FMOS & (vs?) PFS

Subaru Fiber Multi-Object
Prime Focus Spectrograph"s"

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1. Overview of FMOS
2. Spectroscopic survey of galaxies
3. Key specs to science & some technical issues
4. Summary

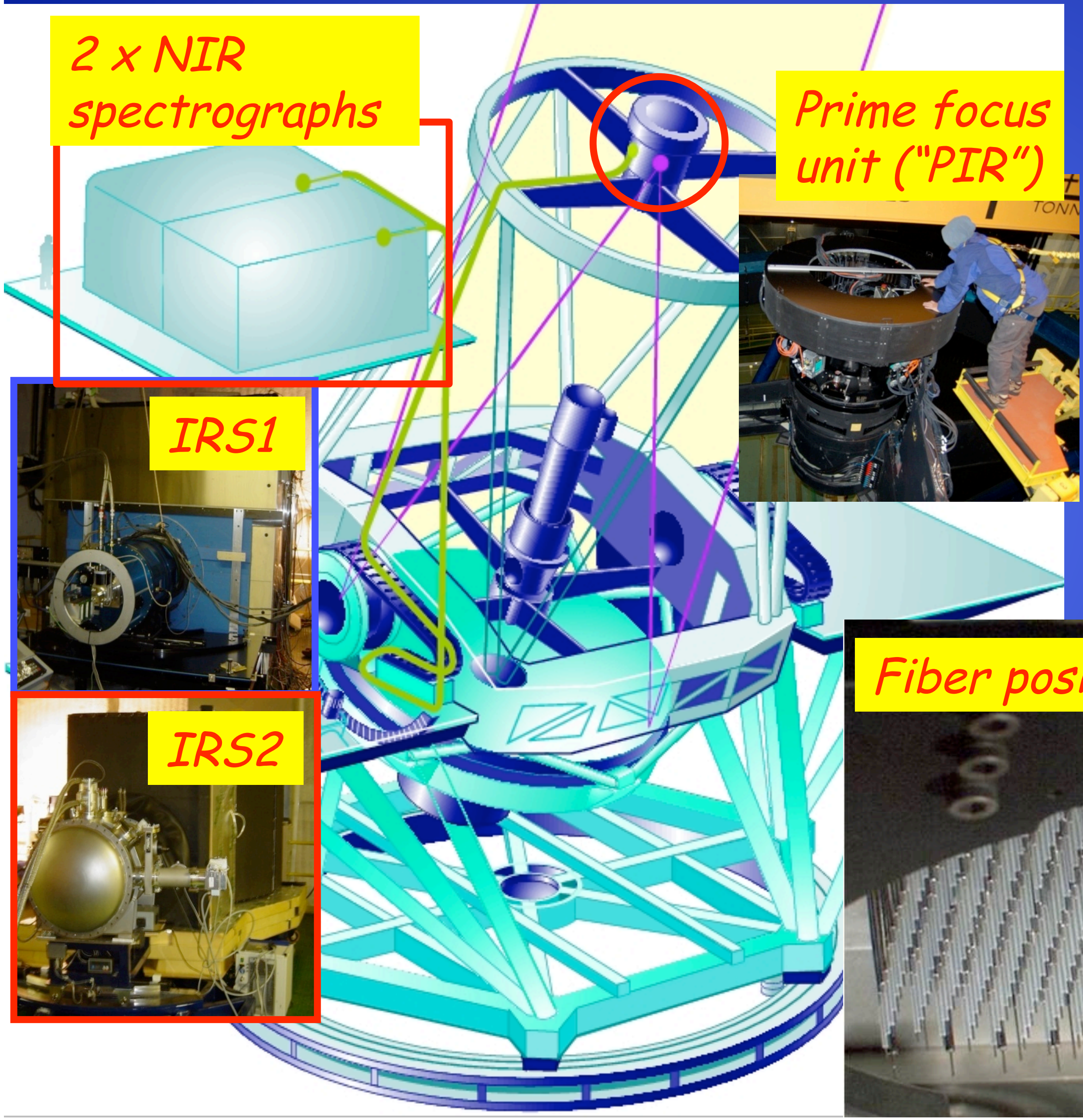
What is Subaru FMOS?

A couple of years ago, when we were struggling hard for its integration and commissioning, I saw a number of people who did not know FMOS, but knew WFMOS …

For details, please visit our section in the Subaru web site:

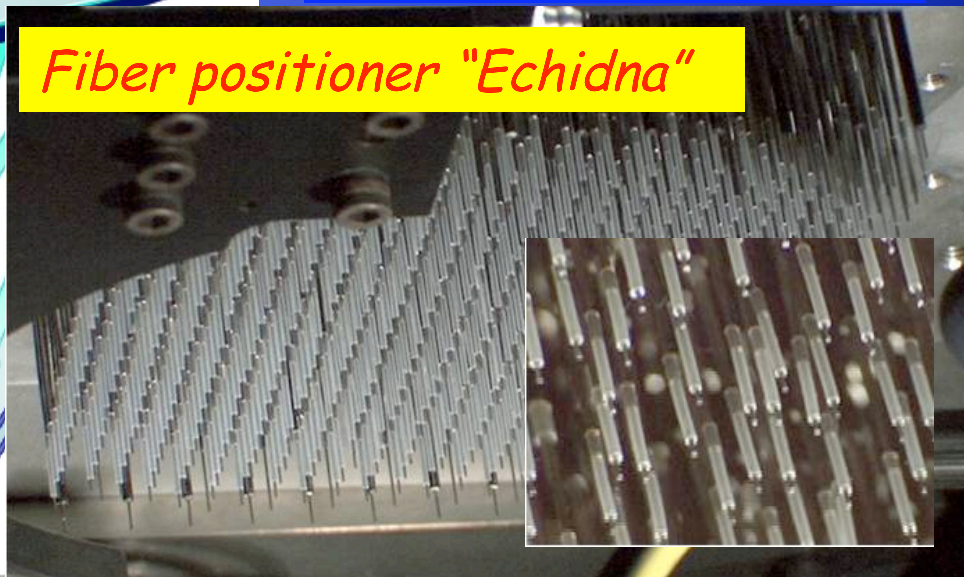
http://subarutelescope.org/Observing/Instruments/FMOS

