Multi Unit Spectroscopic Explorer

Lyon

Leiden

Zurich

Potsdam

ESO

Toulouse

Göttingen

Lyman Alpha Emitters with VLT/MUSE

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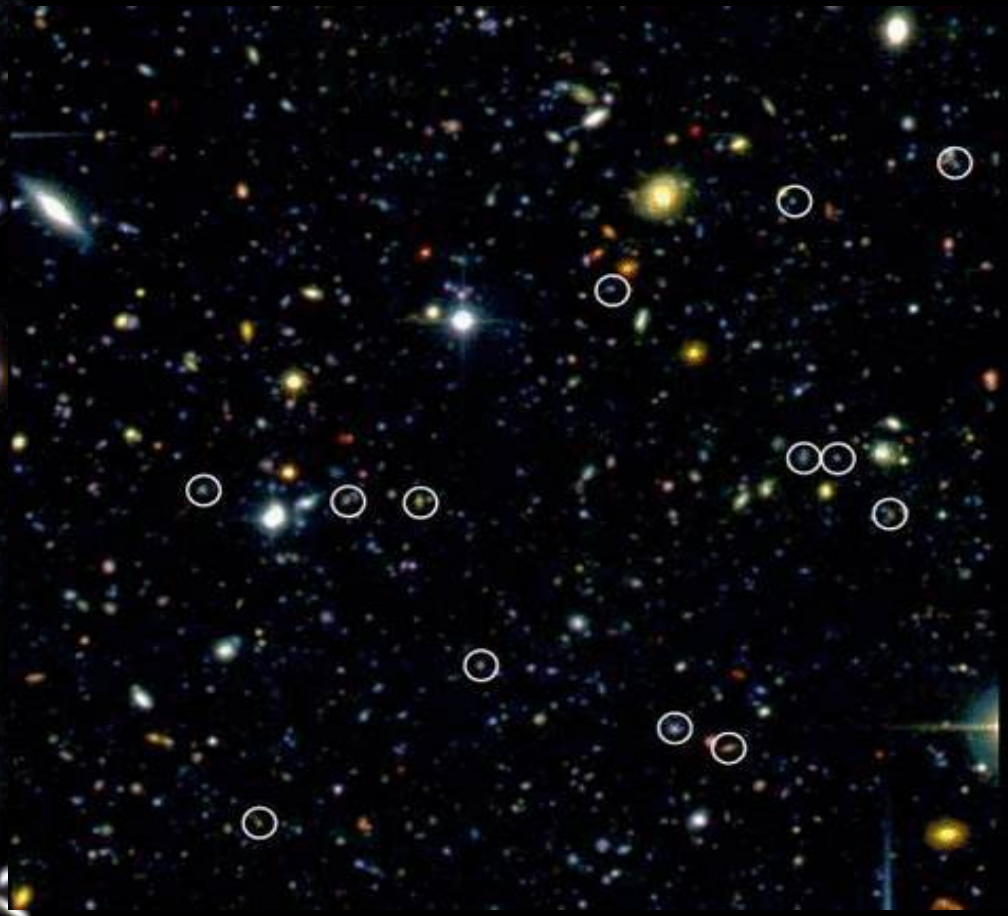
On behalf of the MUSE Consortium

The quest for high z galaxies



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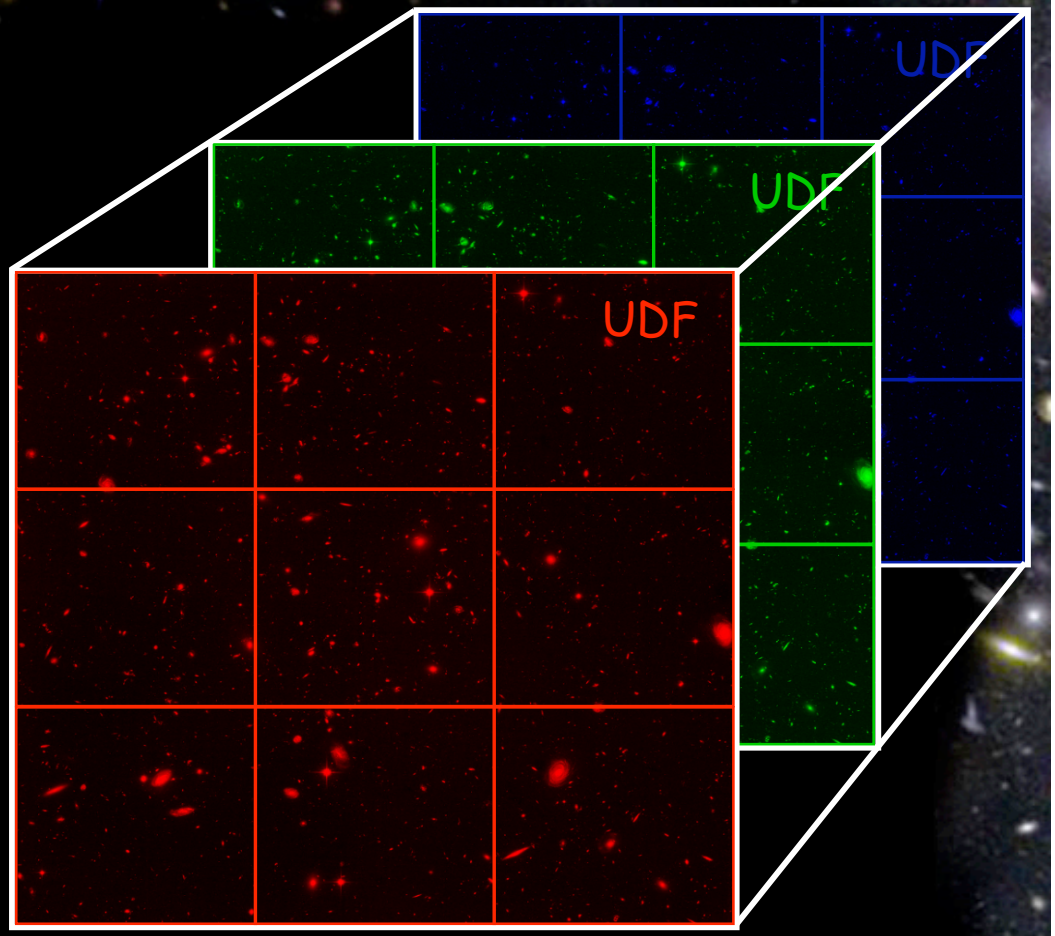
Spectroscopic Surveys with an IFU

Get everything!

- Eliminates pre-imaging
- Eliminates pre-selection
- Observe only once (image +spectra)
- Attack multiple science topics simultaneously
- Large discovery space for serendipitous sources



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The MUSE instrument at VLT

The Multi-Unit Spectroscic Explorer: A new stable, high-throughput IFU spectrograph with a 1 armin^2 FOV and a spectral resolution of R=1800-3800, working at 0.4-0.9 μm, and assisted by AO.

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The Project Vision

- **Challenges**
  - Achieve high throughput
  - Achieve high spatial resolution
  - Achieve high optical quality
- **Innovations**
  - Slicer: Advanced concept
  - Spectrograph: new concept adapted to small industrial series
  - Grating: VPHG with broad response
  - Small series industrial development

MUSE Instrument Overview

Focus	Nasmyth B UT4
Deformable Secondary Mirror	1170 actuators
Laser guide stars	4 x 20-25 Watts
Instrument	Integral Field Spectrograph
Number of IFU units	24
Detectors	4k x 4k Deep depletion CCD
Simultaneous Wavelength Range	480 – 930 nm (nominal) 465 – 930 nm (extended)
Resolving Power	1750@465nm – 3750@930nm
Datacube Size	1570 MB

