MOONS

Multi-Object Optical and Near-infrared Spectrograph for the VLT

Hector Flores
on behalf of the MOONS consortium

AIUC CENTRO DE ASTRO-INGENIERIA UC

CAAUL · FACULDADE DE CIÊNCIAS UNIVERSIDADE DE LISBOA

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

INAF ISTITUTO NAZIONALE DI ASTROFISICA

UNIVERSITÉ DE GENÈVE FACULTÉ DES SCIENCES Département d'astronomie

l'Observatoire de Paris GEPI Galaxies Étoiles Physique et Instrumentation

ESO

UNIVERSITY OF CAMBRIDGE

Science & Technology Facilities Council
UK Astronomy Technology Centre

MOONS in a nutshell

Field of view: 500 sq. arcmin at the 8.2m VLT

MOONS Nutshell

Field of view: 500 sq. arcmin at the 8.2m VLT

Multiplex: 1000 fibers, with the possibility to deploy them in pairs

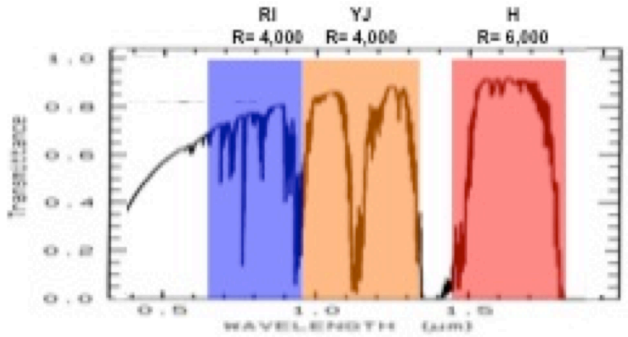
Fibers: Aperture on sky = 1.1arcsec; Close pair = 10arcsec; Max 7 fibers within 2 arcmin

Medium resolution:

Simultaneously 0.64μm-1.8μm

at

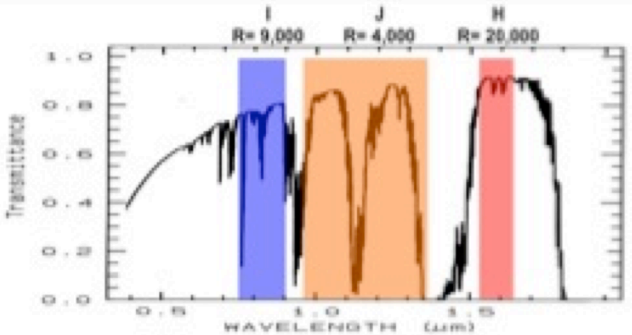
R=4,000 – 6,000



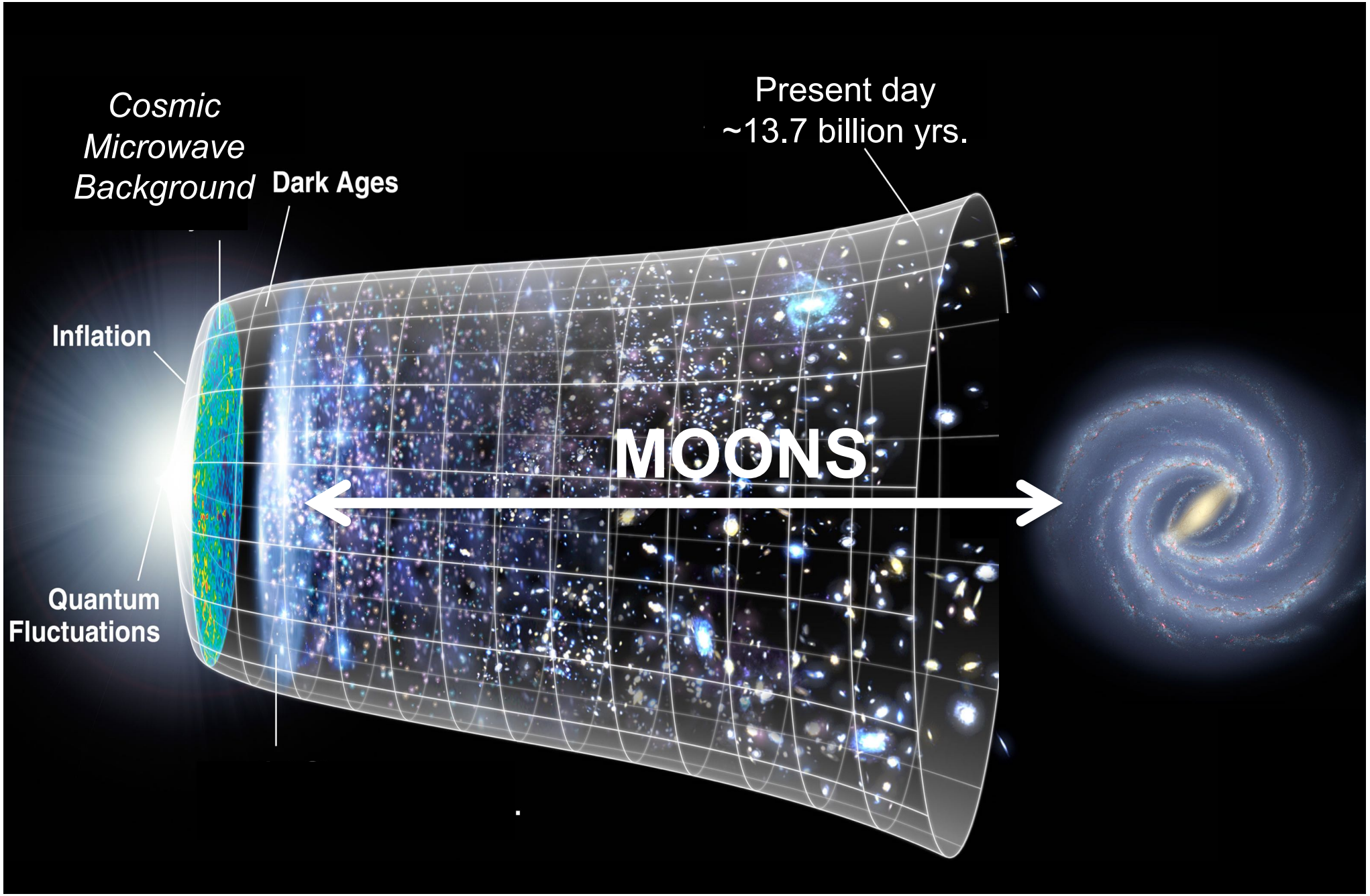
High resolution:

Simultaneously 3 bands:

- 0.76-0.90μm at R = 9,000
- 0.95-1.35μm at R=4,000
- 1.52-1.63μm at R=20,000

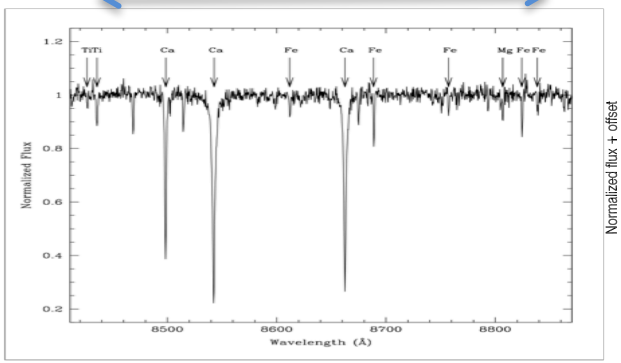


MOONS Science Cases



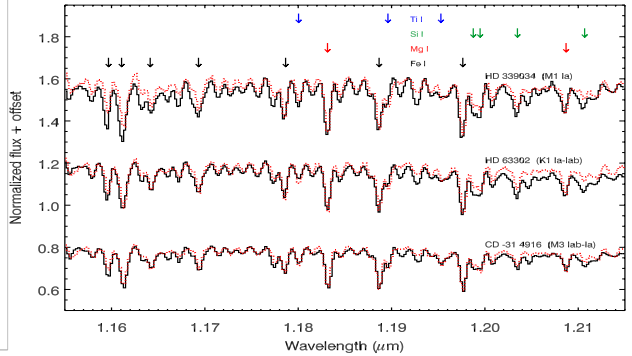
Galactic science cases (100n)

I-band
R=9,000



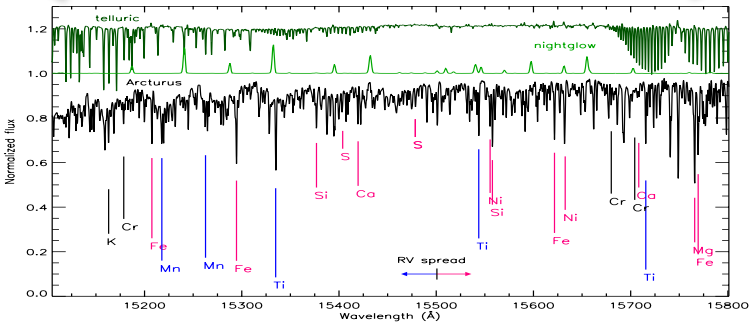
FLAMES
(multiplex = 130)

YJ-band
R=4,500



KMOS
(multiplex = 24)

H-band
R=20,000



APOGEE
(multiplex = 300)

Kinematics – Radial velocities
(<1 km/s)

