

CHRISTOPHER MICHAEL HEIRWEGH

05/2021

Jet Propulsion Laboratory, California Institute of Technology - Planetary Science Section

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EDUCATION

- Ph.D. Applied and Industrial Physics** 2009 – 2014
Guelph-Waterloo Physics Institute (GWPI), Guelph, ON, Canada
Dissertation: Studies of Light Element X-ray Fundamental Parameters Used in PIXE
Supervisors: Profs. John L. (Iain) Campbell and Joanne O'Meara
- M.Sc. Medical Physics** 2006 – 2008
Department of Medical Physics, McMaster University, Hamilton, ON, Canada
Thesis: *In Vivo* Quantification of Bone Strontium Using X-Ray Fluorescence
Supervisor: Prof. David R. Chettle
- Continuing education 2004 – 2006
McMaster University, Hamilton, ON, Canada
English, economics, biology, chemistry and medical physics
- B.Sc. Physical Science – Honours degree** 2000 – 2004
McMaster University, Hamilton, ON, Canada

AWARDS AND CERTIFICATES

- Invited Speaker** – European X-ray Spec. Assoc. Virtual Meeting 2021
- Invited Speaker** – 70th Denver X-ray Conference, *Westminster, Colorado* 2021
- Certificate of Recognition** - Dedication to completion of PXL Flight Sensor Assembly, *JPL* 2020
- Invited Speaker** – Physics Dept. Colloquium, *University of Guelph, Guelph, Canada* 2020
- Mentoring in Action** – Program Completion, *JPL* 2019
- Invited Speaker** – 67th Denver X-ray Conference, *Westminster, Colorado* 2018
- Best Poster Award** – 2nd place, 14th PIXE conference, *Somerset West, South Africa* 2015

PROFESSIONAL EXPERIENCE**Research Scientist** 2018 – *present**Astrobiology and Ocean Worlds, Planetary Science, Jet Propulsion Laboratory, Pasadena CA, USA*

Principle Investigator (PI) – Pyro-electric X-ray Instrument NASA R&TD 2018 – 2021

Co-I and calibration lead – Planetary Instrument for X-ray Lithochemistry (PIXL) 2018 – 2021

Science Payload Downlink Lead (sPDL) – PIXL science operations 2021

PIXL Software Co-developer - PIQUANT and PIXLISE data processing routines 2016 – *present*Manager – PIXL Science Lab. 2018 – *present*

Engineering – Science Liaison – PIXL Integration and Testing (IT) program 2018 – 2019

Test development consultant and analyst – PIXL IT program 2018 – 2019

Caltech Postdoctoral Fellow & JPL Postdoctoral Scholar 2016 – 2018*Planetary Science, Jet Propulsion Laboratory, Pasadena CA, USA*

Calibration Test Lead – began work on PIXL’s elemental quantification

Procedure developer – co-designed PIXL’s flight hardware elemental quantification procedure

Software design consultant – consulted for the development of PIXL’s PIQUANT software

Postdoctoral Fellow 2014 – 2016*Guelph PIXE Group, Guelph-Waterloo Physics Institute, Guelph, ON, Canada***Research Projects**

Refined the elemental quantification procedure used to analyze light elements in geological materials using Proton Induced X-ray Emission (PIXE)

Influence of multi-vacancy X-rays satellite effects in analyzing alpha-particle X-ray spectrometer (APXS) spectra obtained from the Curiosity Rover - Mars Science Laboratory (MSL).

Beamline refurbishment – design and implementation of a magnetic proton deflection systems

TeachingSessional Lecturer: Radiation and Radioactivity – 3rd year undergraduate course in physics**Research Assistant – Doctor of Philosophy** 2009 – 2014*Guelph-Waterloo Physics Institute, Guelph, ON, Canada***Research**

Investigated non-Gaussian line-shapes in semi-conductor spectra

Produced new measurement of the K X-ray fluorescence yield parameter of silicon

Assessed accuracy of light element mass attenuation coefficients used by proton-induced X-ray emission (PIXE) analysis of geological materials

Research Assistant – Master of Science 2006 – 2008*Department of Medical Physics, McMaster University, Hamilton, ON, Canada***Research**

Compared MRI, ultrasound, CT imaging methods to accurately measure soft-tissue thickness

Assessed feasibility of quantifying bone strontium *ex vivo* using XRF

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Temporary Research Assistant (internship)

