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Editor:
Ray Murphy

Articles by:
Geir Aas

Layout:
Geir Aas
Ray Murphy

newsletter@physics.dcu.ie

web: www.physics.dcu.ie
email: physics@dcu.ie
tel: +353 1 7005306

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School of Physical Sciences Newsletter

Welcome from

Professor John T. Costello



Welcome to the School of Physical Sciences newsletter and thanks for taking the time to read it. We hope you find it interesting and informative. We profile a number of our staff and students who talk about their interests both inside and outside physics. We focus on some of the research being conducted in the School by a number of my colleagues on next generation fusion energy sources, physics education, astronomy and biomedical physics. Our research interests extend from the most fundamental to near term applications in astronomy, energy, physics education, lasers, plasma physics, semiconductor materials surface science and biomedical sensors. You are welcome back to visit the website or indeed the school anytime.

Solving World Energy Problems with Plasma

Professor Miles Turner lectures in Physics in DCU. He is also the director of the National Centre for Plasma Science and Technology (NCPST), and has won several national grants and awards including a Science



Foundation Ireland's Principal Investigator Award in January 2008. The award of just over €900k over four years will allow Prof. Turner to continue his work on the fundamentals of processing plasmas and advanced process control.

Prof. Turner explains that the study of plasma "is important because it is an inevitable part of the technological future that can be used to do almost anything."



What is Plasma?

Plasma is achieved when you warm up

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World Leading Biomedical Diagnostics Institute

Brian MacCraith is a professor in Physics at DCU. He is also the current Director of the Biomedical Diagnostics Institute (BDI) and the former Director of DCU's National Centre for Sensor Research (NCSR). From his office in the Physics Department he runs one of Ireland's most exciting, innovative and promising research institutes.

