inSCight

Inspiring stories from the Faculty of Science

ISSUE 13 | DECEMBER 2019

Science in space

Exploding binary stars

We look at the pioneering computer models of how stars are born, live and die

Some liked it hot

What do we know about early life in our Solar System?

Fun facts about space

Best apps, websites and why the Milky Way smells like rum

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

SCIENCE

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December 2019

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The night sky taken from the Southern Ocean shoreline near Christchurch, New Zealand. Babak Tafreshi is an award-winning photographer, a master of night-time photography and nightscape videos, a science journalist and the founder of The World at Night programme. He was guest speaker for the 2019 Beatrice Hill Tinsley Lecture hosted by the Auckland Astronomical Society and the Department of Physics at the University of Auckland.

Cover photo: Babak Tafreshi

A word from the Dean

WELCOME TO THE 2019 edition of *inSCight*. This issue is themed 'Science in space'. We will be exploring some of the many ways in which the faculty has been contributing to, and adopting, space-based research and innovation.

When I assumed the role of Dean of Science just over five years ago, I had no idea I would now be writing about the burgeoning space industry in New Zealand, enabled by Peter Beck and his Rocket Lab start-up. Nor that one of my numerous compliance duties is to ensure that anything we put into space has an 'Orbital Debris Mitigation Plan', so we don't leave space junk floating around.

That we are now a space nation is both something to celebrate, and a pointer to how scientific and technological innovation can be rapid and truly disruptive – in this case by making satellite deployment much more affordable globally and in the process creating a new set of industries for New Zealand.

If we are to succeed as a nation in a future where two of our major export industries, dairy and meat, are under increasing threat from technological disruption (see www.rethinkx.com/food-and-agriculture), we must create more knowledge and technology-based industries to supplement and potentially replace our agrarian ones.

Relevant to the education sector we operate in, it is also interesting that our 'export' – teaching international students – is now roughly equivalent in international income to New Zealand's economy to that of the meat industry.

Supporting alumni and student innovation

Our faculty and the wider University has been quick to take up the opportunity that Rocket Lab has afforded us. Already we run an inter-faculty CubeSat competition for students.

In teams they design, and the winning team implements, a CubeSat for deployment into space using donated launch capacity from Rocket Lab. This has created tremendous interest for space research among students – students like Anastaysia Kiddle, from the 2018 winning team Kessler, whose satellite launch is imminent (see page 20).

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We celebrate the achievements of two of our students.

Our alumni are already finding work in aerospace-oriented industries such as Rocket Lab and Heroux Devtek (see page eight). Insight into the broader New Zealand space industry sector can be found on page 22 in an article by Professor Juliet Gerrard, faculty member, and Prime Minister's Chief Science Advisor.

Founding fundamental research

A University Research Centre, Te Pūnaha Ātea – Auckland Space Institute, was established in 2019 to bring together academics from across the University interested in space-based research. Professor Guglielmo Aglietti was appointed as inaugural director, bringing with him extensive experience at the Surrey Space Centre, working on a range of spacecraft-related topics, from space missions design and delivery, to hardware development (see page four).

Within the Faculty of Science, we have another research centre, Te Ao Mārama – The Centre for Fundamental Enquiry. Its mission is to answer fundamental questions that transcend disciplines, such as the origin of the Universe and the origin of life (see page 14). Professor Kathy Campbell's work on the burgeoning field of astrobiology has an important place in this research (see page 16).

From the sky to the earth and beyond

Beyond Rocket Lab, the faculty has long been involved in space-oriented research activity, from astronomy to space-based remote sensing for applications, such as environmental monitoring and resource management.

Our academics continue to be at the forefront of new approaches to astronomy. Statistician Associate Professor Renate Meyer's work on separating a signal from noise enabled the LIGO experiment to detect gravitational waves and open a new tool for observing the Universe. And astronomer Dr JJ Eldridge and postdoctoral research fellow Dr Héloïse Stevance are conducting ground-breaking research on exploding binary stars (see page six).

We have taken membership of the consortium building the Large Synoptic Survey Telescope (LSST), a new type of telescope in Chile built to rapidly survey the night-time sky, recording the entire visible sky twice each week. The map it produces will serve many purposes, from locating dark matter and characterising properties of dark energy, to tracking transient objects, studying our own Milky Way galaxy in-depth and identifying potentially hazardous asteroids. The data produced and accessible to our astrophysicists will be rich in value, as discussed by Dr Nick Rattenbury and doctoral candidate Martin Donachie (see page 18).

"Our academics continue to be at the forefront of new approaches to astronomy... and astrobiology"

We also have a long history of looking down. I remember Stuart Bradley in Physics downloading and analysing Landsat images while I was doing my PhD many years ago. More recently Associate Professor Rochelle Constantine, Associate Professor Patrice Delmas and Dr Wannes van der Mark have been harnessing equipment from the aerospace industry, as well as artificial intelligence, to identify and understand the megafauna in the Hauraki Gulf (see page 10).

So, I do hope you enjoy this edition of *inSCight*. I wonder what surprising thing I, or my successor, will be writing about in another five years!

PROFESSOR JOHN HOSKING
Dean of Science, University of Auckland

Freedom to develop ideas on the southern space frontier

The University of Auckland's leadership role in New Zealand's fledgling space sector has received a significant boost with the appointment of the internationally leading Professor Guglielmo Aglietti as the inaugural Director* of Te Pūnaha Ātea – Auckland Space Institute.

A FELLOW OF THE Royal Academy of Engineering, Guglielmo graduated in Italy with a first-class honours degree in Aerospace Engineering before working on the Columbus module of the International Space Station. In 1995, he moved to the UK, working initially at the University of Southampton before moving to Surrey as director of the UK's Surrey Space Centre.

"I have always worked in this area between academia and industry trying to bridge the gap by doing research, proof of concepts and ideas that can be developed in industry."

His recruitment was made possible by the Tertiary Education Commission's Entrepreneurial Universities scheme. The scheme aims to attract world-leading entrepreneurial academics who will drive cutting-edge research that grows New Zealand's competitive edge – and strengthens economic growth.

Describing the alignment between research, education and industrial activities as crucial, Guglielmo says that universities are a favourable environment to generate new ideas and new products with commercial potential which can then be spun off to create a virtuous circle of collaboration.

"These companies will grow and will end up sponsoring research at the University, so you'll have a whole ecosystem that really works very well."

After seven years at Surrey and various successful space missions, Guglielmo says it was time for a change and that "starting from scratch" at Te Pūnaha Ātea gives him an opportunity to shrug off a lot of the constraints from his old job and have "almost a blank canvas to get things together".

New opportunities ahead in Aotearoa

As a multi-faculty space science and engineering initiative, one of the key capabilities of Te Pūnaha Ātea is to develop satellite missions to serve New Zealand's strategic scientific and economic goals. Guglielmo says that being able to contribute to the growth of the New Zealand space sector represents a "very nice challenge to put in practice what I've learned".

Collaboration with key commercial partners, like Rocket Lab, is another goal. Being close to the launchers was something that Guglielmo missed in the UK where they had to rely on countries like India, the US or China to get things launched. "Not having direct access to space is always a bit of a problem," he says.

Professor Guglielmo Aglietti, Director of Te Pūnaha Ātea

Rocket Lab founder Peter Beck clearly sees the value of working together with the University, according to Guglielmo, and companies will be encouraged to use the University for cost effective research and development work – rather than invest in their own facilities – "because they can tap into our resources only when they need it".

In that regard, one obvious opportunity could be to support Rocket Lab with its ambitious plan announced in August 2019 to recover and re-fly the company's Stage One Electron launch vehicles. As someone who understands the aerodynamics of re-entry all too well, Guglielmo says "it might be

** Prior to Professor Guglielmo Aglietti's appointment, Professor Richard Easther, Head of the Department of Physics acted as interim Director* the kind of research that can be contracted to the University to provide specific answers".

Te Pūnaha Ātea is currently working on several projects in collaboration with researchers in the US, Germany and Australia, and Guglielmo is keen to contribute to international projects that can produce a critical mass where "everybody benefits from the results, but we only pay a fraction of the bill".

A fundamental education for students

Developing a dedicated ground mission control station like the one in Surrey is also on the drawing board, and it's possible that both space centres could potentially co-ordinate activities across different time zones. "Working together we have much better visibility and much better communication than if we were working independently."

A key influence in the evolution of Te Pūnaha Ātea has been the Auckland Programme for Space Systems (APSS). Over the past three years APSS has attracted more than 400 undergraduates eager to participate in the extracurricular Mission Proposal Competition which involves the design of tiny CubeSat satellites – but offers no course credits.

However, that might be about to change. Guglielmo says he'd like to "enable" students by providing a fundamental education in satellite development that counts in terms of final marks. It means that when they embark on APSS projects they'll "hit the ground running" and go much further, instead of having to learn the basics of space engineering during the project.

Also on the cards is a dedicated multi-disciplinary programme in space engineering or aerospace engineering, with Te Pūnaha Ātea acting as the catalyst, which would draw on the academic talent which already exists within different faculties at the University. As Guglielmo puts it, "if you get these things working together you create a synergy, so the value added is much higher than the value of your single parts working independently".

What's more, he believes that being able to provide a pipeline of graduates is a win-win situation because it helps meet the growing employment needs of companies like Rocket Lab and provides graduates with immediate job prospects. That, in turn, helps the University "because we can show that what we're teaching is actually useful and they can get jobs in real companies, so it really works for everybody".

Tackling real issues can lead to commercial success

During his time at the Surrey Space Centre Guglielmo was the Principal Investigator for the internationally acclaimed RemoveDEBRIS project which successfully tested technologies for Active Debris removal (ADR) such as a net and a harpoon.

The mission was part of a proof of concept exercise which will hopefully pave the way for future commercial development, but Guglielmo says the challenge for Surrey's commercial partners now is

to find a paying customer. "It's a bit like the problem with plastic in the ocean, it's a good idea to clean it up but who is going to pay for that?"

Nevertheless, he says that universities have a duty to address real issues like space junk. "There's a clear need for methodologies to remove new satellites once they have finished their missions – and old pieces of debris – which has a lot of potential to expand technologies and create new commercial opportunities," he says.

In November, Guglielmo's international RemoveDebris team were awarded a prestigious Sir Arthur C. Clarke Award in the Space Achievement: Industry/Project Team category. The award, given out annually, recognises outstanding contributions to space exploration activities. "This is a great honour, as we consider these awards like the 'Oscars' of the UK space sector. I am delighted for the whole team that worked tirelessly on this project," says Professor Aglietti.

As the 2018 winner of the APSS Satellite Mission Proposal Competition, the 'Kessler' team (see page 20) has proposed the use of electrodynamic tethers to retrieve old satellites, and Guglielmo says students are often the ones with good ideas for new products. "We're going to create more opportunities for students to transform their ideas into proper enterprises with commercial values and real products."

