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The Coventry & Warwickshire Astronomical Society visit on a wet Saturday 17th May to the Jodrell Bank Observatory, we were joined by other members of Stratford AS, Heart of England AS and Hinckley AS. The dish looked very clean and tidy in its new paint job.

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Editors Bit

First of all a big thank you to all of you who filled in our C&WAS survey questionnaire a while ago. It proved very useful for the committee to have information on what the members think about the Society. So what are the results of this the second survey?

It seems that most of the members are between 40 and 60+ and no-one ticked the female box!! This is a problem, how do we get younger members? The length of time as members is fairly evenly spread across the years from new beginners, to 4 who have been with us for over 20 years. Also most of us are, we feel, "Average" or "Not Bad" in our Astronomical Knowledge with only a couple at the extremes of beginner and expert. We all seem to live close to Earlsdon, 1 to 15 miles away and no-one travels over 20 miles. We have four members who are members of the BAA and RAS as well as a few other societies.

Most of us read Astronomy Now regularly and a few Sky & Telescope, with other magazines taking up only a few readers. Most of the other main societies people belong to issue their own magazines. A surprising fact is that nearly half the members have a library of 20+ astronomical books of their own with the 6 - 10 book range the next largest.

In the equipment section the most popular telescope is the reflector with most of our members owing one. The most popular size being the 8", but two members ticked the +14" box. It may have been a good idea to split this section into the Newtonian reflectors and the newer SCT types as well as the smaller Meade ETX type of scopes. But every one seems to have a pair of binoculars which range in size from the small 7x42 size to the popular 10x50 size (7 members) to the large industrial size 11x80 and the 16/20x50 size. As Sir Patrick says, every one should have a pair of binoculars to look at the sky and they are the easiest and quickest to use for large objects like comets.

When it comes to the evening lectures just about every one thinks that the level of information and the presentations given by the lecturers is just about at the right level for them with no-one ticking the "I Don't Understand Them" box! So what then are the most popular subjects which the members enjoy with a "very interested" rating? Here the "Solar System" wins hands down with the "Moon", the "Planets" and "Spaceflight" clear leaders in interest. Not far behind are the "Deep Sky" folk with "Galaxies" and "Cosmology" scoring highly. "Double Stars" and "Variable Stars" have a "Fairly Interested" rating only, with no-one "Very Interested". The "Sun" gets a high "Fairly Interested" rating along with "Sky Phenomenon", the "Planets", "Double Stars" and "Galaxies". In the "OK interest" corner "Variable Stars" win with "Double Stars". Only a few ticks marked the "Not Interested" column. So it seems that our Society has a wide range of interests among its members which is always a good thing in a society.

So when you have a clear night, do you then go outside to observe? To the question "How would you say your local sky conditions are with sky glow"? Most members answered with "Average" or "Mediocre" or "Poor", with no-one ticking the "Excellent" box! On the observing question quite a few said "Yes when possible" with "Sometimes" and "A Little" getting a few ticks and a couple saying "Never". So when outside do you recognise the constellations? "Most" and "A Few" were ticked fairly evenly with no-one admitting to know ether all of them or none. This question was linked to "Do you know your way around the sky?" and most members thought they did "Not to Badly" or "A Little", with a few who said "Yes" as well as "No".

The last set of questions concerned the way the Society should go with an observing program, so "Would you like the Society to organise informal viewing sessions for beginners & novices, as well as a regular observing programme, and organise Star Parties?", this attracted a well ticked set of box's, so it seems that most folk in the Society would be interested in attending a session. It will be interesting to see how many of these people will come out to an organised Star Party, but there is a high level of interest in the Society for these events.

On the question of "Do you want the society to build a new observatory?", a overwhelming majority said "No / Not a priority" with just a couple of votes for an observatory. Also a suggestion was made to a possible location along the Tamworth Rd. in Coventry. This will need to be examined as a possible location, but of cause it would not be the best location for everyone. This is in contrast to the large amount of people who think we should have a telescope for loan to members. When asked what size should it be, every one had their own idea from a 4" SCT to a 8" Dob. with the consideration that a easy set-up telescope is a must to allow for easy handling by beginners.

Ivor Clarke

Ring of Fire

by Mike Frost

During my lifetime there will be precisely two central solar eclipses that cross the United Kingdom, the total eclipse of August 11th 1999 and the annular eclipse of May 31st 2003. We all know what happened in 1999; so how did I fare for the annular?

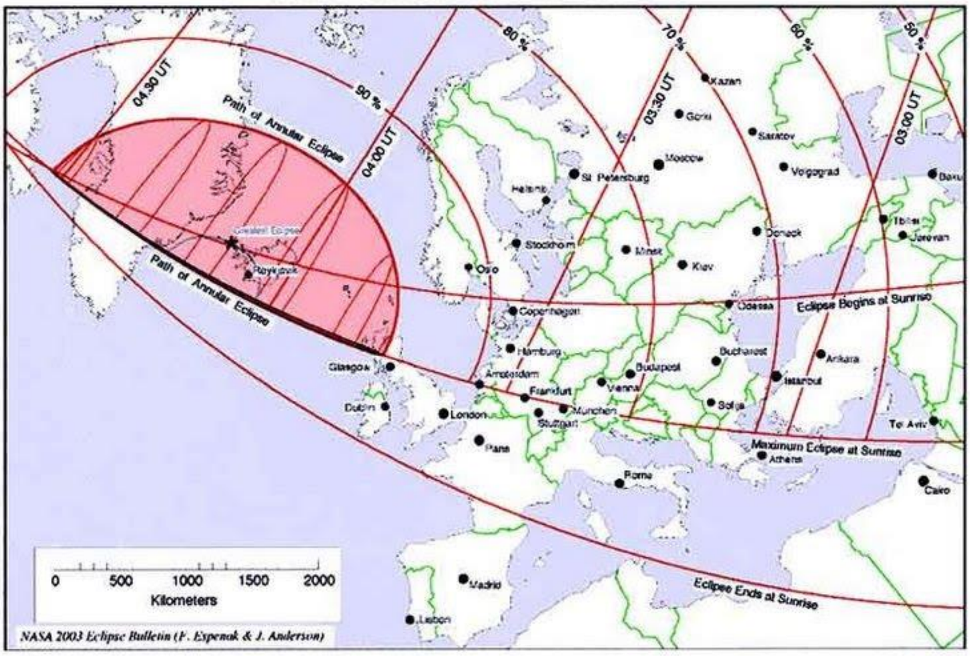
In 1999 the eclipse path crossed southwest England before heading across central Europe and the Middle East. The 2003 annular eclipse, unusually, went the other way, with the track starting in continental Europe as a partial eclipse at dawn, and heading northwest across Scotland, the Faroe Islands, Iceland and Greenland. The reason for this unusual path is quite interesting (well, I think it's interesting). The Moon's shadow intersected the very top of the Earth. Because the Earth's axis is inclined at 23° degrees this meant the shadow was cast above the North Pole, and consequently the path of the eclipse ran from east to west, in the opposite direction to usual. One consequence of this was that the track went backwards through the time zones. Indeed, the final throes of the event, a partial sunset eclipse, occurred in Alaska. On the previous day.

