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Going, going, gone. The Lake Murray meteorite on show prior to auction on 2009-08-18 in Edinburgh. Photograph by Angus Self.
See Angus' article on page 7.

Gravitational mass centres

Summary

The inverse square law for the action of gravity $F = m_1 m_2 G/r^2$ is well established and is applied using the formula with the separation of the masses r equal to the distance between their respective *centres of gravity*. For spheres this is the centre of the sphere, and at least for spheres with uniform density (or only radial variations), has allowed accurate calculation of the motion of (non-intersecting) bodies through the cosmos. In contradiction of widely held teachings (e.g. [1]) it is shown in what follows that the use of the *centre of gravity* (c.o.g.) for objects which are *not* spheres is unjustified. The calculations differ considerably in close-approach situations from those derived from use of c.o.g. These situations can occur with irregular asteroids, and disc or box galaxies.

Split longitudinal mass

In order to present an example without having to use anything but the inverse square law [2] and simple arithmetic, consider an observing point O at unit distance from a finite (but physically small in size) mass m.

Now imagine an object with half the mass nearer by a distance $h/2$, and the other half the same distance away, but still united as a single object by a rigid (negligible mass) connection. All "splits" hereafter have this latter context.

The nearest part will exert twice the previous force and the furthest only 2/9. The effective geometric centre (the square root of the reciprocal) will now be 0.67 instead of unity. Fig. 2 shows the calculation for an extended range of h, including the situation where the nearest mass passes the origin. The *gravitational mass centre* (g.m.c.) then moves steadily away beyond this mass's c.o.g. towards a factor of root 2 times its distance (to allow for the half-mass which now dominates if the two masses are taken as one).

Longitudinal rod

By summing a succession of split masses over a range, it is possible to derive (by integration) the g.m.c. of a small diameter rod-shaped mass pointing towards the observer, and display this as a function of its length.

It is clear in this case that, while the g.m.c. departs from the c.o.g. in a similar way to the case of the split mass, the behaviour is different once the end of the rod passes

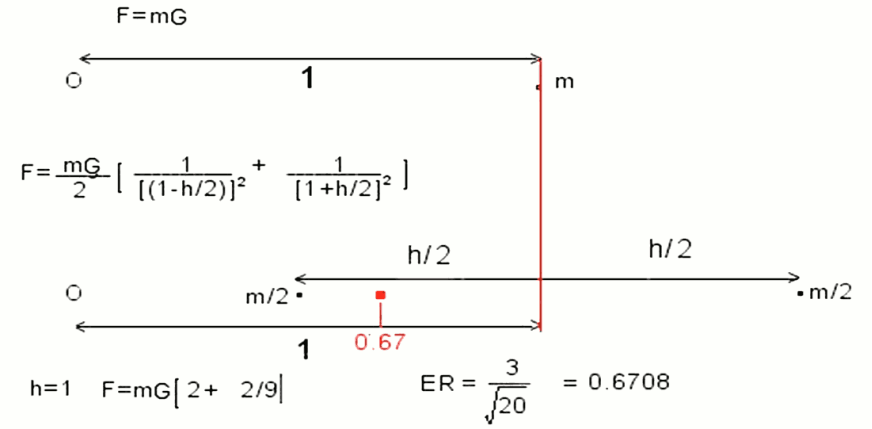


Fig. 1: Split longitudinal mass.

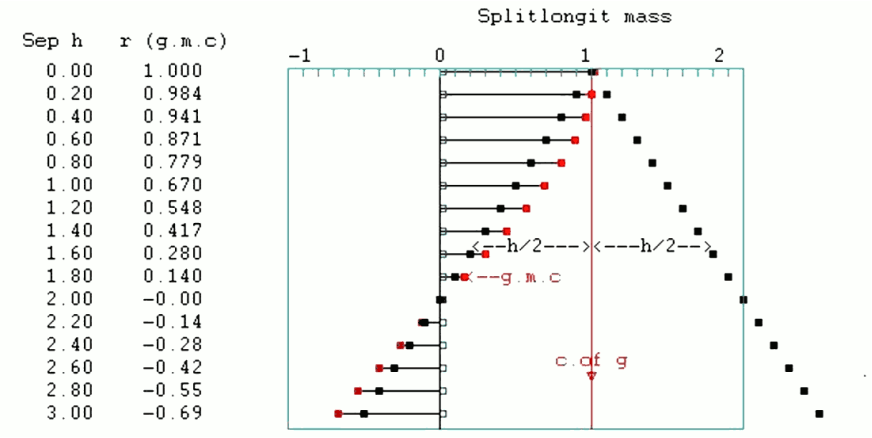


Fig. 2: Split mass object as function of separation.

