

Impact of bursty black hole accretion and feedback on host galaxy formation

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Outline

- Motivation
- Black Hole Growth
- Impact of Feedback
 - Inflows/Outflows
- Conclusions

Basic Model

using AMR code RAMSES

- BH growth follows

$$\dot{M}_B = 4 \pi \alpha \frac{(G M_{BH})^2 \rho}{(c_s^2 + v_{rel}^2)^{3/2}}$$

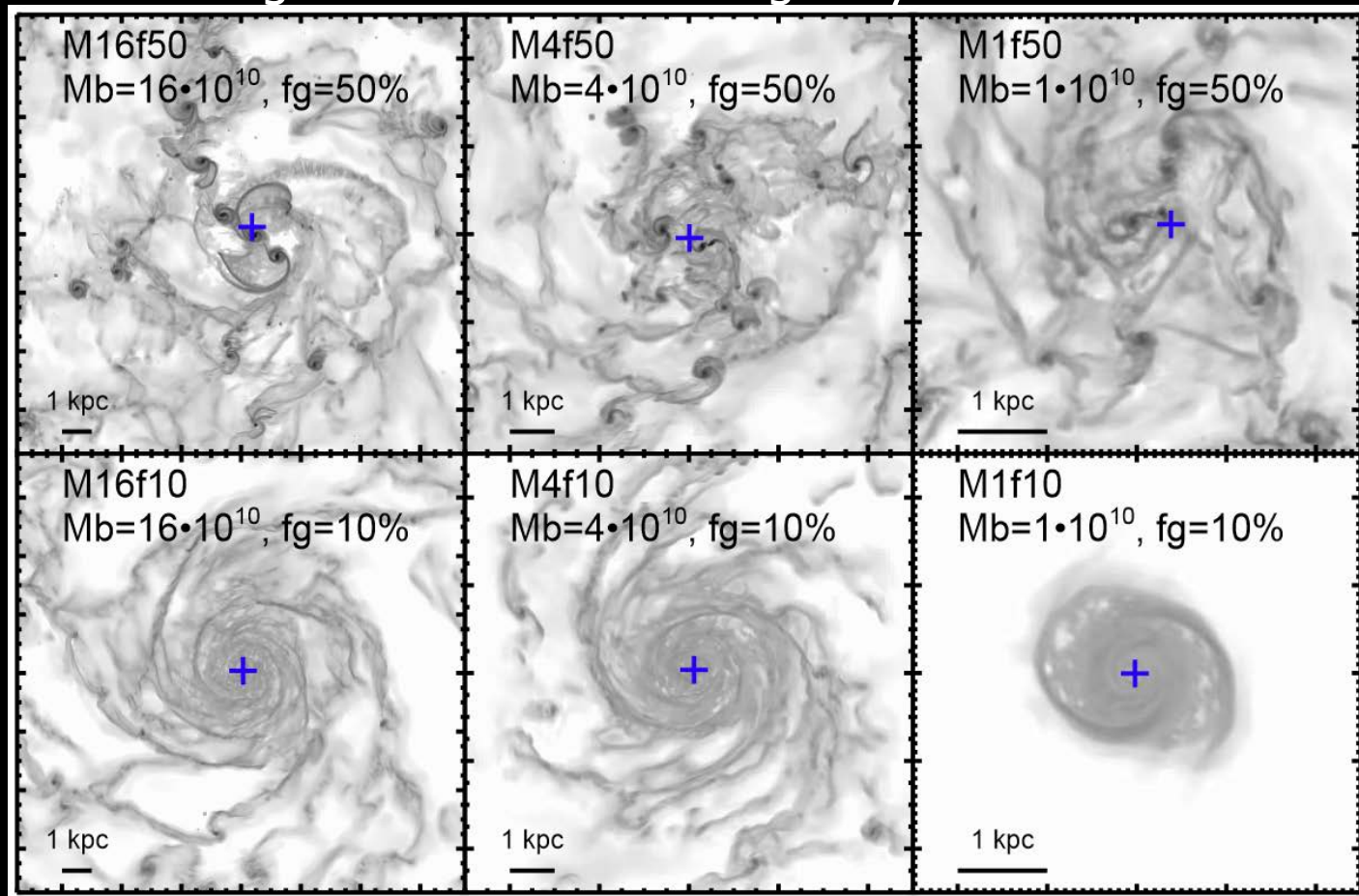
- BH feedback via thermal coupling:

$$E_{\text{feedback}} = f(\eta M c^2)$$

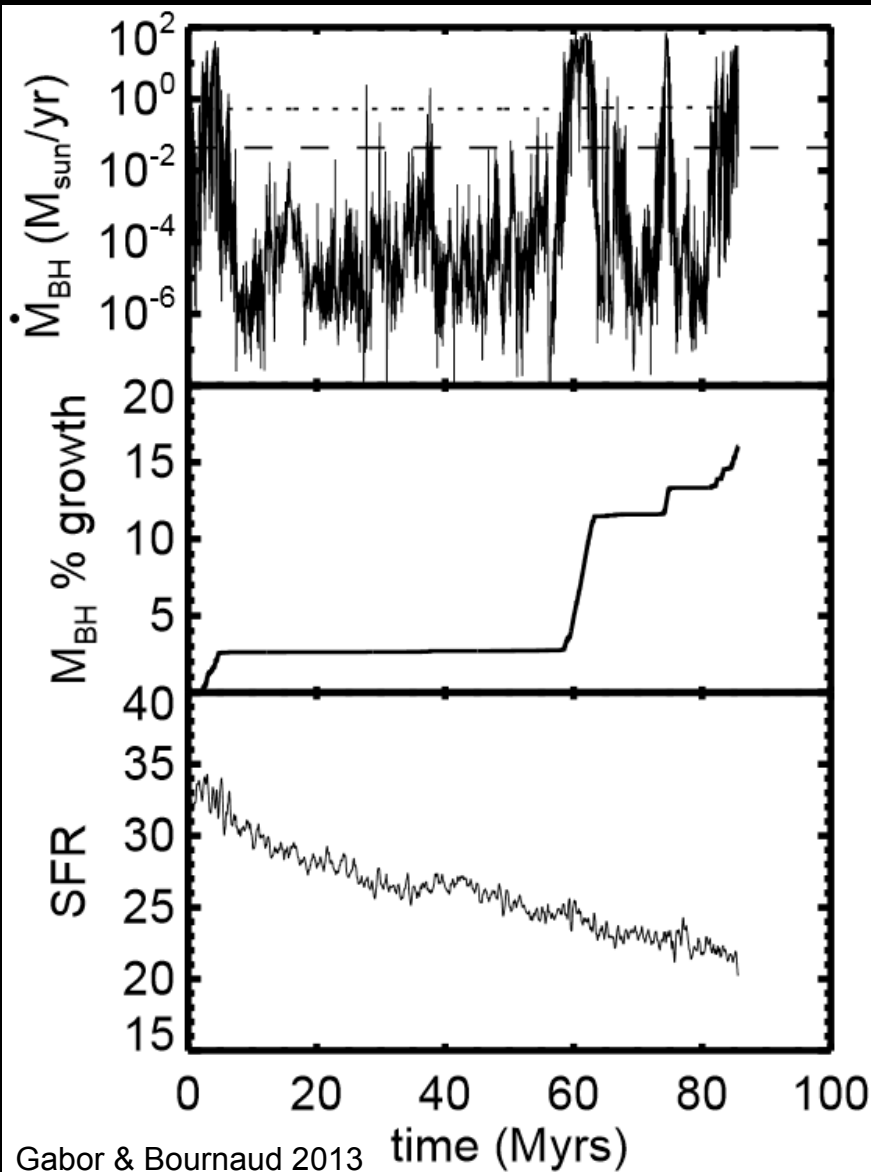
$$F=5\%, \eta=10\%$$

Motivation

High-resolution isolated galaxy simulations

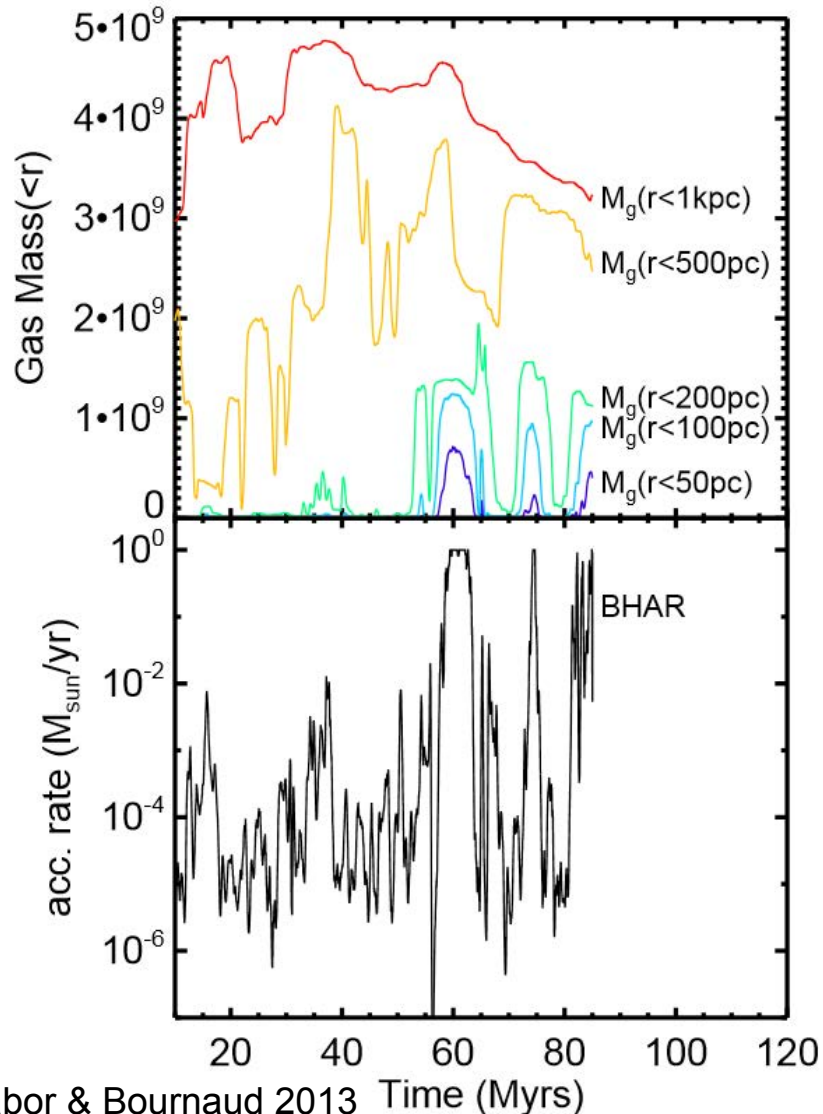


Motivation



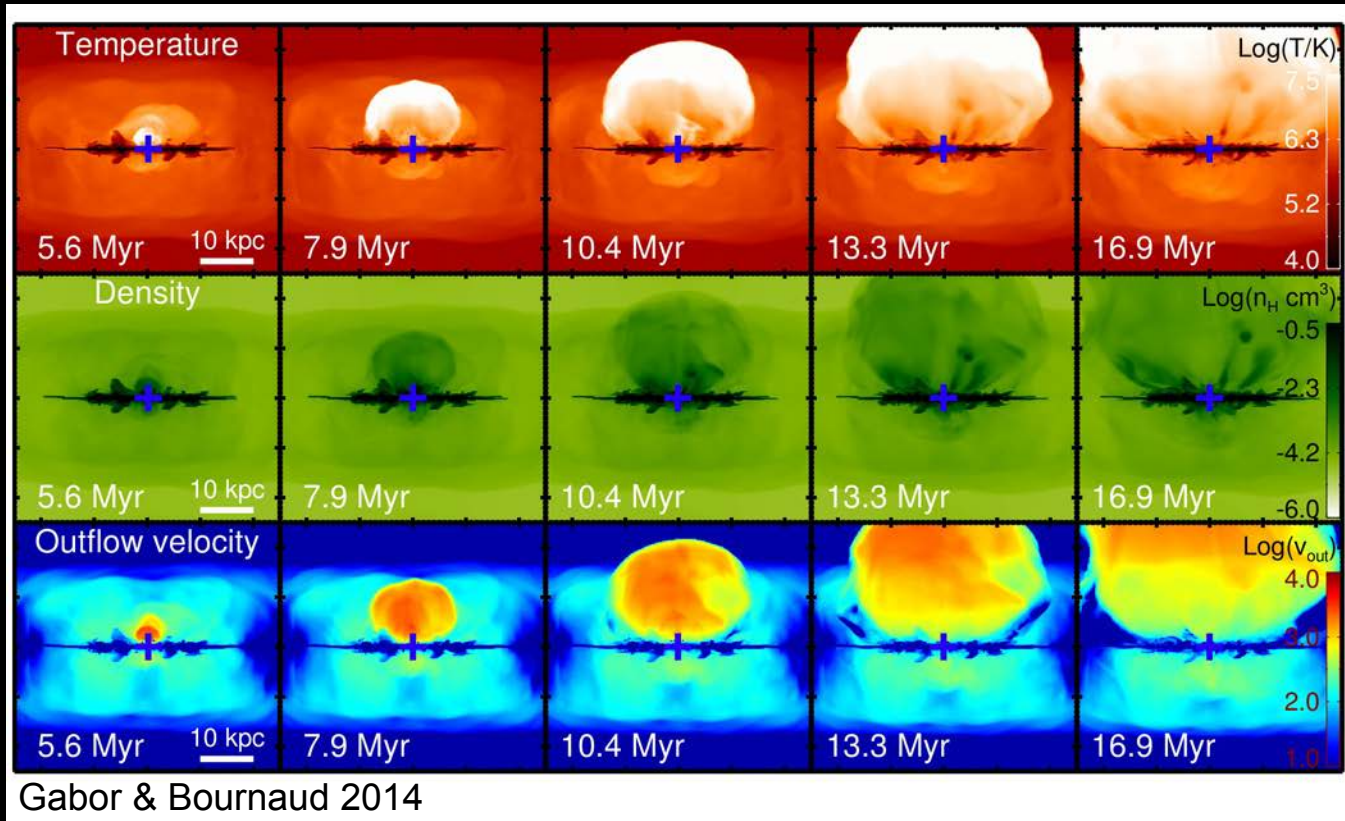
- Black hole accretion dominated by short periods of high-accretion rates

Motivation



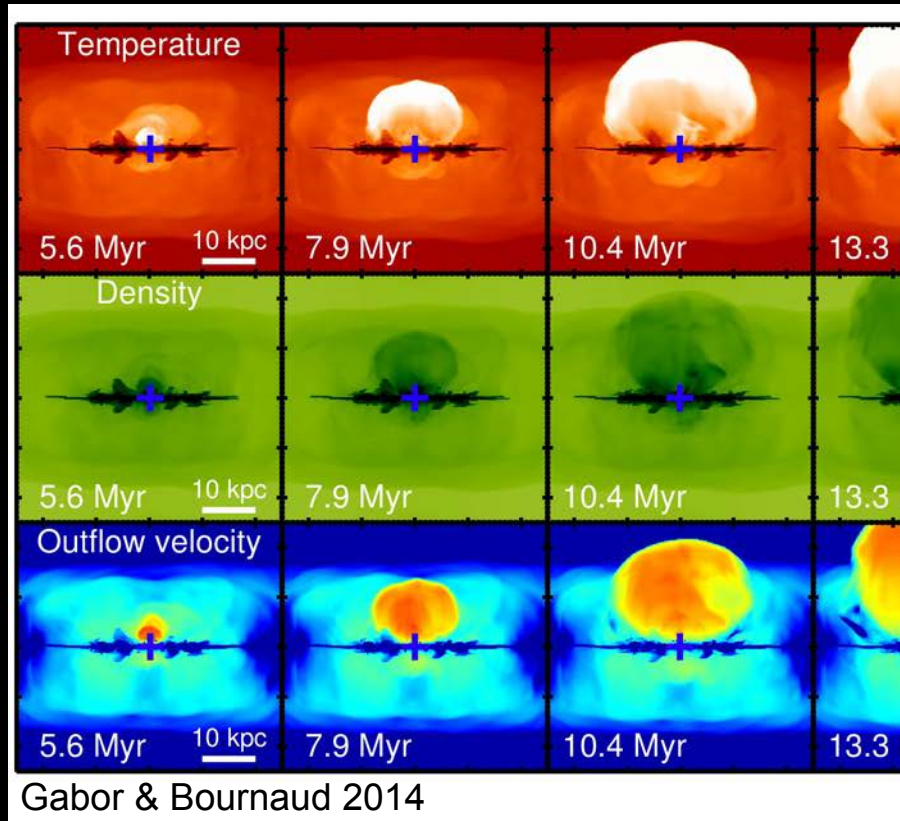
- High resolution isolated galaxy run finds periodic bursts of accretion caused by high-density clumps
- Clumps on scales of $\sim 200 \text{ pc}$
Difficult to resolve in cosmological runs

Motivation

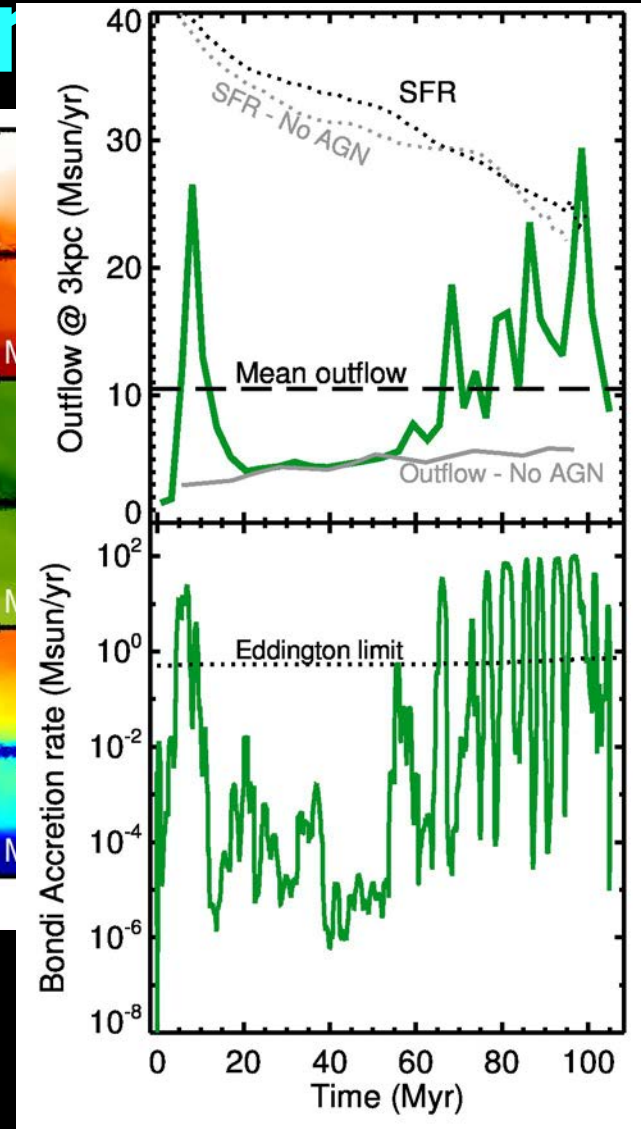


- AGN drives strong unipolar outflows
- Driven by the accretion of dense gas clumps

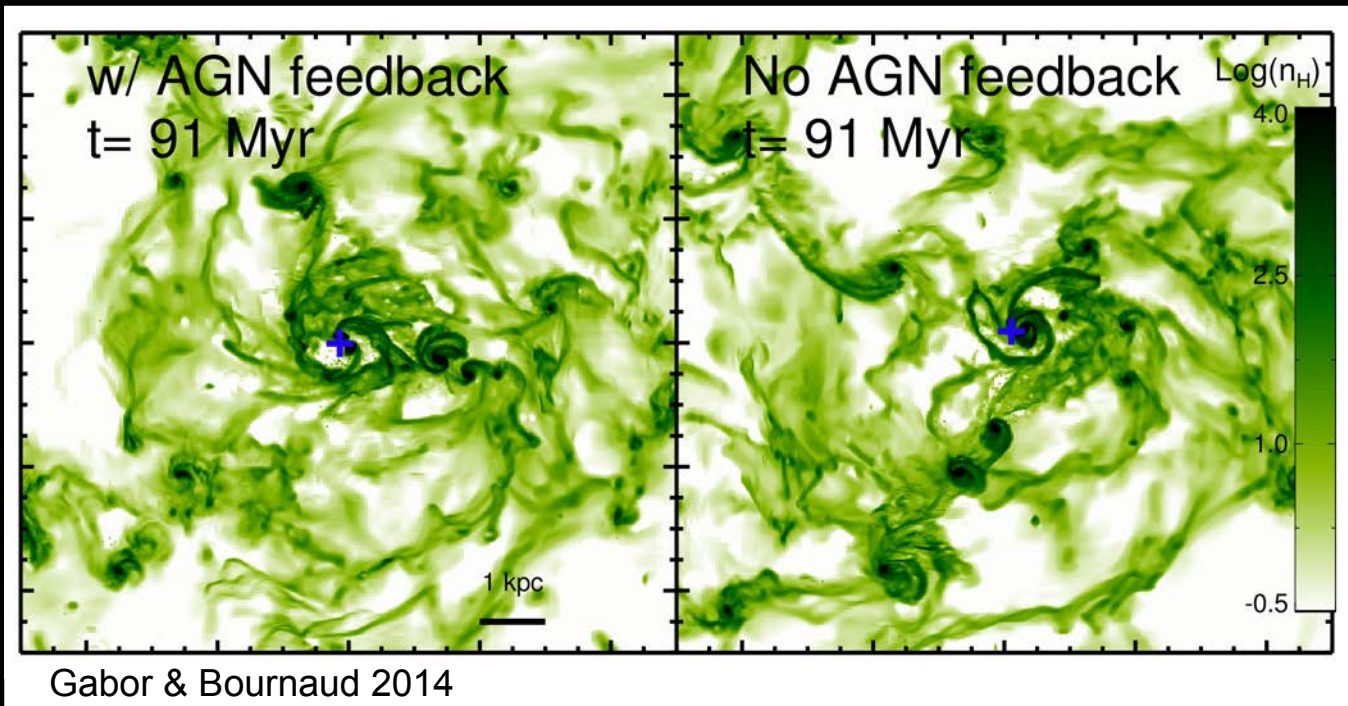
Motivation



- AGN drives strong unipolar outflows
- Driven by the accretion of dense gas clumps
- AGN outflows and heating don't affect SFR

