"Central Massive Objects: The Stellar Nuclei - Black Hole Connection"

@ESO (22-25/06/2010)

What determines AGN activity ?

Importance of circumnuclear disk

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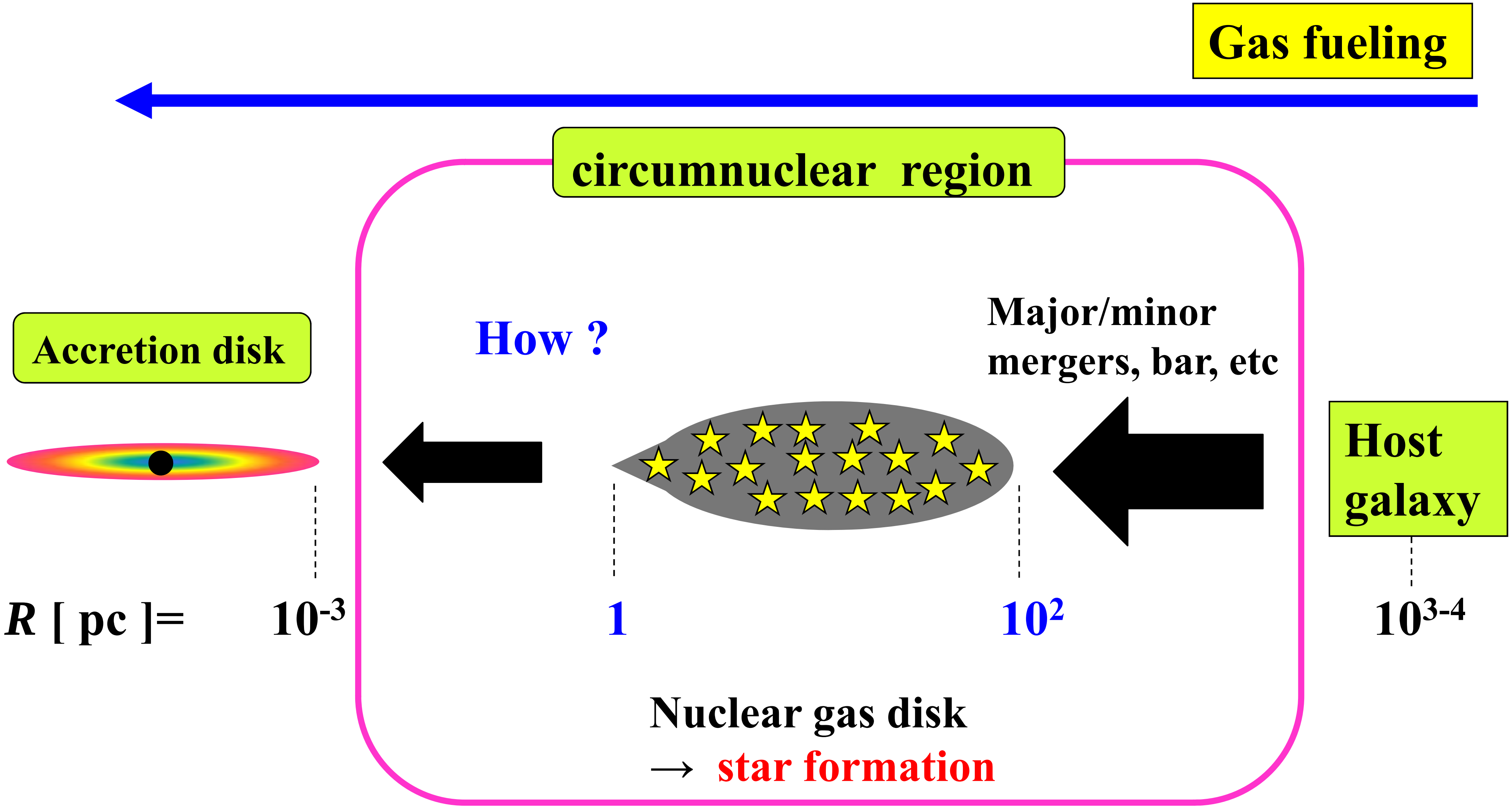
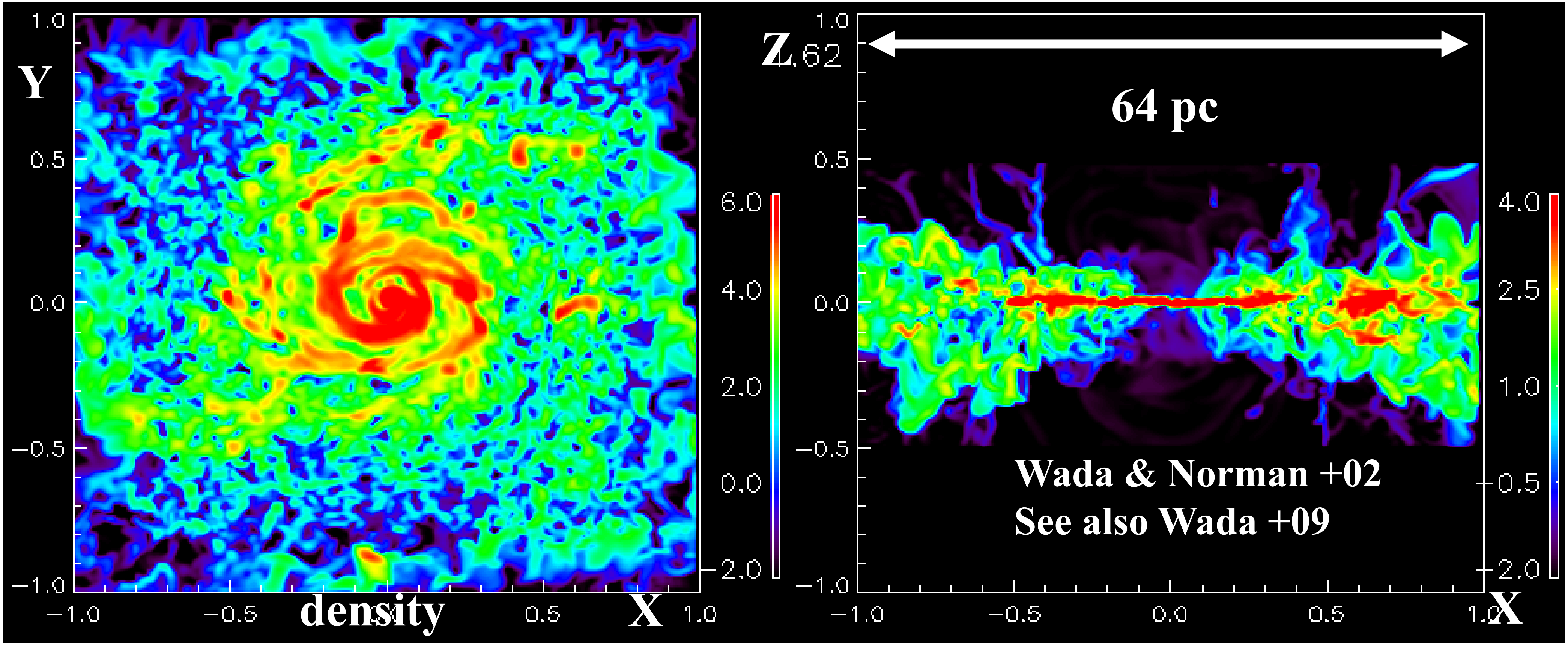
Gas accretion toward SMBH



