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

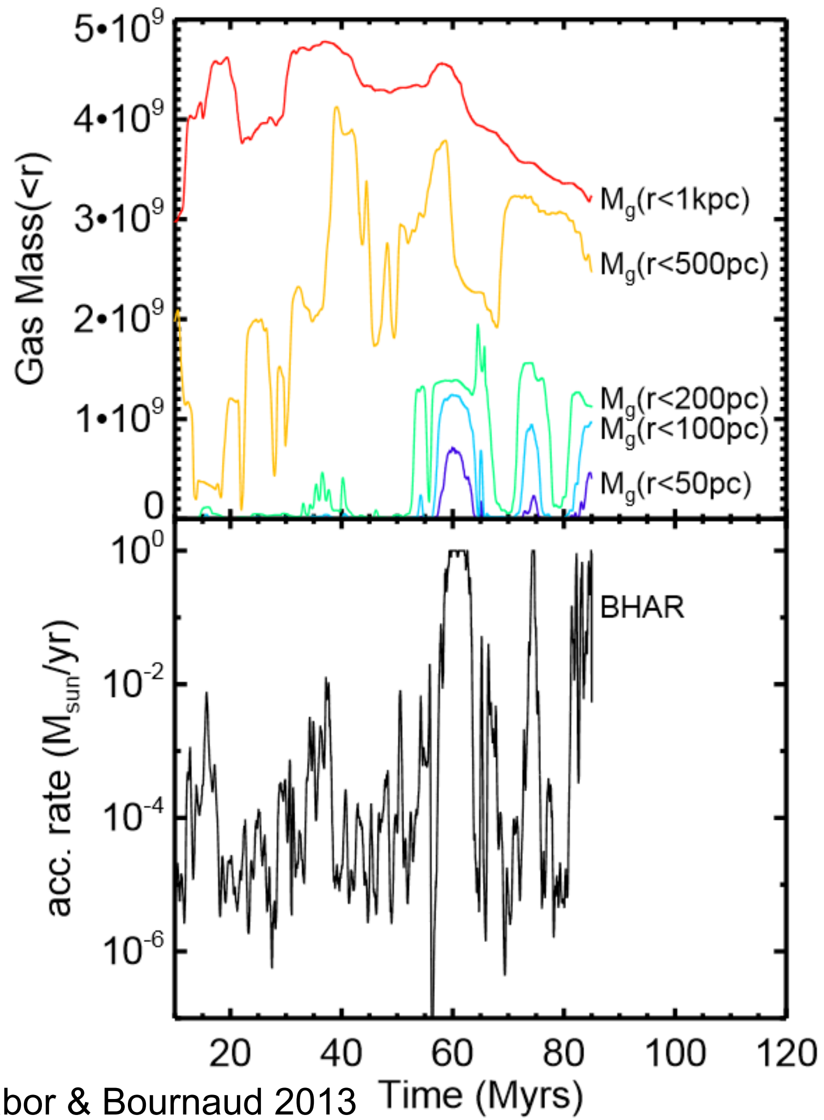
Colin DeGraf
Hebrew University of Jerusalem

Durham AGN Conference
July 31, 2014

Outline

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

Motivation

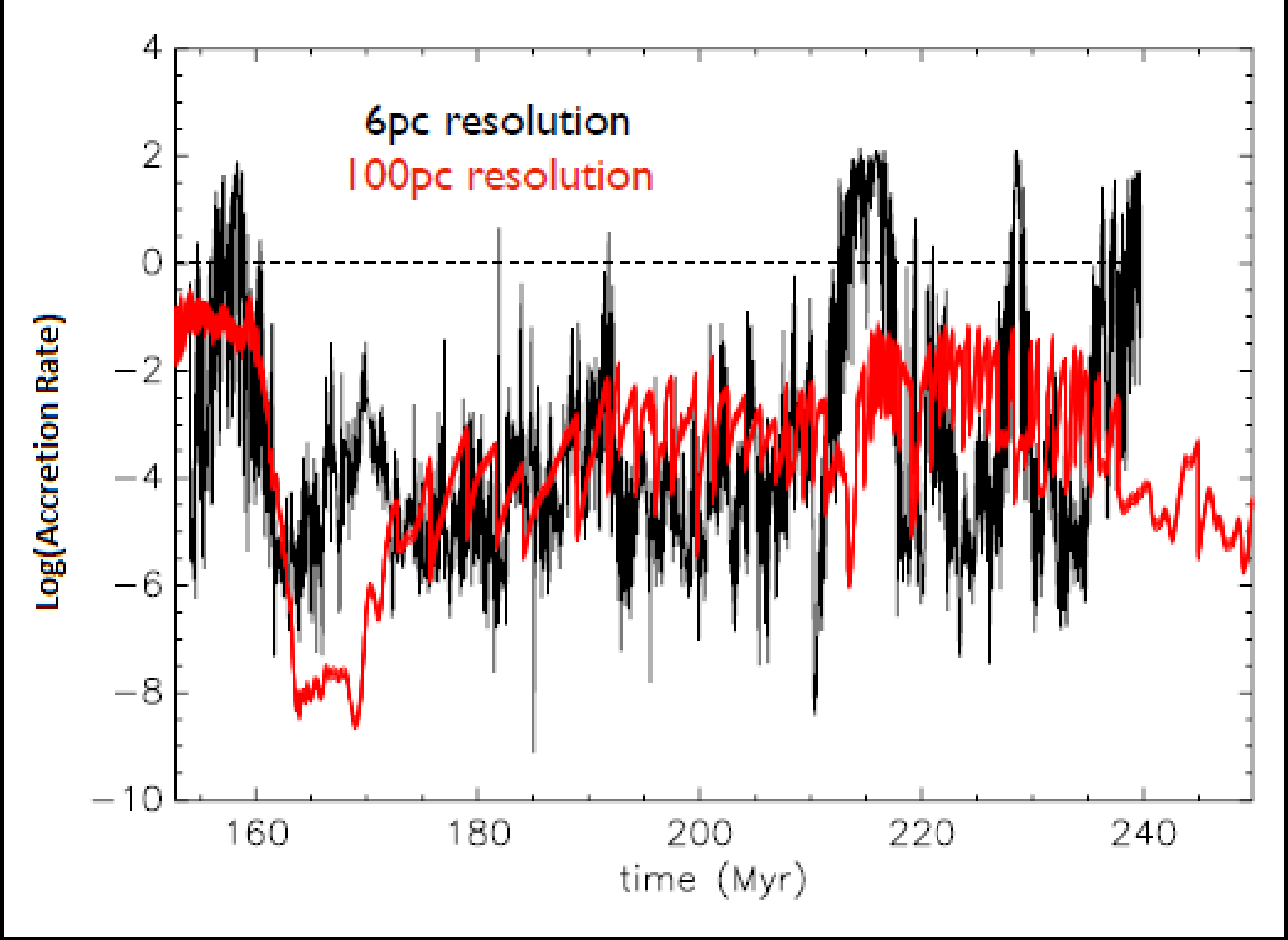


Gabor & Bournaud 2013

- High resolution isolated galaxy run finds periodic bursts of accretion caused by high-density clumps
- What happens with lower-resolution runs?

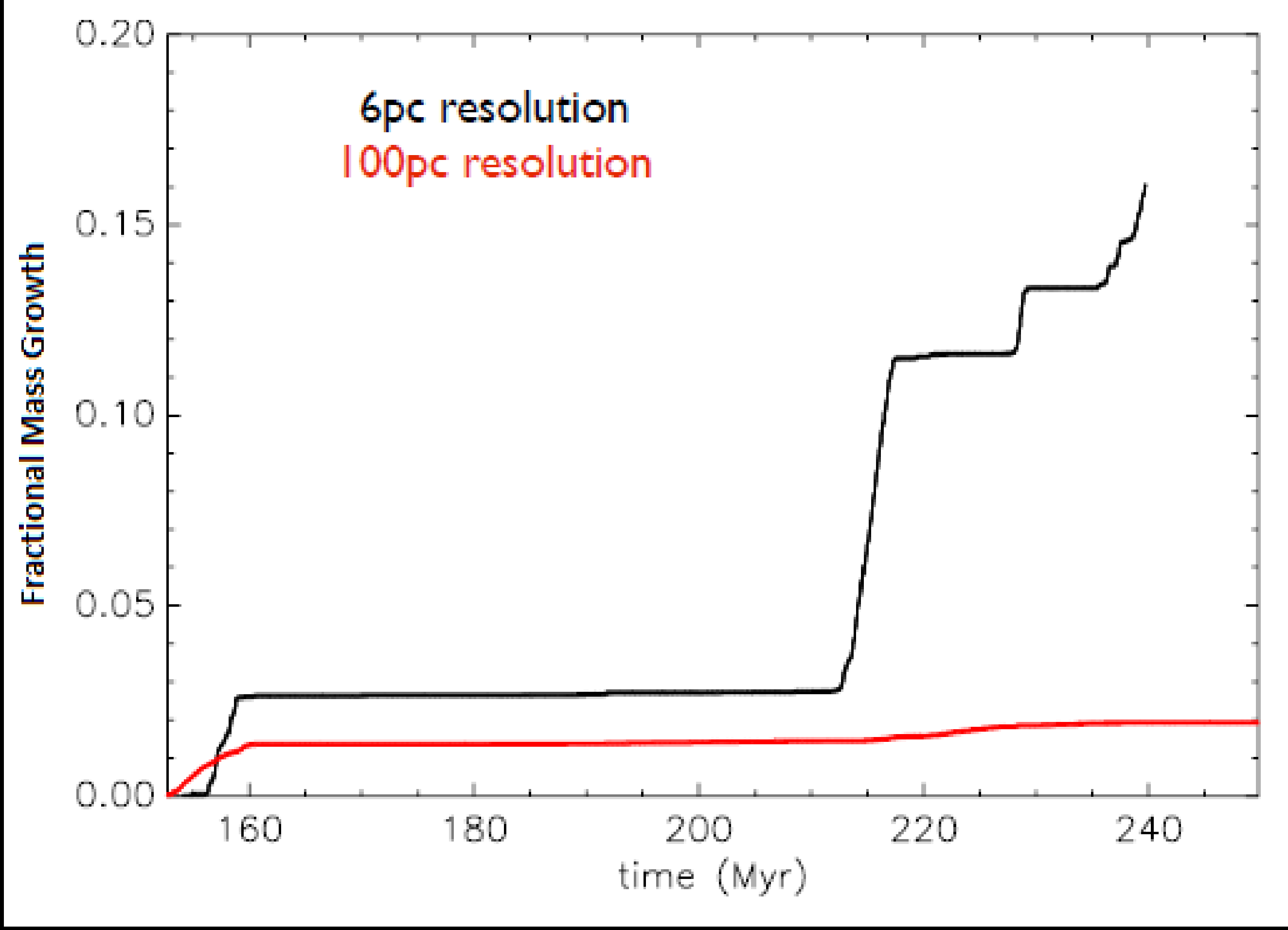
Motivation

- 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



Basic Model using AMR code RAMSES

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

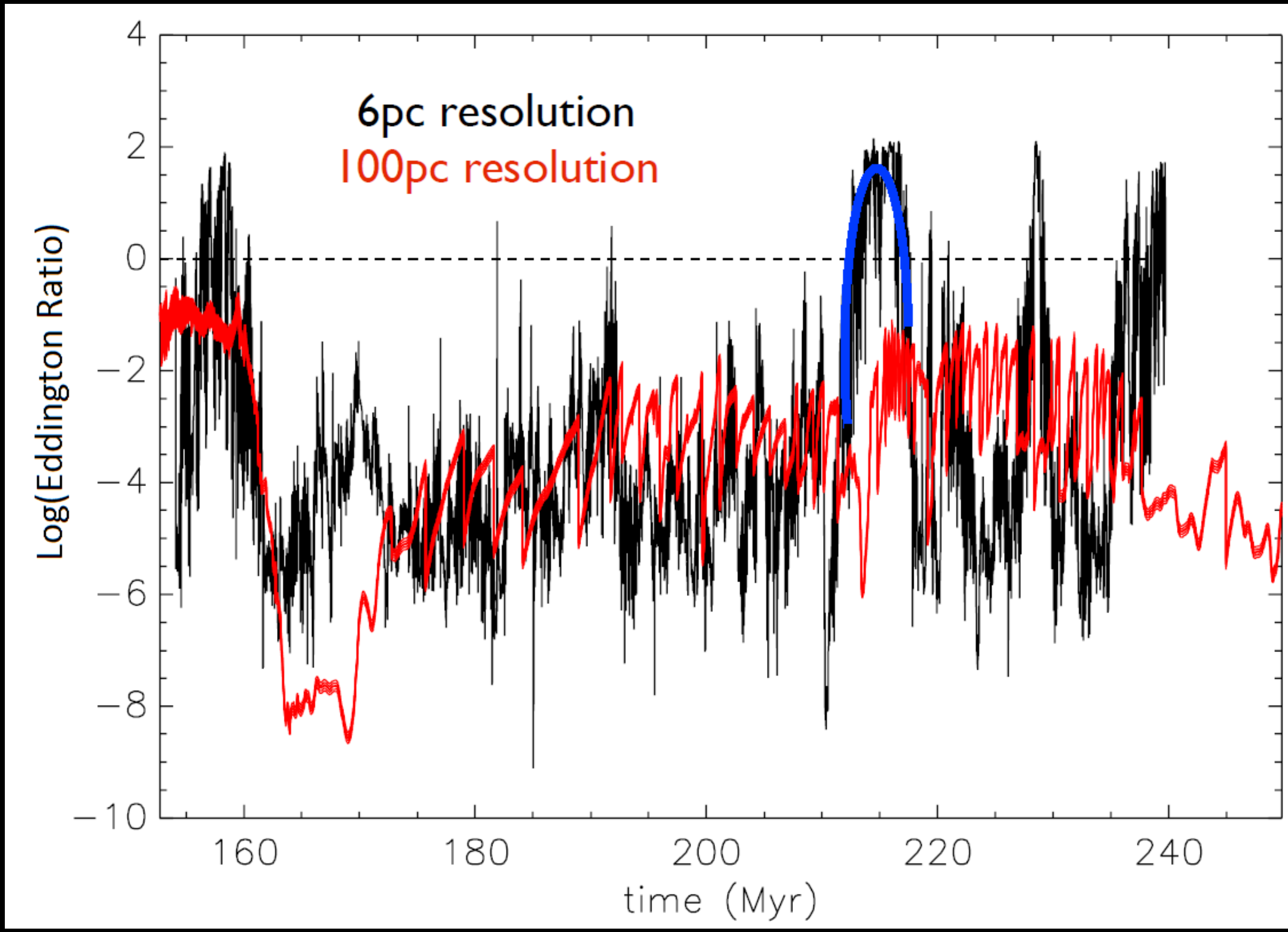
- BH feedback via thermal coupling:

