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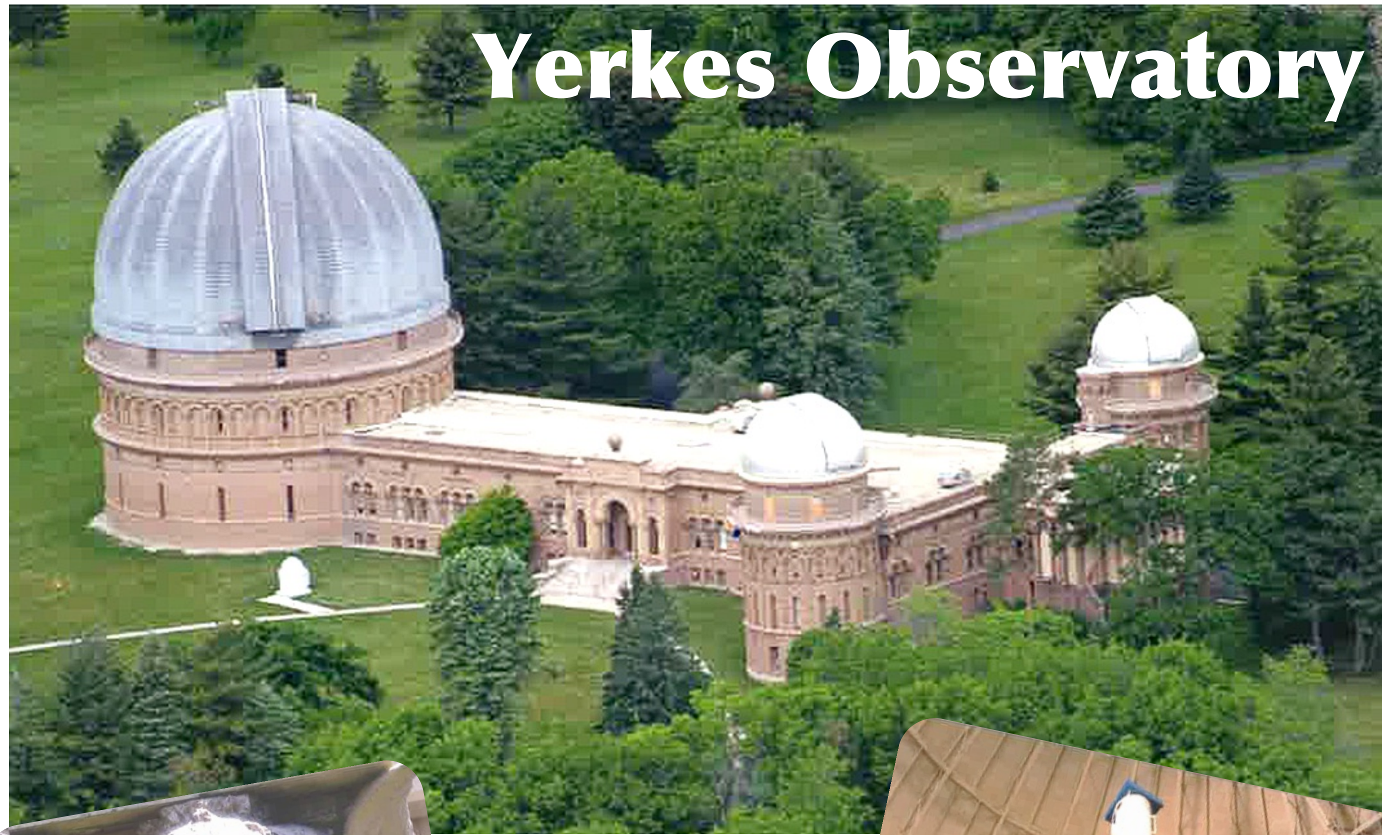

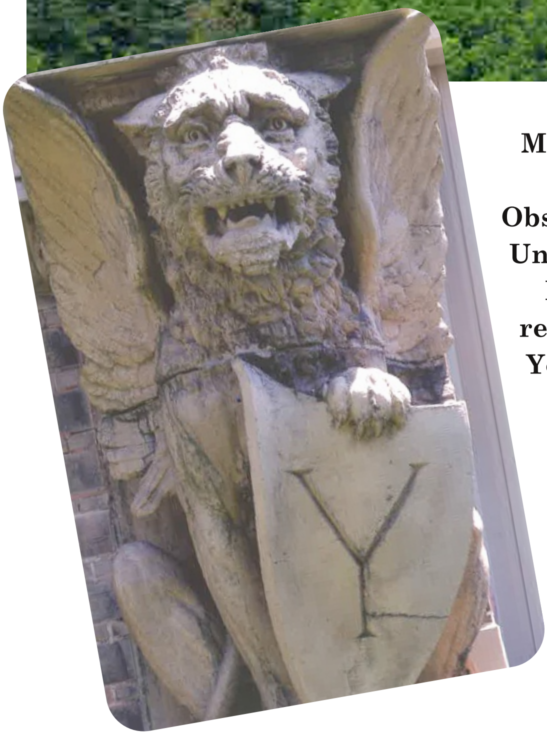

Mike Frost visits the famous Yerkes Observatory run by the University of Chicago. Right the 40-inch refractor and left the Yerkes Lion carving.

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Yerkes Observatory

By Mike Frost

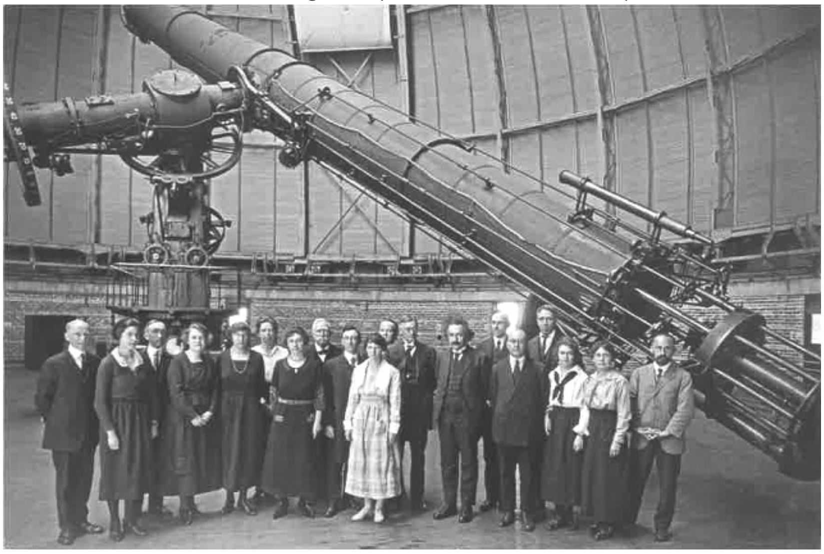
As you might know, my day job – systems engineering in the steel industry – takes me all round the world. I spent the last three months of 2014 in the United States, installing an automation scheme in a steel works in East Chicago, Indiana (just across the state line from Illinois). Steel rolling is a 24-hour process, so we don't get a lot of time off, but the mill goes down one day a week for maintenance, and when I'm not sleeping or doing my laundry, I try to do some sightseeing.