"*FMOS*": Fibre Multi Object Spectrograph

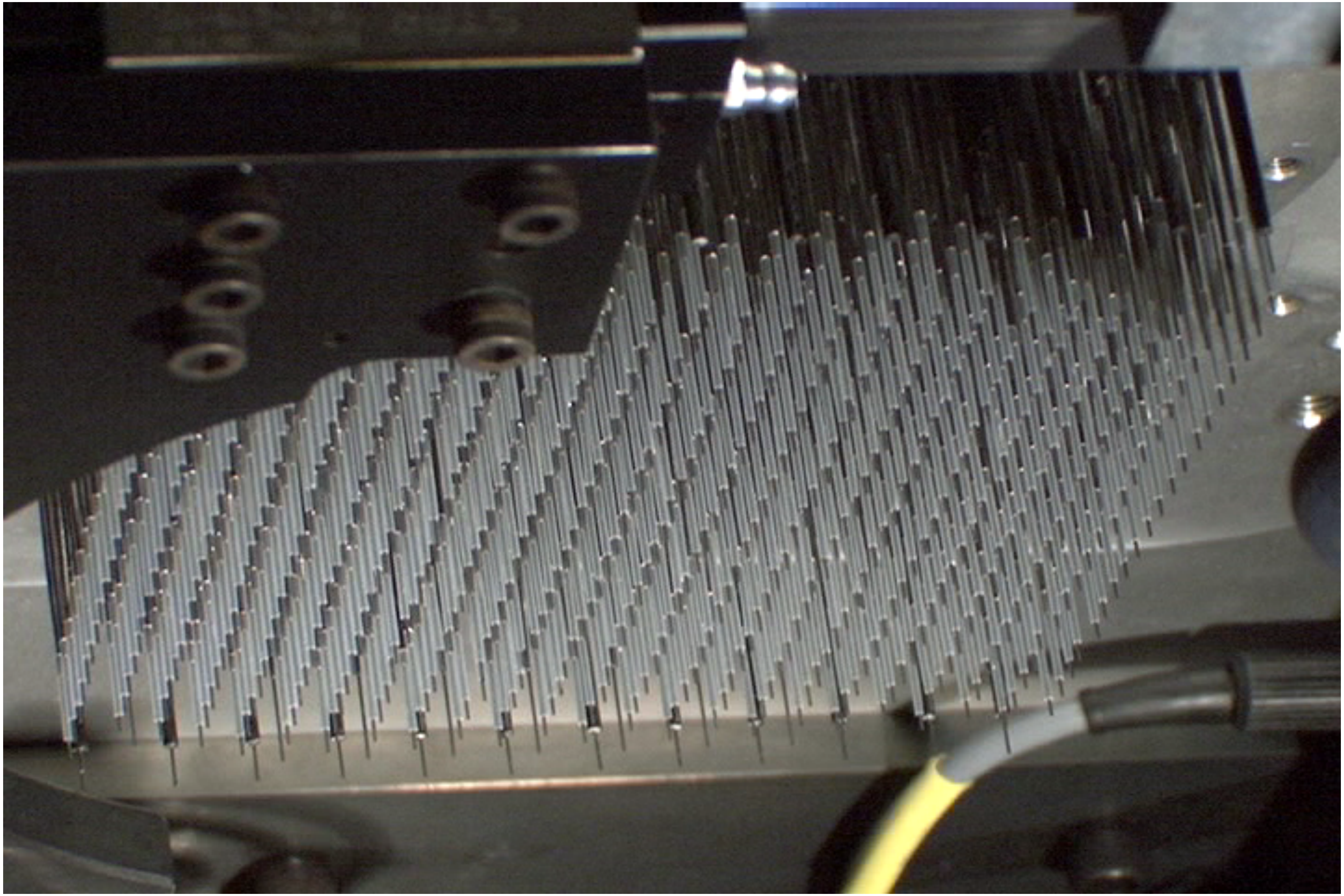


- ★ Subaru M1 8.2m
- ★ 400 fibers in the 30′ diameter FoV
- ★ NIR (0.9-1.8μm) spectroscopy

Unique combination as a multi-object spectrograph



Fiber positioning

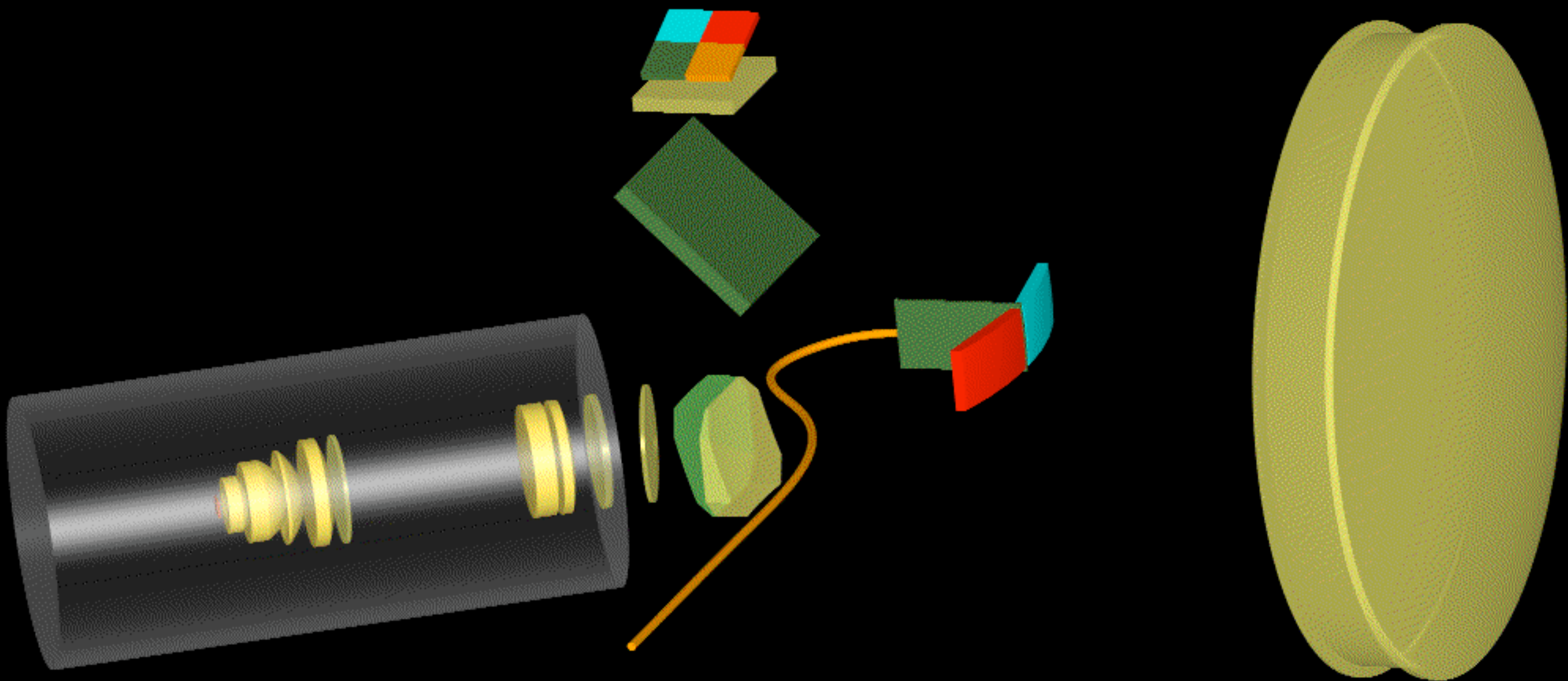


InfraRed Spectrograph

200 fibers are fed to each spectrograph (IRS1 & IRS2).

OH suppression by the mask mirror

“LowR”: R~500 (w/ VPH), “HighR”: R~2200 (w/o VPH)



