Subaru Flexibly Addressable Integral Field Spectrographs (SuFAIFS)

~ Concept of a new instrument
from a collaboration recently renewed ~

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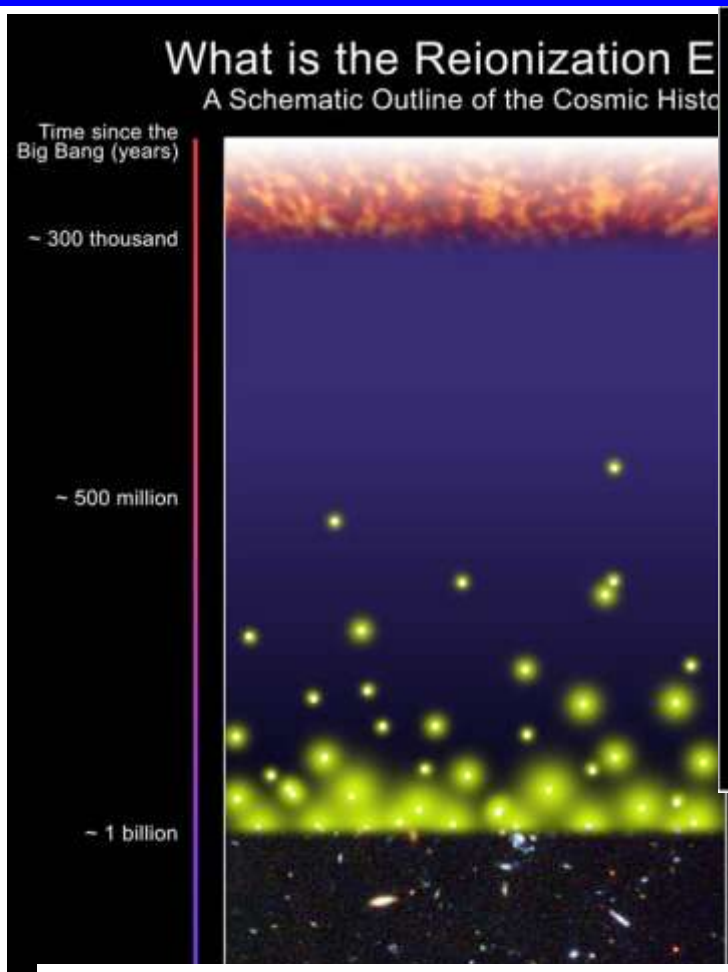
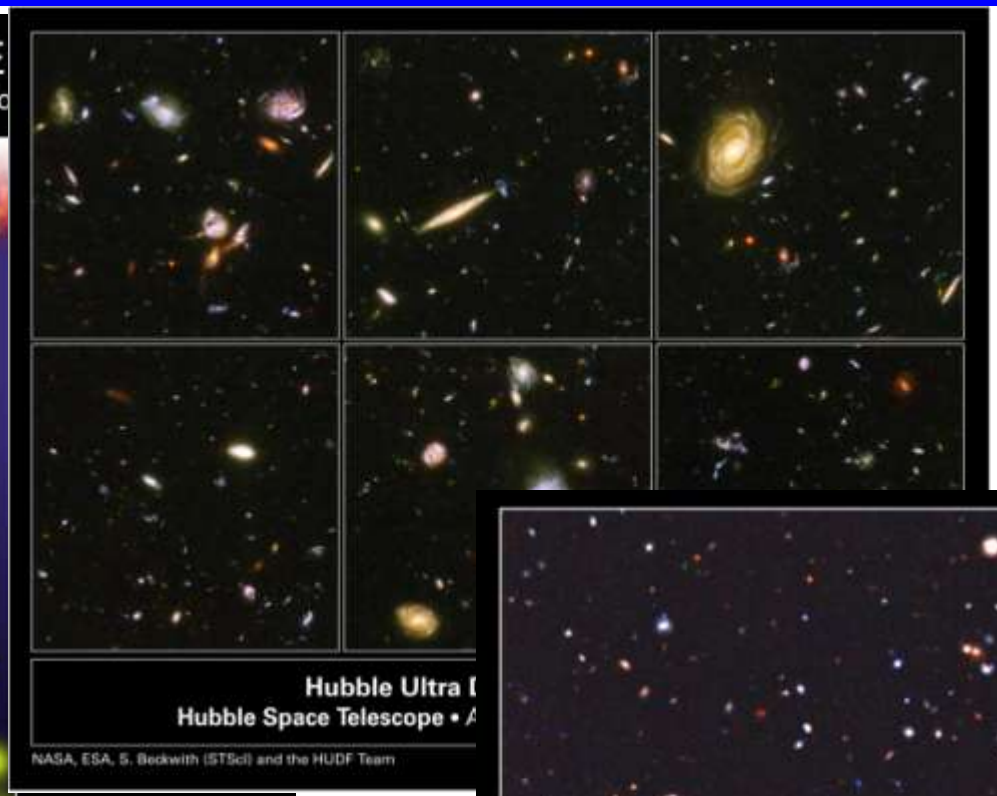
Background





