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EXOSAT OBSERVATIONS OF THE SUPERNOVA REMNANT CAS A

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ABSTRACT

The young supernova remnant Cas A has been observed with the imaging proportional counter (PSD) of the EXOSAT observatory. High quality spatially resolved, spectral data allow for the first time the determination of the temperature structure of the remnant.
Preliminary results on the distribution of temperature and emission measure over the remnant are presented.

INTRODUCTION

Although the nature of Cas A as a type II supernova event has been questioned /4/, it is quite certain that its progenitor was a massive star (up to 24 $M_{\odot}$ has been suggested /1/ that exploded in a inhomogeneous medium approximately 400 years ago. Current knowledge of the X-ray status of the remnant is primarily based on several papers describing its observation with the EINSTEIN observatory /11,2,9/.
The SSS data were fitted with isothermal plasma models in collisional equilibrium. Adequate fits could be obtained for a two temperature model with kT=0.63 and 4 keV, assuming an N_h of $1.5*10^{22}$ cm^{-2} and over-abundances of certain elements like Si and S /2/.

The IPC data in particular, suggested a temperature variation over the remnant, this follows from the hardness ratio plot made over radial annuli /11/. These data clearly indicate the need for better, spatially resolved, spectral data, which are now available from the EXOSAT PSD.

OBSERVATION AND DATA ANALYSIS.

The supernova remnant Cas A has been observed for fourteen hours with the imaging proportional counter (PSD) of the EXOSAT observatory. With this instrument spatially resolved (1 arcmin.), spectral data (E/ F ~ 2.5 at 1 keV/5/) of good statistical quality (typically several thousand cts. per analysis bin) have been obtained.

One of the key problems in analysing the spectral data in the 0.3-2.4 keV band as obtained by the position sensitive detector is the correlation between several spectral parameters. Especially the strength of the Fe-L line complex between 0.5 and 1 keV, as a derived parameter of Fe abundance and plasma temperature, is strongly anti-correlated with the spectral cut off caused by interstellar absorption /2/. Therefore the data will not allow for a determination of both temperature, Fe-abundance and interstellar column density independently. This led us to decide to use the interstellar column density as derived from other data sets in order to be able to determine the temperature structure of the remnant.

The hydrogen column density derived from 21 cm radio observations enables us to correct for the interstellar absorption. Since Cas A is located behind the perseus arm of our galaxy the hydrogen column density is expected to change on a scale size much smaller then the size of the remnant /6/.

The total N_h value along the line of sight towards Cas A is made up of two components. One is constant and represents the hydrogen column density between the earth and the perseus arm and is almost constant, the other shows considerable variation and is due to granularity of the gas in the perseus arm. We used the 21 cm optical depth measurements /8/,obtained with a resolution of 1 arc minute, to assess this second, spatially variant component. The total N_h values thus obtained were weighted with the number of X-ray counts to get N_h values for the 16 elements in which we analysed the remnant (see fig. 1). The resulting N_h values are summarized in table 1.

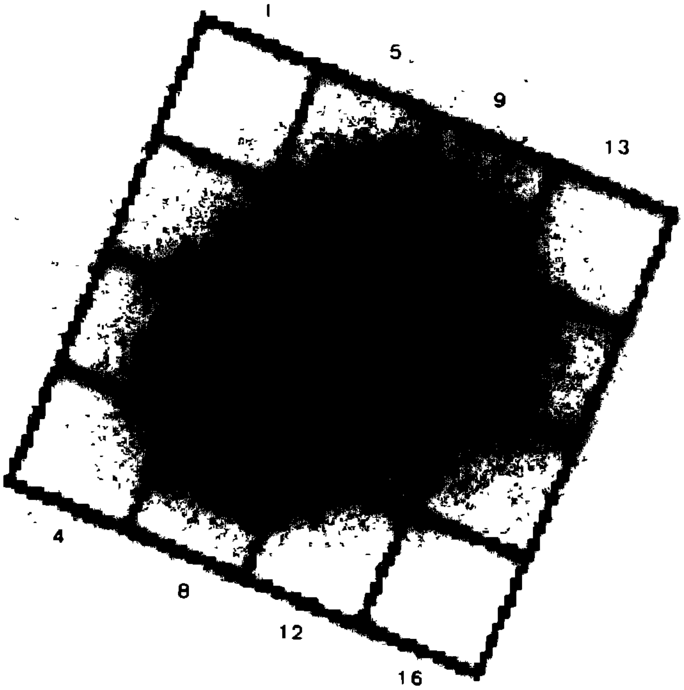

Fig. 1 The PSD image of Cas A. Overlaid are the 16 numbered elements in which the remnant was analysed. These numbers correspond to column one of table 1 (north is up).

Table 1.

