Sagittarius

40th Anniversary Year

The Newsletter of the Astronomy Section of La Société Guernesiaise

October – December 2012

Forthcoming Events

Public Open Evening

(note Monday)

22nd October: 6.30 pm

Astronomy Section Christmas Meal

Tuesday, 4th December: 8.00 pm
(venue to be confirmed)

Section meets at the Observatory every Tuesday evening at 8.00 pm

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Star chart

Sunset, sunrise, moonset and moonrise times

Half a Century of Astronomy

This year the Astronomy Section of La Societe Guernesiaise celebrated its 40th anniversary. We have been fortunate that during those four decades, astronomers have been living in what could be called a 'Golden Age' of astronomy, which began in the years immediately following the Second World War.

'Pre-War' Astronomy

This account begins with a brief review of the state of astronomy as it was before the Second World War (WWII). For several centuries, astronomy was essentially 'optical astronomy', using telescopes that augment the power of the human eye but are sensitive to the same type of radiation. The International Year of Astronomy in 2009 commemorated the achievements of Galileo, who in 1609 used his newly invented telescope to examine celestial objects such as the Moon and Jupiter. Telescopes of larger size were subsequently constructed. A telescope with a wider aperture (whether of lens or mirror) has greater light-gathering power, and can therefore see fainter objects; it also has the ability to reveal greater detail in the images produced. With the 100-inch telescope on Mount Wilson it was possible to discover a vast array of stars and nebulae, which together made up one great cosmic system, the Galaxy, seen from Earth as the Milky Way.

For some time, the Galaxy was assumed to be the whole Universe. Further observations, however, showed that some of the nebulae were too distant to be within the Galaxy, the size of which had already been estimated; these 'extragalactic nebulae' it was concluded could be other galaxies, similar to our own. During the 1920's, Hubble made a systematic study of these nebulae, by then more clearly identified as 'external galaxies', and made a significant discovery: he found that, as indicated by the redshift of their emitted light, they appeared to be receding from us with a speed that was proportional to their distance, a conclusion that came to be known as 'Hubble's Law'. This remarkable result gave rise to the concept of 'The Expanding Universe'.

Meanwhile, the technology of telescope construction proceeded apace, with the building on Mount Palomar of the 200 inch telescope, eventually to be finished in 1954.

That is how the science of astronomy stood in the years immediately before WWII.

Radio Astronomy

It had been realised for a long time that visible radiation is only a small part of a wider spectrum of electromagnetic radiation, ranging from radio waves (with a wavelength greater than ten thousand times visible wavelengths) to X-rays (with a wavelength less than a thousandth of the visible). The Earth's atmosphere is partially or completely opaque to much of the radiation spectrum; but it is transparent to the visible region of the spectrum, and also to the radio region. WWII was mainly responsible for providing the technology which could later be adapted to exploring radio sources in astronomy, and also sources of other forms of radiation on the shorter-wavelength side of the visible. It was this development that enabled astronomy to enter its 'Golden Age'.

Radio astronomy has a much shorter history than optical astronomy, but it is a most distinguished one. Radio telescopes are, because of the much greater wavelength of radio compared with visible radiation, on a much larger scale than optical telescopes; their dimensions can be impressive, and the problems associated with their construction can be formidable. The giant Mark I Telescope at Jodrell Bank in Cheshire has a dish reflector 76 m in diameter; it is now known as the Lovell Telescope, in recognition of Sir Bernard Lovell, who founded the research station there. At Cambridge, Sir Martin Ryle and his colleagues inspired the building of a linear array of much smaller radio dishes, extending over several kilometres. Single large radio dishes were also built at Parkes in New South Wales and Arecibo in Puerto Rico, at about the same time.

