Commissioning status of Subaru/FMOS

~ Last (but long) spurt towards the opening!? ~

Naoyuki Tamura

Instrument scientist
Subaru Telescope, NAOJ

Fibre Multi Object Spectrograph

★ *400 fibres on the prime focus (= 30 arcmin ϕ FoV)*

- *Each fibre (100 μm core) subtends 1".2ϕ on the sky.*
- *~13 minutes for fibre configuration (~15 μm/0".12 accuracy)*

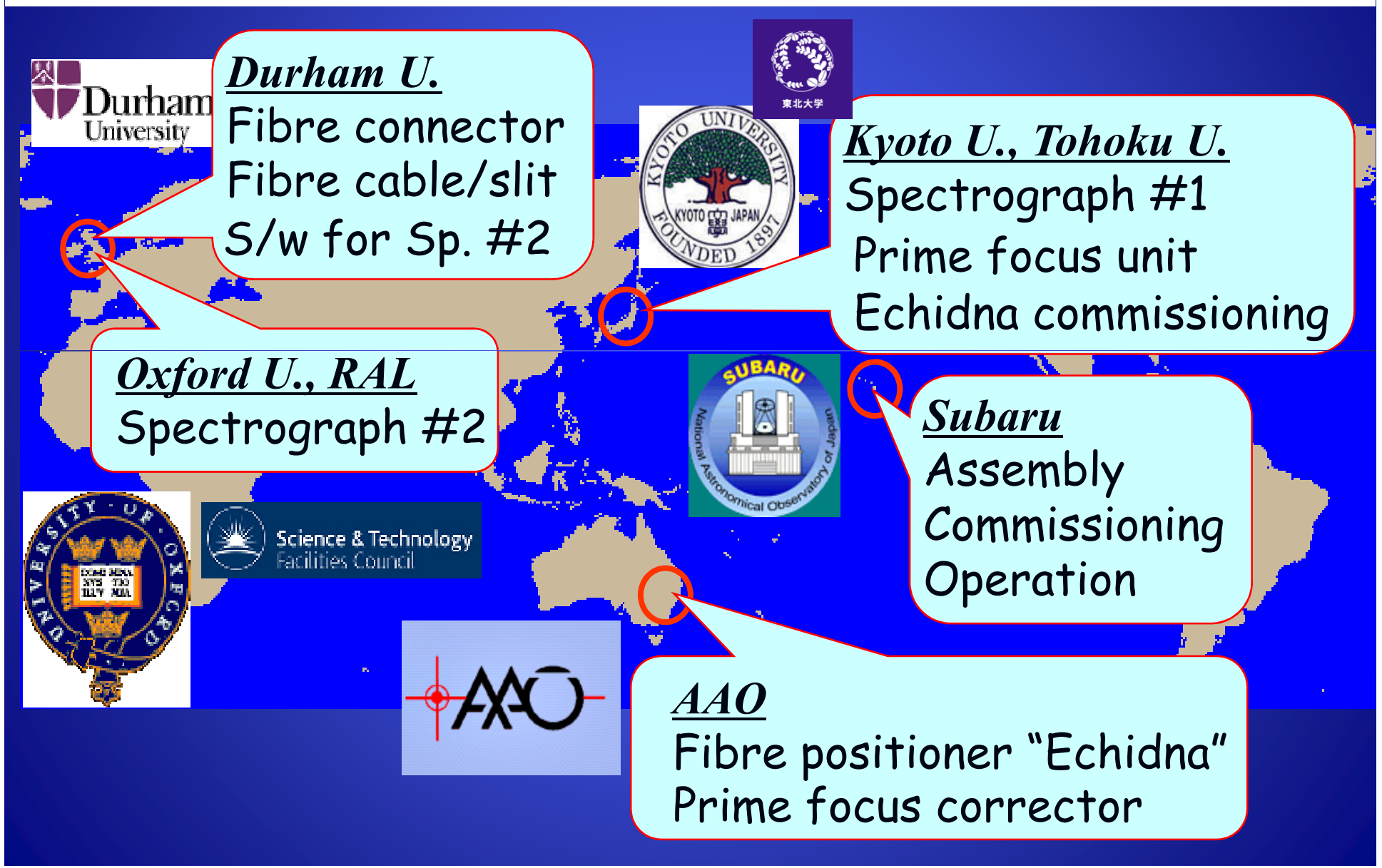
★ *NIR spectroscopy: 0.9 - 1.8 μm*

- *2 spectrographs (200 spectra x 2) operated at T ~ – 55 deg.*
- *OH airglow Suppression (OHS) with a mask mirror.*

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

- *Low R: 0.9 - 1.8 μm is observed at one exposure with R~500.*
- *High R: Any ~ 0.2 μm region is observed with R ~ 2200.*

International collaboration to FMOS



JPN:

M. Akiyama, S. Eto, M. Iino, S. Imai, F. Iwamuro, H. Karoji,
M. Kimura, T. Maihara, D. Mochida, Y. Moritani, Y. Nakajima,
Y. Narita, J. Noumaru, K. Ohta, H. Ohtani, M. Sakai, Suzuki,

Too many to list all here!
All contributions are really appreciated though!!

Here are only some of the "survivors" ...

J. Allington-Smith, C. Baird, C. Blackburn, A. Boksenberg,
D. Bonfield, B. Brooks, N. Cavan, R. Content, E. Curtis-Lake,
G. Dalton, R. Davies, N. Dipper, G. Dodsworth, A. Dowell,
R. Edeson, R. Ellis, T. Froud, D. Gedge, C. Goodwin, S. Hayes,
A. Holmes, I. Hanshin, D. Ives, I. Lewis, P. Luke, R. Makin,
T. Mauch, G. Murray, I. Parry, M. Patel, P. Pattinson, D. Ren,
D. Robertson, R. Sharples, I. Tosh, M. Wallner, G. Woodhouse

JPN F. Iwamuro, K. Ohta, T. Maihara (Kyoto)
M. Akiyama (Tohoku)
N. Takato, M. Kimura, P. Tait, N. Tamura (Subaru)

UK G. Dalton, I. Lewis (Oxford), I. Tosh (RAL),
G. Murray (Durham)

AU:

AU P. Gillingham, S. Smedley, T. Farrell, M. Birchall,
J. Brzeski, R. Muller (AAO)

C. Arridge, S. Barden, M. Birchall, J. Brzeski, M. Colless,
D. Correll, S. Croom, J. Dawson, T. Farrell, M. Francis, G. Frost,
P. Gillingham, J. Griesbach, R. Haynes, D. Horiuchi, D Jones, U

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

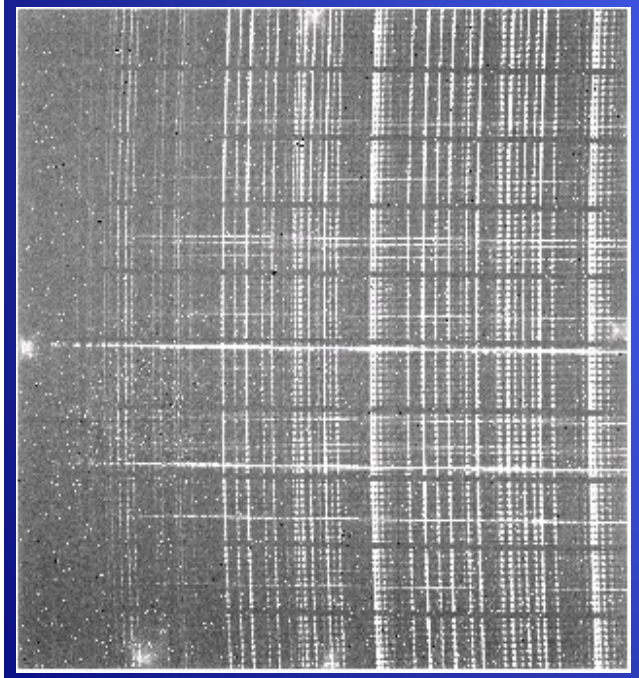
2009.03, 05
In a *Performance verification (PV)* phase

