Dec. 25-28, 2004 将来計画シンポ　東大

NAOJ

サイエンス班 (AGN)
理論シミュレーションから探るAGN形成史と構造

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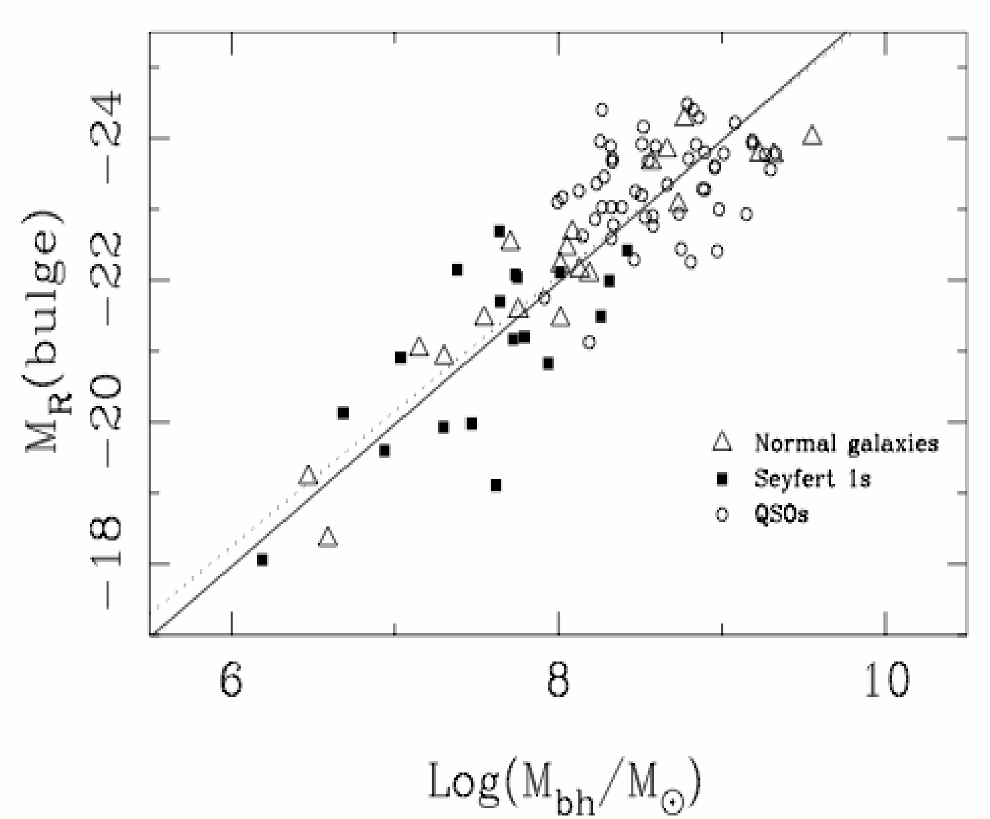
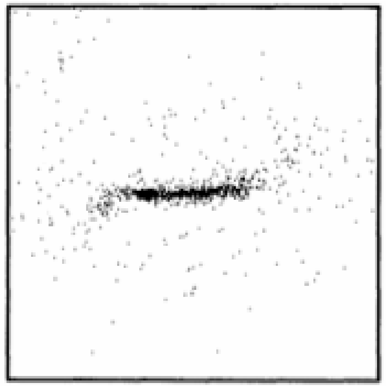
M_{BH}-M_{bulge} correlation

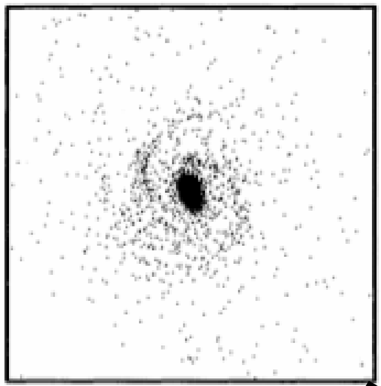
- Galaxy formation, i.e. star formation, contributed to forming SMBH.
- But, How?
- Is this relation true at high-z?
- Is this trend true also in smaller galaxies?
- Is the scatter in this relation intrinsic? What's the origin?



