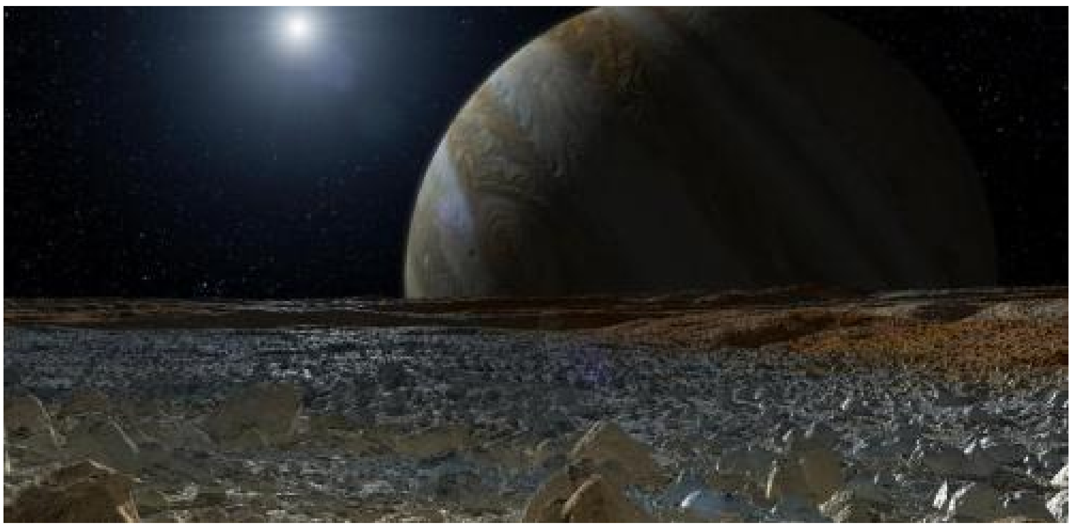
By Jove! Can climate change lead us to life on other planets?

October 2 2013, by Jonti Horner



Not just a pretty planet – Jupiter may provide clues for detecting Earth-like planets. Credit: NASA

Thanks to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, we've recently heard a great deal about how the Earth's climate is changing. The IPCC's cautious assessment of the situation is that we now know, with 95% certainty, that human greenhouse gas emissions are causing global warming – but did you know that the actions of other bodies in our solar system also have huge effects on our climate?

To be fair, this type of warming and cooling takes place over tens or hundreds of thousands of years, far longer than a human lifetime. But, although effects on this scale can feel irrelevant to us right now, we may well be able to use this information to help us in our future search for life on other planets.

A casual glance at the ever-growing catalogues of planets known orbiting other stars reveals that both the number and variety of those planets are increasing at a remarkable rate.

And while we don't currently know of any planets that could be considered truly Earth-like beyond our own solar system, it is only a matter of time before such planets are discovered, and the search for life beyond our solar system begins in earnest.

Rapid rate of discovery

Throughout the history of astronomy, it is almost always the case that, though the discovery of the first of a given class of object is incredibly challenging, many more of that same class will follow quickly on the heels of the first.

Take, for example, the asteroids. The first asteroid, 1 Ceres, was discovered by Italian Catholic priest Guiseppe Piazzi in 1801.

In the few years that followed, three more asteroids were found – 2 Pallas, 3 Juno and 4 Vesta. The fifth asteroid, 5 Astraea, was not discovered until 1845 – but since that discovery, the population of known asteroids has grown rapidly, such that more than 600,000 have been found to date.

More relevant to our current story, the first planet discovered orbiting a Sun-like star, 51 Pegasi b, was found just 18 years ago – yet we already know of more than 700 (or more than 900, depending on which catalogue you use) such planets.