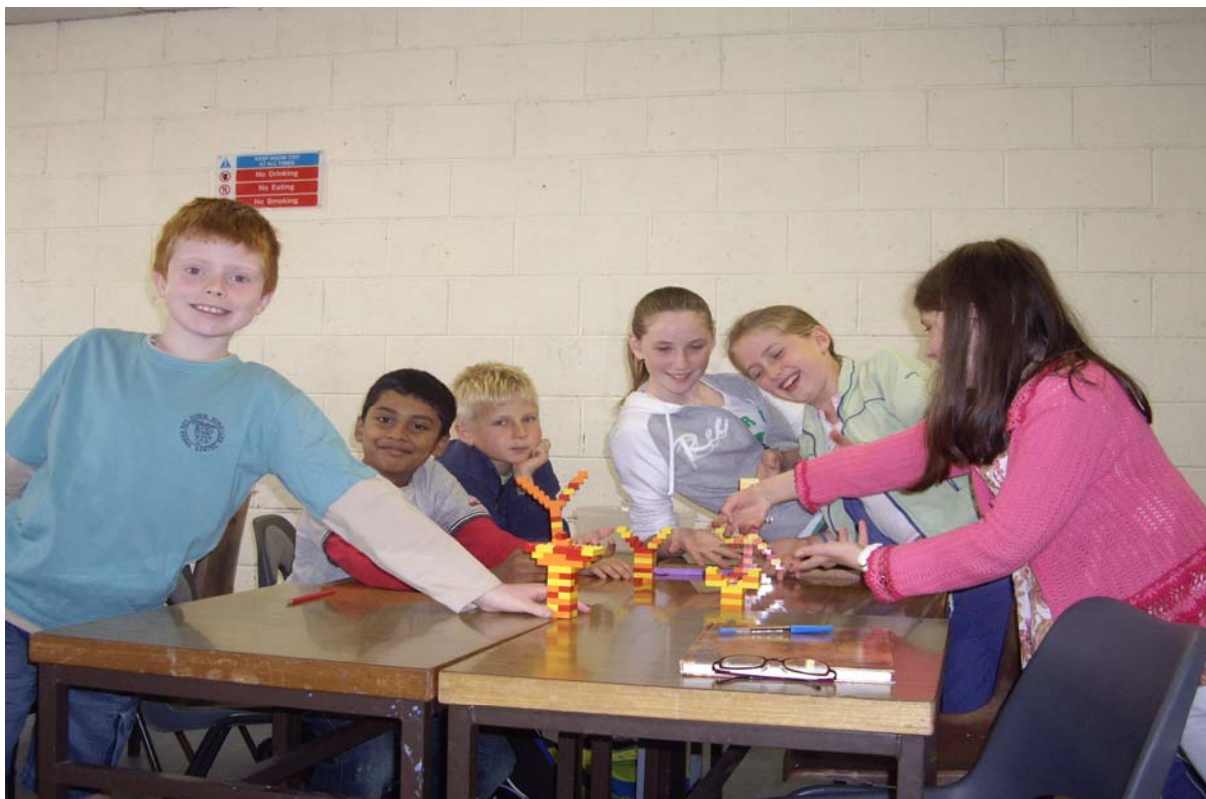


At the opening of the BDI in 2006, former Taoiseach Bertie Ahern said the research carried out at the BDI "has the potential to radically change the way in which we diagnose and manage disease, worldwide."

So what does the BDI actually do?

Prof. MacCraith describes the BDI as a multidisciplinary research programme that fuses together the work of researchers from physics, engineering, chemistry, medicine and biology to potentially revolutionise the health care system of the entire world. In particular, it takes great advantage of the adapta-

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Me And My Body (MAMBO) is an initiative launched by the BDI to help spread interest in science amongst primary school pupils. Here are some students who attended a MAMBO course at the Centre for Talented Youth in Ireland in 2007

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bility of physics to work with any other scientific discipline. The BDI works at the cutting edge of development of diagnostic techniques with the goal of diagnosing diseases rather than waiting until someone is sick before treatment is received. The BDI research will eventually lead to low-cost, rapid, non-invasive and effective ways to test for, amongst other things, cancer and cardiovascular diseases.

Nanobiophotonics

BDI researchers have a particular interest in Nanobiophotonics, which is the combination of Biophotonics and nanotechnology. Biophotonics is, amongst other things, the study of how lasers can be used to detect blood flow, measure body functions and perform surgery, and it's a really good example of how physics can be used to directly influence and even save our lives. This knowledge, combined with expertise in nanomedicine and technology, enables the BDI to come up with cutting edge inventions that influences clinical outcomes.

Physics

One of the four prototypes recently created by the BDI is a small

disposable plastic chip that when given a single drop of blood and inserted into a machine, can tell you within minutes how great a risk you are at of developing heart disease.

"The goal is to eventually have these installed in every clinic and Doctor's office!" Prof. MacCraith continues by pointing out that "the best part of it all is that all the sexy parts of this work are based on physics!"

It sounds a bit strange until he takes us to the lab and shows how the machine reading the chip actually works. It's an intricate system combining light, lasers and mirrors that allows computers to analyze the molecules in a single drop of blood. On the outside the machine looks more like a game console made of metal, which you would expect to be filled with wires, cables and circuit boards, but when you look inside the casing you will be amazed at how simple and logical the whole thing is. It looks like a puzzle anyone could just put together at home.

Prof. MacCraith explains that the logical sense of physics is what attracted him into the field in the first place.

The ability of physics to explain exactly how things work as well as a fascination for lasers and photonics led him to pursue his career in this area. The possibility of combining physics and photonics to solve real world problems from pollution, to detection and treatment of diseases makes it a truly essential part of technologies that can change the lives of coming generations.

Interdisciplinary Research

Disciplinary boundaries are disappearing as researchers from many different fields and many parts of the world come together at DCU and work to make the world a better place. Prof. MacCraith points out that physicists have a distinct advantage as their field is applicable to almost anything. That way it is much easier for a physicist to understand and adapt to the viewpoints of a chemist or biologist than the other way around. By getting a physics education at DCU you will have the opportunity to join Prof. MacCraith and the myriad of other researchers from around the world in revolutionizing modern medicine and changing lives.

Email: Brian.MacCraith@dcu.ie

Web: www.bdi.ie

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gas to several thousand degrees Celsius until the electrons move away from the atoms resulting in free electrons and ions. Plasma is found everywhere in the universe according to Prof. Turner and it can be used to do the most amazing things.

Fusion energy for instance is based on heating a plasma to millions of degrees in a reactor causing nuclear reactions that will produce 10 times the amount of energy that is spent. The perfection of this technology could potentially solve the world's energy problems for ever.