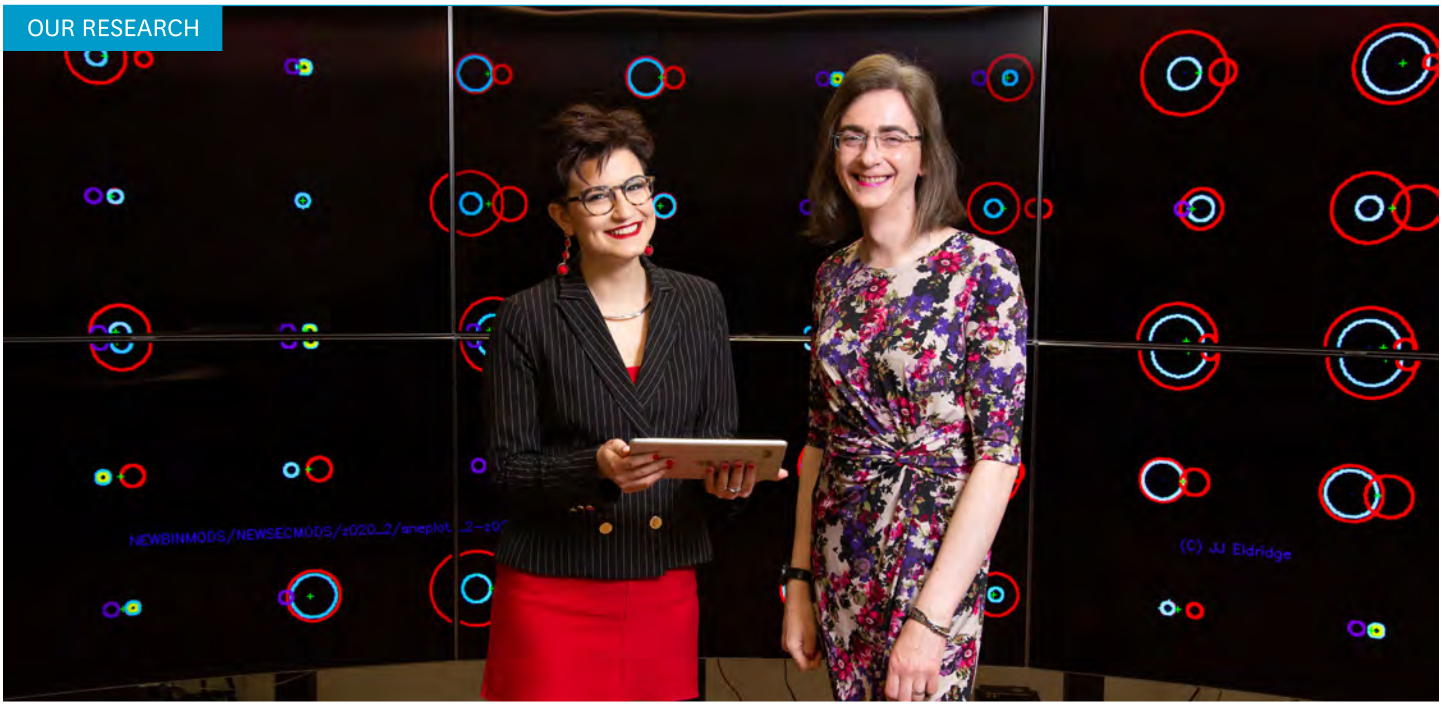
The ultimate aim will be to create a broader space ecosystem by enabling companies to generate a wider range of services and products for further development. "We want to have an entrepreneurial spirit that creates these new companies and helps them to expand and grow on their own strength after they've been initially supported by the University – as well as helping existing companies to prosper."

And it seems that Guglielmo won't be alone in his quest. Given the uncertainties created by Brexit, he says that some of his former colleagues have also indicated a willingness to move to what they consider to be a more fertile environment. "Europe is a relatively crowded place from a space point of view and here there is more freedom to develop new ideas."

APSS – www.apss.space.auckland.ac.nz

Te Pūnaha Ātea – Auckland Space Institute
www.space.ac.nz

"I have always worked in this area between academia and industry trying to bridge the gap by doing research, proof of concepts and ideas that can be developed in industry."



Exploding binary stars

One of New Zealand's most valuable export fish species is about to take on a new persona in the world of astronomy as the chosen name for a software package that could help unlock some of the secrets of the Universe.

"This is where we come from, absolutely. We are made of stardust. That's what Carl Sagan said – and it is true!"

– DR HÉLOÏSE STEVANCE

CALLED *HOKI* BECAUSE it helps "fish through information" about the role of exploding binary stars in the life of our Universe, the computer code has been developed by postdoctoral research fellow Dr Héloïse Stevance who aims to bridge the gap between observations and theory.

"My goal is to write a little piece of software that makes that job very easy and very foolproof for the observer so that they have access to the theoretical code and can compare it to their observations. Focus more on the science and less on the nitty-gritty and the coding – that's my job."

Expected to be released in early 2020, *Hoki* leverages off the Binary Population and Spectral Synthesis (BPASS) codes developed by Héloïse's fellow astrophysicist, Dr JJ Eldridge, whose pioneering computer models of how stars are born, live and die have caused waves throughout the academic community – and changed assumptions about the evolution of the Universe.

"What my models can predict is what the galaxies will look like at different ages," JJ says, "and that tells you something about the stars that merged."

Above and facing page: Dr Héloïse Stevance (left) and Dr JJ Eldridge in the Centre for eResearch Visualisation Suite in front of representations of binary stars and an image of a galaxy.

Stellar mergers and binary interactions

Where JJ differs from peers is the acceptance of the fact that most stars in the Universe are born in binary systems, where two stars orbit around each other and sometimes merge, rather than from single stars like the Sun. And BPASS models show that you only need 65-75 percent of the stars previously thought to exist because binaries interact and merge.

"That number of stars is important because it's how we work out how much stuff is being formed, how many black holes there are, how many neutron stars there are and how many habitable planets there could be. Suddenly if you're decreasing the number of stars, you're decreasing all of that in the Universe."

According to JJ, the reason why single star models were preferred back in the 90s was because binary stars were complicated and potentially involved years of computer time.

"Now we've got so much computing power it becomes so much easier and that's starting to change entrenched views about single star models. Having the computational power to do things that were impossible before is changing people's minds that maybe we can do things that we couldn't."

The BPASS models have also been used to investigate the future and predict what happens to stars 100 billion years from now even though the Universe is currently only 13.7 billion years old. Which raises the age-old question – could there be life forms in other galaxies?

"Will the Universe be more habitable in the future? The answer is probably yes because more of the young stars will die and there'll be fewer supernovae and nasty things that can kill us," JJ says.

Supernovae and the origins of life

Another key driver behind their research is the quest to know more about the collapse of stars called supernovae which produce different types of elements – like oxygen and iron – that are crucial to life as we know it. "The oxygen in your lungs right now was created in a supernova, it didn't come out of nowhere," says Héloïse. "This is where we come from, absolutely. We are made of stardust. That's what Carl Sagan said – and it is true!"

The abundance of oxygen and iron has changed over the history of the Universe because it came from different ages of stars that exploded at different times. However, JJ says it's more difficult to trace the origin of elements like gold, platinum and silver because they came from very rare events such as the neutron star mergers that have led to gravitational waves.

All of which comes back to their current research into gravitational wave events which received fresh impetus in 2017 when the LIGO observatory detected what is known by the purists as GW 170817 – a gravitational wave relatively close to earth that was produced by the dying minutes of two neutron stars spiralling together and finally merging.

Describing it as a violent cataclysmic event which produced "massive fireworks", Héloïse says that neutron stars involve really "extreme physics" because they consist of a ball around 20 kilometres in diameter and 1.5 times the mass of the Sun with gravity so strong that the surface has virtually no discernible bumps on it.

"The Universe can make it, but how does it do it? And how can we reproduce what the Universe is physically making? Knowing that will tell us a lot about the stars that give rise to the things that we actually observe."

Funded by a $936,000 Marsden Fund grant, the current focus for JJ and Héloïse is to use the BPASS and *Hoki* codes to investigate the stars and galaxies associated with the 2017 gravitational wave event by comparing their cosmological simulations with observations from multiple instruments and telescopes.

"The goal is to look at that galaxy and see what we can find with the BPASS models," says Héloïse. "What can we learn about the stars in that galaxy that people haven't found with their single star models?"

Collaboration produces new models

The development of BPASS involves a long-standing collaboration with Associate Professor Elizabeth Stanway from the University of Warwick who JJ has worked with since their PhD days at the University of Cambridge. "She'd been working on galaxies and I'd been working on stars," says JJ, "and we kind of merged."

Eighteen years later, Elizabeth remains part of JJ's gravitational wave project which is also useful because Warwick has a rapid follow up telescope that can track light as quickly as possible. "We can't do each other's job, but we understand a lot about what each other does so have been able to make this BPASS code. It's taken a long time and it is ongoing."

The collaboration has been deepened by the skills which Héloïse has brought from the UK including a PhD and experience as a part-time support astronomer at the Isaac Newton Telescope in Spain. Like Elizabeth, she is a member of the global Engrave collaboration which constantly tracks events like gravitational waves.

For her part, Héloïse is also determined to introduce best practice to her work and has written *Hoki* in Python which is considered the gold standard of astronomy. In the interests of generating more collaboration, the code will also be fully accessible under an open source licence.

And it seems that a new generation of stargazers is already being inspired to continue the research. Supported by tutorials from Héloïse, *Hoki* was successfully trialled at a UK summer school where JJ says students quickly embraced a model that would have traditionally taken much longer to understand. "Rather than taking them days or weeks to work out, it took them a few minutes."

