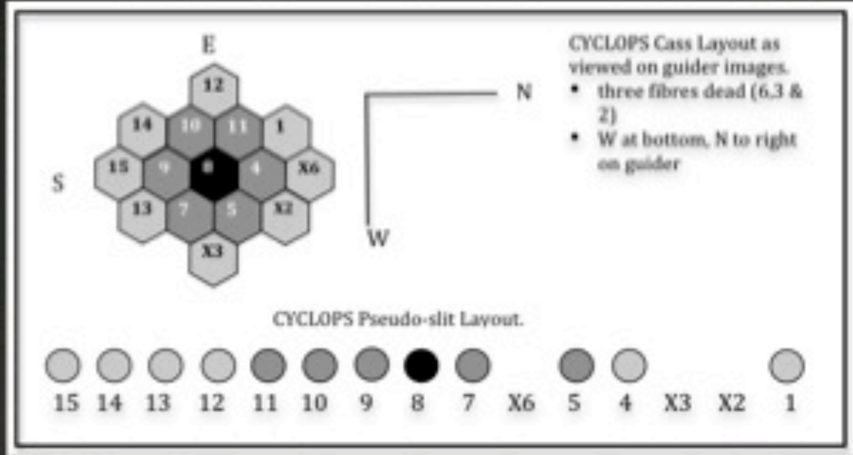
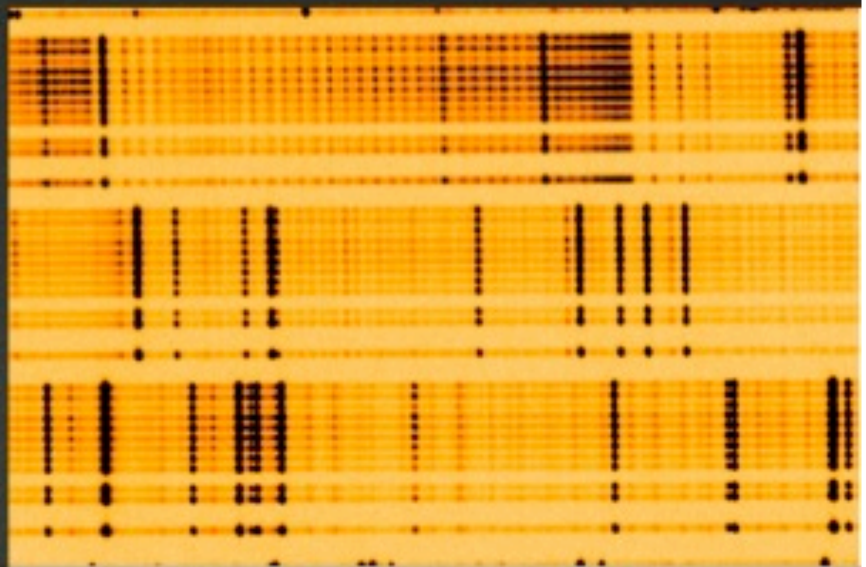
CYCLOPS

- Single object integral field unit
- Input: 15 fibres, 3" aperture
  - 12 working fibres
- Output: 0.63" x 14" (R~70000)
- Typically at 455 – 735 nm
  - Can be varied
- ~30% improved efficiency



