

Starburst-AGN Connection

Viewed from HSC Survey Data



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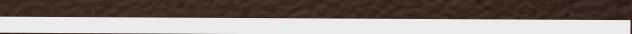
Triggering Mechanisms of AGNs

**- What drives gas fueling
onto a SMBH ? -**

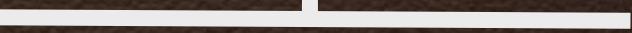
Seyfertization

*(see for Seyfertization,
Taniguchi 1987, ApJ, 317, L57)*

Seyfert



Normal



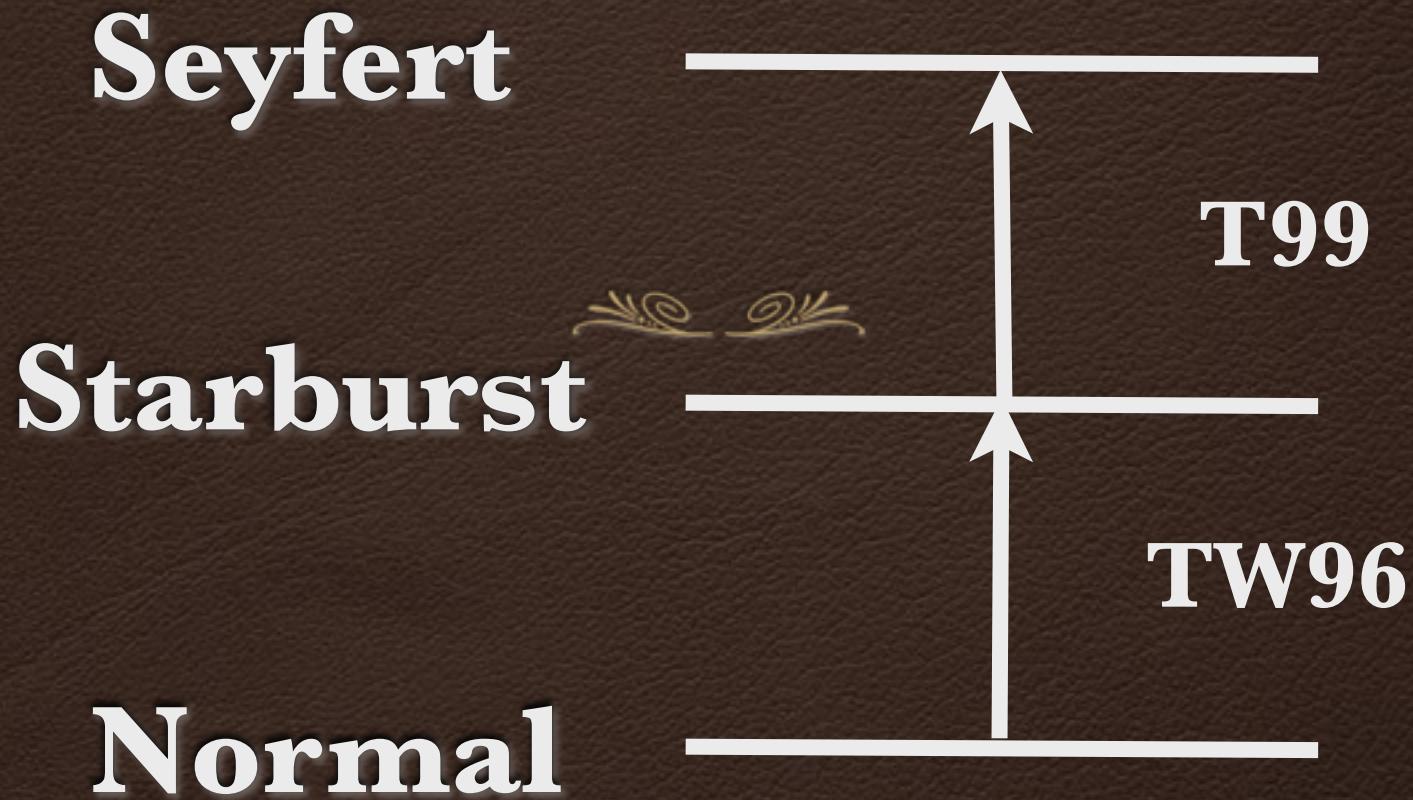
Starburst



Normal



Evolutionary Unified Model



Which do you like ?

Always Model

A single mechanism
works for Seyfertization.

Other mechanisms
never work.



The Unified Model

Sometimes Model

Several mechanisms
work sometimes
for Seyfertization



No Unified Model

Which do you like ?

Always Model

A single mechanism
works for Seyfertization.

Other mechanisms
never work.



The Unified Model

Galaxies are simple

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

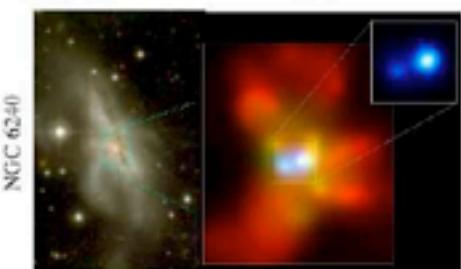
*Gas-rich, major merger driven
quasar formation*

*(Sanders+88, ApJ, 325, 74)
(Hopkins+08, ApJS, 175, 356)*

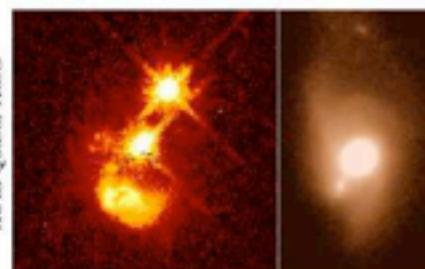
(c) Interaction/“Merger”



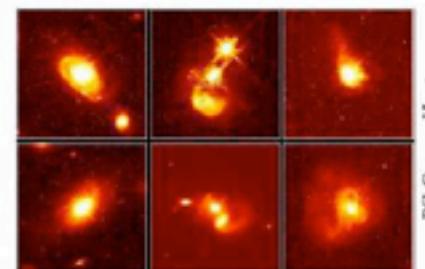
(d) Coalescence/(U)LIRG



(e) “Blowout”



