

PROCEEDINGS OF SPIE

Optics for EUV, X-Ray, and Gamma-Ray Astronomy VI

**Stephen L. O'Dell
Giovanni Pareschi**
Editors

**26–29 August 2013
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 8861

Proceedings of SPIE 0277-786-786X, V.8861

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Optics for EUV, X-Ray, and Gamma-Ray Astronomy VI, edited by Stephen L. O'Dell,
Giovanni Pareschi, Proc. of SPIE Vol. 8861, 886101 · © 2013 SPIE
CCC code: 0277-786X/13/\$18 · doi: 10.1117/12.2046477

Proc. of SPIE Vol. 8861 886101-1

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

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Author(s), "Title of Paper," in *Optics for EUV, X-Ray, and Gamma-Ray Astronomy VI*, edited by Stephen L. O'Dell, Giovanni Pareschi, Proceedings of SPIE Vol. 8861 (SPIE, Bellingham, WA, 2013) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819497116

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445

SPIE.org

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Printed in the United States of America.

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Introduction

The conference, *Optics for EUV, X-Ray, and Gamma-Ray Astronomy VI*, met August 27-29 in San Diego, California, as part of the **SPIE Optics + Photonics 2013** international symposium **Optical Engineering + Applications**. As with previous conferences in this series, it provided an effective forum for discussion of recent progress in imaging and spectroscopic optics for EUV, x-ray, and gamma-ray astronomy. With over 60 papers in 12 sessions, this volume attests to the strength of research in this field, more than 50 years after the first discovery of a cosmic x-ray source and the initial concept of an x-ray focussing telescope, proposed by Giacconi and Rossi. Particularly indicative of the continued vitality of this field was the sustained high attendance throughout the 3-day conference and the participation of numerous graduate-student and post-doctoral researchers.

Approximately 30% of the papers address optics for gamma-ray astronomy (Sessions 1–3); 35%, grazing-incidence telescopes (Sessions 4–5) and supporting technologies (Sessions 6–8) for x-ray astronomy. The remaining papers report on technologies for x-ray gratings (Session 9), on analysis and test methods (Sessions 10–11), and on novel optics (Session 12) for high-energy astrophysics.

OPTICS FOR INDIRECT GAMMA-RAY MEASUREMENT (Session 1) mainly discusses technologies for ground-based Imaging Atmospheric Cherenkov Telescopes (IACTs). IACTs—e.g., VERITAS, MAGIC and HESS arrays—measure energetic (\approx TeV) γ rays through analyzing the blue Cherenkov light that is beamed forward by a γ -ray-induced atmospheric shower of relativistic charged particles. The papers primarily report on implementation of mirrors and telescopes for the forthcoming international Cherenkov Telescope Array (CTA). CTA will utilize nearly 200 telescopes of different sizes, with total reflecting area $> 10000 \text{ m}^2$. Funding limits the areal cost to 2.5 k\$/m², which seems achievable given that the required imaging quality for IACTs—typically, a few-arcminute resolution—is much more relaxed than that for an astronomical optical telescope. Adequately supported (normal-incidence) segmented reflectors based upon glass foils (produced via hot or cold replication) appear very attractive and share several technologies with slumped-glass grazing-incidence mirrors being developed for x-ray telescopes.

LAUE LENSES I AND II (Sessions 2 and 3) address the use of Laue lenses, based on natural crystals, for focusing astronomical γ rays in the energy band 0.1–1 MeV. Although true imaging may not be possible with Laue lenses—due to severe off-axis aberrations for single-reflection grazing-incidence optics—concentrating γ rays into a small area greatly increases the sensitivity for detection and measurement of cosmic γ -ray sources. Papers in these sessions describe scientific prospects for soft- γ -ray astronomy using Laue lenses, potential configurations to broaden the energy range (for continuum measurements), or to enhance effective area over narrow energy bands (for nuclear spectroscopy), and test facilities and results. Several papers report significant progress in fabricating, mounting, and characterizing bent and mosaic crystals for Laue-lens telescopes. As an aside, we note that multilayer-coated grazing-incidence optics (cf. Session 8) may provide an alternative to Laue lenses for soft- γ -ray focusing.