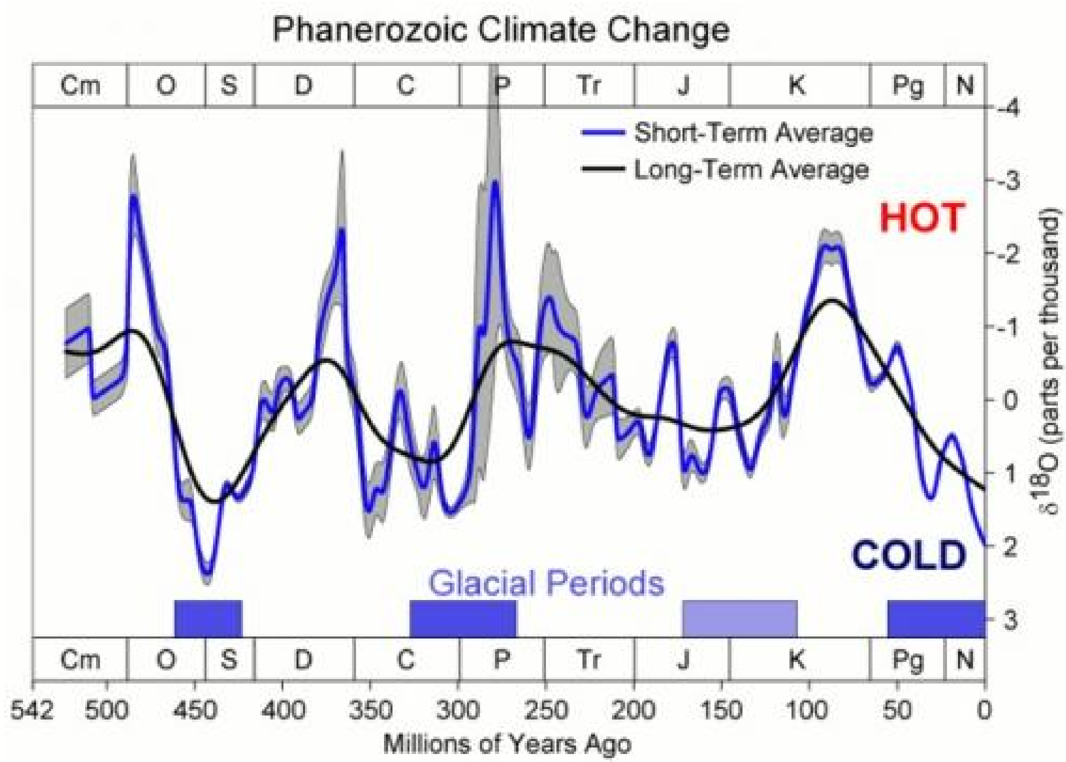
Finding Earth-like worlds

The search for life on these distant worlds will be an incredibly challenging process. In the past decade, several measurements have been made of the atmospheres of planets orbiting other stars.

Those observations have generally targeted "hot Jupiters" – planets far larger and more massive than Earth, orbiting far closer to their host stars. Both these factors make the kind of observations carried out easier than they would be for an Earth-like planet.

But how will we decide which planets represent the best prospects for the detection of life beyond our solar system? While it is possible to imagine an enormous variety of life occupying ecological niches vastly different to those found on Earth (something well serviced by science fiction), the one place that we know life exists and thrives is our own planet.

It therefore makes sense to direct our search to the most Earth-like planets (exo-Earths) we can find since those will offer the best odds of us making a positive detection.



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Milankovi? cycles

We need to build a "checklist of habitability" by which we can assess the many exo-Earths we will detect, and rank them such that the most promising can be identified and targeted by the exhaustive observations needed in the search for life.

Obviously, practical concerns will play a significant role in the target selection – the closer the planet to our solar system, the easier it will be to observe. However, there are many other criteria that will have to be taken into account for us to determine the best place to look.

With that in mind, we have recently started studying the influence of the giant planets in our solar system on the Earth's orbit, and therefore on our planet's climate. It is well known that, over the past few million years, the Earth has experienced a series of glaciations (intervals of time within Ice Ages marked by colder temperatures and glacier advances), with short inter-glacial periods in which the ice retreated, followed by lengthy spells when the ice caps grew outward to bury the north of Europe, America and Asia.

The cause of those glaciations has long been argued to be the Milankovi? cycles – the periodic changes in the Earth's orbit that are driven by our planet's interaction with the other objects in the solar system.

Over time, our orbit twists and flexes under the perturbation of the other planets, and the Earth's rotation axis nods back and forth. This, in turn, causes the average amount of energy the Earth receives from the Sun over the course of a year to vary on timescales of tens of thousands of years. It is that periodic variation that is thought to drive the growth and retreat of the ice caps causing the ongoing series of glaciations.

