iFUN@LBT

Integral Field Unit with NICS @ LBT:

a low budget, fast track near-IR IFU for FLAO

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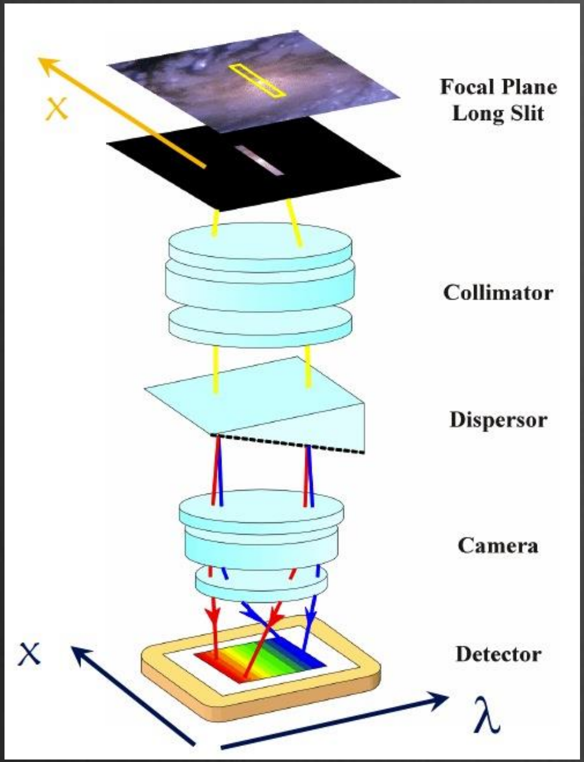
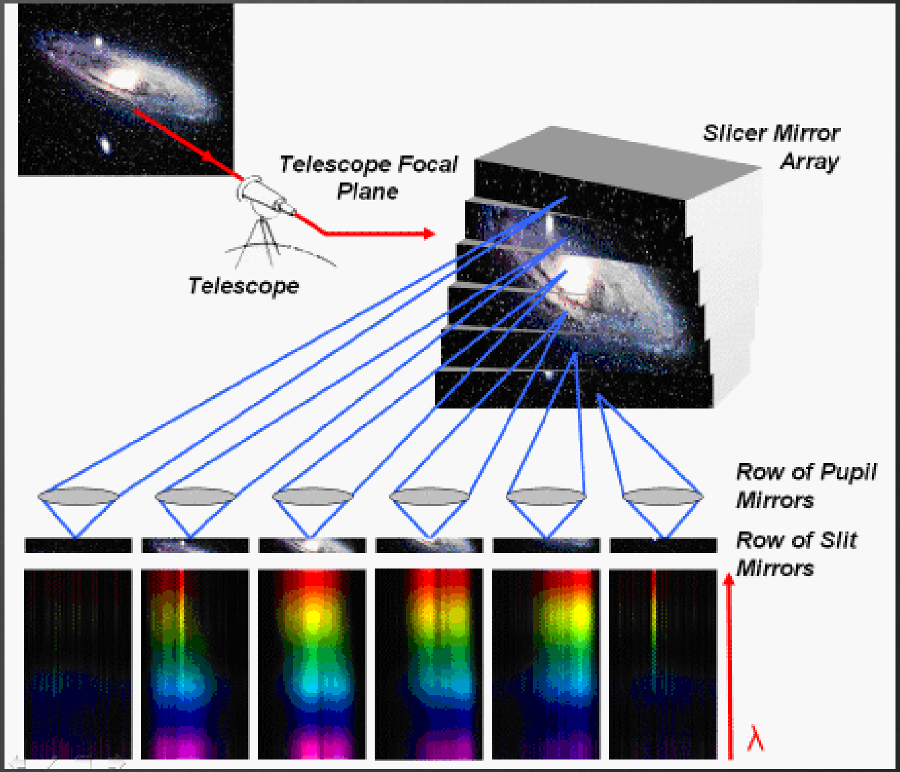
Slit vs Integral Field Spectroscopy



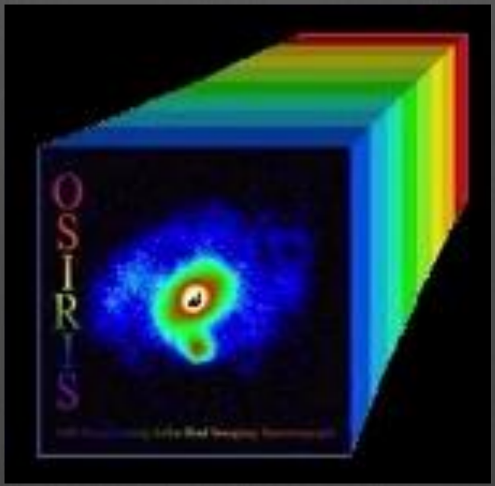


- Morphology of real objects do not follow the slit
- Light losses
- Resolution depends on slit itself…

- A spectrum for each "spaxel"
- No or limited light losses, full sampling of the target
- Save of telescope time
- Coupled with AO provides unique physical details of the target

