Minor-Merger-Driven Nuclear Activity in Seyfert Galaxies

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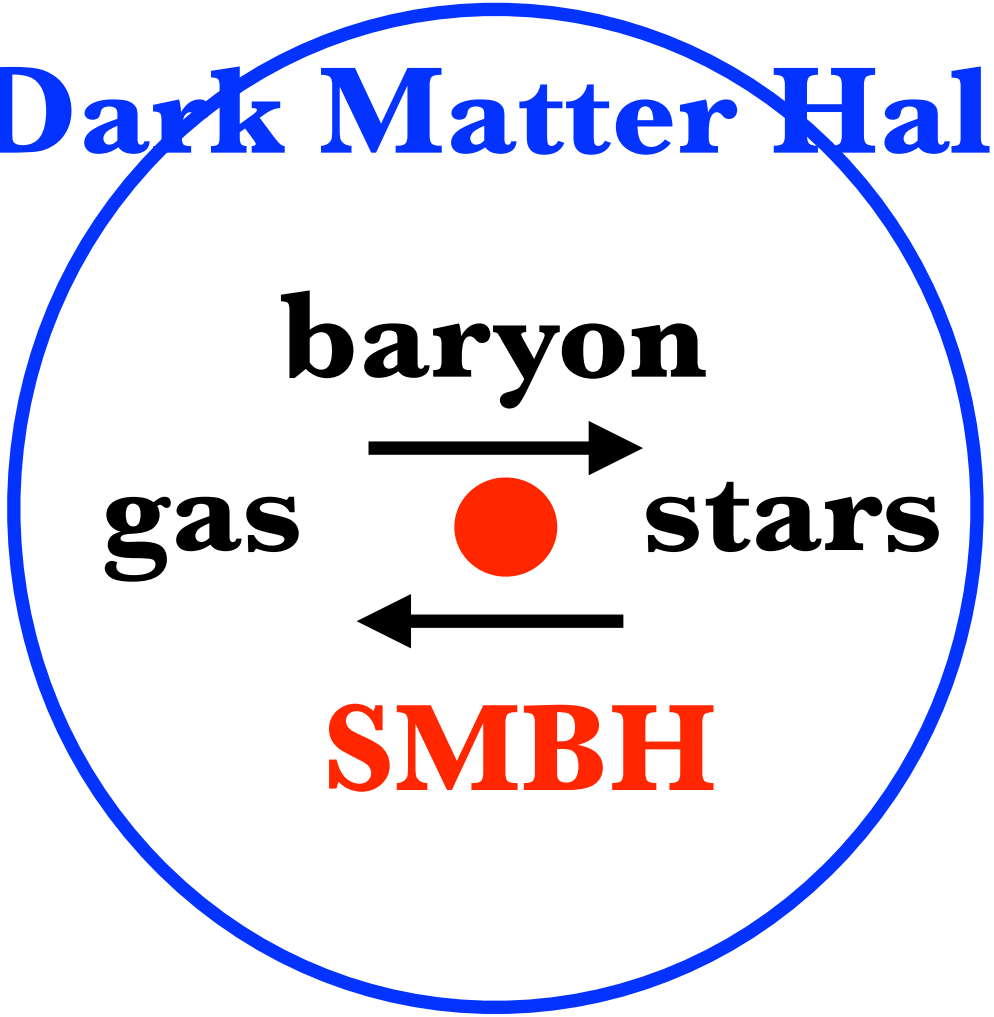
What are galaxies ?



Galaxies are simple

However …

Galaxies are not isolated

Interact with their environ

A question arises as …

How many SMBHs in a galactic center?

Only one ?

Two, or more ?

Difficult to find binary SMBH even in nearby Seyfert galaxies

$M_\bullet \sim 10^7 M_{\rm sun}$ for Seyferts

$r_\bullet \sim 10^{12}$ cm

$r_{\rm AD} \sim 10^{15}$ cm ~ 0.001 pc

Distance of 2nd SMBH $d_2 < 0.1$ pc

$< 10^{-3}$ arcsec @ D=10 Mpc

How many SMBHs in a galactic center?

Only one ?

Two, or more ?

No firm answer, today

AGN paradigm

The central engine
=
Single, accreting SMBH

If this is the case,

What drives the engine ?

Triggering mechanism ?