The strength and frequency of the Milankovi? cycles is tuned by the influence of the other planets in our solar system, and it is easy to imagine scenarios in which those planets moved on slightly different orbits, resulting in the Earth experiencing far greater orbital excursions.

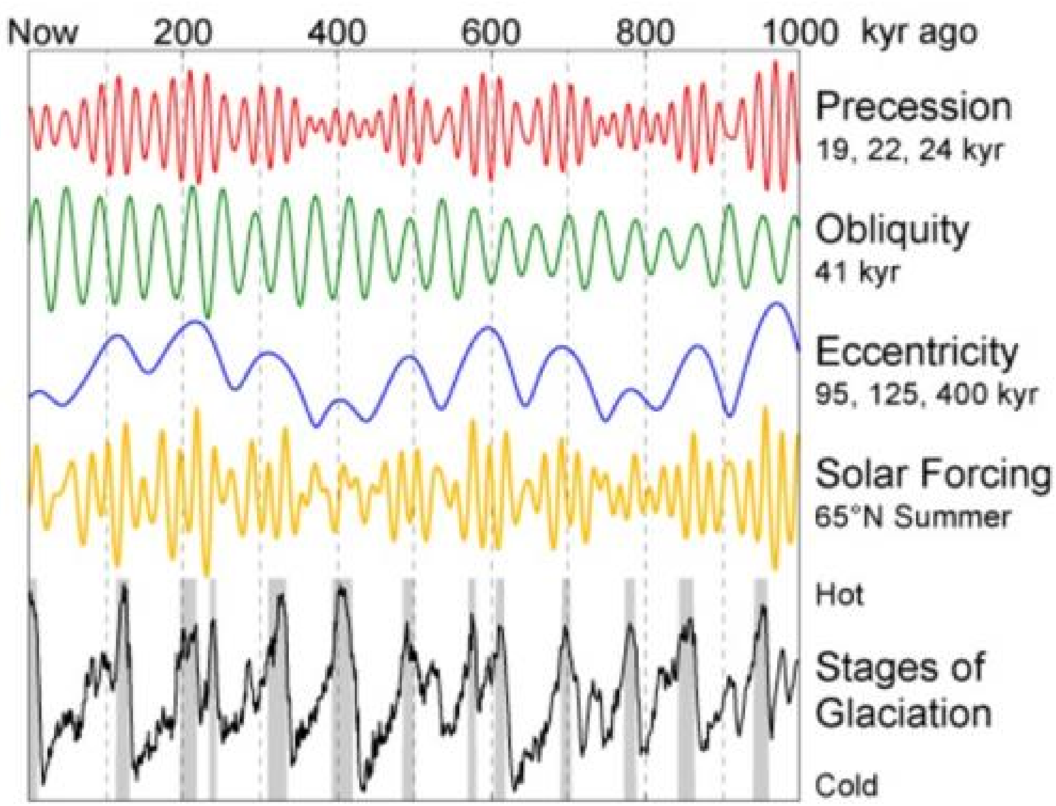
Given that the exo-Earths we will discover around other stars will move in planetary systems vastly different to our own, it is therefore interesting to consider how the Milankovi? cycles would differ had our own planets ended up on different orbits.

Jupiter's effect

Dave Waltham (of Royal Hollway, University of London) and I have begun a series of studies that will examine how the architecture of our solar system would affect the Milankovi? cycles at the Earth.

In our preliminary study, the results of which were presented for the first time at this week's Australian Space Science Conference, we have looked at what would happen to the Milankovi? cycles were Jupiter located further from or closer to the Sun – but the rest of the solar system remained as we see it today.

We set up almost 40,000 scenarios, each of which featured the planets of our solar system initially moving on their current orbits, but with Jupiter shifted from the orbit we see today. In our solar system, Jupiter currently moves on a slightly eccentric orbit, 5.2 times further from the Sun than the Earth.



Credit: Wikimedia Commons

In our study, we considered scenarios with Jupiter orbiting between 4.2 and 6.2 times further from the Sun than the Earth, on orbits that varied from perfectly circular to moderately eccentric.