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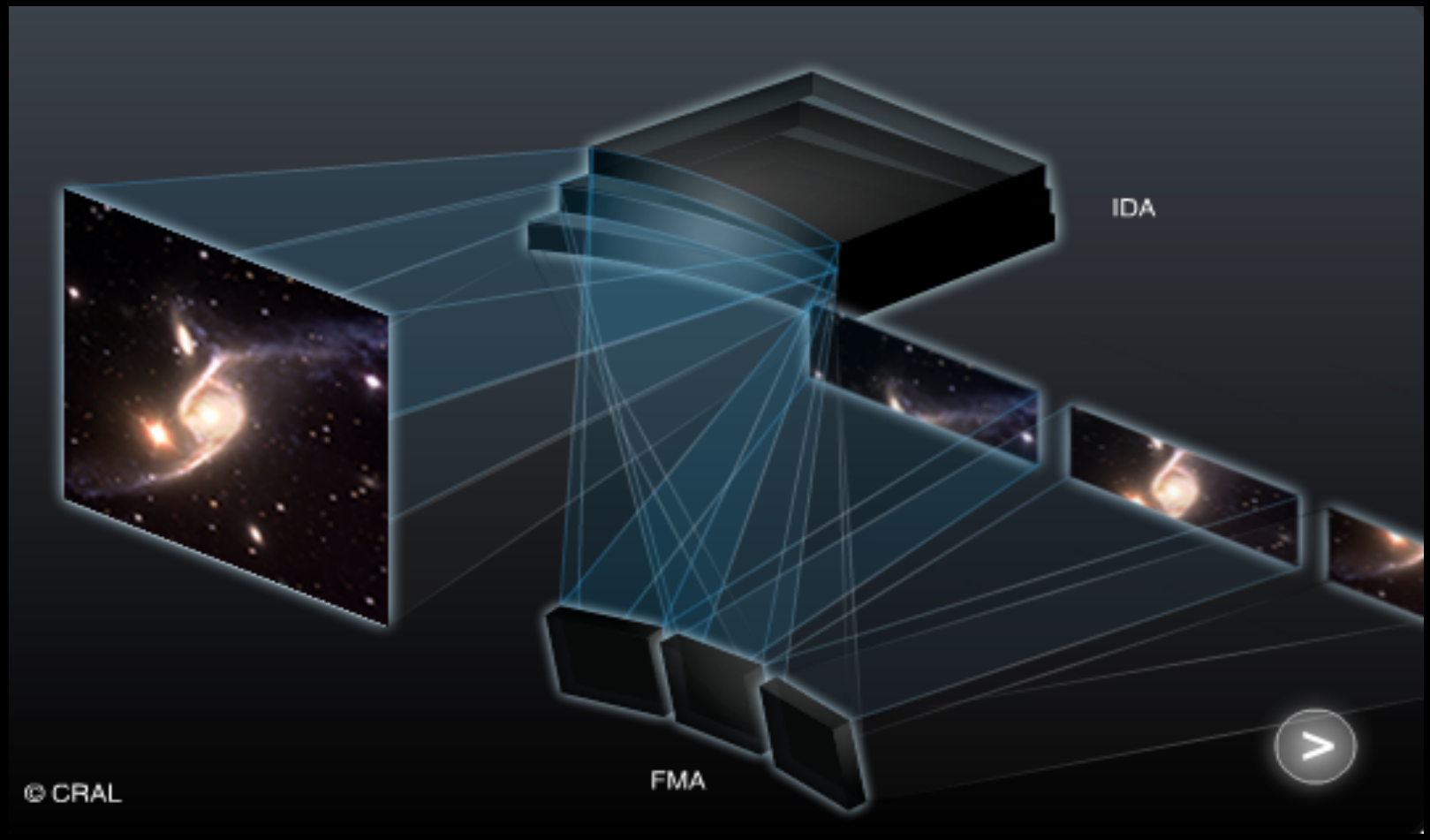
Wide Field Mode

Field of View	1x1 arcmin^2
Spatial Sampling	0.2x0.2 arcsec^2
Spectra/Exposure	90,000
Sky Coverage in AO	70% @ galactice pole 99% @ galactic equator
AO Energy gain wrt seeing	x2

Slicer concept



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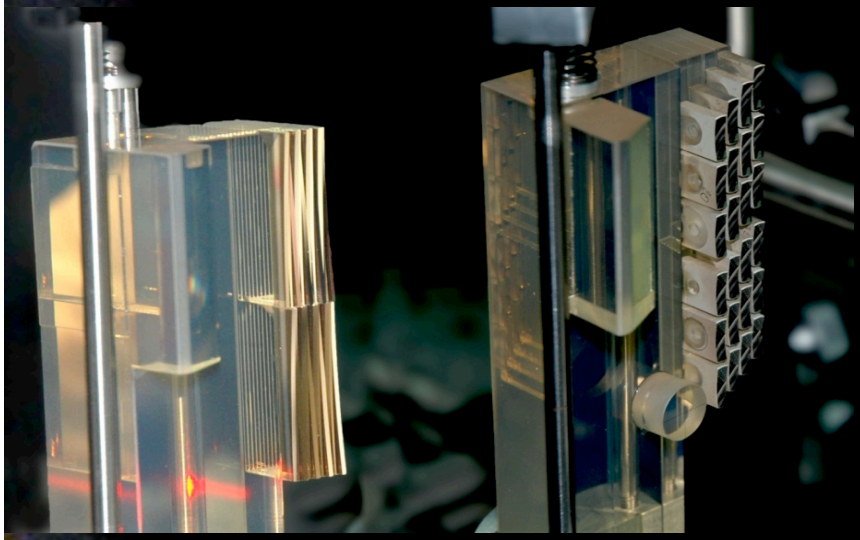
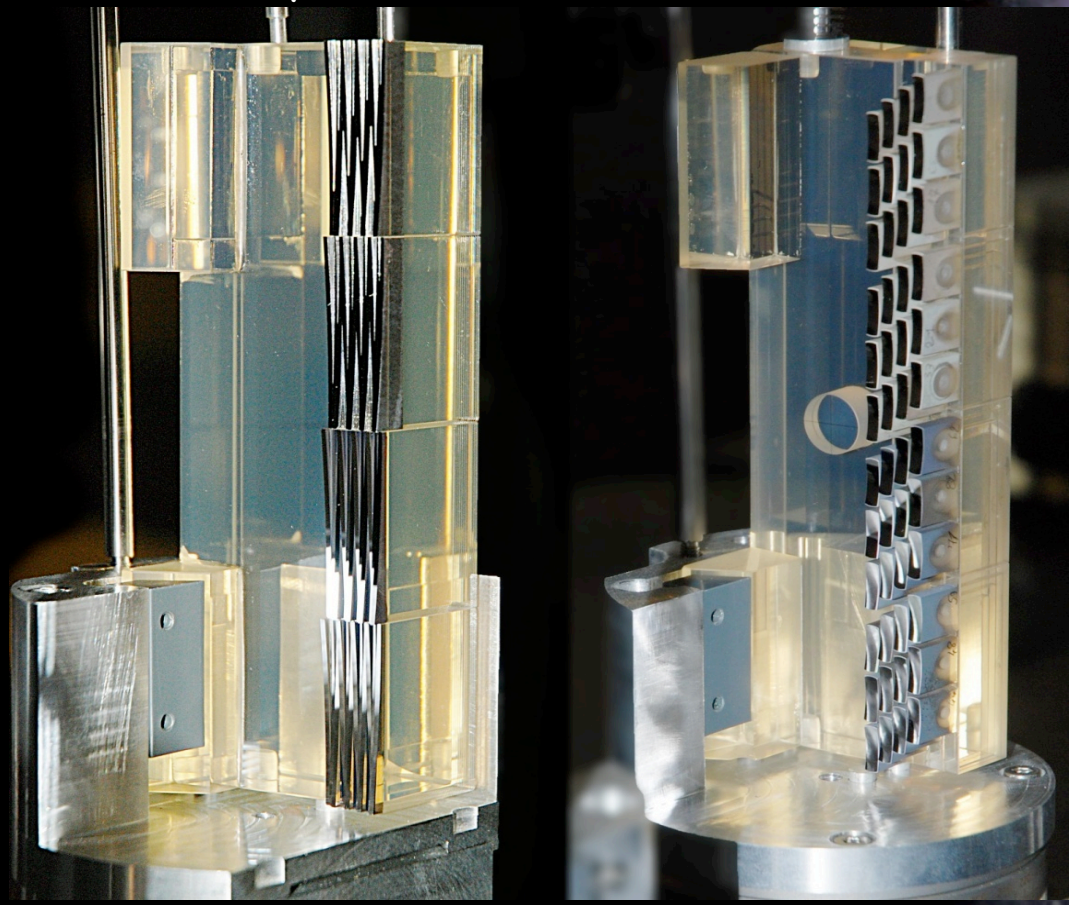
Slicer prototypes



Winlight ISS prototype, ½ slicer
December 2007

Winlight ISS prototype, full slicer
January 2008



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Wavelength range and spectral resolution

