ALMAワークショップ

「AGN銀河の中心1kpc→1pcでの質量降着機構の理解に向けて

核周分子ガス円盤は SMBH成長の担い手となるか？

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[1] 東京大学

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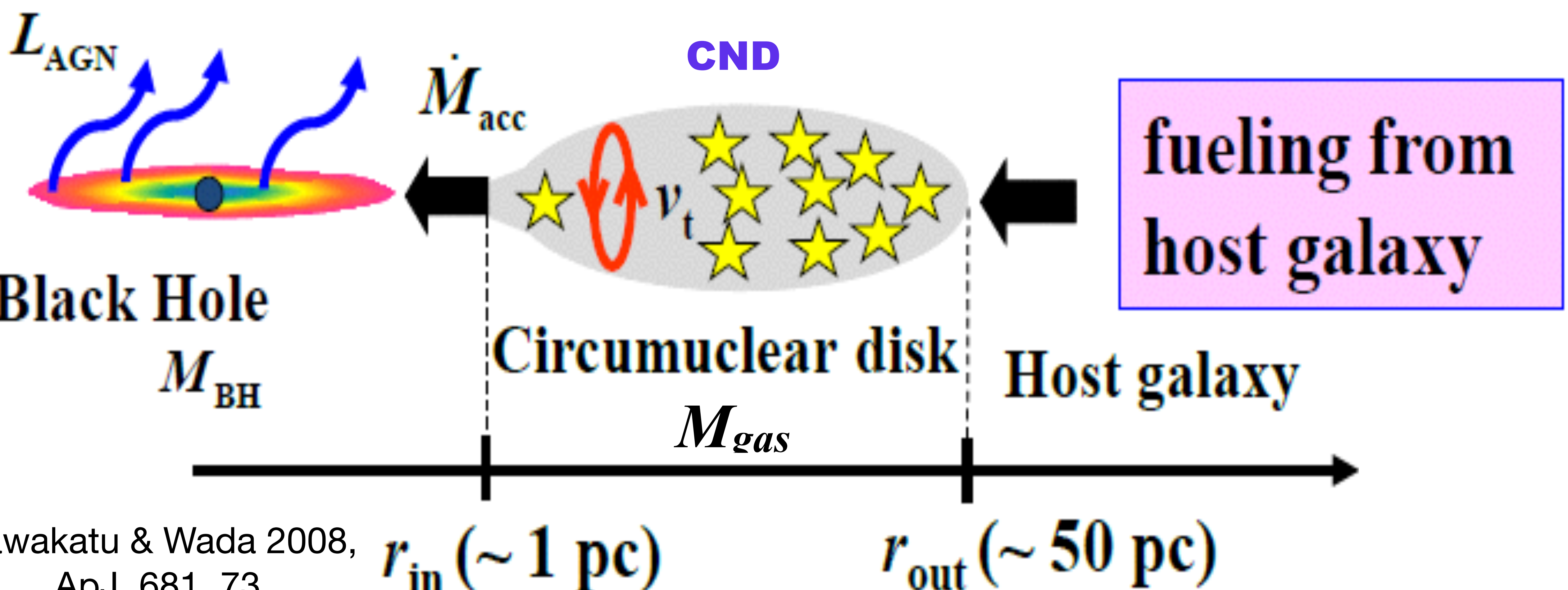
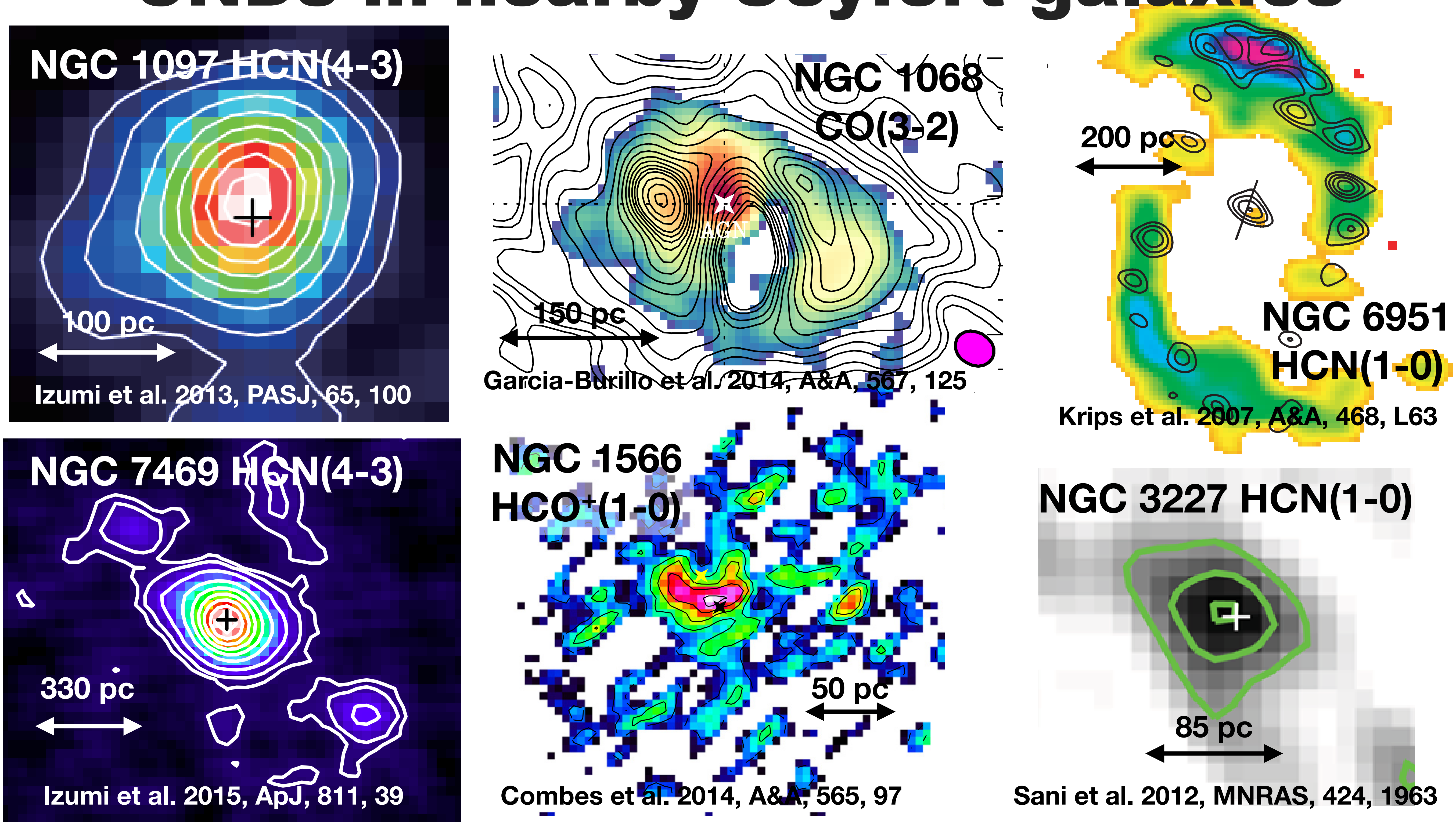
Circumnuclear disk (CND): a direct source of mass supply to a SMBH

- Remaining angular momentum of the accreting gas will form ~10-100 pc scale gaseous CND at the center
- An *outer envelope* of the putative dusty torus? → mass? size? structure? kinematics? fueling?



