The Newsletter of the Orwell Astronomical Society (Ipswich)

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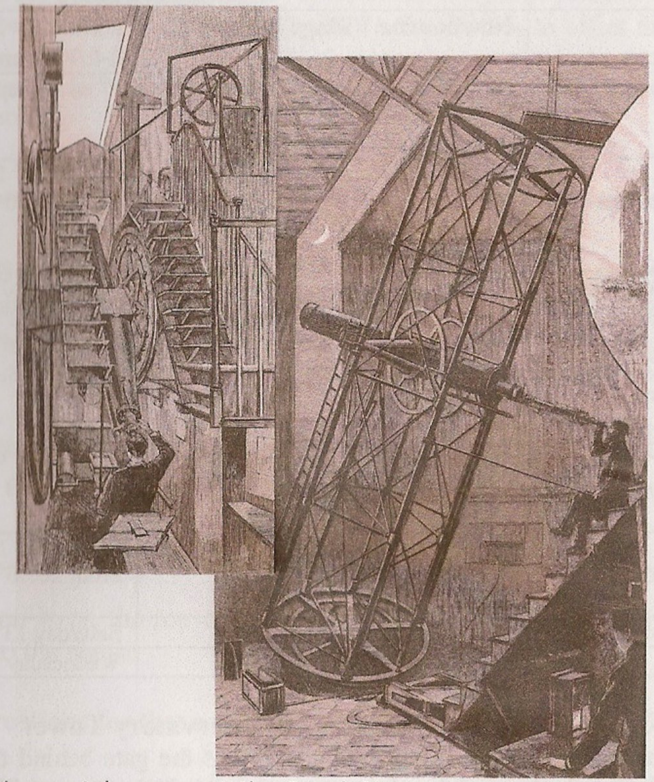


With revolutionary telescopes at the Royal Observatory designed by Sir G B Airy, the heavy components of which were manufactured by Ransomes, Ipswich has made its own contribution towards the development of large aperture instruments. The above images are taken from a series of inset centre fold engravings of the Royal Observatory that appeared in the 'London Graphic' on 1885, August 8th.
On 2008 Friday 12th September we will welcome back a good friend of OASI, Mr Peter Hingley - the Librarian of the Royal Astronomical Society - who will present a talk entitled ***'The Biggest Telescope in the World'***, a look at the development of large aperture telescopes right up to the present day.
(see OASI Diary on back page for details).

Left inset – The Airy Transit Circle (8.1" OG) of 1850
Right Inset – Airy's Gt Equatorial (12.8" OG) of 1859

From the collection of Ken Goward

Society News (Roy Gooding)

1 Committing Meeting Date Saturday 13th September

The date for the next committee meeting is Saturday 13h September from 20:00 at the Methodist Church Hall. This is meeting is open to any member who would like to attend.

2 Events for 2008

This event list will be updated through out the year

Meeting	Venue	Date
Perseid Meteor watch Note new date	**The "Dip" Felixstowe**	**Wednesday 13th August 20:30**
Society Summer Barbecue	**Newbourne Village Hall**	**Saturday 30th August 14:00 to midnight**
Herstmonceux Astronomy Festival	Observatory Science Centre Herstmonceux, Hailsham, East Sussex,	5th to 7th September
Lecture meeting The Biggest Telescope in the World. by Peter Hingley	Methodist church hall	Friday 12th September From 20:00
FAS Cambridge Convention	Institute of Astronomy, Cambridge	Saturday 20th September
Autumn Equinox Sky Camp Organised by Loughton Astronomical Society with the support of the SPA http://www.starparty.org.uk/	Kelling Heath, Weybourne Norfolk.	Monday 22nd September to Thursday 2nd October Main day Saturday 27th
Lecture meeting To Infinity & Beyond by Andy Green	Methodist church hall	Friday 24th October From 20:00
Lecture meeting William Herschel by Tony Dagnall	Methodist church hall	Friday 14th November From 20:00
Geminid Meteor watch	The "Dip" Felixstowe	Saturday 13th December
Christmas Meal		Wednesday 10th December?

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 . (Roy Gooding) alternatively the Observatory mobile is 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

6 Society Summer Barbecue

This year's Summer Barbecue is on Saturday 30th August at **Newbourne** Village Hall. The start time will be at about 14:00. The event will continue to midnight, with observing in the evening using the 19" Dobsonian, if weather permits
There will be a charge of £2 per adult and £1 for children to offset the cost hire of the hall.
Salad and bread will be provided, all you will need to bring are drinks and a selection of meats for cooking

Perseid Meteor Watch Wednesday 13th August 20:30

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

There will be no meeting at the observatory unless the weather is unfavourable

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 20:30
- The Moon will be at first quarter on the 8th
- If the weather is bad there will be a normal meeting at the observatory

Night Sky (August)

All times BST

Moon

New Moon	1st Quarter	Full Moon	3rd Quarter	New Moon
1st	8th	16th	23rd	30th

Object	Date	Times		Mag.	Notes
		Rise	Set		
Sun	1	05:27	20:54		
	31	06:15	19:53		
Mercury	1	05:35	21:13	0.2	Mercury is close to the sun in the morning sky this month, making it difficult to observed
	31	08:42	20:26		
Venus	1	06:47	21:34	-3.8	Venus is the evening twilight sky and will be difficult to see.
	31	08:23	20:36		
Mars	1	09:12	22:12	1.7	Mars moves into Virgo this month
	31	09:03	20:43		
Jupiter	1	19:32	03:22	-2.6	Jupiter remains low down in the southern sky, in Sagittarius this month
	31	17:27	01:13		
Saturn	1	08:07	21:59	0.8	Saturn is in Leo. It is now rapidly disappearing into the evening twilight It will be difficult to observe this month
	31	06:30	20:07		
Uranus	1	22:10	09:40	5.8	Uranus is in Aquarius
	31	20:10	07:36		
Neptune	1	21:15	06:55	7.8	Neptune is in Capricornus
	31	19:16	04:53		

Meteor Showers

Shower	Limits	Maximum	ZHR
α Capriconids	July15th to August 20th	August 2nd	5
ι Aquarids	July to August	August 6th	8
Perseids	July 23 to August 20th	August 12th 09:00	80

Meteor source is the BAA Handbook

Night Sky (September)

All times BST

Moon

1st Quarter	Full Moon	3rd Quarter	New Moon
7th	15th	22nd	29th

Object	Date	Times		Mag.	Notes
		Rise	Set		
Sun	1	06:17	19:51		
	30	07:04	18:44		
Mercury	1	08:46	20:23	0.3	Greatest eastern elongation on the 11th
	30	08:34	18:40		
Venus	1	08:26	20:34	-3.8	Venus is now slowly moving into darker skies this month
	30	09:59	19:35		
Mars	1	09:03	20:40	1.7	As Mars recedes from us its diameter now only 3.8", making it very difficult to see any detail.
	30	08:59	19:17		
Jupiter	1	17:23	01:09	-2.4	Jupiter remains low down in the southern sky, in Sagittarius this month
	30	15:32	23:15		
Saturn	1	06:27	20:03	0.8	Saturn will at conjunction on the 4th. The planet will not be observable this month
	30	04:53	18:16		
Uranus	1	20:06	07:32	5.8	Uranus is in Aquarius
	30	18:10	05:31		
Neptune	1	19:12	04:49	7.8	Neptune is in Capricornus
	30	17:16	02:51		

Meteor Showers

Shower	Limits	Maximum	ZHR
Piscids	September to October	Sept 8th Sept 21st Oct. 13th	10 5 ?

