# The Newsletter of the Orwell Astronomical Society (Ipswich)

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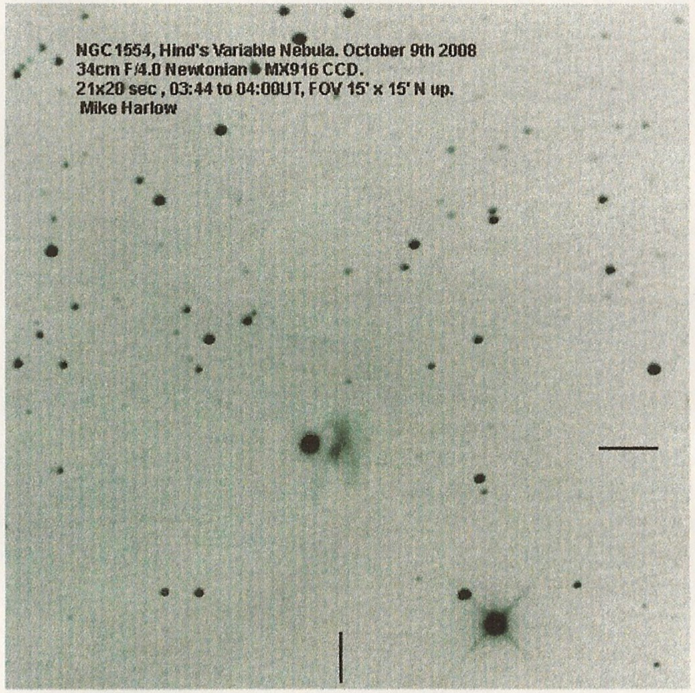
2008 November No 435




**Hinds Variable Nebula (NGC 1554) very near the Hyades in Taurus.**

**The star right next to it is the very young variable star T Tauri.**

**Imaged by Mike Harlow 2008 0ctober 9th**

## Society News (Roy Gooding)

### 1 Observatory Keys

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

### 2 Events for 2008

This event list will be updated through out the year

| Meeting | Venue | Date |
|---|---|---|
| Lecture meeting<br>William Herschel by<br>Tony Dagnall | Methodist church hall | Friday 14th November<br>From 20:00 |
| Astronomy Workshop<br>Sperm Whales, Candles and the Planet Venus<br>Presented by James Appleton | Nacton Village Hall | Wednesday 3rd December<br>Starts At 19:45 |
| Geminid Meteor watch | The "Dip" Felixstowe | Saturday 13th December |
| **Christmas Meal<br>Note change of date<br>The general consensus was to return to the venue we used last year** | **Peak Lodge<br>Suffolk Ski Centre<br>Bourne Hill<br>Wherstead** | **Thursday 11th December<br>20:00 start.** |

### 3 Access into the School Grounds and Observatory Tower

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

### 4 Welcome to New Members

### 5 Lecture Meeting Venue

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

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

### 5 Society Management

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

## Night Sky (November)

All times GMT

### Moon

| 1st Quarter | Full Moon | 3rd Quarter | New Moon |
|---|---|---|---|
| 6th | 13th | 19th | 27th |

| Object | Date | Times | | Mag. | Notes |
|---|---|---|---|---|---|
| | | Rise | Set | | |
| Sun | 1 | 07:00 | 16:35 | | |
| | 30 | 07:49 | 15:57 | | |
| Mercury | 1 | 05:31 | 16:18 | -0.8 | During the 1st week of the month it may be visible low down in the pre-dawn sky Superior conjunction is on the 25th |
| | 30 | 08:12 | 08:12 | | |
| Venus | 1 | 10:39 | 18:03 | -3.8 | Venus remains low down in the early evening sky this month |
| | 30 | 11:14 | 18:45 | | |
| Mars | 1 | 08:01 | 16:55 | 1.6 | Mars will not be visible this month |
| | 30 | 08:03 | 15:57 | | |
| Jupiter | 1 | 12:39 | 16:55 | -2.2 | This month sees Jupiter gets lower down in the western sky. At the end of the month Jupiter will be in conjunction with Venus |
| | 30 | 11:02 | 19:00 | | |
| Saturn | 1 | 02:07 | 15:16 | 1.0 | Saturn's ring tilt reduces from 2° to 1° during the month. In small telescopes they will not be visible |
| | 30 | 00:26 | 13:26 | | |
| Uranus | 1 | 15:03 | 02:20 | 5.8 | Uranus remains in Aquarius. |
| | 30 | 13:08 | 00:24 | | |
| Neptune | 1 | 14:10 | 23:39 | 7.8 | Neptune remains in Capricornus |
| | 30 | 12:16 | 21:47 | | |

### Meteor Showers

| Shower | Limits | Maximum | ZHR |
|---|---|---|---|
| Taurids | October 20th to November 30th | November 3rd | 10 |
| Leonids | November 15th to 20th | November 18th 05:00 | 20 |

Meteor source is the BAA Handbook



## Christmas Meal Thursday 11th December

**Venue: The Lodge Bourne Hill Wherstead 20:00 start**

| **Starters** |
|---|
| Vegetable & Noodle soup and rustic bread |
| Mackerel pate & melba toast |
| Sweet brie & red onion bruschetta |
| Melon & parma ham salad dressed with raspberry vinegar |
| |
| **Main** |
| Traditional roast turkey & trimmings |
| Pan seared duck in red wine with potatoes & vegetables |
| Oven baked cod with orange parmesan & herb crust. With salad and new potatoes |
| Beef & Guinness stew, mustard mash, vegetables and parsnip crisps |
| Courgette, pesto & sweetchilli pasta, tomato and red onion & pumpkin bread |
| |
| **Puddings** |
| Plum pudding |
| Selection of sweets choose on the night |
| |
| Mince pies |
| Coffee and mints |

Cost £24.50
Deposit £5.00

If you would like to attend please contact me (Roy Gooding ) as soon as possible The restaurant requires the deposit of £5 person as soon as I can get it to them to have the booking confirmed. ( Preferably by the end of October )

### Two Meetings in October

The FAS autumn convention was held at the Institute of Astronomy Cambridge on Saturda 20th September. Some years this Paul Whiting. The event followed the normal Programme, trade stands, lectures and the FAS AGM

The following week was the principle Saturday, of the Autumn Equinox Sky Camp Organised by Loughton AS, held at Kelling Heath, Weybourne Norfolk. I went along to thi event. Apart form the trade stands, many of which were in Cambridge the previous week, it interesting just ambling round the camp site looking at the various telescopes on display. There were considerably more telescopes and campers here this year than last year.

## OCCULTATIONS DURING NOVEMBER

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 |
|---|---|---|---|---|---|---|---|
| 06 Nov | 21:21:47 | D | 0.57+ | -45 | 14 | 7.3 | Hip 106922 |
| 08 Nov | 21:42:35 | D | 0.76+ | -48 | 31 | 7.1 | ZC 3411 |
| 09 Nov | 18:17:02 | D | 0.84+ | -19 | 33 | 7.4 | Tyc 590-0060-1 |
| 12 Nov | 18:30:36 | D | 1.00+ | -22 | 28 | 5.7 | 34 Ari,mu Ari |
| 13 Nov | 18:26:23 | D | 0.99- | -21 | 22 | 3.7 | Electra |
| | 19:06:58 | R | | -28 | 28 | | |
| 13 Nov | 19:14:15 | D | 0.99- | -29 | 29 | 2.8 | Alcyone |
| | 20:11:21 | R | | -37 | 37 | | |
| 13 Nov | 19:55:53 | D | 0.99- | -35 | 35 | 3.6 | Atlas |
| | 20:41:31 | R | | -42 | 42 | | |

James Appleton

### Thanks Again.

The first thank-you note published in the newsletter had become corrupted somewhere in transmission. So, here is a thank-you message again, in English this time!

