Subaru/FMOS

"A road to FMOS"
(Dec 2007)

Commissioning:
Brief history & current status

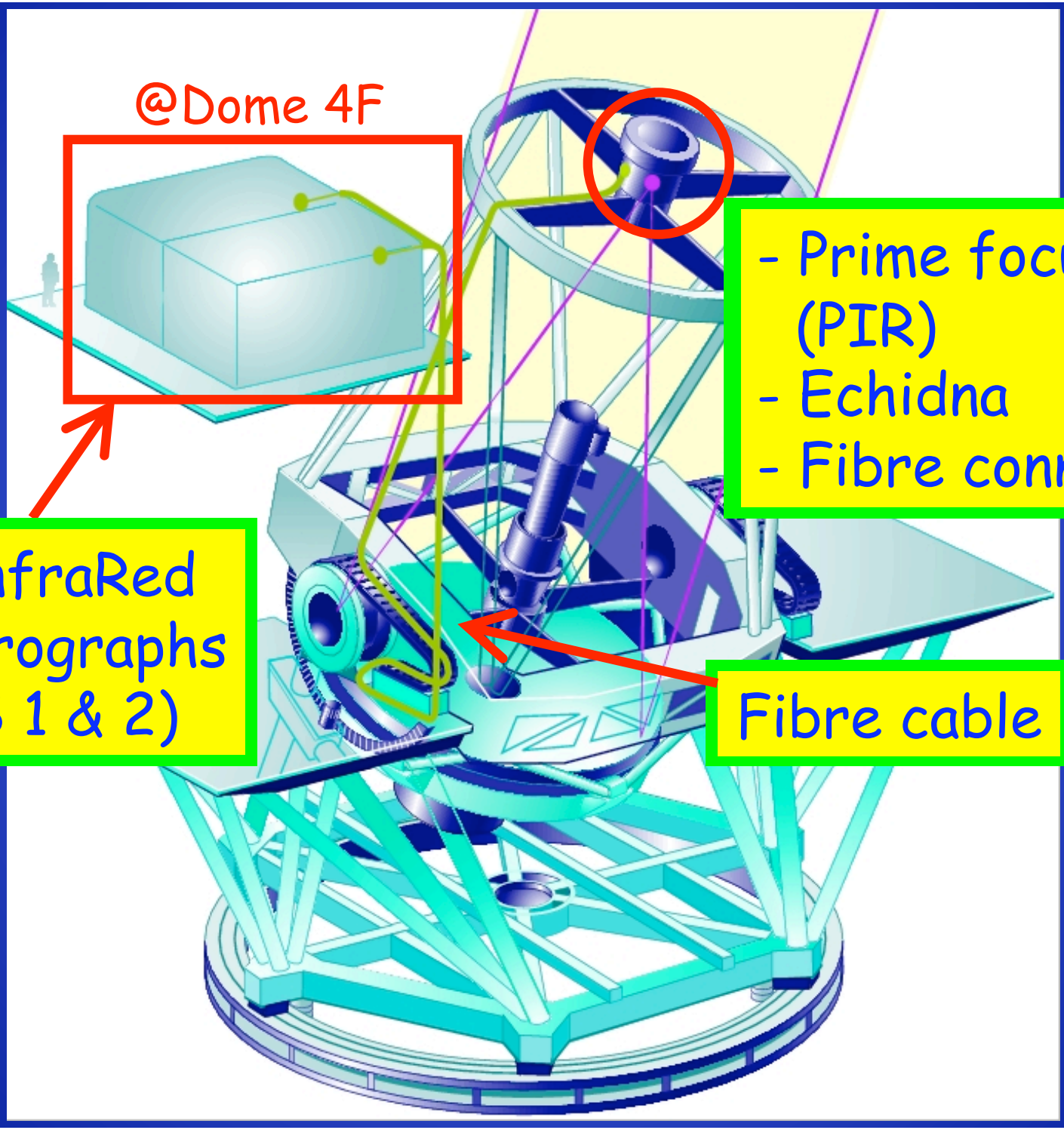
Dalton &
Lewis

Iwamuro

Observation

Expected performance

Naoyuki Tamura
Instrument scientist
Subaru Telescope, NAOJ


@Dome 4F
- Prime focus unit (PIR)
- Echidna
- Fibre connector
2x InfraRed Spectrographs (IRS 1 & 2)
Fibre cable

Engineering observations

2007.12 PIR test on the telescope (I)(II)

2008.01 Echidna test on the telescope (I)

2008.05 Echidna test on the telescope (II)
IRS1, 2 test ⇒ *Engineering First Light!!*

2008.06, 08, 09, 10, 2009.01

Testing fibre positioning & fiber AG
IRS1 & 2 optical alignment
System throughput measurement
Operation & command test

2009.03, 05
In a *Performance verification (PV)* phase

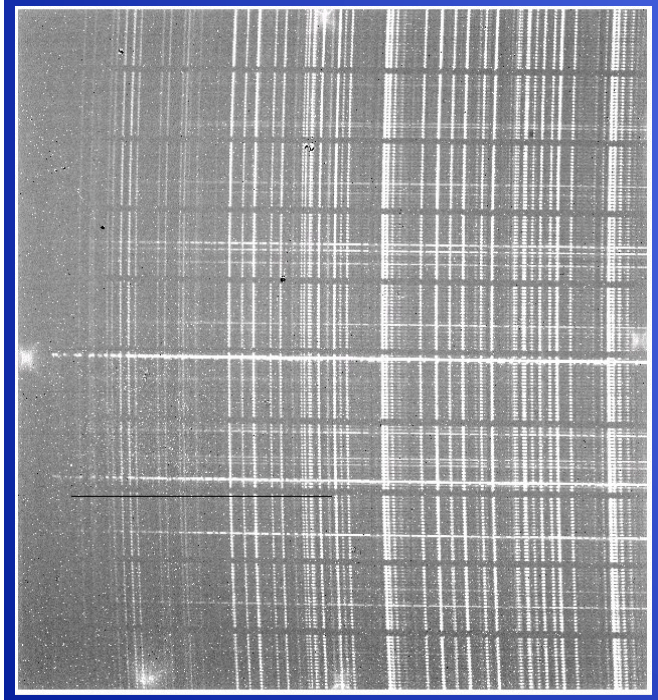
With bug-fixes & necessary upgrades …

Engineering First Light @May 14, 2008

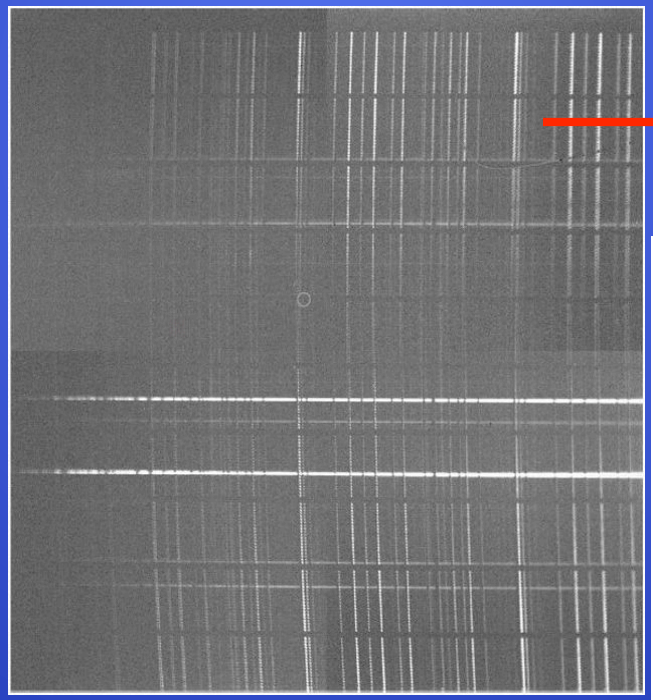
Target: 48 bright stars (V < 15) in Mel 111 (Galactic open cluster)
→ 33 stars were immediately visible after 1 min exposure!!

Note(1): The fibre positioning accuracy was ~ 0".4 in rms (now ~ 0".2)
Note(2): The OHS masks were not well aligned with the actual OH lines.

