Gas Accretion History of Simulated Galaxies

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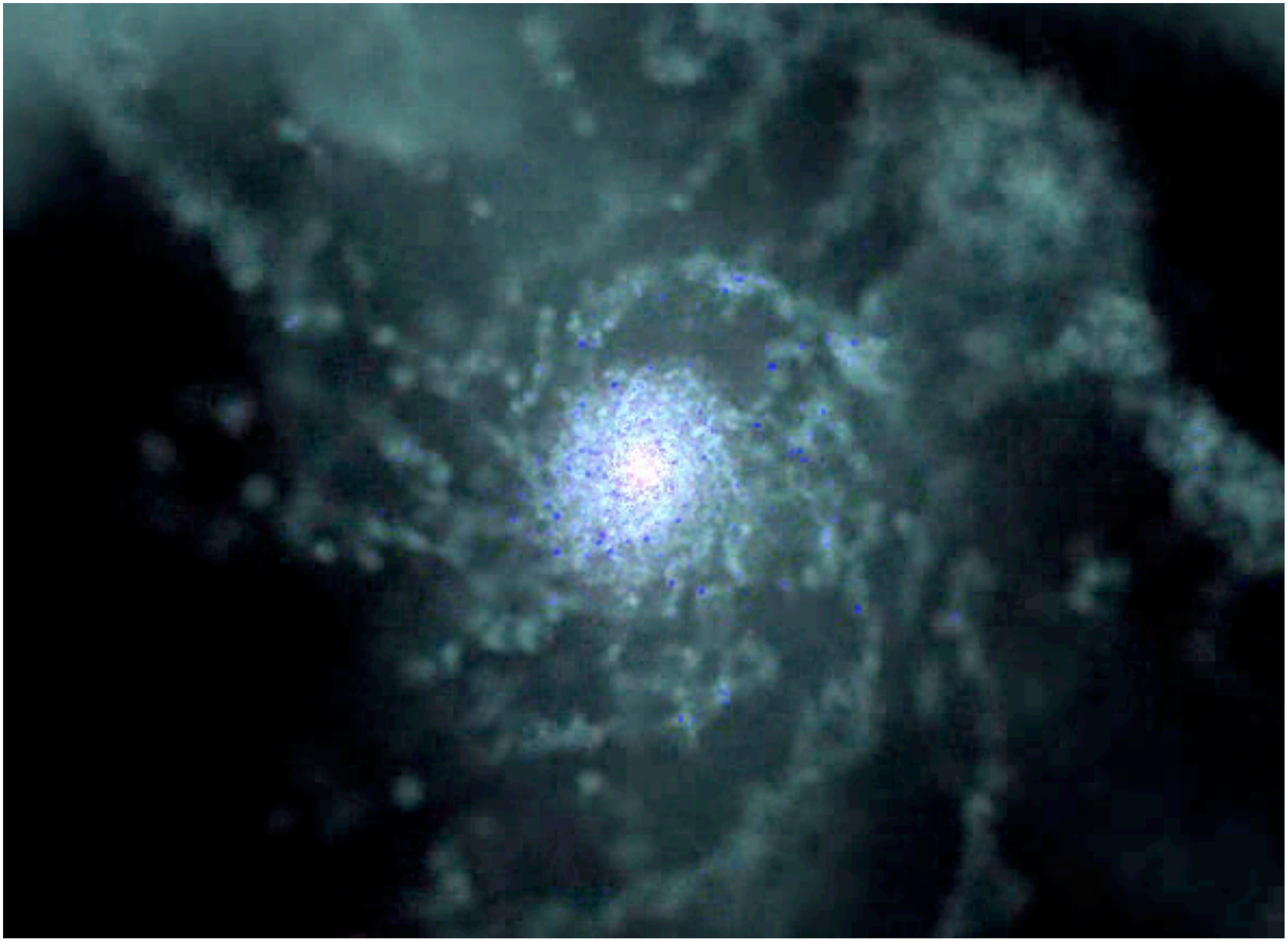
PRELIMINARY!!

Galaxy Formation Simulations



Governato et al.

MUGS: The **M**cMaster **U**nbiased **G**alaxy **S**imulations

Stinson, JB, et al. (2010)

- 16 **randomly**-chosen Milky Way-mass halos from low-resolution dark matter simulation.
- Resimulated at higher resolution (300 pc, 2 x 10^5 $M_\odot$ gas particle mass) with full baryonic physics (GASOLINE: N-body gravity, SPH hydro, metal and H/He cooling, star formation, supernova feedback, energy and metal diffusion; Wadsley et al.).

Gas Accretion onto Halos

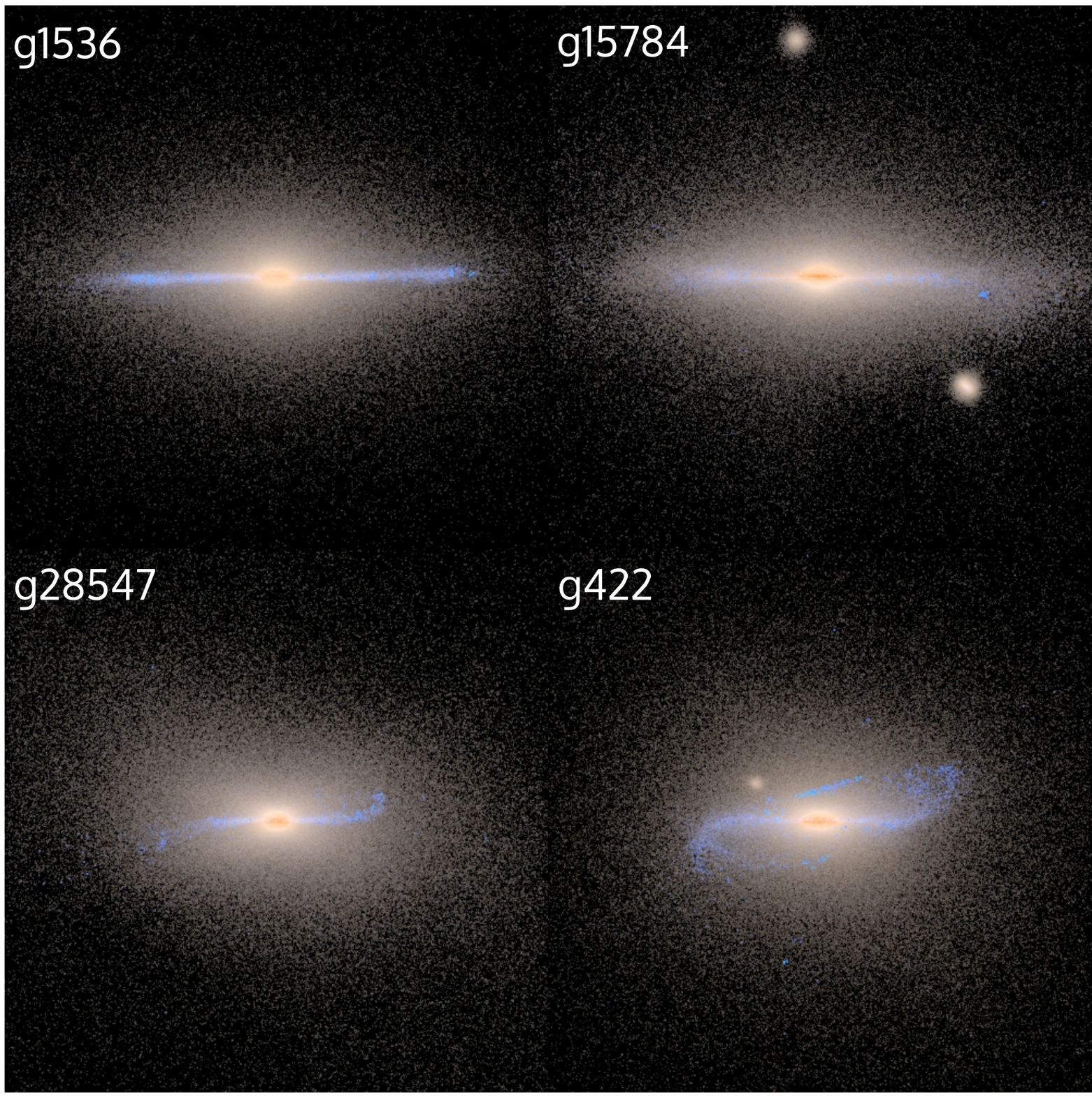
- While the details of star formation/feedback are still uncertain, accretion at the virial radius is much more robust.
  - Accretion onto the main body of the galaxy is more sensitive to details of baryonic physics, so focus here on how much gas makes it into the **halo**.
- Amount of gas available to form stars ≤ amount of gas accreted into the halo, so this is an important constraint on evolution of a galaxy.