Pete and I would like to say thanks for the wedding present and card from OASI members. We had no idea that, when admiring a picture at Martin's house, we were giving people an idea for a wedding present: namely a watercolour painting of the observatory. It was very kind of all who contributed. We had the perfect position for it as well. It balances so well with a picture of some hot air balloons passing over the Suspension bridge in Bristol.

Thanks

Nicky



### Calling OASI Members

#### Officer's Position Available

Are you interested in the post of chair of the society? No experience is necessary (you do not need to be currently on the committee) and the essential role is now the least onerous of any committee officer or position. If you want to be more active you can but the work of the society is done by the other officers, committee members and other members. Those holding the post in the past have done a great deal of work when they have been able to, but they have always been able to relax and let the members run the society if they chose to. At present the committee are working hard so the 2009 post holder can take it easy if they prefer to.

A key reason for considering a non-committee member is that the current committee members are all busy with important tasks. The requirements of the role will be to attend most of the 4 or 5 committee meetings during the year (or delegate to a deputy). You don't need to introduced speakers for workshops or lectures as the workshop and lectures co-ordinators do this themselves. If you are interested you can email [redacted] (this is a special purpose mail address and you don't need to in the mailing list to send to it); alternatively you can use the standard mailing list if you are on that, or you can get in touch directly with a committee member.

The size of the committee has been increased in recent years to reflect the general increase in the number of OASI members and to support the increase in the range of activities run by the society. In most years we have had filled all committee as well as the officer posts, but from time to time people need to, or want to, stand down, so new committee members are always welcomed. Occasionally we have even co-opted additional members to special roles when there have been no vacancies in the general committee and it's a case of the more the merrier!

#### Observatory Restoration Ideas and Suggestions

Since its formation the Orwell Astronomical Society (Ipswich) has worked hard to save the Orwell Park Observatory from irreversible decay and its members have put in a massive amount of work to maintain and restore this important piece of 19th century heritage and make it a viable amateur observatory in the 21st century. What the observatory would benefit from now is major structural and other very expensive restoration work to bring it close to its original condition. The school plan to raise funds for restoration work at the observatory as they have done and are planning for other parts of the school. If OASI members have any ideas or suggestions which could be helpful to the school in this project please let the committee know.

# OASI Committee Contacts & Responsibilities

| | | | |
|---|---|---|---|
| Kenneth J. Goward FRAS | **Chairman** | **☎ 01473 785802** | |
| Roy Gooding | **Secretary** | ☎ [redacted] | **MAIN POINT OF SOCIETY CONTACT**<br>Press Publicity with Chairman.<br>Observatory Decoration.<br>Visits by potential new members. |
| Paul Whiting FRAS | **Treasurer** | ☎ [redacted] | **Finance.**<br>Supervision of Grant Applications.<br>Visits by outside groups.<br>**IYA 2009 Coordinator** |
| James Appleton | Committee | ☎ [redacted] | Committee Meeting Minutes.<br>Web Site. |
| Martin Cook | Committee | ☎ [redacted] | Membership.<br>Tomline Refractor Maintenance. |
| Neil Morley | Committee | ☎ [redacted] | Equipment Curator. |
| Peter Richards | Committee | ☎ [redacted] | Lecture Meetings.<br>School Lighting liaison.<br>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 |



## Diary for November

| | |
|---|---|
| **Monday**<br>**3rd and 17th** | **SMALL TELESCOPES OBSERVING NIGHTS**<br>Main Observational targets:<br>☎ Paddy O'Sullivan [redacted]<br>☎ Gerry Pilling [redacted] |
| **Wednesdays**<br>**From 8PM** | **MAIN OBSERVATORY CLUB NIGHTS**<br>Primary Observational targets:<br>Nebulae and faint objects.<br>☎ Martin Cook [redacted] (mobile) [redacted]<br>☎ Roy Gooding [redacted] (mobile) [redacted] |
| **Thursdays** | **OBSERVATORY VISITS BY LOCAL COMMUNITY GROUPS** |
| **6th 7.30PM** | **St Joseph's College** |
| **13th 8PM** | **Wolsey Theatre Club** |
| **20th 8PM** | **Taster Evening** |
| **27th 8PM** | **Suffolk Humanists**<br>☎ Paul Whiting FRAS [redacted] |
| **Friday 14th**<br>**8PM**<br>**Methodist Church Hall**<br>**Blackhorse Lane**<br>**Ipswich** | **OASI LECTURE MEETING**<br>***'Sir William Herschel'***<br>Presented by Tony Dagnall, Stour Valley Astronomical Society.<br>☎ Peter Richards [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]

# John Isaac Plummer, Colonel Tomline's Astronomer Part 7

## A1 Venus

In the early 1870s astronomers were much interested in observing Venus, and in particular the forthcoming transits of Venus on 09 December 1874 and 06 December 1882 which, they anticipated, would provide an improved estimate of the solar parallax and hence the scale of the Solar System.

Plummer observed Venus at Durham Observatory, at Orwell Park Observatory and as a member of an official expedition sent by the ROG to Bermuda to observe the transit of Venus in 1882. He published four papers on Venus and mentioned the planet in four of his annual reports to the RAS from Orwell Park Observatory.

### A1.1 Opportunity To Estimate The Ellipticity Of Venus

Plummer's first paper on Venus [1873g], published in 1873 while he was at Durham Observatory and communicated to MNRAS by the Reverend Professor Farrer, DD, looked forward to the 1874 transit. He noted that the 1874 transit would provide an opportunity to measure the ellipticity of the planet. He thought that the measurement would be difficult because the ellipticity of Venus was likely to be small, therefore he recommended that the task be undertaken by fixed observatories rather than by the expeditions being organised to observe the transit, since the former generally had much larger instruments at their disposal. Plummer believed that there were sufficiently many observatories in the British Empire positioned to observe the transit, but that they were not in general equipped with suitable large heliometers[1] to undertake the measurements. It would not be possible to provide large heliometers to observatories lacking then in time for the transit, but it would be possible to provide portable Airy double image micrometers at relatively short notice in time for the transit – Plummer believed that such instruments *would probably give us reliable results*. Clearly, Plummer's argument was not entirely logical: he recommended that fixed observatories undertake the observations because they generally had the larger

[1] A heliometer is an equatorially mounted, double-image micrometer used originally for measuring the diameter of the Sun at different seasons throughout the year. See Appendix 17 for an explanation of the double-image micrometer.



instruments but as most lacked suitable fixed instruments they should use relatively small portable instruments instead!

Plummer noted that knowledge of the position of the equator of Venus would assist in measuring the ellipticity of the planet – but there was no published ephemeris for the equator. He speculated that the ellipticity of Venus might be as large as that of Mercury or Mars in which case it would affect the determination of the length of the AU.

The modern accepted value of the ellipticity of Venus is exactly zero, i.e. the figure of the planet is circular [1992a].

### A1.2 Estimates Of The Diameter Of Venus

Plummer addressed estimation of the diameter of Venus in two papers [1873g, 1873h] in MNRAS in 1873. His work drew on the work of the Reverend R Main at the ROG so it is worth considering Main's work in some detail first in order to provide the context for Plummer's papers.

Main [1856b][2] provided a summary of estimates of planetary diameters that he had made using an Airy double-image micrometer. He based his estimates on observations made at the ROG from the date of invention of the instrument in 1840 until 1851. He took account of irradiation in estimating the diameter of Venus and therefore considered separately estimates made in daylight and those made in the evening. (Daylight and evening are of course generally associated with differing degrees of sky brightness and therefore differing levels of irradiation).

Main grouped the daylight observations into two categories for analysis: those made while the planet was near inferior conjunction and those made while it was near superior conjunction. He formed two equations from the two categories and solved them to provide an approximate estimate of the apparent diameter of the planet at unit distance (1 AU) and the constant of irradiation (denoted here D and x respectively). He also performed a regression analysis of the data. Table 16 presents his results.

