Radio Astronomy for Amateurs

Andrew Thomas
artwork@silverbirch/me.uk

Andrew Thomas delves into the fascinating history and scope of amateur radio astronomy, suggests some projects that you can engage with and profiles the United Kingdom Amateur Radio Astronomy Association (UKRAA).

Astronomy is a popular hobby and often in the public eye. Spectacular discoveries make international news and popular science programmes on television and radio attract large prime time audiences, just think of Brian Cox on the BBC.

Astronomy is also one of the sciences where amateur observers can still make valuable contributions to our knowledge. An initiative such as *Zooniverse* enables citizen-scientists to participate in real cutting-edge science by classifying data and images.

A team of advanced amateur astronomical imagers collaborated with NASA to plan some observation targets for the JOVE mission to Jupiter.
www.zooniverse.org

Amateur astronomy is predominantly associated with visual observing. Observers use a telescope to observe stars planets and other celestial objects by eye or camera.

However, the light we can see is only part of the total electromagnetic radiation present in the universe. We tend to think it is the most important part simply because we can see it (Fig. 1).

The first person to find invisible radiation was William Herschel in 1800 when he detected infrared light while studying the Sun's spectrum. Observers had to wait for over 130 years for the next window on the universe to open. That opening required the development of a new theory of electromagnetism by James Clerk Maxwell in 1865 and the development of radio by Marconi and many others in the early 20th Century.

The Beginnings

In 1932, Carl Jansky (1905-1950) of Bell Telephone Laboratories in New Jersey was tasked with investigating the background noise which was affecting the long-distance radio links being developed at that time. He mapped the direction this noise came from and noticed that the strongest source moved across the sky at the same rate as the stars.

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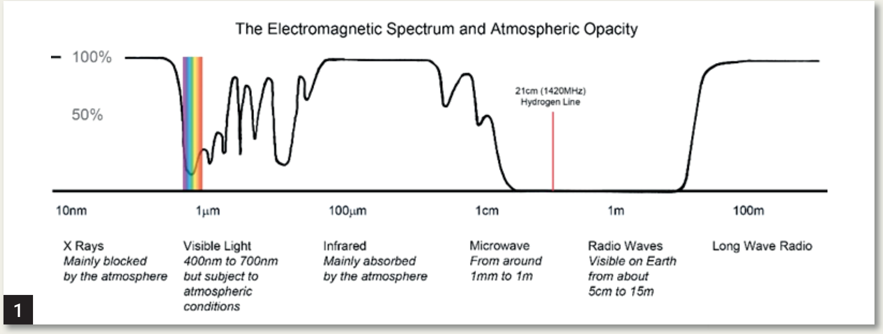

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This phenomenon was dubbed 'cosmic radio waves' in papers for the Institute of Radio Engineers. At the time astronomers took little notice and Jansky moved on to other engineering problems.

At the urging of Bernard Lovell (1913-2012) the UK invested in radio astronomy research. Jodrell Bank's first telescope was built in the 1950s and became a UNESCO World Heritage site in 2019. Since the 1950s radio observations have become a core part of astronomy and led to major discoveries.

Recently an international collaboration combined multiple radio telescopes to form the Event Horizon Telescope equivalent to the size of the Earth. This produced the first image of a black hole (Fig. 3).

Visual observers start using their eyes, and the best next step is to use binoculars to see objects in more detail. Those who become more enthusiastic often move on to a small telescope, and a small number eventually grow into an observatory with complex telescopes and camera equipment.

Beyond Limitations

However, all visual observers suffer from the weather; clear skies are needed. Those in urban areas are limited by light pollution from streetlights, security lights, car lights, and so on.

And the best views of the northern skies are often on cold, clear nights in the depth of winter.

By contrast, radio astronomy is not dependent on clear skies, can be carried out in the daytime and does not involve going out in the cold. I found this is an extremely attractive proposition.

There are several 'entry-level' projects. Some more advanced observers have erected radio dishes able to observe the motion of our galaxy, the Milky Way, and even the flash of pulsars. I am not that advanced an observer, but I have found it fascinating and along the road, I have learnt about radio equipment, electronics, and computers. I even learnt how to write Python computer code.

