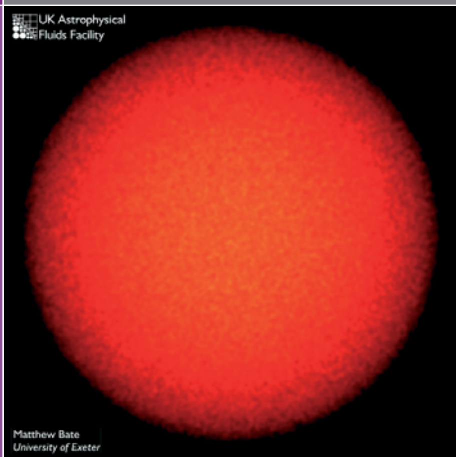
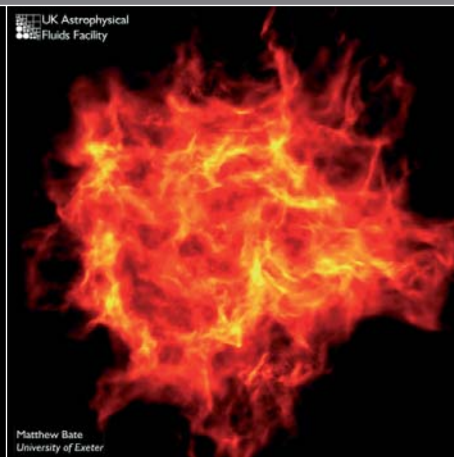
SUCCESS STORY

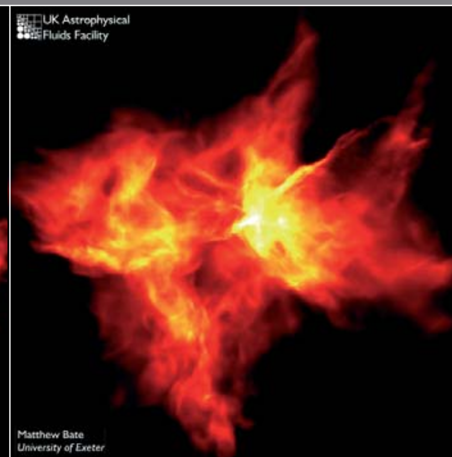
UNIVERSITY OF EXETER



Clouds of interstellar gas are seen to be very turbulent with supersonic motions. We begin with such a gas cloud, 1.2 light-years across, and containing 50 times the mass of the Sun.



As the calculation proceeds, the turbulent motions in the cloud form shock waves that slowly damp the supersonic motions.



When enough energy has been lost in some regions of the simulation, gravity can pull the gas together to form a dense "core".

Supporting a World First in Star Formation Modelling

"Not only was SGI equally or more competitive in terms of its technical solution and the performance of its equipment, it also put together a very good package of support. And, because SGI has historically provided a large number of systems to the scientific community, it has proven expertise in helping to optimise scientific codes that some other vendors do not."

–Professor Matthew Bate, Professor of Theoretical Astrophysics, University of Exeter

The University of Exeter (in south-west England) is highly regarded as a world leader in astrophysics research. Its Astrophysics Group (part of the School of Physics) includes observers and theorists who specialise in the study of star and planet formation throughout our galaxy.

For star formation, the theoretical side of the group's work focuses on fluid dynamical simulations. Starting with a cloud of hydrogen and helium gas, the simulations model the collapse of the gas cloud under the force of gravity, which leads to the process of star formation. Snapshots within this process, together with the end products (stars, binary stars, etc), can then be compared to observations made by members of the group and observers around the world, to see if the models are correct – so increasing knowledge of the process.

The purchase of an 1152-core SGI® Altix® ICE 8200 integrated blade platform has now put the University even further ahead of its competitors, by enabling researchers to undertake simulations with a level of sophistication that has never been seen before, anywhere in the world.

Just how typical is our own sun?