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

Starburst driven "torus" around SMBH

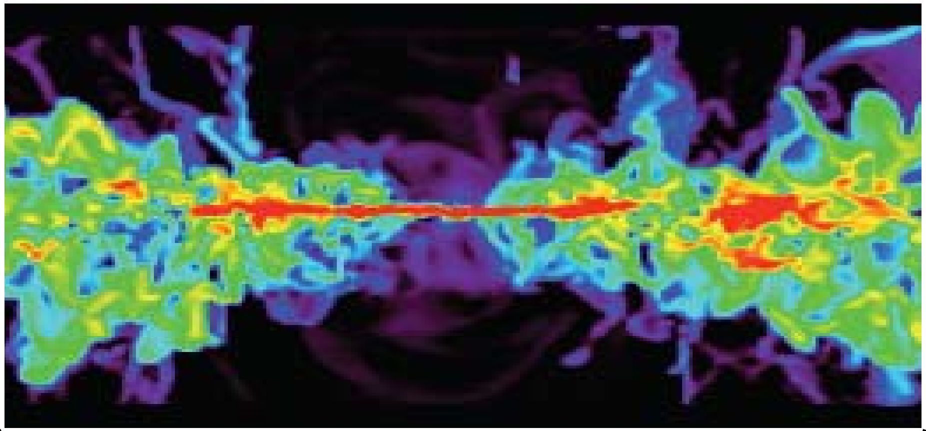


- **Disk has <u>complicated internal structure</u> and velocity fields is <u>turbulent-like</u>.**
- **<u>Global shape</u> is determined by energy balance between turbulent dissipation and SN heating under the influence of the central massive black hole.**
- **The mechanism to transport the angular momentum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

Modeling growth of SMBH and circumnuclear disk

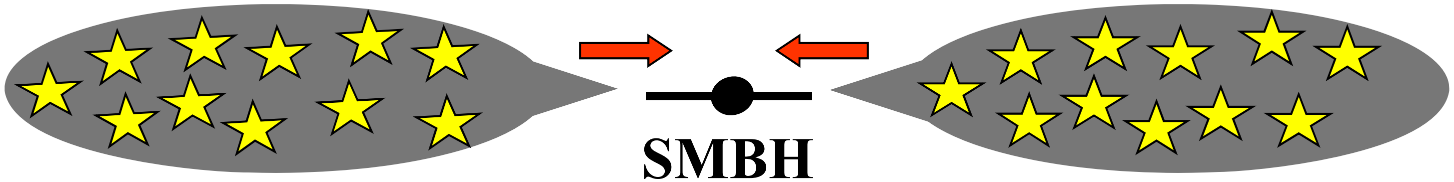
NK & Wada 2008, ApJ, 681, 73

~ 100 pc



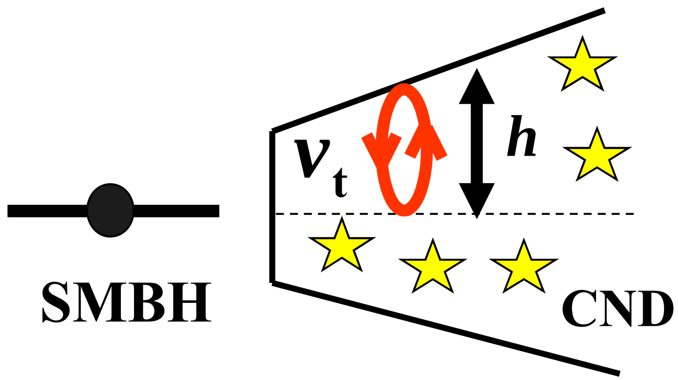
fueling from host

Gas accretion driven by *turbulent viscosity*



Circumnuclear disk (CND)

“Turbulent pressure-supported” circumnuclear disk



(see also Wada & Norman 02; Vollmer & Beckert 03; Vollmer +08; Collin & Zhan 08)

(1)+(2) ⇒ turbulent velocity and scale height

$$v_t \propto C_*^{1/2}, h \propto C_*^{1/2}$$ (e.g., Hickes +09)

(3) ⇒ accretion rate $\dot{M}(t) \propto \dot{M}_*(t)$

Hydrodynamical equilibrium (Turbulent pressure = gravity in vertical direction)

$$\rho_g(r) v_t(r)^2 = \rho_g(r) g(r) h(r) \quad (1)$$

v_t :turbulent velocity ρ_g :gas density

h: scale height of disk

Energy balance (Turbulent Energy dissipation =Energy input from SNe)

$$\frac{\rho_g(r) v_t(r)^2}{t_{dis}} \approx \eta S_*(r) E_{SN} \quad (2)$$

$S_*(r) = C_* \rho_g(r)$:**star formation rate** per unit volume

η: heating efficiency

E_{SN}: total energy (10^{51} erg) injected by an SN

Angular momentum transfer due to the turbulent viscosity

$$\dot{M}(r) = 2\pi \nu_t \Sigma_g(r) \left| \frac{d \ln \Omega(r)}{d \ln r} \right| \quad (3)$$