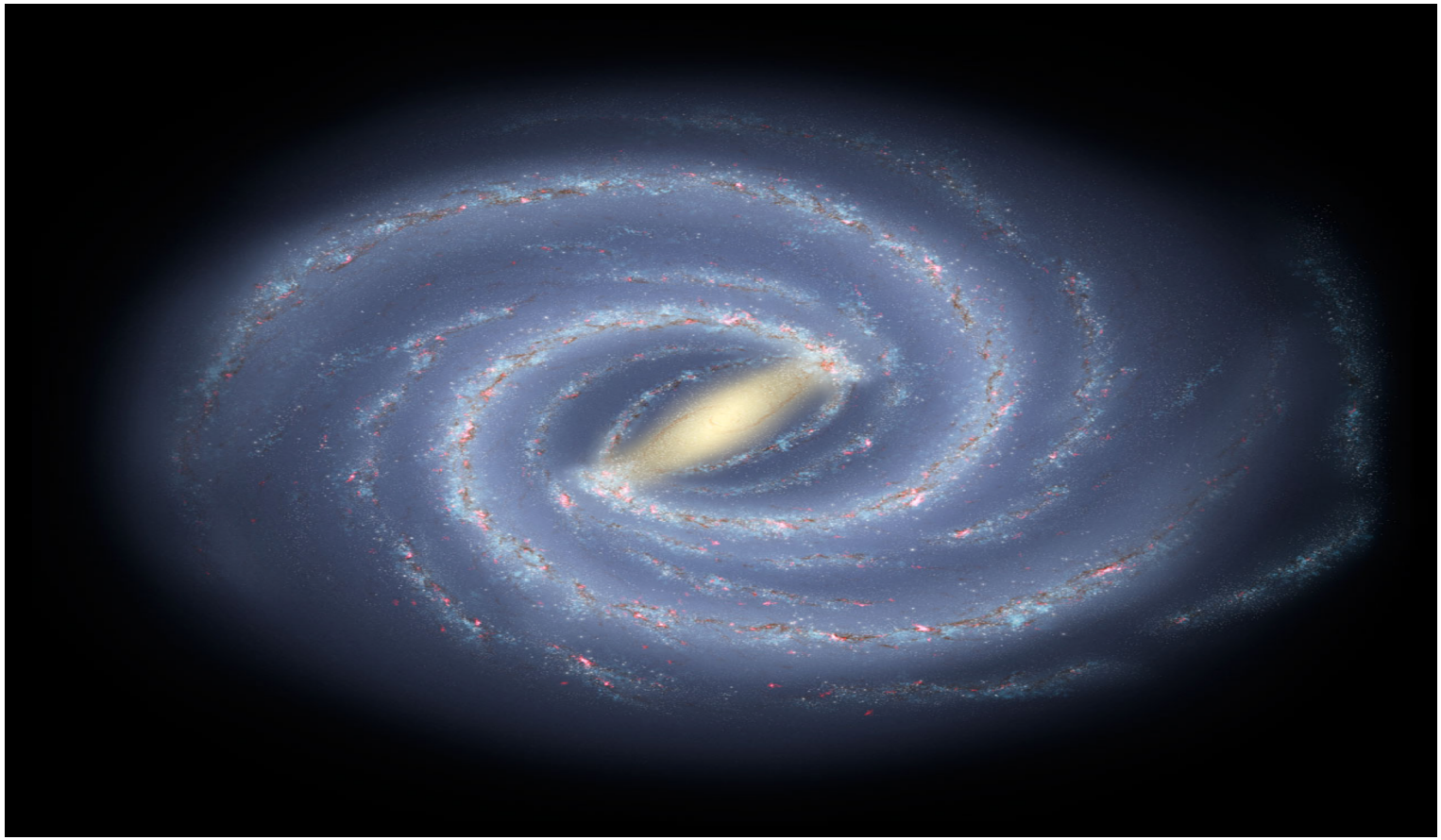
CaT @R=9,000 for I<21 + [M/H] (via Fe,Si,Ti,Mg) @R=4000-6000 (J+H)

Detailed chemical abundances
(< 0.1dex)

(Si, Ca, Ti, Mg, Fe, Cr, Mn, CNO …) @R=20,000 for H_{Vega}<15.5
+
CaT @R=9,000

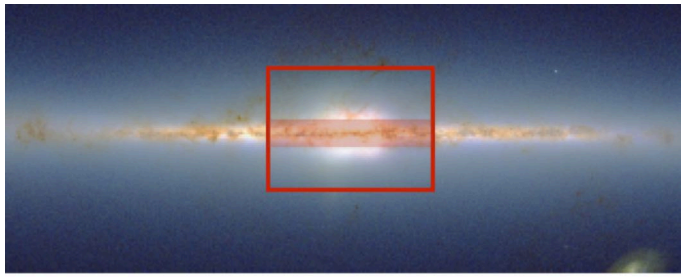
Galactic Archaeology

The resolved stellar populations of the Milky Way provide us with a fossil record of the chemo-dynamical and star-formation histories over many gigayears timescale.



-- Spectroscopic surveys of **GAIA**, STARRS, UKIDSS et VISTA.

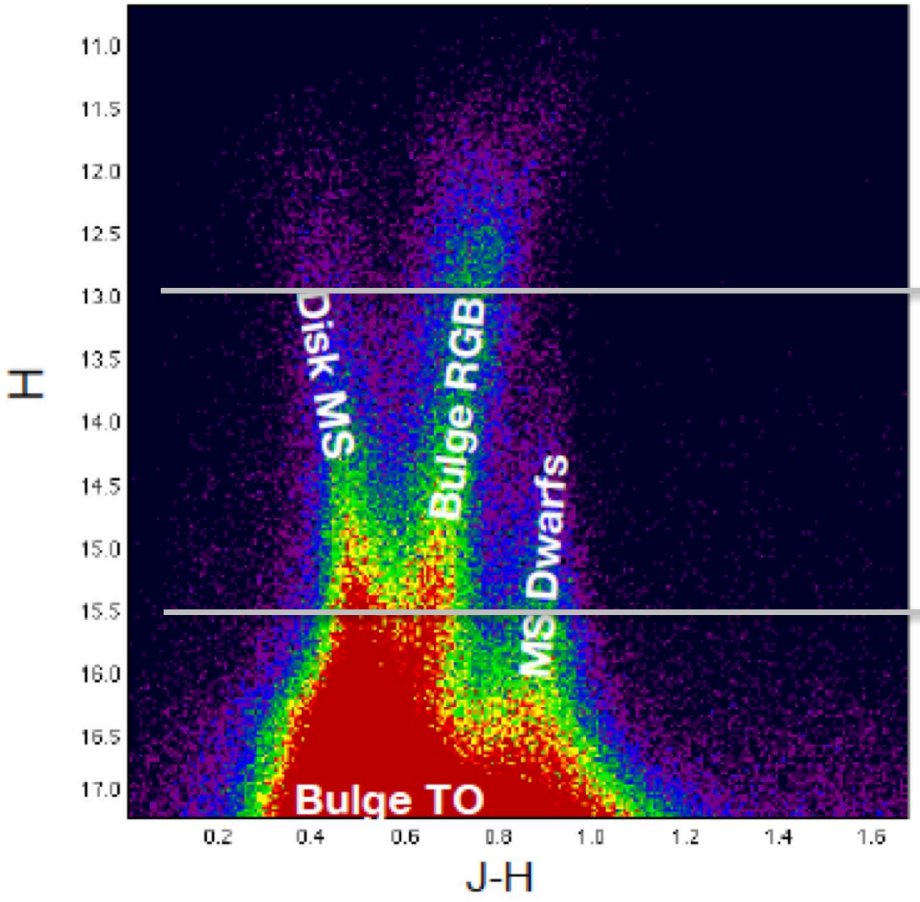
Mapping the inner regions of the Galaxy



The **Bulge** is the **innermost** component of the Galaxy

The dust across the disc makes it very hard to study in the optical

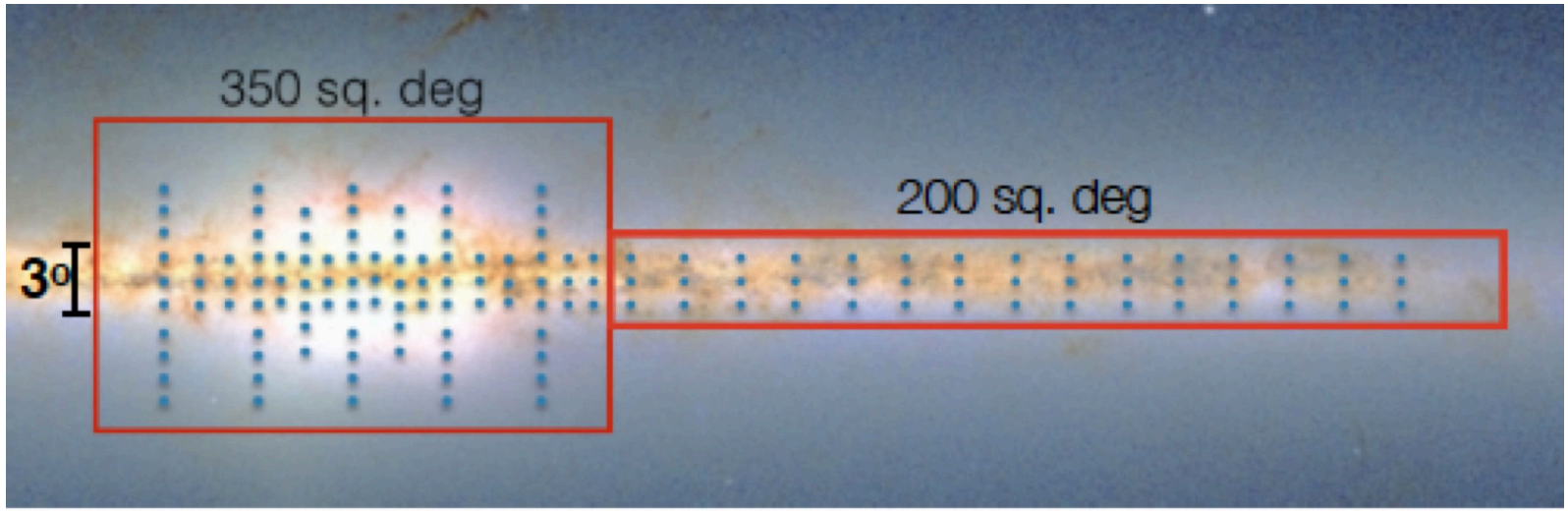
It contains 1/4 of the total stellar mass and its properties are linked to the process involved in the **formation history of the Galaxy**