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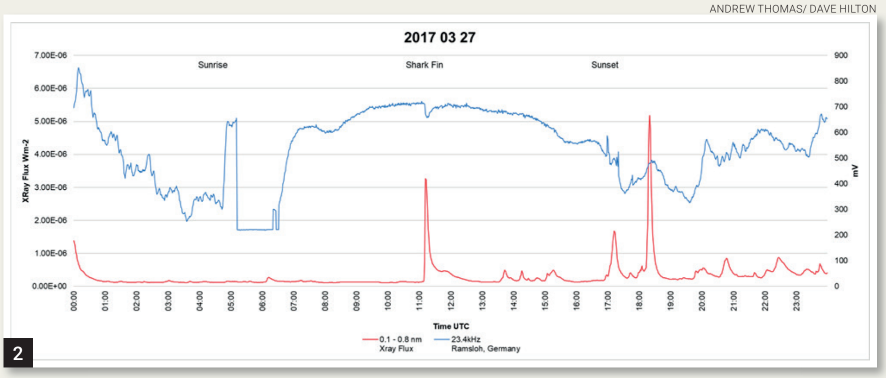

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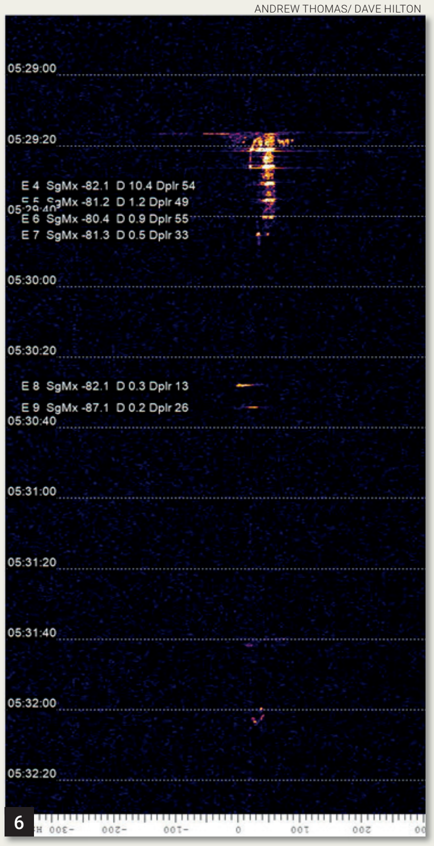

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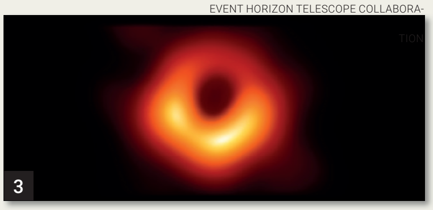
EVENT HORIZON TELESCOPE COLLABORATION



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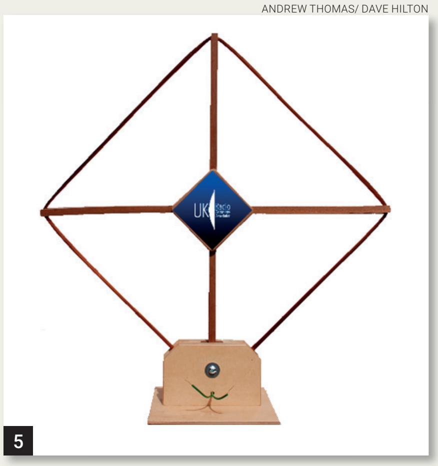

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Fig.1: The Electromagnetic (EM) Spectrum detailing radio wavelengths. Fig. 2: VLF signal (blue) showing a SID 'shark fin'. The orange trace shows a spike in solar X-rays measured by NASA's GOES satellite. Fig. 3: The first image of a black hole, at the centre of the galaxy M87. Fig. 4: A homemade aerial for meteor echo reception. Fig. 5: The UKRAA VLF loop aerial. Fig. 6: Meteor Echoes. There is a large echo here, as well as several less pronounced ones from smaller meteors.

Chasing Meteors

The first experimental observations made at Jodrell Bank were of meteors using a war surplus radar set and receivers. Fortunately, this has become much simpler to do and no longer requires your own radar set. When a meteor burns up in the atmosphere it leaves a trail of hot ionised gas in its wake. It is this gas which reflects radio waves, the meteor itself is far too small, most are the size of a grain of sand. When a meteor passes between the transmitter and receiver, the ionised trail reflects the radio signal, and this increases the strength of the received radio transmission.

