Exploring Supermassive Black Hole Growth with 2m Antarctic infrared telescope

~Importance of distribution of young stars~

Nozomu Kawakatu (NAOJ)

Collaborator: Tohru Nagao (Ehime University)

3/10-3/11@東北大学 GCOEワークショップ「南極における赤外線天文学」

Outline

- Introduction
- What is a problem of SMBH formation ?
- Why distribution of young stars is important ?
- Why PAH mapping with 2m Antarctic infrared telescope ?
- Summary

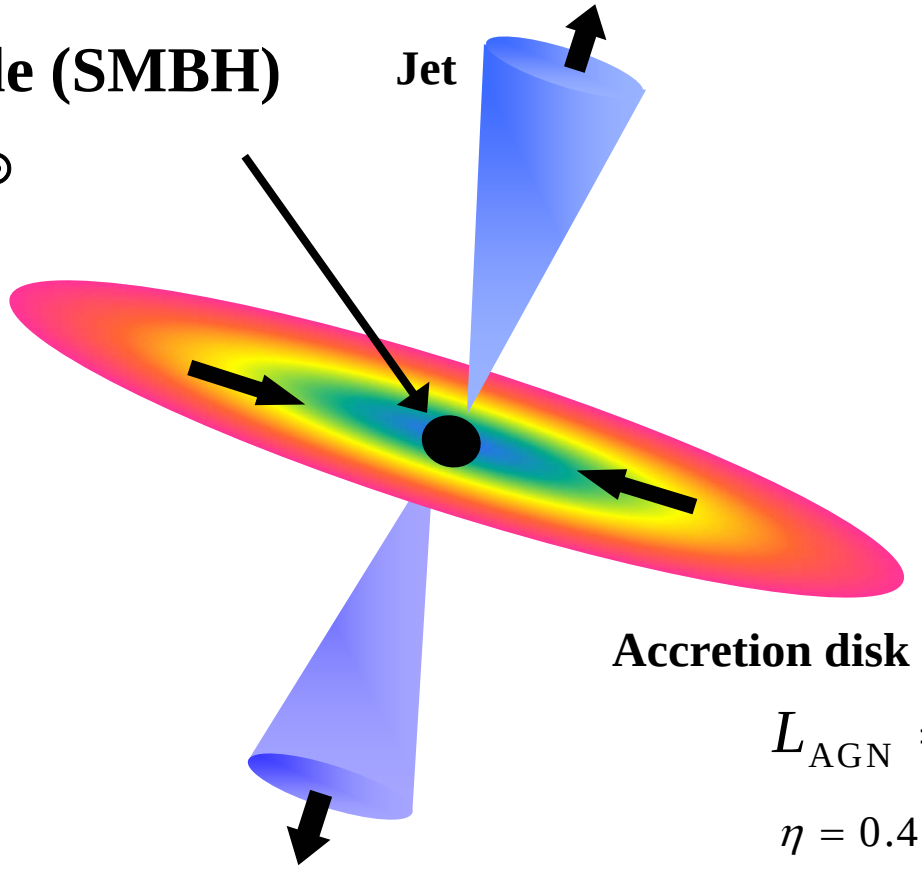
What is Quasar (AGN) ?

Compact (~ 100 AU) and luminous (~ $10^{46\text{-}47}$ erg/s) objects

cf. typical galaxies ~10^{44}erg/s , ~ a few kpc

Supermassive black hole (SMBH)

M_{BH} ~$10^{8\text{-}9}M_{\odot}$

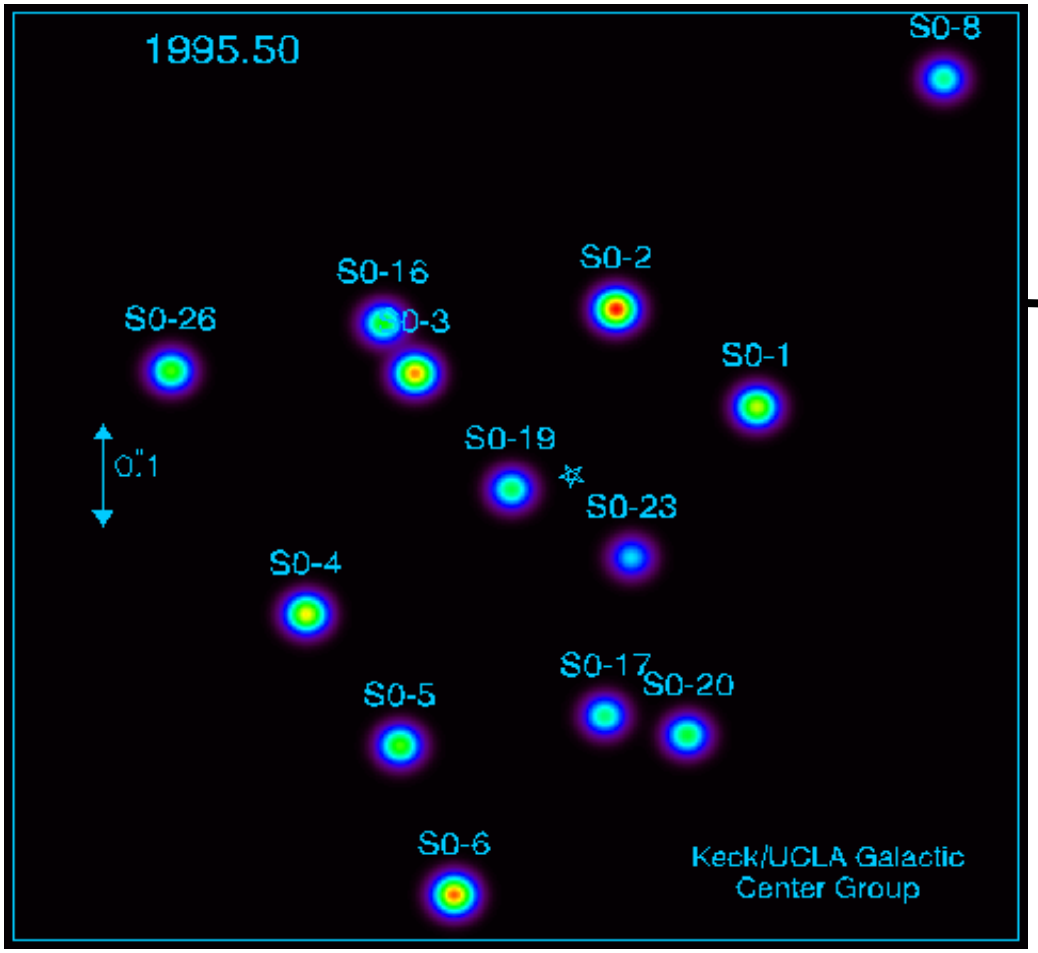


$$L_{\mathrm{AGN}} = \eta \dot{M} c^2$$

η = 0.42 (Kerr BH)