IFUs+AO at the main telescopes

SINFONI@VLT



OSIRIS@KECK

NIFS@GEMINI

New generation of IR IFUs coming in ~2020: ERIS@VLT, NIRspec@JWST…

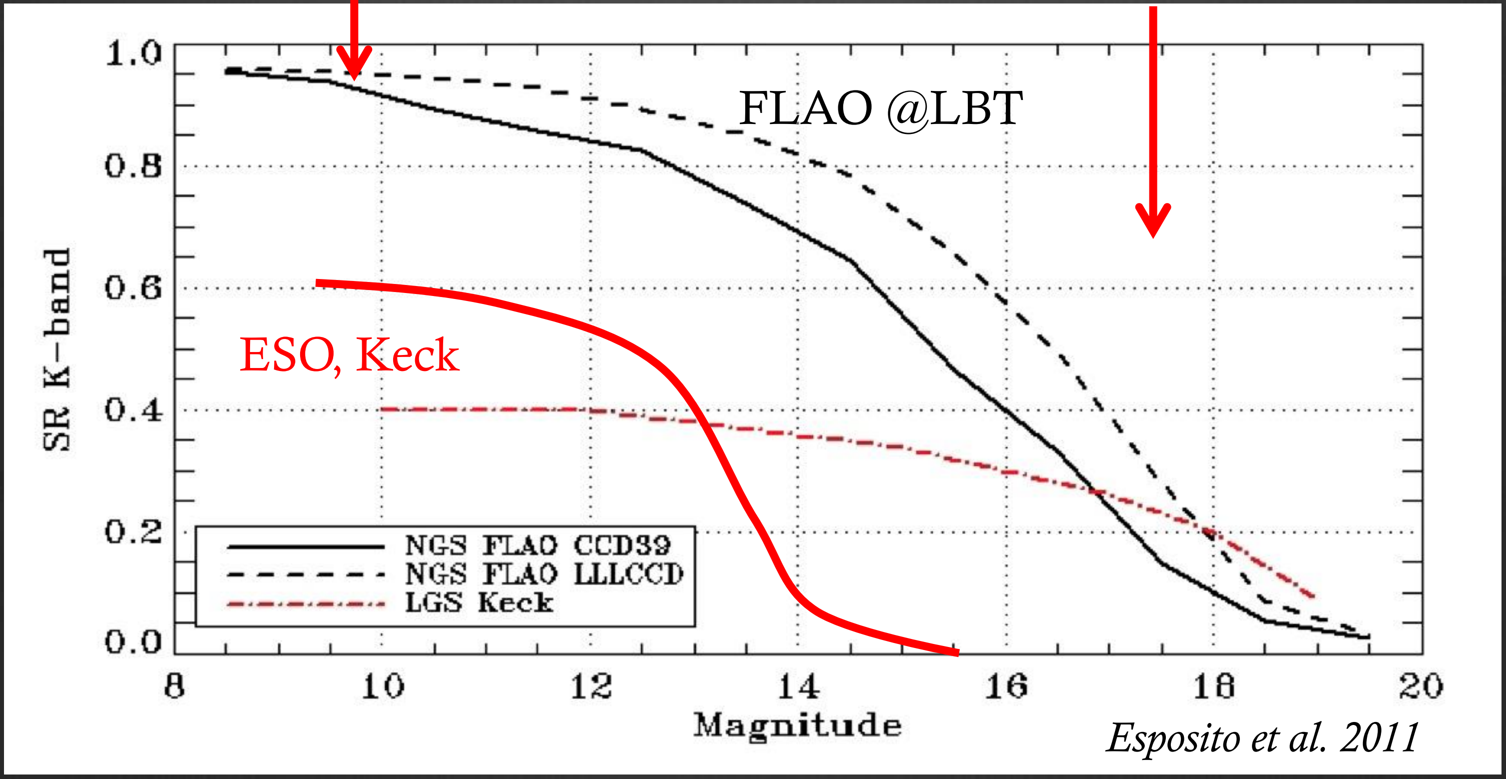
LBT is the only large observatory without a near-IR IFU coupled with AO…

… although it has the best AO facility: FLAO at LBT

FLAO is outperforming other existing AO facilities in both regimes:

A) Bright guide stars:
- much higher SR (~90%), i.e. more photons
- Much higher resolution

B) But it can work with much fainter guide stars, comparable or better to LGS tip-tilt reference stars:
- much larger sky coverage



Esposito et al. 2011

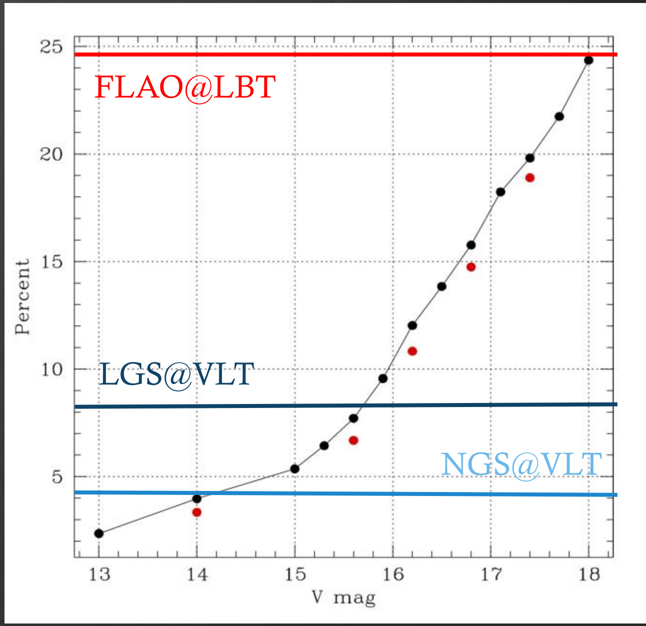
FLAO+NIR IFU

These two aspect perfectly matched by a near-IR IFU with 2 spatial scale regimes:

- 50 mas/spaxel to take advantage of high SR and diffraction limit resolution, making possible to resolve the details of astrophysical object better than any IFU in the world
- 100/150 mas/spaxel ideal for galaxy evolution studies, dealing with low surface brightness objects, taking advantage of the largest sky coverage for an AO system both with respect to NGS and to LGS at other facilities.

