First Passage Quasars: Constraining When Quasars Turn on

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SINGLE AND DOUBLE BLACK HOLES IN GALAXIES, August 24, 2011
How/When QSOs Turn on

**Galaxy Mergers** (e.g., Mihos & Hernquist 1996)
Can occur during two phases
a) After First Passage

Tidal torques $\rightarrow$ Bar Formation $\rightarrow$ Gaseous Inflow

$\approx 100$ kpc
How/When QSOs Turn on

Galaxy Mergers (e.g., Mihos & Hernquist 1996)
Can occur during two phases
a) After First Passage

b) During Final Coalescence

Secular Process: i.e. “Non-Merging”
a) Recycled gas
   (Ciotti & Ostriker 2007)
b) Wild Disk Instabilities
   (Bournaud+ 2011)
How/When QSOs Turn on Galaxy Mergers (e.g., Mihos & Hernquist 1996) can occur during two phases:

1. After First Passage
2. During Final Coalescence

Secular Process: “Non-Merging”

a) Recycled gas (Ciotti & Ostriker 2007)
b) Wild Disk Instabilities (Bournaud+ 2011)
First Passage Quasar

- A quasar that has been triggered during the first passage of a merger event

- Expect a companion galaxy at \(~50\) kpc with comparable mass to quasar host

- Companion galaxy does not necessarily have to be a quasar as well
$z = 0.369$ quasar
\( z = 0.3693 \)

\( \Delta v = 159 \pm 20 \text{ km/s} \)

\( b = 38 \text{ kpc} \)

- QSO photoionizing a bridge of material connecting the two galaxies

- Separation & kinematics consistent with a first passage merger

- Inferred companion galaxy SFH is consistent with a burst triggered during first passage of interaction

$\Delta z < 3\sigma_z$

Completeness Limit = 1:8
Ingredients

- Need a catalog of quasars where we have large numbers at distances where we can expect to see companions
  - \( z < 0.2 \) quasars from Schneider+2010 catalog
- Want photometric redshifts and stellar masses of companion galaxies
  - Obtainable from SDSS photometry
- Want mass of quasar host galaxy
  - Use SMBH mass estimated by Shen+2010 combined with Magorrian Relation
Interlopers

- Generous cut in photometric redshift \( (\Delta z < 3\sigma_z) \) results in a large number of interlopers meeting our criteria

- So we need to compare with a set of control fields to subtract the background
Perform the same experiment on two sets of control fields:
1.) Empty Sky
2.) Mass-matched Control Sample
   - Magorrian Mass is \( M_{\text{magor}} \) not an ideal proxy for stellar mass
   - compare luminosity functions at distance between 1–1.2 Mpc
   - Find a factor of 2 correction
Detected Excess

Matched Excess = 0.08 ± 0.02
Random Excess = 0.24 ± 0.03

- Black: SDSS QSOs
- Green: Matched Control
- Red: Random Sky

Average Number per QSO vs. $\log \frac{M_{\text{major}}}{M_{*, \text{companion}}}$
$\Delta z < 3\sigma_z$
Quasar Triggering Toy Model

![Graph](image)

- $t_{qso}$
- $\phi_{lag}$

Separation [kpc] vs Time [Myr]
Completeness Correction

Cosmological Orbit Distribution (e.g. Wetzel+2010)

Parameterize a Model for QSO Triggering $t_{QSO}$ $\phi_{lag}$

GalMer: Galaxy Merger Simulation Database

Correction Factor

Apply Cut of 30-80 kpc

t_{QSO}=100$ Myr; $\phi=250$ Myr

Projected Separation [kpc]
$t_{\text{qso}} = 10 \text{ Myr}$

$\phi_{\text{lag}} = 250 \text{ Myr}$

Matched Excess = 0.08 $\pm$ 0.02

$\times 2.38 = 19 \pm 5\%$
Assume a fraction of quasars triggered during first passage → infer triggering properties
Future Work

- Study interacting pairs where one galaxy is in a quasar phase
  - Awaiting HST data from successful proposal to study morphologies of galaxies in same merger stage
  - Try to answer the question of why one quasar is on and the other is not
  - Comparison of SMBH and galaxy masses at this intermediate stage will provide insights on evolution along the Magorrian relation

- Search for more pairs with quasar photoionized extended tidal features
  - Study quasar lifetime, isotropy, and triggering
Summary

- Statistical study performed studying companions near $z<0.2$ SDSS QSOs to determine which fraction of quasars are triggered during the first passage stage of a merger

- Determined a significant excess ($>8\pm2\%$) companions with mass ratio $>1:8$ near quasars (30-80 kpc) interpreted as galaxies interacting with quasar hosts

- Used simulations to estimate a completion correction which increases fraction to $\sim20\%$
Open Questions

- What is the dominant triggering mechanism of quasars?

- What does this teach us about SMBHs and their effect on galaxy evolution?

- What are the key parameters that determine why in these pairs one galaxy is in a quasar phase and the other is not?
Thank You