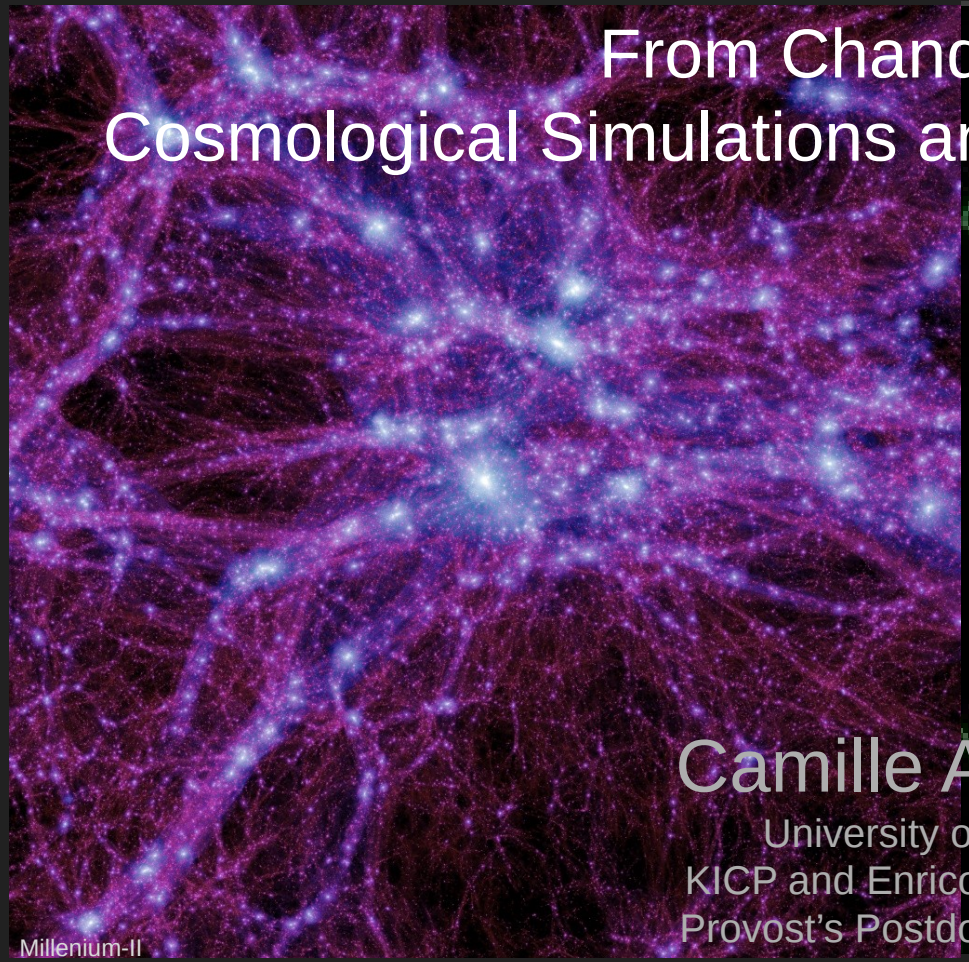
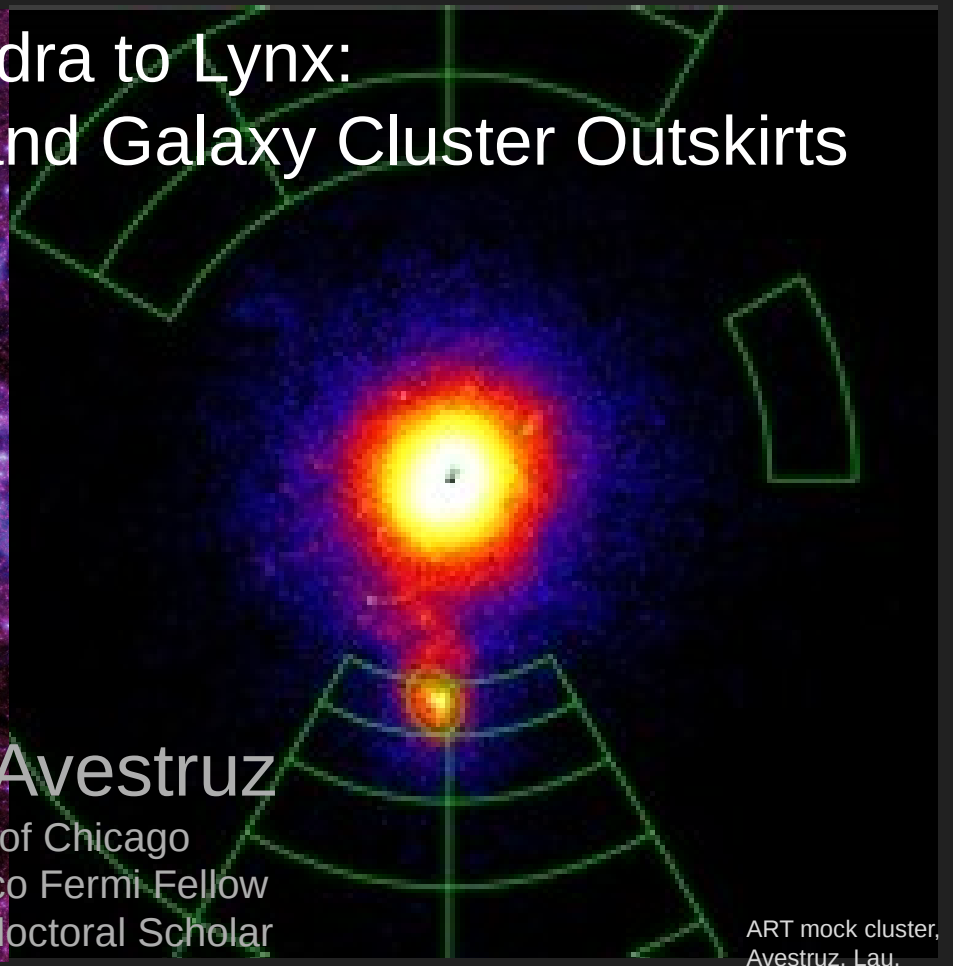
From Chandra to Lynx:
Cosmological Simulations and Galaxy Cluster Outskirts





Camille Avestruz

University of Chicago

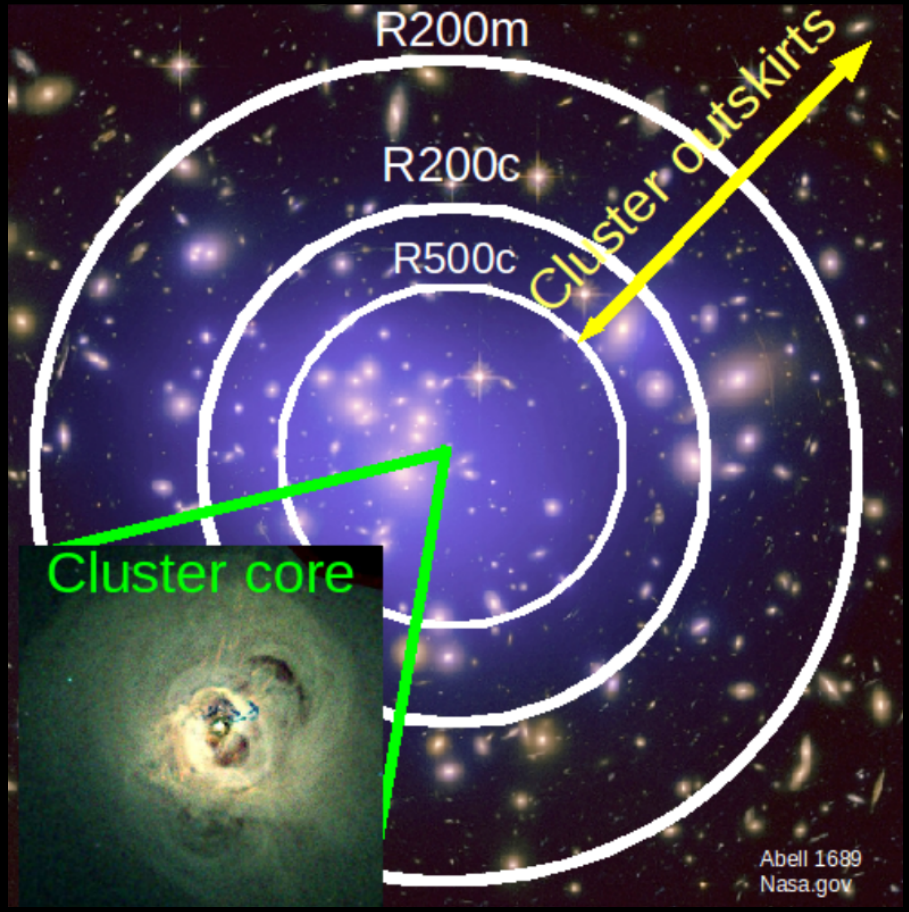
KICP and Enrico Fermi Fellow

Provost's Postdoctoral Scholar

Millenium-II

ART mock cluster, Avestruz, Lau, Nagai, Vikhlinin 14

Outskirts often defined with respect to a reference density



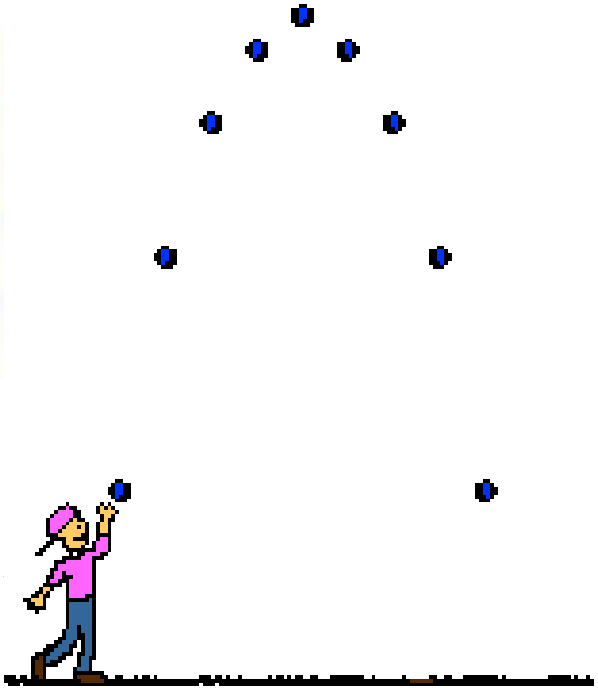
Accretion rate leaves imprints on cluster edges

More, Diemer, Kravtsov 15

Avestruz, Nagai, Lau, Nelson 15

Faster accretion shrinks the edge

More, Diemer, Kravtsov 15



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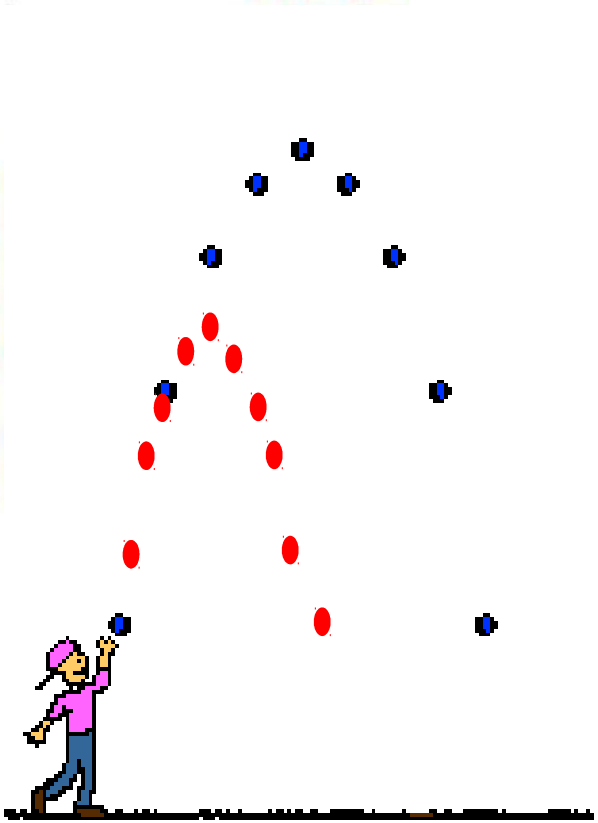

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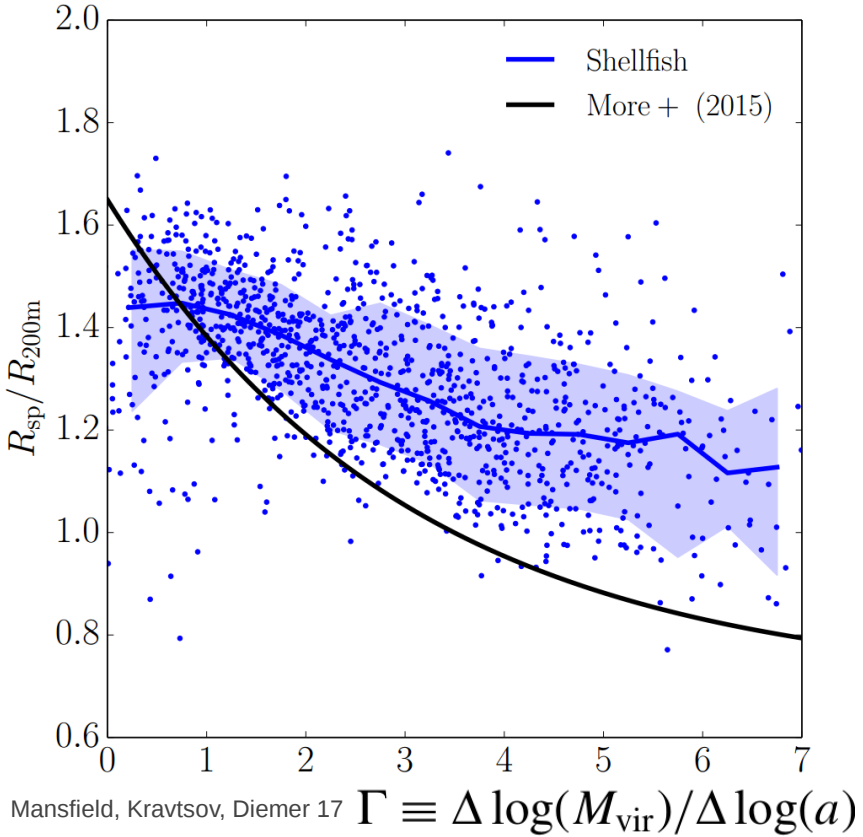