I have worked in the Chicago area before so I have visited many of the museums and other attractions there. For astronomers, there are lots of options. The Adler Planetarium is world-class, as is the Field Museum of Natural History. My favourite is the Museum of Science and Industry, which is home to the Apollo 8 Command Module and the Aurora 7 Capsule. You might remember me writing about "Astronomy in Chicagoland" in MIRA 80.

But on this trip I took time to visit somewhere I had not been to before, the Yerkes Observatory in Williams Bay, on the northern shore of Geneva Lake. It's a two-hour drive to the north-west of Chicago, five miles north of the Illinois-Wisconsin state line.

The Yerkes Observatory is owned and run by the University of Chicago, and offers tours to the general public on Saturday mornings, and by appointment for visiting parties at other times. Through the winter months, there are scheduled evening observing sessions, when the Moon and weather co-operate. There was one scheduled for the evening I visited, but even if I had been able to stay, it was already booked up.

I visited on a rather gloomy November Saturday, in the middle of the Midwest's unseasonably early start to winter; as I travelled north into Wisconsin I started to see snowdrifts. I arrived at the observatory at 11 AM and immediately joined a tour group of 15 people. Our guide began the tour with a history of the observatory.



Albert Einstein's visit in May 1921

The University of Chicago was established in 1892 and wanted to make its name as a leading research establishment. They hired George Ellery Hale, from MIT, as professor of astronomy. Hale, not surprisingly, wanted to found an observatory. He managed to acquire two huge 40-inch diameter blanks for lenses, made by Alvan Clark, from the University of California, and resolved to build the world's largest refracting telescope.

To do this required finance. Hale and the University president, William Rainey Harper, managed to convince financier Charles Tyson Yerkes to fund an observatory. According to our guide, this involved some questionable tactics - for example, announcing that Yerkes had agreed to finance an observatory, when he had only agreed to pay for the telescope. Yerkes donated half-a-million dollars, and further funds were provided by the Rockefeller foundation. Williams Bay was chosen as the site for the observatory because it was close to Chicago, but in open country, with good seeing and clear skies.

The architect was Henry Ives Cobb, who was also university architect. Cobb produced an extraordinary building, with ornate decoration. Our guide showed us many of the carvings which decorate the columns of the building. In addition to astronomical themes, there are caricature figures. Some bear a resemblance to Charles Tyson Yerkes, whose bust looks proudly over the foyer; others to William Rainey Harper. Perhaps the most intriguing are those which look like John Rockefeller, except for an unusually large nose. The carvings of Rockefeller also used to feature a bee, with the implication that the Rockefeller foundation had been "stung" for enough money to fund lavish decoration; no doubt a good joke at the time – until Rockefeller announced that he was coming to visit, at which time all the bees were chiselled off.

The 40-inch refractor was displayed at the Columbian Exposition of 1893 in Chicago, and the observatory was dedicated in October 1897. The final stop on our tour of the observatory was the dome, 90 feet in diameter, which houses the 40-inch refractor.

It's a stunning sight. Our tour group seated

Some of the ornate decoration on the columns of the building. There are caricature figures of Charles Tyson Yerkes, as well ones which look like John Rockefeller with an unusually large nose and William Rainey Harper

themselves around the wall of the dome. In front of us was the huge raiseable floor which enables astronomers to get to the eyepiece or prime focus with ease. At the centre of the dome, completely dominating the building, was the Yerkes refractor. To give some idea of the scale of the building, a life-size "Spiderman" figure had been placed at the pinnacle of the dome; it seemed tiny from the floor.

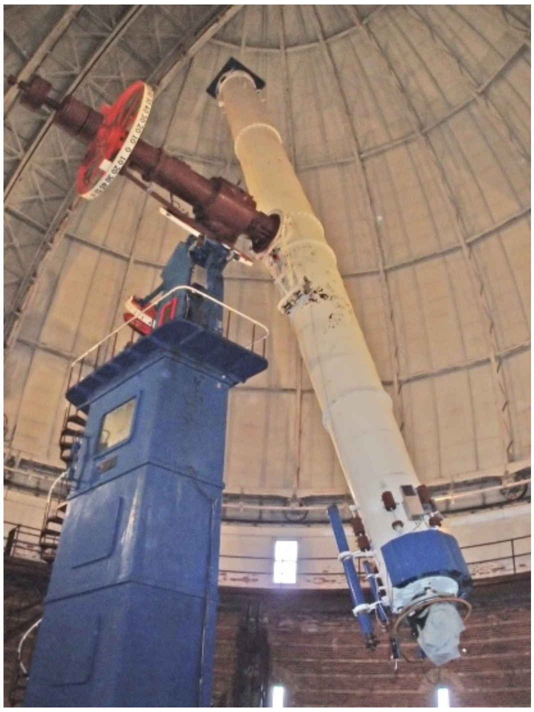
The Yerkes refractor is an extraordinary instrument, but in a number of ways it marked the end of the line for nineteenth-century astronomy. To begin with, it's a refractor, the largest ever used for professional astronomy (a larger lens was exhibited in the Paris Exhibition of 1900, but was never used for observation). But even today it's still not possible to build a useable larger lens, because lenses deform under their own weight. Astronomy has moved down the route of reflecting telescopes, which can be supported from behind. Yerkes was also the last major observatory to be sited close to its sponsoring university for convenience – Geneva Lake is a good place to observe from compared with downtown Chicago, but quality of weather and seeing pale into insignificance compared with mountaintop sites in, say, California or Hawaii. Hale understood this, and had wanted to build a mountain top observatory in California, but was constrained by university politics. Hale went on to establish, first in 1907, an observatory at Mount Wilson, Pasadena, and then the iconic observatory on Palomar Mountain, both of which were at the forefront of twentieth-century astronomy.

But any deficiencies in observing conditions were amply compensated for by the quality of the people who worked there. After the conclusion of the tour I spent a happy half-hour in the observatory museum, where I was suitably impressed by the famous names who worked at Yerkes. Edwin Hubble, for example, studied at Yerkes under Hale before being recruited for Mount Wilson. Edward Emerson Barnard, discoverer of Amalthea and Barnard's Star, and the documenter of dark nebulae in the Milky Way, was an astronomer at Yerkes. Barnard's photographic atlas of selected regions of the Milky Way was completed, after Barnard's death, by the second Yerkes director Edwin B. Frost (no relation) and Mary Calvert. Frost has a special place in the history of Yerkes; in later years he went blind, but continued as observatory director; a rope guideway was built for him between the observatory and his residence. Frost was succeeded by Otto Struve, the renowned Russian-American astronomer, and then by Gerard Kuiper, the planetary astronomer who discovered Miranda and Nereid and gives his name to the Kuiper Belt. Struve's students included Nobel Prize winners Subrahmanyan Chandrasekhar and Gerhard Herzberg. Kuiper's students included Carl Sagan.

After purchasing a few souvenirs in the gift shop, I had a long chat with the guides, in particular Richard Dreiser. I played my BAA card and introduced myself as the historical section director, and was taken to meet Richard Kron, a former director of the observatory, with whom I had an enjoyable conversation. I'm grateful to all the staff for making my day so enjoyable.

