Revisit Taniguchi & Wada (1996)

Keiichi Wada
Kagoshima University

first trial to study interaction between a binary BH and the ISM in a central kpc

“Minor mergers solve everything!”

TW96 is one of theoretical grounds.
Minor merger driven starburst

TW96 studied interaction between BBH and gas disk only

- dynamical friction

- spiral shocks in the circumnuclear gas disk

- nuclear starburst & fueling to the nucleus

Methods & Models

**SPH** (Hernquist & Katz 1989, Monaghan & Gingold 1993)

- no stellar or dark matter component

\[ N_{\text{SPH}} = 16384, \quad h_{\text{min (resolution)}} \sim 50 \text{ pc?}, \quad 1000\text{M}_\odot \]

- include physics:
  - hydrodynamics,
  - *self-gravity* between gas particles, between gas and BHs (GRAPE-3),
  - cooling (*isothermal*),
  - dynamical friction for BHs due to field stars (*Chandrasekhar formula*)
4 models: mass ratio & orbits

<table>
<thead>
<tr>
<th>Model</th>
<th>$f_g^a$</th>
<th>$M_{\text{SBH}}/M_{\text{PBH}}$</th>
<th>Orbit</th>
<th>Morphology$^b$</th>
<th>Final Fate$^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A^+$</td>
<td>0.1</td>
<td>0.1</td>
<td>Prograde</td>
<td>Arm/ring</td>
<td>SFD/HS</td>
</tr>
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<tr>
<td>$B^+$</td>
<td>0.1</td>
<td>0.5</td>
<td>Prograde</td>
<td>Core</td>
<td>NSB with SFD</td>
</tr>
<tr>
<td>$B^-$</td>
<td>0.1</td>
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<td>Core</td>
<td>NSB</td>
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</tbody>
</table>

Ms/Mp = 0.1: spiral-like dense regions are formed

Taniguchi, KW (1996)
Ms/Mp = 0.5

model B+ (M_{SBH}/M_{PBH} = 0.5, prograde)
$M_{SBH}/M_{PBH} = 0.5$, prograde

dense core + arc with star forming regions

6 kpc

model B- ($M_{SBH}/M_{PBH} = 0.5$, retrograde): more destructive

A dense core is formed
Result: summary

mass ratio of BHs is a main factor, difference of orbits is minor

mass ratio = 0.5:
• the gas disk is destroyed and a dense core is formed.
• spiral-like arcs are formed, where gravitational instabilities take place

“best candidates”

- NGC 4736: post starburst (r < 60 pc) with double nucleus (Maoz +1995; Taniguchi+1995)
- He2-10 (Conti, Vacca 1994)
An actively accreting massive black hole in the dwarf starburst galaxy Henize 2-10

Amy E. Reines, Gregory R. Sivakoff, Kelsey E. Johnson & Crystal L. Brogan
Affiliations | Contributions | Corresponding author

Nature 470, 66–68 (03 February 2011) | doi:10.1038/nature09724

~100 pc star-forming arc

![HST 2.1μm](image1)

![HST 0.66μm](image2)

Technical Problems in TW96

but can be solved by ASURA (T. Saitoh)

- classical SPH w/o N-body → modern SPH with N-body
- low resolution (N=16k particles) → 16 M particles
- isothermal gas → realistic cooling/heating & SF & SNe feedback
- No stellar/DM component

  • Dynamical friction model w/ Chandrasekhar formula
  • Effect of spheroidal component of the satellite galaxy

  → more self-consistent treatment of the orbits of BH binary & destruction of the satellite
- No ISM neither in the satellite or in the host galaxy

  → fate of ISM in progenitors, Stars? falling toward BHs?
Unsolved Problems in TW96
but can be solved by ASURA (T. Saitoh)

- Can the gas fall to $r < 1\text{ pc}$?
- How does the binary BH affect the gas dynamics in the core?

- Stellar feedback is positive or negative for the fueling?

What I learned after TW96:
ISM in $r < 100\text{ pc}$ is “trouble”

- Wada (2001)
  - self-gravity, radiative cooling, no BH, no AGN, no SF

- Nomura+ (2016)
  - line-driven wind

- Wada (2012)
  - self-gravity, radiative cooling, rotation
  - BH+AGN radiative feedback