Simulated Galaxy Sample

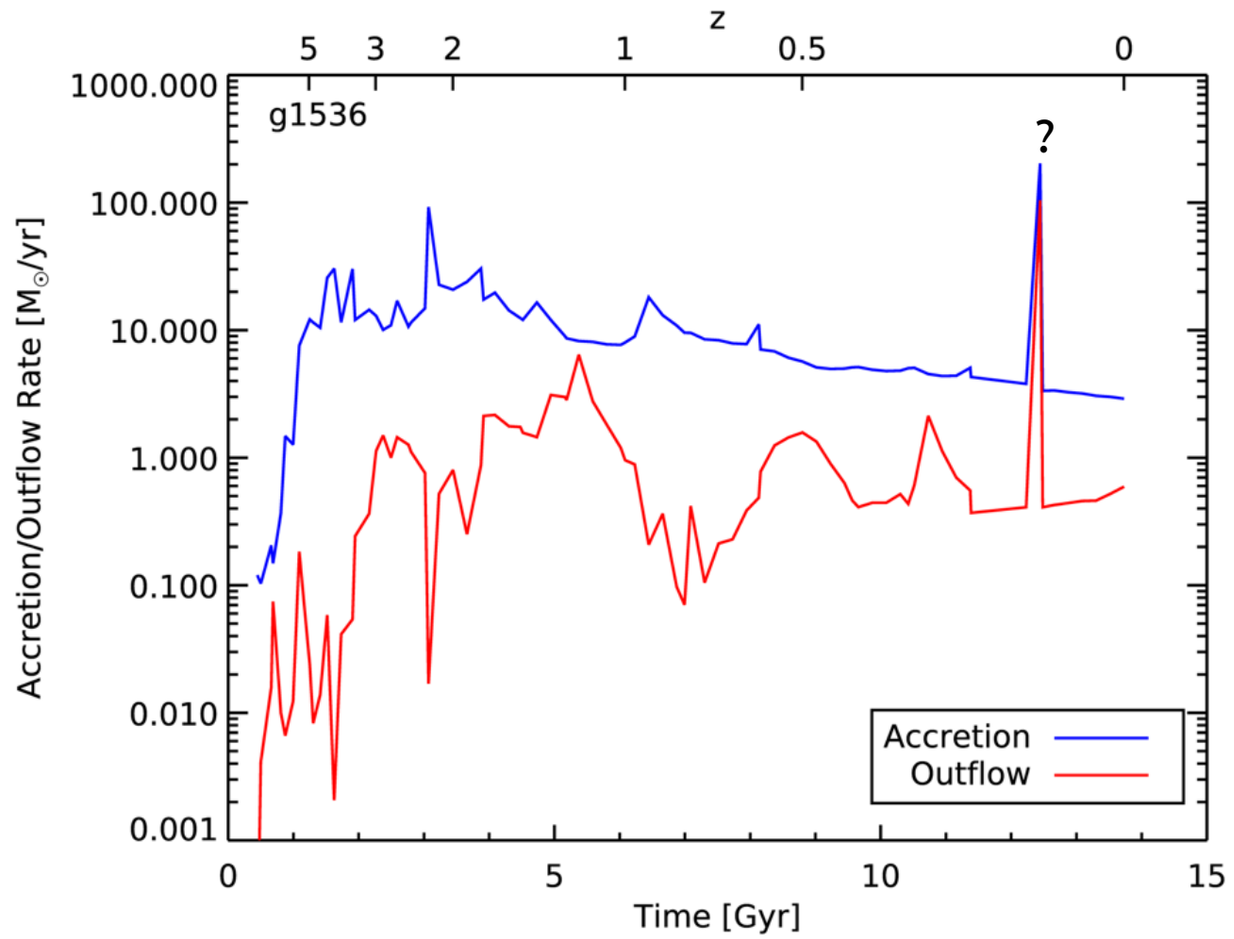
Four Milky Way-mass disk galaxies.

