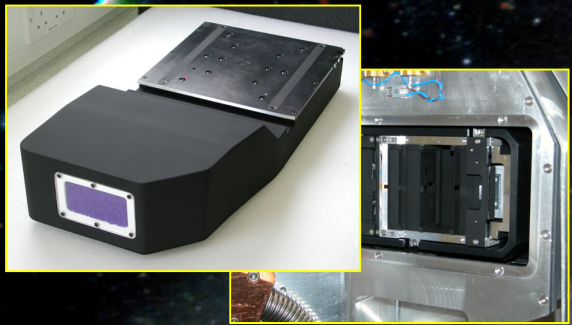
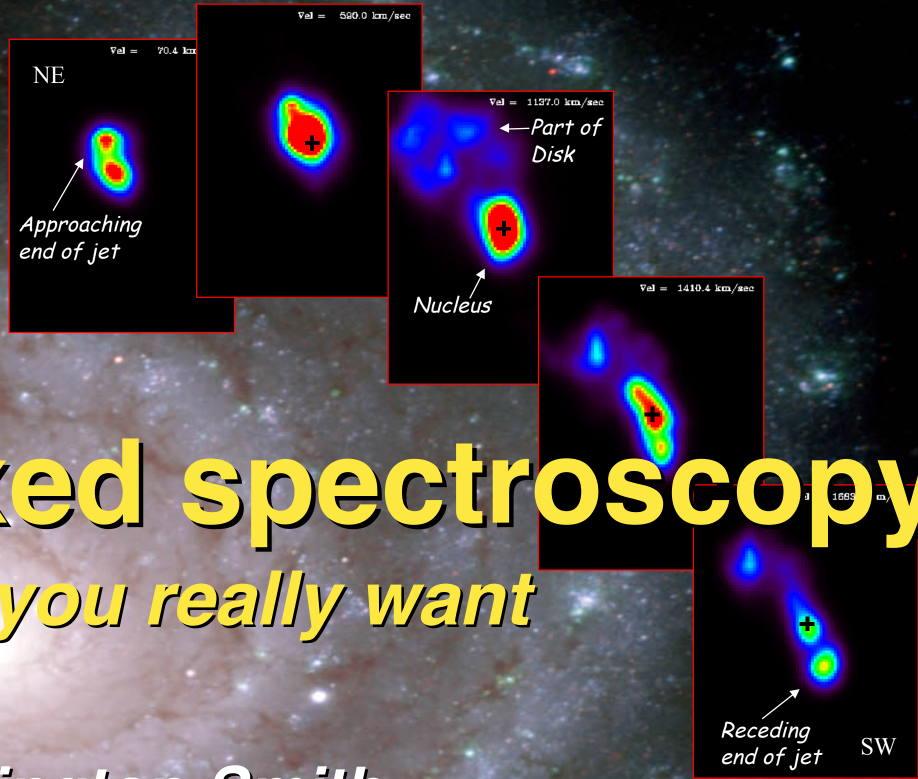




Highly multiplexed spectroscopy

Getting what you really want

Jeremy Allington-Smith
Durham University
Centre for Advanced Instrumentation

Collaborators: Graham Murray, Claire Poppett, Ulrike Lemke, Jürgen Schmoll, Robert Content, George Dodsworth, Ray Sharples, John Girkin, Gordon Love, Joss Bland-Hawthorn, Miles Padgett, Robert Thomson, Ajoy Kar, *AstroPhotonica Europa* partners

The main points

- New and recycled ideas for Highly-multiplexed spectroscopy
  - Diverse Field Spectroscopy: *paradigm and technology*
  - Astrophotonics: *cut-price revolution*
- Key to successful exploitation of new observatories for a wide range of astrophysics
- WHT could be the gateway

Collecting the light that we actually want

Poppett, Allington-Smith & Murray 2009 MNRAS 399,433
Murray & Allington-Smith 2009 MNRAS 399, 209
Allington-Smith 2007. MNRAS 379, 143

Advantages of spatially-resolved spectroscopy

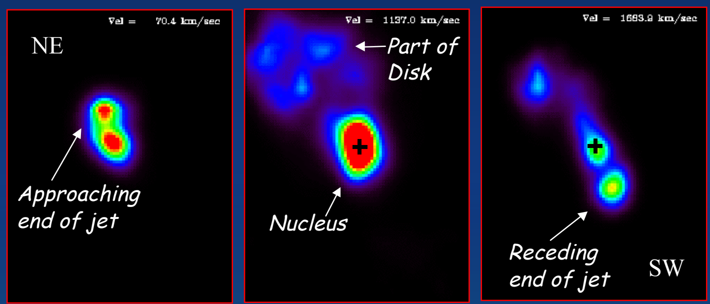
- Avoid aperture effects
- Correct radial velocity
- No ambiguity in slit position
- Spectral and spatial resolution decoupled

The confused and blobby universe

SAURON 24h exposure with WHT of LAB-1/SSA-2 protocluster

Is the whole sky like this at levels accessible to ELTs?

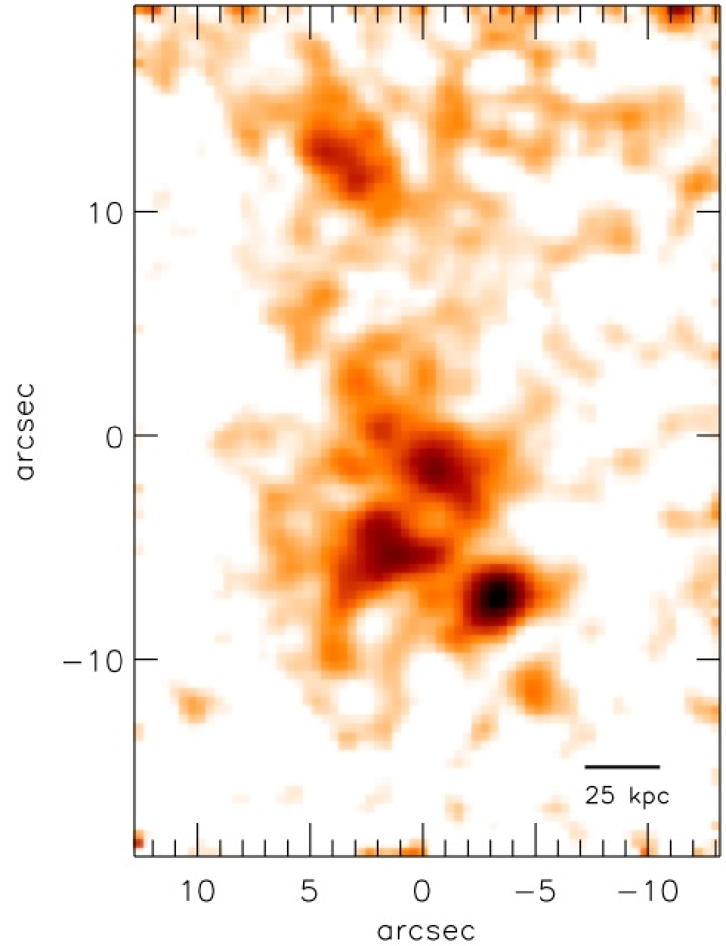
Other traditional targets (GMOS-IFU):



