The Newsletter
of the
Orwell Astronomical Society (Ipswich)

Registered charity No 271313
www.oasi.org.uk

2008 October No 434

Total Eclipse 2008 August 1st

OASI Treasurer, Paul Whiting travelled to Sosnovka, near Novosibirsk in Sibera and was rewarded with an excellent view of the event.

He obtained the above image by stacking around 1000 video frames.

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
FAS Cambridge Convention	Institute of Astronomy, Cambridge Doors open 00:90 Entrance £8	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
Astronomy Workshop Sperm Whales, Candles and the Planet Venus Presented by James Appleton	Nacton Village Hall	Wednesday 3rd December Starts At 19:45
Geminid Meteor watch	The "Dip" Felixstowe	Saturday 13th December
Christmas Meal **Note change of date** **The general consensus was to return to the venue we used last year**	**Peak Lodge** **Suffolk Ski Centre** **Bourne Hill** **Wherstead**	**Thursday 11th December** **20:00 start.**

3 Access into the School Grounds and Observatory Tower

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

4 Welcome to New Members

John Fisher
Trevor Boyd

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 t Police Station, if you are arriving from Civic Drive. The church car park is on the right, ji past the Black Horse pub.

Meetings start at 20:00 doors open at 19:3

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 year there ar 4 or 5 committee meetings

Night Sky (October)

All times BST

Moon

1st Quarter	Full Moon	3rd Quarter	New Moon
7th	14th	21st	28th

Object	Date	Times		Mag.	Notes
		Rise	Set		
Sun	1	07:06	18:41		
	31	07:58	17:37		
Mercury	1	08:25	18:36		Inferior conjunction is on the 6th
	31	06:26	17:19		
Venus	1	10:03	19:33	-3.8	Venus will low down in the western sky after sunset this month
	31	11:36	19:03		
Mars	1	08:59	19:15	1.6	Mars is to close to the Sun this month to be observed
	31	09:00	17:57		
Jupiter	1	15:28	23:11	-2.2	Jupiter is in Sagittarius. It remains very low down on the southern sky, making it difficult to observe without a good southern horizon
	31	13:42	21:30		
Saturn	1	04:50	23:11	1.0	Saturn is still in Leo. It is well placed to observer before sunrise
	31	03:11	16:20		
Uranus	1	18:06	05:27	5.8	Uranus is in Aquarius
	31	16:07	03:24		
Neptune	1	17:12	02:47	7.8	Neptune is in Capricornus
	31	15:14	00:47		

Meteor Showers

Shower	Maximum	Limits	ZHR
Piscids	Sept. 8th Sept. 21st Oct. 13th	Sept. to Oct.	10 5 ?
Orionids	Oct. 20th	Oct. 16th to 27th	25

Meteor source is the BAA Handbook

OCCULTATIONS DURING OCTOBER

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
08 Oct	19:54:04	D	0.64+	-25	15	5.9	4 Cap
09 Oct	20:02:51	D	0.73+	-26	20	6.2	ZC 3086
11 Oct	18:56:37	D	0.89+	-17	24	6.4	67 Aqr
22 Oct	04:53:18	D	0.42-	-16	51	3.9	delta Cnc

James Appleton

Astronomy Workshops

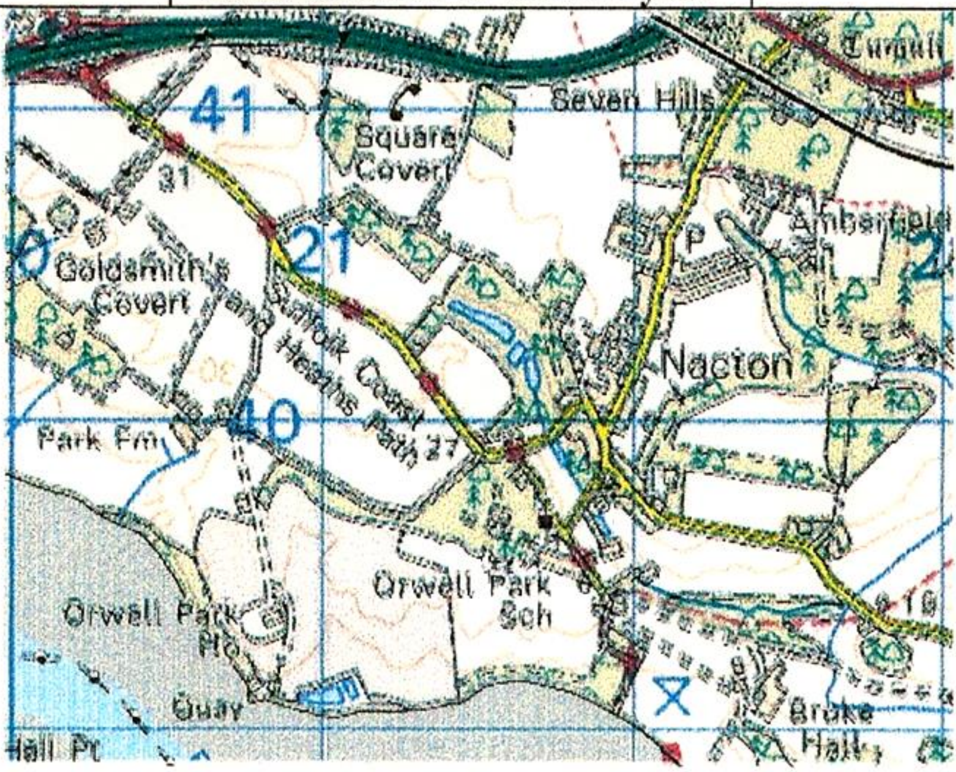
Workshops run on the first or second Wednesday of the month, starting at 7:45pm. (Doors open around 7:30).

Venue: NACTON VILLAGE HALL (next door to the small village school, just to the left of the N in Nacton on the map)

Every Autumn/Winter we run a series of monthly 'workshops', led run by society members who have volunteered to prepare material for them. They cover a wide range of topics - hopefully of interest to amateur astronomers! The current venue is very comfortable and makes for a good informal social gathering as much as a workshop – tea, coffee and biscuits available! If you have any suggestions for topics you'd like to see covered, or even better are prepared to run one yourself, then let me know. No previous experience required!

Mike Whybray [redacted] (Mobile) [redacted] (Home)

Date	Event	Run by...
8th October 08	**The history of the telescope**	Paul Whiting
November	**No workshop** as the only available date is 5th November, on which I expect many people could be at bonfire night events	
3rd December 08	**Of Sperm Whales, Candles and Planet Venus** An investigation of John Isaac Plummer's 1876 estimation of the brightness of Venus.	James Appleton
	More to follow in the new year	



International Year of Astronomy 2009

OASI Logo Merchandise

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

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

www.sharpstitch.co.uk/catalogue.php

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

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

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

THE UNIVERSE
YOURS TO DISCOVER
ASTRONOMY
2009

Orwell Astronomical Society

Pete and I would just like to thank everybody for picture and card. We had no idea that, when admiring a picture at Martin's house, we were giving people and idea for a wedding present. It was very kind of you all. We had a 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.

We had a fantastic day and really good fun. The weather was interesting in that in the ten minutes in the ten minutes it took me to travel from the hotel to the church it blew up a hooley By the time we left the church there was a definite gale blowing but we did manage to get a few photographs done outside of the church before the rain set in. We then adjourned to the village hall, a little earlier than expected.

From then on it was eat drink and party. We had a fantastic barn dance play for us which gave everybody a good laugh, both those participating and those watching. We didn't stop until the car came to take us back to the hotel, exhausted but very happy.

