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

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1. Introduction

TeV selected supernova remnants (SNRs) tend to exhibit strong non-thermal X-ray and thermal X-ray emission, which implies the presence of very high energy electrons and the shock-heated plasma, respectively. Nevertheless, HESS J1534-571 represents the first confirmed TeV SNR (Fig. 1) that is not visible in X-ray observations (Fig. 2).

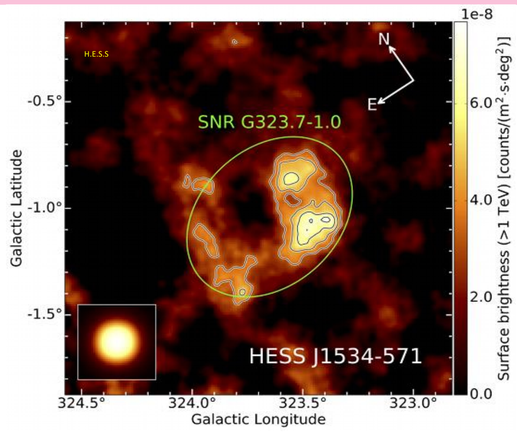

Fig 1. TeV surface brightness map of the newly discovered shell-type SNR HESS J1534-571 (H.E.S.S collaboration 2018). The green ellipse indicates the 843 MHz shell G323.7-1.0.

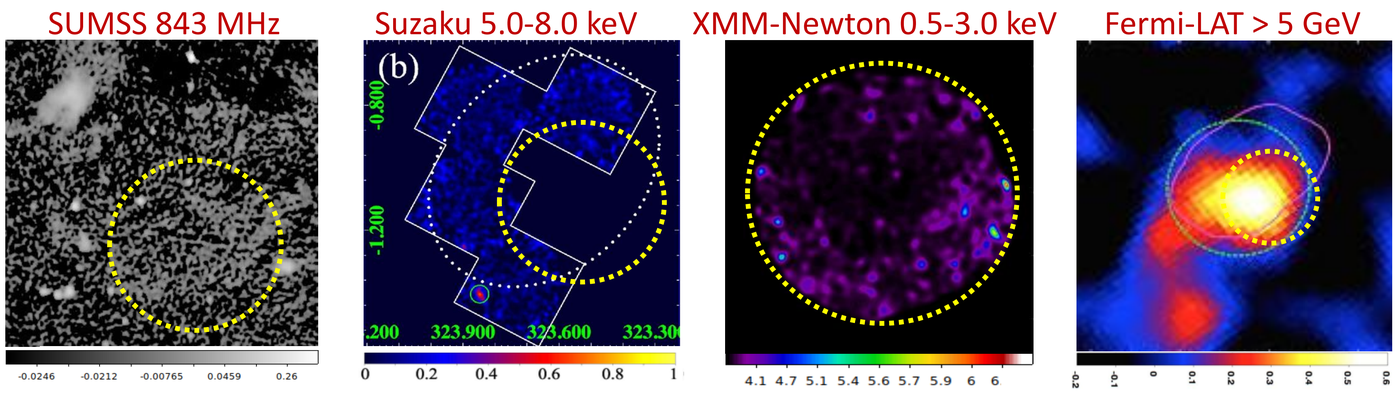

Fig 2. Multiwavelengh studies of HESS J1534-571. The XMM-Newton f.o.v. is represented by the dashed yellow circle in all panels. a) SUMSS 843MHz observation of the source G323.7-1.0 (Green et al. 2014), note the faint elliptical shell. b) The Suzaku image of G323.7-1.0 at 5.0-8.0 keV shows the lack of hard X-ray emission (Saji et al. 2018). The white dashed line indicates the radio ellipse. 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).

In this work, observational XMM-Newton data, together with archived Suzaku data is used in order to:

- Estimate the upper limit of X-ray emission from HESS J1534-571.
- Constrain the cosmic ray production and (re)acceleration scenarios at the site of the SNR.
- Analyze a signal of the neutral Fe Kα line at 6.4 keV found within the TeV shell.

2. Broad band SED analysis

- Upper limit of X-ray flux is estimated by fitting XMM-Newton and Suzaku spectra (Fig 3), assuming a power-law component (index = 2) for the non-thermal X-ray synchrotron.
- $F^{\Gamma=2}_{2-10\mathrm{keV},\ \mathrm{UL}} = 5.62 \times 10^{-13} \mathrm{erg\ cm^{-2}\ s^{-1}}$
- 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.
- Emission models are simulated by *naima* package (Zabalza 2015)