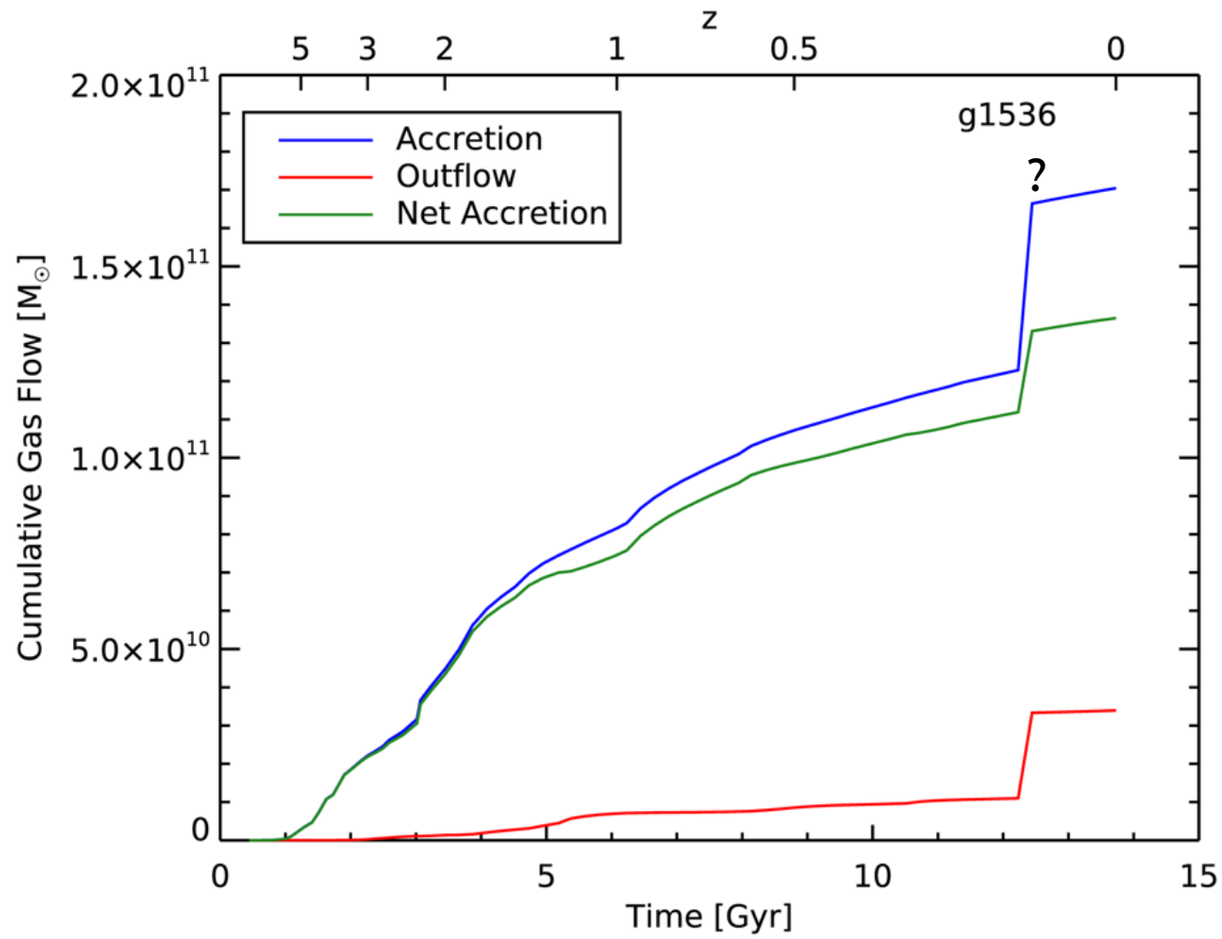
$M_{tot} = 0.8 - 1.4 \times 10^{12}\ M_\odot$