SMBH in the Milky Way

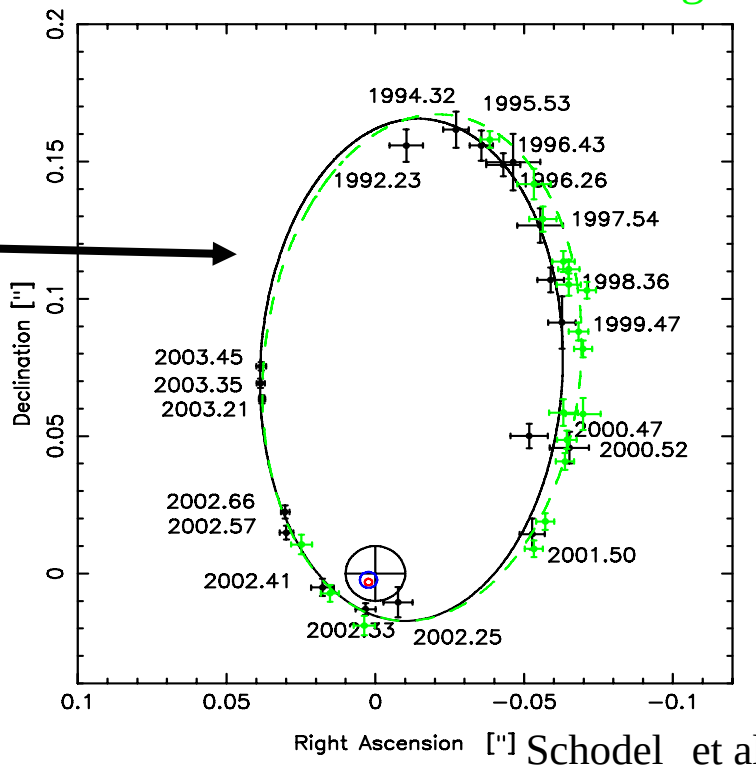
"Orbit of S2 around Sgr A*"



Ghez et al. 0.8" 0.032 pc

NTT+VLT black

Keck green

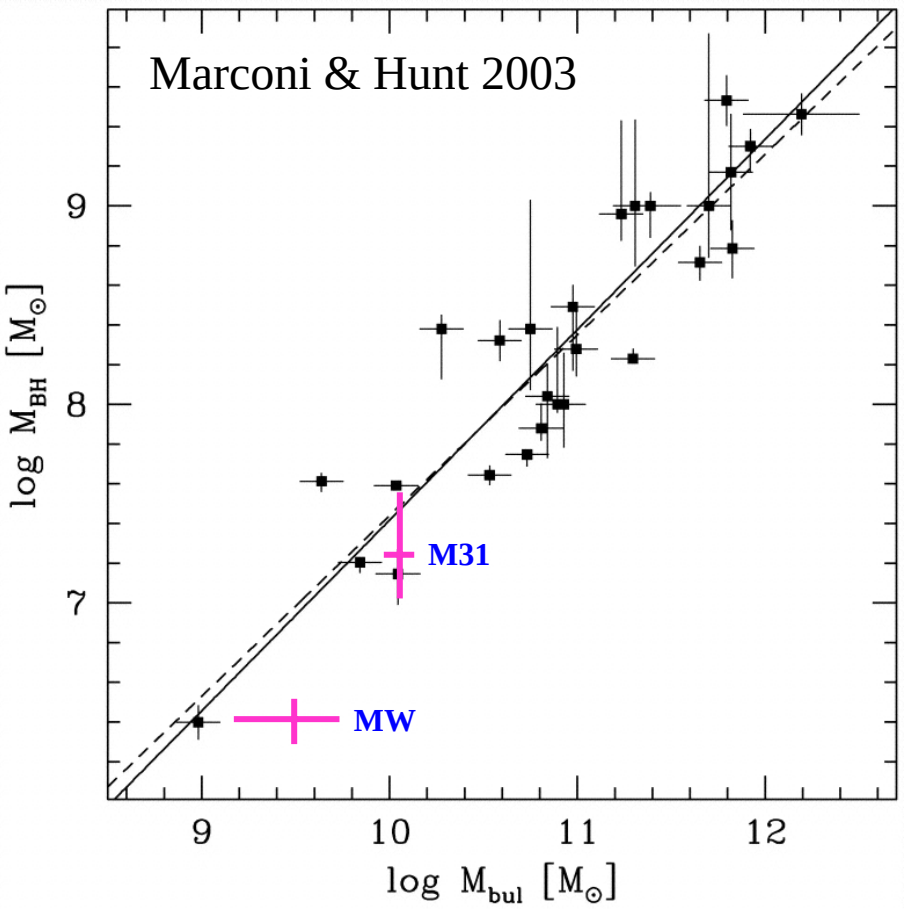


Schodel et al 2004

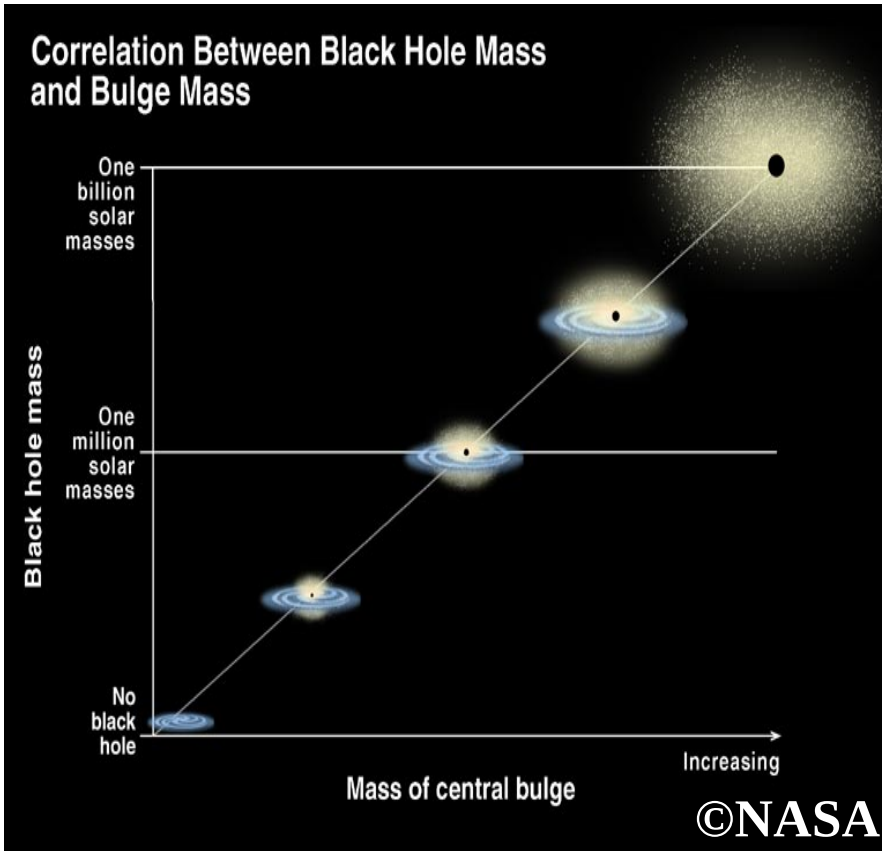
$M_{BH}(<0.02pc)=3.7(\pm 0.4)\times 10^6 M_\odot$

