VIRTUAL TOURS OF THE UNIVERSE

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ABSTRACT

Although primarily an astrophysics research group, the Swinburne Centre for Astrophysics & Supercomputing has placed a strong focus on providing quality public education in astronomy. Two of our biggest success stories have been the interactive AstroTour that uses stereoscopic (3D) projection to immerse the public in the Universe, and Swinburne Astronomy Online (SAO)—a nested online degree program aimed at a graduate level that is available to students from all over the world. We discuss our experiences with both of these programmes and how we have approached our goal of "inspiring a fascination in the Universe".

INTRODUCTION

The Centre for Astrophysics & Supercomputing at Swinburne University of Technology, Melbourne (hereafter, "The Centre"), is one of Australia's newest and most rapidly growing astronomy research groups. Swinburne's original astronomy group formed when Professor Matthew Bailes was recruited from the University of Melbourne in late 1997, bringing with him one postdoctoral researcher and three PhD students to join with Dr Margaret Mazzolini. The Centre was born out of this group the following year, when it became one of several strategic initiatives to receive start-up funding from the University.

A goal of the Centre was to achieve growth at a time in Australia when several physics research groups were shrinking, with the hope of reaching a "critical mass" of high-quality researchers capable of generating ongoing funding from competitive grant schemes. An opportunity was seen to add to this growth by seeking non-traditional (for an astronomy group) forms of funding through commercial projects that might take advantage of the Centre's supercomputing and scientific visualisation resources. By mid-2005, the Centre had reached 42 staff/students, comprising 8 academics (in tenured or ongoing positions), 11 postdoctoral/contract researchers, 15 PhD/Masters students and 8 support/technical staff (including administration, computer support and computer animators).

Contributing to this rapid growth was the strong emphasis on public education and outreach, captured in the Centre's mission statement: *The Centre for Astrophysics & Supercomputing is dedicated to inspiring a fascination in the Universe through research and education.*

Somewhat strangely for a University-based astronomy group, the Centre does not undertake any undergraduate or service teaching. Instead, its two main education activities are:

- Swinburne Astronomy Online: a fully online graduate degree program in astronomy by coursework, reaching ~250 students per semester resident in over 30 countries per semester; and
- AstroTour: a school program presented in the Centre's Virtual Reality theatre, where the audience is immersed in a 3D universe.

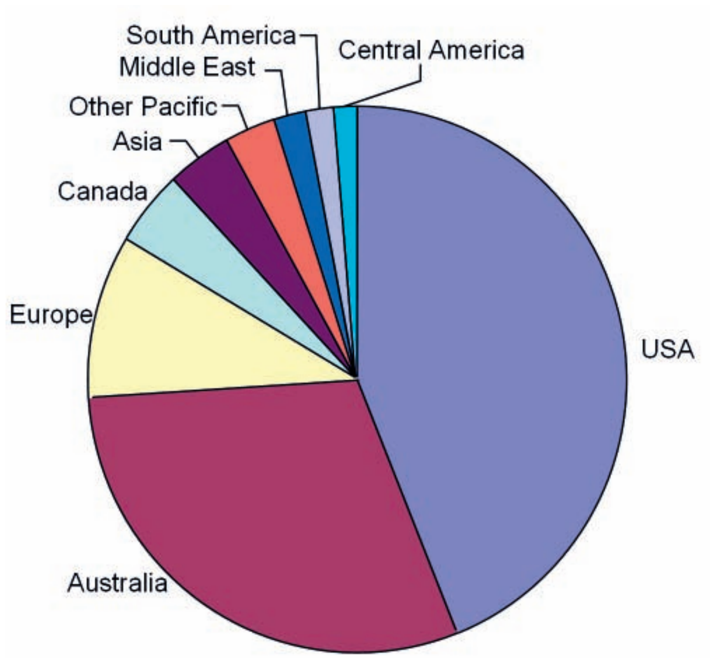
The remainder of this paper will describe these two teaching initiatives in more detail, looking at how they work and the lessons we have learned from their operation.

SWINBURNE ASTRONOMY ONLINE

Swinburne Astronomy Online (SAO) is a fully online graduate astronomy program that began in 1999. SAO concentrates on the fundamental concepts and key issues in contemporary astronomy, rather than its mathematical basis, and as such it is not a training program for professional research astronomy. Instead, SAO units are designed for amateur astronomers, science educators and communicators, people working in astronomy related fields, and anyone with a love of astronomy. SAO concentrates on building a student's skills at communicating their science knowledge. Having just completed its thirteenth semester, SAO is a success story in new techniques of online education.