$M_* = 0.8 - 1.1 \times 10^{11}\ M_\odot$



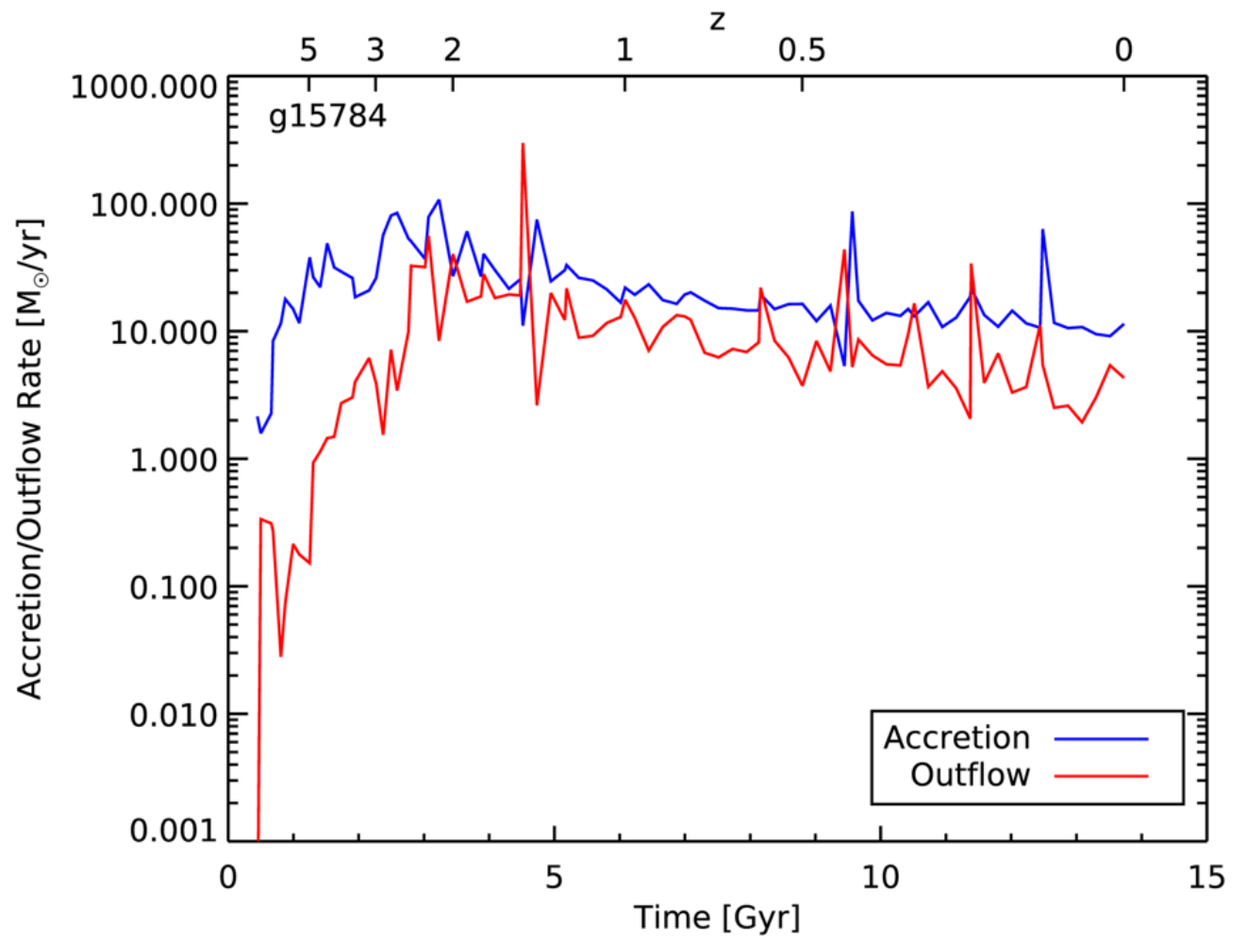
Gas Accretion Histories

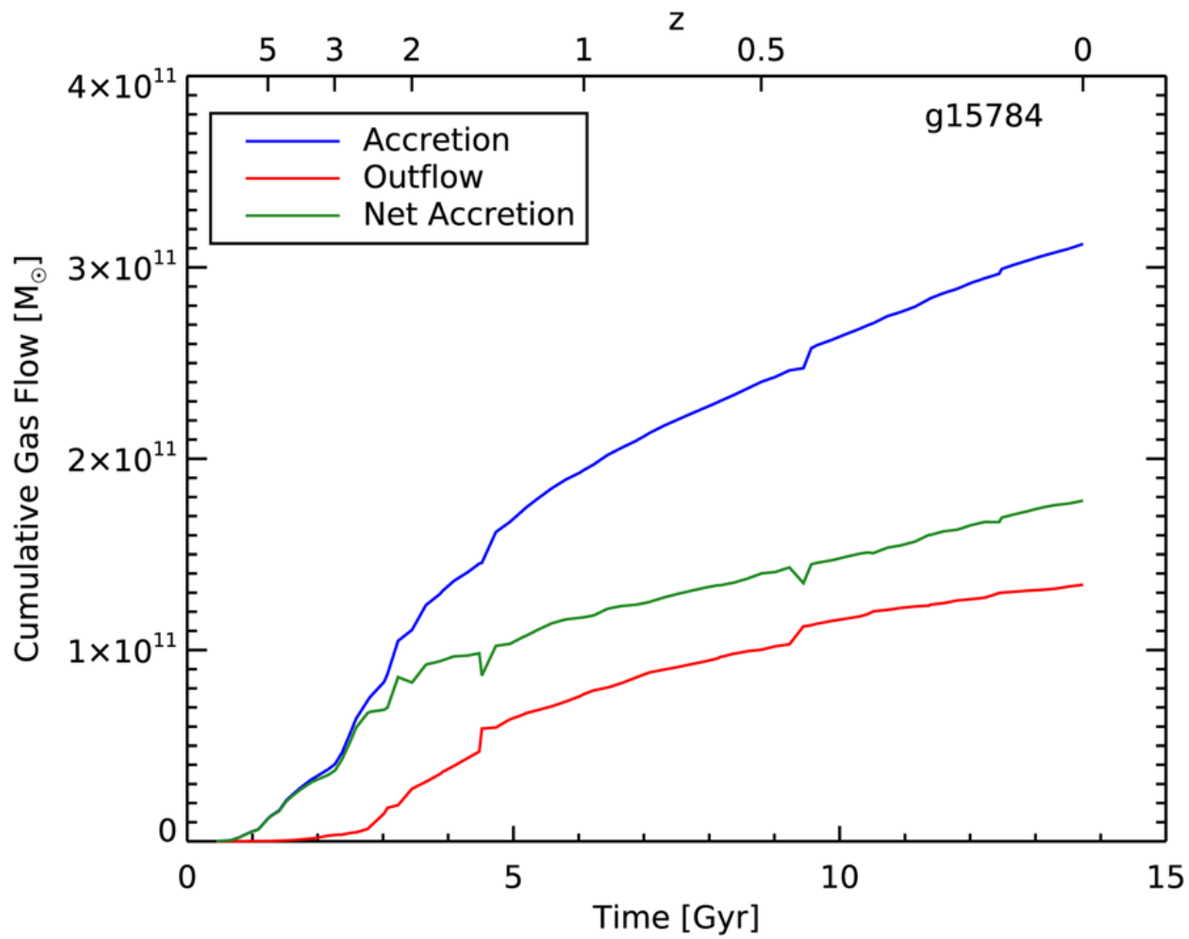




- Rapid accretion for 4-5 Gyr (15 $M_\odot$/yr), slow steady accretion since then (7 $M_\odot$/yr).
- Very little outflow.