"Once we understand a little more about star formation, we can hopefully go forward and make predictions about how the process might vary in different parts of the galaxy – for example in the galactic centre, where there is extreme turbulence and the gas clouds undergo severe shearing motions; where there is a black

"Now we have a machine that is 30 times more powerful than anything we've been able to use before, by mid 2008 we expect to have been able to do a large calculation forming hundreds of stars, including both magnetic fields and radiative transfer. And when we've achieved that, it will be the first time that anyone has done a simulation of this type, anywhere in the world."

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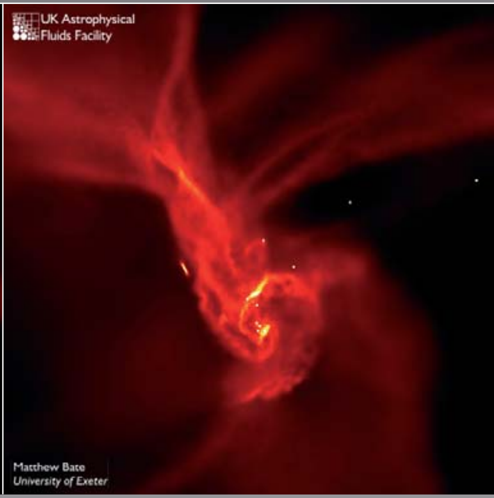
The cloud and star cluster at the end of simulation (which covers 266,000 years). Some stars and brown dwarfs have been ejected to large distances from the regions of dense gas in which the star formation occurs.



Stars and brown dwarfs fall together into a cluster. The objects range in mass from nearly the mass of the Sun down to as small as six times the mass of Jupiter. A star with an edge-on disc is ejected, centre left.

hole nearby; way out towards the edge of the galaxy where the densities are lower and there is relatively little going on; and also earlier in the galaxy's history," explains Professor Matthew Bate, Professor of Theoretical Astrophysics at the University of Exeter.

"Another way of looking at this is that we want to be able to put our own Sun into context. We have no idea how typical our own planet is, but we do know that we're orbiting around a pretty typical star. So we need to understand why stars like the Sun are relatively common, whereas those with 50 times its mass are very rare, and those with a tenth of its mass are more common still. Then, at even lower masses, are brown dwarfs (which are like stars but without an energy source). Although we haven't detected them observationally yet, the very lowest mass brown dwarfs are thought to be just a few times the mass of gas giant planets such as Jupiter. So it's also about predicting what our observers should be seeing, if and when they start detecting these types of objects.

"Complementing this, on the extrasolar planet side our group includes people such as Suzanne Aigrain, who is part of a team of astrophysicists from Europe and Brazil who are working with the new French-led CoRoT space telescope. CoRoT is designed to probe the insides of stars by monitoring tiny variations in their brightness, and also to detect transiting planets around stars other than the Sun.

"With the data from CoRoT, we're primarily interested in understanding how gas giant planets like Jupiter and Neptune have formed. If you have a young star surrounded by a disk of gas and dust, one of the issues is how you can build up the solid core of such planets quickly enough that the gas in the disk hasn't been lost. The gas disk only seems to last 5-10 million years. We think that when a solid core gets massive enough, proto-planets like this rapidly increase in mass by dragging in gas from the disk and building up a huge gaseous envelope around a solid core, which then leads to a giant planet like Jupiter. But again it's about modelling the accretion of the gas. How fast does it happen? Do you have enough time to build Jovian-type planets before the disk is evaporated by the star? And why did Neptune and Uranus not reach Jupiter's or Saturn's mass? So there's a lot of uncertainty about star and planet formation that we're working to unravel."

Giving birth, not just to dozens of stars – but hundreds or thousands

For the past few years, the Astrophysics Group's simulations have been run at the UK Astrophysical Fluids Facility (UKAFF). (Images from one such simulation, following the formation of a cluster of 50 stars and brown dwarfs, can be seen in this success story.) However, this resource, shared between many users, is no longer powerful enough to perform state-of-the-art calculations and faces an uncertain future. Deciding to bring its calculations in-house, in June 2007 Exeter University purchased an SGI Altix ICE 8200 compute cluster with 128 Quad-Core Intel® Xeon® 5300 Processor cores and 11TB of usable disk space.

