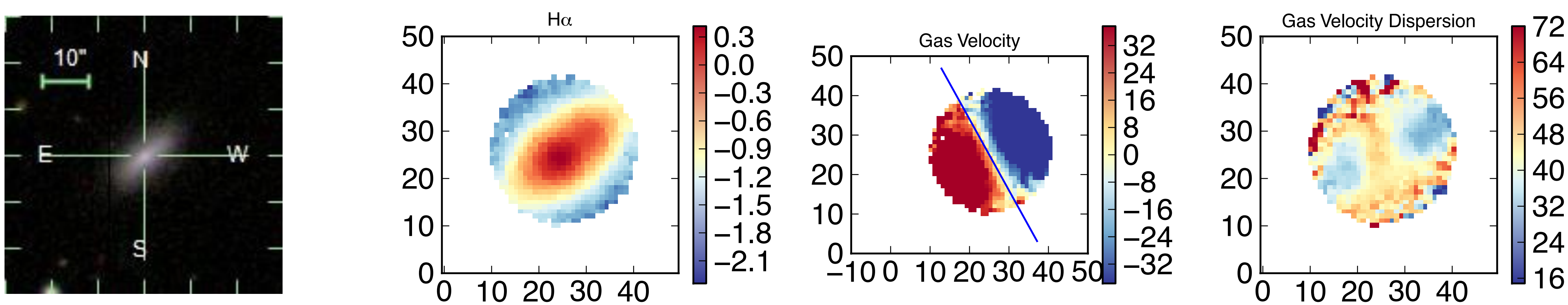
Australian Government
Department of Industry, Innovation and Science

