Galaxy Environments of Extremely Massive Quasars

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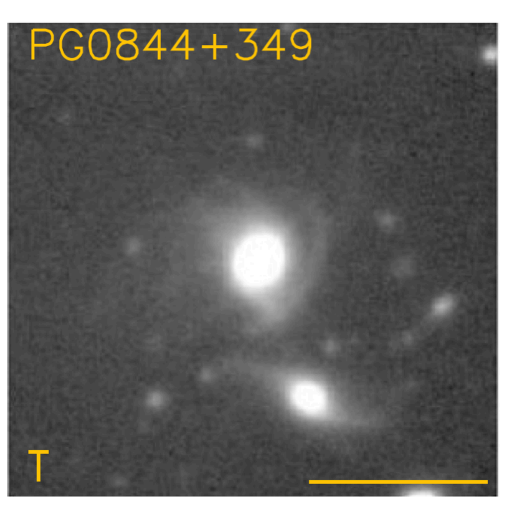
Introduction

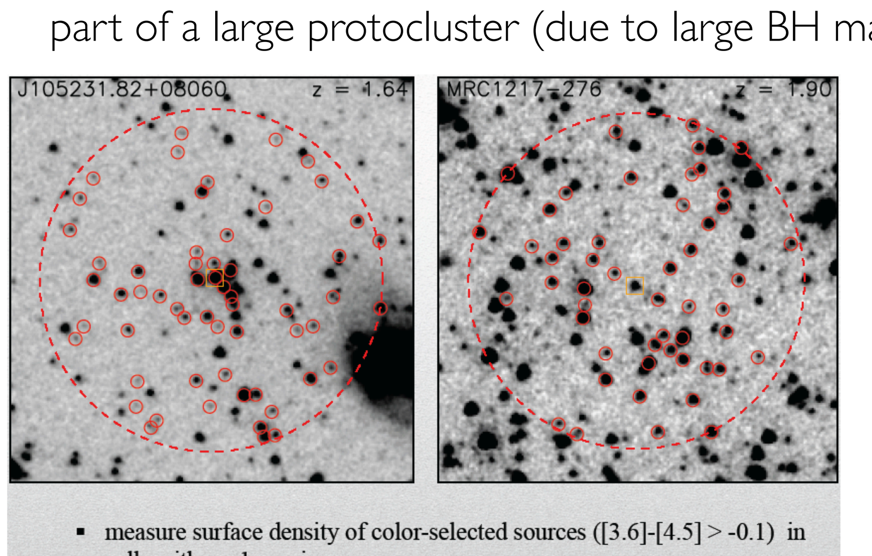
- Quasars (quasi-stellar radio objects) are luminous active galactic nuclei (AGN), powered by accretion onto supermassive black holes (BHs)
- AGN at redshifts of 1-2 are found in a wide range of environments observed through spectroscopy or narrow-band imaging (e.g., Noirot et al. 2018; Stott et al. 2020), and the observational connection between quasars and Mpc-scale galaxy overdensities is yet clear
- Gas-rich major mergers are thought to trigger quasar activity (e.g., Hopkins et al. 2008; Hong et al. 2015), where galaxy mergers are promoted in group environments (e.g., Danese et al. 1980; Rines & Diaferio 2006)

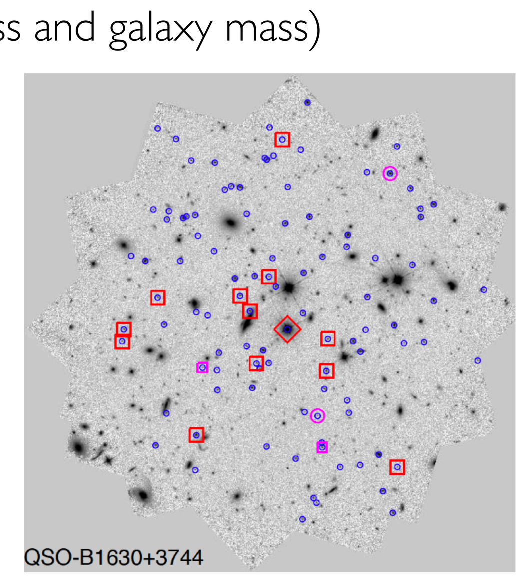


An example of a quasar going through galaxy mergers (left, Hong et al. 2015; right, Hopkins et al., web page http://www.tapir.caltech.edu/~phopkins/Site/Research.html)

