Kepler, exo-planets and more

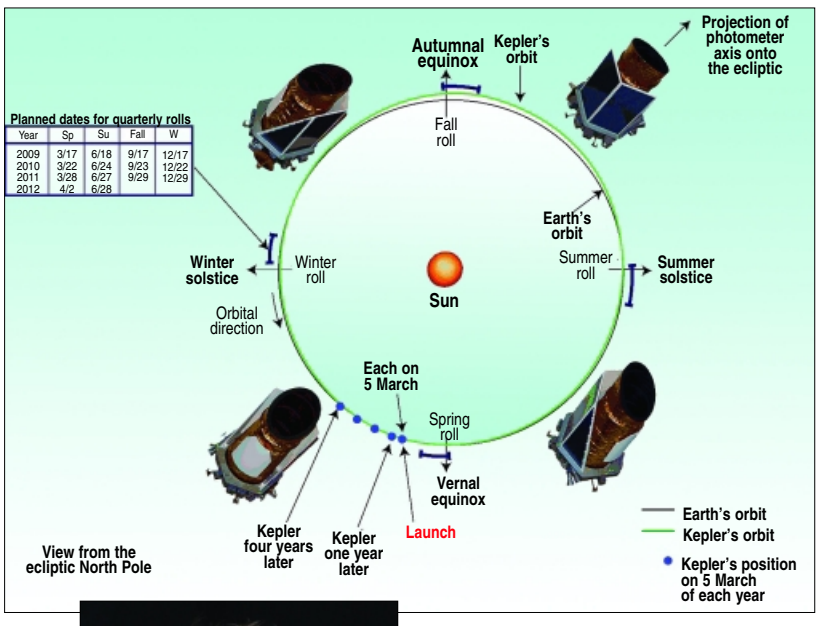
Determining the age of a star would also tell the age of its planets, writes **s ananthanarayanan**

THE last decade saw a great interest in locating planets that orbit stars other than the sun and the last three years have been very fruitful in finding these. And if any such planets seem to have features that could harbour life, then knowing how old these are would help identify those that have been around long enough for finding signs of life on them to be more likely. At the 218th meeting (23 May 2011) of the *American Astronomical*, astronomer Soren Meibom of the Harvard-Smithsonian Centre for Astrophysics announced his team's success in accurately estimating the age of individual stars that, in turn, would be the age of a planetary system.

As planets are typically small, compared to the mother-star, and as they have no light of their own, those of distant stars cannot be detected from earth because of the glare of their luminous parents. The first instance of detection, in 1995, of a giant planet orbiting a star 51 light years away in the constellation Pegasus was indirect – using the slight movement of the mother-star to balance that of the planet as it went round, to deduce its presence. The movement of the parent star affects the frequency of the light it emits, like the speed of an approaching railway engine makes its whistle sound shriller and then drops in pitch as the engine passes and starts moving away. The back and forth movement of the star causes a similar change of frequency of light, which can be detected on earth. The mass and distance of the planet can then be worked out from the timing and extent of the change.

This method, naturally, works best with massive planets that move quite fast in close orbits and the first exo-planets detected were all of this type, clearly too large and too hot, not in any way "earth-like". But a new method was soon devised — to observe the slight drop in the intensity of light from the star at the time the planet passes between the star and the earth. The *Kepler* project is an orbiting observation platform that was launched in 2009 specifically for finding exo-planets using this method, accurately and sensitively, free from distortion by earth's atmosphere.

In February 2011, the *Kepler* team announced that between May and September 2009 that 1,235 planet candidates had been found, circling 997 host stars, more than twice the number known till then. This tally included 68 planetary candidates of *earth-like size* and 54 planetary candidates in the *habitable zone* (neither too hot nor too cold) of their star. A feature of the *Kepler* data is that the orbits of planets detected around a star need to be in the same plane so that they all block starlight flowing in the direction of earth. This limits the number of planets that can be detected, but the *Kepler* team



A team led by astronomer Soren Meibom (left), whose work – based on the Kepler project – has led it to claim success in accurately estimating the age of individual stars that, in turn, would be the age of a planetary system.

estimates that 19 per cent of all stars have multiple planets and six per cent of stars host earth-size planets.