(f) Quasar



- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

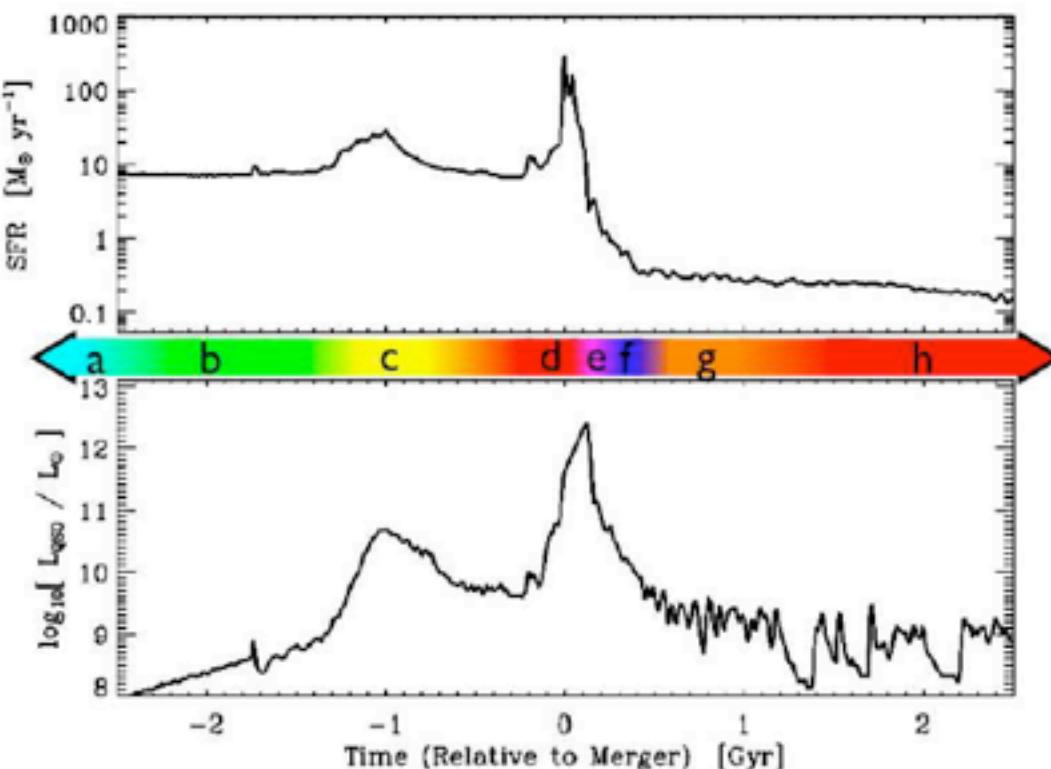
- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host high Eddington ratios merger signatures still visible

- dust removed: now a “traditional” QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(b) “Small Group”



- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently



(a) Isolated Disk



- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- “Seyfert” fueling (AGN with $M_{\text{bul}} > 23$)
- cannot redden to the red sequence

(g) Decay/K+A



- QSO luminosity fades rapidly
 - tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- “hot halo” from feedback
 - sets up quasi-static cooling

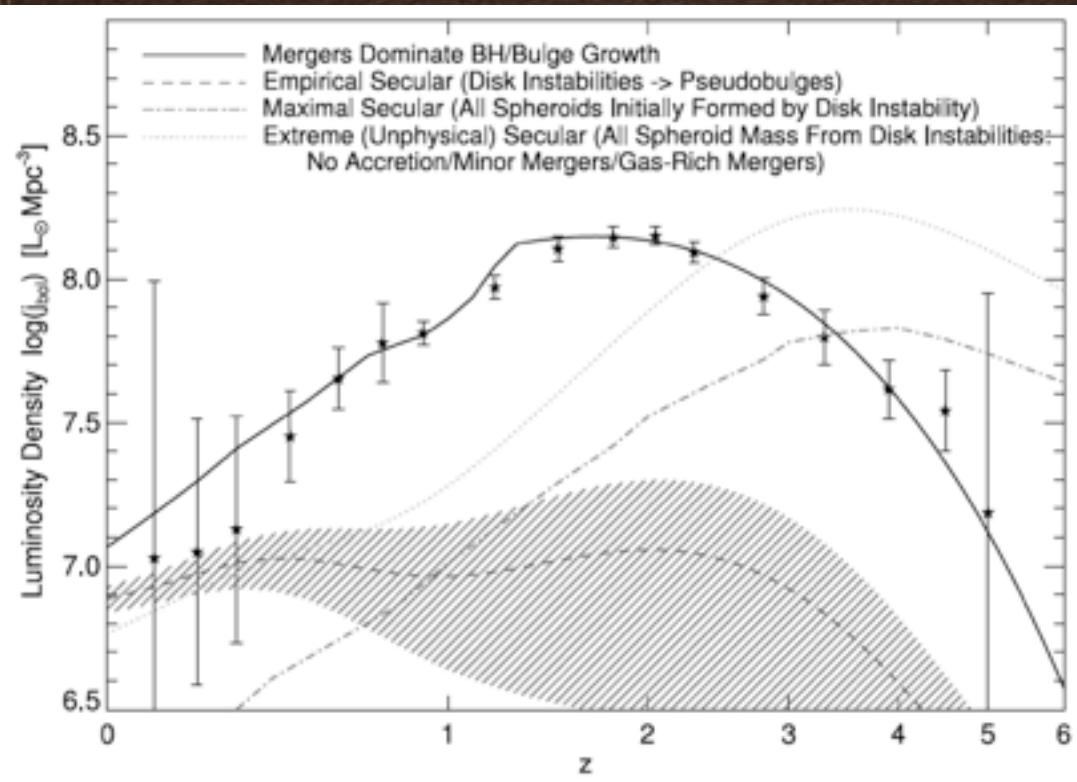
(h) “Dead” Elliptical



- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to “large group” scales: mergers become inefficient
- growth by “dry” mergers

(Hopkins+08, ApJS, 175, 356)

Gas-rich major merger-driven quasar formation model explains everything !



