The Newsletter

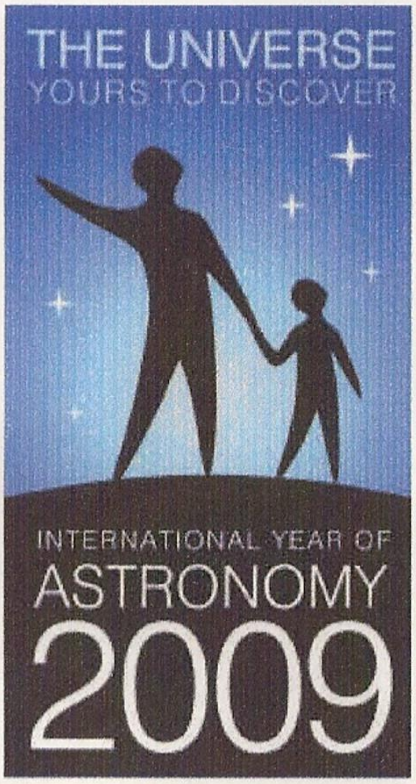
of the

Orwell Astronomical Society (Ipswich)

Registered charity No 271313

www.oasi.org.uk

2009 February — No 438



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

And on it goes ...

Society News (Roy Gooding)

1 Committee Meeting Sunday 1st February

All members are invited to attend the next Committee meeting, on Sunday 1st February at 15:00 at Nacton Village Hall **Please note date, time and venue**

2 Observatory Keys

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

3 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

Bruce Bloom   Clive Webb

5 Lecture Meeting Venue

Our town lecture venue is now at the Methodist Church Halls, in Blackhorse Lane. The Church has a car park, which can take about 30 cars.

Black Horse Lane has only one entrance, which is from Elm Street. This is just past the Police Station, if you are arriving from Civic Drive. The church car park is on the right, just past the Black Horse pub.

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

6 SPA Convention

The SPA convention requires tickets for one of the lectures. If you wish to attend please contact Roy Gooding. The principle theme for this meeting is the Moon.

7 Events for 2009 (International Year of Astronomy)

This event list will be updated through out the year

Meeting	Venue	Date
Workshop Beginners Night Mike Whybray Paul Whiting	Nacton Village hall	Wednesday 4th February 19:45
Astro Fest	Kensington Conference & Events Centre London	6th & 7th February
SPA Convention 2009	Institute of Astronomy Madingley Rd Cambridge	Saturday 7th March 10:00 to 17:30
Astronomy Evening Option 1 *(IYA)*	Orwell Country Park	Saturday 21st March 19:30 to 23:00
Astronomy Evening Option 2 *(IYA)*	Orwell Country Park	Saturday 21st March 19:30 to 23:00
Talk and Telescope Evening *(IYA)*	Nacton Village hall	Monday 30th March 19:30
Talk and Telescope Evening *(IYA)*	Nacton Village hall	Tuesday 31st March 19:30
Sidewalk Astronomy (Night Observing) *(IYA)*	The Ship Levington	Thursday 2nd April 19:30
Open Weekend Spring *(IYA)*		Saturday & Sunday 4th & 5th April 19:30 to 22:00
Summer Barbecue		TBA
Astronomy in the Park Solar observing *(IYA)*	Christchurch Park	Saturday & Sunday 30th & 31st May 11:00 to 16:00
Perseid Meteor watch	The "Dip" Felixstowe	TBA
Open Weekend Autumn *(IYA)*		Saturday & Sunday 24th & 25th October 19:30 to 22:00
Talk and Telescope Evening *(IYA)*	Nacton Village hall	Monday 26th October 19:30
Talk and Telescope Evening *(IYA)*	Nacton Village hall	Tuesday 27th October 19:30
Sidewalk Astronomy (Night Observing) *(IYA)*	The Ship Levington	Thursday 29th October 19:30
Astronomy in the Park Solar observing *(IYA)*	Christchurch Park	Saturday & Sunday 31st October & 1st November 11:00 to 15:00
Geminid Meteor watch	The "Dip" Felixstowe	TBA
Christmas Meal	TBA	Wednesday 16th December

Night Sky (February) All times GMT

Moon

1st Quarter	Full Moon	3rd Quarter	New Moon
2nd	9th	16th	25th

Object	Date	Times		Mag.	Notes
		Rise	Set		
Sun	1	07:45	16:53		
	28	06:53	17:43		
Mercury	1	06:31	15:08	-0.1	Mercury remains in the morning twilight sky, making it difficult to see
	28	06:21	15:24		
Venus	1	09:01	21:19	-4.6	Venus remains a prominent object in the evening sky
	28	07:13	21:18		
Mars	1	07:14	15:19	1.2	Mars is also in the morning twilight.
	28	06:21	15:32		
Jupiter	1	07:35	16:11	-2.0	Jupiter is also in the early morning sky this month.
	28	06:04	15:00		
Saturn	1	20:13	09:20	0.5	Saturn is well placed to observer all night this month
	28	18:16	07:32		
Uranus	1	09:03	20:23	5.9	Uranus moves into the evening twilight this month
	28	07:19	18:45		
Neptune	1	08:12	17:50	8.0	Neptune is at conjunction on the 12th
	28	06:28	16:09		

OCCULTATIONS DURING FEBRUARY

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

Date	Time (UT)	D R	Lunar Phase	Sun Alt (d)	Star Alt (d)	Mag	Star
02 Feb	19:11:22	D	0.48+	-23	53	6.1	26 Ari
02 Feb	22:56:48	D	0.49+	-52	23	6.9	ZC 387
03 Feb	20:57:00	D	0.60+	-38	50	7.4	ZC 513
05 Feb	20:03:35	D	0.81+	-30	64	6.4	ZC 849
05 Feb	23:01:40	D	0.82+	-51	52	7.3	ZC 869
06 Feb	19:30:43 20:38:26	D R	0.89+	-25 -35	55 61	3.1	epsilon Gem
07 Feb	03:53:01	D	0.91+	-33	18	5.2	omega Gem

James Appleton

A Few Days in Copenhagen

Paul Whiting

Initially attracted by the promise of a Christmas market I thought a short trip to Copenhagen could be justified by the sheer amount of astronomical history there. Day one saw a visit to the Round Tower – the oldest functioning observatory in Europe. A 17th Century observatory once used by Ole Rømer and H C Ørsted, that housed a number of ground breaking instruments over the years. It is open to the public on two days of every week. Of course these were the two days I wasn't there ! A long (long) circular, 209m cobbled ramp up the 36m tower, punctuated only by a gallery, a bell ringing chamber (no evidence of bells though) and one of two open plan loos (medieval style) with open drop down to a pit. It is claimed that Hans Christian Andersen once sat there. Having made it up the ramp I was greeted with a locked door to the observatory. Ho hum – at least you could get out on the roof and look over a breathtaking vista of Copenhagen.

The next disappointment came later in the day when I tried to find the times of the boat to Hven (pronounced "Veen" as an indignant hotel receptionist pointed out !), the island containing Uraniborg, the home observatory of Tycho Brahe. No sailings in winter, the museum on the island only being open in the summer. The lady on the phone I called said "please don't waste your time going there in winter. There is nothing to see." Honest at least.

