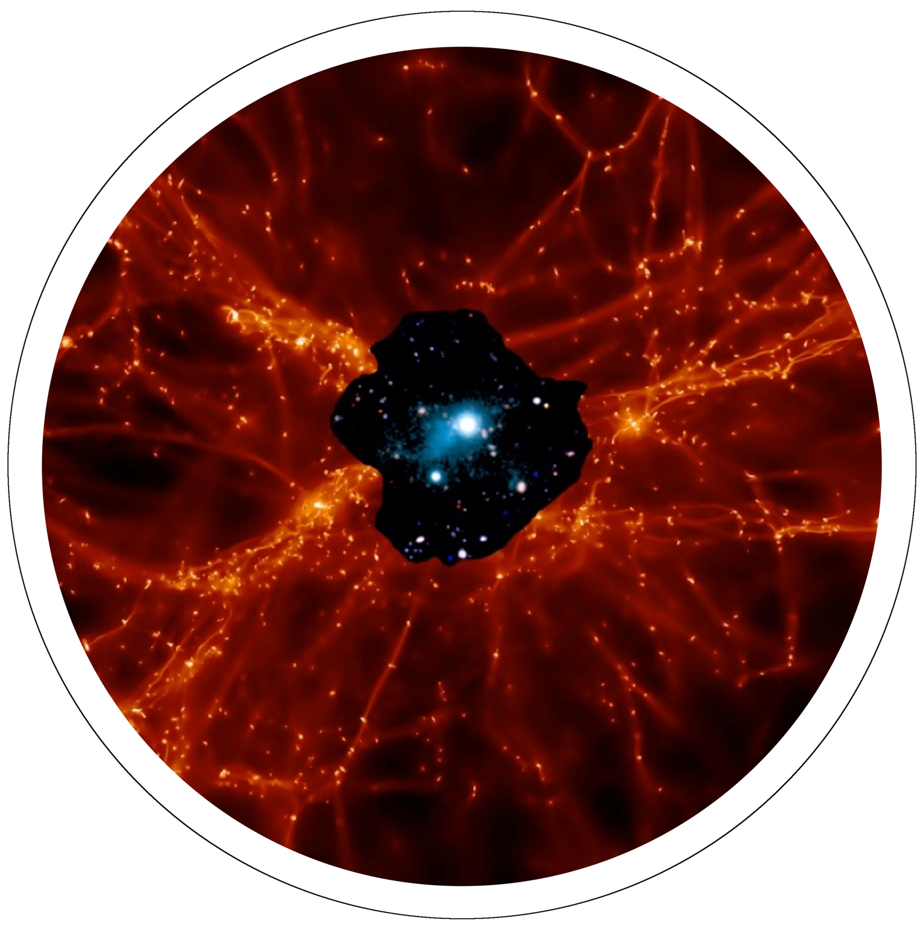
ETH zürich
Department of Physics
Institute for Particle Physics and Astrophysics

“Cosmic Structurer Formation Group”