SAO is a nested graduate degree program, offering a Master of Science (Astronomy), a Graduate Diploma of Science (Astronomy) and a Graduate Certificate of Science (Astronomy). SAO uses high bandwidth course content and supplementary multimedia material delivered via custom CD-ROMs, each of which contains over 1,500 animated slides written by a variety of professional astronomers. There are 16 units to choose from, 12 of which are accompanied by their own CD-ROM, as well as 3 major project units. The latest unit, *HET618 Astrobiology and the Origins of Life*, offers its slide presentations (~1-2 MB each) via download over the internet. The internet is also used for communication, research, and assessment purposes. The SAO community consists of professional PhD astronomers who teach into the program plus ~250 students resident in more than 30 countries (see Figure 1).

__Figure 1.__ SAO Students by country of origin. Australian students make up ~30% of the student body, while ~40% are from the United States.



Students interact with instructors and fellow classmates via asynchronous newsgroups and email, allowing them to study at a time that suits them. This is particularly advantageous for a course where the students and instructors are all in different time zones! The 14-week semester is broken up into seven two-week blocks, with fortnightly newsgroup discussion forums focusing on specific parts of the syllabus.

The SAO assessment mix includes computer-managed tests, an essay, project work and newsgroup contributions (Mazzolini, M., 2000, PASA, 17, 141). The development of good communication skills in astronomy was one of the key aims of SAO, and so the ability of students to communicate astronomy concepts effectively to non-specialist audiences, as well as being capable of researching a topic in depth, were built into the assessment criteria for SAO projects and essays from the start. There are over 100 project topics to choose from and each unit has a choice of at least five essay topics. Considerable thought and research has also gone into designing appropriate assessment for the asynchronous discussion forum component of SAO. It was also necessary to provide online, open book assessment tests to give credit to students who master the overall bulk of the course material.

SAO instructors are professional astronomers, some of whom are Swinburne academic staff, but a number of whom are employed full-time at observatories, universities or research institutions around the world. Depending on the student enrolment numbers, there are about 12 instructors per semester. SAO also uses between 30 and 35 project supervisors including PhD students, postdoctoral fellows and academic staff from Swinburne, as well as professional astronomers and amateurs from outside of Swinburne. Distance education provides flexibility for the instructor—instead of being locked into a regular lecture and tutorial schedule with office consultation times, our astronomers are able to continue research activities such as observing or attending conferences with minimal impact on teaching. The students appreciate reports sent back from astronomers while they are observing at major international facilities, as they can share in the excitement of the research process.

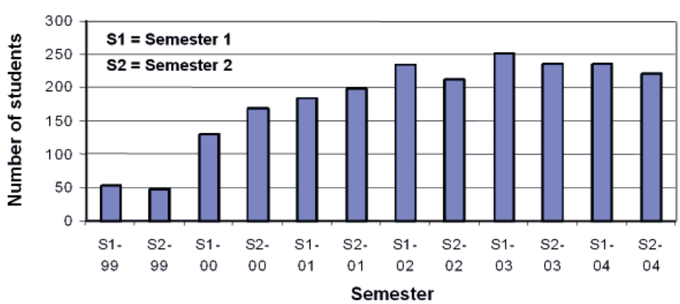


Figure 2. *6 years of semester-by-semester student enrolments in SAO Units from 1999 to 2004.*

Figure 2 shows the semester-by-semester student numbers from 1999 to 2004. The marked growth in student numbers from 1999 to 2000 coincided with the release of the “Clear Skies” CD-ROM on the front cover of the January 2000 edition of Sky & Telescope http://astronomy.swin.edu.au/sao/clearskies/clearskies.html. “Clear Skies” provided a sample of the introductory Units, acting as a self-contained educational tool along with acting as a “teaser” to attract students to the program.

THE IMPORTANCE OF GOOD COMMUNICATION

One of the key distinguishing features of online education, as compared to other forms of distance education, is the opportunity for instructors and students to interact via online asynchronous discussion forums. Asynchronous discussion forums are used to a varying degree in different online academic programs, and in widely different ways. Discussion forums are a key feature of SAO units, initially designed to help build a learning community within distance education, and specifically to encourage active learning (Maddison, S.T., Mazzolini, M., Effective Teaching and Learning of Astronomy, 25th meeting of the IAU, Special Session 4, 24-25 July, 2003 in Sydney, Australia, meeting abstract; Mazzolini, M., 2002, PASA, 19, 448).

