

Martin Asplund: stellar astrophysicist

In the latest of his interviews with distinguished Australian astronomers, **Ragbir Bhathal** spoke to Prof. Martin Asplund about his life and career.

Born in Stockholm, Martin Asplund is a fellow of the Australian Academy of Science and an Australian Research Council Laureate at the Research School of Astronomy & Astrophysics at the Australian National University. His was a well-to-do family in which he had a “comfortable upbringing” while his father worked as CEO of some large companies in Sweden. As a young boy he enjoyed reading books on science, but his interest in astronomy was fired not by the work of Niels Bohr or Max Planck, but by a book his grandfather gave him when he was seven or eight. “I still have that book in my library at home,” says Asplund. “I don’t recall having any scientists as heroes – I was interested about the topic and not about the people. As a child I was more interested in understanding how things worked.” His parents were very supportive of him and his brother and they were able to choose their own careers.

He was not academically challenged at junior school; he was good at mathematics and knew more than his teachers. “I got the freedom from my teachers to go ahead with studying maths, physics and chemistry by myself.” Between Year 11 and 12 he went to the United States as an exchange student. When he came back home he enrolled in Uppsala University by sitting an entrance examination. He received, he recounts, the “best score in the examination”. This was the beginning of his career in astronomy.

He majored in mathematics, physics and astrophysics. Uppsala University is well known for science and counts Anders Angstrom, Anders Celsius, Svante Arrhenius (Nobel Prize 1903) and Hannes Alfvén (Nobel Prize 1970, Gold Medal of the RAS 1967) among its alumni. Asplund ended up working on his PhD with theoretical astrophysicist Bengt Gustafsson, whose book *The Cosmic Journey* had inspired him as a boy.

After completing his PhD he joined the Nordic Institute for Theoretical Physics (NORDITA) in Copenhagen, where he had the freedom to work on any topic of his choice. He was impressed by the work Ake Nordlund, a computational astrophysicist at Copenhagen University, was

doing to develop sophisticated models of stars and stellar convection. Asplund wanted, he says, “to make a splash by drastically improving our understanding of the first generation of stars born after the Big Bang. I had the idea that sophisticated three-dimensional models that included hydrodynamics of stellar convections would be very important for these types of stars.” After two years at this institution he applied for two positions advertised by Uppsala University: observational astronomer and theoretical astronomer. He was successful in securing both jobs, but chose to be an observational astronomer, taking up the position in 1999.