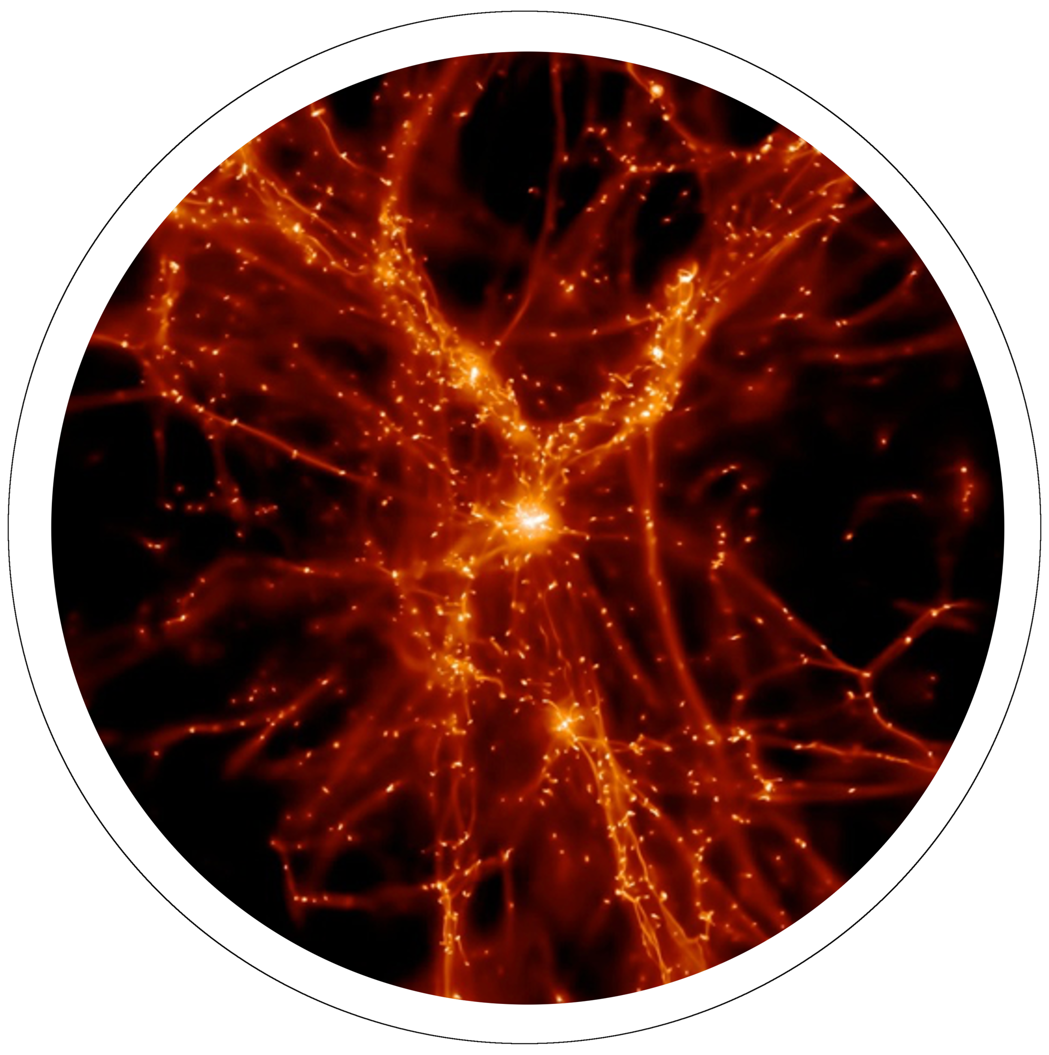
Supervisor: Prof. Dr. Sebastiano Cantalupo

The Bright Universe - Light dominated (Observation)



Illuminating the Dark Universe with Fluorescent Lyα Emission

The Dark Universe - Mass dominated (Simulation)



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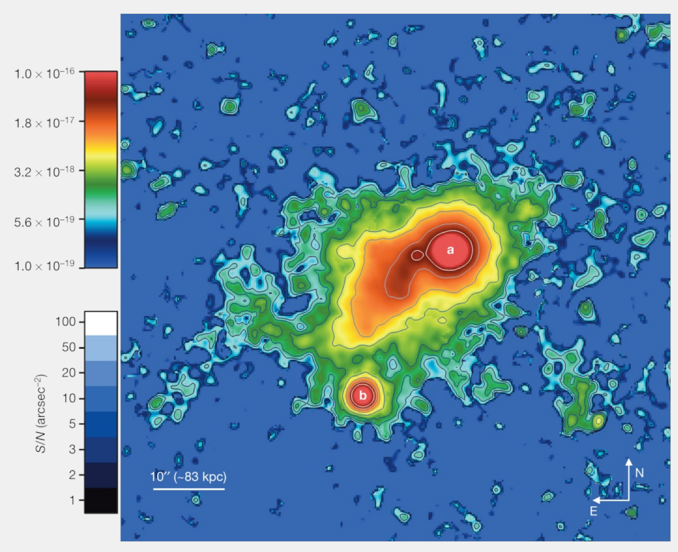
What sets the frequency, size and luminosity of giant quasar Nebulae

