The Newsletter of the Orwell Astronomical Society (Ipswich)

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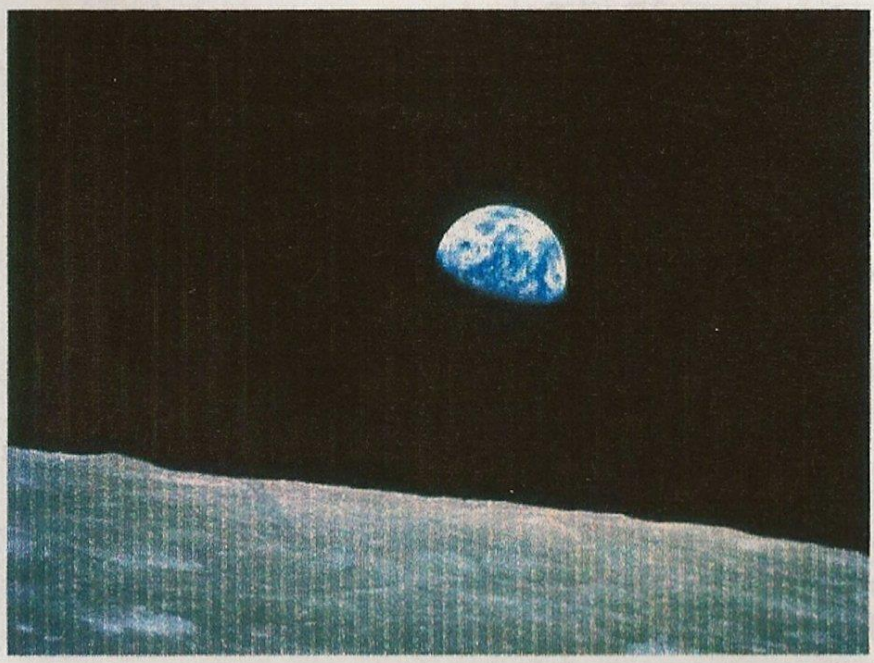
A Christmas adventure like no other



'Earthrise' NASA's iconic image (AS8-14-2383), taken by astronaut William Anders from the Apollo 8 Spacecraft 40 years ago this month. Christmas Eve 1968

"... breaking the chains of the Earth's gravity for the first time and going to another world was extremely important – in many ways more important than the achievements of Apollo 11..."

Apollo 8 post mission comments attributed to Neil Armstrong and quoted in his authorised biography 'First Man' (page 432 James R. Hansen 2005)

Society News (Roy Gooding)

1 Observatory Keys

A new set of observatory key costs the society £18. If you have a set of keys that you no longer need please return them to Roy Gooding

2 Events for 2008

This event list will be updated through out the year

Meeting	Venue	Date
Astronomy Workshop Sperm Whales, Candles and the Planet Venus Presented by James Appleton	Nacton Village Hall	Wednesday 3rd December Starts At 19:45
Gemini Meteor watch	The "Dip" Felixstowe	Saturday 13th December
Christmas Meal **Note change of date** **The general consensus was to return to the venue we used last year** **No more bookings are now being taken**	**Peak Lodge** **Suffolk Ski Centre** **Bourne Hill** **Wherstead**	**Thursday 11th December** **20:00 start.**

3 Access into the School Grounds and Observatory Tower

Please use the third gate into the school grounds, this is the gate behind the Gym. If the Black door entrance at the base of the observatory tower is locked, you will have to phone someone in the observatory to let you in. My mobile number is [redacted]. (Roy Gooding) alternatively the Observatory mobile is [redacted] during meeting hours.

4 Welcome to New Members

5 Lecture Meeting Venue

Our town lecture venue is now at the Methodist Church Halls, in Blackhorse Lane. The Church has a car park, which can take about 30 cars.
Black Horse Lane has only one entrance, which is from Elm Street. This is just past the Police Station, if you are arriving from Civic Drive. The church car park is on the right, just past the Black Horse pub.

Meetings start at 20:00 doors open at 19:30

5 Society Management

A volunteer management committee runs the society. Next year there will be at least one vacancy in the committee. If you are interested in helping to run the society please

consider applying. The job is only as onerous as you would like to make it. In a typical y there are 4 or 5 committee meetings

Night Sky (November)

