Environmental Dependence of AGN activity in the present-day universe

Jong-Hak Woo
Hubble Fellow, UCLA
Why some galaxies have AGN?

• if most galaxies have a supermassive black hole at the center (Kormendy & Gebhardt 2001; Ferrarese & Ford 2005)
• how to trigger AGN activity (fuel supply to the center)?

Triggering AGN activity in different scales

• galaxy merging/interaction (Sanders et al. 1988; Hopkins et al. 2006)
• galaxy internal process (e.g. bar driven gas inflow: Combes 2003)
• local activity near BH (stellar wind: Ciotti & Ostriker 2007; turbulence; Wada 2004)
Are AGN host galaxies different?

1) Excess of bar or local density? (Combes 2003; Maia et al. 2003)
2) No difference in the fundamental plane relation
   (Bettoni et al. 2001; Barth et al. 2003; Woo et al. 2004, 2005)
3) Molecular gas & young stellar population in early-type AGN hosts
   (Scoville et al. 2003; Tadhunter et al. 2005)

Previous studies

- Before SDSS, limited to small sample (~several hundreds)
  (Ho et al. 1997; Hunt & Malkan 2004)
- With SDSS, studies with a large sample available
  (Kauffmann et al. 2003; Heckman et al. 2004; Schawinski et al. 2007;
  Graves et al. 2007)
By comparing AGN host galaxies with non-AGN galaxies
1) how the fraction of AGN changes
   \[ f_{\text{AGN}} = \left( \frac{\# \text{ of AGN}}{\# \text{ of all galaxies}} \right) \text{ at fixed galaxy property} \]
2) how AGN power changes
   \[ P_{\text{AGN}} = \frac{L_{\text{[OIII]}}}{M_{\text{BH}}} \text{ (Eddington ratio indicator)} \]
Sample Selection

Volume limited sample of 144,940 galaxies in the present-day universe ($z < 0.1$)

Using SDSS DR5.

Each subsample with different luminosity limit is corrected for the volume difference.
AGN Sample

Selecting **Type II AGNs** based on emission line ratios

Among 46,520 emission-line galaxies (with \( S/N > 6 \)),
pure AGN \( \sim 2,605 \)
Composite objects \( \sim 8,913 \)

Total AGN sample = 11,518
(AGN fraction \( \sim 8\% \), lower limit)
Morphology classification
based on color and color gradient (see Park & Choi (2005) for details)

Total sample: 41% early-type vs. 59% late-type
AGN sample: 17% early-type vs. 83% late-type
AGN properties
$f_{\text{AGN}}$ dependency on luminosity & velocity dispersion

- $f_{\text{AGN}}$ increases with luminosity
  More luminous galaxies are more likely to host AGN
- $f_{\text{AGN}}$ in early-types decreases with velocity dispersion
  More massive galaxies are harder to host AGN
- $f_{\text{AGN}}$ in late-type peaks at intermediate velocity dispersion (~130 km/s)

Choi (2009, submitted)
\( f_{\text{AGN}} \) dependency on u-r color

\( f_{\text{AGN}} \) peaks at intermediate color (e.g. Nandra et al. 2007, Schawinsky et al. 2007)

AGN activity is related with recent star formation in early-type galaxies
$f_{\text{AGN}}$ dependency on color gradient

$\Delta (g-i) = (g-i) \text{ outer part} - (g-i) \text{ inner part}$

- $f_{\text{AGN}}$ does not strongly depend on color gradient
$f_{\text{AGN}}$ dependency on concentration index \\
($C_{\text{in}} = R_{50}/R_{90}$)

- $f_{\text{AGN}}$ in early-type does not strongly depend on $C_{\text{in}}$, similar to vel. disp.
- $f_{\text{AGN}}$ in late-types is higher for more concentrated galaxies

More massive galaxies (and black holes) are more likely to host AGN
AGN power dependency

- Late-types are dominant host for all AGN power.
- The fraction of early-type host increases at low AGN power (< 1% of Eddington)
AGN power dependency

- AGN power slightly increases for bluer color host galaxies
- color gradient and concentration index do not strongly affect AGN power
Summary and Conclusions

- $f_{\text{AGN}}$ is lower than $\sim$20-30% (lower limit) at any combination of galaxy properties, indicating global galaxy properties are not sufficient condition to trigger AGN activity.

- AGNs in the present-day universe are dominantly hosted by intermediate-mass late-type galaxies.

- Color is the dominant parameter of $f_{\text{AGN}}$. In particular for early-types, $f_{\text{AGN}}$ does not depend on luminosity or velocity dispersion at fixed color and there seems to be a connection between recent star formation and AGN activity.

- High power AGNs are dominantly hosted by late-type galaxies. For both morphological types, Eddington ratio ranges over 3 orders of magnitude, indicating various levels of accretion for given $M_{\text{BH}}$. 