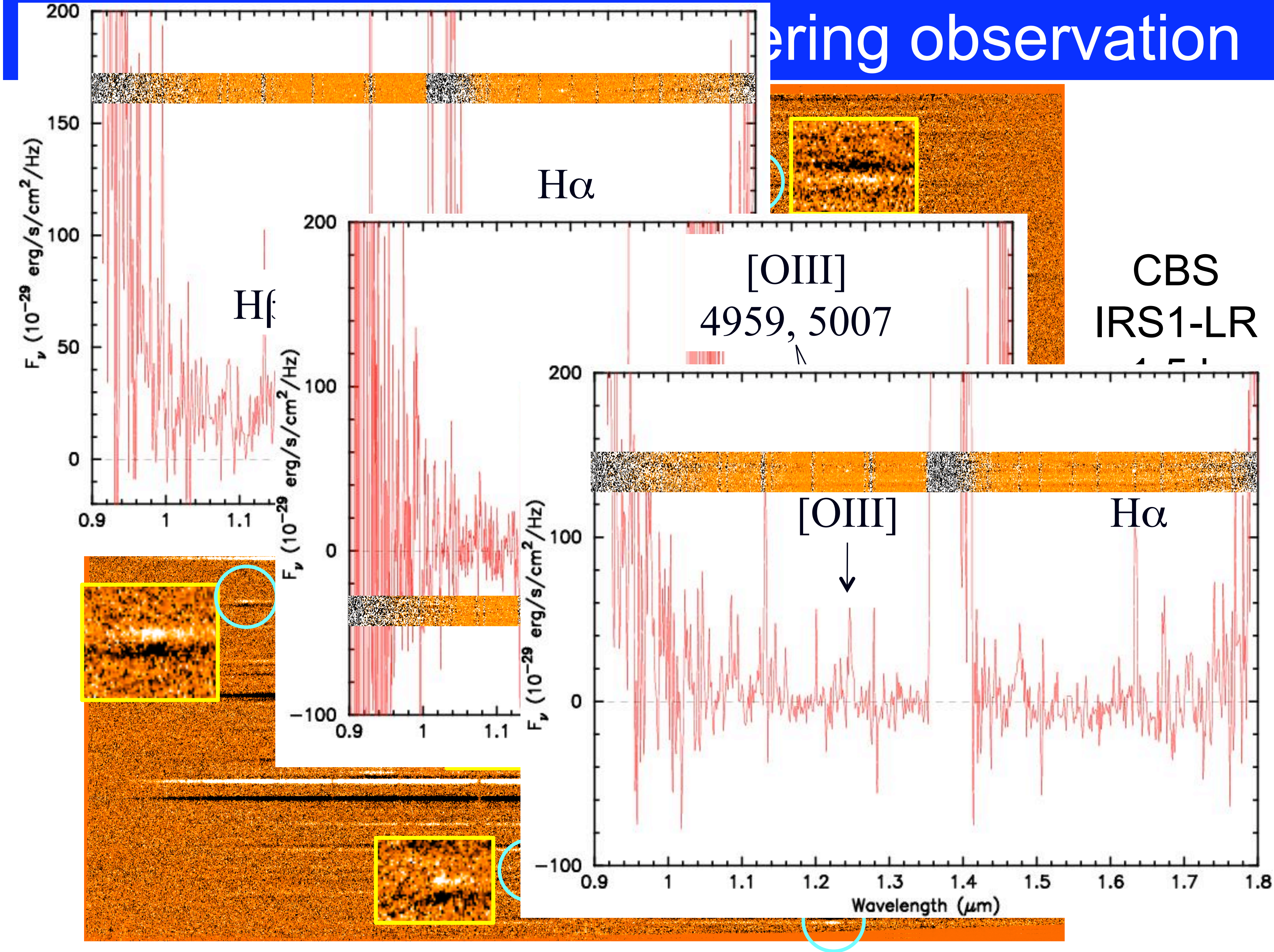
History & current status of Subaru FMOS

- ○ 1997?: Project started.
- ○ 1999: Tamura joined FMOS (optical design, fiber experiment, etc)
- ○ Apr 2002: Tamura moved to Durham (development of fiber cable & fiber connector, cryogenic tests of VPH gratings)
- ○ 2005?: FMOS parts integration & commissioning started in Hawaii.
- ○ Dec 2005: Tamura moved to Subaru.

- Dec 2007: Engineering observation started.
- May 2008: Engineering first light.
- Mar 2009: Performance verification started.
- May 2010: Open use started (IRS1 LR only).
  - 21 nights (8 programs + GTO) completed.
  - No serious troubles on the FMOS side.
- Feb 2011: IRS2 LR will also be available.

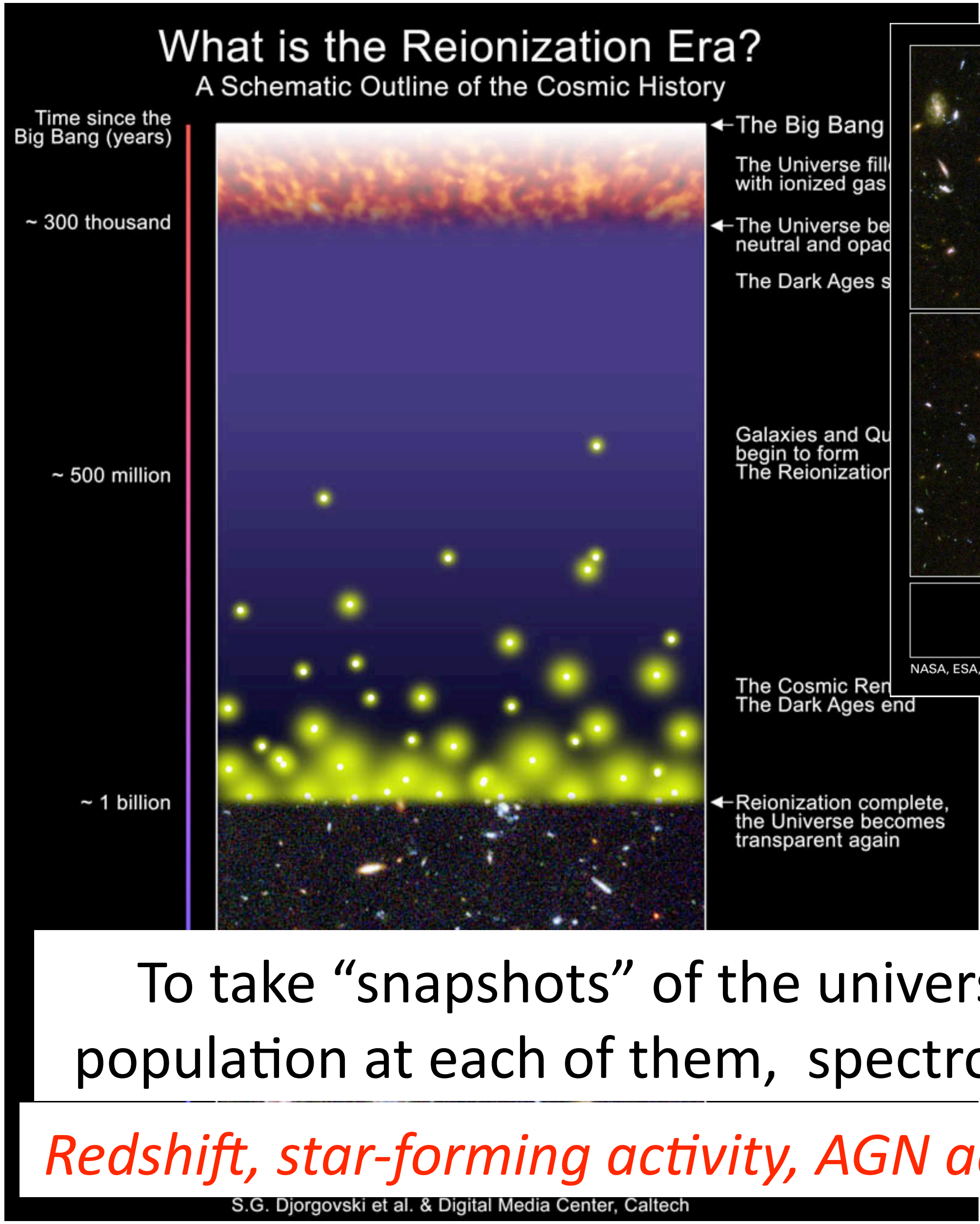
- Sep 2011?: IRS1 HR will be in operation.
- Feb 2012?: IRS2 HR will become available.

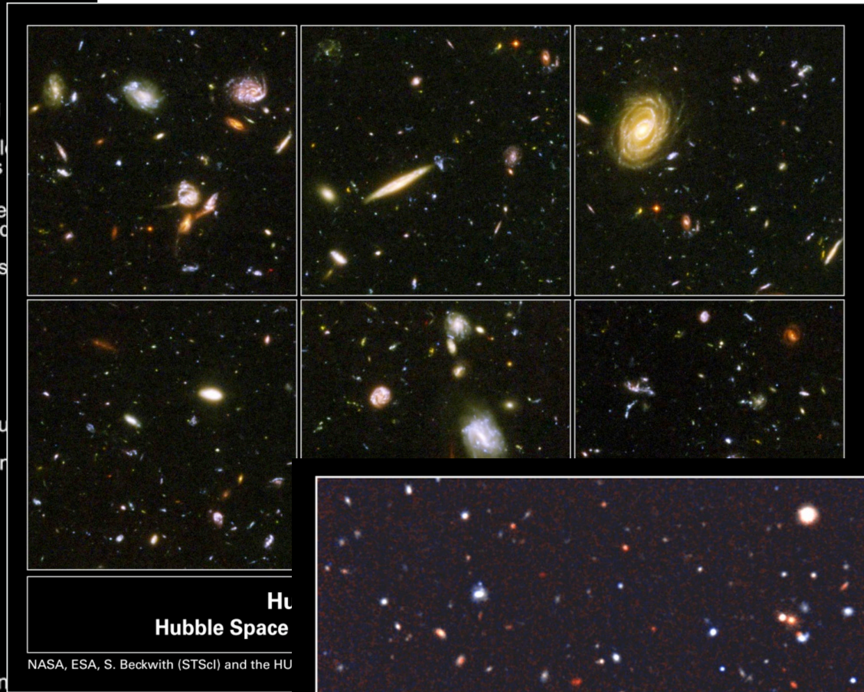
ering observation



CBS
IRS1-LR

Background





To take "snapshots" of the universe and characterize the galaxy population at each of them, spectroscopic information is necessary.