Fusion research at NCPST

The NCPST is part of a research program called ITER that works on building a fusion reactor in Southern France. The main challenges for Prof. Turner and his colleagues in this project are to find effective ways of heating the plasma to the required temperature, and the study of methods on how to contain the plasma within the reactor without particles bouncing off and causing serious damage to the metal walls.

In March 2008 a research team lead by Prof. Turner signed a new contract with the European Commission. This contract is worth between €4 and €5 million and will ensure Ireland's future participation in the development of Nuclear Fusion Energy in Europe.

Microchip development

Fusion energy is, however, just one area within plasma science. Microchip development is another field where plasma technology is important. Ten years ago the big stationary computer in your basement would probably have a hard disk space of about one gigabyte. Now you can fit the same amount of information on a small chip that you put in your mobile phone. A new laptop will today typically have 100 gigabytes of hard disk space. This is all thanks to plasma's ability to alter surfaces. This ability can also be used within the field of medicine and biology - for example by altering the surface of a replacement body part to promote better healing.

There are still many aspects of plasma that are not yet understood

and so the fundamental science that underpins it, like its chemistry, is an important part of the studies done at the NCPST.

Top quality graduates

The centre produces top quality graduates with cutting edge knowledge and understanding of plasma, whose expertise is required for jobs around the world. Prof. Turner also points out that plasma research is "exactly what the government is looking for", and so about a dozen spin-off companies have been established as a result of research at the NCPST.

€100 billion industry

Plasma technology is a fast growing €100 billion industry that generates significant commercial interest even in Ireland. With the increase of knowledge in the fundamental science of plasma the improvement of current technologies as well as the applicability to new industries quickly becomes apparent. Prof. Turner advocates the study of plasma at DCU for people who are looking for intellectual challenges that will have exciting applications.

E-mail: miles.turner@dcu.ie

Web site: www.ncpst.ie



An inductive radiofrequency argon plasma in the BARIS experimental chamber at the NCPST in DCU. Plasma set up and photographed by Dr. Ronan Faulkner, Plasma Research Laboratory.

RDF Instructor and Physics Graduate

Arlene O'Neill is an Applied Physics student who just happens to be a corporal in the Reserve Defence Forces (RDF). There she teaches discipline and military techniques to fresh recruits.

The 22 year old from Lucan in Dublin has been in the RDF for the last 5 years, climbing up the ranks from a fresh recruit to a respected instructor. She considers herself very fitness oriented, and so the RDF was a natural part-time activity to engage in. In addition, her dad and grand-dad were in the FCA (The RDF before 2005) so she grew up hearing stories about the life in the reserve and became interested herself.

Now after 5 years of crawling through mud, weapons training, field craft, orienteering and training undisciplined recruits she doesn't regret a second. "This is a lifetime commitment, I wanna do it forever" she laughs. Arlene chose to physics because she has a natural love and understanding for it. She will graduate with a first class honours degree from DCU this November. In fact, she's enjoyed physics at this university so much that she is even considering doing a PhD.



Shaping the Future of Physics Education

Dr. Paul van Kampen is from The Netherlands. He is a senior lecturer in physics at DCU. He is also a researcher in the fields of Physics Education and Atomic Physics. He graduated from Eindhoven University of Technology with a degree in Engineering Physics in 1994, and received his PhD in Atomic Physics at UCD in 1998. He did postdoctoral research in the Centre for Laser Plasma Research at DCU (1997-2000), and was appointed to the position of lecturer in the School of Physical Sciences at DCU in 2002 with the brief to build up a physics education research profile. Dr. van Kampen's lectures cover many areas of physics and include pre-service teacher education. The focus of his research is in the field of Physics Education.

Common Goal

Dr. van Kampen explains that a common goal of Physics Education is to develop the way students handle physics and physics concepts. This field of research aims to improve the way physics is taught and learnt in schools and at university. The goal is essentially to find out how students can improve their understanding of physics as much as possible when they only have a limited amount of time to do this.

He explains that the research discipline started to blossom in the USA after the launch of

Sputnik, in the late 1950s and early 1960s, when the US government became convinced that it needed to make changes in the educational system to promote science. Since then Physics Education Research has been a growing and developing field around the world. The importance of Physics Education Research can not be stressed enough as it is a study of how to improve the quality of education for future generations. Physics as a subject is one of the most fundamental and essential in school, not only because it explains how the world works, but it's considered necessary for many professions around the globe.

