

Hot Gas & Dark Matter Far Out in the Halos of Massive Galaxies and Groups

David Buote (UC Irvine)

P. Humphrey (UC Irvine), F. Brighenti (Bologna), W. Mathews (UC Santa Cruz), K. Gebhardt (U Texas), H. Flohic (Santiago), C. Canizares (MIT), A. Fabian (IoA, Cambridge), J. Miller (Michigan)

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Outline

Missing Baryons & Feedback

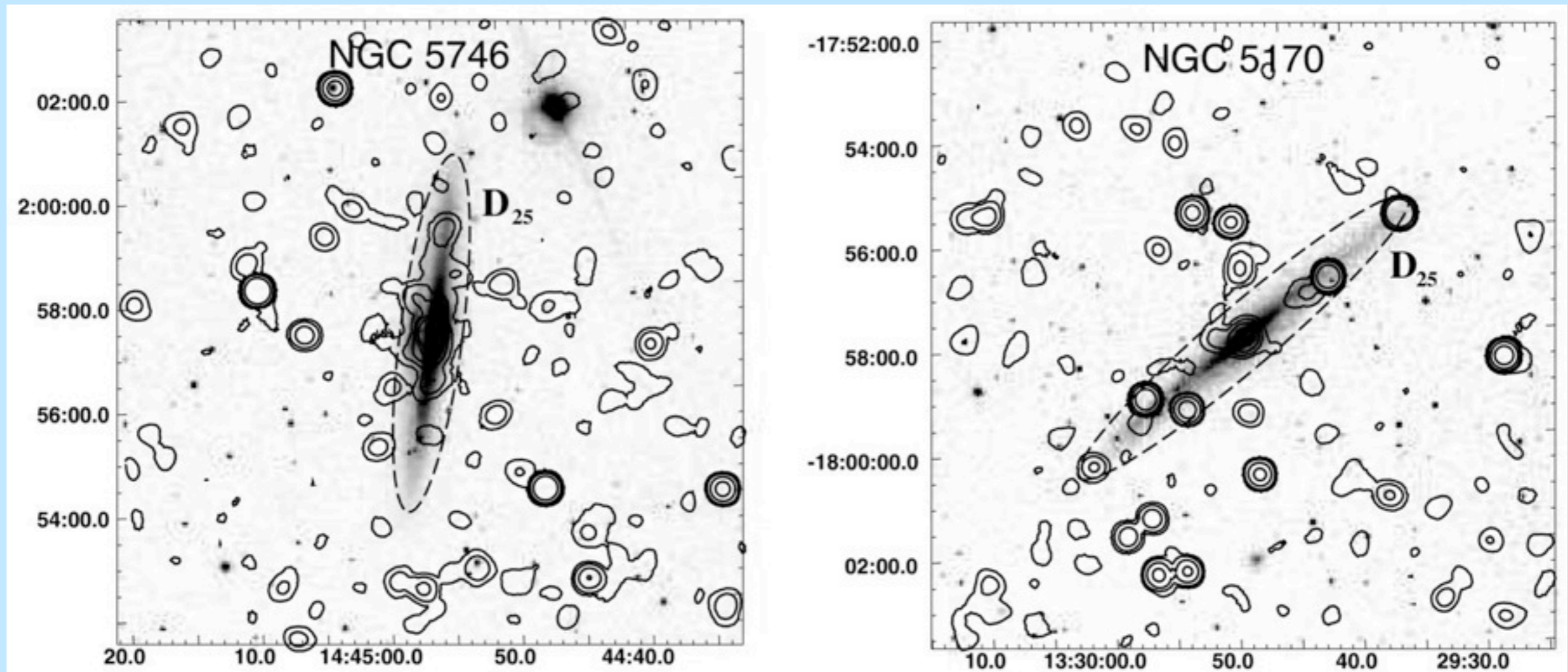
- Isolated Elliptical Galaxy: NGC 720
- Fossil Group/Cluster: RXJ 1159+5531

Tilt of the Fundamental Plane

- Mass Slope -- Size Relation for Ellipticals

Missing Baryons: Hot Gas Around Spirals

(Benson, Bower, Frenk, & White 2000, MNRAS, 314, 557)

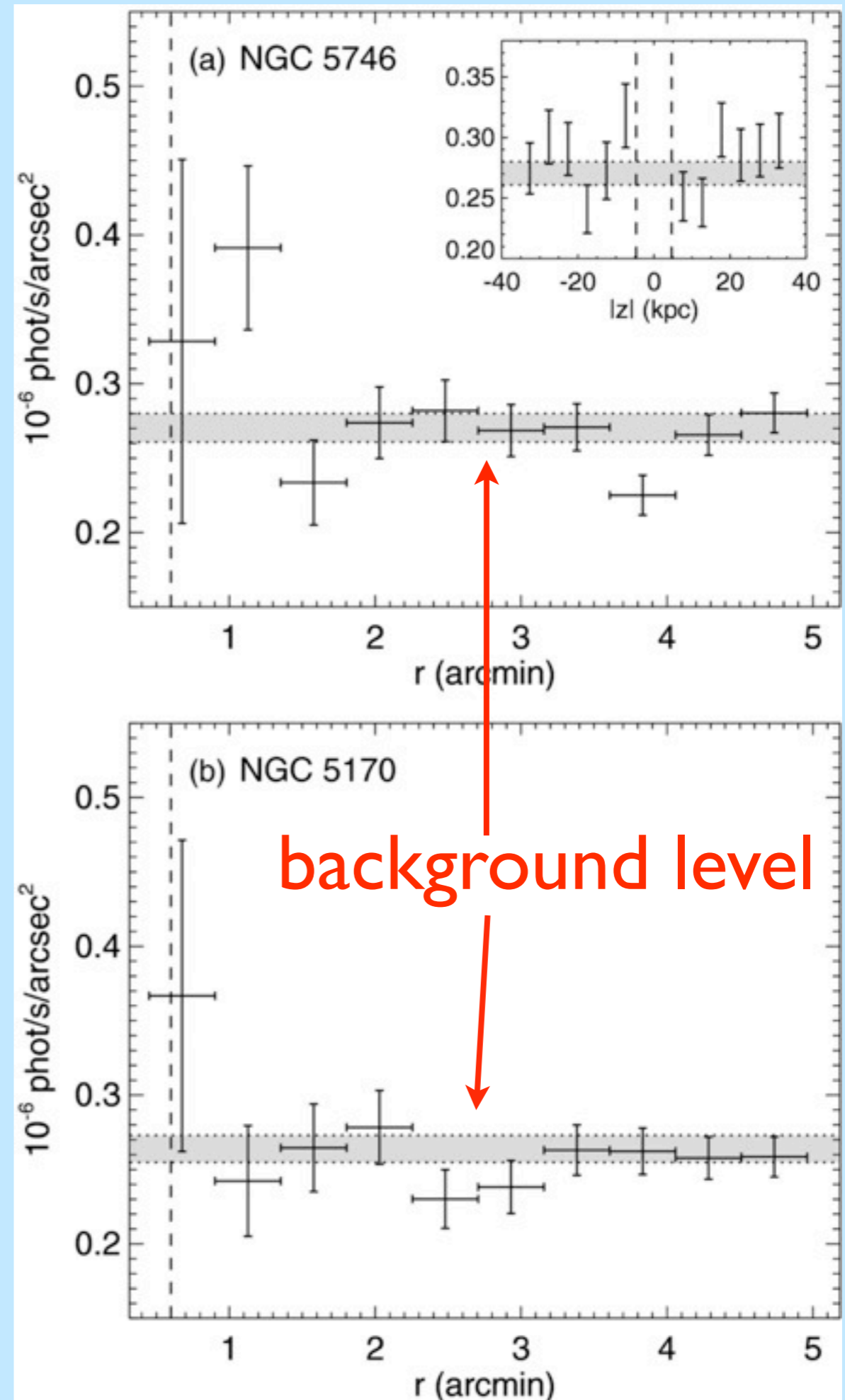


(Rasmussen et al. 2009)

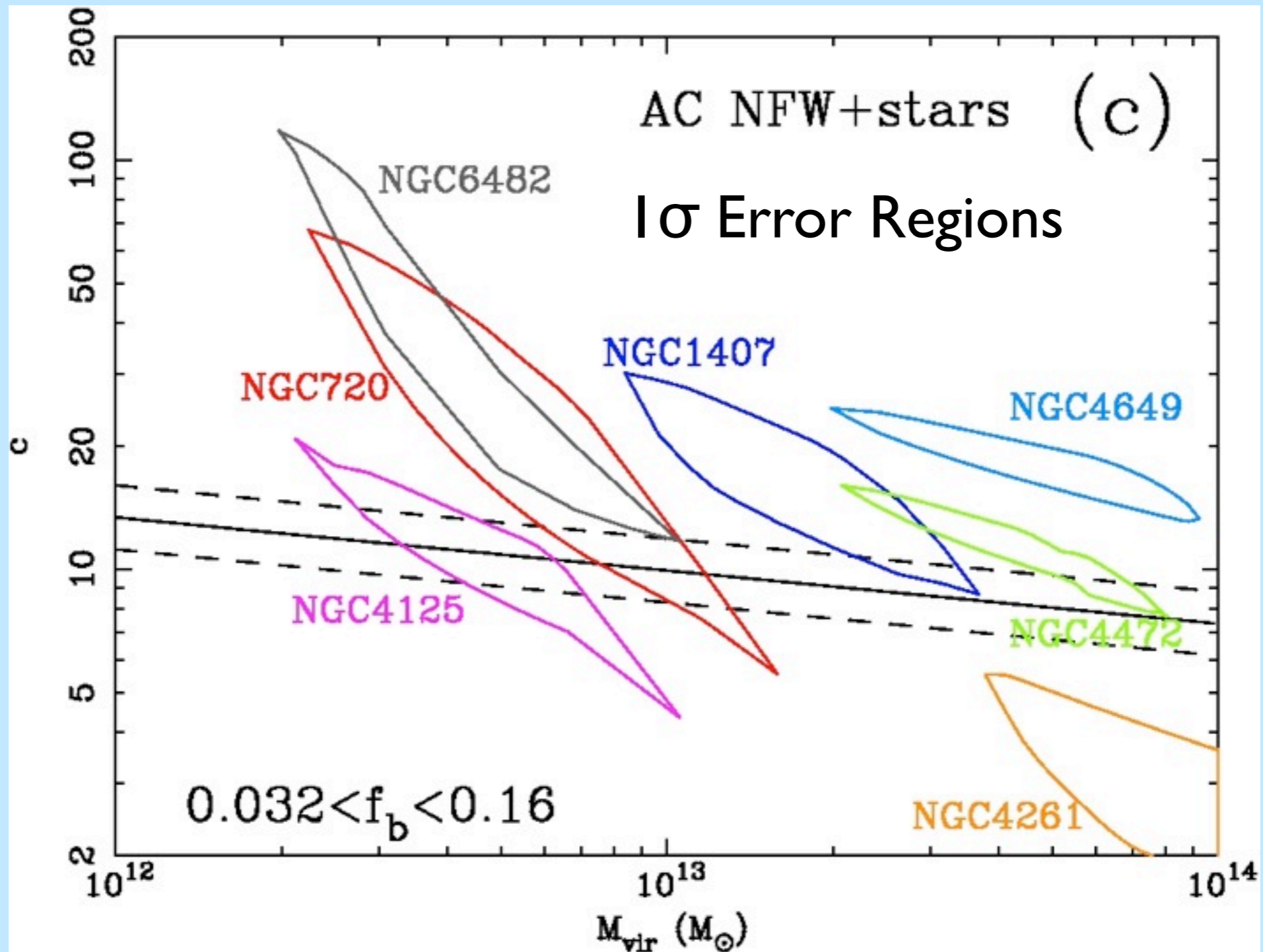
- No evidence for large amount of extended hot gas

- “Missing Baryons” not yet found in disk galaxies

(Rasmussen et al. 2009)



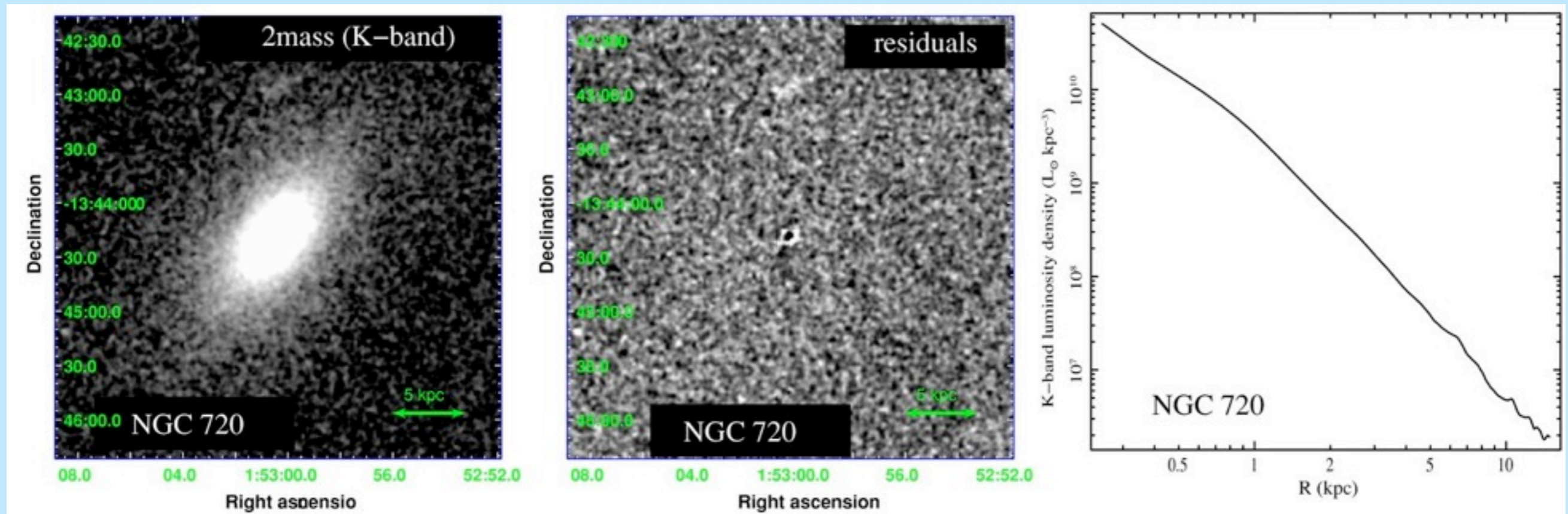
X-Ray Constraints on Masses of Ellipticals