An IFU survey of redshift one galaxies

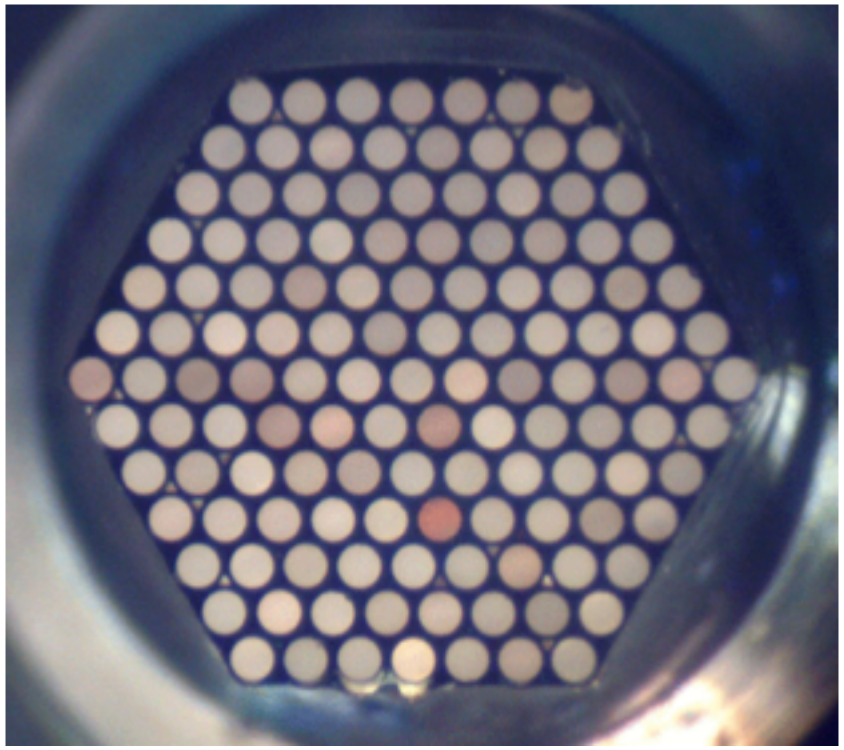
Chris Lidman



With help from Julia Bryant and Scott Croom

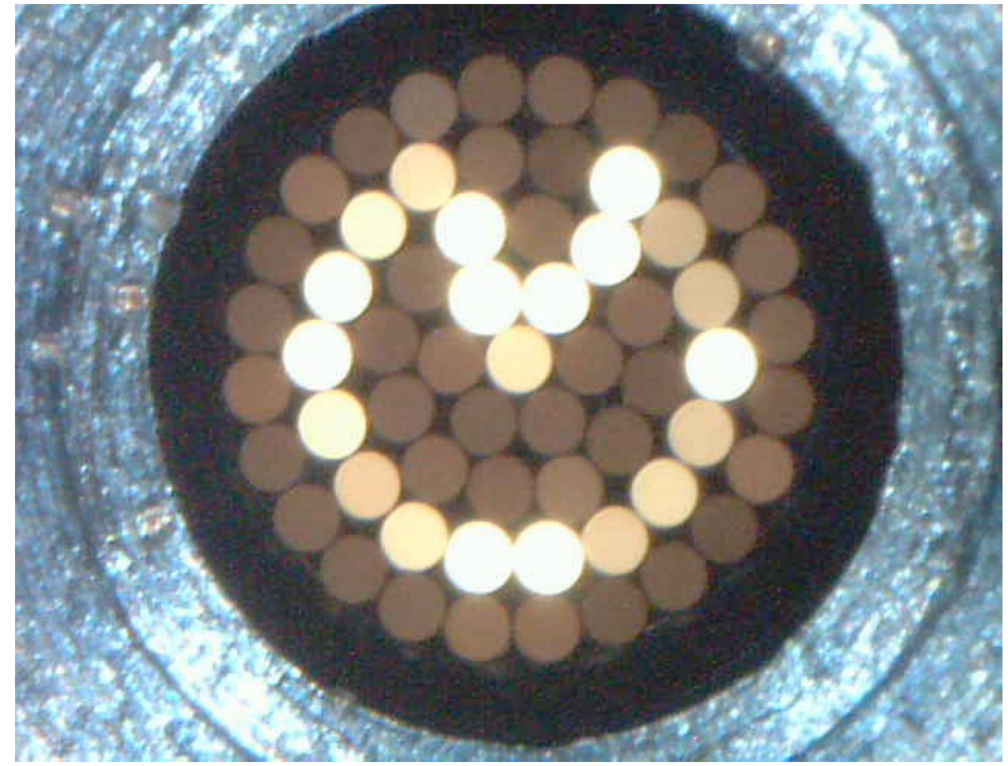
Fibre Integral Field Units

MaNGA

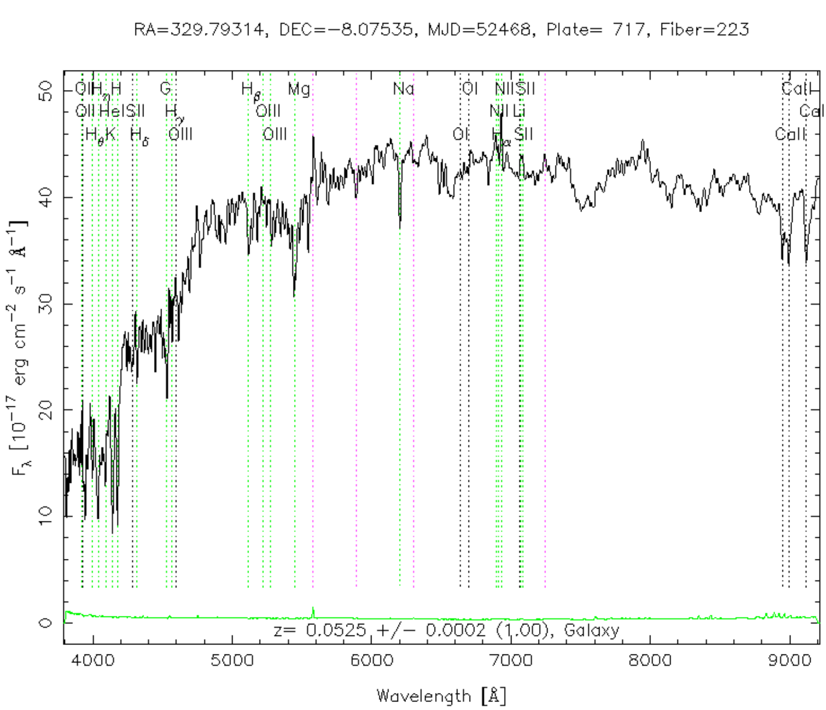


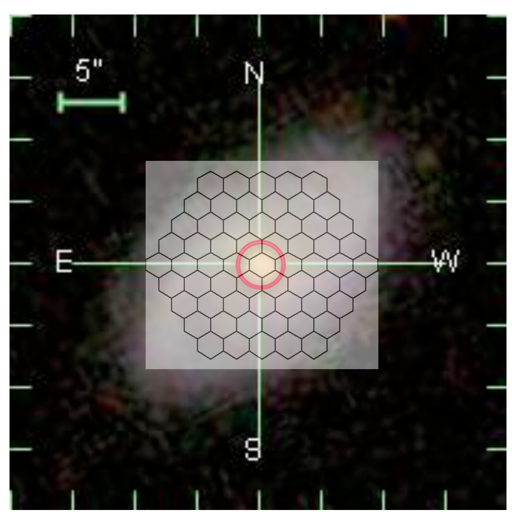
32”

SAMI

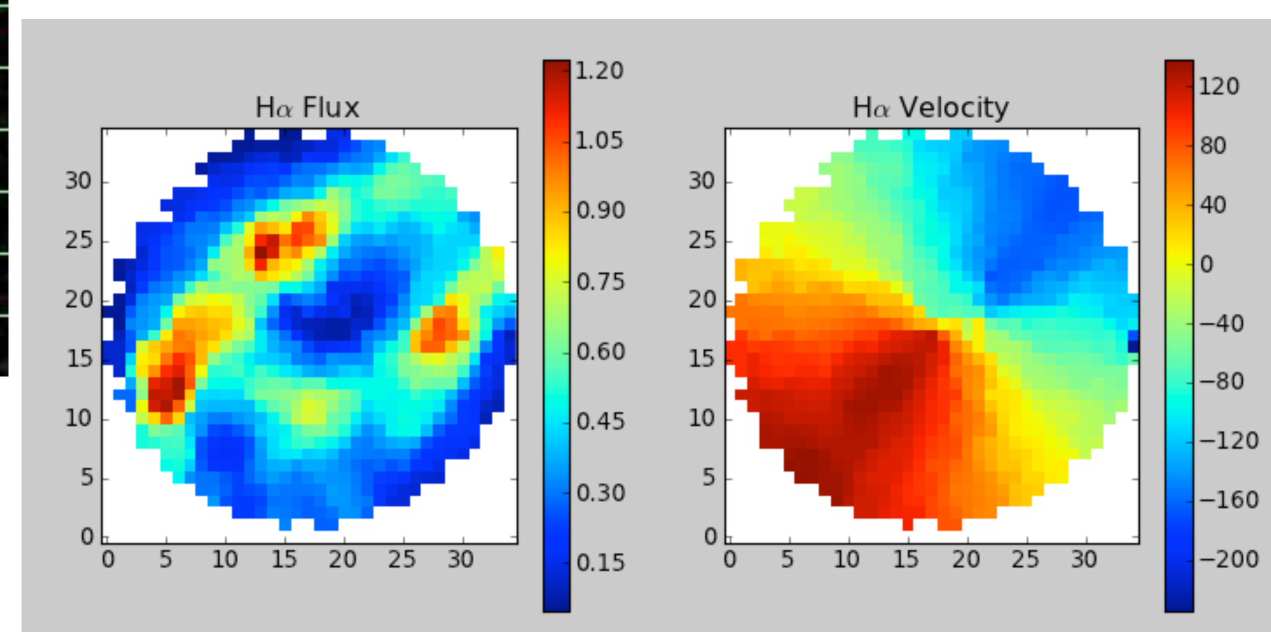


15”





