CASMAG

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Next meeting: 19 July

Open heart surgery on a Canon 300D and layer mask image processing

Speaker: Euan Mason

Supernova SN2009GJ in NGC 134, photographed from Stuart Parker's observatory in Oxford on 20 July. See pages 8-10 for Stuart's account of his discovery.

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Public open nights for 2009 are held every Friday evening from 20 March to 2 October. To make a booking inquiry follow the *Open Nights* link on the CAS website to find out which nights are *available*. For all other inquiries and bookings please contact:

Steve Johnson 027-445-8443
or email bookings@cas.org.nz

CAS Meetings

Monthly meetings are held on the 3rd Tuesday of each month except December & January at 7:45 pm, in Room 105 on the ground floor of the Law School, University of Canterbury. Meetings begin with tea/coffee, followed by a 45 minute talk from an invited speaker as advertised on the front cover of CASMag.

Meetings are preceded by **Practical Astronomy for All Ages**, from 7:00 -7:45 pm in Room 104 of the Law School, next door to the main meeting room. This is a friendly, informal meeting open to all interested people, with particular emphasis on new and beginning astronomers. Check the CAS website for details of the topic to be covered each month. Attendees are welcome and encouraged to stay for both meetings.

CAS Membership

Subscriptions (as listed below) are due 1 April. Fees for current members who renew before 31 May, and new members joining in 2009/10, will be discounted to the amount shown in brackets, i.e., there is a $10 discount for Adult members etc.

Financial year: April to March

Adult (full) membership	$60 ($50)
Family membership	$90 ($75)
All other classes (Junior, Senior citizen, Tertiary student, Educational)	$30 ($25)

Contributions to CASMag

Member contributions to CASMag (e.g., letters, observing notes, articles, news) are most welcome. Please submit articles to The Editor, CASMag, PO Box 25-137, Christchurch 8144, or email to editor@cas.org.nz. **The deadline for the next (July) issue is 1 August**.

Small personal advertisements (less than 8 lines in a column) are free to financial members. Charges for larger items range from $5 to $40; email the editor for full details.

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Contents

CAS Calendar, June 2009 – August 2009

July 2009

Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Monthly meeting

August 2009

Su	Mo	Tu	We	Th	Fr	Sa
30	31					1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

Family day/night

September 2009

Su	Mo	Tu	We	Th	Fr	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Public open night

Coming Events

Tuesday 19th July: Practical Astronomy and Monthly Meeting

Practical Astronomy (7:00-7:45): *Objects of the Night Sky: an Urban Approach*. Don't let urban light pollution get in the way of backyard astronomy. Plenty of great objects are easily visible from urban Christchurch despite the glare of streetlights. This session will help you locate some of the easy but spectacular targets which are readily visible in binoculars or a small telescope. We would also be interested in seeing astronomical photos that people have attempted from home. (*Note: this topic was originally scheduled for the June meeting, but – in response to questions from the floor – this morphed into an impromptu session on setting up your telescope. Which, in our view, is entirely what these meetings are all about.*)

Member's meeting (7:45-9:00): This month's speaker is CAS member (and dedicated astrophotographer) Euan Mason, whose topic is "Open heart surgery on a Canon 300D and layer mask image processing". As Euan puts it: "It's basically a story about how to nearly destroy your digital SLR camera in the quest for better astro-imaging, and how to take advantage of it if the risk pays off."

Saturday 25rd July: Member's Night (6:00 – 8:00 pm, followed by observing)

This month's members' night, July 25th, is ideally placed for the Aquarids Meteor Shower. Bring out the deck chairs, dust off the abacus, and join us out at the observatory for a meteor-counting members' night.

Tuesday 28th July – Wednesday 29th July: Southern Delta Aquarids Meteor Shower

The Delta Aquarids usually produce about 20 meteors per hour at their peak. The shower will peak this year on July 28 & 29, but meteors can usually be seen from July 18 - August 18. The near first quarter moon will set early, providing an excellent viewing experience after midnight. The radiant point for this shower will be in the constellation Aquarius. Best viewing is usually to the east after midnight. See: http://www.seasky.org/astronomy/astronomy_calendar_current.html for more information.

