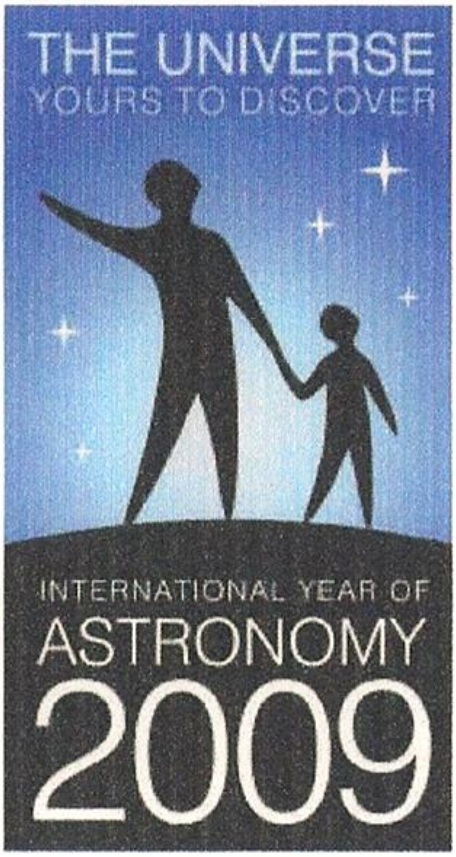
The Newsletter
of the
Orwell Astronomical Society (Ipswich)

Registered charity No 271313
www.oasi.org.uk

2009 January — No 437

Happy New Year !



OASI will be supporting IYA 2009 with a range of public events. Details may be found on the society web site and, of course, within the event and diary pages of this Newsletter.

And so it begins...

Society News (Roy Gooding)

1 2009 AGM Saturday 10th January

All members are invited to attend the 2009 AGM. The venue is at the Methodist Church Halls, in Blackhorse Lane. The meeting will start at 20:00.

2 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

3 Events for 2009 (International Year of Astronomy)

This is a provisional event list, which will be updated through out the year

Meeting	Venue	Date
AGM	**Methodist Church Halls, in Blackhorse Lane**	**Saturday 10th January 20:00**
Astro Fest	Kensington Conference & Events Centre London	6th & 7th February
Talk and Telescope Evening *(IYA)*	Nacton Village hall From 7:30 pm	Monday & Tuesday 30th & 31st March
Sidewalk Astronomy (Night Observing) *(IYA)*	The Ship Levington	Thursday 2nd April
Open Weekend Spring *(IYA)*		Saturday & Sunday 4th & 5th April
Summer Barbecue		TBA
Astronomy in the Park *(IYA)*	Christchurch Park	Saturday & Sunday 30th & 31st May
Perseid Meteor watch	The "Dip" Felixstowe	TBA
Open Weekend Autumn *(IYA)*		Saturday & Sunday 24th & 25th October
Talk and Telescope Evening *(IYA)*	Nacton Village hall From 7:30 pm	Monday & Tuesday 26th & 27th October
Sidewalk Astronomy (Night Observing) *(IYA)*	The Ship Levington	Thursday 29th October
Astronomy in the Park *(IYA)*	Christchurch Park	Saturday & Sunday 31st October & 1st November
Geminid Meteor watch	The "Dip" Felixstowe	TBA
Christmas Meal		TBA

4 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 Bla door entrance at the base of the observatory tower is locked, you will have to phone somec in the observatory to let you in. My mobile number is [redacted]. (Roy Goodir alternatively the Observatory mobile is [redacted] during meeting hours.

5 Welcome to New Members

John Spicer Carol Spicer rejoined
Jack & May Allen
Michael Fisk
Scott Halls
Trefor Harries
Nigel Smith

6 Lecture Meeting Venue

Our town lecture venue is now at the Methodist Church Halls, in Blackhorse Lane. T 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 t Police Station, if you are arriving from Civic Drive. The church car park is on the right, j past the Black Horse pub.

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

7 Society Management

A volunteer management committee runs the society. Next year there will be at least c vacancy in the committee. If you are interested in helping to run the society please consic applying. The job is only as onerous as you would like to make it. In a typical year there a 4 or 5 committee meetings

Night Sky (January)

All times GMT

Moon

1st Quarter	Full Moon	3rd Quarter	New Moon
4th	11th	18th	26th

Object	Date	Times		Mag.	Notes
		Rise	Set		
Sun	1	08:13	16:04		
	31	07:46	16:51		
Mercury	1	09:28	17:34	-0.1	Mercury will be greatest eastern elongation on the 4th and at inferior conjunction about 3 weeks later on the 20th. It will not be well seen this month
	31	06:34	15:13		
Venus	1	10:30	20:14	-4.3	Venus is at greatest eastern elongation on the 14th
	31	09:05	21:17		
Mars	1	07:52	15:22	1.3	Mars will not be observable this month
	31	07:16	15:19		
Jupiter	1	09:17	17:32	-1.9	Jupiter will be at conjunction on the 24th
	31	07:38	16:13		
Saturn	1	22:21	11:23	0.8	Saturn is now moving into the evening sky making it more readily observable
	31	20:17	09:24		
Uranus	1	11:03	22:18	5.8	Uranus remains in Aquarius.
	31	09:07	20:27		
Neptune	1	10:12	19:45	7.8	Neptune remains in Capricornus
	31	08:16	17:53		

Meteor Showers

Shower	Maximum	Limits	ZHR
Quandrantids	3rd January 12:00	1st to 6th January	100?

Source BAA Handbook

OCCULTATIONS DURING JANUARY

The table lists lunar 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
03 Jan	22:04:47	D	0.43+	-53	16	7.0	ZC 29
07 Jan	00:31:12	D	0.76+	-60	29	6.7	ZC 438
07 Jan	17:15:14	D	0.83+	-11	44	6.4	Asterope
07 Jan	17:19:46	R	0.84+	-11	44	3.7	Electra
07 Jan	17:20:21	D	0.84+	-11	45	5.8	Asterope
07 Jan	17:30:01	D	0.84+	-13	46	6.8	ZC 548
07 Jan	17:31:29	D	0.84+	-13	46	6.8	ZC 553
07 Jan	17:39:48	D	0.84+	-14	47	6.3	24 Tau
07 Jan	17:52:54	R	0.84+	-16	49	3.9	Maia
07 Jan	18:00:11	D	0.84+	-17	50	7.0	ZC 557
07 Jan	18:22:42	D	0.84+	-21	53	7.5	1804-0265-1
07 Jan	18:25:37	D	0.84+	-21	53	6.6	ZC 562
07 Jan	18:47:38	D	0.84+	-24	56	7.5	1800-0985-1
07 Jan	18:57:15	D	0.84+	-26	57	7.4	1804-0163-1
10 Jan	19:04:08	D	1.00+	-26	31	5.8	48 Gem

There is also a grazing lunar occultation of Alcyone, magnitude 2.8, on 07 January at 17:55. The track passes within a few kilometres of Ipswich. Please contact me if you are interested in observing this phenomenon.

