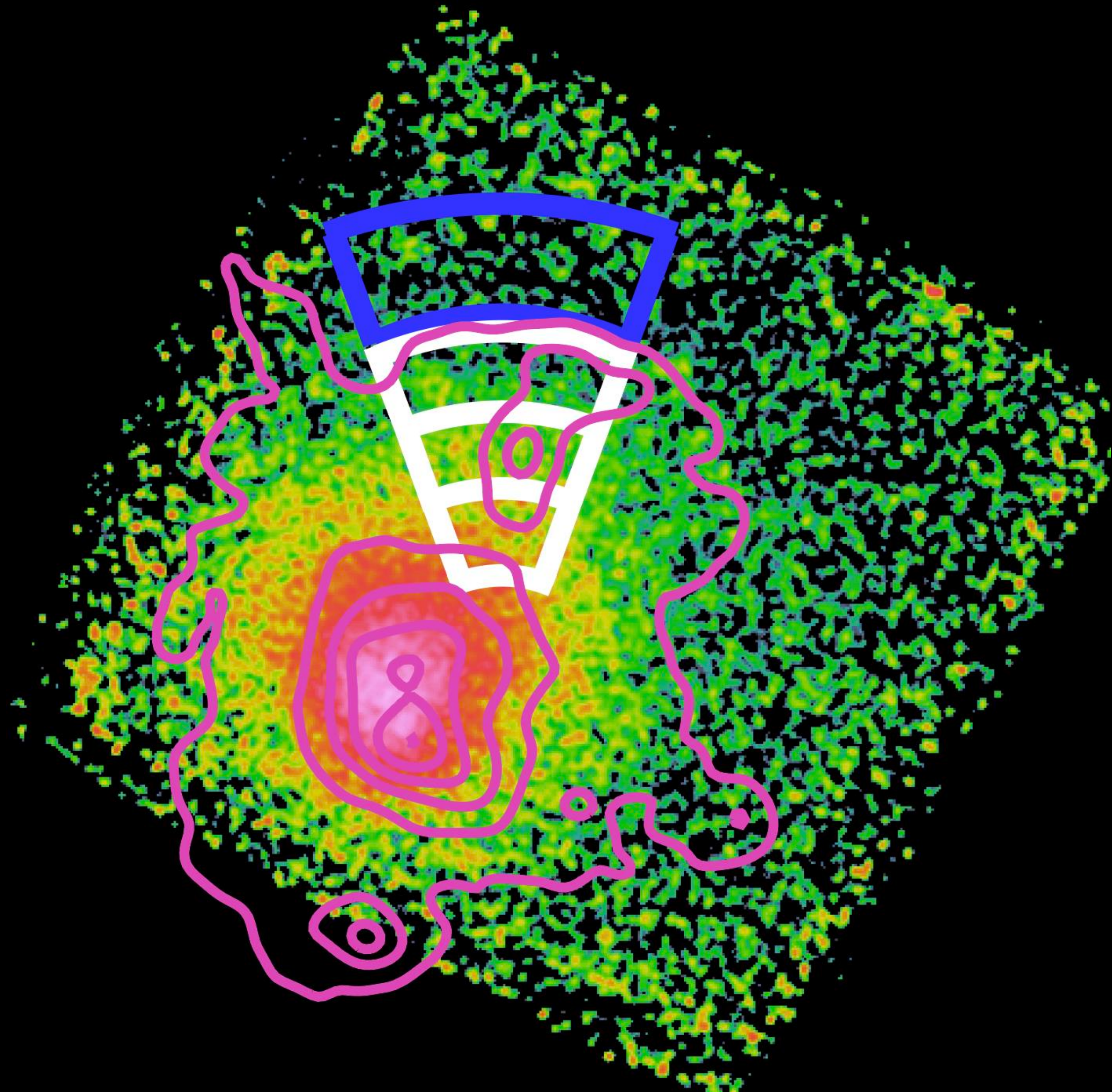


Galaxy Cluster Thermalization

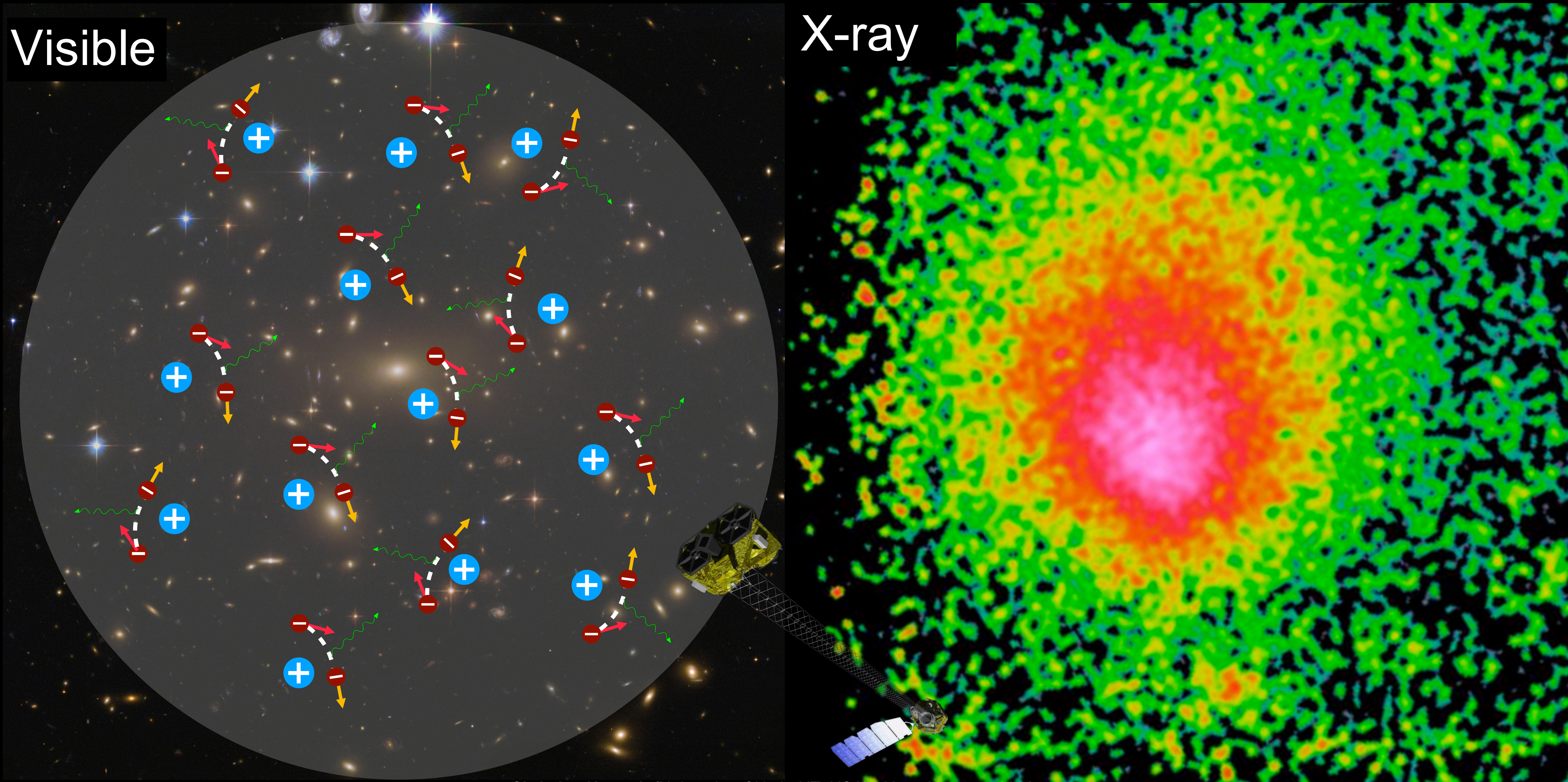
Electron-Ion Equilibration in the
Merging Galaxy Cluster A665