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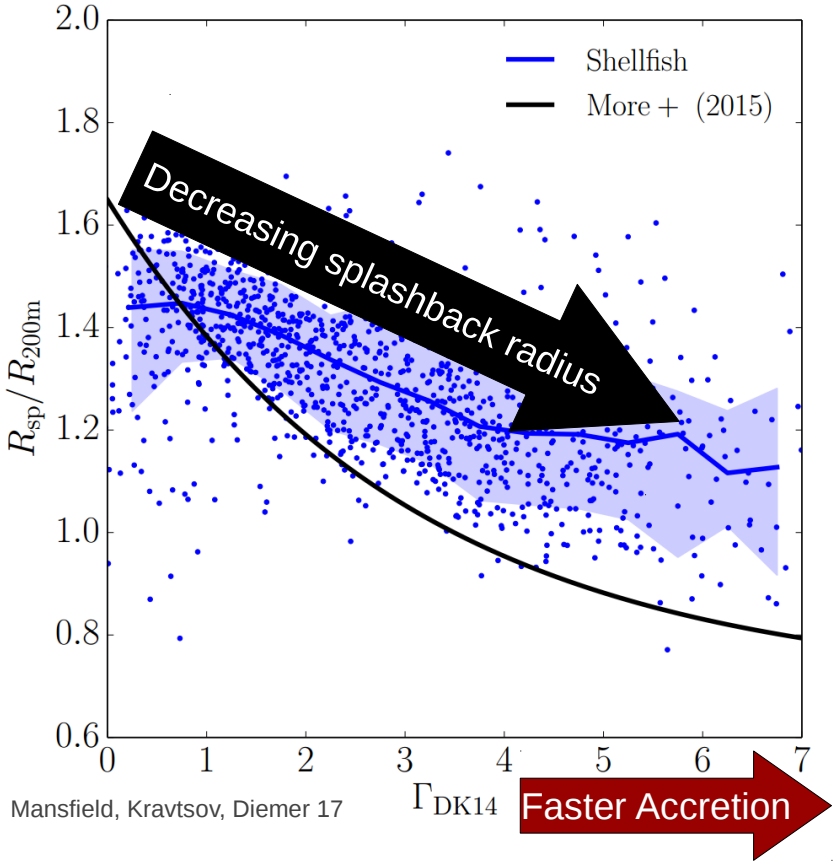
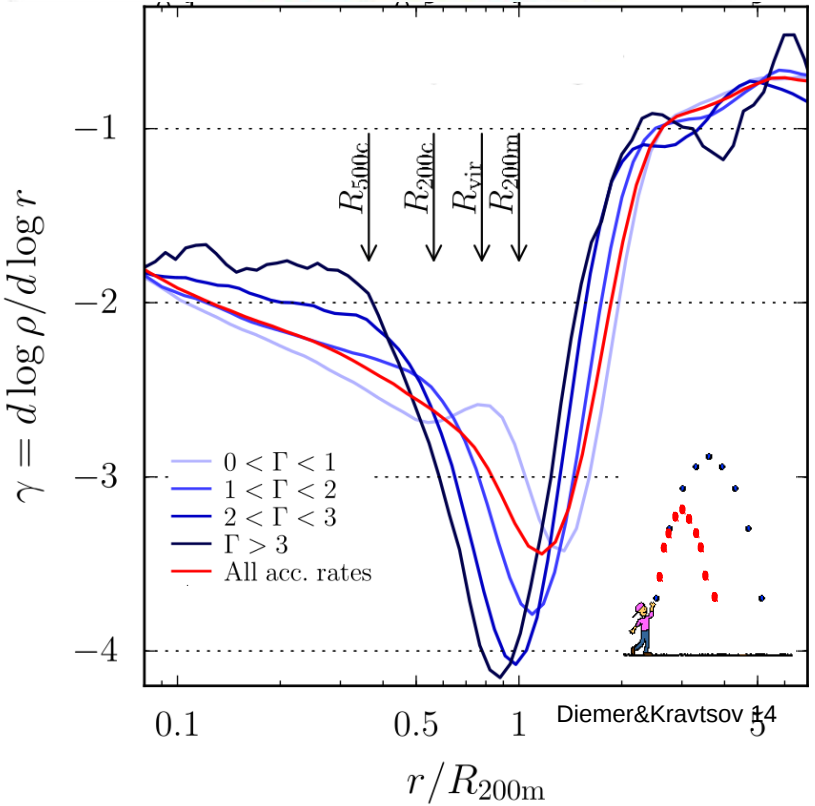


Faster accretion steepens the density profile (DM)



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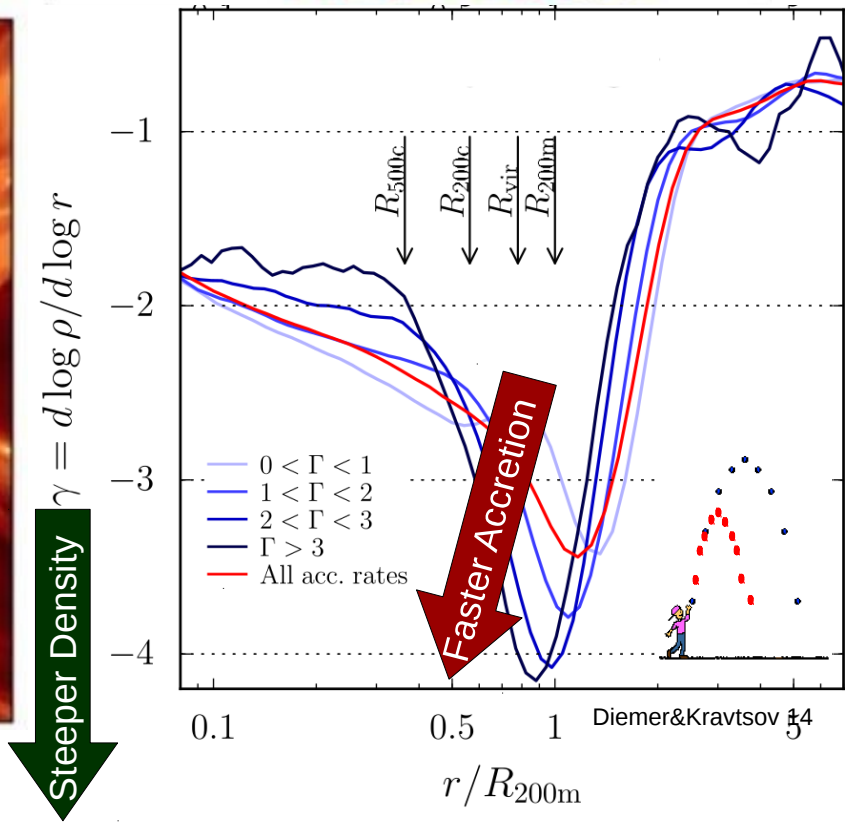
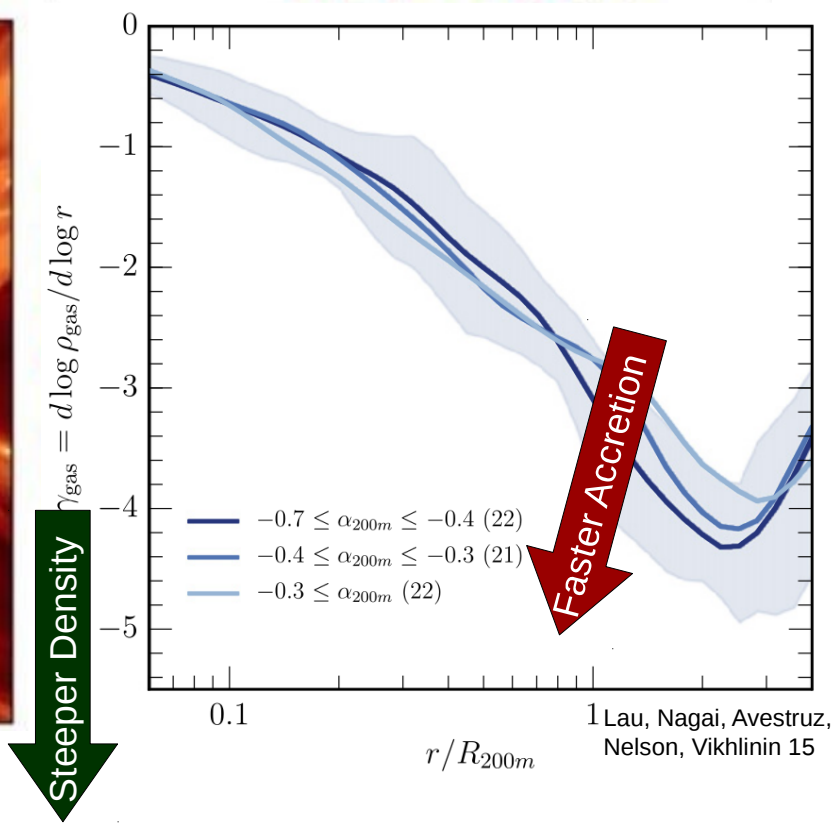
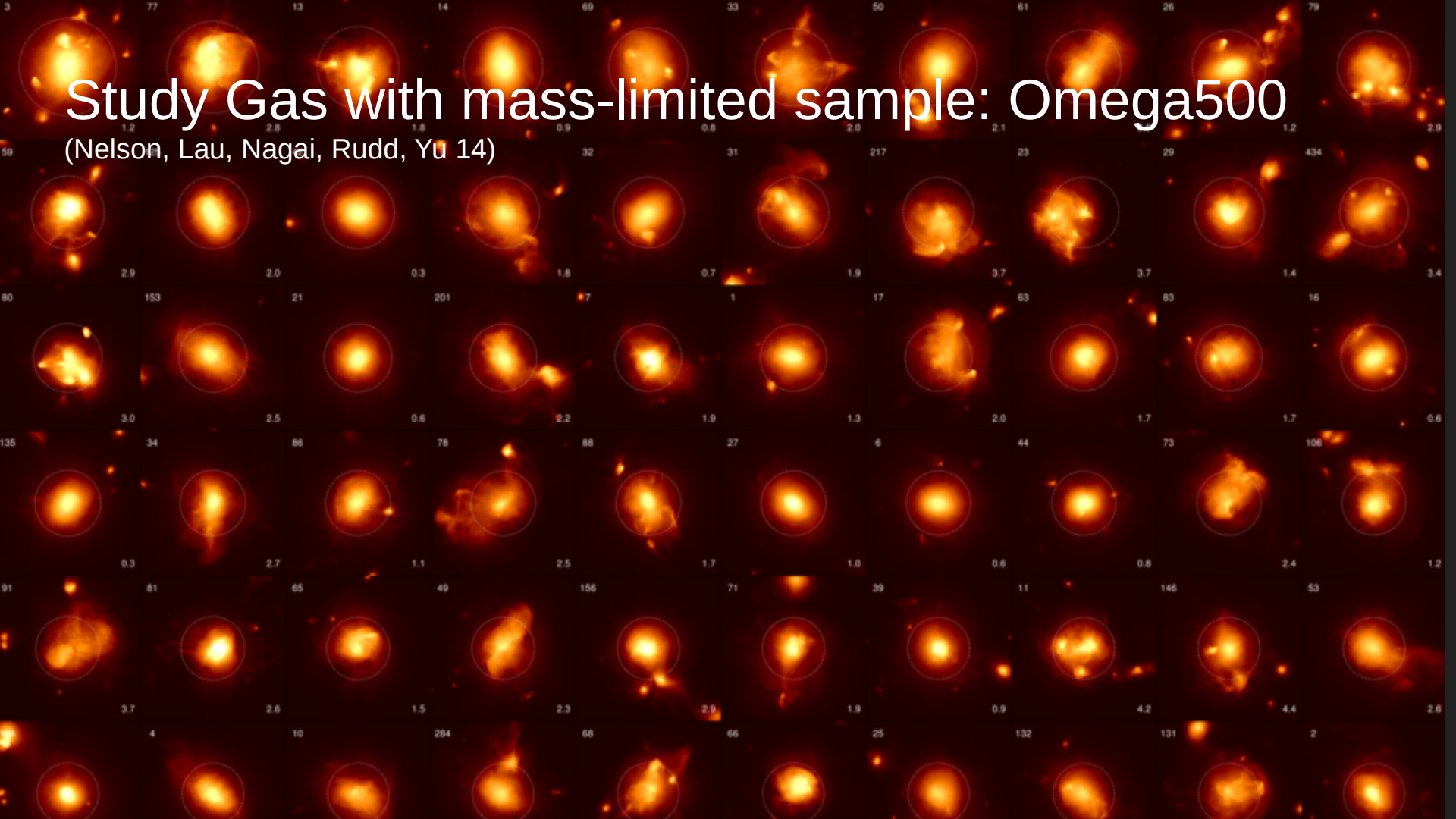


Faster accretion steepens the density profile (gas)