A cosmic web filament revealed in Lyman- emission around a luminous high-redshift quasar

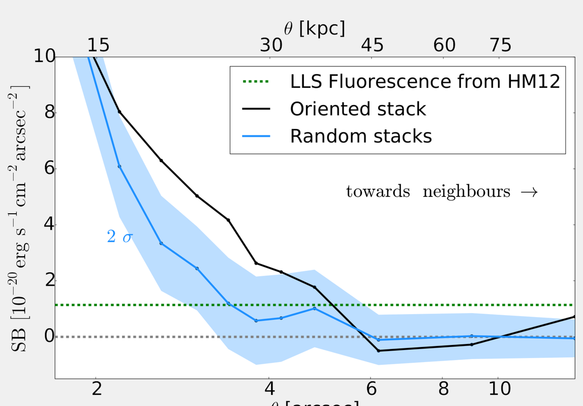


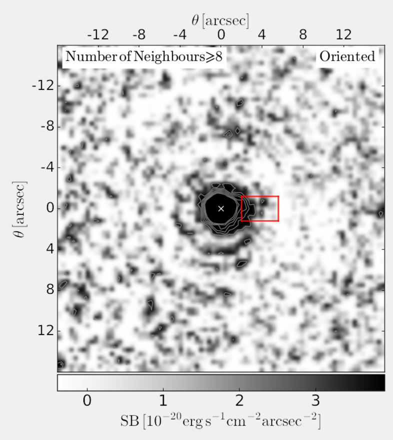
Simulations of structure formation in the Universe predict that galaxies are embedded in a 'cosmic web'1, where most baryons reside as rarefied and highly ionized gas2. This material has been studied for decades in absorption against background sources3, but the sparseness of these inherently one-dimensional probes preclude direct constraints on the three-dimensional morphology of the underlying web. Here we report observations of a cosmic web filament in Lyman- emission, discovered during a survey for cosmic gas fluorescently illuminated by bright quasars4, 5 at redshift z≈2.3. With a linear projected size of approximately 460 physical kiloparsecs, the Lyman- emission surrounding the radio-quiet quasar UM287 extends well beyond the virial radius of any plausible associated dark-matter halo and therefore traces intergalactic gas. The estimated cold gas mass of the filament from the observed emission—about 1012.0±0.5/C1/2 solar masses, where C is the gas clumping factor—is more than ten times larger than what is typically found in cosmological simulations5, 6, suggesting that a population of intergalactic gas clumps with subkiloparsec sizes may be missing in current numerical models.

[Cantalupo, Sebastiano et al. 2017, 2014Natur.506...63C]

Stacking the Cosmic Web in Fluorescent Lyman alpha Emission

Most of the matter in the Universe seems to be distributed along filaments connecting galaxies. Fluorescently illuminated by the light of first stars and quasars, their expected surface brightness (SB) in Lyalpha is beyond current observational limits. By using the deepest MUSE/VLT data available, we perform a stacking analysis around Lyalpha emitting galaxies (LAEs) between 3<z<4, with orientations determined by neighbouring galaxies, reaching a SB sensitivity level bellow the predicted signal. No detectable emission is found on intergalactic scales implying most of our selected regions do not contain filaments given our adopted model. On the other hand, significant emission is found on the circum-galactic medium in the direction of the neighbours, suggesting typically larger gas densities on those directions. The signal is increased around galaxies with a larger number of neighbours but seems independent of any other galaxy properties such as redshift, neighbour distance and luminosity.

