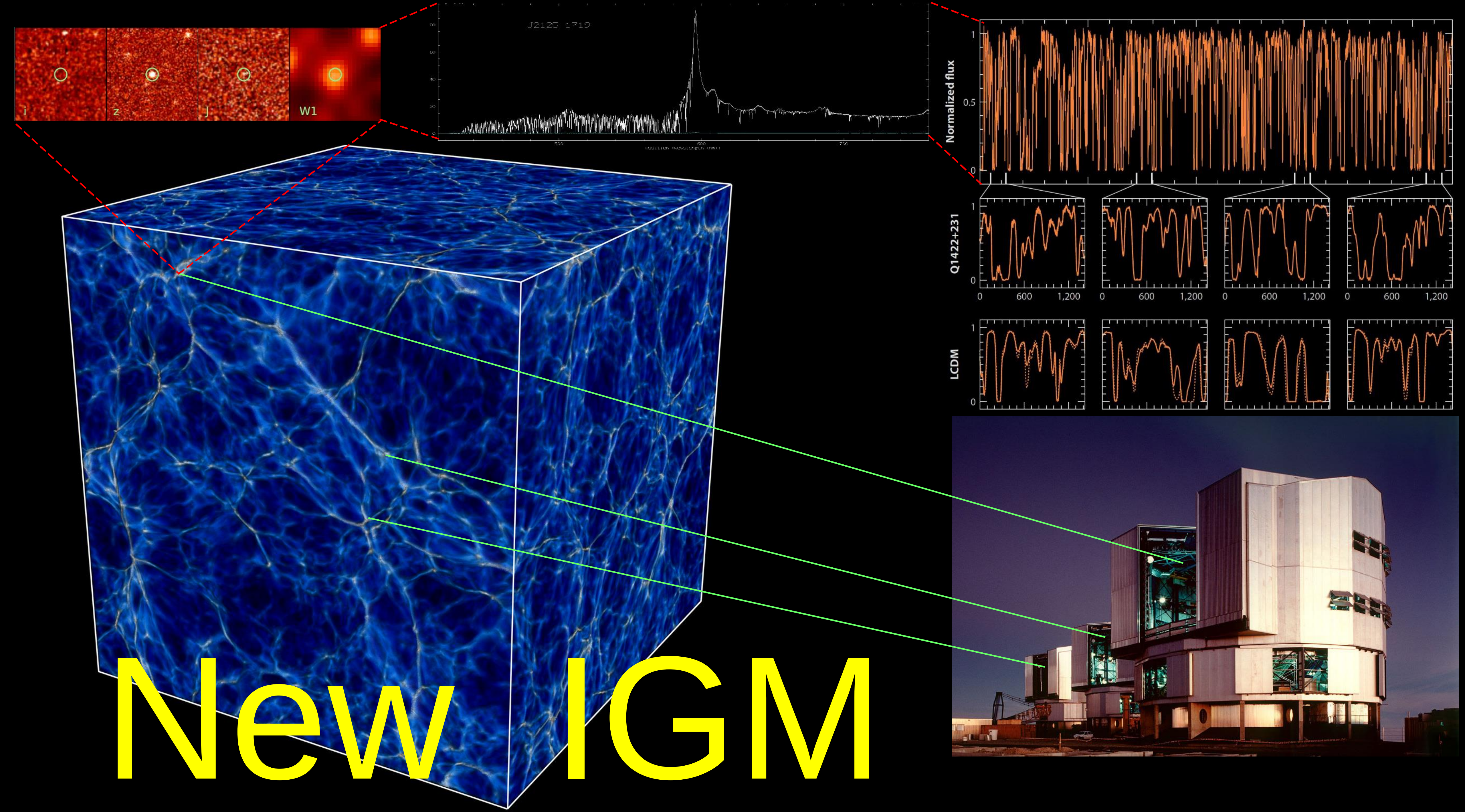
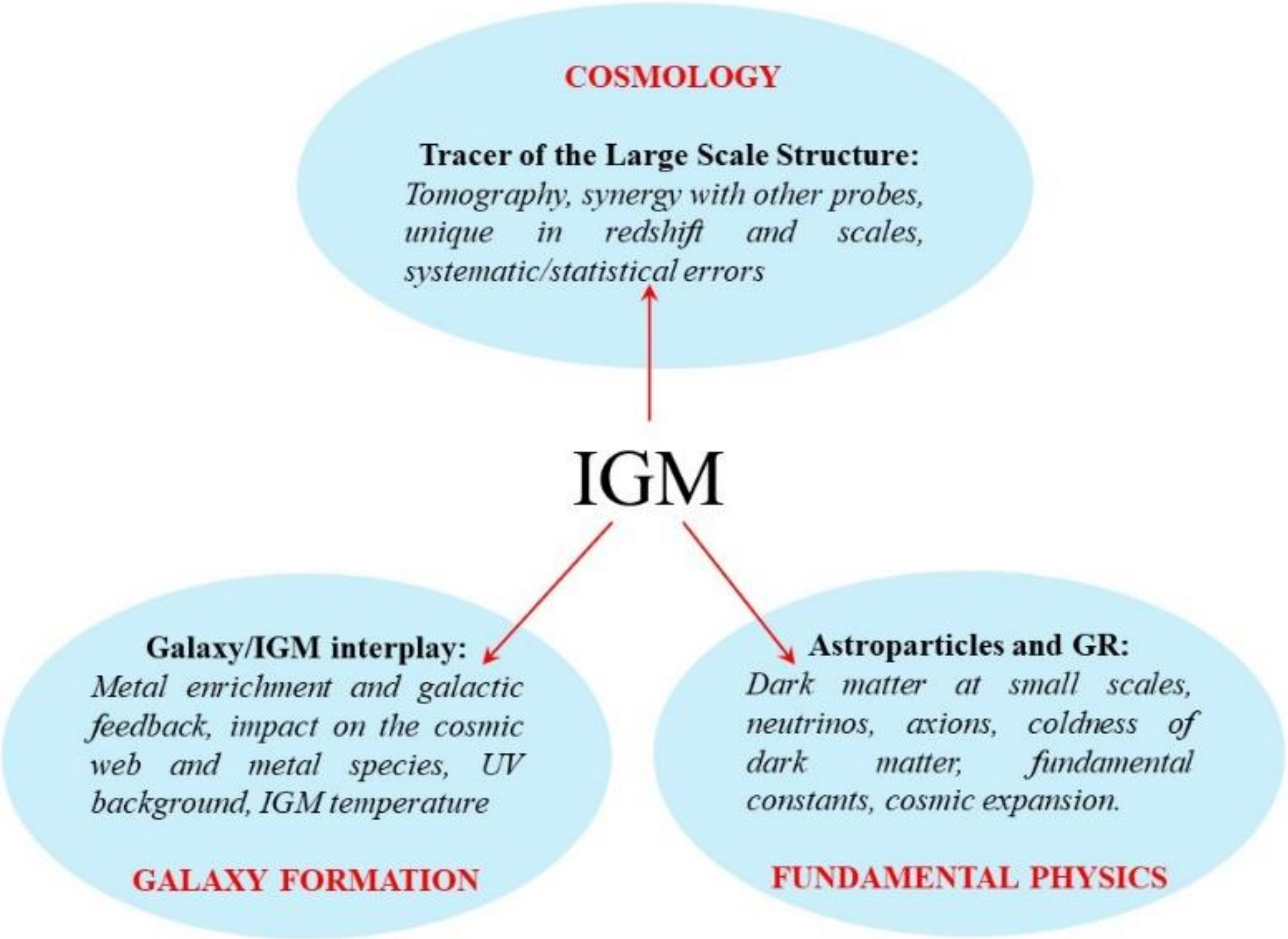
New IGM



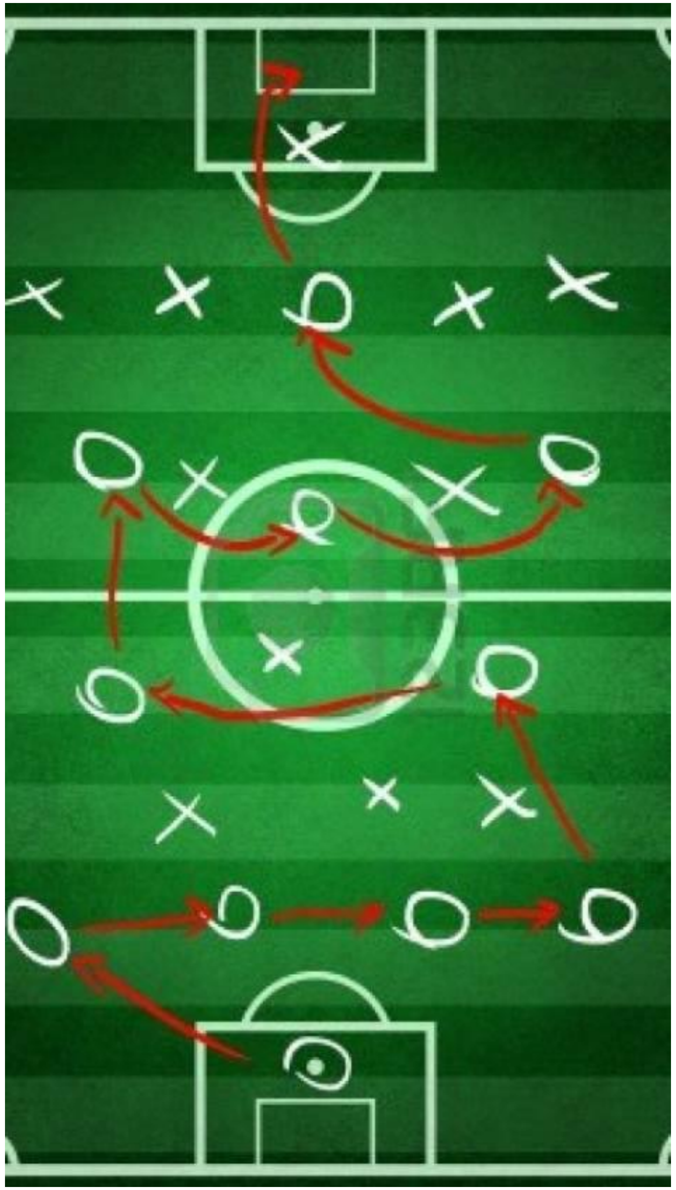
i
z
J
W1
J2125 1719
Normalized flux
Q1422+231
LCDM
0
0.5
1
600
1,200


COSMOLOGY
Tracer of the Large Scale Structure:
Tomography, synergy with other probes, unique in redshift and scales, systematic/statistical errors
IGM
Galaxy/IGM interplay:
Metal enrichment and galactic feedback, impact on the cosmic web and metal species, UV background, IGM temperature
GALAXY FORMATION
Astroparticles and GR:
Dark matter at small scales, neutrinos, axions, coldness of dark matter, fundamental constants, cosmic expansion.
FUNDAMENTAL PHYSICS

NewIGM - The Team

Boera E.
Boutsia K.
Calderone G.
Cristiani S.
Cupani G.
D'Odorico V.
De Lucia G.
Di Gioia S.
Di Marcantonio P.
Fontanot F.

