# The Galaxy Environments of Supermassive Black Holes at z≈2.7

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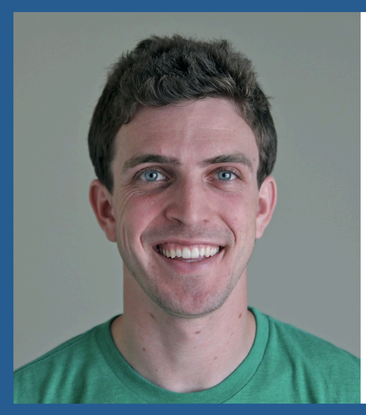

## PROJECT

- We are constraining properties of the environments of hyperluminous QSOs:
  - Host halo mass
  - Total dynamical mass in surrounding region
  - Bias with respect to galaxy population
- Our constraints are based on detailed studies of the 3D distribution of the galaxies surrounding these QSOs (ie. their clustering properties and peculiar velocities)
- QSOs may be fairly average galaxies caught at a special time in an otherwise normal process of evolution
- Understanding QSO environments informs us of the lifetimes and duty cycles of active phases in supermassive black holes

## DATA

- 15 fields centered on hyperluminous QSOs at z ≈ 2.7
  - 1522 galaxies within 3.4' of QSO lines of sight with spectroscopic redshifts 1.4 < z < 3.5
  - Low-resolution (5-10 Å) rest-frame UV spectra taken with LRIS-B (Keck), $\sigma_z \approx 0.002 \approx 120$ km/s
  - QSO redshifts from rest-frame optical spectra taken with NIRSPEC (Keck) and TripleSpec (Palomar 200"), $\sigma_z \approx 0.0005 \approx 30$ km/s
- Halo catalogues from the Millennium Simulation (z = 2.62) were used to determine the mass scale of halos with similar clustering characteristics to our data

Fig. 1

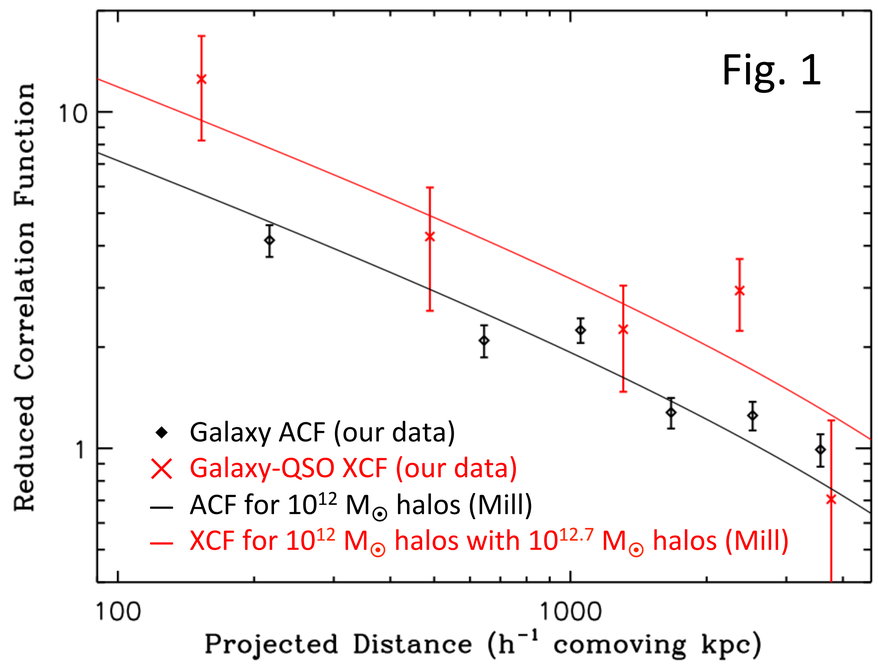


**Fig. 1:** Autocorrelation function for galaxies in our sample (black points) and their cross-correlation function with the nearby QSOs (red points). The galaxy autocorrelation is consistent with the fit to $10^{12.0}$ $M_\odot$ halos from the Millennium simulation (black line), and the galaxy-QSO cross-correlation matches the fit to the cross-correlation between simulated $10^{12.0}$ and $10^{12.7}$ $M_\odot$ halos (red line).

