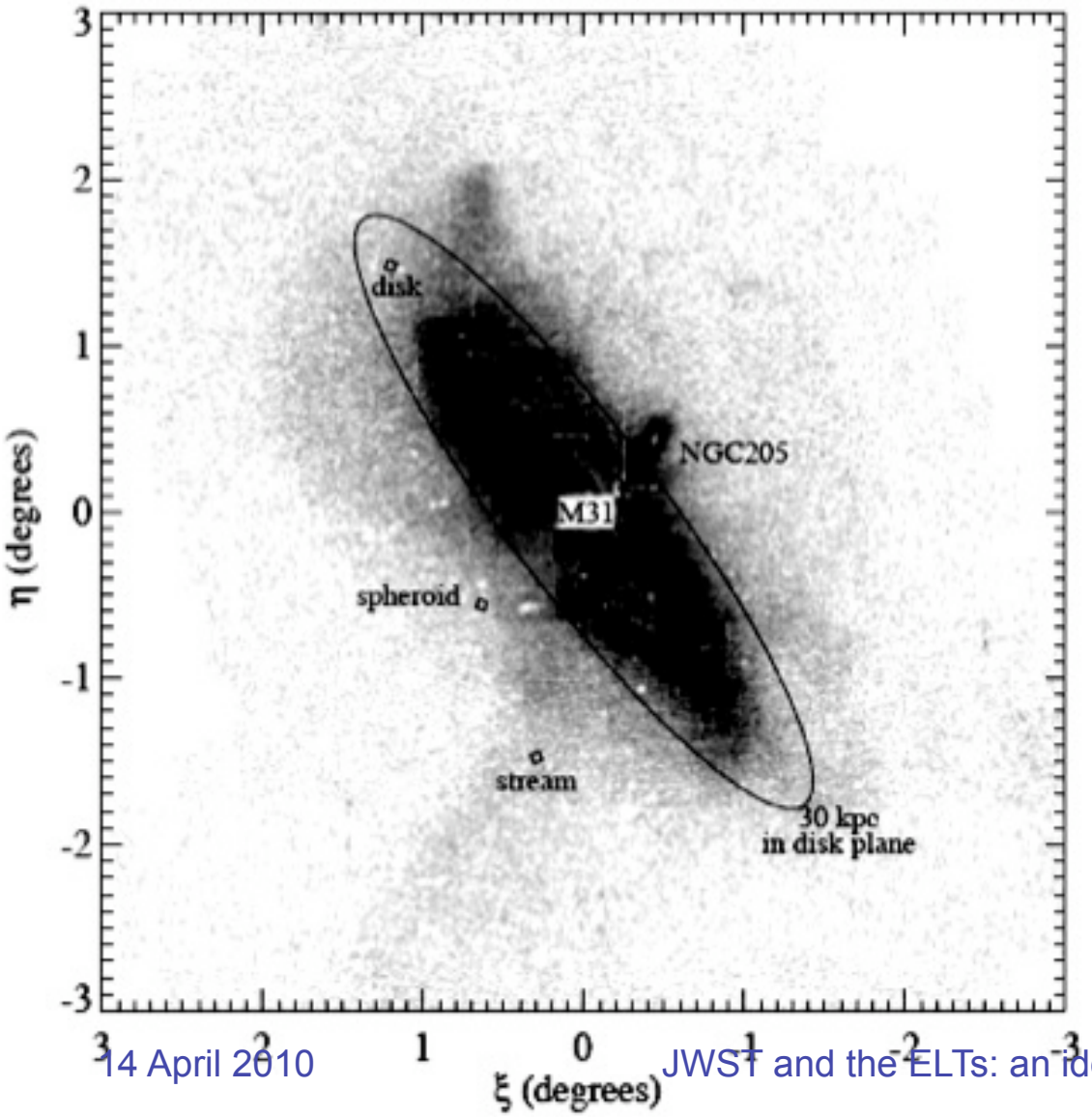
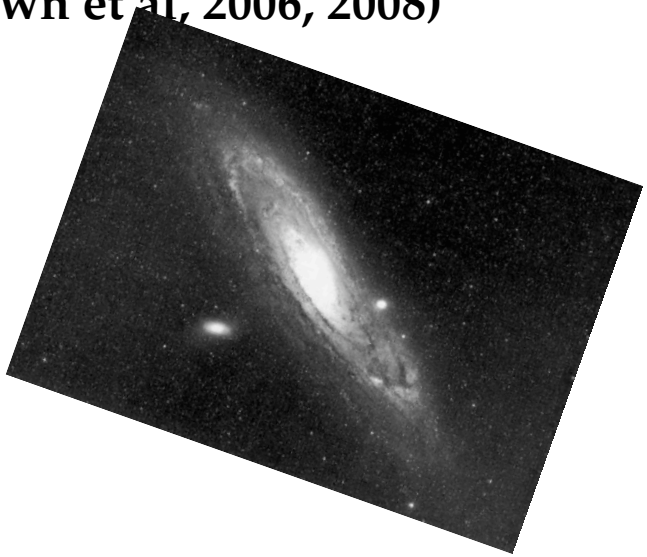
The extended gas surrounding very distant galaxies: investigating the galactic haloes

by François Hammer

The tumultuous history of M31

(Ibata et al, 2001; 2004; Beasley et al, 2004; Brown et al, 2006, 2008)
see also Block et al. 2006 & Mc Connachie, 2009



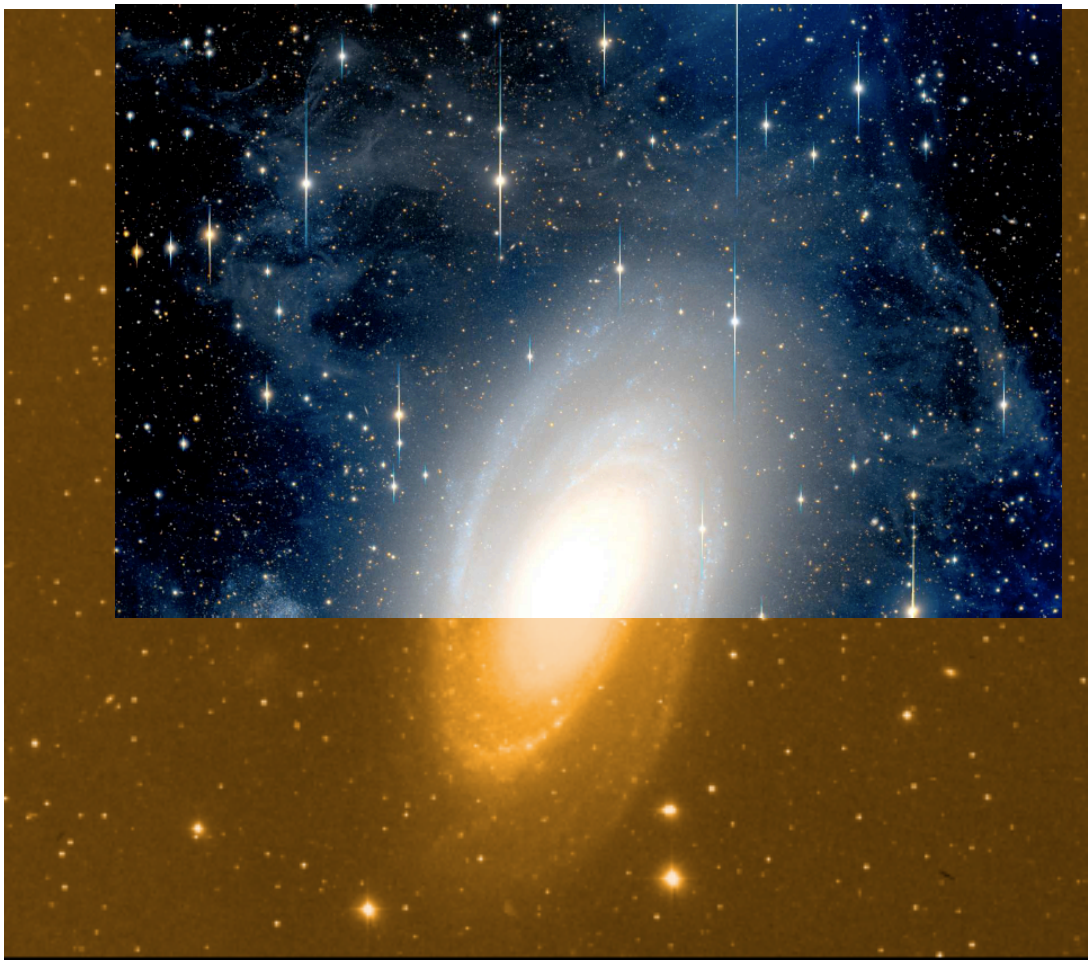


Low surface brigthness features: Giant stream, clumpy disk & outer ring, made of evolved stars

➔ **Either several minor and/or a major merger, 7-8 Gyrs ago?**

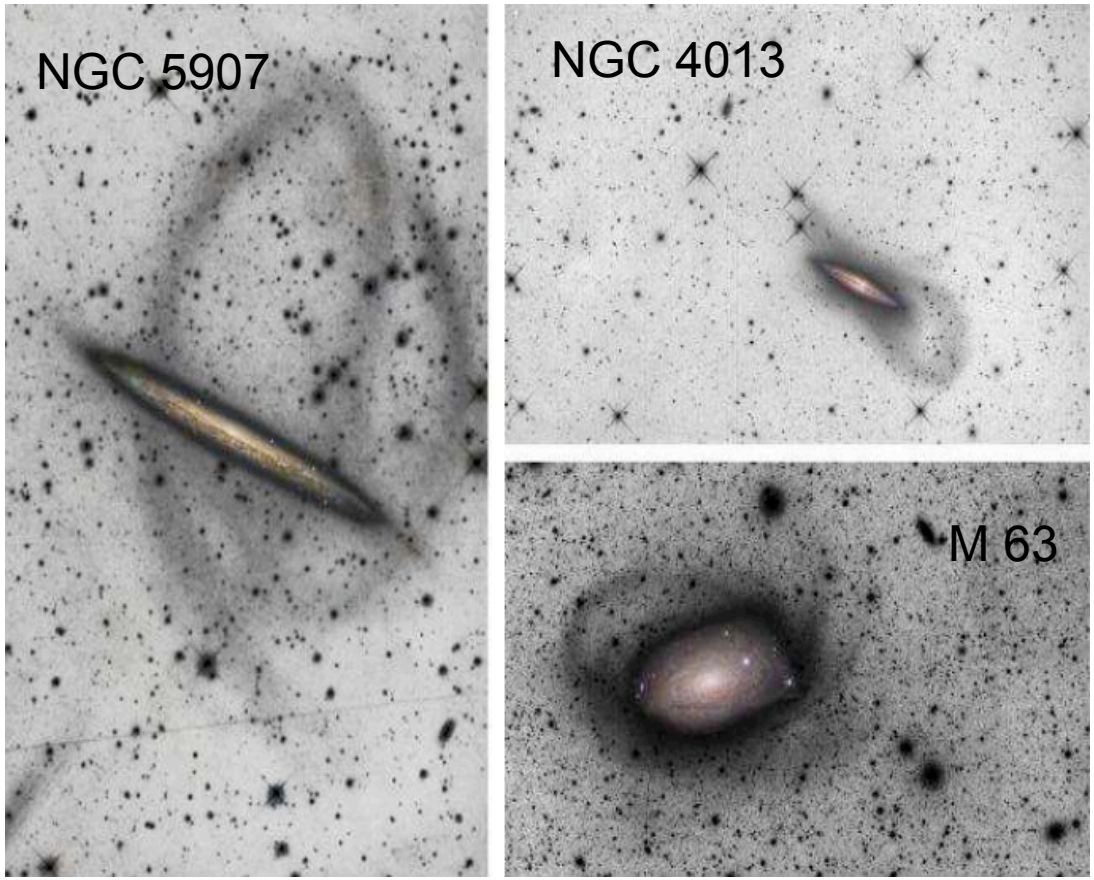
The haunted halo of M81

(Barker+09 see also Davidge09, 09)



Tumultuous history for many spirals

(Martinez-Delgado et al. 2008, 2009)



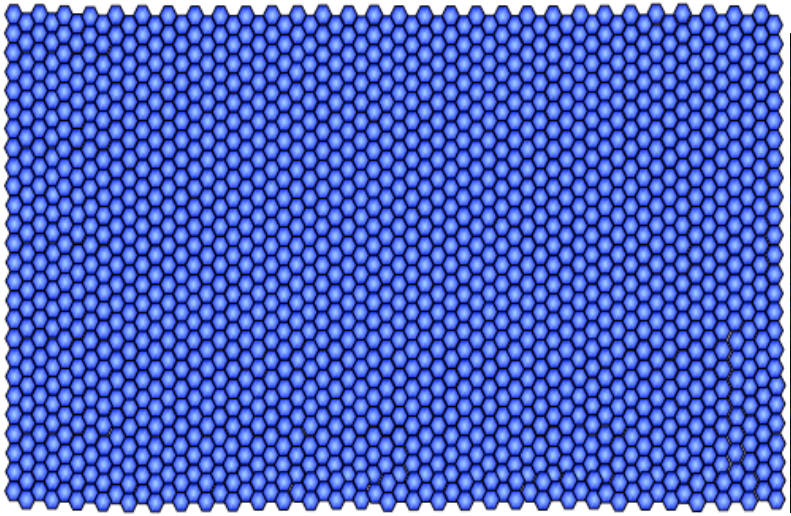
Could be imprints of minor or major mergers occurring one or several billions years ago.

