



Universiteit
Leiden
The Netherlands

From electrons to stars : modelling and mitigation of radiation damage effects on astronomical CCDs

Prod'homme, T.

Citation

Prod'homme, T. (2011, November 22). *From electrons to stars : modelling and mitigation of radiation damage effects on astronomical CCDs*. Retrieved from <https://hdl.handle.net/1887/18136>

Version: Corrected Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/18136>

Note: To cite this publication please use the final published version (if applicable).

Bibliography

- Anderson J., Bedin L. R., 2010, *PASP*, 122, 1035
- Anderson J., King I. R., 2000, *PASP*, 112, 1360
- Bastian U., Biermann M., 2005, *Astronomy & Astrophysics*, 438, 745
- Bombrun A., Lindegren L., Holl B., Hobbs D., Lammers U., Bastian U., 2011, in preparation for *Astronomy and Astrophysics*
- Bombrun A., Lindegren L., Holl B., Jordan S., 2010, *A&A*, 516, A77
- Bristow P., 2003, Technical report, Application of Model Derived Charge Transfer Inefficiency Corrections to STIS Photometric CCD Data
- Bristow P., Kerber F., Rosa M. R., 2005, in A. M. Koekemoer, P. Goudfrooij, & L. L. Dressel ed., *The 2005 HST Calibration Workshop STIS Calibration Enhancement: Wavelength Calibration and CTI*
- Brown S. W., 2009a, Technical report, Further analysis of Radiation Campaign 1. DPAC
- Brown S. W., 2009b, Technical report, Independent Analysis of Astriums Radiation Campaign 2. DPAC
- Burt D., 2003, Technical report, AF CCD Design Report. e2v technologies plc
- Burt D., 2005a, Technical report, AF CCD Design Justification. e2v technologies plc
- Burt D., 2005b, Technical report, Re-Design of the AF CCD (CCD91). e2v technologies plc
- de Bruijne J., 2008, Technical report, CCD pixel pitch, stitch boundaries, and supplementary buried channel. ESA/ESTEC
- de Bruijne J., 2009a, Technical report, Along- and across-scan location-estimation performance. ESA/ESTEC
- de Bruijne J., 2009b, Technical report, Gaia astrometric performance: summer -2009 status. ESA/ESTEC
- de Bruijne J. H. J., 2005, in C. Turon, K. S. O'Flaherty, & M. A. C. Perryman ed., *The Three-Dimensional Universe with Gaia Vol. 576 of ESA Special Publication, Accuracy Budget and Performances*. pp 35–+
- Dolphin A. E., 2009, *PASP*, 121, 655

- Drimmel R., Bucciarelli B., Lattanzi M. G., Spagna A., Jordi C., Robin A. C., Reylé C., Luri X., 2005, in C. Turon, K. S. O'Flaherty, & M. A. C. Perryman ed., *The Three-Dimensional Universe with Gaia* Vol. 576 of ESA Special Publication, *What Gaia Will See: All-Sky Source Counts from the GSC2*. p. 163
- Drimmel R., Spagna A., Bucciarelli B., et al., 2005, Technical report, *What Gaia will see - source counts in G based on GSC2*, <http://www.rssd.esa.int/llink/livelink/open/452346>. INAF
- ESA 1997, *The Hipparcos and Tycho Catalogues*
- Feynman J., Spitale G., Wang J., Gabriel S., 1993, *Journal of Geophysical Research*, 981, 13281
- Fusero F., 2007, Technical report, *Gaia Radiation Analysis Report*. EADS Astrium
- Georges L., 2008, Technical report, *Tests Report of the Radiation Campaign 2*. EADS Astrium
- Georges L., 2009, Technical report, *Radiation Campaign 3 Astrium astrometric regular tests report*. EADS Astrium
- Goudfrooij P., Kimble R. A., 2002, in S. Arribas, A. Koekemoer, & B. Whitmore ed., *The 2002 HST Calibration Workshop : Hubble after the Installation of the ACS and the NICMOS Cooling System Correcting STIS CCD Photometry for CTE Loss*. p. 105
- Grant C. E., Bautz M. W., Kissel S. E., LaMarr B., 2004, in A. D. Holland ed., *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 5501, A charge transfer inefficiency correction model for the Chandra advanced CCD imaging spectrometer*. pp 177–188
- Hall D., 2010, Technical report, *Analysis of the RVS tests in the 3rd Astrium Radiation Campaign*. Open University
- Hall R. N., 1952, *Physical Review*, 87, 387
- Hardy T., Murowinski R., Deen M. J., 1998, *IEEE Transactions on Nuclear Science*, 45, 154
- Høg E., 2008, <http://www.astro.ku.dk/~erik/History.pdf>
- Holl B., Hobbs D., Lindegren L., 2010, in S. A. Klioner, P. K. Seidelmann, & M. H. Soffel ed., *IAU Symposium Vol. 261 of IAU Symposium, Spatial correlations in the Gaia astrometric solution*. pp 320–324
- Holl B., Lindegren L., Hobbs D., 2009, Technical report, *AGISLab A facility for experimental astrometric solutions*. DPAC
- Holland A., Smith D., 2004, Technical report, *Charge injection strategies for Gaia*. Open University

