The Continued Monitoring with Chandra of Tycho's Supernova Remnant for Over 20 Years

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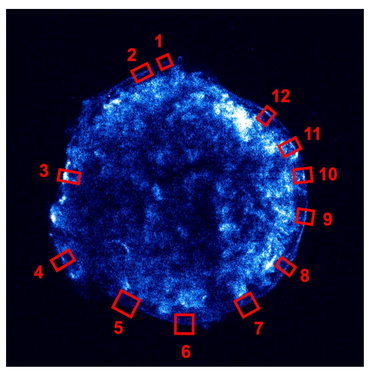
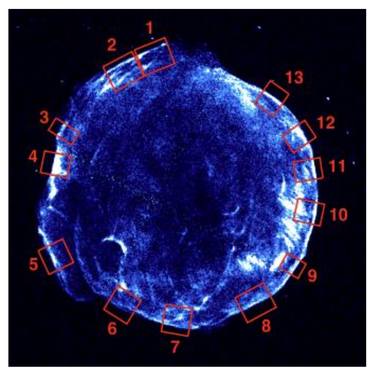
extra images and plots!

Context

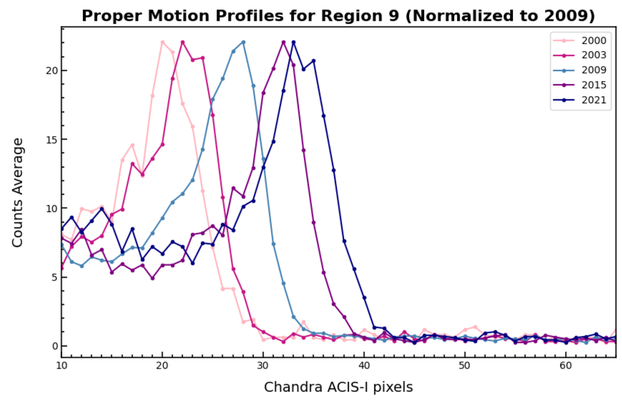
Tycho's Supernova (SN) occurred in 1572 in the Milky Way toward the direction of the constellation of Cassiopeia and was one of the few SN explosions observable by the naked eye in historical records. It is a Type Ia SN, in which white dwarfs in binary systems explode, and the progenitor system of Tycho's Supernova Remnant (SNR) has been actively discussed in the literature and is still under considerable debate. Recently, Tanaka et al. (2021) looked at the proper motion (PM) of Tycho's SNR using data from the Advanced CCD Imaging Spectrometer I-array (ACIS-I) on board the Chandra X-Ray Observatory in the years 2000, 2003, 2007, 2009, and 2015, and found deceleration in parts of the shockwave. Here, I continue Tanaka's research using new data from the 2021 observations, as well as exploring filament widths and performing spectral analysis.

Proper Motion





Our finalized 12 regions (above left) are similar in location to the 13 regions used in Tanaka et al., 2021 (above right). The plot below demonstrates the PM in our Region 9 for each epoch (2007 data omitted from this analysis).



We measured proper motion expansion over 5 epochs (more than 2 decades), allowing us to track changes in velocity with time. The plot below shows the velocity of three six-year consecutive intervals from 2003 – 2021.