Wednesday 29th July / Saturday 1st August: Two interesting occultation events

At about 00:42 on the morning of Thursday 30th July the minor planet 732 Tjilaki is predicted to occult a magnitude 9.3 star in Aquarius. West Melton is almost exactly in the predicted path (see next page), so there is a high probability of seeing an event. Equally fortuitous is that the projected path runs directly across a line from Christchurch to Darfield, so that multiple observations from observers at different locations could yield very precise data in the asteroid's size and shape. In fact, given the uncertainties in its orbital parameters, anyone along a line from Akaroa to Arthurs Pass could potentially catch the event.

This is followed by a grazing lunar occultation of the magnitude 2.9 star Al Niyat (sigma Sco), which will be visible from near Ward just after midnight on July 31. Al Niyat's brightness means that the event will

be easily visible through even a small telescope, and the fact that it is a multiple star with at least three components means that it may well be possible to detect stepped changes in brightness as each component slides in and out of view. See Brian Loader's article on page ?? for more details.

Friday 18th September – Monday 21st September: Herbert Star Party 2009

Now just two months away. Contact Phil Barker (phil.sonja@xtra.co.nz or 383-3683) for more details.

News and Events

Noticeboard

Members' Messier Marathon, Saturday 20th June, Saturday 27th June, 2009.

Well done to those members who participated in the Messier Marathons on June 20th and 27th. The 20th turned out mostly cloudy but with at least a few hours worth of observing achieved by most. Most attendees managed to observe a significant number of objects listed in the observing plan, a great achievement in difficult conditions. Attendees began to trickle away around 11pm, with a few dedicated hopefuls staying to after 3am, and a couple of enthusiastic if a little crazy observers staying to 7am and enjoying great views of Venus in the morning sky. The 27th started out stunningly clear, the few members who attended managed to tick off a number of objects on their list before low fog rolled in around 8:30pm. The fog cleared and returned a number of times over the next few hours, with attendees eventually losing the battle and heading home by 1:00am.

Thanks!

A big vote of thanks to all those members who have turned out to help over KidsFest. This was still in progress as this issue went to press, but has been a great success to date.

CAS Library Service

Please note that you can browse the CAS library catalogue online at www.librarything.com/catalog/caslib (no password required). Members who are not able to visit the library at West Melton can order books through Geoff Wright (wrightgandj@gmail.com), who will bring them to the next members meeting.

The librarything website (which hosts caslib) has recently established a "collections" feature which allows a single library to be split into multiple collections. An excellent way for us to use this feature would be to establish a new collection for astronomy books which are held in the city library, and which are likely to be of interest to other CAS members. It would then be possible to post reviews and rank books on a 1-5 scale, so that members can get a better feel for what is currently available. If you have recently taken out a library book, why not flick us a quick summary – it need be only a few sentences – along with the book title and author, and we'll see it gets added to caslib. If everyone contributes, it shouldn't take long to grow into a valuable resource.

A Good Old Bino Power

The Lovely Star Clusters of Carina

Heather Skinner

In CASMag 664 (April 2009) we ran an item on Carina, describing some of its more easily found treasures. The indomitable Heather Skinner provided the following article at about the same time, so we decided to hold it over until we had sufficient space. Readers who wish to follow Heather's voyage through the constellation may find it useful to refer to the charts which accompanied the earlier feature.

Hello again everyone. After many cloudy nights – you know those days when the sun goes down and the clouds come over – and days of rain, the Monday night of March 23 turned out to be a lovely clear night. Moon not yet rising and the seeing was good, so yours truly decided to pack up her bino gear and head out to the observatory. When I got there it was nice to see a few other people at home out there...

I was just in the mood to see some lovely big open clusters, and where better to look than Carina. If you take a look at the brightest star in Crux (alpha Cru), which most of you know, you will see it is a lovely double like two diamonds. Just drift up from this and you should come across a small group of stars called The Gem cluster. If you take time to let your eyes adjust you will start to see the lovely different colours in it with some reds, and you will see why it gets its name. If you then follow along the Milky Way, naked eye, you will see a hazy patch: point your binos at that. This is eta Carina, although I'm really referring more to the nebulosity which is NGC 3372 than to the star which is eta Car. Through binos you will be able to see all the nebulosity and those marvellous dust lanes – a fantastic object.