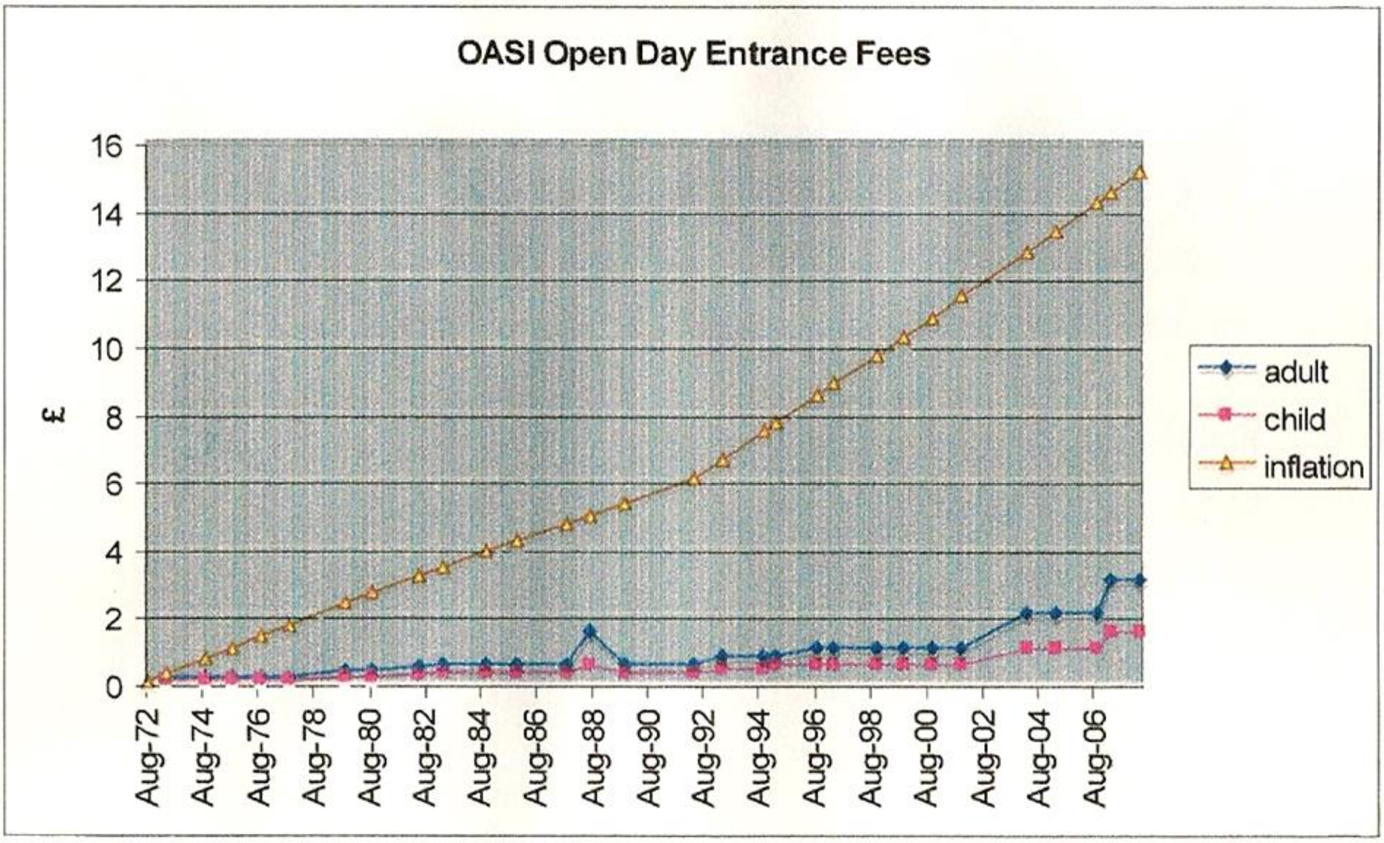
Nicky

Musings from the Treasurer

On a particularly boring train journey, I looked through the archives of the previous OASI Open Days, in particular the cost of admission as shown on the advertising flyers. I also started musing about how these admission prices had kept up with inflation (or not).

So the mathematician in me came to the fore. Here is a graph of Open Day admission prices for adults and children and how inflation (based on annual RPI index published by HMG) would have affected the first Open Day costs.

Something to think about methinks.



The blip in 1988 included a full day of talks. Perhaps a modest rise to £4 and £2 may be in order for the IYA Open Weekends next year?

Paul.

The Siberian Eclipse
(or 140 go mad in Russia)

Paul Whiting *FRAS*

A chance to ride on the Trans-Siberian Express as a means to view the eclipse was not to be missed, so six OASI members plus 3 other friends and partners set off early on Monday 28th July from the notorious Heathrow Terminal 5, not expecting to see our luggage again. However we were delighted to be re-united with it again in Moscow five hours later. Queues seem to be the order of the day in Russia – orderly queues by the Brits and scrummages by the rest! Passports, visas, entry forms and customs declarations later, we got into the airport arrivals hall. There we stayed for over an hour - someone had lost a case in the airport. We then split into two coaches – one for couples and one for singles – an odd split but hey. The first coach set off – followed 90 minutes later by the second. The first coach used the Moscow orbital motorway (Mski 25 ?) and was never seen again – at least not for 3 hours. The second coach went through the city centre and saw the sights, but still took several hours to cover the relatively short journey to the hotel. [note: despite not travelling with Ryanair, we still ended up miles outside Moscow on the wrong side from the hotel] Finally we settled down to a fine buffet dinner at the Aerostar Hotel. Overall the meals in Russia were of a very high standard, but got very repetitive for the vegetarians amongst us.

The second day involved a tour of Moscow – especially the Kremlin and its constituent churches. Unfortunately Red Square was closed off as there was a civic send-off for the Russian Olympic team. Later, on the way to pick up the train, our coach was pulled over by the police to allow Russian President Medvedev and his cavalcade to pass at very high speed.

Finally we reached the train that was to become our home for the next six days. Fourteen carriages consisting of eight first class sleeping cars, one premium sleeping car (with wash basin), two restaurant cars, one bar/function car and a shower car. There was also a staff accommodation car. Over the six days we were to travel over 5000 kilometres from Moscow to Irkutsk, via the eclipse site at Novosibirsk, crossing the Urals from Europe to Asia.

The average day on board consisted of reveille at 7am, breakfast between 7 & 9am, train pulling into stopping station around 10-12, tour round city until 5pm and then back to the train for dinner (in 2 sittings) between 6 & 8pm. The dulcet tones of our German train Manager, Angelika, kept us informed of what was happening and when. As already mentioned, the food was quite good. Salad, garlic and curried carrots, spiced aubergine, lumps of meat (various) and potatoes kept cropping up on the menu, both on the train and elsewhere. Occasional treats of hors d'ouvres such as caviar and olives also appeared. Having said all this, breakfast was a law unto itself. Hard boiled egg, porridge (if you were lucky), cheese/ham/salami (2 small slices of each), fruit, yogurt, chocolate éclairs, sweet cakes, butter ("only for breakfast"), white and black bread, juice ("apple or peach") and tea or coffee (allegedly) all or some served in random order by two very hard working waitresses. One of these resembled Pat Butcher from EastEnders and the other a young graduate in railway engineering working during her final vacation. There were other waitresses, but as we were constrained to the same dining car, I didn't get to meet the others.

We were in coach 1. Dinner was in coach 6. This meant that 30 doors had to be opened and closed from our coach to our dining car. All the other of the Suffolk contingent, I believe, had far fewer. This became the common unit of distance on the train. The bar was 42 doors away and the shower car 48 doors. The shower car was something else. Eight double showers with water that ran out often (despite being re-filled at least twice a day), that usually ran cold (they needed 90 minutes to heat

Continued on page 11

up after a refill) and that usually dribbled out of the tap. But the shower gel and shampoo was provided!

First stop was Kazan, the Gateway to Siberia and the capital of Tartarstan (= Moscow time). A quick tour here – a river trip round a garbage scowl and the sights of several power stations and back ashore to visit a rather beautiful mosque we had just seen from the boat. The city itself was of two halves – old and rundown and a new, renovated sector. State funding was slowly rolling out to Siberia, but tourism was also helping.

Second stop Yekaterinburg (Moscow time +2 hrs) and a visit to the church, which marks the site of where the last Romanov Tsar and his family were killed in 1918. The Russian Orthodox church has been built in their honour, despite their remains being buried in St. Petersburg. It was here the wife of one of our members (mentioning no names) lit a candle to ask for a clear sky for the eclipse the next day. The day ended as usual with an overcast downpour, followed by clear sunny weather.

After our tour, back on the train, our expert Dr Peter Cattermole presented a couple of lectures on what to do at the eclipse one for novices and one for "experts", although they were virtually the same talk! Being a geologist, Peter had presented a talk on the geology of the Ural mountains the day before.

I should point out at this point only about 30% of the train were eclipse chasers, the rest were holiday makers who mostly thought that the eclipse was a gross inconvenience to their train trip. For example one comment overheard – "If I wanted to sit in a muddy field all day in the dark, I could sit in my garden at midnight".

Third stop Novosibirsk (Moscow time + 3 hrs) – the day of the eclipse. The day started out OK – partly cloudy and some sun. A quick breakfast and we were on our designated coaches (4 in total, 3 of us plus a coach full of Danes who had joined our train at Moscow).

First we enjoyed a visit to a geology museum, which was excellent, including a large exhibit of meteorites. However the group I was in overran and so we didn't get to visit the train museum that everyone else enjoyed. We were given the opportunity to take photographs through the locked gates in the darkness much later in the day (wow!). After lunch we all headed to the eclipse site – fair drive out of Novosibirsk, in a village called Sosnovka on Lake Ob. The weather was good – some high cloud that should dissipate, however a lot of rain bearing cumulus suddenly appeared rapidly spreading in from the north-east. This was just as the pattern of the previous few days had promised. The chances of seeing all of the eclipse were dropping rapidly. It was at this point that our coach caught fire – or at least smoke from a burnt out air-conditioning unit flooded into the coach, necessitating a mass evacuation. We were supposed to be awaiting a fleet of smaller minibuses to take us beyond where normal coaches couldn't pass, but of course there was no sign. The eclipse and the cloud drew nearer.

Peter Cattermole suggested that we should set up on the dirt road we were on, given we were only about 5 km from where we were supposed to be. However the minibuses eventually turned up, and the "experts" who needed time to set up their kit were invited to travel on first. The holiday makers would (perhaps) follow on. Luckily they did, the coach with the faulty a/c was still able to go on, despite now being a mobile sauna.

After a lot of driving around woods and fields trying to locate our advanced party, we arrived at the observation site – a field with low grass abutting Lake Ob. There was quite an on-shore breeze, with waves lashing the shingle beach, spray blowing onto our equipment (I knew that plastic bag would come in handy). The wind even blew my tripod over – I thought my video camera lenses were broken, but luckily the UV filter had acted as a sort of break fuse and no harm was done. But what of the cloud? It just disappeared – we had a virtually cloudless sky for the whole eclipse. The lighting of the candle at Yekaterinburg had worked – memo for next time. There were a lot of local people at the eclipse site, one person even had a telescope with a solar filter, but given the TAL telescope factory is in Novosibirsk I'm surprised there were not more about. There was even a cow. We came up with the idea of studying the effects of the eclipse on its behaviour. Perhaps it would lie down or walk off to be milked or something, but unfortunately the farmer came to collect it an hour before the eclipse!

So what of the eclipse. A wonderful 2 minutes and 20 seconds of totality, with the whole eclipse from 1st contact to 4th contact being cloud free. A standard solar minimum corona (round, regular and tight-in) with some linear streamers. No shadow bands were seen before or after. Two planets became visible (Mercury and Venus) out of the four possible that formed a nice little line close to the sun (the other two being Saturn and Mars).