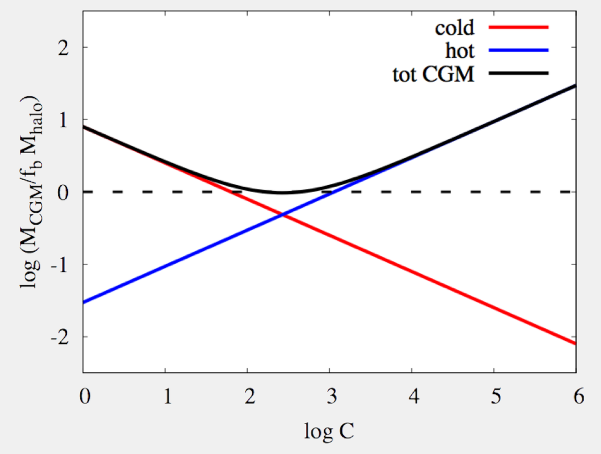




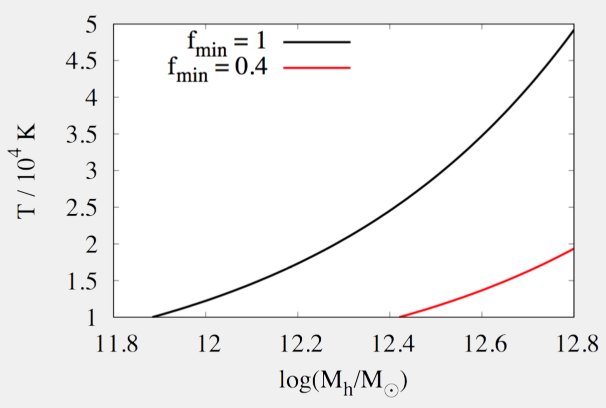
[Gallego, Sofia G. et al. 2017, arXiv:1706.03785]

Constraining feedback models due to the number of baryons in the circumgalactic medium (CGM)

Mass of the CGM in our model of the MUSE Giant Lyα nebulae (in units of the maximum baryon mass $(\Omega_b/\Omega_m)M_h$, marked as a horizontal dashed line), as a function of the clumping factor of the cold gas, assuming fiducial values for halo mass and cold gas temperature of $M_h = 10^{12.3} M_\odot$ and $T = 2 \times 10^4 K$. The red, blue and black lines are for the cold, hot and total gas, respectively. Viable models require a clumping factor $C \approx 300$ and a total baryon fraction very close to the cosmological value.



Minimum total CGM baryon fraction (corresponding to equipartition of the the CGM into the cold and hot phases), as a function of the two model parameters: halo mass and temperature of the cold gas. Low halo masses and high temperatures are inconsistent with cosmology for exceeding the universal baryon fraction. Only the highest halo masses and the lowest gas temperatures are consistent with $f_{CGM} \leq 0.4$, as expected for models with strong ejective feedback at high z.