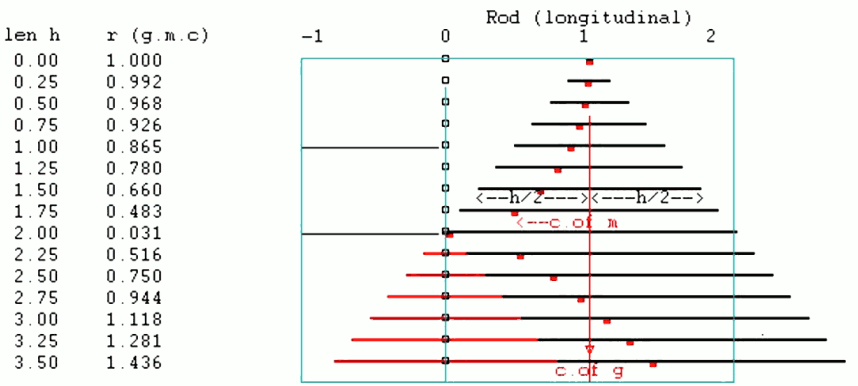


Fig. 3: End-on rod as function of length.

the observer. A well-explored feature in Newton's Principia, is the cancellation of attractions which are symmetrically disposed and equal. This clearly takes place here, the bottom left corner of the diagram (from $h = 2$) showing the cancellation area in red. The g.m.c. then moves with the *remainder* of the rod, which is outwards, and moves towards the c.o.g. of the "uncancelled" part of the rod.

Transverse split mass or ring

Due to symmetry, the g.m.c. of a ring is the same as a split transverse mass, so Fig. 4 covers both cases. As would be expected, nearby rings will have g.m.c.'s relatively further behind the c.o.g., due to the loss of axial force from the larger angles which have to be resolved in the axial direction.

Transverse rod

By integrating the masses of the last section with respect to the vertical height, the result for the transverse (thin) rod is produced as Fig. 5. There is much less force loss due to the presence of central masses, so the g.m.c. extension is less pronounced.

Transverse discs

The transverse disc is particularly simple to integrate as, after multiplying the ring elements by 2π times the radius, many of the force terms cancel out, leaving only a cosine to integrate between appropriate limits.

x	r0
0.0	NAN
0.2	2.334
0.4	1.759
0.6	1.624
0.8	1.614
1.0	1.681
1.2	1.784
1.4	1.912
1.6	2.048
1.8	2.201
2.0	2.368
2.2	2.528
2.4	2.709
2.6	2.883

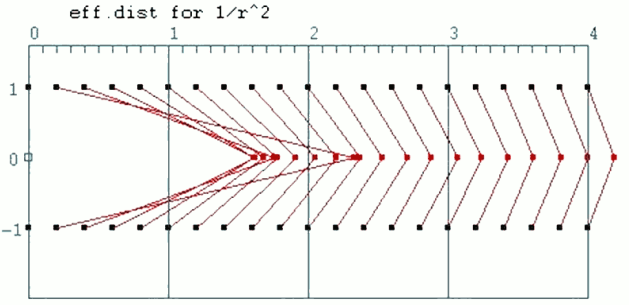


Fig. 4: The ring.

distx,	eff r/x
0.0	NAN
0.2	2.258
0.4	1.640
0.6	1.394
0.8	1.265
1.0	1.189
1.2	1.140
1.4	1.108
1.6	1.085
1.8	1.069
2.0	1.057
2.2	1.048
2.4	1.040
2.6	1.035

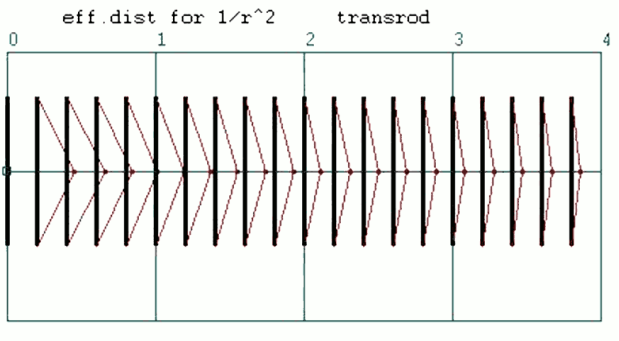


Fig. 5: The transverse thin rod.