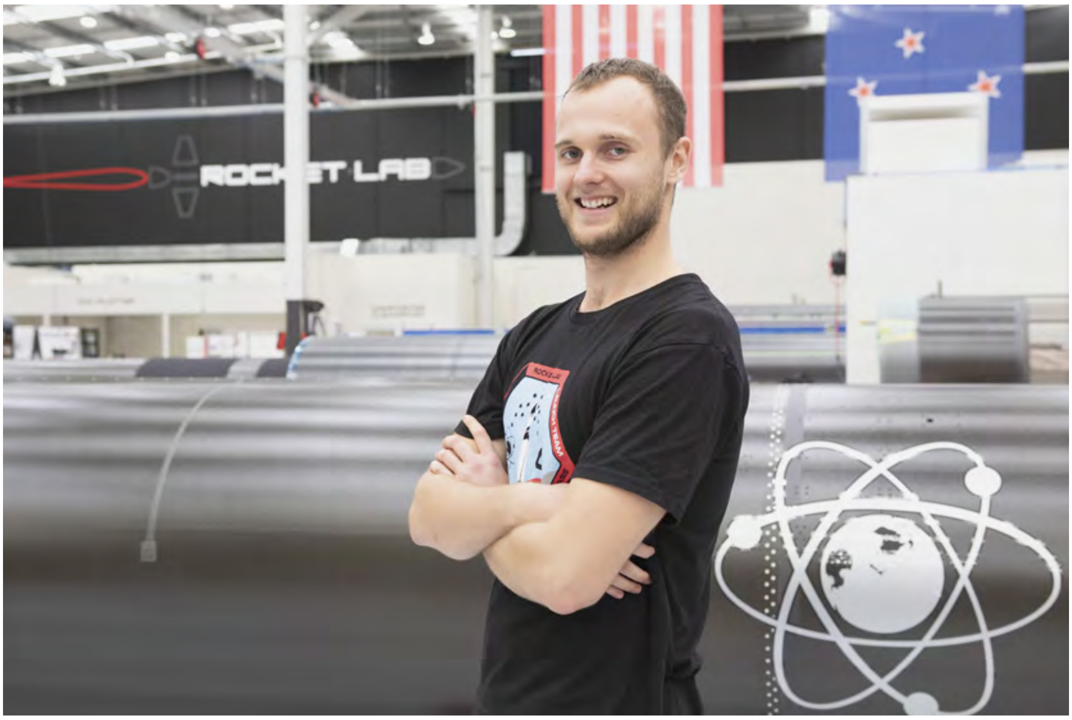
As for their research into the host galaxy of GW 170817, JJ expects to publish something in 2020. They don't know what they're going to find but say "we know this is important, we just don't know how important."

***Watch** Where do all the elements come from? https://youtu.be/b9eFWbjd1Kw*

> ***"The Universe can make it, but how does it do it? And how can we reproduce what the Universe is physically making?"***
>
> – DR HÉLOÏSE STEVANCE

Shooting for the stars

Physics alumnus Joshua Rippon's childhood fascination with the Universe has led to a dream job with Rocket Lab where he can indulge his passion for all things space.



Joshua Rippon. Photo: Rocket Lab

"**I HAVE ALWAYS BEEN** fascinated by the Universe and everything in it. I remember watching documentaries as a child about black holes, space travel, supernovae, string theory, and life on other planets, and I always wanted to find out more. I chose to study physics to follow this passion of mine."

It was a choice Joshua has never regretted. He graduated with a Bachelor of Science in Physics and Mathematics, followed by a Bachelor of Science (Honours) in Physics, and thoroughly enjoyed his time at university.

There were two things he enjoyed most about studying physics. The first was learning a new idea or concept that changed the way he saw the world. The second was being able to share that information with his classmates, or the students that he tutored, and seeing their faces light up.

Where have you been working since you graduated?

Straight after graduating in 2016 I moved to London with my partner to work and travel. I had a number of jobs: I was a teaching assistant at a high school; I worked at a company called Kiwi Movers where I moved people's furniture; and I worked as a software developer at a data analytics company. I moved back to New Zealand a year ago and then got a job as a software engineer at Rocket Lab.

What do you do in your current role at Rocket Lab?

I am part of the business automation team using web and cloud technology to provide internal tooling for the company. Our tools are used for mission management, production, launch operations and vehicle design.

What has been the highlight of your career so far?

Rocket Lab is rare in the space industry in that we've achieved 100 percent mission success for our customers – in short, that means none of our missions have ever failed. I've been part of six of those successful launches during my time at Rocket Lab, and it's an amazing feeling to know that I have played a part in that success.

Where do you see your career heading? What else would you like to achieve?

I am motivated by helping the people around me become better versions of themselves, so I see myself moving towards leadership and management. I would also like to fulfill my childhood dream of going to space!

The New Zealand space industry has really taken off recently (excuse the pun!). Where do you see it heading in the future – what opportunities do you think will come up?

I am optimistic about the future of the New Zealand space industry. I think that we will see many more aerospace companies sprouting up off the back of Rocket Lab's success. Now people realise that it is possible to work in the space industry in New Zealand, I think we will see an ecosystem of companies and organisations working together to explore new frontiers in space.

What kind of impact do you hope your work will have?

At Rocket Lab, we are working on increasing our launch frequency. Our motto is, "we open up access to space to improve life on earth", and increasing our launch frequency and the opportunities to get into orbit for small satellite operators is key to this.

Being part of the business automation team means I can help achieve this goal by increasing efficiency and reducing costs across all of Rocket Lab's teams, and I hope my work will help us get to space more quickly, easily and reliably.

What drives you?

Helping people and teams learn, grow, and achieve their goals.

Finally, tell us something about yourself that we can't learn by Googling you!

I can rap the first verse of "It was a good day" by Ice Cube!

> ***"I am motivated by helping the people around me become better versions of themselves, so I see myself moving towards leadership and management."***

Making the world (a better place)

As a student, Biotechnology and Materials Engineering alumna Yaoyao Ding was inspired by her masters supervisor's passion for the nanomechanical properties of biomaterials. Now she's an entrepreneur making her own mark on the world.

"I'VE ALWAYS BEEN interested in science and how things work. I enjoyed all the practical work and lab experiences in my degrees – it was a chance for me to be creative and make things happen."

Making things happen and, in particular, making *things,* is what Yaoyao has turned her hand to in her career. After graduating from the Faculty of Science in 2008 with a Bachelor of Technology in Biotechnology, Yaoyao shifted to the Faculty of Engineering and took up a masters in materials engineering under supervisor Dr Michelle Dickinson. "From the first moment I talked to her [Michelle], I knew I wanted to become a materials engineer," she remembers.

Yaoyao moved to Montreal, Canada, after her masters graduation, and began her PhD in materials engineering at McGill University. She then spent a year as a postdoctoral fellow at McGill, before taking a position working on additive manufacturing (AM) projects with Heroux Devtek, a landing gear manufacturer.

Additive manufacturing (also known as 3D printing) technology has revolutionised the fabrication and manufacturing industries, making the production of parts and devices simpler, quicker, and more flexible for organisations and individuals.

In 2018 Yaoyao established her start-up company, B3D Performance, which specialises in AM using metal powders and lasers.

How did you become involved with additive manufacturing?

I first became involved with AM during my postdoc at McGill University. My postdoctoral supervisor introduced me to the world of AM, which is filled with fascinating possibilities. I've stayed in the field ever since.

What kind of work do you do at B3D Performance?

At B3D, we work as a team. Our team specialises in AM using metal powders, and serves as a bridge between the technology and the AM technology adopters.

Through our training programmes, we help people to develop a good understanding of the benefits and limitations of AM. Through our support services, we continuously help our customers during their product development processes.

Recently, we've started to develop instruments to monitor the powder quality so we can reduce production costs and minimise the impact on the environment.

Why is it important for companies to be able to make their own parts? Is it just because it's quicker and cheaper? Or is it because sometimes it's difficult to procure the parts they need?

With AM, there's a quicker production development cycle with the ability to prototype parts. Companies can fabricate parts on demand, which reduces their inventory, and it's therefore easier to plan production because you have full knowledge of production capacity.

Can you tell us about a recent project or initiative you've worked on?

One of the challenges associated with AM is producing parts of consistent quality. In metal AM, parts are built by adding (this is why it's called 'additive' manufacturing) multiple layers of metal powder, which is melted with a laser. The commercial and research communities are trying to improve the quality and reproducibility of this process.

B3D was awarded funding by the National Research Council (NRC) of Canada to develop a test tool capable of measuring the density of the metal powder bed. So far we have finished Phase I of this project and have produced a proof-of-concept instrument. We're currently working on building the MVP (most viable product) and commercialisation. It's really exciting.

What kind of impact do you hope your work will have?

I hope to facilitate adoption of AM into different industries, especially the aerospace, biomedical and automotive industries. I hope the machines we are building will help these industries build high quality and cost effective parts.

Yaoyao Ding. Photo: Angelica Ivonne Valencia Ruiz

How do you think AM is going to change the aerospace industry in particular?

AM is going to disrupt the supply chain, and bring product designers close to the manufacturing process. I imagine we'll see a quicker product development cycle, along with more creative part design because of the increased design freedom. A new approach to data security will also be necessary.

What has been the highlight of your career so far?

I love being an entrepreneur. I will be very proud to see my instruments hit the market and make an impact. A highlight for me has been to work with people from very different industries, backgrounds and cultures.

What drives you?

"To make the world a better place." I love this quote from the movie Zootopia. I'm driven to help more people understand AM technology and use it to their advantage.

Finally, tell us something about yourself that we can't learn by Googling you!

I do Latin dancing, and received a silver medal for Hustle. It's a great way of relieving stress!

The Pulse of the Gulf

Space research is playing an influential role in a very down-to-earth project that aims to unlock the biological secrets of the Hauraki Gulf by using satellite imagery, drones, intelligent vision systems and machine learning to inform the public about environmental issues that threaten its future wellbeing.

IT MAY BE NEW ZEALAND'S largest Marine National Park, but very little is known about what goes on beneath the surface. Which is why Associate Professor Rochelle Constantine from the School of Biological Sciences and the Institute of Marine Science is on a mission to better understand the key drivers behind marine megafauna – like whales – that provide important indicators of the Gulf's health.

"The key purpose of this work is to understand the Hauraki Gulf and the megafauna, what makes it function and what's important to keep it functioning under some quite intense pressures."

Covering almost 5,000 square kilometres, the relatively shallow waters of the Gulf have long been recognised as a productive and dynamic ecosystem – from the abundant phytoplankton at the beginning of the food chain to the mussels, rays, dolphins, Bryde's whales and seabirds that were recorded in oral traditions when Māori first arrived.

However, fish and shellfish stocks are only "a shadow" of what they used to be in the Gulf says Rochelle, and she plans to draw on satellite technology that is now being used in marine science to measure everything from whale numbers to sea surface temperatures and phytoplankton. "I want to be able to measure the ocean using some of the remote sensing tools developed for space research."

Capturing an accurate picture of the gulf

Called the 'Pulse of the Gulf', Rochelle's latest project will focus on the feeding aggregations known in fishing parlance as 'work ups' that are a familiar sight to many boaties. "What are the drivers behind these multi species feeding aggregations, what are the things that draw these animals here in this time and place – and how does that change over time?"

In addition to images captured from air surveys, Rochelle wants to "look through the sea" which is where radar, drones and artificial intelligence come in. "The world is a beautiful place when it's in a controlled lab environment setting," says Rochelle, but the reality is that the marine animals operate in a 3D environment and drones and underwater cameras will allow her to step into that a lot better than she's ever been able to.