- Hopkinson G., 2006, Technical report, Final Report Radiation Testing of Gaia AF and MBP CCDs. Surrey Satellite Technology Ltd.
- Hopkinson G., 2008, Technical report, Gaia Cold Irradiation Final Report. Surrey Satellite Technology Ltd.
- Hopkinson G., Short A., Vetel C., Zayer I., Holland A., 2005, *IEEE Transactions on Nuclear Science*, 52, 2664
- Janesick J., 2001, *Scientific Charge-Coupled Devices*. SPIE
- Jordi C., Gebran M., Carrasco J. M., de Bruijne J., Voss H., Fabricius C., Knude J., Valenari A., Kohley R., Mora A., 2010, *Astronomy & Astrophysics*, 523, A48
- Katz D., et al., 2004, *MNRAS*, 354, 1223
- Kohley R., 2011, in *EAS Publications Series Vol. 45 of EAS Publications Series, Next Generation of Light Detectors in Astronomy*. pp 73–80
- Kohley R., Raison F., Martin-Fleitas J. M., 2009, in *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 7439, Gaia: operational aspects and tests of Gaia Flight Model CCDs*
- Lindgren L., 1978, in F. V. Prochazka & R. H. Tucker ed., *IAU Colloq. 48: Modern Astrometry Photoelectric astrometry - A comparison of methods for precise image location*. pp 197–217
- Lindgren L., 1998, Technical report, Charge trapping effects in CCDs for Gaia astrometry, http://www.rssd.esa.int/doc_fetch.php?id=2844371. Lund Observatory
- Lindgren L., 2003, Technical report, Representation of LSF and PSF for GDAAS-2. Lund Observatory
- Lindgren L., 2005, in C. Turon, K. S. O’Flaherty, & M. A. C. Perryman ed., *The Three-Dimensional Universe with Gaia Vol. 576 of ESA Special Publication, The Astrometric Instrument of Gaia: Principles*. pp 29–+
- Lindgren L., 2006, Technical report, Centroid definition for the Astro Line Spread Function. Lund Observatory
- Lindgren L., 2008, Technical report, A general Maximum-Likelihood algorithm for model fitting to a CCD sample data. Lund Observatory
- Lindgren L., 2009, Technical report, Minimum-dimension LSF modelling. Lund Observatory
- Lindgren L., 2010, in S. A. Klioner, P. K. Seidelmann, & M. H. Soffel ed., *IAU Symposium Vol. 261 of IAU Symposium, Gaia: Astrometric performance and current status of the project*. pp 296–305