Explorers Tours, my usual choice for eclipse expeditions, dithered for too long before organising a trip to Iceland; a pity, because I might well have gone with them. Instead I decided to observe my only British annular eclipse from Britain. This meant a trip up into Scotland. Annularity could only be seen from the northern highlands, the Hebrides, the Orkneys and the Shetlands. Initially I was keen to observe from the Outer Hebrides, where the Sun would rise, memorably, in central eclipse, with the much anticipated "Ring of Fire" surrounding the Moon. However I was unable to organise flights to enable this; I wanted to fly on Sundays and at the time I booked there were no flights allowed into Stornoway on the

Sabbath (this has subsequently been relaxed, much to the disgust of the Scottish Presbyterians).

Annular Solar Eclipse of 2003 May 31

FIGURE 1. - THE ECLIPSE PATH THROUGH EUROPE



My second choice was the Shetland Islands, and here I struck lucky, organising my flights, hotel and hire car within a few days. So on May 24th I flew from Birmingham to Glasgow, Aberdeen — and back to Aberdeen. After British Airways had fixed their airplane we continued on to Sumburgh Airport. My first impressions of the Shetlands were very impressive — a beautiful, calm evening, sunny even at 10 PM. I soon learned that appearances were deceptive. Lerwick had seen a tornado that afternoon.

I picked a super hotel for my stay — the Inn on the Hill, a friendly and welcoming establishment, listed in the Good Beer Guide, overlooking Whiteness Voe, a fjord dotted with islands out to the horizon. A wonderful place to view the eclipse from - except that its other name, "The Westings", gave away the fact that it faced in completely the wrong direction. The annular part of the eclipse took place at less than four degrees altitude, so it was vital to find a viewpoint with a clear northeast horizon.

I had made contact with the Shetland Islands Astronomical Society, who told me that their main viewing site was to be from Unst, the most northerly island, with subsidiary viewing spots on the islands of Fetlar and Yell.

For my first two days on Shetland I had company. I had met Henryk Klocek and his son Mark on my Mozambique trip, and Henryk's daughter Klementyna at a Mozambique trip reunion. The Kloceks were veteran eclipse watchers — indeed Henryk was already making plans to observe the November eclipse from Antarctica, joining an icebreaker cruise out of South Africa. They were driving north to observe this eclipse from the Faroe Islands, and had already taken ferries from Wick to Stromness in the Orkneys, and then from Kirkwall to Lerwick in the Shetlands.

We spent two days exploring Esha Ness (no, not the Grand National horse, but a beautiful coastline of cliffs and sea caves), Westerwick Bay and the port of Scalloway. What I liked best about Scalloway was an old plaque, attached to one of the buildings, expounding a splendidly incoherent account of how the tides "really" work. I'm not sure that even the fellow who put up the plaque was completely convinced by his own arguments, as the explanation seemed to peter out mid-sentence. We enquired about the author when we visited Scalloway museum. "Och. . ." said the curator, confidentially, ". . .he was funny!"

On Tuesday evening, Henryk, Mark and Klementyna disappeared northwards on the ferry. I continued to reconnoiter the Shetland Mainland. I was going off my original idea of journeying up to Unst to join the party there. That option left little flexibility for travel if the cloud cover proved to be patchy; besides, sleeping in my hotel bed would be much comfier than the hire car. I reckoned there were three good sites on the Mainland — Sumburgh Head, the most southerly point on the Island, Crossie Geo, between Sumburgh and Lerwick and a headland just north of Lerwick called Kebister Ness, which was only a mile or two east of my hotel. On the day before the eclipse I carried out a dry run and drove to Kebister at dawn. The omens were hardly ideal, as a thick bank of cloud obscured the sunrise completely. However, as far as I could tell, the sun rose out to sea from Kebister, with some small islets in the foreground to compose an interesting panorama. I decided that, if the weather permitted, this was to be my observing site.

The forecast was hardly ideal. Shetland had had a lovely week, by Shetland standards, quite a lot of sunshine and only occasional drizzle. Just as in the rest of Britain, which was enjoying a heat wave, the locals wandered around in T-shirts; unfortunately, as it was fifteen degrees colder than London, the rest of us grockles wrapped up warm in fleeces. The weather forecast for dawn in the north of Scotland was not good. The Hebrides were expected to be clear, the north coast cloudy, Orkney and Shetland under rain clouds. But it was too late to leave the islands.

I set my alarm for 2:45 AM, giving myself plenty of time to drive to Kebister Ness before the 3:55 AM sunrise. The roads into Lerwick were completely deserted, except for one cyclist looking at a map on the way into town. I pulled up by the roadside at the headland. Nobody else was there yet, so I had my choice of parking space. I set up my tripod and camera (Olympus OM10 SLR with 200mm zoom and nifty solar filter fashioned from plastic drainpipe, Baader film and sticky-back plastic). As I did so, the cyclist appeared round the corner and pulled over by my car. I asked if he was here to view the eclipse.

Indeed he was, he told me, and he would have viewed from another site to the north except that he had been involved in a minor accident, which hadn't done him any harm, except that the local taxi drivers were stopping to ask if he was OK, and one of them must have moved the rear light on his bike because a short while after he had cycled off he had spotted that it was missing, and it wouldn't just fall off, and. . .