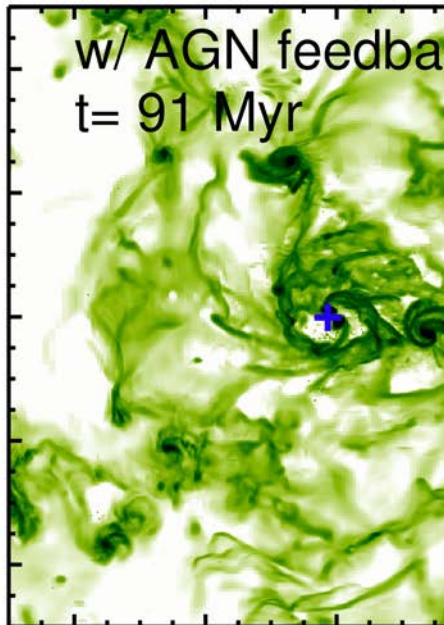


Motivation

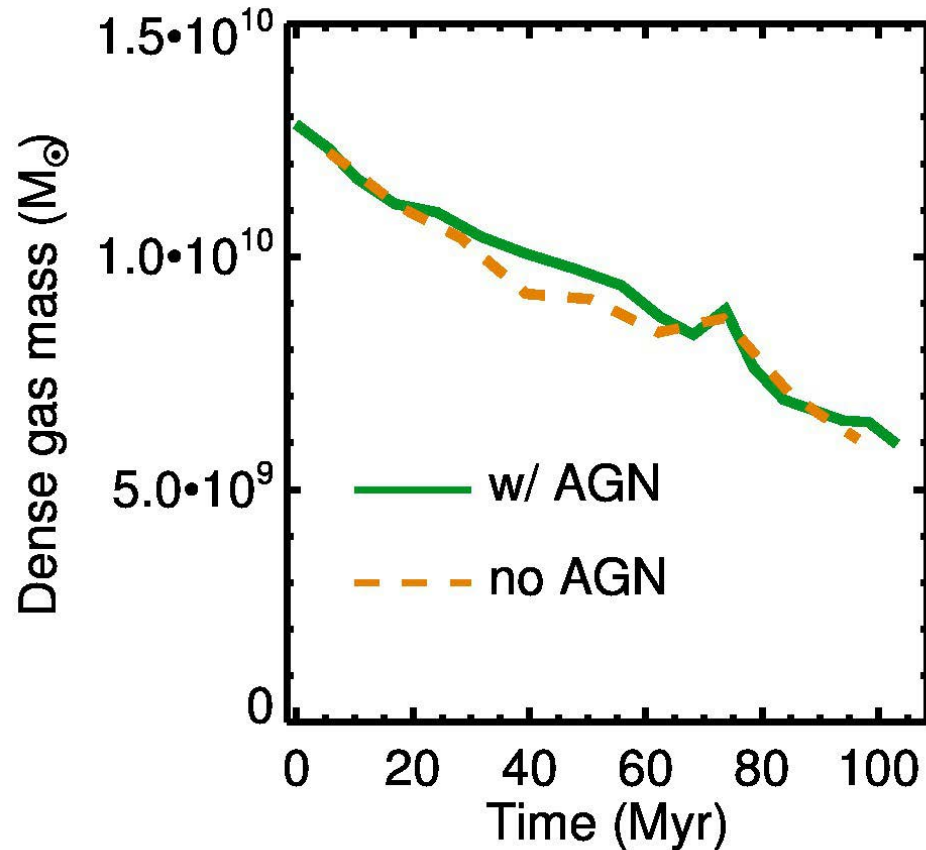


- No qualitative morphological differences due to AGN

Motivation



Gabor & Bournaud 2014



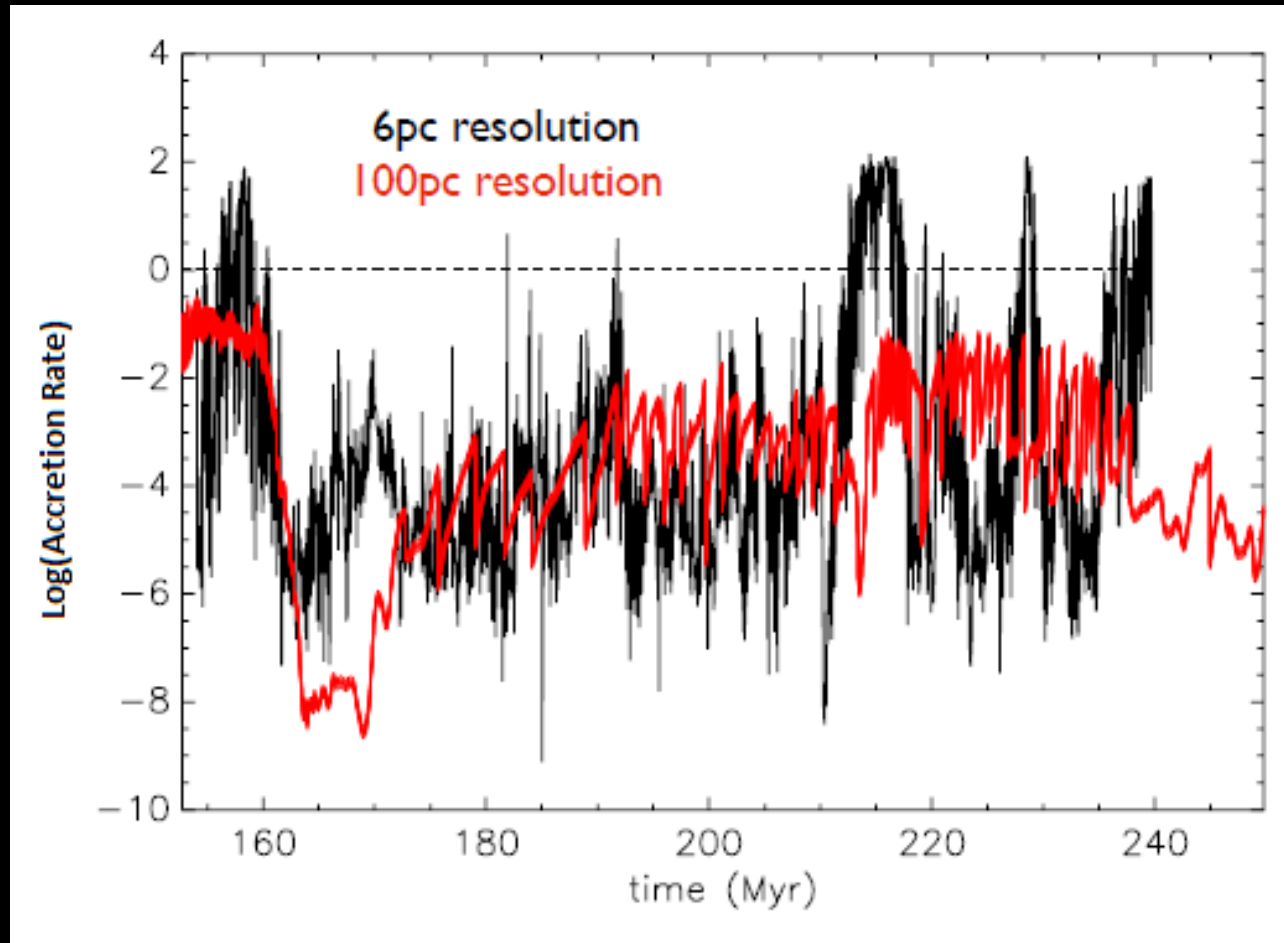
- No qualitative morphological differences due to AGN

Motivation

- Accretion of dense gas clumps drives strong winds
- Has significant impact of BH growth
- Has minimal effect on host morphology, SFR, etc.
- What about cosmological runs?
 - Lower-resolution
 - Longer time
 - Includes inflowing gas and mergers

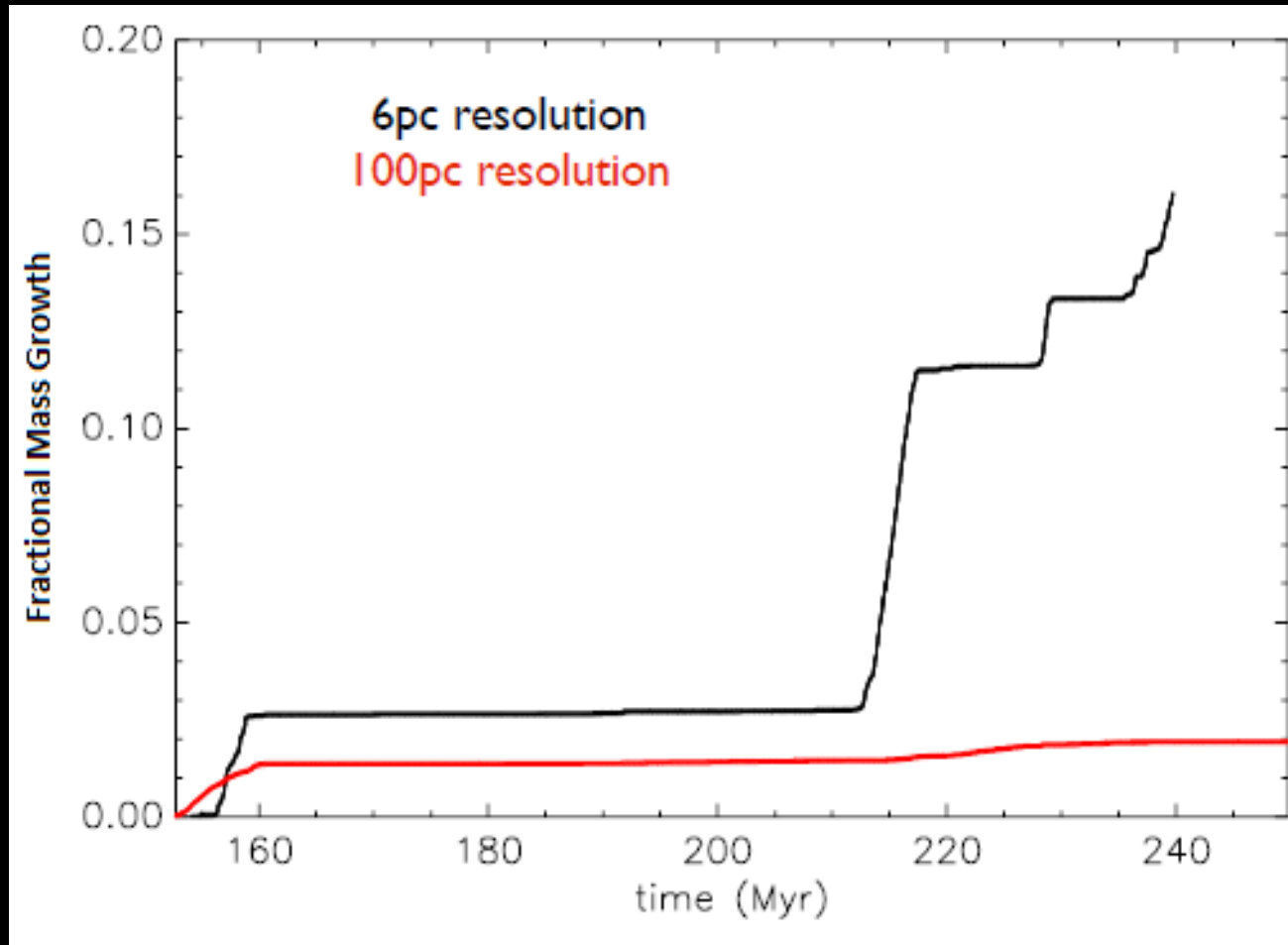
Motivation

- Lower-resolution misses peaks in accretion rate
- Bursts reach Eddington limit
- Smooth accretion lower by 10-100x



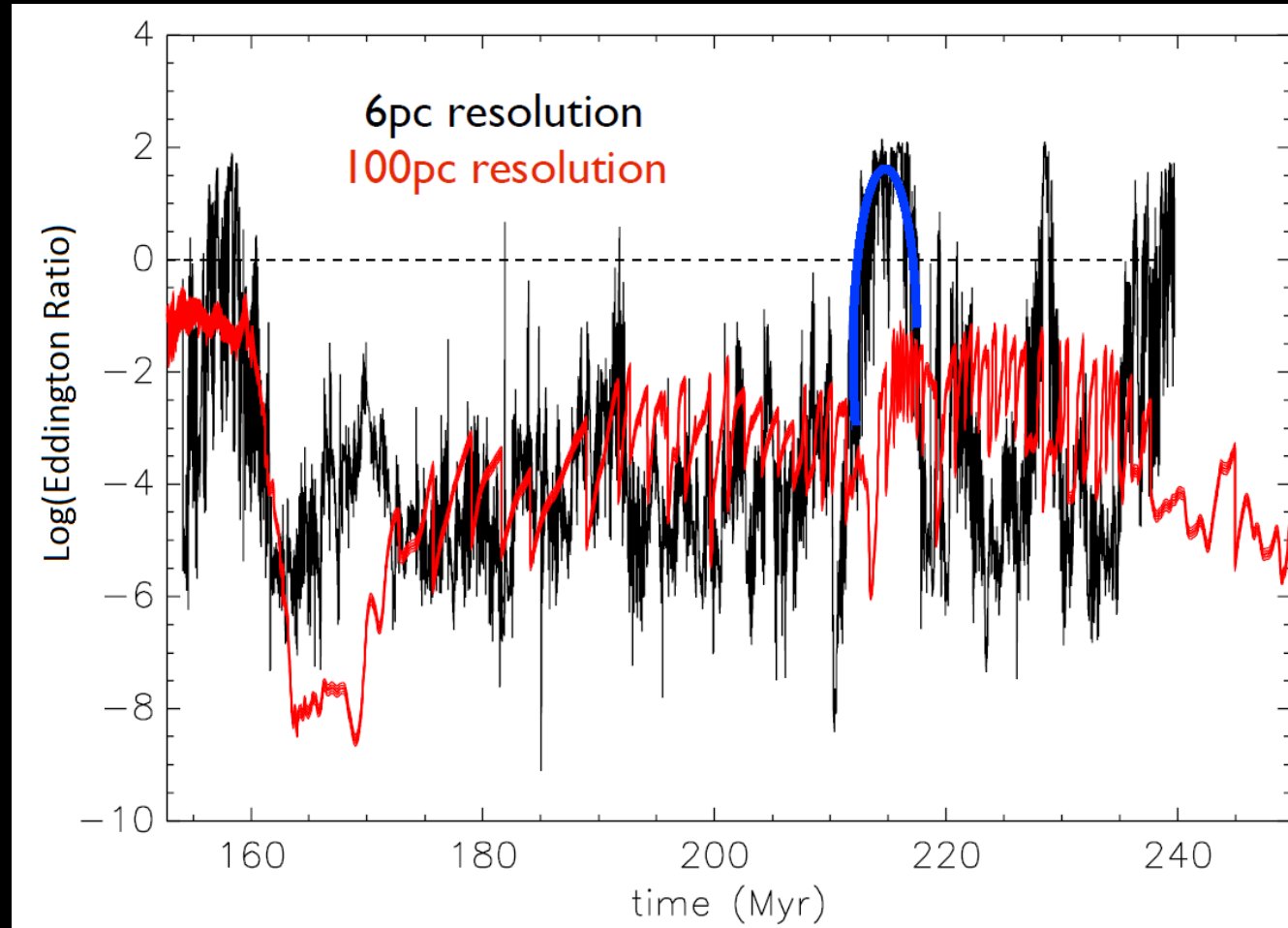
Motivation

- Lower-resolution misses peaks in accretion rate
- Bursts reach Eddington limit
- Smooth accretion lower by 10-100x
- Smooth accretion misses nearly all mass growth

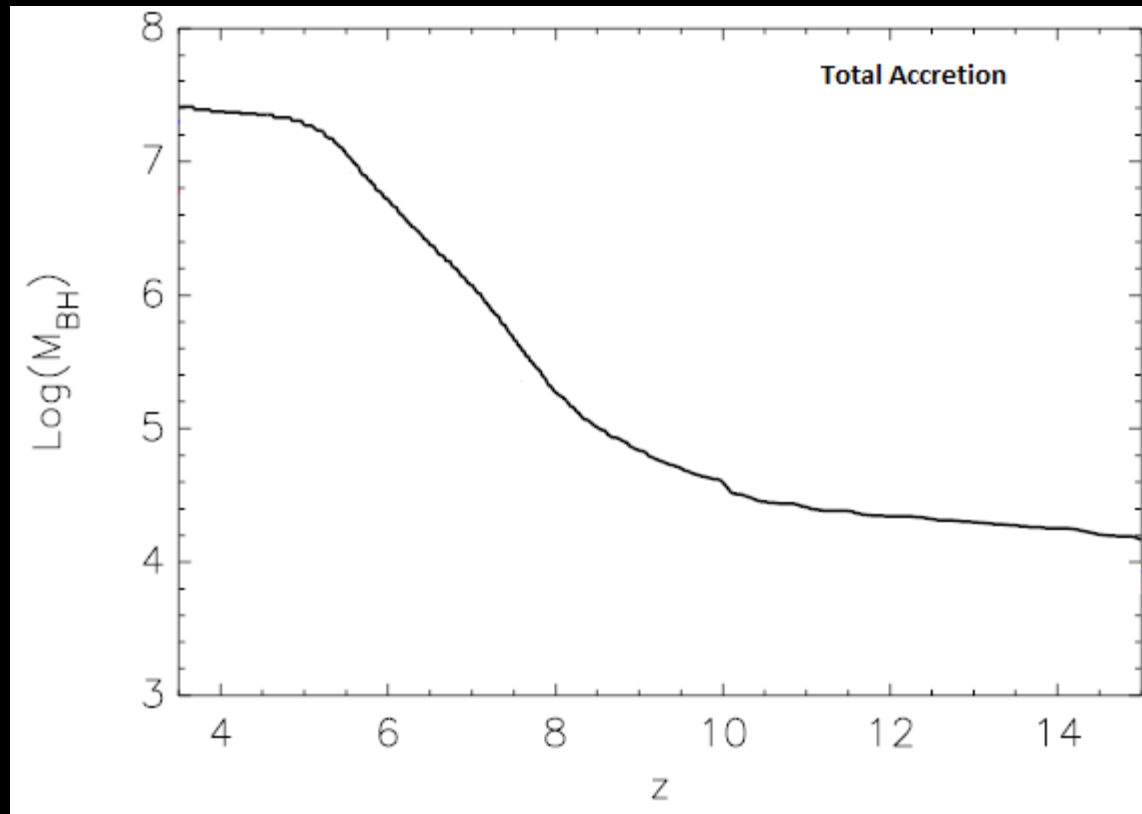


Subgrid Model

- Cosmological volume does not resolve high-density clumps
- Accretion of these clumps can be included as a sub-grid model
- Stochastic Process
 - Each timestep has probability of an incoming 'clump'
 - Calibrated using isolated galaxy runs with 6pc and 100pc resolutions

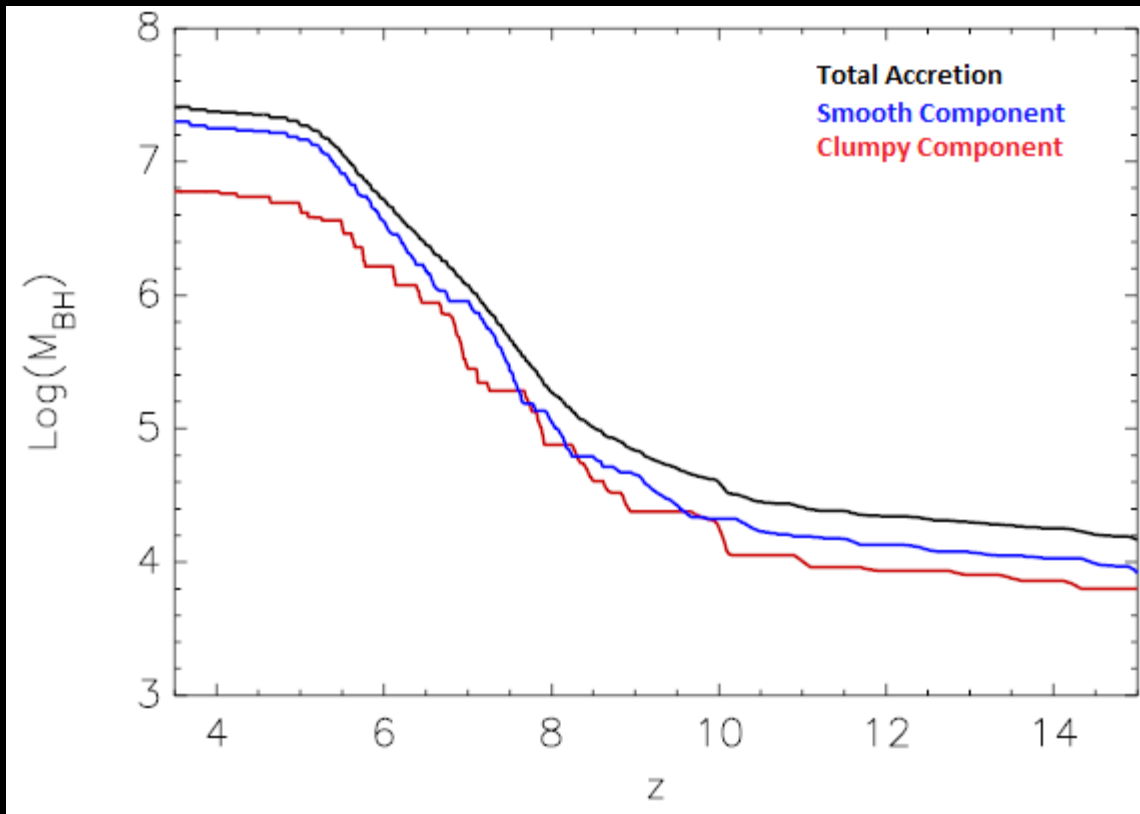


Black Hole Growth

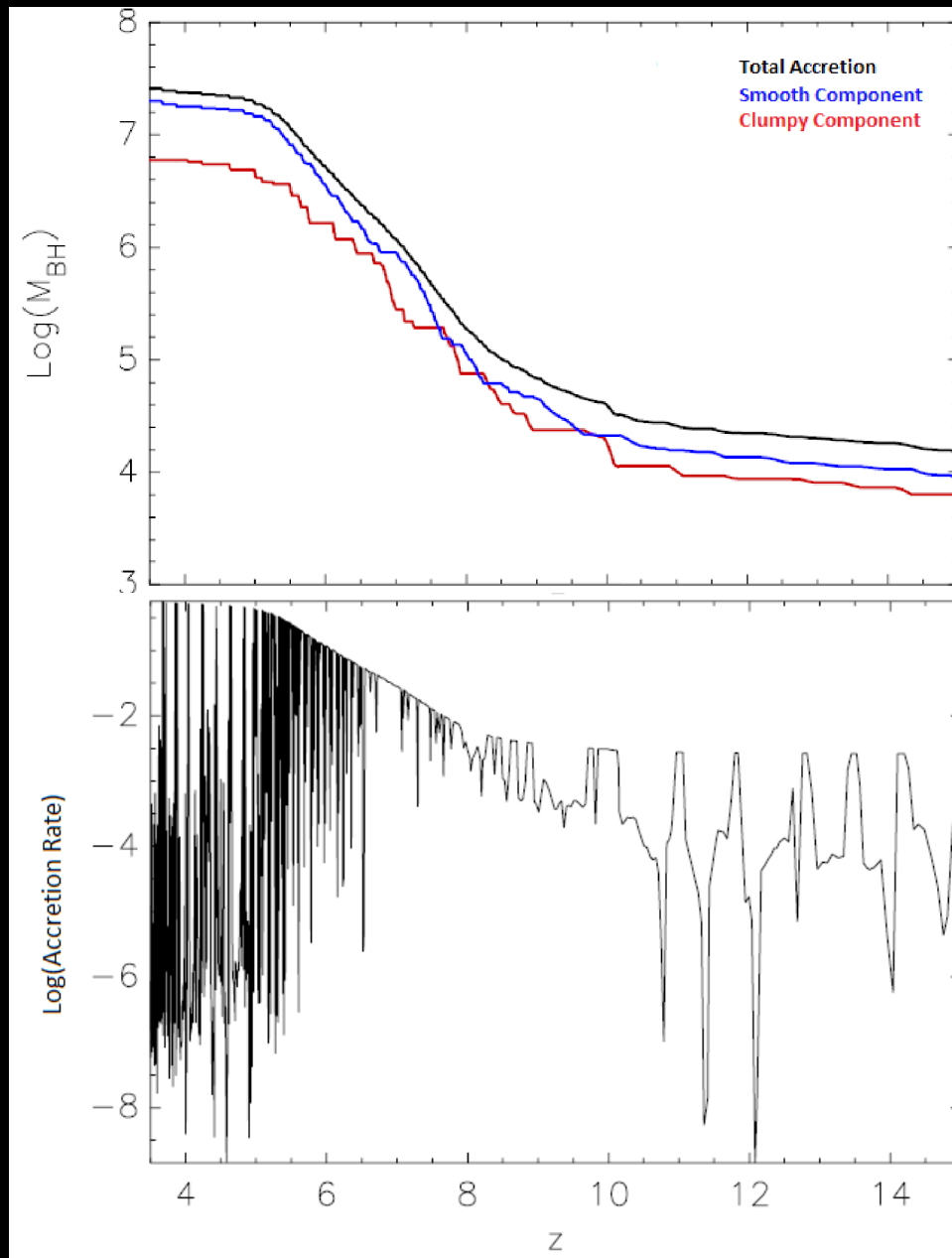


- Typical growth behavior
- Consists of 3 general phases
 1. Initial sub-Eddington growth
 2. Extended Eddington period
 3. Regulated phase

