FMOS

A Wide-field Multi-Object Infra-red Spectrograph
for the Subaru Telescope

David Bonfield, Gavin Dalton

Wide Field NIR Spectroscopy

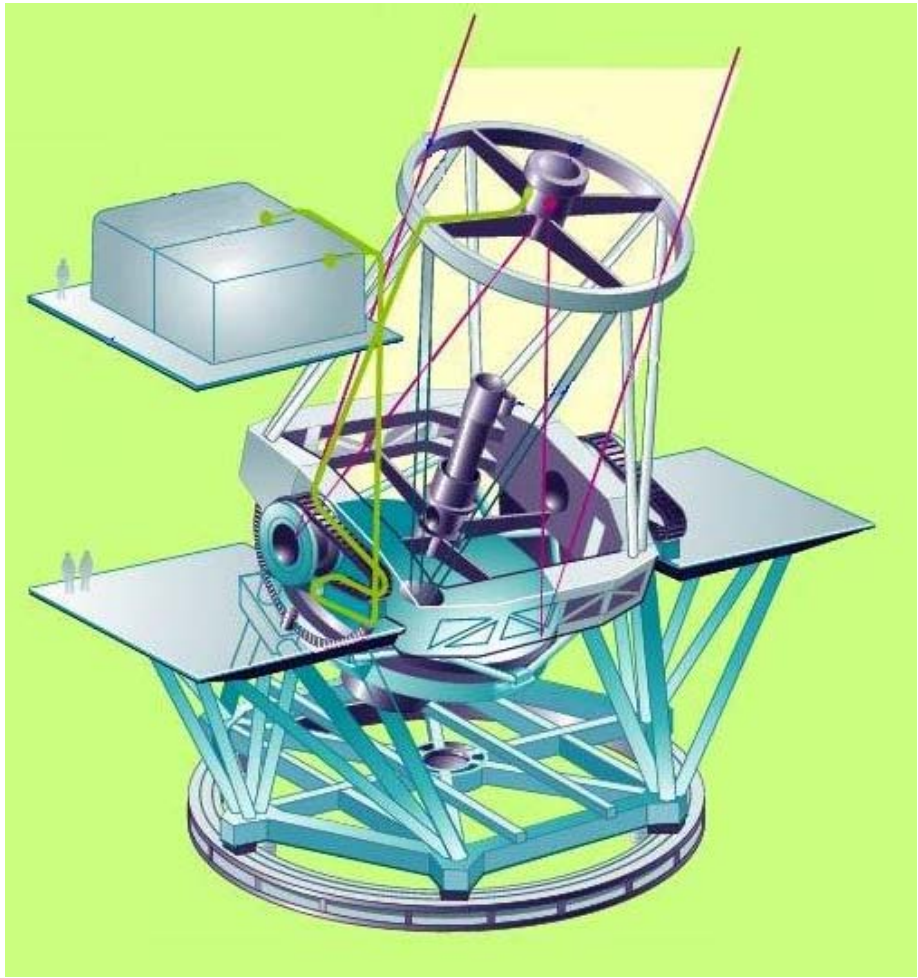
- WFCAM, VISTA are about to deliver lots of high-quality, deep near-IR imaging data
- Lots of science can be done with images, but vast amounts of information to be gained from spectroscopic follow-up of targets
- Want to do this in the infra-red
  - rest-frame optical features for high(ish) redshift objects
  - some cool objects more luminous in NIR
  - can look through dust obscuration better
- Need a wide-field multi-object capability, with high sensitivity (=> 8-metre telescope)