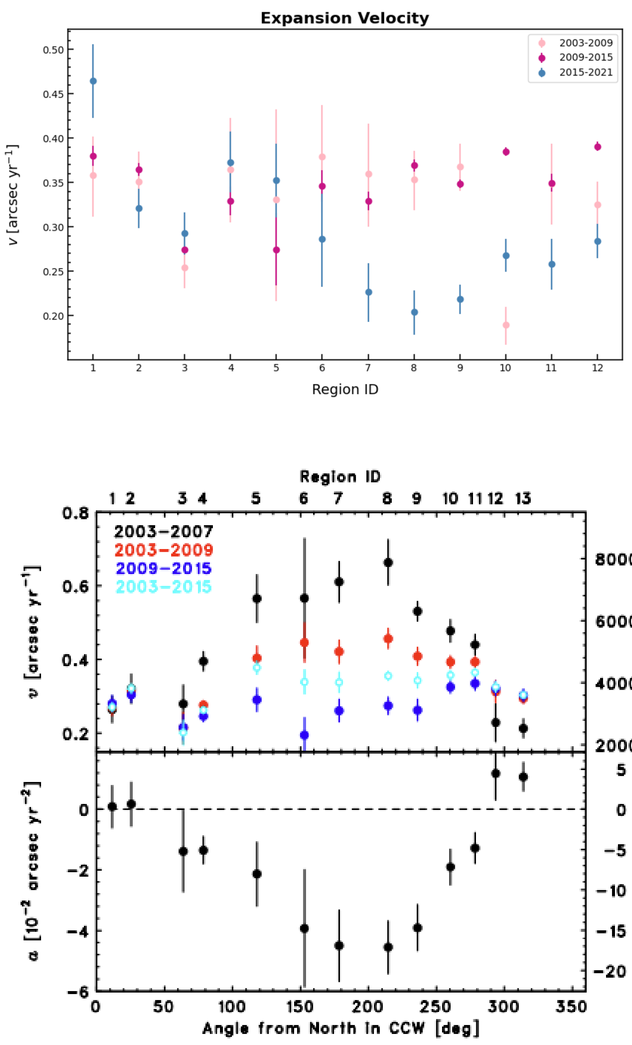
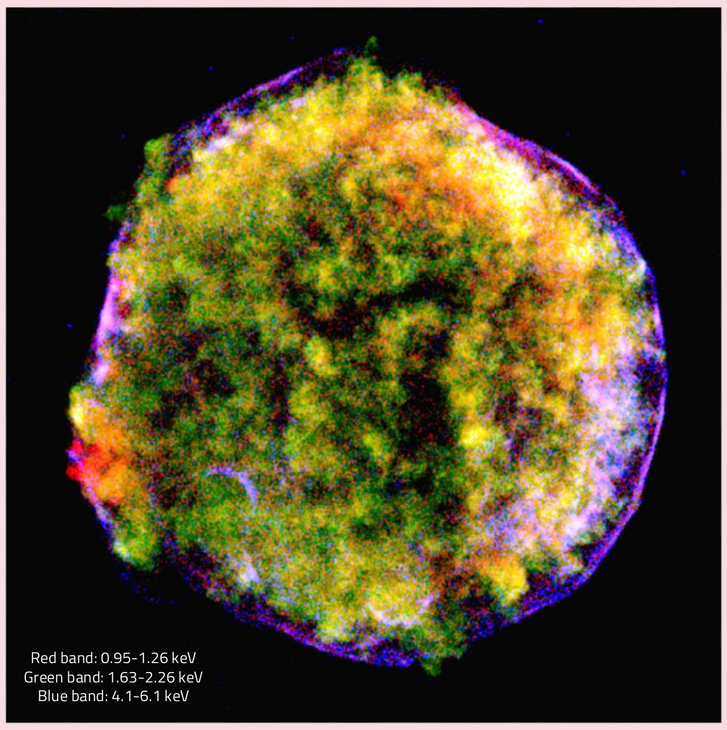


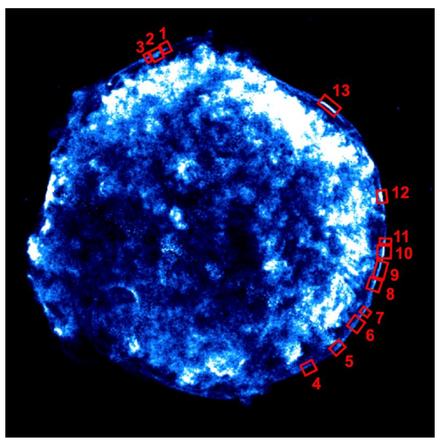
Figure 2 from Tanaka et al. (2021)

Confirms non-uniform deceleration in parts of the shockwave also found in Tanaka et al. (2021) when incorporating the new data

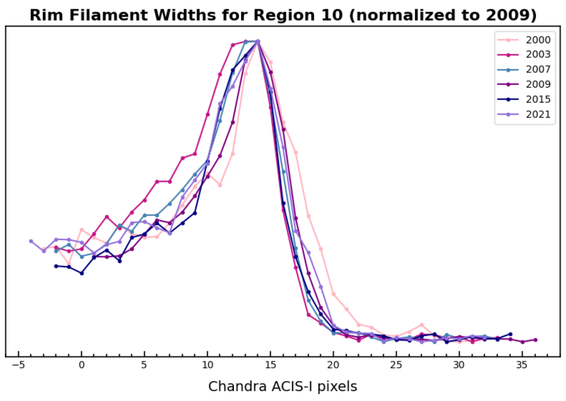


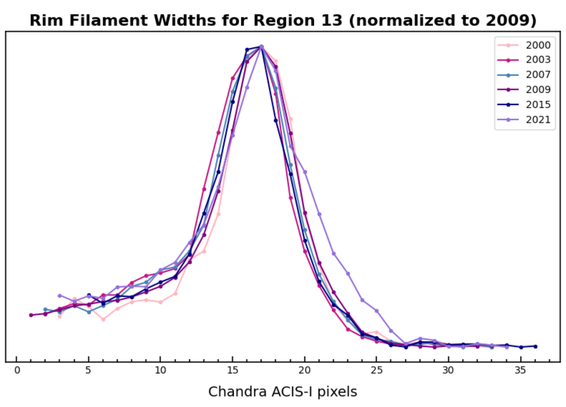
RGB image of 2021 epoch (above)