McLure & Dunlop (2002)

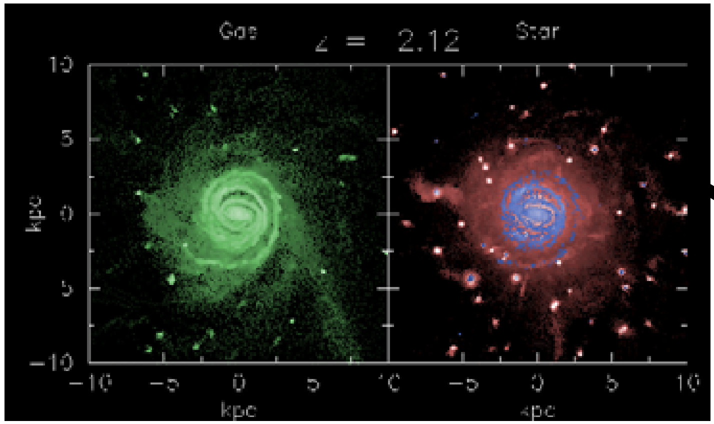
See also Kormendy & Richstone (1995)
Merritt & Ferrarese (2001)

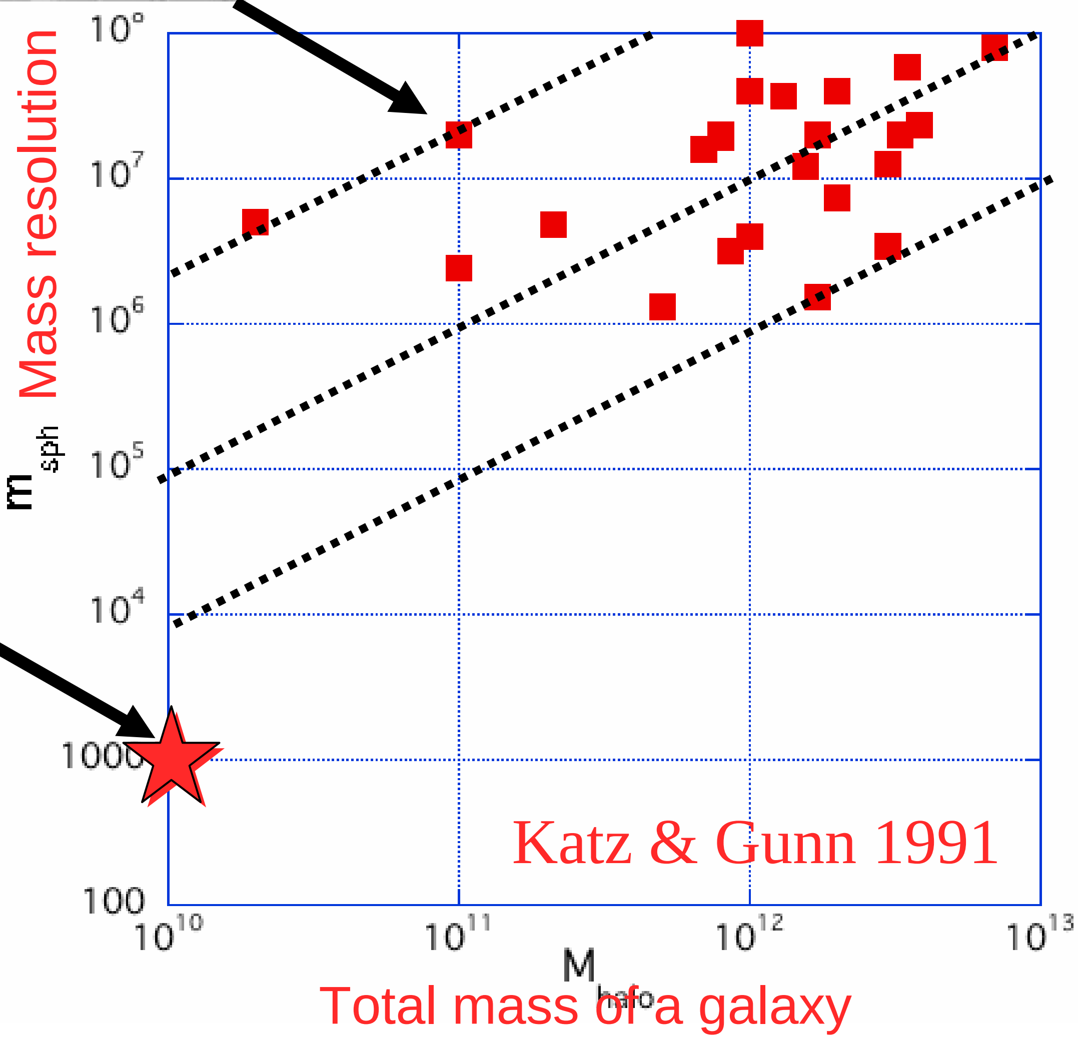




Past N-body/SPH simulations of spiral galaxies formation

