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This grant funded a number of related investigations on the physics of high energy emission from active galactic nuclei, such as Seyfert galaxies and quasi-stellar objects. Here we describe briefly the chief conclusions of the work, and provide citations to the papers supported by this grant and published in the refereed scientific literature.

Research Accomplishments

"Warm" Galaxies Observed in X-rays

Infrared, optical, and X-ray observations are presented for a sample of "warm" infrared selected galaxies listed in the IRAS Point Source Catalog (PSC). These galaxies have also been observed serendipitously in X-rays by the *Einstein* Observatory. From low resolution optical spectra, we find that all have emission lines, indicating a Seyfert or H II region type nucleus. Many of these galaxies were previously uncatalogued. Based on the X-ray detection rate of our small sample, we conclude that large numbers of warm IRAS Seyfert 1–1.9 galaxies may be detectable in X-rays by future surveys such as *ROSAT*. This work has been more fully described by Green *et al.* (1989).

X-ray/Infrared Correlations in Galaxies

For a large, heterogeneous sample of active and normal galaxies, we contrast *Einstein* X-ray and IRAS infrared emission, using survival analysis to exploit the information contained in upper limits. X-ray to infrared flux ratios prove to be an excellent criterion for selection of

broad-line optical emission. A strongly significant correlation exists between luminosities in the $60\mu m$ and 0.5-4.5 keV bands, with a clear offset separating broad-line from normal and narrow-line galaxies. Among individual galaxy classes, radio-loud quasars show a significant correlation of L_X to $L_{60\mu m}$ that is not seen in radio-quiet quasars or Seyferts as individual classes. Our analysis of the empirical relationship between L_X and $L_{60\mu m}$ for normal and narrow optical emission line galaxies (excluding Seyfert 2s) allows us to convert published 60μm IRAS luminosity functions into estimates of the 2 keV X-ray luminosity function of IR-emitting galaxies. We use this luminosity function to estimate the contribution to the soft X-ray background of these lower-luminosity IR-emitting galaxies out to $z_{max} = 3$, deriving contributions of 5-25% depending on the evolutionary model applied. This work has been more fully reported by Green *et al.* (1991, 1992).

The Contribution of Active Galaxies to the Cosmic X-ray Background Radiation

The contribution of very faint QSOs to the cosmic X-ray background (XRB) is investigated using an optically-selected QSO sample in SA 68.2, in conjunction with archived *Einstein* X-ray images. The use of an optically "complete" sample avoids many of the uncertainties that have plagued previous estimates, and a highly flexible form of the IPC data base permits easy selection of X-ray data to achieve optimal S/N. A new generalization of the "X-ray image stacking" technique is presented; this new approach tests for a positional "correlation" between positive X-ray fluctuations, and the locations of the optically selected QSOs. Although the available X-ray data are of only modest depth, correlation with thirty SA 68.2 QSOs permits a highly sensitive ($\sim 5\sigma$) measurement of the *ensemble mean* X-ray flux for QSOs with $19 < B_J < 22$; effectively, a limiting sensitivity of 1.2×10^{-14} erg/sec/cm^2 (0.3–3.5 keV), equivalent to a 600,000 sec IPC exposure, is achieved. Including the contribution from such faint QSOs, (at least) $\approx 31 \pm 5\%$ of the XRB can be directly attributed to discrete sources. Application of the correlation approach to *Einstein* and ROSAT deep survey images will permit a probe of the XRB contribution of faint QSOs (and other objects) to well below the $\sim 10^{-14}$ erg/sec/cm^2 level typically achieved for *individually-detected* objects. This work has been more fully described by Wu *et al.* (1991) and Wu and Anderson (1992).

An Unusual X-ray Emitting Starburst Galaxy

We report observations of a remarkably bright ($V \sim 13$) starburst nucleus, 0833+652, which we have detected at radio, infrared, optical, ultraviolet, and X-ray wavelengths. Despite an observed flux at each of these wavelengths which is comparable to that of NGC 7714, often considered the "prototypical" example of the starburst phenomenon, 0833+652 appears to be a previously uncatalogued object. Its ease of detectability throughout the electromagnetic spectrum should make it useful for a variety of problems in the study of compact emission line galaxies. This work has been described by Margon *et al.* (1988).

Publications

1. An Exceptionally Bright, Compact Starburst Nucleus (B. Margon, S. F. Anderson, M. Mateo, M. Fich, and P. Massey), *Astrophysical Journal*, **334**, 597, 1988.

2. Infrared-Selected Warm Galaxies Observed in X-Rays (P. J. Green, M. Ward, S. F. Anderson, B. Margon, M. H. K. deGrijp, and G. K. Miley), *Astrophysical Journal*, **339**, 93, 1989.

3. The Cosmic X-ray Background and QSOs to $B < 22$: A Search for Correlated Fluctuations (X. Wu, S. F. Anderson, B. Margon, P. L. Schechter, and S. D. M. White), *Bulletin of the American Astronomical Society*, **23**, 957, 1991.

4. The Observed Relationship of X-ray and Infrared Emission in Active and Normal Galaxies (P. J. Green, S. F. Anderson, and M. J. Ward), *Bulletin of the American Astronomical Society*, **23**, 957, 1991.

5. A Compilation of Active and Normal Galaxies Observed in Both Infrared and X-rays (P. J. Green, S. F. Anderson, and M. J. Ward), *Monthly Notices of the Royal Astronomical Society*, **254**, 30, 1992.

6. The Cosmic X-ray Background and QSOs to $B < 22$: A Fluctuations Correlation Approach (X.Wu and S. F. Anderson), *Astronomical Journal*, **103**, 1, 1992.