$\nu_t = \alpha v_t h$:viscous parameter

$\Sigma_g = 2h\rho_g$:surface density of gaseous matter

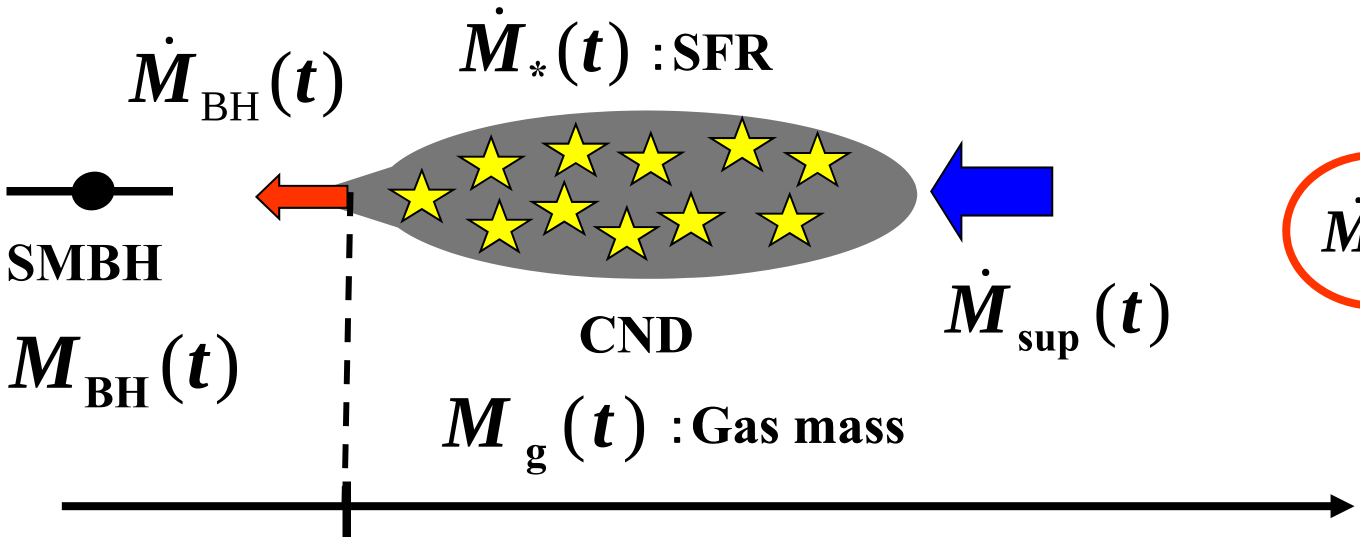
Ω :angular velocity

SMBH growth and States of the CND

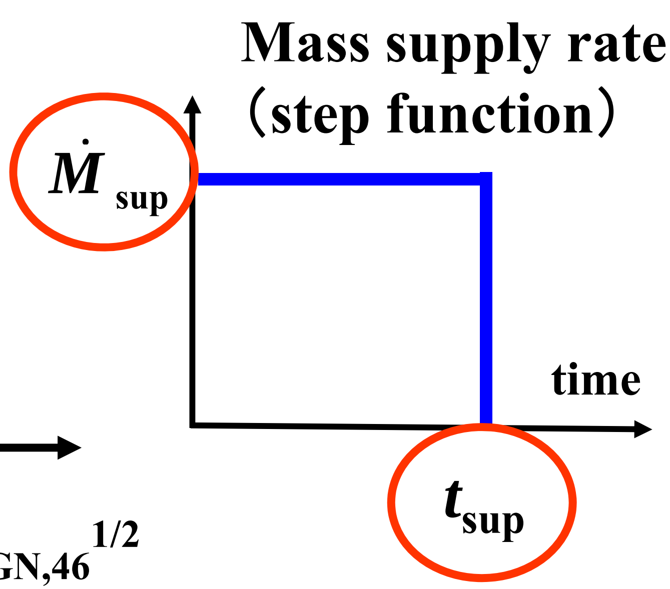
■ Mass conservation（without mass loss from CNDs due to starburst wind）

$$M_{\rm g}(t) = \int_0^t [\dot{M}_{\rm sup}(t') - \dot{M}_*(t') - \dot{M}_{\rm BH}(t')]dt'$$