- ρ_L evolution
- lum. function
- quasar fraction
- host colors
- clustering

(Hopkins+08, ApJS, 175, 356)

What shall I do ?

normal galaxy

Bar-driven gas fueling?

f_{bar} is the same ($\sim 70\%$)

BOTH for Seyf. & normal

(Mulchaey & Regan 97, ApJ, 482, L135)

(Hunt+99, ApJ, 510, 637)

(Lee+12, ApJ, 750, 141)

No reason to adopt this idea



No fit to ALWAYS MODEL

Secular evolution ?

Non sense



Galaxies are not always ISOLATED



No fit to ALWAYS MODEL

*Angular momentum transfer
from galactic disk
to accretion disk*

*have to reduce angular momentum
by a factor of 10^5
for typical Seyferts
(e.g., Peterson 97, Chap 3)*

Impossible !

Interaction-induced fueling ?

$f_{\text{companion}}$ $\sim 10\%$ *at most*

for Seyferts

(Rafanelli+95, AJ, 109, 1546)

No reason to adopt this idea



No fit to ALWAYS MODEL

Minor-merger-induced fueling

$f_{\text{satellite}} \sim 100\%$



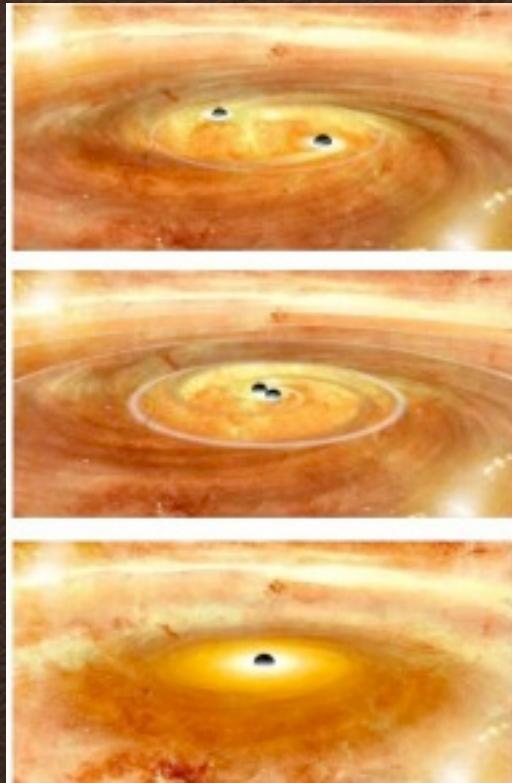
All galaxies have satellites



*Fit to **ALWAYS MODEL !!!***

*If the partner is nucleated,
two SMBHs can inspiral
and then merge into one*

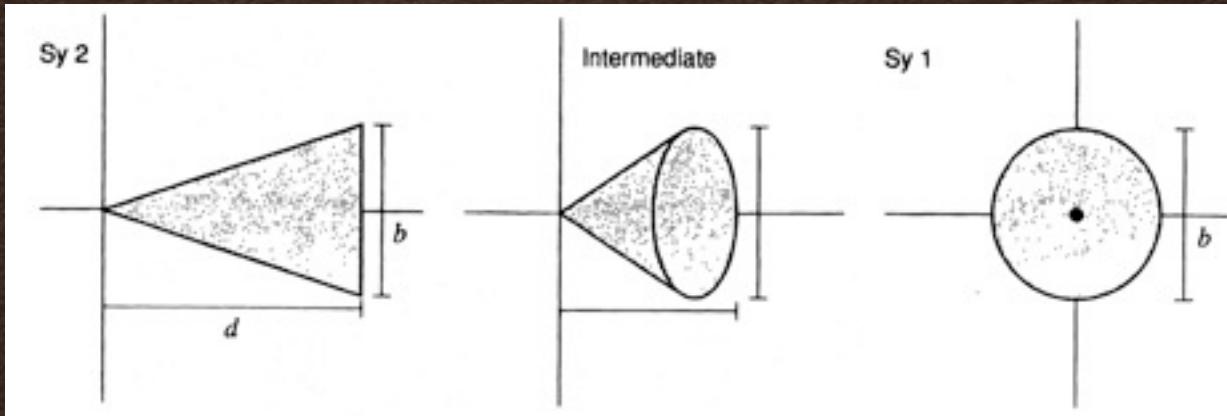
*~ 1 Gyr
journey*



(Satoru Iguchi)

(see also Khan+12 ApJ, 756, 30)

Minor Merger Model explains Random Orientation of NLRs in Seyferts



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

(Schmidt & Kinney 96, ApJ, 463, 498)

What drives Seyfertization ?

*Minor Mergers
with a Nucleated Satellite*

(Taniguchi 99, ApJ, 524, 65)

Billiard Classification of

Triggering Mechanisms



**bar
secular evolution**

no break shot

**minor merger
major merger**

nice break shot

interaction

miss break shot

**One SMBH accreted onto
a primary SMBH**



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

ONLY Major Merger → *Quasar*

(Sanders+88, ApJ, 325, 74)

(see also Hopkins+08, ApJS, 175, 356)

(see also Taniguchi+12, ApJ, 753, 78)

