Merger growth of a massive black hole in a primordial galaxy: conditions for successive merger of multiple massive black holes

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2012/10/31 EANAM

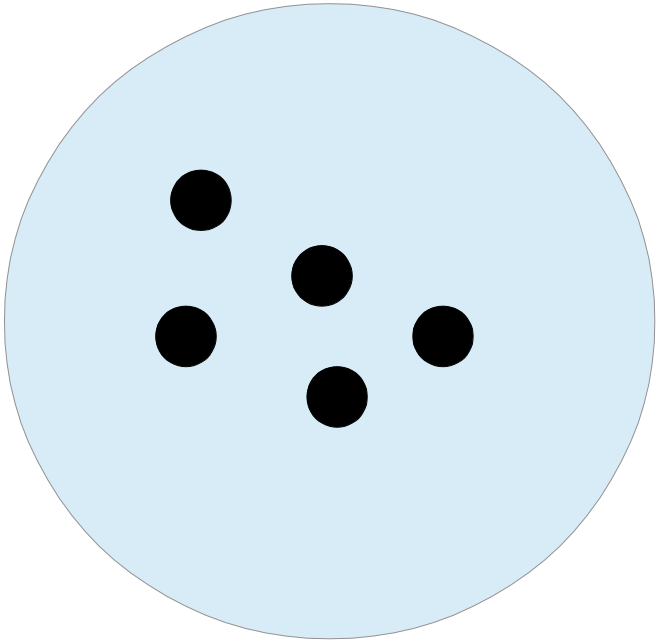
Super Massive Black Hole (SMBH)

- Site：galactic center
- Mass：$>10^6 M_{sun}$
- Formation epoch
  - SMBH > $10^9 M_{sun}$ @z~6 (e.g. Fan et al. 2001)
- Formation process
  - Most of mass acquired by gas accretion (e.g. Soltan 1982)

Problem of formation process

- SMBH: $10^9 M_{sun}$ @ z ~ 6 (universe age ~ 1Gyr)
- If a seed of SMBH is massive star remnant, ...
  - Mass of first stars <$100 M_{sun}$
  - Seed mass: <$100 M_{sun}$ @ z ~ 20
  - Grow to $10^9 M_{sun}$ if Eddington accretion continues
- Solution
  - Super Eddington accretion
  - Formation of super massive star (~ 10^4 M_{sun})
  - Merger growth of SMBHs

This work



- N-body simulation
  - No gas
  - Merger of SMBHs when $r = 10r_{sch}$
- Setup
  - 10 SMBHs in one galaxy

    c.f. Major merger → hyper star cluster → IMBHs (Matsui et al. 2012)