An example:

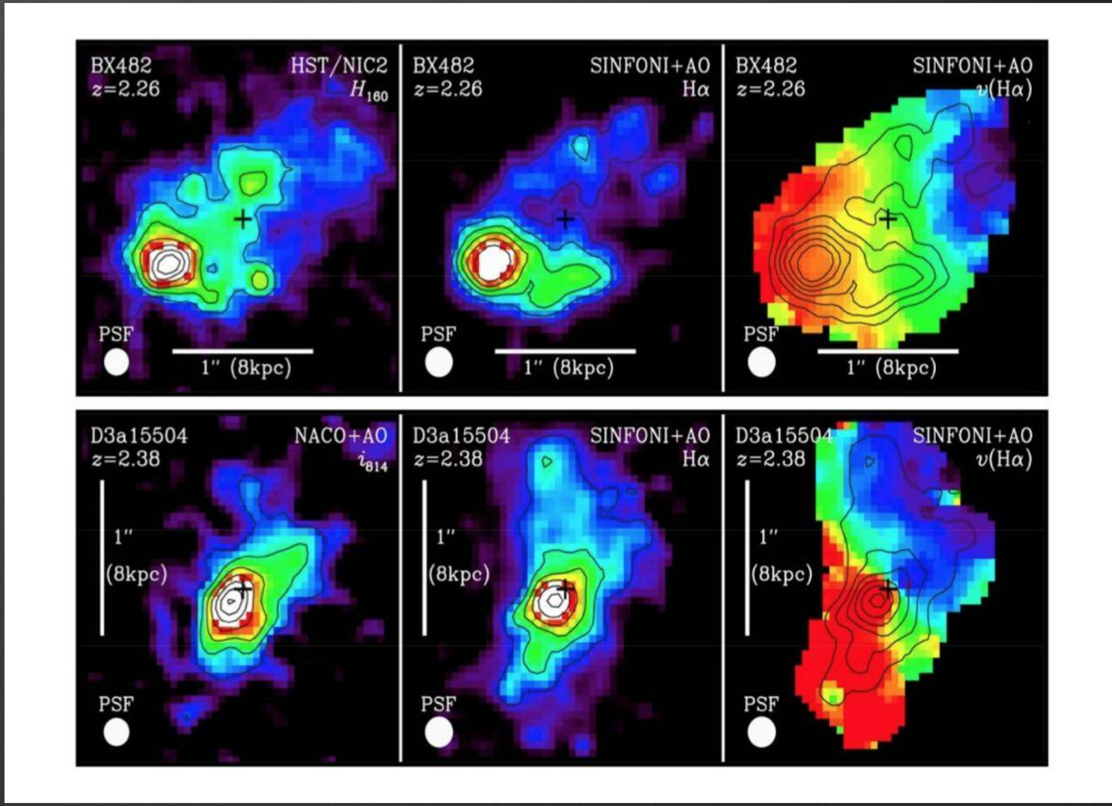
The fraction of z=3 LBG from the actual sample of Steidel et al. (2003) with a suitable star for AO guiding in 30”, plotted as a function of the guide star magnitude:
FLAO allows to observe with a SR of 30% or better more than 25% of the targets, while less than 4% is currently observable with SINFONI@VLT with NGS, and only ~8% with LGS.



Science cases:
1. Kinematics of high z galaxies

Ionized gas kinematics of z~1.5-3 galaxies as traced by emission lines is providing fundamental insights on high-z galaxies. The first results obtained with IFUs have strongly supported a paradigm shift in the general picture of galaxy formation and evolution, from a major merger-dominated one to a “cold flow/stream-fed” accretion mechanism.

A major limitation of the current samples is that most of the data are seeing-limited conditions (0.5” – 0.6”, or ~4–5 kpc). iFUN@LBT will represent a major breakthrough, providing gas kinematics on scales of less than 1 kpc