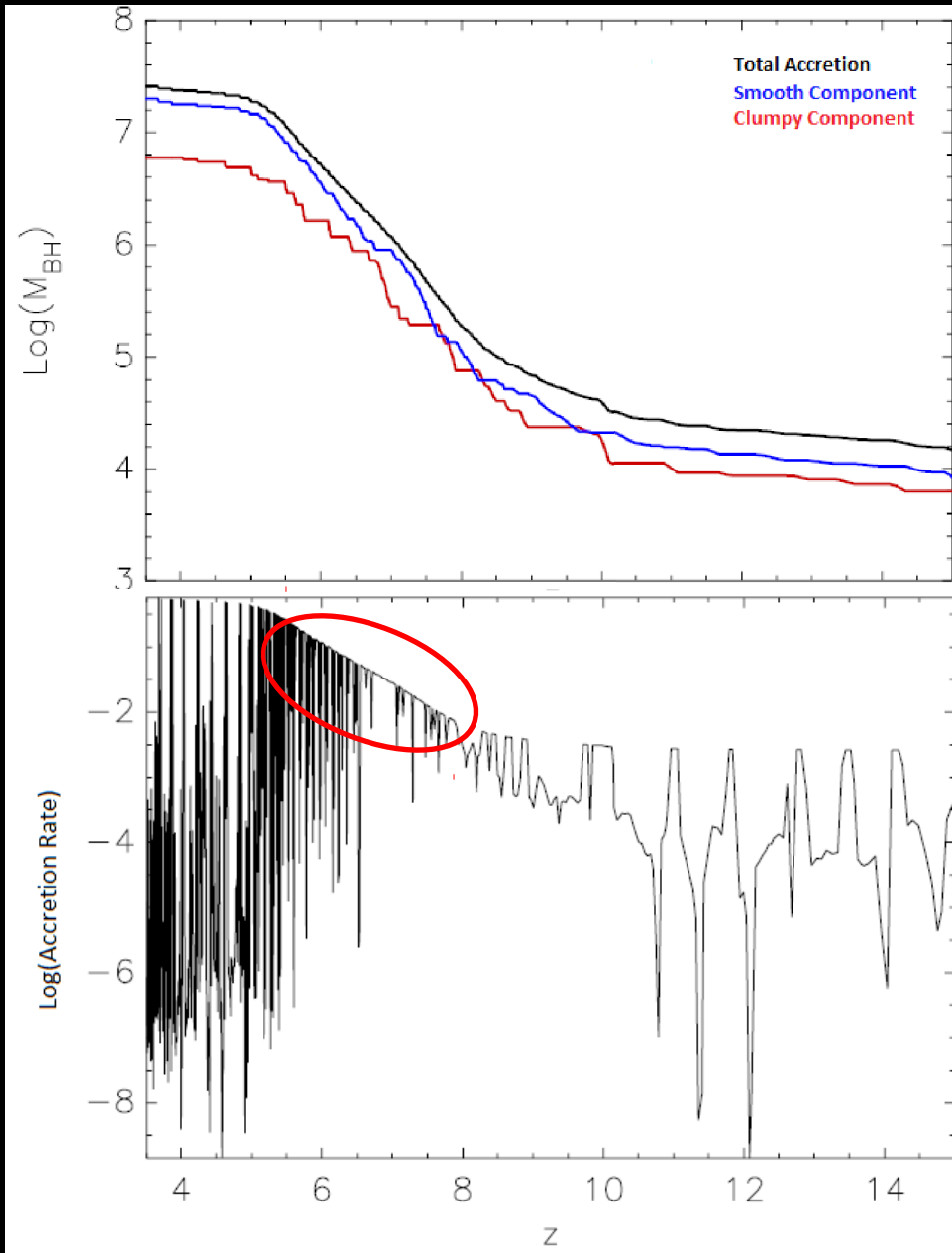
Black Hole Growth



Black Hole Growth

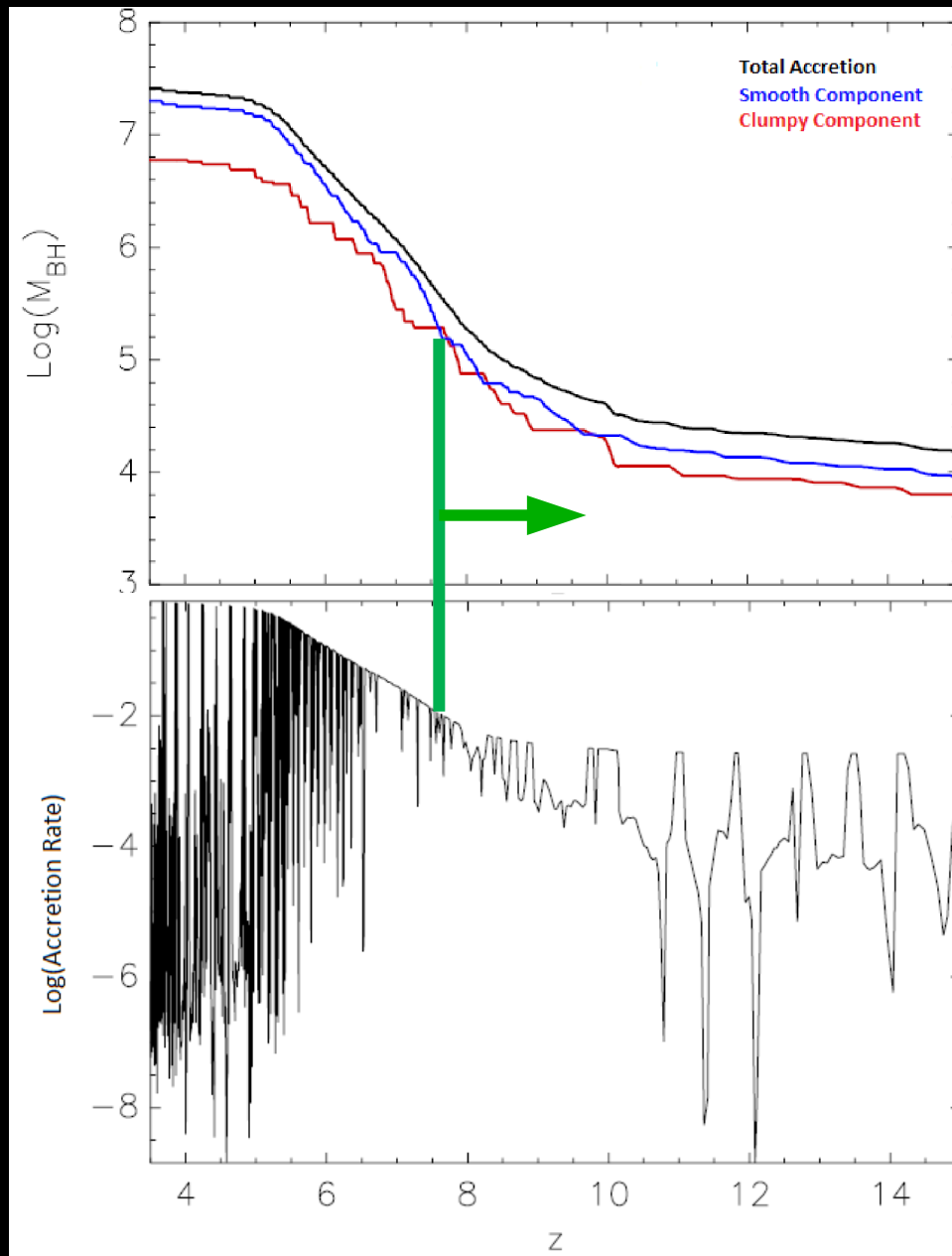


Black Hole Growth



Clumps have no effect on accretion during Eddington phase

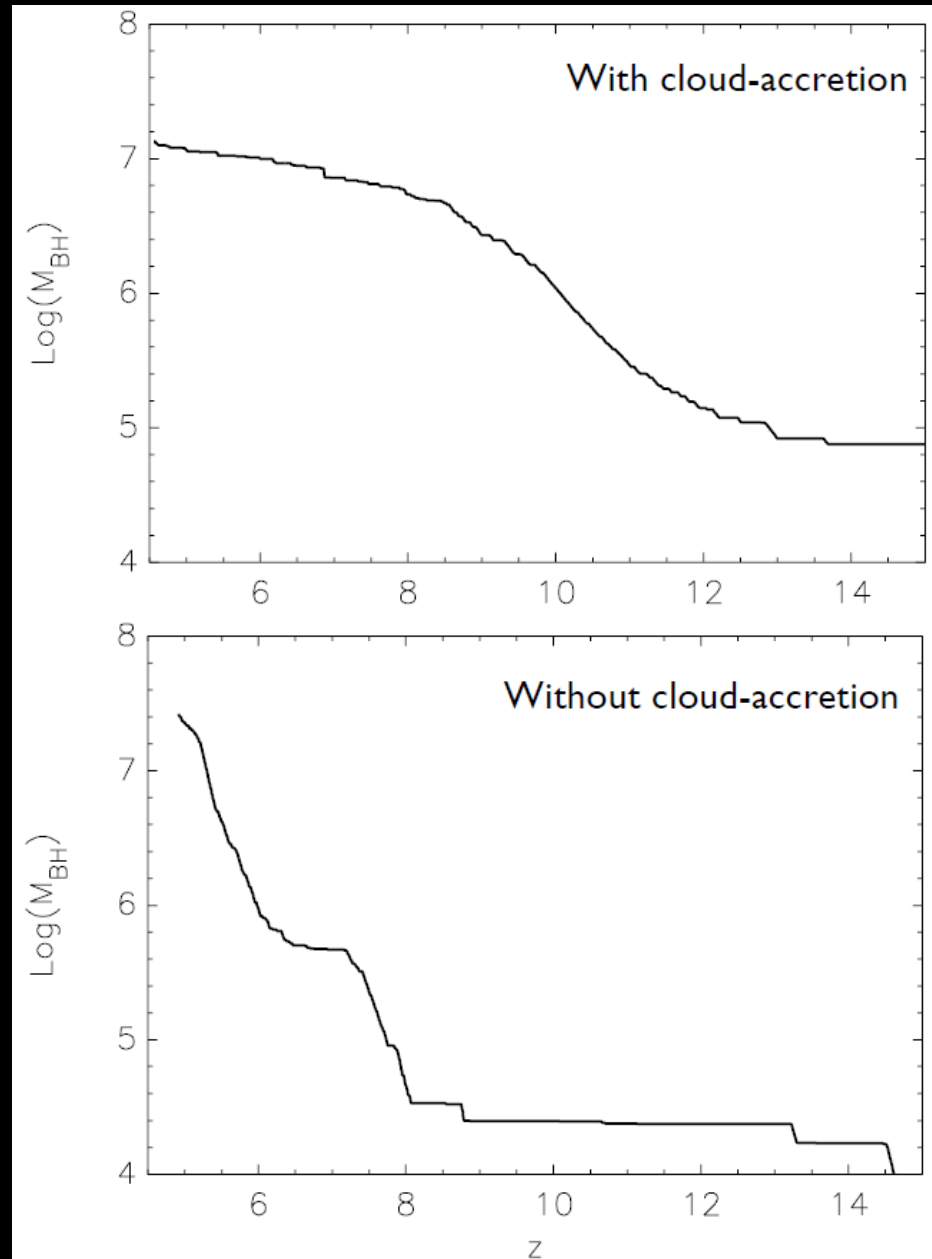
Black Hole Growth



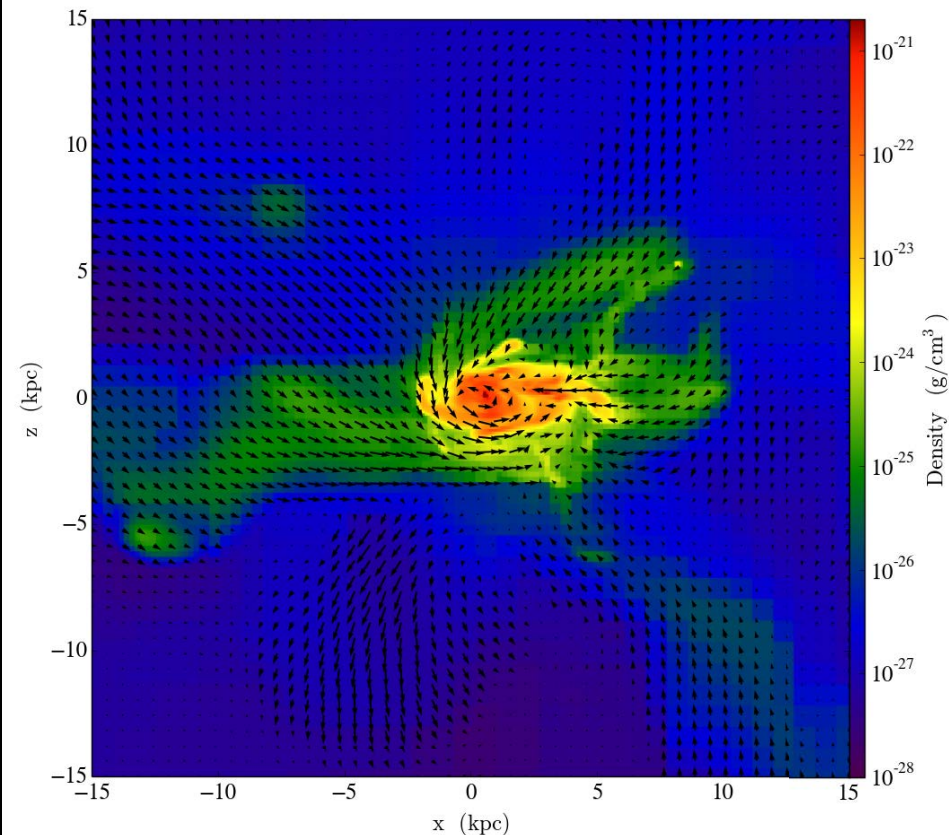
Pre-Eddington:
Clump accretion is
important

Black Hole Growth

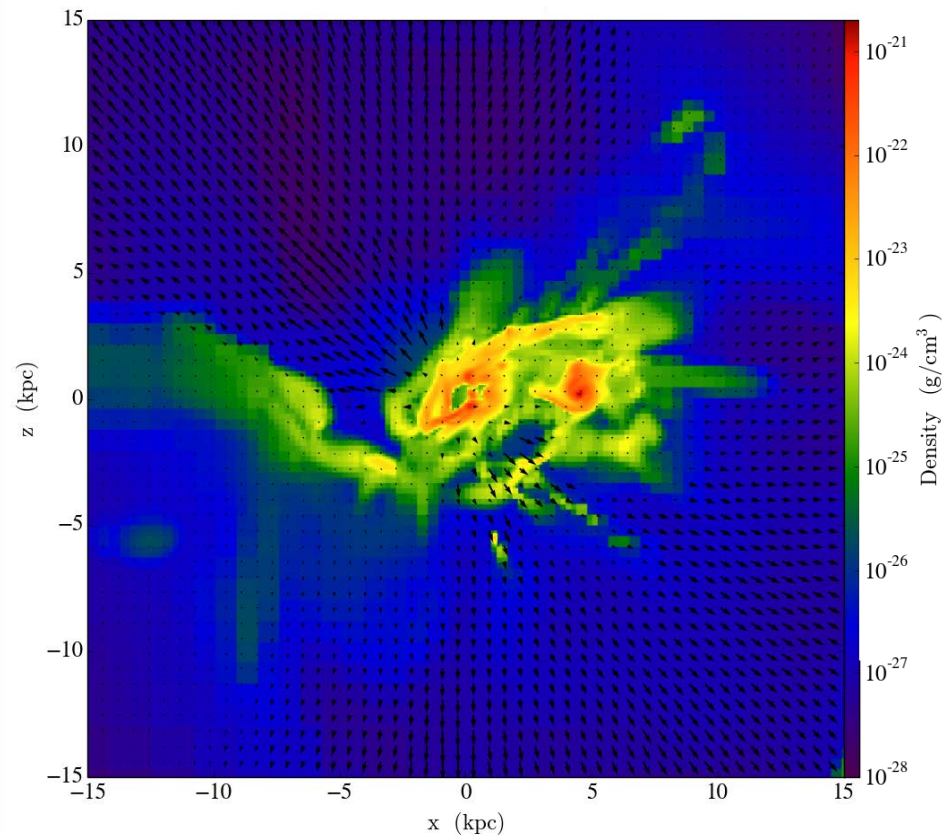
- Clump accretion grows BH faster at early times
- Initial increase in growth rate compounded by exponential growth
- Clumpy accretion can have significant impact on growth over cosmological scales



