X and γ–ray emission of RX J1713.7-3946

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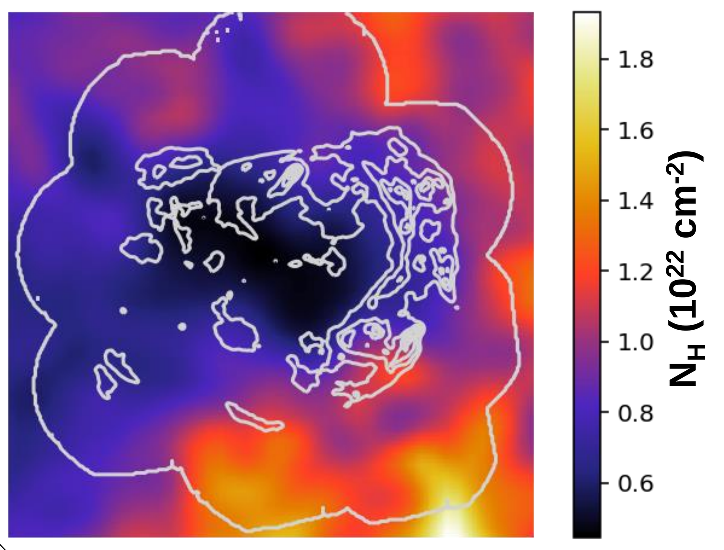
Abstract : RX J1713.7-3946 is the brightest TeV supernova remnant, so it is an important test case for cosmic-ray acceleration. The absence of ambient thermal X-ray emission (together with only moderate absorption) indicates that the gas is tenuous. Since a Central Compact Object sits at the center of the remnant, the mainstream view is that the SNR develops into the wind of its high-mass progenitor and now reaches a shell of denser gas around.

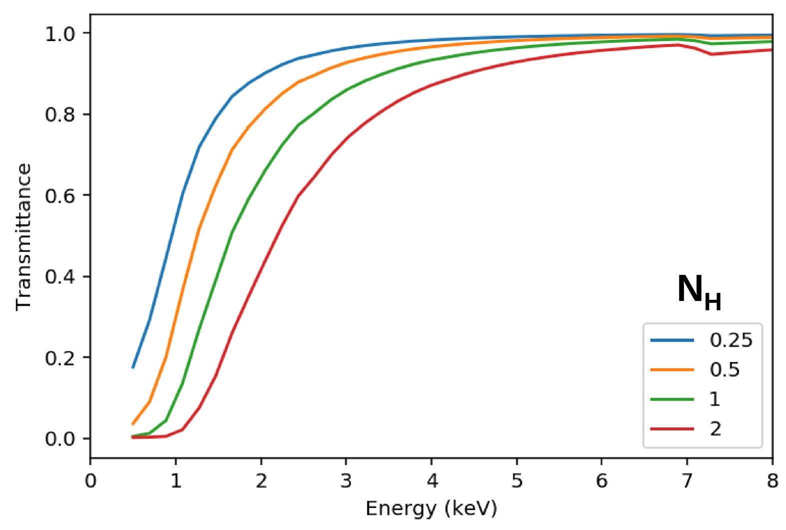
The γ rays are well correlated with the X-ray emission, which is dominated by synchrotron emission from accelerated electrons, but the correlation is very non linear (approximately $F_\gamma \propto \sqrt{F_X}$). In that context, the most natural model (Acero et al 2009, A&A **505**, 157) is that γ rays are dominated by inverse Compton emission (leptonic). The X to γ-ray ratio is modest, implying a low magnetic field.

We have obtained deep full coverage of RX J1713.7-3946 with XMM-Newton (PI F. Acero). Together with the good TeV map (HESS collaboration et al 2018, A&A **612**, A6), it allows testing the γ/X correlation into the faint areas, in particular the external boundary of the SNR where the HESS collaboration reported γ-ray emission beyond the X-ray border, which could be due to escape of cosmic-ray protons. We do not confirm that finding.