MUSE

465 nm

R=1800

930 nm

R=3800

SAURON

480nm 535 nm

R=1200

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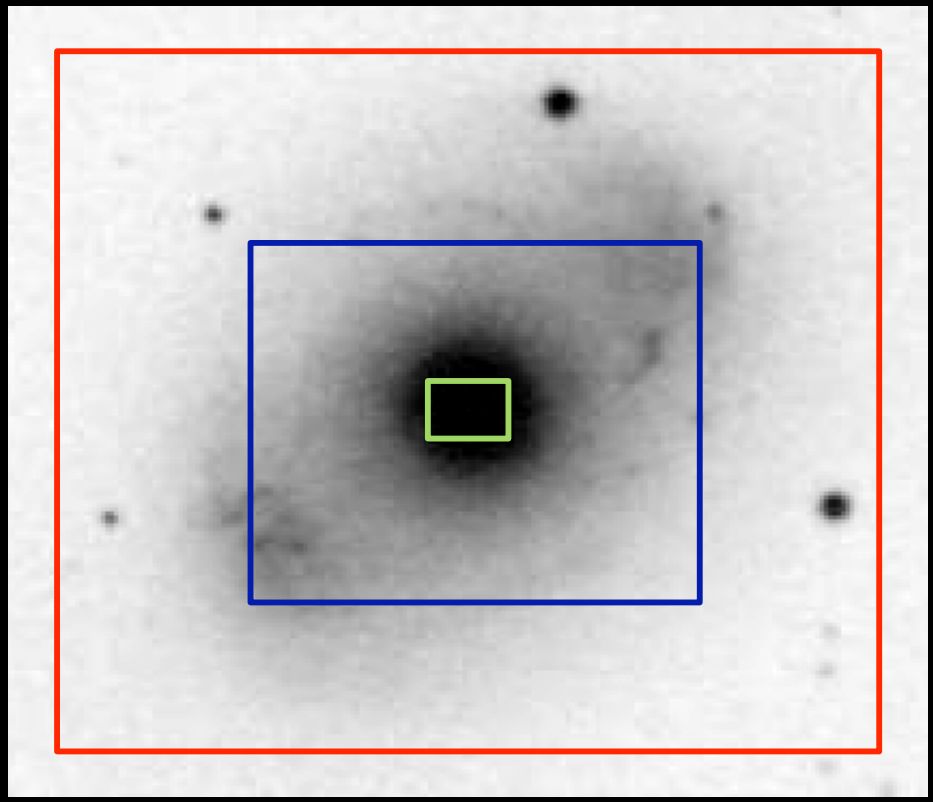
Field of View and spatial resolution

- MUSE WFM
  - 60x60 arcsec^2
  - 0.2 arcsec sampling
  - 0.3 arcsec resolution
- SAURON
  - 40x30 arcsec^2
  - 0.94 arcsec sampling
  - 1 arcsec resolution
- OASIS
  - 10x7 arcsec^2
  - 0.27 arcsec sampling
  - 0.6 arcsec resolution



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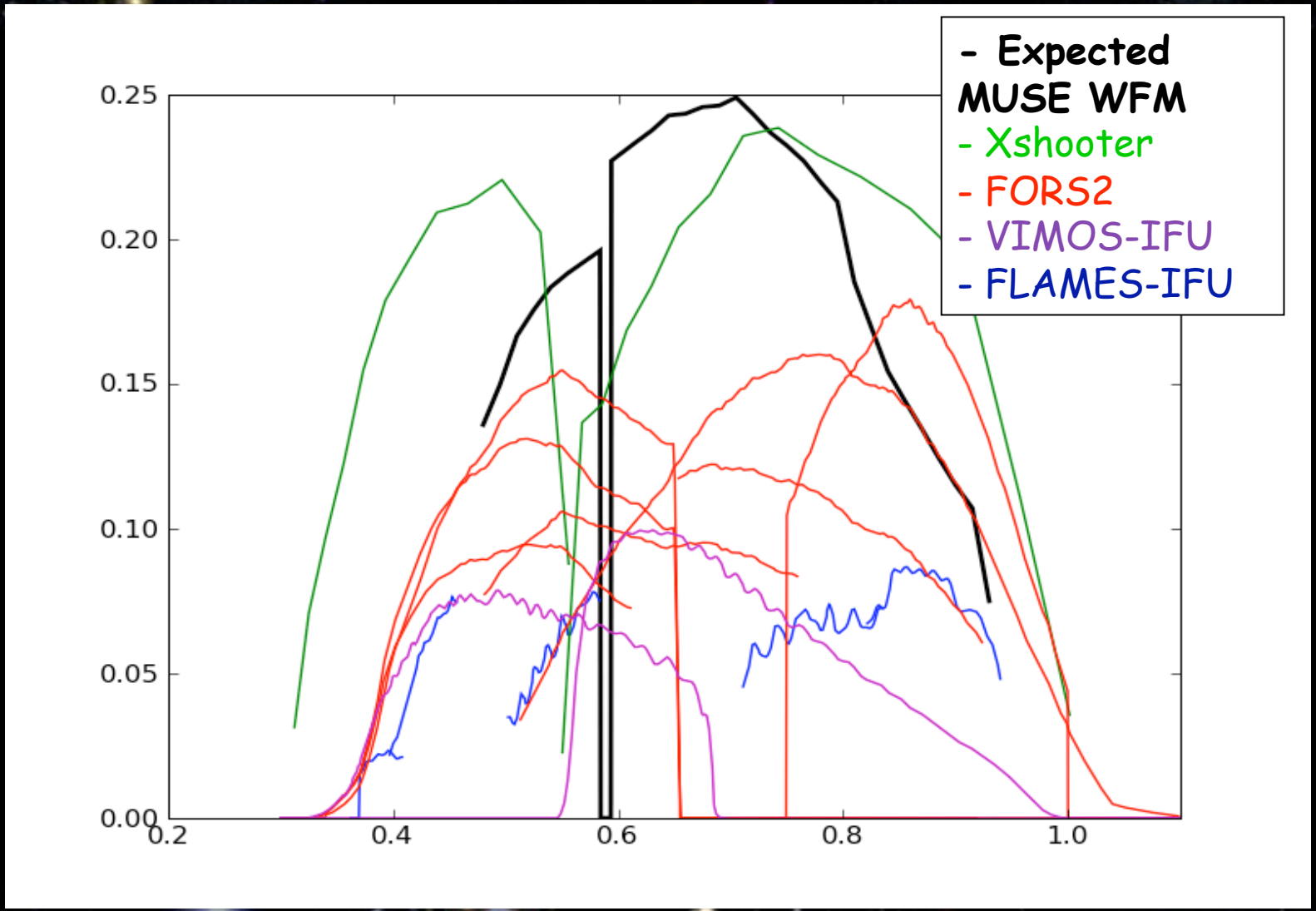
Throughput Comparison



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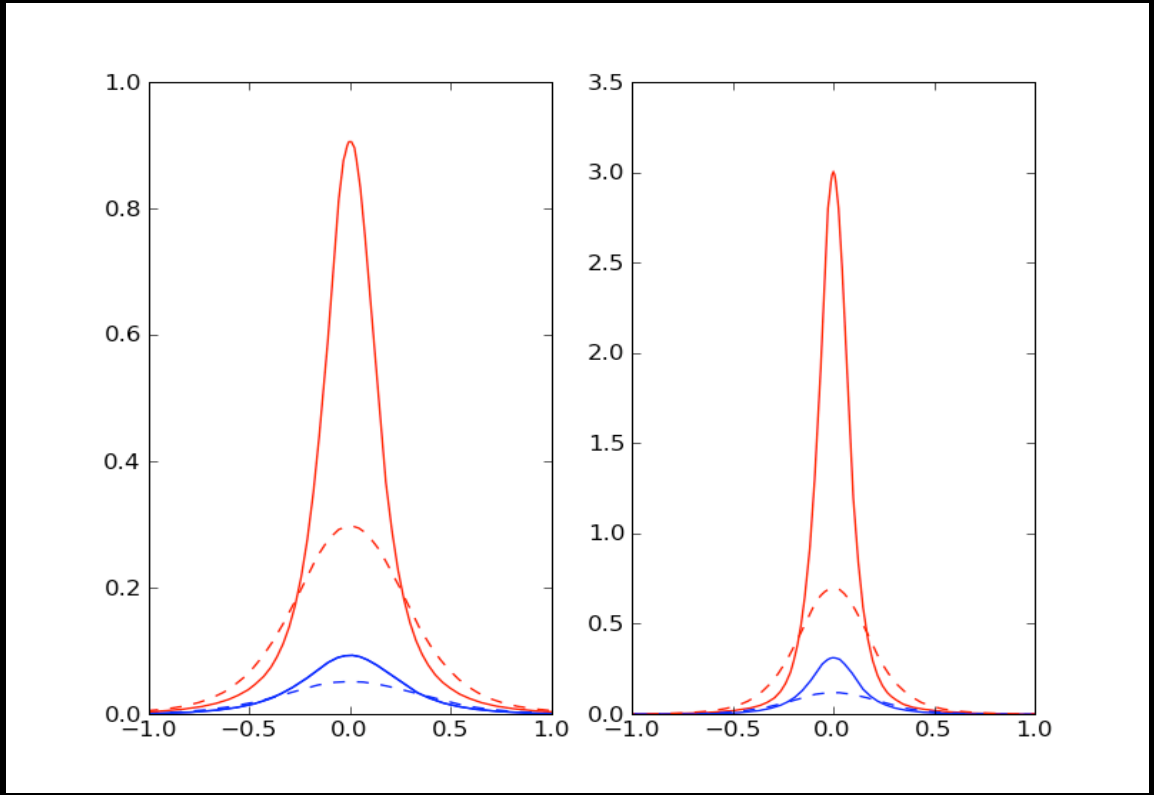
Spatial PSF in WFM

