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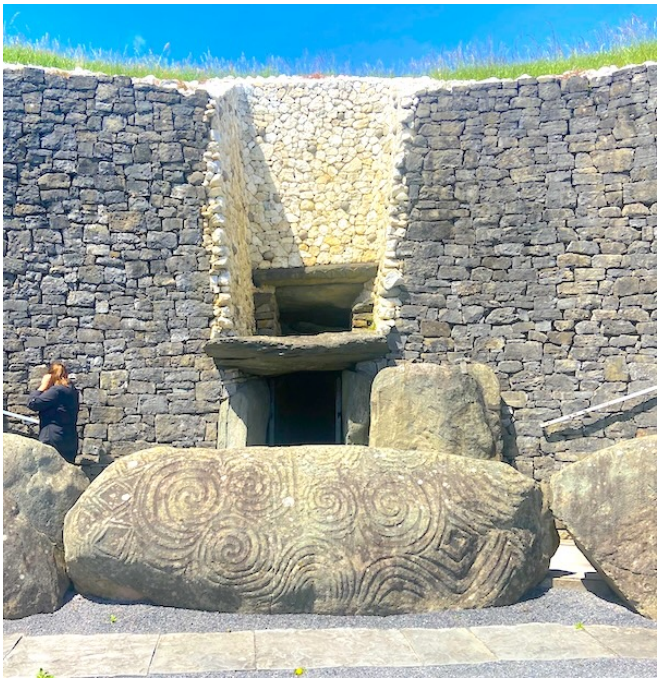
Mike Frost led the Society for the History of Astronomy on a trip to Ireland, first stop at the Leviathan of Parsonstown, the world's first 72"inch telescope at Birr Castle. The picnic party, in front of the restored Leviathan.



Left: Next day, a visit to Newgrange and Knowth neolithic sites. The entrance to the Newgrange passage tomb, is protected by carved stones. Right: Also a visit to Dunsink Observatory, with the 12" James South Telescope.

CONTENTS

Birr Castle

By Mike Frost

Birr Castle, from the star-shaped moat

I am Meetings Secretary for the Society for the History of Astronomy. One of the events which I organise is our annual picnic, held at a site of astronomical historical interest. In 2024, I organised a picnic at Rugby School, so that we could visit the school's Temple Observatory. In 2025, we went to Jodrell Bank.

One of the perks of being the organiser is that you have a big say in deciding where the next picnic will be. For 2026, I decided to try something more ambitious. I had never been to the astronomical sites of Ireland, and so I suggested that we held our picnic at Birr Castle, in County Offaly, near Limerick in central Ireland.

Why did I suggest this location? Because for seventy years, from 1845 to 1914, it was home to the world's largest telescope, the Leviathan of Parsonstown (the old name for Birr). The telescope fell into disrepair during the twentieth century, but in the 1990s, with the advocacy of Sir Patrick Moore, it was restored.

As we had other events planned, we based ourselves in Dublin and hired a coach for each day. Our coach driver, John was helpful and knowledgeable and improved our trip no end. We set off from Dublin's Maldron Hotel, where many of us stayed, at 9 AM on Saturday June 13th, and arrived at Birr an hour and forty minutes later.

Birr Castle and Demesne (meaning castle lands) is one of Ireland's top tourist attractions. Many people come simply for the lovely gardens, or the kids' playground, which features Ireland's biggest Tree House. Florence and I took time to wander round the formal gardens and admire the world's tallest box hedge, before joining a tour of the castle and the telescope.

Birr Castle is still lived in by the Parsons family, so it is usually closed to the public, but guided tours of the castle are available, and we had booked one. Gerard Gilligan, our ex-chair, had written to Lord and Lady Rosse, and was allowed to spend time in the archives, looking at letters from William Lassell to the Victorian Lord Rosse. He met Lady Rosse during his visit.

Our guide, Joan, gave us a history of the family. Birr Castle dates from the 12th century but passed into the Parsons family, Sir Lawrence Parsons, in 1620. In a somewhat complicated history, the family eventually became the Lords Rosse. The given name of the eldest son alternated through the generations, as happens in many families, in this case between William and Lawrence. Many of the eldest sons married Yorkshire lasses, although there was one wife, from Nymans Gardens in Sussex, who brought ideas on how to model the gardens. In recent years, the Armstrong-Jones family were inlaws, so Lord Snowdon took wedding photographs and Princess Margaret was a visitor.

Birr Castle has played a role in many of the pivotal moments of Irish history. During the potato famine, Lord Rosse undertook a series of building projects to provide work for the locals, including a high wall around the estate, and a faux moat for the castle, built in a star shape. During the independence uprising in the 1920s, the castle was occupied by the IRA. At the castle entrance there is a memorial to three IRA members executed in the castle in January 1923 for committing robbery.

But for most of its history, Birr has been a quieter and more productive location. The Parsons family were innovative engineers. In 1820, they built the oldest wrought iron suspension bridge in Ireland over the River Camcor – it still exists, just outside the castle, but these days is closed for health and safety reasons. In 1839, the third Lord Rosse, William Parsons, built a thirty-six-inch diameter reflecting telescope. This was a success, and Lord Rosse decided on a more ambitious follow-up – a huge reflecting telescope, with a speculum mirror 72 inches in diameter, located at the bottom of a tube, which was mounted between two large brick walls running north-south. The other end of the tube could be winched to any desired elevation. So, the telescope could be pointed towards any object which passed due south, with a small amount of leeway to the east or west, and even a possibility of pointing to the north. A secondary mirror was at the entrance to the tube, allowing the observer to view from a precarious observing platform, which was winched up in the air with the telescope. The 36-inch telescope was repurposed with a thermocouple to measure the temperature of the Moon.

The renovated Leviathan is an impressive

construction, which dominates the gardens in this part of the Demesne. Visitors aren't allowed onto the telescope, so instead we posed for a group photograph in front of it. In principle, the telescope can still be used for observing, though this is difficult so doesn't happen often. Lord Rosse had similar problems. The Irish countryside is not an ideal location for astronomy; there were too many cloudy nights, and the speculum mirrors tarnished continually and had to be replaced regularly. Nevertheless, the telescope was important, and visitors came from all over Europe – some to observe, some as sightseers. The observing program was a re-examination of the objects in Messier's and Herschel's catalogues. In particular, when Lord Rosse observed M51 in Bootes, he saw a spiral structure which had not been previously observed. Perhaps he was influenced by the eddies in the river as it flowed past the castle? The spiral structure was genuine, and so Lord Rosse was the first person to identify spiral galaxies.

Charles Parsons, younger brother of the next Lord Rosse, Laurence Parsons, continued the engineering traditions of the family. He invented the steam turbine, one of the key technologies of the late nineteenth century, making a fortune for the Parsons company. A retired turbine from the local Ferbane power station sits in the courtyard of the Castle Gatehouse, which is the entry point to the castle. The gatehouse also houses the splendid *"Ireland's Historic Science Centre"* which highlights the engineering and astronomical achievements of the Parsons family, in the context of the history of science in Ireland. A particular star of the show is Mary Parsons, Countess of Rosse, who was a pioneering photographer. Her darkroom was recently rediscovered in an unused room in the castle and now forms one of the science centre tableaux.

