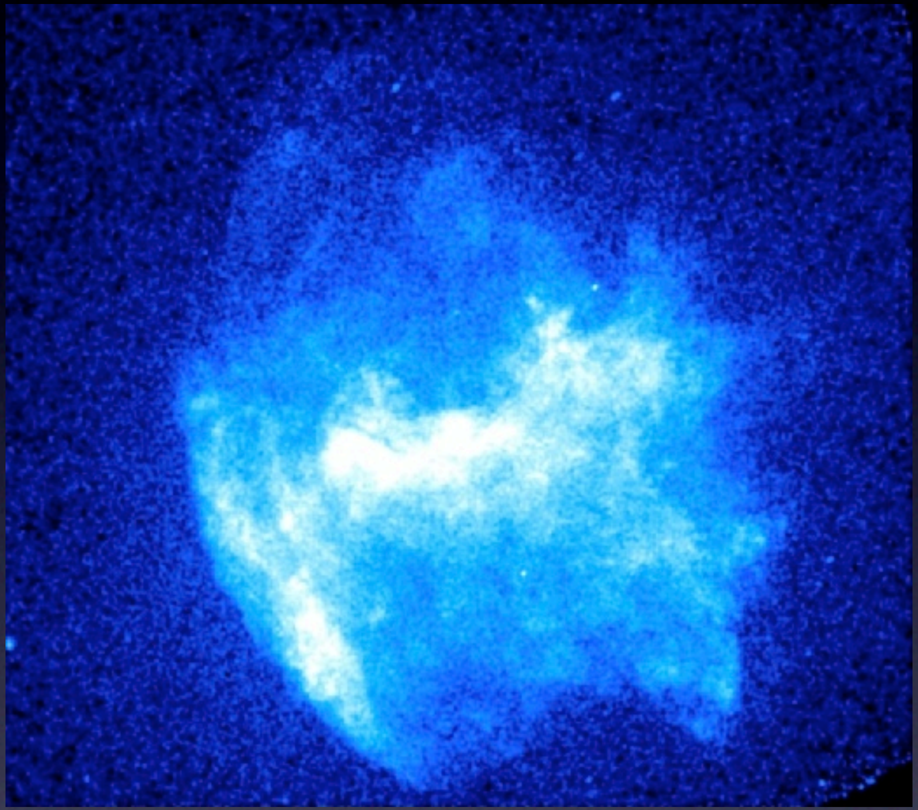
Unraveling the Origin of Overionized Plasma in the Galactic Supernova Remnant W49B



Sarah Pearson (University of Copenhagen)

3 January 2013

In collaboration with: Laura A. Lopez (MIT), Enrico Ramirez-Ruiz (UCSC), Daniel Castro (MIT), Hiroya Yamaguchi (CfA), Patrick Slane (CfA), Randall Smith (CfA)

Outline

- Introduction to supernova remnants and project
- How do supernova remnants (SNRs) get overionized?
- Methods for analysis of W49B
  - Electron temperature, T_e
  - Ionization temperature, T_z
- Results from project

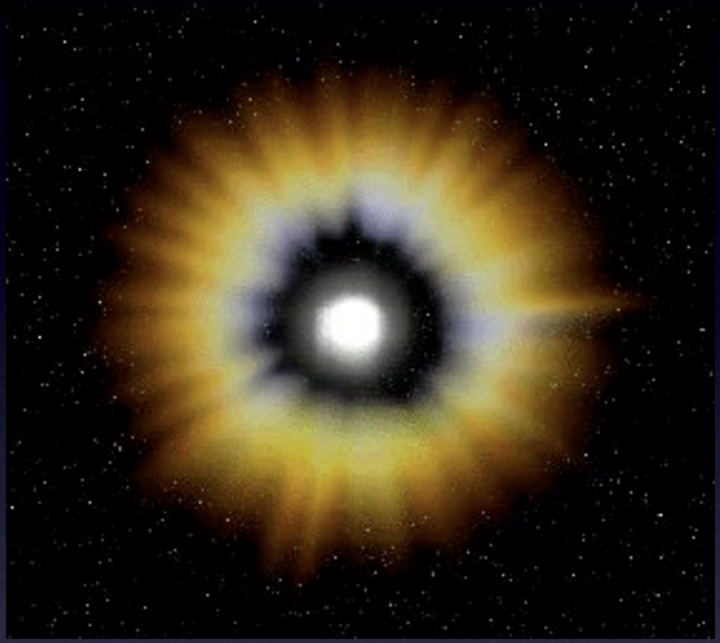
Supernovae

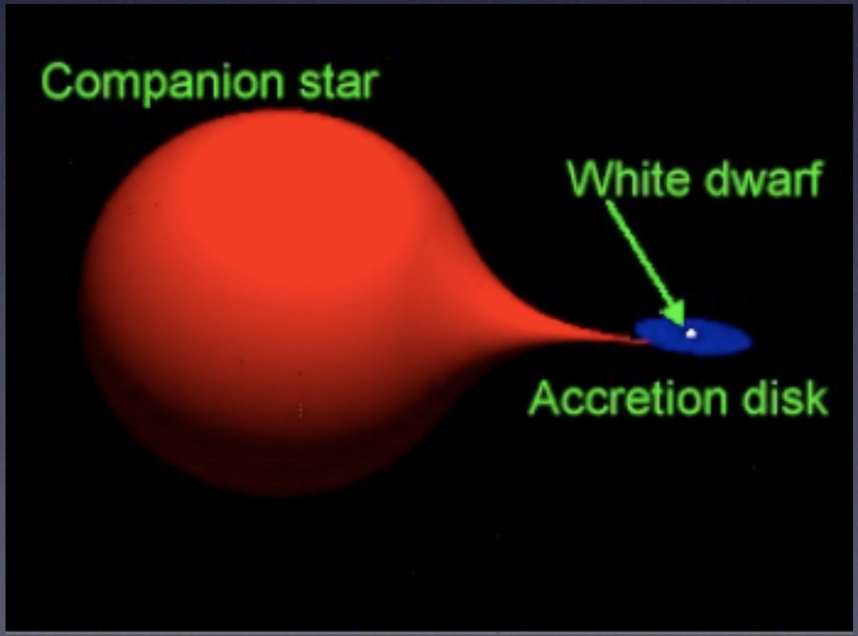
- The death of certain stars

- They come in two types:

    - Core-collapse supernovae (Type Ib/Ic and Type II)
        - M > 8 M_sun

    - Thermonuclear explosions (Type Ia)