Radio sources discovered in radio astronomy are of several different kinds: there are supernova remnants; there are normal galaxies such as our own, and of which the Andromeda Galaxy is an example; and then there are 'active galaxies' displaying very energetic phenomena such as the radio galaxy 'Cygnus A' (see Figure 1). The sources discovered in the survey

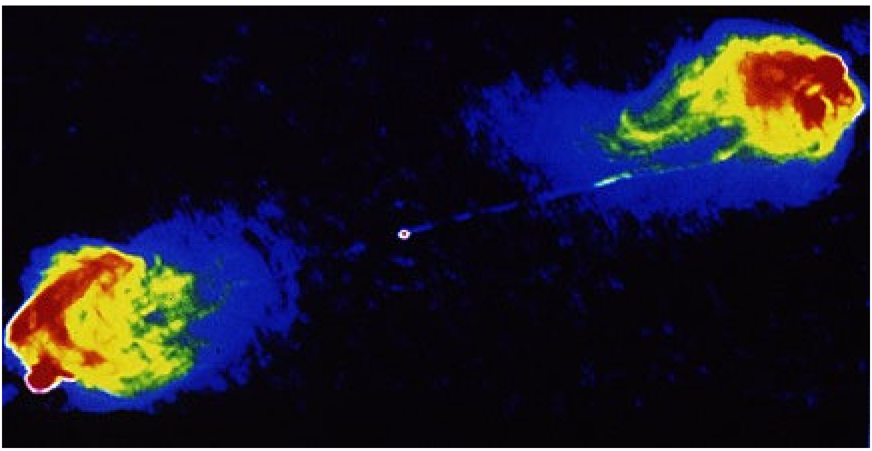

Figure 1 Radio Galaxy "Cygnus A",showing contours of radio "brightness". Note small image, at centre, of galactic nucleus.

with the Cambridge radio telescope are listed in a comprehensive catalogue; the most often quoted being the 3C catalogue, where sources are listed by number, e.g. 3C273.

Cosmology: 'The Big Bang'

The Cambridge survey, during the late 1950's, was of great importance in resolving a fundamental problem in cosmology, which is the study of the whole Universe as a single physical system. For several decades following the discovery of the expansion of the Universe, there were two opposing theories to explain its evolution. One was that the Universe began in a single event, later called 'The Big Bang', which occurred in a small region of space at a particular moment of time, calculated from the measured universal expansion rate to have been about 15 billion years ago. The alternative theory, which avoided the idea of a moment of creation, was the 'Steady State' theory. According to this theory, devised by Hoyle, Bondi and Gold, the expansion of the Universe is accompanied by the continuous creation of matter in space, which exactly compensates for the general dilution of matter caused by the expansion process. On the 'Steady State' theory, the Universe should always appear the same.

It was radio astronomy that was able to decide between these two theories, 'Big Bang' or 'Steady State'. The essential argument upon which the crucial observations were based may be set out as follows: (1) galaxies may be assumed to be fundamentally similar, wherever they are in the universe; (2) if a galaxy appears fainter than another then it is simply because it is farther away from the observer; and (3) if it is farther away then, because of the finite speed of light, it is being observed further back in time. What the Cambridge radio astronomers discovered was that they observed too many faint galaxies for these to form a uniform population in space and time. In other words, the Universe was different in the remote past from what it is at present, and was therefore definitely not in a 'Steady State'. The concept of a cosmic 'Big Bang', although difficult to accept at first, therefore provided a better description of the observable Universe.

It was not long before observatories, from a different and quite unexpected quarter, gave further support to the 'Big Bang' theory. If the Universe began by expanding from a very small volume, but with great energy consistent with the energy evident in its expansion, then it would be reasonable to assume that it was initially in a very hot, as well as a very dense, state. High-temperature radiation in equilibrium with matter in this initial state could be expected to cool as the Universe expanded, and could perhaps be detectable at the present epoch. Cosmological theory based on the rate of expansion, as determined by Hubble, suggested that the temperature of the radiation after a million years should be about 3,000 K; and that at the present epoch it should have cooled to a temperature for which the characteristic wavelength should be about 2 mm, that is, it should be detectable in the microwave region of the spectrum. In 1965, this 'cosmic background radiation' was discovered by Penzias and Wilson; it was subsequently shown to have the right spectral characteristics for thermal radiation. With this discovery, the 'Big Bang' theory became generally accepted. It can now confidently be described as one of the most significant advances made by astronomy in the twentieth century.