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

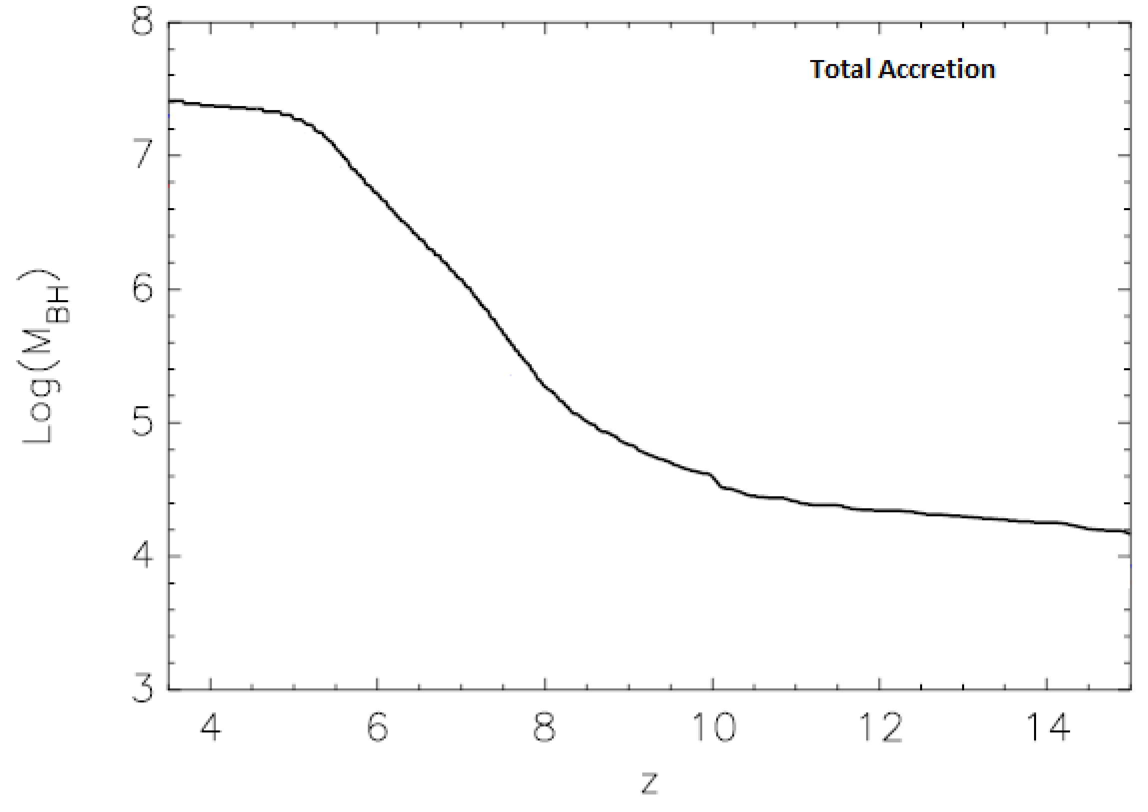
  F=5%, η=10%

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

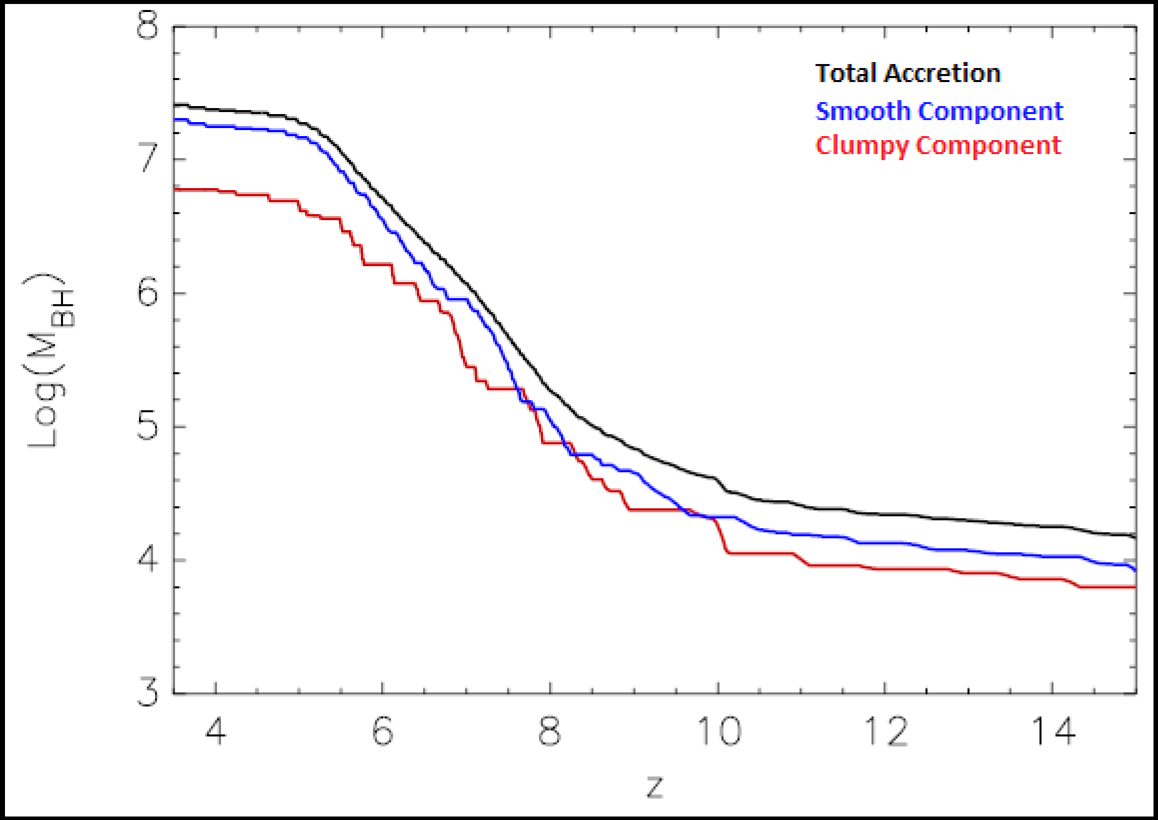


Black Hole Growth

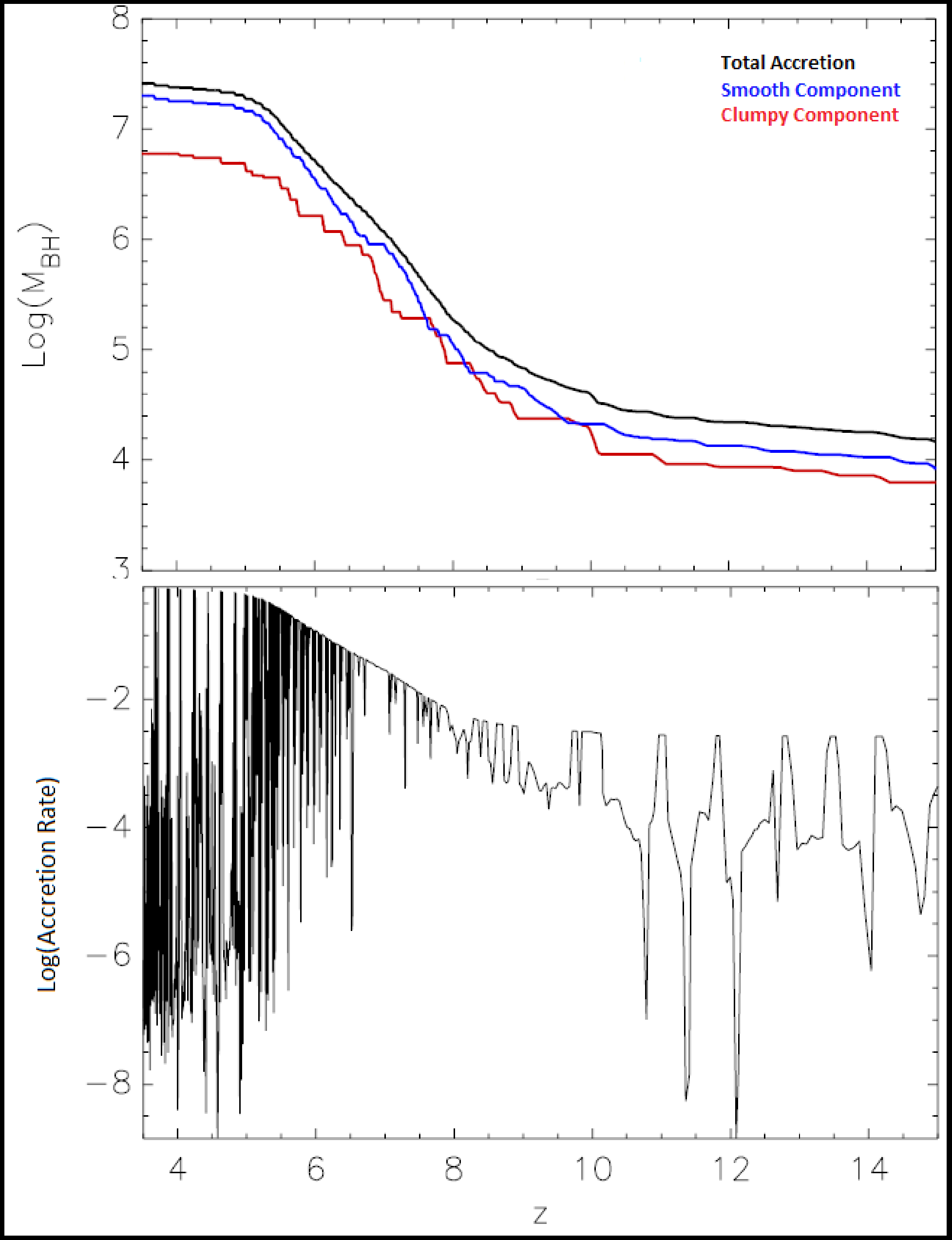


- Typical growth behavior
- Consists of 3 general phases
  1. Initial sub-Eddington growth
  2. Extended Eddington period
  3. Regulated phase

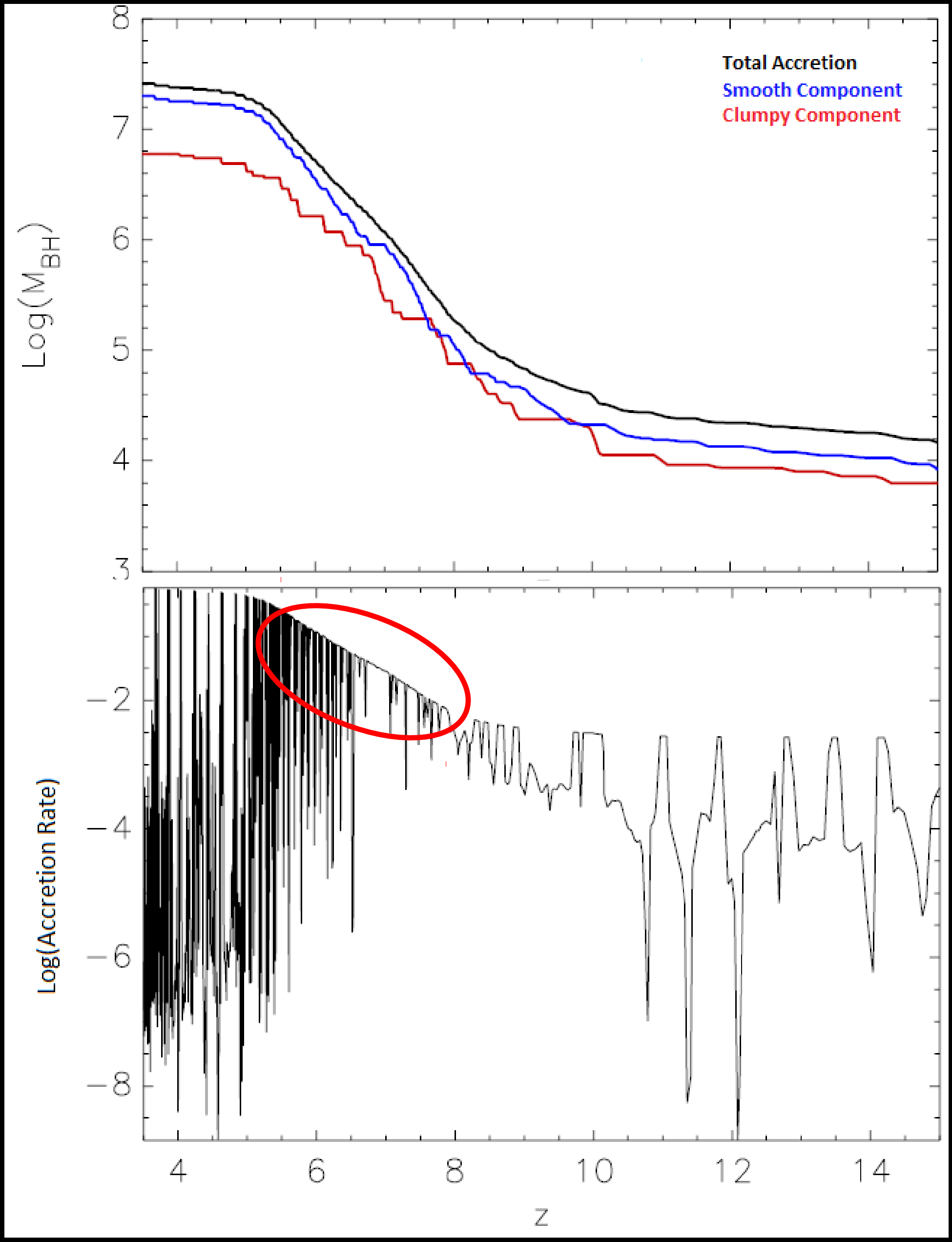
Black Hole Growth



Black Hole Growth

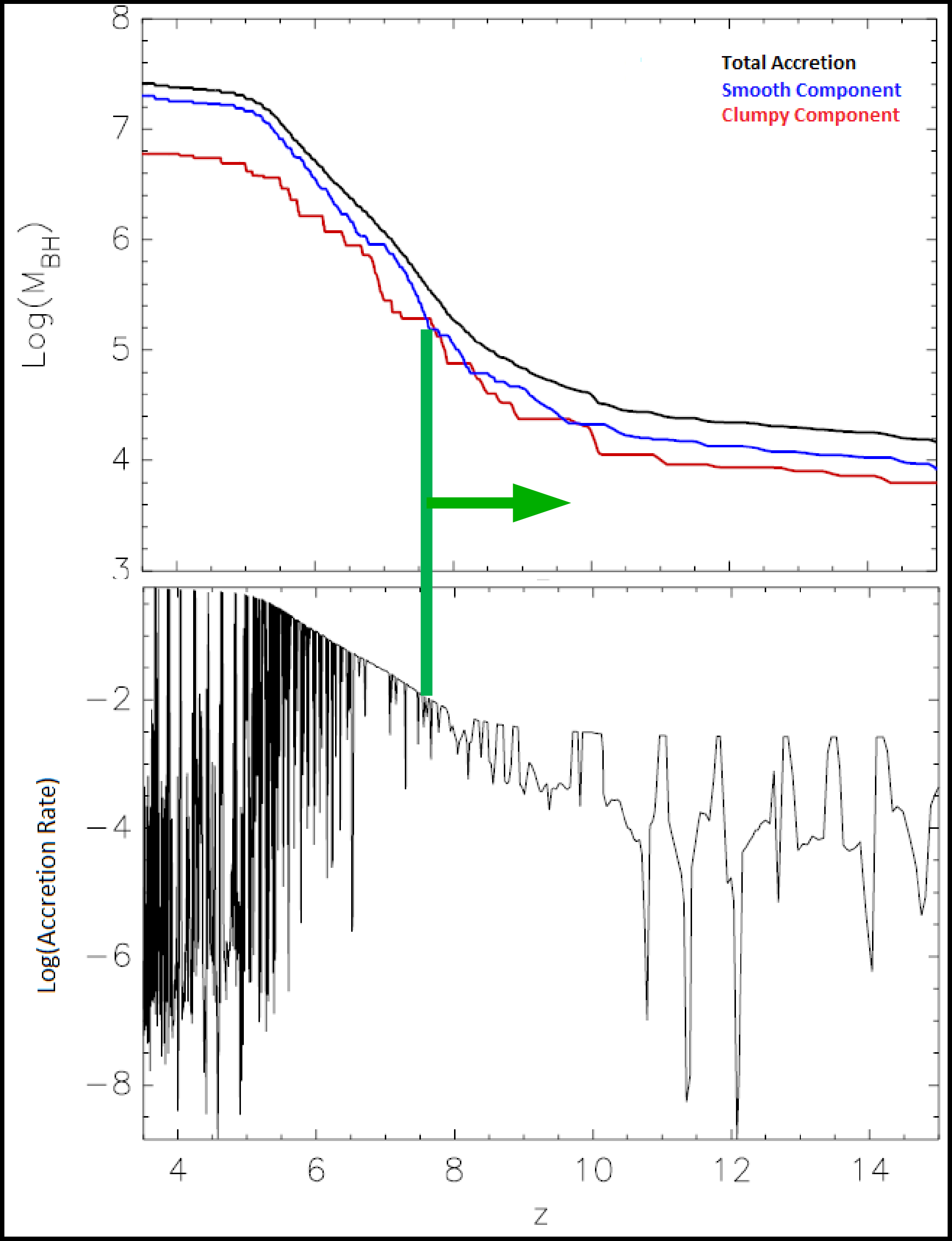


Black Hole Growth



Clumps have no effect on accretion during Eddington phase

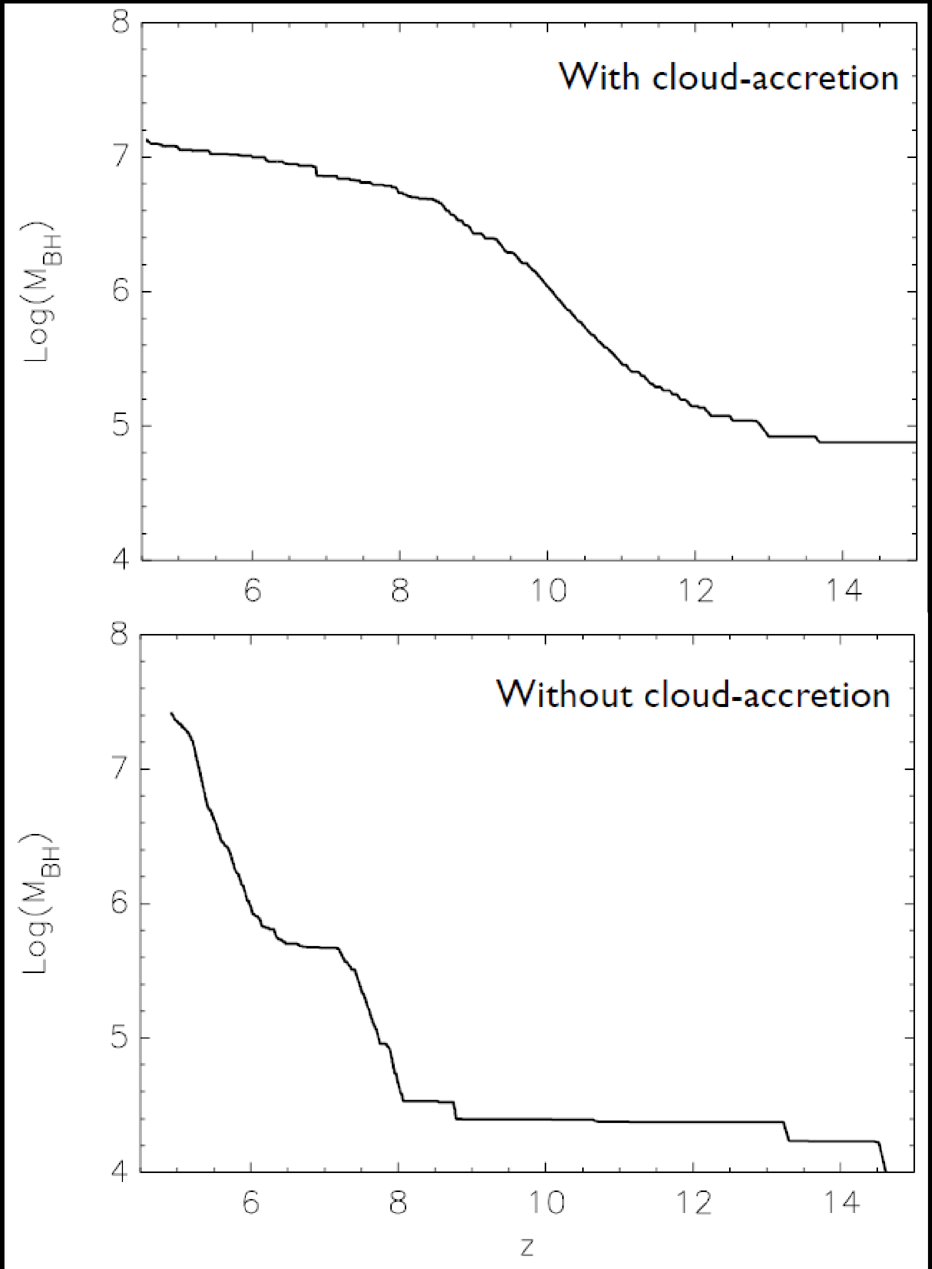
Black Hole Growth



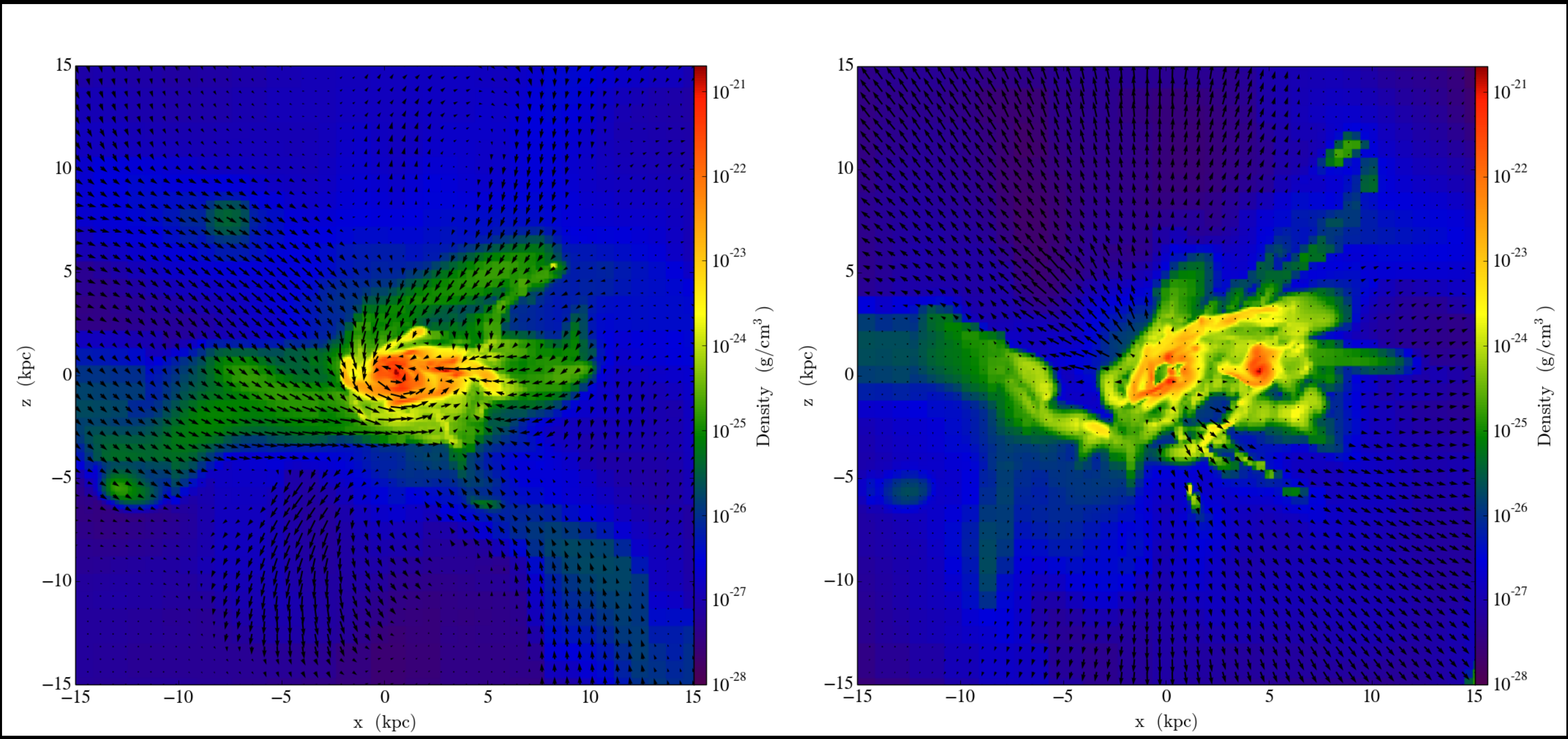
Pre-Eddington: Clump accretion is important