The system gave the group several times the computational capacity of the UKAFF facility, and enabled it to undertake

Supporting a World First in Star Formation Modelling

similar sorts of calculations, but more of them. Then, in December 2007, the University took delivery of an 1152-core SGI Altix ICE 8200, based on Quad-Core Intel Xeon 5400 Series Processors. The new solution is over an order of magnitude more powerful than anything the group had previously had access to – enabling it to run much larger and more complex calculations than ever before.

“In terms of what the new system means for star formation, what we really need is to be able to add more physics to our calculations,” continues Matthew Bate. “Up until now when we’ve been modelling collapsing gas clouds to produce stars and star clusters, the models we’ve used have only involved gravity and the hydrodynamics of the fluid. What we haven’t been able to include are magnetic fields, or ‘feedback’ from the stars. (i.e. the fact that as a star forms it heats the gas around it, and that then alters the way it subsequently collapses.)

“Over the last few years we’ve therefore been developing techniques to add in magnetic fields and radiation transport. Towards the end of 2007 we started doing those calculations, but while UKAFF and our initial SGI system allowed us to do small calculations, what we really want is to simulate clouds that are big enough that we end up with hundreds or thousands of stars. Because if we can form that many stars all at once, we can look at the statistical properties of the stars and compare them to real observations.

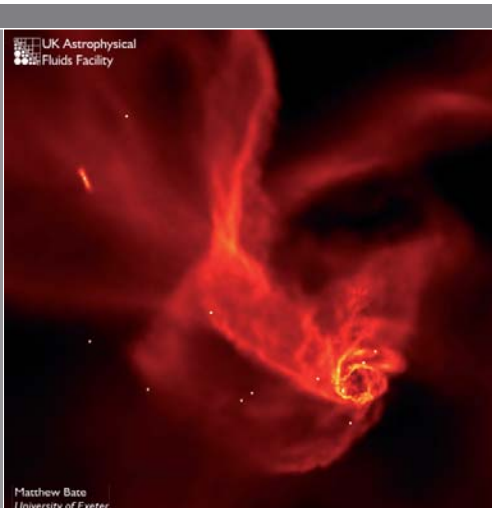
“If you only form a couple of dozen objects, then you typically get a few brown dwarfs, a few stars and one or two binaries. But you can’t really compare that to observations where you have maybe 500 stars, and you can therefore get a very precise distribution of masses, look in detail at how many are in binary star systems, how many are single like the Sun, and so on.

“Prior to purchasing our latest Altix ICE, we couldn’t do numerical simulations that were big enough to compare to those sorts of observations, so it made it very hard for us to know whether our models were right or wrong. But now we have a machine that is 30 times more powerful than anything we’ve been able to use before, we expect that by mid 2008 we’ll have been able to do a large calculation, i.e. one that forms hundreds of stars, including both magnetic fields and radiative transfer. And when we’ve achieved that, it will be the first time that anyone has done a simulation of this type, anywhere in the world.”

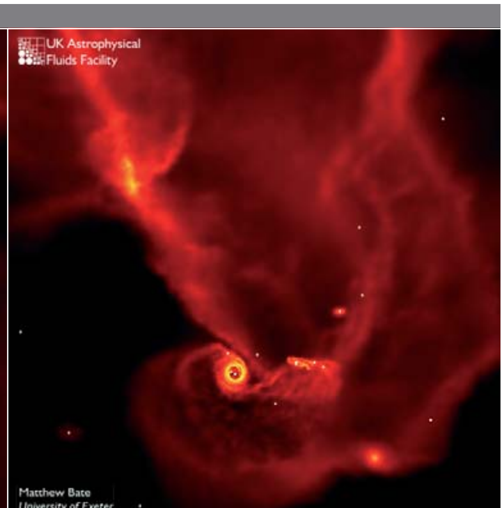
Why SGI?

