The British Astronomical Association
Historical Section

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From the Director
Mike Frost

Let me start by introducing you to our deputy section director and newsletter editor, Bill Barton. Bill is a long-standing member of our historical section and, like me, a founder of the *Society for the History of Astronomy*. At the 2019 SHA AGM, Bill won the SHA's Roger Jones award, for his contributions to their County Survey of astronomers, having also previously won it in 2017. Section members will recall that Bill has spoken at each of the last two section meetings, on *Alice Grace Cook: an East Anglian Meteor Observer*, and *Fiammetta Wilson: Mandolins and Meteors*. He will also be speaking at the BAA meeting of 2020 May 27, on *The BAA in Suffolk between the World Wars*. Bill has already carried through a very successful initiative, to create a database of Journal Obituaries for BAA members. I am sure he will bring new ideas and new enthusiasm to the post, and I am very much looking forward to working with him.

We also have a date for your diaries. The next section meeting will take place on Saturday 2020 November 21, at the *Birmingham and Midland Institute*, Margaret Street, Birmingham. This will be a familiar venue to many of you; we held the 2016 section meeting there, and it's the home of the SHA's Sir Robert Stawell Ball library; once again James Dawson has offered to open the library for us (thank you James!). We have three confirmed speakers – Professor Clive Ruggles from Leicester University; Dr Geoff Belknapp, head curator at the Science and Media museum in Bradford, and the renowned and entertaining lecturer Andy Lound. We will announce the full program in our autumn newsletter.

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One of the pleasures of being section director is receiving emails via the "Contact the Director" facility of the BAA website. I never know what will arrive in my inbox, yet pretty much without exception this unsolicited correspondence is fascinating, often leading me into new lines of research.

In June 2019 I received an enquiry from David van Voorst, a teacher at Rangiora High School on the South Island of New Zealand, asking about the provenance of two antique brass telescopes owned by the school. One was a Dollond (London) three inch brass refractor and the other a Watson and Son 'Century' three and a half inch refractor (London, but also with a Melbourne address). I posted appeals for information on the BAA forum and SHA Facebook pages, and suggested that David contacted the US-based Antique Telescope Society. David tells me that these appeals generated a lot of information, particularly about the history of the Dollond Company, but unfortunately nothing specific on the provenance of the Rangiora instruments. The most promising information was from Roger Davis, of Rogers' Optics and Restoration, Padstow NSW, Australia, who was able to offer a lot of information on the Melbourne origins of the Century Telescope. Unfortunately we don't have any further provenance on the scope after it was sold, but thanks to Roger we do have insights into how telescopes were exported to Australia and beyond during the Victorian and Edwardian eras.

In December I had another fascinating email from Rob Hansen, who was keen to tell me about some BAA-related pictures posted on the website of Philip Turner, the son of two BAA members, Harry and Marion Turner (nee Eadie). These two characters were quite extraordinary and I am surprised that I had never heard of either of them previously. In the 1930s, Harry was a leading member of the Manchester Interplanetary Society, who were enthusiastic rocketeers, and the British Interplanetary Society, and was friends with many members of the British science fiction community. Marion Eadie, living in Glasgow, was the founder and president of the Junior Astronomical Association, an organisation completely unknown to me - it is not the same organisation as the Junior Astronomical Society, founded in 1952 and now known as the Society for Popular Astronomy (although Philip tells me that his mother was also involved with the JAS). The JAA had Sir James Jeans as its patron, and published a journal, Urania, through the late 1930s and into the 1940s, until paper shortages during the war stopped publication. Contributors to Urania included Arthur C. Clarke. Harry contributed artwork to Urania, including many of the covers. Please take the opportunity to visit Philip's websites, commemorating:
Marion Eadie: http://www.htspweb.co.uk/fandf/romart/mft/mftidx.htm
Harry Turner: http://www.htspweb.co.uk/fandf/romart/het/hetobit.htm
Urania: http://www.htspweb.co.uk/fandf/romart/mft/urania.htm#uranlist

I'd love to bring these websites to a wider audience, perhaps through a paper in the BAA Journal. Does anyone have any further information on Harry and Marion, or indeed on the Junior Astronomical Association?

