Multi Unit Spectroscopic Explorer

Lyon

Leiden

Zurich

Potsdam

ESO

Toulouse

Göttingen

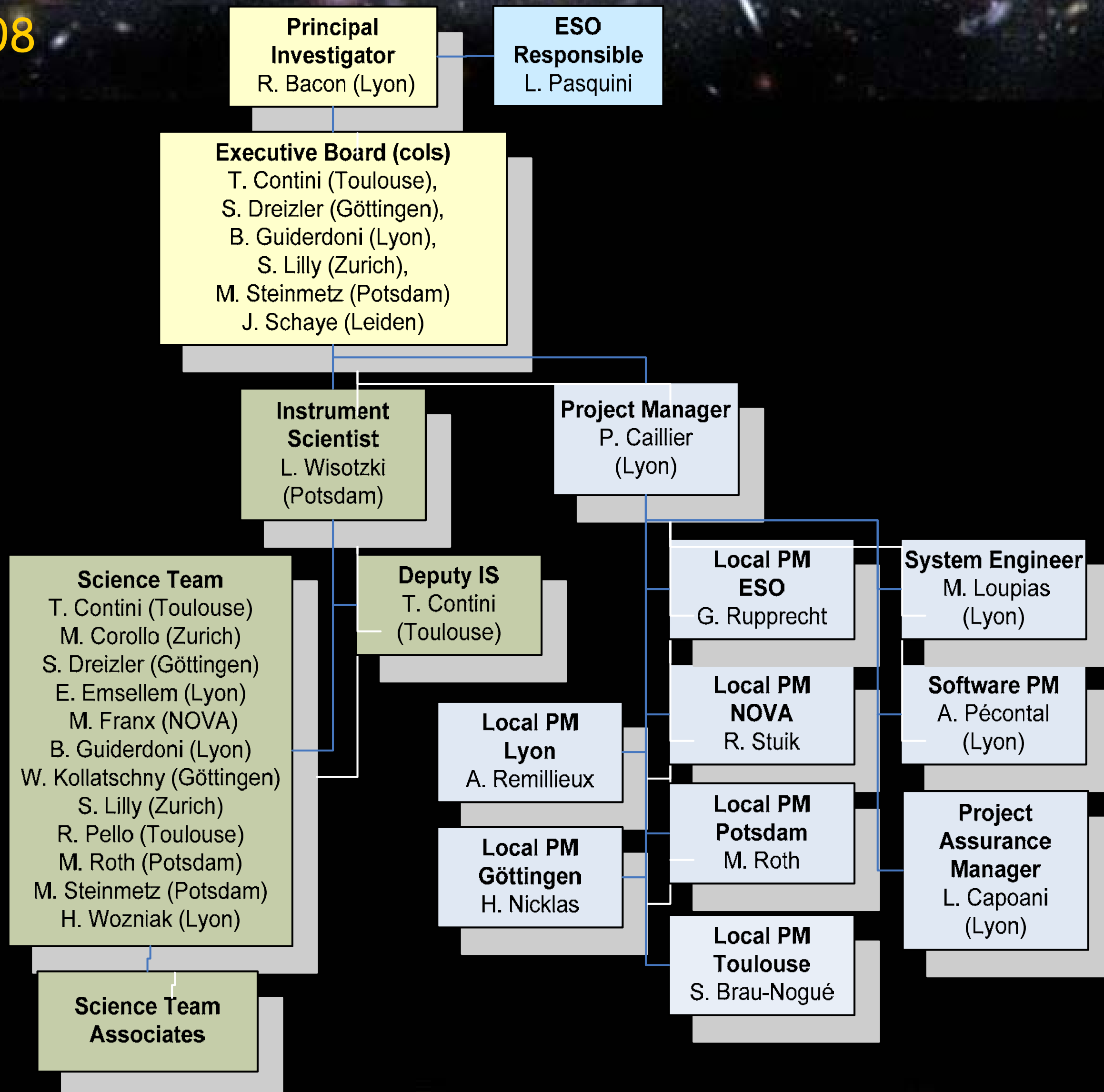
The MUSE project
Goals, Status

R. Bacon &
MUSE science team

PNC-PNG April 3, 2008

Organisation & People

PNC-PNG April 08



MUSE

PNC-PNG April 08

NOVA (Leiden)
AO interface
ASSIST (AOF)

CRAL
Project Office
Slicer
Spectrograph
Integration

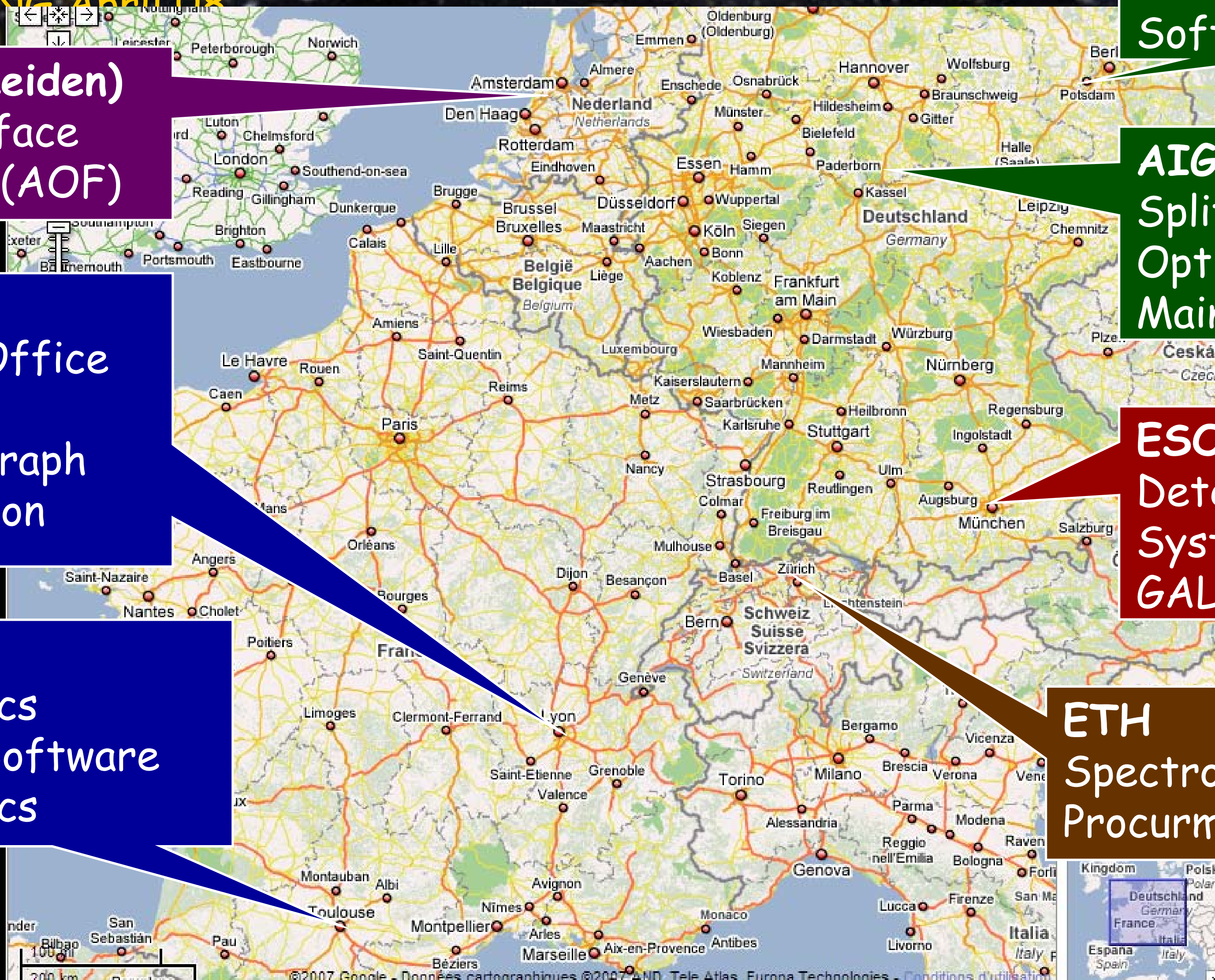
LATT
Electronics
Control Software
ForeOptics

AIP
Calibration Unit
Data Reduction
Software

AIG
Splitting & Relay
Optics
Main Structure

ESO
Detector
System
GALACSI

ETH
Spectrograph
Procurment



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MUSE

Instrument Overview

Focus	Nasmyth B UT4
Deformable Secondary Mirror	1170 actuators
Laser guide stars	4 x 5-10 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

Wide Field Mode

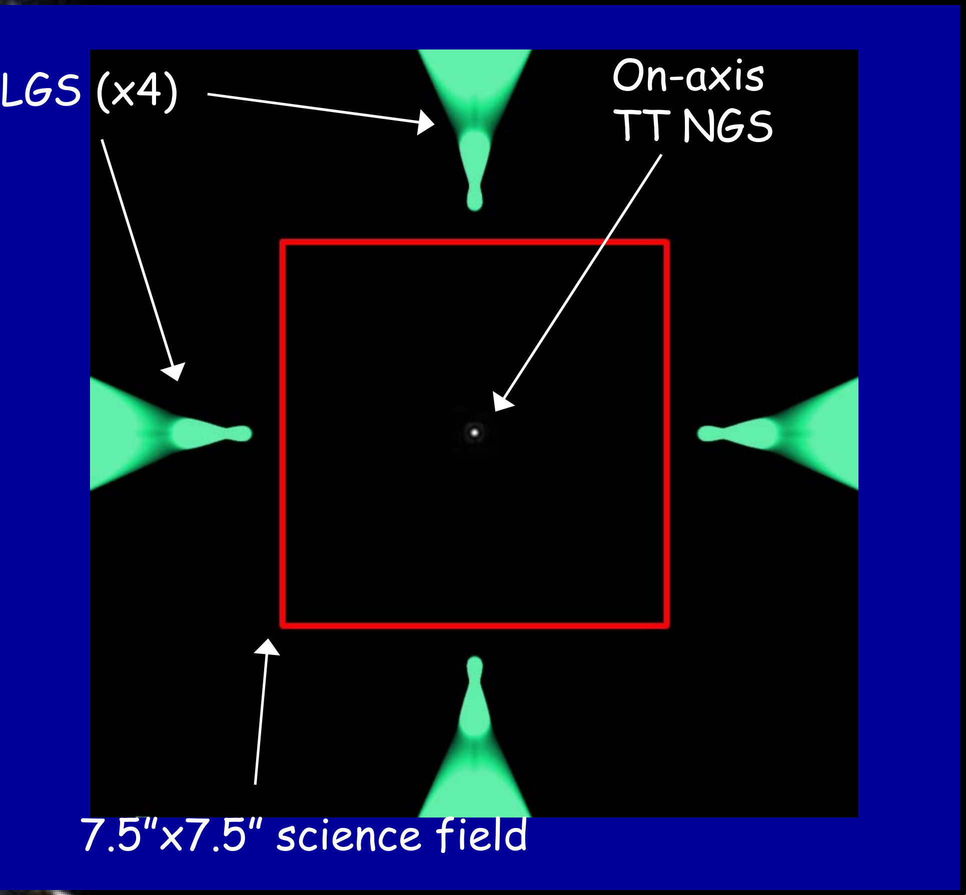
Field of View	1x1 $arcmin^2$
Spatial Sampling	0.2x0.2 $arcsec^2$
Spectra/Exposure	90,000
Sky Coverage in AO	70% @ galactice pole 99% @ galactic equator
AO Energy gain wrt seeing	x2