In SAO discussion forums, students are divided into groups containing up to ~30 students per instructor, and each group has its own set of discussion forums, with a new forum opened every fortnight during the semester. In each of these forums students can discuss the course material currently being studied, and relevant astronomy press releases can also be channelled into the forums. Students are required to post questions and/or comments about the current course material, and attempt to answer each other's questions. Instructors act as 'guides on the side', aiding the discussions by contributing extra information and follow-up questions. They intervene in discussion threads that have 'gone off the rails', but avoid dominating the discussions. In this approach, it is vital that the students see each other as a resource to obtain answers to their questions, rather than rely on instructors as oracles.

The discussion forums contribute 30% of the total assessment marks, comprising a component for regular participation, plus a mark awarded for three postings nominated by the student as being their best contributions over the course of the semester. Counting forum contributions towards the final grades recognizes the time and effort put in to researching forum contributions, and encourages contributions from all students, not just the most confident.

The discussion forums operate in asynchronous mode, where students make postings at times to suit themselves. Necessity was the initial motivation for the use of asynchronous forums, given the truly international nature of the program. In online synchronous chat room discussions involving more than a few participants, it is easy for the various discussion threads (topics) to become hopelessly entangled. In contrast, in asynchronous forum discussions, each discussion thread is clearly identified under its own heading, which is an important consideration with thirty or so contributors. Discussions conducted via asynchronous forums can be surprisingly flexible and engaging, providing a form of peer group contact so frequently missing in distance education. The asynchronous nature of the discussions also gives participants time to research and reflect before they post answers to each other's questions. An additional benefit exists for students who do not have English as their first language, as these students have time to compose their answers (which may include translation from their native language) and contribute equally, whereas in a real-time discussion forum, they may get left behind.

In SAO, the forums are delivered using newsreader technology. When necessary, this allows participants to download discussions, deal with them offline, and then resynchronize and upload postings on their next login. Students also participate in the discussions through a variety of well known browsers. A recent development is the use of video introductions of unit instructors, available for viewing by their students. The videos are about 90 seconds in duration and allow the instructor to describe themselves, their research background, and discuss specific or interesting aspects of the upcoming unit and assessment items.

At the end of each semester, students are invited to provide feedback on the course content, quality of teaching and other aspects of SAO delivery. This feedback is provided to the unit instructors, and problems are discussed within a subject panel consisting of the instructor, the SAO coordinator and typically an instructor of another unit. The Centre holds an annual SAO planning day, and the progress of the SAO program is reviewed by an external advisory committee. Prior to the start of each semester, the CD-ROMs go through an intense period of revision to include recent discoveries. Unlike traditional textbooks, the SAO content is continually evolving to cope with advancements in astronomy and the changing requirements and interests of our students.

Further details on Swinburne Astronomy Online can be found at the program's home page http://astronomy.swin.edu.au/sao.

FROM ASTRONOMY VISUALISATION TO ASTRONOMY EDUCATION

As part of the transition from informal Astronomy group to strategically-funded research Centre in 1999, funding was made available to develop an immersive, stereoscopic (3D) visualisation facility. While existing commercial products were investigated, such as the SGI Reality Center (http://www.sgi.com/products/ visualization/realitycenter/) and the WEDGE (http://wedge.anu.edu.au/) developed by the Australian National University, a decision was made to use local expertise to design a stereoscopic theatre with `off-the-shelf' components. The Mark I Virtual Reality (VR) Theatre comprised a CRT projector (modified to project with a refresh rate of 120 Hz, rather than the usual 60 Hz), a Dec-Alpha computer and graphics card, and several pairs of wireless electronic shutter glasses. The projection equipment was installed in part of Swinburne's old film and television school, in a room with a $\sim$6 m high ceiling providing a projection area of 4.8m x 3.6m. The final important ingredient was the hiring of Paul Bourke as visualisation researcher to develop software tools and provide visualisation support to the Centre and the wider Swinburne research community.

As an early demonstration of the VR Theatre's capabilities, a basic, interactive solar system program was developed that would show each of the planets and allow the user to fly from one planet to another. Additional content included interactive tools to display and manipulate datasets generated by the Centre's astronomers, such as the Swinburne Intermediate Latitude Pulsar Survey (Edwards, R.T., Bailes, M., van Straten, W., Briton, M.C., 2001, MNRAS, 326, 358) and cosmological N-body simulations. The VR Theatre soon began a regular stop for the Vice-Chancellor when showing visiting dignitaries highlights of the campus.