And finally... in November, I and several other BAA Council members were contacted by Dan Twist of the TV production company STV, asking if we had any photographs of Elizabeth Brown, the pioneering solar astronomer and (arguably) prime mover of the BAA. You will recall that Elizabeth featured strongly in the last edition of this newsletter. Unfortunately, the photograph which accompanied John Harris's article on Elizabeth is the only known portrait of her, and Dan already had the RAS's permission to use this, so I couldn't help further.

Elizabeth Brown featured in the episode of Antiques Road Trip which aired on 2020 January 14, starring Charlie Ross and Izzie Balmer. I hope you caught it! If not, you can watch it (the feature on Elizabeth Brown comes at about 23 minutes in) on catch-up at https://www.bbc.co.uk/iplayer/episode/m000dcgw/antiques-road-trip-series-20-episode-7

Council has designated 2020 as the year of Highlighting Women in Astronomy, an initiative launched by the current solar section director, Lyn Smith. It is good to see Lyn's eminent predecessor Elizabeth Brown receiving the recognition she richly deserves. I'm sure Elizabeth would be proud and supportive of the current generation of women solar observers.

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The last issue of the newsletter also featured an appeal for speakers. There were several responses; one of the more unusual was from Ronan Newman in Ireland. Ronan has recorded a presentation on the life and works of variable star observer John Birmingham, discoverer of T Corona Borealis. Birmingham is an astronomer who deserves to be a lot better known, and you can find out more about him by watching: https://www.youtube.com/user/KNOXVILLE2626/videos

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Two good friends of the Historical Section have passed away since the last edition of the newsletter. Stuart Williams, who passed in late 2019, was one of the founders of the Society for the History of Astronomy. He spoke at our 2012 section meeting at Soho House, Birmingham, when he his subject was *William Henry Robinson: from Red Books to the Red Planet*. Robinson was a resident of Walsall, where Stuart was also based, and his interests in local history often informed his interests in the history of astronomy. I also recall him speaking to the SHA about his lifelong interest in the work of H.P. Lovecraft.

As I was writing this editorial, news came in of the passing of Dave Gavine. Dave was a popular and long-standing member of our Association, and Director of its Aurora Section for many years. Yet he had also studied the history of astronomy. He was the keynote speaker at our 2018 section meeting at the Smith Museum in Stirling, where he lectured on Thomas Dick of Dundee, a Victorian populariser of astronomy, and evangelist. I spent the week leading up to the section meeting on holiday in Stirling. Two days before the meeting, Dave caught the bus over from Edinburgh, and we spent a very enjoyable afternoon in a café near the bus station, with Dave showing me many pictures from his astronomical life. He also told me of his role as a technical adviser on Liz Lochhead's short film, *Latin for a dark room*, based loosely around events in the history of the Outlook Tower, Edinburgh's camera obscura.

We will miss them both.

A Proposed Memorial Sculpture to Honour the Father of English Astronomy

Gerard Gilligan, Chairman for the Society for the History of Astronomy

Dr Allan Chapman admires the maquette of the proposed statue of Jeremiah Horrocks

The three hundred and eighty year old story of a humble son of a yeoman farmer, who only just out of his teenage years, who went onto revolutionize our views and ideas of the solar system. Is this tale almost a bit of fiction? No, the acclaimed Liverpool born astronomer Jeremiah Horrocks (1618 - 1641) is the subject of what some have described as very ambitious but well overdue project to create at least one life-size bronze statue to honour Horrocks.

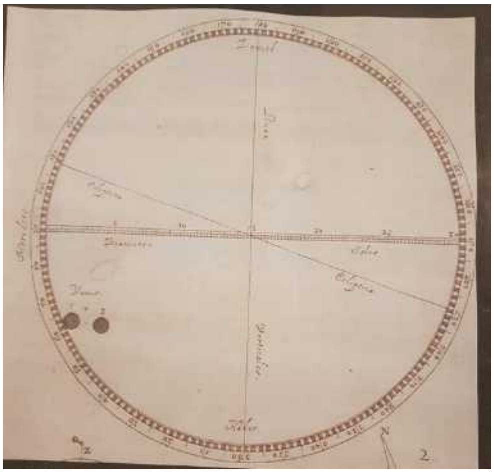
An informal group of local enthusiasts have formed a statue steering group and came together on Saturday, November 30th at the majestic Edwardian Hornby Library, at the Liverpool Central Library, to launch a two year project to publicize and begin a crowd funding campaign to raise over £150,000 for the creation and site two statues. One to be sited in Liverpool city centre, and the other to be placed in a planned new site at the Campus of the University of Central Lancashire in Preston.