Filament Width



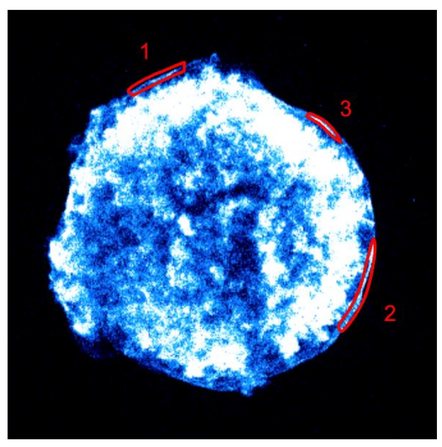
Here, we examine the widths of the synchrotron filaments that were resolved with Chandra from the 13 selected regions (above). We fit a standard Gaussian to each curve as a proxy for measuring filament width (below).



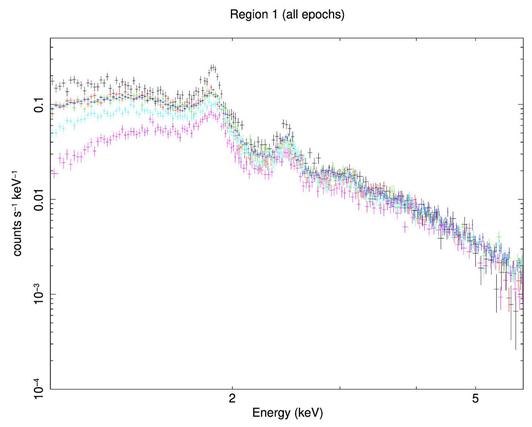


No systematic trend of filament width varying with time over 20+ years

Spectral Analysis

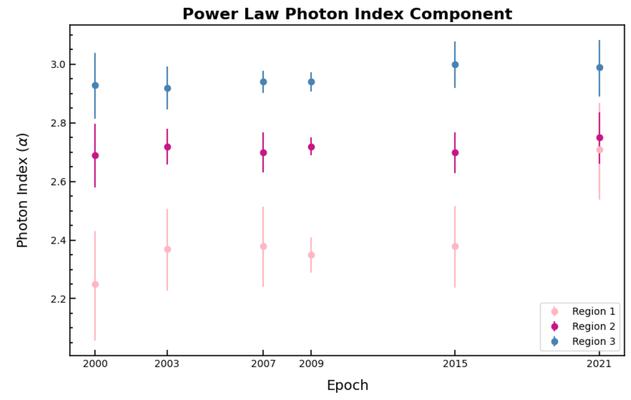


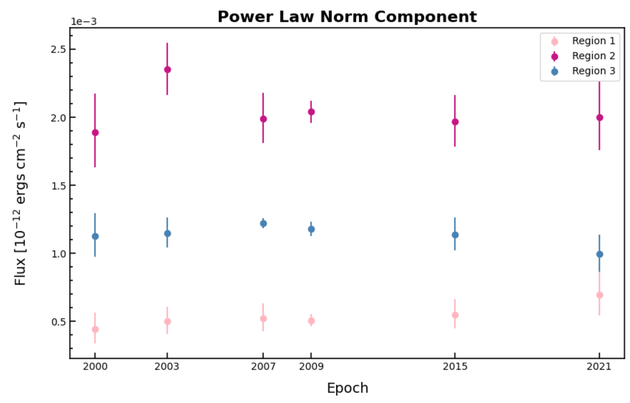
We examined spectral variation with time and chose regions that had good signal to noise (above). The spectra was extracted from each region for all obsIDs, and then we performed a joint fit of the obsIDs for each epoch (below).



Summary curves for joint fits of each epoch prior to fitting the model

We used an absorbed thermal model and power law. The thermal model was only present to account for a handful of spectral lines—we were more interested in the variation of the power law slope and flux (below).





No systematic trend of spectral variation in slope or flux of power law component