James Appleton

International Year of Astronomy 2009

OASI Logo Merchandise

A large range of clothing in various colours and sizes is now available with a stitched IYA and OASI logo on the left breast.

Have a look at this web site to see what is available.

www.sharpstitch.co.uk/catalogue.php

If you are interested in any items let Paul Whiting know the following and he'll get you a price (no obligation).

- Item description (eg. polo shirt)
- Item number
- Colour
- Size

As a guide T-shirts and polo shirts are around £10 plus VAT, rugby shirts around £25 plus VAT. I have a polo and a rugby shirt and both are very good quality.

Orwell Astronomical Society

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

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

More Astronomy Workshops

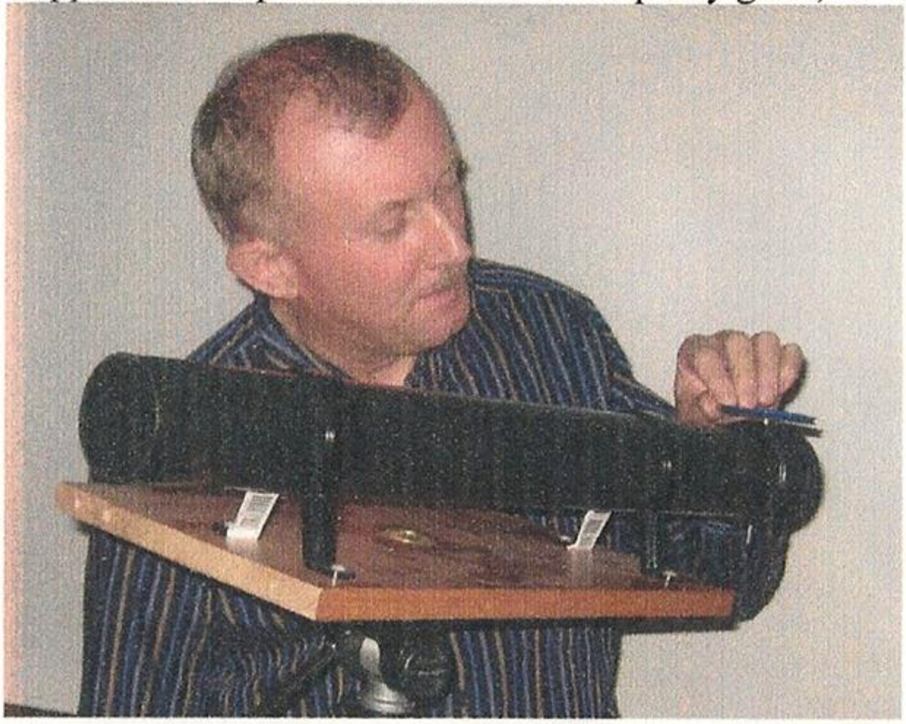
Doors open at 7:30pm.
Workshops START at 7:45pm

Venue: NACTON VILLAGE HALL IP10 0EU (next to the smal village school, just below and left of the N in Nacton on the map)

Date	Event	Run by...
14th January 2009	**NASA 16mm Film Night** OASI was donated about twenty reels of 16mm films made by NASA – mainly about the Apollo moon landings. Tonight I'll be dusting off a couple more of these (each about 30 minutes long) and projecting onto the big screen. You don't need to be an astronomer to enjoy these historic films. Intermission with tea, coffee & biscuits. No ice-creams I'm afraid!	**Mike Whybray**
4th February 2009	**Beginners Night** We've had several new members join in the last few months, so we're having an evening to introduce some of the basics of astronomy – how telescopes work and how to use one, what you can see with one, and the structure of our universe. We'll have one or more telescopes for you to play with, and hope you will have lots of questions for us. No question is too naïve – we all started somewhere!	**Paul Whiting and Mike Whybray**
	More to come – dates and topics still being finalised	

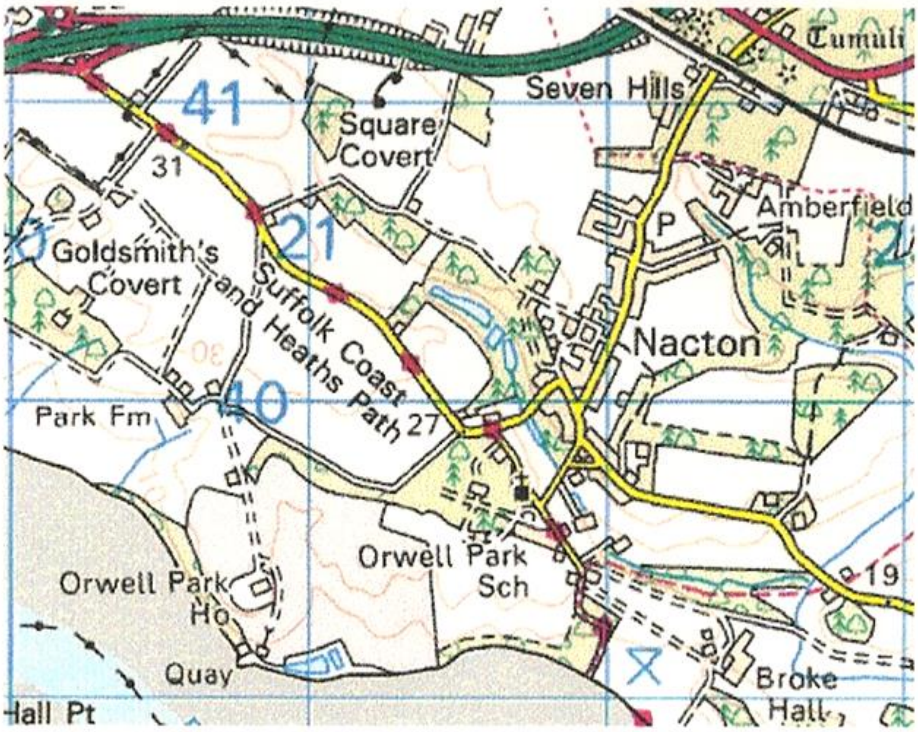
Mike Whybray
Workshops organiser
(Mobile)
(Home)

On 3rd December, James Appleton ran a well attended workshop explaining how John Isaac Plummer, the resident astronomer at Orwell park in the 19th Century, used a method of comparing the strength of shadows cast by a candle and by Venus to measure variations in the brightness of Venus. James had rigged up an apparatus to allow members to repeat the basic method used, but comparing a candle to small lightbulb rather than Venus, so we experienced first-hand some of the difficulties Plummer encountered. It appears his experimental method was pretty good, however he was let down



by slips in his subsequent calculations – not having the benefit of computers and spreadsheets as we do now! Here is a photo of James with some of his home-made apparatus.

Map of Nacton. Venue: NACTON VILLAGE HALL IP10 0EU (next to the small village school, just below and left of the N in Nacton on the map)



LUNAR OCCULTATIONS DURING 2009

By James Appleton

This article provides a summary of lunar occultations visible from East Anglia during 2009. There is a comprehensive listing at Orwell Park Observatory containing full observational details.