IRS1 (25 stars)



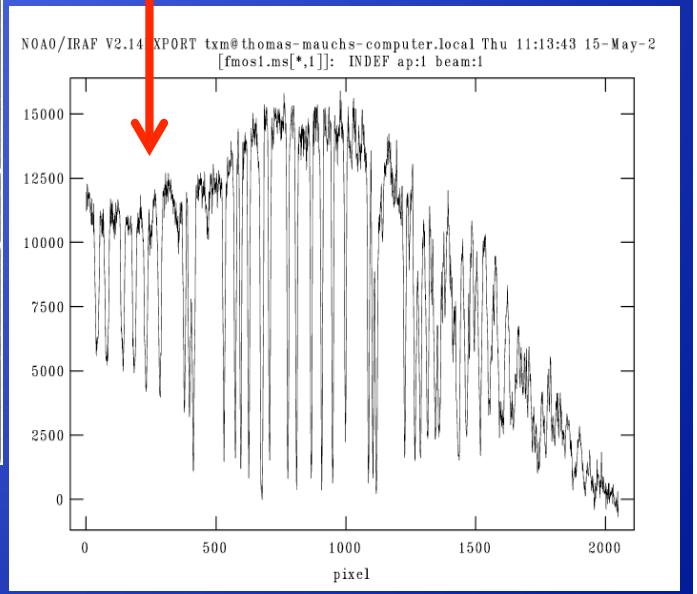
IRS2 (8 stars)



λ

HR mode, J long (1.1-1.3 μm), 1 min exp., no AG

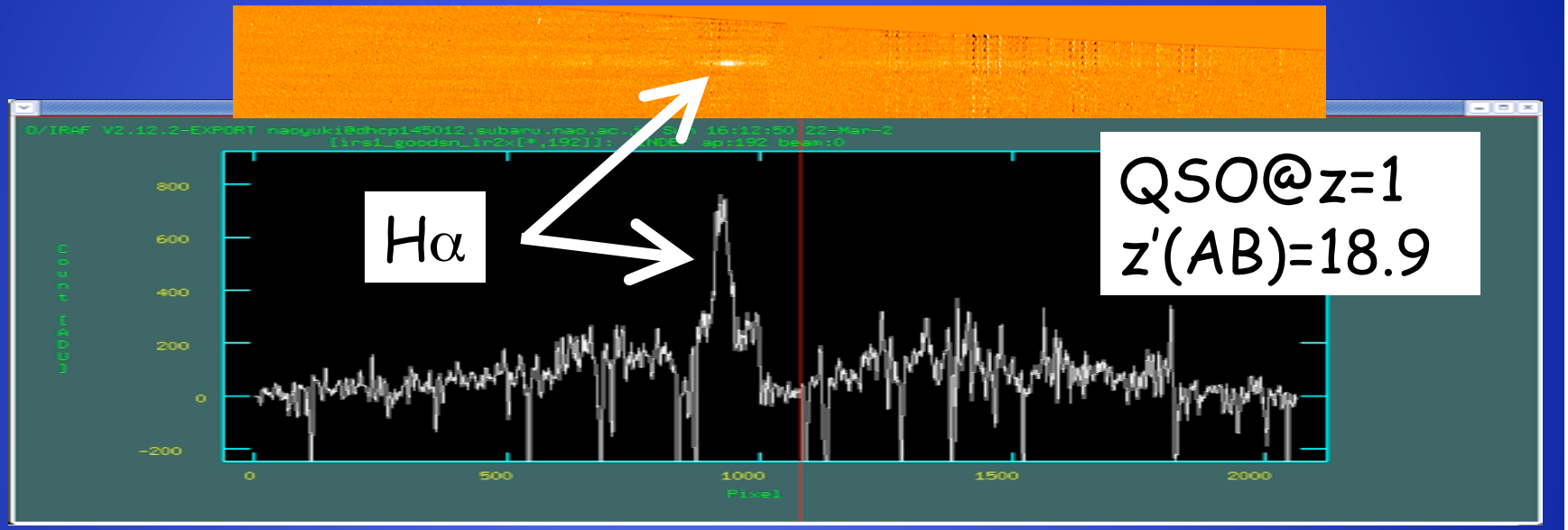
A stellar spectrum is extracted.

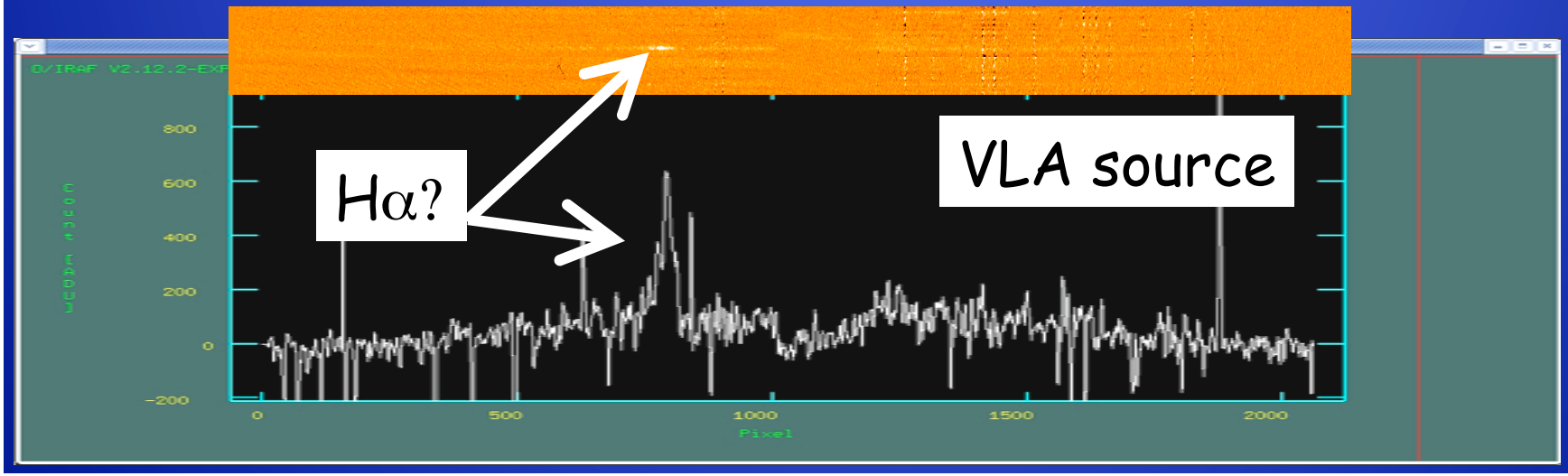


"PV" First Light @Mar 12, 2009

Long exposure of fainter objects with fibre auto guiding

GOODS-N field, Low Res, 15 min "on" minus 15 min "off" x 3





Observation: Actual sequence

(1) Telescope pointing & fiber configuration

The fibres are configured with the telescope slewing.

(2) Fine tune of telescope pointing and instrument PA

~ 15 min.

Take images of bright stars with a CCD camera on Echidna ("sky camera"), then calculate the offset & rotation for correction. Repeat this 2-3 times.

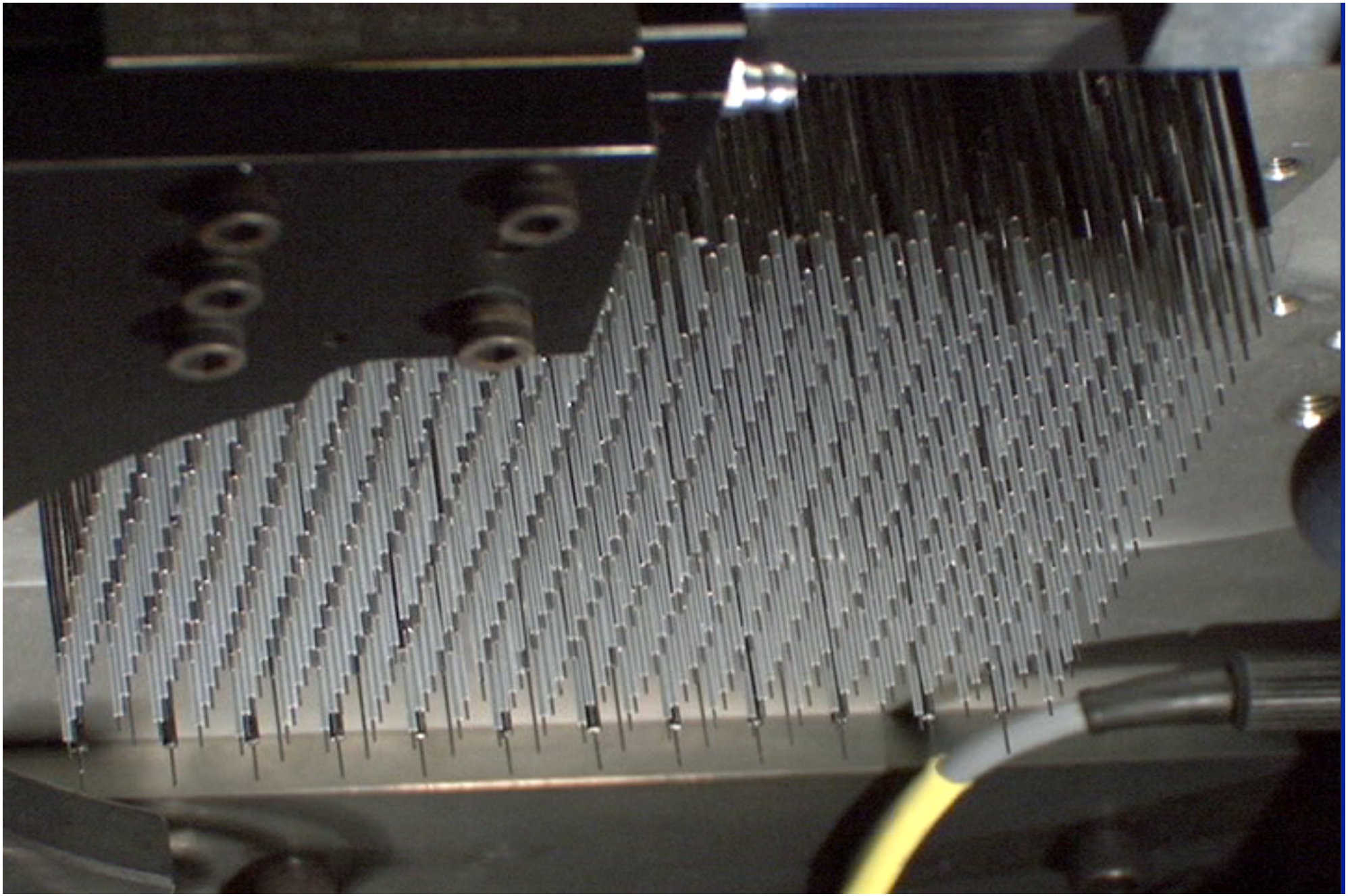
cf. Pointing accuracy ~ a few arcsec.
FoV of guide fibre bundle ~ 2 arcsec.