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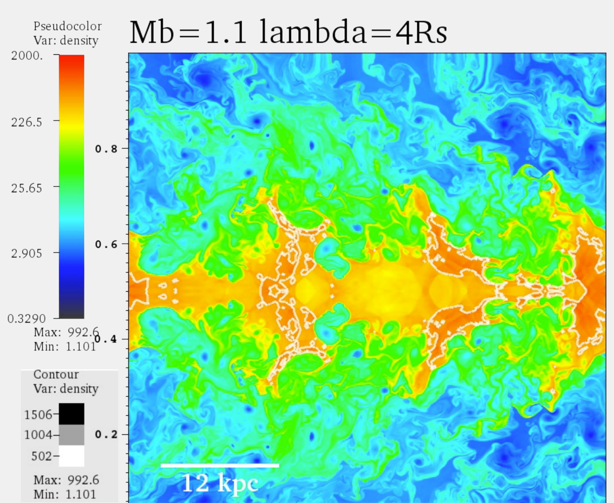
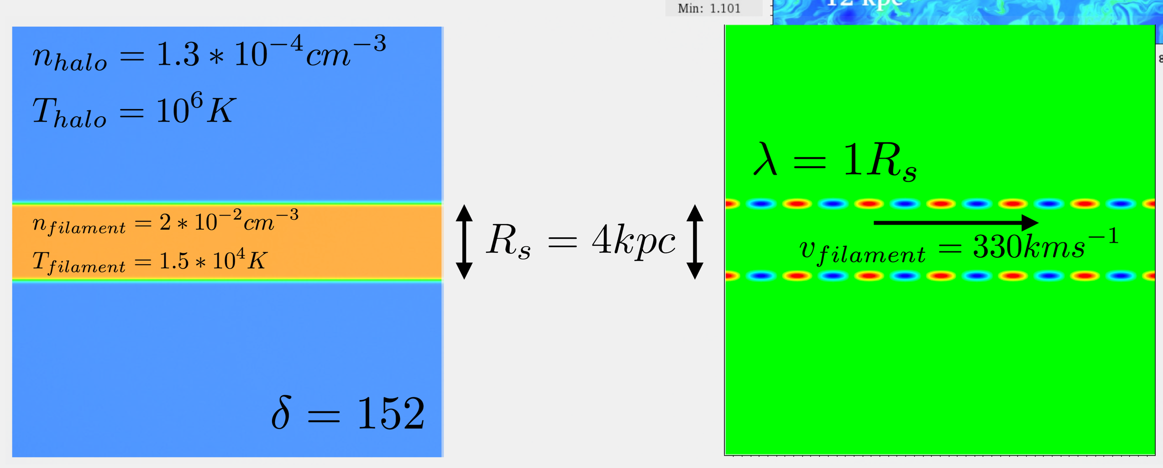
What is the origin of the IGM/CGM clumps?

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum.





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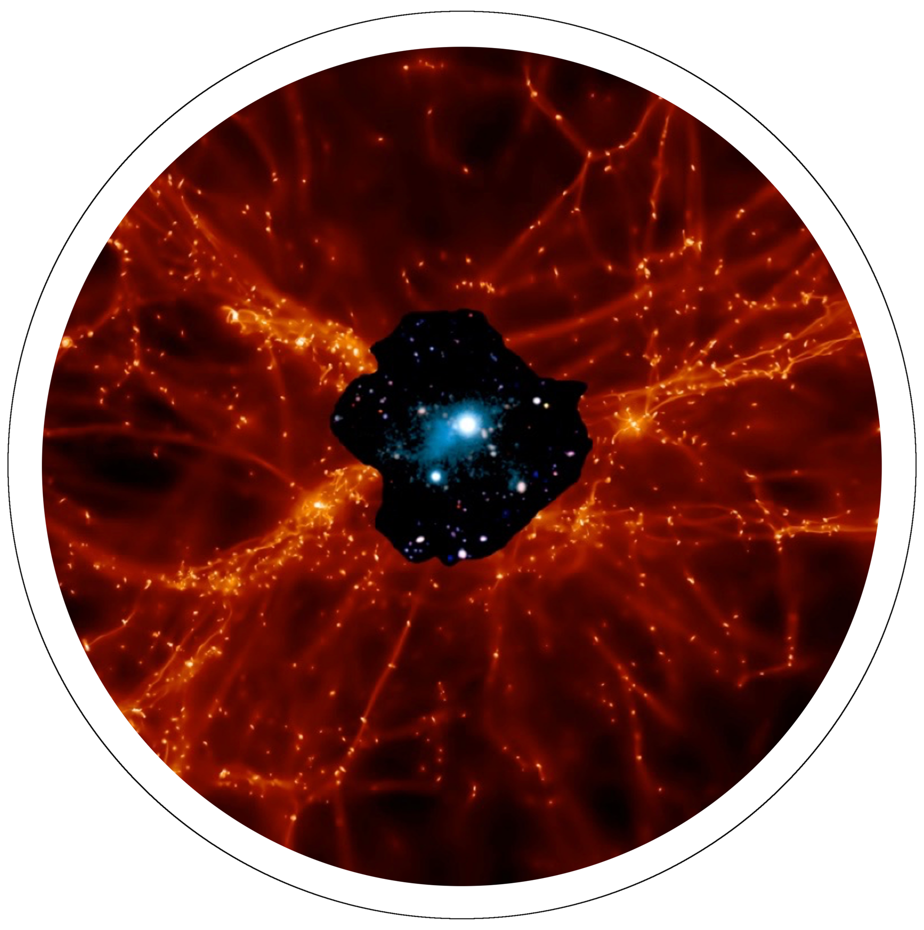