Giallongo E.
Grazian A.
Guarneri G.
Menci, N.
Milakovic D.
Molaro P.
Murphy M.
Omizzolo A.
Romano M.
Vanzella E.
Viel M.



> 15 FTE in 3 years - 10 @ INAF


espresso
What else

IGM - Absorption Lines – Why?

What were the physical conditions of the primordial Universe?

What fraction of the matter was in a diffuse medium and how early did it condense in clouds?

Where are most of the baryons at the various redshifts?

How early and in what amount have metals been produced?

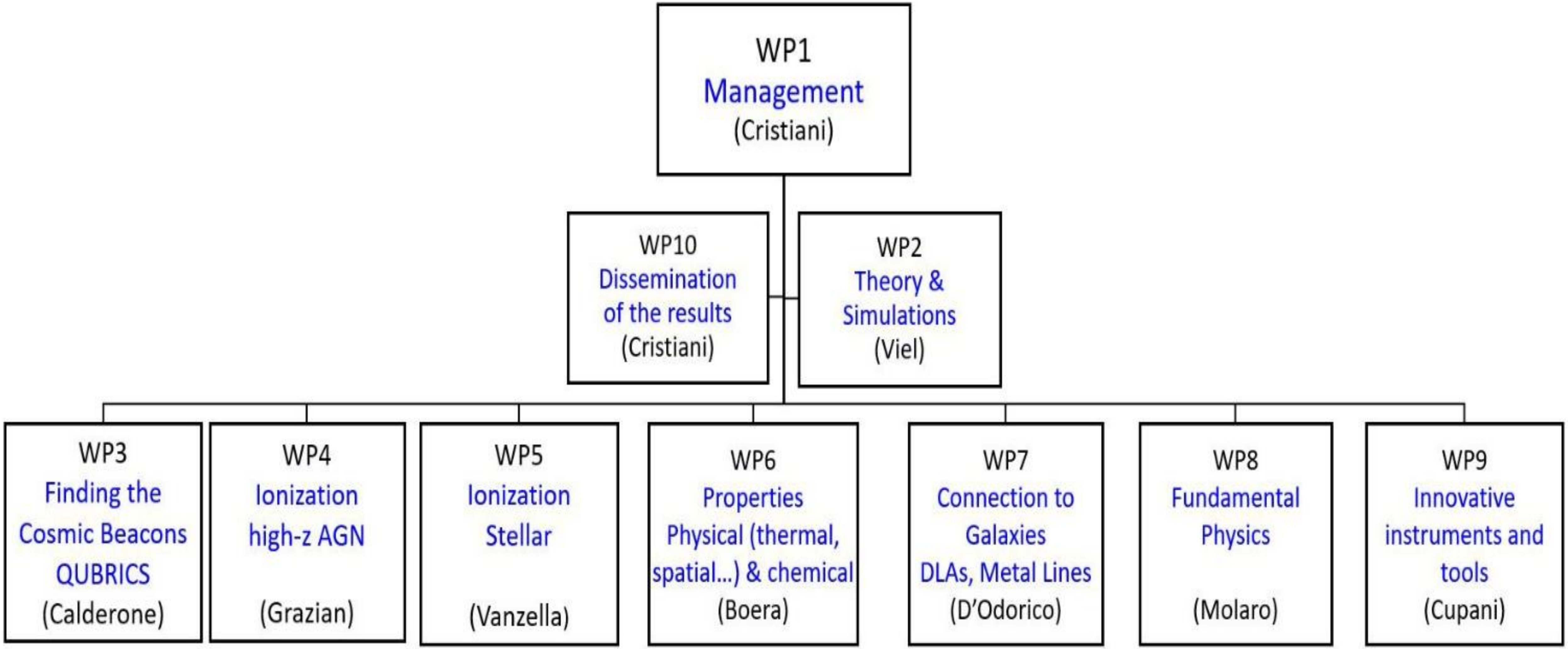
Which constraints on cosmology & types of DM (e.g. ν) are derived from the IGM LSS?

What was the typical radiation field, how homogenous, and what was producing it?

When and how, after the Dark Ages following recombination, did the Universe get reionized?

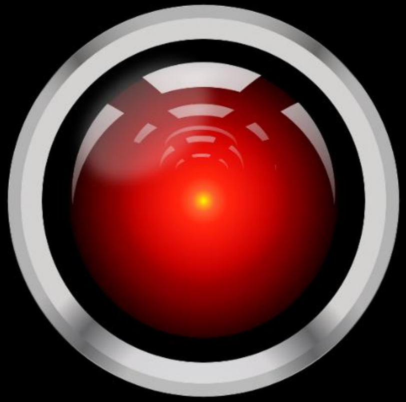
Does the SBBN correctly predict primordial element abundances and CMB T evolution?

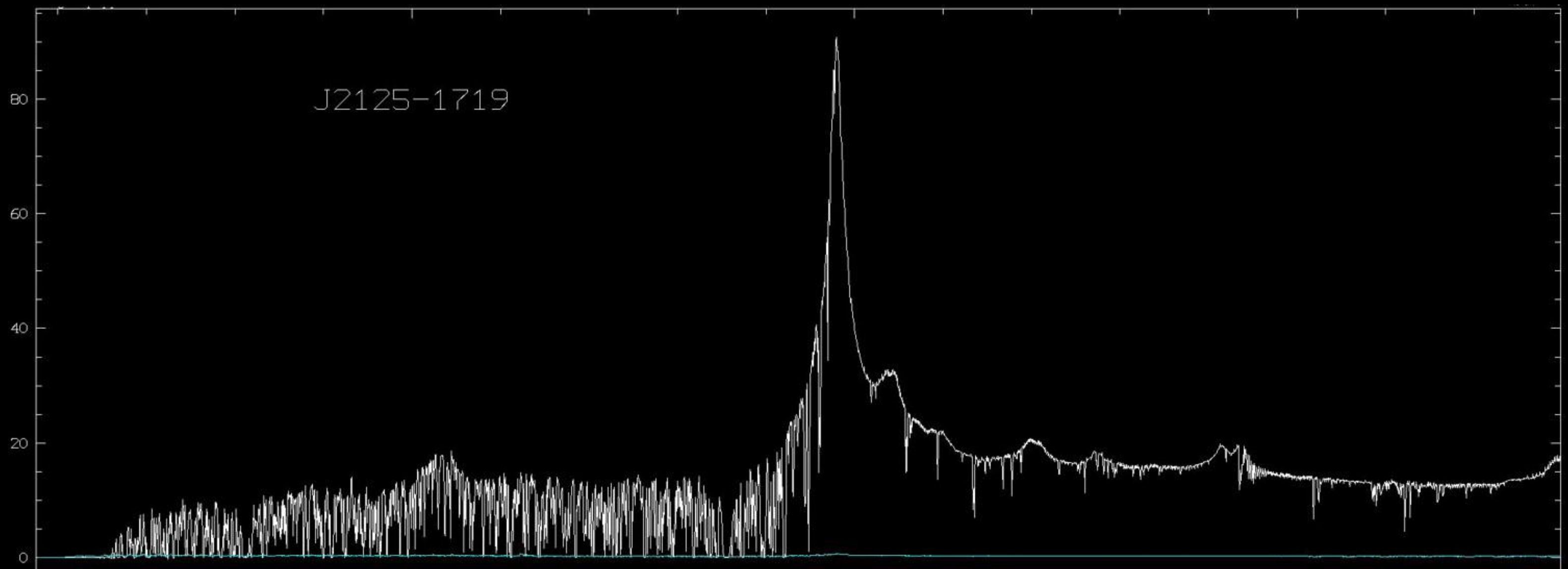
Do fundamental constants of physics (e.g. α, μ) vary with time?