(3) Start fibre AG, and exposure

3 observation modes:
Point & stare | Beam switching | Cross beam switching

"Fibre tweak" (2-3 min.) is necessary for long exposure.

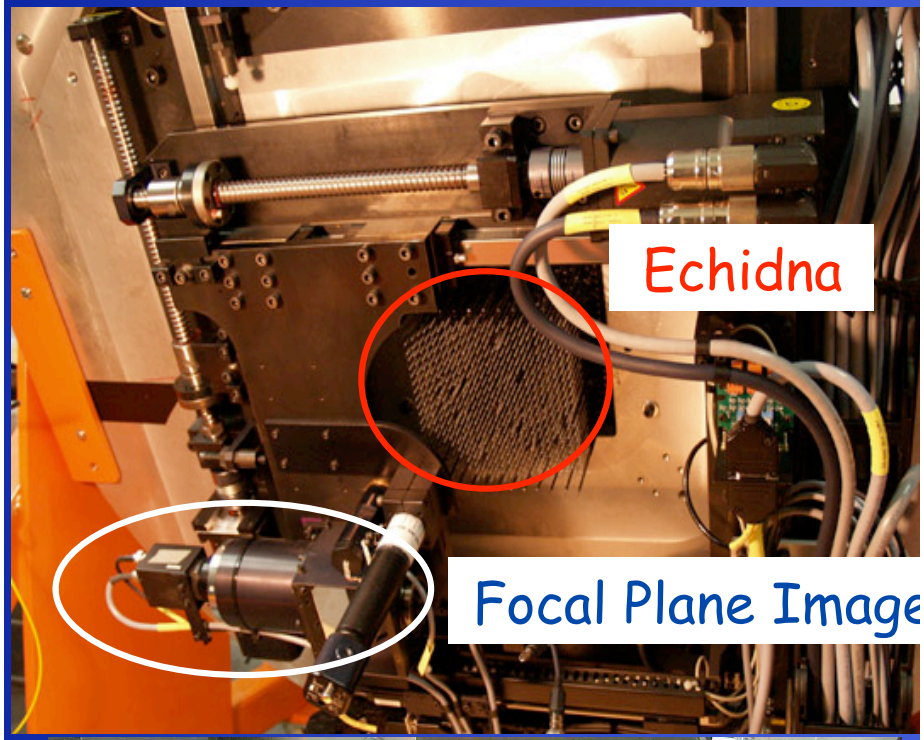
Fibre positioning

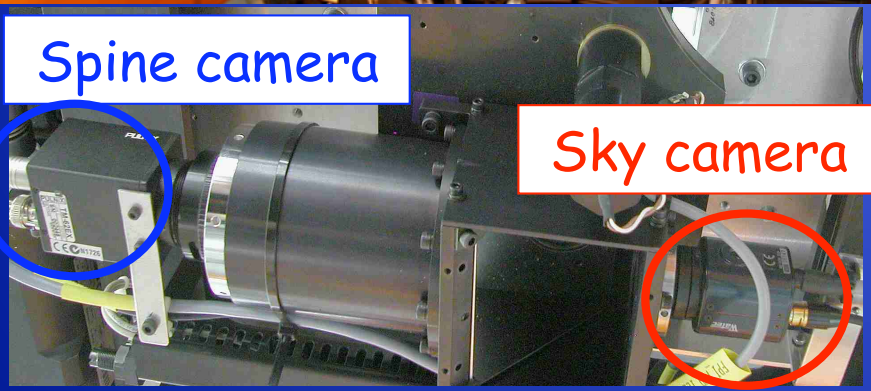


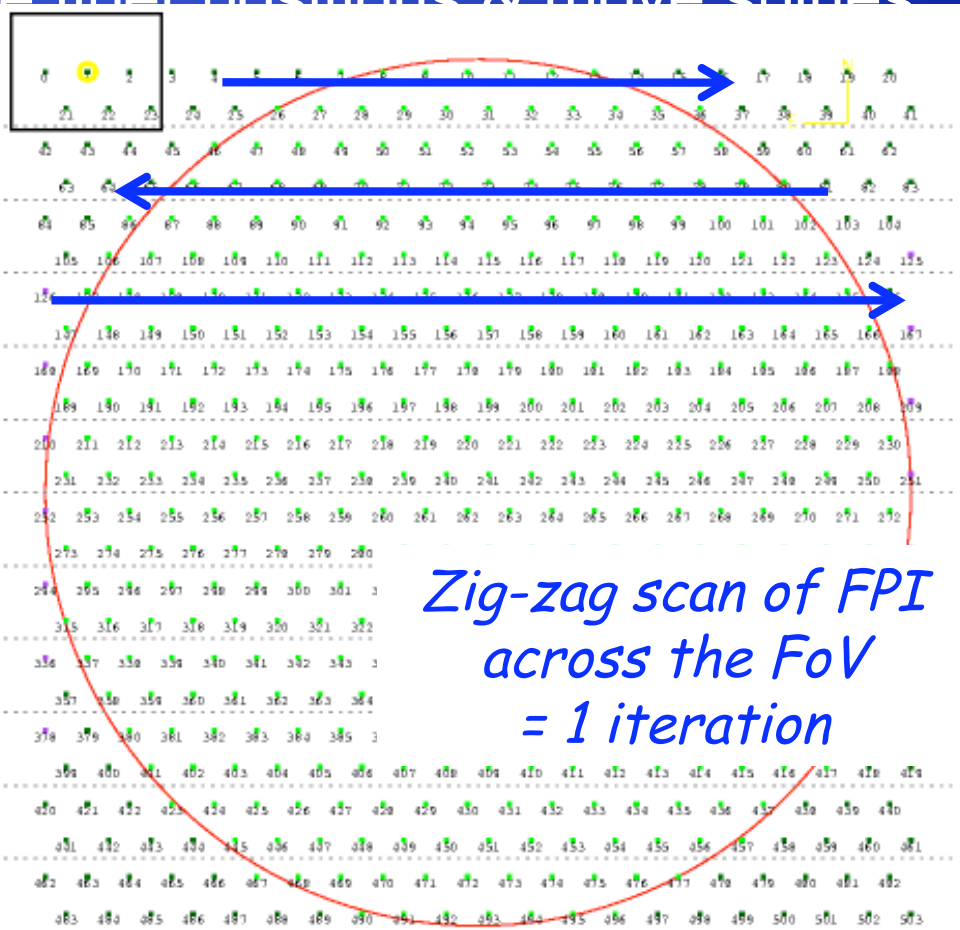
Fibre positioning

Iterative process: Measure fiber positions & move spines

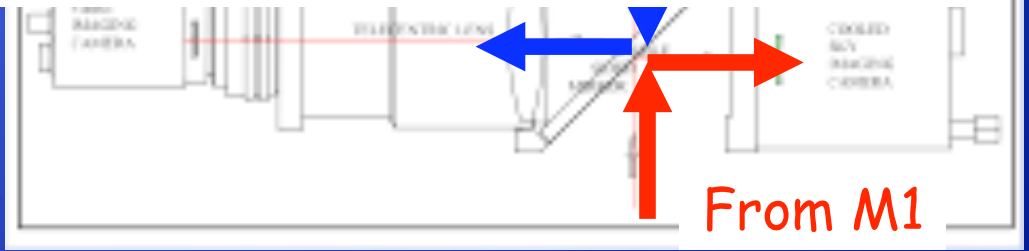
(with "ba







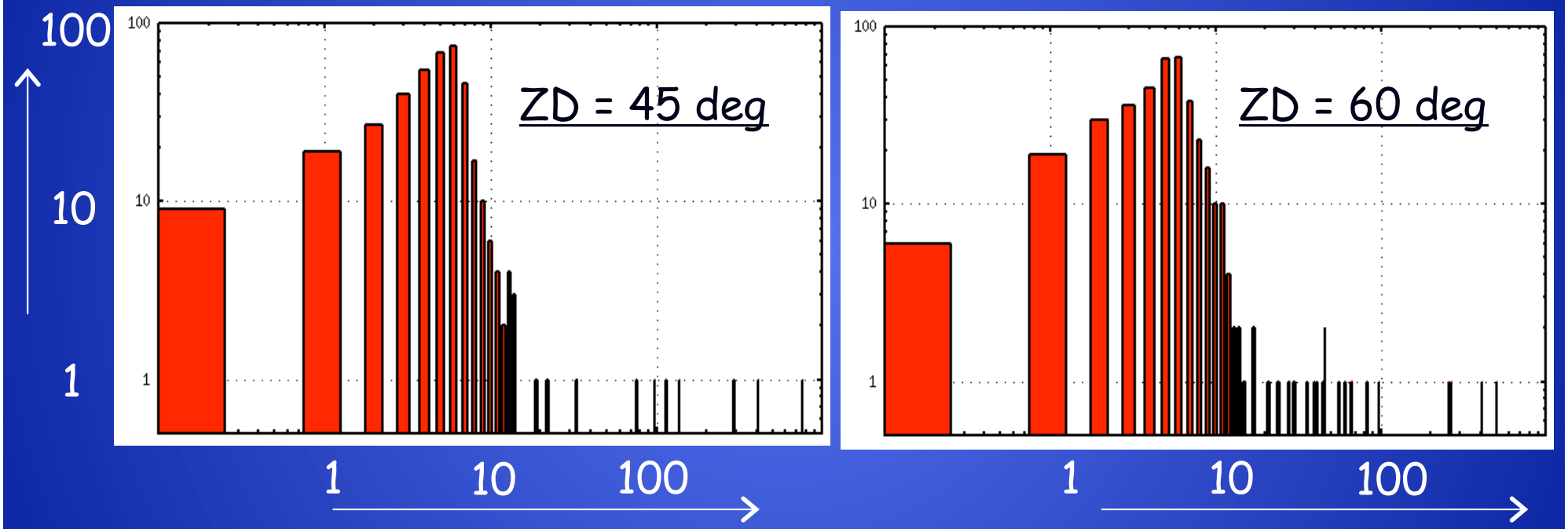
Zig-zag scan of FPI across the FoV = 1 iteration



Positioning accuracy & required time
(Test results at a lab)

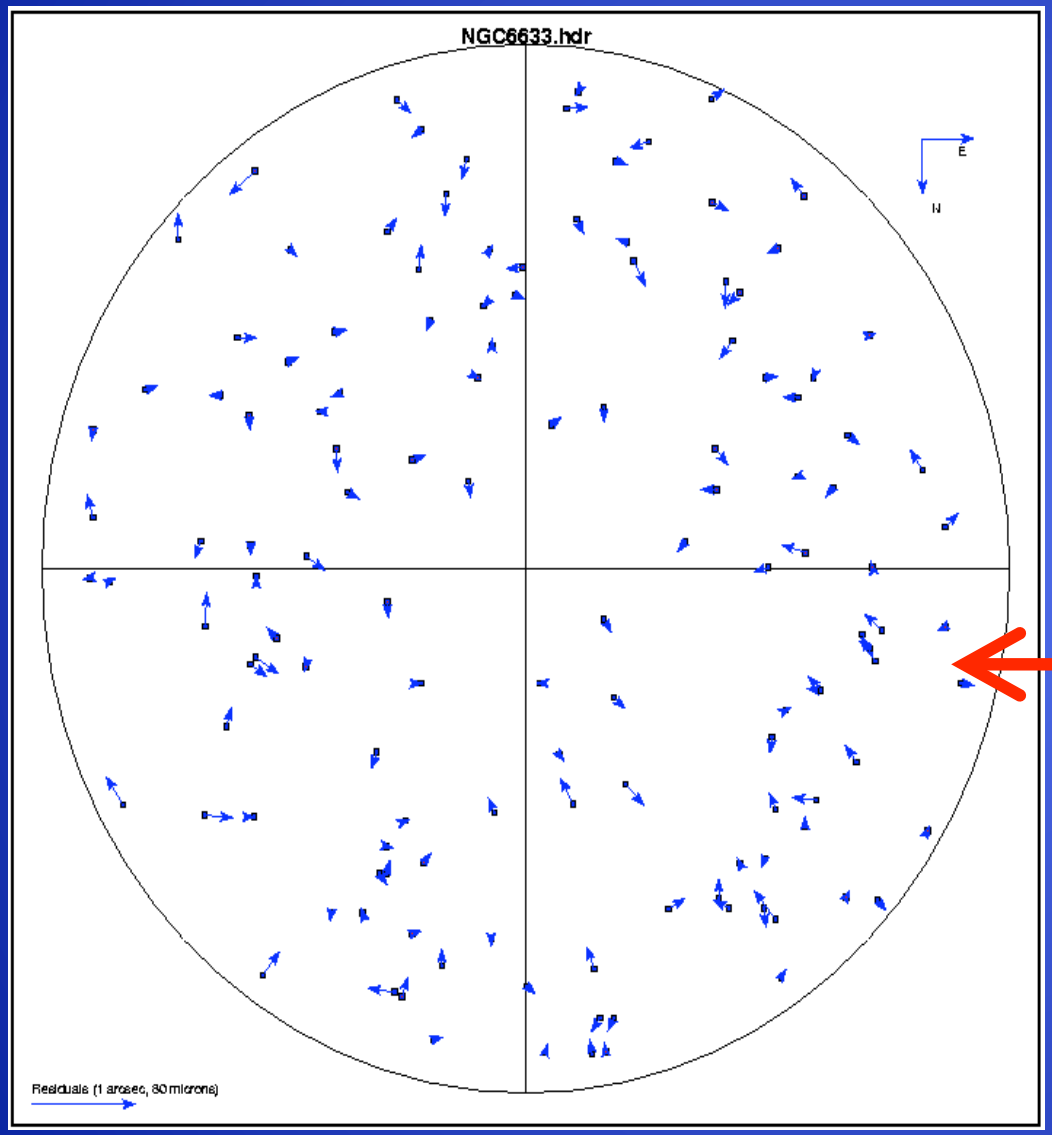
Number of spines

After 7 iterative motions to requested positions



~ 95% of the spines are positioned with < 12 μm accuracy (~0".1) in 7 iterations (~13 minutes) at ZD < 60 deg.

Fibre positioning: Residuals on sky



Open cluster NGC 6633 (α, δ ← UCAC2)