Main found the effect of irradiation to be negative, implying that the visual observer reported a diameter smaller than it was in reality. Main believed that this was due to the *feebleness of the light at the cusps and borders of the planet*, which caused the observer to record not the true cusp or border, but a point lying within it by approximately 0".25. Main claimed that this was *a result which might have been in some degree expected*, presumably on the basis that the extremities of the cusps and borders are visibly dimmer than the surrounding daylight sky brightness.

[2] In fact Plummer [1873g] provides a reference to the Rev R Main's work in the Memoirs of the Royal Astronomical Society, XXV, p46. However, [1856b] provides a summary of Main's paper which is more easily accessible.

| Parameter | Approx Estimate (") | Regression Estimate (") |
|---|---|---|
| D | 17.61 | 17.55 |
| x | -0. 61 | -0.50 |
| Apparent diameter of Venus at unit distance | 17.00 | 17.05 |

**Table 1. Estimates by the Rev R Main of the diameter of Venus.**

Main found the evening measures of the diameter of Venus to be *totally free from the effects of irradiation*. As Venus is such a bright planet this result was completely unexpected. However, Main did not quote an estimate of D from the evening measurements, therefore there is no opportunity to compare it with the values estimated from the daytime measures.

In [1873g] Plummer reported making, between 19 March and 20 June 1868, a series of estimates of the diameter of Venus using a double image micrometer. His final estimate of the diameter at standard distance, based on 28 observations each of 12 contacts, was D=17".695, slightly larger than Main's estimate. However Plummer's measurements indicated a coefficient of irradiation *considerably larger* than that estimated by Main, and for this reason he had not published his results. Plummer reported that he was repeating the observations with *greater care and precaution*, and that to date his new observations confirmed the earlier results. On the basis of his measurements, he believed that the following estimates of the diameter of Venus at unit distance, which were in widespread use at the time, were too small:

- The estimate by Encke of 16".61, based on an analysis of observations of the 1791 transit of Venus. The *Nautical Almanac* had adopted Encke's estimate.
- The estimate of 16".944 by Stone [1865b], working at the ROG. Stone's figure was based on 589 estimates of the vertical diameter of Venus made by various observers at the ROG using Troughton's Mural Circle and the Great Greenwich Transit Circle during the period 1839 – 1862. Astronomers of the time held Stone's figure in high regard – for example Dunkin [1873b] referred to Stone's figure as *the best possible modern determination* [of the semidiameter of Venus]. Plummer's challenge of Stone's figure betrayed temerity!

Plummer's second paper on estimating the diameter of Venus [1873h] provided a natural conclusion to his earlier paper. He discarded his 1868 data and undertook a new set of measurements of the diameter of the planet using an Airy double image micrometer during the period 18 February – 23 July 1872, following the inferior conjunction of the planet on 26 September 1871.

Possibly conscious of the need to tread carefully in casting doubt over Stone's determination of the diameter of Venus, Plummer took care to assure the quality of his



measurements. He endeavoured to achieve a steady image by equalising the temperature of the air in the observing room with the ambient temperature and he rejected observations made when the definition of Venus appeared poor. However, he did not attempt to associate a quality score to his measurements, and instead assigned each an equal weight during his subsequent analysis of the observational data. He reported calibrating the micrometer screw over four evenings during 1868 – presumably this referred to the calibration that he had undertaken previously prior to his earlier measurements in 1868. He used a magnification of 113x and made all measurements in full daylight, with the planet near the meridian. He corrected his estimates for the effect of differential atmospheric refraction on the two cusps of the planet.

Having made a total of 26 measurements, Plummer fitted the following model to the data:

$$d = D/\Delta + x \qquad (1),$$

where D and x are as defined above and

d = apparent angular diameter of Venus.

Δ = distance of Venus from Earth at time of observation (from the *Nautical Almanac*).

Plummer's approach to fitting the model provided an approximate result with minimal calculation. He had to undertake the computations by hand, without the assistance of a computing assistant, and therefore was no doubt keen to minimise the complexity and number of calculations. Following Main's approach, he divided the measurements into two groups depending upon the distance between Venus and the Earth, and calculated average quantities within each group. This generated two equations in two unknowns, which he solved to give estimates of D and x.

Modern computers enable rigorous regression techniques to be applied to data sets without the need to average subsets of data in the way that Plummer did. Table 17 compares Plummer's results with those of a full regression analysis to fit model (1).

| Parameter | Plummer's Estimate (") | Regression Estimate (") |
|---|---|---|
| D | 17.321 | 17.260 |
| x | -0.546 | -0.423 |
| Apparent diameter of Venus at unit distance | 16.775 | 16.837 |

**Table 2. Estimates of the diameter of Venus.**

For comparison, the currently accepted value of the apparent diameter of Venus at unit distance (1 AU) is 16.82", referring to the cloud tops [1991a]. Note that as with Main, Plummer's estimate of the effect of irradiation is negative, so that the effect of irradiation is to decrease the apparent diameter of the planet.

Plummer’s analysis yielded an estimate of the diameter of Venus at unit distance which is close to the modern accepted value. However there are significant problems with the way in which he treated the potential effect of temperature and atmospheric transparency on his results.

Plummer was anxious to understand the potential impact of temperature on irradiation. He wrote: *As the investigation of the correction due to irradiation was an important item in this enquiry, it was necessary that any change in this value depending on temperature should be eliminated. This has been done simply and effectually by spreading the observations over that period of the year during which temperature is continually increasing, the planet attaining its maximum diameter about the middle of the period. The results, however, do not appear to indicate that any sensible change actually exists.*

Plummer’s intent to control his measurements for the effect of temperature was laudable, but alas his execution was woeful! His attempt to eliminate the effect of temperature on irradiation would have been valid if the subsequent analysis treated temperature as a control variable; unfortunately, it did not! Plummer’s observations spanned the temperature range 39.8ºF - 81.0ºF and the way in which he divided his data into two groups for averaging to estimate the quantities D and x resulted in average temperatures for the groups of 56.1°F and 58.1°F. Plummer made no allowance for this temperature difference in analysing the data. He stated that his measurements did not indicate any significant effect of temperature on irradiation; however he provided no detail or evidence to support this statement, and unfortunately, it appears that he did not find a link between temperature and irradiation primarily because he did not look for one!

The regression model fitted to (1) achieves a very good fit, with adjusted coefficient of determination, $R^2 = 0.9993$. Figure 11 confirms this, showing very good agreement between the regression model and the measurements of the diameter of Venus.



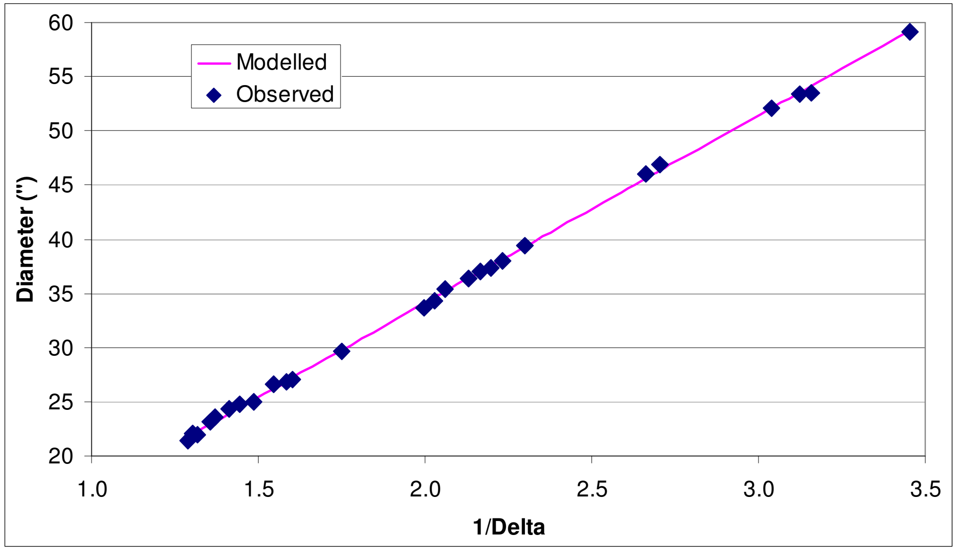



**Figure 1. Regression model fitted to Plummer’s measurements.**

Figure 12 shows the residuals of the model plotted against temperature: it shows no obvious association between the residuals and temperature. However, fitting the regression model (2) to Plummer’s data provides a further check for a possible association:

$$d = D/\Delta + AT + B \qquad (2).$$

Model (2) represents irradiation as a linear function of temperature of the form AT + B, where A and B are coefficients to be determined, d, D and Δ are defined as above and T is the ambient temperature.

