Mergers vs. Cold Flows: How do Black Holes get their Gas?

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Mergers, or...?

What role do they really play?
GASOLINE

• SPH $N$-body code (Wadsley et al. 2004)
  – Star formation, supernova feedback, metal diffusion, metal line cooling
    
    See Governato+09,10; Brooks+07,09; Zolotov+09; Pontzen+08,10; Stinson+06

• New additions:
  – Seed BH formation
  – BH mergers
  – BH accretion
  – BH blastwave feedback
How do galaxies get their gas?

Gas enters the virial radius, shocks, and falls in to the disk

See Brooks et al. 2009
How do galaxies get their gas?

Low-mass galaxies simply accrete cold gas.
How do galaxies get their gas?

Even when a shock develops, cold filaments can penetrate the shock.
How do galaxies get their gas?

Of course, **mergers** deliver gas as well.
How do galaxies get their gas?

- **Cold** accretion
  - low mass, filaments
- **Shocked** accretion
  - high mass
- **Clumpy** accretion
  - mergers
How do Black Holes get their gas?

• **Cold** accretion
  – low mass, filaments

• **Shocked** accretion
  – high mass

• **Clumpy** accretion
  – mergers
Seed BH Prescription

• Forming Seed BHs
  - Form seed black holes out of cold, dense, zero-metallicity gas
  - Seed mass same as gas particle
    \[(10^4 - 10^6 \, M_\odot)\]
  - Probability of forming star or black hole

Purely local prescription
Seeds form early
Milky Way - like galaxy

At z=0:
\[ M_{\text{tot}} = 8 \times 10^{11} \, M_\odot \]
\[ M_{\text{BH}} = 1.7 \times 10^{7} \, M_\odot \]
\[ i = -22 \]
MW galaxy to $z=0$

A few % of $L/L_{\text{edd}}$

L$_{\text{BOL}}$ comparable to a Seyfert galaxy

**Graph:**
- Eddington Ratio vs. time (Gyr)
- $dE/dt$ (ergs/sec) vs. time (Gyr)

**Annotations:**
- Major merger

**Legend:**
- L$_{\text{BOL}}$: Emission Lines
Once major mergers begin, the central BH predominantly accretes clumpy gas.
MW galaxy to $z=0$
High redshift galaxy:

At $z = 6$:

$M = 1.4 \times 10^{11} \, M_\odot$

$M_{\text{BH}} = 6.4 \times 10^6 \, M_\odot$

$SFR = 20 \, M_\odot/\text{yr}$
High $z$ BH history

Approaches Eddington-limited accretion

$L_{\text{BOL}} \sim 10^{44}$ ergs/s
High z gal to z=6
High z gal to z=6
What does it all mean...

<table>
<thead>
<tr>
<th></th>
<th>MW halo</th>
<th>MW BH</th>
<th>High z halo</th>
<th>High z BH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>37%</td>
<td>30%</td>
<td>63%</td>
<td>56%</td>
</tr>
<tr>
<td>Clumpy</td>
<td>45%</td>
<td>61%</td>
<td>30%</td>
<td>34%</td>
</tr>
<tr>
<td>Shocked</td>
<td>18%</td>
<td>9%</td>
<td>6%</td>
<td>9%</td>
</tr>
</tbody>
</table>

BHs accrete clumpy gas more efficiently than cold gas.
Summary

- A Milky Way-like galaxy’s BH grows mainly through clumpy accretion (i.e. gas from mergers)
- Clumpy gas more efficient at fueling BHs
- BUT! secular processes (i.e. smooth gas accretion) can fuel a quasar at high z!
Time Delays

Time delay from entering halo to BH accretion

- total
- cold
- shocked
- clumpy
High z gal to z=6

Time delay from entering halo to BH accretion
Bulge Morphology

The diagram illustrates the relationship between $V_{\text{max}}/\sigma$ and $\varepsilon$, with different symbols representing various types of bulges. The plot shows a distinction between oblate and prolate systems based on their morphology.