Morphological Impact

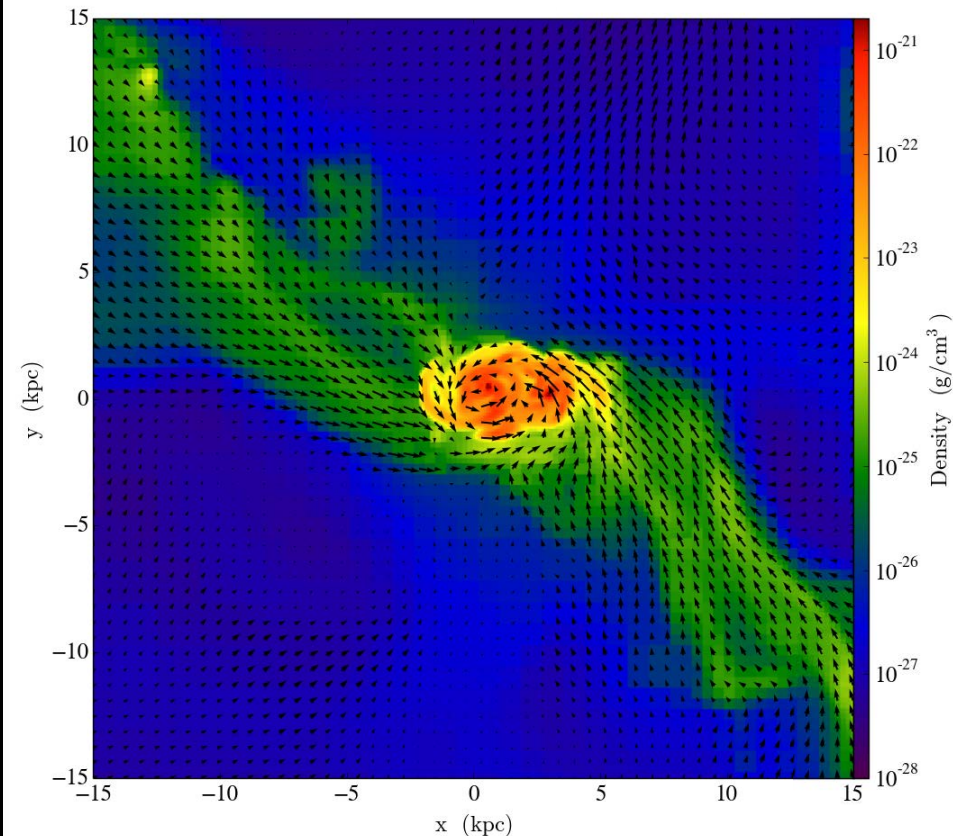


Standard Accretion

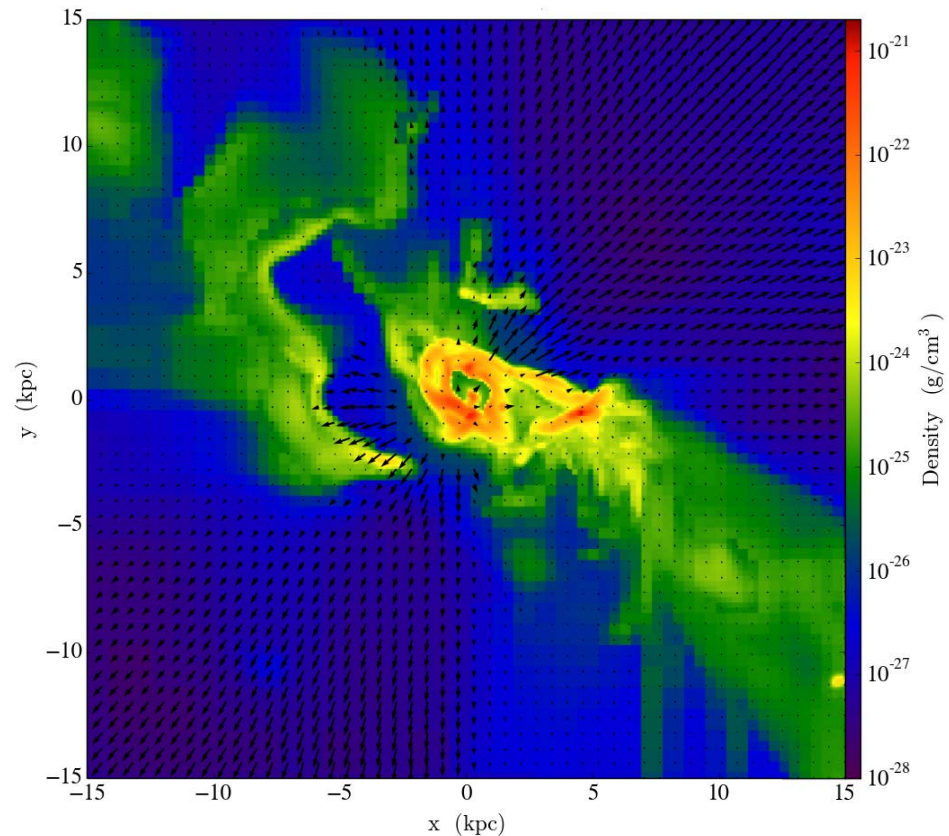


Clumpy Accretion

Morphological Impact



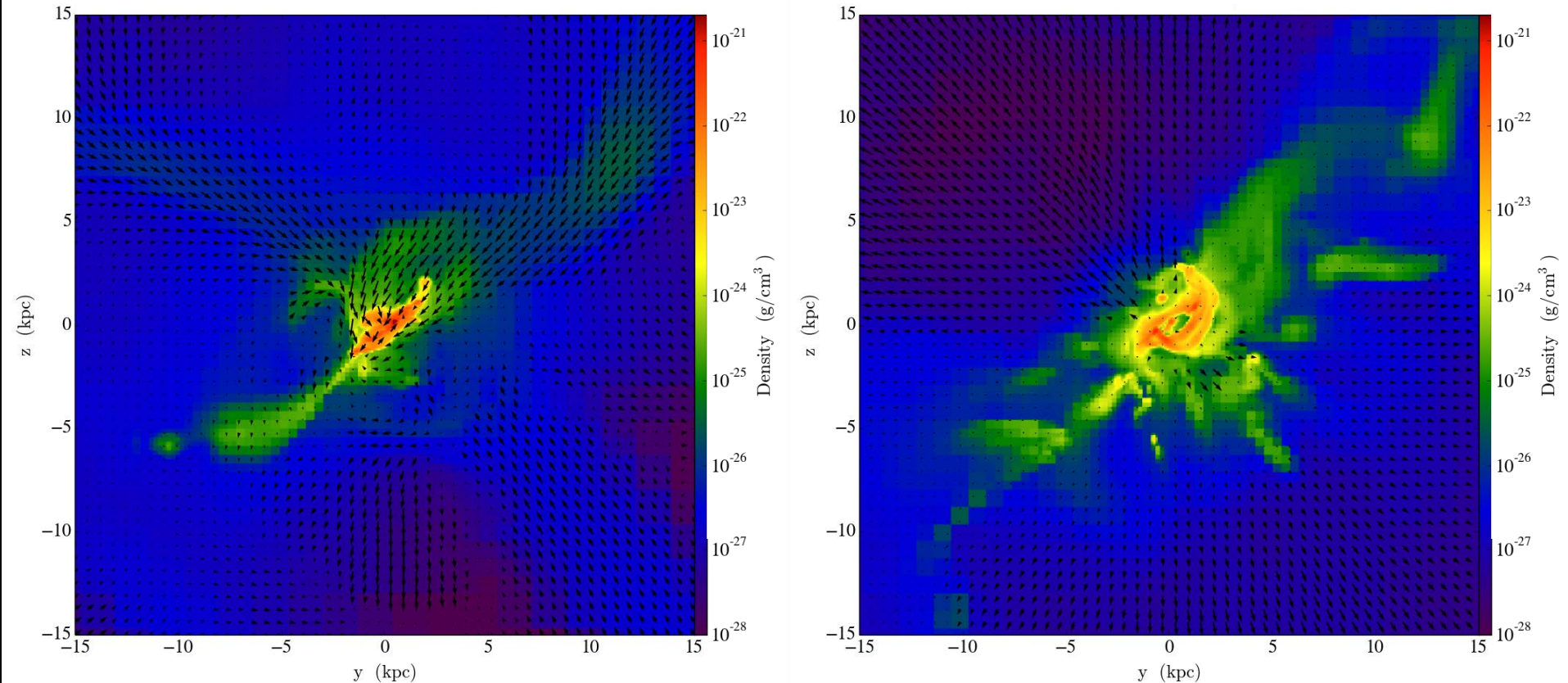
Standard Accretion



Clumpy Accretion

Central region evacuated
Inflowing streams disrupted

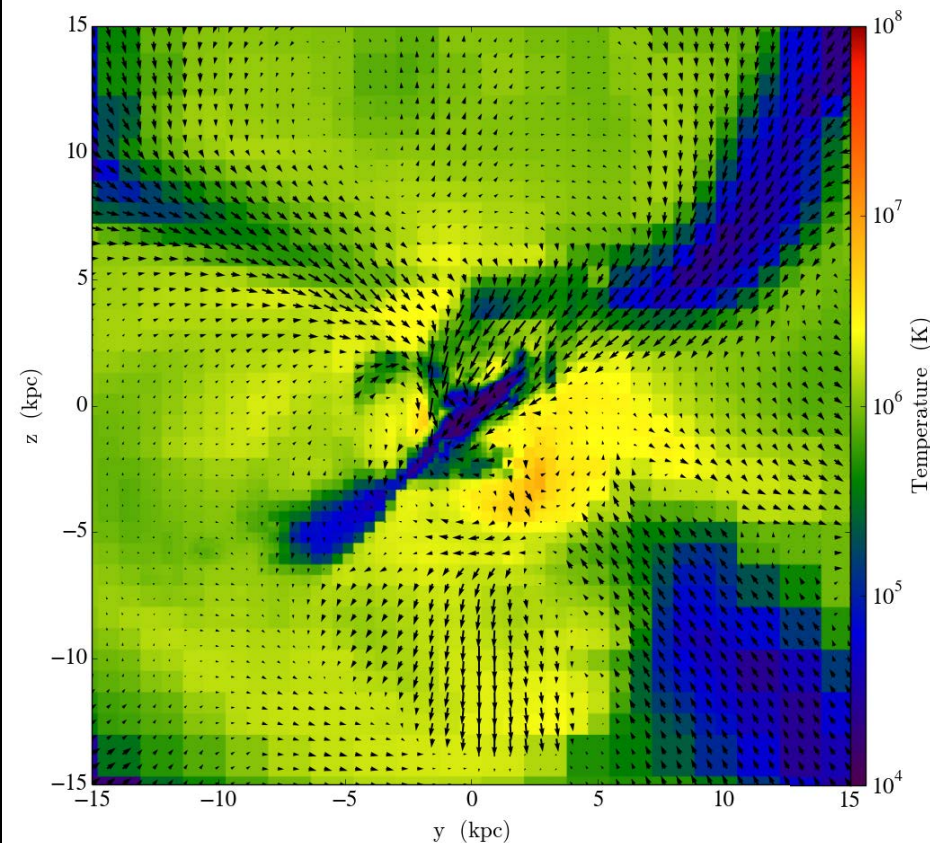
Morphological Impact



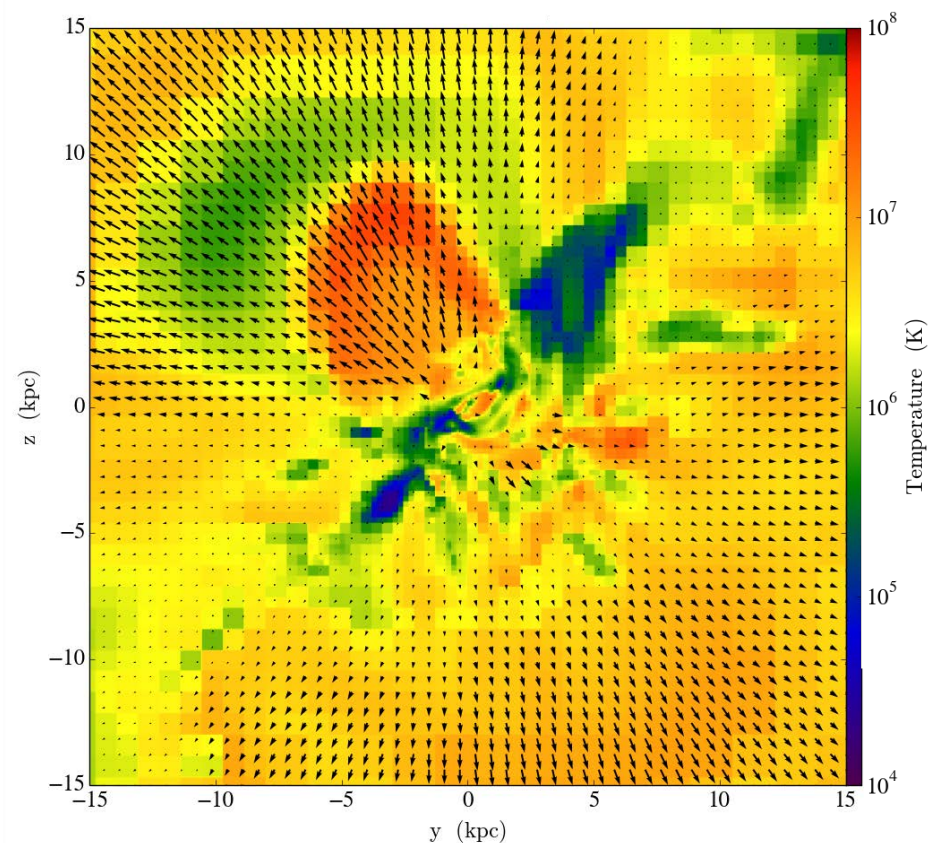
Standard Accretion

Clumpy Accretion

Morphological Impact

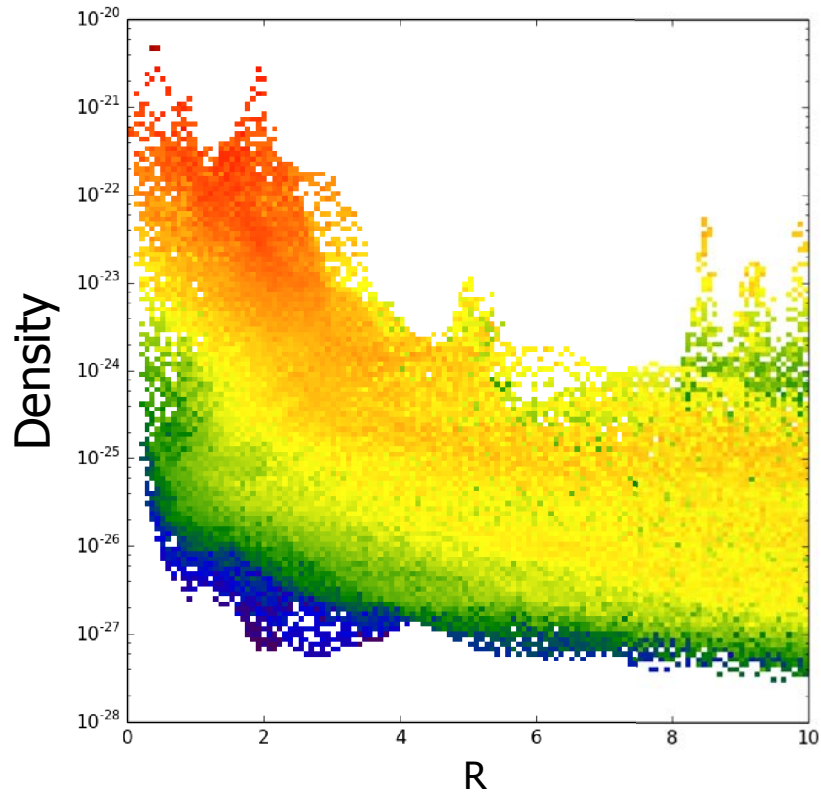


Standard Accretion
Minimal heating

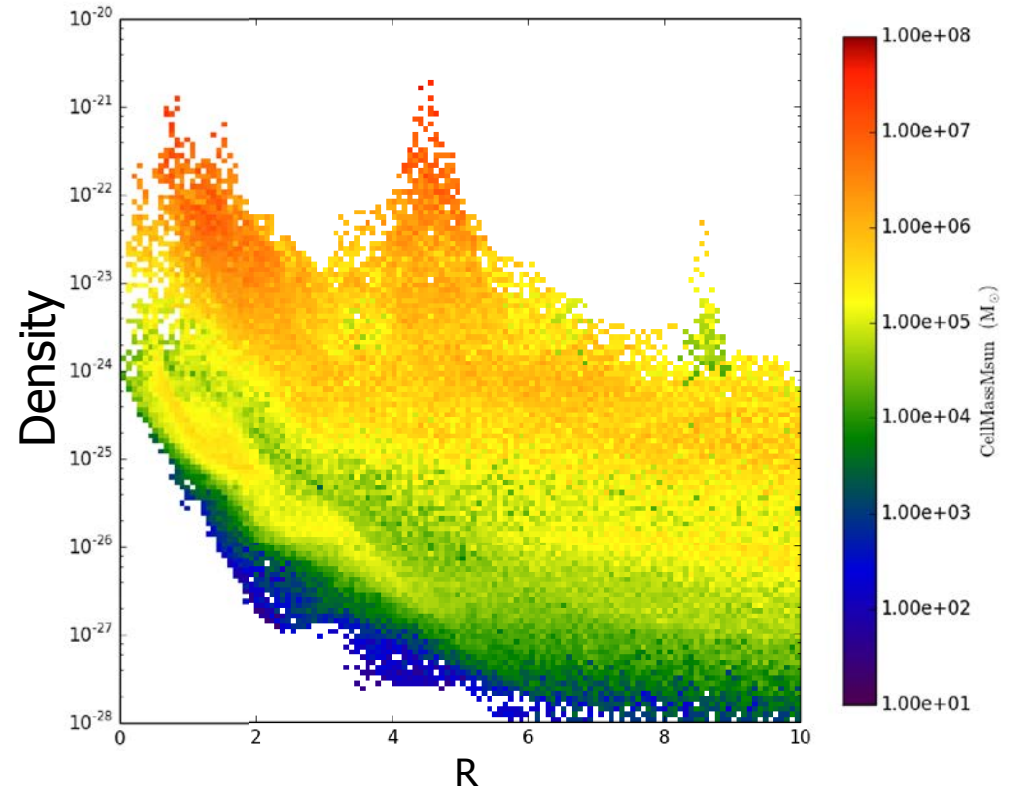


Clumpy Accretion
Substantial heating inflating
asym. bubbles

Gas Properties

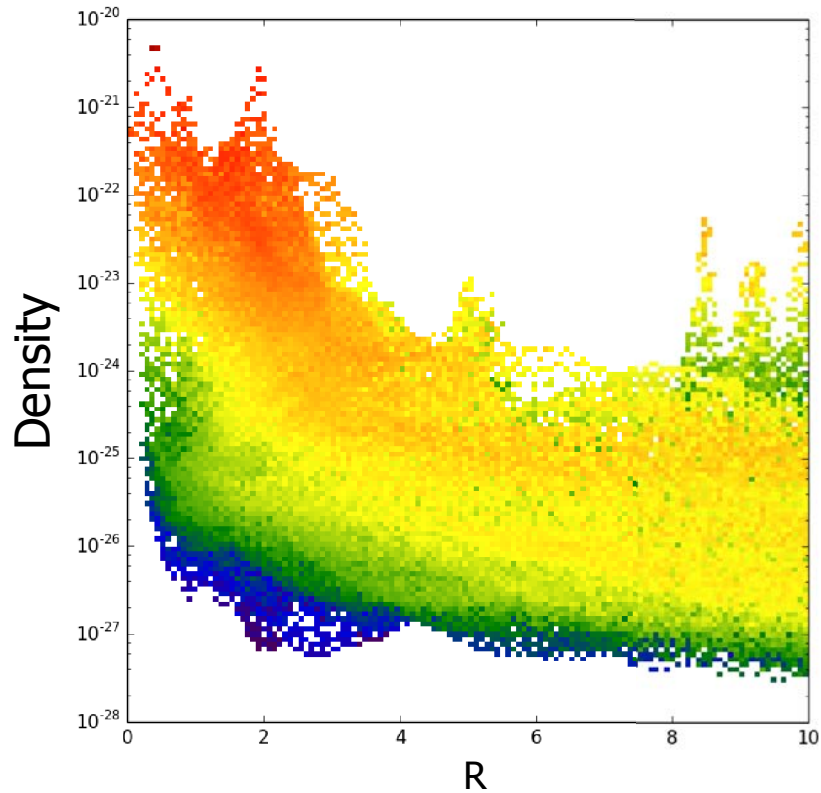


Standard Accretion

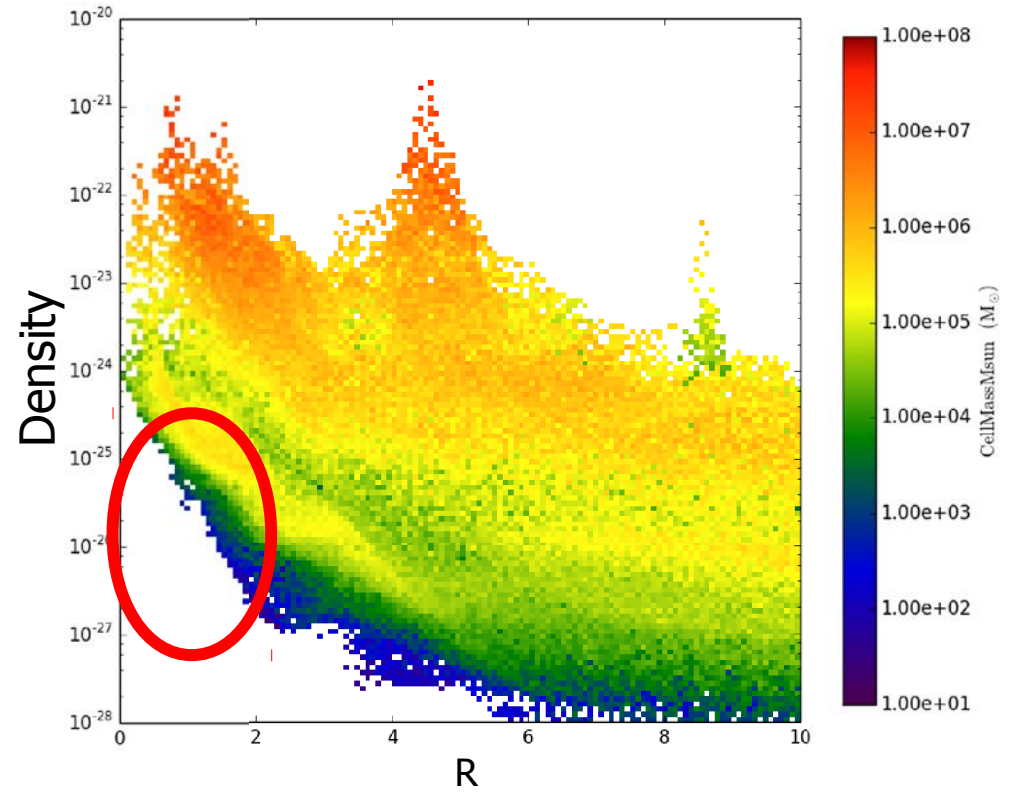


Clumpy Accretion

Gas Properties

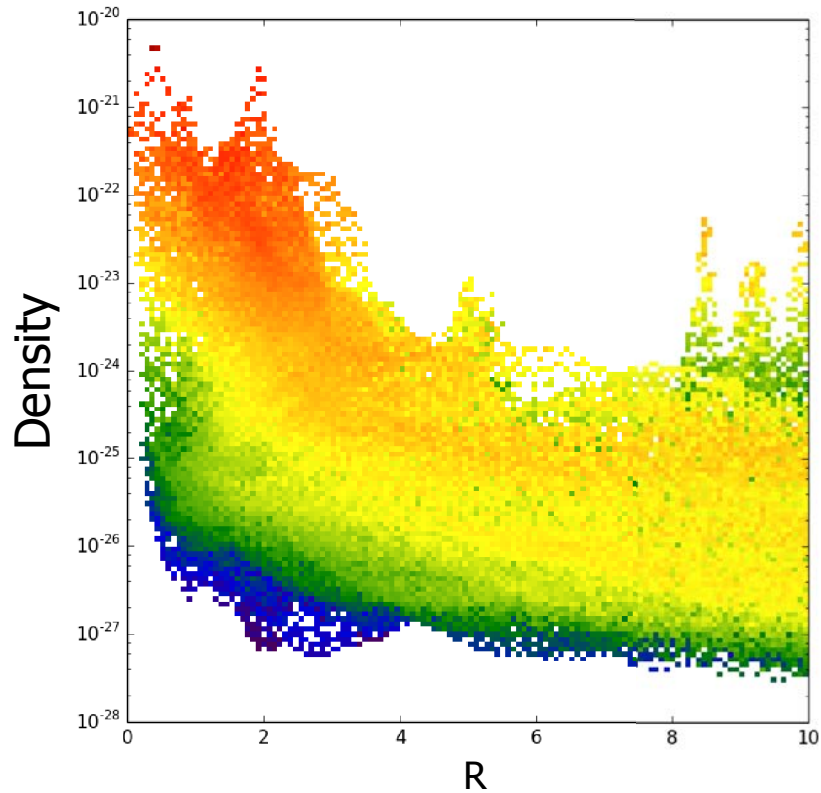


Standard Accretion

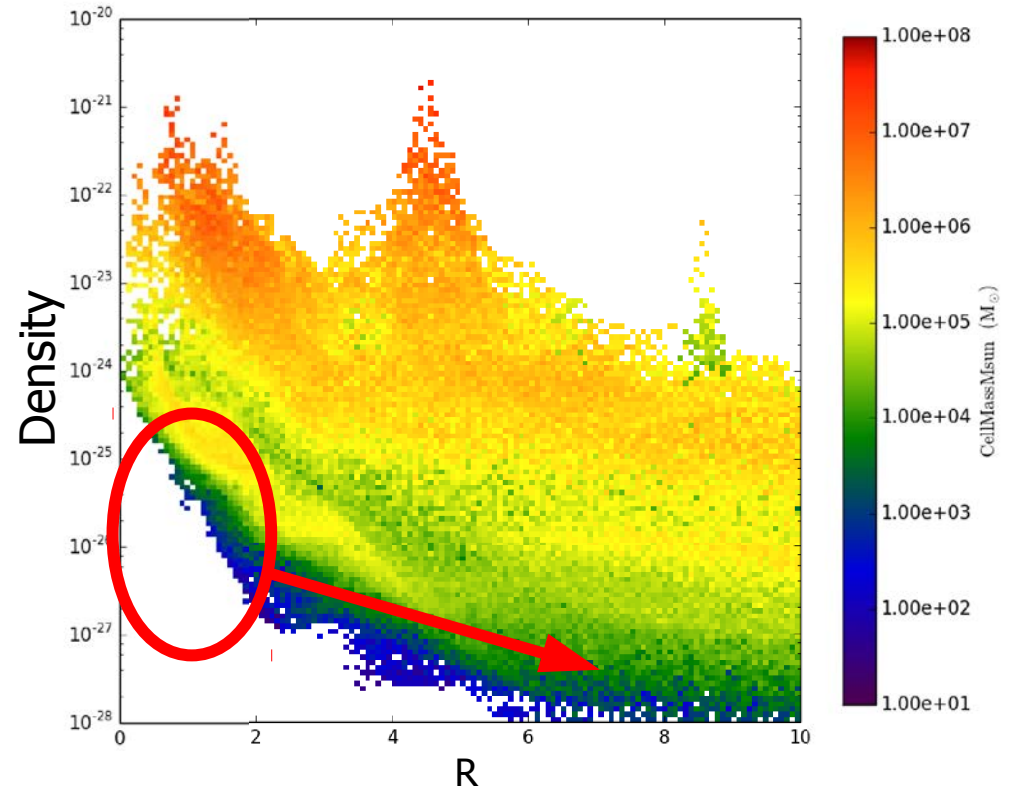


Clumpy Accretion

Gas Properties

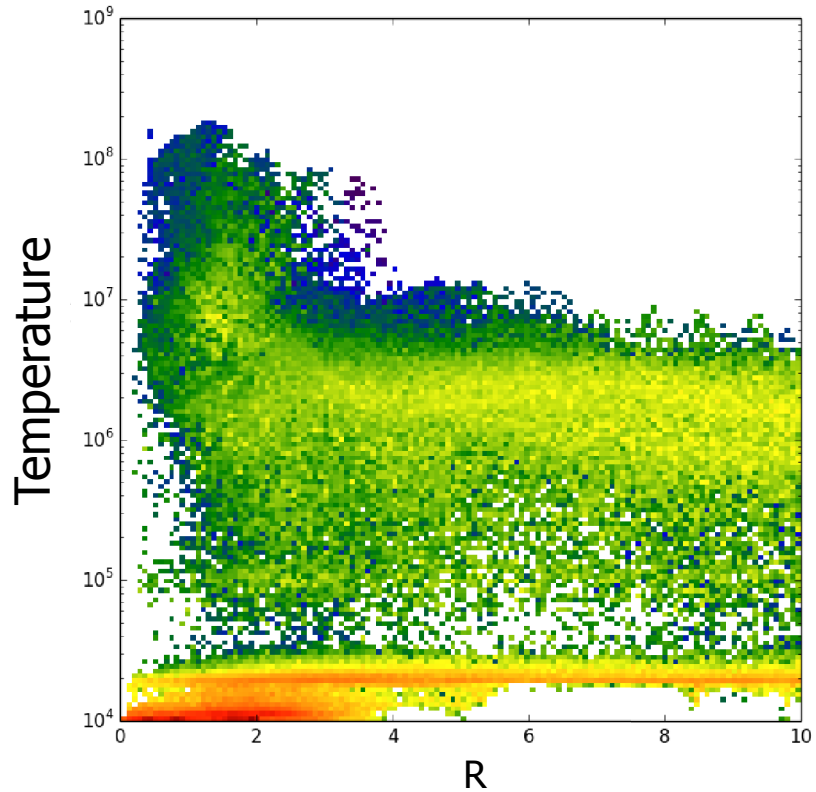


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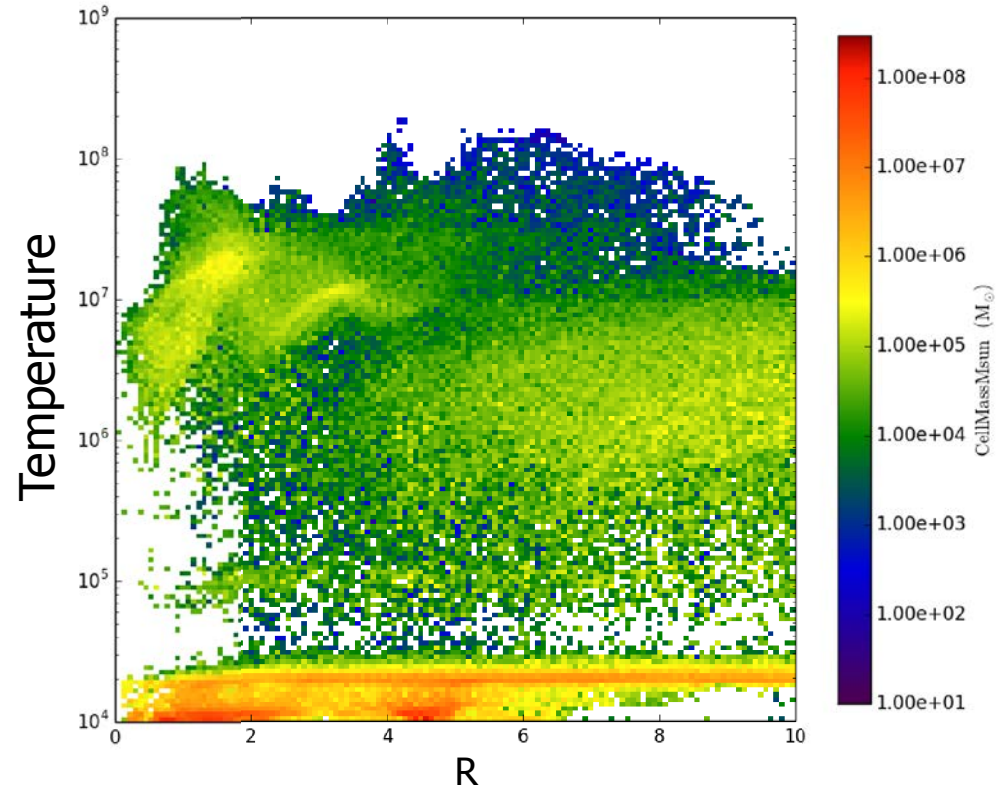