Objective

- Since the most massive galaxies are found in present-day clusters, we test whether the most massive quasars trace galaxy overdensities in the intermediate redshift, as much as radio AGN do
- A pilot study using narrow-band H-band imaging of a z=1.47 quasar field, named PG 1630+377 (Green et al. 1986)
- We i) measure the narrow-to-broad H-band colors to identify H-alpha emitters ii) compute the density map of galaxies near PG 1630+377 with an expectation that its local environment is similar to a group (due to quasar luminosity), and is part of a large protocluster (due to large BH mass and galaxy mass)

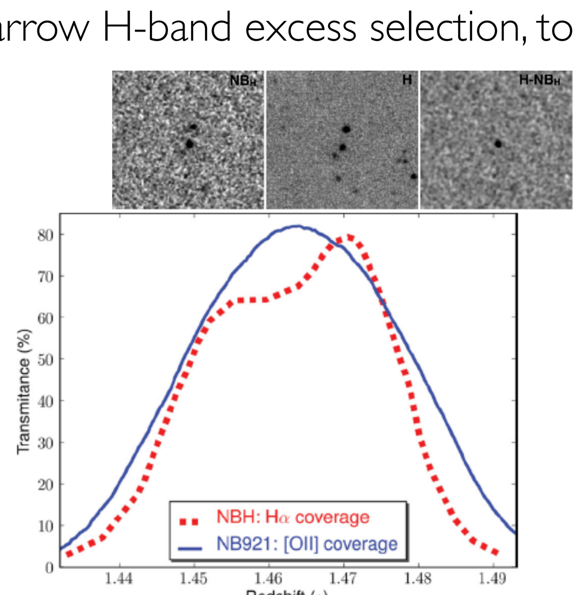


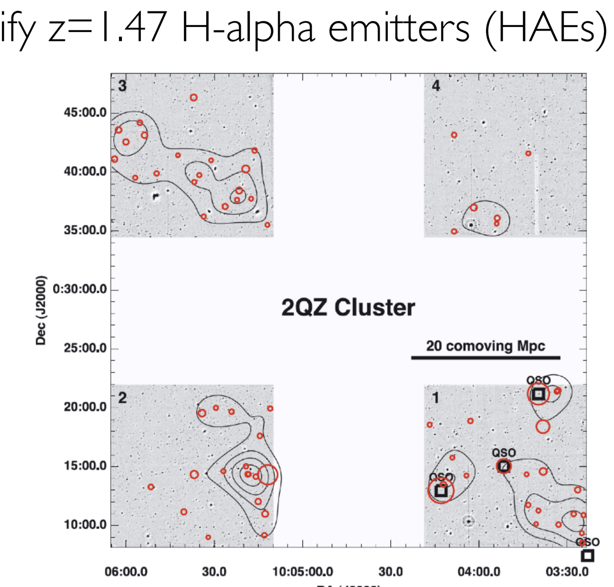


Overdense galaxy environments around radio AGN (left, Wylezalek et al. 2013), Hubble Space Telescope imaging of PG 1630+377 (right, Stott et al. 2020)

Observation and Analysis

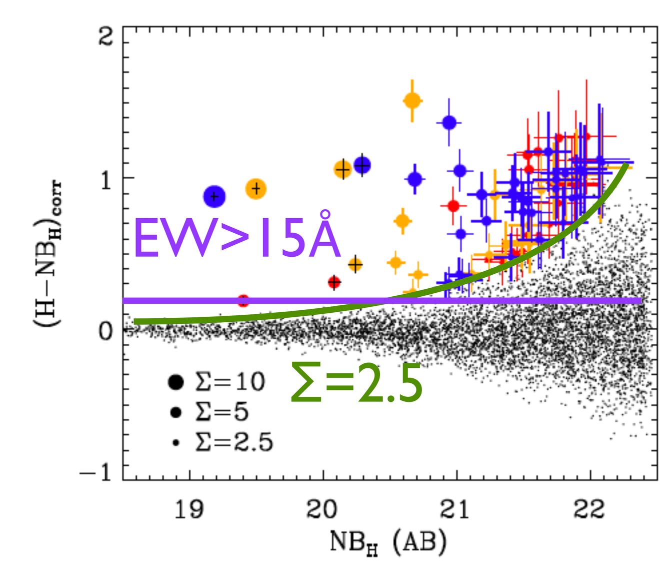
- UKIRT (United Kingdom Infrared Telescope) *JHK* and narrow *H* near-infrared imaging (2011-2013), four 13.'65x13.'65 detectors to measure galaxy densities
- Hubble Space Telescope WFC3 near-IR spectroscopy available for the central ~Mpc region (Stott et al. 2020)
- Large Binocular Telescope LBC *griz* optical imaging available for the extended region (Prochaska et al. 2019; J. C. Howk, private communication)
- Narrow H-band excess selection, to identify z=1.47 H-alpha emitters (HAEs)