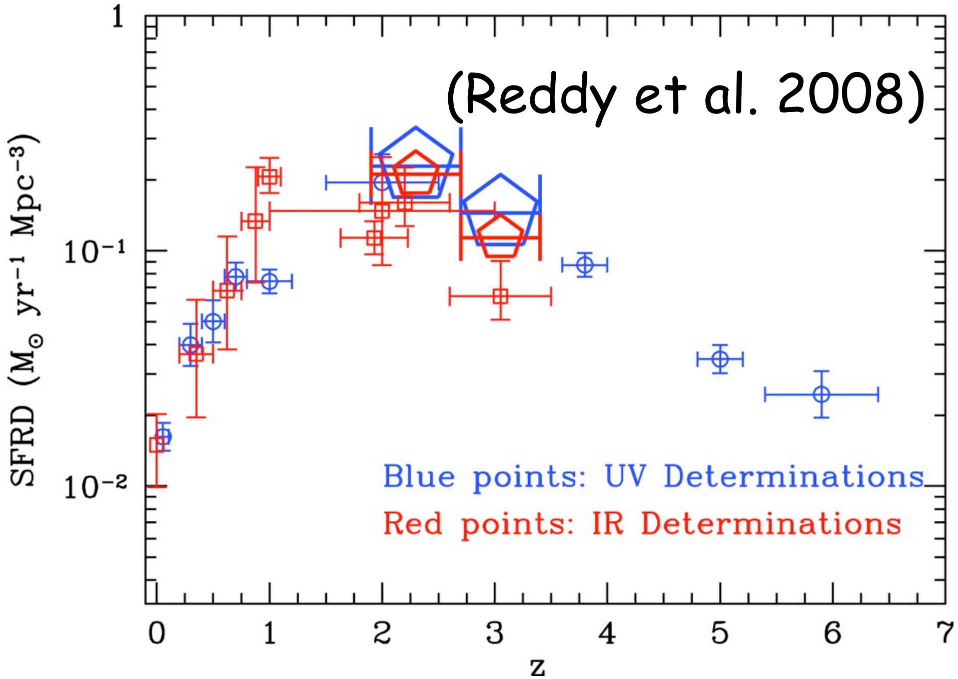
Redshift, star-forming activity, AGN activity, abundance, stellar age, etc

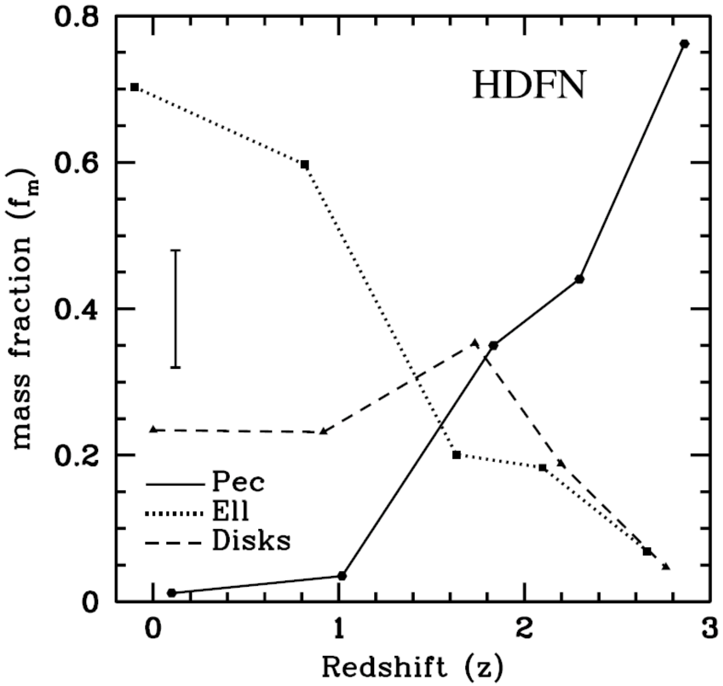
Background

Properties of galaxies & AGNs are found "different" at high redshift in various aspects, especially at z>1, from those at z=0.

Imaging survey → Galaxy sample → Follow-up spectroscopy

How could one make sure that a "complete" galaxy sample is constructed with no significant missing population?





(Conselice et al. 2003)

Background

Existing/on-going surveys:
SDSS, DEEP2, COSMOS, VVDS, SXDS, K20, GMASS, …

Why can we not yet fully understand galaxy evolution by looking at the data from these surveys?

Any missing pieces, especially in spectroscopy?

- *"Redshift desert"*
- *Optically faint (red) objects*

Dusty red & old red

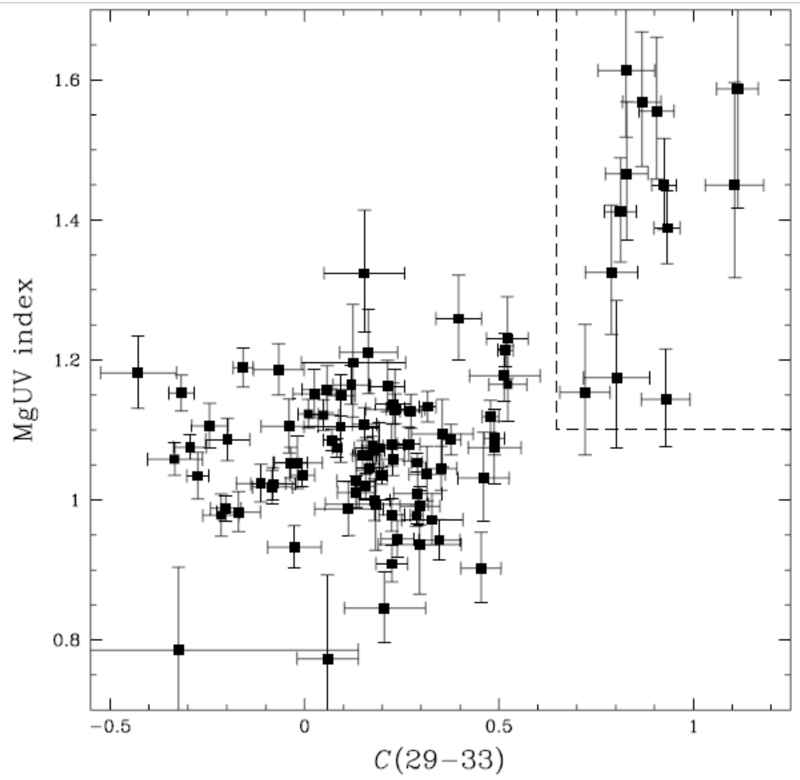
↑ Massive survey in NIR with FMOS, with better statistics over a wide area of sky.
(but probably limited to emission-line objects)

Nothing missing in relatively bright blue populations?