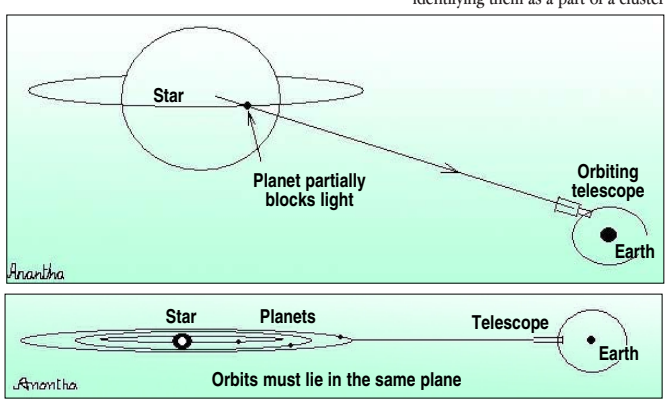
Now some of these earth-sized candidates would also be in the habitable zone and then it becomes a question of great interest to see if they contain signs of life. But for this quest, it is useful first to know how old the planetary system is, as the probability is greater in older systems.

Age of planet systems

In the case of stars in a cluster, which could be considered to have evolved together, it is found that two parameters – the brightness and the spectral colour of the stars — show a relationship. The parameters change as the stars age, but they change uniformly, for all the stars in the cluster and the relation corresponds to the age of the cluster. Thanks to the known age of some clusters, the age of any cluster can hence be estimated. But this method, which works for clusters, is not reliable for individual stars – for which the Harvard-Smithsonian Centre team reports the success of a new method.

The origin of stars lies in the collapse of molecules of gas, spread over thousands of light years, by the effect of mutual gravity. As the gas crashes in and gets more dense, it gets hot and energetic and with the tremendous pressures and temperatures there is nuclear fusion, or the formation of new elements from simpler ones. Fusion also releases huge energy and the star gets hotter still and begins to expand. The expansion, in turn, causes cooling and compression starts again, for another cycle of element formation, and so on, till finally the star settles into a steady burning of nuclear fires for millions of years.

In the process of collecting together the sparse gas over vast distances, any slight net rotational movement of the mass of gas would get concentrated and enhanced in the compressed star, in the same way as an acrobat spinning with his/her arms outstretched can suddenly spin faster just by drawing the arms in. Stars are, thus, invariably in a state of fairly rapid spin, just like earth and planets also have a period of rotation. But unlike planets that have little influence, except gravity, on other bodies in space, stars are fiercely hot and transfer energy to their surroundings. The result is that stars gradually lose energy and begin to spin slower and slower.



Gyrochronology

The Harvard-Smithsonian Centre team measured the spin rates of stars in clusters of known ages. Determining the rate of spin was done with the help of the *Kepler* orbiting observatory in the same way as detecting exo-planets. To start with, the team looked for changes in the brightness caused by dark spots on the surface of a star. Every time the dark spot appeared in the path of the star facing the telescope, it caused a slight dip in the total light emitted from the star. Once the spot went out of view, the brightness went back to the original value. By watching for drop and restoration of brightness, in this manner the *Kepler* data is able to exactly provide the period of rotation of a star.

For more than four years the Harvard-Smithsonian team isolated and studied about 7,000 stars, first identifying them as a part of a cluster and then measuring their speed of rotation. The data collected showed a strong relationship between the speed and the age of the stars — which can then be used to estimate the age of a new star with the help of its speed of rotation.

The team is in the process of refining the method by testing the relationship in older star clusters, where the rate of spin is slower and there are fewer dark spots to use as markers.

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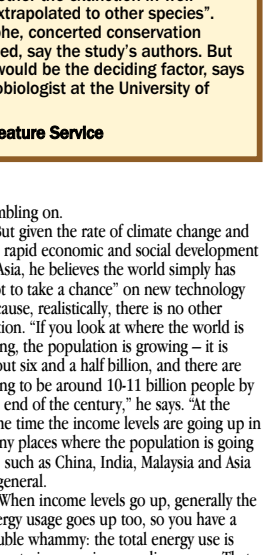
On the verge of mass extinction

This phenomenon has occurred five times so far and the sixth, according to researchers, could arrive in three to 22 centuries, says **tiasa adhya**

EARTH is heading towards mass extinction if researchers at the University of California, Berkeley, are to be believed. The last time plant and animal species became extinct on a mass scale was 65 million years ago when dinosaurs perished.