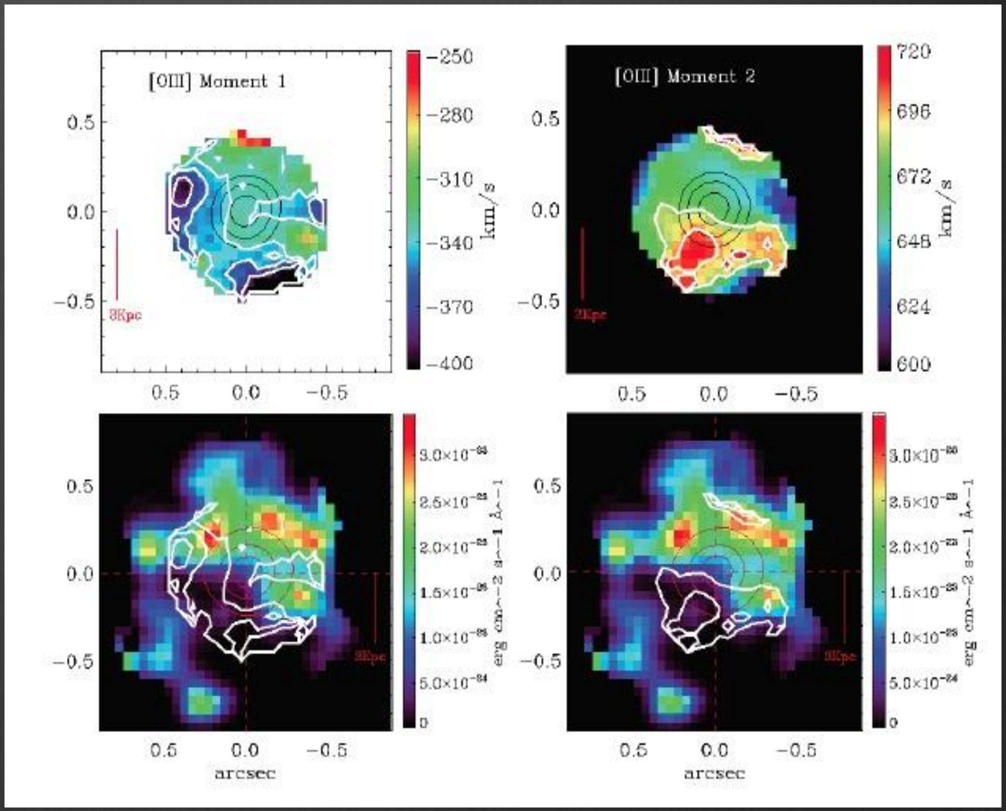


Genzel 2011, Forster-Schreiber 2011

Science cases:
2. AGN feedback

Feedback of quasar (QSO) nuclei on their host galaxies is currently thought to be a crucial process regulating the evolution of galaxies. Although it is invoked by most theoretical models of galaxy evolution, direct observational evidence of this mechanism at work, especially during luminous quasar phases, are still scarce.
Near-IR IFU observations are proved to be successful in detecting such powerful outflows in ionized.

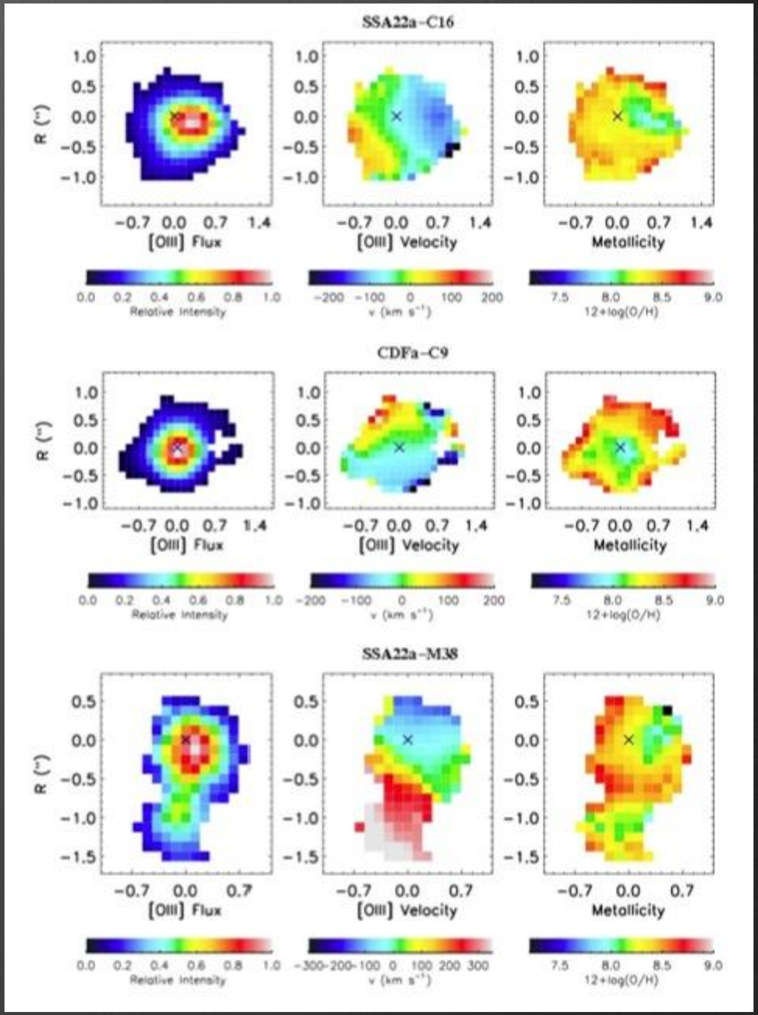
High spatial resolution [OIII] 3D spectroscopy on a large sample of high-z QSOs and AGNs will be fundamental to study the properties of these outflows (e.g. mass loading factor, velocity, energy etc.), and to better constraint the galaxy evolution models.



Cano Diaz et al. 2012

Science cases:
3. Metallicity Gradients

Metallicity and its spatial distribution is one of the most fundamental properties of a galaxy, tracing the cumulative history of baryonic assembly: gas accretion, star formation, and gas outflow/inflow. However, the shape of the metallicity gradient at high redshift is still debated: first pioneering works find inverted gradients at high-z

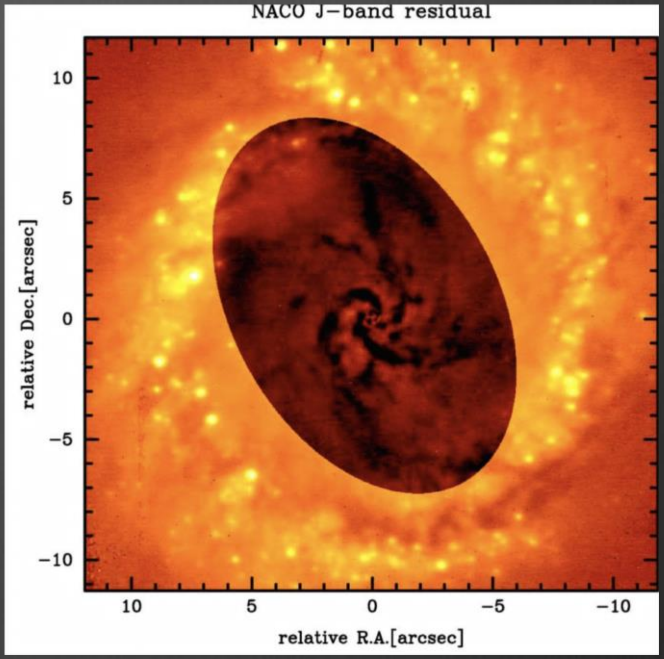


Cresci et al. 2010

The use of an IFU facility, combined with the high resolution of the FLAO adaptive optics, will allow an accurate determination of the distribution of the metal content of galaxies in different cosmic epochs, and to disentangle the evolution with time of their gradients.

