Concurrant star formation and black hole growth in the most massive galaxies

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High Redshift Radio galaxies

Using *Spitzer*-IRS mid-IR data we perform spectroscopy on a sample of high redshift radio galaxies (HzRGs, 1.5<z<2.6). HzRGs are the hosts of radio-loud type II AGN, whose jets are oriented approximately perpendicular to our line of sight. They are massive systems (10^{10}-10^{12} $M_{\odot}$; Pentericci +01; Zirm +03, Seymour +07, De Breuck +10) and appear to be the precursors of modern day elliptical galaxies.

Sample selection

Our sample consists of the 7/9 radio galaxies from the *Spitzer* HzRG project (SHzRG; Seymour +07, De Breuck +10) that have been observed with the IRS. These HzRGs are very luminous (L_{3GHz} = $10^{27\text{-}28}$ WHz^{-1}) and have $S_{24\ \mu m}$> 0.4 mJy.

Spectral decomposition

To measure their properties, we decompose the mid-IR spectra of these powerful, obscured radio-loud AGN into star-forming and AGN components. We model the AGN contribution as a power-law and use template spectra of local starburst galaxies to represent the host galaxy component. Obscuration of the AGN component is taken into account using a dust extinction law.

We calculate star formation rates (SFRs) from the 7.7 μm polycyclic aromatic hydrocarbon (PAH) emission feature of the host-galaxy component and from silicate absorption at 9.7 μm, we calculate the optical depth of the obscuring dust in these AGN.

