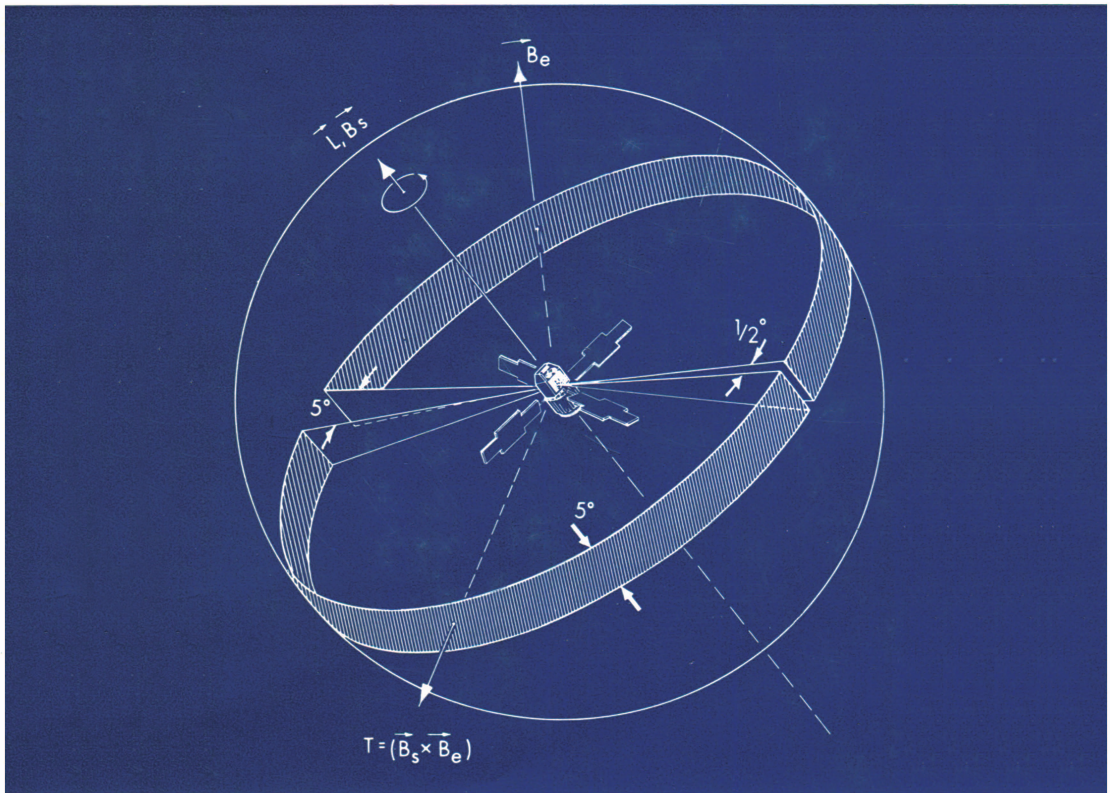


INTERNATIONAL ASTRONOMICAL UNION

SYMPOSIUM No. 37

NON-SOLAR X- AND GAMMA-RAY ASTRONOMY

Edited by L. GRATTON



INTERNATIONAL ASTRONOMICAL UNION

D. REIDEL PUBLISHING COMPANY / DORDRECHT-HOLLAND

NON-SOLAR X- AND GAMMA-RAY ASTRONOMY

SYMPOSIUM No. 37

Interstellar absorption divides the electromagnetic spectrum into two low energy regions and a high energy region. The latter is the subject of the present book. From the point of view of the observational requirements, it is convenient to further subdivide this region into sub regions of soft X-rays, hard X-rays, and γ -rays, respectively.

High energy astronomy is a very young science: it began in the early '60's and has evolved with remarkable speed. As the development of new observational techniques has played a crucial role in its progress, the book begins with a discussion of these techniques, including those that are planned for future work. Other subjects dealt with are: the results on individual X-ray sources and on the diffuse background, the relation of X-ray stars to other galactic objects, the physical phenomena responsible for the strong X-ray emissions by the discrete sources, and background radiation.

The papers many of which are original, written by the best specialists on the subject, make this work the most complete study on X-ray and γ -ray astronomy now available.

**D. REIDEL PUBLISHING COMPANY
DORDRECHT - HOLLAND**

NON-SOLAR X- AND GAMMA-RAY ASTRONOMY

INTERNATIONAL ASTRONOMICAL UNION
UNION ASTRONOMIQUE INTERNATIONALE

SYMPOSIUM No. 37

HELD IN ROME, ITALY, MAY 8-10, 1969

NON-SOLAR X- AND GAMMA-RAY
ASTRONOMY

EDITED BY

L. GRATTON

Dudley Observatory, Albany, N.Y., U.S.A.



