

HETDEX: Evolution and Environmental Drivers of Star Formation Over 12 Gyr

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Summary

We will use the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX; Fig. 1) spectroscopic survey, along with optical and near-IR photometry to conduct a powerful exploration of how galaxies form stars and grow their dark matter halos (Figs. 3+4) in different environments over $0 < z < 3.5$. This dataset will deliver orders of magnitude more spectroscopic redshifts, photometric redshifts, spectral energy distributions, and stellar masses than all previous surveys. Our study will use Ly α at $1.9 < z < 3.5$ over 28 deg², and [O II] λ 3727 at $z < 0.5$ over 450 deg² from HETDEX to trace the cosmic web over two gigantic comparable comoving volumes (0.3–0.5 Gpc³). This will enable us to explore galaxy growth across a very wide range of environments (Fig. 2) at two critical epochs: the era $1.9 < z < 3.5$ where massive proto-clusters form, the cosmic star formation (SF) and AGN activity peak, and galaxies grow much of their mass, galaxies grow much of their mass, and the era $z < 0.5$ where more mature environments develop over the last 5 Gyr.

HETDEX and Ancillary Data

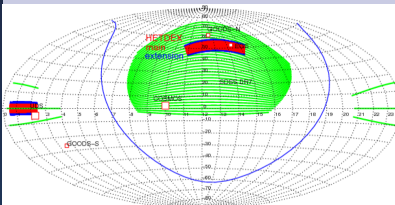


Fig. 1: HETDEX sky coverage in relation to other surveys

- HETDEX is a blind spectroscopic survey, covering a 300 deg² northern field and a 150 deg² equatorial strip over a 3-year period (Fig. 1). It will provide IFU data ($R=800$) over $\lambda = 3500-5500$ Å, reach over 4 mag. deeper than SDSS, and trace 8×10^5 Ly α emitters (LAEs) at $1.9 < z < 3.5$, 10^6 [O II] emitters at $z < 0.5$, 10^5 AGN at $z < 3.5$.
- The Dark Energy Survey (DES) and Subaru Hyper Suprime-Cam (HSC) surveys will provide deep optical imaging over the HETDEX field.
- The Spitzer-HETDEX Exploratory Large Area (SHELA) provides deep IRAC data over 28 deg² of HETDEX.

A powerful leverage on environment galaxy growth at $1.9 < z < 3.5$

Our study at $1.9 < z < 3.5$ will focus on the 28 deg² field covered by HETDEX, DES, and SHELA where:

- HETDEX will provide 200,000 spectroscopic redshifts from LAEs -- over an order of magnitude larger than all current spectroscopic surveys.
- It will measure the local density field, bias, and halo mass to an unprecedented accuracy of $\sigma(\text{bias})/\text{bias}=0.02$ and $\sigma(\log(M_h))=0.04$ dex for $\log(M_h/M_\odot) = 12-13$.
- At $1.9 < z < 3.5$, we map a huge comoving volume of 0.5 Gpc³, hosting several 10s-100s high mass ($\log(M_h/M_\odot) > 13.5$) halos (Fig. 2a) -- the first statistically significant sample of proto-clusters at $z > 2$. This volume hosts the progenitors of several 10s of Coma-type clusters, over 100 Virgo-mass systems, and several 100s of group-like structures (Fig. 2b).

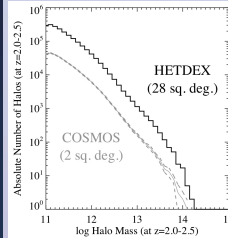


Fig. 2a: Based on the Millennium 1 simulation, which covers a 0.3 Gpc³ volume, we expect that at $2 < z < 3$, the 28 deg² HETDEX/SHELA field will contain 10-100 massive ($\log(M_h/M_\odot) > 13.5$) halos -- over an order of magnitude more than the 2 deg² COSMOS survey.

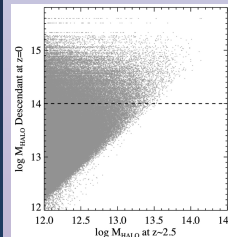


Fig. 2b: These massive ($\log(M_h/M_\odot) > 13.5$) halos at $z = 2.5$ will evolve into today's rich clusters ($\log(M_h(z=0)/M_\odot) > 14$), such as Coma and Virgo.

- SHELA IRAC data will provide stellar masses for over 300,000 galaxies, down to $1-3 \times 10^{10} M_\odot$, nearly a dex below the characteristic stellar mass at $z = 2$.
- DES will provide SEDS + photometry for 10^6 galaxies.

Science Questions

- How does environment manifest itself on different scales (e.g., halo mass, galaxy density, galaxy mergers)?
- When and where does the relation between SF, color and environment emerge?
- At $z > 1$, is SF enhanced or suppressed in regions of highest densities or in the most massive halos (Fig. 3)?

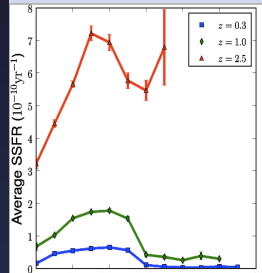


Fig. 3 -- HETDEX will map the specific SFR (SSFR) as a function of dark halo mass. The plot shows theoretical predictions (Khochfar & Silk 2011): the mean SSFR rises with redshift due to shorter cooling and dynamical times. The SSFR drops in halos with mass $> 10^{12} M_\odot$ due to the cooling shut off applied.

- How efficiently do galaxies of different halo masses build their stars? The relation between stellar and halo mass at $z > 1$ is under debate, with a large mismatch between theory and empirical abundance matching. HETDEX/SHELA will make one of the most accurate measures of (M_*/M_h) over $0 < z < 3.5$ (see Fig. 4)

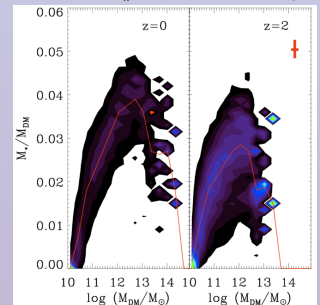


Fig. 4 -- The Stellar-Halo Mass Relation: The red error bar in the RHS panel is the statistical error we expect from HETDEX/SHELA for a halo of $\log(M_h/M_\odot)=12.5$ at $z=2.5$. The two panels show theoretical predictions (Khochfar & Ostriker 2008): the efficiency of stellar mass growth rises with dark halo mass till feedback and environmental effects reverse the trend above some mass

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