The future of Yerkes Observatory is by no means assured. In 2005, the University of Chicago wanted to realise a real estate asset in a prime location, and made plans to sell the site for housing. Fortunately for astronomy, a concerted campaign led to the observatory being saved – at least for now. Plans are being developed for a science centre on the Yerkes site, which hopefully will continue to include the 40-inch refractor and the historic buildings.

I concluded my visit to the Yerkes Observatory by



Mike's view of the 40-inch refractor

Yerkes main Entrance

taking a walk around the estate; there are a number of smaller domes, and houses for observatory staff. The ground underfoot was snowy and wet, so it wasn't the best day for a stroll. Nonetheless, I enjoyed my look around the grounds. This is a place that oozes history – the chance to walk in the footsteps of Hale, Hubble, Barnard, Kuiper, Struve, Chandrasekhar and co. is not to be missed.

Albert Einstein visited the observatory once, in May 1921. In a short tour around the United States, he had one day off. He was offered the choice between a visit to Niagara Falls and a visit to the Yerkes Observatory. He chose Yerkes, and I can understand why.

Do try to visit if you are ever in the area.

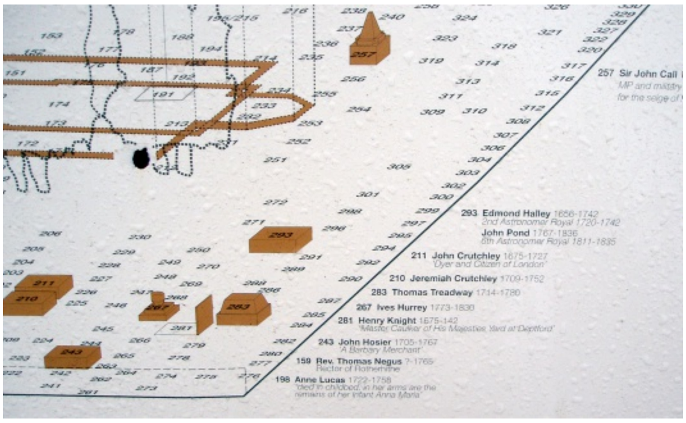
HUNTING HALLEY

BY MIKE FROST

As you may know, on Saturday March 28th I ran a very successful section meeting of the BAA Historical Section at the National Maritime Museum in Greenwich, jointly with our sister society, the Society for the History of Astronomy. We had a stellar line-up. My predecessor as section director, Tony Kinder, began proceedings with a talk on *"The Empire of the BAA"*, about his researches into the BAA membership records. Kevin Johnson then delivered a talk on behalf of Roger Jones, who was in poor health, about the SHA's Survey of the history of astronomy by County, of which Roger has been co-ordinator for many years.

The morning session was rounded off by Professor Jay Pasachoff, from Williams College Massachusetts. Jay began by showing us his pictures from the Svalbard eclipse of the Sun, then moved on to describe his recent researches in seventeenth-century astronomy. He has been investigating Galileo's ground-breaking drawings of the Moon, observed through a telescope for the first time, which are difficult to reconcile with modern-day lunar maps. Jay went on to tell us about the battles for priority between Galileo, who was first to observe the moons of Jupiter, and Simon Marius, who gave them the names we know them by (Io, Europa, Ganymede and Callisto – Galileo wanted to name them for his employers, the Medici family).

The afternoon session began with a barnstorming presentation by Bob Marriott on *"William Dawes and William Rutter Dawes"*, father and son. William Rutter Dawes, the son, is well-known to astronomers as a superb visual observer, but his father, also an astronomer but much less well-known, is a fascinating figure, who was involved in the American war of independence, the early years of the Australian colony (he founded the Sydney Observatory) and the abolitionist movement in Sierra Leone. Bob was followed by Stuart Clark, who told the story of Richard Carrington and the great solar flare of 1868. Carrington's observations of the flare, probably the strongest ever recorded, were crucial to our understanding of the link between solar activity and aurorae, but Carrington's hugely promising career was



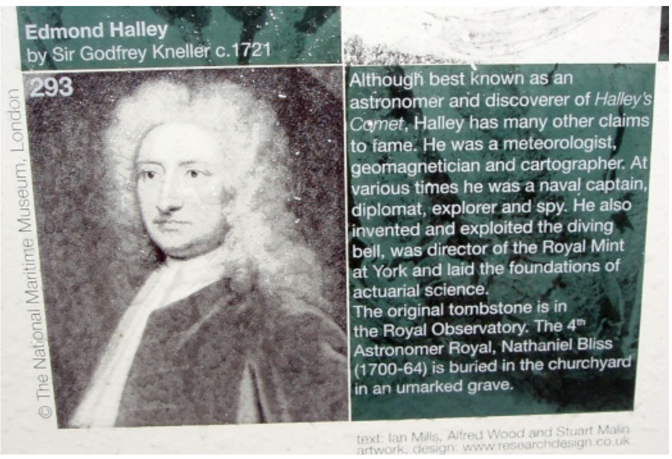
wrecked by his catastrophic personal life.

Our keynote speaker was another American, Dr Bill Sheehan from Minnesota, who took us on a tour of *"Mars: From Canals to Curiosity"*. Bill outlined the curious history of Martian observations, and presented physical and psychological reasons why astronomers might have interpreted fleeting features, at the limits of visibility, as linear canals.

A superb day. At the end of proceedings, the general consensus was that we should retire to the nearby "The Admiral Hardy" to sink a few pints and chew over the proceedings. Bill Sheehan and Jay Pasachoff had other ideas. Bill suggested that they take a walk through Greenwich Park to visit Edmond Halley's tomb. I indicated that whilst I was happy to accompany them on a stroll, I wasn't sure exactly which church Halley was buried in. There was a church spire visible from the south end of the park, but it might not be the right church. In the end Bill and Jay decided that they would pass on the opportunity. I spent the next hour or so in the Admiral Hardy, then joined Bill and Debb, Jay and Naomi, Roger Hutchins of the SHA and his friend Gloria, and Catherine Hohenkirk of HM Nautical Almanac Office, for a very enjoyable dinner in the De Vere hotel where many of us were staying.

I met up with Jay and Naomi Pasachoff the next morning at breakfast. Jay had been doing some research. Edmond Halley was buried in the churchyard of St Margaret's church, Blackheath. They had been right not to try walking there the previous night, as the church is not the one visible from Greenwich Park. Halley's tombstone had been removed, and forms part of the wall of the camera obscura within the Greenwich Observatory, but the tomb's location was known. I offered to drive Jay and Naomi to see Halley's tomb.

So we drove up the hill from the de Vere hotel, next door to the Maritime Museum, on to Blackheath Common, familiar to me as the start of the London Marathon. (Ask! I've started it twice, in 1984 and 1986, and finished it once; the other time I ended up in hospital). In central Blackheath we crossed the railway and then turned right into Lee Terrace. Half a mile along Lee Terrace we came to St Margaret's.



We started to look in the churchyard. We had neglected to make detailed notes on where exactly the grave was, but Jay recalled it was by a wall, so we started checking the graves by the side of the church. It took ten minutes to ascertain that none of them had Halley's name legibly written on them.

We would have gone on to check the rest of the graves on the churchyard, but I spotted a lady making her way into the churchyard, to open the door into the church. We intercepted her and asked if she knew where we could find Halley's grave. Yes of course, she said… it's in the graveyard across the road.