Interstellar absorption

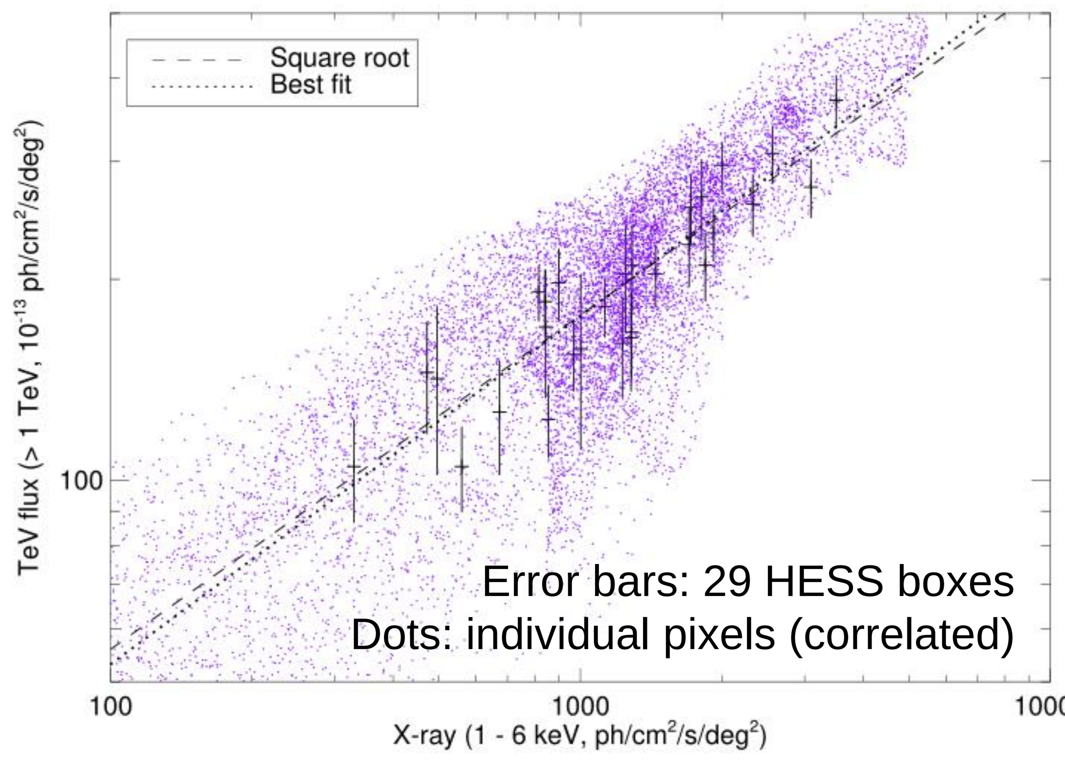
- The absorption toward RX J1713.7-3946 is not constant, and correlated with CO emission (Cassam-Chenai et al 2004, A&A **427**, 199)
- The X-ray absorption is well correlated with optical extinction toward stars (Sano et al 2015, ApJ **799**, 175), implying that Av traces clouds in front of the SNR
- We have used the Av map (bottom left) to correct the integrated X-ray flux. Largest correction is toward the southwest ($N_H > 10^{22}$ cm^{-2})
- Even for B = 20 μG, IC on CMB at 1 TeV corresponds to 0.2 keV synchrotron, so we need to integrate as low as possible. Start at 1 keV (too large N_H correction below that, bottom right), integrate up to 6 keV
- Subtract background using the model outlined in poster S42.