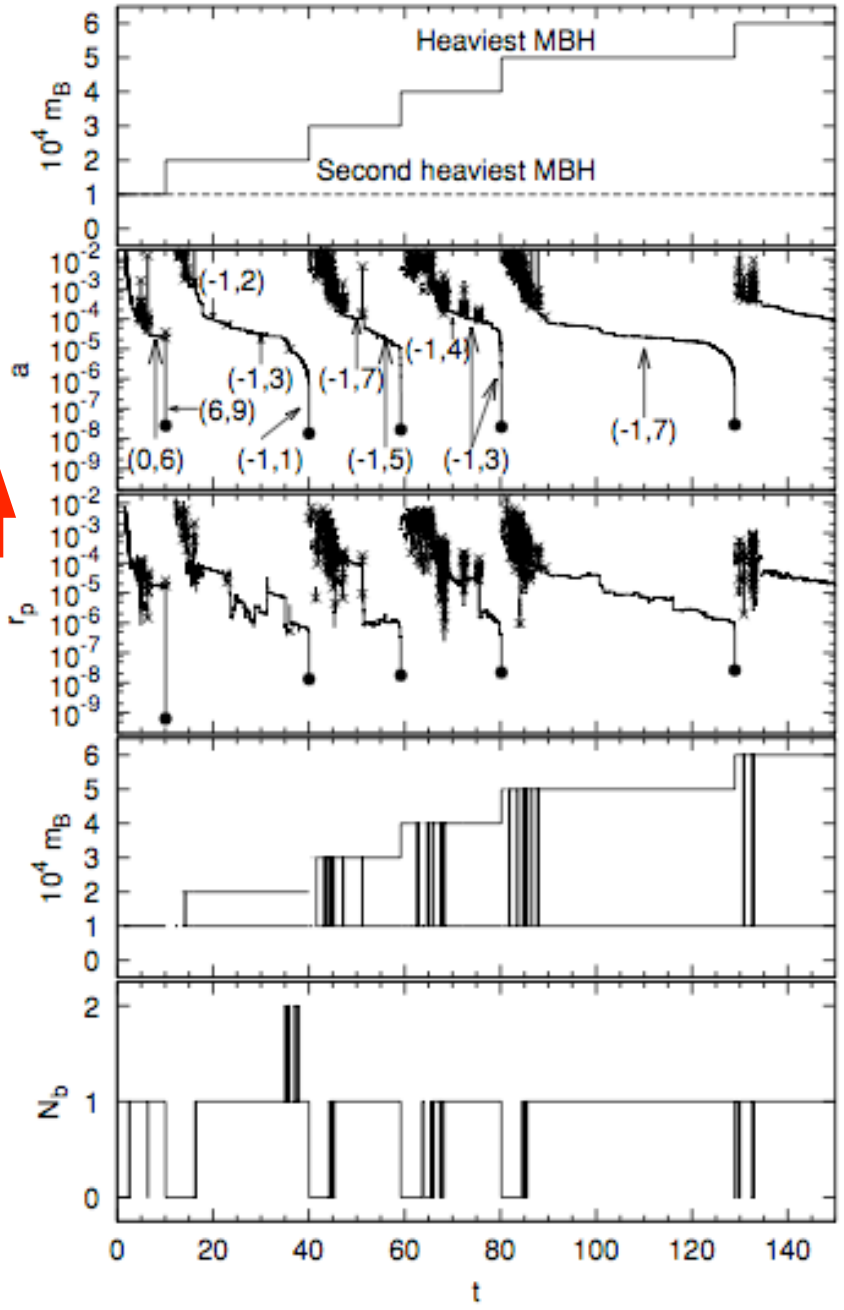
Method

- Collisional N-body simulation
  - SMBH-SMBH
    - 1 – 2.5 PN(Kupi et al. 2009)
    - GW kick >200km/s just after merger (Kesdan et al. 2010)
- Initial conditions
  - Galaxy
    - Hernquist model (N=512k)
    - 3D velocity dispersion: 120km/s – 350km/s
  - SMBH
    - The number of SMBHs: 10
    - Mass ratio of 10 SMBH to the galaxy: 0.1 %

