Time evolution of the synchrotron X-ray emission in Kepler's SNR: the effects of turbulence and shock velocity

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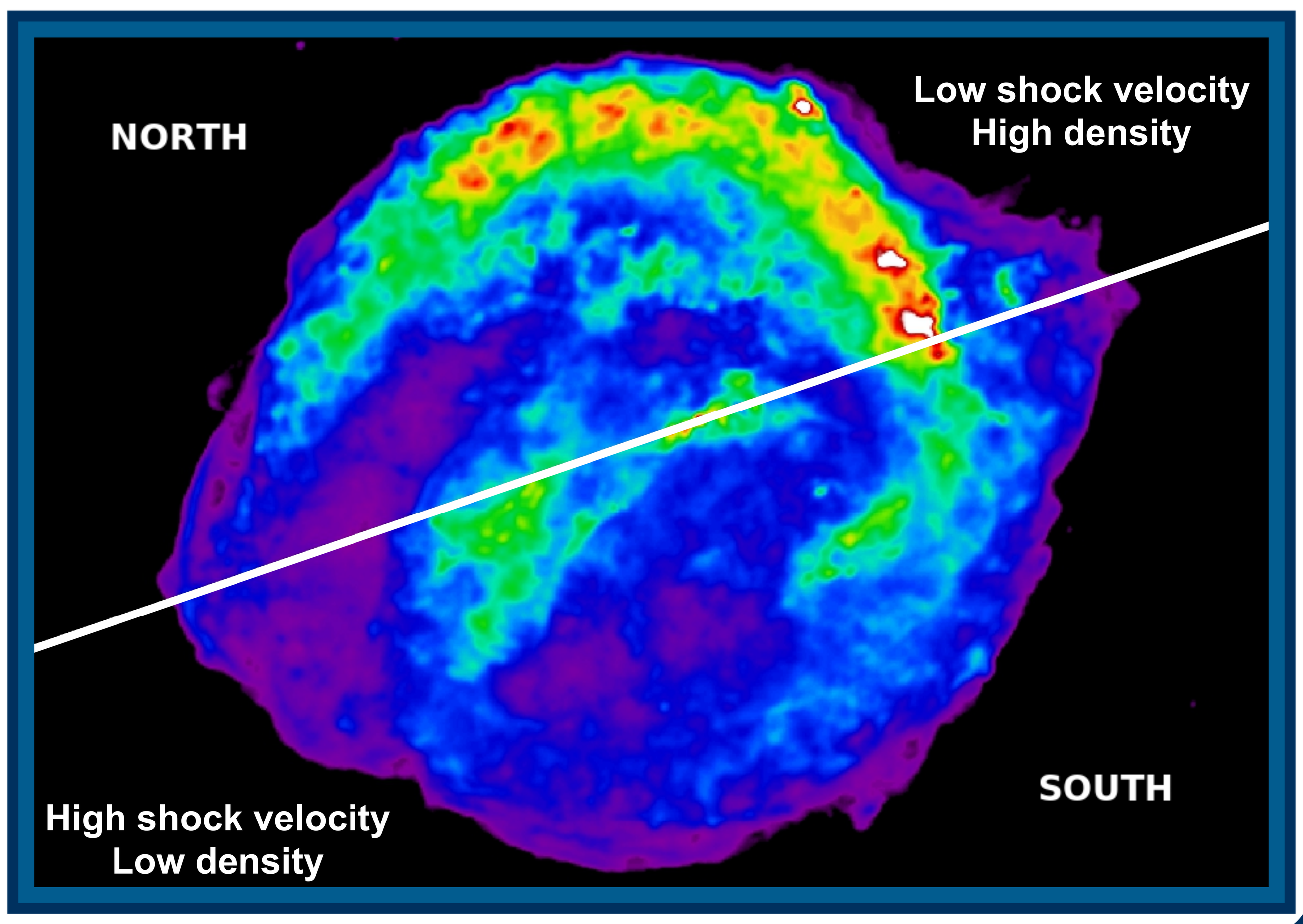
1. Kepler's SNR: Two different regimes of acceleration