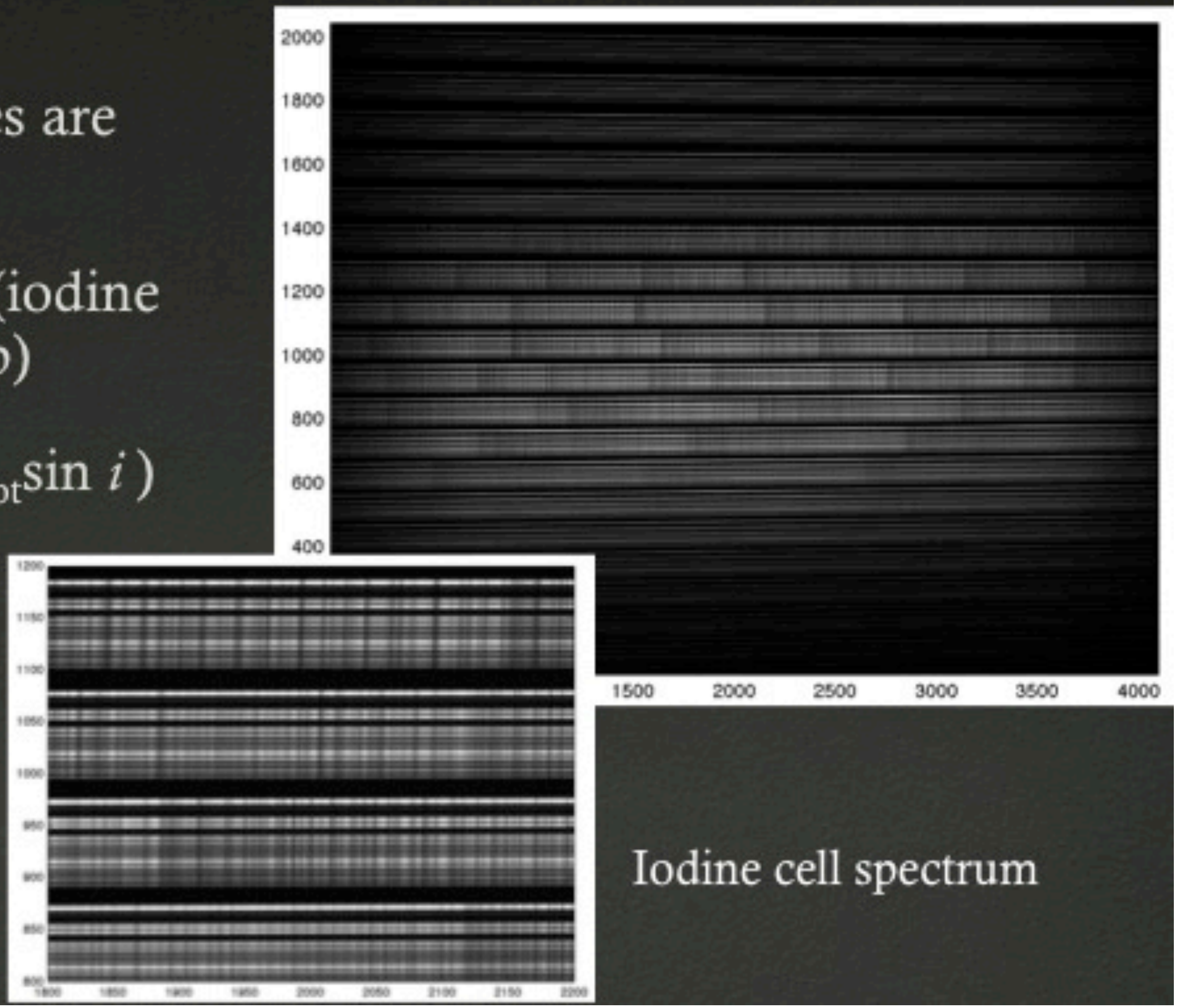


CYCLOPS-2

- Input: 19 + 1 fibres, 3" aperture
  - Simultaneous arc lamp calibration
- Output R~70000 (the same 79 lines/mm grating)
- Similar wavelength coverage (flexible)
- Further improved efficiency with more fibres (and none broken!)
- Commissioning in April (or May)

Radial velocity precision in planet searching

- Typical planet amplitudes are ~1-20 m/s
- Wavelength Calibration (iodine cell, laser comb, arc lamp)
- RV information (SpT, $V_{rot} \sin i$)
- Stellar jitter (pulsation)