Clumpy Accretion

Gas Properties

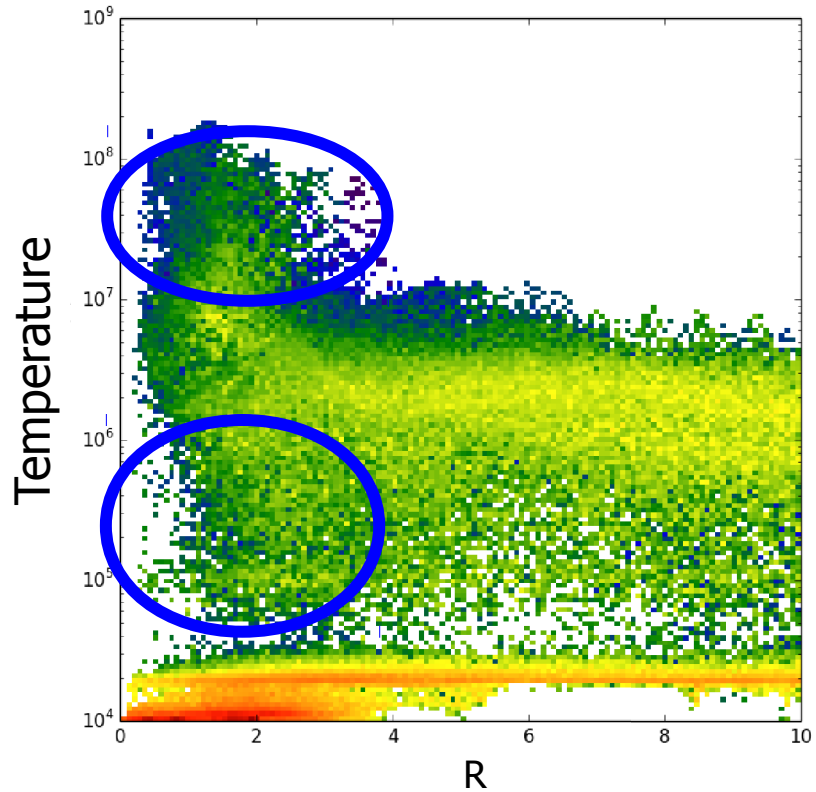


Standard Accretion

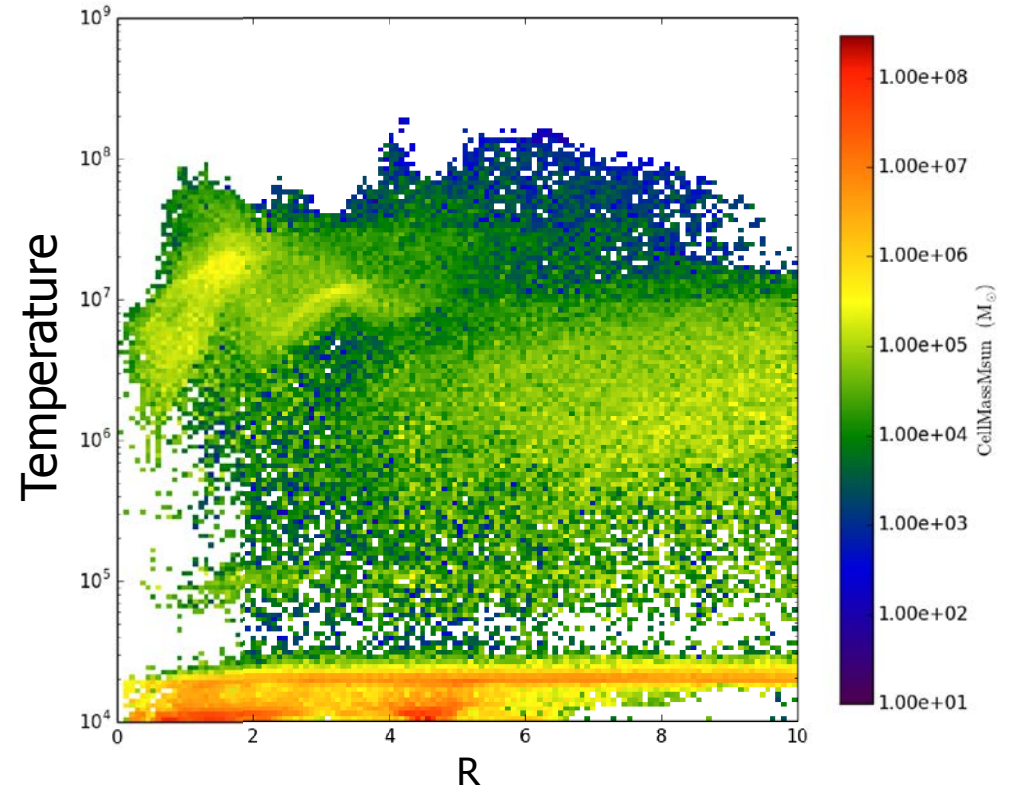


Clumpy Accretion

Gas Properties

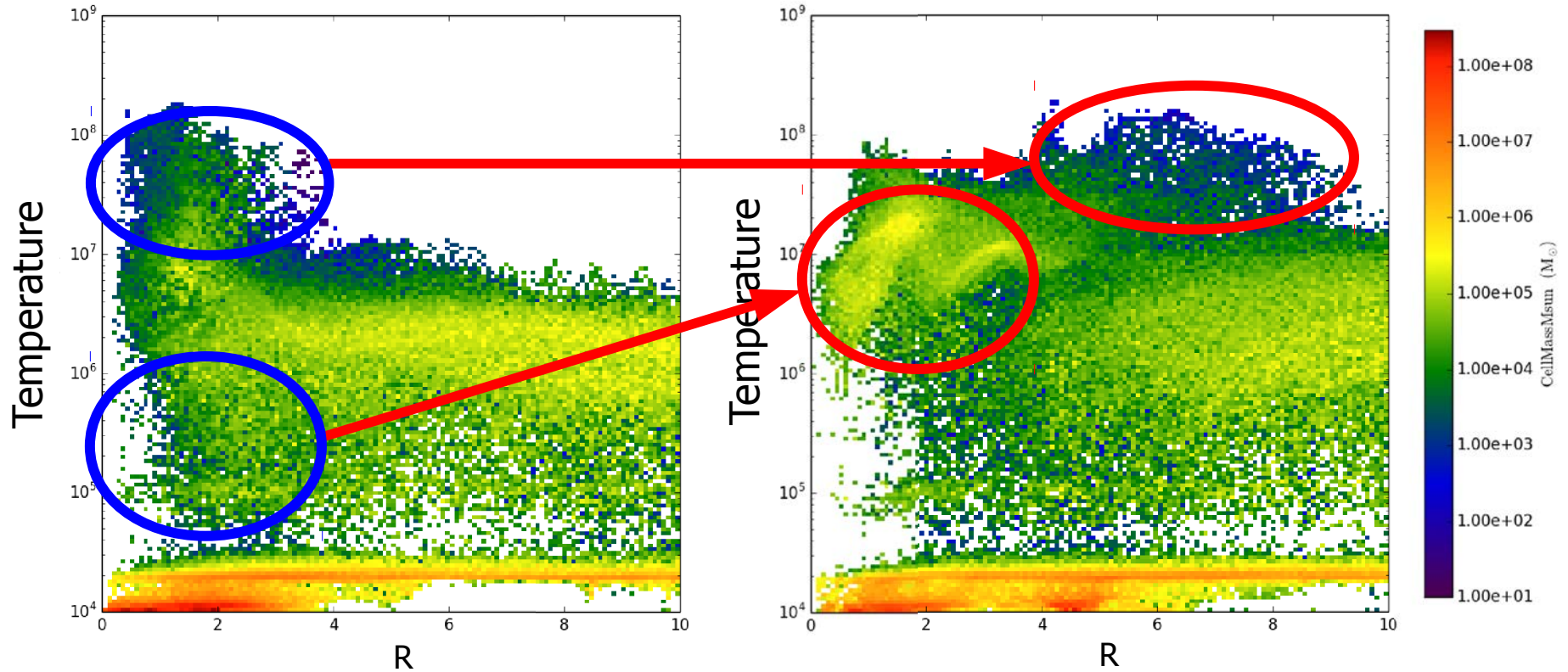


Standard Accretion



Clumpy Accretion

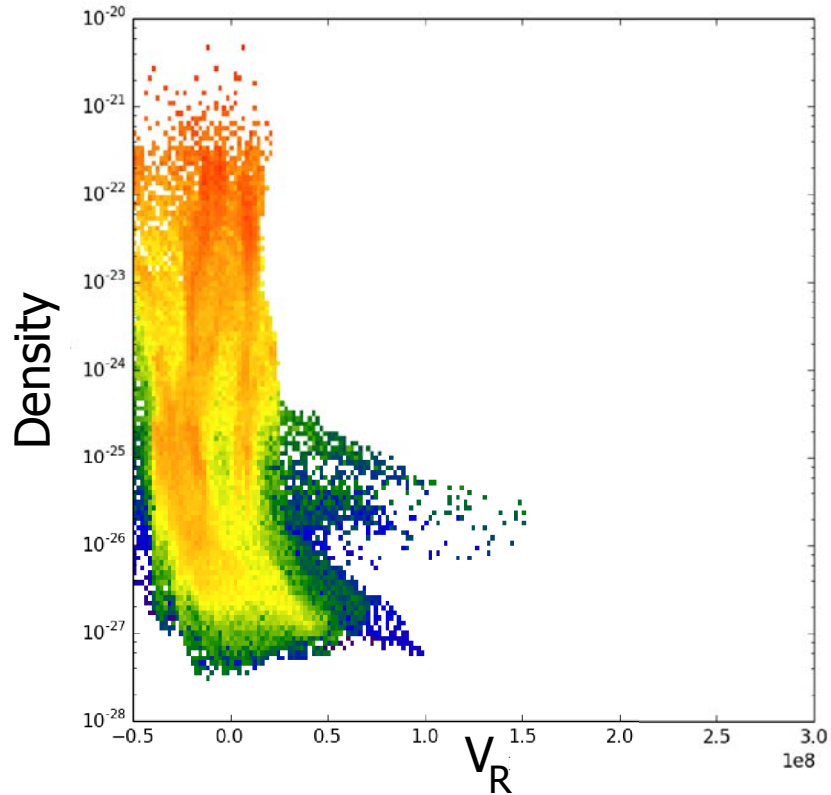
Gas Properties



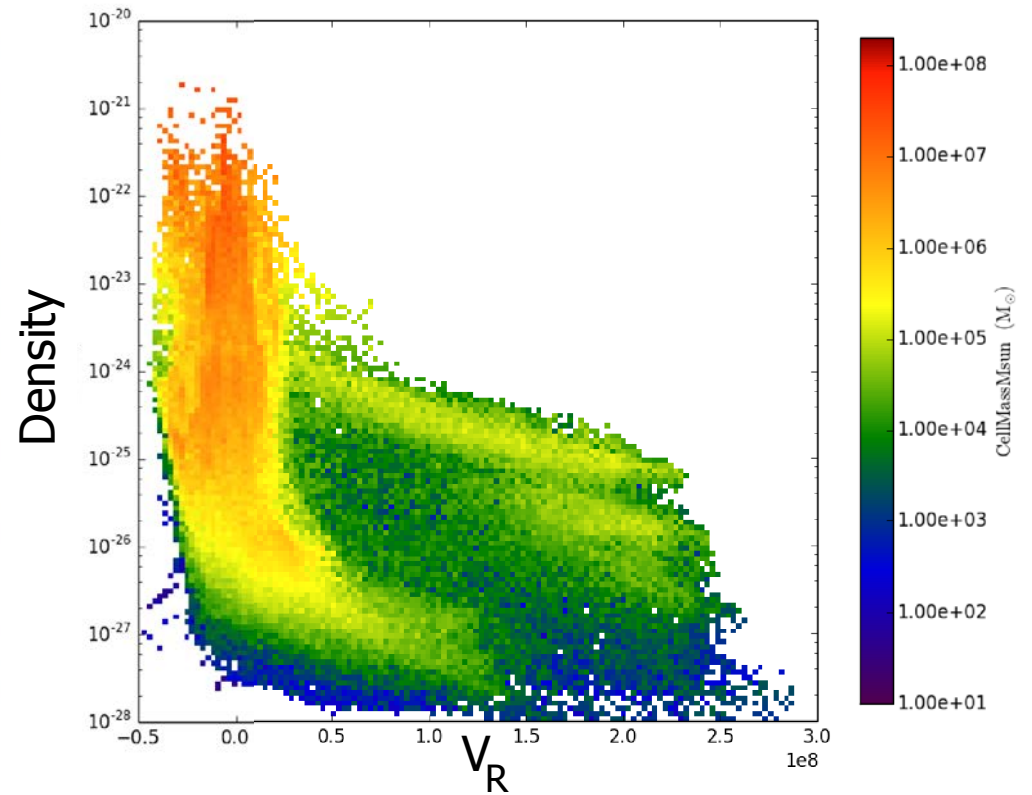
Standard Accretion

Clumpy Accretion

Gas Properties

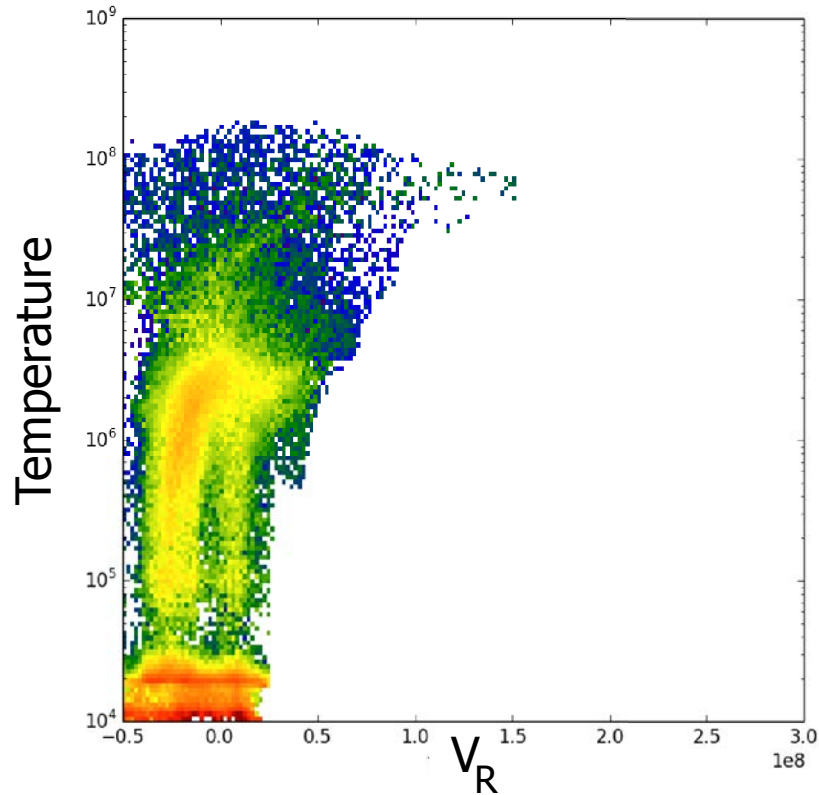


Standard Accretion

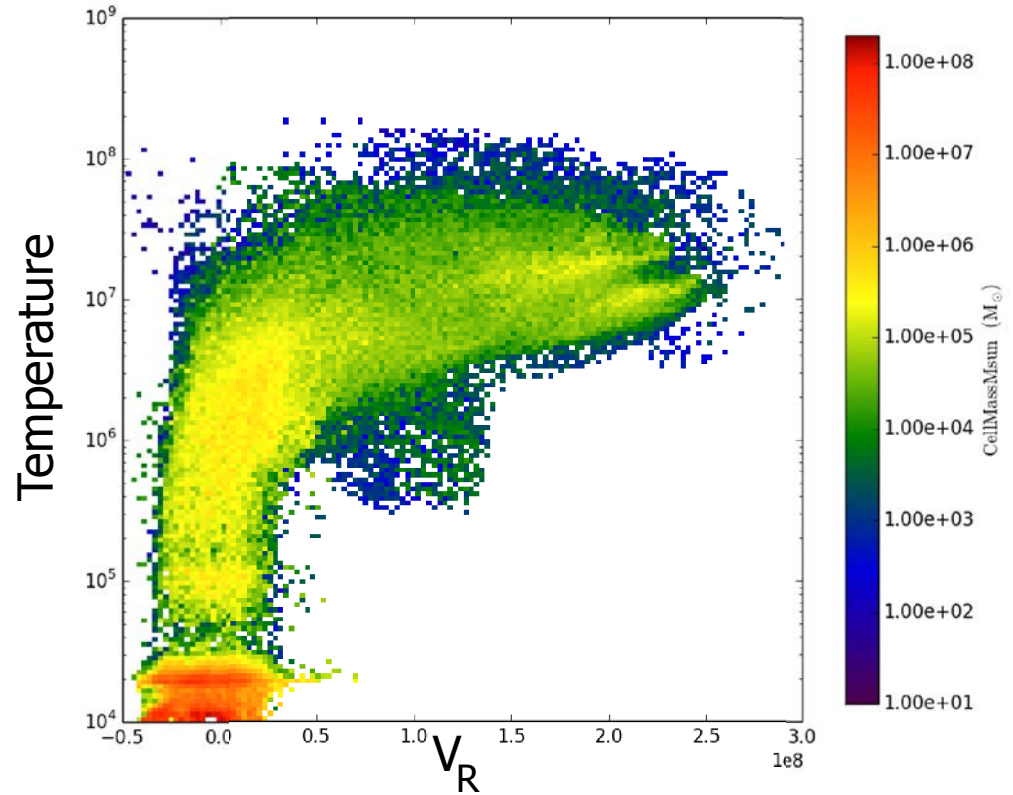


Clumpy Accretion

Gas Properties

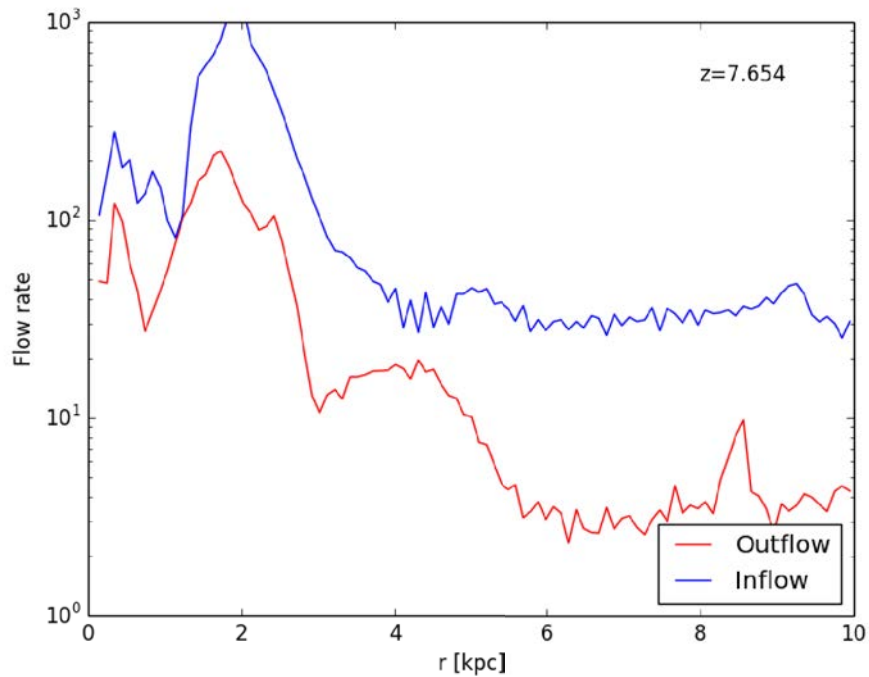


Standard Accretion

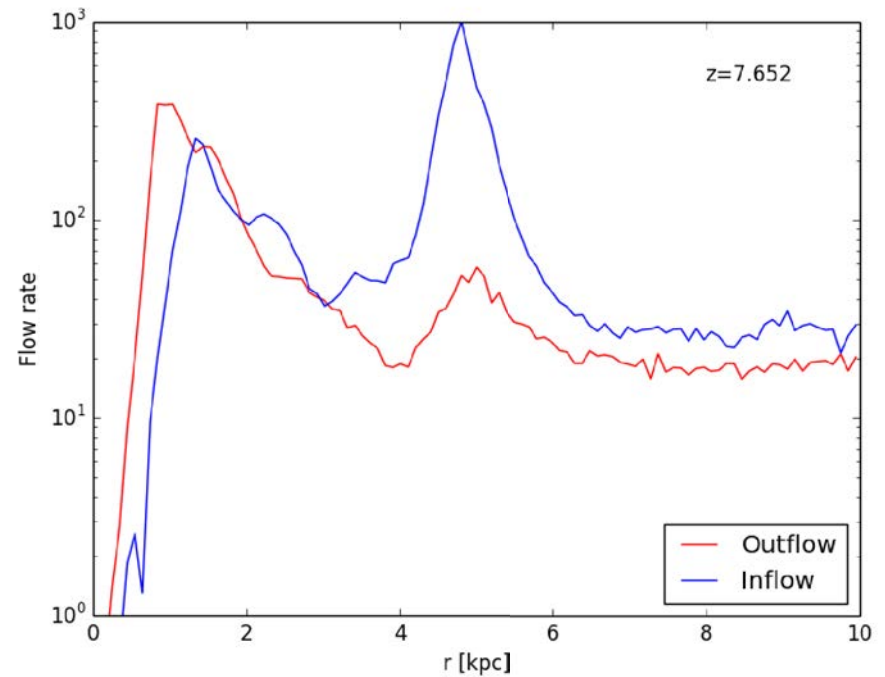