distx	eff r/x
0.0	0.707
0.2	0.788
0.4	0.891
0.6	1.014
0.8	1.154
1.0	1.306
1.2	1.468
1.4	1.638
1.6	1.813
1.8	1.993
2.0	2.176
2.2	2.361
2.4	2.549

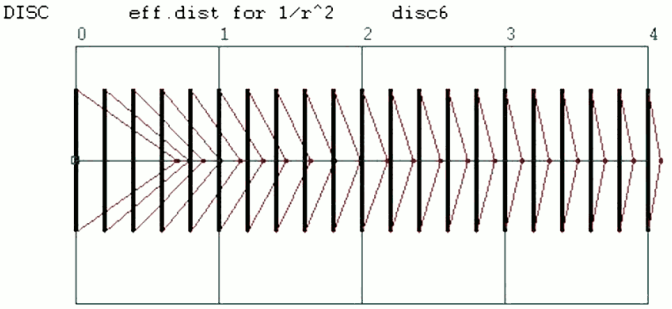


Fig. 6: The transverse thin disc.

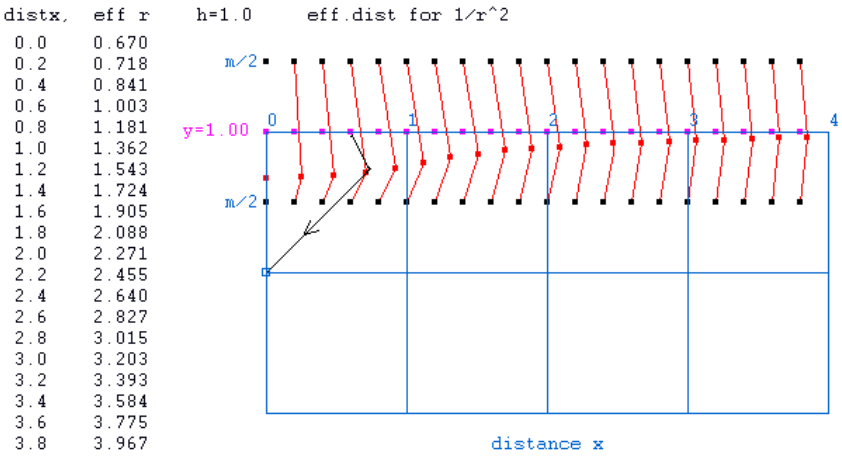


Fig. 7: The displaced split (dumbell).

Displaced and rotated objects

For simplicity the above examples have all been viewed along an axis pointing at the c.o.g. and oriented either at right angles or in-line with the view line. In the general case, the objects can present any angle, and it is worth showing the result of displacements sideways from the original axis. The mass shown in Fig. 7 has been displaced sideways by its width i.e. $y = h = 1$. The obvious and important point is that the line to the g.m.c. only approaches the c.o.g. *when the object is at* $x =$ *infinity*. In general it leans towards the nearest part of the object (as black line example shown). In such cases, the acceleration in this direction would give a *torque* about the c.o.g., and produce rotation of the object (if the object at the origin had noticeable comparative mass).

Note that the r for $x = 0$ is, as expected, the same as derived for the split longitudinal mass, i.e. 0.67.

Conclusions

The statement [1] that the geometric centre to be used for Newton's gravity formula is the centre of gravity is *only* true of separated spheres (and shells). Calculating the c.o.g. for a body involves integrating *mass times distance*, while the g.m.c. uses *mass divided by the square of distance*. Apart from spherical bodies this does not give

the same answer. I believe this misconception has come about from the difficulty of interpreting the language in Newton's Principia (see [3]) together with the display of an irregular object in Principia [4]. Close examination of the latter indicates this deals with equivalence of the objects' c.o.g. to an appropriate sphere, not to its geometric mass centre.

References

1. Andrew Zimmerman Jones (2009). "Newton's law of gravity", http://physics.about.com/od/classicalmechanics/a/gravity.htm. *About.com Physics*.
2. Isaac Newton (1687). *Philosophiae naturalis principia mathematica*, vol. 1, p. 193.
3. Michael Hoskin (1996). *The Cambridge illustrated history of astronomy*, p. 163.
4. Isaac Newton (1687). *Philosophiae naturalis principia mathematica*, vol. 1, p. 217, proposition LXXXVIII, theorem XLV.