Saitoh et al. 2004





Formation of a small spiral galaxy

Saitoh et al. (2004)

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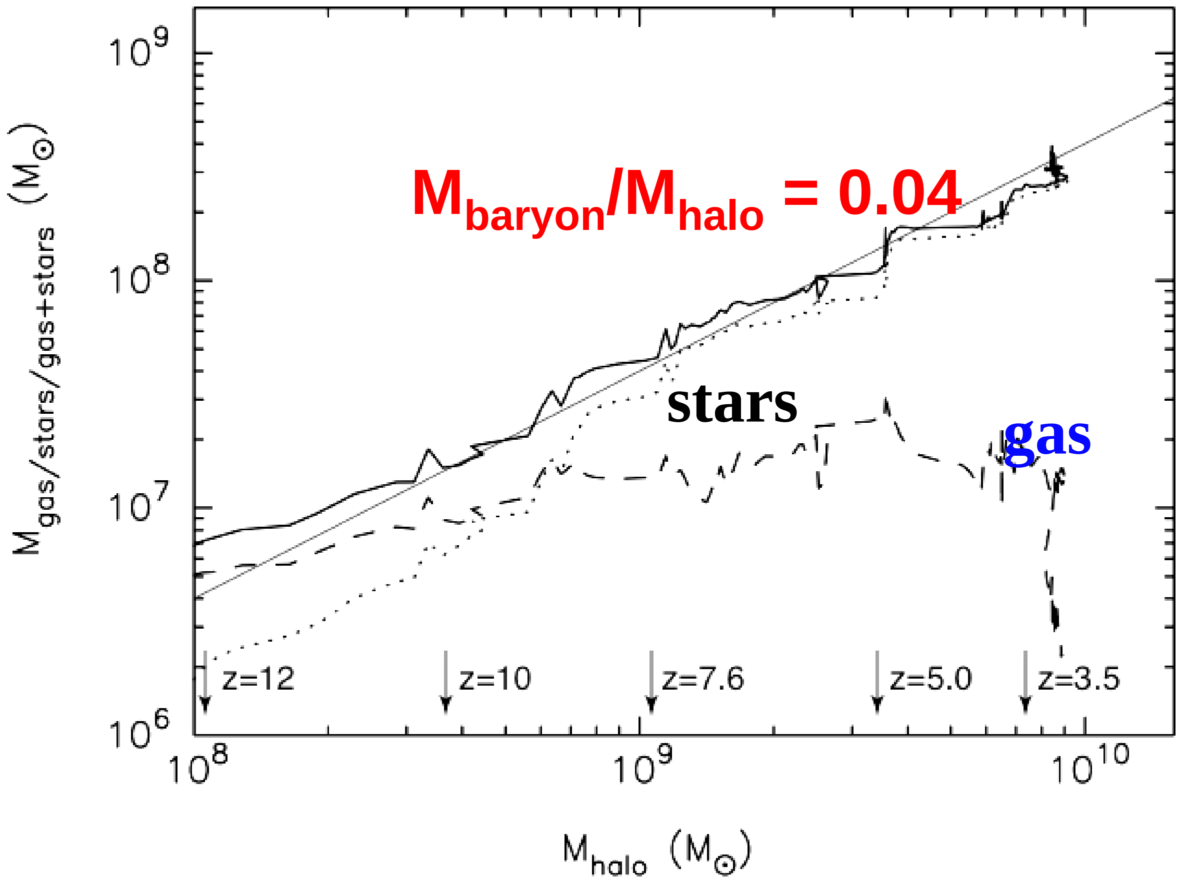
Coevolution of M_{core}(r<0.3 kpc) and M_{halo}