A number of us bumped in to two of the three most successful eclipse chasers alive today. All of these guys have been under 27 total or annular eclipses. John Beattie (25 clear) and Jay Pasachoff (26 clear) were at Novosibirsk. John actually came up to have a look at the solarscope I was using to project the sun's image.

And so on to dinner back in Novosibirsk and back to the train and bar for the post eclipse celebration, and a sore head for some the next day.

Another hour forward and the next day we headed for fourth stop Krasnoyarsk (Moscow time +4 hrs). But before we arrived, Pieter Morpurgo (a former producer of the Sky at Night programme) treated us to a talk of anecdotes of working with Patrick Moore on programme assignments around the world. When we eventually started our town tour - another Kremlin, more domed churches, more statues of Lenin, more impressive railway stations (not that I was getting a bit jaded by this time), we were destined for a 45 minute cruise on the River Yenisseij. The first group set off and didn't come back – they broke down. Their cruise turned into a 90 minute ride of about 400 metres. We in the second group were very uncertain whether we should have a go, despite assurances that the boat was now repaired. In the end we did and spent 45 minutes 100 metres off the pier keeping pace with the fast flowing tide, just in case ! Then back to the train and bar.

The final train destination was Irkutsk (Moscow time +5hrs). After a final breakfast and another "tipping everybody that moved" session, we disembarked for the final time. It rained. We got wet, our bags (which went on before us) got wet. Our day long coach tour of the city was a waste of time given that the windows were steamed up and it was raining so fast you couldn't see much anyway. The local tour guide (the best English speaker to date) was quite intrepid. We had paid for multiple walks around and so, deluge or not, we were going to have these walks around. Some of us stood (or rather sat) firm in the dry, but others went on to take more photos of domed churches, statues of Lenin and another impressive railway station. Eventually they allowed us in to the former state controlled "InTourist" hotel, which had apparently been recently renovated. On our floor that meant putting new carpet over broken tiles or cobbles that cracked as you walked over them. A woman sat at a desk by the lift on each floor, to whom keys should be given when leaving the hotel, from whom water and other goodies could be purchased and through whom telephone calls could be made. At least the water purchase option worked OK.

The rooms here were OK, but you definitely had the feeling of microphones being present in the lampshades. The pillows were lumpy too ! However the great redeeming feature was the London Bar, where copious quantities of London Stout and Newcastle Brown were consumed. There was even a miniature red telephone box.

The second day at Irkutsk was spent in a coach ride to the shores of Lake Baikal and a nice little village consisting mainly of dachas or holiday homes for the folk of Irkutsk. Here we had time to chill and shop at the market. Hah. The market consisted of a house clearance table, twenty identical tables of the local tourist tat (animals made from the local mineral, stackable dolls etc) and a bar full of locals that stared at you if you dared to look in. We did, however, find a relatively pleasant little café to while away our free time here.

Legend had it that anyone who bathes in the water of Lake Baikal will look 10 years younger; I can tell you from experience it doesn't work.

On the way home to Irkutsk we stopped for a badly kept secret folklore evening – a dinner interspersed with local singers and dancers. I hate these sorts of things – I usually get dragged out to join in, but I must admit these guys were quite good and it was not all too embarrassing. The restaurant was in the middle of a muddy, wooded trail and small zoological garden, although they only appeared to have a couple of deer. One local told me that they had had a wild bear there a few weeks before but it had gone away. On the way back along the muddy trail to the coaches four of us spotted an easier method of transport – a Russian Troika or 3 horse pulled cart – great fun.

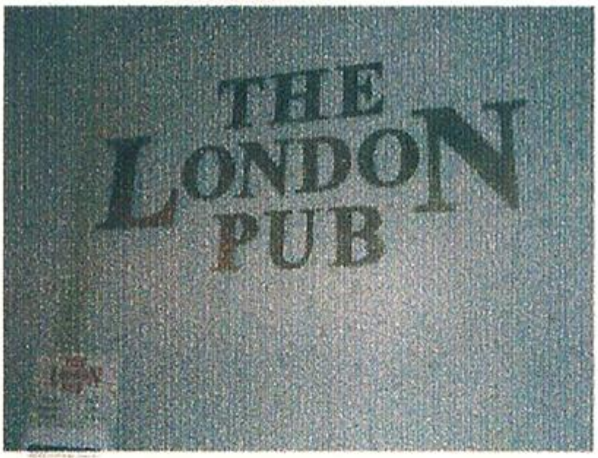
The next morning saw our long trek home. Firstly on a chartered Caucasus Mineral Water Airways flight (Mineral Water is actually a place in the Caucasus). This flight was late arriving (bearing in mind it brought our tickets with it) so no panic here then about missing the connecting flight back from Moscow to London. Our dinner and city tour around Moscow were cancelled, not with too much regret as the so called snack on each flight was very filling. I also found time to sample some Turkmenistan dumplings and some caviar sushi at Moscow Airport.

A long day later (we started at 6 am (10pm BST); we arrived at Heathrow at 6pm (BST) after 20 hours of travelling. We then had to get home, which added another 3 or 4 hours on the day. At least the baggage didn't get lost anywhere along the way.

I haven't made reference to the public toilets in Russia, quite deliberately – I'm trying to forget.



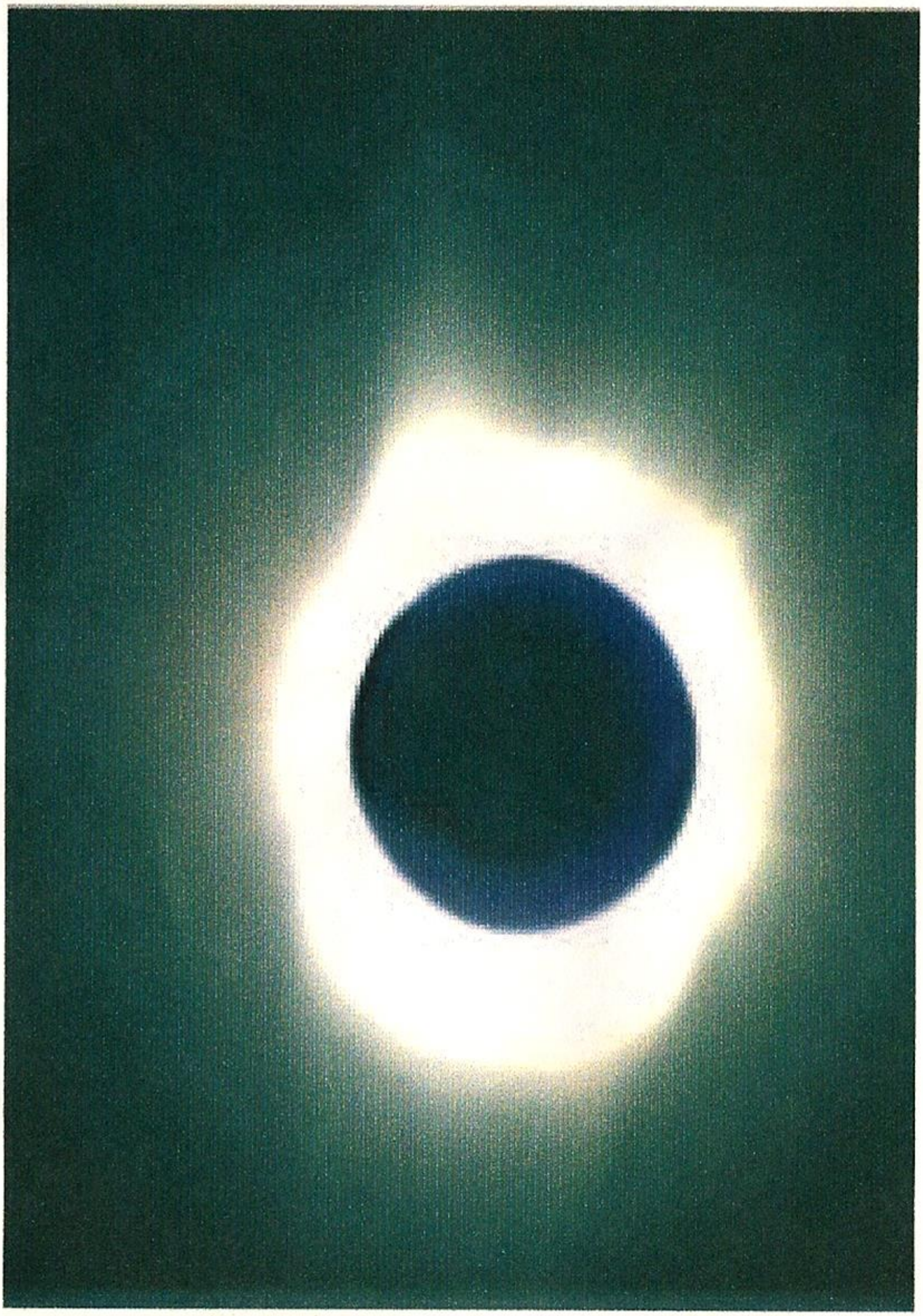


(a) The cow; (b) first contact; (c) the hat; (d) the honeymoon couple; (e) the onion domes in Moscow; (f) The London Pub in Irkutsk

The Trans Siberian Express train - our home for 6 days.


Venus and Mercury become visible during the eclipse.