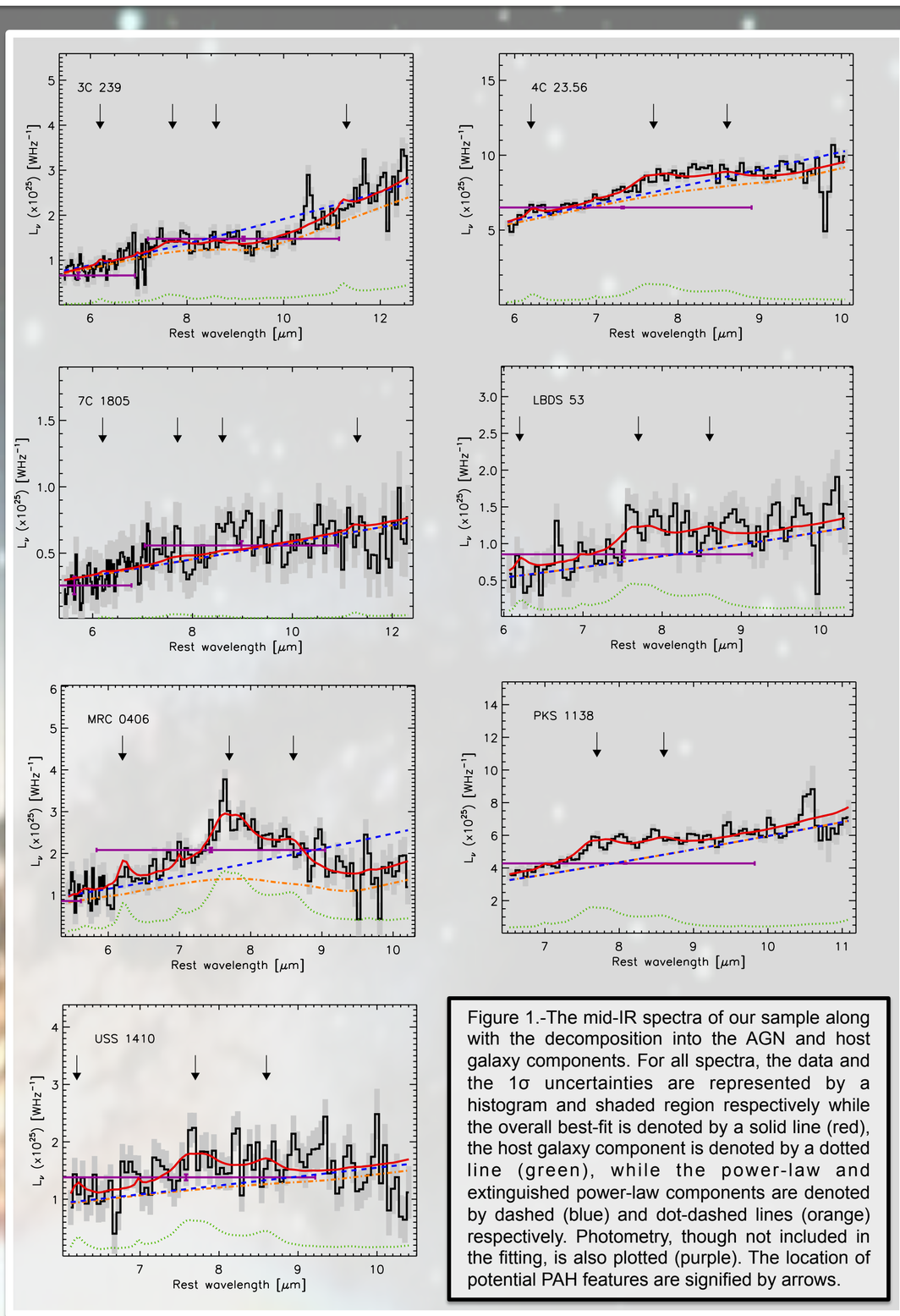

Figure 1.-The mid-IR spectra of our sample along with the decomposition into the AGN and host galaxy components. For all spectra, the data and the 1σ uncertainties are represented by a histogram and shaded region respectively while the overall best-fit is denoted by a solid line (red), the host galaxy component is denoted by a dotted line (green), while the power-law and extinguished power-law components are denoted by dashed (blue) and dot-dashed lines (orange) respectively. Photometry, though not included in the fitting, is also plotted (purple). The location of potential PAH features are signified by arrows.

Results

- From the spectral decomposition, we detect PAH emission in the spectra of 6/7 HzRGs and also in the mean spectrum. We find a wide range of SFRs, ranging from ~1000 $M_{\odot}$/yr to no detected star formation. The very high SFRs are comparable to those of sub-mm galaxies (SMGs; Pope +08, Coppin +10).
- We also detect silicate absorption for 4 of the HzRGs and derive 9.7 μm optical depths of up to 0.8. This means the AGN can be relatively unobscured in the mid-IR and implies their dust have a more clumpy rather than homogenous distribution.
- We show that SFR does not strongly correlate with radio power (figure 3) although some of the HzRGs that have higher radio luminosities than the Seymour +11 radio-loud AGN sample also have higher SFRs.
- In figure 4, we find a weak correlation between 6 μm AGN luminosity over star-forming luminosity (a proxy for black hole accretion power over star-forming power) & radio jet length (a proxy for the radio-loud phase lifetime) which indicates that the production of radio emission from the AGN marks the transition between a galaxy being star formation dominated and AGN dominated.

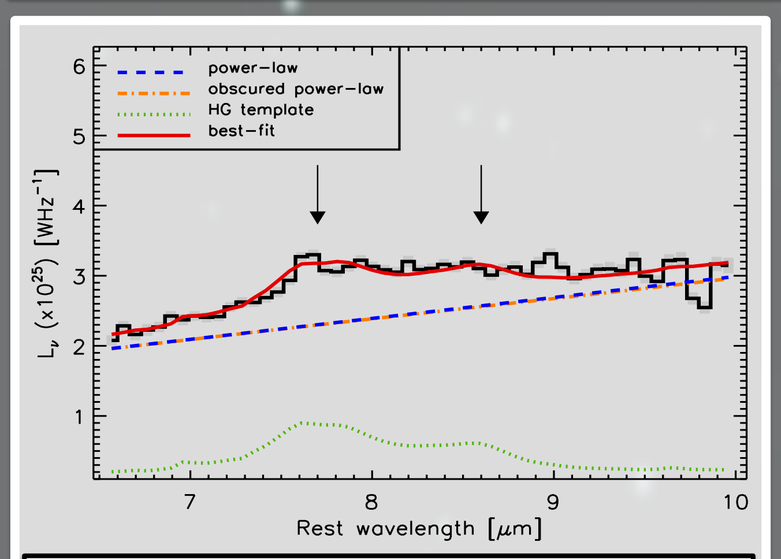

Figure 2.-The mean spectrum of the seven radio galaxies in the sample, with the same fitted component as those in figure 2. The location of potential PAH features are signified by arrows.