Ah, yes, that would explain why the church seemed rather less than 400 years old. The ruins of the original church were on the far side of Lee Terrace, surrounded by the original churchyard. We crossed Lee Terrace and inspected our second cemetery through the railings.

There was a display board just inside the cemetery outlining where the graves of famous inhabitants were located. It turned out that Halley and Mrs Halley shared a grave with another Astronomer Royal, John Pond (quite what Mrs Halley made of this, I don't know) and the grave was located by the eastern wall of the cemetery.

I tried the gate into the old cemetery. It wouldn't open. So we knew where Halley's grave was, we just couldn't get to it. I assessed the railings between us and the cemetery. They were only a couple of feet high, sitting on a low wall. If I climbed onto the wall, lodged my foot into the base of the railings, and swung my foot over… I could climb into the cemetery! Jay looked at me quizzically, and Naomi gave a disapproving look. Then Jay climbed up onto the wall and, like me, swung his leg over the railings and into the cemetery.

Now we knew where it was, we went straight to the grave. Pond's name was prominent, but Halley's name didn't appear at all, the gravestones having been removed to the observatory. We took pictures until there was nothing left to photograph, then had a stroll round the rest of the cemetery, whilst Naomi watched on from the other side of the wall.

Then it was time to climb out again. Fortunately the climb was symmetric, so we weren't at risk of being locked in. Nor did anyone strain anything. The lady who'd pointed us in the right direction was coming out of the church. As we made our way back to the car we passed her, and she asked if we'd found the grave.

"Yes", we said, "but we'd had to climb in – it was a pity that the gate was locked."

"It isn't locked", she told us.

I ran back across the road, pushed the gate again, this time a bit harder, and it opened…

So, if you want to visit Halley's grave… make sure you go to the right church, don't expect a gravestone… and try pushing the gate a bit harder.

Or you could try climbing the railings. It's more fun that way!

A Laboratory named Diamond

By Paritosh Maulik

In Chilton, Oxfordshire, not far from the Berkshire border, there is a doughnut shaped laboratory called Diamond Light Source. This laboratory is very close to the Harwell Atomic Energy and Rutherford Appleton Laboratory and is a part of National Physical Laboratory campus, Harwell. In this laboratory very intense beam of light in the range of x-ray to infrared radiation, produced by a synchrotron radiation source, is used to examine materials in different fields including proteins, viruses, metal, semiconductors, minerals, also archaeology objects. The beam is not only very intense but very fine as well; this allows high resolution analysis of difficult to study objects.

Daresbury Laboratory in Cheshire was the second-generation Synchrotron Radiation Source and produced mainly high intensity x-ray beams. Daresbury laboratory was instrumental in design of the third generation synchrotron source, the Diamond Light source. The facility opened in 2007 with 7 set ups and it is being extended in phases and it is hoped to have about 32 set ups by 2017.

The laboratory is run by the Science & Technology Facilities Council in partnership with Welcome trust as a non-profit limited company. We shall look at how the powerful beam is produced and then look at a few examples how the beam is being used.

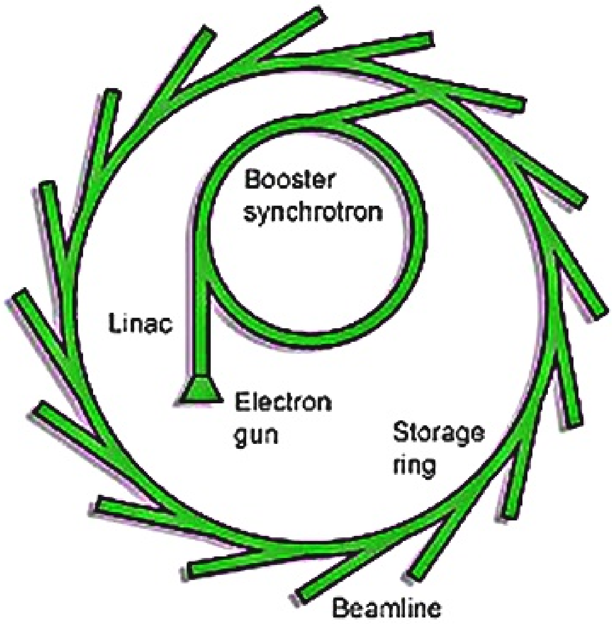
Synchrotron Radiation

The first generation of particle accelerators were called cyclotrons. In a cyclotron, particles are accelerated by the application of a high frequency alternating current. Then came the synchrotron. In a synchrotron, a bending magnetic field is used to accelerate charged particles. The early versions of synchrotrons were developed in the 1940s to study nuclear collisions.

In a synchrotron, electrons are accelerated and the electrons emit electromagnetic radiation. This is called synchrotron radiation. In this way a by product of the synchrotron accelerator is the synchrotron radiation. This radiation can be used to study properties of materials. Now a days, perhaps we all carry a particle accelerator. In mobile phones electrons are accelerated in the aerial and it generates radio signal, so in effect it is also a particle accelerator. In the synchrotron (light) source, the path of high velocity charged particles, moving close to the velocity of light, is changed by a magnetic field; it gives off electromagnetic radiation in the range of x-rays to microwaves. Velocity has two components, speed and direction; when either of these is changed, there is emission of radiations. These radiations can be very powerful and can be used for analysis of small samples. In the earlier synchrotron facility at Daresbury, the electron were boosted only by magnets. The resulting electromagnetic radiation was only in the x-ray range. Now in the third-generation synchrotron source in the Diamond Laboratory, the energy of the electrons is boosted by injecting additional electromagnetic energy and passing though strong magnets of alternating polarity. Here we can briefly mention that astronomical objects also emit synchrotron radiations from the interaction between the ultra-high velocity electrons and magnetic field. Now we shall see how the synchrotron radiations is produced in the laboratory.

Electron Gun

An Electron Gun is the source of electrons. A sharply pointed tungsten tip is heated under a vacuum. It is kept at a negative potential and under such a condition the tungsten tip gives off surface electrons. These are



Layout of the Diamond Light Source

attracted to a positively charged mesh. Electrons build up on this mesh. The positive charge to the mesh is periodically switched off. When there is no charge on the mesh, the electrons pass through the mesh. These electrons are then accelerated to about 90 keV by a series of electrodes and we get a high energy beam of electrons.

Increasing the Energy of Electrons

These electrons then enter a radio frequency cavity. It is a specially designed chamber through which the electrons pass under the influence of electromagnetic energy. The electrons are now boosted to very high energy level, in the order of 100 MeV (0.1 GeV). There are three units like this. This section is called Linac (Linear Accelerator).

The energy of the electrons exiting from Linac, is further energised by magnets and radio-frequency in an athletic track shaped ring called the Booster Synchrotron. The energy of the electrons by now is in the order of 3GeV.

Storage and Dispensing of Electrons

Electrons now enter the storage ring. It is another ring shaped tube with a circumference of 652m. There are 48 straight tangential sections to the ring. As the electrons travel round the ring it gives off radiation from x-rays to infra-red range; these radiations escape the storage ring through the straight tangential sections. Beams from these straight sections are used for used for experiments. Electromagnets called bending magnets, keep the electrons in the path of the ring. Power from radio-frequency source maintains the energy of the electrons in the storage ring.