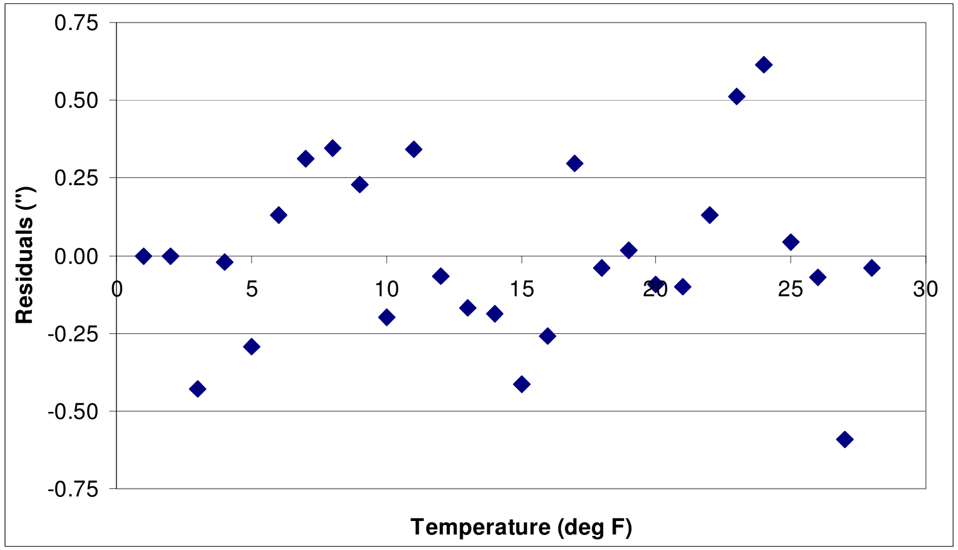



**Figure 2. Plot of residuals versus temperature.**

The regression model (2) offers a very slightly improved fit (adjusted $R^2 = 0.9994$). However the coefficients A and B are not statistically significant. This validates Plummer's opinion that his data shows no significant effect of temperature on irradiation.

Plummer examined the residuals of his model (1) in detail, and although they are generally small (maximum absolute value 0".66) he provided some anecdotal evidence as follows to suggest that changes in the transparency of the sky could influence irradiation:

- During his first five observations *the sky was unusually clear*, and the measured diameter of Venus was greater than anticipated. (In fact the empirical measurements exceeded the corresponding estimate of the model (1) by an average 0".31.)
- During the observations on 17 June, 18 June and 23 July *the sky was hazy* and the measured diameter of Venus was smaller than expected. (In fact the empirical measurements were lower than the estimate of the model (1) by an average 0".35.)

Plummer did not regard the anecdotal evidence as a conclusive demonstration of the link between the transparency of the sky and irradiation, and indeed he noted cases which the preceding reasoning could not explain. However, he appeared to harbour a suspicion that the transparency of the sky influenced irradiation, because two years later, in his annual report to the RAS [1876d] for 1875, he wrote: *Some measures of the diameter of Venus, made a few years ago, having given rise to a strong suspicion that the factor of irradiation varies with the transparency of the atmosphere…*



Plummer appears to have missed an obvious opportunity to undertake a much more rigorous analysis of his observations. He could have recorded the state of atmospheric transparency for each of his observations of Venus, perhaps by estimating his ability to see various distant terrestrial objects. This would have enabled him to undertake a more rigorous analysis of the supposed association between irradiation and atmospheric transparency, possibly enabling him to build a regression model to quantify the correlation between the two quantities.

## A1.3 Estimates Of The Brilliance Of Venus

In a paper published in 1876 that is nothing if not innovative, Plummer [1876f] noted that although Venus and Jupiter when at their brightest were capable of casting shadows, astronomers had not used this fact to compare the intensity of their light with that of the Full Moon or with any terrestrial light source. He therefore set out to determine whether it was possible to use simple equipment (rather than an expensive photometer) to estimate the intensity of planetary light and to estimate how the brightness of Venus varied as a function of the phase of the planet. He noted that several famous astronomers had addressed the problem of estimating the relative brightness of stellar bodies, but they had generally paid little attention to Venus due to its apparent proximity to the Sun.

Plummer constructed a simple Rumford photometer, comprising a reference light source, two identical 1.8mm (1/14th inch) diameter wire rods and two identical white paper screens. He placed each wire rod 2.7m (nine feet) in front of its associated screen, and housed the rods and screens in a dark room. He arranged for the reference light source to cast a shadow of one rod onto one screen and for Venus to cast a shadow of the other rod onto the other screen. Plummer operated the instrument by adjusting the distance of the reference light source until the intensity of the shadow which it cast was equal to the intensity of the shadow cast by Venus. The inverse square of the distance of the reference light source acted as a measure of the brightness of the planet. Plummer used a standard spermaceti whale oil candle, burning 120 grains of oil per hour[3], as reference light source. For protection from the elements, Plummer placed the candle inside a lantern, open on one side, which in turn he placed inside a wooden box, painted black on the inside, also open on one side. Plummer did not state where he conducted his photometric experiments, but it was presumably in the grounds of Orwell Park Mansion.

Before attempting to make measurements with his equipment, Plummer conducted some trials to check that it operated satisfactorily. On 29 March 1876, with a four day old Moon situated only 12° distant from Venus, Plummer observed the shadows cast by Venus and the Moon simultaneously on the same screen, and noted that the shadow cast by Venus was *conspicuous*. Further, he found that when direct moonlight was excluded from the observing room, even Sirius, with a light intensity roughly 1/9th that of Venus, cast *an*

[3] The standard 120 grains per hour spermaceti candle was the reference light source of its day. Eventually, standards bodies formalised its light output in the SI unit the *candlepower*.

*appreciable shadow*. He believed that his equipment would work with any planet brighter than Venus, but was deterred from applying it to Mars and Jupiter by the difficulty of attaining a sufficient distance at which to place the reference candle! (A later publication [1877e] indicated that the practical maximum distance to the candle was 125 m (135 yards).

As further verification, Plummer noted that on 26 April, he observed the light from Venus and a three day old Moon fall upon a plaster wall in the open air, and each cast a *distinctly observable* shadow of neighbouring buildings[4].

Plummer reported eight observations of the brightness of Venus, made from 20 March to 13 May 1876. Unfortunately, moonlight spoilt one of his observations, and another suffered from being made with the planet at a very low altitude (only 6º). This left six good measurements, for each of which the sky was *brilliantly clear* and the *equality of the shadows has been considered satisfactory by at least two persons*. (He did not reveal the identity of the persons judging the equality of the shadows.) He restricted his subsequent analysis to the six good measurements.