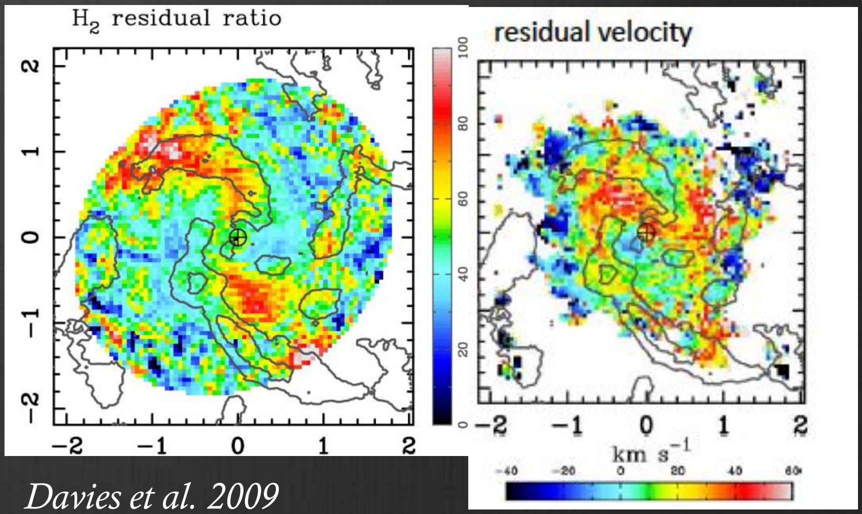
Science cases:
4. BH accretion in local AGNs

Two dynamical models are currently competingas the main actor in dragging gas from bulge scales to 10s of parsecs: (I) a starburst driven circumnuclear disk (Kawakatu & Wada 2008) where turbulent viscosity due to supernovae explosions transports the angular momentum, or (II) ordered gas motion along nuclear spiral arms which are generated by asymmetries/torques in galactic potential in turn due to a central bar/circumnuclear ring (Maciejewski 2004a,b).



Prieto et al 2005

iFUN@LBT will allow to characterize the feeding process by measuring the SF activity, the inflow geometry and the net inflow rate

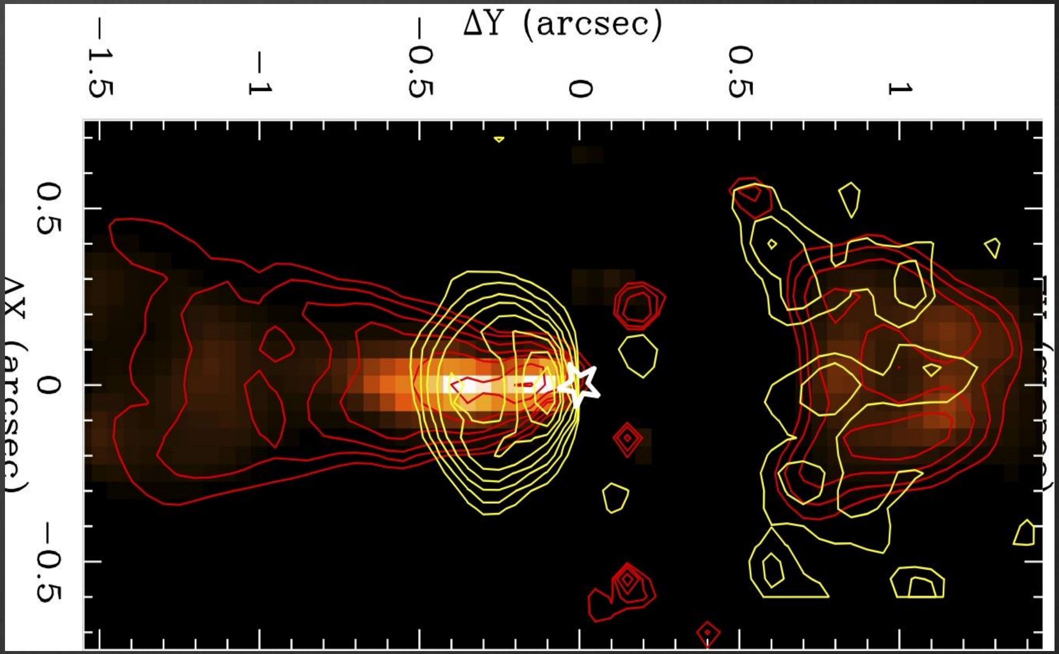


Davies et al. 2009

Science cases:
5. Stellar Jets

To understand the formation of stars and planets one has to clarify the observed tight correlation between accretion from the circumstellar disk and ejection of matter in jets.
Stellar jets emit bright shock–excited NIR lines as [FeII] and H_2.
To provide clues on the launch mechanism and on the feedback on the disk structure where planets are going to form, one has to observe jets close to the star with 0.1” angular resolution or higher

Observing with an IFU provides 2D reconstructed images of the jet both in line brightness and in derived physical quantities, such as total density and velocity in the flow, that determine the jet dynamics and its impact/feedback on the ambient and on the star/disk system.