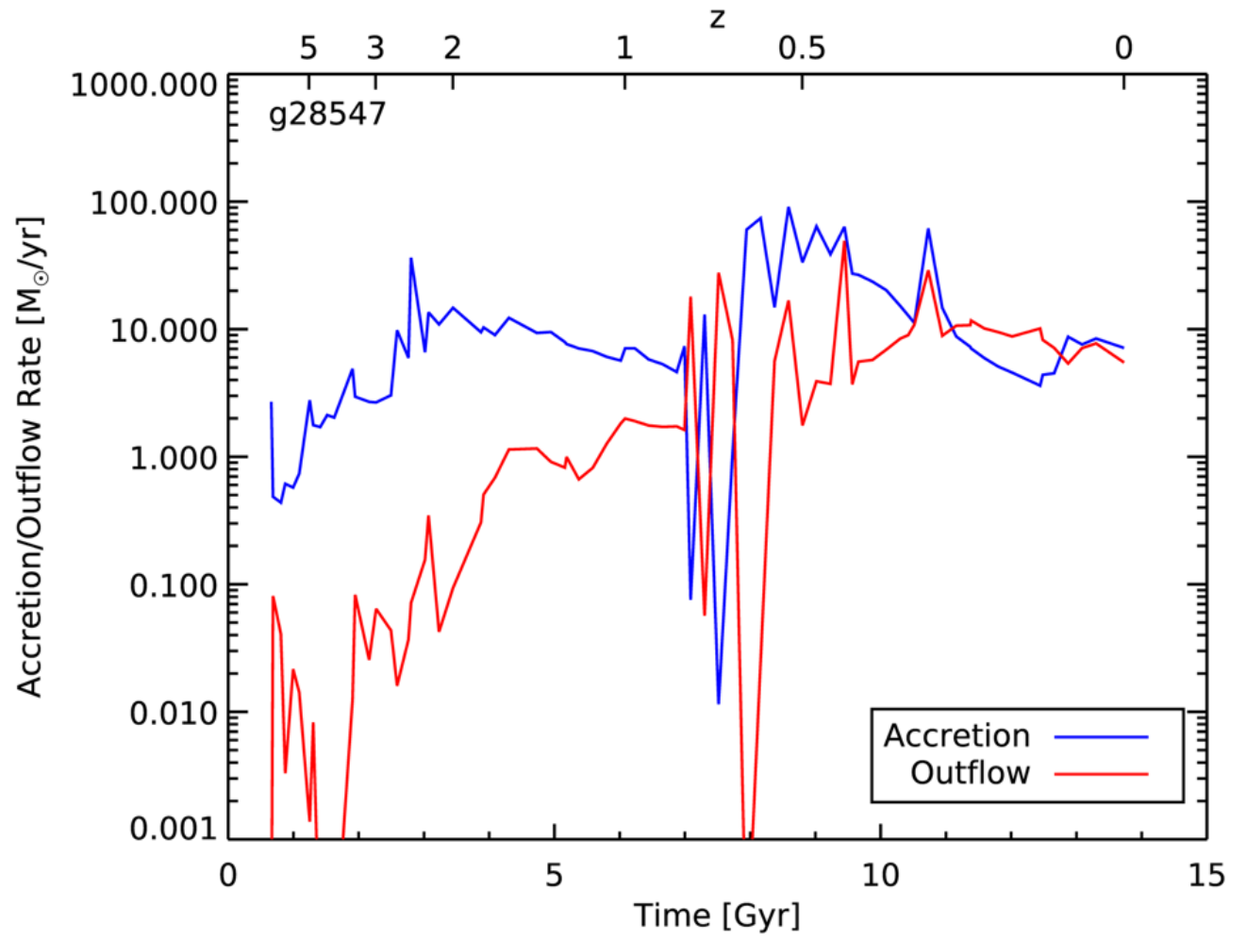
Gas Accretion Histories

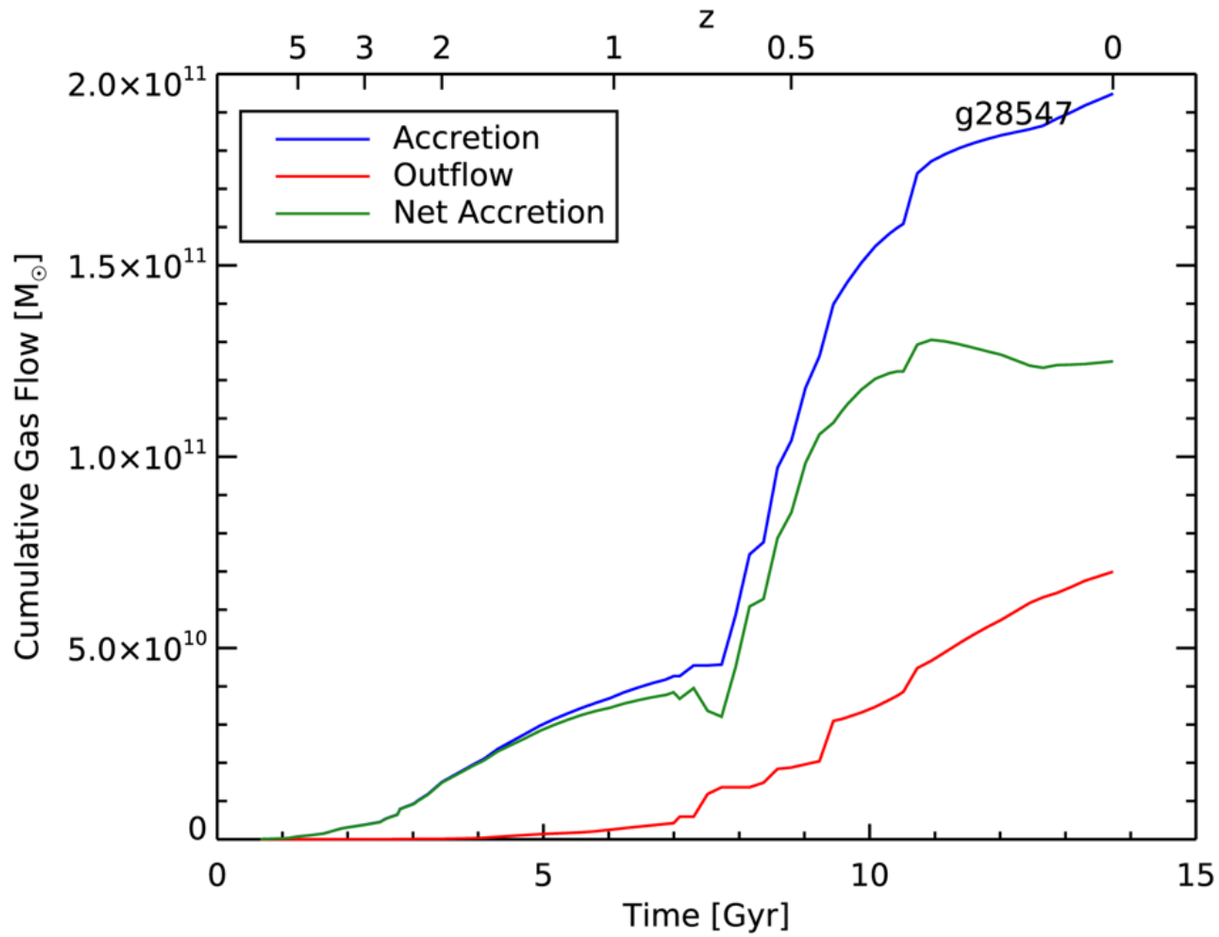




- Rapid accretion for 3 Gyr (30 $M_\odot$/yr), slow steady accretion since (10-20 $M_\odot$/yr).
- Second phase accompanied by 1/3 outflow.