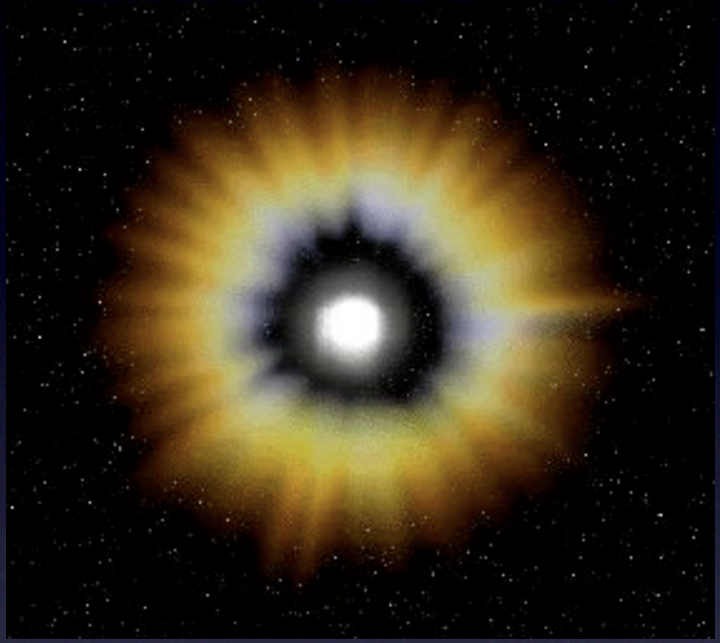




Supernovae

- The death of certain stars

10^{44} J



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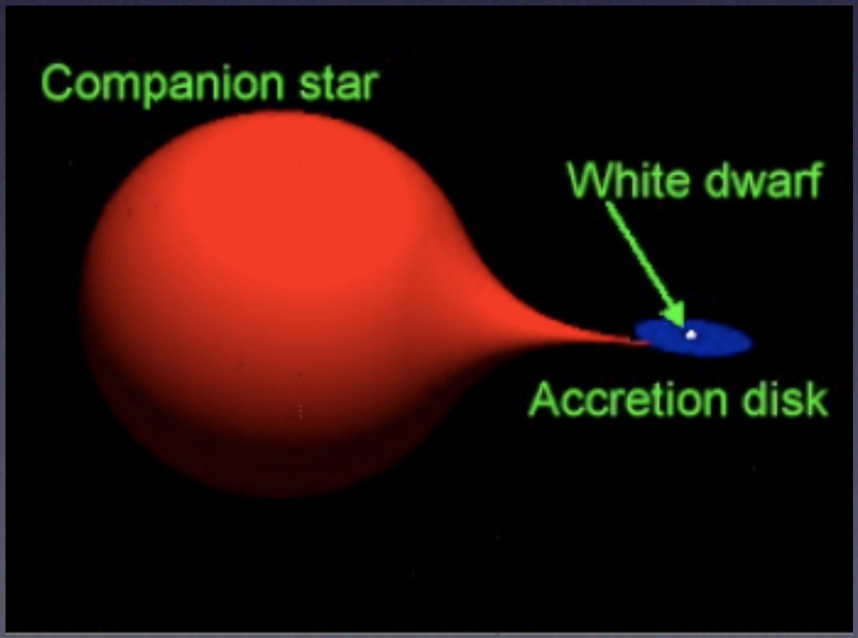
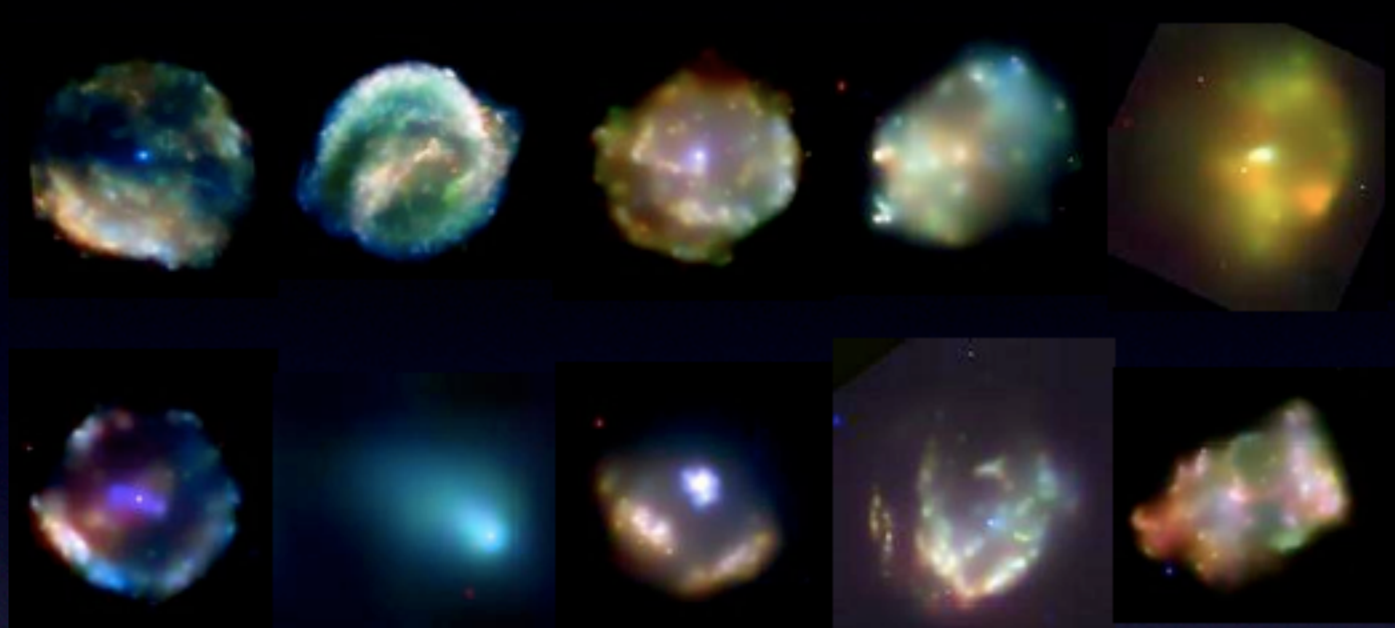
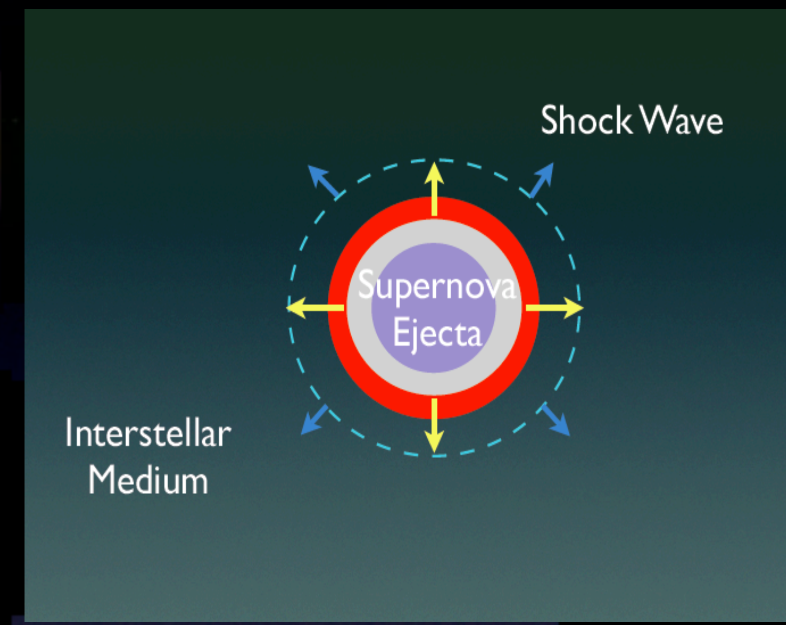


Supernova remnants (SNRs)

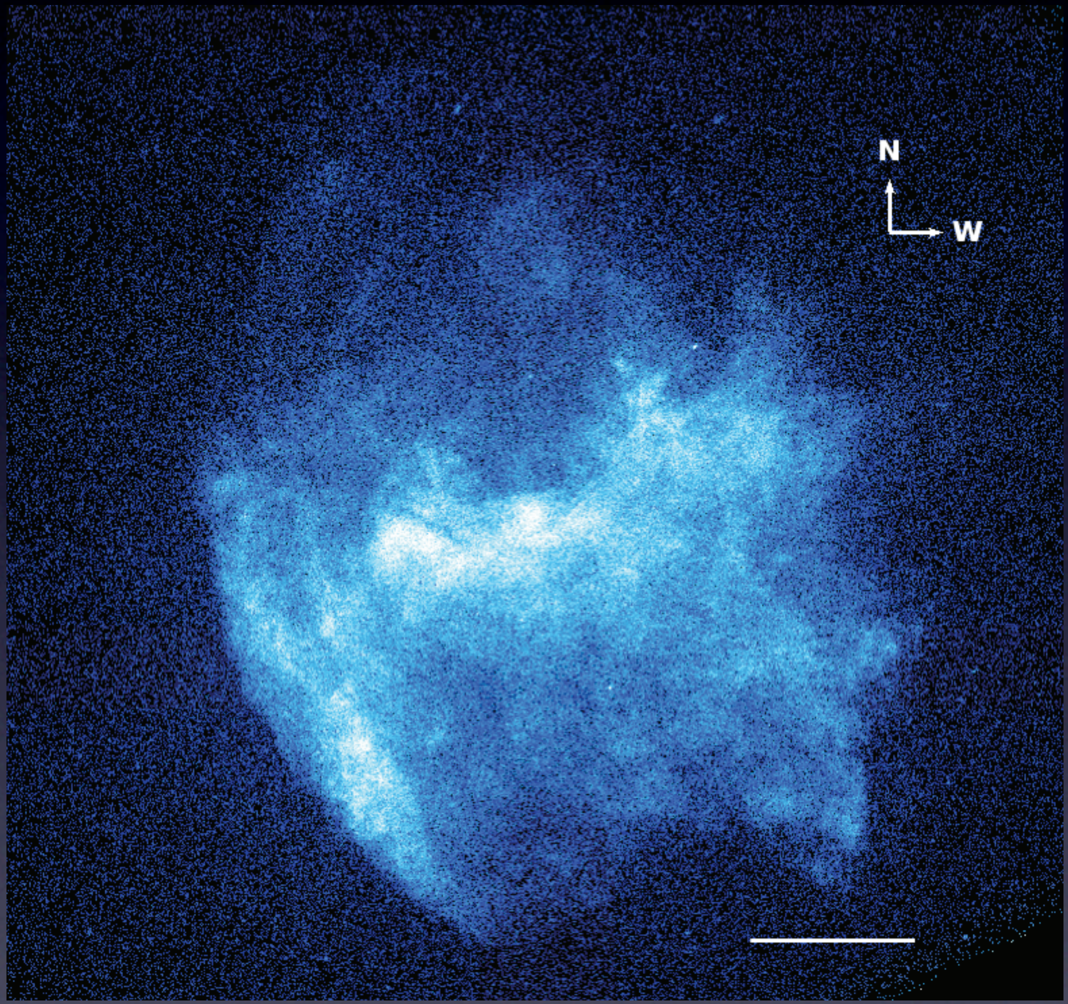




- Interaction of supernova ejecta with surrounding medium
  - Interstellar medium (ISM) & circumstellar medium (CSM)
- SNRs provide knowledge of redistribution of elements in the Universe
- SNRs are extremely complex and diverse objects

Galactic SNR W49B

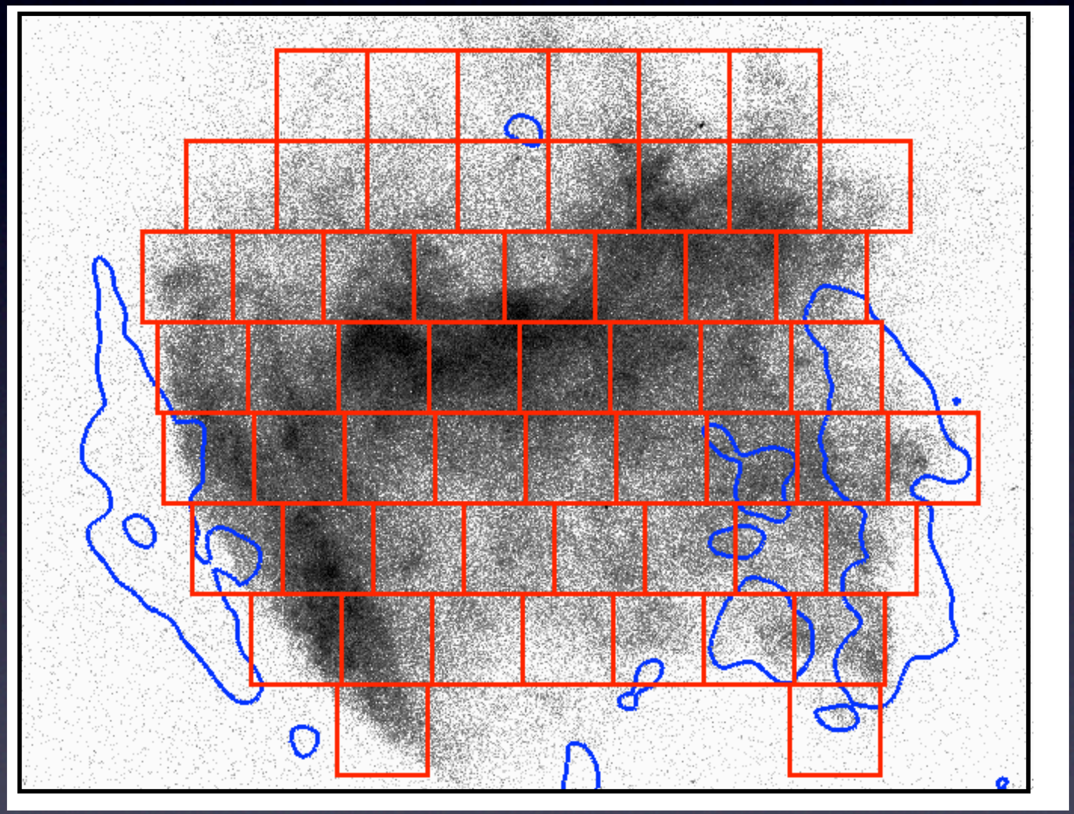
- Most luminous supernova remnant in x-rays
- Ejecta dominated ~ young remnant (1000 years)
- Complex morphology
- Shows overionization features
    - Ions stripped of more electrons than expected



Lopez et al. (2012)

We present...