SMBH – Galactic bulge Relation @ z=0

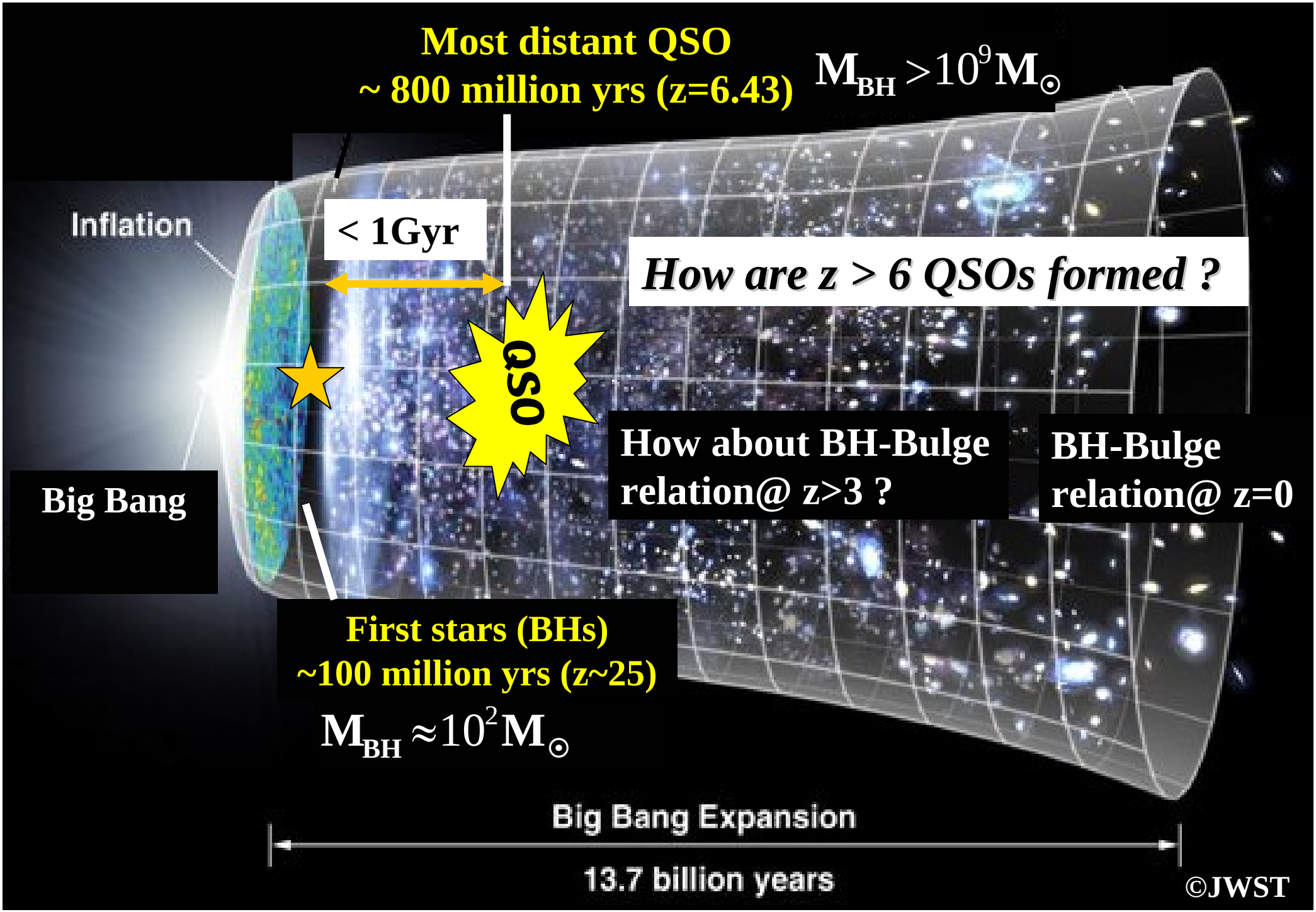
$M_{BH}/M_{bulge} \sim 0.001$



Kormendy & Richstone 1995; Richstone et al. 1998; Ferrarese & Merritt 2000; Marconi & Hunt 2003