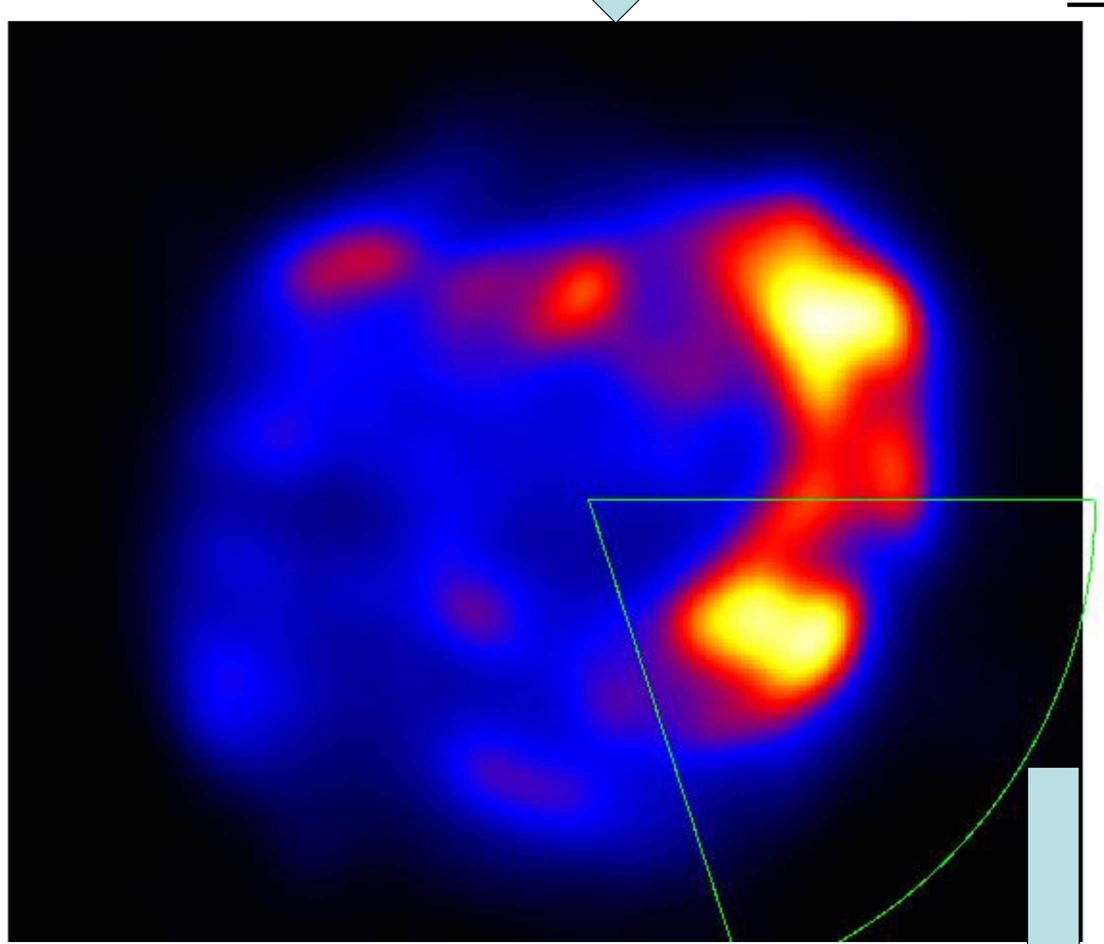


X/γ correlation

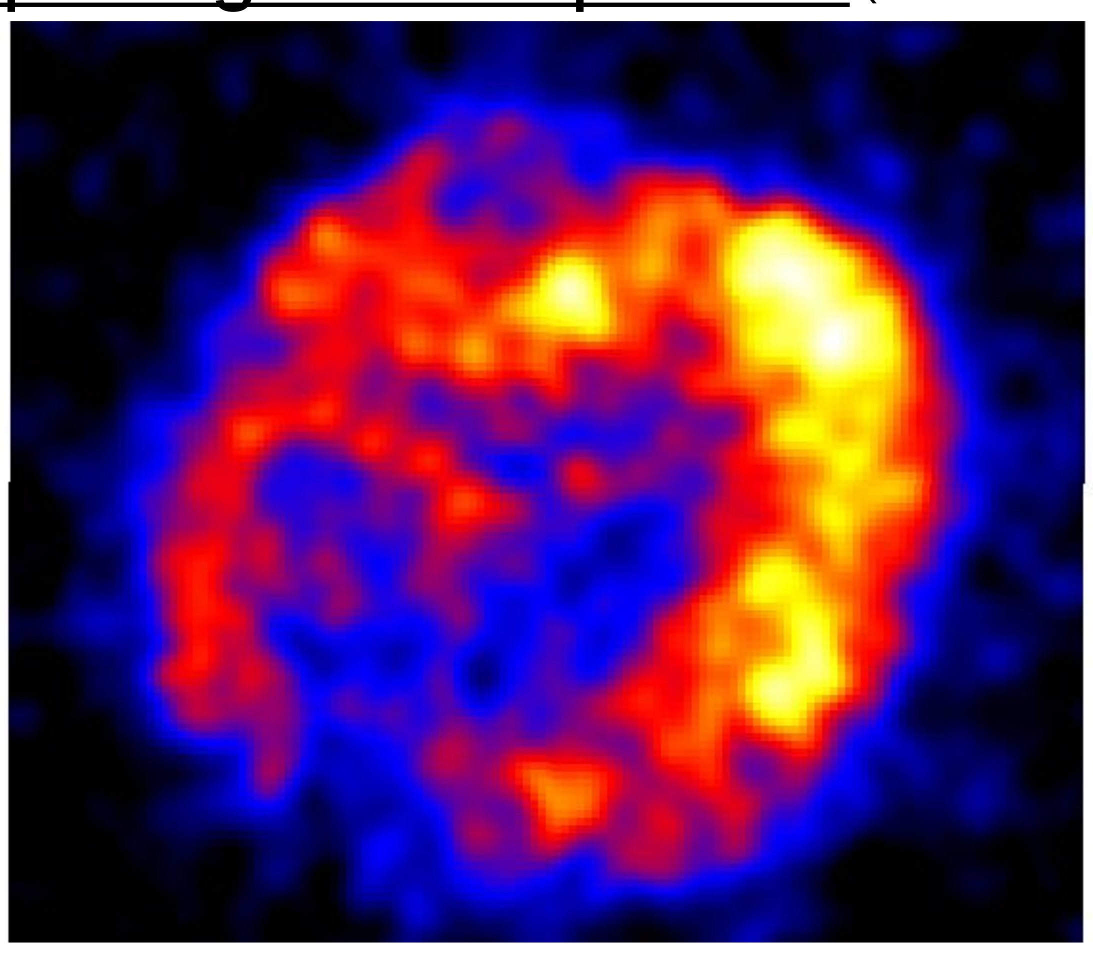
- Convolve X-ray map with approximate HESS PSF (scaled from public DL3 HESS PSF to have the same R_{68} as in the RX J1713 paper). Resulting map below left.
- Much larger contrast in X-rays than in γ-rays (Acero et al 2009, A&A **505**, 157). Natural in IC model (B is positively correlated with electron energy density) although not so easy to explain quantitatively. Not expected at all in hadronic model of γ-ray emission
- Update the correlation with current X and γ data. Larger range
- Fit straight line (power-law dependence): best slope is 0.52 +/- 0.04
- Simplify as $F_\gamma \propto \sqrt{F_X}$
- Requires excellent X-ray data to reach γ-ray threshold. Could not be done accurately with the previous shallow X-ray observations
- Use that relation to generate from the X-rays a model of IC γ-ray emission, to compare with the actual γ-ray data (below right)