(Gerssen et al. 2006)

What is the most efficient way to address such targets?

(Weijmans et al. 2009)



Dilute sampling

ELTs ➔ 10^{10} - 10^{12} $\lambda(\mu m)^{-2}$ spatial elements in fully-corrected FOV

$\Rightarrow$ 10^{14} - 10^{16} $\lambda(\mu m)^{-2}$ detector pixels for spectroscopy

WHT ➔ 10^{8} - 10^{10} $\lambda(\mu m)^{-2}$ spatial elements in fully-corrected FOV

$\Rightarrow$ 10^{12} - 10^{14} $\lambda(\mu m)^{-2}$ detector pixels for spectroscopy

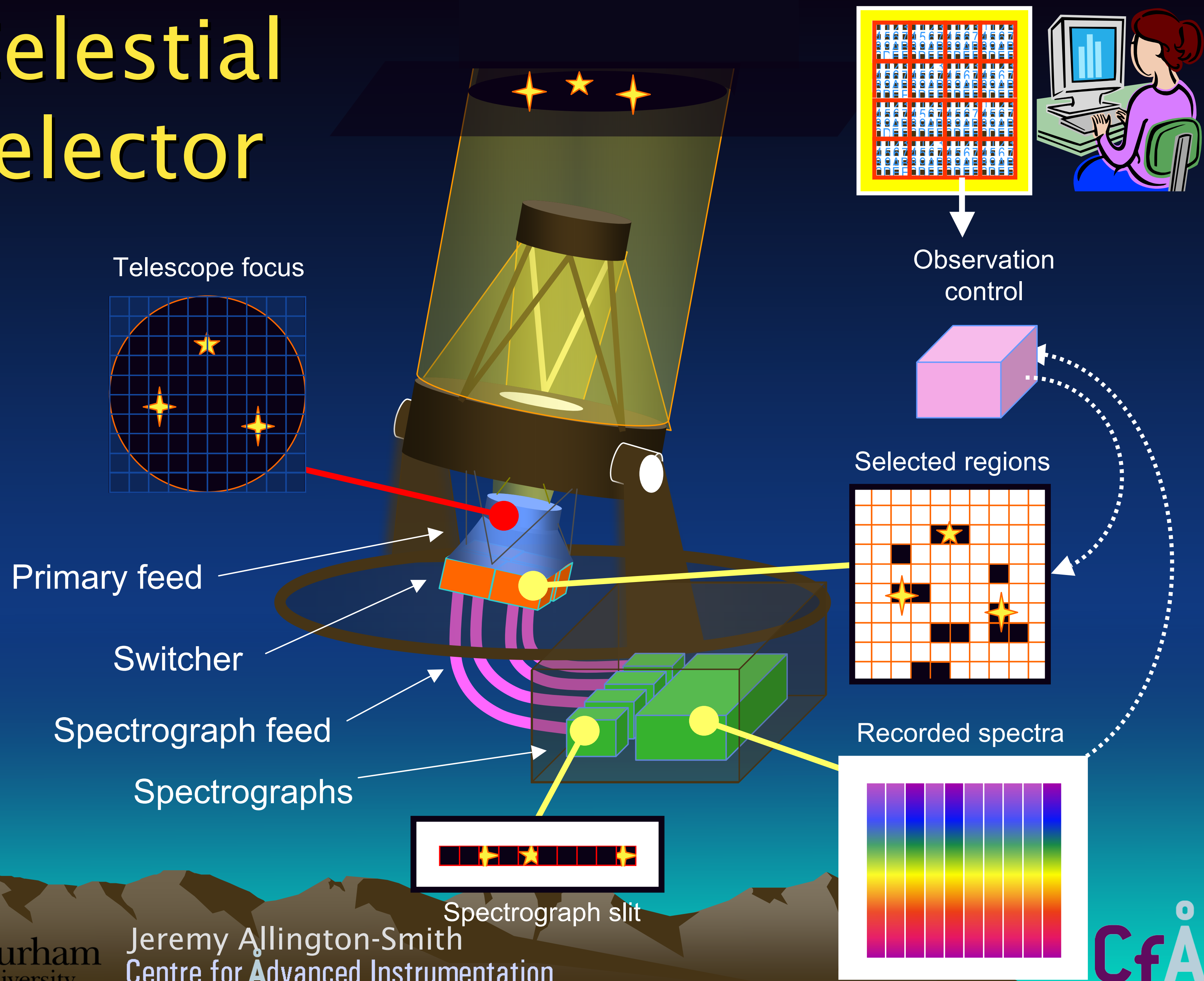
$\Rightarrow$ select only specified Regions of Interest (RoIs)

ELTs will often target clumpy & confused distributions
(proto-galactic objects under assembly; IMBH & SMBH hosts)