Kawakatu & Wada 2008, ApJ, 681, 73

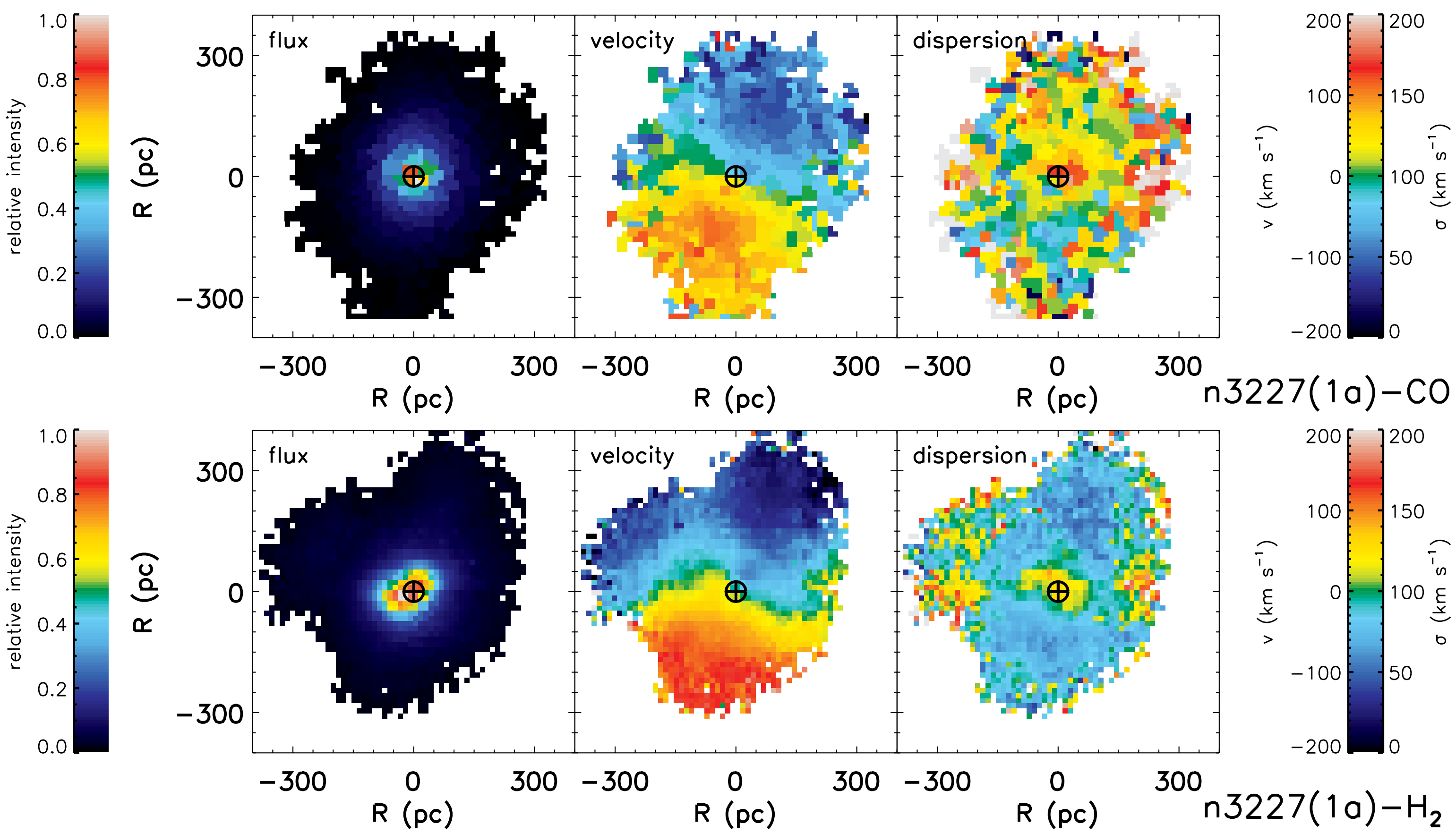
CNDs in nearby Seyfert galaxies

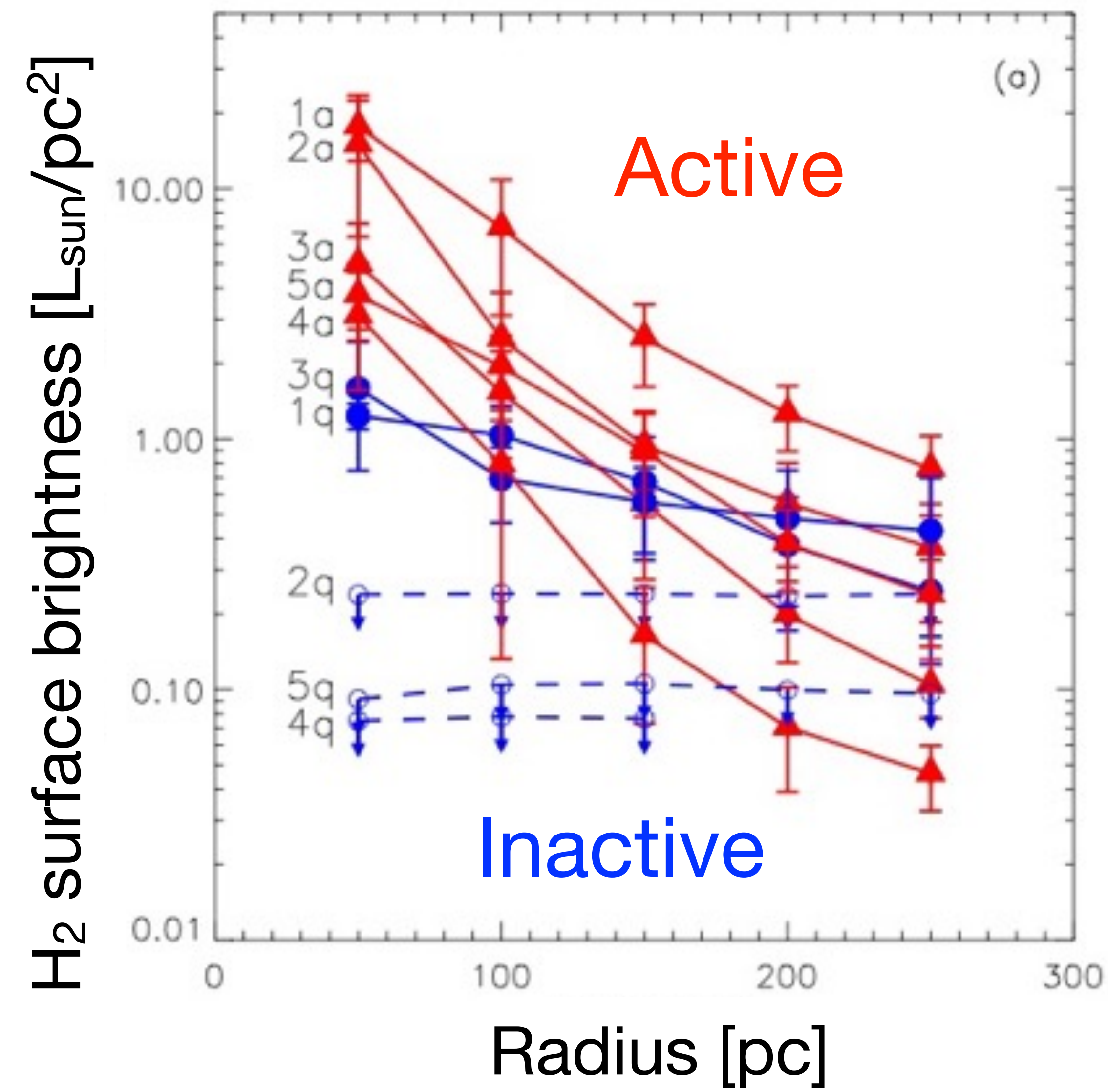


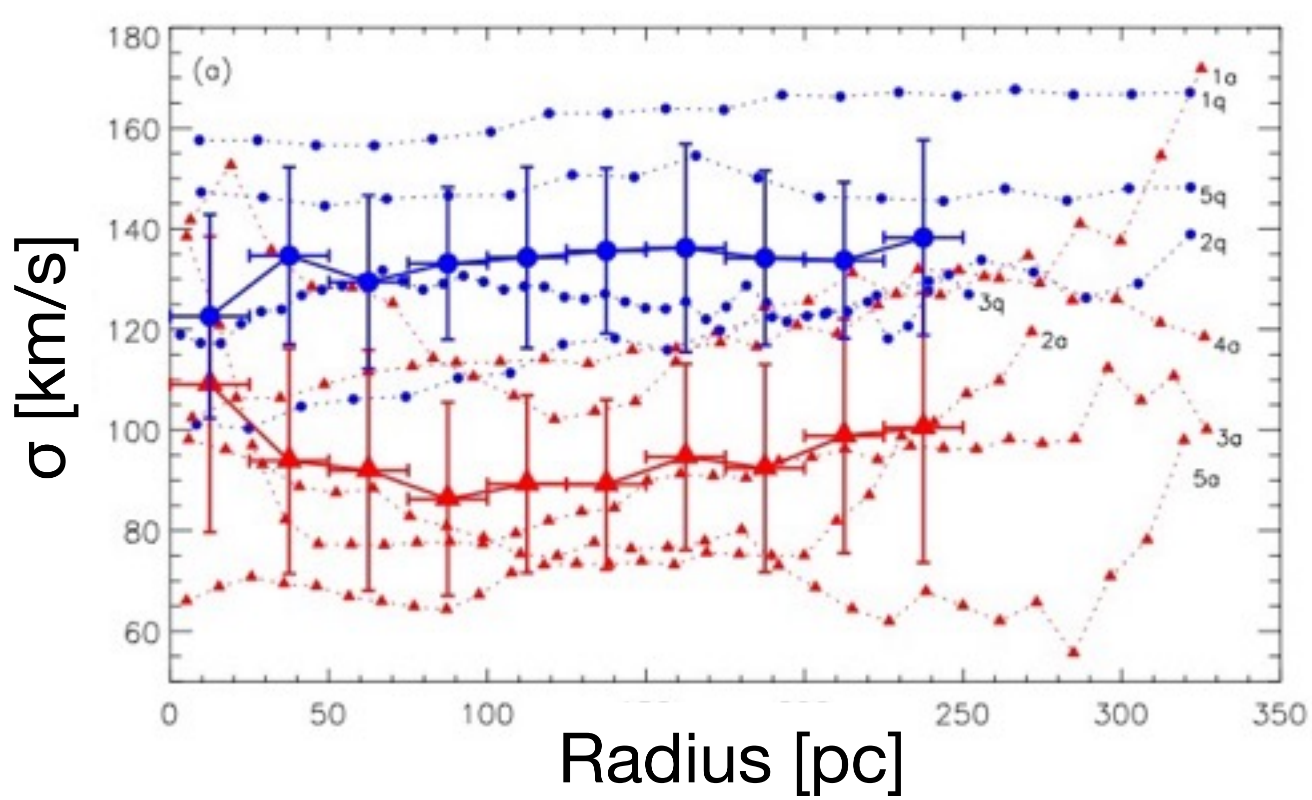
Spatial scale: ~100 pc or less (they are not fully resolved)

Missing link in the scenario of AGN-fueling!!