The exact location in Liverpool has yet to be determined, but the Preston University campus already has an Institute for Mathematics, Physics and Astronomy named in honour of Jeremiah Horrocks, and is located just a few miles south of the Lancashire hamlet of Much Hoole, from where Horrocks famously observed the transit of the planet Venus across the solar disc on 1639 November 24 (O.S.) An event in planetary mechanics which he predicted at a notably young age and on the eve of the English Civil War. Horrocks is generally acknowledged as the link between the greats of orbital and observational astronomy from Galileo, Copernicus, Kepler to Newton, Halley, and many others who followed. Horrocks sadly died in 1641, at the age of 22 years, had he lived however who knows what he might have achieved. Indeed if Newton had died at such a young age he would surely have been almost as forgotten by astronomical history as Horrocks now is.

During the afternoon of November 30th, and as part of the fundraiser launch event, speakers and supporters were introduced by myself, as Chairman of the Society for the History of Astronomy (SHA), among them, Dr Allan Chapman, the well known Oxford historian of science and astronomy, Frank Cottrell Boyce writer, and film maker, and also Philip Garrett the talented Liverpool based artist whose proposed design was unveiled in the form of a maquette. This depicts a young Horrocks taking a star distance or stellar angular measurement. Other speakers included Professor Andy Newsham from the Institute of Astrophysics at Liverpool John Moores University and also Michaela Mitchell who gave details of the strong educational and public outreach programme, which appropriates Horrocks into the syllabus for local Merseyside schools, and users the young astronomer as a role model for future scientists and as a standard bearer for social mobility. Sadly representatives from the University of Central Lancashire were unable to attend on the day.

All the speakers related Horrocks' influences on culture, social, history and scientific discovery.

The Statue project has strong support both locally and nationally, namely Local astronomical Societies from Liverpool, Manchester, Salford and Preston. The project has received the endorsement and wishes of success from the Society of the History of Astronomy, and members of the heritage committee of the Royal Astronomical Society. With thanks to members of the Steering group, Liverpool A.S. members, BBC Radio Merseyside and staff at Liverpool Central Library. Images courtesy of LAS members Maureen & Phil Williams.



Dr Chapman speaks to those attending the fundraiser event on November 30th (left), and Horrocks partial observation of the Transit of Venus of 1639 November 24 (right)

When the Dust Settles
Mike Frost

A recent article on the BAA website got me thinking. It's by Gerry Gilmore and Gudrun Tausch-Pebody of the Institute of Astronomy, Cambridge, and it's called "Why have we all heard of Einstein?" Gerry Gilmore, who is a superb speaker, will be giving the Alfred Curtis Lecture at the BAA Winchester Weekend in April, entitled "Eddington, Einstein, 1919: truth and consequences", and I imagine it will cover the same subject.

The article appeared on the website on November 6th 2019, one hundred years to the day after perhaps the most significant meeting ever to be held by the Royal Astronomical Society. On November 6th 1919, at Burlington House, Arthur Eddington presented the results of the observations he and others had made of the solar eclipse of May 29 that year. Eddington viewed the eclipse from Principe, off the west coast of Africa, and another party observed from Recife in Brazil.

Why was this eclipse so significant? Albert Einstein had recently published his general theory of relativity, a comprehensive overhaul of gravity, and his theory made the prediction that light would bend in a gravitational field. The magnitude of the effect is small, and so in 1919 could only be observed close to the most massive body in the solar system, the Sun, which is of course overwhelmingly bright. So the only time any meaningful observations could be made was during the brief minutes of totality during a solar eclipse. The eclipse of 1919 was the first to occur after the devastating disruption of the Great War.

I suspect most readers of this article will be aware of the results of the observations. Einstein was right! The positions of the stars closest to the blocked-out sun had shifted, by a tiny but measurable amount, consistent with Einstein's predictions. The endorsement of Einstein's theory by Eddington, perhaps the leading astronomer of the day, sealed Einstein's reputation, and (with a little help from the press) propelled him to the celebrity status he enjoyed for the rest of his life.

But, if you have heard the story of Eddington's observations, you will likely know that they were not without controversy. Eddington had to compare the positions of stars on two sets of photographic plates; one set taken at night, the other during the daytime, during an eclipse, when conditions vary wildly over very short timescales. Moreover, the observations from Recife were inferior in quality, because of the weather, and Eddington chose to ignore some of these.