Kepler's SNR (Kepler hereafter) is very well known young supernova remnant:

Age (yrs)	Distance (kpc)	Origin
420	5.1	Type Ia SN

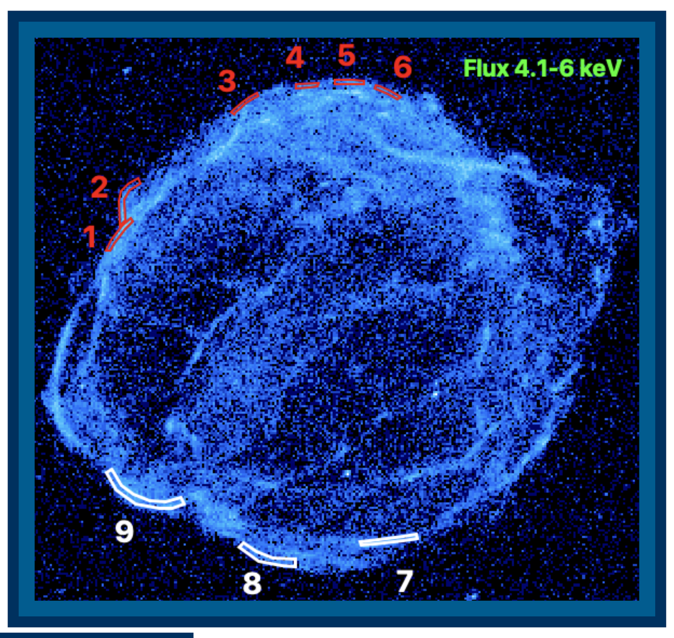
- Shock Interacting with dense N rich CSM in the north ($v_{sh} \sim 2000$ km s^{-1})
- Shock expanding in subtle homogeneous medium ($v_{sh} \sim 5000-6000$ km s^{-1})
- **Sapienza et al. (2022) found a more efficient acceleration in the north (i.e., lower Bohm factor) than in the south.**

Is this scenario true also at small scales, (single filaments)?
We studied the evolution of the synchrotron flux in Kepler using Chandra observations in 2006 and 2014.