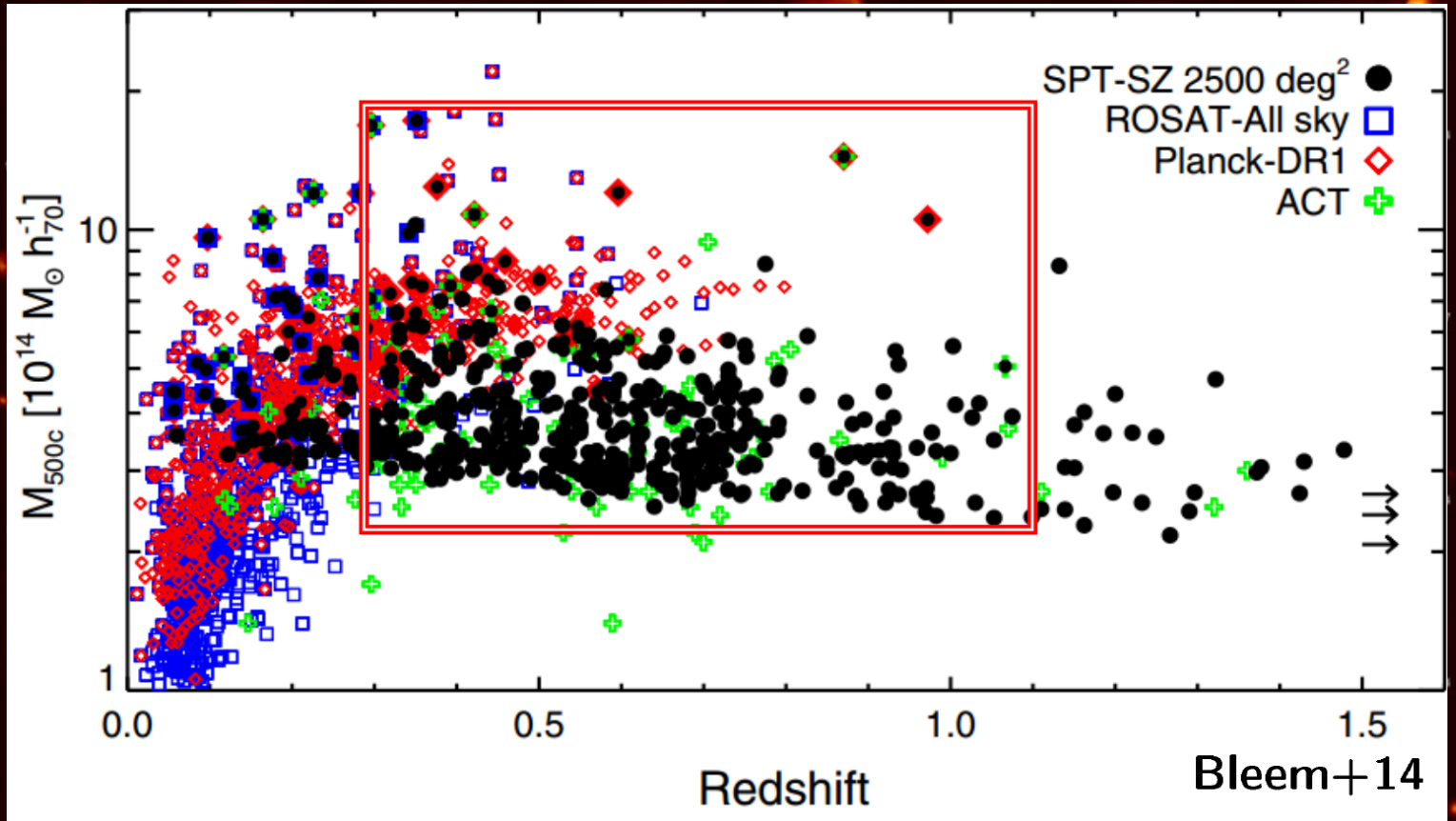


Study Gas with mass-limited sample: Omega500

(Nelson, Lau, Nagai, Rudd, Yu 14)



Study Gas with mass-limited sample: SPT-like

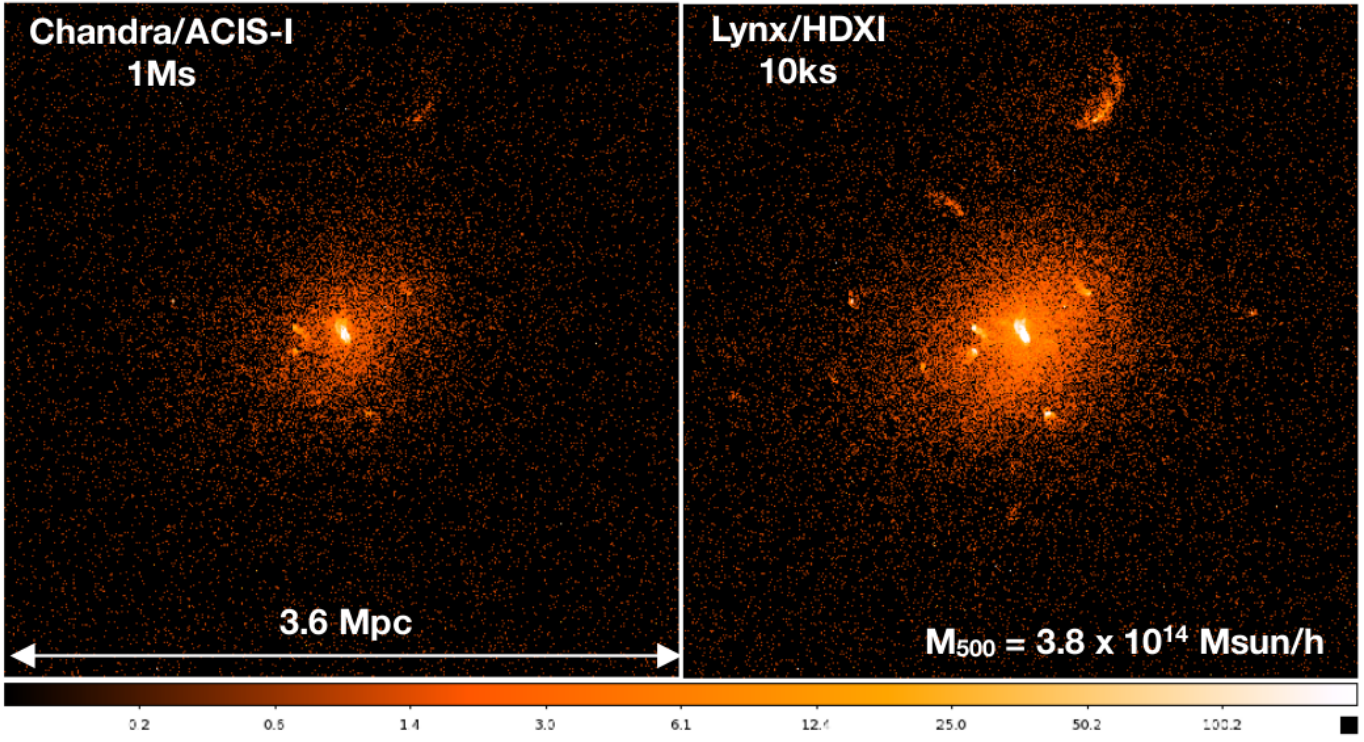


Chandra vs Lynx Mock Simulations of Omega500 Galaxy Clusters

High-Resolution *N*-body+Gasdynamics Cosmological Simulation with Adaptive Refinement Tree (ART) code on Yale's Omega HPC Cluster

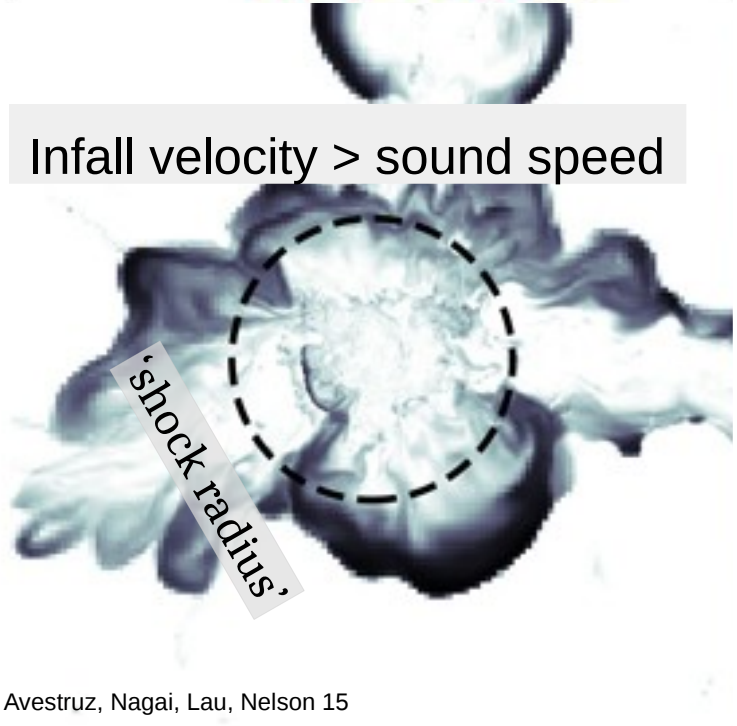
Box size = $500h^{-1}$ Mpc, DM particle mass ≈ $10^9 h^{-1} M_\odot$, Peak Spatial Resolution ≈ 3.8 h^{-1} kpc

Mock Chandra vs. Lynx maps of a simulated cluster with gas cooling, star formation, and thermal AGN feedback



Accretion rate leaves imprints on cluster edges

More, Diemer, Kravtsov 15



Avestruz, Nagai, Lau, Nelson 15

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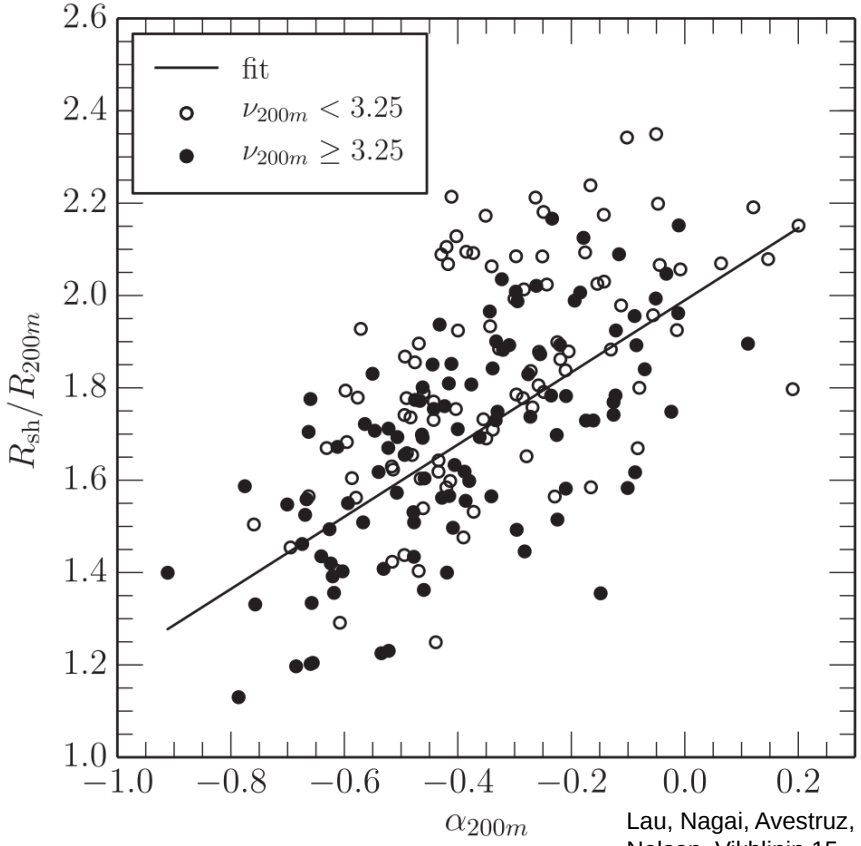
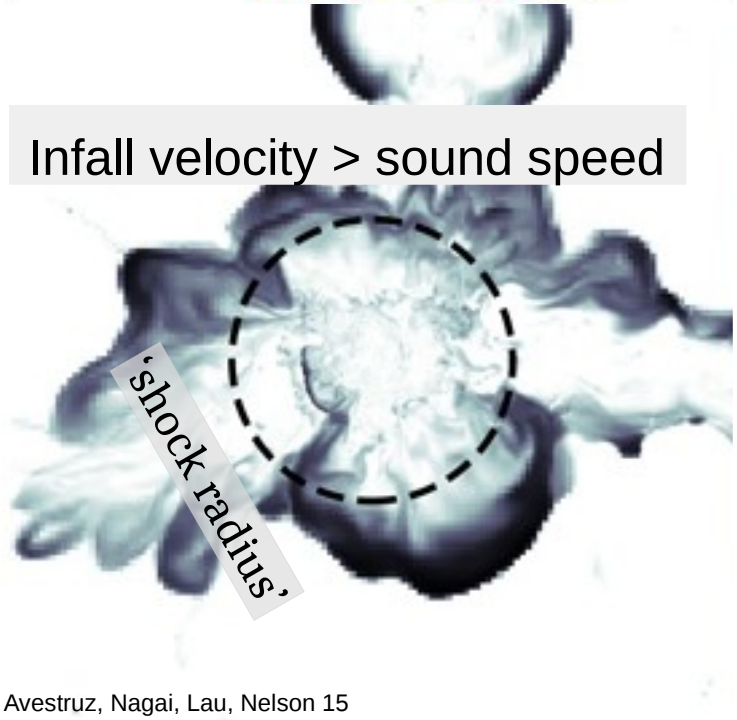