Meteor source is the BAA Handbook

OCCULTATIONS DURING AUGUST

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
16 Aug	21:18:43	D	1.00-	-16	16	9.9	Tyc 5800-0450-1
	22:05:49	R		-20	20		
16 Aug	21:52:38	D	1.00-	-19	19	9.5	Tyc 5800-0995-1
	22:39:52	R		-22	22		
16 Aug	22:13:58	D	1.00-	-21	20	8.6	Hip 107735

On the evening of 16 August there is a partial lunar eclipse. Times of umbral contact are as follows (UT): U1 – 19:36, U4 – 22:44. When the Moon is in umbral eclipse the glare which it produces is markedly reduced enabling observation of occultations of much fainter stars than would normally be possible.

James Appleton

OCCULTATIONS DURING SEPTEMBER

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
20 Sep	02:26:26	D	0.73-	-27	59	3.9	20 Tau,Maia
	03:19:40	R		-21	62		
23 Sep	01:44:08	D	0.40-	-33	29	5.7	37 Gem
	02:45:34	R		-26	39		

James Appleton

OASI Committee Contacts & Responsibities

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

IYA 2009 – ADVANCE DATES NOTICE

- Monday March 30th - Sunday April 5th - **Saturn Week**
- Monday July 20th - Sunday July 26th - **Moon Week**
- Monday October 26th - Sunday November 1st - **Jupiter Week**

Diary for August & September

Wednesdays **FROM 8PM** **Please Note** *The Observatory will not be open on Wednesday 13th August, unless the weather is unfavourable for the below …*	**MAIN OBSERVATORY CLUB NIGHTS** Primary Observational targets: Nebulae and faint objects. ☎ Martin Cook [redacted] (mobile) [redacted] ☎ Roy Gooding [redacted] (mobile) [redacted]
Wednesday 13th August from 8.30PM The 'Dip' Felixstowe – Behind the Refreshment Hut	**Perseid Meteor Watch** **NB** If weather unsuitable – there will be a normal meeting at the Orwell Park Observatory. ☎ Roy Gooding [redacted] (mobile) [redacted]
Friday 12th September 8PM Methodist Church Hall Blackhorse LaneIpswich	**OASI LECTURE MEETING** ***'The Biggest Telescope in the World'*** Presented by Peter Hingley, Librarian of the Royal Astronomical Society. ☎ Peter Richards [redacted]
Saturday 30th August **2PM 'till late** **Newbourne Village Hall** **£2 Adults £1 Children**	**OASI SUMMER BARBEQUE** **Bring your own meats/veggie equivalents.** Bread, salad and basic sauces are provided. Solar observing during afternoon, dark site observing at night. Other entertainments may be provided (short quiz etc) ☎ Paul Whiting [redacted]

Society Primary Contacts

Chairman: Kenneth J. Goward FRAS ☎ [redacted] (daytime & evenings)
Secretary: Roy Gooding ☎ [redacted] (daytime) [redacted] (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

[redacted]

Also on in our region and worth a visit:

- ***Saturday 20th September*** *at the Institute of Astronomy, Madingley Road, Cambridge.* ***Federation of Astronomical Societies Annual Convention.*** *See* ***www.fedastro.org.uk***
- ***Monday 22nd September*** *to Thursday 2nd October – main event day* ***Saturday 27th September****. Kelling Heath, Weybourne N Norfolk.* ***Autumn Equinox Sky Camp****, organised by Loughton AS. See* ***www.starparty.org.uk***

John Isaac Plummer,
Colonel Tomline's Astronomer
Part 5

A1 Occultations

Plummer published four papers on lunar occultations, dealing with three aspects of the subject:

- Report on observations of some occultations [1869c].
- Calculation of the circumstances of an occultation for a particular location [1869f].
- A theory to explain the supposed phenomenon of *projection on the limb* [1873c, 1873e].

He published the four papers during the period 1869-1873. He retained an interest in the subject subsequently and later papers [1880b, 1881c, 1885a, 1889a] during the period 1881-1889 mention his intention to undertake further occultation observations as a means of studying the figure of the Moon and investigating the phenomenon of projection on the limb. However, he appears not to have reported any of the intended later observations, so it is likely that he did not succeed in making them.

A1.1 Report On Observations Of Some Occultations

One of Plummer's first published papers, written at Durham Observatory and communicated to MNRAS by Professor Temple Chevallier [1869c], is an observing report of lunar occultations. It deals with observations during the period 06 November 1867 – 04 May 1868 of the following stars: Lambda Aquarii, 10 Ceti, 130 Tauri, c Leonis, Gamma Tauri, Eta Librae and l^2 Virginis. Plummer noted Gamma Tauri on 28 March 1868 as being *attached to the lunar limb* for five seconds before disappearance; this is an example of the supposed phenomenon of *projection on the limb* to which Plummer returned in later papers.

Table 10 summarises Plummer's empirical results together with modern theoretical estimates of event timings based on a value $\Delta T = 2.35$ seconds. Columns one, two and three respectively list the date of the occultation, the star concerned and its magnitude (taken from the Hipparcos catalogue [1997b]). Column four lists the lunar phase (i.e. proportion of the disk illuminated). Column five lists the phenomenon, D for disappearance and R for reappearance. Column six indicates the state of illumination of the lunar limb at the point where the star appears or disappears, B for a bright limb and D

for a dark limb. Columns seven and eight respectively list Plummer's empirical event timings and the modern calculated timings - all rounded to the nearest second.

Date	Star	Mag	Phase	Phen	Limb	Event Time Plummer (GMT)	Event Time Modern Calc. (UT)
06 Nov 1867	Lambda Aquarii	3.7	71%	D	D	22:24:58	22:25:00
				R	B	23:33:52	23:33:50
06 Nov 1867	78 Aquarii	6.2	72%	D	D	23:57:19	23:57:22
08 Nov 1867	10 Ceti	6.2	87%	D	D	19:10:06	19:10:14
				R	B	20:23:08	20:22:59
11 Dec 1867	130 Tauri	5.5	100%	D	B	20:47:39	20:47:51
				R	D	21:33:24	21:32:57
17 Dec 1867	c Leonis	5.0	61%	D	B	01:54:24	01:54:33
				R	D	03:01:57	03:02:04
04 Feb 1868	130 Tauri	5.5	82%	D	D	18:55:09	18:55:15
28 Mar 1868	Gamma Tauri	3.7	22%	D	D	21:01:05	21:01:07
				R	B	21:56:04	21:56:01
10 Apr 1868	Eta Librae	5.4	91%	D	B	01:30:13	01:30:38
				R	D	02:06:15	02:06:06
04 May 1868	l^2 Virginis[1]	4.7	96%	D	D	21:06:46	21:06:53
				R	B	22:17:43	22:17:39

Table 1. Plummer's occultation observations and modern predictions.