Orbital motions may help to constraints the halo structure.

Haloes were much richer of stars & gas in the past

Distant galaxies are forming stars (e.g. LIRGs) and have extended ionised gas. They often show debris and substructures in their outskirts.

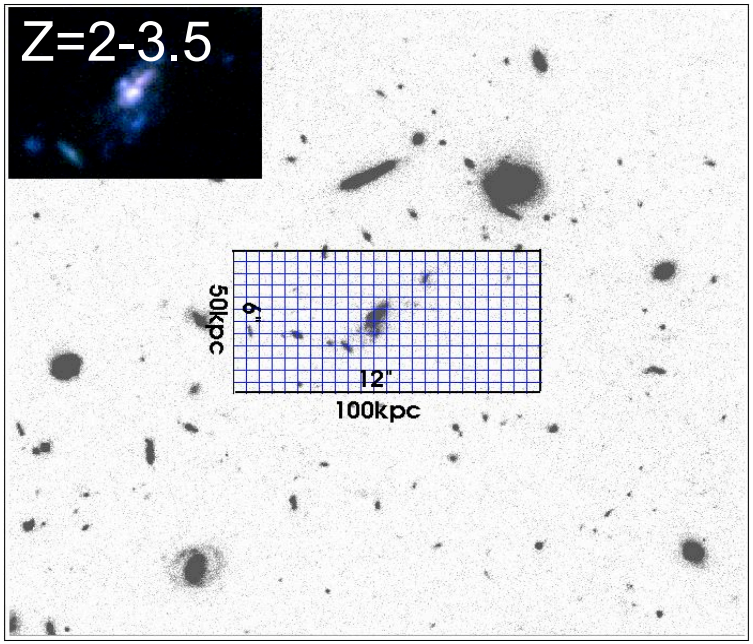
One Large IFU using 0.3'' fibres and covering 7.8x13.5''



extended gas surrounding very distant galaxies: investigating the galactic haloes

Kinematics of 100kpc haloes up to z=3.5

OPTIMOS-EVE @E-ELT



- f([OII] 372.7nm)=10^{-19} ergs/s/cm^2 may detect down to SFR= 0.03 Mo/yr, the debris and satellites of massive galaxies at z=2.5.

- Such fluxes can be reachable in 10 hrs with OPTIMOS-EVE@E-ELT.

- OII is observable up to z=3.5 in the H band.

Large IFU: detect and measure extended sources

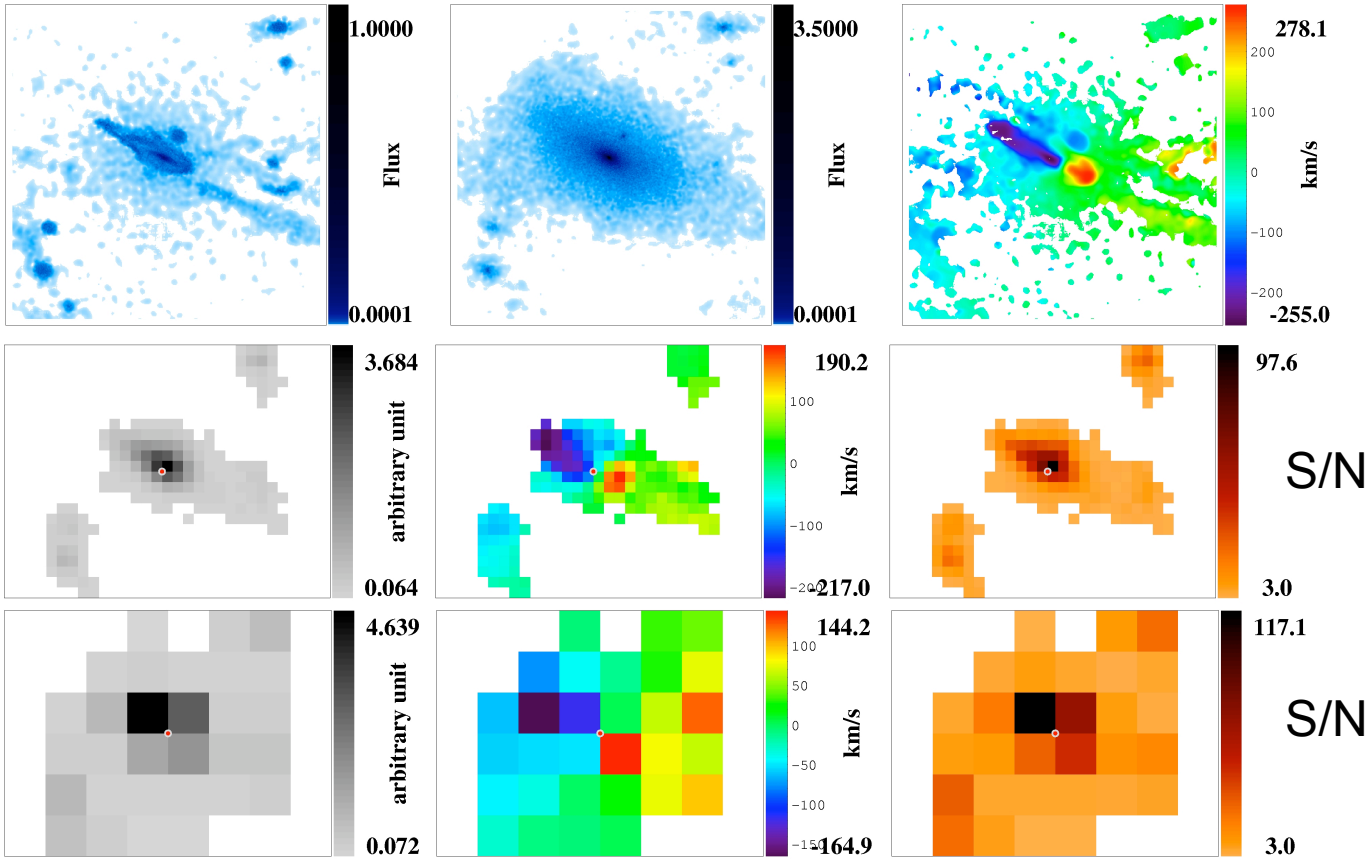
Extreme Visual Explorer

Top: the hydrodynamic model (Cox+07) for input to the simulations (shown is the high resolution stellar distribution).

Middle: LI mode simulation. From left to right: flux distribution, velocity field, and the S/N map.

Bottom: same as above but using a spatial binning of 4x4 spaxels.

m(AB)=24 galaxy at z=3 after 10 hours of integration

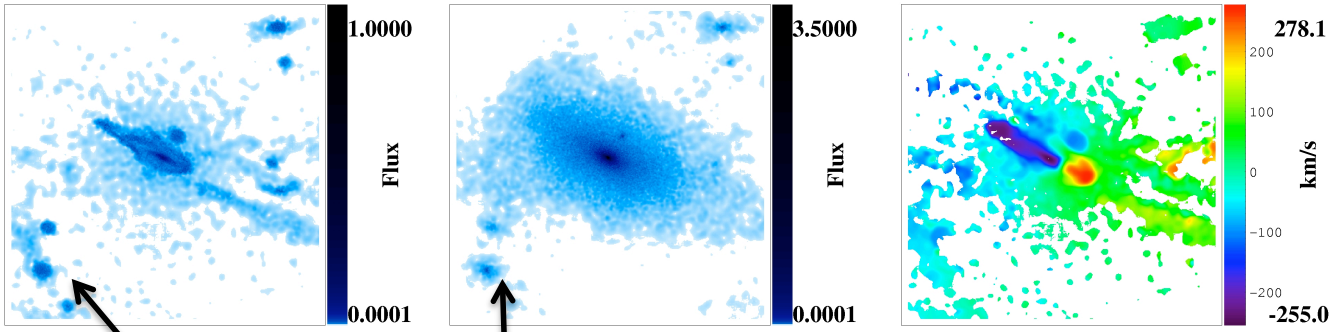


Intensity (OII 10^{-18}erg/s/cm^2) Velocity field S/N

Large IFU: detect and measure extended sources

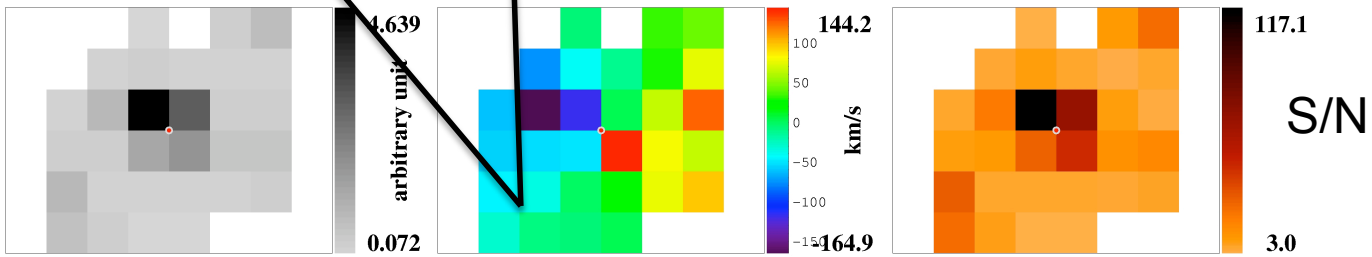
m(AB)=24 galaxy at z=3 after 10 hours of integration

Top: the hydrodynamic model (Cox+07) for input to the simulations (shown is the high resolution stellar distribution).



Combined with JWST/NIRCAM images: for detecting streams and orbital motions in the halo

Bottom: same as above but using a spatial binning of 4x4 spaxels.