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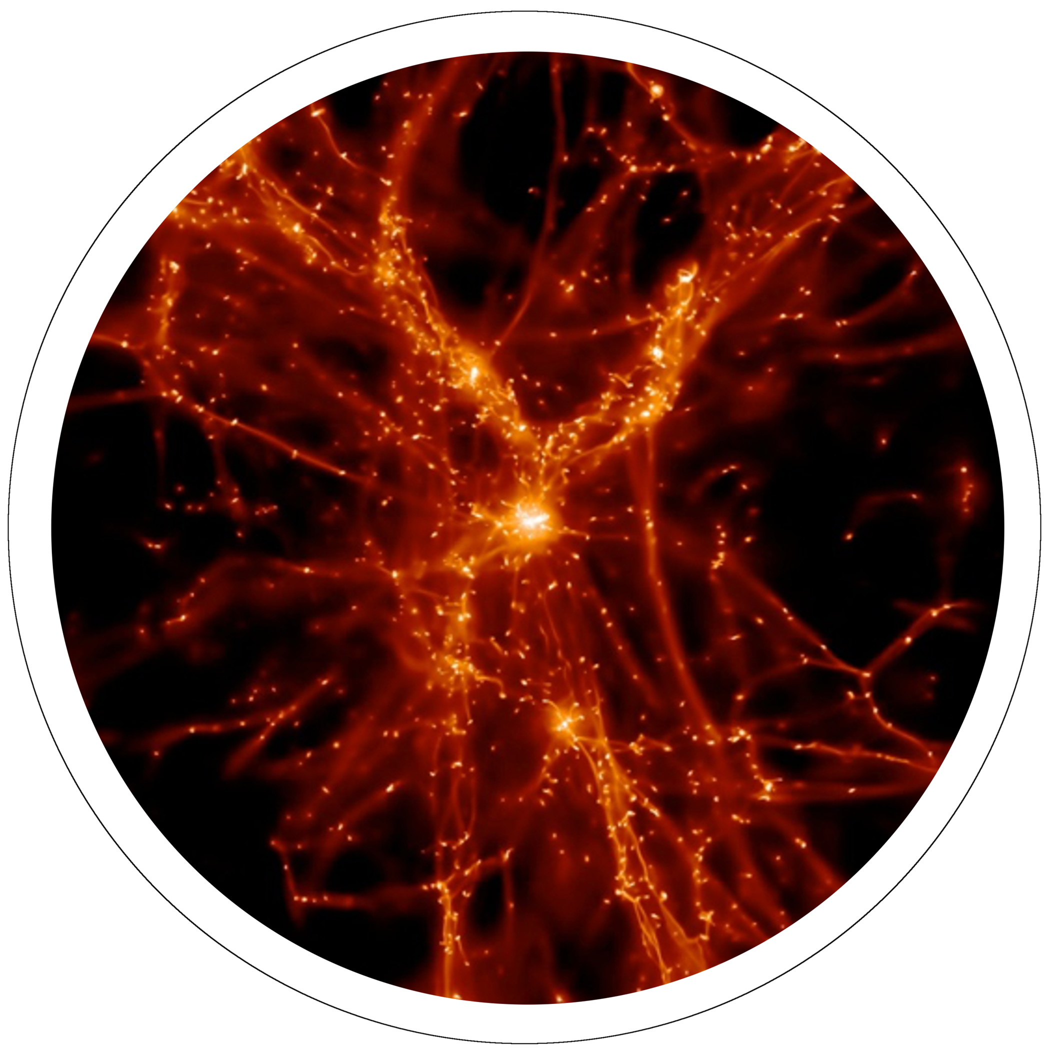