Error

(α, δ) → (x, y)

Model

Error

Echidna spine

RMS ~ 0".15

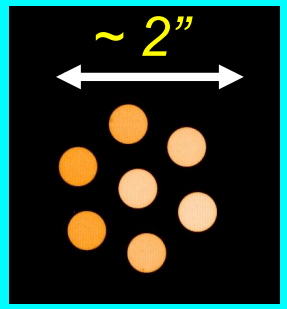
was achieved in Oct 2008.

Fibre Auto Guiding (AG)

- Already operational.
- Long exposures have been successful with AG.

400 science fibres populated within this 30' diameter FoV

14 fibre bundles for AG (7 at one side)



7 fibres consist of a guide fibre bundle.

R ~ 17 mag stars work for AG (although this strongly depends weather & seeing)

Snapshots of guide stars on guide fibre bundles

FMOS InfRared Spectrograph (IRS)

★ *"IRS1" (Kyoto) & "IRS2" (Oxford/RAL/Durham)*

200 fibers are fed to each IRS.

197+200 fibres are available: 3 spectra on IRS1 are focused outside the detector (all from near the edge of FoV).

★ *Near-infrared (NIR) spectroscopy: 0.9 - 1.8 μm*

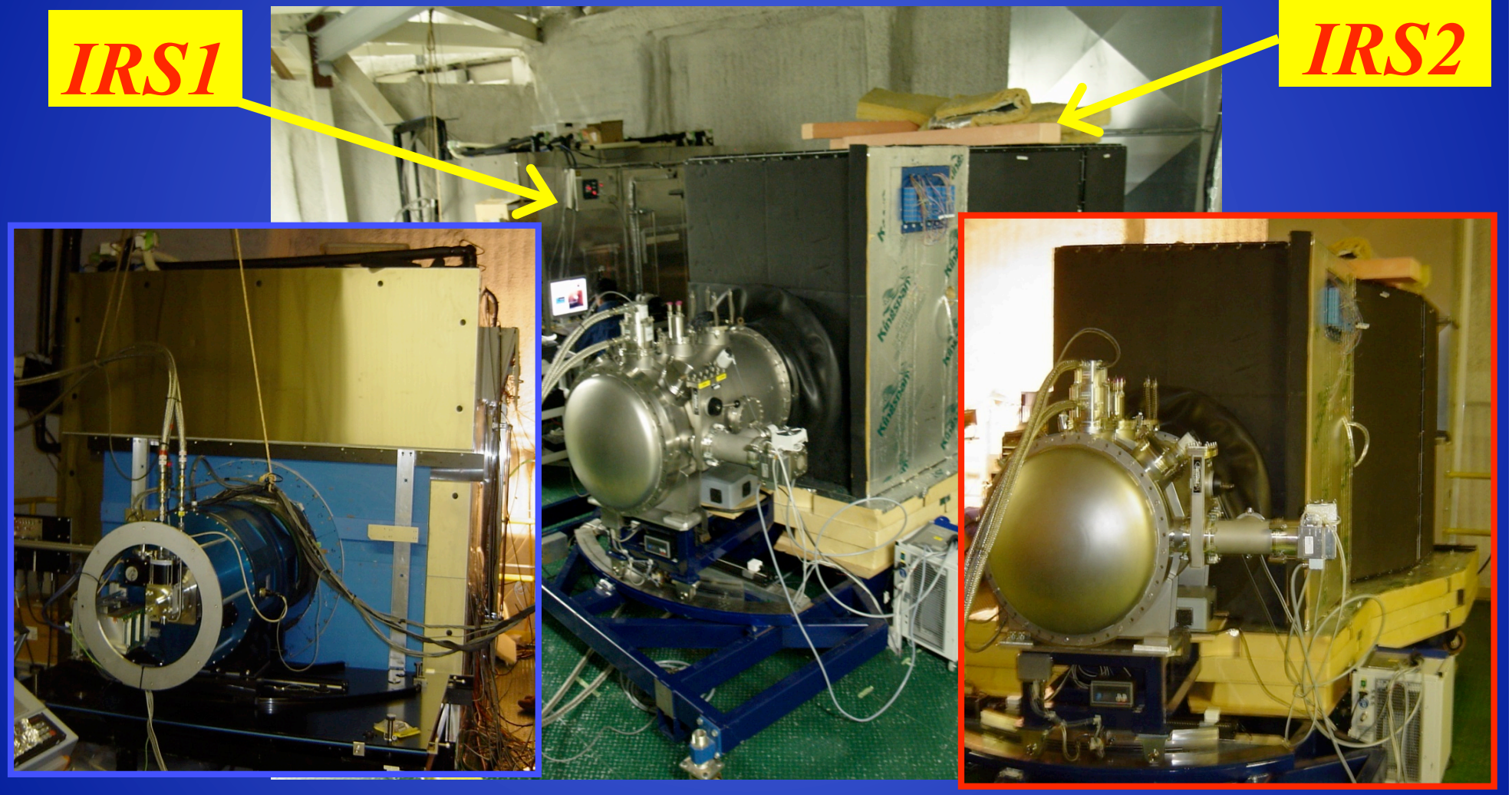
★ *OH airglow suppression with a mask mirror*