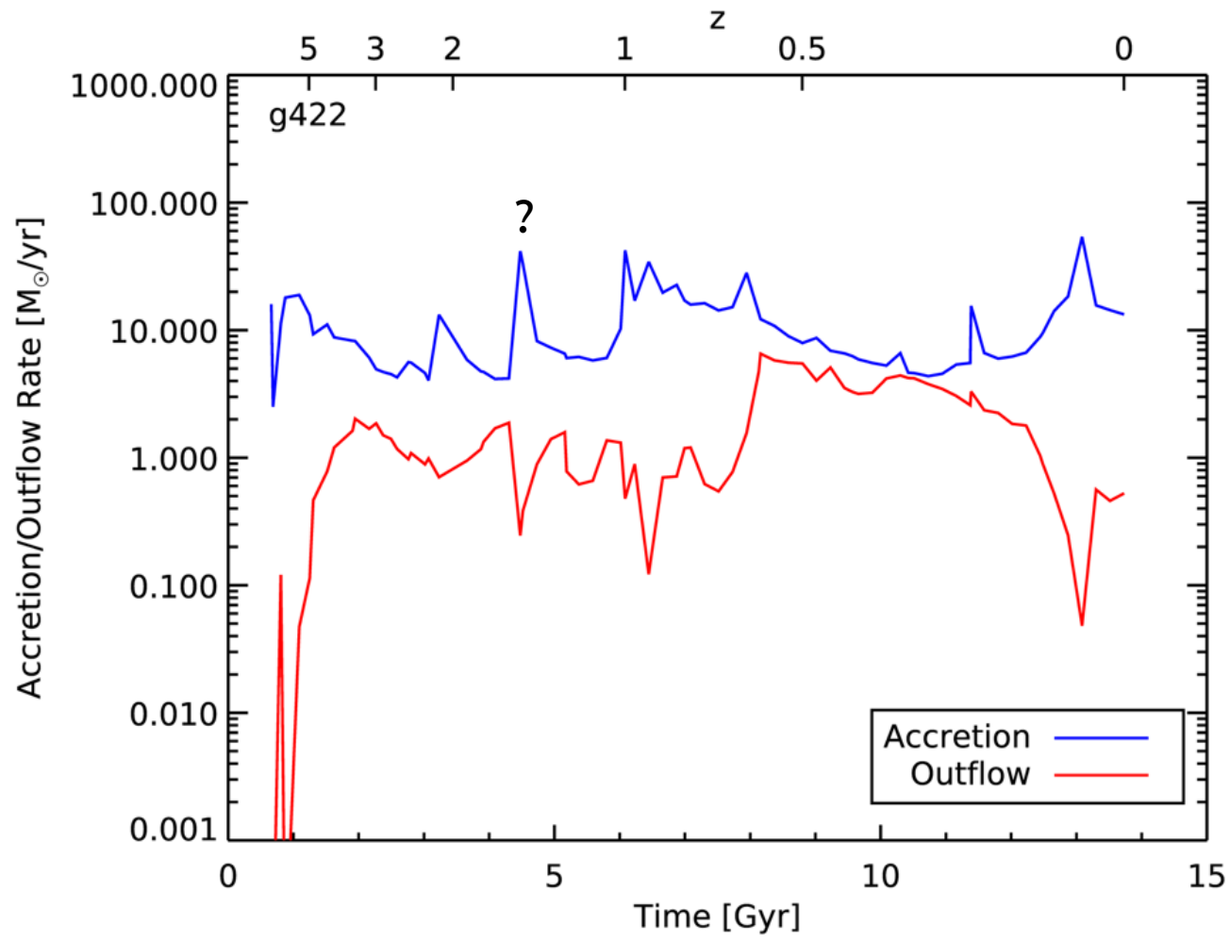
Gas Accretion Histories

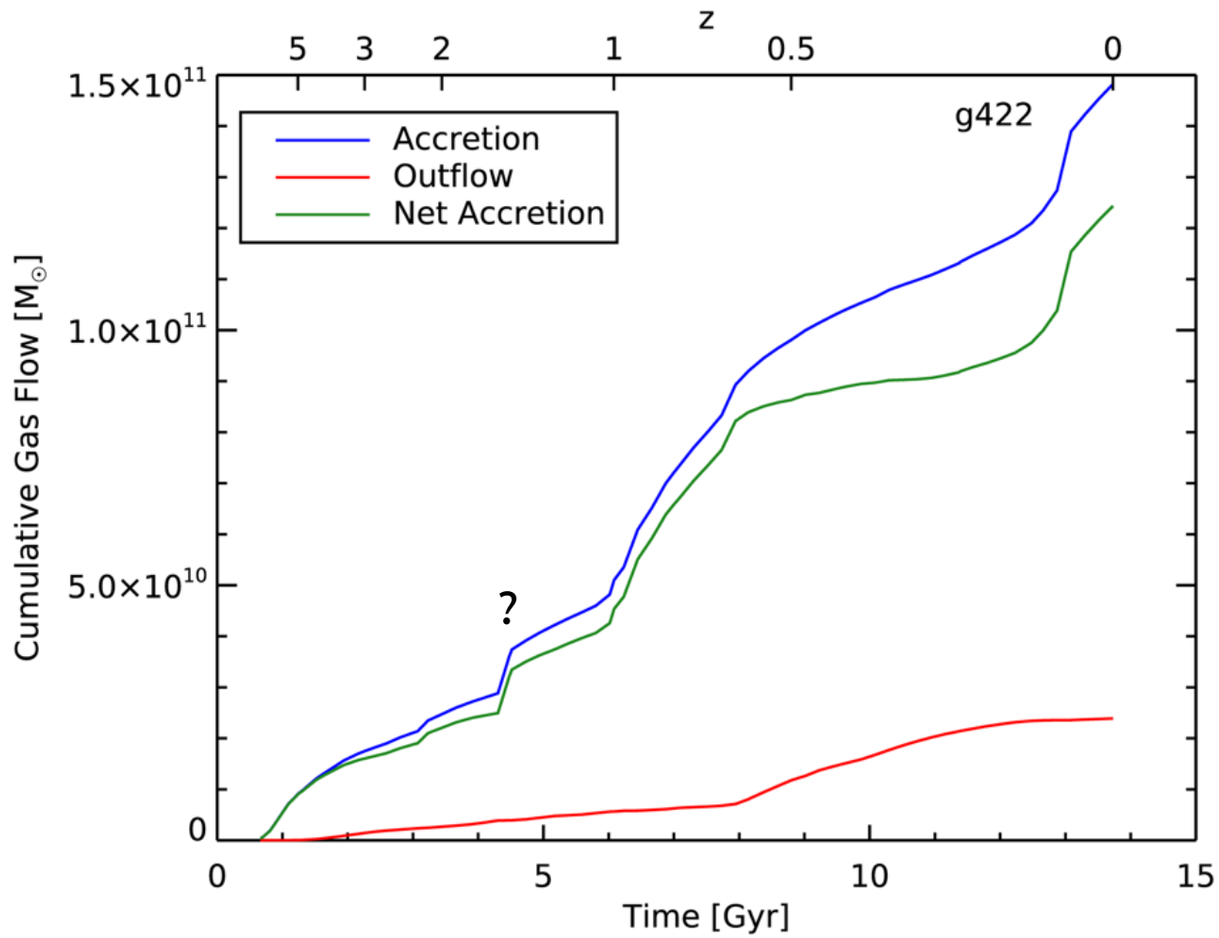




- Steady accretion (10 $M_\odot$/yr) for 7 Gyr, rapid accretion (35 $M_\odot$/yr) for 3 Gyr, steady accretion (5 $M_\odot$/yr) since.
- Outflows become increasingly important with time.