Mount Stromlo to Max Planck Institute

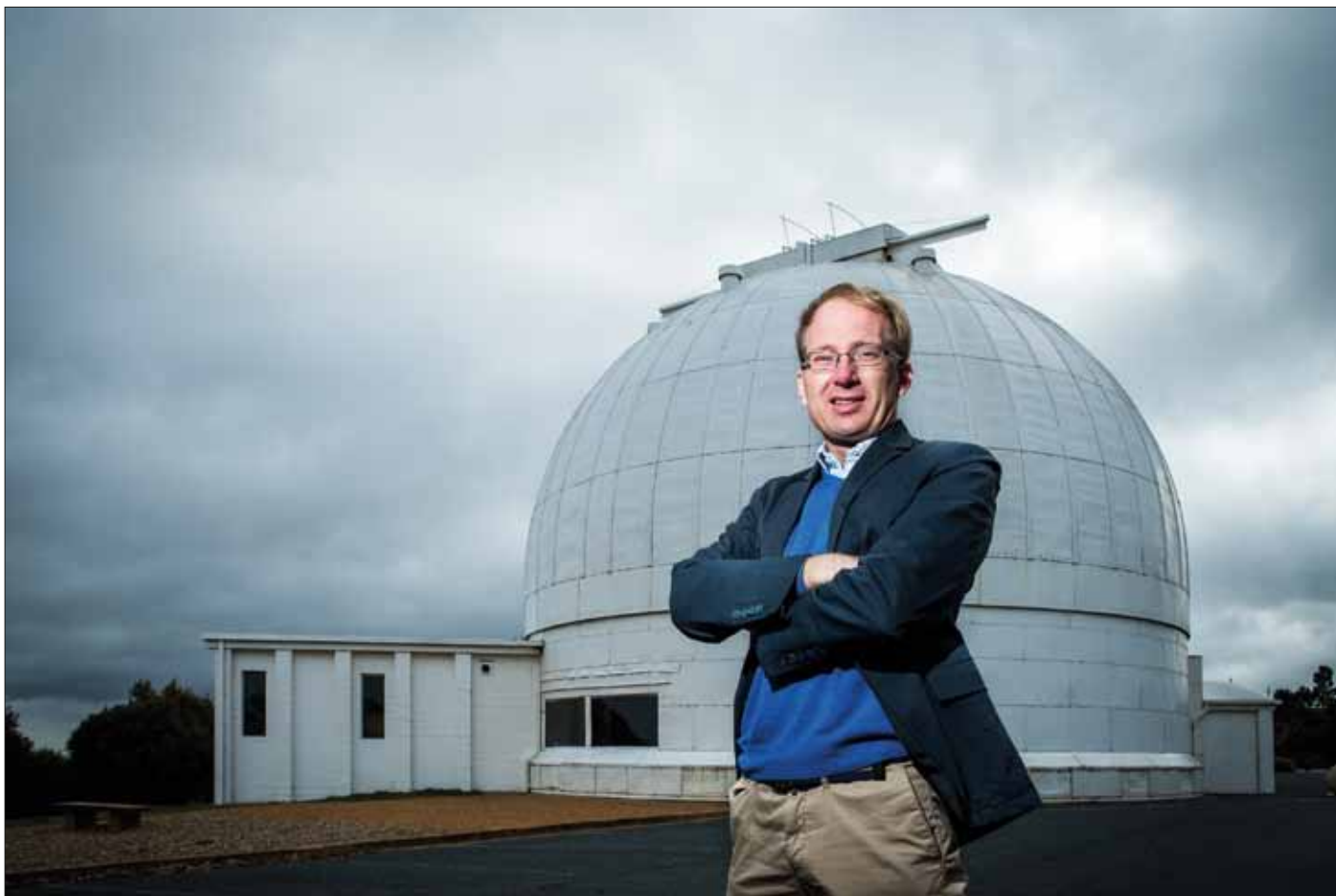
In 2002, Asplund joined Mount Stromlo Observatory as a research fellow. He was recruited by Jeremy Mould, now at Swinburne University, who was then the director. Asplund picked this position “because Mount Stromlo is the best place for astronomy in Australia. There were several

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astronomers I really wanted to work with – John Norris, Mike Bessell, Ken Freeman and others. They were all working on related topics in my own area of interest.” In

the five years (2002–07) he spent there he moved from research fellow to professor – a remarkable achievement.

Asplund was on the move again in 2007. He was headhunted and appointed director of the prestigious Max Planck Institute for Astrophysics in Garching, Germany, from 2007 to 2011. “It was a once in a lifetime opportunity to become the director of the Institute. You work in an environment that is incredibly encouraging and surrounded by incredibly smart people.” He found a difference in the research atmosphere between the Max Planck Institute and Mount Stromlo Observatory. “Both institutions are very welcoming, but they are different sorts of institutes. Max Planck is very hierarchical. At Mount Stromlo the research programme is decided by the astronomers. They choose their own topics. At Max Planck, the director decides the research structure for the whole department. When I joined, Simon



Martin Asplund at the Research School of Astronomy and Astrophysics, Mount Stromlo. (Stuart Hay/ANU)

White, an astronomer who came from the British–American system, changed the MPI by making it more international. It used to be very much German. Now it is an international institute – almost half of the directors are non-German.”

Supercomputers and models

Asplund has made significant contributions in a number of fields in astrophysics. One of his strategies for success in this highly competitive field has been the use of large computer simulations and 3D models. The introduction of supercomputers allowed him to undertake 3D radiative hydrodynamical convection simulations to study the formation of iron lines in stars (Asplund *et al.* 2000). Traditionally this was done in one dimension because, as he says, “we had a one-dimensional model for the Sun or the star”. He and his collaborators have pioneered this new method of analysis over the past 15–20 years. They have investigated solar-type stars, metal-poor stars such as A and F stars, and red giants where granulation is expected to be much more vigorous than it is in the Sun.