Need to address arbitrary distributions of targets: MOS+IFS =

Diverse Field Spectroscopy

Celestial Selector



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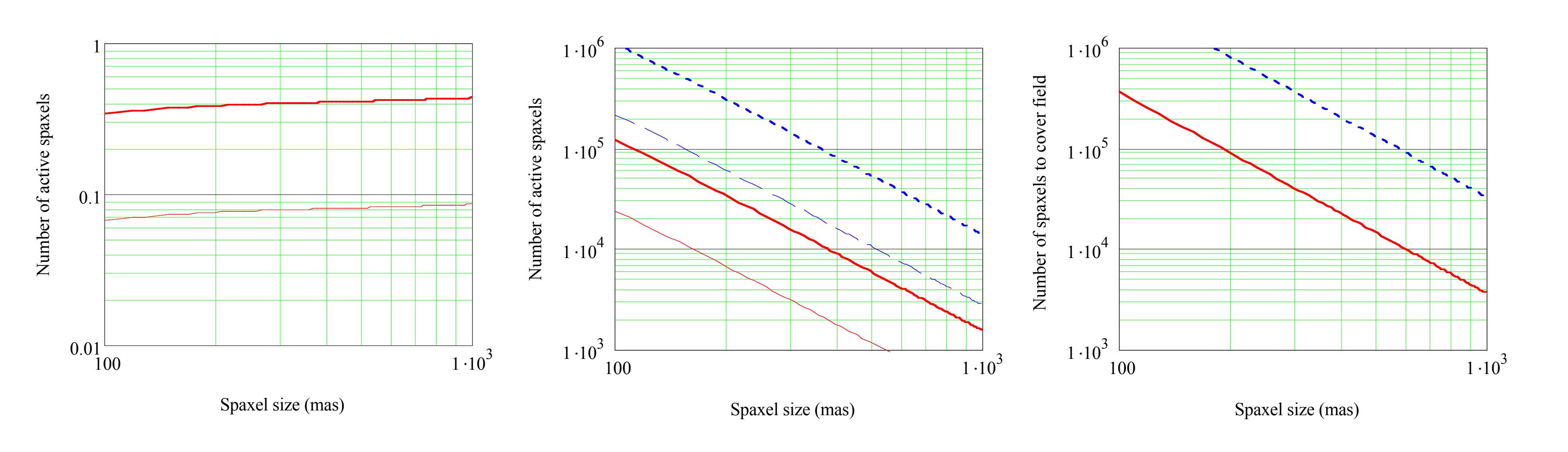
CfAI

DFS requirements

Cosmological applications (ELT FOV) ➔

– 10^5 - 10^6 potential inputs
– 10^3 - 10^4 selectable outputs
– Downselection factor 10-100

- But smaller formats useful (e.g. microscopy, demonstrators)