CNDs in nearby Seyfert galaxies

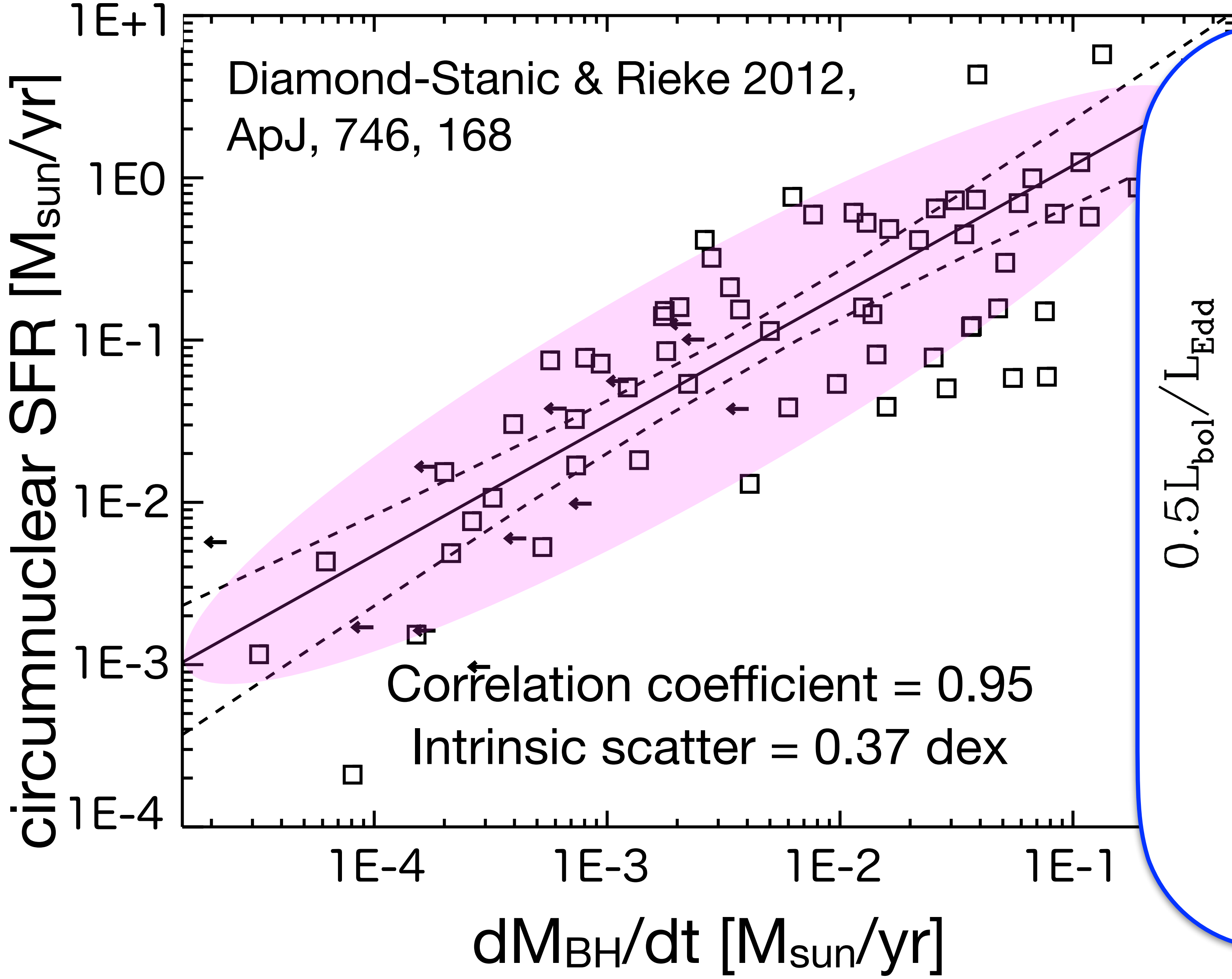


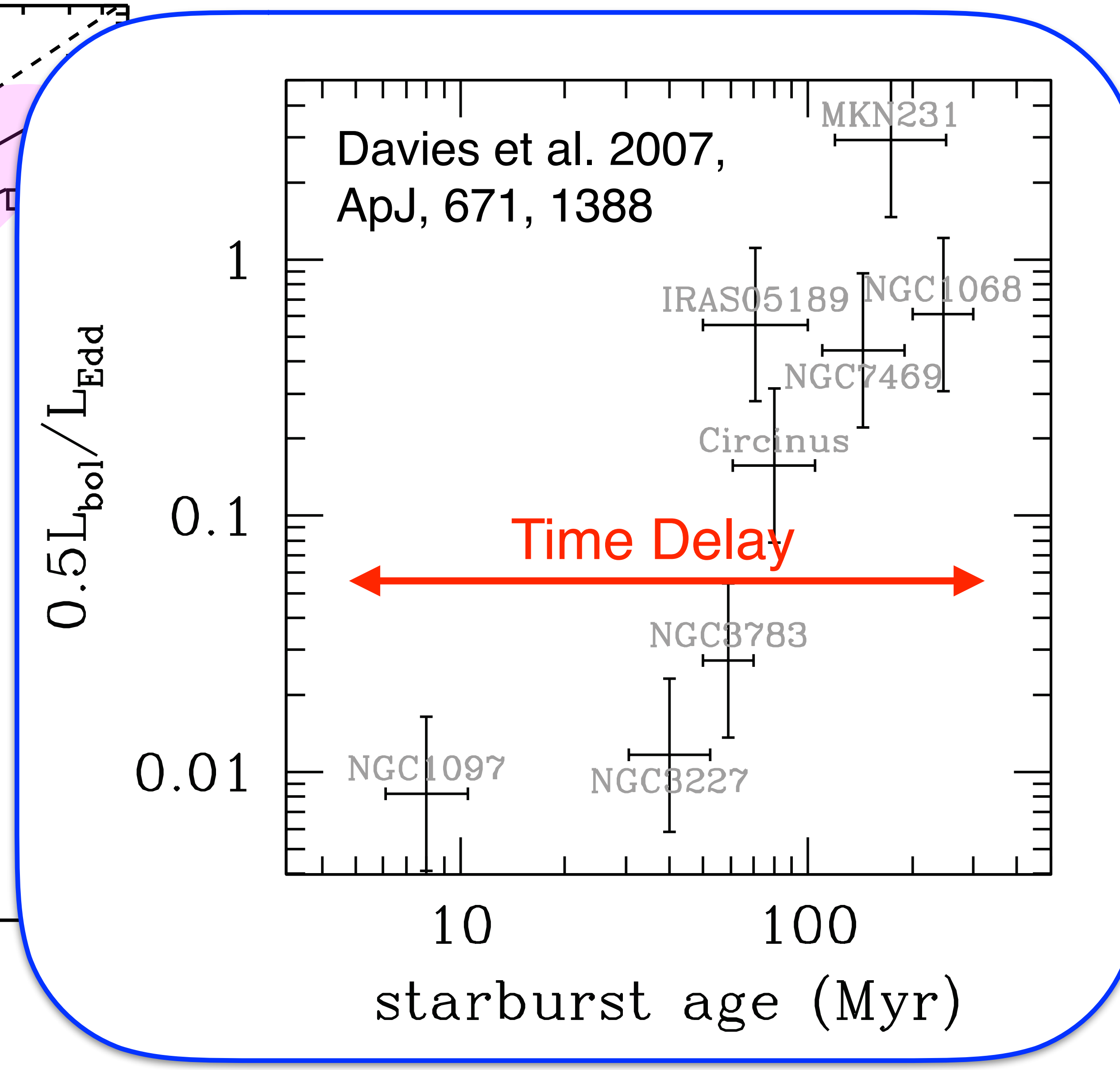




AGNs seem to have gaseous disk, whereas non-AGNs do not.
(Hicks et al. 2013, ApJ, 768, 107)

AGN-SB connection@CND?



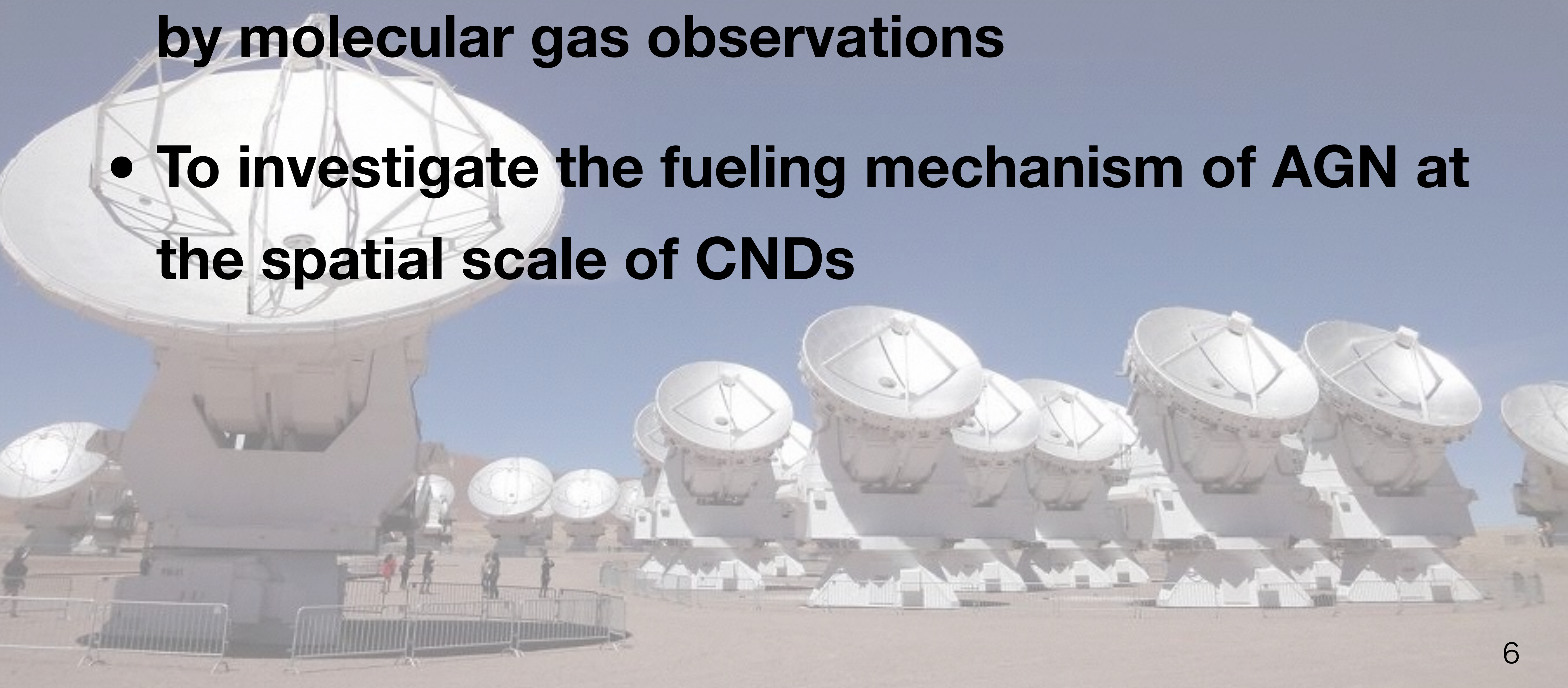


- SFR—dM_{BH}/dt correlation
- Its origin is unknown
- Time delay → causal link?

If circumnuclear starburst regulate the mass accretion onto the SMBH, how?

This study

- To rebuild the AGN-SB connection individually by molecular gas observations
- To investigate the fueling mechanism of AGN at the spatial scale of CNDs



Data

Total 32 Seyfert galaxies with the following data are used

- **HCN(1-0) line luminosity** → M_{dense}

  - selectively probe orders of magnitude denser gas than that CO(1-0) does

  → e.g., Gao & Solomon 2004, ApJ, 606, 271; Krips et al. 2008, ApJ, 677, 262

  - 9 interferometric data (ALMA, PdBI, NMA, θ_{med}=200 pc) + 23 single dish data (NRO45m, IRAM30m, etc, θ_{med}=6.2kpc)

  → ***"from the host galaxy to the CND"***

- **Absorption corrected 2-10 keV X-ray luminosity** → dM_{BH}/dt

  - bolometric correction: Marconi et al. 2004, MNRAS, 351, 16

  - η = 0.1 is assumed, e.g., Alexander & Hickox 2012, New A. Rev. 56, 93

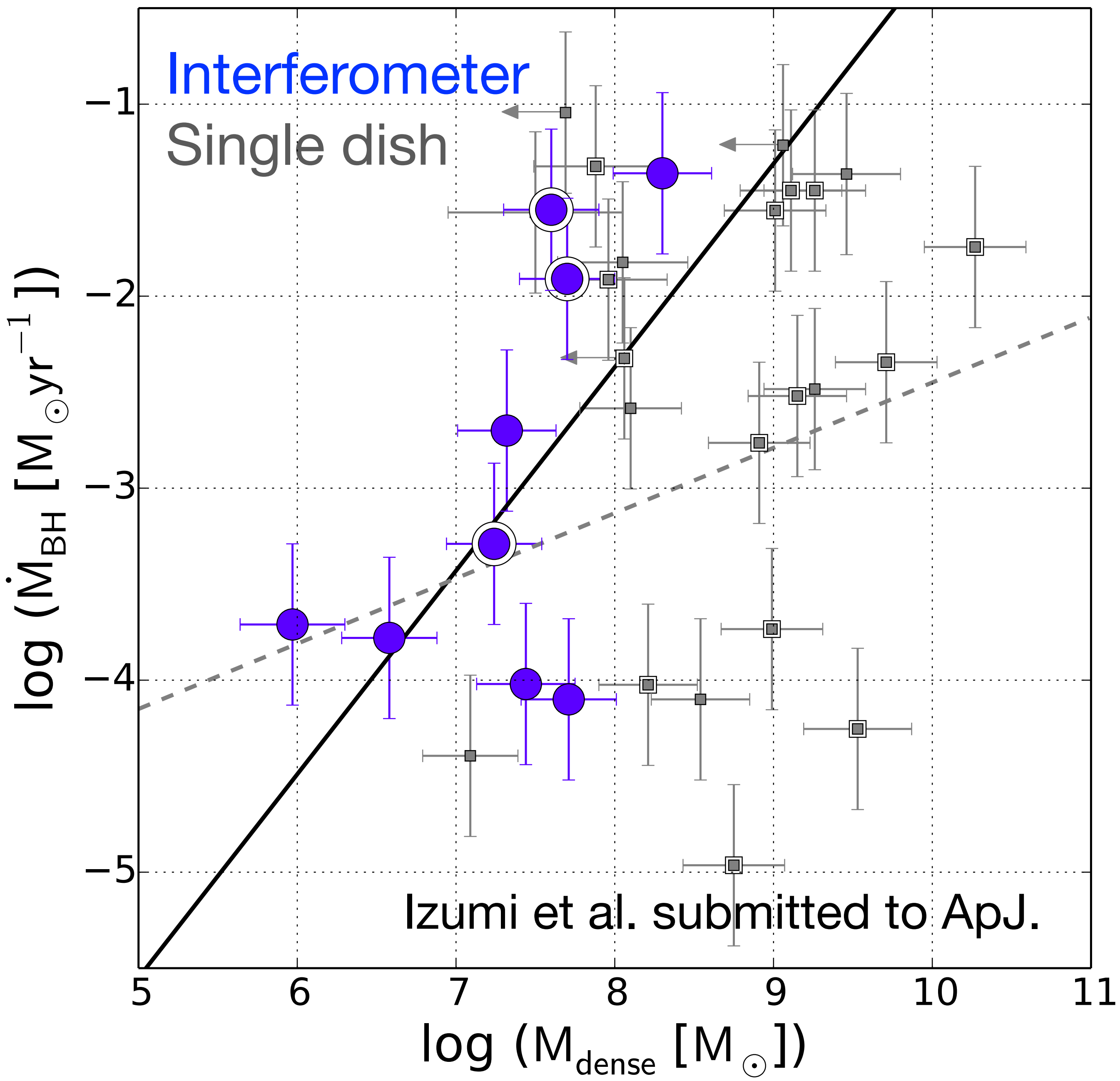
- **M_{BH}**: Stellar/gas kinematics, maser, reverberation, M-σ_*