The afternoon of Day 1 saw a trip to the University Geology Museum – reputed to have a large collection of meteorites. It may have a large number of meteorites but has precious few on show. However there were some good videos of meteorite collection in Antarctica and other interesting places. Apparently the boss of the museum collected 900+ samples in 6 weeks at the South Pole, whereas only 3 samples have been found in the last century in Denmark. Probably worth freezing one's meteors off then !

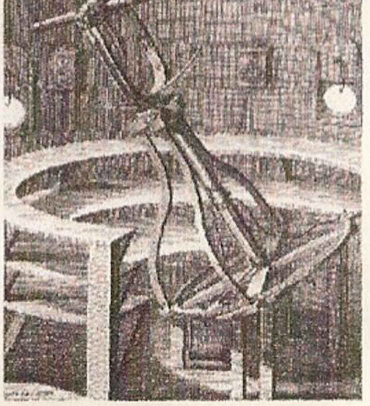
Day 2 started with Jens Olsen's astronomical clock at the Town Hall. A truly impressive piece of engineering. It shows planetary positions, earth's precession, Julian and Gregorian dates, lunar phase, solar, sidereal and local time. I'm sure it also tells the price of tomatoes at Tesco if you look hard enough. It is a relatively modern chronograph – early 20th century, which is probably a good thing as the maker of an earlier astronomical clock in Prague had his eyes poked out to prevent him building another for someone else.

Then on to the highlight of the trip – the Tycho Brahe Planetarium and Museum. I've never been so under whelmed. To my mind a museum of astronomy should be packed to the gunnels with exhibits, information, models and interactive experiences. What I found was a minimalist approach, dare I say Ikea. Perhaps twenty exhibits from big bang to aurora, with plenty of computer screens – all in Danish. Fair enough you may think, but the posters were bi-lingual (Danish / English), how difficult would it have been to put a select language option on these screens? Still the coke machine was good.

The planetarium was OK – a quick whiz round the night sky (in Danish) with a what's on view tonight. This was followed by an IMAX presentation on the history of the Grand Canyon (not much Tycho Brahe there then). There was also a smaller 3d theatre, which was quite good – it at least had a space theme, a cosmic roller-coaster ! The adverts claimed that the astroshop there was full of books on astronomy. Great I thought. I found Celestron & Meade telescopes, eyepieces and filters. There were bits of meteorite (3 times the price than at the Geological Museum) and all sorts of tat "authorised by the London Science Museum", but not one single book on astronomy or indeed anything else.

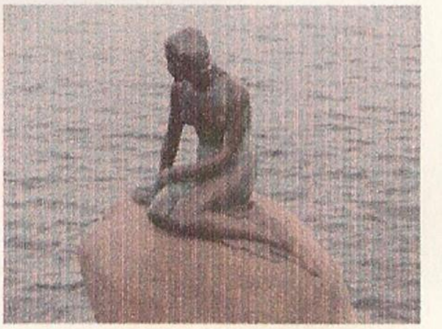
Time did not permit visits to sites beyond Copenhagen, such as the Kroppedal Museum of Astronomy, the Orion Planetarium at Rødding, The Planet Earth in Lemvig or the Steno Museum in Århus.

Oh well at least the City itself was interesting and the food, although expensive, was exquisite. Oh and I didn't get round to the Christmas Market at Tivoli Gardens after all.



Early telescope in the Round Tower

Tycho Brahe



Little Mermaid

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.

Chairman's Chat... Neil Morley

As a result of the AGM, I have been elected as your new chairman. For those who don't know me, I have held a strong interest in astronomy since an early age. My main interests are visual astronomy and maintaining astronomical telescopes. I have been a member of OASI for sixteen years and have served on the Committee as equipment curator for around a quarter of that time. Originally from Birmingham, I trained initially as a professional musician in London. Having spent a few years as a professional cellist in London and Dublin with the RTE Symphony Orchestra, I took a complete change of course studying for a communications engineering degree at Leeds Polytechnic. Sixteen years later, I'm still in Ipswich working at the former research facilities of a large global telecommunications company!

My aims as OASI Chairman are as follows:

1. Make the post of Chairman less intimidating for those wishing to succeed me!
2. Maintain our relationship with Orwell Park School.
3. Promote International Year of Astronomy 2009 (IYA2009) and encourage the local community, particularly younger people.
4. Grow our membership through further "taster" sessions and workshops.
5. Promote observing projects and encourage contributions towards the newsletter.

6. Actively encourage more members to present at workshops and lecture meetings involving external speakers.
7. Maintain links with other astronomical organisations including local societies.

The International Year of Astronomy 2009 (IYA2009) is now upon us. As an occasion, it is truly significant; providing a global celebration of astronomy and its contributions to society and culture. It coincides with the 400th anniversary of the first use of an astronomical telescope by Galileo. Initiated by the International Astronomical Union (IAU) and UNESCO, the aim is to "help people rediscover their place in the Universe" and "stimulate a personal sense of wonder and discovery". Further information can be found via the websites www.astronomy2009.org (IYA globally) and http://www.astronomy2009.co.uk/ (IYA UK including OASI events in Suffolk).

Now, this is going to be a busy but I trust worthwhile year for OASI! We have 19 events in our calendar presently, with 12 dedicated to IYA2009. I expect this list will grow as the year progresses. We need more volunteers to come forward and get involved in helping run our events. Your society needs you to get involved! With this in mind, the date for the next Committee Meeting is Sunday 1st Feb, start time 3pm and venue Nacton Village Hall. The main topic is 2009 events and any member is welcome to attend. Please do keep an eye on the OASI web site, email list and Newsletter as details of events unfold. If you require an Astrocalendar detailing astronomical events in 2009, Paul Whiting (Treasurer) has a few left! If you have any other suggestions, questions or issues/concerns about OASI please get in touch either with me directly or via another committee member.

Finally, I would like to express my gratitude to my predecessor Ken Goward. Under his leadership, we've seen OASI's profile considerably raised through many memorable occasions including Allan Chapman's lectures, the official unveiling of the Tomline Refractor, the opening of the library by Pete Hingley following refurbishment by OASI members, transit of Venus, 19" Millennium Telescope, further exciting discoveries about our heritage, lecture meetings, workshops, social events, visits, and more. All this is a true reflection on Ken's input, the strength of OASI and its membership as a whole.

As many of you will know, Ken has not been in very good health and hasn't been able to attend the observatory or workshops/events for some time. Ken, we wish you all the very best for your recovery. Special thanks also to Roy Gooding (Secretary), Paul Whiting (Treasurer) for keeping OASI on course as well as the Committee, Trustees and society members for their hard work this past year.

I wish you all the very best for a successful 2009 and let's make it a memorable one for IYA!