2009 promises to be a good year for occultation observers! There are approximately 700 total lunar occultations which are potentially observable from East Anglia during the year, although many involve faint stars. In 2009 the Moon occults the Pleiades twice, providing evenings with multiple occultations of bright stars. Two grazing occultations are visible during the year. There are no good planetary occultations visible from the region during 2009.

The remainder of this article summarises the circumstances of the best occultations during the year. It provides details for the location of Orwell Park Observatory; however, differences will in general be negligible for locations throughout East Anglia.

OCCULTATION PREDICTIONS

The Moon occupies a band through the sky lying within ±6.75° of the ecliptic. This band therefore defines the area of the sky within which to search for lunar occultations. I use a suite of computer software to search for occultations. The software models the motion of the Moon and planets in detail, and by comparing the position of the Moon at each instant with the locations of planets and stars, it evaluates the precise time at which lunar occultation events occur. Once the time of an event is known, the software runs additional algorithms to calculate other observational details.

The software is based on the algorithm *Occult* in *Astronomy On The Personal Computer*, 2nd edition by O.Montenbruck and T.Pfleger, Springer-Verlag, 1994. I have added numerous enhancements to improve accuracy and to filter out predictions occurring under unfavourable circumstances. The software uses the NASA Jet Propulsion Laboratories' ephemeris DE-405 to provide the position of the Moon and planets and the Hipparcos, Tycho2, PPM and XZ94F star catalogues to provide stellar positions. DE-405 and Hipparcos/Tycho2 represent the latest and most accurate sources of astrometric data currently available. The PPM and XZ94F catalogues provide coverage in areas of the sky that Hipparcos/Tycho2 do not cover in depth. The software uses IOTA's electronic Watts charts to correct predicted timings for the local lunar limb profile. (This typically makes a difference of several seconds to predicted event times.)

BRIGHT OCCULTATIONS

There are 12 occultations during the year of stars down to magnitude 5.0 where other circumstances of the event are favourable. Table 1 lists the occultations.

Date	UT	D R	Lunar Phase	Sun Alt (d)	Star Alt (d)	Mag	Star
07 Jan	16:52:46 17:52:54	D R	0.83+	-8 -16	40 49	3.9	20 Tau, Maia
07 Jan	16:53:15	D	0.83+	-8	41	4.3	19 Tau, Taygeta
07 Jan	17:19:46	R	0.84+	-11	44	3.7	17 Tau, Electra
06 Feb	04:05:38	D	0.83+	-31	9	4.8	139 Tau
06 Feb	19:30:43 20:38:26	D R	0.89+	-25 -35	55 61	3.1	epsilon Gem
16 Jun	00:44:29 01:47:29	D R	0.49-	-14 -11	8 18	4.5	18 Psc, lambda Psc
30 Jun	20:57:02 21:51:15	D R	0.64+	-5 -10	16 11	4.8	69 Vir
03 Jul	21:49:24	D	0.89+	-10	12	5.0	ZC 2298
18 Jul	01:21:40 02:01:44	D R	0.22-	-15 -12	13 19	4.1	23 Tau, Merope
18 Jul	02:01:04 02:20:40	D R	0.22-	-12 -11	19 22	2.8	25 Tau, Alcyone
18 Jul	02:20:49 03:13:26	D R	0.22-	-11 -6	22 30	3.6	27 Tau, Atlas
04 Dec	20:56:41 21:53:07	D R	0.91-	-46 -53	23 31	3.5	55 Gem, delta Gem
07 Dec	04:30:43 05:35:32	D R	0.70-	-29 -19	49 47	5.0	5 Leo, xi Leo

Table 1. Occultations of stars of magnitude 5.5 or brighter.

The first two columns of table 1 list the date and time (UT) of the occultation. Column three gives the phenomenon: 'D' denotes a disappearance and 'R' a reappearance. The table lists circumstances of D and/or R as dictated by the visibility of each phenomenon (determined by altitude, lunar phase, etc). Column four details the lunar phase ('+' denoting waxing and '-' denoting waning). Columns five and six give the altitude of the Sun and the star, both in degrees. (A negative solar altitude implies that the sun is below the horizon.) Columns seven and eight provide the star's magnitude and identifier (catalogue number and common name, where one exists).

All of the occultations of table 1 should be readily visible in binoculars or small telescopes.

OCCULTATION SEASONS

The Moon's orbit is defined by a range of periodicities, both short and long term. The short term periodicities mean that the Moon's path through the sky follows a pattern whereby it almost repeats itself every month. However, the longer term periodicities gradually shift the orbit so that no particular pattern of approximate repetition can last more than a few years. This results in so called "occultation seasons", lasting for some years, during which particular stars are repeatedly occulted, or repeatedly not occulted.

During 2009, there are repeated occultation of the stars of Taurus.

NIGHTS WITH MANY OCCULTATION EVENTS

During the year, the Moon traverses some rich star fields. When this happens, a large number of occultations can occur during a single evening. Table 2 lists all evenings throughout the year when the Moon occults more than 10 stars. The precise number of occultations which an observer will record during any of the evenings listed in table 2 will depend in large part on his or her skill and the sky conditions.

Date	No. occs.	Date	No. occs.	Date	No. occs.
01 Jan	16	07 Jan	18	30 Jan	17
31 Jan	18	01 Feb	11	02 Feb	13
01 Mar	14	02 Mar	13	29 Mar	14
30 Mar	26	01 Apr	24	02 Apr	12
28 Apr	57	29 Apr	60	27 May	16
28 May	13	21 Nov	21	21 Dec	14
31 Dec	14				

Table 2. Evenings with 10 or more occultations.

The large numbers of occultations on the evenings of 29 March - 02 April are associated with the passage of the Moon in front of the rich fields of faint stars in Leo.

There is a parial lunar eclipse during the early evening of 31 December 2009 and during the period when the Moon is eclipsed several faint stars are occulted.

PLANETARY OCCULTATIONS

There are no good planetary ocultations visible from the region until 2012.

GRAZING OCCULTATIONS

The tracks of two grazing occultations pass through East Anglia during 2008. Table 3 summarises the circumstances.

Date (2009)	Time (UT)	Lunar Phase	Sun Alt (deg)	Star Alt (deg)	Star Azi (deg)	Limb	Mag	Star
07 Jan	17:55	0.84+	-16	49	117	S	2.8	Alcyone
18 Jul	02:08	0.22-	-12	20	78	N	6.3	24 Tau

Table 3. Grazing occultations.

The first and second columns of table 4 give the date of the graze and the approximate time of closest approach to Orwell Park. Column three gives the lunar phase ('+' for waxing and '-' for waning), while column four gives the altitude of the Sun (below the horizon). Columns five and six give the position of the star. Column seven specifies the lunar limb which grazes the star, while the final two columns detail the star and its visual magnitude.

Figure 1 illustrates the graze tracks over East Anglia as follows:

Alcyone, 07 Jan: Braintree, through Hadleigh, Claydon, just S of Halesworth and out to sea just S of Lowestoft.