■ Growth rate of SMBH $\quad \dot{M}_{\rm BH}(t) = \dot{M}(r_{\rm in}, t)$

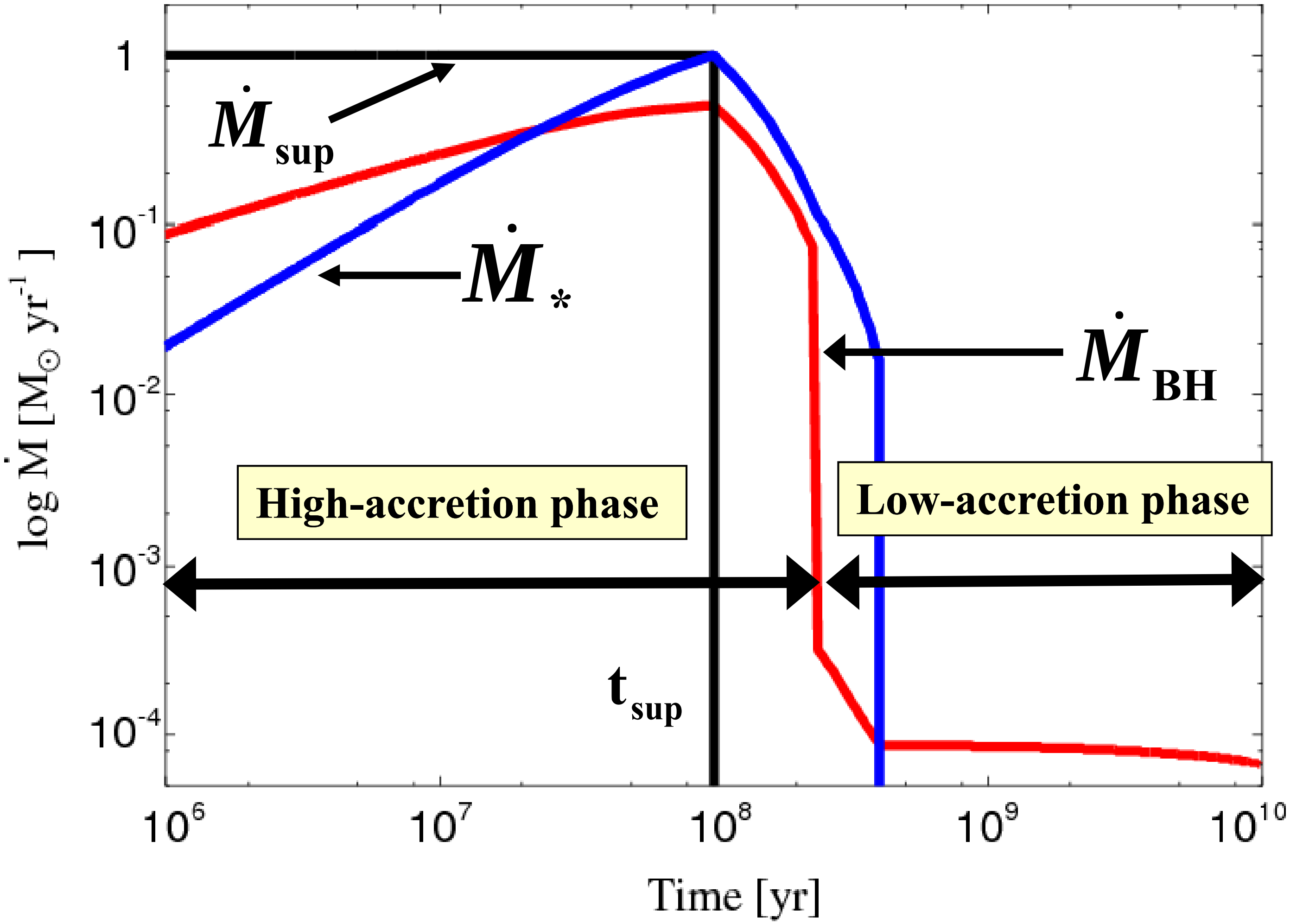


$r_{\rm in}$:dust sublimation radius ~3 pc $L_{\rm AGN,46}^{1/2}$

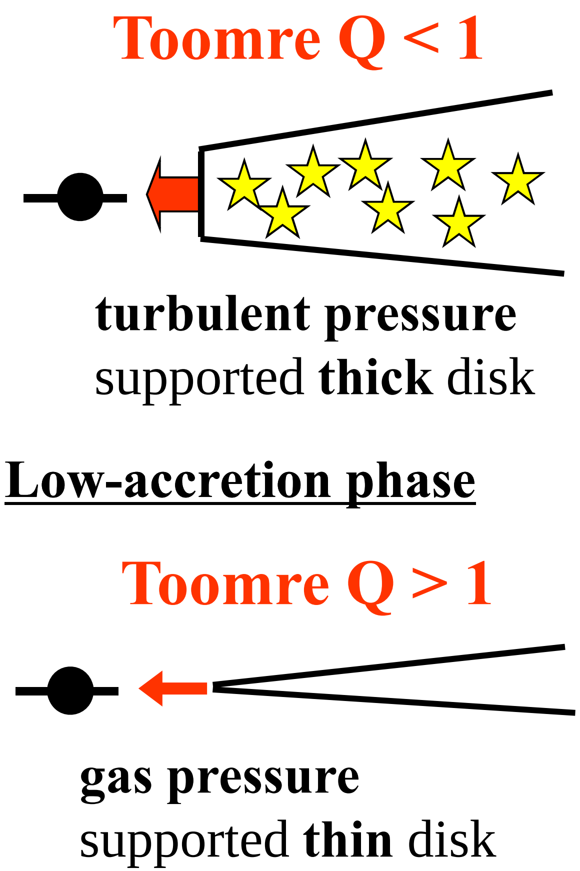


The growth rate of SMBH and SFR