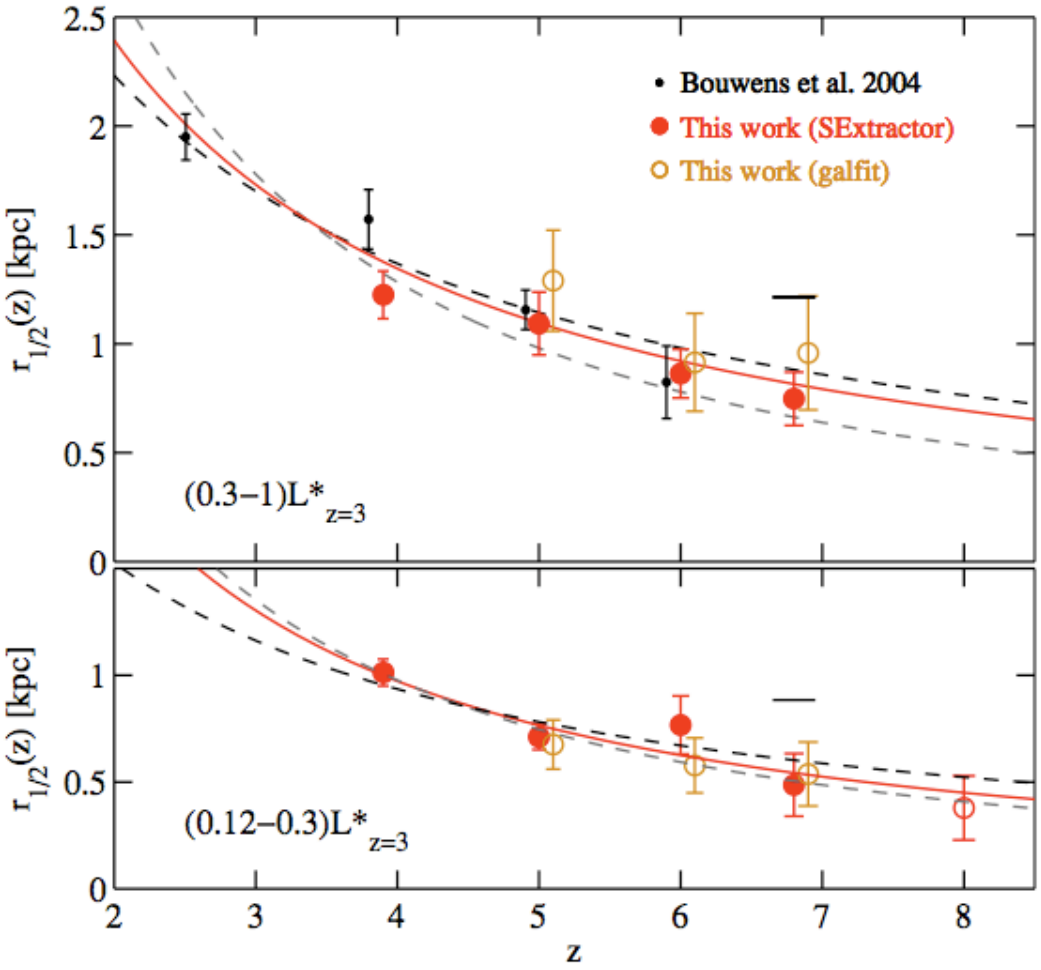


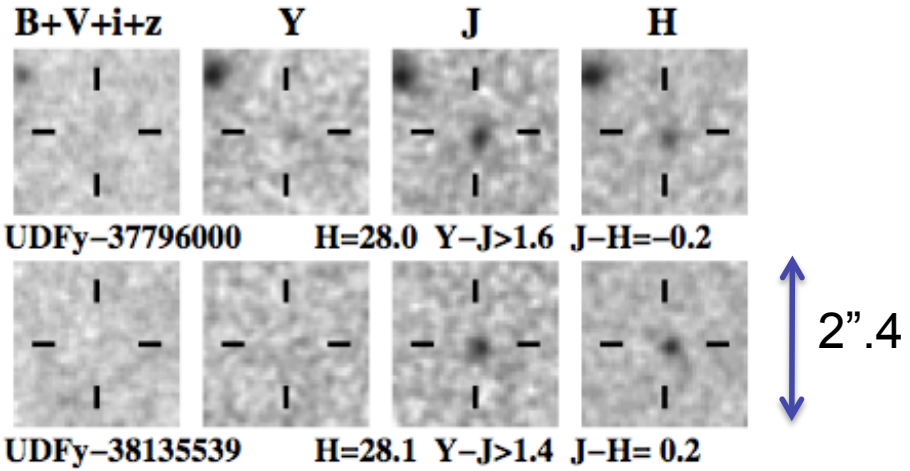
Intensity (OII 10^{-18}erg/s/cm^2) Velocity field S/N

Sizes of distant galaxies

Oesch+10

REST-CONTINUUM=UV-STARS





z~8 candidates from Bouwens+10 (HST-WFC3)

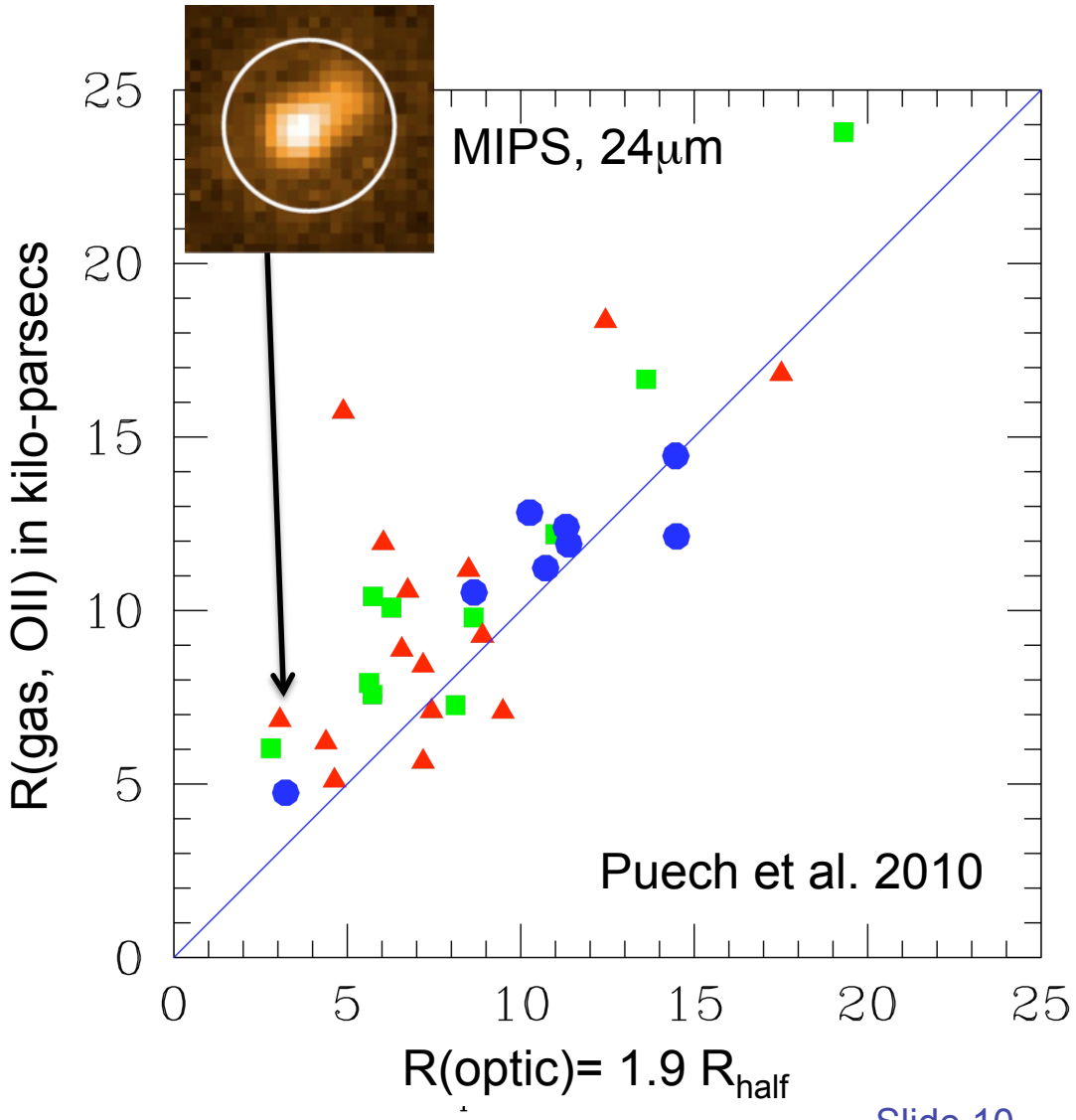
Spatial extent: ionised gas versus continuum

At z = 0.65

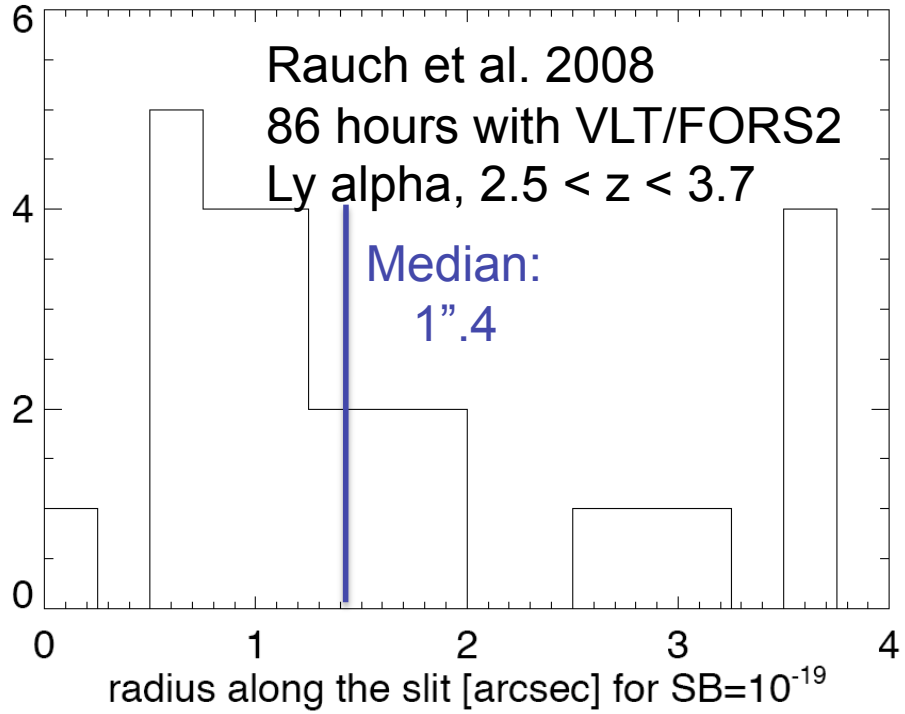
R_{gas} from GIRAFFE [OII] maps

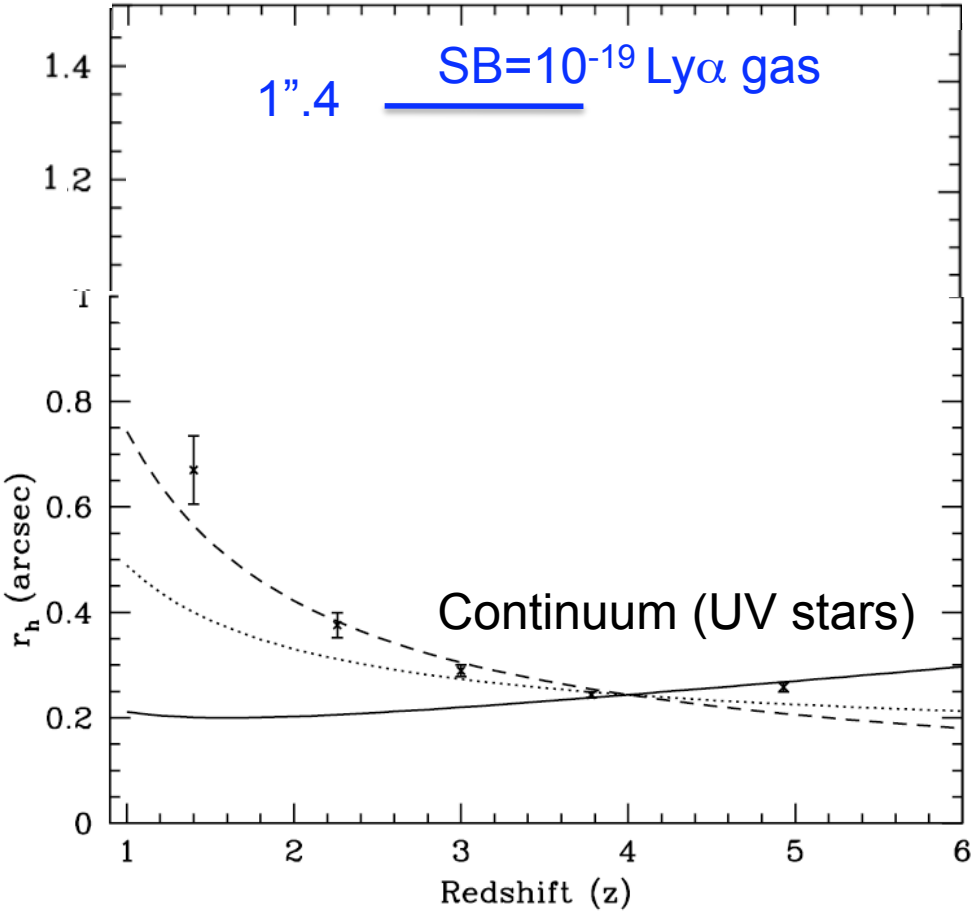
Deconvolved from IFU pixel grid & seeing using Monte-Carlo simulations