Clumpy Accretion

Inflows and Outflows

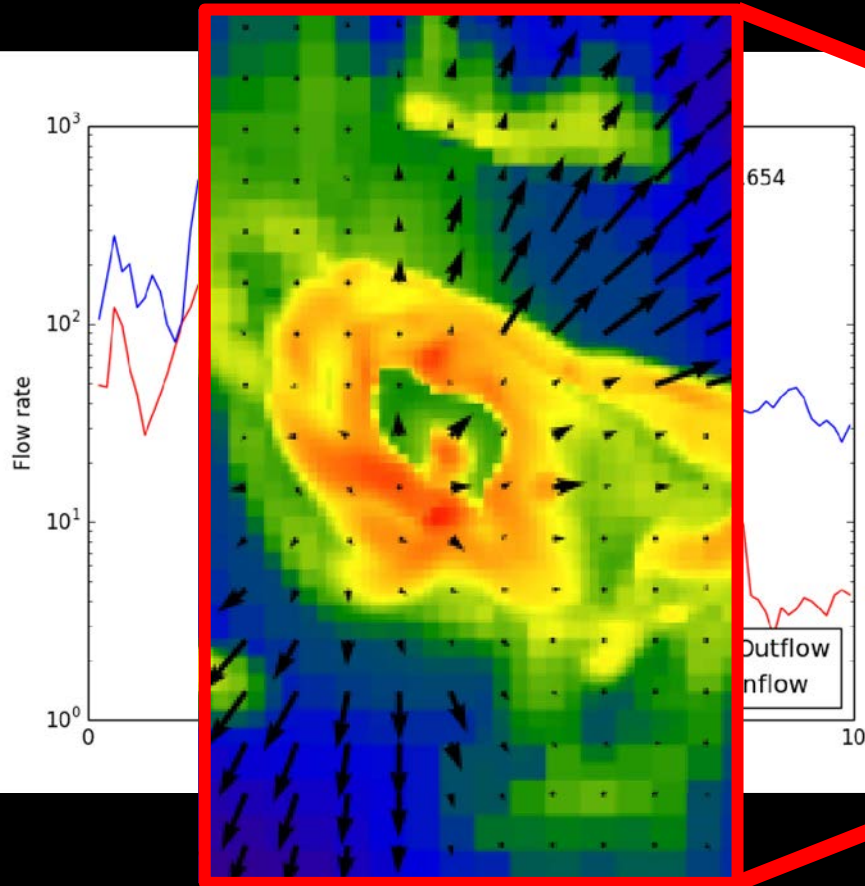


Standard Accretion

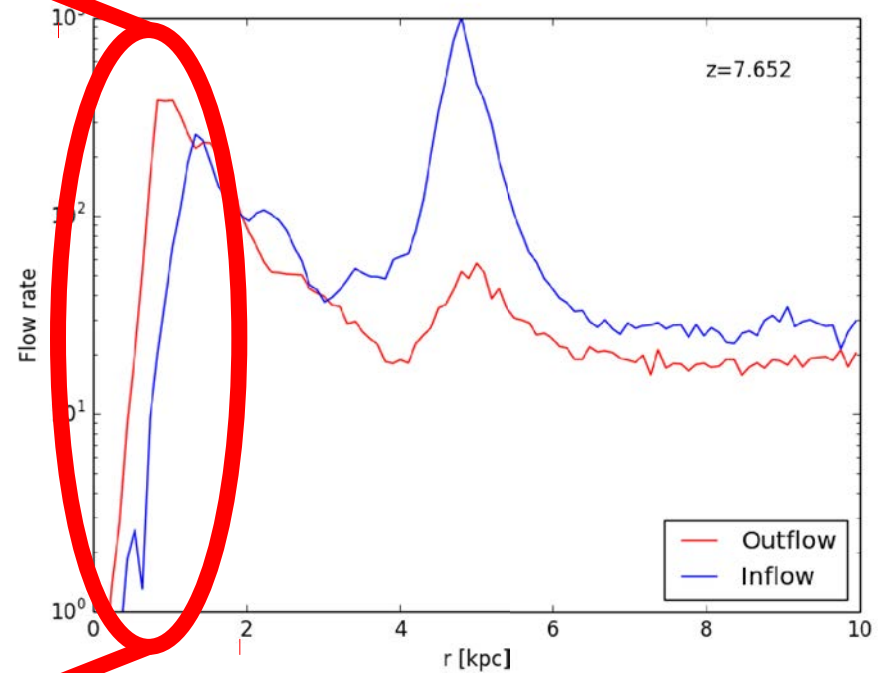


Clumpy Accretion

Inflows and Outflows

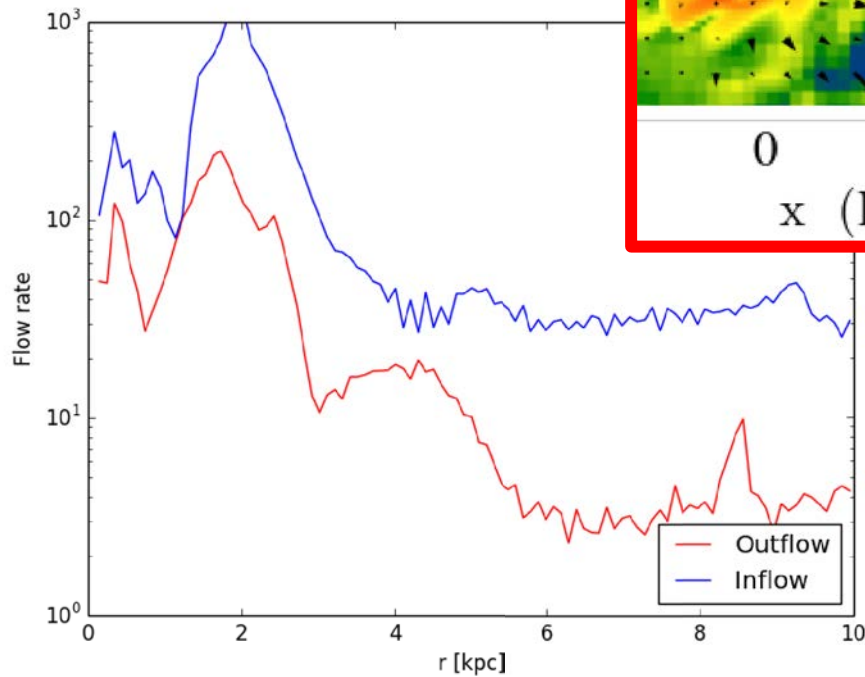


Standard Accretion

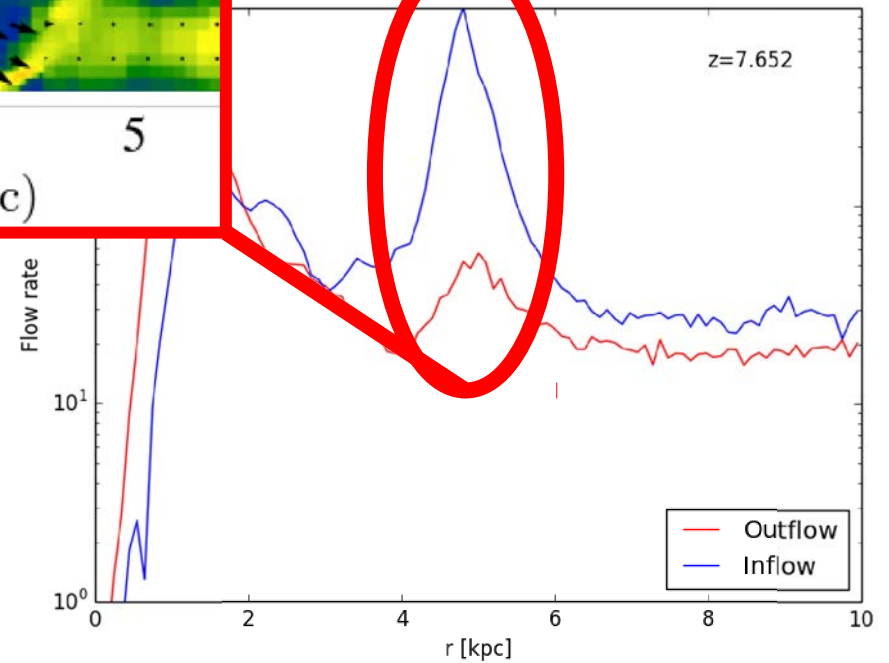
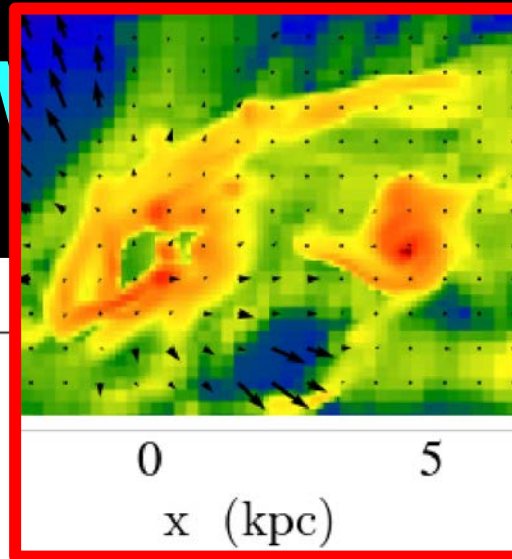


Clumpy Accretion

Inflow outflows

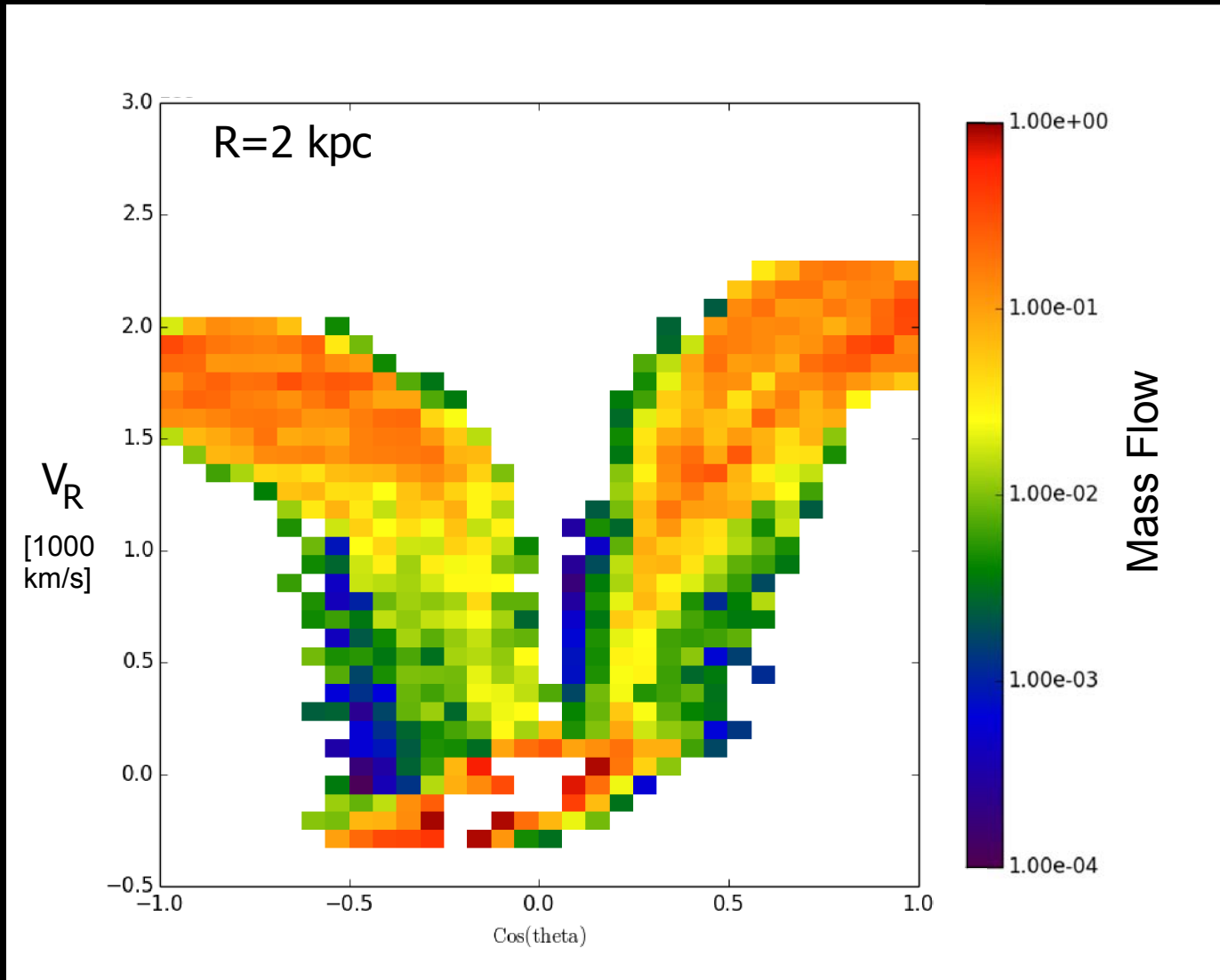


Standard Accretion

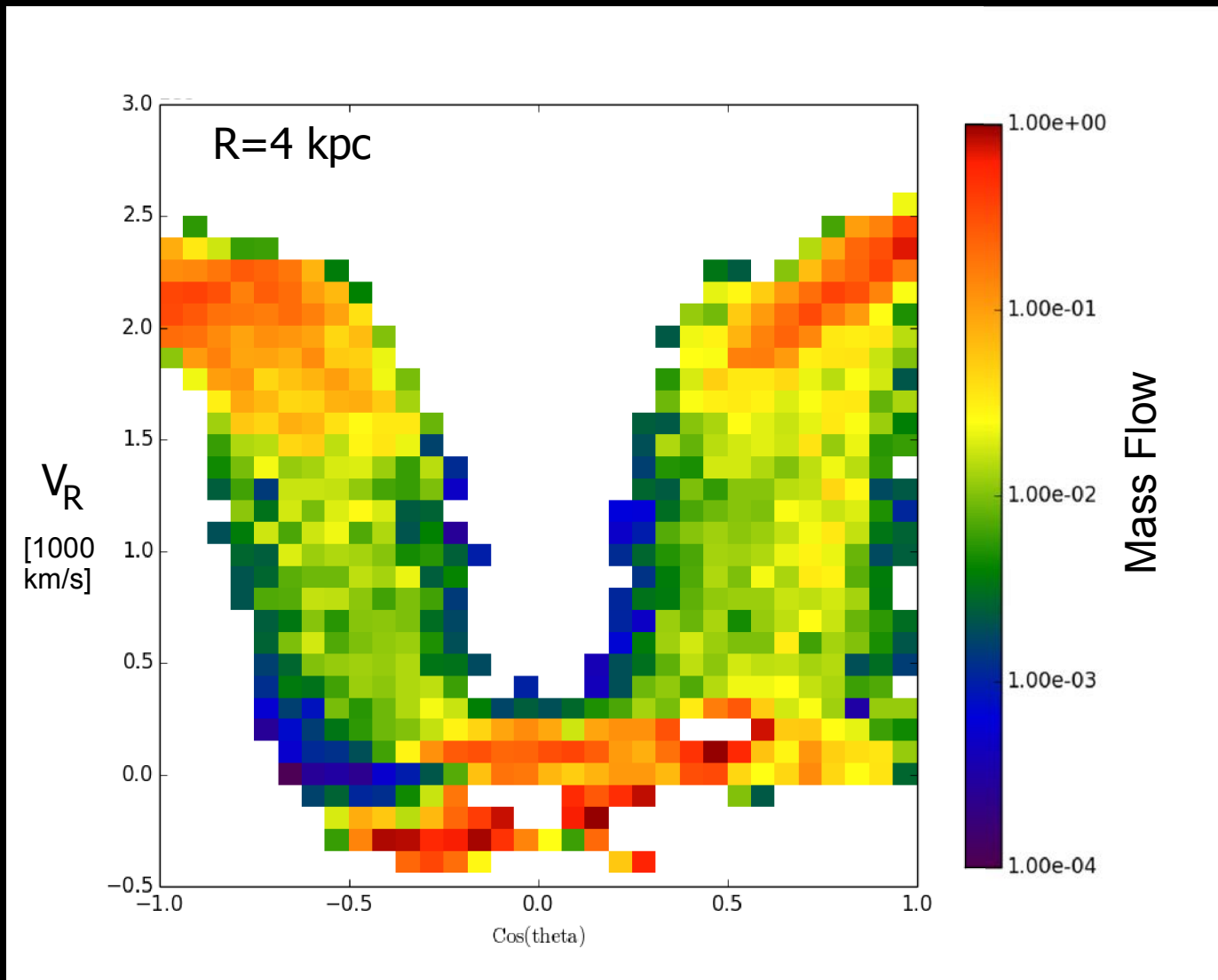


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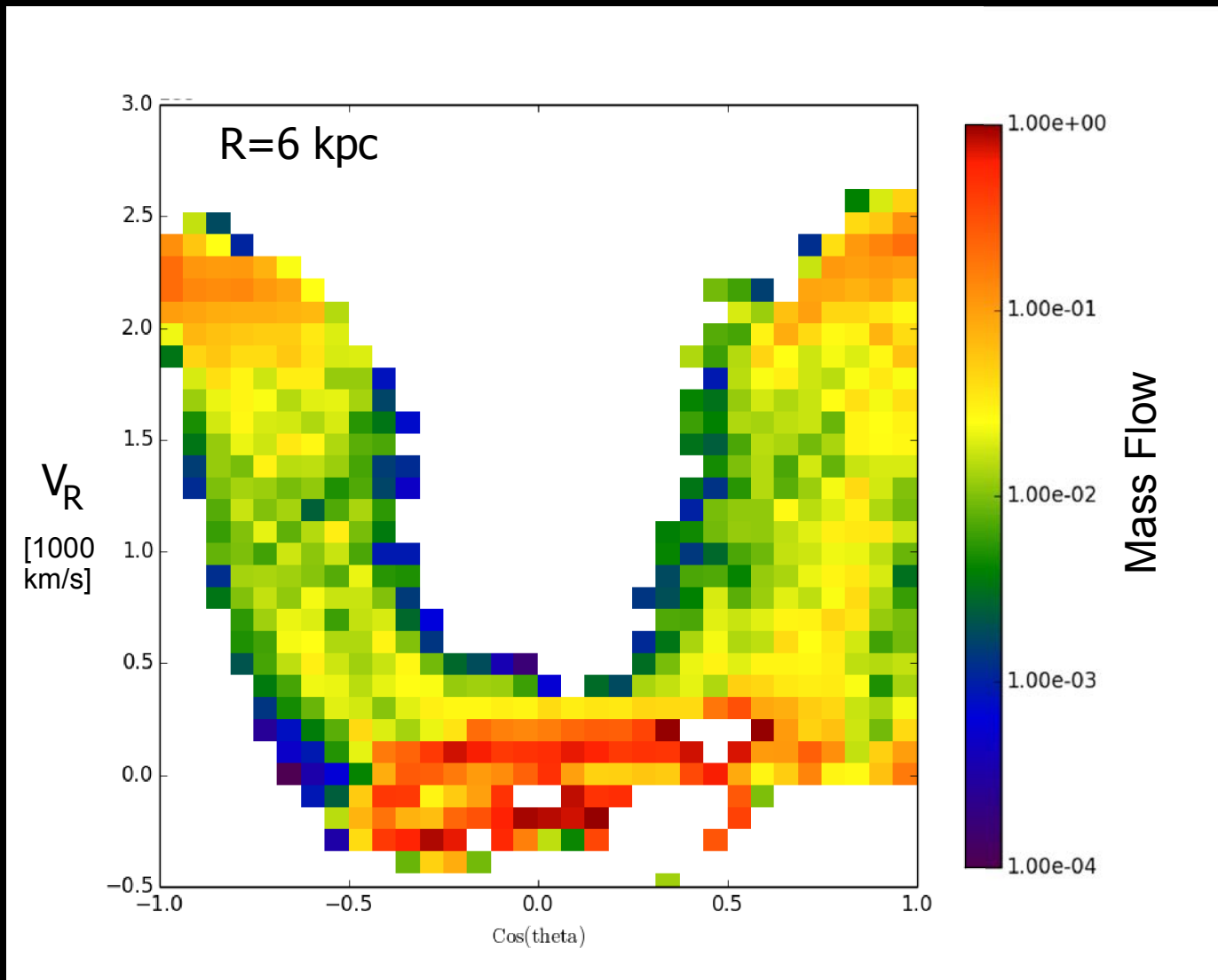
Inflows and Outflows – In- vs. Out-of-plane