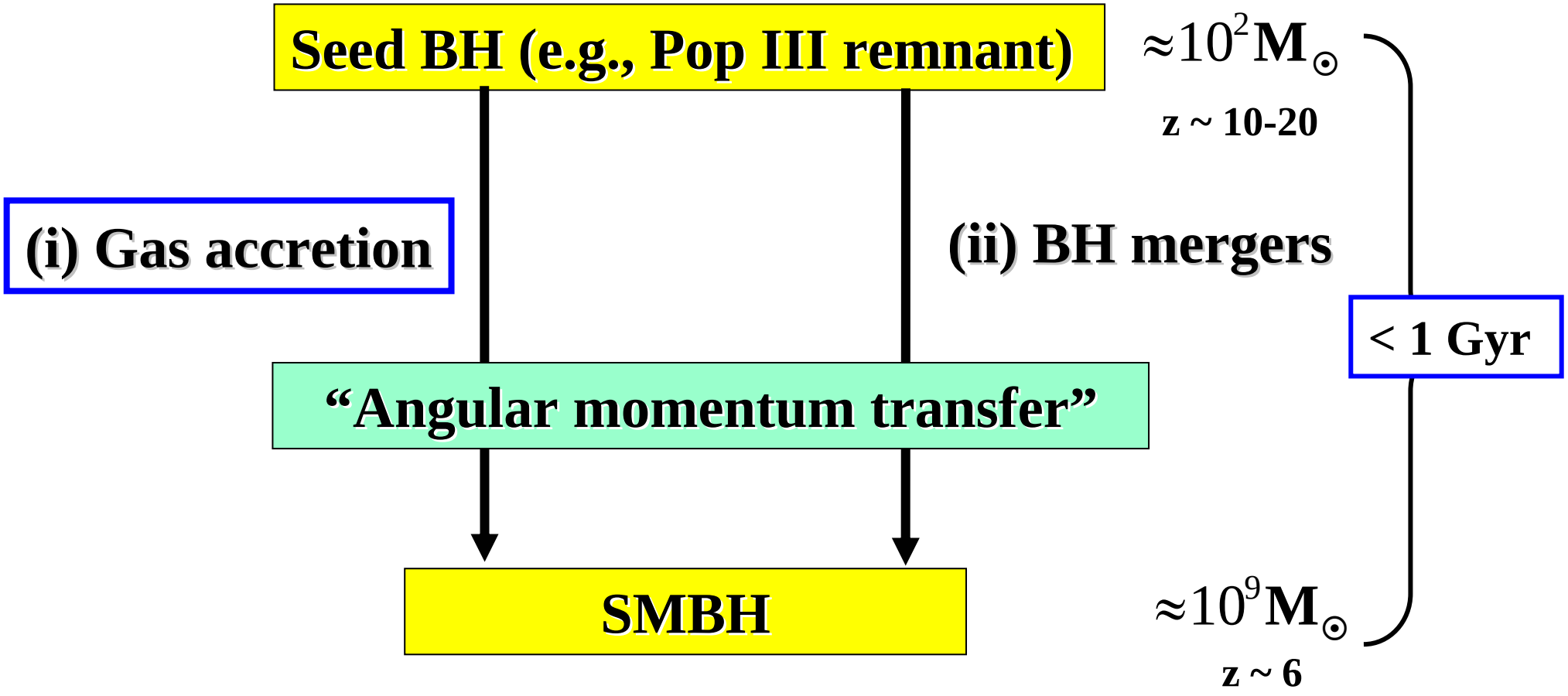


SMBH formation is closely related to bulge (star) formation.


Most distant QSO
~ 800 million yrs (z=6.43)
$M_{BH} > 10^9 M_\odot$
Inflation
< 1Gyr
QSO
How are z > 6 QSOs formed ?
How about BH-Bulge relation@ z>3 ?
BH-Bulge relation@ z=0
Big Bang
First stars (BHs)
~100 million yrs (z~25)
$M_{BH} \approx 10^2 M_\odot$
Big Bang Expansion
13.7 billion years
©JWST

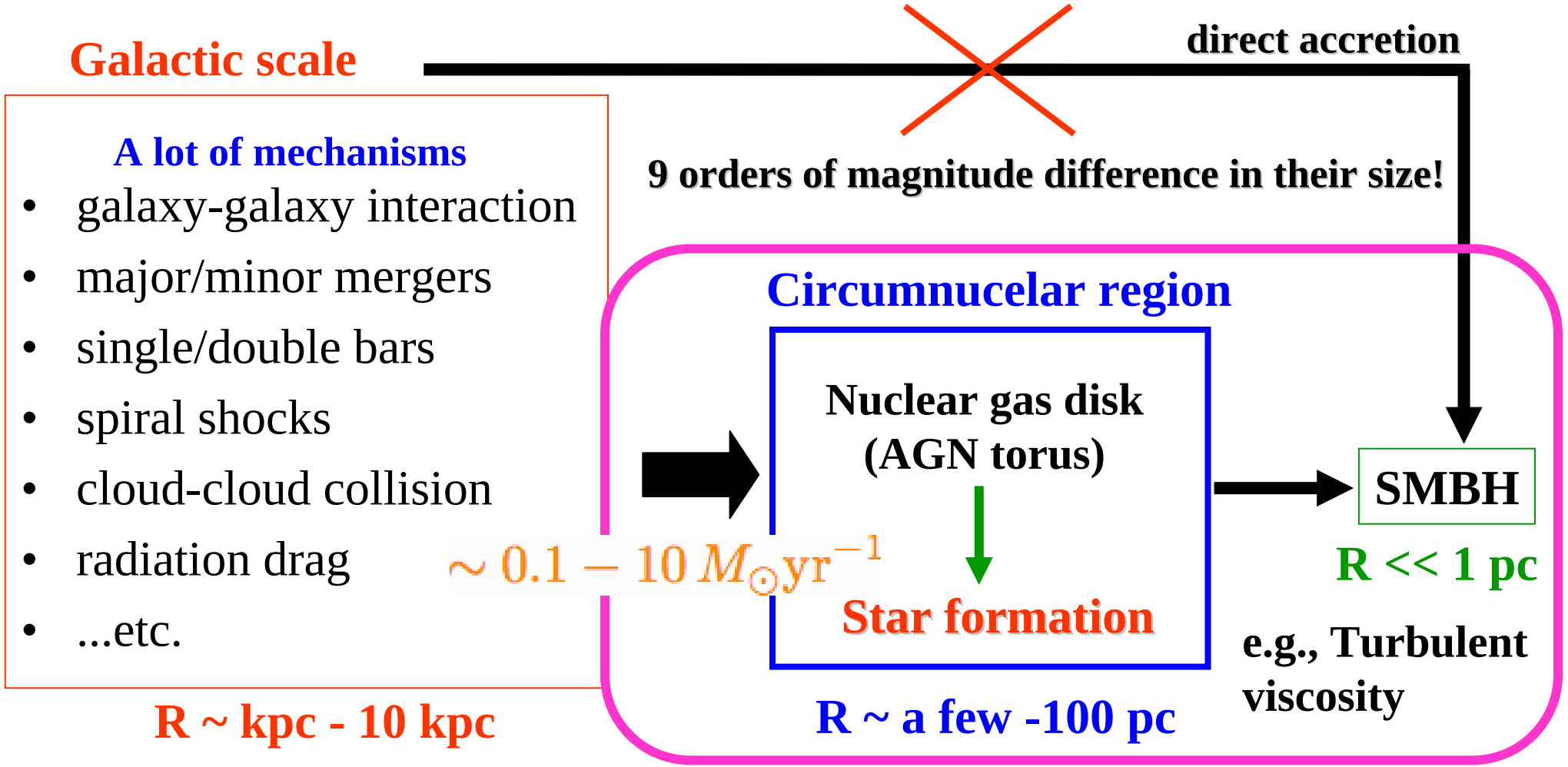
A Scenario of SMBH Formation

(e.g., Rees Diagram 1984)