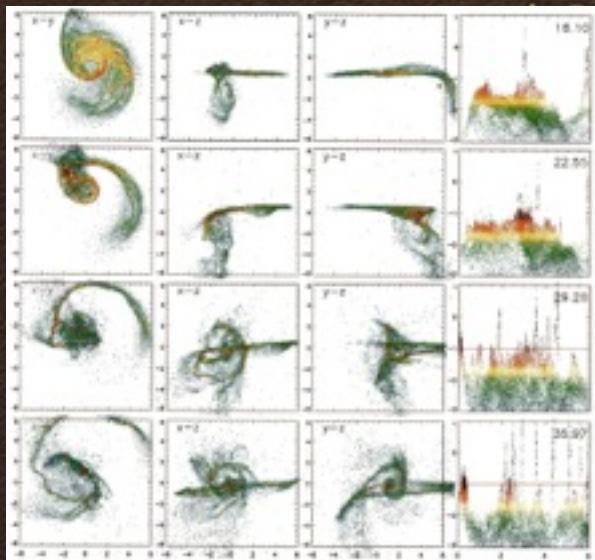
ONLY Minor Merger → *Seyfert*

(Taniguchi 99, ApJ, 524, 65)

*How about
Starburst-AGN
Connection ?*

*Major-Merger Drives
Ultraluminous Starburst
Prior to Quasar*

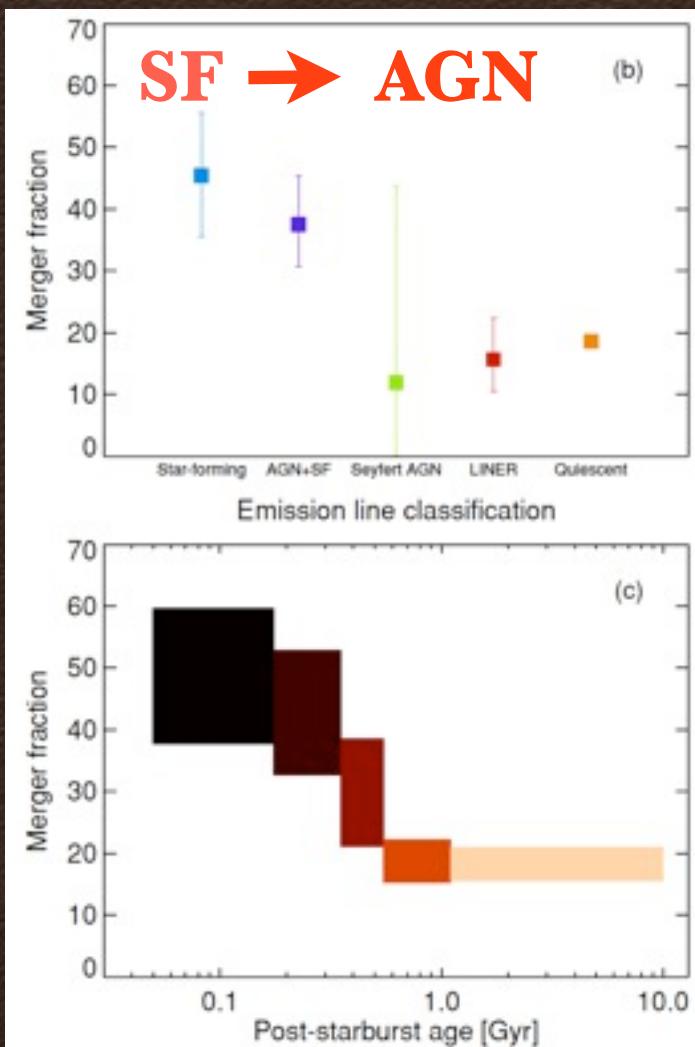
*Minor-Merger Drives
Nuclear Starburst
Prior to Seyfert*



*SMBH binary makes
strong shocks,
driving nuclear starburst*

(Taniguchi & Wada 1996, ApJ, 469, 581)

Evolutionary connection from starburst to AGN ?