---- Non AO
—— WFM AO median Cn^2 profile

465 nm
930 nm



Dimm seeing: 1.1 arcsec 0.65 arcsec

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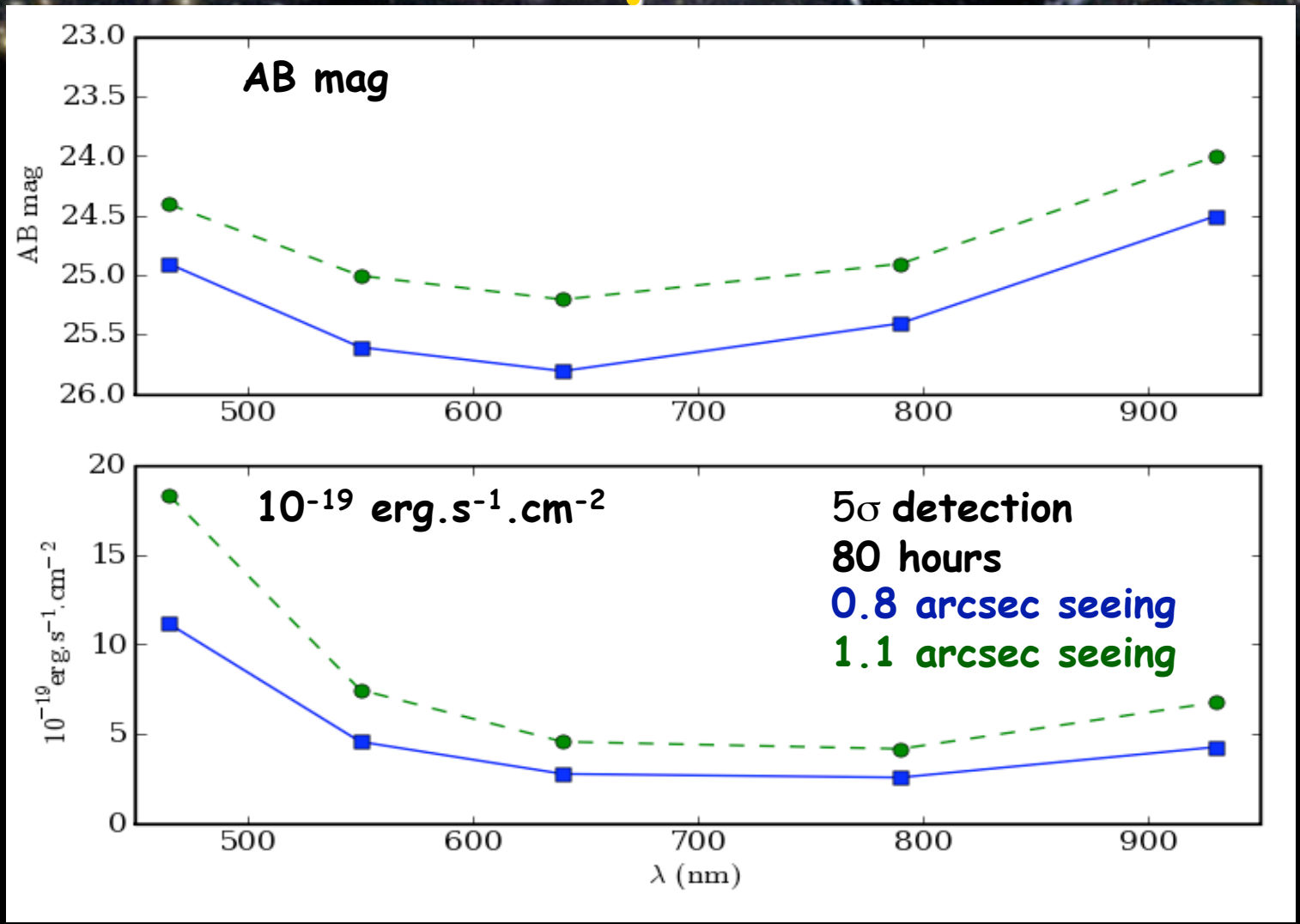
WFM performances



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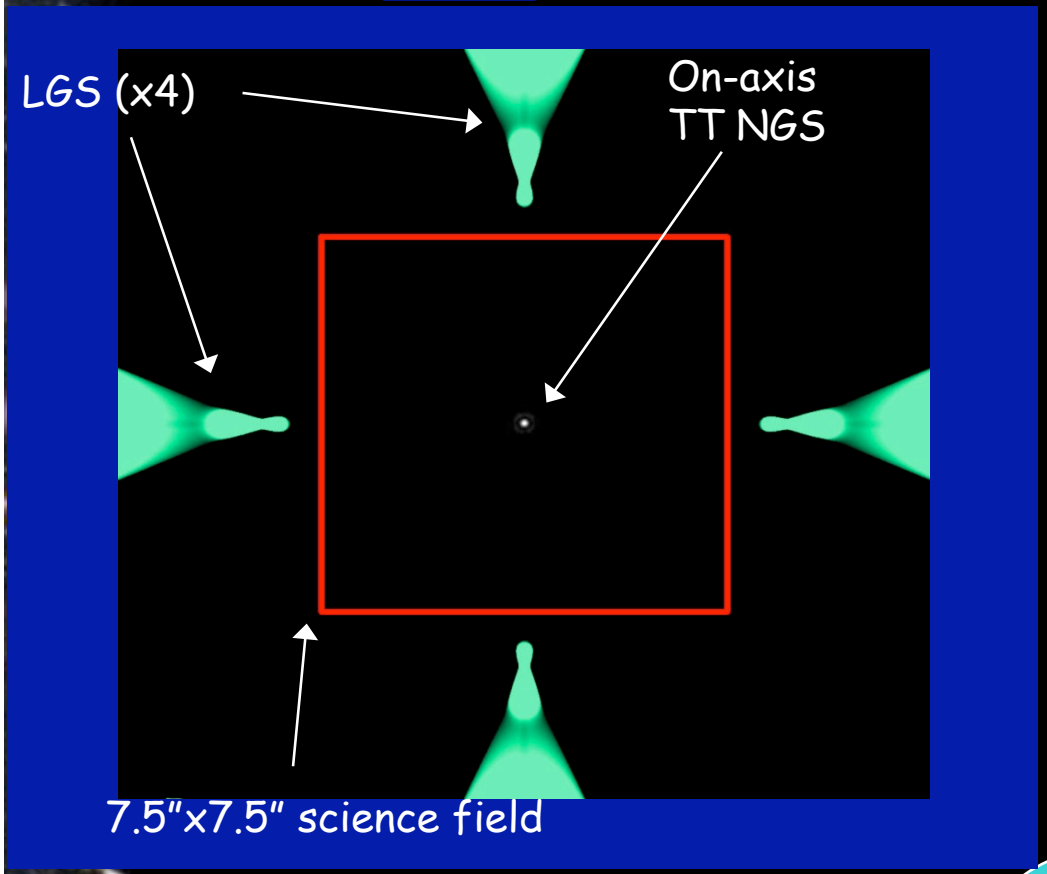
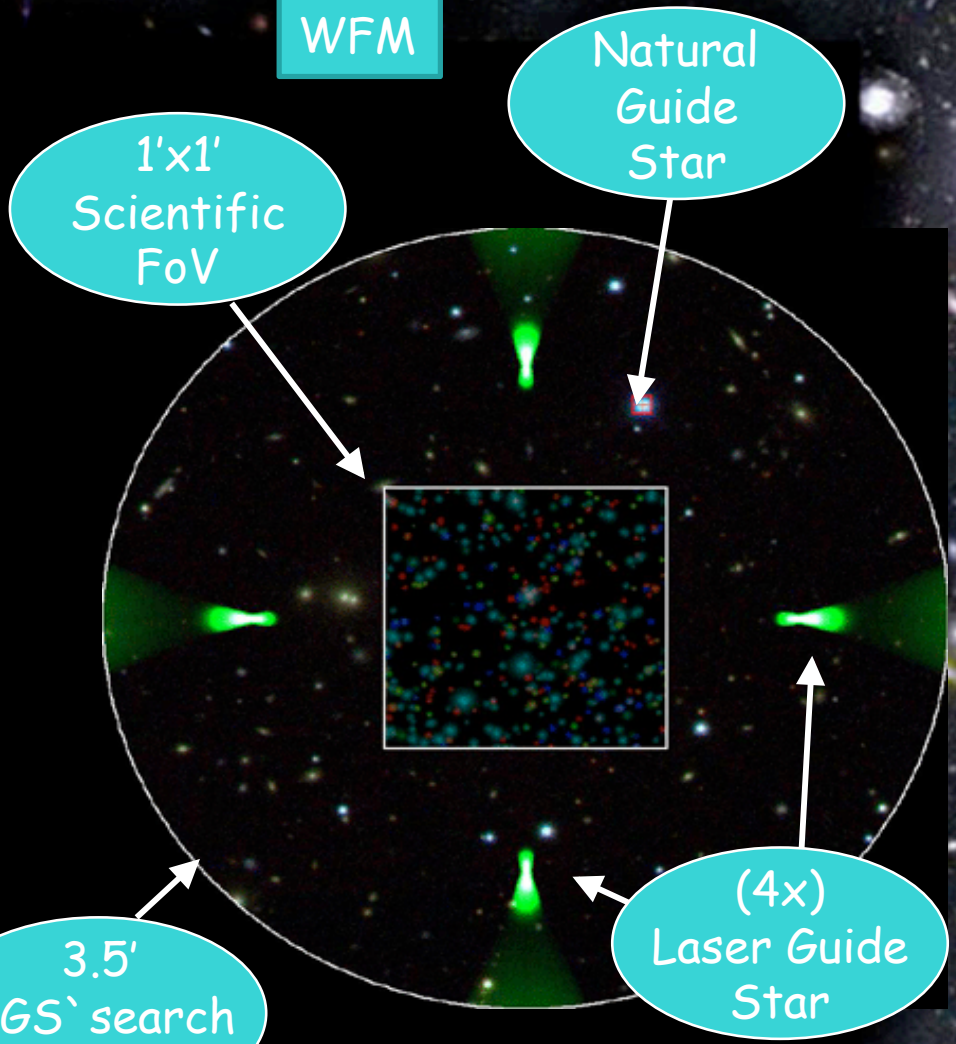
GALACSI AO subsystems