- FMOS: a Fibre-fed Multi-Object Spectrograph

Instrument Overview

David Bonfield – Oxford University

Instrument Overview

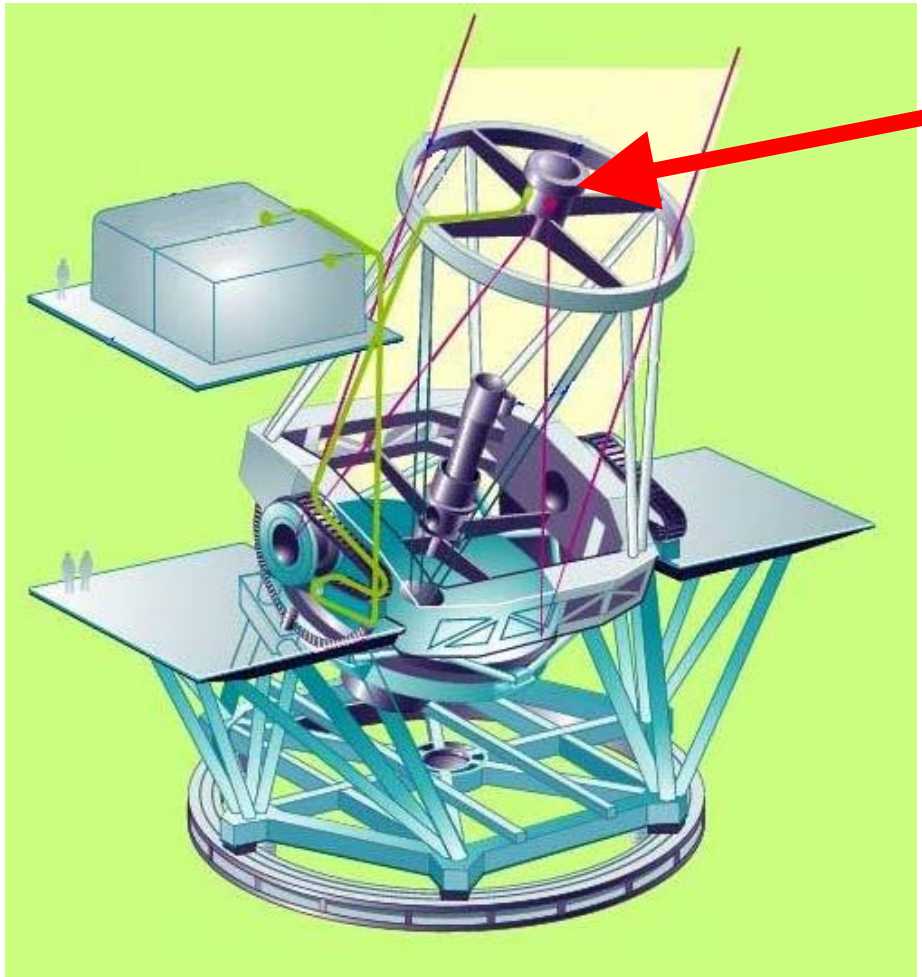


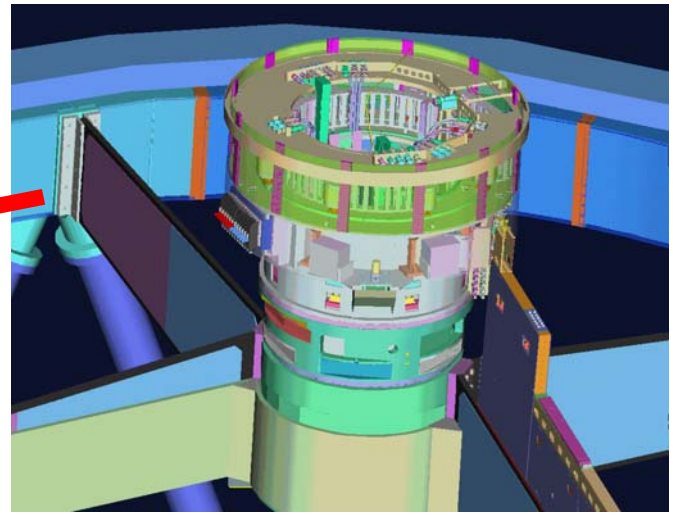
- NIR spectrograph
  - zJH band sensitivity
    (0.9 to 1.8 microns)
- 30 arcminute field of view
- 400 fibres
- R ~ 3000 / R ~ 500
  (quarter / full wavelength range)
- OH-suppressed
- At prime focus of the Subaru 8.2-metre telescope on Mauna Kea

The FMOS Instrument Team

- Kyoto
  - Instrument PI (Toshinori Maihara)
  - Prime focus instrument bay
  - One OHS spectrograph
  - Observation software
  - Mosaic Gratings
- Oxford/RAL
  - Spectrograph Design
  - One OHS spectrograph
  - Project Scientist
  - Fibre back-illumination system
- Durham
  - Fibre cables
  - Top end fibre connector
  - Slit assemblies
  - Spectrograph software
  - VPH grating cold tests
- AAO
  - ECHIDNA fibre positioner & software
  - Prime Focus Corrector
  - DR pipeline software
- Subaru
  - New floor to house spectrographs

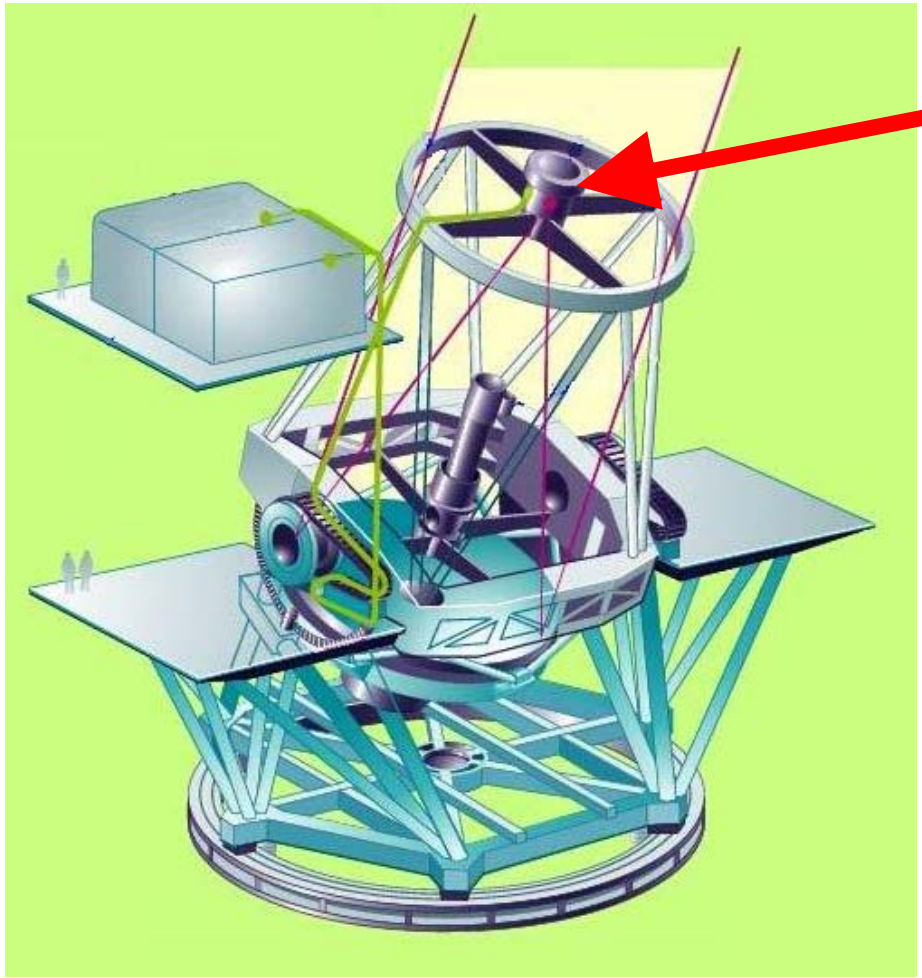
Prime Focus Unit

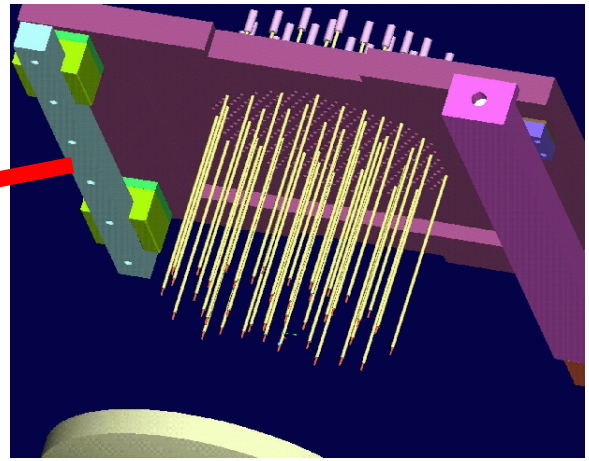




- Existing optical corrector no good for wavelengths > 1μm
- New 3-element refractive corrector for infra-red
- Atmospheric dispersion corrector (ADC) not required
- Houses Shack-Hartmann unit for active optics system, plus the Echidna fibre positioner…