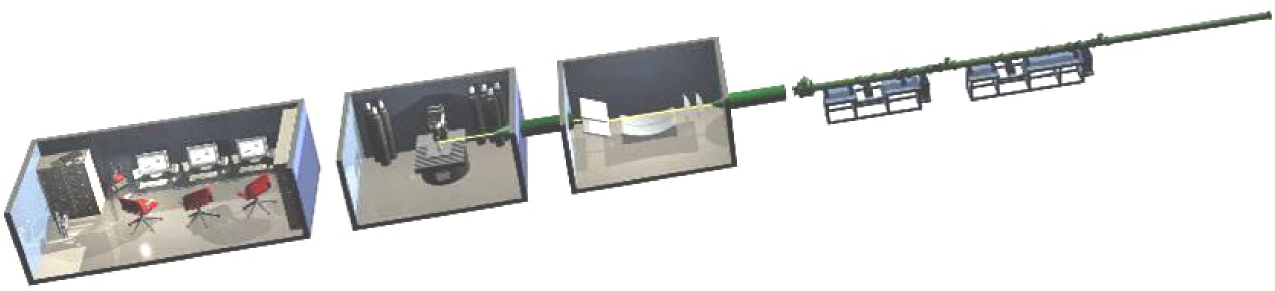
Electrons take about two millionths of a second to travel round the ring and last for about 20 hours. A very high vacuum is maintained in the storage ring to minimise the energy loss of electrons by collision with air molecules. Currently, electrons are added twice a day, but in future electrons would be added as required to maintain a steady bright electron beam.

We have seen that straight sections are attached to the storage ring. In these straight sections there are two sets of magnets called wiggler and undulators. The wigglers produce very high energy x-rays of 100 keV. These x-rays have high penetrating power. A typical example may be using the x-ray beam to penetrate thicker samples such as pinhead shape diamond anvil. Such devises are used to generate high pressure for geological experiments to study properties of minerals under high pressure.

Undulator magnets on the other hand produce bright white (wide range of wavelength) x-rays. From such beam x-rays, a narrow wavelength is selected and used for crystal structure determination and spectrography work.

Experimental set up

Before we go further, a few characteristics of x-ray radiation. A x-ray beam has higher penetrating power than optical rays, this why x-rays are used in radiography as in health care. Radiography is also used to examine defects like holes in metal casting or cracks in welded joints. Depth of penetration depends on the energy of the beam. The x-ray beam used in radiography used is white, i.e. wide wavelength range. Unlike optical or infra-red light, we can not use mirrors to bend x-ray beams. X-rays are reflected by the orderly arrangement of atoms in a crystal. We can use this property to produce a monochromatic x-ray beam from a white x-ray beam. This is called mono-



Beam line From right; the straight sections attached to the storage ring. The first chamber, the Optics Hutch; houses slits and mono-chromator to select the the X-ray of suitable wavelength. The next chamber in the middle is the Experimental Hutch or set up, where the the x-ray beam interacts with the sample and the detectors to collect the relevant information. The experiment is monitored and controlled by the operators from the left chamber, the control Room.

chromator. However in some experiments white x-ray beam is used. The reflection of x-ray by crystals can be used to determine the crystal structure and therefore to identify the crystal. The synchrotron x-ray beam is about 100 billion times more powerful than the x-ray beam used in medical facilities.

X-ray beams from the straight section enters first into the Optics Hutch. Here by using slits and mirrors (reflection from crystal planes) the x-ray beam of selective wave length is chosen. The beam is now a few hundredth of mm diameter. Collimated beam then enters the Experimental Hutch, which houses the the experimental setup and detectors to pick up signals from the experiment. The next room is the Control Room, from where the operators monitor the experiment.

Broadly the experiments carried out in the Diamond Synchrotron Laboratory comes under three categories

1) Diffraction It is used to identify crystal structure (arrangement of atoms or molecules in crystal planes) of materials, metallic, non-metallic such as rocks and biological samples like proteins. Study of crystal structure of biological molecules helps us to understand how these molecules function. There are various techniques available to study the different properties of the sample under investigation. In one experiment the sample is irradiated with a white x-ray beam. The sample gives off characteristics diffracted beam; this is then analysed to study internal strains present in the sample such as an engineering component. The high energy of the synchrotron beam allows quick data collection and analysis of large industrial scale samples.

2) Imaging This is somewhat similar to radiography we commonly come across, but the high intensity x-ray beam can reveal far more information. Thicker samples can be examined. Image resolution can be enhanced by using phase contrast techniques. We can get information about the materials on nano-metre (10^{-9} m) scale. The terms "nano" is used somewhat widely. It means much finer than commonly used. There is no cut off size, below which the size is termed as nano (particle). Such information is very useful in understanding solid state electronic devises such as storage discs and novel magnetic materials. Computer aided tomography can be used to get three dimensional images. Fine x-ray beam irradiating a surface can give off optical radiation. The optical radiation can be processed to be displayed as microscopic image.

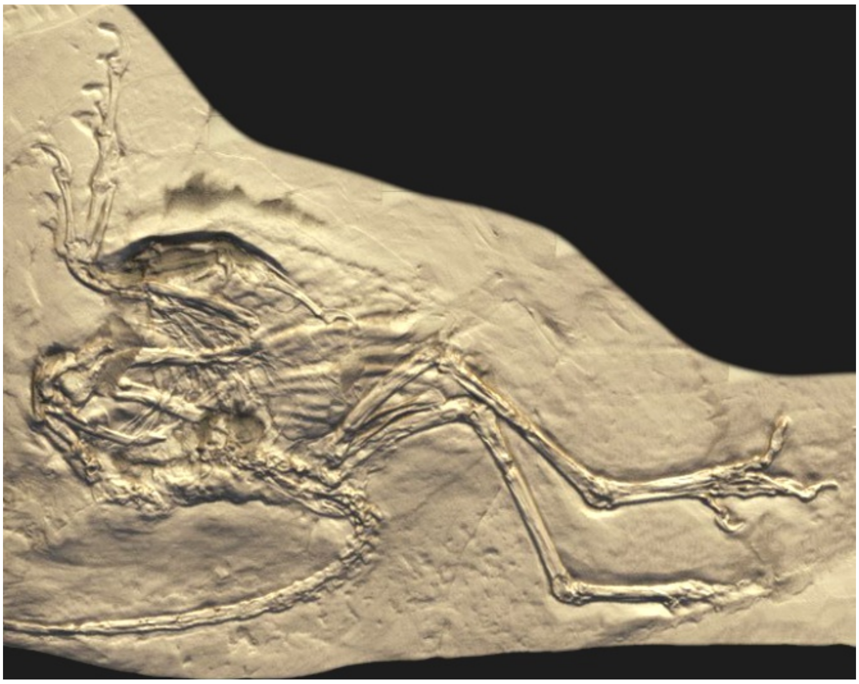
3) Spectroscopy When x-rays fall on any material, the material may absorb and radiate (fluorescence) characteristic x-ray radiation. From this fluorescence radiation we can find out about the important characteristics about the elements present and their chemical state. A similar method is uses to analyse minerals in rocky planetary bodies. X-ray from the Sun hits the minerals; minerals gives off (fluorescence) x-ray and this is analysed by spectrograph on board space instruments.