All times GMT

Moon

1st Quarter	Full Moon	3rd Quarter	New Moon
5th	12th	19th	27th

Object	Date	Times		Mag.	Notes
		Rise	Set		
Sun	1	07:49	15:57		
	31	08:13	16:03		
Mercury	1	08:12	15:56	-0.8	Mercury is low down in the evening twilight sky at the end of the month
	31	09:29	17:29		
Venus	1	11:14	18:45	-3.8	Venus remains low down in the evening twilight sky this month
	31	10:32	20:11		
Mars	1	08:03	15:57	1.6	Mars will be at conjunction on the 5th
	31	07:52	15:22		
Jupiter	1	11:02	19:00	-2.2	Jupiter will be moving into the evening twilight sky this month. It will very close to Venus on the 5th
	31	09:20	17:35		
Saturn	1	00:26	13:26	1.0	Saturn is now becoming well place to observe before midnight this month
	31	22:24	11:27		
Uranus	1	00:24	13:08	5.8	Uranus remains in Aquarius.
	31	11:07	22:22		
Neptune	1	12:16	21:47	7.8	Neptune remains in Capricornus
	31	10:16	19:49		

Meteor Showers

Shower	Limits	Maximum	ZHR
Geminids	December 7th to 16th	December 13th 18 hours	15
Ursids	December 17th to 25th	December 22nd	10

Meteor source is the BAA Handbook

Gemini Meteor Watch Saturday 13th December 20:00

The venue is behind the Refreshment Hut at the "Dip" end of Felixstowe

This location is on the top of the cliff, which gives unrestricted views from the north east to the south.

Directions for those who do not know this part of Old Felixstowe

- From the Hamilton Road roundabout, take the turning into High Road East
- Travel to the open area of grass where Brackenbury Fort was once located.
- There is a parking area, on the right just past the open area of grass, in front of the Refreshment Hut.
- The meeting time 20:00
- The Moon will be full on the 12th. Making this an unfavourable meteor watch
- If the weather is bad there will be a normal meeting at the observatory
- Please contact Roy Gooding, Martin Cook or James Appleton to confirm event is on

OCCULTATIONS DURING DECEMBER

The table lists stellar occultations which occur during the month under favourable circumstances. The data relates to Orwell Park Observatory, but will be similar at nearby locations.

Date	Time (UT)	D R	Lunar Phase	Sun Alt (d)	Star Alt (d)	Mag	Star
04 Dec	19:32:06	D	0.39+	-34	20	6.9	KN Aqr
04 Dec	20:17:06	D	0.39+	-40	16	7.5	Hip 109236
06 Dec	21:46:06	D	0.60+	-53	26	4.5	lambda Psc
	22:31:27	R		-57	20		
09 Dec	20:43:32	D	0.88+	-44	56	7.4	AD Ari
10 Dec	03:19:31	D	0.90+	-40	14	6.1	26 Ari
11 Dec	19:32:38	D	0.99+	-34	44	5.4	chi Tau
13 Dec	21:08:21	D	0.98-	-48	38	3.1	epsilon Gem
	22:11:21	R		-56	47		

James Appleton

Spring Star Party 2009

Thursday 23rd to Sunday 26th April

Kelling Heath, Norfolk

www.starparty.org

The Spring Star Party at Kelling Heath is now being organised by the Norwich Astronomical Society (www.norwich.astronomicalsociety.org.uk). The star party was initially purely an observing event aimed more at the experienced observer. However it is gaining popularity with over 100 pitches booked at the 2008 event and a number of trade stands present.

Because of its increasing popularity, Kelling Heath have reserved both the Red and Yellow fields for the 2009 event. We aim to have more trade stands and one or two speakers for the Saturday 25th but will keep the main focus on observing. The event has been moved to the new moon weekend in April in the hope of improved weather conditions.

For more Information visit the website: www.starparty.org (Check for updates) or contact Andrew Robertson on [redacted]

For bookings, contact Kelling Heath direct on 01263 588181 and quote 'Spring Star Party'.
Pitches are £10 per night for this event including electrical hookup.

Kelling Heath website: www.kellingheath.co.uk

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Some people are just on a different planet

I WAS most disappointed to hear this week that Pluto is no longer officially designated as a planet.
What next? Will we find that Donald is no longer a duck?

This article was noticed in the Star by Tina Hammond one of our members On the 14th of June this year. It proves that the media is not keeping up with the rest of the population on the state of the Universe.

E.W.F. Sims

OASI Committee Contacts & Responsibities

Kenneth J. Goward FRAS	**Chairman**	☎	
Roy Gooding	**Secretary**	☎	**MAIN POINT OF SOCIETY CONTACT** Press Publicity with Chairman. Observatory Decoration. Visits by potential new members.
Paul Whiting FRAS	**Treasurer**	☎	**Finance.** Supervision of Grant Applications. Visits by outside groups. **IYA 2009 Coordinator**
James Appleton	Committee	☎	Committee Meeting Minutes. Web Site.
Martin Cook	Committee	☎	Membership. Tomline Refractor Maintenance.
Neil Morley	Committee	☎	Equipment Curator.
Peter Richards	Committee	☎	Lecture Meetings. School Lighting liaison. Email Distribution Lists.
Eric Sims	Committee	☎	Newsletter.
Mike Whybray	Committee	☎	Librarian & Workshops.
Bill Barton FRAS	Committee	☎	Safety & Security.
John Wainwright	Co-opted	☎	Forward planning & Strategy

