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Galaxy evolution in extreme environments: Molecular gas content, star formation and AGN in isolated void galaxies

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Abstract. Since the early redshift surveys of the large scale structure of our universe, it has become clear that galaxies cluster along walls, sheet and filaments leaving large, empty regions called voids between them. Although voids represent the most under dense parts of our universe, they do contain a sparse but significant population of isolated galaxies that are generally low luminosity, late type disk galaxies. Recent studies show that most void galaxies have ongoing star formation and are in an early stage of evolution. We present radio, optical studies of the molecular gas content and star formation in a sample of void galaxies. Using SDSS data, we find that AGN are rare in these systems and are found only in the Bootes void; their black hole masses and radio properties are similar to bright spirals galaxies. Our studies suggest that close galaxy interactions and gas accretion are the main drivers of galaxy evolution in these systems despite their location in the underdense environment of the voids.

Keywords : galaxies – active galactic nuclei – molecular gas – star formation – voids

1. Void galaxies: AGN, black hole masses and radio emission

Voids contain a sparse but significant population of galaxies that are low luminosity, late type, gas rich galaxies. A small fraction are interacting and show considerable star formation and even AGN activity.We examined the SDSS spectra of ∼ 80 known

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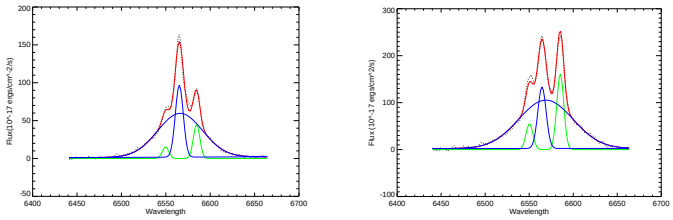

Figure 1. The Hα emission line in the nuclei of CG693 (left) and Mrk 845 (right) decomposed into the broad and narrow components. The total emission is in red and components in green and blue.

void galaxies (eg. Kreckel et al. 2012; Szomoru et al. 1996) but found AGN emission from only 4 void galaxies. Of these, two galaxies had Sy 1 nuclei and two had Sy 2 nuclei. We used GANDALF to separate the stellar and AGN emission lines (Sarzi et al. 2006). We fitted the broad Hα component for both Sy 1 nuclei and derived their black hole (MBH) masses (Figure 1; CG 693 had a $MBH \sim 3.9 \times 10^6$ and Mrk 845 had a $MBH \sim 6.8 \times 10^6$). We also derived their central velocity dispersions σ. Both galaxies (Mrk845 and CG693) lie on the M-σ correlation for bright galaxies. We examined the radio emission from void galaxies using NVSS and VLA FIRST maps. Two of them (CG 693-CG692, SBS 1428+529) show strong radio emission from their AGN. A few others show emission due to star formation.

2. Detection of molecular gas and star formation

We observed 5 void galaxies in CO(1-0) emission using the 45m Nobeyama Radio Observatory (NRO)during April, 2013. The galaxies had either relatively high IRAS fluxes or high Hα luminosity. Molecular gas was detected in four out of the five observed galaxies. One of the detected galaxies, CG0598 lies in the Bootes void and shows strong star formation. SBS1325+597 shows a distinct double horned profile indicating a rotating disk. SDSS1538+3311 has a narrow peaked emission. Very little is known about the cold gas content of void galaxies and there has been only one earlier study in which 3 galaxies were detected in CO(1–0) (Sage et al. 1997). We have also observed several void galaxies with the Himalayan Chandra Telescope (HCT) in order to measure the Hα emission. The star formation is located within the nucleus or inner disk of the galaxies.

3. Conclusions

1. AGN are rare in voids. We have found 4 from a sample of 80 void galaxies. All 4 are located in the Bootes void. We derived their black masses; they lie close to the M-σ. correlation. Three of of these AGN also show radio emission as they are bright in the NVSS and FIRST maps. **2.** We have detected molecular gas in 4 void galaxies. All

four show signs of star formation in their optical spectra. These results clearly show that void galaxies are not alwaysly low luminosity, dark matter dominated systems as predicted in early studies.

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