Fig. 2

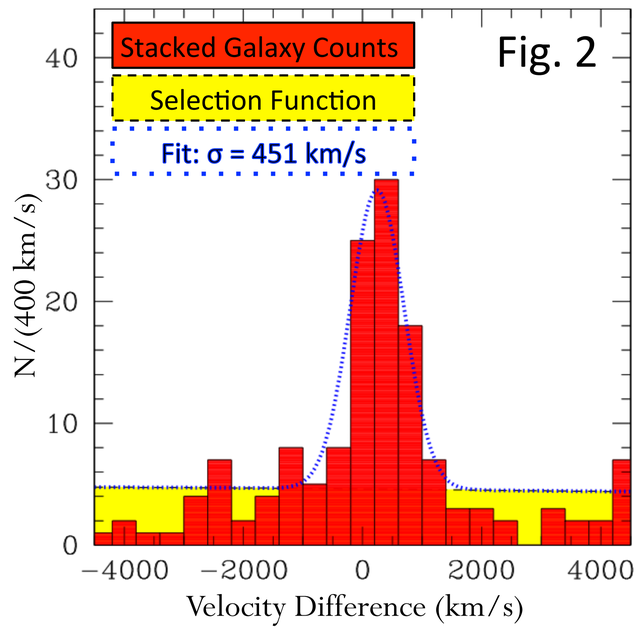


**Fig. 2:** Line-of-sight distribution of galaxies in units of velocity with respect to their nearby QSOs. There is a large overdensity at the location of the QSOs with a velocity dispersion σ ≈ 430 km/s (corrected for redshift errors), which we attribute to peculiar velocities.

| | Gal-Gal ACF | Gal-QSO XCF |
|---|---|---|
| $r_0$ ($h^{-1}$ comoving Mpc) | 5.5 ± 0.3 | 7.7 ± 0.9 |
| γ (fixed) | 1.5 | 1.5 |
| $\langle z \rangle \pm \sigma_z$ | 2.34 ± 0.44 | 2.67 ± 0.10 |
| $\log M_{min}$ ($M_\odot$) | 11.75 | 12.5 |
| $\log M_{ave}$ ($M_\odot$) | 12.0 | 12.7 |

**Fig. 3:** LRIS G-band image of the field surrounding the QSO Q1549+1919. The red circles correspond to galaxies with spectroscopic redshifts suggesting they are associated with the QSO, while blue (green) circles denote galaxies in the foreground (background) of the QSO.