Diary for December

Monday **1st & 15th**	**SMALL TELESCOPES OBSERVING NIGHTS** Main Observational targets: Pisces, Pegasus and nearby Messier Objects. ☎ Paddy O'Sullivan ☎ Gerry Pilling
Wednesdays **From 8PM**	**MAIN OBSERVATORY CLUB NIGHTS** Primary Observational targets: Nebulae and faint objects. ☎ Martin Cook (mobile) ☎ Roy Gooding (mobile)
Wednesday 3rd **From 7.45PM** **NACTON VILLAGE HALL**	**OASI WORKSHOP** ***'Of Sperm Whales, Candles and the Planet Venus'*** An investigation of J I Plummer's 1876 estimation of the brightness of the Planet Venus. Presented by Dr James Appleton ☎ Mike Whybray
Thursday 4th **From 7.30PM**	**OBSERVATORY VISITS BY LOCAL COMMUNITY GROUP** 14th Ipswich Cubs ☎ Paul Whiting FRAS
Thursday 11th **From 8PM** **Peak Lodge** **Suffolk Ski Centre** **Bourne Hill** **Wherstead**	**OASI CHRISTMAS MEAL** **Limited capacity – early booking via Roy Gooding is essential** ☎ Roy Gooding

Society Primary Contacts

Chairman: Kenneth J. Goward FRAS ☎ (daytime & evenings)
Secretary: Roy Gooding ☎ (daytime) (evenings)
E-Mail queries: Ipswich@ast.cam.ac.uk

Society Trustees

Mr Roy Adams Mr David Brown Mr David Payne

Society Honorary President

Professor Allan Chapman D.Phil MA FRAS

Observatory Telephone Number

Meeting nights only

Have a Very Merry Christmas!

John Isaac Plummer, Colonel Tomline's Astronomer Part 8

A1.1 Transit Of Venus, 06 December 1882

Transits of Venus occur in pairs, with the transits of each pair separated by eight years, and each pair separated from the next pair by alternating periods of 105.5 and 121.5 years. Transits of Venus present an opportunity for observers at locations on the Earth distant from one another to estimate the apparent parallax of Venus against the solar disk, and then, using trigonometric arguments, to estimate the distance from the Earth to the Sun. In fact, it is difficult for observers to estimate directly the position of Venus against the solar disk, and observers find it much more straightforward to estimate contact times, when the limb of Venus appears to first touch or first separate from the solar limb. Sophisticated mathematics must then be employed to calculate from the estimated contact times the distance from the Earth to the Sun.

By the late nineteenth century, astronomers used Kepler's third law to relate the orbital periods of the planets to their relative distances from the Sun and had developed several techniques for estimating the absolute distance from the Earth to the Sun in order to fix the scale of the entire Solar System. Observations of the transit of Venus provided the most accurate method of determining the distance from the Earth to the Sun. Governments and observatories had sent astronomers to observe the transits of 1761, 1769 and 1874. Astronomers looked forward to the transit of 1882 to provide an opportunity to refine earlier observations and obtain a more accurate value for the distance from the Earth to the Sun; in particular, they hoped that the newly developed technique of photography would enable estimates of contact times to be made with unprecedented accuracy. Governments and observatories therefore sent numerous expeditions to observe the phenomenon in 1882.

In his annual report to the RAS for 1881 [1882b], Plummer noted that *in view of the value to science of the observation of the forthcoming Transit of Venus* Colonel Tomline had granted him permission to volunteer for service.

The ROG dispatched three expeditions from the UK to observe the 1882 transit. One expedition journeyed to the Cape of Good Hope and Madagascar, where the transit began in mid-afternoon and the Sun would set before the transit was complete. Another expedition travelled to the West Indies and Bermuda, where the transit would begin in the morning and end in the afternoon. The final expedition had the longest journey, to

Australia and New Zealand, to observe the end of the transit. Each expedition comprised three or four observing teams which were to set up stations at considerable distances from one another so as to increase the chance of at least one team enjoying clear skies. The expedition to the West Indies and Bermuda comprised three observing teams which stationed themselves at Jamaica, Barbados and Bermuda. Plummer was a member of the team that journeyed to Bermuda.

There appears to be no surviving record of the observations of any of the observing teams dispatched by the ROG. However, Captain G Mackinlay RA, who was second observer in the Jamaica team, wrote an account [1883a] of the preparation for the expedition and the expedition itself. His account is probably serves as a guide for the other expeditions.