Triggering = Gas fueling

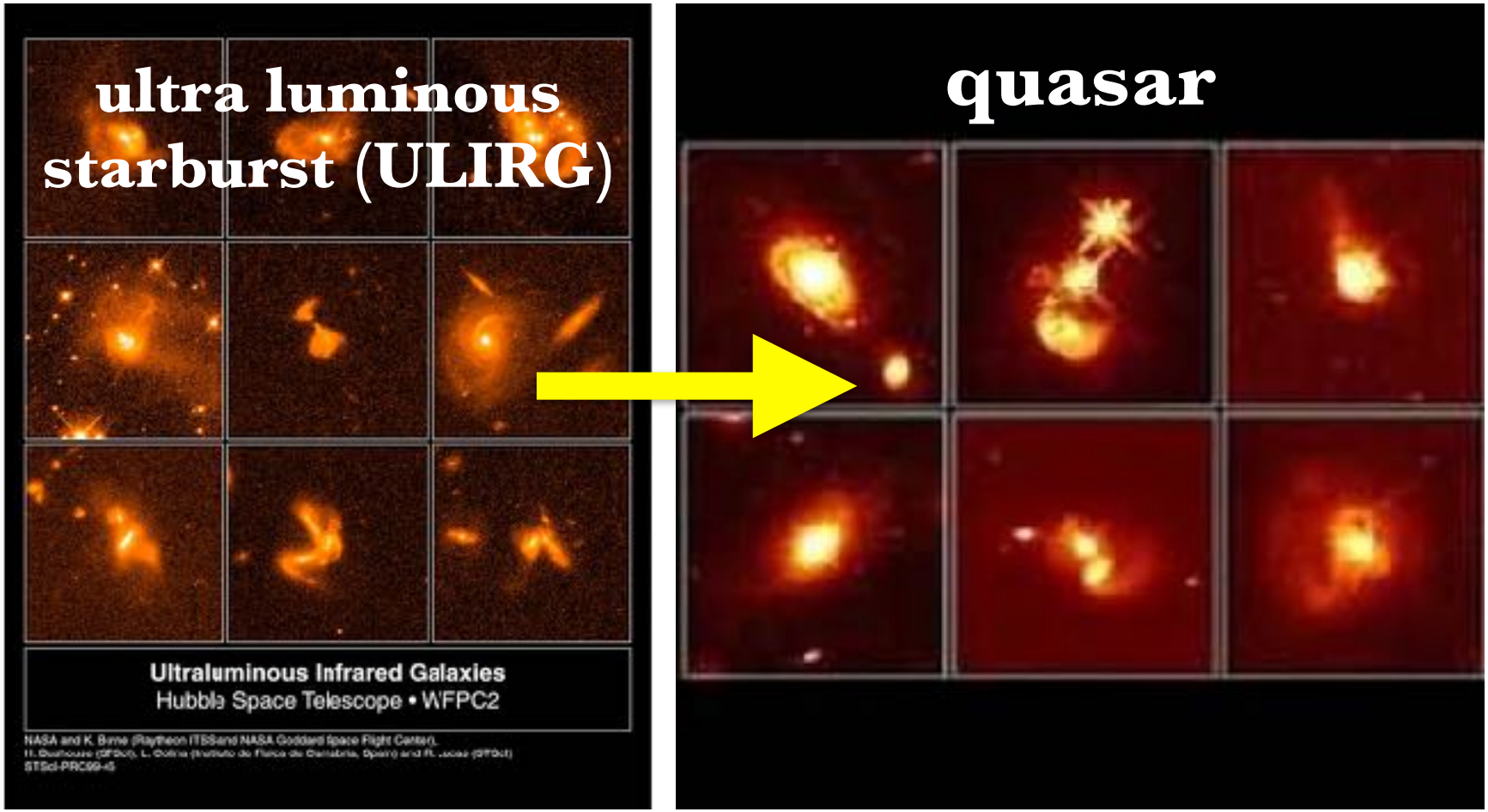
For Seyferts

secular evolution
bar-driven inflow
galaxy interaction
minor merger

major merger

For quasars

Major mergers between gas-rich galaxies drive quasar formation



(NASA/ESA/STScI)

Important Suggestion from quasar formation

Starburst comes first and then AGN comes later

Starburst-AGN connection

Seyfertization

THE ASTROPHYSICAL JOURNAL, 317:L57–L61, 1987 June 15

BLUEWARD ASYMMETRICAL EMISSION-LINE PROFILES OF A STARBURST-NUCLEUS GALAXY MARKARIAN 52

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Therefore, when we adopt an idea that the broad component is photoionized by putative dilue power-law continuum sources, we may observe just the onset of *Seyfertization* in the nucleus.