★ *Operated with cooled down to ~ - 55 deg.*

★ *Two observing modes: Low Res. & High Res.*

LR: 0.9-1.8 μm is observed at one exposure with R~500.
HR: R~2200. 0.9-1.8 μm is scanned by 4 exposures.

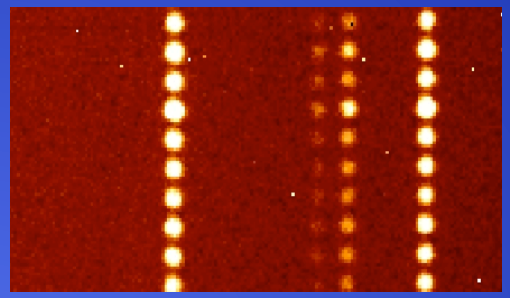
Two optically identical IRSs in the Subaru dome



~ 2.5m x 2.5m x 5m

IRS optical alignment

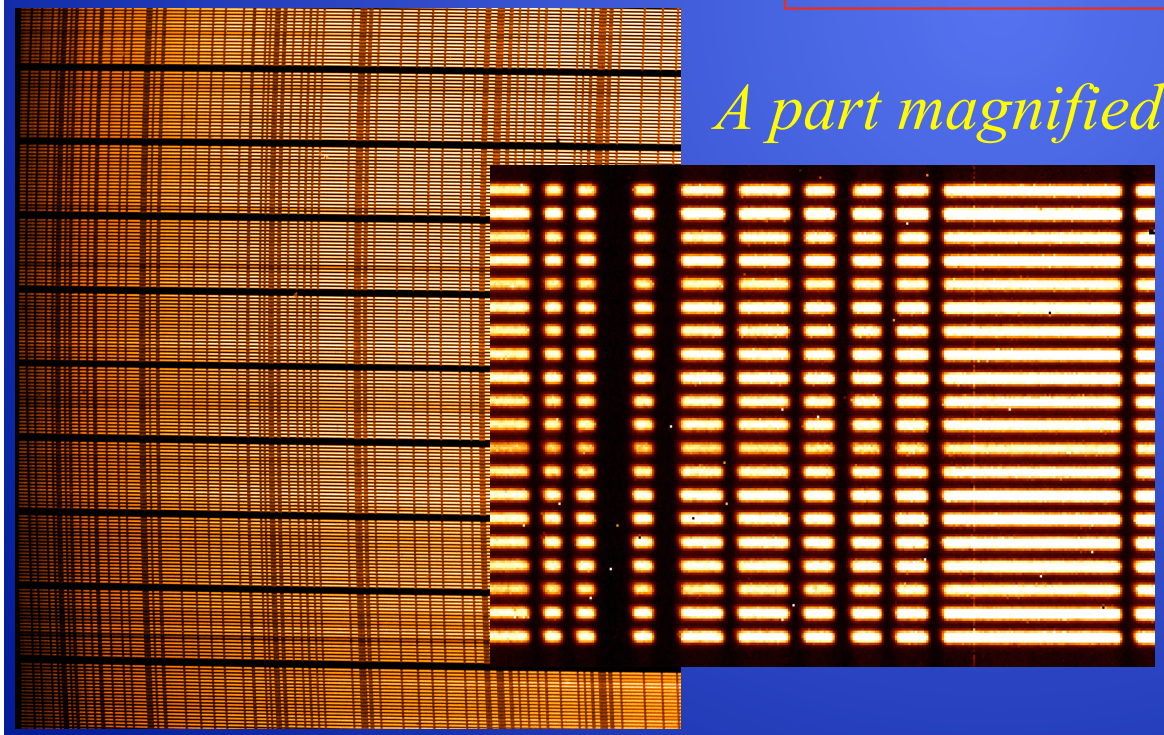
FWHM = 4 - 5 pix
at ~ -55 deg of T(IRS)
as designed.