SMBH mergers

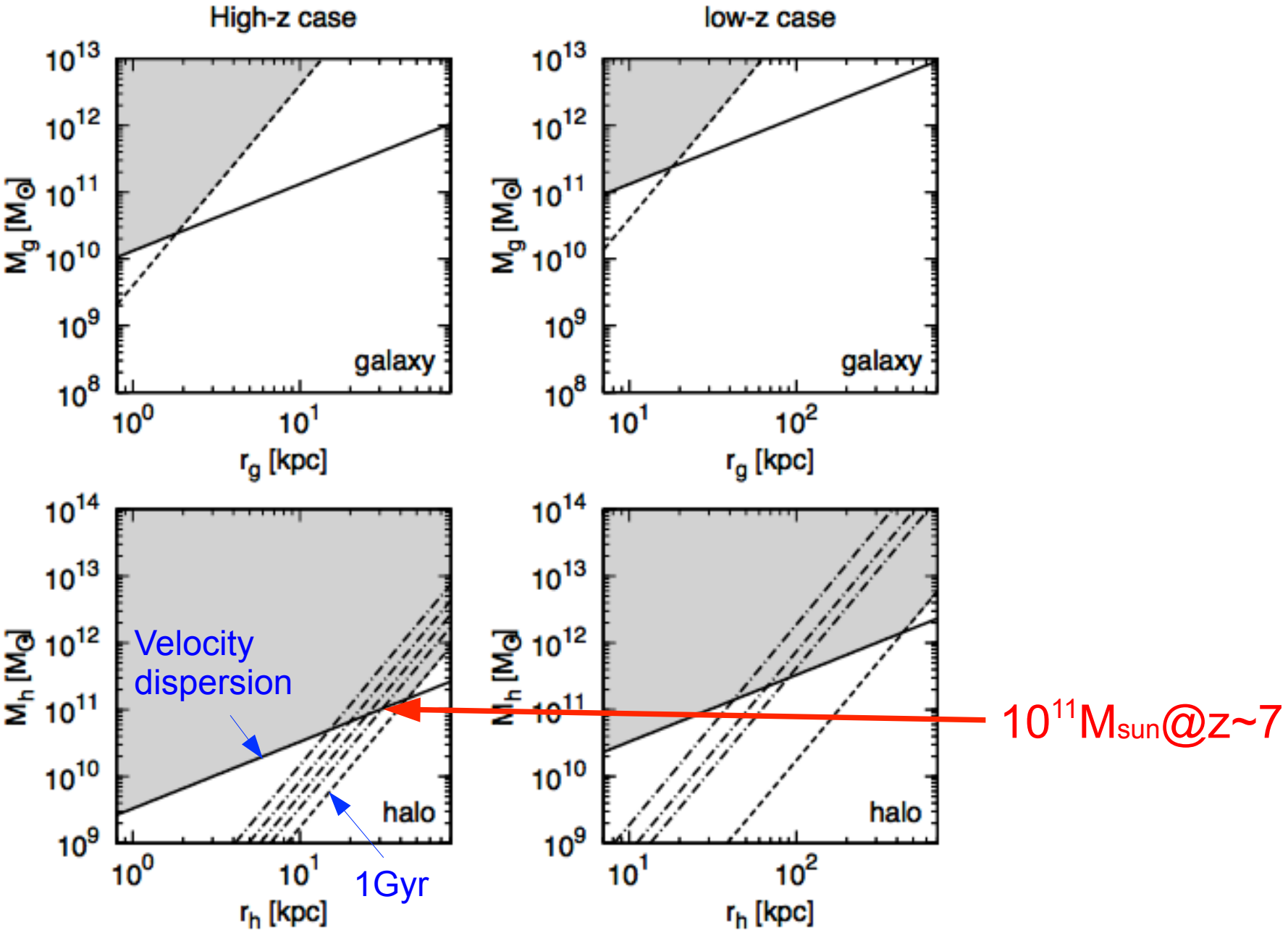
Model	N_B	v_g [1]	v_{GW} [1]	v_{GW}/v_g	$m_{B,p}$ [2]	$m_{B,s}$ [1]	$N_{B,ej}$
$A_{0,1}$	10	350	0	0	4	3(e)	2
$A_{0,2}$	10	350	0	0	4	1	3
$A_{0,3}$	10	350	0	0	6	1	1
A_1	10	350	500	1.4	6	1	1
B_0	10	240	0	0	6	1	1
B_1	10	240	500	2.1	4	2(e)	2
C_0	10	180	0	0	5	1	1
C_1	10	180	200	1.1	3	2	1
D_0	10	120	0	0	3	1	2
BH0	0	–	–	–	–	–	–
BH2	2	–	–	–	–	–	–