This was all rather stream-of-consciousness and so I carried on preparing my equipment. There was broken cloud cover for as far as I could see in all directions, so there seemed little point in a late change of venue. Indeed, the clearest direction seemed to be towards the northeast horizon. Most worrying, perhaps, was a fresh breeze that threatened the stability of tripod mounts. It also threatened the stability of my cyclist friend, who, I noticed, only had cycling shorts to keep his legs warm. He gratefully accepted my offer to sit in the car and prepare his own equipment out of the breeze.

I found out eventually that his name was Joe, and that he was cycling round northern Scotland, and that he had caught the last ferry from Bressay the previous evening, except that he had nearly missed that ferry because he forgot to set his alarm, but fortunately. . .

As dawn approached, more cars began to arrive, and eventually we had a dozen cars plus a minibus, whose occupants tramped up the hill in search of a slightly higher viewpoint. The sky lightened again, but at 3:55 there was no immediate sign of the Sun. Fortunately we didn't have to wait long. Within a few minutes the Sun broke through into the gap lining the horizon and gave us a lovely site, a deep red oval with a chunk bitten out of the side. Somebody described it as a Pacman.

Unfortunately our view didn't last too long. After ten minutes the Sun rose into a bank of clouds and disappeared from view. We began a long and frustrating wait to see if any other breaks in the cloud would appear. The occupants of the minibus came back down the hill and poured themselves drinks from flasks (now why hadn't I thought of that?) I had a chat with various of the car occupants. A German guy showed me his digital image of the sunrise. The minibus people, a church group from the midlands, I think, offered us some of their tea — gratefully accepted. Joe got out a photo album and showed us all some neat shots of the '99 eclipse, which he'd managed to see from the Lizard in Cornwall. We listened to Phalab Ghosh, on Radio Five Live, interview a bunch of people on Unst who weren't at their sharpest at four in the morning. The best comment was sent in by a listener from England. "Solar Eclipse. . ." he texted, sarcastically, "Great Radio!" The mid-eclipse, time for annularity, came closer and closer, the sky darkened. At 4:47 the sky was still cloudy, and the 105 seconds of annularity passed without the sun being visible.

I have to say though that the moment lacked the drama of my clouded out total eclipses (all too many of course - Mongolia, Devon and Mozambique). Because the Sun was never covered completely there was not the sudden, "switching off" of light, which characterises the onset of totality. All that happened was that the sky stopped dimming and gradually started brightening again; indeed, it would have been difficult to tell exactly when the mid-point was. All of which goes to show that an annular eclipse simply isn't as exciting as a total.

We were delighted, however, when the Sun finally did emerge from cloud at 5:05 AM, some 15 minutes after mid-point, still 70% eclipsed; so everyone with filters was able to rattle off a few more pictures. This time the Sun stayed in view for 25 minutes. By the time it disappeared, the eclipse was nearly over. I stayed, of course, right till the bitter end, but by the fourth contact, everybody else had left.

Except for Joe, of course, who was still telling me about his job at the sorting office and how that meant he was on the wrong shift for the lunar eclipse of. . .

I gather that the story from Kebister Ness was very similar to others on Shetland. From Unst, there was a good view of the sunrise, but the annular phase was missed. BBC Scotland carried pictures of the partial phase from Sumburgh, but tellingly they featured no ring of fire. The Hebrides, Orkneys and Faroe islands were pretty well clouded out. Friends at John O'Groats peered unsuccessfully through the mist for two hours; friends in Nairn fared little better. Patrick Moore and Brian May, observing from Sutherland, only managed to see annularity with the help of infrared cameras that could penetrate light cloud.

So was my visit worthwhile? Of course! The eclipse day weather was hardly ideal, but I did observe a sunrise eclipse, to go with the sunset eclipse that I saw from Turkey in 1996. I enjoyed the Shetlands immensely, rather more than I thought I was going to; the islands are very beautiful and the people are very friendly and hospitable. The islands are at their best when it's sunny, though, and that isn't always very frequent. Take warm clothes!

And as for the ring of fire — well, it probably isn't worth going half way round the world for an annular eclipse, the sight simply isn't as spectacular as a total eclipse.

On the other hand, there is one crossing over Madrid in October 2005. . .

The Saga of the Universe

By Paritosh Maulik

It is now accepted that the universe was created from a point source and grew into the enormous size it is today. We can not see the entire universe, it is very big, so light from its most distant part has yet to reach us, but we can estimate its size. We do not know what led to the point source evolving into this present structure, but we know the various processes that took place from time zero to the present. At the beginning of the beginning there was the biggest heat wave and this has now cooled down to about 3°K. This is called Cosmic Microwave Background radiation and it is reasonably uniform across the sky. Theories worked out during the forties are still being refined. The first experimental proof came in the sixties; ever since then, astronomers are trying to improve the resolution of their measurement to examine the term reasonably uniform and to verify various aspects of the theory. In the first section we shall take a brief look at what happened at different ages of the universe. Then we shall look at a few of the experimental set ups used. These set ups are somewhat different from the telescopes we see around us.

At the beginning of the beginning, there was a point source and it began to expand like an exploding firecracker. A cracker is a small tube like object and it busts into enormous heat, light, noise and smoke. There is an increase in volume. We do not know, if at the birth of the universe there was a noise, but we are certain there was heat and light. Since everything started at that instant the term coined was Big Bang, the biggest explosion ever to have taken place.

At the very early moment of the birth of the universe i.e. soon after the big bang say around 10^{-6} sec the temperature was very high, $1x10^{12}$°K. The size of the universe was about the size of the solar system we see today. At such high temperatures the energy is very high. It can create photons and also particles and antiparticles. At the very early moments there were almost equal numbers of particle and antiparticles and photons. Most of the particle - antiparticle pairs combined and were annihilated. This caused more radiation in the form of photon. But some particles did survive. This indicates that there was some asymmetry in the process. Photons are electromagnetic particles and can behave like wave as well. These are the only "particles" which can travel at the speed of light. The other particles were quarks. After the formation of quarks, a group of particles called Leptons formed. This group of particles includes, electron, muon and neutrino. Quarks combined to form neutrons and protons. Protons and Neutron are called hadrons. This period is called the Hardon - Quark transition.

After about 1 second, the size of the universe had expanded to about 1000 times the size of the solar system; the temperature was about $1x10^{10}$°K. Neutron and proton combine to form deuterium and helium. This phase is called primordial nucleosynthesis and lasted for several seconds.