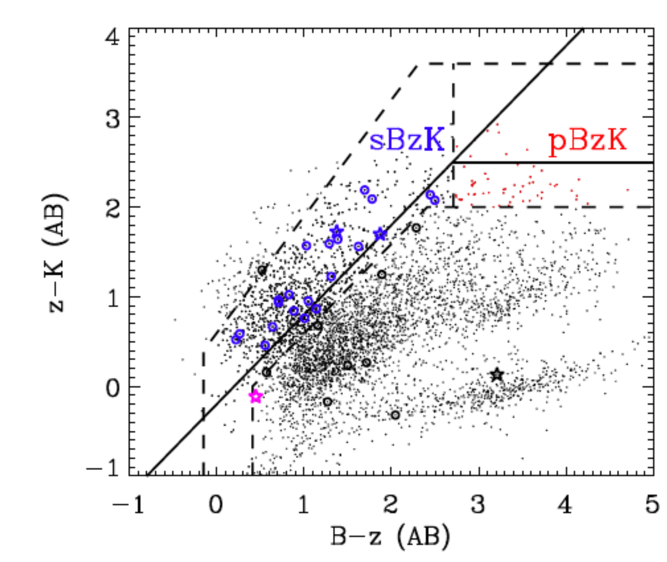




UKIRT narrow-band H-filter transmission and an example narrow H-band excess object (left, Sobral et al. 2012), UKIRT FoV (right, Matsuda et al. 2011)

- H-NB_H colors are corrected to show zero colors overall
- HAE selection: NB_H fluxes stronger than H by more than 2.5 times the uncertainty, rest-frame line equivalent width wider than 15 angstroms
- BzK selection: B-z and z-K color-selected z~1.5 galaxies

