NASA CR-159990

DATA REDUCTION AND ANALYSIS OF SAS-I DATA

Contract NAS5-20048

Final Report

Principal Investigator:
Dr. Riccardo Giacconi

February 1979

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
and the Harvard College Observatory
are members of the
Center for Astrophysics

DATA REDUCTION AND ANALYSIS OF SAS-I DATA

Contract NAS5-20048

Final Report

Principal Investigator:
Dr. Riccardo Giacconi

February 1979

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
and the Harvard College Observatory
are members of the
Center for Astrophysics

PREFACE

This is the Final Report for NASA Contract NAS5-20048. The objective performed under this contract was the analysis of X-ray observations from the UHURU X-Ray Observatory (SAS-I). This report lists the results of our investigations which were published in scientific journals and presented at scientific meetings.

Table of Contents

X-RAY ASTRONOMY HIGHLIGHTS FROM UHURU: April, 1974 - October, 1978

A. Energy Spectra of 43 Galactic X-Ray Sources Observed by UHURU. (C. Jones). The Astrophysical Journal, volume 214, page 856, 1977.

B. X-Ray Binaries

1. Parameters of X-Ray Binaries (H. D. Tananbaum and J. B. Hutchings). Seventh Texas Symposium on Relativistic Astrophysics, edited by P. G. Bergmann, E. J. Fenyves, and L. Motz, page 299. New York Academy of Science, 1975.

2. The Long-Term Intensity Behavior of Centaurus X-3 (E. Schreier, K. Swartz, R. Giacconi, G. Fabbiano, and J. Morin). The Astrophysical Journal, volume 210, page 642, 1976.

3. UHURU Observations of Hercules X-1 During the Low State of the 35-Day Cycle (C. Jones and W. Forman). The Astrophysical Journal (Letters), volume 209, page L131, 1976.

C. Transient and Burst Phenomena

1. Transient X-Ray Sources in the Galactic Plane (L. Cominsky, C. Jones, and W. Forman). The Astrophysical Journal, volume 224, page 46, 1978.

2. UHURU and Ariel V Observations of 3U1630-47: a Recurrent Transient X-Ray Source (C. Jones, W. Forman, H. Tananbaum, and M. J. L. Turner). The Astrophysical Journal (Letters), volume 210, page L9, 1976.

3. UHURU Observations of 4U1608-52: the "Steady" X-Ray Source Associated with the X-Ray Burst Source in Norma (H. Tananbaum, Lola L. Chaisson, W. Forman, C. Jones, and T. A. Matilsky). The Astrophysical Journal, volume 210, page 642, 1976.

4. UHURU Observations of a Transient X-Ray Source Associated with the Globular Cluster NGC6440 (W. Forman, C. Jones, and H. Tananbaum). The Astrophysical Journal (Letters), volume 207, page L25, 1976.

5. Studies of Cluster X-Ray Sources: Size Measurements (E. Kellogg and S. Murray). The Astrophysical Journal (Letters), volume 193, page L57, 1974.

6. UHURU Observations of the Globular Cluster X-Ray Source NGC6712 (L Cominsky, W. Forman, C. Jones, and H. Tananbaum). The Astrophysical Journal (Letters), volume 211, page L9, 1977.

X-Ray Astronomy Highlights from UHURU (continued)

7. UHURU Observations of an X-Ray Burst at High Galactic Latitude Centered on the X-Ray Globular Cluster NGC1851 (W. Forman and C. Jones). The Astrophysical Journal (Letters), volume 207, page L177, 1976.

D. Extragalactic X-Ray Astronomy

1. Studies of Cluster X-Ray Sources: Energy Spectra for the Perseus, Virgo, and Coma Clusters (E. Kellogg, R. Baldwin, and D. Koch). The Astrophysical Journal, volume 199, page 299, 1974.

2. UHURU Observations of X-Ray Emission from Seyfert Galaxies (H. Tananbaum, G. Peters, W. Forman, R. Giacconi, C. Jones, and Y. Avni). The Astrophysical Journal, volume 223, page 74, 1978.

3. The Detection of Large X-Ray Halos in Clusters (W. Forman, C. Jones, S. Murray, and R. Giacconi). The Astrophysical Journal (Letters), volume 225, page L1, 1978.

4. X-Ray Clusters of Galaxies and the Luminosity-Richness Relation (C. Jones and W. Forman). The Astrophysical Journal, volume 224, page 1, 1978.

5. Evidence for X-Ray Emission from Superclusters of Galaxies Determined from UHURU (S. Murray, W. Forman, C. Jones, and R. Giacconi). The Astrophysical Journal (Letters), volume 219, page L89, 1978.

6. The Fourth UHURU Catalog of X-Ray Sources (W. Forman, C. Jones, L. Cominsky, P. Julien, S. Murray, G. Peters, H. Tananbaum, and R. Giacconi). The Astrophysical Journal, Supplement Series, volume 38, number 4, 1978.

UHURU (SAS-A) FINAL REPORT

NASA Contract NAS5-20048

BIBLIOGRAPHY

1. 1974 Upper limit on 2.5-second pulsations from Hercules X-1 (Y. Avni, J.N. Bahcall, P.C. Joss, D.Q. Lamb, E. Schreier, and H. Tananbaum). The Astrophysical Journal (Letters), volume 188, page L35.

2. 1974 Correlation analysis of X-ray emission from Cygnus X-1 (A.C. Brinkman, D.R. Parsignault, E. Schreier, H. Gursky, E.M. Kellogg, H. Tananbaum, and R. Giacconi). The Astrophysical Journal, volume 188, page 603.

3. 1974 Observations of Circinus X-1 from UHURU (C. Jones, R. Giacconi, W. Forman, and H. Tananbaum). The Astrophysical Journal (Letters), volume 191, page L71.

4. 1974 Studies of cluster X-ray sources: size measurements (E. Kellogg and S. Murray). The Astrophysical Journal (Letters), volume 193, page L57.

5. 1974 The binary X-ray stars: the observational picture (H. Gursky and E. Schreier) I.A.U. Symposium #67 (Moscow), August.

6. 1974 UHURU observations of short-time-scale variation of the Crab (W. Forman, R. Giacconi, C. Jones, E. Schreier, and H. Tananbaum). The Astrophysical Journal (Letters), volume 193, page L67.

7. 1974 X-ray astronomy in the UHURU epoch and beyond (E. Kellogg). The Astrophysical Journal, volume 197, page 689.

8. 1974 Galactic X-ray sources (M.P. Ulmer). International Conference on X-rays in Space, August.

9. 1974 Studies of cluster X-ray sources: energy spectra for the Perseus, Virgo, and Coma clusters (E. Kellogg, R. Baldwin, and D. Koch). The Astrophysical Journal, volume 199, page 299.

10. 1974 X-ray sources and their optical counterparts. I (C. Jones, W. Forman, and W. Liller). Sky and Telescope, volume 48, page 289.