MUSE

NFM



WFM



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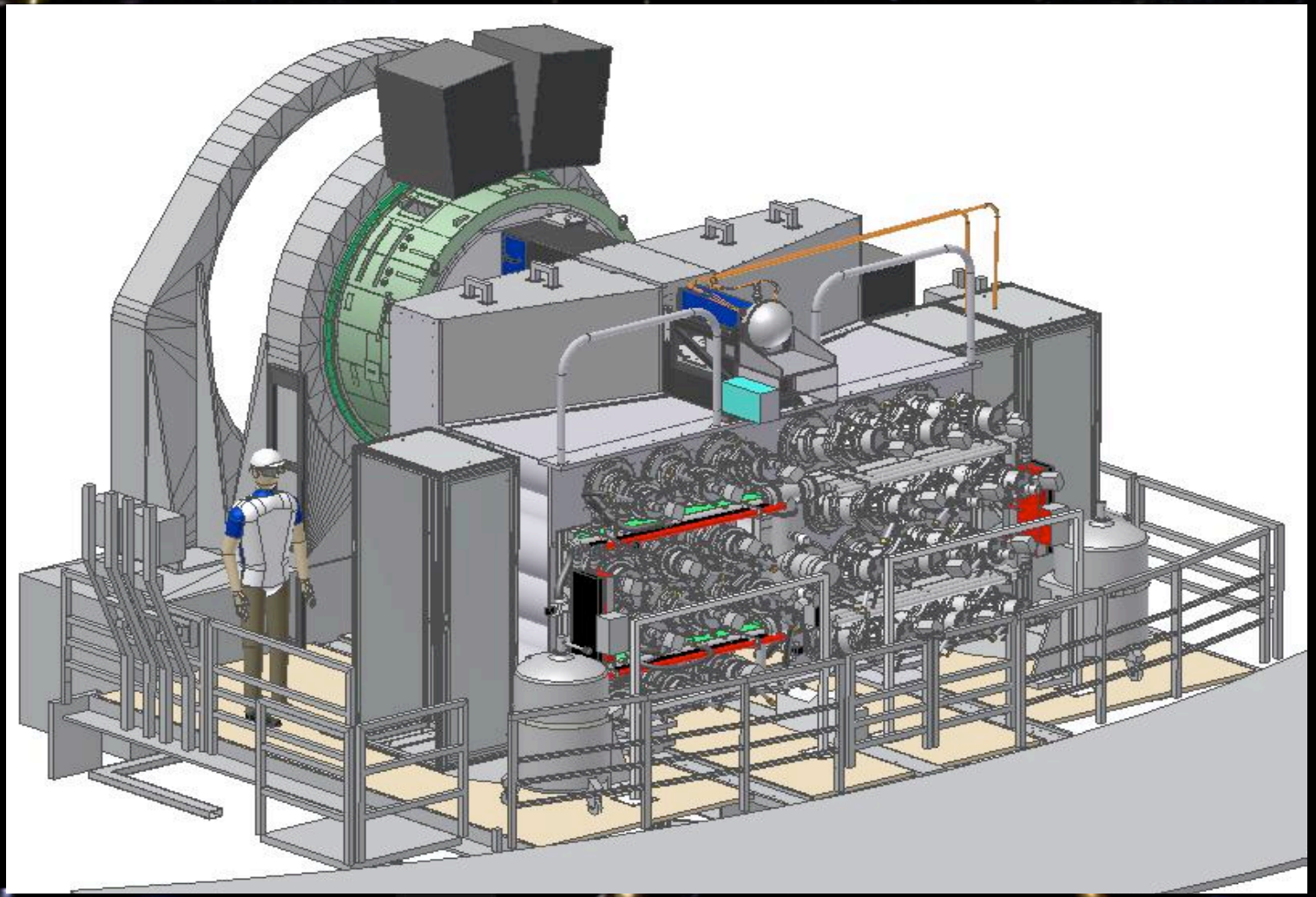
MUSE



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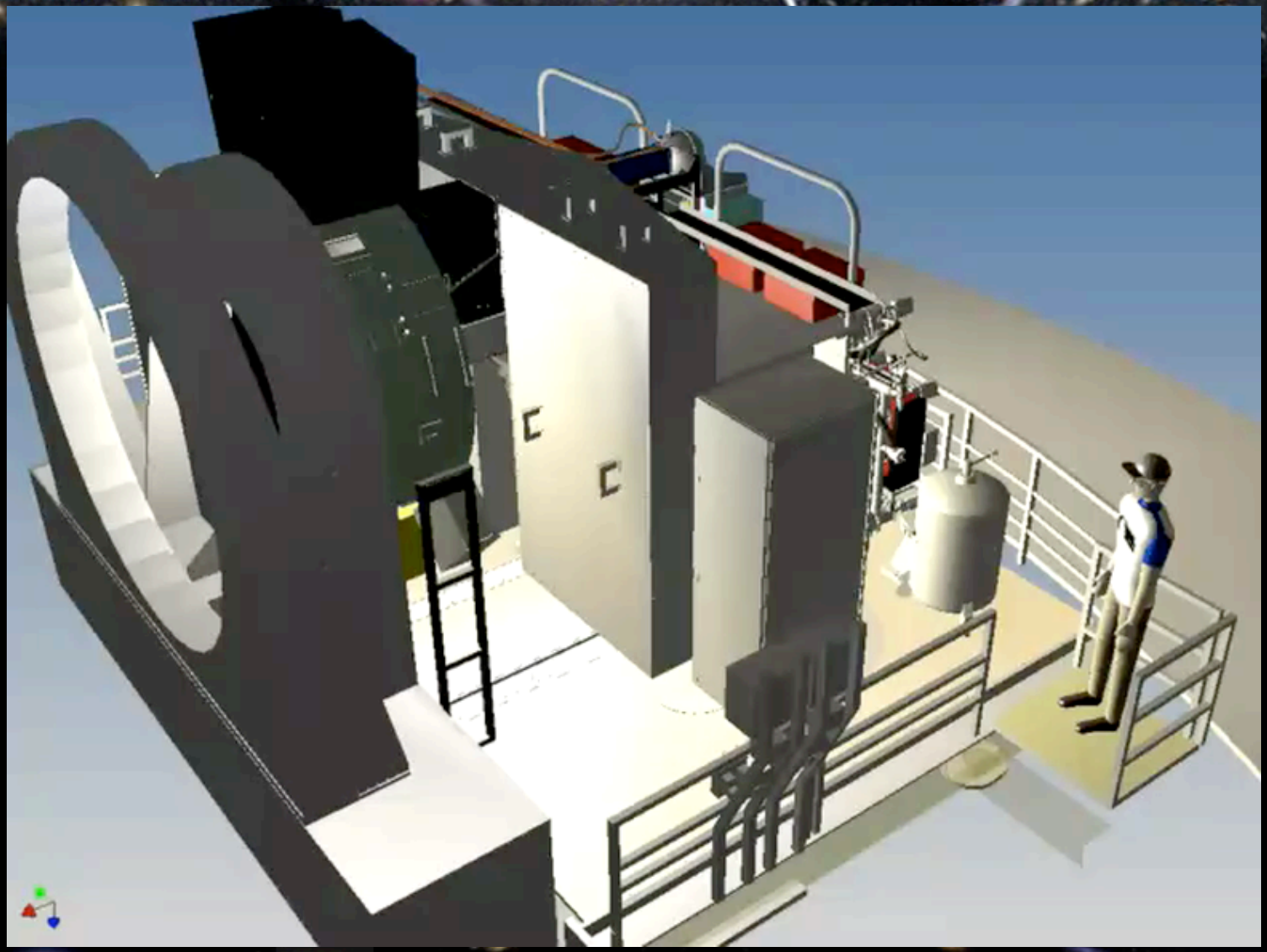
MUSE