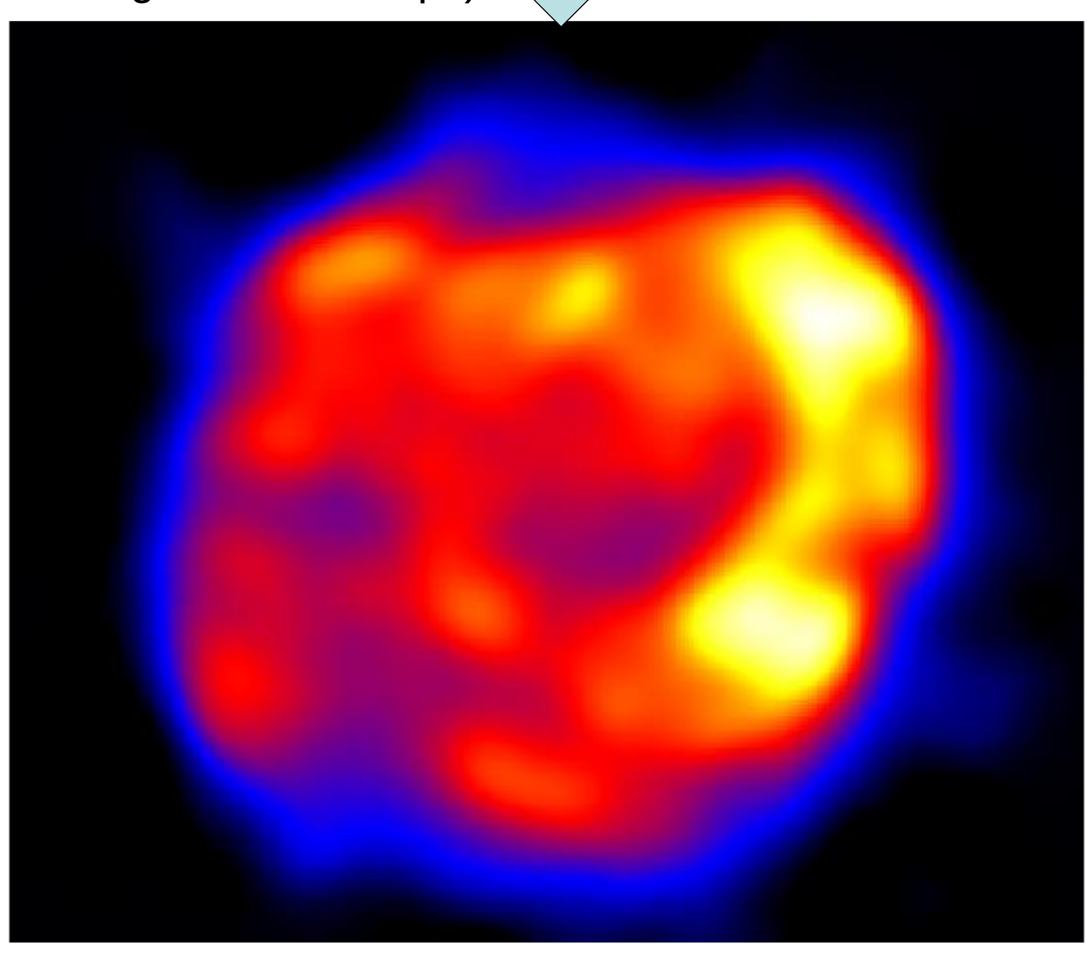
Morphological comparison (linear color scale starting at 0 in all maps)



X-ray map 1 to 6 keV, background subtracted, absorption corrected and smoothed by HESS PSF. More azimuthal contrast than TeV, looks smaller