After about 3 minutes since the birth of the universe, the temperature was about $1x10^{9}$°K; too high for a nucleus to capture electrons to form real atoms.

From 3 minutes to 300,000 years, free electrons scattered light or photons. The photons were not free to travel; like in a fog the photons were trapped. The expansion led to a drop in energy. After about 300,000 years, the temperature dropped to about 1000°K due to the expansion of the universe. Electrons then combined with nuclei to form neutral hydrogen atoms. Photons are no longer scattered by electrons and are now free to travel. Even at this stage the universe was small, but the temperature was dropping all the time.

This period is called the decoupling era. At an earlier time period these photons were of very high energy such as gamma rays. As the decoupling process continued, the expansion caused a drop in the energy of photons. This means that there were fewer high energy photons of ionising radiation such as gamma rays and x-rays. Absence of these ionising radiations means that the newly formed hydrogen would not be split and the formation of neutral atoms could continue. This process is called recombination and occurred when the universe was 300,000 to less than a million years old. Decoupling also happened earlier. For example, the neutrino - photon decoupling occurred when the universe was about 1 sec old.

We must remember that these photons originated at the beginning of the process i.e. the Big Bang, but only managed to get free after six months of their origin. After about 6 months the temperature was about 1 million K. There has been a significant drop in density, the number of photons is far in excess to that of electrons and protons. The photons are not absorbing any more energy, their fate has been decided, they can now only lose their energy with the expansion of the universe. This "six month old" radiation now floods the universe and anywhere we look there is the remnant of this radiation. Of course while measuring this radiation one has to take into account hot spots like stars etc.

At the end of this recombination process, there were only a few free electrons left. The photons were free and all the time loosing their energy. This loss of energy means a drop in wavelength. The wavelength and energy of the photons are connected. This heat wave of photons has cooled sufficiently today. This heat haze now shows a temperature of about 3°K (2.726°K to be precise). The drop in temperature from about 4000 - 3000°K to 3°K corresponds to the expansion of the universe by a factor of about 1000. The peak wavelength corresponding to 3°K is about 1mm. This is in the microwave range of the electromagnetic spectrum, about 1mm in wavelength. This radiation is now called **C**osmic **M**icrowave **B**ackground (CMB) radiation.

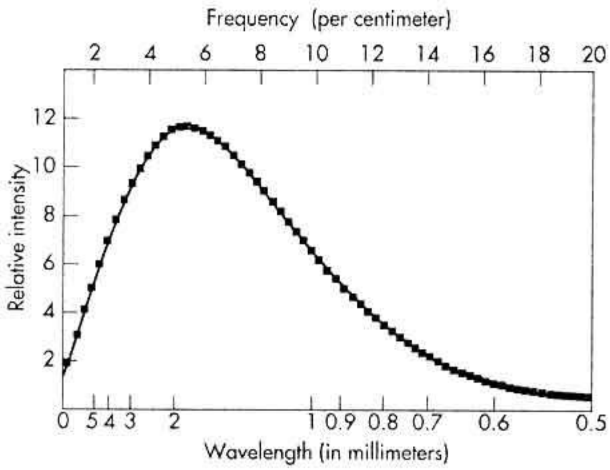
Once the temperature dropped sufficiently, particles like electron-proton-neutron combined to form hydrogen or helium. As elements like hydrogen and helium began to form, these began to cluster. These clusters attracted more atoms. There was not enough energy to break these clusters. There are two types of matter, observable or baryonic and dark matter.

When lumps of matter about a million times heavier than the sun came together, it formed stars, these clusters were the seed corn of galaxies and clusters of galaxies we see today. The size of the universe was about 1/30 of its present size. Although the universe was essentially smooth at this point, there must have some structure, which led to these clumps forming. Photons passing these clumps were slowed down by their gravity. This in turn left its signature on the photons, which have reached us now. The denser the region, the higher its gravity, so slowing down the photons and the lower is the photons energy. Therefore detailed properties of light such as polarisation, wave-length, intensity can give us a great deal of information about this time period.

However as the stars formed, they created a lot of ultraviolet radiation, re-ionising the neutral hydrogen atoms to electrons and protons. After half to a million years since the origin, galaxy formation is well on the way. Quasars began to form; the size of the universe is about 1/5 of the present size. As the time went on, nucleosynthesis inside stars formed elements other than hydrogen. These are collectively known as metals.

The size of the universe is now about 1/2 the present size, and about $1x10^9$ years have gone past since the beginning of time. The Sun formed after about $1x10^{10}$ years after the Big Bang; the solar system formed about 4 billion years ago and bacteria perhaps appeared 3.8 billion years ago.

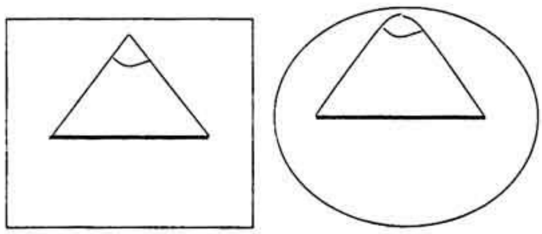
This basic theory of the origin of the universe in the big bang explosion was worked out by the late nineteen forties, but it was only detected as microwave radiation by Penzias, Wilson and identified as such by Dickey in 1965. Theories predicted that the entire universe is a black body. Therefore the CMB radiation should show the characteristics of black body radiation. A black body is in peace with its surroundings: i.e. in thermal equilibrium with its surroundings. It gives out a specific amount of radiation at specific wavelengths or frequency. If we plot the intensity of radiation we get a peak at a given wavelength (or frequency). This means that the maximum amount of radiation is given out at that wavelength and there is a formula that connects the wavelength and the temperature. Therefore from a wavelength vs intensity plot one can determine the temperature. As we have seen earlier, the CMB radiation is about 3°K now; and this corresponds to an electromagnetic radiation wavelength of about 1mm. If we plot the intensity of energy of the background radiation at different wavelengths, the energy intensity will peak around 1mm. This is very close to the theoretical prediction. Fig. 1, below, shows the CMB radiation obtained from COBE experiment.