WP1
Management
(Cristiani)
WP10
Dissemination of the results
(Cristiani)
WP2
Theory & Simulations
(Viel)
WP3
Finding the Cosmic Beacons QUBRICS
(Calderone)
WP4
Ionization high-z AGN
(Grazian)
WP5
Ionization Stellar
(Vanzella)
WP6
Properties Physical (thermal, spatial...) & chemical
(Boera)
WP7
Connection to Galaxies DLAs, Metal Lines
(D'Odorico)
WP8
Fundamental Physics
(Molaro)
WP9
Innovative instruments and tools
(Cupani)

QUBRICS – finding the cosmic beacons

QUasars
BRIllanti
per la
Cosmologia
nel
Sud





WP3 - Machine Learning Techs to find the needles in the haystack

Canonical Correlation Analysis (CCA):
Calderone+2019

Probabilistic Random Forest (PRF):
Guarneri+2021

eXtreme Gradient Boost (XGB, Chen T., Guestrin C., 2016; Calderone+2021)

PRF selection of QSO candidates

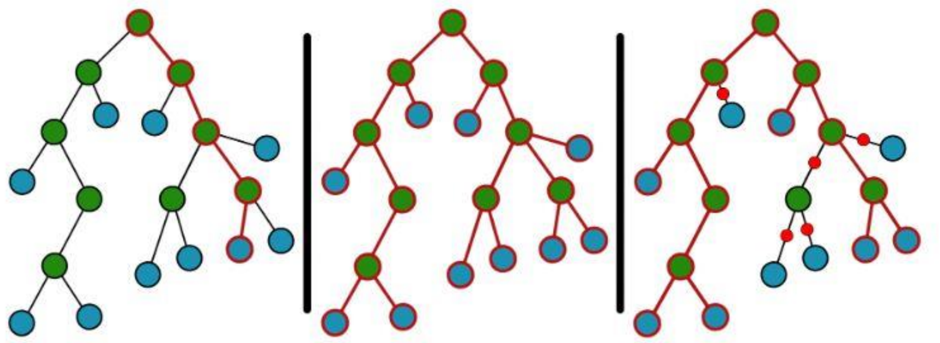
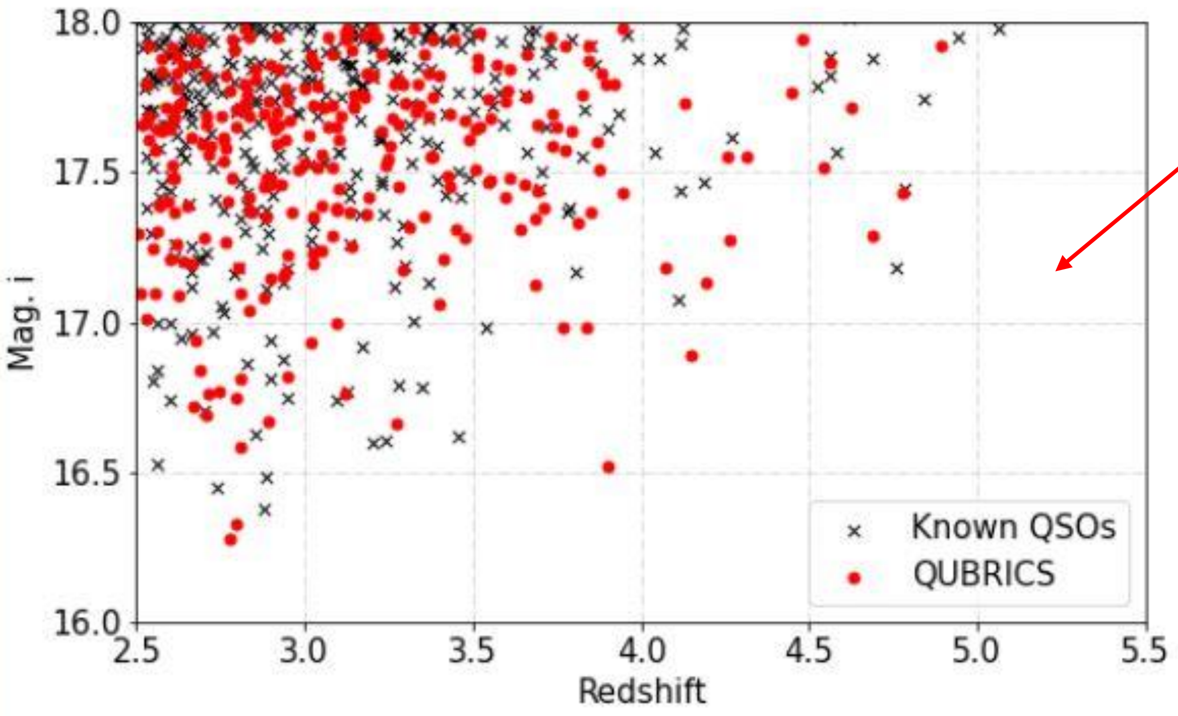


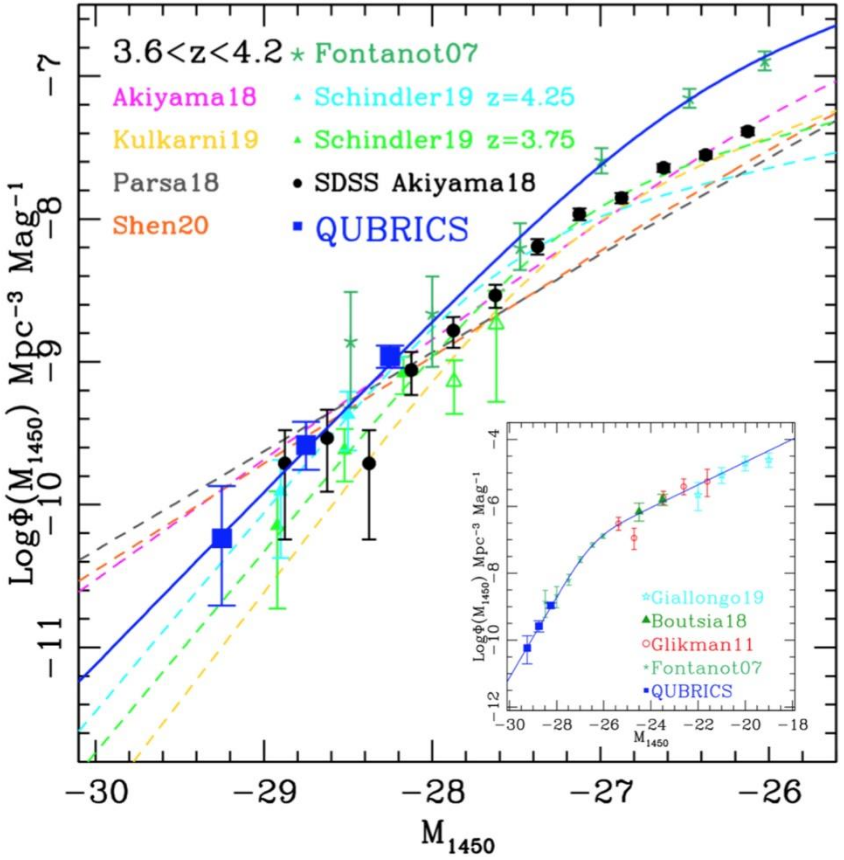
Figure 1. An object propagates through a decision tree. Terminal nodes (leaves) are light blue coloured. The path of an object along a tree is marked by red lines, black lines show all possible paths. The left panel represents the propagation in the classic RF approach: an object propagates either to the left or right node for each split. The middle panel shows an ideal PRF model: an object propagates along the whole tree, reaching all terminal nodes at the same time, and each object may reach several leaves (although with different probabilities). The right panel shows a "pruned" PRF (i.e. with a set probability threshold): red dots represent nodes which can't be reached due to low probabilities associated with those splits. Adapted from Reis et al. (2019).

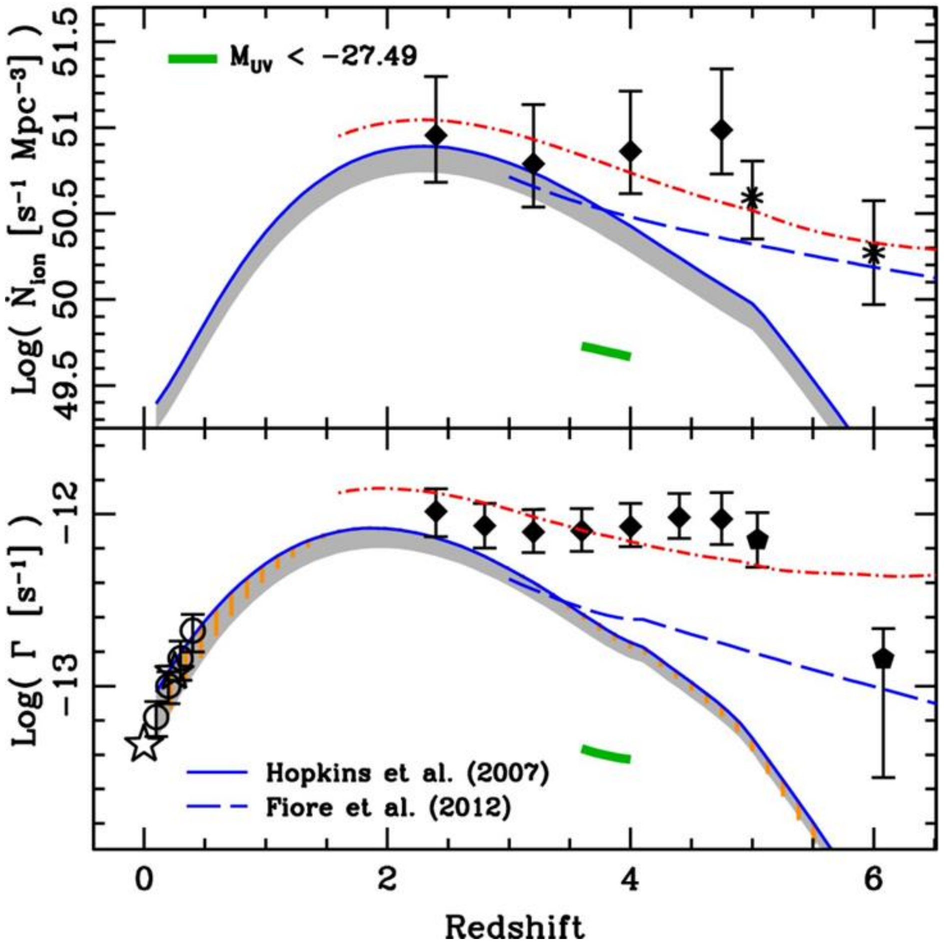


Guarneri+2021

WP4 - High-z AGN: ionization

The Luminosity Function of Bright QSOs at z~4 and Implications for the Cosmic Ionizing Background: Boutsia, Grazian+2021