Quasars and Pulsars

Other important discoveries were also made in radio astronomy. One of the most exciting was that of 'quasars', or 'quasi-stellar radio sources' which, although they were comparable to whole galaxies in their apparent radio 'brightness', resembled stellar sources more in their apparent size. Subsequent observations with optical telescopes, notably of the quasar 3C273 by Schmidt in 1963, with the 200-inch telescope, revealed redshifts that indicated very great distances, and therefore great intrinsic power. It is now believed that quasars represent a species of Seyfert galaxy, a type of active galaxy having a very bright and concentrated central region ('nucleus'): quasars could be the bright nuclei of Seyfert galaxies so distant that their outer structure is too faint to be seen.

Another exciting discovery in radio astronomy, made in 1967 by Hewish and Bell at Cambridge, was that of 'pulsars'. Pulsars produce regular pulses of radio emission, so regular in fact that initially it was thought that the pulses could be signals sent out by some alien intelligence. The first observed pulsar, which produced pulses at a regular interval (period) of 1.337s, was referred to as LGM1, with the letters standing for Little Green Men (!). A whole series of such sources were discovered, with periods ranging from 4 s to as little as 0.006 s. Pulsars are thought to be radio sources produced by rotating neutron stars. A neutron star can be formed in a supernova event, which occurs when a massive star, at the end of its lifetime, becomes unstable and implodes catastrophically; the production of the neutrons forming the star accompanied by the production of neutrinos. Neutron stars are very dense, with one solar mass of material being concentrated in a space of only about 10 km in diameter. They can also be in a state of high-speed rotation, which means that any beams of radiation emitted can appear as regular 'flashes' when intercepted by an observer, with the effect being similar to that produced by the rotating beam of a lighthouse.

New Branches of Astronomy

In the sources studied in radio astronomy, the radiation is produced by electrons circulating in magnetic fields and is usually termed synchrotron (non-thermal) radiation. Across the whole of the remaining part of the spectrum, however, the radiation from the sources that are studied in astronomy is usually thermal radiation, as emitted by gases and plasmas at a whole range of temperatures; the temperature defines the characteristic wavelength of the radiation, and therefore the region of the spectrum in which the radiation is emitted. Table 1 below shows the ranges of temperature appropriate to the different types of radiation, with each type now being associated with a different branch of astronomy.

Temperature / K	**Type of radiation (region of spectrum)**
100	
1,000	Infrared (IR)
10,000	Visible
100,000	Ultraviolet (UV)
1,000,000	
10,000,000	X-ray
100,000,000	

Infrared radiation lies in the region of the spectrum between the radio and the visible. Infrared sources in astronomy can be studied using techniques adapted from those used in optical astronomy. Because the Earth's atmosphere is partially opaque to most infrared wavelengths, infrared telescopes are usually sited at high altitudes, and the first ones to be used were mounted on high-flying aircraft. Current observational facilities include the UK Infrared Telescope (UKIRT) at 4200 m altitude on Mauna Kea in Hawaii; and on a nearby site is the James Clerk Maxwell Telescope (JCMT), with its 15 m diameter dish reflector.

Some of the most interesting infrared sources are gaseous nebulae consisting of hydrogen, and also more complex molecules, where stars are being formed: the gas heats up as it condenses, to form protostars which then evolve to become stars generating their own energy.

There are challenges to be overcome in the (shorter wavelength / higher frequency) part of the spectrum beyond the visible lie the ultraviolet and X-ray regions. To study sources emitting these types of radiation, which are so seriously obscured by the Earth's atmosphere, requires observation from extreme altitudes. Following the launch of 'Sputnik' in 1957, and the birth of the 'Space Age', it became possible for astronomers to employ satellite-borne instrumentation, making accessible whole new fields of astronomy. The most successful of the satellites dedicated to the exploration of UV sources was the International Ultraviolet Explorer (IUE) launched by NASA in 1978, and which provided a wealth of observational data during the whole decade when it was in orbit. In UV astronomy, many of the sources observed are stars with surface temperatures greatly exceeding that of the Sun (5800K), so this branch of astronomy is able to reveal a whole new component of the stellar population, including massive stars in the early phases of their evolution.

