A Model of the Soft X-Ray Background as a Blast Wave Viewed from Inside

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ABSTRACT

The suggestion that the soft x-ray background arises in part from the Sun being inside a large ($R \sim 100$ pc) supernova blastwave is examined by producing models of spherical blastwaves. Such models can produce quantitative fits to both surface brightnesses and energy band ratios (for the lowest energy bands) when $t \sim 10^5$ yr, $E_o = 5 \times 10^{50}$ ergs, and $n_o \simeq 0.004$ cm^{-3}.

Such models can be generalized by varying the relative importance of such factors as thermal conduction, Coulomb heating of electrons, and external pressure; by allowing the explosions to occur in pre-existing cavities with steep density gradients, or by examining the effects of large obstructions or other anisotropies in the ambient medium.

I. INTRODUCTION

One suggestion that has been advanced (e. g. McKee and Ostriker 1977) to explain the soft x-ray background ($0.1 \lesssim E \lesssim 1.0$ keV) is that the solar system lies within a blast wave of present radius ~100 pc which was caused by a sypernova.

Cox and Anderson (1982, CA) examined this idea quantitatively by producing spherical blast wave models in a uniform ambient medium (with finite pressure). By following the ionization history of each gas parcel as it is shocked and moves into the interior of the supernova remnant (SNR), it was possible to calculate x-ray spectra despite the fact that the ionization state of the gas is far from equilibrium in the x-ray emitting region. It was found that essentially all of the emission comes from quite near the shock, so that the location of the observer within the bubble is unimportant.

The CA models produced qualitative agreement with the all-sky average count rates measured by the Wisconsin group (McCammon et al 1983 and references therein) in the lowest energy bands. Both surface brightness and the band ratio B/C (analogous to B-V colors in the optical) could be fit for the boron (B) and carbon (C) bands. These fits constrained the ambient density closely to $n_o = 0.004$ cm^{-3}, and

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suggested that the age of the SNR is roughly 10^5 yr, for explosion energy $E_o = 5 \times 10^{50}$ ergs.

Current efforts are directed to answering questions such as the following, representative of those suggested by the CA study.

(1) CA produced a set of SNR parameters (n_o, shock radius R_s, age t) that fit the B and C band data for $E_o = 5 \times 10^{50}$ ergs. What ranges can these parameters take on without substantially impacting on the quality of the fit?

(2) How would these ranges change if E_o is allowed to vary?

(3) Is it possible (for example, by setting off the explosion in a pre-existing cavity) to make models that will produce a more significant fraction of the M-band (medium energy) flux that is observed?

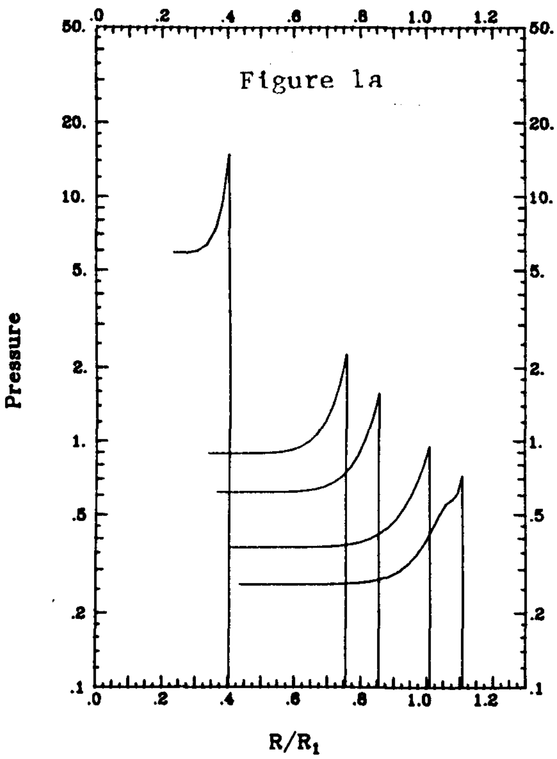
(4) Are there parameter choices for which the x-rays could be produced without at the same time generating a large local O VI component?

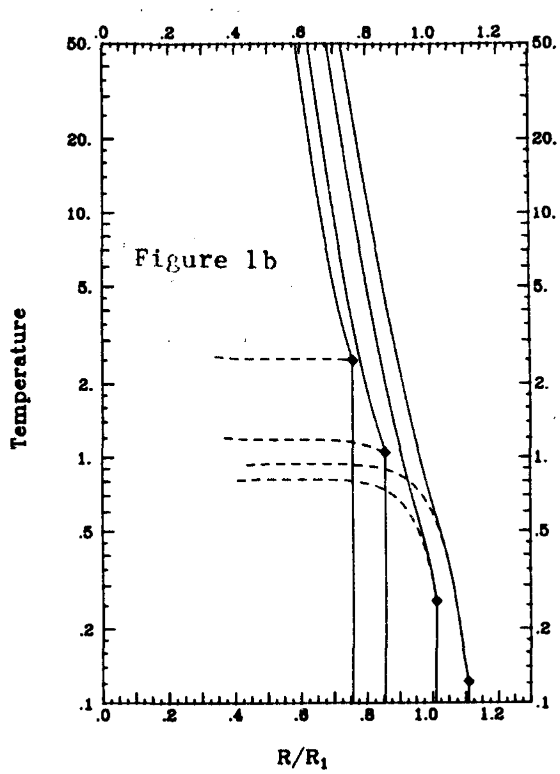
(5) Is it possible that the soft x-ray background arises from a much older (and hence larger) cavity than those studied by CA? If so, the solar system need not be situated in quite such a special place for the models to apply.