Lau, Nagai, Avestruz, Nelson, Vikhlinin 15



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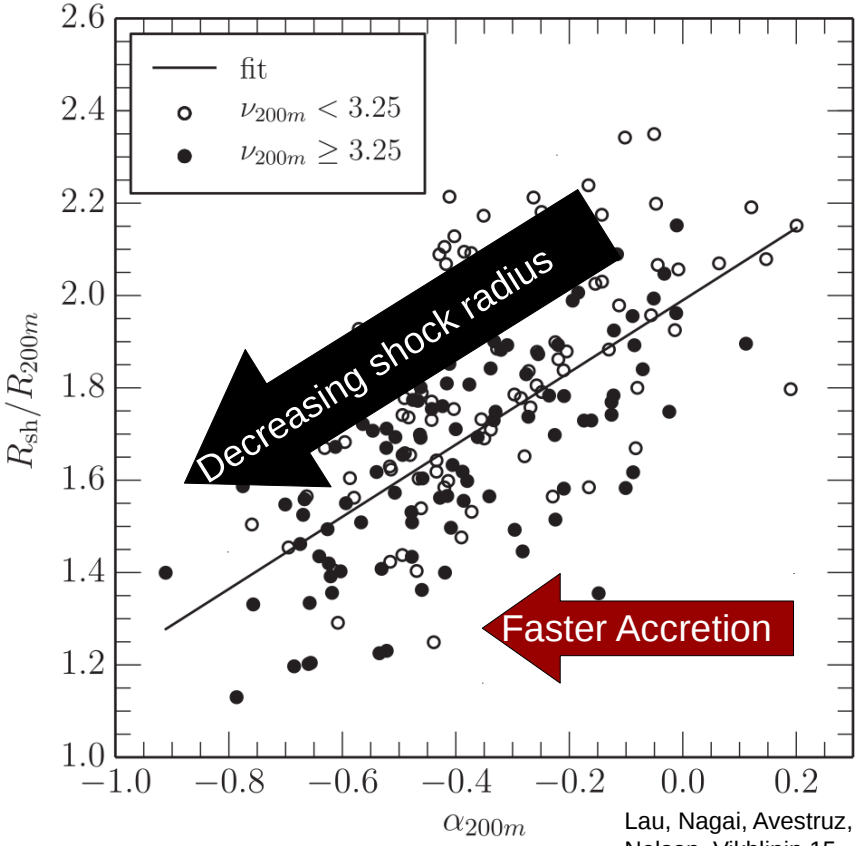
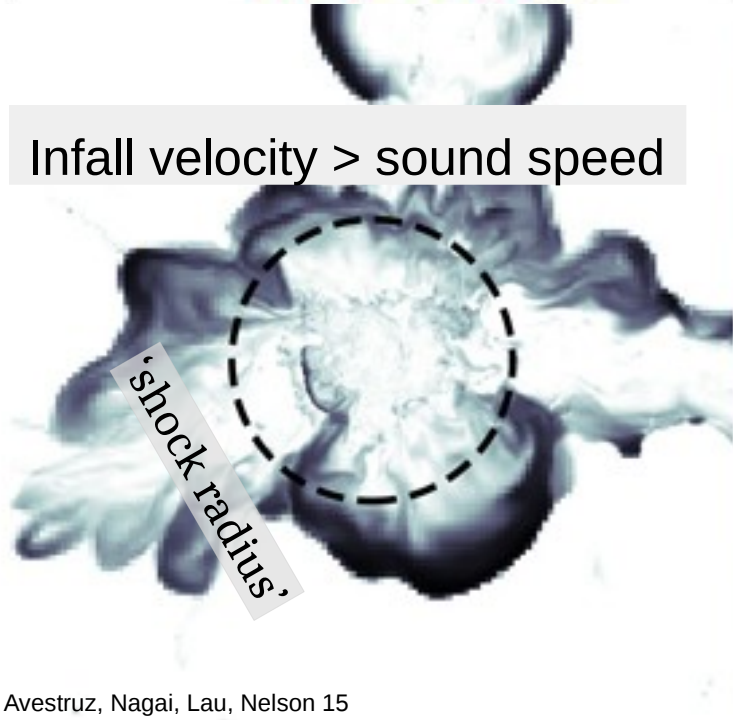
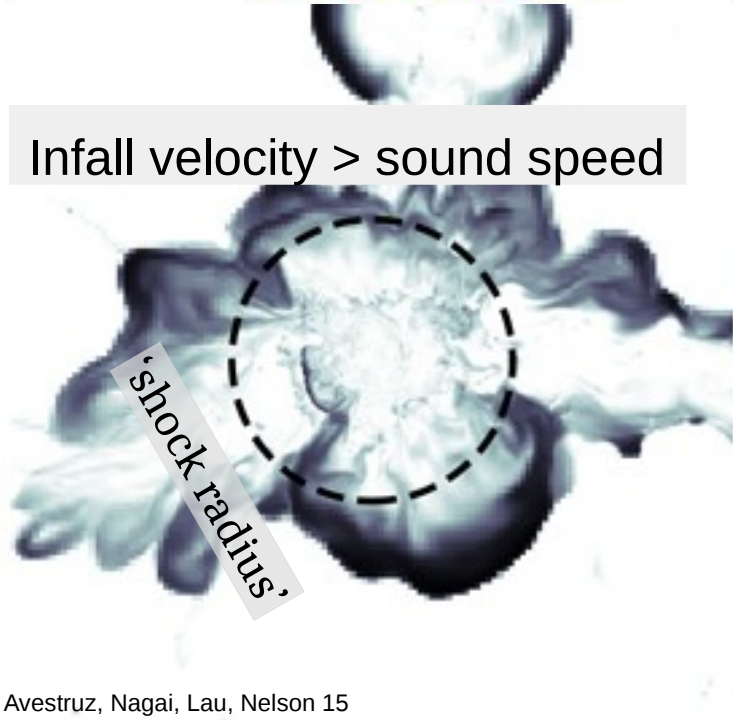


Lau, Nagai, Avestruz, Nelson, Vikhlinin 15



Avestruz, Nagai, Lau, Nelson 15

Accretion stirs the outskirt intracluster medium



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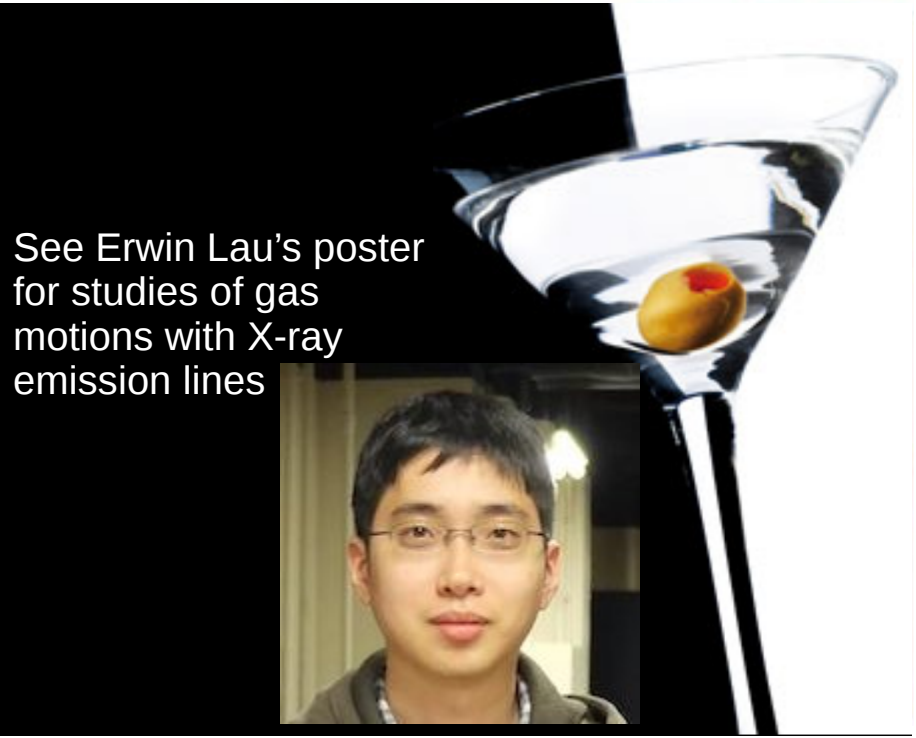
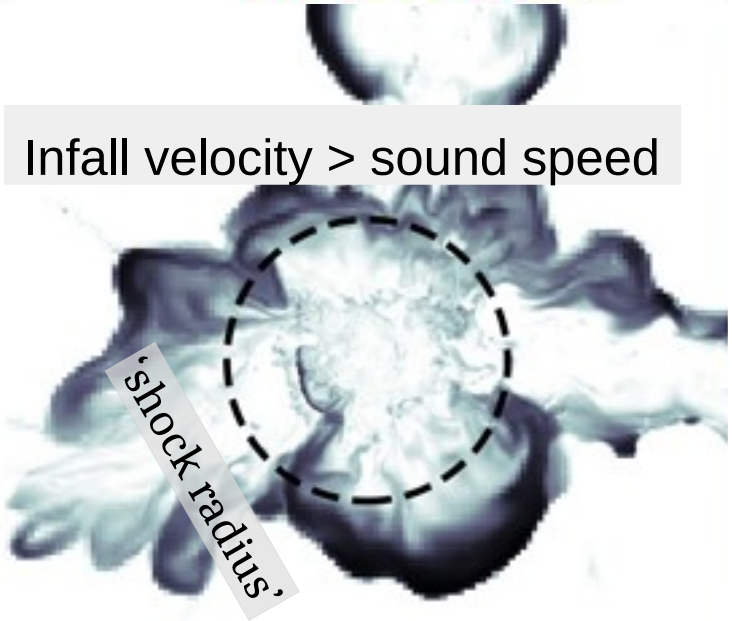


See Erwin Lau's poster for studies of gas motions with X-ray emission lines



Avestruz, Nagai, Lau, Nelson 15

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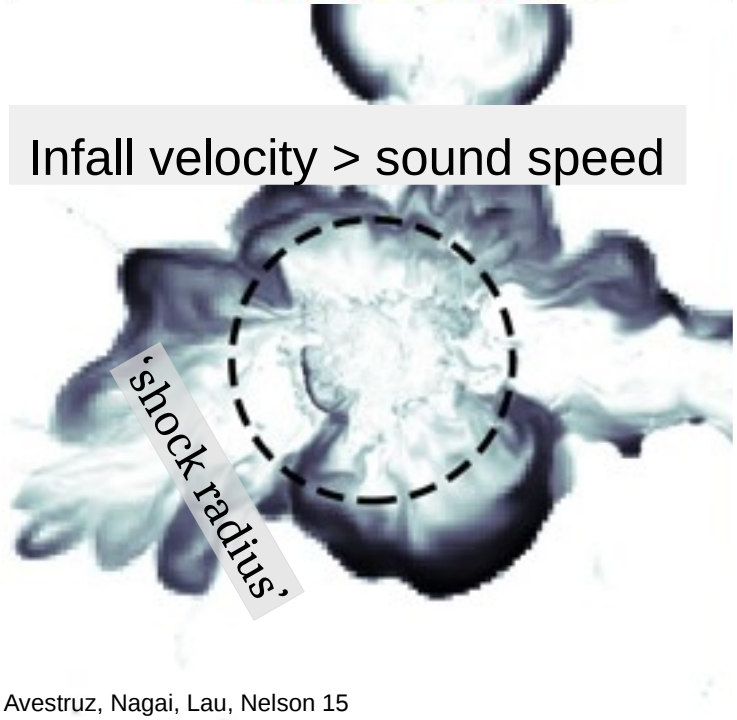
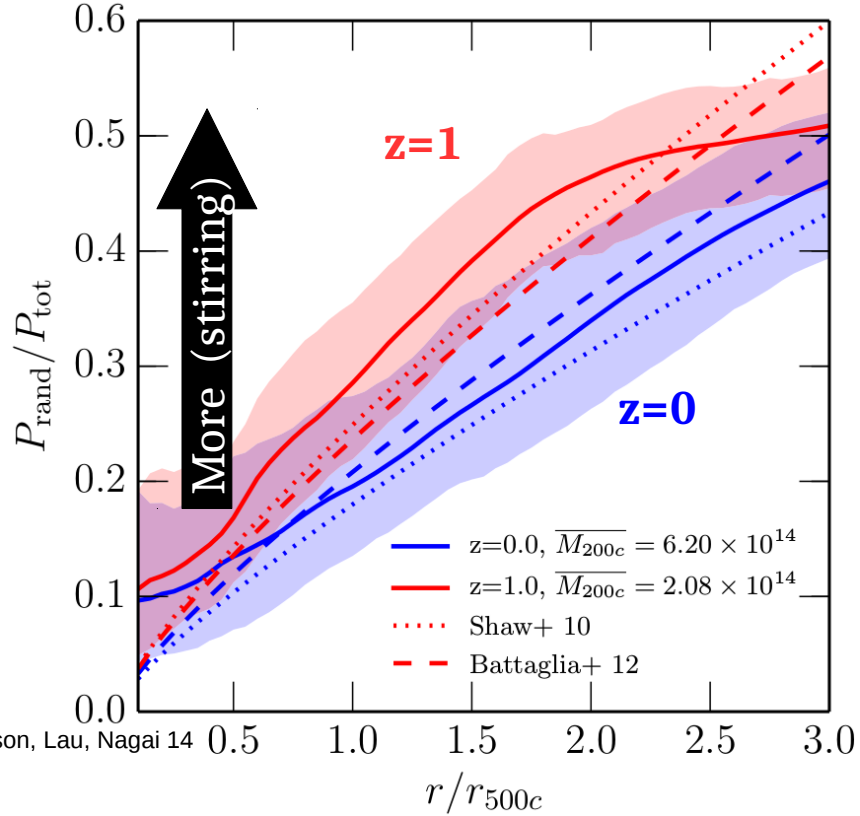
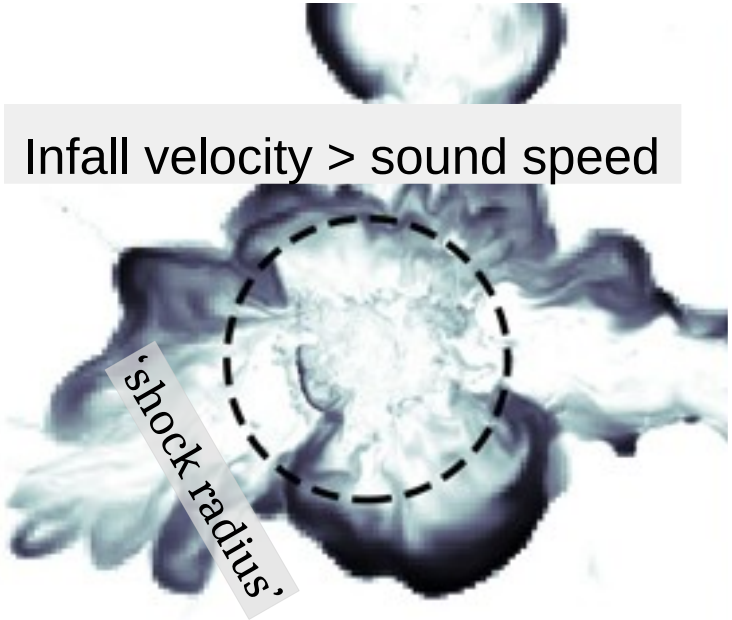