Following a letter from an 8-year old boy to Professor Bailes, the first school group presentation was made in the VR Theatre in 1999—a very successful event, that was greatly enjoyed by all of the students. The Centre saw an opportunity to provide a unique educational program to Victorian school students, and successfully applied to the Victorian State Government for money to purchase 30 pairs of shutter glasses and a programmer to develop content. Swinburne contributed to the costs of installing seating and the *AstroTour* program was up and running. Along with providing content that met with the curriculum requirements of Victorian students from Grades 3 to Year 12 (final year of high school), the Centre wanted to challenge and inspire students by incorporating its own research work.

ASTROTOUR

The AstroTour school program is targeted at students from primary school (Grades 3-6) and secondary school (Year 7-Year 12). At each school level, we aim to cover the requirements of the Victorian Curriculum Standards Frameworks (CSF) and the Victorian Certificate of Education (http://www.vcaa.vic.edu.au). The AstroTour content is sufficiently flexible that we can use the same interactive demonstrations for all age levels, and simply change the information the AstroTour guide provides.

AstroTour sessions are presented by PhD students and researchers from the Centre. As each researcher has their own particular area of specialisation, the AstroTours are also able to adapt to reflect the presenter's interests. We feel that it can be very rewarding for a student to hear about discoveries in cosmology, planet and star formation or pulsars from researchers who actually work in those fields. It is also an excellent training ground for PhD students to improve their own science communication and teaching skills.

A typical AstroTour (http://vr.swin.edu.au/content.html) lasts for 50 minutes, with at least 5 minutes of question time. We find that younger students (Grades 3-6) are very uninhibited when it comes to asking questions about the content we have shown, or other areas of astronomy and space that they are aware of. The level of questioning drops off sharply around Year 9 & 10, particularly when dealing with students from general science courses. The situation improves again at Year 11-12, as the groups tend to be specialised physics or chemistry classes. Sessions include a mix of interactive and pre-rendered (movie) content and we encourage questions from the students at (almost) any time. Worksheets are available for primary school teachers to use in follow-up activities in class. AstroTours are usually scheduled by schools at the beginning of teaching the astronomy portion of the curriculum to provide a solid introduction to the topic, or at the end of the course so that it provides a conclusion to the ideas they have been studying in class.

As the Swinburne VR Theatre is only able to hold about 30 students at one time, we are limited in the number of sessions that can be offered throughout the year. On average, we have $\sim$1500 students through the Theatre each year. In addition to the school program, we provide regular professional development sessions for teachers. These can consist of either a version of the AstroTour program that we would show to their students, or a more in-depth discussion of a particular area of the curriculum that can be supported by the 3D demonstrations. During school holidays, the Centre offers family sessions, which are usually sold out, with a large number of repeat visitors who come back to see new content.

To date, the Centre has not undertaken any formal evaluation of the effectiveness of the AstroTour program as a method for astronomy education. However, we are encouraged by the very positive responses from students and teachers during and after AstroTour sessions. Another indicator of success and popularity of the program is the number of schools that bring back students every year. Audiences of all ages regularly attempt to jump out of their seats and catch stars and galaxies as they come whizzing towards them—it is clear that we are engaging with the students, which is an important step towards helping them learn more about the Universe. As anecdotal feedback, consider the following responses from teachers:

- *Just a Big Thank You for the time you gave us the other day. It was greatly appreciated. Students commented very positively –"inspired"* (by one to his mother), *"I'll never see the night sky the same way again"* (from another). *They are reasonably smart and tuned in students and I think the level of presentation was just right. A good base that they had already encountered, but also significant extension of ideas.* (P-12 Teacher)
- *… a wonderful excursion and start to our unit of work on the Solar System. This is the second visit for me and I still don't know if I am more impressed with the way you can manipulate the display to make a point or just blown away with the information about the vastness of the Universe.* (Primary school teacher)
- *…fascinated and enthralled…the subject matter you discussed is just the kind of exciting, up-to-date material which will motivate my students…*
- (from a Teacher Professional Development session)
- *... the kids want to come back and see more!* (Secondary school teacher)

TAKING 3D ASTRONOMY EDUCATION TO THE WORLD

At the completion of a study mission in late 2000 by Dr Christopher Fluke to explore virtual reality technologies in the US and the UK, including their potential use for education within museum environments, a decision was made by the Centre to produce a 20 minute long stereoscopic movie. While this would add to the content of Swinburne's own AstroTour program, a version was also to be installed at the Parkes Observatory Visitors' Discovery Centre in New South Wales. An important change to the projection system was required—due to the expensive nature of the electronic shutter glasses, and the risks of damage and theft, the Parkes VR Theatre was to use polarising glasses. This meant a change from a single CRT projector to two DLP projectors and the addition of a polarisation preserving projection screen. The topic chosen for the first production was the life cycle of the Sun and other stars. With a script written by Dr Sarah Maddison and Fluke, "Our Sun: What a Star!" was completed over a period of six months, opening at Parkes at Easter 2001, and in the upgraded Swinburne VR Theatre shortly afterwards. Following the success of "Our Sun: What a Star!" and the Parkes Observatory installation, with approximately ∼10,000 visitors in the first six months after opening, the Centre began to explore other opportunities to take its 3D astronomy education to Australia and the world.