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

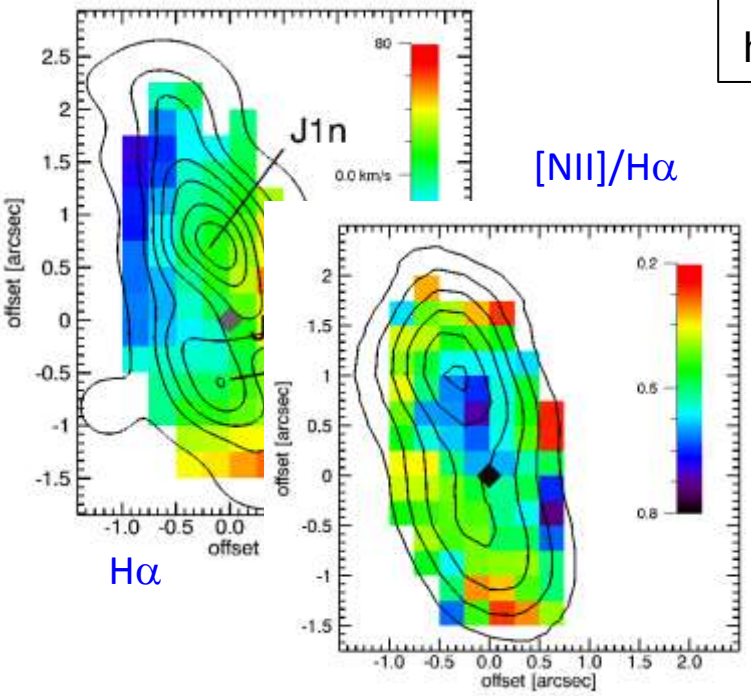
Plus integral field (i.e. 2D) spectroscopy (IFS):

Spatial distribution, kinematics/dynamics, dynamical mass …

Clues to knowing what they are, what's going on & why (→ physics)

Internal structures of galaxy main body (~10 kpc)

An SMG at z~2.5

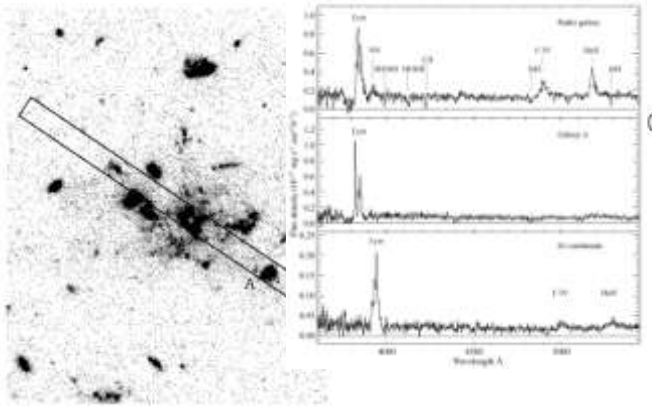


Nesvadba et al. (2007)

Extended/diffuse components, halo part of a galaxy (~50-100 kpc)

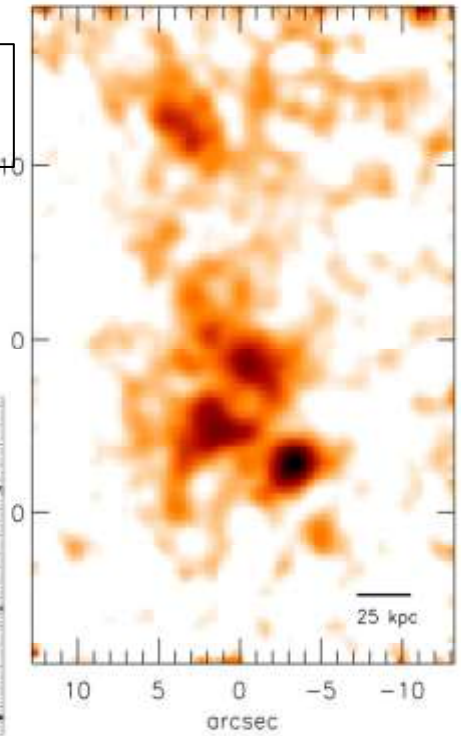
Diffuse star formation in massive galaxies & cluster assembly?

MRC1138-262@z~2



(Hatch et al. 2008)

SAURON 24h exposure with WHT of LAB-Z/SSA-22 protocluster



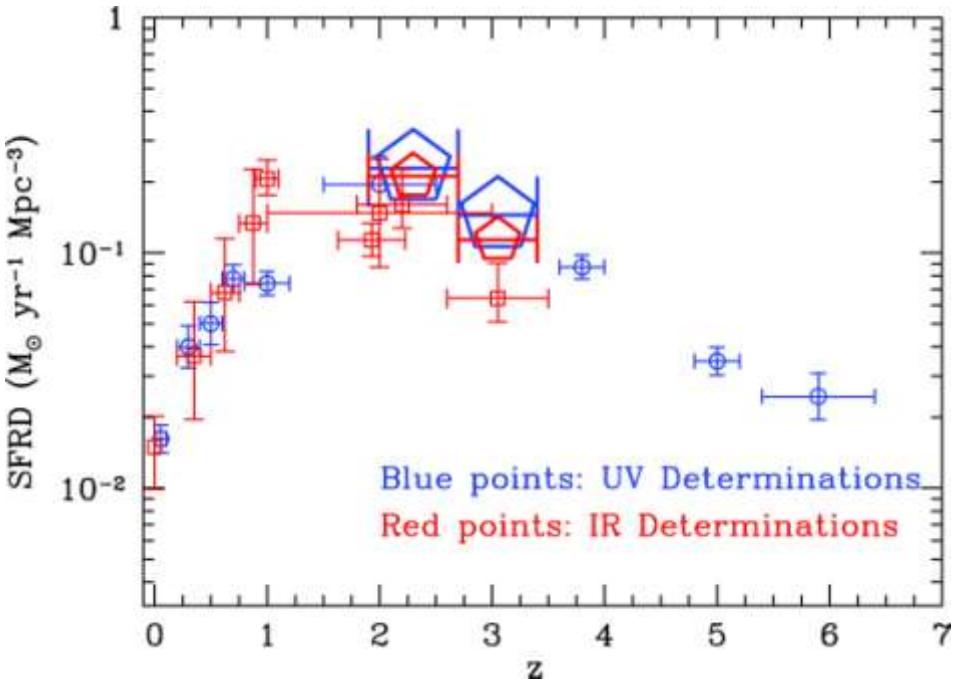
(Weijmans et al. 2009)