Figure 5 plots for each occultation event the difference between observed and calculated times (in the sense observed – calculated) in seconds. It reveals a pattern that is familiar to many visual observers of occultations:

- Plummer recorded disappearance events generally too early by several seconds. In the observationally difficult case of Eta Librae on 10 April 1868, with the Moon close to full and a bright limb disappearance, the discrepancy amounted to 25 seconds. In his note for this event, Plummer stated: *Star faint. Observation not satisfactory*.

[1] The star l^2 Virginis is also catalogued as 74 Virginis. Plummer referred to it as τ^2 Virginis.

- Plummer recorded reappearance events generally too late by several seconds. In the observationally difficult case of 130 Tauri on 11 December 1867, with a Full Moon, the discrepancy amounted to 27 seconds. In his note for this event, Plummer stated: *Not good; the star faint*.

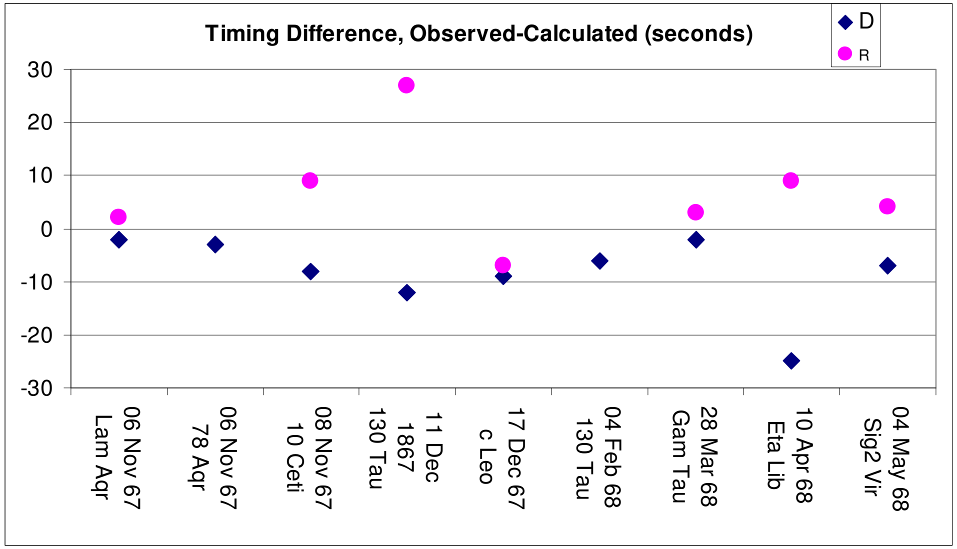


Figure 1. Comparison of Plummer's occultation times with modern calculated times.

However, one of Plummer's observations does not fit the above pattern. The discrepancy concerns the star c Leonis[2] which Plummer observed on 17 December 1867. His observing report gives a reappearance time seven seconds earlier than modern theory predicts. The discrepancy is too great to be explained by a faulty lunar limb profile: the passage of the Moon in front of the star is close to central meaning that there is no appreciable multiplier effect on limb profile errors such as a grazing incidence can cause. The star is relatively bright and close to the ecliptic, and hence its position would have been accurately known in Plummer's time. There are no bright stars in the neighbourhood of c Leonis which could be confused with the latter. In fact, c Leonis is a double star, the magnitude 5.0 primary component being accompanied by a magnitude 12.6 secondary component at a distance of 46".8, PA 221° (data from the Washington Visual Double Star Catalogue [1996a] for the year 1878). The calculated time above concerns the primary component. It is inconceivable that Plummer could have confused the two components of the star; indeed

[2] Equivalent catalogue identifiers are 59 Leonis, Hipparcos 53824 and Tycho 0268-1064-1.

the secondary component would not even be visible close to the illuminated portion of the Moon. There is at present no explanation for the discrepancy.

A1.2 Circumstances Of An Occultation At A Particular Location

Mr John Joynson, FRAS, [1869d] reported in the pages of MNRAS timings of occultations of four stars during December 1868 and January 1869. The stars were BAC1526[3], Aldebaran, 115 Tauri, 119 Tauri and 120 Tauri.

Joynson compared his empirical timings with predictions in the *Nautical Almanac*. Differences were generally at most five minutes, but rose to approximately nine minutes for the reappearance of 119 Tauri on 24 January 1869 and to approximately 12 minutes for the reappearance of 120 Tauri later in the same evening. Some differences were to be expected as the *Nautical Almanac* listed predictions for the location of the ROG whereas Joynson was situated at Waterloo, near Liverpool. Joynson believed his timings on 24 January (i.e. 115, 119 and 120 Tauri) to be *exact in each case, though in some cases they differ more than I think they should from the times stated in the "Nautical Almanac"*.

Table 11 summarises Joynson's empirical timings and his statement of their differences from predictions in the *Nautical Almanac*. Note that Joynson quoted his empirical timings to a precision of 0.1 seconds and timings predicted in the *Nautical Almanac* to a precision of one minute. In the table, Joynson's empirical timings are rounded to the nearest second. As previously, column 3 denotes the phenomenon, D for disappearance and R for reappearance; other columns should be self-explanatory.

Plummer [1869f] responded to Joynson in the pages of MNRAS with a set of predicted occultation times for Aldebaran, 119 Tauri and 120 Tauri for the locations of the ROG and Joynson's observatory. He did not state the method that he used to generate the predictions, but he probably relied upon calculations using Besselian elements tabulated in the *Nautical Almanac*.

Plummer's predictions for the ROG agreed exactly (to the precision quoted) with those in the *Nautical Almanac*. His predictions for Joynson's observatory accorded well with Joynson's empirical timings in all cases except the reappearance of 120 Tauri for which Plummer's predicted time was almost five minutes later than the empirical time. Plummer concluded that systematic calculations were required to provide topocentric predictions of occultations for locations remote from Greenwich.

[3] BAC is the British Association Catalogue – modern designations of the star are ZC741, Hipparcos 23043, Tycho 1285-1704-1.