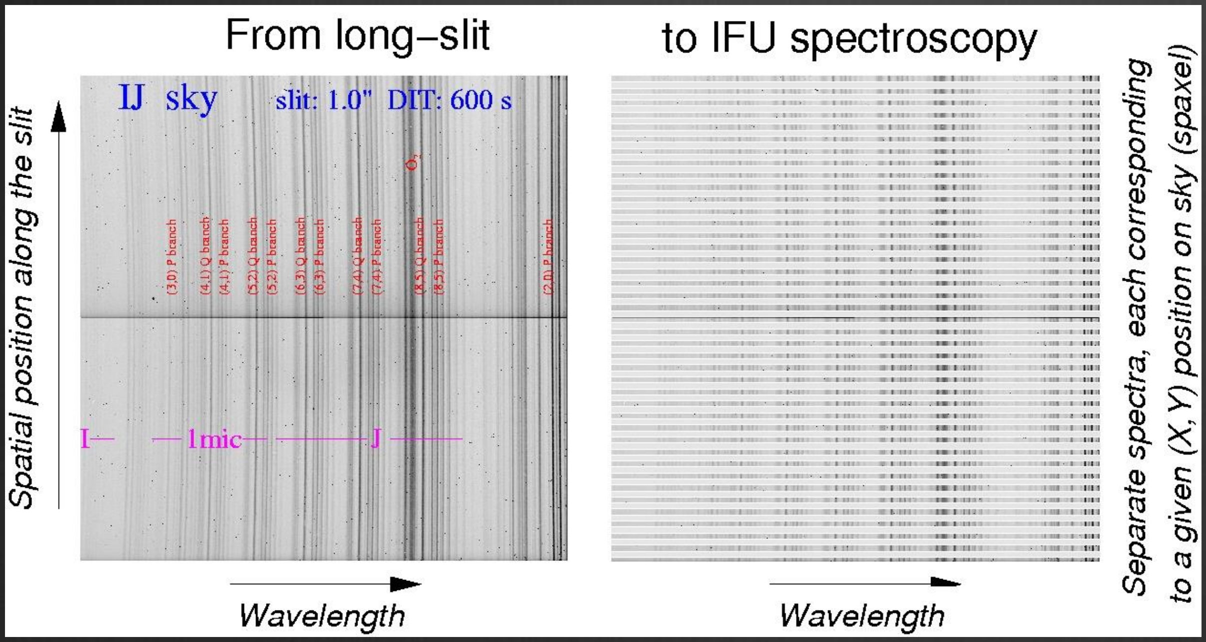
Agra-Amboage et al. 2014

A fast track, low budget, NIR IFU: how?

Attaching a fiber fed IFU to an existing spectrograph

NICS @ TNG will be decommisioned in the near future, but still in very good shape!

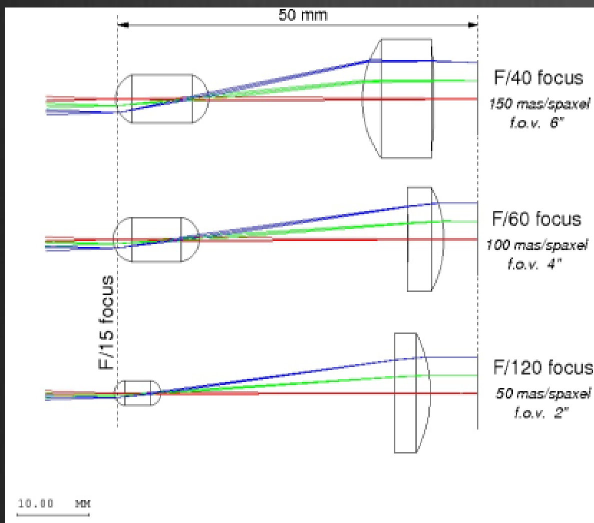
Spectral coverage & resolution are preserved in IFU