Regards,

Neil Morley, OASI Chairman

OASI Committee Contacts & Responsibities

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

DIARY FOR FEBRUARY

Monday 2th & 23rd	**SMALL TELESCOPES OBSERVING NIGHTS** Main Observational targets: Gemini, Cancer & Saturn ☎ Paddy O'Sullivan [redacted] ☎ Gerry Pilling [redacted]
Wednesdays **From 8PM**	**MAIN OBSERVATORY CLUB NIGHTS** Primary Observational targets: Nebulae and faint objects. ☎ Martin Cook [redacted] (mobile) [redacted] ☎ Roy Gooding [redacted] (mobile) [redacted]
Wednesday 4th **From 7.45PM** **NACTON VILLAGE HALL**	**OASI WORKSHOP** Beginners Night We've had several new members join in the last few months. So we're having an evening to introduce some of the basics of astronomy-how telescopes work and how to use one,what you can see with one, and the structure of our universe. We'll have one or more telescopes for you to play with. ☎ Mike Whybray [redacted] Paul Whiting [redacted]
Thursday • 5th @ 7.30pm • 19th @ 8.00pm	**OBSERVATORY VISITS BY LOCAL COMMUNITY GROUP** 1st Bramford Cubs Group First Contact Night ☎ Paul Whiting FRAS [redacted]
Sunday 1st @ 3pm **Nacton Village Hall**	**Committee Meeting** ☎ Roy Gooding [redacted]

Society Primary Contacts

Chairman:

Secretary: Roy Gooding ☎ [redacted] (daytime) [redacted] (evenings)

E-Mail queries: lpswich@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 10

A1 Formation Of Planetary Systems

In 1755 the philosopher Immanuel Kant proposed the *nebular hypothesis* to explain the formation of the Solar System. In 1796 the French mathematician Pierre-Simon de Laplace further developed the theory. The theory proposed that the Solar System formed from an enormous cloud of gas and dust which collapsed under its own gravitational attraction, forming a flattened disc, the *solar nebula*. The nebula was rotating, and to conserve angular momentum, the disc rotated more rapidly as contraction progressed. The central part of the nebula became the Sun. Laplace proposed that rings of material became detached from the spinning disk when the velocity at the edge exceeded a critical value, and that the material in these rings later coalesced to form the planets. In a similar manner rings of material shed by the planets in turn became the planetary satellites. Astronomers continued to refine the nebular hypothesis, and indeed widely accepted modern theories of the formation of the Solar System are generally developments of the nebular hypothesis.

In the second half of the nineteenth century, although Laplace's theory provided astronomers with a plausible theory for the formation of the Solar System, there was a very considerable problem concerning the longevity of the Sun. Geologists and palaeontologists were uncovering evidence that the Earth, and hence the Solar System, was hundreds of millions of years old or possibly even older. This posed a problem in that there was no mechanism known at the time to sustain the energy output of the Sun for such an extended period. It was not until the mid twentieth century that astronomers developed theories to explain the energy production of the Sun based on the conversion of hydrogen to helium via nuclear fusion, with an attendant release of energy, which could sustain energy output for a period of several billion years.

In 1875 Plummer [1875d] published a nine page paper (his longest astronomical paper) providing a commentary on the nebular hypothesis and developing an extension of the theory intended to provide an explanation for the longevity of stars. Three years later, Dr James Croll [1878a] published an alternative supposed explanation for the longevity of stars. Plummer [1878b] responded quickly to Croll, and utterly disparaged his explanation. However, by this time Plummer was muted in his support for his own earlier theory, as *recent discoveries* had caused him to *somewhat modify* his earlier views, so he was unable to offer an alternative theory. (Plummer did not give details of the *recent discoveries*.) The correspondence was short lived, and Croll did not appear to respond to Plummer.

A1.1 The Nebular Hypothesis

In 1875 Plummer [1875d] noted that the nebular hypothesis was one of the most debated scientific theories ever. The simplicity and comprehensiveness of the theory were in its favour, but Plummer stated that there was much evidence to the contrary. Prior to the advent of spectroscopy, it appeared as if ever larger telescopes would eventually resolve all the nebulae into star clusters. However, spectroscopy revealed that a considerable proportion of the nebulae unresolved by the largest telescopes of the time were in fact gaseous in nature, being composed of three gases. Two of the gases were hydrogen and nitrogen; but the third gas had no terrestrial equivalent at the time, although Plummer noted that it might be a terrestrial element under circumstances in space different from those on Earth causing it to manifest an unrecognised spectrum. Unfortunately for the nebular hypothesis, the spectra of nebulae showed very narrow lines, indicating that nebulae were very tenuous, with no evidence of dense regions that could be responsible for the formation of stars and planets. Plummer pointed out that there might be a mechanism causing spectroscopes to indicate false densities; however this was speculation and unless some evidence could be found to justify it, the tenuous nature of all the nebulae studied would appear to rule out the nebular hypothesis.

Plummer then listed some other difficulties with the nebular hypothesis:

- In order to form a body such as the Sun at high temperature, the gas of the nebula must be at high temperature, but there was no obvious mechanism to achieve this.
- The gases identified in the nebulae were not adequate to form a star and planets similar to the Solar System: other materials were required in addition.

Plummer proposed that comets could both provide an explanation for the high temperature of the nebula and act as a vector to bring fresh materials from outside into the nebula. In order for his theory to be plausible, it was necessary that the nebulae were at not too great a distance from the Solar System, and that comets had an appreciable mass, so he first developed arguments to support these suppositions.

He argued that the nebulae were relatively close to Earth, in fact closer than some of the fixed stars. He could not offer any direct supporting evidence, so his argument was an indirect one as follows. Although astronomers originally thought of many star clusters as nebulae, the advent of spectroscopy and large telescopes showed that in fact star clusters and true *gaseous* nebulae were quite different classes of objects; therefore the fact that some examples of the former were situated at great distances did not signify that the latter were too. Further, if the nebulae were at a significantly greater distance than the nearer fixed stars, they would be so much larger than the Solar System as to make the latter quite unique. Plummer noted rather wishfully: *the mind experiences a sense of relief in believing that the nebulae are our nearest neighbours…* As a corollary, Plummer concluded that the nebulae were almost within range of the comets which visited the Solar System.

Plummer then challenged the notion that comets have insignificant mass. In 1842 Encke estimated the mass of the comet which bears his name (Encke's Comet, 2P) by estimating the perturbation that it caused in the orbit of Mercury, and concluded that the mass of the comet was negligible compared to that of the planet. However, Plummer noted that Encke's comet had made many revolutions around the Sun, on each one losing some of its mass. Similarly, in 1767 and 1779, Lexell's Comet (D/1770 L1) passed close to Jupiter but did not noticeably perturb the Galilean satellites. Laplace estimated that Lexell's comet had less than 0.02% the mass of the Earth. However, Lexell's Comet was also a short period comet which could reasonably be expected to have lost much of its initial mass. Plummer noted that comets in their orbits are accompanied by streams of meteors, and may be composed at least in part of a dense aggregation of meteors. He concluded that comets may indeed carry appreciable mass.

Plummer next tackled the issue of whether comets were capable of supplying nebulae with the materials necessary to form suns and planetary systems. He noted that comets have various compositions. Astronomers undertaking spectroscopic analysis had detected carbon in three or four comets out of a considerable number examined. Some other comets exhibited spectra similar to that of carbon. Plummer hypothesised that many comets may be similar in composition to meteorites, which had been shown by chemical analysis to consist of many terrestrial elements, especially iron, which were not found in the spectra of nebulae.