Moving my binos up just a smidgeon from this I came across a nice little star cluster – a miniature sprinkling of stars almost in a diamond shape. Going down just a tweak and to the left from eta Car you will find the outstanding cluster NGC 3532. That will fill your whole binos – beautiful. The prominent yellow-white super-giant is not part of the cluster but is a background star five times further away. If you take time with this cluster, you should be able to start to make out some orange stars there too.

Going back to eta Car and moving your binos to the right, move down from a prominent white star and you will be dazzled by the white diamonds of IC2602, also known as the Southern Pleiades, It is easy to see why. Another nice cluster I like is to the right and up a little from eta Car, which is NGC 3114. I like the shape of this cluster because the stars appear to be arranged in chain patterns.

If you have (or can borrow) the book Collins Stars and Planets all these may be easier to find than trying to follow my directions - which may be as clear as mud! On a dark night these clusters are really beautiful to see, and scanning your binos along the Milky Way is lovely too. And don't forget the three naked eye diamonds - Crux, the Diamond Cross, and the False Cross. Hope you can get to find and enjoy some of these lovely clusters.

Happy hunting

from Heather

Occultations for beginners

Two Interesting Events for Late July

Brian Loader

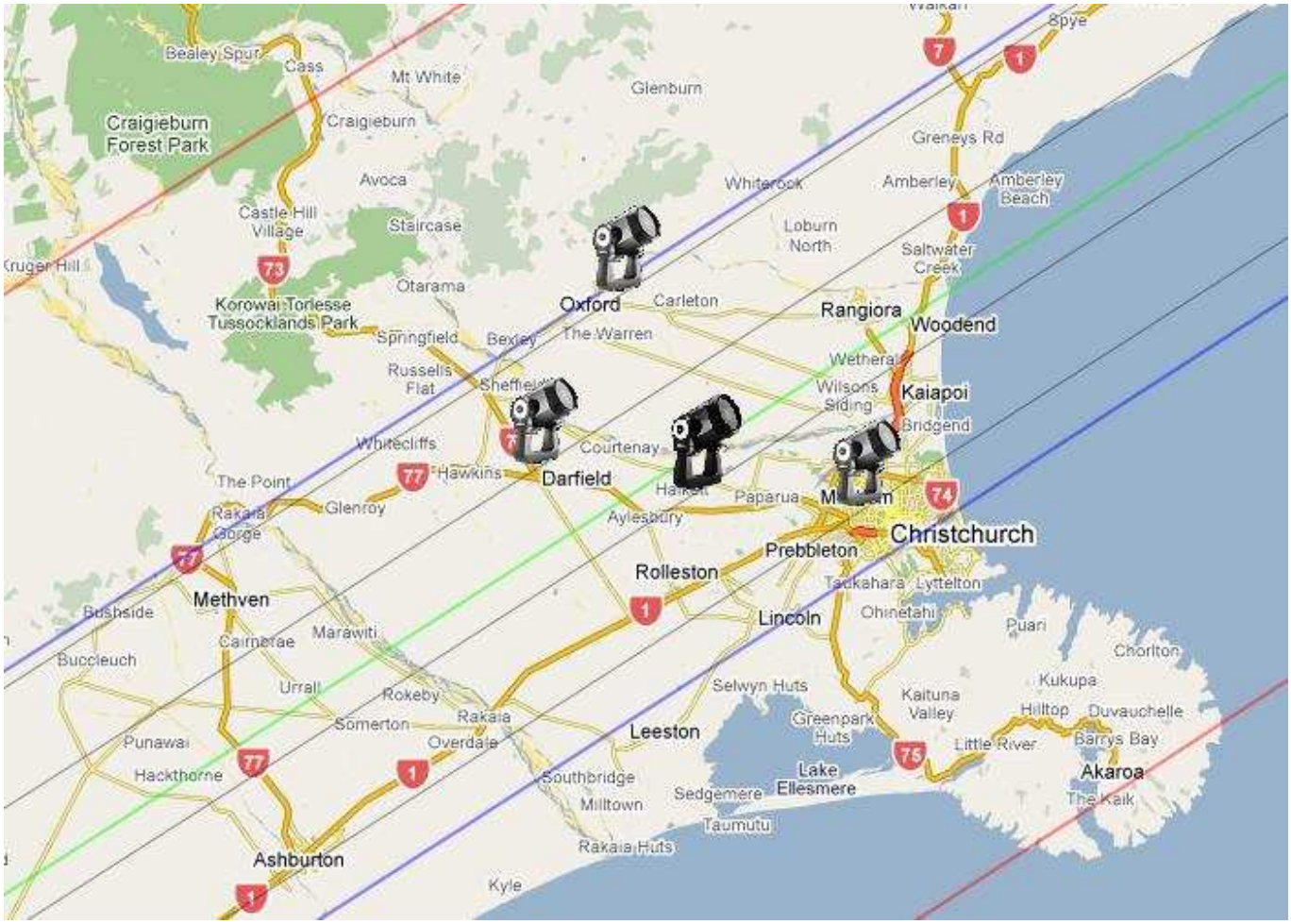
In the June CASMag I waxed lyrical about the pleasures of backyard astronomical research. The gods must have been listening, as they have scheduled two very favourably timed events for the last few days of July. Brian Loader takes up the story.