G.M. Clarke

The Rob Elliott meteorite auction

Meteorite auctions don't happen very often in the UK. There is eBay of course, but to see a well known collection being put up for auction is very rare.

I got to know Rob Elliott in 2001 just as my interest in astronomy led towards meteorites; I was introduced to him by a fellow Astronomical Society of Edinburgh member. The person in question had been working in Oman in the oil industry and taken a week off to search for meteorites. His quest was fortuitous and a new strewnfield was found yielding approximately 100 chondritic meteorites. Some of these were distributed around the Astronomical Society members' meeting in 2000 and when I held this stone that was so incredibly ancient and had travelled from the depths of the asteroid belt I had shivers going up my spine. I felt the kind of excitement that I had felt as a teenager when I got my first Pink Floyd ticket! I needed to know more about these stones. I wanted one really badly!

I was invited to see Rob and look at his collection in Milton of Balgonie in Fife; about 45 minutes' drive from my Edinburgh home. On meeting Rob I was welcomed into his home by Irene, his wife, and shown the meteorite room. It was a large room with locks to make Fort Knox look like a tool shed, CCTV cameras, humidity control and

Campo del Cielo, 160 kg (foreground).

the most astounding collection I have ever seen. Museums don't show the majority of their collections and so the public are starved of the wealth of samples in their vaults.

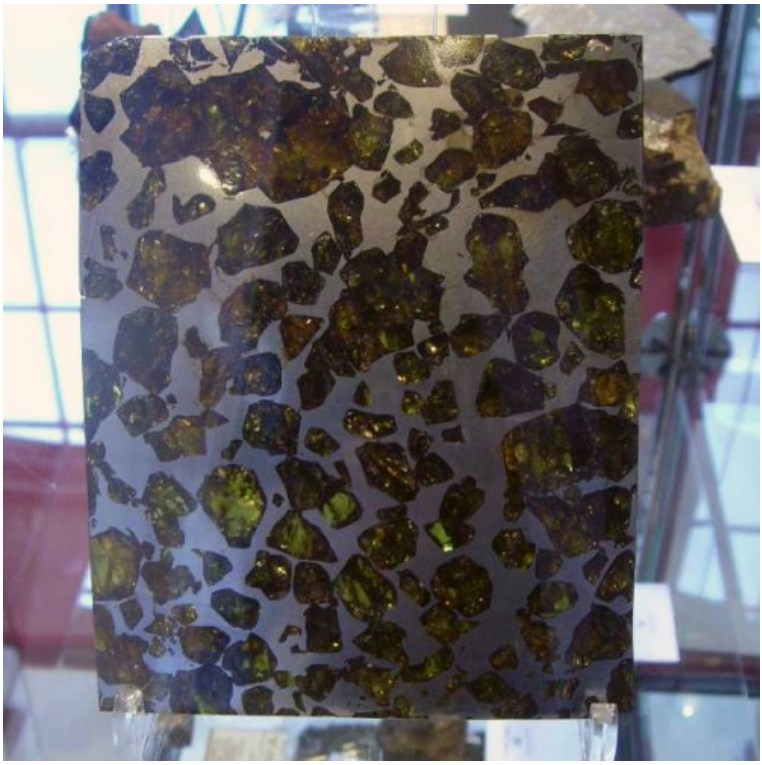
Rob kindly showed me around the various glass cases with labelled irons, pallasites, chondrites and even a Salyut spacecraft helium tank. This was where I started buying meteorites and I purchased samples of Sikhote Alin, Gibeon, Juancheng and Allende. On my next visit to see Rob he lent me a Gibeon weighing 9.5 kg and the 14.5 kg main mass of the Bechar chondrite. Big, heavy and impressive rocks that people go "wow" over. I took these to some meteorite talks that I started to give at my daughters' school, also at Rotary and Probus clubs. After several further visits to see Rob, each time adding to my collection he told me about the meteorite he and Irene had found whilst searching in the English countryside, now known as the Hambleton pallasite.

Hambleton, 5.8 kg and 725 g.

Gibeon wedding rings (top row) and Wold Cottage.