Earlier studies suggested that the cosmic back ground radiation is uniform, but the COBE satellite results in 1992 showed that the background radiation is not smooth, but there is very small scale temperature fluctuation in tens of micro-Kelvin. 1 micro-Kelvin is 0.000001 or $1x10^{-6}$°K. It has been suggested that as the galaxies formed, they cast their imprint on the background radiation and these small fluctuations in the CMB are the results of these shadows. This is called Sunyaev-Zelëdovich effect; this has been observed to occur, but the fluctuations in the CMB can be very well explained by as due to localised mass fluctuation in the earlier period.

One of the major stumbling blocks of the big bang theory is that it does not explain what caused the expansion. One explanation is the Theory of Inflation. It goes something like this. Very close to the big bang, there were no photons or no particles, only energy. Since no particles are present, it is a vacuum. But this vacuum is not empty; it contains energy. According to the formula E=mc2, energy and mass are interchangeable, and if mass can cause gravitational pull, so can the energy. Mathematically it was shown that in such a vacuum system the energy due to gravity will act as a repulsive, rather than attractive force. This repulsive force causes the universe to expand from the near point size at birth. This inflation started about 10^{-36} second and was finished by about 10^{-33} second. If this rapid expansion did not take place the size of the universe would have been about 1cm since the big bang, but the inflation caused the expansion to be in the order of hundreds of billions of light years. The Theory of Inflation is still a very hot topic of discussion.

Since the early detection by Penzias and Wilson, there has been lot of attempts to map the cosmic microwave background. Detailed maps will give an idea about the earliest period of the cosmic history. We know that mass and energy can cause curvature of space-time. This is gravity. If we can determine the curvature we can estimate the amount of mass and energy in the universe. This in turn can tell us, if the universe will grow or collapse.



The two lines in this image, Fig. 2, above are of same length, but one is on a flat surface and the other is on a curved surface. When we see a distant object, we measure its length in angle. On a flat surface the angle is smaller than on curved surface. If we can measure the size of the distant hot and cold spots in the CMB, we can work out the curvature of space.

During the early nineteen thirties it became clear that signals at longer wavelengths than infrared, i.e. in the radio range, are coming to the Earth from outer space. These were detected by either dish or dipole type antennae. Some of these were arranged in an interferometer pattern to improve the resolution. Then in the mid sixties came the results of Penzias and Wilson. Astronomers got an idea about the wavelength range to look at. Horn antennas work very well in this wave length region, so most of the instruments looking for CMB use horn antenna arranged in different ways.

In this section we shall look at some of these instruments. These instruments do not look like conventional telescopes and produce fuzzy images such as the famous COBE image, but it is case of horses for courses and beauty is in the eye of beholder etc. These instruments will not be discussed in any particular order.

Horn Antenna

This was used by Penzias and Wilson. It is basically a truncated cone or pyramid (the horn) connected to a wave guide, another box at the smaller end and then electronics process the signal, it does not look like a very elegant piece of apparatus. The wavelength to be detected depends very critically on the dimension of the horn and the wave guide. The detection is highly directional, it is these characteristics of this humble device which allows design of horns of high sensitivity. Since the early days of Penzias and Wilson horn antennas have come of age.

Radiometer

This instrument is in Tenerife operated by the Jodrell Bank Observatory. The basic instrument consists of two horn antennas and two receivers. Each horn is separated by 8° and each looks at different directions in the sky. Each detector can look through either of the horns. This switching is done electronically. If the observed information is analysed directly, errors can creep into the measurement. These errors are mainly due to changes in the characteristics of the instrument, and emission from the background. In order to overcome this problem, the difference in the power received by the detectors is collected. The switching of the detectors is done 32 times a second.

The resolution is further improved by not pointing these horns directly at the sky. The horns look at the refection of the sky from reflecting aluminium panels. These panels are again oscillated by 8° sideways. All these procedures vastly reduce the background noise and makes the image very directional. The detectors operate below 20°K (-250°C). There are three sets of double antennas operating at 5, 10 and 15GHz.

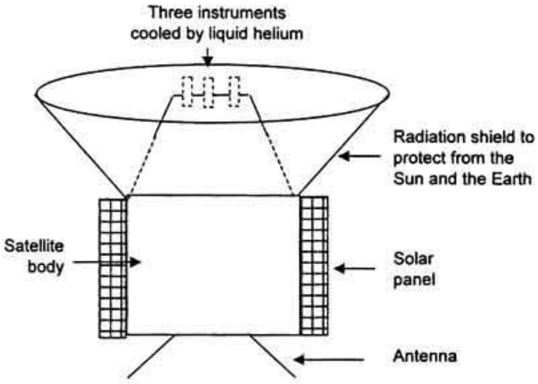
Cosmic Microwave Background Experiment

COBE, Fig.3 below, was the first attempt to produce a two dimensional map of the three dimensional temperature (microwave range) variation of the sky. It was a satellite born experiment carrying three instruments. The aim was to measure

i) the absolute microwave radiation,

ii) the angular distribution of radiation and

iii) the absolute magnitude of the Cosmic Infrared Background radiation in the range of 1.25 to 240 microns.



COBE set up

CIB gives an idea of the total infrared emission to date from the stars and galaxies since their birth.

It was flown at an altitude of 900km., this height is a compromise between a lower altitude were the results are affected by the residual atmosphere of the Earth and a higher altitude, were charged particles in the Earth's radiation belt interfere with the measurements.

The total weight of the satellite was 2,570kg. It had an orbital period of 103 min and orbited the Earth 14 times per day. The power consumption was 542W, provided from solar panels. The instruments were kept at 1.4°K, but inside the radiation shield the temperature was 180°K. The spacecraft was launched at the end of 1998 and within about six months, the liquid helium refrigerant ran out, but by then the sky had been surveyed 16 times. Some of the instruments still continued to operate even after this period.

It carried three instruments.

Far **I**nfrared **A**bsolute **S**pectrometer: **FIRAS** It compared the CMB radiation with a built-in standard black body. It used a set of flat mirrors and a beam splitter to compare the incoming radiation and that of the standard black body source. Its results showed that the CMB radiation follow the Black Body rule and the maximum energy corresponds to a temperature in the range of 2.7251° to 2.7249°K.

