# Venus on the move

**bipash das gupta explains what viewers can expect from this phenomena**

IN our Solar System only three objects can come between earth and the sun at regular intervals while circumambulating in their respective orbits — the moon, earth's satellite; Venus, also called the "Jewel of the Sky"; and Mercury. The last two are considered "inferior planets" but it must be mentioned that the planes of orbit are not the same.

On 6 June this year, India will witness a rare moment in astronomy when Venus passes over the northern part of the sun, appearing as a black spot. However, the initial phases will not be visible as the planet's transit across the sun will commence before sunrise. It will move in a north-south direction, also known as the descending node, and the five positions of the Venus disc will occur, in Universal Time, between 10 pm on 5 June and 5 am the next day.

From the diagram we see that Venus enters from the left as it makes its way westward. Each of the black spots represents the position of the planet's centre at those instants. Venus is shown immediately before and after it appears over the sun at mid-transit and, similarly, just before and after leaving the solar disc from the right.

The angle at Ingress-Exterior Contact (I), which is 41°, as well as at Egress, Exterior Contact (IV) at 290°, are measured counter-clockwise along the solar limb from the North through East-South-West for the transit of Venus on 6 June. The position angle at Ingress, Interior Contact (II) is 38° and that of Egress, Interior Contact (III) 293°, both determined by the same process.

The position angles of Venus' transit on 8 June 2004 were ascertained by the same procedure for the five positions of the Venus disc as shown below the ecliptic – the apparent path of the sun. In the southern part of the solar disc, Venus has been traced across the face of the sun as a black circular spot. Venus transits are rare, with only 81 transits between 2000 and +4000.

Eight years after a transit, another can be expected at the same node, which often happens — the reason being that 13 sidereal revolutions of Venus are nearly equal to eight sidereal revolutions of earth, namely:
*Venus sidereal period:* 224.70080 earth days x 13 = 2921.11040 earth days; *Earth sidereal period*: 365.25636 earth days x 8 = 2922. 05088 earth days. (Nearly equal.); *Five synodic period of Venus* = 5 x 583.9234 earth days = 2919.617 earth days; *152 synodic period of Venus* = 152 x 583.9234 earth days = 88,756.3568 earth days = 243 years + two or three days (depending on the number of leap-years.)

The synodic period is the interval of time the planet takes to cross two successive identical configurations in space with respect to earth. At the end of this period, Venus and earth have returned very nearly to their former positions, not only with respect to each other but also with respect to nodes.

The nodes are the two imaginary points in space at which an orbit crosses a given plane, such as the plane of the ecliptic. Transits repeat with great similarity and are separated by a time belonging to the same series.

In the case of long period series, at each return the path which Venus appears to take across the sun is slightly displaced southwards. The series ends with a grazing transit at the southern limits of the solar disc.

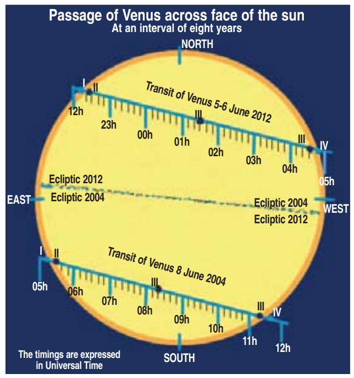
For the transits in pairs for 1874-1882 and 2004-2012, the path of Venus across the face of the solar disc at the second transit of such a pair is parallel to that of the previous but lies about 24' south for transits at the ascending node in December or 20' north at the descending node in June. After 16 years, the variation becomes 48' or 40', which exceeds the apparent 32' diameter of the solar disc. So it is impossible to have three transits in a period of 16 years.

After 243 years, the circumstances of the transits are similar. There is one single or double transit at the ascending node and one single or double transit at the descending node in between the nearest transits of consecutive transit seasons, a little more than a century's lapse with 1882-2004 as an example.

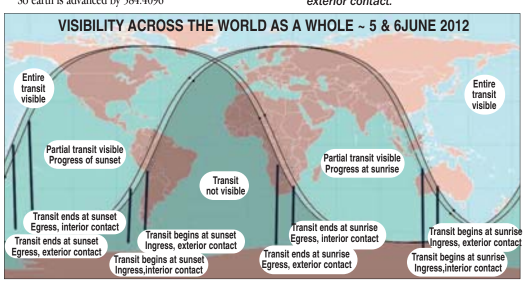
Venus orbits the sun in 224.701 earth days, while earth revolves in 365.265 days. As such, Venus is moving slightly faster. It orbits the sun 2.6 times while earth does so 1.6 times before the two planets are again aligned. The earth-Venus alignment while revolving around the sun in their respective orbits is thus: For earth — 365.256 earth days x 1.6 times = 584.4096 days.
For Venus: 224.701 earth days x 2.6 times = 584.2226 earth days.