Single fibre



Local galaxy IFU surveys

The SAMI survey - http://sami-survey.org/

- 3,400 galaxies
- Median redshift z~0.05
- Started in March 2013, ends 2018

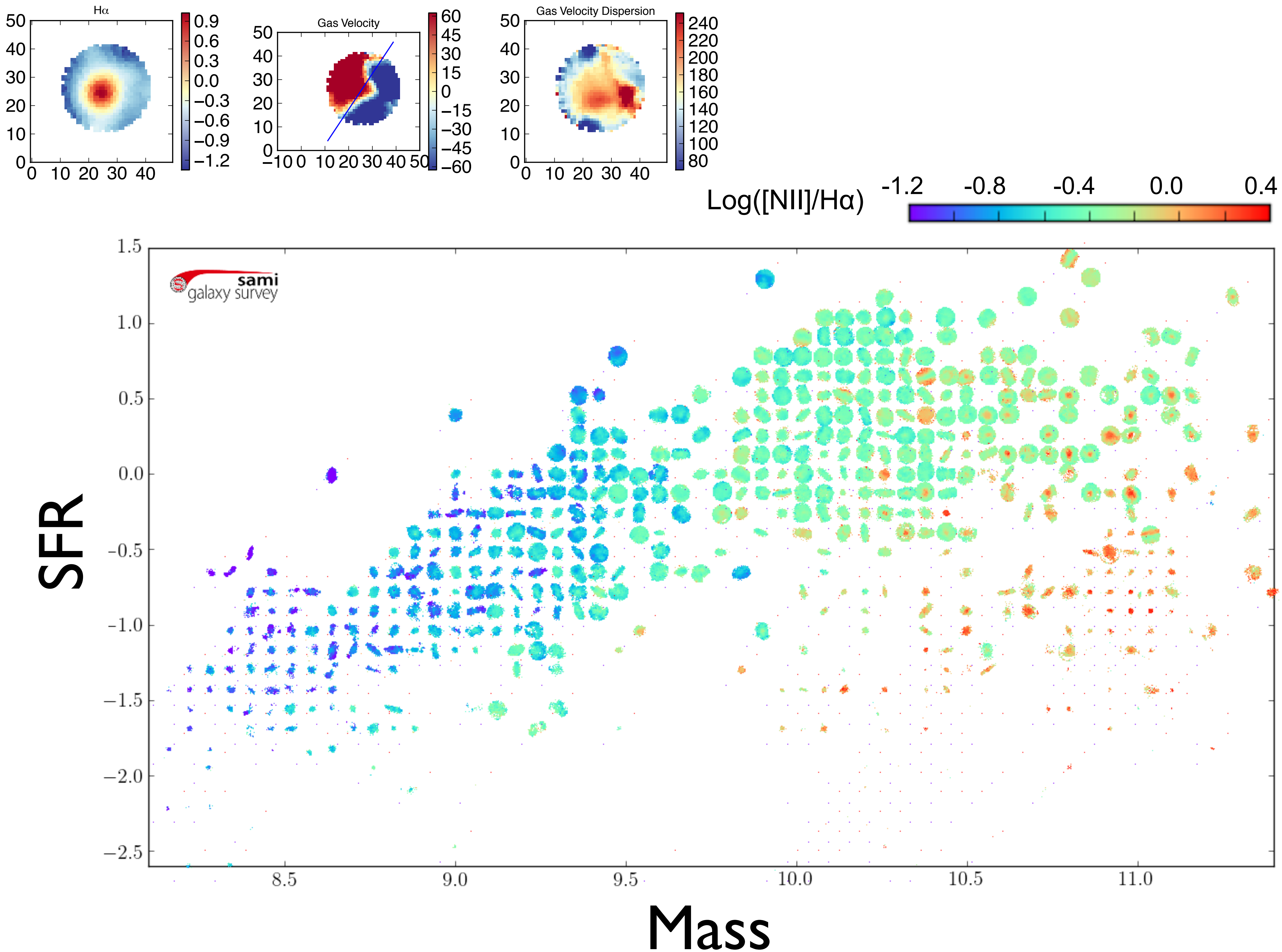
The MaNGA survey - http://www.sdss.org/surveys/manga/