Christian Norseth
University of Utah, UT, USA
X-ray Universe 2026



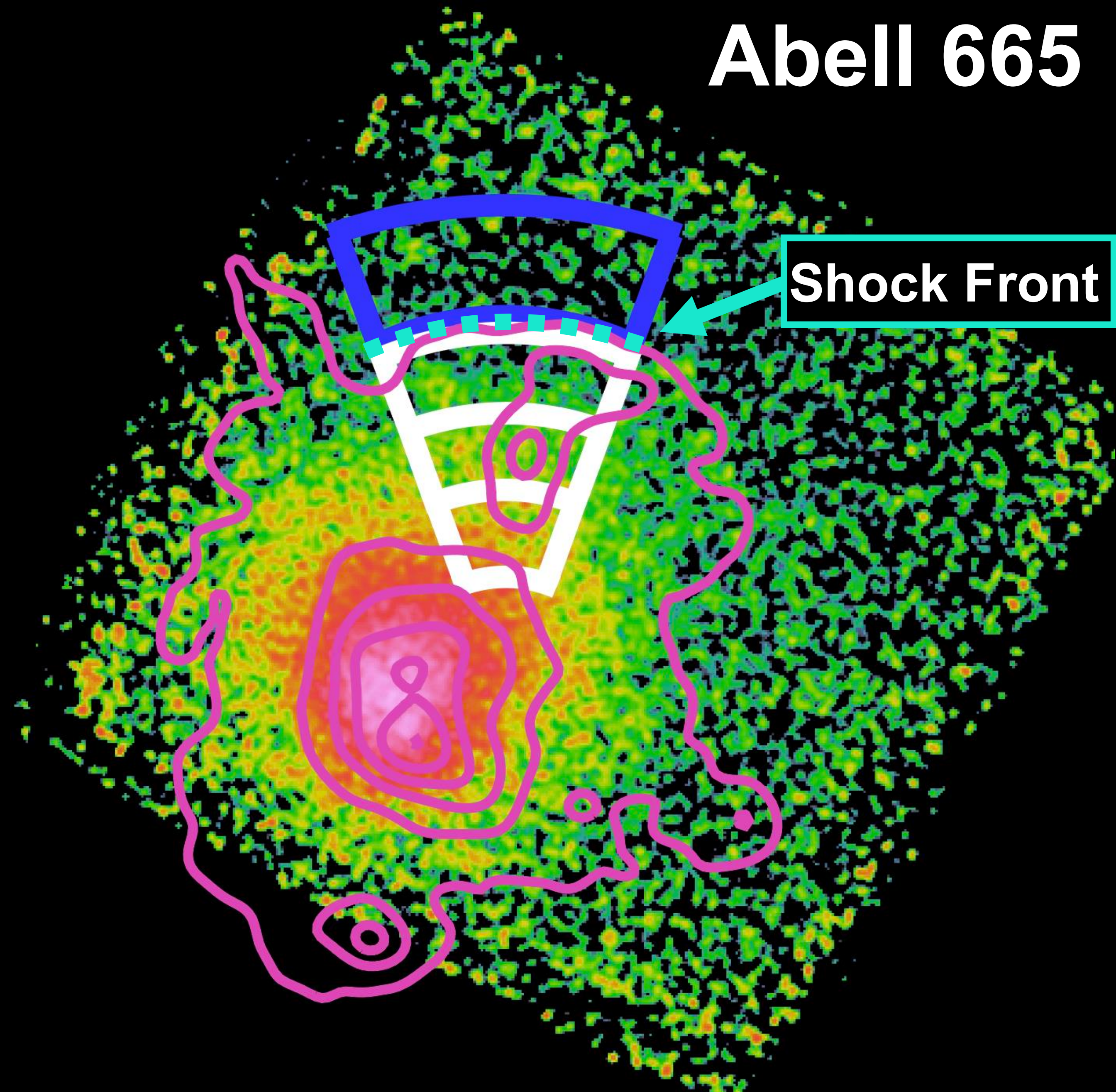
Visible

X-ray



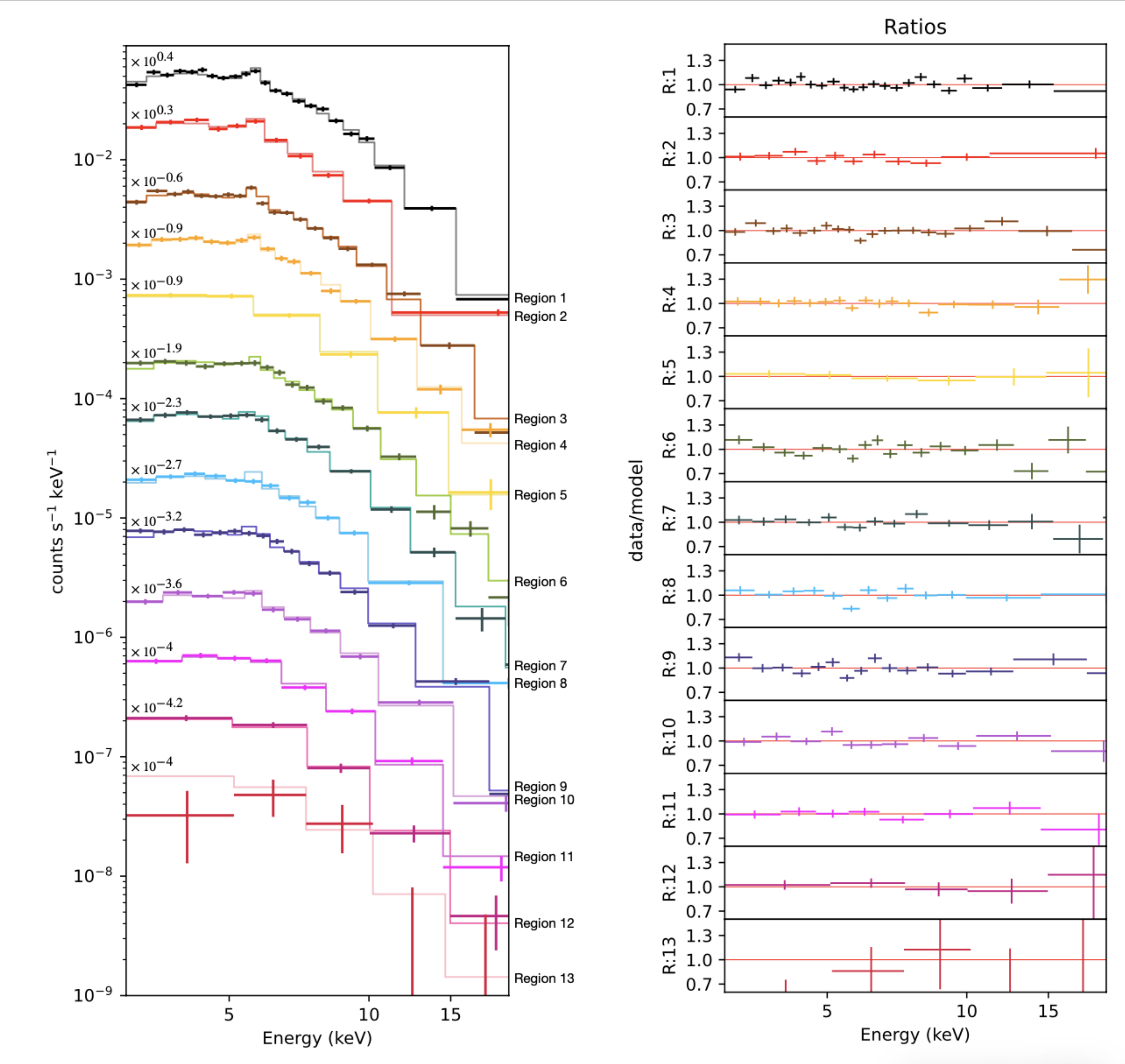
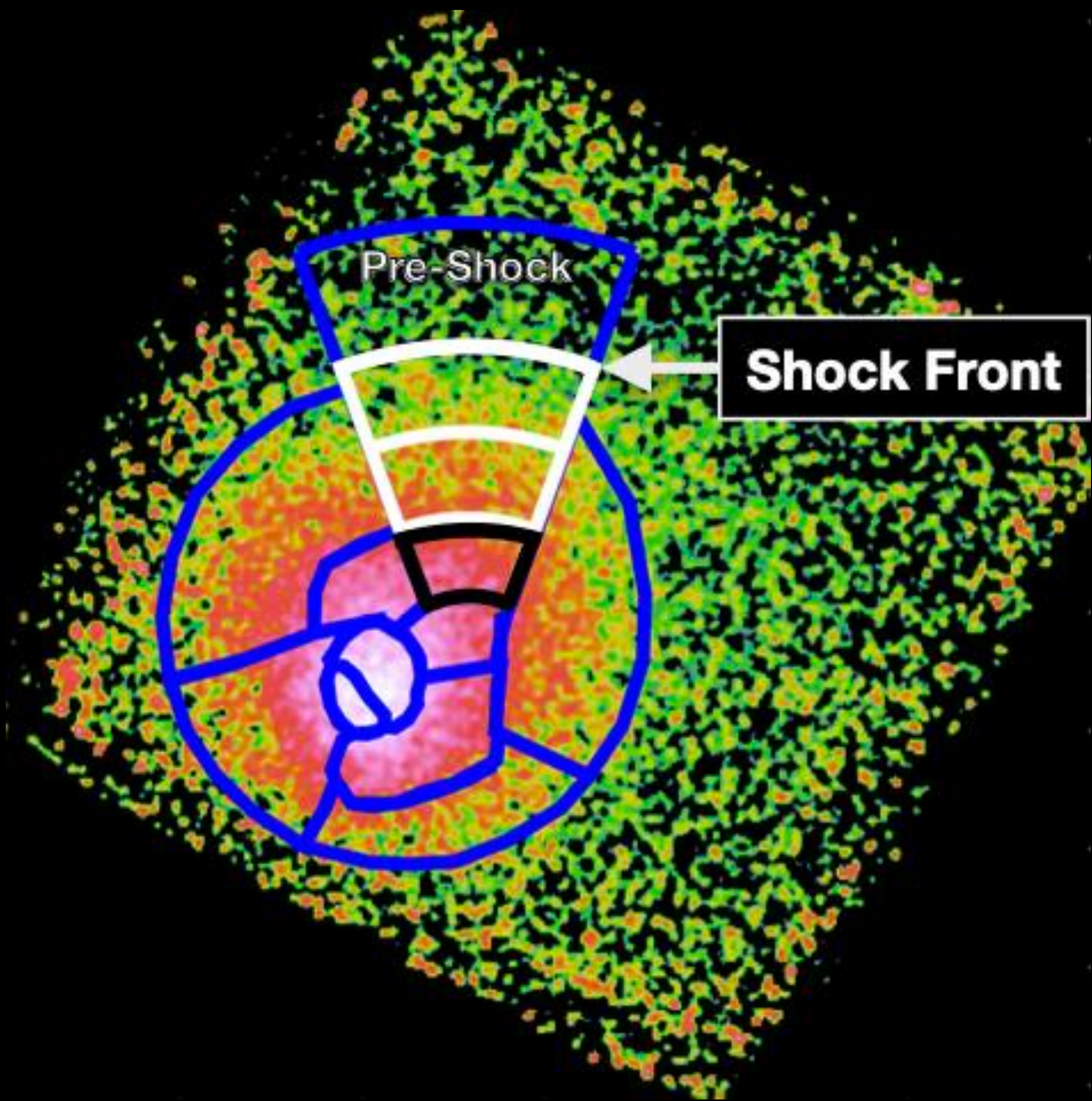
Abell 665

$t = 0.00 \text{ Gyr}$

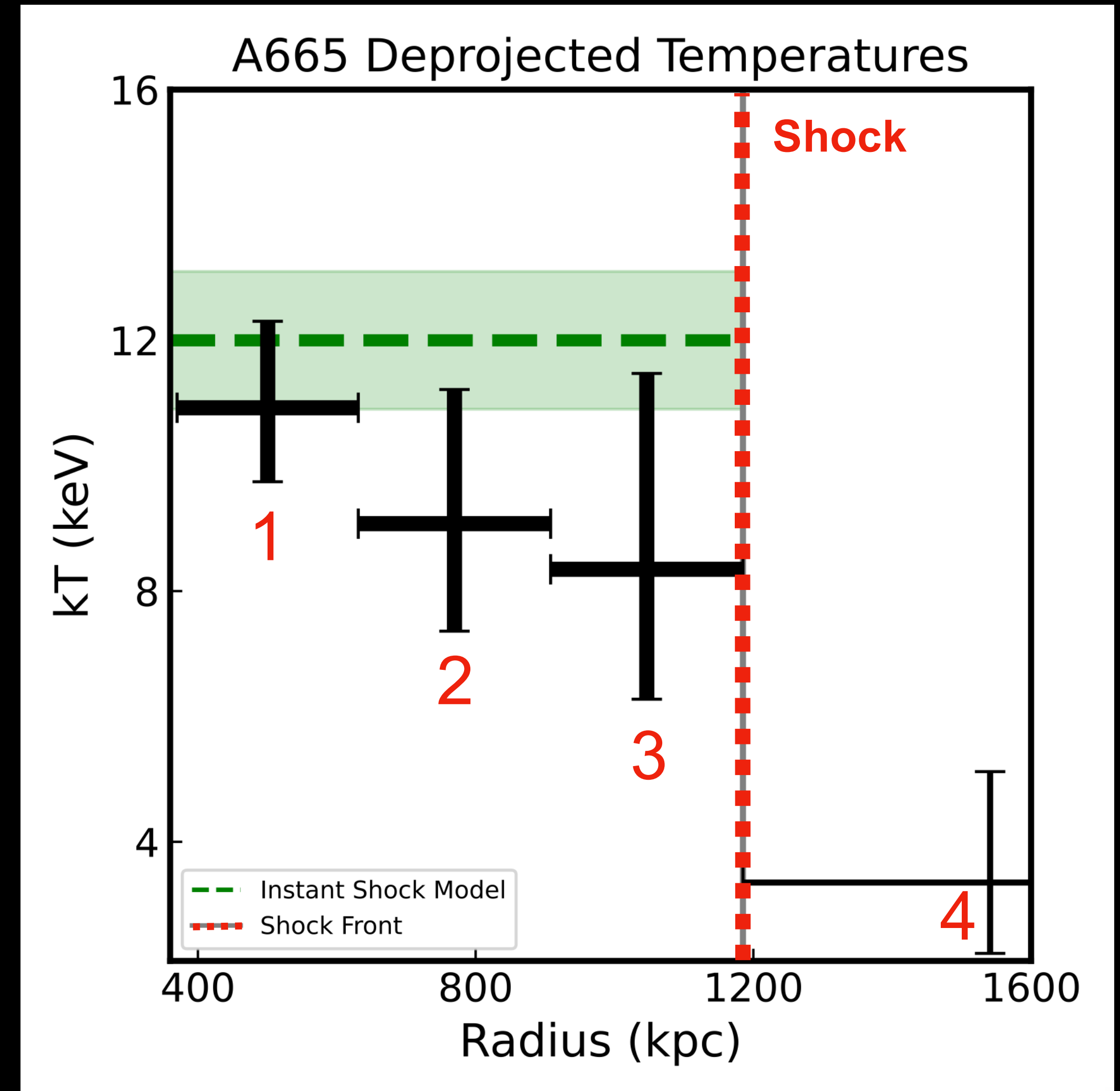
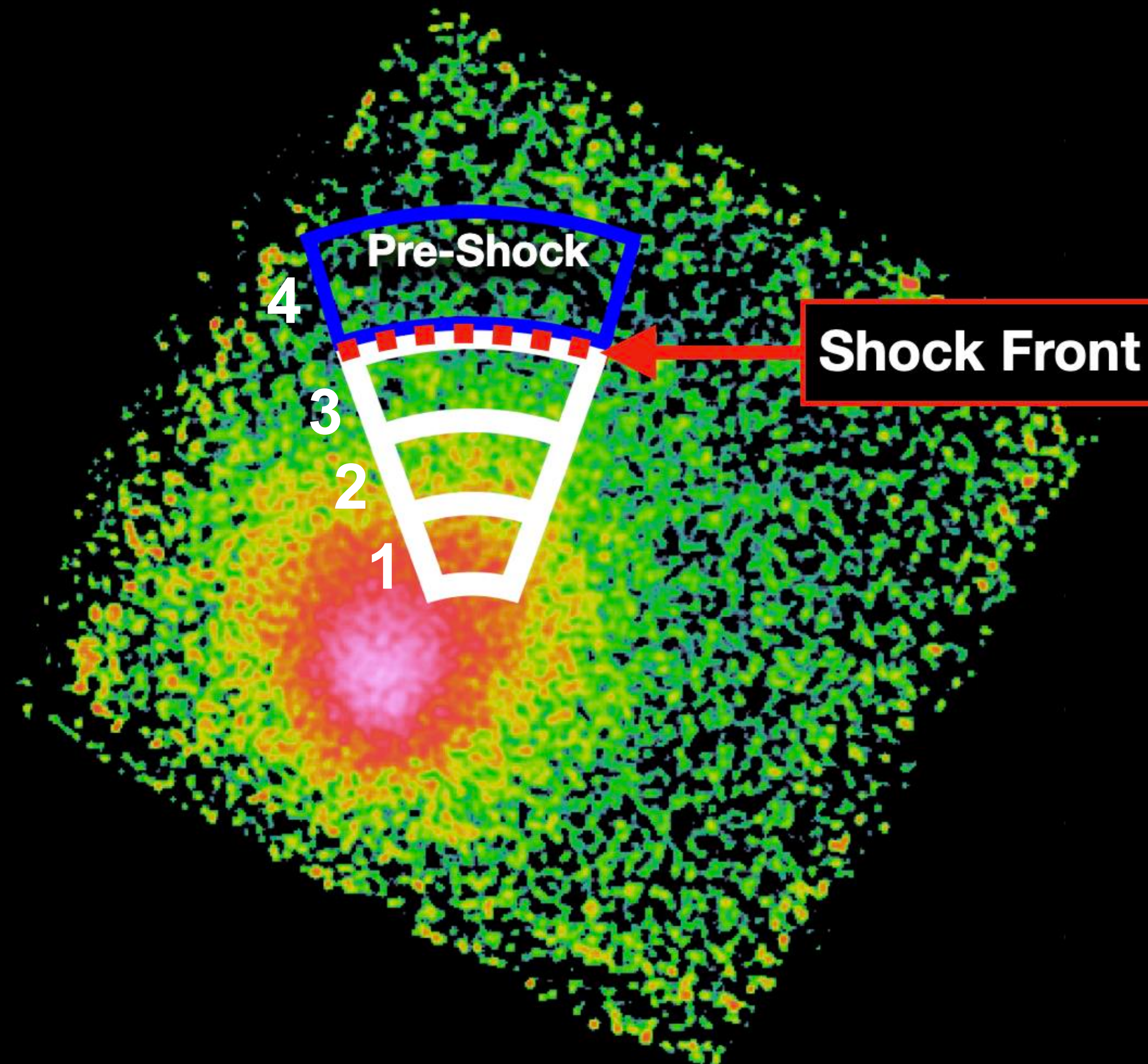