Laplace did not assign comets a significant role in the nebular theory. However, he believed that if a comet encountered a nebula, friction would cause it eventually to spiral in to the centre of the nebula. Plummer argued that when a nebula assimilated a comet in this way, the result would be the liberation of much heat from friction as the material of the nebula retarded the comet and from the chemical reaction between the material of the comet and that of the nebula. Plummer admitted that *we cannot pretend to explain the exact chemical effects produced* but went on to assert confidently that *in any case, an enormous development of heat is certain to result*. He noted that *Those familiar with the extraordinary convolutions of many of the nebulae will not fail to see how easily many such appearances may be explained, by imagining a long stream of meteoric bodies in the track of a comet pouring into the nebulous matter, and being retarded and absorbed in their passage through it*. Plummer believed that the chemical reaction between the comet and nebula would generally produce a liquid rather than gaseous result – the evidence for this was the faint continuous spectrum which accompanies the bright emission lines in many nebulae. In any case, the comet inside the nebula would form a point of locally increased density, and after a nebula absorbed a large number of comets and meteor streams it would comprise the remnants of the original gaseous constituents, within which were located many liquid nuclei all tending towards the common centre of mass in spiral orbits, the centre itself being occupied by a brilliant, white-hot, liquid or gaseous mass. Such a nebula would have a much higher temperature than one which had not been subject to cometary bombardment; the high temperature would tend to retain a region of gaseous material, counteracting the increased gravitational pull from the liquid centre. Eventually, a nebula might evolve into either a gaseous object, with the intense heat at the centre vaporising the liquid nuclei, or into a compact liquid mass: Plummer speculated that a considerable number of the latter objects awaited discovery. However, he conceded that there was evidence for gaseous nebulae, for example, telescopes could not resolve M31 (the Andromeda Nebula) and spectroscopes showed that it had an anomalous spectrum, which he interpreted as (weak) evidence that it contained a gaseous centre with an essentially continuous spectrum.

Plummer then explored the final stages of creation of the planetary system. As each comet entered a nebula the mass and hence the force of gravitational attraction produced by the latter grew, increasing the likelihood of it capturing further comets. Eventually, presumably through chemical reactions leading to the formation of liquid nuclei (Plummer did not state the supposed mechanism for this), little of the gaseous matter would remain, and the comets would describe their orbits around the newly-formed sun. The radiating sun would lose heat, but this would be offset by the accretion of material from incoming meteors and comets. Plummer speculated that the Sun might be a nebulous star surrounded by a greatly extended atmosphere, containing a large number of orbiting meteoric bodies visible as the zodiacal light. The meteoric bodies, falling into the Sun, provided a means of maintaining the energy production of the latter. He quoted a *universally held belief* that the solar heat is increased during years noted for large comets and stated that this might be explained by large comets bringing increased quantities of meteoric material into the Solar System, contributing to the heat output of the Sun.

He also noted that there was much evidence that the nearer and larger planets, when near perihelion simultaneously, had an effect on the solar surface by producing sunspots and other phenomena, and that these in turn affected the energy output of the Sun. He argued that this made it more plausible that comets, which could approach the Sun much closer at perihelion than any planet, could also affect solar radiation.

In conclusion, Plummer noted that understanding the role of comets was one of the key questions of science of the time. Adopting an overtly religious perspective he stated that *Every known body in the universe appears to have an important and appropriate function to perform in the development or maintenance of systems like our own…* and positioned his work as uniting the theories of others into a consistent whole.

From a modern perspective, there are major problems with the nebular hypothesis. In particular, it indicates that the Sun should be spinning so fast as to be on the verge of rotational instability and it cannot explain why the Sun accounts for almost 99.9% of the mass of the Solar System but only 2% of its angular momentum. Further, more refined calculations than were possible in Laplace’s era indicate that the rings of material shed by the rotating nebula would not have formed planets. However, modern theories are in general modifications of Laplace’s theory, and in the late 1990s images by the Hubble Space Telescope showed emerging proto-planetary disks (*proplyds*) forming around stars in the Orion Nebula.

Plummer’s idea to invoke meteors and comets as a mechanism to explain the longevity of the Sun was in widespread circulation at the time. In his textbook [1873a] Plummer stated that the amount of material incoming to the Sun via comets and meteors necessary to balance the energy lost through solar radiation in a year equated to a layer 7.3 m (24ft) deep over the entire solar surface. Although at first sight this appears like a significant flux of material that would be associated with large numbers of comets and meteors visible to observers on the Earth, a simple calculation indicates that it equates to a layer of material only 0.16 mm thick at the distance of the Earth from the Sun.

Plummer gave no details of the assumptions used to calculate the required annual material deposition on the Sun to balance the radiated energy loss. However he appeared to rely at least in part on the comets and meteors falling into the Sun bringing kinetic energy with them. If it is assumed that the Sun produces heat by ordinary combustion, the amount of coal or equivalent material necessary to replace that lost through burning annually would equate to a layer 57 km deep over the entire solar surface[1] (equivalent to a layer over 1 m thick at the distance of the Earth from the Sun).

Finally, the paper [1875d] may provide a clue as to why Colonel Tomline decided [1875e] that Orwell Park Observatory would concentrate primarily on *observation of comets, both periodical and occasional*. Plummer clearly believed that comets and meteors played an important role in the formation of the Solar System and the longevity of the Sun and were therefore worthy of study, and this view may have influenced Tomline in defining the role of his observatory.

A1.2 Dialogue With Croll On Sustaining The Solar Output

Croll proposed in *Nature* [1878a] a mechanism to sustain the longevity of the Sun. He noted that both palaeontology and geological evidence indicated that the Sun must have sustained its radiant output for a very lengthy period of time. He quoted Professor Haeckel, *one of the highest authorities on the subject*, as indicating that evolutionary theory might require aeons measured in trillions of years (10^{12} years) to effect its transformation of species. Croll claimed to have demonstrated, based on geological evidence, that the Earth must be at least 90 million years old, but unfortunately, the physical theories current at the time showed the Sun to be much younger than this.

Croll quoted the radiant power density of the Sun as 7000 HP/ft^2, equivalent to 56.2 MW/m^2 in SI units, comparable to the modern accepted figure [1989a] of 62.9 MW/m^2. He noted that were the Sun composed of coal, combustion would support the estimated rate of solar radiation for only some 5000 years. Astronomers regarded gravitational collapse, a theory propounded by Helmholtz, as an additional source of heat energy – however, detailed calculations indicated that the energy liberated by contraction of a nebula to an object the size of the Sun could have been responsible for at most 20-30 million years' worth of solar radiation.

Croll noted that the radiation energy of the Sun (indeed of any star) was determined in part by the initial temperature of the nebular mass which coalesced to form it. A higher initial

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[1] Based on an assumed energy density of coal of 34.8 GJ/m^3 [2007c].

temperature would result in a higher temperature star, with greater energy to radiate. Croll then invoked kinetic energy as a mechanism to explain a high initial temperature. The kinetic energy associated with a given mass varies as the square of the velocity according to the formula $E = ½mv^2$, where E = kinetic energy, m = mass, v = velocity. By assuming an appropriate velocity, Croll could associate an arbitrary kinetic energy with a mass. Were two such masses to collide head on, instantaneously their sum kinetic energy would be converted into heat, which would radiate into space. By choosing appropriate initial velocities for the two masses Croll could thereby arrange for an arbitrary release of heat energy at the moment of impact.

Croll provided some numerical examples. He postulated two bodies, each half the mass of the Sun, projected directly towards one another at the same speed and approaching head on. The bodies collided and converted their kinetic energy into heat, which they then radiated into space. He calculated the time taken to dissipate the heat energy created in the collision at the estimated rate of solar radiation. (He did not address the obvious question of how the rate of dissipation was limited in this way.) He made an allowance for the effect of gravity in speeding up the final approach velocity of the bodies beyond the initial velocity at which they were projected one towards the other: this he estimated at 440 km/s (274 miles/s), but his reasoning here is unclear. Table 22 summarises Croll’s examples.

