

# Wesley C. Fraser

## Ph.D. in Astrophysics

H index = 16  
623 Citations

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### Thesis

#### **The Size Distribution of the Kuiper belt: Constraints on Accretion**

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I have performed multiple wide and deep optical ecliptic Kuiper belt surveys on the Canada-France Hawaii and Subaru telescopes. The sample of 107 Kuiper belt objects I discovered was used to measure the Kuiper belt size distribution. The size distribution is well described by a broken power-law that is steep for the largest objects that breaks to a much shallower slope at  $D \sim 200$  km. The creation of which required a prolonged collisional evolution that has disrupted bodies as large as the roll-over diameter. A numerical collisional evolution model developed by myself was used to calculate the evolution of the size distribution through collisional processing. I found that creation of the break through collisional processing is not possible in the current Kuiper Belt. Rather, the early Kuiper Belt was at least an order of magnitude more massive and experienced a heightened dynamical state. The belt must have undergone a basic history as follows:

After a short period of quiescent planet growth in a dynamically cold disk lasting no more than roughly 100 Myr, some event - likely the migration of the gas-giant planets - stirred up the belt and emplaced objects onto excited orbits comparable to what we observe today. This caused mutual collisions to be catastrophic rather than accretional, halting growth, and resulting in a massive collisional disruption event. This phase of enhanced collisional comminution lasted no more than 100 Myr, and modified the size distribution for all but the largest objects. After the size distribution attained a shape similar to that observed, a rapid mass depletion occurred, effectively halting the collisional evolution. The belt we see today is the remnant of this history and has evolved minimally since the epoch of mass depletion.

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## Most Significant Contributions to Research

**Fraser, W. C.**, Brown, M. E., Morbidelli, A., Parker, A., and Batygin, K. “*The Absolute Magnitude Distributions of Kuiper Belt Objects*”, 2014, *The Astrophysical Journal*, vol. 782, 100F. 43 citations.

We compiled all useable survey data to measure the absolute magnitude distributions of the dynamically excited (hot) and quiescent (cold) Kuiper Belt Objects (KBOs). We found that their distributions, while both well described as broken power-laws, are formally incompatible. Further, unlike the cold objects, we found that the hot objects and Jupiter Trojans possess indistinguishable absolute magnitude distributions. This is in agreement with predictions of the Nice model - total mass and bulk properties - in which the hot KBOs and Trojans originated from the same primordial population, and thus share the same size distribution. Our results disagree with that model though, demonstrating that the cold KBOs do not share the same cosmogony as the hot KBOs or Jupiter Trojans.

**Fraser, W. C.**, and Brown, M. E. “*The Hubble Wide Field Camera 3 Test of Surfaces in the Outer Solar System: the Compositional Classes of the Kuiper Belt*”, 2012, *The Astrophysical Journal*, vol. 749 33 F. 28 citations

We acquired substantial HST photometry from which we were able to develop a simple mixing model framework which successfully explained the enigmatic surface properties (colour, composition, albedo) of small Kuiper Belt Objects. This model led to the hypothesis that the compositions of Kuiper Belt Objects were not a result of formative processes, but a result of their residence locations within the primordial disk.

**Fraser, W. C.** and Brown, M. E. “*Quaoar: A Rock in the Kuiper Belt*” 2010, *The Astrophysical Journal*, vol. 714, pg. 1547. 20 citations.

From high resolution imagery, we determined the orbit and system mass of the Quaoar-Weywot Kuiper Belt binary. We found that Quaoar has an extremely high density demonstrating that many Kuiper Belt Objects are not composed primarily of ice, but are in fact predominantly rocky.

**Fraser, W. C.** “*The Collisional Divot in the Kuiper Belt Size Distribution*” 2009, *The Astrophysical Journal*, vol. 706, pg. 119F. 33 citations.

In this work I demonstrated that the break in the size distribution of Kuiper Belt Objects can be collisionally generated within the framework of the preferred formation model of the outer Solar System. Specific features of the size distribution predicted to exist by my model have recently been detected providing the first direct evidence that the Solar System evolved according to my model's predictions.

## Science Programs and Collaborations

### **Gemini Telescope Large Program, Col-OSSOS: The Colours of the Outer Solar System Origins Survey**

Principal Investigator of the ColOSSOS Large Program on the Gemini Telescope. I have been awarded 386 hours of observing time between 2014 and 2018. Observing activities have started. The program will characterize the surfaces of 140 Kuiper Belt Objects discovered by the Outer Solar System Origins Survey.