11. 1974 X-ray sources and their optical counterparts. III (C. Jones, W. Forman, and W. Liller). Sky and Telescope, volume 48, page 372.

12. 1975 X-ray sources and their optical counterparts. III (C. Jones, W. Forman, and W. Liller). Sky and Telescope, volume 49, page 10.

13. 1975 The X-ray, optical, and radio behavior of Scorpius X-1: the 1971 coordinated observations (H.V. Bradt, L.L.E. Braes, W. Forman, J.E. Hesser, W.A. Hiltner, R. Hjellming, E. Kellogg, W.E. Kunkel, G.K. Miley, G. Moore, J.W. Pel, J. Thomas, P. Vanden Bout, C. Wade, and B. Warner). The Astrophysical Journal, volume 197, page 443.

14. 1975 Further observations of Cygnus X-3 with the UHURU satellite (R.W. Leach, S.S. Murray, E.J. Schreier, H.D. Tananbaum, M.P. Ulmer, and D.R. Parsignault). The Astrophysical Journal, volume 199, page 184.

15. 1975 Parameters of X-ray binaries (H. Tananbaum, and J. B. Hutchings). Seventh Texas Symposium on Relativistic Astrophysics, edited by P.G. Bergmann, E.J. Fenyves, and L. Motz, page 299. New York Academy of Science.

16. 1975 "Cen X-3 and Her X-1 revisited", Annals of the New York Academy of Sciences, volume 262, page 312. Presented at the Seventh Texas Symposium on Relativistic Astrophysics, 1974.

17. 1975 View of the X-ray sky (H. Gursky). PRIRODA, April.

18. 1975 Binary X-ray stars and supernovae of Type I. (H. Gursky). I.A.U. Symposium #73, July.

19. 1975 The "other" galactic X-ray sources. (H. Gursky). Symposium on X-ray Binaries, Goddard Space Flight Center, October.

20. 1975 Recent UHURU results on Cen X-3 (E. Schreier and G. Fabbiano). Symposium on X-ray Binaries, Goddard Space Flight Center, October.

21. 1976 "Progress in X-ray astronomy" (R. Giacconi). Presented at 34th Richtmyer Memorial Lecture of the American Association of Physics Teachers, 1975. American Journal of Physics, volume 44, page 121.

22. 1976 On the nature of celestial X-ray sources and on the correspondence between X-ray sources, radio sources, and optical objects (R. Giacconi). in "La Riscoperta del Cielo", SCIENZA E TECNICA 76 of the Enciclopedia della Scienza e della Tecnica - Mondadori Publishing Co., Milano, Italy.

23. 1976 X-ray observations of radio sources (R. Giacconi). Lecture presented at the NATO Advanced Study Institute, Urbino Italy, 1975. "The Physics of Non-Thermal Radio Sources", D. Reidel Publishing Co., Dordrecht, Holland.

24. 1976 The long-term intensity behavior of Centaurus X-3 (E. Schreier, K. Swartz, R. Giacconi, G. Fabbiano, and J. Morin). The Astrophysical Journal, volume 204, page 539.

25. 1976. Measurement of fluctuations in the X-ray background by UHURU (D. Schwartz, S. Murray, and H. Gursky). The Astrophysical Journal, volume 204, page 315.

26. 1976 Studies of the average pulse shape of Centaurus X-3 in the 2-20 keV range (M.P. Ulmer). The Astrophysical Journal, volume 214, page 548.

27. 1976 UHURU observations of the galactic plane in 1970, 1971, and 1972 (W. Forman, C. Jones, and H. Tananbaum). The Astrophysical Journal (Letters), volume 206, page L29.

28. 1976 UHURU observations of a transient X-ray source associated with the globular cluster NGC6440 (W. Forman, C. Jones, and H. Tananbaum). The Astrophysical Journal (Letters), volume 207, page L25.

29. 1976 UHURU observations of an X-ray burst at high galactic latitude centered on the X-ray globular cluster NGC1851 (W. Forman and C. Jones). The Astrophysical Journal (Letters), volume 207, page L177.

30. 1976 Search for X-ray emission from BL Lacertae objects and nearby Seyfert galaxies (M.P. Ulmer and S.S. Murray). The Astrophysical Journal, volume 207, page 364.

31. 1976 Survey of the intensity variability of strong galactic X-ray sources from UHURU (W. Forman, C. Jones, and H. Tananbaum). The Astrophysical Journal, volume 208, page 849.

32. 1976 Search for X-ray emission from globular clusters using UHURU data (M.P. Ulmer, S. Murray, H. Gursky, and J. Bahcall). The Astrophysical Journal, volume 208, page 47.

33. 1976 Eclipse duration of the X-ray pulsar 3U0900-40 (Y. Avni). The Astrophysical Journal, volume 209, page 574.

34. 1976 UHURU observations of Hercules X-1 during the low state of the 35-day cycle (C. Jones and W. Forman). The Astrophysical Journal (Letters), volume 209, page L131.

35. 1976 UHURU observations of the Norma X-ray burster (J. Grindlay and H. Gursky) The Astrophysical Journal (Letters), volume 209, L61.

36. 1976 UHURU observations of 4U1608-52: the "steady" X-ray source associated with the X-ray burst source in Norma (H. Tananbaum, Lola L. Chaisson, W. Forman, C. Jones, and T.A. Matilsky). The Astrophysical Journal (Letters), volume 209, page L125.

37. 1976 Energy spectra of X-ray clusters of galaxies (Y. Avni). The Astrophysical Journal, volume 210, page 642.

38. 1976 Observations of high latitude X-ray sources with the UHURU satellite (S. Murray and M.P. Ulmer). The Astrophysical Journal, volume 210, page 230.

39. 1976 UHURU and Ariel V observations of 3U1630-47: a recurrent transient X-ray source (C. Jones, W. Forman, H. Tananbaum, and M.J.L. Turner). The Astrophysical Journal (Letters), volume 210, page L9.

40. 1977 UHURU observations of the globular cluster X-ray source NGC6712 (L. Cominsky, W. Forman, C. Jones, and H. Tananbaum). The Astrophysical Journal (Letters), volume 211, page L9.

41. 1977 A measurement of the spin-up rate of the SMC X-1 X-ray pulsar (P. Henry, and E. Schreier). The Astrophysical Journal (Letters), volume 212, page L13.

42. 1977 Energy spectra of 43 galactic X-ray sources observed by UHURU (C. Jones). The Astrophysical Journal, volume 214, page 856.

43. 1978 Evidence for X-ray emission from superclusters of galaxies determined from UHURU (S. Murray, W. Forman, C. Jones, and R. Giacconi). The Astrophysical Journal (Letters), volume 219, page L89.

44. 1978 X-ray luminosity function of Abell clusters (D. Schwartz). The Astrophysical Journal, volume 220, page 8.