Almost immediately, there were claims that Eddington's reduction of data was suspect. As Gilmore and Tausch-Pebody explain, even in the 1980's, analysis cast doubt on the veracity of the reduction. However, the authors have re-analyzed the original plates, and confirm that Eddington's reduction was valid and his conclusions hold.

Yet the story persists – Eddington's reduction of data was flawed, his conclusions invalid; relativity suspect; Einstein wrong. This is certainly the mantra of many a crank scientist, but the first assertion, flawed reduction, has had some decidedly non-crank supporters. For example, in an essay in 1968, Arthur C. Clarke claimed that "*One of the world's leading astrophysicists (he may have changed his mind now, so I will not identify him beyond saying that his name begins with Z) once shook me by remarking casually, as we were on the way up Mount Palomar, that he regarded all three proofs of the general theory as disproved*". Evidence elsewhere suggests that "Z" was Fritz Zwicky, the man who posited both neutron stars and dark matter; not someone to be taken lightly.

So why didn't astronomers just repeat the observations? This turns out to be more difficult than one might expect. Total solar eclipses only happen every eighteen months or so, and not always in accessible parts of the world (I know this well!). Moreover, the Sun's location in the sky for the 1919 eclipse was serendipitous; the Sun was crossing through the Hyades Cluster, and so in a region of the sky rich with stars; not many succeeding eclipses had sufficiently bright stars so close to the Sun.

But of course attempts were made to repeat the observations. In 1922, for example, Lick Observatory organized an expedition to near Broome on the remote north-western coast of Australia. John Evershed, director of the Kodaikanal observatory in India arranged to join them, accompanied by his wife Mary, an accomplished solar observer in her own right (and of course my predecessor as director of the BAA historical section). Tracy Daugherty's recent biography of Mary details the expedition, which for the Eversheds was beset by technical difficulties. The Americans declared that they had confirmed Eddington's observations – but, notably, John Evershed remained unconvinced through his life.

Technology moves on, and there have been many more attempts to repeat the observations. Most notably, in the last few years the wide availability of CCD/CMOS technology has allowed amateurs to contribute accurate and measurable images of totality, and in 2017 the Great American Eclipse allowed observers along a long track of totality to submit observations. Once again the claim was that Einstein had been confirmed – but, to play devil's advocate, the size of the measurement to be taken was typically less than a pixel on most cameras, and so the data reduction relied on the averaging of many observations.

However, in the professional field, the accuracy of measurement is reaching jaw-dropping levels, enabling us to see the bending effects of the Sun's gravitational field a long way away from the bright disk. Gerry Gilmore also works on the Gaia satellite, and another of his talks is about that staggeringly successful mission. Gaia is so accurate at measuring star positions that the gravitational bending of starlight by the Sun can be seen even looking at right angles to the Sun.

Another technique of taking relevant observations is to observe in different parts of the electro-magnetic spectrum. The Sun, overwhelmingly bright in visual wavelengths, is a relatively quiet emitter in radio wavelengths, and so can be studied continuously. When the Sun passes in front of a distant radio source such as a quasar, the bending of light is clear and easily measurable.

Moreover, the effects of gravitational bending of light can now be seen with many other astronomical objects. Einstein could only have dreamed of being able to see multiple images of a distant quasar, lensed gravitationally by an intervening cluster of galaxies, yet such observations are now commonplace.

So the gravitational bending of light by the Sun, and other astronomical bodies, is now proven by multiple observations, multiple techniques, and multiple contexts. Yet the suspicions of the bending of light round the Sun remain in some quarters. Why?

I think it's to do with the way in which we report scientific advances. As a society, we favour the new and the sensational. We crave the big news stories and the announcement of groundbreaking advances. I remember being at Astrofest a few days before the announcement of the first observation of gravitational waves (another prediction of Einstein, of course). The excitement was palpable. Every speaker at Astrofest knew something huge was about to be announced, and none of them was allowed to tell us – except for Stuart Clark, who as a science journalist had accurate sources and knew exactly what was going to be announced.

But, for every groundbreaking discovery - gravitational waves, black hole images, Higgs Bosons – there's a discovery that turns out to be not quite what it seemed. Who can forget the announcement of cold fusion? Microbe life in Martian meteorites? Faster-than-light neutrinos? These turned out not to be valid discoveries.