OASI Committee Contacts & Responsibities

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

- Monday October 26th - Sunday November 1st - **Jupiter Week**

IYA 2009 – ADVANCE DATES NOTICE

- Monday March 30th - Sunday April 5th - **Saturn Week**
- Monday July 20th - Sunday July 26th - **Moon Week**

Diary for October

Monday **6th and 20th**	**<u>SMALL TELESCOPES OBSERVING NIGHTS</u>** Main Observational targets: Constellations Lyra & Cygnus ☎ Paddy O'Sullivan [redacted] ☎ Gerry Pilling [redacted]
Wednesdays **From 8PM**	**<u>MAIN OBSERVATORY CLUB NIGHTS</u>** Primary Observational targets: Nebulae and faint objects. ☎ Martin Cook [redacted] (mobile) [redacted] ☎ Roy Gooding [redacted] (mobile) [redacted]
Wednesday 8th **From 7.45pm** **Nacton Village Hall**	**<u>WORKSHOP MEETING</u>** ***'The History of the Telescope'*** Presented by Paul Whiting FRAS ☎ Mike Whybray [redacted]
Thursdays **From 7.30pm** • **2nd** • **9th** • **16th** • **23rd** • **30th**	**<u>OBSERVATORY VISITS BY LOCAL COMMUNITY GROUPS</u>** 42nd Ipswich Brownies Private visitor party 12th Ipswich Boys Brigade Belstead Townswomen's Guild Badingham WI ☎ Paul Whiting FRAS [redacted]
Friday 24th **8PM** **Methodist Church Hall** **Blackhorse Lane** **Ipswich**	**<u>OASI LECTURE MEETING</u>** ***'To Infinity and Beyond – Postcards of Astro Discovery'*** Presented by Andy Green, Director of StarDome Astronomy and Astronautics. ☎ 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

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 6

A1 Aurorae

Plummer published three very different papers on aurorae.

His first paper on the subject [1869e], written and published in 1869 while he was an assistant at Durham Observatory, dealt with the use of a spectroscope to examine the light of the aurora. In fact, Plummer wrote the paper in two parts, the first part written on 06 April 1869 following spectroscopic observation of an aurora and the second part written on 17 May 1869 following correspondence with Mr Huggins and observation of the spectrum of a second aurora. The Mr Huggins who corresponded with Plummer was one of the pioneers of astronomical spectroscopy, namely William Huggins (1824 – 1910). Huggins constructed specialist instruments and obtained the spectra of stars and nebulae. He was knighted in 1897 in recognition of his work and a 65km diameter lunar crater is named in honour of him. Huggins informed Plummer that Angström and Struve (generally regarded as the pioneers in the field) undertook similar work to Plummer in winter 1867-68. However, Plummer was unaware of this.

Plummer described in [1869e] how soon after midnight on 02 April 1869, he witnessed *a very fine aurora* from Durham. Visually, the aurora appeared *white, perhaps slightly bluish, and not of the more common ruddy hue; there were few or no rays, but broad sheets or waves of light succeeded each other rapidly, proceeding from the arch to a height of about 30° from the horizon*. Plummer observed the aurora with a spectroscope, and found that the spectrum consisted of a single bright (emission) line, sometimes hazy and sometimes well-defined. At the brightest part of the auroral arch the line was similar in intensity to the most conspicuous line in the Orion Nebula. Plummer had difficulty measuring the position of the line accurately, but was reasonably confident that it did not coincide with any of the main lines in the spectrum of the Sun or of the Earth's atmosphere, and instead was in a similar position to the more conspicuous lines in the spectra of Aldebaran and Betelguese. (Plummer had measured the spectrum of Betelguese twice in February 1869 and the solar spectrum in March 1868.)

Plummer confirmed his observations on a second aurora on 13 May 1869. He described the second aurora as of *surpassing magnificence* and stated that *a corona was formed, and every part of the sky for a short time was filled with streamers*. A white arch formed after the corona and arch disappeared. Some of the streamers were of a deep red colour, and Plummer found them to exhibit a single bright spectral emission line, coincident with that of the white arch. (In fact, Plummer's several measures of the position of the line were not precisely the same, but they were within the level of measurement error that he reported on 02 April.) Plummer saw no other spectral lines in the aurora that night.

Plummer noted that the matter of the aurora must be extremely tenuous, as he was able to observe Winnecke's Comet (C/1868 L1) using the 165 mm (6.5") refractor of Durham University through one of the densest streamers of the aurora with the only inconvenience being a bright field of view.

A modern physical description of the aurora provides an easy identification of the auroral spectral line seen by Plummer. An aurora forms when electrons emitted by the Sun collide with atoms in the Earth's upper atmosphere, typically at an altitude of 80 – 150 km, to produce light. The spectrum of an aurora is usually dominated by emission lines of atomic oxygen[1]: a greenish line at 557.9 nm and a dark red line at 630.0 nm. Plummer noted that the line which he observed was similar to the more conspicuous lines in the spectra of the red giant stars Aldebaran and Betelguese (spectral classes respectively K5 and M2), so it is likely to have been the 630.0 nm red emission line of oxygen.

Plummer expressed his measurements of spectral lines in terms of revolutions of a spectroscope screw, a measure that is unique to the spectroscope in question. However, comparison with spectra obtained from other spectroscopes was possible by reference to the position of standard lines in the solar spectrum or a terrestrial reference light source. As a matter of good technique, Plummer noted that on each occasion when he measured a spectrum he calibrated his measurements by reference to a sodium flame at the start and end of his observations – this ensured that all his measurements were consistent and comparable.

Plummer's observation of the spectrum of the aurora was innovative. He was unaware of the similar pioneering work undertaken slightly over a year earlier by Angström and Struve. Plummer did not publish any further papers concerning spectroscopic observations. In his first paper published after he moved to Orwell Park [1874d] he stated that *Colonel Tomline's Observatory will be furnished with spectroscopic appliances before the next apparition of the zodiacal light* and he looked forward to using the appliances. However it appears that the equipment was in fact not provided, as Plummer made no subsequent reference to it.

Plummer wrote his second paper on aurorae, while at Durham Observatory, in response to a report by Captain S P Oliver [1874a] in the 19 February 1874 edition of *Nature*. Oliver, writing from Buncrana, County Donegal, reported seeing in the sky on 05 February 1874 a *luminous meteor cloud* which he described as *a broad band of silvery white and luminous cloud extending in an arc from SE by E to NW by W, from horizon to horizon, but tapering at the extremities*. The band passed 3° - 4° above the upper stars of Orion. Oliver stated that stars shone brightly through the cloud, and that the edges of the cloud were well defined. Oliver noticed several meteors during the evening, one of which appeared to

---

[1] In fact, oxygen atoms in the lower atmosphere are combined as molecules of O_2 and scientists did not identify atomic oxygen as such until 1925.

come from the SE edge of the cloud – this may be what led him to describe the phenomenon as a *luminous meteor cloud*.

Plummer, clearly anxious to dispel Oliver's misconception as to the nature of what he had witnessed, responded in the following week's edition of *Nature* [1874b]. He had observed the phenomenon from Durham, and reported to *Nature* that in fact it was an auroral arch rather than a *luminous meteor cloud*. He reported that the arch was visible for half an hour, crossed Ursa Major, and drifted southward before disappearing, and that it was visible in the sky at the same time as an "ordinary" aurora, the two jointly presenting two parallel bands of light. Plummer stated that he had observed several auroral arches, and that the phenomenon of 05 February was the brightest and most complete example which he had ever seen.

Plummer noted that the night was *remarkably clear* and that the zodiacal light was *plainly visible earlier in the evening*. Few if any modern observers have witnessed the zodiacal light from the UK, and Plummer's description of it as *plainly visible* clearly highlights the detrimental effects of modern day light pollution!

Plummer contributed his final publication on aurorae [1880e], while he was at Orwell Park Observatory, in response to a work *Aurorae and Their Spectra* by Mr Rand Capron[2]. Plummer considered that there was less uncertainty about the height of the aurora than was generally supposed, and he described two methods for practical estimation of their height.

The first method relied on measuring the altitude and amplitude of auroral arches and assuming that each arch was a circle centred on the magnetic pole. This method gave a wide range of results, probably because not all arches were centred exactly on the magnetic pole. However, the method was thought to give good results on average, especially if doubtful cases were excluded. The method yielded an average height of approximately 160 km (100 miles) for the ordinary, white auroral arch which forms some 95% of auroral phenomena visible in the UK.

The second method relied on the application of trigonometry to observations of aurorae made at two or more separate observing stations. This method had been used in the UK since 1843, and gave a height of 110 – 120 km (70-74 miles) for the aurora. Plummer stated that the method was capable of producing estimates within 1.5-3 km (1-2 miles) of the true value.

Plummer expressed doubts that auroral arches formed at altitudes below approximately 110km (70 miles). He dismissed reports of low-altitude aurorae (at elevations comparable with those of natural objects) as not being based on accurate measurements. However, he accepted that streamers at right angles to an auroral arch might reach to greater or lesser heights than the arch itself.

By way of comparison, modern estimates put the height of aurorae in excess of 100km (e.g. [1989a] 1994a]).

---

[2] It has as yet proved impossible to obtain a copy of Capron's work.

Plummer reported witnessing three auroral arches during 10 years of observing, although none from Orwell Park due to its southerly location.

As a footnote, Plummer indicated that he was quoting from memory the figures of 110 - 120 km (70-74 miles) as the height of the aurora estimated by trigonometric means, as he had *no library at hand to which to refer*. One may detect a critical tone in this statement. Yet in 1875, only five years earlier, Professor J C Adams had placed the library of Cambridge Observatory at Plummer's disposal (see section 2) – it is not clear what happened in the intervening period: did Adams' offer lapse, or was Plummer unable to travel to Cambridge to use the library? At present the answer is not clear.

