CHRISTOPHER MICHAEL HEIRWEGH

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EDUCATION

2009 – 2014 **Ph.D. Experimental Physics**
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

2006 – 2008 **M.Sc. Medical Physics**
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

2004 – 2006 Continuing education in English, economics, biology, chemistry and medical physics
McMaster University, Hamilton, ON, Canada

2000 – 2004 **B.Sc. (Honours) Physical Science**
McMaster University, Hamilton, ON, Canada

SCHOLARSHIPS AND AWARDS

- Invited talk – 67th Denver X-ray Conference, Westminster, Colorado, 2018
- Best Poster Award – 2nd place, 14th PIXE conference, Somerset West, South Africa, 2015
- Ontario Graduate Scholarship, Physics, Guelph, 2009-2012 (3 years)
- Graduate Student Scholarship, Medical Physics, McMaster, 2006-2008 (2 years)
- Entrance Scholarship, Medical Physics, McMaster, 2006

PROFESSIONAL EXPERIENCE

2018 - 2019 **Scientist, Astrobiology and Ocean Worlds**
Planetary Science, Jet Propulsion Laboratory, Pasadena CA, USA
- X-ray Spectroscopy scientist for the Planetary Instrument for X-ray Lithochemistry (PIXL), selected for Mars 2020 – supporting instrument elemental calibration.
- Science – Engineering liaison for PIXL Integration and Testing (IT) program.
- Test development consultant and analyst for PIXL IT program.
- PIXL Science Lab Manager.

- -Principle Investigator (PI) - **P**yro-electric **I**nstrument for **R**ock **Ana**lysis (PIRANA) – JPL internally funded Research and Technology Development (R&TD) grant.
- Design consultant for PIQUANT software used to process PIXL data.

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

- Calibration Test Lead for PIXL, Mars 2020
- Lead developer of PIXL quantification procedure for flight instrument
- Design consultant for PIQUANT software used to process PIXL data

2014 – 2016 **Postdoctoral Fellow**
Guelph PIXE Group, GWPI, Guelph, ON, Canada

- Refinement of Proton Induced X-ray Emission (PIXE) techniques for Light Element Analysis of geological materials
- 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 – implementation of magnetic and electrostatic deflection systems

2009 – 2014 **Research Assistant** – Doctor of Philosophy
Guelph-Waterloo Physics Institute, Guelph, ON, Canada

- Investigation of non-Gaussian line-shapes in semi-conductor spectra
- Measurement of the K X-ray fluorescence yield of silicon
- Assessing X-ray database fundamental parameter accuracy for proton-induced X-ray emission (PIXE) studies of geological materials

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

- Comparison of medical imaging techniques: MRI, ultrasound, CT to accurately measure soft-tissue thickness
- Feasibility assessment of quantifying bone strontium *ex vivo* using XRF

2003 **Temporary Research Assistant (summer)**
Juravinski Cancer Center, Hamilton, ON, Canada

- Study of anti-angiogenetic 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

- Energy- and wavelength-dispersive X-ray analysis methods
- Experimental work to improve accuracy of X-ray fundamental parameters
- Charge induced multiple-shell vacancy effects on X-ray emission

PUBLICATIONS

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

CONFERENCES, POSTERS AND WORKSHOPS (* - presenter)

- 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 Conference on X-ray Spectrometry, June 2018, Ljubljana, Slovena.

- 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

2015 – 2019 **Publication Peer Reviewer**
Short communication - Nuclear Instruments and Methods A
Articles - Journal of X-Ray Spectrometry
Articles – Journal of Synchrotron Radiation
Article - The Journal of Biological Trace Element Research
Conference proceeding - Nuclear Instruments and Methods B.

2018 **Principle Investigator**
NASA Research and Development (R&TD) funded proposal – A Pyroelectric Instrument for Elemental Lithochemistry – granted to Christopher Heirwegh (FY'19), David Flannery (FY'18).

2018 **Acting Principle Investigator**
(3 mos. While PI on leave – responsible for grant report and closure process)
NASA Research and Development (R&TD) funded proposal – Micro Focus XRF Quantification for Applications in Planetary Science – granted to Abigail Allwood (FY'16 – FY'19).

2017 - 2018 **Intern Supervisor**
Supervised two (2017) and four (2018) summer interns at the Jet Propulsion Laboratory for concurrent 10 week work terms.

2018 **NASA New Technology co-contributions**
PIXELATE, an Astrobiology visualization tool Software, NTR #50960
PIQUANT X-ray Fluorescence Quantification Software. v.2, NTR #50887

2018 **Co-Investigator (not-selected)**
NASA ROSES PICASSO - 17-PICASSO17-0112 - NNH17ZDA001N-PICASSO.
Title: Development of a new X-ray source for X-ray analysis in Mars and other planetary missions, PI – Dr. Jose Velazco (3330).

2012 – 2016 **Committee member**
Accelerator Management Committee (AMC), University of Guelph, Canada – participated in quarterly meetings to address business related to accelerator operations, safety protocols, funding and research-driven changes to beam chamber setups.

2015 **Collaborator**
University of Western Ontario - guest of Prof. Lyudmila Goncharova. Feasibility study using Rutherford backscatter to measure thickness of thin Ti layers.

2015 – 2016 **Assistant supervisor**
To students in undergraduate and graduate research projects.

2014 **Collaborator and speaker**
J. Stefan Institute, Ljubjlana, Slovenia – guest of Dr. M. Kavčič.
Wavelength dispersive x-ray fluorescence measurements of Si satellite intensity and delivered a seminar talk.

2013 **Collaborator**
Soleil Synchrotron, St. Aubin, France – guest of Dr. M.-C. Lépy (CEA).
Observed measurements of mass-attenuation coefficients in the soft x-ray region.

2008 **Field-work assistant**
Xstrata Zinc Inc., Belldune, New Brunswick – supervisor: Dr. D. R. Chettle
Performed bone lead XRF measurements on smelter workers as part of a multi-institutional project to monitor occupational lead levels *in vivo*.

TEACHING AND MENTORSHIP

2017 – 2018 **Mentor**
Undergraduate university students participating in the JPL summer research internship opportunities. Two students in 2017 and four in 2018.

2015 **Instructor**
Radioactivity and Radiation Interactions - 3rd year undergraduate physics course.
Concepts in nuclear and atomic physics, radiation interactions, dosimetry and shielding
Dept. of Physics, University of Guelph, Guelph, Ontario

2009 – 2012 **Teaching Assistant**
First year physics labs and tutorials
Dept. of Physics, University of Guelph, Guelph, Ontario
Supervisor: Prof. M. Williams

2008 **Teaching Assistant**
First year statistics labs and tutorials
Dept. of Mathematics, McMaster University, Hamilton, Ontario
Supervisor: Prof. A. Childs

2004 – 2008 **Teaching Assistant**
First year physics labs
Dept. of Physics, McMaster University, Hamilton, Ontario
Supervisor: Prof. K. Hughes