Narrow Field Mode

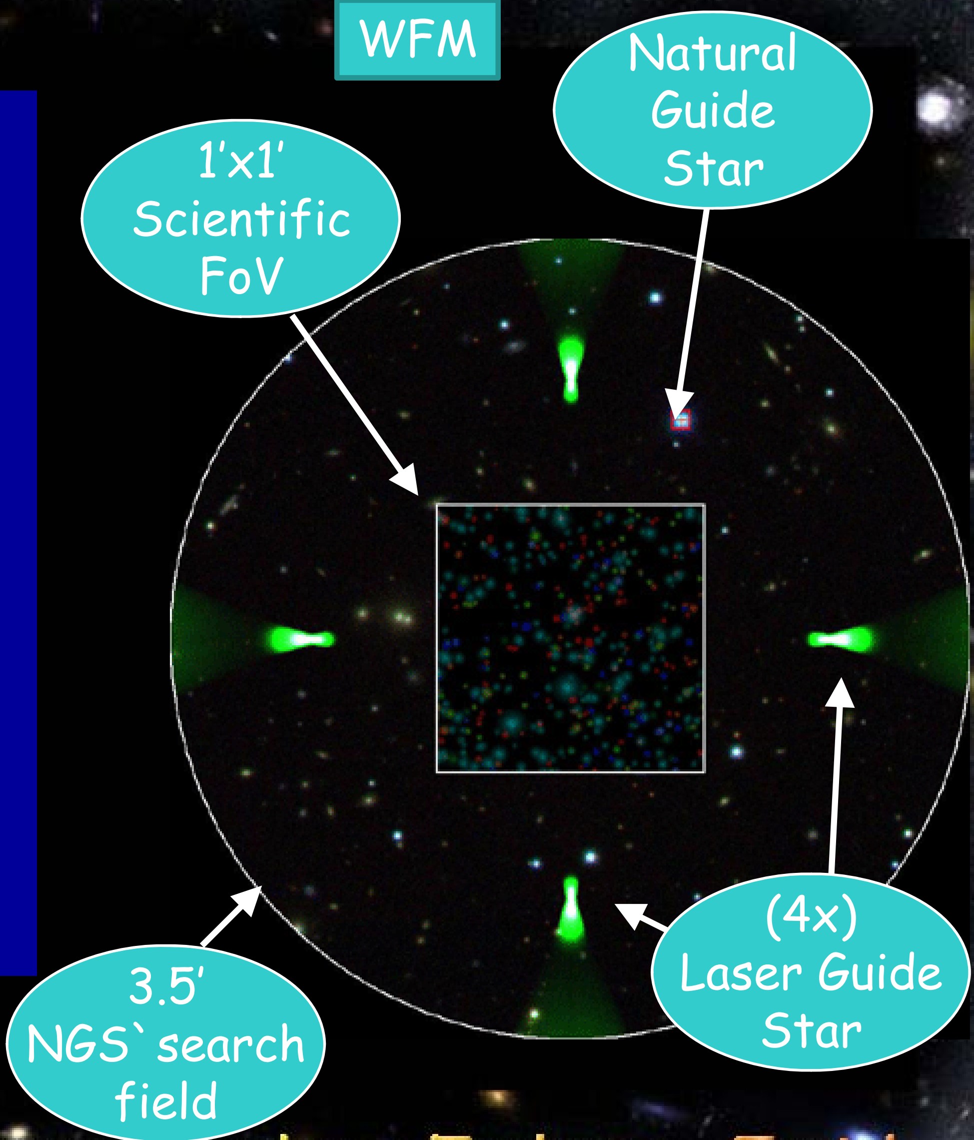
Field of View	7.5x7.5 $arcsec^2$
Spatial Sampling	25x25 $milliarcsec^2$
Spectra/Exposure	90,000
Spatial resolution	5-10% Strehl Ratio @ 650nm 10%-20% Strehl Ratio @ 850nm