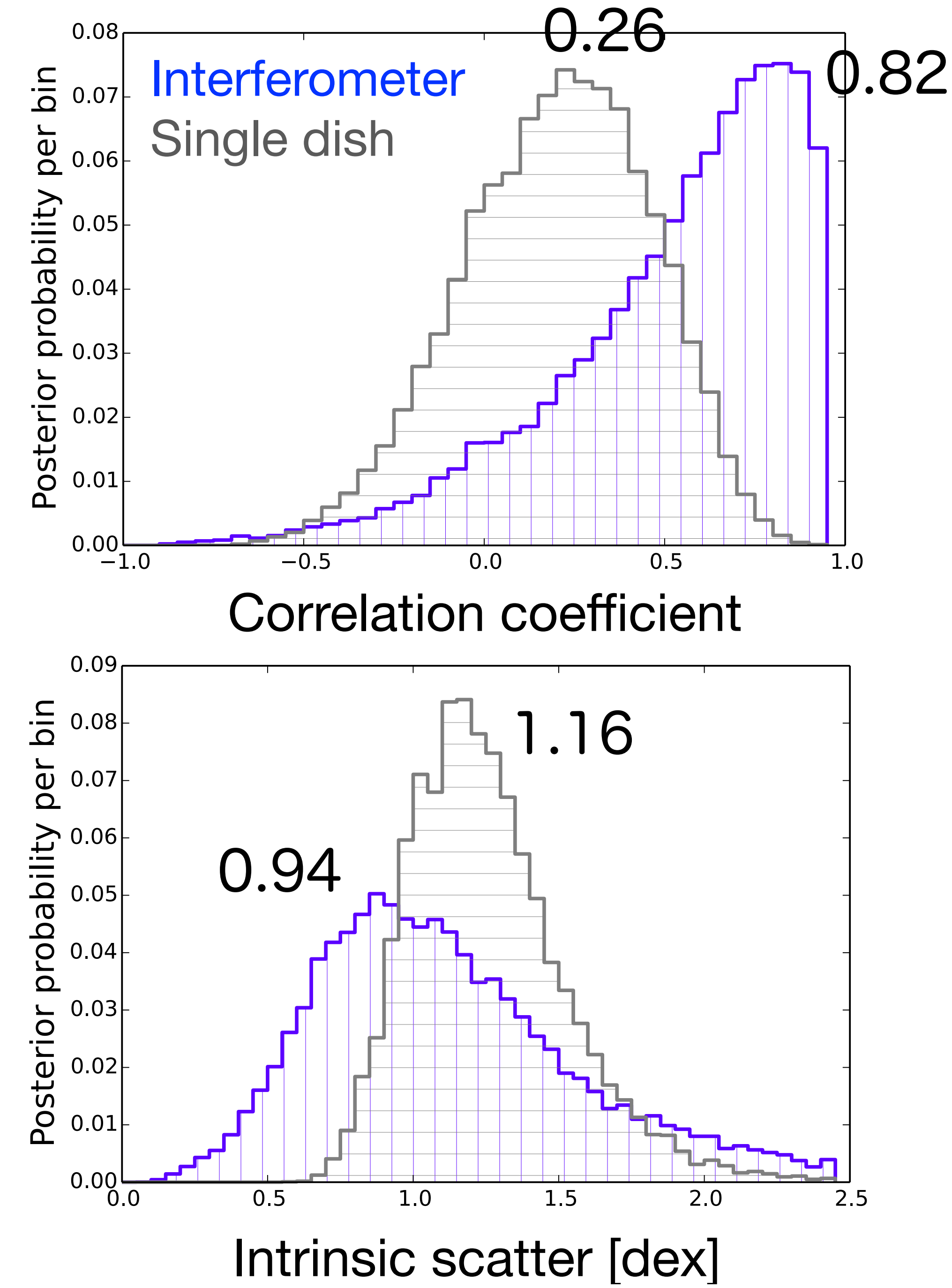
- Bayesian-based regression analysis

  - linmix_err (IDL routine); Kelly 2007, ApJ, 665, 1489

  → posterior distribution of each regression parameter can be obtained

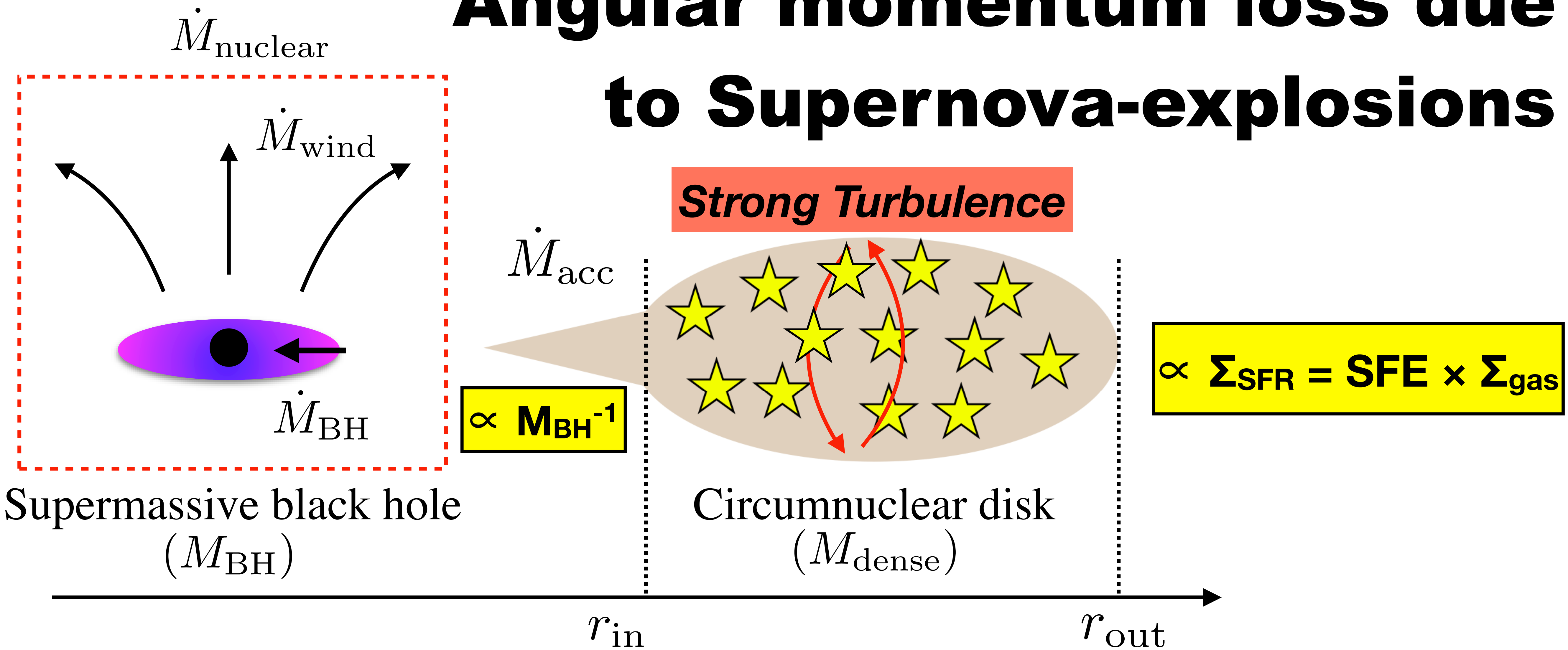
Result: M_{dense}-dM_{BH}/dt correlation





- Positive correlation: importance of external regulator on dM_{BH}/dt?
  → virtually equivalent to SFR-dM_{BH}/dt correlation
- Large scatter: need for other parameters?

Angular momentum loss due to Supernova-explosions



$$\dot{M}_{\rm acc}(r) = 2\pi \nu_t \Sigma_{\rm g}(r) \left| \frac{d\ \ln\Omega(r)}{d\ \ln r} \right|$$

$\nu_{\rm t}$:viscous parameter

Ω :angular velocity

$\Sigma_{\rm g} = 2h\rho_{\rm g}$:surface density

$$\nu_{\rm t} = \alpha_{\rm SN} v_{\rm t} h, \quad \Omega \propto r^{-3/2}$$

SFE → $C_{*,-7}$

Gas surface density $\propto$ M$_{\rm dense}$ → $\Sigma_{\rm g,1}$

BH mass → $M_{\rm BH,7}^{-1}$

$$\dot{M}_{\rm acc}(r) = 3\pi \alpha_{\rm SN} \eta E_{\rm SN} C_* \Sigma_{\rm g}(r_{\rm in}) \left(\frac{r_{\rm in}^{\ 3}}{G M_{\rm BH}} \right) = 0.13 \alpha_{\rm SN,1} r_{\rm in,3}^{3} C_{*,-7} \Sigma_{\rm g,1} M_{\rm BH,7}^{-1} [M_\odot/{\rm yr}]$$

Kawakatu & Wada 2008, ApJ, 681, 73

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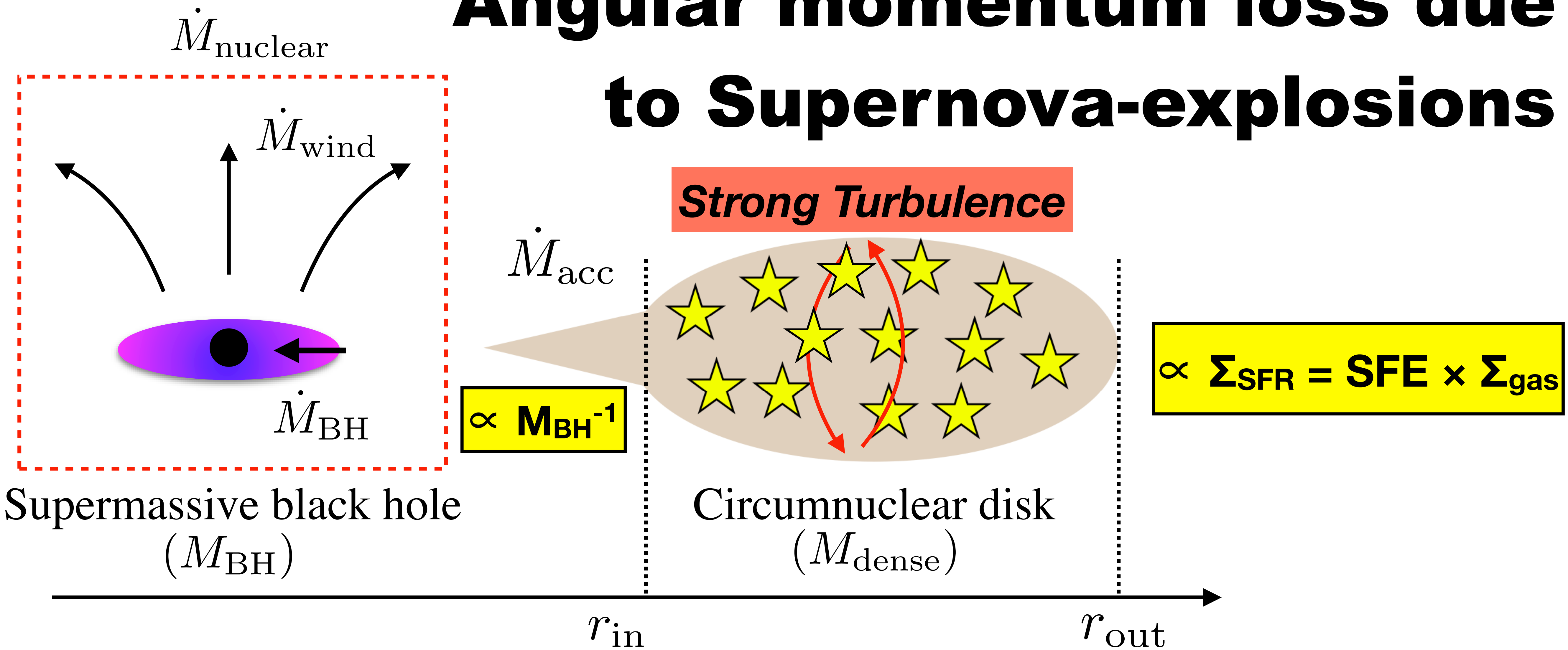

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Direct comparison with the model

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SFE
Gas surface density
BH mass

