Exploring the universe with supercomputing

The Center for Computational Astrophysics in Japan recently upgraded its ATERUI supercomputer, doubling the machine's theoretical peak performance to 1.058 petaFLOPS. Eiichiro Kokubo, director of the center, tells iSGTW how supercomputers are changing the way research is conducted in astronomy.

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Andrew Purcell
European editor

What's your research background?

I investigate the origin of planetary systems. I use

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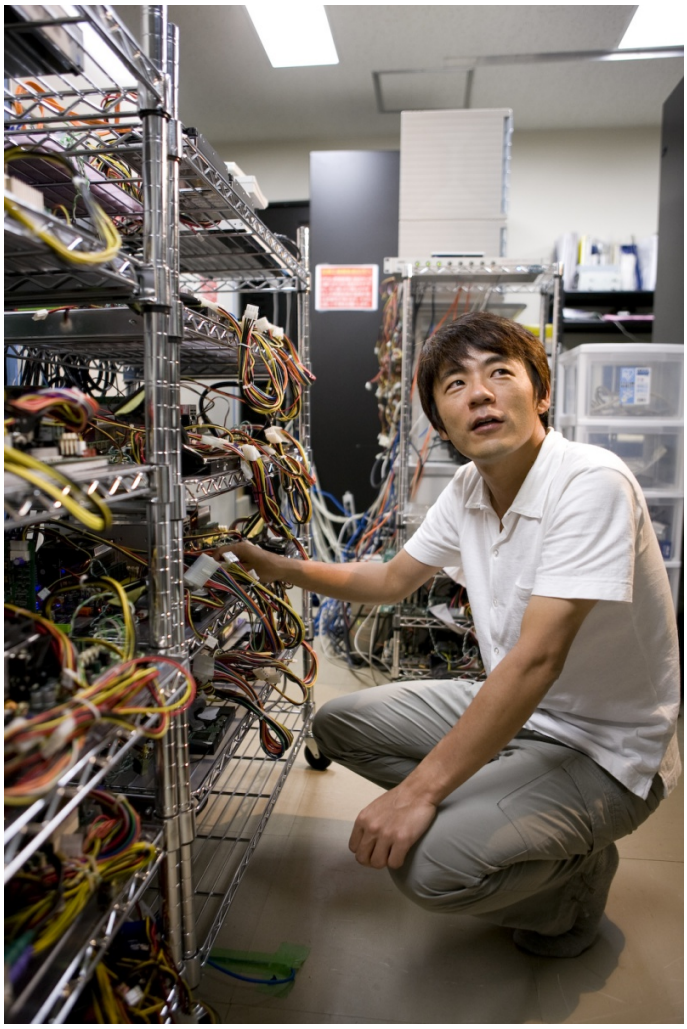

"Supercomputers act as telescopes for phenomena we wouldn't otherwise be able to see," says Kokubo.

many-body simulations to study how planets form and I also previously worked on the development of the Gravity Pipe, or 'GRAPE' supercomputer.

Why is it important to use supercomputers in this work?

In the standard scenario of planet formation, small solid bodies - known as 'planetisimals' - interact with one another and this causes their orbits around the sun to evolve. Collisions between these building blocks lead to the formation of rocky planets like the Earth. To understand this process,

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you really need to do very-large-scale many-body simulations. This is where the high-performance computing comes in: supercomputers act as telescopes for phenomena we wouldn't otherwise be able to see.

The scales of mass, energy, and time are generally huge in astronomy. However, as supercomputers have become ever more powerful, we've become able to program the relevant physical processes - motion, fluid dynamics, radiative transfer, *etc.* - and do meaningful simulation of astronomical phenomena. We can even conduct experiments by changing parameters within our simulations. Simulation is numerical exploration of the universe!

How has supercomputing changed the way research is carried out?

'Simulation astronomy' has now become a third major methodological approach within the field, alongside observational and theoretical astronomy. Telescopes rely on electromagnetic radiation, but there are still many things that we cannot see even with today's largest telescopes. Supercomputers enable us to use complex physical calculations to visualize phenomena that would otherwise remain hidden to us. Their use also gives us the flexibility to simulate phenomena across a vast range of spatial and temporal scales.

Simulation can be used to simply test hypotheses, but it can also be used to explore new worlds that are beyond our current imagination. Sometimes

you get results from a simulation that you really didn't expect - this is often the first step on the road to making new discoveries and developing new astronomical theories.

ATERUI has made the leap to become a petaFLOPS-scale supercomputer. Image courtesy NAOJ/Makoto Shizugami (VERA/CfCA, NAOJ).

In astronomy, there are three main kinds of large-scale simulation: many-body, fluid dynamics, and radiative transfer. These problems can all be parallelized effectively, meaning that massively parallel computers - like the Cray XC30 system we've installed - are ideally suited to performing these kinds of simulations.

What research problems will the ATERUI enable you tackle?

There are over 100 users in our community and they are tackling a wide variety of problems. One project, for example, is looking at supernovae: having very high-resolution 3D simulations of these explosions is vital to improving our understanding. Another project is looking at the distribution of

galaxies throughout the universe, and there is a whole range of other things being studied using ATERUI too.

Since installing ATERUI, it's been used at over 90% of its capacity, in terms of the number of CPUs running at any given time. Basically, it's almost full every single day!

Don't forget, we also have the K computer here in Japan. The National Astronomical Observatory of Japan, of which the CfCA is part, is actually one of the consortium members of the K supercomputer project. As such, we also have plenty of researchers using that machine, as well. High-end supercomputers like K are absolutely great, but it is also important to have middle-class supercomputers dedicated to specific research fields available.

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