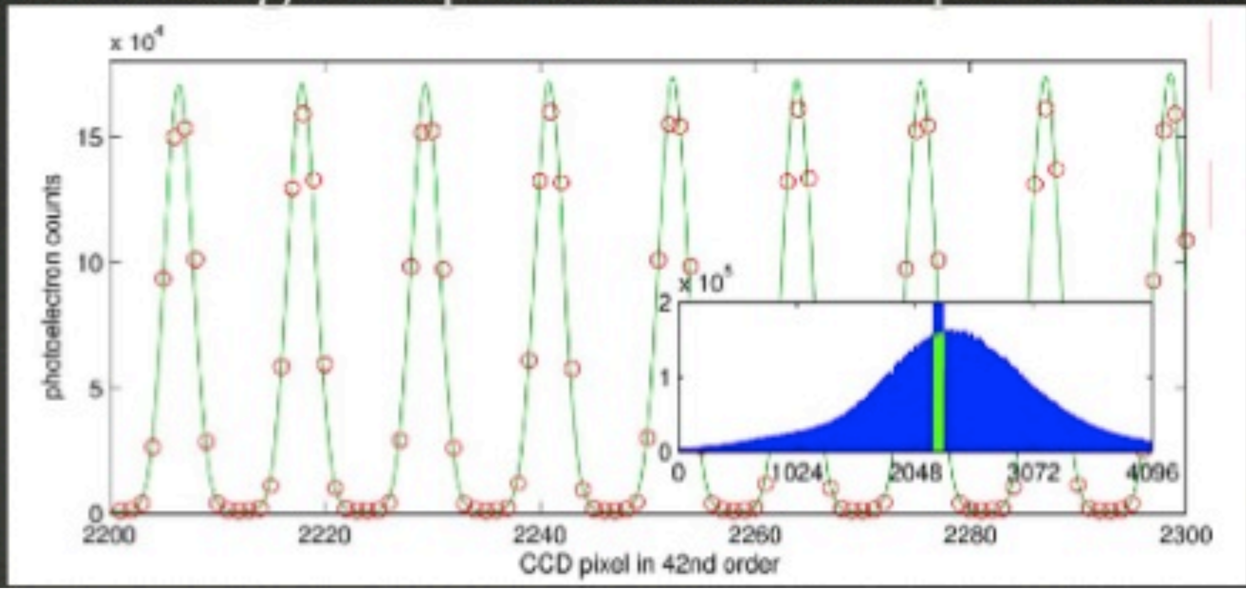


Iodine cell spectrum

Wavelength Calibration

- Iodine Cell: RV information superimposed on the stellar spectrum fixed at zero velocity (only over 500 – 600 nm for bright stars)
- Laser comb: many thousands of lines per spectrum
- Differential ThAr calibration: model ThAr spectrum changes in 2D image (more complex changes require a more complex model)