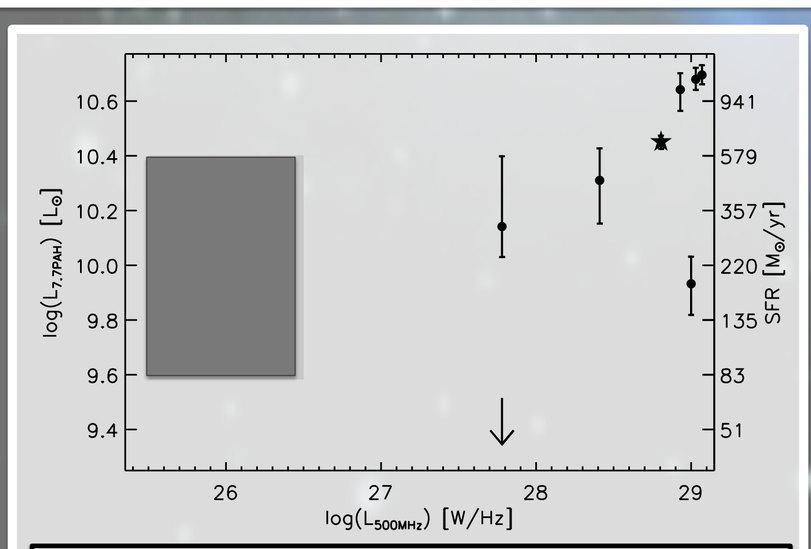

Figure 3.- 7.7 μm PAH luminosity (and corresponding SFR) as a function of AGN radio luminosity density. Also plotted, in grey, is the region in parameter space covered by the Seymour +11 high redshift (1.2 < z < 3) sub-sample of radio-loud AGN. The mean is represented by a star.

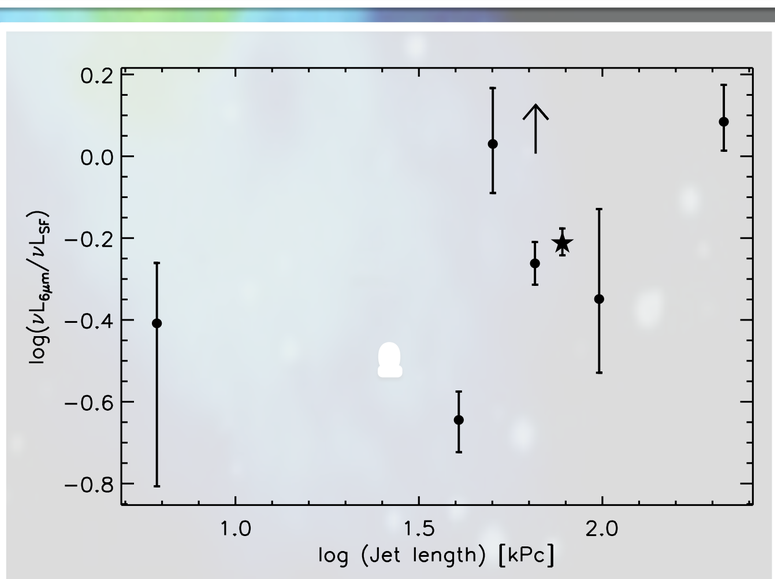

Figure 4.- BH accretion over star formation as a function of projected radio jet length.

Background image: Centaurus A radio galaxy; NRAO/AUI/VLA and NASA/ESA Hubble Space Telescope * Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Surrey, RH5 6NT