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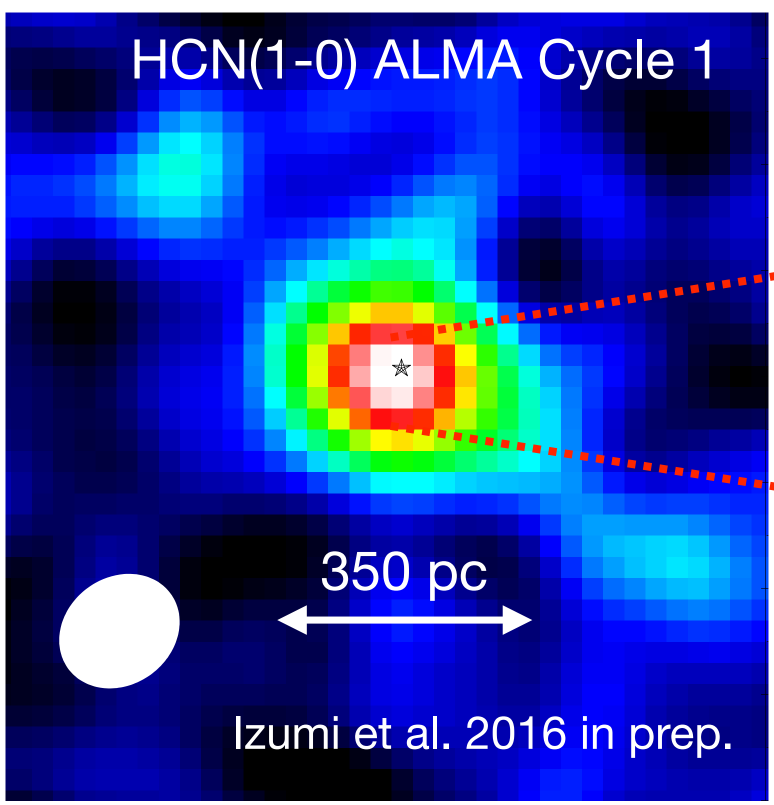
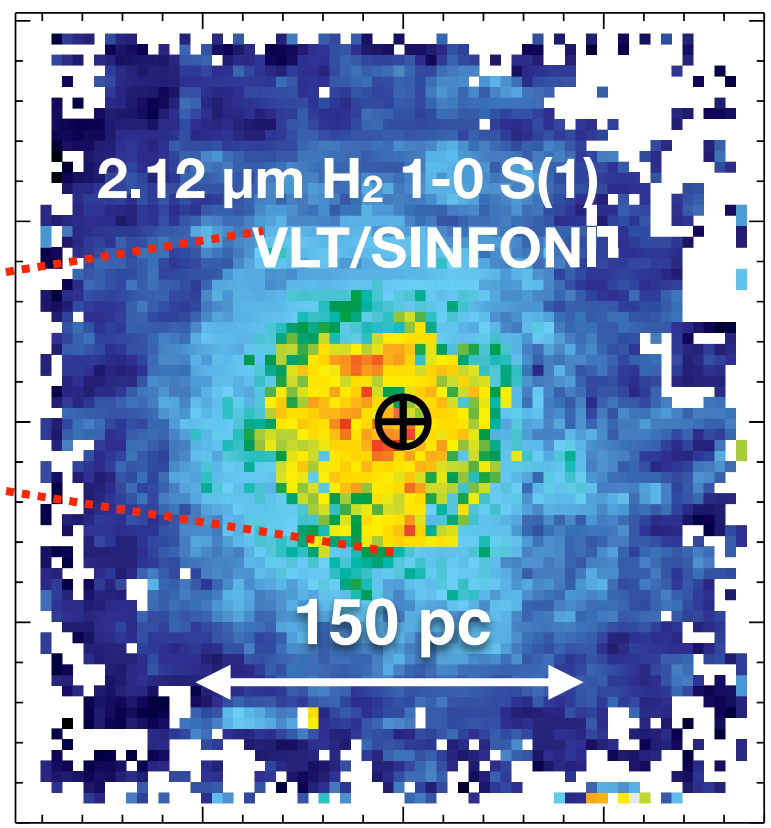
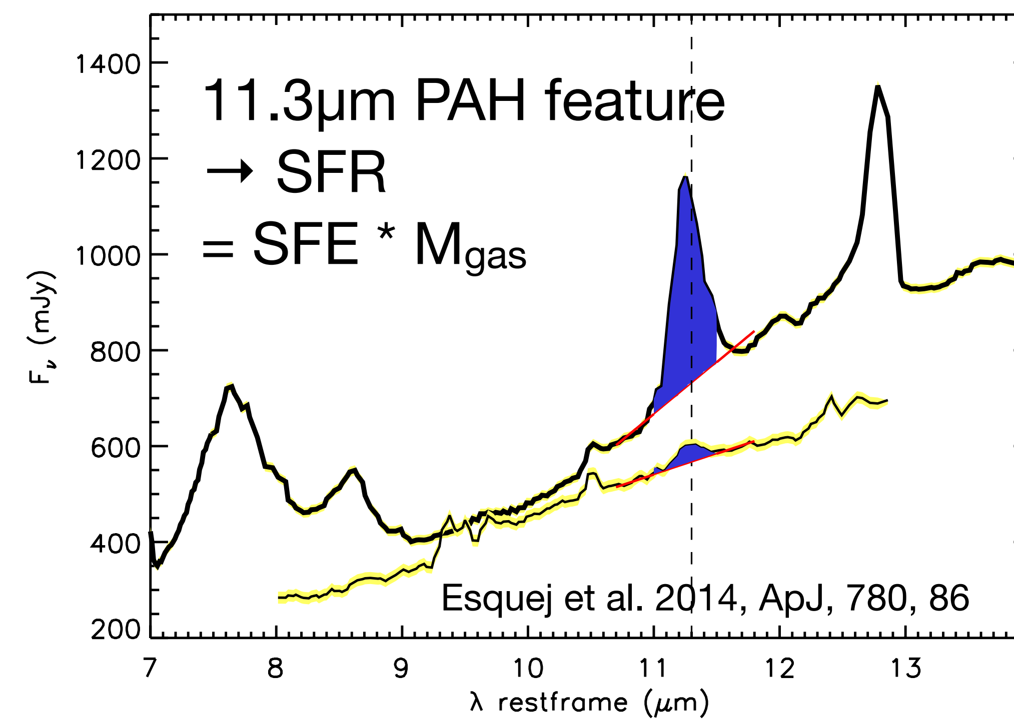
<u>The case of NGC 7469</u>





Hicks et al. 2009, ApJ, 696, 448



reverberation → M_{BH}
(Peterson et al. 2014, ApJ, 795, 149)

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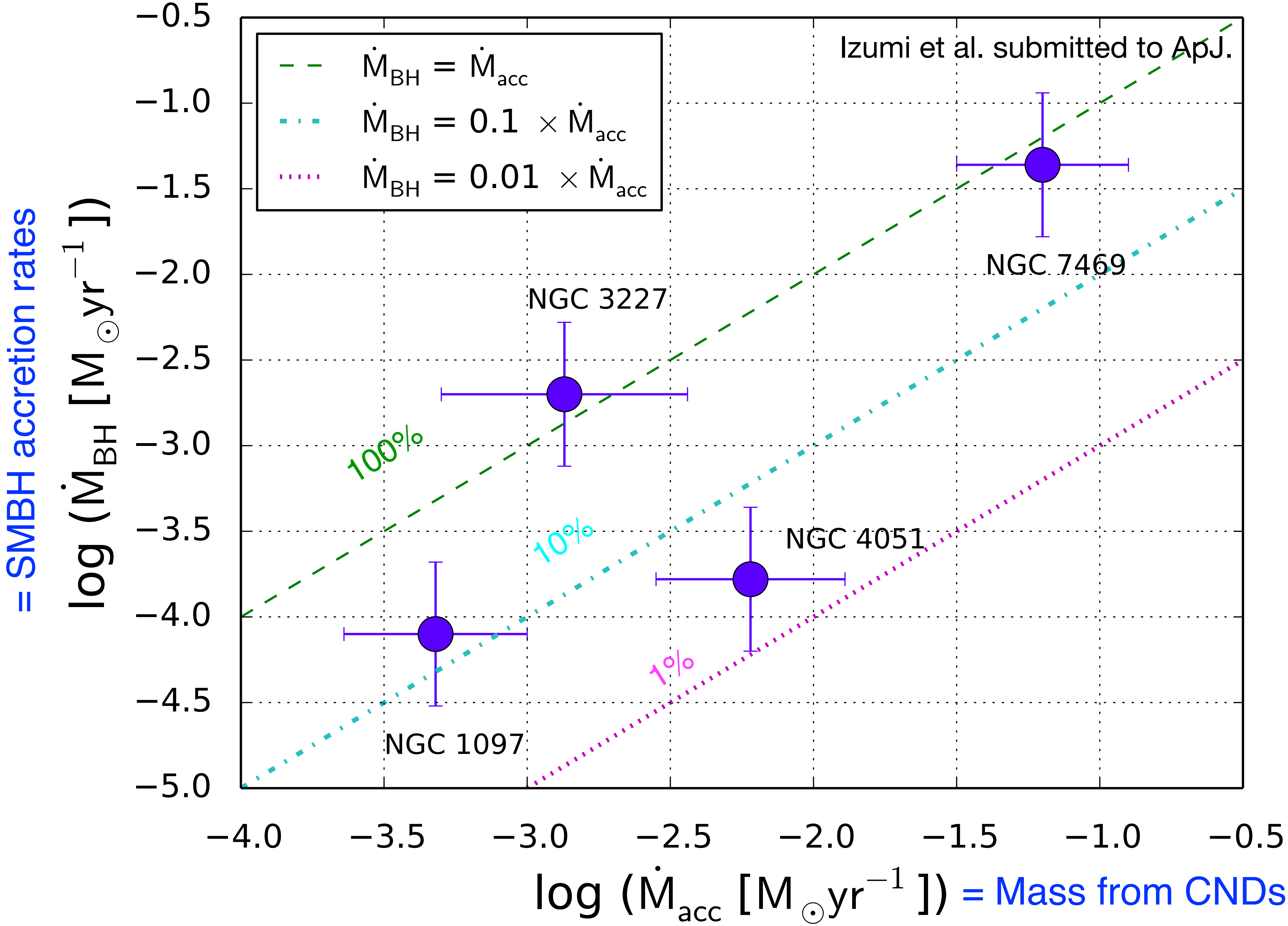