APOGEE-II in 4 hrs

MOONS in 1 hr

MOONS Inner Galaxy Survey



MOONS Inner Galaxy survey + low latitude disc

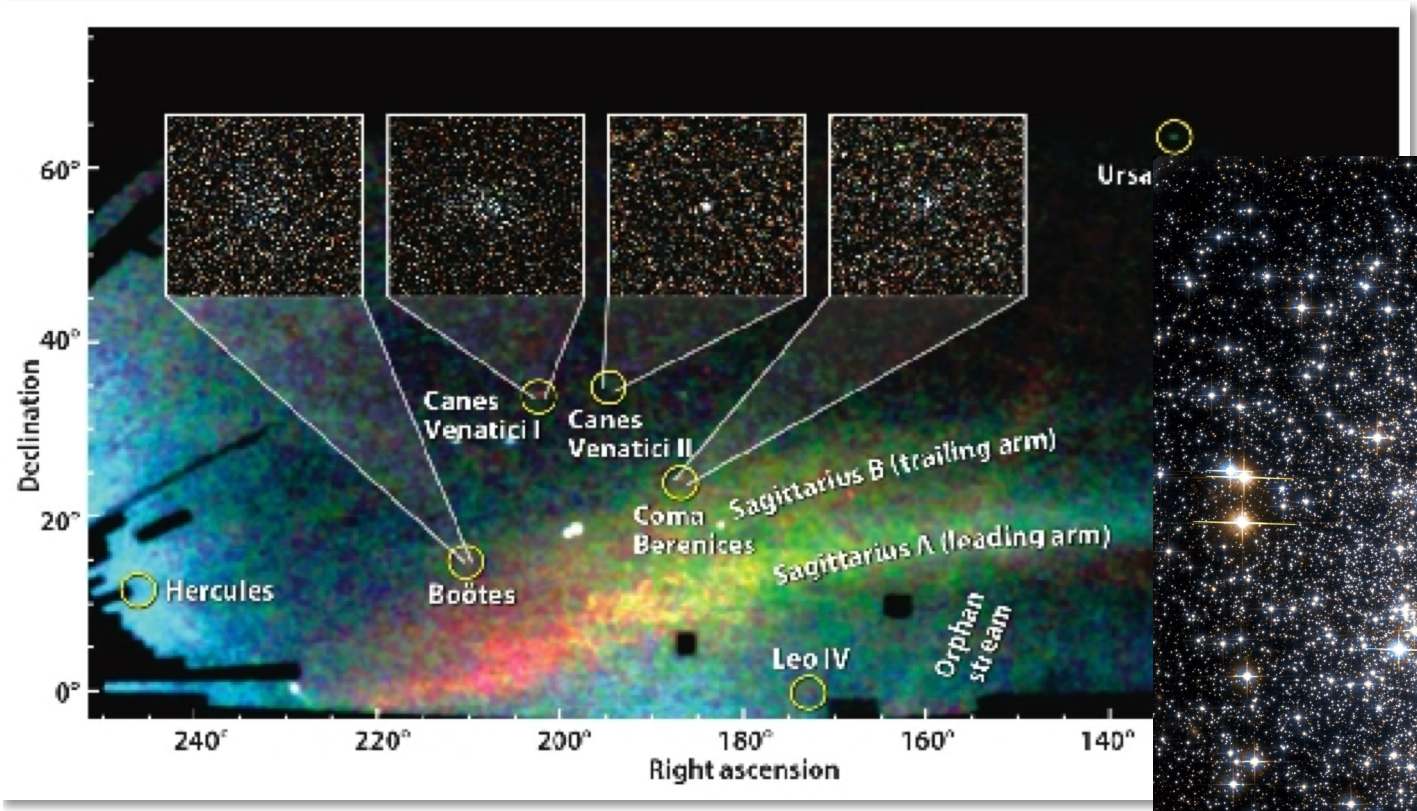
>10^6 stars in 550 sq. deg (S/N>50)

- **Chemo-dynamics of inner bulge and disc:**
  - Is there a distinct large-scale inner bulge structure?
    - *Inner/nuclear bar* (Alard+01, Nishiyama+05, Gonzalez+11)
    - *Metal-poor central spheroid* (Schultheis+15)
    - *kpc-scale nuclear stellar disc* (Debattista+15)
  - Nuclear bulge characterisation (inner 0.5 deg / 200 pc) (Launhardt+02)
  - Galactic disc - bar transition (Bono+15)
  - Complete the global/detailed view of a B/P bulge (Gonzalez+16, Zoccali+14)

Galactic Archaeology

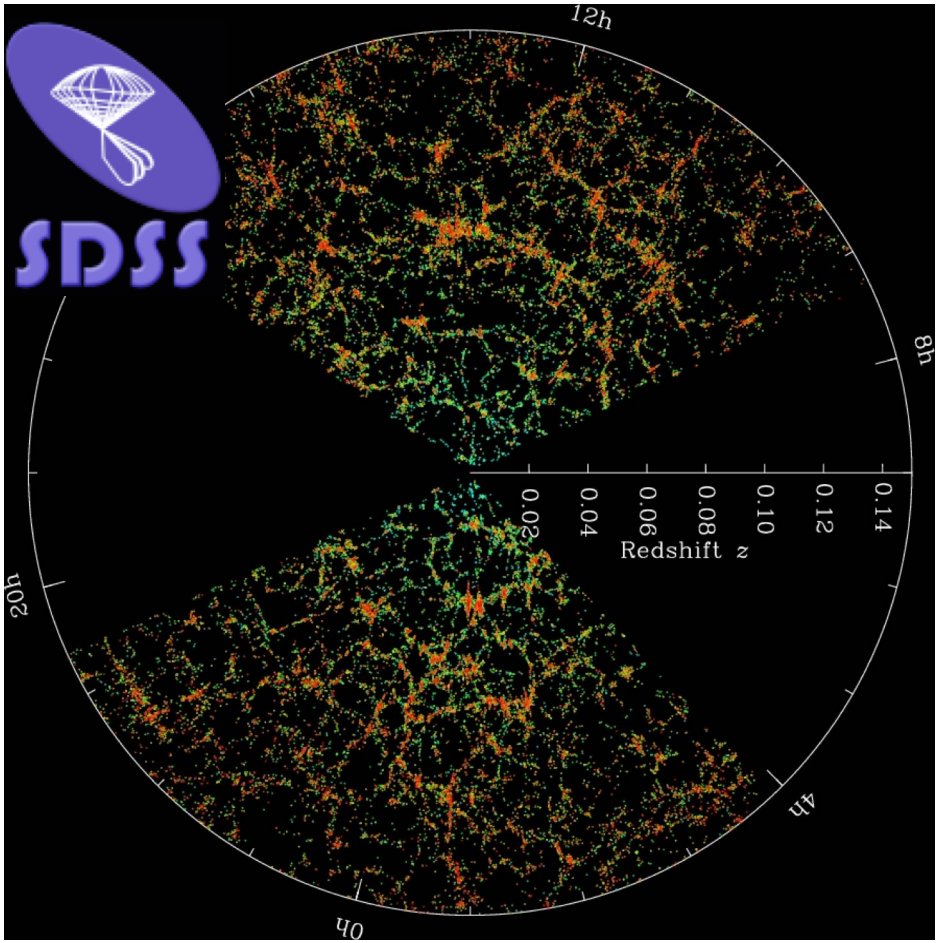
Streams in the Halo field and clusters

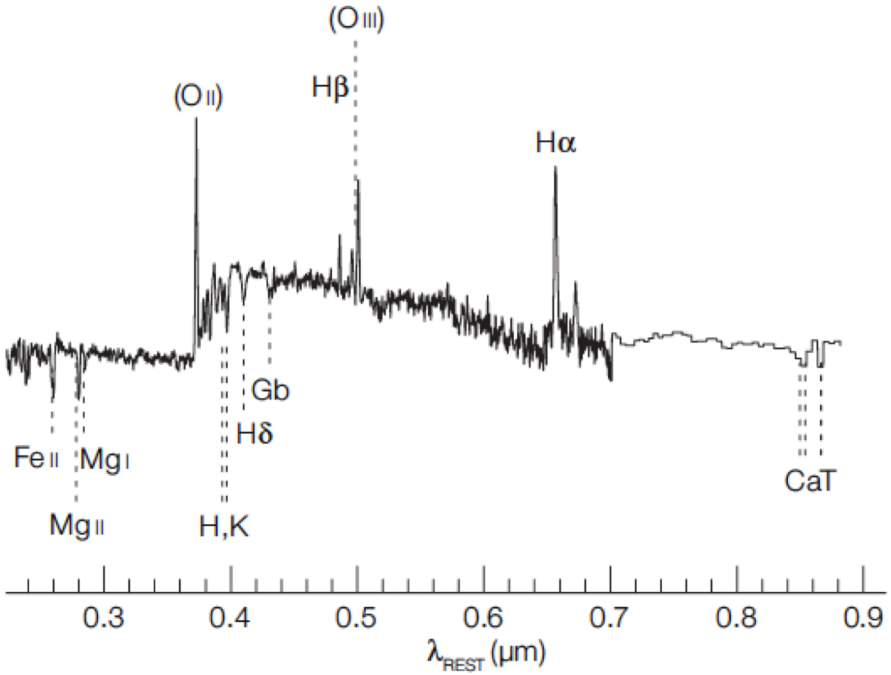
Photometrically selected with Gaia, SDSS, Pan-STARRS, VISTA, UKIDSS, LSST etc.