Background

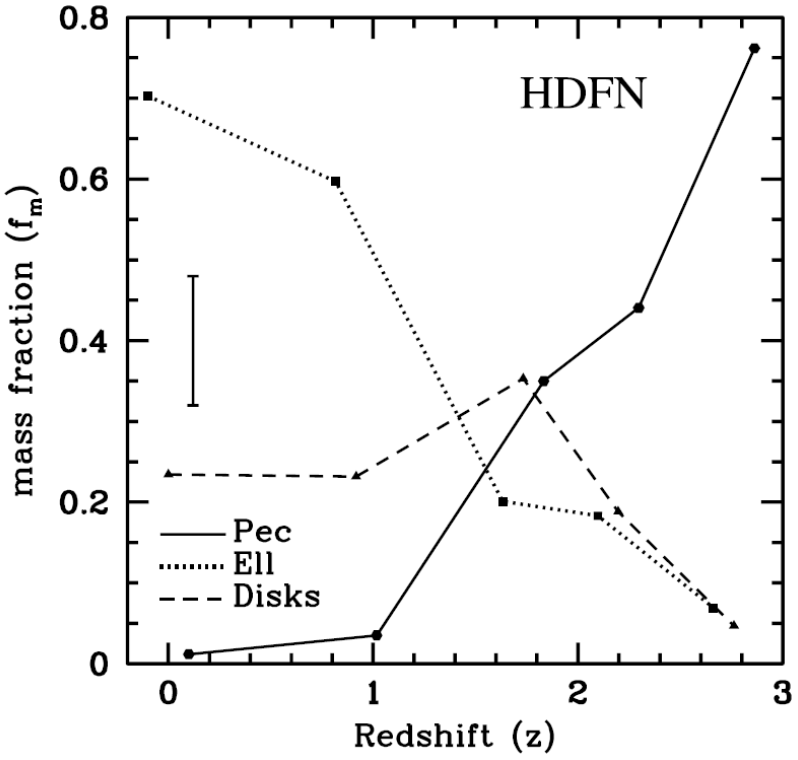
What should Subaru try to address?

Light-gathering power is a key for IFS. TMT should be coming with IFS & AO.
SuFAIFS would be a late comer of IFS among 8-10m class telescopes … etc

Little has been explored by IFS, so there should be plenty to do to understand physical process at *various redshift*, while coordination would be necessary.



(Reddy et al. 2008)



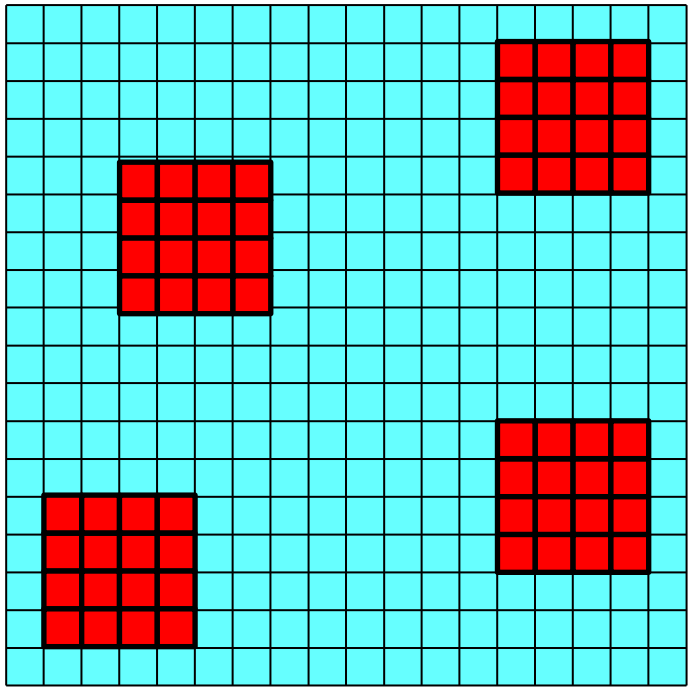
(Conselice et al. 2003)

Integral Field Spectroscopy (IFS)

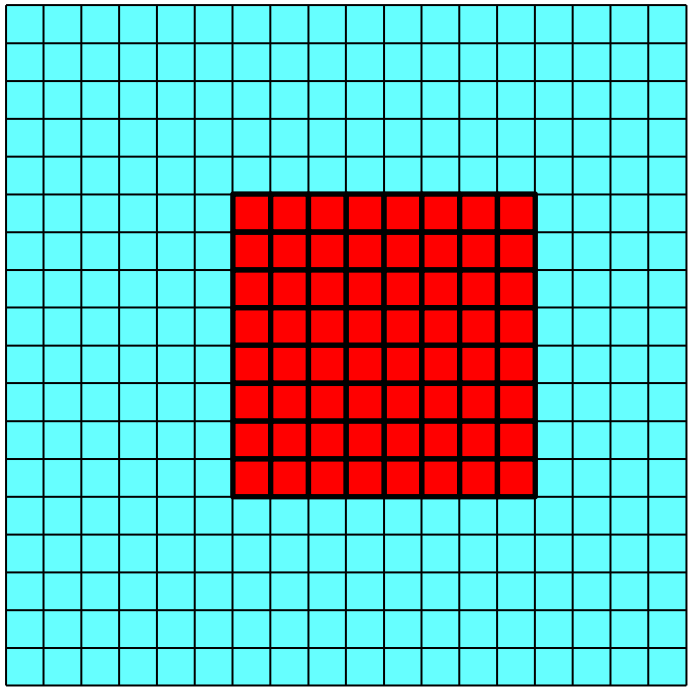
Deployable multi-Integral Field Units (IFUs) over an FoV