Saitoh & Wada (2004) ApJ 615, L93



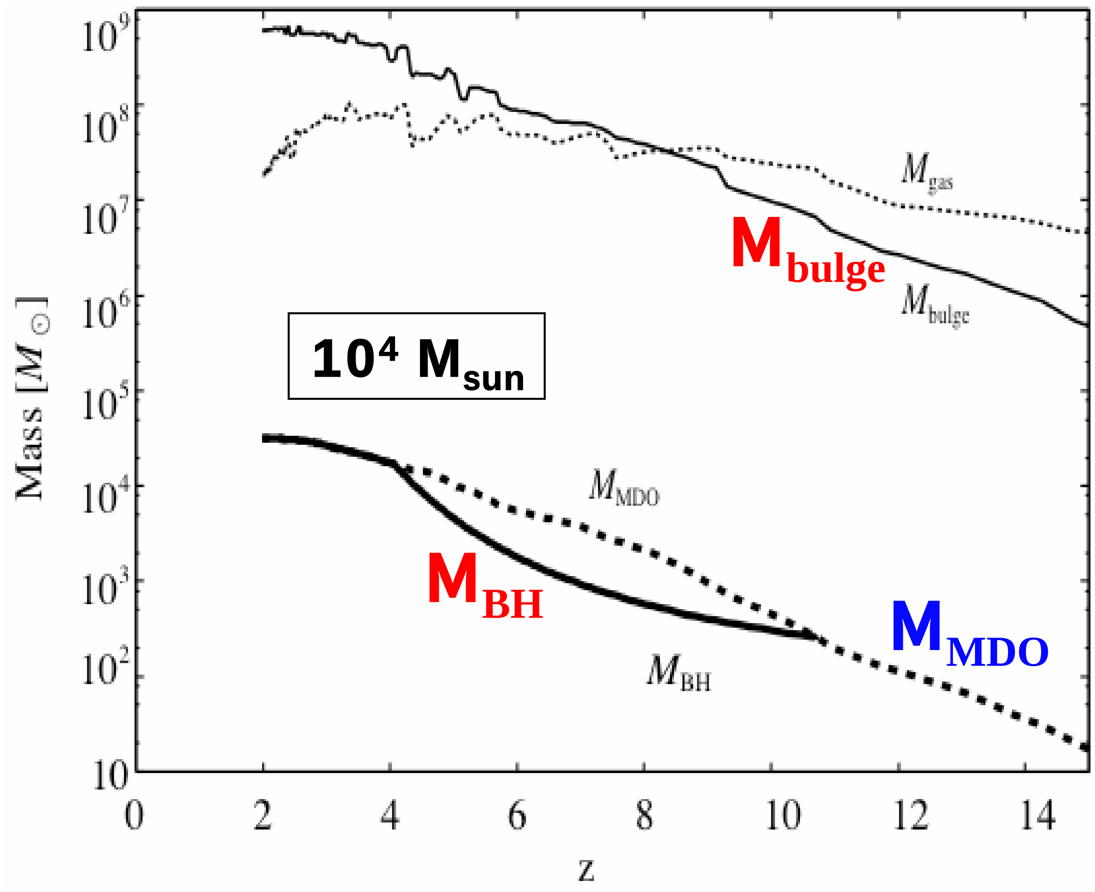
Next question: M_{BH}/M_{core} (z) = ?