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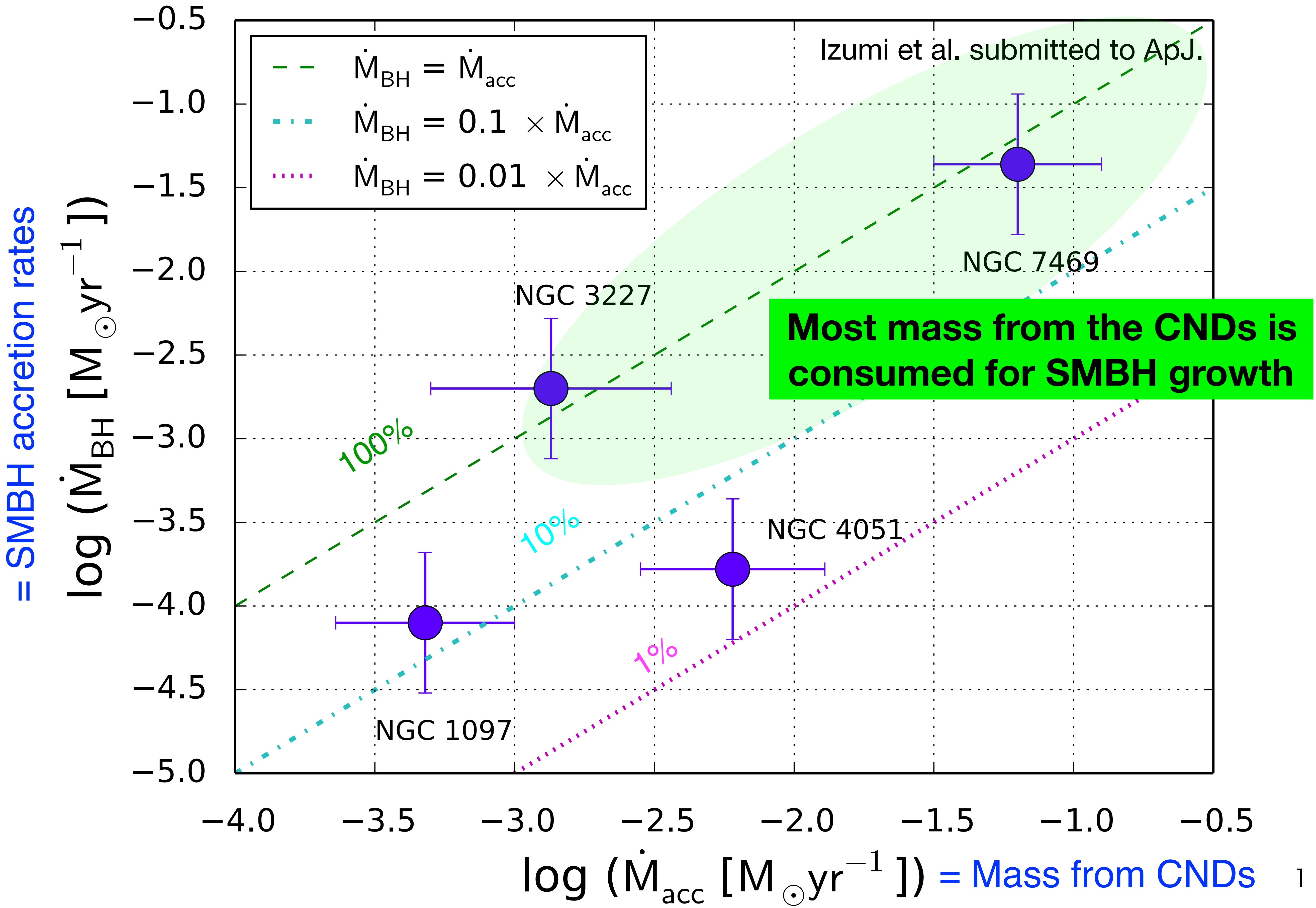

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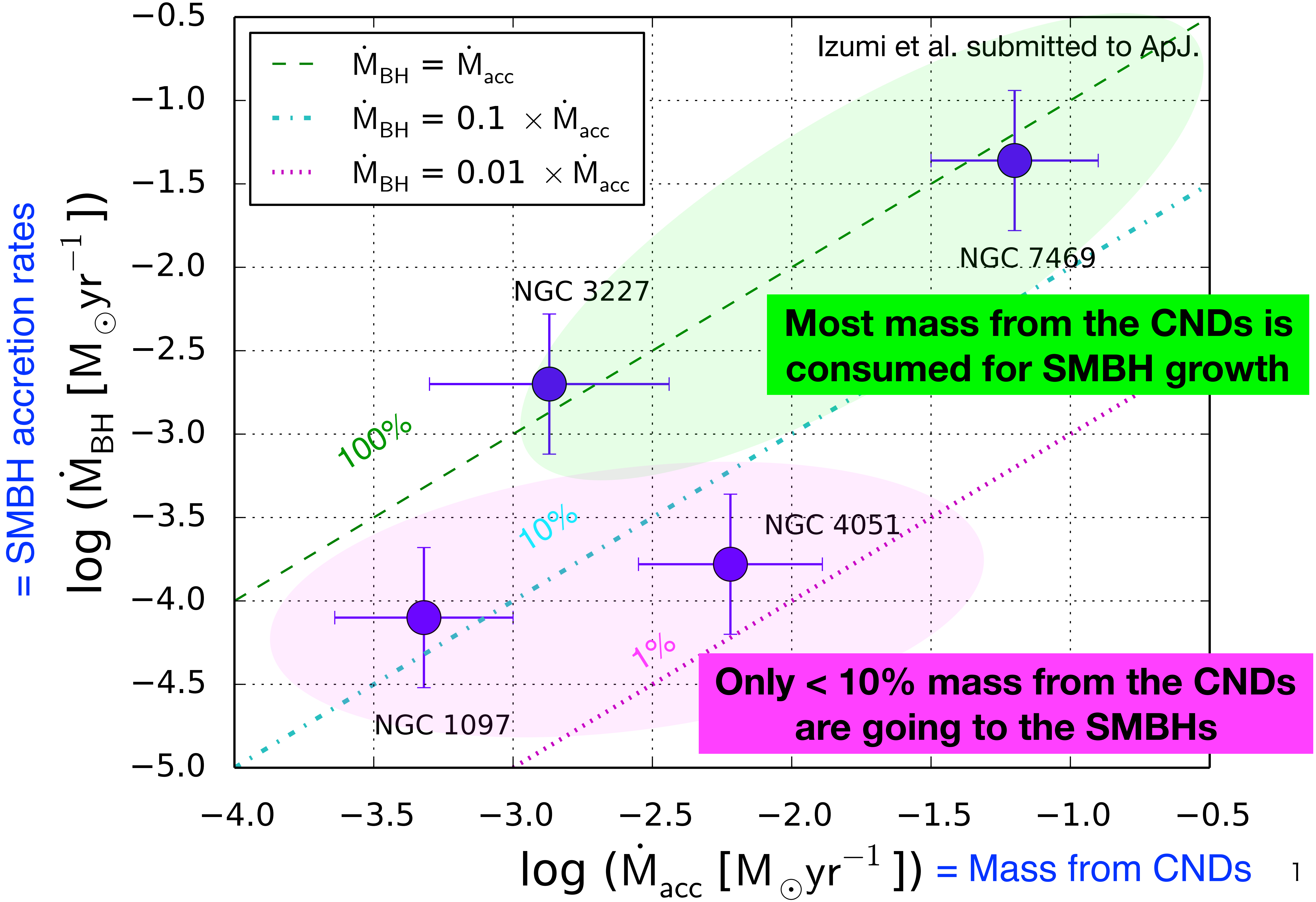

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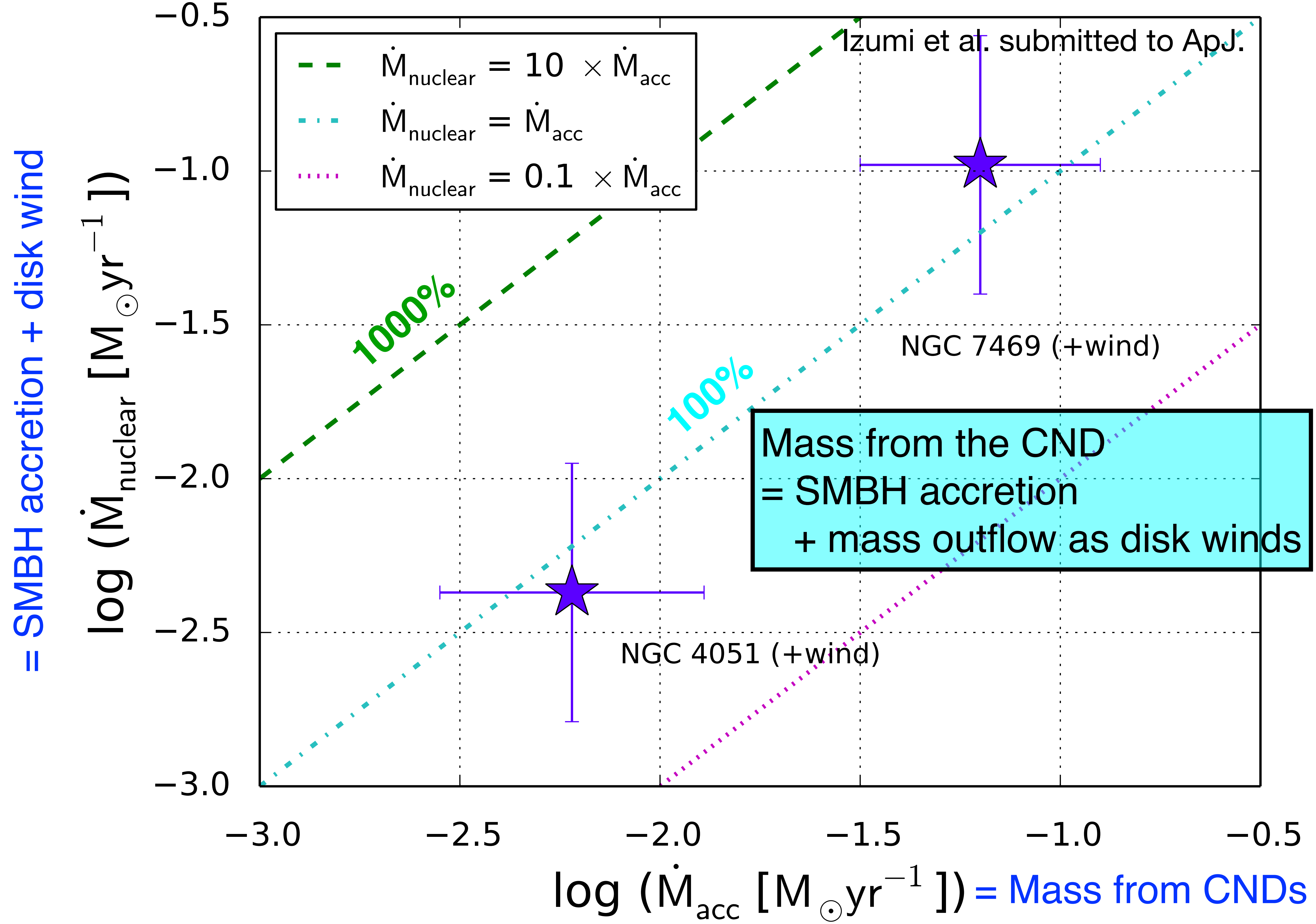

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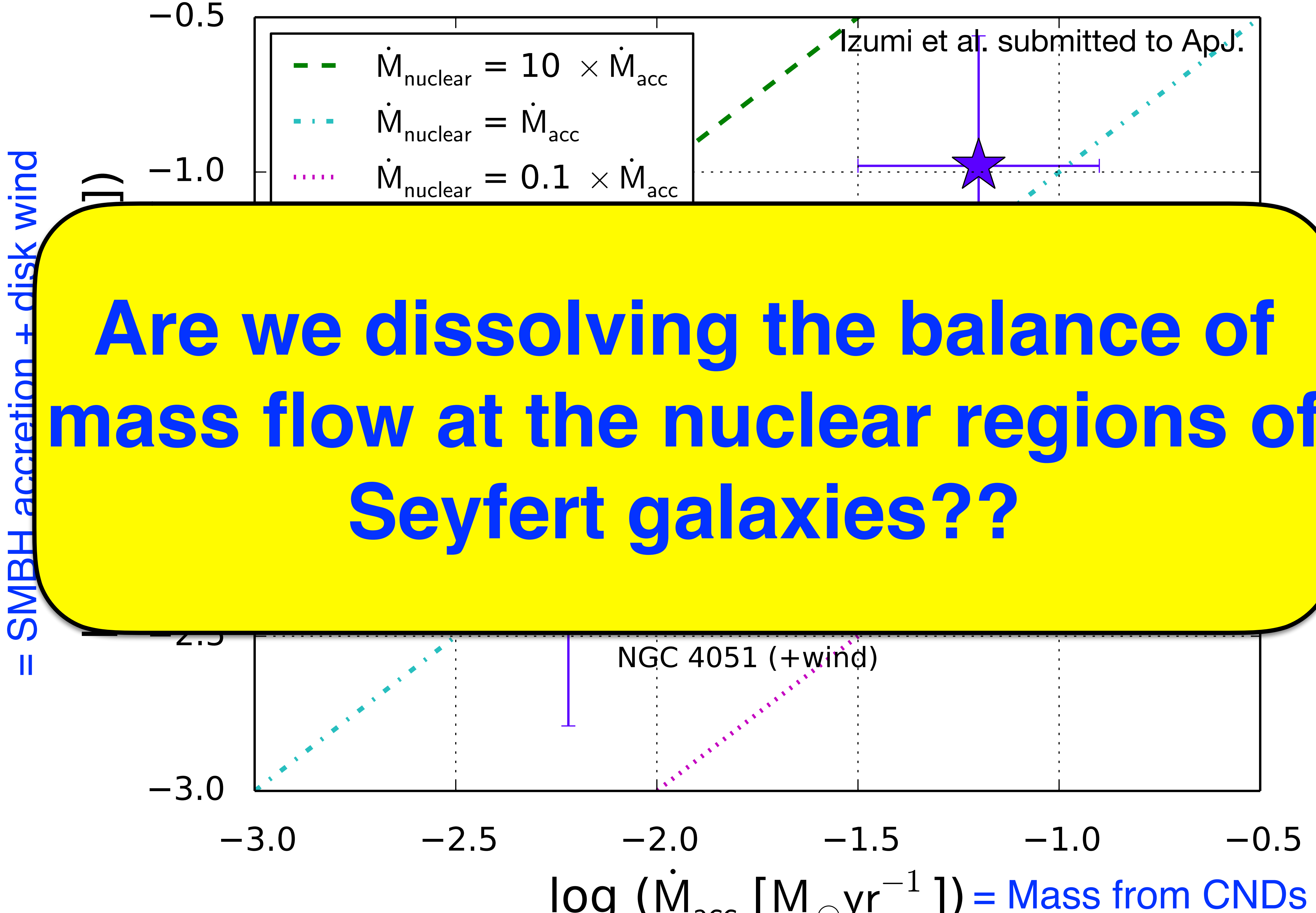