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



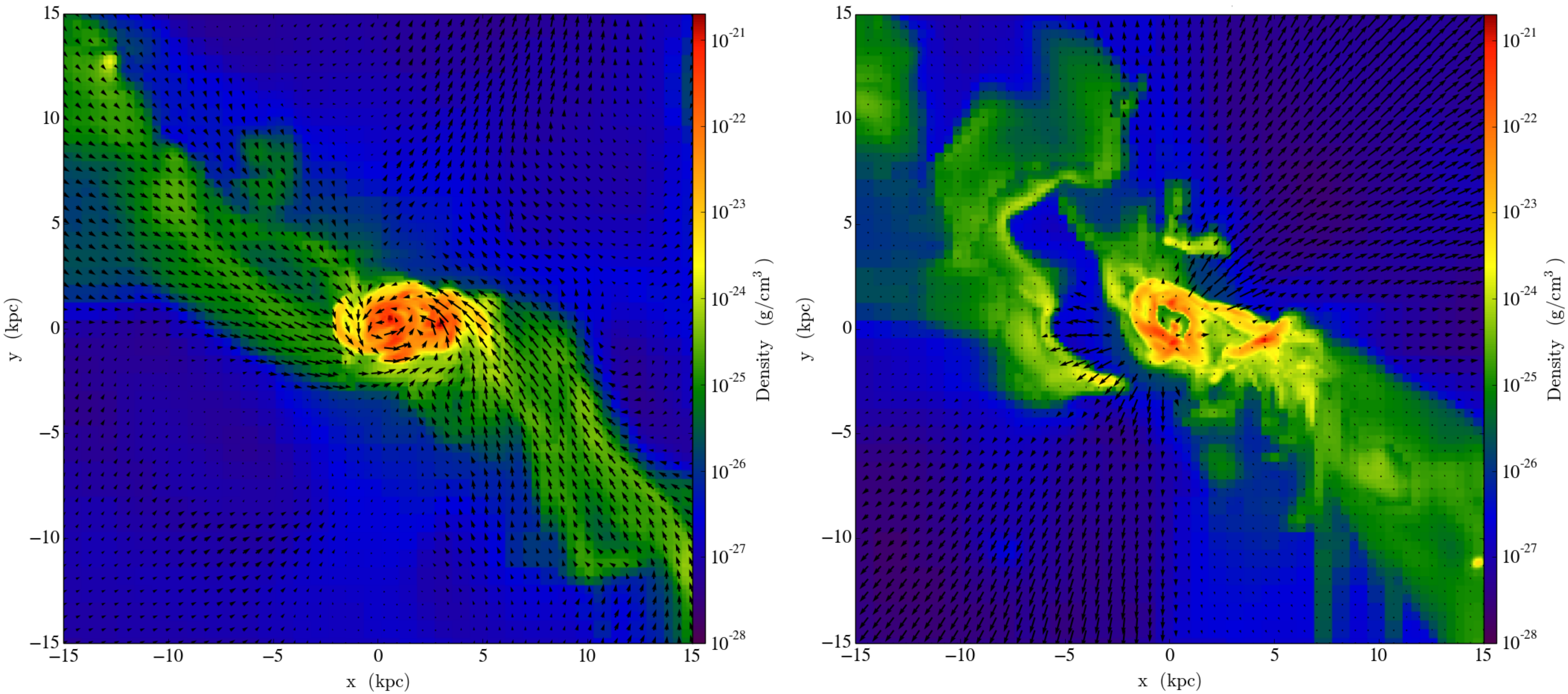
Morphological Impact



Standard Accretion

Clumpy Accretion

Morphological Impact



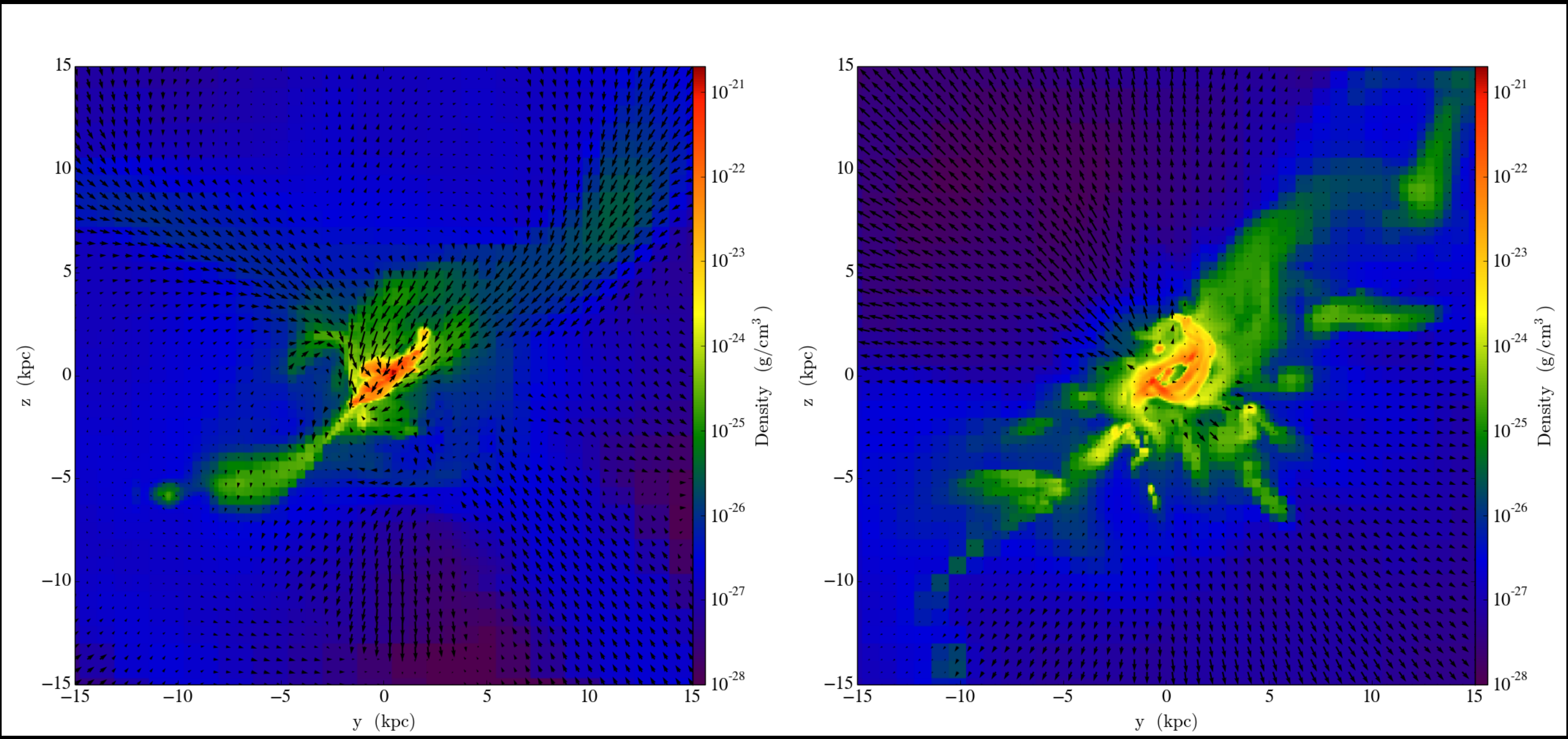
Standard Accretion

Clumpy Accretion

Central region evacuated

Inflowing streams disrupted

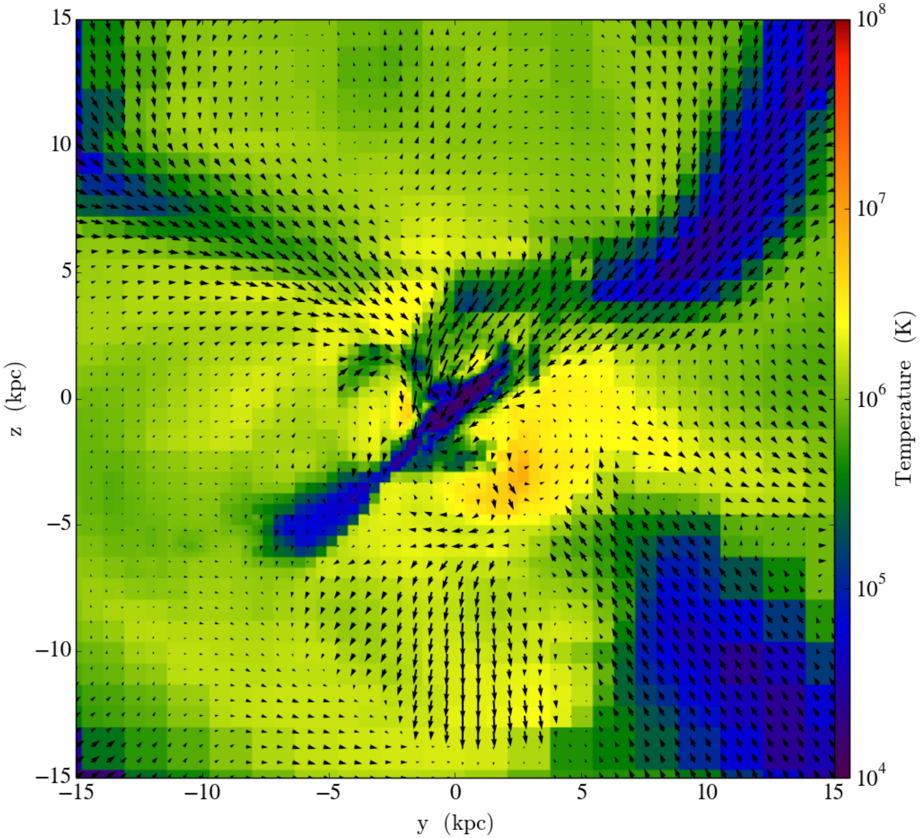
Morphological Impact

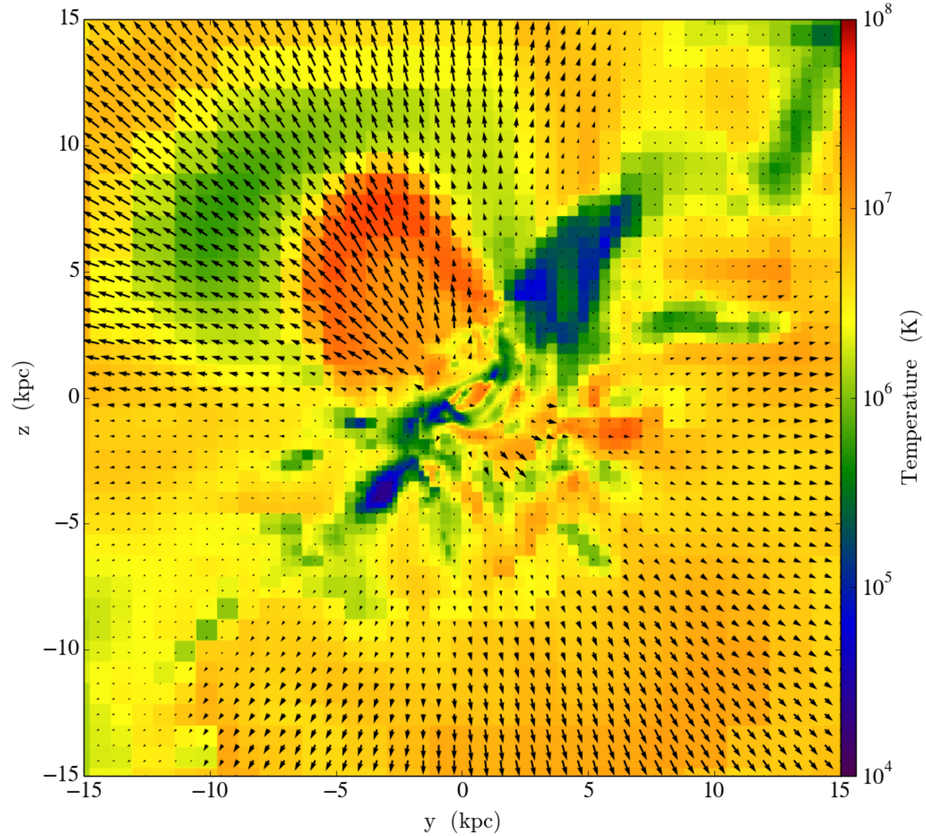


Standard Accretion

Clumpy Accretion

Morphological Impact





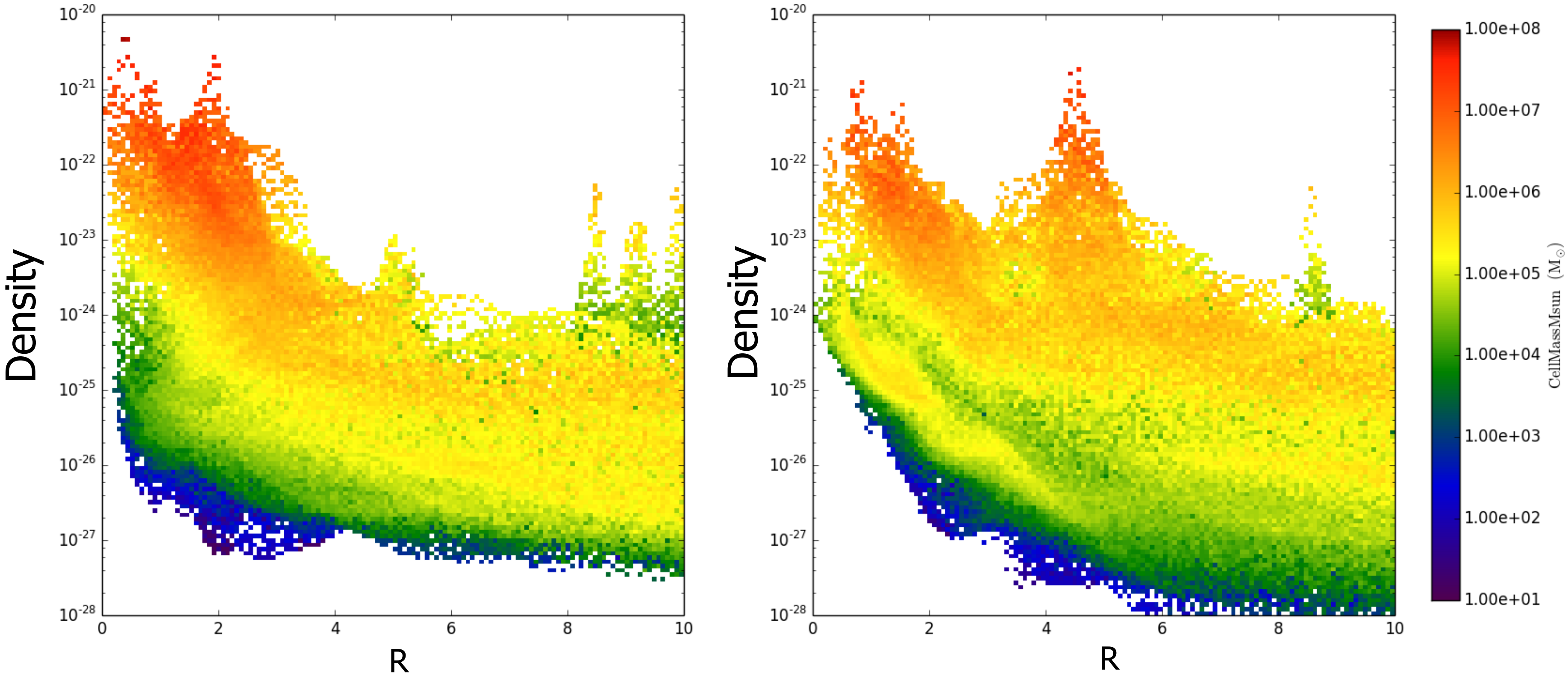
Standard Accretion

Minimal heating

Clumpy Accretion