Avestruz, Nagai, Lau, Nelson 15

More stirring at higher redshift



Nelson, Lau, Nagai 14



Avestruz, Nagai, Lau, Nelson 15

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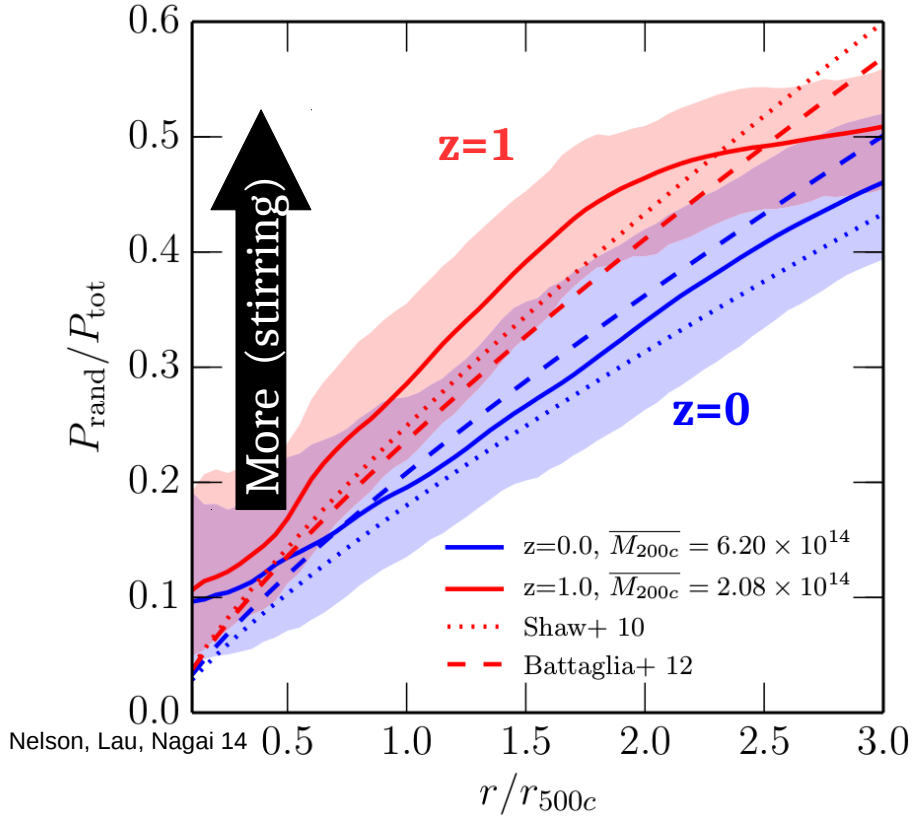
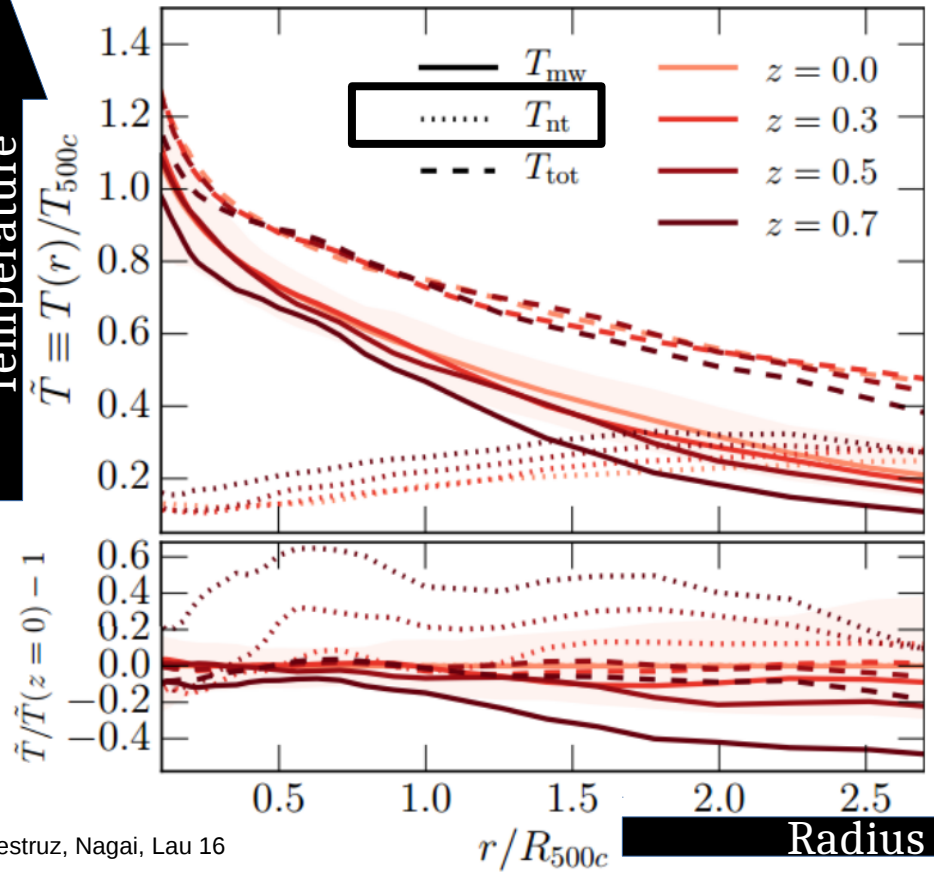


Nelson, Lau, Nagai 14

Non-thermal Temperature:

$k_b T_{nt} \equiv 1/3\ \mu\ m_p \langle v^2_{gas} \rangle_{mw}$

Less thermalized gas at higher redshift: T evolution



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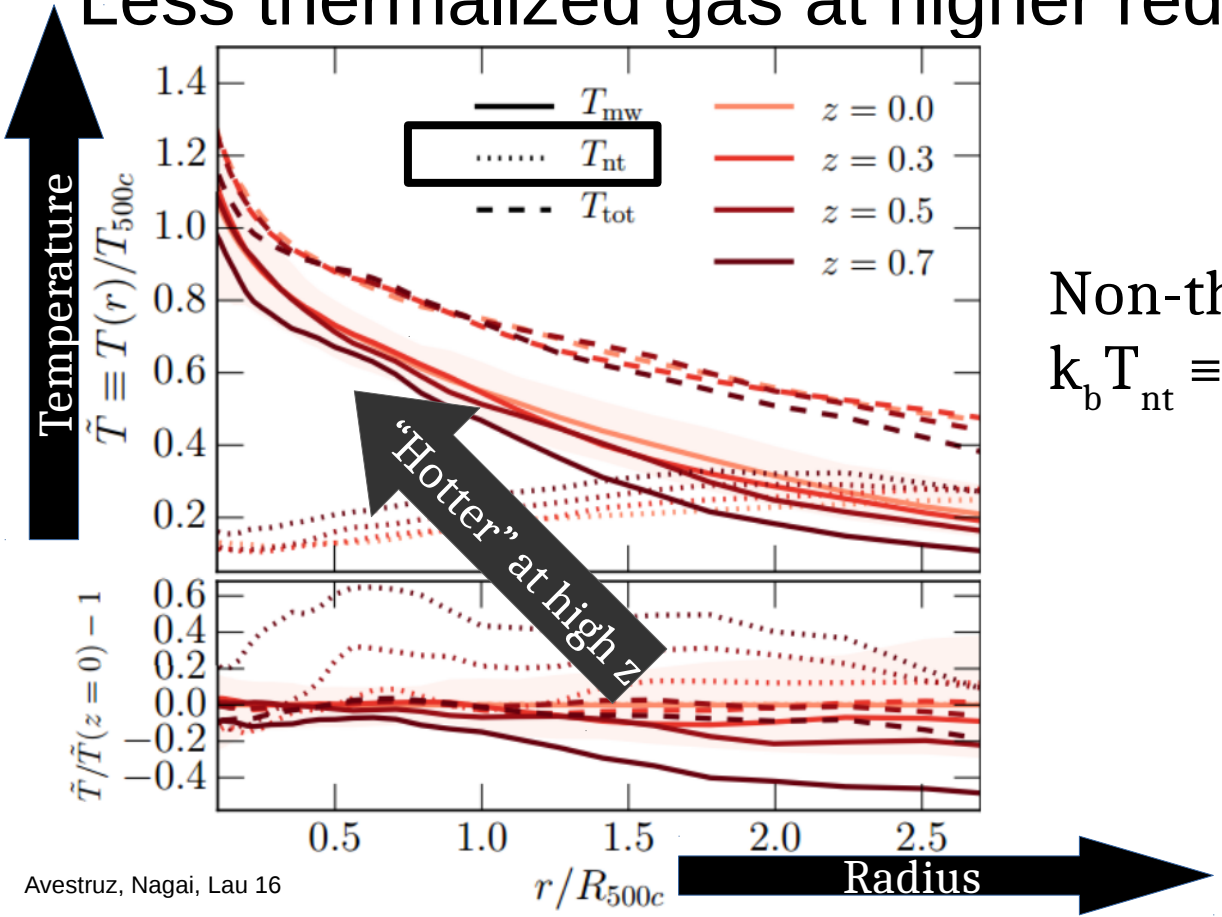

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Avestruz, Nagai, Lau 16

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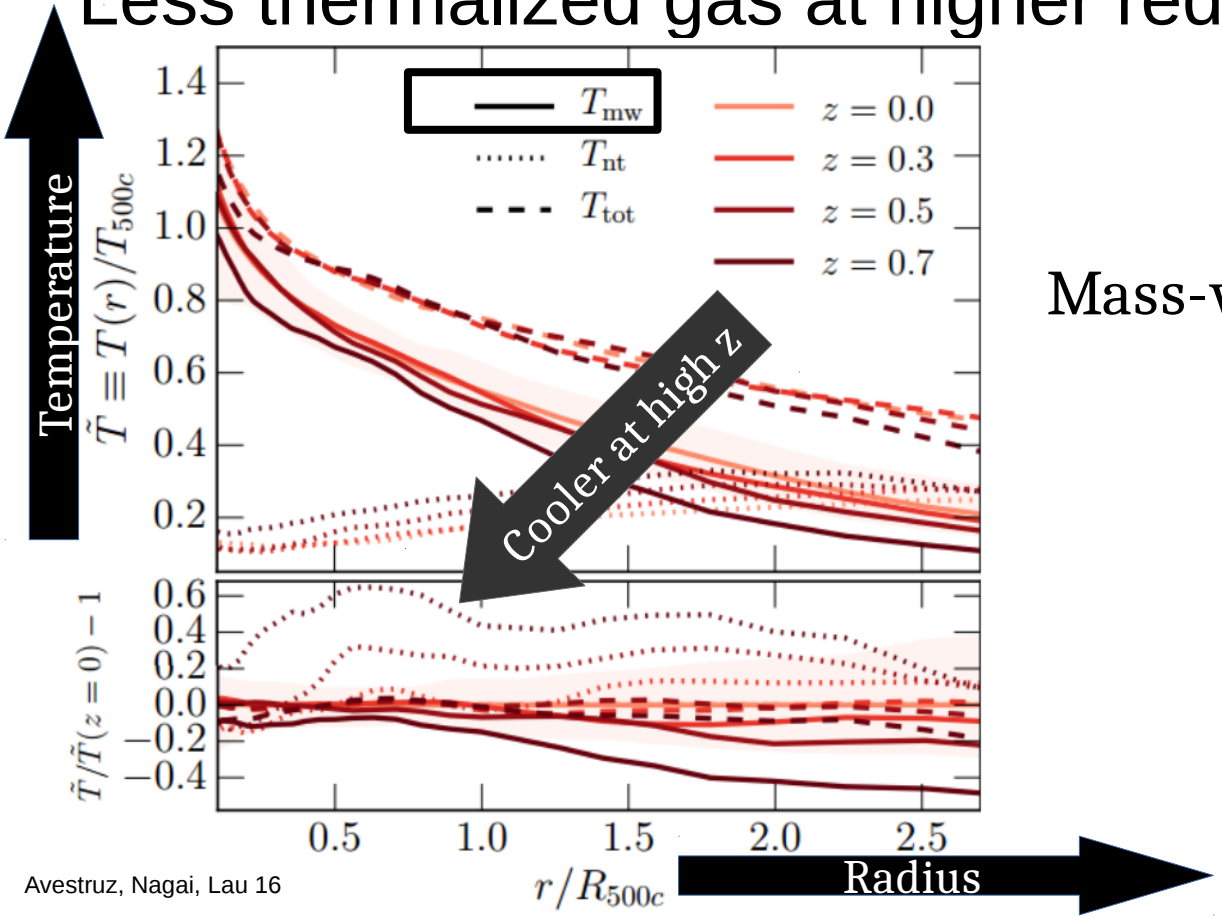
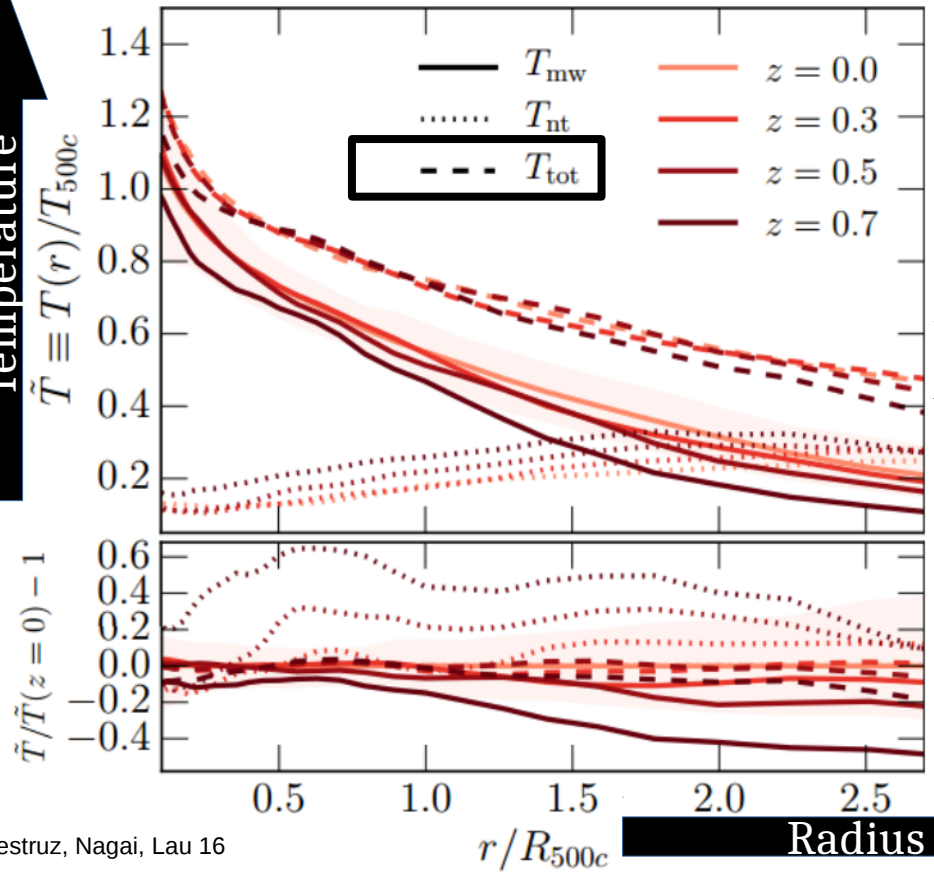