GALACSI AO subsystems

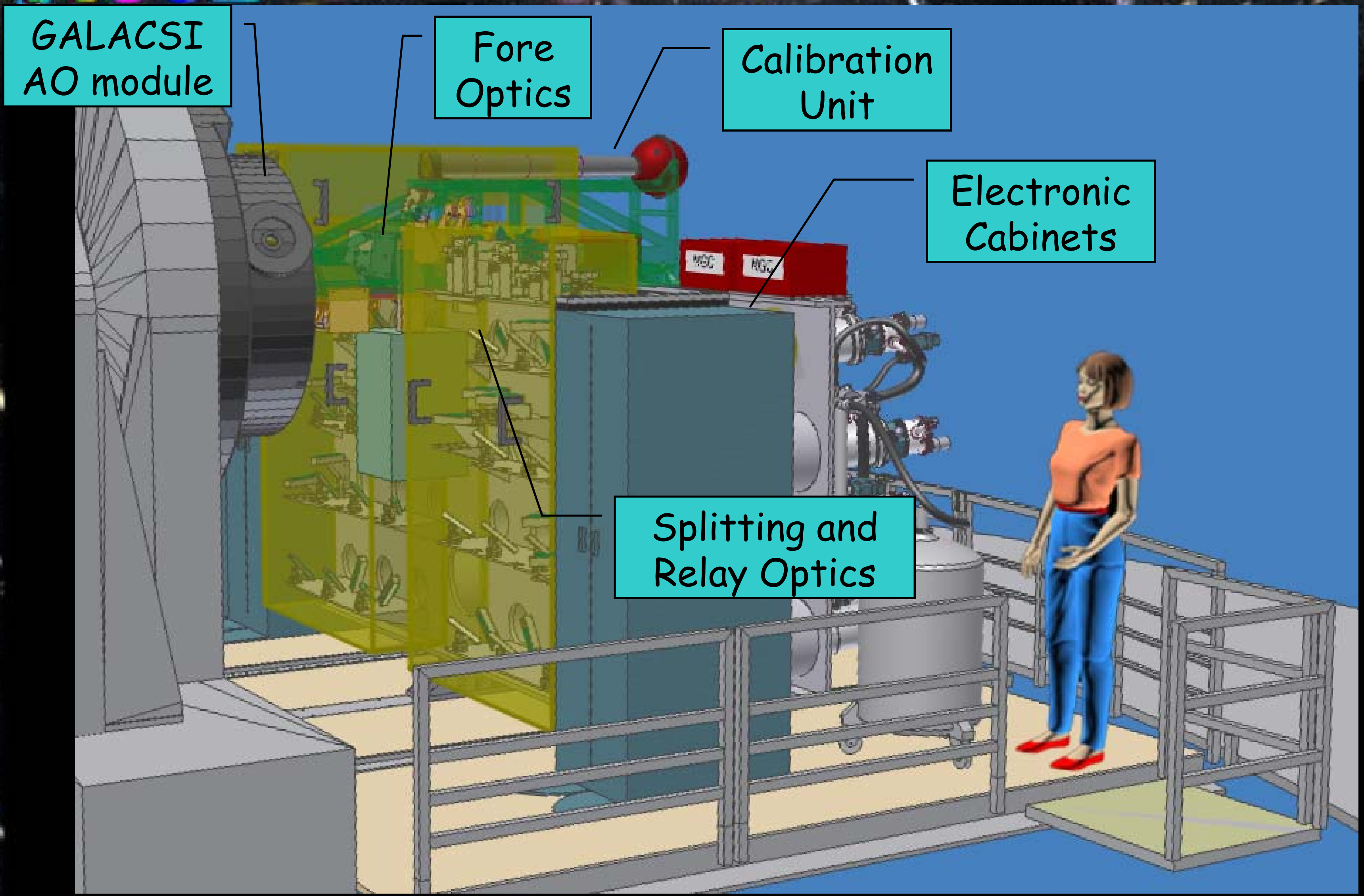
NFM



WFM

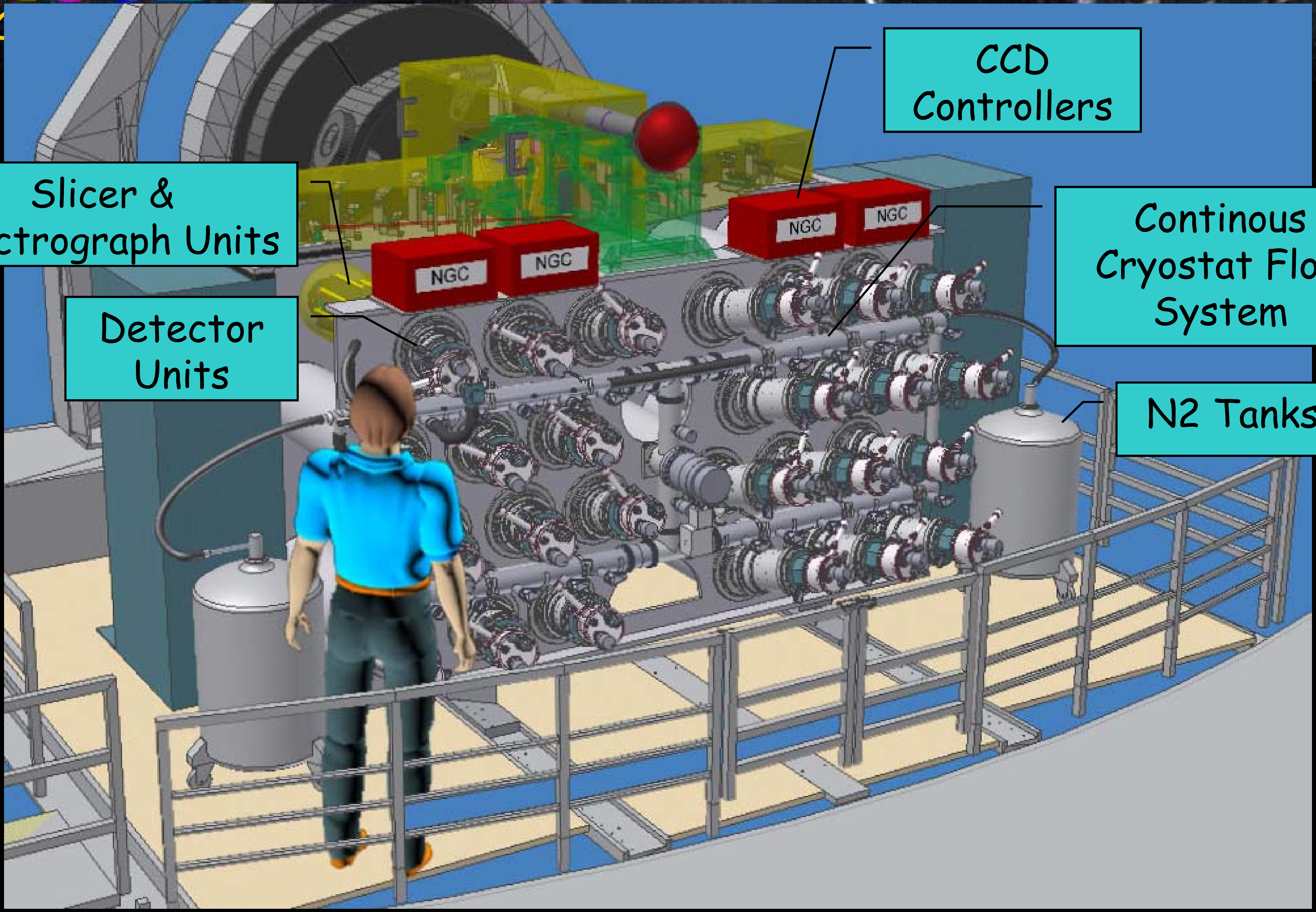


Instrument Design (1)



Instrument Design (2)

PNC



Total throughput

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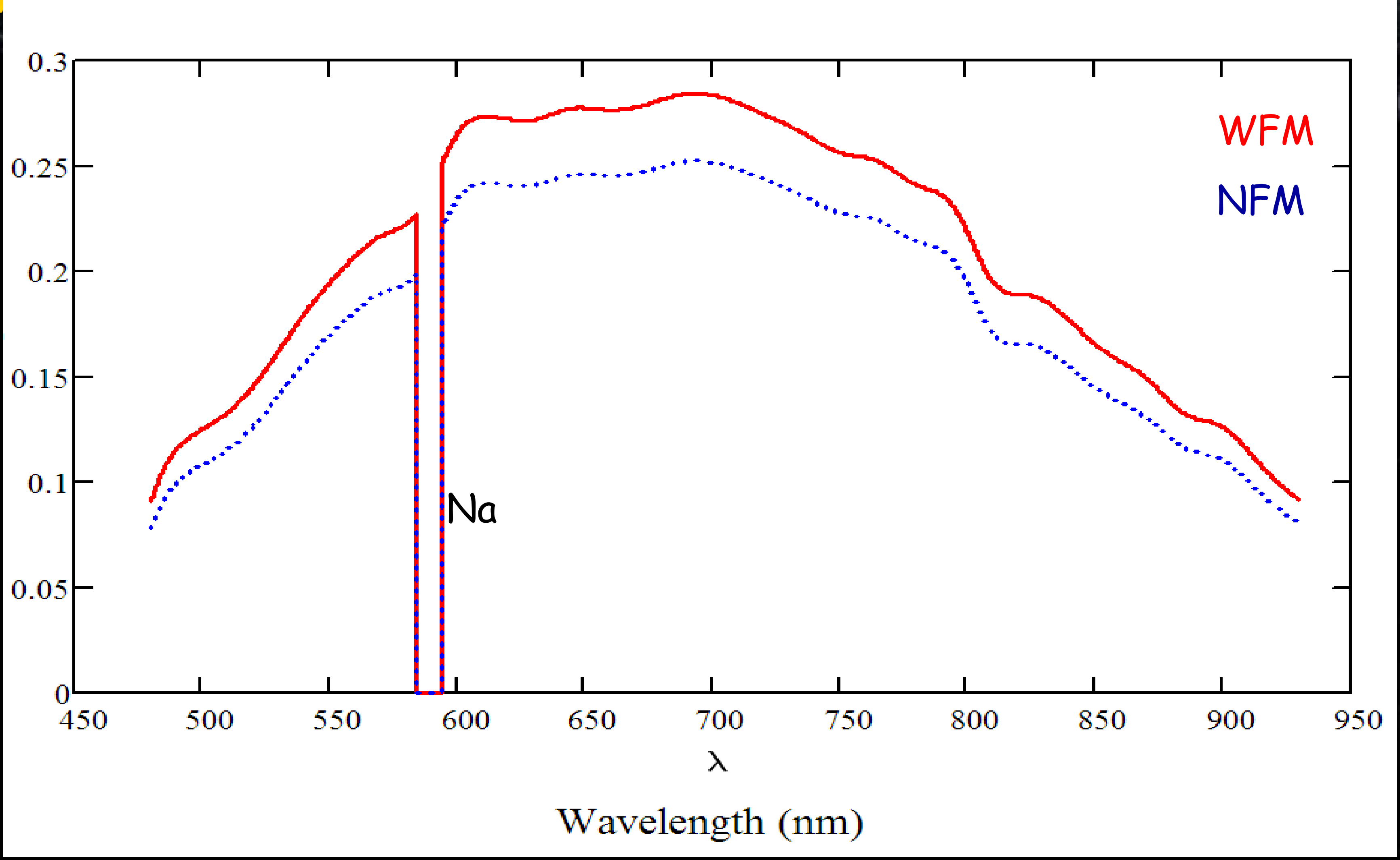


Wavelength Range

MUSE

465 nm — 930 nm

R=1800 — R=3800

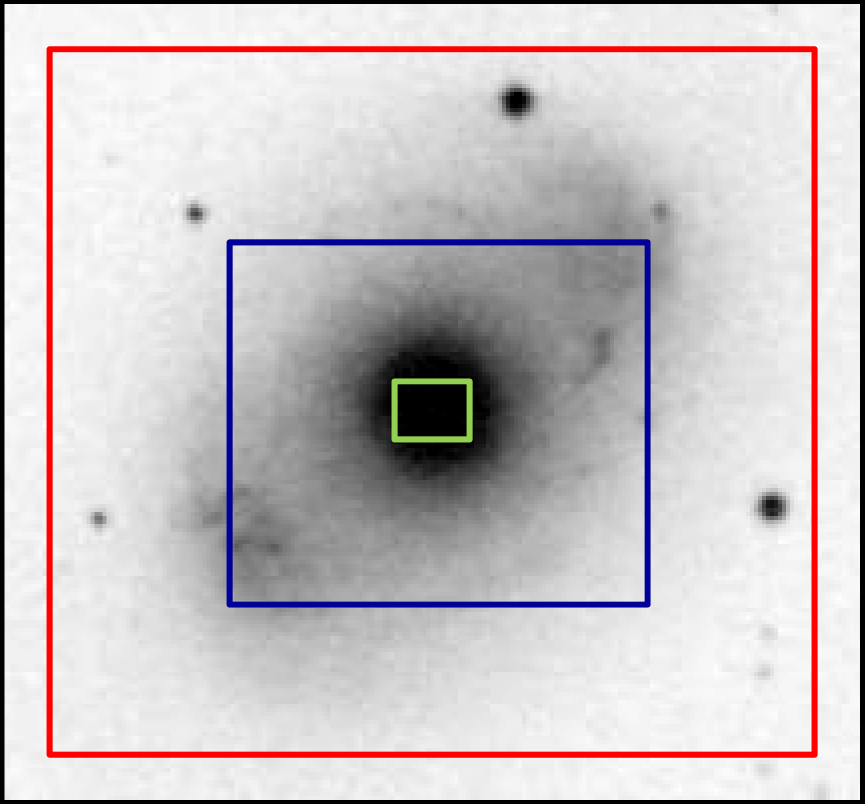
SAURON

480nm — 535 nm

R=1200

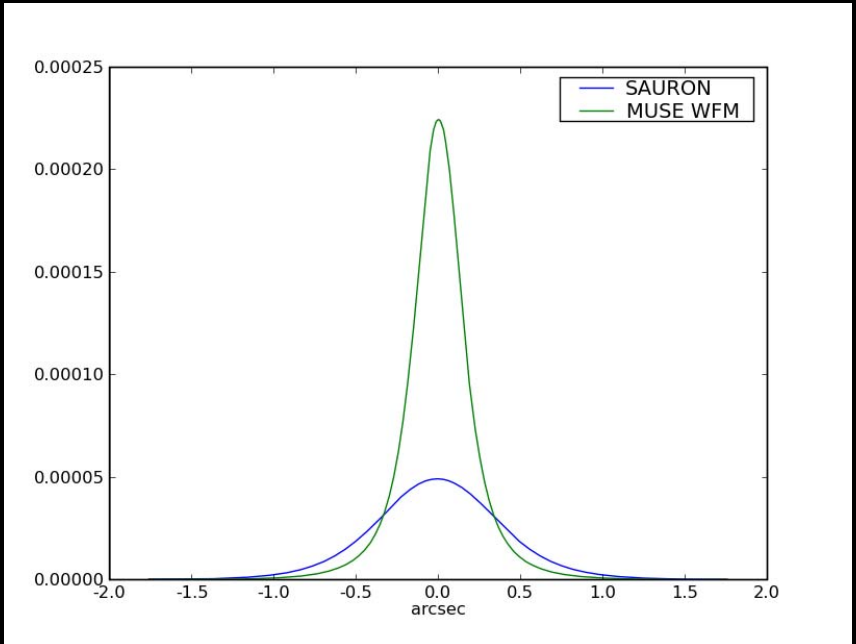
Field of View

- MUSE WFM
  - 60x60 arcsec ^{2}
  - 0.2 arcsec
- SAURON
  - 40x30 arcsec ^{2}
  - 0.94 arcsec
- OASIS
  - 10x7 arcsec ^{2}
  - 0.27 arcsec