Substantial heating inflating asym. bubbles

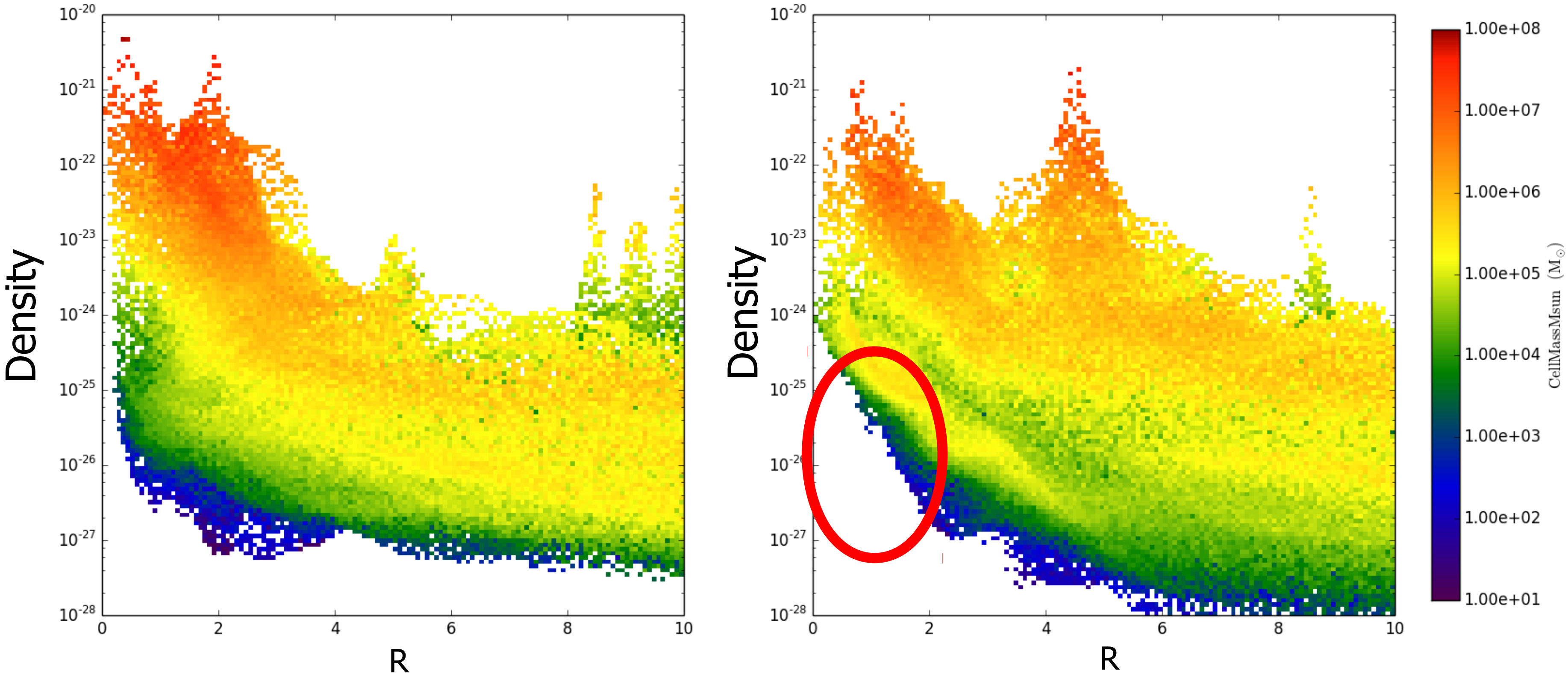
Gas Properties



Standard Accretion

Clumpy Accretion

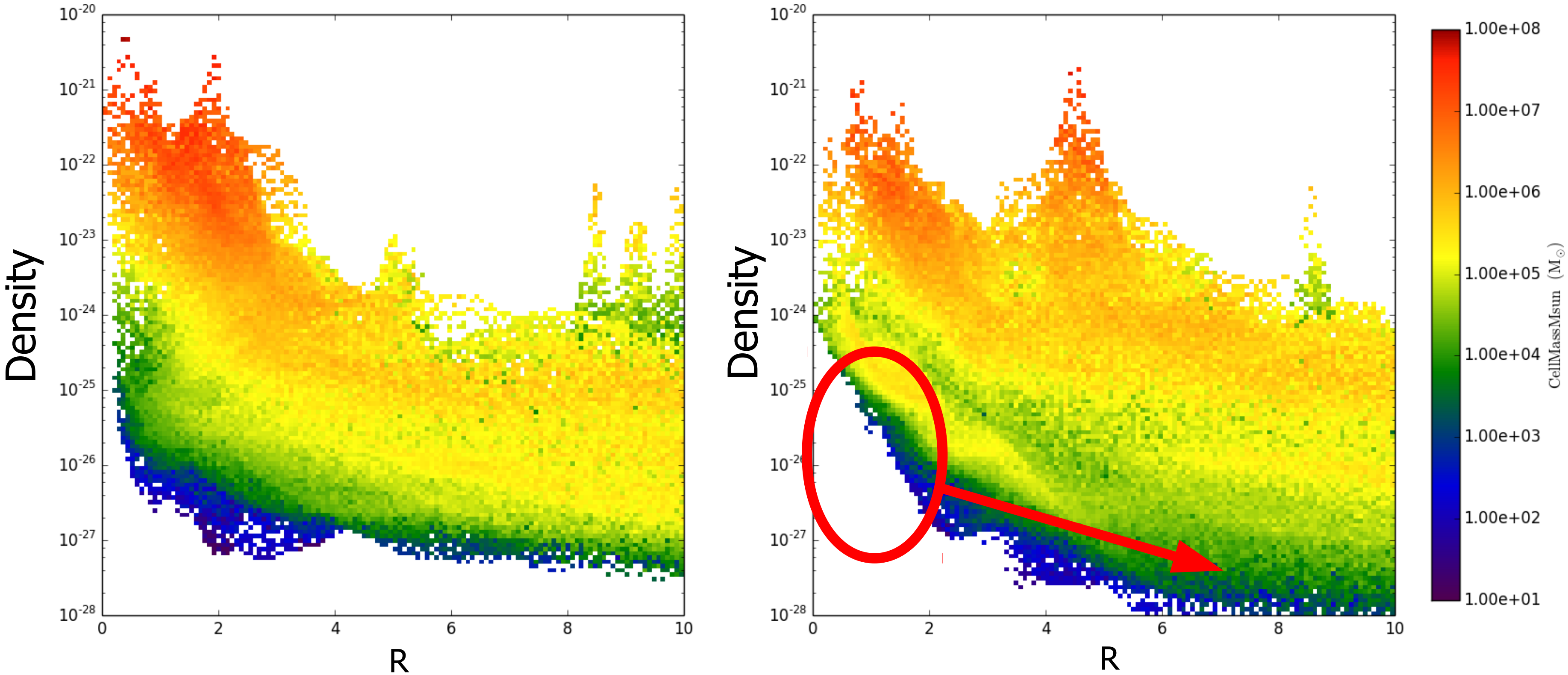
Gas Properties



Standard Accretion

Clumpy Accretion

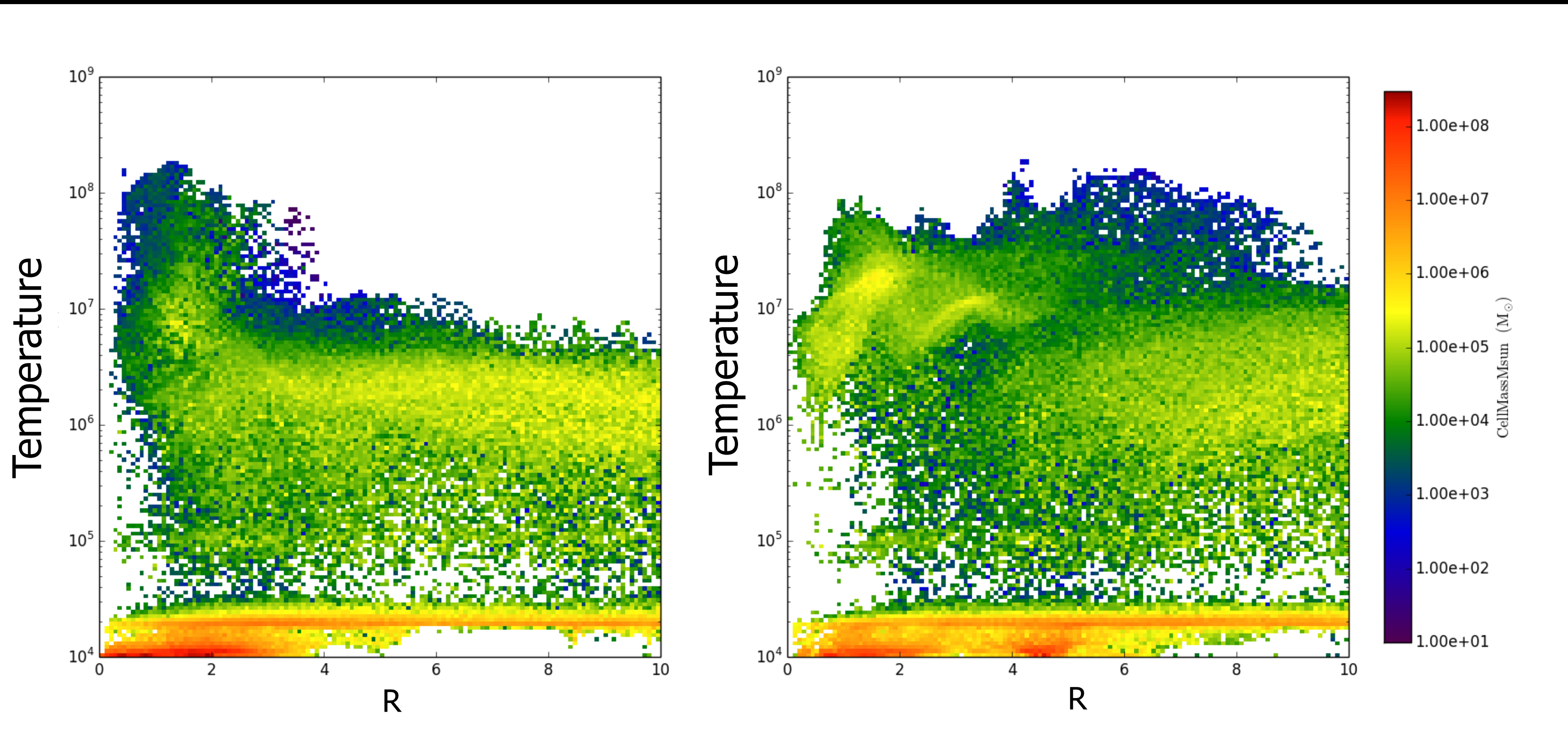
Gas Properties



Standard Accretion

Clumpy Accretion

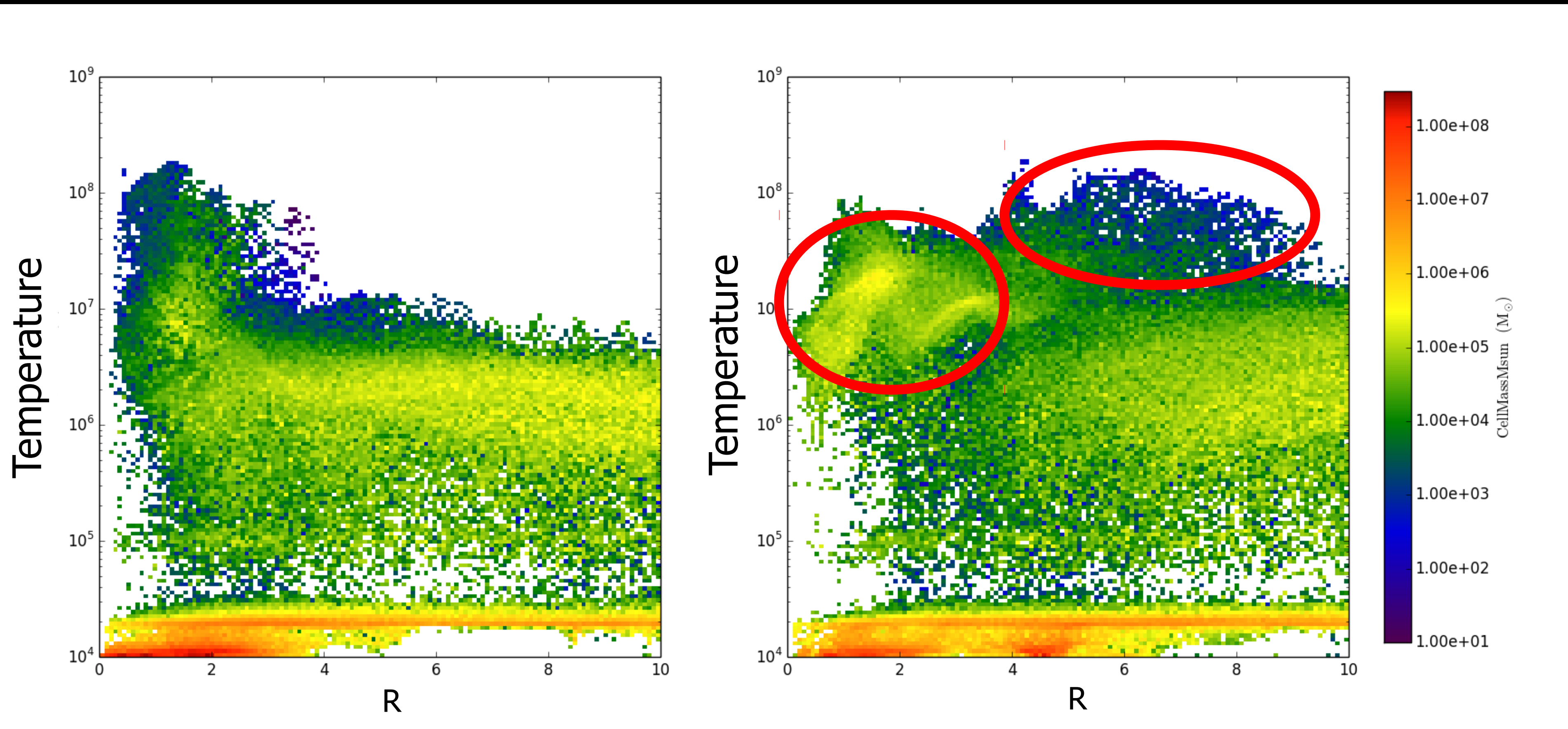
Gas Properties



Standard Accretion

Clumpy Accretion

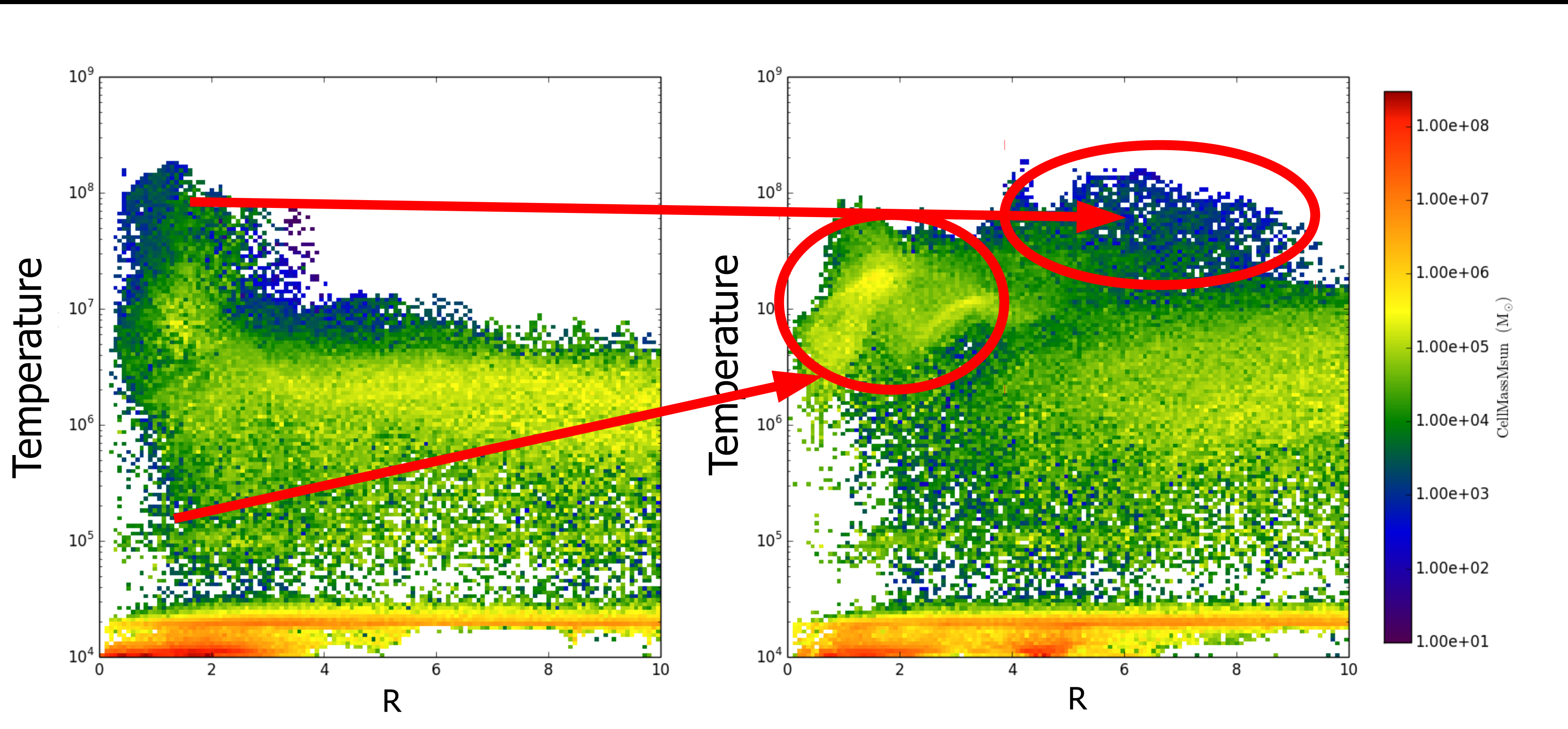
Gas Properties



Standard Accretion

Clumpy Accretion

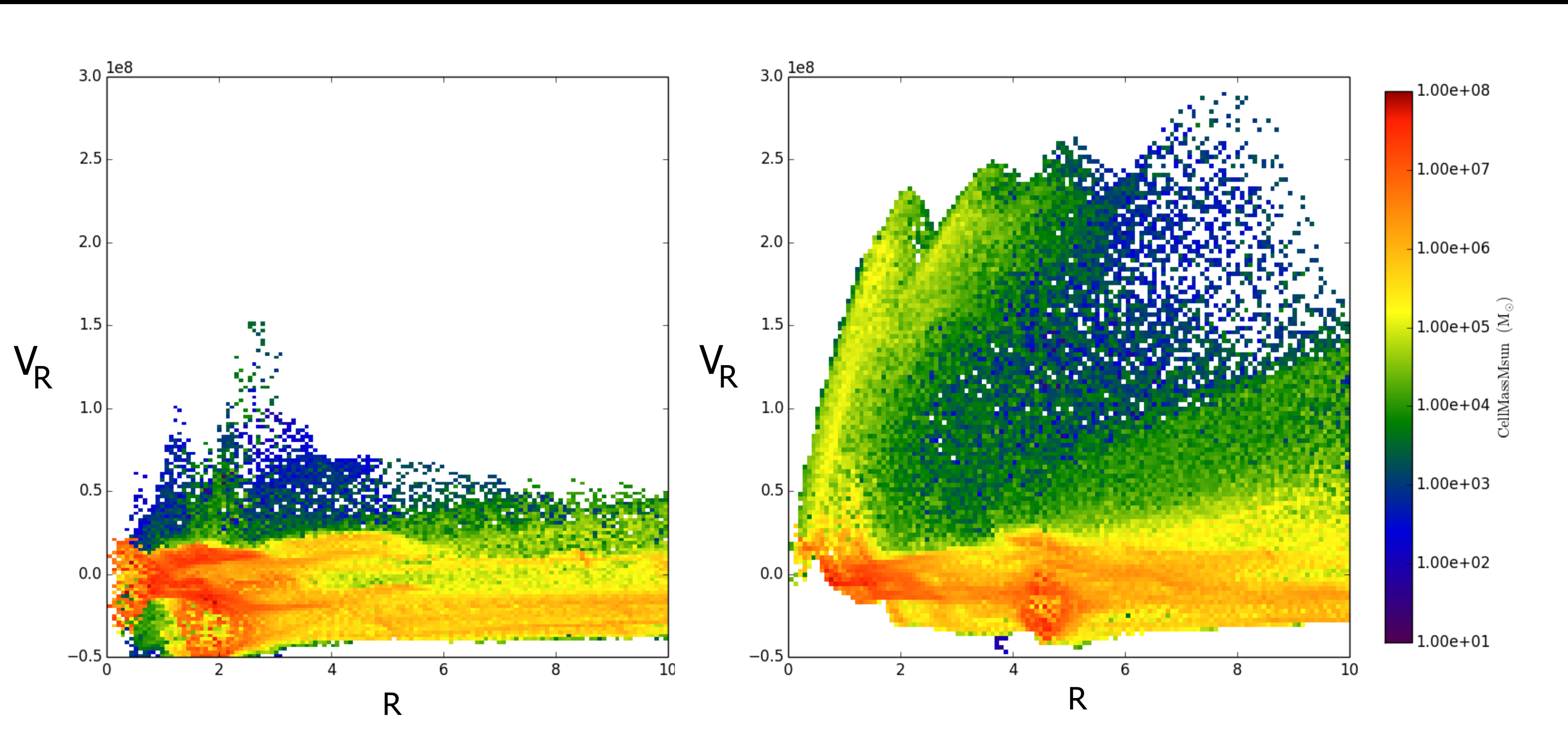
Gas Properties