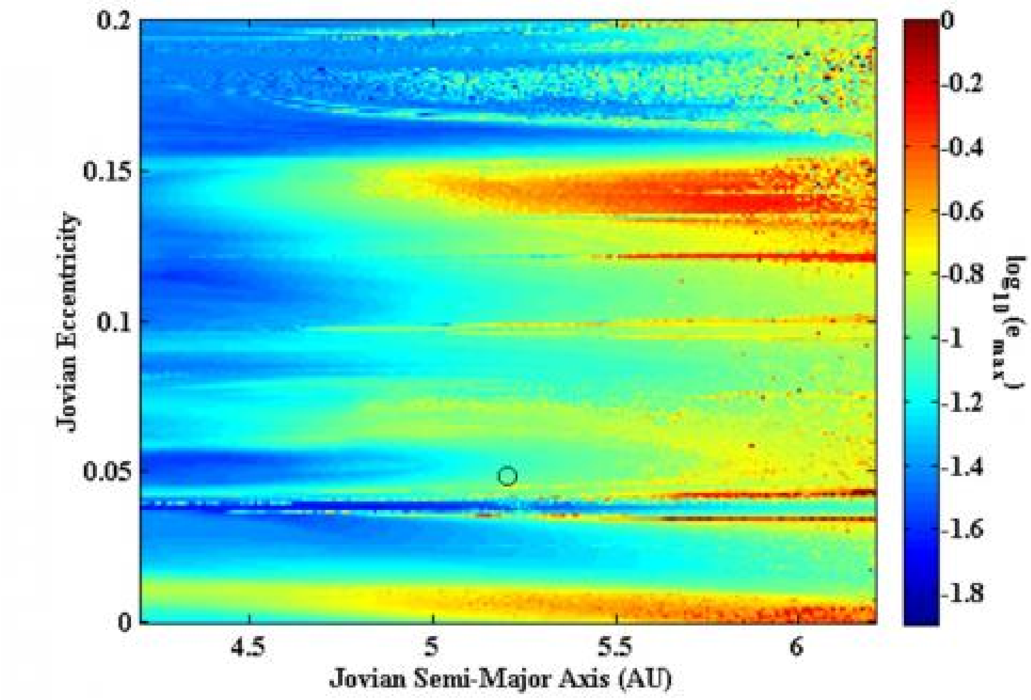
For each of the 39,601 systems we studied, we followed the orbital evolution of the planets for a million years – long enough for the Earth's orbit to flex and tilt a number of times.

We were then able to calculate the rate at which our planet's orbit varied from scenario to scenario, along with the amplitude of those variations.

Not quite 'Rare Earth' …

Proponents of the "Rare Earth" hypothesis have long argued that the origin and survival of life on the Earth is the result of such an unusual chain of circumstances that we are almost certain to be alone in the universe.

That viewpoint is based on the idea that the combination of factors that have made the Earth so habitable are so unlikely to occur as to be next to impossible.



The maximum eccentricity of the Earth's orbit, over a period of 1 million years, as a function of the orbit of Jupiter. The orbit of Jupiter in our own solar system is marked by the open circle. Whilst there are many regions where the Earth's orbit is driven to high eccentricity (and therefore to significant climate variability), it is noticeable that there are also many solutions for which the variation in the Earth's orbital eccentricity is lower than that for our own solar system. Results to be presented at the 13th Australian Space Science Conference

At least in terms of the Milankovi? cycles, our preliminary results suggest that the Earth is not that unusual – it turns out that you can move Jupiter significantly without greatly increasing the amplitude or frequency of the periodic changes in the Earth's orbit.

We do find a large number of planetary architectures that result in significantly greater swings in the Earth's orbit than those we observe on our own planet. However, we also find that the majority of architectures tested result in orbital variations comparable to, or even less significant, than those we experience.

Our results are clearly only preliminary, but they do reveal one technique by which we could whittle down our list of potentially habitable worlds to help select the most promising targets for the search for life.

By the time we have found exo-Earths in a given system, we will have a very good handle on the existence of, and orbits of, the more massive planets in the system. It will then be fairly easy to simulate the orbits of those planets, to see how the exo-Earth's orbit is nudged and tweaked over time.

This will allow us to work out which of those exo-Earths will suffer the greatest excursions in their orbits, on timescales of thousands and tens of thousands of years – allowing us in turn to target those that are the most "Earth-like" in our search for life elsewhere.

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