1. Asteroid (732) Tjilaki occults a 9.3 magnitude star

On the night of July 28/29 shortly after midnight the asteroid (732) Tjilaki, which is about 38 km across, is predicted to briefly occult, that is pass in front of and hide, the 9.3 magnitude star known as TYC 5186-00724-1. The path of the event is predicted to go across Christchurch. In effect Tjilaki will cast a shadow of the star on the surface of the Earth with the shadow moving across the South Island. Anyone watching the star from somewhere in the path, would see the star disappear from view for up to 3.6 seconds. The time in Christchurch is about 12.42.36am, that is soon after midnight, on the morning of 29 July.

The map (see page 6) shows the expected path of the shadow across part of Canterbury as it moves from southwest to northeast. The expected limits of the path are shown as blue lines, with the centre of the path shown in green. This is the predicted path, the actual path may differ somewhat from this due to small uncertainties in both the position of the asteroid and star. There is about a 70% chance that the actual occultation path will overlap the predicted path, and it is almost certain that it will at least in part be between the two red lines at the top left and bottom right of the chart.

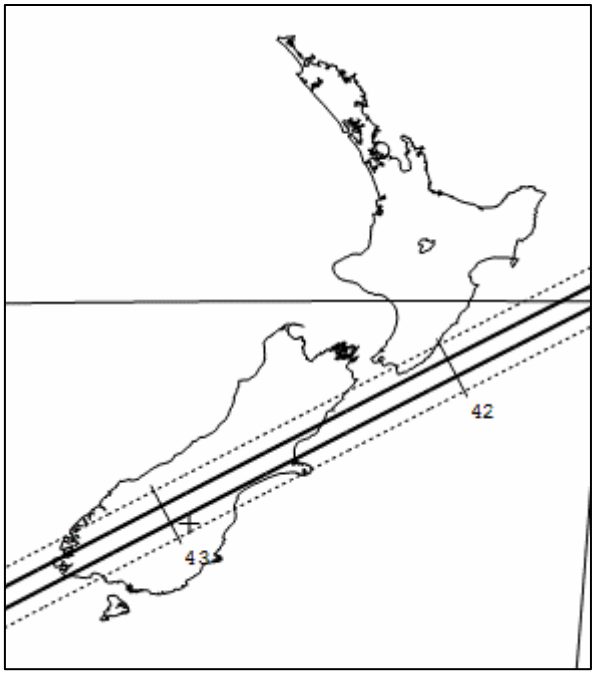
Any observation of the occultation will help refine the positions of the asteroid and star still further. If we can get several accurately timed observations across the width of the path, very precise positions can be determined, as can the size and even the shape of the asteroid.



The projected path of the Tjilaki event on the morning of July 30th. The green, blue, and red lines line show the centre, edge, and one sigma error bounds for the projected path. Observations from anywhere within the blue and red zones, such as Rangiora, Sumner, Halswell, Tai Tapu, and Akaroa, would be of great value.