I think that the headlines given to all these extraordinary announcements, followed by scepticism and then, in some cases, retraction, gives the general public a sense that all such announcements are provisional and therefore suspect. We do not do a good enough job reporting successful confirmation. I remember the scepticism over black hole mergers, when people realized that the interferometers could also record tremors and even be set off by passing traffic. Couldn't the tiny, brief patterns recorded, near-simultaneously, in Washington and Louisiana states, simply be co-incidental tremors? Well, probably not, but even if the first observation was a co-incidence (it wasn't), what about all the follow-ups? We're up to eleven detections now, but do any of the others get a mention? And other detectors have come online, making the odds against simultaneous chance events large. But does this ever get reported?

The bending of light by the gravitational field of the Sun is an extreme case. It's a technically challenging observation which for decades could only be carried out on the rare occasion of a solar eclipse. Yet during these decades, steadily improving observational technology, and alternative modes of observation, enabled multiple confirmations of the hypothesis, few of which received much attention.

In one sense science is always provisional. Observations can always come along which force us to overturn, or at least modify, our theories as to how the universe works. But I simply don't think that we do enough to explain that what was once new and untested is now canonical, sitting comfortably within an interconnected web of evidence.

To begin with, a theory such a General Relativity might only have provisional and tentative evidence in support of it. But when the dust settles, and the evidence becomes overwhelming, someone needs to be able to point out that the evidence is no longer provisional.

And that should be the job of the science historians.

Sources

"Why have we all heard of Einstein?" Gerry Gilmore and Gudrun Tausch-Pebody
https://www.britastro.org/node/19749

"*Possible, That's All*", by Arthur C Clarke, appeared in the October 1968 edition of the Magazine of Fantasy and Science Fiction, as a riposte to Isaac Asimov's "*Impossible, That's All*" in the February 1967 edition of the same magazine. The essay was reprinted in "*Greetings, carbon-based bipeds*" (Voyager, 1999) and another essay in the same collection reveals that Zwicky gave Clarke a tour of Palomar in 1962.

Chapter 18, "*Wallal*" of "*Dante and the Early Astronomer*" by Tracy Daugherty (Yale 2019) tells the story of the 1922 eclipse expedition to Australia.

Tycho Brahe: The Father of Precision Astronomy

Robert Persse

[This article examines the work of Tycho Brahe, some parts of which are not generally known to modern astronomers.]

In the late sixteenth century the positions of stars were not known accurately. Predictions of events could be wrong by several days, even using the latest tables - the Prutenic Tables, based on the work of Copernicus. Tycho Brahe resolved to fix this problem believing, like most astronomers of the time, that accurate positions would improve the reliability of horoscopes. He aimed to measure the position of any celestial body to an accuracy of one minute of arc (1'). This is the angle of an object 3mm across at a distance of 10 metres, and is the limit for naked-eye astronomy. Modern analysis of Tycho's data shows that sometimes he achieved this accuracy and sometimes he just missed.
How did Tycho do this? The biographies I read gave plenty of dates, names and other historical detail, but only a few technical explanations. These were often not clear and were sometimes incorrect. This article attempts to clarify some important but rarely mentioned facts.

Tycho built his observatory between 1576 and 1580 on the island of Hven - a small, flat island between Denmark and Sweden with a low horizon all round. He made observations from Hven for 21 years before going into exile in 1597. He designed large and accurate observing instruments, and supervised their construction by highly skilled craftsmen. He tested the instruments very carefully and rebuilt those that were not good enough. He also employed several research assistants who must have done much of the observing and calculating work, and may have contributed useful ideas. He was a full-time observatory director at a time when most astronomers were amateurs. This work was paid for by the Danish king and was about 1% of the king's budget.

Unfortunately, Tycho's instruments have all been lost. But not long before his death he published *Astronomiae Instauratae Mechanica* (*Instruments for the Restoration of Astronomy)*, which I will call '*Mechanica'*. This is an excellent source of information. There are short chapters for each of his main instruments, with a diagram and a couple of pages of explanation. There is also a chapter on things he accomplished, and things yet to be done. Here are links to a facsimile of the book, including diagrams, and an English translation. There is much more information about Tycho in *Opera Omnia (All Works),* 1913, edited by J. Dreyer. This is available on the internet, but the only versions I could find were in Latin.