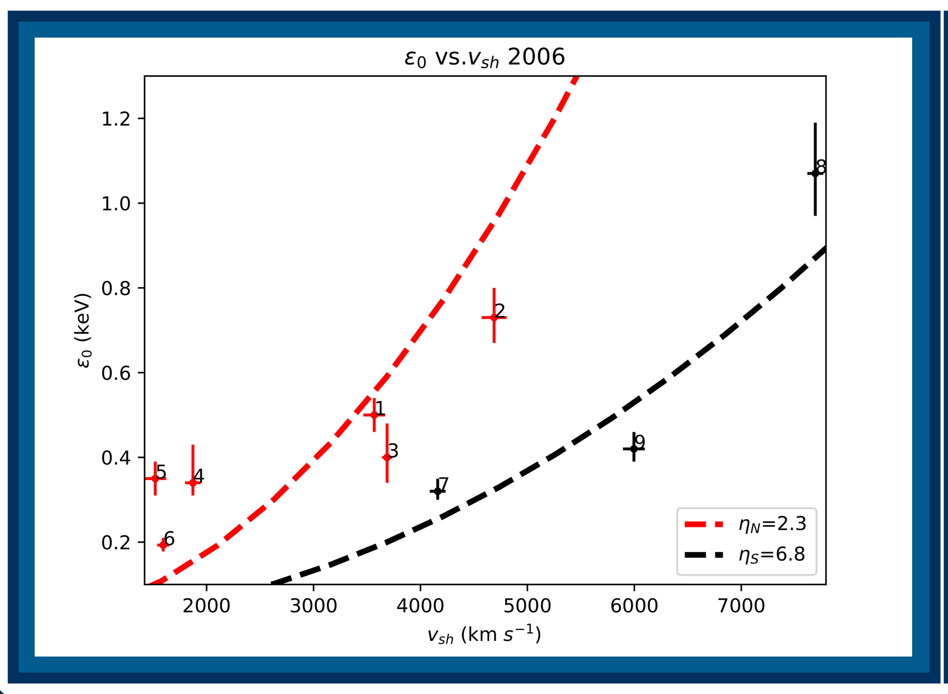


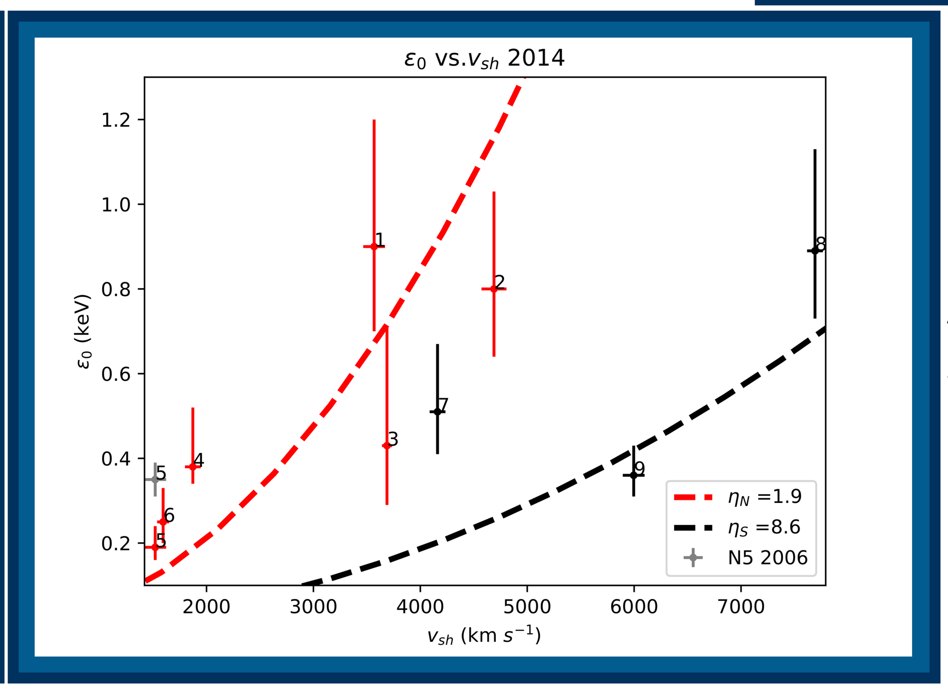
2. Cutoff Photon energy vs. Shock Velocity

- We identify 6 filamentary regions in the north and 3 in the south
- Source spectra were fitted using the loss-limited synchrotron radiation model (Zirakashvili & Aharonian 2007, measuring the cutoff energy)
- We measured the proper motion from 2006 to 2014 in all the nine regions
- We confirm the existence of two distinct regimes of electron acceleration
- In particular, $\eta_S/\eta_N = 3.0 \pm 0.7$ (2006) and $\overline{\eta}_S/\overline{\eta}_N = 3.6 \pm 2.0$ (2014), with η being the Bohm factor.