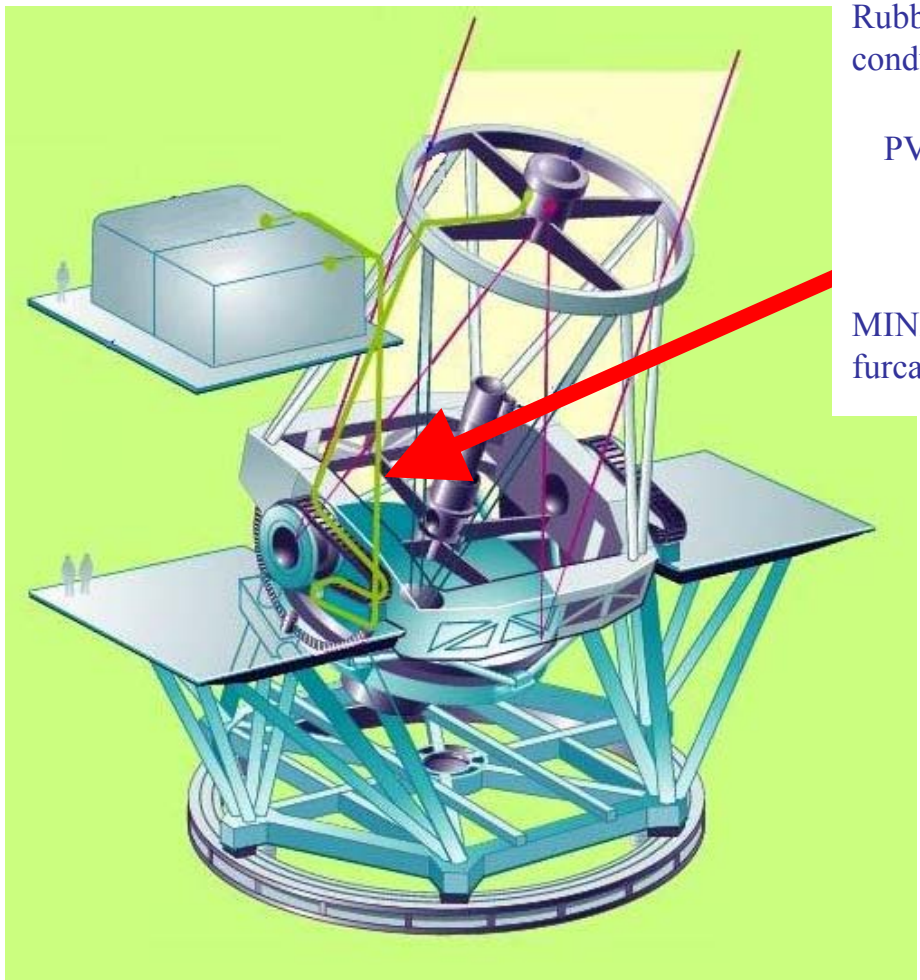
‘Echidna’ Fibre Positioner

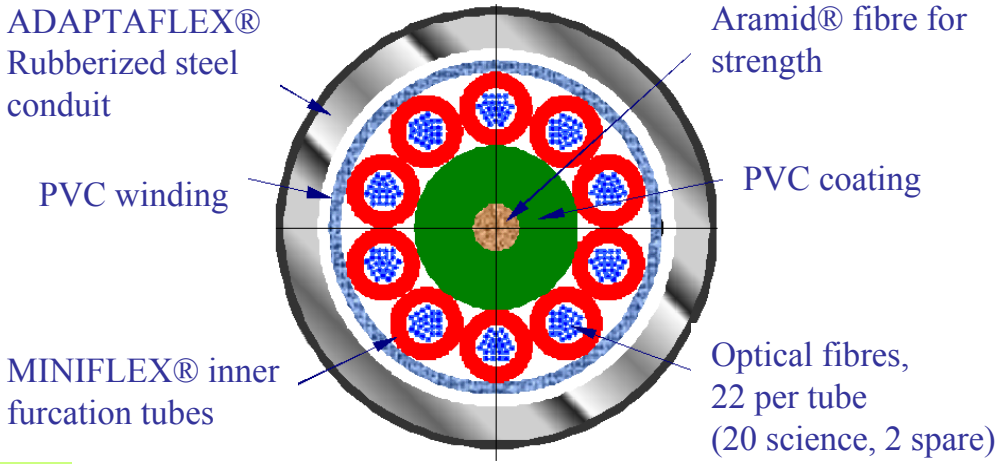




- 400 piezo-actuated spines
- close-packed into ~150mm diameter
  - 7mm spine pitch/patrol radius
- 100 micron / 1.24” fibre cores
- 0.2” positioning accuracy using focal plane imager
- 10 minutes to configure field