The distance from candle to screen was typically around 100m (300 ft) and Plummer stated that he could determine the distance of the candle to within at most 2m (six feet), yielding a relative accuracy of circa 2% at worst.

Plummer analysed his data as follows:

1. He first tabulated the distance to the candle for each of the observations. By virtue of the inverse square law of illumination, the inverse square of the distance to the candle acted as a measure of the intensity of the light of the planet.
2. Using tables by Seidel[5], Plummer estimated the effect of atmospheric extinction on the light from Venus. He corrected his brightness measurements for a standard altitude of 18° (approximately the mean altitude of Venus during his observations). At this point, he partially averaged the brightness measurements to give mean results for the dates 22 March, 17 April and 11 May, and concluded that *Venus approaches its point of maximum brilliancy on June 6 very gradually indeed*.
3. He then normalised the brightness estimates for the distances Venus-Sun and Venus-Earth on 11 May 1876, the date of his last satisfactory measurement of the brightness of the planet. This produced estimates of the brightness of the planet as a function solely of its phase.
4. He averaged the data to give an estimate of the brilliance of Venus at average phase (40%).

[4] As with Plummer's observations of the zodiacal light, the contrast with our modern light polluted skies is marked: few 21st Century observers claim to have observed Venus cast a shadow!

[5] Plummer gave no reference for Seidel's tables and it has not yet been possible to obtain a set to compare with modern formulae for atmospheric extinction. This is unfortunate given the difficulty which Plummer experienced in normalising his data for the effect of extinction.



5. He extrapolated from the data to predict the brilliance of Venus (in terms of candle distance!) when the planet would be at its greatest brightness.
6. He then estimated the brilliance of the Full Moon, using essentially the same method as for Venus, but with a Bunsen photometer rather than a Rumford photometer. (The Bunsen photometer uses a paper screen with a grease spot placed upon it such that when it is illuminated equally from both sides, the spot appears neither lighter nor darker than the paper but becomes almost invisible. Plummer positioned the spermaceti whale candle on the other side of the screen to the Full Moon.)
7. By comparing the estimates of the brilliance of Venus and the Full Moon, Plummer concluded that the light from Venus at greatest brilliance had an intensity 0.125% that of the mean Full Moon.

Plummer searched the literature for comparable work. He was able to locate only one work, by Bond[6], which was relevant. Bond gave the ratio of the light of Jupiter at mean opposition to that of the mean Full Moon as 1:6430, and the light of Venus at greatest brilliance to that of Jupiter as 4.864:1. Combining the two results gave the ratio of the light of Venus at greatest brilliance to that of the mean Full Moon as 1:1322, or 0.076%. Plummer's estimate of the greatest brilliance of Venus was more than half as much again as that deduced from Bond's work, but he did not consider the discrepancy to be significant in view of the dissimilar methods employed, the fact that Bond was primarily concerned with the Moon and Jupiter rather than with Venus and finally the fact that Bond had generally been able to observe the Moon and Jupiter at much greater altitudes than those at which Plummer had observed Venus.

Plummer presented several intermediate steps in his calculations and it is possible to rework them from a modern perspective. Unfortunately, a modern reworking shows that Plummer's analysis is fatally flawed.

Table 18 shows Plummer's empirical data and the initial stages of his analysis. The rows shaded in grey are those which Plummer did not take forward in his analysis (due to interference from moonlight on 26 April and due to the low altitude of Venus on 13 May).

Column one specifies the date of Plummer's observation. Column two details the distance to the candle: the brightness of Venus is proportional to the inverse square of the distance. Column 3 details the altitude of Venus at the time of observation, and column four indicates the correction factor to normalise the distance in column two to an altitude of 18°. Note that Plummer did not tabulate his correction factors but it is easy to deduce them from the other data presented. Column five, "Phase, v", is in fact 180° out of phase with the modern quantity *phase angle*, which is defined (e.g. [1991a]) as the angle between the vectors Venus-Sun and Venus-Earth. It is probable that Plummer calculated the phase, v, from the *Nautical Almanac*. Column six tabulates the quantity C, the square of the distance to the candle, normalised to an altitude of 18°.

[6] *Memoirs of the American Academy*, vol. viii. (Full reference not available.)

| Date | Distance to Candle (ft) | Venus Altitude (deg) | Altitude Correction (to 18 deg) | Phase, v, (deg) | C ($ft^2$) |
|---|---|---|---|---|---|
| 20 Mar | 290.65 | 12.7 | 1.8 | 114.9 | 148,423 |
| 24 Mar | 334.50 | 13.5 | 1.0 | 113.1 | 107,498 |
| 14 Apr | 286.25 | 19.7 | 1.4 | 102.5 | 115,771 |
| 21 Apr | 263.75 | 20.3 | 1.9 | 98.9 | 133,937 |
| 23 Apr | 265.00 | 19.6 | 1.9 | 97.9 | 135,581 |
| 26 Apr | 306.00 | 17.8 | 1.2 | 96.4 | 107,424 |
| 11 May | 275.42 | 15.5 | 1.9 | 84.1 | 144,710 |
| 13 May | 314.19 | 6.6 | 2.3 | 83.2 | 230,303 |

**Table 3. Plummer's measurements of the brightness of Venus.**

Table 18 reveals the following problems with the data and Plummer's initial analysis:

- Plummer reported the altitude of Venus on 13 May at 22:26 GMT as 6.6°; however, the modern reference ephemeris DE-405 gives an altitude of 9.3°. The corresponding correction factors to normalise the results to an altitude of 18° are respectively 0.45 and 0.62 (using a modern formulae [1991b] for atmospheric extinction), signifying a significant difference in the actual brightness of Venus. In any case, because of the low altitude, Plummer did not take this observation forward in his analysis.
- Plummer's altitude corrections, used to normalise his observations to an altitude of 18°, appear to fluctuate wildly, and without apparent relation to the altitude of the planet. For example, on 14 April and 23 April, the planet is at almost the same altitude (19°.7 and 19°.6 respectively) yet Plummer's correction factors for altitude are respectively 1.4 and 1.9.
- The empirical distances of the candle on 20 and 24 March appear discordant one with another. The distance to the candle on 20 March was only 87% of that on 24 March, although on the earlier date the observations were made with Venus at a lower altitude, which would tend to militate towards a greater distance to the candle. Figure 13 plots the value of C (square of distance to candle), normalised to an altitude of 18° using a modern formulae [1991b] for atmospheric extinction. It clearly shows that the observation of 20 March is suspect, and appears to correspond to an estimate of the magnitude of Venus which is considerably too bright. This faulty estimate appears to follow through into Plummer's conclusions (see below). This highlights one of the fundamental problems with Plummer's approach: he had no means of correcting for the transparency of the sky in his analysis. Had his photometer been a little more sensitive, it would have offered the possibility to use bright stars of known magnitude visible throughout the period of his observations, e.g. Sirius, Arcturus and Spica, as references against which to estimate the magnitude of Venus.