TELESCOPES (FLIGHT) (Session 4) reports on the status and on recent calibration of mirror assemblies for two x-ray-astronomy satellites to be launched in 2015. The JAXA *Astro-H* satellite will carry 2 Soft-X-ray Telescopes (SXT, provided by NASA Goddard Space Flight Center) and 2 Hard-X-ray Telescopes (HXT, provided by Nagoya University). The SXT and HXT mirror modules utilize epoxy-replicated formed aluminium foils, similar to those flown aboard JAXA's *Suzaku* satellite. The Russian *Spectrum-Röntgen-Gamma* satellite will carry 7 eROSITA (soft-x-ray) mirror modules (provided by the Max-Planck-Institut für extraterrestrische Physik, MPE) and 7 ART-X (medium-x-ray) mirror modules (provided by the Russian Space Research Institute, IKI). The eROSITA and ART-X mirror modules utilize electroformed-nickel replicated shells, similar to those flown aboard ESA's *XMM-Newton* satellite.

TELESCOPES (DEVELOPMENT) (Session 5) summarizes technology development for future x-ray telescopes. Most prominent are potential ESA or NASA large x-ray missions, with effective area $> 1 \text{ m}^2$ and angular resolution $< 10''$ half-energy width (half-power diameter). Achieving such large aperture areas calls for a scalable, modular design using segmented grazing-incidence optics. In terms of performance and technology readiness, the currently most advanced approaches employ either silicon pore optics (ESA's leading candidate) or slumped-glass mirrors (NASA's leading candidate, ESA's back-up).

MIRROR TECHNOLOGIES (Session 6) addresses research into fabrication of precision grazing-incidence mirrors—both segmented and full-shell. Papers on slumped-glass segments discuss various approaches to slumping, glass-strength issues, and post-slumping figure correction. Papers on full-shell grazing-incidence mirrors report on research into plasma-spray replication and into direct fabrication of monolithic thin shells.

ALIGNMENT AND ASSEMBLY (Session 7) describes various issues in alignment, mounting, and assembly of slumped-glass mirrors. Owing to their flimsy nature, the ability to align and mount thin glass foils without significant distortion is essential to achieving the angular resolution needed for future missions.

COATINGS (Session 8) emphasizes depth-graded multilayer x-ray optical coatings, which enhance reflectance at high energies. Successfully implemented in *NuSTAR* and the up-coming *Astro-H*, multilayer or complex coatings for x-ray telescopes are a reality. This demonstrated technology is now under study for future x-ray telescopes (e.g., *ATHENA+*) and as an alternative to Laue lenses (Sessions 2 and 3) for soft- γ -ray telescopes. In addition, we note that multilayer coatings have wide applicability outside x-ray astronomy—e.g., biomedical, neutron, and cosmic-ray instrumentation.

SPECTROGRAPHS (Session 9) reports on research into gratings for high-resolution dispersive spectroscopy for x-ray astronomy. Combined with sub-aperturing to minimize image size in the dispersion direction, either critical-angle transmission (CAT) gratings or off-plane reflection gratings offer the prospect of achieving resolving powers $R > 3000$ below 1 keV, as needed for plasma diagnostics in future x-ray astrophysics missions. The last paper of the session describes a novel polarimeter using laterally-graded multilayer-coated optics matched to a grating spectrometer.

DESIGN AND ANALYSES (Session 10) includes diverse topics. The papers report on designs for baffling stray x rays, on analysis of intrafocal x-ray images as a metrology tool, and on modeling mirror mounting schemes to minimize distortions.

TEST METHODS (Session 11) describes facilities, instrumentation, and techniques for precision metrology and for EUV and x-ray performance testing of mirrors and of telescopes.

NOVEL OPTICS (Session 12) concludes these Proceedings with concepts for advanced x-ray imaging telescopes, ranging from wide-field x-ray telescopes to x-ray interferometers. Papers on technology development for active (adjustable) x-ray telescopes address possible approaches for alignment adjustment and figure correction of mounted, thin, grazing-incidence mirrors—either on-ground or in-space. Such techniques might be needed to realize the next next-generation x-ray observatory—a large-aperture-area (few m^2) telescope with *Chandra*-class (sub-arcsecond) angular resolution.

We thank the Program Committee for helping to organize the technical program and for fostering broad participation, and the session chairs and presenters for a successful and stimulating conference. We also appreciate the efforts of the SPIE staff in organizing and implementing the Conference and in publishing these Proceedings.

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