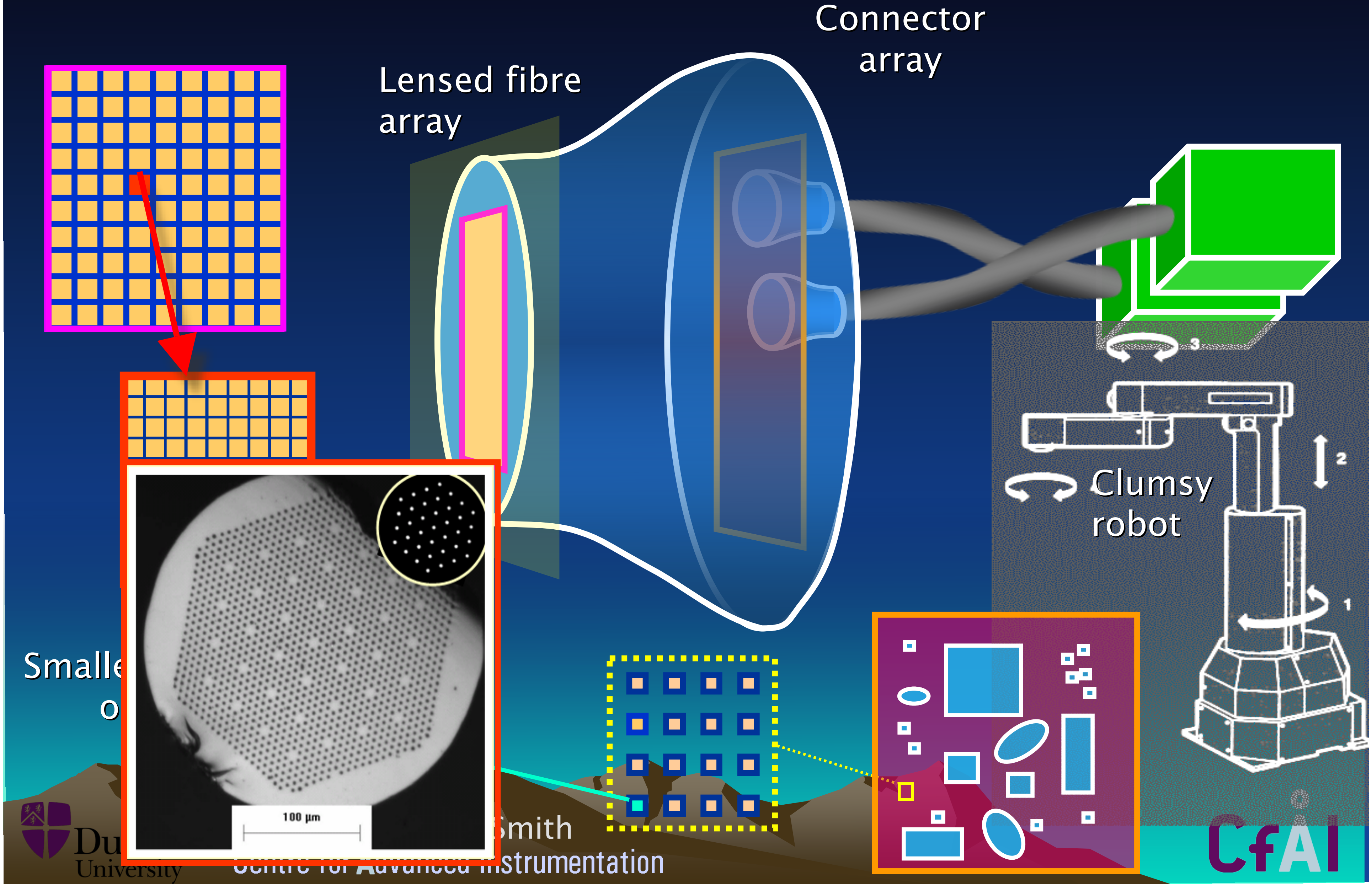
DFS Technology

Durham University
Jeremy Allington-Smith
Centre for Advanced Instrumentation

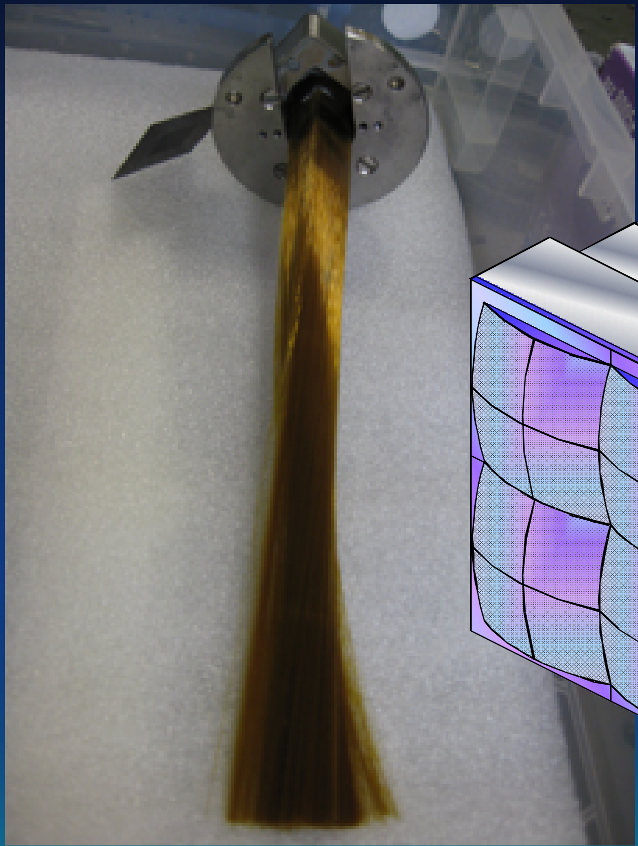
CfAI

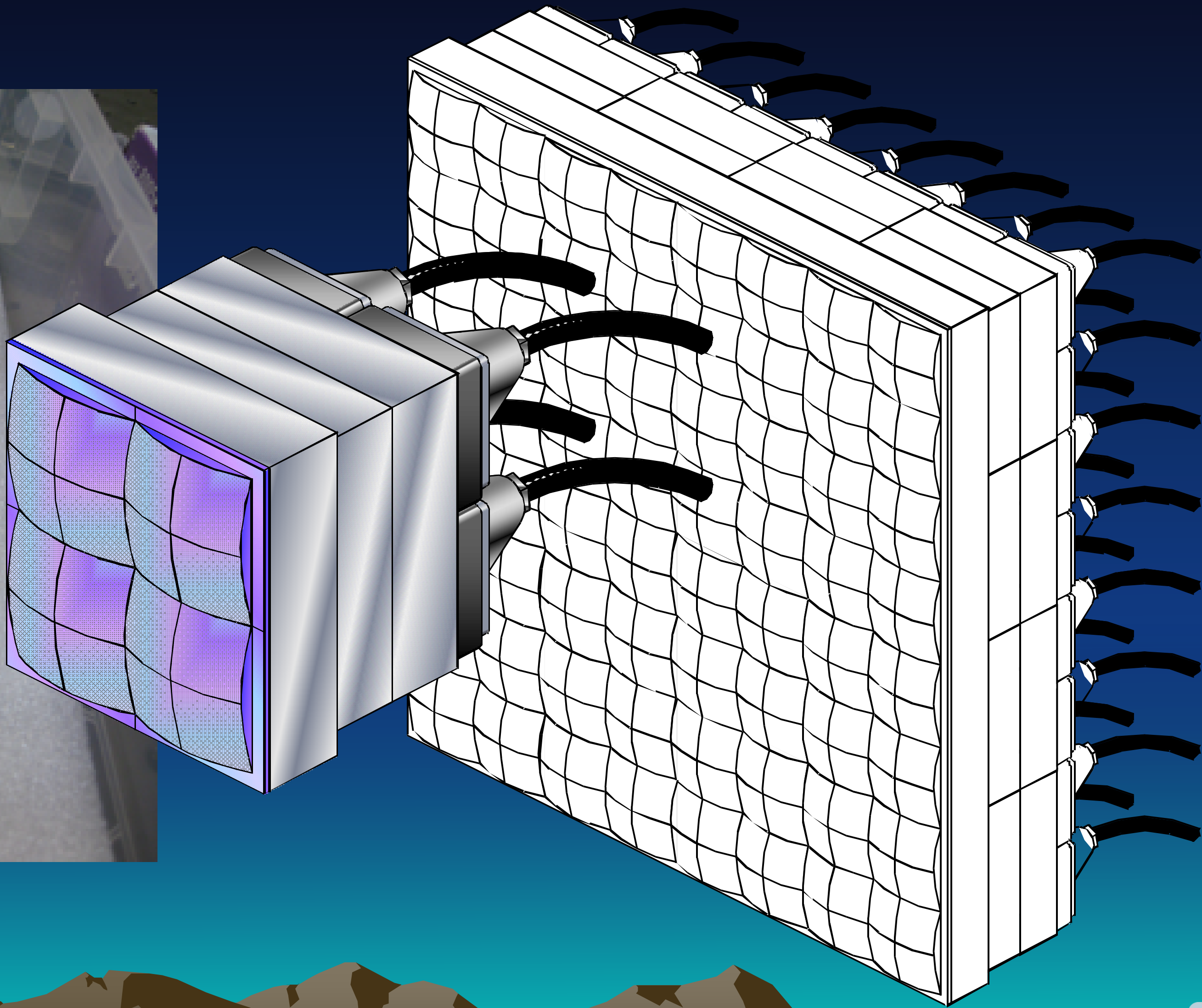
Graham Murray, CfAI, Durham)