There is a lovely walk along the river, through some of the planted woods and avenues and alongside a lake created by diverting the river. Toward the southern end of this walkway is one final scientific treat. Ireland was hoping to build a radio telescope array to be part of LOFAR, the Low Frequency Array of radio telescopes which stretches across seven European countries. It was suggested that Birr, with its long and distinguished astronomical history, would be a suitable location, and the current Lord and Lady Rosse agreed. I-LOFAR (the I stands for Ireland) is the Irish contribution to the array, which is a pathfinder array for the future Square Kilometre Array. The site started with a radio telescope in 2012, 98 years after observing ended on the Leviathan, and I-LOFAR opened in 2017.

It is fitting that Birr is still at the forefront of astronomy. And radio astronomy does not require cloudless skies!

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The I-LOFAR array

Newgrange and Knowth

By Mike Frost

As you may have just read, the Society for the History of Astronomy held its annual picnic at Birr Castle in central-west Ireland on June 13th. But why stop there? As we were already in the Irish Republic, we had decided to visit more astronomical sites. On Sunday June 14th, we headed north from Dublin, along the M1 motorway toward Drogheda, to the beautiful Boyne Valley.

On a long bend of the River Boyne, there is a campus of neolithic sites – in particular the barrows of Newgrange, Knowth and Dowth, although excavations have revealed many other sites (at least 90) including tree henges, standing stones and enclosures. Dowth is not in good repair at present and not open to visitors, but Newgrange and Knowth are popular with tourists. We had signed up for a tour of both sites.

Our first port-of-call was the visitor centre at Bru na Boinne, from where the tour departed. There is an excellent set of immersive displays on the history and archaeology of the sites. The neolithic sites date from around 3200 B.C.E., were rediscovered in the seventeenth century, placed under government ownership from 1882 onwards and excavated by archaeologists from the 1960s onwards.

After a quick lunch in the café, we left the visitor centre, crossed a footbridge over the river, and got on a bus which took us to the first of our sites – the Knowth barrow. Knowth is a large passage tomb, which is to

Top: Knowth barrow and one of the satellite tombs. Below: A wider view of the Newgrange tomb.

say that there is an internal chamber, which can be reached through a stone passage. In fact, Knowth has two such chambers at the end of two such passages, although neither of them are open to the public at present. The central barrow is surrounded by eighteen smaller satellite tombs. To protect the remains, the site can only be accessed as part of a guided tour. We had Colm as our tour guide.

Perhaps the most interesting feature of Knowth is a series of 127 large kerbstones, which line the exterior of the barrow. Many of these kerbstones carry carved designs. This neolithic artwork is an extraordinary resource – it is claimed that about a third of all known neolithic artworks in Western Europe can be found at Knowth. There has been a lot of speculation as to what the carvings mean. At least two have been suggested to be representations of solar eclipses, and one bears a resemblance to the lunar mare visible to the naked eye.

During the iron age, there was a settlement on top of the Knowth barrow. Modern steps have been built into the barrow to allow visitors to access the flat area on top where the settlement used to be. There is also a reconstruction of a tree henge.

After forty-five minutes touring Knowth and its small visitor centre, we got back on the bus, which took us to Newgrange, a mile away. Here, another guide took us to another passage tomb.

The tomb passage entrance at Newgrange is impressive, a wall of white quartz. At Knowth, the archaeologists have decided that the quartz found there formed a pavement on the floor in front of the tomb. At Newgrange, the interpretation is that the quartz decorated the tomb walls. It's still debated which interpretation is correct, but Newgrange is visually more impressive. There is also a stone barrier in front of the tomb entrance, featuring striking spiral artwork.

Unlike Knowth, Newgrange does allow visitors to enter the tomb. The chamber can only hold fifteen people, so our guide split us into two groups. Mine was the second group in, so I spent ten minutes photographing the standing stones around the main tomb. Newgrange barrow used to be surrounded by 38 standing stones, of which 12 remain.

Once the first group had emerged from the tomb, our group climbed over the tomb entrance barrier on a wooden walkway and then made our way into the tomb. The passageway was low, so that I had to duck at several places and hold my hand over my head to avoid unexpected bumps. It was also very narrow, so that at two points I had to twist my body to get through a narrow gap. Two members of our group had to turn back at this point as they felt unable to progress.

One of the kerb stones, decorated with neolithic art. Some people think these carvings picture phases of a solar eclipse.

The passageway is 19m long and slopes gently upwards.

We gathered in the chamber at the end of the passage. Above us was a large stone dome, 6m high, built of overlapping slabs of stone. The dome is tightly sealed, and the arch stones have grooves on the outside to guide water away, so the inner chamber is still waterproof after five thousand years. There are three off chambers, in a cruciform arrangement, which we were not allowed to go into. The side chambers both have large stones, that originally held cremated remains of the chamber occupants. The stones of the chambers contained many markings. Some dated from the tomb construction, more swirls and spirals; some are graffiti from the seventeenth and eighteenth century after the tomb was rediscovered.

Newgrange is world-famous for its solar alignments. Above the entrance is a box which allows in sunlight when the Sun is at a particular position in the sky, which only happens shortly after sunrise on the winter solstice and for a few days either side. If it's not a cloudy day, the rays of the rising Sun pass through the box, and into the inner chamber, illuminating it with natural light for up to seventeen minutes. Every year there is a lottery draw to determine who gets to stand inside the tomb if this happens. For the benefit of visitors at other times, a simulation has been installed. Our guide switched off the lights, plunging us into complete darkness. Then, we watched as a shaft of light made its way along the passageway and into the chamber. Electrifying! The passageways at Knowth align east-west so there are possible astronomical alignments with equinox sunrises and sunsets, but at Knowth the passageway entrances have been modified since the barrow was built so alignments can only be speculative.

The two tombs of Newgrange and Knowth are fascinating, but also contrasting, perhaps offering different ideas as to how they were actually built. Our SHA chair, Carolyn Kennett, worked on the excavations at Knowth, so was able to give us some insights into the work which goes on to reconstruct what the tombs looked like in 3200 BC.

When I planned our visit to Newgrange, I allocated too much time to look round the visitor centre, so we ended up with an hour to spare. John, our driver, suggested that we paid a quick visit to the site of the Battle of the Boyne, only two miles away. This is a significant site in Irish history. It took place on 1st July [O.S.] 1690, between the deposed King James II of England and Scotland, and his successor King William III (who ruled jointly with Queen Mary). William won, which secured protestant rule in Ireland, and is still celebrated by Loyalists in Northern Ireland.

The battlefield site is now owned by the Irish State and is run as a park, with a small museum. We were there, briefly, on a sunny day, so the site was full of people enjoying a summer Sunday. It's extraordinary to think that this narrow stretch of a river, now a beautiful peaceful place, has been such an integral part of Irish history of thousands of years.

The whole area is worth a visit.

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Dunsink Observatory

By Mike Frost

So. . . we had visited Birr Castle and the neolithic complex at Newgrange. Where else could we go to in Ireland? We discussed visiting the observatory at Armagh, but this was quite a distance from Dublin, and across the border in Northern Ireland. Besides, many SHA members, including me, had visited Armagh when the British Astronomical Association met there in 2019 (See MIRA 106). So, we decided against visiting Armagh. Perhaps another time.