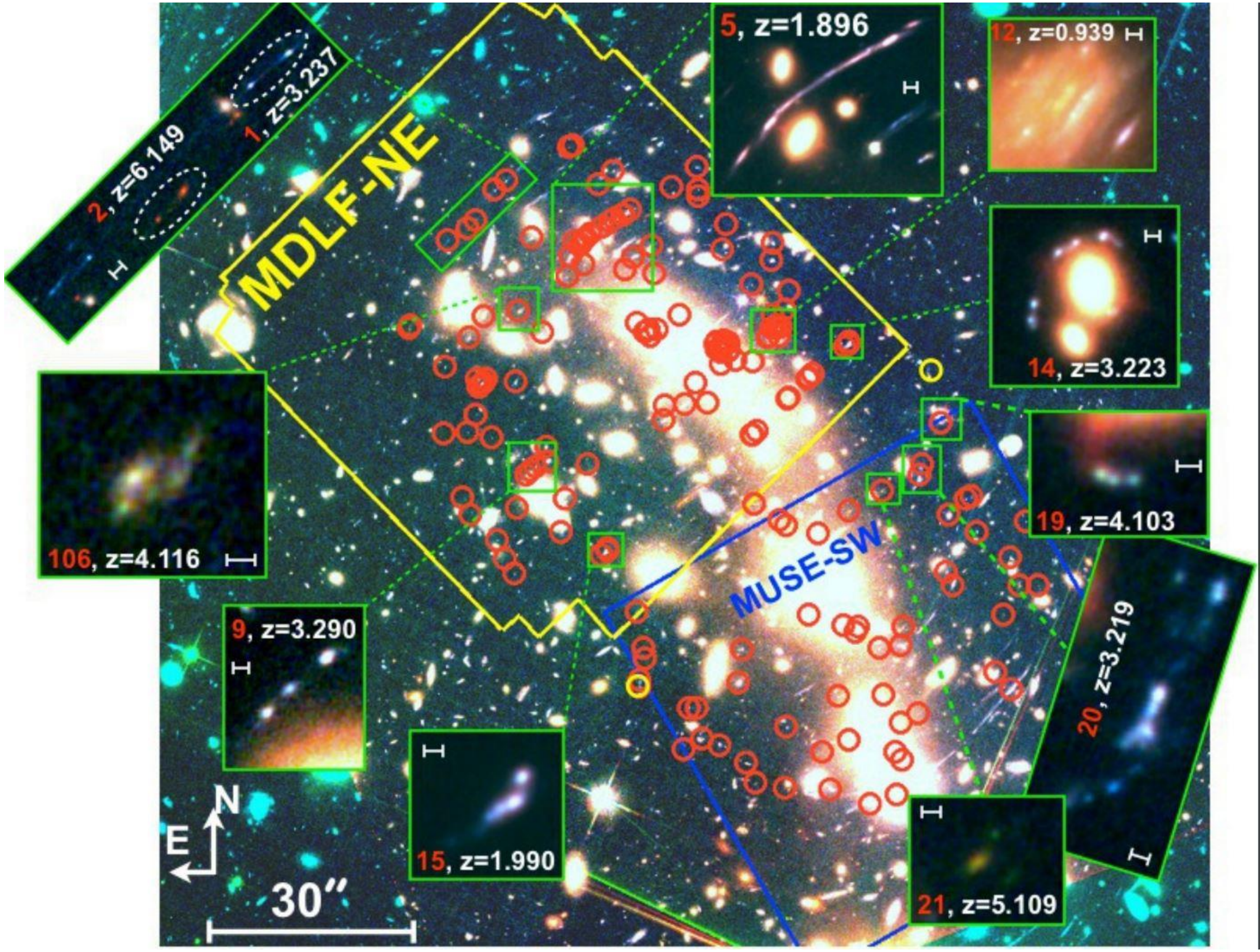




Fontanot+2014-2021

WP5 - Ionization from stellar sources

search for analogs of the z>6.5 ionizers near the peak of cosmic star formation of the Universe (z>2, e.g., Du et al., 2019 and references therein), in particular those showing bursty star formation events compatible with large specific star formation rates (>50-100 Gyr-1) and the presence of hot and massive stars. We want (1) access the faintest star-forming galaxies ever at z>2; (2) identify the internal constituents of high-z (z>2) galaxies down to star-forming complexes (100 pc) and single star clusters (< 30 pc).



Vanzella+2010-2021

(see also Zooming)

WP6 - Physical Properties of the IGM

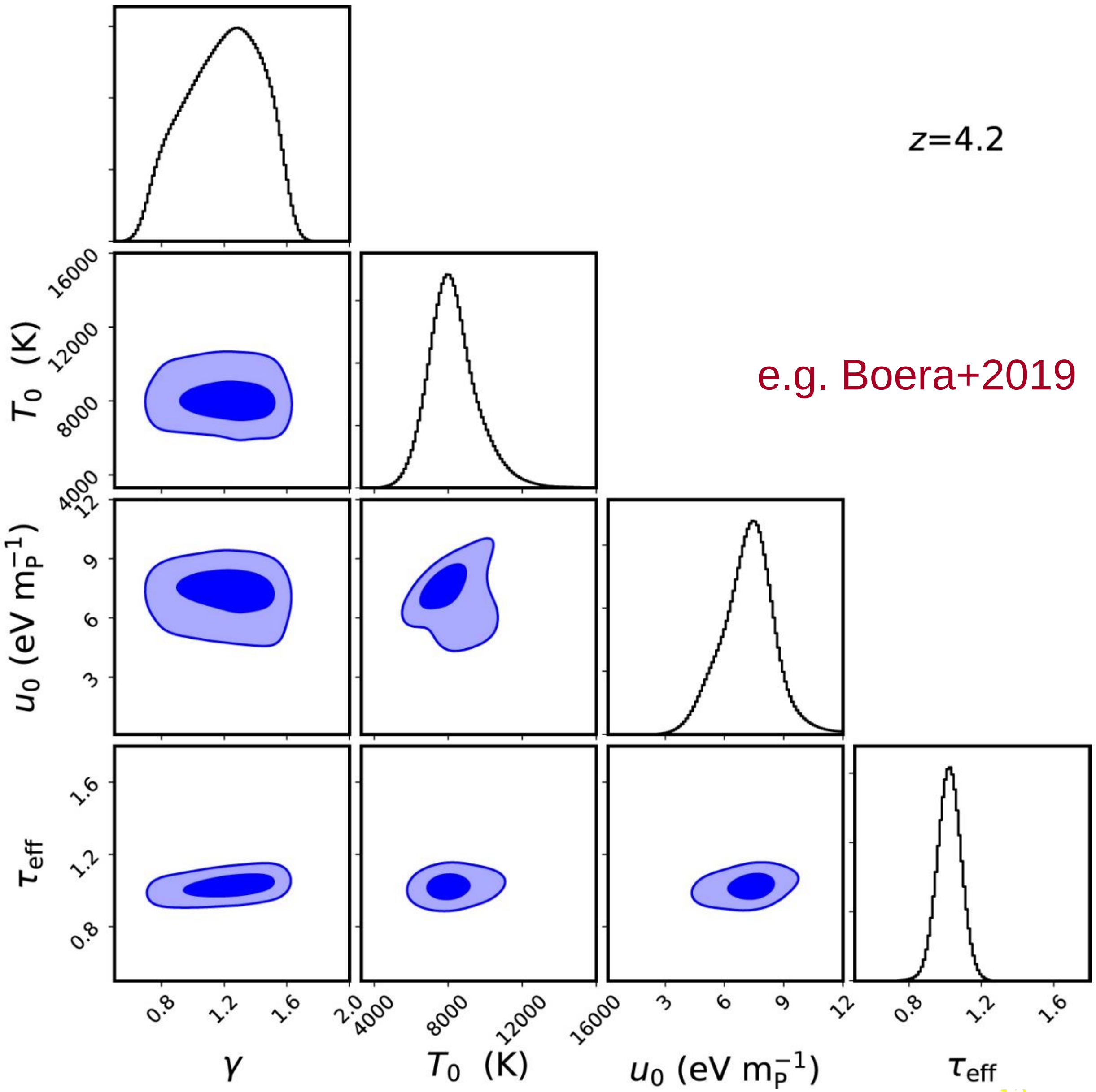
constraints, in particular the thermal state, using new data and applying new statistical methods to the analysis of the structures of the HI Lyman forest

- compare with theoretical predictions from different reionization models.
- application of current deep learning techniques for the analysis of the HI Lyman forest in QSO spectra at z>5.

Best-fitting Values and Marginalized 68% Confidence Intervals for the Fits to Our Power Spectrum Measurements

z	$T_0/10^3$ (K)	u_0(eV m_p^{-1})	γ	$\tau_{\rm eff}$
4.2	$8.13^{+1.34}_{-0.97}$	$7.29^{+0.98}_{-1.35}$	$1.21^{+0.23}_{-0.28}$	$1.02^{+0.04}_{-0.04}$
4.6	$7.31^{+1.35}_{-0.88}$	$7.10^{+0.83}_{-1.45}$	$1.29^{+0.19}_{-0.26}$	$1.41^{+0.08}_{-0.09}$
5.0	$7.37^{+1.67}_{-1.39}$	$4.57^{+1.37}_{-1.16}$	$1.33^{+0.18}_{-0.27}$	$1.69^{+0.10}_{-0.11}$

Note. The power spectrum redshift (Column (1)) is reported along with the best-fitting values of T_0 (Column (2)), u_0 (Column (3)), γ (Column (4)), and $\tau_{\rm eff}$ (Column (5)).



