Starburst-AGN Connection
Toward the Merger-Driven Unified Model for Triggering Nuclear Activities

Yoshi Taniguchi
Research Center for Space & Cosmic Evolution
Ehime University
NGC 1068 = Archetypical Seyfert

Once upon a time, NGC 1068 was Seyfertized.
Seyfertization

AGN excited state is quantized

Seyfert

triggering

Normal

no fueling
Starburst excited state is quantized

Starburst

triggering

Normal

no trigger
or little gas
Evolutionary Unified Model

Seyfert

Starburst

Normal


(Taniguchi & Wada 96 [TW96], ApJ, 469, 581)
Always Model

A single mechanism works for Seyfertization.
Other mechanisms never work.

Sometimes Model

Several mechanisms work sometimes for Seyfertization.

Which do you like?

The Unified Model

No Unified Model
Triggering Mechanisms of AGNs
- What drives gas fueling onto a SMBH?

Bar
Secular evolution
Galaxy interaction
Minor merger
Major merger

Quasar Formation
The Case of Quasars

Gas-rich, major merger driven quasar formation

(Hopkins+08, ApJS, 175,356)
starburst comes first

AGN comes later

(Hopkins+08, ApJS, 175, 356)
Gas-rich major merger-driven quasar formation model explains everything!

- $\rho_L$ evolution
- lum. function
- quasar fraction
- host colors
- clustering

(Hopkins+08, ApJS, 175,356)
How about Seyferts?
Triggering Mechanisms of AGNs - What drives gas fueling onto a SMBH? - Seyfert Formation ???

Bar
Secular evolution
Galaxy interaction
Minor merger

Major merger
Quasar Formation
Bar-driven gas fueling?

\( f_{\text{bar}} \) is the same (~70%) both for Seyfert & normal


No reason to adopt this idea
Secular evolution?  

Non sense

Galaxies are not always ISOLATED
Interaction-induced fueling?

\( f_{\text{companion}} \sim 10\% \text{ at most} \)

for Seyferts

(Rafanelli+95, AJ, 109, 1546)

No reason to adopt this idea
Minor-merger-induced fueling

\[ f_{\text{satellite}} \sim 100\% \]

All galaxies have satellites

A way to UNIFIED MODEL!
Minor Merger Model explains Random Orientation of NLRs in Seyferts

NLR axis // disk spin axis for S1 Random orientation for S2

Bar-driven & Secular evolution models cannot explain

But, m2 mode ???

Minor-merger models can explain
If the partner is nucleated, two SMBHs can inspiral and then merge into one

~ 1 Gyr journey

(Satoru Iguchi)

(see also Khan+12 ApJ, 756, 30)
Minor merger with a nucleated satellite

Host is not so disturbed!

SMBH binary in a single cusp after 40 Myr

(Khan+12 ApJ, 756, 30)
Minor merger with a nucleated satellite

\[ T_{\text{coal}} \sim 3 \text{ Gyr} \]

\[ \Delta R_{\text{BH}}(\text{pc}) \]

sinking by dynamical friction with DM & stars

coalescence by GW

\[(\text{Khan}+12 \text{ ApJ, 756, 30})\]
What drives Seyfertization?

Minor Mergers with a Nucleated Satellite

$M32 = \text{nucleated satellite with } M_{BH} \sim 10^6 M_{\text{sun}}$

$M31 \text{ will be Seyfertized}$

$LMC = \text{non-nucleated satellite}$

$MW \text{ will NOT be Seyfertized}$
Billiard Classification of Triggering Mechanisms
bar
secular evolution

no break shot

minor merger
major merger
with a nucleated partner

nice break shot

interaction

miss break shot
Triggering Mechanisms of AGNs

Bar
Secular evolution
Interaction

Minor merger
Major merger

non-nucleated

no nuclear activities

nucleated

starburst
AGN
MERGER-Driven *ALWAYS* MODEL for Triggering AGNs

ONLY Major Merger $\rightarrow$ Quasar
(see also Hopkins+08, ApJS, 175, 356)
(see also Taniguchi+12, ApJ, 753, 78)

ONLY Minor Merger $\rightarrow$ Seyfert
How about Starburst-AGN Connection?
starburst comes first

AGN comes later

(Hopkins+08, ApJS, 175, 356)
Nucleated Minor Merger Drives Nuclear Starburst Prior to Seyfert Activity

SMBH binary makes strong shocks, driving nuclear starburst


After that, the satellite nucleus is going to fuel

Evolutionary connection from starburst to AGN

Starbursts: more disturbed early phase

Seyferts: little disturbed late phase

Starburst comes first

AGN comes later

(see also Hopkins+08, ApJS, 175,356)
Merger-Driven
EVOLUTIONARY Unified Model
for Triggering Nuclear SB & AGNs

(Taniguchi 13, ASPC, 477, 265)
How to obtain observational evidence

1. Kinematic Survey for Double Nuclei
2. Deep Imaging Survey for Minor Merger
3. ALMA Survey for Nuclear Asymmetry
Kinematic Survey for Double Nuclei

1. Double-Peaked NLR
   - Shen+11 ApJ, 735, 48 (SDSS) ~30 objects
   - Ge+12 ApJS, 201, 31 (SDSS) ~3000 objects
   - Comerford+13 ApJ, 777, 64 (AGES) several objects
   - Shi+14, arXiv:1404.7218 (LAMOST) ~200 objects

2. CCF Search for Multiple NLR
   - Garcia-Lorenzo 13, MN, 429, 2903
     [multiple NLRs in NGC 1068]

3. PCA Search for SMBH Binary in BLR
   - Eracleous+12, ApJS, 201, 23
Double-NLR System

(Shen+11 ApJ, 735, 48)
Deep Imaging Survey for Minor Merger

1. Imaging Survey for Merger Remnants

2. Imaging Survey for Offset Nuclei
e.g., Comerford+13 ApJ, 777, 64

3. Imaging Survey for Recoiling SMBHs
e.g., Civano+10 ApJ, 717, 209

Also, Spectroscopic Survey for Recoiling SMBHs (shift between NRL & BLR)
e.g., Lusso+14, MN, 441, 316
Deep Imaging Survey for Minor Merger

What shall we do with HSC?
# HSC-SSP

Wide-Field Imaging with Hyper Suprime-Cam: Cosmology and Galaxy Evolution

(Miyazaki et al.)

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<tr>
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<td>15</td>
<td>grizy+3NBs (r \approx 27)</td>
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<tr>
<td>Ultradeep</td>
<td>3.5</td>
<td>2</td>
<td>grizy+3NBs (r \approx 28)</td>
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</table>
We can conduct Systematic Search for Minor Mergers in a Large Sample of Nearby Galaxies
What shall we do with ALMA?
ALMA Survey for Nuclear Asymmetry

Targets: Nearby Nuclear Starbursts & Seyferts

Working hypothesis

All Nuclear Starbursts & Seyferts came from minor mergers
Prediction

Starburst comes first
Seyfert comes later

Normal : un-disturbed
Starburst : more disturbed $< 10 - 100 \text{ pc}$
Seyfert : little disturbed $< 1 - 10 \text{ pc}$

Let’s confirm using ALMA!
The case of NGC 1068

ALMA Band 9 Continuum  TW96 Simulation
We have to make NICE BREAK SHOT

Thank you very much!