(Taniguchi 1987, ApJ, 317, L57)

AGNs are transient

n_{quasar} peaks at $z \sim 2$ - 3

Few quasars in the local universe

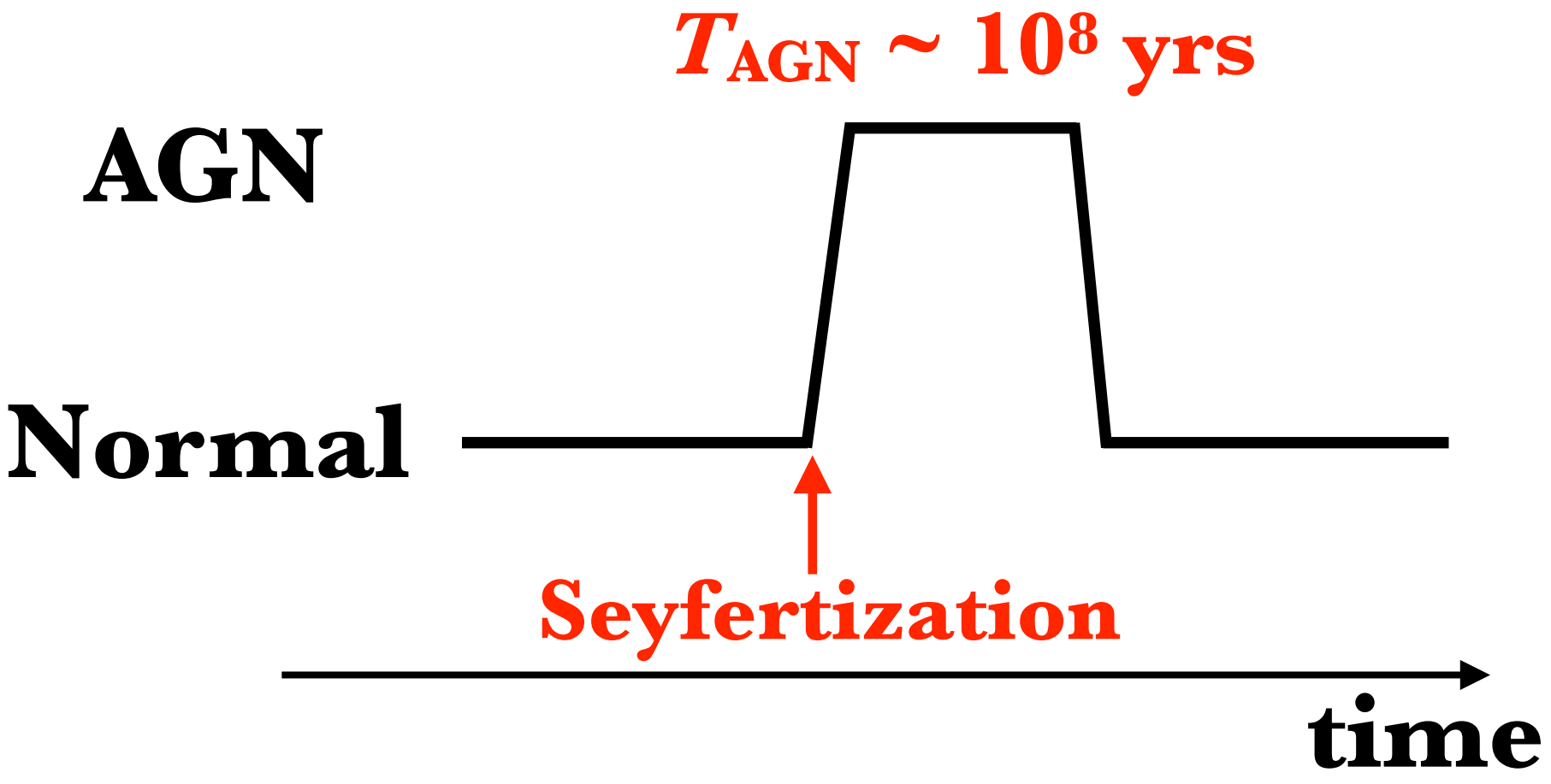
The dead quasar problem

(Rees 1990, Science, 247, 817)

f_{Seyfert} ~ several % of spirals

$T_{\mathrm{AGN}} \sim 10^8$ yrs

Important Suggestion



Important Suggestion from theory

Serious problem
in angular momentum transfer
from kpc-scale to 10^{-3} pc-scale

(e.g., Peterson, 1997, Introduction to AGN)