Standard Accretion

Clumpy Accretion

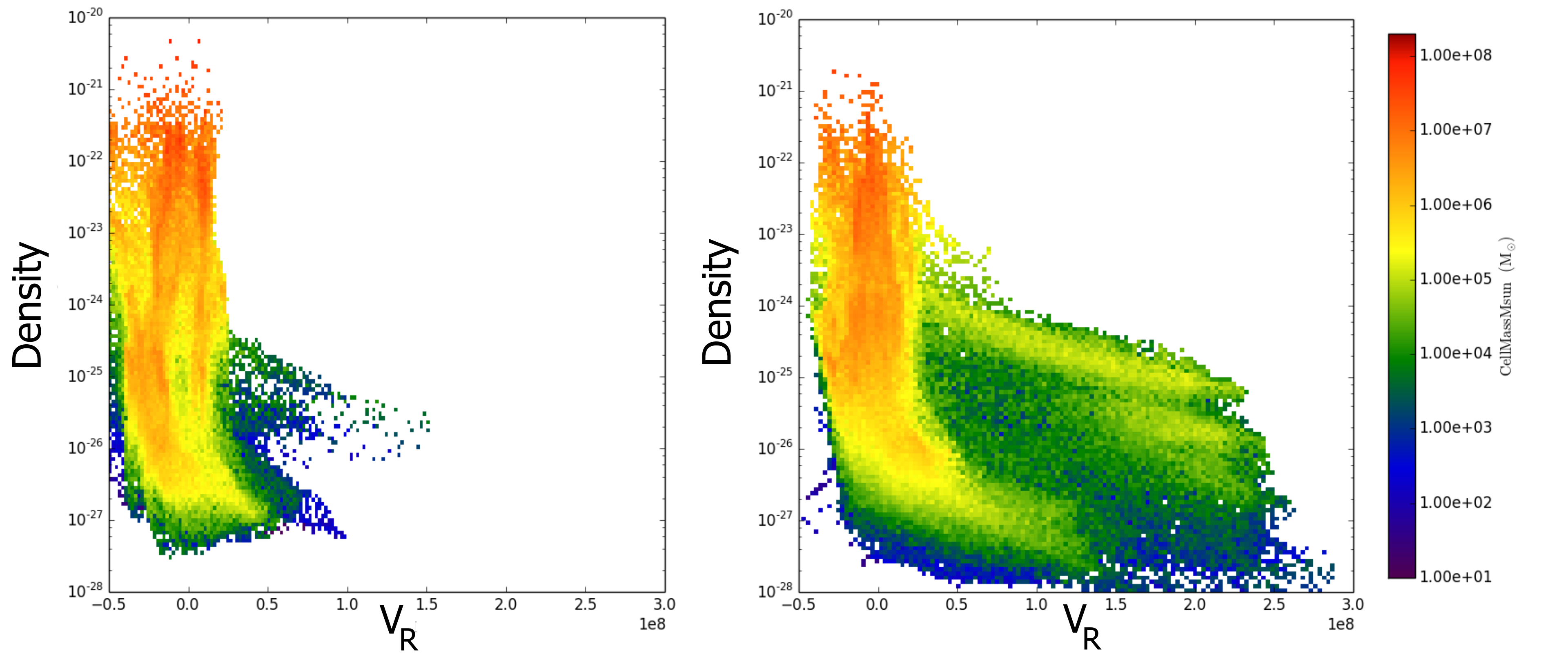
Gas Properties



Standard Accretion

Clumpy Accretion

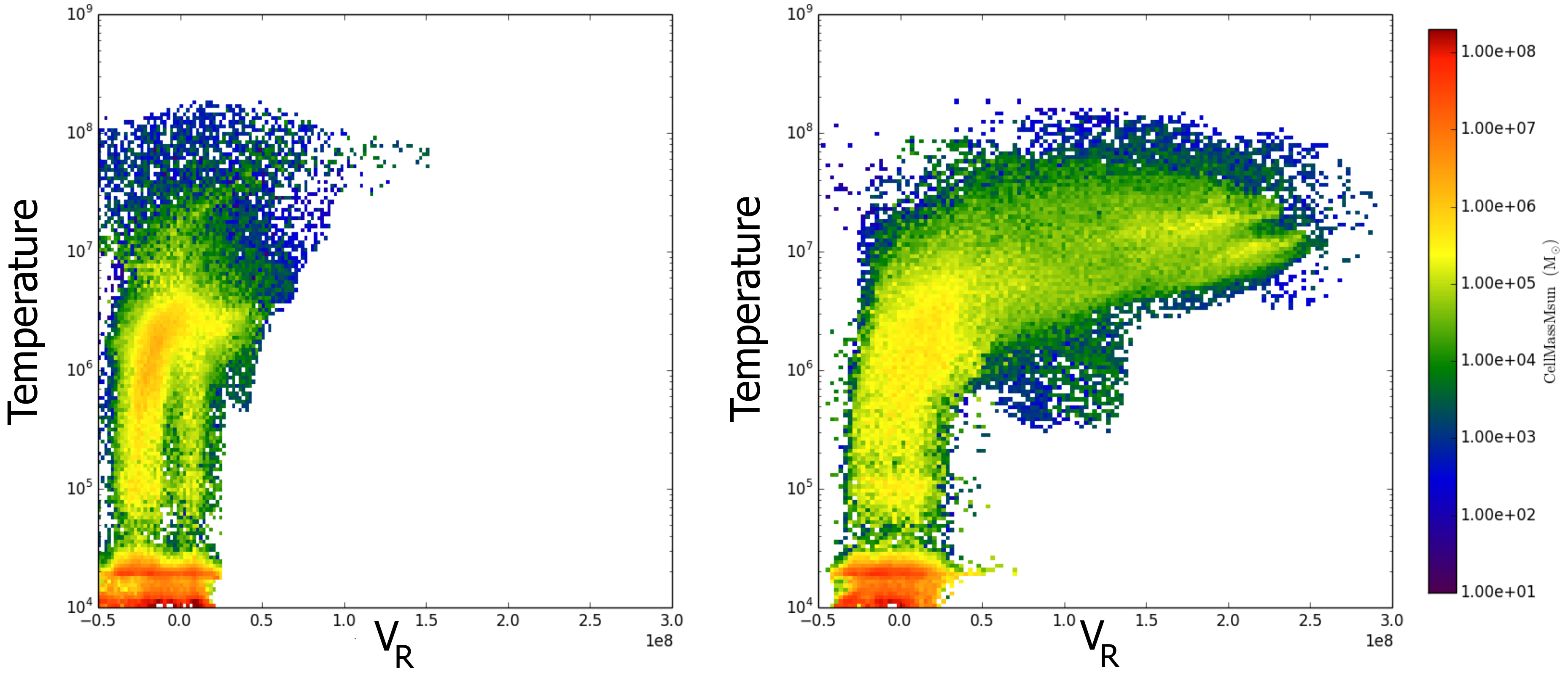
Gas Properties



Standard Accretion

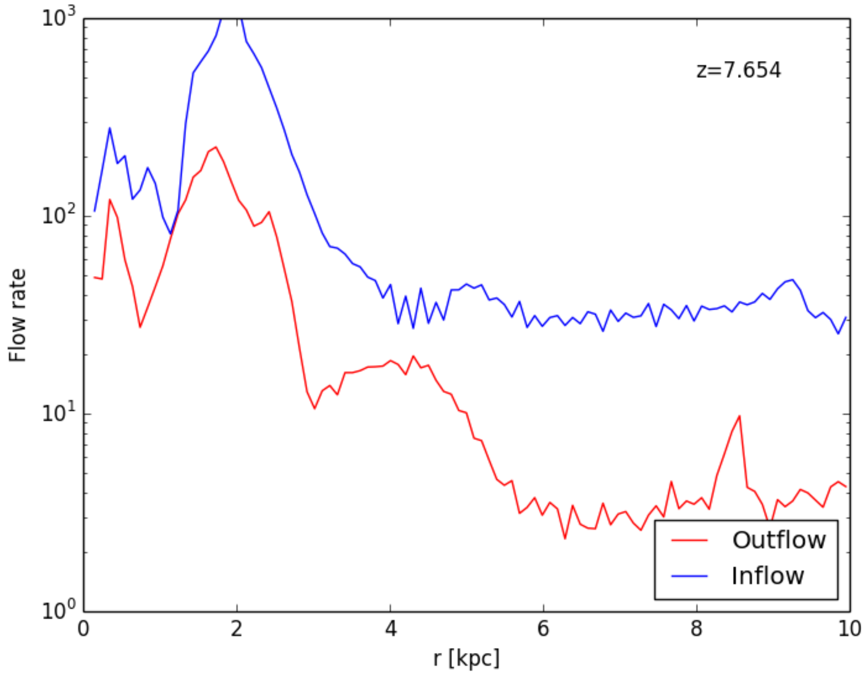
Clumpy Accretion

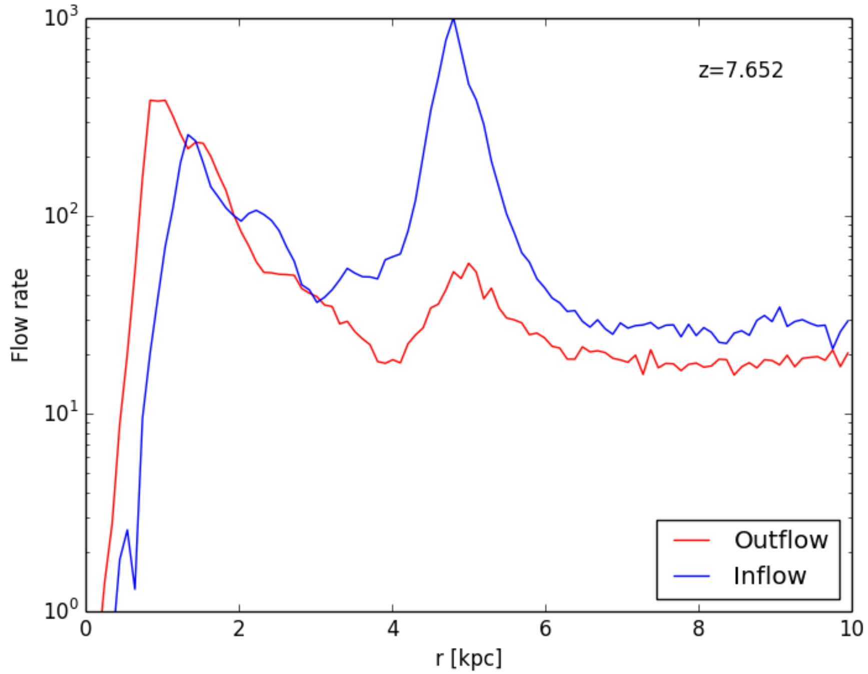
Gas Properties



Standard Accretion Clumpy Accretion

Inflows and Outflows

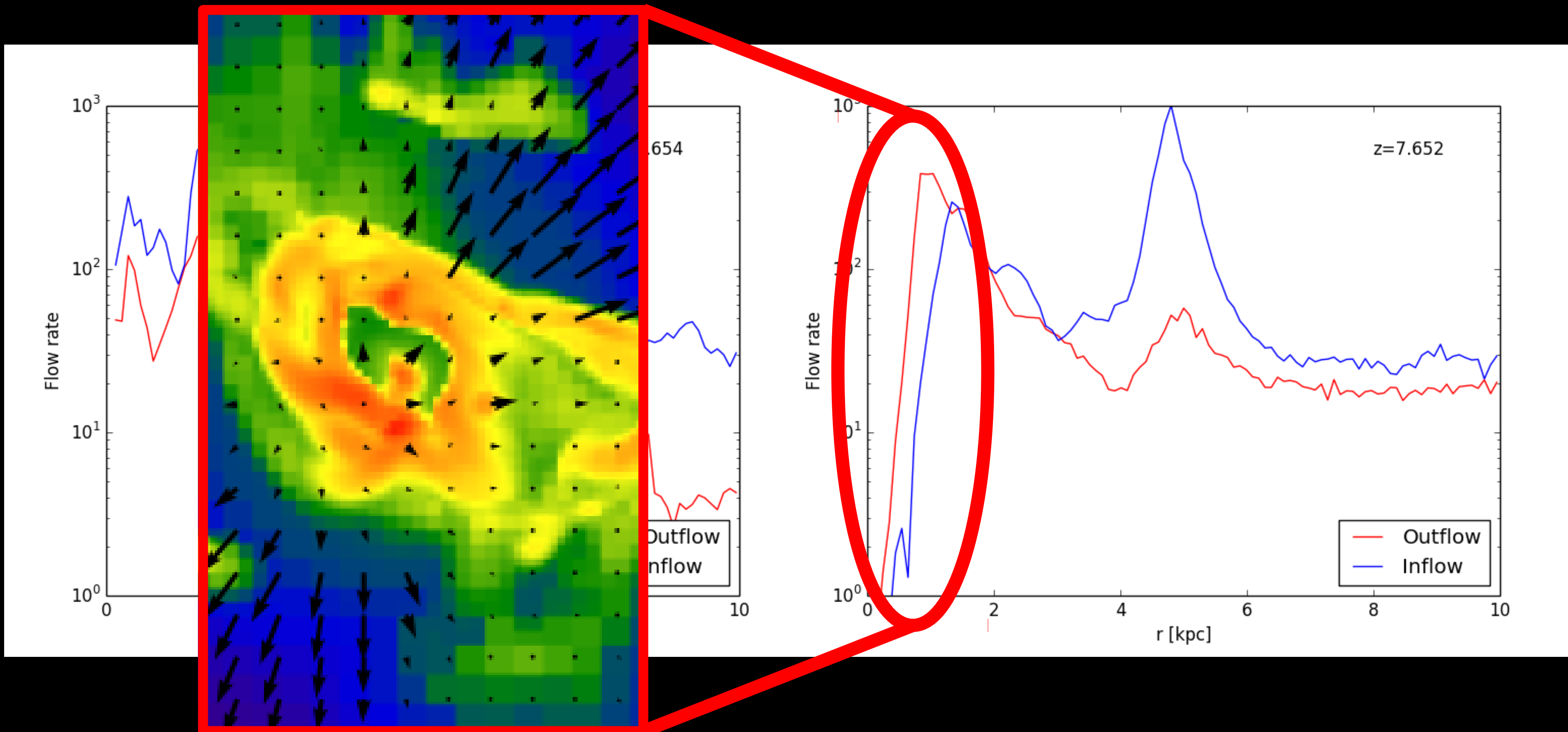




Standard Accretion

Clumpy Accretion

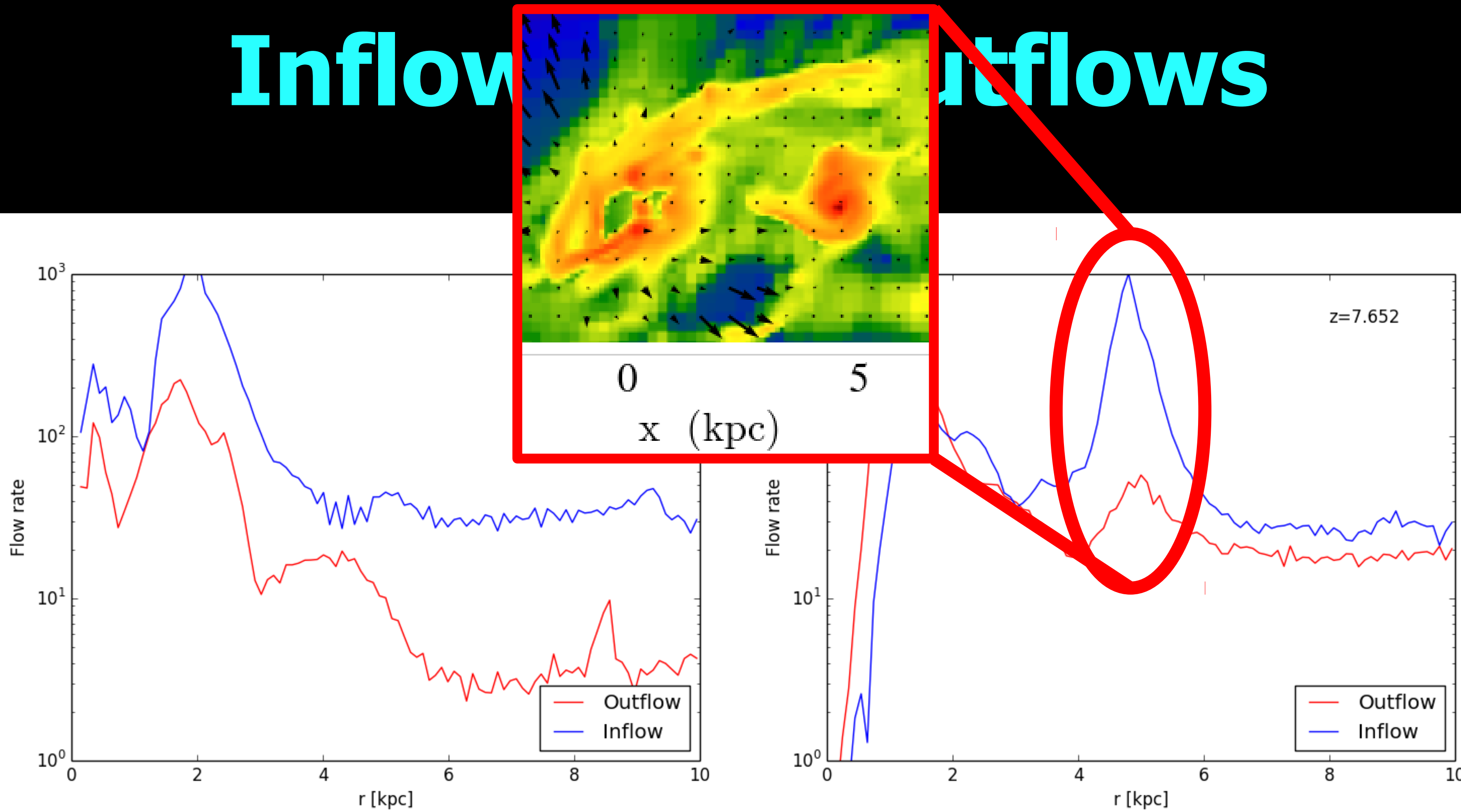
Inflows and Outflows



Standard Accretion

Clumpy Accretion