Date	Star	Phen	Joynson's Timing GMT	*Naut. Alm.* Pred'n GMT	Joynson's timing relative to the *Nautical Almanac* prediction
27 Dec 1868	BAC1526	R	19:25:36	19:22	~3m later, as it should be
23 Jan 1869	Aldebaran	D	20:44:16	20:49	~5m earlier, should be later
23 Jan 1869	Aldebaran	R	~22:00:00	22:05	~5m earlier, should be later. Passing cloud spoiled the view.
24 Jan 1869	115 Tauri	D	17:27:05	17:29	~2m earlier, as it should be
24 Jan 1869	115 Tauri	R	18:16:39	18:12	~3m later, as it should be
24 Jan 1869	119 Tauri	D	20:17:26	20:14	~3m later, as it should be
24 Jan 1869	119 Tauri	R	21:00:45	21:10	~9m earlier, as it should be - but hardly so much?
24 Jan 1869	120 Tauri	D	20:46:27	20:48	~2m earlier, should be later
24 Jan 1869	120 Tauri	R	21:48:13	22:00	~12m earlier, as it should be - but hardly so much as 12m?

Table 2. Comparison of Joynson's timings with predictions in the Natical Almanac.

Plummer then described the approximate method devised by Temple Chevallier [1850a] for calculating occultation predictions for an observer's location based upon knowledge of circumstances for another known location. Chevallier's method was a graphical one, executed as follows in the fundamental plane, i.e. the plane running through the centre of the Earth perpendicular to the line from the centre of the Earth to the star which is occulted. Suppose that occultation circumstances are known for the ROG (or other known location) and that it is desired to predict circumstances for another observing station, X. Plot in the fundamental plane the projection of the lunar disc and the projection of the ROG, G, at the instant of occultation disappearance. At this instant G lies on the projection of the lunar limb. Plot also the projection of X and calculate the offset, O, from G to X – see figure 6(a).

Next add to the diagram the circumstances of the reappearance event at the ROG and the offset, O, to X. (At the instant of reappearance the projection of the ROG again lies on the projection of the lunar limb.) The line segment D-R in figure 6(b) represents the course of the Moon between disappearance (D) and reappearance (R) at the ROG. Suppose that the elapsed time between D and R is y. By assuming that the velocity of the Moon is constant during the time in question it is a simple matter of geometry and linear interpolation and/or extrapolation from figure 6(b) to estimate the times of disappearance and reappearance at X and the associated position angle of the star on the lunar limb.

Plummer stated that he had used Chevallier's method on more than twenty occultations and found it to be of good accuracy (mean error 34 seconds in time, 0.7º in position angle).

Magnanimously, he offered to use Chevallier's method to calculate tables of occultation predictions for any observatory.

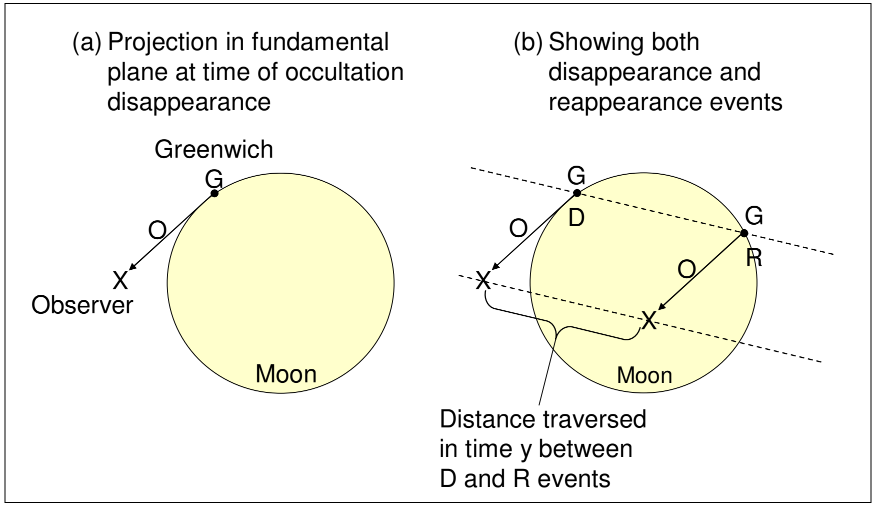


Figure 2. Chevallier's graphical method for occultations.

Modern computers enable an astronomer with suitable software to calculate accurate occultation predictions for any location at any epoch. As a result there is little need nowadays for approximation methods such as Chevallier's to enable transformation of occultation parameters from one location to another. However, the BAA does still publish (e.g. [2007a]) occultation predictions for the standard UK observing locations of the ROG and the Royal Observatory, Edinburgh (and other locations overseas) and includes for each prediction the values of station coefficients, a and b, which indicate how the contact times vary with geographic longitude and latitude respectively. This provides a concise, modern-day analogue of Chevallier's method for the benefit of the astronomer who does not have the necessary computer and software to predict occultations directly for his or her location.

Table 12 compares various predictions of occultation times for an observer stationed at the ROG for the stars considered by Plummer (Aldebaran, 119 Tauri and 120 Tauri). Columns one, two and three list the date of the occultation event, the star and the phenomenon respectively. Column four lists predicted occultation times in the *Nautical Almanac*. Column five lists Plummer's predictions. Column six lists modern predictions based on a value $\Delta T = 2.0$ seconds, with corrections for the local lunar limb profile. Column seven lists modern predictions without corrections for the local lunar limb profile. No survey of the lunar limb had been carried out in the 19th Century so the predictions in the *Nautical Almanac* assumed a smooth, circular limb profile. Column eight lists the difference in seconds between Plummer's prediction of an event time and the modern prediction without limb correction (in the sense Plummer's – modern). Note that Plummer published his predictions with a precision of six seconds (0.1 minutes) and that the modern predictions are rounded to the nearest second.

Column eight provides a like-for-like comparison between Plummer's occultation predictions and those of the modern era. This provides insight into the fundamental accuracy of the ephemeris data and star catalogue employed by Plummer. The column shows differences of up to 17 seconds in absolute magnitude – this is likely due primarily to differences between the lunar ephemeris used in Plummer's era and the modern reference ephemeris DE-405, since the positions of the brighter stars were known with good accuracy in Plummer's era.

Date	Star	Phen	Prediction				Diff in Preds.
			Naut. Alm. (GMT)	Plummer (GMT)	Modern With Limb Corr'n (UT)	Modern No Limb Corr'n (UT)	Plummer – Modern, No Limb Correction (seconds)
23 Jan 1869	Aldebaran	D	20:49	20:48:42	20:48:24	20:48:28	14
		R	22:05	22:04:42	22:04:31	22:04:31	11
24 Jan 1869	119 Tauri	D	20:14	20:14:30	20:14:42	20:14:42	-12
		R	21:10	21:09:30	21:09:29	21:09:27	3
24 Jan 1869	120 Tauri	D	20:48	20:47:48	20:47:48	20:47:48	0
		R	22:00	21:59:36	21:59:17	21:59:19	17

Table 3. Comparison of predicted occultation event times for Greenwich.