A2 Plummer’s Textbook

In 1873 Plummer published a textbook [1873a] entitled *Introduction to Astronomy*. The publisher was William Collins, Sons & Company, Limited of London and Glasgow. The subtitle of the work, *For the Use of Science Classes and Elementary and Middle Class Schools*, indicated its intended readership. In the preface, Plummer expanded on the aim of the book and its intended readership, arguing that astronomy was not taught in the UK to the same extent as on the Continent and in America, and that this was in part due to the lack of suitable inexpensive school textbooks (which he intended his textbook to remedy). Plummer set out lofty aims for the textbook: he aimed to *imbue the youthful mind with a love for science in its true aspect* and hoped that the text would *lead some to seek for deeper knowledge in other more advanced works*.

Plummer’s book naturally reflected the era in which it was written. Compared with modern times, astronomers of Plummer’s era had a very limited understanding of the mechanisms of the universe. Thus the textbook emphasised the description of objects and phenomena rather than explaning the mechanisms involved. For example, Plummer provided a good observational description of the Sun, but could offer no explanation for its energy output and its longevity; by contrast modern astronomical textbooks, even at an introductory level, generally provide some explanation of the physics of the Sun. The exception to this approach was the universal law of gravitation, which astronomers had developed to a high degree by Plummer’s era. Plummer provided a comprehensive description of how gravity governs the motions of double stars and bodies in the Solar System.

The majority of the textbook dealt with the Solar System; in fact only the final chapter covered the universe outside the Solar System. In Plummer’s era, astronomers knew well the scale of the Solar System but had little knowledge of the bodies which it comprised and the forces which shaped it. Plummer and his contemporaries understood the Solar System to comprise the eight major planets and their brighter moons, 125 known asteroids (with more discoveries anticipated), comets and meteor streams. They knew almost nothing of the composition or characteristics of the bodies of the Solar System. The discovery of Pluto lay almost 60 years in the future and the Oort cloud and Kuiper belt objects were unsuspected. They did not appreciate the key role that phenomena such as gravitational resonances, magnetic fields and the solar wind play in shaping the structure of the Solar System.

Astronomers of Plummer’s era had a very poor understanding of the large-scale features and structure of the universe. Although they were aware that the Solar System was located within a vast lenticular system of stars (the Milky Way or galaxy), they were unaware that many of the nebulae visible in their telescopes were in fact similar vast galaxies of stars at distances of tens of millions of light years. Although some astronomers speculated that some of the nebulae might lie outside the Milky Way, the consensus view was that the bulk of the universe was in fact contained within the Milky Way.

Plummer’s textbook lacks the colour prints that adorn modern textbooks on astronomy. The science of photography was still young, and colour photography had not been invented. However Plummer clearly shared the Victorian love of geometrical figures and his descriptions make considerable use of them. Reinforcing the target readership of the textbook, Plummer provided a comprehensive set of questions at the end of each chapter to enable the student to reinforce his knowledge.

The remainder of this Appendix summarises the main themes of Plummer's textbook and compares the ideas of the time with modern astronomical thinking. Note that the grouping of material below differs from that in Plummer's textbook in order to make for a concise exposition.

A2.1 Form And Dimensions Of The Earth

Plummer began his textbook in chapter one with a description of the form and dimensions of the Earth. He provided proofs of the approximate sphericity of the Earth and described the use of trigonometric surveying to determine its diameter. He quoted the following values (by Airy & Bessel) for the diameter of the Earth: equatorial diameter 12,755.02 km (7925.6 miles); polar diameter 12,712.36 km (7899.1 miles). The corresponding accepted modern values [1992a] are respectively 12,756.272 km and 12,713.504 km. Plummer then presented evidence showing that the Earth rotates and how its rotation is associated with its deviation from an exact sphere. He described the effect of the Earth's rotation on the atmosphere, and how the movement of the atmosphere created trade winds and cyclones. Little could Plummer have known, as he drafted the text, that some two decades later he would be employed at Hong Kong Observatory, an institution responsible for studying the very same meteorological phenomena! The final section of chapter 1 dealt with the Earth's atmosphere, atmospheric refraction and twilight.

A2.2 Position And Time In Astronomy

Plummer covered two of the most fundamental aspects of astronomy, the definition and measurement of position and time, in chapter two. He began the chapter with a description of the usual celestial coordinate systems: horizon (altitude, azimuth), equatorial (Right Ascension, Declination) and ecliptic (ecliptic latitude and ecliptic longitude). Plummer wove a description of the Sun's apparent motion and of the seasons throughout his description of equatorial coordinates.

He then described the principles of operation of the refracting telescope and its operation as a transit instrument. The transit telescope and observatory chronometer were the essential instruments of the era for measuring the RA of celestial objects. Plummer noted that there were several errors that could affect the accuracy of operation of the transit telescope, and that *it is the duty of the practical astronomer to find out these errors and make allowance for their effects*. Unfortunately, he considered the explanation of how to control these errors as outside the scope of the book: had he decided otherwise, it might have eased the task of understanding his difficulties three years later with the transit telescope at Orwell Park! (See Appendix 11.2.) Plummer then described the mural circle, used to measure the declination of celestial objects. He described briefly equatorial and altazimuth mountings for telescopes and the principles of the Newtonian reflector.

He concluded chapter two with a description of time in astronomy, and an explanation of how inappropriate assumptions about the length of the tropical year resulted in a discrepancy between the calendar and the seasons which forced Pope Gregory to abandon the Julian calendar and introduce the Gregorian calendar, adopted in England in 1752. Plummer noted that the Julian calendar was still in use in Russia.

A2.3 Planetary Motions

Plummer addressed gravity and how it is responsible for planetary motion in chapters three and eight. He began with a description of the apparent motion of the planets, and how these were explained in ancient times by the Ptolomaic system of epicycles and differents. He went on to describe how the work of Copernicus, Brahé and Kepler overturned the Ptolomaic system and introduced essentially the explanation of planetary motions that we accept today, describing Kepler's laws in detail.

Plummer stated that Newton's law of gravitation explained Kepler's laws and in that sense is more fundamental; however he did not provide details to justify this argument, as that would have involved advanced mathematics well beyond the scope of his text. He articulated the law of gravitation in its full generality as *every particle of matter in the universe attracts every other particle, with a force varying directly as the mass of the attracting particle and inversely as the square of the distance between them*, but in fact restricted discussion of its effect essentially to the Solar System: in his era astronomers had not grasped the effect of gravity in sculpting the large scale structure of the cosmos.

In chapter eight Plummer dealt briefly with gravitational perturbations within the Solar System. He first explained the tides on Earth, detailing how the gravity of the Moon and Sun determines their general characteristics and why the tides are highest when the Moon is in syzygy. He then described how the gravity of the Sun and Moon results in the nutation of the Earth's axis and described how perturbations due to the Sun are responsible for the main terms in the lunar orbit.

Plummer described how mutual perturbations result primarily in changes to the eccentricity, line of nodes, line of apsides and orbital inclination of the planets. However, the changes to eccentricity and inclination are small, and mutual perturbations do not change the major axes of planetary orbits at all. He concluded that the Solar System was stable, that the orbits of the planets were not jeopardised by their mutual perturbations and that even if the Sun's gravity were to alter, the planets would simply move into different orbits to compensate. Plummer based his conclusion on observational evidence rather than a rigorous analysis; he could not have envisaged the interest among astronomers in the late 20th and early 21st Centuries in using powerful, custom-built super-computers to perform numerical investigations into the long term evolution of planetary orbits and into the long term dynamical stability of the Solar System spanning periods of hundreds of millions of years (see e.g. [1993a]).

A2.4 The Scale Of The Solar System

Plummer described estimation of the scale of the Solar System in chapter three. The mean distance between the centres of the Earth and the Sun, defined as the Astronomical Unit (AU), is of fundamental importance to astronomy because it defines the scale of the entire Solar System via Kepler's Third Law ($P^2 \propto a^3$, where P is the orbital period of a planet and a is the semi-major axis of the planet). Astronomers customarily express the AU in terms of the solar parallax, defined as the angle subtended by the equatorial radius of the Earth at a distance of exactly 1 AU. (From knowledge of the Earth's equatorial radius and the solar parallax it is a matter of simple trigonometry to calculate the length of the AU.) Unfortunately, attempts to measure the solar parallax directly had proven unreliable because the Sun is too distant and its heat disturbs the atmosphere to too great an extent. Astronomers therefore had tried to estimate the solar parallax by applying trigonometric arguments to measures of the angular distance between the centres of the Sun and the Moon when the latter was at dichotomy (assuming the distance to the Moon to be known). However, this method too proved inaccurate because features on the lunar surface prevented determination of the exact instant of dichotomy. Therefore, observers in Plummer's era had turned to observation of transits of Venus as a means of estimating the solar parallax. The last pair of transits of Venus prior to Plummer's time as an astronomer had occurred in 1761 and 1769. Encke had undertaken a comprehensive analysis of the 1769 observations and had computed a value of the solar parallax of 8''.5776[3] with a corresponding mean Earth-Sun distance of 153,359,400 km (95,293,100 miles). Encke's values became widely accepted. However, by the early 1870s, evidence from several techniques [2001a] began to suggest that Encke's value of the solar parallax was too large. For example, E J Stone [1863b] of the ROG published an estimate of 8''.932 based on observations of the planet Mars close to opposition in 1862 made at the ROG and at Williamstown, Victoria, Australia. (Plummer in fact referred to observations of the planet Mars in 1862, but quoted a slightly different final estimate of the solar parallax, namely 8''.94.) Observers had perhaps misinterpreted observations of the transit of Venus due to the "black drop" effect, resulting in an under-estimate of the solar parallax. Astronomers therefore looked forward to the forthcoming transits of Venus on 09 December 1874 and 06 December 1882 to provide an opportunity to derive a more accurate value. Sharing the general suspicion of the previously accepted value of the solar parallax, Plummer adopted in his textbook the value 8''.94, equating to a mean Earth-Sun distance 147,142,700 km (91,430,200 miles). The modern accepted values [1992a] are 8''.794144 and 149,597,870.66 km.