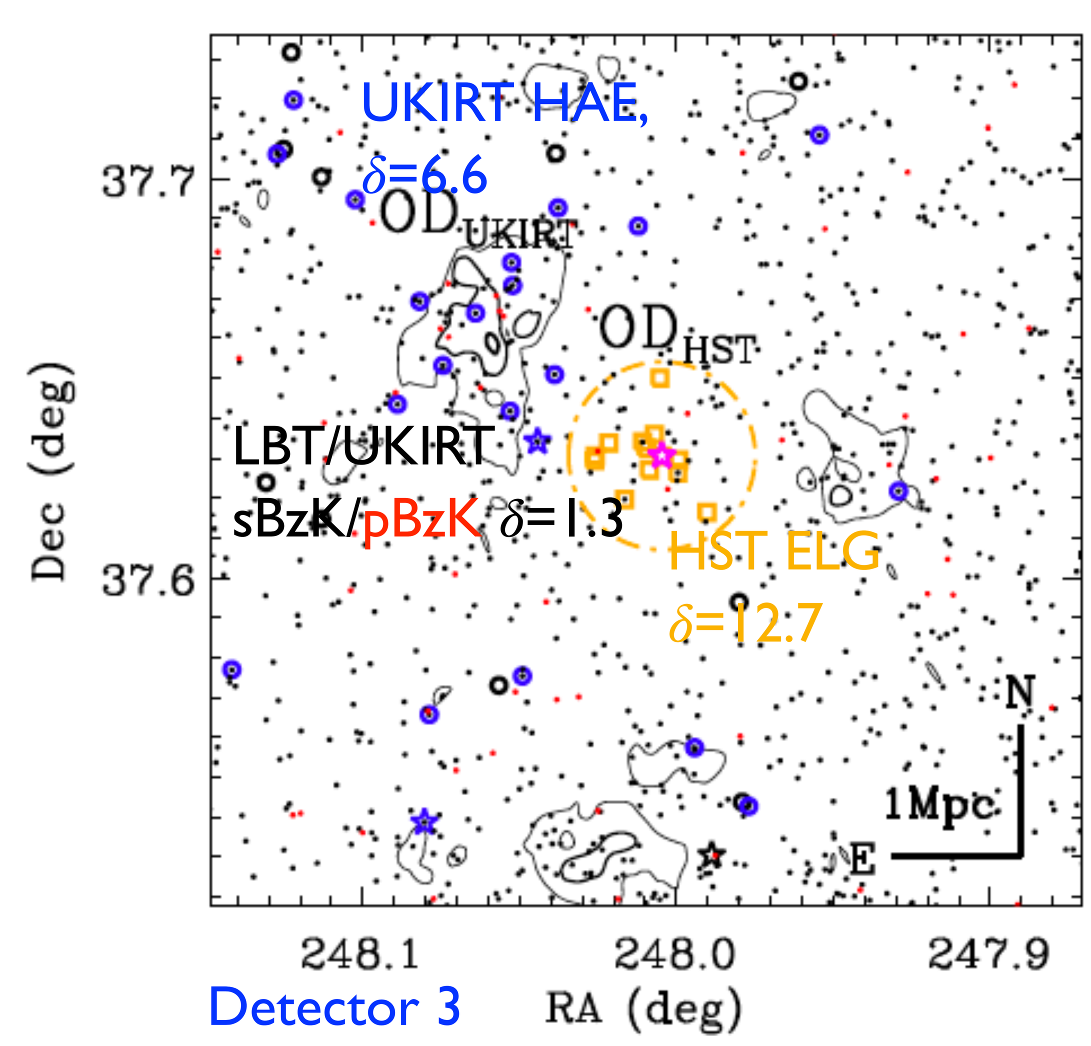


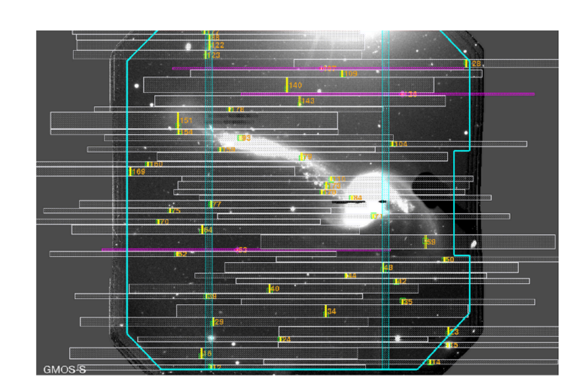


HAE selection (left, red, yellow, and blue colors for detectors 1-3), BzK z~1.5 galaxy selection (right, blue: star-forming BzK, red: passive BzK, magenta: PG 1630+377, circles: HAEs, stars: point-like HAEs)

Results

- We identify an overdensity of HAEs with δ=6.6 (OD_UKIRT), overlapping with the overdensity of BzK galaxies (δ=1.3)
- The overdensity is the strongest one in the surveyed field, ~2.1 proper Mpcs NE of PG 1630+377 and the overdensity (δ=12.7) of HST emission-line galaxies (OD_HST)
- The two overdensities will become a single massive cluster at z=0 (log M_halo/M_sun=14.71), if they collide into each other





Overdensities of various types of galaxies detected near and around PG 1630+377 (left), Gemini/GMOS multi-object spectroscopy planned this semester (right, Gemini web page, https://gmmps-documentation.readthedocs.io/en/latest/ngo.html)

Conclusions & Ongoing work

Through near-infrared narrow-band imaging and complementary spectro-photometric observations of galaxies near PG 1630+377 we find that

• A massive protocluster is found ~2 pMpc from the massive quasar and a group-like structure closer to the quasar, consistent with predictions

• A statistical study is required for generalizing such behavior

• Gemini/GMOS observations are planned in 2022A (hopefully by the end of this month), to further test whether the two overdensities around PG 1630+377 are within a close enough distance for large-scale mergers

•References: Danese et al. 1980, A&A, 82, 322; Green et al. 1986, ApJS, 61, 305; Hopkins et al. 2008, ApJS, 175, 356; Hong et al. 2015, ApJ, 804, 34; Jun et al. 2021, ApJ, 920, 74; Matsuda et al. 2011, MNRAS, 416, 2041; Noirot et al. 2018, ApJ, 859, 38; Prochaska et al. 2019, ApJS, 243, 24; Rines & Diaferio 2006, AJ, 132, 1275; Sobral et al. 2012, MNRAS, 420, 1926; Stott et al. 2020, MNRAS, 497, 3083; Wylezalek et al. 2013, ApJ, 769, 79

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