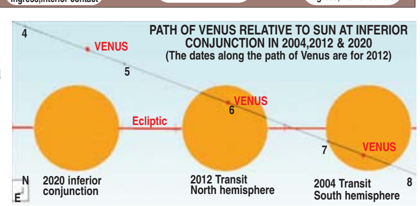
So earth is advanced by 584.4096 earth days - 584.2226 earth days = 0.1870 earth days. Thus the significant alignment point may be obtained by the following method: *For earth* — 584.4096 - (0.1870 x 2.6 times that of Venus) = 584.4096 - 0.4862 = 583.9234 days or 584 days. *For Venus* — 584.2226 - (0.1870 x 1.6 times that of earth) = 584.2226 - 0.2992 = 583.9234 days, or 584 days.

The period of 584 days as calculated above is called the earth-Venus synodic cycle, which means "place of meeting". An alignment of earth, Venus and the sun is taking place in space. A new earth-Venus synodic cycle begins at inferior conjunction, while the superior conjunction marks mid-point in the synodic cycle. Each alignment occurs at about 215.6° further than the previous one. This process continues as five unique Venus-earth locations are created in the ecliptic. The result is a pentagonal synodic series that takes about eight years and consists of five synodic cycles. This near perfect pattern, also known as "grand quintile", occurs due to five cycles.




*The position of Venus at "I" – showing first contact — Ingress, exterior contact; the position of Venus at "II" — showing second contact — Ingress, interior contact; the position of Venus at "m" showing least angular distance; the position of Venus at "III" — showing third contact – Egress, interior contact; and the position of Venus at "IV" — showing fourth contact — Egress, exterior contact.*




*The path of Venus relative to the sun in 2004, 2012 and 2020. As can be seen, in 2020 Venus will pass north of the sun, so there is no transit.*

The entire four contacts of the transit of Venus will be visible from eastern Australia, New Zealand, New Guinea, the Philippines, northern Asia, eastern China, Korea, Japan, the islands of the western Pacific Ocean, Hawaii, Russia, Alaska and north-west Canada. In the far north, the entire transit can also be seen since the sun will not set. From eastern Canada, the USA, Central America, the Caribbean and northwest South America only the first part of the transit will be visible because first contact occurs in the afternoon of 5 June and the sun sets while the transit is still in progress. The last part of the transit will be visible in western Asia, Europe, West Asia and eastern Africa.

However, no portion of the transit will be visible from Portugal or southern Spain, western Africa and a portion of southeastern South America.

The greatest transit is the instant of minimum separation between Venus and the sun, as seen from earth, on 6 June at 6:59:37 am Indian Standard Time. The chief importance is that their timings add to information about the motion of the planet in its orbit. The whole transit lasts for approximately six hours, 39 minutes and 50 seconds.

Observers of the 1761 transit of Venus noticed that when the planet partially overlapped the sun's disc, part of its limb extending beyond the sun appeared to be surrounded with a radian aureole, inferring the presence of atmosphere on Venus. Second, it was after the second contact, when Venus just touched the limb of the sun on the inside, that a little dark thread known as a black drop-like connection developed and was sustained for several seconds. When the thread broke up, the planet was seen completely over the sun's disc. As such, time of contact could not be determined accurately in those days due to the black drop effect. It was presumed that this was due to atmospheric agitation and diffraction or an instrumental factor.

On the morning of 6 June, people in India will witness sunrise with Venus seen as a dark circular spot on the sun's face. As such, the beginning of the transit — Contact-I at Ingress, exterior contact and Contact-II at Ingress — will not be visible over India. Both contacts will occur when the sun remains below the horizon. However, the ending of the transit, which includes Contact-III at Egress, interior contact and Contact-IV at Egress, will be visible throughout the country.

**The writer is scientific officer, MP Birla Institute of Fundamental Research, MP Birla Planetarium, Kolkata**

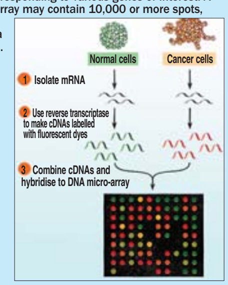
# Powerful tool

**tapan kumar maitra explains how DNA micro-arrays allow the expression of thousands of genes to be monitored simultaneously**

ALTHOUGH the preceding kinds of observations reveal that different sets of genes are transcribed in different cell types, they cannot easily identify which individual ones are turned on or off. One method for determining whether a particular gene is active is to assay for its corresponding mRNA using a technique that is somewhat fancifully called Northern blotting because it is essentially the "opposite" of Southern blotting. In Northern blotting, an RNA sample is size-fractionated by gel electrophoresis and transferred to a special blotting paper. The paper is then exposed to a radioactive DNA probe containing the gene sequence of interest and the amount of mRNA is quantified by measuring the bound radioactivity.