X-ray astronomy, which was first attempted by employing rocket-borne detectors, also benefitted greatly from satellite technology. X-ray satellites, first launched in 1978, have included EXOSAT, the Einstein Observatory and ROSAT (named in honour of Rontgen, the discoverer of X-rays). Some X-ray sources observed are supernova remnants, where plasma ejected in a supernova event interacts with the surrounding interstellar gas, heating it up to a high temperature at which it can radiate X-rays (see Table 1). The production of X-radiation has also been observed in high-temperature plasma in galactic clusters, originating in the spaces between the galaxies.

Black Holes

Perhaps the most interesting type of X-ray source is produced in a particular type of binary-star system by a process of accretion, in which gaseous material from the extended atmosphere of one star in the binary falls on to a compact companion star, generating a high-temperature plasma at the compact-star surface. If the star is sufficiently compact, it can exist in the form of a black hole, which can be identified from a study of the dynamics of the binary. The first stellar-mass black hole to be identified in this way is the star associated with the X-ray source Cygnus X-1.

The nuclei at the centres of galaxies may contain 'supermassive' black holes, with masses a million or more times that of the Sun, and which produce powerful sources of X and other radiation as a result of interacting with their gaseous surroundings. It has been suggested, by a study of a complex of infrared sources related to the radio source Sagittarius A* at the centre of our Galaxy, that a black hole of mass 2.6 million times the mass of the Sun may exist there. The Seyfert galaxy NGC 4151 (see Figure 2) may contain a black hole of even greater mass, a hundred million times the solar mass. If quasars are indeed the bright nuclei of distant Seyfert galaxies, then the powerful radiation emission characteristic of quasars could also be attributed to supermassive black holes contained within them.

Figure 2. Seyfert Galaxies: NGC 1068 / M77 (left) and NGC 4151 (right)

Satellite-based astronomy: IRAS, COBE and HST

Most branches of astronomy can benefit from satellite-based observatories, because the Earth's atmosphere is bound to be a hindrance, to some extent. There are several other projects worthy of mention here. The first is the infrared satellite IRAS, launched in 1983, which provided a mass of data from sources of radiation in the far-infrared part of the spectrum (adjacent to the radio) which would not have been accessible by ground-based telescopes. IRAS was succeeded in space by ISO (the Infrared Space Observatory).

A satellite which made a great contribution to cosmology was the Cosmic Background Explorer (COBE), launched in 1989; it was able to make a detailed scan of radiation over a wide range, and including the microwave region, of the spectrum. COBE was able to confirm that the background radiation did indeed have a thermal spectrum, with a temperature precisely determined to be 2.74K; it also showed that the radiation is isotropic (that is, uniformly the same from all directions in space), thus confirming its cosmic origin. It has been said that the discovery of the cosmic background radiation had a significance for cosmology as great as that of Hubble's discovery of the expansion of the Universe.

Perhaps the space-satellite that has had the widest appreciation in astronomy is the Hubble Space Telescope (HST), which over the period 1990-2010 produced remarkable images, catching the public imagination with their appearance, not only in the amateur-astronomy journals, but even in the national newspapers.

Particle Astronomy: Cosmic Rays

Coming down to Earth, as it were, these are some new branches of astronomy that can be pursued at ground level (or sometimes even below that), and that do not depend on observation with any kind of radiation. Particles, as well as radiation, can carry information about the Universe and are studied in 'particle astronomy'.