It was with quite a shock that I heard Rob was to sell his entire collection, and give up dealing meteorites. When I heard they were to be auctioned in Edinburgh I knew this was going to be an event to witness first hand. The catalogue first came to my attention through a web link on the BIMS [1] daily digest in July and then the published catalogue in print a few weeks later. The photos and details of the meteorites on auction were worth the purchase price of £ 10 and a delightful addition to the meteorite library.

I made three trips to Lyon and Turnbull in Broughton Place to view the collection prior to sale. It was strange to see the collection that I had got to recognise in another location. A bit sad as well because that was it going for good, no more trips to Rob's to gaze fondly at meteorites and have a beer or two. Also the national media had



Esquel, 383 g.

picked up on the story. I saw several newspaper articles and heard radio and TV coverage of the run up to the auction.

August 18th came around and having taken a half day from work I went into the auction room and immediately saw Rob and Irene. They greeted me like an old friend and I was able to sit with them during the auction. Rob popping away from time to time to speak to reporters from press and radio. There was even a film crew from Russia in the room! The seats were about 80% full, with desks either side of the hall for phone and Internet bidding. The sale got off to a start at 2.00pm and the bidding was very quick. The first lot was a 20.2 kg Campo del Cielo. It was sold for £1800. Several further Campos (individuals and etched slices) went but the biggie, a 160 kg individual which had taken 4 guys and a strong rug to lift in place went for £1000. It didn't have quite the aesthetic beauty of the 20.2 kg but what a door stop!

Lot 5 was an 11 kg Gao Guenie which failed to sell, but its neighbour, a 4 kg Gao, went for £800. Not bad as the catalogue was offering it from between £1800 and £2400. I was surprised that the main mass of Béchar 001 did not sell, but perhaps an

Salyut 7 helium tank.

L5 chondrite of 14.5 kg is not that much of a temptation when there is some Mars and lunar rock of less than 1 g up for grabs!

One of the big surprises of the day was the beautiful 6.95 kg Estherville slice being purchased over the phone from a buyer in Estherville, Iowa. It's going back home for the princely sum of £6800 plus a first class seat I guess.

There was a fearsome phone fight for the Zagami Shergottite 1.7 g. The reserve was £250 but it went for a colossal £600. A slice of the planet Mars will always get a good price, but I didn't expect that. And yet the same thing happened for a 0.67 g

Estherville, 6.95 kg.

fragment of Dar al Gani, a lunar breccia which went for £1100. While we're on the subject of small pieces, one of Rob's own discoveries was the Glenrothes meteorite. 0.6 g was up for sale with a reserve of £100 but it went for £400. There is only a total known weight of 14.8 g of the Glenrothes, but apparently Rob has only a few crumbs left. All has gone to collectors, museums or the person who bought probably the last piece for sale.

The oldest meteorite with a terrestrial age of 110 million years was probably my favourite. It is a 3.9 kg slice of the Lake Murray iron. A fabulous etched slice showing broad 115 mm wide bands of kamacite and taenite and with lovely "rosettes" of swirling schreibersite inclusions (see cover picture). It had lain in Antler Sandstone in Oklahoma for 110 million years prior to being found in 1933 and then recognised as a meteorite in 1952. It went for £4000.

There were two micro meteorite collections on sale with quite healthy sized pieces. The first collection, from around the world, had pieces mostly in the 15 g to 30 g range. This collection had a piece of bark from Tunguska and I felt obliged to bid

on this lot. However, it went way beyond my budget so I had to bow out gracefully. The second was of smaller pieces in the 1 g to 5 g range of American and Australian polished part slices.

Of the more unusual items on sale there were four Gibeon irons turned into wedding rings. Each one was etched and showing the Widmanstätten (Thomson) structure. Two had been gold plated and the others rhodium plated. All were sold for between £160 and £220.

All the time I was trying to take notes of which lot went for what price, but chatting to Rob and Irene made me lose my place occasionally and find I had missed several lots. Never mind, I discovered through BIMS [1] that Lyon and Turnbull have put it all on the web [2].

One of the ones that got away was the Hambleton meteorite. Of the 18 unsold items (out of 171), neither the main mass of 5.8 kg nor the polished part slice of 725 g went anywhere, but back home. Perhaps the reserve of £25k put off the punters. As Rob said to me "you need deep pockets for this one". No kidding!

However, the Salyut helium tank went off to a new home for £1650. A very fine piece of titanium with many micrometeorite impact craters pock-marking its surface. They have just the same structure as other impact craters on the Moon, Mars or elsewhere and are a fine sight in a lens, but only 1-2 mm across.