One possible astronomical site remained – Dunsink Observatory, just outside Dublin. This is a working academic establishment with a historic telescope. There was a problem – Dunsink is only open to the public for stargazing sessions, not usually during the day. However, the Society for the History of Astronomy are a well-connected organisation. One of our members, Alex Pratt, had attended a meeting at Dunsink. He suggested that I contact Michael O'Connell, who directed me to Jonathan Mackey, who passed me on to Sadhbh Leahy. Sadhbh (pronounced "Sive") turned out to be exactly the right person to talk to – she is in charge of outreach at Dunsink, and very pleased to invite us along. I later met her at an "Observatory Networks" event at Greenwich and she told me that the people at Dunsink were particularly impressed that our SHA library in Birmingham is named for Sir Robert Stawell Ball, a former director at Dunsink.

By a roundabout route, we had managed to organise a trip to Dunsink. And so on Monday June 15th, our coach drove west out of Dublin, past Phoenix Park, and took a side road just before reaching the Dublin ring road. The observatory is still, just about, in a rural location, although there is a large landfill site to the north, and plans to build houses to the south. The site consists of a gatehouse, a larger observatory building with a dome on top, and a smaller standalone dome.

We were welcomed to the observatory by Sadhbh

The Observer's House, Dunsink Observatory

and by the current director, Professor Peter Gallagher. We were shown into the meridian room, where the shutters were still in place, although there has been no telescope there in over a century; it's now a lecture room. Peter started by giving us a history of the observatory. It was founded in 1774 by a bequest of £3000 from Francis Andrews of Trinity College – Andrews' family weren't happy with their inheritance being squandered on astronomy, and sued, but lost. The first director was Revd Henry Ussher, who spent his time building the observatory; the second director, and first Royal Astronomer of Ireland, Revd John Brinkley, who calculated the longitude of the observatory, and made observations to try to find stellar parallax, for which he developed mathematics which were a precursor of the least-squares techniques.

The third director was William Rowan Hamilton, who was selected, in 1821, at the age of 21, ahead of future Astronomer Royal George Biddell Airy. Hamilton is revered in Ireland as their greatest scientist. Physicists know him for the Hamiltonian, a formulation for solving problems in mechanics and quantum mechanics. Mathematicians know him for the discovery of quaternions, a generalisation of complex numbers which has modern-day uses in computer graphics. Hamilton first visualised the fundamental equations of quaternions ($i^2 = j^2 = k^2 = ijk = -1$, which appear, incompletely, on an Irish stamp) whilst walking into Dublin from the observatory, along the Royal Canal. Scared that he would forget, he carved these equations into the stonework of a bridge over the canal. The Broom Bridge is now a tourist attraction for nerds. Every year, on the anniversary of the carving, a procession sets off from Dunsink to visit the bridge and honour their former director. Hamilton also predicted the phenomenon of conical refraction through a biaxial crystal. This was a theoretical prediction, not observed in the laboratory until a few months later. Sadhbh brought in a piece of apparatus to demonstrate conical refraction to us.

For all his undoubted genius, Hamilton was not a great success as observatory director. He was accused, a little unfairly, of not doing enough observing. He employed his sisters as observing assistants (shades of the Herschel family). He died in office in 1865 and was replaced by Franz Brunnow. Robert Stawell Ball took over eight years later. Later in his career, Ball was a famous populariser of astronomy, the Patrick Moore of his day, but in his time at Dunsink his major contribution to science was a treatise on the theory of the screw. Peter showed us a copy of it – it looks dreadfully boring.

At the start of the twentieth century Dunsink was an important part of the European network of observatories. It maintained the time for Dublin and for Ireland; famously, *"Dunsink Time"* is mentioned in James Joyce's Ulysses. But as the century progressed, and Ireland became independent, the observatory became less relevant; in 1936 Trinity College withdrew financial support and the observatory ceased to do astronomy.

After the second world war, renaissance came from an unlikely direction. Eamon de Valera, the president of Ireland, wanted to establish a Dublin Institute for Advanced Studies (DIAS), concentrating on subjects dear to his heart. Fortunately, these included astronomy, and so Dunsink became part of DIAS, where it remains today. A chance meeting of de Valera and Harlow Shapley at Shannon airport led to the setting up of the Harvard-Dunsink-Armagh telescope in South Africa – a good chance to encourage cross-border scientific collaboration in Ireland but hamstrung by the

rise of apartheid in South Africa.

Back at Dunsink, there was a fire in the meridian room on October 3rd 1977. No-one was injured, but a major casualty was the Moon rock given to Ireland by Richard Nixon. The display case survived the fire, but the rock itself went missing; the working theory being that it was thrown out with the fire debris by accident and now sits somewhere in the landfill across the road from the observatory.

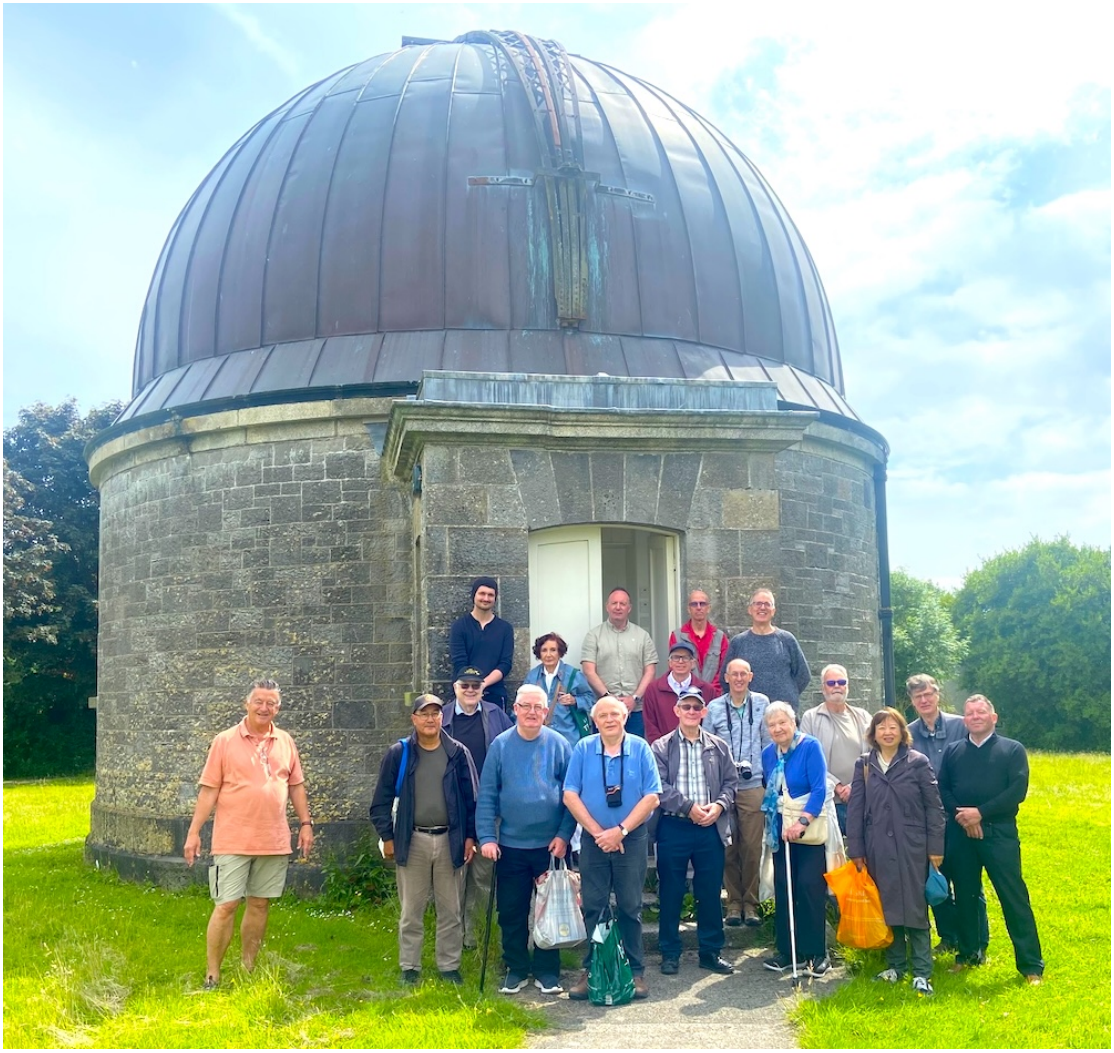
These days Dunsink houses offices for DIAS researchers. Peter Gallagher leads a team of solar researchers, and one of the instruments he uses to study the Sun is the I-LOFAR array at Birr, of which he is also director. There are also groups studying star formation, planetary magnetospheres and high-energy astroparticles. Peter is also directing the renovation of the observatory building, with the eventual aim of applying for world heritage site status for Birr, Dunsink and Armagh, once again encouraging cross-border co-operation. It helps that the design of the Dunsink observatory, with a dome on top of the building, was innovatory – but actually, the dome was not very successful, with vibration problems.