Teaching first-year students

At DCU, Dr. van Kampen and postgraduate research students David Smith and Thomas Wemyss are currently investigating how the first year undergraduates learn physics in labs. Their aim is not just to improve the student's knowledge and understanding of physics, but to let them develop a useful set of skills in an environment that students enjoy, so that they can both make and test scientific hypotheses on their own and obtain, report and interpret experimental results. This



Dr. Paul van Kampen with his research students and Junior Certificate Science teachers at the 2008 Summer School in DCU.

approach is executed by spending the first part of the semester helping the students develop and use scientific 'tools' like graph interpretation, tabulation and how to operate different pieces of equipment. The last part of the semester is spent testing hypotheses in more-or-less open ended investigations.

The focus of his physics education research is, however, not only on DCU

students. In the summer of 2008 the Physics Education Group at DCU, organised and ran an intensive three week course for Junior Certificate Science teachers, which will help them teach science as an exciting process of investigation.

Dr. van Kampen explains that there is also physics education research going on in DIT and UL. The DCU and DIT groups are well-known within and outside Ireland, and they are frequently invited to the UK to speak at conferences and present their findings.

What Dr. van Kampen enjoys the most about his work is the interaction with students. He explains that it makes him very happy to see real results from his research; like seeing a student who has previously had bad experiences or fears related to physics starting to understand and enjoy it.

E-mail: Paul.van.Kampen@dcu.ie

Web: www.castel.dcu.ie

Lisa Cusack's soaring dream

23-year-old Applied Physics student **Lisa Cusack** just happens to be the only one in her class that regularly flies

planes. Ever since she was a little girl and grew up in Lucan outside Dublin, within walking distance of Weston airport, Lisa has loved planes.



When she was given a flying lesson on her thirteenth birthday it sealed her fate. Now flying is all she wants to do; she's been doing it on a weekly basis over the last year and is definitely getting the hang of it. She wanted to join the air force as they could sponsor her educa-

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Monitoring Health Through Next Generation Biomedical Diagnostics

Professor Jens Ducree is a German physicist and a very recent addition to the Biomedical Diagnostics Institute and the DCU School of Physics. His areas of research within physics are microsystems, in particular microfluidic lab-on-a-chip technologies for biomedical diagnostics and microhydrodynamics.

At DCU he wants to engage in application-focused research in order to develop next generation microfluidic platforms. Diagnostic devices that are smart, but easy to operate will be a major development trend in medicine according to Prof. Ducree. With a single drop of blood on a microchip you could give a vast array of different diagnoses.

"Ideally people will be able to monitor their health at home all on their own without having to see a doctor" Prof. Ducree explains. Medicine today is quite general and the type and amount of drugs prescribed to you is often just the personal opinion of a doctor. In the future, we like to see a more personalised ap-

proach. This in particular concerns the administration of drugs which ought to reflect much more the individual health state of the patient, e.g. to avoid overdosing or adverse side effects.

Prof. Ducree explains that people are often worried about their health even though they are not sick and these new diagnostic devices have the ability to give them first hand information, and advice within minutes after taking a test. The advice could also include individual recommendations for a healthy lifestyle in the future to minimise future risks.

Lab-on-a-chip

Historically Prof. Ducree has led a plethora of research projects in the field of "lab-on-a-chip" technologies. This is a technology that places functions presently only available with complicated laboratory test equipment, on a microchip. By manipulating microfluids on these chips, test results can be given almost within minutes. This has the potential to revolutionise the health care of the third world by providing cheap, effective, accurate, available, robust and uncomplicated microchips that are able to diagnose a series of diseases including malaria and HIV.

The BDI is a unique, world class institution attracting researchers from around the globe to work at constructing and developing these devices. Antarctica and Oceania are the only continents not represented in Prof. Ducree's own research team. In addition, the funding situation in Ireland is quite favourable for this type of research as both the government and international institutions recognise the importance of the work done at the BDI.

Prof. Ducree believes that if a significant amount of capital is put into the projects we could see these innovations being commercialised within 3-5 years. This does, however, require a

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tion, but she turned out to be 3 inches too short. It doesn't seem to bother her much though. Her passion for flying was even the reason she decided to study Applied Physics. Although no degree is actually needed to go to flying school, a degree in Physics is a great platform to start on when applying. So the next step of Lisa's plan is Oxford Aviation Academy!