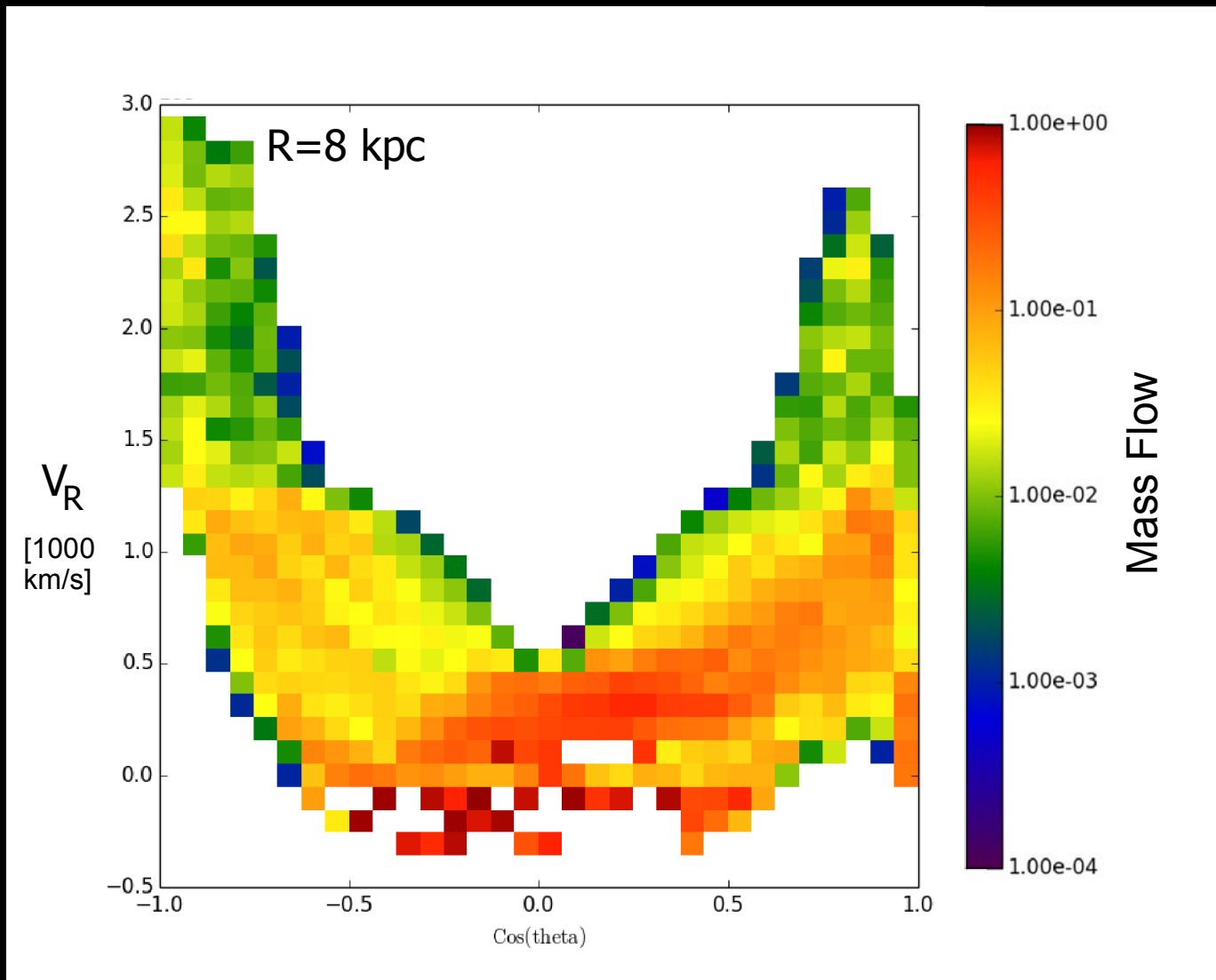
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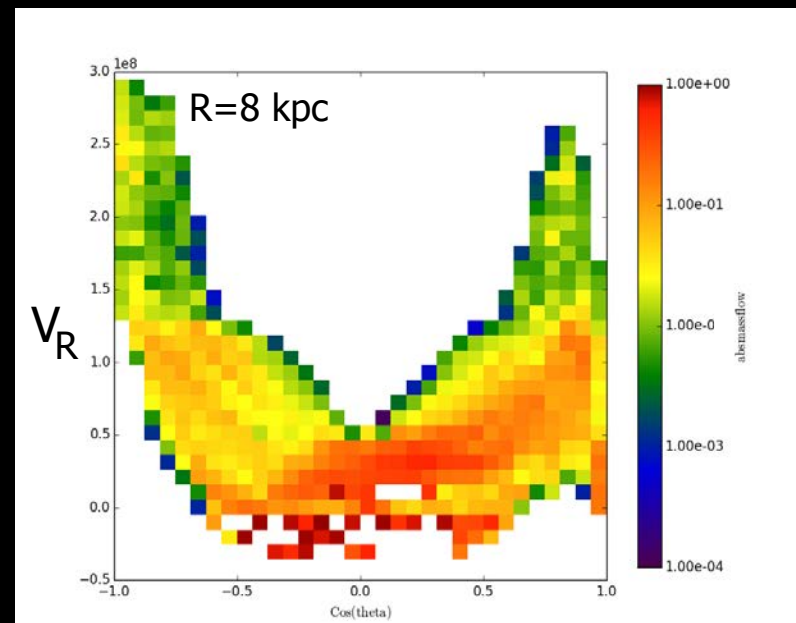
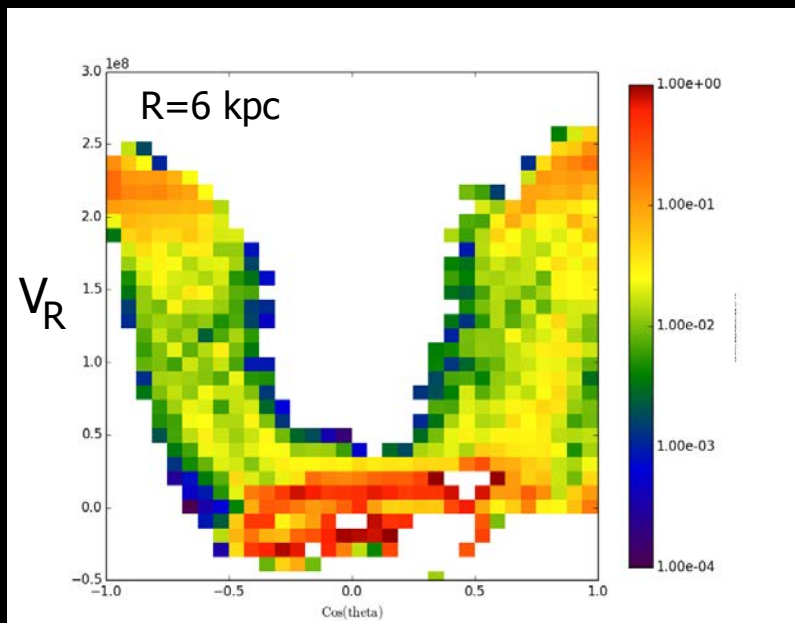
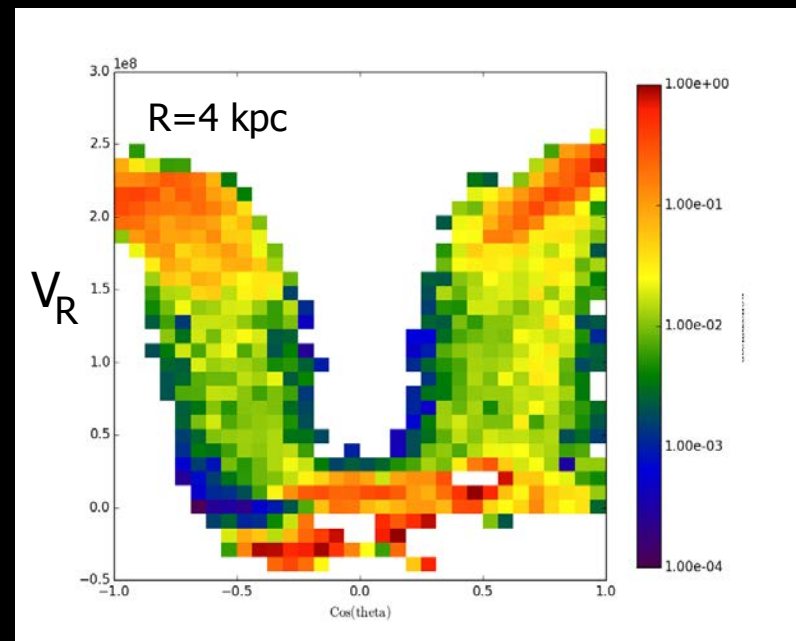
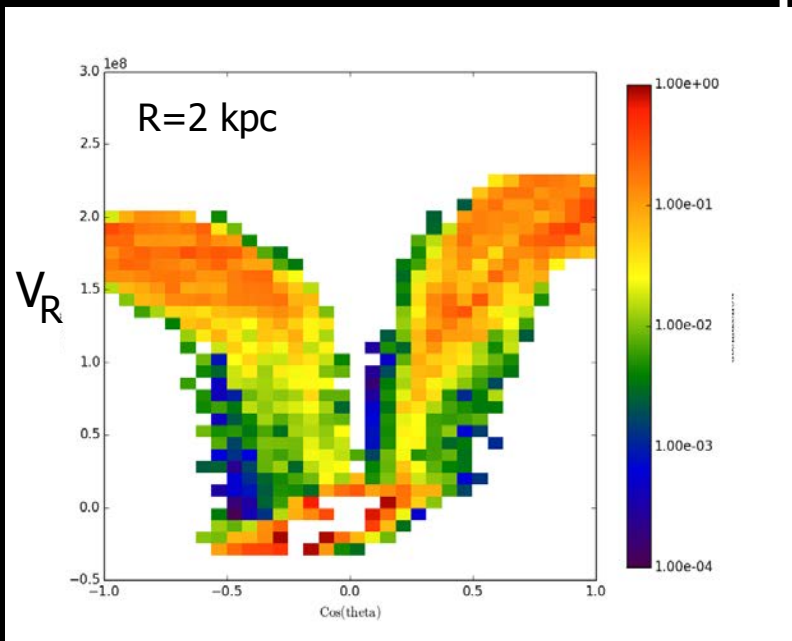
Inflows and Outflows – In- vs. Out-of-plane



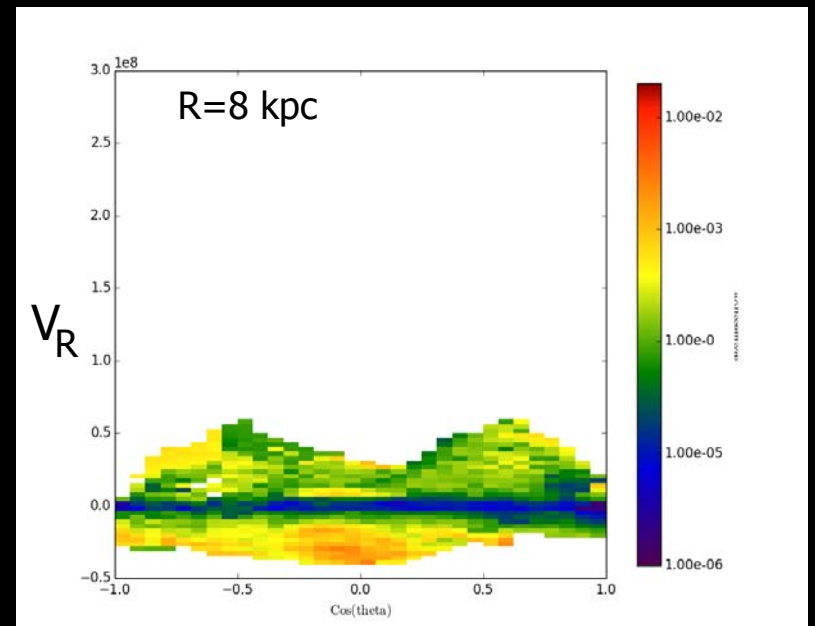
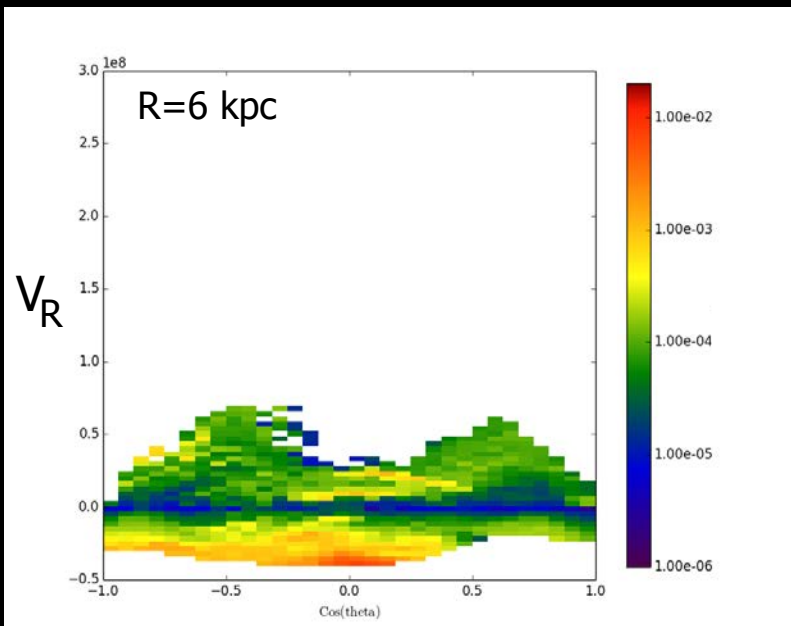
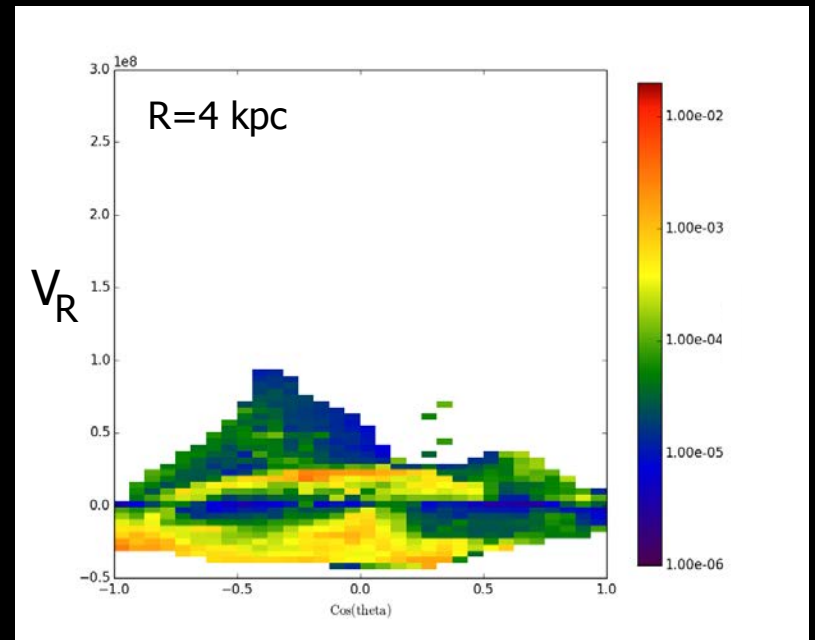
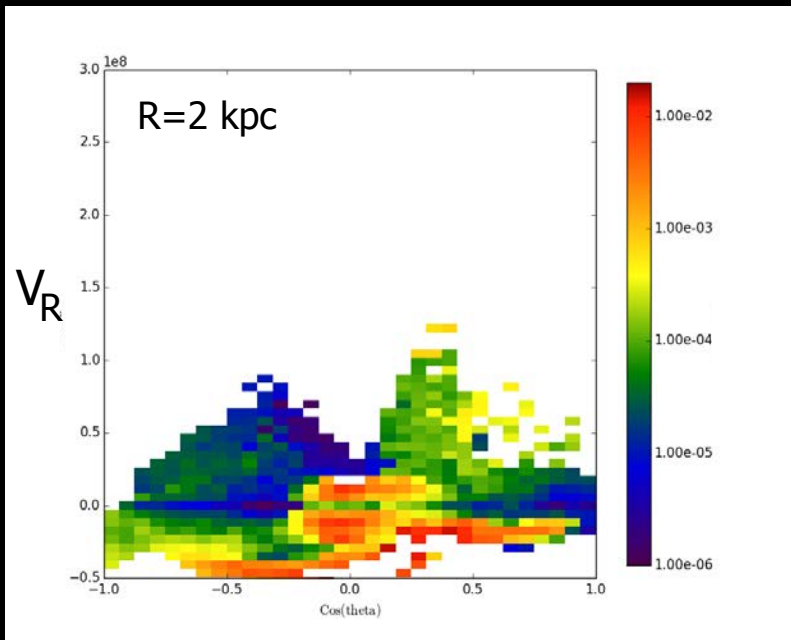
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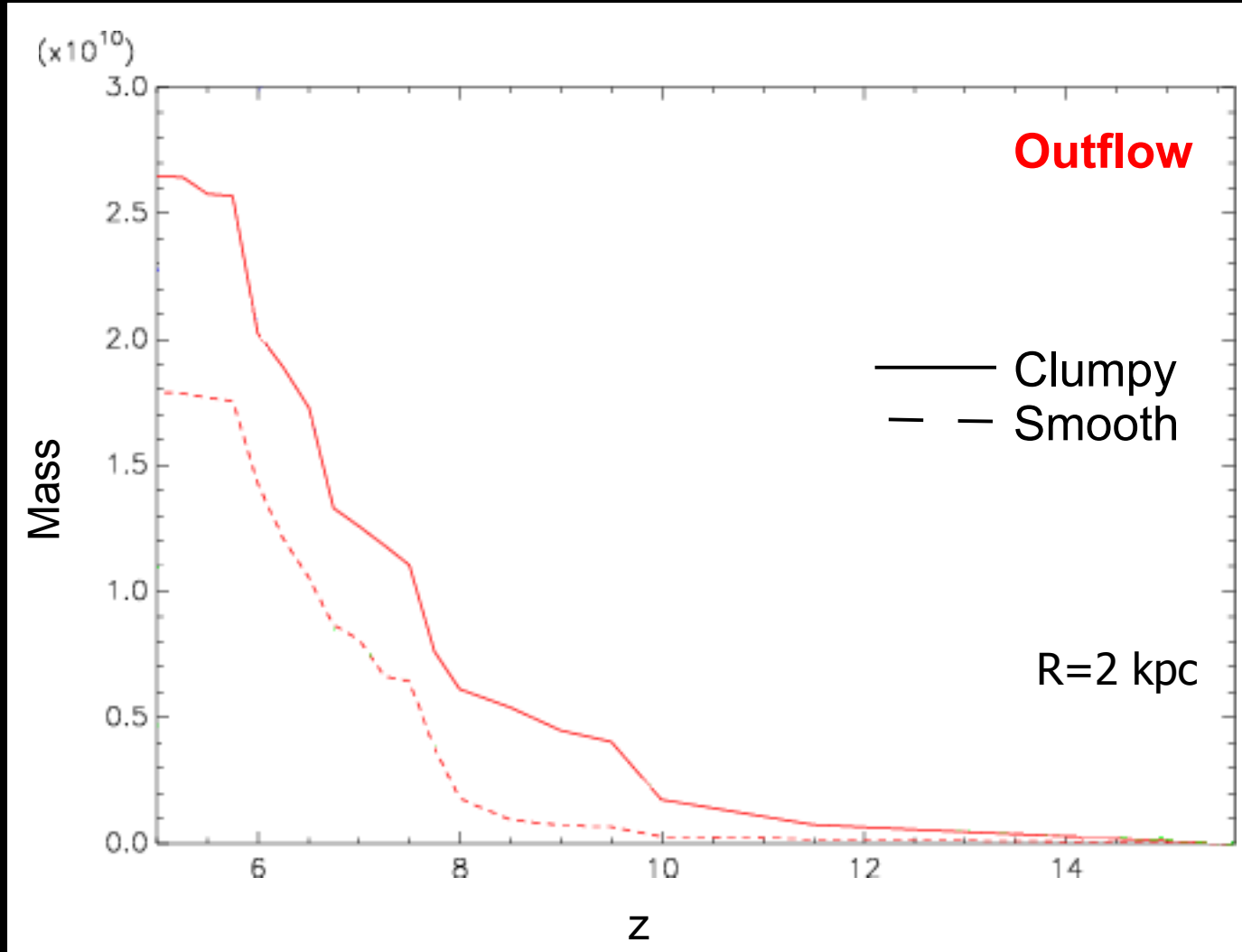
Clumpy Accretion