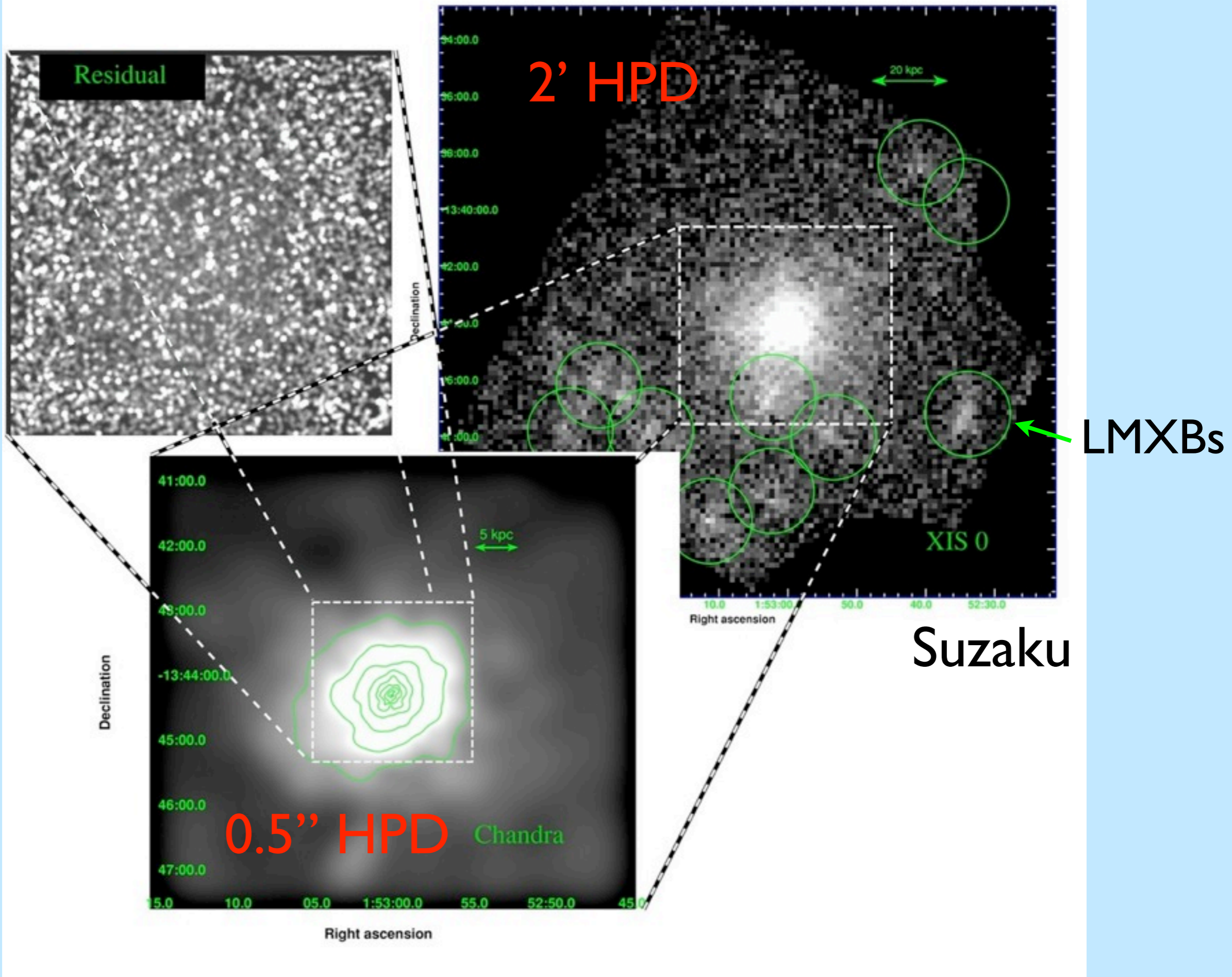
(Humphrey, Buote, Gastaldello, Zappacosta, Bullock, Brighenti, & Mathews 2006, ApJ, 646, 899)

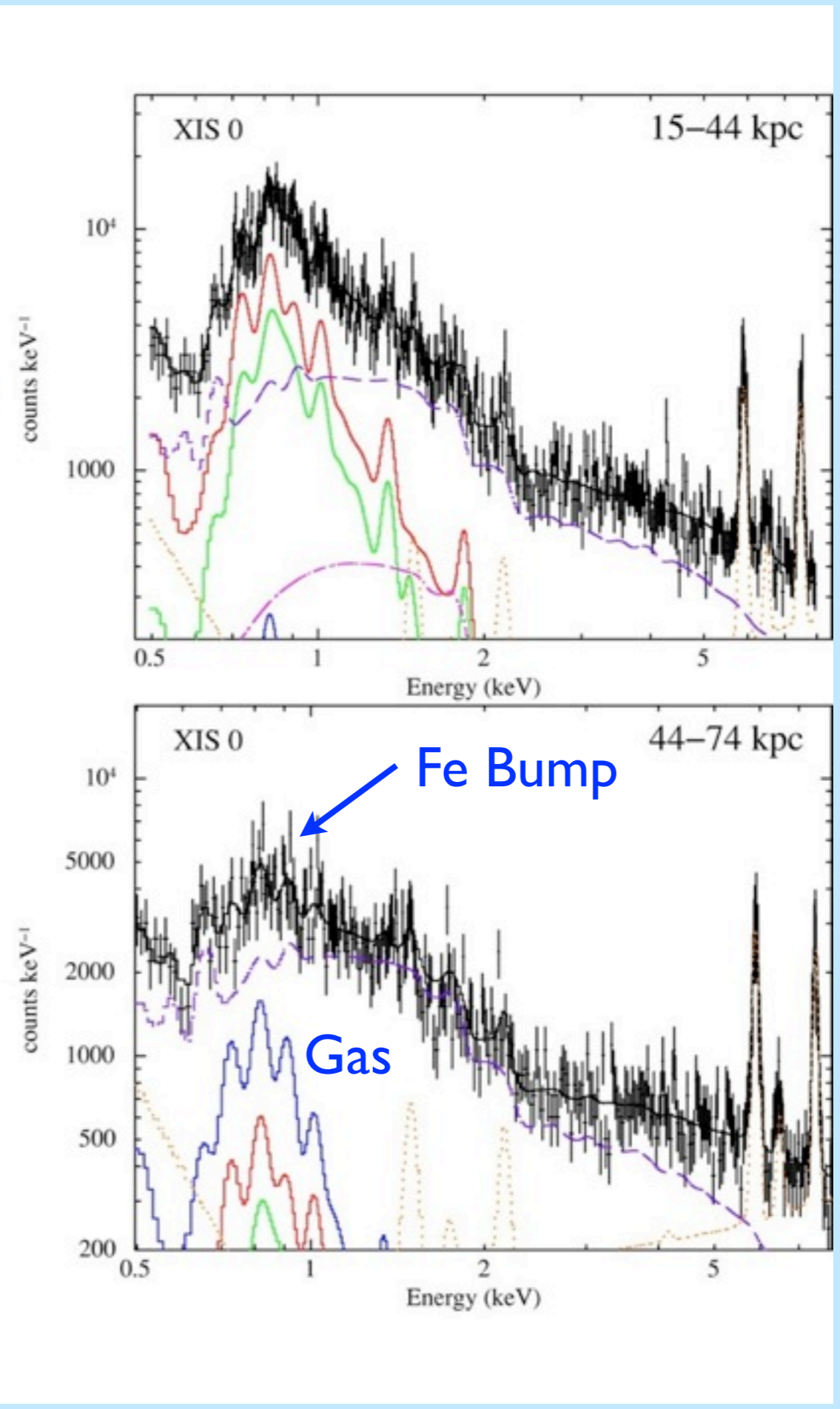
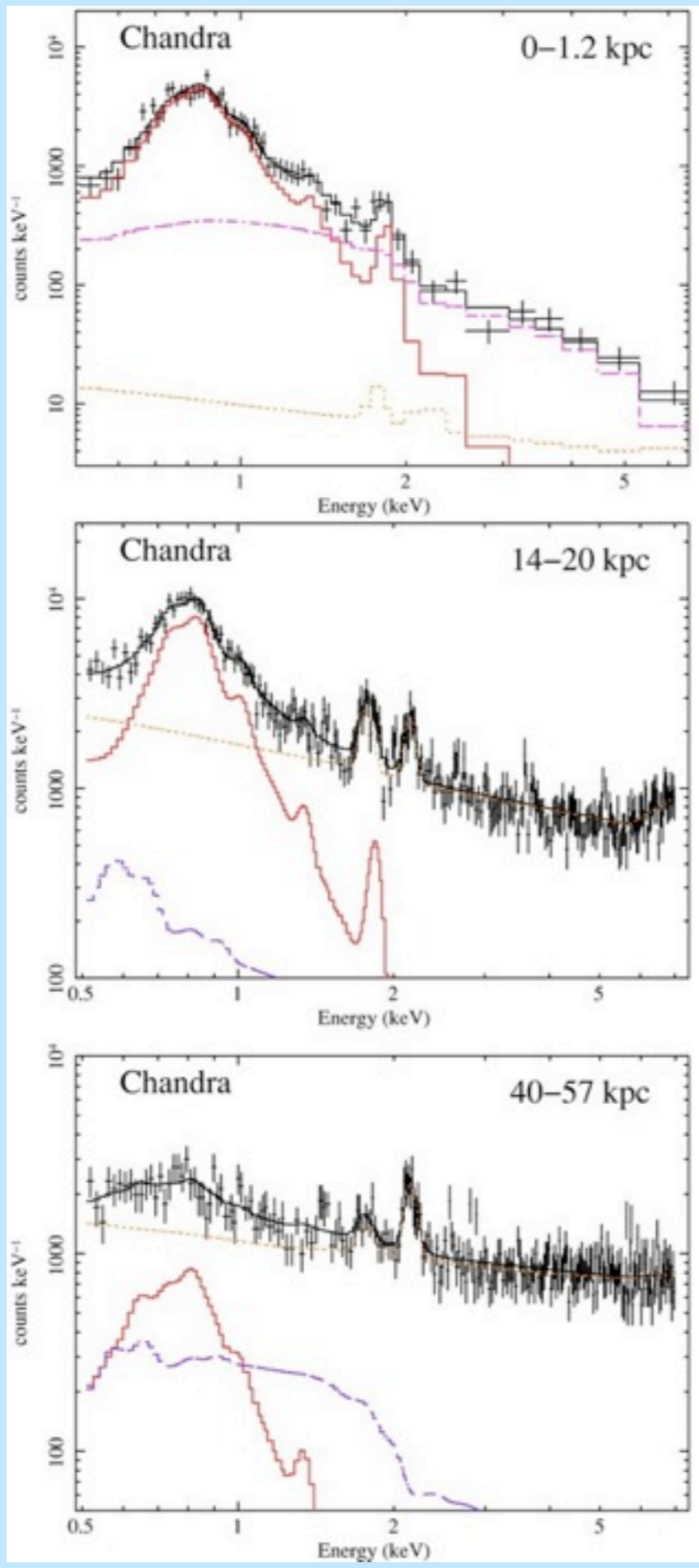
NGC 720