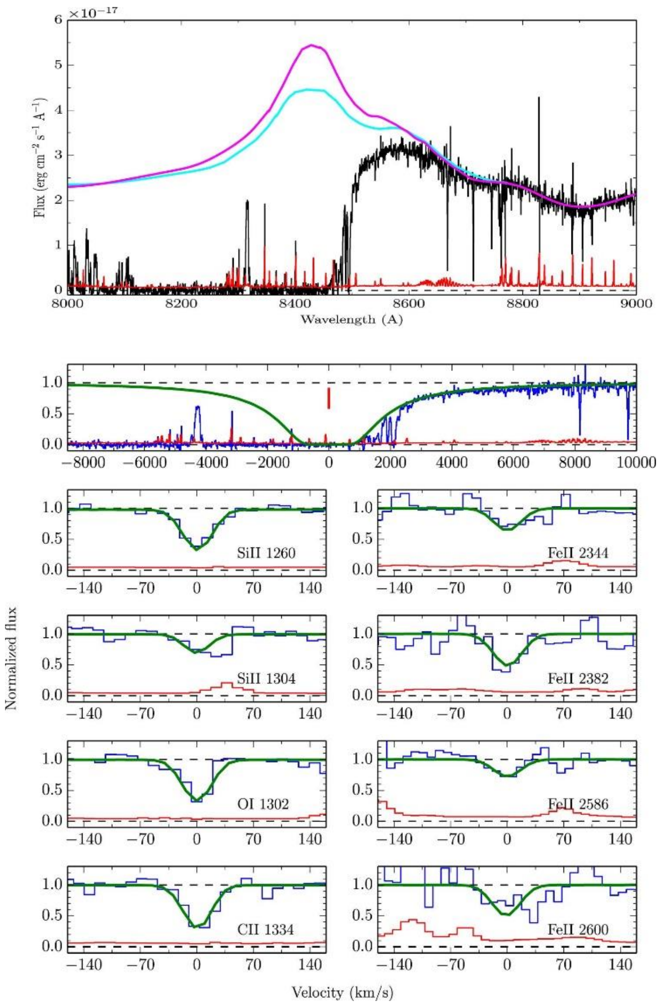
e.g. Boera+2019

WP7 - Interplay and connection with Galaxies

properties of metal absorption lines and constraints on the interaction and connection between the IGM and galaxies in the redshift range z~2-7, using intermediate- to high-res, high-SNR QSO spectra.

-highest SNR (>100), hi-res (>40,000) QSO spectra at z~2-4 to measure the metal absorption lines associated with HI Ly-α lines tracing the IGM characteristics overdensities (down to the mean density) and intermediate resolution spectra in the range z=3.5-7 (e.g. XQ-100) to derive the statistical properties of metal absorption lines (CIV,SiIV, MgII) and determine their evolution with redshift [see also XQR-30, D’Odorico et al.]

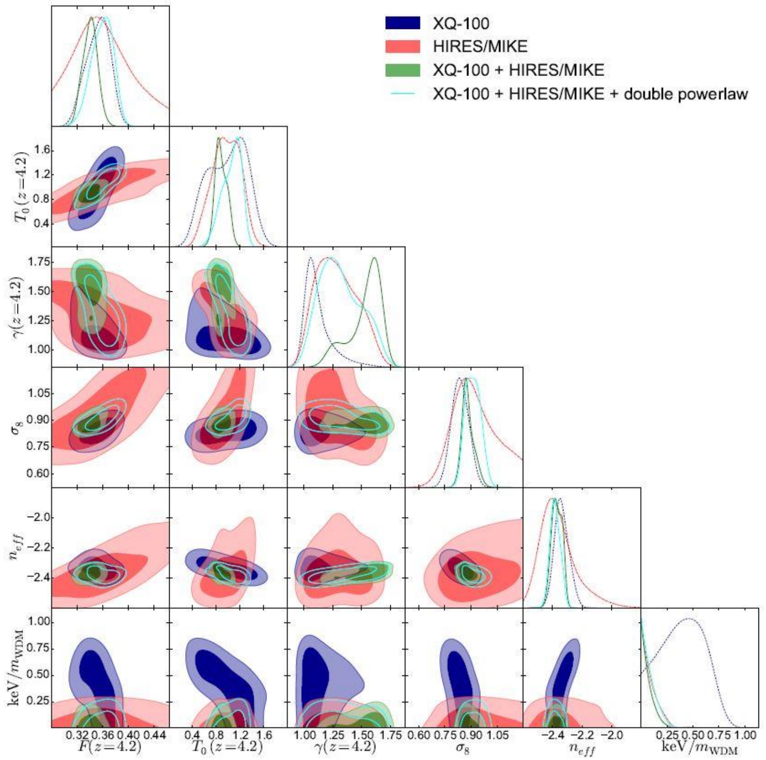
- Compare statistical properties of DLAs with theoretical models, in particular with GAEA.



e.g. D’Odorico+2018

Di Gioia+2020

WP8 – Fundamental Physics

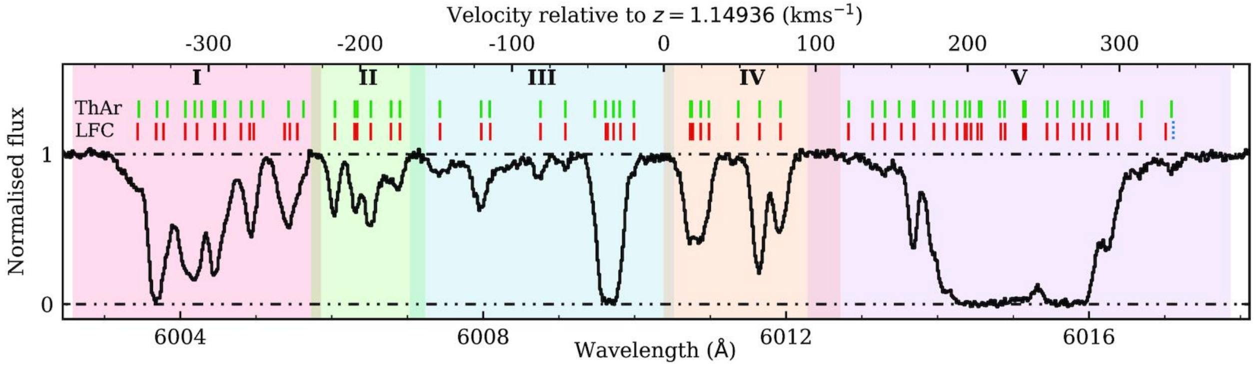


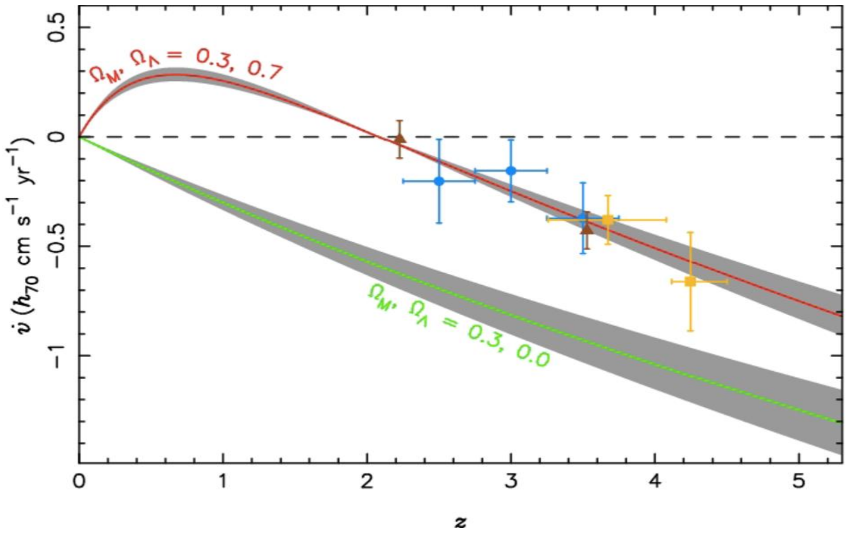
- Constraints on DM coldness and fraction of cold/warm DM over total. Constraints on more general particle physics DM models (e.g. sterile neutrinos, fuzzy DM)

- Variation of fundamental constants (α,μ)

- Abundance of primordial elements, BBN (D)

- Sandage Test [long term goal]





e.g. Iršič, Viel +2017, Milaković+2021, Molaro+ 2013

Fundamental? Constants?:

See Murphy ESO 50yrs

- *[Note: Only low-energy limits of constants discussed here]*
- *Why "fundamental"?*
  - *Cannot be calculated within Standard Model*
- *Why "constant"?*
  - *Because we don't see them changing*
  - *No theoretical reason – see above*
- *Best of physics: Relative stability of α ~< 10^{-18} yr^{-1} (Lange et al 2021)*
- *Worst of physics: Sign of incomplete theory?*