In z= 0.65 compact galaxies: gas extents much farther than UV light



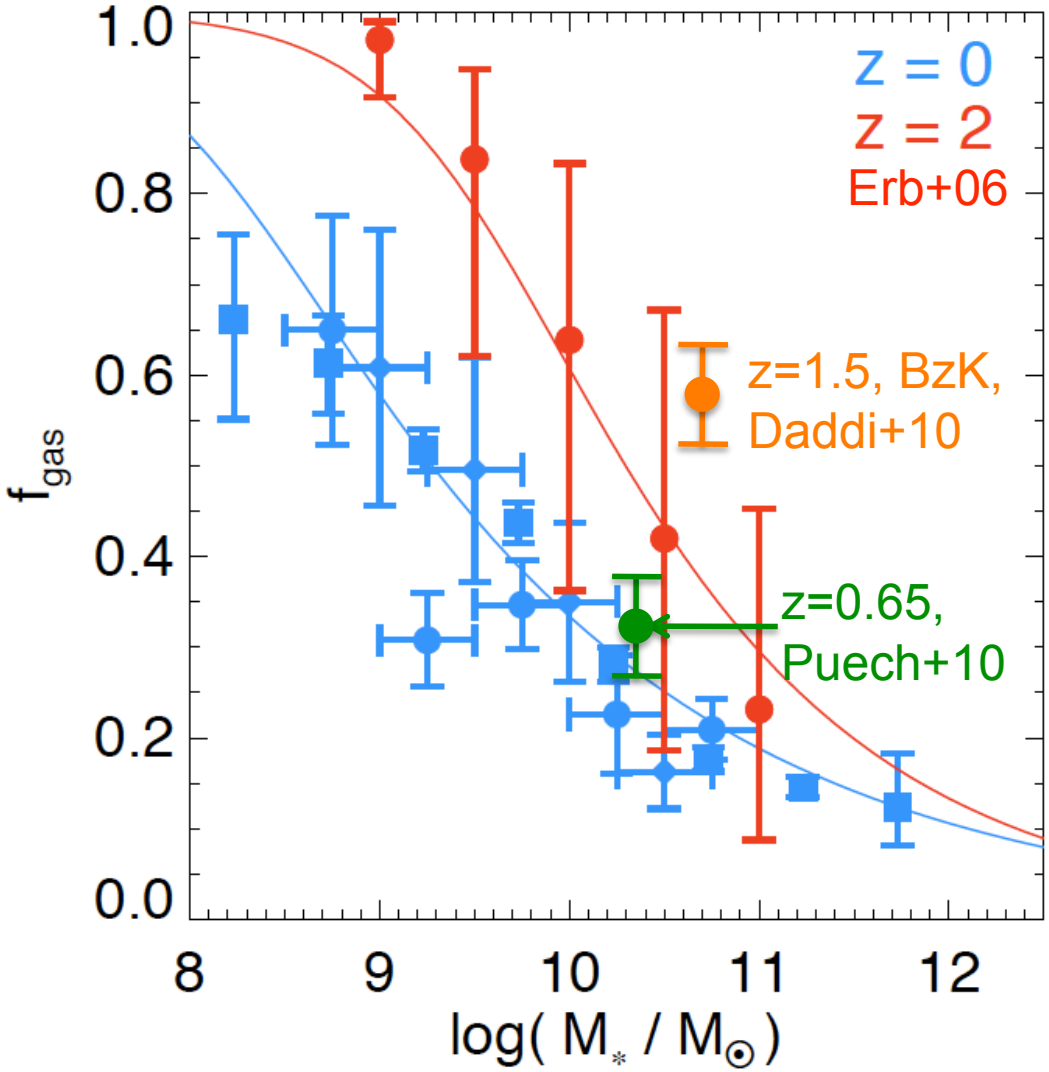
Spatial extent of the ionised gas, down to faint limits





Ferguson+05 from GOODS (HST/ACS)

Distant galaxies are full of gas



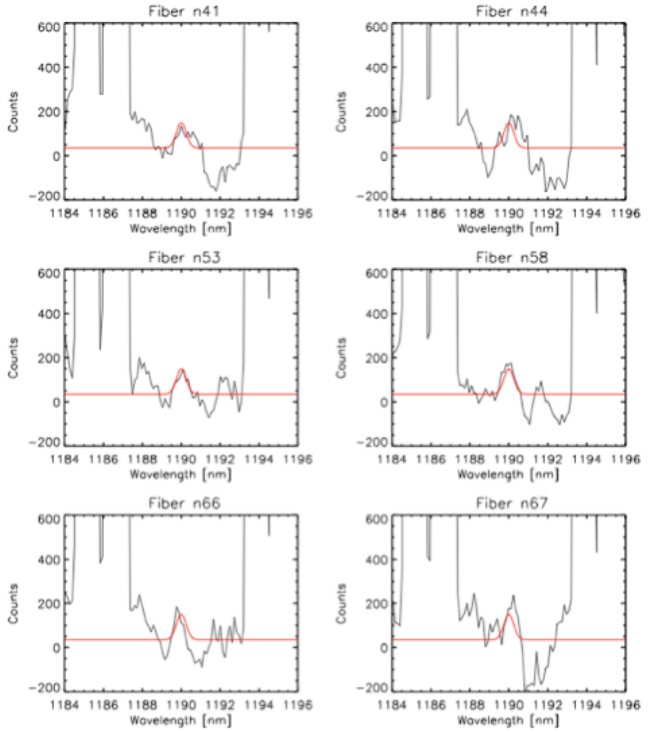
The search for very distant galaxies is for very gas-rich objects;

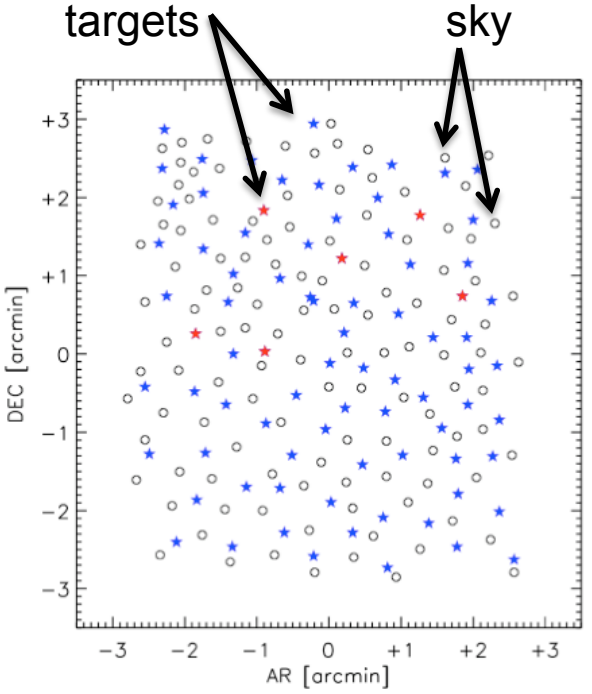
Among the most promising is the detection of Ly alpha emitters

Detect numerous first galaxies

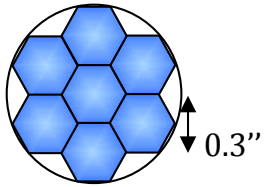
Extreme Visual Explorer

Simulation of 82 galaxies at z=8.8 in the J-band observed during 40 hours in the MO mode with GLAO. All galaxies have J(AB)=28 with Lyα line flux of 10^{-19} ergs/ cm^2/s (fwhm=150km/s)

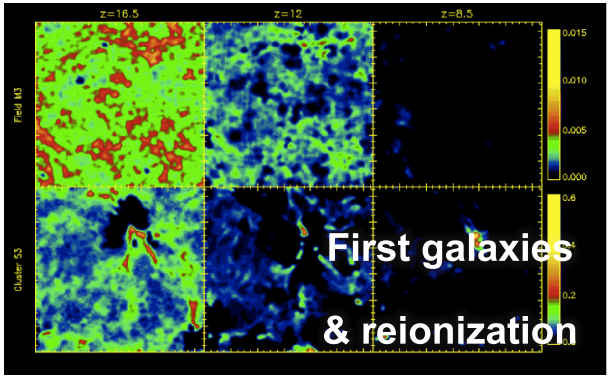




Multiplex up to 240 x



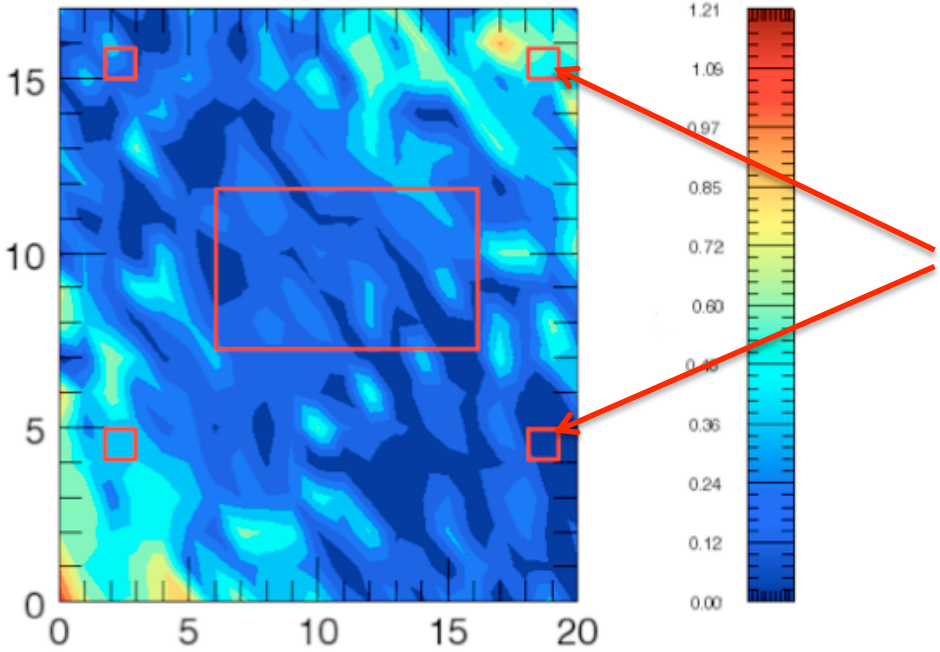
R=6000



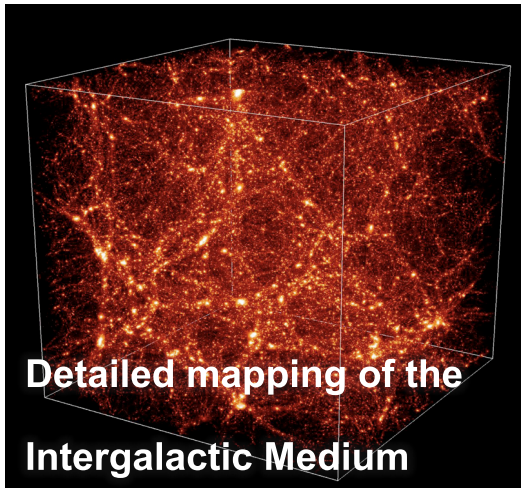
30 medium, deployable IFUs with the best sky correction

Extreme Visual Explorer

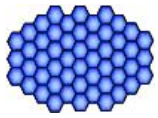
Smallest sky residuals (few 0.1%) with the medium IFU: sky can be sampled in all directions



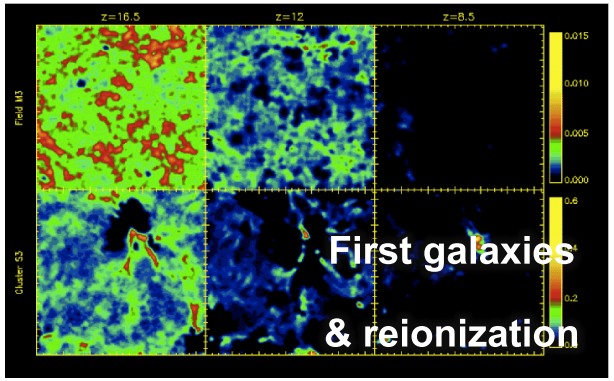
4 dedicated sky fibers



1.8''x2.9''