Evolution of proto-SMBH

simulation + radiation drag model

$$dM_{drag}/dt \sim L_{stars}\,[1-\exp(-\tau)]/c^2$$

- A seed BH (260 M_{sun}) grows with Eddington accretion rate until $M_{MDO} \sim M_{BH}$.
- An intermediate-mass BH (10^4 M_{sun}) can be formed by z~4 in a forming galaxy (M_{DM} $=10^{10}$ M_{sun})
- $M_{BH}/M_{bulge} \sim 10^{-4}$ for z<4.



Kawakatsu, Saitoh, KW (2005)

Coevolution of M_{BH} and M_{halo}

M_{BH}/M_{halo} is nearly constant from z~8 to z~2.

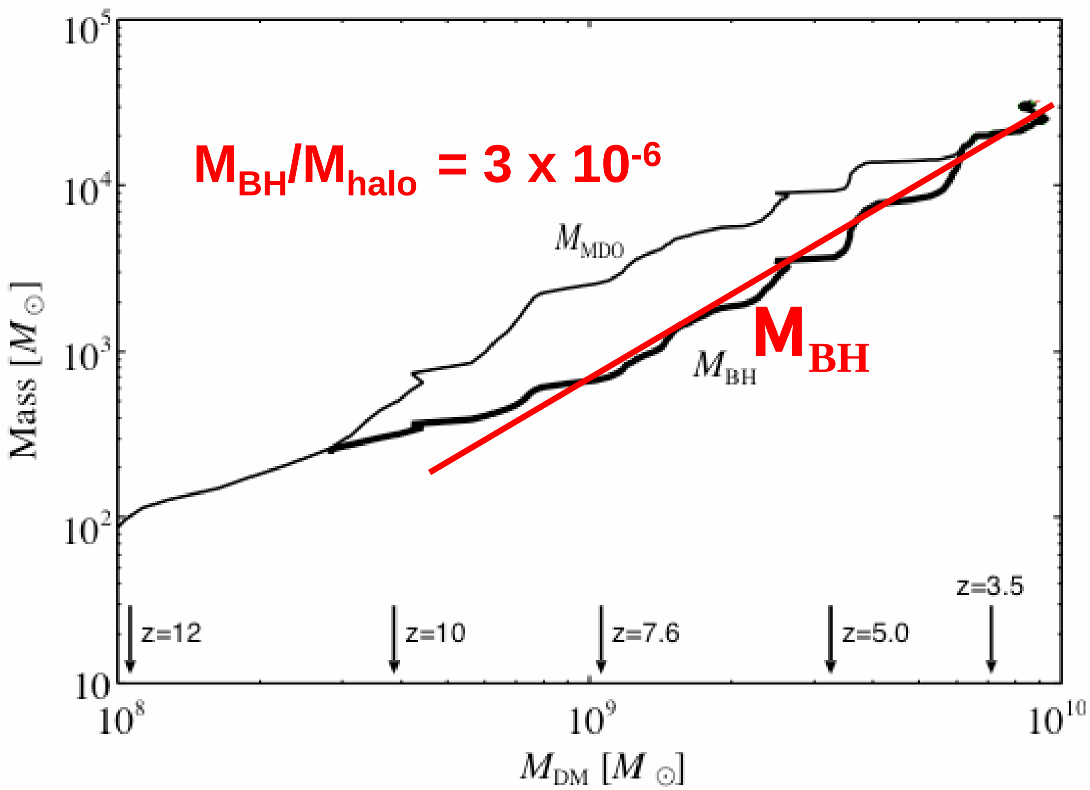
1) The halo grows by mergers.