Joynson [1869g] responded to Plummer, accepting the latter's analysis of the situation and even going so far as to apologise to Plummer for *the considerable amount of trouble* which he caused him! Joynson also reported occultation observations made during February-May 1869 of the following stars: 48 Tauri, Zeta Cancri, Chi_2 Cancri, g Geminorum, 119 Tauri, 120 Tauri, and Regulus.

Table 13 compares Joynson's empirical timings December 1868 – May 1869 with modern predictions.

Columns one, two and three respectively list the date of the occultation, the star concerned and the lunar phase (i.e. proportion of the disk illuminated). Column four lists the phenomenon, D for disappearance and R for reappearance. Column five indicates the state

of illumination of the lunar limb at the point where the star appears or disappears, B for a bright limb and D for a dark limb. Columns six, seven and eight respectively list Joynson's timing of the event, the corresponding modern predicted event timing, and the difference in seconds between Joynson's timing and the modern prediction, in the sense Joynson – modern. All timings in the table are rounded to the nearest second.

Date	Star	Lunar Phase	Phen	Limb	Joynson's Timing (GMT)	Modern Prediction (UT)	Difference (seconds)
27 Dec 1868	BAC1526	0.96+	R	B	19:25:36	19:25:18	18
23 Jan 1869	Aldebaran	0.78+	D	D	20:44:16	20:44:19	-3
			R	B	22:00:00	21:59:54	6
24 Jan 1869	115 Tauri	0.85+	D	D	17:27:05	17:27:07	-2
			R	B	18:16:39	18:16:11	28
24 Jan 1869	119 Tauri	0.86+	D	D	20:17:26	20:17:27	-1
			R	B	21:00:45	21:00:43	2
24 Jan 1869	120 Tauri	0.86+	D	D	20:46:27	20:46:28	-1
			R	B	21:48:13	21:53:06	-293
19 Feb 1869	48 Tauri	0.51+	D	D	21:04:40	21:04:45	-5
23 Feb 1869	Zeta Cancri	0.90+	D	D	22:11:40	22:11:50	-10
24 Feb 1869	Pi2 Cancri	0.96+	D	D	22:45:17	22:45:19	-2
			R	B	23:43:03	23:42:56	7
22 Mar 1869	g Geminorum	0.68+	D	D	21:17:17	21:17:19	-2
			R	B	22:26:22	22:25:18	64
16 Apr 1869	119 Tauri	0.21+	D	D	19:29:44	19:29:47	-3
			R	B	20:23:20	20:23:01	19
16 Apr 1869	120 Tauri	0.21+	D	D	20:18:26	20:18:29	-3
			R	B	20:52:48	20:52:36	12
18 May 1869	Regulus	0.50+	D	D	21:54:28	21:54:34	-6
			R	B	22:07:25	22:07:05	20

Table 4. Joynson's occultation observations and modern predictions.

Figure 7 plots the entries in the difference column. Joynson's disappearance timings are generally a few seconds in advance of modern predicted times. Excluding the reappearance of 120 Tauri on 24 January, Joynson generally reported reappearance timings which are later than modern predictions by up to a few tens of seconds (as much as 64 seconds in the case of g Geminorum on 22 March). This situation is as expected. However, the occultation reappearance of 120 Tauri on 24 January 1869 is far off the scale of the figure, as indicated by the arrow! For this event, Plummer's prediction agrees exactly with the modern prediction. It is possible that Joynson's timing for the occultation reappearance of 120 Tauri on 24 January 1869 is mistaken – if Joynson had made an error reading his observatory chronometer and reported a time exactly five minutes early, the true time of his observation would be seven seconds after the predicted time, a discrepancy comfortably within the range of his other reappearance observations.

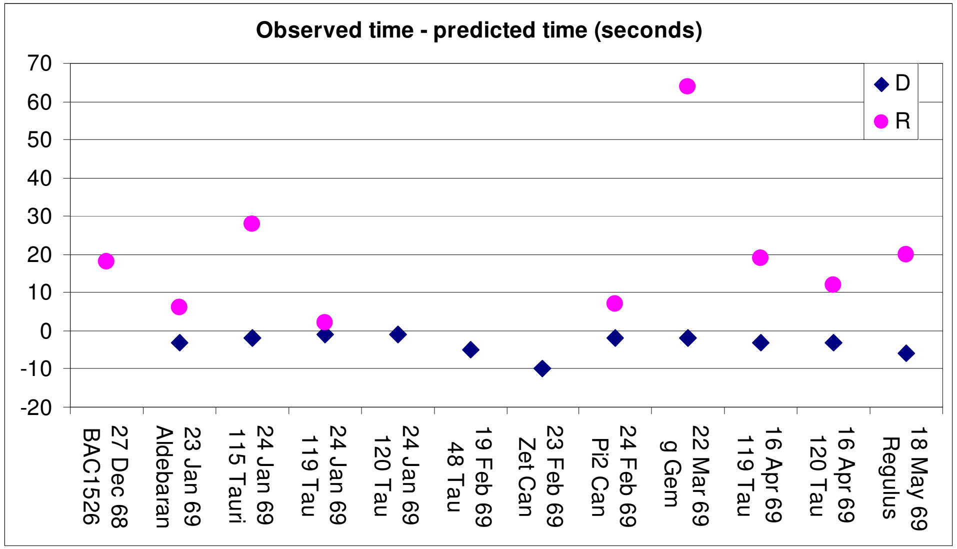


Figure 3. Comparison of Joynsons's occultation observations with predictions.

A1.3 Projection On The Limb

Nineteenth century astronomers reported the phenomenon of *projection on the limb* (or *hanging on the limb*, or *attached to the limb*) when a star about to be occulted by the Moon appeared to be projected upon or to hang upon or to be attached to the lunar limb for a few seconds before disappearing. A few astronomers reported a similar phenomenon at reappearance events. The phenomenon attracted much interest in the 19th Century, although modern observers do not report it.

Plummer [1873c] referred to South and Airy for an overview of the phenomenon as follows.

South

James South [1828a] reported witnessing the phenomenon of *projection* when he observed the occultation disappearance of Delta Piscium on 06 February 1821. The Moon was young, 20% waxing, and South reported that the night was *beautifully fine* and both the limb and the unilluminated portion of the disk were unusually distinct. The occultation proceeded as usual until the lunar limb appeared to touch Delta Piscium. The star then appeared to hang upon the limb, without any diminution in its brightness or alteration in its position on the limb for almost nine seconds until it instantaneously disappeared. Baily[4] and von Littrow[5], who independently observed the occultation, reported nothing unusual. Later in the evening, South noted: *a star of the 8th or 9th magnitude suffered occultation by the Moon's dark limb, nearly at the same part, at which δ Psc entered upon the disk*. This time there was no projection on the limb. The star in question appears to have been the magnitude 8.1 star Hipparcos 3963, for which in fact the occultation was close to a graze from South's location.