45. 1977 Timing effects in rotating neutron stars (E. Schreier). Annals of the New York Academy of Science. Proceedings of the 8th Texas Symposium on Relativistic Astrophysics, volume 302, page 445.

46. 1978 UHURU observations of X-ray emission from Seyfert galaxies (H. Tananbaum, G. Peters, W. Forman, R. Giacconi, C. Jones, and Y. Avni). The Astrophysical Journal, volume 223, page 74.

47. 1978 Extragalactic X-ray sources (I) (R. Giacconi). Paper delivered at the Symposium on Quasars and Active Nuclei of Galaxies, Copenhagen, Denmark; Physica Scripta, volume 17, number 3.

48. 1978 The origin of X-ray emission from clusters (R. Giacconi). Paper presented at the Workshop on the "Missing" Mass; Symposium on Quasars and Active Nuclei of Galaxies, Copenhagen, Denmark; Physica Scripta, volume 17, number 3, March.

49. 1978 Transient X-ray sources in the galactic plane (L. Cominsky, C. Jones, and W. Forman). The Astrophysical Journal, volume 224, page 46.

50. 1978 X-ray clusters of galaxies and the luminosity-richness relation (C. Jones and W. Forman). The Astrophysical Journal, volume 224, page 1.

51. 1978 Faint X-ray sources detected near Cos-B gamma ray positions (P. Julien and H. Helmken). Nature, volume 272, page 699.

52. 1978 The fourth UHURU catalog of X-ray sources (W. Forman, C. Jones, L. Cominsky, P. Julien, S. Murray, G. Peters, H. Tananbaum, and R. Giacconi). The Astrophysical Journal, Supplement Series, volume 38, number 4.

53. 1978 Long term behavior of MXB 1730-335 (J. Grindlay and H. Gursky). The Astrophysical Journal (Letters), volume 218, page L117.

54. 1978 X-ray flares in NGC 4151: a thermal model and constraints on a central black hole (A. P. Lightman, R. Giacconi, and H. Tananbaum). The Astrophysical Journal, volume 224, page 375.

55. 1978 The detection of large X-ray halos in clusters (W. Forman, C. Jones, S. Murray, and R. Giacconi). The Astrophysical Journal (Letters), volume 225, page L1.

56. 1978 Properties of the 2-6 keV pulse profiles of Hercules X-1 (P. C. Joss, W. B. Fechner, W. Forman, and C. Jones). The Astrophysical Journal, volume 225, page 994.

57. 1978 Review of X-ray observations of compact sources (R. Giacconi). Lecture presented at the International School of Physics "Enrico Fermi", Varenna, Italy. (Course on Physics and Astrophysics of Neutron Stars and Black Holes), July 14 - July 26, 1975. Proceedings, page 17.

58. 1978 Recent observations from UHURU and ANS (H. Tananbaum). Lecture presented at the International School of Physics "Enrico Fermi", Varenna, Italy. (Course on Physics and Astrophysics of Neutron Stars and Black Holes), July 14 - July 26, 1975. Proceedings, page 256.

59. 1978 Number-intensity distribution of high galactic latitude X-ray sources (S. Murray). Submitted to The Astrophysical Journal (Letters).

UHURU (SAS-A) FINAL REPORT

NASA Contract NAS5-20048

ABSTRACTS

ABSTRACTS

1. UPPER LIMIT ON 2.5-SECOND PULSATIONS FROM HERCULES X-1.
Y. Avni, J.N. Bahcall, P.C. Joss, D.Q. Lamb, E. Schreier, H. Tananbaum.

No pulsed power is detected with a period of 2.5 seconds in the 1972 January UHURU observations of Her X-1. An upper limit of 7 percent is derived for the amount of 2.5-s pulsed modulation relative to the observed amount of 1.24-s pulsed modulation (corresponding to an upper limit of 5×10^{-3} for the ratio of signals in the power spectrum).

2. CORRELATION ANALYSIS OF X-RAY EMISSION FROM CYGNUS X-1.
A.C. Brinkman, D.R. Parsignault, E. Schreier, H. Gursky, E.M. Kellogg, H. Tananbaum, R. Giacconi.

Normalized autocorrelation and cross-correlation coefficients have been calculated for the X-ray emission of Cygnus X-1 in two energy bins, 2.1-5.1 keV and 5.1-12 keV. The analysis shows a strong correlation between the pulsations in the two energy bins, with the low-energy pulsations lagging behind the high-energy ones, or alternatively a shorter duration of the pulse trains in the high-energy bin. The power spectral density derived from the autocorrelation functions indicates a larger contribution of the high-frequency components for the higher-energy X-rays.

3. OBSERVATIONS OF CIRCINUS X-1 FROM UHURU.
C. Jones, R. Giacconi, W. Forman, H. Tananbaum.

Analysis of UHURU observations of the X-ray source Cir X-1 (3U1516-56) suggests that the source may be a binary with a period longer than 15.0 days. Significant intensity variations have been observed on all time scales from 0.1 seconds to days. Changes in the X-ray energy spectrum from 2 to 20 keV also have been found. A refined X-ray position containing no obvious optical counterpart is also reported. The similarities between Cyg X-1 and Cir X-1 suggest that the X-rays from Cir X-1 also may be produced by accretion onto a massive collapsed object.

4. STUDIES OF CLUSTER X-RAY SOURCES: SIZE MEASUREMENTS.
E. Kellogg, S. Murray

We present best-fit values of the size for nine cluster X-ray sources. The brightness (i.e., volume emissivity) function is derived from the thermal bremsstrahlung-isothermal gas sphere model for these sources, so the

derived parameters are presented as core radii. New results for Abell 2256, Abell 262, and the Centaurus cluster (3U1247-41) are given. Upper limits on the core radii for the Abell clusters 1060, 1367, 2199, 2319, and 401 and for 3C129 are also given. Comparison with optical galaxy counts suggests that the X-ray source is two to three times larger than the galaxy distribution, on the bremsstrahlung model. We also compare our derived gas densities with those required to explain Miley's observations and the model of Jaffe and Perola for radio head-tail galaxies. We find that for the case of NGC1265 in the Perseus cluster, the agreement is within a factor of 2. There is also good agreement for NGC4869 in Coma and NGC6166 in Abell 2199. The gas density required to explain both head-tail radio galaxies and the extended X-ray sources in clusters appears to be the same for all known cases. This is a new and powerful argument for the existence of a hot intergalactic medium in clusters of galaxies.

5. NO ABSTRACT

6. UHURU OBSERVATIONS OF SHORT TIME SCALE VARIATION OF THE CRAB.
W. Forman, R. Giacconi, C. Jones, E. Schreier, H. Tananbaum.