### **Large Synoptic Survey Telescope, Solar System Science Collaboration, UK**

Point of Contact I am the UK representative to the LSST Solar System Science collaboration, acting as liaison between the North American and UK groups.

### **Occultations Science Team of the Outer Solar System Origins Survey**

Science Team Leader for the Occultations group of the Outer Solar System Origins Survey. The purpose of the group is to predict and observe stellar occultations by targets discovered in OSSOS.

### **Surfaces Science Team of the Outer Solar System Origins Survey**

Science Team Member for the Surfaces group of the Outer Solar System Origins Survey. The purpose of the group is to characterize the surface compositions of Kuiper Belt Objects discovered by the OSSOS.

## Academic Background

<b>Degree</b>	<b>School</b>	<b>Location</b>	<b>Date</b>
Ph. D. Astrophysics	University of Victoria	Victoria, BC	Sept. 2008
BSc. H. (Theoretical Physics)	McMaster University	Hamilton, ON	April 2004

## Fellowships, Awards, and Scholarships

Title	Institution	Date
Queen's Research Fellow	Queen's University, Belfast	Aug 2015 - Current
Plaskett Fellow	Herzberg Institute of Astrophysics	Sep-2011 - Aug 2015
Canadian Graduate Scholarship Doctoral	National Sciences and Engineering Research Council of Canada	Sep-2006 - Aug-2008
Graduate Student Scholarship	National Research Council of Canada	2006 - 2008
Canadian Graduate Scholarship Masters	National Sciences and Engineering Research Council of Canada	Sep-2004 - Aug-2006

## Complete Publication List

**Fraser, W. C.**, Alexandersen, M, Schwamb, M. E., Marsset, M., Pike, R. E., Kavelaars, J. J., Bannister, M. T., Benecchi, S., Delsanti, A. “*TRIPPy: Trailed Image Photometry in Python*”, 2016, The Astronomical Journal, vol. 151, 158F.

Muntean, E. A.; Lacerda, P.; Field, T. A.; Fitzsimmons, A.; **Fraser, W. C.**; Hunniford, A. C.; McCullough, R. W. “*A laboratory study of water ice erosion by low-energy ions*”, 2016, MNRAS, vol. 462, issue 3.

Bannister, M., ++ Fraser, W. C., and 35 co-authors. “*The Outer Solar System Origins Survey. I. Design and First-quarter Discoveries*”, 2016, The Astrophysical Journal, vol. 152, 70B.

Chen, Y., Lin, H. W., Holman, M. J., Payne, M. J., **Fraser, W. C.**, Lacerda, P.; Ip, W.-H., Chen, W.-P., Kudritzki, R.-P., Jedicke, R., Wainscoat, R. J., Tonry, J. L., Magnier, E. A., Waters, C., Kaiser, N., Wang, S.-Y., Lehner, M. “*Discovery of a New Retrograde Trans-Neptunian Object: Hint of a Common Orbital Plane for Low Semimajor Axis, High-inclination TNOs and Centaurs*”, The Astrophysical Journal Letters, vol. 827, 24C.

Parker, A., Pinilla-Alonso, N., Santos-Sanz, P., Stansberry, J., Alvarez-Candal, A., Bannister, M., Benecchi, S., Cook, J., **Fraser, W.**, Grundy, W., Guilbert, A., Merline, B., Moullet, A., Mueller, M., Olkin, C., Ragozzine, D. “*Physical Characterization of TNOs with the James Webb Space Telescope*” 2016, Publications of the Astronomical Society of the Pacific, vol. 128, 8010P.

Lin, Hsing Wen; ++ **Fraser, W. C.**, and 15 co-authors “*The Pan-STARRS 1 Discoveries of five new Neptune Trojans*”, Accepted for publication in the Astrophysical Journal.

Bannister, M.; ++ **Fraser, W. C.**, and 33 co-authors “*OSSOS: IV. Discovery of a dwarf planet candidate in the 9:2 resonance with Neptune*” Accepted for publication in the *Astrophysical Journal*.

**Fraser, W. C.**, Brown, M. E., Glass, F. “*The Hubble Wide Field Camera 3 Test of Surfaces in the Outer Solar System: Spectral Variation on Kuiper Belt Objects*”, 2015, *The Astrophysical Journal*, vol. 804, 31F.