- 10,000 galaxies
- Median redshift z~0.03
- Started in March 2014, ends 2020

The HECTOR survey

- 10,000+ galaxies
- Starting in 2019
- Larger IFUs

The SAMI survey

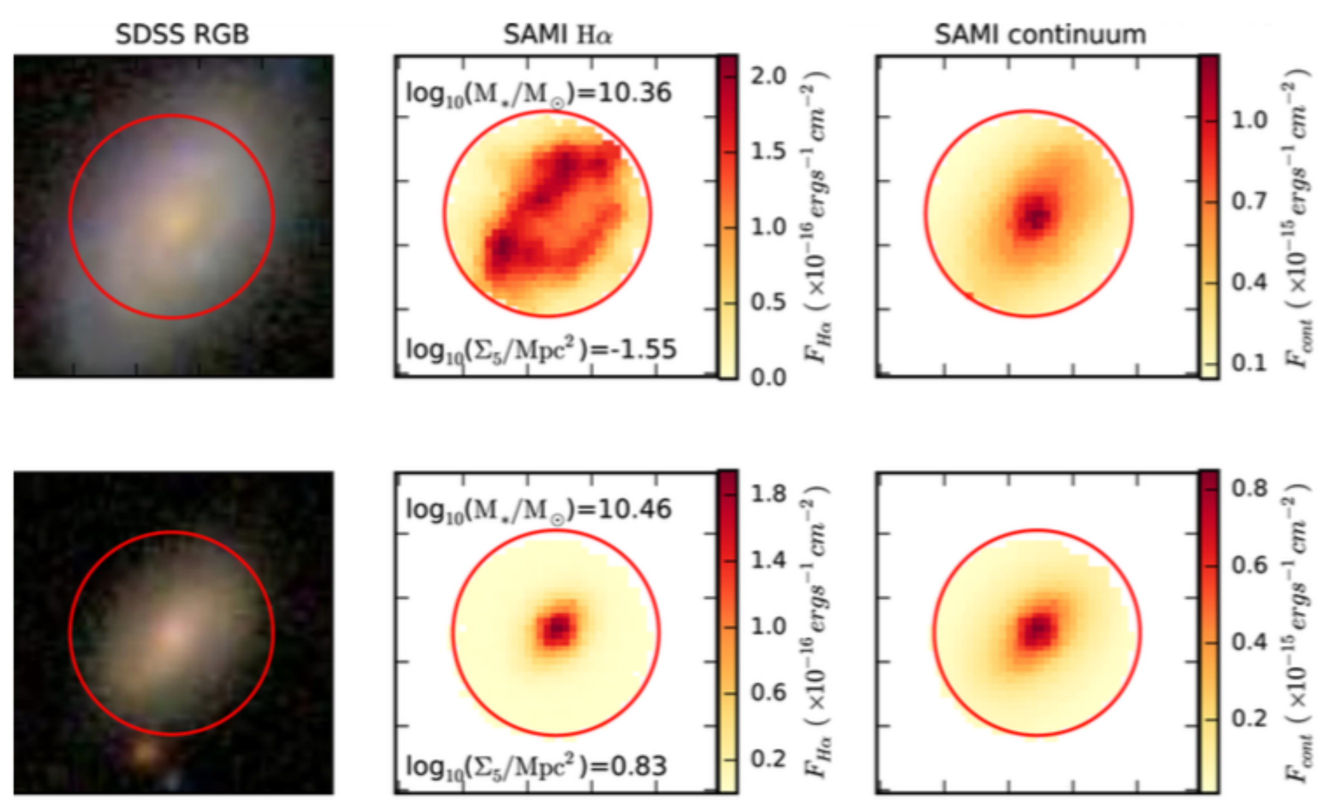


Science results from SAMI and MaNGA

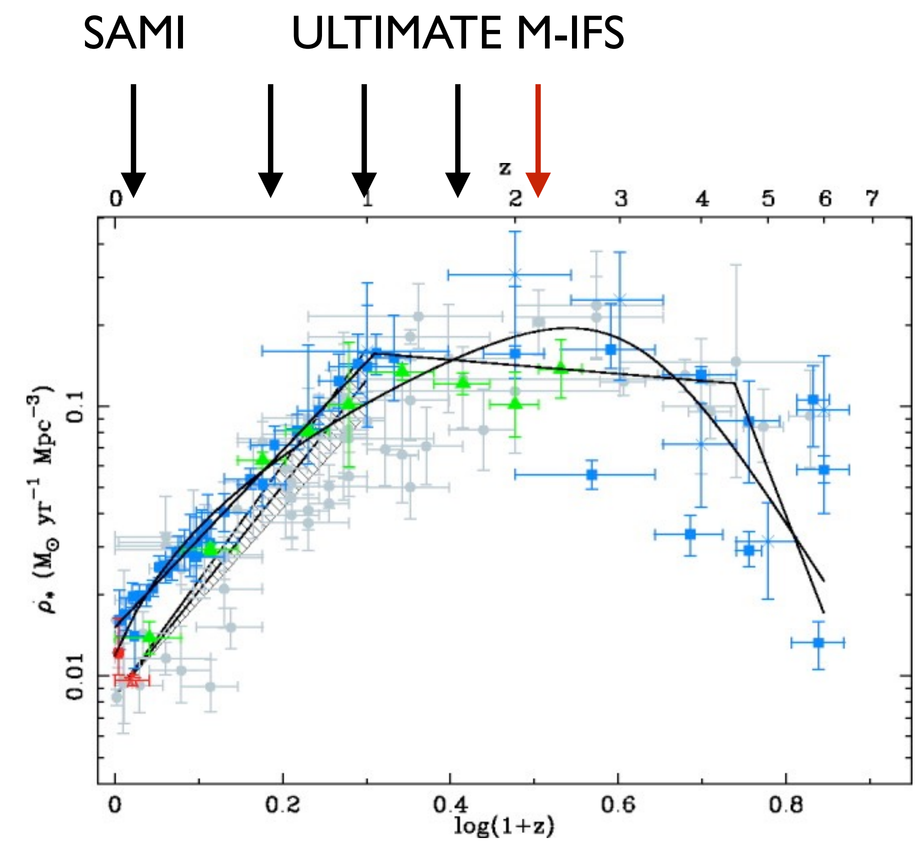
146 papers with SAMI or MaNGA in the title

Enormous diversity in the science

- Environmental quenching occurs outside-in (Schaefer++2017)
- Mass quenching occurs inside-out (Ellison++2018)
- Star formation is not enough to explain gas turbulence in disk galaxies (Zhou++2017)
- The "Kinematic" morphology - density relation (Green et al. 2018, Brough++2017)
- The ubiquity of low-ionisation emission line regions (Belfiore++2016)
- The ubiquity of galactic scale outflows - 40% of edge on galaxies (Ho++2016)
- Tight local mass density - metallicity relationship (Barrera-Ballesteros++2016)



The Universe at z=1



- It is 7.8 billion years younger (middle age)
- It is 8 times denser
- The SFR density is 10 times higher, i.e. more SNe
- The AGN number density is ~100 times higher
- Galaxy clusters are a factor of 3 less massive
- Higher gas fractions

How do the processes that shape galaxies at z=1 differ in importance from the ones we see today?