*Starbursts:
more disturbed
early phase*

*Seyferts:
little disturbed
late phase*

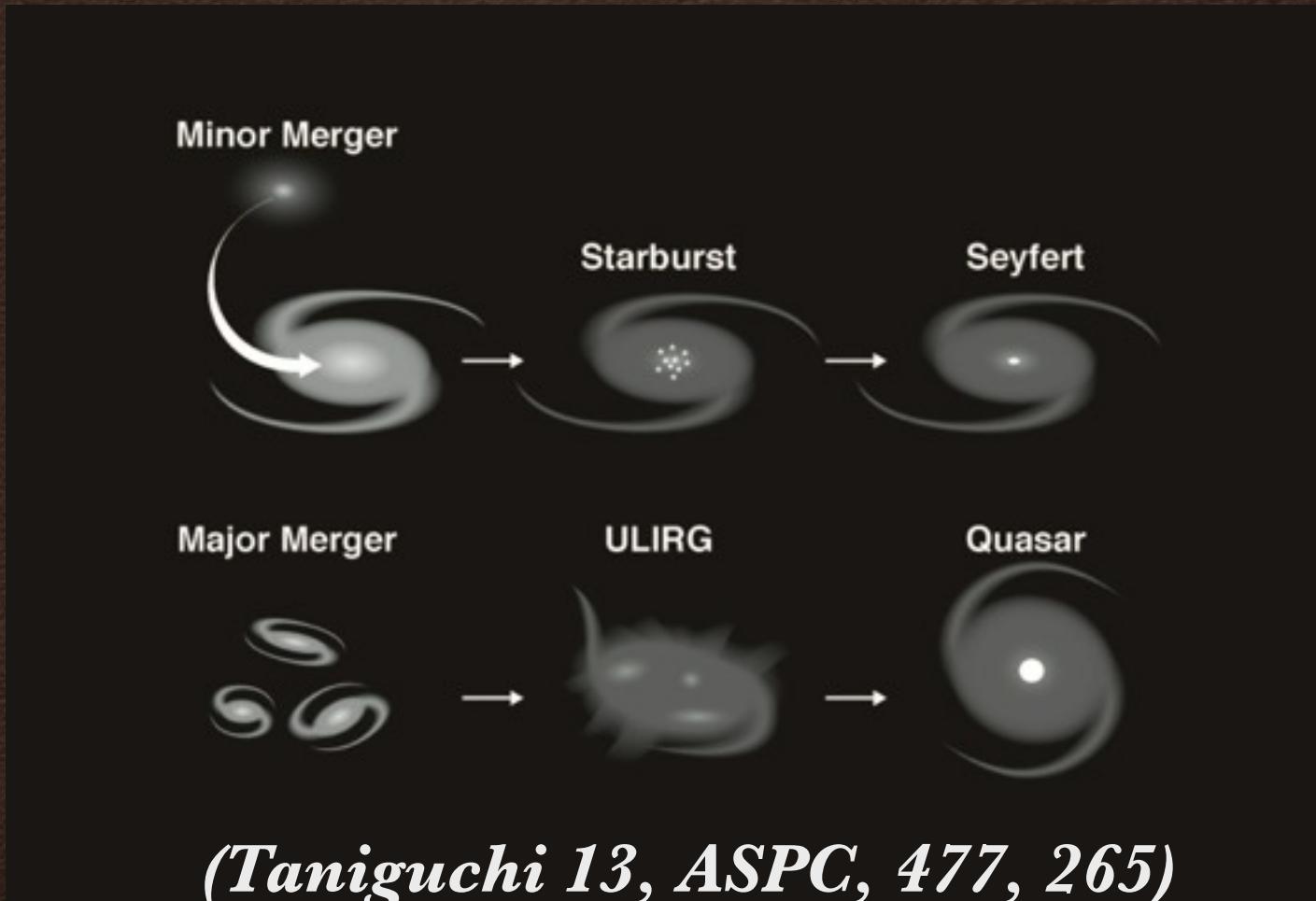
Starburst comes first



AGN comes later

(see also Hopkins+08, ApJS, 175, 356)

Merger-Driven
EVOLUTIONARY Unified Model
for Triggering Nuclear SB & AGNs



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]

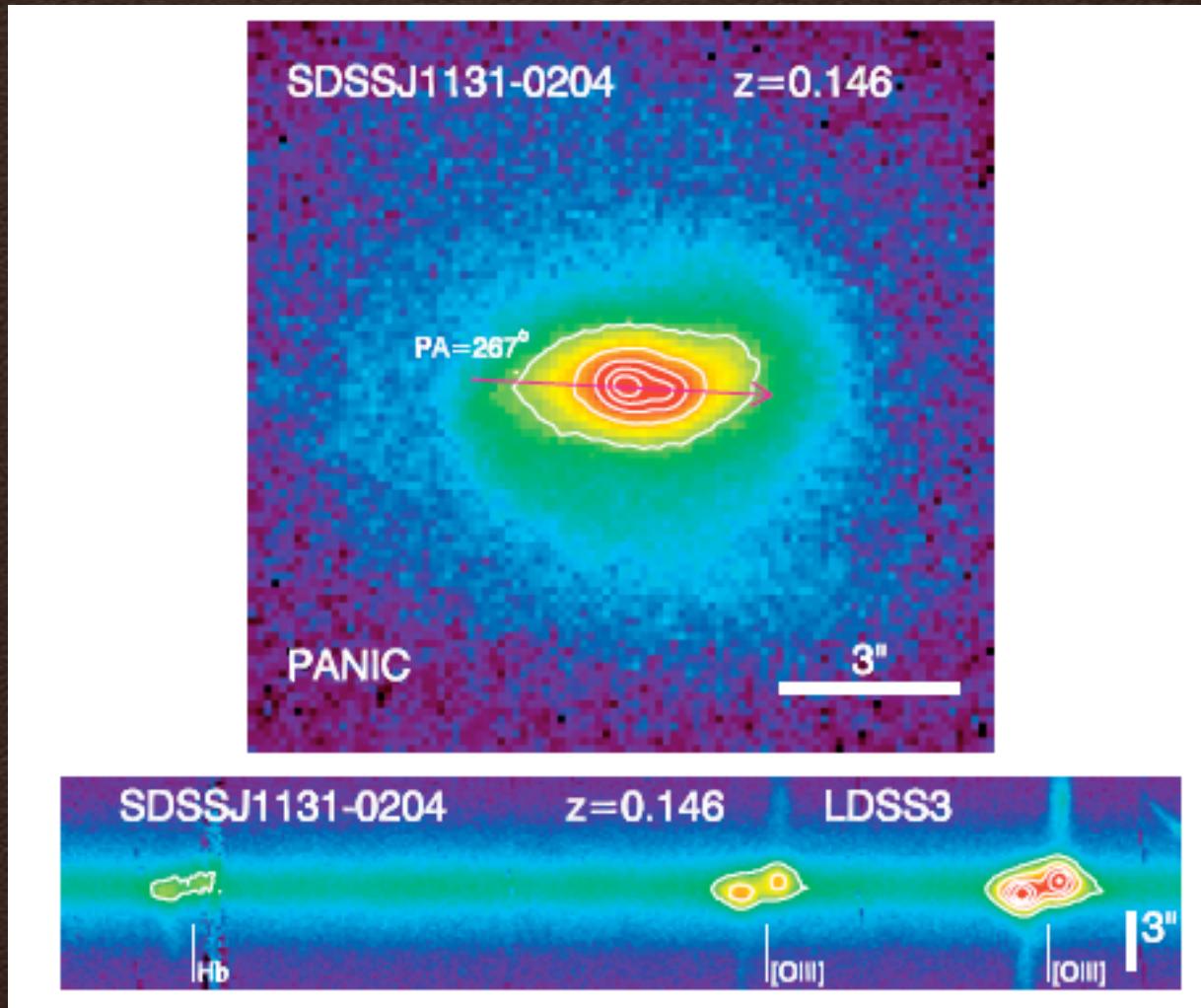
3. PCA Search for SMBH Binary in BLR

Eracleous+12, ApJS, 201, 23

Ju+13 ApJ, 777, 44

Liu+14 ApJ, 789, 140

Double-NLR System



(Shen+11 ApJ, 735, 48)