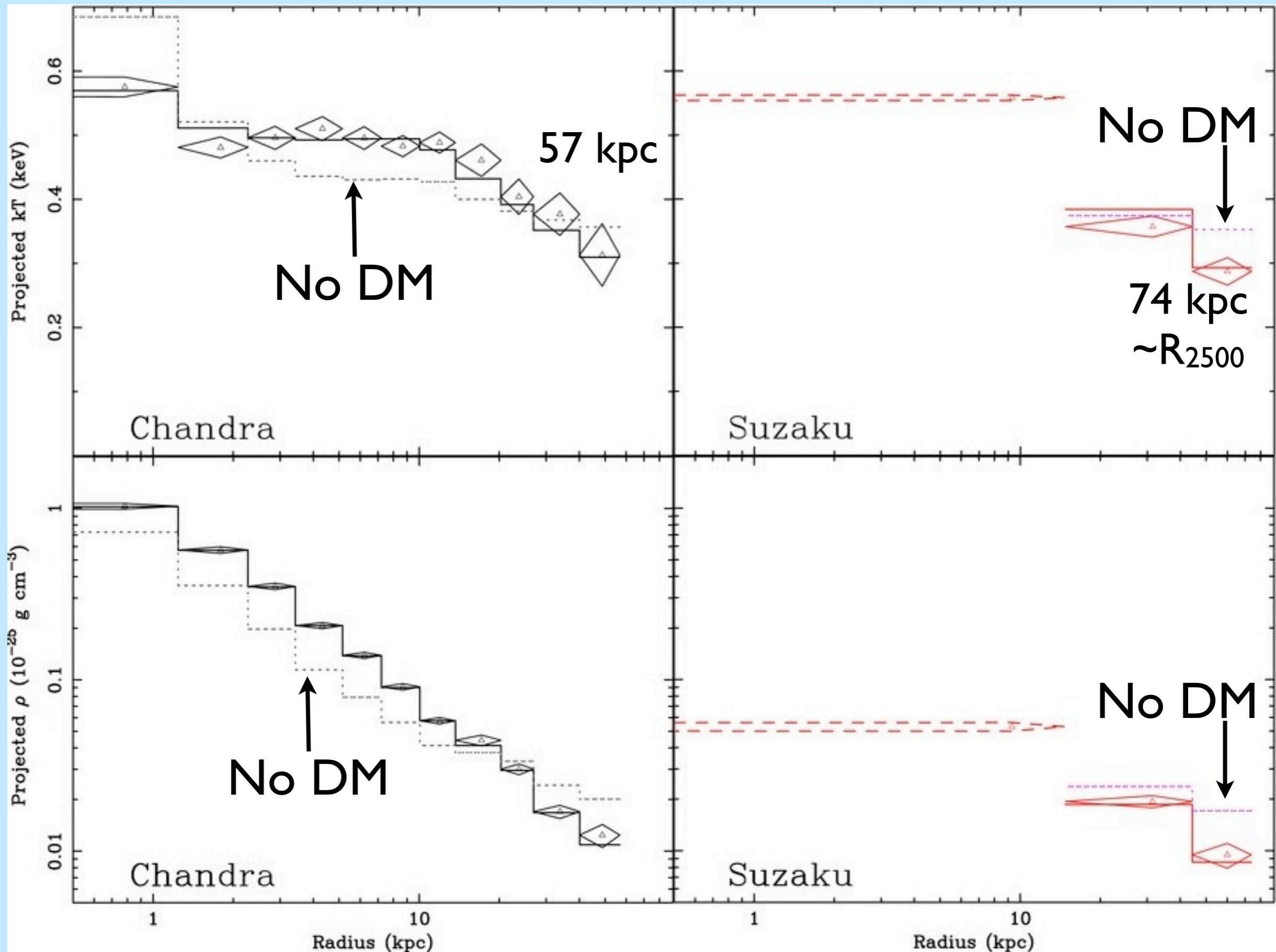
- $D=26$ Mpc
- E4
- Very Isolated, No AGN disturbance



(Humphrey, Buote, Canizares, Fabian, & Miller 2011, *ApJ*, 729, 53)







Mass Determination Method

Input $S(r)$ & $M(r)$

Solve \Downarrow H.E.

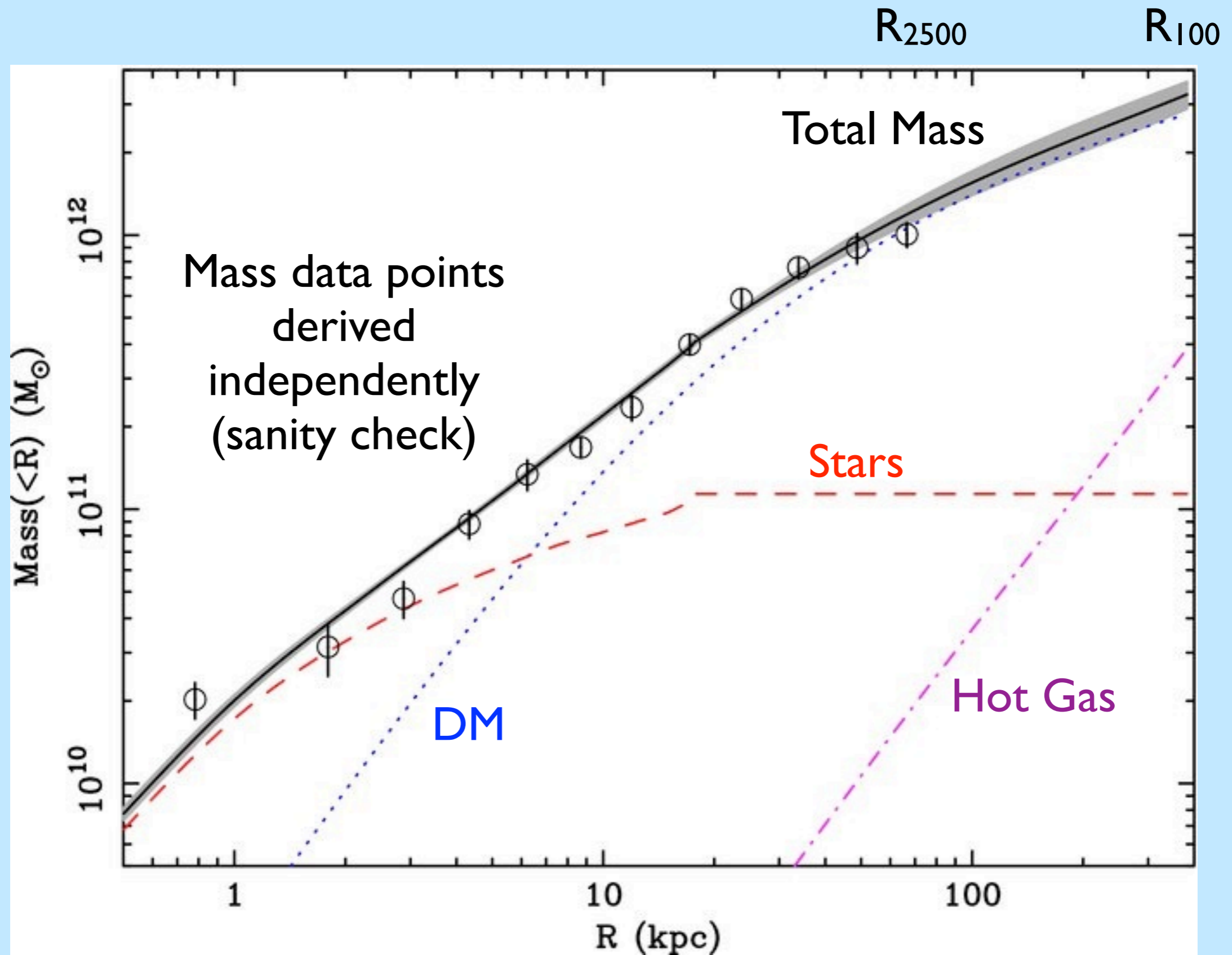
Output $\rho_{\text{gas}}(r)$ and $T(r)$

We use assumed parameterized models of S & M
and then fit the ρ_{gas} & T data

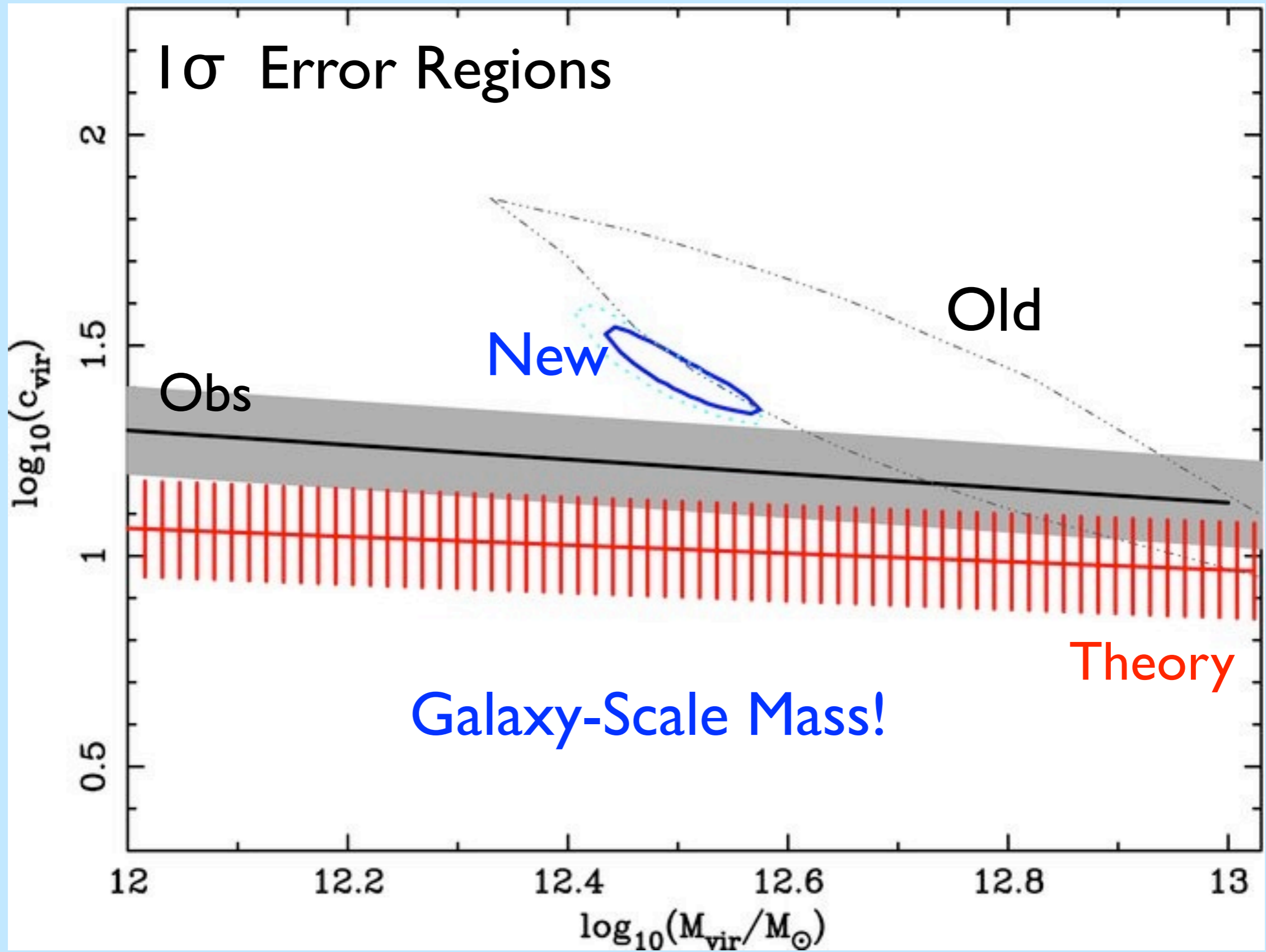
Free Parameters

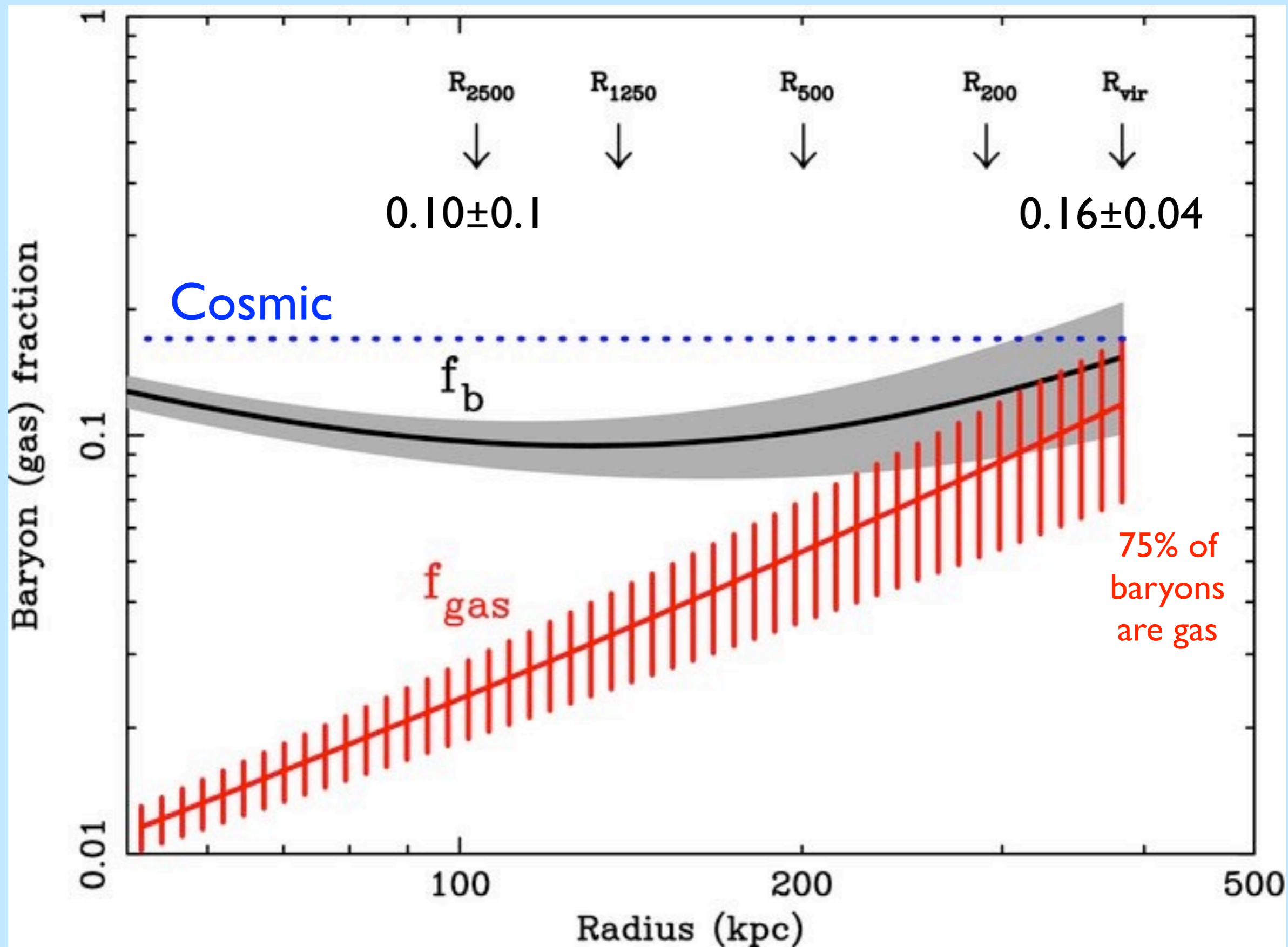
- Temperature/Pressure -- normalization (1)
- $S \propto \rho^{-2/3}T$ -- broken power-law + const (5)
- M (3)
 - Black Hole -- M_{BH} (fixed)
 - DM Halo -- NFW C_{Δ}, M_{Δ} (2)
 - Stars -- M_{\star}/L_j (1)