His research on the oxygen abundance of the Sun was hotly debated. The Sun matters because it is taken as a reference standard in the study of the chemical compositions of stars, planets, galaxies and gas clouds in astronomy. “We had to know the chemical

make-up of the Sun very accurately. So, I set out to determine the chemical composition of the Sun ... Unfortunately you can’t read off exactly how much oxygen there is in the Sun or how much iron there is in the Sun just by looking at the solar spectrum.” In order to get a proper view of the Sun, Asplund began to use 3D hydrodynamical simulations that required supercomputers (Asplund *et al.* 2004).

He had started this approach when he was a postdoc at Copenhagen University with Nordlund. Their more sophisticated analysis gave quite different results to the traditional, one-dimensional approach. They found that, for its age, the Sun was not as metal-rich as had been believed in the traditional literature. “The Sun,” he says, “is quite normal in terms of its chemical composition for stars of that age compared to stars that are born today in the solar neighbourhood.” In fact, he notes that most people in the astronomical community have now embraced and adopted “our solar abundance values”, although astrophysicists using helioseismology take a different view. Asplund believes that if you make a “model for how the solar interior works, you need a relatively high chemical composition of heavy elements like oxygen. That is not consistent

with what we measure from spectroscopy from the outer layers.”

In 2005, Asplund was invited to write a review on stellar abundance analyses for the *Annual Review of Astronomy & Astrophysics* (Asplund 2005). It was a critical review. “I basically assessed the potential problems in the traditional way of model-

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ling stars, namely in one dimension and the local thermodynamic equilibrium for radiative transfer.” He noted that a much better way to go about this was to

use time-dependent, 3D hydrodynamical model atmospheres as they are a better alternative. It took some time for the astronomical community to accept his ideas. Fortunately his predictions were “more or less correct”.

In 2009, he wrote a major review paper on the chemical composition of the Sun (Asplund *et al.* 2009), a key ingredient in our understanding of the Sun and other celestial bodies. According to him there are three methods that one can use to study the chemical composition of the solar system: meteorites, solar spectroscopy and helioseismology. He is aware of the limitations of all three methods, but especially of the limitations of measuring photospheric abundances. It is important to bear in mind the dynamic environment and the

relatively short timescale one is investigating, to consider magnetic fields, sunspots and atomic processes, as well as deal with everything from hydrodynamics to radiative transfer. “Even the most sophisticated computer models that my group is using do not allow us to resolve the smaller spatial scales on the Sun,” according to Asplund. They do not have “the computational power to solve everything perfectly”.

Since Nicholas Grevesse and Jack Sauval’s (1998) compilation of the solar chemical composition, there have been many revisions. “They have been working in this field for a long time and it is very time-consuming work,” notes Asplund. “The traditional way is for a research group to study one element at a time and then combine this with different studies and critically evaluate them.” The compilations by Grevesse and Sauval and an early work by Anders and Grevesse (1989) were based

on other people’s work, critically assessing the work of different groups and combining the different studies to make sure the astrophysical community had “the best estimate of the solar abundances”. Asplund started working with them in early 2004. He realized, he says, “that the work we were doing and the work I was doing in developing these solar models would have a large impact on this field”. Both Grevesse and Sauval had expertise in atomic physics and solar spectroscopy – skills that Asplund needed. “We decided to do a systematic study ourselves of all the different elements. This was the first time this had been done.” Their work made a huge impact on astronomy. “Not only because it is the most complete, but also because we changed the reference standard,” he says.