OR

Complete spectroscopy of a certain (usually small) part of an FoV



"Be clever" type (e.g. VLT/KMOS)



"Get everything" type (e.g. VLT/MUSE)

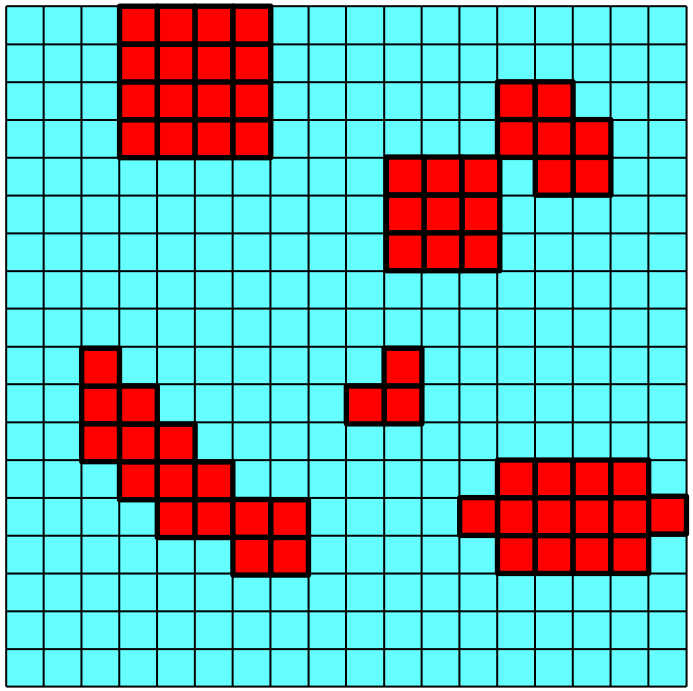
Usually too ambitious to do an IFS over a wide area of sky.

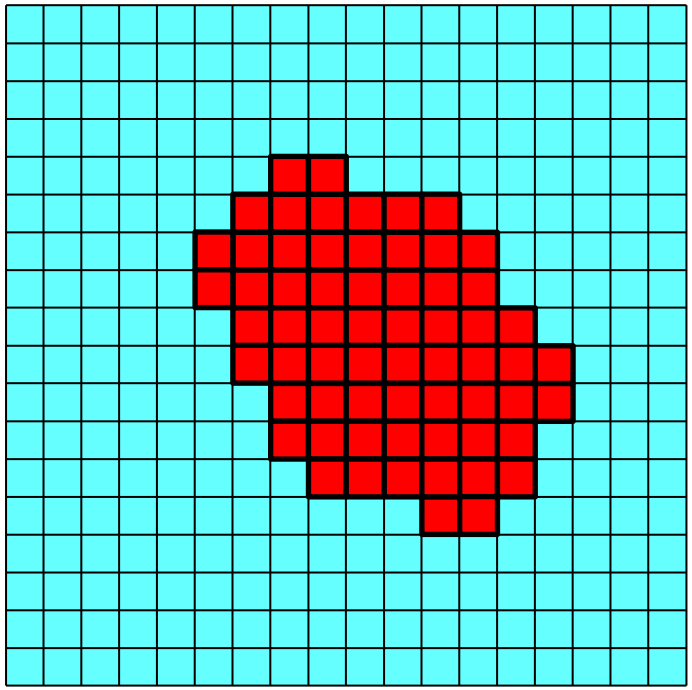
Is there any way to address targets optimally/efficiently?

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.



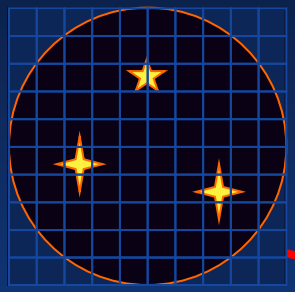


Both will be in choice on SuFAIFS: *"Diverse Field Spectroscopy (DFS)"*

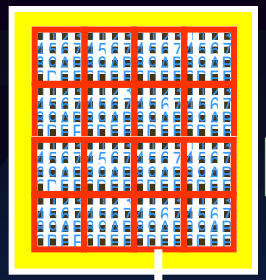
Selected spaxels may be distributed to more than one spectrographs

→ Possibility of *additional versatility to spectral domain*.

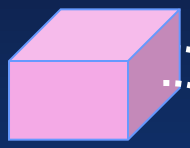
Celestial Selector

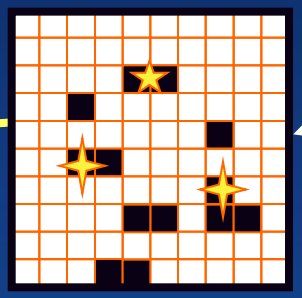


Telescope focus



Observation control





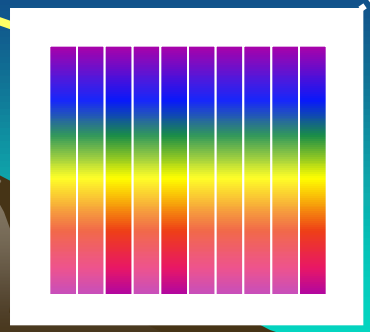
Selected regions

Primary feed

Switcher

Spectrograph feed

Spectrographs



Recorded spectra

Spectrograph slit

Murray, Allington-Smith (2009)
Poppett, Allington-Smith, Murray (2010)