Ar lines images

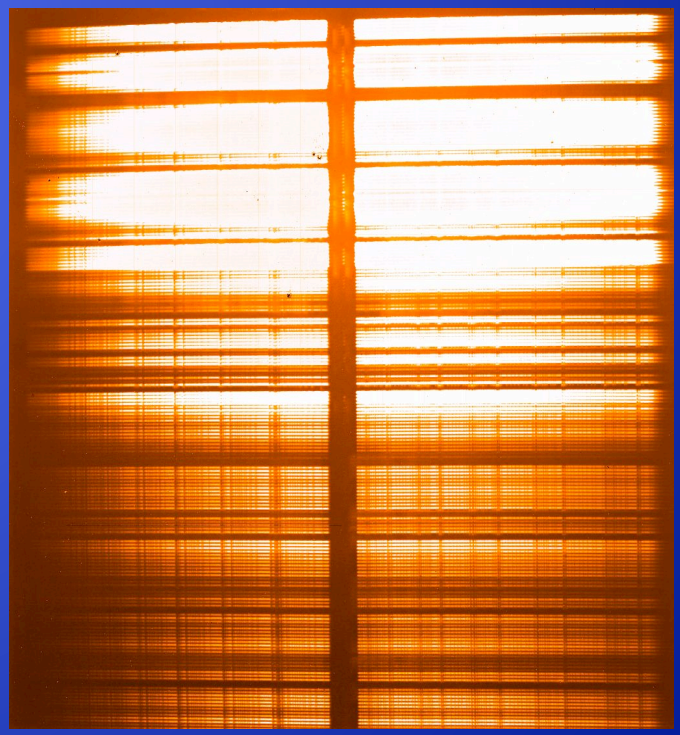
Halogen lamp spectra

High Res. mode



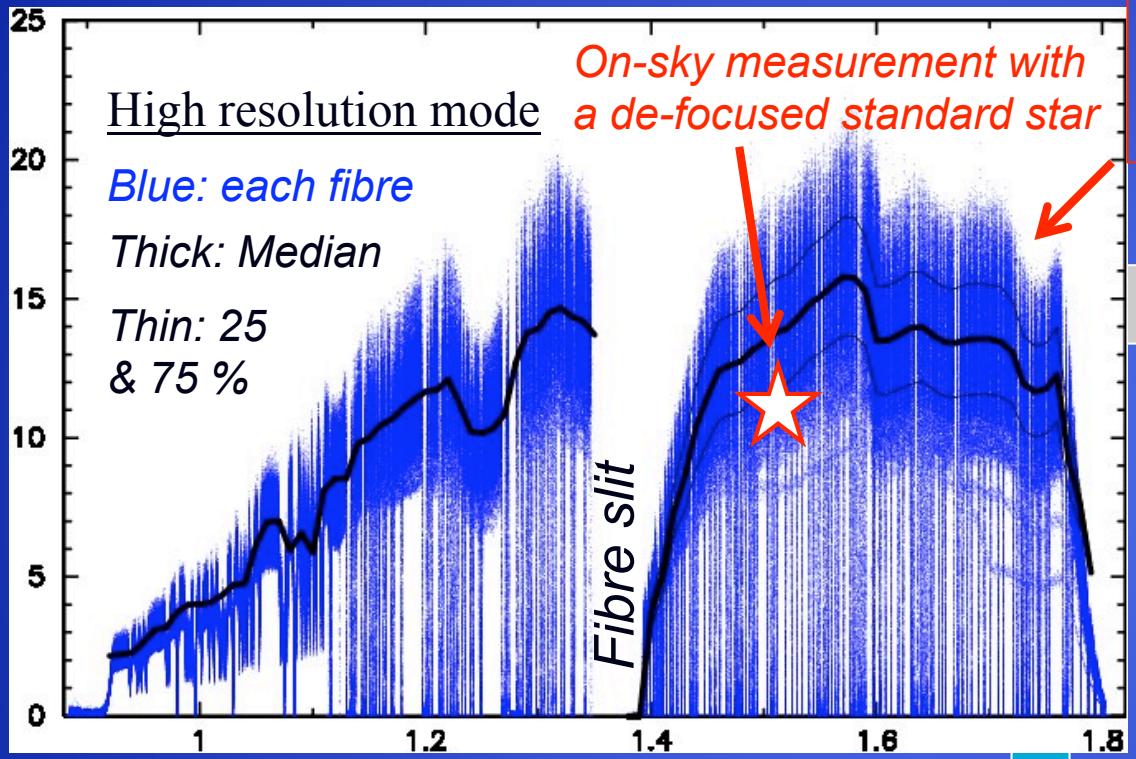
A part magnified …

Low Res. mode

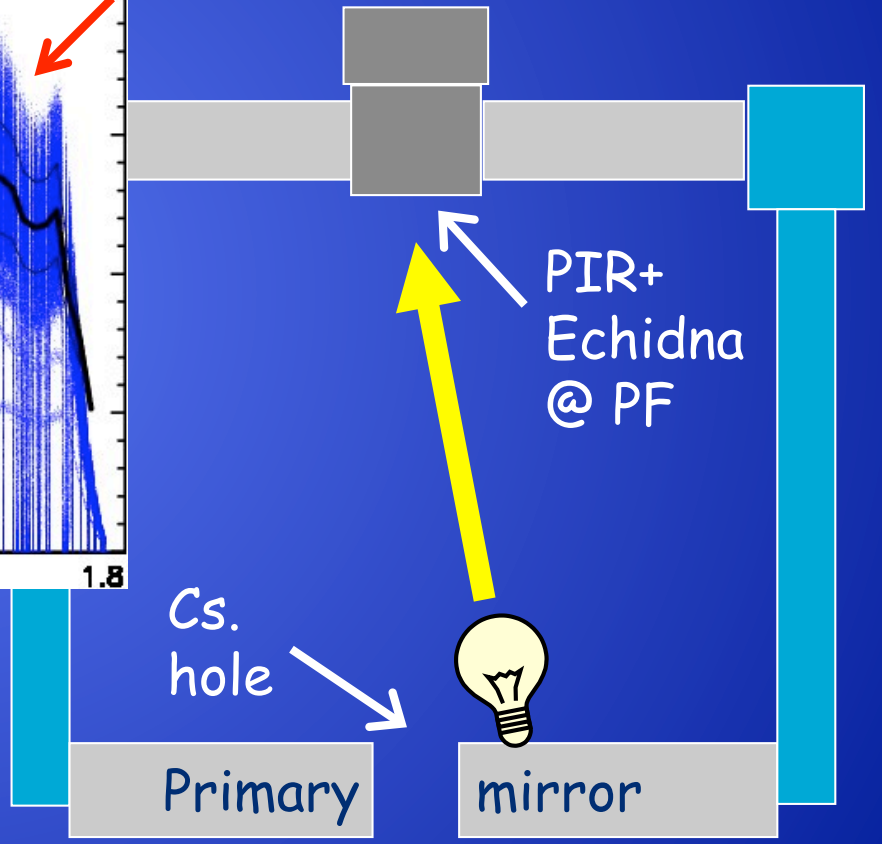


System throughput measurement

Using a black-body radiation source



Low at ~0.9, 1.4, & 1.8 μm.
Fibre-to-fibre variation:
a factor of ~1.2 around med.



(PF corrector + Echidna
+ fibre + fibre connector
+ IRS + Cam + detector)
x 0.9 (Primary mirror)

System throughput measurement

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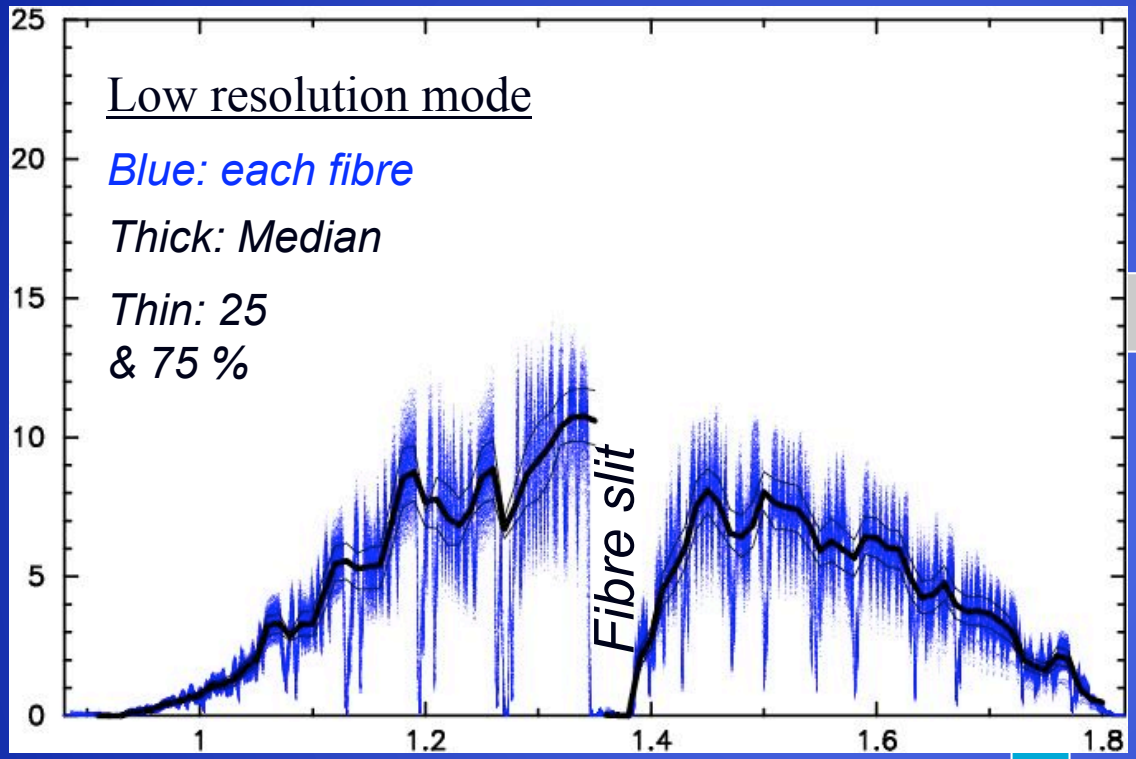
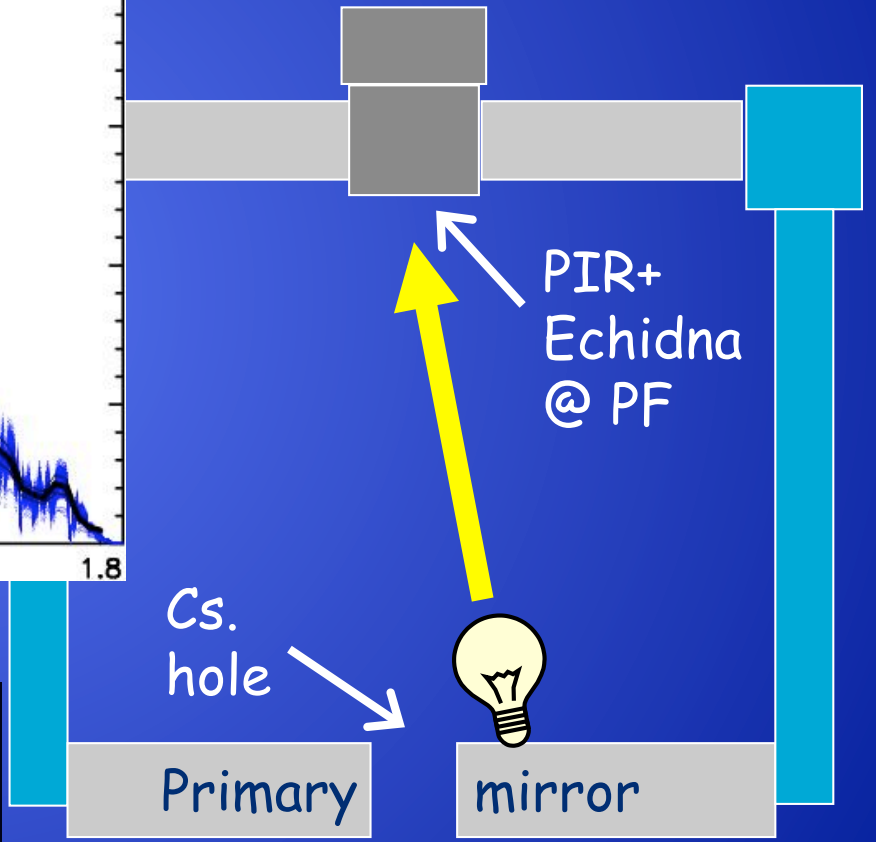