Experience of previous transits had indicated that it was important that all observers should be consistent in their estimation of event times. Accordingly, all observers, regardless of experience, were assembled at the Radcliffe Observatory, Oxford in summer 1882 under the direction of E J Stone FRS, head of the Observatory and executive member of the committee of the Royal Society with responsibility for the British observing expeditions. Stone explained to each observer the instructions for observing the transit, based on the experience of previous transits. For practice, the observers used a model of the Sun and Venus, which represented the apparent motion of the planet against the solar disk, positioned 180m (200 yards) from three telescopes. The observers recorded times of apparent contact of the edges of the discs, representing the contact times of the apparent limbs of Venus and the Sun, which were *very fairly accordant*. However, the model had no means of representing the brightness of the Sun or the atmosphere of Venus, and some astronomers were of the opinion that over-reliance on such a model to train observers prior to the 1874 transit had in fact vitiated the quality of some observations as astronomers strained to record what they had been trained to observe rather than what they actually saw.

Each observing team comprised two observers, who were to make independent observations of the transit, and a soldier of the Royal Marine Artillery as assistant. Each team came in turn to the Radcliffe Observatory, Oxford, and stayed for about a month, during which time the team members practiced using the telescopes and other equipment. The equipment of each team was as follows:

- Two 150mm equatorially mounted refractors, one for each observer.
- Two huts, to form observatories for the refractors.
- An altazimuth mounted transit telescope for establishing local time.
- One or two sidereal clocks and several chronometers.

In total, the equipment amounted to *47 large packages and boxes*. The observers used the grounds of the Radcliffe Observatory to practice setting up and using their observing equipment and to store packed equipment ready for transportation to observing sites. Before leaving the UK, the observers researched the climate and possible observing locations at their intended destinations.

The West Indies expedition took passage on a Royal Mail steamer which left Southampton on 17 October 1882. The observers saw a bright, pre-dawn comet during the voyage: this was probably Comet Barnard 1882 III (C/1882 R2).

Once each observing team arrived at its destination, the first job was to select a suitable location to establish a temporary observatory. Once this was set up, the observers could practice using their instruments, undertake observations to determine local time, check the regularity of the chronometers and establish the position of the selected location in relation to other, known locations.

On the day of the transit itself, once observations were complete, each observer documented his observations independently, in order to obtain unbiased results. The observers then communicated results to the UK briefly by telegram, and in more detail by mails sent independently so as to reduce the chances of both being lost. Finally, for a few days following the transit the observers continued to make transit observations of the heavens so as to check the regularity and accuracy of the chronometers.

The expedition to Bermuda took Plummer away from Orwell Park for about four months. As a result of his absence from the UK, he was unable to send an annual report to the RAS for 1882 and his next report to the RAS [1884a] covered the period January 1882 – December 1883.

A2 Zodiacal Light

The zodiacal light is a faint glow visible in the west after sunset and in the east before sunrise. It is shaped like a slanting cone extending from the horizon, tapering along the direction of the ecliptic, and visible over an extent of circa 20°. Spectroscopic analysis shows the zodiacal light to be sunlight scattered by minute particles in the inner solar system.

Nineteenth century observers were not afflicted by the scourge of light pollution which so blights their modern successors and the dark skies of the 19th Century meant that observers then were much more able to observe very faint phenomena such as the zodiacal light. Plummer referred to sightings of the zodiacal light in two papers.

His first mention of the zodiacal light [1874b] was in one of his last papers from Durham Observatory, dealing primarily with observations of the aurora of 05 February 1874. He mentioned in passing that *the night was remarkably clear, and the zodiacal light had been plainly visible earlier in the evening*.

His second mention of the zodiacal light [1874d] was in his first observing report from Orwell Park Observatory (communicated to MNRAS by E Dunkin). He reported that while observing Coggia's Comet (1874 III) in early-morning hours in the months up to and including November 1874 he witnessed *repeated brilliant exhibitions of the zodiacal light*. On seven mornings in September and October 1874 it rivalled the Milky Way in brightness. Plummer believed that the zodiacal light was much more distinct and bright in autumn 1874 than it was usually. He believed that this was the case also in spring 1866 and spring 1874, and he speculated that the zodiacal light might be subject to a periodic (annual) variability which had not previously been recognised – in view of this he thought that the phenomenon might be prominent again in spring 1875. However, he did not appear to confirm this theory by making appropriate observations.

Plummer then noted that although more southerly locations might be best for making spectroscopic observations of the zodiacal light, it should be possible to monitor intensity variations from England. He noted that Orwell Park Observatory was to be furnished with *spectroscopic appliances* before the next apparition of the zodiacal light and he looked forward to studying the phenomenon with their aid. None of Plummer's subsequent papers from Orwell Park make reference to the use of spectroscopic appliances, so it appears that the equipment was in fact not provided.

