SPECTRAL OBSERVATION OF THE COMPOSITE SUPERNOVA REMNANT G 29.7 - 0.3

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ABSTRACT. The X-ray properties of the supernova remnant G 29.7 - 0.3 are discussed based on spectral data from the EXOSAT satellite. In the 2 to 10 keV range a featureless power-law spectrum is obtained, the best-fit parameters being: energy spectral index α = -0.77, hydrogen column density on the line of sight $N_H = 2.3.10^{22}$ cm^{-2}. The incident X-ray flux from the source is (3.6 ± 0.1) 10^{-11} erg cm^{-2}s^{-1} in the 2 to 10 keV range corresponding to an intrinsic luminosity of about 2.10^{36} erg s^{-1} for a distance of 19 kpc. The source was not seen with the imaging instrument thus constraining the hydrogen column density to be N_H = (3.3 ± 0.3) 10^{22} cm^{-2} and the energy spectral index α = 1.0±0.15. This new observation is consistent with emission by a synchroton nebula presumably fed by an active pulsar. An upper limit of ~ 1.5% for the pulsed fraction in the range of periods 32ms to 10^4 s has been obtained.

1. INTRODUCTION

The intriguing supernova remnant G 29.7 - 0.3 has been studied intensively in several energy bands. The radio properties have been discussed by Becker and Kundu (1976), Becker and al (1983) and Becker and Helfand (1984). High resolution maps obtained with the VLA show two spectrally distinct components, a flat spectrum core surrounded by a shell. The central component has a spectral index of 0.0 from 20cm through 2cm, is 25% polarized and has a centrally peaked radio brightness distribution characteristic of Crab-like remnants. The shell component has a spectral index of - 0.73 between 6 and 20cm. The neutral hydrogen absorption measurements place the two components at the same distance of ~ 19 kpc. While not visible at optical wavelengths, due to the high visual absorption on the line of sight, G 29.7 - 0.3 is a very bright object in X-rays. Observations with the Einstein Observatory high resolution imager (HRI) and the imaging proportional counter (IPC) have been discussed by Becker et al (1983) and Becker and Helfand (1984). X-ray diffuse emission coïncident with the Crab-like radio core was observed. For a distance of 19 kpc this component had a luminosity of ~ 4.10^{36} erg s^{-1} assuming an energy spectral index of - 1 and an absorbing hydrogen column density of ~ 5.10^{22} cm^{-2}.

A marginal detection of soft X-ray diffuse emission from the western-south shell was reported, amounting to less than 10% of the emission of the Crab-like core. If

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the ratio of radio to X-ray luminosities is an accurate gauge of age for the Crab-like SNRs as argued by Becker et al (1982), G 29.7 - 0.3 is the youngest Crab-like remnant yet identified including the Crab nebula. But recent modeling of the evolution of pulsar-driven SNRs by Reynolds and Chevalier (1984) show that the X-ray luminosity can vary quite independantly of the radio luminosity, meaning that a ranking of Crab-like SNRs by L_X/L_R might have no physical significance.

The present paper shows EXOSAT results obtained with the imaging instrument (CMA) and the medium energy proportional counters (ME). We derive the spectral parameters in the 2 to 10 keV range from the ME data. The upper limit given by the CMA observation constrains the hydrogen column density on the line of sight and thus the energy index. From the featureless power-law spectrum obtained we assume that the emission is synchroton radiation from relativistic electrons and derive constraints on magnetic field and age.

2. OBSERVATION AND RESULTS

The Exosat imaging instrument and the medium energy proportional counters are described in details in Taylor et al (1981) and Turner et al (1981). G 29.7 - 0.3 was observed on 29 August, 1984 for 4.10^4 s with both instruments. The source was not seen by the CMA using the Lexan 3000 Å thick input filter. The 3σ upper limit on the CMA counting rate is 4.10^{-4} s^{-1}.