2003

Juravinski Cancer Centre, Department of Research, Hamilton, ON, Canada

Studied anti-angiogenic properties of doxycycline on avian embryos *in vivo*

RESEARCH INTERESTS

Development of X-ray instrument concepts for use on spacecraft
Application of spectroscopic analysis techniques to planetary science research
Semiconductor detector physics and spectral line-shapes peak fitting
X-ray fundamental parameter accuracy refinement
Energy- and wavelength-dispersive X-ray analysis methods
Charge-induced multiple-shell vacancy effects on X-ray emission

MEDIA AND OUTREACH

Interview – *Mars Exploration* – special issue in the Journal, Applied Spectroscopy, Society for Applied Spectroscopy (SAS), forthcoming. 04/07/2021
https://journals.sagepub.com/topic/collections-asp/asp-1-mars_exploration/asp

Interview – *Ancient Life on Mars? U of G Grad Aims to Find Out* – Portico, University of Guelph, Guelph, ON Canada. 04/02/2021 <https://porticomagazine.ca/2021/03/ancient-life-on-mars-u-of-g-grad-aims-to-find-out/>

Interview – *Simcoe scientist helping NASA find signs of ancient life on Mars* – The Hamilton Spectator, Hamilton, ON Canada. 03/02/2021 <https://www.thespec.com/news/hamilton-region/2021/03/02/nasa-mars-norfolk-perseverance-rover.html>

Speaking Engagement – *The Role of X-ray Spectroscopy in Investigating the Red Planet* – 6th grade class, Grimsby Elementary School, Grimsby, ON Canada. 12/17/2020.

Interview – *NASA's New Mars Rover Will Use X-Rays to Hunt Fossils* – JPL Media Coverage, JPL, Pasadena, CA USA. 09/22/2020 <https://www.jpl.nasa.gov/news/nasas-new-mars-rover-will-use-x-rays-to-hunt-fossils>

Speaking Engagement – *The Role of X-ray Spectroscopy in Investigating the Red Planet*, Simcoe Rotary Club, Simcoe, ON Canada. 11/03/2020 <https://www.norfolksunrise.org/Stories/nasa-visits-rcns>

Interview – *Simcoe native helps prepare Mars Perseverance* – The Simcoe Reformer, Simcoe, ON Canada. 08/12/2020 <https://www.simcoereformer.ca/news/local-news/simcoe-native-helps-prepare-mars-perseverance>

PUBLICATIONS

- Heirwegh, C.M. Elam W.T., O’Neil, L.P. The Focused Beam X-ray Fluorescence Elemental Quantification Software Package PIQUANT, *Spectrochim. Acta B*, 2021 (**Accepted, pending revision**).
- Heirwegh, C.M., Clark, B.C., Elam, W.T., Liu, Y., O’Neil, L.P., Sinclair, K.P. Tice, M., Hurowitz, J.A., Allwood, A.C., Calibrating the PIXL Instrument for Elemental Analysis of Mars, 2021 *LPSC Abstract, poster presentation*.
- Campbell, J.L., Cureatz, D. J. T., Flannigan, E. L., Heirwegh, C. M., Maxwell, J.A., Russell, J. L., Taylor, S.M., The Guelph PIXE Software Package V. *Nucl. Instrum. Meth. B.*, 2021 (**Accepted, pending revision**).
- VanBommel, S.J., Berger, J.A., Rampe, E.B., Heirwegh, C.M., In-Situ X-ray Spectrometers in Space Exploration, in *Advances in Portable X-ray Fluorescence Spectrometry - Instrumentation, Application and Interpretation*, publisher: The Royal Society of Chemistry, 2021.
- Allwood, A.C., Wade, L.A., Foote, M.C. et al. PIXL: Planetary Instrument for X-ray Lithochemistry (vol 216, 134, 2020), *Space Sci. Rev.* **217** (2021) 28. <https://doi.org/10.1007/s11214-021-00801-2>
- Allwood, A.C., Wade, L.A., Foote, M.C. et al. PIXL: Planetary Instrument for X-ray Lithochemistry, *Space Sci. Rev.* **216** (2020) 134. <https://doi.org/10.1007/s11214-020-00767-7>
- Allwood A C, Rosing M T, Flannery D T, Hurowitz J A and Heirwegh C M, “Reassessing Evidence of Life in 3,700 million year old rocks of Greenland,” *Nature* **563** (2018) 241 – 244. <https://doi.org/10.1038/s41586-018-0759-x>
- Heirwegh C M, Elam W T, Flannery D T and Allwood A C, An empirical derivation of the x-ray optic transmission profile used in calibrating the Planetary Instrument for X-ray Lithochemistry (PIXL) for Mars 2020, *Powder Diffraction Journal* **33** (2018) 162 – 165. <https://doi.org/10.1017/S0885715618000416>
- Heirwegh C M, Petric M, Fazinić S, Kavčič M, Božičević Mihalić I, Schneider J, Zamboni I, and Campbell J L, Multiple ionization X-ray satellites of Mg, Al and Si in alpha particle PIXE, *Nucl. Instrum. Meth. B.* **428** (2018) 9 – 16. <https://doi.org/10.1016/j.nimb.2018.05.005>
- Menachekanian S, Flannery D T, Heirwegh C M, Tuite M L, Jamieson C S, Hodyss R, Williford K, “Investigating photochemical effects of micro-XRF analysis on common geochemical compounds,” *Advances in X-Ray Analysis* (2018) 61.
- Campbell J L, Ganly B, Heirwegh C M and Maxwell J A, Separation of detector non-linearity issues and multiple ionization satellites in alpha-particle PIXE, *Nucl. Instrum. Meth. B.* 414 (2018) 38 – 44. <https://doi.org/10.1016/j.nimb.2017.10.001>

