Introduction. Progress in astronomy: from gravitational waves to space weather

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This brief paper introduces and reviews the ‘visions of the future’ articles prepared by leading young scientists throughout the world for the first of two Christmas 2008 Triennial issues of Phil. Trans. R. Soc. A, devoted, respectively, to astronomy and Earth science. Contributions in astronomy include the very topical gamma-ray bursts, new ideas on stellar collapse and the unusual atmospheres of synchronized planets orbiting nearby stars.

Keywords: black holes; gravitational waves; gamma-ray bursts; stellar collapse; supernovae; extrasolar planets

The collection of articles by young researchers for Christmas 2008 is devoted, by virtue of the triennial cycling (table 1) through the physical sciences established in 2002, to astronomy and Earth science. These are now spread between two issues of Phil. Trans. R. Soc. A to reflect the higher frequency of the journal, which stepped up from 12 to 24 issues per year in January 2008.

The present introductory paper relates to the first of these two issues devoted to astronomy. Here, the first two papers are at the cosmic end of the size scale. In the first paper, Gair (2008) describes how researchers should soon be able to detect gravitational waves for the first time, opening up new horizons in astronomy. These waves, predicted by Einstein’s General Theory of Relativity should be observable with a new generation of laser interferometers, some of which are already in operation. Astronomers will then be able to probe some of the most exotic and energetic events in the Universe associated with the merging of black holes, and make very precise checks on the theory of relativity in a new physical arena. In the second paper, Baugh (2008) explains how cosmologists regularly generate synthetic universes of galaxies using computer simulations, and discusses the different physical processes that the models must attempt to mirror. The results facilitate the analysis and exploitation of real galaxy surveys.

The next three papers are devoted to gamma-ray bursts and high-energy cosmic rays. The gamma-ray bursts are the most energetic explosions in the Universe, occurring at cosmological distances. Discovered in the 1960s as brief
flashes of gamma radiation, they originate in distant galaxies and comprise two distinct populations, one of which may arise from the supernovae deaths of massive stars. Starling (2008) describes how the launch of the Swift satellite in 2004 has brought a flurry of new discoveries that have advanced our understanding of the sources and the galaxies in which they lie. She highlights, in particular, a number of key results already gleaned from the Swift era. The paper by Ryde (2008) deals specifically with the origin of the gamma-ray bursts. He points out that the initial phase of the emission from these bursts stems from a highly relativistic outflow. The peak in the photon spectrum seems to be due to the black body emission of the photosphere of the outflow, having a temperature of approximately 109 K. An additional non-thermal spectral component can be attributed to additional dissipation of the kinetic energy in the outflow. Finally, in this section, Fraschetti (2008) describes how ultra-high-energy cosmic rays hit the Earth’s atmosphere, with the energy of a tennis ball moving at 100 km h$^{-1}$ concentrated within a single particle. The flux of particles is, however, so low that only a few have been detected over the past 50 years. He then explains how recent experiments have discovered an apparent clustering of the highest energy events towards nearby active galactic nuclei, with some consensus emerging that the particles are accelerated within the radio-bright lobes of these sources.

There follows a two-paper section devoted to the evolution and collapse of stars. Wareing (2008) describes the extensive research that has been done on Mira A, which was noted in the seventeenth century for its peculiar brightness variability. Mira A is the primary star in a binary system, and is reaching the end of its life with a period of enhanced mass loss. Recent observations have shown a surrounding arc-like structure and a stream of material stretching 12 light years away in opposition to the arc. Wareing reviews recent modelling of this cometary appearance, and discusses the implications for our own star, the Sun. Next, Eldridge (2008) explains that the study of supernovae explosions used to be a forensic study, working backwards from the remnants of the star. This changed in 1987, however, when the first progenitor star was identified in pre-explosion images. This sparked a new avenue of supernova research that has led to many

Table 1. Millennium and triennial statistics. (Here M denotes millennium and T denotes triennial. Under issue is given the publication number. Pprs signifies the number of contributed papers. The author column gives the number of authors, including co-authors, followed in brackets by the number of female authors. Age denotes the average age of the corresponding authors in years.)