South noted that reports by UK observers of projection upon the limb were rare, but that many experienced observers on the Continent had observed the phenomenon and there could therefore be little doubt as to its existence. He found in the international astronomical literature reports of more than 20 stars exhibiting projection. For most stars exhibiting projection he found only a single report of the phenomenon, however for Regulus he found three and for Aldebaran he found 20. In some cases reports from different observers of an occultation confirmed the occurrence of projection and in some cases they contradicted it. However, there was insufficient detail in many of the observing reports to draw firm conclusions.

South proposed five possible explanations for the phenomenon:

1. Lively imagination of the observer! He dismissed this explanation as more than 60 instances of projection had been reported by very experienced observers.
2. Inferior optics, with chromatic aberration introducing a spurious lunar limb causing confusion to the observers. South dismissed this explanation because of the range of good-quality, achromatic telescopes which had been used by observers reporting projection.
3. A lunar atmosphere. South noted that if there were a lunar atmosphere capable of explaining projection, it would be expected to manifest itself during all occultations, which it does not. He therefore dismissed this explanation.

[4] In 1836 Baily described and give his name to the phenomenon of Baily's beads visible sometimes at solar eclipses.

[5] Von Littrow had a lunar crater and rille named in his honour. On 11 December 1972 Apollo 17 landed close to von Littrow's features in the Taurus-Littrow region at the edge of Mare Serenitatus.

4. Irradiation. South noted that irradiation could not explain projection at the dark limb (such as he witnessed) so he dismissed it as a possible explanation.
5. Differing degrees of refraction of light from the star and from the Moon in passing through the Earth's atmosphere to reach the observer. Such an effect was possible in principle if the light from the star had a significantly different wavelength to that from the Moon. South dismissed this possibility by noting that astronomers had reported projection in the case of white stars (presumably thought to have spectra broadly similar to moonlight) as well as red stars such as Aldebaran yet had not reported it in the case of Mars, which is even more red than Aldebaran.

Failing to advance a satisfactory explanation, South called for UK observers to study the 1829-1830 occultations of Aldebaran in the hope of finding an explanation for the phenomenon.

Airy

George Biddell Airy (seventh Astronomer Royal) reported [1859a] that he had observed the phenomenon of projection in 1829 (nearly thirty years earlier!) and that it *made a strong impression on his mind*. Unfortunately, Airy did not provide details of the exact date or star so it is not possible to re-examine his observation with the benefit of modern models of the position of the Moon and of the lunar limb profile. Airy aimed to provide an explanation for the phenomenon of projection in terms of optical principles. He noted that in many cases a red star was the subject of projection, and that for such stars, a potential difference in the degree of refraction between the light of the star and the (whiter) light of the Moon in passing through the Earth's atmosphere might provide an explanation for the apparent projection. (This is in fact explanation #5 of South [1828a], which the latter dismissed.) Such a mechanism, if it occurred, could result in apparent projection for red stars incident on the north limb of the Moon and an apparent early disappearance of stars incident on the south limb. In order to test this hypothesis, Airy arranged for an assistant at the ROG to analyse all recorded observations of projection: the results of the analysis did not support the hypothesis.

Airy then reported an observation by Mr George Innes at Aberdeen of a bright limb disappearance of Aldebaran on 23 October 1831. Innes stated that when Aldebaran came within about six seconds of the limb, it passed through the remaining distance very rapidly, its apparent velocity being some five or six times that previously. Aldebaran appeared then to hang on the lunar limb for about five seconds then disappear suddenly.

Airy accepted Innes' account of the observation without question and attempted to explain it in terms of recognised optical and physiological principles. He noted that a point source of light in a telescope produced a set of diffraction rings. He considered that every luminous point of the Moon's disc would produce a set of diffraction rings in the telescope, and the net result of the superposition of all the rings would be a band of illumination fringing the apparent geometrical limb of the Moon. Airy was unable to calculate the amount of illumination falling outside the lunar limb but believed it to be "considerable". He then speculated that under normal circumstances, the observer's brain would expect the intensity of light outside the limb to fall according to a given regime, and that this expectation would condition the observer so as not to be conscious of the light outside the limb. However, when intently observing an occultation, the observer could become increasingly sensitive to the diffracted light outside the lunar limb: this could result in the Moon appearing to increase in size, and explain the phenomenon of the star apparently rushing towards the lunar limb as described by Innes. However, Airy had no explanation for why the phenomenon of projection was seen sometimes by one observer but not by another and why it could vary so much.

Plummer first described witnessing the phenomenon of projection in one of his early papers [1869c], written at Durham Observatory in 1869 and communicated to MNRAS by Professor Temple Chevallier. (The paper is considered in detail above). In the paper he reported timings of lunar occultations of several stars, among them Gamma Tauri which on 28 March 1868 he noted as being *attached to the lunar limb* for five seconds before disappearance. He gave no other details of the phenomenon.

Plummer's next mention of projection in the published literature [1873c] was in 1873 (communicated to MNRAS by Professor A S Farrer). In this paper Plummer stated that there was no satisfactory explanation for the phenomenon of projection. He noted that South proposed several explanations but rejected them all and that Airy's explanation appeared to fail in the case of dark limb occultations. He proposed therefore that several mechanisms might be at work simultaneously.

Plummer then provided further description of the phenomenon of projection which he witnessed during the occultation of Gamma Tauri on 28 March 1868 (note that in [1873c] he incorrectly referred to the star as Zeta Tauri). He reported that the atmospheric conditions were *eminently favourable*, and that the lunar limb was clearly visible. The star appeared on the lunar disk for at least five seconds, at a considerable distance from the limb, i.e. inside the limb. Note that in Plummer's initial report of the occultation [1869c] he simply stated that *the star was attached to the Moon's limb, which was distinctly visible by Earthlight, at least five seconds before the disappearance* – he made no mention of the star appearing *inside* the lunar limb.

Plummer proposed a new theory to explain some cases of projection. The theory was based on refraction of the light of the star by a supposed lunar atmosphere. Plummer assumed that the Moon's figure was that proposed by Hansen [1856a], namely an ellipsoid with three axes of rotation, for which the centre of mass was not coincident with the geometric centre. This configuration meant that lunar libration determined the thickness of atmosphere apparent at the limb and the resulting degree of refraction of light from the star, and therefore the apparent position of the latter in relation to the lunar limb. Plummer noted that his explanation was a refinement and extension of South's explanation #3 [1828a].

Plummer investigated his theory by examining cases of maximum projection in the preceding 20 years, and for each evaluating the libration at the point of projection on the lunar limb. Table 14 summarises his analysis. Note that the occultation on 04 April 1854 is in fact of Epsilon Geminorum as stated below, not Alpha Geminorum as stated by Plummer. Plummer admitted that his investigations were not conclusive, but noted that in no case of projection is the libration zero, and he therefore hoped that his data would provide some evidence in favour of his proposed explanation.