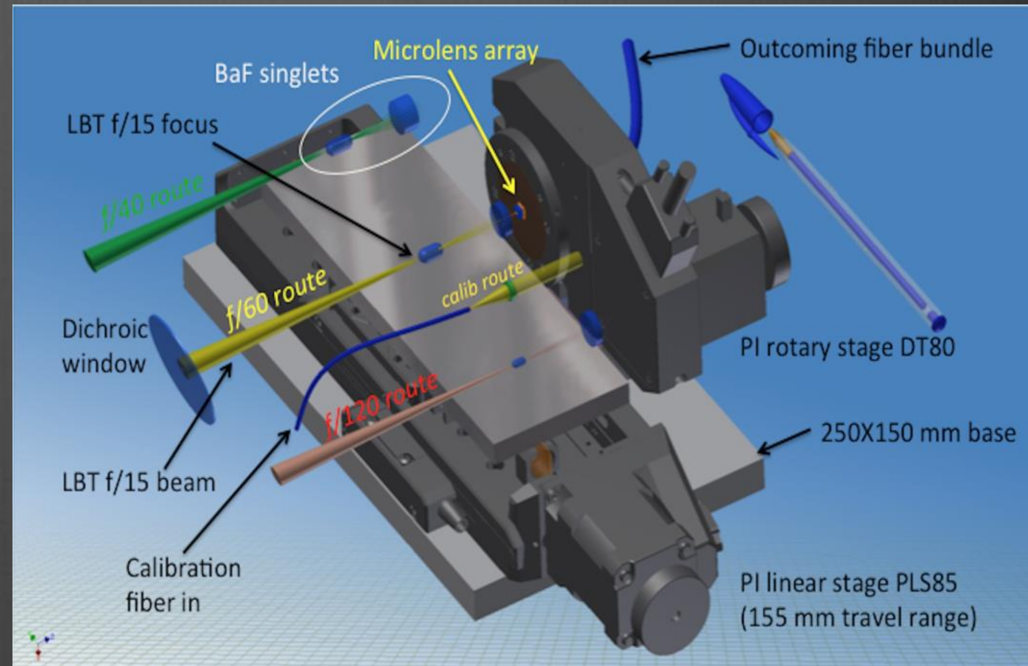


MR: R~2500 Y J H K
LR: R~1000 IJ HK JK'
Amici: R~100 I-K
HR: R~10000 possible

Focal adapter

Three focal reducers will be used to obtain the required spaxel scales



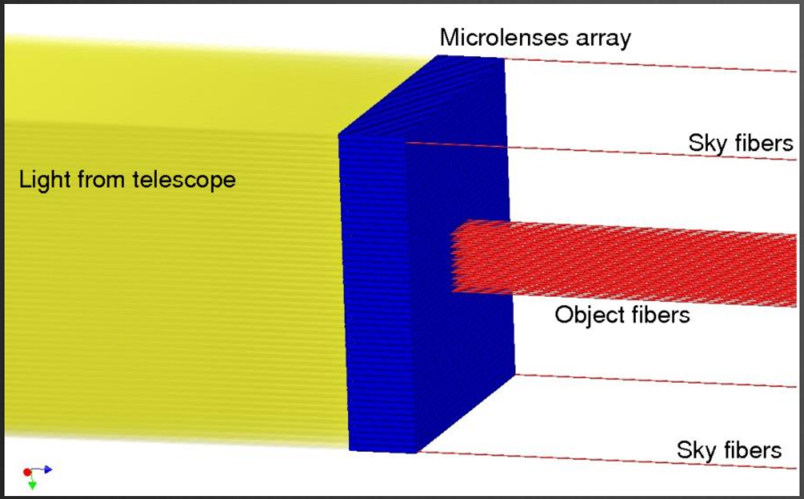


Very compact! Fits inside a box of about 300x200x150 mm^3

We will be able to fit 256 spectra on the NICS detector, producing a 16x16 spaxels IFU

Input beam	mas/ spaxel	Final FOV
F/120	50	0.8”x0.8”
F/60	100	1.6”x1.6”
F/40	150	2.4”x2.4”

Fibers and microlenses

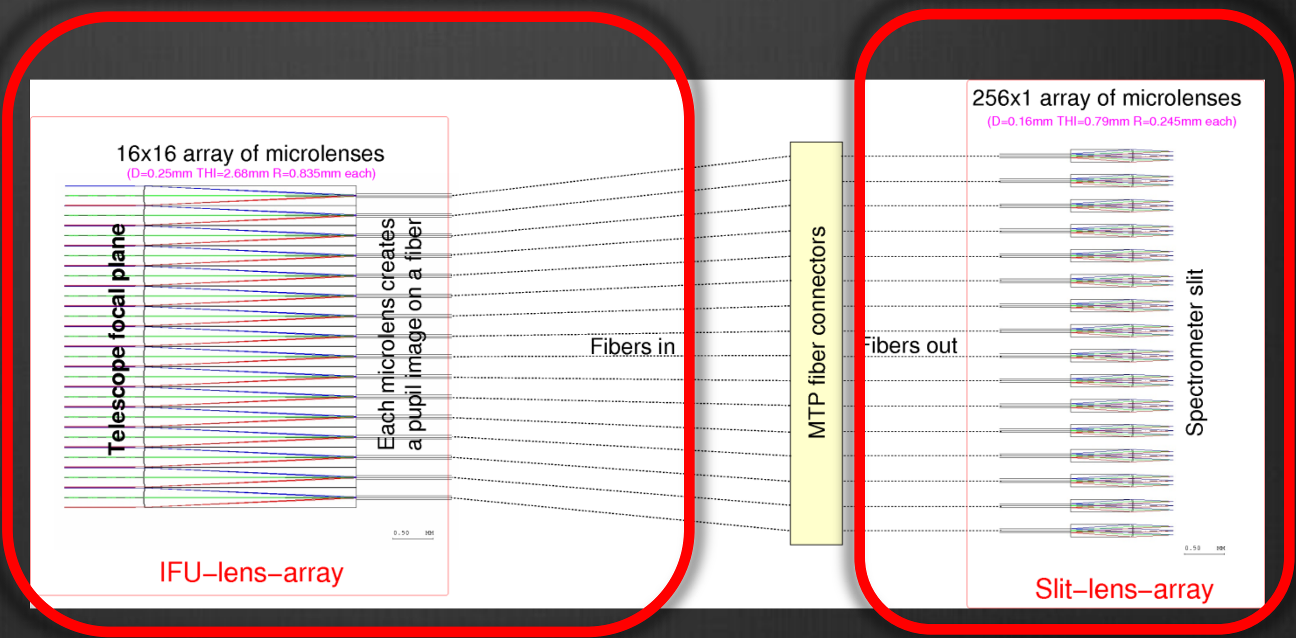


The interface between LBT and the IFU will be an *IFU-lens-array*: a 16x16 microlenses array with a fiber glued at the outer surface of each microlens.

The fraction of energy falling inside the fiber is >75% including diffraction even at larger spatial scale

The fibers are rearranged along a "slit" (*slit-lens-array*) to feed the spectrometer

Standard telecommunication fibers can be used up to ~2.2 μm (if short<10m)