A3 Star Catalogues

Much of Plummer's work addressed positional estimates of astronomical bodies, in particular comets and minor planets. To estimate the position of an astronomical body he used a micrometer to make several estimates of the apparent offset in RA and declination of the body from a star of known position (the star was known as a comparison star). When the body in question was moving rapidly, for example Comet Brorsen (1879 I) [1880a], he used two or three comparison stars during an evening. Subsequent analysis (reduction) of his measurements yielded estimates of the RA, declination and distance of the body.

Plummer's technique relied on the existence of suitable comparison stars with accurately known positions. He did not mention in the published literature any difficulties with the availability of star catalogues while at Durham Observatory. However, while at Orwell Park Observatory, he appears to have suffered severe difficulties in simply accessing suitable star catalogues! Initially, his situation in this regard appeared promising, and in his first report on cometary observations from Orwell Park in 1875, he stated [1875a] that *for the positions of the comparison stars I have to acknowledge the courtesy of Prof J C Adams, who has kindly placed the library of the Cambridge Observatory at my service for the catalogue places*. However, it appears that Plummer's access to the Cambridge Observatory library was short lived for in his annual report to the RAS for 1877 [1878c] he complained that *the want of astronomical literature, and particularly of star catalogues, is found to be a great drawback to the successful prosecution of the work which is regarded as the proper sphere of labour for this Observatory*. It is not known why Plummer's access to Cambridge Observatory library ceased, and this remains a potential area for future research.

Of course, the star catalogues of the 1870s and 1880s were vastly inferior to their modern counterparts, and even when Plummer did have access to up to date catalogues, they sometimes proved inadequate to the task in hand.

Table 19 lists, for each of Plummer's papers concerned with estimating the positional elements of an astronomical body, the number of comparison stars that he used and the problems and/or special measures (if any) that he reported in utilising the comparison stars.

Ref	Object(s) under study	No of Comp´n stars used	Problems Reported with Catalogue Positions of Comparison Stars or special Measures Adopted
[1869a]	Minor planets and a comet	26	Took all positions from catalogues except for one star, for which obtained position by equatorial comparison with a catalogue star.
[1869b]	Minor planets and a comet	22	Found it necessary to measure RA for six stars using observations on the meridian.
[1870a]	Minor planets	23	For all except four stars measured RA on the meridian and used catalogue places only for declination.
[1871a]	Comet	18	Measured RA of each star and used catalogue places only for declination.
[1871b]	Minor planets	24	For all except one star measured RA and used catalogue places only for declination.
[1872a]	Minor planets	28	Took positions of stars from the latest and most authoritative catalogues *few of them having been observed on the meridian at Durham*.
[1874c]	Comet	8	No problems reported
[1875a]	Comet	26	Found it necessary to determine positions of seven comparison stars by equatorial comparison with catalogue stars.
[1877a]	Venus	1	No problems reported
[1879a]	Comets	41	Made allowance for proper motion of only one star (102 Aquarii) in the data reduction – but concluded that there was evidence of proper motion for at least four others. Found it necessary to determine positions of six comparison stars by equatorial comparison with catalogue stars.
[1880a]	Comet	28	Found it necessary to determine position of two comparison stars by equatorial comparison with catalogue stars.
[1861b]	Comet	1	No problems reported
[1882a]	Comets	51	Found it necessary to determine positions of eight comparison stars by equatorial comparison with catalogue stars.
[1882c]	Comet	12	No problems reported

Ref	Object(s) under study	No of Comp´n stars used	Problems Reported with Catalogue Positions of Comparison Stars or special Measures Adopted
[1882d]	Comet	43	Found it necessary to determine positions of 12 comparison stars by equatorial comparison with catalogue stars. These included four stars listed in Argelander's *Durchmusterung* but not in other catalogues.
[1884b]	Comet	42	Found it necessary to determine positions of 11 comparison stars by equatorial comparison with catalogue stars.
[1884c]	Comet	11	Found it necessary to determine positions of three comparison stars by equatorial comparison with catalogue stars.
[1885b]	Comet	33	Found it necessary to determine positions of four comparison stars by equatorial comparison with catalogue stars.
[1886a]	Comet	17	Obtained positions of several comparison stars from published observing reports of the comet by other observers. Found it necessary to determine positions of seven comparison stars by equatorial comparison with catalogue stars.
[1886b]	Comets	25	Found it necessary to determine positions of four comparison stars by equatorial comparison with catalogue stars. In the case of 12 comparison stars adopted a weighted mean of positions listed in up to four catalogues.
[1887b]	Comets	113	Found it necessary to determine positions of 26 comparison stars by equatorial comparison with catalogue stars. In the case of 37 comparison stars adopted a weighted mean of positions listed in up to four catalogues. Noted five other discrepancies between catalogue positions, the largest being 1^m in RA and 3' 6".4 in declination.