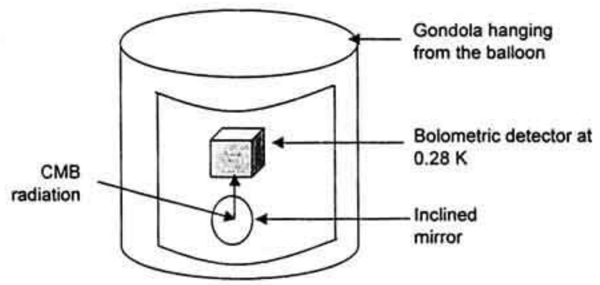
Differential **M**icrowave **R**adiometer: **DMR** At the heart of the instrument was six differential radiometers. Each radiometer measured the differential radiation from two portions of the sky separated by 60° by using horn antennas. The aim was to monitor the non-uniformity or distribution of the CMB radiation. The results indicated that the distribution is not smooth and there are fluctuations albeit at a very small scale, 1 in 100,000. These fluctuations were present before the birth of the galaxies and the process which caused these fluctuation, ultimately led to the clumping of the material and ultimately the galaxies or cluster of galaxies.

Diffuse **I**nfrared **B**ackground **E**xperiment: **DIRBE** This instrument measured the Cosmic Infrared Background. This gave some useful information on cumulative infrared emission of stars and galaxies since their origin. It used a three mirror fold way telescope.

The next two instruments to be discussed were based in Antarctica. Because of the reduction of ambient noise at lower temperature, a lot of electronic detectors used for detecting electromagnetic radiation at longer end of the wavelengths work better at lower temperatures. The low temperature in this context is cryogenic temperature and not the low temperature at Antarctica. But there are reasons for selecting choosing Antarctica as observation site. The observing is being done at very close to the Earth's axis. Hence the object could be observed for a long period.

There have been a few balloon borne detectors. These balloons can rise to about 37km. At such a height, the density atmosphere is about 0.3% of the ground level, so absorption by the atmosphere is relatively small. The balloon is under constant sunlight from above and also reflected from the snow or cloud. This helps to main a steady atmospheric temperature and hence the height of the balloon. The weather patterns, caused by solar heating of the stratosphere is very predictable in the Antarctic summer and helps the recovery of the balloon.

Balloon **O**bservation **O**f **M**illimetric **E**xtra-galactic **R**adiation and **G**eophysics: **BOOMERANG** Fig. 4, below was an attempt to try to observed the variation in CBM or anisotropies in it with finer resolution. The telescope system was kept in a gondola hanging from a balloon. During its flight, the balloon circumnavigated the Antarctic for 10.5 days at an altitude of 37km. It had about 35% better resolution than COBE. The 1.3m diameter mirror of the telescope focused the image up wards to the detector. This detector was kept the at centre of a gondola hanging from a balloon. The detector was kept cool to 0.28°K, by a liquid helium refrigerator. The telescope scanned repeatedly one area of the sky. Any stray light from the sun and the Earth was shielded from the detector.



Boomerang light path

The detector was of a bolomtetric type. In this detector micron size silicon nitride discs are arranged in a circular pattern. As the microwave radiation falls on these discs, their temperature rises and a germanium thermister measures the rise in temperature. The area of the sky covered was about 1800 square degrees, about 3% of the sky. The final result was a plot of the angular distribution of hot and cold spots of the background radiation.

Theory predicted that if the universe is

i) flat, i.e. parallel line remains parallel, the angular distribution should be of the order of 1°. On the other hand, if the universe is curved, the curvature of the space will distort the distribution of the hot and cold spots.

ii) If the universe is closed like a sphere, parallel lines merge, the distribution pattern will be larger than 1° and

iii) if the universe, i.e., space, is open, i.e., like a saddle, the parallel line diverge, the pattern will be smaller than 1°.

BOOMERANG results found the distribution of hot and cold spots are very close to 1°. Just to point out that the difference between the hot and cold region is of the order of 0.0001°C. BOOMERANG covered about 3% of the sky.

Degree **A**ngular **S**cale **I**nterferometer **DASI**

This instrument was set up in the Antarctica. It is a 13 element horn antenna interferometer. These are fixed on a face which can be rotated on its axis allowing one segment of the sky to be observed at different parallactic angles. This face plate could also be moved in altitude - azimuth mode. A mechanically driven polariser, oscillating at +/- 45° picked up polarisation. The detectors were cooled to 10°K. In order to cut down stray radiation, a ground shield was erected. The top portion of this shield could be removed to observe a test beam or other astronomical object. Precautions were also taken to eliminate the noise from the Sun. Theory predicts that the polarisation would be 1 part in a million. It is very small indeed, but the DASI team did succeed in detecting this polarisation. When the electromagnetic radiation, in our case the CBM radiation, strikes an electron, the electron re-emits the radiation, but this re-emitted beam is now polarised. The CMB radiation from the hot portion of the sky is more polarised than the cold region of the sky. The net effect is that there is residual polarisation when all the electric field is considered.

Now, if we consider the fact that this scattering of light by electrons happened during the last scattering epoch, i.e. the electron and radiation are free to go their own way and the electron can combine with nuclei to form neutral atoms. The CMB we see today comes from this period. Hence this polarisation data is useful information to verify the theoretical models such a how quickly the electrons and protons came together to form hydrogen atoms.

Polarisation can also throw light on another period called re-ionisation. As the majority of the intergalactic hydrogen is ionised, there are two possibilities.

1/ the very first set of stars born after the big bang produced ultraviolet rays and it ionised the hydrogen or: **2/** ultraviolet rays from the quasars in the early galaxies ionised the hydrogen. But this period happened so early on that it may be difficult to observe directly. However more refined polarisation observation can give some information on this period.

Very Small Array

The material content and the physical processes operating in the early universe, have caused unevenness or anisotropy in the CBM. VSA has attempted to plot the intensity distribution vs. angle directly. It looked at a 8° x 8° section of the sky in three directions and scanned to a resolution of 1/3°. This set up is run by the University of Cambridge, Jodrell Bank and the Institute of Astrophysics, Canaries Island.

It uses a bank of horn antennae arranged on a tilt table. These horns receive signals reflected from a paraboloid reflector or elements. Each reflector is 15cm across and looks like satellite TV antenna. The angle of tilt can be adjusted to look at the desired section of the sky. The output from a pair of horns is combined in an interferometric mode. The interference pattern corresponds to one point in the sky. This is called aperture synthesis and was originally developed in Cambridge. There are 14 elements and 91 pairs of horns. This means that the intensity vs. angle relationship can be measured very accurately. In order to reduce the effects of terrestrial background microwave, this assembly is kept surrounded by a metal shield. The detectors are kept at 15°K (-260°C). The observatory is at an altitude of 2.4km above sea level in Tenerife.