The counting rate due to the source on the ME Argon counters half-array is 2.7 s^{-1}. The background was subtracted using counter offset data. The observed spectral distribution is shown on figure 1. The best-fit (χ^2= 21.7 for 23 degrees of freedom) was obtained assuming a power-law spectrum ($dN/dE = 1.3 . 10^{-2} E^{-1.77}$ photon cm^{-2} s^{-1} keV^{-1}) and an absorbing hydrogen column density of $\sim$ 2.3 10^{22} cm^{-2}. The 90% and 99.7 % confidence level contours N_H vs α are shown on figure 2.

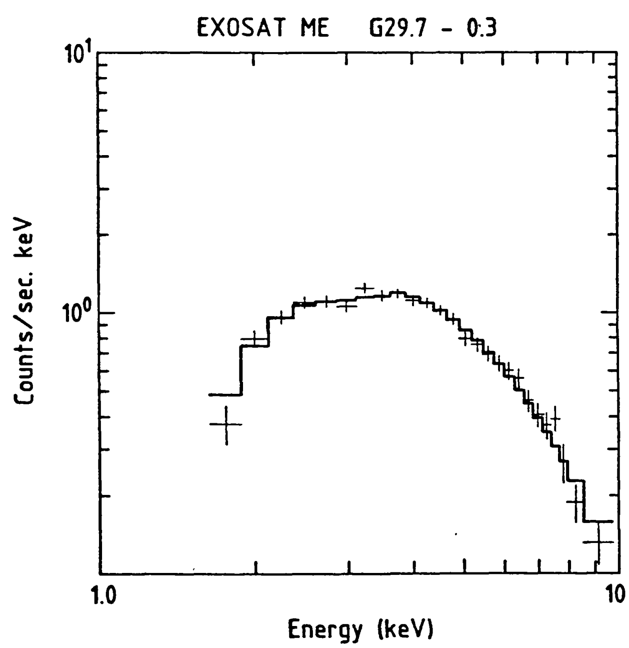

Figure 1: The observed ME spectrum of G 29.7-0.3 (full array). The thin bars represent the observed data points with $\pm$ 1σ errors. The thick histogram is the predicted distribution for a power-law spectrum with energy index α = -0.77 and an absorbing column density of N_H= $2.3.10^{22}$ cm^{-2}.

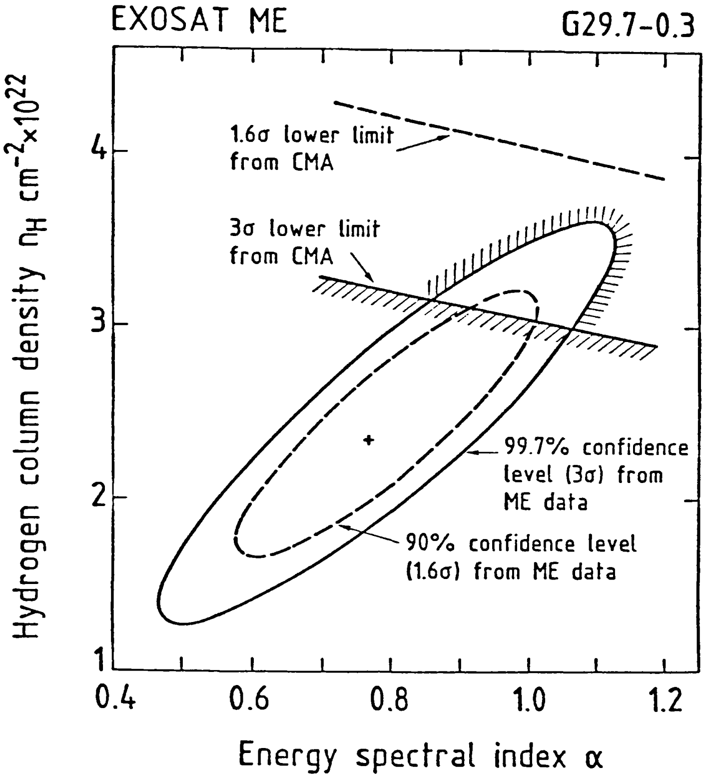

Figure 2: The 90% and 99.7% confidence limit contours N_H vs α from the ME data and the 1.6 σ and 3 σ lower limits from the CMA observation of G 29.7-0.3.