2) Nuclear starburst is triggered.

3) Radiation energy density increases in the core region.

4) Radiation drag removes A.M. from the the gas.

5) The gas accretes to the central seed BH.

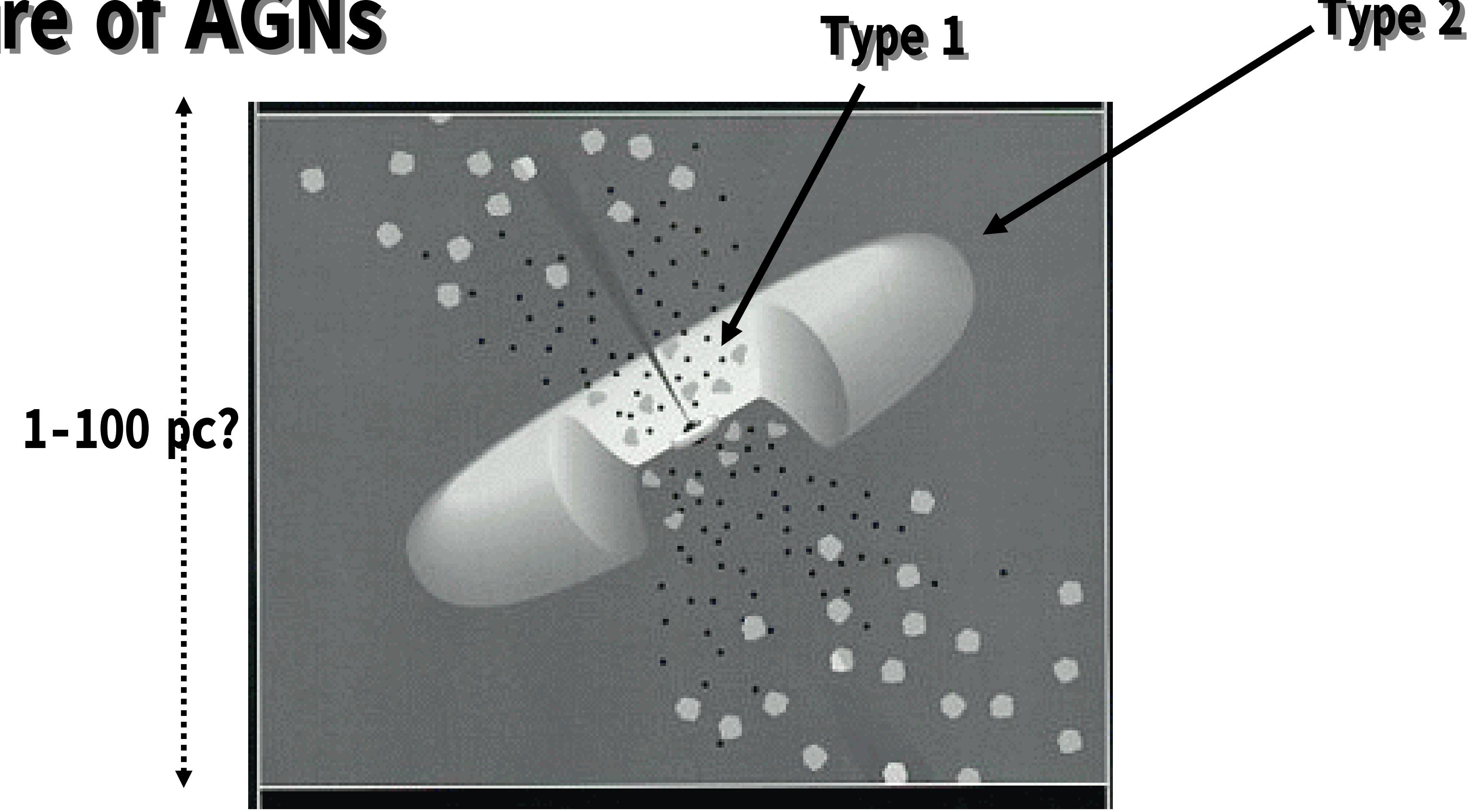


Baes et al. (2004)

$$\frac{M_{BH}}{10^8\,M_\odot} \sim 0.11 \left(\frac{M_{DM}}{10^{12}\,M_\odot}\right)^{1.27}$$