Fig. 3

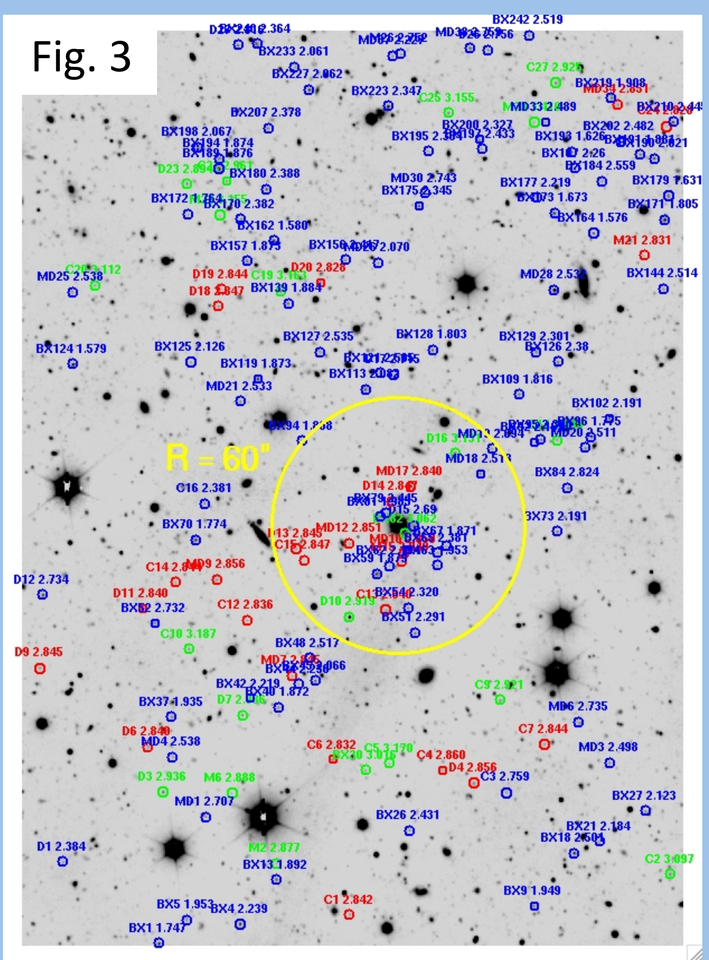


Fig. 4

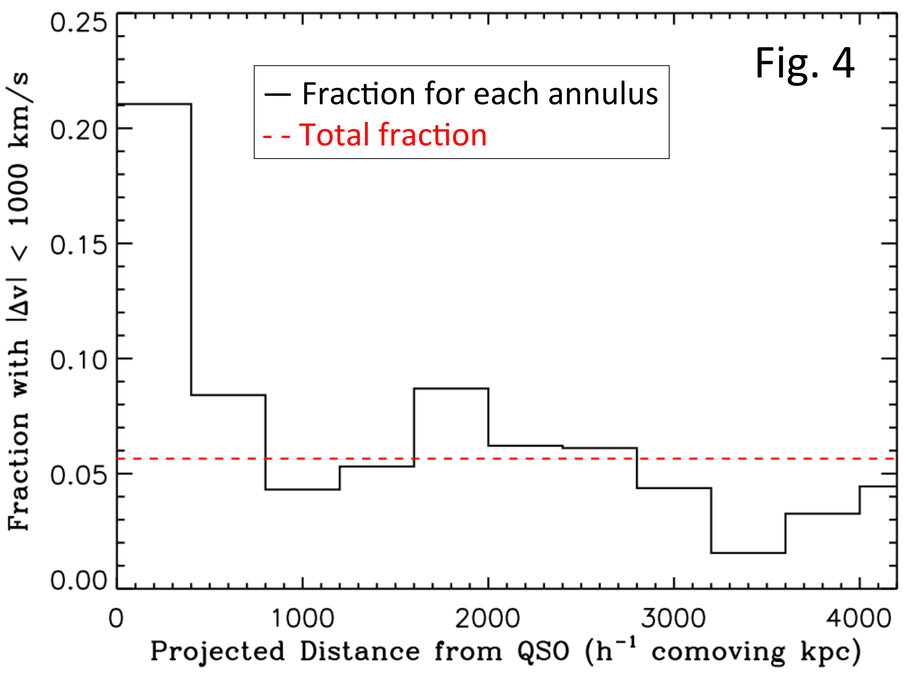


**Fig. 4:** For each projected circular annulus, the fraction of galaxies within that annulus that are also within 1000 km/s of the QSO (black). The red line denotes the fraction of all galaxies within this velocity range. The overdensity of galaxies is localized to a transverse scale R ≈ 500 $h^{-1}$ comoving kpc.

## RESULTS

- Hyperluminous QSOs are associated with significant overdensities in the distribution of surrounding galaxies
- The projected scale (R ≈ 500 $h^{-1}$ comoving kpc) and velocity scale (σ ≈ 500 km/s) of these overdensities imply (via virial arguments) a dynamical mass scale $M_{dyn} \approx 10^{13}$ $M_\odot$ for the overdensities, consistent with a proto-group environment
- The galaxy autocorrelation function, when compared with results from halo catalogs, suggests our galaxies have halo masses $M_{gal} \approx 10^{12.0}$ $M_\odot$, in agreement with previous measurements
- The galaxy-QSO cross-correlation function suggests that these hyperluminous QSOs inhabit halos $M_{QSO} \approx 10^{12.7}$ $M_\odot$, only ~5x more massive than the typical galaxy in our sample

## FUTURE WORK

- We are finishing a survey for narrow-band Lyα-selected objects in 8 of the hyperluminous QSO fields, which may exhibit fluorescence
- Results reveal the Mpc-scale distribution of gas around bright QSOs and the effect of QSOs on this environment