To identify the optimum solution to its needs, the University undertook a comprehensive tender process involving all the major potential suppliers. SGI was selected because it offered a complete solution incorporating superior application expertise, best of breed support, and strong collaboration ties enabling SGI’s specialist knowledge to be embedded into the group’s core engineering teams and so maximise their scientific output. SGI also provided a “fuller” solution delivering best in class performance, proven support capabilities, the advantages of a strategic partnership, and environmental benefits.

Because Altix ICE features optional water-cooled doors capable of dissipating up to 95% of rack heat, it has almost no effect on a data centre’s ambient temperature – significantly reducing cooling equipment power consumption, and increasing overall system reliability. Its energy-optimised



An unstable system of five stars breaks up and ejects stars from the cloud in three different directions.



The stars and discs in the main star-forming region at the end of the calculation.

"The research we're doing is about answering the big questions of where we came from, and how many other planets out there are like ours. We therefore need to be able to attract the very top scientists in their respective fields, together with the funding we need to take our research to the next level, and having a solution as powerful as Altix ICE certainly helps us to do that."

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components (including 90% efficiency redundant power supplies) can also save 33% on electricity costs compared to typical cluster implementations – and double that through increased infrastructure efficiency.

Altix ICE typifies SGI's dedication to the environment. A member of The Green Grid^{SM}, in February 2008 SGI extended its long-held commitment to environmental stewardship by joining the Climate Savers Computing Initiative^{SM} – a non-profit group of consumers, businesses and conservation organisations dedicated to improving the power efficiency and reducing the energy consumption of computers.

"Not only was SGI equally or more competitive in terms of its technical solution and the performance of its equipment, it also put together a very good package of support, which included sponsoring a programmer to help with the optimisation and parallelisation of our compute codes to run on the new machine," says Matthew Bate. "The other attraction was that because SGI has historically provided a large number of systems to the scientific community, it has a good reputation, and proven expertise in helping to optimise scientific codes that some other vendors do not."

In addition to supporting the Astrophysics Group's research, the Altix ICE will be used for condensed matter research in the School of Physics, and by the University's Mathematics Research Institute.

The aim of the Theoretical Condensed Matter Group is to understand and predict the properties of materials such as semiconductors, their surfaces, nanostructures, and the interaction of molecules with surfaces. Doing this requires the solution of the quantum mechanical Schrödinger equation, which is extremely difficult because of the interactions between electrons.

One current problem that is being studied is how to lower the price of silicon-based solar cells. Currently, the most efficient cells use expensive refined silicon that has had transition metal impurities removed, whereas the cost of a cell would fall dramatically if dirty silicon could be used in place of refined silicon. Recent experimental investigations in the US and Japan suggest that not all transition metal defects are equally active in degrading solar cell performance, and small precipitates or those at special low angle grain boundaries are the most damaging. This is important as it suggests that it may be possible to grow the less damaging precipitates at the expense of the more damaging ones by defect engineering. Exeter has begun a study of the structure and electrical properties of these precipitates and hopes to use the Altix ICE to complete this work.

In the Mathematics Research Institute, meanwhile, the system will be used for research into the generation of magnetic fields in the Sun and in planets, and also the dynamics of planetary atmospheres – so complementing the Astrophysics Group's work in planetary formation.

"Ultimately, the research we're doing is about answering the big questions of where we came from, and how many other planets out there are like ours," concludes Matthew Bate. "To answer those questions, we need to be able to attract the very top scientists in their respective fields, together with the funding we need to take our research to the next level, and having a solution as powerful as Altix ICE certainly helps us to do that."

"Our work on hydrodynamical simulations over the last few years has meant that we're already leading the way – as even now, other groups are only just starting to compete. So being able to add radiative transfer and magnetic fields, and hopefully get our first results by mid 2008, will put us another leap ahead – which is where we really want to be!"

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