24 Tau, 18 Jul: The track crosses land in East Anglia for a few kilometres, running through Orford.

I will calculate and print more detailed maps if there is interest from members of OASI in mounting graze observing expeditions.

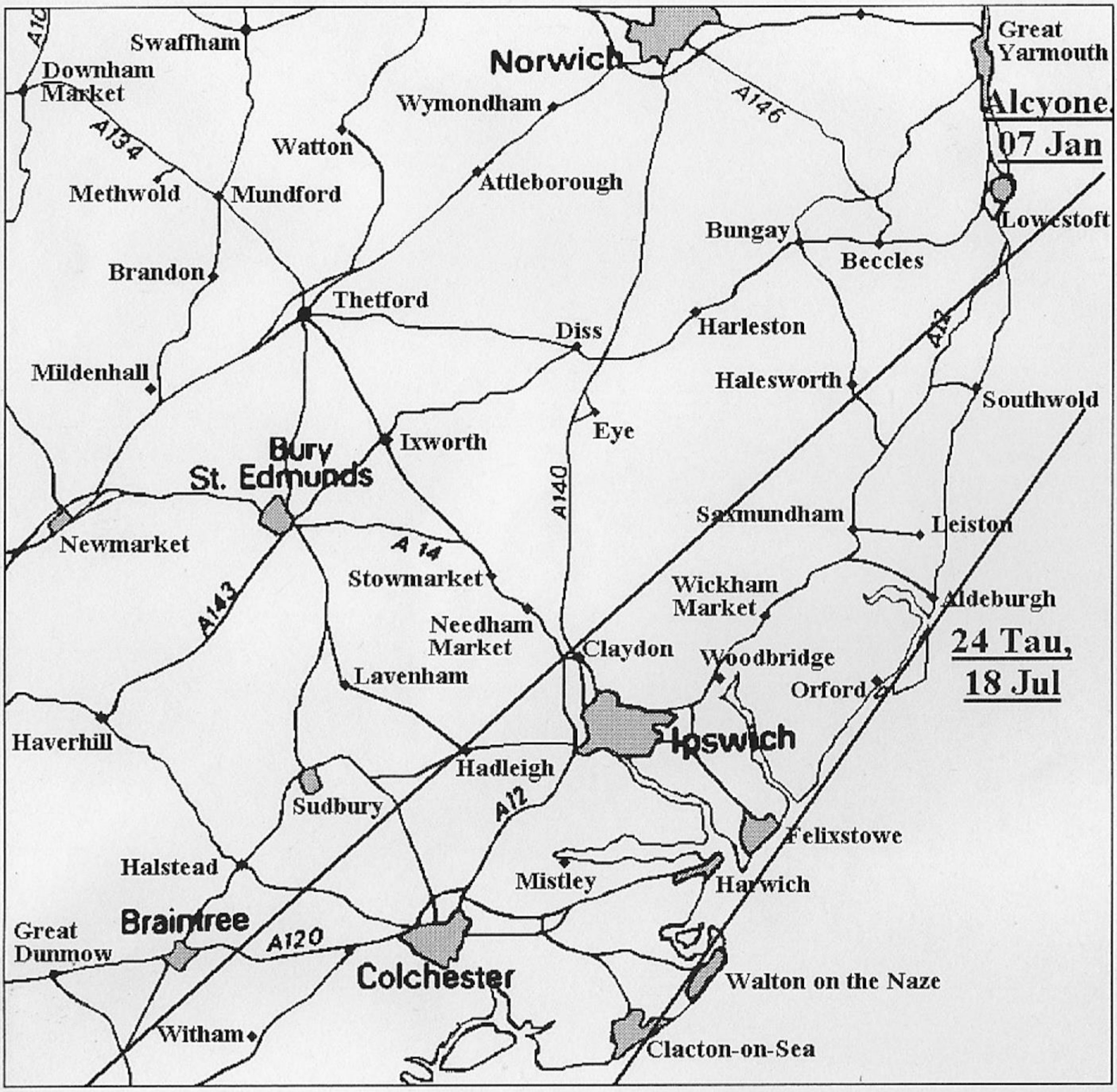


Figure 1. Graze tracks for 2008.

James Appleton

OASI Committee Contacts & Responsibities

Kenneth J. Goward FRAS	**Chairman**		NB Standing down at AGM New Chair to be elected
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 January

Monday 5th & 19th	**SMALL TELESCOPES OBSERVING NIGHTS** Main Observational targets: Triangulum, Taurus and nearby Messier objects. ☎ Paddy O'Sullivan [redacted] ☎ Gerry Pilling [redacted]
Wednesdays **From 8PM**	**MAIN OBSERVATORY CLUB NIGHTS** Primary Observational targets: Nebulae and faint objects. ☎ Martin Cook [redacted] (mobile) [redacted] ☎ Roy Gooding [redacted] (mobile) [redacted]
Wednesday 14th **From 7.45PM** **NACTON VILLAGE HALL**	**OASI WORKSHOP** NASA 16mm Film Night "OASI was donated about twenty reels of 16mm films made by NASA – mainly about the **Apollo moon landings**. Tonight I'll be dusting off a couple more of these (each about 30 minutes long) and projecting onto the big screen. You don't need to be an astronomer to enjoy these historic films. Intermission with tea, coffee & biscuits. No ice-creams I'm afraid!" ☎ Mike Whybray [redacted]
Thursday • **8th @ 7.30pm** • **22nd @ 8.00pm** • **29th @ 7.00pm**	**OBSERVATORY VISITS BY LOCAL COMMUNITY GROUP** 1st Ipswich Scout Group First Contact Night Kyson Primary School (1st Group) ☎ Paul Whiting FRAS [redacted]
Saturday 10th @ 8pm **Methodist Church Hall** **Blackhorse Lane** **Ipswich**	**ANNUAL GENERAL MEETING** ☎ Roy Gooding [redacted]

Society Primary Contacts

Chairman: Kenneth J. Goward FRAS (Standing down at AGM)
Secretary: Roy Gooding ☎ [redacted] **(daytime)** [redacted] **(evenings)**
E-Mail queries: Ipswich@ast.cam.ac.uk

Society Trustees

Society Honorary President

Professor Allan Chapman D.Phil MA FRAS

Observatory Telephone Number

Meeting nights only

[redacted]

John Isaac Plummer, Colonel Tomline’s Astronomer Part 9

A1 Orwell Park Transit Instrument

Orwell Park Observatory is equipped with a 75 mm (3") transit telescope (see figure 1), housed in a transit chamber on the NE side of the equatorial dome. Plummer’s primary use of this instrument was to estimate the position of stars on the meridian. He also used it to determine the longitude of the observatory and to estimate local siderial time.

The transit telescope has a small aperture and is therefore limited in its capabilities. Nonetheless, in his early years at Orwell Park, Plummer used the instrument extensively. He indicated [1875c] that up to September 1875, only 16 months after he began employment at Orwell Park Observatory, he had observed at least 500 transits. Slightly more than a year later, in his annual report to the RAS for 1876 [1877b], he reported briefly on an examination of apparently aberrant stellar positions and noted that he had measured the positions of each of 196 stars on the meridian on three separate occasions. In an update on this work, in his annual report to the RAS for 1878 [1879b] he mentioned briefly that he had completed a *great number* of transit observations.