Projected Velocity (km/s [miles/s])	**Final Approach Velocity (km/s [miles/s])**	**Time That Energy of Collision Could Power the Sun (million years)**
325 [202]	765 [476]	50
1090 [678]	1610 [952]	200
2735 [1700]	3175 [1974]	800

Table 1. Energy released during head-on collision of bodies.

By way of putting his assumed approach velocities into context, Croll noted that a Sun-grazing comet in an elliptical orbit extending at aphelion to the orbit of Neptune would attain a velocity of 630 km/s (390 miles/s) at perihelion. Croll quoted the escape velocity of the Solar System as 645 km/s (400 miles/s) close to the modern figure [1994a] of 617.7 km/s.

Croll struggled to dismiss the obvious question: where did the two bodies get their initial motions? He believed that it was as easy to conceive that such bodies were always in motion as to conceive that one or other was at rest. In the vastness of the universe, he stated, *the difference between a motion of 202 miles per second, and one of 1,700 miles per second to a great extent disappears, and the one velocity becomes about as probable as the other*. He envisaged a large number of non-luminous bodes in motion through space, only generating light when they collided to form visible nebulae and stars.

Plummer [1878b] responded in *Nature* one month later. He congratulated Croll on the *boldness and originality* of his theory, and then noted that *the great majority of scientific men* believed in both the theory of evolution and the nebular hypothesis, although there were serious difficulties with both. Both theories would be strengthened if it were possible to dovetail them together, but Croll had failed to do so. Having thus dispensed with the pleasantries, Plummer went on to disparage Croll's ideas!

He noted the two main difficulties with Croll's hypothesis: the improbability of two rapidly moving bodies colliding, and the lack of observational evidence of such collisions. He noted that the Sun's motion through space was 6.5 km/s (4 miles/s), that stellar proper motions exceeding 50 km/s (30 miles/s) were rare, and that there was probably no well authenticated case of a stellar velocity exceeding 65 km/s (40 miles/s). While it was possible that the solar nebula derived its heat from the collision of two rapidly moving bodies which resulted in a very low net motion, it was not credible that the net motion from such collisions should always be below 65 km/s.

Plummer went on to note that the initial intense heat generated by the collision of two fast moving bodies would rapidly dissipate into space, and that such a collision mechanism could not provide an explanation for the longevity of the Sun, for which a mechanism for continuous generation of heat was required. Helmholtz's theory of solar gravitational contraction could be one such mechanism, but Plummer believed it to be insufficient on its own. He drew attention to his ideas expressed in [1875d] for other mechanisms to provide continuous heat generation.

At this point, rather inconclusively, the correspondence between Plummer and Croll ended.

A2 Light Of The Stars

As astronomers used ever more powerful telescopes to probe the night sky to fainter magnitudes, the number of stars visible increased rapidly. In 1877, E J Stone (Her Majesty's Astronomer at the Cape of Good Hope) considered why this might be so [1877c]. He quoted a table of measured stellar parallaxes from Sir John Herschel's *Outlines of Astronomy* which exhibited a range in excess of 20:1, from 0".976 for α Centauri to 0".046 for Capella. The range of stellar parallaxes equated to an equivalent range of stellar distances. However, Stone noted that measurements of parallax less than 0".1[2] could not be made reliably, and in fact, he expressed confidence that the table represented in reality only a range of 10:1, making an allowance for the numerical inaccuracies of the values under 0".1. However, he believed that there was no empirical evidence of a stellar distance limit equating to a parallax of circa 0".1 and in fact he believed that the range of stellar distances was unbounded.

Stone inclined to the view that distance was the principal determinant of the apparent brightness of the stars. He developed a mathematical model of stellar apparent luminosities based on the following three simplifying assumptions:

- The distribution of stellar intrinsic luminosities was a finite set of discrete values {1,…,n} rather than a continuum.
- There were equal numbers of stars of each intrinsic luminosity.
- The distribution of stars in space was isotropic and homogeneous.

He applied straightforward geometric arguments to estimate the distribution of stellar apparent magnitudes. He used empirical estimates of the distribution of stellar apparent magnitudes by Sir John Herschel and by Richard Carrington[3] to enumerate two versions of his model with different calibrations. Herschel adopted α Centauri as the standard of brightness and his data covered the range from the brightest stars down to magnitude four, during which he adopted the brightness ratio of 1/(n+0.414) to define the brightness of a star of magnitude n in relation to that of α Centauri. Stone extended the use of Herschel's ratio to magnitude six. Carrington's data covered magnitudes five to nine, with a ratio of 1/2.75 between the brightness of a star of magnitude n+1 and that of a star of magnitude n. Stone extended the use of Carrington's ratio to cover the range of magnitudes one to nine. In both cases Stone normalised his model so that it agreed exactly with the number of stars of magnitude one in Argelander's *Durchmusterung* catalogue, namely 20.

Stone then compared the predictions of his model with the distribution of stellar magnitudes in the *Durchmusterung*. Figure 23 summarises the results. By construction, Stone's model agreed with the number of stars of magnitude one in the *Durchmusterung*. When calibrated with Carrington's data, the model showed generally good agreement with the *Durchmusterung*. When calibrated with Herschel's data, agreement was less good, and

[2] Equates to a distance of 32.6 light years.

[3] Famous for the determination of the rotation period of the Sun.

the range of predictions much reduced. Stone considered that in general terms, his model was a *somewhat close approximation to the truth*. However, he cautioned that it applied to the statistical mass of stars and did not indicate whether any particular star of a given magnitude was relatively close to or distant from the Earth. Note that Stone's model, calibrated with Carrington's data, underestimates the number of stars of magnitude nine by more than 39,000; however he noted that *this discrepancy is not greater than would arise from an uncertainty of estimation of about a tenth of a magnitude at the end of the scale*.