The ultraviolet and infra-red present in the synchrotron beam can also be used for spectral analysis. Infra-red spectroscopy is very useful for identification of organic and biological samples. High energy and narrow beam size of the synchrotron beam allows high resolution nanometre scale analysis.

In the next section we shall look at some experiments which have been carried out in the Diamond laboratory.

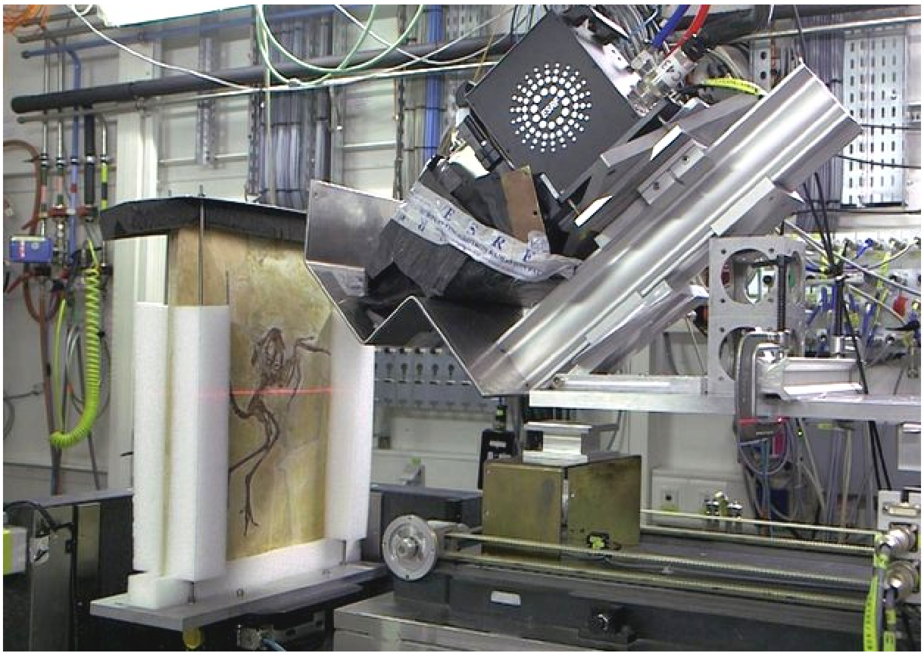
Daresbury laboratory is now working on a gamma ray source based on synchrotron radiation for a joint European project. In this case, the energy of the electrons would be boosted by laser beams, rather than radio-frequency radiation as in the Diamond source. The change in velocity of electrons would produce gamma rays.

General Reading
`www.diamond.ac.uk/Home.html`



Imaging Archaeopteryx

Palaeontologists often use x-ray techniques to probe inside the fossils. Some of the fossils could be very large or embedded in the rock to apply conventional x-ray techniques. Synchrotron radiation has come to the rescue of palaeontologists to image difficult to study fossils. Recently a synchrotron beam facility in France has examined a fossil of an Archaeopteryx by high intensity x-ray beam. Since the



Experimental set up and the image of the Archaeopteryx fossil

discovery of the first Archaeopteryx fossil, the palaeontologists have debated if it is a bird or a dinosaur. Like birds it had feathers, but it also had teeth and claws like reptiles. The aim was to obtain high definition image of the fine features of the fossil. The fossil came from Germany. It is embedded in the large piece of rock of about 50cm thick and not easily amenable to conventional CT method. In the French synchrotron laboratory they used a pin hole camera, camera obscura, method to scan the fossil. A very thin high intensity x-ray beam scanned the fossil and the transmitted beam from the fossil was detected by the detector to form a high resolution 3D image of the fossil still embedded in the rock.

Science with Synchrotron Radiation at the Diamond Laboratory

Life Science

Nearly seven million cattle were lost due to Foot and Mouth Disease Virus (FMDV) in 2001. The cost to the country was about £2 billion. This disease is wide spread in Africa, Middle East and Asia. Each year about 3 – 4 billion vaccinations are used to control the disease. The vaccine against the foot and mouth disease has to be stored at a lower temperature which creates a logistical problem to carry out vaccination in the developing countries. Since vaccines are generally made by inactivating the live viruses, vaccines have to be made in laboratories with high biological security. Now a new approach has been taken to synthesise the vaccine for FMDV without involving the potentially harmful live virus. The Diamond Synchrotron Facility has played a major role in the development of a synthetic vaccine.

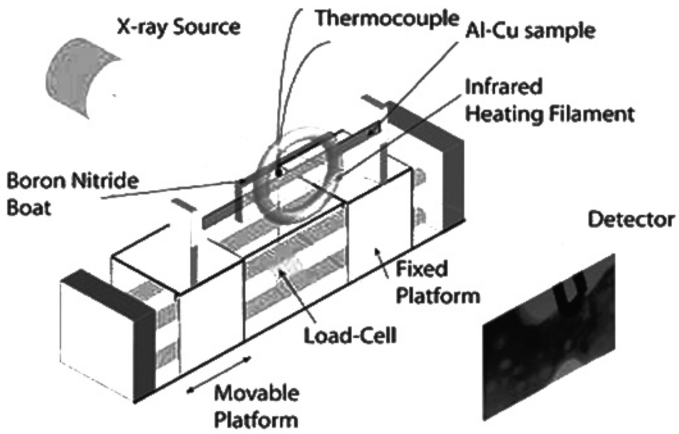
This development of the synthetic vaccine is a culmination of nearly 25 years of work. The structure of the FMD virus was worked out in the Synchrotron radiation source at Daresbury in 1989. Them a team from Reading University using protein molecules synthesised the virus.

The Diamond x-ray source confirmed that the synthetic version of the virus is a close match to the vaccine developed from live virus. The synthetic molecule is very small and its x-ray scattering property (from crystal structure) is week. The high intensity and small x-ray beam of Diamond could overcome these difficulties.

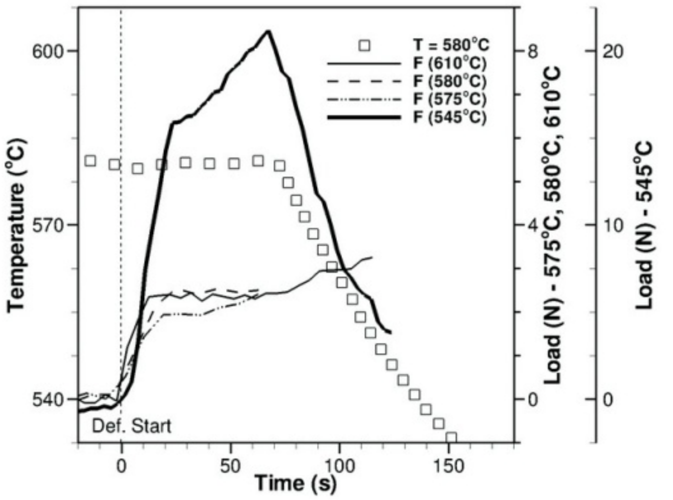
Pirbright Institute, Surrey, has done extensive work on the FMD virus and now they are conducting immunisation trials with the newly developed synthetic virus. This new form is stable up to 56°C and in addition no live infectious virus is involved in making the vaccine. If the trial is successful, it would be a major breakthrough in the development of other vaccines.