Mass-weighted temperature

Avestruz, Nagai, Lau 16

Less thermalized gas at higher redshift: T evolution

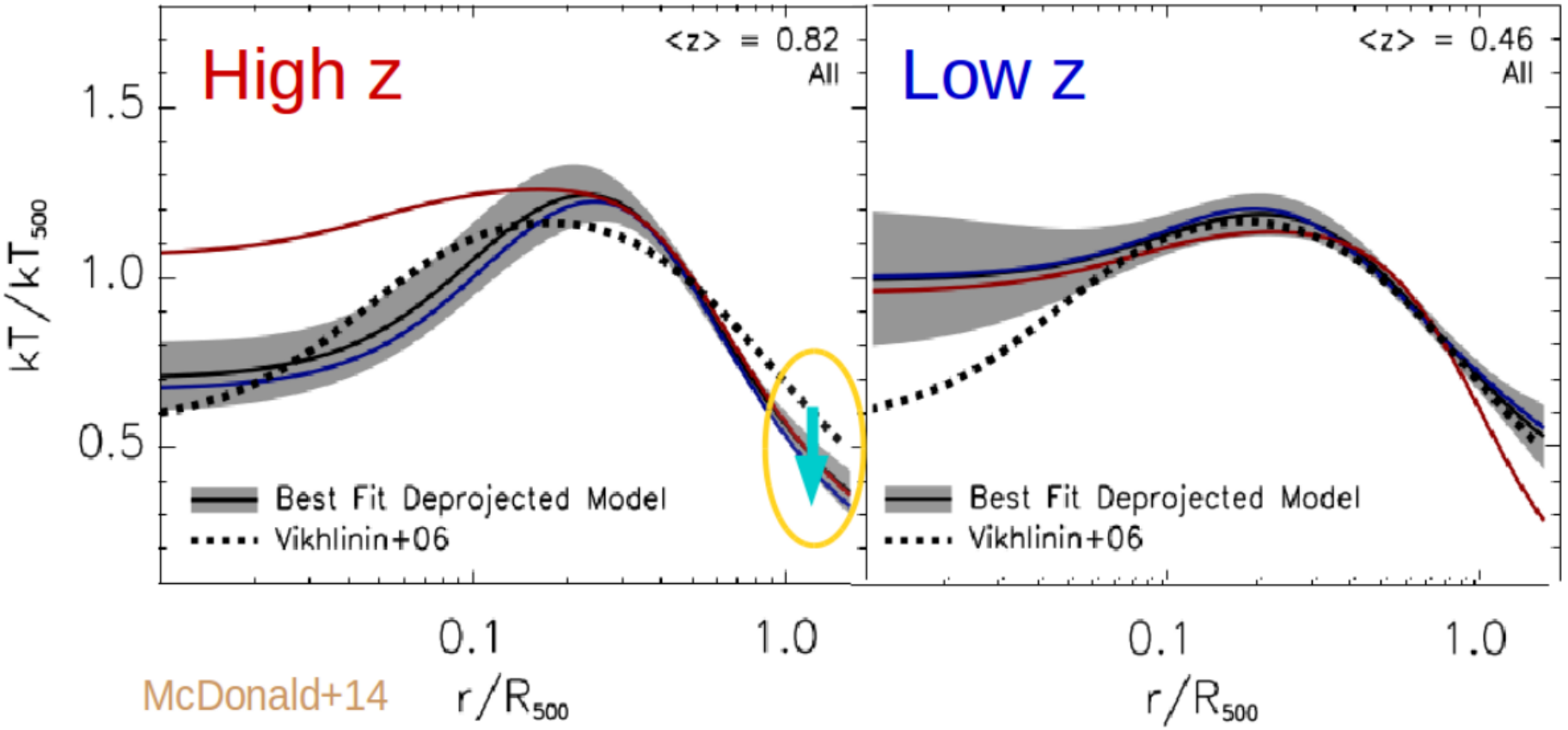


“Total” temperature

No evolution

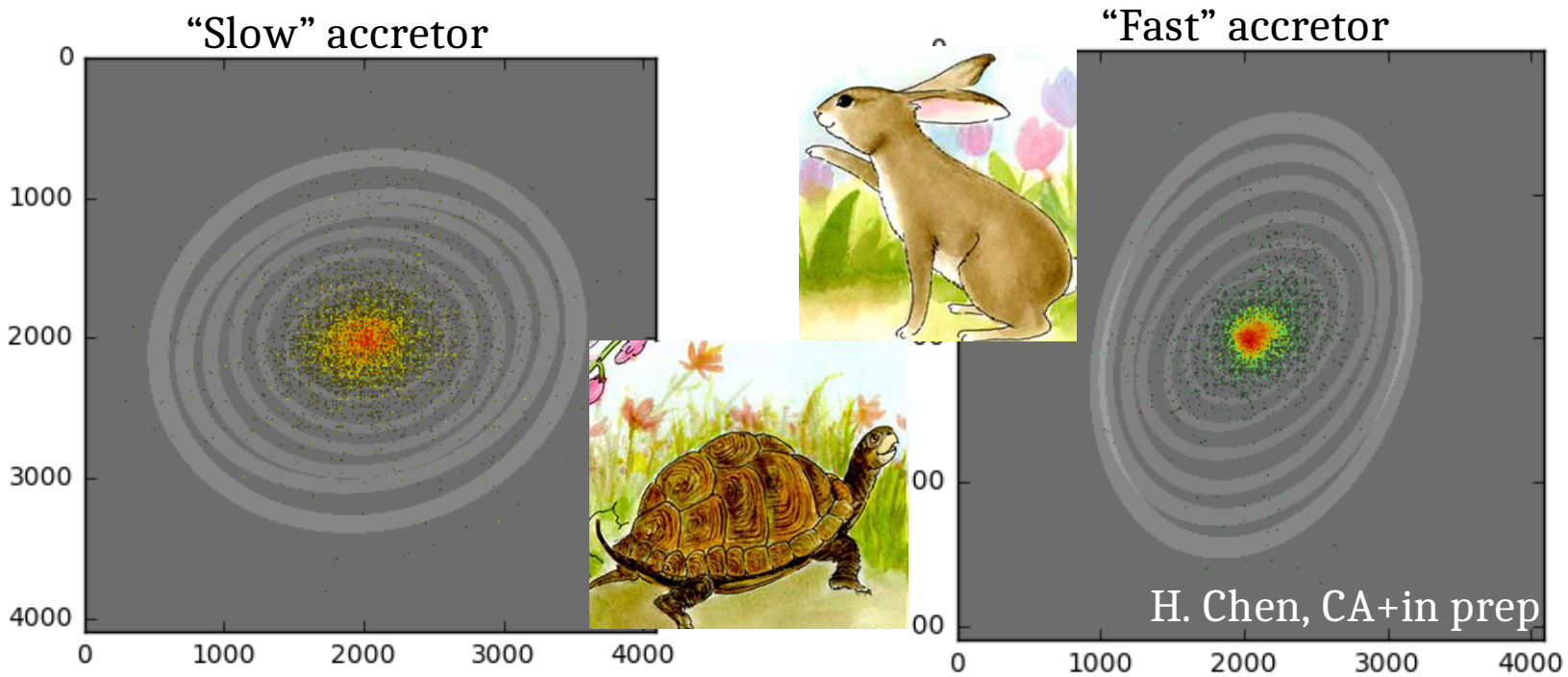
Avestruz, Nagai, Lau 16

Less thermalized gas at higher redshift: T evolution



McDonald+14

Accretion elongates cluster shape



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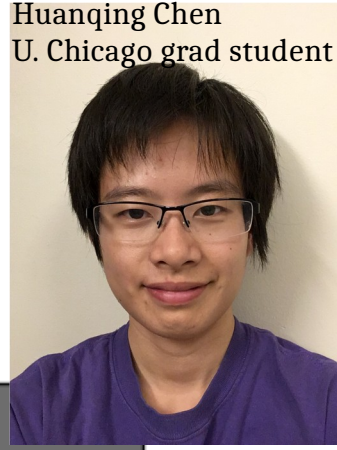
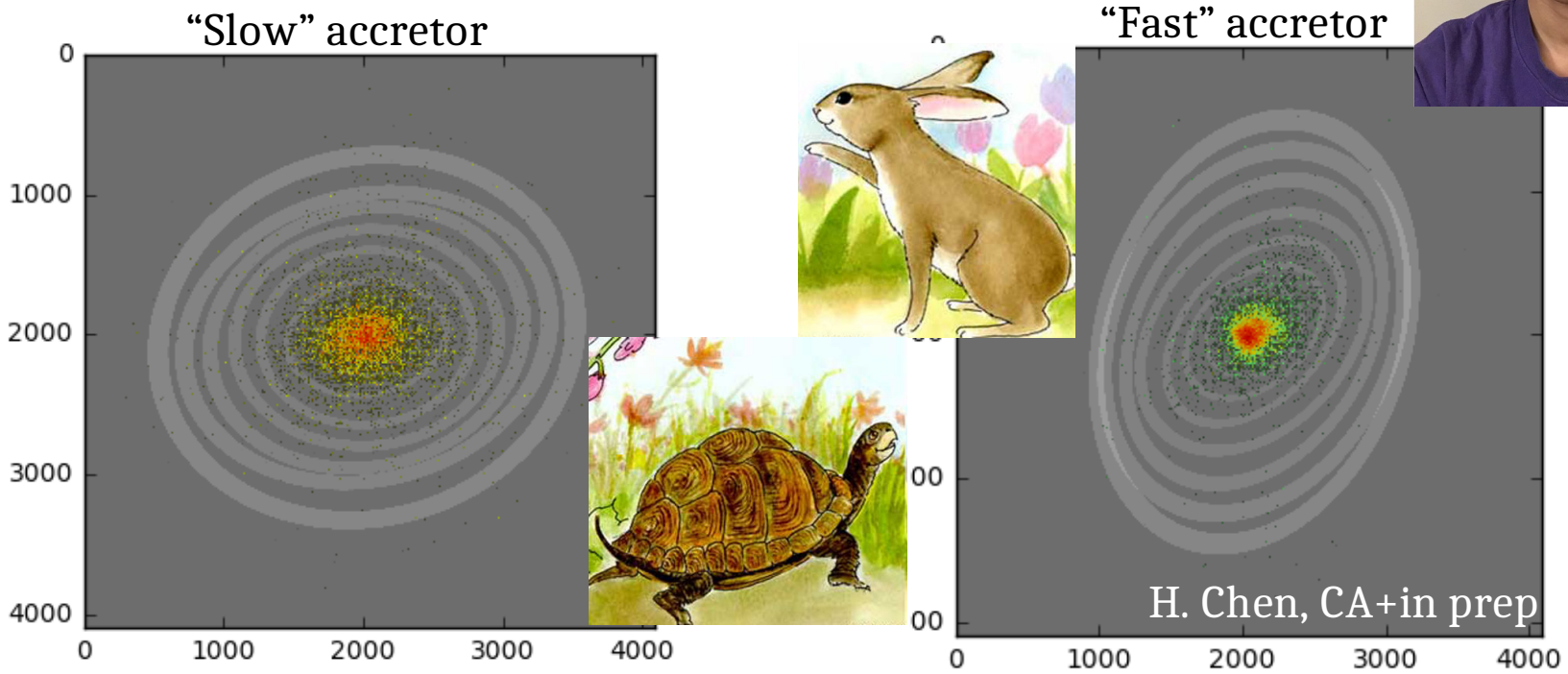
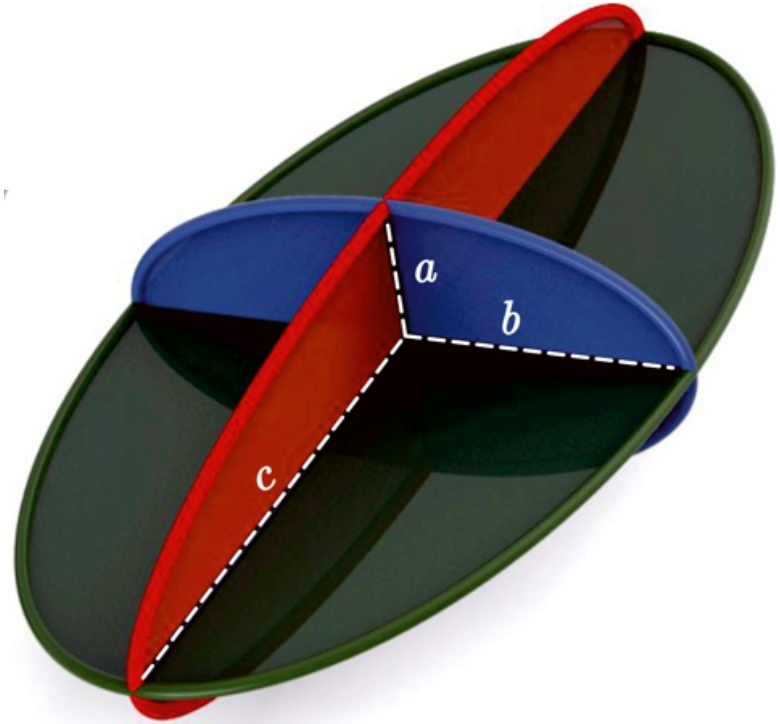
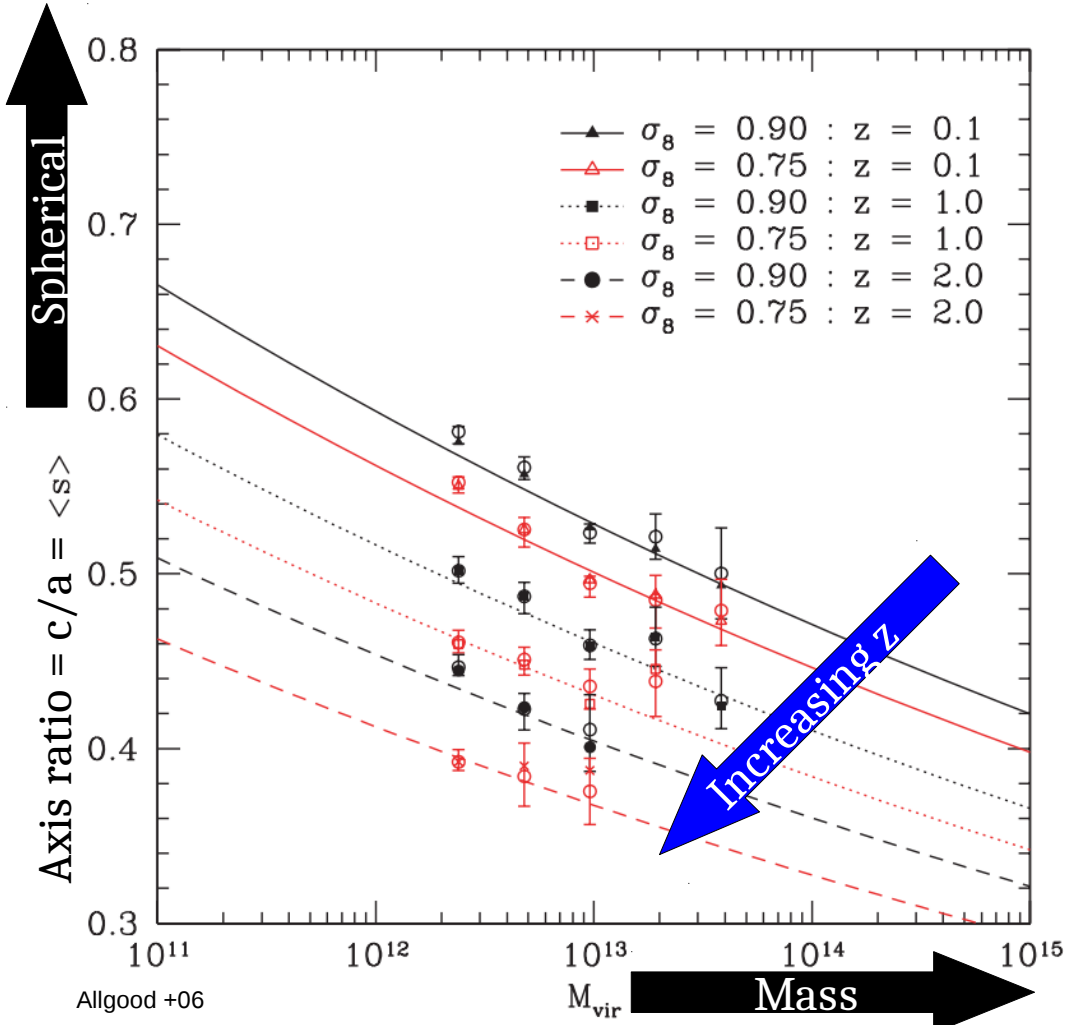