Plummer experienced difficulties with the instrument and indeed in his annual report [1882b] to the RAS for 1881 went so far as to express his dissatisfaction as follows: *the Observatory not being furnished with a meridian instrument suitable for the observation of the comparison stars...* It seems that as he studied the characteristics of the instrument closely, he became aware of problems which prevented it from undertaking accurate astrometric observations.

A1.1 Determination Of The Longitude Of Orwell Park Observatory

Knowledge of the precise position of Orwell Park Observatory was important in the analysis of observational data. The first maps drawn by the Ordnance Survey (OS) showed the observatory approximately 3" east of the modern accepted position (see [2006e] and [2007e]). However, by the end of Plummer’s time at Orwell Park Observatory the OS [1889a] showed the observatory essentially at the modern accepted position.

Table 20 compares various estimates of the location (particularly the longitude) of the observatory. The table presents longitudes and latitudes in terms of the Airy 1830 reference ellipsoid (as used by the OS). Google Earth and GPS, widely used nowadays for precise determination of position, present coordinates relative to the WGS 84 reference ellipsoid, and these have been transformed to the Airy 1830 reference ellipsoid for presentation in the table. See [2006c] for an introduction to coordinate systems and reference ellipsoids used in the UK.

Estimate of Position	Longitude	Latitude
OS 1838 map of the region, consulted by OASI member Paul Whiting (see [2006e])	1° 13' 58.8" E	Not recorded
OS 1889 six inch to the mile scale map of Nacton and Levington [1889a]	1° 13' 55".6 E	52° 0' 34".0 N
Google Earth (consulted by the author on 02 November 2007)	1° 13' 55.8" E	52° 0' 33.6" N
Latest OS *Explorer* series map #197 for Ipswich [2006d]	1° 13' 55.8" E	52° 0' 33.6" N
Handheld Global Positioning System (GPS) receiver used by OASI member Paul Whiting in October 2007 [2007e]	1° 13' 56.4" E	Not recorded

Table 1. Estimates of the position of Orwell Park Observatory.

A longitude difference of 1" corresponds to a linear distance on the Earth's surface of approximately 19 m at the latitude of Orwell Park Observatory; therefore the discrepancy between the 1838 OS longitude and the 1889 OS longitude amounts to a linear discrepancy of 61 m, and the discrepancy between the modern Google Earth / OS *Explorer* and GPS estimates of longitude amounts to a linear discrepancy of 11 m.

However, although the OS had established the position of Orwell Park Observatory with high accuracy, Plummer chose to estimate the position of the observatory by astronomical means. It is comparatively easy to establish latitude by astronomical observations, for example by measuring the altitude of stars. However, determination of longitude by astronomical observations is much more difficult, and in general terms, techniques rely on the fact that the Earth rotates once on its axis in 24 hours sidereal time[1]. This immediately establishes the correspondence 360° = 24 hours, or 15° = 1 hour, etc. Thus, if a star culminates at a given time as observed at the ROG, it will culminate at another observing station one hour later for every 15° longitude West of Greenwich. If an observer had access at his observatory to a chronometer reading sidereal time at Greenwich, he could

[1] The rotation period of the Earth with respect to the fixed stars is $24^h\ 00^m\ 00^s.84$ according to [1992a].

readily determine his longitude by noting how much earlier or later a star culminated at his location than it did at Greenwich. In Plummer's era the chief practical difficulty was in making Greenwich sidereal time available at the observer's location. The most accurate techniques were to synchronise a chronometer at Greenwich and then to transport it to the observer's location, or to use telegraphy to synchronise a chronometer at the observer's location to Greenwich time. Unfortunately, both techniques were cumbersome, and not lightly undertaken. Plummer made no mention in his publications of techniques for synchronising chronometers and instead referred to the techniques of the *Moon*, *culminators* and *occultations* in determining the longitude of Orwell Park Observatory. He did not provide details, but a typical exercise of these techniques in his era would have been as follows:

- The *Moon*, or *lunars*. To "take a lunar" the observer used a sextant to measure the angular distance of the Moon from one of a selection of bright objects (the Sun, brighter stars and brighter planets). The *Nautical Almanac* tabulated predicted angular distances for a geocentric observer (tabulated every three hours). The observer had to undertake some calculations, carried out according to a standard method, but involving some heavyweight arithmetic, to produce an estimate of Greenwich Siderial Time. References [2004a, 2004b] provide some historical explanation of *lunars* and a modern example of estimating longitude by a *lunar*.
- *Culminators*: the observer timed the culmination of a standard star or the Moon. The *Nautical Almanac* listed predicted times of culmination at Greenwich. Providing the observer had a local chronometer reading Greenwich Siderial Time, he could compare the predicted culmination time at Greenwich with his local time of culmination and readily estimate his longitude from the difference between the two.
- *Occultations*: the observer timed the occultation of stars by the Moon, and compared event times with timings made by an observer at Greenwich or with predicted times for an observer at Greenwich. By using published values of the occultation station coefficients, which describe how occultation event times change as a function of the latitude and longitude of the observer, he could derive an estimate of his position.

It is likely that Plummer used the method of *lunars* to set a chronometer to Greenwich Siderial Time and then used the transit telescope to observe culminating stars to estimate his longitude. He may have intended to use observation of occultations to check his results. Reference [1863b] gives an account of the use of Moon culminations to determine the longitude of the US Naval Observatory at Washington and provides an illustration of the techniques used.

Plummer experienced considerable difficulty in determining the longitude of Orwell Park Observatory. Table 21 lists the chronology of his attempts. (Note that Plummer expressed longitude in minutes of time, and the table shows his original estimates together with the equivalents expressed in degrees of longitude.)

Publication	Longitude Estimate	Note
[1875a] Report on observations of Coggia's Comet 1874e (Comet C/1874 Q1).	4^m $55^s.8$ E 1° 13' 57.0" E	Plummer's first published estimate of the longitude of Orwell Park Observatory.
[1875e] First annual report to the RAS from Orwell Park, covering work in 1874.	4^m $55^s.8$ E 1° 13' 57.0" E	Noted that his estimate of the coordinates of Orwell Park Observatory was based on a *preliminary determination*.
[1876d] Annual report to the RAS for 1875.	-	Reported making meridianal observations of the Moon and culminators for the determination of longitude *on every available occasion*.
[1877b] Annual report to the RAS for 1876.	-	Reported completing work to determine the longitude of Orwell Park Observatory, but did not state the value.
[1878c] Annual report to the RAS for 1877.	-	Reported some curious results which he intended to communicate to the RAS. He found that the level and azimuthal errors of the transit instrument were *subject to an annual fluctuation which is extremely regular in its development* and which he believed was caused by heat radiated from the nearby pier of the equatorial refracting telescope
[1879b] Annual report to the RAS for 1878.	4^m $57^s.75$ E 1° 14' 26.25" E	Estimated longitude by the methods of the Moon and culminators.
[1880b] Annual report to the RAS for 1879.	-	Reported completing determination of the coordinates of the Observatory *after some difficulty* and intended to supplement his results by observation of occultations during 1880.
[1881c] Annual report to the RAS for 1880.	-	Reported that he had observed *a number of occultations of stars by the Moon*. However, he did not publish the analysis of his observations.