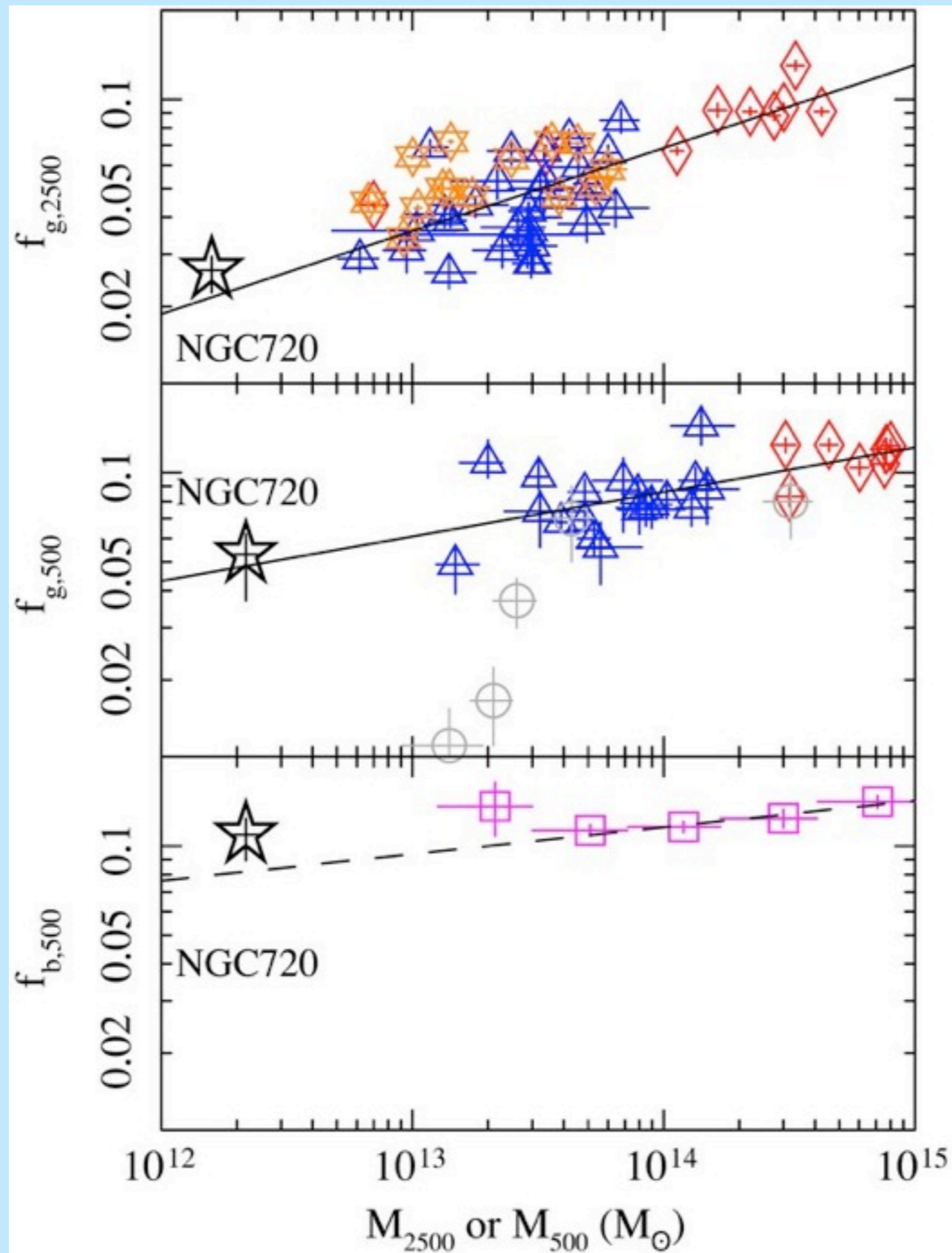
9 Free Parameters Constrained by 26 Data Points



(spherically averaged)







Group and Cluster Data
from:

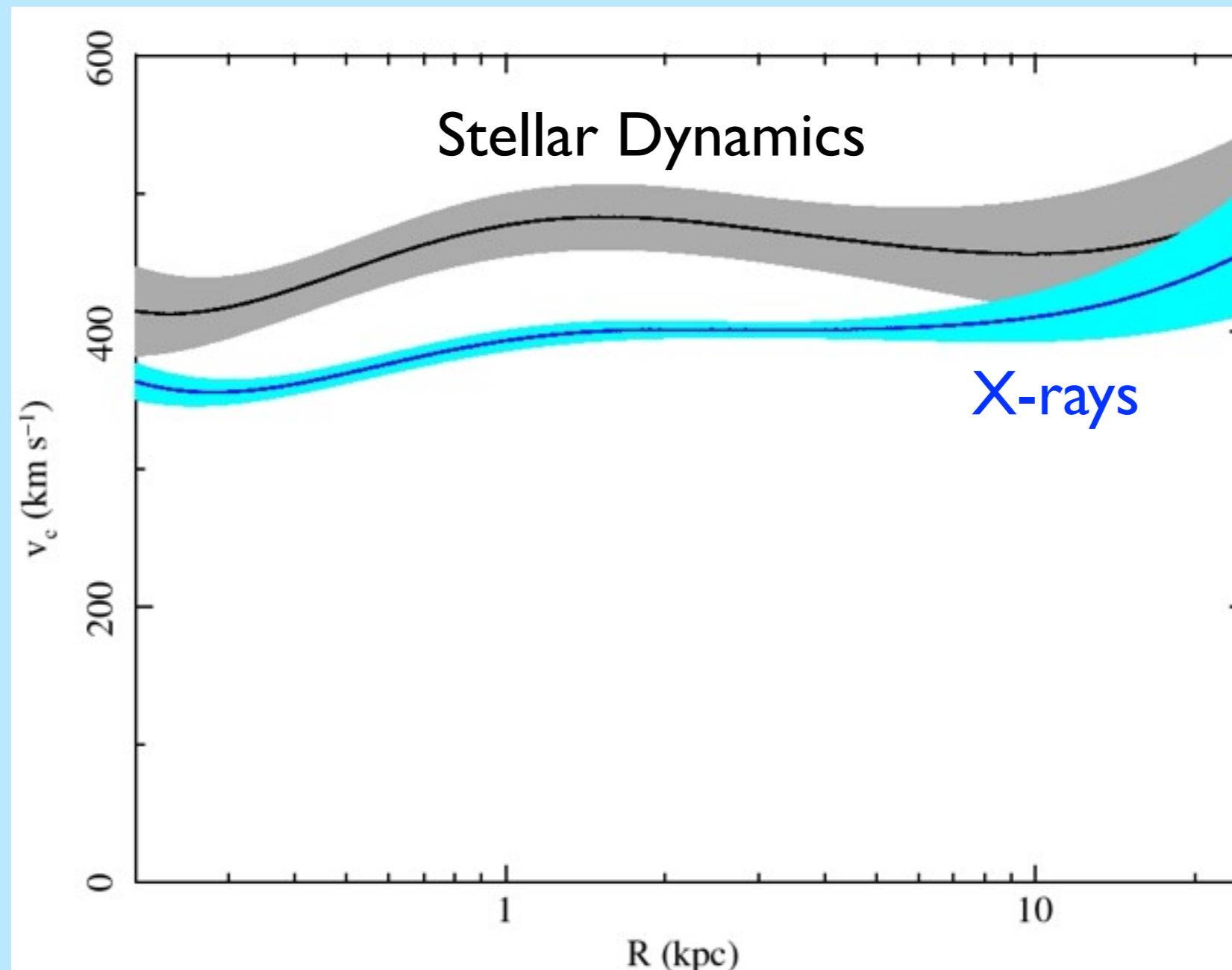
Gastaldello et al. 2007;
Sun et al. 2009;
Vikhlinin et al. 2006;
Dai et al. 2009

Baryon fractions from
Giodini et al. 2009

Future Work

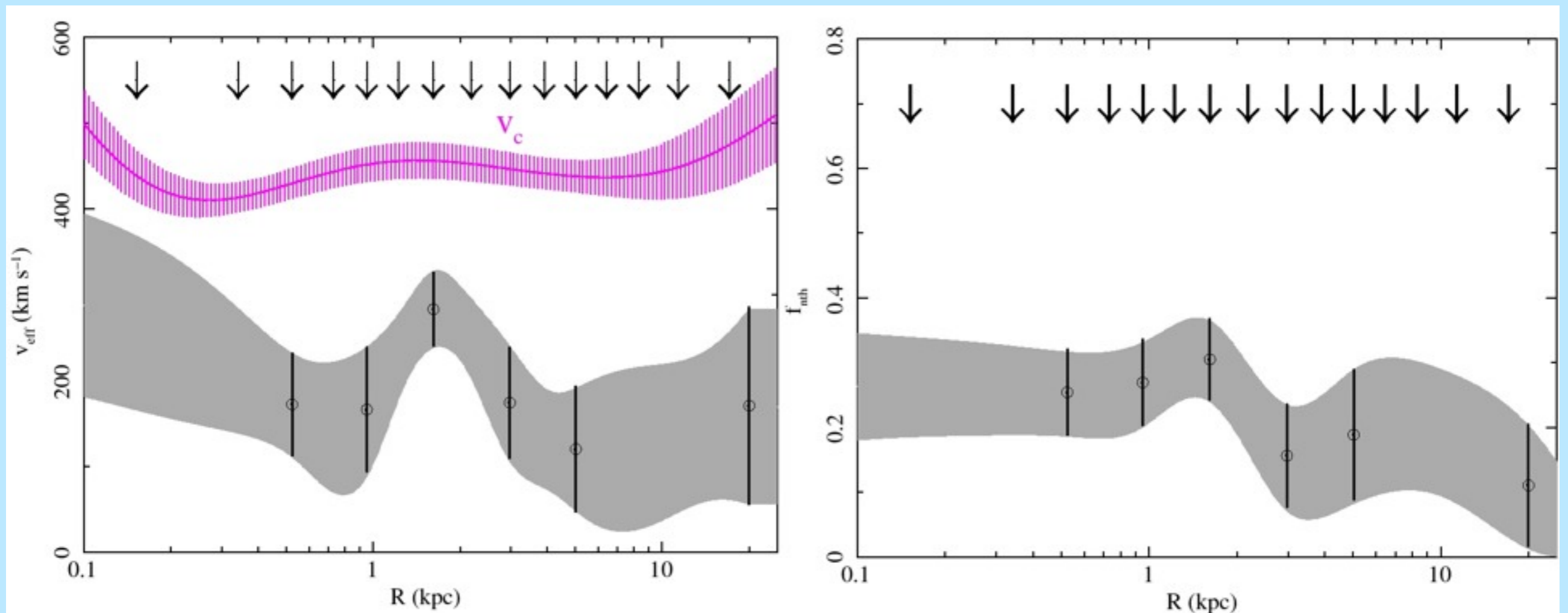
- Deep, Offset Suzaku Data for N720 to go out to R_{500}
- Follow-up of X-ray snapshot sample of 35 isolated ellipticals -- w/ T. Ponman, E. O'Sullivan (Birmingham) & C. Topchyan (UC Irvine)
- Combine X-rays & Stellar Dynamics