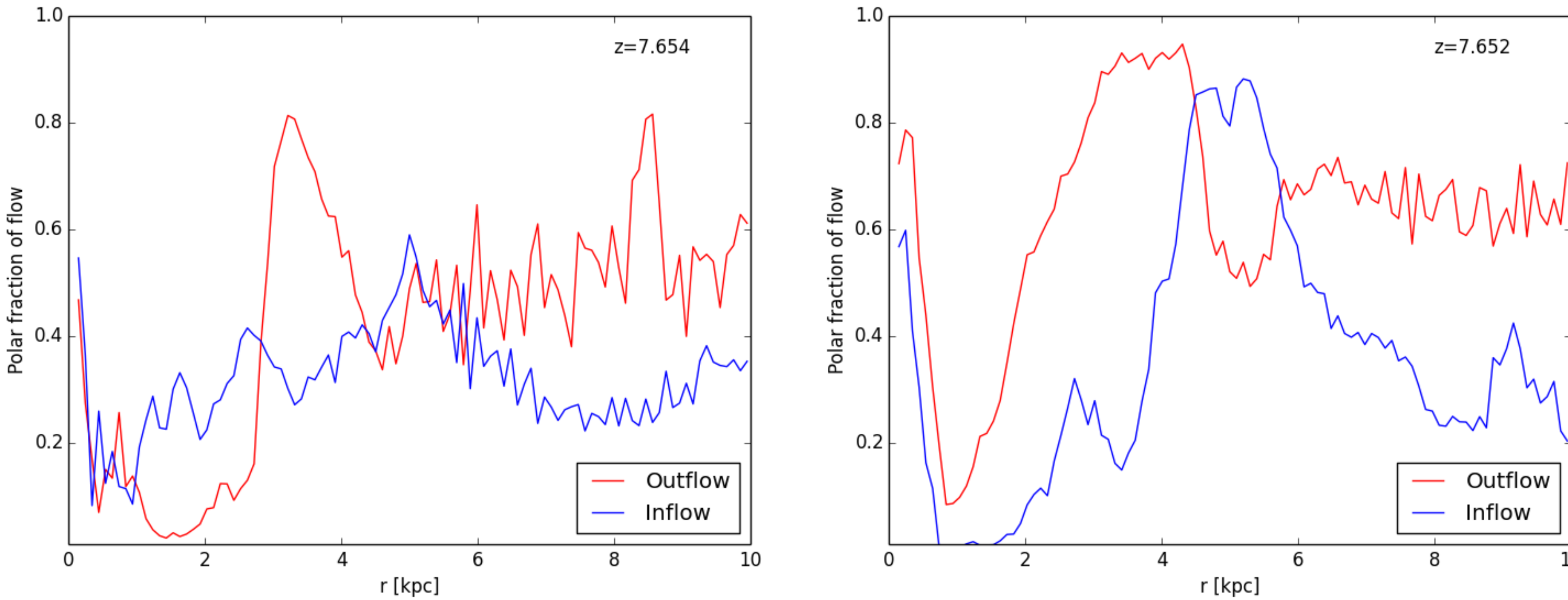
Inflow utflows



Standard Accretion

Clumpy Accretion

Out-of-plane component

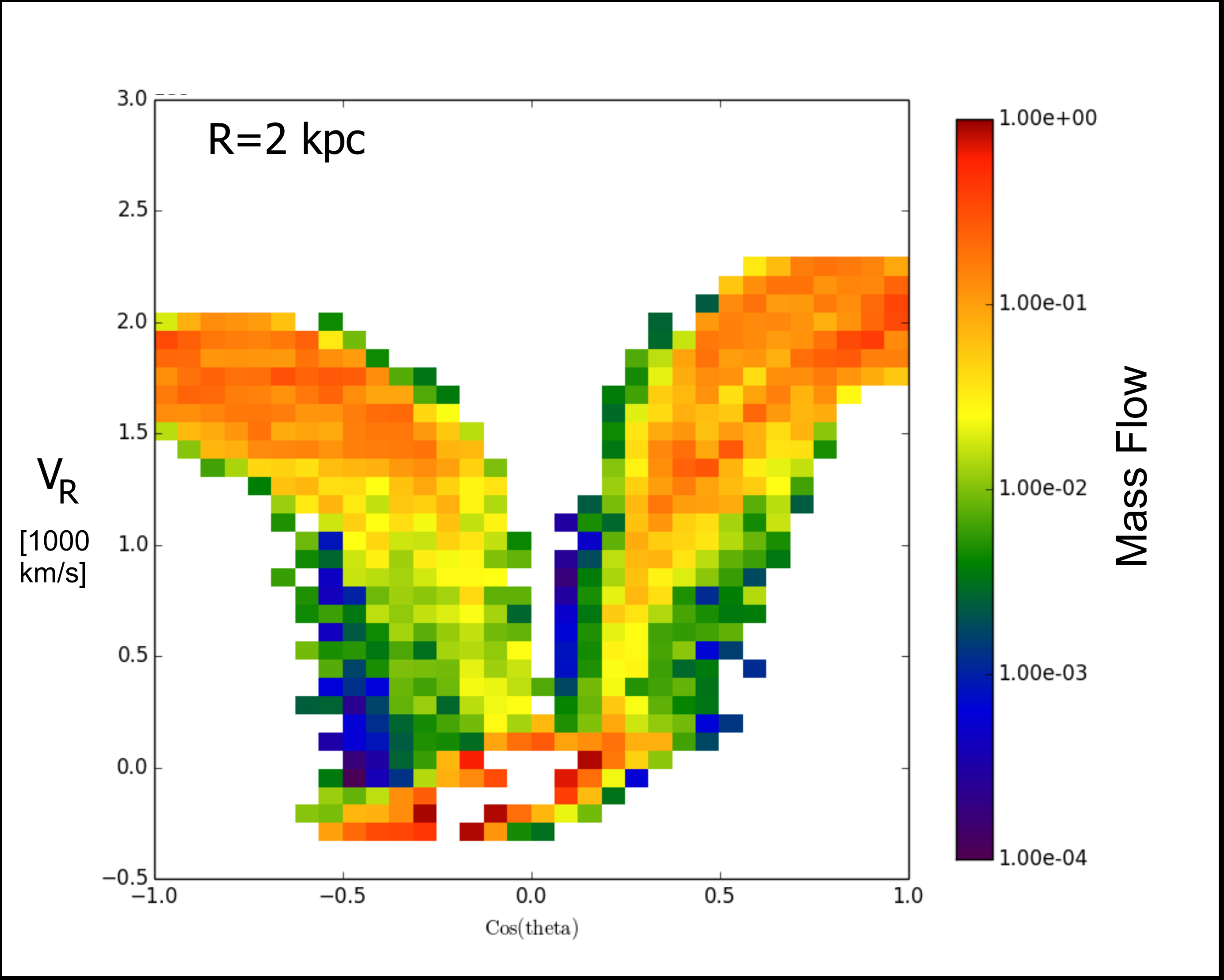


Standard Accretion

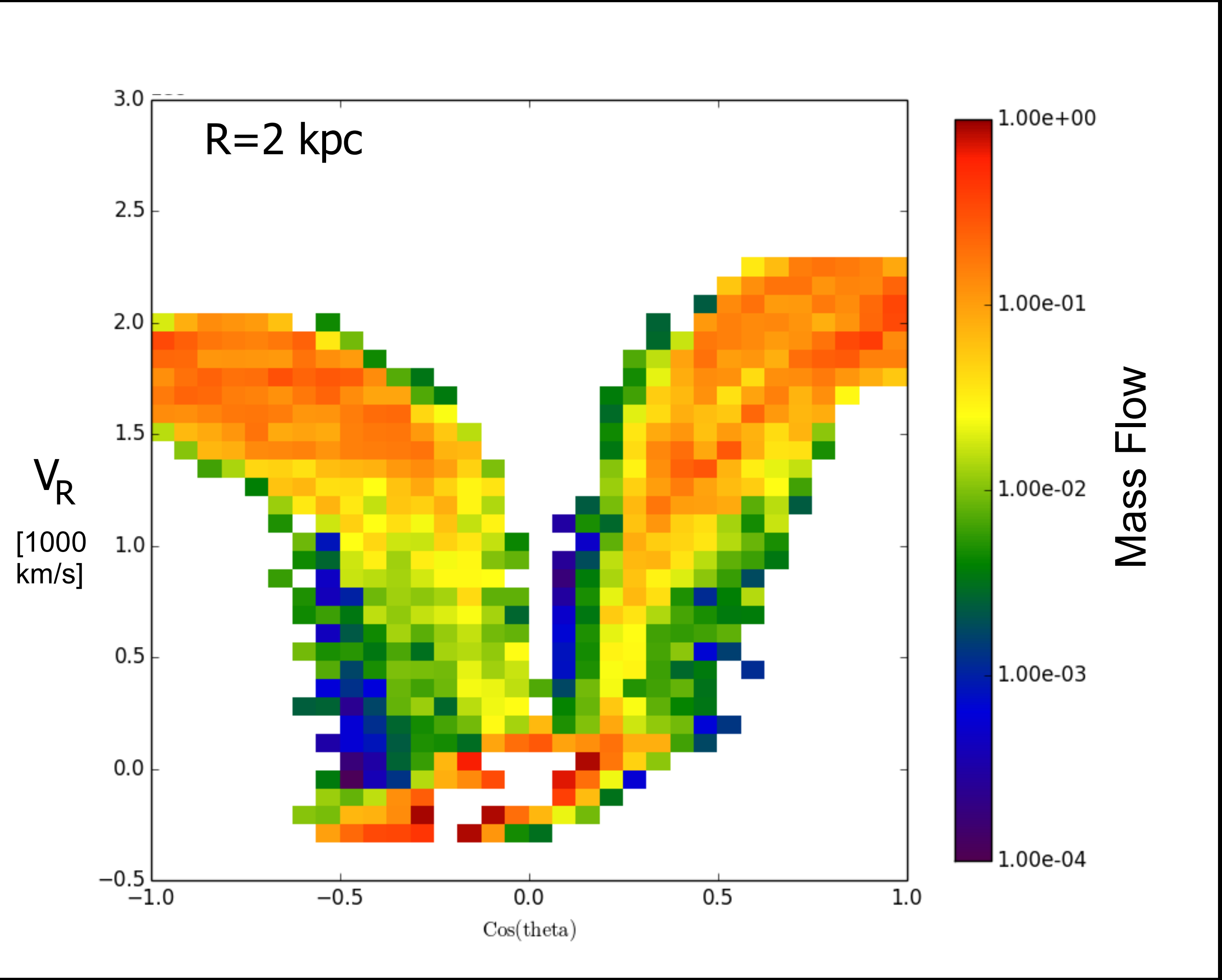
Clumpy Accretion

- Stronger feedback from clumpy accretion → outflows much more concentrated out-of-plane

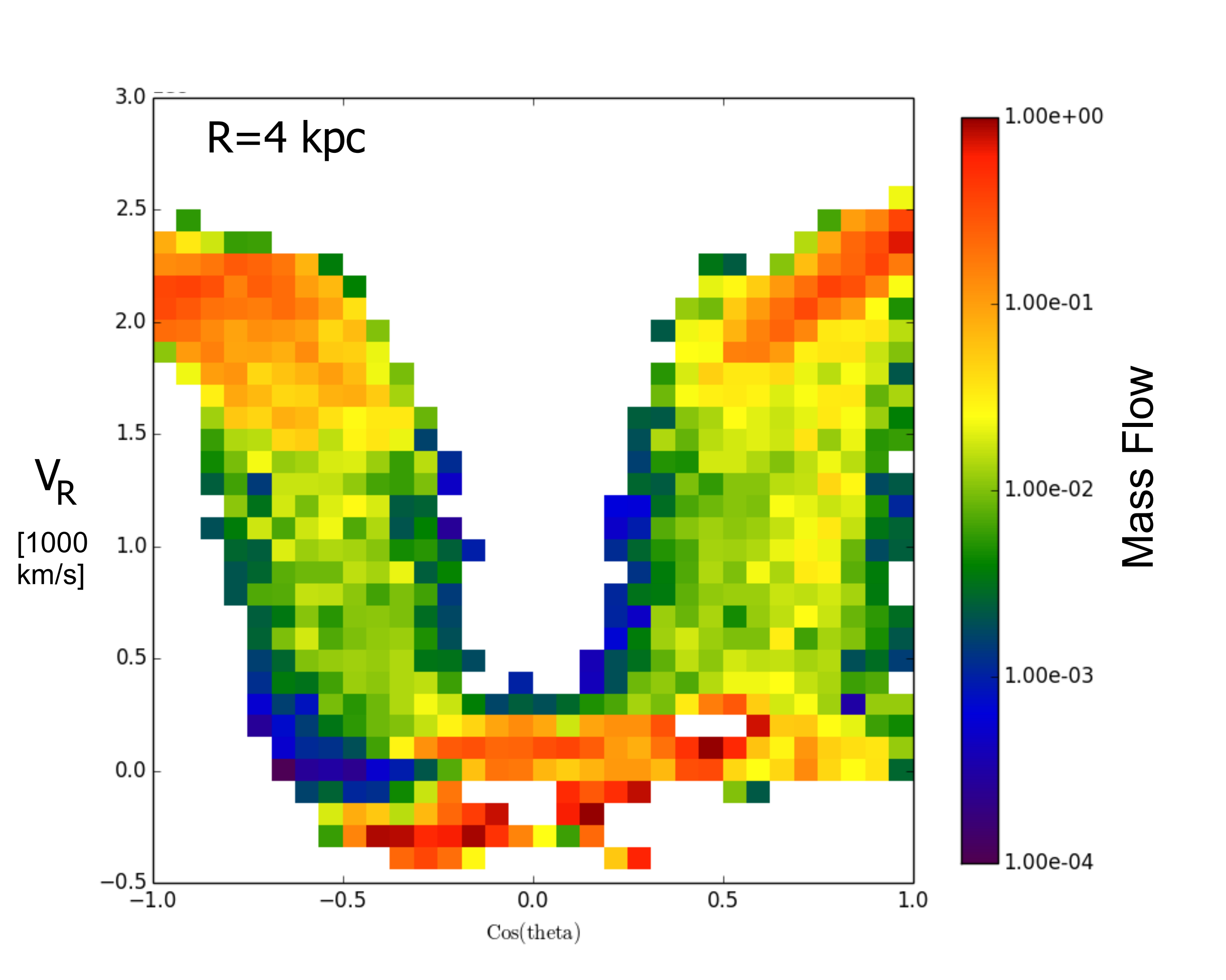
Inflows and Outflows – In- vs. Out-of-plane



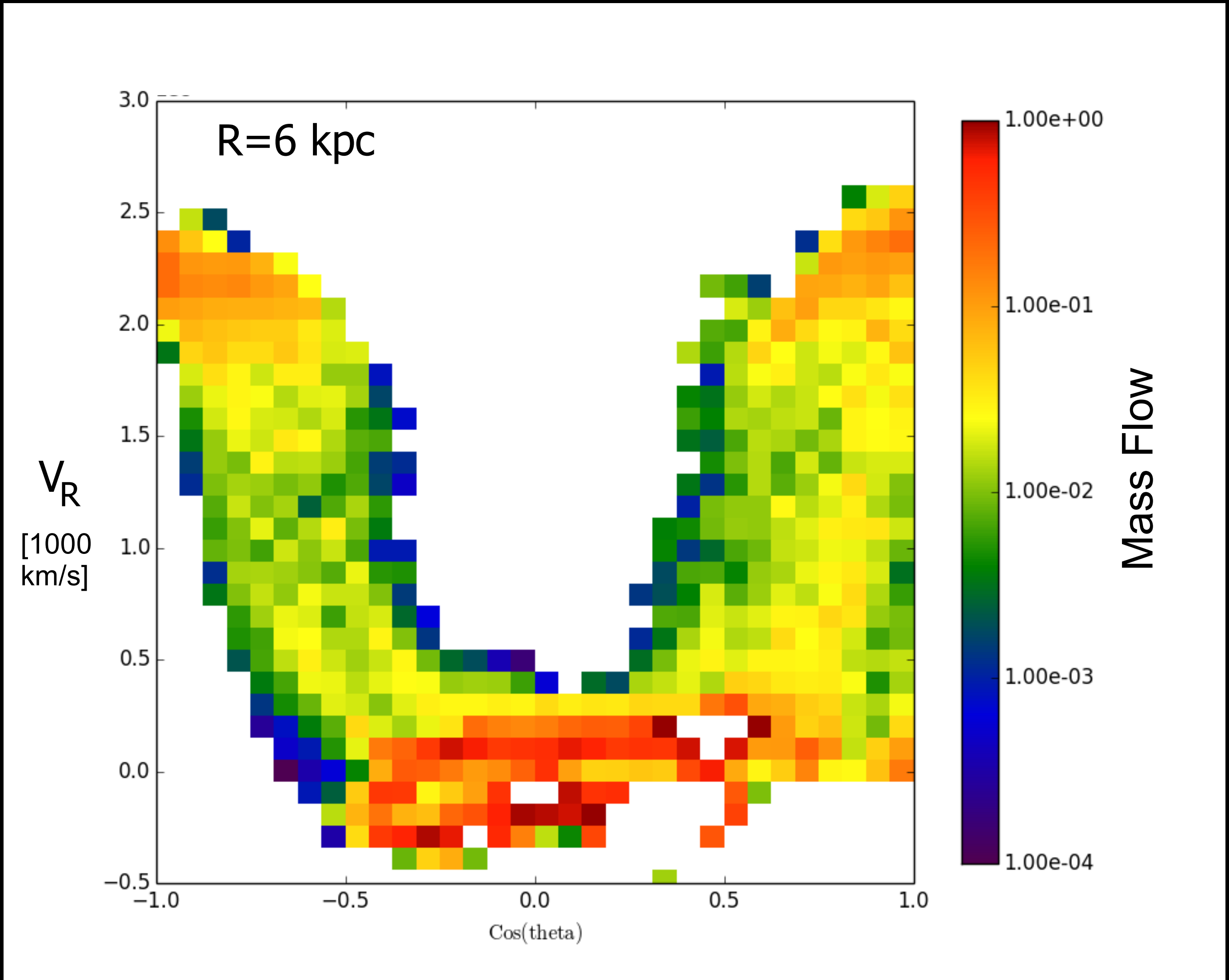
Inflows and Outflows – In- vs. Out-of-plane



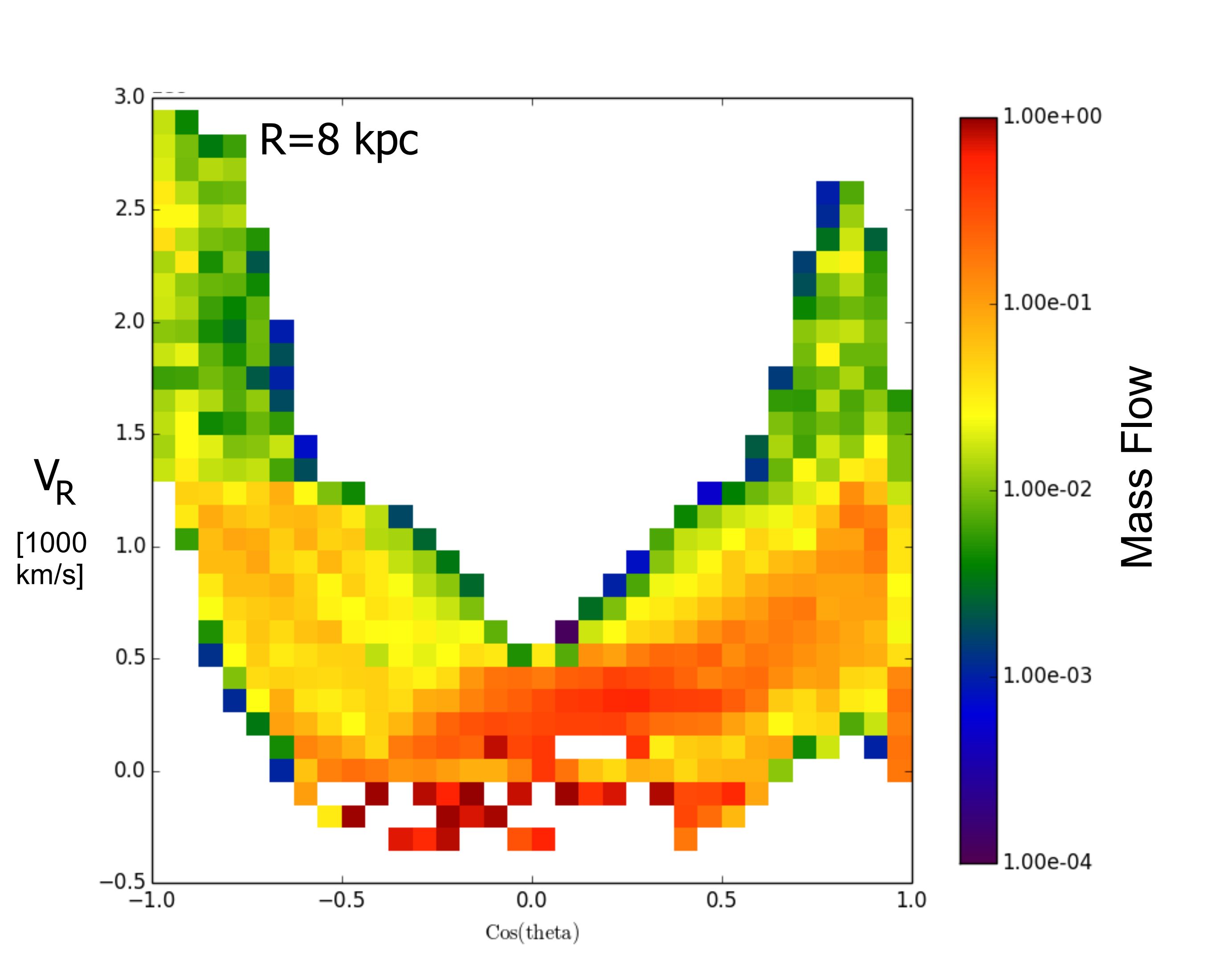
Inflows and Outflows – In- vs. Out-of-plane



