A close look at reflection

How earth appears from afar may help detect life in distant worlds, says s ananthanarayanan

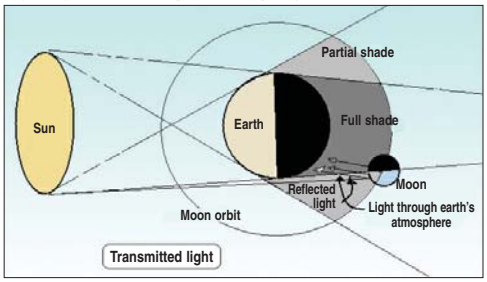
THERE has been interest in getting a good external view of earth so that we are better equipped with what to look for when scanning for "earth-like" planets around distant stars. Pictures taken from satellites are not good enough and we need a little more perspective — a picture from the moon is not bad. In 2009, a group in Tenerife, Spain, managed pictures of earth's *transmission spectrum*, or the light that passes through our planet's atmosphere, as seen on the moon. But Michael F Sterzik, Stefano Bagnulo and Enric Palle, in Chile, the UK and again in Tenerife have looked at aspects of reflected earthlight that shines on the moon to identify features that could indicate the presence of life!

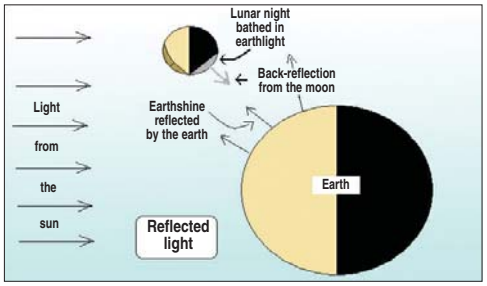
The last decade has been fruitful in finding planets that, we hope, resemble earth, in orbit around distant stars. A planet that has no light of its own, of a distant star, is not visible from earth, as the glare of the mother star prevents any reflected light from the planet from being seen. While the first method to detect planets was, hence, through the slight wobble that they create in the position of the mother star, which affects the colour of the light it emits, a more effective way has been with planets that pass between the star and earth and cause a minute dip in the light received. With some refinement, it should also be possible to detect the effect that the gasses in the planet's atmosphere have on the light that passes very near the planet's surface. To be ready to draw conclusions from these effects, it was of interest to see what effect earth had on light from the sun, as the light grazed earth and passed on into space.

The Tenerife experiment was conducted during a lunar eclipse, where the moon is dark as earth's shadow is upon it, but there is still some light that has passed through earth's atmosphere. This light, which dimly illuminates the eclipsed moon, also reflects back to earth and the reflected light was examined for indicators of the components of earth's atmosphere. Sure enough, analysis in the visible and infra-red region showed signs of ozone, water, carbon dioxide and methane and also of calcium and of some gases arising from human activity. And so, there is interest in refining the effect of earth's known gases on transiting sunlight so that we can make sense out of similar data from a distant planet.

Reflected light

The other kind of external view of earth is by its reflected light, like the light we see coming from the moon. Here again, a handy observation post is the moon, not in eclipse but in a quarter moon position. The dark part of the moon, where it is "night", is then bathed in reflected light from earth, as *earthlight*, corresponding to *moonlight*, which we have on earth. And this earthlight that shines on the moon reflects off the lunar surface and can be detected, albeit faintly, by sensitive, large-diameter telescopes on earth. The light detected is then not transmitted light but reflected light from earth, and it would carry not only the effect of the atmosphere but also the effect of reflection by different surfaces, like the clouds, the sea, rocks or plants.





The main effect in the case of transmitted light was that the gasses through which the light passed absorbed light at particular frequencies, which are characteristic of the gases. Analysis of the spectrum of the light then showed the frequencies where there was absorption and, hence, the presence of the gases. In the case of reflected light also, there is the effect of absorption, as the light does pass through atmosphere, but there is also the effect of reflection.

Apart from frequency, which is a property that light waves share with sound waves, light has another property of the direction of periodic movement. A sound wave is a progression of compressions and rarefactions of air, set up by a vibrating object and detected by creating the same vibrations in another object, like a eardrum or a microphone diaphragm. The variations in density are, hence, in the same direction as the motion of the wave. But it is different in light waves, and the movement is like the waves on the surface of a pond.

