EXPOSING NEW COMPONENTS OF THE X-RAY BACKGROUND WITH MULTI-WAVELENGTH SKY SURVEYS

E.C. MORAN
Lawrence Livermore National Laboratory

1. Introduction

The evolving class of objects responsible for the majority of the cosmic X-ray background (XRB) remains at large nearly three and a half decades after the discovery of the XRB. Surveys of sources selected on the basis of their X-ray properties *alone* provide an unbiased picture of the X-ray sky, but to date they have not been ideal for the discovery of rare types of X-ray sources at faint fluxes: large-area X-ray surveys have been restricted to bright sources, while deep X-ray surveys have been limited to very small patches of sky. X-ray selection coupled with another selection criterion, *e.g.*, a radio or infrared detection, complements "pure" X-ray surveys by (1) permitting the exploration of large areas of sky to faint flux limits for types of extragalactic X-ray sources not well represented in other surveys, and (2) assisting the location of the optical counterparts of these X-ray sources. Using this approach, I have searched for new components of the XRB among the faintest X-ray sources detected by the *Einstein Observatory*.

2. The Einstein Two-Sigma Catalog

For certain applications, the limiting signal-to-noise threshold for sources in an astronomical catalog may be considerably lower than commonly accepted values (*i.e.*, 4σ or 5σ), provided that one can determine the statistical reliability of the catalog. To facilitate the study of X-ray sources fainter than those contained in the *Einstein* Medium Sensitivity Survey (EMSS; Gioia *et al.* 1990), we have constructed a new catalog of 46,186 sources and fluctuations exceeding 2σ significance in 2520 high-latitude *Einstein* IPC images. We have employed various tests to validate our source-search

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algorithm for both high- and low-significance sources, and to identify and remove the small number of spurious sources induced by our detection procedure. Based on the known properties of the *Einstein* optics, the background characteristics of the IPC, and the measured X-ray $\log N - \log S$ relation, we have modeled the number of real sources expected in the catalog in order to evaluate its statistical properties below 4σ significance. Our model suggests that $\sim 28\%$, or $\sim 13{,}000$, of the sources in the Two-Sigma Catalog are real celestial X-ray sources. This is an increase of ~ 9100 over the number found in previous analyses of the same IPC images. Full details of the manufacture and evaluation of the Two-Sigma Catalog are described in Moran *et al.* (1996).

3. New Components of the Cosmic X-ray Background

The primary motivation for assembling large samples of faint X-ray sources is to search for possible new components of the X-ray background. As a means of selecting real celestial X-ray sources in the Two-Sigma Catalog for further study, we have applied astronomical catalogs at other wavelengths as filters. The cross-correlation of these catalogs with the Two-Sigma Catalog produces samples of hundreds of faint X-ray sources that are reliable at the 90% level. The specific filters we have used are catalogs from surveys of the radio and infrared sky.

Optical spectroscopy of 77 unidentified radio- and IR-selected Two-Sigma Catalog sources has turned up several surprises, illustrating the merits of selecting X-ray sources by a variety of methods. In addition to the types of objects one would expect to find in these samples, we have discovered high-redshift quasars (one at $z = 4.30$), which are absent in the EMSS, X-ray-luminous radio-loud elliptical galaxies with optical spectra devoid of emission lines, and infrared-bright AGNs with optical spectra dominated by starburst galaxy features (Moran *et al.* 1996). Follow-up X-ray observations are being carried out with *ROSAT* and *ASCA* to clarify the nature of these objects and to determine if any of them represents a previously unrecognized component of the X-ray background.

References

Gioia, I. M., *et al.* 1990, Astrophys.J.Supp. 72, 567.
Moran, E. C., Helfand, D. J., Becker, R. H., & White, R. L. 1996, Astrophys.J. 461, 127.