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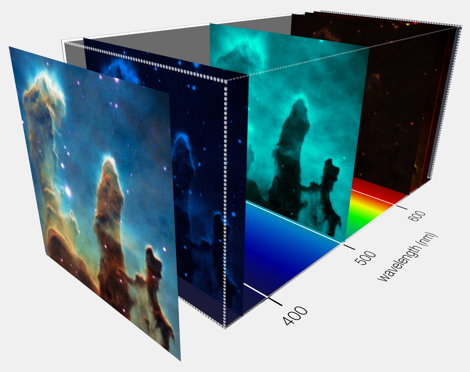
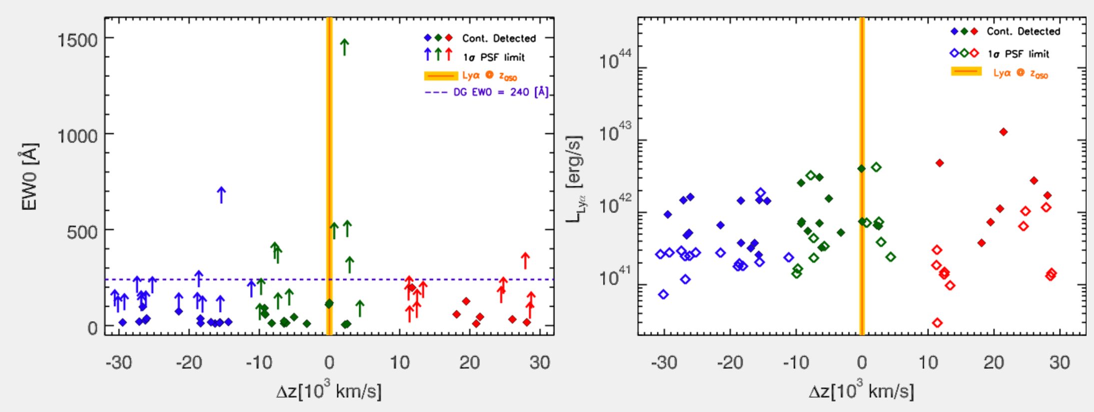
Multi-Unit Spectroscopy Explorer (MUSE)

The Multi Unit Spectroscopic Explorer (MUSE) is a second generation instrument installed on the Nasmyth focus of UT4 at the Very Large Telescope (VLT) of the European Southern Observatory (ESO). MUSE is a powerful spectrograph fed by a new adaptive optics system. it is uniquely well suited to the study of faint galaxies in the early Universe as well as to objects in our own solar system.



Dark Galaxy Candidates at Redshift 3.5 Detected with MUSE

Recent theoretical models suggest that the early phase of galaxy formation involves an epoch when galaxies are gas-rich but inefficient at forming stars: a "dark galaxy" phase. We perform an integral field survey for dark galaxies fluorescently illuminated by quasars at z>3 with MUSE, which provides us a nearly uniform sensitvity coverage over a large volume in redshift space, compared to previous narrow-band imaging surveys. By comparing the rest-frame equivalent width (EW_0) distributions of the Lyalpha sources detected in proximity to the quasars and in control samples, we detect a clear correlation between the locations of high EW_0 objects and the quasars, not seen in other properties such as Lyalpha luminosities or volume overdensities, suggesting the possible fluorescent nature of at least some of these objects. Among these, we found 6 dark galaxy candidates with EW_0 limits larger than 240 Angstrom with similar properties to previously detected candidates at z 2.4. Our results also provide a lower limit of 60 Myr on the quasar lifetime.