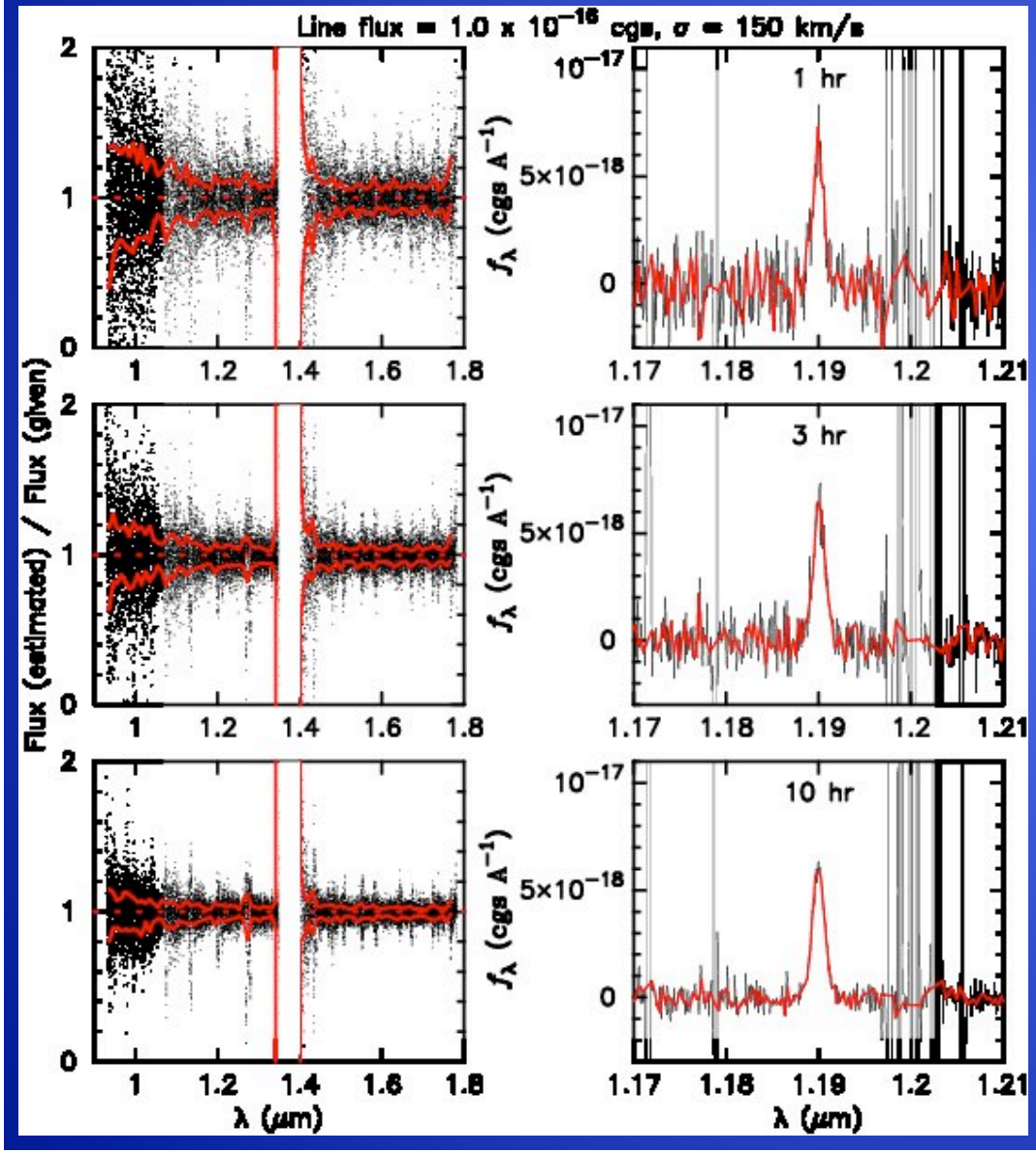
Note: Throughput is lower than HR because the VPH grating is inserted.



(PF corrector + Echidna + fibre
+ fibre connector + IRS *(w/ VPH)*
+ Cam + detector)
x 0.9 (Primary mirror)

Feasibility estimation

Measure the flux of a simulated emission line



Parameters given:

Line flux = 1x10^-16 cgs
Line width: σ=150 km/s
Obs mode: HR
3 cases of integration time:
1hr(top), 3hr(mid),& 10hr(bot)

What's been done:

Simulating an emission line at every angstrom and measure the flux. Repeat this 20 times.

Left panels:

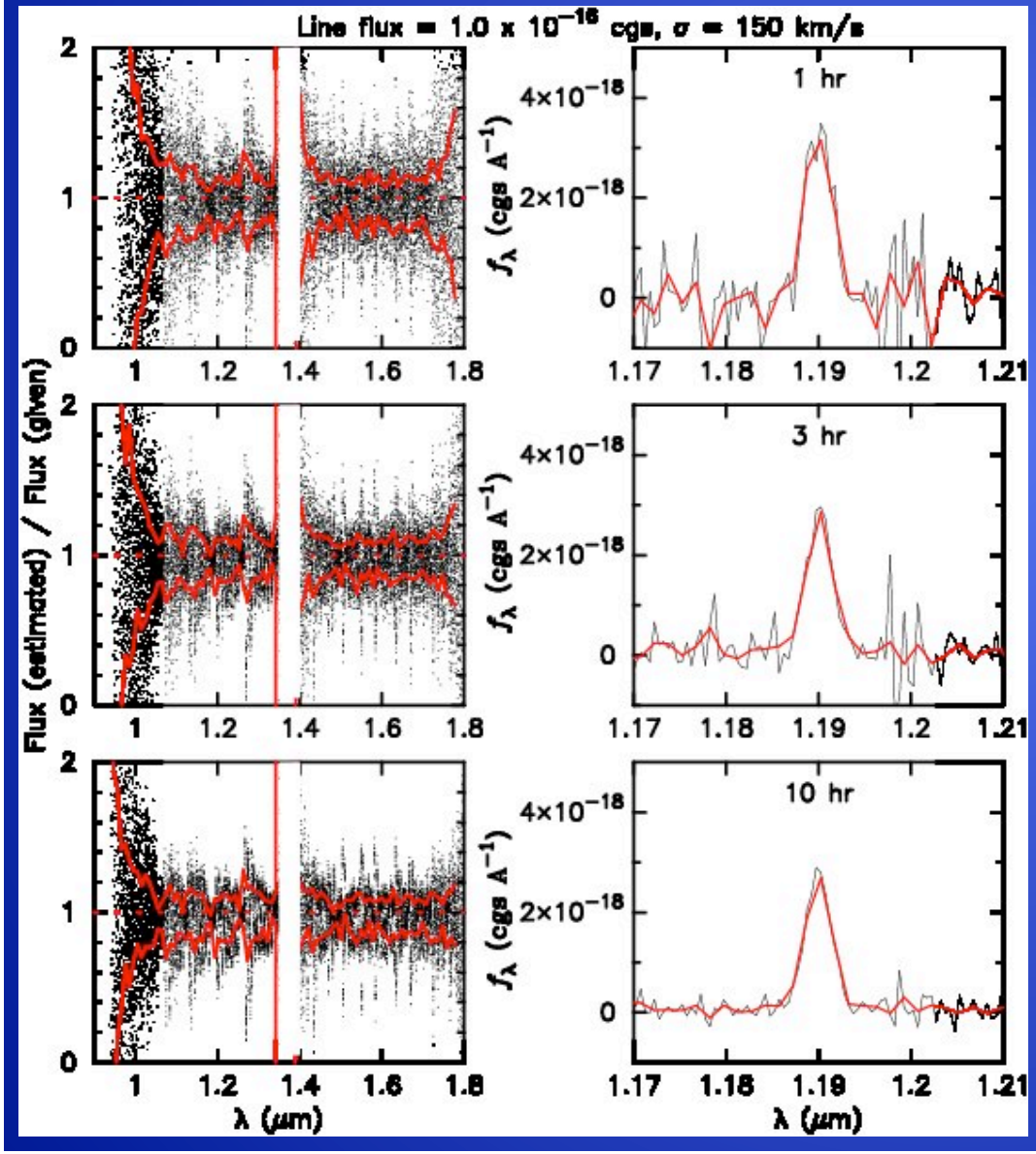
Measured flux vs. λ. Red lines show the 25 & 75 percentiles of the data distribution.

Right panels:

Examples of simulated lines.