D. REIDEL PUBLISHING COMPANY

DORDRECHT-HOLLAND

1970

*Published on behalf of
the International Astronomical Union
by
D. Reidel Publishing Company, Dordrecht, Holland*

*All Rights Reserved
Copyright © 1970 by the International Astronomical Union*

Library of Congress Catalog Card Number 71-115885

SBN 90 277 0160 1

*No part of this book may be reproduced in any form, by print, photoprint, microfilm,
or any other means, without written permission from the publisher*

Printed in The Netherlands by D. Reidel, Dordrecht

TABLE OF CONTENTS

1.	B. B. Rossi	Introductory remarks (Invited discourse)	1
2.	H. Gursky	A survey of instruments and experiments for X-ray astronomy (Invited discourse)	5
3.	H. Friedman*	General survey of X-ray sources (Invited discourse)	34
4.	P. W. Sanford, A. M. Cruise, and J. L. Culhane	Techniques for improving the sensitivity of proportional counters used in X-ray astronomy	35
5.	W. N. Charman, R. W. P. Drever, J. H. Fruin, and J. V. Jelley, J. L. Elliot, G. G. Fazio, D. R. Hearn, H. F. Helmken, G. H. Rieke, and T. C. Weekes	Upper-air fluorescence as a tool in X-ray astronomy and searches for X-rays from NP 0532 and other pulsars	41
6.	A. P. Willmore	A proposal for an X-ray experiment for Cos-B	50
7.	G. W. Clark	Studies of discrete cosmic X-ray sources at M.I.T. (Invited discourse)	54
8.	L. E. Peterson	Properties of individual X-ray sources (Invited discourse)	59
9.	K. G. McCracken*	Properties of individual X-ray sources (Invited discourse)	81
10.	D. J. Adams, B. A. Cooke, K. Evans, and K. A. Pounds	Rocket observations of Virgo XR-1	82
11.	R. Batstone,* B. Cooke, R. Gott, and E. Stewardson	Intensities and spectra of several galactic X-ray sources	87

* An asterisk means that the author(s) has (have) not delivered the text of his (their) paper.

12.	U. R. Rao, E. V. Chitnis, A. S. Prakasarao, and U. B. Jayanthi	X-ray flux from discrete sources	88
13.	P. C. Agrawal, S. Biswas, G. S. Gokhale, V. S. Iyengar, P. K. Kunte, R. K. Manchanda, and B. V. Sreekantan	Energy spectra of several discrete X-ray sources in the 20–120 keV range	94
14.	P. C. Agrawal, S. Biswas, G. S. Gokhale, V. S. Iyengar, P. K. Kunte, R. K. Manchanda, and B. V. Sreekantan	Sudden changes in the intensity of high energy X-rays from Sco X-1	104
15.	R. Giacconi	Properties of individual X-ray sources (Invited discourse)	107
16.	G. J. Fishman, F. R. Harnden, Jr., and R. C. Haymes	The flux of hard radiation from M87	116
17.	S. Hayakawa, T. Kato, F. Makino, H. Ogawa, Y. Tanaka, K. Yamashita, M. Matsuoka, S. Miyamoto, M. Oda, and Y. Ogawara	A rocket observation of cosmic X-rays in the energy range between 0.15 and 20 keV	121
18.	M. Matsuoka, S. Miyamoto, J. Nishimura, M. Oda, Y. Ogawara, and M. Wada	Angular size and position of the X-ray source Cyg-X-1	130
19.	P. Gorenstein, E. M. Kellogg, and H. Gursky	Interstellar absorption of X-rays emitted by supernova remnants	134

20.	S. S. Holt, E. A. Boldt, and P. J. Serlemitsos	The possible detection of iron line emission from Sco X-1	138
21.	W. H. G. Lewin, J. E. McClintock, and W. B. Smith	Hard X-rays from the southern sky	144
22.	R. Novick*	X-ray polarization from Sco X-1 and Tau X-1	145
23.	S. Ananthkrishnan, S. C. Chakravarty, and K. R. Ramanathan	Ionospheric effects of X-rays from discrete galactic sources	146
24.	H. M. Johnson	Non-solar Gamma and X-ray astronomy: optical observations (Invited discourse)	151
25.	L. Gratton	Spectroscopic and statistical properties of X-ray sources (Invited discourse)	162
26.	W. E. Kunkel and V. M. Blanco	Identification of X-ray sources at Cerro Tololo inter-American observatory	173
27.	R. C. Bless, A. D. Code, T. E. Houck, C. F. Lillie, and J. F. McNall	OAO observations of Sco X-1	176
28.	G. S. Mumford	On the magnitude-color relation for Cygnus X-2 and WX Centauri	177
29.	S. Sofia	On the nature of the X-ray sources Scorpio X-1 and Centaurus X-2	180
30.	B. Rossi	An X-ray pulsar in the Crab Nebula	183
31.	G. J. Fishman, F. R. Harnden, Jr., and R. C. Haymes	A search for pulsed hard radiation from the Crab Nebula	185
32.	H. Friedman*	X-ray pulsar in the Crab Nebula	190
33.	R. Novick*	X-ray pulsar in the Crab Nebula	191
34.	G. G. Fazio, D. R. Hearn, H. F. Helmken, G. H. Rieke, and T. C. Weekes	A search for high-energy γ -rays from pulsars	192
35.	B. Bertotti, A. Cavaliere, and F. Pacini	Radio, optical and X-ray emission from pulsars	196
36.	W. H. Tucker	Rotating neutron stars, pulsars, and cosmic X- ray sources	202