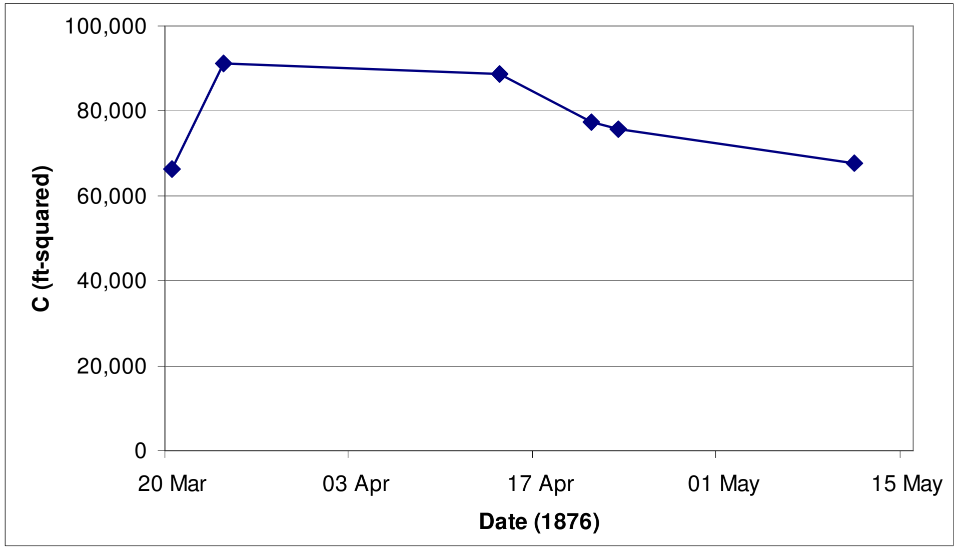



**Figure 3. Squares of distances to the candle, normalised to an altitude of 18° by modern extinction formulae.**

Unfortunately, as the analysis proceeded, further problems occurred. Plummer's initial conclusion, based on averaging the data presented in table 18, is that *Venus approaches its point of maximum brilliancy on June 6 very gradually indeed*. Figure 14 compares Plummer's estimates of the brightness of Venus with the brightness calculated using the modern reference ephemeris DE-405 [1997a]. (Both sets of brightnesses are normalised with respect to their values on 11 May.) Plummer's results give an increase in brightness of Venus over the period 22 March – 11 May from 88% to 100% of its final value. Calculations using DE-405 indicate an increase from 80% to 100%, a considerably larger change. Plummer's suspect observation on 20 March (which contributed by means of averaging to his estimate of the brightness of the planet on 22 March) is one of the contributing factors to this discrepancy.

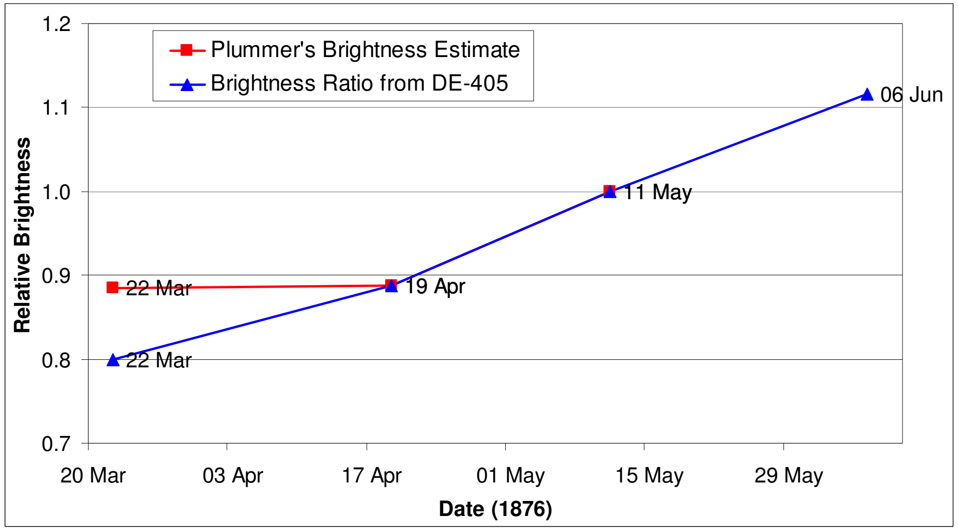



**Figure 4. Venus' approach to maximum brightness on 06 June 1876.**

Figure 15 illustrates estimates of the brightness of Venus as a function of the *phase*, v. The estimates are normalised for the distances Venus-Sun and Venus-Earth on 11 May 1876. The abscissa of the graph runs from a phase of 120° down to a phase of 80°, corresponding to the period 09 March – 19 May. During this period the illuminated proportion of the planet's disk shrank from 71% at Plummer's first observation on 20 March to 45% at the time of Plummer's last observation on 11 May.

The figure shows two theoretical predictions (Euler's formula and Lambert's formula), Plummer's analysis of his brightness estimates and a modern reworking (correction) of Plummer's analysis as follows:

- Euler's formula: $\Theta = \sin^2(v/2)$, where Θ is the illuminated fraction of the planetary disk and v is the phase. Plummer assumed that the brightness of Venus was proportional to Θ.
- Lambert's formula: $\Theta = (\sin(v) - v\cos(v)) / (\sin(v_0) - v_0\cos(v_0))$, where Θ and v are as above and $v_0$ is the phase at the time of Plummer's last observation, on 11 May 1876. As above, Plummer assumed that the brightness of Venus was proportional to Θ.
- Plummer's analysis of his observations, intended to be a comparison of the brightness of the planet with its brightness on 11 May 1876. The graph shows Plummer's individual data points together with a second degree best fit polynomial.
- A modern reworking (correction) of Plummer's analysis. Again the graph shows individual data points together with a second degree best fit polynomial.



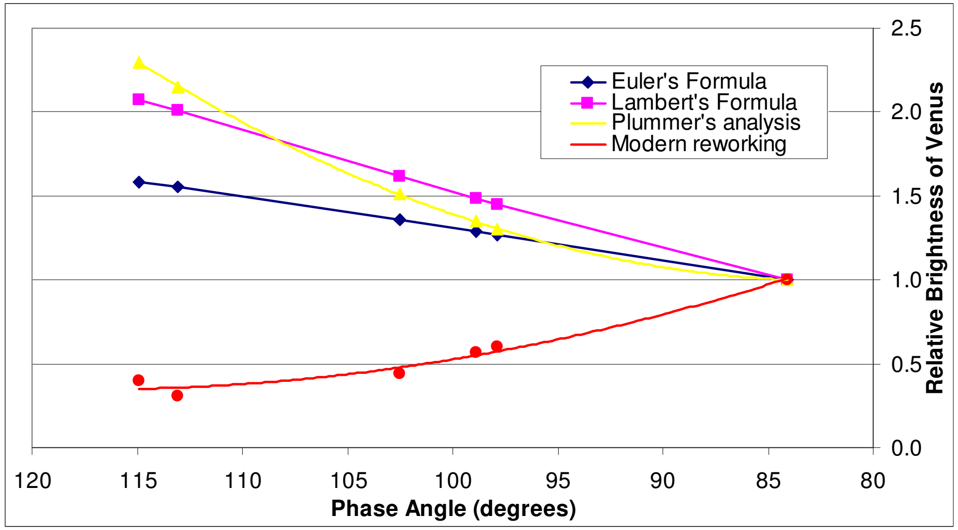



**Figure 5. Approach to maximum brightness of Venus.**

The graph shows that Euler's and Lambert's formulae are in reasonable agreement with one another and that Plummer's analysis of his measurements is broadly in line with both. Unfortunately Plummer's analysis of his data is seriously in error, as he used C, the square of the distance to the candle to represent the brightness of Venus, whereas in fact, it is the reciprocal of this quantity which represents the brightness of the planet! Unfortunately, the modern reworking of Plummer's data, adopting 1/C as the measure of brightness, shows a planetary brightness which increases as the phase decreases – clearly, not the anticipated result. Plummer also appears to have introduced some minor errors into his analysis, likely the result of excessive approximation. Thus, he estimates the ratio of the brightness of Venus at greatest brilliance to the brightness of the mean Full Moon as 0.125%; a modern reworking of his calculations using high precision arithmetic yields a ratio of 0.109%.

The modern accepted magnitudes [1989a] of Venus at greatest brilliance and the mean Full Moon are -4.7 and -12.7 respectively, giving a brilliance ratio of 0.063%, very close to the value deduced from Bond's work.

It is easy, from a modern perspective, to be critical of Plummer's mistakes in his analysis. However, as far as is known he undertook his analysis alone, with no assistant or colleagues to offer advice or to check his methodology. This plus the absence of modern computational aids must have rendered the burden of data analysis considerable, and in the circumstances it is not surprising that some mistakes occurred.