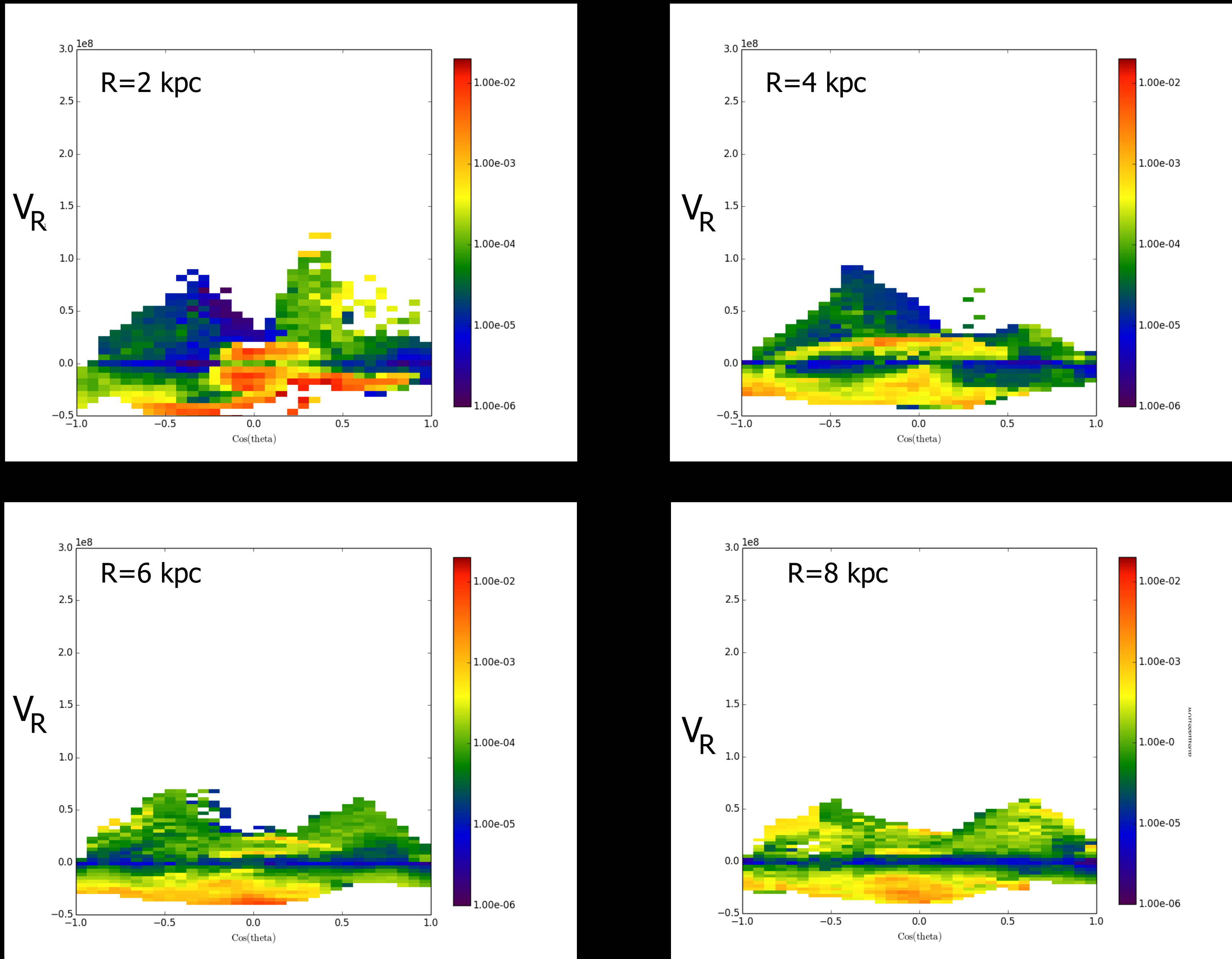
Inflows and Outflows – In- vs. Out-of-plane



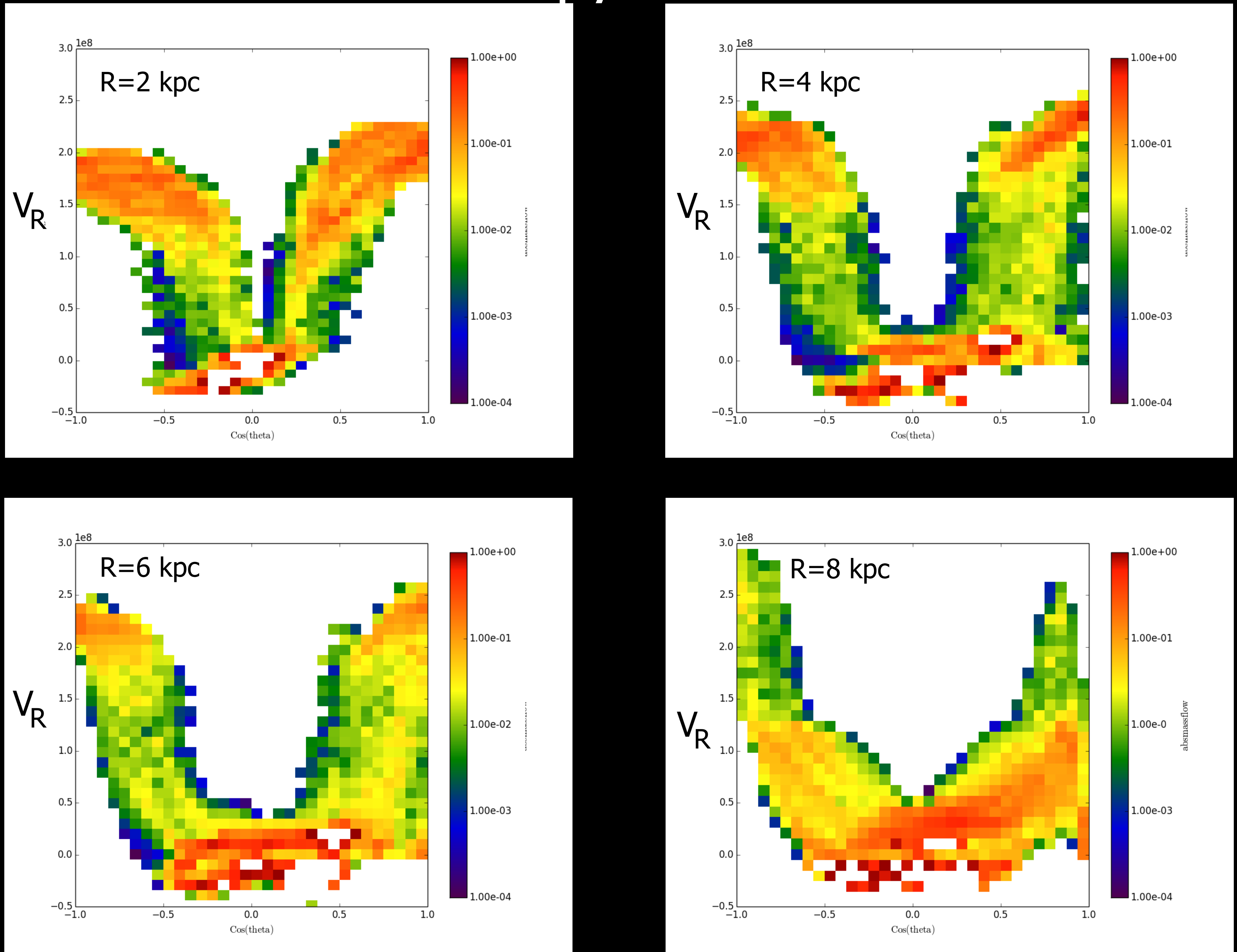
Inflows and Outflows – In- vs. Out-of-plane