Date	Star	Observer	Location	Phen	Projection Duration	Libration
04 Apr 1854	Epsilon Gem	Mr Dunkin	Greenwich	R	4 sec	3º 43'
19 May 1858	Regulus	Two unnamed observers	Greenwich	R	5 sec	6º 58'
19 Mar 1866	31 Arietis	Mr Talmage	Leyton	D	Not specified	2º 52'
28 Mar 1868	Gamma Tau	J I Plummer	Durham	D	>5 sec	7º 14'
14 Oct 1870	Zeta Tau	W H M Christie	Greenwich	D	Not specified	4º 47'

Table 5. Libration angles for cases of *projection*.

Plummer noted that the lunar atmosphere, if it existed, must be very tenuous. He briefly mentioned an unsuccessful attempt to use a spectroscope to search for an atmosphere – however he clearly had no expectation of success and he stated that the spectroscope was *manifestly ill suited*.

Finally, as a postscript, Plummer noted that he had ignored cases of projection reported by Captain Jacob at the Madras Observatory, as the reports lacked sufficient detail and in two cases appeared according to later reports to be in some doubt.

Richard Proctor of Cambridge University responded [1873d] to Plummer, and there ensued a correspondence between the two in the pages of MNRAS. Proctor assumed that the Moon had a surface comprising two spherical surfaces, the surface with the smaller radius being closest to the Earth (he noted that other authorities did not accept this model). He claimed that this was the lunar figure described by Hansen [1856a], but it is not – the figure described by Hansen is a triaxial ellipsoid of rotation. Proctor then argued that the lunar atmosphere, should it exist, would be thinnest at the points closest to the Earth and furthest from the Earth, and most dense at intermediate points which would appear on or

close to the lunar limb. This view supported Plummer's hypothesis, in that whatever lunar atmosphere existed would be preferentially disposed around the lunar limb and therefore positioned to refract the light of a star undergoing an occultation.

Plummer [1873e] responded that his hypothesis depended on the Moon having a figure similar to that proposed by Hansen, rather than the figure described by Proctor. Plummer considered it likely that the figure of the Moon was in fact an ellipsoid of rotation which was very close to being spherical, largely because he knew of no physical mechanism which would tend to produce a highly elliptical ellipsoid. Plummer then noted that of the several methods for demonstration of the existence or non-existence of a lunar atmosphere, none had invariably given negative results. Note that in the opening lines of [1873e] Plummer stated … *the possibility of our atmosphere enveloping that portion of the lunar surface remote from the Earth,…* This appears to imply that his theory related to the lunar atmosphere in fact being a tenuous extension of the atmosphere of the <u>Earth</u> extending to the distance of the Moon. However, the text is somewhat ambiguous and it is not certain that this is the intended interpretation!

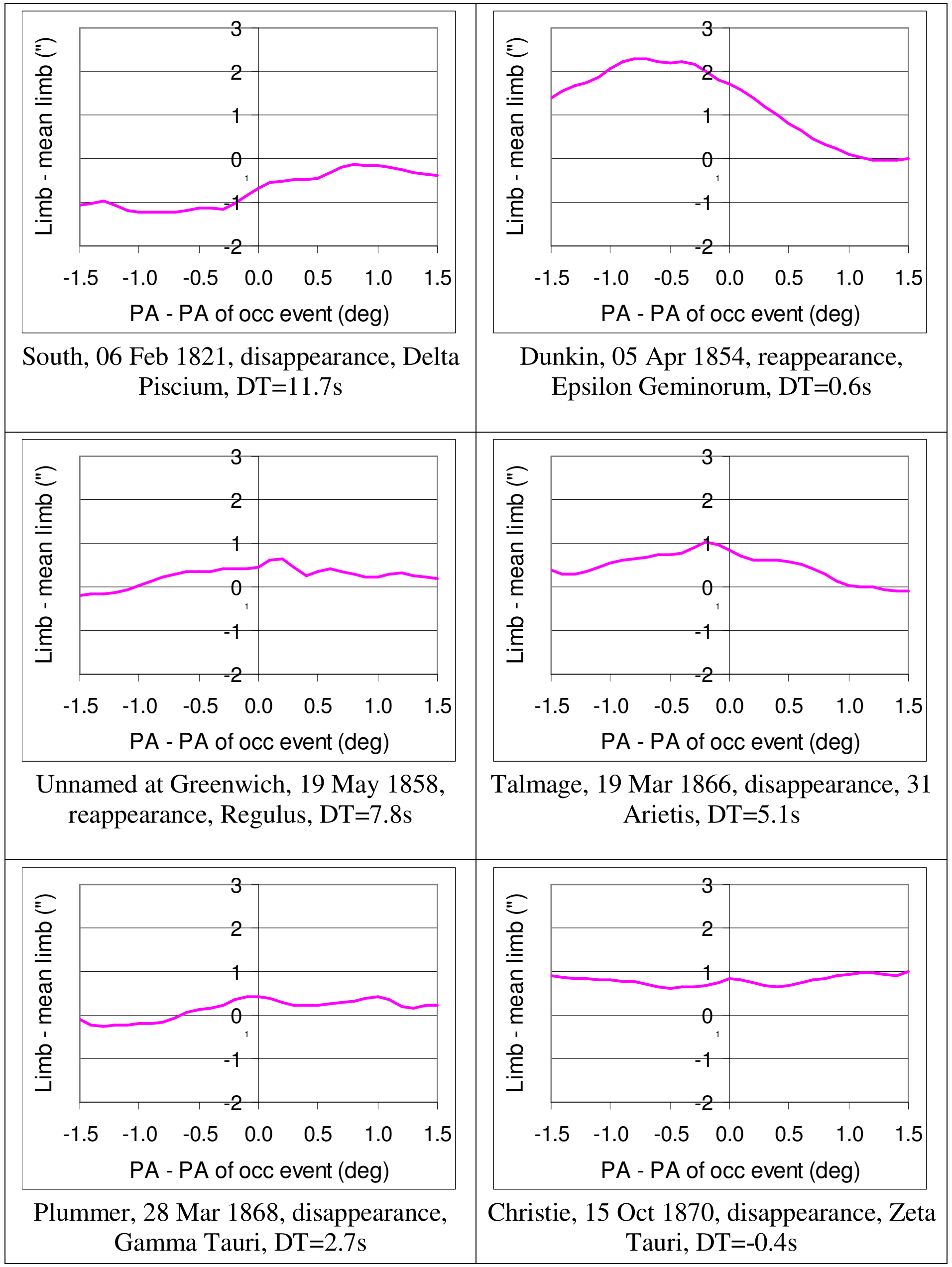
Proctor [1873f] replied that the fact that many highly experienced observers had never observed the phenomenon of projection tended to militate against Plummer's theory (since by the laws of averages some would have witnessed occultations occurring at significant lunar librations). Instead, he proposed the existence of deep lunar clefts as a mechanism to enable an occulted star to appear to hang upon the limb, as its light continued to reach the Earth through a deep ravine after the star had apparently passed within the circumference of the lunar disk. The vagaries of lunar geography would explain why some observers of an event witnessed the phenomenon of projection whereas others at different locations did not: starlight through a lunar cleft could reach one observer but not another observer situated some distance away. Proctor argued further that if refraction of starlight due to a lunar atmosphere were the cause of projection, one would expect a projected star to fade gradually rather than disappear suddenly.