The residuals between the observed spectrum and the best-fit power-law spectrum shown on figure 3, demonstrate that the incident spectrum is a featureless power-law (figure 4).

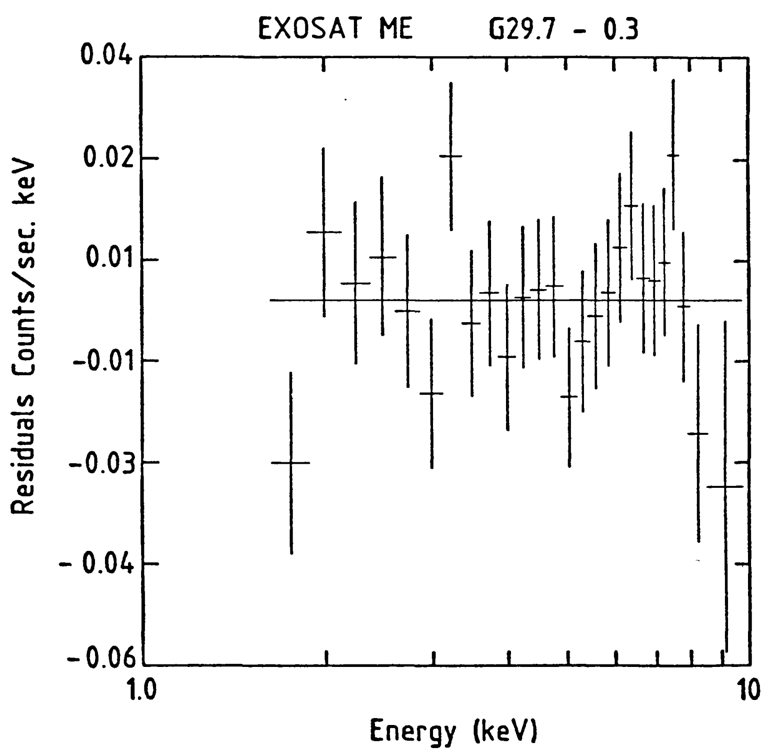

Figure 3: Residuals in counts s^{-1} keV^{-1} between the observed spectrum and the best-fit power-law spectrum of G 29.7 - 0.3 in the 2 to 10 keV range.

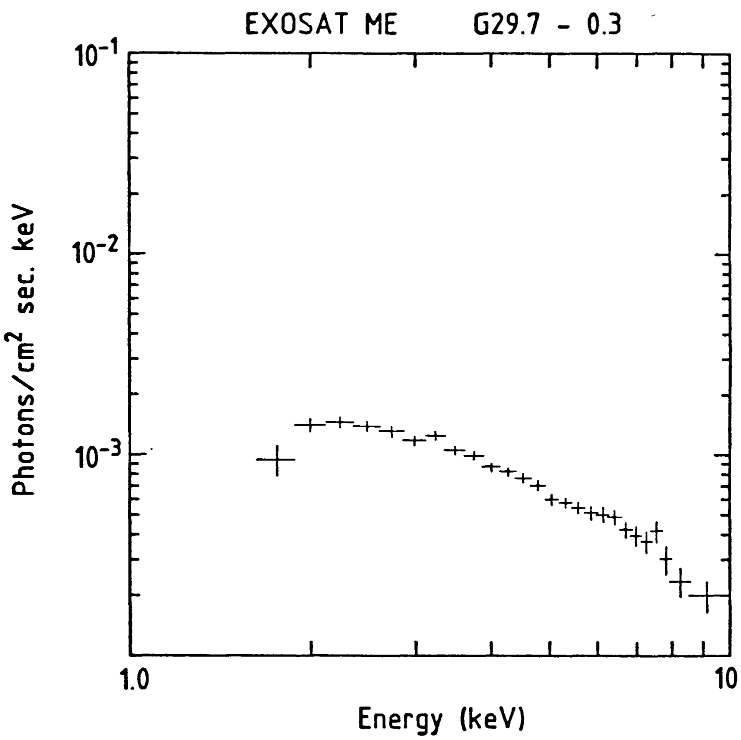

Figure 4: The incident photon spectrum of G 29.7-0.3 as deduced from the EXOSAT ME data.