Massively multiplexed fibres



Prototyping





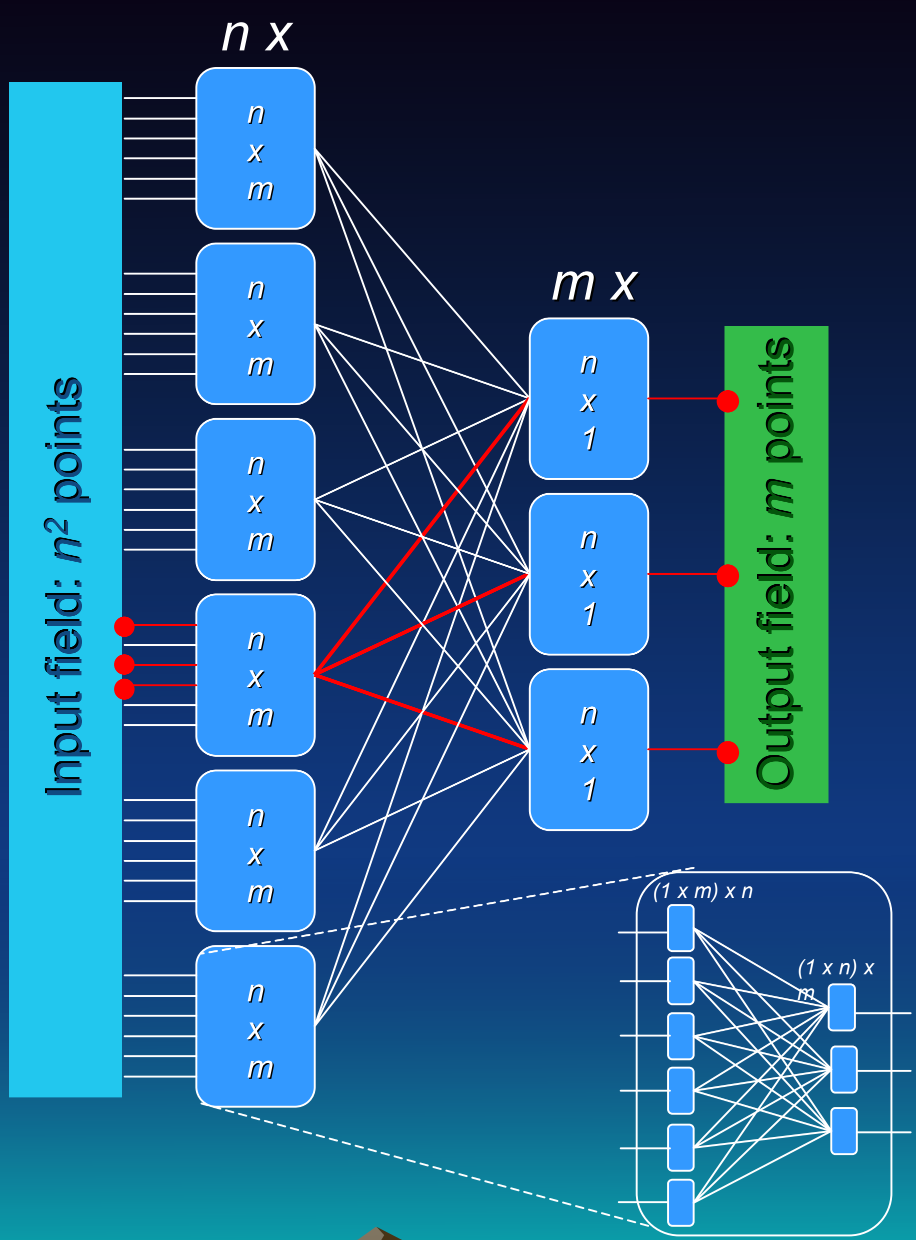
Fibre optical switches

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, $F = n^2/m$

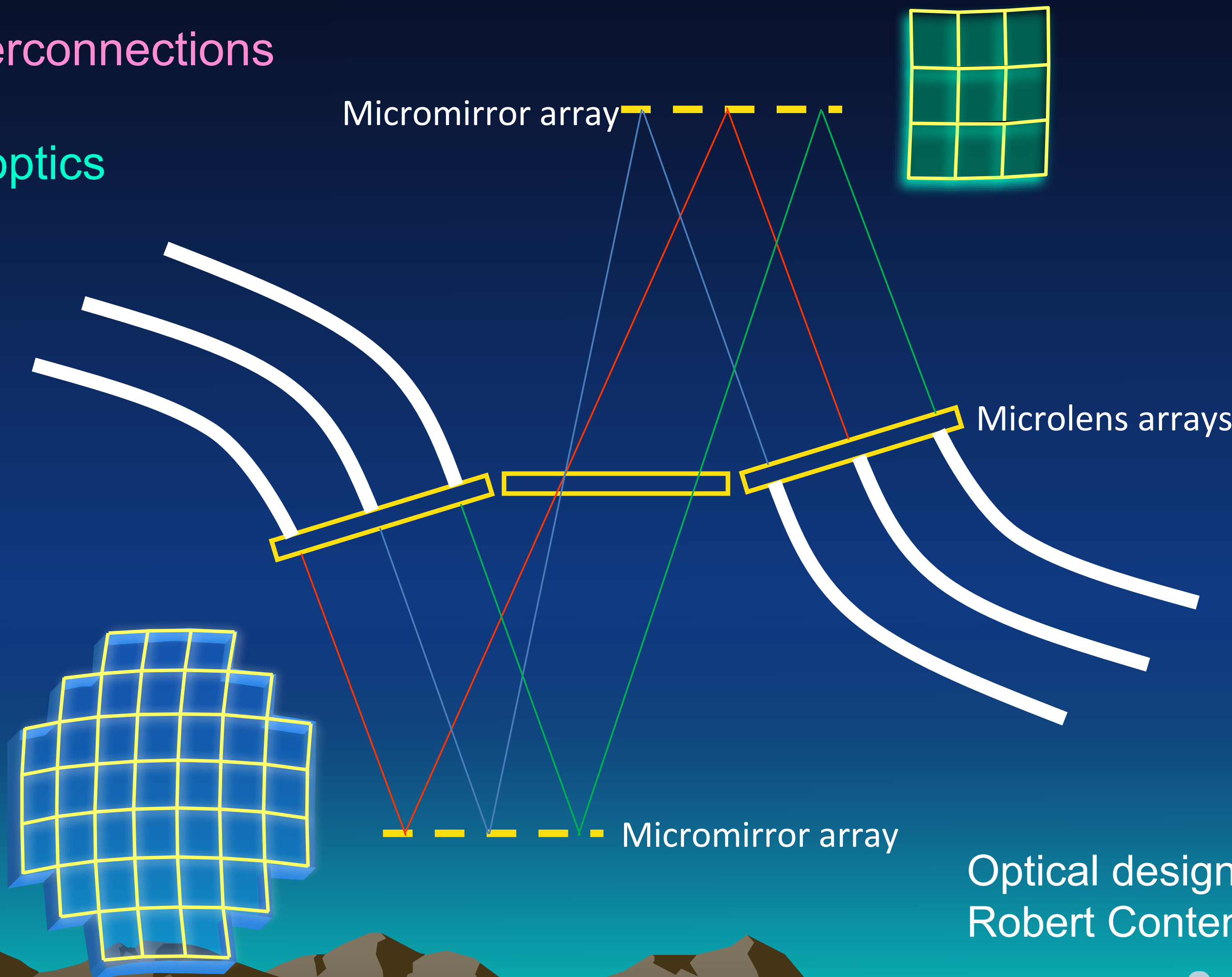
Example shown: $n = 6$, $m = 3$ with contiguous field (red) so $N_I = 36$, $N_O = 3$, $F = 6$