Non-Thermal Gas Support in NGC 4649



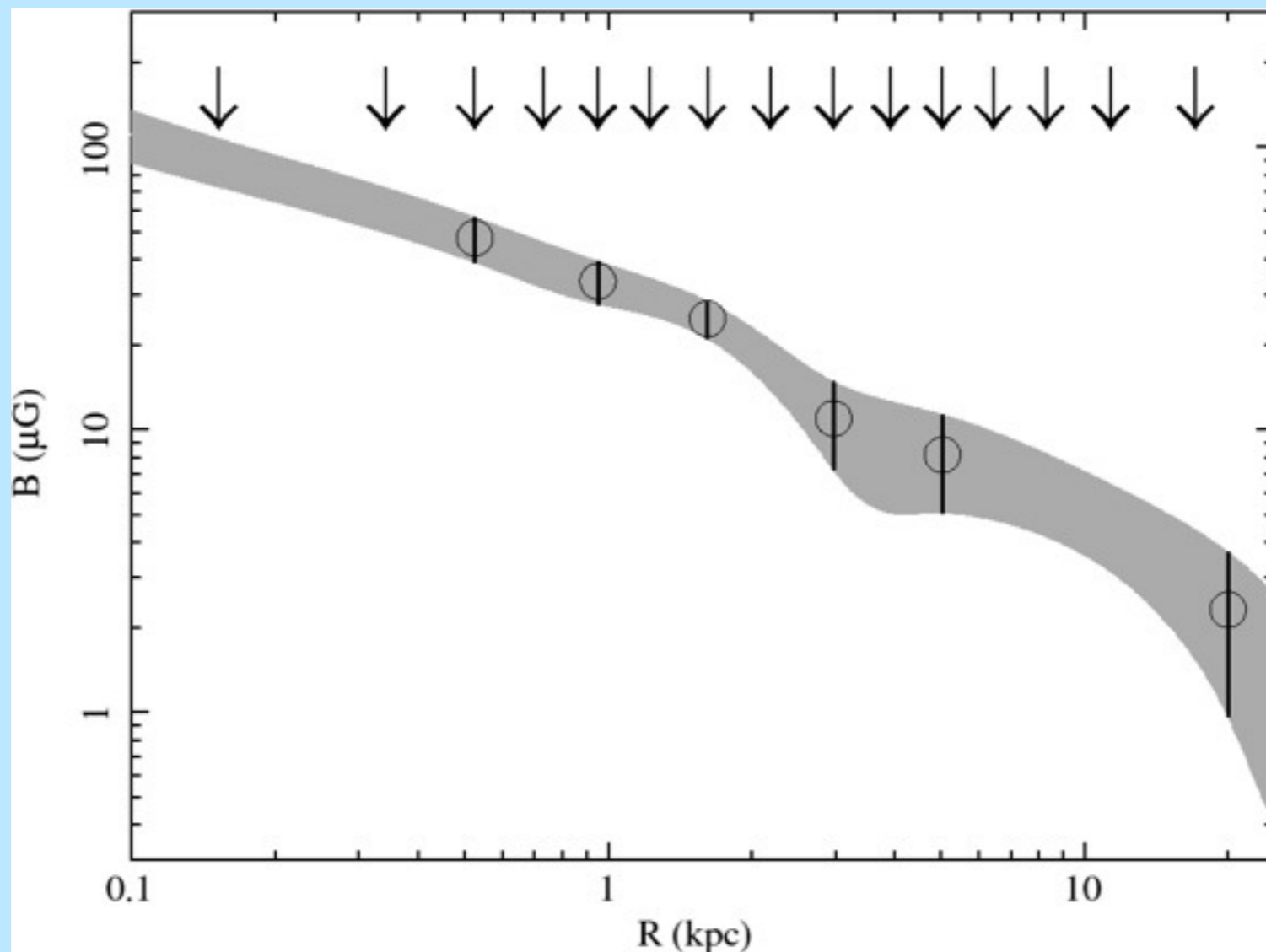
(Humphrey, Buote, Gebhardt, Brighenti, & Mathews, in prep)

Non-Thermal Gas Support in NGC 4649



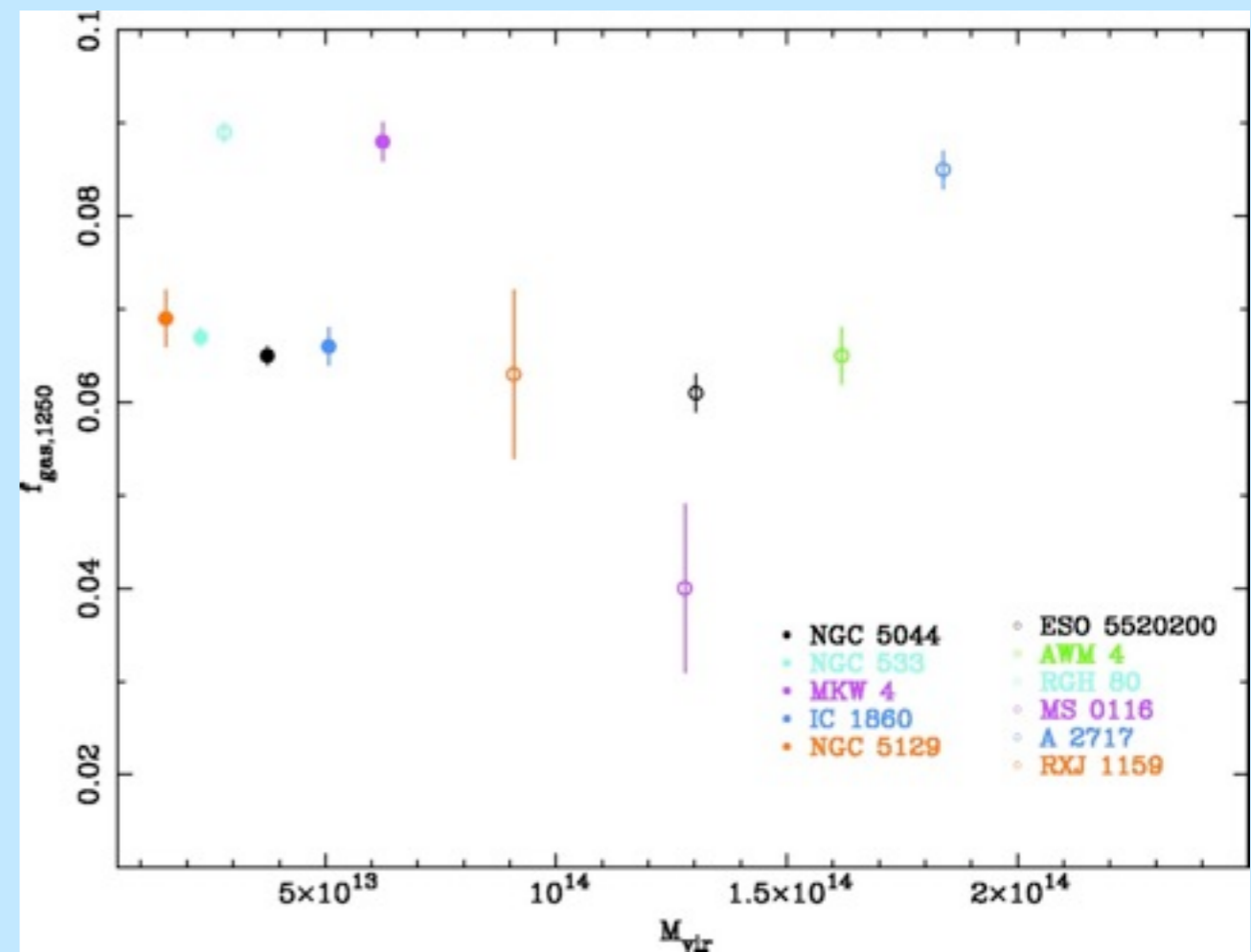
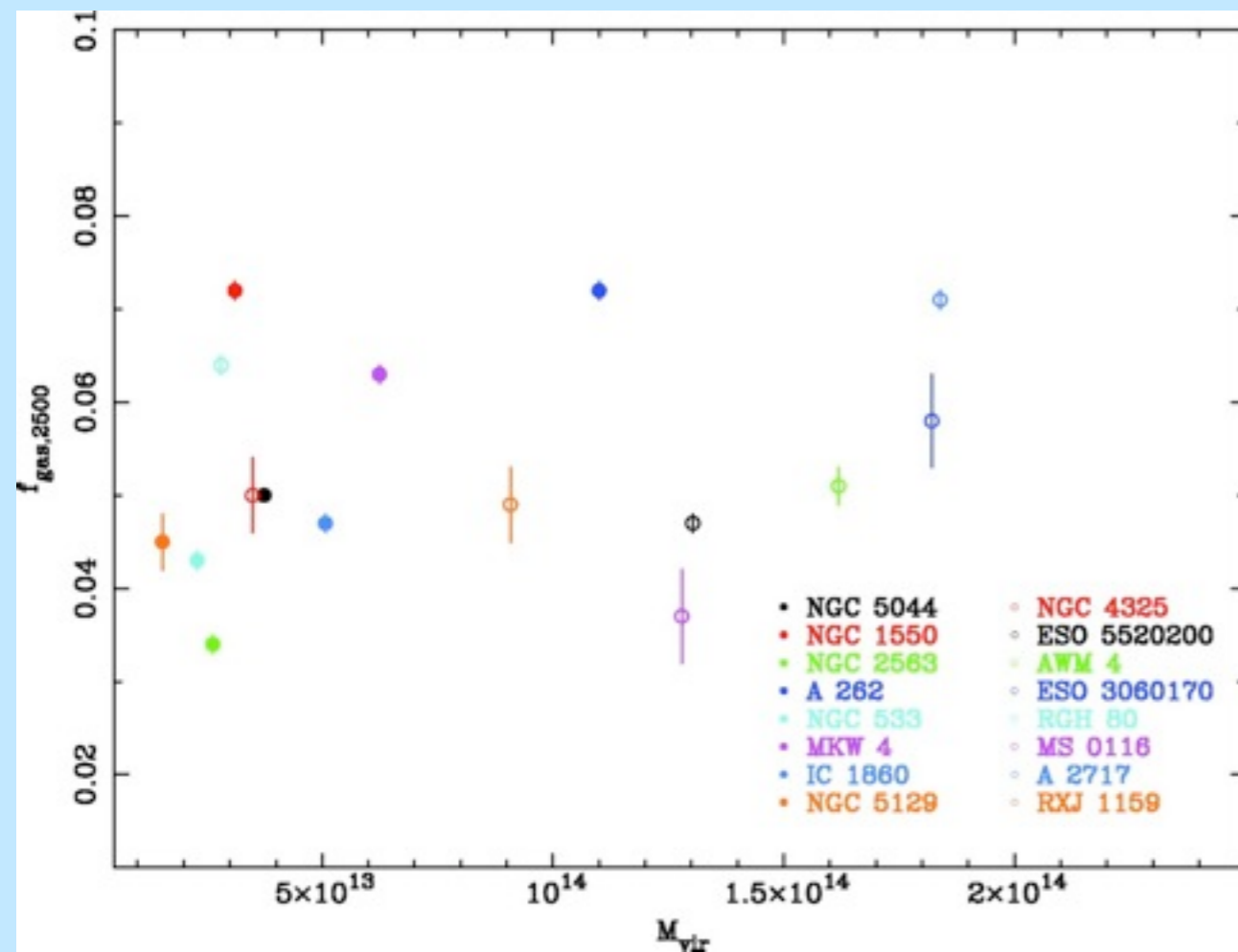
(Humphrey, Buote, Gebhardt, Brighenti, & Mathews, in prep)

Non-Thermal Gas Support in NGC 4649



(Humphrey, Buote, Gebhardt, Brighenti, & Mathews, in prep)