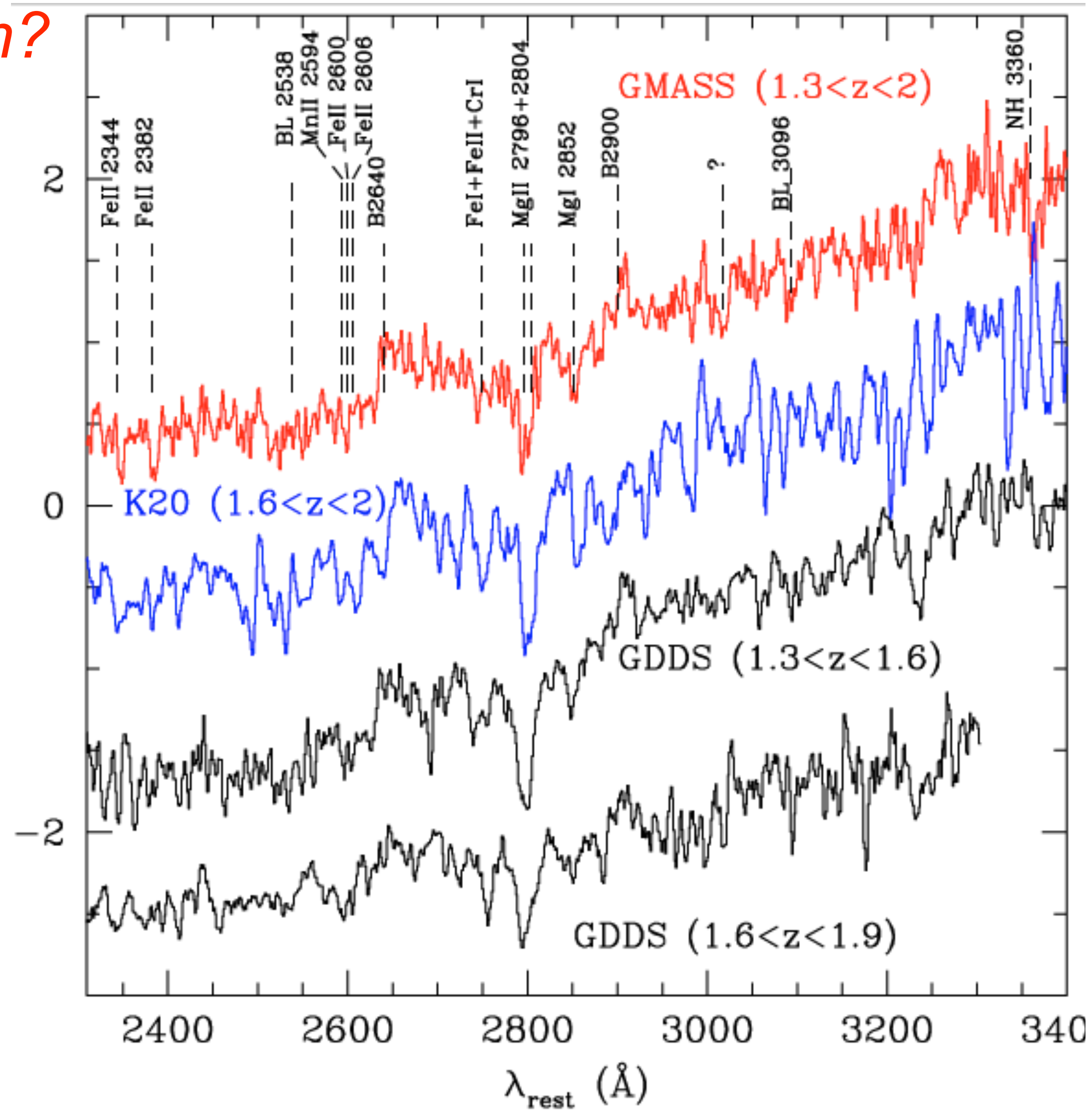
Which piece(s) will be addressed by SuMIRe/PFS?

To have a “complete” view of galaxy population

How about a magnitude (or mass) limited survey with enough sensitivity to quiescent galaxies & those with weak-emission lines due to dust extinction?



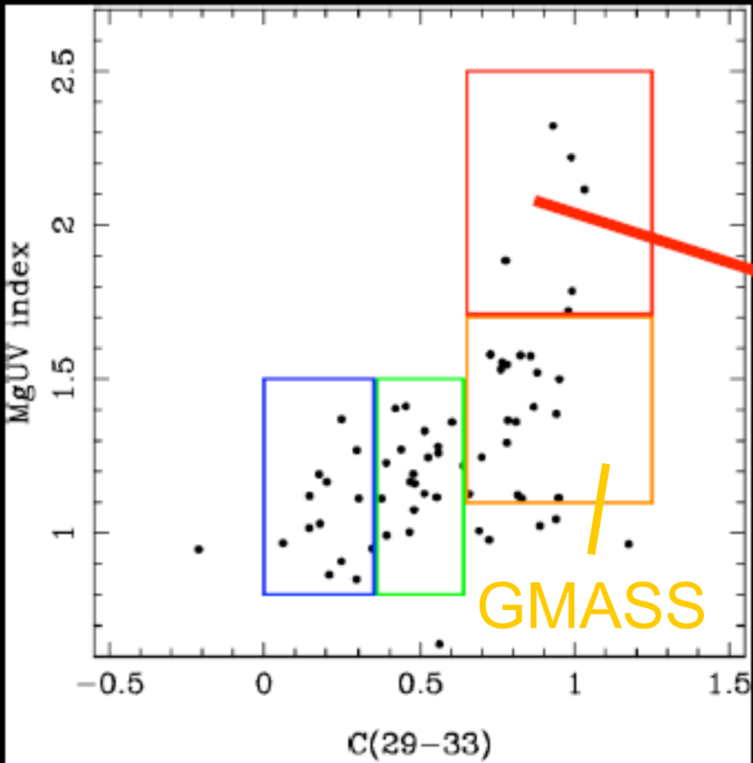
Cimatti et al. (2008)

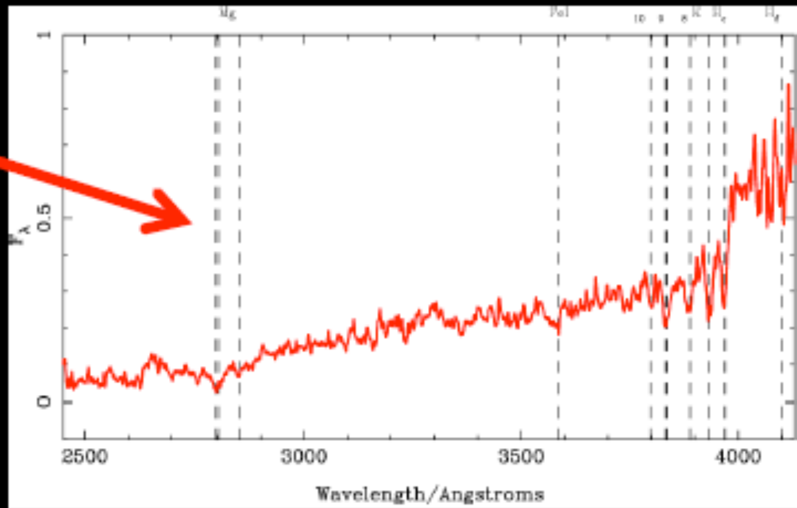


UDS FORS2 programme: initial results

Old galaxies at high redshift

"UDSz": An ESO large program





very old composite

Courtesy of Ross McLure, Henry Pearce (Edinburgh), UDSz team

Why non-active population in the active era?

- Galaxies (massive?) that already assembled.

- Formation of red sequence: Nature or nurture.

- Characterizing “green valley” population

- Elucidating star formation histories of galaxies:

  - Continuous, short-term burst-like, or sporadic.
  - Physics of mass acquisition:
    Accretion, interaction. etc
  - Roles of AGN activities

Key specs to science

- Fiber density
- Field coverage

How big can the sample be at the end? Survey speed?

- Spectral coverage, resolution

Which features can be accessed?

- System throughput (as a function of λ)

Even to study composite spectra, redshift needs to be determined for individual galaxies.

- Strategy of sky subtraction

PFS: High resolution option?