The French government has kindly provided a powerful radar system, which is ideal for detecting meteors. Its real purpose is to monitor satellites and space junk. The transmitter is called GRAVES and is located near Dijon transmitting at 143.05MHz. There is another beacon called BRAMS in Belgium which is dedicated as a meteor scatter detector and this operates at 49.97Mhz or just under 50Mhz.

The reflected signals can be easily received in the UK (Fig. 4). Receiving them requires an antenna, a radio receiver, and a computer. I built an antenna out of wood and copper water pipe and simply placed it on the shed roof for use.

The simplest way to receive the signal is to use a Software Defined Radio, which is a radio receiver directly controlled by a computer. These are inexpensive but very versatile and useful devices for amateur radio astronomers.

On top of this, I use *Spectrum Lab* to display the signals echoed back from the meteor (Fig. 5).

Spectrum Lab is free to download, and only the SDR and some cables need to be purchased.

www.qsl.net/dl4yhf/spectra1.html

This can be a low-cost DIY project and a good introduction to astronomy and observing meteors.

One interesting observation I made in the past was of the *Perseid* Meteor shower. By recording over several days, I was able to see the number of meteors increasing toward a peak around the 14^{th} August 2018.

Solar Flares

The brightest object in the sky is the Sun, both visually and at radio frequencies. Solar activity directly affects the Earth, solar flares can interfere with radio signals and satellites, and magnetic storms cause the aurora and can disrupt electrical supply systems. Forecasting 'space weather' has become an important branch of science.

The US National Oceanic and Atmospheric Administration (NOAA) website, for example, offers space weather forecasts and plenty of background information.

www.swpc.noaa.gov

Sudden Ionic Disturbances, known as SIDs, are caused by the X-rays emitted from solar flares changing the ionosphere at an altitude around 70km. The Earth's ionosphere is highly effective in protecting us from these X-rays by absorbing them at this altitude.

This changes the way radio waves travel around the Earth and these changes in the signals show when a solar flare occurs.

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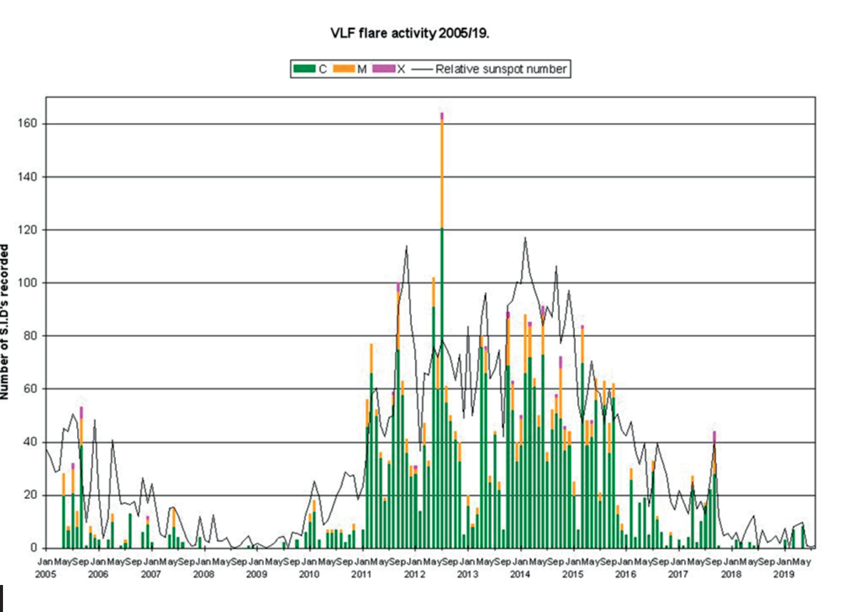

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Fig. 7: SIDs record 2005-2019 showing the solar cycle. Fig. 8: A dish antenna under construction. Fig. 9: This is a suitable radio astronomy primer for the layperson. Fig. 10: This book (and the one by Arnold, 2021) offer easy projects you can build. Fig. 11: This is the latest addition to the Radio Astronomy hobby literature.

I monitor a radio station in Ramsloh in Germany which transmits at 23.4Khz, using a UKRAA loop aerial (Fig. 6).

During a typical day, a slowly-changing signal is received between sunrise and sunset. When a solar flare occurs, there is a sudden change in the signal which looks like a 'shark's fin' (Fig. 3).

The orange trace in Fig. 6 reveals the strength of the solar X-rays measured by NASA's GOES satellite. The spike in X-rays emitted by a solar flare can be seen at just after 11:00. There was an even larger spike at approximately 18:30, which did not cause a SID. This is because it occurred after the Sun had set.