Baryon Fractions of Galaxy Groups

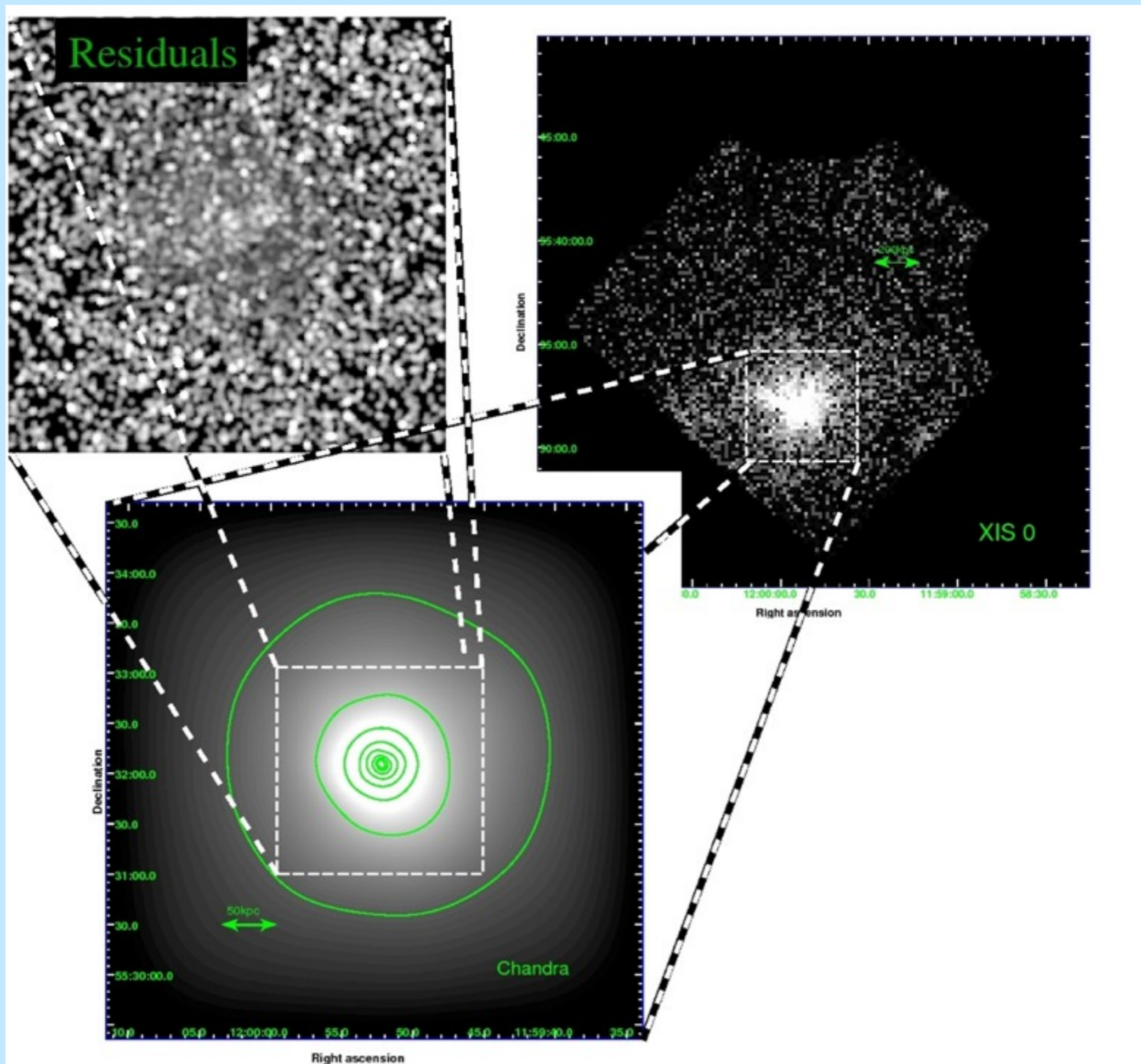


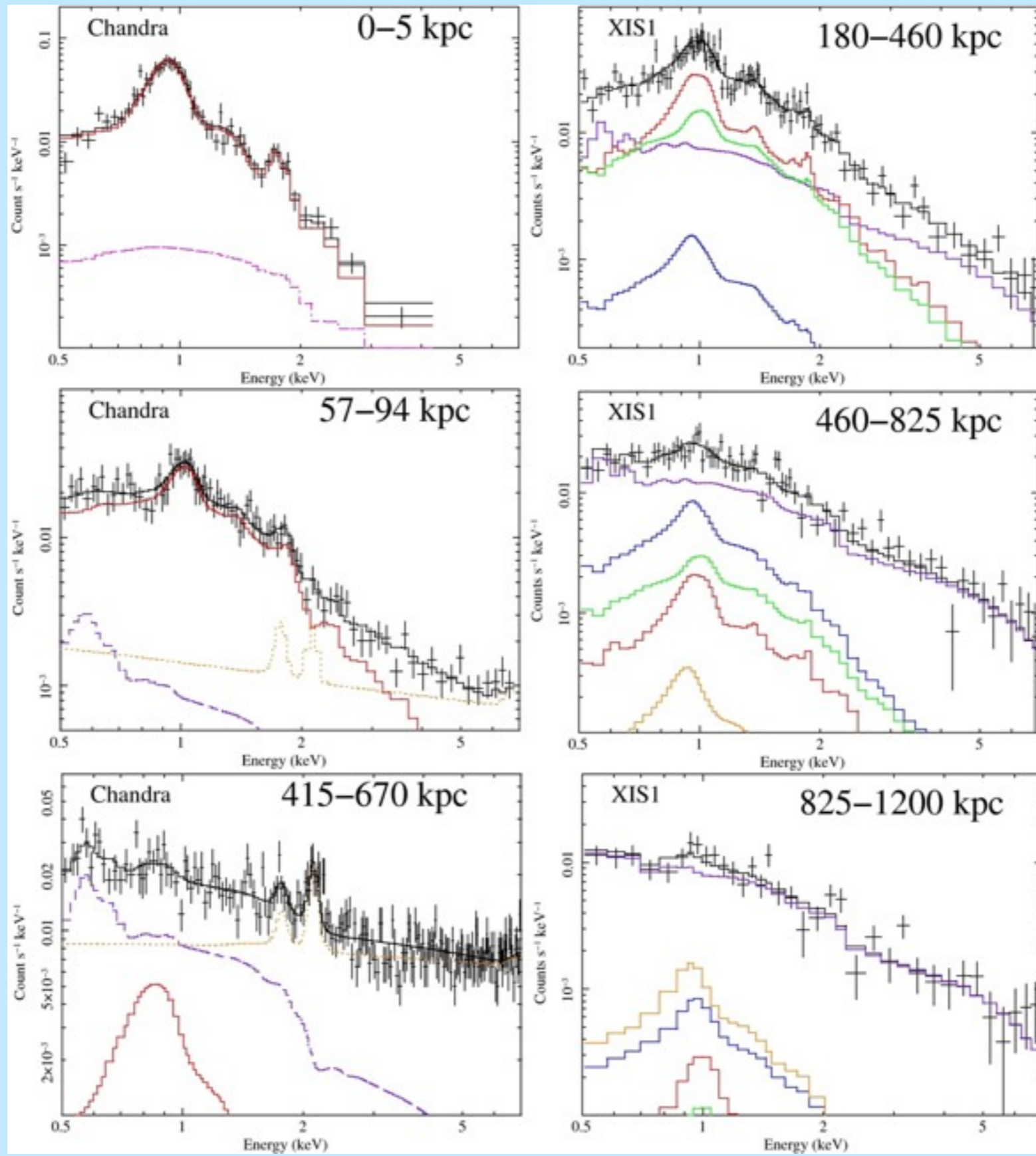
(Gastaldello, Buote, Humphrey, Zappacosta, Bullock, Brighenti, & Mathews 2007, ApJ, 669, 158)

RXJ 1159+5531

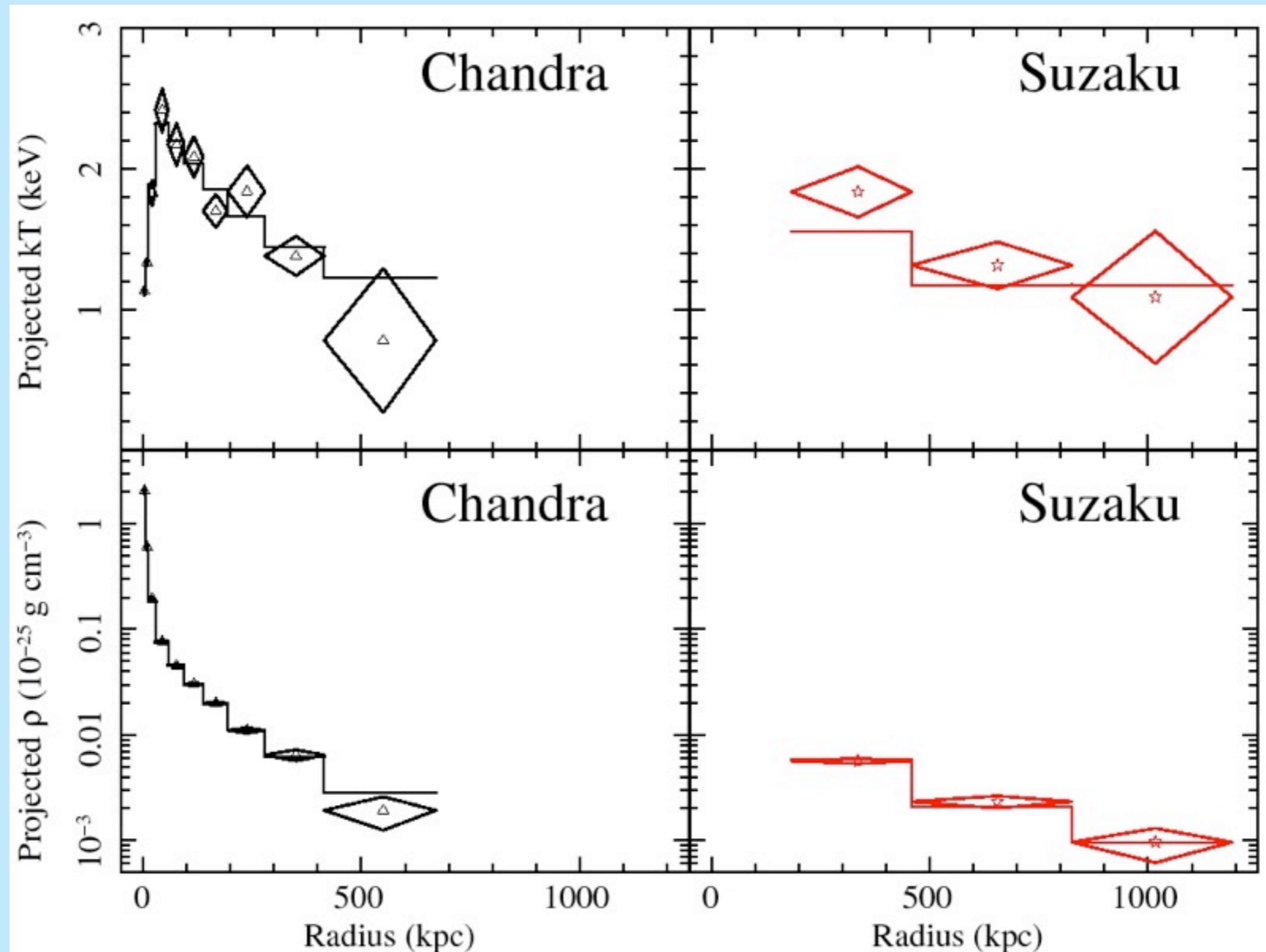
- Fossil Group/Cluster ($\sim 10^{14} M_{\text{sun}}$)
- Redshift 0.08
- Virial Radius (R_{100}) fits on single Suzaku pointing

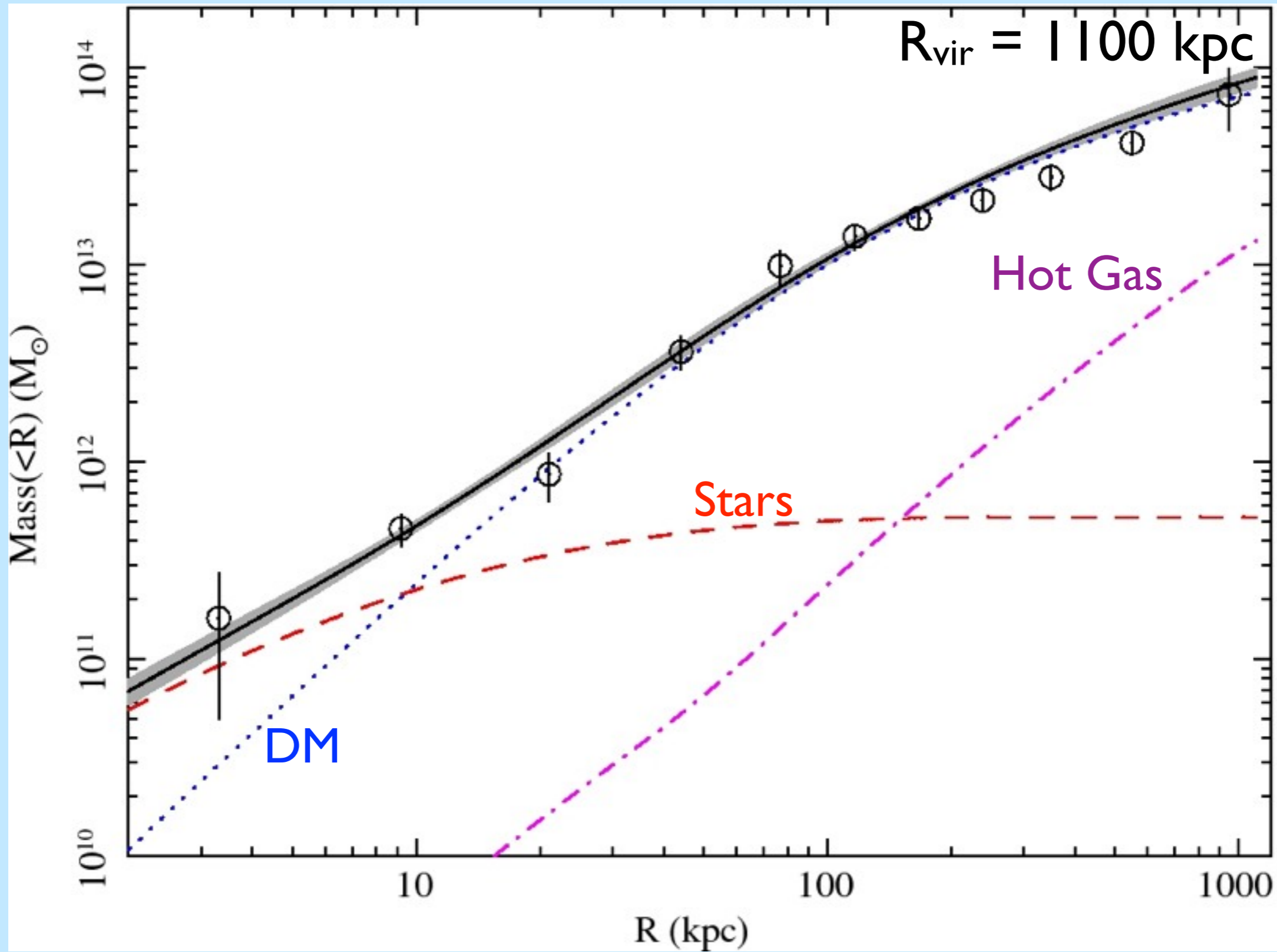
(Humphrey, Buote, Brighenti, Flohic, Gastaldello, & Mathews, in prep)