Extinction is a common phenomenon — 99 per cent of the four billion species estimated to have evolved on earth over the past 3.5 billion years have disappeared. But mass extinctions — the rate of extinction of a species outpaces that of its origination, resulting in a loss of 75 per cent species in a period of one to eight million years — have occurred only five times, the earliest 443 million years ago. The sixth may arrive in three to 22 centuries, the researchers say. They could not predict the date with certainty because of insufficient data and different rates of extinction for various species.



Lead author Anthony Barnosky.

Previous mass extinctions were caused by factors such as volcanic activity, glacial impact and a spike in CO_2. The next one will be human-induced, caused by a population explosion, habitat destruction or climate change, says the study published in *Nature* on 3 March. "Recovery from mass extinction episodes occurs on timescales encompassing millions of years. This obviously indicates that frogs, toads and mammals that are facing extinction, and even us, for that matter, will not recover in time to survive into the future," says lead author Anthony Barnosky, professor of integrative biology.

To ascertain if the present pace of extinction was unusual, the scientists needed to tally two types of data — one from the fossil record that showed forms and features of species through time and the other from historical records compiled by biologists. But tallying the records proved difficult. "It was like comparing two things with different units," says co-author Elizabeth Ferrer.

To begin with, the fossil record counted only species with identifiable anatomical hard parts that fossilise well. Besides, the International Union for Conservation of Nature has catalogued the conservation status of less than 2.7 per cent of the 1.9 million species that exist at present because of lack of data. For these reasons, the researchers chose to start with a well-studied taxon — mammals — to arrive at a reliable extinction rate.

An estimated 80 of 5,570 mammal species have become extinct in the past 500 years. This rate is slower than what was witnessed during the previous mass extinctions, termed the Big Five. But that might be an incorrect assessment because "many clades (taxa) are grossly understudied", says the study's co-author, Charles Marshall.

The scientists concluded that if all threatened species disappeared in 100 years, the time taken to reach mass extinction levels for mammals would be a little over three centuries. Marshall, however, says that "a major unknown is whether the extinction in well studied taxa can be extrapolated to other species".

To avoid a catastrophe, concerted conservation efforts would be needed, say the study's authors. But for that, political will would be the deciding factor, says David Jablonski, paleobiologist at the University of Chicago.

CSE/Down To Earth Feature Service

Green power broker

In the USA, one man is already pumping money into hi-tech clean energy ideas. **phil boucher** meets Dr Arun Majumdar

IF there's a great woman behind every successful man, then there's a shrewd investor behind every cutting-edge technology. And if you're working within the American scientific community, that investor is likely to be Dr Arun Majumdar, head of the Advanced Research Projects Agency – Energy, otherwise known as Arpa-E. Born in Kolkata and educated in Mumbai, the former Professor of Mechanical Engineering at The University of California, Berkeley, has been at the helm of Arpa-E since it was created by Congress in 2009 to "enhance the economic and energy security of the United States".

Arpa-E has invested close to £350 million in a string of unproven clean energy technologies, such as Green Electricity Network Integration and Solar Agile Delivery of Electrical Power Technology, which exist on such a high-risk scientific fringe that private sector investors won't touch them.

Majumdar has spoken of creating a "Sputnik moment" for Barack Obama's administration through work funded by Arpa-E. Though he admits it will be a minimum of four years before any of these investments bear fruit, it's hoped Arpa-E will ultimately harness the finest ideas of scientific America and radically alter how the planet's second biggest polluter generates, stores and utilises energy. By extension, the USA could then begin to wean itself off fossil fuels and its geopolitical commitments in West Asia. The scientific stakes couldn't be any higher.