$M_{sup} = 10^8 M_\odot, C_* = 3\times10^{-8} yr^{-1}$



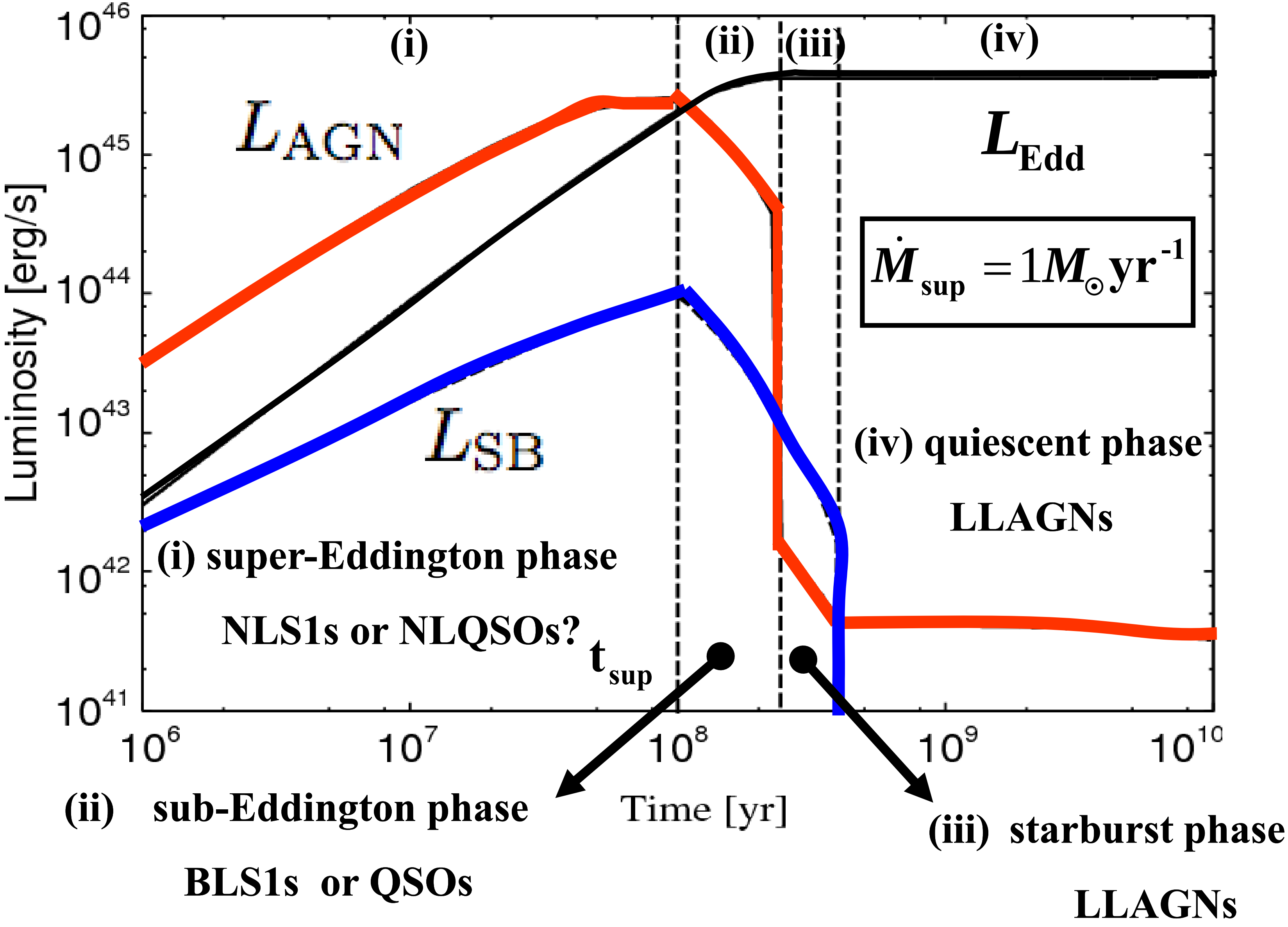
High -accretion phase



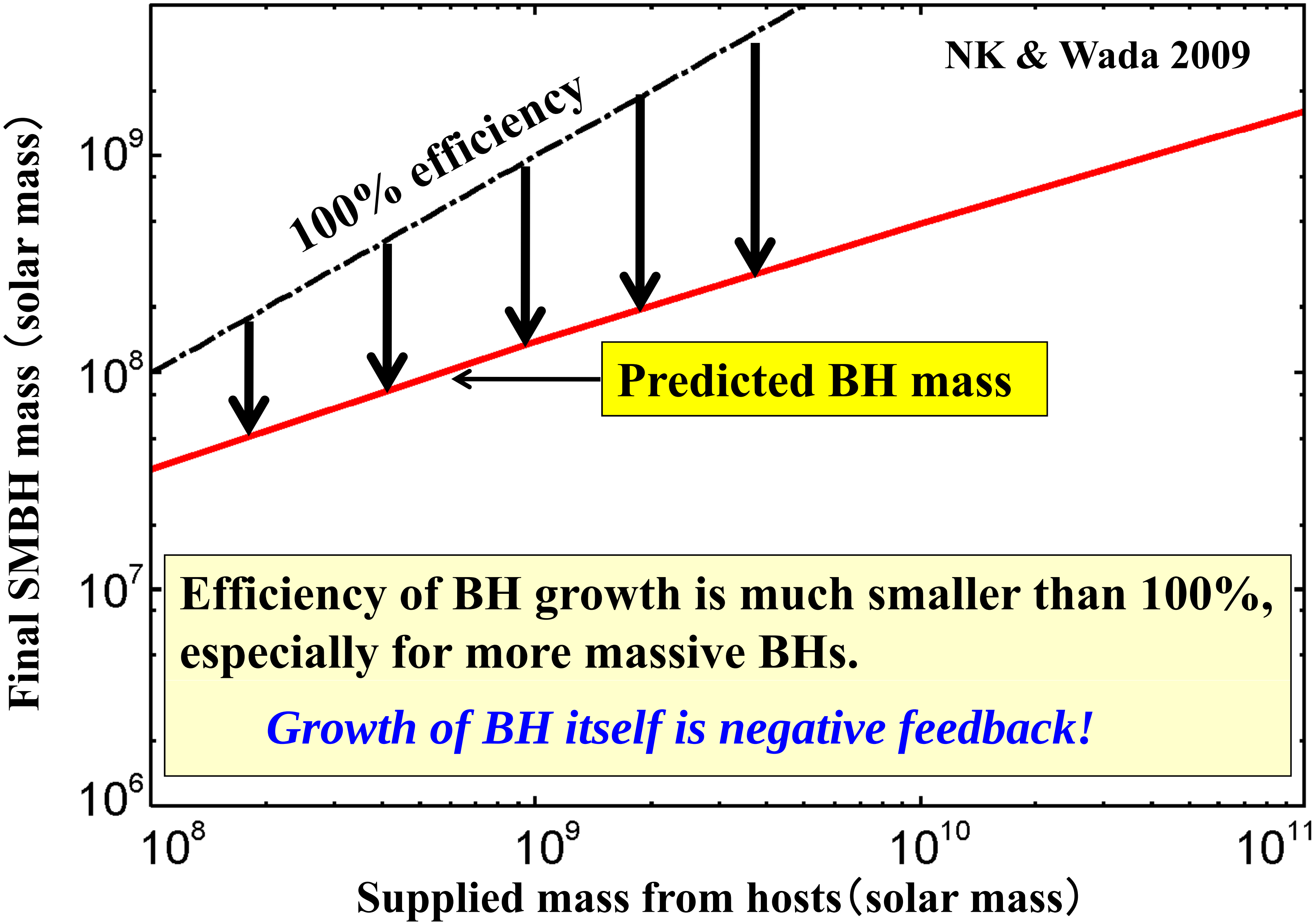
The growth of SMBHs is changed from high accretion phase to low one.