- Flannigan E L, Heirwegh C M and Campbell J L, Role of the mass attenuation coefficient database in standardization of a silicon drift X-ray detector for PIXE analysis, *X-Ray Spectrom.* **47** (2018) 63 - 71. <https://doi.org/10.1002/xrs.2812>
- Campbell J L, Heirwegh C M and Ganly B, Non-linearity issues and multiple ionization satellites in the PIXE portion of spectra from the Mars alpha particle X-ray spectrometer, *Nucl. Instrum. Meth. B* **383** (2016) 143 – 151. <https://doi.org/10.1016/j.nimb.2016.07.004>
- Heirwegh C M, Campbell J L and Czamanske G K, Refinement of of major- and minor-element PIXE analysis of rocks and minerals, *Nucl. Instrum. Meth. B* **336** (2016) 40 - 50. <https://doi.org/10.1016/j.nimb.2015.10.018>
- Heirwegh C M, Pradler I and Campbell J L, 2015 Choice of mass attenuation coefficients for PIXE analysis of silicate minerals and rocks, *X-ray Spectrom.* **44** (2015) 63 - 68. <https://doi.org/10.1002/xrs.2583>
- Heirwegh C M, Pradler I and Campbell J L, 2013 An accuracy assessment of photo-ionization cross-section databases for 1-2 keV x-rays in light elements using PIXE, *J. Phys. B: At. Mol. Opt. Phys.* **46** (2013) 185602. <https://doi.org/10.1088/0953-4075/46/18/185602>
- Hopman T L, Heirwegh C M, Campbell J L, Krumrey M and Scholze F, An accurate determination of the K-shell fluorescence yield of silicon, *X-ray Spectrom.* **41** (2012) 164 - 171. <https://doi.org/10.1002/xrs.2378>
- Heirwegh C M, Chettle D R and Pejović-Milić A, *Ex vivo* evaluation of a coherent normalization procedure to quantify *in vivo* finger strontium XRS measurements, *Med. Phys.* **39** (2012) 832 - 841. <https://doi.org/10.1118/1.3673787>
- Heirwegh C M, Chettle D R and Pejović-Milić A, Evaluation of imaging technologies to correct for photon attenuation in the overlying tissue for *in vivo* bone strontium measurements, *Phys. Med. Biol.* **55** (2010) 1083 - 1098. <https://doi.org/10.1088/0031-9155/55/4/012>

JPL INTERNAL REPORTS

- Heirwegh C M, Elam, W T, “PIXL Flight Unit Elemental ReqID 76420 – Elemental Calibration Accuracy Report,” *Bravo-Doc-2373632*. (June 24, 2020) 15 pages.
- Heirwegh C M, Foote, M C, Elam, W T, “PIXL Elemental Composition Accuracy. ReqID 704208,” *D-94107*. (June 9, 2020) 12 pages.
- Heirwegh C M, Elam, W T, Sinclair K P, “PIXL Flight Unit Detectable Elements 76419 Report,” *Bravo-Doc-410*. (June 20, 2019) 16 pages.