The X-rays were invisible over the UK and Germany and did not affect the ionosphere.

The British Astronomical Association (BAA) Radio Astronomy Section collates the observations from a group of observers and produces a graph of the numbers of SIDs recorded each year. The records for the last 15 years show that the frequency of SIDs follows the 11-year solar sunspot cycle (Fig. 7).

The year 2020 marked the start of a new solar cycle, and so the Sun is currently quiet. Over the next 5 years, the Sun will become increasingly active with more flares and SIDs to record.

Studying the ionosphere and radio propagation remains important to radio amateurs and hobbyists. The VLF signals used to detect SIDs are used by various governments to communicate with submerged submarines and short wave is used for long-distance secure communications as a backup to satellites links.

The two examples described are both projects I have built, and which I contribute regular SIDs observations to the BAA. Neither project needs much more than enthusiasm and a small amount of space in either the house or garden.

Advanced Projects

There are, however, some amateurs who are much more ambitious (Fig. 8): They have built larger telescopes and can observe our Milky Way galaxy in detail. By receiving the 21cm radio signal from Hydrogen molecules in the gas clouds between the stars they have been able to map the shape of the Galaxy and measure its rotation.

At the frontier of amateur radio astronomy, a small group of advanced observers can detect pulsars. This is a major technical achievement with a home installation.

Throughout the Galaxy hydrogen exists in atomic form and, in extremely rare events, an electron can change state emitting energy. When an electron, with a spin that is parallel to the nucleus spin, suddenly 'flips', so that the electron and nucleus are spinning in opposition, this causes the emission of a photon of energy with a frequency of approximately 1420MHz, a wavelength of 21cm. Amateurs can detect and plot the position of galactic hydrogen to produce a survey map of the distribution of hydrogen throughout the Milky Way.

Many amateur projects have succeeded in detecting and mapping Galactic hydrogen. Radio Astronomy dishes of around 2 metres or more are often used (Fig. 8) but also Yagi aerials and waveguide horn antennas are reliable detectors. You can learn more in this interesting video by Dr Laurence Newall on *YouTube*.

https://tinyurl.com/y6pv2gmu

The weak signals are fed to low noise amplifiers (LNAs) and a suitable filter centred around 1420MHz. The signals are processed by software such as *Spectrum Lab* or *Radio Eyes*. By making regular and frequent observations of signals strength over a long period eventually, a map of the hydrogen throughout the Galaxy can be plotted.

You can read about the various amateur projects at this URL:

https://tinyurl.com/yxms8agg

Furthermore, the books in Figs. 9 to 11 can be recommended as introductory reading to this fascinating branch of the radio hobby.

The UK Radio Astronomy Association (UKRAA)

The UK Radio Astronomy Association was established in 2008 as a registered charity (registration no 1123866) by the British Astronomical Association's Radio Astronomy Group (RAG). UKRAA's objectives are to promote the science of radio astronomy and all branches of radio astronomical research.

Before UKRAA's formation, RAG members had designed and built working prototypes of a VLF Receiver and Magnetometer. However, BAA rules did not permit the sale of products under the BAA banner. UKRAA was set up to handle the manufacture and sale of these products and the production of technical manuals covering the use of the products and the background science.

Consequently, over the past 12 years, UKRAA has developed several new radio astronomy products and modules. To promote radio astronomy to amateur astronomers. Members give talks to local astronomical societies and exhibit at astronomy shows. UKRAA regularly attends the *Astrofest* in London, although the 2021

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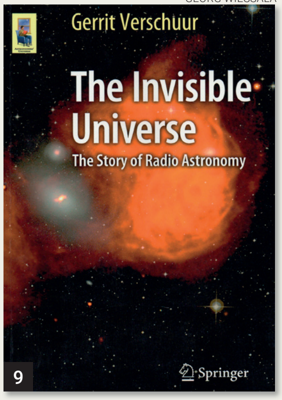

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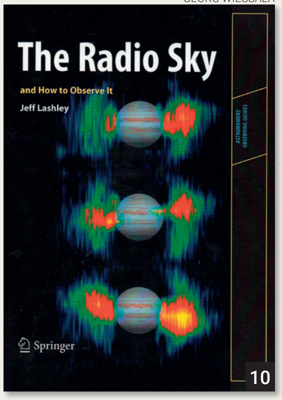