Lisa also reached a high level in her final year project where she developed an 'Infinity Walk' floor mat to help primary school students with coordination and learning difficulties.

massive amount of testing and legislating.

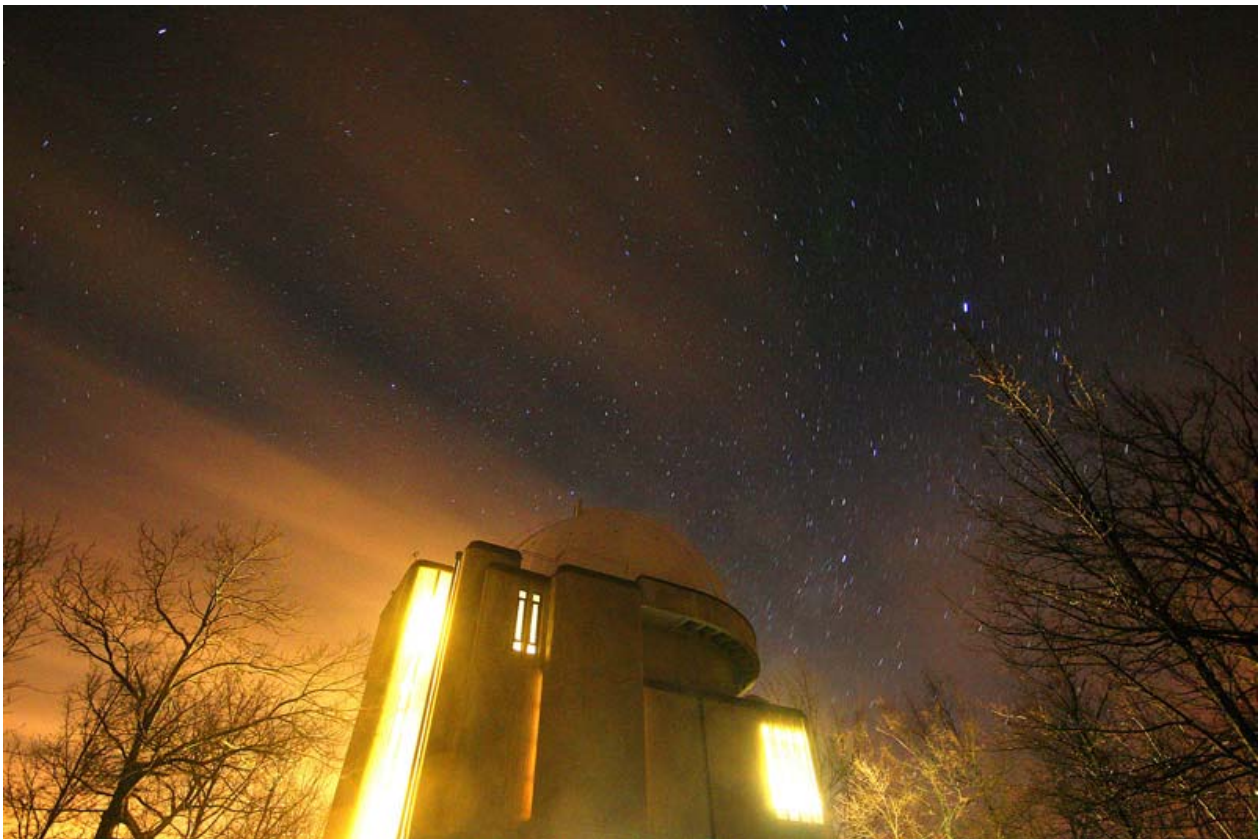
CD players and Diagnostics

Prof. Ducree can also tell us about research being done on CD players and their potential applicability in medicine and diagnostics. By using the centrifugal force generated by a common, commercially available CD player, you can actually separate body fluids on microchips. This is necessary to analyze the different constituents of the fluid. The idea is that a CD-format chip will be constructed and sold in stores or pharmacies and when you apply a drop of blood on this chip and insert it into your old CD player you will be able to get a message back, perhaps even on the CD display itself, telling you how your health is fairing within a few minutes, only.

Prof. Ducree explains that physicists are in great demand in Irish and European industry. They can work in almost any field because a physics degree is so diversified. Personally he rarely met a single person that couldn't get a good job with the skills developed in his group.