Ordinary processes
may not work

Seyfertization

nucleated

Only minor mergers drive Seyfert activity

(Taniguchi 1999, ApJ, 524, 65)

Nucleated or Not

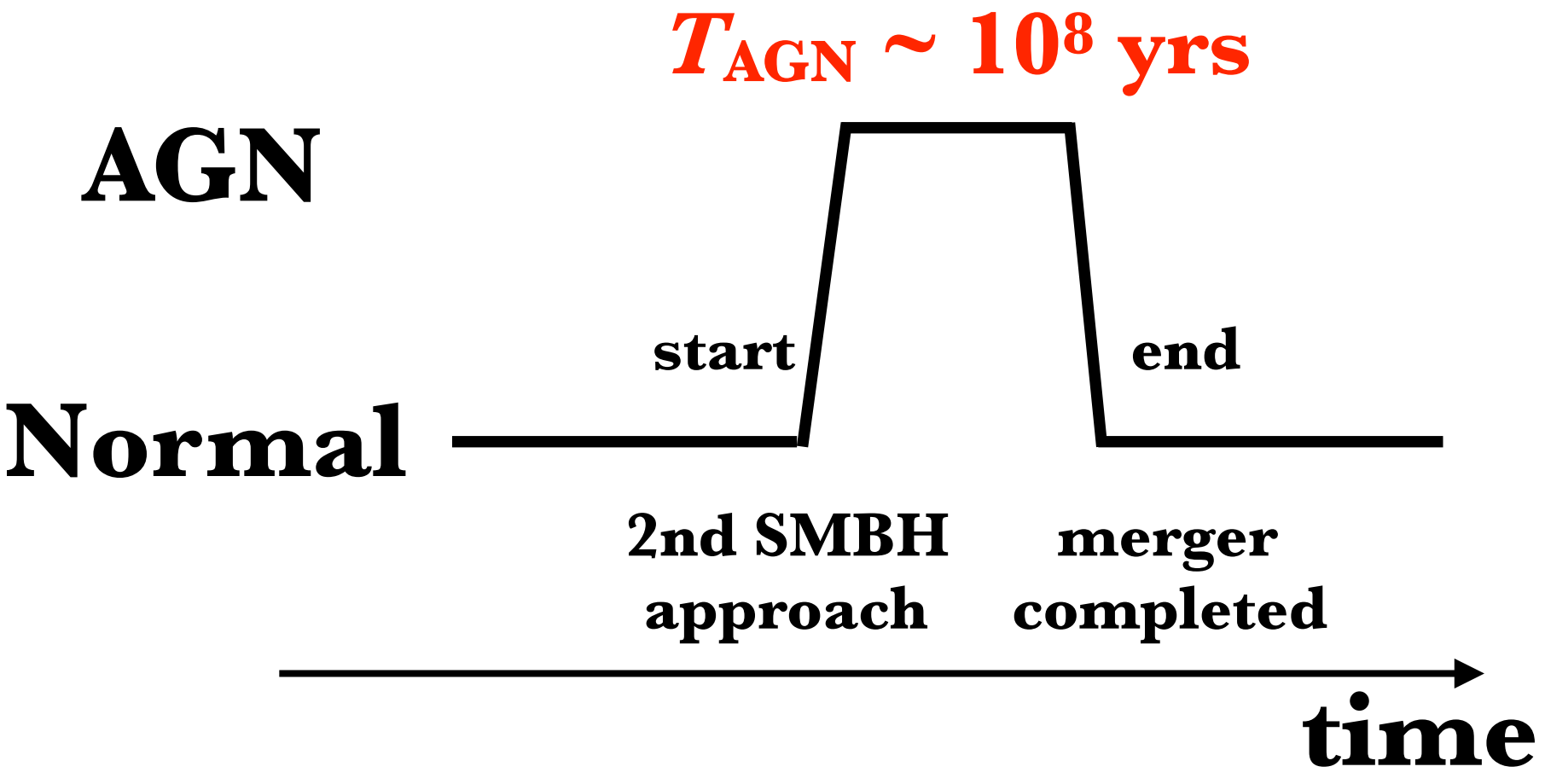
M32
= nucleated satellite
(M_{SMBH} ~ 10^6 M_{sun})