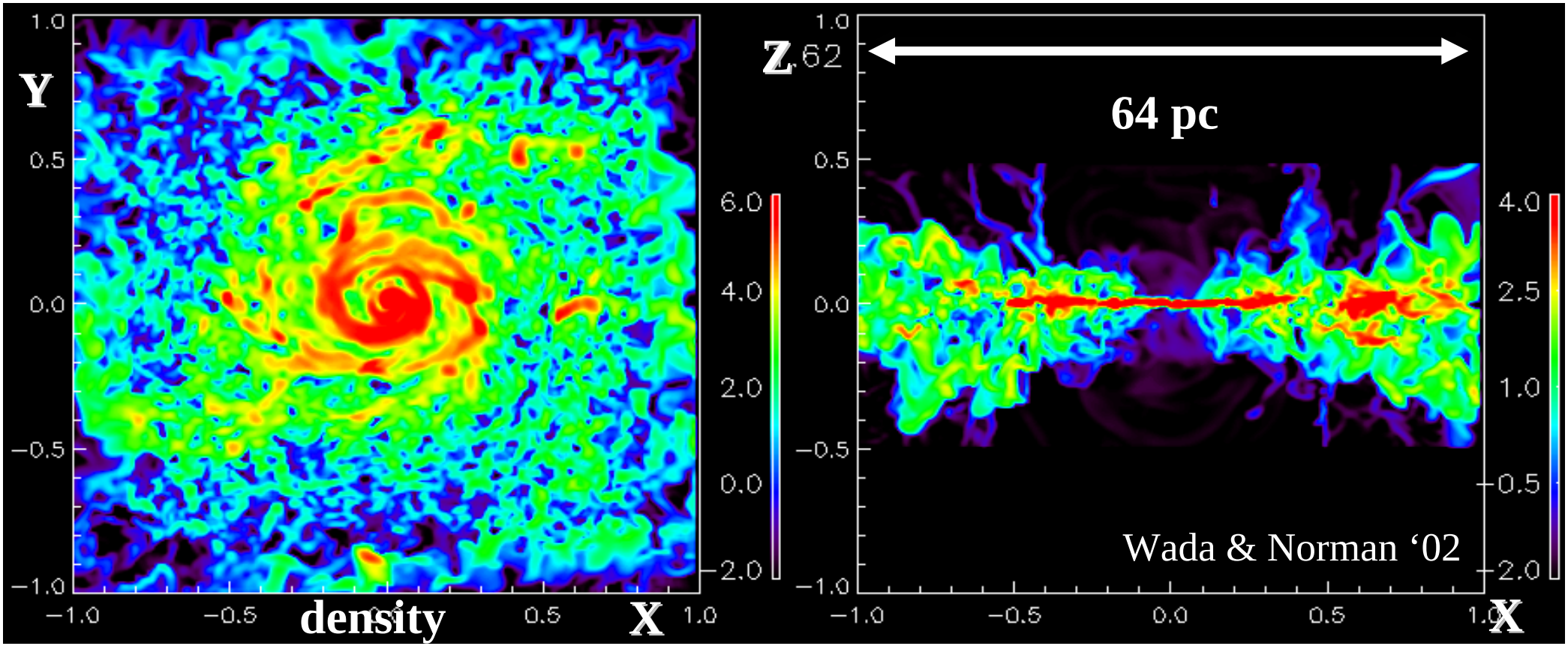
Gas accretion toward SMBH

The physics of angular momentum transfer is inevitable for formation of SMBHs.



It is crucial to link the mass accretion processes from a galactic scale with those from an accretion disk via the circumnucelar disk (CND).