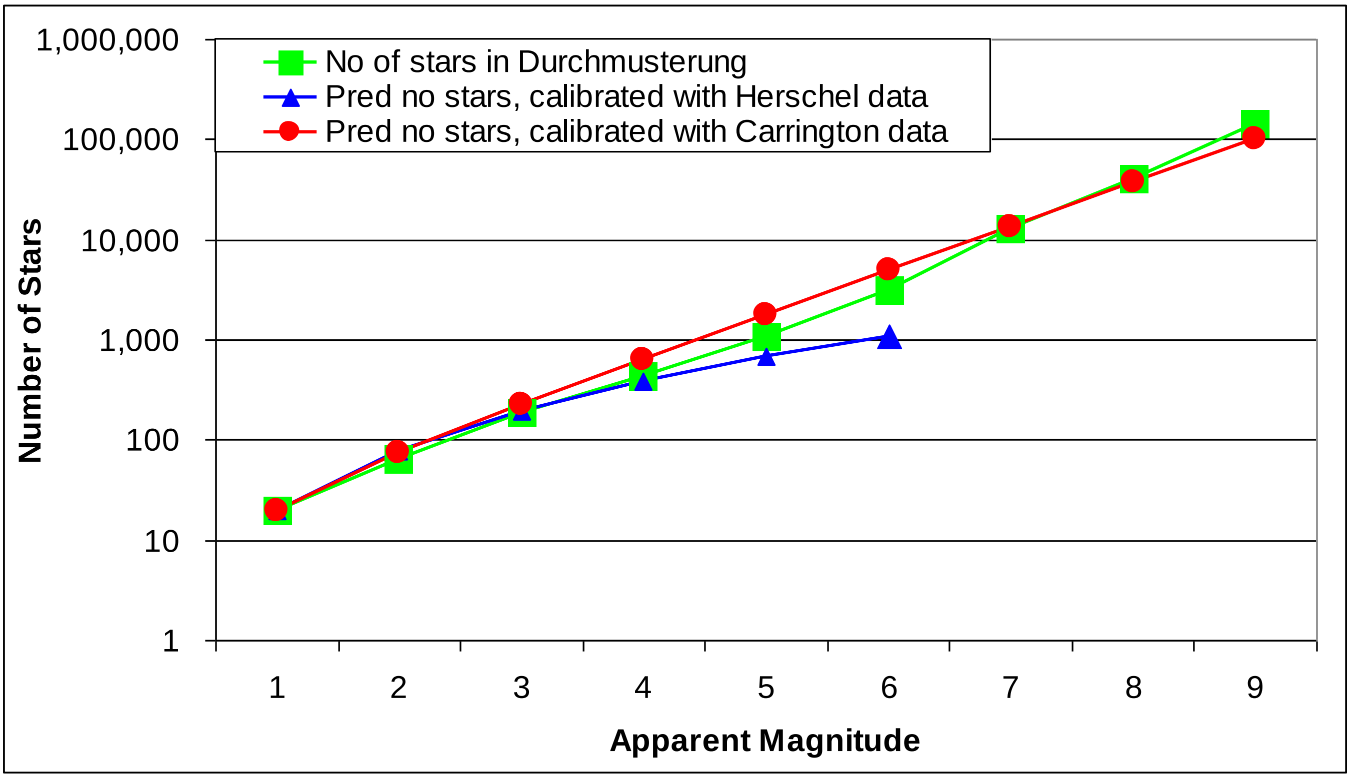

Figure 1. Distribution of stellar apparent magnitudes (Stone).

Plummer [1877d] responded promptly to Stone in the pages of MNRAS. Plummer had been undertaking work to determine the combined brightness of all the stars in the heavens and in doing so had found a deviation from Stone's conclusion for stars around magnitude nine.

Plummer stated that the number of stars at each magnitude was well understood, and that all stars, no matter how faint, contributed to the general illumination. He tabulated, for each magnitude class in the *Durchmusterung*, the number of stars in the northern hemisphere together with the number of magnitude six stars that would give an equivalent light level – see table 23. Note that Plummer followed Littrow in defining the magnitude classes each to be of unit range, except for magnitude class nine which spanned the range 9.0 to 9.5.

Magnitude class	Lower Limit Mag	Upper Limit Mag	No of Stars in *Durchmusterung*	Equivalent no of mag 6 Stars
1	1.0	1.9	10	647
2	2.0	2.9	37	957
3	3.0	3.9	130	1,345
4	4.0	4.9	312	1,291
5	5.0	5.9	1,001	1,657
6	6.0	6.9	4,386	2,904
7	7.0	7.9	13,823	3,661
8	8.0	8.9	58,095	6,154
9	9.0	9.5	237,131	12,069
		Total	**314,925**	**30,685**

Table 2. Summary of magnitude classes in the *Durchmusterung*.

Plummer then performed some calculations relating to stellar magnitudes, using the brightness of a sixth magnitude star as standard unit. He noted Pogson's ratio 2.512 between the brightness of stars with a difference in magnitude of precisely 1.0 (the basis upon which the modern magnitude scale is based) but in performing the calculations adopted instead the rounded value 2.500, presumably to ease the arithmetic. He was easily able to calculate that on a fine night under the northern sky, roughly ¾ of starlight came from stars individually invisible to the naked eye, and the total illumination from stars down to magnitude 9.5 was equivalent to 10.2 times that of Venus at greatest brilliance, or to 1.3% that of the Full Moon.

Plummer noted a difficulty with fainter stars. He found that if their numbers increased in the same ratio as obtained for brighter stars, *only a small portion of the stellar light has been here taken into account*. In fact, unless some other factor intervened, the total brightness of all the stars would be infinite, and the night sky would be brilliantly illuminated (this is the well-known Olbers' Paradox).

To investigate further, Plummer developed a simple model of the bulk characteristics of northern hemisphere stars down to magnitude 9.5. He assumed that stars in this magnitude range were uniformly distributed and could each be considered to be of average intrinsic brightness, with each star's apparent magnitude therefore defined by its distance. With these assumptions, he was easily able to calculate the relative proportion of stars of each apparent magnitude class. To calibrate the model, he set the proportion of stars in apparent magnitude class eight (stars in the magnitude range 8.0 – 8.9) in the model equal to the proportion of stars in the same magnitude class in the *Durchmusterung*. This enabled him to predict the number of stars in every other magnitude class.

Figure 24 illustrates the results, showing:

a) the distribution of stellar magnitudes of northern hemisphere stars in the *Durchmusterung*,

b) the theoretical distribution of stellar apparent magnitudes that would result if all the stars in the *Durchmusterung* were uniformly distributed and of average intrinsic brightness with apparent magnitude determined by distance,

c) Plummer's model: the distribution as in (b) calibrated such that the density of stars in magnitude class eight agreed precisely with the *Durchmusterung*.