There is much history in the building. Peter and Sadhbh showed us the mirror from the Harvard-Armagh-Dunsink telescope, and the coelostat which the Sobral party used to observe the 1919 solar eclipse and take the pictures which verified the predictions of Einstein's Theory of General Relativity.

These days the only observing that takes place on the site is public observing sessions in the smaller dome. These use the James South telescope, a 12-inch refracting telescope on a mounting by Grubb. The lens is a Cauchoix, which originally belonged to Sir James South, a leading observer from the mid-nineteenth century and one of the founders of the Royal Astronomical Society. It was meant to be part of a major telescope for South, but he got into a damaging legal dispute with Edward Troughton, and the telescope never came to fruition.

Peter and Sadhbh demonstrated the telescope to us, opening the dome and engaging the clock drive (of course, it was daytime, so no actual observing was possible). The telescope is well-balanced and moves easily; the dome moves smoothly.

We finished with a group photograph outside the South Dome, and then set off, to drop off most of our party at Dublin airport. As we were leaving the site, John informed us ('I wasn't going to tell you this till we left') that Dunsink Lane, being a quiet country road close to the city centre, was a favourite spot for Dublin crime families to dump their bodies. Perhaps not a great place to do night-time observing these days?!



The party, outside the dome

Catharine Octavia Stevens (1865–1959)

By Mike Frost

Last October, I gave a talk to Abingdon Astronomical Society, just south of Oxford. I was due to have a pre-talk meal with my old friend and fellow eclipse-chaser Gwyneth Hueter of Abingdon AS. However, I set off early, because I wanted to carry out some historical investigations. Instead of heading straight to Abingdon, I went first to the west of Oxford, to the village of Boars Hill. I wanted to find the house owned by a pioneering astronomer and meteorologist called Catharine Octavia Stevens.

I first came across Catharine in a paper in the Journal of the Society for the History of Astronomy, The Antiquarian Astronomer, by the American astronomer and historian Kristine Larsen: *"Shooting Stars: The Women Directors of the Meteor Section of the British Astronomical Association [BAA]"* (I met Kristine when the AAVSO, the American Association of Variable Star Observers, held a joint meeting with the BAA at Warwick University in 2018). Kristine's paper tells the story of three women astronomers who were early directors of the BAA's meteor section. I already knew of two of these astronomers – Grace Cook and Fiammetta Wilson, who jointly ran the meteor section during the Great War. Both came originally from Suffolk, and my deputy director Bill Barton, who lives in Ipswich, has done much research on these two remarkable women. But I had no idea that there had been an earlier female director of the meteor section, in the early years of the twentieth century.

Catharine Octavia Stevens was born at the Rectory, Bradfield, Berks, on 25th Jan 1865. Her father was Revd Doctor Thomas Stevens (1809-1888), Rector of Bradfield and her mother Susanna Stevens, nee Marriott (c1824-1866), daughter of Revd Robert Marriott of Cotesbach, Leicestershire (a few miles north of Rugby). Wikipedia tells us that her elder sister Mary Ann Stevens married John Oldrid Scott, son of the architect, George Gilbert Scott. According to her BAA obituary, by J.H.D. (James Henry Drake, of Boars Hill), Catharine was given her middle name because she was the eighth daughter in the family. However, when I acquired a copy of her birth certificate, I found that J.H.D. had got two important details wrong. He stated that she was born in 1864, not 1865, and gave her first name as "Catherine" where her birth certificate says "Catharine" with an "a". The latter is a mistake which has persisted.

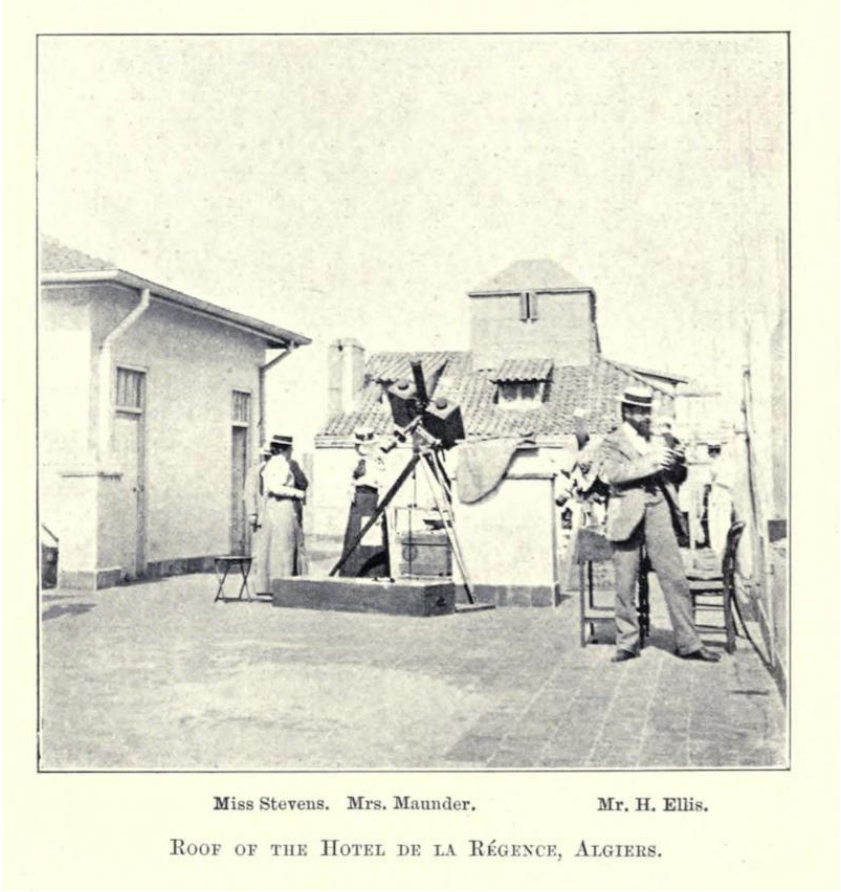
Throughout her adult life, Catharine was known to all as "C.O.S.". She joined the BAA on 25th May 1891, a few months after its formation. Her proposer was R.J. Ryle and seconder H.K. Nield, and once again her name is mis-spelled as "Catherine". Her initial interest was solar observing, and she owned a three-inch refractor to do this. Her first paper for the BAA was *"On the growth and decay of sunspots in 1891"*.