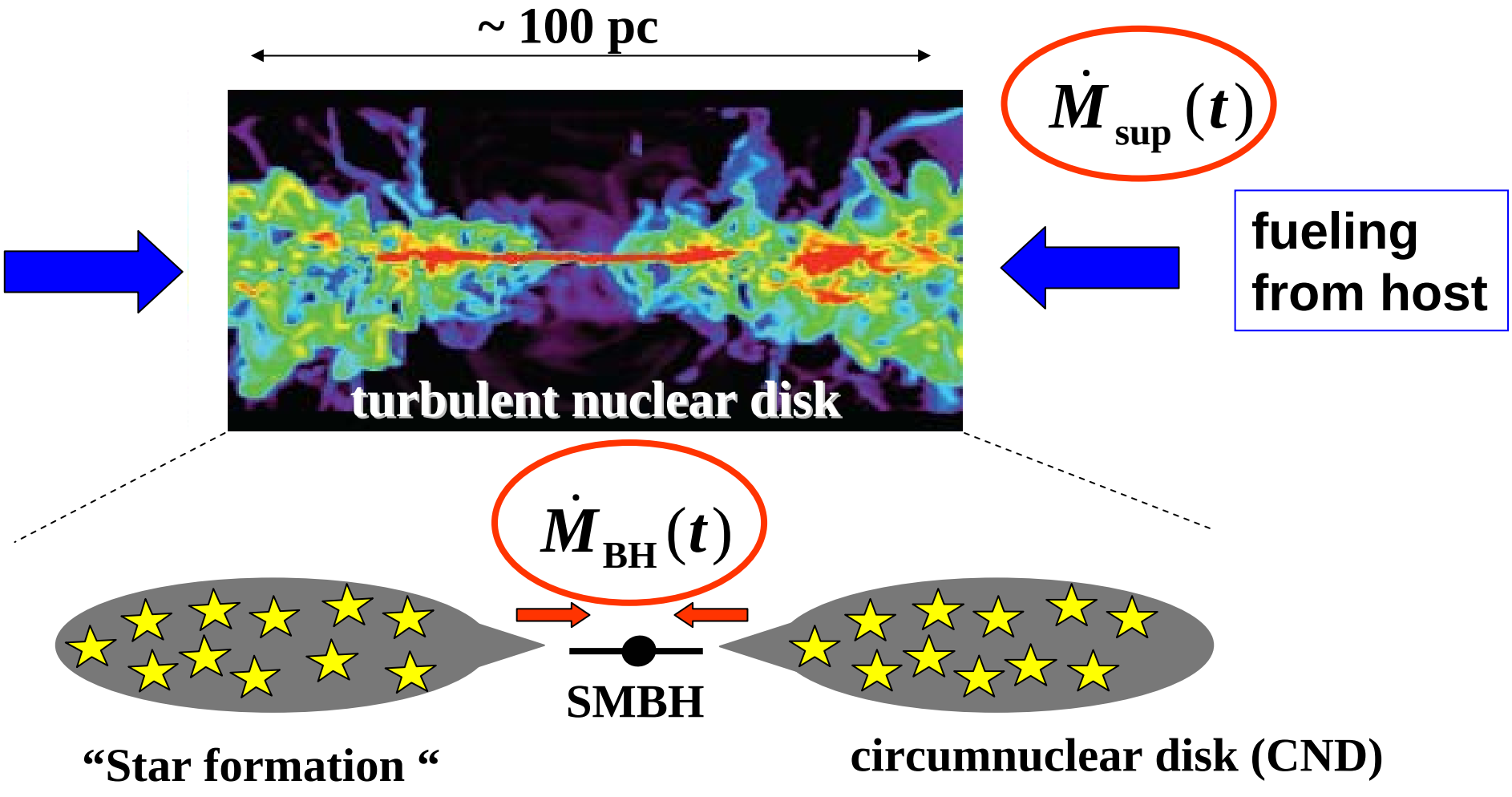
Starburst driven “torus” around SMBH



- Disk has complicated internal structure and velocity fields is turbulent-like.
- Global shape is determined by energy balance between turbulent dissipation and SN heating under the influence of the central massive black hole.
- The mechanism to transport the angular momentum is the turbulent viscosity.

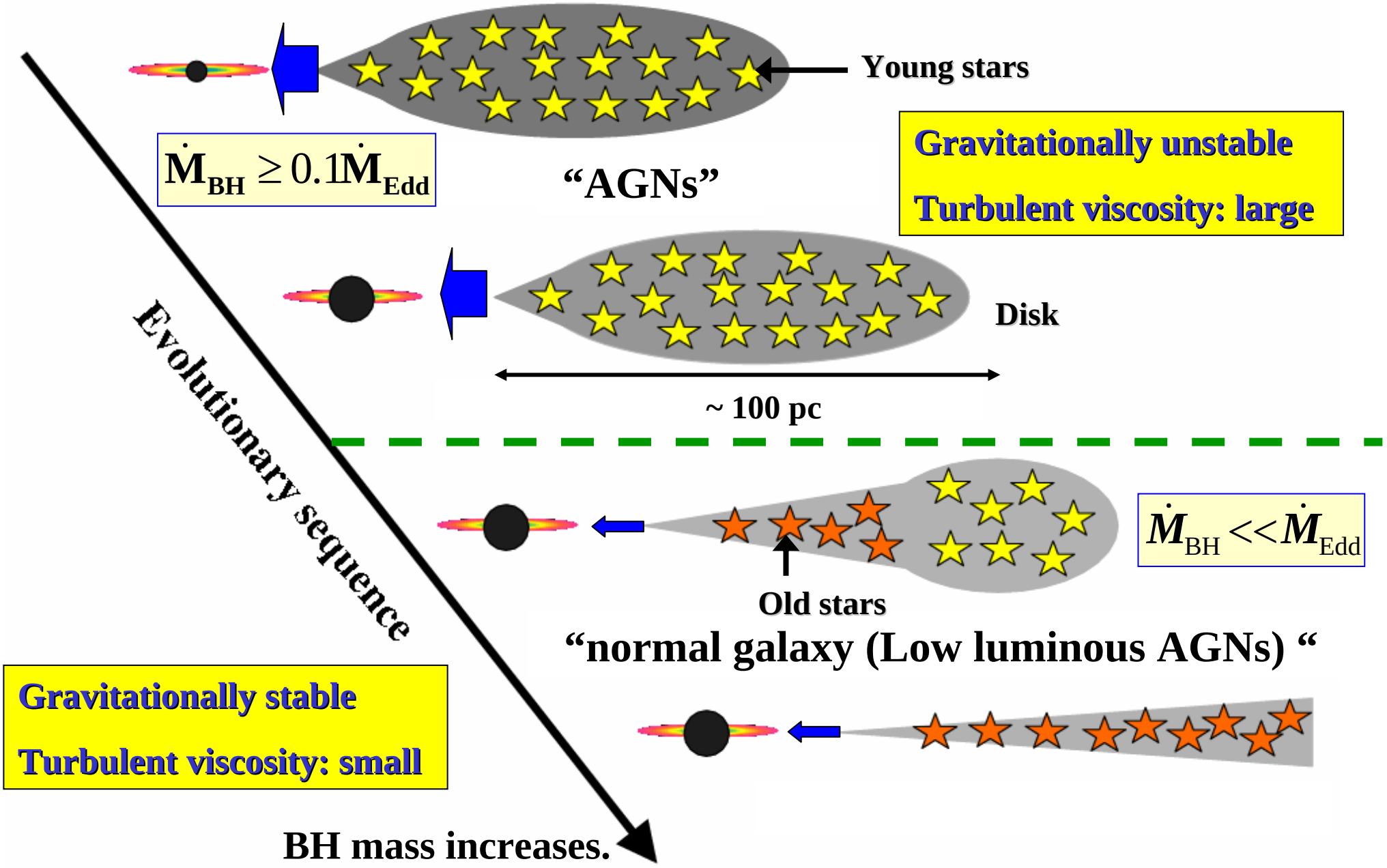
Modeling growth of SMBH and circumnuclear disk

(NK & Wada 2008)

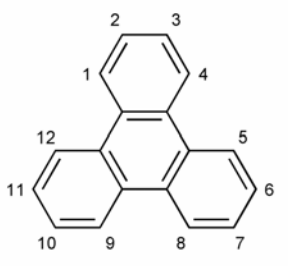


$$\dot{M}_{\rm BH}(t) = f(\dot{M}_{\rm sup}(t))$$

AGN activity vs. Distribution of young stars in dusty torus



Why PAH mapping ?