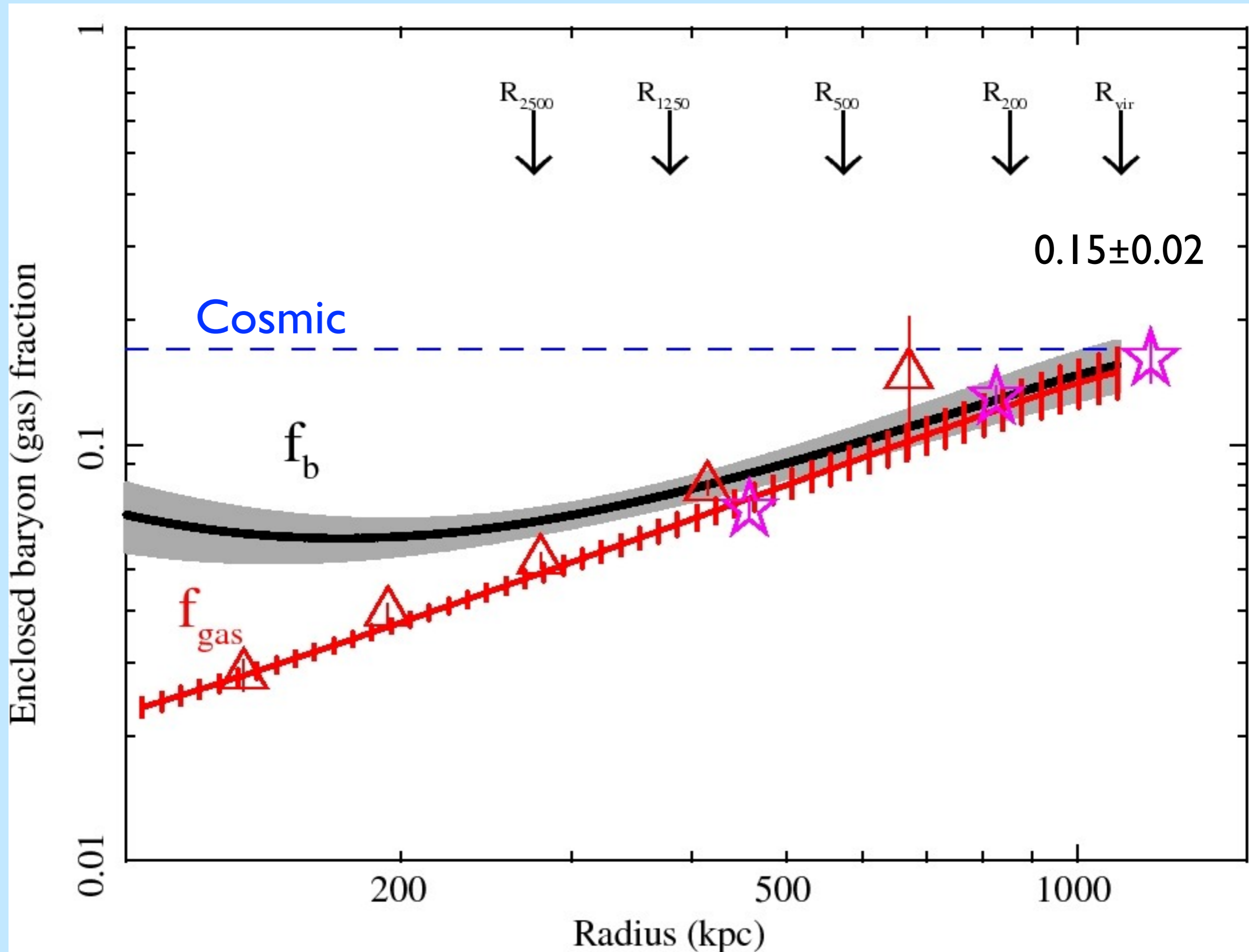


$R_{\text{vir}} = 1100 \text{ kpc}$

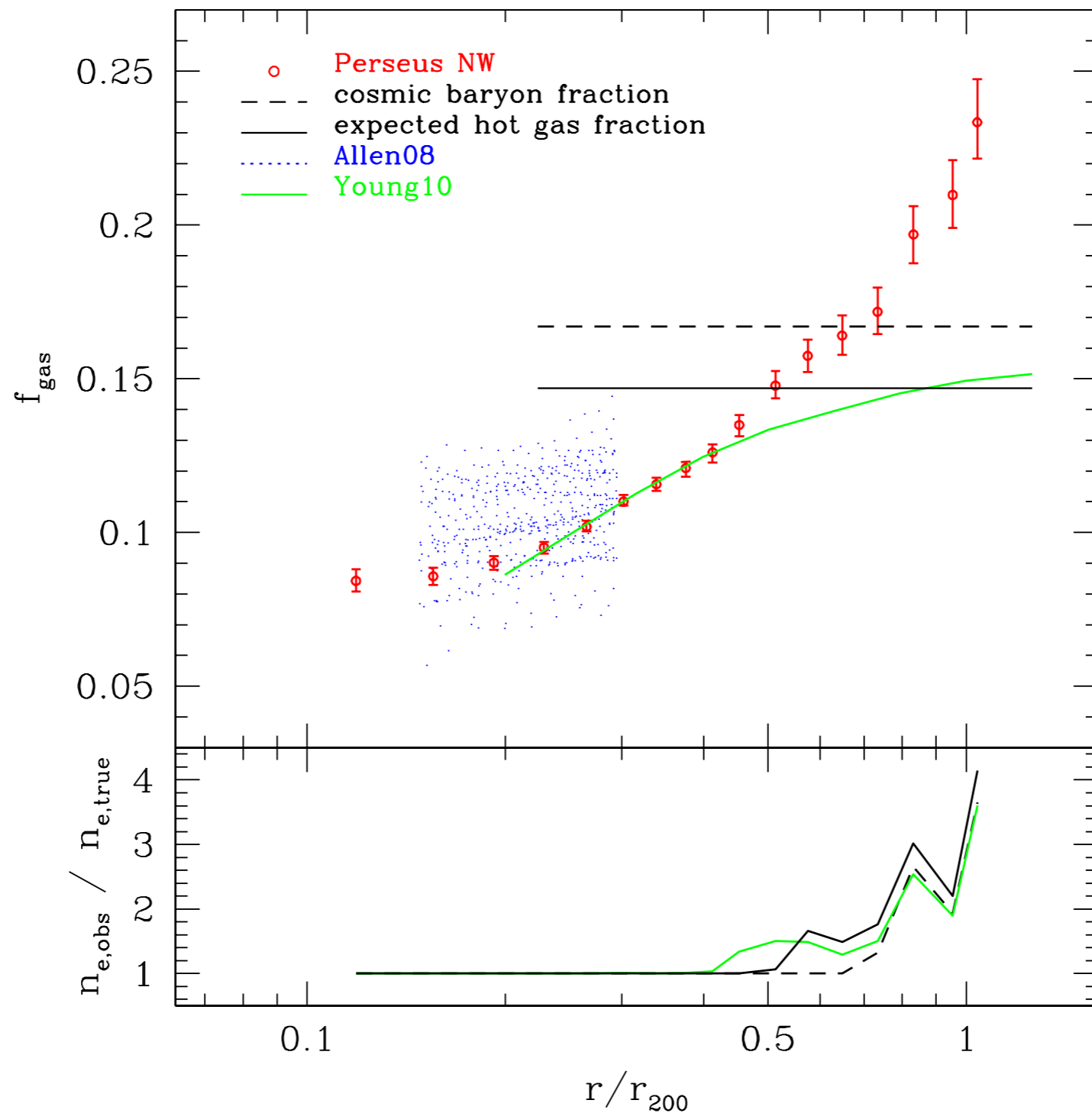




(spherically averaged)



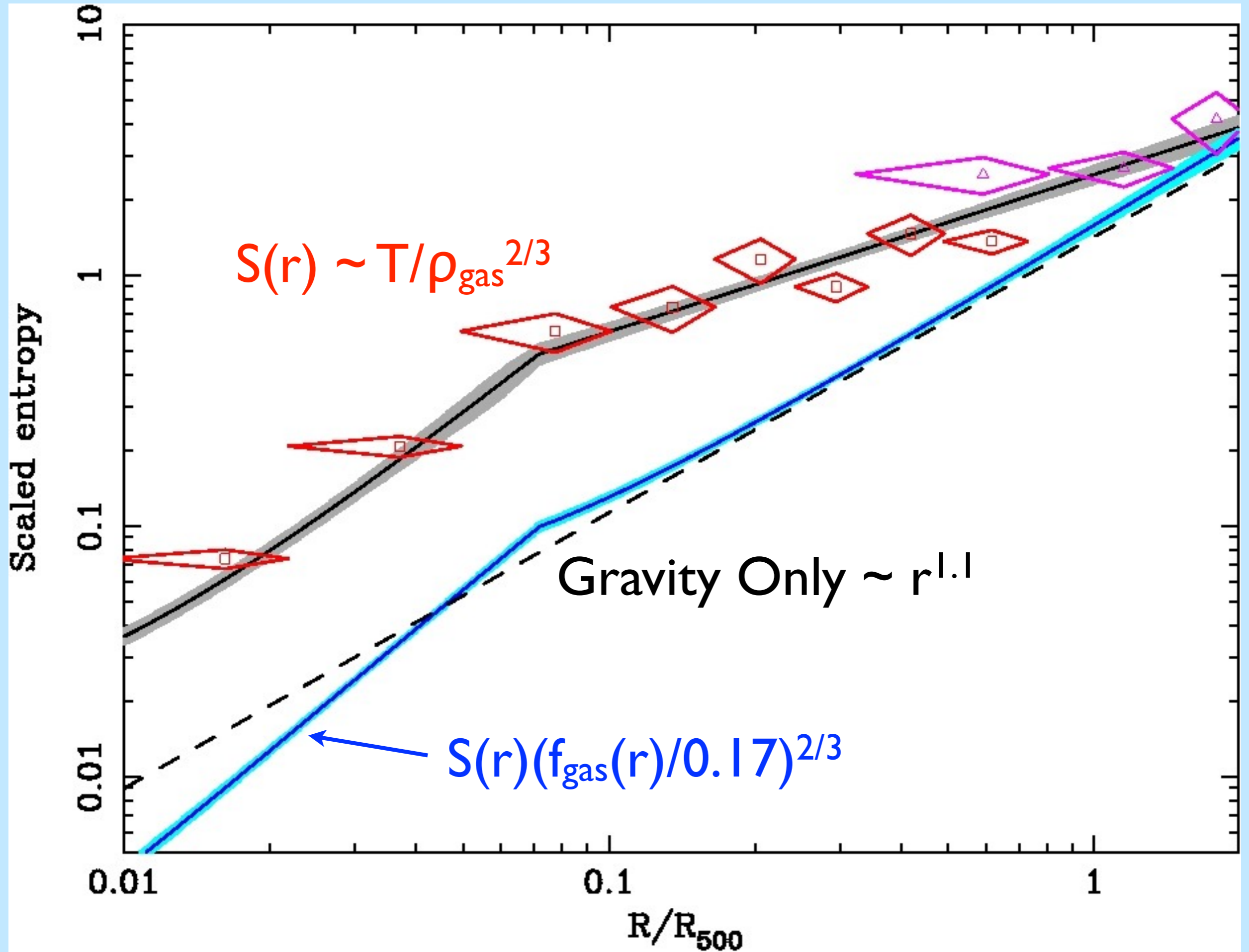
Virgo Cluster



Strange
behavior
at large
radius

Gas
Clumping?

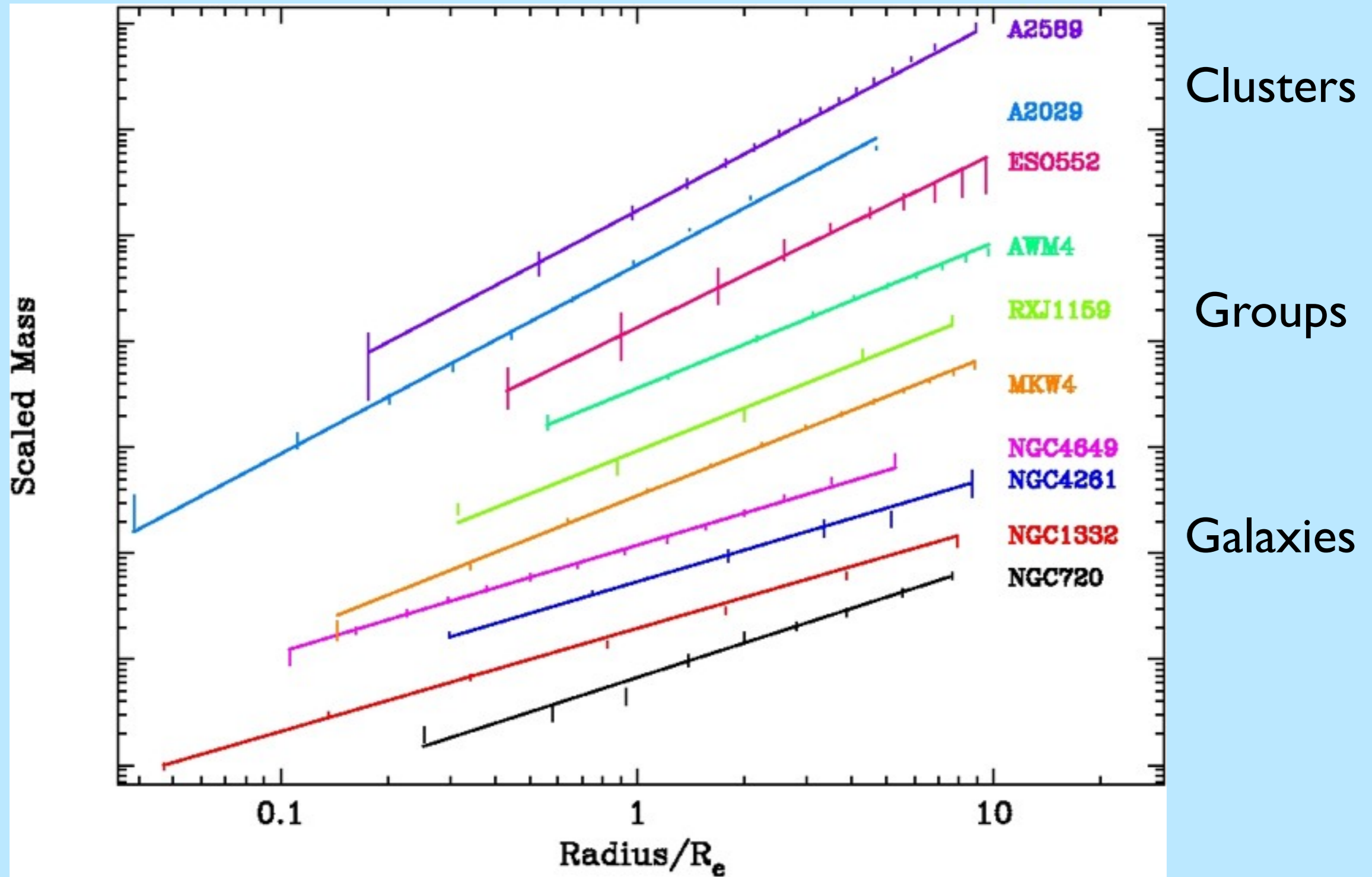
(Simionescu et al. 2011, arXiv:1102.2429)