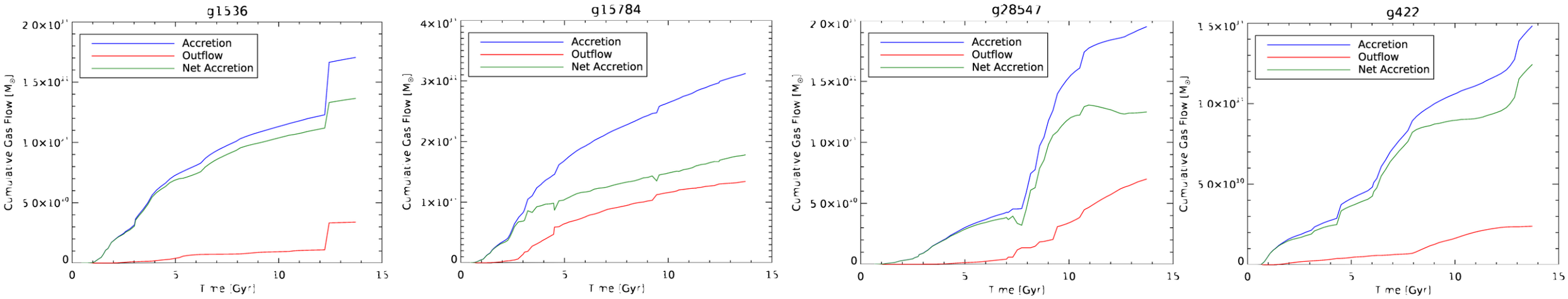
Gas Accretion Histories





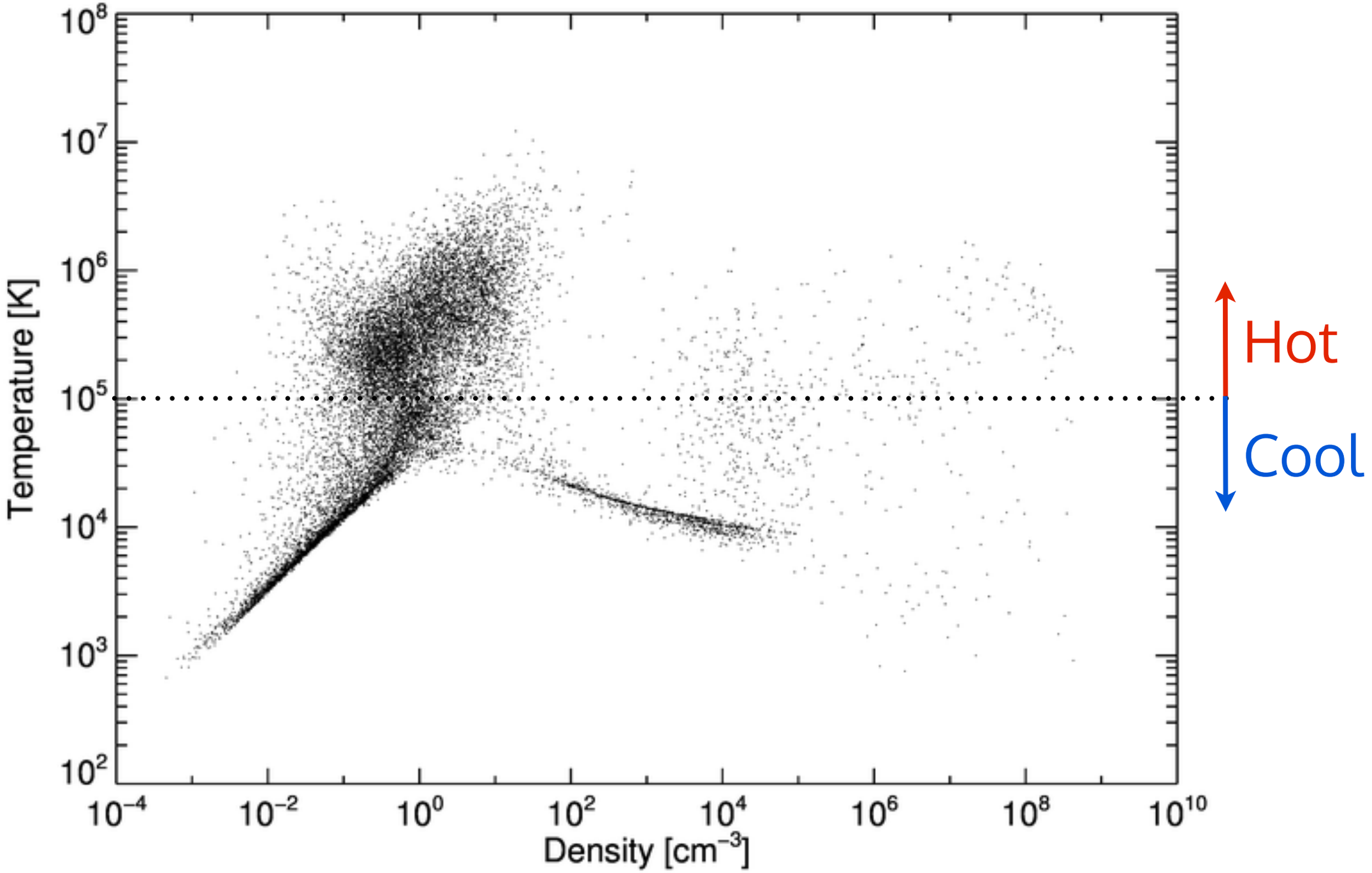
- Alternating periods of rapid (25 $M_\odot$/yr) and slow (5 $M_\odot$/yr) accretion.
- Outflows small except in one slow period.

Four Galaxies Tell Us…



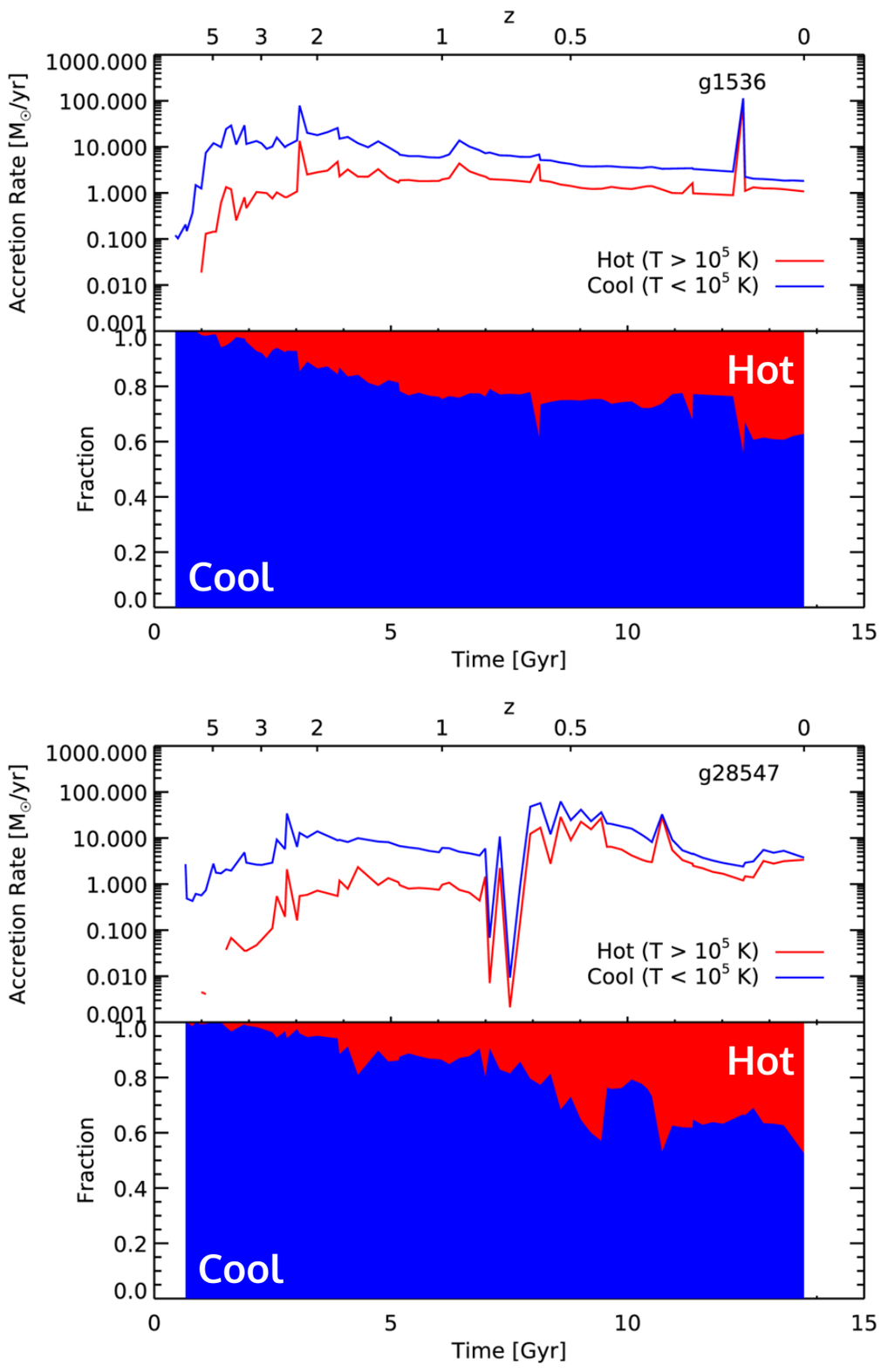
- Very different gas accretion histories can form Milky Way-ish galaxies!
- Periods of rapid and slow gas accretion. Duty cycles of these periods are stochastic.
- Accretion rates range from 5 - 35 $M_\odot$/yr.
- Importance of outflows vary significantly, but rarely dominate.

