Galaxy collisions, black holes, and quasars: the big picture

Tim Hamilton
Shawnee State University
Ch. 1: The discovery

“All science is either physics or stamp collecting.”
—Ernest Rutherford
William Herschel (1811)
Edwin Hubble’s “Tuning fork diagram” (1936)
Hubble’s Galaxy Classification Scheme

Examples from the “Galaxy Zoo”
galaxyzoo.org
Seyfert Galaxies

NGC 1068  
NGC 4051  
NGC 7469

Seyfert Galaxies
Radio Galaxies

Cygnus A

Centaurus A

Hydra A

Radio Galaxies
Quasar 3C 273
Quasar host types

Ellipticals

Spirals
Ch. 2: How do they work?
Nearly all galaxies have massive black holes.

Black hole mass proportional to galaxy bulge mass

Velocity dispersion (related to galaxy bulge mass)
Ch. 3: The AGN merger sequence
Jonsson (2011)
Hubble Space Telescope
Extended merger features; otherwise undisturbed.

Host asymmetry at all radii. Note extra light above nucleus.

High AGN/host luminosity ratio. Processing is necessary to see host at all.
The galactic merger history, we have an evolutionary explanation for the differences between radio-loud and radio-quiet QSOs. Since the presence or absence of a core may be tied to quiets are in coreless ellipticals and spirals.

The difference between radio-loud and radio-quiet QSOs is not simply one of host morphology. While extremely luminous objects (log $L_X > 44.9$) are nearly all found to be radio-loud. But those with low $L_X < 44.9$ are mostly constrained to the larger hosts (though not all are core). These core & coreless galaxies tend to have a 2:1 preference for core. But there is a complete loss of all coreless radio-louds after Kormendy (2008).

At high accretion rates (judging by nuclear x-ray luminosity), nearly all the QSOs are RLQs are in core hosts. At lower accretion rates, a 2:1 preference for core. Rarely have strong radio sources associated with these types. While smaller ones ($r < 10$ kpc) are mostly in core ellipticals. Usually coreless ellipticals, bulge from the disk.

Our data consist of 42 low-redshift (0.06 < z < 0.1) weak QSOs for which the host morphology was identified groupings by host morphology, radio loudness, etc. We have used it for classification. QSOs lie in a thin plane within this 3-D parameter space. By plotting QSO locations in this plane, we come up in the analysis below.

Note the presence of several non-core RLQ hosts. Rarely have x-ray gas, star formation, etc. associated with these types, while smaller ones ($r < 10$ kpc) tend to have more massive hosts. Growth by major mergers.

Coreless galaxies have extra light at the center, compared to the Sersic profile. Core ellipticals have less light at the center than the Sersic profile would predict. Coreless galaxies have a wider range of sizes, except 3C 93. Core galaxies have a narrow range of sizes, except 3C 93. Rarely have x-ray gas, emission from non-quasars is associated with core.

First, note that radio-quiets are mostly in coreless, RLQ ~10 $< r < 22$ kpc. Younger stars. Core galaxies have Brighter ($M_V < -21.6$).

**Core galaxies**
- Brighter ($M_V < -21.6$)
- Boxy isophotes
- Mostly older stars
- Have x-ray gas
- Have strong radio sources
- Growth by major mergers

**Coreless galaxies**
- Fainter ($M_V < -21.6$)
- Dishy isophotes
- Younger stars
- Rarely have x-ray gas
- Rarely have strong radio sources
- Growth by minor mergers
There are two kinds of ellipticals:

- **Core (missing light) elliptical:** built from major mergers
- **Coreless (extra light) elliptical:** built from minor mergers
Ch. 4: However…
Fig. 1.—Left panel: Fraction of AGNs showing mergers as a function of the AGN bolometric luminosity. Colors indicate AGN selection method (red: infrared, blue: X-rays, black: optical). Symbols used for each survey are presented in Table 1. Encircled symbols show samples at \( z < 1 \). Solid line shows a fit to the data assuming a linear dependence of the fraction on \( \log(L_{\text{bol}}) \), while the dashed line assumes a power-law dependence.

Right panel: Fraction of AGNs showing mergers as a function of redshift. There is a clear luminosity dependence, but no redshift dependence, suggesting that redshift is a second-order effect in determining the dominant AGN triggering mechanism.

Fig. 2.—Spectral energy distribution of the extragalactic X-ray "background" (which is actually the sum of AGN emission), as a function of observed-frame energy. Observational data points are summarized by Treister et al. (2009a). Merger-triggered AGN (blue line) contribute roughly equal amounts to black hole growth (red line). Most of the X-ray background emission comes from \( z < 1 \) (Treister et al. 2009a), hence the relative importance of secularly-triggered AGN. The extragalactic background light from higher redshift AGN peaks in the optical/UV and is dominated by luminous, merger-triggered AGN. The spectral shapes of the merger and secular contributions are slightly different since the fraction of obscured sources is a function of luminosity.

Our results so far refer only to the integrated black hole growth. Assuming that the Eddington ratio does not depend strongly on black hole mass (Woo & Urry 2002), it is clear that the most massive black holes are gaining most of their mass in episodes triggered by major mergers at relatively high redshifts, \( z \gtrsim 1.5 \). Smaller black holes are either growing slowly at all redshifts in episodes not related to major mergers or are experiencing their epochs of active growth (Hopkins & Hernquist 2009). This calculation adopts the simplifying assumption that the accretion efficiency, average Eddington ratios and AGN duty cycle are constant and the same for secular and merger-triggered AGN. While this is obviously an idealized approach, it is justified by the good agreement between model results and observations of the integrated black hole mass function at \( z = 0 \) (Treister et al. 2009a).

Recently, Draper & Ballantyne (2012) reported a more sophisticated simulation, in which they assumed a distribution of Eddington ratios (and in general AGN light curves) for secular and merger-triggered AGN. Qualitatively, however, the results are very similar and consistent.

While it is clear that at the major galaxy mergers are responsible for the highest luminosity events, it is expected that these AGN while eventually fade to lower luminosities. According to model AGN light curves (e.g., Hopkins & Hernquist 2009), the nuclear luminosity can decrease by \( \sim 4 \) orders of magnitude in \( \sim 10^8 \) years. This is much shorter than the typical duration of the merger sequence, \( \sim 10^9 \) years (Di Matteo et al. 2005). Hence, it is unlikely that sources classified as secularly-triggered correspond to merger-triggered AGN in which the merger signatures are lost. Furthermore, and as shown by e.g., Simmons et al. (2011), most low-luminosity AGN show significant disks, and thus they probably did not experience a relatively recent major merger.

Only the brightest active galaxies are triggered by mergers.
Galactic Mergers Fail to Feed Black Holes

By comparing 140 galaxies that had Active Galactic Nuclei with over 1200 galaxies in a 'control group', the likelihood that mergers are the cause of AGN has been brought into doubt. Image Credit: NASA, ESA, M. Cisternas (Max-Planck Institute for Astronomy)
Ch. 5: Pushing the limits
Dwarf Galaxy Mergers
Tiny Titans (TNT) Survey
Ultra-Luminous Infrared Galaxies (ULIRGs)

Source of obscured AGN?
Spherical Accretion of Theoretical Astrophysicists Onto a Fashionable New Idea

Dick McCray
1979 Cambridge AGN Meeting
Supplemental Slides