M31 will be Seyfertized

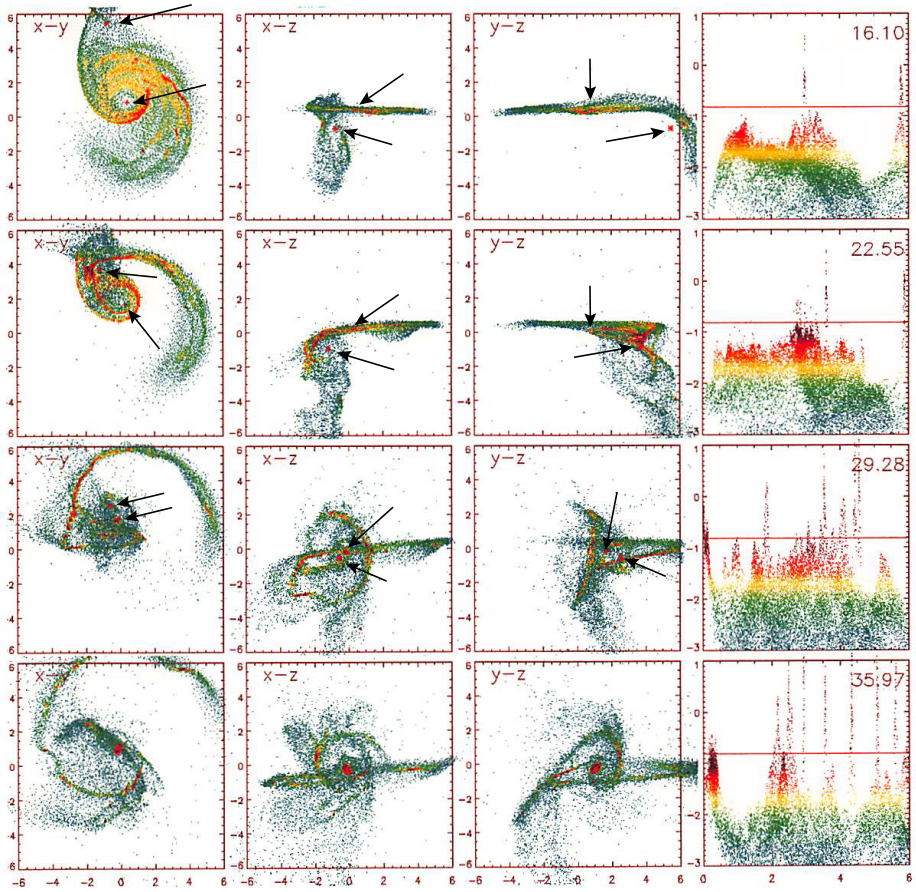
LMC =
non-nucleated satellite

MW will NOT be Seyfertized

Nucleated-merger-driven fueling has a finite lifetime



Nucleated Minor Merger drives nuclear starburst



$M_{\mathrm{SMBH1}} = 10^7\ M_{\mathrm{sun}}$

$M_{\mathrm{SMBH2}} = 10^6\ M_{\mathrm{sun}}$

← Jeans criterion

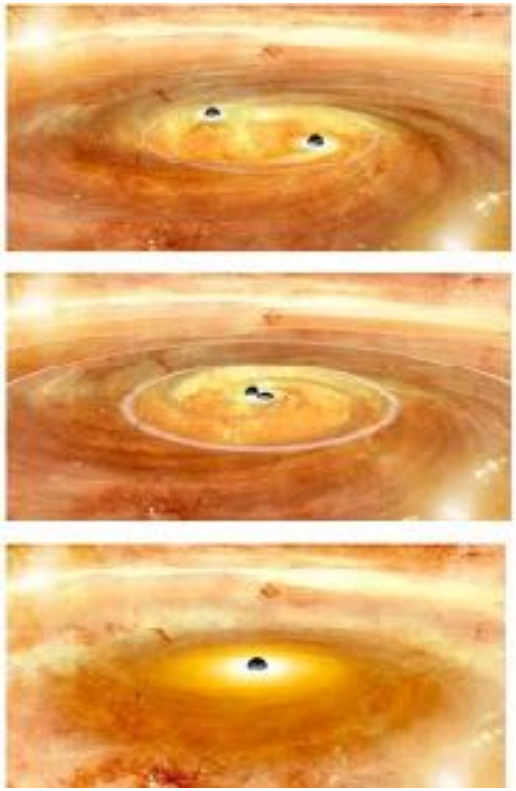
(Taniguchi & Wada 1996, ApJ, 469, 581)