[Marino, Raffaella Anna et al. 2017, arXiv:1709.03522]

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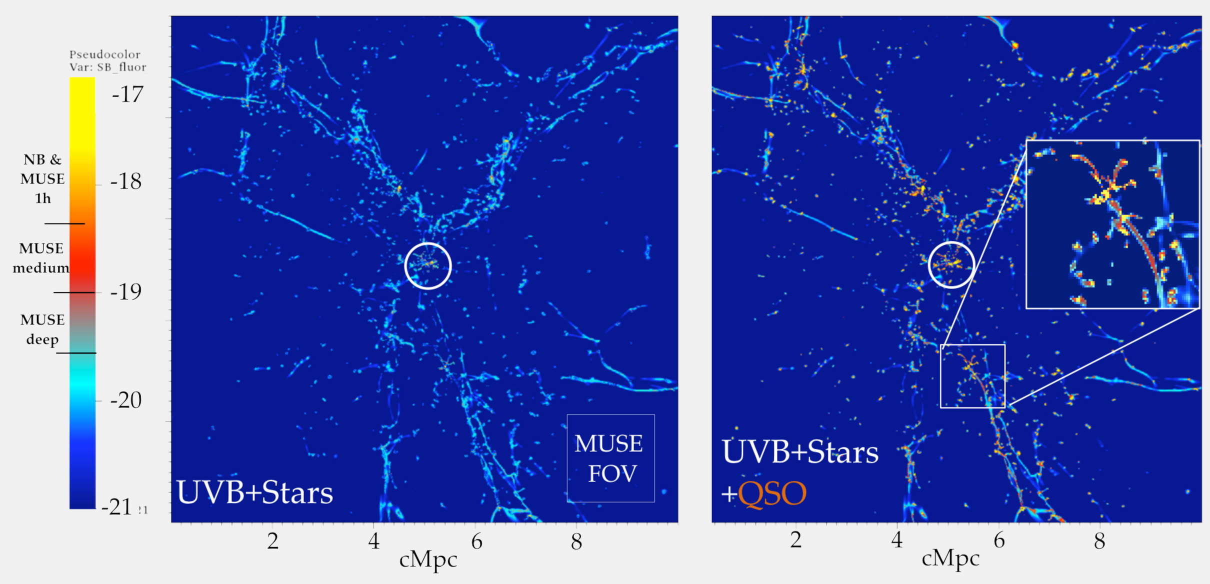
A very deep question about something!

cosmological radiative transfer for Adaptive Mesh Refinement simulations

We present a new three-dimensional radiative transfer (RT) code, RADAMESH, based on a ray-tracing, photon-conserving and adaptive (in space and time) scheme. RADAMESH uses a novel Monte Carlo approach to sample the radiation field within the computational domain on a "cell-by-cell" basis. Thanks to this algorithm, the computational efforts are now focused where actually needed, i.e. within the Ionization-fronts (I-fronts). This results in an increased accuracy level and, at the same time, a huge gain in computational speed with respect to a "classical" Monte Carlo RT, especially when combined with an Adaptive Mesh Refinement (AMR) scheme. Among several new features, RADAMESH is able to adaptively refine the computational mesh in correspondence of the I-fronts, allowing to fully resolve them within large, cosmological boxes. We follow the propagation of ionizing radiation from an arbitrary number of sources and from the recombination radiation produced by H and He. The chemical state of six species (HI, HII, HeI, HeII, HeIII, e) and gas temperatures are computed with a time-dependent, non-equilibrium chemistry solver. We present several validating tests of the code, including the standard tests from the RT Code Comparison Project and a new set of tests aimed at substantiating the new characteristics of RADAMESH. Using our AMR scheme, we show that properly resolving the I-front of a bright quasar during Reionization produces a large increase of the predicted gas temperature within the whole HII region. Also, we discuss how H and He recombination radiation is able to substantially change the ionization state of both species (for the classical Stroemgren sphere test) with respect to the widely used "on-the-spot" approximation.



[Cantalupo, S & Porciani, C 2011, 2011MNRAS.411.1678C]