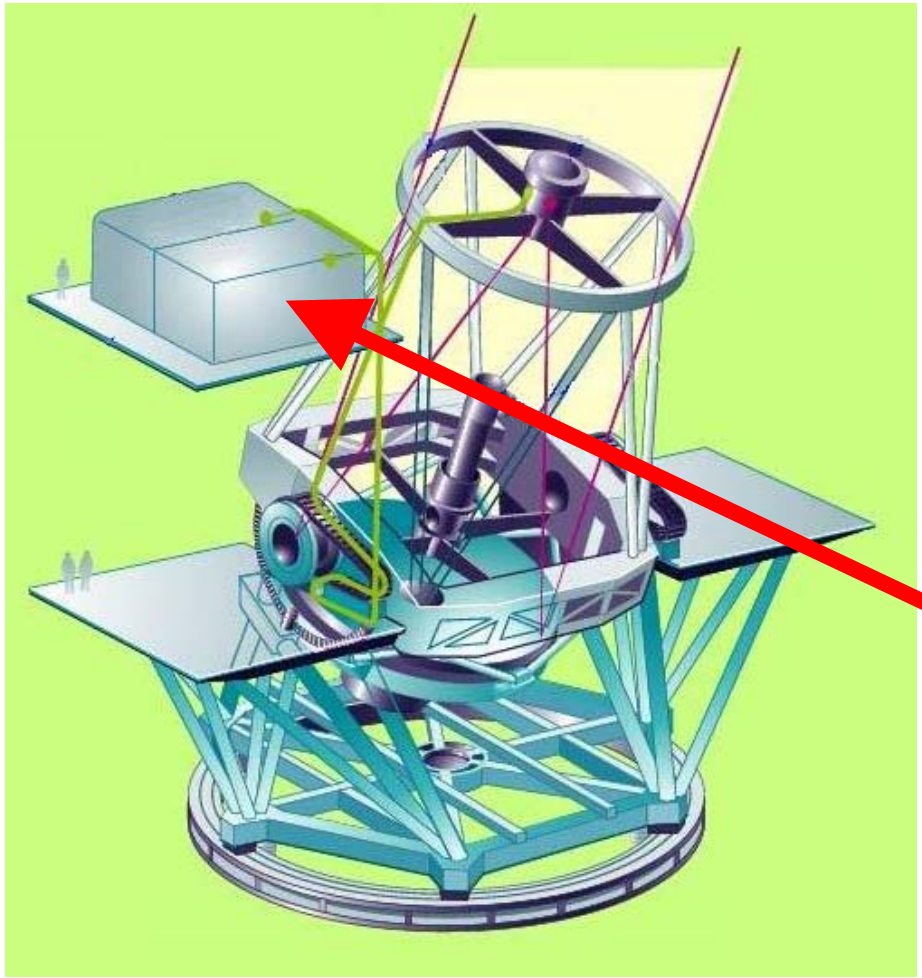
Fibre System



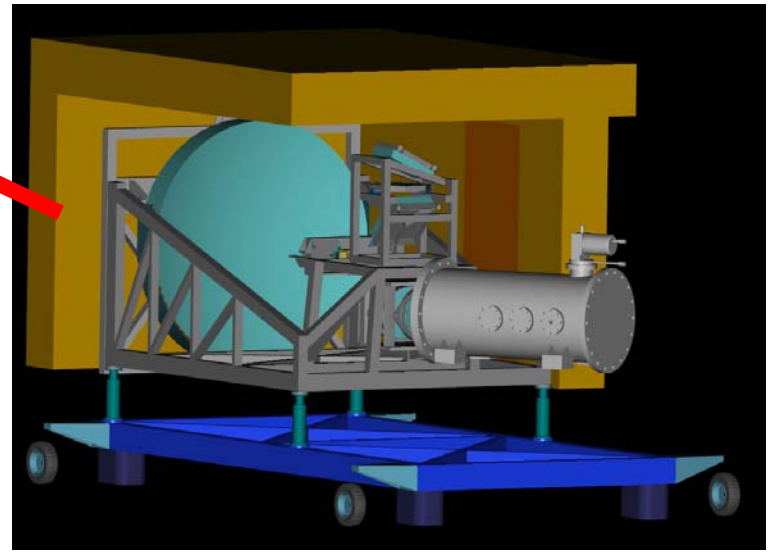


- 400 x 50 metres of optical fibre
- Top-end connector
  - allows exchange of prime focus unit without removing fibres
  - reduces f-ratio: f/2 -> f/5
  - illuminates fibres for focal plane imager
- Strain minimised with armoured cable and strain relief boxes

Spectrographs

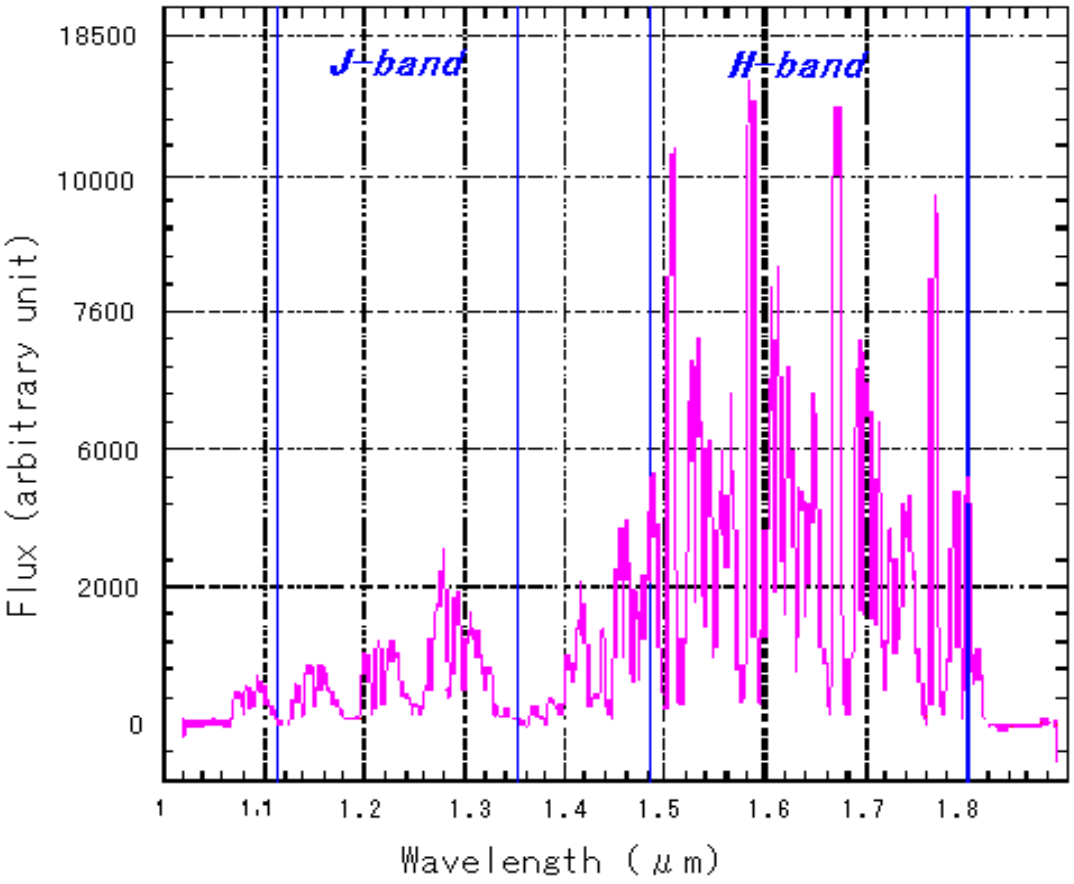


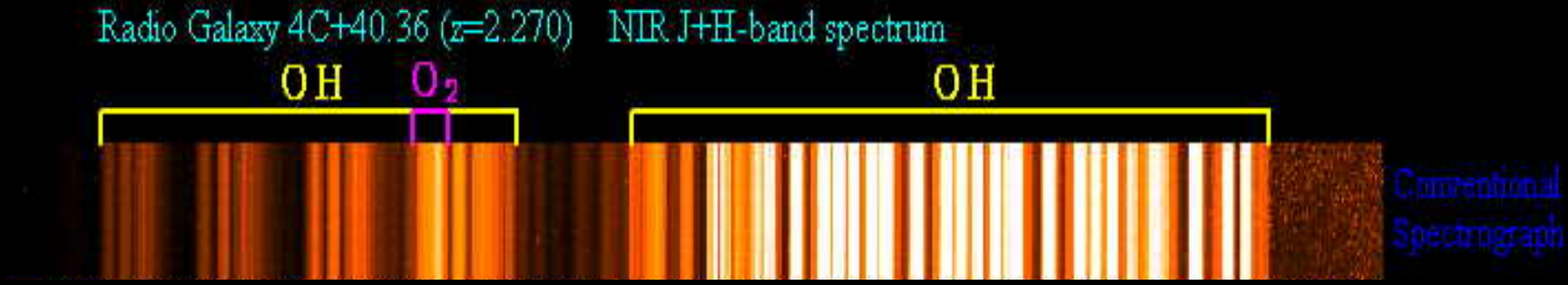
- Twin IR spectrographs
  - 200 fibres each
  - built at Oxford/RAL and Kyoto
- Cryogenic camera: one Hawaii-2 detector per spectrograph
- OH-suppressed spectrograph optics cooled to ~ 210K