From the upper limit of the CMA counting rate obtained on a 20 arc sec circle centered on the diffuse source seen by the Einstein HRI we have deduced a 3σ lower limit for the absorbing column density on the line of sight of $\sim 3\ 10^{22}$ cm^{-2}. This lower limit of N_H is slightly dependant on the energy spectral index as shown on figure 2. The marginal consistency between the CMA and ME data impose the following spectral parameters:

$\alpha = -1.0 \pm .15$ and $N_H = (3.3 \pm 0.3)\ 10^{22}\ cm^{-2}$

These values are deduced from the overlapping of the 3σ contours on figure 2; the uncertitude corresponds to the size of the overlap region. No consistency is obtained at the 90% confidence level (1.6σ).

3. DISCUSSION

The total hydrogen column density we have deduced $N_H = (3.3 \pm 0.3)\ 10^{22}\ cm^{-2}$ is in good agreement with previous Einstein estimations of 3 to 5.10^{22} cm^{-2}(Becker et al, 1983). It can be compared with the lower limit of $N_{HI} = 2.10^{22}\ cm^{-2}$, inferred from neutral hydrogen radio absorption measurements, assuming a spin temperature of the gas of 100°K, by Becker and Helfand (1984). The incident X-ray flux from the source is $(3.8 \pm 0.1)\ 10^{-11}$ erg $cm^{-2}\ s^{-1}$ in the 2 to 10 keV range, corresponding to a intrinsic luminosity of 2.10^{36} erg s^{-1} for a distance of 19 kpc. This large distance was estimated by Milne (1979) from the surface brightness/diameter Σ.D relationship for SNRs and confirmed by the Becker and Helfand (1984) VLA results. The total X-ray luminosity in the 0.1 to 10 keV range is about 5.10^{36} erg s^{-1} assuming that the same power-law spectrum holds.

We assume a synchrotron nebula similar to the Crab nebula on the basis of our X-ray spectrum and of the radio data (flat power-law spectrum and linear polarization) : the diffuse emission at all wavelengths is the result of synchrotron emission from relativistic electrons accelerated by the central stellar remnant. The observed ratio of X-ray luminosity of the nebula to its radio luminosity $L_R = 2.10^{34}$ erg s^{-1} in the 10^7 to 10^{11} Hz is $L_X / L_R \simeq 250$, a factor ~2 lower than the theoretical minimum deduced by Reynolds and Chanan (1984) from the modeling of the evolution of the particle spectrum in Crab-like SNRs.

Assuming that the nebula contains a uniform magnetic field H, that all particles have energy such that maximum synchrotron emission is at 1 keV and that the energy of the nebula is equally divided between relativistic electrons and magnetic field, then $H = 25\, L_x^{2/7} V_x^{-2/7}$ Gauss, $E_p = E_H = \frac{H^2}{8} V_x$ ergs, (V_x being the X-ray emitting volume) and the radiation lifetime of the electrons is $\tau = 3000\, H^{-3/2}$ s (Seward, 1983).

Taking the angular radius of the synchrotron nebula in G 29.7 - 0.3 to be 10 arc sec from the Einstein HRI estimation, one finds: $H \simeq 7.10^{-5}$ Gauss, $E_H = E_p \simeq 6\ 10^{46}$ ergs and $\tau \simeq 150$ years. This simple model is useful to compare the properties of G 29.7 - 0.3 to those of the eleven alleged diffuse synchrotron nebulae presented in Seward (1983). G 29.7 - 0.3 appears to be the third brightest synchrotron nebula with the equipartition energy E_p three times greater than that of the Crab and MSH 15-52 and the electron lifetime five times that of the Crab. The table 1 shows the properties of G 29.7-0.3 and of the three synchrotron nebulae containing a compact object observed to pulse in X-rays (Seward, 1983 and references therein, Seward et al, 1984).