Engineering First Light @May 14, 2008

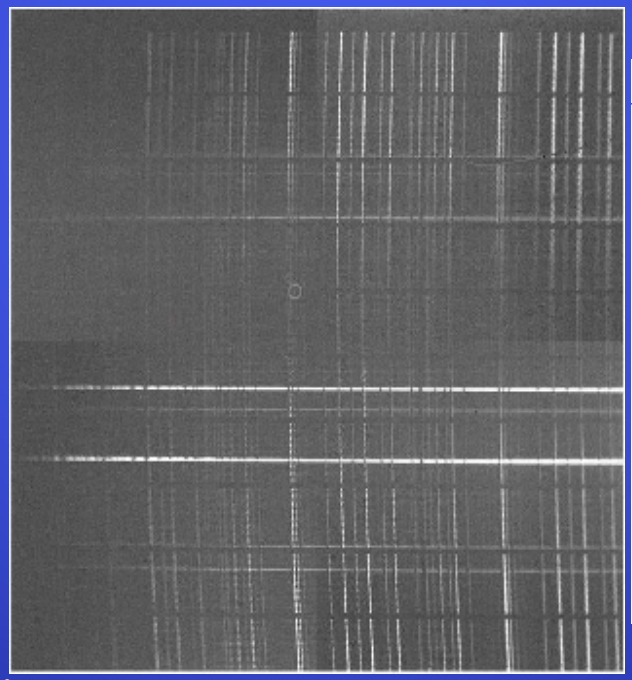
Target: 48 bright stars (V < 15) in Mel 111 (Galactic open cluster)
→ 33 stars were immediately visible after 1 min exposure!!

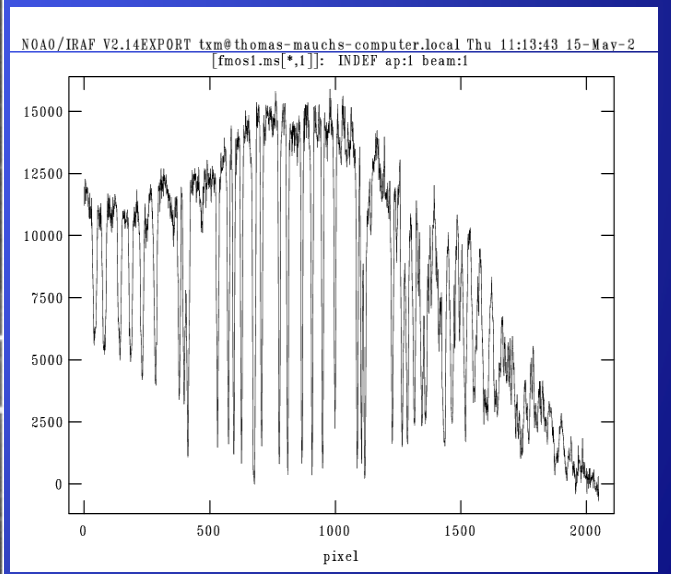
Note(1): Current fibre positioning accuracy is ~ 0".4 in rms (Goal: ~ 0".2)
Note(2): The OH masks are not well aligned with the actual OH lines.

IRS1 (25 stars)



IRS2 (8 stars)





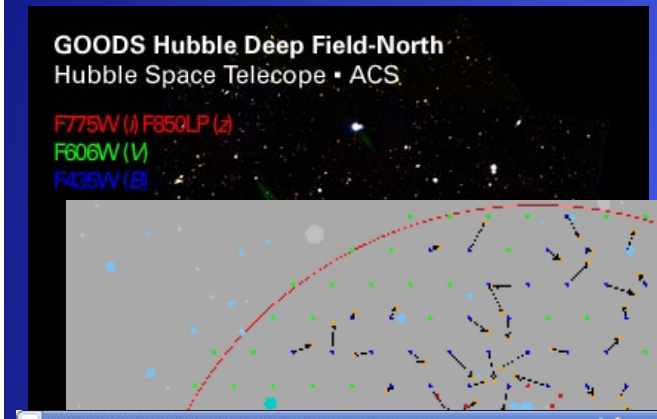
λ

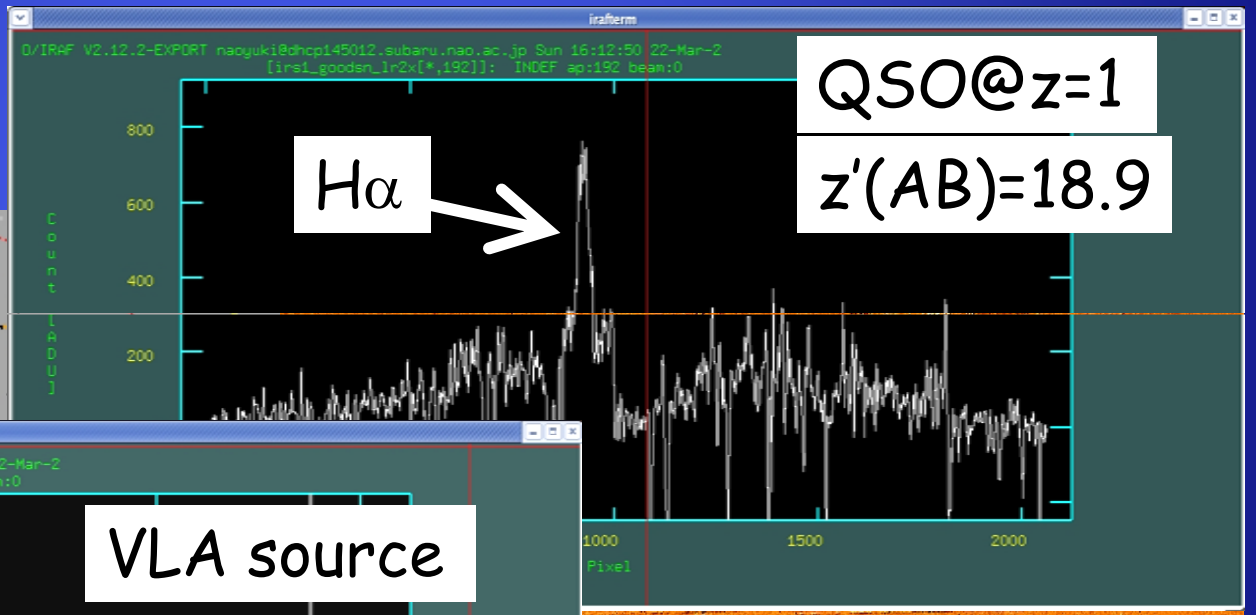
HR mode, J long (1.1-1.3 μm), 1 min exp.