<table>
<thead>
<tr>
<th>topics</th>
<th>year</th>
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<tr>
<td>M1  astronomy, Earth science</td>
<td>1999</td>
<td>1763</td>
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<td>17(04)</td>
<td>34</td>
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<tr>
<td>M2  maths, physics, engineering</td>
<td>2000</td>
<td>1765</td>
<td>19</td>
<td>25(02)</td>
<td>34</td>
</tr>
<tr>
<td>M3  chemistry, biophysics</td>
<td>2000</td>
<td>1766</td>
<td>14</td>
<td>21(01)</td>
<td>34</td>
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<tr>
<td>T1  astronomy, Earth science</td>
<td>2002</td>
<td>1801</td>
<td>18</td>
<td>19(04)</td>
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<tr>
<td>T2  maths, physics, engineering</td>
<td>2003</td>
<td>1813</td>
<td>21</td>
<td>27(05)</td>
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<td>T3  chemistry, life science</td>
<td>2004</td>
<td>1825</td>
<td>16</td>
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<tr>
<td>T4  astronomy, Earth science</td>
<td>2005</td>
<td>1837</td>
<td>16</td>
<td>18(02)</td>
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<tr>
<td>T5  maths, physics</td>
<td>2006</td>
<td>1849</td>
<td>22</td>
<td>30(12)</td>
<td>36</td>
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<tr>
<td>T6  chemistry, engineering</td>
<td>2007</td>
<td>1861</td>
<td>19</td>
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interesting conclusions, including the confirmation that the progenitors of the most common supernovae are red supergiants. However, no progenitors have so far been detected for the less common hydrogen-free type of supernovae.

In the next section are two papers devoted to astrophysical magnetic fields. Silvers (2008) discusses recent developments concerning magnetic fields and dynamos in stars, planets and accretion discs. She looks, in particular, at some of the situations where weak magnetic fields may play a more significant role than previously thought, and poses some of the questions that need to be addressed in the future. Meanwhile, Bushby (2008) concentrates on magnetic fields in the solar photosphere. He describes how recent high-resolution observations of the surface of the Sun have revealed the fine structure of a vast array of complex photospheric magnetic features. He then discusses the progress that has been made in the modelling of photospheric magnetic fields, focusing on the complex structures that are observed within the umbrae and penumbras of sunspots.

The issue ends with two papers devoted to extrasolar planets and space weather, respectively. First, Cho (2008) looks at the atmospheric dynamics of tidally synchronized extrasolar planets. As our Moon, which presents a fixed face to the Earth, these synchronized planets present a fixed face to their central star, so that the stellar radiation is on the same face throughout their orbit. Despite this unusual property, a study of their atmospheres could enrich our understanding of planetary atmospheres nearer to home. Finally, Eastwood (2008) examines the physics of space weather, beginning with an overview of the main causes of variability in the near-Earth space environment. Many plasma phenomena contribute to this variability, but one of the most important is magnetic reconnection. As society increases its dependence on space, the necessity of predicting and mitigating space weather is becoming more acute. Indeed, the need for a clearer understanding of space plasmas has already stimulated a new generation of scientific space missions at the international level.

A number of previous ‘young scientist’ collections, from which the present one is historically derived, might be of interest to today’s readers. The first such collection, assembled to celebrate the new millennium, appeared as three special issues of Phil. Trans. R. Soc. A. The first of these issues was devoted to astronomy and Earth sciences and appeared as issue number 1763 on 15 December 1999: details can be found in Thompson (1999). The three Millennium Issues of the journal formed the basis of three popular paperback books published by Cambridge University Press, the first being likewise devoted to astronomy and Earth science (Thompson 2001).