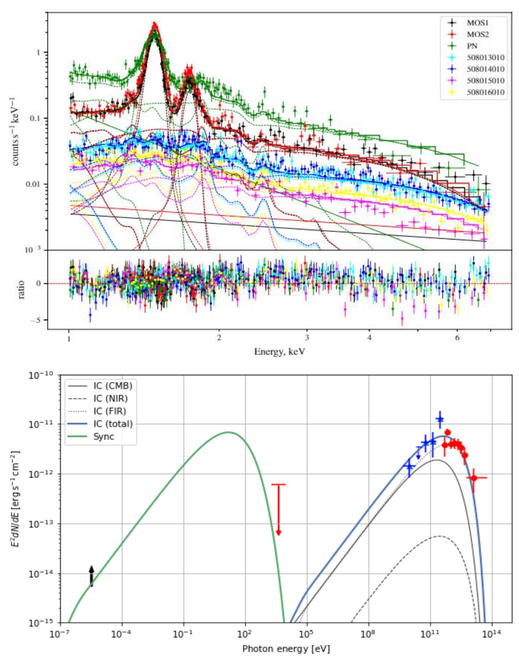

Fig 3. Upper: Spectra fitting of HESS J1534-571. Lower: SED analysis of HESS J1534-571. The red arrow shows the X-ray upper limit flux in the range 2.0-10.0 keV (this work). A leptonic model of gamma ray production is plotted.

3. Neutral Fe Kα line emission

- Although: no visible sign of strong synchrotron emission coming from the source in the broader X-ray energy bands (Fig. 2b, c).
- However: patchy emission in both Suzaku and XMM-Newton pointings in 6.3-6.5 keV (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.
- Interaction of dense gas with ~MeV cosmic ray protons can explain this emission.

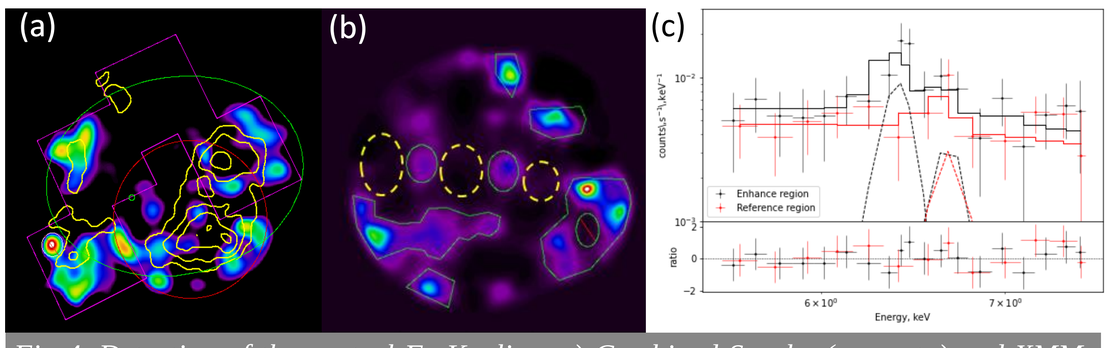

Fig 4. Detection of the neutral Fe Kα line. a) Combined Suzaku (magenta) and XMM-Newton (red) pointings. Yellow contours and green ellipse depict the TeV surface brightness and radio shell, respectively. b) XMM-Newton image of the narrow band 6.3-6.5 keV for enhanced and reference regions. c) XMM-Newton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

- We perform a set of 10.000 simulations to estimate the significance of this 6.4 keV Fe Kα emission from XMM-Newton observations.
- $\sim 3\sigma$ significant, or a moderate detection over statistical fluctuation (Fig. 5).

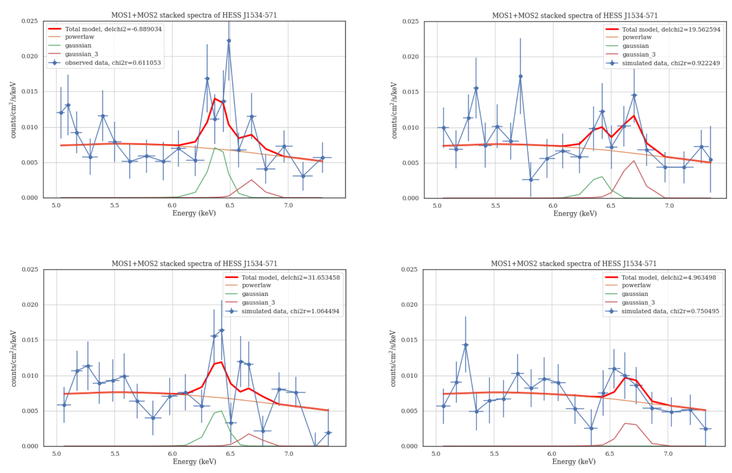

Fig 5. Statistical upward fluctuation can result in a Gaussian line at 6.4 keV at least as strong as our data. The significance of detection is then the probability of the 6.4 keV line not being caused by the statistical fluctuation.

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^{-13} erg/cm²/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 hard 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.

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Reference: **[1]** H. E. S. S. Collaboration, Abdalla, H., Abramowski, A., et al. 2018a, A&A, 612, A8. **[2]** Green, A., Reeves, S., & Murphy, T. 2014, Publications of the Astronomical Society of Australia, 31. **[3]** Araya, M. 2017, The Astrophysical Journal, 843, 12. **[4]** Saji, S., Matsumoto, H., Nobukawa, M., et al. 2018, Publications of the Astronomical Society of Japan, 70, 23.