For example, one might expect galaxy scale winds to be far more common

ULTIMATE Multi-object IFU Galaxy Survey

A SAMI-like at three (four) redshift intervals: z~0.6, 0.9, and1.4 (2.2)

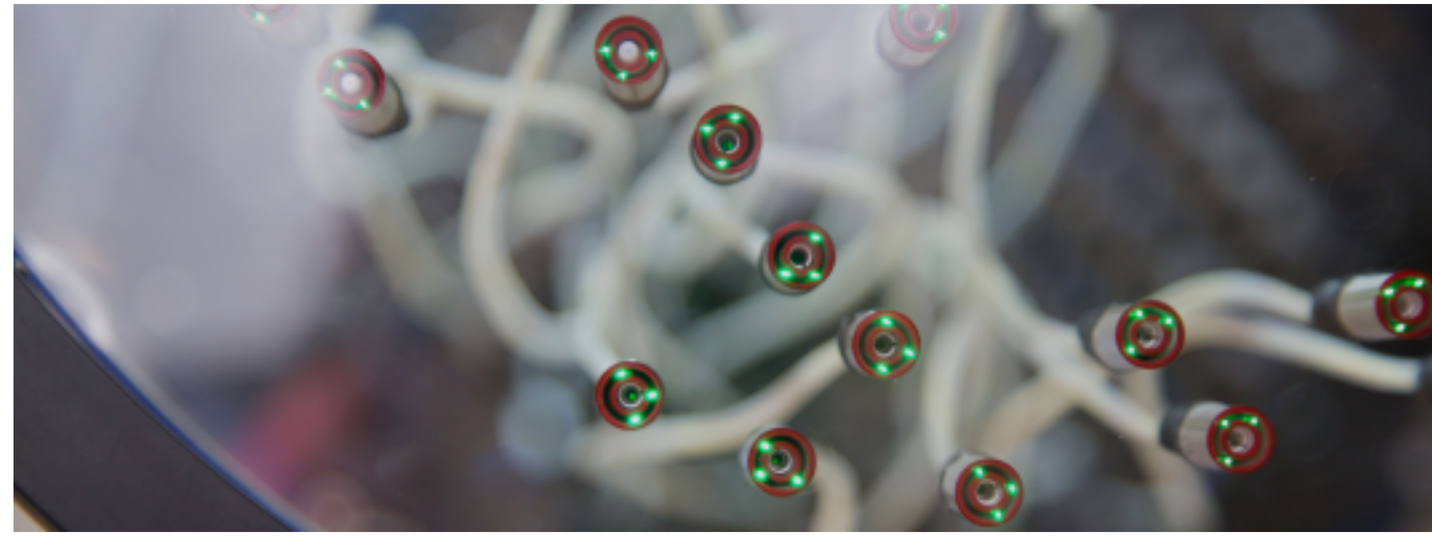
• 3000 galaxies
• Targets from the COSMOS and SXDF-UDS fields (HSC ultra-deep survey and forerunner ULTIMATE imaging surveys)

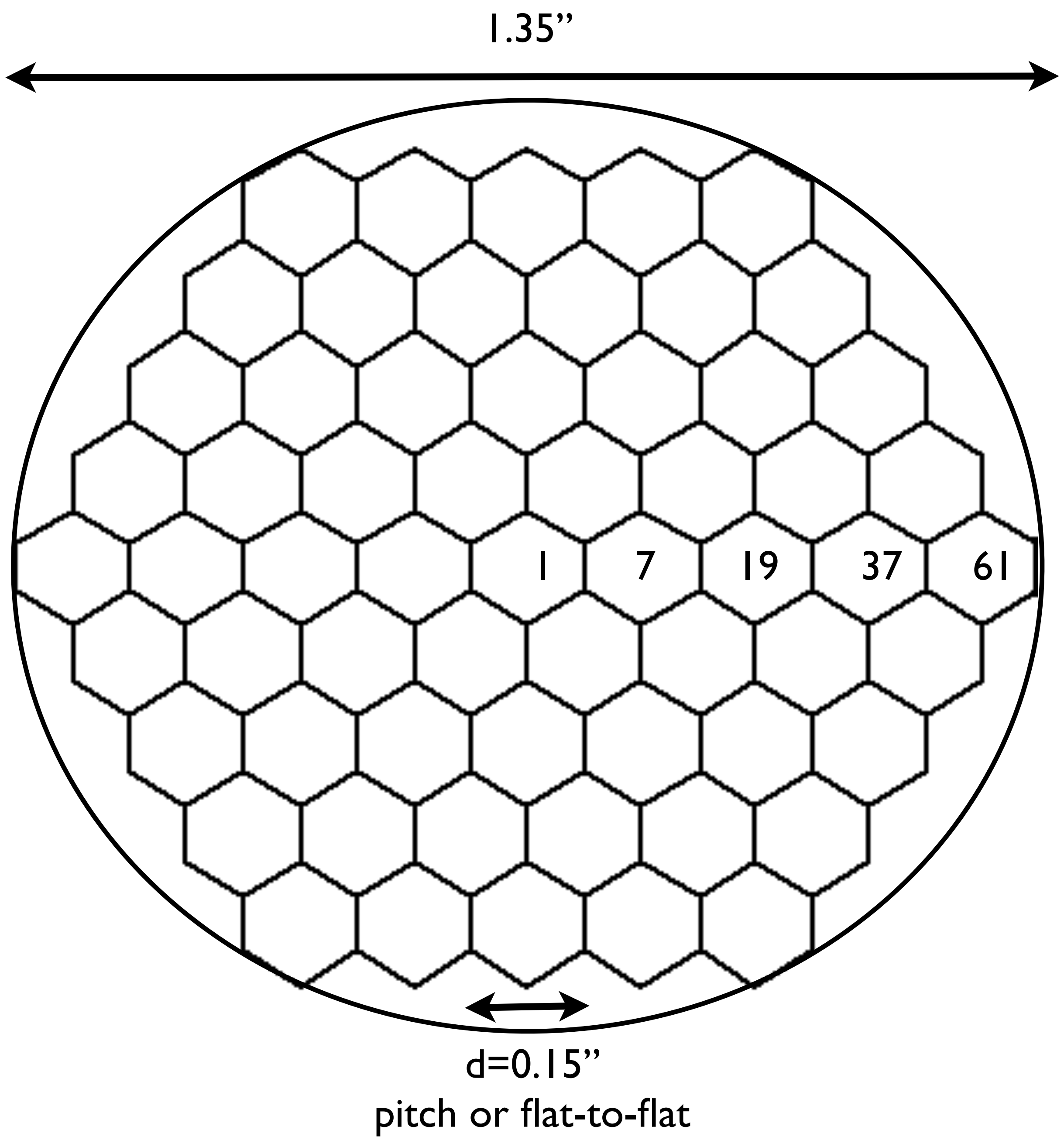
› **What are the physical processes responsible for galaxy transformations?**
- Morphological and kinematic transformations; internal vs. external; secular vs. fast; ram pressure stripping; harassment, strangulation; galaxy–group/cluster tides; galaxy-galaxy mergers; galaxy-galaxy interactions…