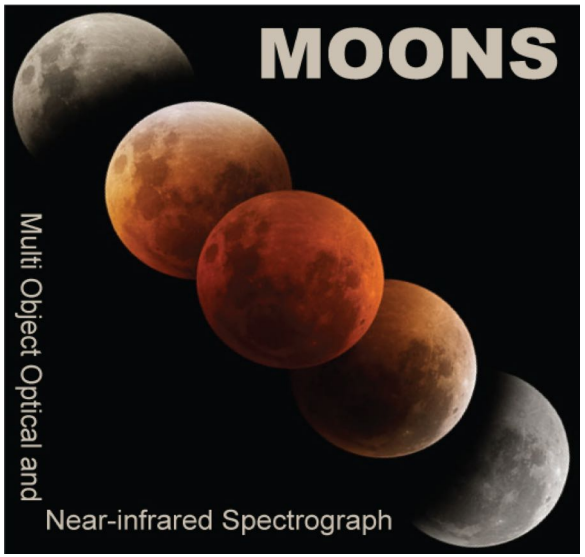
Extragalactic science case (200n)

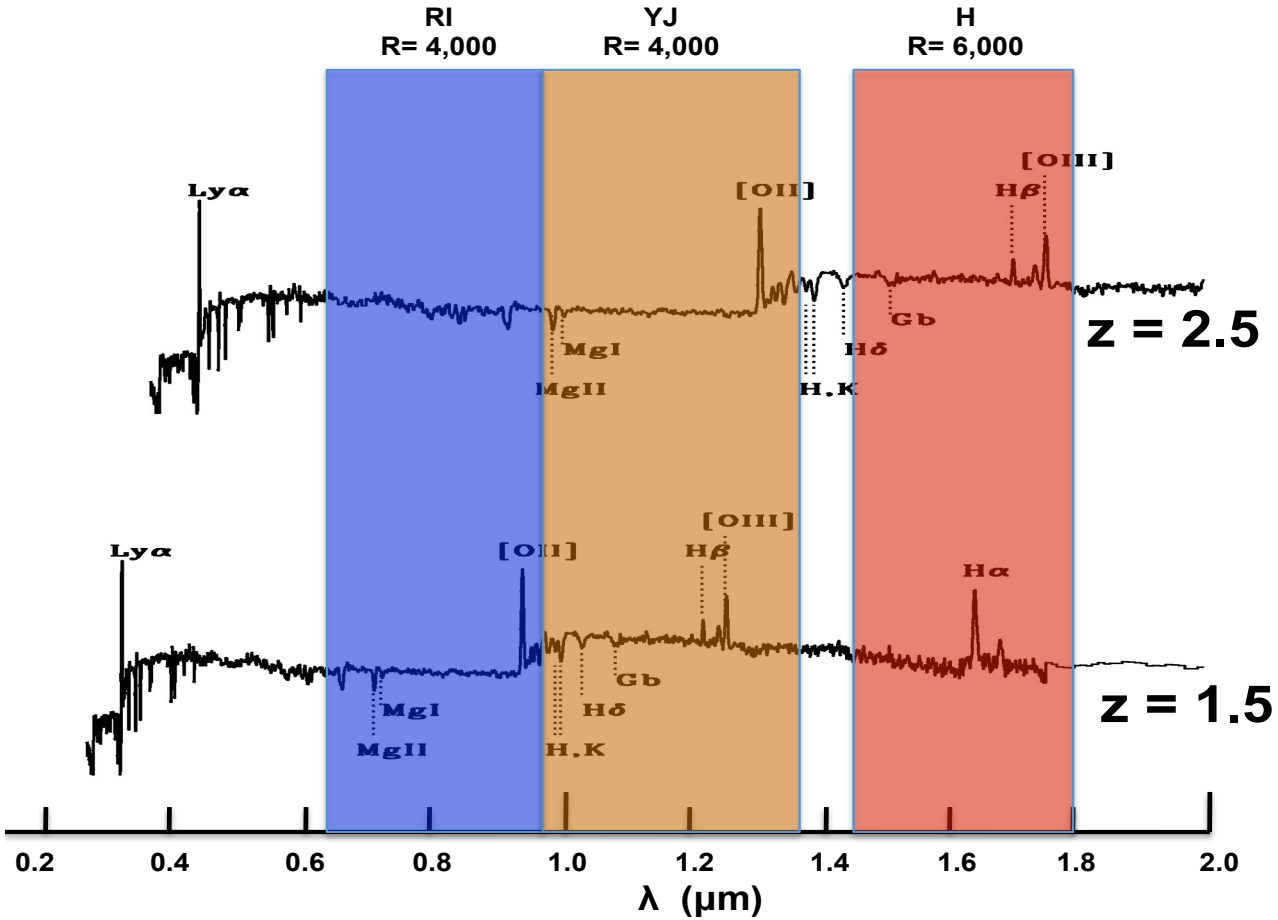
In the local Universe the SDSS has been extremely successful due to both size and spectral quality.



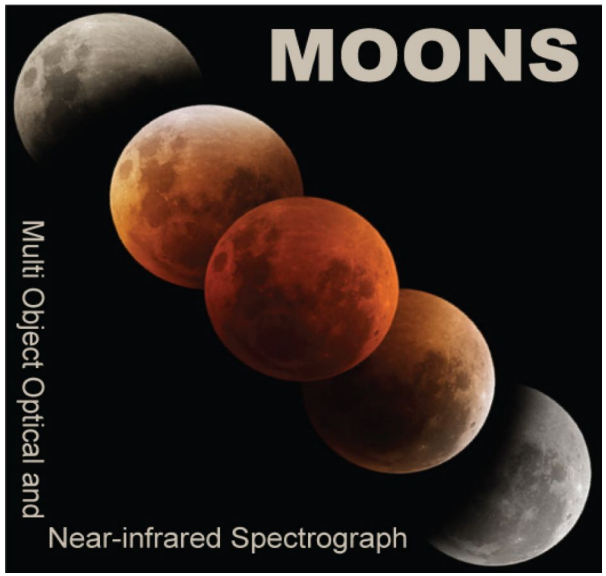


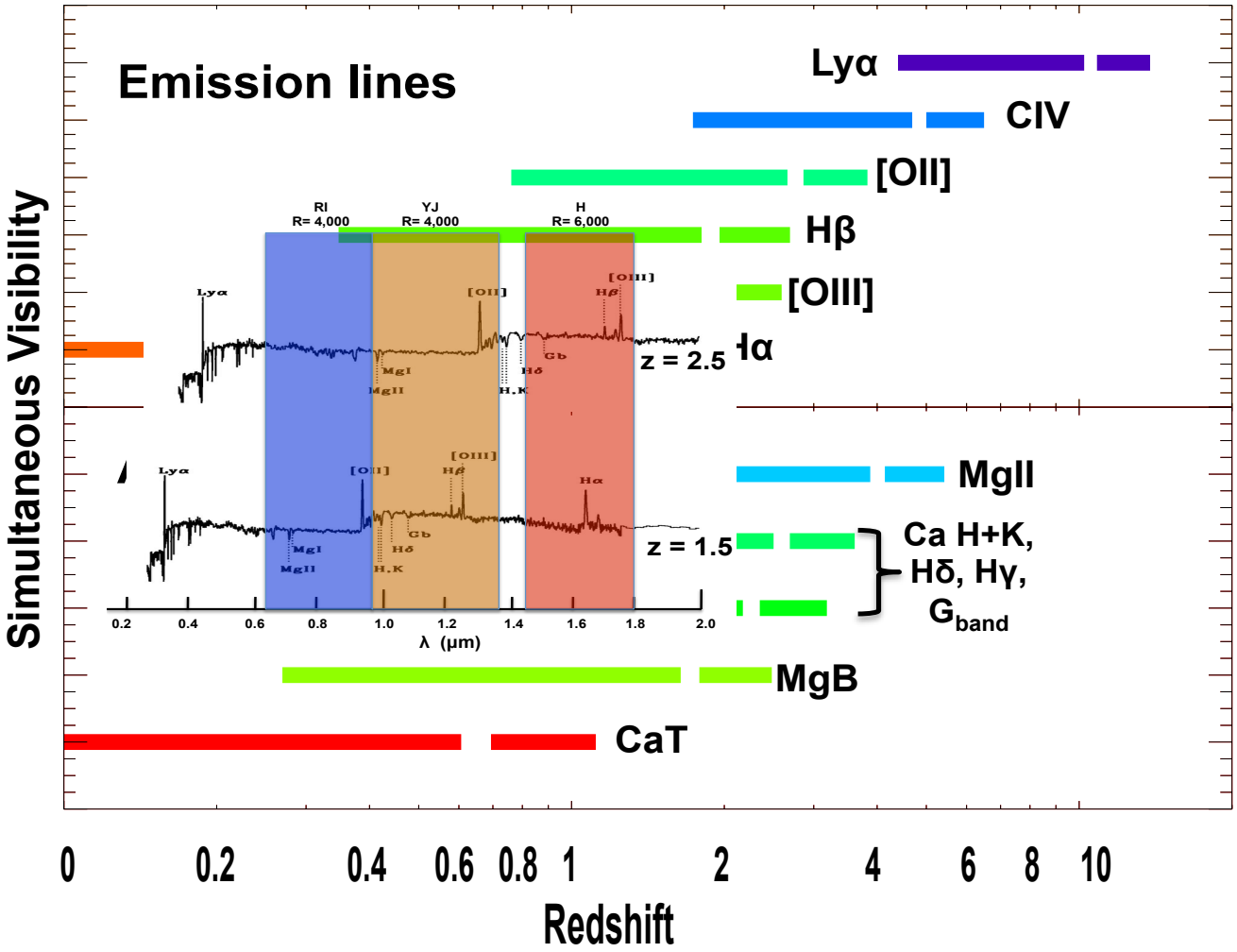
MOONS: a SDSS-like machine probing the peak of galaxy and black hole formation