Deep Imaging Survey for Minor Merger

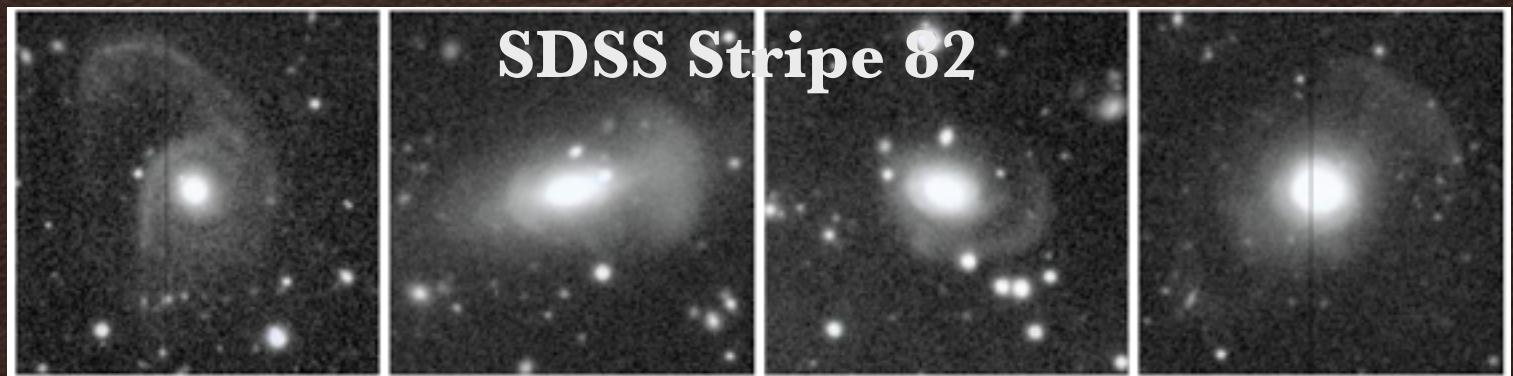
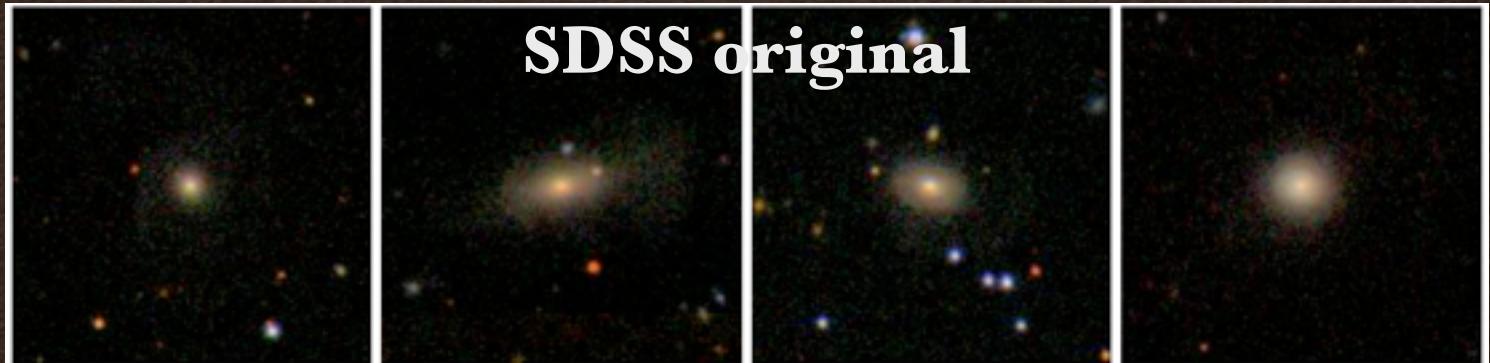
1. Imaging Survey for Merger Remnants
e.g., Schawinski+10, ApJ, 714, L108