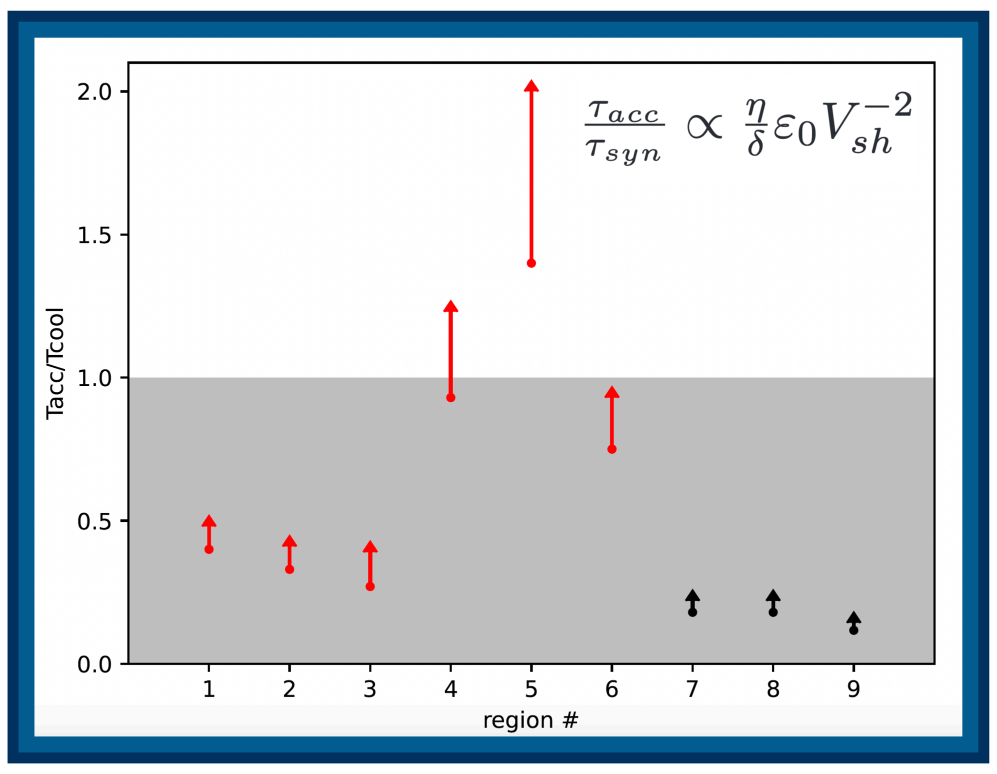
Chandra flux map in 4.1-6 keV





Cut-off photon energy vs. shock velocity in 2006 (left) and 2014 (right)