Components

✓ Focal plane array of spaxels & primary feed

- *A focal plane is covered by a micro-lens array with a high filling factor.*
- *Fiber bundles (input fibers) can provide fiber connectors remote from the actual focal plane.*

✓ Switcher

N(input fibers) >> N(output fibers)

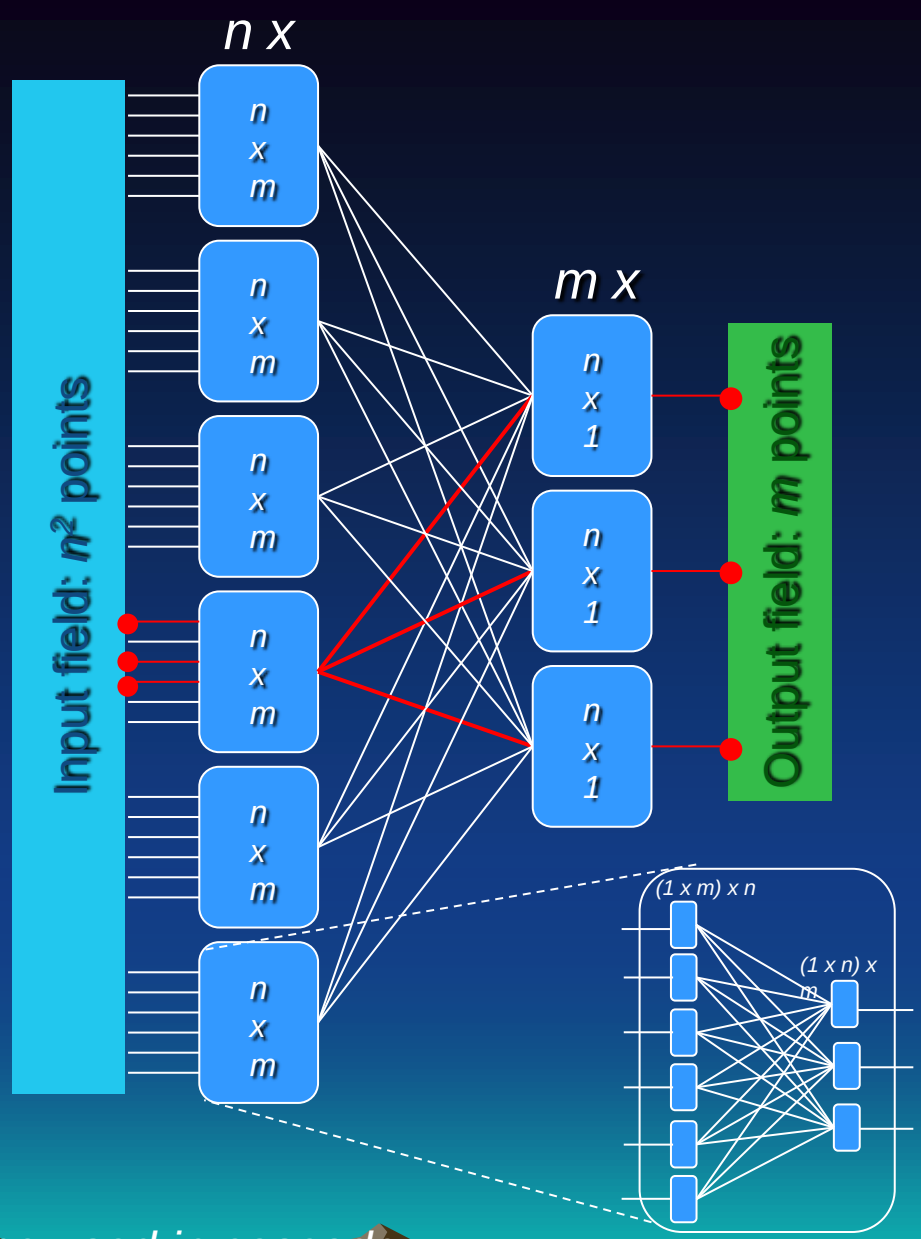
→ *"Down-selection" of output fibers routed to spectrographs.*