**Fraser, W. C.**, Brown, M. E., Morbidelli, A., Parker, A., and Batygin, K. “*The Absolute Magnitude Distributions of Kuiper Belt Objects*”, 2014, *The Astrophysical Journal*, vol. 782, 100F.

**Fraser, W. C.**, Trujillo, C., Stephens, A. W., Gimeno, G. Brown, M. E., Gwyn, S., Kavelaars, J.J. “*Limits on Quaoar’s Atmosphere*”, 2013, *Astrophysical Journal Letters* vol. 774L..18F.

**Fraser, W. C.**, Gwyn, S., Trujillo, C., Stephens, A. W., Kavelaars, J. Brown, M. E., Bianco, F. B., Boyle, R. P., Brucker, M. J., Hetherington, N., Joner, M., Keel, W. C., Langill, P. P., Lister, T., McMillan, R. J., Young, L. “*Kuiper Belt Occultation Predictions*”, 2013, *Publications of Astronomical Society of the Pacific*. vol. 125..1000F.

**Fraser, W. C.**, Batygin, K., Brown, M. E., Bouchez, A. “*The Mass, Orbit, and Tidal Evolution of the Quaoar-Weywot System*”. 2013, *Icarus*. vol. 222. 357F.

**Fraser, W. C.**, and Brown, M. E. “*The Hubble Wide Field Camera 3 Test of Surfaces in the Outer Solar System: the Compositional Classes of the Kuiper Belt*”, 2012, *The Astrophysical Journal*, vol. 749 33 F

Brown, M. E., Schaller, E. L., **Fraser, W. C.** “*Water Ice in the Kuiper Belt*”, 2012, *The Astronomical Journal*, vol. 143 146B.

- I provided key observational evidence to support the model presented in this manuscript.

Brown, M. E., Schaller, E. L., and **Fraser, W. C.** “*A Hypothesis for the Color Diversity of the Kuiper Belt*”, 2011, *The Astronomical Journal Letters*, vol. 739 L60.

- I contributed the necessary photometry and arguments against why the proposed model might be correct

Brown, M. E., Burgasser, A. J., and **Fraser, W. C.** “*The Surface Composition of Large Kuiper Belt Object 2007 OR10*”, 2011, *The Astronomical Journal Letters*, vol. 738 L26.

- I contributed optical and NIR spectro-photometry of 2007 OR10.

**Fraser, W. C.**, Brown, M. E., and Schwamb, M. E. “*The Luminosity Function of the Hot and Cold Kuiper belt Populations*” 2010, *Icarus* vol. 210.

Konstantin, B., Brown, M. E., and **Fraser, W. C.** “*Retention of a Primordial Cold Classical Kuiper Belt in an Instability-Driven Model of Solar System Formation*”, 2011, The Astronomical Journal, vol. 738 13B.

- I guided the numerical experiments which led to the development of the resultant dynamical model.

Brown, M. E., Ragozzine, D., Stansberry, J., and **Fraser, W. C.** “*The Size, Density, and Formation of the Orcus-Vanth System in the Kuiper Belt*”, 2010, The Astronomical Journal, vol. 139 pg. 2700.

- I contributed photometry and astrometry of the Orcus-Vanth binary system

**Fraser, W. C.** and Brown, M. E. “*Quaoar: A Rock in the Kuiper Belt*” 2010, The Astrophysical Journal, vol. 714, pg. 1547.

**Fraser, W. C.** and Brown, M. E. “*NICMOS Photometry of the Unusual Dwarf Planet Haumea and its Satellites*” 2009, The Astrophysical Journal Letters, vol. 695, pg. 1F

**Fraser, W. C.** “*The Collisional Divot in the Kuiper Belt Size Distribution*” 2009, The Astrophysical Journal, vol. 706, pg. 119F.

**Fraser, W. C.** and Kavelaars, J. J. “*The Size Distribution of Kuiper belt Objects for  $D > 10$  km*” 2009, The Astronomical Journal, vol. 137 pg. 72F

**Fraser, W. C.** and Kavelaars, J. J. “*A derivation of the luminosity function of the Kuiper belt from a broken power-law size distribution*” 2008, Icarus, vol. 198, pg. 827F

**Fraser, W. C.**, Kavelaars, J. J., Holman, M. J., Pritchett, C. J., Gladman, B. J., Grav, T., Jones, R. L., MacWilliams, J., and Petit, J.-M. “*The Kuiper belt luminosity function from  $m(R)=21-26$* ” 2008, Icarus, vol. 195, pg. 827F.