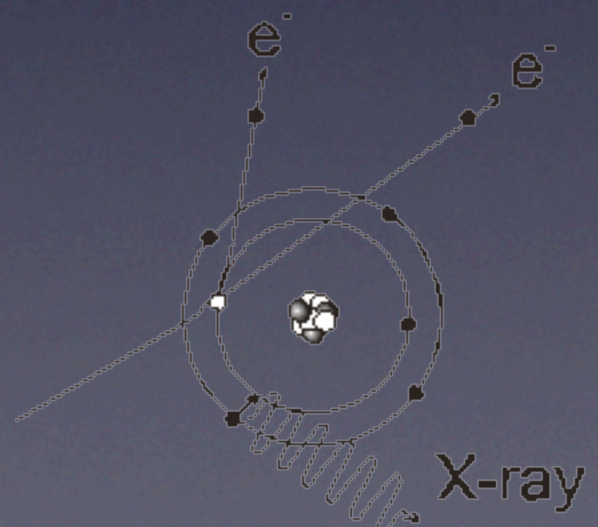
- ... first spatially-resolved analysis of plasma conditions in W49B
- Using a 220 ks observation from NASA's Chandra X-ray Observatory



Pearson et al. (2013)

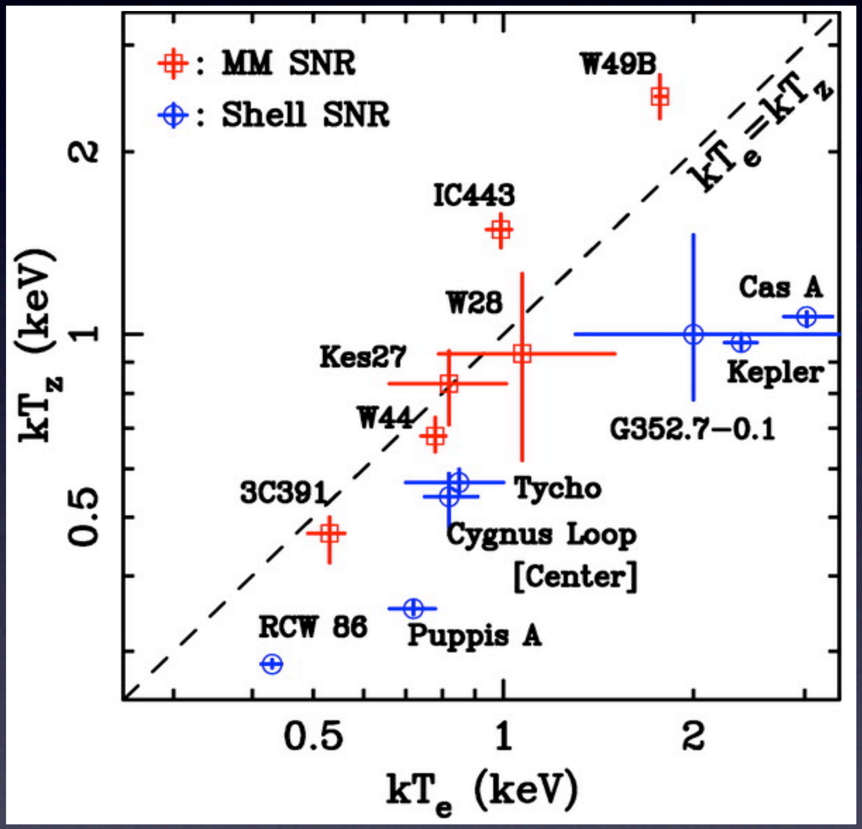
Ionization

- Supernova remnants are normally underionized:
  - Disperse medium ~ low densities
  - Only excitation/ionization through collisional excitation of ions with electrons
  - Long timescale for electrons to collisionally ionize ions
  - Ions are not stripped of as many electrons as we would expect



kT_z VS kT_e

- Electron temperature, kT_e:
  - Actual kinetic energy of electrons and ions



Kawasaki et al. (2005)

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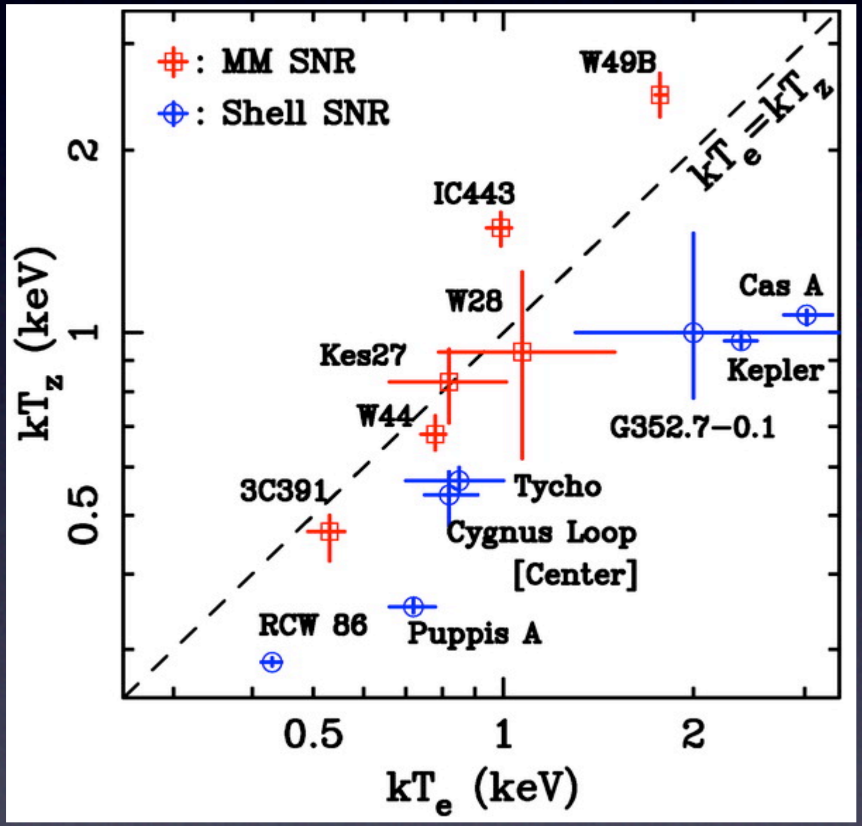

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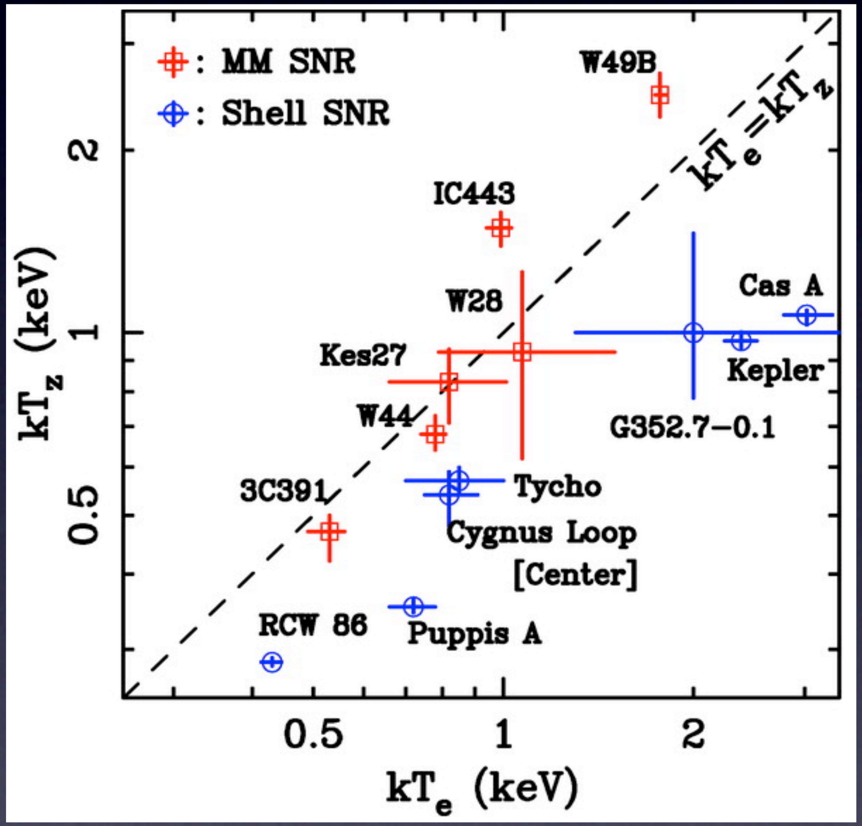

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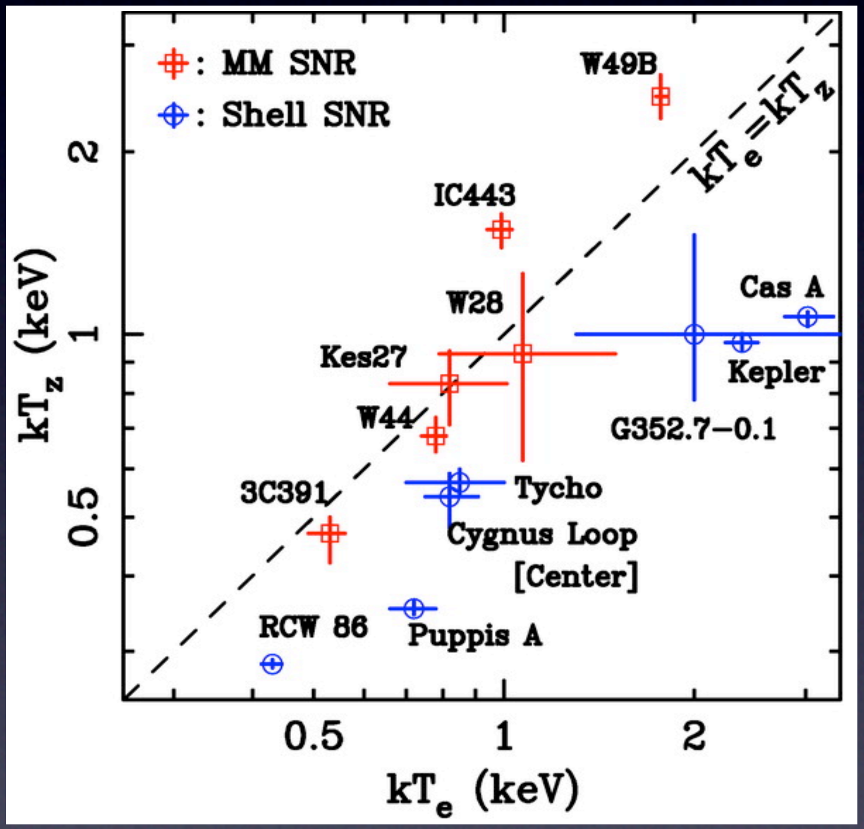