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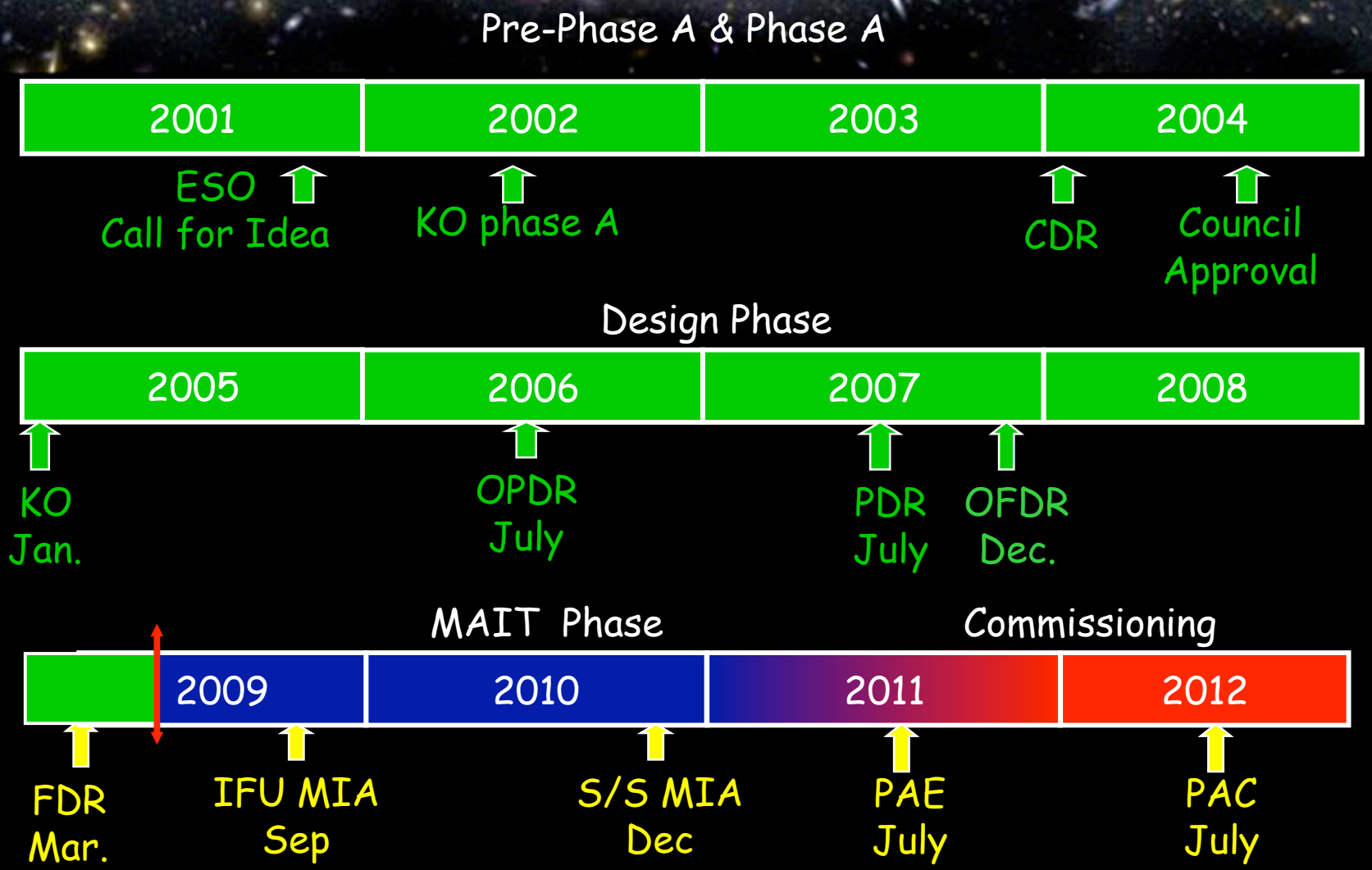
Planning



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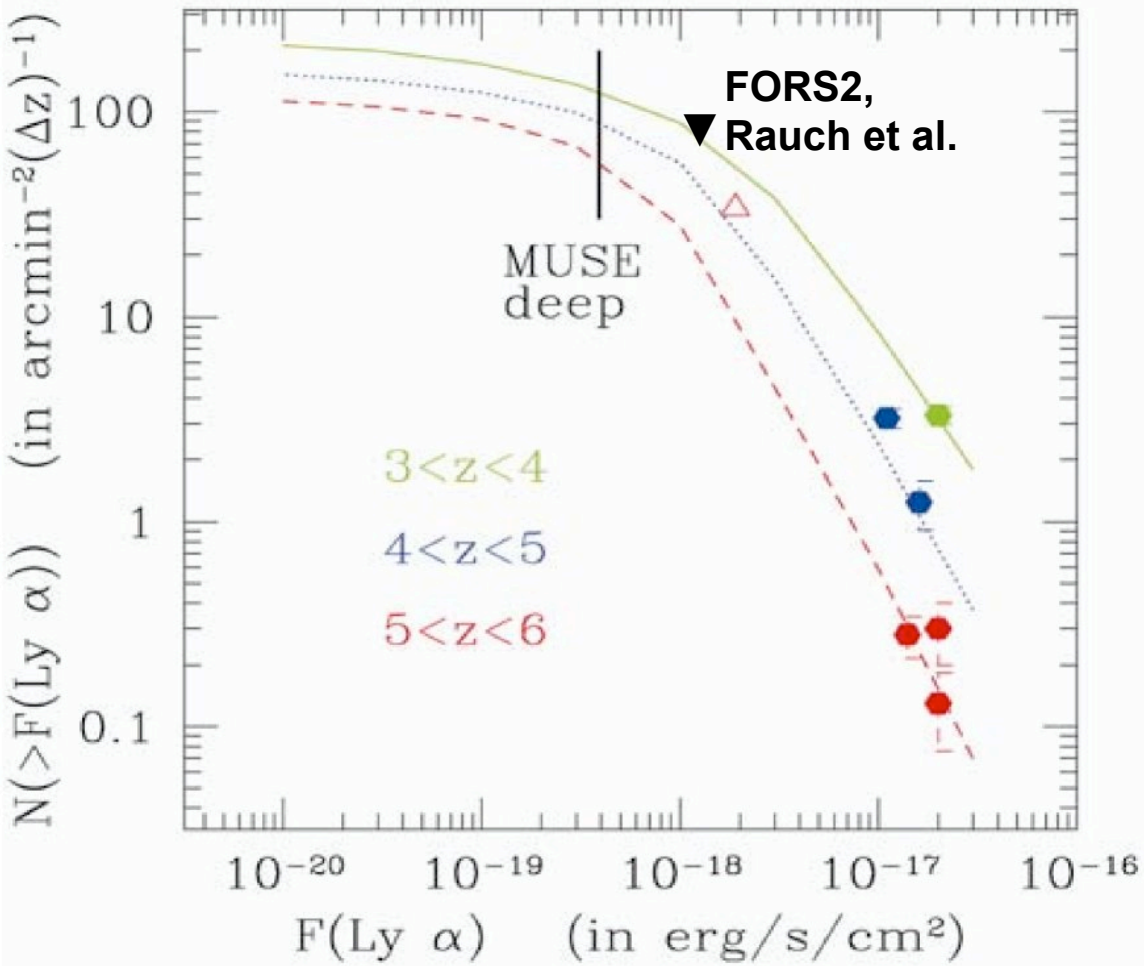
Lyman α emitters: Prediction vs. data