HARPS laser comb example

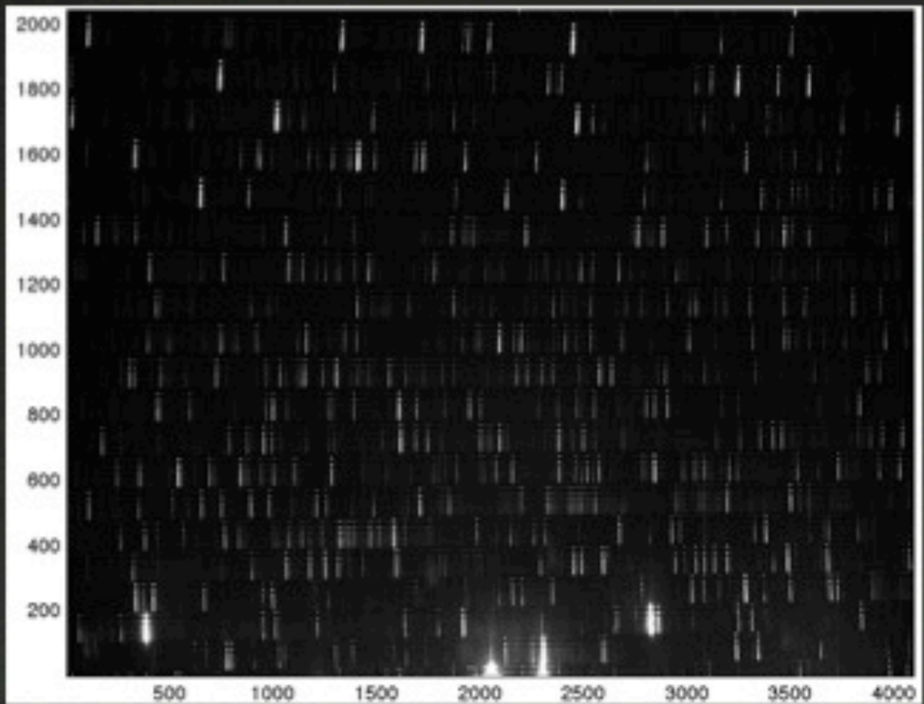


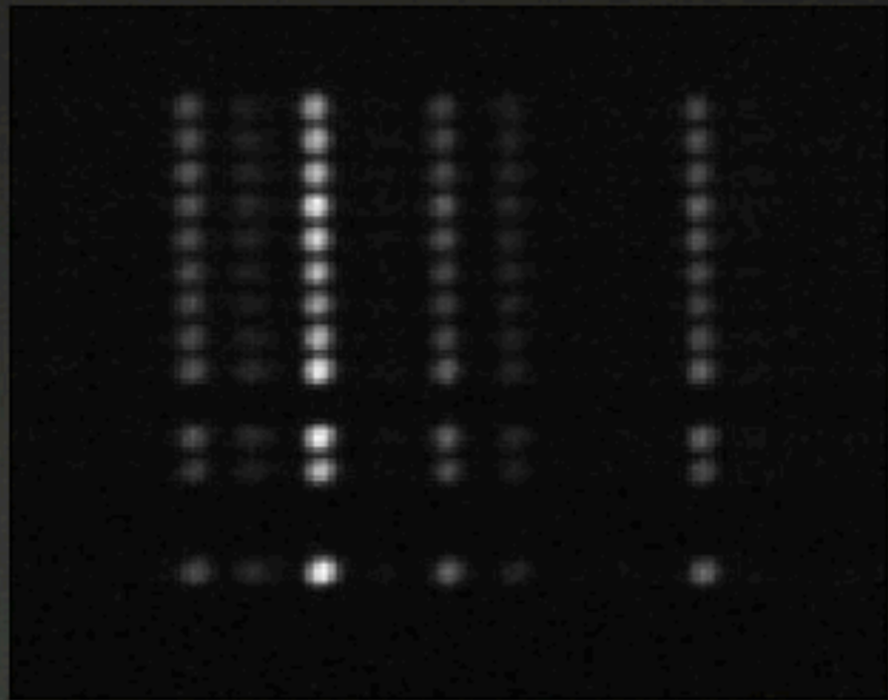
Wavelength calibration difficulties for UCLES

- Spectrum drift with atmospheric pressure, temperature etc.
  - Drifts up to ~0.6 pixels (~700 m/s)
  - ThAr single line precision ~0.03 pixels (~40 m/s)
  - Only ~400 useable ThAr lines per spectrum
  - 12 working fibres of the same spectrum with slightly different properties
  - Traditional Arc calibration can achieve ~15 m/s
  - Iodine cell work has achieved ~3 m/s