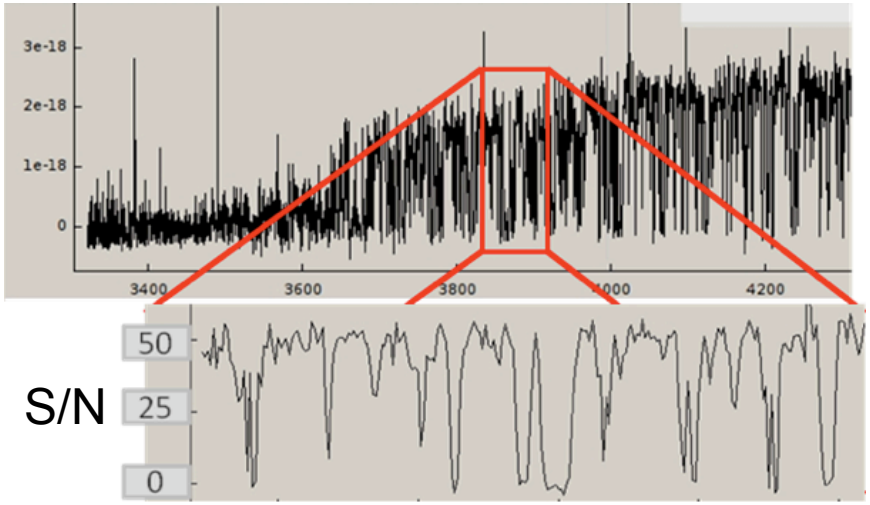
30 x 

R=6000

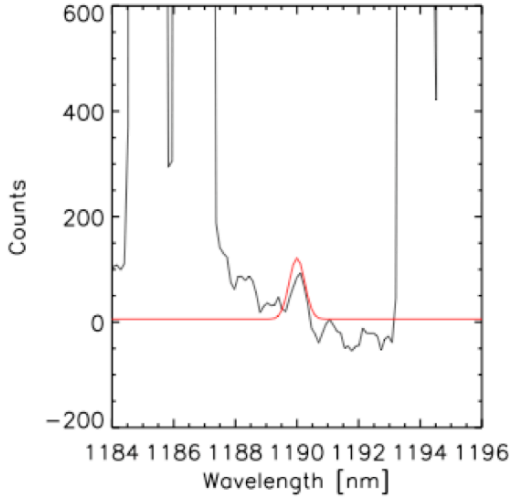


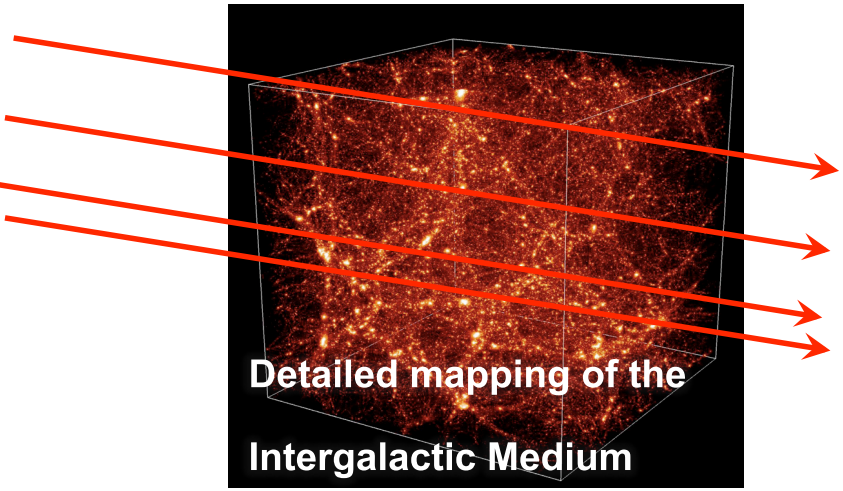
Medium IFUs: the best sky correction

m(AB)=24 Lyman break galaxy at z=3.0 (10hrs)

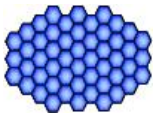


m(AB)=30 at z=8.8 or more

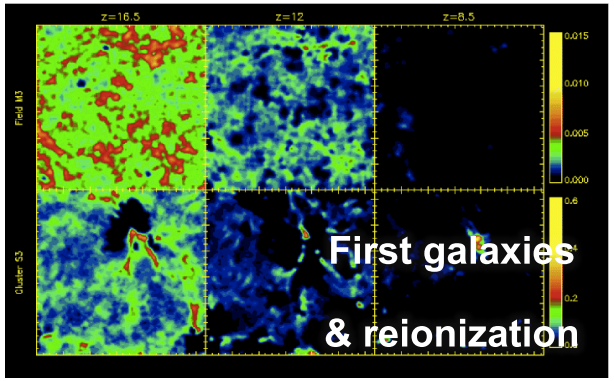




1.8”x2.9”

30 x 

R=6000



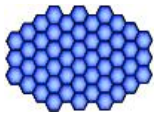
Diffuse emission of Lyα kinematics, chemistry

m(AB)=30 at z=8.8 or more

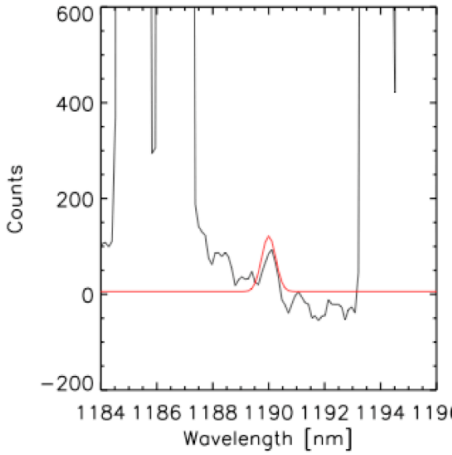
Galaxie	f_{esc} (%)	$f_{diffuse}$ (%)
Haro 11	2.6	74
ESO 338-IG04	8	70
SBS 0335-052	0.25	∼ 100
NGC 6090	0.56	73
IRAS 08+65	7	65
Tololo 65	1.7	∼ 100

Excerpt from H. Atik PhD thesis
(see also Kunth et al. 2003)

1.8"x2.9"

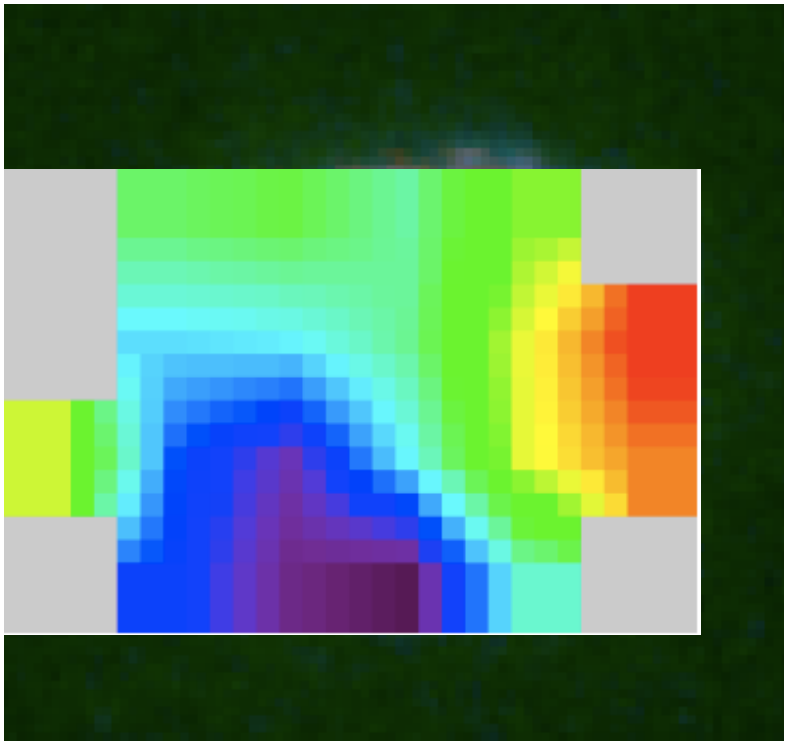
30 x 

R=6000

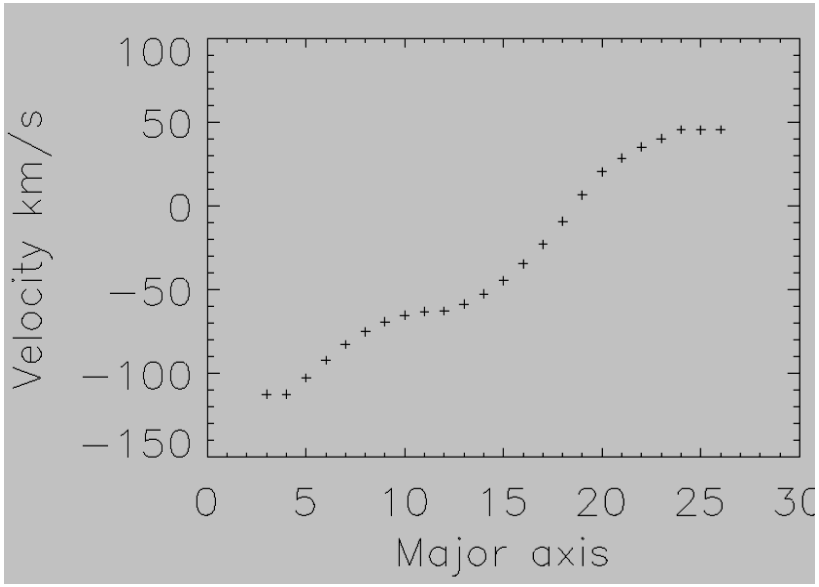


To be combined with JWST-MIRI-IFU to follow Balmer emission lines and provide the escape fraction of Lyα photons

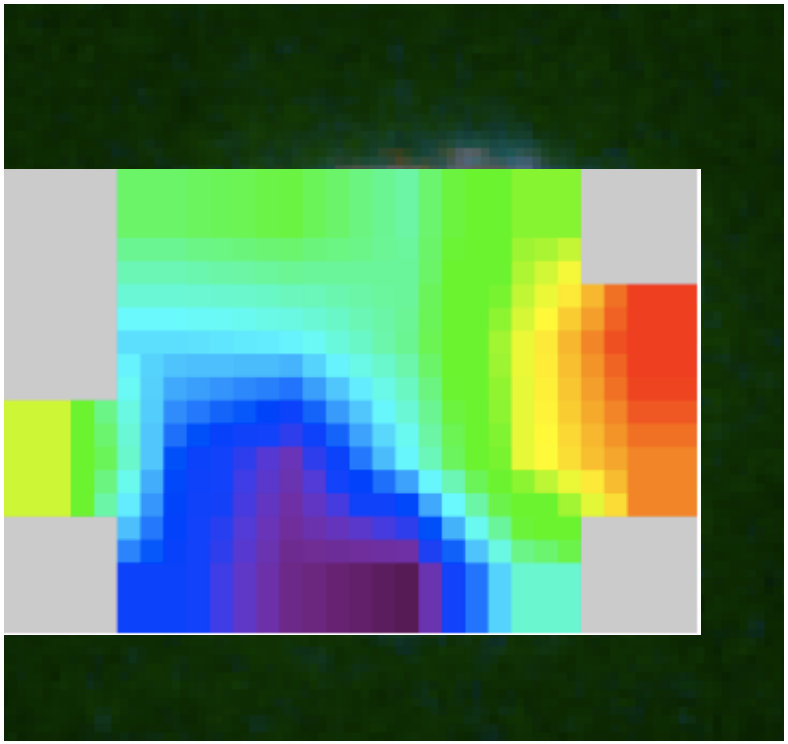
IFUs with seeing conditions or GLAO: enable kinematics/chemistry over the whole emitting areas of distant galaxies

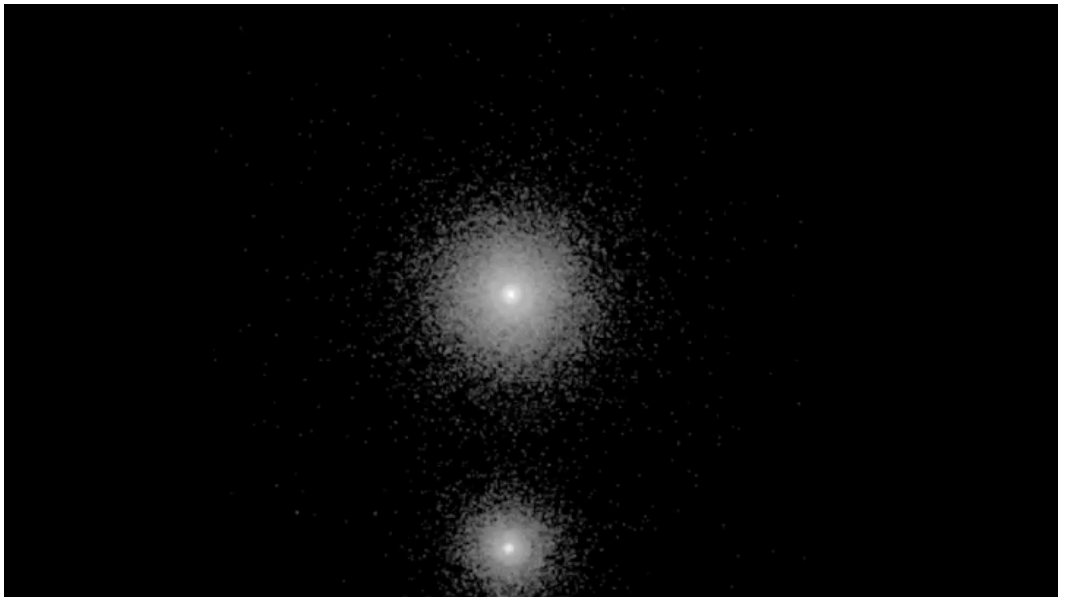


A rotating disk?