Ref	Object(s) under study	No of Comp´n stars used	Problems Reported with Catalogue Positions of Comparison Stars or special Measures Adopted
[1888b]	Comet	5	In the case of two comparison stars adopted a weighted mean of positions listed in two catalogues.
[1888d]	Comets	50	Found it necessary to determine positions of seven comparison stars by equatorial comparison with catalogue stars. In the case of 31 comparison stars adopted a weighted mean of positions listed in up to four catalogues. Noted five other discrepancies between catalogue positions, including apparent mis-identification of stars and errors in RA, dec and proper motion.
[1889b]	Comets	66	Found it necessary to determine positions of 18 comparison stars by equatorial comparison with catalogue stars. In the case of 30 comparison stars adopted a weighted mean of positions listed in up to five catalogues. Noted six other discrepancies between catalogue positions, including apparent mis-identification of stars and errors in RA, dec and proper motion.
[1890b]	Comets	82	Found it necessary to determine positions of 21 comparison stars by equatorial comparison with catalogue stars. In the case of 30 comparison stars adopted a weighted mean of positions listed in up to three catalogues. Noted six other discrepancies between catalogue positions, including apparent mis-identification of stars and errors in RA and dec.

Table 1. Difficulties in positional estimates caused by problems with star catalogues.

The main difficulties that Plummer faced with star catalogues were as follows:

- **Poor quality (or suspected poor quality) positional data.** In many cases, different authorities quoted different stellar position data, through errors, mis-identification of stars, or poor quality positional astronomy. While based at Durham, Plummer [1869b] stated in 1869 that he: *intended in future to observe the right ascensions of*

all the comparison stars upon the meridian, which will give a much greater reliability to the results in this element… Indeed he did adopt a dual approach to the positions of comparison stars for some subsequent observations, using declinations from published catalogues but undertaking meridional observations to establish RA values. Although he was able to sustain this approach for the next few sets of observations the amount of labour involved meant that he was not able to do so indefinitely. At Orwell Park he indicated [1882b] that his reduction of positional data was hampered by the necessity to use old positions for comparison stars: *It is much to be regretted that many of the positions* [of comparison stars] *depend either on old Catalogue places of stars or, still more doubtfully, on micrometrical comparisons with such, the Observatory not being furnished with a meridian instrument suitable for the observation of the comparison stars.* It may be that he simply found the transit instrument at Orwell Park too small to observe faint comparison stars, or it may be that the difficulties that he reported with the transit instrument (see Appendix 11.2) prevented him from using it satisfactorily. From 1886 onwards, in cases where different authorities quoted different positional data for a star, Plummer either made a choice of which authority to use or adopted the weighted mean of positional data from up to five catalogues in an attempt to improve positional accuracy.

- **No suitable comparison stars within the field of view of the object in question.** In Plummer's era astronomers had been able to measure accurately the positions of only a few thousand of the brighter stars: this meant that the average number of stars with known coordinates was too low to ensure that there was always a suitable comparison star within the field of view of the object in question. In some cases Plummer did not have positional data for a comparison star but it was available from other observers' reports - for example during observation of Comet Wolf (1884 III) [1886a]. When no positional data was available for any stars in the field of view Plummer had to choose a suitable field star with unknown position as comparison star and then use a micrometer to measure the offset of the comparison star from other nearby stars with known positions. In [1884a], Plummer complained that 22% of the comparison stars in his observations of comets in 1882 and 1883 had not previously been observed on the meridian and that he needed to undertake such measurements before he could complete his reduction of cometary positions. By contrast, the modern astronomer is much better served by a dense net of accurately measured stellar positions. In the last few years of the 20th Century the USNO (United States Naval Observatory) published the star catalogue A2.0 [1996b] containing coordinates of 526,280,881 stars, computed from digitised photographic plates, giving an average density of 12,760 stars per square degree. In the 19th Century the situation was far different, and two of the catalogues that Plummer worked with had average densities of only 0.26 and 0.13 stars per square degree (see below).