He worked with Zazralt Magic (his PhD student) and Remo Collet (his PhD student and postdoc) in a systematic exploration of how convection works in different types of stars (Magic *et al.* 2013), with the aim of understanding the physics of convection, which he regarded as the biggest unsolved problem in stellar physics, for many decades. They used the Stagger code which was developed by Ake Nordlund. In 2009, Asplund, Nordlund and Robert Stein (Michigan State University) published a comprehensive review paper including insights into the numerical models of

the hydrodynamics and magnetohydrodynamics of solar surface layers. The models they developed are becoming more realistic because of, as Asplund remarks, “the steady growth of computing power and because of the incorporation of increasingly complex physical mechanisms in the models”. The biggest problem that remains to be understood is how solar magnetic fields are generated and how they manifest themselves in such different ways (Nordlund *et al.* 2009).

Metal-poor stars

In his study of the formation of the first – or metal-poor – stars after the Big Bang, Asplund and his colleagues were confronted with the lithium problem (Asplund *et al.* 2006, Israelian 2012).

“[For] lithium-7 we observe too little,” he says, “and for lithium-6 we observe too much compared to expectations.” The problem has not

been fully resolved but their work “sharpens the discrepancy with the standard Big Bang nucleosynthesis”. However, their observations of lithium isotopic abundances in metal-poor halo stars have resulted in very-high-quality spectra of 24 metal-poor halo stars.

Galactic archaeology has become one of the hot topics in astronomy and cosmology. Mount Stromlo Observatory has been a significant player in this field with Freeman, Norris and Bessell making significant contributions. Asplund and his colleagues observed extremely metal-poor stars in the Milky Way bulge (Howes *et al.* 2015) and discovered one star with an iron abundance about a thousand times lower than the solar value, without any noticeable carbon enhancement. Further data showed that it had “ten million times less iron than in the Sun”, says Asplund. “That is, of course, something like a hundred times lower content of iron than anybody has ever found in any star before.”

Asplund and his colleagues wrote a critique and conducted a reanalysis of the Geneva–Copenhagen Survey (Nordstrom *et al.* 2004), the most comprehensive catalogue of late-type solar neighbourhood stars (Casagrande *et al.* 2011). The survey was an ambitious project which began in 1980; its results were published in 2004. At the time, it was the largest stellar survey.

Asplund and his colleagues “determined better temperatures which implied changes in the metallicities of the stars and the ages that you can infer”. Luca Casagrande, a member of Asplund’s team, used the infrared flux method to calculate the temperatures of the stars. It is a “much more precise and homogenous method”. Since the Geneva–Copenhagen Survey there have been more ambitious and even larger surveys of the Milky Way and the cosmos, such as the Sloan Digital Sky Survey, the 2dF Galaxy Redshift Survey, the HI Parkes All Sky Survey, the MACHO Project and the current GALAH Survey.

Extrasolar planets

Research in extrasolar planets and the formation of planetary systems has become an exciting and vigorous field of research in the more than 20 years since the first discovery. The thousands of discoveries so far have raised interesting questions about the formation of planets. Asplund and his colleagues Melendez, Gustafsson and Yong conducted a study of 11 solar twins (Melendez *et al.* 2009). What they found surprised them. According to Asplund: “It turned out that the Sun is unusual in its chemical composition ... It had a lower content of refractory elements (iron, magnesium, etc).” He concluded “that some of these refractory elements were basically locked up in the planets during the formation of the solar system. So the natural conclusion from this hypothesis is that the other stars would not have formed as many planets or certainly not as efficiently as the Sun. This is a prediction that we’re making and it’s a hypothesis that we’ve put forward.” Time will tell.

Conclusion

Asplund’s interesting and very productive career has been achieved by moving seamlessly from one country to another after completing his PhD in Sweden. He belongs to a new breed of global scientists who see the world as their intellectual oyster. Today, most of the major creative universities have a group of scientists who cross national boundaries in search of knowledge and collaborations on research projects – Mount Stromlo’s varied staff fit this model nicely and their successes support the goal of becoming a global astronomical institution. ●

AUTHOR

Ragbir Bhathal is a visiting fellow at The Research School for Astronomy & Astrophysics, Australian National University. His latest book, with Harvey Butcher and Ralph Sutherland, is *Mount Stromlo Observatory: from Bush Observatory to the Nobel Prize*. He is writing *Mount Stromlo Astronomers: the Endless Frontier*.

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