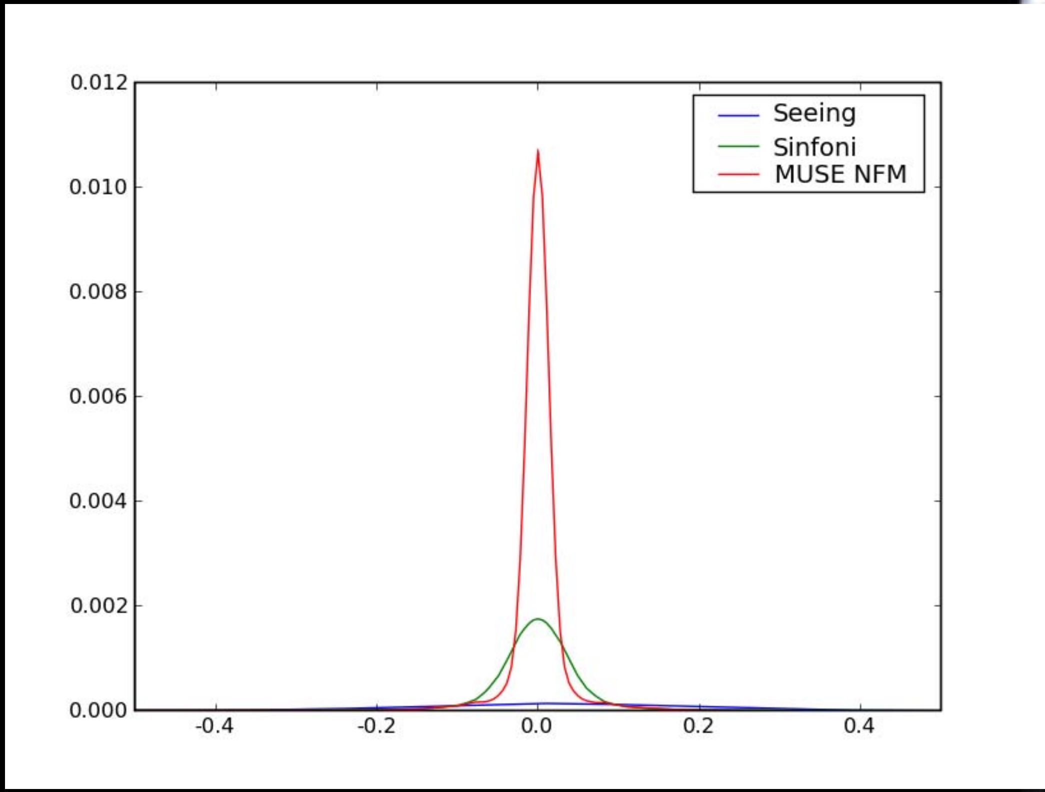
Spatial Resolution in WFM

- SAURON
  - 1 arcsec
- MUSE WFM
  - 0.3 arcsec



FOV & Spatial Resolution in NFM

- MUSE NFM
  - 25 mas sampling
  - 7.5x7.5 $arcsec^2$
- SINFONI
  - 25 mas sampling
  - 0.8x0.8 $arcsec^2$



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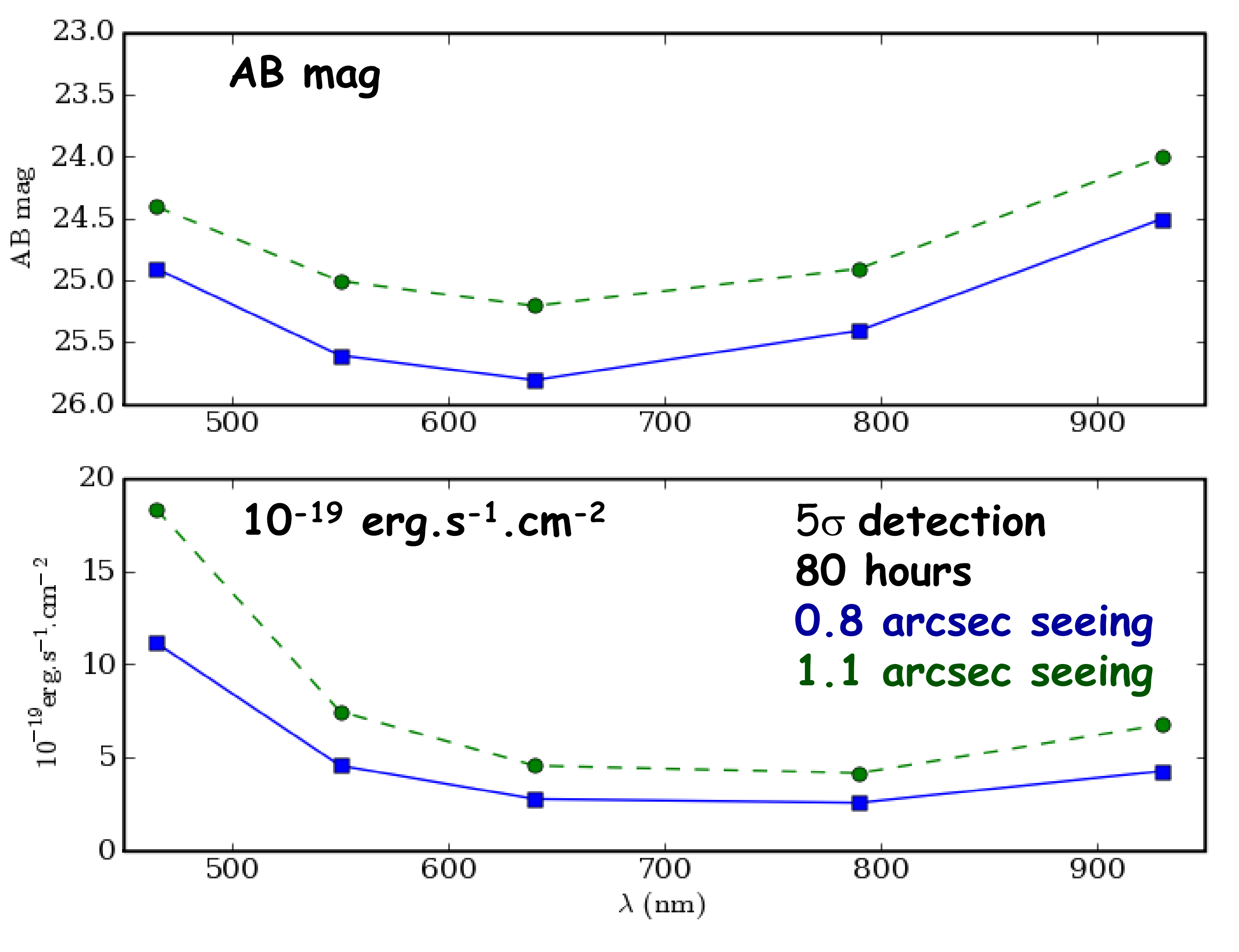
WFM performances



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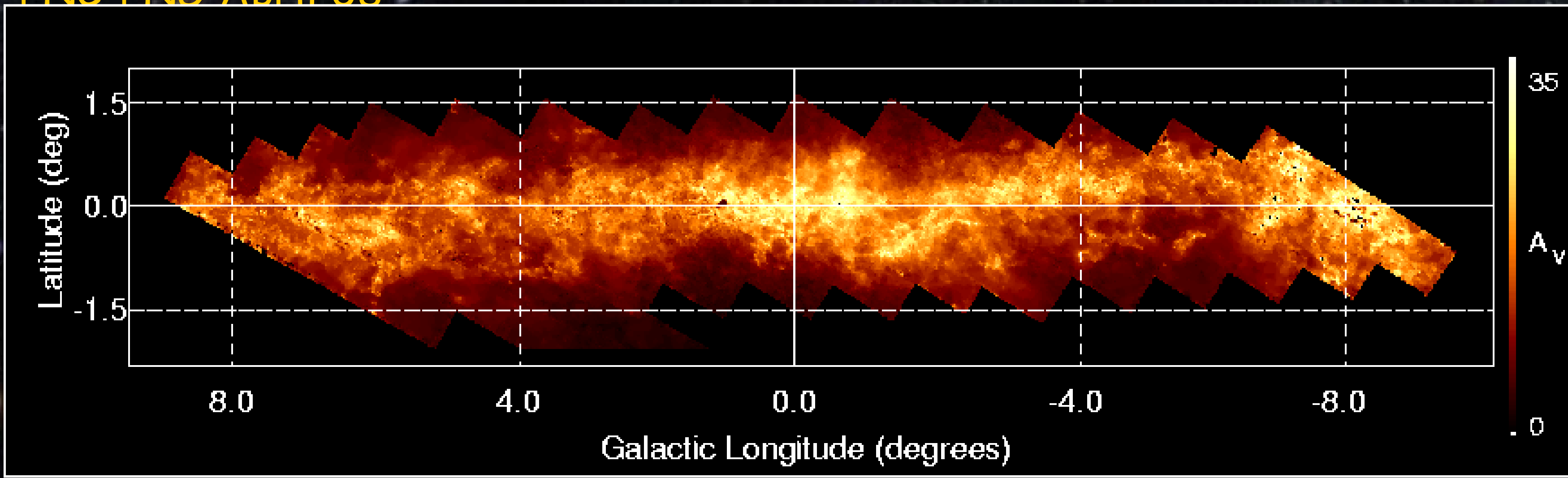
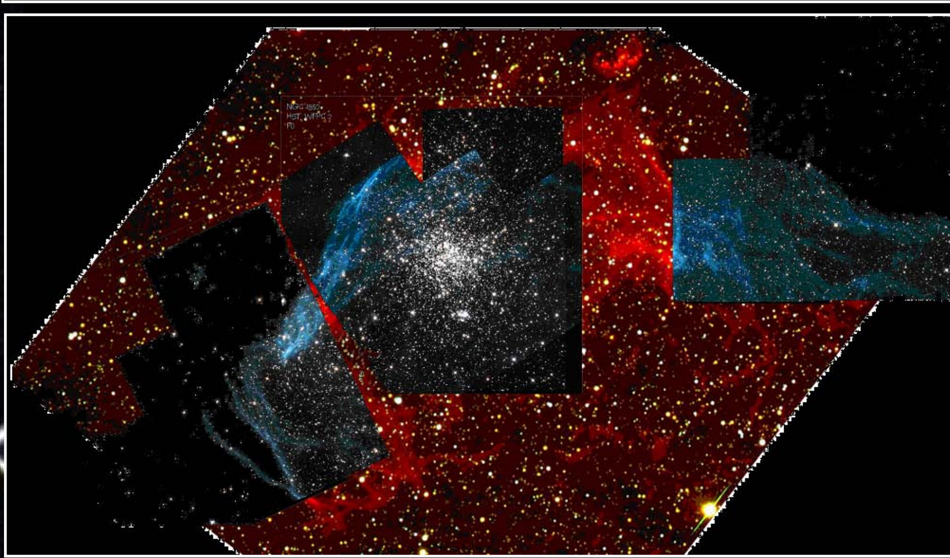
Hardware