See, for new beautiful simulations, Kawaguchi & Wada (2017)

P5-03 Mass Accretion to Black Holes in Merger Process

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

~ several Gyr journey



(Satoru Iguchi)

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

Important Suggestion

If nucleated minor mergers work in Seyfertization,

Starburst comes first
and then
AGN comes later

Starburst-AGN connection, again

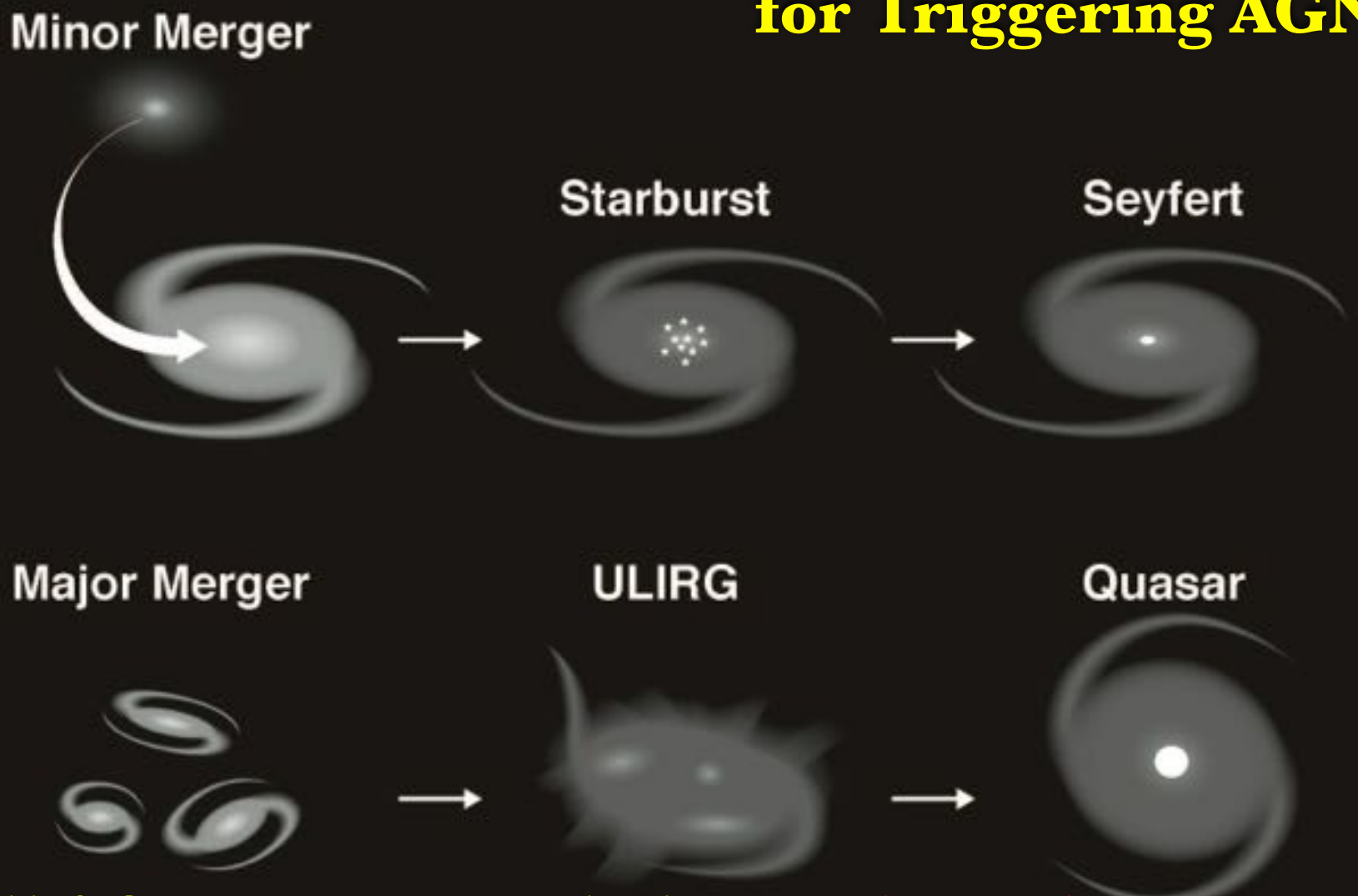
Comparison of fueling mechanisms based on observations & theory

	finite T_{AGN}	angular momentum transfer	starburst-AGN connection
Secular	×	×	×
Bar	×	×	×
Interaction	△	×	×
Minor Merger	○	○	○

Important Implication

In the case of non-nucleated mergers, no activities occur

The Nucleated-Merger-Driven Unified Model for Triggering AGNs



All AGNs were made by nucleated mergers !