[1] km/s
[2] initial MBH mass

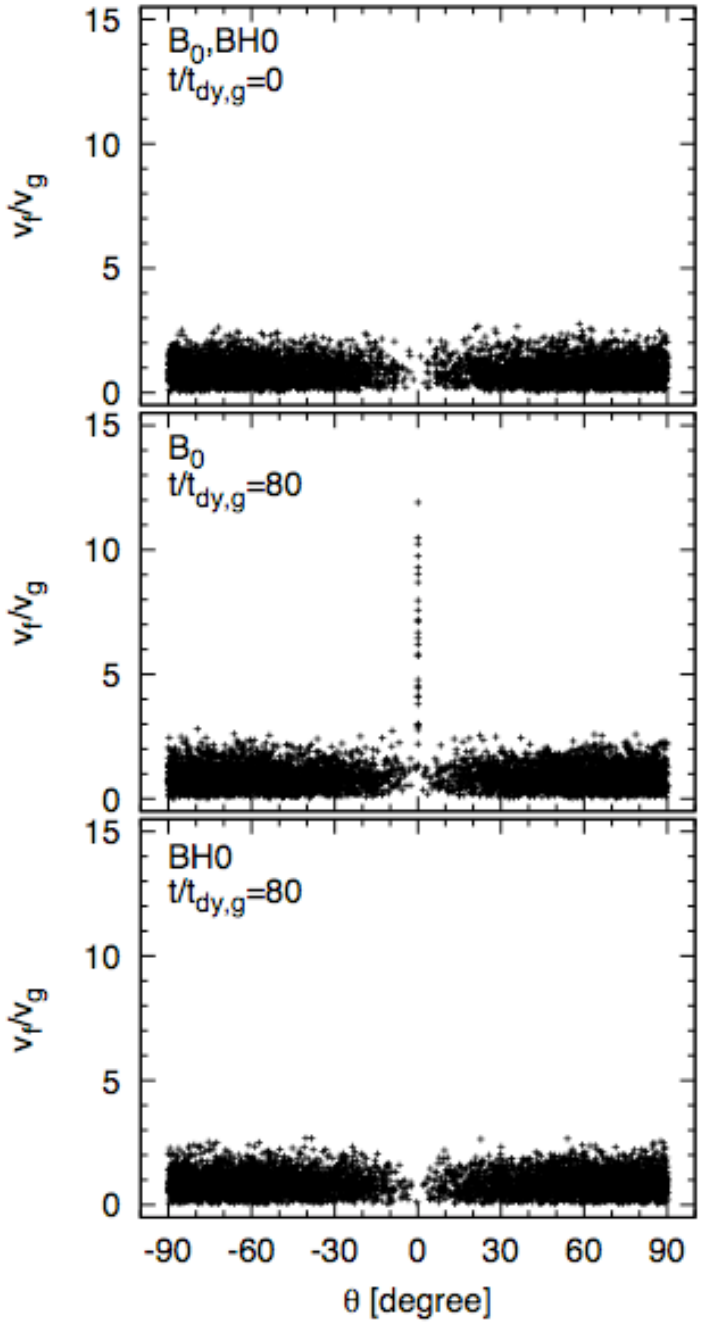


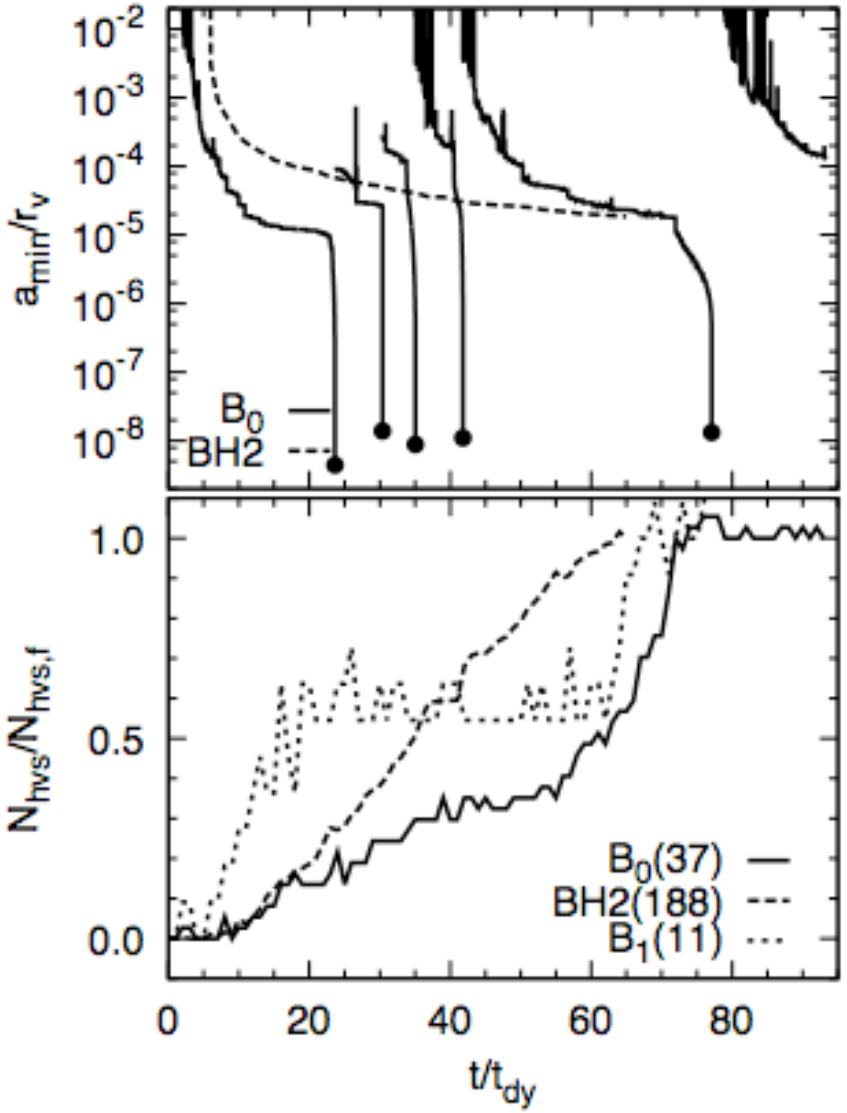
- Only one SMBH grows
- In a galaxy with >~ 200km/s

Corresponding galaxy and dark halo



High-velocity star





Summary

- N-body simulation with 10 SMBHs + galaxy
- ~5 SMBHs merge within 100 crossing time if a galaxy has 3D velocity dispersion of > 240km/s.
- Such a galaxy is formed in a dark halo with 10^{11} M_{sun} at z ~ 7.
- High-velocity stars may be footprints.