Alternatively, to monitor the expression of hundreds, or even thousands of genes simultaneously, a tool known as a DNA micro-array can be used. A DNA micro-array is a thin, fingernail-sized chip made of plastic or glass that has been spotted at fixed locations with thousands of DNA fragments corresponding to various genes of interest. A single micro-array may contain 10,000 or more spots, each representing a different gene.

To determine which genes are being expressed in any given cell population, RNA molecules (which represent the products of gene transcription) are isolated from the cells and copied with the enzyme reverse transcriptase into single-stranded cDNA molecules, which are then attached to a fluorescent dye. When the DNA micro-array is bathed with the fluorescent cDNA, each cDNA molecule will bind by complementary base-pairing to the spot containing the specific gene from which it was transcribed.




*Gene expression in cancer cells and normal cells is compared by (1) isolating mRNA from the two populations of cells and (2) using reverse transcriptase to make cDNA copies of the mRNA that are labelled with a green fluorescent dye for the normal cDNAs and a red fluorescent dye for the cancer cell cDNAs. A DNA micro-array containing thousands of DNA fragments representing different genes is then bathed (3) with a mixture of the two cDNA populations (only a small section of the DNA micro-array is illustrated). Red spots represent genes expressed preferentially in cancer cells, green spots represent genes expressed preferentially in normal cells, yellow spots represent genes whose expression is similar in the two cell populations, and dark regions (missing spots) represent genes that are not expressed in either cell type.*

The diagram illustrates how this approach can be used to compare the pattern of gene expression in two different cell populations.

The use of DNA micro-arrays for gene expression profiling is a powerful basic research tool that also has practical applications. For example, human cancers that appear to be the same disease when examined with a microscope are sometimes found to exhibit different gene expression profiles when examined using DNA micro-array technology. Such information is beginning to allow cancers from different patients to be more accurately characterised, thereby improving the prospects for custom-tailored treatments that are most appropriate for each individual person.

**The writer is associate professor and head, Department of Botany, Ananda Mohan College, Kolkata**

# Putting solar cells on the assembly line

**They are growing cheaper and hardier, says s ananthanarayanan**

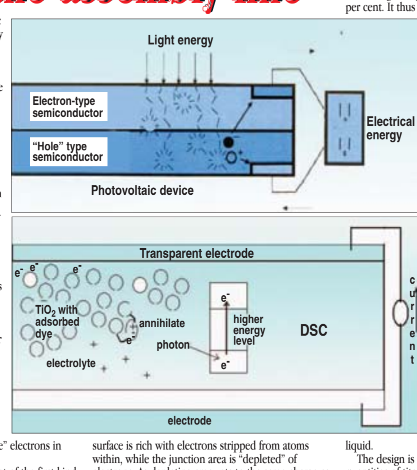
THE solar cell takes the direct path from sunlight to electricity. Conventionally, it is in resources like coal, oil and natural gas that solar energy is stored and theses materials are mined for generation of electricity, for transport to distant places and use. The complete process involves the fixing of atmospheric carbon into vegetation over centuries and then quick release when electricity is generated. But direct conversion of sunlight, on a large scale, could avoid the release of greenhouse gases into the atmosphere. It would also facilitate the use of electrically operated devices where there are no sources of conventional electricity.

When solar cells were first developed the world was not conscious of the need to reduce the burning of coal and oil. The applications were also only in areas where the difficulty of carrying an electric cable was extreme, like in outer space. The devices, hence, stayed based on expensive silicon and there was no emphasis on low cost mass production. But progress in electronics and awareness over the past few decades have led to advances and prices have fallen, with less-than-electronics-quality silicon wafers and, later, even other materials being used for building photocells. This last category, the dye sensitised solar cell, is promising, but it has a liquid layer in its construction that makes it less robust. In Chung, Byunghong Lee, Jiaqing He, Robert PH Chang and Mercouri G Kanatzidis, of Northwestern University, Illinois, report in the journal *Nature* an effective solid state replacement for this function.