Credit: John ZuHone

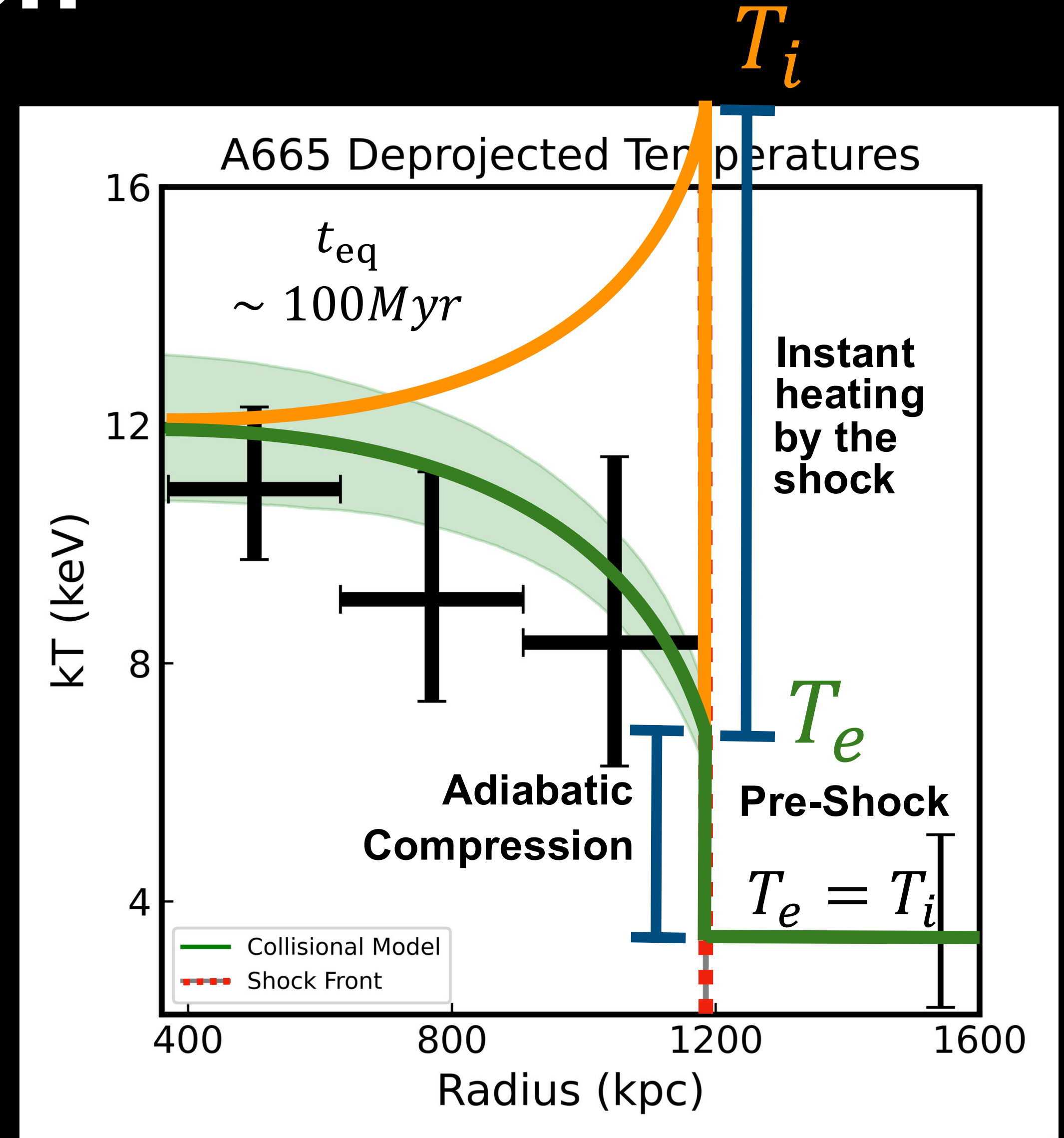
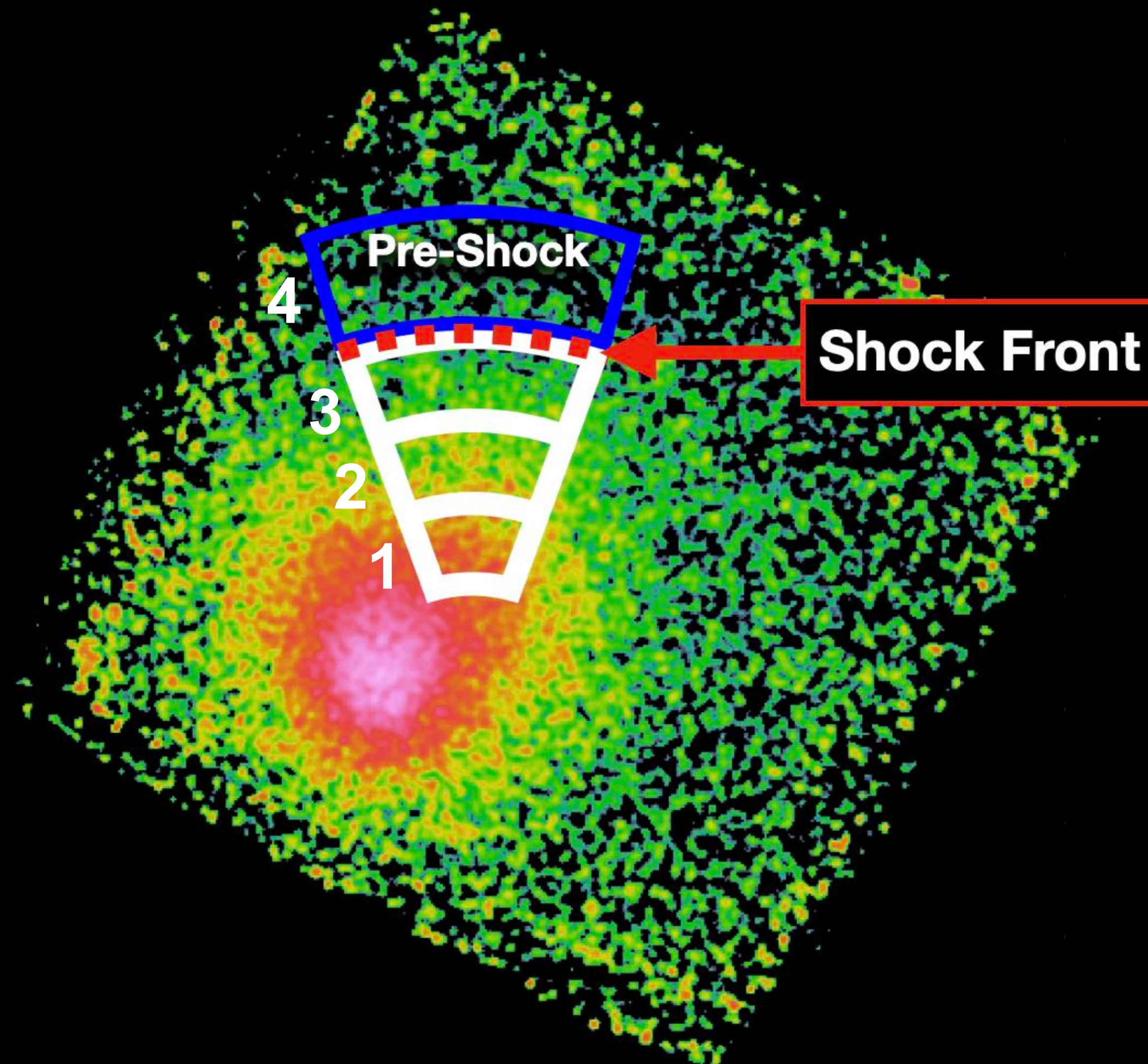
PSF Scattering



Electron-Ion Equilibration

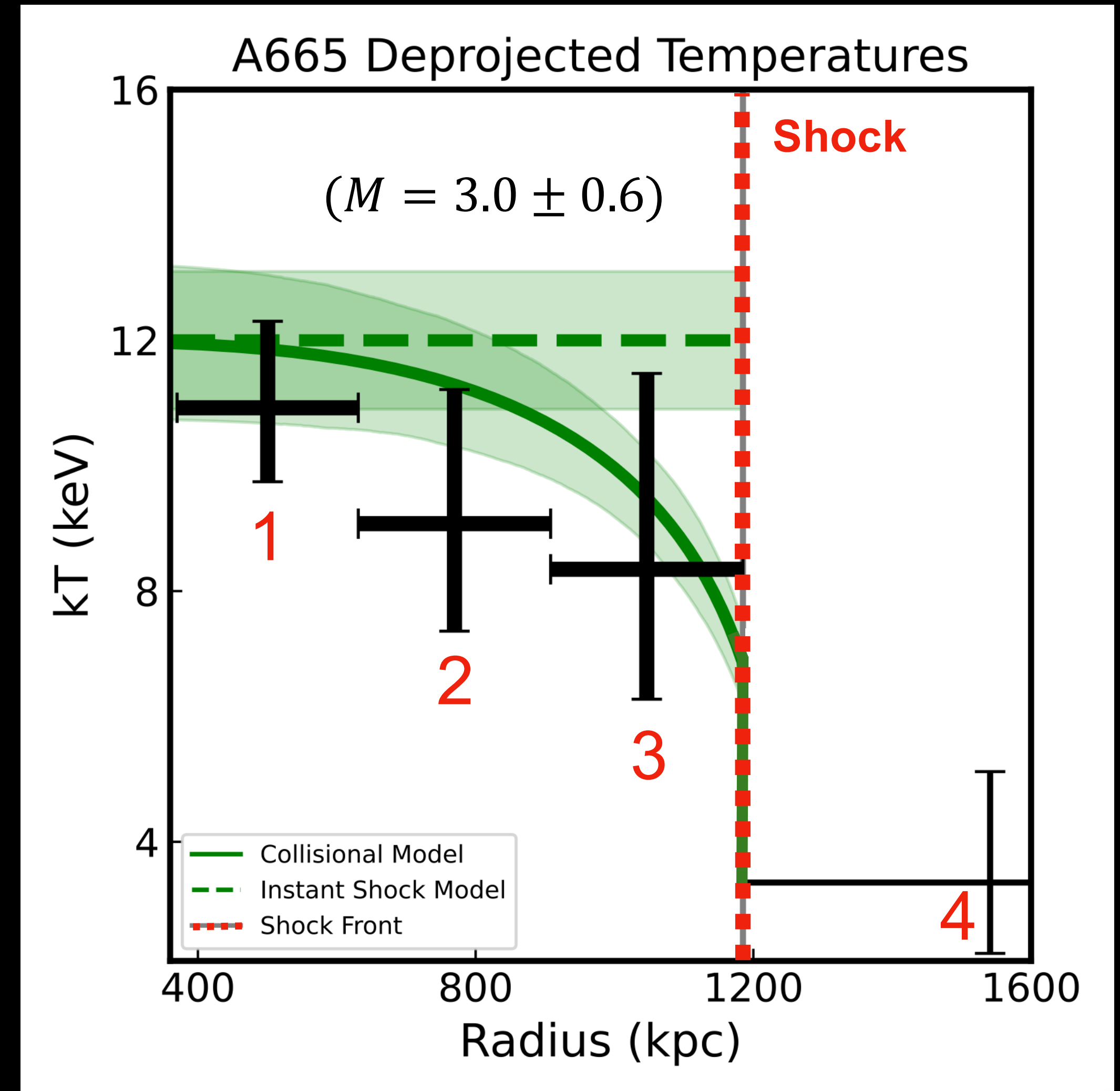
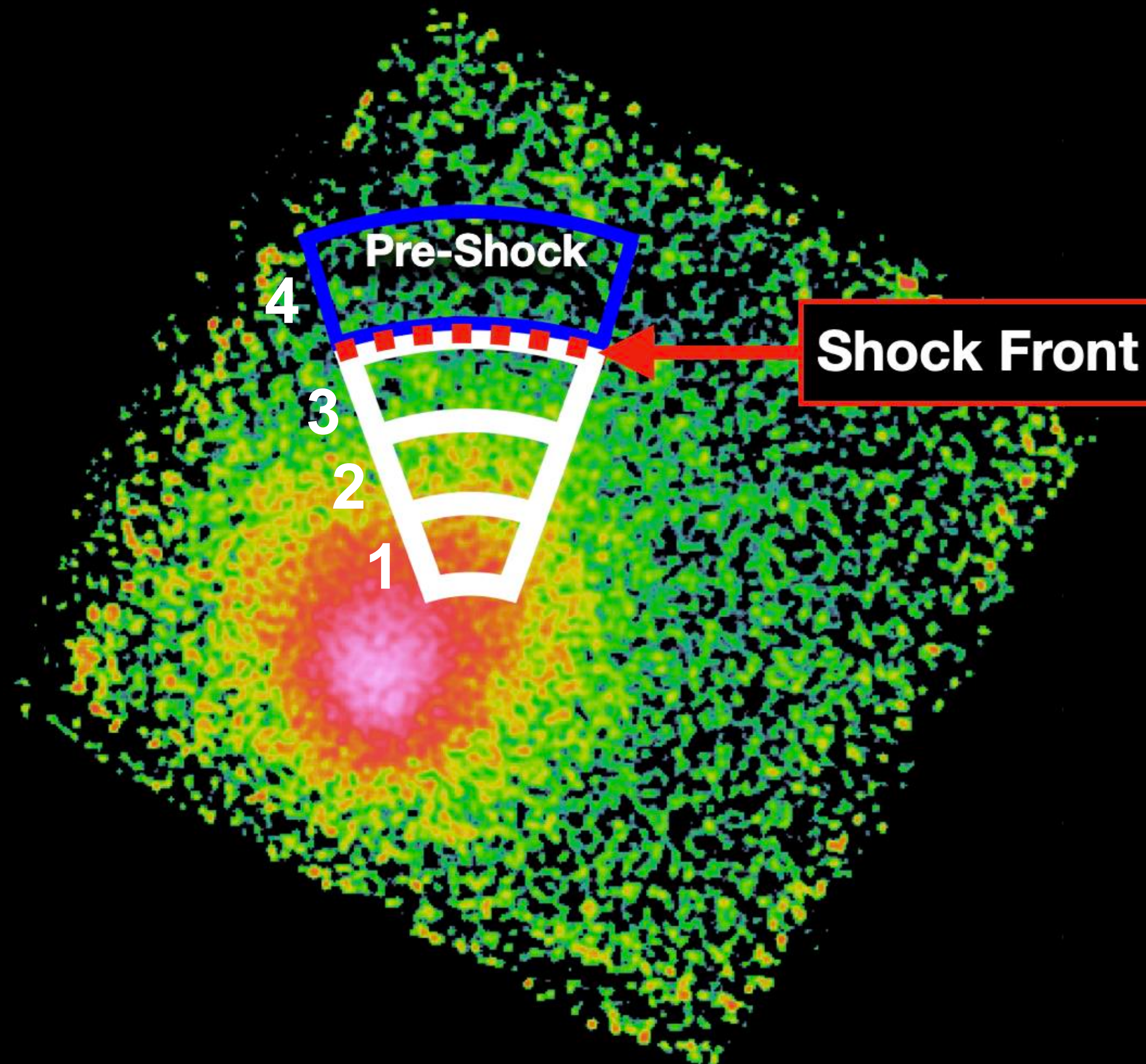