We have analyzed UHURU X-ray observations of the Crab and found statistically significant variability in the intensity on time scales of several tenths of a second. Our results imply either that the X-ray emission from the pulsar NP0532 is highly variable or that we have observed a previously undetected compact source of X-rays.

7. X-RAY ASTRONOMY IN THE UHURU EPOCH AND BEYOND.
E. M. Kellogg

A review of results from the UHURU satellite is presented. An intensive treatment of two subjects is given, rather than a broad review. First, Cyg X-1, a stellar X-ray source and a candidate for a black hole, is discussed; second, the X-ray source in the Perseus cluster of galaxies, which may be a cloud of hot intergalactic gas, is treated. In both cases the train of logis used in establishing the nature of these objects is presented and evaluated. For both, while alternative explanations cannot be completely eliminated, they become more difficult to sustain when examined in detail, suggesting that the candidate explanations are more likely correct.

8. GALACTIC X-RAY SOURCES.
M. P. Ulmer

A review of galactic X-ray sources is given, with particular emphasis on UHURU and UCSD OSO-7 results. The spectra and variability of SMC X-1,

Vela XR-1, Cen X-3, Sco X-1, Her X-1, Cyg X-1, Cyg X-3, and Cyg X-2 are compared, and it is suggested that there are two distinct classes of X-ray sources, one type with flat (spectral number index $\lesssim 1.5$) low energy ($\sim$ 2-20 keV) spectra, the other type with steep (number index $\gtrsim 2$) low energy spectra. At present, none of the X-ray sources with steep spectra has been found to have X-ray eclipses. Possible explanations for this are briefly discussed.

9. STUDIES OF CLUSTER X-RAY SOURCES. ENERGY SPECTRA FOR THE PERSEUS, VIRGO, AND COMA CLUSTERS.
E. Kellogg, J.R. Baldwin, D. Koch

We present the final UHURU X-ray differential-energy spectra for the Perseus, Virgo, and Coma clusters of galaxies. The power-law and isothermal bremsstrahlung model forms, both with a low-energy cutoff, are given. For bremsstrahlung, the energy-dependent Gaunt factor is calculated by an improved method. The spectra, best fits to the UHURU 2-10 keV data, are also compared with other observations of these sources in the energy range 0.1-100 keV. For Perseus, the data above 20 keV favor the bremsstrahlung fit marginally. For Virgo, the data of Catura et al. between 0.25 and 1.0 keV clearly favor the bremsstrahlung curve. For Coma, the weakest of the three sources, the data are less precise, but there is some evidence for a low-energy turnover or cutoff. The implications of such a cutoff are discussed briefly.

In the course of describing our data-fitting procedure, we discuss the problem of parameter estimation for this situation, where we are fitting a nonlinear function containing three parameters - normalication, slope, and low-energy cutoff - with two of the parameters strongly correlated. A framework for presenting the results is described, equivalent to giving all the elements of the covariance matrix, but more readily useful in this case. We quote 68 percent confidence error bars for the "independently" determined slope and cutoff parameters, corresponding to the diagonal terms of the covariance matrix. We also plot the 68 percent confidence limits for the fitted spectral functions, which correspond to giving both the diagonal and the off-diagonal terms of the covariance matrix.

10. NO ABSTRACT

11. NO ABSTRACT

12. NO ABSTRACT

13. THE X-RAY, OPTICAL, AND RADIO BEHAVIOR OF SCORPIUS X-1: THE 1971 COORDINATED OBSERVATIONS.

H. V. Bradt, L. L. E. Braes, W. Forman, J. E. Hesser, W. A. Hiltner, R. Hjellming, E. Kellogg, W. E. Kunkel, G. K. Miley, G. Moore, J. W. Pel, J. Thomas, P. VandenBout, C. Wade, B. Warner.

Sco X-1 has been monitored at radio, optical, and X-ray wavelengths for 21 days during the period 1971 February 23 through 1971 April 2. The UHURU satellite was used for the X-ray observations. The X-ray intensity was found to fluctuate rapidly (time constants < 6 min) by a factor of about 2 during periods when the object was in a bright and flaring optical state. The X-ray flux was constant to within ~ 5% during the faint and relatively quiescent optical periods. No correlation between the X-ray/optical activity and radio flaring was noted.

14. FURTHER OBSERVATIONS OF CYGNUS X-3 WITH THE UHURU SATELLITE.

R. W. Leach, S. S. Murray, E. J. Schreier, H. D. Tananbaum, M. P. Ulmer, D. R. Parsignault.

We present observations of the periodically varying X-ray source, Cygnus X-3, made with the UHURU satellite between 27 December 1970 and 13 January 1973. Our results are:

1. A value for the period $P = 0^d.1996811 \pm 0^d.0000016$; the 2σ upper limit to a continuous change in the period is

$$\frac{1}{P}\frac{dP}{dt} \leq 2 \times 10^{-12} \text{sec}^{-1}.$$

2. No systematic change is observed in the effective low energy absorption across the $0^d.2$ cycle.

3. Cyg X-3 exhibits different average intensity levels which have been seen to persist for as long as 9 days at a time. The hardest spectra (2-10 keV range) are derived from the times of lowest 2-6 keV intensity.

4. Cygnus X-3 was observed with UHURU during the large radio outburst first noted on 3 September 1972. The spectral parameter kT for thermal bremsstrahlung emission increased systematically from ~ 2 keV to ~ 3 keV from ~ 30 August to ~ 3 September, and then decreased back to ~ 2 keV by 7 September. During this time, the 2-6 keV intensity of Cygnus X-3 fluctuated by a factor of 4 ranging from ~ 150 cts/sec to ~ 600 cts/sec which is the highest intensity yet observed for this source.

15. NO ABSTRACT

16. NO ABSTRACT

17. NO ABSTRACT

18. BINARY X-RAY STARS AND SUPERNOVAE OF TYPE I.
H. Gursky.

Most of the strong galactic X-ray sources must be low mass, close binary systems such as Hercules X-1 and Scorpius X-1. Two evolutionary scenarios are discussed, both involving Type I Supernovae that occur when a mass accreting white dwarfs are driven over their mass limit. In one, accepting the correctness of the idea that a neutron star (black hole) is the seat of the X-ray emission, the SN occurs before the system is an X-ray source. Another possibility is that the white dwarf is the X-ray source, just prior to its collapse and the ensuing SN.

19. THE "OTHER" GALACTIC X-RAY SOURCES.
H. Gursky.

There is by now a "standard" model for X-ray sources comprising a binary system containing a compact star and powered by mass accretion. It can be argued that the majority and perhaps all the galactic X-ray sources are of this kind. In this paper I discuss three kinds of sources which may be qualitatively different from these; namely, low luminosity sources such as 3U0352+30 (= χ Perseus ?), the sources associated with the globular clusters, and the transient X-ray sources.