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
Lena+14, ApJ, 795, 146

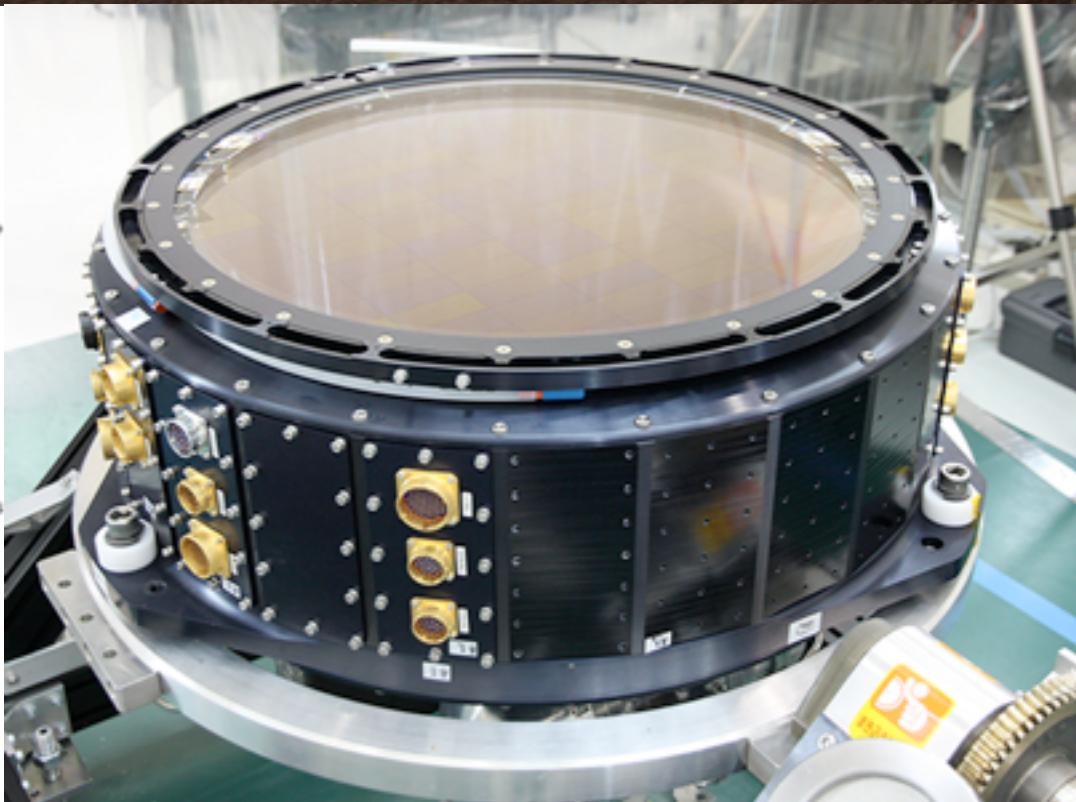
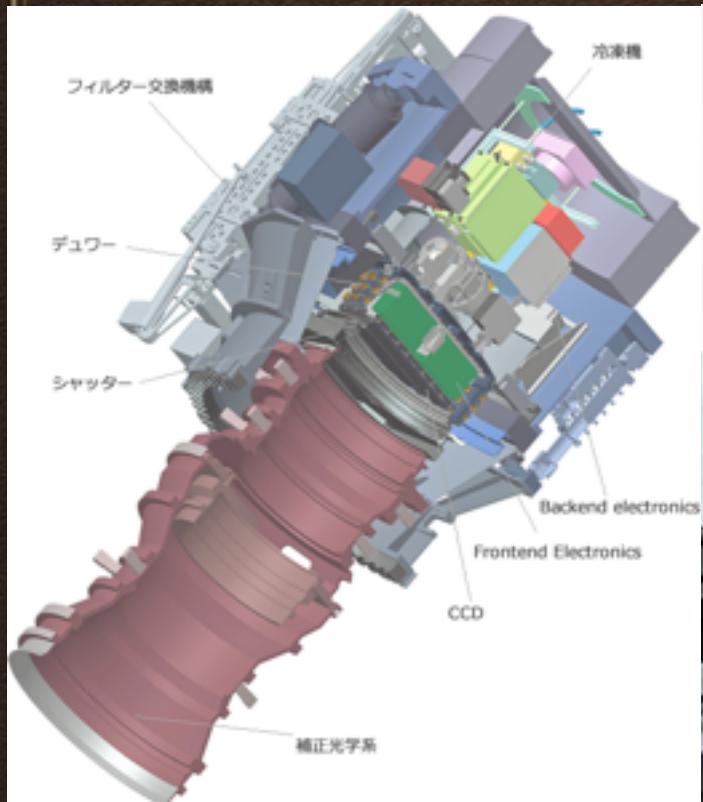
**Also, Spectroscopic Survey for Recoiling
SMBHs (shift between NRL & BLR)**
e.g., Lusso+14, MN, 441, 316

Deep Imaging Survey for Minor Merger



(Schawinski+10, *ApJ*, 714, L108)

What shall we do with HSC ?



HSC-SSP

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

S. Miyazaki et al.



Layer	Area [deg ²]	# of HSC fields	Filters & Depth
Wide	1400	916	<i>grizy</i> ($r \simeq 26$)
Deep	27	15	<i>grizy+3NBs</i> ($r \simeq 27$)
Ultradeep	3.5	2	<i>grizy+3NBs</i> ($r \simeq 28$)

SDSS original $r = 23$

SDSS Stripe 82 $r = 25$

HSC SSP Wide $r = 26$

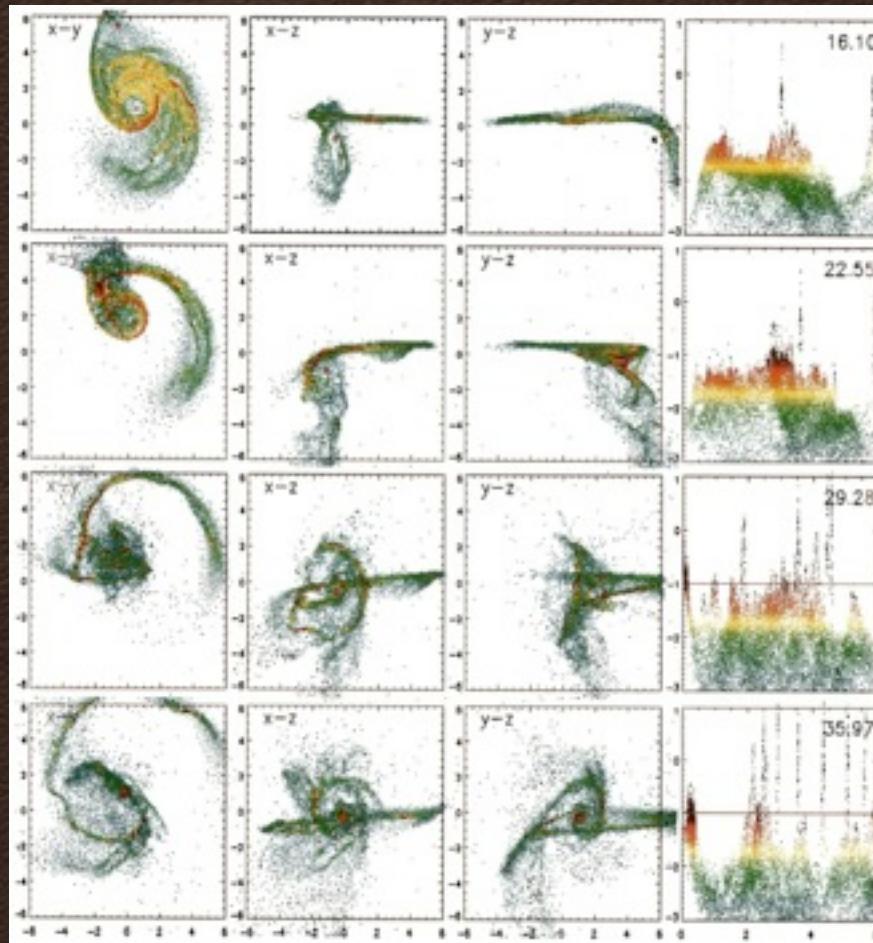


We can conduct
Systematic Search for
Minor Mergers in a Large Sample of
Nearby Galaxies