Science Case

- Stellar populations
- Nearby galaxies
- Formation and evolution of galaxies

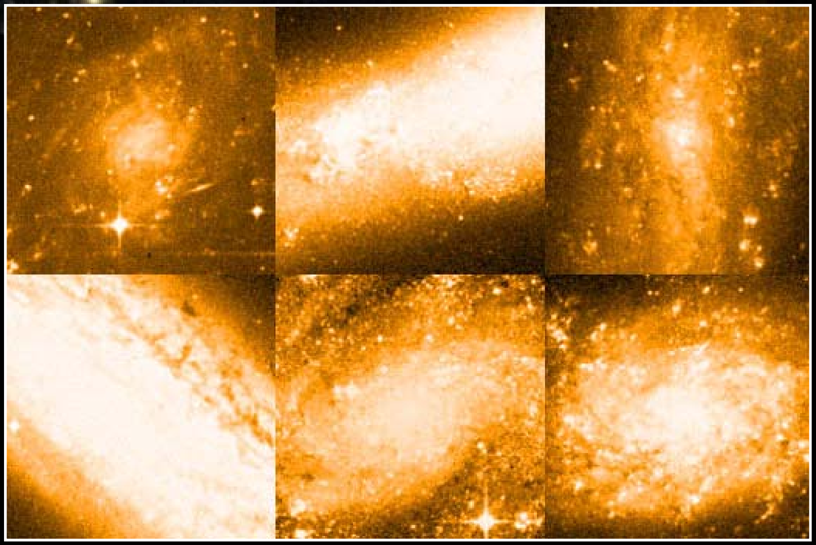
Resolved Stellar Spectroscopy: Dense Fields





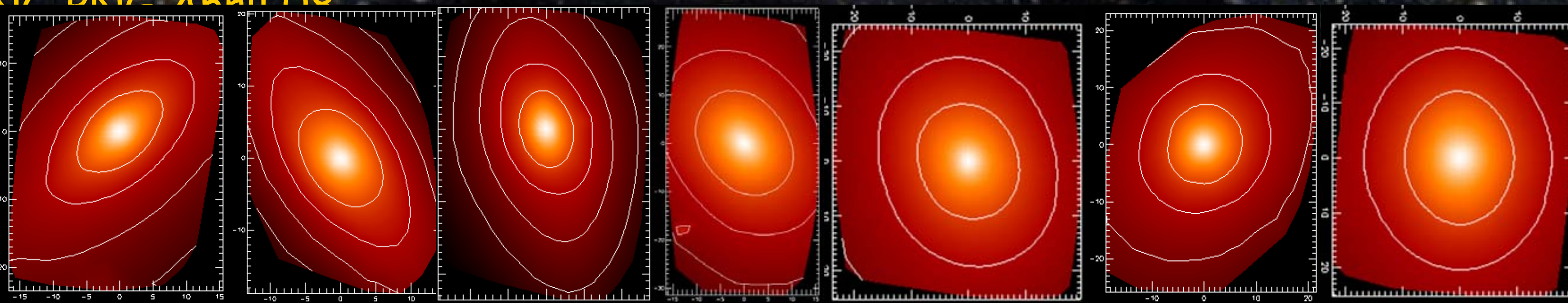
- Gaia spectroscopy will be limited in crowded fields
- MUSE can complement:
  - Low-extinction regions allow optical study of galaxy disk/bulge
  - Study of MW clusters

Resolved Stellar Spectroscopy: X-Gal

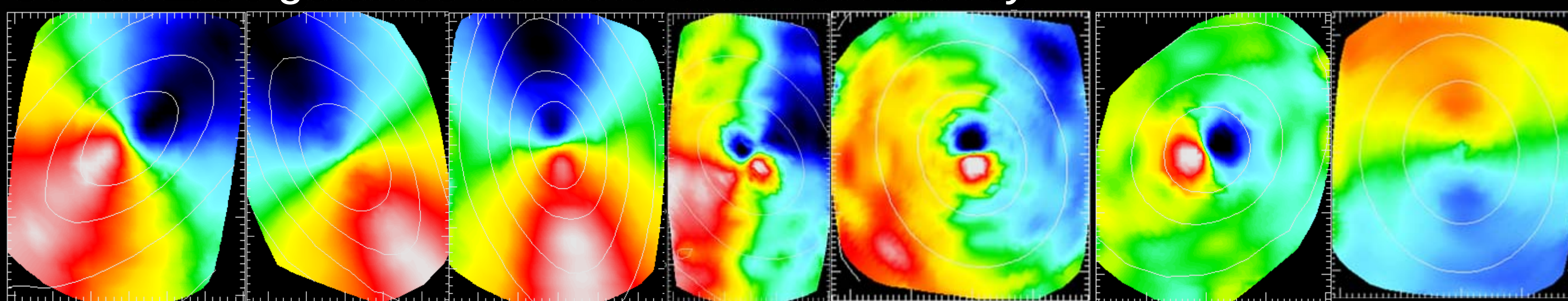


- Survey of nearby disk galaxies
  - 25 exposures of 4 hour: 5x5 arcmin^2
- Search for
  - Massive stars
    - 1000/galaxy
  - Planetary nebulae
    - ~100/galaxy
  - HII regions
  - Rare objects
    - Exotic stars (LBV, B[e])
    - SNR, novae, ultra-luminous X-ray source
  - Diffuse ISM

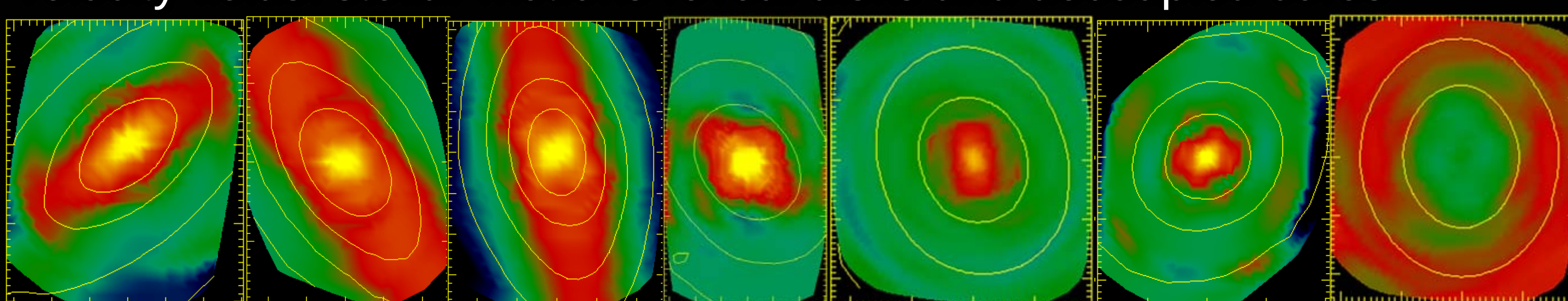
Kinematics & Linestrengths



Seven E/S0 galaxies from the SAURON survey



Velocity fields: stellar motions reveal disks and decoupled cores



Maps of magnesium line strength: age and metal abundance of stars

Super stellar clusters in Mergers

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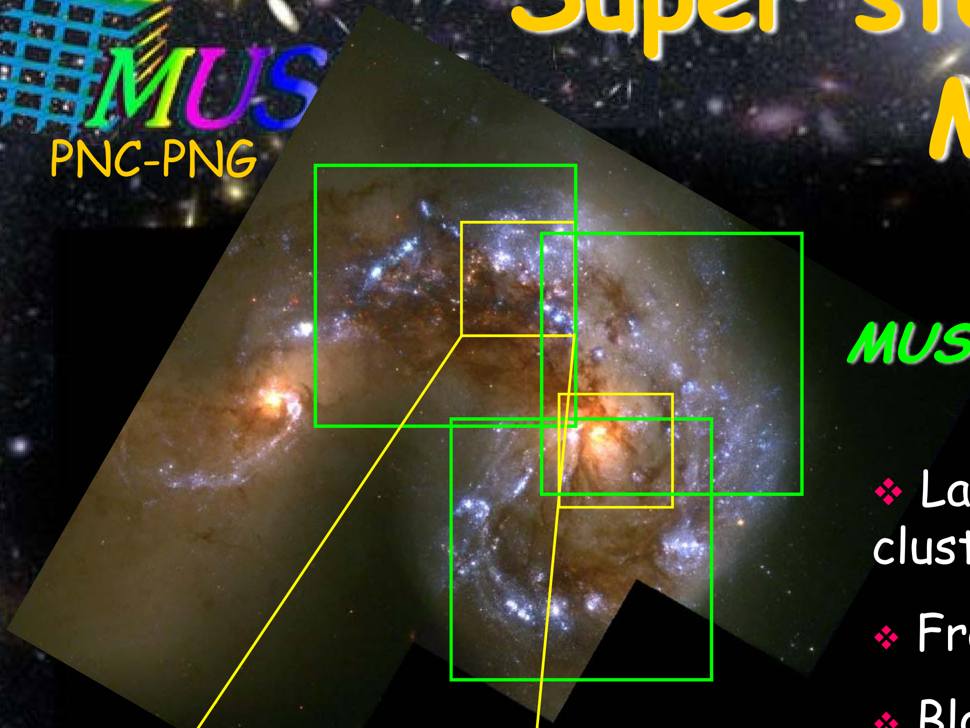
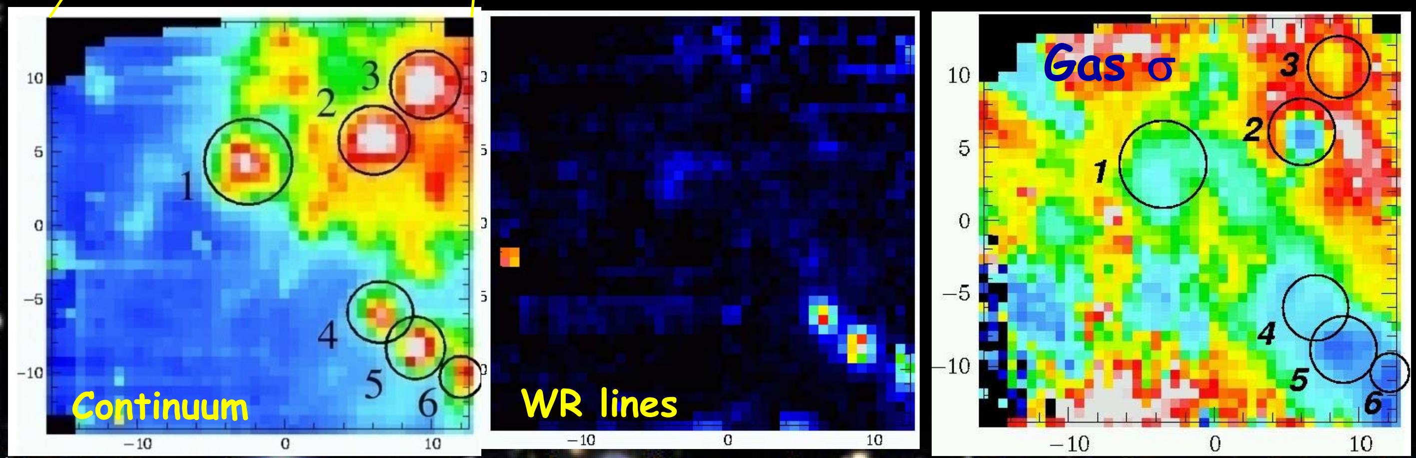