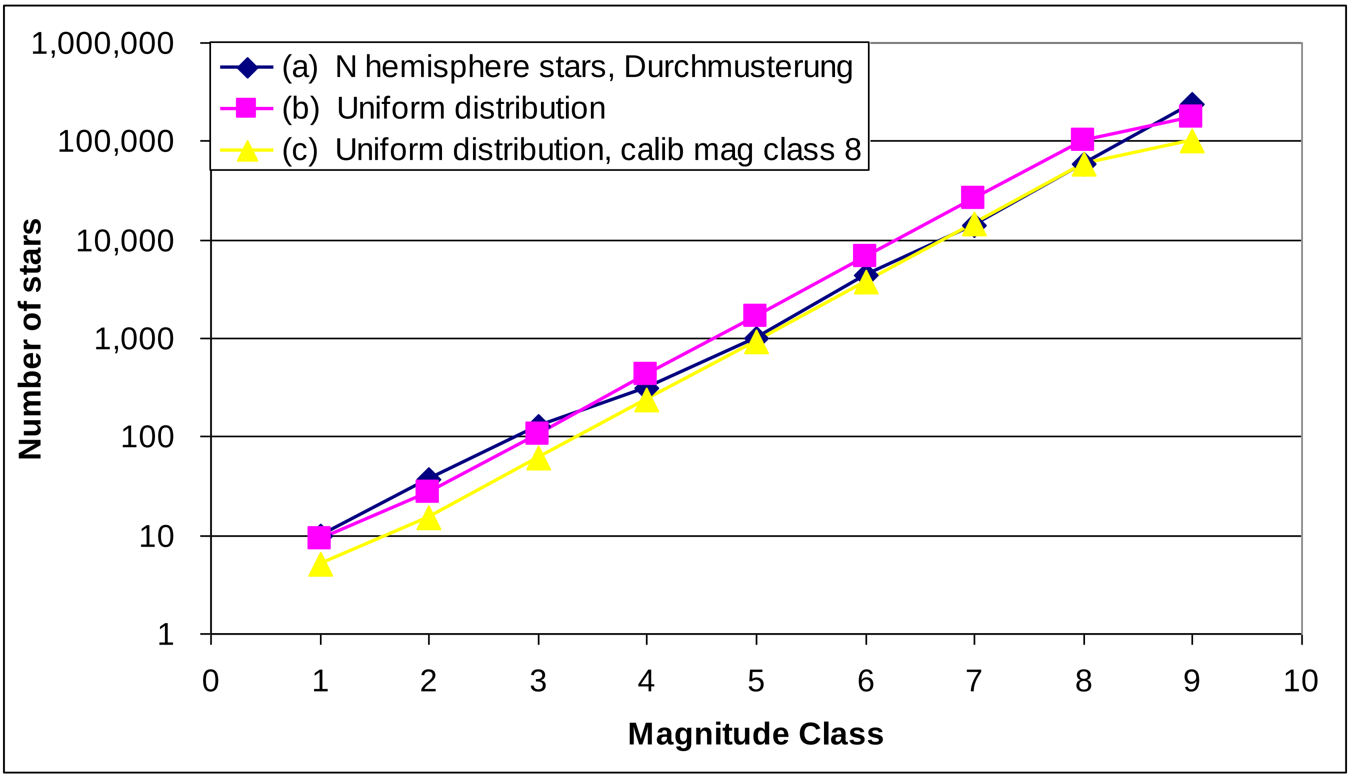

Figure 2. Distribution of stellar apparent magnitudes (Plummer).

Note that although curves (b) and (c) both model the overall form of the distribution of stellar magnitudes tolerably well, they predict significantly different numbers of stars from the *Durchmusterung* in particular magnitude classes. The *Durchmusterung* contains only 489 stars in total in magnitude classes one to four inclusive, and with such a low number, major discrepancies from the predictions of mathematical models in these classes has no great significance. However, magnitude class five contains 1001 stars and fainter magnitude classes contain increasingly large numbers of stars, and in this realm it is possible to compare the results of models with the empirical counts of stars without undue risk of excessive statistical variability.

Curves (a) and (b) together indicate that the *Durchmusterung* contains more stars in magnitude classes one, two, three and nine and fewer in the other magnitude classes than a uniform distribution predicts. Some of the discrepancies are significant: for example in magnitude class seven a uniform distribution predicts 89% (12,267) more stars than are present in the *Durchmusterung* and in magnitude class nine there are 25% (60,264) more stars in the *Durchmusterung* than predicted by a uniform distribution.

Plummer’s model (curve (c)) consistently and significantly underestimates the number of stars in the *Durchmusterung* in magnitude classes one to six inclusive. In magnitude class seven, the model overestimates the number of stars in the *Durchmusterung* by 6%. In magnitude eight the model agrees exactly with the *Durchmusterung* by construction. However, in magnitude class nine the model underestimates the number of stars in the *Durchmusterung* by 59% (predicted 99,631 stars versus 237,131 in the *Durchmusterung*). Plummer stated that the comparison would have been similar had either of the four magnitude classes four, five, six or seven rather than class eight been used to calibrate the model. Reworking the calculations shows that this is indeed broadly correct.

Both curves (b) and (c) significantly underestimate the number of stars in magnitude class nine in the *Durchmusterung*. Plummer concluded from this that the magnitude estimates in the *Durchmusterung* were incorrect and the catalogue contained many stars which although rated of magnitude class nine were in fact fainter, or there existed an unexpectedly dense stratum of stars at a distance from Earth corresponding to magnitude class nine. In any case, he recommended further investigation.

J L E Dreyer [1877f] responded to Plummer. He pointed out briefly that a report by Professor Shönfeld in Bonn describing work to extend the *Durchmusterung* to the south indicated a slightly different classification of the faintest stars compared to that employed originally. In the new scheme, the old magnitude 9.4 equated to magnitudes 9.4 and 9.5; and the old magnitude 9.5 equated to magnitudes 9.5 - 10.0.

Plummer responded [1877g] with a brief paper describing the effect on his previous analysis if the 237,131 stars in magnitude class 9 of the *Durchmusterung* were considered distributed evenly over the magnitude range 9.0-9.9 or 9.0-10.0 rather than 9.0-9.5 as assumed previously. The effect was to provide a much improved fit between the number of stars in magnitude class nine in the *Durchmusterung* and that predicted by a uniform distribution of stars, either normalised to magnitude class eight or not (curves (b) and (c) above respectively).

However, the precise lower limit of the faintest magnitude stars in the *Durchmusterung* was uncertain. Plummer had no definitive view on this, and proposed further research to address the question. One of his proposals was to use the brighter minor planets as a means of comparing the magnitudes of the fainter stars with those of the brighter stars, although he did not give details of how to accomplish this.

It is interesting to rework Plummer’s analysis with modern star catalogues. Unfortunately there is no single modern star catalogue which provides both comprehensive coverage at faint magnitudes and accurate estimates of the magnitudes of the brightest stars. It is possible to overcome this difficulty by creating a compilation from several star catalogues, each providing data for a specific magnitude range. This is the approach adopted below. Table 24 lists the catalogues used to create the compilation and the magnitude range and associated number of stars drawn from each.

Catalogue	Magnitude range	No of Stars Used
Hipparcos [1997b]	2.0 – 6.9	15,405
Tycho 2 [1997b]	7.0 – 11.9	1,914,977
USNO A2.0 [1996b]	12.0 – 18.9	440,026,674
	Total	**441,957,056**

Table 3. Star catalogues used to extend Plummer's analysis.

Figure 25 shows the following distributions of stellar apparent magnitudes over the range -2.0 to 19.0:

a) The empirical distribution of stars in the *Durchmusterung*. (As curve (a) in fig. 24.)

b) The theoretical distribution based on an assumption that the stars are uniformly distributed and can each be considered to be of average intrinsic brightness, with each star's apparent magnitude defined by its distance. (Same methodology as used to generate curve (b) in figure 24.)

c) The distribution of stars in the compilation of modern star catalogues described above.

Note that whereas the *Durchmusterung* covers only the northern sky, the compilation catalogue covers the entire sky.

Clearly, although the compilation catalogue based on modern star data provides far superior coverage and depth to the *Durchmusterung*, over a range of 20 magnitudes its distribution of magnitudes deviates significantly from the theoretical distribution.