[Note: IP protected]



Free-space optical switches

Many fewer interconnections
but
More complex optics

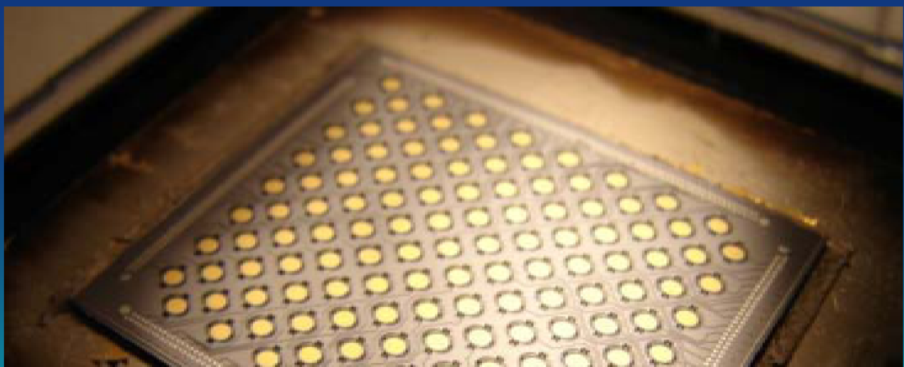


Optical design:
Robert Content

Durham University
Jeremy Allington-Smith
Centre for Advanced Instrumentation
CfAI

Free-space technologies

Fully Steerable MEMS



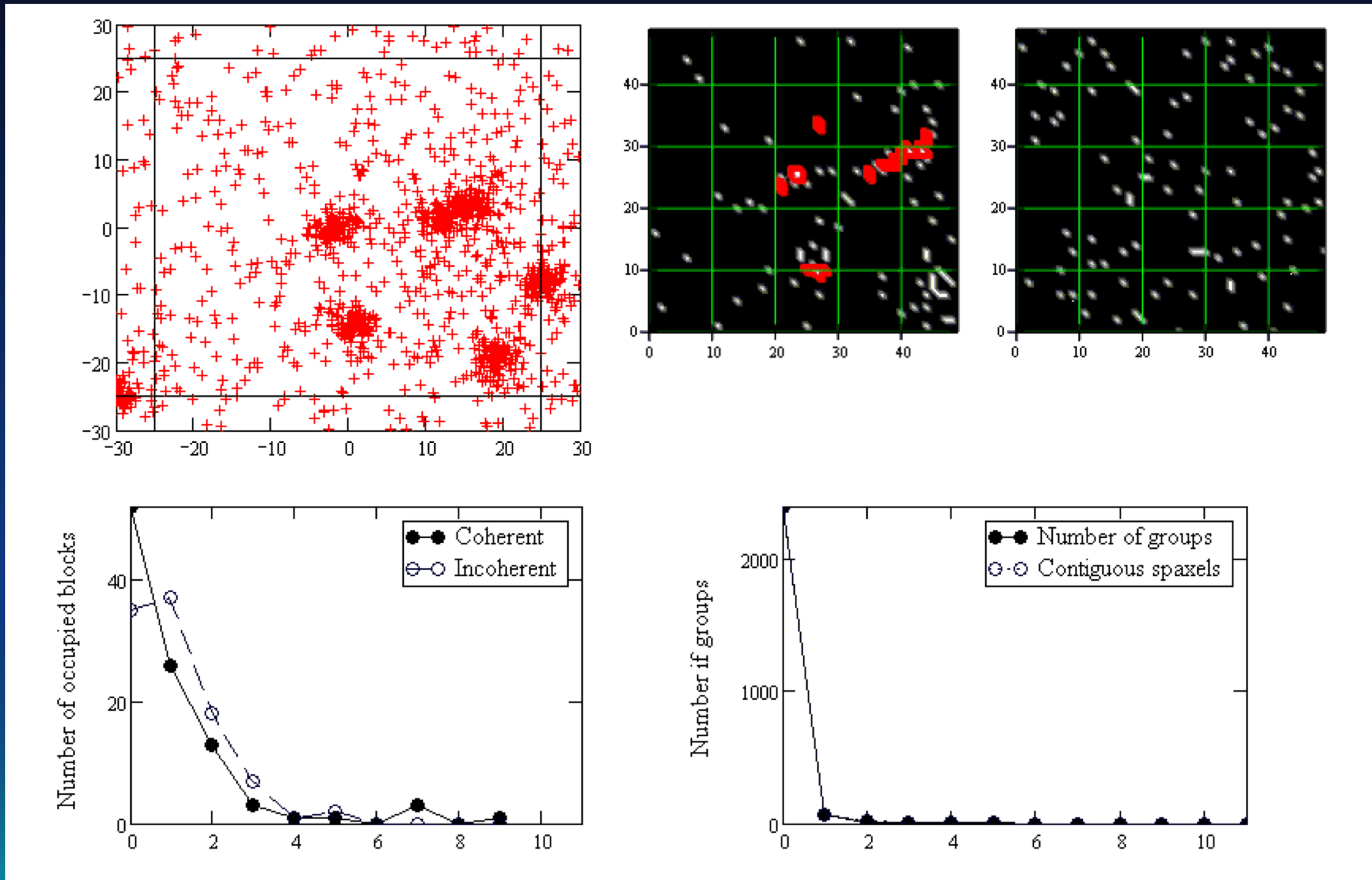
Remapping

- If you cannot use switches in cascade
  - $N_O = m$ points in the field of $N_I = n^2$ points can be routed to the output with downselection factor, $F = n^2/m$
  - But only n x 1 switches are available (no cascade)