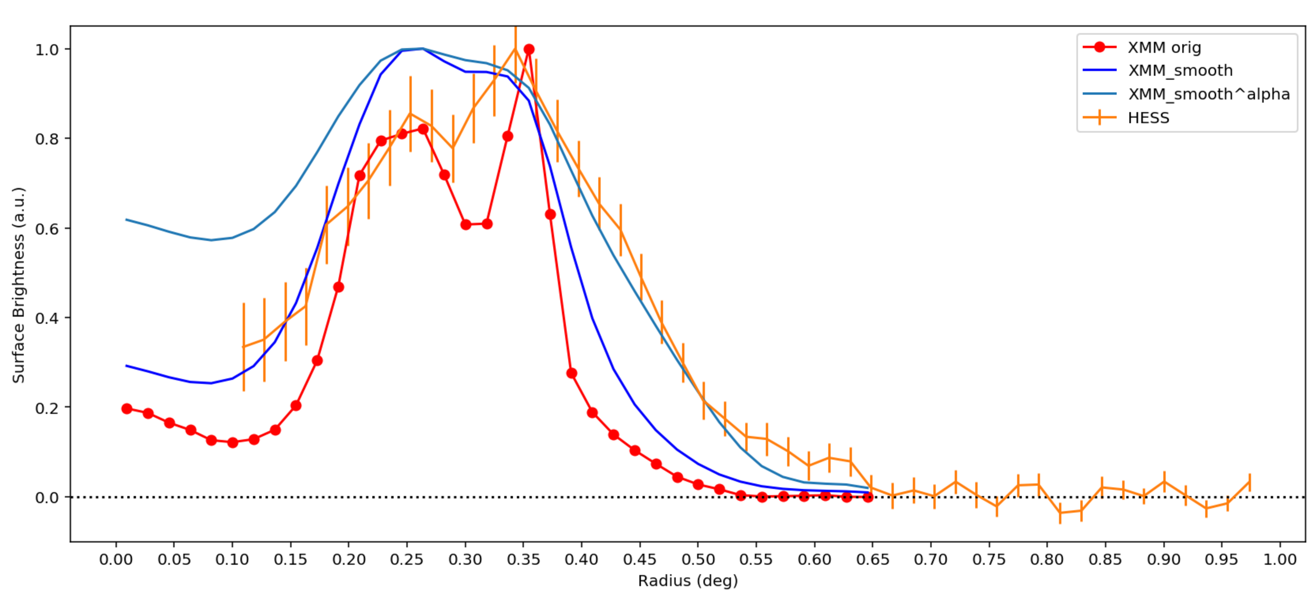
HESS map > 250 GeV, from HESS collaboration et al 2018, A&A **612**, A6



Square root of the full-resolution X-ray map, convolved by HESS PSF. Azimuthal contrast and radial extension are similar to TeV. Center brighter

Radial profile

- We have extracted radial profiles from an angular sector of 360/5 = 72° toward the southwest, as in the HESS paper
- The new data cover the outer parts of the SNR much better
- After the $\sqrt{F_X}$ transformation, decreases outwards similarly to the γ-rays
- Predicts too much emission inside, possibly due to contamination by ejecta (poster S42)



γ-ray profile (orange) compared with Av corrected X-ray profile (red), after smoothing (dark blue) and smoothed $\sqrt{F_X}$ (light blue)

Discussion

- In our interpretation, the azimuthal variations are due to varying density of the gas encountered by the shock
- The X-ray emission goes as $B^{1.5}$ (assuming an E^{-2} particle spectrum), explaining why it is more contrasted than the γ-rays (the main Inverse Compton target is the CMB) if B and particle energy density both increase with gas density
- Correcting for interstellar absorption has a sizable impact
- We find that the larger radius observed in γ-rays (particularly toward the southwest) can be entirely explained by the larger contrast and interstellar absorption
- This implies that there is no observational indication that the outermost γ-rays come from a precursor physically outside the blast wave, due to hadrons (which have a larger precursor than electrons, because they are not cooling-limited)

Conclusion

- ✓ **We have used the deeper full X-ray coverage of the RX J1713.7-3946 SNR to update the X to γ comparison, adding Av correction**
- ✓ **We confirm the $F_\gamma \propto \sqrt{F_X}$ correlation over a larger range**
- ✓ **When accounting for all this, we do not confirm that the γ-rays extend further than the X rays**