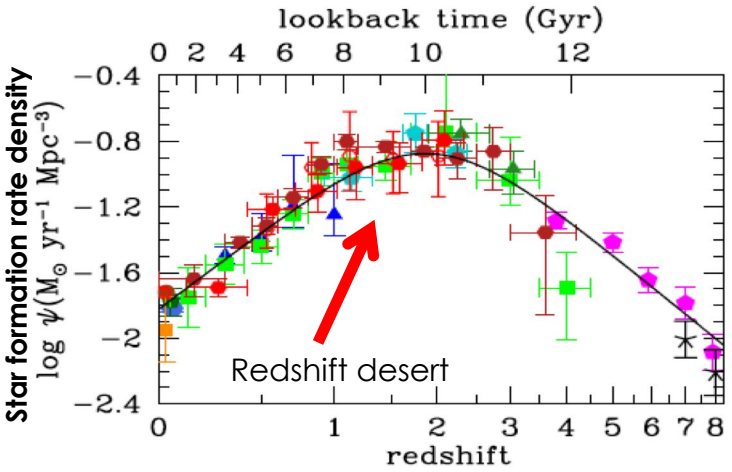
MOONS: a SDSS-like machine probing the peak of galaxy and black hole formation





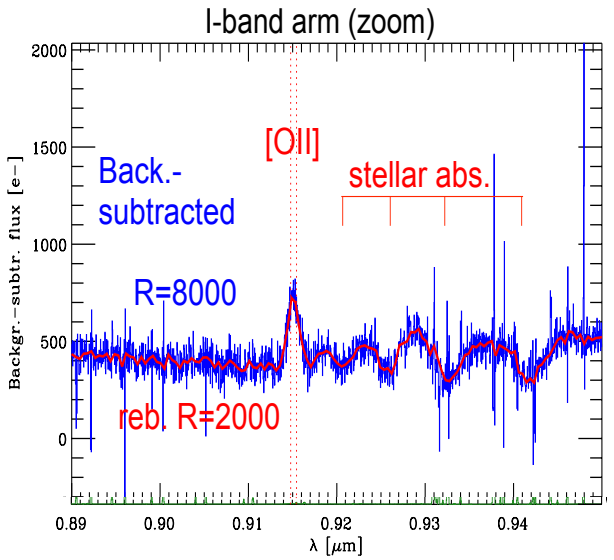
Extra Galactic Science Case

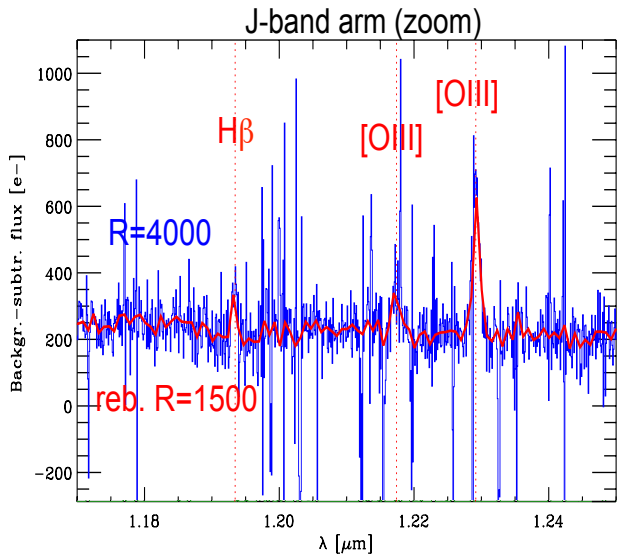
SDSS-like survey
galaxies at z>1 across the peak of star-formation and black hole accretion, up to the very first galaxies at z>7-8

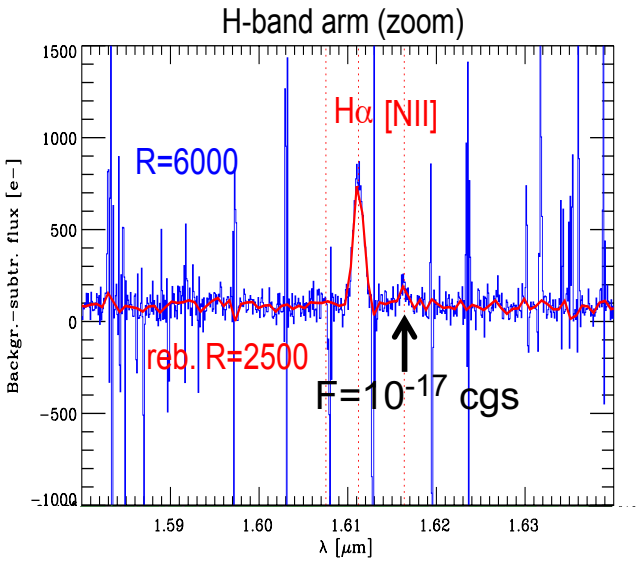


Diagnostics for passive and star-forming galaxies

- ***Metallicity (R_{23},N_2, stellar indices)***
- ***SFR (Hα, Hβ, [OII])***
- ***Stellar populations***
- ***Galaxy transformation (quenching) mechanisms***



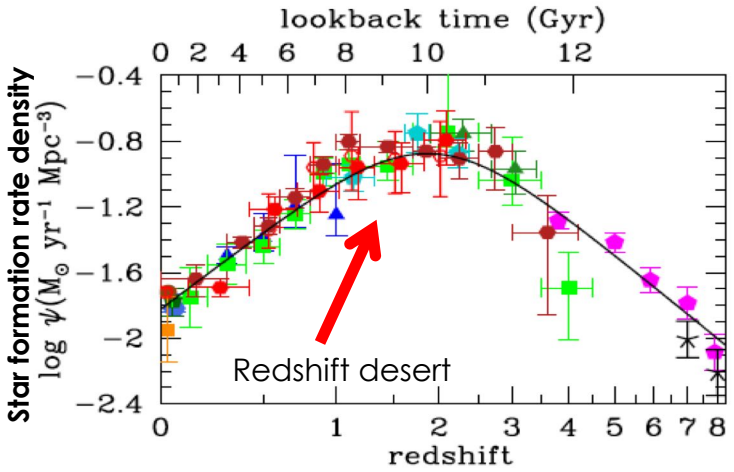




z=1.45, H_{AB}=22.7, 1hr

Extra Galactic Science Case

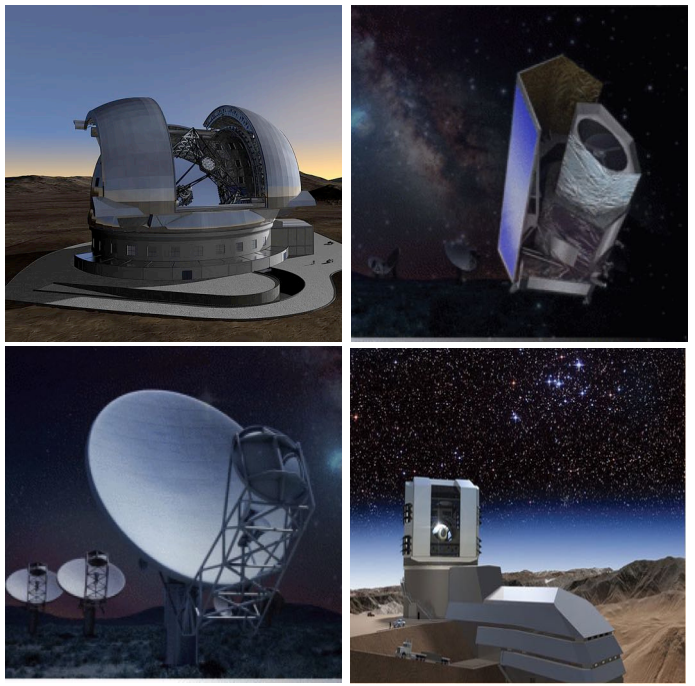
SDSS-like survey
galaxies at z>1 across the peak of star-formation and black hole accretion, up to the very first galaxies at z>7-8