- Lindegren L., Babusiaux C., Bailer-Jones C., Bastian U., Brown A. G. A., Cropper M., Høg E., Jordi C., Katz D., van Leeuwen F., Luri X., Mignard F., de Bruijne J. H. J., Prusti T., 2008, in W. J. Jin, I. Platais, & M. A. C. Perryman ed., IAU Symposium Vol. 248 of IAU Symposium, The Gaia mission: science, organization and present status. pp 217–223
- Lindegren L., Bastian U., 2011, in EAS Publications Series Vol. 45 of EAS Publications Series, Basic principles of scanning space astrometry. pp 109–114
- Lindegren L., O’Mullane W., Hobbs D., Lammers U., 2011, A& A, in preparation
- Massey R., Stoughton C., Leauthaud A., Rhodes J., Koekemoer A., Ellis R., Shaghoulain E., 2010, MNRAS, 401, 371
- Mignard F., 2005, in C. Turon, K. S. O’Flaherty, & M. A. C. Perryman ed., The Three-Dimensional Universe with Gaia Vol. 576 of ESA Special Publication, Overall Science Goals of the Gaia Mission. pp 5–+
- Mignard F., Bailer-Jones C., Bastian U., Drimmel R., Eyer L., Katz D., van Leeuwen F., Luri X., O’Mullane W., Passot X., Pourbaix D., Prusti T., 2008, in W. J. Jin, I. Platais, & M. A. C. Perryman ed., IAU Symposium Vol. 248 of IAU Symposium, Gaia: organisation and challenges for the data processing. pp 224–230
- Mignard F., Drimmel R., 2007, DPAC: Proposal for the Gaia Data Processing, GAIA-CD-SP-DPAC-FM-030-02
- Nelder J., Mead R., 1965, Computer Journal, 7, 308
- O’Mullane W., Banday A. J., Górski K. M., Kunszt P., Szalay A. S., 2001, in A. J. Banday, S. Zaroubi, & M. Bartelmann ed., Mining the Sky Splitting the Sky - HTM and HEALPix. p. 638
- Pasquier J.-F., 2011, in EAS Publications Series Vol. 45 of EAS Publications Series, Native and irradiated Charge Transfer Inefficiency characterization. pp 61–66
- Paulet P., 2009, Technical report, Video processing unit (VPU) specification. EADS Astrium
- Perryman M. A. C., de Boer K. S., Gilmore G., Høg E., Lattanzi M. G., Lindegren L., Luri X., Mignard F., Pace O., de Zeeuw P. T., 2001, Astronomy & Astrophysics, 369, 339
- Press W., B.P. F., Teukolsky S., Vetterling W., 1992, Numerical recipes in Fortran. Cambridge University Press
- Prod’homme T., 2011, in EAS Publications Series Vol. 45 of EAS Publications Series, Radiation effects on Gaia CCDs, Modelling to mitigate the threat. pp 55–60

- Prod'homme T., Weiler M., Brown S., Short A., Brown A., 2010, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 7742, Comparison of a fast analytical model of radiation damage effects in ccds with experimental tests
- Rhodes J., Leauthaud A., Stoughton C., Massey R., Dawson K., Kolbe W., Roe N., 2010, Publications of the Astronomical Society of the Pacific, 122, 439
- Rhodes J. D., et al., 2007, ApJ, 172, 203
- Robin A. C., Reylé C., Derrière S., Picaud S., 2003, A&A, 409, 523
- Robin A. C., Reylé C., Grux E., The Gaia Dpac Consortium 2009, in M. Heydari-Malayeri, C. Reylé, & R. Samadi ed., SF2A-2009: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics Simulating Gaia observations using a "Universe Model". p. 79
- Schrabback T., et al., 2010, A&A, 516, A63
- Seabroke G., Holland A., Burt D., Robbins M., 2010, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 7742, Silvaco ATLAS model of ESA's Gaia satellite e2v CCD91-72 pixels
- Seabroke G., Holland A., Cropper M., 2008a, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 7021, Modelling radiation damage to ESA's Gaia satellite CCDs
- Seabroke G., Holland A., Cropper M., 2008b, in Dorn D. A., Holland A. D., eds, High Energy, Optical, and Infrared Detectors for Astronomy III Vol. 7021 of Proc. SPIE (Bellingham, WA, USA), Modelling radiation damage to ESA's Gaia satellite CCDs
- Seabroke G. M., Holland A. D., Burt D., Robbins M. S., 2009, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 7439, Modelling electron distributions within ESA's Gaia satellite CCD pixels to mitigate radiation damage
- Shockley W., Read W. T., 1952, Physical Review, 87, 835
- Short A., 2007, Technical report, A physical model of electron trapping effects in Gaia (TDI mode) CCDs. ESA
- Short A., Hopkinson G., Laborie A., Pouny P., Vetel C., Eaton T., Steward R., Holland A., Hutchinson I., Smith D., de Bruijne J., Gare P., Perryman M., Sarri G., Zayer I., 2005, in T. J. Grycewicz & C. J. Marshall ed., Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 5902, Gaia astrometric CCDs and focal plane. pp 31–44
- Short A., Prod'homme T., Weiler M., Brown S., Brown A., 2010, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 7742, A fast model of radiation-induced electron trapping in ccds for implementation in the gaia data processing