Publication	Longitude Estimate	Note
[1882b] Annual report to the RAS for 1881.	-	Expressed dissatisfaction with the capabilities of the transit instrument as follows: *the Observatory not being furnished with a meridian instrument suitable for the observation of the comparison stars…* Published no subsequent papers on the longitude of the Observatory.

Table 2. Estimates of the longitude of Orwell Park Observatory.

Plummer's initial estimate of the longitude of Orwell Park Observatory was only 1" east of the current OS value, corresponding to a linear discrepancy of 19 m. Unfortunately, his final estimate was 30".25 east of the current OS value (nearly 30" east of the OS value pre-1889), corresponding to a linear discrepancy of over half a kilometre. Plummer was aware of the discrepancy, yet did not appear to consider it serious enough to warrant revising his longitude estimate. It may, however, have contributed to his eventual disenchantment with the transit instrument.

At present there is no definitive reason for the discrepancy between Plummer's estimate of the longitude of Orwell Park Observatory and the modern figure; however, suspicion centres on the accuracy of alignment of the transit instrument (see below). Equally, it is not clear why Plummer did not try to reconcile his estimate with the contemporary OS position for the observatory.

A1.2 Errors Of The Transit Telescope

Figure 18 shows the adjustment mechanisms on the east and west axes of the transit telescope at Orwell Park Observatory. Each axis of the transit telescope sits in a U-shaped mounting. The east mounting is adjustable laterally, providing an azimuth adjustment, and the west mounting is adjustable vertically, providing a level adjustment. The adjustments are by means of screwed threads which can be secured in position by locking collars. For accurate transit timings, the observer must adjust the mountings of the transit telescope so that the instrument is level and its optical axis is aligned precisely with the meridian of the observer. However, in Plummer's era the process of aligning a transit telescope involved a very lengthy process of successive refinements, and it was common practice to achieve the best alignment possible after a reasonable amount of effort then to measure the residual errors of alignment regularly and apply them in the reduction of observations.

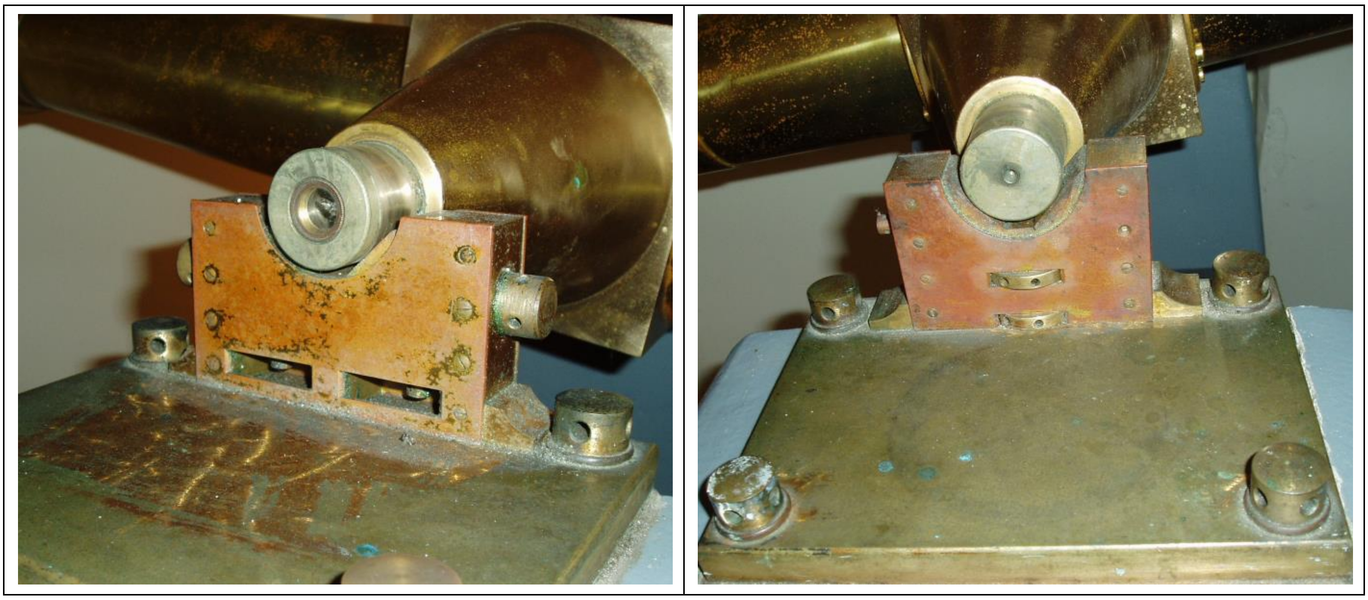


Figure 1. East (L) and west (R) mountings of the transit telescope. By James Appleton, 20 February 2007.

In early 1878, Plummer reported [1878c] that he had nearly completed the reduction of transit observations made in 1875-76 and that he had obtained some peculiar results: the errors of the Orwell Park Observatory transit telescope exhibited a regular annual variation which he thought was associated with the radiation of heat by the massive masonry pier which supported the adjacent equatorial refractor. Later that year, he reported [1878d] his findings in detail. He noted that his work with the transit telescope during 1875-76 required strict attention to errors and he therefore estimated the level error *upon each evening of observation*. He gave no details of his procedure for doing this, but it was likely to have been by use of a "striding" spirit level supplied for the purpose by the makers of the telescope itself. Use of a spirit level was much simpler and quicker than reliance on astronomical measurements; however he would have made astronomical measurements occasionally as an additional check on alignment. He estimated the azimuth error *as often as was deemed necessary or as circumstances permitted*. He gave minimal details, stating only that his method was *generally the observation of a polar and a low southern star…* It is likely that he observed culminations of the stars to check that the centre line of the transit telescope was aligned with the meridian. Observation of both a polar and a low southern star provided a degree of cross-checking of the level error. Reference [1995a] provides a description of techniques for aligning a transit telescope.

Plummer analysed observations which he made during the period August 1875 – November 1876. He found that both level and azimuth errors followed a pattern whereby they remained relatively constant for an interval, and then changed significantly to enter another interval during which values remained relatively constant, and then changed significantly again, and so on. He presented a summary of results (not the raw data) showing the mean error during each interval of relatively constant error.

On 27 June 1876, the level error became troublesomely large and Plummer altered the adjusting screws. The adjustment rendered the level errors more unsteady, so a month later Plummer tightened the screws to minimise the variation. The adjustments altered the error profiles, which eventually became significantly smaller in amplitude. Figure 19 plots the mean error of each interval of relatively constant error; the dates shown are the end dates of the intervals.