Diagnostics for passive and star-forming galaxies

- ***Metallicity (R_{23},N_2, stellar indices)***
- ***SFR (Hα, Hβ, [OII])***
- ***Stellar populations***
- ***Galaxy transformation (quenching) mechanisms***
- ***AGN power (BPT)***
- ***Dust extinction (Hα/Hβ)***
- ***Galaxy mass (σ_v)***
- ***BH mass (BLR)***
- ***Dependence on environment (large scale structures)***

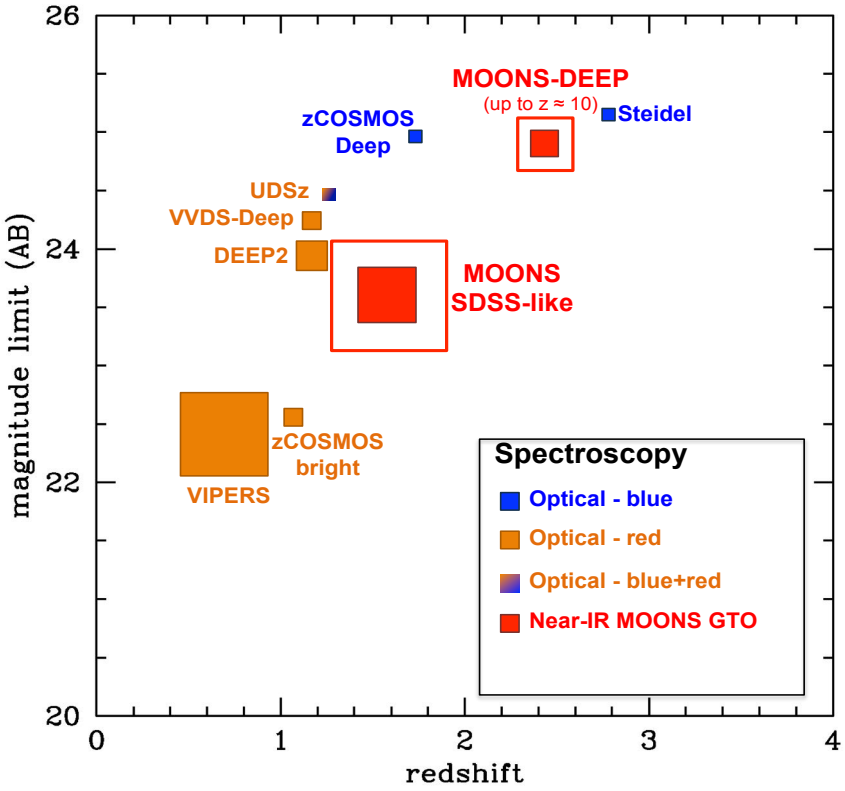
✓Follow-up of large-area imaging surveys: VISTA, Herschel, DES, UKIDSS, eRosita, etc.



MOONS Extragalactic Surveys

SDSS-like + Deep Surveys

Physical, Chemical and Environmental properties for
Goal ~1M galaxies at 0.8 < z < 10



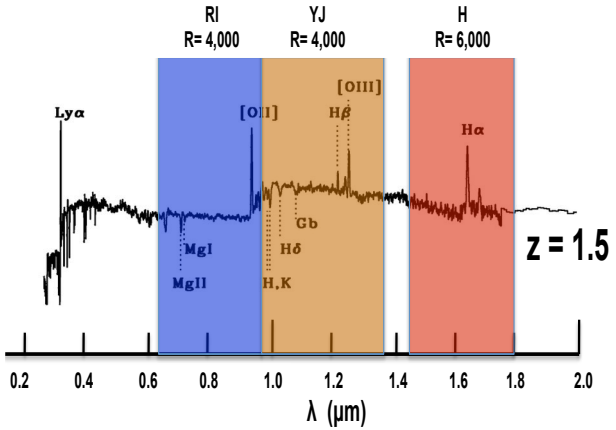
Optimised observation strategy:

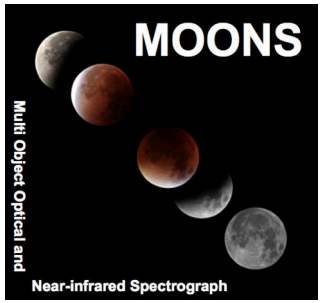
$H_{AB} < 23.5$ 1-8hr over 30sq. deg.

$23 < H_{AB} < 25$ 8-40hr TBD.

$M \sim 10^9\ M_\odot$ and $SFR < 1\ M_\odot/yr$ at z~1-2
with multiple lines diagnostics to measure:
SFR, Metallicity, Ionisation state, AGN, Dust, Environment, etc …

Considerably deeper if only interested in determining the redshift





MOONS France

Groupe instrumental MOONS-France

Nom (Fonction)

H. FLORES (Co-PI)
I. GUINOUARD (Projet Manager/WP Manager Fibres)
F. ROYER (WP Manager DRS)
J.P. AMANS(WP Manager Shutter)
R. HAIGRON (WP DRS)
Y. YANG (WP DRS)
F. REIX (WP Fibres)
D. HORVILLE (WP Fibres)
J. M. HUET (WP Fibres/WP Shutter)

Science team
Nom (Laboratoire)
H. FLORES (GEPI)

Groupe stellaire
E. CAFFAU (GEPI, responsable)

P. BONIFACIO (GEPI)
P. Di MATTEO (GEPI)
M. HAYWOOD (GEPI)
R. IBATA (Obs. Strasbourg)
V. HILL (OCA)
N. MARTIN (Obs. Strasbourg)
A. RECIO-BLANCO (OCA)
M. SCHULTEIS (OCA)
F. ROYER (GEPI)

Groupe extragalactique
M. PUECH (GEPI, responsable)

H. ATEK (IAP)
V. BUAT (LAM)
D. BURGARELLA (LAM)
T. CONTINI (IRAP)
E. DADDI (CEA)
H. DOLE (IAS)
F. HAMMER (GEPI)
S. MAUROGADATO (OCA)
R. PELLO (IRAP)
S. VERGANI (GEPI)

Science WG

MOONS Board

Galactic Surveys (~ 100 nights)
WPs coordinator L. Origlia

SURVEY Science WGs
-Inner Milky Way (70%) – Lead by O. Gonzalez
-**Dwarfs/streams, the Galactic Halo (15%) – Lead by E. Caffau**
-SMC, LMC (15%) – Lead A. Mucciarelli

SURVEY Tools WPs
-Photometric Surveys. Coordinator: E. Dalessandro
-Science pipeline + calibration. Coordinator: O. Gonzalez
-Archiving Science products. Coordinator: W. Taylor

Extragalactic Surveys (~ 200 nights)
WPs coordinator R. Maoilino

Extragalactic Science WGs
E-WG1: Physics of ISM F. Mannucci IT
E-WG2: Passive galaxies & stellar continuum R. McLure UK
E-WG3: Environment P. Norberg / S. Lilly UK / ETHZ
E-WG4: Large Scale Structures M. Magliocchetti / Kneib IT/Geneva
E-WG5: AGNs J. Afonso /F. Bauer PT/Chile
E-WG6: Blind MOONS Survey H. Flores FR
E-WG7: High-z Universe and Re-ionisation P. Oesch Geneva
E-WG8: Clusters/Protoclusters E. Daddi FR
E-WG9: Transients and variability F. Bauer Chile

Extragalactic Technical WGs
TE-WG1: Input Catalogues C. Pappalardo PT
TE-WG2: Coordination with other facilities S. Serjeant UK
TE-WG4: Mock catalogues from simulations P. Norberg UK
TE-WG5: Fibres allocation tool (Observation Preparation Tool) B. Garilli IT
TE-WG7: Det. of redshift and physical parameters from spectra Pozzetti / Wild IT/UK
TE-GW8: Det. of Environmental Parameters S. Maurogordato / P. Jablonka FR/Geneva
TE-GW9: Data Flow Myriam Rodrigues / … UK / …

The science case will define the surface and the deep of both surveys

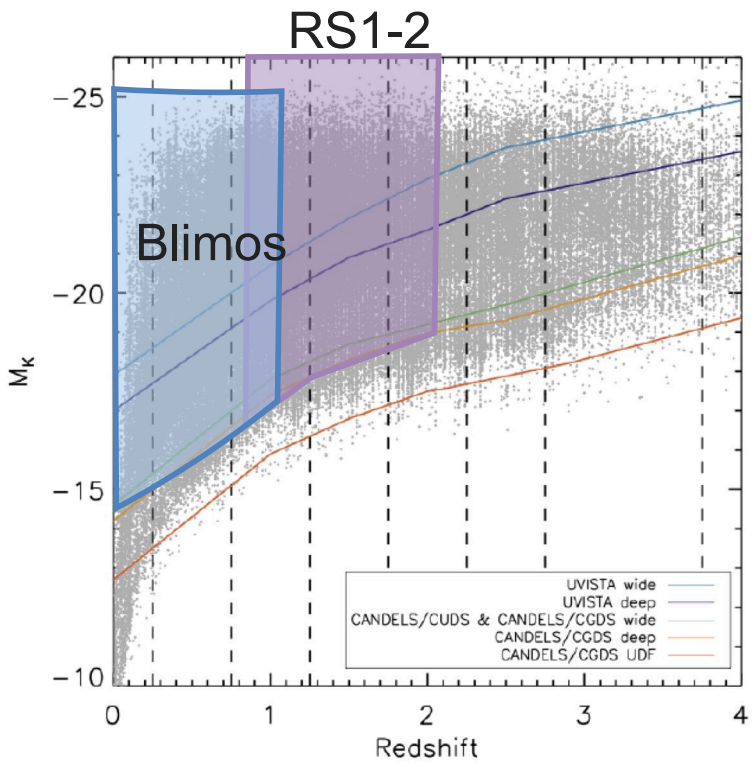
Blind MOONS Survey

- WG 6 : H. Flores, R. Amorin, J. Brinchman, F. Buitrago, V. Buat, D. Burgarella, E. Daddi, F. Hammer, C. Papaderos, P. Papaderos, L. Pozzetti, M. Puech, M. Rodrigues, R. Sanchez-Janssen