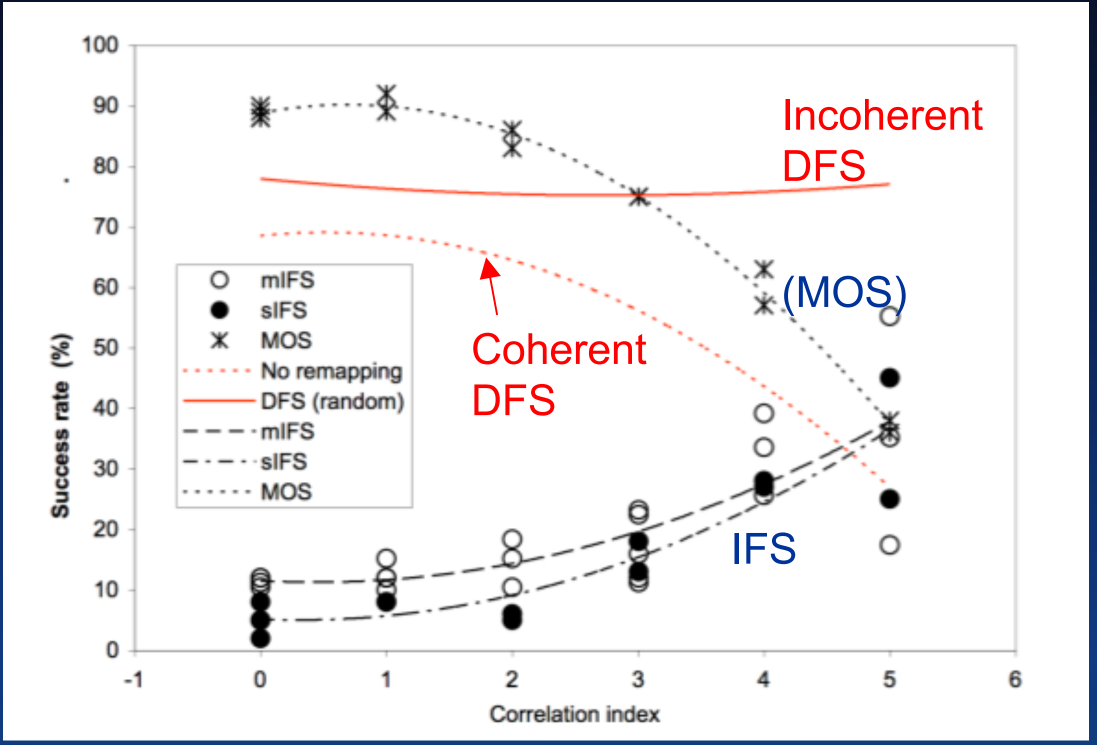
- ⇒ *Contiguity is lost since only 1 output from each group of n*
- *can be switched to the output*

- *Solution:*
  - Randomise input-output mapping in fibre bundle to give finite probability that adjacent inputs can be routed to the output

Simulated RoI selection



Incoherent remapping

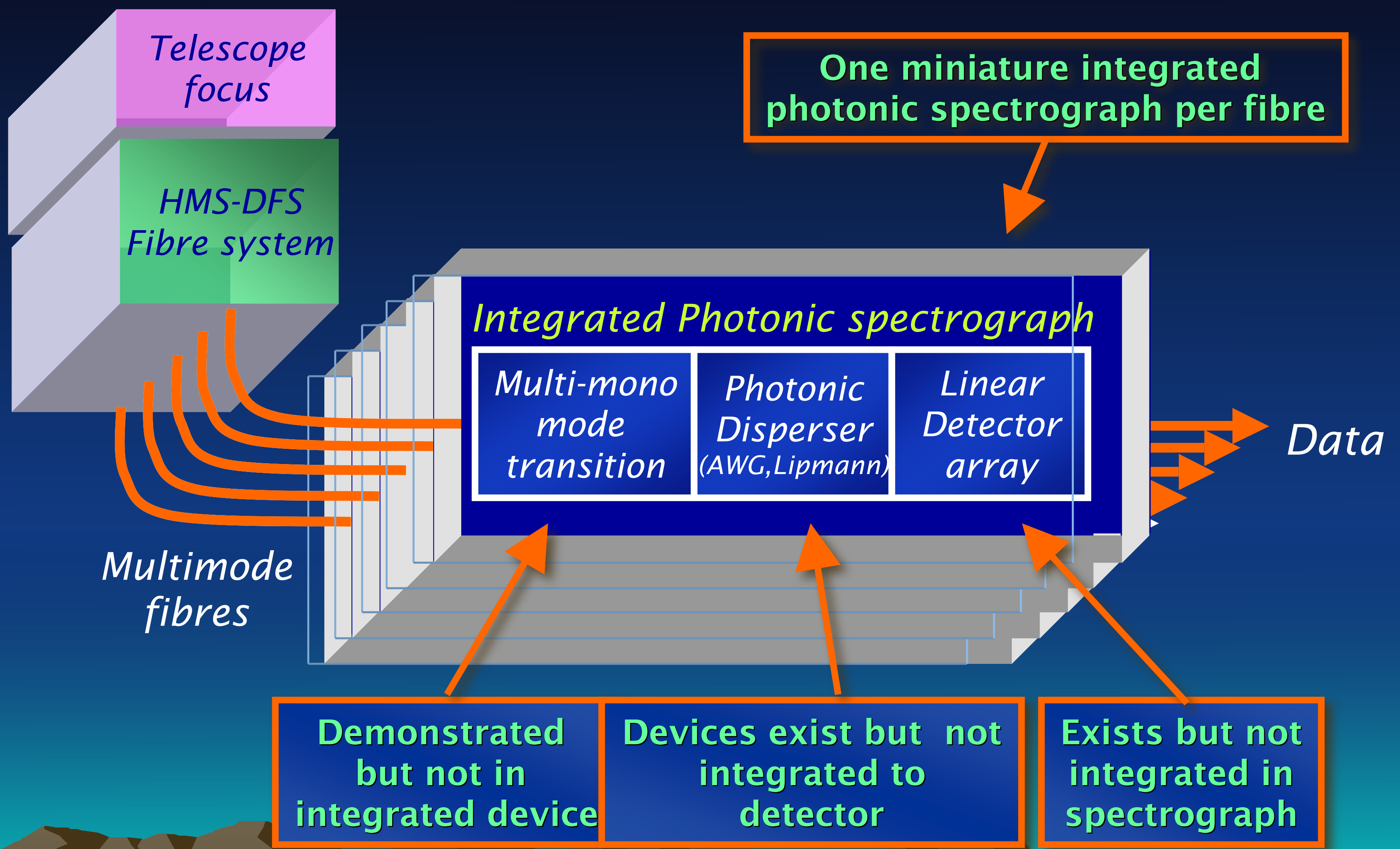


(Poppett, Allington-Smith and Murray 2009, MNRAS)