Electron-Ion Equilibration



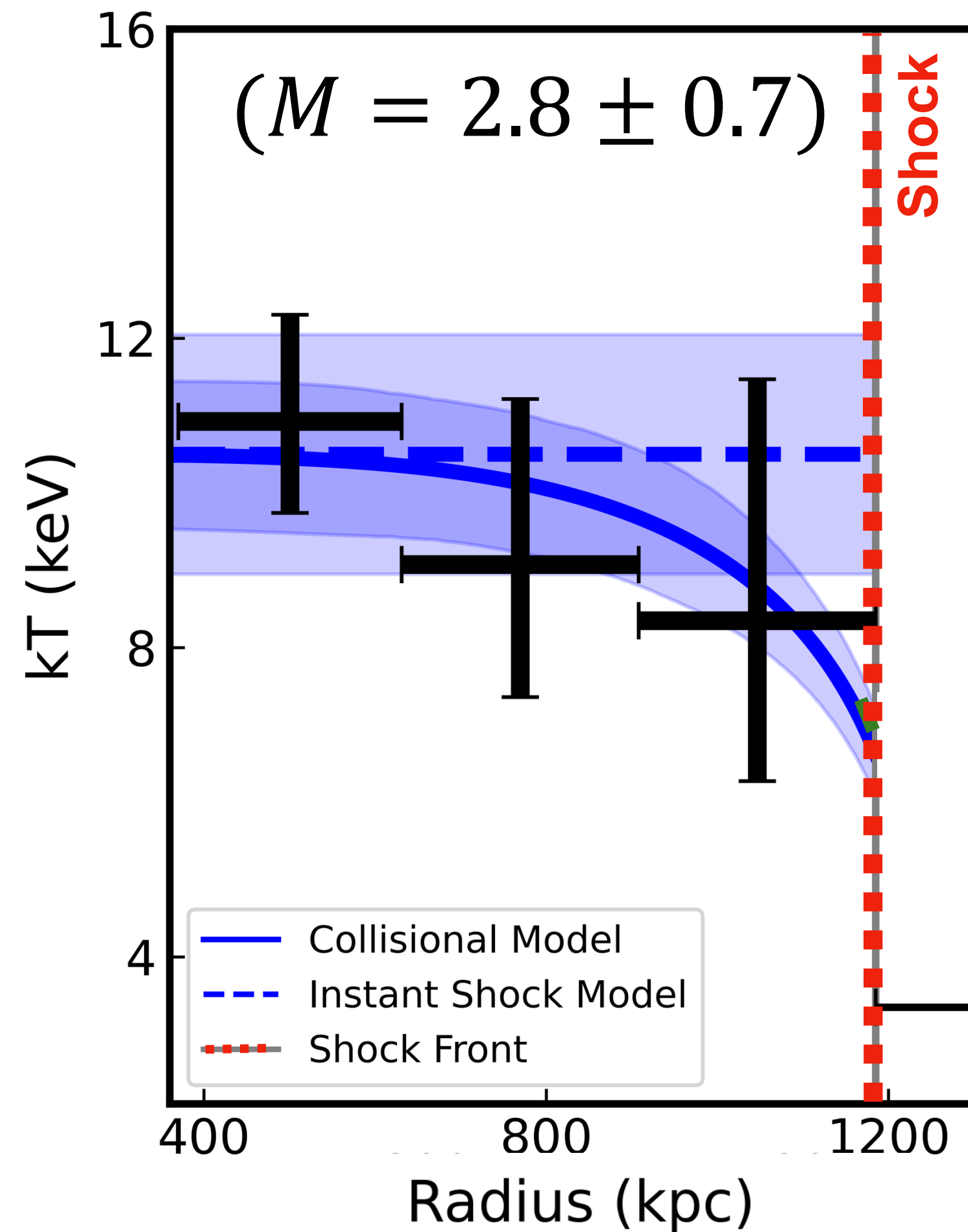
Electron-Ion Equilibration

Delayed Equilibration Favored

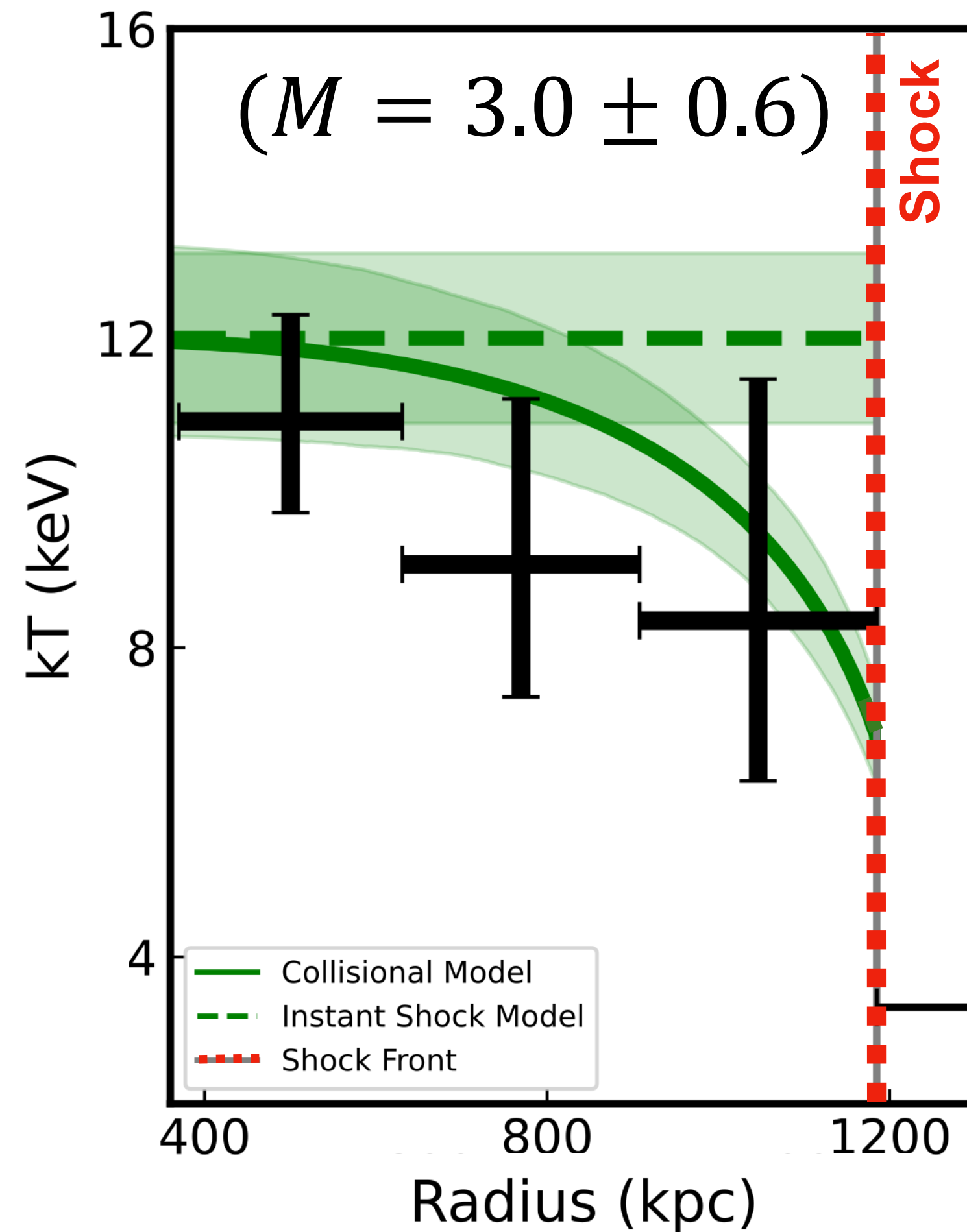


Mach Number

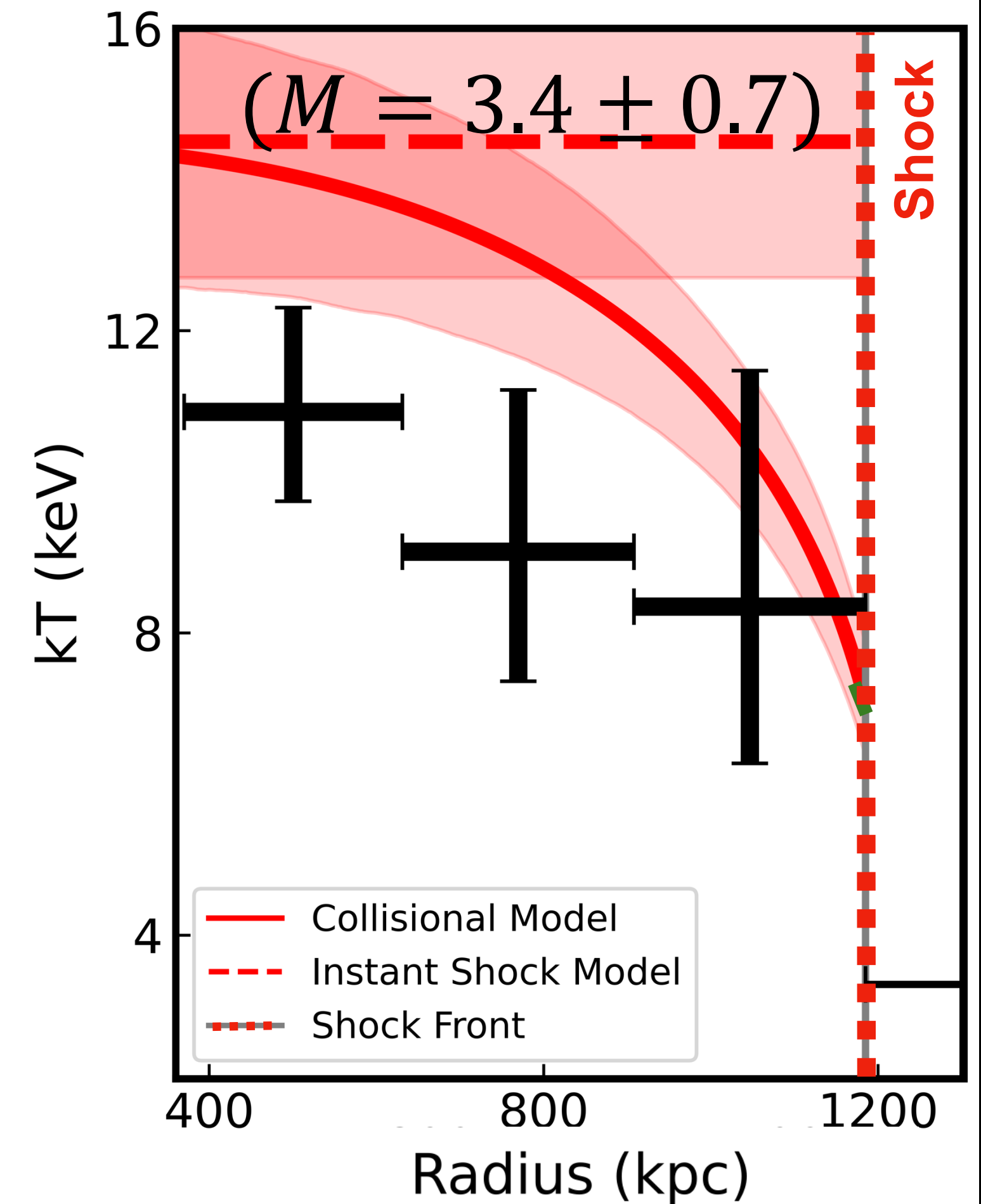
NuSTAR Temperature Jump



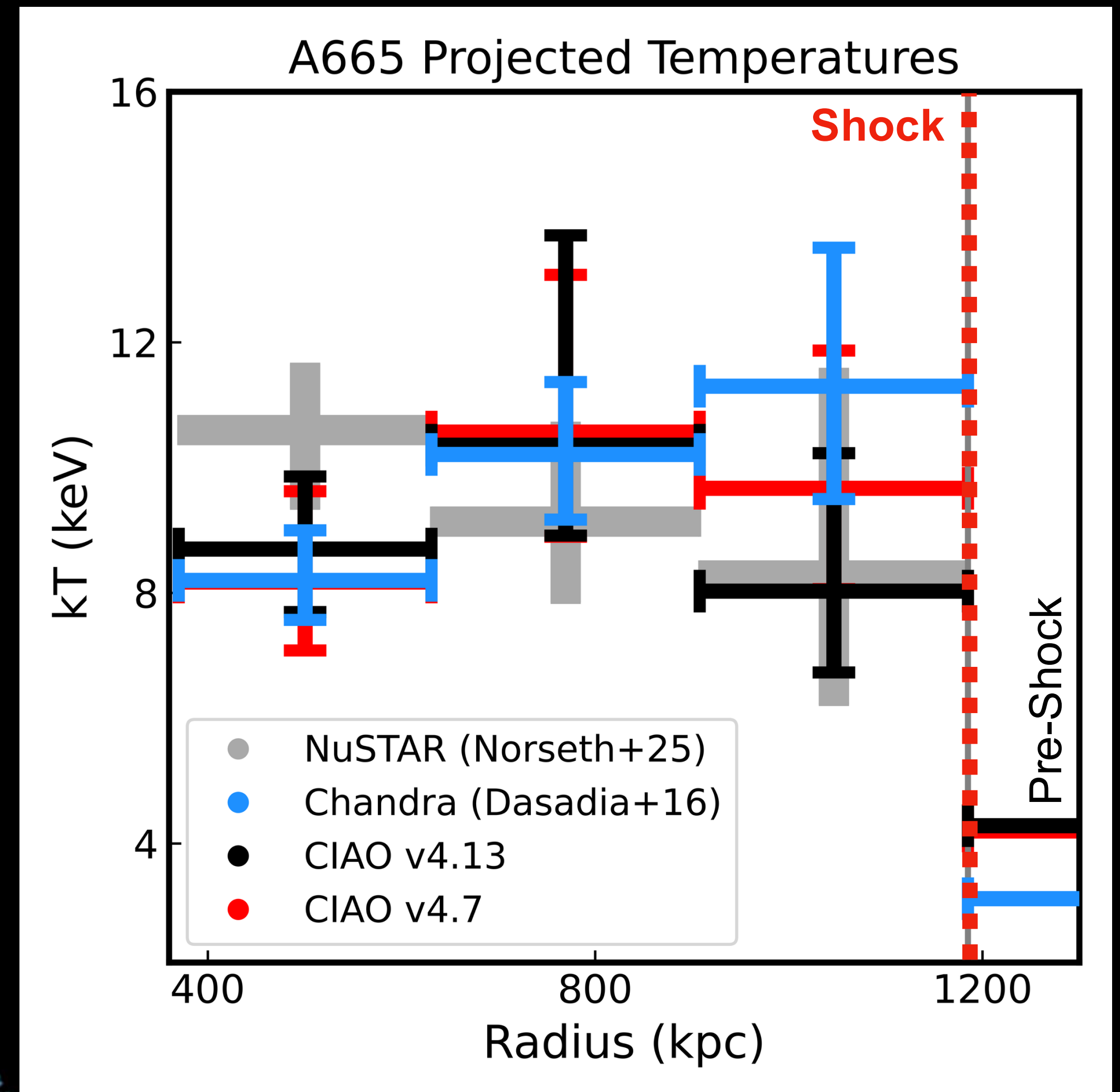
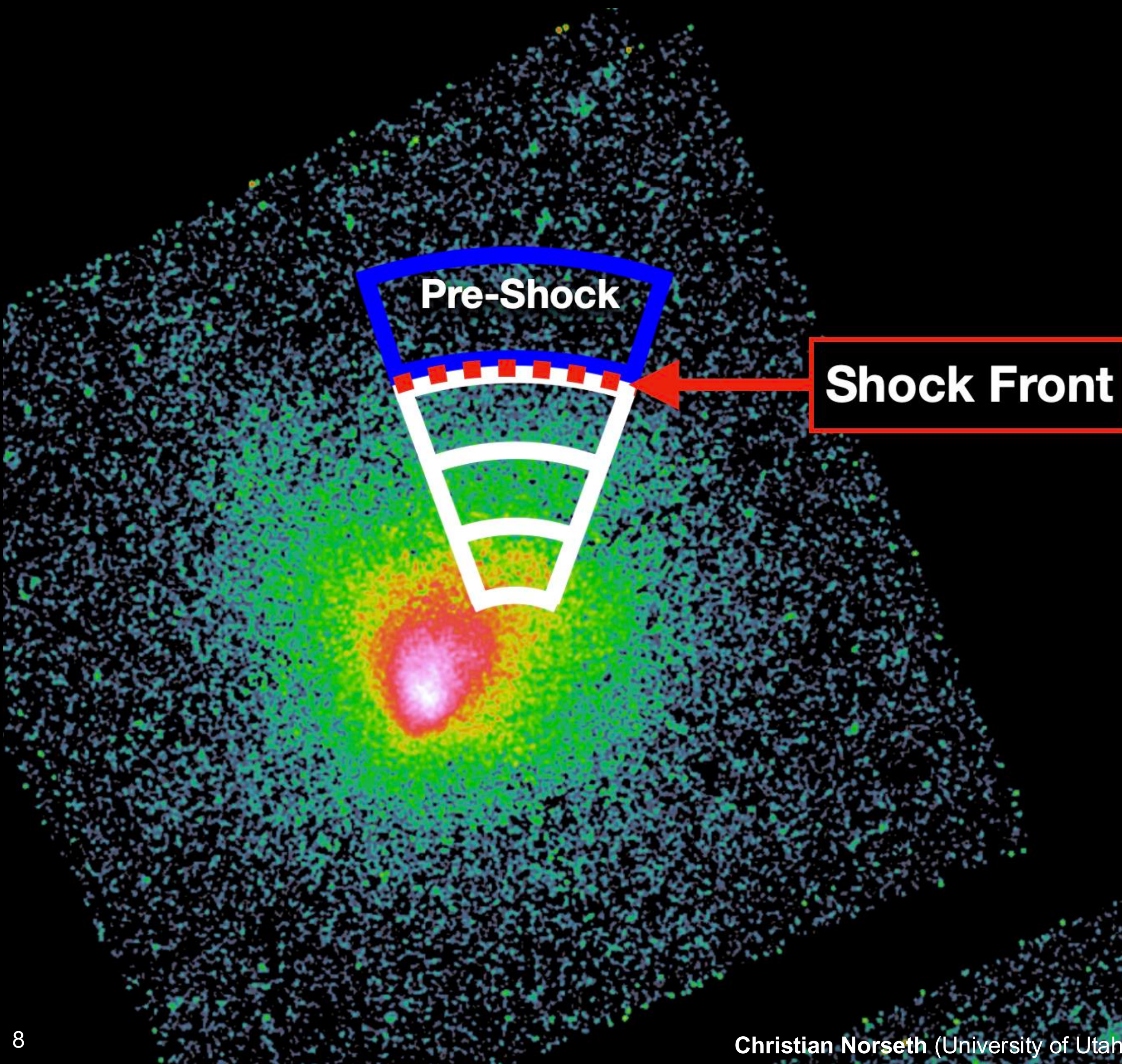
Chandra Temperature Jump