TABLE 1. PROPERTIES OF DIFFUSE SYNCHROTRON NEBULAE

Names	Distance kpc	Size pc	Lx erg s^{-1}	H Gauss	Ep ergs	τ Years
G 184.6-5.8 (Crab)	2.0	0.6	$2\ 10^{37}$	$2\ 10^{-4}$	$2\ 10^{46}$	30
G 29.7-0.3 (KES 75)	19	1.8	$5\ 10^{36}$	$7\ 10^{-5}$	$6\ 10^{46}$	150
LMC 0540-693	55	1	$1\ 10^{37}$	$2\ 10^{-4}$	$1\ 10^{47}$	33
G 320.4-1.2 (MSH15-52)	4.2	6.4	$1.6\ 10^{35}$	$9\ 10^{-6}$	$2\ 10^{46}$	$4\,10^3$

The synchrotron nebulae in G 29.7 - 0.3, in LMC 0540-693 and in the Crab are very similar with small size, relatively strong magnetic field and short electron lifetime. The presence of a compact object feeding the synchrotron nebula may be inferred in G 29.7 - 0.3 from these similarities. The age of the SNR have been estimated by Clark and Caswell (1976) from the surface brightness Σ at 408 MHz assuming that the dynamical evolution of the shell is described by the Sedov equation i.e. unaffected by the presence of the central pulsar, then:

$\Sigma = 1.25\ 10^{-15}\, t^{-6/5}$ giving $t \simeq 660$ years for G 29.7 - 0.3 .

Search for pulsations.

Regular pulsations were searched for in the ME data by performing a fast Fourier transform. No statistically significant period has been found between 32ms and 10^4 s. The resulting upper limit of pulsed fraction in this period range is $\sim 1.5\%$.

4. CONCLUSIONS

The featureless power-law spectrum observed between 2 and 10 keV justify the classification of G 29.7 - 0.3 as a composite Crab-like shell supernova remnant. The intrinsic X-ray luminosity of the inferred synchrotron nebula is 5.10^{36} erg s^{-1} in the 0.1 to 10 keV range. The great similarity of the physical properties of G 29.7 - 0.3 and of the three synchrotron nebulae containing a compact object observed to pulse in X-rays, makes G 29.7 - 0.3 a very promising candidate for further search for pulsed emission at periods smaller than 32ms, the lower limit of our present search. Further observations of this object at infra-red wavelengths might reveal the break in the emitted spectrum expected from the radio and X-ray power-law indices and give us information on the production of the electron populations responsible for the emission of the nebula in these various wavelength ranges (Reynolds and Chanan, 1984).

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REFERENCES

Becker R.H., Kundu M.R., 1976 Ap.J. 204, 427.
Becker R.H., Helfand D.J., Szymkoviak A.E., 1982 Ap.J. 255, 557.
Becker R.H., Helfand D.J., Szymkowiak A.E., 1983 Ap.J.Lett. 268,L93.
Becker R.H., Helfand D.J., 1984 Ap.J. 283, 154.
Clark D.H., Caswell J.L., 1976, M.N.R.A.S. 174, 267.
Milne D.K. 1979, Australian J.Phys. 32, 83.
Reynolds S.P., Chevalier R.A., 1984 Ap.J. 278, 630.
Reynolds S.P., Chanan G.A., 1984, Ap.J. 281, 673.
Seward F.D. 1983, in Supernova Remnants and their X-ray emission, Symposium IAU 101, ed.J. Danziger and P.Gorenstein, p.405.
Seward F.D, Harnden Jr F.R., Helfand D.J., 1984, CFA preprint n° 2064.
Taylor B.G., Andresen R.D., Peacock A., Zobl R. 1981, Space Sci.Rev. 30,479.
Turner M.J., Smith A., Zimmerman H.U. 1981, Space Sci.Rev. 30, 513.