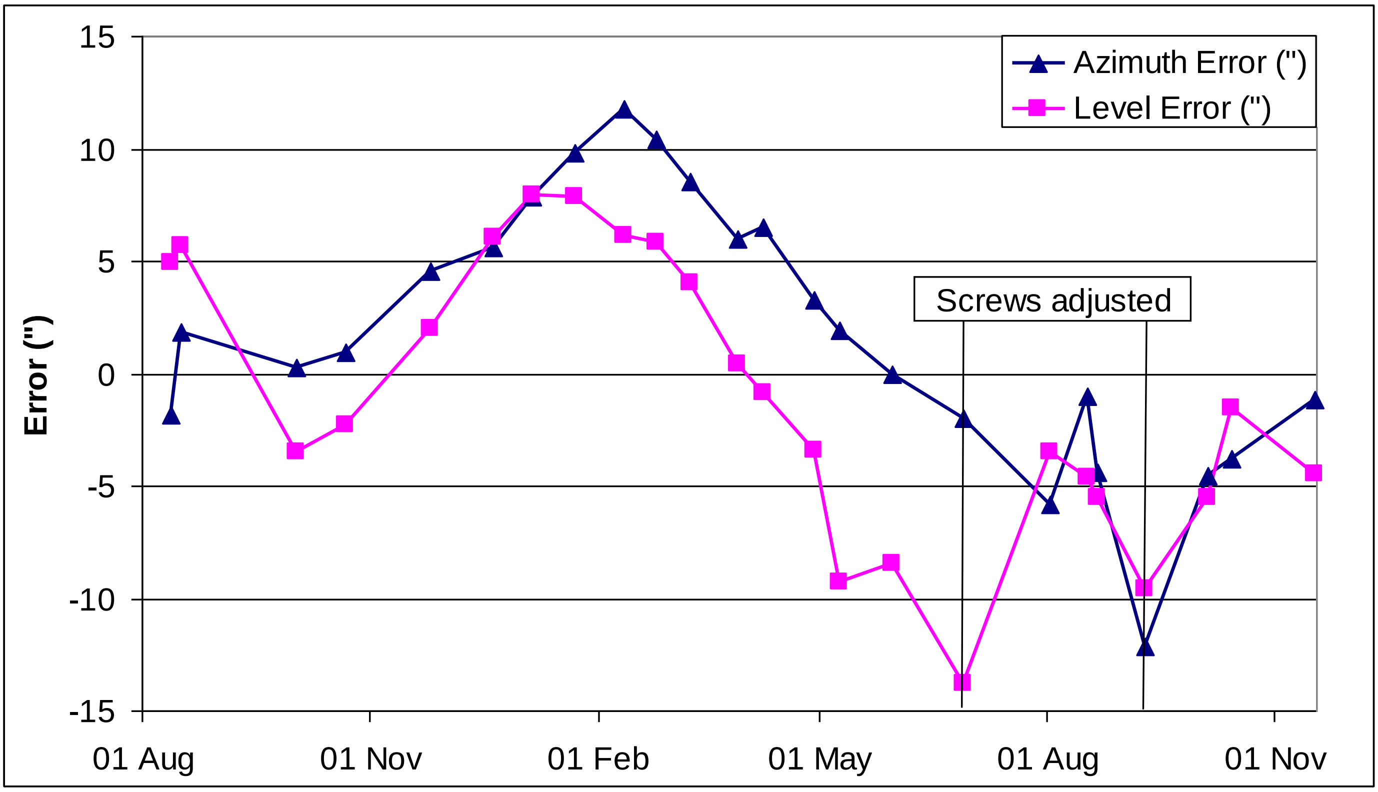


Figure 2. Errors of the Orwell Park transit telescope, 1875-1876.

Both azimuth and level errors showed some evidence of cyclic variability, rising from a minimum circa October 1875 to a maximum in winter 1875 – 1876 and then to a minimum at the end of June 1876, at which point Plummer adjusted the screws, altering the pattern of variability. Initially, changes to the azimuth and level errors occurred approximately in phase with one another, but after winter 1875 – 1876, the level error led the azimuth error by approximately a month. Although there is clearly evidence of an annual variability, there is considerable random variation, particularly after Plummer adjusted the screws. The range of data is too short and the amount of random variation too great (particularly at the beginning and end of the period in question) to support a definitive analysis of the situation.

Plummer concentrated on the azimuth errors, writing: *A casual inspection of the above azimuth errors is sufficient to indicate a marked and regular fluctuation, of which the maximum and minimum coincide closely with the periods of greatest cold and heat respectively, and for which no sufficient reason immediately suggests itself*. However, he noted that 4.3 m (14 feet) WSW of the western pivot of the transit instrument was situated the pier of the equatorial refractor, which together with its surrounding wall formed a masonry cylinder some 2.75 m (nine feet) in diameter. He suggested that thermal radiation from the pier could cause an uneven temperature distribution across the pillars of the transit instrument, producing the seasonal error profile.

Plummer's explanation was superficially plausible but completely unproven. He made no mention of any attempt to validate his explanation, for example by measuring the temperature profile in the transit room or by estimating the daily variation in temperature. Other equally plausible explanations exist. For example, variation between wet and dry seasons in the moisture content of the earth around the observatory tower could be responsible for slight changes in the angle of the entire edifice.

Plummer concluded by recommending that astronomers pay attention to the surroundings of important transit instruments, so that they did not suffer similar problems.

In fact, less than a year before Plummer began his sequence of measurements of the errors of the transit telescope, Wilfrid Airy, design engineer for Orwell Park Observatory, had articulated a potential explanation for the apparent annual variation of errors. The occasion was an ordinary general meeting of the Royal Institution of British Architects on 16 November 1874 [1875f]. At the meeting, John Macvicar Anderson, architect of Orwell Park Observatory, read a paper entitled "The Orwell Park Observatory" in which he described design considerations for the observatory. Airy, who had held responsibility for the design of astronomical aspects of the observatory and its equipment, described his considerations for the brief and there followed a discussion between Anderson, Airy and some of the audience. During the discussion, there was some consideration of the notion that *buildings are really found to be sensibly influenced by changes of temperature, due to the hours and seasons* and that such an effect might make it impossible to undertake the most demanding astrometric positional measurements. Airy gave the meeting an illuminating insight into his design for the transit room and instrument:

> *With regard to the foundation of the transit instrument, it is not a perfect foundation; but seeing that it could not, with any convenience, be combined with the foundation of the equatorial; (and it seemed out of the question to carry up such a large mass of masonry as would be required for the separate foundation of the transit instrument), I was content with the sufficiently solid foundation afforded by some powerful wrought-iron girders which were used in the construction of the building, and these carried the transit room and instrument. I have already mentioned the transit instrument as being, in the present instance, not of the first importance, but mainly to be used as an adjunct to the equatorial. There is no fear of its getting seriously out of order: it may get a very little movement in consequence of the expansion and contraction of the iron girders, but iron, when entirely enclosed in masonry, does not contract or expand in the same degree as iron exposed to the atmosphere. I was therefore, content with a foundation of that kind, although I should not think of*

adopting such a foundation for a transit instrument used solely for transit observations of the highest accuracy.