Holman, M. J.; Winn, J. N.; Fuentes, C. I.; Hartman, J. D.; Stanek, K. Z.; Torres, G.; Sasselov, D. D.; Gaudi, B. S.; Jones, R. L.; **Fraser, W. C.** “*The Transit Light Curve Project. Five Transits of Exoplanet OGLE-TR-10b*” 2007, The Astrophysical Journal vol. 655, pg. 1103.

- I assisted in the observations and data-reductions for the transits observed at Magellan

Grav, T., Holman, M., **Fraser, W. C.** “*Photometry of Irregular Satellites of Uranus and Neptune*” 2004, The Astrophysical Journal, vol. 612, pg. L77.

- I assisted in the data-reductions and photometry of these sources

Holman, M. J., Kavelaars, J. J., Grav, T., Gladman, B. J., **Fraser, W. C.**, Milisavljevic, D., Nicholson, P. D., Burns, J. A., Carruba, V., Petit, J.-M., Rousselot, P., Mousis, O., Marsden, B. G., Jacobson, R. A. “*Discovery of five irregular moons of Neptune*”, 2004, Nature, Issue 7002.

- I was one of the primary scientists involved in the moving object search process, and was heavily involved in the observation of these objects.

Kavelaars, J. J., Holman, M. J., Grav, T., Milisavljevic, D., **Fraser, W. C.**, Gladman, B. J., Petit, J.-M., Rousselot, P., Mousis, O., Nicholson, P. D. “*The discovery of faint irregular satellites of Uranus*” 2004, *Icarus*, vol. 169, issue 2, pg. 474.

- I was one of the primary scientists involved in the moving object search process

Canadian LRP White Paper - J. Kavelaars, B. J. Gladman, A. Hildebrand, **W. C. Fraser**, R. E. Pudritz, P. Wiegert. “*Planetary Astronomy: Minor Planets and Planet Formation*” 2010 White paper for the Canadian Astronomy Long Range Plan. <http://www.casca.ca/lrp2010/>

### Select Press and Media Interactions

“The Night Sky and Astronomy” Reoccurring bi-weekly radio segment on CFX Radio (BC broadcast). First recording permalink: <https://soundcloud.com/saturday-programming-cfax/sep-13-cafe-victoria?in=saturday-programming-cfax/sets/saturday-programming>

“Some Planet-like Kuiper Belt Objects Don’t Play Nice” Universe Today, 2014 by Matthew Francis. Permalink: <http://www.universetoday.com/108189/some-planet-like-kuiper-belt-objects-dont-play-nice/>

Quirks and Quarks Holiday Question Show, 2013. Permalink: <http://www.gemini.edu/node/12081>

“Limits on Quaoar’s Atmosphere” Gemini News Cast #51, 2013 by Nancy Levinson. Permalink: <http://www.gemini.edu/node/12081>

“Probing the Solar System’s Icy Fringes” Forbes, 2013 by Bruce Dorminey. Permalink: <http://www.forbes.com/sites/brucedorminey/2013/08/22/probing-the-solar-systems-icy-fringes/>

“Astrophile: the Changing Face of Icy Dirt-Ball Quaoar” New Scientist, 2013 by Victoria Jaggard. Permalink: <http://www.newscientist.com/article/dn23951-astrophile-the-changing-face-of-icy-dirtball-quaoar.html#.UthkQmRDtHE>

“*Is Densest Kuiper Belt Object a Wayward Asteroid?*” New Scientist, 2010 by David Shiga. Permalink: <http://www.newscientist.com/article/dn18739-is-densest-kuiper-belt-object-a-wayward-asteroid.html#.UthjrWRDtHE>

### Minor Planet Circulars (2 of ~50)

Schwamb, M. E., **Fraser, W. C.**, Brown, M. E., Rabinowitz, D., Marsden, B. G. “2008 ST291” Minor Planet Circular 2009-V68.

**Fraser, W. C.**, Schwamb, M., Gladman, B. J., Kavelaars, J. J., Petit, J-M. Jedicke, R. Parker, J., Marsden, B. G. “2008 KV42” Minor Planet Circular 2009-N32.