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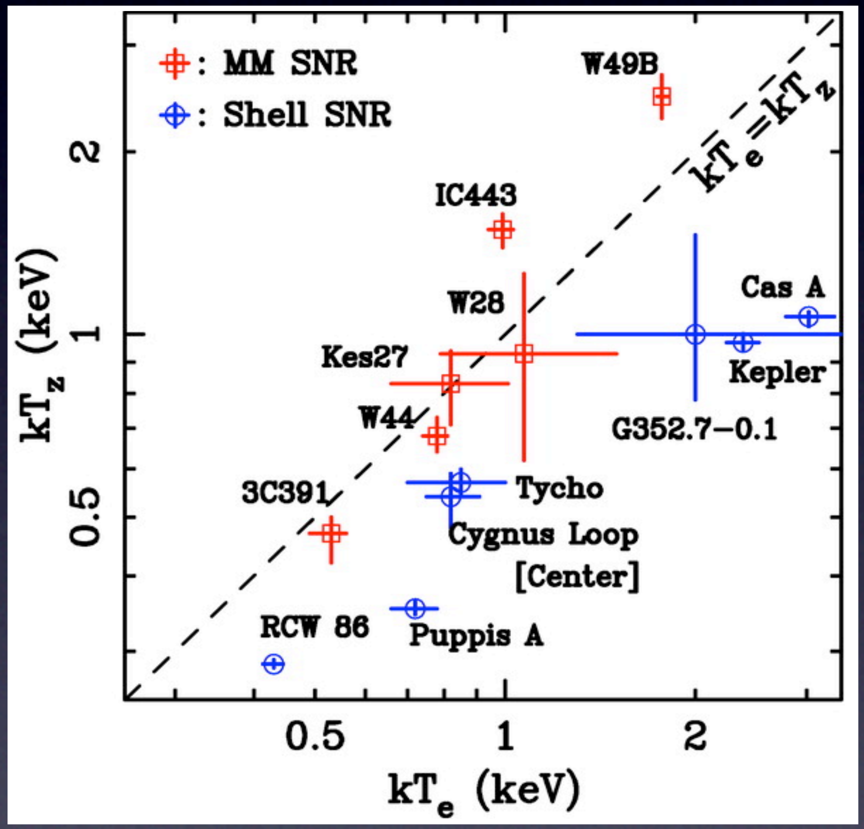

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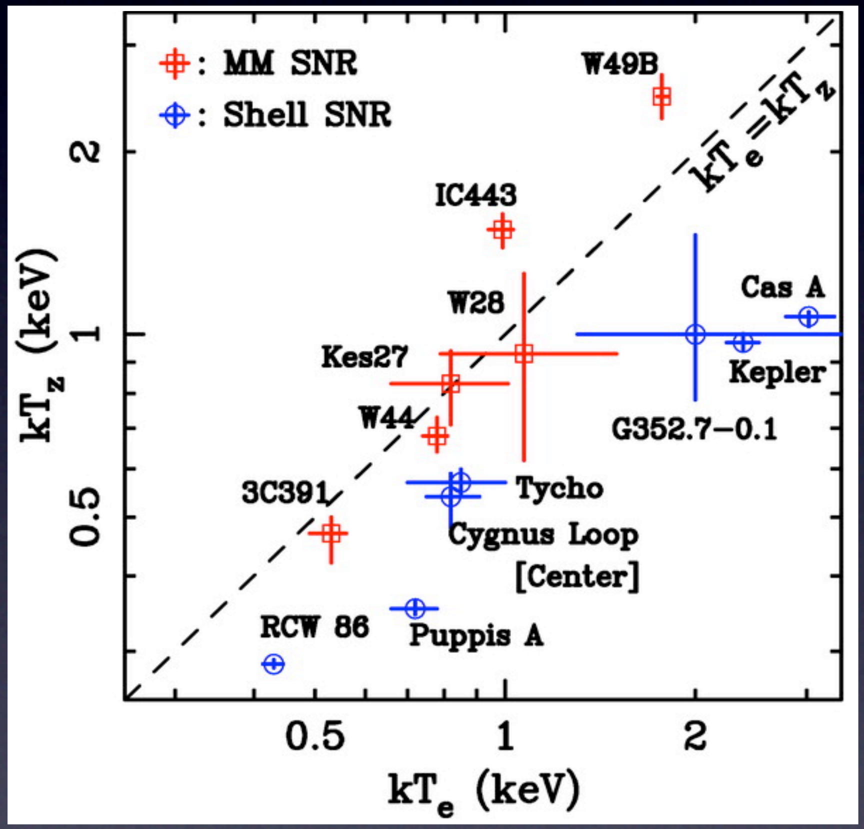
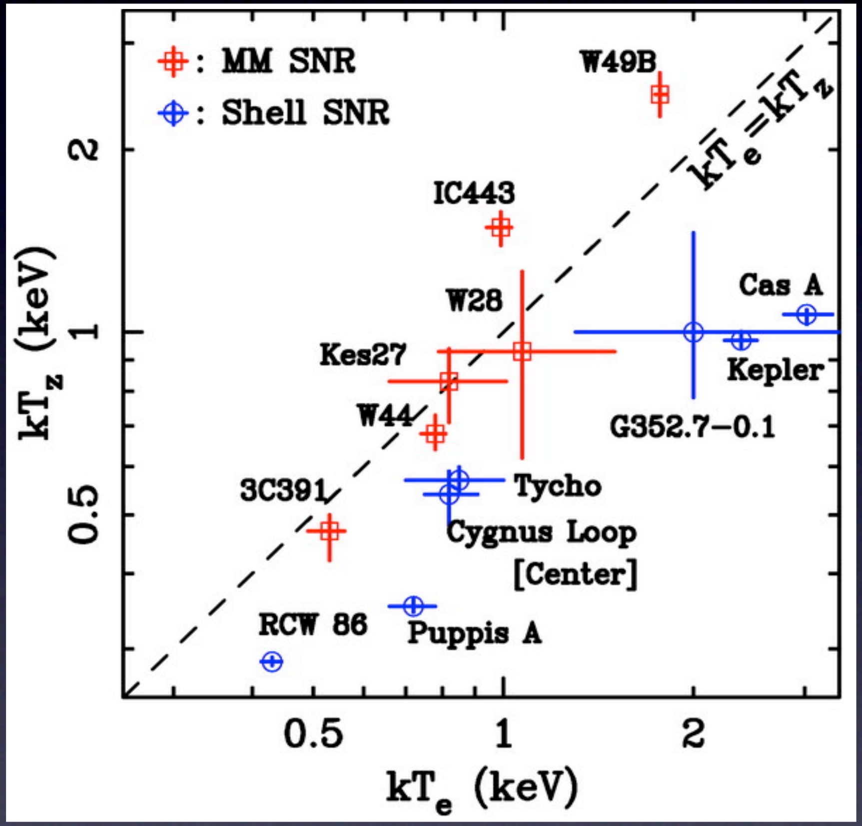
  - Excitations balanced by de-excitations



Kawasaki et al. (2005)

How to get overionized young supernova remnants

- Higher densities => shorter time to reach collisional ionization equilibrium (CIE)
- CIE followed by rapid cooling of electrons
- $t_{recombination} > t_{cooling}$ => overionized plasma



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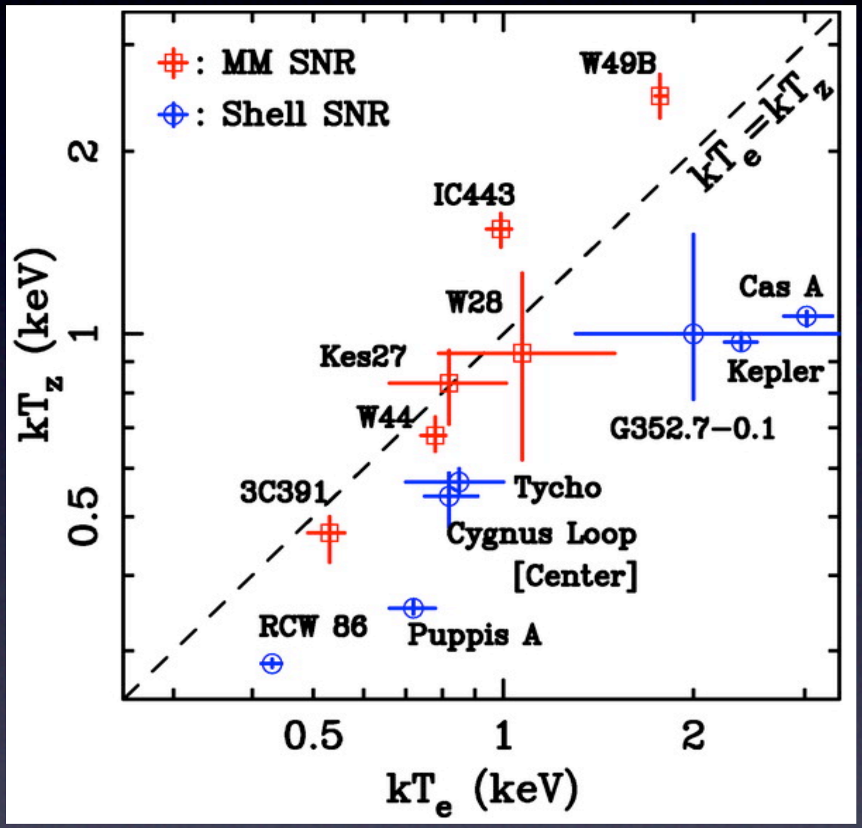

Kawasaki et al. (2005)

Cooling mechanisms

- Cooling through adiabatic expansion
- Cooling through thermal conduction

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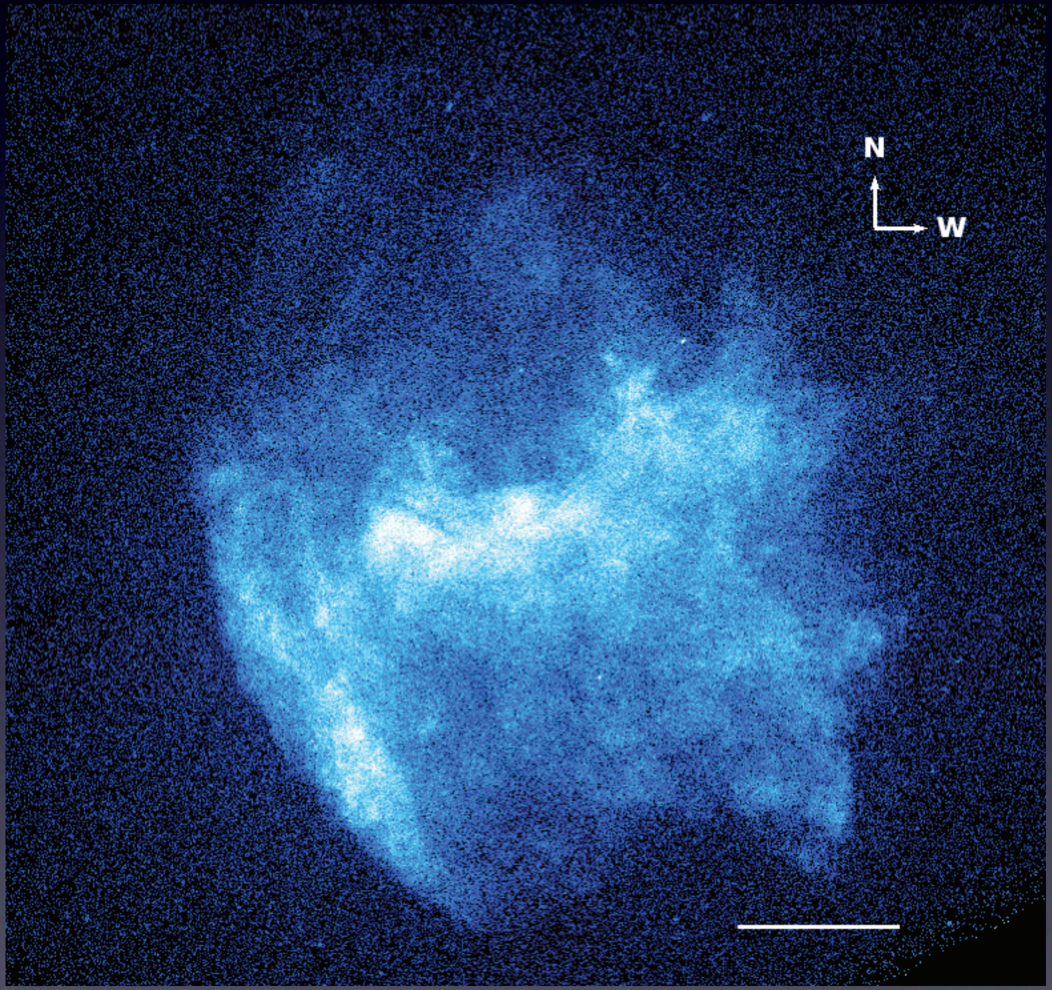
- Cooling through adiabatic expansion
- Cooling through thermal conduction
- $t_{cooling} < t_{recombination}$
- Examining the overionization features helps us determine, what physical mechanisms are important