A2 Influence Of Observer On Measurements

In June 1875 the journal *Nature* published an article [1875b] concerned with the quality of data produced by the Meteorological Office (MO). The article was an example of the investigative journalism of its day!

Nature reported that self-recording meteorological instruments had been in operation at the seven MO observatories since January 1869 and that they were the *best and most complete anywhere for recording continuously the atmospheric pressure, temperature, humidity and rainfall and the velocity and direction of the wind*. The MO had made the data available from 01 January 1869. One of the principal objects of the seven meteorological observatories was to establish the meteorological "constants" for different locations within the British Isles. Detailed regulations were in place to ensure accurate recording of data, incorporating adjustments to measurements of temperature as small as 0°.01.

Nature investigated the quality of data obtained from the self-recording instruments and published by the MO in its Quarterly Weather Reports. Unfortunately, *Nature* found that errors abounded in the summary data, including errors of temperature, date, time and errors relating to when instruments were in service and out of service. Specific problems included:

- At least two errors in every month examined by *Nature*.
- Published errata were also themselves frequently in error.
- The distribution of digits after the decimal point in temperature readings was highly skewed: each figure should have had an equal chance of appearing, but in practice there was a noticeable preponderance of the figure ".0", implying rounding to the nearest whole degree.
- Problems with the placing of some of the thermometers. Some were located in very confined locations and did not experience the true ambient temperature – this was borne out in particular by anomalous temperature readings for the mean increase of temperature during daytime hours in summer at Aberdeen. There were also anomalies in the location of other instruments.

Overall, *Nature* judged the data published by the MO to be of such poor quality as to write: *the results, as tabulated and published, can scarcely lay claim to a higher value than eye-observations of third-rate observers* and *it is not easy to see how one can make a scientific use of the tabulations*. *Nature* went on to note that pressure of work could not be an excuse for the poor quality of published data, as the MO was in complete control of its publication schedule and some reports were published almost four years after the corresponding data was collected.

Further, in 1873 (the latest year for which data was available), the Meteorological Committee of Parliament employed 24 persons, with a total salary of £3727 and expenses of £2722. *Nature* judged this to be a generous level of remuneration.

The article concluded with a statement of regret that *Nature* had been forced to take such a negative stance, but noted that it was the duty of the journal to draw attention to the work done by the MO in return for its annual grant from Parliament of £10,000. The view of *Nature* was that the MO did not provide good value for money!

Plummer responded in the September 1875 issue of *Nature* [1875c]. He pointed out that in general, subjective factors caused individuals making empirical measurements to prefer certain digits, which could cause the overall distribution of digits to differ from the expected uniform profile. By way of supporting evidence, he examined empirical transit times published by the ROG in the *Greenwich Observations* for 1864 (the latest volume that he had to hand). He examined transit timings made during the three days 19 April, 21 April, and 05 November 1864, covering a total of 1283 transits, and counted the number of times which each digit occurred as the tenth of a second figure. Theoretically, each digit should have had an equal chance of occurring, but Plummer's analysis showed a preponderance of the digit zero, i.e. an excess of whole seconds, and also other features which could be ascribed to subjective factors.

Finally, Plummer compared transit timings made by himself in 1875 and by two observers, Dunkin and Ellis, made in 1864 at the ROG. Again he noted the unequal distribution of occurrences of digits representing tenths of seconds. All three observers showed personal idiosyncrasies, including a similar fondness for the digit "8"! Figure 22 shows the distribution of tenths of second digits for the three observers.

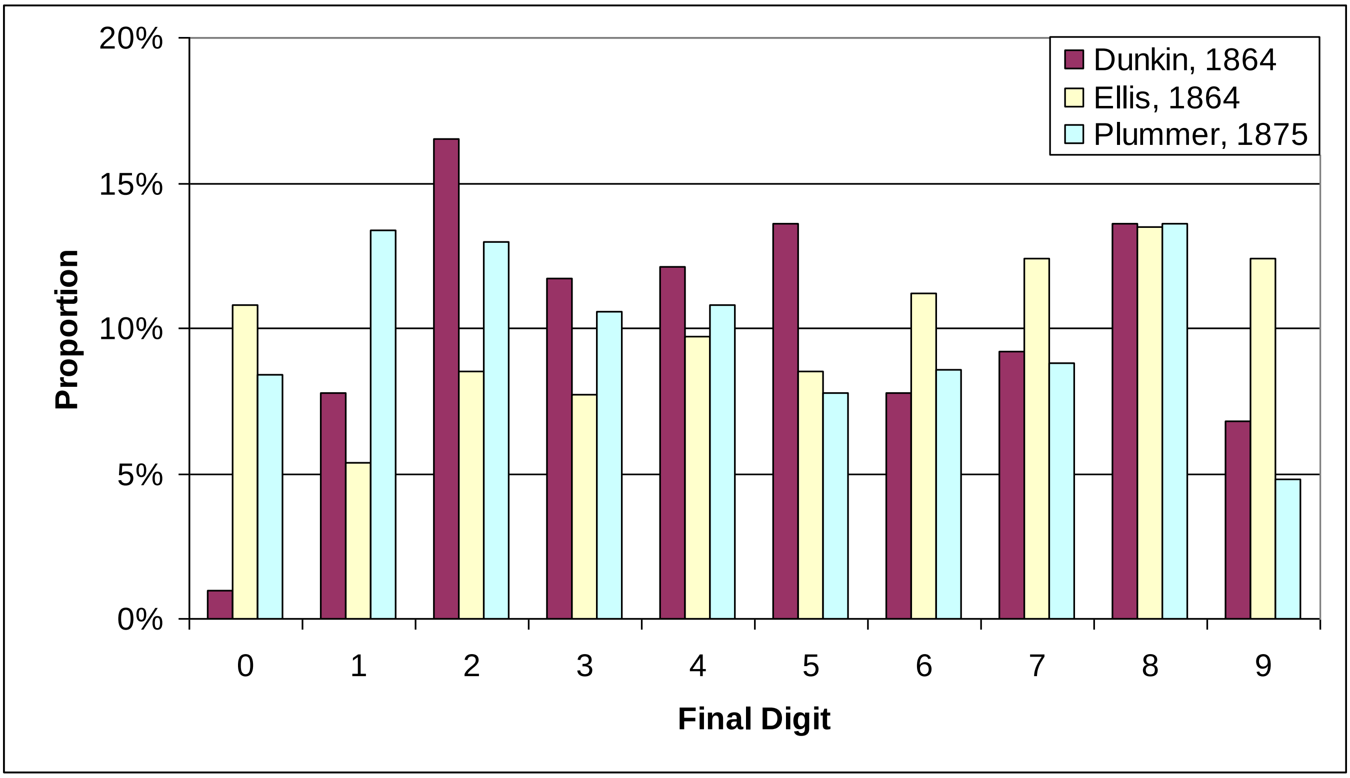


Figure 3. Distribution of tenths of seconds digits.

--- To be continued ---