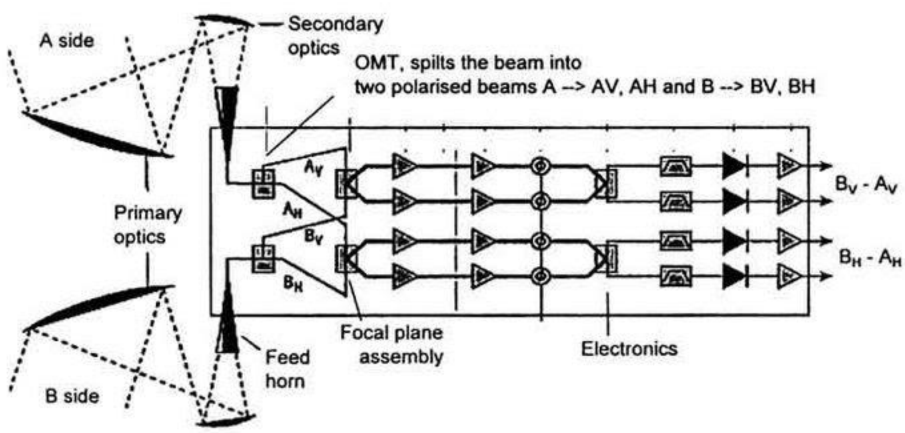
VSA is not the only instrument trying to measure the anisotropy. There are other instruments as well working on different modes. Each is trying to reduce unwanted noise. The interferometer mode of the VSA reduces the effects from radio galaxies and quasars.

Cosmic Anisotropy Telescope

It was operated by Cambridge using 3 antennas of 70 cm each mounted on a single turntable, which tacked the azimuth. But each antenna had its own elevation control. The signal was collected in interferometric mode. This arrangement allowed detection of polarisation as the field of view changed. In order to reduce background noise, the telescope was surrounded by a 5m earth bank lined with aluminium. Experience gained from this telescope was transferred to VSA at Tenerife.

Microwave Anisotropy Probe

Although observations at Antarctica allow circumpolar observation of half the sky, but for a coverage of the near full sky, a satellite born observatory is more useful. This is being attempted with NASA's MAP probe and also with higher resolution. The resolution of the COBE probe was about 7°, about 14 times the size of the moon. Since its launch this probe has been renamed as **W**ilkinson **M**icrowave **A**nisotropy **P**robe: **WMAP**. Fig 5 below,



Optical path of WMAP telescopse

Wilkinson was involved in the designing of earlier sensitive antenna with Dicke. In this probe the primary and the secondary mirrors form a Gregorian telescope. These mirrors are made from carbon fibre composite and are coated with aluminium and silicon oxide. At the focal plane there are feed horns, which operate in 5 frequencies. Signals from each frequency fall on a device called an Orthomode Transducer, OMT. This device detects polarisation and sends the signals on for further processing. The entire system is duplicated in side A and side B. For a given frequency, signals from side A are compared with that of side B. and processed for useful information. This type of instrument is called a radiometer. The MAP probe weighing about 850kg was put to the orbit at the second Lagrangian point, about 1.5x106km from the Earth in 2001. The instrument always collects data away from the Sun, the Earth and the Moon. The mission is expected to continue for a period of two years. The way MAP will plot the temperature plot is as follows. The difference in temperature, DT, as seen by side A and B respectively T(A) and T(B) is given by

DT = T(A) - T(B), therefore

T(A) = DT + T(B).

T(B) is an assumed figure from a previous survey and then with a process of iteration DT is determined. This computation process has an inherent error margin of less than 0.2×10^{-6}°K. This represents a very precise measurement considering the fact that a Galactic feature can introduce a peak brightness of 60×10^{-3}K. Stray radiation from the Earth and the sun are shielded from the detector. The very first set of results have recently been announced and some of the highlights are

a) The universe is about 13.7 billion (13.7×10^{12}) years old.

b) It is flat and is expanding.

c) Polarisation results suggest that the first stars began to appear when the universe was about 200 million years old.

d) The composition of the universe is about 4% visible, such as from people to galaxies, 23% dark matter, an illusive mass and 73% dark energy, which is causing the universe to expand. However a separate work suggests that the so-called dark matter in fact is baryonic or observable matter, but with very high energy and low density levels. We have not been looking for these properly and we need to develop new viewing methods.

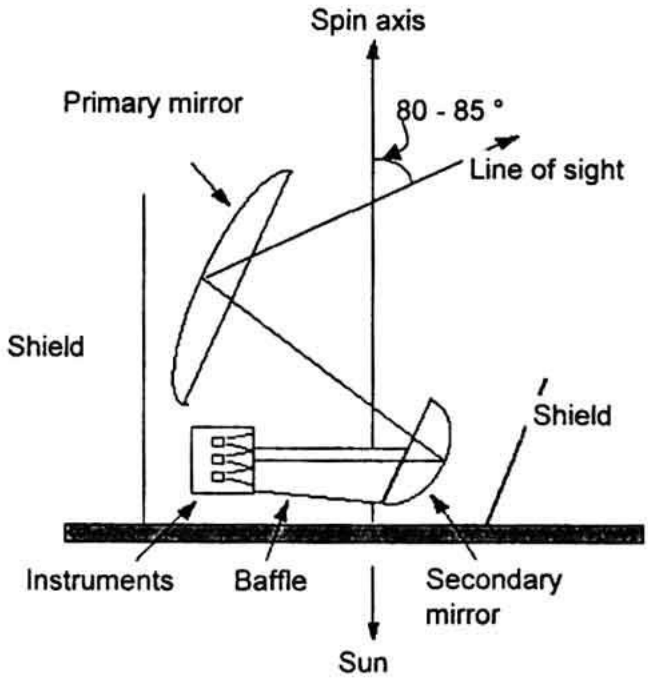
PLANCK

Planck is the next generation of instrument, an improvement on MAP, to be launched in 2007, together with the Far Infrared Telescope, Herschel. These two will separate and will take up different orbits. Let us have a few words about the shape of the universe. The majority of observations suggest that the universe is (nearly) flat and expanding. A piece of paper is flat; it can be finite now, but if it grows with time, in an infinite time it will be infinite in size. Now if we take this sheet of paper and roll it into a cylinder and join its ends to make a torus (doughnut. shape), the infinite piece of paper in the shape of a torus, becomes finite. The Universe could be either flat and infinite, or it could be finite like a torus. If we draw a triangle on the surface of a sphere, the sum of the angles will not be 180°, but it will be so for a torus, because its surface is flat, although it does not appear to be flat. Thus we can visualise the Universe to be flat and finite. However for certain, we do not know, if it is infinite.