On Rochelle's shopping list is a fixed wing drone costing in the order of $200,000, and work is now underway using machine learning algorithms to train computers to recognise a plethora of high resolution images of sea life that have already been taken in the Gulf. But visually tracking a gannet that plummets into the sea at 100 kilometres an hour and leaves a trail of bubbles before emerging a few seconds later is easier said than done.

Artificial intelligence helps process visual imagery

With a PhD in Computer Vision, Faculty of Science technical manager Dr Wannes van der Mark is providing technical and logistical support for the project. He says that while humans have exceptionally good visual abilities, such as finding a face in a crowd, when it comes to the natural environment "trying to get a computer to do this is another matter".

Rising to that challenge is Associate Professor Patrice Delmas, head of the Intelligent Vision Systems laboratory within the School of Computer Science, who admits that New Zealand's harsh light and strong wind present a challenging environment and that gannets do "lots of terrible things to our images. This is not a simple problem".

Funded by the Vice-Chancellor's Strategic Research Initiatives Fund, postgraduate students are developing an interface for annotation tablets that will translate and extract data from the images which can then be subjected to artificial intelligence (AI) techniques like deep learning to help understand how the various animals move in time and space.

"I'm quite confident we'll get something out of it and it will be quite exciting," says Patrice, whose "end game" is to have the data on marine life available online for anyone to use. "I want to be an

"There's this really lovely marriage that's coming from accessing the tools and techniques that have been developed for space research."

– ASSOCIATE PROFESSOR ROCHELLE CONSTANTINE

enabler of these new technologies so that people don't need to understand what's behind it but can still get something interesting."

For Rochelle, trying new things is "where interesting discoveries are made" and the use of AI tools will be a very efficient way to process visual imagery – and save valuable time. "These new technologies are incredibly powerful and affordable," she says, "and the more information that you put into machine learning and AI development the better they get."

The collaboration between the biological, computer and space sciences will hopefully allow Rochelle to build up detailed and minute layers of environmental information – including radar images of ocean-surface micro-eddies that may influence phytoplankton – to better understand the biology and ecosystem connectivity and relationships between the animals and their environment. "There's this really lovely marriage that's coming from accessing the tools and techniques that have been developed for space research."

Creating a framework to preserve the environment

The inaugural winner of the Blake Environmental Leadership award in 2018, Rochelle successfully fought to slow the passage of ships through the Gulf to prevent the killing of Bryde's whales and says part of the overall vision of the project is to get people talking about the marine environment beyond it being a great place to hook snapper.

"It's actually a place with a lot of life that needs to be looked after a lot better than we do and hopefully the health and the mauri of the Gulf will improve a lot as a result of this kind of work."

Likewise, Patrice says the move towards automated systems could eventually provide people with a snapshot every day and create a framework for future generations to better understand and preserve the environment. "Kids get excited at school to be part of it, it's very easy now to engage like that."

The 'Pulse of the Gulf' will also put the University of Auckland RV *Hawere* to good use by deploying more conventional research tools such as hydrophones to record both natural and boat sounds.

Water samples will also be collected to look for dimethyl sulfide – the so-called 'smell of the sea' produced by phytoplankton – which some seabirds and maybe whales use to detect prey. And, if Rochelle has her way, an array of cameras and hydrophones will be submerged amongst a work up in order to capture it from within. "That's a challenging part, but hopefully we'll get data using that."

Behind the scenes, Wannes is helping to develop sensible tools and standard operating procedures for use in the marine environment – and smoothing the way through the regulatory framework for the use of drones. As he puts it, "you don't want headlines about drones crashing into a boat full of school children!"

Funded by generous grants from the Foundation North G.I.F.T. programme, the George Mason Centre for the Natural Environment, the Chisholm Whitney Charitable Trust, the Auckland Council, DOC, and the Waiheke Brewing Company, Rochelle hopes the project will inform people about what's changed in the Gulf over the next decade "and we're hoping it'll change for the better".

Above: Senior technician Esther Stuck (left) launching the drone with the support of photojournalist Richard Robinson. Photo: Dr Charlotte Johnson

Top: (from left) Associate Professor Patrice Delmas, Associate Professor Rochelle Constantine and Dr Wannes van der Mark.

Facing page: Bryde's whale feeding in the Hauraki Gulf. Photo: Stephanie Behrens

Did you know...

The time travel

If you want to time travel, all you have to do is look up. The glimmers you see are snapshots of the distant past. The Andromeda galaxy is the most distant object readily visible to the naked eye at 2.5 million light-years away. So, the light you see from it tonight is 2.5 million years old. You're seeing it as it was at the time long before modern humans existed.

The width

The Milky Way galaxy is 105,700 light-years wide. It would take a modern spacecraft 450,000,000 years to travel to its centre.

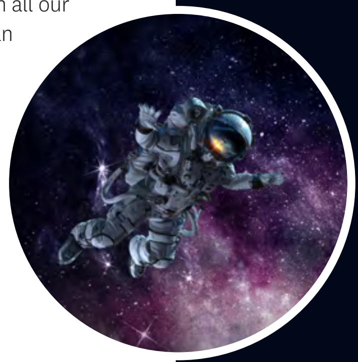
The smell and taste

The centre of the Milky Way smells like rum and tastes like raspberries. This was discovered by the IRAM radio telescope, which zeroed in on a gas cloud called Sagittarius B2 at its centre. The IRAM detected a chemical called ethyl formate which gives rum its distinct smell and raspberries their distinct flavour.

The make up

68 percent of the Universe is dark energy and 27 percent is dark matter. Both are mysterious and invisible. That means that the rest – everything on Earth, everything ever observed with all our instruments, all normal matter – adds up to no more than five percent of the Universe.

The silence

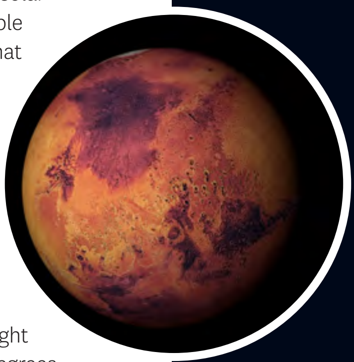


In space, no one can hear you scream. This is because there is no air in space – it is a vacuum. Sound waves cannot travel through a vacuum.

Searching for alien worlds

Astronomers are discovering more and more exoplanets – planets outside our Solar System – and finding out how different solar systems form. However, what excites people is the possible discovery of another 'Goldilocks' planet like ours – one that could support extraterrestrial (alien) life.

Orion, the future of space exploration



NASA is developing Orion to transport humans past Earth's orbit, to our Moon, and ultimately on a longer journey than anyone has ever taken: to Mars – and back. Orion's heat shield was put to the test on an uncrewed flight in 2014, and it withstood temperatures of over 2,000 degrees Celsius. That's about twice the temperature of molten lava.

Looking for space and astronomy sites on the internet? Try these!

Royal Astronomical Society of New Zealand
www.rasnz.org.nz

Stardome Conservatory and Planetarium
www.stardome.org.nz

Space Place
www.museumswellington.org.nz/space-place

Dark Sky Project
www.darkskyproject.co.nz

The World at Night (TWAN)
www.twanight.org

Astronomers Without Borders (AWB)
www.astronomerswithoutborders.org

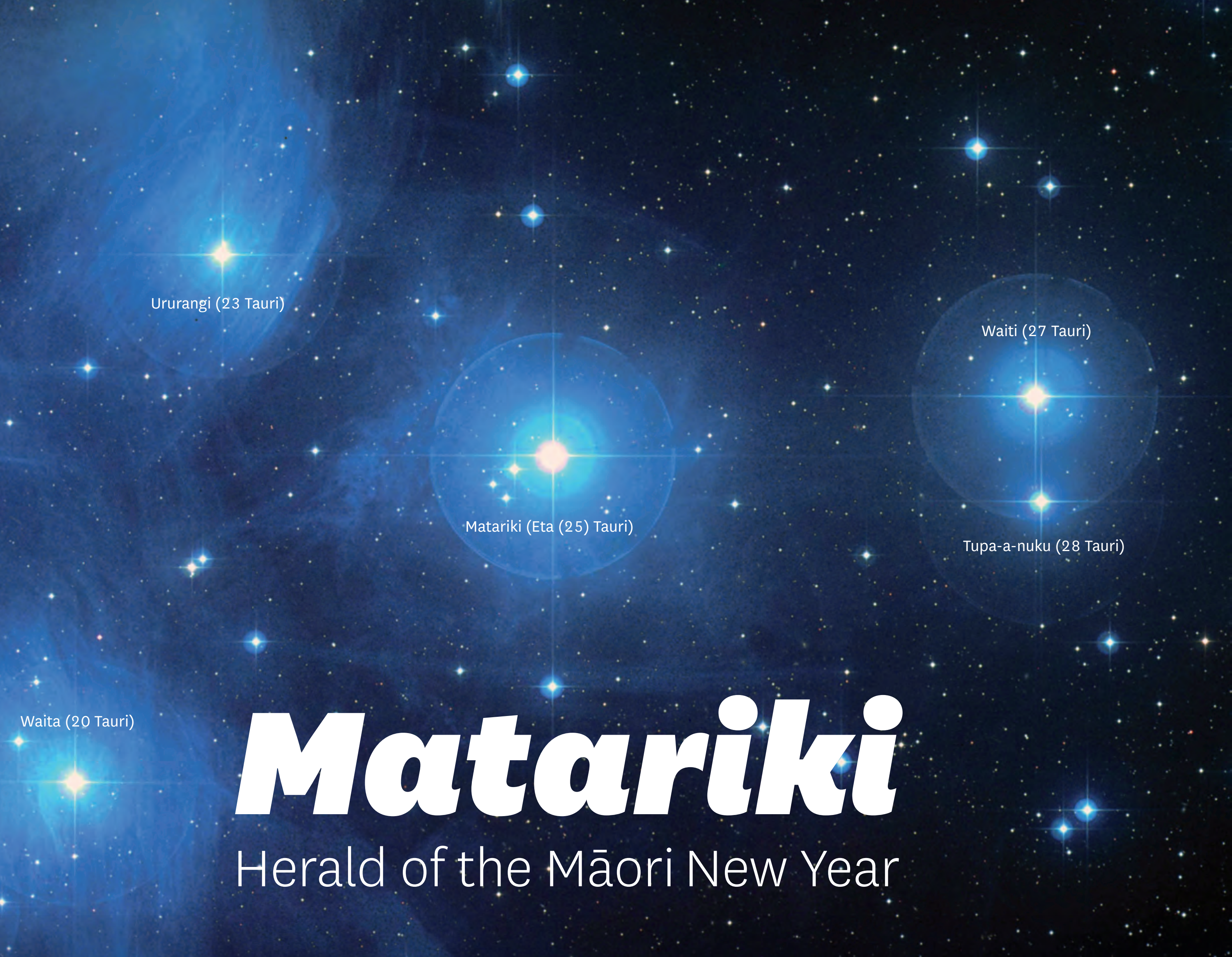
National Aeronautics and Space Administration (NASA)
www.nasa.gov

Space.com
www.space.com

Sky & Telescope
www.skyandtelescope.com

Space Calendar
www2.jpl.nasa.gov/calendar

HubbleSite
www.hubblesite.org



Matariki

Herald of the Māori New Year

In Aotearoa New Zealand, Matariki is seen in the northern sky, rising in the northeast and setting in the northwest. The cluster disappears from view in late autumn when it is too close to the sun to be seen. Its reappearance in the pre-dawn sky in early winter (the end of May or beginning of June) signals the beginning of the Māori New Year, a uniquely New Zealand festival.