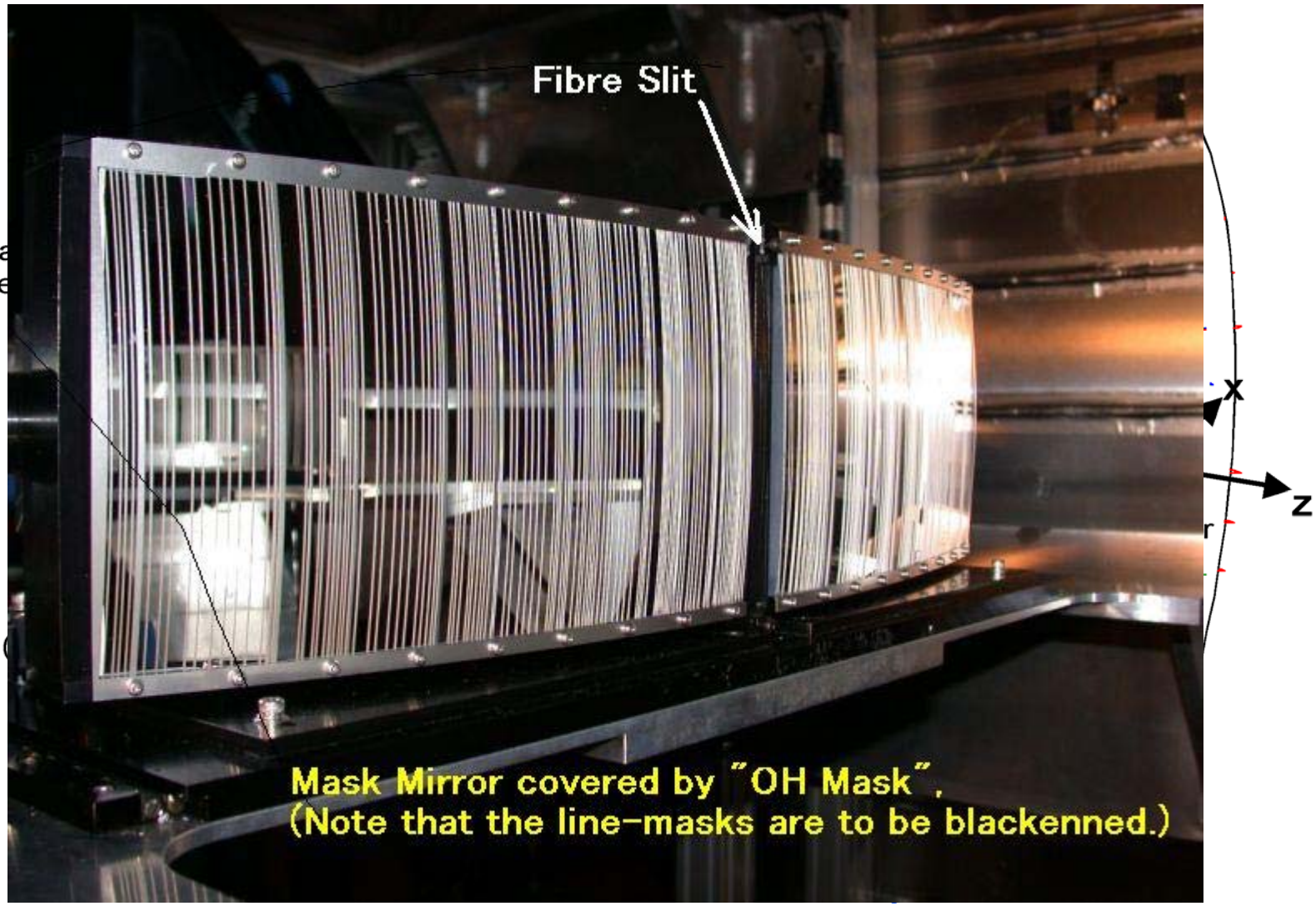
Why OH-suppression?

- Sky OH emission dominates NIR spectra of faint objects
- OH
- Cou nes, but
  - r
  - i
  - s
- For ines at hi reso
- Prov