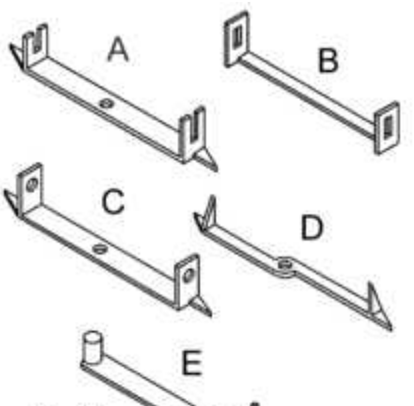
General Description of Instruments

Tycho used different instruments for different types of observation. He built several quadrants, sextants and armillaries as well as some other devices. Some of these were large and very accurate, and some were smaller and easier to use, but less accurate. Some instruments needed two or three people to operate them. The accuracy of readings was improved by using transversals – a similar idea to verniers.

Alidades

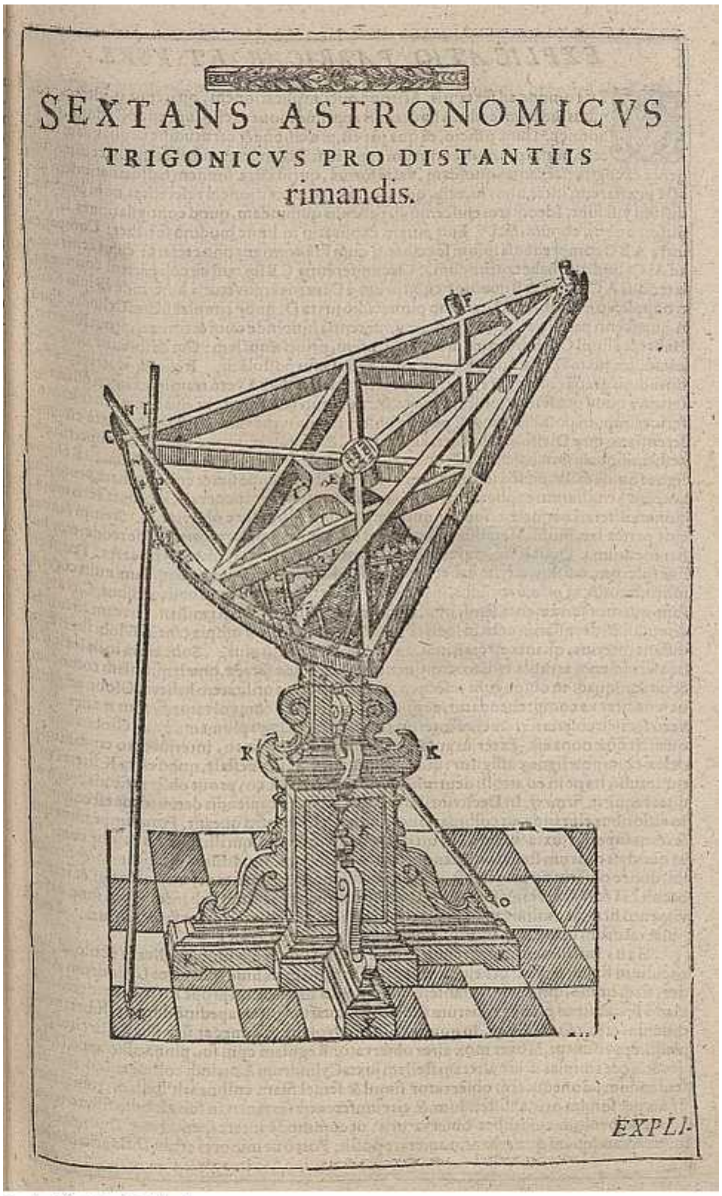
There were no telescopic sights in Tycho's day, so his instruments used pointing devices called alidades. He describes several different types in *Mechanica*. At each end of the alidade is a pinnule. The observer aimed the alidade at the object and could read the position on the attached scale.

To avoid problems when sighting the Sun, Tycho used a pin hole to project an image of the Sun onto the lower pinnule. The alidade was accurately aligned when the image was centred. There is a very good overview of alidades in Wikipedia.