Plummer described Bode's law and went on to describe a scale representation of the Solar System expounded by Sir John Herschel. Herschel's model represented the Sun by a globe of diameter 60cm (two feet) and the planets out to Neptune by objects varying in size from

[3] Note that this value is slightly larger than the value 8''.577 quoted by Plummer in the preface to his book.

a grain of mustard seed representing Mercury to a moderate sized orange representing Jupiter, in orbits with a diameter up to 4 km (2.5 miles) for Neptune.

Plummer concluded his description of the scale of the Solar System by noting that the velocity of the Earth in its orbit about the Sun was so great that it was necessary to take account of the aberration of light due to the motion of the observer when making accurate measurements of the position of bodies. He also described the need to allow for light travel time when determining the position of a distant object at a specific instant.

A2.5 The Sun

Plummer described the Sun in chapter four. He gave the diameter of the Sun as 1,372,260 km (852,680 miles), close to the modern accepted value [1992a] of 1,392,000 km. He gave extensive comparisons of the bulk, gravity, mass and density of the Earth and the Sun.

He also gave an extensive observational description of sunspots, as they had enabled astronomers to deduce several facts about the Sun. By making careful observations of sunspots on the solar limb, astronomers had deduced that they were depressions on the solar surface. By tracking the evolution of sunspots across the solar disk, astronomers had estimated the location of the solar axis and the solar rotational period. Surprisingly, Plummer made no mention of differential solar rotation, whereby rotation at the equator is faster than at the poles. In Plummer’s era, astronomers did not know of the solar wind, or coronal mass ejections. However, Plummer described evidence as follows that events on the Sun could influence the Earth: *…an observation which was made by two observers in 1859. A bright mass of the photosphere was seen projected over the black nucleus* [umbra] *of a spot, and, after moving with rapidity, disappeared. Simultaneously there was a great disturbance in the direction of the magnetic needle, and a magnetic storm of great violence prevailed for some time afterwards, accompanied by a vivid display of aurora borealis.* It is possible that the observers witnessed the aftermath of a large scale solar disturbance. Plummer noted as a *recent discovery* by Schwabe the 11-year periodicity in the frequency of sunspots, but added that attempts to demonstrate a similar periodicity in meteorological phenomena on the Earth had been unsuccessful.

Plummer then turned to solar eclipses and how they reveal the structure of the solar atmosphere. Figure 9 (from the frontispiece of his book) shows the total eclipse of the Sun of 07 August 1869 illustrating clearly how it reveals the corona and prominences.

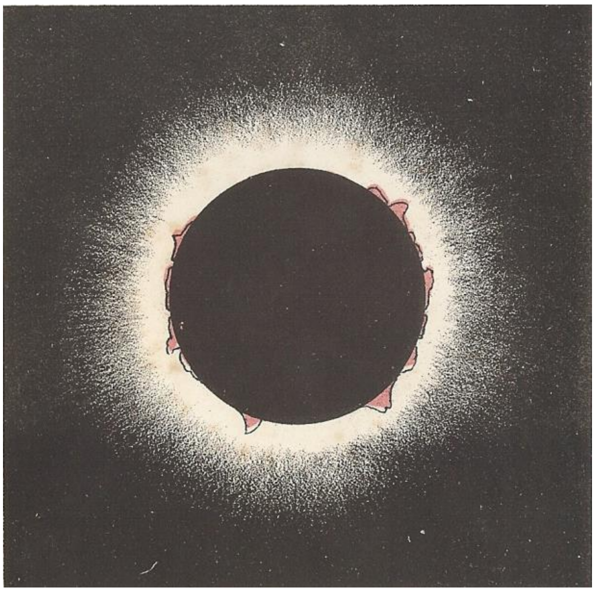


Figure 1. Solar eclipse of 07 August 1869.

Plummer stated that astronomers believed that the Sun consisted of an opaque solid body, visible as the nucleus (umbra) of sunspots, surrounded by a total of six atmospheric strata, in the following order outwards from the centre:

1. A dense, non-luminous, cloudy layer visible as the penumbra of sunspots. This layer strongly reflected the light of the next layer outwards.
2. A highly luminous photosphere, which produced the heat and light of the Sun.
3. A highly heated region of luminous metallic gases. The recently-developed science of spectroscopy had revealed the existence of this layer.
4. The chromosphere, comprising a very hot, tenuous gas, within which prominences sometimes occurred.
5. The self-luminous and reflective inner corona.
6. The much broader, non-luminous, outer corona or halo.

Unfortunately, although astronomers of the era had succeeded in fitting observational phenomena into a coherent model, their lack of understanding of solar physics resulted in the model being quite wrong.

Plummer concluded his description of the Sun by attempting to convey an impression of its scale. He noted that the Earth received only one part in $2.4*10^9$ of the output of the Sun, but that even such a tiny proportion was sufficient to melt in a year a layer of ice 35 m (38 yards) thick covering the entire planet. Astronomers in Plummer's era did not have an explanation for the source of such prodigious energy, and in fact Plummer stated that it *is a problem upon which even speculation fails, and the question must remain to be solved in the future*. Nuclear fusion was undiscovered in Plummer's era, and physicists of the time could only assume that the Sun "burned" through the mechanism of everyday combustion. They considered that a possible explanation for the longevity of the Sun was the arrival of fresh material in the form of meteors to replace that lost through combustion. Plummer indicated that a layer of meteoric material 7.3m (24 ft) deep all over the surface of the Sun each year would be required to replace the material lost through combustion (see also Appendix 13.1). The existence of the zodiacal light, indicating the presence of a mass of material particles surrounding the Sun, gave some credence to this theory, but Plummer noted that the theory was far from being universally accepted.

A2.6 The Earth And Moon

Plummer addressed the Earth, its orbit around the Sun, the Moon and its orbit around the Earth in chapters three and five.

He first described the Earth's orbit around the Sun, the seasons and techniques for determining latitude and longitude on Earth. He then described four approaches which scientists had used to estimate the density of the Earth:

- Estimate the mass of a mountain by surveying it and taking samples of its material. Then compare the mass of the mountain with that of the Earth by measuring the gravitational attraction of the mountain on a plumb line (referred to the direction of stars near the zenith). Knowledge of the radius of the Earth then enabled calculation of its density. Astronomers first used this method on the mountain of Schiehallion, above Loch Tay in Scotland.
- As above, but estimate the mass of the mountain by comparing the period of a pendulum at sea level and at the top of the mountain.
- Compare the period of a pendulum at sea level and down a deep mine. This provided a comparison of the density of the Earth at depths greater than that of the mine with the density of the shell of material on the surface of the Earth of thickness corresponding to the depth of the mine. The density of the upper layers of the Earth could be estimated from geological considerations, facilitating an estimate of the density of the entire Earth.
- Cavendish's torsion balance. This consisted of a two metre (six feet) wooden rod suspended from its centre by a fine wire with a 5 cm (2 inch) diameter lead sphere attached to each end. A separate suspension system held two 30 cm (12 inch) diameter lead spheres in position each approximately 23 cm (9 inches) from one of the smaller spheres. The gravitational attraction between each pair of large and small spheres caused the wooden rod to rotate slightly against the twisting force of the wire. By using a telescope to measure accurately the angle of the rod, and knowing the torque of the wire, Cavendish estimated the force between the two pairs of masses. He estimated the gravitational force of the Earth on one of the smaller spheres simply by weighing the latter. By comparing the ratio of the gravitational force exerted by the Earth with that exerted by the large spheres, Cavendish could estimate the density of the former.

The above methods gave an average density of the Earth of 5.67 times that of water, very close to the modern accepted figure [1992a] of 5.515g/cm^3.

Plummer described how astronomers had been able to make direct estimates of the parallax of the Moon at widely spaced observatories (for example the ROG and Her Majesty's Observatory at the Cape of Good Hope) and to estimate from their observations the average distance between the centres of the Earth and the Moon as 384,393 km (238,851 miles). The modern accepted value [1992a] is 384,400 km.

He gave a comprehensive account of the dimensions of the Moon, its orbit around the Earth, libration and phases. He noted that although observers had found no evidence of polar compression of the Moon, there were suspicions that it was slightly egg-shaped, with the thin end directed towards the Earth, since if the Moon had once had a fluid form the Earth's gravity would have caused it to adopt such a shape. Plummer believed that all planetary moons kept the same face turned towards the parent planet, in the same way as the Moon does to the Earth. Plummer noted *That our satellite is destitute of any sensible atmosphere is shown by a variety of facts,…* The facts included the absence of twilight upon the borders of the darkened hemisphere of the Moon; the sharpness of shadows on the Moon; the lack of a bright line due to atmospheric refraction around the lunar limb during a solar eclipse; and the sudden disappearance of a star when it was occulted by the lunar limb. Plummer's view on the possible shape of the Moon and his confidence that the evidence demonstrated the lack of a lunar atmosphere deserted him later in 1873 when he proposed in the pages of MNRAS a new theory to explain the supposed phenomenon of *projection upon the limb* during lunar occultations: his theory was based on the Moon having the form of an ellipsoid of rotation with an atmosphere of sufficient density to refract starlight appreciably. In subsequent correspondence with Proctor in the pages of MNRAS he confirmed his belief that the figure of the Moon was in fact an ellipsoid of rotation which was very close to being spherical. See Appendix 5.3 for further details.

Plummer stated that the craters on the Moon were almost certainly volcanic in origin, as their shapes were the same as terrestrial volcanoes. For many years astronomers debated whether lunar craters were primarily caused by volcanoes or by the impact of bodies arriving from space; nowadays the consensus of is that they are primarily caused by impacts (see e.g. [1999a]).