She participated in three BAA solar eclipse expeditions – to Algeria in 1900, to Majorca in 1905, and to Quebec in 1932. In the official account of the 1900 eclipse, she appears in the background of one of the photographs, talking to Annie Maunder, although we only know this figure is "Miss Stevens" from the labelling, as her face is obscured. She also contributed a drawing of the solar corona to the official report.

The view of the 1900 eclipse from Algiers was unobscured, but the weather for the 1905 eclipse was not as good, and third contact could not be observed. However, she did report on the appearance of shadow bands, shortly before totality. Shadow Bands became a major preoccupation of C.O.S. throughout her life. She published three separate papers and letters in the BAA Journal during the 1920s on the subject. I have written a separate article on shadow bands, explaining C.O.S.'s insights, which accompanies this paper.

Early in the 1900s, C.O.S. visited New Zealand, to visit family. But she also spent a week in Rotorua on the North Island, staying with a Maori woman, who spoke no English. They communicated by sign language. She also spent a year in Shetland (the obituary does not say when), studying the aurora borealis.

She became director of the BAA's Meteor Section in 1905. She published one section report, in 1908, and a paper on *"The Physical Relation of Comets and Meteors"* but otherwise didn't do much work on meteors during her six-year directorship. Around this time, however, she was also producing papers on



Miss Stevens talking to Mrs (Annie) Maunder, on the roof of the Hotel de la Regence, Algiers, during the 1900 BAA eclipse expedition, from the official account.

meteorological topics – *"Mock Suns"*, *"Halos and Rainbows"*, and a letter to Nature on *"A Curious Rainbow"*.

In 1910, her BAA obituary informs us, she had a house built, "The Plain", in the village of Boars Hill. She is listed in the 1911 census at this address, as an astronomer employed by the BAA. In the 1921 census she says she is a meteorologist and astronomer; ditto for a 1939 registration document. In all three of these documents, she writes her name as "Catharine" rather than "Catherine".

With some guidance from Abingdon AS members, I was able to locate "The Plain" quite easily. It is at the western end of the village. The house is situated on the edge of Oxford Preservation Trust land, created by the purchase of the Old Berkeley golf course in 1928, giving an exceptional view over the city of Oxford.

I was able to contact the current owners of the house, Jenny and Lindsay, who very kindly shared with me what they knew about C.O.S.'s time in their house. They were aware that a famous astronomer and meteorologist had lived in the house and had done some research on her. There was no sign of an observatory in the grounds of the house, but they did report that there was still an external L-shaped upper storey platform, with good views to the north and west, and a safety balustrade. This could easily have housed her 3" refractor, and would have been fine for observing meteors, meteorology and aurorae.

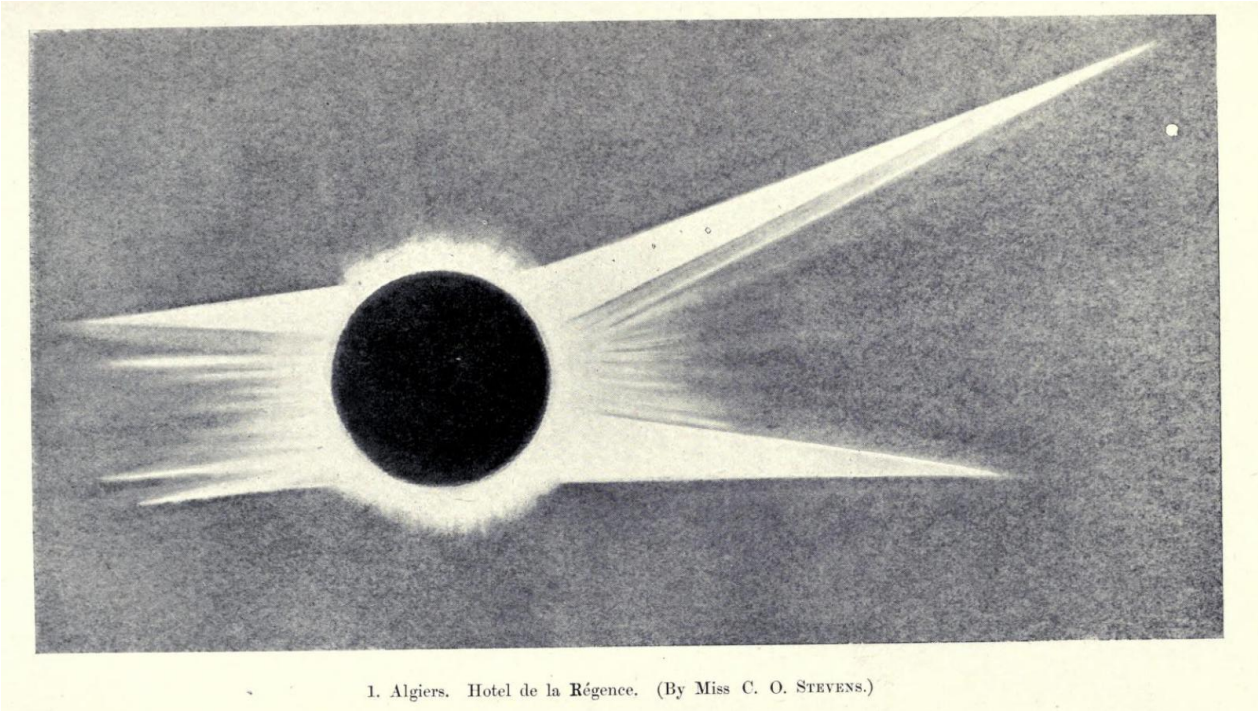
They also reported that C.O.S, was a sociable lady, who played a big part in the life of the village. One room of the house was used as a theatre, for small audiences, with a back door to an outer terrace which could be used as a dressing room. The census returns for "The Plain" suggest she took in boarders. J.H.D., in her obituary, wrote *"To cross the threshold of the house at Boars Hill was to walk into the age where scientific curiosity was still largely the province of the amateur. Within one found, beside the usual paraphernalia of telescopic and spectroscopic adjuncts and the barograph, carefully docketed and stored bric-a-brac that would delight any collector's heart. Silver-bearing ore from the Rocky Mountains, coral from the Barrier Reef, monstrous insects from the Antipodes immured these many years in alcohol, and bundles of letters from people all over the wide world."*

C.O.S.'s final paper for the BAA was her report of the total eclipse of August 31st 1932, seen from Three Rivers, Quebec, Canada. Catharine set up equipment to measure the movement of shadow bands and made a prediction of which way they would travel, based on observed wind speeds. Alas, no shadow bands were seen by her at this eclipse. C.O.S.'s party had a good view of totality, but clouds covered the Sun shortly after third contact.