This celebration begins at the sighting of the next crescent Moon in June near the Winter Solstice. In 2019 Matariki was officially celebrated on 25 June. Traditionally it signalled a new beginning; a time for planting trees and preparing the land for crops. It is now recognised as an important national event that brings family and communities together to reflect on the past and the future and to share knowledge, food and entertainment.

The brightest stars in the Matariki cluster

Matariki (Eta (25) Tauri), Waiti (27 Tauri), Waipuna-a-rangi (17 Tauri), Waita (20 Tauri), Ururangi (23 Tauri), Tupu-a-rangi (19 Tauri), Tupa-a-nuku (28 Tauri).

Our thanks to the Stardome who have provided all content and the Matariki image on pages 12 and 13.

The Matariki star cluster is visible from most places on the globe, so it has many names and stories in different cultures. The cluster formed from a vast cloud of gas and dust about 100 million years ago. The stars are therefore 'young' by stellar standards (our Sun is 4,600 million years old).

Telescopes reveal the cluster consists of nearly 1,000 stars travelling together through space. Over the next few hundred million years, they will gradually drift apart as they orbit around the Milky Way galaxy. Matariki is one of the closest star clusters to the Sun. Yet at a distance of 440 light years*, it is more than 100 times further away than the nearest star, Alpha Centauri, which is 4.2 light years away.

Matariki contains a number of hot blue stars that light up vast sheets and filaments of nearby dust, which the star cluster is now passing through. It appears to the unaided eye as an exquisite grouping of seven stars on the shoulder of the constellation of Taurus the Bull. These stars are also commonly known as the Pleiades and the 'Seven Sisters'.

*A light-year is the distance light travels in 1 year – approx. 9.5 trillion kilometres.

View the night sky by downloading these apps from Google Play or the App Store

SkyView® Lite uses your cellphone's camera to precisely spot and identify celestial objects in the sky – day or night.

Stellarium Mobile Sky Map has a catalogue of over 600,000 stars displayed as a real time zoomable sky map. You will be able to identify stars just by pointing your phone at the sky!

Redshift Take 3D flights to travel to any location within our Solar System; orbit the planets and their moons, and land on their surfaces.

Distant Suns (Max) has one of the most realistic displays of the night sky, while being one of the easiest to use astronomy apps for casual sky watchers as well as serious astronomers.

Cosmic Watch includes a celestial calendar providing you with all the important information and significant celestial events that are visible from your location.

Orion StarSeek 5 by holding your device up to the sky the dynamically changing map will identify stars, constellations, planets as you pan around.

Remember to keep looking up!

Perspectives on Life in the Universe

Are we alone? Is there life elsewhere? How did life begin? There is something vaguely 'Trekkie' about searching for the answers to questions about life in the Universe. Yet this is what the University of Auckland's Te Ao Mārama – Centre for Fundamental Inquiry focuses its attention on.

BASED IN THE FACULTY OF SCIENCE, Te Ao Mārama is one of a handful of organisations and institutes worldwide interested in the deep, simple "fundamental" questions that are hard to answer and which transcend traditional disciplinary boundaries. Its name means the "world of life and light", the idea of breaking into light from darkness, and it is committed to working on these questions by drawing from both mātauranga and science.

This year Te Ao Mārama was honoured to host the Vice-Chancellor's Lecture Series – three evening lectures and a panel discussion – themed "Perspectives on Life in the Universe". World leading scientists shared how new developments in astrobiology, astronomy, astrophysics and fundamental science are expanding our understanding of the origin and evolution of the Universe. Their research efforts range from our planet, to our Solar System, to exoplanets so far away they almost defy imagination.

Finding the planets that are not too hot and not too cold

Until 1995 the idea of life on other planets was mostly confined to science fiction. Then along came the Doppler technique – an indirect method for finding extrasolar planets – and the study of planets orbiting other stars became a key area of astronomy. Other techniques for detecting planets use reflex motion and oscillation, radio velocity, transit method and gravitational microlensing.

New Zealand is uniquely positioned for these astronomical observations because, as Professor David Bennett explains, "we need to see into the centre of our galaxy and the centre is 30 degrees south of the equator, so it is much easier to observe from the southern hemisphere".

Being able to observe planets orbiting around other stars has helped us to develop theories on how planets form, including a standard calculation of the 'habitable' zone.

"If planets are too close to a sun, any water will dissipate into vapour and if planets are too far away from a sun, any water will freeze," David says. "Planets in the habitable zone have liquid water and are often called "Goldilocks" planets.... we know that life is possible within the habitable zone, but not outside it."

So far, we have discovered 4,000 planets but only about 30 of these planets have the temperature and conditions that could potentially hold liquid water. In the meantime, there are many other questions to explore such as 'what is life from first principles?'.

"If we can agree on an answer to this, maybe we will find other places we should be looking for life, like the methane lakes of Saturn," David says.

He says one of the keys to finding signs of life is spectra, "a prism that breaks light down into its different spectrums so we can see what consistency of methane, carbon dioxide and oxygen a planet has".

"The presence of oxygen on earth is entirely due to plants. If we destroyed all the plants, the oxygen would rapidly go away. If we observe oxygen on an earth 'twin' that's a good sign that there might be life there."

Defining life as we understand it

So how exactly are scientists tackling the search for extraterrestrial life in all the nooks and crannies of our Solar System? And is there any point in searching for life on other planets if we don't even understand what life is, or how and where it forms?

Professor Maria-Paz Zorzano discussed the latter as one of the panellists and during her own lecture.

"What is life? We were discussing this and decided that it was pretty difficult to define," she says. "Life is something that uses energy in a chemical form. All the life forms that we know of on earth are based on carbon chemistry – so they have carbon, hydrogen, oxygen and nitrogen.

"We also know that life forms try and fight against ageing and damage from the environment, as well as creating extra copies of themselves containing genetic information that comes from the 'parent'."

Defining life is an ongoing debate which leads on to questions about what life needs to thrive and flourish. There is agreement that carbon-based life forms need liquid water and nutrients, "but then we also need to investigate 'what are the limits of life'?" says Maria-Paz.

"We are not particularly tolerant, we need protection from ultraviolet radiation, we need a moderate temperature, we need certain pressures. But there are micro-organisms we've investigated that can enlarge our concept of limitations."

This is where Professor Kathy Campbell's astrobiology research comes in (see page 16). Her focus is on life in the Universe at the microbial level, because the single cell life form is the simplest we are aware of and may leave remaining biosignatures inside rocks on other planets, such as Mars.

"Is there other life in the Universe? The answer is we don't know that yet. We know that planets and their satellites had different conditions in the past. So, we are looking for remnants of carbon chemistry and microbial forms inside a rock – a protective environment for one or two cells to survive," Maria-Paz says.

> ***"Believe it or not – the question 'what is life' is still unanswered. We are still fighting and arguing about whether you can define life."***
>
> – PROFESSOR KATHY CAMPBELL

> ***"Everything – and I do mean everything – that we touch or see or smell or taste is made out of atoms."***
>
> – PROFESSOR RICHARD EASTHER

Building the Lego of the Universe

From a physicist's perspective, there are two truly fundamental ingredients for life: material that is able to support complex systems and a Universe that can supply the energy needed to sustain it.

World-leading cosmologist and physicist, Professor Richard Easther, says particle physics and cosmology can shape our thinking about the existence and persistence of life in the Universe, as well as when and where it can form.

"Physicists are 'reductionists', we know that almost everything is made out of something else," he says. "Everything – and I do mean everything – that we touch or see or smell or taste is made out of atoms."

But like Lego even these can be broken down into smaller 'parts' – protons, neutrons, electrons, quarks, gluons, etc. Given these raw materials and the laws of physics, Richard says it is possible to build up the properties of all the atoms that exist and all the compounds they can form.

"However, it is not just enough to have the 'possibility of atoms' – the Universe actually has to make them. Everything we can imagine has once been part of a star and it takes billions of years to build up the supply of atoms that went into our Solar System. But if we are going to have chemistry or anything else we need chemical elements and that takes time."

Where does that leave our quest to find the origins of life and the existence of life elsewhere in the Universe? The research is moving forward, constantly adapting and evolving in small steps and giant bounds, as Te Ao Mārama and other international initiatives confront these big questions at the frontier of science and philosophy.

Our advice while we are waiting for new insights? To quote our world-leading cosmologist, "Given that no one seems to have all the answers yet, we should take this time to appreciate that the level of emergent complexity in the Universe is truly amazing!"

Thank you to all our guest speakers.

Listen to Fundamental Questions on Life in the Universe *A Panel Discussion with Kim Hill*
www.rnz.co.nz/national/programmes/smart_talk

Vice-Chancellor's Lecture Series guest speakers

LECTURE 1

Discoveries of Extra-Solar Planets and the Search for Evidence of Extraterrestrial Life

Professor David Bennett, NASA Goddard Space Flight Centre and the University of Maryland

LECTURE 2

Searching for Alien Life in the Solar System

Professor Maria-Paz Zorzano, Astrobiology Center of the National Institute of Aerospace Technology

LECTURE 3

Letting Life Happen: from Particles to People

Professor Richard Easther, University of Auckland

PANEL DISCUSSION

Fundamental Questions on Life in the Universe

Professor Maria-Paz Zorzano; Dr Heather Hendrickson, Massey University; Dr Dan Hikuroa, University of Auckland; Professor Kathy Campbell, University of Auckland. Chaired by Kim Hill, Radio New Zealand

Te Ao Mārama – Centre for Fundamental Inquiry

The centre is led by director Professor Kathy Campbell from the School of Environment. She is joined by co-founders Professor Richard Easther from the Department of Physics, Dr Daniel Hikuroa from Māori Studies and Dr Emily Parke from the School of Philosophy. The wider team includes researchers from Biological Sciences, Business, Computer Science and Engineering Science.

www.teaomarama.auckland.ac.nz

Some liked it HOT

The relentless quest to prove whether there once was life on Mars is a key driver behind two trans-Tasman research initiatives that are simultaneously looking into the evolution of microbes in hot pools near Rotorua and beneath the parched red earth of Western Australia.