20. RECENT UHURU RESULTS ON CENTAURUS X-3.
E.J. Schreier, G. Fabbiano.

The current status of the analysis of Cen X-3 data from UHURU concerning pulsations, orbital period and eccentricity, and extended lows, are reviewed. The pulse period decreases irregularly, with $\dot{p}/p \approx -3 \times 10^{-4}$ year^{-1} over 1971-1972. The pulsed fraction (2-7 keV) is 70-90% for single pulses but significantly less for superpositions of pulses, due to variability in shape. The pulses are narrower at higher energies with a correlated increase in fraction pulsed. The orbital period is found to both decrease and increase with $\dot{p}/p$ on the order of a few times 10^{-5} year^{-1}. A three sigma upper limit on the eccentricity of .003 is obtained; if no significant periastron motion is allowed over two years, the

upper limit becomes .0016. The orbital period is found to be detectable during some extended lows but with a significantly decreased ratio of eclipsed to non-eclipsed intensity. Two transitions between normal high states and extended lows are caused by both burying the source in an increased stellar wind from the companion, and starving the source by decreasing the stellar wind. Changes in fraction pulsed during transitions and systematic differences in the harmonic content of the pulses are also found.

21. PROGRESS IN X-RAY ASTRONOMY.
R. Giacconi.

The discovery in the last two decades of the large amounts of energy released in supernovae, of radio galaxies and quasars, of the microwave background radiation, and more recently of X-ray sources and pulsars, have brought us to the conclusion that high energy processes play a major, and possibly a decisive role in our Universe.

In these processes the energy released per gram is much greater than for normal stellar matter. Gravitational forces, weak in our normal experience, become, for instance, all important in the late phases of stellar evolution. Matter is crushed to inconceivably large densities and the stars can release enormous amounts of energy of the order of 10 to 40% of their total mass energy as compared to less than 1% liberated by nuclear burning during their entire previous life.

The study of these high energy processes defines a new field, high energy astrophysics, the central problem of which is an understanding of the source of the energy released in X-ray sources, supernovae, radio galaxies, quasars, etc. and the processes by which the high energy particles, responsible for the radiation from these objects, are produced. The resolution of these problems constitutes one of the most important and fascinating tasks in all of physics.

Since the production of high energy photons is to be expected wherever high energy particles exist, it is understandable that observations in the X-ray and gamma ray range of the electromagnetic spectrum should become important, as soon as the means to carry them out became available.

In the last two decades, space exploration was made possible by the development of rockets and satellites and this development allowed us for the first time in man's history to observe the sky unimpeded by the atmospheric blanket that surrounds the Earth. High energy photons, from a few hundred electron volts to several million electron volts, which do not penetrate the atmosphere could now be observed. The promise of unsuspected discoveries, which is intrinsic in this statement, has been realized by X-ray astronomy.

22. NO ABSTRACT

23. NO ABSTRACT

24. THE LONG-TERM INTENSITY BEHAVIOR OF CENTAURUS X-3.
E. Schreier, K. Swartz, R. Giacconi, G. Fabbiano, J. Morin.

In three years of observation from UHURU (1970 December - 1973 June) the X-ray source Cen X-3 appears to alternate between "high states," with an intensity of 150 cts/sec (2-6 keV) or greater, and "low states" where the source is barely detectable. The time scale of this behavior is of the order months and no apparent periodicity has been observed.

The analysis of two transitions between these states is reported. In particular, during two weeks in July 1972, the source increased from about 20 cts/sec (2-6 keV) to 150 cts/sec. The detailed nature of this turn-on, including orbital phase, spectral variation, and fractional power pulsed is interpreted in terms of a model in which the supergiant's stellar wind decreases in density. A second transition, a turn-off in February 1973, is similarly analyzed and found to be consistent with a simple decrease in accretion rate. The presence of absorption dips during transitions at orbital phases 0.4 - 0.5 as well as at phase 0.75 is discussed. Analysis of data from extended lows shows the persistence of the 2-day binary period with the intensity varying from 4.6 ± 1.1 cts/sec to 10.7 ± 1.1 cts/sec (2-6 keV).

The data are consistent with a stellar wind accretion model, with different kinds of extended lows caused by increased wind density masking the X-ray emission or by decreased wind density lowering the accretion rate.

25. MEASUREMENT OF FLUCTUATIONS IN THE X-RAY BACKGROUND BY UHURU.
D. Schwartz, S. Murray, H. Gursky.

We have used the data from UHURU to search for fluctuations in the 2-7 keV X-ray background. Fluctuations, intrinsic to the sky, are observed to be 3.0 percent of the mean X-ray background, over an effective solid angle of 0.004 ster. These fluctuations are less than the minimum predicted from the LnN vs LnS curve previously estimated from UHURU, and force renormalization of that curve by a factor of order 1/2.

About 1/3 of the UHURU sources with galactic latitude $|b| > 20^{o}$ are identified with extragalactic objects. The predicted level of fluctuations is based on assuming that all the unidentified high galactic latitude sources form a homo-

geneous volume distribution of extragalactic sources. The discrepancy between measured and predicted fluctuations does not easily disappear if all the unidentified sources are galactic. Therefore, we conclude that a portion of the unidentified sources represent a class of objects at cosmological distances.

26. STUDIES OF THE AVERAGE PULSE SHAPE OF CENTAURUS X-3 IN THE 2-20 keV RANGE.
M. P. Ulmer.

We report an analysis of the average pulse shape of Cen X-3 versus energy (2-20 keV) on time scales of hours to days derived from UHURU observations during 1971 May 5-7 and 1971 December 18-20. The pulsed fraction varied with energy from 0.42 ± 0.02 to 0.80 ± 0.10 over the 2-20 keV range. The 2-6 keV pulsed fraction did not show statistically significant variations ($> 2\sigma$) over the phase of the 2.087 day eclipse cycle. Individual measurements of the 2-6 keV pulsed fraction ranged from 0.45 - 0.56.

27. UHURU OBSERVATIONS OF THE GALACTIC PLANE IN 1970, 1971, and 1972.
W. Forman, C. Jones, H. Tananbaum.

We have analyzed UHURU observations of the galactic plane in 1970, 1971, and 1972. The great majority of the galactic X-ray sources are not "transient." Some of the so-called transient sources persist for long periods of time at an intensity of a few percent of their peak values. The data suggest that the transient sources may be quite similar to the other galactic sources with outbursts caused by changes in the accretion rate.

28. UHURU OBSERVATIONS OF A TRANSIENT X-RAY SOURCE ASSOCIATED WITH THE GLOBULAR CLUSTER NGC6440.
W. Forman, C. Jones, H. Tananbaum.

Analysis of UHURU observations show that a transient X-ray source is associated with the globular cluster NGC6440. The location of the X-ray source, first detected by OSO-7 (Markert et al. 1975), is improved and a light curve covering almost two years is presented.

