RX J1713-3946 XMM-Newton Large Program: First results

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RX J1713.7–3946 is the poster-child of cosmic-ray accelerator and is among the brightest X- and gamma-ray non- thermal emitters. While previous XMM-Newton programs focused their attention on a few regions, other parts of the remnant were only observed for ~10 ks and some outer and fainter regions were never observed. With a diameter of 1°, a 700 ks LP, completed in 2018, was necessary to obtain a deep exposure (80-120 ks) across the remnant.
Here we will present the first results of this program focusing on the thermal emission of a bright clump in the SNR (shocked circumstellar material ?), and a detailed study of a direct shock-cloud interaction region. With the increased statistics brought by the Large Program we can produce a data cube (x,y,E) and search for spectral features (e.g. thermal emission) in a new way.

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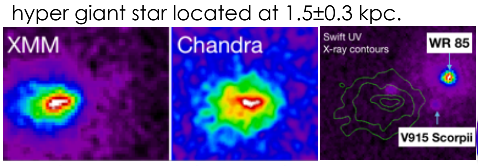
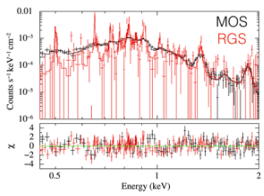
Shocked CSM clump ?

This source is the brightest after the CCO and was previously thought to be associated with a Wolf Rayet star (WR 85). The source is in fact extended and 20''away from the WR star. Nearby is also V915 an hyper giant star located at 1.5±0.3 kpc.



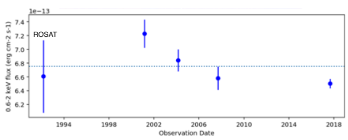
Source is extended (R~15 arcsec)

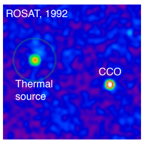
The source has a soft Nitrogen rich, thermal spectrum. N_H is compatible with RXJ.



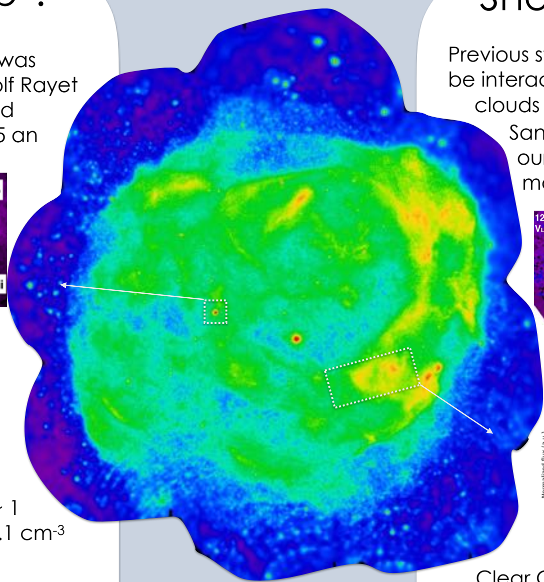
$N_H = 0.72\times10^{22}$ cm^{-2}
kT = 0.55±0.05 keV
[N] = 11±6
[O, Ne, Mg, Si,Fe] ~ 1
Log(tau) = 10.78±0.1 cm^{-3} s

The source was already detected with ROSAT and its flux is stable over 30 years.





Then what is the nature of this mysterious thermal blob ?
A possible scenario is that this is a shocked clump from CSM (clump left in the cavity carved by the progenitor stellar wind). If true there should be other such clumps.
Another possible scenario is interaction of stellar winds from V915 with dense material.
If you have any pro/cons arguments for this strange source, don't hesitate to contact me !

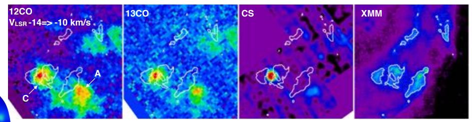


New XMM image (0.5-5 kev) in Log scale obtained with 700 ks &12 pointings.
Fainter shocks outside the bright regions seen in N & SW may indicate density contrast along the line of sight.

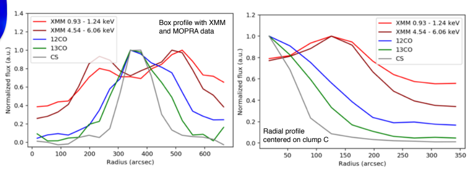
Scan me to see a movie of RXJ as a function of energy.

Shock-Cloud interaction

Previous studies have shown that the shock is likely to be interacting with clouds A & C, the most massive clouds in the vicinity (~50 $M_\odot$ or greater; Maxted+12, Sano+13). Using MOPRA data (Braiding+19) and our new XMM maps, we compare the morphologies and spectral signatures.



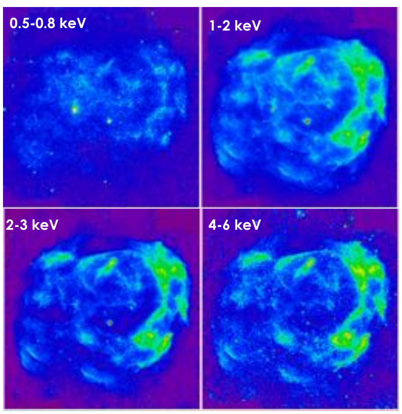
Box & radial profiles:



Clear Gas/X-rays anti-correlation and no X-ray morphological energy dependence is observed. Cloud is probably in the background of the SNR (no absorption effect). The fact that no X-ray peak from cloud center at 5 keV indicate that high energy e$^-$ do not penetrate cloud deeper than low energy e$^-$. An increased B-field on the envelope may shield the cloud from CRs penetration (e.g Inoue+19, Celli+18).

Spectral analysis
Same fitted $N_H = 0.7\times10^{-22}$ cm^{-2} in outer/central part support cloud interaction is in the background.
Outer part of the clump has a harder index (Γ=2.02±0.2) than the core (Γ=2.12±0.4) of the cloud.
Is the harder spectral index due to B-field compression ? Re-acceleration in B vortices ?

A flux and background model cube (x,y,E)



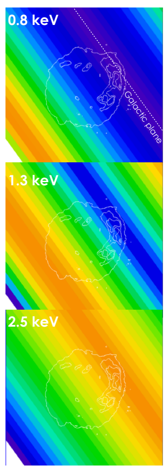
Data cube: With the increased statistics brought by the Large Program we can produce a data cube with up to 20 slices in energy showing the evolution of RX J1713-3946 evolution with energy. Left panel shows a few examples of those images.
The low energy is dominated by the interior of the remnant due the lower Nh and some thermal emission. The thermal clump discussed above is the brightest source will fading away after 1 keV.

Astrophysical background model: close to the plane and 1° in diameter the astrophysical background is not constant across the SNR. Using four other XMM pointings around the SNR and the OFF regions in our pointings (up to 2° apart), we built an analytical model with only a latitude dependence. This model is used to compare the SNR in gamma-ray in poster S4.1. The Xspec model used is:

*apec(0.2 keV) + N_H(N1*apec(0.75 keV)+N2*apec(2.7 keV)+pow(1.41))*
Local Bubble thermal component thermal component CXB

In this model N_H, N1 and N2 decrease with increasing |b|.

Flux images of our bkg model



The higher N_H in the plane hides the thermal and CXB component.

At higher energies the higher surface brightness of the thermal component dominates the galactic plane.