IRONICALLY, THE ROTORUA research is being funded by the Australia Research Council while a West Australian drilling campaign is supported by a New Zealand Marsden grant, but Professor Kathy Campbell from the School of Environment says they share a common purpose.

"Each one of the projects ties the bigger picture together about early life in our Solar System. Did it only happen on Earth? Or did it also happen on Mars?"

Exploring the geothermal mixing zones of Rotorua

The Rotorua project aims to get a better understanding of the biological influences on the formation of silica-rich hot spring deposits that may be morphologically similar to the cauliflower-shaped knobby growths of silica known as spicules that were discovered by NASA's Mars exploration rover, *Spirit*.

All the nutrients for life can be found in hot pools that have very different chemistries, temperatures and colours. The research focus is on the so-called 'mixing zones' where outflows meet. "Maybe it's in those zones where things get complex in the pre-biotic chemistry," says Kathy. "Is that the place where you generate the spark for life?"

"It's this question of where did life originate? Could it have originated in mixing zones in hot pools – on land?"

– PROFESSOR KATHY CAMPBELL

School of Environment PhD student Chanenath 'Kitty' Sriaporn from Thailand is studying the microbiology and says she loved star gazing as a youngster. "I find this stuff quite fascinating, the origins of life and the possibility of there being extraterrestrial life."

In addition to sampling the Mars-like spicules in Rotorua, Kitty is looking at the microecology of the pools to determine what organisms live where and what they're doing. "Could this environment lead to more evolutionary streams of some life forms? Do they favour adaptation and mutation, and if so, was it also possible for this to happen three billion years ago?"

While it is too early to draw any conclusions, Kitty says that organisms living in the New Zealand hot springs tend to be further along the evolutionary chain – and more robust – than similar organisms found elsewhere. "The strains that we found at the hot springs here tend to have a higher evolutionary distance – they have evolved more," she says.

Along the way, Kathy is challenging the age-old theory that life on Earth evolved from hydrothermal vents in the ocean. "What if life evolved on land instead of the sea and went in the opposite direction?"

While she admits that life on land early in the Earth's history would have been "horrible" because of the extra UV radiation, Kathy says that microbes in hot springs may have been protected from the radiation by minerals like silica – whereas the ocean environment was simply too diluted for the right chemistry to occur. "It's this question of where did life originate? Could it have originated in mixing zones in hot pools – on land?"

Above: Champagne Pool, Wai-O-Tapu, Rotorua.

Facing page (left): Professor Kathy Campbell with PhD students, Chanenath 'Kitty' Sriaporn and Michaela Dobson.

Facing page (right): Studying Scanning Electron Microscope (SEM) images of hot spring spicules.

Pilbara's ancient hot spring deposits yield clues

More than five thousand kilometres away in the Pilbara region of Western Australia, another School of Environment PhD student, Michaela Dobson, has been looking for signs of early life in 3.5 billion-year-old hot spring deposits. As Kathy puts it, "getting down into the nitty-gritty of the relationship between the microbes and the minerals that preserve them."

Michaela chose geology as a core subject and spent time around Rotorua's Hells Gate geothermal area, where she completed her fourth-year honours, before being recruited to analyse the fresh core samples that have been drilled from 70 metres below the rusty surface of Pilbara.

"You need to study fresh drill cores underneath the red weathered land surface to understand the original environmental conditions under which the organisms were living," Kathy says. "That tells you what type of chemistry these organisms were using. They were doing some sort of sulphur cycling and then sulphate and sulphide minerals were forming around the microbes."

Using a hand lens and various scanners, the cores are being logged to identify any microbial or mineral remnants that compare to those found in Rotorua. "Is it like a hot spring in Rotorua or is it more like a deep-sea vent – or something else?" says Kathy.

So far the UNSW-UOA* group's research has produced a couple of surprises, one being possible evidence of the bio-mediated geyserite that forms around hot spring geyser vents which Michaela says "may be the earliest evidence of life on land."

What was totally unexpected was the discovery of tiny spherical shards of glass that appear to be impact spherules that resulted from asteroid strikes 3.5 billion years ago. "That's exciting," Kathy says, "because it's new and could be one of the earliest examples of impact horizons that might have frustrated the life that was starting to grow. Or it might have somehow enhanced it by bringing nutrients and rich elements from outer space – we don't know."

Discovering past life on Mars

What Kathy really wants is to retrieve samples from Mars; however, her hope that a new rover mission scheduled for launch in July 2020 might do just that were dashed when NASA chose a different location to the site where the Martian geothermal features were detected.

Not to be denied, she and colleagues are now pitching a Mars mission proposal to the Japan Aerospace Exploration Agency (JAXA). Kathy describes JAXA as "a whiz at landing on asteroids and bringing back samples", not to mention Japan's very high-tech laboratories for analysis.

One impediment to the Japanese mission might be the high price tag but, like Mr Spock of Star Trek fame, Kathy would love to go back and "interrogate the samples" while NASA's Captain Kirk approach explores new and amazing things over the horizon. "We think Mr Spock is going to find life on Mars and we're not totally sure that Captain Kirk will," she muses.

A key feature of the research effort is the international collaboration with other groups conducting similar work in Chile's El Tatio geyser field high in the Andes and North America's Yellowstone National Park.

"It's a very wide web that we're connected to," Kathy says. "There are lots of different people working on the question of whether there is any other life in our Solar System past or present and it's the researchers who are driving the direction of the science rather than any specific country or institution."

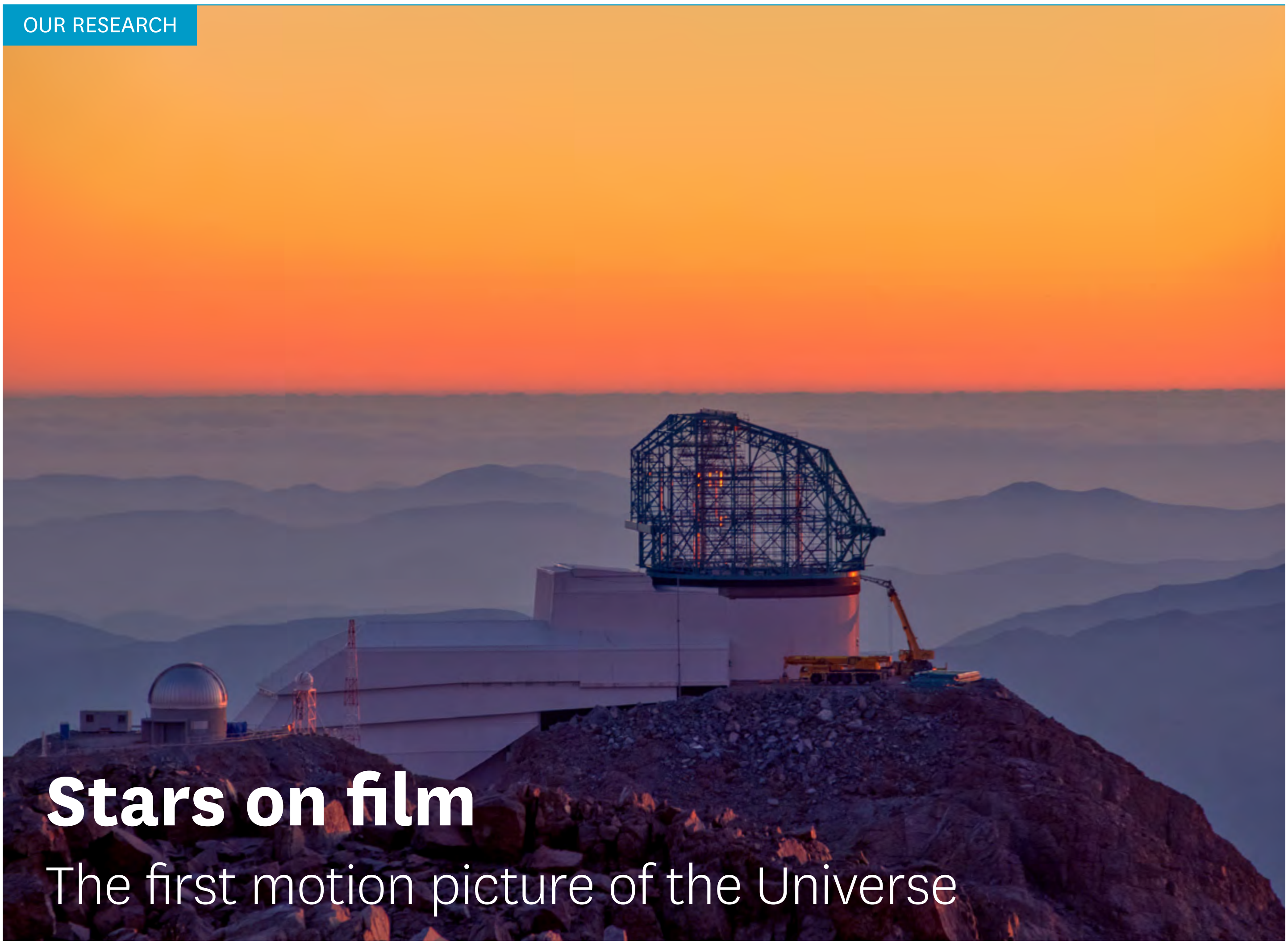
> ***"Maybe it will be human exploration of Mars in the future that locates the microbial Martians that may be lurking there."***
>
> – PROFESSOR KATHY CAMPBELL

That said, the University of Auckland's Te Ao Mārama – Centre for Fundamental Inquiry is playing its part by connecting researchers across disciplines. The new Te Pūnaha Ātea – Auckland Space Institute will add further impetus by perhaps contributing engineering expertise to the proposed Japanese space mission.

As for the future, Kitty is likely to eventually return to Thailand to work for the National Astronomical Research Institute (NARIT) which Kathy says will boost collaboration with that country. Once her PhD is completed, Michaela likes the idea of doing a post doc at one of the world's big research centres before becoming a lecturer.

For Kathy, her lifetime of extreme environment research is ongoing, but she concedes that if JAXA doesn't pick up the Mars mission and NASA is busy elsewhere then it might take quite a long time to find out whether life evolved on Mars. "Maybe it will be human exploration of Mars in the future that locates the microbial Martians that may be lurking there."

** University of New South Wales – University of Auckland.*



Stars on film

The first motion picture of the Universe

The science of star gazing will be taken to an entirely new level in 2022 when a next-generation telescope fitted with the world's largest digital camera starts to capture what's been described as the first motion picture of the Universe.