Heirwegh C M, Elam, W T, Sinclair K P, “PIXL Flight Unit Detectable Elements 76418 Report,” *Bravo-Doc-2306924*. (June 10, 2019) 16 pages.

MENTORSHIP AND TEACHING

Sessional Lecturer

Guelph-Waterloo Physics Institute, Guelph, ON, Canada

Clinical Applications of Physics in Medicine – undergraduate & graduate physics course 2021
Radioactivity and Radiation Interactions - 3rd year undergraduate physics course. 2015

Mentor

2017 – 2019

Early career JPL employee and undergraduate university students participating in the JPL summer research internship opportunities. Two students in 2017, four in 2018, one in 2019.

Co-supervisor

2015 - 2016

M.Sc. Student in applied physics – University of Guelph, Guelph, Canada
Dept. of Physics, University of Guelph, Guelph, Ontario

Teaching Assistant

Year 1 physics labs and tutorials, Physics, University of Guelph, Guelph, Canada 2009 – 2012
Year 1 statistics labs and tutorials, Math, McMaster University, Hamilton, Canada 2008
Year 1 physics labs, Physics, McMaster University, Hamilton, Canada 2004 – 2008

CONFERENCES, POSTERS AND WORKSHOPS (* - presenter)

Heirwegh C M*, Liu Y, Clark B C, Elam W T, O’Neil L P, Sinclair K P, Tice M, Hurowitz J A, Allwood A C. Calibrating PIXL for Elemental Analysis on Mars (Poster) 2021 Lunar and Planetary Science Virtual Conference, March 2021.

Heirwegh C M*, Tallarida N and Wade L A. Positioning capabilities of the Planetary Instrument for X-ray Lithochemistry (Presentation – IXCOM) Joint meeting – 68th Denver X-ray Conference and 25th International Congress of X-ray Optics and Microanalysis, August 2019, Chicago, Illinois, USA.

Munguia-Flores H, Zhong B H, Uckert K, Hodyss R P and Heirwegh C M*. Concept testing of a low power pyroelectric X-ray source for application in planetary explorations (Poster - DXC) Joint meeting – 68th Denver X-ray Conference and 25th International Congress of X-ray Optics and Microanalysis, August 2019, Chicago, Illinois, USA.

Kavčič M, Petric M, Fazinić S*, Božičević Mihalić I, Zamboni I, Heirwegh C M, Schneider J, and Campbell J L. Multiple ionization of K X-ray satellites of Mg, Al, Si in alpha particle PIXE. (Poster) EXRS 2018 – European Conf. on X-ray Spectrometry, June 2018, Ljubljana, Slovenia.

- Heirwegh C M*, Elam W T, Flannery D T and Allwood A C. A first look at the quantification capabilities of the prototype Mars 2020 Planetary Instrument for X-ray Lithochemistry. (Presentation) 24th International Congress on X-ray Optics and Microanalysis, September 2017, Trieste, Italy.
- Menachekanian S*, Flannery D T, Tuite M L, Heirwegh C M, Allwood A C, Jamieson C S, Hodyss R and Williford K. Investigating photochemical effects of micro-XRF analysis on common geochemical compounds. (Poster) 66th Denver X-ray Conference, July 2017, Big Sky, Montana, USA.
- Heirwegh C M*, Elam W T, Flannery D T and Allwood A C. Calibration of a μ -XRF prototype instrument used in modelling the performance of the Planetary Instrument for X-Ray Lithochemistry (PIXL) for Mars 2020. (Presentation) 66th Denver X-ray Conference, July 2017, Big Sky, Montana, USA.
- Flannigan E L*, Campbell J L and Heirwegh C M. Standardization of a silicon drift detector using PIXE. (Poster) 15th International Conference on Particle Induced X-Ray Emission, April 2017, Split, Croatia.
- Heirwegh C M and Campbell J L*. Spectrum artefacts due to non-linear response in silicon drift detector systems (Poster) 15th International Conference on Particle Induced X-Ray Emission, April 2017, Split, Croatia.
- Heirwegh C M*. Improvement to Major Element PIXE Analysis through Accuracy Assessment of Mass Attenuation Coefficients (Presentation) Symposium on Applications of Fundamental Parameters in X-ray Analysis, June 3-4, 2016, University of Western Ontario, London, Canada.
- Heirwegh C M* and Campbell J L. Refinement of major and minor element PIXE analysis of rocks and minerals (Presentation) 14th International Conference on Particle Induced X-Ray Emission, February 2015, Somerset West, South Africa.
- Campbell J L, Russell J L, Maxwell J A and Heirwegh C M*. GUPIX and GUMAP (Presentation) 14th International Conference on Particle Induced X-Ray Emission, February 2015, Somerset West, South Africa.
- Heirwegh C M*, Pradler I and Campbell J L. Comparison of x-ray mass attenuation coefficients used in PIXE analysis of silicate minerals and glasses. (Poster) 14th International Conference on Particle Induced X-Ray Emission, February 2015, Somerset West, South Africa.
- Heirwegh C M*, Pradler I and Campbell J L. A comparison of attenuation coefficient databases used in μ -PIXE analysis – XCOM, Chantler or...? (Presentation) 13th International Conference on Particle Induced X-Ray Emission, March 2013, Gramado, Brazil.