The Large Sextant

The large sextant was used to directly measure angles between objects. It had two alidades - one fixed and one movable - and was mounted on a large spherical bearing so it could be oriented in any direction. One observer aimed the fixed alidade at one object while another observer adjusted the movable alidade to point to the other object. Then they turned the sextant slightly to the west and waited. When the stars disappeared behind the respective pinnules the observers called out. The sky rotates 1' in 4 seconds of time, so if the two stars were near the equator a difference of 4 seconds between calls meant an error of 1' in angle. By making adjustments and using several repeated observations the angle could be measured to a fraction of a minute.



Quelle: Deutsche Fotothek

The Mural Quadrant

The mural quadrant was used to measure the altitudes of objects crossing the meridian. It was operated by one observer, with two assistants who read the time and recorded the observations. Its scale divided minutes of arc into six parts, and transversals are easily visible in the picture. Painted on the wall above the quadrant was a picture of Tycho, his dog and various scenes.

The Equatorial Armillary

The Equatorial Armillary was Tycho's workhorse. Using this he made direct measurements of right ascension (RA) relative to a reference star, as well as declination.

The Great Brass Globe

The easiest way to observe and record positions is using RA and Dec. But calculating orbits requires ecliptic coordinates – latitude and longitude. Tycho had to convert positions from one system to the other which was very tedious. So he built a large globe to use as an analogue computer. It was almost 183 centimetres in diameter (6 feet) and accurate to one minute of arc. It was made from wood, with a brass covering and showed the stars' positions at epoch 1600, which was the closest century.

Other Instruments

Tycho built several instruments to measure altitude and azimuth, as well as several instruments used for other specific purposes. He also designed others that were never built.

Observing the Sun

Measuring the Sun's position relative to the background stars was very difficult to do because stars are not visible in daylight. But this data was essential for understanding how planets move.

The Sun's path is the ecliptic, a great circle on the celestial sphere. It cuts the celestial equator at two nodes exactly 180° apart. The Sun passes these nodes at the times of the equinoxes. The March equinoctial point, where the Sun crosses the equator moving north, is called the First Point of Aries. It is the origin (zero) for both RA and ecliptic longitude. It was crucial for Tycho to know the position of this point as accurately as possible so he could give accurate positions of the stars and planets.

Near the equinox the Sun's declination changes rapidly - it crosses the equator at a rate of 24' per day. So if Tycho could measure the Sun's declination to 1', he could calculate the time of the equinox correct to about one hour. But Tycho had to find the position of the Sun relative to the stars.

Ancient astronomers did this by measuring the angle between the Sun and Moon when both were visible. Then a few hours later, after dark, they measured the angle between the Moon and nearby stars. Combining the two measurements gave the position of the Sun. However the Moon moves a little over ½° every hour relative to the stars. This gives a large error in the calculation unless the timing between the two observations is very accurate.

Tycho tells us in *Mechanica,* in the chapter on his accomplishments, that he used this method with Venus instead of the Moon. Venus can be seen in daylight when it is far enough away from the Sun. At that time it moves only about one degree of RA per day. Errors caused by time are much smaller than with the Moon, even with crude clocks. But Venus is very hard to spot in daylight unless you know exactly where to look. The easiest way is to view it before dawn, keep track of it until the Sun comes up, then make the measurement. Tycho would have used a team of observers to do this as one person would lose concentration. And if Venus was in the evening sky, they could measure its declination and then search for it systematically along the same declination during daylight.

By making observations of the position of the Sun whenever he could during his time on Hven, Tycho was able to calculate a reasonably accurate position for the First Point of Aries. By doing this over several years he was able to measure the slow drift of this equinoctial point - about 0.8' each year – caused by precession of the equinoxes. He also verified that the Sun's path was slightly irregular – a fact known to the Babylonians.

Clocks

The accurate measurement of time was a major problem for Tycho. A century later astronomers would use pendulum clocks to time meridian transits. By comparing these times with sidereal time, they could quickly calculate the right ascension for any object. Tycho measured some things without using clocks at all - the declination of any celestial body, angles between bodies, the obliquity of the ecliptic, and the refraction of the atmosphere. And since most planets move fairly slowly from night to night, his inaccurate clocks were good enough to time planetary observations.