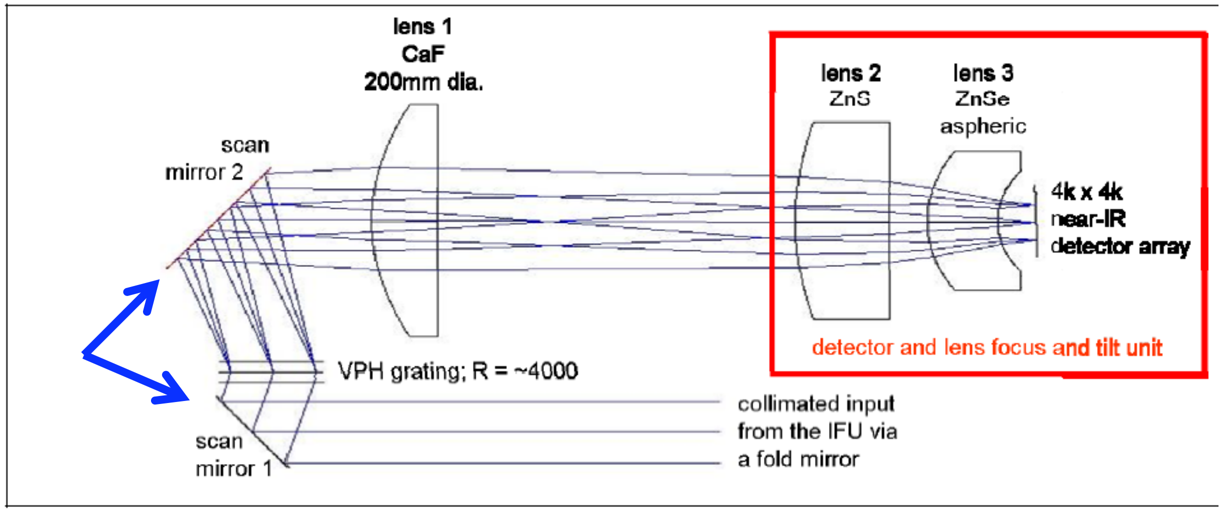


Figure 4: Layout of the Spectrograph optics for a spectral resolution of 4000

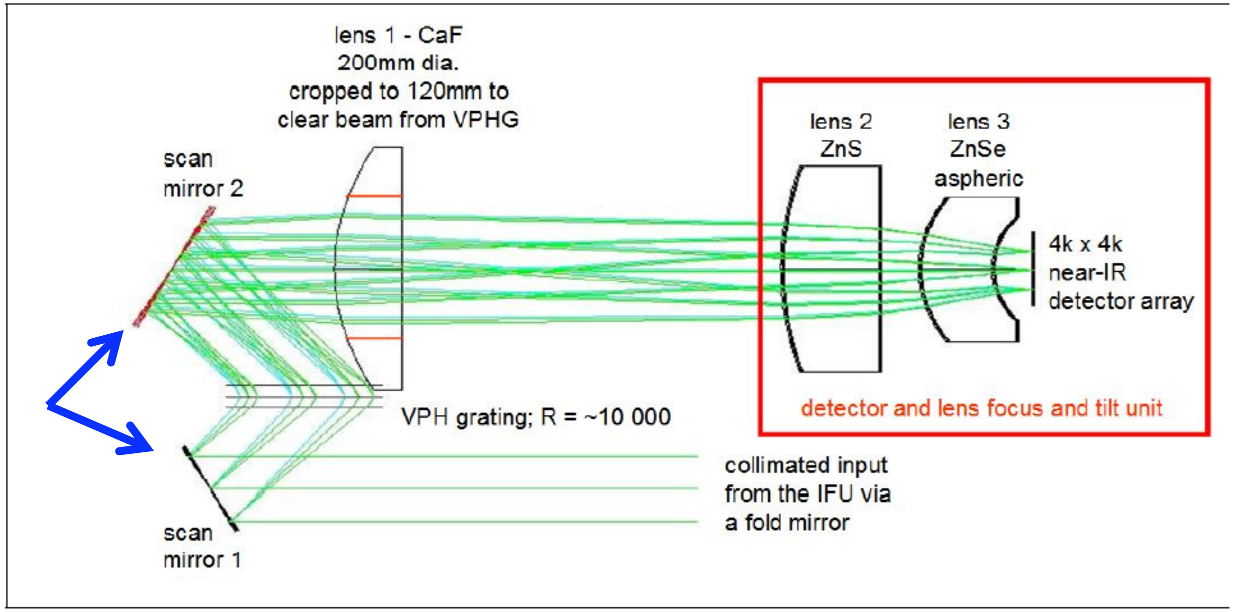


Figure 5: Layout of the Spectrograph optics for a spectral resolution of 10000

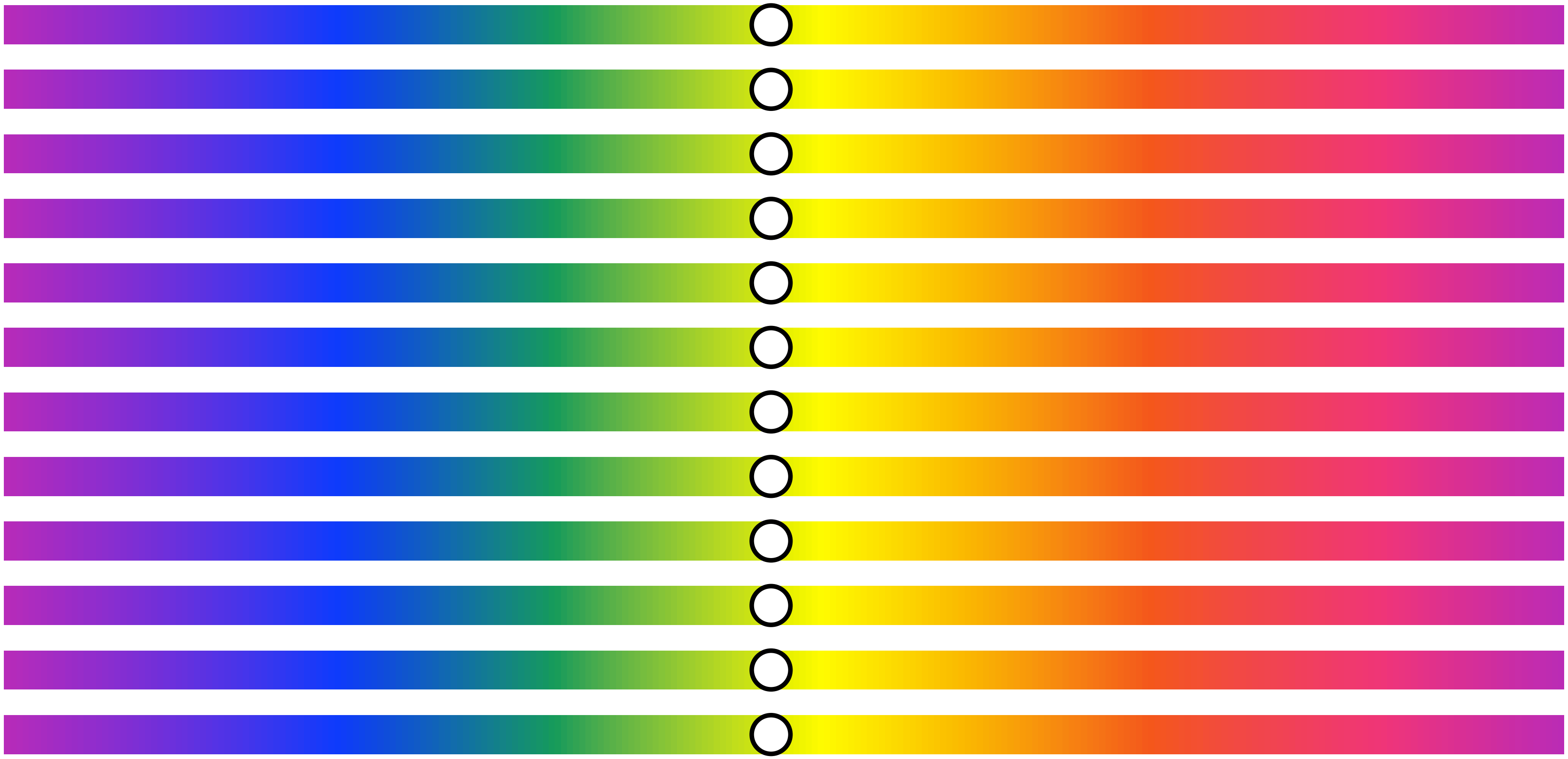
Butterfly mirror system?

By rotating two mirrors at once, more than one gratings with different spectral resolutions may be accommodated.

Hastings et al. (2010)
(See also Bernstein et al. 2002)

PFS: High resolution option?