### Select Recent and Published Conference Proceedings

Invited Talk - **Fraser, W. C.**, “The LSST’s revolution of outer Solar System, small body science.” 2016, LSST-Europe2, Belgrade, Serbia.

Invited Talk - **Fraser, W. C.**, “The Kuiper Belt through the eyes of the UVOIR space telescope.”, 2016, Goddard Space Flight Centre

Invited Talk - **Fraser, W. C.**, “The binarity, composition, and a few sizes of Kuiper Belt Objects” Hubble 25th Anniversary Meeting, 2015, Space Telescope Science Institute.

Invited Talk - **Fraser, W. C.**, “Adventures in the Kuiper Belt”, 2013, McGill Colloquium Series.

Invited Talk - **Fraser, W. C.**, “H/WTSOSS: Compositions of Small KBOs” 2011, Las Cumbres Observatory Global Telescope.

**Fraser, W. C.**, and 13 co-authors “Col-OSSOS: A new ugrJ taxonomy for trans-Neptunian objects”. 2016, Division of Planetary Sciences, AAS, AGM.

**Fraser, W. C.**, Brown, M. E., and Emery, J. The nonlinear spectra of transneptunian objects: Evidence for organic absorption bands”. Asteroids, Comets, and Meteors, 2015, Helsinki.

**Fraser, W. C.**, Gwyn, S., Trujillo, C., Brown, M. E., Kavelaars, J., Stephens, A., Gimeno, G. “Predicting Occultations by Kuiper Belt Objects”. 2013 Division of Planetary Sciences, AAS, AGM.

**Fraser, W. C.**, Brown, M. E., Batygin, K., Bouchez, A. “Tidal Evolution of the Quaoar-Weywot System”. 2012 American Astronomical Society AGM.



## Employment History

<b>Position</b>	<b>Supervisor</b>	<b>Location</b>	<b>Date</b>
Queen's Research Fellow/lecturer	Professor Smartt	Queen's University, Belfast	Aug 2015 - Current
Plaskett Fellow	Dr. Jim Hesser	Herzberg Institute of Astrophysics	Sep-2011 - Aug 2015
Contract Researcher	Dr. Mike Brown	California Institute of Technology	June 2014 - Aug 2015
Postdoctoral Scholar	Dr. Mike Brown	California Institute of Technology, Geological and Planetary Sciences,	Oct-2008 - Sep-2011
Research Assistant	Dr. JJ Kavelaars	Herzberg Institute of Astrophysics	May-2004 - Sep-2004

## Technical/Observational Experience

### Graduate Student:

- Florian Glass, Masters. Thesis: Calibrating the WFC3 PSF.

### CCD mosaic imaging/Photometry:

- many observing nights on various 4+ meter telescopes including the CFHT, Magellan Bade, Subaru, and Keck telescopes.
- extensive experience with space based observations, primarily with the HST (PI on GO 12234 and Co-I on GO 11644).
- observing experience mainly geared towards, discovery, tracking, and characterization - both astrometrically and photometrically - of Solar system bound moving objects.

### Optical-NIR Spectroscopy

- low resolution ( $R \sim 100$ ) visible wavelength and NIR (JHK-band) spectroscopy of moving Solar System targets utilizing Keck and HST.
- high resolution ( $R \sim 5000$ ) UV/Vis/NIR spectroscopy of moving Solar System targets with the VLT+Xshooter.

### Numerical Simulations/Non-observing Experience

- extensive programming experience in python, C/C++, fortran, matlab.
- well versed in GPU computing utilizing the NVIDIA-CUDA API for highly-parallel computing
- written both N-body and collisional evolution software to be executed on graphics card hardware
- mysql database experience
- Linux/Fedora system administrator

## References

### Mike Brown

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Professor  
Division of Geology and Planetary Sciences  
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California Institute of Technology

### JJ Kavelaars

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Adjunct Assistant Professor  
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Herzberg Institute for Astrophysics  
University of Victoria

### Alessandro Morbidelli

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Professor  
Laboratoire Lagrange,  
Conseil National de la Recherche Scientifique  
Observatory of Nice B.P. 4229, 06304 Nice Cedex 4 France  
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Department Cassiopee, Observatoire de la Cote a'Azur

### David Nesvorny

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