IFUs with seeing conditions or GLAO: enable kinematics/chemistry over the whole emitting areas of distant galaxies

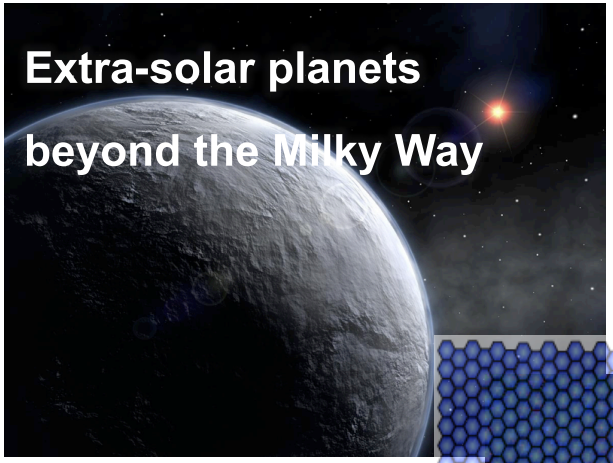




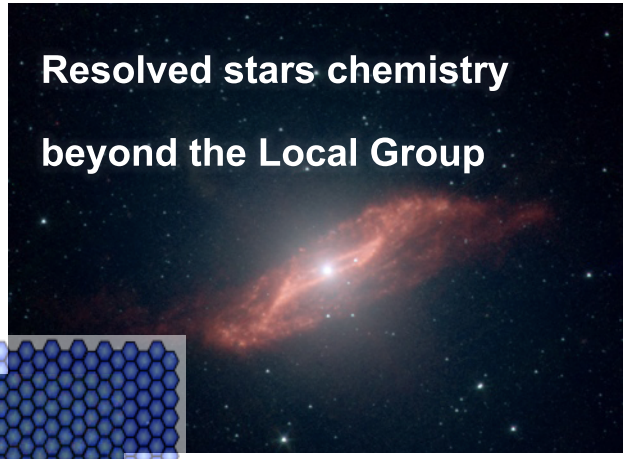
Peirani et al. 2009

Multi-apertures & spectral resolutions

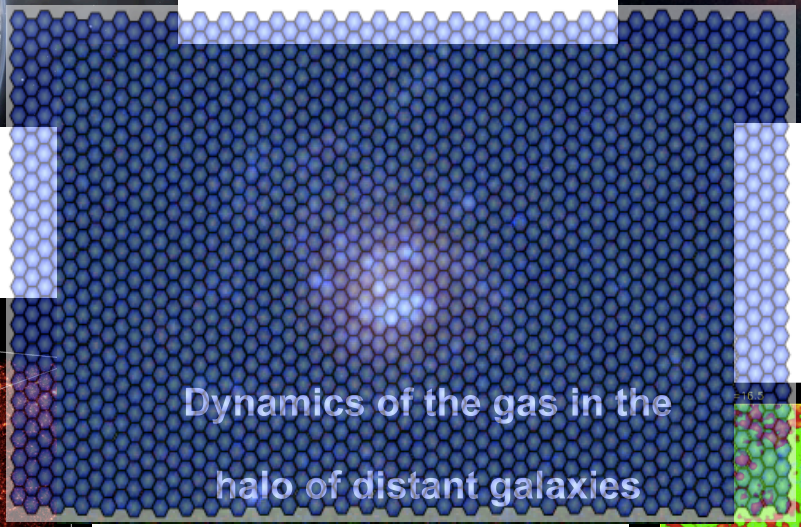
Extreme Visual Explorer



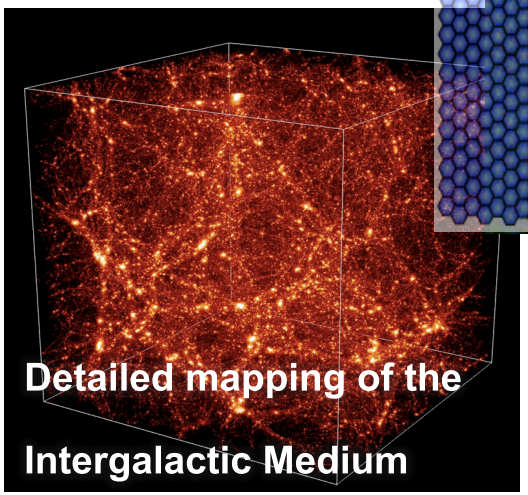
40x 0.09" R=30000



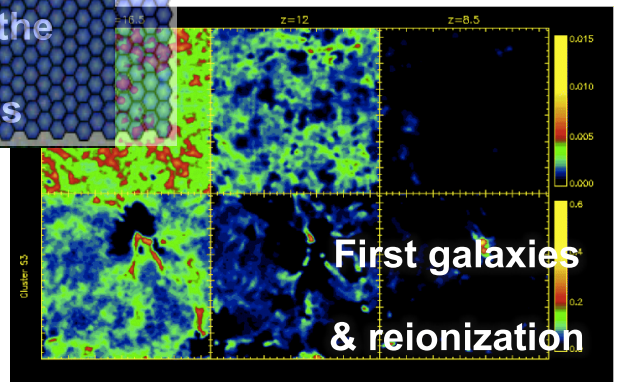
70x 0.18" R=18000



7".8x13".5



1.8"x2.9"
30 x R=6000



240x 0".3 R=6000

Conclusion

• OPTIMOS-EVE concept built on FLAMES/GIRAFFE (and on X-SHOOTER);

• It is unique in covering the largest space in (multiplex, spectral resolution) plane and this for a relatively large spectral range (370-1600nm);

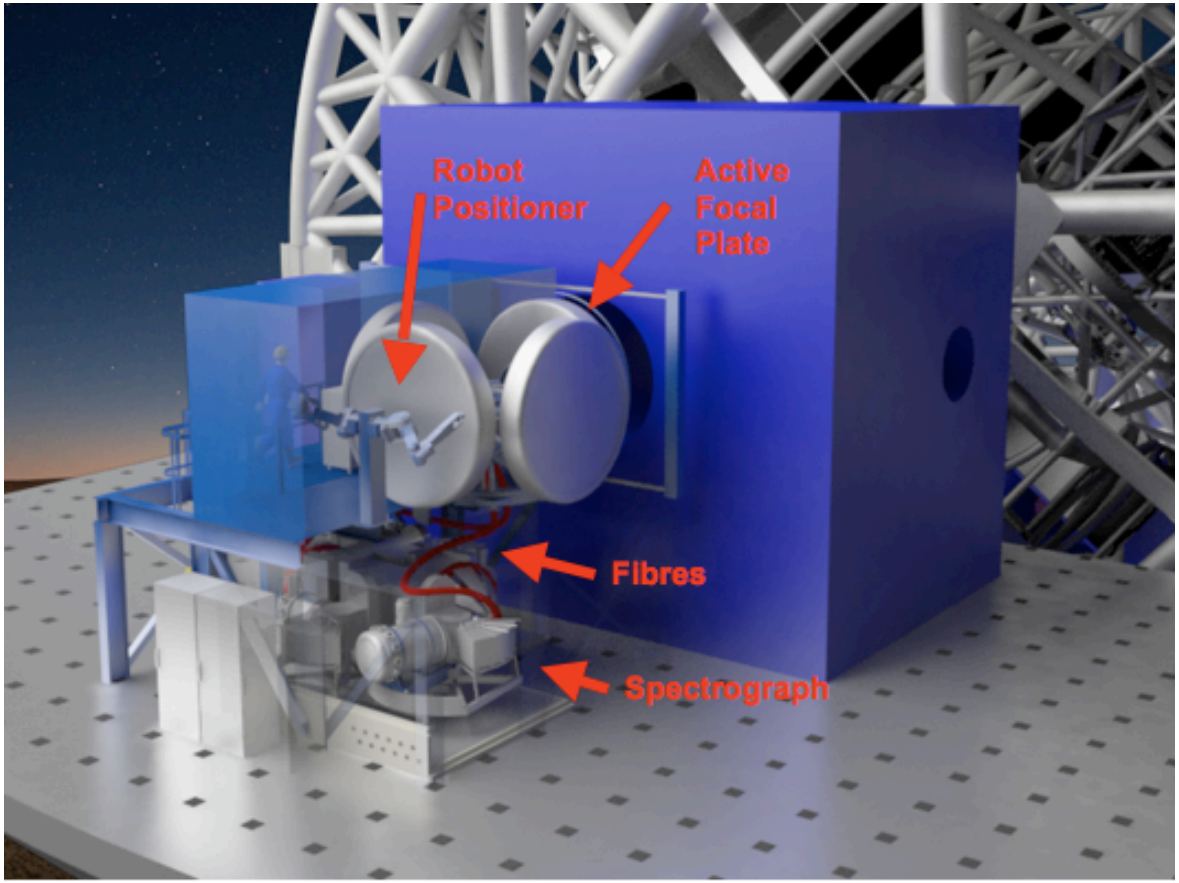
• Covers many E-ELT-DRMs: S3: detection/evolution of extra-solar planets; S9: circumstellar disks; G4: resolved stellar populations in galaxies; C4: the highest redshift galaxies; C7: enrichment of the low density IGM & C10: physics of high redshift galaxies;

• Implies numerous synergies with JWST, ALMA, GAIA etc;

• Simple operational concept ("a la FLAMES") and low risk development (existing components & technology);

• Design compliant with science cases & with telescope interfaces.

Instrument overview

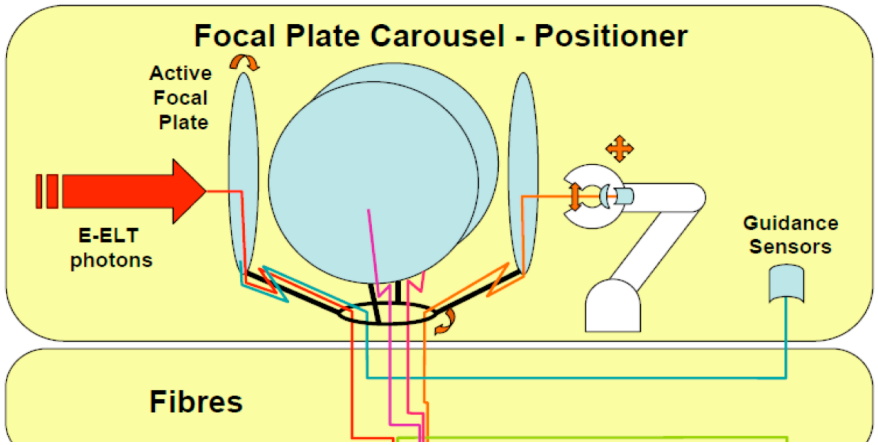


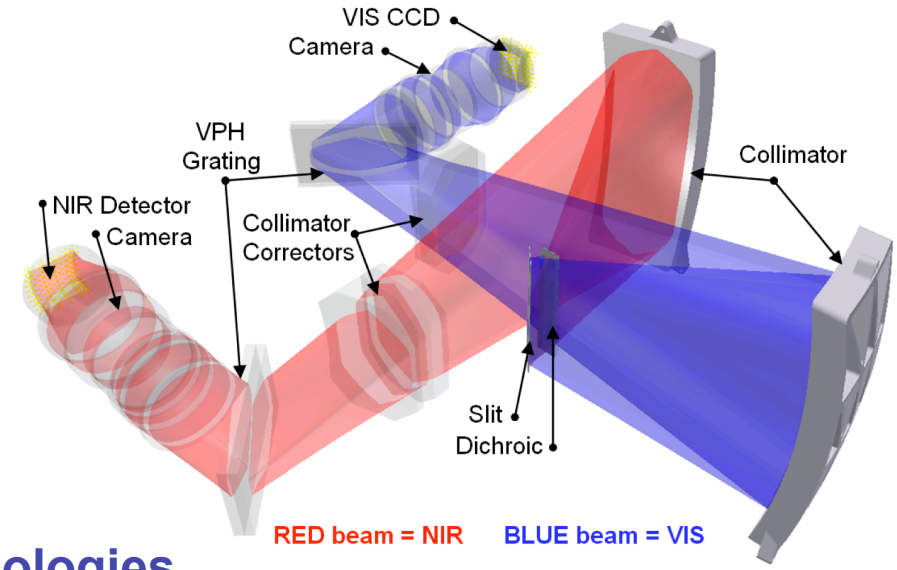
Instrument overview

An off the shelf pick-up and place positioner (e.g. OzPoz) with 4 plates to allow configuration in parallel with observation.