37.	L. Woltjer	Emission mechanisms in X-ray sources (Invited discourse)	208
38.	J. E. Felten	Theories of discrete X-ray and γ -ray sources (Invited discourse)	216
39.	C. de Loore and C. de Jager	Predicted X-ray fluxes of stellar coronas	238
40.	R. E. Wilson	Physical processes in Cyg X-2	242
41.	K. M. V. Apparao	The electromagnetic spectrum of the Crab Nebula	247
42.	G. G. Fazio, H. F. Helmken, G. H. Rieke, and T. C. Weekes	A lower limit to the magnetic field in the Crab Nebula from cosmic γ -ray experiments at 10^{11} eV	250
43.	P. A. Feldman and J. I. Silk	Some possible implications of the radio emission of Sco X-1	257
44.	M. Oda	Observational results on diffuse cosmic X-rays (Invited discourse)	260
45.	G. W. Clark, G. P. Garmire, and W. L. Kraushaar	Review of observational results on γ -ray background (Invited discourse)	269
46.	B. A. Cooke, R. E. Griffiths, and K. A. Pounds	Evidence for a galactic component of the diffuse X-ray background	280
47.	P. C. Agrawal S. Biswas, G. S. Gokhale, V. S. Iyengar, P. K. Kunte, R. K. Manchanda, and B. V. Sreekantan	Observations on diffuse cosmic X-rays in the energy range 20–120 keV	289
48.	J. A. M. Bleeker, J. J. Burger, A. J. M. Deerenberg, H. C. van de Hulst, A. Scheepmaker, B. N. Swanenburg, and Y. Tanaka	Search for galactic γ -rays with energies greater than 500 MeV on board OGO-5	297
49.	G. W. Hutchinson, A. J. Pearce, D. Ramsden, and R. D. Wills	Spark-chamber observation of galactic γ -radiation	300

50.	B. G. Wilson and A. J. Baxter	The low energy diffuse cosmic X-radiation	306
51.	E. A. Boldt, U. D. Desai, S. S. Holt, and P. J. Serlemitsos	2–20 keV X-ray sky background	309
52.	C. E. Fichtel, D. A. Kniffen, and H. B. Ogelman	γ -ray astronomy balloon results	315
53.	D. Brini, F. Fuligni, and E. Horstman-Moretti	Measurement of the cosmic X-ray background in the 25–200 keV range	321
54.	M. Niel, G. Vedrenne, and R. Bouigue	Results of two balloon flights for the detection of high energy γ -rays	325
55.	J. I. Vette, D. Gruber, J. L. Matteson, and L. E. Peterson	The cosmic γ -ray spectrum near 1 MeV ob- served by the ERS-18 satellite	335
56.	A. N. Bunner, P. L. Coleman, W. L. Kraushaar, D. McCammon, T. M. Palmieri, A. Shilepsky, and M. Ulmer	Intensity and galactic absorption of soft back- ground X-rays	342
57.	G. Setti and M. J. Rees	Origin of the cosmic X-ray background (Invited discourse)	352
58.	S. Hayakawa	Cosmic background X-rays produced by inter- galactic innerbremsstrahlung	372
59.	S. Hayakawa, and Y. Tanaka	A model of γ -ray sources in the Galaxy	374
60.	J. Bergeron	The X-ray emission of a hot dense intergalactic plasma	377
61.	F. W. Stecker	Possible initial evidence of extragalactic cosmic- ray protons and the age of extragalactic cosmic- ray sources	382
62.	G. Steigman and J. Silk	Galactic line emission from 1–10 keV	385
63.	J. Silk	Diffuse cosmic X-rays from non-thermal inter- galactic bremsstrahlung	392

64.	M. J. Rees and G. Setti	Interactions of non-thermal X-rays and ultra- violet radiation with the intergalactic gas	402
65.	M. J. Rees	Soft X-rays from the Galaxy	406
66.	E. Boldt, A. Klimas, and G. Sandri	X-ray emission from the solar wind	408
67.	O. P. Manley and S. Olbert	Mechanism for X-ray production in extars	413
68.	L. Gratton	Concluding remarks	424