Box nr.	Mean RA HH:MM:SS	Mean DEC DD:MM:SS	N_h (10^{20} cm^{-2})	T^* (keV)	Counts	EM**
1	23:21:19	58:45:50	133	0.34±0.05	437	10.8
2	23:21:23	58:44:29	146	0.42±0.05	1291	32.7
3	23:21:28	58:43:08	142	0.48±0.03	2150	43.0
4	23:21:33	58:41:27	121	0.53±0.07	919	11.1
5	23:21:09	58:45:18	150	0.38±0.03	2380	74.6
6	23:21:13	58:43:56	151	0.45±0.01	6042	155.0
7	23:21:17	58:42:35	152	0.52±0.01	8584	188.0
8	23:21:22	58:40:55	145	0.53±0.03	4267	79.2
9	23:20:58	58:44:45	156	0.43±0.03	3620	109.3
10	23:21:02	58:43:24	154	0.47±0.02	7018	178.6
11	23:21:07	58:42:02	149	0.49±0.02	5196	112.3
12	23:21:12	58:40:22	147	0.51±0.03	2670	51.9
13	23:20:48	58:44:12	158	0.42±0.04	1173	35.6
14	23:20:52	58:42:51	157	0.59±0.03	3249	66.6
15	23:20:56	58:41:29	153	0.53±0.03	2552	52.4
16	23:21:01	58:39:49	147	0.50±0.05	831	15.7

*) Errors are 90 % confidence levels

**) Emission measure in units of 10^{57} cm^{-3} for a distance of 2.8 kpc

The average value of $1.5*10^{22}$ cm^{-2} obtained for the remnant as a whole is equal to that derived earlier /2/. For the calculation of the X-ray absorption by hydrogen we used the most recent values /10/.

To fit our data we used a plasma spectrum model /7/. In order to determine the elemental abundances needed in such a code we started out by fixing all elements but silicon to their solar abundance. This was done because the PSD with its limited spectral range and resolution (as compared to the EINSTEIN SSS) is most sensitive to the Si lines around 1.8 keV and almost insensitive to the S lines around 2.4 keV. The Fe abundance was not changed because of the aforementioned correlation. We thus obtained a ratio to solar abundance for Si of 2.3±0.4 (90% confidence). Comparing this result to the Einstein SSS value for Si of 1.7±0.1 and considering that we use a different plasma code and hydrogen absorption for X-rays, we conclude that there is a good consistency between our data and the Einstein data. This led us to use the Einstein abundances for all further analysis /2/.

Therefore, using the N_h values from table 1 we obtained temperatures and emission measures for all 16 elements over the remnant, these values are summarised in table 1. A fit to the data for the whole remnant is shown in fig. 2.

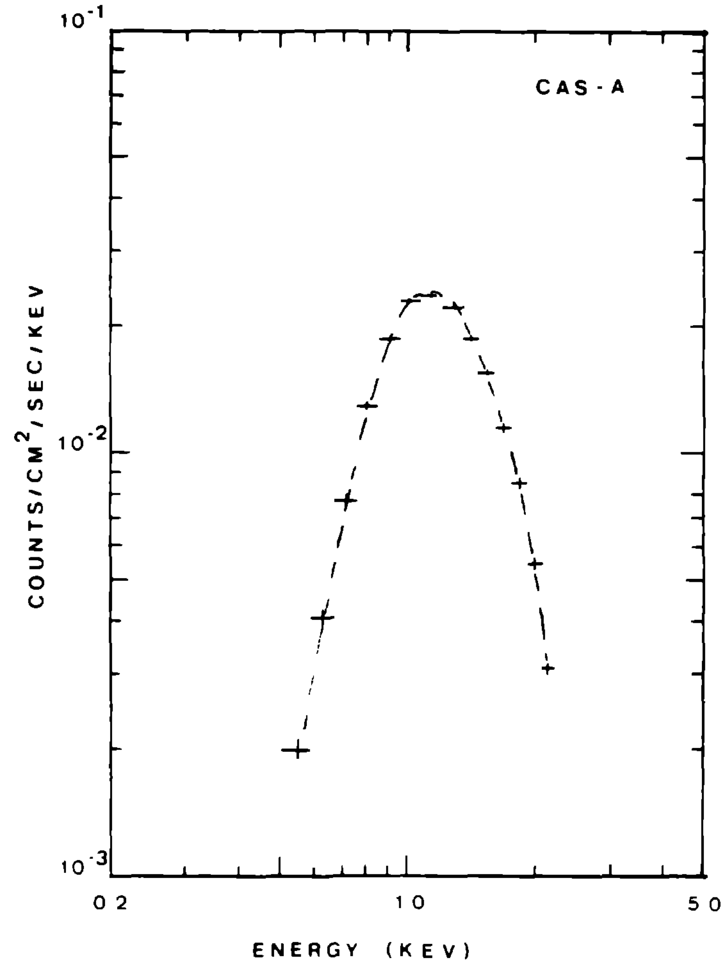

Fig. 2 The Observed spectrum of the total remnant (crosses), the dashed line is the optimum fit for $<kT> = 0.47$ keV
$<N_h> = 1.47*10^{22}$

DISCUSSION AND CONCLUSIONS

The temperatures derived from our data show a clear variation over the remnant. Assuming isothermal plasma model spectra there appears to be a trend of temperature increase from the northern to the southern part of Cas A. However, the observed average temperature of 0.5 keV cannot explain the strength of the iron line at 6.7 keV as it is observed by the EXOSAT GSPC.

It is obvious however that for Cas A Non Ionisation Equilibrium (NIE) models should be applied in view of its age. This has a influence on temperatures as well as abundances /12/. The use of NIE-models to arrive at a selfconsistent model explaining the PSD and GSPC spectra is the subject of a forthcoming paper.

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