If light is travelling on the surface of a torus, it can travel either along a straight line or it can take a spiral path on the surface. The geometry is somewhat complicated on the surface of a torus, but by examining the pattern of the travel of light we can get some idea about the geometry of the universe. If we can measure the time taken by the light originating in the Big Bang, we can get an idea about size of the torus (Universe), but if the Universe is infinite we shall not see the signal from the Big Bang and we can say that the Universe is larger than a given size.

Planck Telescope

It is an off axis tilted Gregorian type telescope. The advantage is that there is little dead spot and it is compact. The tilt of the mirror and layout gives a good quality image, at large focal plane minimum polarisation introduced by the telescope. And like any other instrument measuring CMB, the main instrument is protected by heat shield from stray radiation Fig. 6, below.



Layout of the Planck probe

The mirrors are made from a honeycomb like structure sandwiched between two carbon fibre skins. This has been made by winding carbon fibre on an aluminium mandrel and arranging these mandrels into a honeycomb like shape and then machined into shape.

The face of the mirror is made in a mould. A graphite block is machined and polished into shape. On this surface a coating like magnesium fluoride or silica is vapour deposited, then a layer aluminium. On this layer an epoxy resin is applied with carbon fibre in layers. Once dried the sandwich structure is lifted from the mould. The magnesium fluoride or silica layer protects the aluminium reflecting layer and allows the pre-flight testing of the system without the need of ultra clean room and the mirror would be given a clean prior to launch. The advantage of this system is that it is dimensionally stable, the structure is stiff. It is light and the overall thermal expansion is very low.

The main reflector mirror is an off axis paraboloid, 1.5 x 1.3m in size, with a focal length of 0.72m. The focal length of the telescope is 1.8m. The instruments consist of two groups of detectors; Low Frequency Instruments (LFI) and High Frequency Instruments (HFI). The LFI use horn antennae and electronic detectors, while the HFI uses bolometer type detectors. The HFI detectors are arranged at the focal plane of the instrument and the LFI form a ring around these HFI detectors. The LFI detectors are maintained around 20°K and the HFI are cooled to 0.1 - 0.15°K by the Joule - Thompson refrigerator principle i.e. the expansion of a compressed gas through a small orifice as in our household fridges. To obtain such a low temperature, these cooling units operate in series.

These are some of the instruments trying to find out the evolution of the universe. Since the signal strength is very low, corrections have to be made to eliminate interference from other sources. The sources of interference are terrestrial sources, the solar system, galactic and extra-galactic system. Different set ups use different methods of correction and also looking at different aspect of the process. Results from WMAP are coming in and these will be complimented by the higher resolution of PLANCK. As the resolution of the instruments improve, theories will be rigorously tested. In a recent meeting in the US, to discuss the WMAP results, the significance of the Inflation Model was raised again. There still remains a lot unknown, for example, the number of electrons and protons has been estimated with reasonable confidence, but the number of neutrinos are yet to be estimated. Although gravity is a weak force and, appears to dominate the universe, at quantum or atomic scale nuclear forces are far more powerful than gravitational forces.

If we want to look into the distant past of the universe, when things were very small, we need smaller and smaller wavelengths to resolve two events. When the energy of photon is about 1019 times the rest mass of the proton and if it is packed into space smaller than 1019 times the size of proton, it collapses into a black hole; all information is lost. This is the shortest distance one can measure and it is called Planck length. The time taken by light to cover the distance is 10-43 sec., and is the shortest time that could be measured. When the universe was this size, we are uncertain about the state of affairs and the role of gravity may not be negligible. Therefore will we ever find out everything about the universe and its story, or as Stephen Hawkins has recently said, perhaps some of it will remain unknown, but at least it will not be for lack of trying.

Acknowledgement. Thanks are due to Mark Edwards for comments

Further reading

The Big Bang, J Silk; W H Freeman, 2001

Just Six Numbers, M Rees, Weidenfeld and Nicolson, 1999

New Scientist, 5 April 2003

Astronomy Now, April 2003

http://lambda.gsfc.nasa.gov/index.html

http://www.jb.man.ac.uk

*http://astro.estec.esa.nl./planck/technica*l

Astronomical Pop Quiz 3 - The Answers

By Mike Frost

How well did you do in the Astronomical Pop Quiz 3, which was in the last issue of MIRA, No 64? For those folk who are not sure of the answers to the questions, here they are.

Round 1:

1. Orchestral Manoeuvres in the Dark (OMD)
2. Smash Mouth
3. Jamiroquai
4. Sheila B Devotion
5. Inspiral Carpets
6. Babylon Zoo
7. Madonna
8. Dean Friedman
9. Ash
10. Train
11. ELO
12. The Waterboys
13. Jonathan King

Round 2:

1. Carly Simon - "You're So Vain"
2. Paul Simon - "The Boy in the Bubble"
3. Lightning Seeds - "Pure"
4. Pink Floyd - "Astronomy Domine"
5. Blur - "Far Out"
6. Gerri Halliwell - "Bag it Up"
7. Stevie Wonder - ":I just called to say I love you"
8. Paul Simon - "Old"

Round 3:

1. Robbie Williams - "Millennium"
2. Dion and the Belmonts - "Teenager in Love"
3. Abba - "Summer Night City"

Round 4:

1. Spiritualized - Jason Pierce - from Rugby
2. Sting
3. Linkin Park
4. Beatles
5. Paul Simon
6. Pink Floyd
7. The Byrds
8. Frank Sinatra (and many others)
9. Oasis

CONGRATULATIONS TO ANYONE WHO GOT MORE THAN 50% CORRECT

If you can devise a astronomical quiz which to puzzle the members then please let me have it for MIRA