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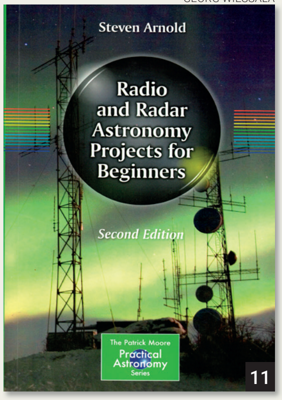

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Further Resources

- Arnold (2021): *Radio and Radar Astronomy Projects for Beginners* (Springer: 2nd ed. 2021)
- BAA (Radio Astronomy Group): VLF Observations: **https://www.britastro.org/node/20957**
- Bradley, M. (2013) 'Monitoring Solar Flares by Radio Astronomy': **https://tinyurl.com/yb9vw454**
- British Astronomical Association (BAA, Radio Astronomy Group) **http://www.britastro.org/radio**
- Fielding, J. (2006/ 2010) *Amateur Radio Astronomy* (RSGB)
- Graham-Smith, F. (2013) *Unsees Cosmos – The Universe in Radio* (Oxford: OUP)
- Judge, P. (2020) *The Sun – A Very Short Introduction* (Oxford: OUP)
- Lashley, J. (2010) *The Radio Sky and How to Observe It* (London: Springer) (Chapter 9 is on a VLF Solar Monitor)
- Palmer, P.I. (2017|) *The Atmosphere – A Very Short Introduction* (Oxford: OUP)
- Sichla, F. (2020) *Kosmische Kommunikation* (Marburg: beam Verlag [in German])
- Verschuur, G. (2015) *The Invisible Universe* (Springer)
- Whitham Reeve Article Collection: **https://tinyurl.com/y2vlzrzf**
- Wiessala, G. (2020) *'Observing the Sun and ionosphere in VLF'* (RadioUser, December 2020: 34-38)
- Reeve, W.D. (2010) *'Listening to the Sun's Radio Storms'* (RadioUser, March 2010: 34)
- -- (2019) 'Monitoring LF Propagation with a Software-Defined Radio Receiver': **https://tinyurl.com/y69y572a**
- RadioUser Reading List: **https://tinyurl.com/yxoyndx7**

show will probably be an online event. Moreover, UKRAA has provided support to schools and university departments on educational projects. The current Covid restrictions make it difficult to plan for next year. However, if UKRAA plans to attend radio and astronomy shows, this will be announced this on the association's website.

https://www.ukraa.com

UKRAA consists of a small group of volunteers who design and make the astronomy products sold. In addition to official UKRAA activities, trustees pursue their own interests and observations.

This includes participation in the *European Conference on Amateur Radio Astronomy (EUCARA)* and the (US) *Society of Amateur Radio Astronomers (SARA).*

https://tinyurl.com/y5taky5u
https://www.radio-astronomy.org

All net proceeds from the sale of UKRAA products are spent on radio astronomy development and outreach. The association does not have a 'membership' as such, like the British Astronomical Association.

Nevertheless, UKRAA is always happy to hear from interested hobbyists who may be willing to join in.

UKRAA sells radio astronomy equipment through its online store. There is an extensive range of VLF Receiver equipment, a magnetometer and E-Field equipment. UKRAA is also an authorised distributor of the Lab Jack U3-HV multifunction data acquisition module, which is in widespread use in the radio hobby community.

Last but not least, UKRAA also sells books on radio astronomy suitable for all levels.

[Andrew Thomas is a Trustee of UKRAA. His long-standing interest in astronomy was re-energised when he discovered amateur radio astronomy. This was a chance encounter at a business conference with a self-declared 'amateur radio astronomer'. Before that, he had no idea that such things were possible. Andrew enjoys building the instruments needed for making observations and encourage others to have a go. Not unlike the editor, he currently observes VLF signals (RadioUser, December 2020: 34), ionospheric disturbances and occasionally meteors. Andrew's present project is to add a magnetometer to his observatory and observe the impact on the Earth's magnetic field of the solar wind and coronal mass ejections. The author wishes to convey his sincere thanks to Dave Hilton for providing further input to this article. Dave Hilton is also a trustee of UKRAA. Electronics and astronomy have always been his favourite hobbies. Following retirement after a career lecturing in healthcare technology at Nottingham University, Dave rekindled these interests. A presentation at his local astronomy club by a leading researcher from Jodrell Bank made him realise how accessible radio astronomy could be to the amateur – ***Ed.****].*