N-body simulations predict shape





Allgood +06

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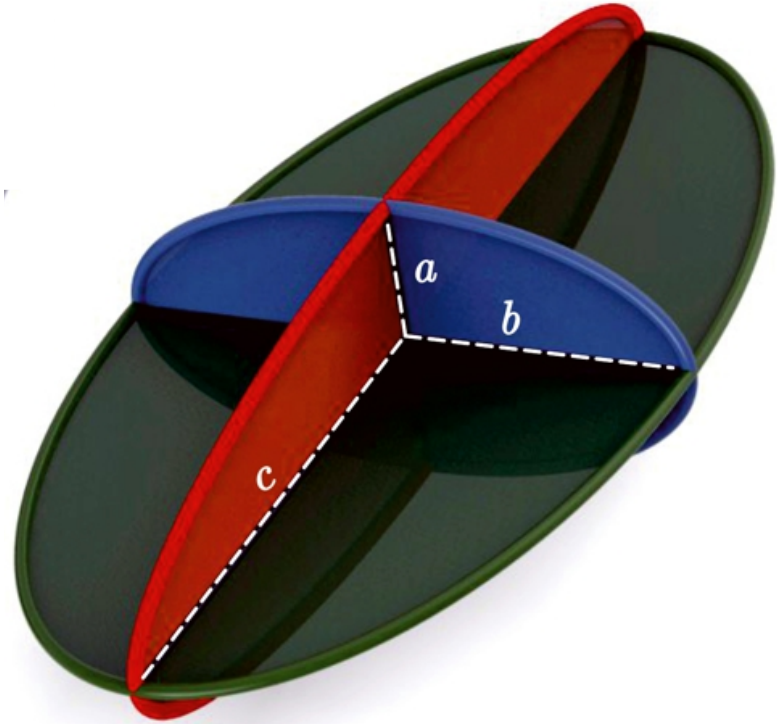
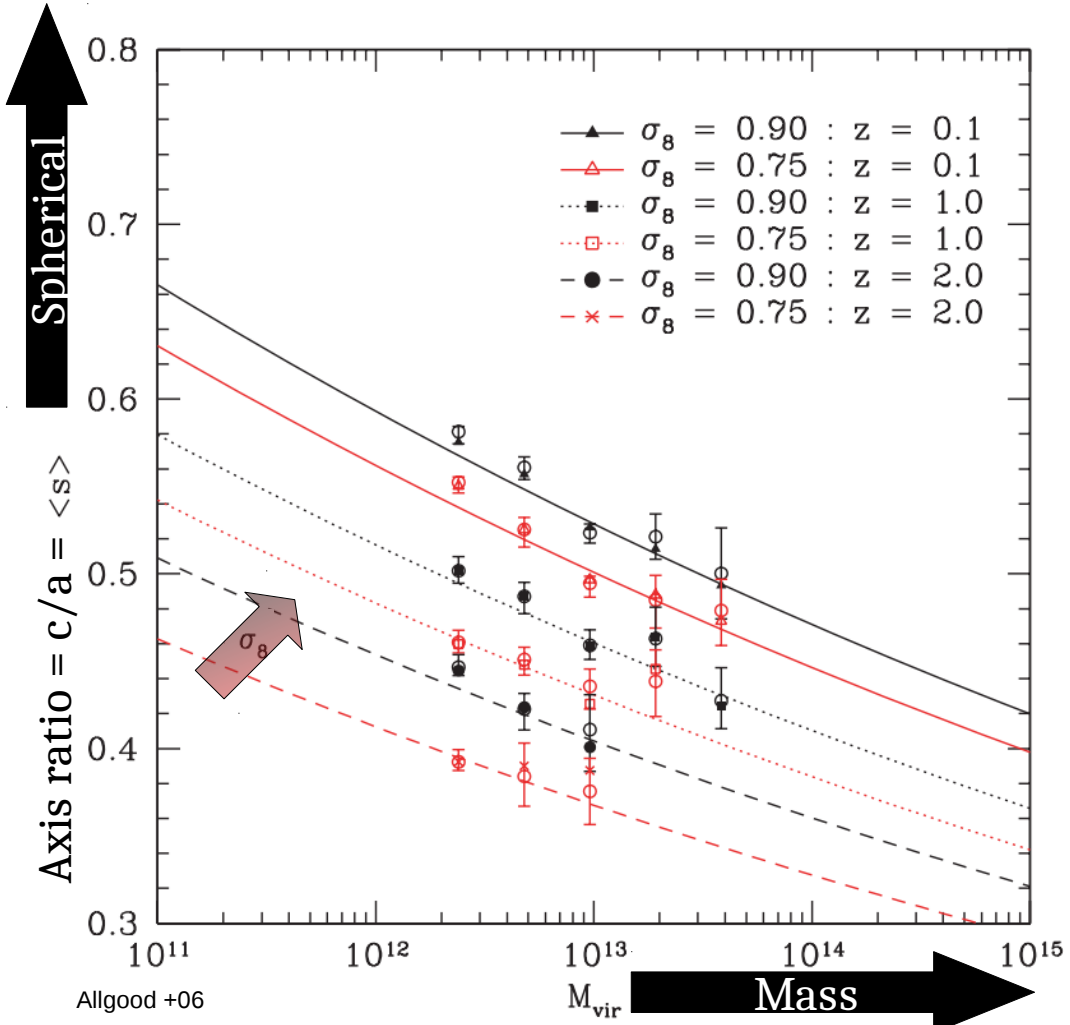
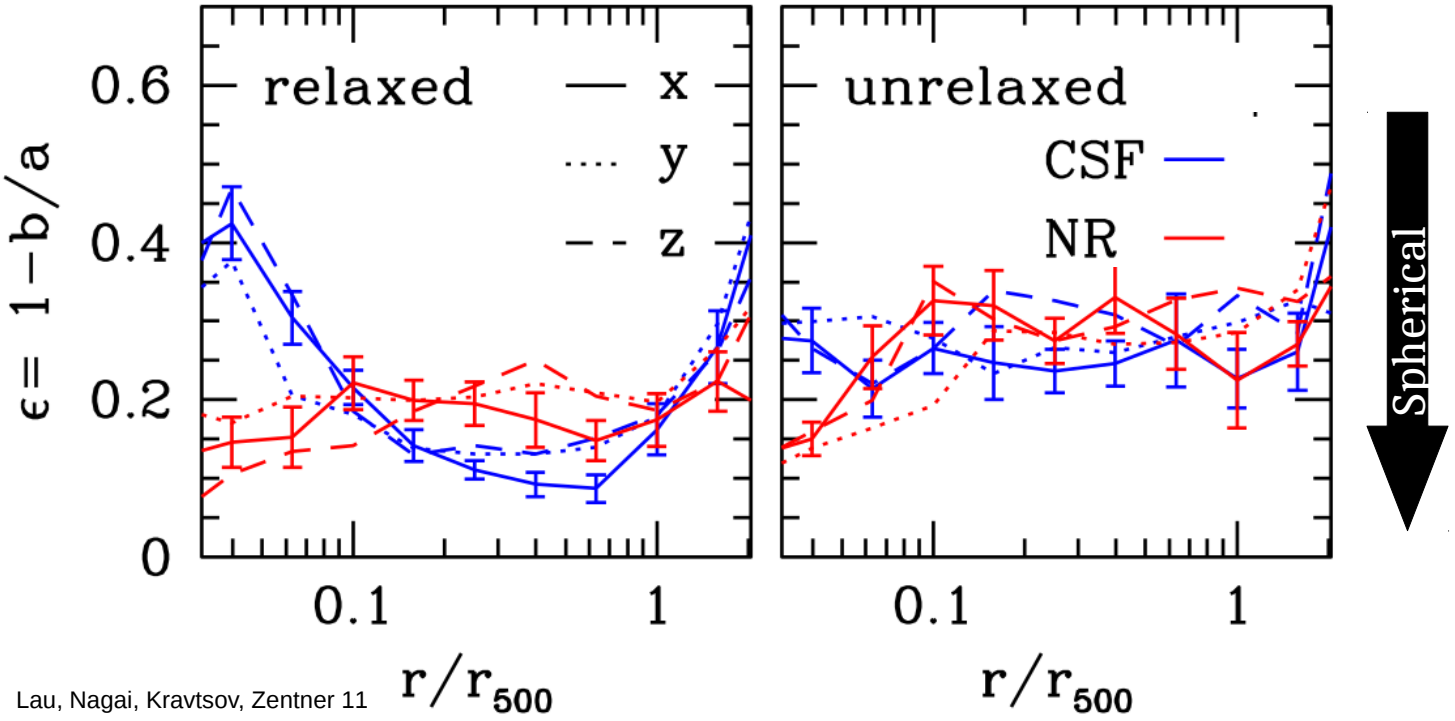