No doubt Plummer found his experiences of star catalogues frustrating. Perhaps as a result of this, while at Durham Observatory he commenced a thorough investigation of the

quality of available stellar positional data, and continued this work for some time after he moved to Orwell Park. In his report [1876d] to the RAS for 1875, he noted that he had identified *a number of stars likely to show some irregularity of proper motion* and that he was pushing forward the observation of these stars *with vigour*. In 1876, he published a paper [1876b] giving details of his preliminary conclusions. The work concerned difficulties with the British Association Catalogue (BAC) of stars, published in 1847 and in common use in the mid-1870s. He pointed out that the BAC was becoming rather antiquated, and that a new definitive star catalogue was needed. Many of the proper motion estimates in the BAC were based on a comparison of early positional estimates by Bradley (1692-1762) or Piazzi (1746-1826) with more recent estimates. Plummer considered it possible that errors, either occasional or systematic, in the earlier catalogues could translate into significant positional errors in his era. Although many positional errors had been located and corrected, many were thought to remain. Plummer suggested that reliance on more recent observations, even though spanning a much shorter period of time, might yield more accurate estimates of positions and proper motions. Note that Plummer was not alone in recognising problems with the BAC and attempting to quantify and correct them: see for example Downing [1878ai]. However, Plummer had no known association with any of the other professional stellar cataloguing work of his era.

Plummer also stated that he had discovered evidence that proper motions had varied during the 120 years since Bradley's observations: *Again, I do not know that we have any right to assume that proper motion is in all cases constant both in direction and amount during the long interval of 120 years which has elapsed since Bradley's observations, and indeed I believe that I have already discovered some evidence to the contrary*. Frustratingly, Plummer did not reveal the evidence!

Plummer reported starting a programme of work to determine which of the brighter stars in the BAC had positional data most in need of correction. He compared the positions and proper motions of stars in the catalogue *Armagh Places of Stars* [1859b] with those in the 1864 *Greenwich Seven Year Catalogue* [1869h]. The catalogues typically had 25-35 years between their mean dates of stellar positions, and they had over 2000 stars in common. The *Armagh* catalogue contained data on 5345 stars, and the *Greenwich* catalogue contained data on 2022 stars[1]. His description of his technique is not entirely clear; however, it appears that he searched for significant discrepancies between the catalogues using the following procedure for each star which they had in common.

1. Let E_1 and E_2 denote the epochs of the earlier and later catalogue entries for the star. Let (α_1,δ_1) and (α_2,δ_2) denote the positions of the star at epochs E_1 and E_2 respectively in the two catalogues.
2. Calculate (α_P,δ_P), the effect on position (α_1,δ_1) of proper motion and precession from epoch E_1 to epoch E_2.

[1] Assuming that each catalogue covers approximately a hemisphere of the sky, the average density is 0.26 stars per square degree for the *Armagh* catalogue and 0.13 stars per square degree for the *Greenwich* catalogue.

3. Estimate the proper motion from the two catalogues as ($pm\alpha$, $pm\delta$) =

$$((\alpha_2,\delta_2) - (\alpha_1,\delta_1) - (\alpha_P,\delta_P)) / (E_2-E_1)$$

4. Compare the magnitude of each element of proper motion calculated in step #3 with a pre-defined threshold. If the magnitude of the difference exceeds the threshold, consider it as a *change of position* and worthy of additional investigation. Otherwise, consider any small difference as an *error of observation* not worthy of further consideration.

He discussed the setting of the thresholds at some length. He appeared to adopt the values 2".5 in declination and $0^s.25*\sec(\delta_2/2)$ in RA. However, his text was by no means unambiguous on this matter, and appeared to lack consistency: a table of RA threshold values as a function of declination does not appear to correspond to the preceding formulae upon which it is supposedly based.

Plummer found that declination positions in the two catalogues were systematically different, those in the *Armagh* catalogue being greater than those in the *Greenwich* catalogue. He had no explanation for this, and abandoned further examination of differences in declination.

To end the paper, he listed 55 stars, covering the first six hours of RA, with positional differences in RA in excess of the threshold. For each of the 55 stars he computed the proper motion in RA as above, $pm\alpha$, and compared it with the proper motion listed in the *Greenwich* catalogue. Figure 19 plots the 55 differences as a function of declination. (The differences are taken in the sense $pm\alpha$ - proper motion listed in *Greenwich* catalogue). As one might expect, the differences in proper motion are most pronounced at high northern declinations. The RMS value of the difference in proper motion in RA is $0^s.04$/yr; however, if the six numerically largest differences are regarded as outliers and excluded, this figure falls to $0^s.02$/yr.

The paper is one Plummer's most difficult to follow, in part because he did not draw any substantive conclusions from the analysis, so it does not present a completed piece of work. For example, although he began the paper by complaining of difficulties with the BAC, he did not then relate the subsequent analysis and the differences in estimates of proper motion in RA to the positional accuracy of stars in the BAC – yet that would be the obvious end point of the paper. He may have regarded the paper as "work in progress" and expected to write a better structured document at a later date, when he had undertaken further analysis and was in a position to present a well researched conclusion; however, this is speculation at present which is not confirmed by the text.

In his annual report to the RAS for 1876 [1877b], Plummer provided an updated summary of his analysis. In a comparison of the RA of 2028 stars, he found that 196 had proper motions with values which differed from the adopted proper motions of the era more than could reasonably be attributed to errors in catalogue places. He reported observing each of the 196 stars on the meridian on three separate occasions and stated that he had the data reduction in hand. However, he does not appear to have completed and published the results of his observations.