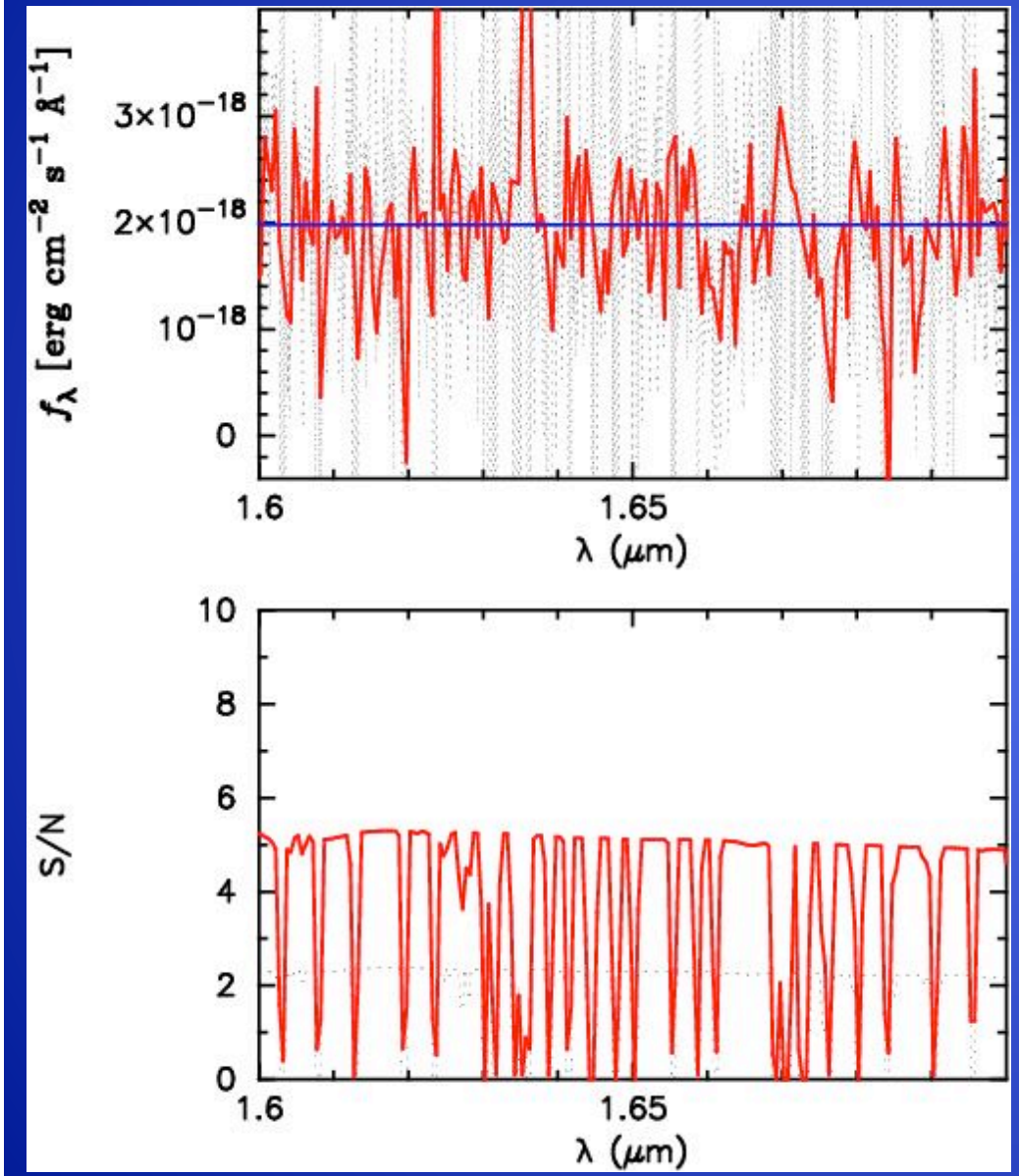
Feasibility estimation

Measure the flux of a simulated emission line



Same as the last slide, but for LR mode.

Feasibility estimation



Simulation for continuum emission

← E.g. J band, HR

Red solid (black dotted) line after (before) 5pix binning, respectively.

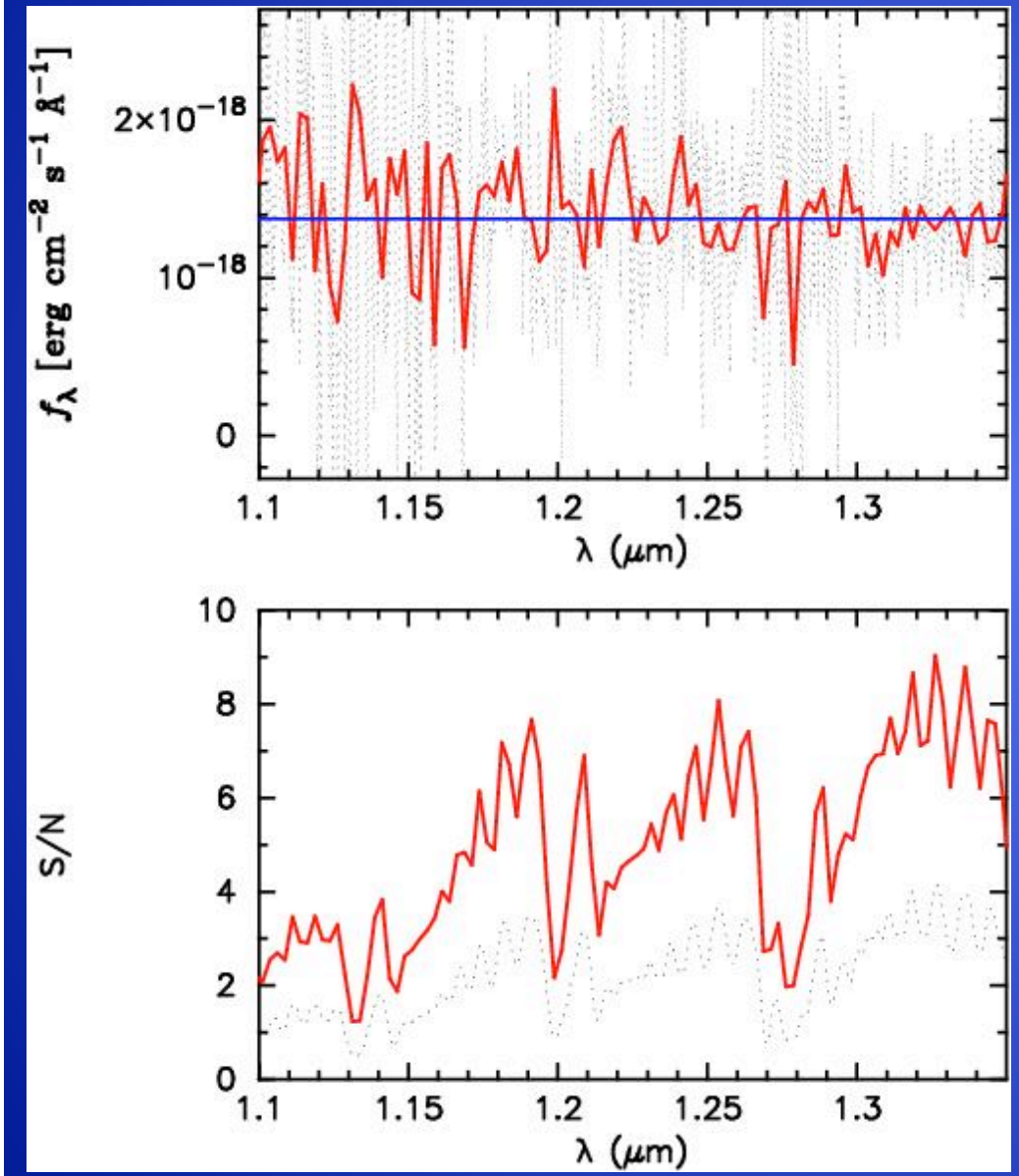
Magnitudes giving S/N = 5 with 1 hour exposure, per $\Delta\lambda$ (~5 pix):

HR mode: J=20.3, H=19.4

LR mode: J=20.9, H=19.8

(Zeropoint is Vega)

Feasibility estimation



Simulation for continuum emission

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Magnitudes giving S/N = 5 with 1 hour exposure, per $\Delta\lambda$ (~5 pix):

HR mode: J=20.3, H=19.4

LR mode: J=20.9, H=19.8

(Zeropoint is Vega)

Summary of FMOS status

✓ *Echidna & PIR are fully operational.*

Fibre positioning accuracy is ~0".2 in RMS by ~13 mins.

(Need to confirm performance of tweak more quantitatively)

✓ *Some remaining issues on the spectrographs.*

- (Both) Confirm the instrument background level.
- (Both) Mask alignment to actual OH lines.
- (IRS1) Small shift of spectrum positions on the detector from one exposure to another due to deflection of the floor. A new platform will be installed to resolve this.
- (IRS1) Stabilize the detector focus mechanism.
- (IRS2) Optimise and characterise the detector readout system.
- (IRS2) Stabilize HR ↔ LR at -55 deg.

✓ *Performance estimation*

F(line) = 0.5 – 1.0 x 10^-16 cgs for a few hours integration?

1 hour, 5 pix binned, S/N=5: J=20.5-21, H=19.5-20 (Vega)

Tentative schedule of FMOS

2009.07 IRS1 new platform installation & test stability

2009.08 Announcement of call for proposal in S10A

2009.08-09

IRS1 & IRS2 fine alignment of optics
IRS1 detector stage work
IRS2 detector readout system work

(2009.09 Proposing a pilot survey program?)

2009.10 Engineering observation

2009.12 Engineering observation

2010.02 Start open use S10A (with a shared-risk mode) [TBD]