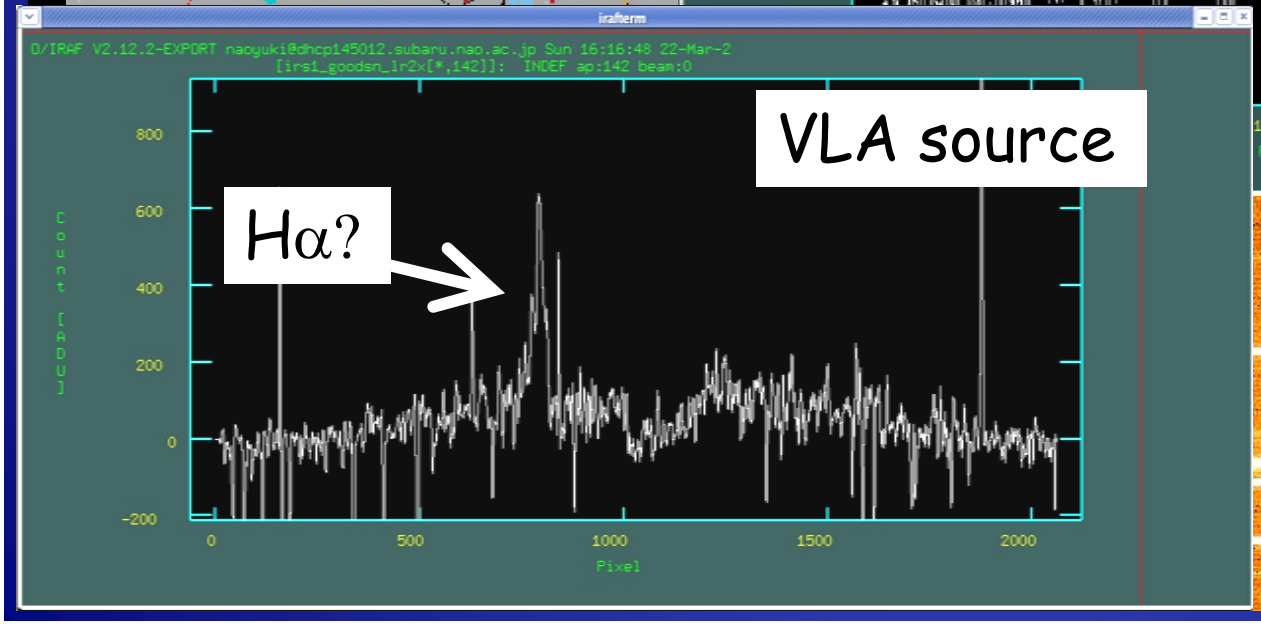
"PV" First Light @Mar 12, 2009

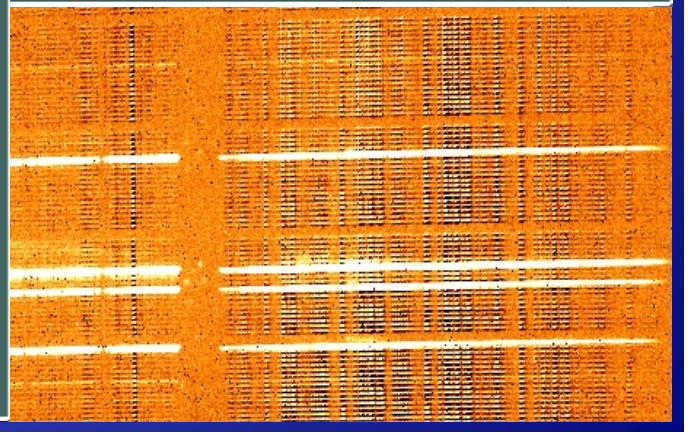
Long exposure of fainter objects with auto guiding

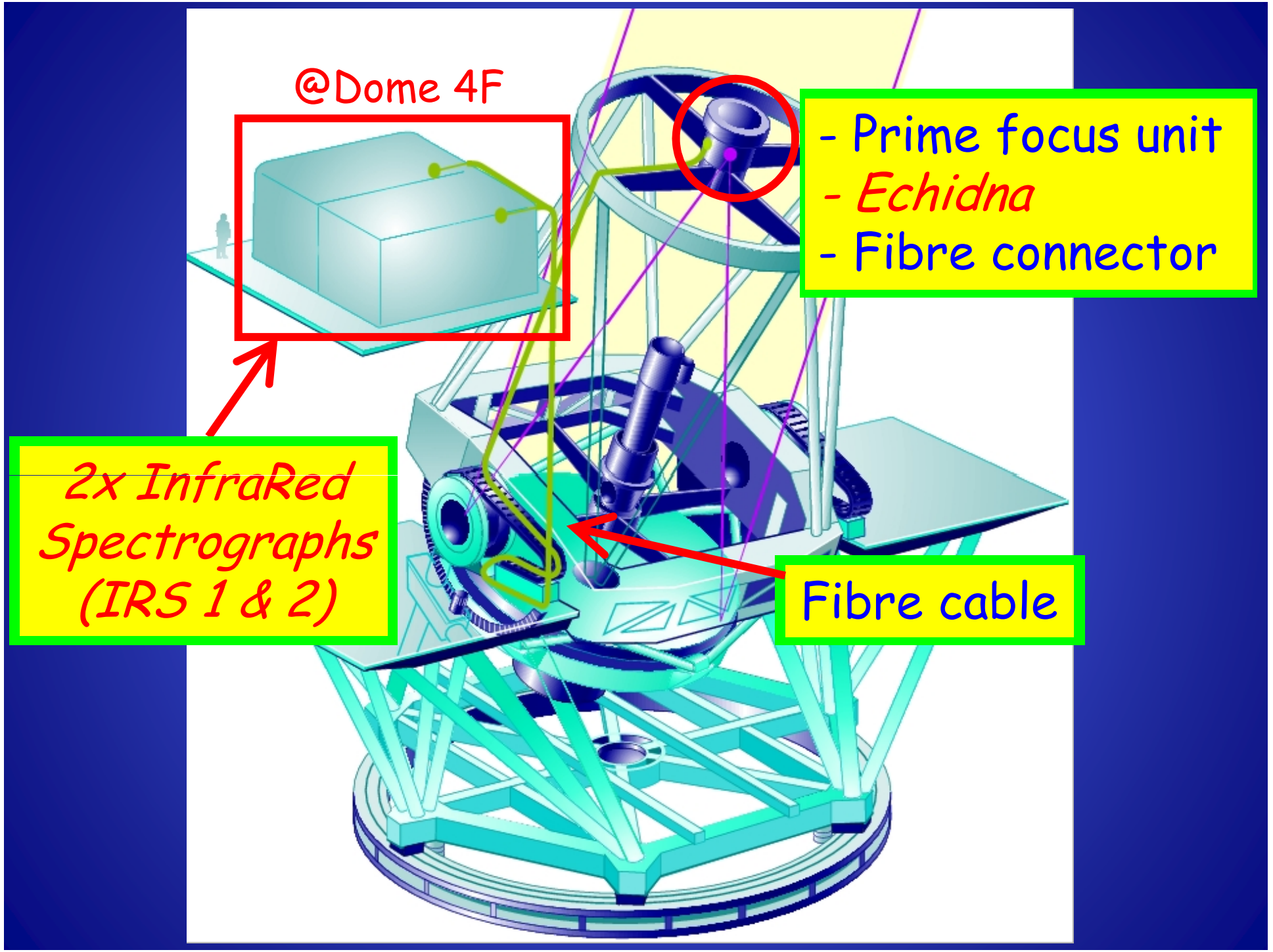
GOODS-N field, Low Res, 15 min "on" minus "off"







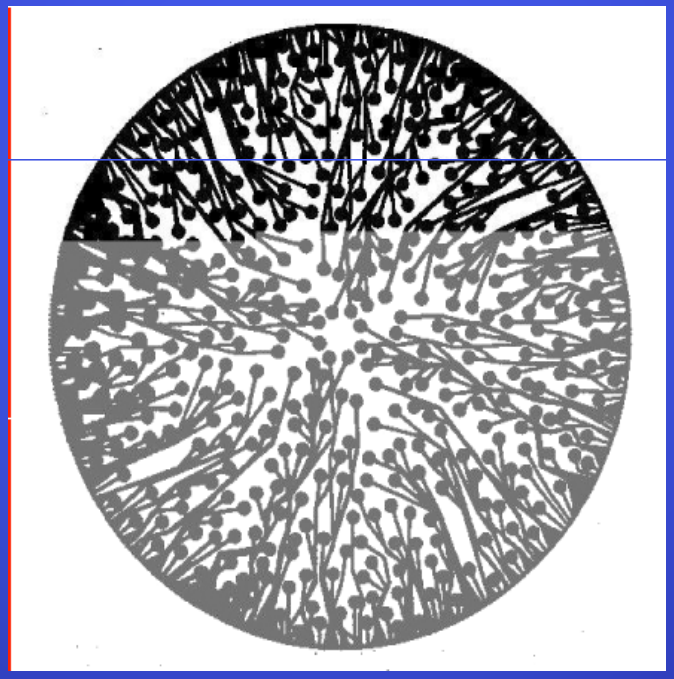



@Dome 4F
- Prime focus unit
- Echidna
- Fibre connector
2x InfraRed Spectrographs (IRS 1 & 2)
Fibre cable

It started more than a decade ago.
(And it's still in progress!)

