X-ray studies of the TeV-discovered supernova remnant HESS J1534-571

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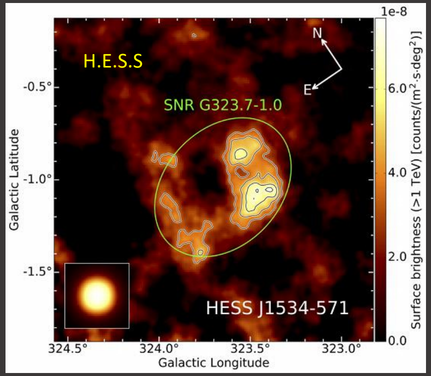

Fig 1. TeV surface brightness map of the newly discovered shell-type SNR HESS J1534-571 (H.E.S.S collaboration 2018). The green ellipse indicates the 843 MHz shell G 323.7-1.0.

1. Motivation

Supernova remnants (SNRs) are powerful sources that can fuel our galaxy with high energy cosmic rays. Cosmic ray protons and electrons may go through different interactions to produce gamma rays up to TeV energy, which can be captured by TeV instruments like H.E.S.S.

HESS J1534-571 is a shell type SNR that has been discovered in the context of H.E.S.S. Galactic plane survey (Fig. 1). While a radio and GeV counterpart has been identified, a putative X-ray counterpart of the shell has eluded detection so far (Fig. 2). Observational XMM-Newton data, together with archived SUZAKU data are used in order to: 1/ search for X-ray emission from the direction of the SNR. 2/ constrain the cosmic ray production and (re)acceleration scenarios. 3/ analyse a signal of the neutral Fe Kα line at 6.4 keV which is found within the TeV shell, and which implies the presence of low energy cosmic rays at ~MeV energy.

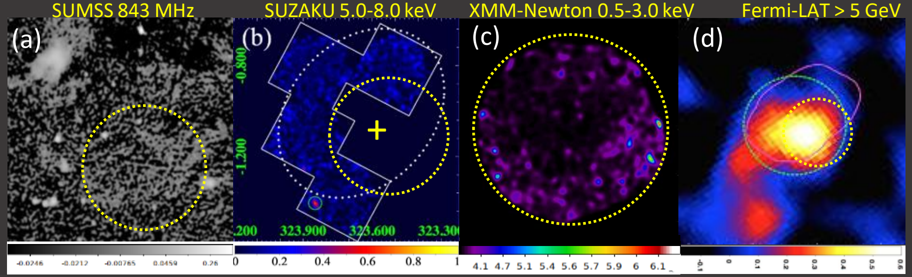

Fig 2. Multiwavelengh studies of HESS J1534-571. The XMM-Newton f.o.v. is represented by the dashed yellow circle in all panels. a) SUMSS 843MHz observation of the source G323.7-1.0, note the faint elliptical shell. b) The SUZAKU image of G323.7-1.0 at 5.0-8.0 keV shows the lack of hard X-ray emission (Saji 2018). The white dashed line indicates the radio ellipse. The yellow cross shows the center of the GeV emission. c) Adaptively smoothed XMM-Newton image in the band 0.5-3.0 keV (this work). d) Residual image at above 5 GeV from Fermi-LAT data, the dashed line denotes the best-fit disk source model and the magenta line follows the radio shell (Araya 2017).

2. Broad band SED analysis

Using the python package *naima* (Zabalza 2015), we simulate different possible types of SNR induced cosmic ray interactions. As for cosmic ray electrons (Fig. 3a), emission is mainly created via synchrotron and inverse Compton scattering, which leave imprints over the radio, X-ray and GeV-TeV windows. For the cosmic ray protons (Fig. 3b), inverse Compton scattering and pion decay are responsible for the highly energetic gamma rays. The classical "bump" in the high energy range of the leptonic model provides a relatively good fit to the current data, while the expected corresponding synchrotron emission is not in conflict with the X-ray limit.

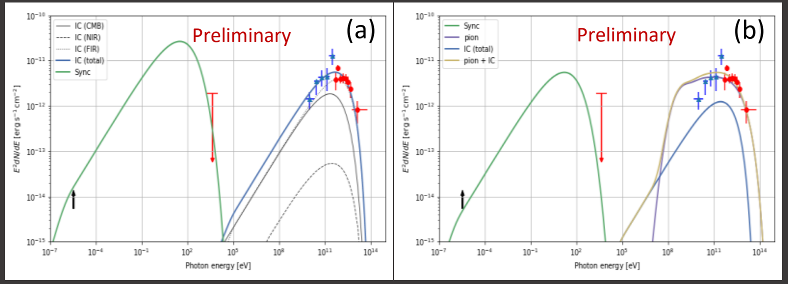

Fig 3. SED analysis of HESS J1534-571. Radio lower limit, Fermi-LAT and H.E.S.S data points are plotted in black arrow, blue and red points, respectively (Green et al. 2014, Araya 2017, H.E.S.S. 2018). The red arrow shows the X-ray upper limit flux in the range 2.0-10.0 keV derived in this work. A leptonic model of gamma ray production is plotted in a) and a hadronic model in b).