Catharine remained in the Boars Hill house until 1956. She died on 16th June 1959 and was buried next to her father at Bradfield.

There are two addenda to this story. First, Catharine Octavia Stevens was one of the pioneering

"The Plain" from the (former) Old Berkeley Golf Course, Boars Hill



1. Algiers. Hotel de la Régence. (By Miss C. O. Stevens.)

Catharine's drawing of the solar corona for the 1900 eclipse

women astronomers after whom the BAA historical section, with the help of Rik Hill, were able to name main-belt asteroids. Asteroid 50728 is now named Catherinestevens, perpetuating the incorrect spelling of her name.

And second: I was once lecturing about the Pioneering Women of the BAA. When I got to Catharine Octavia Stevens, I realised – mid lecture – that she was Cat Stevens! So perhaps she was drawn to eclipse observing by the chance to see the Moon Shadow.

I am very grateful to Jenny Tyler and Lyndsay Judson, the current occupants of The Plain, for the information they supplied about the house and what they knew of its previous resident.

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Shadow Bands

By Mike Frost

As you might be aware, I quite enjoy going to see total solar eclipses.

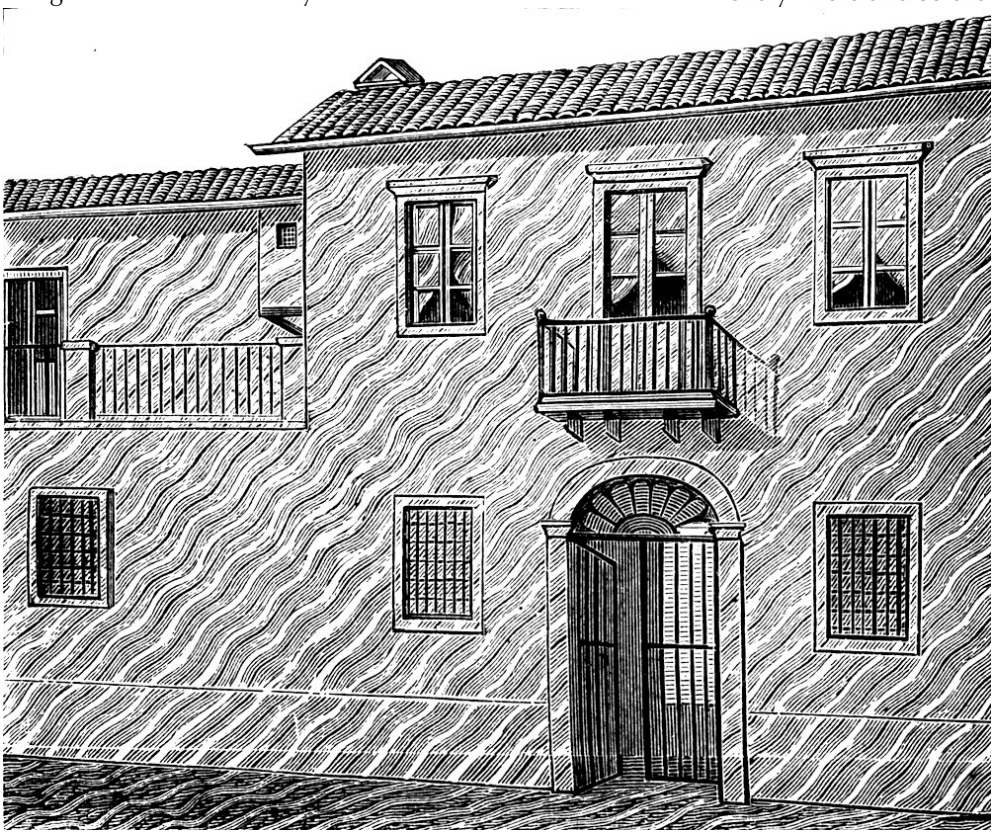
There are several reasons for this. A total eclipse of the Sun is, in my opinion, the single most spectacular predictable natural phenomenon it is possible to see; eclipses happen all around the world, enabling me to indulge my love of travel to obscure places; the eclipse-chasing community is very sociable. And then there are the things that you can only ever see during a total eclipse – the beautiful pearly white solar corona; the fiery red prominences of the Sun.

But there's one rather subtle phenomenon that I am unreasonably obsessed with – shadow bands.

If you have ever seen a total eclipse, you will know how overwhelming the period around totality is. In the seconds leading up to totality, so many things are happening simultaneously: the Sun is reduced to a narrow crescent by the ever-encroaching Moon; the horns of this crescent break up into beads of light, Baily's Beads, as the remaining sunlight feeds through the deepest valleys on the Moon. The temperature drops and the ambient light drops off steeply to twilight levels. Birds roost, swarms of insects appear from nowhere, humans get very excited. Above you, the solar crescent narrows to a single point, the diamond ring, and the shadow of the Moon shoots overhead to bring on the start of totality.

But, in amongst all this, you might take a quick look downwards and see something very disconcerting; bands of light and dark, sweeping across the ground. These are shadow bands. At their strongest, they seem to be everywhere, running over you and your fellow observers. Cameras pointing at the Sun can record strobe effects as the bands sweep across the lens. It can be very disorienting, as if the Earth was slipping off its axis. In the 2006 eclipse which crossed the Libyan desert, Martin Mobberley described them as *"writhing snakes"* on the desert sands. Shadow bands can also be seen after the end of totality. They are visible up to a minute before or after totality but are strongest in the seconds immediately before second contact (the start of totality) and after third contact (the end of totality).

I have seen them at several eclipses; first at the eclipse which crossed Curacao in 1998; most memorably in Svalbard in 2015, but also in several recent eclipses; Oregon in 2017 and Argentina in 2019. Perhaps I am getting better at spotting them; perhaps I prioritise looking down for shadow bands over watching the arrival or departure of the Moon's umbra. I'm not sure. To up your chances of seeing shadow bands, it's a good idea to put a large white sheet, perhaps "borrowed" from your hotel (they won't mind) onto the ground. At Svalbard there was snow everywhere and so the ground was already white everywhere; in Oregon the uniform desolation of the Snake River valley meant that we could see shadow bands crossing the hills.



Shadow bands sweeping across an Italian villa in the eclipse of December 1870 from Gela in Sicily by Demetrio Emilio Diamilla Müller, reproduced by G.F. Chambers in "The Story of Eclipses" (1900)

For a long time, there were only still photographs of shadow bands, but modern technology has made the production of video much easier. In 2015 my friend Lilia Pegg took video of the end of totality at Svalbard, and you can clearly see the shadow bands, with a wavelength of perhaps 20 cm, scooting along the ground at fast walking pace. They appear to be linear, not radial (they are not spokes pointing toward the Sun). Several experimenters have put direction pointers and scale marks onto their white sheets, to confirm that shadow bands follow the template which we observed at Svalbard.