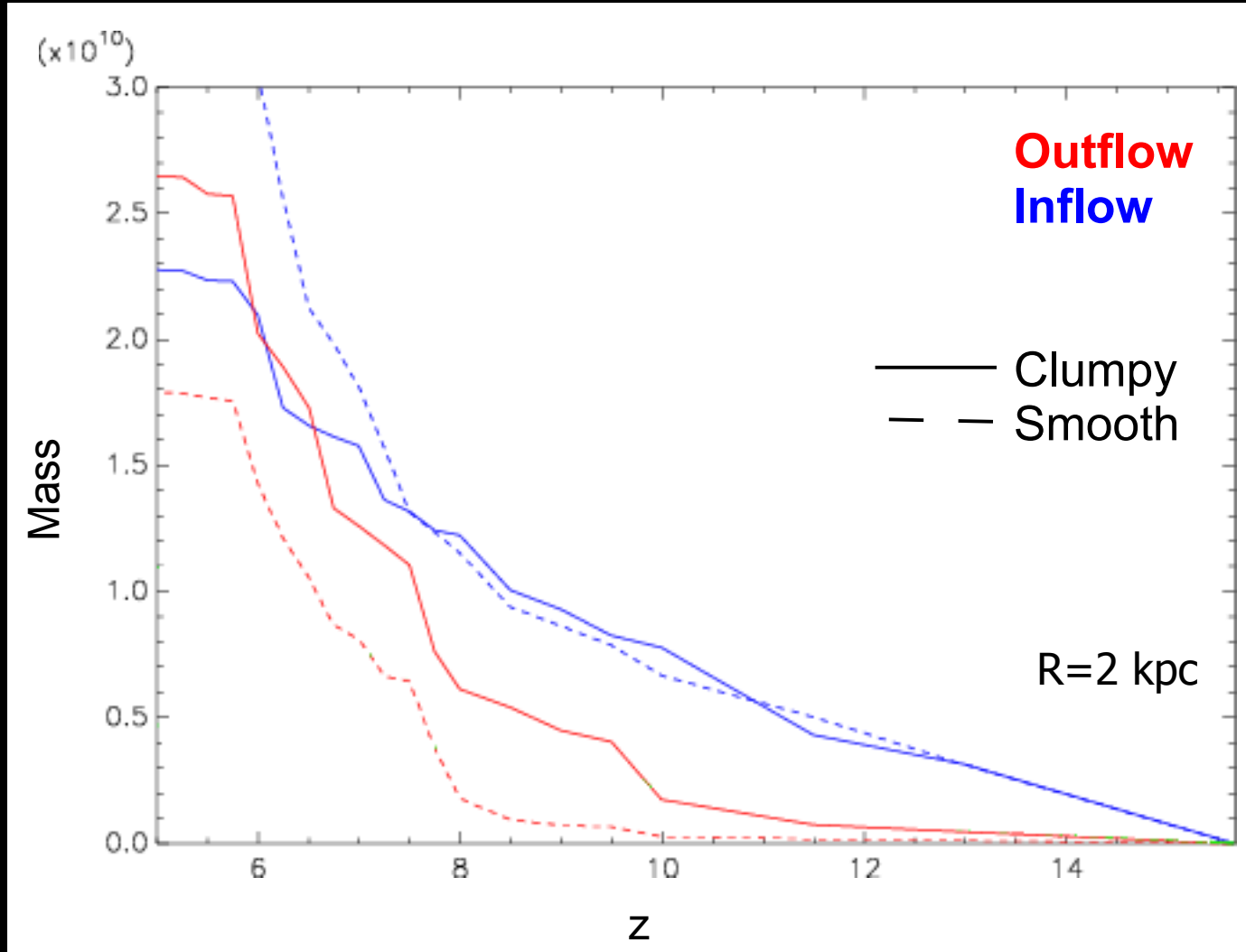
Standard Accretion



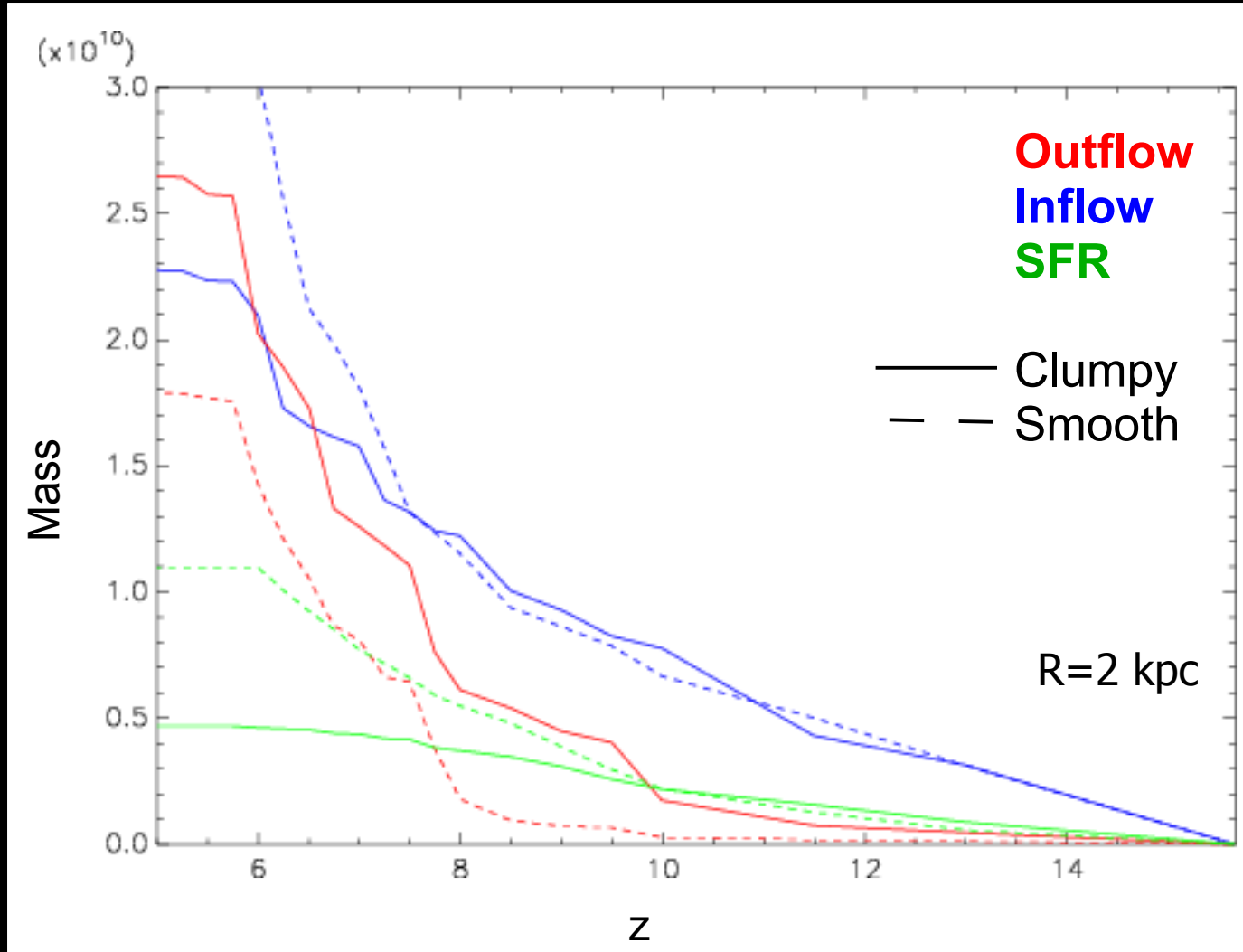
Cumulative Inflows & Outflows



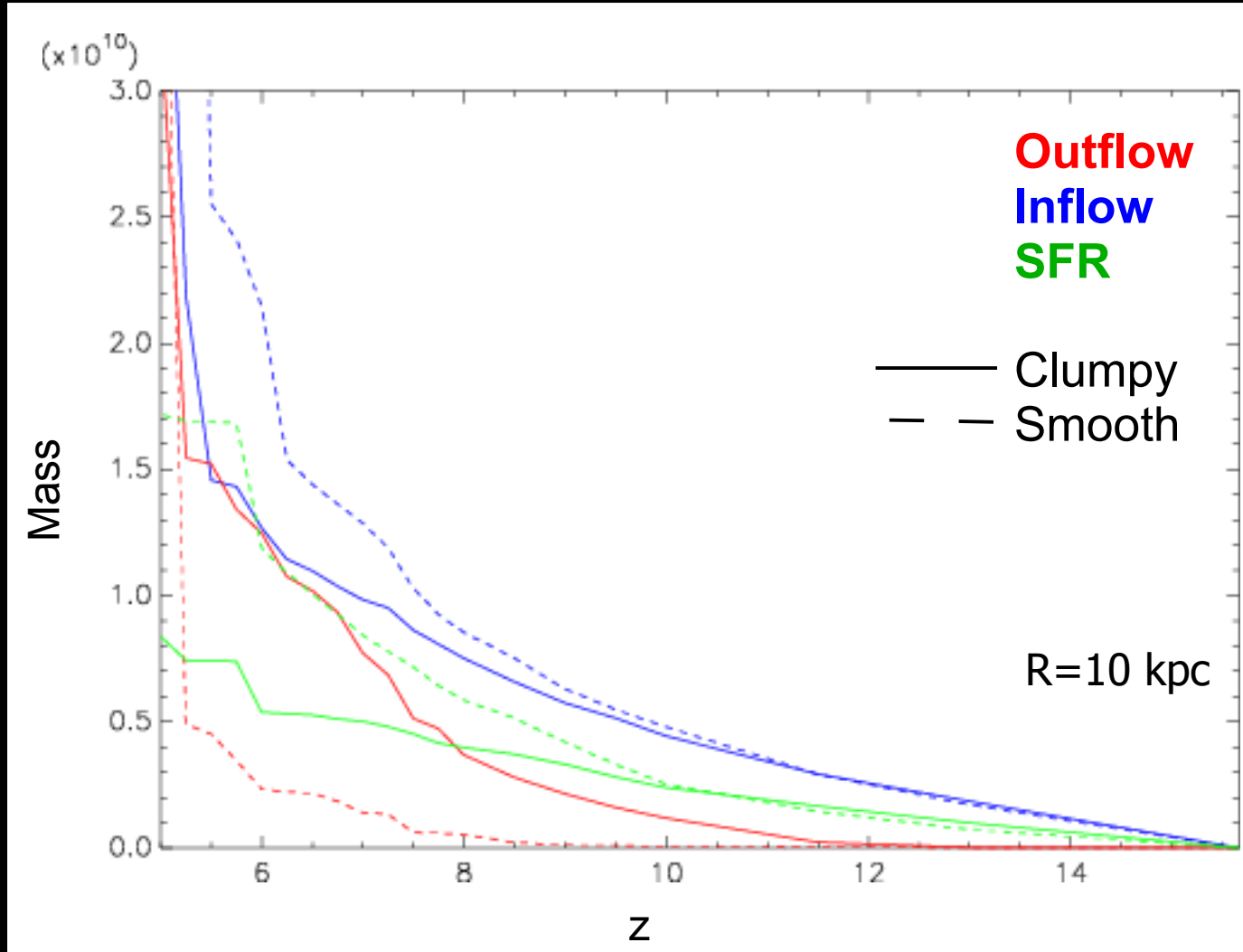
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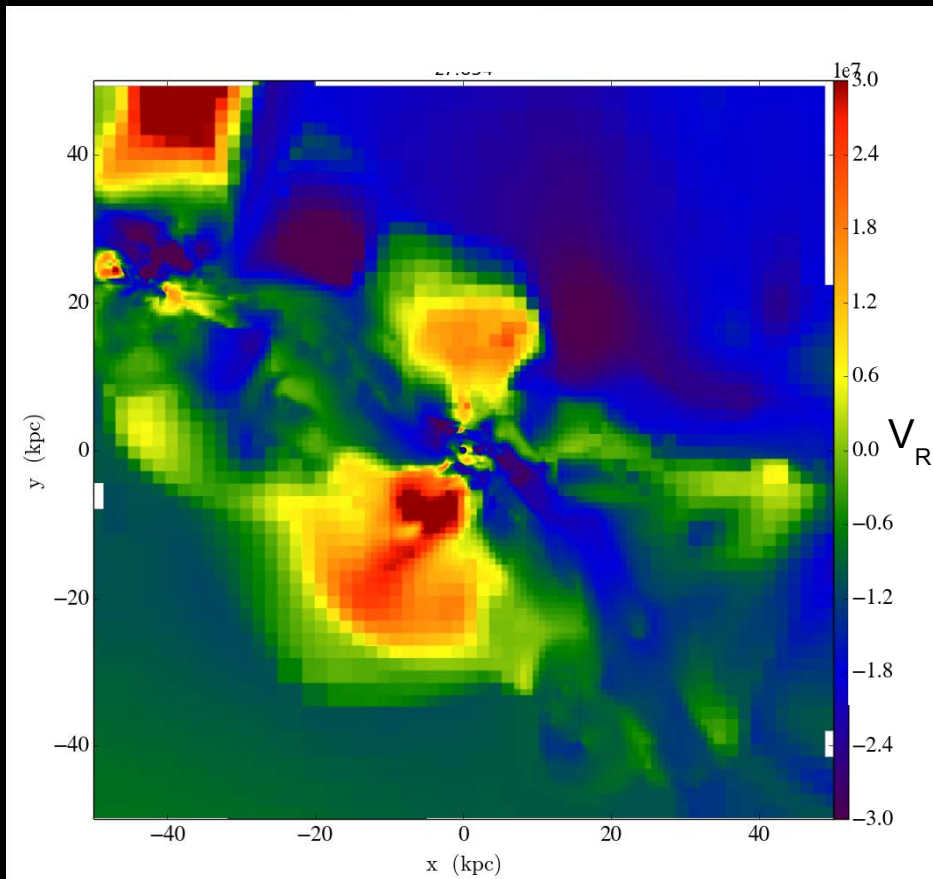
Cumulative Inflows & Outflows



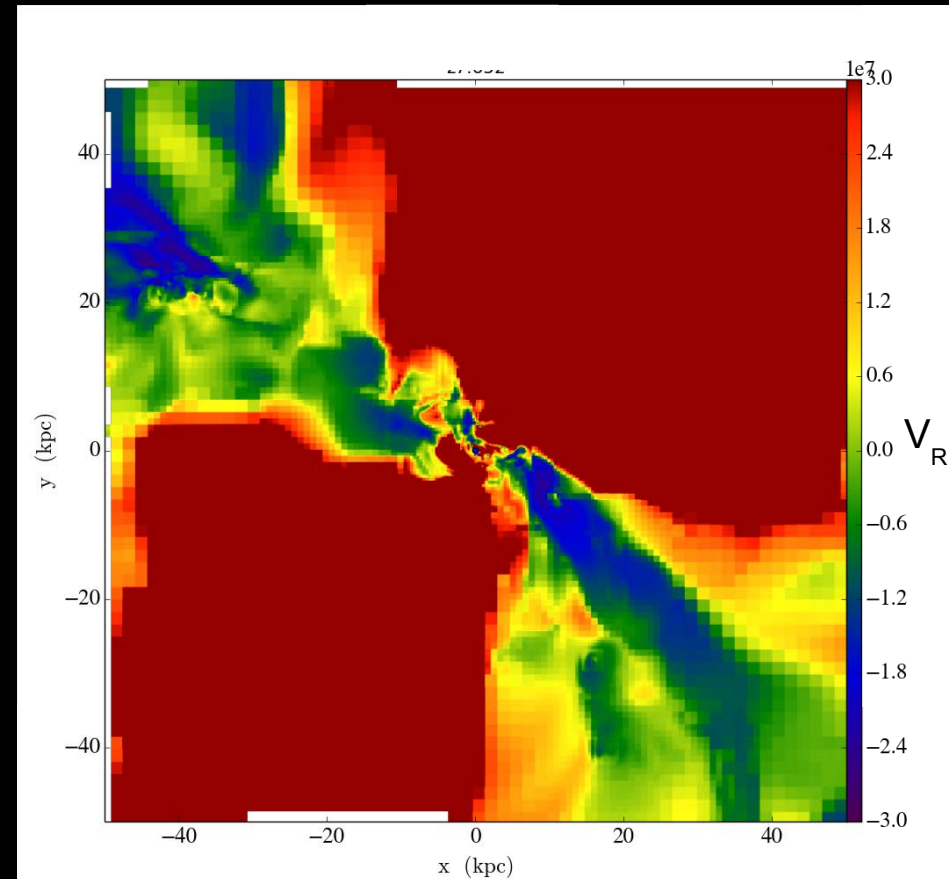
Cumulative Inflows & Outflows



Inflow/Outflow Interaction

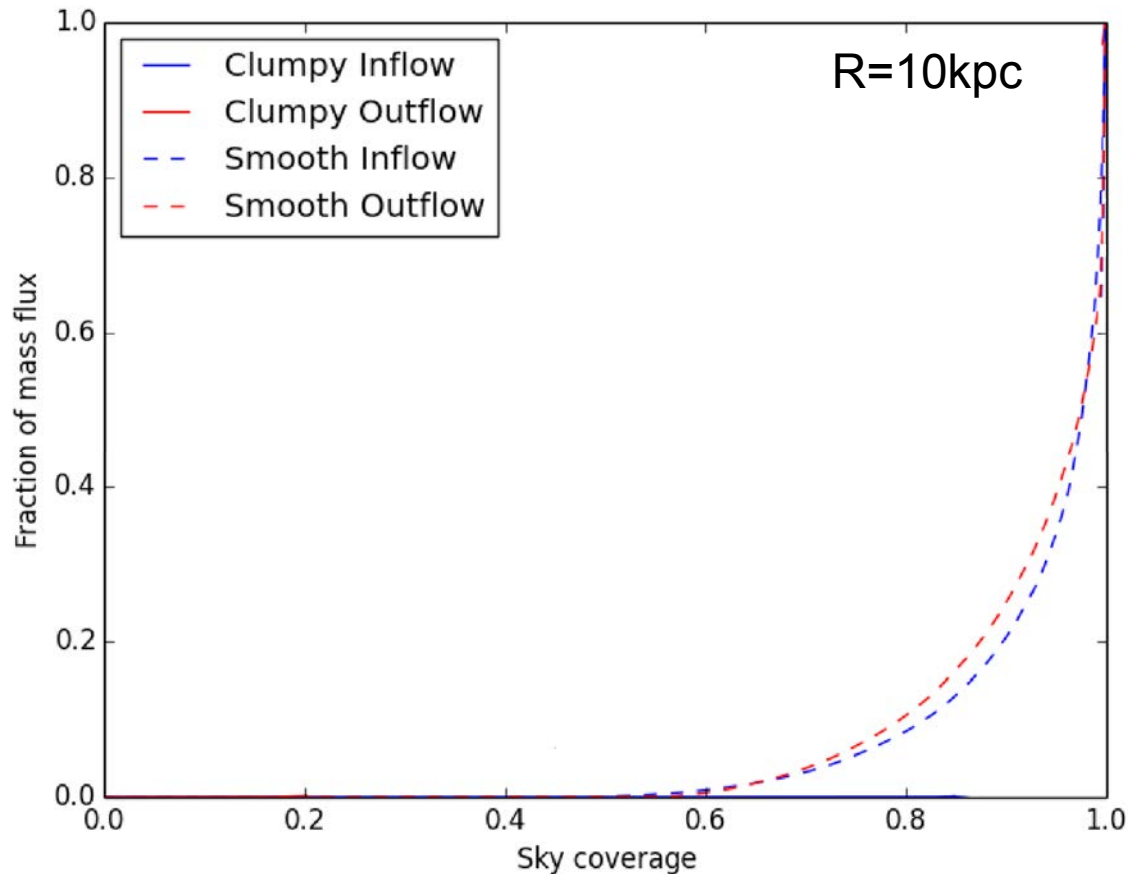


Standard Accretion



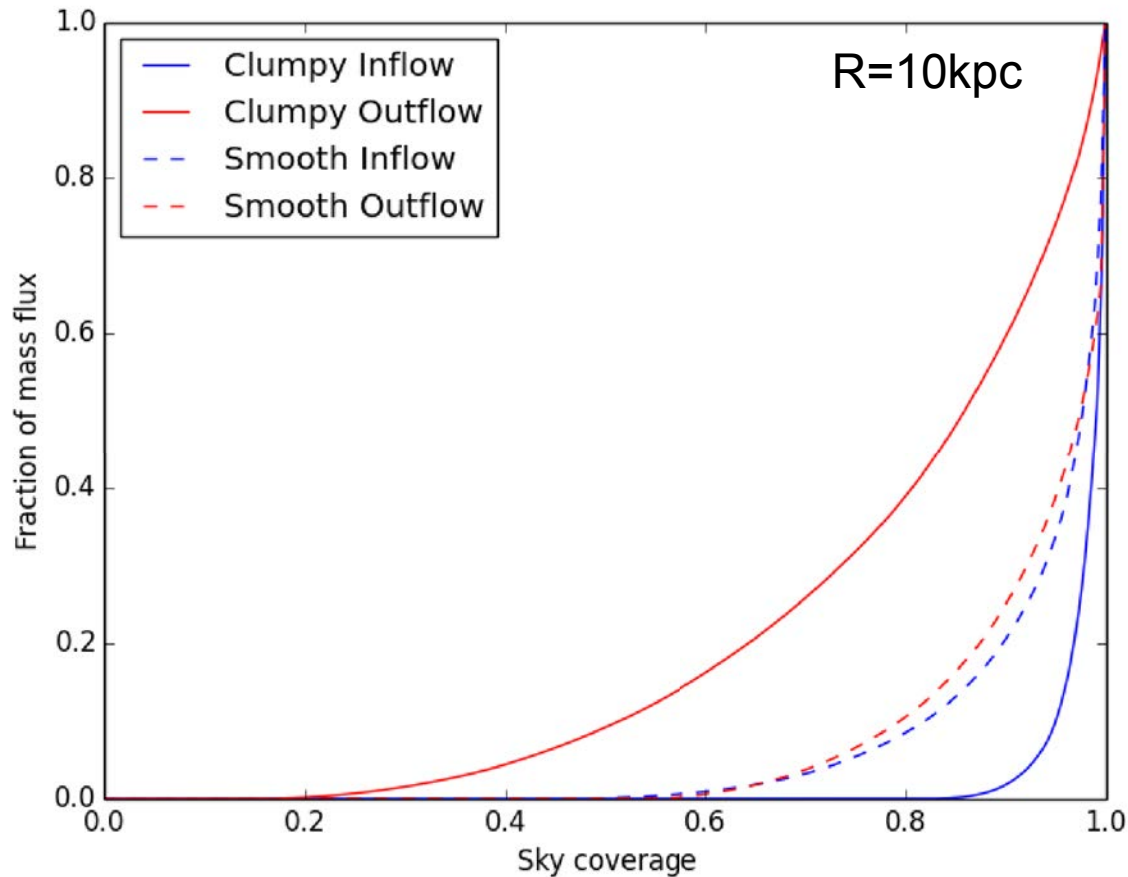
Clumpy Accretion

Inflow/Outflow Interaction



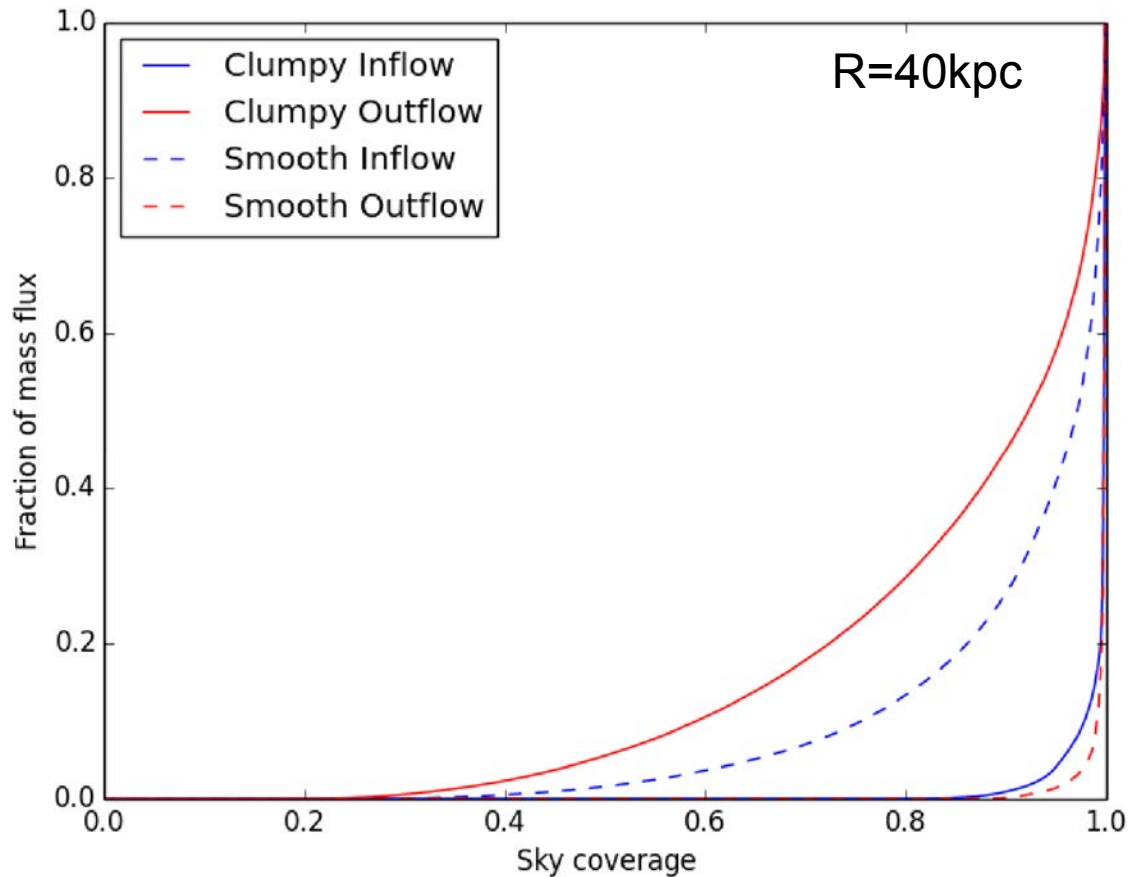
- Smooth accretion: Inflow and outflow show similar sky coverage
- Clumpy accretion: Outflow much more widespread → shrink inflow streams

Inflow/Outflow Interaction



- Smooth accretion: Inflow and outflow show similar sky coverage
- Clumpy accretion: Outflow much more widespread → shrink inflow streams

Inflow/Outflow Interaction



- At large scale impact of strong feedback is seen more clearly: more widespread outflow and smaller inflows

Conclusions

- Incorporation of clumpy accretion has significant impact of black hole growth
 - Grows faster during early periods
- Morphologically affects the host galaxy
 - Evacuation of central region
- Strong outflows of high-temperature, low density gas driven out of galaxy
 - Outflows up to 10x stronger than in absence of clumpy accretion
 - Only at later times, when black hole has reached (or passed) Eddington growth phase
 - Despite isotropic feedback, AGN-driven outflows primarily out-of-plane
- Inflows also suppressed by outflowing gas/hotter gas halo
 - Only dense inflow streams survive
 - Outer parts of streams are stripped away
- SFR reduced in clumpy accretion model