Fibre optical switches

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

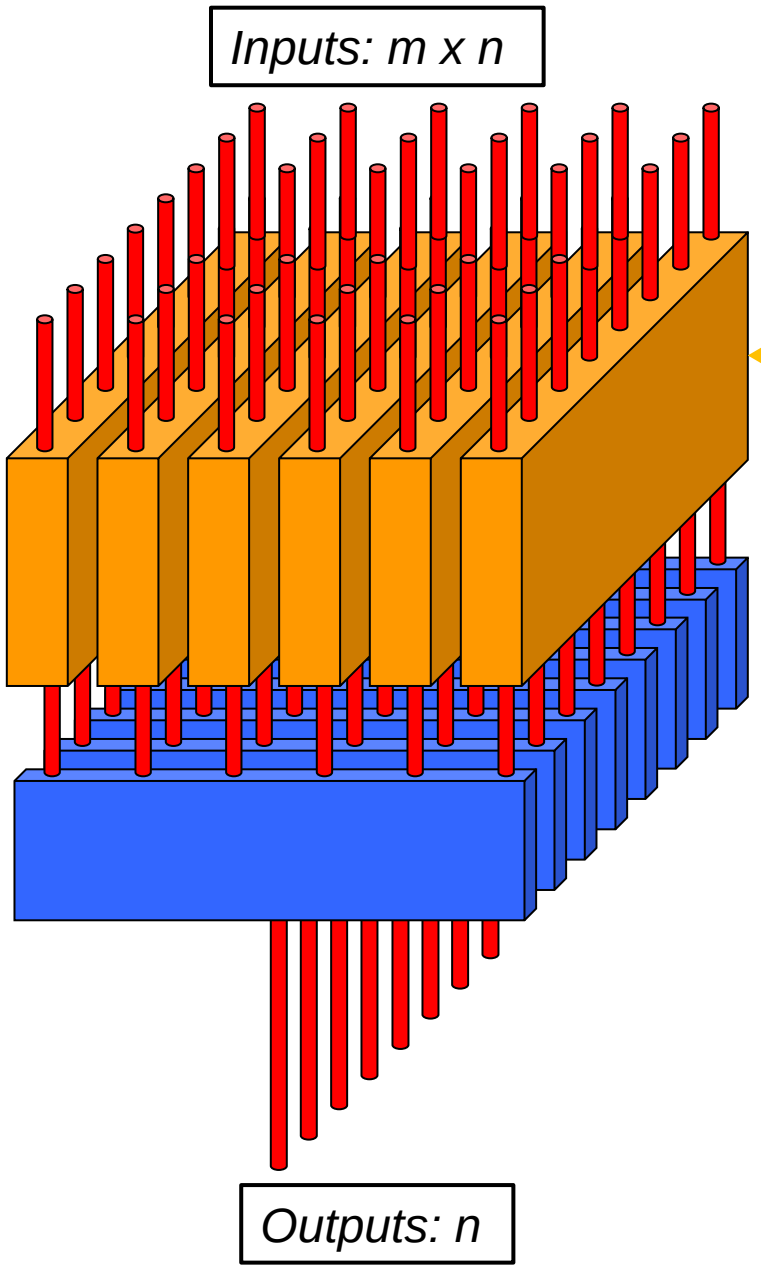
Any $N_O = m$ points in the field of $N_I = n^2$ points can be routed to the output with downselection factor, $F = n^2/m$

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



Note: If more than one switches could not be used in cascade as above, incoherent remapping would be necessary to enhance flexibility in choice of spaxels on the focal plane.

An alternative with less fiber interconnections



A two-layer, downselection switching architecture using the two basic switch modules: the n × n and the m × 1 devices.

- Here, n = 8, m = 6
- There are m × (n × n) modules (orange)
- There are n × (m × 1) modules (blue)
- Number of inputs = n × m
- Number of outputs = n
- The rectangularity of the input dictates the downselection ratio; here 6:1
- For the (n × n) modules proposed by an industrial partner, n = 1000 is feasible
- Similarly, there is no obstacle in principle to an (m × 1) switch, where m = 1000
- This technology therefore appears to be the most practical route to DFS systems with >10^6 channel counts.

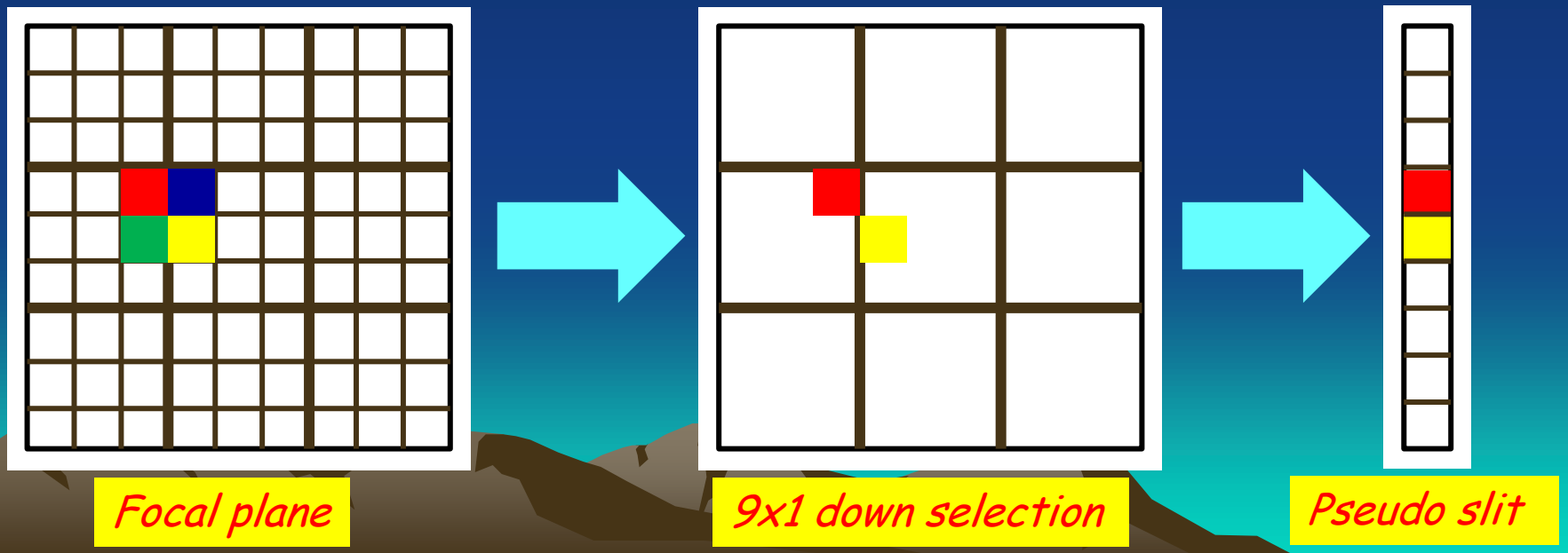
Remapping spaxels

- If fiber switches are not used in cascade …

  The focal plane is divided by cells, from each of which only one spaxel can be selected to be routed to a spectrograph.