Material Science

If we cool water to 0°C, it will turn into ice. In a water – ice mixture, the water temperature is close to, but not quite 0°C. Pure metals melt and solidify at a given fixed temperature and this is constant for that metal. We rarely use a pure metal. Often pure metals do not have useful properties. To get the right properties we mix more than one metal and these are then called



Experimental set up to study deformation behaviour of aluminium alloy and the changes in the microstructure close to the melting point.



The variation in measured force with time for the four semi-solid deformation experiments

alloys. Alloys do not have a fixed melting point; alloys melt or freeze over a temperature range.

During melting or freezing of alloys, solid and molten metals exist together. As the alloy solidifies, it shrinks. The process of shrinking leads to strain in the semi frozen mass and causes liquid metal to flow in between the solidified portion of the alloy. This movement of liquid ultimately causes formation of pores and cracks in the solidified metal (alloy). These defects often cause weak points in the solidified metal and metal fails when the metal is shaped by rolling or forging. Most of the engineering structure we see around us is formed into shape be rolling or forging of ingots.

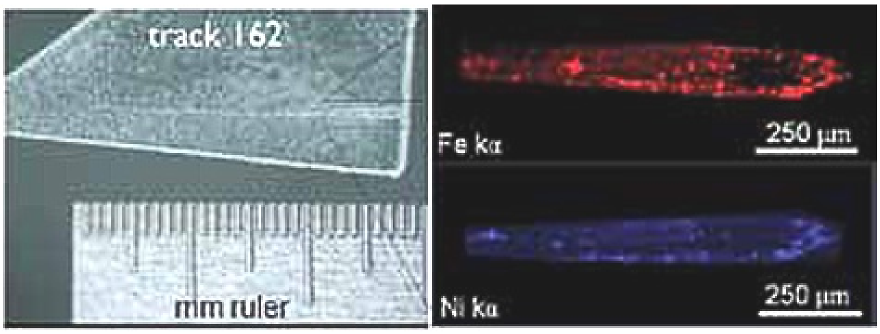
In order to visualise the process at the Diamond Light Source, an experiment has been carried out using an aluminium – copper alloy as a model material. Thin strips of the alloy, 1mm thick, was heated in a furnace. There was a means to apply tensile and compression stress on the sample. Both stress and strain of the sample were measured. The aluminium – copper alloy strips were heated close to the melting point and the cooled down to various temperatures. These temperatures were chosen such that the alloy strips were in the solid – liquid state with different amounts of solid/liquid ratio and also one temperature, where it is completely solid. The samples were loaded and the amount of deformation of the samples were recorded. The furnace had a slit cut, through which a bright x-ray beam shone on the sample and real time radiography of the sample was recorded. From the recorded image it was possible to monitor movement of the liquid metal in the semi-solid mass under the action of applied loading.

Analysis of Dust from Comet

Although comets occur in the colder region of the solar system, these often contain compounds which can only form at higher temperatures. Formation of some of the compounds need reaction with water at higher temperature. These observations tend to suggest that perhaps cometary dust formed near the Sun and then moved to the colder region of the solar system. In order to have a better understanding of such processes there is an interest to study the anatomy of comets.

NASA's Stardust mission collected dust from the comet Wild 2 and it was brought back to the Earth. Dust from the comet struck a collection plate made from aerogel at a velocity of 6.1km/second. The action of striking formed a few mm long tracks on the collection plate and most of the particles came to a halt at the end of the track. As a result of the collision the cometary dust particles broke down into finer particles of sizes of micron (10^{-6}m) and below. The cometary particles perhaps were altered by the heat generated in collision with the collection plate. Larger dust particles were about tens of microns in size and probably least damaged by the heat.

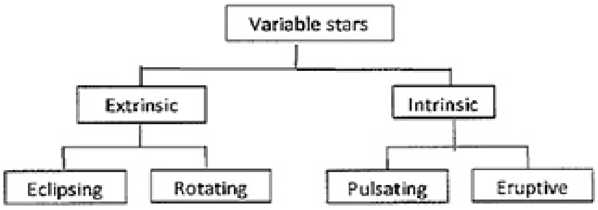
In order to analyse very small particles, we need very small beam size. At the diamond source, a x-ray beam of 2 – 3 microns was used in analysis of these fine dust grains. The method used was x-ray fluorescence. When a x-ray beam of suitable power and wavelength strikes an object, the elements present in the object produce characteristic x-ray fluorescence radiation, which can be used to chemically identify the object and also it is possible to produce an elemental distribution map of the object being analysed. The analysis suggested the cometary dust contains silicate, sulphide and oxide minerals.

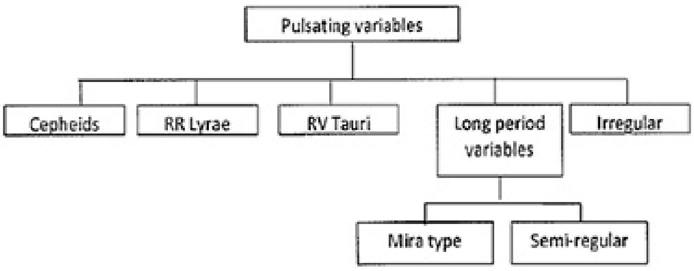


X-ray maps of one of the Stardust tracks.
Cometary track on the aerogel plate, left, and the elemental distribution of iron (green) and nickel (blue) in a particle, right. Since both iron and nickel occur over the same area, we conclude that iron and nickel are intimately mixed i.e. alloy of iron and nickel.

The elemental mapping of the larger tracks suggested to be consisted of iron – nickel alloy. Some iron – nickel sulphides and oxides were also present. The oxides might have formed as a result of heat produced during the collision.

These are only some of the experiments carried out in the Diamond Laboratory. For other experiments in different fields, please see `www.diamond.ac.uk/Home.html`





A new type of variable star has recently been reported from European Southern Observatory in the open cluster NGC3766 in the southern constellation of Centaurus (The Centaur). This cluster is estimated to be about 20 million years old

Over a seven year period, a team of Swiss astronomers monitored more than three thousand stars with a 1.2 m telescope from Chile. They noted that 36 stars in the cluster undergo small, about 01%, variation in their brightness. The period of variation is 2 to 20 hours. These stars are similar to the Sun, but a bit brighter and hotter.

The detailed mechanism for the variation is yet to be fully explained, but the initial suggestion is that these stars are pulsating due to some unexplained internal phenomenon. According the current theoretical models these stars are not expected to show periodic variation. However, it has also been observed that these stars rotate very fast. The rotational velocity is about half of their critical velocity, the velocity at which the the materials from the surface of the star are ejected. It is thought that this fast rotation sets in some not yet understood internal process. As yet, there is no name given to this type of variable stars.

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We live in privileged times. We have lived through the start of the Space Age. We are the first people in all history to have seen pictures of all the major planets in our solar system (and lots of minor bodies and moons). We have started to explore Mars with landers and robots and 12 men have walked on the Moon.