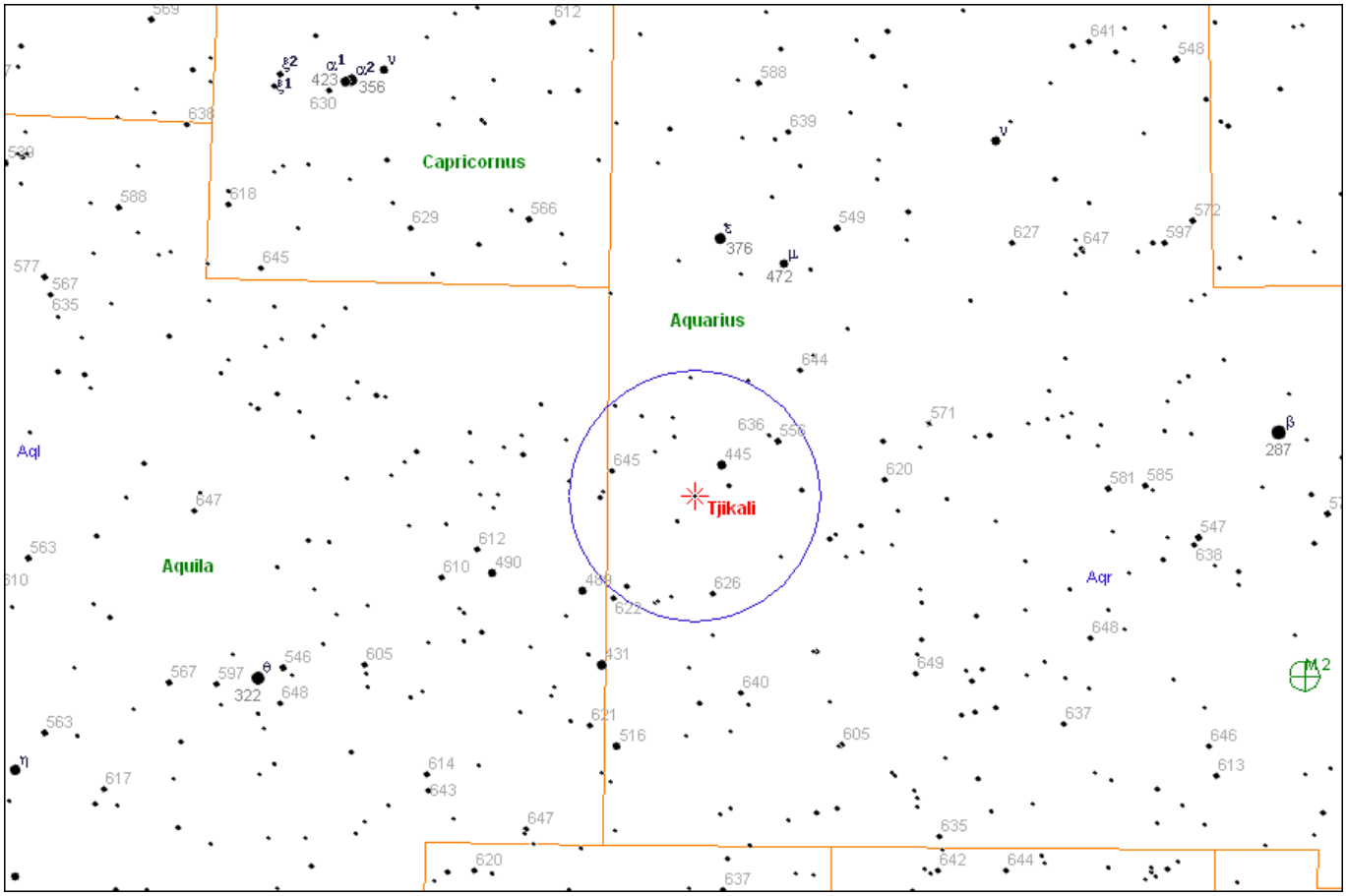
The telescopes on the map show the positions of 4 observers who have already signed up to time the event, near Oxford, at West Melton, Darfield and in Christchurch. The grey lines show their position projected along the occultation path. Further south of Christchurch the path includes Ashburton, Geraldine, and much of the McKenzie Country and Central Otago (see graphic at lower right), so by all means get involved if you happen to be travelling at the time.

We can't have too many observers! Ideally we would like accurate times of both the instant the star disappears and when it reappears. Even if you aren't able to make accurate timings, I would encourage you to observe and maybe see what is quite a rare event on a comparatively bright star. A 10 to 15cm telescope should be sufficient to see the event.