Future Work

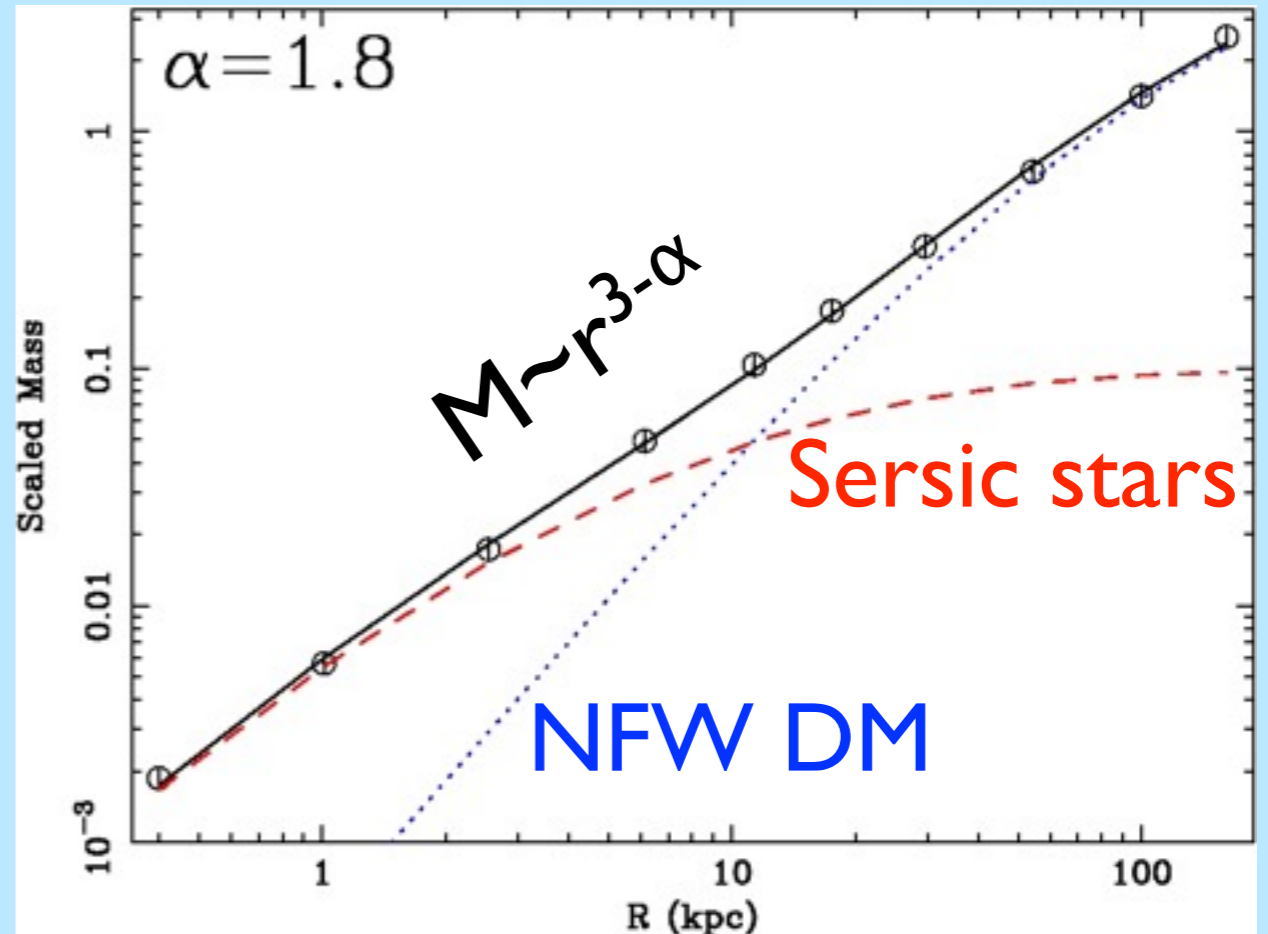
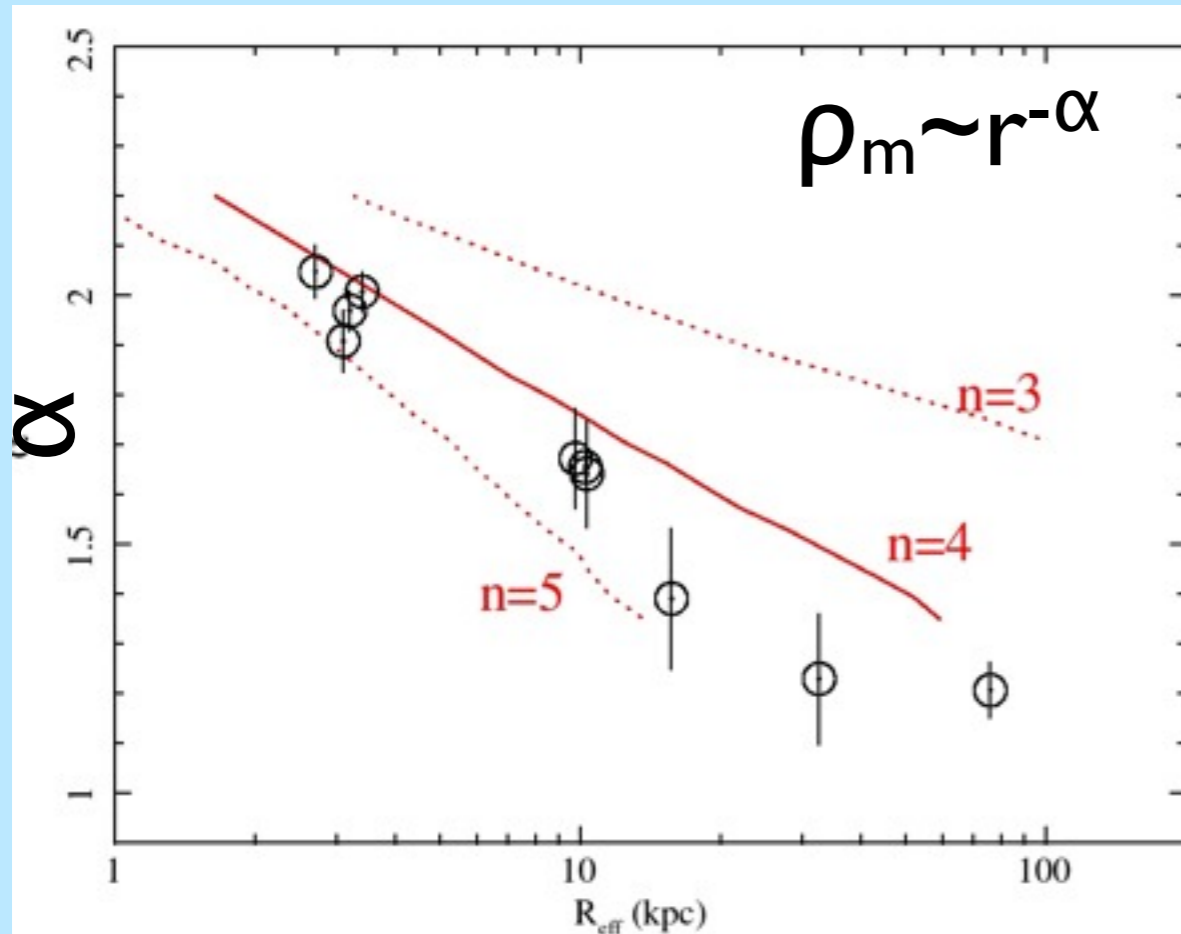
- Additional targets with virial radius observed in single Suzaku obs
- Systematic study of 15 X-ray--selected Groups

Power-Law Mass Profiles



(Humphrey & Buote 2010, MNRAS, 403, 2143)

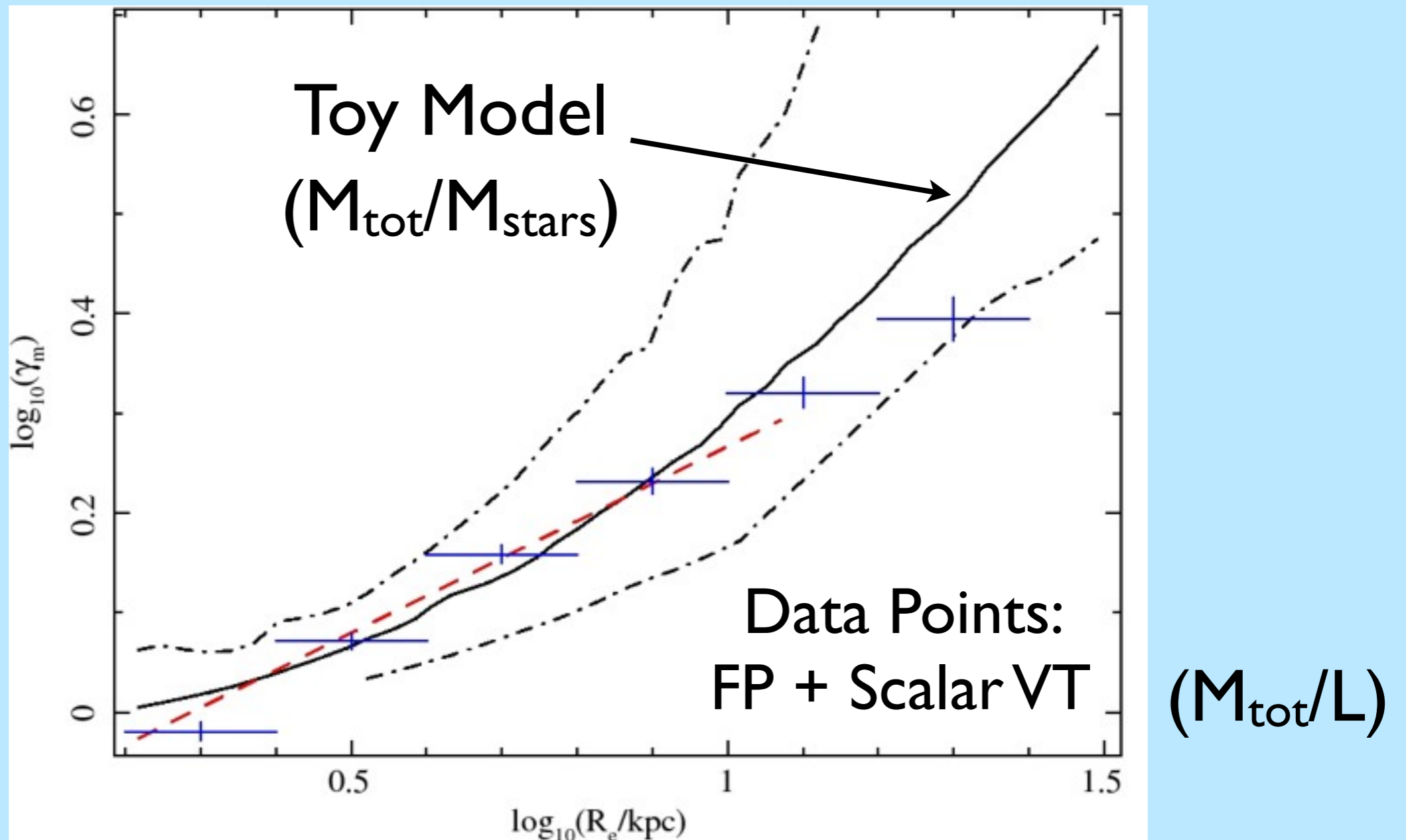
Slope- R_e Relation



(Humphrey & Buote 2010, MNRAS, 403, 2143)

Similar α - R_e relation confirmed by SLACS
(Auger et al. 2010, ApJ, 724, 511)

Tilt of Fundamental Plane



Are Nearly Power-Law Mass Profiles a Fundamental Feature of Galaxy Formation?