E-mail: jens.ducree@dcu.ie

Web site: www.bdi.ie



Declan McCormack took this photograph of the Loiano Observatory in Italy which was visited by DCU Physics and Astronomy undergraduate students in 2007.

Exciting Astrophysics Research at DCU

Dr. Laura Norci from Italy is a lecturer and a researcher in the field of Astrophysics at DCU. Her research is focused on massive stars; stars many thousands of times bigger, and more powerful than our Sun. In addition to being much bigger, these stars also have very different characteristics from the sun in our own solar system. Whereas our Sun's surface temperature is approximately 6,000 degrees Celsius, massive stars can have a surface temperature of 50,000 degrees Celsius. Not only are massive stars too big to have planets circulating around them, but they wouldn't even have the same colour as our sun. The characteristic colours of these stars are blue or white.

Dr. Norci tells us that the study of stars and planets provide essential information that can be applied here on earth. Stars can be considered the ultimate nuclear fusion reactors, and the study of stars in astrophysics provides us with an understanding of the principles underpinning the design and development of fusion power plants here on earth. There are continuous chemical reactions releasing massive amounts of energy in each star. So technically the ultimate solution to our energy problem would be to create a star here on earth, Dr. Norci tells us with a smile on her face!

We are made of stars

The massive stars are also much shorter lived than normal stars. The lifetime of our sun is likely to be billions of years, whereas the biggest stars only will live a few million years.

It is the massive heat that causes them to burn out much faster than smaller stars. They are constantly losing mass, and parts of their surface are peeled off and released into space as heavy elements. In fact many of the elements that are essential for life, like carbon, did not exist on their own after the Big Bang. They resulted from the release of matter from these stars. Dr. Norci explains it by saying that "every part of you has been in a star. We are all actually made from stardust." The study of astrophysics is essentially the study of how life in the Universe began, and how it is evolving.

Astrophysics at DCU

A unique part of astrophysics is that the lab is not under the control of the researchers. You are completely de-

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pendent on the movement of the stars and galaxies and if you don't get the results that you are looking for the first time you conduct a project, then that's too bad. The project can simply not be repeated in exactly the same way. This makes for particularly interesting data and excitement when a project is a confirmed success.

When a massive star collapses it releases gamma rays that are sent through the Universe. The rays travel practically at the speed of light. This massive release of energy was undocumented until a few years ago, and DCU, among others, are measuring how fast these gamma rays actually travel. A 'gamma ray burst' might in fact lead to the destruction of the entire earth if it were to happen sufficiently close to our solar system and so astrophysics can be con-

sidered an interesting study of the environment of Planet Earth.

New discoveries of stars, solar systems and planets are constantly being made, and the demand for research done on these is high. Astrophysicists are therefore needed to conduct research and provide explanations related to these discoveries.

By studying astrophysics at DCU students will join a team of leading researchers working particularly on the new and exciting occurrence of gamma ray bursts. The Astrophysics group at DCU has important international connections. During the 3rd year of study, students will travel abroad to visit an observatory and conduct real, potentially revolutionising experiments.

E-mail: laura.norci@dcu.ie

Web site:

www.astrophysics.dcu.ie

Astrophotographer and Physics Undergraduate

Declan McCormack is an electrician by profession, but his fascination for astronomy and astrophotography led him to begin a degree in Physics and Astronomy at the age of 34. He is one of the many mature students at DCU. Having grown up next to Newgrange in County Meath he has always been fascinated by the mysticism and history connected to the place. As he got into astrophotography he determined to show the entire world how beautiful and special Newgrange is, and what kinds of fascinating astronomical events occur there. His pictures have been published on several web sites like www.mythicalireland.com and www.twan.com. One of his images was even on the front cover of the astronomy magazine "Astronomy & Space" in June 2008. Declan explains that Physics and Astronomy is the perfect degree to combine with such a hobby. The more he studies and goes to college the more he understands his pictures and techniques, and the better they become. Below you can see two of Declan's favourite photos.



The image on the left shows Newgrange at night and was declared Photo of the Month for April 2008 on www.mythicalireland.com. While the image on the right shows a 'star trail' over Baltray Standing Stones in Co. Louth and was featured on the front cover of "Astronomy & Space". Both photos were taken by DCU Physics and Astronomy student, Declan McCormack.