The auction ended just before 4.00pm and I had to rush away for a prior engagement with U2 at Hampden Park in Glasgow. On departing, Rob said he was pleased with the outcome and invited me over for a beer or two in the near future.

I'll take him up on his offer and I wonder what will be in the former meteorite room.

References

1. The British and Irish Meteorite Society (BIMS). http://www.bimsociety.org
2. Lyon & Turnbull (2009). *Auction sale #262, results.* http://www.lyonandturnbull.com/asp/searchresults.asp?pg=1&ps=25&st=D&sale_no=262++++
3. Cordelia o'Neill (2009). "Collector over the moon as space rock makes £113k at auction". *The Scotsman*, **2009-08-19**. http://news.scotsman.com/science/Collector–over-the-moon.5565658.jp

Angus Self FBIMS

Society news

At most Ordinary Meetings Alan Pickup gives a presentation about the sky in the forthcoming month, usually including snippets of recent news in the fields of observational astronomy and spaceflight.

On 2009-07-03, Rachel Gilmour showed us a day and night in the life of the Very Large Telescope, a group of four 8-metre telescopes at the European Southern Observatory in Chile. As our new venue is used during the Fringe, we took a summer break in August and September. On 2009-10-02, Lyndsay Fletcher gave a most interesting talk on sunspots; however, she could not yet say whether sunspots would return in significant numbers.

Autumn Moon watch

The week from 2009-10-24 to -11-01 was designated by the International Year of Astronomy as a period of autumn Moon watch. The Royal Observatory Edinburgh invited the Society to join in some of their observing events, which were supported by a grant from the Royal Astronomical Society. When approached for venues, the City of Edinburgh proposed to use the City Observatory on Calton Hill for one of the events. We welcomed the opportunity to return to the City Observatory and to use the Cooke telescope once more. The history of astronomy on Calton Hill goes back to the late 18th century. We hope that the City of Edinburgh will be able to restore the site and that then the telescope will once more be put to astronomical use.

In the end, the Society participated in two events. On 2009-10-28, Ken and Rachel Thomas took their telescope to Our Dynamic Earth. The weather was teasing at best and cloudy much of the time, but we did manage a few glimpses of the Moon through cloud and of Jupiter with the four Galileian satellites all on one side of the planet. 2009-10-31 on Calton Hill, we had quite reasonable weather, although haze moved in during the hours of observation. The Moon was quite full, and Jupiter was perhaps the more rewarding object, with Callisto casting its shadow on the planetary disc.

The Royal Observatory had organised the events such that attendees had plenty to see and do even in case of bad weather. At the City Observatory, the Society was also involved in these aspects, with David Small showing the Cooke telescope and Horst Meyerdierks showing the Fraunhofer meridian circle and speaking about the 19th century time service based on its observations. From the Society, Ken and Rachel Thomas, Vincent Balfour, Frank Howie and Alan Ellis also helped make the event a success.

Telescope to a good home

We have received the following from Bob Lovie:

> I have an 8 inch reflector on an equatorial mount with hand controls and 3 lenses, which I bought from John Braithwaite at Dalserf some years ago. I no longer have any use for it and it is therefore 'free to a good home'. ... I am on 0131-332.9801.

Forthcoming events

2009-11-06	20:00	Dr Catherine Smith
	AUC	**Robert Burns and astronomy**
2009-12-04	20:00	Douglas Cooper, Stirling Astronomical Society
	AUC	**Imaging the night sky**
2010-01-08	20:00	TBD
	AUC	**TBD**
2010-02-05	20:00	TBD
	AUC	**TBD**
2010-03-05	20:00	TBD
	AUC	**TBD**
2010-03-26	20:00	**Annual General Meeting**
	AUC	
2010-05-07	20:00	TBD
	AUC	**TBD**

AUC:

Augustine Church Centre,
41 George IV Bridge, Edinburgh, EH1 1EL.

PLDS:

Dark Site near Pearie Law, 4 km south of West Calder,
NT 003 579, $\lambda = -3^\circ 35' 28''$, $\phi = +55^\circ 48' 17''$.

Our meetings are open to the public, unless otherwise stated. We are always happy to see new faces. Ordinary meetings take place at 20:00 (Civil Time), usually in the Augustine Church Centre on the first Friday of the month. Any changes to our meeting arrangements will be put on our website http://www.astronomyedinburgh.org

Contents of this issue

About the ASE Journal

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