With respect to FORS2:
92h => 27 LAE @z=3 in Δz = 1
and with f>10^{-18} erg/s/cm^2

MUSE Total Gain x ~100
-FOV x 5.5
-Δz x 3.6
-No edge loss
-Spatial Resolution x 4
-R=2000-4000

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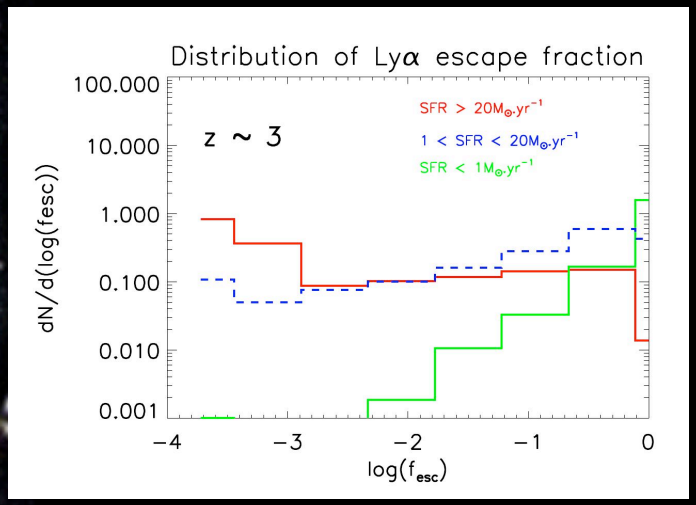
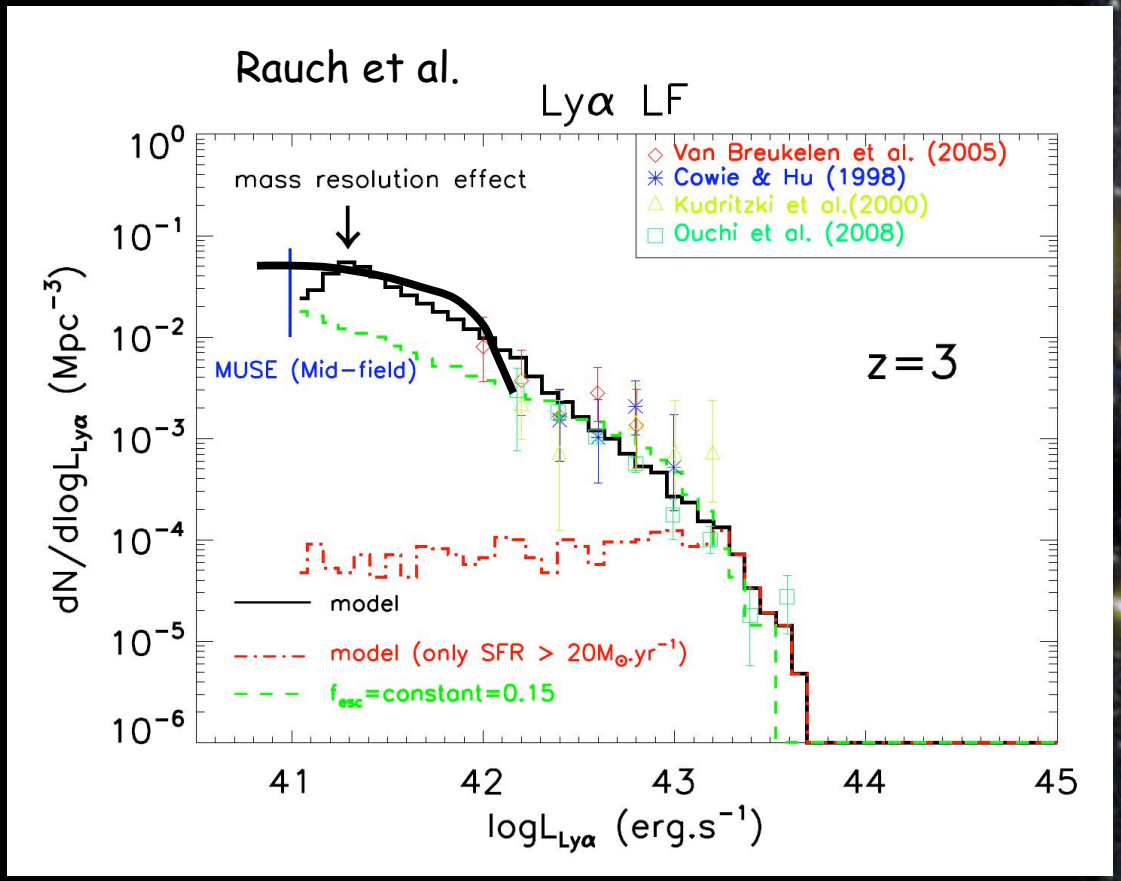
Faint slope of LAE LF ?

F_{esc} consistently computed with the MCLya transfer code, within the GalICS semi-analytic model of galaxy formation





See Garel et al. 2009, poster

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A typical « wedding cake » survey strategy

	Exp. Time	Flux Limit
SF	1h	$5\ 10^{-18}$
MDF	10h	$1.1\ 10^{-18}$
DF	80h	$3.9\ 10^{-19}$
UDF	80h	$1.3\ 10^{-19}$

Field Id.	Obj. by field		Nb fields	Total objects
SF	2.8<z<4	27	200	5400
	4<z<6.7	8	200	1600
MDF	2.8<z<4	100	40	4000
	4<z<6.7	70	40	2800
DF	2.8<z<4	150	3	450
	4<z<6.7	140	3	420
UDF	2.8<z<4	65	2	130
	4<z<6.7	65	2	130

In cluster field. Assume a typical factor 3 magnification

Total : about 15 000 sources for a large, 1000 h programme

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GalICS-predicted properties of Galaxies from Deep Lyman Break and Lyman Alpha searches

	$<m_{stars}>$ (M_{sun})	$<M_{halo}>$ (M_{sun})	$<I_{AB}>$
z=3 LBG R_{AB}<25.5	$3.6\ 10^{10}$	$2.6\ 10^{12}$	24.7
$2\ 10^{-17}$ & 2.8<z<6.7	$3.4\ 10^{10}$	$1.2\ 10^{12}$	27.1
$4\ 10^{-18}$ & 2.8<z<6.7	$1.2\ 10^{10}$	$4.6\ 10^{11}$	27.7
$3\ 10^{-19}$ & 2.8<z<4	$4.4\ 10^{9}$	$3.4\ 10^{11}$	28.4
$3\ 10^{-19}$ & 4<z<6.7	$2.8\ 10^{9}$	$1.2\ 10^{11}$	29.3

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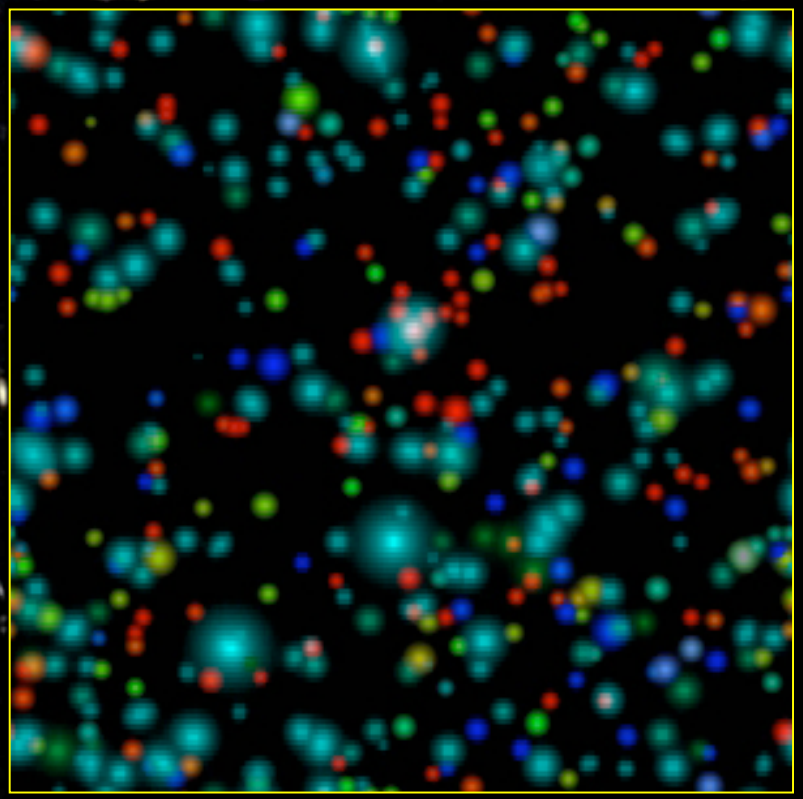
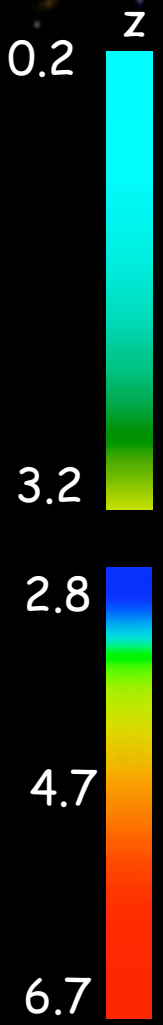
3D deep field