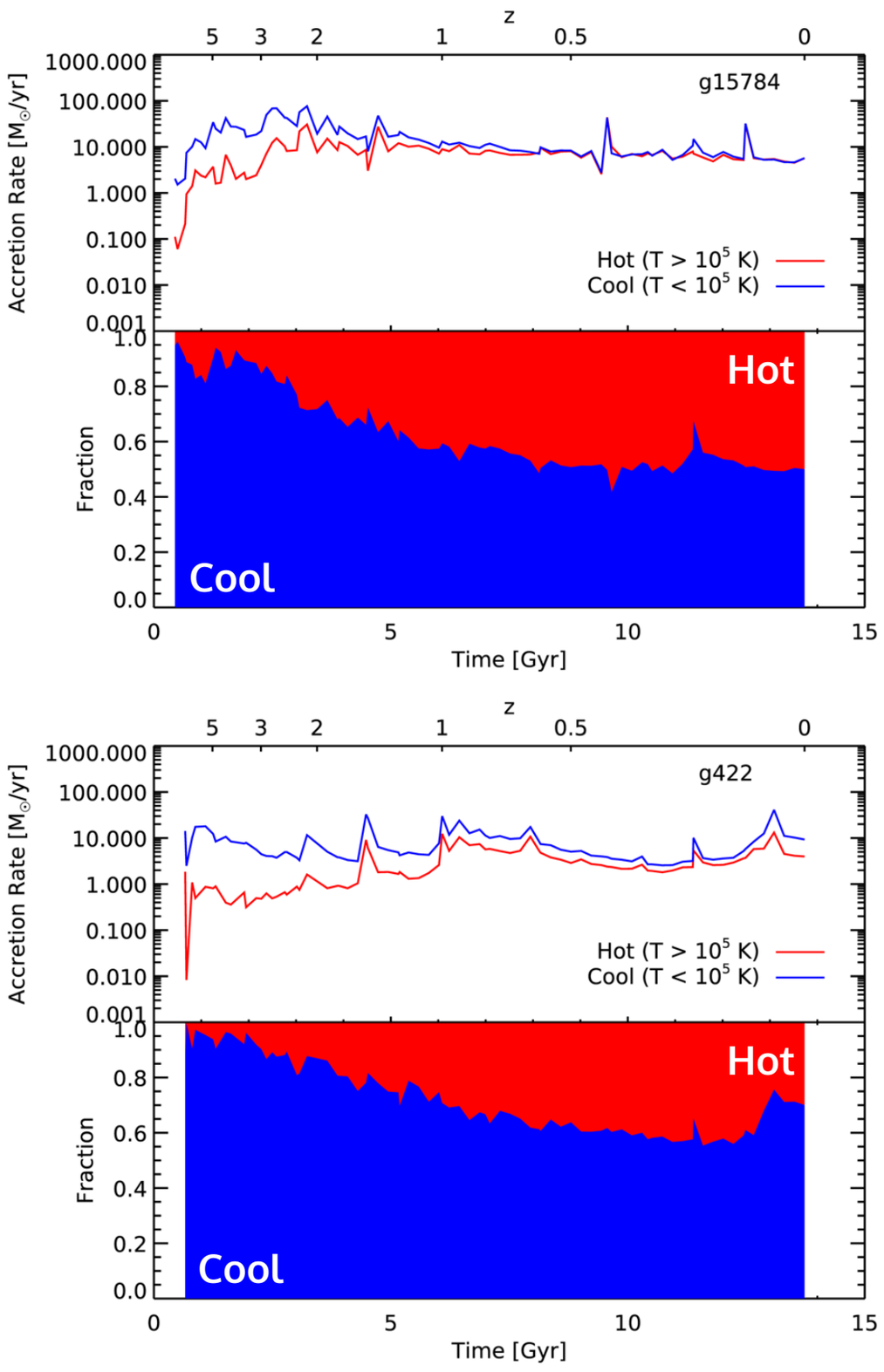
Phase Diagram of Accreted Gas



Accretion Mode

Cool/hot accretion histories have same shape: mostly coming from same structures with evolving multi-phase medium





Accretion/Star Formation

- Simulated gas accretion rates (5-35 $M_\odot$/yr) >> Milky Way SFR ~1 $M_\odot$/yr.
- At least one of the following must be true:
  - SF fuel supply is increasing (unlikely).

Gaseous halo becoming more massive

- Most accreted gas never reaches the disk (e.g. hot component).
- Outflows from the disk stronger than outflows from halo.
- Outflows from halo are underestimated.

Conclusions

- Gas accretion histories of four simulated MW-like galaxies show significant variation, but all have alternating rapid vs. slow periods.
- Cool and hot gas are accreted in multiphase structures, not independently of each other.
- Most halo accretion must never reach disk, and/or outflows must be dominant.
- **There is more than one way to build a Milky Way!**