3. Acceleration vs. Cooling

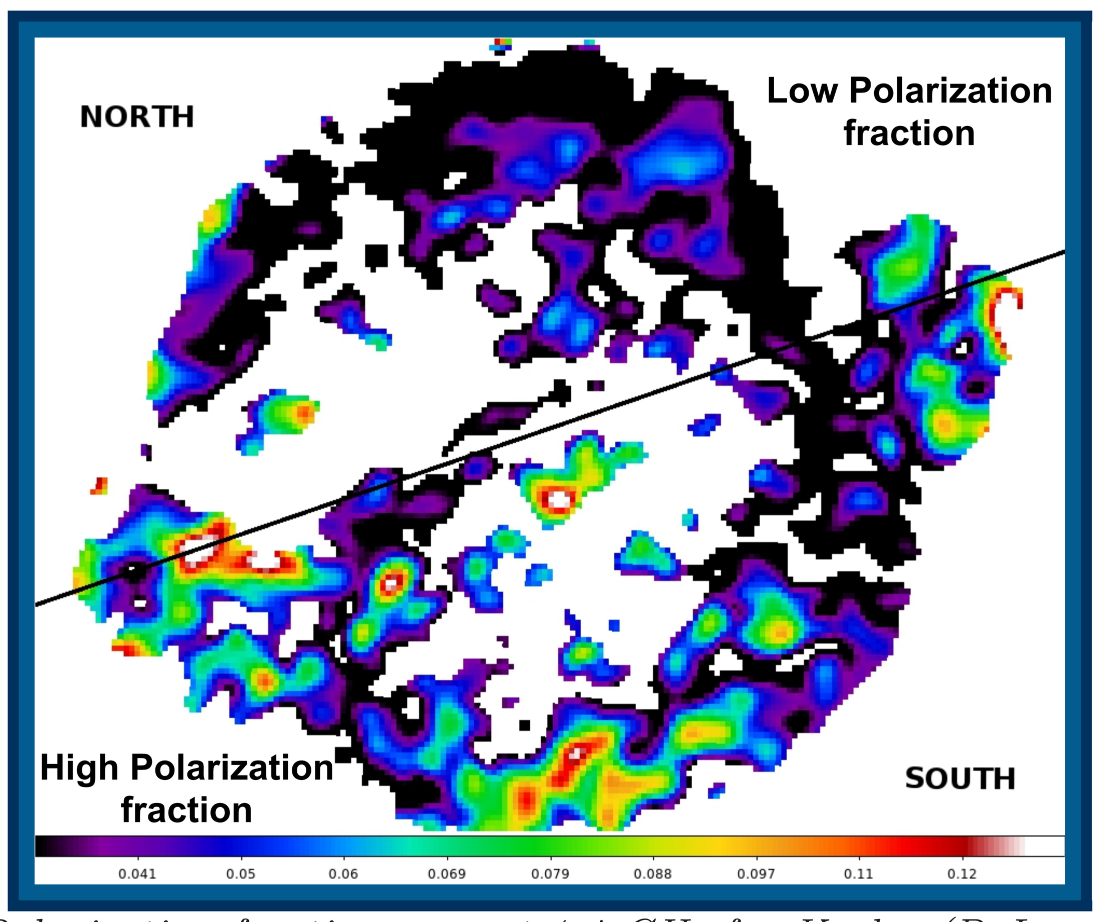


- We estimated the lower limit of the ratio τ_{acc}/τ_{sync} for each region (with $\delta = \eta = 1^a$)
- Except for region 5, $\tau_{acc} < \tau_{sync}$, i. e., loss-limited conditions (τ_{acc}/τ_{sync}=1) can be achieved with $\eta \geq 1$
- In region 5 $\tau_{acc}/\tau_{sync} > 1$, even with $\eta = 1$
- The figure also shows a sort of trend for regions 4-6, which exhibit relatively high ratios.

[a] δ accounts for the energy dependence of the diffusion coefficient

5. Radio Polarization Fraction

- Polarized Radio emission has 'memory' of $\vec{B}$
- **Turbulent $\vec{B}$ should result in a low Polarization fraction**
- $\eta_S/\eta_N = 3.3 \pm 0.4$ from the radio map.



Polarization fraction map at 1.4 GHz for Kepler (DeLaney et al. 2002)

References

DeLaney, T., Koralesky, B., Rudnick, L., & Dickel, J. R. 2002, ApJ, 580, 914
Sapienza, V., Miceli, M., Bamba, A., et al. 2022, ApJ, 935, 152
Zirakashvili, V. N. & Aharonian, F. 2007, A&A, 465, 695