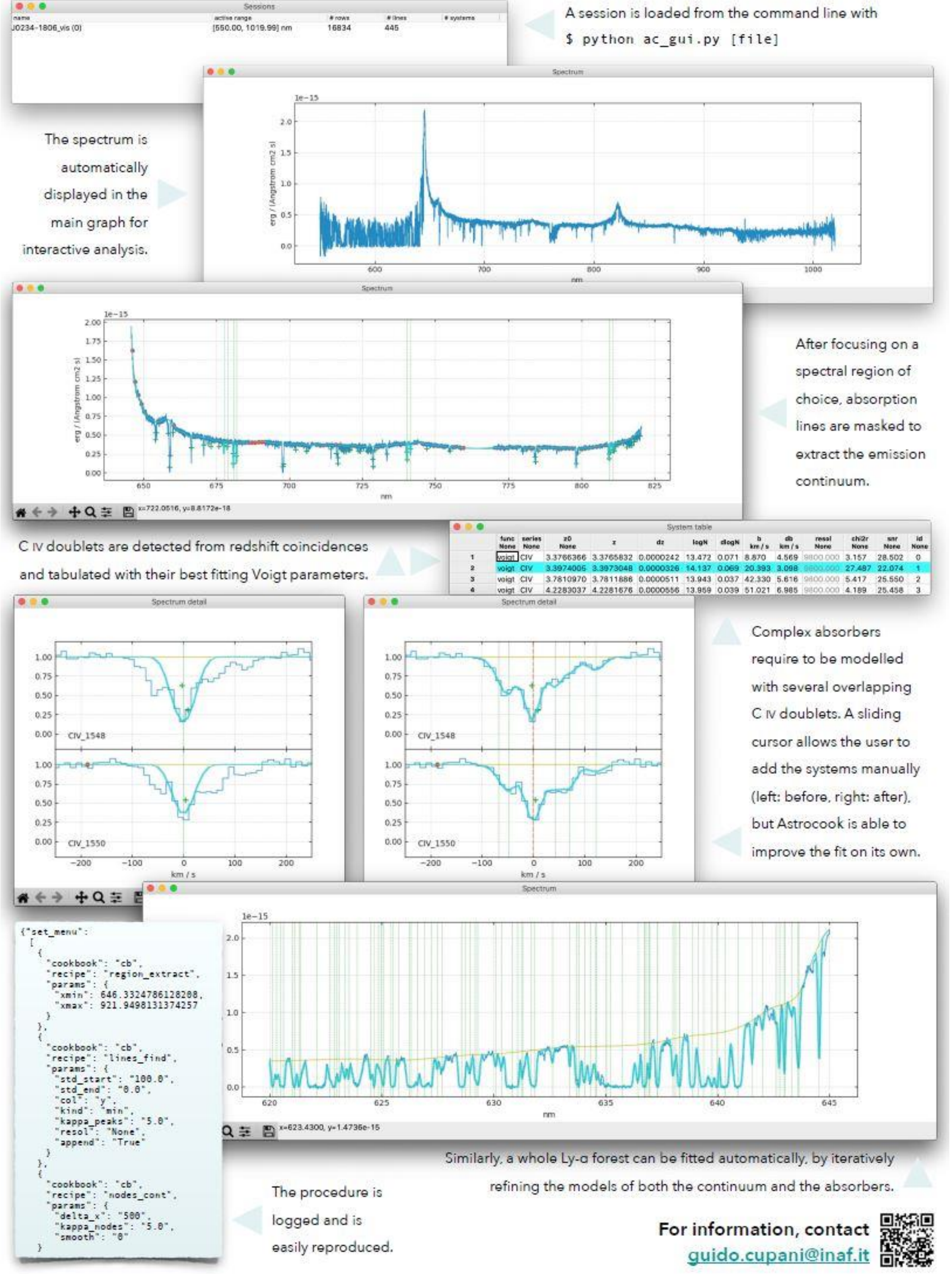
- *Constancy based on Earth-bound, human time-scale experiments*
- *Extension to Universe seems a big assumption*

WP9 – Innovative instruments and tools

- Enforce a proper treatment of the currently available data (both observational and simulated), with a focus on the repeatability of the procedures;

- Use the products of data treatment to assess the requirement of future instrumentation (in terms of efficiency, resolution, wavelength coverage, stability, etc.)

e.g. Astrocook: Cupani, D'Odorico, Cristiani, Russo, Calderone, Taffoni, 2020, SPIE

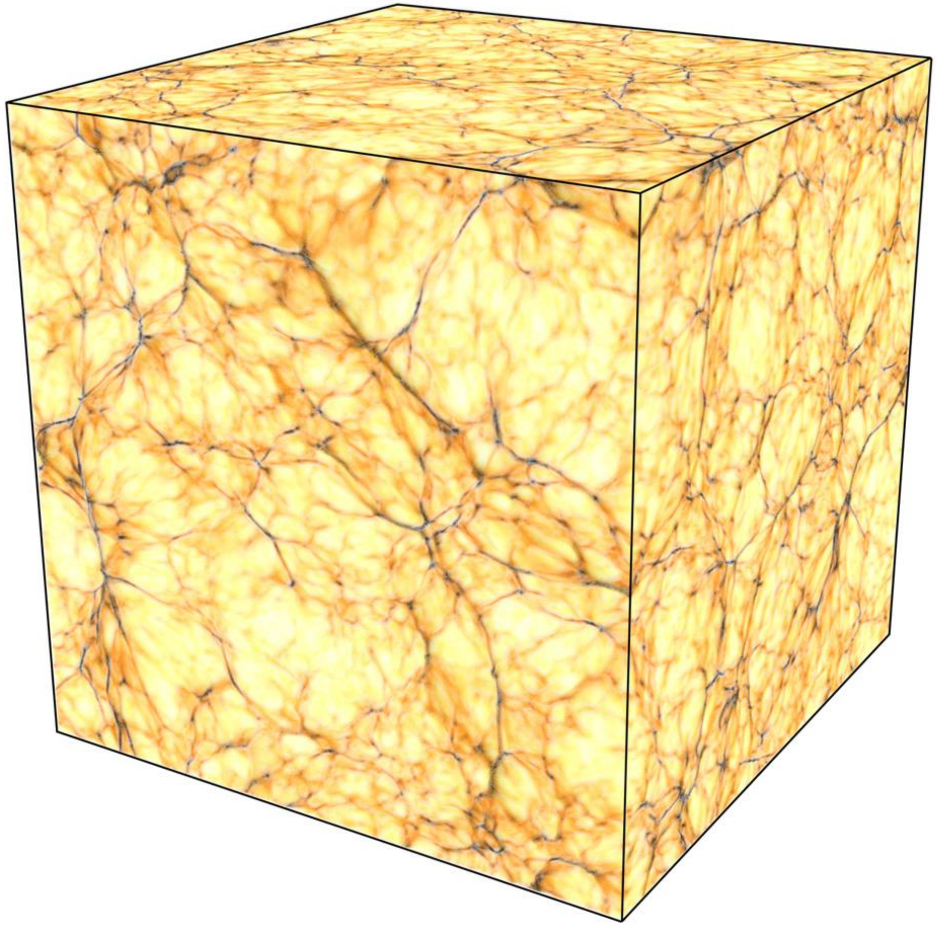


WP2-Theory and Simulations

Define a set of cosmological parameters in the standard LCDM scenarios and in alternative cosmological models: warm DM (WDM), mixed cold and warm DM models (CWDM) models with an arbitrary suppression of power at small scales able to capture different small scales departure

Specify the resolution and box sizes needed to address the scientific goals of NewIGM. Where possible use simulations developed and available to us (Sherwood, Relics simulation suite). Otherwise, the simulations will be run in dedicated supercomputing machines like the Ulysses supercomputer at SISSA.

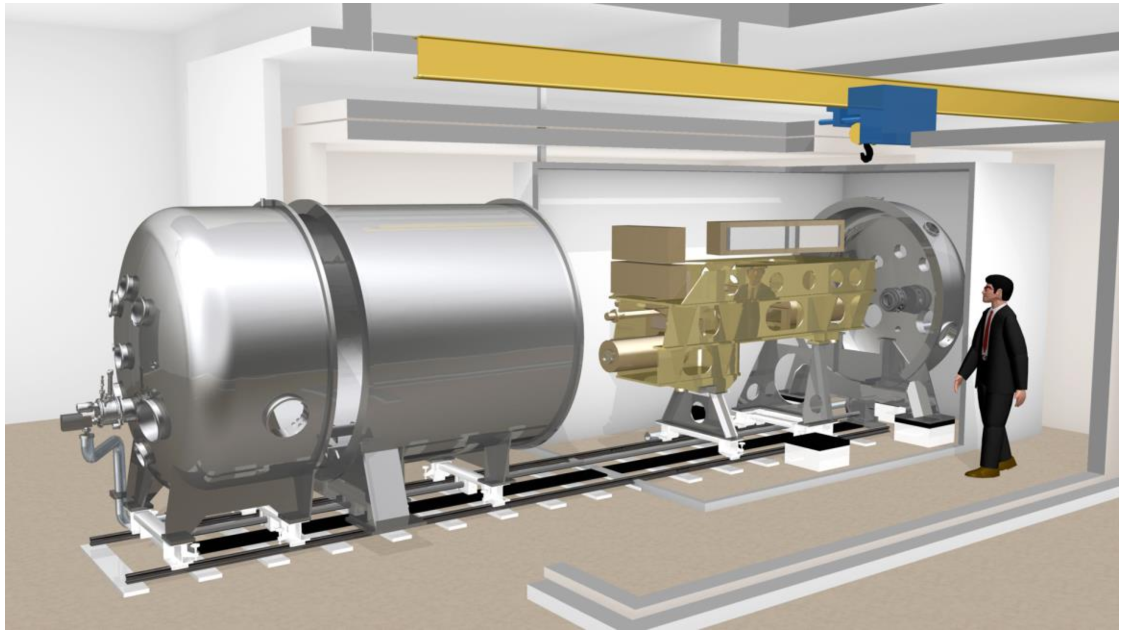
Define, both in the context of LCDM and beyond LCDM scenarios the astrophysical parameters: thermal evolution of the IGM, reionization redshift, astrophysical modelling of radiative transfer (UV/temperature fluctuations), etc.