So with the New Horizon spacecraft speeding past Pluto into the strange outer reaches, heading for the stars through the Kuiper Belt and into the Oort Cloud, the first phase of us exploring our system has now ended nearly 60 years after it started with the first Earth satellite Sputnik 1 on October 4^{th} 1957. Two years later the first visit to the Moon by Luna 2, (it crashed onto the surface). Soon the race to put men on the lunar surface started. The first successful planetary flyby was by Mariner 2 in 1962 when it passed Venus. This was followed by Mars in 1965 by Mariner 4, perhaps one of the biggest disappointments was seeing all the craters on Mars with no sign of water or life. The giant outer planets of Jupiter and Saturn were reached in 1973 and 79 by Pioneers 10 and 11. Mercury was reached by Mariner 10 in 1974.

Of all the first reconnaissance missions the most successful was undoubtedly the Voyager 1 and 2 missions to the outer planets which started off on August 20^{th} 1977. Passing Jupiter then Saturn, Voyager 2 passed Uranus in 1986, then Neptune in 1989. It is travelling at about 15 km/s, well above the escape velocity of the sun at its distance of over 100 AU. So it will soon be in interstellar space along with Voyager 1 and Pioneer 10, soon to be joined by New Horizons.

All of this exploration has been made possible with the rapid advances in technology, computing, rocket design, lightweight materials, as well as the miniaturising of all the electronic components to save weight and the increase in the reliability of all types of equipment. Look how phones have developed in the last 20 years. Big challenges remain, it is still expensive to fly into orbit and the cost of replacing the shuttle fleet has not yet fully began. Batteries still don't last long enough as anyone with a smart phone will tell you. And for deep space travel, only nuclear radioisotope thermoelectric generators can be used as solar power is impractical after Jupiters orbit.

What will the next 60 years bring? I remember reading Dan Dare in the *Eagle* comic when I was a lad and the first story was about going to Venus to try to find food to feed the Earth, but they found the green coloured Treens and the Mekon instead. All of which was to be happening in the far future of 1997! So much for that future. So will there be bases on the Moon and Mars? I should hope so by then and maybe exploring the asteroids for minerals and rare metals. The one thing you can say for certain is we will be surprised at what's found and excited by the pioneers exploring these distant worlds, proving that we are a race of explores who always like to see whats over the horizon.

Ivor Clarke

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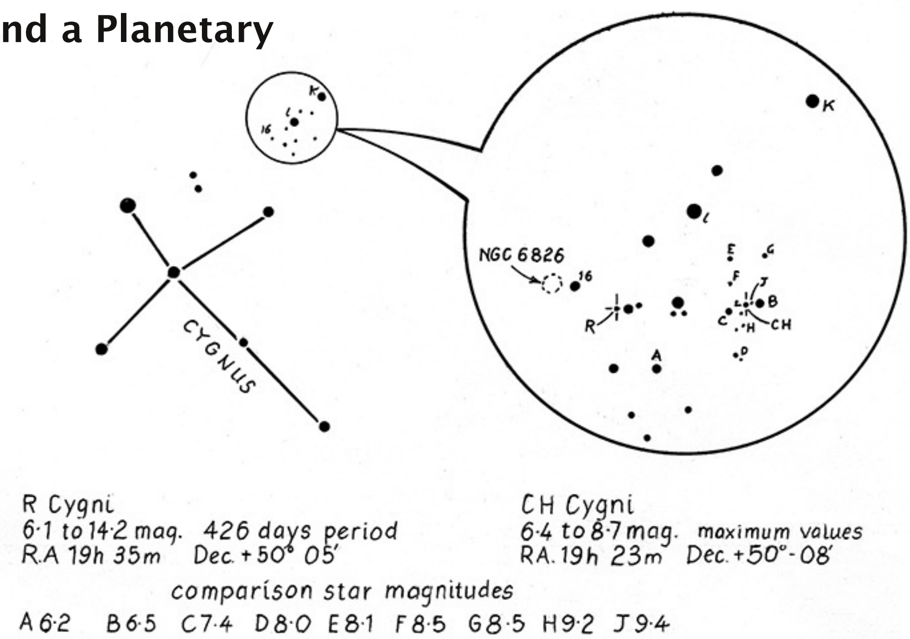
Two Variables and a Planetary

By Vaughan Cooper



CH Cygni — a Z Andromedae type semi-variable star.

CH Cygni is a symbiotic variable star, a term introduced over 60 years ago to describe a pair of very dissimilar stars which orbit each other causing the behaviour of their mutual interactions to affect each other, which we observe as semi-regular changes in brightness. The light changes of CH can occur in several ways. Firstly we have a hot white dwarf star and a large cool red giant orbiting and possibly mutually eclipsing each other. Secondly the giant is losing material as a disc or shell which surrounds the dwarf star, which may vary in thickness, thus affecting the light we receive in a semi-regular manner and thirdly, the large cool giant may vary as a Mira type long period variable star.

Although CH Cygni is a Z Andromedae type star which are known to produce rare nova like outbursts (CH Cygni has yet to produce a mayor outburst) it has under gone a series of minor outbursts during the 1970's which took it around to mag 5.6. By 1985 it had faded to mag 8.0 and a sudden further drop to mag 9.0 in 1988, but it seems to fluctuate regularly between mag 6.0 to 7.0.

The few observations I've made of CH Cygni with 10 x 50mm bins;

I recorded in July 2011; — not visible and below 8.1 mag the faintest star I could see in the field of view at the time, and mag 7.8 in July 2014.

Much patience and perseverance will be required to see any major changes to CH Cygni, but regular fluctuations of mag 1.5 should be achievable.

Although very bright outbursts of Z And type variable stars are rare, amateur astronomers do useful work in monitoring the fluctuations of these unpredictable stars which help professional astronomers gain a better understanding of their behaviour and how much they have in common with faster ordinary nova. These consists again of a close binary, but this time, of a cool main sequence star and a hot white dwarf, with the outbursts occurring on the white dwarf as a result of explosive nuclear burning of material shed by the cool main sequence star.

R Cygni — a Mira type star

A long period variable of 426 days with a range mags 6.1 to 14.2, however the maximum brightness of this star can vary considerable with values as faint as 9.5 mag have been recorded with the average maximum being 7.5 mag. The date of the next minima is due in August 2015, followed by maxima in December 2015. As its so close to CH Cygni it might be worth seeking out later in the year.

NGC 6826 — The Blinking Nebula. RA 19h. 44m. Dec 50° 31'

Once you have identified the telescopic star field around R Cygni try if you can se the above planetary nebula as it lies a little over 1° to the west of R Cygni. Frequent mention has been made about NGC 6826 is that it disappears once you centre your attention on it, look to one side (averted vision) it suddenly reappears, hence it's name Blinking Nebula. But for me I can't get it to perform, perhaps the disappearing / reappearing act only applies to telescopes of a certain aperture. Anyway the biggest surprise was I could see vivid colour cobalt blue, the same colour as the sky. The few reference catalogues I've referred to never mention any colour, except in Walter Scott Houston's book Deep Sky Wonders where he sees this planetary as a faint greenish disk and not blue. I would be very pleased if someone would confirm or refute any of the points above and correct me where I'm wrong. As for the members who contribute images of the night sky, give this object your attention as I feel very little enhancement will be needed to bring out the colour.