1 arcmin

One deep field (80 hours)
450 galaxies



- High z Lyα emitters
- Reionization
- Intermediate z galaxies
- Fluorescent emission
- Feedback processes
- Gravitational lensing
- Spatially resolved spectroscopy
- Late forming pop III (?)
- Active galactic nuclei
- Merger rate
- Development of dark haloes

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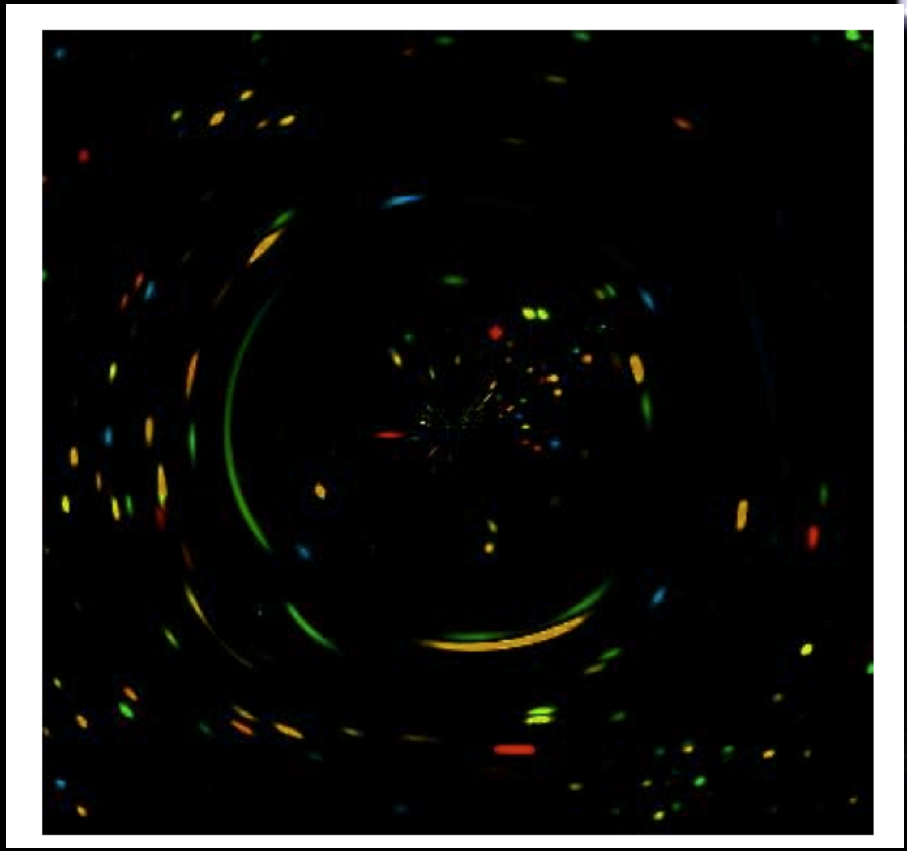
MUSE Ultra-Deep Field

- Simulation of an 80 h MUSE observation of lensed Lyman alpha emitters behind a cluster with an Einstein radius 30 arcsec.
- Colours code redshifts between 2.8 and 6.7 (redder is higher z)



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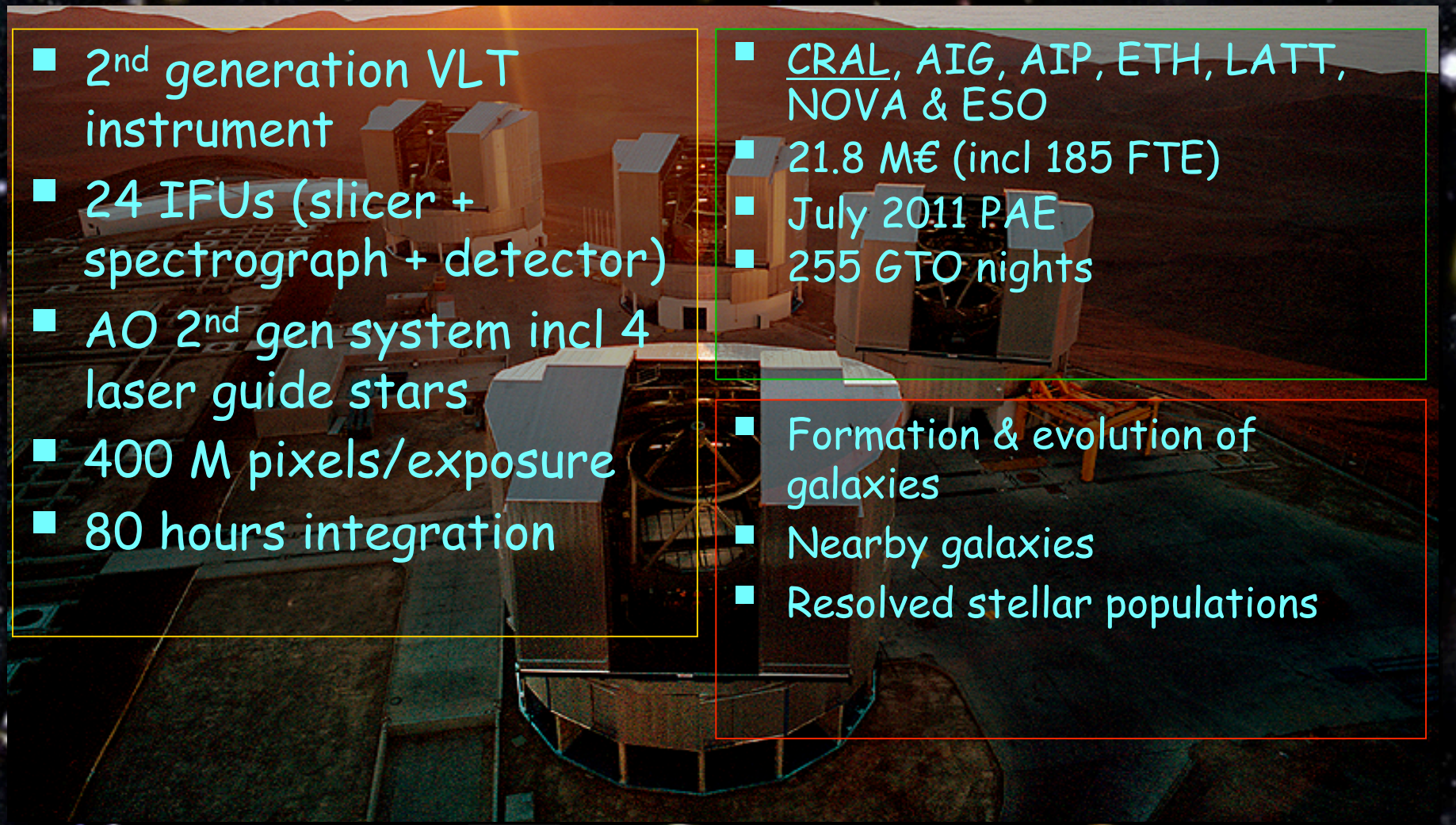
MUSE fast facts



- 2nd generation VLT instrument
- 24 IFUs (slicer + spectrograph + detector)
- AO 2nd gen system incl 4 laser guide stars
- 400 M pixels/exposure
- 80 hours integration

- CRAL, AIG, AIP, ETH, LATT, NOVA & ESO
- 21.8 M€ (incl 185 FTE)
- July 2011 PAE
- 255 GTO nights

- Formation & evolution of galaxies
- Nearby galaxies
- Resolved stellar populations

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