'Cosmic radiation' is not radiation at all, but consists of particles which continuously rain down upon the Earth, uniformly from all directions in space. Cosmic rays are actually high-energy atomic nuclei, and they carry a total amount of energy that is as much as that received in the form of starlight from all the stars visible in the heavens. Their origin was for many years a mystery, but it is now believed that it could be related to pulsars, where conditions appear to be suitable for the acceleration of charged particles to high energies. The mechanism for the acceleration is, however, unknown; one distinguished researcher in the field has commented that "the ingredients are there … but the recipe evades us".

Ultra-high-energy cosmic rays (UHCR's), which can have an energy per particle up to a million times the particle energy attained in the Large Hadron Collider at CERN, could originate in 'active galaxies'; they could be produced in some currently unknown acceleration process related to the supermassive black holes that are believed to exist there.

Neutrino Astronomy

The other particles that have considerable relevance in astronomy are neutrinos. It is generally accepted that the nuclear fusion of light elements, specifically helium from hydrogen in a series of nuclear reactions, is the basic process that generates energy in the solar interior. Neutrinos are one product of these nuclear reactions, so the observation of solar neutrinos can provide a direct check on the nuclear fusion theory. Neutrinos have a very weak interaction with matter, so neutrino detectors can be sited underground, to screen them from cosmic rays and other possible forms of background noise from space. Unfortunately, neutrinos also interact weakly with neutrino-detecting apparatus; but over a period of several years a sufficient number of neutrinos have been recorded to allow certain conclusions to be drawn. It has been concluded from these neutrino-detection records that there is good evidence for the emission of neutrinos from the Sun; but it is at a level lower that expected, so that further research has to be carried out to explain the discrepancy between their theoretical rate of production and their observed rate of detection at Earth.

Only very rarely has a supernova actually been observed to occur. Tycho Brahe had witnessed one such astronomical event in 1572, and Johannes Kepler another in 1604. Four hundred years later, in 1987, a supernova in the Large Magellanic Cloud (LMC) was observed by Shelton from Las Campanas Observatory in Chile. It was an historic event because it was the first to be studied using modern astronomical observation techniques. SN1987A, as it was called, had occurred in a blue supergiant star of about 20 solar masses; it had observed characteristics that were in good agreement with those theoretically predicted for that type of supernova (Type II). What was most remarkable, however, was that the visible event observed by astronomers with optical telescopes was preceded by a burst of neutrinos which was detected at a number of different locations around the world. A typical neutrino-burst event was about 12 seconds in duration, recorded about 3 hours before the visible supernova appeared. From the measured flux of neutrinos at Earth it could be estimated that at the source of SN1978A in the LMC, which is at a distance of 166,000 light years, most of the prodigious amount of energy produced in the supernova would have been carried away, not by the light emitted, but by the neutrinos.

Postscript

This review of 'Half a Century of Astronomy' was intended to cover the period from the early post-war years until the end of the millennium, but there seems to be no end in sight to the 'Golden Age' of astronomy.

In science generally, nature has taught us the lesson that our knowledge of the world around us is always incomplete. Perhaps it is in astronomy, where we make our acquaintances with the apparently limitless Universe and its wonders, that this lesson is best illustrated. Whatever our state of knowledge at any time may be, there is one thing that we can know for certain: this is that in the future, the Universe will always have many more surprises in store for us.

David Falla

Geoff Falla's regular roundup of articles from popular Astronomy and Space Journals

Possible Travel to the Stars. The idea of travel to other stars has always seemed to be science fiction, with the Alpha Centauri system more than four light years away. It is now thought feasible to plan a visit to the system, by using more advanced technology. The journey would take many years, at a high proportion of the speed of light, but the time taken by the astronauts could be much reduced by a time dilation effect. (Astronomy, July 2012)

Dark Energy's New Face. The study of supernova explosions is helping astronomers to learn more about what causes them, and how uniform they are, which should improve the understanding of "dark energy" in the expansion of the universe. (Astronomy, July 2012)