Wavelength Calibration

Thorium-Argon arc lamps





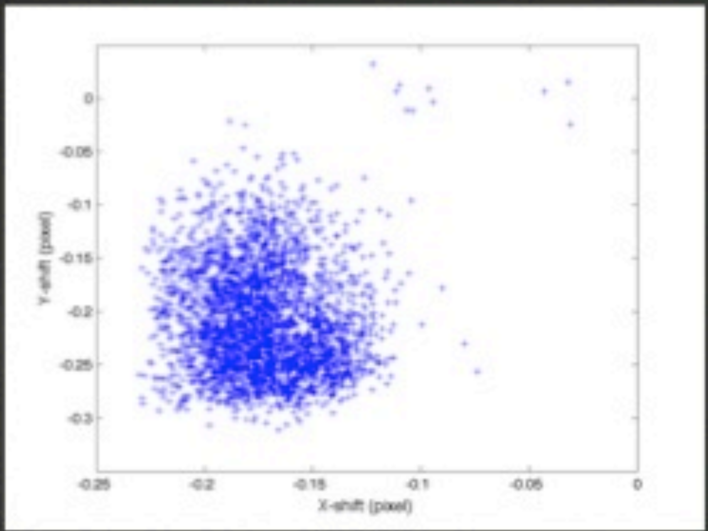
Typical calibration

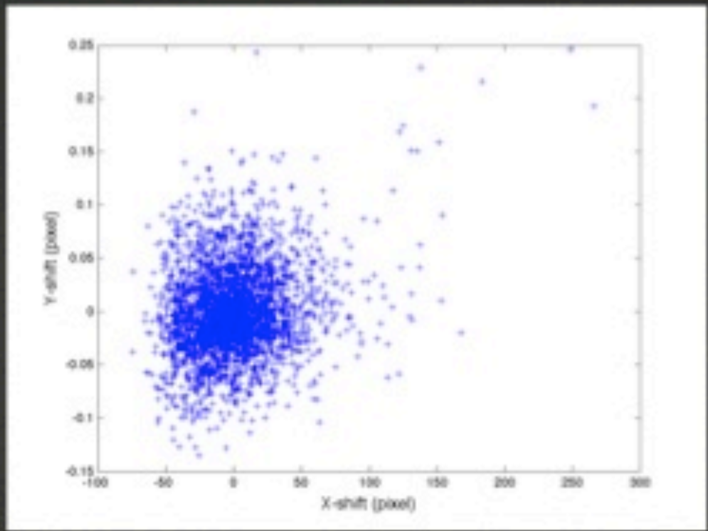
- ThAr wavelength solution is generated by fitting hundreds of lines and fitting a polynomial surface to the x-pixel vs Abs order (m) vs m x lamda
- Typical internal precision of ~20 m/s (order to order)

For 3D Figures of ThAr data go to MATLAB

Differential Calibration 1

- First create a wavelength solution in the normal way
- Fit the shift in the wavelength dispersion direction from ThAr image to ThAr image (3D MATLAB plots)
- For each ThAr use the same wavelength solution fit and re-evaluate it at the shifted positions





Differential Calibration 2

- Interpolate wavelength solutions on to the stellar spectrum (not necessary for CYCLOPS2)
- Chop up the spectrum and compute an RV for each piece
- Compare the RV of the same piece in different observations (do not compare different pieces in the same observation)
- We are just now working on the piece-by-piece cross-correlation code, results out very soon

Things to note

- Differential approach could be applied to 1D extracted spectra but the changes are 2D in nature so they are best modeled and applied in 2D.
- The size to make the spectrum pieces is dependent on the complexity of the fit to the differences
- Excellent for fibre fed echelle spectrographs due to spatial information suppression.
- The gains are mostly in keeping a single solution and in comparing consistent sections differentially instead of internally

Application to CYCLOPS

- 12 points per ThAr line (12 working fibres) and ~700 detectable lines = lots of 2D position information
- X-Y shifts account for 99% of variation (precision of ~4m/s after removal of X-Y shifts)
- Higher order effects are complex = higher order polynomial = smaller spectrum pieces (precision of <2m/s after removal of higher order effects)
- Different fibres have different dispersions etc. and so are treated separately and not combined