Like many phenomena

Shadow bands projected onto clouds at Fortin Nogueyra, Argentina, just before the eclipse of December 2020. Note how the shadow bands are parallel to the narrow remaining slit of sunlight. Photo by Chris Chotas Alexander

connected with solar eclipses, shadow bands were first described during the first half of the nineteenth century. Before then, the main effort went into predicting exactly where solar eclipses were going to be total; but as more and more people travelled to see totality, there began to be a closer analysis of what was going on phenomenologically – Francis Baily named his beads in 1836, for example. The first person to specifically note shadow bands appears to be the German/French observer Hermann Goldschmidt, in 1820. I haven't seen his account of what he saw.

George Bidell Airy, the seventh Astronomer Royal, saw shadow bands at his first total eclipse in 1842. *"As the totality approached, a strange fluctuation of light was seen upon the walls and the ground, so striking that in some places children ran after it and tried to catch it with their hands."*

A famous illustrations of shadow bands sweeping across an Italian villa was a lithograph of the eclipse of December 1870 from Gela in Sicily by Demetrio Emilio Diamilla Müller. It was reproduced by G.F. Chambers in his popular *"The Story of Eclipses"* (1900).

Catharine Octavia Smith (C.O.S.) saw them on the BAA expedition to the solar eclipse of 1905, in Majorca. In the BAA report of the expedition, C.O.S. wrote *"As to the character of their appearance and mode of progression, it was observed that they swept along with a flight that was at once rapid and orderly, there was no confusion of the wavy lines with one another, but all bore along in one and the same direction in parallel formation, traversing the ground as water-wave reflections may be seen to do on the under surface of a boat, only that there seemed in the case of the shadow-bands to be a more distinct expression of a forward movement."*

C.O.S. went on to write a series of papers and letters about shadow bands, in Nature, The Observatory and the BAA Journal, in which she outlined her theory as to what caused shadow bands. Essentially, she proposed that shadow bands were caused by the Sun twinkling.

What do we mean by this? It's well-known that little stars twinkle, appearing to dither around in the sky, sometimes throwing darts of colour. Sirius, low in the winter sky, is renowned for its twinkling. But if you were to observe the light of Sirius from above the Earth's atmosphere, for example from the International Space Station, you would see a perfectly steady, unchanging light from this star. It is the Earth's atmosphere which creates twinkling, which is why Sirius twinkles so much when it is low in the winter sky, and its light travels through more atmosphere.

The atmosphere consists of a series of air cells, which can be modelled as prisms, concentrating light in some directions and spreading it out in others. The passage of the light through these cells deflects the path and splits out colours. The angle of deflection is small and variable.

Why don't we see the Sun twinkling? Because it has an angular size greater than the amount by which twinkling moves the light. Instead, the surface of the Sun appears to "boil". The same is true for the planets

(and is easier to see), leading to the adage *"stars twinkle, planets don't"*. The image of a planet through a telescope may be blurred by twinkling, but the overall disk gives a steady light when observed with the naked eye.

However, when we get close to totality, the Sun is no longer a disk; instead, it is a crescent of increasing thinness. In a short 1927 paper in the Monthly Notices of the RAS, Percy Ryves, BAA Mars section director, suggested that this crescent, almost a narrow linear feature close to totality, was the reason why shadow bands were linear. He argued *'that the shadow bands [at the eclipse of 1905, 22 years previously] were the result of light from a very small source, a small segment of the Sun's disc, revealing the irregularities of density in the atmosphere, in a manner similar to that in which the irregularities in the glass of a window pane are revealed by the light of the planet Venus.'*

Why do the bands move? This is due to the wind moving cells of air in the atmosphere. So the speed of the bands across the ground matches the component speed of the wind higher in the atmosphere in the direction of the shadow speed. Note that this has a number of implications for the visibility of shadow bands. If wind speed is zero, the bands stay put on the ground, making the bands much less easy to spot. If the wind speed is too high, the bands will move too quickly to be discernible. If the wind direction is parallel to the orientation of the bands, the bands will be stationary and difficult to see. These are reasons why shadow bands aren't seen at every eclipse.

The ideas of C.O.S. and Percy Ryves were developed by J.L. Codona in the 1980s. Wolfgang Strickling has an excellent site which explains this theory, illustrated with Wolfgang's own videos. I saw these videos and met Wolfgang at the "Totality Day" conference in Milton Keynes in 2003.

In the latter part of the twentieth century, an acknowledged expert on shadow bands was Barrie Jones of the Open University. His main speciality was astrobiology, but he carried out measurements of shadow bands at several eclipses through the 1990s, including the 1998 eclipse in Curacao. I met Barrie at one or two OU related events; he was a charismatic man and much respected.

Someone else I know and respect is Stuart Eves, an astrophysicist and planetary scientist. He spoke to the BAA historical section in 2017 about *"Herschel and the Rings of Uranus"* though unfortunately I was working in Argentina and had to miss my own meeting. Somewhat to my surprise, as I was researching this article, I discovered that Stuart had suggested an alternative theory for shadow bands, which gained some traction in the 2010's, even appearing in a BBC news article. His suggestion was that the arrival and departure of the Moon's umbra, and the attendant change in temperature, created infrasonic shocks in the atmosphere. Infrasound is sound of too low a frequency to be heard by the human ear. Stuart's suggestion was that the temperature drop caused by the arrival of the Moon's umbra triggered a series of infrasound sonic booms.

This might explain shadow bands, but Stuart suggested that infrasonic shock waves would also explain other phenomena, such as the behaviour of animals, whose hearing range extends to the frequencies expected for infrasonic booms. More speculatively, he suggested that infrasonic shock waves might explain the Allais effect. This is a phenomenon noted by the Nobel-prize winning economist Maurice Allais (1911-2010), who claimed that Foucault pendulums behaved erratically during solar eclipses. Allais, who was not a trained physicist, speculated that the effects indicated previously unknown gravitational effects – he thought it might be necessary to re-instate the luminiferous aether, which had been ousted by relativity. Most astronomers are very sceptical of this. It has proved difficult to reproduce Allais's measurements, and, even if the Allais effect is a genuine phenomenon, other less contentious effects such as temperature drops might be responsible. Stuart's infrasonic waves could be such an effect.

Barrie Jones, however, was unimpressed by infrasonic waves as an explanation of shadow bands: *"The theory works; there's no need to seek an alternative."* I emailed Stuart Eves to ask if he stood by his theory. Stuart replied:

Hi Mike, Many thanks for your interest in my shadow bands idea.

I guess the first thing to say is that I don't agree with the quote from Barrie Jones... If the existing "slit" theory were accurate, then shadow bands would be seen at every eclipse, (since the geometry is essentially the same each time), and as your own testimony demonstrates, that simply isn't the case.