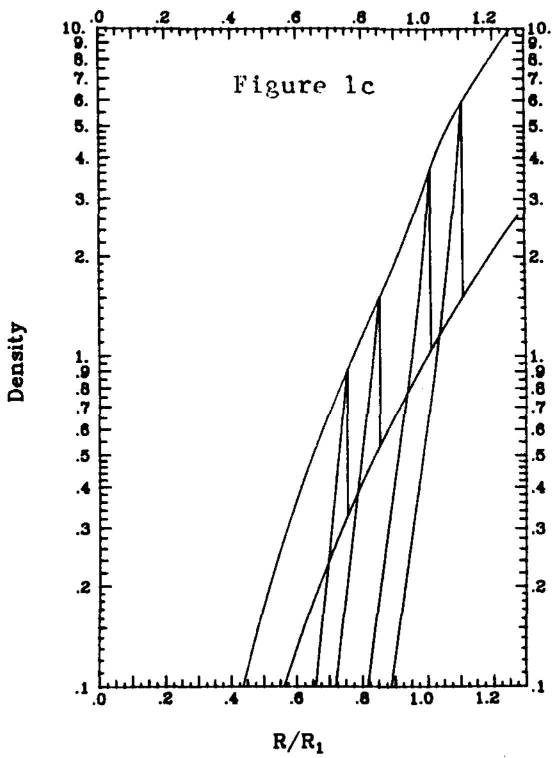
(6) Can the observed variations in the B and C bands over the sky be explained as the result of moderate variations in the pre-shock ambient density? For example, if large clouds were present in some directions (and not in others) prior to the explosion, would the resulting non-spherical blast wave exhibit variations in surface brightness correlated (or anti-correlated) to the H I column densities?

II. BLAST WAVES IN CAVITIES

Cox and Franco (1981), Cox and Edgar (1983) and Edgar and Cox (1984, in press) have produced dynamical models of blast waves in cavities in an attempt to address these questions. Such a cavities might have been produced by the previous supernovae of members of an OB association so that the present explosion finds the ambient density rising steeply with R. In particular, we have explored the cases with $n_o \propto R^0$, R^2, and R^4 (uniform density and two steepnesses of cavities) with models which include non-Coulomb shock heating of electrons and the consequent significant (and partially saturated) thermal conduction flux. Representative structures are shown in Figure 1 for the R^4 case. Figure 1a shows pressure profiles of five snapshots at various radii as the SNR expands. Figure 1b shows electron (dashed lines) and average (solid lines) temperature profiles, and figure 1c shows density structures, as well as the ambient and post-shock densities (lower and







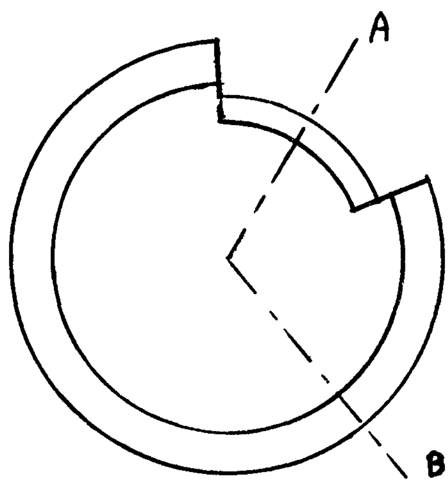


Figure 2

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upper envelopes, respectively). Present work includes producing model spectra for a class of such cavity models. Models produced to date for the R^4 case show comparable spectral results to those of CA, but with thinner emission regions and hence higher present-day ambient densities ($n_o \sim 6$-10×10^{-3} cm^{-3}) for similar counting rates.

III. LARGE OBSTRUCTIONS IN THE AMBIENT MEDIUM

As a first approximation, we are modelling such things as large clouds protruding into the pre-existing cavity as follows. Let the ambient density $n_o \propto R^4$, but pick the constants of proportionality to be larger in some directions (toward the cloud, A), producing an ambient density contour plot like Figure 2. We then use two carefully selected spherically symmetric blast wave models to compare the two regions A and B. Clearly, with this crude level of approximation, nothing can be said reliably about the edges of the "cloud".

The two spherical blast wave models are selected to have equal ages and the same central pressure history (since the interiors of the two remnants clearly communicate). They need not have the same (or even simply related) explosion energies E_o; indeed, we adjust E_o to satisfy the above constraints. It can be shown that the smaller remnant A reaches maturity faster than the larger remnant B, because it processes more material in a given period of time.

One such pair of models has been generated, and suggests that in fact the cloud (direction A) is somewhat brighter in the B and C bands. Further work is needed in this area, especially as a general anticorrelation between soft x-ray brightness and H I column density is observed (e. g. McCammon et al 1983). Our present result, that directions with higher densities will be brighter rather than dimmer, was anticipated from scaling CA results. However, this scaling should fail as the blast waves in the clouds slow to very low velocities, and it is our expectation that the observed anticorrelation can be accommodated by modelling the hot central regions of blast wave pairs older than those studied by CA. We expect to succeed in suppressing the O VI column density as well, though again only in the more mature remnants.

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