The success of these collections triggered the present series of Triennial Christmas Issues, which now form a three-year cycle, as shown in table 1.

As we can see, the previous Triennial Issues devoted to astronomy and Earth science appeared in 2002 and 2005; details of the emerging series and its contents being given by Thompson (2002) and Thompson & Wang (2005). The interest of the Research Councils is reflected by Morgan & Thompson (2002). Finally, a selection from the triennial papers in astronomy, together with some additional contributions, appears in the first book of a series published by Imperial College Press (Thompson 2005).
References


AUTHOR PROFILE

J. Michael T. Thompson

J. Michael T. Thompson FRS was born in Cottingham, Yorkshire, in 1937, and attended Hull Grammar School. He graduated from the University of Cambridge with first class honours in mechanical sciences in 1958, winning the three top prizes of the Engineering Department. One of these was the prestigious Rex Moir Prize. He was later awarded two Cambridge doctorates, a PhD in 1962 and an ScD in 1977. Recently, in 2004, he received an honorary DSc from the University of Aberdeen.

While a postdoctoral research fellow at Peterhouse, he spent a year as a Fulbright visitor in the Department of Aeronautics and Astronautics at Stanford University in California. Joining University College London (UCL) in 1964, he was appointed as a professor in 1977, and subsequently the Director of the Centre for Nonlinear Dynamics in 1991.

Based on his research into elastic buckling phenomena, he published three books on instabilities, bifurcations and catastrophes. A fourth book published in 1986 is now in its second edition as *Nonlinear Dynamics and Chaos* (Wiley, 2002). Over 14 000 copies of this seminal work have been sold worldwide, and it has been translated into Japanese and Italian.

Michael was elected a Fellow of the Royal Society in 1985, and served on the Council of the Society. He won the OMAE Award of the American Society of Mechanical Engineers in 1985 in recognition of his outstanding originality and significance. Seven years later, in 1992, he was awarded the James Alfred Ewing Medal on the joint nomination of the presidents of the Institution of Civil Engineers and the Royal Society. The award, founded in memory of Sir Alfred Ewing, is made for special meritorious contributions to the science of engineering in the field of research. He was a senior fellow of the Science and Engineering Research Council from 1988 to 1993.

From 1998 to 2007, Michael was the editor of the *Philosophical Transactions of the Royal Society A*, the world’s longest running scientific journal. His special Millennium Issues of the journal, in which young scientists were invited to give their visions of the future, were re-published as three popular paperback books by Cambridge University Press in 2001. As a follow-up to this successful venture,
Michael has created a running programme of Christmas Issues, which he is using as the basis of his new Royal Society Series on Advances in Science. The first book in the series is *Advances in Astronomy: from the Big Bang to the Solar System* (ed. J. M. T. Thompson, Imperial College Press, 2005). The second is *Advances in Earth Science: from Earthquakes to Global Warming* (eds P. R. Sammonds & J. M. T. Thompson), and the third is *Advances in Nanoengineering: Electronics, Materials and Assembly* (eds A. G. Davies & J. M. T. Thompson).

Michael is now Emeritus Professor of Nonlinear Dynamics at UCL, and an Honorary Fellow at the Department of Applied Mathematics and Theoretical Physics (DAMTP) of the University of Cambridge. He is active in promoting a greater understanding of science and mathematics among the general public. Two popular lectures in the Millennium Mathematics Project, delivered at DAMTP, are now streamed from the web, and also available on DVD. In 2004, Michael was awarded a Gold Medal by the Institute of Mathematics and its Applications (IMA) at their 40th anniversary meeting for his lifetime contributions to mathematics.

In April 2006, Michael was appointed, part-time, as a distinguished Sixth Century Professor in Theoretical and Applied Dynamics at the University of Aberdeen. Married with 2 children and 10 grandchildren, his recreations include astronomy with his grandchildren, wildlife photography, badminton and tennis. He is pictured with his wife Margaret.