Overionization in W49B

- Collision with molecular cloud in left part
  - Thermal conduction
- Free expansion in right part
  - Adiabatic expansion



Lopez et al. (2012)

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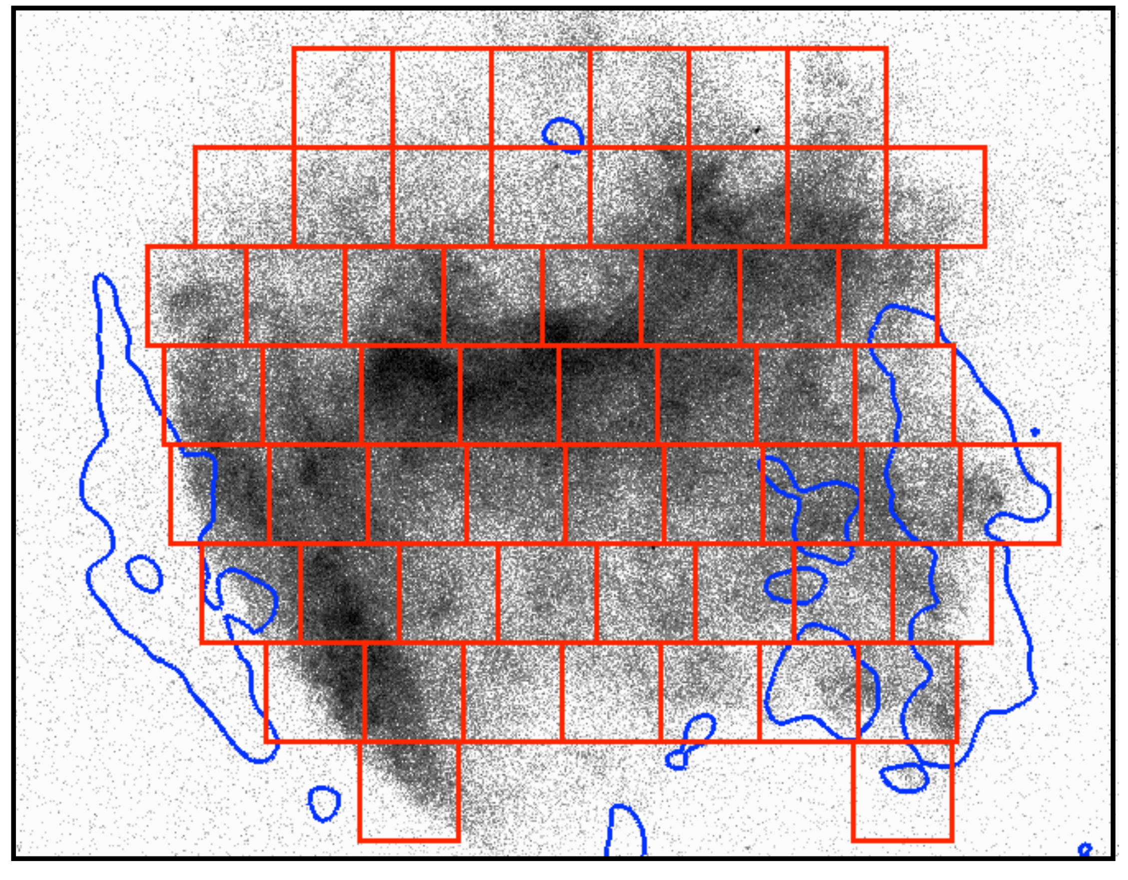


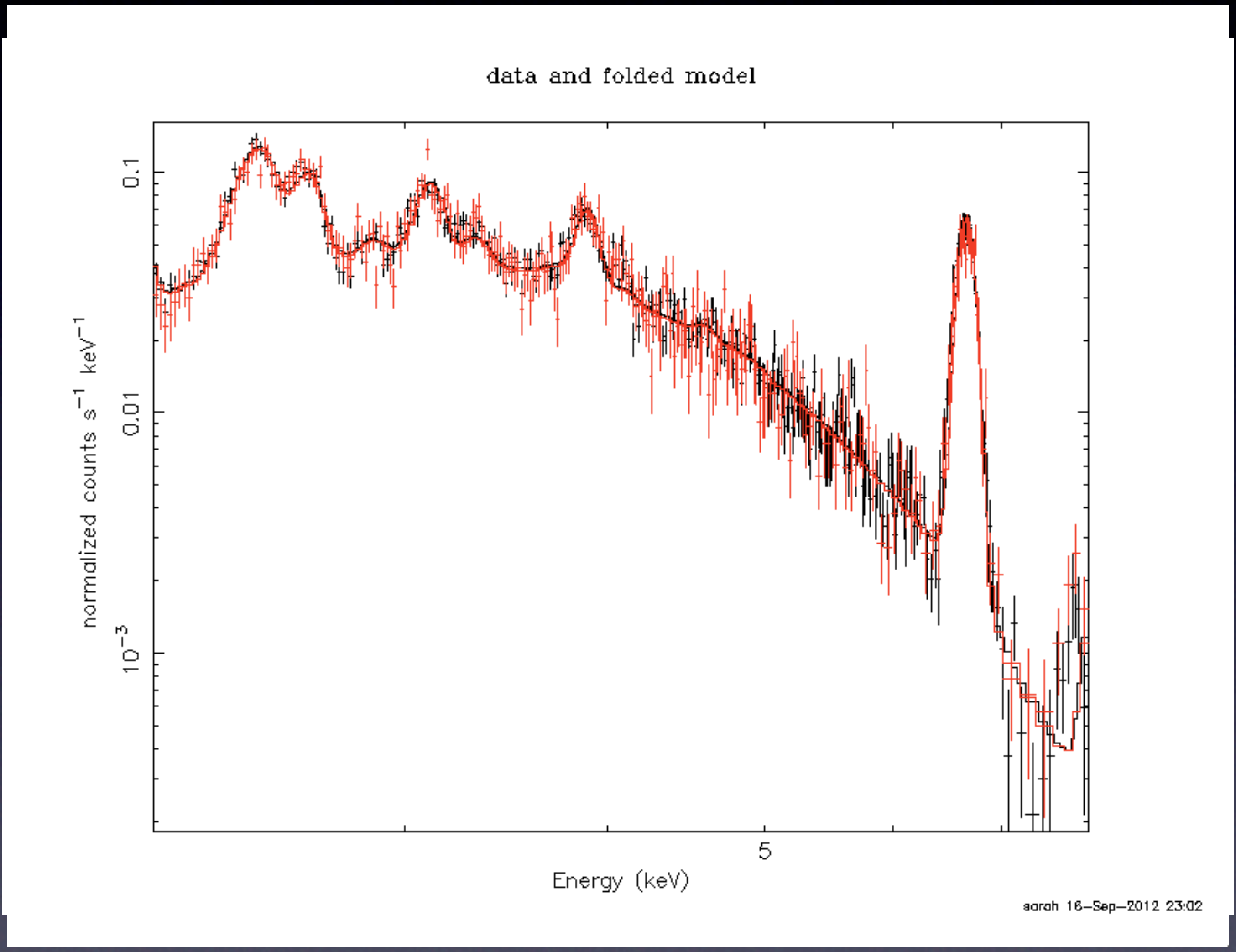
Lopez et al. (2012)

Disposition

- Introduction to supernova remnants (SNRs), x-ray astronomy and project
- How do we get overionized SNRs?
- Methods for analysis of W49B
  - Electron temperature
  - Ionization temperature
- Results from project

Measuring electron temperature

- Model spectra for 56 and 13 different regions
  - XSPEC - modeling of plasma
  - For each region the best fit electron temperature is notified



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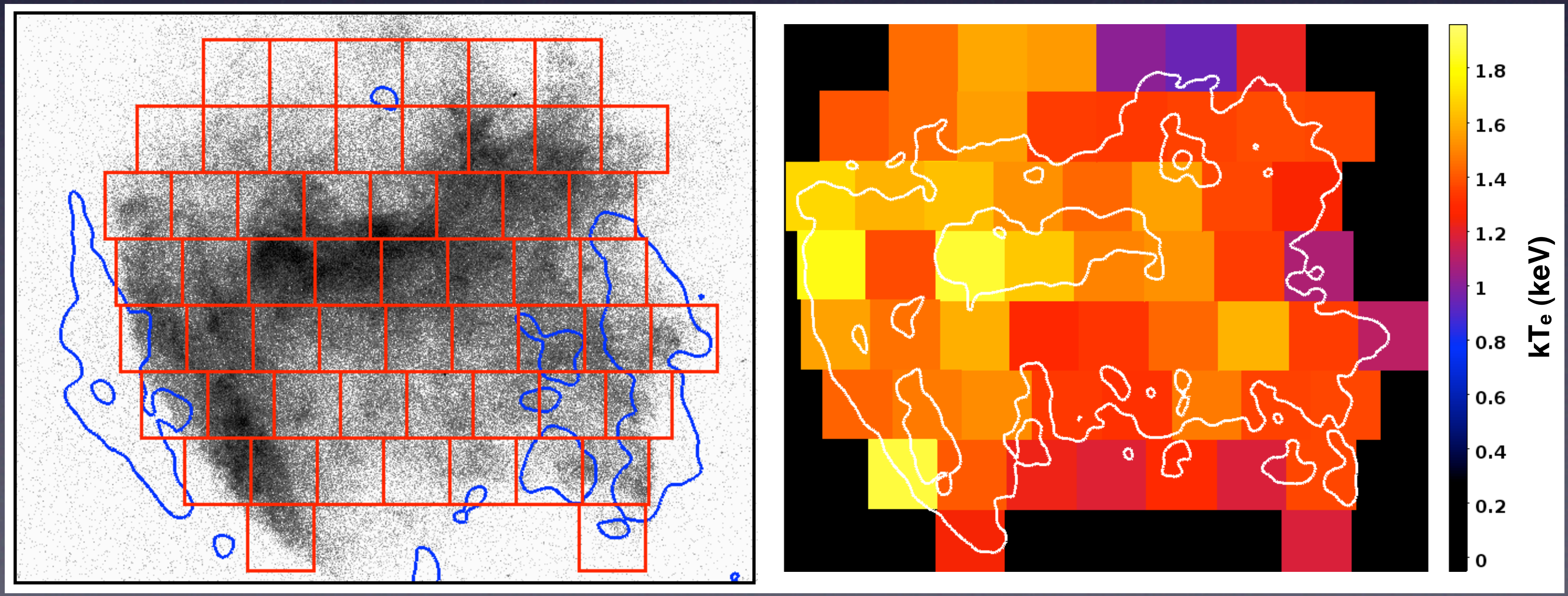