29. UHURU OBSERVATIONS OF AN X-RAY BURST AT HIGH GALACTIC LATITUDE CENTERED ON THE X-RAY GLOBULAR CLUSTER NGC1851.
W. Forman, C. Jones.

We have detected an X-ray burst from a $0.5^{\circ} \times 10^{\circ}$ region centered near NGC1851 (MX0513-40) in observations made with the UHURU X-ray observatory on 19 September 1972. The source was observed for 15 seconds with a

peak rate of 0.5 that of the Crab (2-6 keV) and was not detected above 0.01 of the Crab in observations 4.5 minutes before or after this event. During the observation the spectrum developed a low energy cutoff. NGC1851 is the second globular cluster identified as a source of X-ray bursts which suggests that all X-ray bursts may originate in globular clusters, some of which may be optically obscured.

30. SEARCH FOR X-RAY EMISSION FROM BL LACERTAE OBJECTS AND NEARBY SEYFERT GALAXIES.
M.P. Ulmer, S.S. Murray.

We set upper limits to the 2-6 keV X-ray flux of 5 nearby Seyfert galaxies (NGC1068, 1566, 3227, 4051, 6814) and 6 BL Lac type objects (PK0537-44, OJ287, ON325, ON231, AP LIB, BL LAC). The 3σ upper limits based on observations with the UHURU satellite during December 1970 through June 1971 were (for the order given above) 6.2, 1.5, 1.5, 0.9, 3.5, 1.5, 7.4, 1.4, 1.6, 2.1, and 5.5 cts/sec. The conversion factor used in the 3U catalog, which we assume applies here, is that 10 cts/sec (2-6 keV) $\approx$ 1.7×10^{-10} ergs/cm^2-sec (2-10 keV).

31. SURVEY OF THE INTENSITY VARIABILITY OF STRONG GALACTIC X-RAY SOURCES FROM UHURU.
W. Forman, C. Jones, H. Tananbaum.

X-ray observations made with the UHURU satellite have been used to study the characteristics of the intensity of 19 strong galactic sources. On a time scale of 0.1 - 1.0 seconds all but 2 of these sources showed variability at a significant level greater than 3σ. On longer time scales - minutes to hours - all but 3 sources showed variations above the 3σ level.

In addition to characterizing in a systematic way, the broad range of variability of the galactic X-ray sources we have applied our results to specific models of Cygnus X-1 and Cygnus X-3. We also comment on the similar nature of the strong galactic center X-ray sources and the globular cluster sources.

32. SEARCH FOR X-RAY EMISSION FROM GLOBULAR CLUSTERS USING UHURU DATA.
M.P. Ulmer, S. Murray, H. Gursky, J. Bahcall.

We searched the UHURU data for X-ray emission from 40 globular clusters. We were unable to extend the list of known globular cluster X-ray sources (NGC1851, 6440, 6441, and 7078). Our 3σ upper limits ranged from $\sim 2 \times 10^{34}$ ergs/sec to $\sim 10^{36}$ ergs/sec (2-10 keV).

33. ECLIPSE DURATION OF THE X-RAY PULSAR 3U0900-40.
Y. Avni

A generalization of the Roche potential for eccentric binary orbits in the approximation of quasi-static equilibrium is derived. This potential is used to estimate for the 3U0900-40 system, the critical radius of the optical primary and the ranges of acceptable inclination angles that are implied by the X-ray eclipse duration. The importance of measuring more accurately the orbital elements and the length of the X-ray eclipse are emphasized.

34. UHURU OBSERVATIONS OF HERCULES X-1 DURING THE LOW STATE OF THE 35-DAY CYCLE.
C. Jones, W. Forman.

We have observed X-ray emission from Hercules X-1 during the 23-day low state of the 35-day cycle. During this time we observe all the activity normally present during the high state - regular eclipses, absorption "dips", and 1.24 second pulsations. We compare our observations with the models of Her X-1 derived by Robert, Gerend, and Boynton (1976), Katz (1973), and Petterson (1975). We also suggest that a hot, optically thin corona along both faces of the accretion disk (Shakura and Sunyaev 1973) can produce the unpulsed component of emission observed during both the high and low intensity states.

35. UHURU OBSERVATIONS OF THE NORMA X-RAY BURSTER.
J. Grindlay, H. Gursky.

Upon re-examination of the UHURU data accumulated between 1970-1973, we have found 4 events which can be interpreted as X-ray bursts from the same region in Norma where 10 bursts were seen by the Vela satellite. The characteristics of the events makes it likely that the source is an X-ray burster such as found by ANS near NGC6624. We report the position of the source and the spectral and temporal characteristics of the bursts.

36. UHURU OBSERVATIONS OF 4U1608-52: THE "STEADY" X-RAY SOURCE ASSOCIATED WITH THE X-RAY BURST SOURCE IN NORMA.
H. Tananbaum, Lola L. Chaisson, W. Forman, C. Jones, T.A. Matilsky.

Data are presented for the X-ray source 4U1608-52 summarizing its light curve, location, and spectral parameters. Evidence is presented showing that this source is the "steady" X-ray counterpart of the X-ray burst source in Norma. The spectrum of the "steady" source is compared to the spectrum observed during two bursts, and we note that there is substantially more low energy absorption during the bursts. Using the "steady" source spectral

data, we examine the optical data and conclude that if the X-ray spectrum is thermal then a globular cluster counterpart probably would have been detected (whereas none has been). Further X-ray and optical observations are suggested for this source, since an optical identification may be central in determining whether all X-ray bursts have a common origin and if this origin requires a globular cluster environment.

37. ENERGY SPECTRA OF X-RAY CLUSTERS OF GALAXIES.
Y. Avni.

A procedure for estimating the ranges of parameters that describe the spectra of X-rays from clusters of galaxies is presented. The applicability of the method is proved by statistical simulations of cluster spectra; such a proof is necessary because of the nonlinearity of the spectral functions. Implications for the spectra of the Perseus, Coma, and Virgo clusters are discussed. The procedure can be applied in more general problems of parameter estimation.

38. OBSERVATIONS OF HIGH LATITUDE X-RAY SOURCES WITH THE UHURU SATELLITE.
S. Murray, M.P. Ulmer.

We observed 22 high galactic latitude $|b| \geq 20^{0}$ X-ray sources during 1970 - 1973 with the UHURU satellite. We verified the existence of $\sim$ 85% of these sources and showed that at least two were variable (3U0042+32 and 3U1809+50).

39. UHURU AND ARIEL V OBSERVATIONS OF 3U1630-47: A RECURRENT TRANSIENT X-RAY SOURCE.
C. Jones, W. Forman, H. Tananbaum, M.J.L. Turner.

We have analyzed UHURU and Ariel V observations of 3U1630-47 from December 1970 to May 1976. During this time the X-ray source underwent four transient-like outbursts separated by approximately 600 days. This is the first example of a transient X-ray source exhibiting separate, regularly spaced outbursts. The observed features of the light curve can be applied to a model employing a collapsed object in a highly eccentric system as described by Avni, Fabian, and Pringle (1976) to predict an eccentricity ≥ 0.65.