(Taniguchi 2013, ASPC, 477, 265)

Future

Optical (Subaru/HSC) deep imaging to find evidence for past minor merger in Seyfert galaxies

High-resolution radio (ALMA) spectroscopy to study very nuclear gas kinematics in Seyfert galaxies

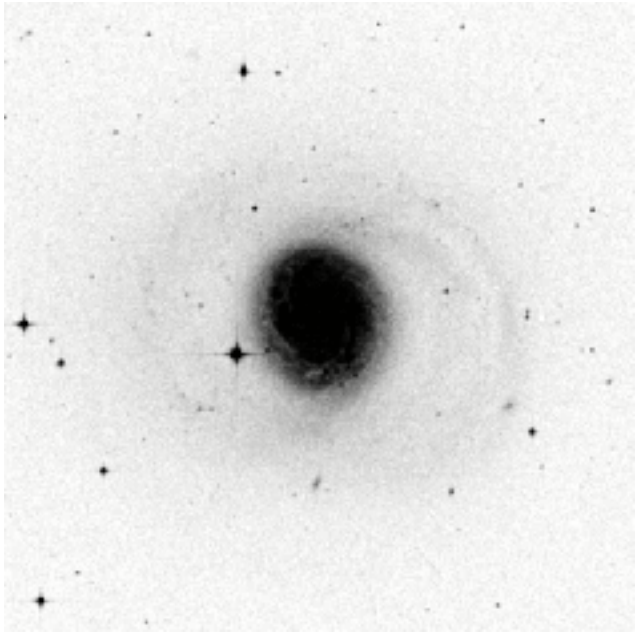
Can we use SDSS for galaxy morphology ?

Sloan Digital Sky Survey (original)

Sloan Digital Sky Survey (Stripe 82)

(Schawinski et al. 2010, ApJ, 714, L108)