Rub of the green: Dr Arun Majumdar (right) holds the pursestrings at Arpa-E, the US government's green energy investment fund. Its work aims to make America the world's leading producer of clean energies, such as solar power.

"When oil prices go up and gas prices go up, we hit the panic button, and when oil prices go down we hit the snooze button," Majumdar says of US society. "That really is not a long-term, sustainable way to run any nation." But there's a problem: while he has funded 120 cutting-edge projects and drawn in £60 million from impressed private investors, the USA is lagging far behind the European Union and China in turning good ideas into what Majumdar describes as "game-changers".

He say, "It is a question of making sure the impact on the real world, the business side and the employment side actually happens." To his mind, this can come only through developing US domestic demand for clean energy. But in a nation that consumes three gallons of oil per person, per day, this is obviously much easier said than done. "It is not going to be overnight. It will take some time," Majumdar admits. "President Obama has said that we will reduce a third of our energy imports by 2025 and that is a target now. Just like President Kennedy said, 'We are going to go to the moon and come back safely within a decade.' Here now is President Obama's target."

To achieve this, Majumdar sites several options, such as the electrification of US transportation, the development of biomass fuels, the full utilisation of America's natural gas supplies and the relatively simple task of making US cars more fuel-efficient through the Corporate Automobile Fuel Efficiency standards. Yet he admits that effective, palpable change in US energy production will arrive only when corporate America and US society sees a financial advantage in utilising clean energy.

"There is a project on grid-level storage using compressed air, which is very innovative as, if you can get grid-level storage at low cost, then the idea of storing up or maximising the utilisation of renewable energy becomes much easier," Majumdar reveals. "There is also a technology where the module cost of generating solar (energy) from silicon can be cut by 80 per cent. This is significant as, if you can make electricity from solar really cheap, it is a total game-changer. But it really is all about the cost and whether you can be market competitive. If you can bring down the cost, then the market will force it to scale without subsidy."

Majumdar believes it is Arpa-E's job to achieve this by supporting the basic science and engineering and, to some extent, the translation of this science into breakthrough technologies. Yet he would also like to forge a stronger working partnership between the USA and China, which holds the ironic distinction of being the world's largest polluter and the global leader in the introduction of electric vehicles, as a result of the $9 billion Ten Cities, Thousand Vehicles Programme launched in 2009.

Chinese President Hu Jintao has also called for an ambitious cut in emissions per unit of economic output by 40-45 per cent of 2005 levels by 2020. "China is doing what it really should be doing for its citizens," explains Majumdar. "The question is: can we leverage that and can we learn from their experience in growing the economy the way that they are doing? They are, in fact, leapfrogging in cleaner technologies because they are doing things today and they are so new."

So what, then, does the future hold for us all? Well, despite a recent fall in US vehicle emissions through increased engine efficiency and a higher uptake of biofuels, Majumdar believes it will be a minimum of 10 years before anything truly revolutionary emerges from the USA. He also philosophically appreciates that he's likely to back far more bad investments than good ones, given the cutting-edge table he's gambling on.

But given the rate of climate change and the rapid economic and social development in Asia, he believes the world simply has "got to take a chance" on new technology because, realistically, there is no other option. "If you look at where the world is going, the population is growing – it is about six and a half billion, and there are going to be around 10-11 billion people by the end of the century," he says. "At the same time the income levels are going up in many places where the population is going up, such as China, India, Malaysia and Asia in general.

"When income levels go up, generally the energy usage goes up too, so you have a double whammy: the total energy use is going to increase in a non-linear way. That is what the world is going into and, on the one hand, you have to be able to support the economy and feed all of those people, but to do that you need the resources for energy, agriculture, materials and so on.

"We are in a finite world, so to some extent those resources are constrained. On the other hand, the waste we produce, particularly emissions, can't be infinitely produced either. So we are looking at a system where the population is growing, the energy use will grow, we are constrained on the supply side and constrained on the waste side. This, in the long run, is an unsustainable way of running the world. So we have to figure out a way to close the loop to make it sustainable. Hopefully, what we are doing here will help provide some options to do that."

Majumdar adds, "It is like the human genome project. When you go back in history, it was risky, but it had to be done because the benefits to society were potentially enormous."

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