White Dwarfs - the Afterlife of Stars. A set of articles focusing on White dwarf stars. The process of a dying star is explained, through the red giant stage and as a planetary nebula to a small dwarf star. It is also thought that dust clouds in space may come from explosive white dwarfs - and the possibility that planets may also exist in orbit around these stars. (Astronomy Now, July 2012)

Misfit Stars. Since the first discoveries were confirmed in 1995, there are now reckoned to be as many brown dwarf stars or "failed stars", as there are conventional stars. Infrared observations including the WISE wide field survey mission have confirmed that these previously unknown forms are relatively cool and are typically about the size of Jupiter. (Astronomy Now, July 2012)

The Universe in Supercomputer Modelling. The use of supercomputers is now allowing cosmologists to understand the composition, structure and evolution of the universe, with simulations and prediction processes which can be tested by observations of the real universe. (Sky and Telescope, July 2012)

The Quest for Totality. The experiences of travellers crossing the globe to view solar eclipses, with visits to China, Africa, South America, and to the Antarctic - where the first solar eclipse to be viewed from there was seen in 2003. (Sky and Telescope, July 2012)

Will Curiosity find Life on Mars? The latest robotic mission to be sent to Mars landed at Gale crater on August 6th. This heaviest and most advanced spacecraft "Curiosity" will analyse rock and soil composition, and will help to determine if there is evidence of past or present life on Mars. (Astronomy, August 2012)

How Twin Rovers found Water on Mars. A detailed summary of the Mars rovers; Spirit and Opportunity which landed on the planet in 2004, with significant findings including the discovery of carbonate minerals left by water, and with the Opportunity rover still returning information. (Astronomy, August 2012)

Curiosity on Mars, and planned European Mission. This is a set of articles focusing on the complex procedures of the successful landing, the aims of the mission, and a look forward to a European rover mission. (Astronomy Now, August 2012)

How the Universe found its Mass. It was recently announced that a new particle has been discovered by physicists at CERN, using the Large Hadron Collider. If further tests confirm that the discovery is the long-sought Higgs Boson particle, as expected, what will this mean for our understanding of the universe? (Astronomy Now, August 2012)

Quest for the Most Distant objects. Since the discovery of the Big Bang, it has been known that the universe has evolved from a beginning more than 13 billion years ago. A new generation of telescopes will now give astronomers the ability to look even further back in space and time to an earlier stage in its evolution. (Astronomy, September 2012)

Black Holes in the Milky Way. Black holes are found to be the most astonishing objects in the universe, and it is now known that there are many of these objects in our own Milky Way galaxy. (Astronomy, September 2012)

Plans for UK's Hawaii telescopes to be decommissioned. It has been announced that two mainstays of UK astronomy at its base in Hawaii, the UKIRT infrared 3.8 metre telescope and the James Clerk Maxwell sub-millimetre wavelength telescope for charting starbirth and the evolution of galaxies, may be decommissioned in the next year or so, as a result of an agreement to concentrate more resources on the European facilities in Chile. (Astronomy Now, September 2012)

The Formation and Growth of Galaxies. This is a set of articles focusing on the process of galaxy formation during the early history of the universe, also the structure of galaxies, and how they have grown since their formation. (Astronomy Now, September 2012)

Storm Chasing in the Solar System. Extreme weather is experienced on our own planet in the form of hurricanes and tornadoes, but there are similar disturbed conditions elsewhere in the solar system, with the dust storms and whirlwinds of Mars, the permanent "storm" of the Great Red Spot on Jupiter, and major electrical activity in Saturn's atmosphere.
(Sky and Telescope, September 2012)

Close-up Views of Dwarf planet Vesta. Dramatic views of Vesta have been obtained by NASA's DAWN spacecraft, showing remarkable features including a huge mountain, almost as high as Olympus Mons on Mars, within impact basins in the south polar region. (Sky and Telescope, September 2012)

New Meteor Showers discovered. Networks of low-light video cameras are now being used to identify or confirm meteor showers. As a result, some additional ones have been found, in particular during the first week of December, when more than a dozen meteor showers and their radiants are now known. (Sky and Telescope, September 2012.)

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