40. UHURU OBSERVATIONS OF THE GLOBULAR CLUSTER X-RAY SOURCE NGC6712.
L. Cominsky, W. Forman, C. Jones, H. Tananbaum

Results are presented from the analysis of two years of UHURU observations of the X-ray source A1850-08, first reported and tentatively identified with the globular cluster NGC6712 by Seward et al. (1976). An improved location confirms

the identification of A1650-08 with NGC6712. X-ray variability is observed on time scales ranging from seconds to days and is discussed in relation to current models for globular cluster X-ray sources.

41. A MEASUREMENT OF THE SPIN-UP RATE OF THE SMC X-1 X-RAY PULSAR.
P. Henry and E. Schreier

A re-analysis of the 1971 UHURU observations of SMC X-1 has determined the pulsation period to be 0.71748 ± 0.00026 s. Combining these early epoch UHURU observations with other more recent observations, we have determined that the average spin-up rate of the SMC X-1 X-ray pulsar is $\dot{P}/P = -(7.7 \pm 0.8) \times 10^{-4} yr^{-1}$. We interpret this to imply that the dissipative processes which maintain the spin-up rate of Her X-1 and Cen X-3 at a relatively low value are not an important factor in the SMC X-1 accretion process.

42. ENERGY SPECTRA OF 43 GALACTIC X-RAY SOURCES OBSERVED BY UHURU.
C. Jones.

X-ray observations from the UHURU satellite have been used to obtain the energy spectra from 2 to 20 keV for 43 galactic X-ray sources, which then were used to classify the X-ray sources. This survey has shown that galactic sources exhibit different spectra with a temperature range from $\leq 10^7$ °K to $\geq 2 \times 10^8$ °K. For the sources included in this survey, no significant increase was observed in the number of sources with very cool temperatures ($< 4 \times 10^7$ °K) or with very hot temperatures ($\leq 2 \times 10^8$ °K). Ten of the eleven X-ray sources which have been reported to pulsate regularly on time scales of seconds to minutes have temperatures exceeding $\sim 10^8$ °K. The four globular cluster X-ray sources, 3U1820-30, 3U1746-37, A1850+09, and MX1746-20, have spectra similar to the strong galactic center sources with temperatures between 4×10^7 °K and 9×10^7 °K. The spectra of several of the steady sources associated with the burst sources also can be described by temperatures in this range.

43. EVIDENCE FOR X-RAY EMISSION FROM SUPERCLUSTERS OF GALAXIES DETERMINED FROM UHURU.
S. Murray, W. Forman, C. Jones, R. Giacconi.

We detect X-ray emission from three Class II clusters of rich clusters of galaxies. Using a definition for these objects based in part on Abell's description (1961), we find only 12 candidate superclusters of distance class 5 and 6 clusters within the area of sky covered by the 4U catalog. The probability of these 3 X-ray sources accidently coinciding with the superclusters is less than 0.003 (i.e., 3σ). We find equally low probabilities that the X-ray emission is due to either a single luminous cluster or the combined emission of all members of the supercluster. A possible explanation for these sources is

thermal bremsstrahlung emission from a hot tenuous gas pervading the supercluster. The mass of the gas can be as much as 10 times the mass of the galaxies in the supercluster and comparable to the virial mass necessary to gravitationally bind the supercluster. Should such regions of enhanced gas density be found to be associated with all groups of clusters (multiplicity ≥ 2) then this gas may provide a significant fraction of the mass required to close the Universe.

44. THE X-RAY LUMINOSITY FUNCTION OF ABELL CLUSTERS.
D. A. Schwartz

X-ray sources identified with Abell clusters of galaxies in distance classes ≤ 3 give a quantitative estimate of the volume luminosity function for those clusters emitting between 10^{44} and 10^{45} ergs/sec in X-rays. At higher luminosities, tentative identifications with more distant clusters can be interpreted at least as an upper limit. This limit allows a smooth extension of the luminosity function, but with a fairly steep decrease in the range 10^{45} to 10^{46} ergs/sec. No direct information is available for luminosities less than 10^{44} ergs/sec because current X-ray surveys are limited to nearby distances with very few Abell clusters; however, constraints at the low luminosity end can be set by considering the total volume density of Abell clusters and the upper limit to the numbers of undientified X-ray sources. The luminosity function must flatten or turn over below 10^{44} ergs/sec; therefore, counts of distant X-ray clusters to such a faint intrinsic luminosity can yield cosmological information.

45. TIMING EFFECTS IN ROTATING NEUTRON STARS.
E. J. Schreier

Observations of timing effects in rotating neutron stars are discussed from the standpoint of the nature of neutron stars. In particular, the observational data concerning the binary X-ray pulsars are reviewed and interpreted, and parallels are drawn with the radio pulsars.

The existence of pulsations and of binary behavior suggests the canonical model of a compact object accreting matter from a binary companion. The periods of the pulsations, and the observed speed-up rates indicate rotating magnetized neutron stars as opposed to white dwarfs. The comparison of observed to predicted speed-up rates further argue for the presence of accretion disks and of dissipative torques.

Finally, the detailed period changes are shown to reflect the balance between the Alfven radius and the corotation radius for accreting matter. The study of these changes can lead to limits on the magnetic field of the neutron star.

46. UHURU OBSERVATIONS OF X-RAY EMISSION FROM SEYFERT GALAXIES.
H. Tananbaum, G. Peters, W. Forman, R. Giacconi, C. Jones, Y. Avni.

Using a point summation technique, we have systematically analyzed UHURU data for X-ray emission from the 88 Seyfert galaxies listed by Weedman (1977), plus MCG8-11-11 reported by the Ariel V group (Cooke et al. 1977; Ward et al. 1977) in addition to measuring the average X-ray intensity for 15 sources reported in the 4U and 2A catalogs, we find 3 new candidate sources. X-ray variability has previously been reported for NGC4151, 3C390.3, and MCG8-11-11; Mkn 279 is now also found to vary. Furthermore, we have observed significant flaring activity from NGC4151 with as much as a factor of 10 increase in intensity on a time possibly as short as 730 seconds. We find that from 9% to 19% of the diffuse 2-10 keV X-ray background can be attributed to emission from Seyfert galaxies. Our data show that the luminosity function for X-ray Seyferts is rather steep, with $\frac{dN}{dL} \propto L^{-2.3 \pm 1}$.

47. EXTRAGALACTIC X-RAY SOURCES.
R. Giacconi.

Observations of X-ray emission from the nuclei of active galaxies are briefly summarized and their relevance to models for galactic nuclei discussed. Particular emphasis is given to the recent observations of X-ray emission from Seyfert galaxies, their luminosity function, and the time scale for variability.