Are we dissolving the balance of mass flow at the nuclear regions of Seyfert galaxies??

Speculation on this scenario

- CNDは星形成活動を示すので、SNeも自然と期待できる。

  e.g., Esquej et al. 2014, ApJ, 780, 86

  → ~ $10^{3\text{-}4}$ yrに一回爆発

- 爆発の影響で、ガスはclumpyな構造に。

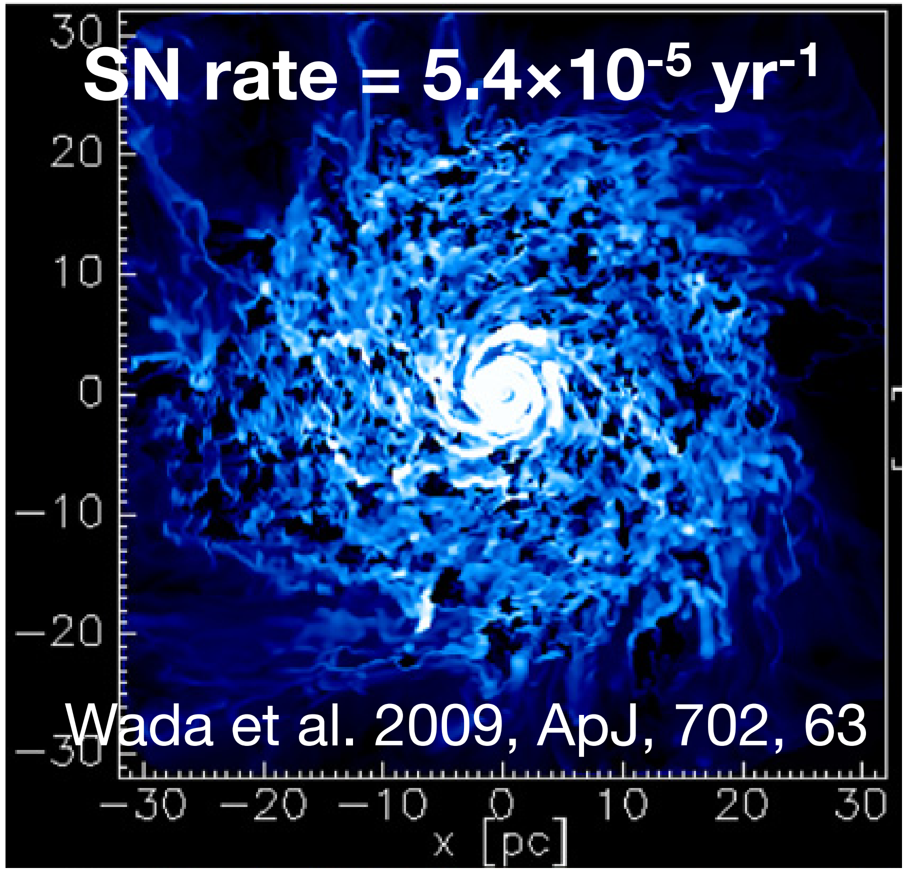
  → **clumpy torus**? nuclear obscuration?

- 粘性降着のタイムスケールは、

  - CND: a few Myr
  - 降着円盤: < ~a few×10 Myr

- 星形成の持続時間は~100Myr程度

  → AGN-SBの**causal** connectionは可能



Wada et al. 2009, ApJ, 702, 63

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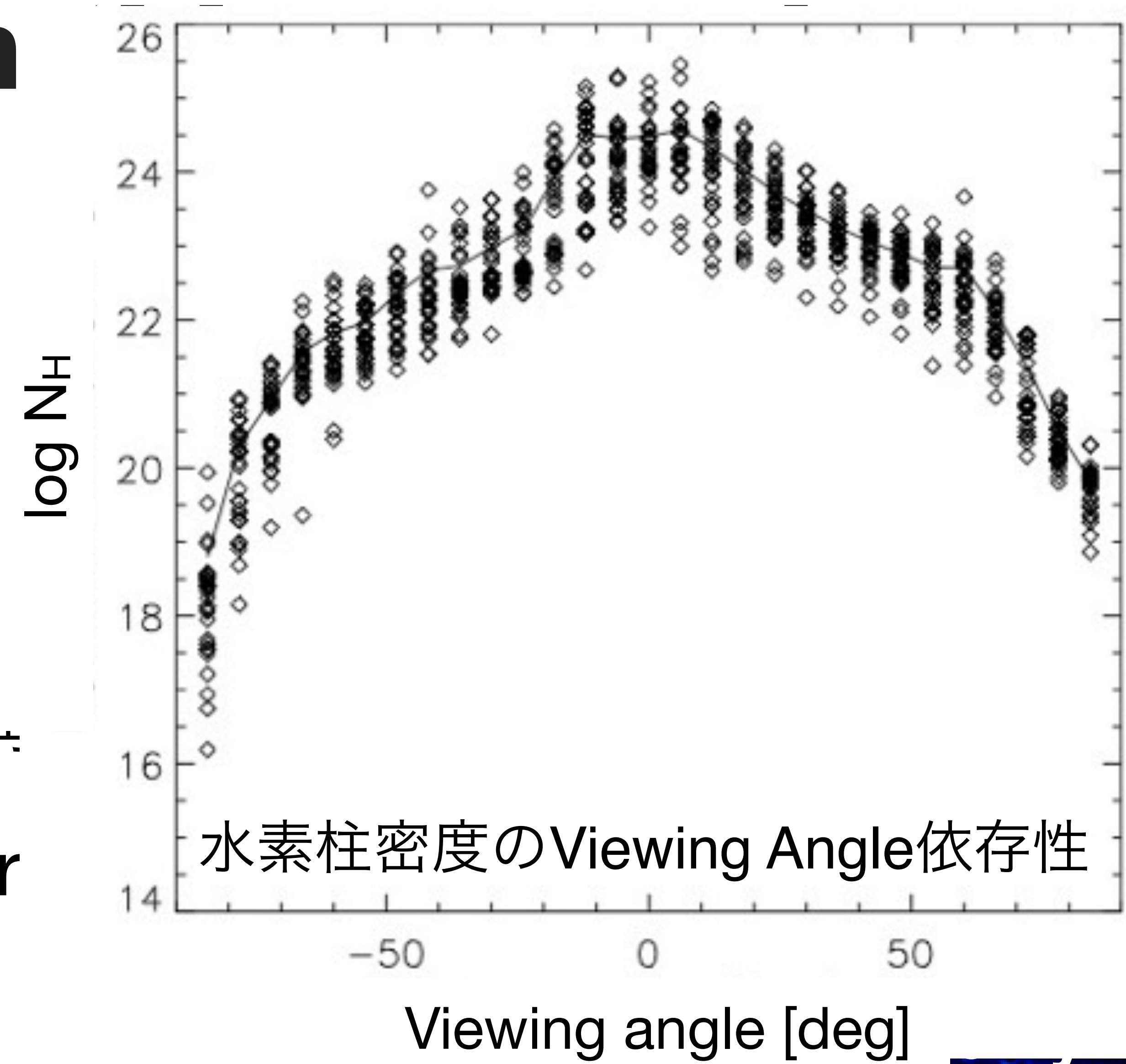
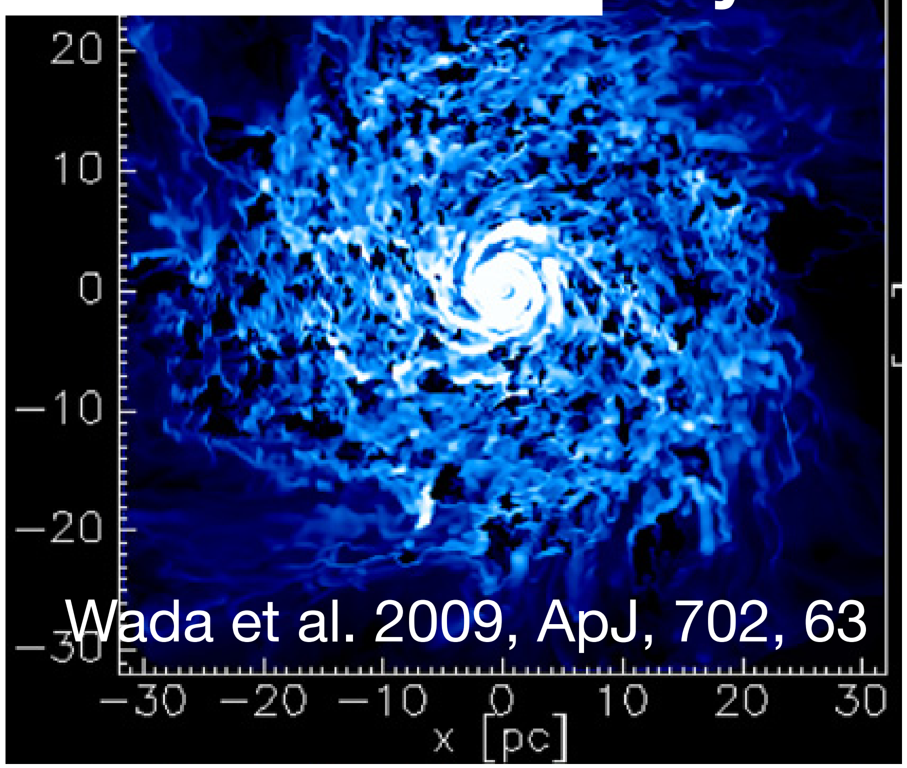