e.g. Bolton+2017; Puchwein+2019

Viel

ESPRESSO: designed for stability



$\Delta RV = 1$ m/s

$\Delta T = 0.01$ K

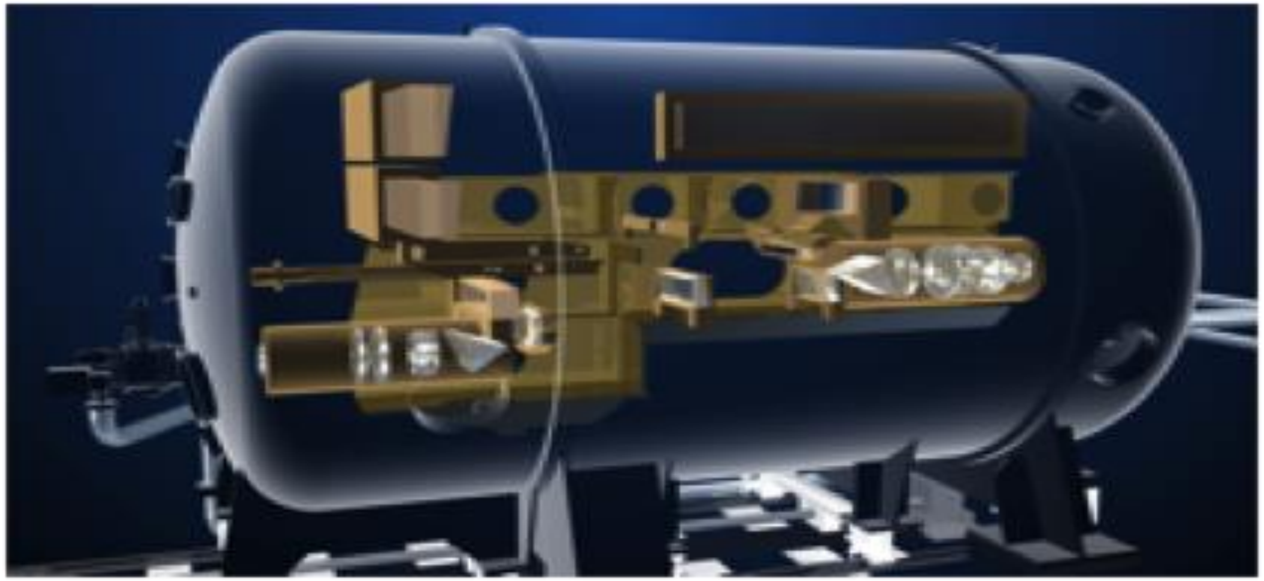
$\Delta p = 0.01$ mBar

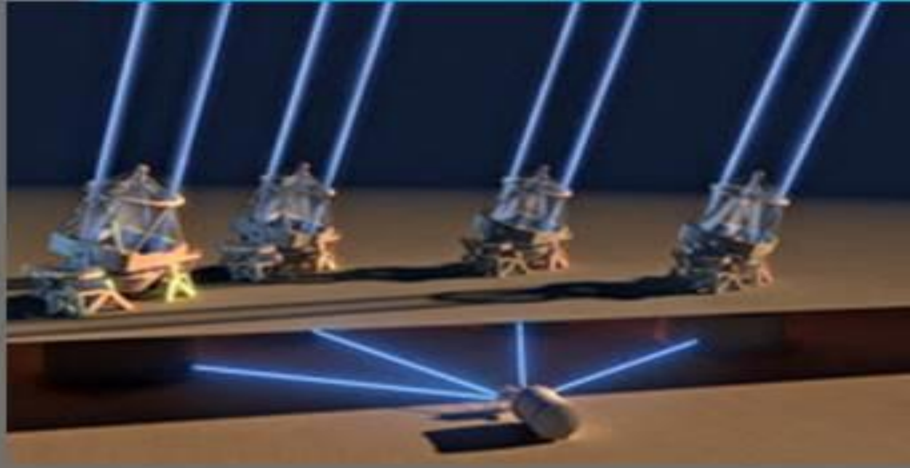
$\Delta RV = 1$ m/s

$\Delta\lambda = 0.00001$ A

15 nm

1/1000 pixel





The Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations

Francesco A. Pepe, Stefano Cristiani, Rafael Rebolo Lopez, Nuno C. Santos

Matteo Aliverti, Antonio Amorim, Gerardo Avila, Veronica Baldini, Willy Benz, Alexandre Cabral, Giorgio Calderone, Pedro Carvas, Roberto Cirami, João Coelho, Maurizio Comari, Igor Coretti, Guido Cupani, Hans Dekker, Bernard Delabre, Paolo Di Marcantonio, Valentina D'Odorico, Michel Fleury, Ramòn Garcia Lòpez, Matteo Genoni, Ian Hughes, Olaf Iwert, Florian Kerber, Marco Landoni, Jorge Lima, Jean-Louis Lizon, Gaspare Lo Curto, Christophe Lovis, Charles Maire, Antonio Manescau, Carlos Martins, Denis Mégevand, Paolo Molaro, Mario Monteiro, Manuel Monteiro, Christoph Mordasini, Giorgio Pariani, Luca Pasquini, Didier Queloz, José Luis Rasilla, Jose Manuel Rebordão, Marco Riva, Samuel Santana Tschudi, Paolo Santin, Alex Segovia, Danuta Sosnowska, Paolo Spanò, Fabio Tenegi, Stéphane Udry, Maria Rosa Zapatero Osorio, Filippo Zerbi

ESPRESSO Commissioning – Nov 2019

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

Science & Technology Facilities Council
UK Astronomy Technology Centre

ZAH ZENTRUM FÜR ASTRONOMIE

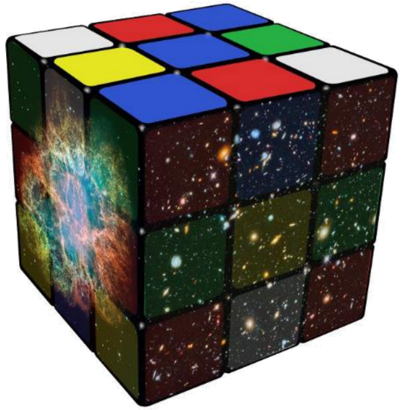
CAMK PAN

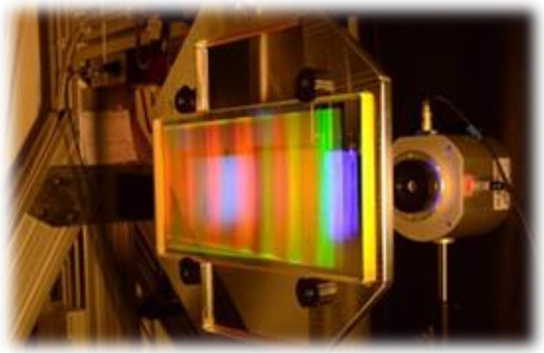
MACQUARIE University SYDNEY·AUSTRALIA

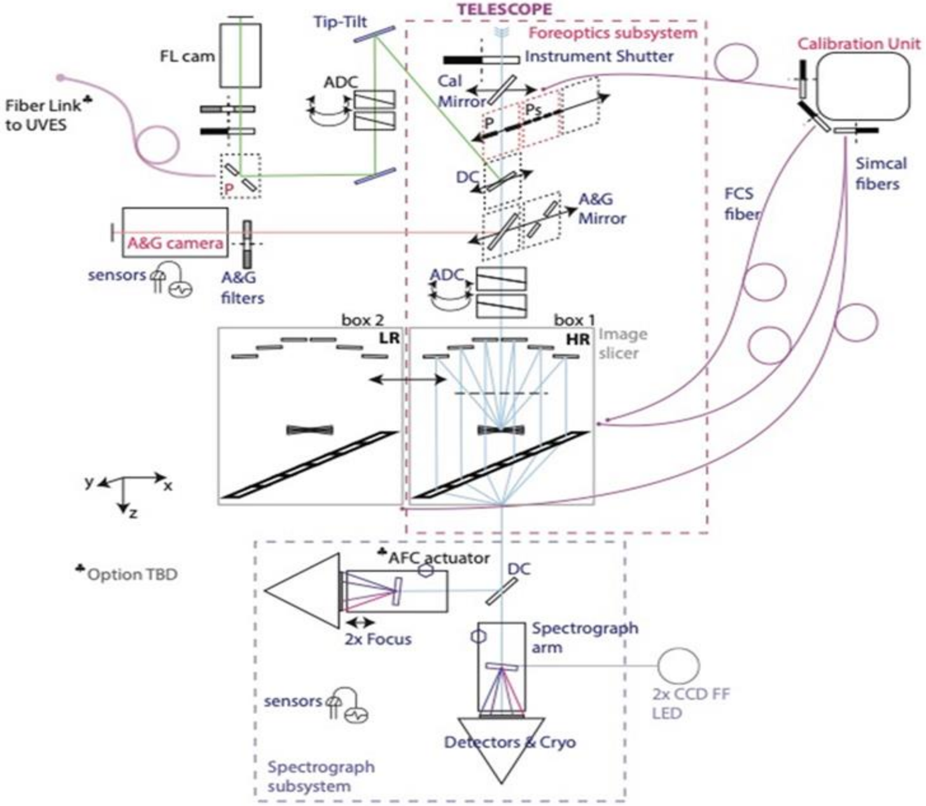
Universidade de São Paulo
Instituto de Astronomia, Geofísica e Ciências Atmosféricas