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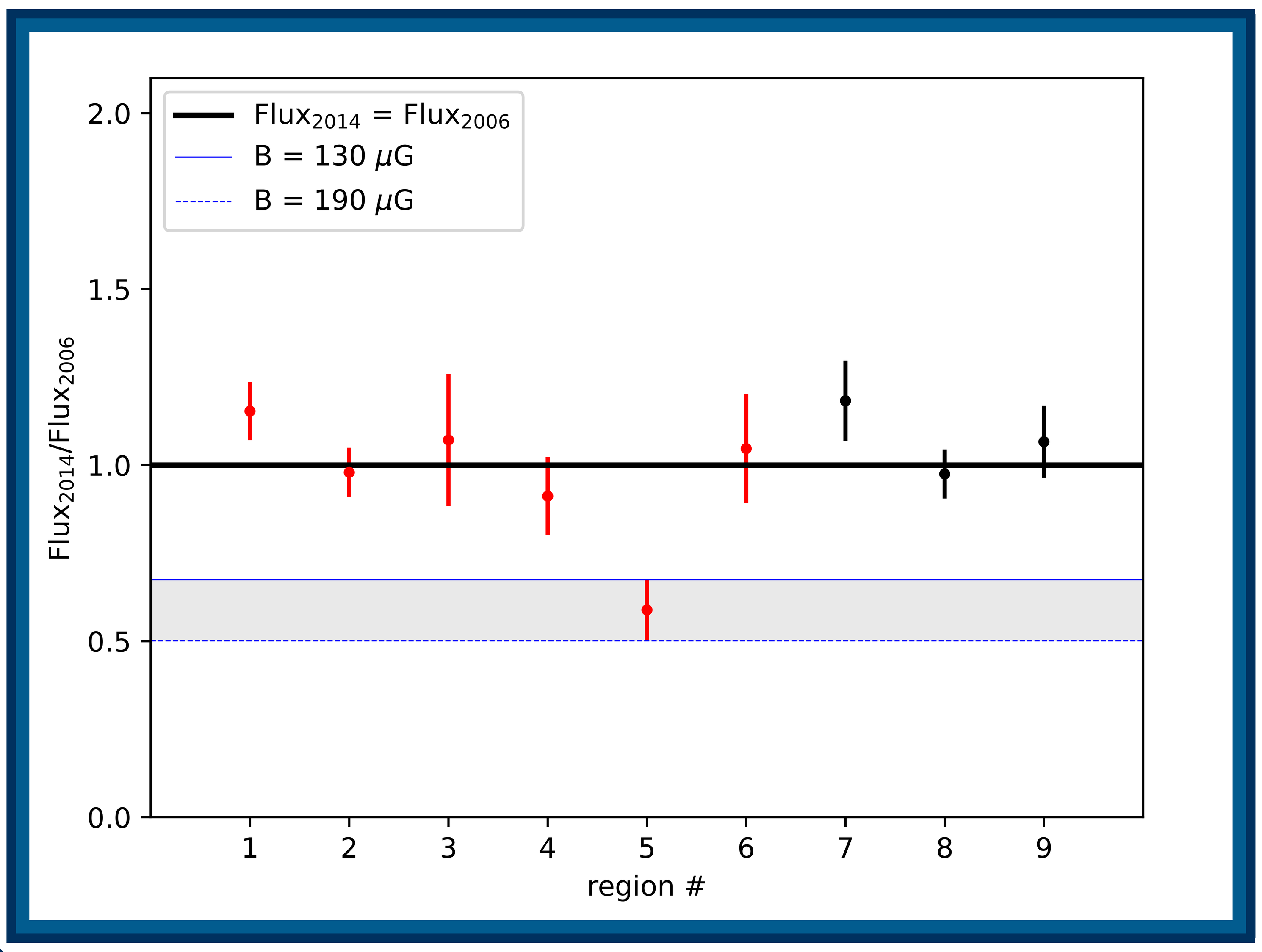
4. Non-thermal X-ray Flux evolution



- Except for region 5, the examined regions do not show any significant decrease in flux
- This confirms that these regions have remained within a loss-limited regime
- Region 5 show a significant decrease of the synchrotron radiation over this 8 year baseline
- This effect results from the synchrotron losses dominating over the acceleration efficiency, see Box 3.

Ratio of the non-thermal flux in the selected regions between 2006 and 2014.

6. Summary

- Our research has confirmed the existence of two distinct regimes of particle acceleration in Kepler
- The interaction between the shock and dense CSM in the north results in **amplified turbulence of $\vec{B}$** enhancing the acceleration process
- Further evidence of this are provided by **low polarization fraction observed in the north**
- In one region (characterized by a very low shock speed) we find that the radiative losses dominate over the acceleration process (**first evidence of fading synchrotron emission**)
- Our study provides a coherent and comprehensive understanding of the electron acceleration in Kepler.