Expected Throughput

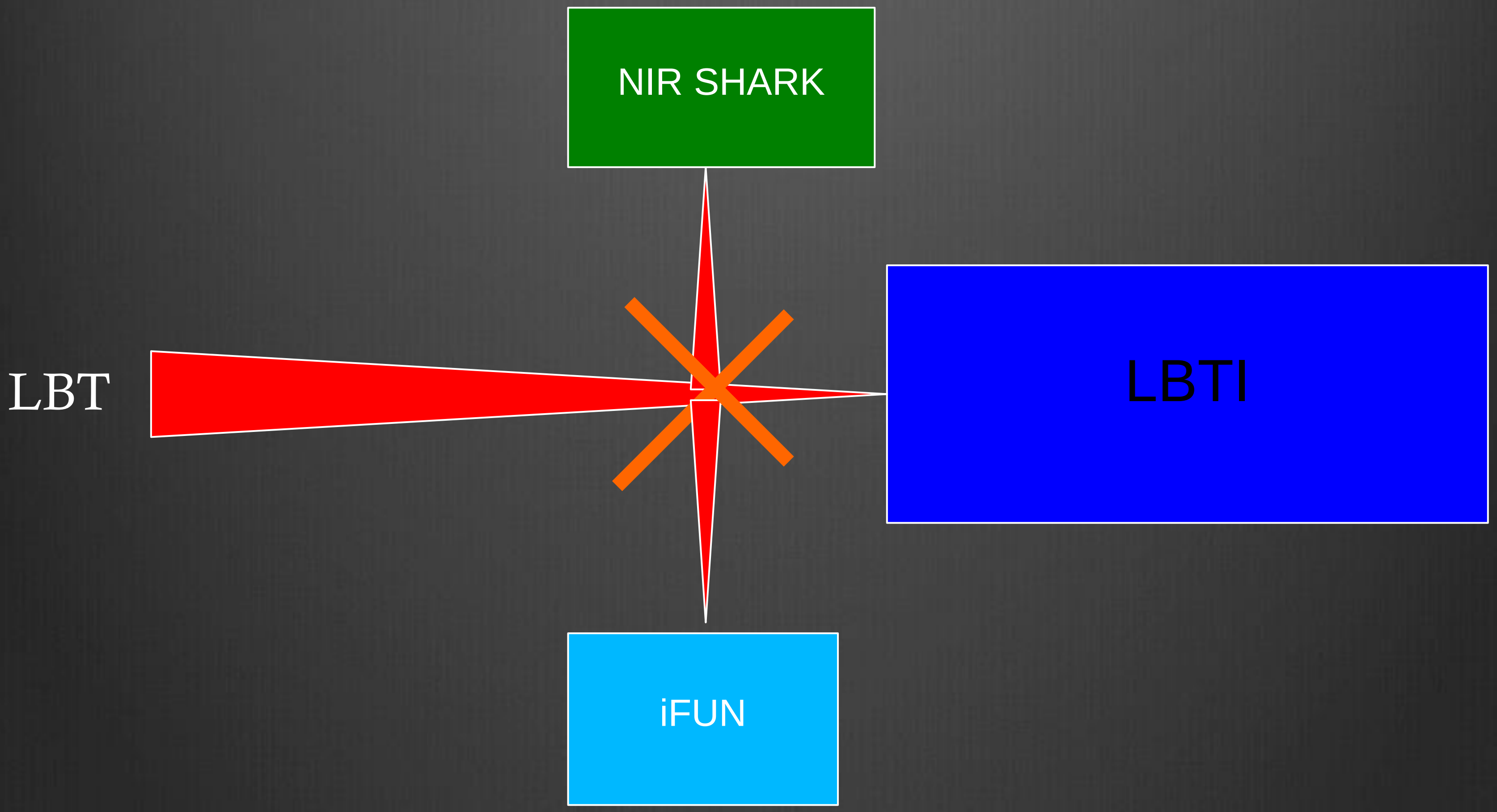
Given the lower efficiency of fibers compared to image slicer, a crucial point is the expected throughput of the system

Element	Throughput
Reflection losses in focal adapter and microlens	0.93
Filling-factor of IFU-lens array (circular lenses in hexagonal pattern)	0.91
Fraction of light falling inside input fiber (Table 3)	0.86
Fiber focal ratio degradation	0.89
Reflection losses in output microlens	0.97
NICS efficiency	0.40
TOTAL	**0.25**

For comparison:

- SINFONI@VLT throughput ~0.30
- OSIRIS@Keck ~0.19
- NIFS@Gemini ~0.20

Position at LBT: parallel to one Shark?



The LBT-IFU interface will be positioned at one of the AO-corrected F/15 foci of LBT. Preliminary contacts with P.Hinz indicate that the small LBT-IFU-interface could be easily positioned at the focus of the LBTI beam-combiner, allowing feeding of the fibers by either of the telescopes, parallel to the SHARK focus.

Resources needed

WP #	Type	Name	Time(yr)	Cost (k€)	FTEs
2.1.1.1	Basic	Fibers-in, standard fibers	0.1	2	0.1
2.1.2.1	Basic	Slit-lens-array (include fibers gluing)	1.1	29	0.9
2.1.3.1	Basic	NICS modifications (include vacuum feedthroughs)	0.9	21	1.7
2.1.4.1	Basic	MTP connectors	0.2	3	0.1
2.2.1.1	Basic	Focal adapters	0.9	34	1.2
2.2.2.1	Basic	IFU-lens-array (include fibers gluing)	1.1	39	0.8
2.2.3.1	Basic	Fibers-out, standard fibers	0.1	2	0.1
2.2.4.1	Basic	MTP connectors	0.2	3	0.1
2.3.1.1	Basic	Transport, custom, insurance etc.	-	27	-
2.3.1.2	Basic	Travels	-	40	-
		Total Basic	**1.4**	**200**	**5.0**
2.1.1.2	Plus	Fibers-in, ZBLAN fibers	0.5	110	0.1
2.1.3.2	Plus	New Silicon grisms for NICS	2.0	250	1.8
2.2.3.2	Plus	Fibers-out, ZBLAN fibers	0.5	350	0.1

Basic: minimum works necessary for the implementation of iFUN@LBT. They can be completed in 1.4 yr using 5 FTEs (INAF employees) and with an hardware cost of 200+30 (contingencies) k€

Plus: desirable works for optimizing the performances of iFUN@LBT.

Conclusions
iFUN: A quick NIR fiber-fed IFU on LBT

- Many interesting science cases, from galaxy evolution to stellar jets and disks
- Three spatial scales/FoV defined by science cases
- Full use of the unique LBT AO capabilities
- Spectrometer NICS already available! Fast and low budget: 200 k€, 5 FTEs, 1.4 yrs
- Ensures edge science at LBT for several years (until ERIS@VLT and NIRSpec@JWST ~2020)
- Good complement for future sodium laser guide star AO