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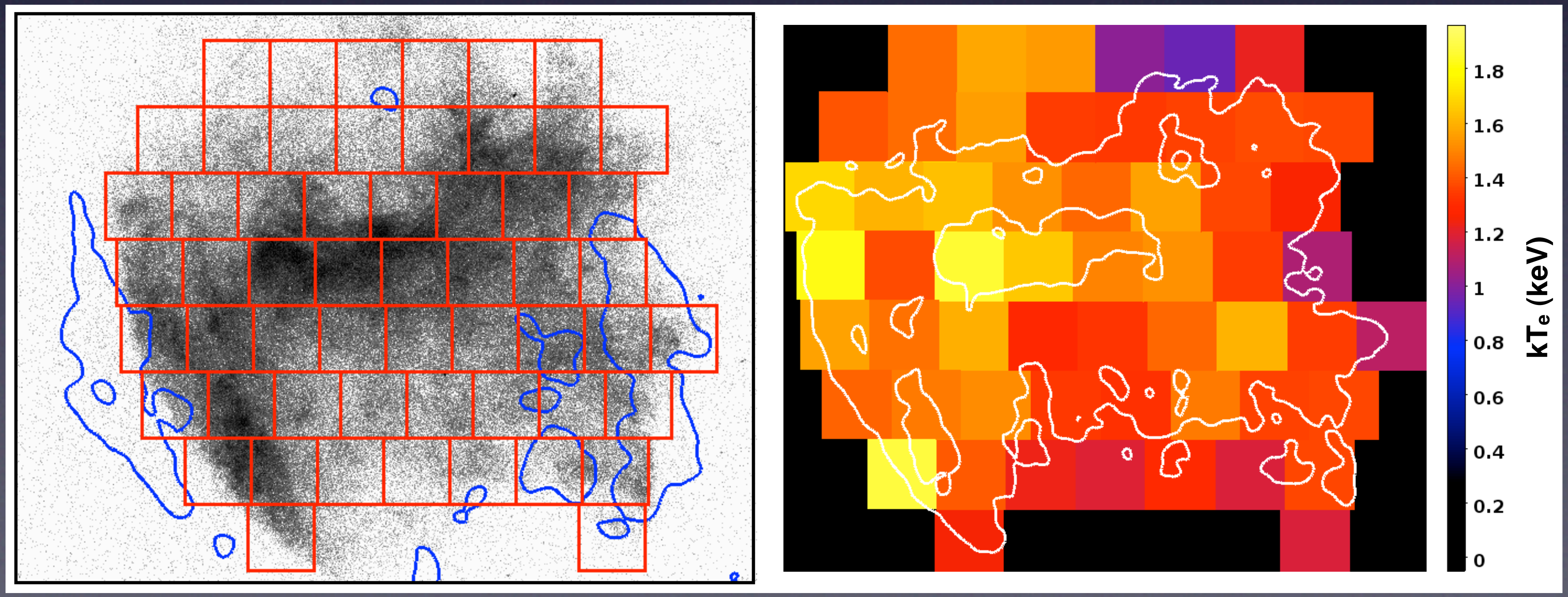
Temperature gradient

←



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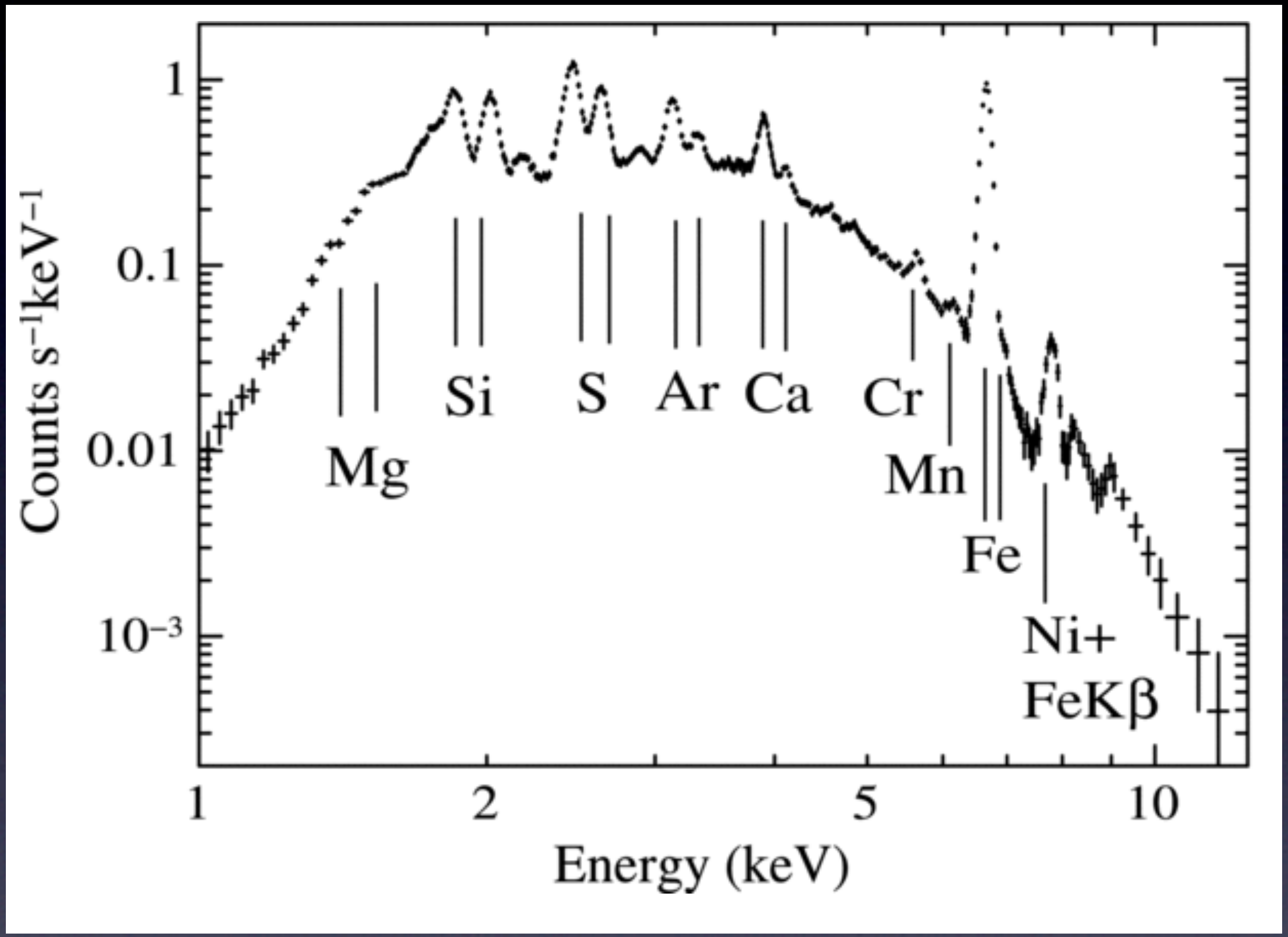
Measuring T_z from line ratios

- Use parameters from plasma model
- Fit Gaussians to H-like and He-like lines of S, Ar and Ca
- Calculate the flux ratio
- Derive ionization temperature, $kT_{z,}$ from flux ratio



Ozawa et al. 2009

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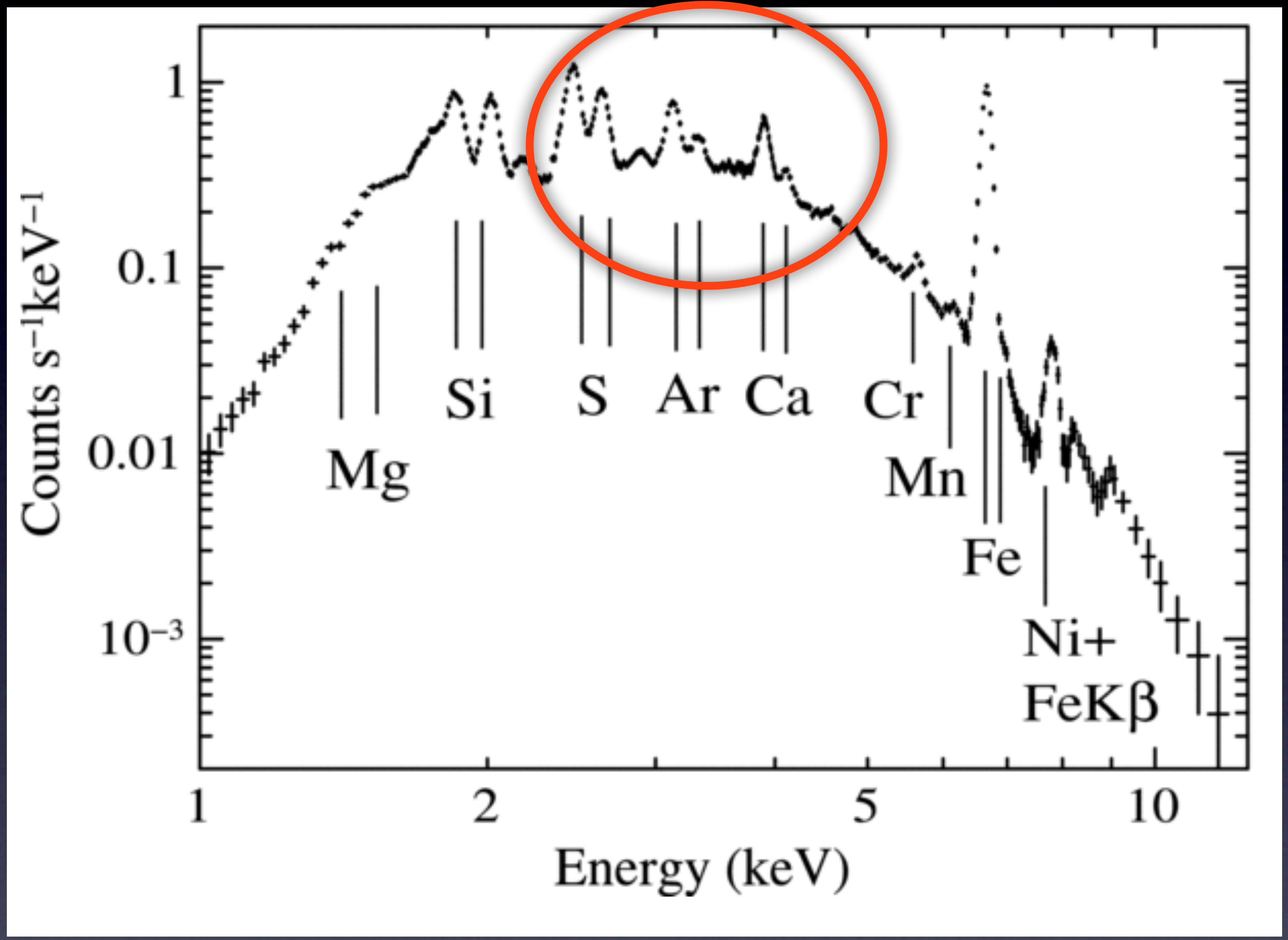