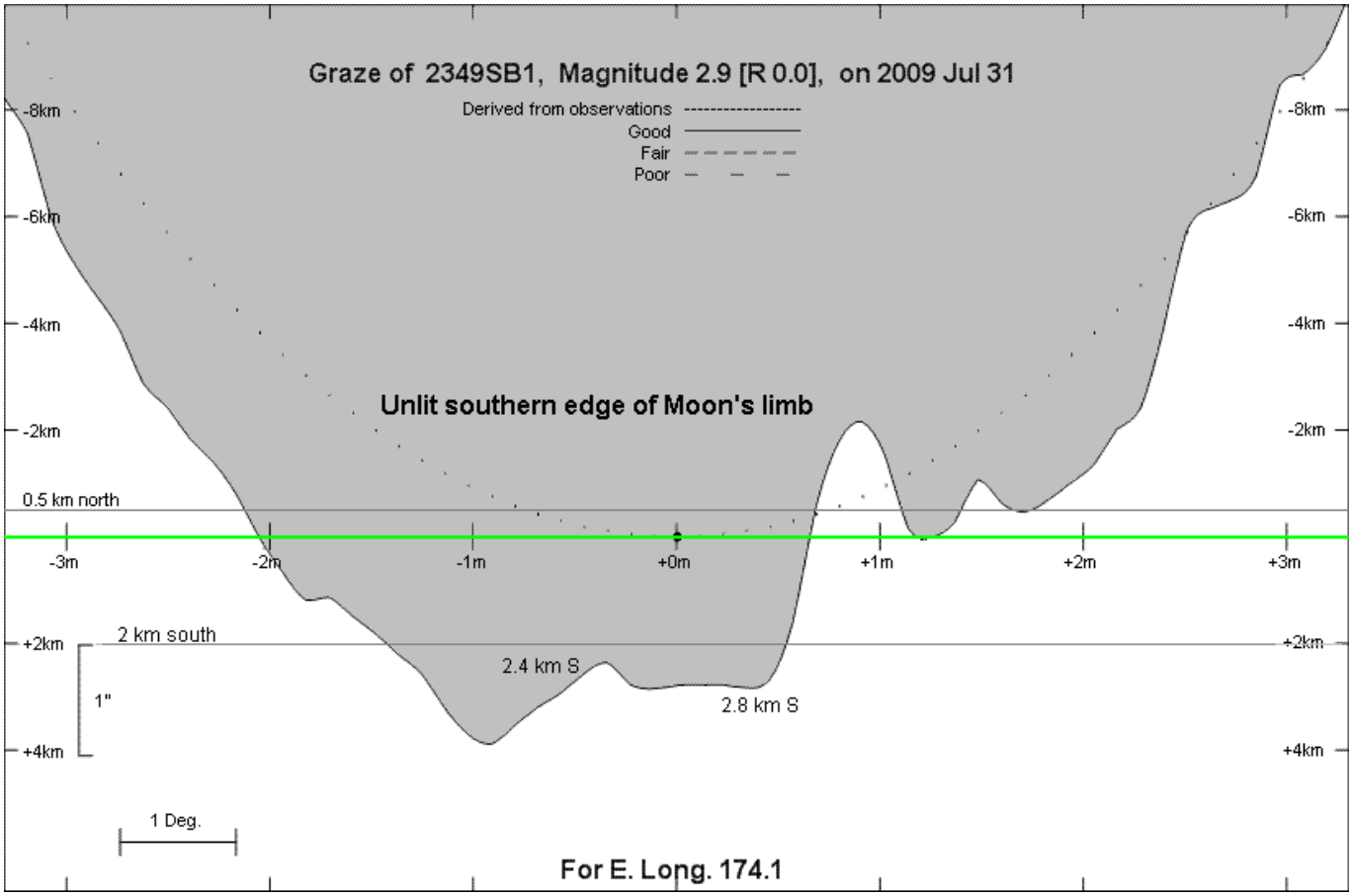


But you do need to realise that even if you are inside the predicted path, you may not see an event as the real path may miss you. Equally even if you are a little way outside the path as shown. Say somewhere between the red lines, it's worth observing as you could be lucky. Probably most of the events of this type I have seen have been when I was a little way outside the predicted path! However your observation could be very useful even if you see no event, as it could help limit where the edge of the path was.