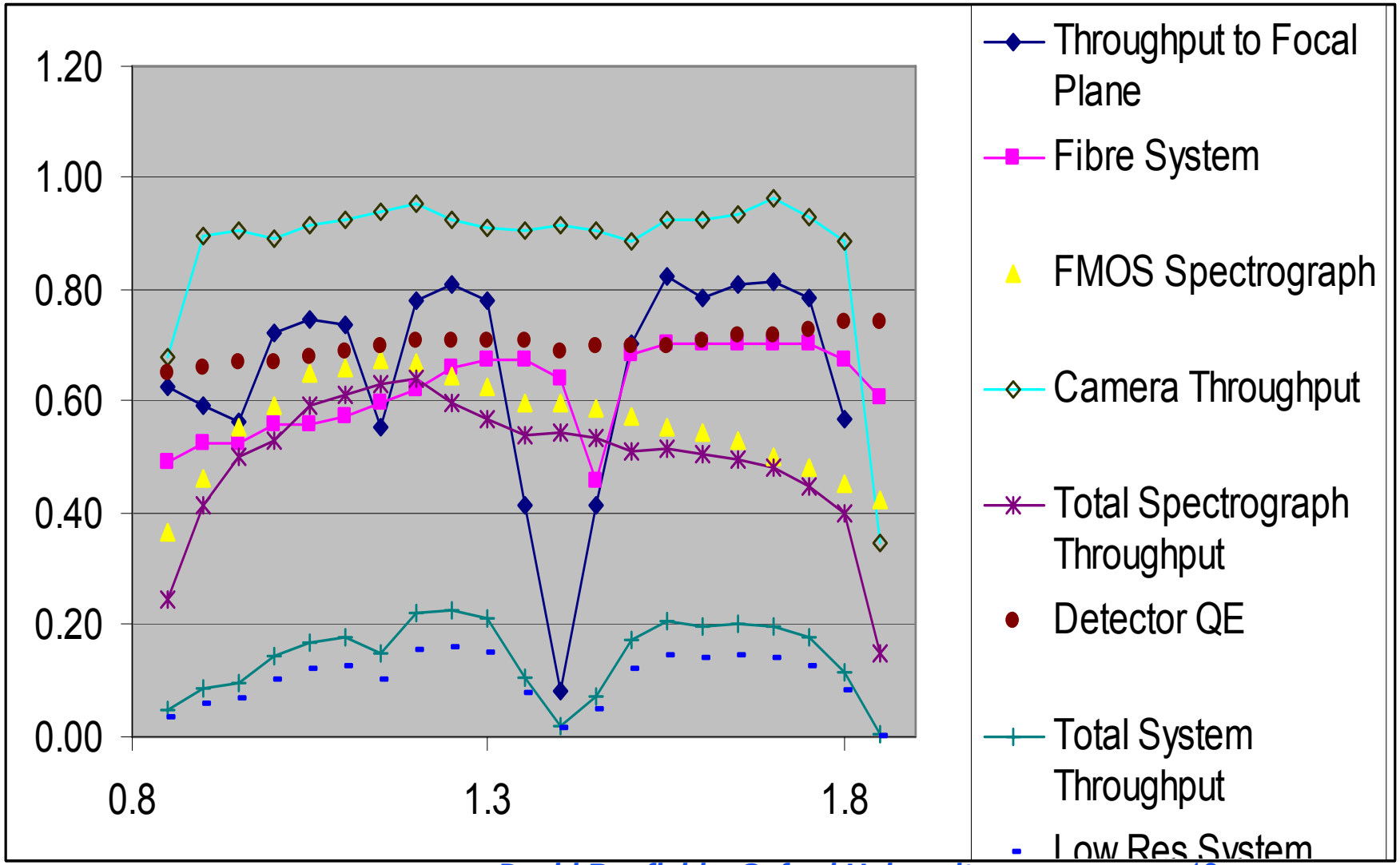



Radio Galaxy 4C+40.36 (z=2.270)
NIR J+H-band spectrum
OH
O_2
OH
Conventional
Spectrograph

Spectrograph Optical Layout



System Throughput