→ **$M_{BH,max}$ ~ 3 x 10^4 M_{sun} at z~2**

Structure of AGNs



Super massive BH (10^{6-8} M_{sun}) ＋ accretion disk (AU scale) ＋ BLR + NRL + Obscuring molecular torus (1-100 pc) + Jet + ENLR

Energy source： mass accretion (0.01- 1 Msun yr^{-1})

Wada & Norman (2002) ApJ 566, L21

Obscuring "torus" around a supermassive BH with nuclear starburst

256^2 x 128, uniform grid, 0.25pc/grid

Radiative cooling (5-10^8 K), SN feedback, selfgravity

$M_{BH} = 10^8\ M_{sun}$, $M_{gas} = 10^7\ M_{sun}$, SNR = 0.8 yr^{-1}

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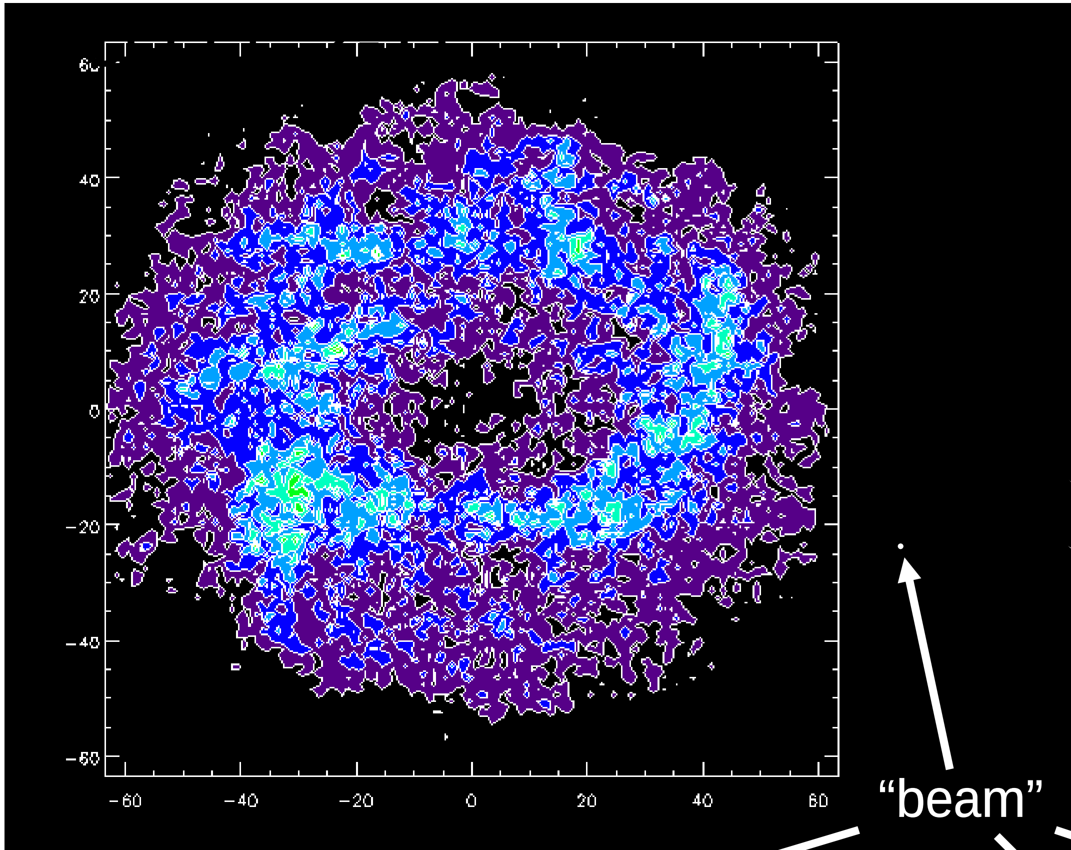
64 pc