Fibre bundles for various spectral resolutions and for integral field units

2 identical dual-beam VIS and NIR spectrographs including VPH gratings working at 1st order





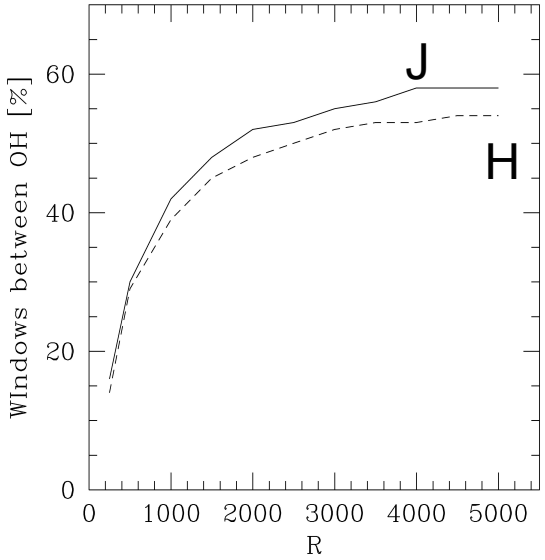
Can be manufactured using existing technologies

A fibre-fed instrument

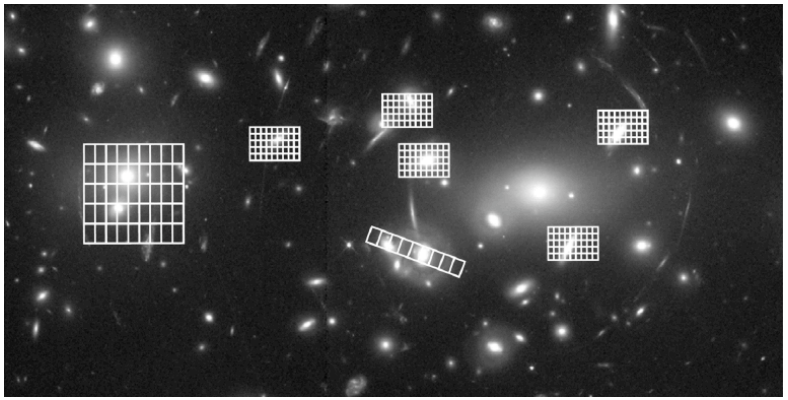
Extreme Visual Explorer

•Spectral range from 370 to 1600 nm

• R≥ 5000 to warrant to be background limited for λ > 720 nm, to properly resolve the OII doublet for kinematics, and to optimise detection of faint Lyα lines with observed FWHM down to 150 km/s; many science cases require R to 18000 and up to 30000;



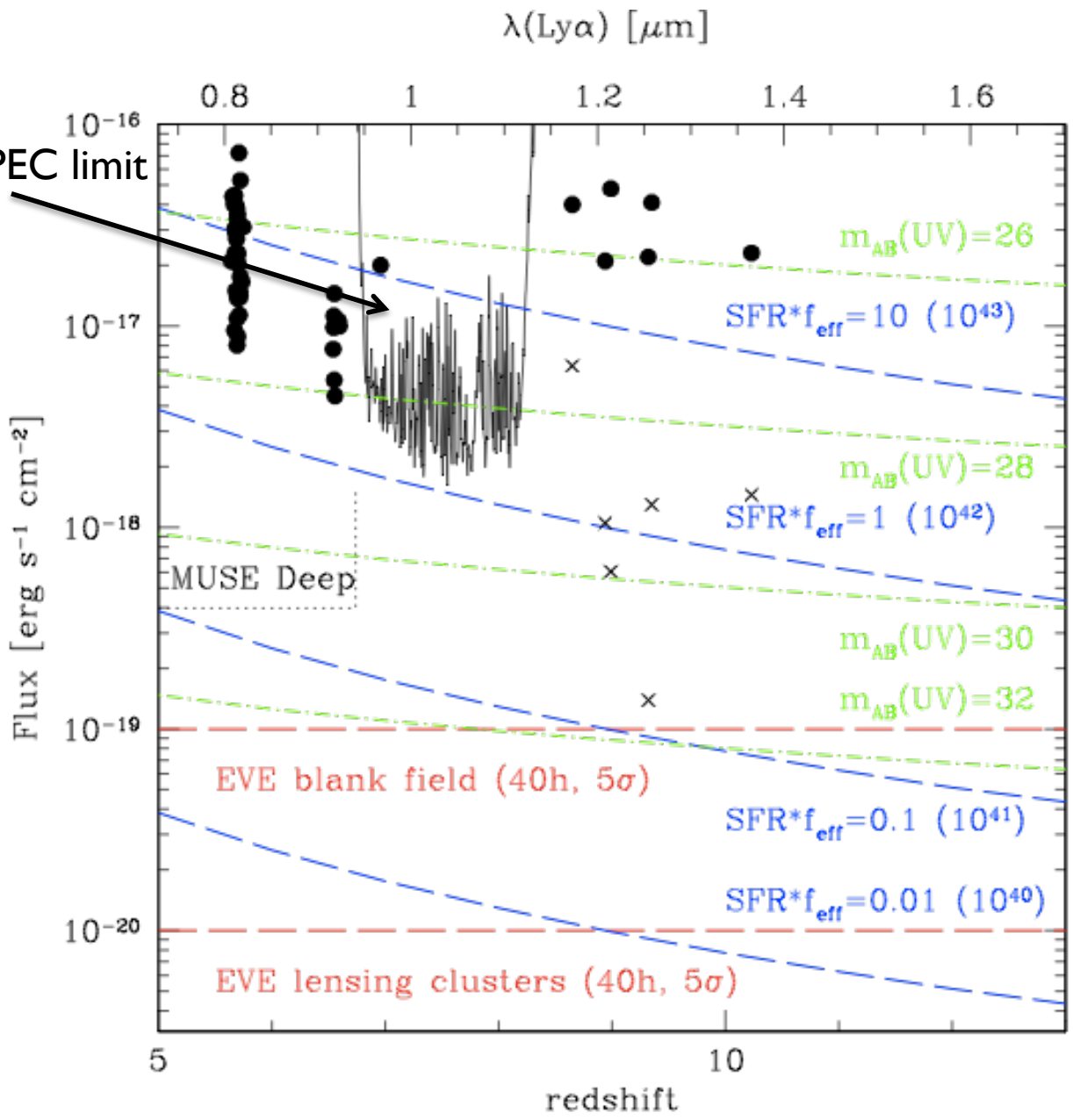
• Multiplex > 200 and the largest FoV available on the E-ELT (7' ➔ goal= 10');



•The large variety of astrophysical objects requires different apertures on sky and often spatially resolved spectroscopy (mapping of kinematics, chemistry etc…).

Search for very distant sources

Extreme Visual Explorer



Keck/NIRSPEC limit

OPTIMOS-EVE

x lensed candidates

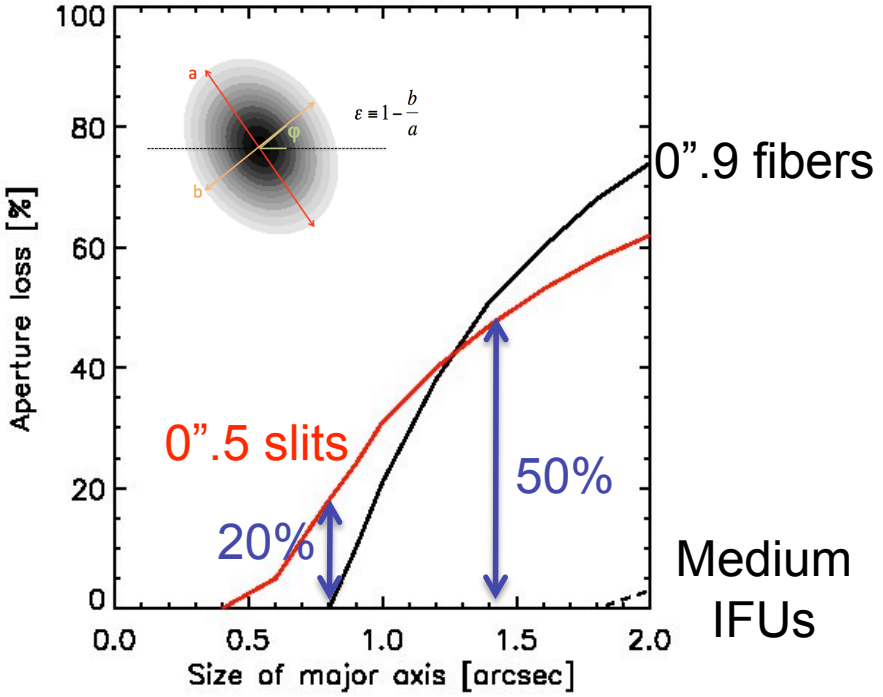
Efficiency

From focal plane to detectors: 26% in MO-LR and LI-LR, 19% in MI-LR

Throughput of the fibres is 64%

Partially or fully compensated by smaller aperture losses for < 1” objects (0”.9 fibers vs 0”.5 slit) or for extended Lya sources (medium IFUs vs 0”.5 slit)

The most demanding program is for the detection of very distant galaxies: requires a fair comparison between different concepts of sky correction, aperture losses, flexure effects, required multiplex, spectral resolution etc…

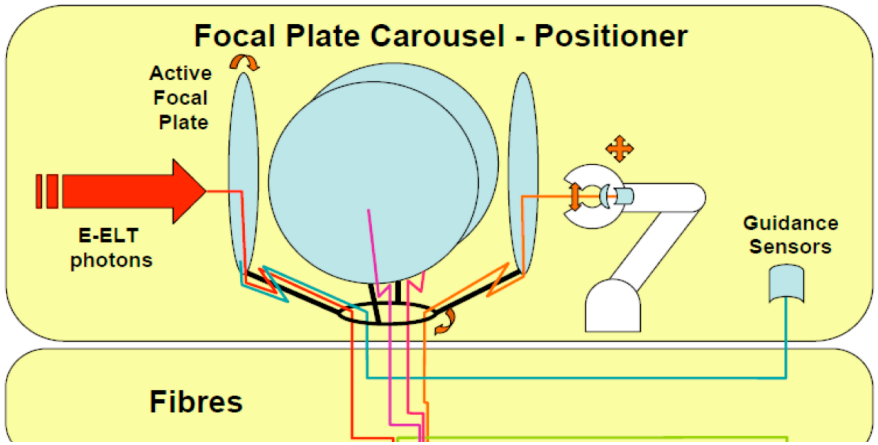


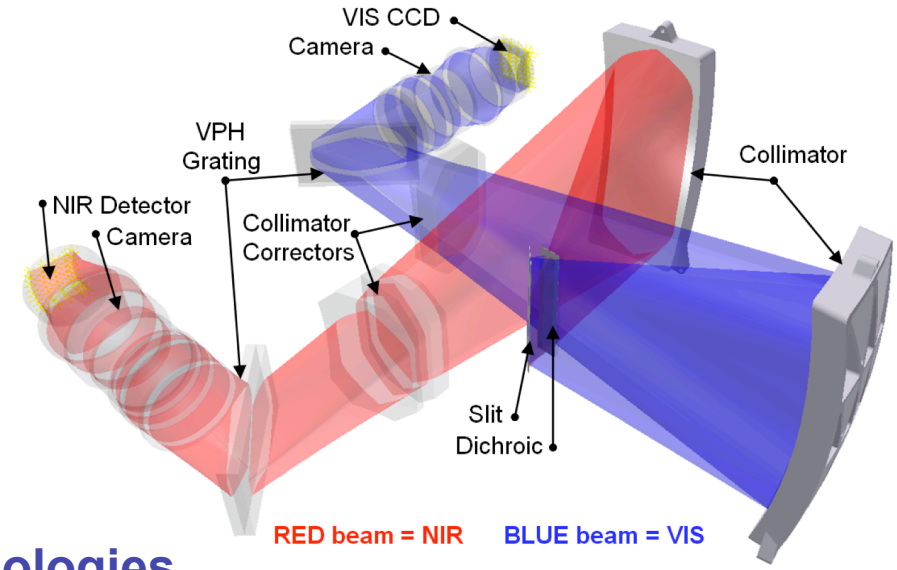
Instrument overview

An off the shelf pick-up and place positioner (e.g. OzPoz) with 4 plates to allow configuration in parallel with observation.