Evolution of AGN and Nuc. SB luminosity

$L_{AGN} = f(\dot{M}_{BH}, \dot{M}_{Edd})$ ← **Watarai et al. 2000**



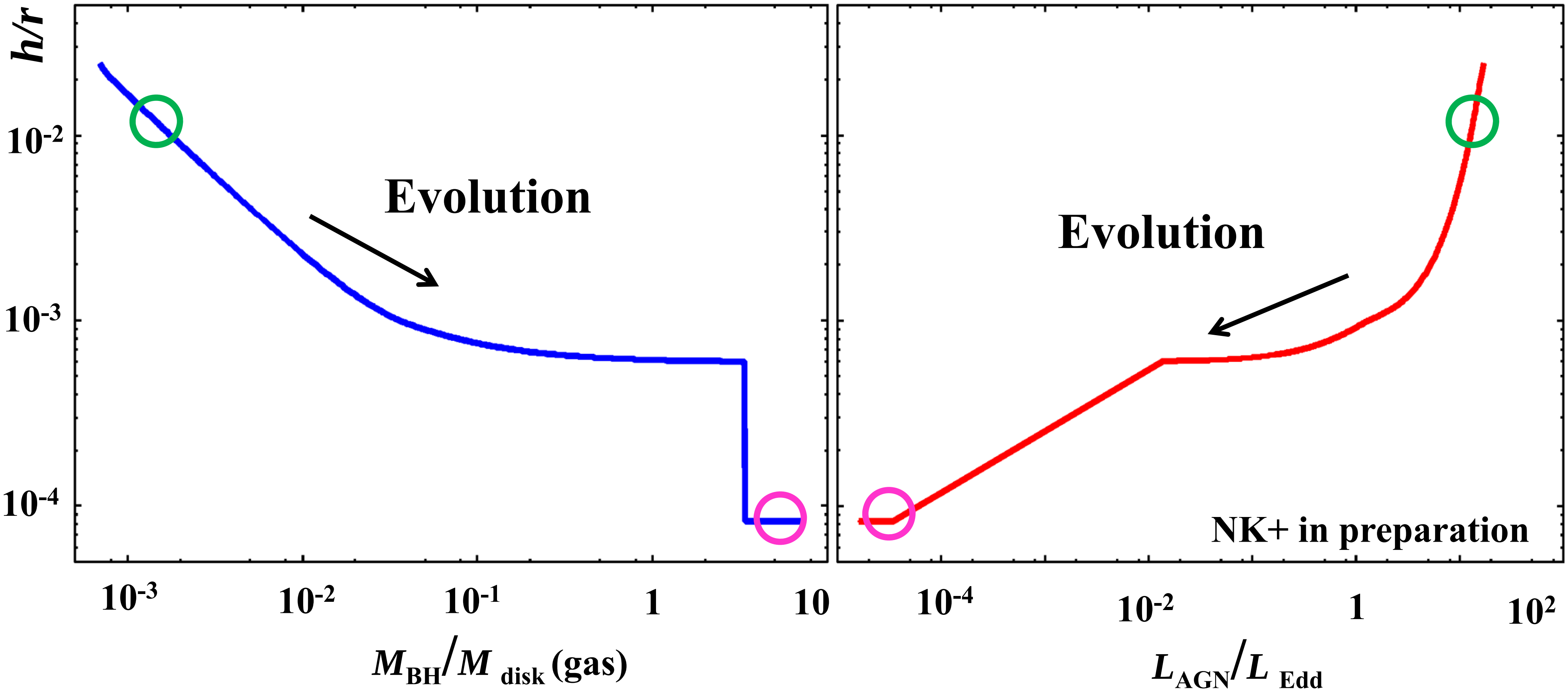
Efficiency of SMBH growth



Efficiency of BH growth is much smaller than 100%, especially for more massive BHs.

Growth of BH itself is negative feedback!

AGN activity vs. Physical states of CNDs

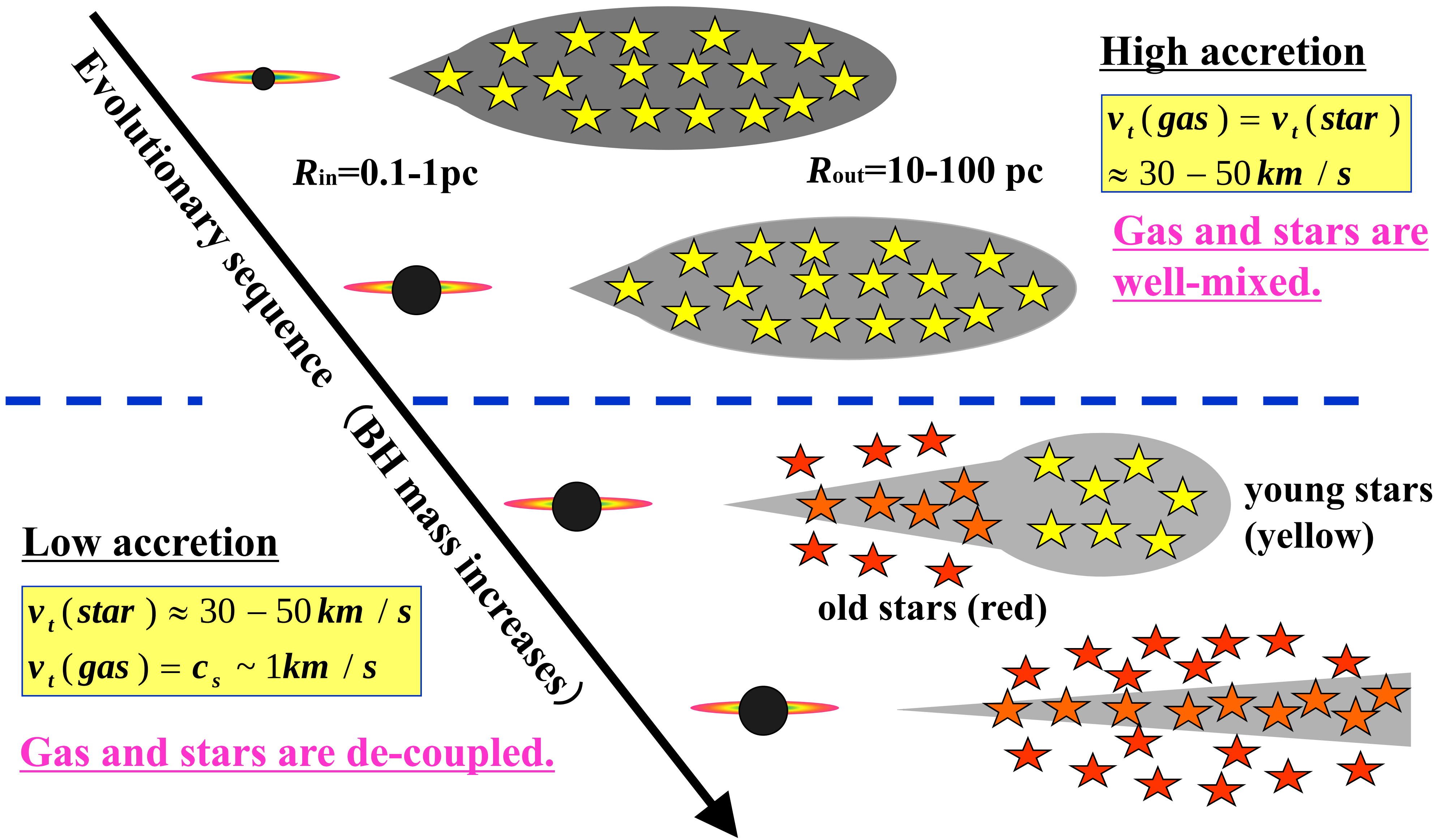


High accretion rate : geometrically thick CND, $M_{\rm disk}$ (gas) > $M_{\rm BH}$

Low accretion rate : geometrically thin CND, $M_{\rm disk}$ (gas) < $M_{\rm BH}$

ALMA

Coevolution of a SMBH and a circum-nuclear disk



Key points: Distribution of stars and gas TMT, E-ELT, GMT

Summary

Our model provides the growth rates of SMBHs, gas mass, and stellar mass in the central 10s pc as a function of gas supply rate from host galaxies.