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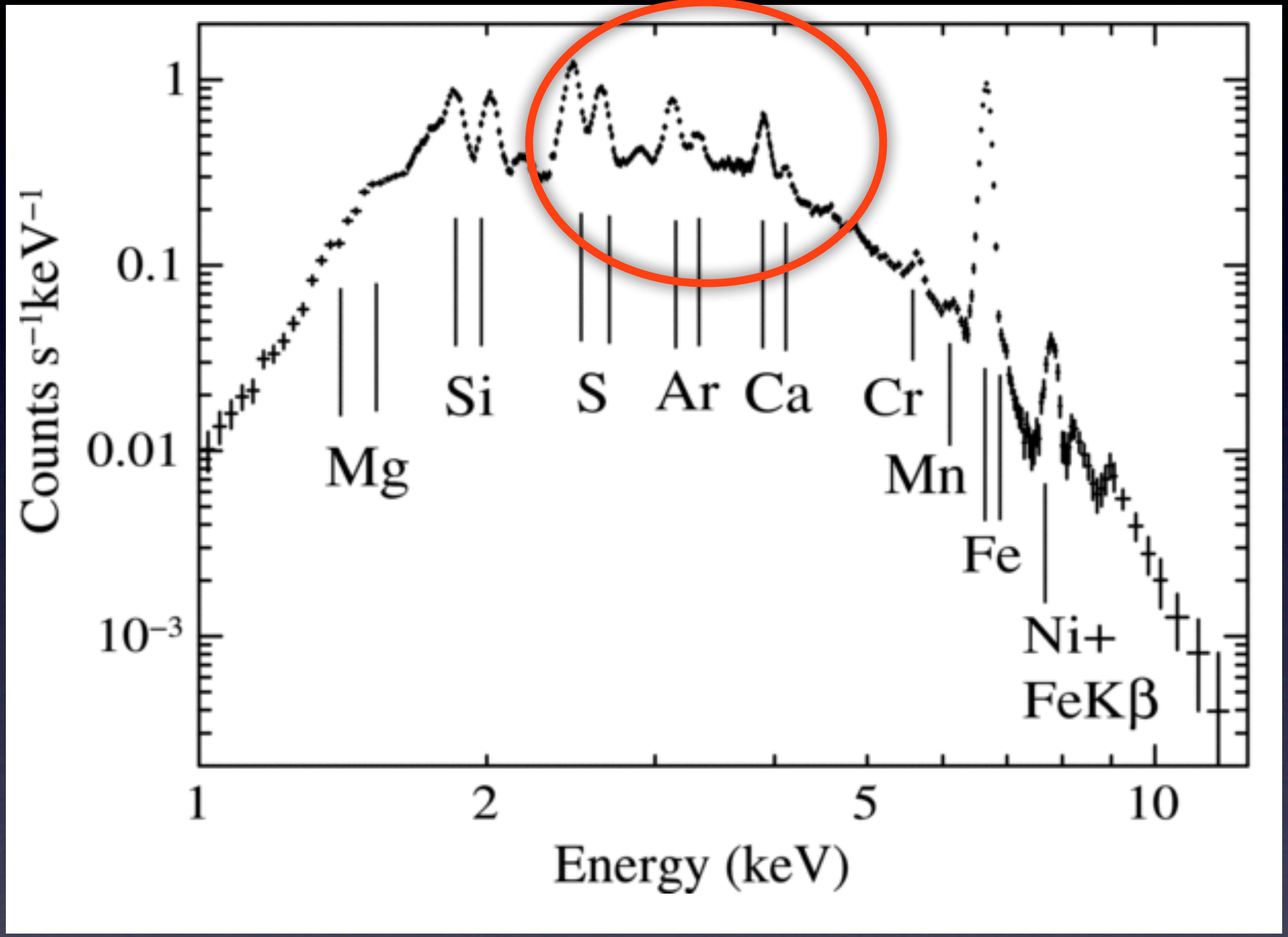
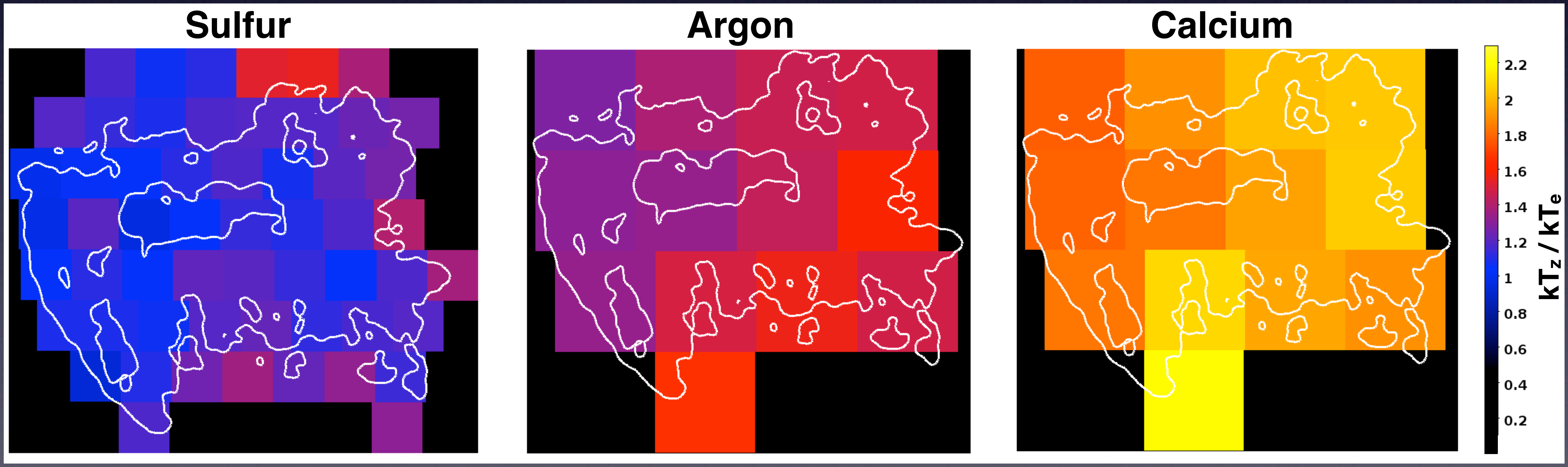


Ozawa et al. 2009

Results kT_z/kT_e



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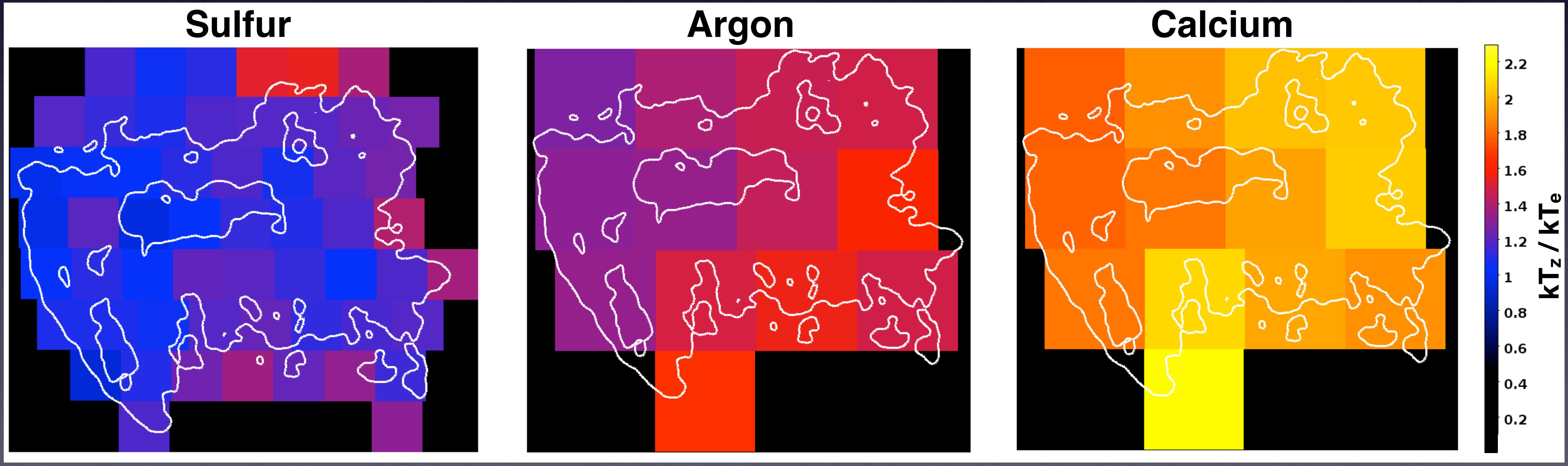
Results kT_z/kT_e