Finally in his coverage of the Earth and the Moon he gave a comprehensive account of solar and lunar eclipses.

A2.7 The Planets And Asteroids

Plummer described the planets and asteroids in chapters four, five and six. For each planet he provided key orbital and physical data and described the known physical characteristics. Table 15 compares Plummer's key planetary and orbital data (converted to SI units) with accepted modern values. The modern values are taken from [1992a] except for the sidereal period which is taken from [1989a] (sidereal periods quoted in [1992a] in fact appear to refer to tropical years rather than sidereal years). In the table, shading indicates data where Plummer’s estimate differs by more than 10% from the modern accepted value.

Planet	Src	Mean Density (g/cm^3)	Equat-orial Radius (km)	Siderial Period of Axial Rotation (d h m s)	Mean Orbital Radius ($*10^6$ km)	Siderial Period (days / years)	Orbital Eccent-ricity
Mercury	P	7.27	2,382.6	24h 5m 30s	56.958	87.969d	0.206
	M	5.43	2,439.7	58d 15h 30m 32s	57.909	87.969d	0.206
Venus	P	5.36	6,043.9	23h 21m 23s	106.432	224.701d	0.007
	M	5.24	6,051.9	243d 0h 14m 24s (R)	108.209	224.701d	0.007
Earth	P	5.67	6,377.5	23h 56m 4.09s	147.142	365.256d	0.017
	M	5.515	6,378.1	23h 56m 4.10s	149.598	365.256d	0.017
Mars	P	2.82	3,959	1d 0h 37m 22.735s	224.201	687d	0.093
	M	3.94	3,397	1d 0h 37m 22.663s	227.939	686.980d	0.093
Jupiter	P	1.32	71,125	9h 55m 21.3s	765.554	11.862y	0.048
	M	1.33	71,492	9h 55m 29.9s	778.298	11.862y	0.049
Saturn	P	0.756	57,858	10h 29m	1403.564	29.457y	0.059
	M	0.70	60,268	10h 30m 0s	1429.394	29.457y	0.056
Uranus	P	0.990	26,573	-	2822.548	84.014y	0.047
	M	1.300	25,559	15h 36m 0s (R)	2875.039	84.010y	0.046
Neptune	P	0.848	30,722	-	4419.661	164.5y	0.008
	M	1.76	24,764	18h 25m 55s	4504.450	164.793y	0.009

Table 1. Comparison of Plummer's data with modern values. “P”=Plummer, “M”=modern. “R” = retrograde rotation.

Plummer’s data for the major planets is generally in fair agreement with modern accepted values. The exceptions are:

- Axial rotation periods for Mercury, Venus, Uranus and Neptune. These planets lack pronounced visual surface features and astronomers of Plummer’s era were therefore unable to estimate their rotation periods accurately.
- Density of Mercury. The planet has no satellite and astronomers were therefore forced to estimate its density from its effect on passing comets, a technique which did not produce accurate estimates.
- Densities of Uranus and Neptune. Inaccuracies here may be ascribed in part to general difficulties in Plummer’s era of observing such distant planets.
- Equatorial radius of Neptune. The planet is so distant and difficult to observe from the Earth that it presents a very minute disc (never larger than 2".3) and astronomers in Plummer’s era were unable to estimate its equatorial radius accurately.

- Orbital eccentricity of Neptune. When Plummer drafted his text, Neptune had been known for less than 30 years[4] and since its discovery had progressed through only a small fraction of its orbital path; therefore astronomers did not know its orbital parameters with the precision that we enjoy today.

Astronomers in Plummer's era had only a minimal knowledge of the physical constitution and composition of the planets, other than the Earth, and Plummer took only a page or so to describe each. Only three planets (Mars, Jupiter and Saturn) show evidence of consistent features in modest telescopes and Plummer provided an illustration of each. Planetary photography was not well developed at the time, so his illustrations are sketches, reproduced in figure 10. The sketches show considerable detail, and appear to be the product of a practised observer; however Plummer did not name the astronomer concerned. (The sketches are not thought to be Plummer's handiwork, as he made only one reference in his published papers [1874d] to sketching at the eyepiece – namely the sketches of Comet III 1874 (Coggia's first comet) which he sent to the RAS Library in 1874.)

Mercury

Plummer wrote: *…very little is known of its physical constitution. Its lustre is most brilliant, and effectually hides its features; but it is believed to possess a dense cloudy atmosphere…* Observers had reported seeing mountain tops through the supposed atmosphere, from which they had estimated its rotation period. Unfortunately, the astronomers of Plummer's era were quite wrong: Mercury possesses no appreciable atmosphere and its rotation period is very different from the early estimates. (Due to the difficulty of observing surface features on Mercury it was not until 1964 that Gordon H Pettengill and Richard B Dyce used radar to show that the rotation period of the planet is 58.6 days (exact value in table above) locked into a 3:2 resonance with the planet's orbital period.) Plummer also noted that Mercury undergoes transits across the solar disk, and explained as an effect of irradiation the black drop effect, which is often visible around the times of internal contact of a transit.

Venus

Plummer emphasised the brilliance of the planet, claiming to have observed it at noon and to have seen it cast a shadow at night. He reported that, as with Mercury, astronomers had detected mountains protruding through a dense atmosphere, and to have estimated from them a rotation period. Unfortunately, again the estimates were badly wrong and it was not until the modern era of radar mapping that astronomers were able to obtain accurate estimates of the rotation period.

Mars

[4] Neptune was discovered on 23 September 1846 by Johann Gottfried Galle and Heinrich D'Arrest at the Berlin Observatory.

Plummer wrote some five years before Asaph Hall's discovery of the two moons of Mars[5] and therefore stated that Mars had no moon. From Mars' distance from the Sun, Plummer knew that the intensity of solar radiation on the planet was only 43% that on the Earth. However, despite this, Mars' polar caps were not greater, in relation to the size of the planet, than those of the Earth and they grew and receded in a similar fashion to those of the Earth. Plummer concluded that Mars must enjoy a temperate climate similar to that of the Earth, and must be covered by a very dense atmosphere or be composed of material which retained the solar heat very effectively. Plummer noted that *permanent markings and conspicuous diversity of colour upon the disc of the planet clearly indicate the existence of continents and seas; but, curiously enough, the larger portion of the surface would appear to be land.* Plummer attributed the red glow of Mars to the soil of its land masses, which he speculated was probably similar to red sandstone on Earth.

Asteroids

Astronomers in Plummer's era had identified and calculated orbits for 125 asteroids. He gave the approximate limits of the asteroid belt as defined by the orbits of Flora and Camilla, orbiting the Sun at the following mean distances respectively: 323,127,000 km (201,273,000 miles) and 523,856,000 km (325,509,000 miles).

Plummer stated that an early theory to explain the asteroids, namely that they were the remnants of a large planet which had exploded or had been subject to a collision, was largely discredited. The then current theory was that a large ring (similar to the rings of Saturn) had existed between the orbits of Mars and Jupiter, but that it had somehow lost structural integrity and disintegrated into the bodies known as asteroids.

Jupiter

Plummer wrote that *Jupiter is certainly surrounded by a dense cloudy atmosphere, capable of strongly reflecting the solar light. The dark belts are, in all probability, rifts or fissures in the clouds, exposing the surface and caused by violent permanent winds, more or less resembling our own sub-tropical trade winds.* Plummer also mentioned the phenomena of small round bright spots which he conjectured might be masses of cloud hanging around the summits of mountains, and small round dark spots, which were also occasionally visible, which he thought could be the mountain-tops themselves, unobscured by cloud. Plummer did not mention the Great Red Spot – although it was observed intermittently from at least circa 1700, it was as late as 1879, when it was surrounded by white clouds and was very well defined, that it first attained particular prominence among astronomers.

Plummer devoted four pages to a description of the motions of the Galilean satellites, what phenomenon they would present to a hypothetical observer on the surface of Jupiter, and how Roemer used them to estimate the velocity of light. Although astronomers generally credit Galileo Galilei with discovering the satellites, a German observer, Simon Marius, who claimed to have observed them before Galileo, suggested the names Io, Europa,

[5] Hall discovered Phobos and Diemos in 1877.

Ganymede and Callisto. Galileo disputed Marius' claim to have first observed the satellites and accused him of plagiarism. For many years therefore astronomers referred to the satellites simply as Jupiter I, II, III and IV to avoid crediting a possible plagiarist with their discovery. Plummer adopted this convention. It was as late as 1975 that the scientific community officially accepted the names Io, Europa, Ganymede and Callisto [1997c].

Saturn

Plummer concentrated in his description of Saturn on the planet's rings. He stated that astronomers had discovered three rings (the A, B and C rings) and quoted their thickness as *certainly not more than 250 miles* [400 km]*, and in all probability very much less*. Nowadays, astronomers recognise six main rings (A-G) and have identified a huge number of individual narrow ringlets. The modern accepted value of the thickness of the rings is several tens of metres [1999a].

Plummer stated that the rings revolved around a point some 725 km (400 miles) distant from the centre of the globe of Saturn. Historically, observers have differed greatly over whether the rings revolve around the centre of the globe or are offset from it. For example, Alexander [1962a] noted that Barnard, observing at Mount Hamilton in 1894 and 1895, concluded that the rings were centred on the globe but that Lowell and Slipher, observing in February – May 1915 estimated the centre of the B ring as offset respectively 1700 km and 520 km from the centre of the globe[6]. Modern textbooks generally take the view that the particles forming the rings of Saturn are in circular orbits around the centre of the globe - for example, see [1983b] (which notes also that the particles of the B ring do not follow Keplerian orbits, and that the distance of the outer edge of the B ring from the centre of Saturn varies by approximately 140km).

