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COSMIC X-RAY PHYSICS

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Introduction

This is our semi-annual progress report for NASA grant NAG5-629 "Cosmic X-ray Physics".

I. Soft X-rays and Interstellar Medium

The primary area of our research is the study of the soft X-ray diffuse background and the nature of its origin in the interstellar medium. It appears fairly certain that much of the volume of space within ~100 pc of the Sun contains gas at temperatures near one million degrees. It is not yet known whether such regions are rare and the Sun in one by unlikely accident, or whether large fraction of the galactic disk contains such material, with the well-known cool component of interstellar gas confined mostly to sheets and bubble walls separating the hot regions.

We are currently combining our soft X-ray sky survey data with results from our UXT sounding rocket payload that can make measurements near 0.1 keV, where the interstellar mean free path is a factor of seven or so shorter than for the lowest energy band of the sky survey. With this long 'lever', very strong constraints can be placed on models of the origin of the soft diffuse background. In general, additional observational constraints force more complicated and 'realistic' models. Rather surprisingly, in this case there is still a very simple model that appears consistent with all observations. This simplest possible picture is that essentially all of the observed 0.1-0.3 keV X-rays (Be, B, and C band) are produced by hot gas in a cavity surrounding the Sun. Variations in X-ray intensity in different directions are produced by variations in the extent of the cavity. By assuming a uniform volume emissivity, one can then map out the three-dimensional structure of the hot gas. Small temperature variations in different directions are required to provide the observed variations in C/B ratio or 'color'; according to current models of equilibrium X-ray emisssion, these temperature variations are entirely consistent with the constancy of the Be/B ratio observed on flights of our new payload. (Steve Snowden and Don Cox have developed the details of this model and presented it at the COSPAR XXVI conference in Toulouse. They are now completing a more detailed paper for the Astrophysical Journal.)

Two less-than-satisfactory aspects of this model are the observed constancy of the soft X-ray flux in all directions in the galactic plane, which requires the Sun to be rather well-centered, and the existence of at least one cloudlet of cooler gas (in which the Sun happens to be embedded) within the volume of X-ray emitting material. Mike Juda is just completing his thesis on an investigation of the latter problem, placing limits on the number and size of such cloudlets within the cavity that can be consistent with both soft X-ray observations and the results of the 21 cm measurements we have been making.

Another interesting aspect of the Be band observations is that according to Raymond's emission models, most of the observed X-rays are produced in a small number of line complexes, and the relative intensities of these are very sensitive to the details of the physics of the hot gas. This provides a unique opportunity to do some detailed 'spectroscopic' work with proportional counter resolution. Jeff Bloch (see below) is pursuing this as part of his thesis, using a detailed model of the proportional counter operation we have developed (now described in a paper submitted to

Nuclear Instruments and Methods) to extract as much information as possible from the shape of the pulse height spectrum.

We would naturally like to extend the rather small amount of Be band data we have to confirm the above results and search for deviations from the simple single-source model. We had planned a sounding rocket flight for this fall, but it is now uncertain whether or not this can be supported due to NASA commitments to the supernova expeditions. If this flight must be delayed, we can usefully concentrate our efforts on developing our next new sounding rocket payload, discussed below under IV.

II. UXT Data Analysis

Since the last report, we have made significant progress extracting more detailed spectral information from the UXT data set. In May, we completed work on a second generation proportional counter response model which has greatly improved the confidence with which we can infer the spectral properties of the soft X-ray emission from the local cavity between 70 and 111 eV. Equilibrium plasma emission models predict that the majority of low energy x-rays seen by the UXT Be Band detectors should come from two line complexes, one at 95 eV and another at 70 eV. These lines are emitted by highly ionized states of iron in the plasma. Preliminary analysis using the improved UXT detector model shows that the equilibrium emission models are inconsistent with the observed pulse height distribution, and that either 1) most of the emission comes from the 95 eV complex or 2) that the 95 eV line complex is greatly reduced and that the 75 eV complex is present, along with another line at 105 eV. We are pursuing these results further to determine the spatial dependency of these findings, and how models with non-equilibrium conditions and/or non-standard abundances fit in with these constraints. We will shortly apply similar methodology to the UXT B band detector with the hope that we will find similar results.

By combining the UXT B band and Be band detector spectral model fits we may be able to place much better constraints on diffuse plasma soft X-ray emission models than were possible before.

The UXT payload includes 3 counters with beryllium, boron and aluminum oxide windows. Our useful results to date have come only from the beryllium (Be) and boron (B) filtered counters. The aluminum oxide counter, probably because of its very thin window, has had low energy electron contamination in both flights and we have been unable to devise a reliable procedure for subtraction of this background. At the moment we are undecided as to whether to continue with further attempts to get data in the unexplored oxygen (O) band region that the aluminum oxide windows could provide.

III. Sounding Rocket Calorimeter Payload

The new sounding rocket payload referred to above (under I) will be centered about the high resolution calorimeter being developed here and at Goddard. On the first flight we will incorporate only a simple mechanical collimator to study the diffuse background. On subsequent flights, we hope to put the same detector system at the focus of a light-weight conical foil mirror and use it to map supernova remnants such as the Cygnus Loop at high spectral resolution. This would permit accurate tests of the detailed theoretical work that has been done recently on the evolution of the Cygnus Loop. This payload is being developed in conjunction with the X-ray group at Goddard Space Flight Center.

We have recently completed a laboratory test version of a flyable cryogenic system. The laboratory version weighs about 100 lbs., reached a minimum temperature of 32 millikelvins, and can hold the design operating temperature of 100 millikelvins for more than twelve hours. We should be able to scale this system down in size by a factor of several, and are currently working on the mechanical design.

IV. Theoretical Studies

This period saw the submission of a major collaborative paper on comparison between theory and observations of a Cygnus Loop filament, as well as that of an Annual Reviews article by Cox and Reynolds on the Local Interstellar Medium.

The Cygnus Loop results suggested that cosmic rays could contribute appreciably to the post shock pressure, encouraging Cox to indulge his interest in cosmic ray acceleration by shocks. A paper is in preparation by Ahmed Boulares (one of Cox's students) on this topic, as applied to the Cygnus Loop. Cox's other student funded on this grant, Jon Slavin, has continued to work on the emission expected from the conductive surface layer which may be present on some surfaces of interstellar clouds. The equilibrium ionization assumption used initally led to surface emission sufficient to generate noticeable ionization in the Local Cloud, if its surface is suitably conductive.

For the Penticton meeting (IAU colloquium 101), Cox gave the overview of the interstellar medium paper opening the meeting. He argued vigorously that the assumption of a widespread coronal component is based on specious evidence, that diffuse HI could well be the major constituent of the intercloud medium, and that the strong role of magnetic pressure in the ISM has been widely under appreciated. In short, he proposed a substantial revision of our understanding of the interstellar environment, based on both observational and theoretical developments.

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PUBLICATIONS

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