- If many magnetic buttons with fibres (like 2dF) were used on the prime focus of Subaru, it would be something like:

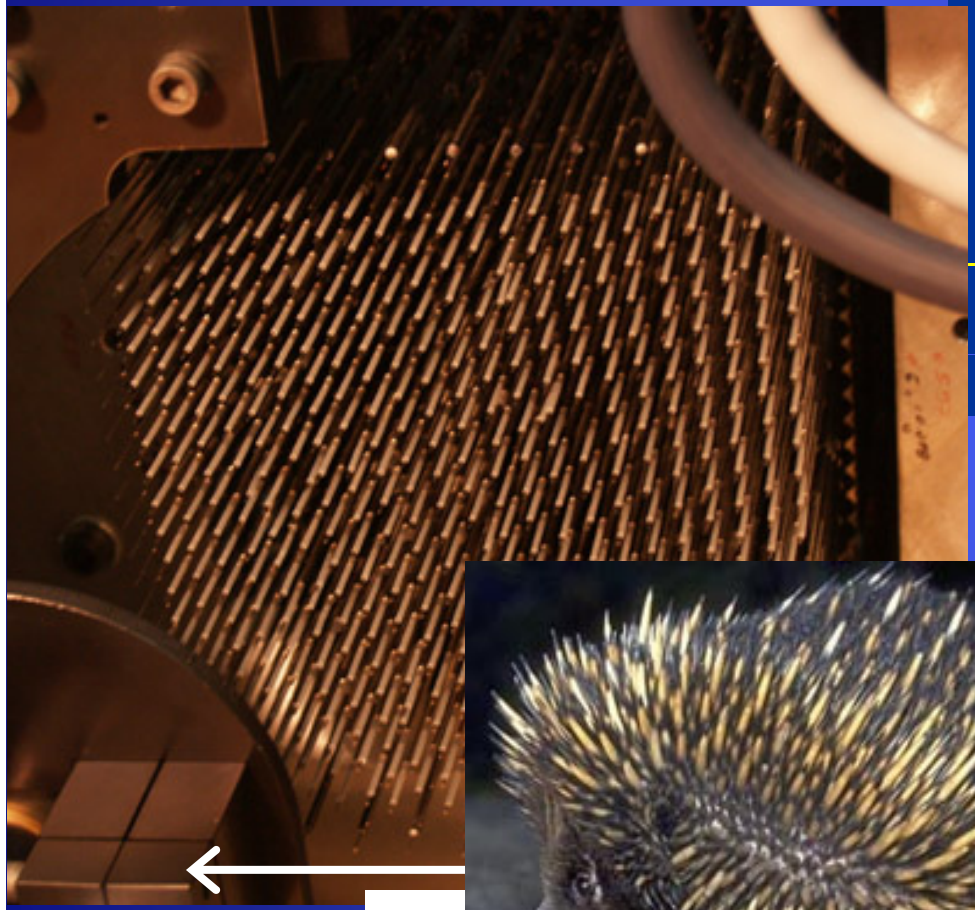
150 mm
~ 30 arcmin



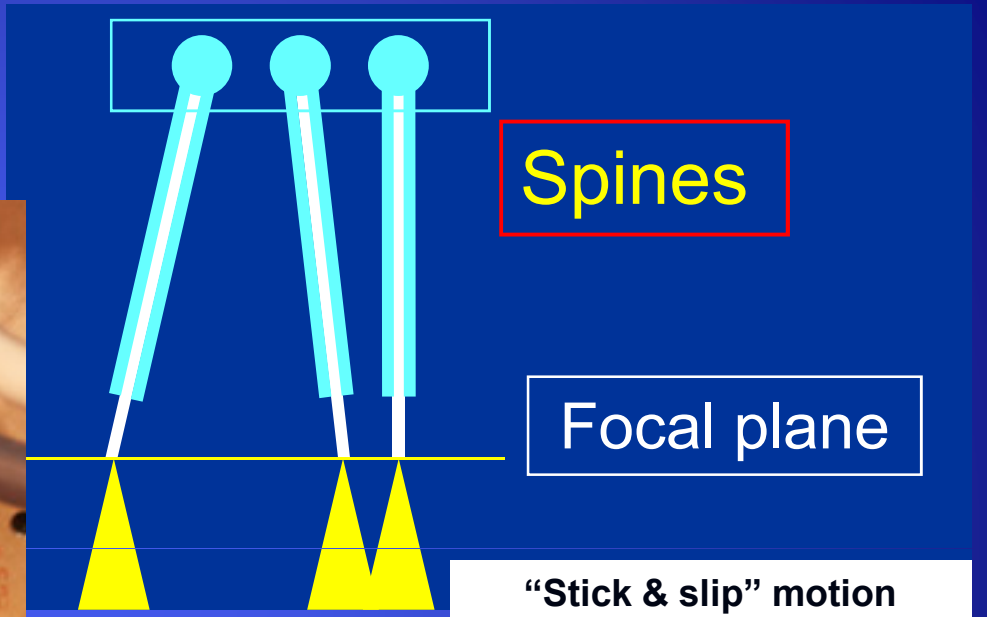
A different method is necessary to position fibres …

Fiber positioner "*Echidna*"