The next major project was the creation of a futuristic flight to Mars, using data from Mars Orbital Laser Altimeter (MOLA) experiment on Mars Global Surveyor. Working with Melbourne animation company, Act3Animation, and co-producer Bob Weis (Weis Films Pty Ltd), the Centre produced "Elysium 7" for the major national exhibit "To Mars and Beyond" staged by Art Exhibitions Australia. The exhibition ran for eleven months (December 2001 to October 2002) at the National Museum of Australia in Canberra, followed by four months at Melbourne Museum (December 2002 to April 2003), with more than 100,000 visitors seeing the 3D show. "Elysium 7" continues to be a popular component of AstroTours.

While the museum VR theatres were temporary installations, two permanent theatres opened at the Jodrell Bank Observatory Science Centre (UK) in October 2002 and at the Sydney Observatory (New South Wales, Australia) in December 2002. Both Parkes and Jodrell Bank were equipped for movie-playback only (although both are in the process of upgrading), whereas Sydney Observatory had a full system with interactive content and movies, allowing the Observatory to run its own version of AstroTour. Additional installations are summarised in Table 1 below.

Location	Country	Opened	Seats
Mahidol Wittayanusorn School	Thailand	May 2005	200
Papalote, Museo interactivo Infantil (theatre installation by Spitz Inc.)	Mexico	Oct 2004	–
CosmoDream	South Korea	July 2004	20
Melbourne Museum: To Mars and Beyond (temporary)	Australia	Dec 02-Apr 03	25
Sydney Observatory 3-D Space Theatre	Australia	Dec 2002	25
Jodrell Bank Observatory Science Centre	United Kingdom	Oct 2002	25
National Museum of Australia: To Mars and Beyond (temporary)	Australia	Dec 01-Oct 02	25
Parkes Observatory Visitors Discovery Centre	Australia	May 2001	25
Swinburne University of Technology	Australia	Dec 1999	40

Table 1. *Swinburne Virtual Reality Theatre Installations.*

The Centre has continued to produce at least one new stereoscopic movie each year, and was heavily into production of the fifth show at the time of writing. A brief synopsis of these movies is given in Table 2.

Table 2. *Swinburne Stereoscopic Movies*

Show	Year	Synopsis
Our Sun: What a Star!	2001	The closest star to the Earth is the Sun. Where did it come from, and what will happen to it and the Solar System in the future? This 3D movie tells the life-story of the Sun and other stars: from birth to sometimes violent death.
Elysium 7	2001	Take a futuristic tourist flight to the Red Planet on board Elysium 7. Produced for the exhibition To Mars and Beyond, this 3D journey uses NASA's Mars Orbital Laser Altimeter (MOLA) dataset to reconstruct the actual surface features of Mars.
The Little Things	2003	Comets. Asteroids. Kuiper Belt Objects. This is the story of the amazing little things in the Solar System, and the incredible space explorers that have visited them.
After Stars	2004	Red supergiant star MB-8782 is about to end its life - but when the star explodes, will it produce a black hole or a pulsar? Join Margus, Dr Jozalin and WLR-309 as they find out...
Spinning in Space	2005	An astronaut on-board the International Space Station is helping to install a new galaxy-finding telescope. With the help of his temperamental robotic assistant, he starts to learn about spiral galaxies – their features, origin and evolution.

CONCLUSIONS

Through Swinburne Astronomy Online and AstroTour, researchers from the Centre for Astrophysics & Supercomputing at Swinburne University of Technology (http://astronomy.swin.edu.au) have been able to share their passion for astronomy with an international public. Both programmes show the advantages and enjoyment that an audience can receive using modern technologies—the internet—as a means of on-line education for SAO and computer-generated stereoscopic movies in a Virtual Reality theatre for AstroTour. The Centre aims to continue developing these and other forms of astronomy education, such as involvement in the Faulkes Telescope project (http://www.faulkes-telescope.com/ & http://astronomy.swin.edu.au/faulkes/) in its ongoing mission to inspire a fascination in the Universe.