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The X-Ray Spectral Index Measurement of SNR MSH 15-52 (G 320.4–1.2)

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Abstract— The youngest Supernova Remnant MSH 15-52 (G 320.4–1.2) in our Milky Way galaxy, consists of two bright X-ray compact sources within the shell. The strong X-ray pulsations (with a period of 0.150s) of associated pulsar 4U 1509-58 overlaps with another source situated within Hα nebula RCW 89 in SNR, resulting in unusual X-Rays morphology. In this paper, the spectral energy distribution (SED) of SNR MSH 15-52 in the X-Ray region of the electromagnetic spectrum has been analyzed to understand the underlying physical mechanism. The spectral index in the X-ray region is calculated by fitting a power law on the published data of flux density and frequency. The spectral index in the x-ray region comes out to be $\alpha_{x-ray} \approx 0.8841 \pm 0.2066$ which is found to be in good agreement with the published values. Results also indicate SNR MSH 15- 52 has a harder x-ray spectrum than the Crab Nebula.

Indexed Terms— Plerion, spatial variation, spectral index, Supernova remnant

I. INTRODUCTION

The supernova remnant (SNR) MSH 15-52(G 320.4–1.2) along with its pulsar PSR 1509-58 popularly known as the 'Hand of God' and is located at 15h 14m 07s, -59°09' 27" [1], with estimated age 10^4 years, about 17,000 light-years away in the constellation of Circinus [2]-[3]. SNR has a radiant northern region coincident with a filamentary H_α nebula RCW 89 and a fainter southern region [4]-[6].

The associated rotation-powered pulsar PSR B1509-58 is observed to have high spin-down luminosity, the shortest spin-down timescale of about 1700 years with a surface magnetic field 1.5 x 10^{13}G [6],[7], forming strong X-ray-emitting pulsar-wind nebula (PWN) observed by the Chandra X-ray Laboratory Beppo SAX and ROSAT[6]-[9].

Further, the SNR MSH 15-52 and its pulsar have been observed in two regions of electromagnetic spectrum- X-ray and radio regions [10]. The thermal emission from the north nebula, located at 10' from the pulsar, coincides with the H_α nebula RCW 89 whereas the southern positioned component of the pulsar PSR B1509-58 is non-thermal forming unusual morphology making SNR as a composite supernova remnant [9][11]-[13].

The study of spatial variation of the spectral index for SED of SNR MSH 15-52 becomes significant for understanding the structure and dynamics of different physical mechanisms which are taking place in the X-Ray region. In the present paper, SED in the x-ray energy region of the electromagnetic spectrum is produced and fitted with power-law to calculate the value of the spectral index in the spectrum. The schematics of the paper include as follows: section 2 consisting the details of the data used which is collected from available different sources for the x-ray region, section 3 describes the applied flux method of getting the spectral index of with frequency, and section 4 is about data analysis and in section 5, discussion and conclusions are presented.

II. DATA COLLECTION

The data has been collected through various sources for a frequency range of x-ray region over 10^{16} to 10^{19} Hz. The data is accessed through various catalogs available on NASA Extragalactic Database (NED) catalogs Chanmaster, I/252/out, I/284/out, II/246/out, Chandra X-ray Laboratory, Beppo SAX, MAXI, Integral, Swift.

Table 1: flux values obtained from the different catalog corresponding to their frequencies

Name	Frequency (Hz)	Flux (Jy)	References
0.2-0.5 keV Chandra	9.67E+16	6.95E-06	2020CSC...C2..0000 (NED)
0.2-0.5 keV Chandra	9.67E+16	6.46E-06	2020CSC...C2..0000
0.2-0.5 keV Chandra	9.67E+16	7.26E-06	2020CSC...C2..0000
0.2-0.5 keV Chandra	9.67E+16	5.69E-06	2020CSC...C2..0000
0.5-1.2 keV Chandra	2.22E+17	2.88E-07	2020CSC...C2..0000
0.1-10 keV Chandra	3.63E+17	9.54E-07	2020CSC...C2..0000
0.1-10 keV Chandra	3.63E+17	9.13E-07	2020CSC...C2..0000
0.5-7 keV Chandra	5.56E+17	1.24E-06	2020CSC...C2..0000
………	……..	……..	
14-195 keV (Swift)	2.53E+19	1.09E-06	[14]
14-195 keV (Swift)	2.53E+19	1.03E-06	[14]
100-150 keV INTEGRAL	3.02E+19	1.99E-07	[15]