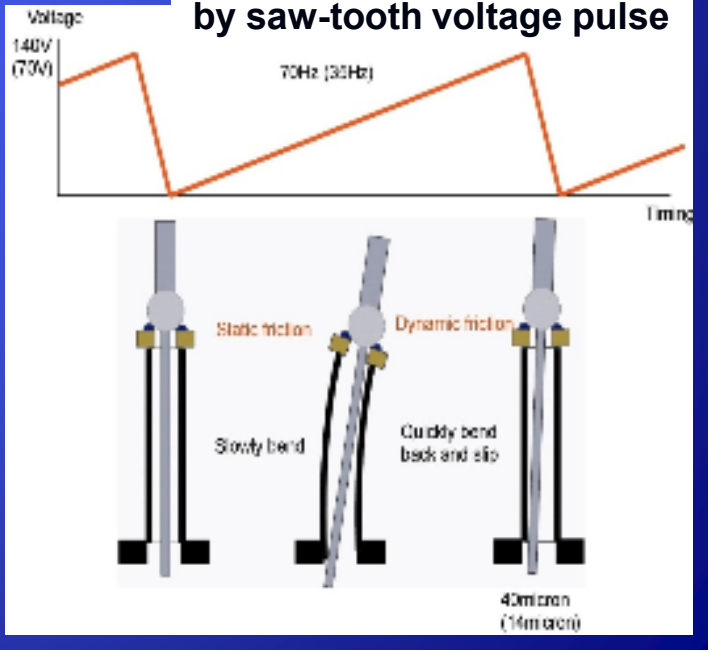
400 fibers
in the 30′ϕ FoV



~ 1

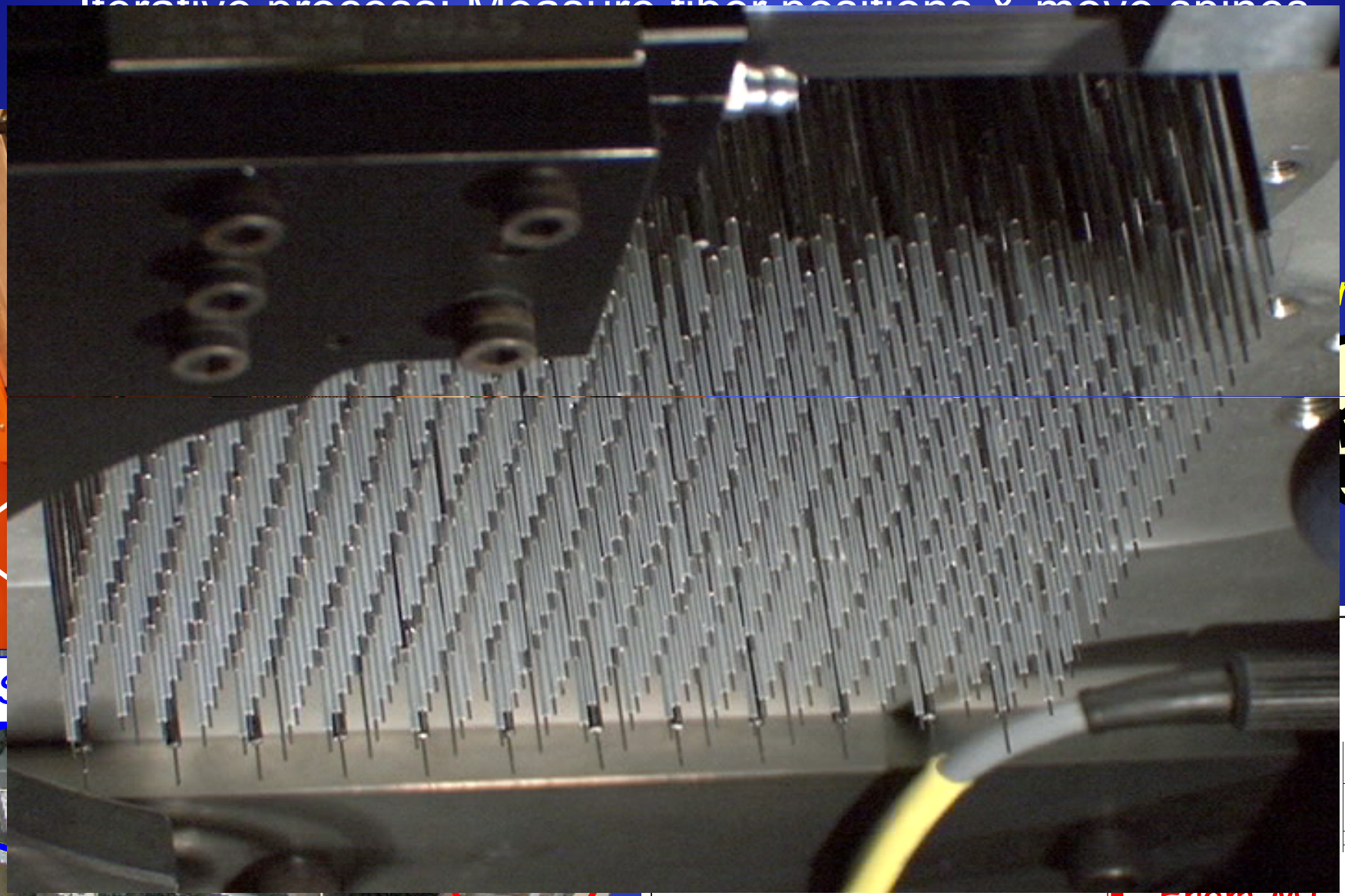


"Stick & slip" motion by saw-tooth voltage pulse



Fiber positioning

Iterative process: Measure fiber positions & move spines

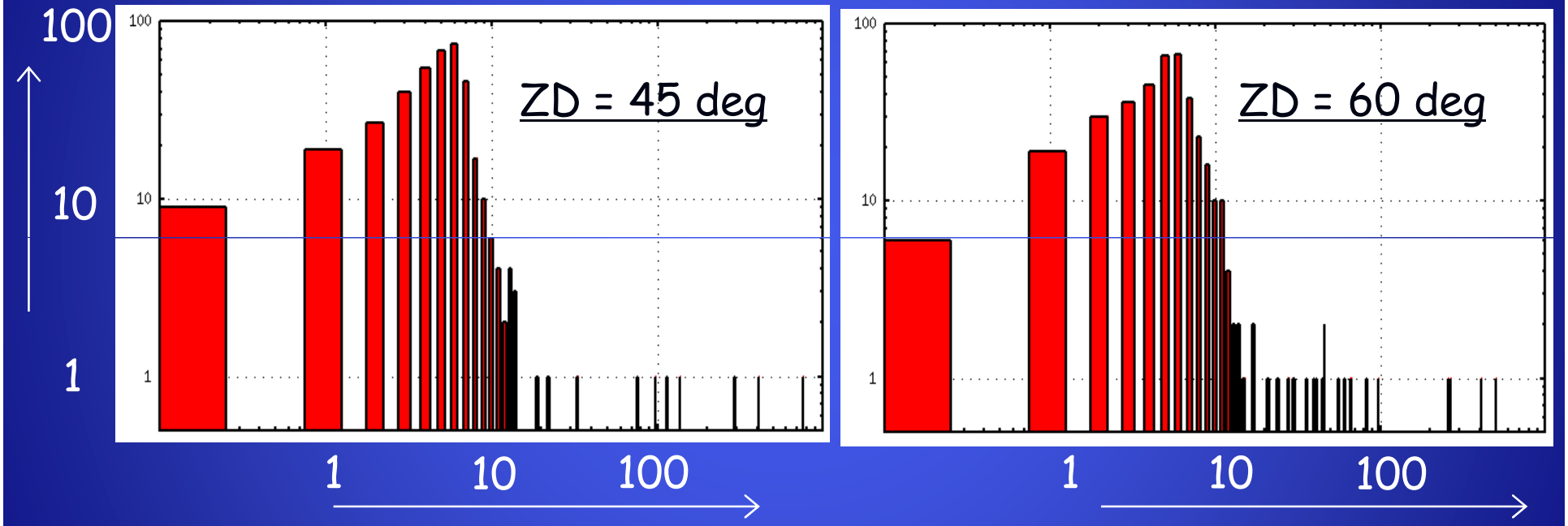


From MI

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

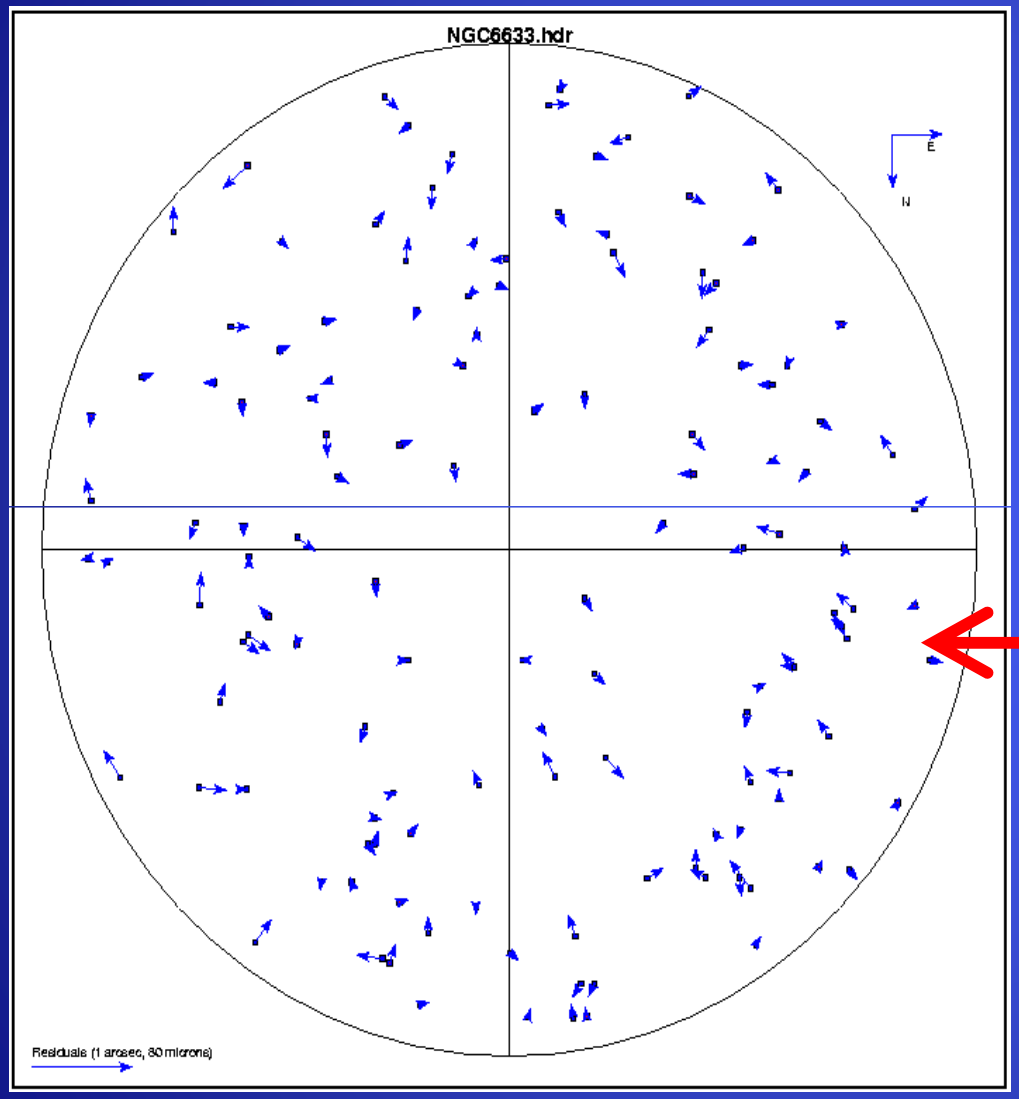
Number of spines

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

$(\alpha, \delta) \rightarrow (x, y)$

Model

Error

Echidna spine

RMS ~ 0".15

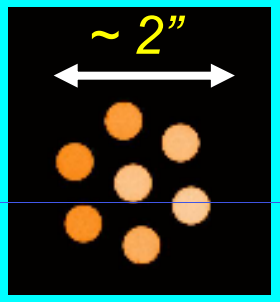
was achieved in Oct 2008.