3. Neutral Fe Kα line emission

As can be seen in Fig. 2 b) and c), there is no visible sign of strong synchrotron emission coming from the source in the broader X-ray energy bands. However, the narrow band 6.3-6.5 keV image shows a hint of patchy emission in both SUZAKU and XMM-Newton pointings (Fig. 4a). Spectra from the enhanced and reference regions (Fig. 4b) are extracted and fitted to the model [power law + gauss (6.4 keV) + gauss (6.68 keV)] (Fig. 4c). While the emission line at 6.68 keV can be explained by the Galactic Ridge X-ray emission and is consistent amongst the two regions, the 6.4 keV line from the enhanced region is visually stronger than that from the reference region. Photoionization by ~MeV protons can explain this emission. Furthermore, we perform a set of 10000 simulations to estimate the significance of this Fe Kα emission at 6.4 keV, which returns a probability corresponding to a moderate detection over statistical fluctuation (Fig. 5).

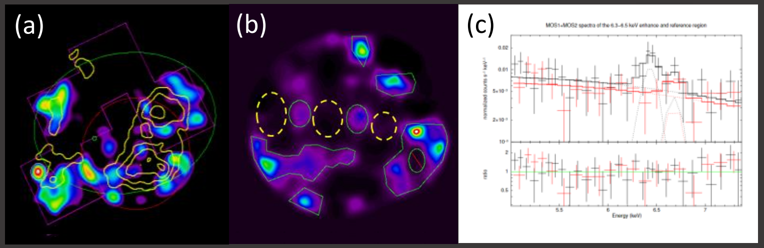

Fig 4. Detection of the neutral Fe Kα line. a) Combined SUZAKU (magenta) and XMM-Newton (red) pointings. Yellow contours and green ellipse depict the TeV surface brightness and radio shell, respectively. b) XMM-Newton image of the narrow band 6.3-6.5 keV enhanced (green) and reference (yellow dash line) regions. c) XMM-Newton spectra of the 6.3-6.5 keV enhanced (black) and reference (red) region.

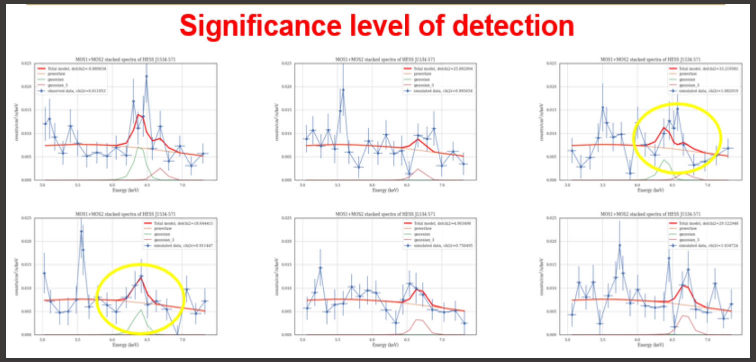

Fig 5. Calculating the significance level of the Fe Kα line detection. From the best-fit baseline model, the xspec command fakeit is used to generate simulated spectra. The simulated spectra are then fitted to a model consisting of the baseline and two fixed Gaussian lines at 6.4 keV and 6.68 keV. Statistical upward fluctuation can result in a Gaussian line at 6.4 keV at least as strong as our data (examples are marked by yellow circles). The significance of detection is then the probability of the 6.4 keV line not being caused by the statistical fluctuation.

4. Conclusion

- There is no prominent X-ray emission from HESS J1534-571 as seen from current instruments. The upper limit of an X-ray source of order of 10^{-12} erg/cm^2/s at the energy range 2.0-10.0 keV is derived from a joint spectral fitting of SUZAKU and XMM-Newton.
- HESS J1534-571 belongs to a class of evolved SNRs, where it is harder to detect non-thermal X-ray.
- The SED analysis of the SNR shows that the highly energetic gamma rays could be produced leptonically.
- A faint, statistically marginally significant signal was found at 6.4 keV with XMM-Newton, in agreement with earlier SUZAKU findings. This could be evidence of interactions between ~MeV cosmic ray protons and spatially co-located dense gas.