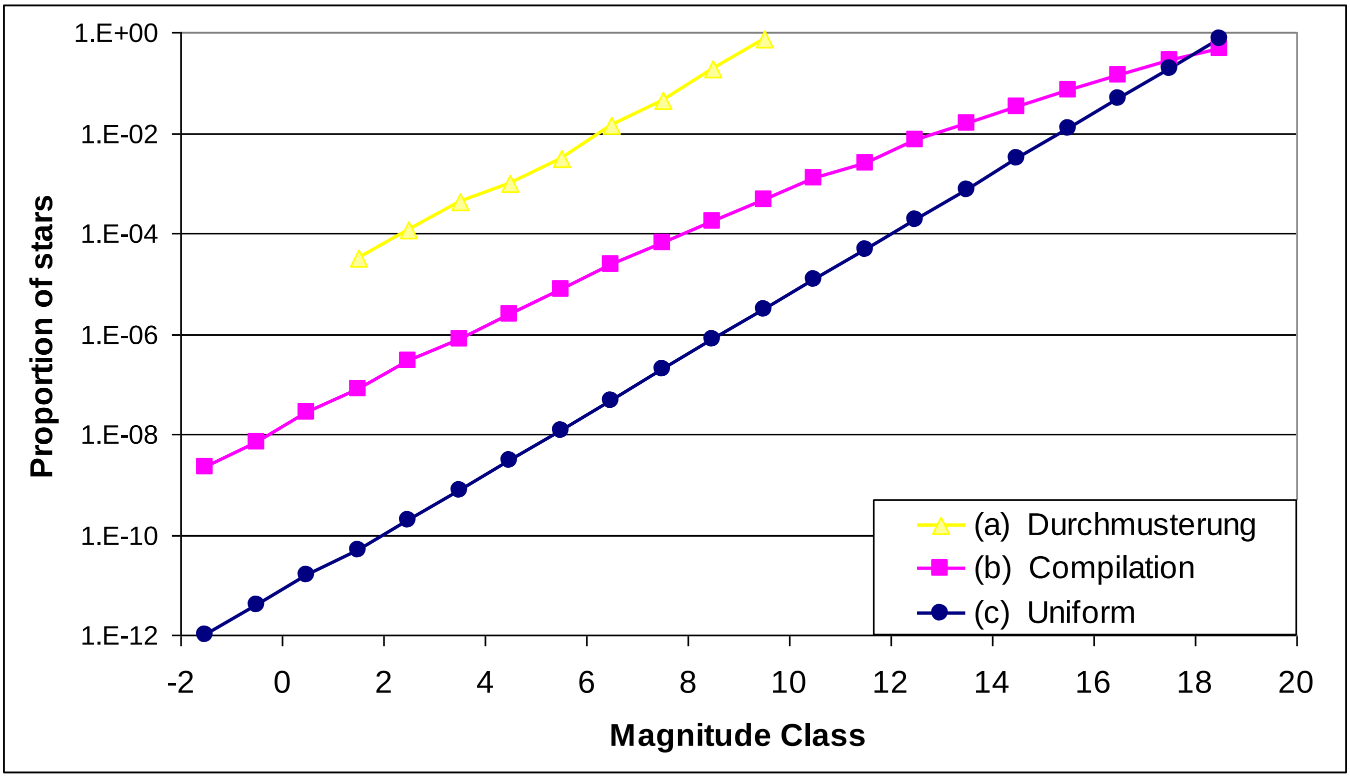

Figure 3. Distribution of stellar apparent magnitudes (modern reworking).

Plummer's approach appears hopelessly naïve by modern standards. However, Plummer was hampered by three factors that we now take for granted:

- In 1851, Lord Rosse discovered the spiral structure of M51, and this created some speculation as to whether such spiral nebulae might be distant galaxies similar to the Milky Way. However, by 1905, Agnes Clerke in *The System of the Stars*, declared confidently that all nebulae were part of the Milky Way, forming a single aggregation of matter in the Universe. It was not until the 1930s, through the work of Hubble and others, that the reality of galaxies as *island universes* was accepted. Plummer's approach fits with the notion that the Milky Way constitutes the entire Universe, and does not take account of the granularity of stellar structures on the largest scale.
- It was only some 20 years prior to Plummer's paper that Pogson had proposed (in 1856) the ratio 1.2512 of brightness between stars whose magnitudes differs by exactly 1.0. The magnitude scale had not become fully established at the period in question and this is reflected in the uncertainty over magnitude classes that Plummer adopted.
- The science of astrometry was not well developed. Whereas astronomers nowadays have ready access to all-sky catalogues containing precise positional data on hundreds of millions of stars, the situation in Plummer's era was quite different. Automated techniques for estimating magnitudes were not available and subjective errors could affect the magnitude estimates of observers.

A3 Miscellaneous Astronomical Publications

Plummer published three astronomical papers which do not fit into the previous categories. The following subsections provide summaries.

A3.1 Astronomical Nomenclature

In a brief article in MNRAS in 1876, Plummer [1876c] expounded proposals for a new nomenclature for minor planets and stars. For minor planets he proposed a nomenclature based on the order of discovery and a class indicating the brightness at opposition: thus, for example, Pl.IV.107 would indicate a planetoid of the 4th magnitude class, 107th in order of discovery. For labelling naked eye stars in constellations he proposed to employ three magnitude groups (a, b, c), take stars in RA order within each group, and number the stars 1-100 in group (a), 101-200 in group (b) and 201-400 in group (c). The numbers would be written after the nominative form of the constellation. Thus for example Canis Major 129 would be the 29th star in RA order of the second magnitude class.

Needless to say, the astronomical community at large adopted neither of Plummer's schemes. In fact, it is difficult to believe that he could seriously have expected any different reaction!

A3.2 Stellar Distance Scale

In a very brief paper in 1890, Plummer [1890d] noted an interesting coincidence. On a scale where the Earth-Sun distance is represented by one inch, the distance of an object from the Earth in light years (ly) is very close numerically to its distance in miles. This scale provides an intuitive idea of the isolation of the Solar System in space - for example, the distance 7.464 ly to the relatively nearby star 61 Cygni is represented by 7.499 miles.

A3.3 Photometry

Following his successful measurement of the brilliance of Venus in early 1876 (see Appendix 8.3), Plummer [1877b] entertained the hope in his annual report to the RAS for 1876 that he would be able to undertake stellar photometry in 1877.

In fact he did not report any stellar photometry work during 1877. However he did report [1877e] unsuccessful attempts to make photometric estimates during the lunar eclipse of 23 August 1877. He set out to measure the light from the Moon during the eclipse and that immediately after the eclipse so as to compare the sunlight received directly by the Moon with that refracted onto the Moon by the Earth's atmosphere. He hoped to use his observations to understand better the variation in intensity of lunar eclipses.

He used the technique described in Appendix 8.3 ([1876f]). Fundamentally his approach was to use a Bunsen photometer and a Romford photometer to compare the intensity of shadow cast by the Moon with that cast by a standard spermaceti candle at known distance. Unfortunately, the maximum distance that he could place the candle was 125 m (135 yards) and at the start of totality this proved insufficient to provide an intensity of shadow equal to that of the Moon. He concluded that the light of the eclipsed Moon was certainly less than 0.04% that of the uneclipsed Full Moon and was probably less than 0.02%.

At this time, Mars cast a shadow of intensity midway between that of the eclipsed Moon and the candle at 290 m (315 yards). The shadow cast by Mars was much sharper than that cast by the Moon.

He reported that at mid-totality the eclipsed Moon became dimmer, and its shadow was similar in intensity to that of Sirius, which he stated had an intensity 0.013% that of the Full Moon. Plummer did not state the source of this figure, but it appeared to be based on his previous photometric results to estimate the brightness of Venus at greatest brilliance as a proportion of the mean Full Mean [1876f]. In the earlier work, Plummer estimated empirically that the intensity of Venus was 0.125% that of the Full Moon, and he stated (without supporting measurements) that the intensity of Sirius was approximately 1/9th that of Venus. Combining these two figures gives the intensity of Sirius as 0.014% that of the mean Full Moon. The corresponding modern value, computed from magnitude data in [1989a] is 0.0032%.

Plummer's observations during the egress phase of the eclipse indicated a rapid increase of brightness during that time.

In his annual report to the RAS for 1877, Plummer [1878c] noted that although his efforts at lunar photometry on 23 August 1876 were *only partially successful*, they did show that the Earth's atmosphere refracted only a small fraction of the Sun's light into the lunar shadow cone. He also stated that he found it *necessary to postpone entirely for the present the project to determine the photometric value of the magnitudes of the fainter stars.* Unfortunately, Plummer gave no details of why this was so.

--- To be continued ---