SIDC-team 2011, Monthly Report on the International Sunspot Number, online catalogue

Townsley L. K., Broos P. S., Garmire G. P., Nousek J. A., 2000, *ApJ*, 534, L139

Townsley L. K., Broos P. S., Nousek J. A., Garmire G. P., 2002, *Nuclear Instruments and Methods in Physics Research A*, 486, 751

van Leeuwen F., 2007a, Technical report, Dealing with CCD radiation damage in the Gaia data processing. DPAC

van Leeuwen F., 2007b, *Hipparcos, the New Reduction of the Raw Data. Astrophysics and Space Science Library Vol. 350*

van Leeuwen F., Lindegren L., 2007, Technical report, Outline of the Radiation Calibration Strategy for Astrometry, Photometry and Spectroscopy. DPAC

List of acronyms

Acronym	Definition
ABD	Anti-Blooming Drain
ACS	Advanced Camera for Surveys
AC	ACross scan
AF	Astrometric Field
AGIS	Astrometric Global Iterative Solution
AIV	Assembly, Integration, and Verification
AL	ALong scan
AU	Astronomical Unit
BAM	Basic-Angle Monitor
BC	Buried Channel
BP	Blue Photometer
CCD	Charge-Coupled Device
CDM	Charge Distortion Model
CEMGA	CTI Effects Models for GAia
CI	Charge Injection
CMOS	Complementary Metal-Oxide-Semiconductor
CTE	Charge Transfer Efficiency
CTI	Charge Transfer Inefficiency
DM	Demonstration Model
DOB	Diffuse Optical Background
DPAC	Gaia Data Processing and Analysis Consortium
EADS	European Aeronautic Defence and Space company
ELSA	European Leadership in Space Astrometry
EM	Engineering Model
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESTEC	European Space Research and Technology Centre
eV	electronvolt
FM	Flight Model
FOV	Field Of View
FPA	Focal Plane Array
FPR	First Pixel Response
FWC	Full Well Capacity
FWHM	Full Width at Half Maximum

GASS	GAia System Simulator
GIBIS	GAia Instrument and Basic Image Simulator
GSC	Guide Star Catalogue
HST	Hubble Space Telescope
HTM	Hierarchical Triangular Mesh
ID	Injection Diode
IG	Injection Gate
JASMINE	Japan Astrometry Satellite Mission for INfrared Exploration
JPL	Jet Propulsion Laboratory
L2	Lagrangian Point 2
LED	Light-Emitting Diode
LOS	Line Of Sight
LSF	Line Spread Function
μ as	micro-arcsecond
mas	milli-arcsecond
MeV	Mega-electronvolt
MIM	Minimum Injection Method
MOS	Metal-Oxide-Semiconductor
ML	Maximum-Likelihood
MNRAS	Monthly Notices of the Royal Astronomical Society
NIEL	Non-Ionizing Energy Loss
NOVA	Netherlands Research School for Astronomy
NSL	Nominal Scanning Law
PEM	Proximity Electronics Module
PKA	Primary Knock on Atom
PSF	Point Spread Function
QE	Quantum Efficiency
RC	Radiation Campaign
RP	Red Photometer
RVS	Radial Velocity Spectrometer
SEU	Single Event Upset
SIDC	Solar Influences Data Center
SM	Sky Mapper
SBC	Supplementary Buried Channel
SRH	Shockley-Read-Hall
SSTL	Surrey Satellite Technology Limited
TDI	Time-Delayed Integration
TID	Total Ionizing Dose
TDA	Technology Demonstration Activities
VTM	Voltage-Tunable Method
WFC	Wide Field Camera
WFS	WaveFront Sensor

Table 6.8 — List of acronyms used in this paper by alphabetical order.