  = *“Coherent DFS”, with direct mapping & down selection.*

  ← *Not optimal to observe a largely extended object (although this is intended to be a 2D spectroscopy!)*

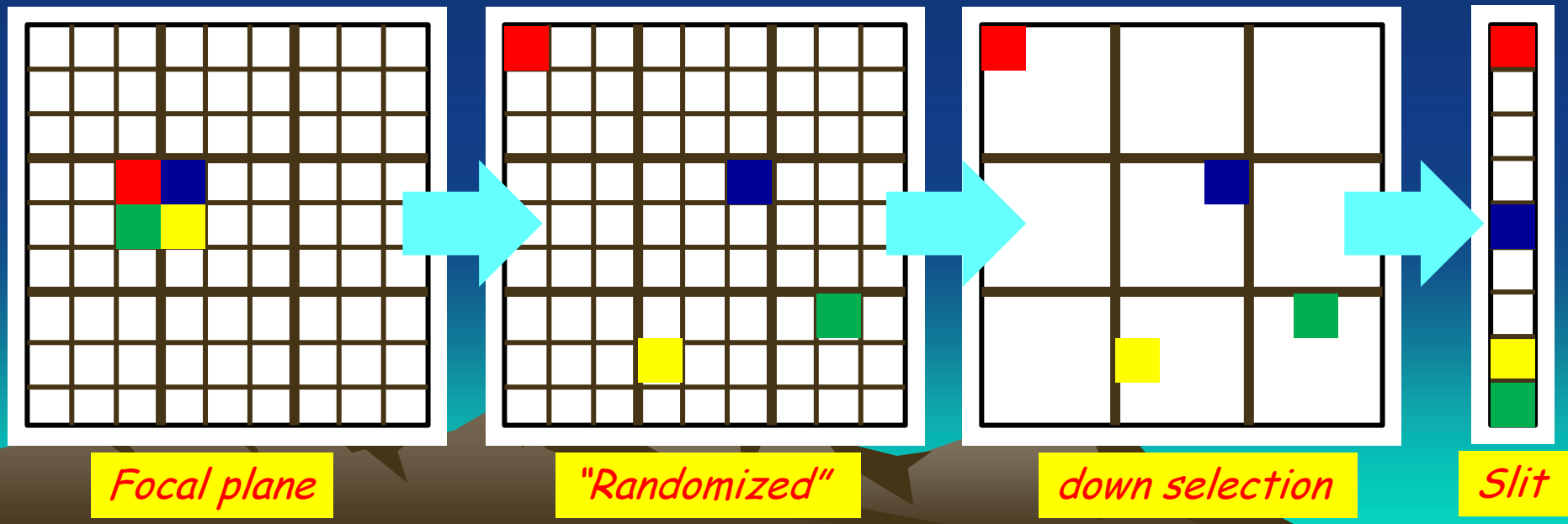


Remapping spaxels

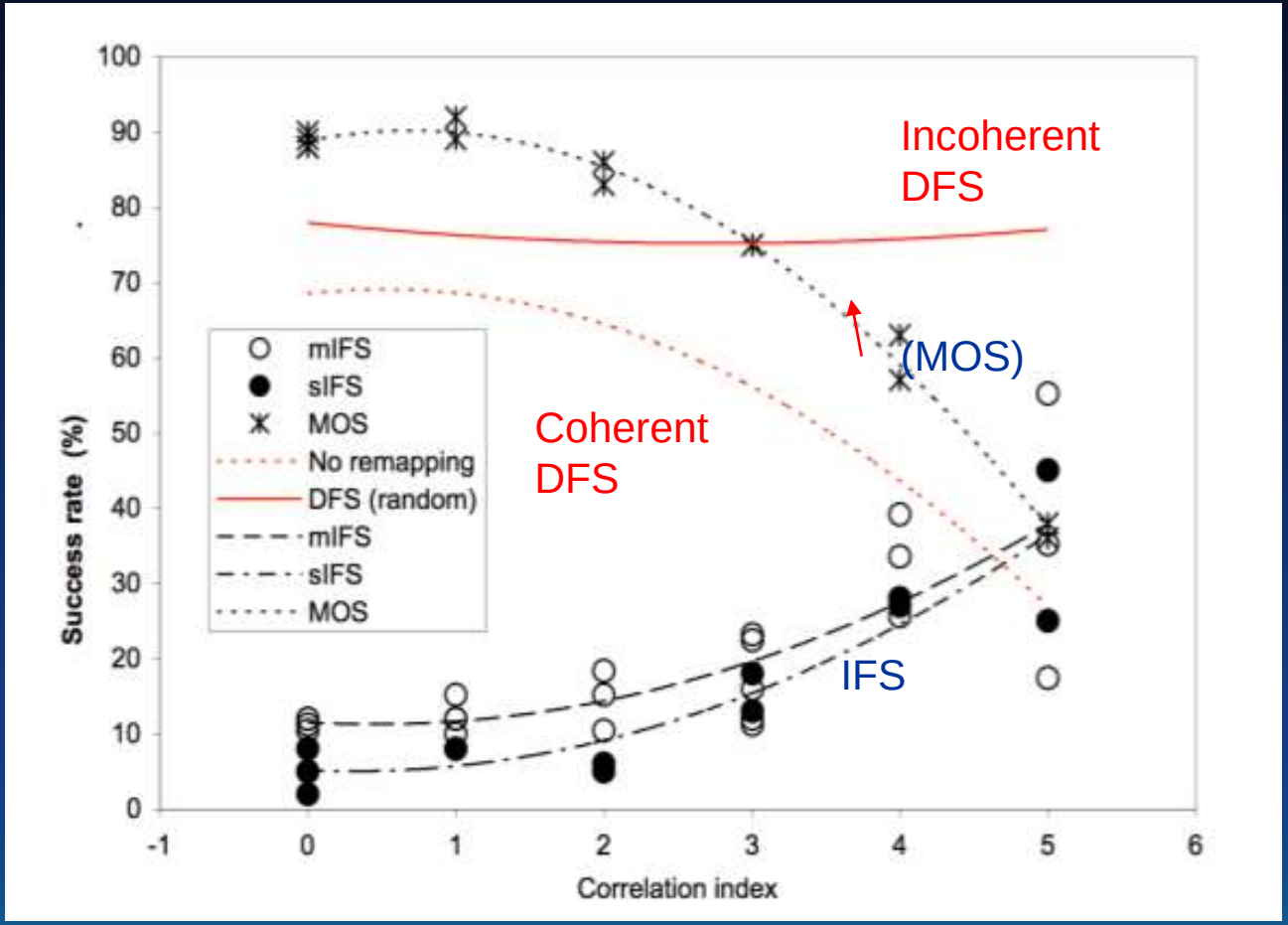
- If Nx1 switches cannot be used in cascade …
  - ✓*Solution*