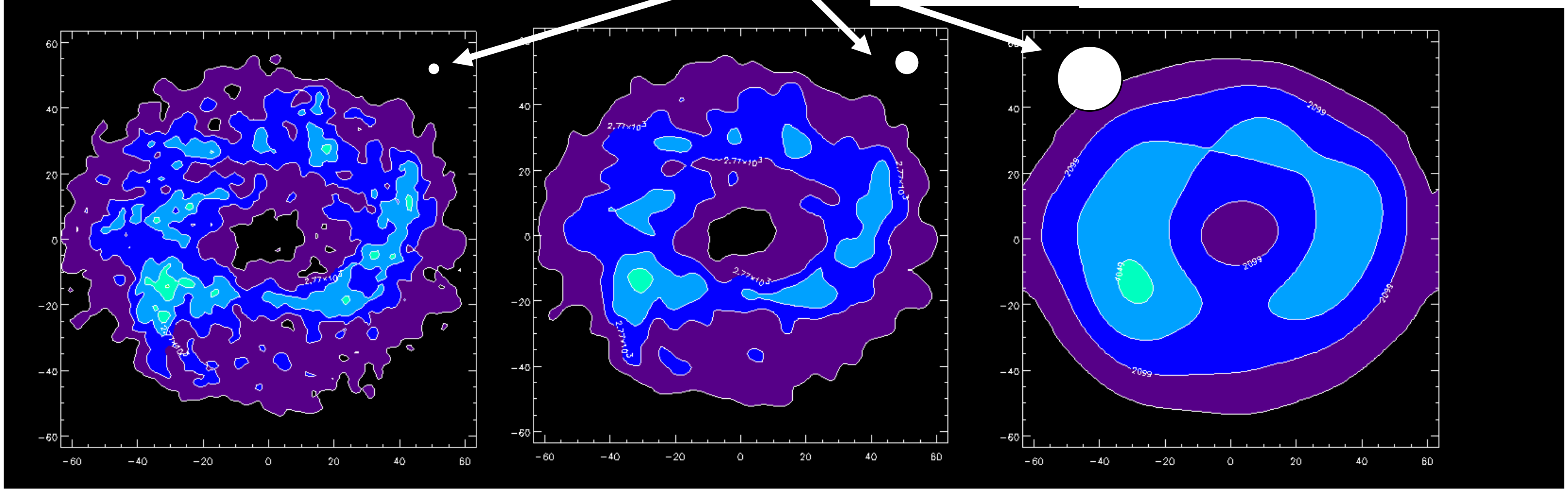
Integrated intensity maps of an obscuring molecular torus

viewing angle = 45 deg



Clumpy structure of the “torus” could be detected with ALMA.
(0.01” ~ 0.8 pc @Virgo)

KW & Tomisaka (2005)



AGNのシミュレーションによる研究の今後

- 銀河形成と巨大ブラックホール形成

予想：10^{-6} M_{halo}のIMBHがz>4に多数ある

??: BHの成長はmergingかaccretionか

  - よりself-consistentに
    - 高解像度 ==> 天の川創成プロジェクト
    - 輻射輸送 ==> FIRST プロジェクト
  - さまざま条件で
    - 銀河の多様性とAGNの多様性の起源

- AGNの構造

予想：非一様なトーラス、非定常なaccretion

??: 輝線ガス領域(BLR, NLR), jetの構造と起源

  - 輻射,磁場とカップルした流体
    - 現在も限定的なモデルで進行中 (e.g. 大須賀、渡部、佐藤、町田、加藤)
  - 輻射輸送計算による観測との直接比較
    - さまざまな分子輝線, continuum