48. ORIGIN OF X-RAY EMISSION FROM CLUSTERS.
R. Giacconi.

The results on the X-ray emission from clusters are reviewed. Correlations with morphological properties of the clusters are discussed. Recent findings on this topic, as well as on the possible detection of X-ray emission from superclusters, are highlighted.

49. TRANSIENT X-RAY SOURCES IN THE GALACTIC PLANE.
L. Cominsky, C. Jones, W. Forman.

UHURU observations of the galactic plane indicate the presence of four X-ray sources not previously characterized as transient: MX0836-42 (Markert et al. 1975a), A1918+14 (Seward et al. 1976), 4U1730-22 and 4U1807-10 (Forman et al. 1977). X-ray light curves as well as positional and spectral information are presented for these sources and for 4U1908+00, a recurrent transient source. The frequency, duration, and intensity of galactic plane transients during the UHURU lifetime are discussed. Transient X-ray sources appear to be divided into 2 classes, due primarily to an observed bimodal spectral temperature distribution.

50. X-RAY CLUSTERS OF GALAXIES AND THE LUMINOSITY-RICHNESS RELATION.
C. Jones, W. Forman.

Combining the Second Ariel and Fourth UHURU catalogs of X-ray sources (Cooke et al. 1977, Forman et al. 1978), we have generated a reliable and comprehensive list of X-ray sources associated with clusters of galaxies. These cluster X-ray sources represent the most numerous class of identified extragalactic X-ray emitters. We have also obtained X-ray spectra for 14 clusters.

Using our present sample of X-ray clusters, we have explored various correlations in the measured parameters of clusters and find that X-ray luminosity is related to cluster richness (i.e. richness 2 clusters are more luminous than richness 0 and 1 clusters) and thereby to cluster mass. Other apparent correlations with X-ray luminosity such as Rood-Sastry or Bautz-Morgan morphological types can be explained as products of the richness-luminosity relation.

51. FAINT X-RAY SOURCES DETECTED NEAR COS-B GAMMA RAY POSITONS.
P. F. Julien, H. F. Helmken.

The UHURU data has been superposed with a point summation technique (PST) on the positions of the eleven unidentified COS-B gamma ray source positions (Hermsen et al. 1977). For the two other COS-B sources, SAS-II has identified CG185-5 with NP0532 (Crab Pulsar) and CG283-2 with the Vela Pulsar Thompson et al. 1975, Thomson et al. 1977, Lamb et al. 1977). We describe here: a) the reanalysis by the PST of three weak 4U sources which lie within COS-B error circles; b) a survey of the remaining COS-B positions which has uncovered a new X-ray source within the CG075+1 error circle; and c) the results of an investigation of the region surrounding CG195+4 and CG189+1.

52. THE FOURTH UHURU CATALOG OF X-RAY SOURCES.
W. Forman, C. Jones, L. Cominsky, P. Julien, S. Murray, G. Peters, H. Tananbaum, R. Giacconi.

Positions and intensities are presented for 339 X-ray sources observed by the UHURU (SAS-A) X-ray satellite observatory. We find good agreement between the sources in this catalog and those in the 3U and 2A catalogs. Optical and radio counterparts are suggested based on positional coincidence. The major classes of identified objects include binary stellar systems, supernova remnants, Seyfert galaxies, clusters of galaxies, and possibly the new class of superclusters of galaxies.

53. LONG-TERM BEHAVIOR OF MXB1730-335.
J.E. Grindlay, H. Gursky.

The rapid burster MXB1730-335 was detected on at least two occasions in 1971 and 1972 by UHURU, and coverage is available from late 1970 to early 1973. Combined with ANS coverage in 1975 and 1976, as well as published SAS-3 and Ariel 5 observations (1976-1977), a unique record of long-term burst activity is now available for this source. There appear to be burst-active states of $\sim$ 1- to 2-month duration that occur with a $\sim$ 15% duty cycle. The burst activity appears to be recurrent with a $\sim$ 0.5-1 year time scale. Implications for burster models are discussed.

54. X-RAY FLARES IN NGC4151: A THERMAL MODEL AND CONSTRAINTS ON A CENTRAL BLACK HOLE.
A.P. Lightman, R. Giacconi, H. Tananbaum.

Motivated by the recent discovery that the Seyfert galaxy NGC4151 exhibits rapid X-ray flaring, we discuss a thermal model for this source. Inverse Compton scattering of soft photons gives a predicted relationship for rise-time vs energy during X-ray flares. A second prediction, arising from the large optical depth to pair production deduced for the source, is that the power law spectrum should not extend to energies $\gtrsim m_e c^2 \sim 500$ keV. If it is assumed that NGC4151 is powered by accretion onto a black hole, then we deduce a black hole mass $M \lesssim 4 \times 10^6 M_\odot$ for the source, and suggest constraints on such black hole models in general.

55. THE DETECTION OF LARGE X-RAY HALOS IN CLUSTERS.
W. Forman, C. Jones, S. Murray, R. Giacconi.

Evidence is presented for the existence of extended X-ray halos around several X-ray clusters. Data were analyzed from the $0.5^\circ \times 5^\circ$ and the $5^\circ \times 5^\circ$ collimators on the UHURU satellite. Measured cluster intensities were compared with those detected by OSO-8 and Ariel 5 experiments. Higher counting rates for larger fields of view indicate extended X-ray emission. The implications are discussed with respect to the mass of the cluster gas and for models of super-cluster X-ray emission.

56. PROPERTIES OF THE 2-6 KEV PULSE PROFILES OF HERCULES X-1.
P.C. Joss, W.B. Fechner, W. Forman, C. Jones.

We have reanalyzed UHURU data of 2-6 keV X-ray pulsations from Hercules X-1 during three high states of the source. We find that the pulse amplitude and pulsed fraction vary systematically with $1^d.7$ orbital phase and with phase in the 35^d high-low cycle of the source. However, the shapes of the pulsations other-

wise show little variation with time, and the intensity of unpulsed X-rays does not vary greatly during most of each high state. From Monte Carlo simulations of the data, we find that the observations are consistent with no pulse-to-pulse shape fluctuations and with small but nonzero extrastatistical intensity fluctuations on time scales between ~ 0.1 sec and ~ 10 sec. Our results support models wherein the 35-day cycle is due to variable obscruation of the X-ray star by a wobbling accretion disk.

57. NO ABSTRACT

58. NO ABSTRACT

59. NUMBER-INTENSITY DISTRIBUTION OF HIGH GALACTIC LATITUDE X-RAY SOURCES.
S. Murray.

We calculate the corrections which should be applied to X-ray source count data due to intensity uncertainty and source confusion effects. For the source counts of the 3U Catalog, these corrections reduce the normalization of the count-flux relation $N(>S) \propto S^{-3/2}$ by about 20%.