MUSE FOV

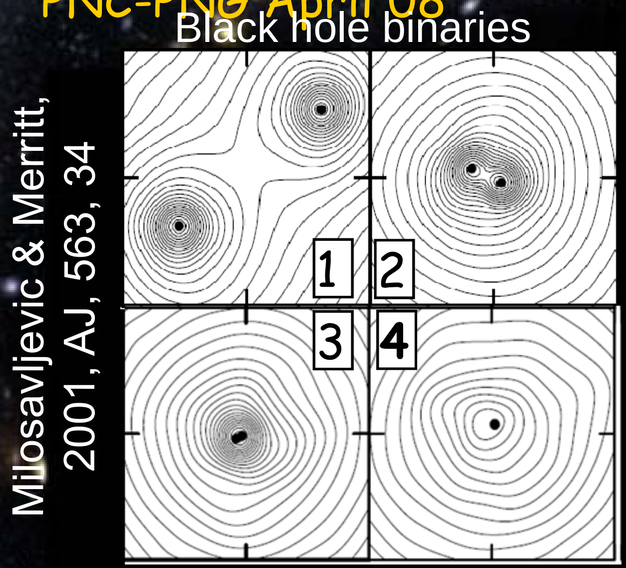
- Largest scale for forming super star clusters ~500 pc
- Fragmentation
- Blowing the seed GMC

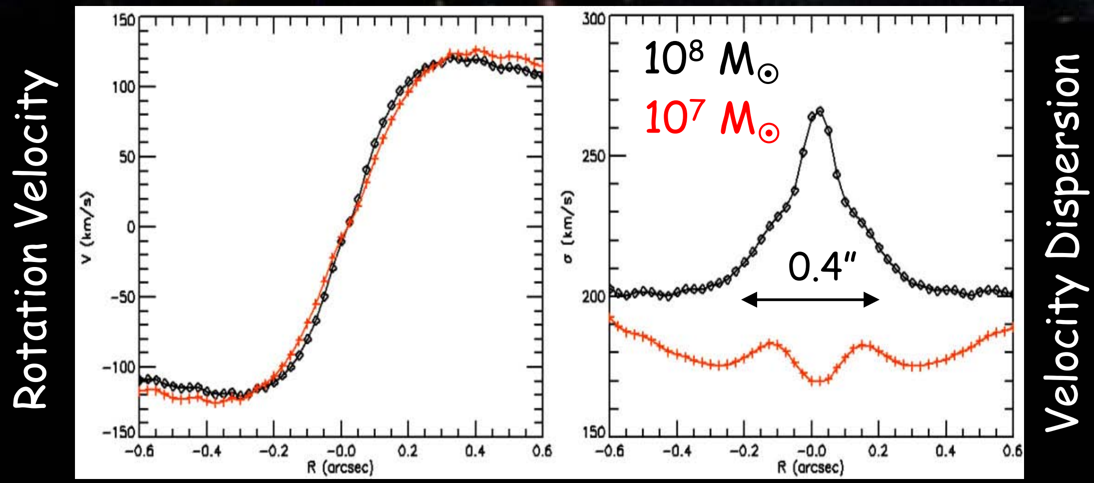
NGC 4038 / 4039



Bastian et al. 2006

NFM Science: Black Holes

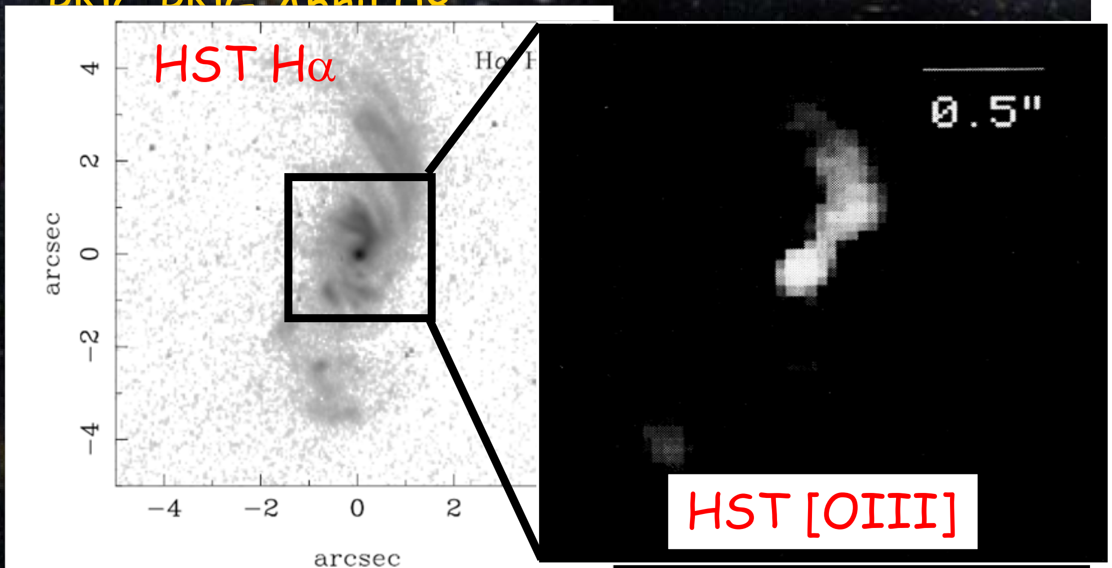


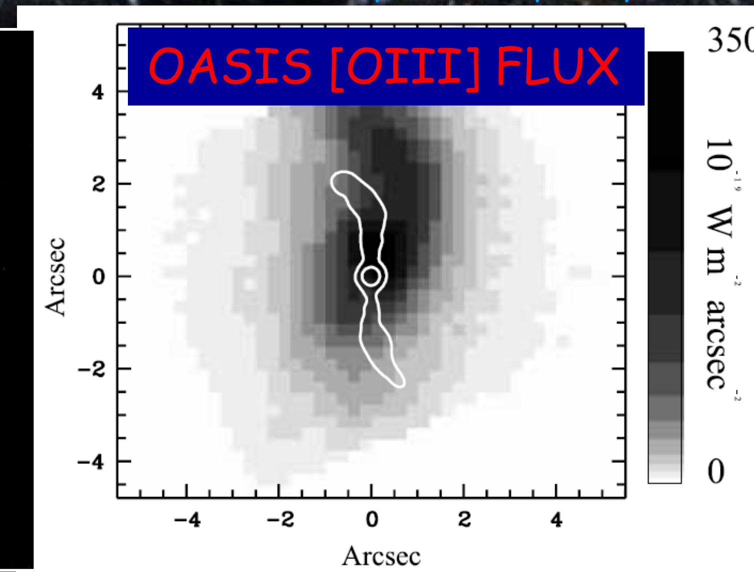


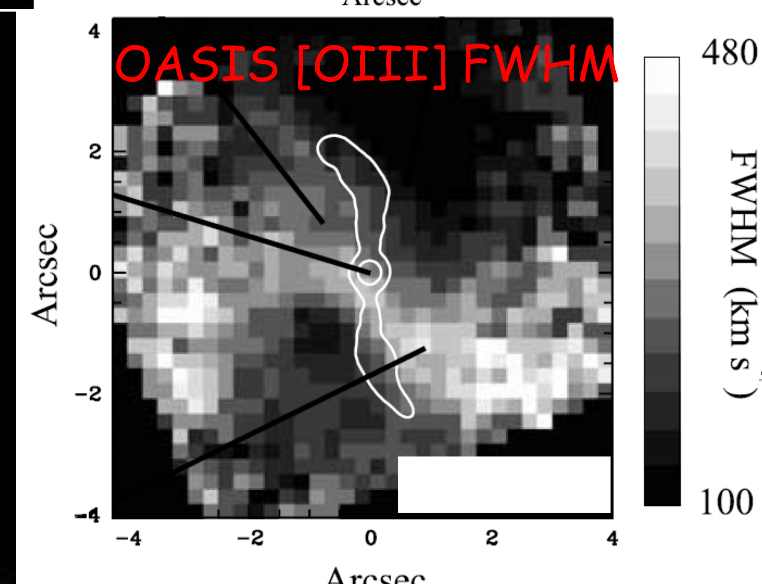
- Stellar dynamics at 0.05″ scales – black hole masses and formation scenarios
- Optical spectra give stellar populations and gas properties 'for free'
- Low background allows low-surf. brightness objects

AGN with NFM

Ferruit et al 2004, MNRAS, 352, 1180







- MUSE ideal for complex nuclear emission regions on pc scales
- Spectral information yields new insights over imaging fluxes
- Improved continuum removal gives fainter limits