## A1.4 Conjunction Of Venus And Lambda Geminorum

In 1876 Edwin Dunkin of the ROG reported [1876e] that Dr Krüger of Helsingfors had drawn the attention of the Astronomer Royal (Sir G B Airy) to a forthcoming close approach of Venus to the star λ Geminorum (54 Geminorum) on the morning of 18 August 1876. Dunkin stated that a series of measures of the apparent distance between planet and star made in both hemispheres *would be of some importance*. He did not elaborate, but it is likely that he had in mind the use of such observations to estimate the distance from the Earth to Venus from the apparent parallax of the latter against the background of fixed stars – this in turn, through the application of Kepler's Third Law, would enable estimation of the scale of the solar system and the Astronomical Unit (AU).

In the Americas, the closest approach of Venus to λ Geminorum would occur before sunrise. In Europe, closest approach would occur after sunrise, but Dunkin hoped that astronomers with large telescopes would nevertheless be able to take measurements while the two bodies were in close proximity. To assist potential observers, Dunkin published a table showing the geocentric apparent position of the planet and star for each hour from 04:00 to 12:00 GMT on 18 August 1876.

Dunkin's paper provides an opportunity to assess he accuracy of the astronomy of the day. Dunkin's position of the star differs by only $0^s.15$ in RA and 0".11 in declination from the modern accepted position for the epoch in question [1997b]. His positions of Venus differ slightly from those given by the modern reference ephemeris DE-405 (using a value $\Delta T = -3.9s$): Dunkin's position over the period in question is on average $1^s.2$ greater in RA and 0".73 greater in declination than that of DE-405.

Figure 16 illustrates the geocentric trajectory of Venus in relation to the star during the period 04:00 – 12:00 UT on 18 August 1876 according to Dunkin. Note that the figure shows the offset of both objects from the point RA 107d 37' 45", dec 16d 43' 45" (at the bottom left of the chart).



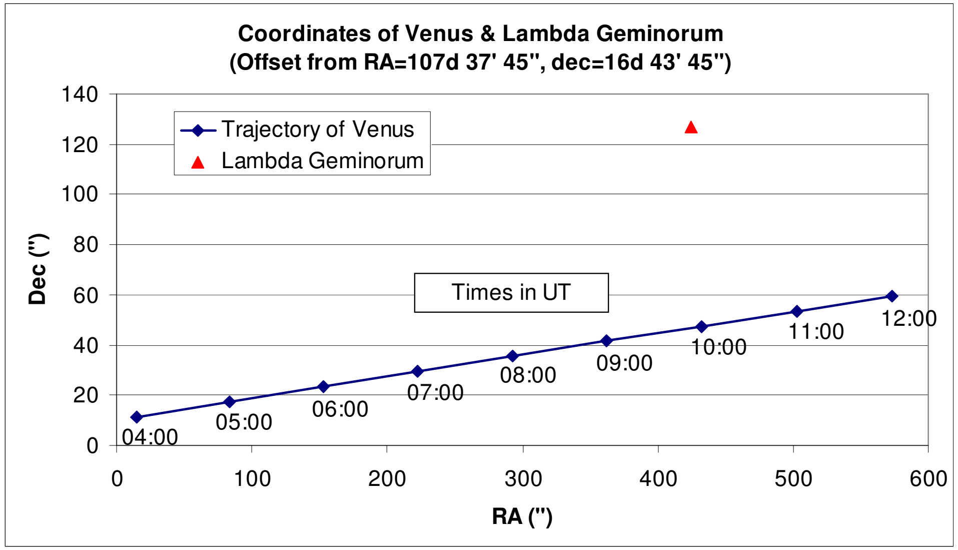



**Figure 6. Coordinates of Venus and Lambda Geminorum, 04:00 – 12:00 UT on 18 August 1876.**

Plummer responded to Dunkin's call for observations and in 1877 published [1877a] his analysis of the close approach: the publication was his last dealing with Venus. The closest approach of Venus to Lambda Geminorum as seen from Orwell Park Observatory occurred at 10:04 GMT on 18 August 1876. Plummer began his observations once Venus had attained an altitude of 20°, which it did at approximately 04:00 GMT, and continued until he was clouded out at 06:46 GMT. His results span the period 04:27:16 - 06:39:56 GMT.

Plummer used the Orwell Park Refractor and a parallel wire micrometer, with a power of 315, to measure differences in the declination of the planet and star. He had hoped to achieve an average measuring error of at most 0.1 arcseconds, but unfortunately found that sky conditions were such that both the star and planet appeared poorly defined. He accepted that because of the poor sky conditions, his measurements were not sufficiently accurate for estimation of the solar parallax, and instead he analysed his data to yield information on the irradiance of Venus. Summarising his efforts in his annual report to the RAS for 1876 [1877b], he recorded a *partial success* and stated that *some facts were elicited that have been thought of sufficient interest to merit the notice of astronomers.*

Plummer obtained and analysed his data as follows:

1. He made ten estimates of the difference in declination between the limb of Venus and Lambda Geminorum (measured in the sense limb – star). Denote the estimates $D_i$ for i=1,…,10. His estimates alternated between the North Limb (NL) and the South Limb

(SL) of Venus, so that $D_i$ for i=1,3,5,7,9 referred to the NL and $D_i$ for i=2,4,6,8,10 referred to the SL. Each estimate was based on five individual comparisons of declination made with the parallel wire micrometer. He assigned a weight (confidence factor) to each estimate based on the condition of the sky at the time.

2. He converted each of the ten estimates of the difference in declination to a difference in North Polar Distance (NPD), $N_i$, and applied a correction for atmospheric differential refraction, $R_i$, i.e. $N_i = -(D_i + R_i)$ for i=1,…,10. The maximum absolute value of $R_i$ was 0".141.
3. He used the *Nautical Almanac* to calculate theoretical estimates, $T_i$ for i=1,…,10, of the difference in NPD corresponding to each of his observational estimates. In Plummer's era there was uncertainty as to the precise value of the apparent diameter of Venus and in calculating the $T_i$ he adopted the pragmatic approach of using the value for the semidiameter of Venus which best fitted his observations, namely 8".698 at standard distance (1 AU). He stated that this value *is very slightly larger than that determined by myself with the double-image micrometer in 1873 (8".661), but is less than the well-known determination of Mr Maine*[7] *(8".775).*
4. He formed the differences $X_i$ between observational and theoretical estimates of the differences in NPD: $X_i = N_i - T_i$ for i=1,…,10. The quantities $X_i$ for i=2,4,6,8,10 and $-X_i$ for i=1,3,5,7,9 represent raw estimates of the irradiation of Venus. He stated that the probable error of an estimate *does certainly not exceed 0".21*, but that absolute values of the differences $X_1,\ldots,X_{10}$ were much larger (in fact the mean and maximum absolute values were 0".2 and 1".6 respectively).
5. He then calculated X as the weighted mean of the $X_i$ and formed the quantities $Y_i$ as follows:

$$Y_i = -(X_i - X) \text{ for } i = 1, 3, 5, 7 \text{ and } 9 \text{ (NL)},$$

$$Y_i = +(X_i - X) \text{ for } i = 2, 4, 6, 8 \text{ and } 10 \text{ (SL)}.$$

   The $Y_i$ represent the variation of irradiation about the value X. Note that the value X is not the mean value of irradiation: it is likely that Plummer intended it to be such, but he did not calculate it from the $X_i$ with appropriate regard to the sign of $X_i$ for i=1,3,5,7 and 9. The result of this was to provide a different baseline for the subsequent analysis of variability to that which would have prevailed had Plummer calculated X as the mean value of irradiation. Note also that in fact Plummer's estimate of irradiation corresponding to $Y_2$ on p.104 of [1877a] is incorrect: the figure quoted as +0".806 should read +0".826.
6. The $Y_i$ exhibited considerable variability. Plummer concluded however that they indicated a general, gradual decrease in the irradiation of Venus as the sky brightness increased and a more sudden decrease around the moment of sunrise (sunrise at Orwell Park Observatory occurred at 04:44 GMT).