A switching layer (3 x 1 in the example shown below) to select fibers for use & keep more space on the detector allowing cross dispersion



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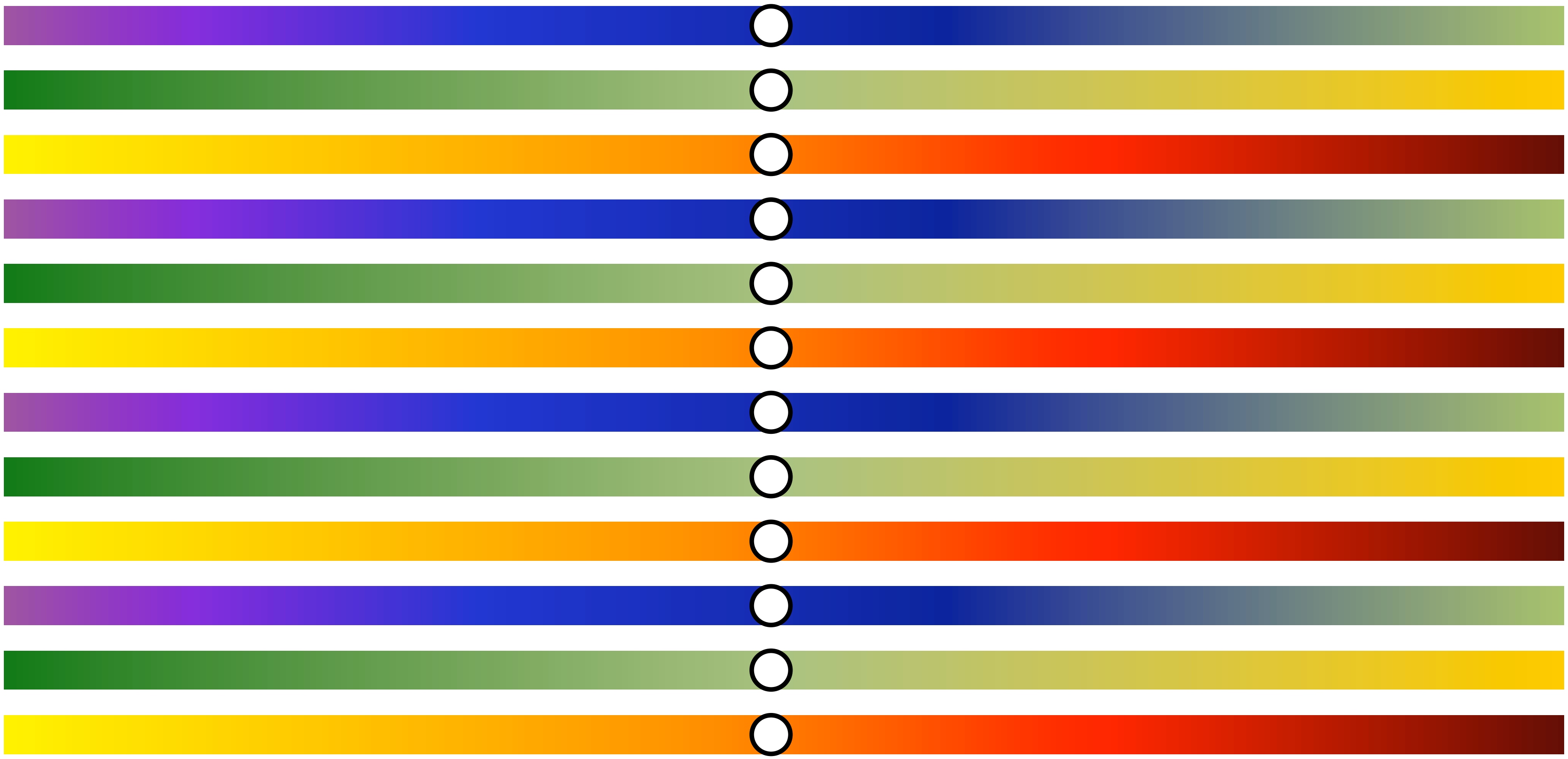


Subaru Flexibly Addressable Integral Field Spectrographs (SuFAIFS)

(Exploiting fiber optical switch)

~ A preliminary proposal for future instrumentation ~

Naoyuki Tamura (Subaru)

J. R. Allington-Smith, G. J. Murray, "DFS" collaboration
(Centre for Advanced Instrumentation, Durham Univ., UK)

(2010/08/31, an internal meeting at Subaru)

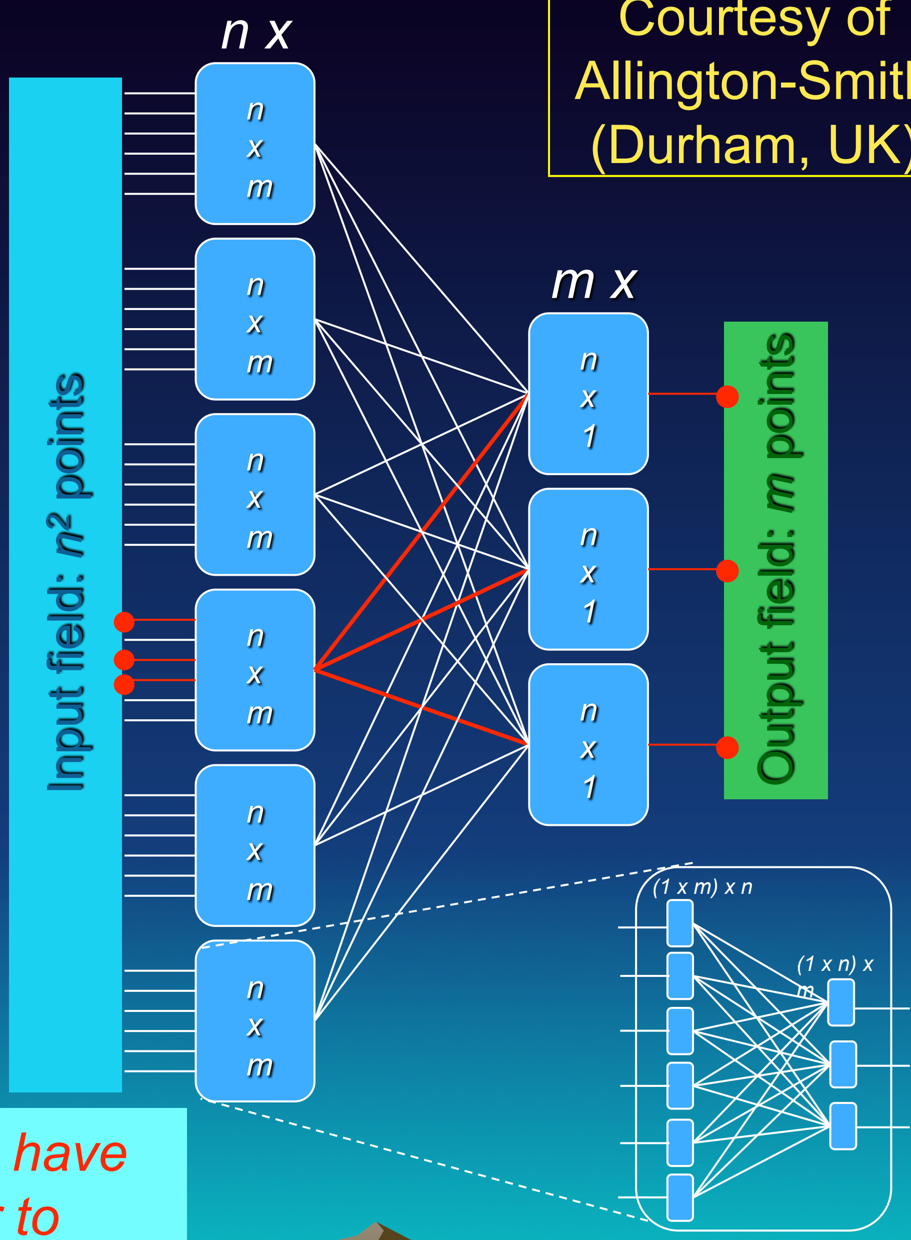
Fibre optical switches

n x *m* switch made from 3 layers of *n* x 1 switches

<u>Any</u> $N_O = m$ points in the field of $N_I = n^2$ points can be routed to the output with a down-selection factor, $F = n^2/m$

Example shown: *n* = 6, *m* = 3 with contiguous field (red) so $N_I = 36, N_O = 3, F = 6$

Courtesy of Allington-Smith (Durham, UK)