Current Status

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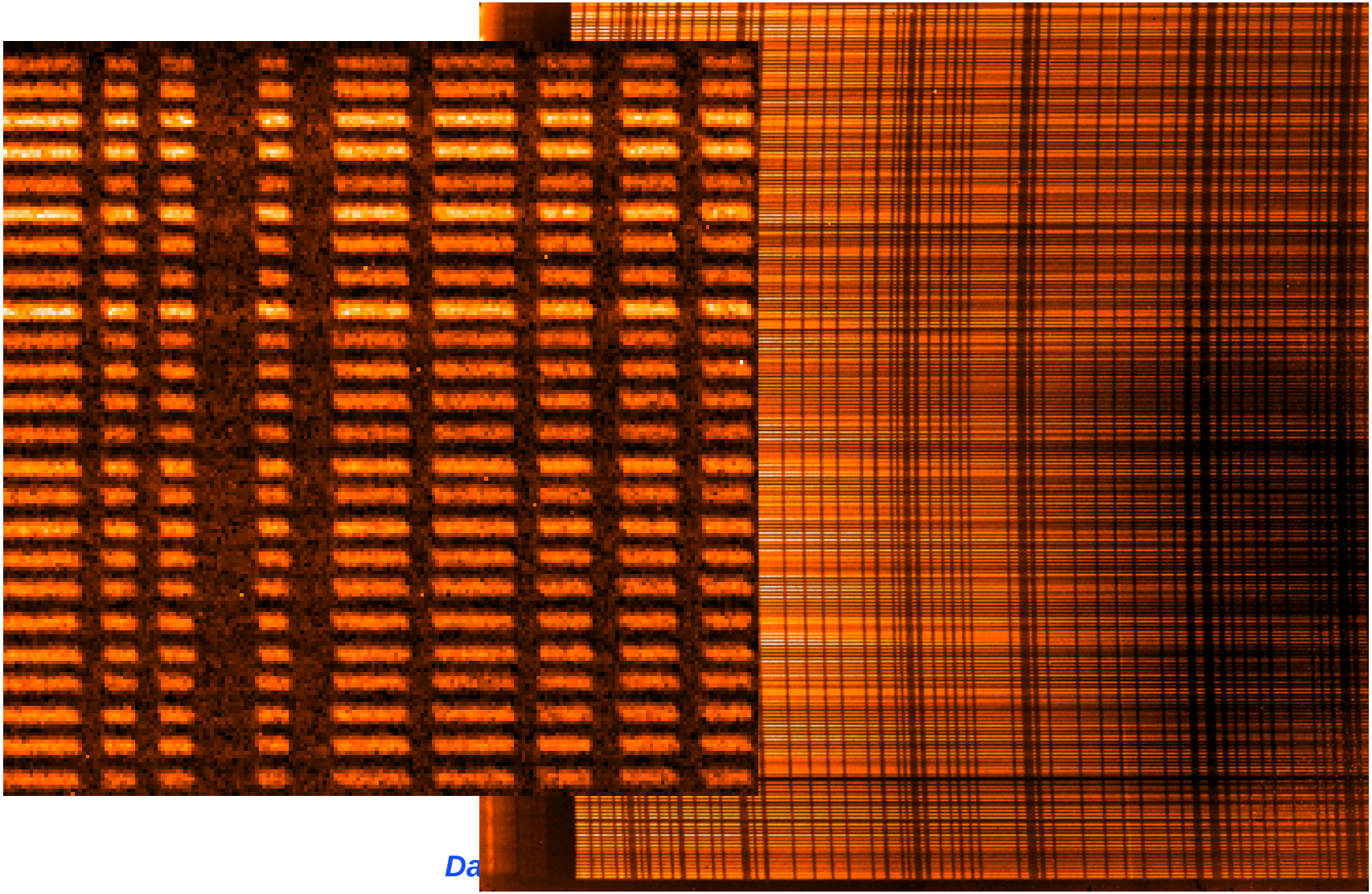
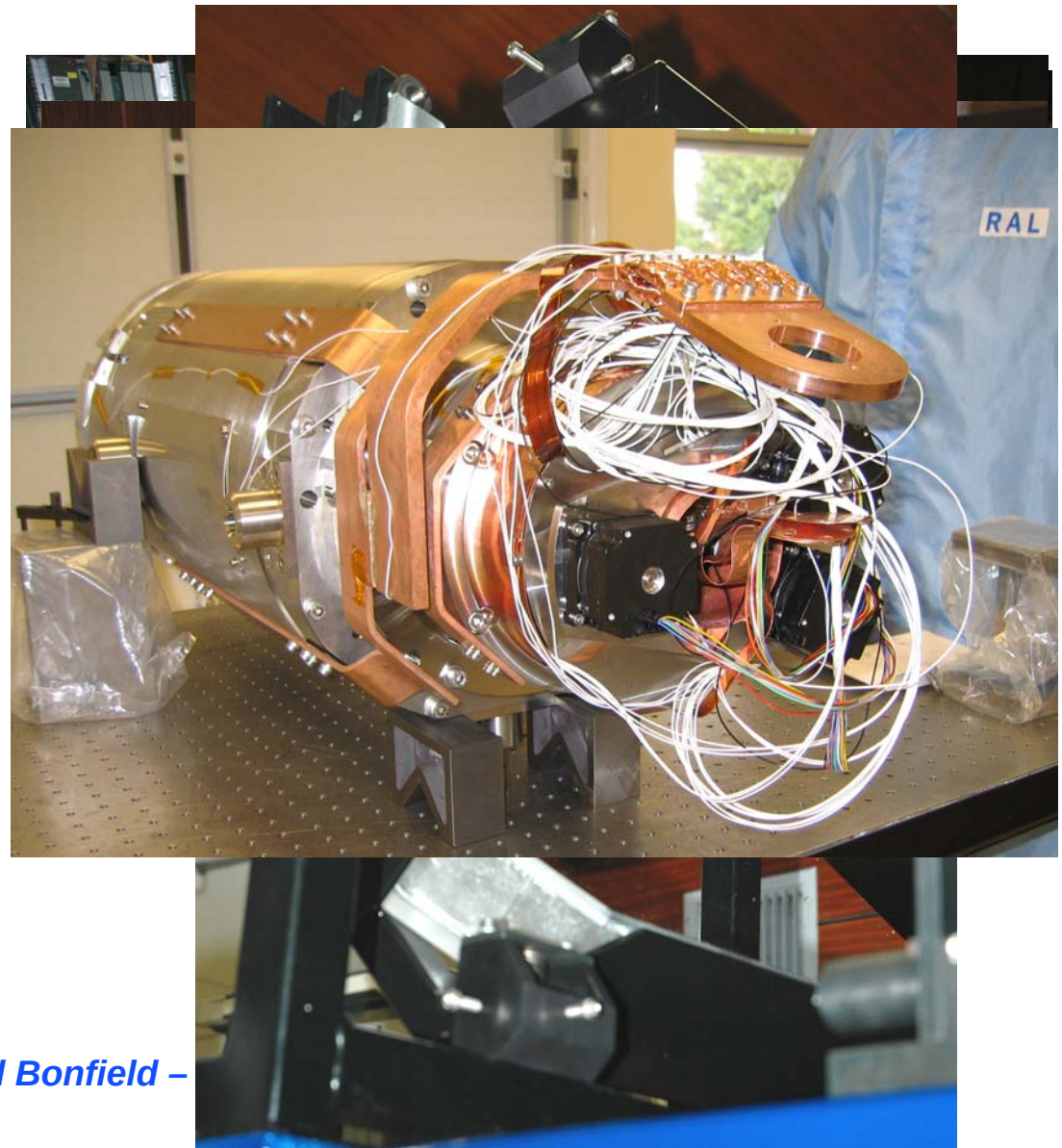
Kyoto Spectrograph