[7] Plummer incorrectly spelled the surname Main with a final "e".



7. In order to make visible the trend of the $Y_i$, Plummer grouped them into three groups plus a singleton. He calculated the weighted mean of each group as follows: $W_1$ = wtd mean{$Y_1$, $Y_2$}; $W_2$ = wtd mean{$Y_3$, $Y_4$, $Y_5$}; $W_3$ = wtd mean{$Y_6$, $Y_7$, $Y_8$, $Y_9$}; $W_4 = Y_{10}$. The four values of $W_i$ represented in sequence the apparent excess of the semidiameter of Venus (due to irradiation) about the value X throughout the observing period as follows:

   $W_1$: before sunrise,

   $W_2$: after sunrise with the Sun at low altitude,

   $W_3$: Sun above the horizon haze,

   $W_4$: observing through some cirrus cloud.
8. Plummer concluded that the $W_i$ confirmed his theory that the apparent semidiameter of Venus reduced as the brightness of the sky increased and also showed that the effect of the cirrus cloud at the end of his observations was to diminish significantly the apparent planetary semidiameter. His analysis also showed that the irradiation of the planet varied significantly on a timescale of minutes.

Plummer provided a tabulation of several of the steps in his data reduction and it has been possible to confirm and rework his analysis. Figure 17 illustrates his estimates of the apparent difference in declination between the limb of Venus and Lambda Geminorum (the $D_i$ for i=1,…,10). It also shows an estimate of the apparent semidiameter of the planet, calculated from the difference between linear regression lines fitted to Plummer's estimates of the differences in declination. For comparison, the figure shows also the apparent semidiameter of the planet calculated using the ephemeris DE-405 (the value is almost constant at 19".2 over the period in question).

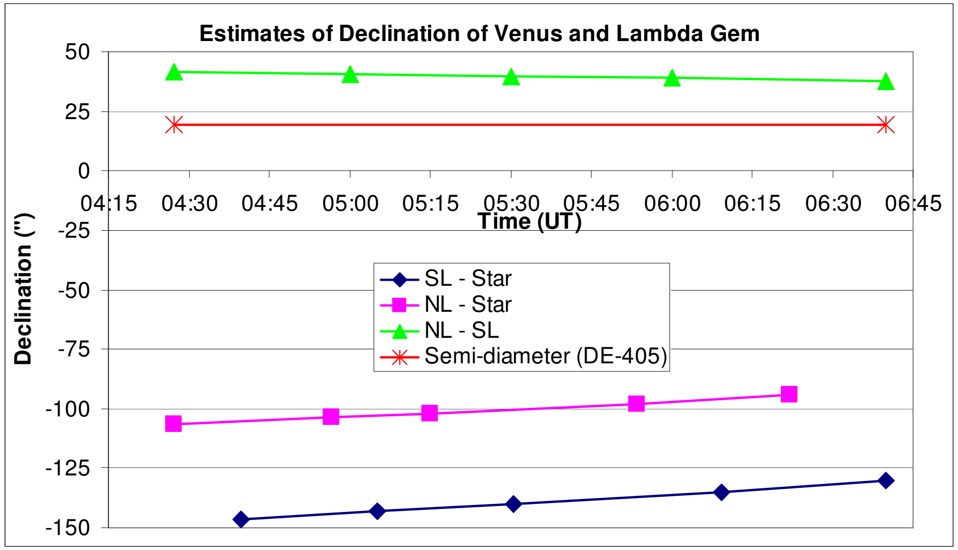



**Figure 7. Declination estimates of Venus and Lambda Geminorum.**

It is possible to recreate the numerical calculations in Plummer's data reduction to a close approximation (maximum absolute discrepancy in value of any $W_i$<9%) by the following approach:

- Employ the modern reference ephemeris DE-405 with ΔT=-3.9s to provide the coordinates of Venus.
- Apply a position offset of +0".75 to the declination of Venus calculated using DE-405. This figure is the average offset in declination between the positions calculated from the *Nautical Almanac* quoted by Plummer[8] and those given by DE-405 during the period in question.
- Adopt Plummer's assumed values for the semidiameter of Venus.

This gives confidence that Plummer indeed adopted the technique that he described, without any significant undocumented additions. With confidence thus obtained that Plummer's data reduction was as he described it, it is possible to rework his analysis correcting the apparent error in the value of X (calculating X as the mean value of irradiation, which is likely what Plummer intended). Figure 18 illustrates Plummer's estimates of the irradiation of Venus and the results of a modern reworking. It shows the following:

[8] Plummer adopted the same declination for Lambda Geminorum as Dunkin [1876e], namely +16° 45' 51".84.



$Y_i$ Plummer's estimate of the variation of irradiation around the value X (=0".27).

$W_i$ Plummer's estimate of the smoothed variation, calculated as the weighted average of the $Y_i$ as described above.

$W'_i$ modern recalculation of the $W_i$. Bases the declination of Venus on the ephemeris DE-405 with ΔT=-3.9s and an offset of +0".75 (to match approximately the positions employed by Plummer from the *Nautical Almanac*). Calculates X (0".81) as the mean value of irradiation (with correct interpretation of sign of the $X_i$). This is an approximation to the result that Plummer likely intended to produce.

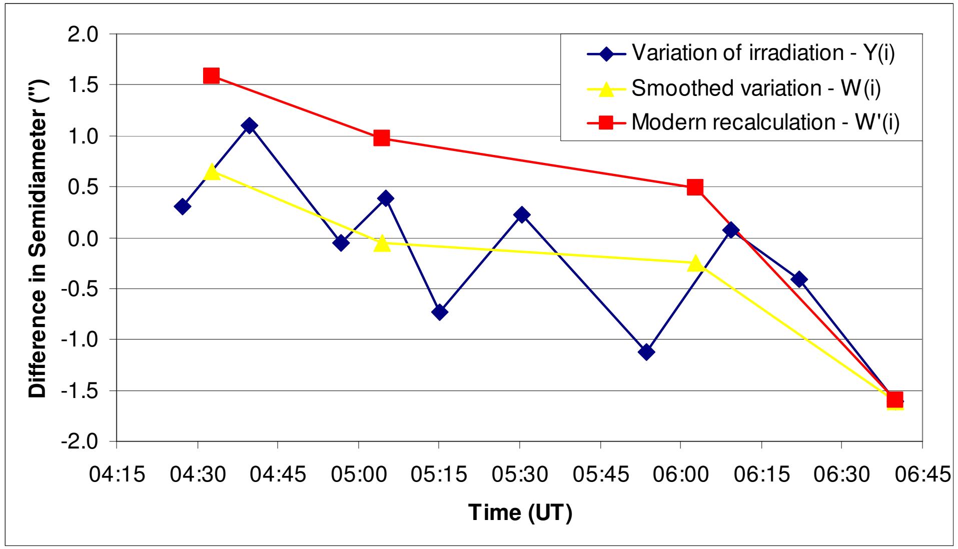



**Figure 8. Estimates of irradiation of Venus.**

The figure confirms Plummer's conclusion that the empirical semidiameter of Venus decreased as the sky brightness increased, that the effect of the cirrus cloud at the end of the observation period was to decrease significantly the irradiation of the planet and that irradiation can alter markedly over a period significantly less than one day in duration. In fact, it exhibits an even more marked alteration than Plummer found in the effect of irradiation due to the onset of cirrus cloud.

--- To be continued ---