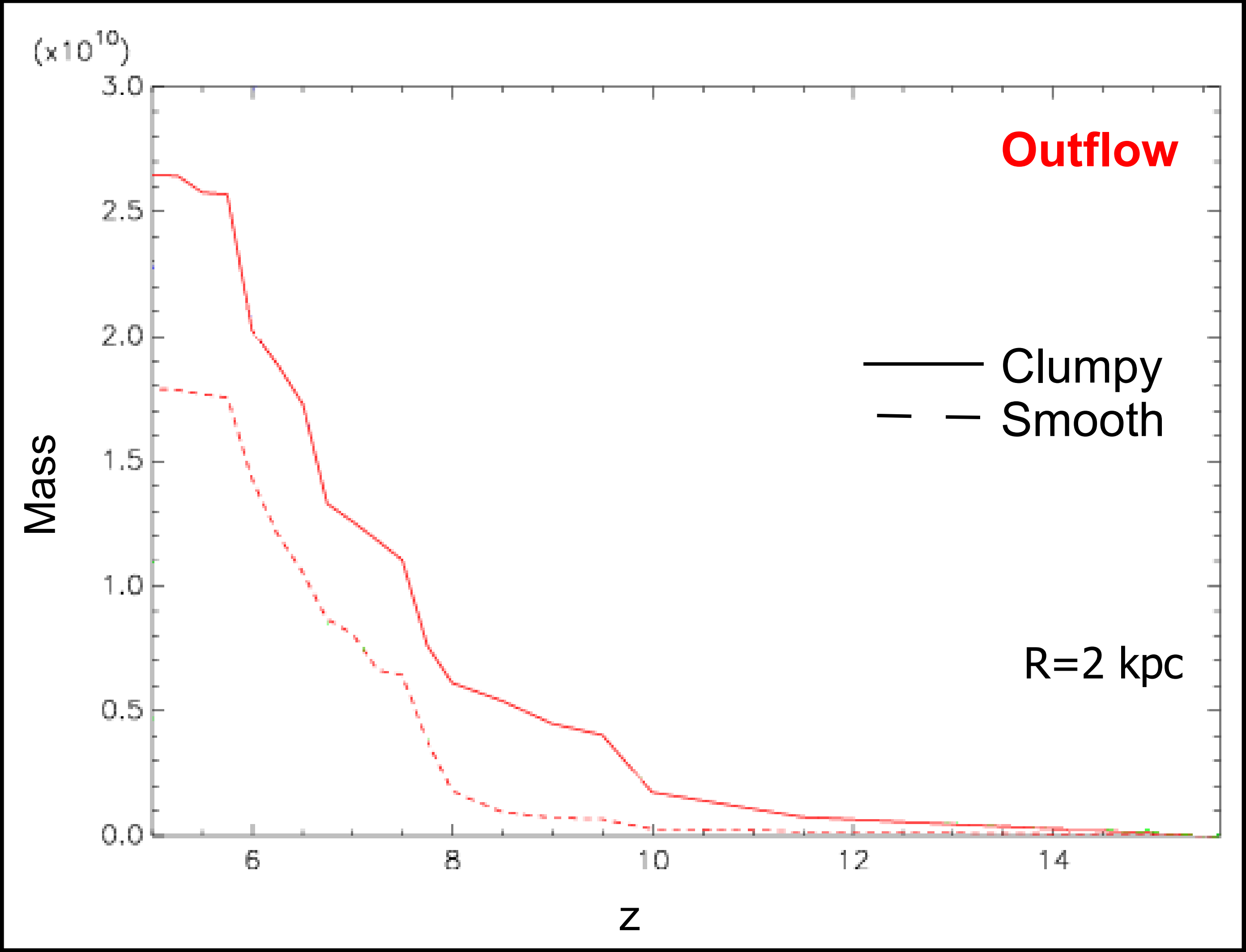
Standard Accretion



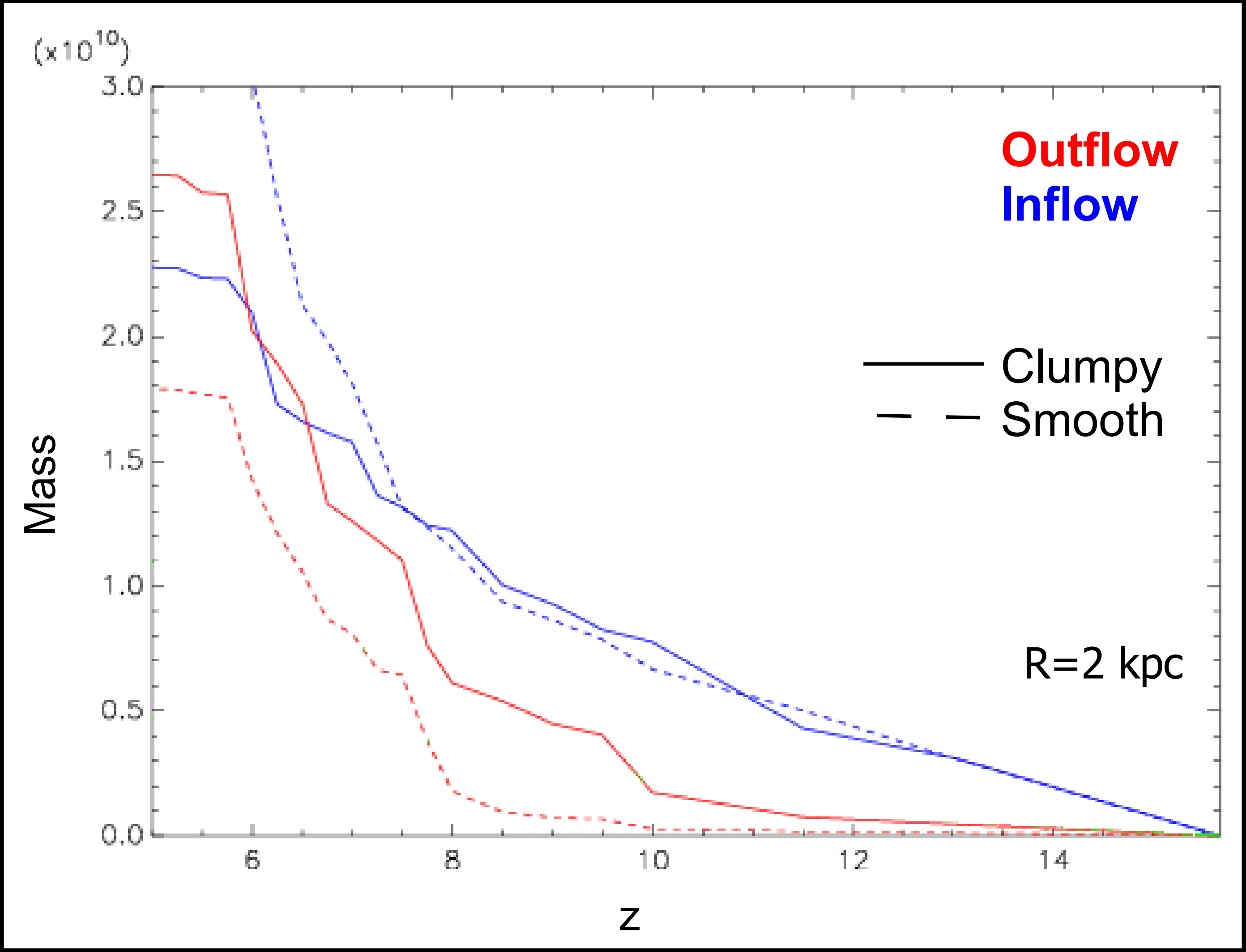
Clumpy Accretion



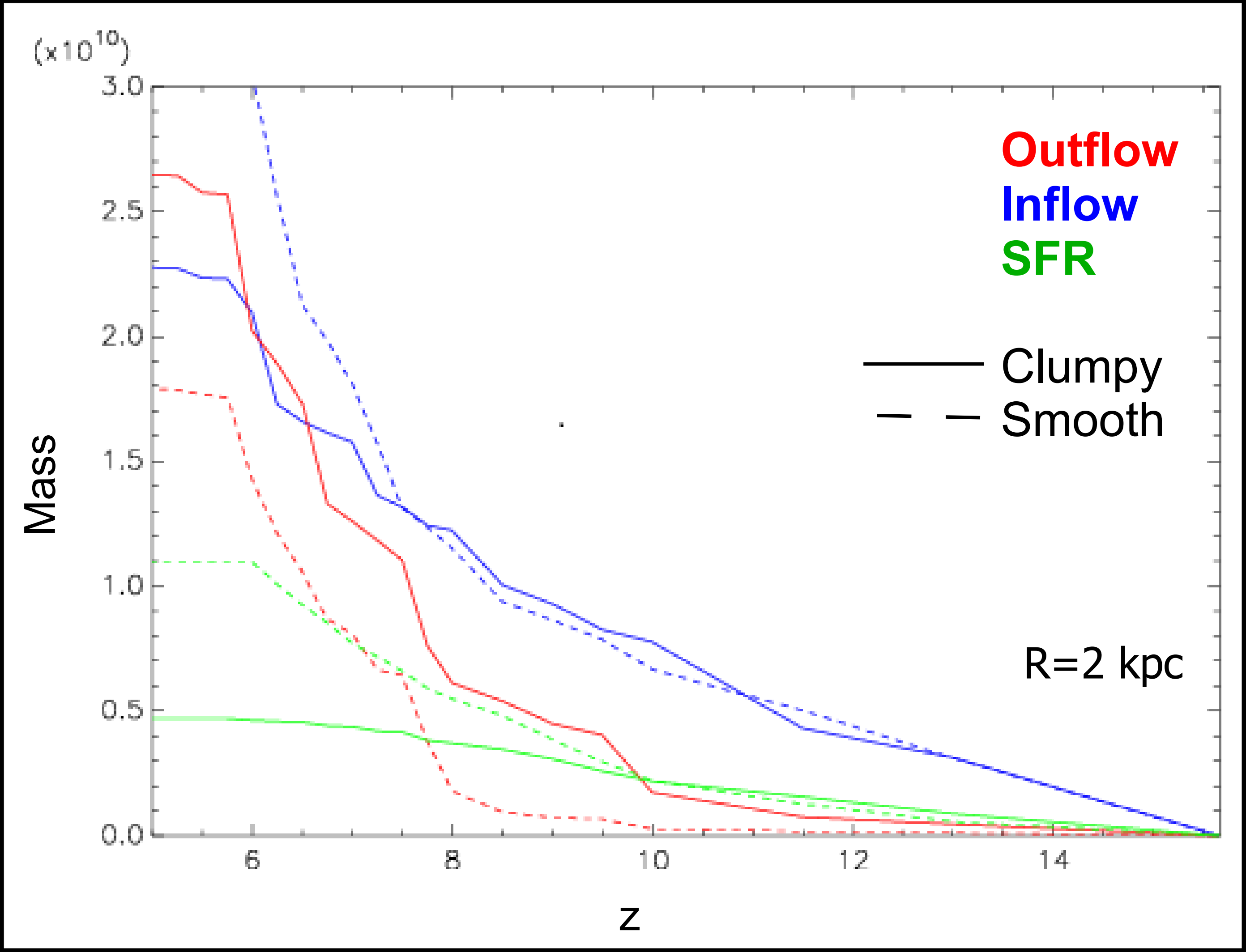
Cumulative Inflows & Outflows



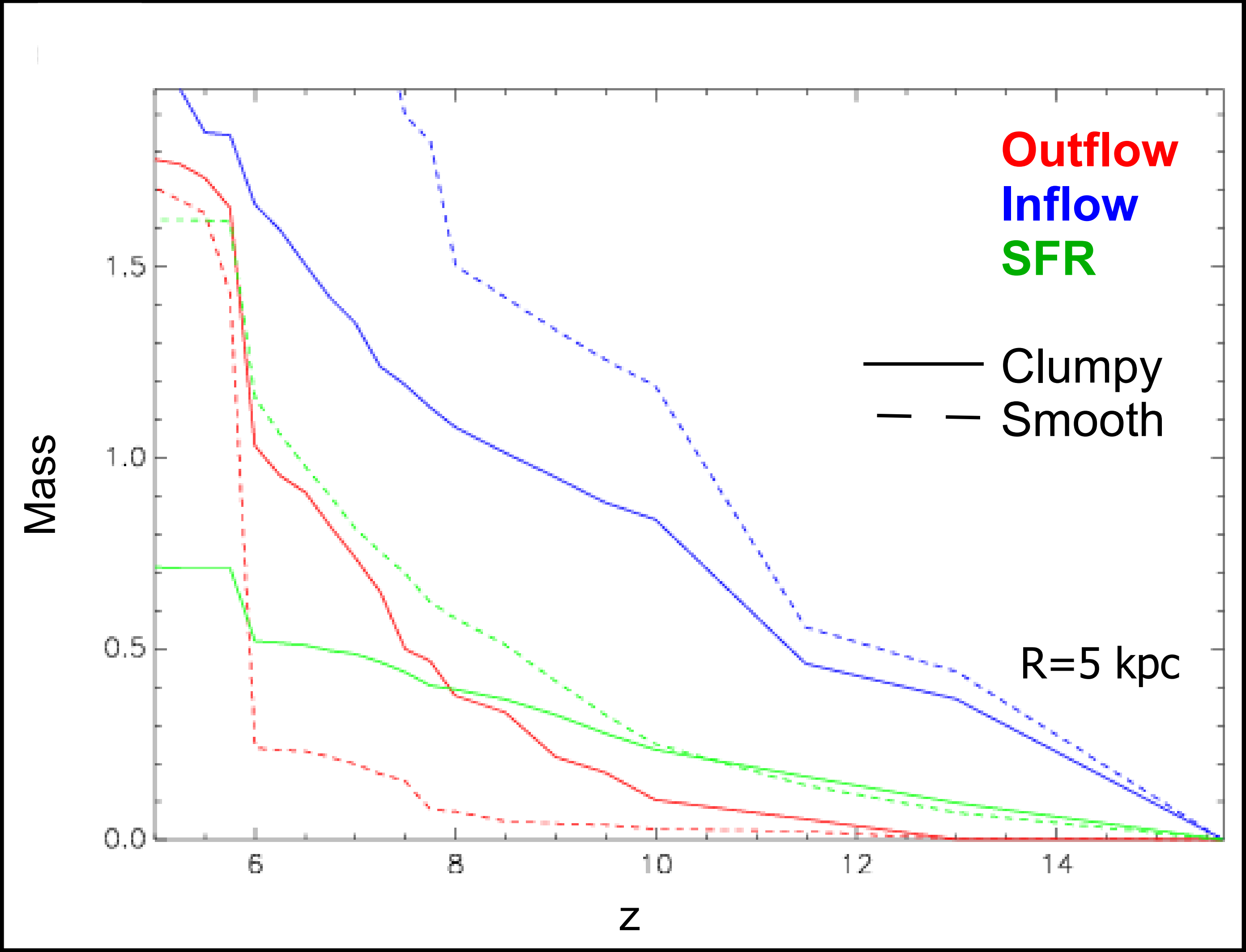
Cumulative Inflows & Outflows



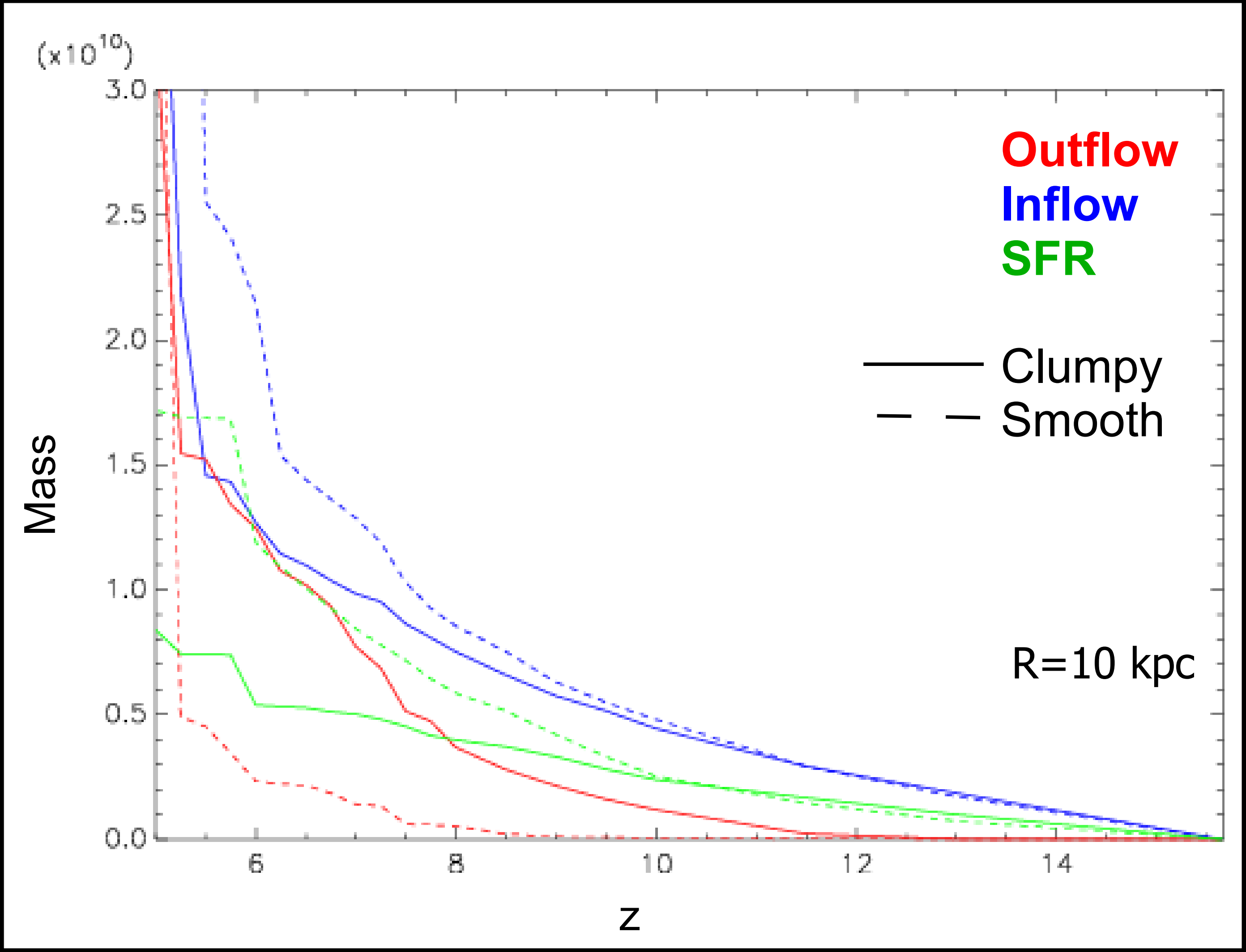
Cumulative Inflows & Outflows



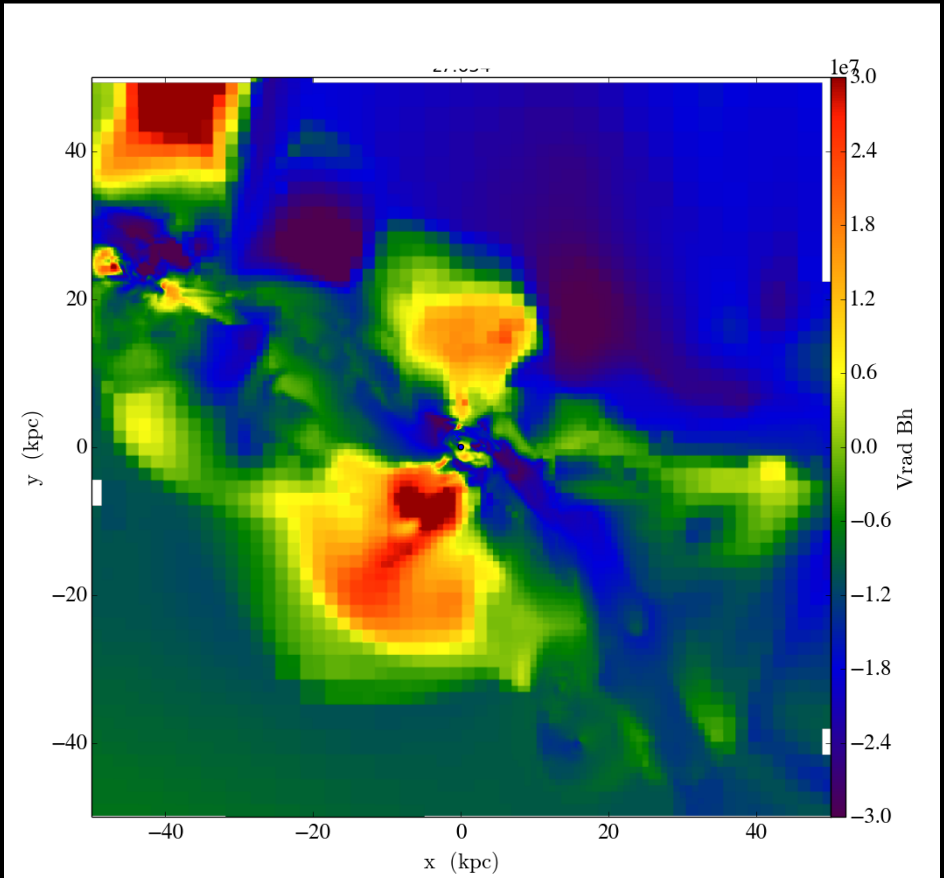
Cumulative Inflows & Outflows



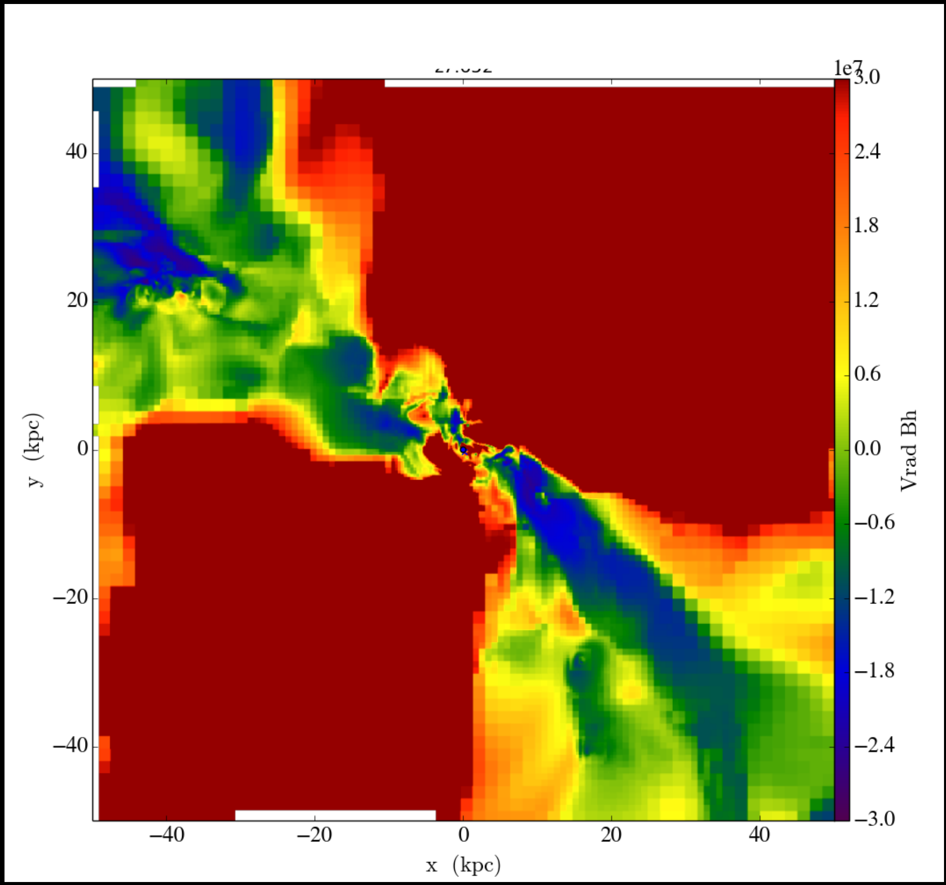
Cumulative Inflows & Outflows



Inflow/Outflow Interaction

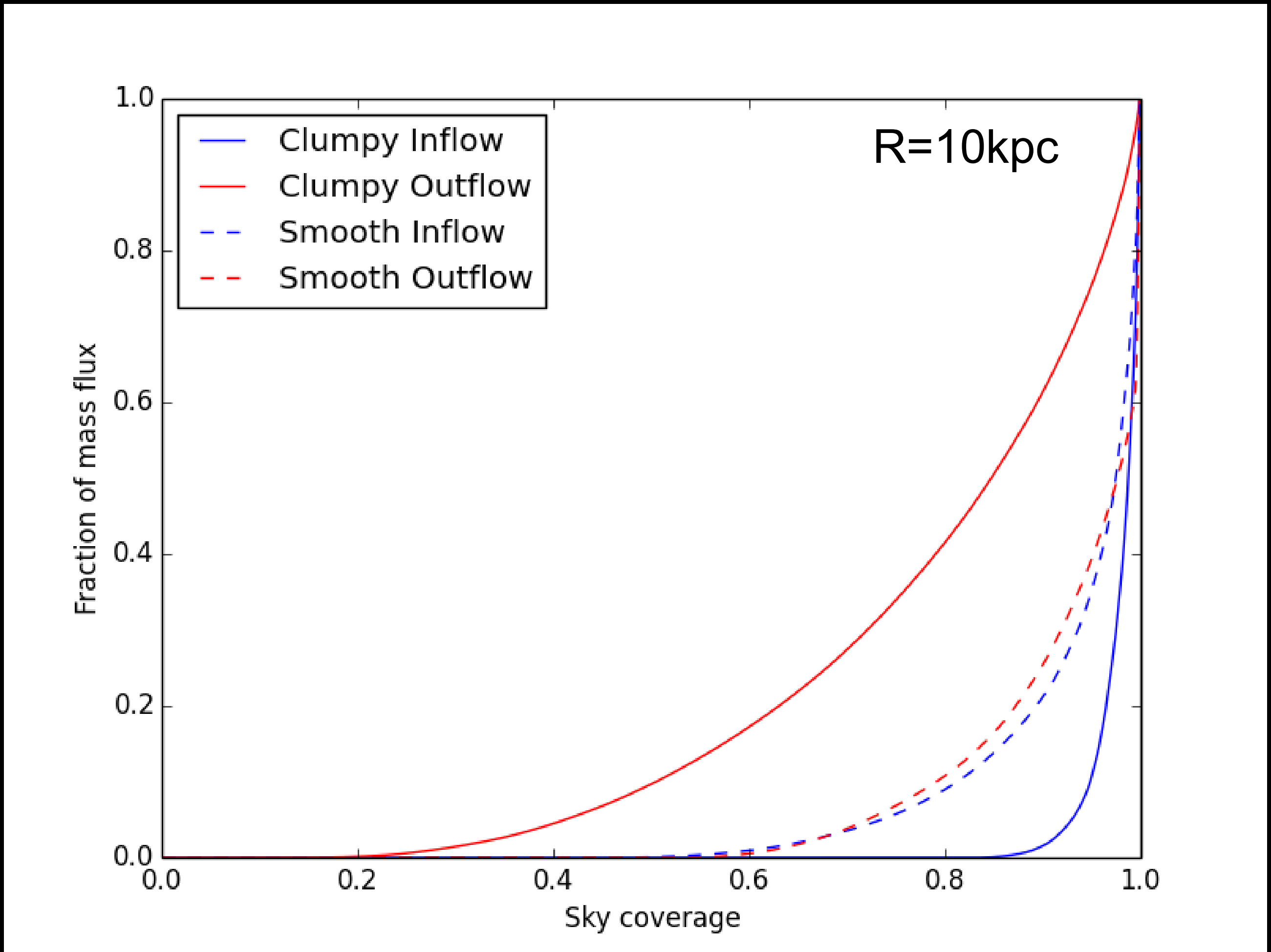


Standard Accretion



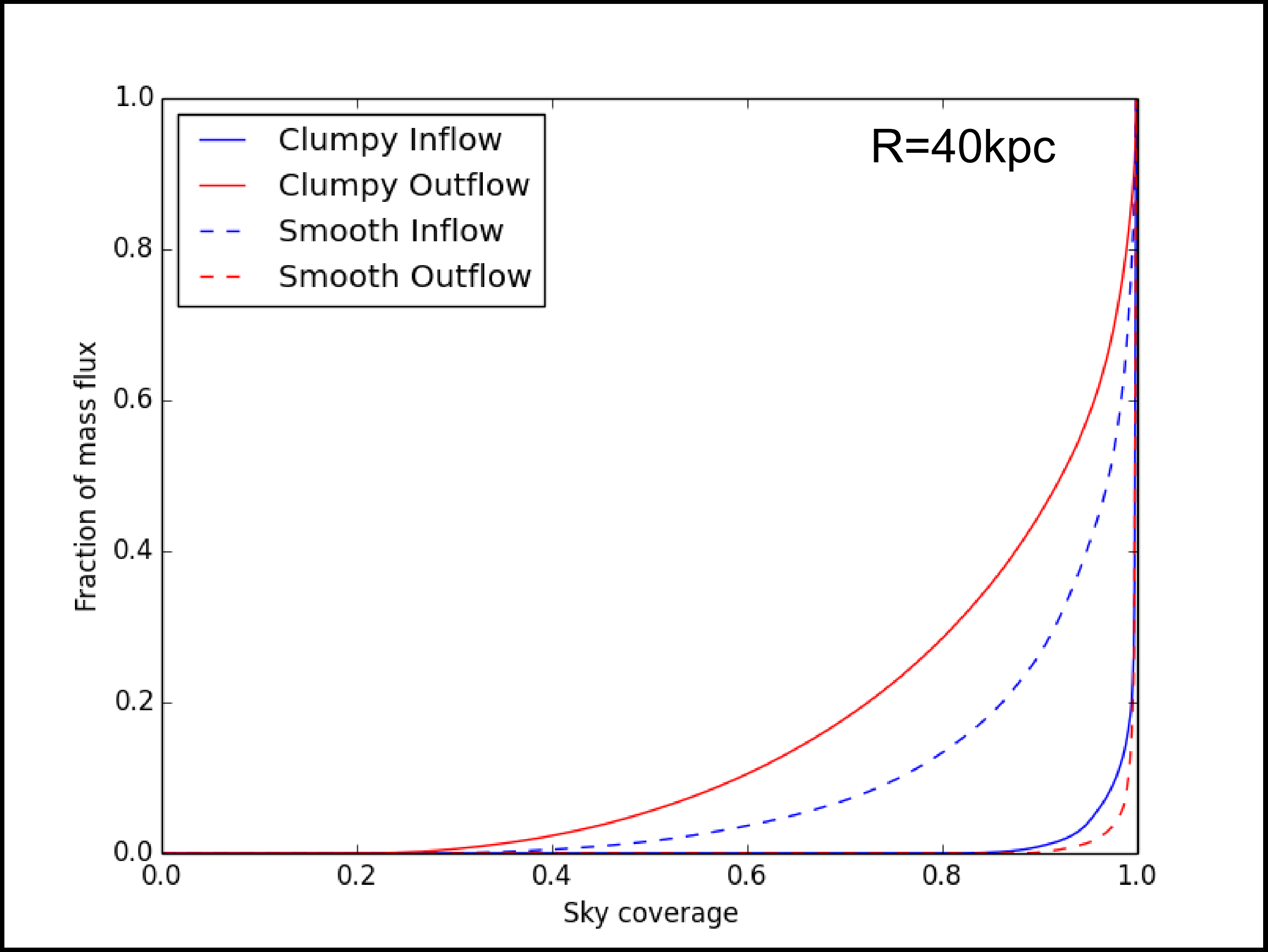
Clumpy Accretion

Inflow/Outflow Interaction



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

Inflow/Outflow Interaction



- 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