Plummer's next and final mention of the work was in his annual report to the RAS for 1878 [1879b] in which he mentioned briefly that he had completed reduction of a great number of transits of stars which he *expected to yield some interesting results bearing on proper motion*. However, he gave no details, and did not subsequently publish papers on the work.

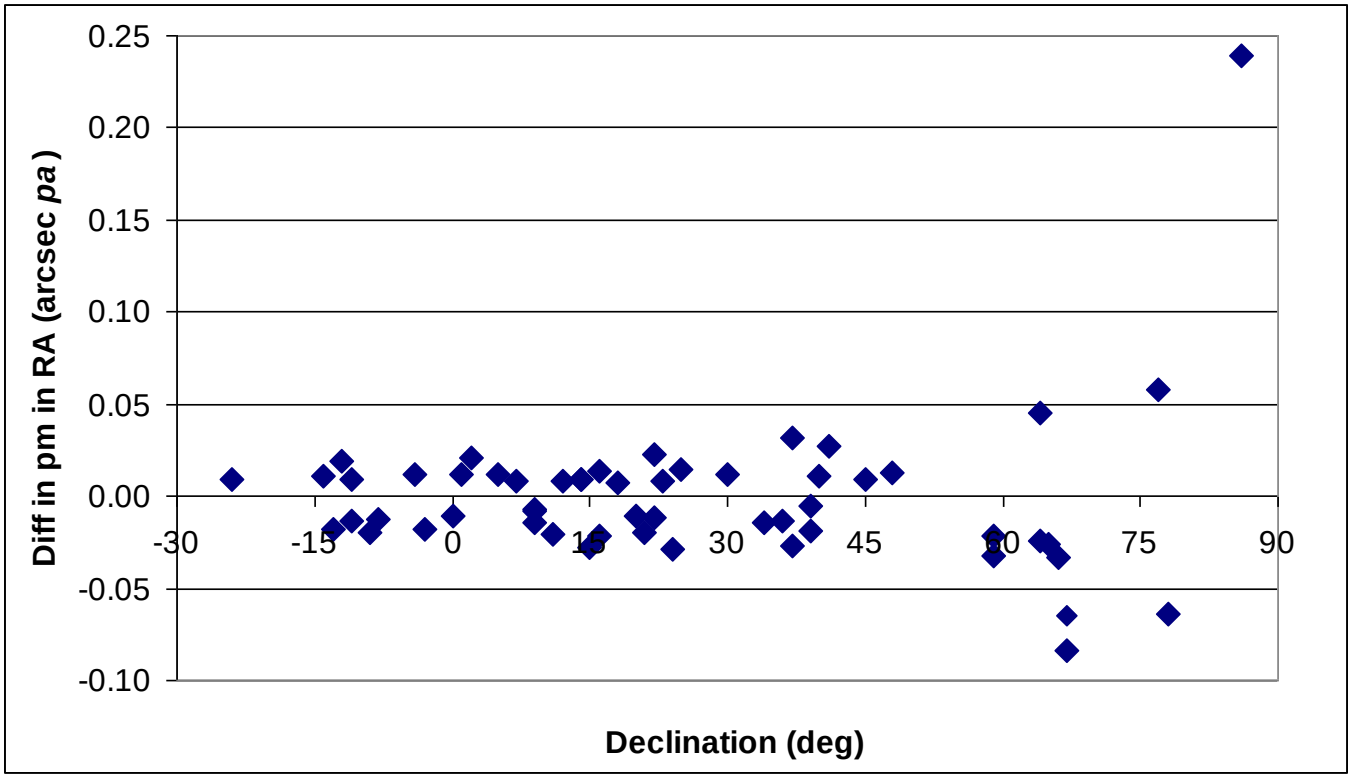

Figure 1. Difference in proper motion in RA as a function of declination.

Plummer's efforts to identify stars with aberrant positional data were not rigorous from a modern perspective, but were a valiant, direct approach to a problem that dogged the astronomy of his day. It is clear that he undertook a considerable amount of observational work and calculation in this project, and he may also have experienced difficulties with the transit instrument at Orwell Park Observatory (see Appendix 11.2) which made it difficult to check accurately positional estimates in star catalogues. It is possible that the sheer amount of observation and analysis which the project entailed finally overwhelmed Plummer and prevented him from completing the work.

However, even if this speculation is valid, it does not explain the complete absence of definitive results from the work. Plummer could for example have concentrated efforts on stars with the largest positional errors, or on bright stars with significant positional errors, or on some other subset of his data so as to reduce the amount of labour involved.

--- To be continued ---