› **How does mass and angular momentum build up?**
- The galaxy velocity function; stellar mass in dynamically hot and cold systems; galaxy merger rates…

› **Feeding and feedback: how does gas get into galaxies, and how does it leave?**
- Winds and outflows; feedback vs. mass; triggering and suppression of SF; gas inflow; metallicity gradients; the role of AGN…

ULTIMATE IFUs

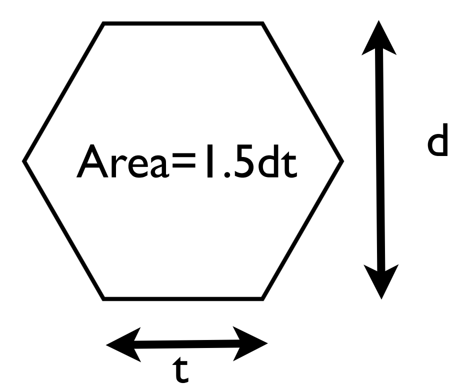




Area= 61 1.5 $d^2 / \sqrt{3}$

=

1.18 sq. arc seconds



SAMI, MaNGA and ULTIMATE IFU

Characteristic	SAMI @ z~0.05	MaNGA @ z~0.03	ULTIMATE @ z~1
Number of IFUs	13	17	13
FoV of positioner	3.6 Mpc (60') diameter	3.2 Mpc (90') diameter	7.2 Mpc (15') diameter
FoV of IFU	15 kpc (15")	7.2-19.3 kpc (12"-32")	11.0 kpc (1.35")
Number of fibres per IFU	61	19-127	61
Fibre pitch	1.6 kpc (1.6")	1.2 kpc (2")	1.2 kpc (0.15")
Minimum sep.	30kpc (30")		160 kpc (20")
Spectral resolution	1,700-4500	2,000	3,000-5,000
Telescope	3.9m	2.5m	8.2m

SINFONI, KMOS and ULTIMATE IFU

Characteristic	SINFONI @ z~1	KMOS @ z~1	ULTIMATE @ z~1
Number of IFUs	1	24	13
FoV of positioner	-	3.5 Mpc (7.2') diameter	7.2 Mpc (15') diameter
FoV of IFU	24.4 kpc (3")	22.7 kpc (2.8")	11.0 kpc (1.35")
Number of fibres per IFU	1024*	196*	61
Fibre pitch	0.8 kpc (0.1")	1.6 kpc (0.2")	1.2 kpc (0.15")
Minimum sep.	-	49 kpc (6")	160 kpc (20")
Spectral resolution	2000-4000	2,000-4,200	3,000-5,000
Telescope	8.2m	8.2m	8.2m
Wavelength	1.1-2.4 mic	0.8-2.5 mic	0.8-1.8 mic

What are we learning from surveys done with SINFONI and KMOS

- SINS, SHiZELS, MASSIV, AMAZE/LSD (one object at a time and prior to KMOS)
- KMOS surveys (24 objects at a time, long integrations)

IFU FoV and spatial resolution: Ideally, a 2” FoV with 0.1” resolution

Spectral resolution: Ideally R=4500 / (1+z)

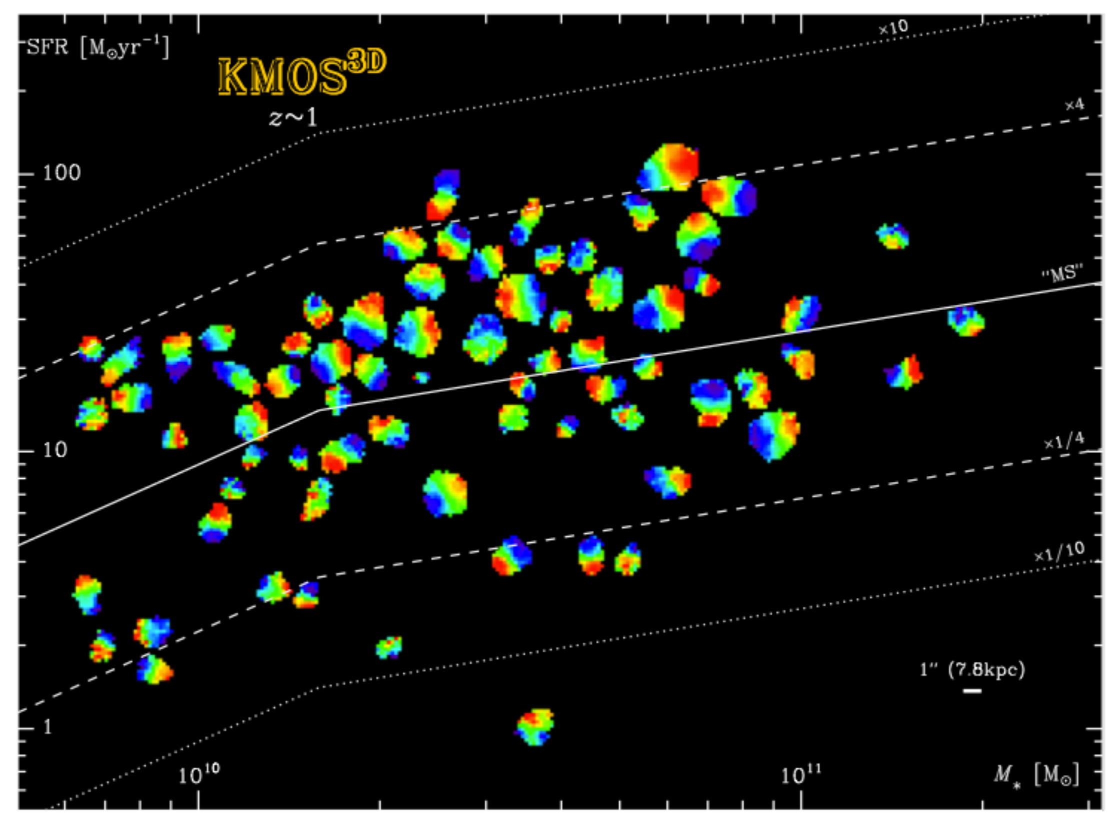
Observations (especially at high-z) are photon starved, integrations are long, and most papers focus on the properties of the gas.