Fibre bundles for various spectral resolutions and for integral field units

2 identical dual-beam VIS and NIR spectrographs including VPH gratings working at 1st order



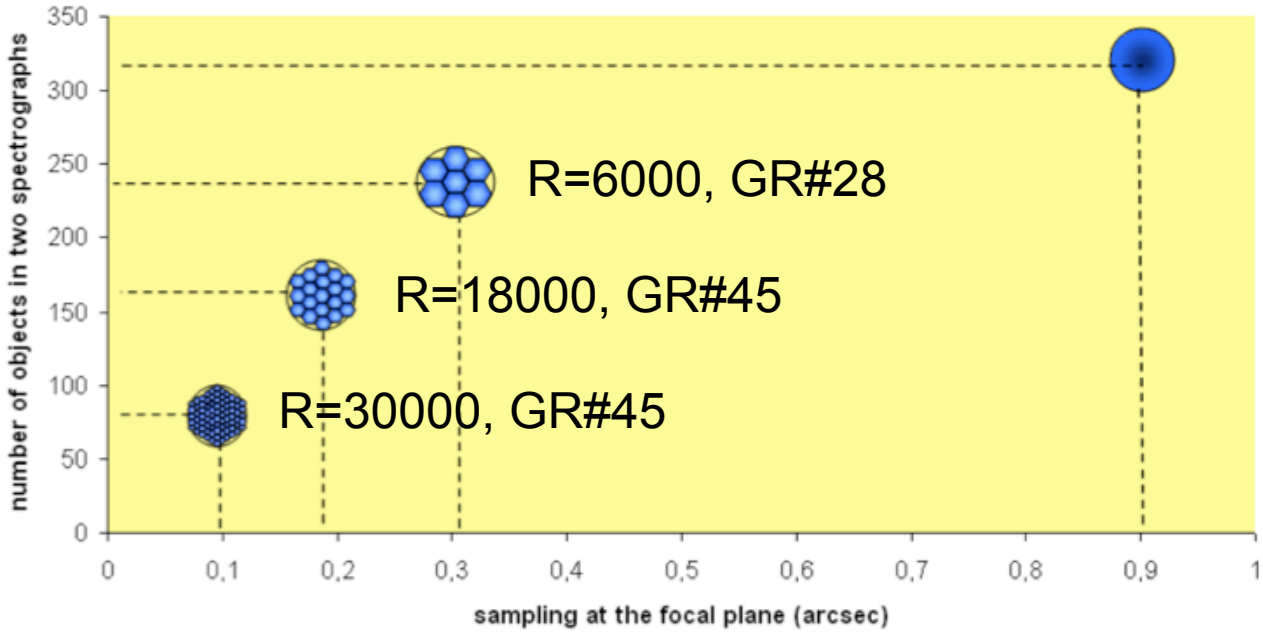


Can be manufactured using existing technologies

Field of view & spectral resolution

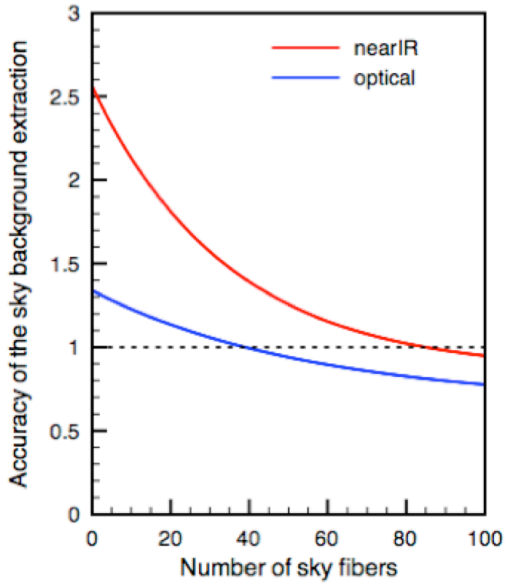
Field of view: fibres can be positioned at any available location of the ELT FoV, without any flexure;

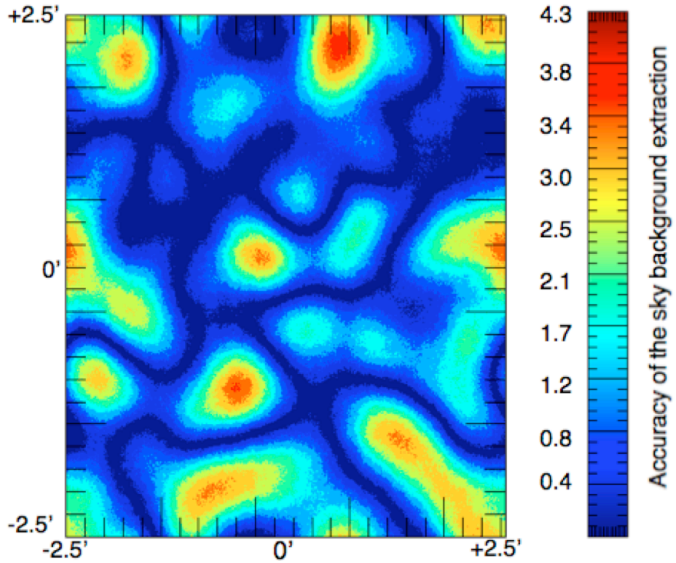
OPTIMOS-EVE is unique in offering in multiplex mode, 3 resolutions from R=5000 to R=30000, with only 2 gratings.

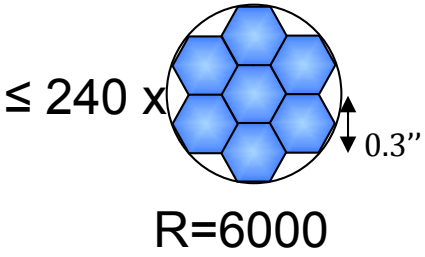


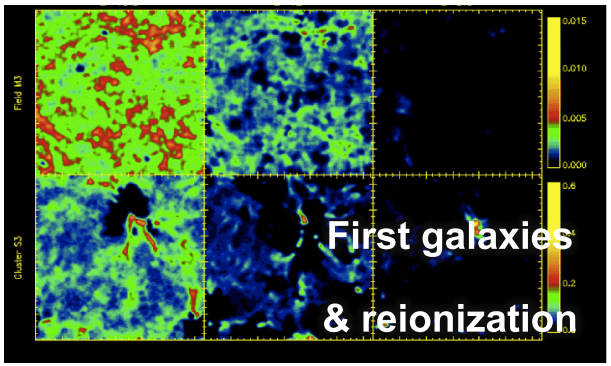
Sky correction

Sky correction: mapping the temporal sky fluctuations with fibres over the whole FoV.



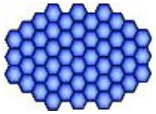






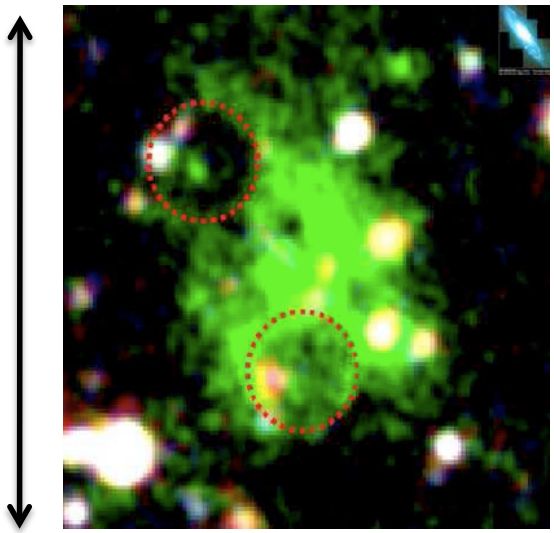
Lyα blobs: kinematics & chemistry

1.8”x2.9”

30 x 

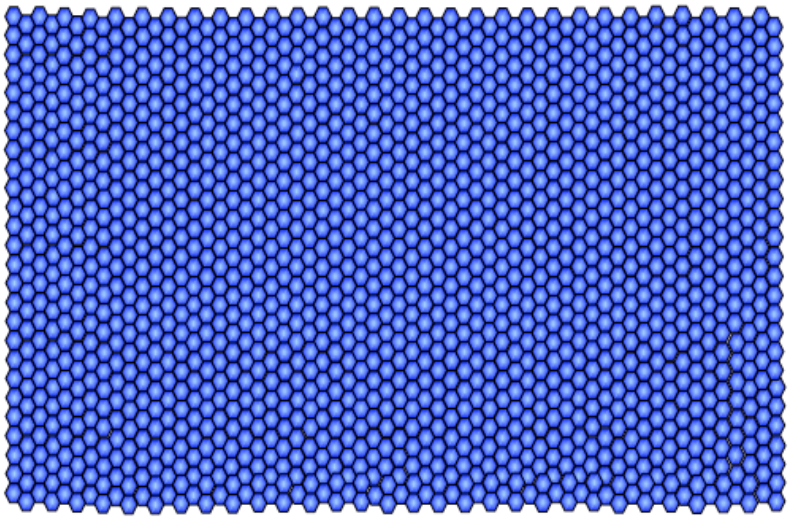
R=6000

From 2 to 9 arcsec



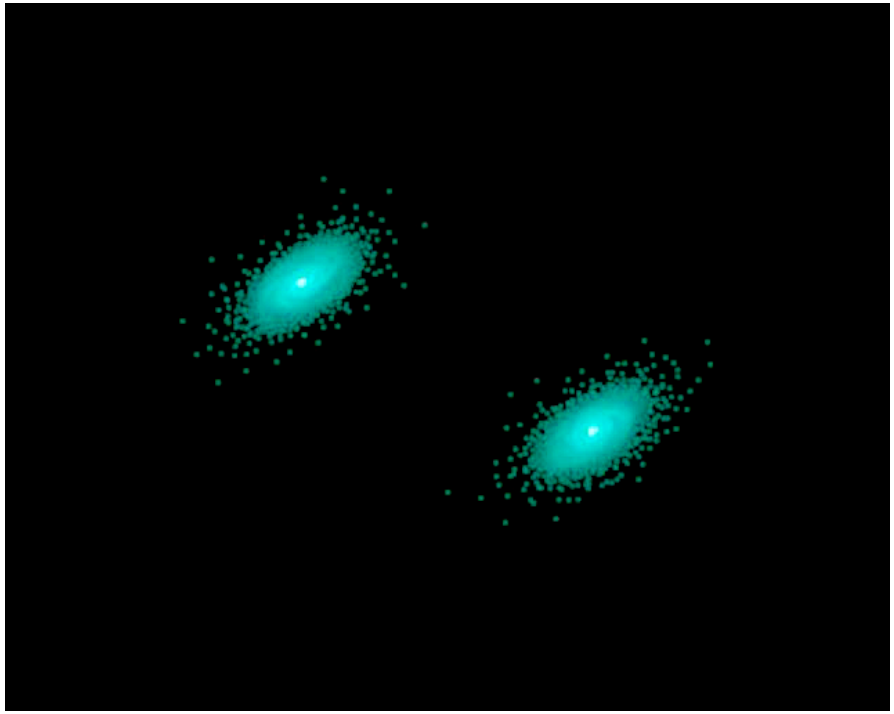
OPTIMOS-EVE

One Large IFU using 0.3” fibres and covering 7.8x13.5”

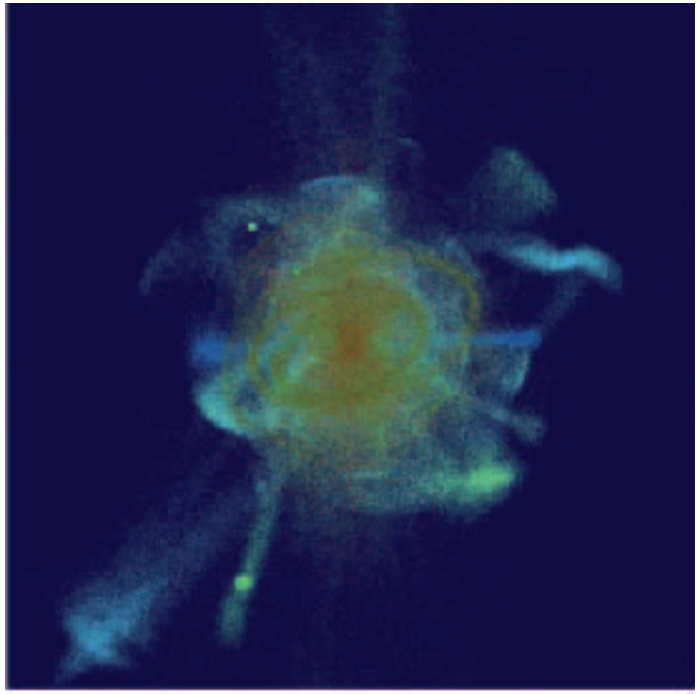


To be combined with JWST/MIRI-IFU to follow Balmer emission lines and provide the escape fraction of Lyα photons and to JWST/NIRCAM to detect filaments

Haloes were much richer of stars & gas in the past



Adapted from Barnes 2002 (8 Gyrs duration) (courtesy Y.B. Yang)



Simulations from Font et al. 2006