Spatially-Resolved spectroscopy at z=0.5-1

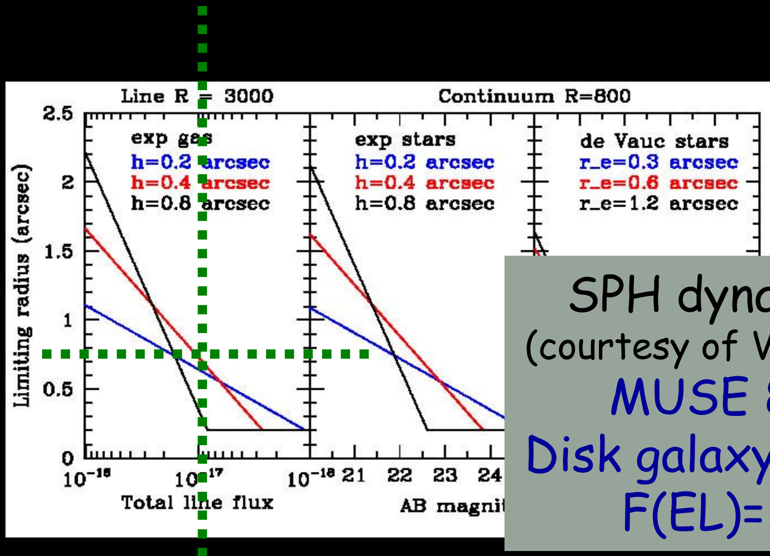
- ✓ Evolution of the star formation & metal enrichment histories of spheroïds, disks & irregulars over the last 10 Gyr
- ✓ For each galaxy, relationships between local kinematics, gas metallicity & reddening, and the stellar population ages & metallicities
- ✓ Census of the $0.5 < z < 1.0$ galaxy populations at level of details comparable to SDSS
- ✓ Crucial tests for galaxy evolution scenarios (eg. downsizing)

Galaxy kinematics at z~1

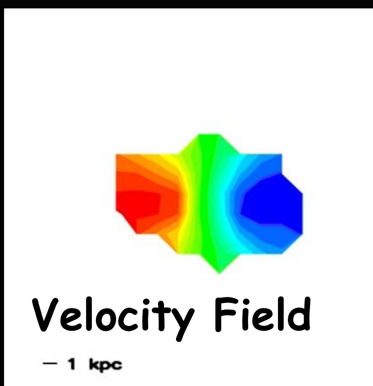
Spatially-resolved kinematics from 2D velocity fields in emission lines

At z~1, the velocity field can be mapped with MUSE to ~2 x disk scale length

Emission-line SB



SPH dynamical simulations
(courtesy of V. Debattista & L. Mayer)
MUSE 80h integration
Disk galaxy at z~1 with h=0.4"
F(EL)=10^{-17} ergs^{-1}cm^{-2}



Stellar populations at z~1

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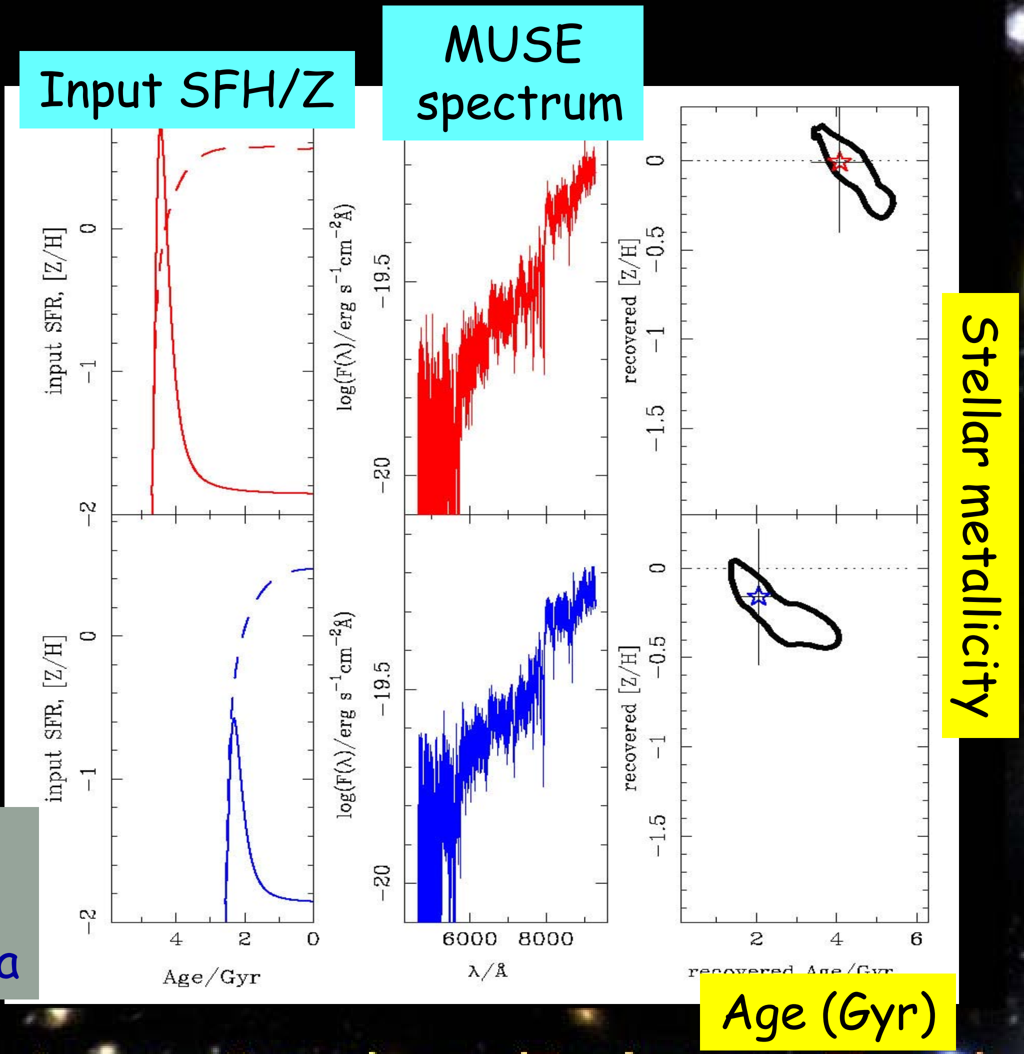
Stellar populations

At z~1, the spatially-resolved stellar ages & metallicities of galaxies should be recovered from MUSE spectra

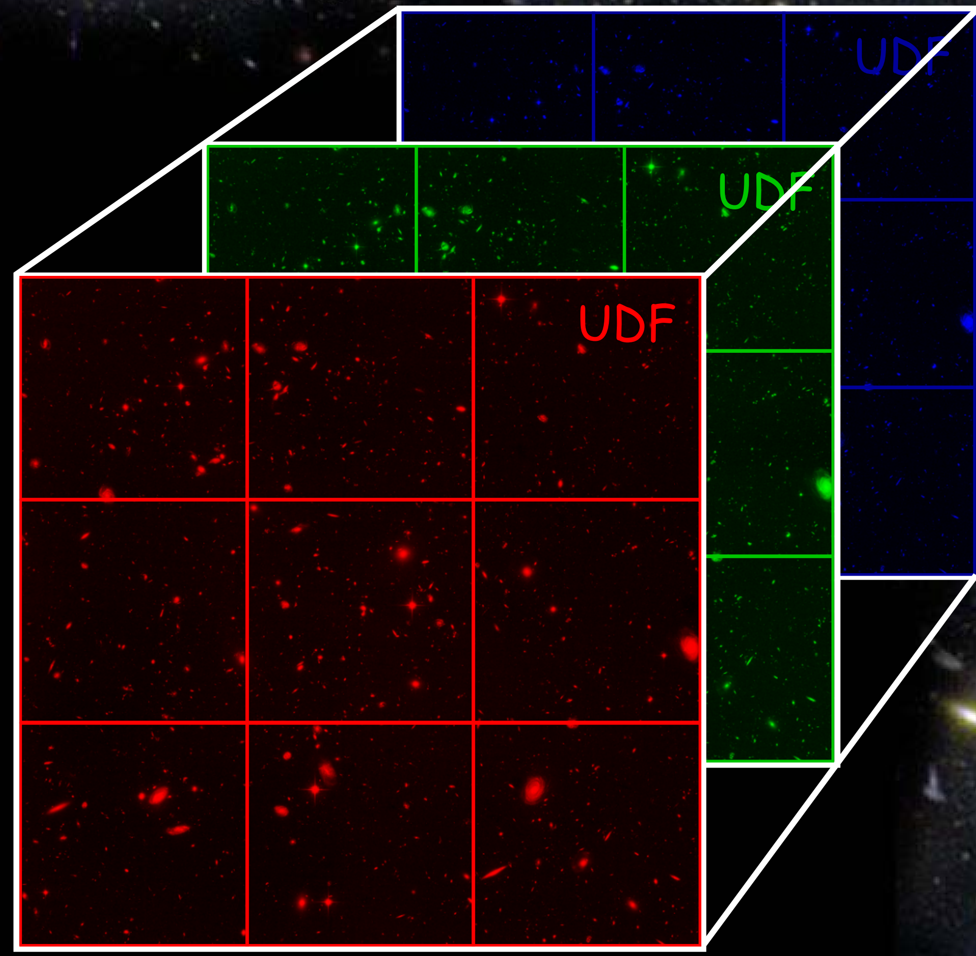


Simulations using BC03
MUSE 80h integration
Galaxy at z~1 with S/N=15 spectra

Spectroscopic Surveys - IFU

Get everything!