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

More radical options

Photonic spectrograph



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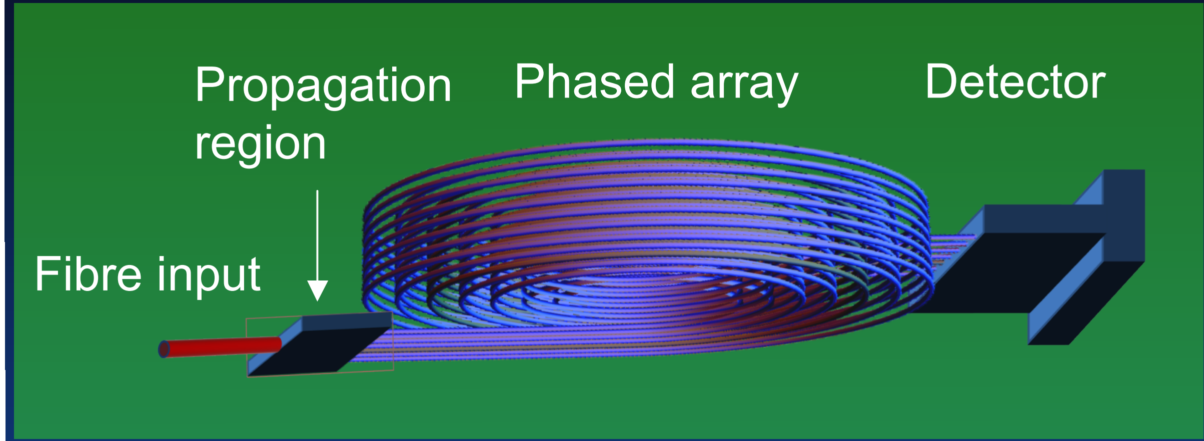
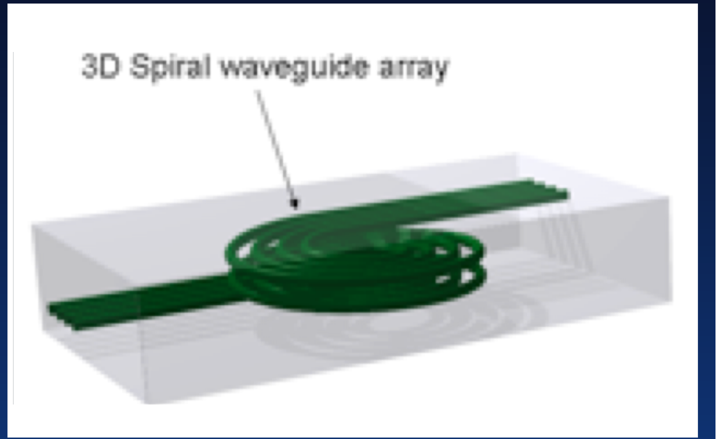
Phased photonic disperser

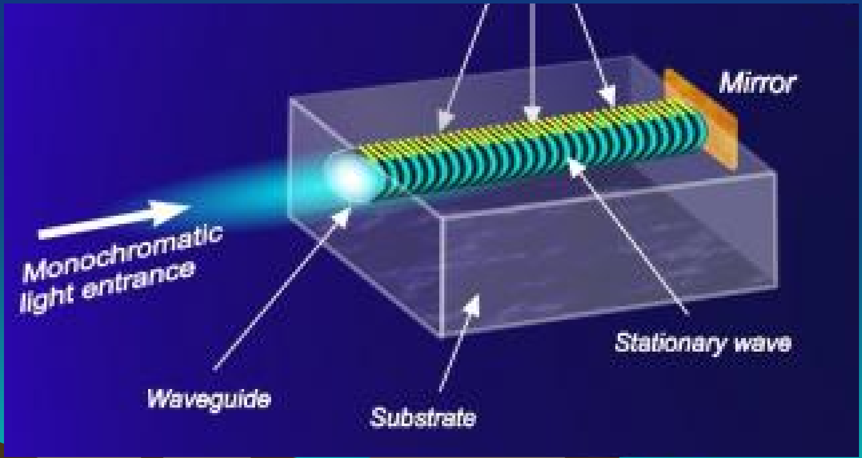




Highly compact AWGs adapted and prototyped (Sydney)

Implementation with Ultrafast Laser Inscription (HWU)

Lipmann interferometry (Grenoble)



Conclusions

- Maximum flexibility in sampling the field using *Diverse Field Spectroscopy*
- More radical options using *Astrophotonics*
- To demonstrate the technology we need *money and telescope access!*
- **Could the WHT become the channel through which these ideas become reality?**

Allington-Smith & Bland-Hawthorn; MNRAS in press
Czetojevic et al. 2009. Optics Express, Vol. 17, No.21, 18643
LeCoarer et al. Nature 2007. Photonics 1, 473
Thomson, Kar & Allington-Smith, 2009. OpEx 17, 1963
Poppett, Allington-Smith & Murray 2009 MNRAS 399,433
Murray & Allington-Smith 2009 MNRAS 399, 209
Allington-Smith 2007. MNRAS 379, 143

Issues to address

- *Unique facility aimed at niche science?*
  - What aspects of the telescope are unique? [but photon-starved]
  - What niches are compelling? [Cosmic EoS; G-archeology, planets]
  - Dedicated to follow-up? [planets]
  - What is the competition & window of opportunity?
- *Excellent facility to empower community?*
  - Who are the community, what are their interests?
  - Is the telescope excellent in every area?
  - What other facilities are available?
- *Testbed for future observatories?*
  - Relevance and scalability? [few photons, low spatial resolution]
  - Who pays?