In these waves, the water bobs up and down, setting up a similar movement of water, in expanding circles, but the movement of the water is not in the direction of the wave, it is transverse. In light, the wave is really one of electrical and magnetic effects that rise and fall, not in the direction of the beam of light, but in the transverse plane.

And here they are different even from the waves on water – the water moves only up and down and the electrical and magnetic effects can be in any direction in the plane that is at right angles to the beam of light.

Now with certain substances, when a beam of light passes through them, the electromagnetic effects are transmitted only in one plane, and the light that comes through is weakened, but richer in the selected plane of transmission. Light like this is called *polarised* light. If such light is again shone on the same material, but turned at right angles, then the light will not pass! A certain amount of polarisation also takes place when light reflects off a surface, depending on the angle of incidence. This is the reason that *Polaroid* lenses can cut the glare on a sunny day – by controlling the amount of reflected light that it allows to pass.

Sterzik and colleagues report in the journal *Nature* that they used the 8.2 metre Very Large Telescope in Chile to analyse the polarisation spectrum of earthshine reflected back from the moon. They found that the linear polarisation of light scattered by air molecules, aerosols and cloud particles and also by reflection was a more sensitive measure of distribution of atmospheric gases or land/water/vegetation features than usual spectroscopy. The results, for the earth, show unusual abundance gases like oxygen and methane, which are themselves *bio-signatures*, or indicators of life systems.

There is also a sharp increase in long wavelength reflection, which indicates the presence of vegetation. The analysis indicates the separate contribution of clouds and ocean and is sensitive to even 10 per cent changes in visible vegetation. The results, they say, "represent a benchmark for the diagnostics of atmospheric composition, mean cloud height and surface of exoplanets".

Christoph U Keller or Leiden University, The Netherlands, adds in a commentary that measuring yet another property of the reflected light could more sensitively indicate the presence of life. An effect of reflection or passing through some substances, by polarised light, is that the electrical and magnetic components of light waves be put "out of step". When this happens, the plane of polarisation keeps changing, in a spiral manner, as the wave moves on and this is called *circular polarisation*.

While crystal structures or plates made from such materials can be created to turn the plane of polarisation, it is found that living tissue uniformly causes circular polarisation in only one sense, that is right-handed or left-handed. Finding *bandedness* in circular polarisation of light reflected by an exoplanet would then point a finger to living materials!

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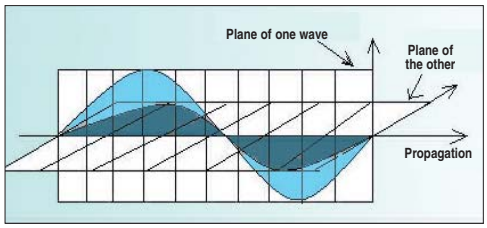


A hard, dry future

As global bodies gather in Marseilles to discuss water supplies, sarah morrison **reports on the waste that will create a thirsty world by 2050**

THE world is wasting water on a truly colossal scale, according to the United Nations, and more than 80 per cent of the used water is neither collected nor treated — the equivalent to the planet leaving the taps full on and the plugs out.

This and other equally worrying realities will be presented this week to around 35,000 people from 180 countries at the World Water Forum, a gathering held every three years, which will hear the most disturbing reports yet on the state of the world's rivers, lakes and aquifers.

Demand for water is expected to increase by 55 per cent over the next four decades, according to a new study to be presented at the forum in France. Framing the Water Reform Challenge, from the Organisation for Economic Cooperation and Development (OECD), points out that rapid urbanisation, climate change and the altering global economy are putting growing pressures on supplies. In around 40 years' time, more than 40 per cent of the world's population — 3.9 billion people — are likely to be living in river areas in the grip of a severe "water-stress". The UN warns this could also be felt in parts of Europe, affecting up to 44 million people by 2070.

Anthony Cox, head of a water programme run by the OECD, said the world was experiencing a water "crisis". He added, "More people in cities now don't have access to water than back in 1980. In developing countries, especially, there is a tremendous economic and human cost to this."