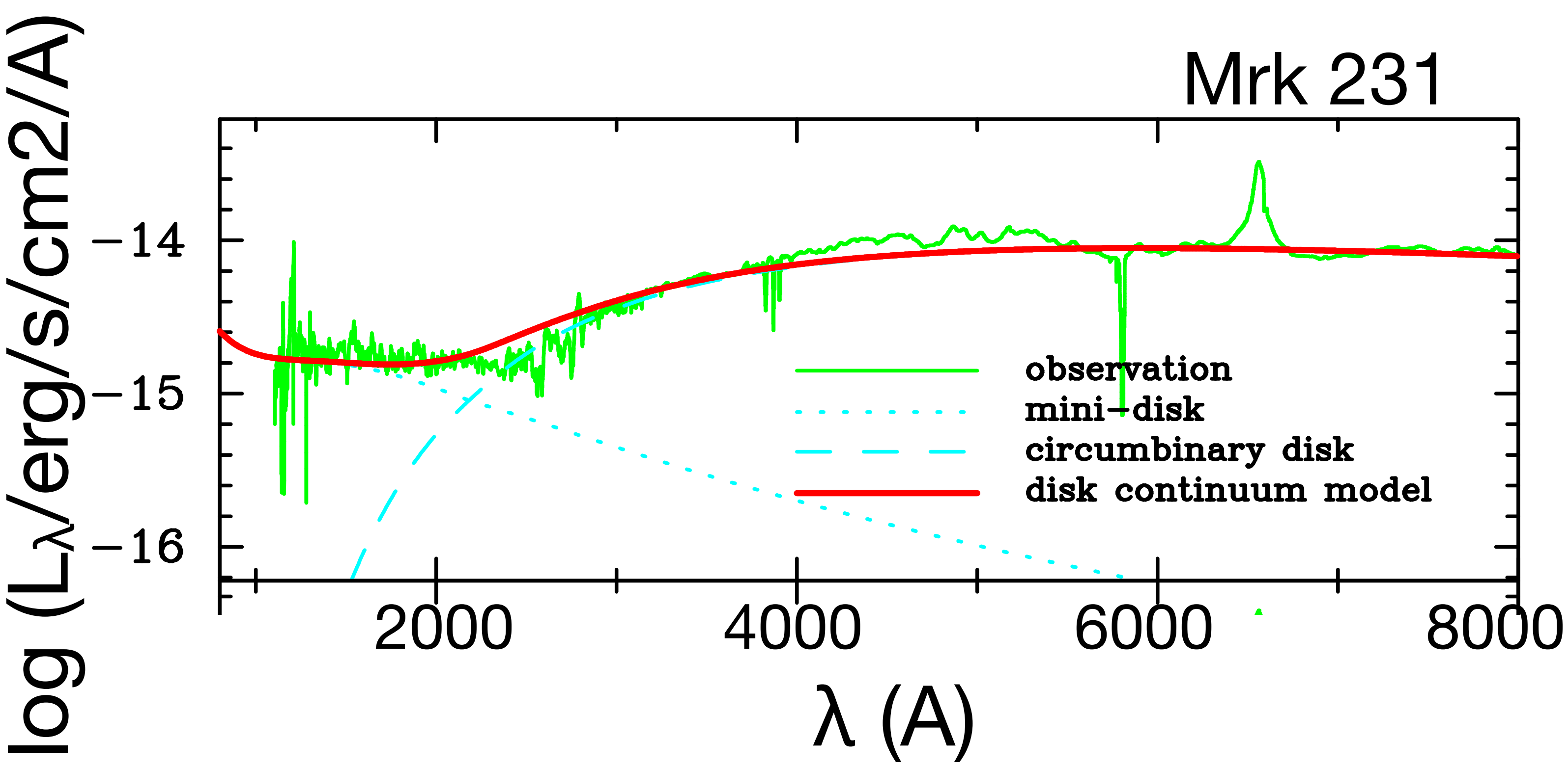


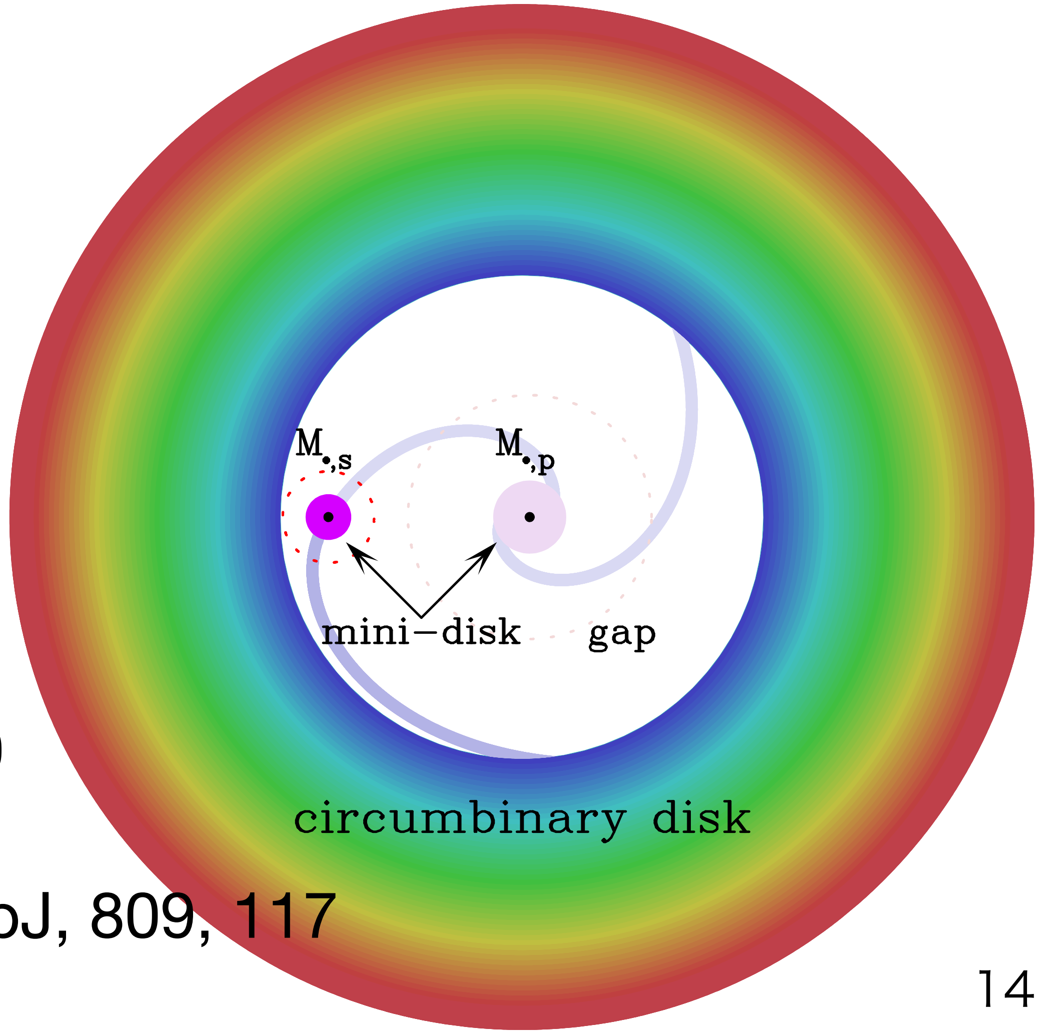
Wada et al. 2009, ApJ, 702, 63

Speculation on this scenario

- Can we form high mass end (M_{BH} ~ 1e9 M_{sun}) SMBHs within 1e9 year?
  - Partial fraction of the CND's gas will consumed for SF
  - Enormous amount of gas (>~1e10-11M_{sun}) is required even when we assume the SMG-class SFE

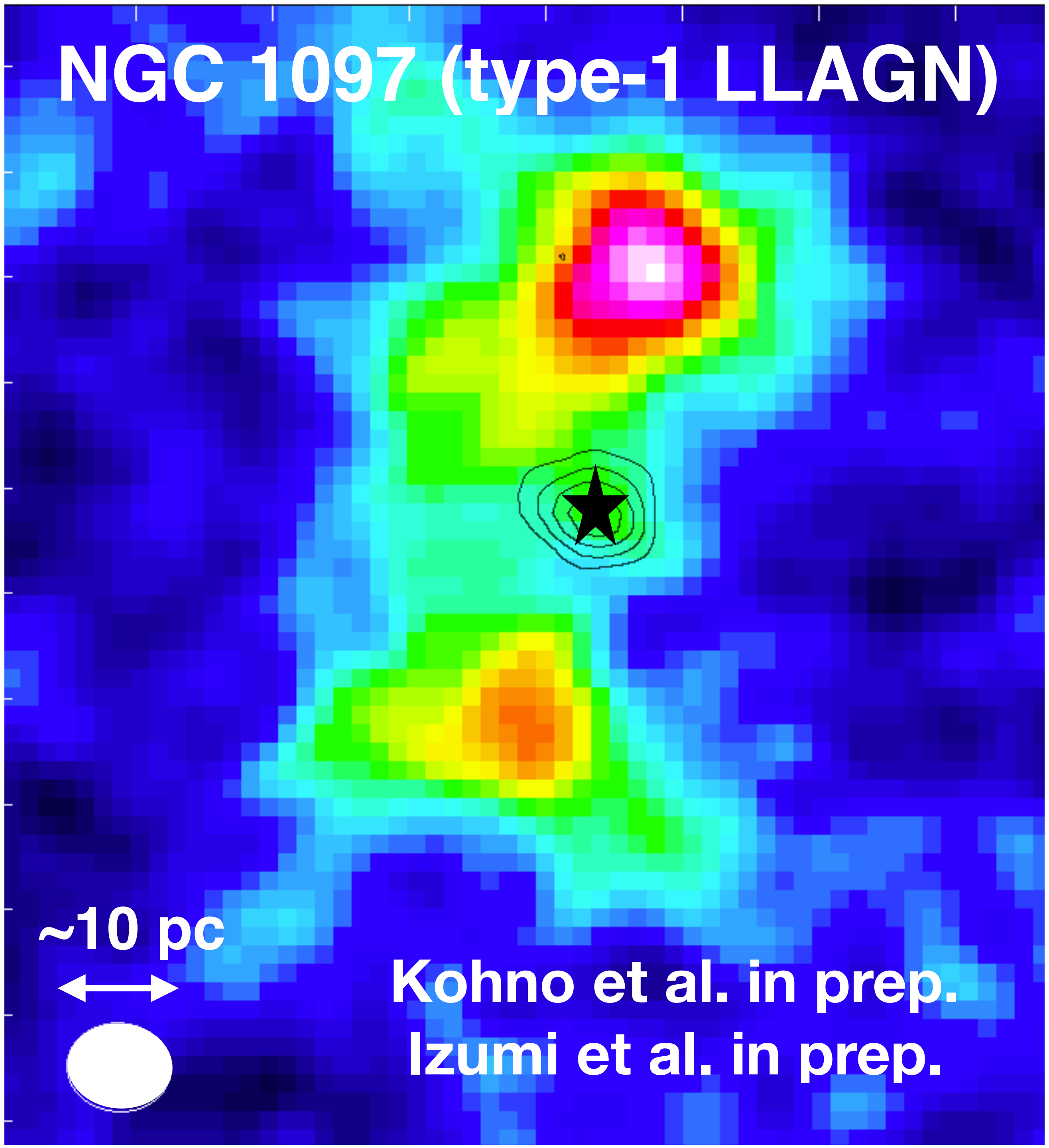
- SMBH merger is critical for making high-mass-end objects?





Yan et al. 2015, ApJ, 809, 117

First 10 pc (!) scale view of the nuclear region of a type-1 AGN



- Colour = HCN(4-3)
- Contour = continuum@350GHz
  → significant time variability!
- Surprisingly, no emission of HCN(4-3), as well as the dust continuum, were detected at the nucleus of this LLAGN
  → disappearance of dusty torus in the low-luminosity regime?

Summary

- Positive correlation between M_{dense} and dM_{BH}/dt
  - virtual equivalence to the SFR-dM_{BH}/dt correlation
  - large scatter (need other parameters?)
  - better correlation for nuclear scale gas than the galactic one

- Invoke SN-driven turbulence model to discuss mass accretion

- Direct comparison of dM_{BH}/dt and mass accreted from the CND
  - part of the gas from the CND is consumed for the black hole growth
  - with accounting for the disk wind, we found a fairy good agreement in NGC 4051 and NGC 7469

  → *start to dissolve the balance of mass flow!?*

→ see more details in Izumi et al. (submitted to ApJ)