Plummer acknowledged that the rings could not be solid, as differential rotation would create internal stresses which would shatter a solid body; he inclined toward the view that the rings were composed of small solid bodies each in an independent orbit around the planet.

Plummer noted that astronomers had discovered eight of Saturn's moons, but that they knew *very little* about them.

Uranus and Neptune

Both planets are so far from the Sun that astronomers of Plummer's era knew very little about them. Plummer noted that Uranus was accompanied by four faint satellites, and that *Neptune possesses one minute satellite, and possibly another*[7].

---

[6] Alexander quotes the offsets as 0".24 and 0".075 at a standard planetary distance from Earth of 9.53885 AU.

[7] In fact, it was not until 1949 that G P Kuiper discovered Nereid, the second moon of Neptune.

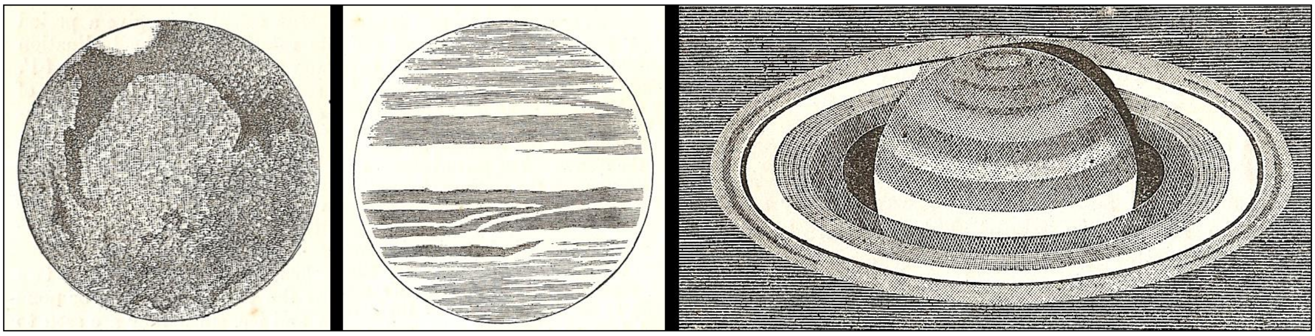


Figure 2. Mars, Jupiter & Saturn from Plummer's textbook.

A2.8 Comets

Plummer described comets in chapter 7. He first gave a general description of comets and their significance to sky-watchers of old and then detailed their structure in terms of the usual coma, nucleus and tail.

He then described the typical development of the tail as a comet approached the Sun. Astronomers in Plummer's era did not know of the solar wind and therefore Plummer had no explanation for the way in which the Sun appeared to repel the tails of comets. Indeed, the observational evidence must have been confusing, as Plummer noted that on approach to the Sun a comet appeared to emit material in the form of a tail, and that as the comet subsequently receded from the Sun it *appears to absorb again the matter that it has emitted*. However, he clearly believed in this case that appearances might be deceptive, as he noted later: *it further seems almost inconceivable that the matter thus emitted* [the cometary tail] *can be collected again by the feeble attraction of a comet*. Plummer adduced some evidence which revealed the connection between the Sun and the tail of the comet, for example, that the great comets in 1680 (C/1680 V1 or Kirch's Comet) and 1843 (C/1843 D1), both of which were sun-grazing, exhibited enormous tails, and that short-period comets generally appear less bright at each succeeding apparition. However, he did not make the intellectual leap necessary to associate the solar heating of the comet during its perihelion passage with the outgassing of material lost to the comet and dispersed into the Solar System.

Plummer described two demonstrations of the tenuous nature of comets. Observations of close approaches of comets to Jupiter's moons and to Mercury revealed no measurable perturbation of the motion of the latter bodies thus demonstrating that the mass of a comet must be very low. The ability to observe faint stars through the tail and coma of a comet demonstrated that the material of those parts of the comet must be extremely tenuous.

Plummer stated that comets shone by reflecting sunlight and through self luminosity, the latter mechanism having been revealed by spectroscopic observations. Astronomers nowadays understand that comets shine purely by reflecting sunlight. Plummer did not provide details of the spectroscopic observations which supposedly demonstrated self luminosity, but the misunderstanding was likely associated with the highly complex nature of the spectrum of a typical cometary nucleus.

He noted that observations showed that Encke's Comet, discovered by Pons in 1786, was slowly spiralling into the Sun. Encke had proposed an explanation for this in terms of a *resisting medium* throughout the Solar System, rare enough not to perturb significantly the orbits of bodies such as planets, but dense enough to retard the motion of tenuous objects such as comets.

Finally Plummer noted that astronomers had discovered an apparent connection between some comets and meteor showers. An annual meteor shower is associated with an annulus of small particles in orbit around the Sun, in a path which crosses the Earth's orbit: when the Earth crosses the annulus, its gravity pulls particles in the vicinity into its atmosphere where frictional heating causes them briefly to become incandescent, and some to become visible. For the more prominent meteor showers, astronomers had been able to estimate the position of the radiant, which in turn yielded an estimate of the orbital parameters of the annulus of meteors. In this way astronomers were able to associate the orbital parameters of meteor particles with known comets. Plummer detailed two associations made in this way which were known at the time: the Leonid meteors with comet 55P/Tempel-Tuttle[8] and the Perseid meteors with comet 109P/Swift-Tuttle[9].

A2.9 The Stars

Plummer described the astronomy of stars in chapters three and nine. He noted that the stars are not distributed evenly throughout the sky, but are concentrated in the zone of the Milky Way galaxy and that the most probable explanation for this is that the Sun is situated towards the centre of a mass of similar bodies which collectively have the shape of an immense, irregular lens.

Astronomers had attempted to estimate the distances of stars by measuring their parallaxes. However, there were very significant practical difficulties with this approach because even using the diameter of the Earth's orbit (almost 300 million km) as baseline, parallaxes proved too small to estimate for all but the nearest stars. However, despite the enormous practical difficulties in obtaining precise measurements of minute angles, by the time of Plummer's publication, astronomers had succeeded in obtaining satisfactory estimates of the parallax of approximately 10 stars. He drew attention in particular to 61 Cygni, the first star to have its parallax measured (by Bessel, in 1838). He quoted its distance as 9.3 ly and its absolute proper velocity as 2060 million km *per annum*. By way of comparison, the equivalent modern values, calculated from data in [1989a] are 11.1 ly and 2670 million km *per annum* respectively.

Plummer stated that in no case did the observed annual parallax of a star exceed 1", and that in the case of the star thought to be nearest to the Earth, Alpha Centauri, the annual

[8] Plummer referred to the comet as *Tempel's comet …which had been visible in the year 1866*.

[9] Plummer referred to the comet as *a comet observed in 1862*.

parallax was measured as 0".9158, equating to a distance of 3.5 ly; the modern value [1989a] is 4.3 ly.

Plummer noted that, at least in regard of the Milky Way, there is *neither limit of distance nor of number to the fixed stars* and that *each successive increase of optical power brings into view fainter and fainter specks of light, to which we are obliged to attribute greater and greater distance*. This is a topic that he returned to five years later in response to publications by other astronomers (see Appendix 14).

Plummer explained that by surveying proper motions over the population of stars at large, astronomers had determined that the entire Solar System was in motion in the direction of Pi Herculis at a velocity of 240 million km (150 million miles) *per annum*. The corresponding modern value is 615 million km *per annum* [1989a].

Plummer noted that some 6000 double stars were known of which some 650 were known to be true, gravitationally interacting, systems. He speculated that *many others will probably, in the course of some years, be added to the number*. This was a prescient remark, but he could not have foreseen the situation at the beginning of the 21st Century, when it is generally accepted that the majority of stellar systems comprise two or more gravitationally-bound components. He noted that double stars provided a test of the law of gravitation outside the Solar System.

Plummer pointed out that in some cases the components of a double star shone with contrasting colours – he speculated that the inhabitants of a planet orbiting such a system would enjoy days of variously-coloured light. He provided some evidence from the historical record that stars could change their colour, e.g. Sirius and Tycho's star of 1572.

The physics of novae and supernovae were not known in Plummer's era, and he referred to them as *temporary stars*. He stated that there had been approximately 20 recorded instances of such stars, and that relatively little was known about them. However, in the most recent instance of a *temporary star*, in 1866 in Corona[10], spectroscopic observations had indicated that the increase in brightness was associated with the ignition of hydrogen.

Plummer next considered variable stars. He described the variety of phenomena exhibited and then distinguished three main types of variable: long period variables such as Mira (Omicron Ceti), eclipsing variables such as Algol (Beta Persei) and irregular variables such as Eta Argus (Eta Carinae in modern designation).

Plummer noted that several thousand star clusters existed, which telescopes of appropriate power could resolve into stars. However, some clusters resembled clouds and defied all attempts at resolving into stars even with very fine telescopes on nights of good seeing. Such irresolvable objects were termed nebulae and he indicated that they were at *extreme distances* from the Earth. He listed several forms that the nebulae could take, such as

---

[10] The star is now designated as a recurrent nova, T CrB, also known as the Blaze Star. It is usually of brightness magnitude 10, not visible to the naked eye. Twice it became bright enough to be seen without optical aid: first reported in 1866, it reached magnitude 2; in 1946 it brightened again and reached magnitude 3.

elliptical (e.g. Andromeda), planetary disk, convoluted spiral forms and irregular. The nebulae were found near the poles of the Milky Way, whereas resolvable star clusters in the main were found in the plane of the galaxy. Plummer noted that if some star clusters were thought of as galaxies similar to the Milky Way, their distance would be enormous, several thousands of light years. He forecast that improvements in optical instrumentation would be necessary to elucidate the true structure of the irresolvable nebulae.

--- To be continued ---