Fibre Auto Guiding (AG)

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

400 science fibres populated within this 30' diameter FoV

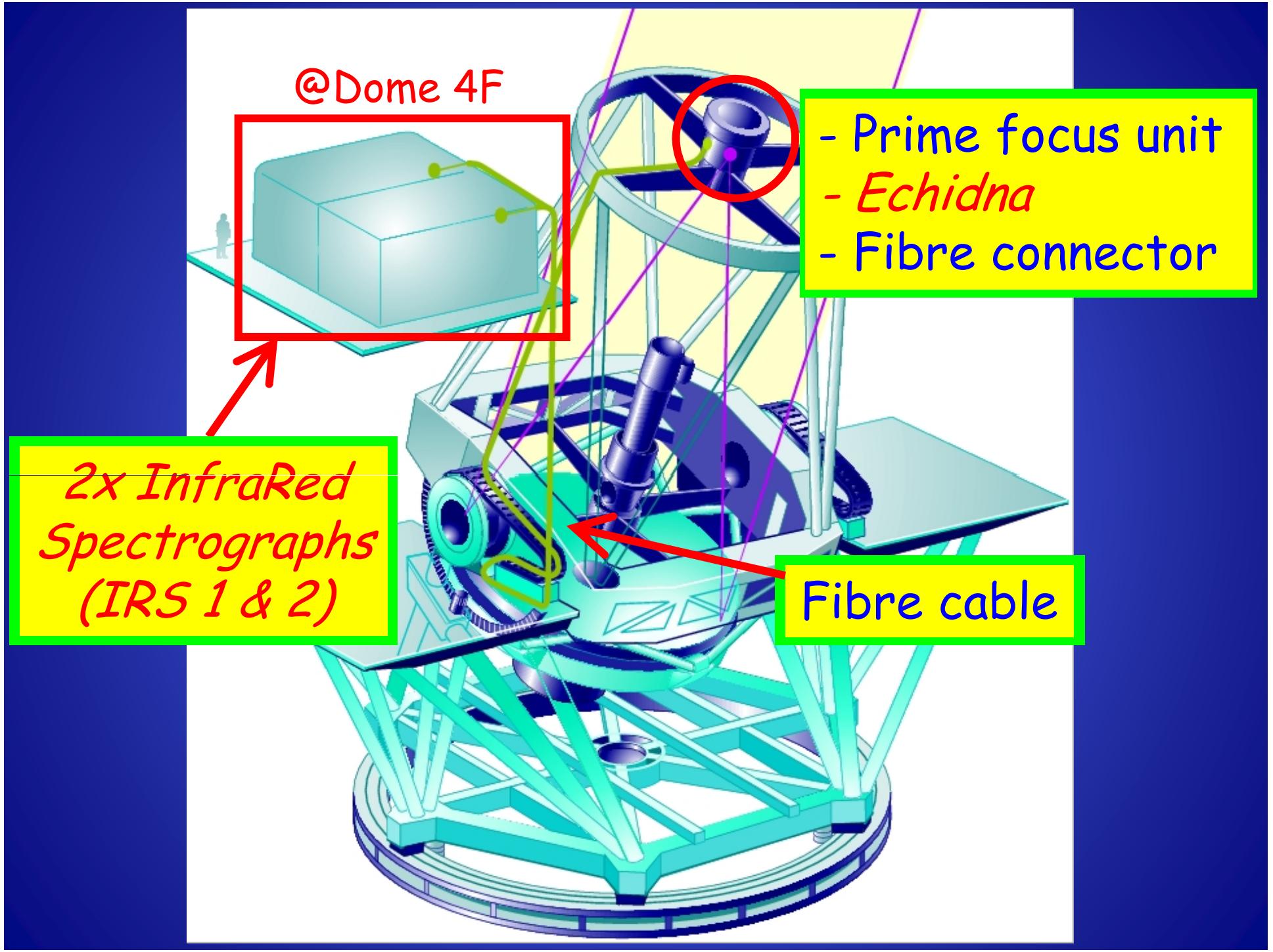
14 fibre bundles for AG (7 at one side)



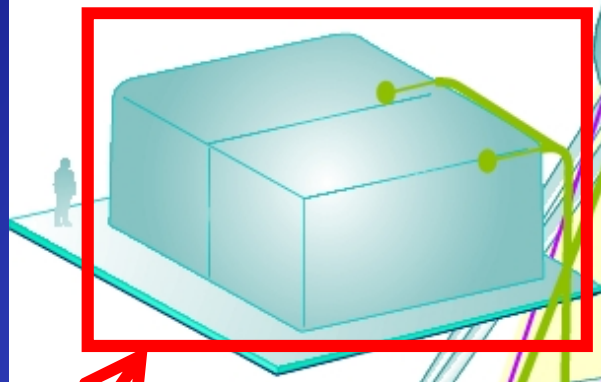
7 fibres consist of a guide fibre bundle.

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

Snapshots of guide stars on guide fibre bundles


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

@Dome 4F



- Prime focus unit

PIR

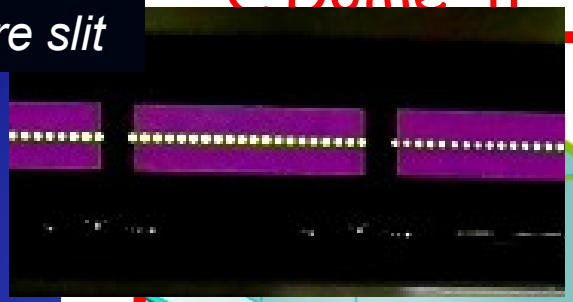
Wide field corrector lenses

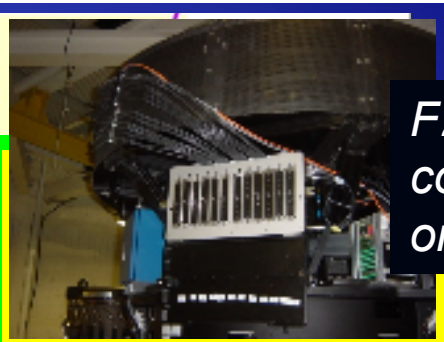
2x InfraRed Spectrographs (IRS 1 & 2)