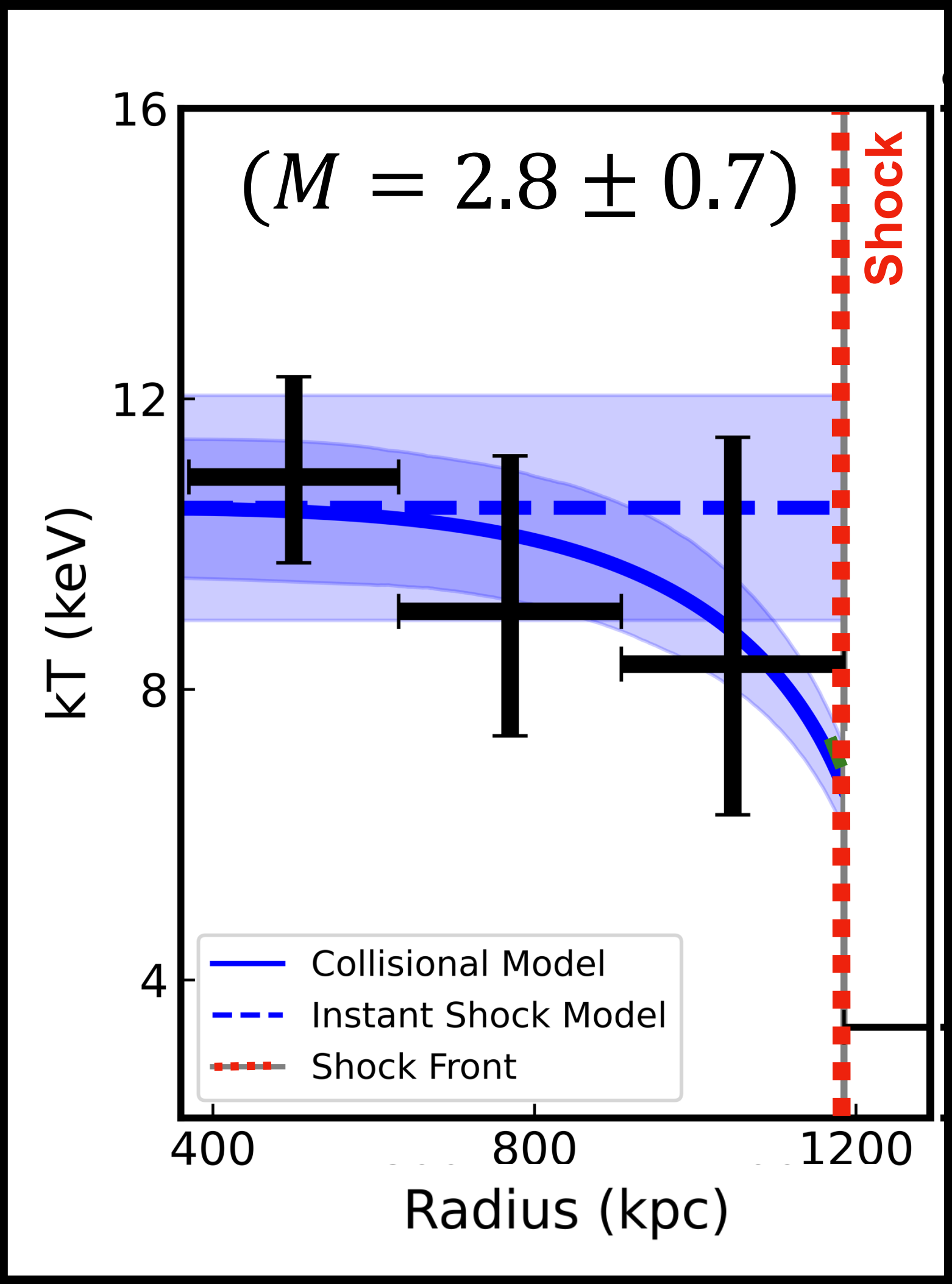
Chandra Density Jump



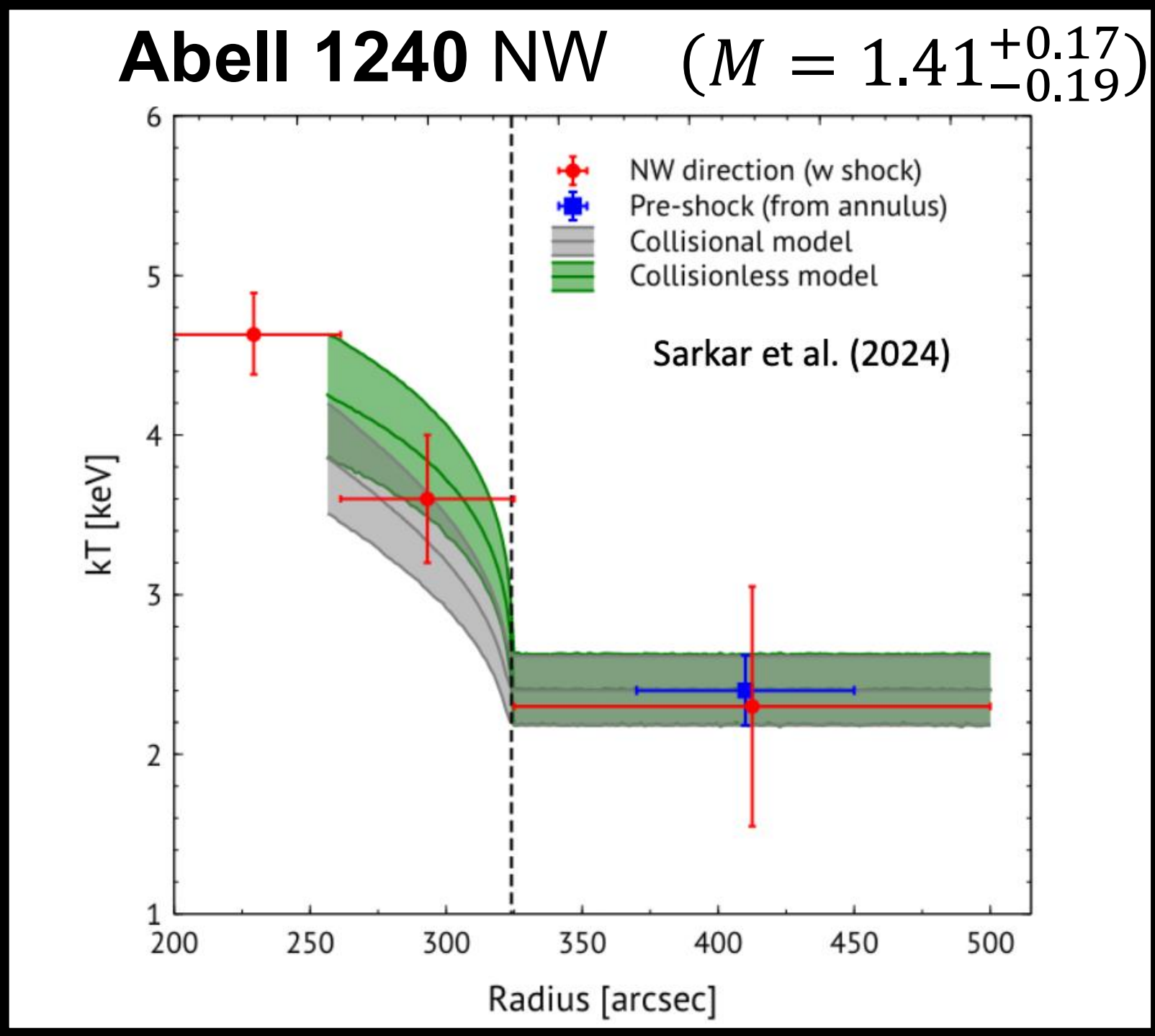
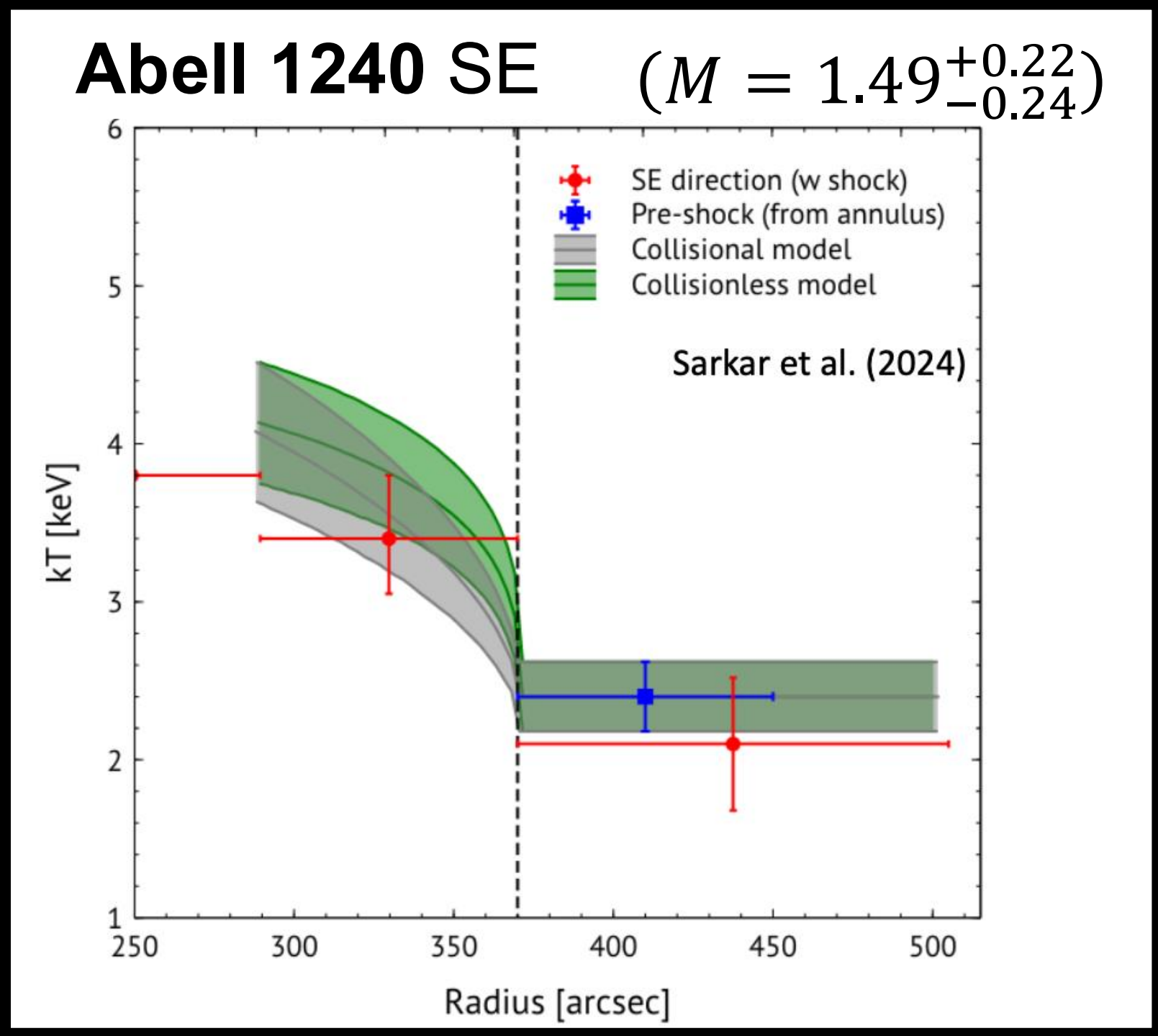
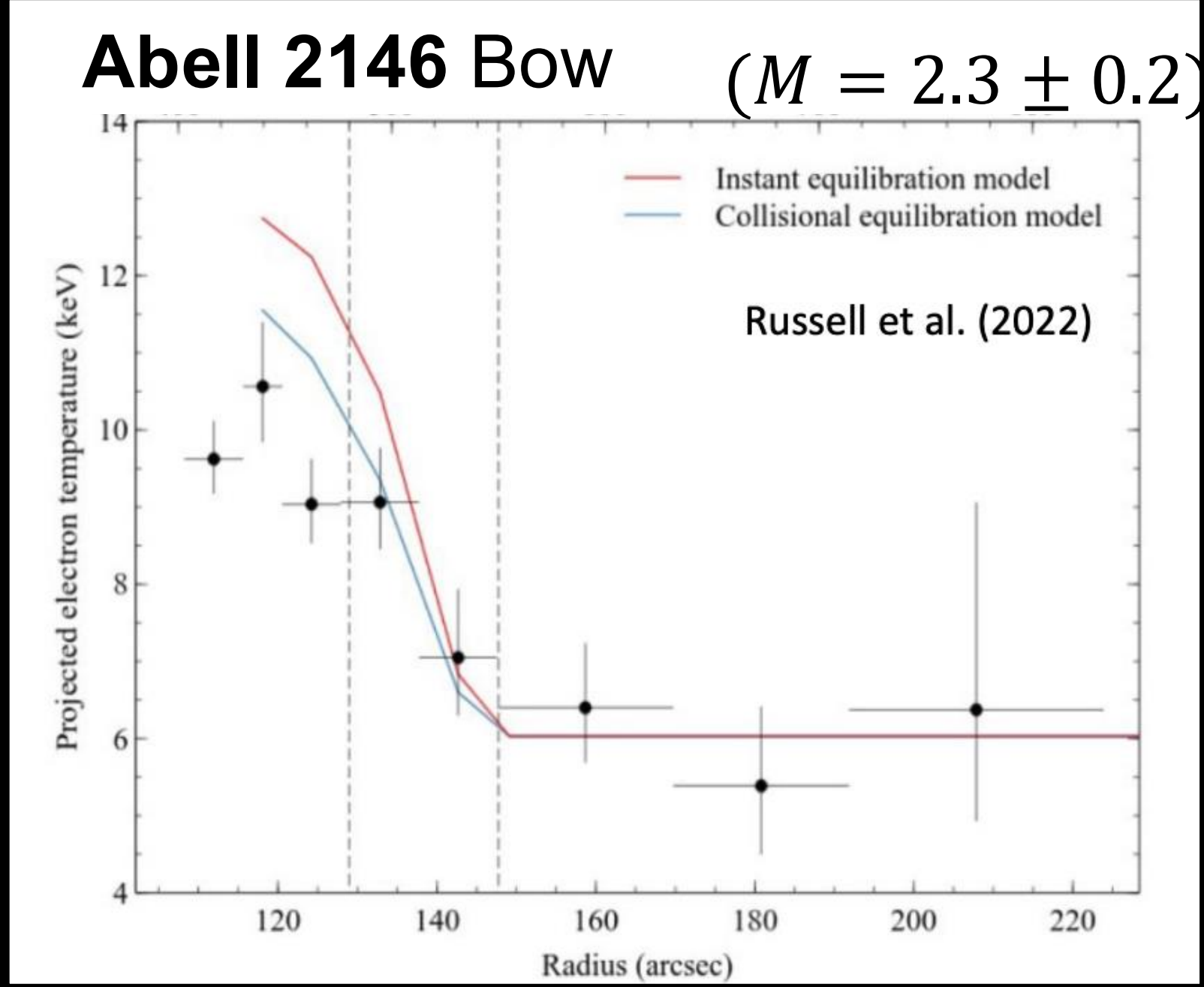
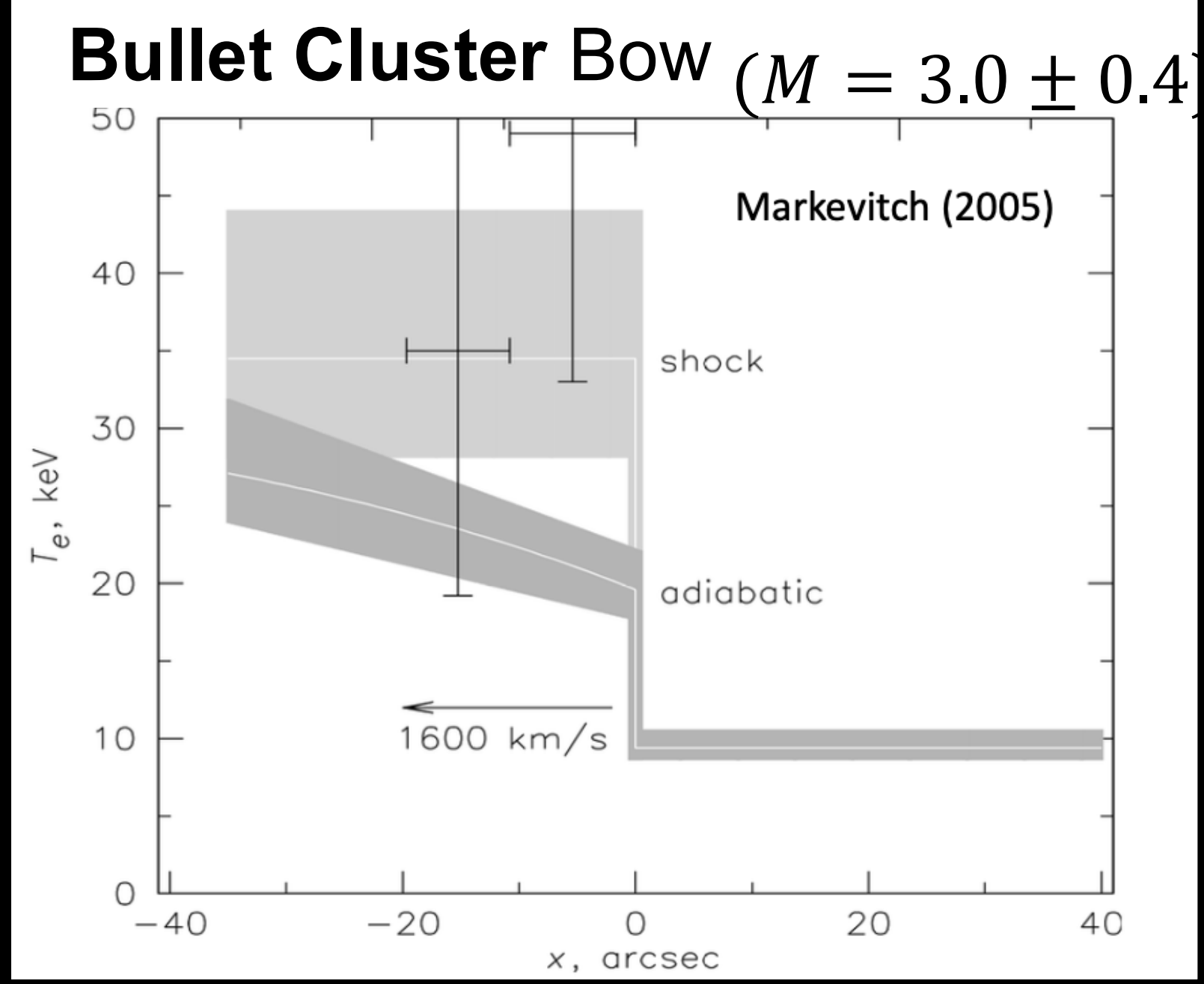
Cross-Calibration