CURRENTLY UNDER CONSTRUCTION in Chile, the USD626 million Large Synoptic Survey Telescope (LSST) is a joint venture between the United States Department of Energy and National Science Foundation but is being supported by scientific communities from many countries including New Zealand.

Conceived in the late 1990s, the LSST was originally called the Dark Matter Telescope because of the desire to explain the dark matter that makes up about 85 percent of the mass of the Universe. Since then, the project has evolved to address some of the most pressing questions about the structure and evolution of the Universe based on four key science pillars:

- Understanding the nature of dark matter and dark energy
- Detecting hazardous asteroids and cataloging the remote Solar System
- The formation and structure of the Milky Way
- Exploring the transient sky

Programming surveys of the night sky

While most telescopes make observations more or less on demand, Dr Nick Rattenbury from the Department of Physics says the LSST is completely different because it will be programmed – with a certain degree of flexibility – in advance for a ten year survey over half the night sky. "They're going to set it all up to start off with and say we're going to use the telescope this way, hit go, and sit back and let the data flow."

Which is why Nick has engaged PhD student Martin Donachie to conduct simulations, which are also being conducted by scientific communities worldwide, to determine how the telescope might satisfy potentially conflicting research needs as it trawls the sky every two or three nights.

Partially funded by Nick's Royal Society of New Zealand Rutherford Discovery Fellowship, the simulations will form the basis of proposals submitted by several international collaborations to the LSST Science Advisory Committee which is expected to announce an initial observing strategy in early 2021 that will be optimised to address the four key science pillars.

"It's a giant optimisation problem," says Martin. "It's about trying to collaborate and find common ground to advocate for the observations that are best for your science, without trying to kill anyone else's science."

Detecting dark matter

The specific focus of Martin's research is on exploring what's known as the 'transient sky' using a technique called microlensing – an astronomical effect predicted by Einstein's General Theory of Relativity – in which matter bends the space around it and creates a 'lens' that distorts and magnifies distant objects. Crucially, the lens does not need to emit any light in order for it to be detected, which makes microlensing ideally suited to the detection of faint or dark objects.

Microlensing is the only technique sensitive enough to detect low mass planets orbiting at large distances from their host star. But what gets astrophysicists like Nick out of bed in the morning is the search for black holes – and dark matter. "We've got to come up with some kind of way of explaining a large fraction of the mass of this Universe which we can't see."

By regularly monitoring the entire Milky Way, Martin says the LSST will find many more events that are currently going undetected. "This, in turn, will tell us about the mass distribution across the galaxy, which will have implications for galaxy formation, planetary theory and dark matter science by revealing the presence of black holes and extrasolar planets within our galaxy."

Dark matter kicked off the microlensing game back in the late 1980s, and Nick says the hunt is still on for some hidden component of matter or new particle which carries some mass, but which is extraordinarily hard to detect. Hopes are high that the LSST can also shed some new light on the 'dark energy' that is causing the Universe to expand at an ever-faster rate – and tear itself apart.

"These two components of the Universe account for an embarrassing amount of mass and energy in the Universe which we simply do not understand. So that's why we build these sorts of things."

Exploring theories about the expansion of the Universe

Described as potentially one of the greatest scientific experiments in human history, the LSST is expected to observe 20 billion galaxies, 20 billion stars and discover hundreds of thousands of Near-Earth Objects during its ten year mission. The images produced will be deep enough to detect the faintest and most distant galaxies and Martin says, "we will be able to see how stars and galaxies change over that time in exquisite detail which will reveal new insights in fundamental areas of physics and astronomy".

It is also expected to test our fundamental understanding of the Universe. Whereas the first theories about the accelerating expansion of the Universe were based on the discovery of around 40 supernovae in the late 1990s, Martin says the LSST will find ten times that many in its first night and will likely result in many theories having to be refined or dumped. "Every conceivable area of astronomy is going to be impacted and benefited by the project," he says.

The project will generate an estimated ten million alerts every night and, as Nick puts it, "the LSST is going to eat everybody's lunch in terms of how much data and how much sky it observes, it's just extraordinary".

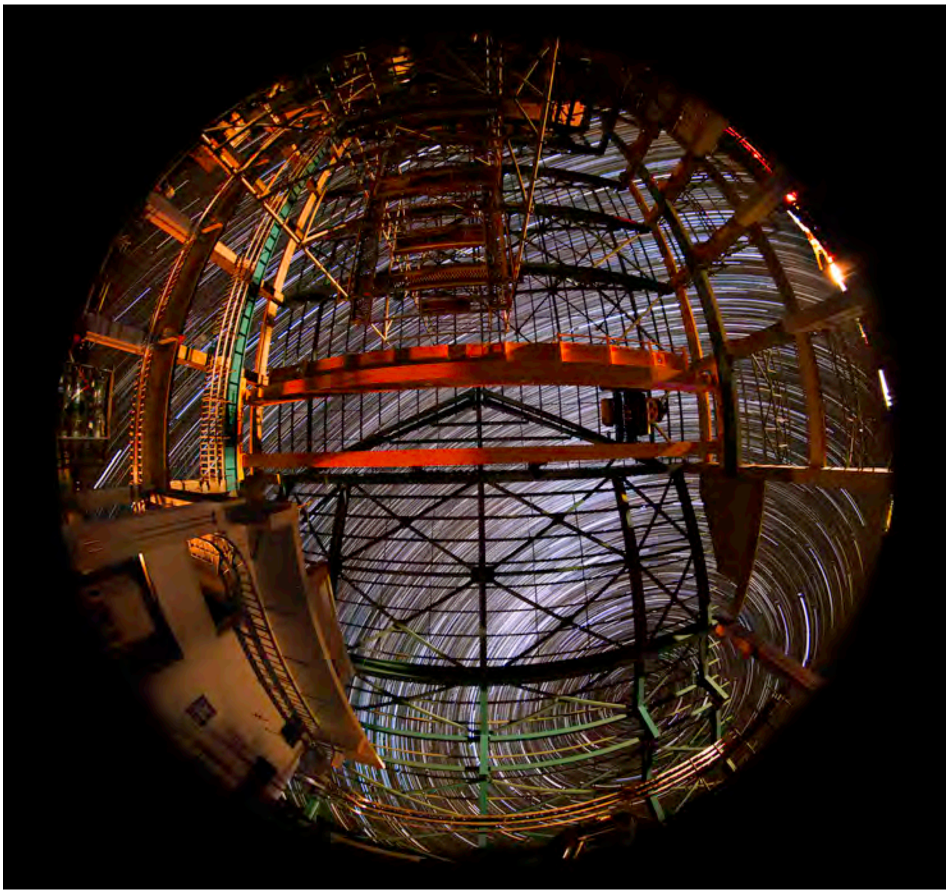
Discovering extrasolar planets and extraterrestrial life

The challenge for scientists like Martin will be to find the interesting events hidden in the avalanche of data. Which is why the scientific community will conduct follow up observations using other telescopes including the University of Canterbury Mt John Observatory near Lake Tekapo (part of the Microlensing Observations in Astrophysics (MOA) collaboration with Japan and the US). MOA has been staring at the centre of our galaxy for the past two decades and observes hundreds of events per year. When there are millions of stars you need to monitor all of them just to see a few microlensing events. "The more stars you can see the more chances you've got, it's an odds game," Martin says.

The MOA collaboration is currently building a second telescope in South Africa that will operate in the infra-red and perform precursor observations for yet another major project called the Wide Field Infra Red Space Telescope (WFIRST).

Operated by NASA and costing an estimated USD3.2 billion, the WFIRST space observatory is expected to launch around 2025 with the goal of precisely measuring the effects of dark energy and probing the expansion history of the Universe.

Future plans for WFIRST include a microlensing survey in tandem with LSST which Martin says is expected to detect thousands of extrasolar planets including hundreds of Earth-mass planets – considered to be one of the ultimate goals for astrophysicists because of the prospect of finding other life forms.



Above: Dr Nick Rattenbury (left) with PhD student Martin Donachie.

Top: Summit Multimedia Visit 2017.
Photo: M. Park/Inigo Films/LSST/AURA/NSF

Facing page: LSST at sunset, Cerro Pachón, Chile.
Photo: W O'Mullane/LSST Project/NSF/AURA

Indeed, one of the more exciting aspects for Nick is the prospect of discovering all sort of planets and very low mass worlds that contain moons, like Jupiter's Europa, that have a cold outer surface with a liquid ocean beneath which could conceivably harbour extraterrestrial life.

"If we start speculating that life could exist in a sub-surface ocean, then discovering these sorts of worlds adds more information to how many worlds are out there where life could take hold – that's part of the excitement for WFIRST."

LSST – www.lsst.org

The curiosity and wonder of it all

Applied Mathematics and Physics student Anastasiya Kiddle says she's never personally experienced any gender bias, but she's heard a lot of stories from friends who have.

"WHEN I FIRST walked in to my lectures I did notice that there were so many guys. It's not just something that's statistics on paper, it was visible," she says.

"It would be nice if there were more women in my subjects. I mean, different genders see different things – there have been papers published in this area – if you're searching for a specific thing, get a woman, you know?"

Auckland Programme for Space Systems (APSS-II) 2018 CubeSat competition winners Kessler knew they were on to something when they got Anastasiya.

As the youngest member of Kessler, Ana started off doing intensive research for tether operations. For the layperson, tether operations embodies the science behind a satellite's electrodynamic tether – something that is sent out by a satellite to de-orbit it at an accelerated rate.

"We don't just have rubbish on Earth, we have rubbish in space. Kessler Syndrome (what our team is named after) is the idea that as we increase our space exploration and commercialisation, all the defunct satellites in low Earth orbit (LEO) are more likely to collide, break apart, and cause more and more rubbish."

Collisions between objects in LEO have potentially disastrous implications for anything that relies on satellites, such as GPS, television broadcast, military operations, and scientific research. Even small objects less than one centimetre across could cause significant damage because they're travelling at such high speeds.

And this is where Kessler's satellite tether comes in. Sending out the tether means that magnetic and electric fields will exert a force on it, which will slow the satellite down and pull it out of the LEO. The goal, says Ana, is for the old or broken satellite to disintegrate in the atmosphere, eliminating the build-up of 'space junk' and therefore reducing Kessler Syndrome.

But before the team can even begin to build their tether into their satellite, they need another crucial device – an emitter, which emits electrons. Ana spent a full year researching the different types of emitters, which would work best for Kessler's purposes, and who might be able to supply them.

She's now at the point where she's almost finished her research and can start thinking about the physical testing. "I'm asking myself, 'If we get the emitter, what's going to break it?' These things take such a long time, and you're working with equipment on such a small scale. The wires on the emitter are like a strand of hair, so I'm always worried I'm going to break it if I breathe on it! Everything is expensive; expensive and fragile."