    Randomize input-output mapping in fiber bundle so that a large fraction of adjacent inputs can be routed to spectrograph(s).

    = *"Incoherent DFS", with incoherent remapping incorporated.*



Power of incoherent remapping



(Poppett, Allington-Smith & Murray 2010)

Montecarlo realization of spaxel distribution and selection for spectroscopy:

High (low) correlation index
→ Uniform (clumpy)

Spaxel is routed to a spectrograph?
Yes → Success.

- Remapping is very beneficial for clumpy distributions
- DFS is much more versatile than IFS or MOS

Components

✓ Focal plane array of spaxels & primary feed

✓ Switcher

✓ Spectrograph feed & spectrographs

Output fibers are re-organized as a slit and are input to spectrographs.

- *Existing spectrographs?* (FMOS, MOIRCS, IRCS, FOCAS …)
  Given a fiber-feed option can be added …
  → A single focal plane can be shared.
  → Heterogeneous/Multi-mode spectroscopy is possible.
- *New spectrographs?*
  E.g. SuMIRe/PFS → Better "homogeneity" & much higher multiplicity may be offered.

Preliminary specifications

✓ Focus: Ns → Assisted by MOAO?
Cs → Assisted by GLAO?

✓ Spectral coverage:
Fiber feed, AO assistance → (RI)zYJH?

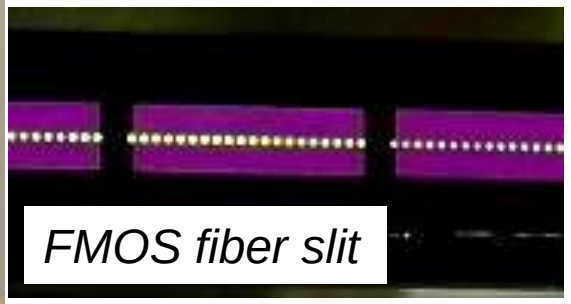
✓ Spaxel size:
AO assistance → ~0”.1?
Natural seeing → ~0”.2?

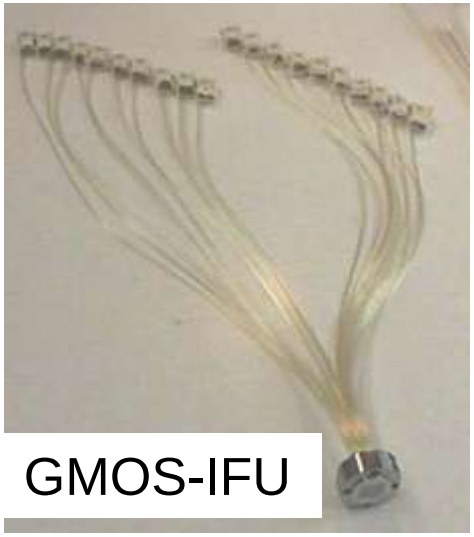
☐ Max. # of spaxels that can be routed to spectrographs
cf. FMOS IRS1 & IRS2 has 400 multiplicity in total.

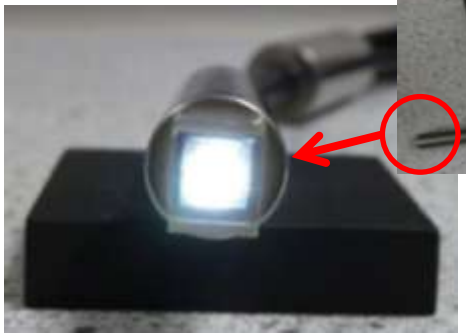
☐ Available spectral resolution

→ Need to await for detailed design studies …

Achievement & on-going progress







Prototype of fiber bundle & IFU with an incoherent fiber re-mapping.

Summary

"SuFAIFS": Subaru Flexibly Addressable Integral Field Spectrographs
Adding a new significant observing capability to the telescope

Main features

- ✓ Flexible & optimal selections of spaxels on the focal plane will be allowed: "DFS" → MOS+multi IFU+IFS
- ✓ A single focal plane is "shared" by N(>=2) spectrographs.

Other details (mostly tentative)

- Ns/Cs focus, (RI)zYJH? → Could be assisted by MOAO/GLAO.
- Adding a fiber-feed option to existing spectrographs?(FMOS, MOIRCS, IRCS, FOCAS …)
  → Heterogeneous/multimode spectroscopy
- More spaxels? Better "homogeneity" on a focal plane?
  → Spectrographs for SuMIRe/PFS may be a possibility?
  Still AO-assisted in the (RI)zY band with full-depletion type CCD?

Current status & near-future plans

- R&D is on-going in Durham, exploring collaborations including other reseaerch areas (including industrial partners).
- Trying to wrap up technical details & scientific potentials expected by them (with instrument throughput predicted).