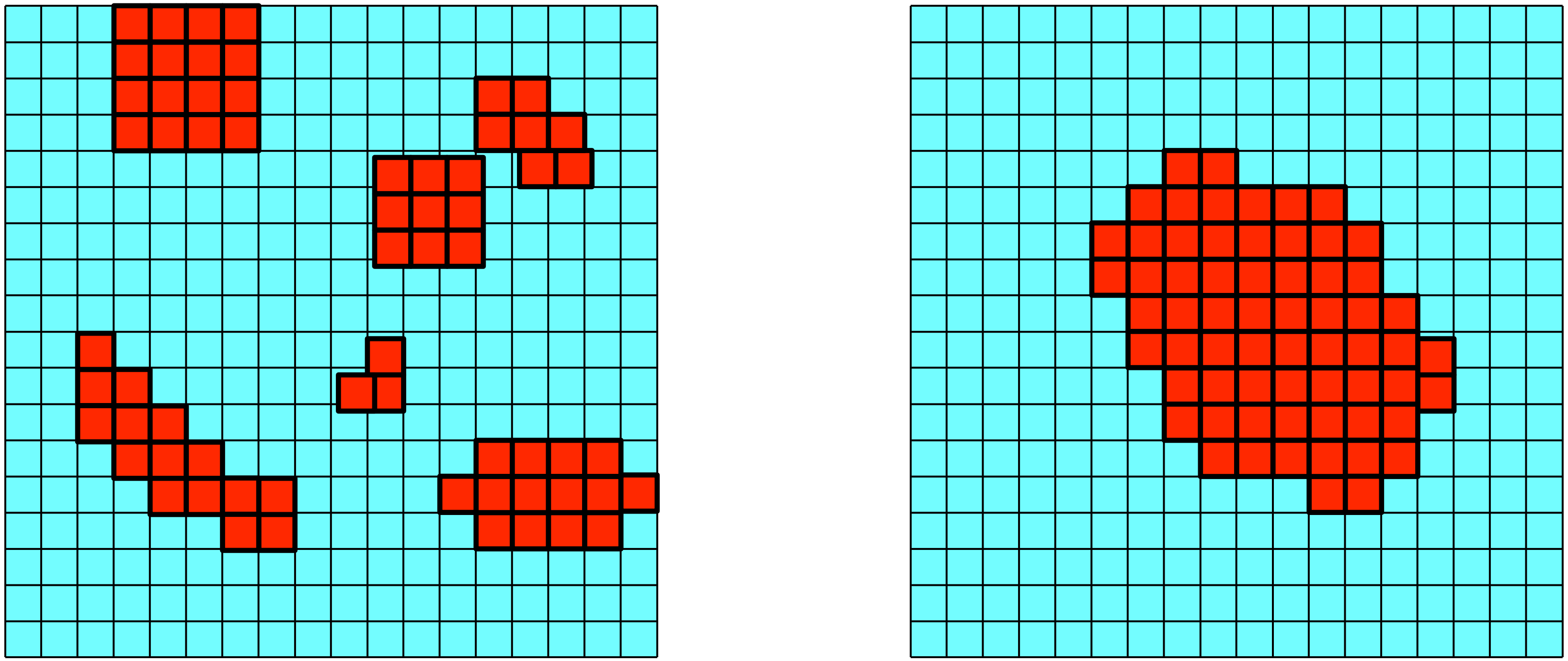


Durham Univ. (& Tamura from Subaru) have been working with an industrial partner to optimize a telecom device (single mode) for astronomy (multi-mode) with high throughput.

Goal of SuFAIFS

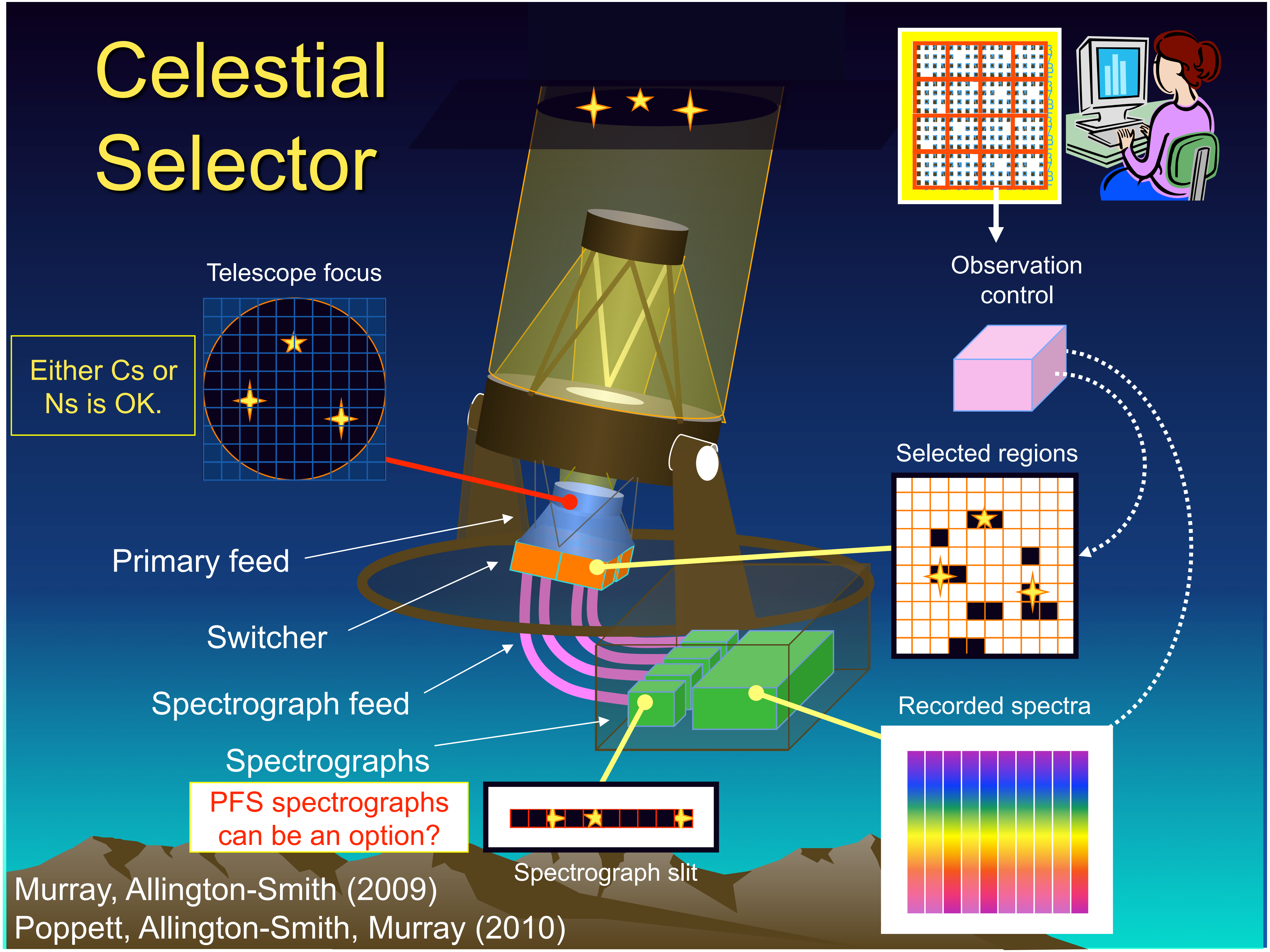
Allows a flexible selection of regions for spectroscopy among the 2D array of available spaxels on a focal plane, given a limitation in multiplicity of spectrograph(s).

E.g. Number of spaxels to be routed to spectrographs = 64.



Both will be in choice on SuFAIFS – Let's be even cleverer!?

MOS+IFS (w/ optimal shape) → Diverse Field Spectroscopy (DFS)


Celestial Selector
Observation control
Telescope focus
Either Cs or Ns is OK.
Selected regions
Primary feed
Switcher
Spectrograph feed
Spectrographs
PFS spectrographs can be an option?
Recorded spectra
Spectrograph slit
Murray, Allington-Smith (2009)
Poppett, Allington-Smith, Murray (2010)

Summary

FMOS is working in a good condition.

Clear identification of missing piece(s) in the existing/on-going surveys that would be addressed by SuMIRe/PFS to better understand galaxy evolution.

To make a “snapshot” of a redshift with a “complete” view of galaxy population, surveys sensitive enough also to quiesecent galaxies would be critical.

Fiber optical switch may be a key technology for high resolution option, making PFS more versatile in its spectral domain.