The photocell is based on the photoelectric effect — that energetic photons, or particles of light, can dislodge loosely bound electrons from atoms and set them free as an electric current. Normally, such electrons would return to the atomic shells they came from and the energy obtained from the photon would be dissipated. But if there is a voltage that draws the released electrons away, or there is a way to prevent the electrons from directly returning to their source, then the energy of the photons can be converted to electricity. In the photocell, it is the second of these conditions that is effective — the photocell consists of silicon semiconductor layers that allow a stream of electrons to flow in one direction only.

Silicon consists of a special kind of atom whose outer electron shell, with four electrons, is half-way from being in the ideal, stable state, of none or eight electrons. A lattice of silicon atoms can thus have electrons "holding hands", with each atom simulating the "eight electron" condition. Now if an impurity is introduced, of atoms that have either five or three outer shell electrons, the lattice would be peppered with either an "extra" electron or with a "missing electron", ie, a "hole". In semiconductors, these "extra" or "missing" electrons are freely passed from one atom to another and can act as carriers of charge, like the "free" electrons in metals.

Now if there is a junction, of a sheet of the first kind of semiconductor stuck on to a sheet of the second kind, free electrons from the first sheet can travel to the second sheet but there can be no current in the opposite direction because the sheet with "holes" in its lattice cannot pass electrons from atom to atom. If such a junction is exposed to energetic photons, which is to say visible light or ultra-violet light, the surface is rich with electrons stripped from atoms within, while the junction area is "depleted" of electrons. As depleting amounts to the same charge as that of a "hole", the "holes" in the other part of the junction are repelled and collect at the surface. As the two surfaces are thus oppositely charged, connecting them with a wire would drive an electric current.




## Solar cells

This simple design can thus readily convert sunlight into electricity. But the trouble is the need for very pure silicon crystals and the efficiency of converting sunlight to electricity, at best, is about 10 per cent. It thus has a high *cost to output ratio* and its use was limited to areas where very low currents were needed or where there was really no alternative. Solar cells were hence used for powering a satellite in orbit around the earth or on a mission to another planet! There have also been applications for devices in remote places on earth, and these applications have multiplied when solar energy started to become cheaper to produce and arrange in panels.

The major development for possible widespread application is the *Dye-sensitised Solar Cell*. In this arrangement, the active component is an organic dye placed in contact with a metal oxide in a conducting liquid medium, like the acid in a lead acid battery. When the dye is bathed in light it creates a charge at the surface of the metal oxide, in this case *nano-particles of titanium oxide*, while oppositely charged particles move to the platinum sheet that is placed on the other side of the oxide sheet. Connecting the two sides then drives a current and neutralises the effect on the conducting liquid.

The design is conceptually simple and if the quantities of titanium and platinum are limited the cost is not high. Manufacture is not complex and the cell can take different shapes or be flexible. It is much less efficient that the normal solar cell, but the cost per unit of electricity produced can be competitive. The problem is really the conducting liquid, the electrolyte. The electrolyte may freeze and stop working or cause damage. Heat may cause decomposition of damage to seals by expansion. The dye and conducting glass material is costly and the electrolyte permeates plastics and has components that cause harm if allowed to leak. These disadvantages have prevented wide use and integration with flexible structures. There have been solid state alternatives, in the form of solidified melted salts, but these are found to degrade, are not flexible and are not notably efficient.

## Efficient solid state

Chung and others at Evanston, Illinois, have demonstrated that an inorganic semiconductor solid, in place of the liquid electrolyte, acts as an efficient carrier of "holes" that arise on exposure to light, with better results and more stability. The working of DSCs depends on a mono-molecular layer of the photosensitive dye working between the surface of titanium dioxide and the electrolyte, which carries "holes" away from the working material. Liquid electrolytes are good "hole" conductors and prevent instances of photo-generated electron – "hole" pairs coming together and annihilation before they form part of the photocell current. Solid state materials used so far have been poor "hole" conductors and, hence, inefficient. The semiconductor material used by Chung and others is a crystalline compound of caesium, tin and iodine with trace impurity of fluorine. This material can be dissolved in organic solvents and made to crystallise within the crevices provided by the titanium dioxide nanoparticles. The material has high "hole" conductivity and performs as well as liquid electrolyte. With the solid state material used, in fact, there is a double advantage of any diffusion of electrons to neutralise "holes" being completely avoided.

The conversion efficiency is shown to be 10.2 per cent, which is comparable with liquid based DSCs . The material also allows more efficient use of light in the red and infrared regions, over the normal DSCs. The family of solution-based semiconductors, to which the caesium-tin-iodine compound belongs promises more efficient materials for solar cells.

**The writer can be contacted at simplescience@gmail.com**