- Eliminates pre-imaging
- Eliminates pre-selection
- Observe only once
- Attack multiple science topics simultaneously
- Large discovery space for serendipitous sources



Prediction vs. data

MUSE
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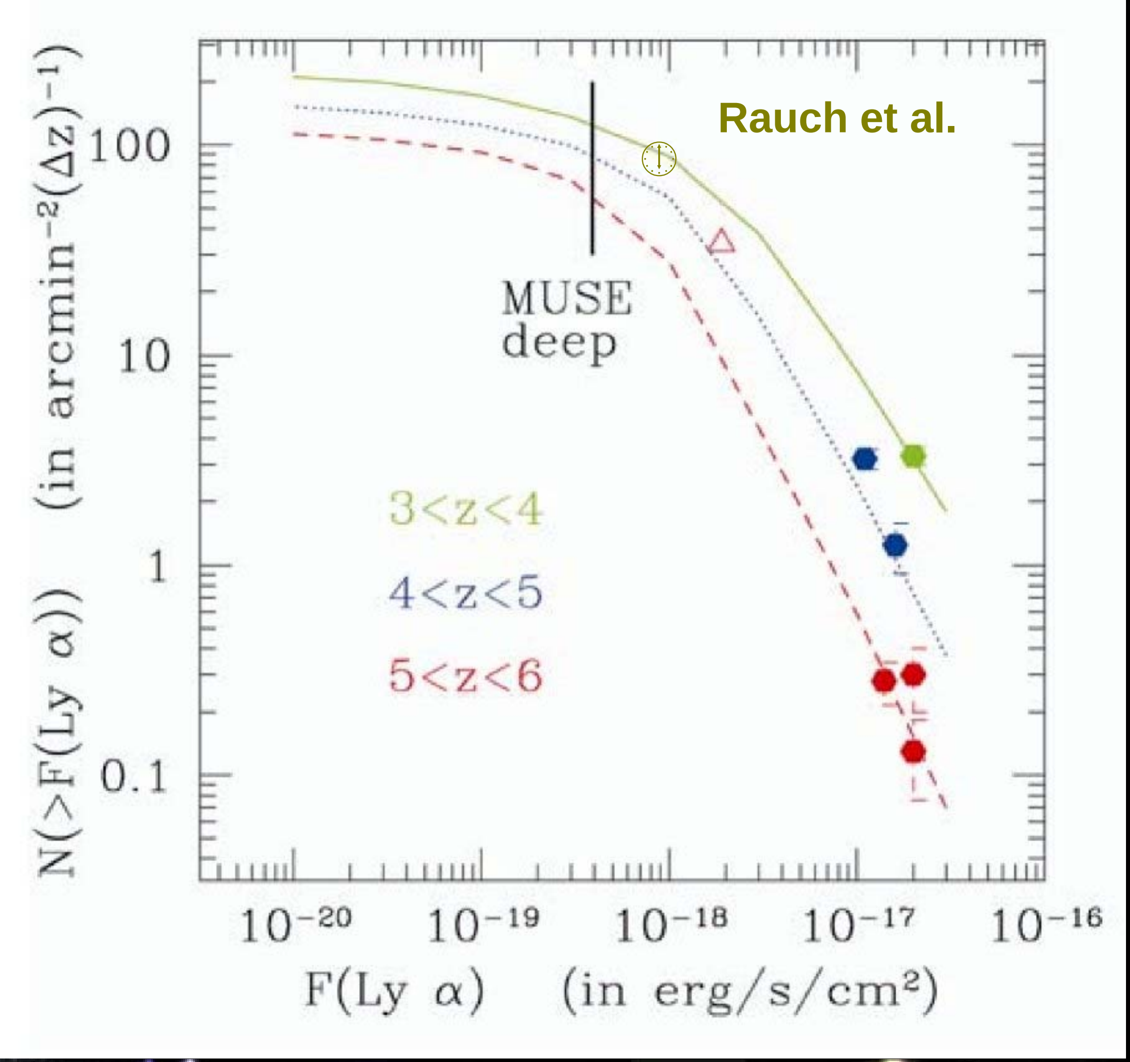
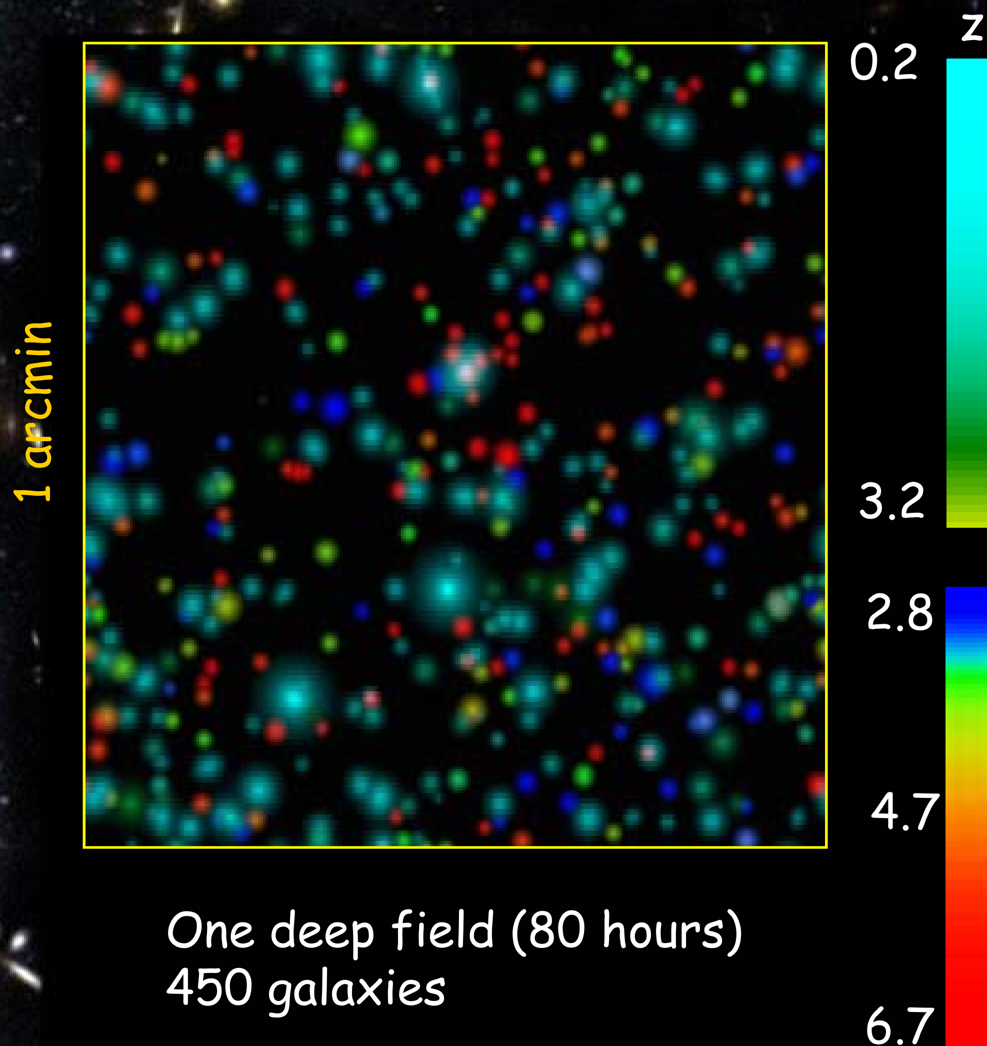
MUSE: 10,000 LAE in 1000h



3D deep field



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 halo

Project Planning

Pre-Phase A & Phase A

2001	2002	2003	2004

ESO Call for Idea
KO phase A
CDR
Council Approval

Design Phase

2005	2006	2007	2008

KO Jan.
OPDR July
PDR July
OFDR Dec.
FDR Nov.

MAIT Phase
Commissioning

2009	2010	2011	2012

IFU MIA Feb.
S/S MIA Oct.
PAE July
PAC July

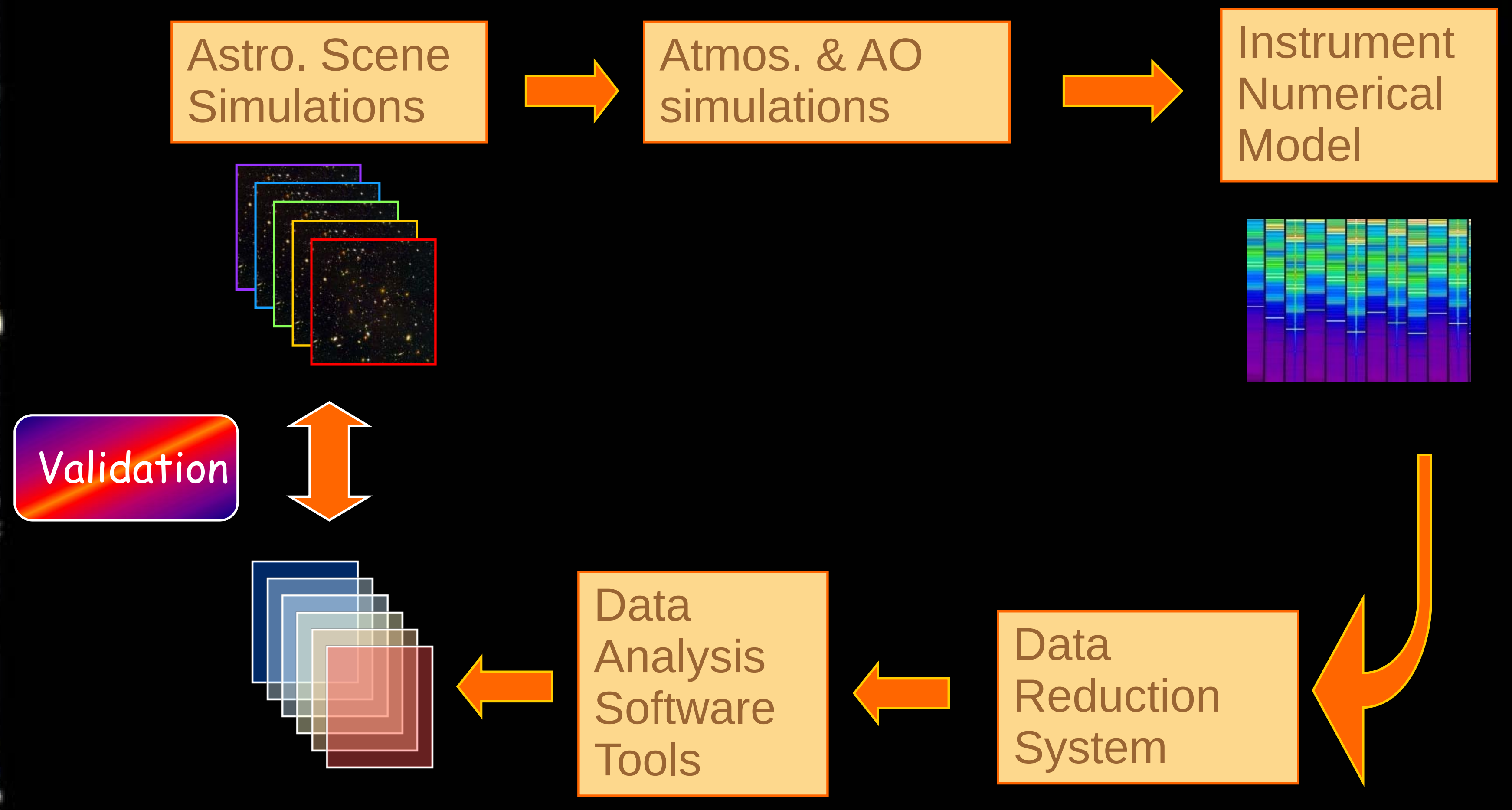
MUSE

PNC-F

2012,
Start of
255 GTO
nights
program

Are we
ready?

End to End Modelling



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