Wisnioski++

Sample size: At high z, samples are ~500
(Cf. At low z, samples are ~10,000)

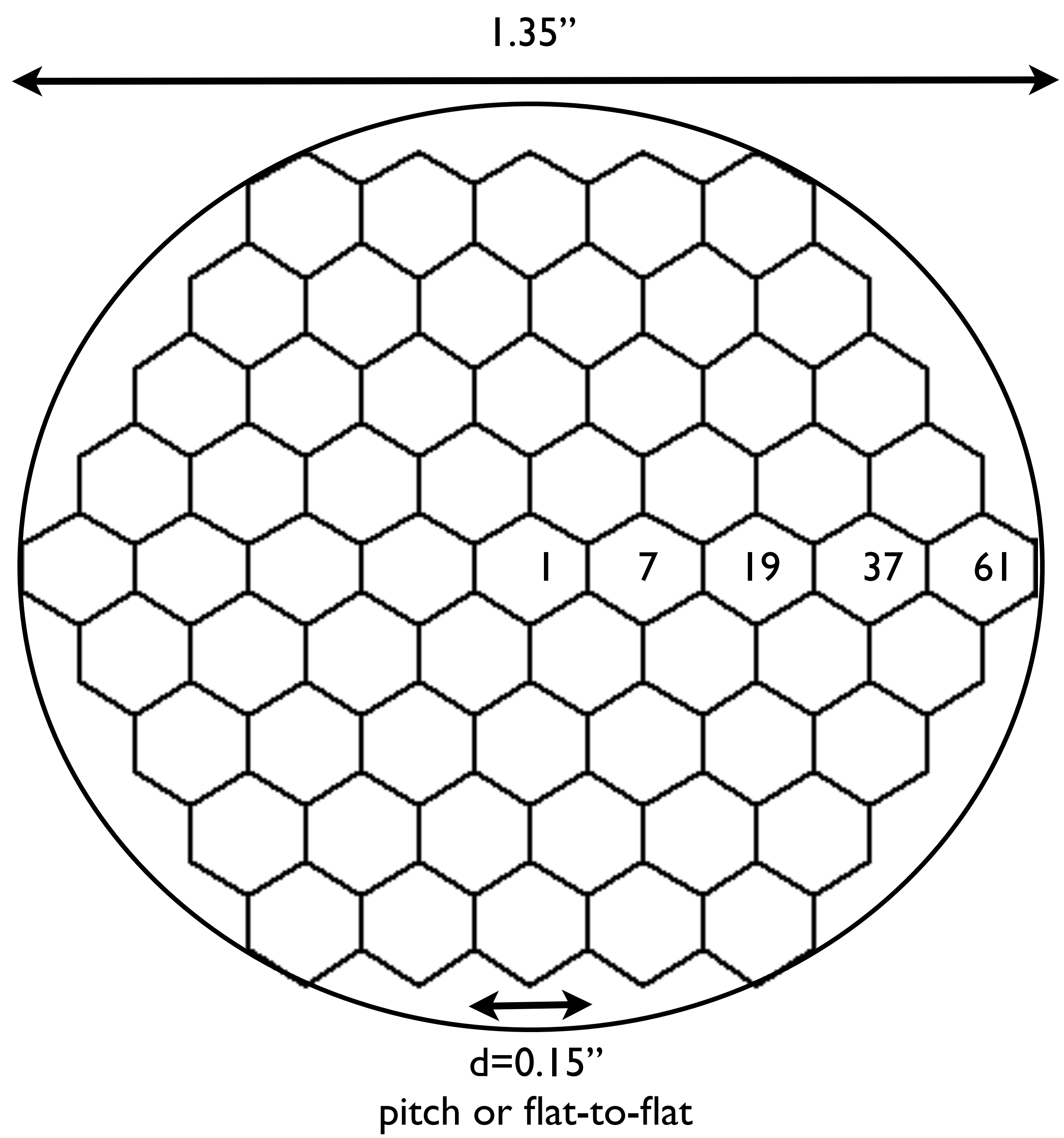
Sample sizes at high redshift are trimmed by factors of 2-4 after selection cuts are made.

Specially resolved studies of the stellar continuum at z~1 will require TMT, MNT or ELT.