Blind survey

15 NIGHTS

- A single selection criteria $H_{AB} < 25$
- No preselection in redshift
- Complete (~95%) on the MOONS deep survey field
- One MOONS field (25 arcmin diameter)



~11 300 objects between z=0 and z=1

(in addition to RS1-2; TBC)

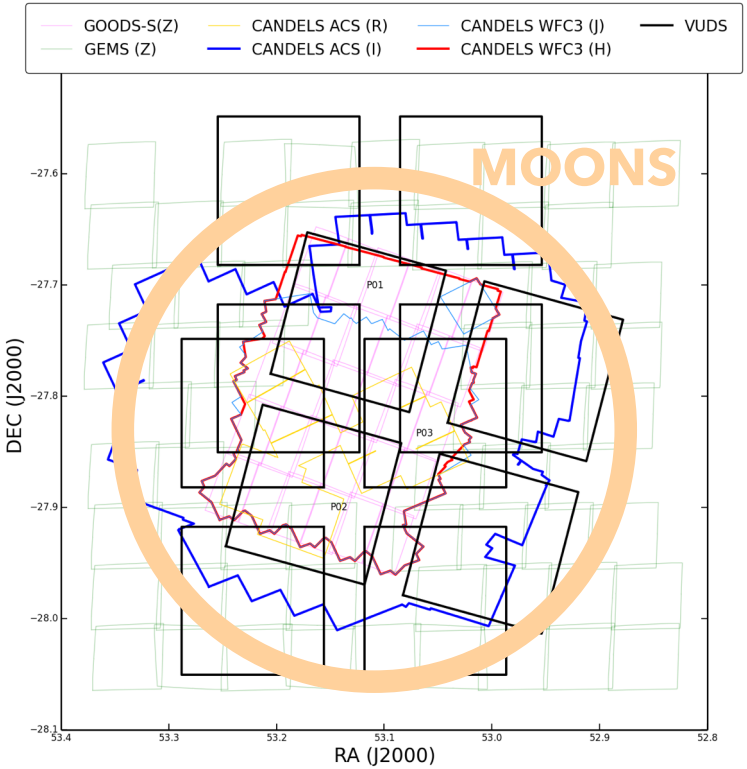
CDFS Field

- High resolution images

  (HST and later EUCLID)

- Multi-lambda observations
- Already observed by RS1-2
- Goal: Observe all remaining sources
- Preliminary estimation: 15n

  Tint = 1 to 3hr (Good S/N in YJ)



BUT for final estimation we need to:
-count galaxies with redshift bins (ongoing)
-construct our own photometric catalog (VIDEO tup o m=25)
-The astrometry !!! need to be checked and improved using GAIA

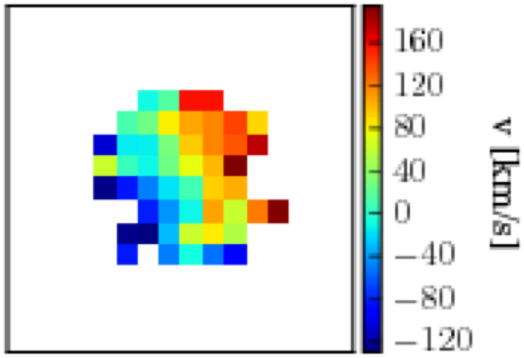
BLIMOS -

CDFS Field

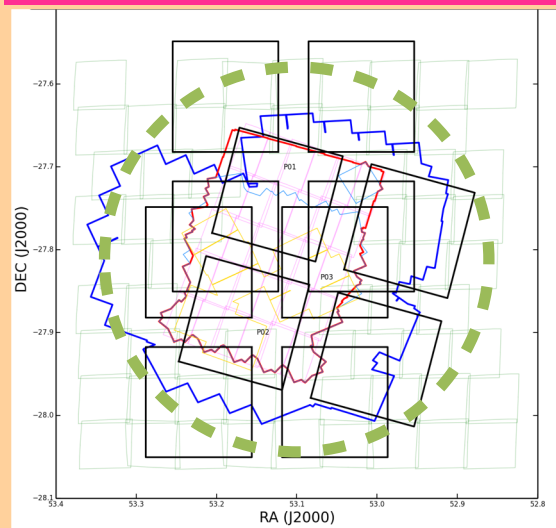
HIGH RESOLUTION IMAGES

- Morphology
- Light distribution

KINEMATICS (MUSE+KMOS)



BLIMOS



Z

CDFS database
ACE survey
etc

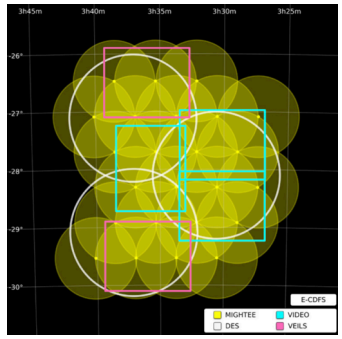
H-BAND PHOTOMETRY VIDEO

Sample section

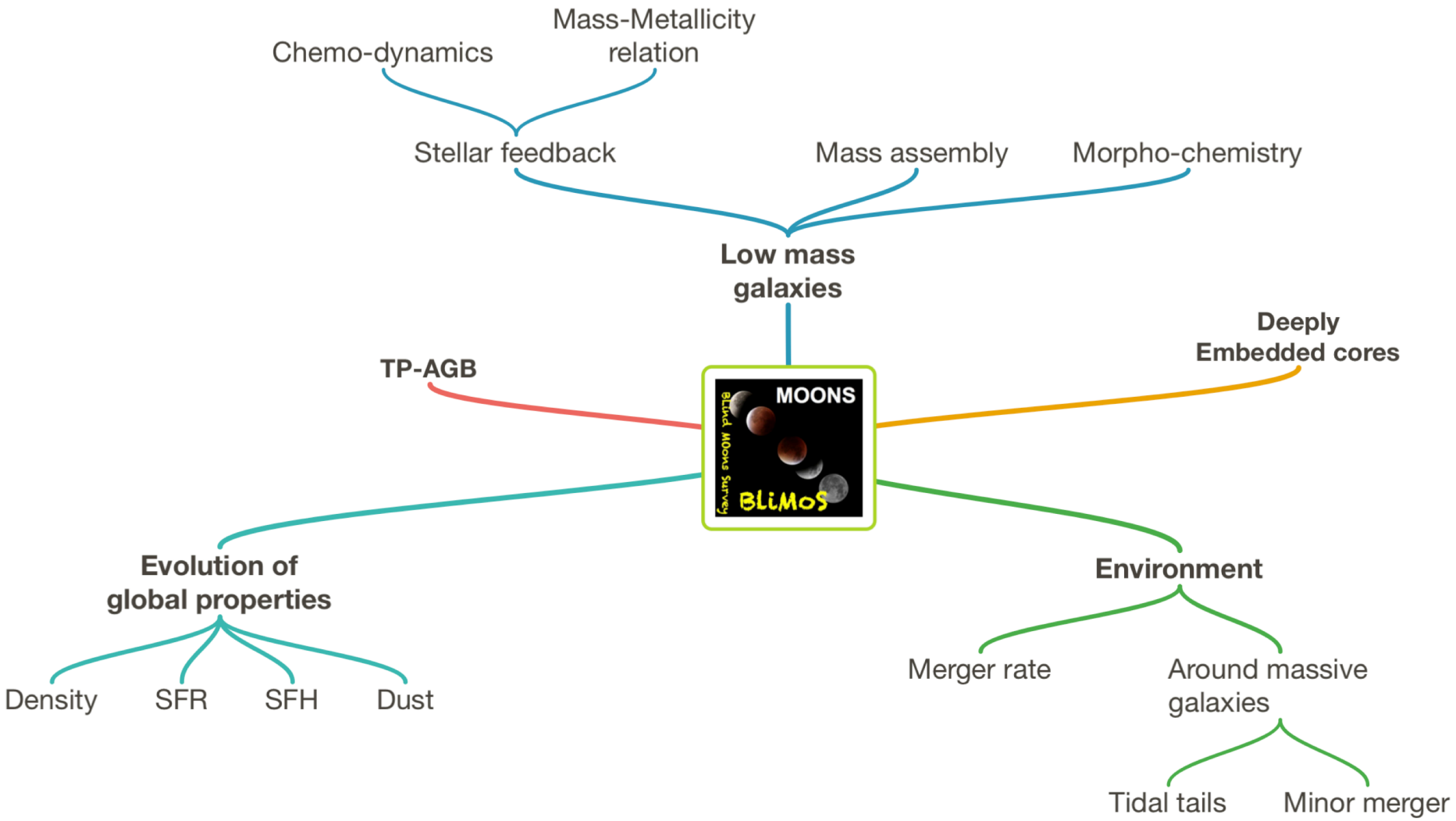
MULTI-LAMBDA OBSERVATIONS

NIR-VIDEO
VIS - VOICE
Spectral energy distribution
- Stellar mass
- Attenuation

Radio follow-up
(MIGHTEE-MEERKAT)



Science cases



Ongoing …. Catalog needs to be checked
Redefinition of completeness and deep (H=24,5)

MOONS: Synergies

Follow up

VISTA near-IR imaging surveys (**Ultra-VISTA, VIDEO, VIKING, VVV, VMC)**

Gaia (ESA).