Since 1900, more than 11 million people have died because of drought, according to the UN, and more than two billion have been affected by it — more than any other physical hazard. The OECD is calling for "urgent reform" of water management and suggests using economic instruments, such as taxation, tariffs and transfers, to encourage greater "water efficiency".

Olcay Unver, coordinator of the United Nations World Water Assessment, said it would be a "game-changer" if the world could tackle environmental challenges without using water-wasting technologies such as biofuels. "Water underpins all aspects of development," he said. "It is the only medium through which all crises can be jointly addressed. It should be seen as an explicit element in any decision-making framework."

Unver is lead author of a UN report up for publication that warns that unprecedented growth in the demand for water is threatening global development goals and will exacerbate inequality between countries, sectors and regions. Managing Water under Uncertainty and Risk shows that while 86 per cent of the population in developing regions are expected to have improved access to safe drinking water by 2015, there are still nearly one billion people without such access and, in cities, the numbers are growing.

Water management can no longer be seen as a local issue, said Unver; it had to be treated as a global one. "Water is not only what we drink, what we wash with, or what we use to irrigate; it is also embedded in the products that we eat, consume and use," he said. "This gives us a totally different perspective to water — it is subject to trade policies, and one nation, or one corporation, can have an impact on water shortages somewhere else."

His warning backs up analysis by the Royal Academy of Engineering, which found that Britain and other developed countries depended heavily on importing hidden or "virtual" water from places prone to droughts and shortages. In a 2010 report, the academy estimated that two-thirds of all water that Britain needed came embedded in imported food, industrial products and clothes such as cotton. In 2008, a study published by the conservation group, WWF, found that about 60 per cent of Britain's water footprint was felt outside the UK.

Ashok Chapagain, the WWF's senior water adviser, said, "Water scarcity affects at least 2.7 billion people in 201 river basins for at least one month a year. International trade and the globalisation of the supply chain... make water scarcity a global issue."

But the need is not expected to lessen. Increasingly, underground water sources have been tapped to respond to growing demand and, under what the UN report called a "silent revolution", this process has tripled over the past 50 years. Transnational land acquisition, where countries acquire land outside their jurisdiction to get access to water, has risen from 20 million hectares in 2009 to more than 70 million today.

To illustrate the political, technical and financial solutions to the world's water problems, a 400 square-metre Vilage of Solutions will be built inside the Water Forum this year, housing a school, library, town hall, factory and bank. Different funding mechanisms and technologies will be explained.

However, the forum, organised by the French government, the World Water Council and the City of Marseille, where it is being held, has been criticised for being merely a "talking shop".

Said Daniel Yeo, WaterAid's senior policy adviser for water security, "They will have the big debates there, but it's not where change happens. The real situation is that dirty water kills more kids in sub-Saharan Africa than tuberculosis, malaria and Aids combined. We have the technology to change this; what we need is the political will and the internal capacity to deliver it in developing countries."

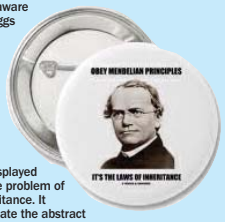
Olcay Unver: Water management can no longer be seen as a local issue.

The Independent, London

Meiosis & Mendel

tapan kumar maitra dwells on the backbone of classical genetic analysis

THE Mendelian laws of genetics form the backbone of classical genetic analysis; the basic tool is the inheritance test, in which phenotypes produced by pairs of *alleles* are followed through successive generations. In haploid organisms such as *Neurospora*, 1:1 ratios are regularly observed for single pairs of alleles, and the phenotypes of all genes are directly observed. In diploid organisms such as the garden pea used by Mendel, the phenomena of phenotypic dominance and recessiveness are encountered, and the familiar 3:1 ratio for single pairs of alleles, and the 9:3:3:1 ratio for two independent alleles, are customarily observed.