:eting

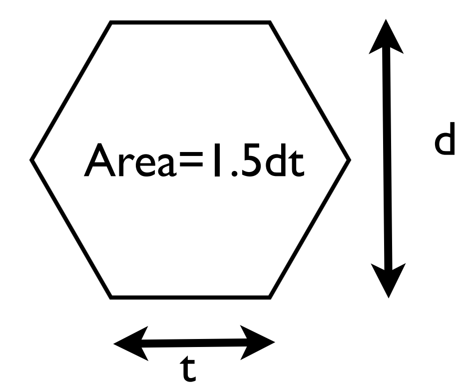
The original concept



Area= 61 1.5 $d^2 / \sqrt{3}$

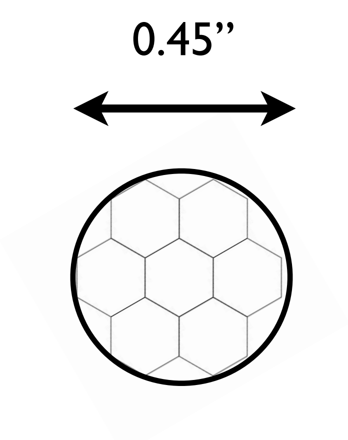
=

1.18 sq. arc seconds

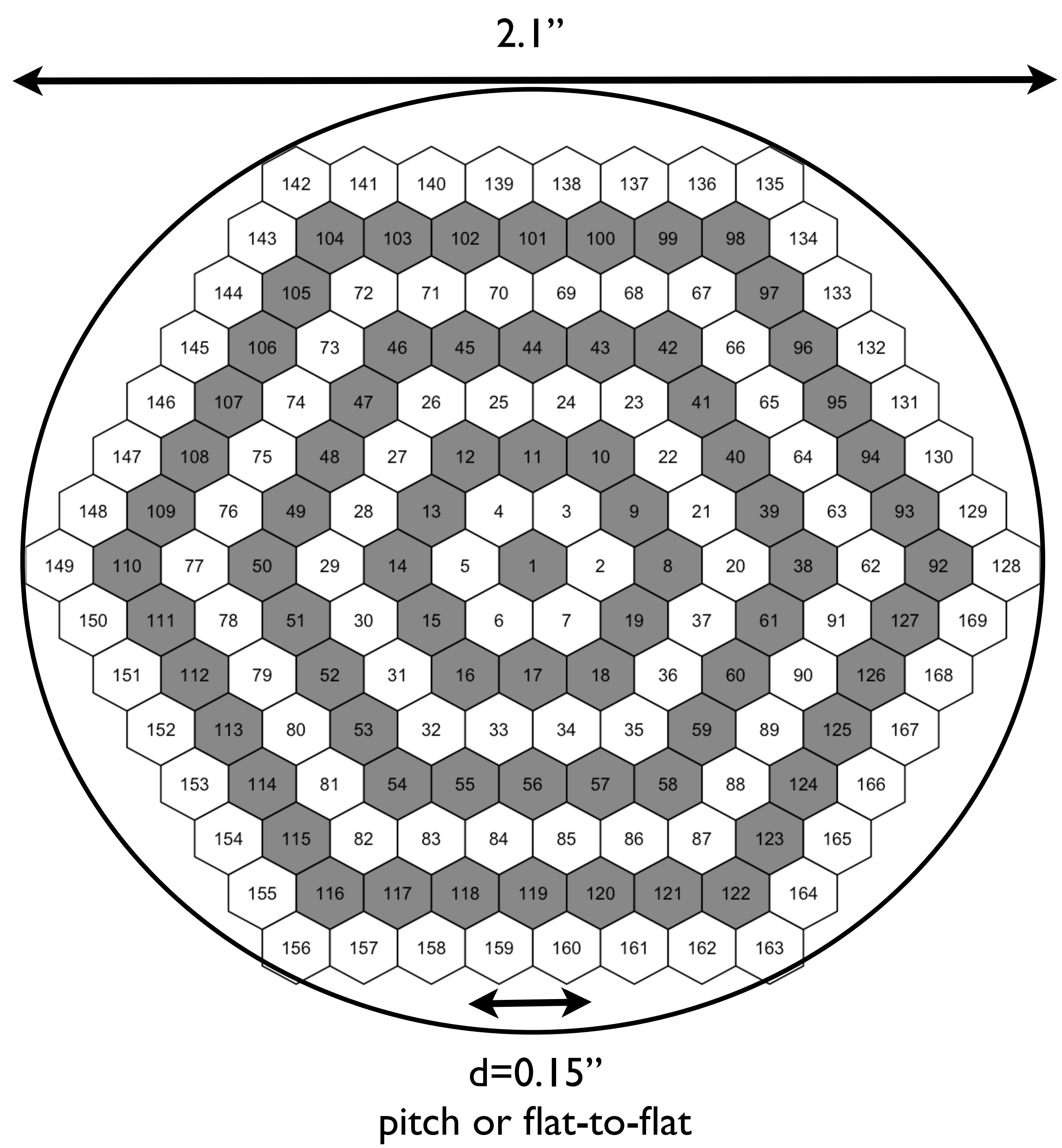


Not optimal for galaxies or points sources

A revised concept



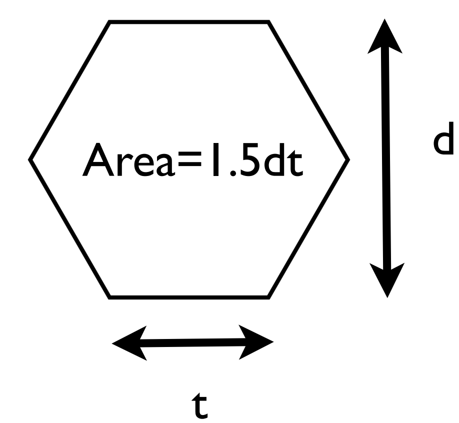
Points sources (stars, high-z galaxies)



Area= 169 1.5 $d^2 /\sqrt{3}$

=

3.3 sq. arc seconds



Technical challenges

The increase in the number of fibres from 61 to 169 means three times fewer IFUs with the same detector. To recover the multiplex one needs larger detector and multiple spectrographs => $$$

Two sets of IFUs means that a slit exchanger is required => $$$

d

What will the landscape look like in 10 years?

Characteristic	ULTIMATE @ z~1	GMTIFS @ z~1 (see also HARMONI)
Number of IFUs	4-5 (2k detectors)	1
FoV of positioner	7.2 Mpc (15’) diameter	NA
FoV of IFU	17.0 kpc (2.1”)	36x18 kpc (4.4”x2.3”)
Number of fibres per IFU	169	1980
Fibre pitch	1.2 kpc (0.15”)	0.05-0.4 kpc (6-50 mas)
Minimum sep.	160 kpc (20”)	NA
Spectral resolution	3,000-5,000	5,000-10,000
Telescope	8.2m	25m
Wavelength	0.8-1.8 mic	0.9-2.5 mic

Also GIRMOS on Gemini and IRIS/NFIRAOS on TMT

Issues that need more work

I. What is the optional fibre spacing on the detector? (assumed 5 pixels)

II. Can we install a slit exchanger?

III. Using fibres that transmit in the K band

VI. Is an ADC needed for the small IFU?

VII. Further development of the science cases

IV. Detailed feasibility calculations

Thank You