All this detailed work is in addition to Ana's main programme of study. APSS is entirely extracurricular and students receive no credits towards their courses. So how does she manage to balance everything?

Anastasiya Kiddle

"I use Google calendars for everything! It definitely fluctuates. It's just time management and prioritising – I try not to overload myself."

But the passion for her subjects is what keeps Ana going. She typically spends about five hours per week working on Kessler's tether operations, and when semester break comes along and she has a respite from assignments, she likes to spend longer working on the project. "I can hop in the lab and work for nine hours straight and not even notice the time passing."

Ana comes from a line of engineers (her dad is a civil engineer, and both grandfathers were mechanical engineers) and, while she did consider pursuing a Bachelor of Engineering, it was the fundamental sciences that really ignited her interest. "It was the curiosity and wonder of it all. My favourite thing is to look at something and think, 'I can explain that mathematically, at the fundamental, physical level'. The more you learn, the more amazing things seem."

A competition in Year 13 piqued her interest in space science. She led a team investigating the question: 'How much money do you need to colonise the moon?', which she says was an eye-opening experience for her. "I already knew I liked science, but the competition was a pivotal moment for me because I realised that I wanted to pursue it as a career."

How that career will evolve is one question that Ana will leave open for a while. She knows she wants to do postgraduate study, but she's aware that experience in New Zealand's space industry will be invaluable. Still only in the second year of her Bachelor of Science, Ana is already planning for her future, which includes the pull of the overseas experience. "I'm learning French, Japanese and German, and I'd like to be fluent so I can have the freedom to work in different countries."

While much of Ana's scientific focus is above the planet, the gravity of her social conscience keeps her grounded. She loves people, and wants to see humanity succeed.

"All around the world we've got suffering, and I think physics can help change that for the better. I feel that by doing my best in whatever I choose to do, I can help others and increase people's standard of living and happiness."

Launched in 2016, the extracurricular Mission Proposal Competition organised by the Auckland Programme for Space Systems (APSS) requires cross-faculty student teams to identify a societal need and design a solution using a 10 x 10 x 10cm satellite called a CubeSat. The winners of the competition get their CubeSat launched into space.

Learn more:
www.apss.space.auckland.ac.nz

Astronomy, astrophysics and asteroids

For Amelia Cordwell, the symbiosis between a curious mind, a thirst for learning, and exposure to research has created an enduring love and respect for physics and the scientific study of space.

AMELIA IS IN HER third year of a Bachelor of Science in Physics, and she thinks space is 'cool'. It's an expression she uses a lot when talking about the astrophysical research world she now occupies. An expression which seemingly belies the complexity of space and humankind's fixation for our 'final frontier' throughout the ages. The study of space creates more questions than answers. And yes, it is very, very cool.

Amelia's interest in space has been a slow burn from her teenage days in Wellington when she planned to become a software developer and occasionally attended events at the Wellington Astronomical Society (WAS).

Before Amelia passed her driver's license, her mum would transport her, a friend, and a large telescope lent to them from the WAS, up to Mt Victoria where they would gaze at the night sky just for fun.

After a semester studying Engineering at the University of Auckland, back home in Wellington, Amelia realised she wanted to study physics to broaden her education.

"I got a summer internship as a software developer and I thought this is fun, but there is so much more I want to learn," she says. "I changed my focus to physics because it's so expansive and you develop really interesting ways of thinking about the world. I decided to get involved in a bunch of things at uni and try out everything I can."

Once Amelia's focus zeroed in on physics, and having been accepted into the Science Scholars Programme at the Faculty of Science, the world of research beckoned.

But it was while taking part in the Auckland Programme for Space Systems (APSS) undergraduate CubeSat competition that Amelia met Dr Nick Rattenbury, Senior Lecturer at the Department of Physics. Although not a part of the winning team, the networking opportunity provided a catalyst for pursuing ongoing opportunities in the astrophysical field.

Amelia attended the Australian National University's research school of Astronomy and Astrophysics Winter School ten-day programme, and grabbed the chance to spend two weeks setting up and monitoring the Microlensing Observations in Astrophysics (MOA) telescope that is based at the Mt John University Observatory in Tekapo, before embarking on a Summer Research Project with Nick using data from the MOA telescope to characterise asteroids.

Nick is in awe of her passion to pursue and satisfy her curiosity. "Amelia's skills in programming were vital for making progress in our work. Amelia has access to a large amount of data which requires skills in database management. Each of the images in the database have to be combined in particular ways and analysed to extract the signals that are of interest to us," says Nick. "The photometric analysis codes that Amelia developed herself are computationally intensive and her algorithms have the ability to handle exceptions gracefully."

Amelia Cordwell

Even though Amelia's Summer Research Project ended months ago, in between lectures and assignments, you will find Amelia in the APSS lab at the heart of the University of Auckland's City Campus, trawling through images taken by the MOA telescope and using her programming skills to data mine her findings.

She continues to look for asteroids, small solar system bodies that are orbiting the Sun. The goal is to find out where they appear to get an idea of how their brightness changes over time.

"If you have enough data and an idea of their shape it's possible to distinguish them from stars and potentially study how individual asteroids as a whole system have evolved, and how they are tied together with everything else in space," says Amelia.

Amelia's work creating a data set from these images is part of a bigger picture of collaboration in research, which she considers to be a necessity, especially in the field of astronomy.

"This isn't a project that can be done by one person. If I generate data and generate results from this, the results can be somewhat important, but they're more important when we can ask 'how do we look at this from a whole system?'" she says.

Testament to this is the study of physics itself which encompasses mathematics and computer science. Nick explains, "While physics seeks to understand natural world phenomena, mathematics is the language that describes what we see around us and how we encode our theories of the natural laws which give rise to what we observe. Physics uses computer algorithms to embody the mathematics. Running these algorithms can solve those mathematical problems and allow us to test our theories against observed data."

Amelia agrees, "If you want to understand something that you observe, physics gives you all the tools to do that."

Women in Science Fund

Supporting and encouraging more women to study science is a priority for the University of Auckland. There has never been a time when it was more important to acknowledge the value of women scientists and the work they do. We want to achieve full and equal access to and participation in science for women and girls. Please help us to support more women in science by making a donation of any amount to the Women in Science Fund.

www.giving.auckland.ac.nz/womeninsciencefund

Space is for everybody

More than a few researchers we meet on our travels raise an amused, sceptical eyebrow at the thought of Kiwis being among those with an interest in space, but, in fact, Aotearoa New Zealand has a long history in space science and technology.

STARTING WITH BILL PICKERING leading NASA's Jet Propulsion Lab from 1954 to 1976, and Beatrice Tinsley's pioneering astronomy from the 1960s to the 1980s, through to Peter Beck and his team at Rocket Lab, we can confidently say, 'we have form!'.

Indeed, in 2017, New Zealand was the first country in the world to host a fully-private launch operator, Rocket Lab, offering dedicated small satellite launches from their own facility on the Mahia Peninsula. Its frequent launch model and Electron launch vehicle draws on cutting-edge technology from across New Zealand's science and innovation system – supported by government effort led by the New Zealand Space Agency (NZSA), located within the Ministry of Business, Innovation and Employment (MBIE).

As well as having a track record in science and technology, our legislation, the Outer Space and High-altitude Activities Act, enables a responsible, secure and innovative New Zealand-based launch industry and allows ready connections with the global space sector, which is fast growing and inherently research and development intensive.

Professor Juliet Gerrard and Marta Mager in front of the White House, Washington DC.

"Space is for everybody. It's not just for a few people in science or math, or for a select group of astronauts. That's our new frontier out there, and it's everybody's business to know about space."

– CHRISTA MCAULIFFE (1948–1986)

An increasing number of other commercial companies are launching, manufacturing, and operating satellites. This creates an increasing market for downstream products and services using the data generated by these satellites. The application of space-based services and products is becoming more common, opening new ways of communicating, navigating and understanding our natural environment using satellites for observation.

Our journey as a space-faring nation began in the 'New Space' era – a term that describes the accelerating pace of private sector investment and innovation that is transforming the global space economy. Unlike most space-faring nations, New Zealand does not have a legacy in traditional, large-scale government-led space programmes, but we do have a particularly collaborative and agile approach to space, and our 'space ecosystem' is evolving rapidly. Beyond Rocket Lab, we already have great space start-ups across the country (including some that have come out of the University of Auckland) and opportunities to grow. We're off to a promising start: a recent Deloitte report has found New Zealand's space sector contributed $1.69 billion to the economy in the 2018/2019 financial year and employs 12,000 people.

Earlier this year, the New Zealand Space Agency supported a delegation of nine space companies and research organisations at the world's largest annual space convention, the International Astronautical Congress in Washington DC. Professor Guglielmo Aglietti, inaugural director of Te Pūnaha Ātea – Auckland Space Institute, and Dr John Cater from the Faculty of Engineering represented the University of Auckland. New Zealand signed several agreements, including a memorandum of understanding with the Australian Space Agency.

Another milestone in 2019 was the completion of US Company LeoLabs' Kiwi Space Radar in Naseby, Central Otago, which helps tracks objects in lower earth orbits down to two centimetres. And MBIE's Peter Crabtree recently spoke about how New Zealand met its responsibilities under the Outer Space Treaty, as well as our ambitions to maximise the opportunities for science and technology around the space opportunity.

So, despite those raised eyebrows, we predict exciting times ahead.

PROFESSOR JULIET GERRARD
Prime Minister's Chief Science Advisor
Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia

MARTA MAGER
Head of Agency/ Minister Counsellor
Science & Innovation, USA & Canada, MBIE

Watch *NZ's diverse and fast-growing space sector: www.youtube.com/watch?v=MSc3I-S9HCQ&feature=youtu.be*

Read *www.spacenews.com/leolabs-kiwi-radar-opens and www.spacenews.com/nzsa-priorities and www.beehive.govt.nz/release/nz-space-economy-worth-169-billion*

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SCIENCE

2020 Alumni and friends events

19 March	Bright lights | St Matthew in the City, Auckland
20 March	Distinguished Alumni Awards Dinner | University of Auckland Pavilion, Auckland
27 April	Kuala Lumpur Alumni and Friends Reception | Kuala Lumpur
30 April	Singapore Alumni and Friends Reception | Singapore
5 May	Graduation Gala Concert | Supper Room, Town Hall, Auckland

Keep in touch with what's happening

Find recent alumni news announcements, event invitations, public lecture recordings, and photo galleries gathered in one place

www.auckland.ac.nz/en/alumni/whats-happening

Please note: Event dates are subject to change. Before booking travel to an event, please check with the Alumni office **alumni@auckland.ac.nz**

Don't miss out on an invitation to network

To ensure you receive invitations to events in your area, make sure your details are up-to-date

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