- Overionization features more prominent in right part of remnant



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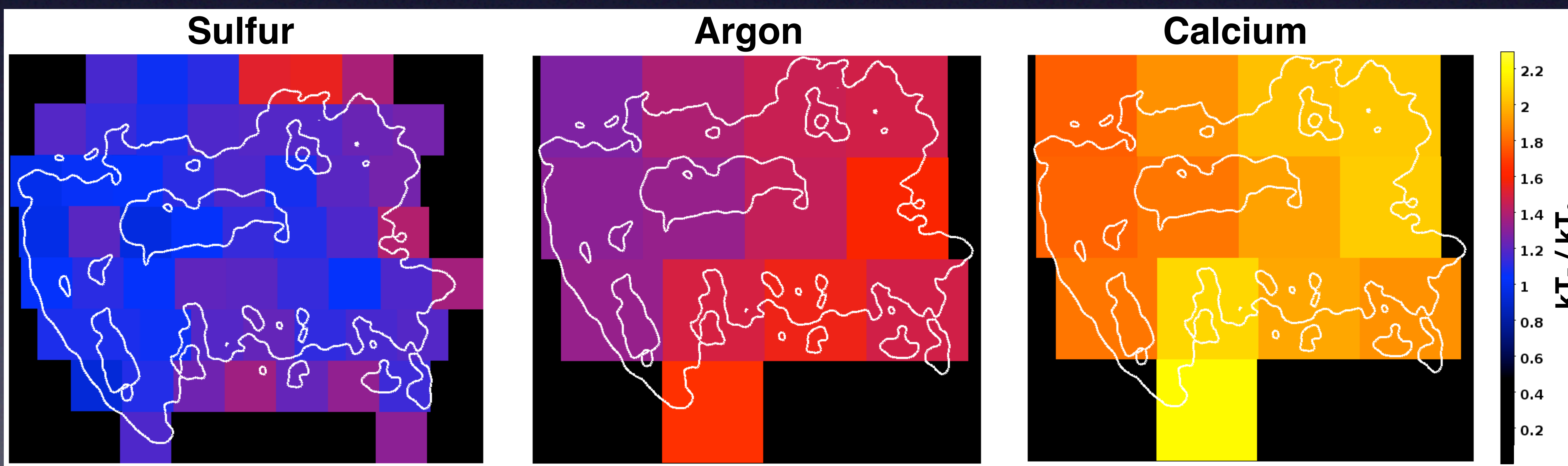
Results kT_z/kT_e

- Overionization features more prominent in right part of remnant
  - Supports cooling from adiabatic expansion



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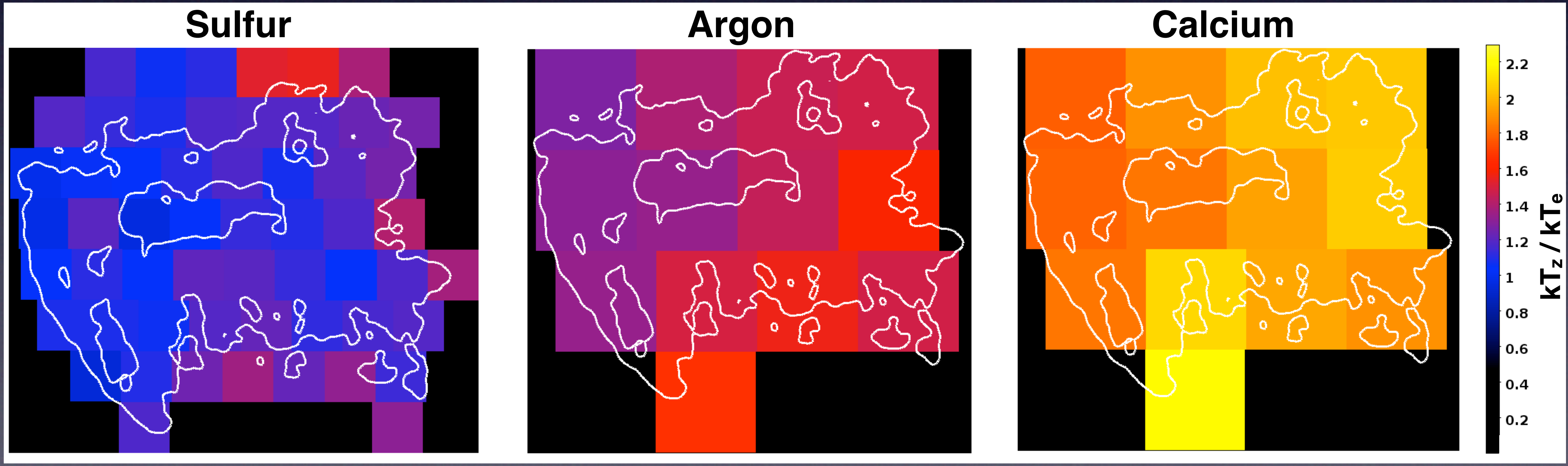

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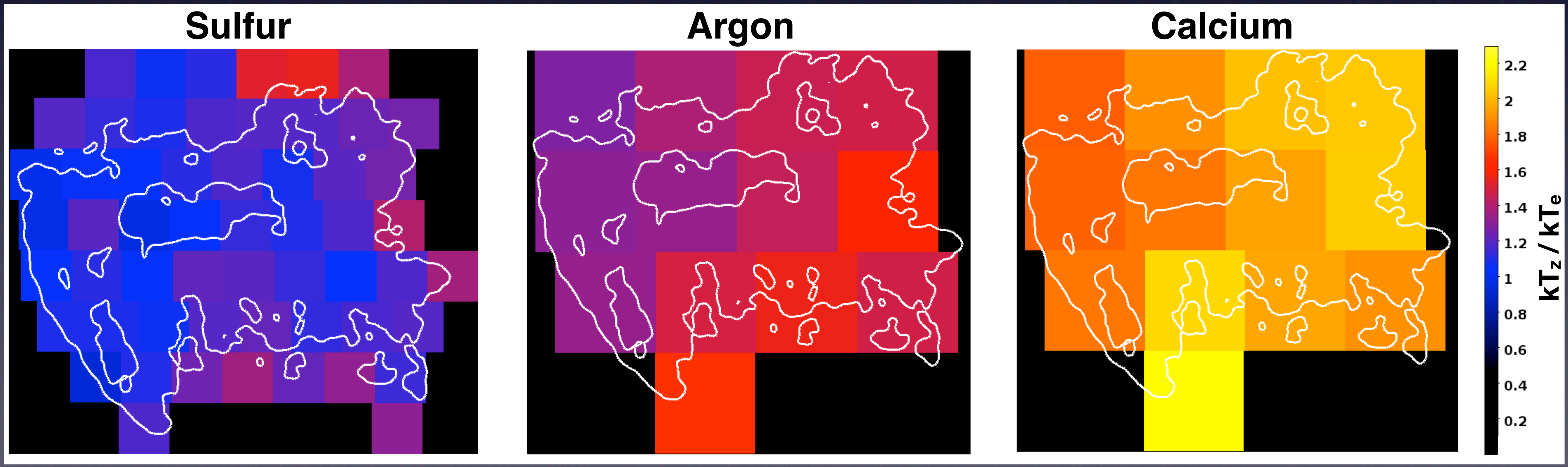
Results kT_z/kT_e

- Overionization features more prominent in the heavier elements



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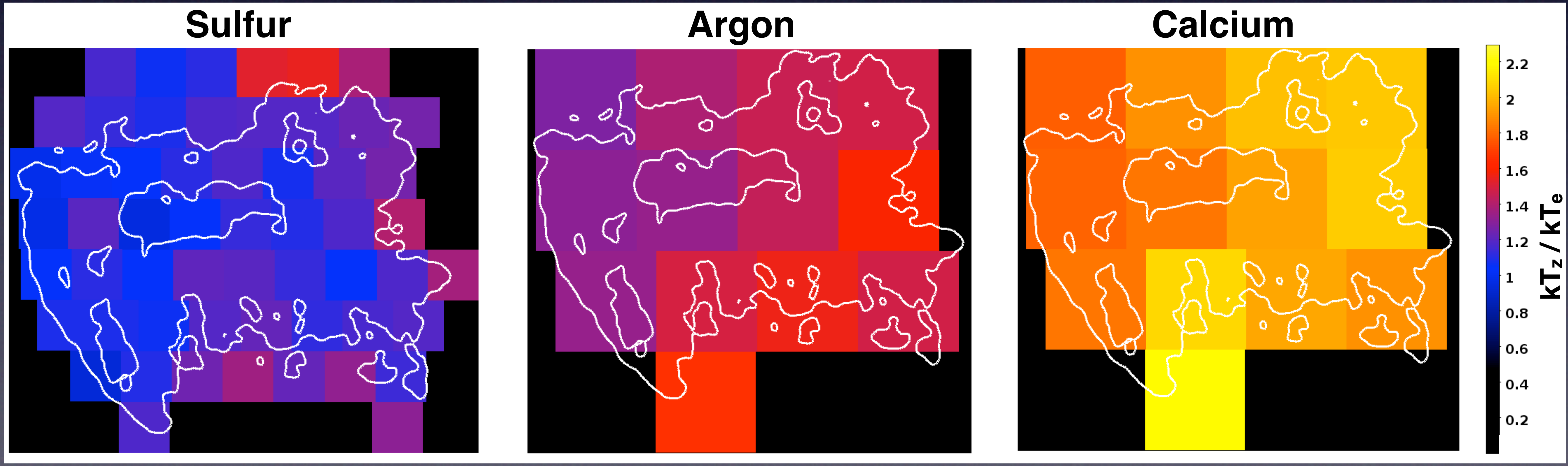

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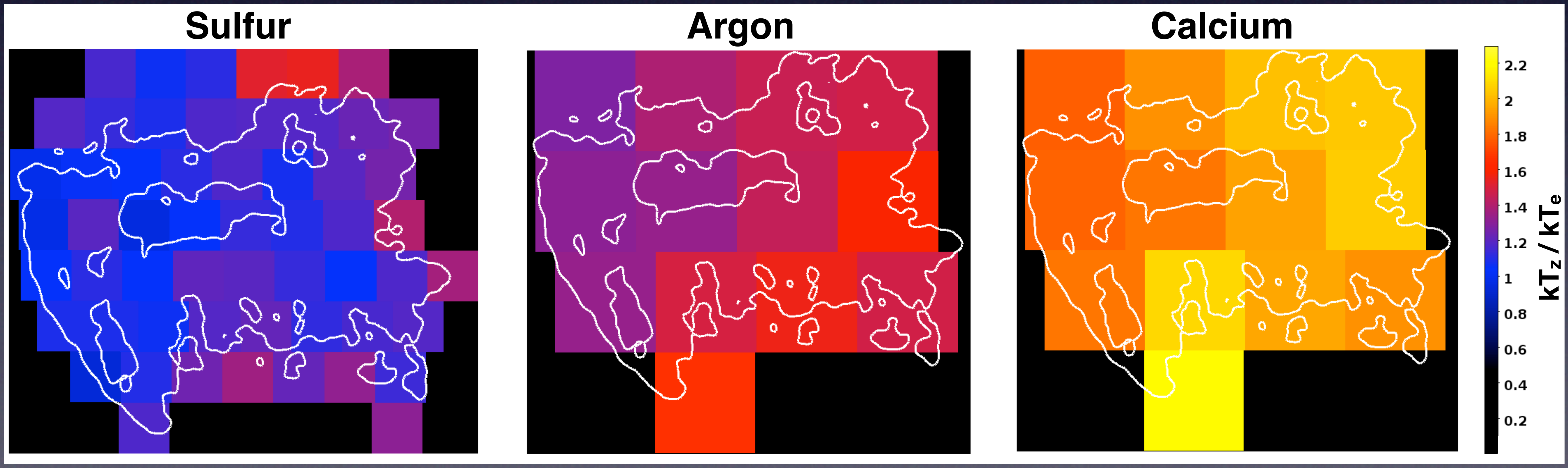
  - Timescales: $RRC_{Sulfur} < RRC_{Argon} < RRC_{Calcium}$



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Questions?