III. METHODOLOGY

The composite MSH 15-52 consists of both thermal emission and also diffuse emission due to a non-thermal synchrotron emission source [16]. The flux method is used over-collected flux within 0.3-195keV, and is applied to its spectral energy flux as a function frequency which is given by the power law,

$$F(\nu) = A.\ \nu^{-\alpha} \quad (1)$$

where, F (ν) denotes the flux density, which is a measure of the strength of radiation emitted from a source, A is a constant, ν is the frequency and α is a spectral index.

The calculation of spectral index is done through a fit equation which was formulated by taking flux density function [17],

$$\log(f) = a + b.\log(\nu) + c.\log^2\nu \quad (2)$$

$$f(\nu) = 10^{a+b.\log(\nu)} \quad (3)$$

The application of the fit equation obtained using the GNU plot is to apply it to the collected data obtained from different sources. The value for the spectral parameter is calculated by taking the slope of the plot for every two points and then taking the average value of it for the x-ray region, where spectral parameter "b" is defined as the spectral index value.

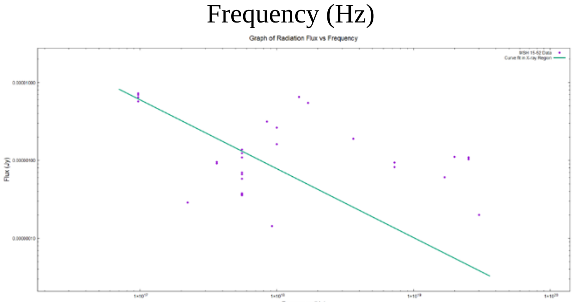
IV. DATA ANALYSIS

The spectral index is determined using the Flux method where a graph is plotted between flux vs frequency and the gradient of the graph of the curve gives the spectral index over the frequencies. The data is plotted using the computation tool GNU plot as shown in figure 1. The abscissa represents the frequency (Hz) while the ordinates represent the net flux (Jy). The data fit equation fits the data and gives a graph for the x-ray region. The average spectral index value of the x-ray region was found to be $\alpha_{x-ray} \approx 0.8841 \pm 0.2066$ which is close to the values reported as given (table 2) and the corresponding obtained graph is shown in fig.1.

Table 2: Spectral index values for MSH 15-52 in X-ray region

EM Region	Amplitude a	Spectral index b	References	
X-Ray ($10^{17}-10^{20}$)	9.8066 ± 3.437	0.8841 ± 0.2066 (present work)	0.3 (2- 60 keV) $0.4^{+0.4}_{-0.2}$ (0.5-4keV) 0.6 0.89 (~3keV) 0.86 1.15±0.02	[18] Einstein (SSS) [19][20] Einstein (IPC) [19][20] [13] [21] [18]

Figure 1: Graph between Flux Density (Jy) and Frequency (Hz)



V. CONCLUSION

The spectrum obtained in this region consists of two parts RCW 89 thermal component and PSR B 509-58 plerionic synchrotron component in the complex SNR MSH 15-52 [13]. The plotted graph (figure1) comes out to be curved as expected, due to different observatories Einstein, EXOSAT and Ginga have used overlapping energy ranges (as shown in table1) and taking different hydrogen column densities, N_H [13]. SED in the x-ray energy region of the electromagnetic spectrum is produced and fitted power law to calculate the value of the spectral index in the spectrum successfully and comes out to be for synchrotron emission, $\alpha_{x-ray} = 0.8849 \pm 0.2066$, in the energy range of 0.3-195keV with represents synchrotron emission from electrons within the PWN. The pulsed radiation has a spectral index of *0.8849* ± 0.2066 which is a harder x-ray spectrum than Crab nebula =1.5 [9] which is also found in the range of other published results. The observed spectrum consists of thermal and nonthermal components of composite SNR MSH 15-52 in this region.

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