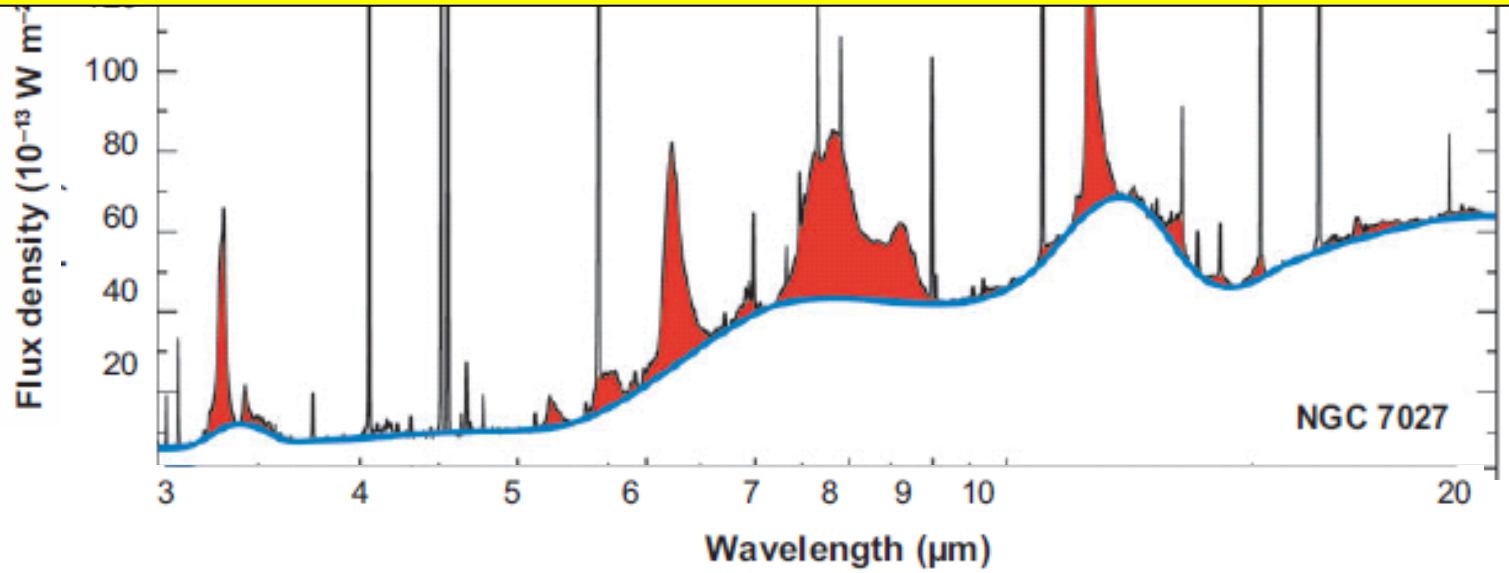
PAH (Polycyclic aromatic hydrocarbons)

-Infrared emission features: 3.28, 6.2, 7.7, 8.6, 11.25 μ m

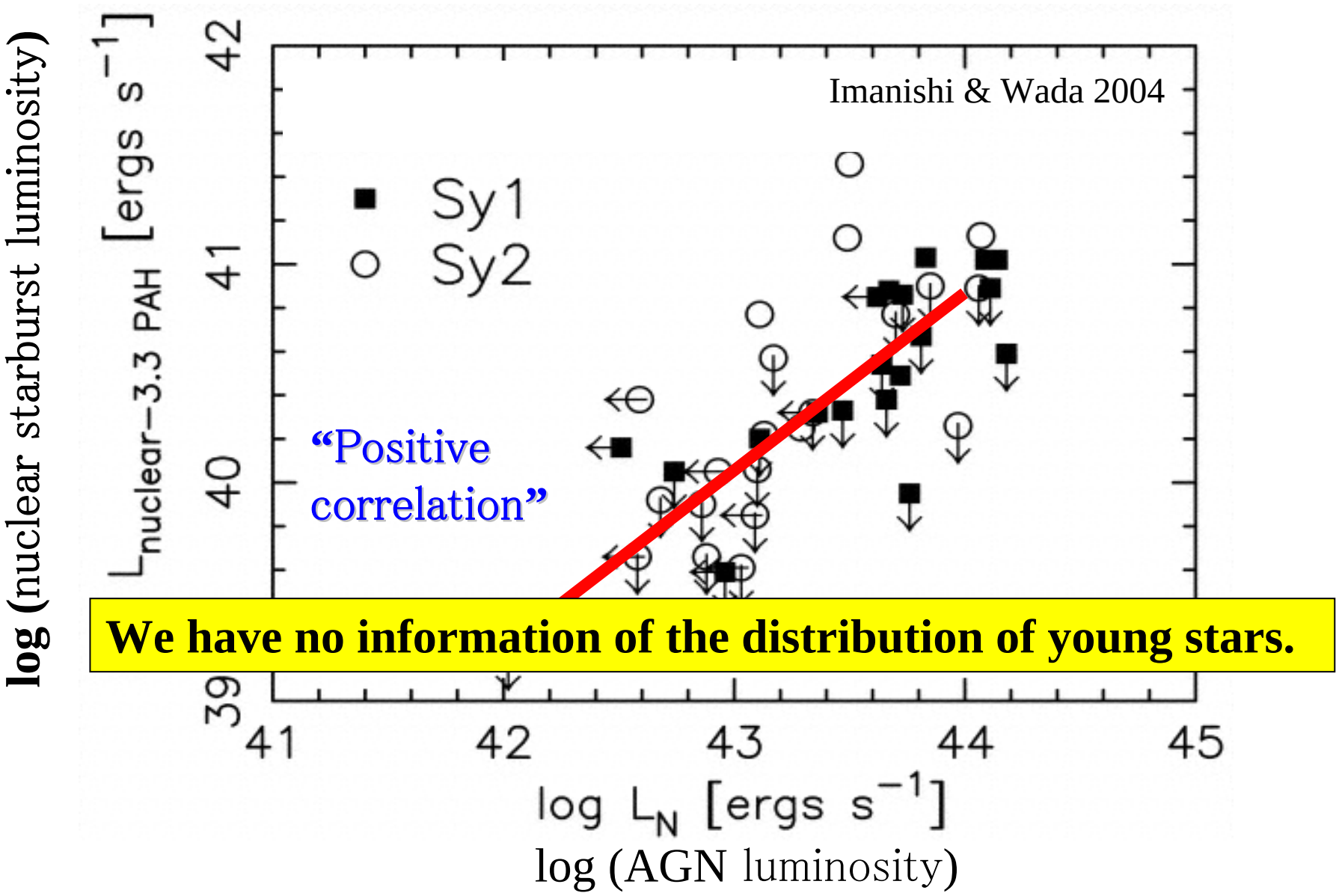
-PAH are excited in starburst PDR but destroyed near an AGN.

- Dust extinction is much lower at $\lambda > 3\,\mu$m (< 0.05 A_v)

We can examine modestly obscured (A_v < 15 mag) distribution of young stars by PAH emission line !