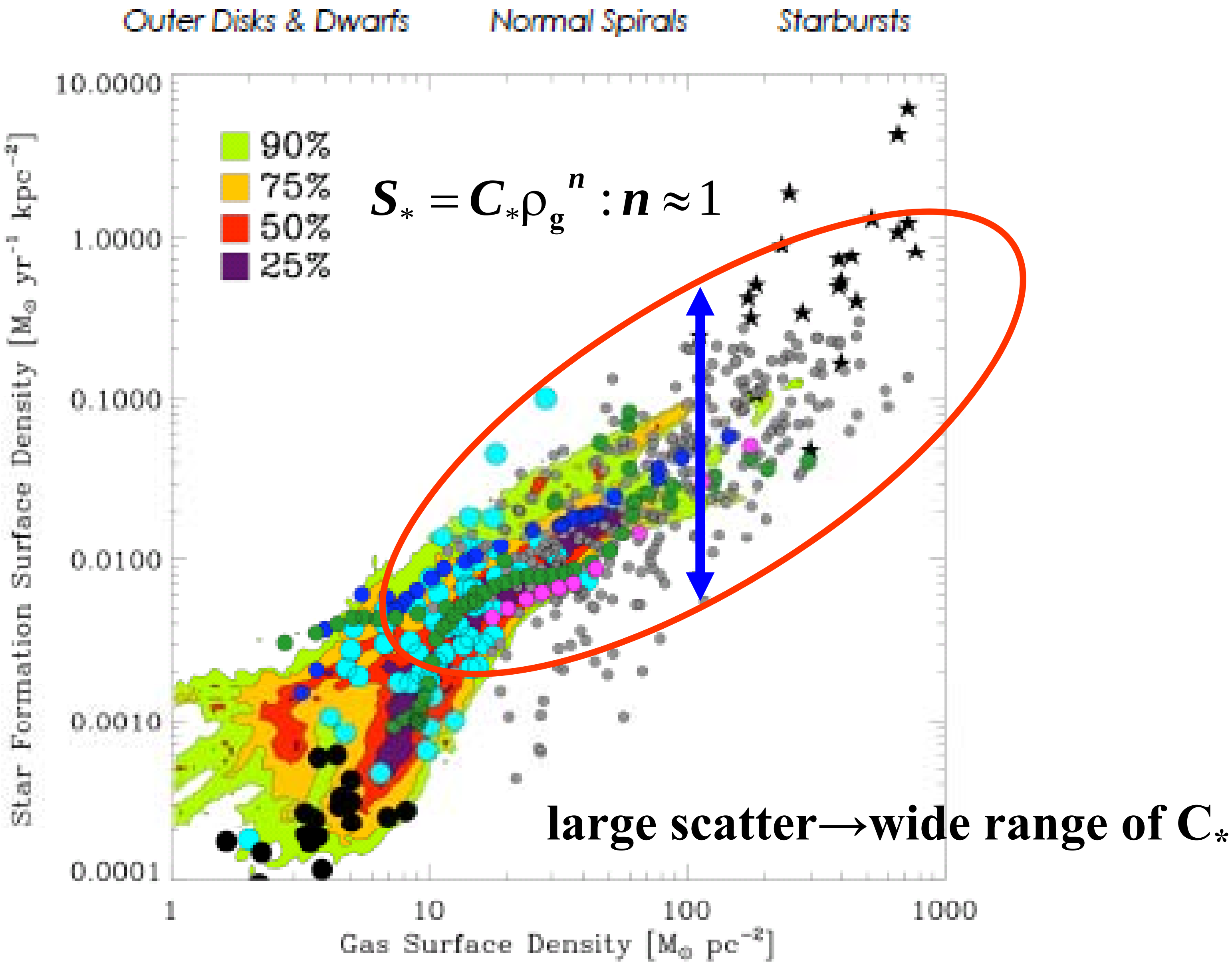
- The drastic change of the accretion rate depends on whether stars are formed in the inner region of the circumnuclear disk (CNDs), therefore **it depends on M_{BH}**.
- **Growth of SMBH itself provides negative feedback; the growth in more massive SMBH is less efficient,** because the mass accretion becomes smaller due to kinematic viscosity in the turbulent, clumpy circumnuclear disk.
- **AGN activity is related to the scale height of CNDs, distribution of stars and gas, and whether the mass of CNDs is more massive than that of central BHs.**

ALMA, TMT, E-ELT, GMT

Future consideration:

NSC formation, AGN feedback, mass accretion from a few pc to accretion disk

Bigiel +08



Kennicutt (1998) spirals and ★bursts; Wong & Blitz (2002); Schuster et al. (2007)
Wyder et al. (2007); Kennicutt et al. (2007); Crosthwaite & Turner (2007)