Allgood +06

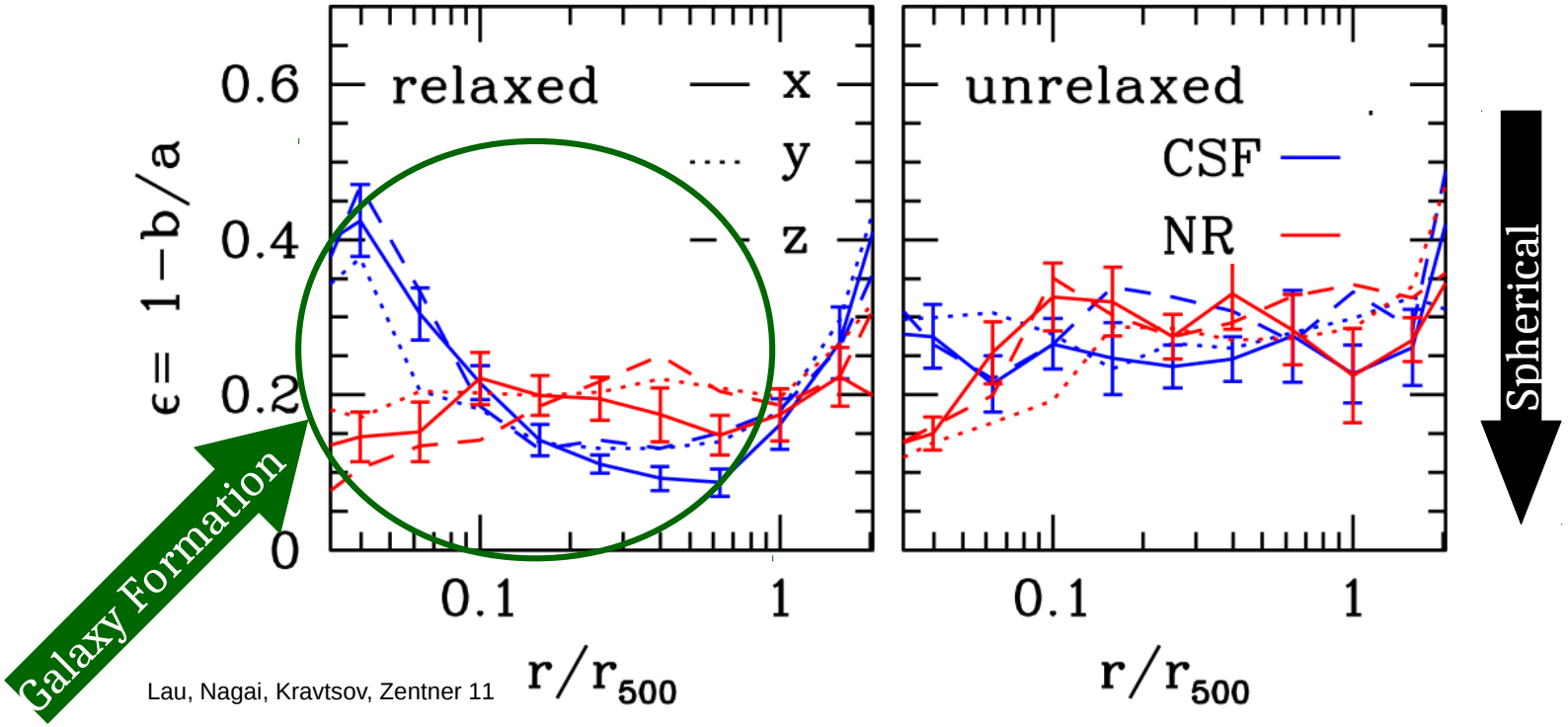
Central shape sensitive to baryonic implementation



Lau, Nagai, Kravtsov, Zentner 11

Minimize systematics at outskirts

Central shape sensitive to baryonic implementation

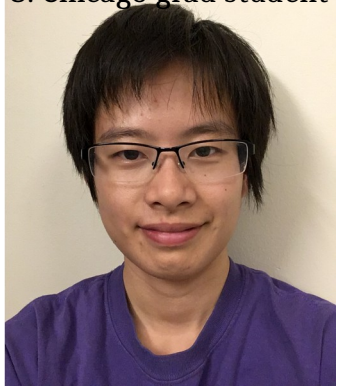


Lau, Nagai, Kravtsov, Zentner 11

Minimize systematics at outskirts

Lynx enables robust outskirt shape measurements

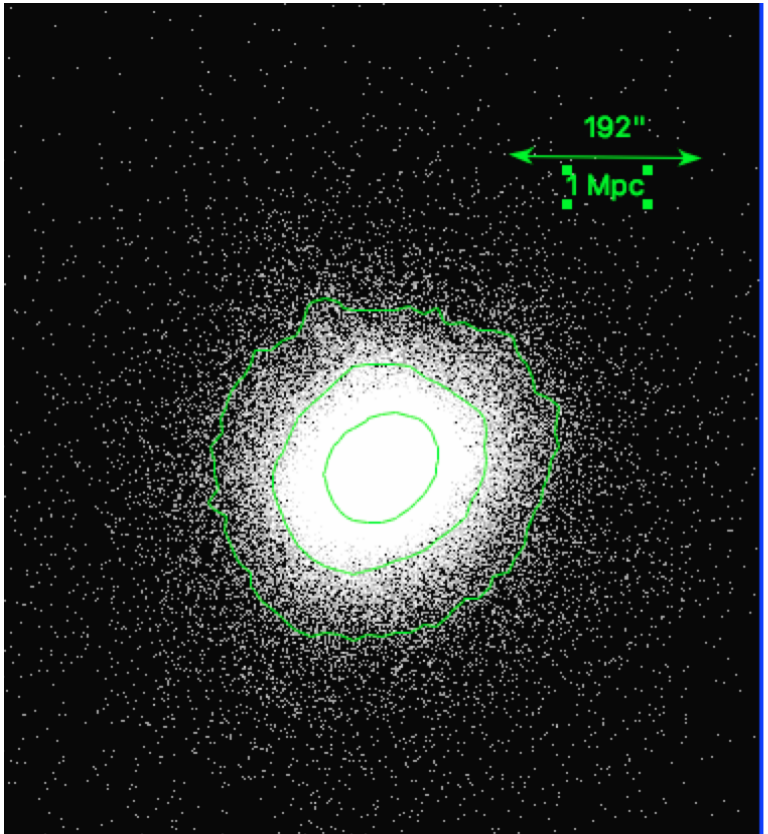
Huanqing Chen
U. Chicago grad student

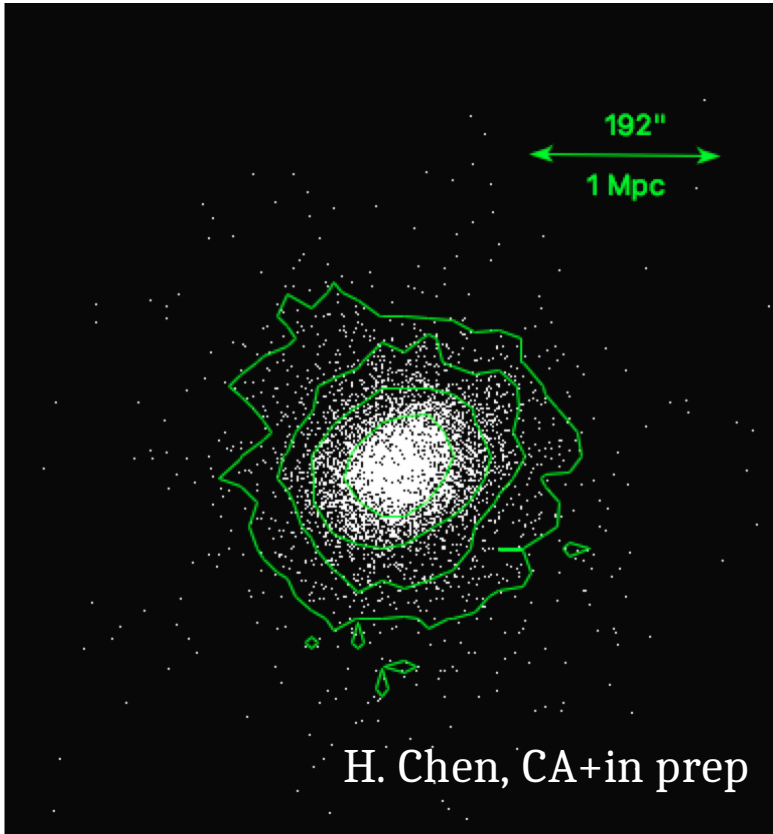


texp = 20 ks

zobs = 0.37

$M_{500c} = 6x10^{14}$





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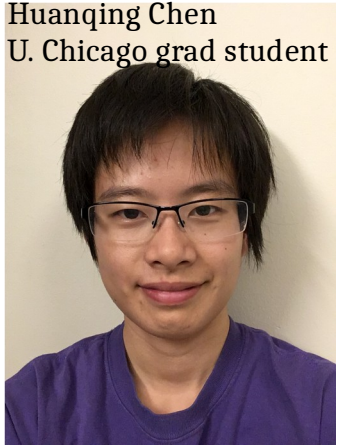

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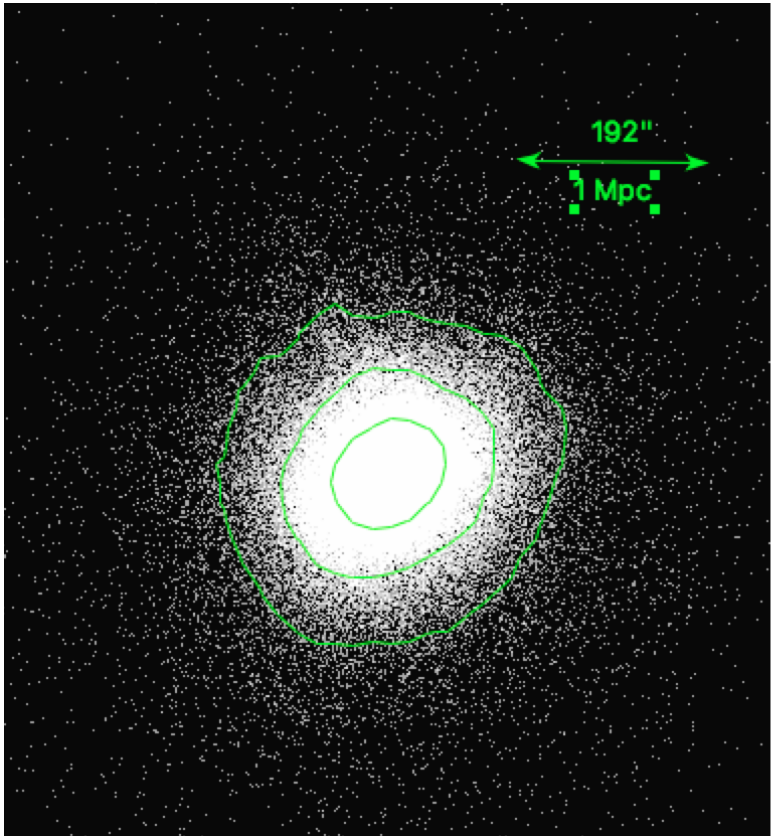
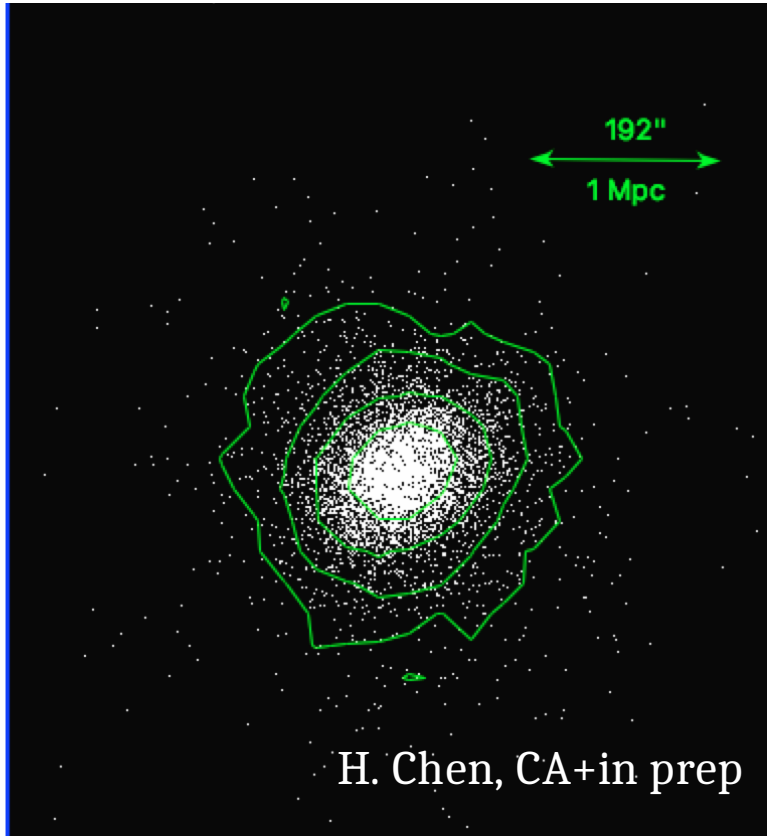
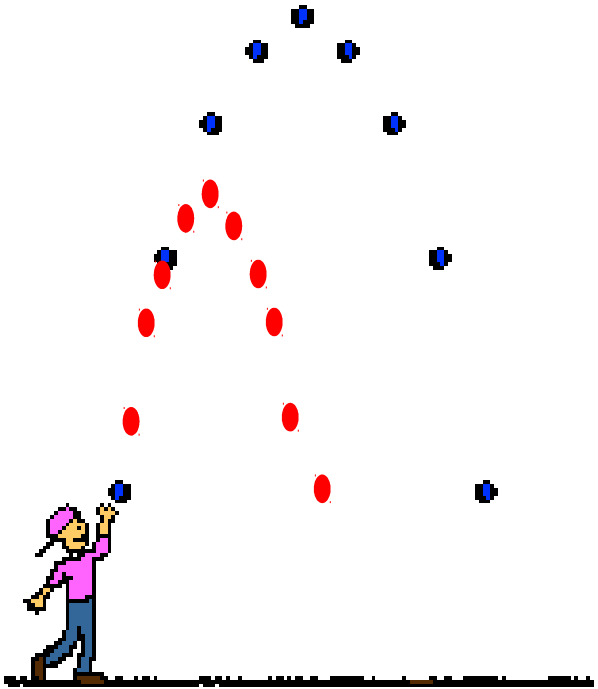




Summary

- Fast accretion shrinks the splashback radius and steepens the outer density
- Un-thermalized accretion generated gas motions outskirt profiles
- Fast accretion elongates halos, with shapes measurable in the X-ray



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More, Diemer, Kravtsov 15

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