UK Spectrograph

- Started later due to funding
- A few months ago
  - Lots of components
- Now
  - Integration and testing well underway
  - Optical alignment beginning
  - Camera mostly complete
- Plan to be at telescope spring 2006

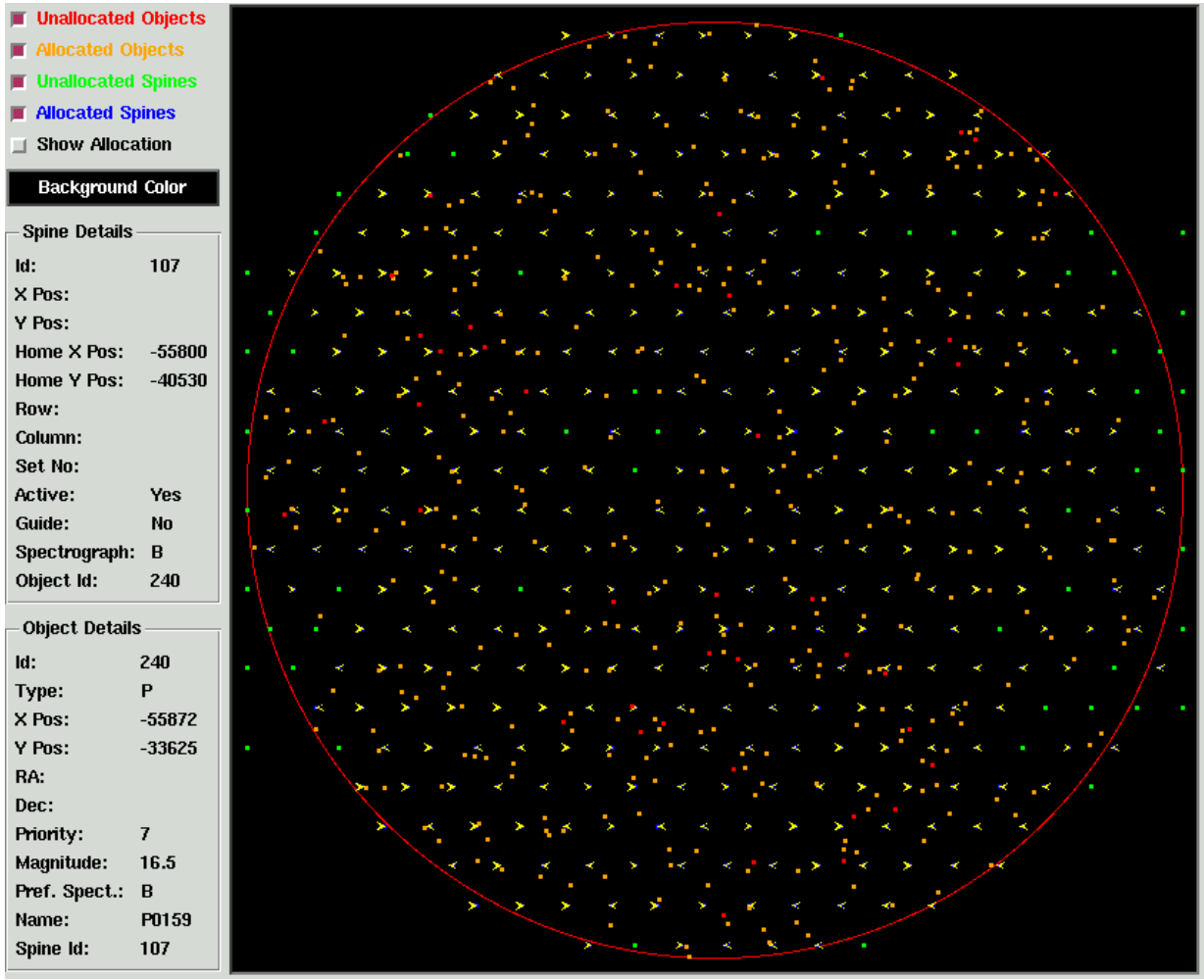


Echidna and Fibre System

- Echidna largely complete - awaiting fibres, expected Feb 2006
- Fibre train will be ready at same time
- Integration at Subaru expected spring 2006

Software

- Fibre allocation / Echidna control software ready
- Spectrograph control systems being tested
- Data reduction pipeline underway at AAO



Potential Science

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Survey Possibilities

N.B. H~20 continuum source → S/N=10 in 1 hour

10^{-17} erg/cm^2/s line → S/N=10 in 20 minutes

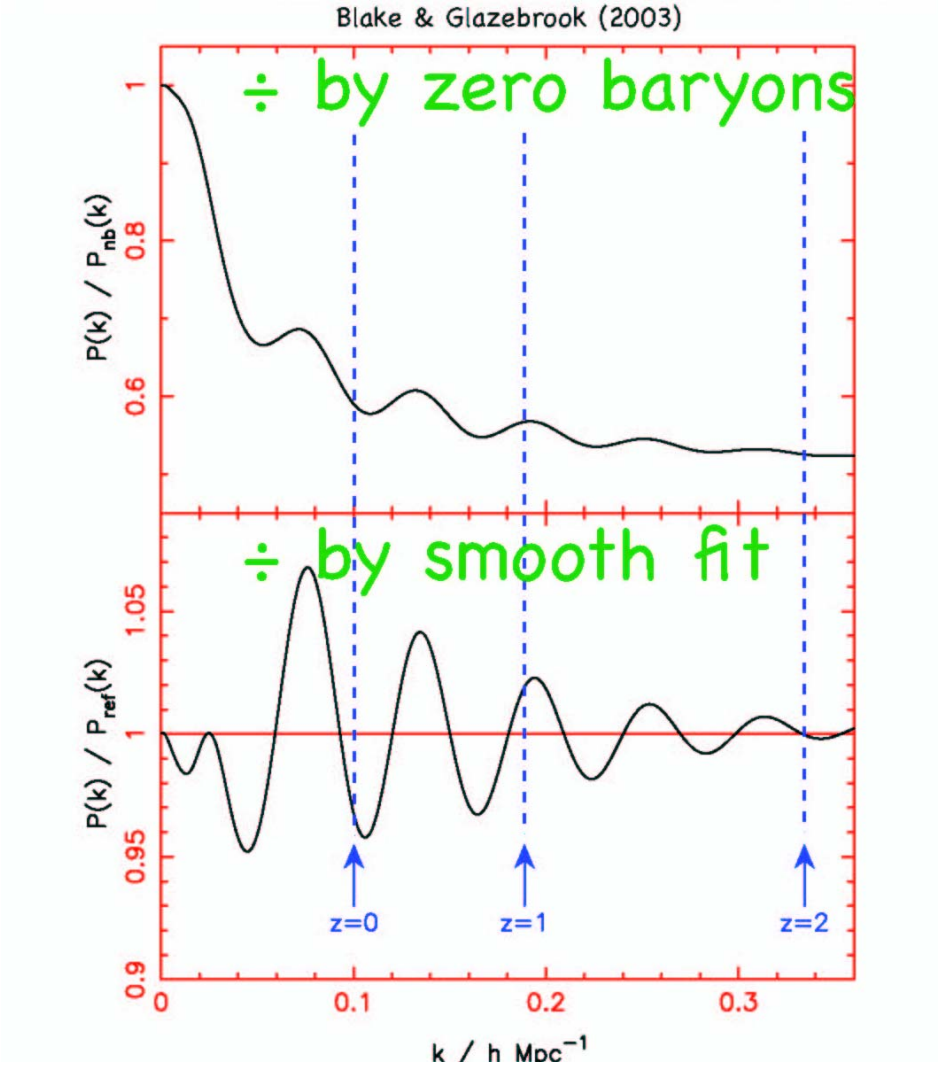
- Extreme Deep survey in SXDS/UDS field
  - Pick up many bright sources during long (100hr?) exposures on high priority faint targets.
- LSS/Galaxy Evolution Survey (2dFGRS Analogue)
  - ~100 square degrees, ~100,000 galaxies
- Wide angle survey (30 min exposures)
  - First attempt at Dark Energy measurements from P(k)
- Galactic targets
  - Star forming regions, Y-dwarfs, Galactic centre

Next generation z surveys

- Galaxy Evolution Studies
  - 1.3 < z < 1.8 (Beyond DEEP2/VVDS, J < 21, J-K select)
  - Ellipticals above z=2.5 (UKIDSS UDS)
  - Highest redshift galaxies (Lyman alpha @ z > 7)
- Large-Scale Structure
  - Evolution of LSS, nature of bias, morphology-environment relations
  - Equation of state of Dark Energy (First Pass)
- AGN Studies
  - Obscured high-redshift AGN (Sub-mm sources)
  - High-z QSO population (z > 7?)

Example: Dark energy at z~1.5

- Use baryon oscillations as ruler → H(z) and $D_A(z)$
- Target bright H-alpha emitting galaxies at 1.3 < z < 1.7
  - Emission line flux limit in 20 minutes ≈ SFR of 1 M_{solar} per year
- Issue is selection of brightest H-alpha emitters
  - Rest-frame UV? Jointly with K-band?
  - Mid-IR selected? (Spitzer / ASTRO-F)
  - Pilot study needed…



Summary

- FMOS is a near IR multi-object spectrograph
  - 30 arcminute diameter field of view
  - 400 simultaneous objects
  - R ~ 500, full 0.9 - 1.8 micron coverage in one exposure
  - R ~ 3000, quarter of full wavelength range
- Will be commissioned on Subaru in 2006
- UK to get 30% of instrument time for 5 years
- FMOS will be fastest wide-field NIR survey spectrograph for many years to come