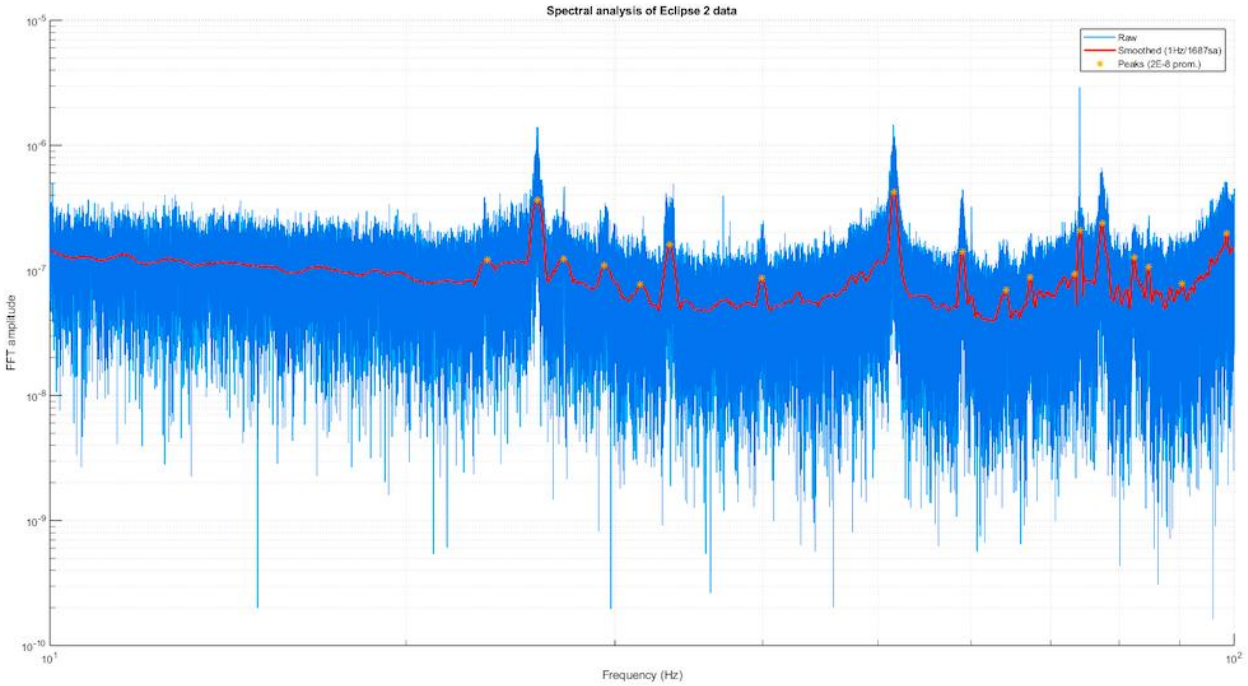
Support for the theory comes from the 2017 eclipse, where residents of a place called Lawson in Missouri actually heard and recorded an audible sonic boom. This was exactly the location at which the speed of the eclipse shadow went through Mach 2.

In 2024, my son-in-law Jon, (who is helpfully an acoustic engineer), and I took some recording gear to Ohio. We saw some shadow bands then, and the recorded data from the eclipse date looks visually different to the comparison data we collected at the same time of day two days previously.

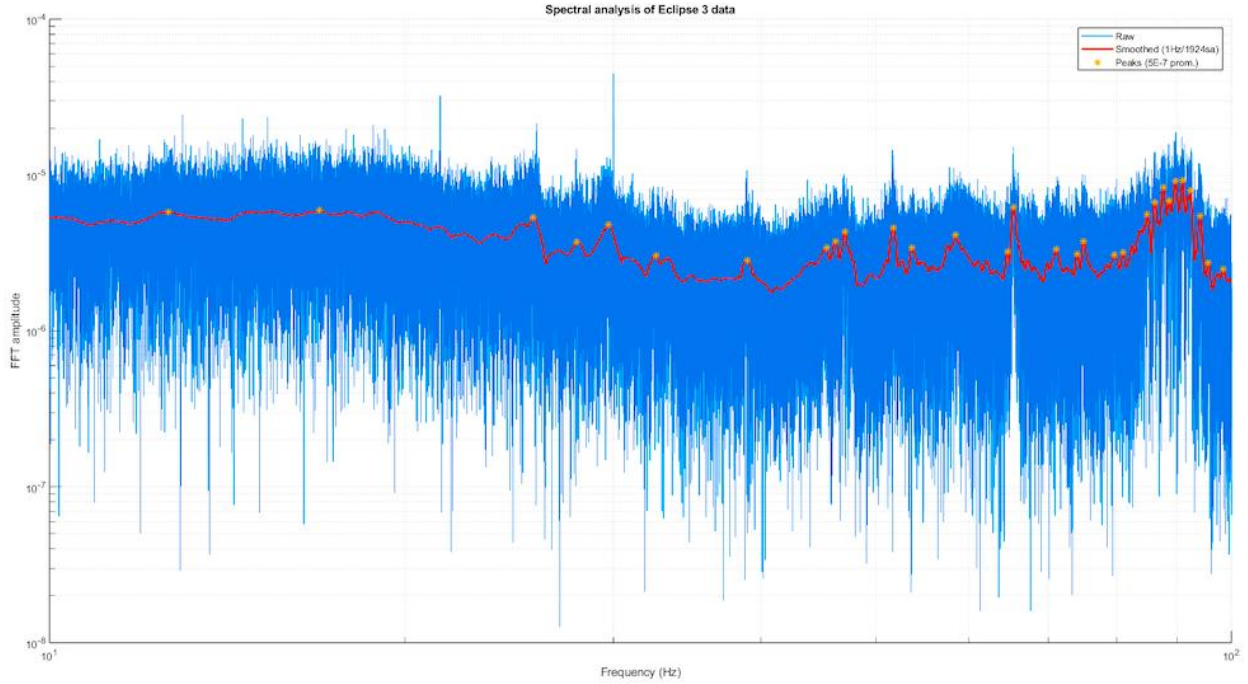
I'm kinda hoping that we can put the data "out there" on the internet to allow folks with more data processing skills to take a look at it. (One of the complicating factors is that there's probably a Doppler shift involved, so the frequency is continually changing).

With Stuart's permission, I have reproduced his results here. There is one set of frequency measurements during the eclipse, where there are distinct peaks at several frequencies, and another set from two days before, with no clear peaks. The significance of these totality peaks is not clear.

The Wikipedia page on shadow bands suggested that balloons were launched for the 2024 solar eclipse to test Eves' theory, but there are no signs of any results from these experiments. My own feeling is that we



Infrasound1 – Frequency analysis of sound measurements during the eclipse. Note the frequency peaks which are not present out of eclipse. It's not clear what these mean



Infrasound2 – Frequency analysis two days previously

need more experiments; first, to see if there are infrasonic waves, second to see if the Allais Effect is genuine.

Of course, observations move on. At the solar eclipse of 2010, seen from Hao Island in the mid-Pacific, several observers, including the BAA's Nick James, were surprised to see shadow bands projected onto the clouds above them. I wasn't able to go to this eclipse, but we had them again at the "pandemic eclipse" of December 2020, seen from Fortin Nogueyra in Argentinian Patagonia. I have included Chris Chotas Alexander's wonderful photograph of these. Note how the shadow bands run parallel to the direction of the narrow crescent of the uneclipsed Sun.

So, next time you go to see a total eclipse, I would commend you to take a look at the ground just before or just after totality, to see if you spot the shadow bands. There is a lot else to see during eclipses, but if you manage to spot them, you'll have seen something remarkable.

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