Things improved in 1586, halfway through Tycho's time at Hven. He received a letter from Wilhelm IV, Landgrave of Hesse-Kassel, who was a keen astronomer and former associate of Tycho's. The letter described clocks which had been recently invented by Jost Bürgi, an instrument maker who worked for Wilhelm. They had minute hands, showed seconds, and were accurate to one minute per day. In *Mechanica* the picture of the Mural Quadrant shows two clocks. The text says they could register minutes and even seconds. It is very likely that Tycho acquired these clocks from Bürgi.

These clocks were useful, but 'accurate to one minute per day' means that they were still not sufficiently regular and consistent for the most exacting observations of positions. In one minute of time the sky rotates through 15' of arc – half the diameter of the full Moon. Tycho needed positions accurate to 1' of arc or better for all objects. Only clocks accurate to 4 seconds of time per day could give this.

Clocks which were consistently too fast or slow could be adjusted, or their readings could be corrected by calculation. A more important problem was unpredictable variations in rate. Tycho would have timed transits of reference stars on several nights to show discrepancies and get an idea of how variable his clocks actually were.

Conclusion

Using a combination of accurate observation and careful calculations over his whole career, Tycho amassed positional data on the Sun, Moon, planets, comets and about 1000 fixed stars.

He was meticulous, checking reliability of every observation, repeating observations whenever possible, and checking one instrument against others. Long before statistical theory was discovered, he understood that an average of several measurements is more accurate than a single one. He used the true scientific method for his research and theories. His interests in alchemy and astrology occupied relatively little of his time and do not detract from his scientific achievements.

He died in 1601 without completing the work he had set himself. But he left enough accurate data to enable his former assistant, Johannes Kepler, to discover his three laws of planetary motion.

Image Credits

The picture of Alidades is from Wikipedia. Other images are from Mechanica, found on the internet.

Does anyone know the whereabouts of a replica telescope built by Peter Fay?

Anders Nyholm, Stockholm University

Anders Nyholm of the Department of Astronomy, Stockholm University, Sweden, has emailed, asking if anyone knows the whereabouts of a replica telescope built by former BAA member Peter Fay (thought to be deceased, although obviously we'd love to hear otherwise!).

Back in 1996, Peter, along with Sally Beaumont translated "Observations Concerning the Planet Venus" by the early-eighteenth century astronomer Francesco Bianchini of Verona. As part of his research, Peter constructed and tested a telescope similar to the one Bianchini had used.

Anders asks "Does anyone in the BAA know where the replica aerial telescope built by Peter is now? In a museum, perhaps? It was described in

https://ui.adsabs.harvard.edu/abs/1996ocpv.book.....B/abstract

Replies to the director or directly to Anders at anders.nyholm@astro.su.se

Dates for Your Diary

SHA Spring Conference 2020 will take place at the IoA, Cambridge on Saturday 25 April. Pre-booking essential, £10 (SHA Members) £15 (others). An on-site lunch is available at extra cost (see poster below).

SHA Summer Picnic 2020 will take place at Lacock Abbey, Wiltshire on Saturday 20 June. Lacock was the home of William Henry Fox Talbot the pioneer of photography.

SHA Autumn Conference & 2020 AGM will take place on Saturday 24 October at the Birmingham and Midland Institute, 9 Margaret St., Birmingham.

BAA Historical Section Meeting 2020 will take place on Saturday 21 November also at the Birmingham and Midland Institute, 9 Margaret St., Birmingham.

Mike Frost and friends at the unveiling of a Green Plaque to RAS Founder Rev. Dr. William Pearson, South Kilworth, Leicestershire on 2020 January 16 (image credit: Leicestershire County Council)

Society for the History of Astronomy

ioa

SHA Spring Conference 2020

10:00 am – 5:00 pm Saturday 25th April 2020

Institute of Astronomy, Cambridge University, Madingley Road, Cambridge, CB3 OHA

Confirmed speakers

Philipp Nothaft – *The Walcher of Malvern*
Steve Barrett – *The 200" Hale Telescope*
Christopher Taylor – *The Astronomers and the birth of Atomic Physics*
Lee Macdonald – *Proposals to move Greenwich Observatory, 1836-1945*

Tours of the IoA telescopes will occur during the lunch break

Conference fees: £10.00 for members, £15.00 for non-members (includes tea/coffee)
An on-site buffet lunch will be available for £10; this must be pre-booked

There is ample free onsite parking. The venue is a long way from Cambridge railway station. Recommend either taxi or bus from there. There are no cafes or restaurants open near the site.

For more details and to register please contact:
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www.shastro.org.uk