Mendel was aware of the role of eggs and sperm in fertilisation but quite unaware of meiosis as it is known today, a fact that only serves to emphasise the remarkable ingenuity he displayed in analysing the problem of character inheritance. It remained to relate the abstract factor, or gene, to some cellular structure. This was done by Sutton, Boveri and de Vries in 1902-1904, shortly after Mendel's laws had been rediscovered. The following facts indicate that the behaviour of the Mendelian genes in inheritance is mirrored in the behaviour of the chromosomes in fertilisation and meiosis.

Fertilisation in both plants and animals involves the union of maternal and paternal nuclei, providing a means for the union of parental characteristics in the offspring. The contribution of the sperm consists primarily of nuclear materials; so the sperm nucleus is the source of all paternal genetic contributions. It is the genetic equivalent of the egg nucleus, despite the fact that egg and sperm differ radically in size and morphology.

Meiosis provides for a reduction in the number of chromosomes in the egg and sperm, with fertilisation restoring the somatic number in the zygote. The somatic, or diploid, chromosome number is therefore made up of two equivalent haploid sets of chromosomes, one of maternal and the other of paternal derivation. Every chromosome has a mate with which it is linearly and genetically homologous.

A mechanism for the segregation of the maternal and paternal derivatives of every chromosome pair is provided through the process of synapsis. The two members of every pair synapse in meiotic prophase, separate from each other, and pass to opposite poles at anaphase, and thus are incorporated into the nuclei of different gametes.

If we substitute "genes" or "alleles" for "chromosomes" in the above statements, we are describing the inheritance and transmission of Mendelian factors. The first critical demonstration of the relationship of a particular character to a particular chromosome was that involving sex determination. Although chromosomes now known to be sex or X chromosomes were first found, in an insect, in 1891, it was not until 1901-1902 that a particular chromosome was actually shown to possess a sex-determining role.

This stemmed from the observation that two types of sperm are produced in equal numbers by an XO male (one X chromosome as opposed to two in an XX female), and that the two sexes are produced in equal numbers. The two types of sperm differ only in that one type has an X chromosome while the other lacks one; so the X chromosome must be influential in determining the sex of the offspring. The egg receives a single X chromosome as the result of chromosome segregation; whether the resulting zygote will be male or female is determined by the type of fertilising sperm.

It remained for Morgan and Bridges to demonstrate, in a classical series of studies, that a particular gene was to be found in a particular chromosome. Morgan had shown that the transmission of white, a recessive eye colour in *Drosophila melanogaster*, depended on which sex carried the allele initially. For example, if a white-eyed male is crossed with a homozygous red-eyed female, the F_1 flies of both sexes are red-eyed, the F_2 females are all red-eyed, and F_2 males are red and white-eyed in equal numbers. With the sexes being produced in equal numbers, this gives a normal 3:1 ratio of the eye colours but with the added qualification that the white-eyed flies are always male. When the reciprocal cross is made, using a white-eyed female and a red-eyed male, the F_1 males are white-eyed and the F_1 females red-eyed. In the F_2 generation, half the males and female are white-eyed and the other half red-eyed.

This type of inheritance paralleled the transmission of the X chromosome; Bridges showed conclusively that the gene white was located on the X chromosome. When making a cross between a white-eye female and a red-eyed male, he noted the appearance of exceptional individuals, whose genotype was such as to suggest a failure of the usual type of inheritance of the X chromosomes. Thus, in an F_1 population that should have contained only red-eyed females and white-eyed males, there appeared an occasional white-eyed female or red-eyed male, with the exceptional females occurring with a frequency of one in 2,500. The frequency of exceptional males was about one in 1,200.

LV Morgan discovered, in 1922, a strain of *Drosophila melano gaster* that apparently gave 100 per cent non-disjunction. As in the case of Bridges' exceptional individuals, the daughters appeared to receive both X chromosomes from their mother, and the sons a single X chromosome from their father. Examination of the chromosomes of the female showed two X chromosomes attached to each other in the neighbourhood of their centromeres, with the result that they always passed to the same pole. The AY chromosome is present in these females, and it segregates from the joined X chromosomes. Evidence that the random assortment of two pairs of alleles (Mendel's second law) is paralleled by the random assortment of paired chromosomes was provided by Carothers in 1913.

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