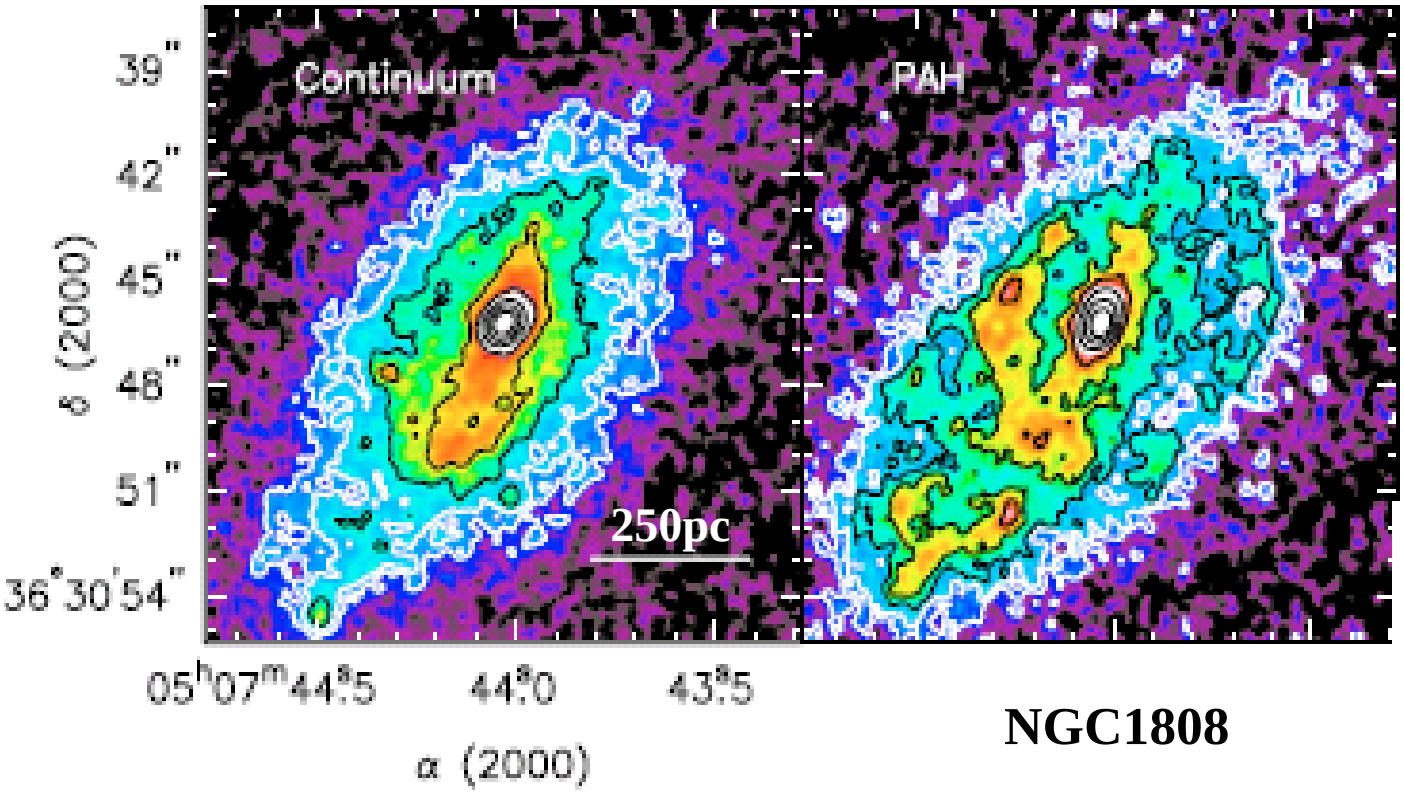
AGN-Nucelar Starburst (<100pc) connection



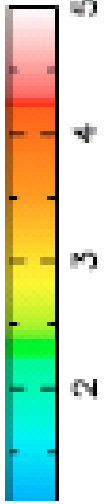
We have no information of the distribution of young stars.

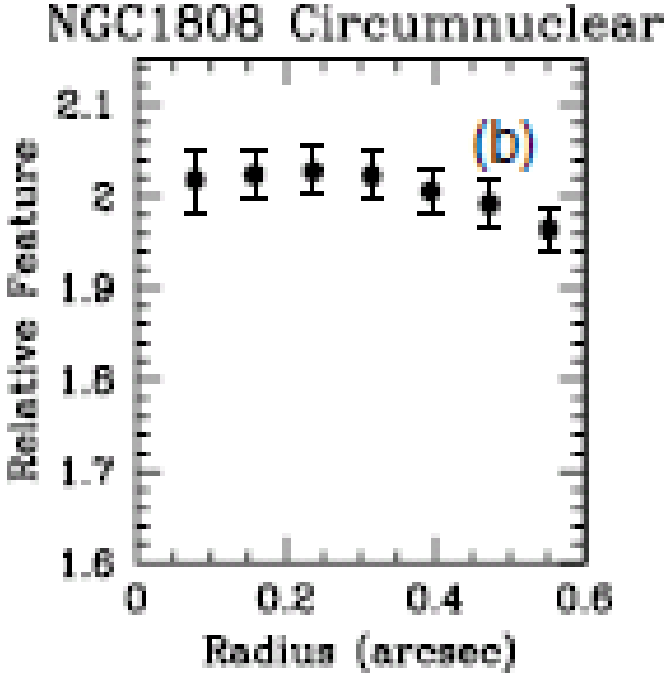
PAH mapping with ISAAC at VLT

Tacconi-Garman et al. 2005



NGC1808





Only two nearby starburst galaxies !

We should compare nearby AGN with normal galaxies statistically.

Why 2m Atlantic infrared telescope ?

Distribution of young stars is important to reveal the physical process onto SMBHs.

⇒ PAH mapping (high spatial resolution at near-IR) is essential !

Required spatial resolution: ~ 0.1”

Nuclear starburst (~100pc) : ~10 pc @ z=0.05

Targets : Seyfert galaxies (AGNs), normal galaxies

2m Antarctic infrared telescope: ~0.3” @ 3 μ m (diffraction limit)

Space telescope (Spitzer, AKARI, …) : > 3”

Ground based telescope (Subaru, VLT, …) : ~1-2”

Ichikawa-san’s talk

Summary

- **To reveal the SMBH formation, the distribution of young stars in dusty torus is essential.**
- **PAH mapping is a powerful tool to investigate the distribution of young stars, which are buried in the optically thick torus.**
- **Infrared observation with high spatial resolution by 2m Antarctic infrared telescope is crucial to reveal a difference in the distribution of young stars between AGNs and non-AGNs statistically.**

High spatial resolution at the near-infrared band & plenty of telescope time

Thank you very much !