Euclid (ESA)

E-ELT (ESO) :

-DRS and fiber link

and:

-Sci target for the E-ELT

MOONS and Radio survey

Recurrent problem with imagery → construct a catalog of sources with redshift

Large number of facilities **but** only MOONS with H band spectroscopy

To study properties (Z, SFR) // environment // etc

Deep MOONS survey can help (H < 25)

Goal:

Study the properties of distant radio sources, identify the best candidate when multiple sources are detected.

MOONS timeline

- [x] Phase A: Mars 2013
- [x] Kick-off Phase B: Juillet 2014
- [x] Preliminary Design Review (PDR): Octobre 2015
- [x] Final Design Review (FDR): Mars 2017

Next steps:

- [ ] Integration Readness Review (IRR): Debut 2020 à Edimbourg (ATC)
- [ ] Test Readness Review (TRR): 02 2021
- [ ] Preliminary Acceptance Europe (PAE): 06 2021
- [ ] Preliminary Acceptance Chile (PAC): 12 2021

Summary

MOONS is the long-awaited near-IR MOS for the VLT

Construction phase started in June 2014

Operational by 2020-21

Field of view	500 sq. arcmin
Multiplex	1024 fibres
Low resolution mode	R = 4,000-6000 λ = 0.64µm – 1.8µm simultaneously
High resolution mode	R=9,000 for CaT + R=4,000 in YJ-band + R=20,000 in H band
Throughput	> 30 %

Main science cases:

Galactic Archaeology:

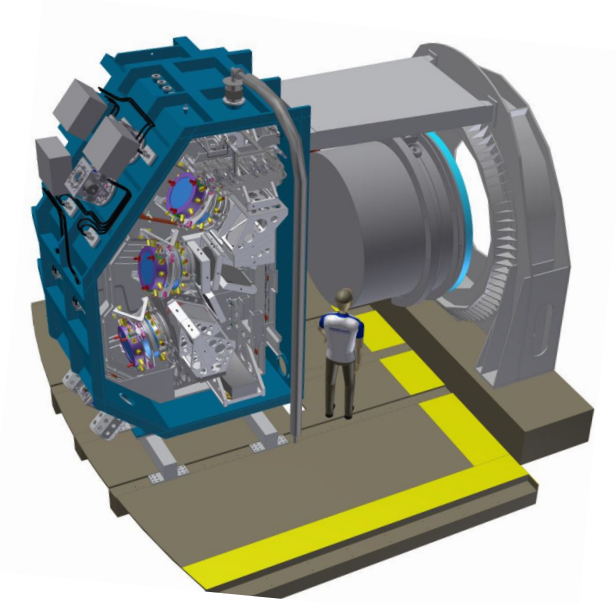
✓ Radial velocities and detailed chemical abundances for **several million stars** in our own Galaxy.

Galaxy evolution:

✓ Formidable **SDSS-type survey for >1M galaxies at z>1**. Unique insight into the effect of environment, chemical and physical evolution.

Synergies:

✓ Essential follow-up of large-area imaging surveys: Gaia, VISTA, Herschel, DES, UKIDSS, LOFAR, eRosita, Euclid, LSST, SKA



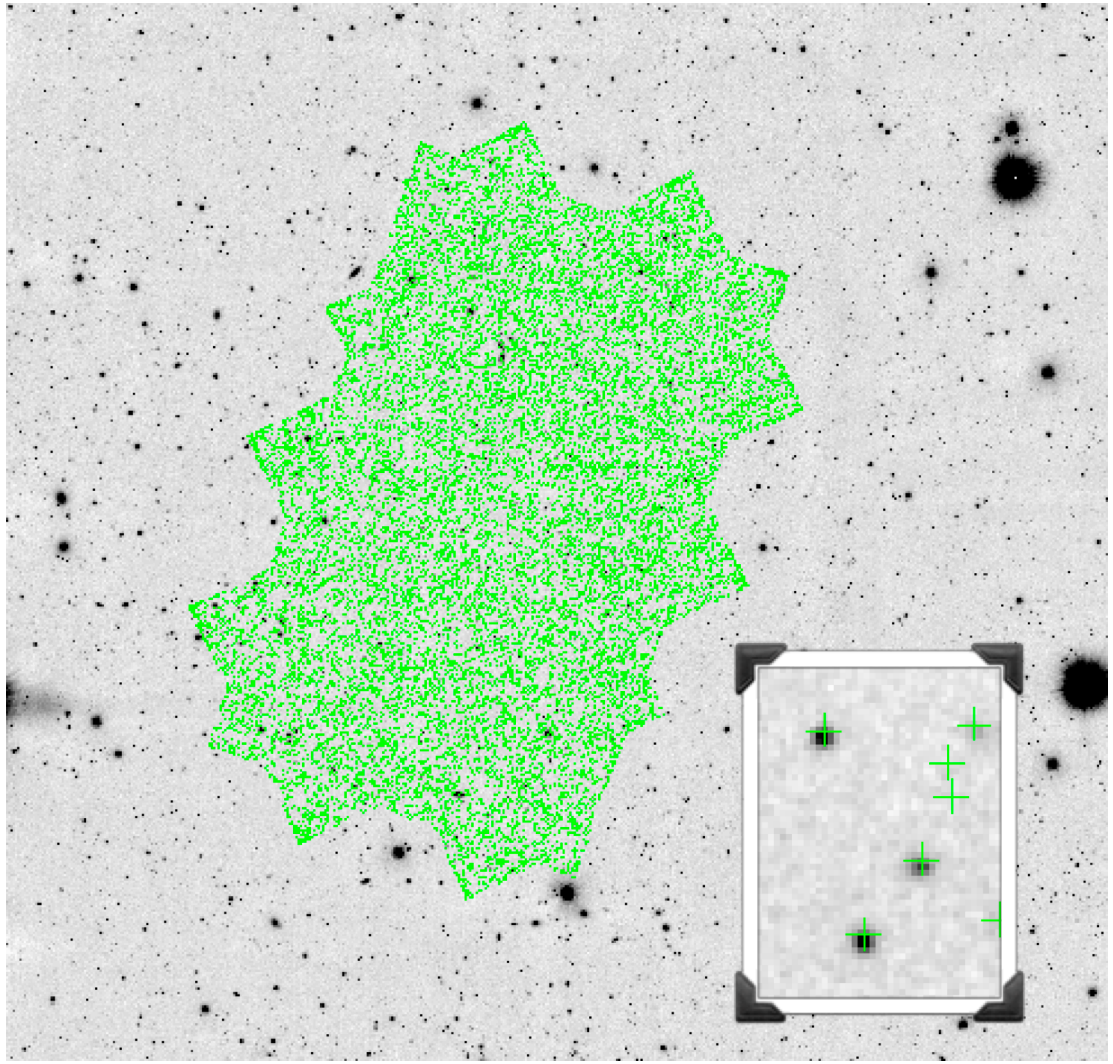

MOONS
Multi Object Optical and
Near-infrared Spectrograph

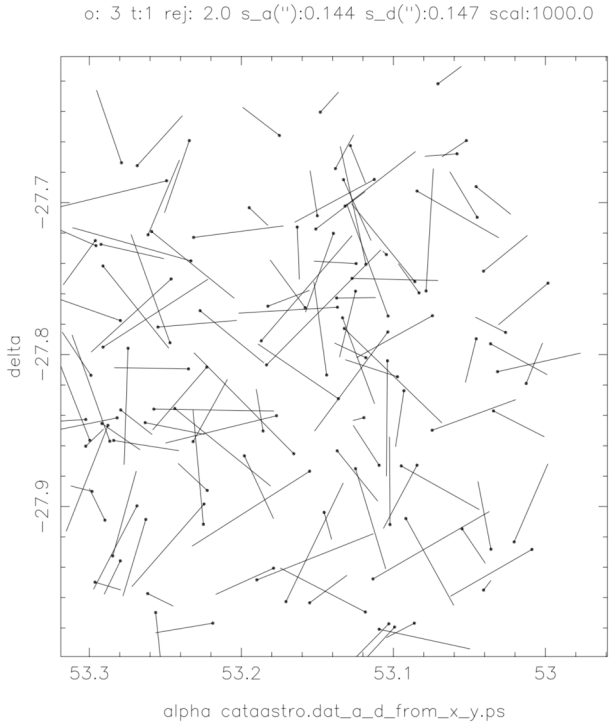
Thanks

BLIMOS

CDFS Field

VIDEO H ban





WORK in progress
Small distorsion on the field:
Astrometric solution needed
New photometric catalog
Deep 25 (sig=4)