Heirwegh C M, Pradler I, Campbell J L. A comparison of attenuation coefficient databases used in PIXE analysis – XCOM, Chantler or...? (Presented on our behalf by M.-C. Lépy) 7th Workshop, International Initiative on X-Ray Fundamental Parameters, March 25-26th, 2014, Paris, France.

Heirwegh C M*, Butler R, Chettle D R, Pejović-Milić A. Evaluation of MR, CT and ultrasound imaging modalities for estimation of finger soft-tissue thickness: efforts to improve normalization of in vivo strontium x-ray fluorescence measurements. (Presentation) June 2008, 7th International Topical Meeting on Industrial Radiation and Radioisotopes Measurement Applications conference, 2008 in Prague, Czech Republic.

Da Silva E*, Heirwegh C, Pejović-Milić A, Heyd V. Use of hydroxyapatite bone composites for the calibration of in vivo EDXRF – based systems for bone strontium quantification. (Poster) June 2008, European Conference on X-ray Spectrometry, Cavtat, Dubrovnik, Croatia.

Heirwegh C M*. The use of chick chorioallantoic membranes in cancer research. (Presentation) November 2003, Canadian Undergraduate Physics Conference, McGill University, Montreal, Quebec, Canada.

SCHOLARLY AND PROFESSIONAL ACTIVITIES

Publication Peer Reviewer

2015 – 2021

Articles – Journal of Synchrotron Radiation

Article – Advances in X-ray Analysis – Denver X-ray Conference Proceedings

Article – Icarus

Articles - Journal of X-Ray Spectrometry

Communication - Nuclear Instruments and Methods A

Article - The Journal of Biological Trace Element Research

Conference proceeding - Nuclear Instruments and Methods B

Project Principle Investigator

NASA Research and Technological Development (R&TD) funded proposal

A Pyroelectric Instrument for Elemental Lithochemistry

2019 – 2021

Micro Focus XRF Quantification for Applications in Planetary Science (acting 3 mos.)

2018

Academic Supervisor

Supervised undergraduate students of the JPL Summer Internship Program, JPL

2017 – 2019

To students in undergraduate and graduate research projects.

2015 – 2016

NASA New Technology co-contributions

PIXELATE, an Astrobiology visualization tool Software, NTR #50960

2018

PIQUANT X-ray Fluorescence Quantification Software. v.2, NTR #50887

2020

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Accelerator Group Committee member

Accelerator Management Committee (AMC), University of Guelph, Canada 2012 – 2016
Quarterly meeting participation on accelerator operations, projects, upgrades, safety and funding.

Collaborator

University of Western Ontario - guest of Prof. Lyudmila Goncharova. 2015

Feasibility study using Rutherford backscatter to measure thickness of thin Ti layers.

J. Stefan Institute, Ljubljana, Slovenia – guest of Dr. M. Kavčič. 2014

Wavelength dispersive x-ray fluorescence measurements of Si satellite intensity

Soleil Synchrotron, St. Aubin, France – guest of Dr. M.-C. Lépy (CEA). 2013

Observed measurements of mass-attenuation coefficients in the soft x-ray region.

Field-work assistant

Xstrata Zinc Inc., Belldune, New Brunswick – supervisor: Dr. D. R. Chettle 2008

Performed bone lead XRF measurements on smelter workers as part of a multi-institutional project to monitor occupational lead levels *in vivo*.