PIR on TUE

@Dome 4F

Fibre slit





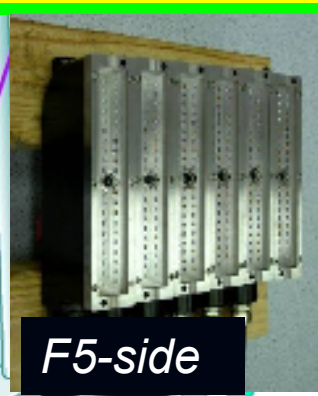
F2-side connectors on PIR

- Fibre connector

2x Infr
Spectrog
(IRS 1

Fibre cable installation

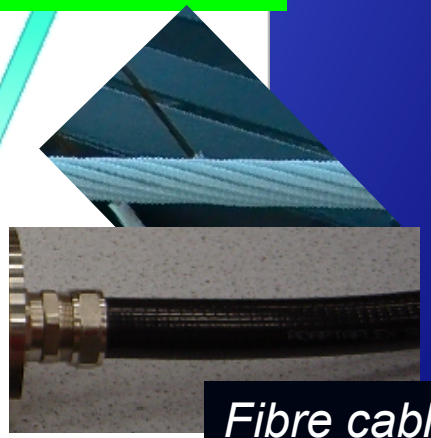
Fibre cable in process



F5-side

F2-side

Fibre cable



Fibre cable

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*

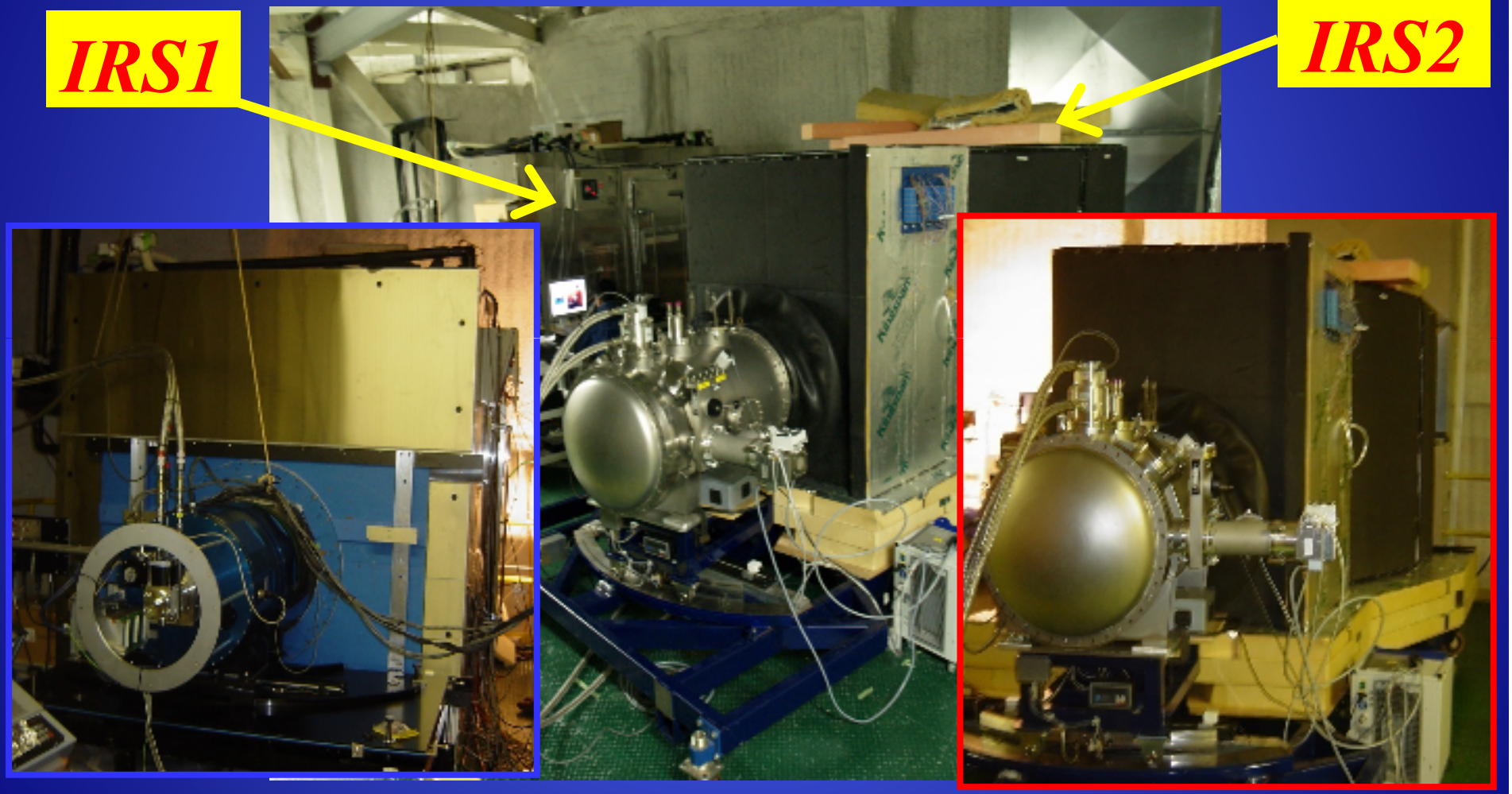
★ *OH airglow suppression with a mask mirror*

★ *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.

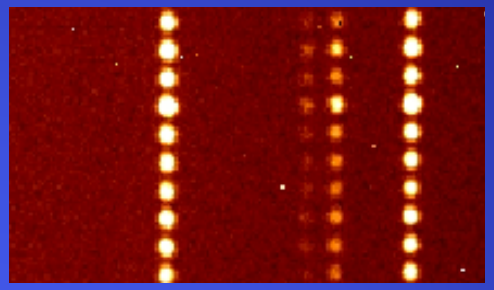
Two optically identical IRSs in the Subaru dome



~ 2.5m x 2.5m x 5m

IRS optical alignment

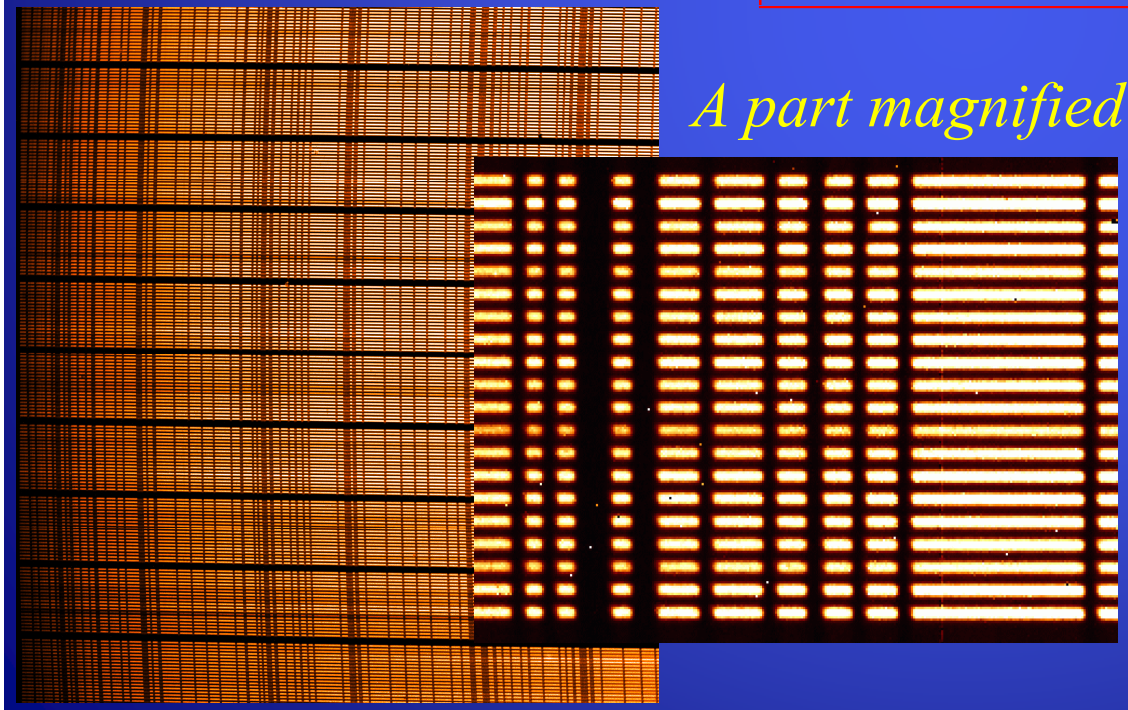
FWHM = 4 - 5 pix
at ~ -55 deg of T(IRS)
as designed.