*What shall we do
with ALMA ?*



ALMA Survey for Nuclear Asymmetry



(*Taniguchi & Wada 1996, ApJ, 469, 581*)

Targets: Nearby Nuclear Starbursts & Seyferts

Working hypothesis

*All Nuclear Starbursts &
Seyferts came from
minor mergers*

Prediction

***Starburst comes first
Seyfert comes later***

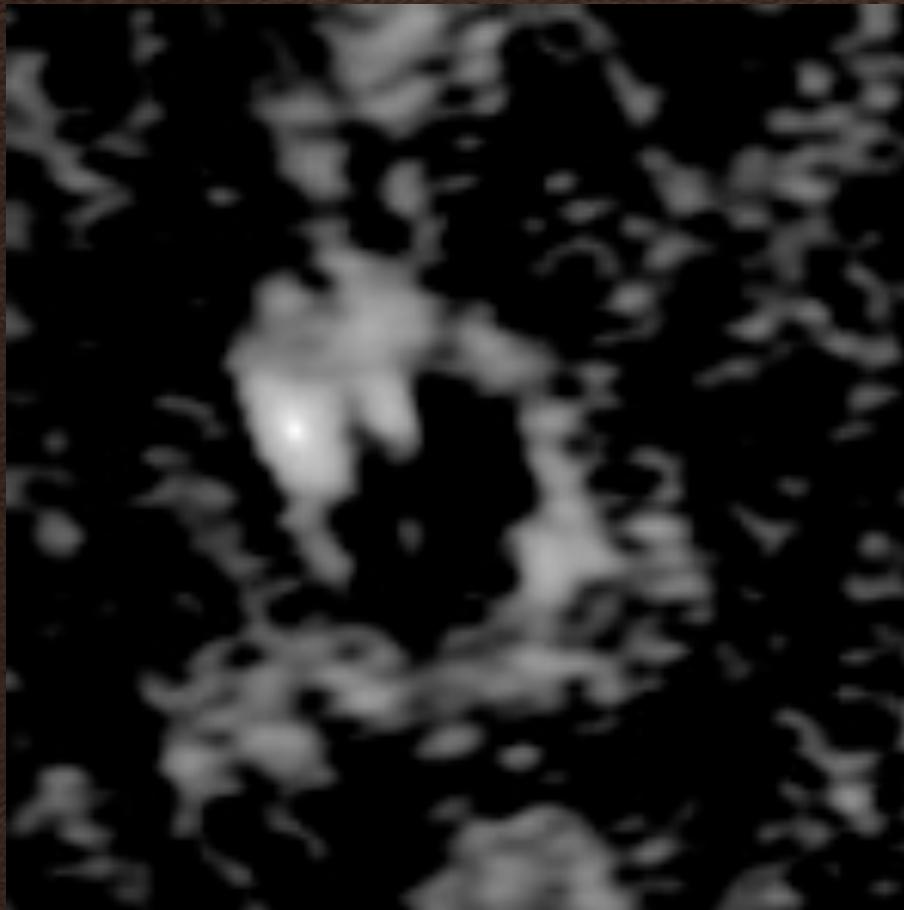
Normal : un-disturbed

Starburst : more disturbed $\frac{< 100 \text{ pc}}{\text{}}$

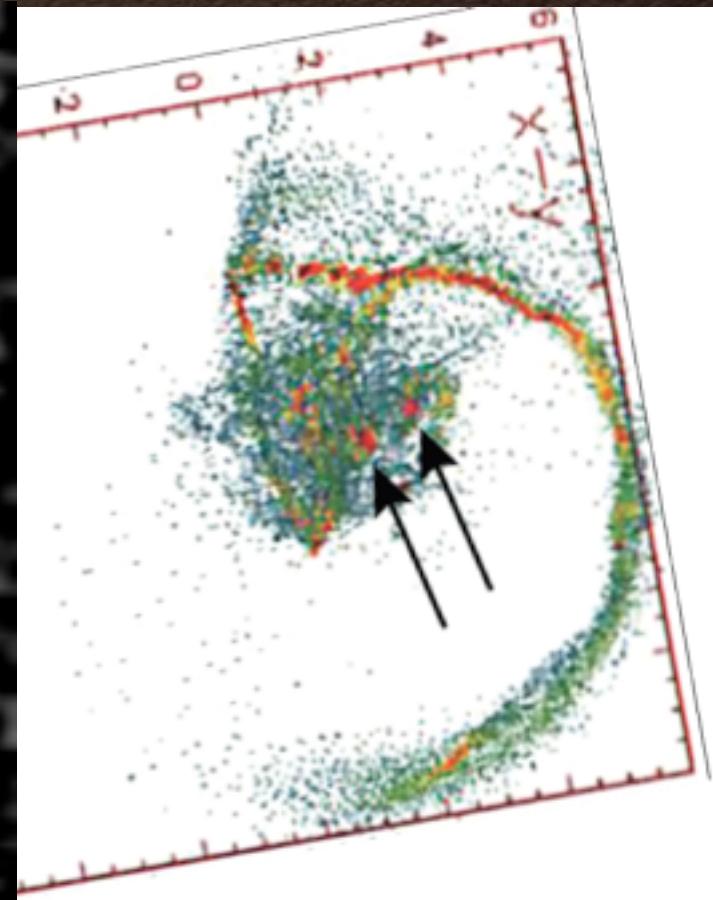
Seyfert : little disturbed $\frac{\text{}}{< 10 \text{ pc}}$

Let's confirm using ALMA !

The case of NGC 1068



ALMA Band 9 Continuum



TW96 Simulation

*I have to make
BREAK SHOT*

Thank you very much !



BLUE BACKS

クエーサーの謎

宇宙でもっともミステリアスな天体

谷口義明

クエーサーの正体は、
超大質量ブラックホール
だった!?

巨大ブラックホール と 宇宙

谷口 義明 和田 桂一著

丸善出版