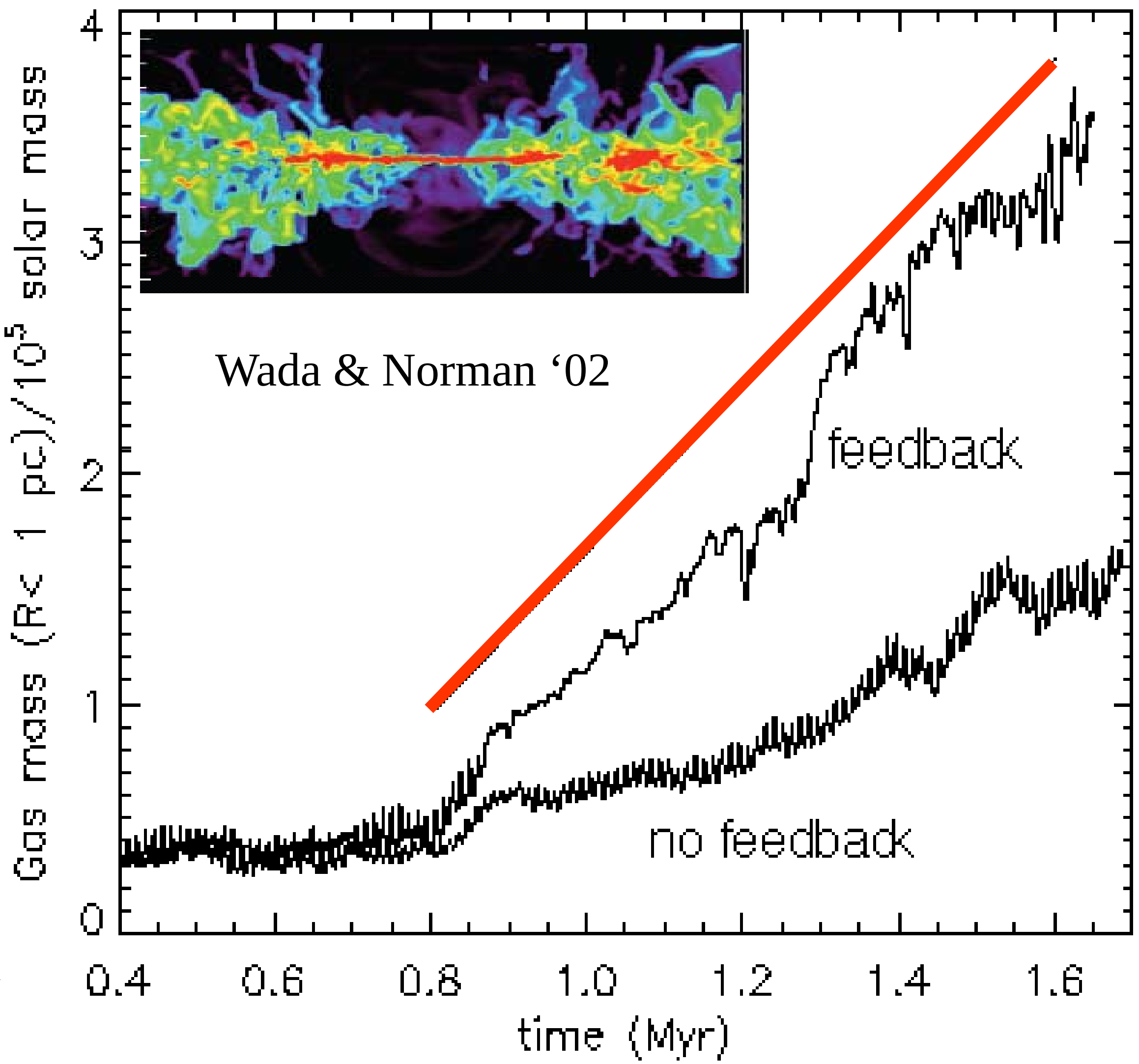
Gas accretion in a turbulent nuclear disk

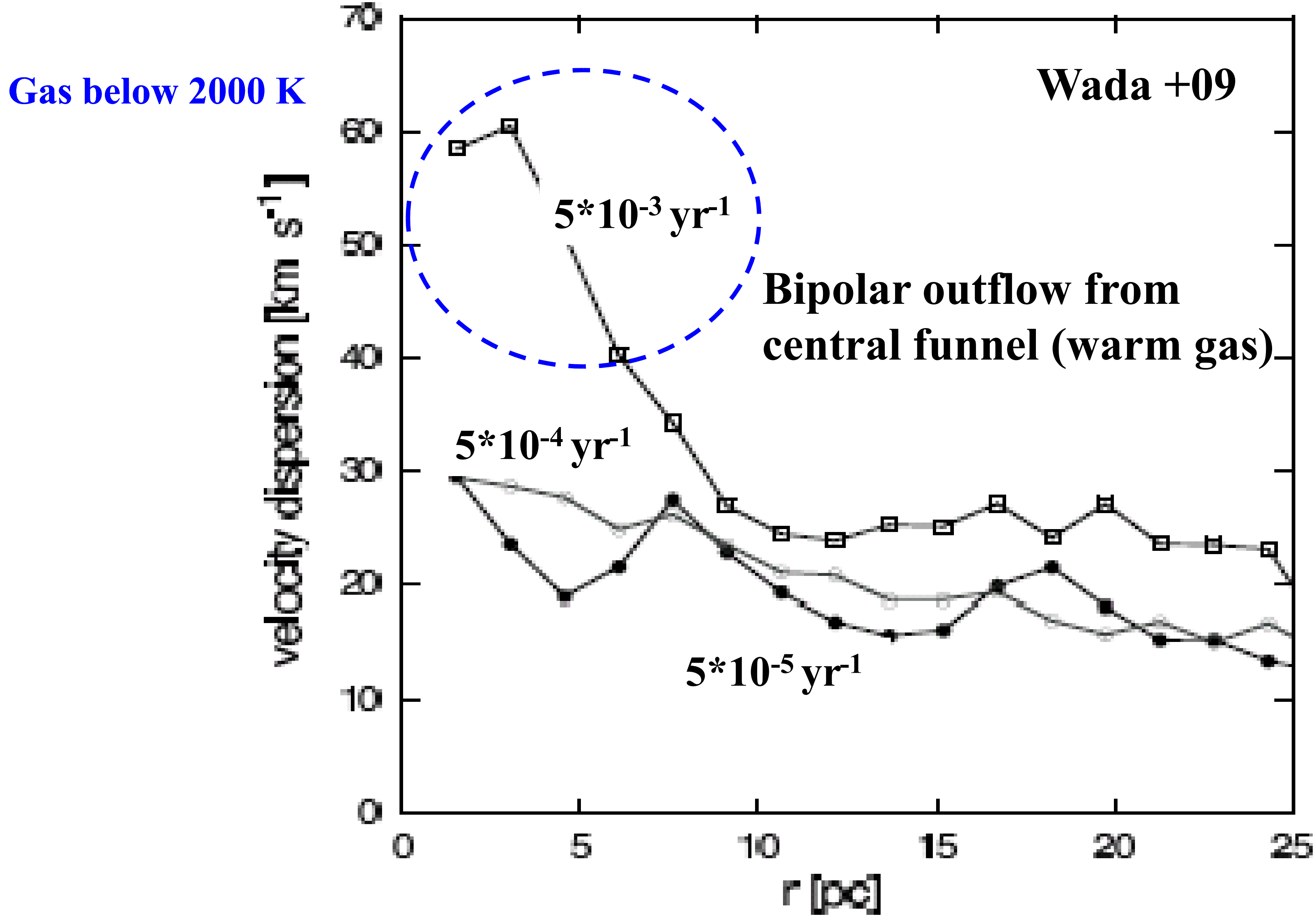
Accretion rate is enhanced by the starburst.

Average accretion rate ~ 0.1 $M_\odot$/yr

Turbulent viscosity dominates the accretion process in the circumnuclear region with star formation.

$$\nu = \alpha v_t h : \alpha \approx 1$$





Gas below 2000 K
Wada +09
5*10-3 yr-1
Bipolar outflow from
central funnel (warm gas)
5*10-4 yr-1
5*10-5 yr-1
velocity dispersion [km s-1]
r [pc]
0
10
20
30
40
50
60
70
0
5
10
15
20
25