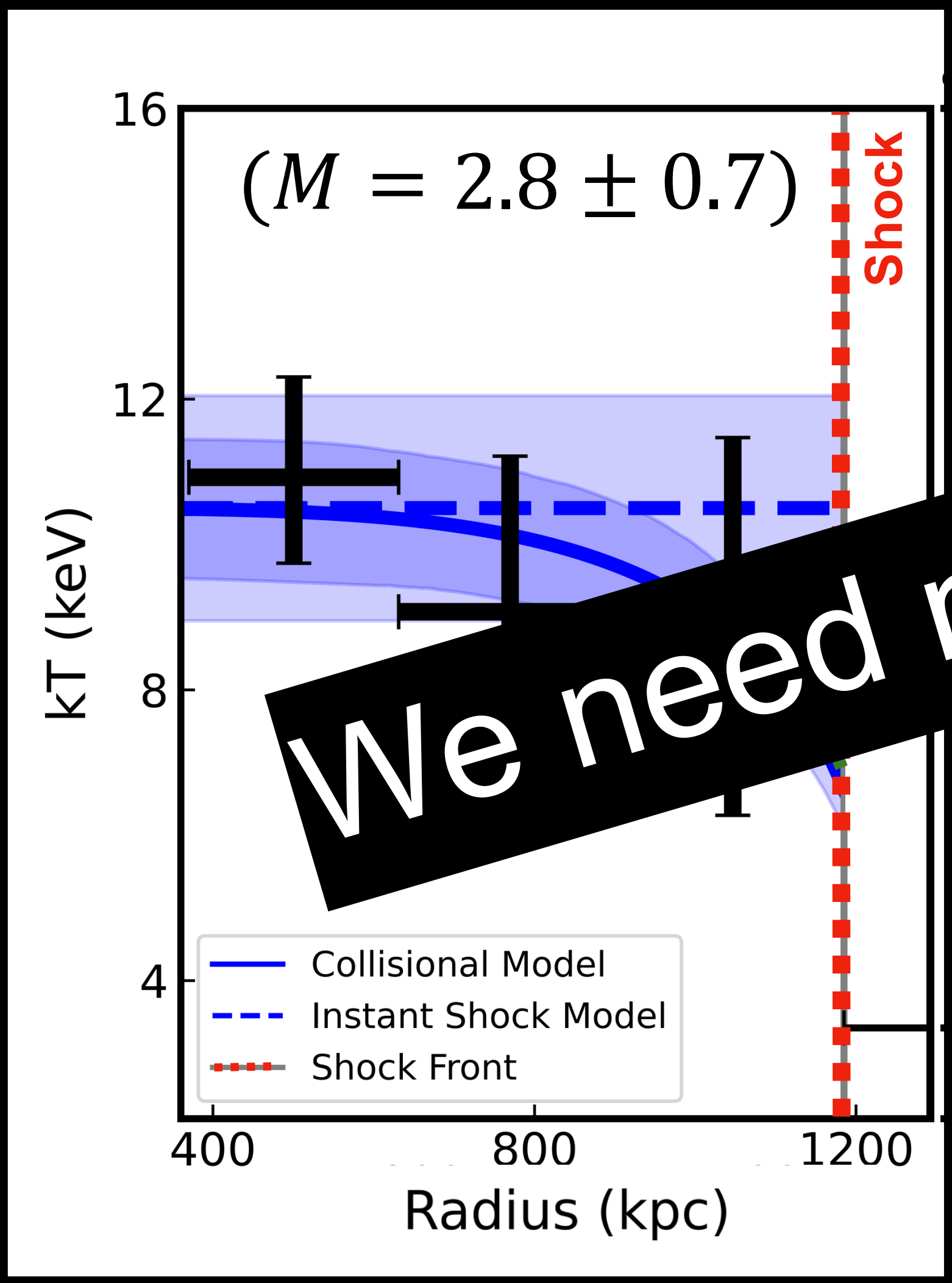
Addition to small handful of other such work:



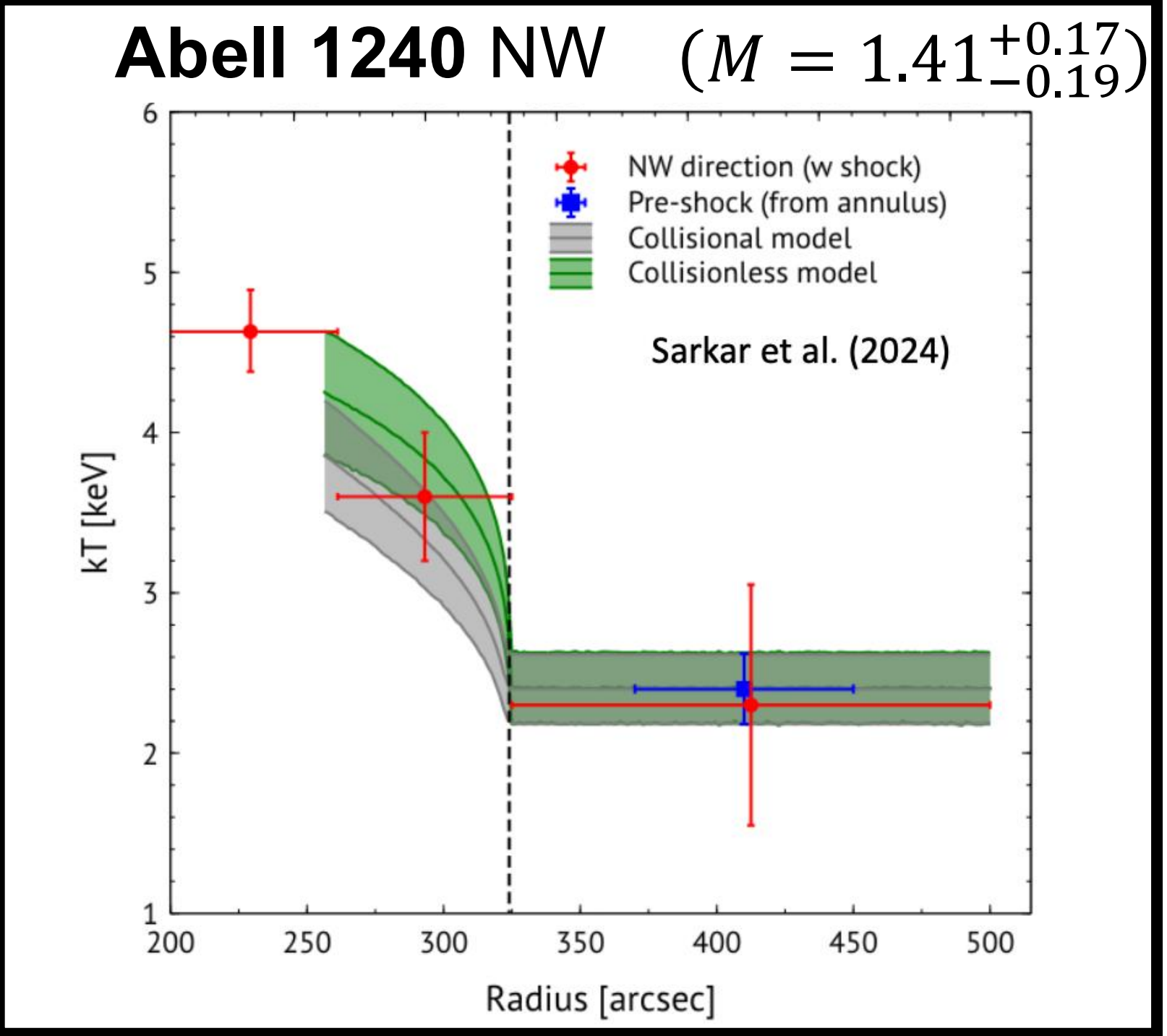
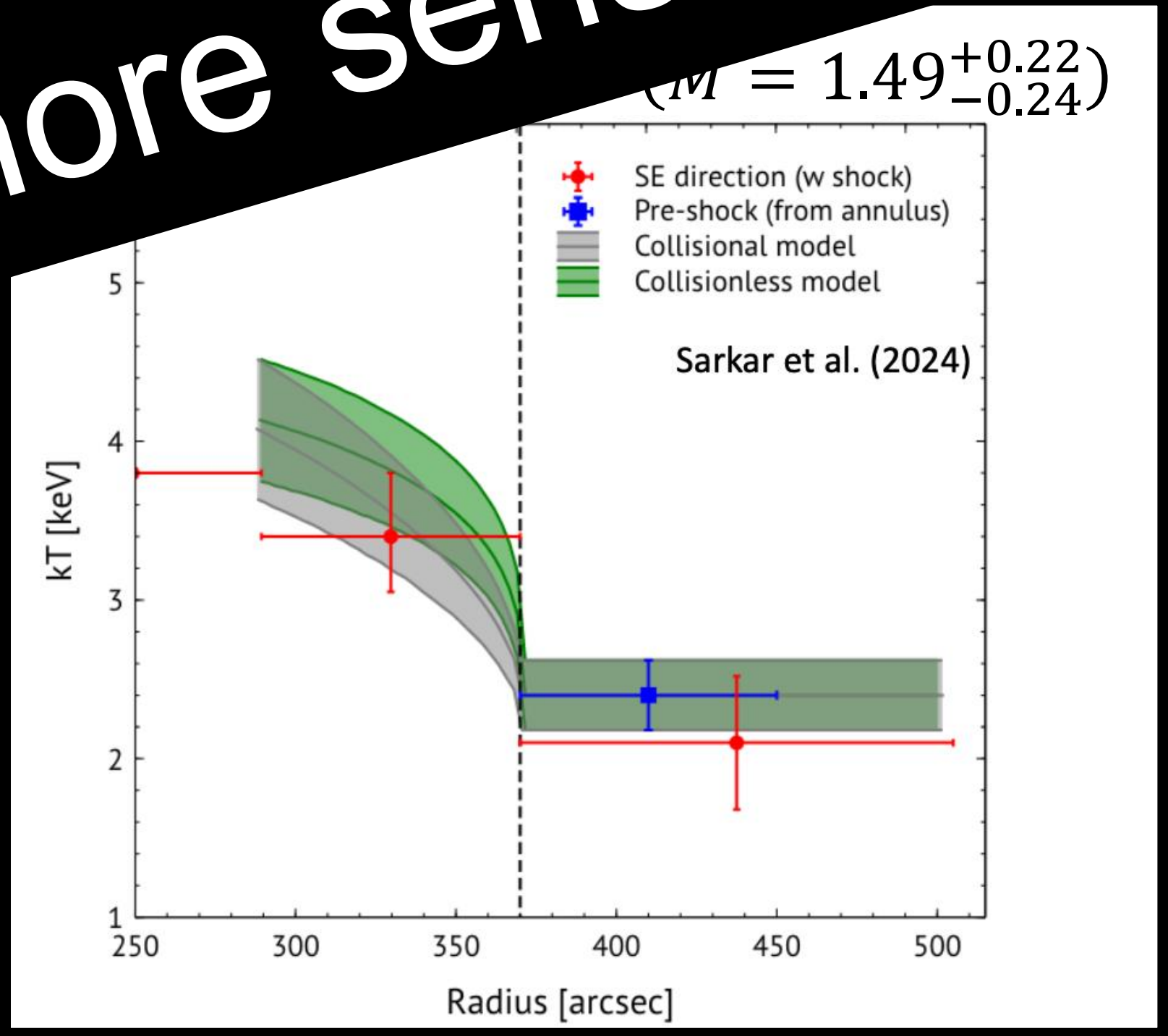
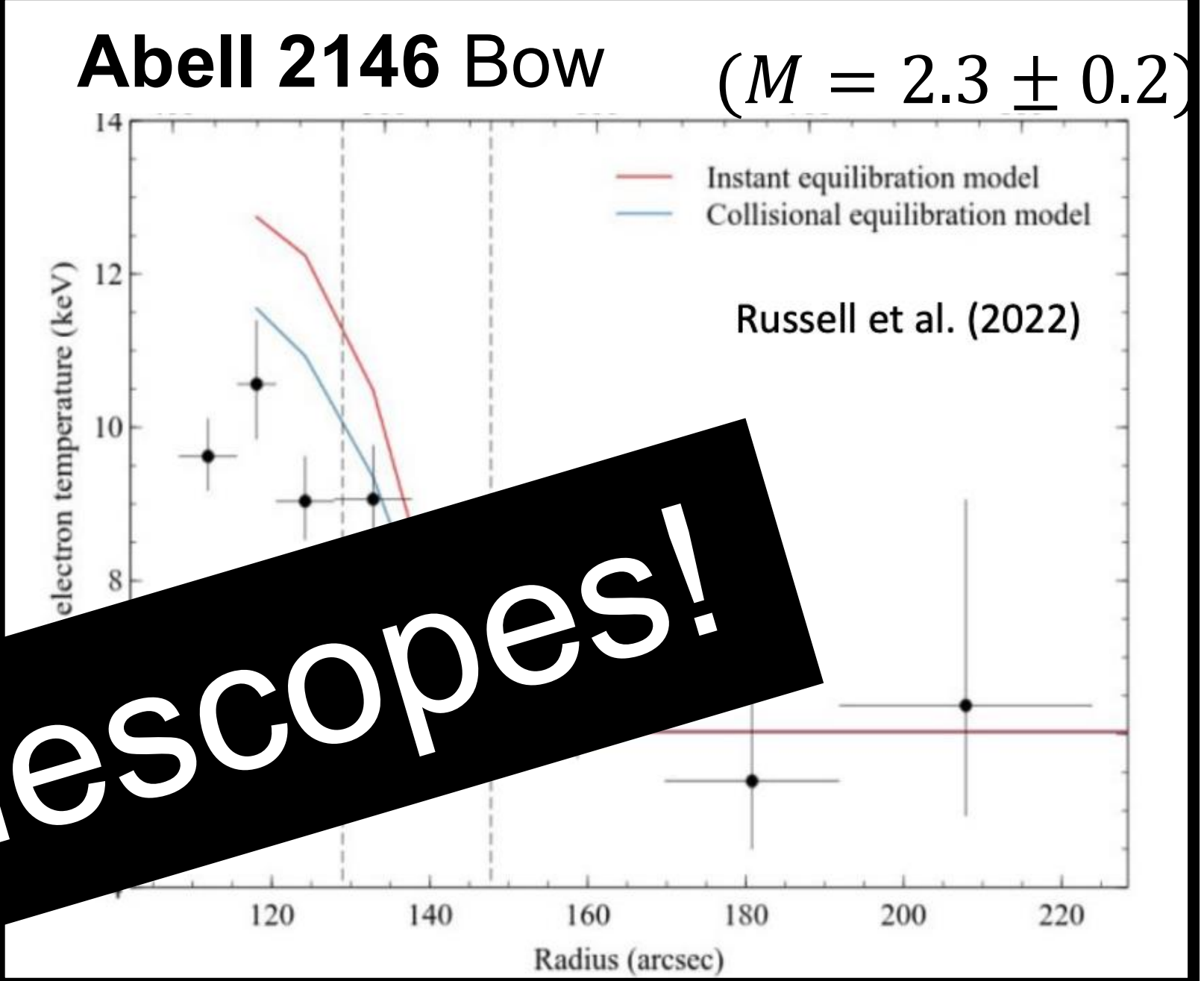
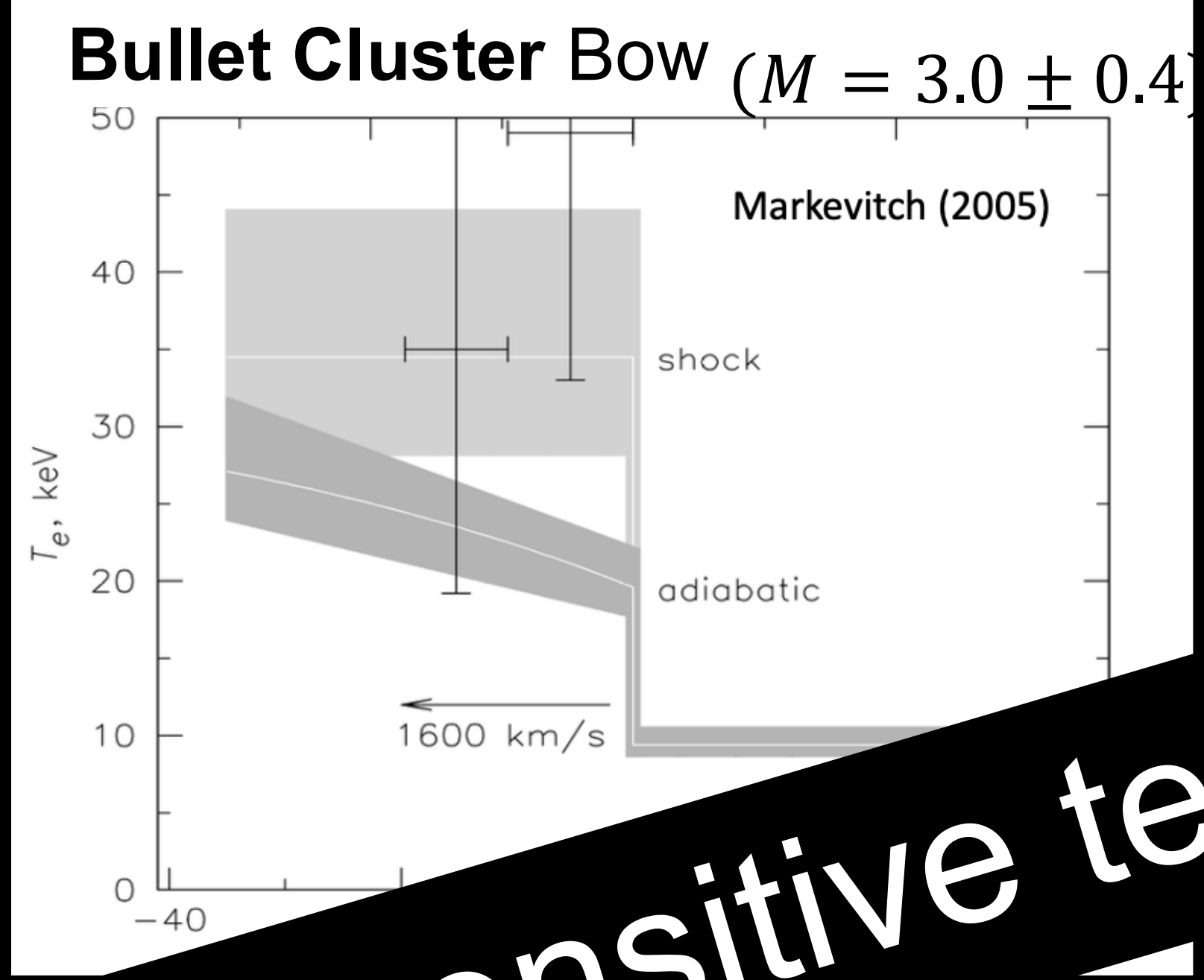
Norseth+2025



Addition to small handful
of other such work:



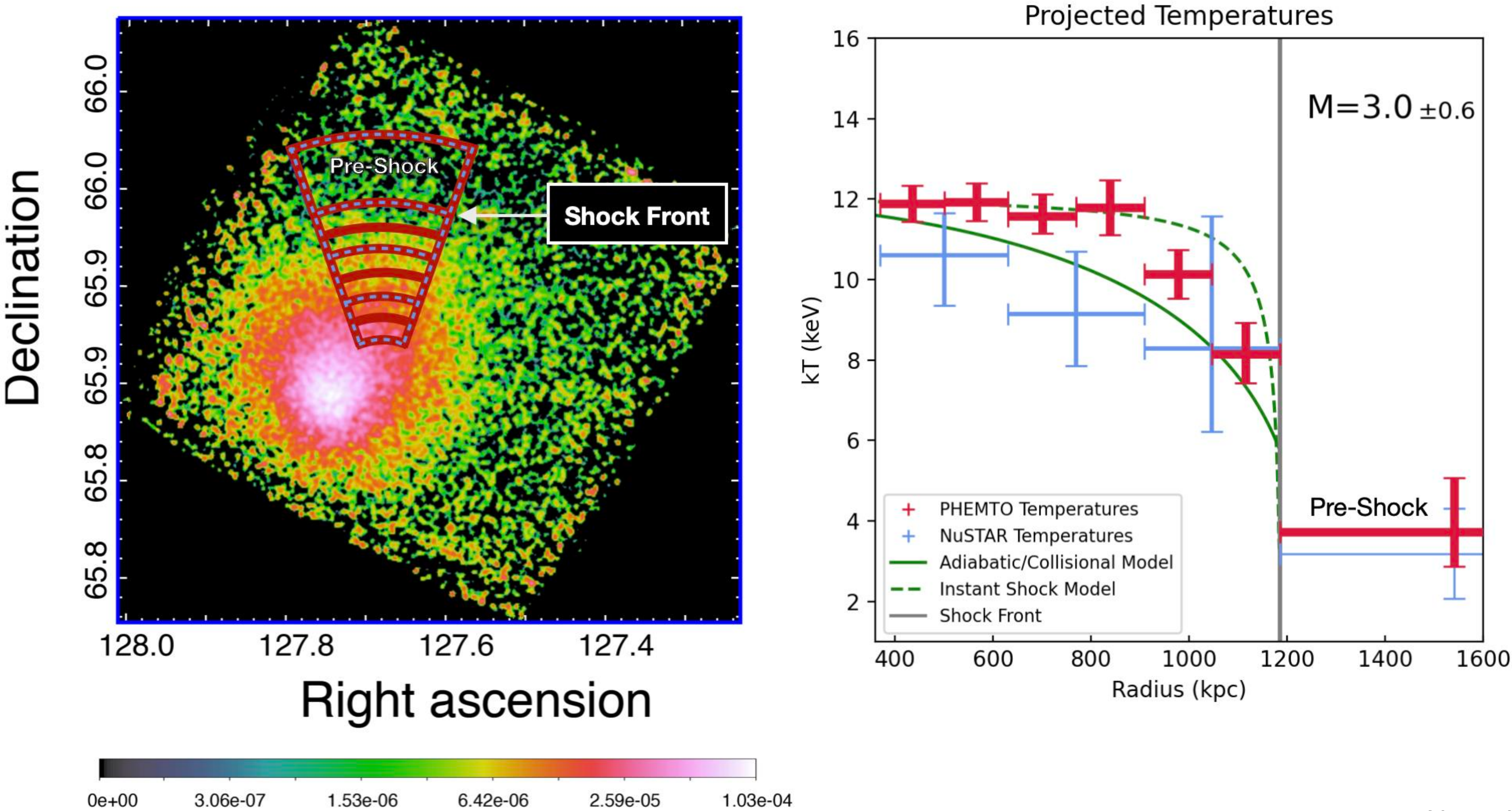
Norseth+2025



We need more sensitive telescopes!

PHEMTO

The Polarimetric High-Energy Modular Telescope Observatory



Summary

chrisitannorseth.com

- Cluster merger shocks thermalize the ICM:

Instant model:

- Electrons and ions **both** heated by shock

Delayed model:

- Ions receive more energy from shock
- Electrons adiabatically compressed
- Collisionally equilibrate over ~ 100 Myr

- NuSTAR data favors delayed heating
- Improves understanding of ICM microphysics
- We need more sensitive telescopes