Proctor then pointed out that analysis at the Imperial Observatory at Wilna (Vilnius, in modern day Lithuania) of photographs taken by de la Rue resulted in a model of the Moon similar to an egg, with the smaller end pointed towards the Earth (although the difference from a sphere was very minor). This evidence supported his assumption of the lunar figure quoted in [1873d]. He noted also that Sir John Herschel expected that due to the low gravity of the Moon, any atmosphere centred primarily on the far side of the Moon would nonetheless manifest itself occasionally on the limb.

Although Proctor's reply in [1873d] was couched in conciliatory phrases, his final paragraph essentially aimed to contradict and correct some specific assumptions and definitions employed by Plummer and it is clear that he considered Plummer's theory to be fatally flawed. At this rather unsatisfactory and inconclusive point the correspondence between Plummer and Proctor ended.

From a modern perspective, the discussion over *projection* appears hopelessly qualitative and unscientific. Modern observers do not report the phenomenon of projection, and it is known that the Moon has no appreciable atmosphere capable of causing refraction (instruments left by the Apollo 17 astronauts on the Moon detected trace elements of atmospheric gases such as hydrogen, helium, neon and argon, however the density of the lunar atmosphere does not exceed 10^{-14} times that of the Earth's [1983b]). However, because many respected 19th Century astronomers (e.g. South, Airy, Dunkin and Christie) reported the phenomenon, astronomers of the era accepted the supposed phenomenon as real, and attempted to find an explanation. In this regard, Plummer's hypothesis was at least as good as the other explanations of his era.

The only physical explanation from those proposed above which could conceivably be responsible for the phenomenon of projection, if it existed, would be deep clefts on the lunar limb through which the star would be visible, apparently inside the disk, to an observer suitably aligned. Figure 8 examines this possibility, showing the limb profile for each case of projection reported above, drawn to a common scale. The limb profiles are derived from IOTA's electronic Watts data [1963a] digitised at a granularity of 0°.2. To appreciate the scale of the figure, note that a deviation from the mean limb of one arcsecond corresponds to an elevation of approximately 1.9 km at the mean lunar distance. By way of comparison, the diameter of the Moon is 3476 km [1989a], equivalent to 1865 arcsec at mean lunar distance. Clearly none of the profiles as shown provides evidence of a feature capable of explaining projection. However, the lunar limb data is not available at sufficiently fine granularity to rule out the existence of narrow, deep gorges.



South, 06 Feb 1821, disappearance, Delta Piscium, DT=11.7s

Dunkin, 05 Apr 1854, reappearance, Epsilon Geminorum, DT=0.6s

Unnamed at Greenwich, 19 May 1858, reappearance, Regulus, DT=7.8s

Talmage, 19 Mar 1866, disappearance, 31 Arietis, DT=5.1s

Plummer, 28 Mar 1868, disappearance, Gamma Tauri, DT=2.7s

Christie, 15 Oct 1870, disappearance, Zeta Tauri, DT=-0.4s

Figure 4. Lunar limb profiles for cases of projection.

A1.4 Intended Later Observations Of Occultations

Plummer published his last paper on lunar occultations in 1873, but appeared to retain an interest in the subject subsequently.

In his annual report to the RAS for 1879, Plummer [1880b] stated that he intended to undertake occultation observations during 1880, as a means of validating his determination of the geographical coordinates of Orwell Park Observatory. He gave no further details, however Appendix 11.1 describes what he may have intended. In his annual report [1881c] to the RAS for 1880 he confirmed, without any details, that he had observed *a number of occultations of stars by the Moon*. However, he gave no details to indicate that he had been able to undertake any analysis of his observations.

Plummer also proposed in [1881c] to *watch for the unpredicted occultations of small stars at the dark limb of the Moon during the early days of each lunation, in the hope of detecting and elucidating the phenomenon of projection on the limb*. He noted that he had made some trial observations which had indicated that his approach would enable him to observe many occultations, at various points around the limb, in a comparatively short space of time.

In 1884, W Döllen [1884d], writing from Pulkowa Observatory (St. Petersburg), proposed the ideal project for occultation observers. His objective was to organise a large number of occultation observations and to use the results to estimate the diameter of the Moon. Döllen noted that due to irradiation it was almost impossible to estimate the diameter of the Moon when the lunar disk was illuminated. Previous estimates from occultation observations had been unsatisfactory because local features of the lunar limb had caused a significant spread of results. Döllen therefore proposed a new approach: to observe occultations during the lunar eclipse of 04 October 1884 and to pool results for many stars observed by many geographically dispersed observers. This approach avoided the problems associated with irradiation and averaged out the effect of local lunar limb profiles. It also had the benefit that faint stars could be relatively easily observed during the lunar eclipse.

Döllen provided a list of 116 stars down to magnitude 10 which were occulted by the eclipsed Moon on 04 October 1884. He stated that he had provided preliminary prediction data to 60 observatories from Helsinki and Oslo in the North to the Cape of Good Hope in the South and from Markree and Lisbon in the West to Tashkent and Madras in the East! Among the 60 observatories were in the UK Edinburgh, Glasgow, Dun Echt (near Aberdeen), Cambridge, Oxford and Greenwich and in Eire Markree and Dublin. Continuing his energetic approach, Döllen offered to provide preliminary calculations for any observatories or private individuals not in the initial 60. He clearly hoped to receive very many observing reports and he therefore proposed a two-stage approach to reducing the data. A preliminary reduction would assign weights to individual observers, followed by a final reduction based on the weighted results. However, he did not provide full details of his intended data analysis.

Plummer had intended to participate in Döllen's project, but in his annual report to the RAS for 1884 [1985a], he noted that clouds unfortunately prevented observations. In fact, it appears that cloud cover prevented most if not all observations and Döllen was unable to proceed to estimate the lunar diameter. (An earlier effort by Döllen at organising a large scale set of observations, on 09-10 April 1884, had similarly been clouded out.)

Döllen organised another mass-observation of lunar occultations for the lunar eclipse of 28 January 1888, aiming to analyse the results to estimate the diameter of the Moon. In Plummer's annual report to the RAS for 1888, he noted [1989a] that he had intended to observe occultations of faint stars during the eclipse but that cloudy weather had prevented him from making observations. It is possible that he intended once more to contribute occultation observations to Döllen, although he did not state this. Although cloud prevented Plummer from observing, many astronomers were more fortunate and were able to make observations and report details: by the end of March 1882, Döllen [1888c] reported receiving 783 observations from various observers across Europe and America.

Plummer made no mention of occultations in his publications after 1884.

--- To be continued ---