Ar lines images

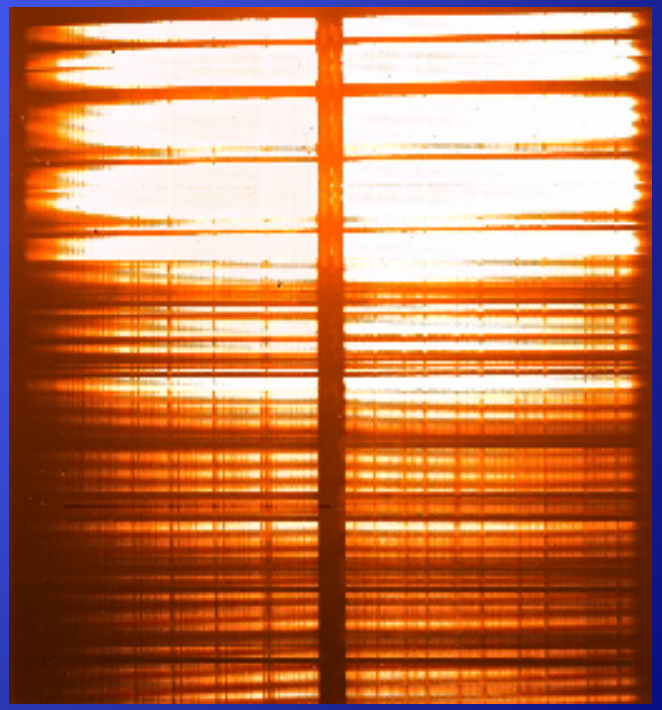
Halogen lamp spectra

High Res. mode



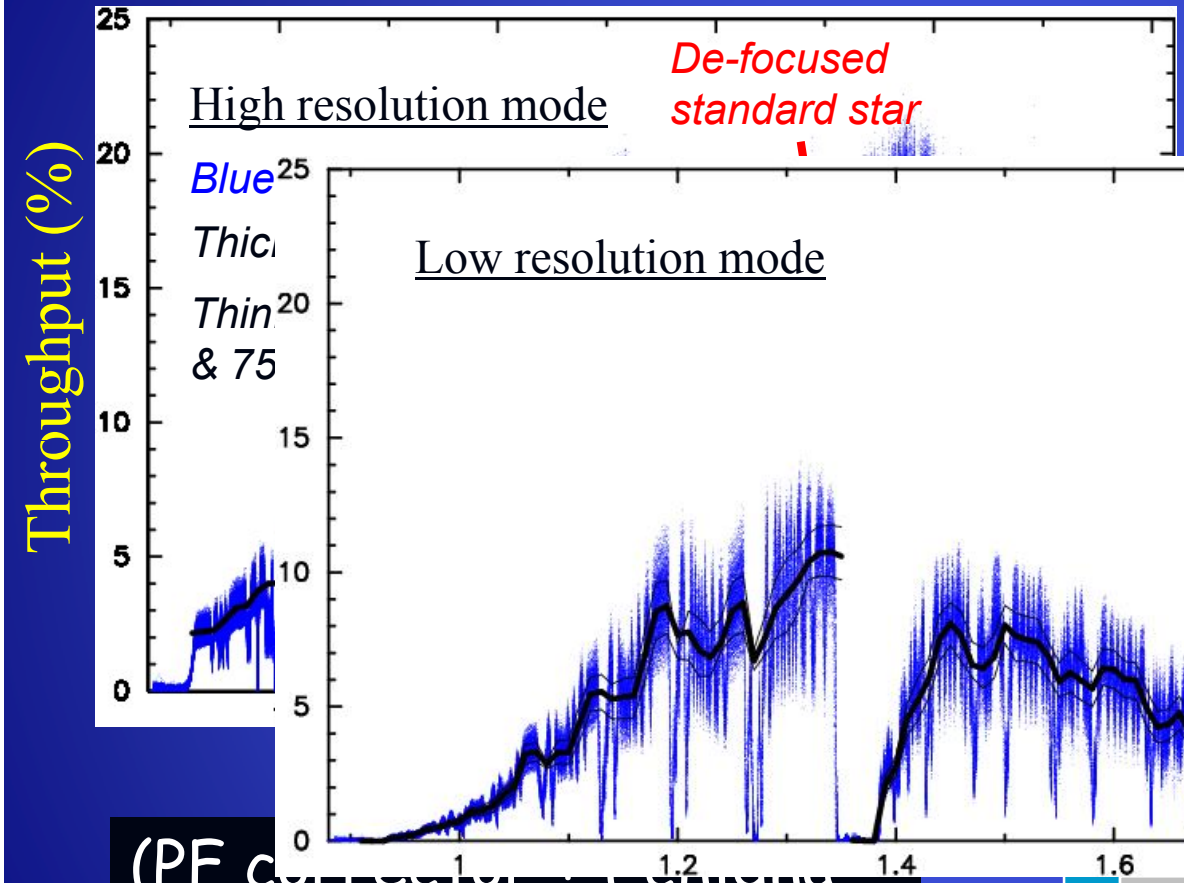
A part magnified ...

Low Res. mode

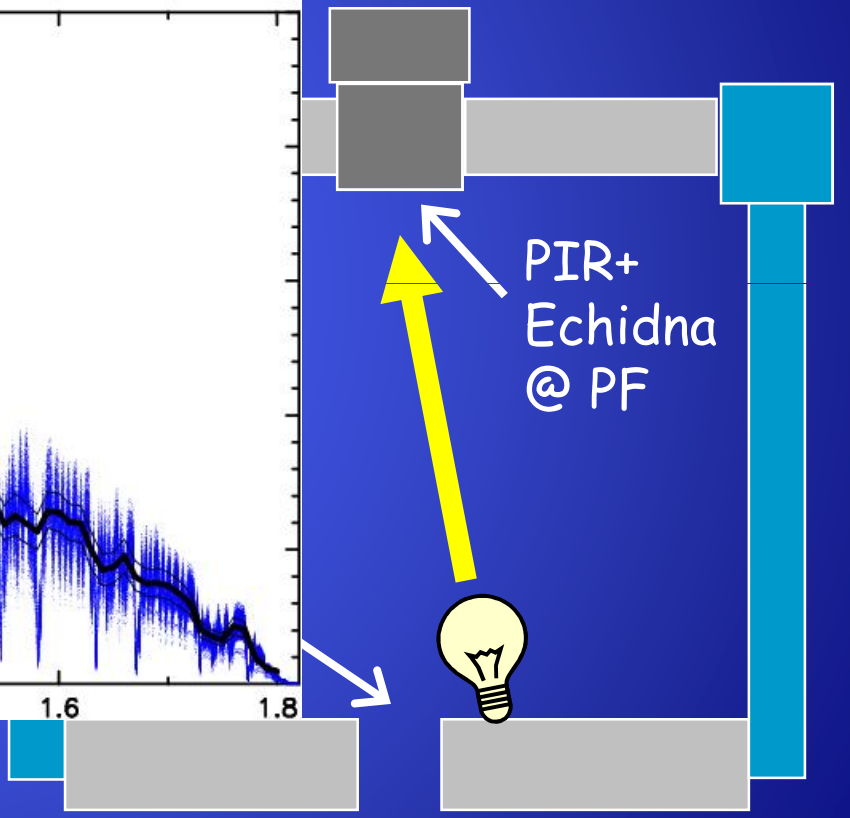


System throughput measurement

Using a black-body radiation source



- ~20% fibre-to-fibre variation
- Low at ~0.9, 1.4, & 1.8 μm.



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

Strengths of FMOS

High multiplicity (max ~400 fibres)

Wide FoV (30 arcmin diameter)

Wide spectral coverage of (z)YJH

- Good statistics even for rare objects.
  (e.g., massive galaxies, AGNs, galaxy clusters, post-starbursts, …)
- Allow to sample targets in a less biased manner.
- Allow to aceess to various galaxy environments.
- Access to rest-frame optical spectral features for objects at $z > 1$.

Desiging large survey program(s)

Discussions are in progress for GTO+SSP (& IP).

Next: May 23 in Kyoto (JPN), Jun22-23 in Oxford (UK+JPN)

Survey of galaxies and AGN at z > 1

- *An unbiased census of high-z galaxy populations*
- *Coevolution of galaxies and AGN/QSO/SMBH*
- *Cluster survey & environmental effects*
- *Power spectrum, baryonic oscillation, and "w"*

... etc

Local objects are also possible targets.

- *Galactic archaeology*
- *Globular cluster populations in nearby galaxies.*

... etc

Summary (+α: To start open use)

~ Progress & success ~

Engineering observations since Dec 2007

→ Engineering First Light on May 2008

→ Performance verification phase since Mar 2009

Echidna is fully operational.

Fibre positioning accuracy is ~0".2 in RMS.

~ More works are needed on … ~

Spectrographs!!

Background, mask mirror alignment, temporal distotion, readout system …

Operation system (commands & GUI), data reduction software

~ Tentative schedule ~

Two more engineering runs (& lots of daytime works …) in 2009

Open use with a shared risk mode from S10A?

← To be decided before next call for proposal (early Aug)