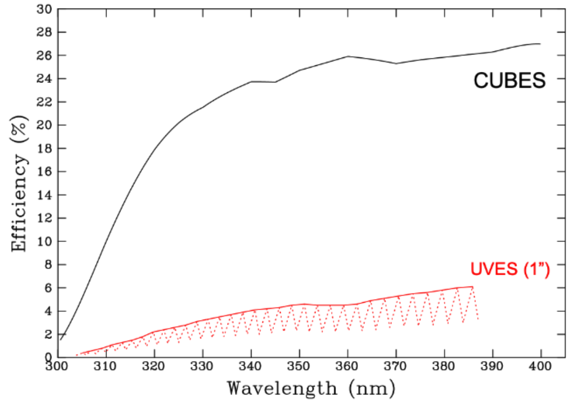
Durham University

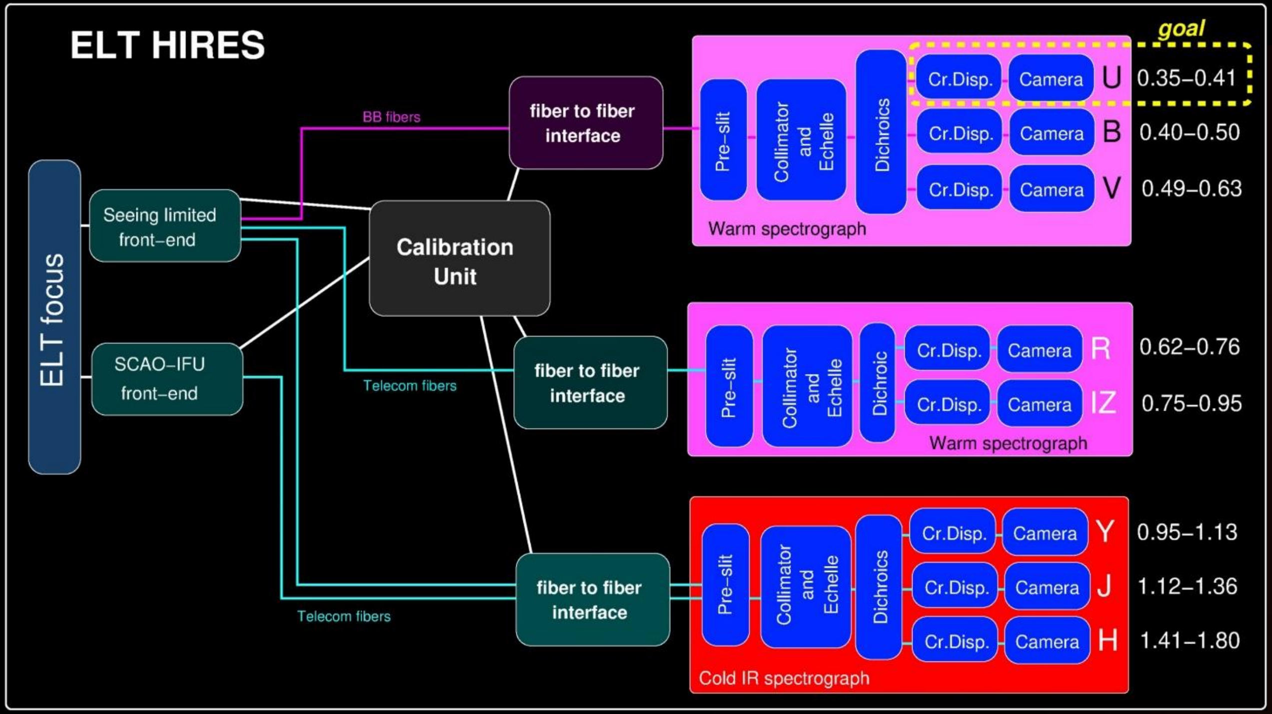
CUBES Cassegrain U-Band Efficient Spectrograph

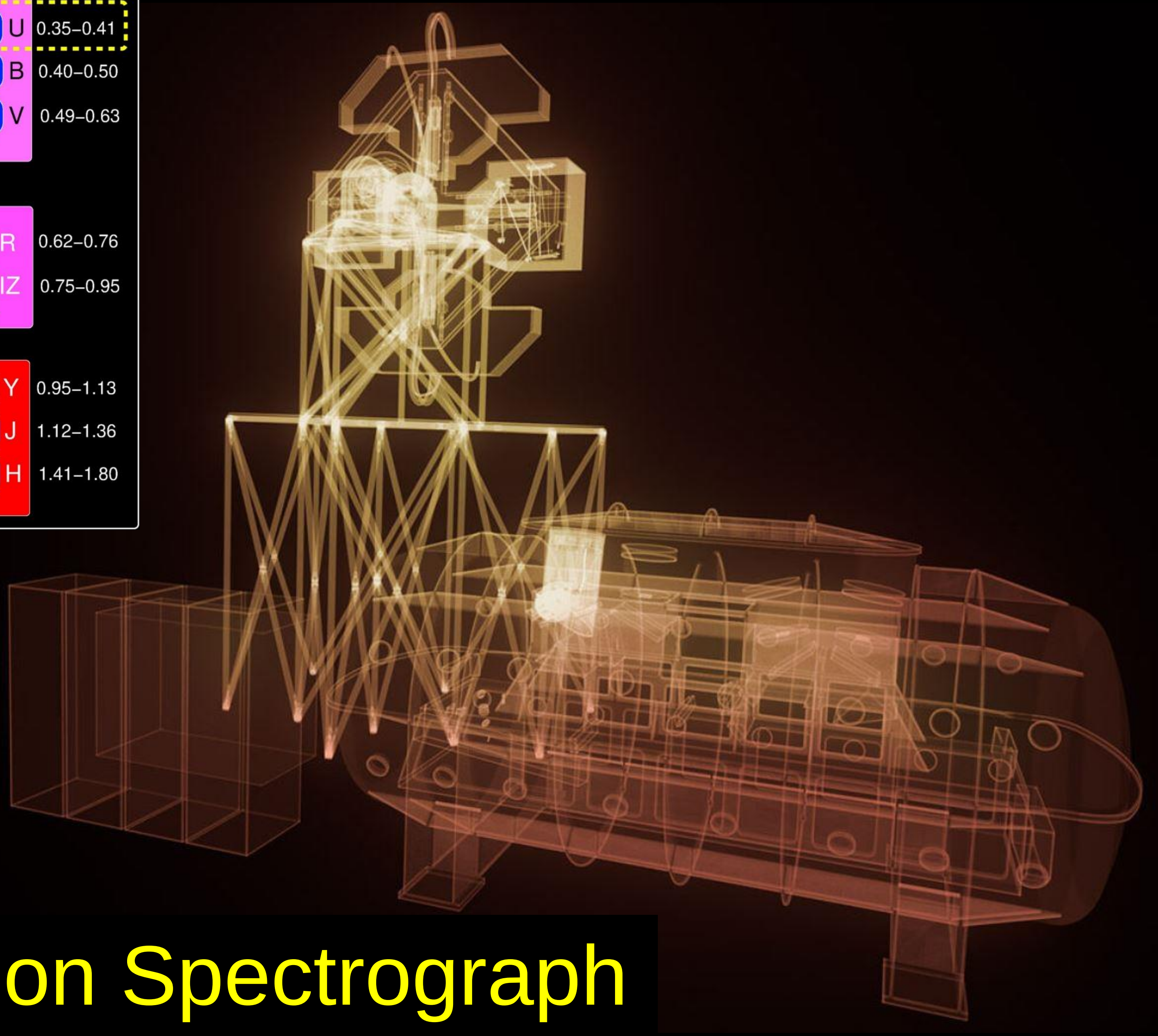












The high-resolution ELT instrument HIRES will allow astronomers to study astronomical objects that require highly sensitive observations. It will be used to search for signs of life in Earth-like exoplanets, find the first stars born in the Universe, test for possible variations of the fundamental constants of physics, and measure the acceleration of the Universe's expansion.

HIRES - HIgh REsolution Spectrograph

Papers *(~10/yr)*

1. "*Fundamental physics with ESPRESSO: Towards an accurate wavelength calibration for a precision test of the fine-structure constant*", Schmidt, T. M., Molaro, P., Murphy, M. T., et al., 2021, A&A, 646, A144
2. "*The Luminosity Function of Bright QSOs at z ~ 4 and Implications for the Cosmic Ionizing Background*", Boutsia, K., Grazian, A., Fontanot, F., et al., 2021, ApJ, 912, 111
3. "*A new era of fine structure constant measurements at high redshift*", Milaković, D., Lee, C.-C., Carswell, R. F., et al., 2021, MNRAS, 500, 1
4. "*ESPRESSO at VLT. On-sky performance and first results*", Pepe, F., Cristiani, S., Rebolo, R., et al., 2021, A&A, 645, A96
5. "*Probing the circumstellar medium 2.8 Gyr after the big bang: detection of Bowen fluorescence in the Sunburst arc*", Vanzella, E., Meneghetti, M., Pastorello, A., et al., 2020, MNRAS, 499, L67
6. "*The Spectroscopic Follow-up of the QUBRICS Bright Quasar Survey*", Boutsia, K., Grazian, A., Calderone, G., et al., 2020, ApJS, 250, 26
7. "*Damped Ly α absorbers and atomic hydrogen in galaxies: the view of the GAEA model*", Di Gioia, S., Cristiani, S., De Lucia, G., et al., 2020, MNRAS, 497, 2469
8. "*On the AGN Nature of Two UV-bright Sources at z_spec~5.5 in the CANDELS Fields: An Update on the AGN Space Density at M(1450) ~ -22.5*", Grazian, A., Giallongo, E., Fiore, F., et al., 2020, ApJ, 897, 94
9. "*Ionizing the intergalactic medium by star clusters: the first empirical evidence*", Vanzella, E., Caminha, G. B., Calura, F., et al., 2020, MNRAS, 491, 1093
10. "*Sub-damped Lyman α systems in the XQ-100 survey - II. Chemical evolution at 2.4 ≤ z ≤ 4.3*", Berg, T. A. M., Fumagalli, M., D'Odorico, V., et al., 2021, MNRAS, 502, 4009
11. …

Criticalities

1. Difficult to attract (and keep!) researchers from abroad (CS#7: 28/4-13/5 2021) – The ERC example
2. Career of (not anymore so [sic]) young people
3. Bureaucracy in the procurement of HW/SW and contracts of people, especially from abroad (see 1) [MePa, CVP, causing delays and increase in costs 😱]
4. Rolling grants? (CS#7: 28/4-13/5 2021)