Seyfert galaxy NGC 1068

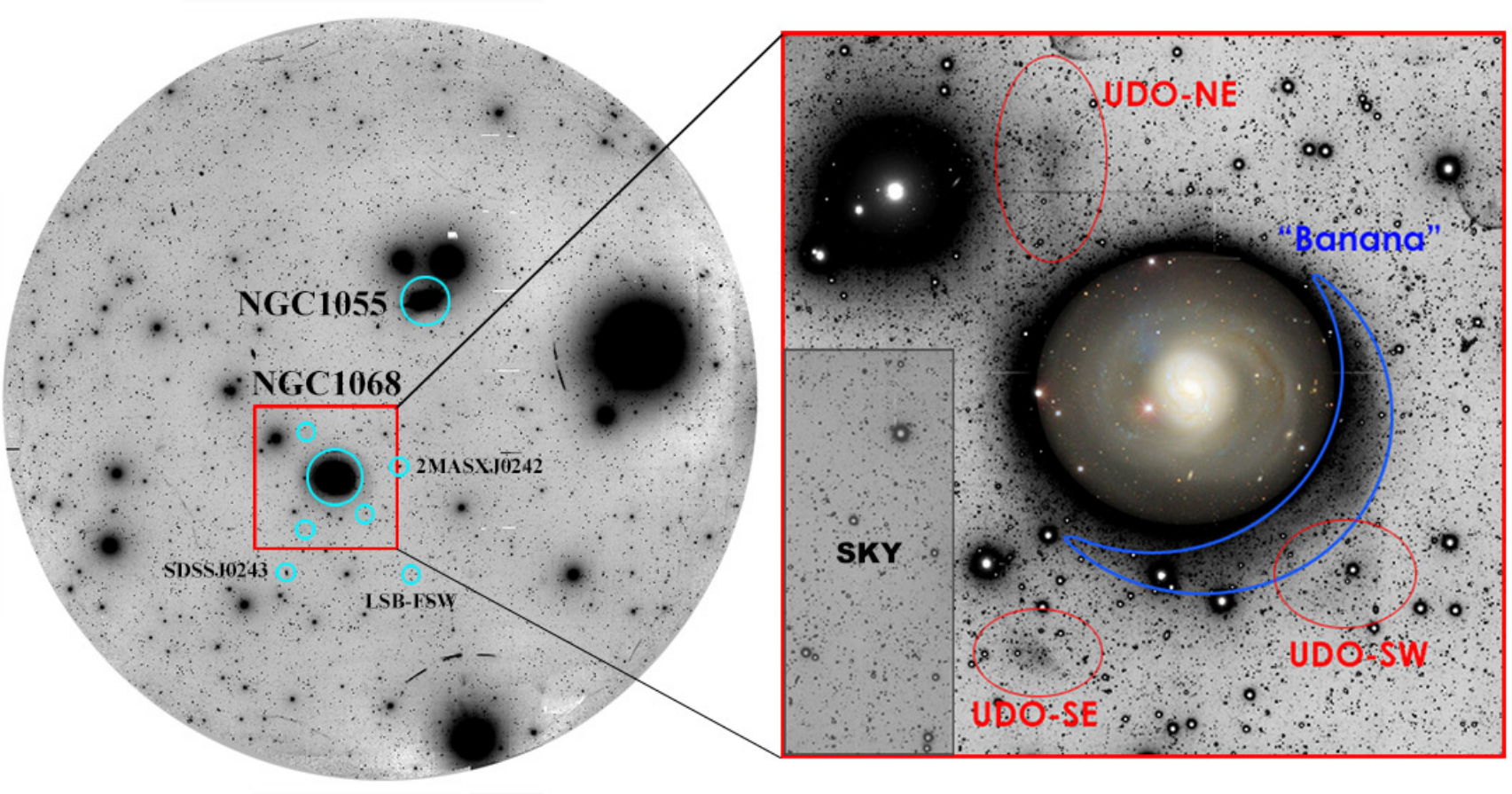


POSS

SDSS

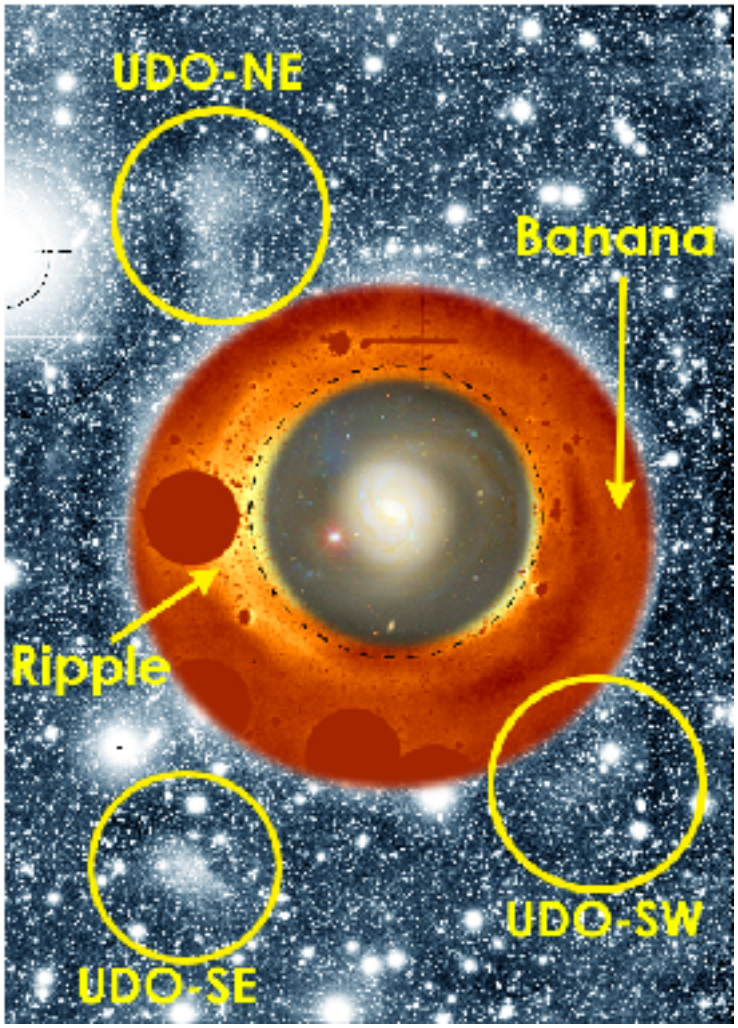
(Credit：M. Brighton)

Subaru/HSC view of NGC 1068



(Tanaka et al. 2017, PASJ, 69, in press)

Subaru/HSC view of NGC 1068



(Tanaka et al. 2017, PASJ, 69, in press)


Binary SMBH here !

Thank you very much