The star which will be occulted lies in the constellation Aquarius, quite close to its boundary with Aquila. It is in the same part of the sky as, and about 20 degrees from,



Large scale finder chart for the Tjilaki event in the morning of ?? July. See http://occsec.wellington.net.nz/planet/2009/finders/090728_732_17769_Finder.htm for more detailed charts.



Lunar profile for the sigma Sco graze on the morning of 1 August. The dotted line shows the hypothetical surface profile assuming a spherical moon, compared to the currently known profile (solid grey shading). The sequence of events seen by each observer depends on their location with respect to the central graze line (green).

Antares. It will be nearly due north at the time of the event and at an altitude of 51 degrees above the horizon, a comfortable observing position.

The star chart on page 7 shows the sky round the target star. Stars to magnitude 8 are shown, plus the position of the target star and Tjilaki. The sky is oriented for the New Zealand view. The circle round the target has a diameter of 5 degrees. If you want more detailed charts, send me an email (see below).

2. A grazing occultation of sigma Scorpii.

Three nights later, on the night of Friday 31 July cum Saturday 1 August, again a little after midnight, there is a grazing occultation of the 2.9 magnitude star sigma Scorpii, by the Moon. That is the edge of the Moon will just touch the star – provided you are in the right position. The "right position" includes Arthurs Pass and the road leading up to Lewis Pass, both not very convenient, but also at Ward in Marlborough. Provided the weather is fine, a few of us intend travelling to Ward to see the event. During a grazing occultation the star being grazed is likely to be alternately hidden and exposed over the course a minute or two as the Moon goes by. This is caused by the star being hidden by mountains and exposed in valleys on the edge of the Moon. Again timings of the disappearances and reappearances of the star will give useful information, in this case improving our knowledge of a small position of the edge of the Moon. The lunar altitude in the vicinity of the graze varies by about 4 km (see page 7), so that the sequence of events seen by each observer is very sensitive to small changes in their location. For example, an observer 200 m south of the central line may see only a single disappearance and reappearance separated by several minutes, while an observer 800 m to the north may see three.

Due to the brightness of the star this is likely to be quite a spectacular event, made more so by the fact that the star is multiple, with a very close companion which may briefly be visible at some part of the graze, and another star a little further out. If you are interested in joining, contact me by email at palbrl@clear.net.nz .

Supernova SN2009GJ

In Search of a Dying Star

by Stuart Parker

When discussing Stu Parker's discovery of supernova SN2009GJ with non-astronomer acquaintances, I have several times had to counter the suggestion that he was merely lucky. There is certainly an element of serendipity in his discovery, but to see it as merely a matter of luck is to miss the point completely. Far more important than luck are the motivation to go supernova hunting on the first place, the technical skills to pull this off from your backyard, and the persistence to keep at it long enough to make an eventual discovery an odds on bet. Stuart – who clearly has all three qualities – provides a graphic example of how to make a significant contribution to serious astronomical research with equipment which is well within the reach of a committed backyard observer.

Twenty years ago I read a book called *The Supernova Search Charts* by Gregg D. Thompson and James T. Bryan Jr. I was completely taken with the concept of exploding stars that were visible in amateur telescopes. I thought that one day it would be great to be the first one in the world to see the light from one. My interest remained and in the early 2000s I started a small search programme with a 12 inch Meade on an alt-az mount. But I didn't have any contacts and the time to do a proper job. However I did image many supernovas that had been found by other amateur and professional astronomers. Over the years I got better equipment and better skills at CCD imaging. Two years ago I made contact with Peter Marples, an amateur astronomer from Queensland who had found a couple of supernovae. He was a great help in giving me ideas in setting up a proper search programme. Over that time I shifted to a better observing spot with a lot more clear nights and a permanent observatory where I do a lot of things in amateur astronomy including CCD imaging, planet imaging and occultation work. So six months ago I began to set up for a proper supernova search programme including getting all the reference maps and the right software to start a search. I began to start searching a couple of months ago but just on and off doing a lot of reference imaging and trying to work out the bugs in the set up and software. I imaged many supernova from previous discoveries and helped Peter Marples with his third discovery with a confirmation image so I felt that I was ready to go.

Now you see it, now you don't. Stuart's classy before and after images of NGC134 taken through his 14” Meade, with Supernova SN2009gj (arrowed) clearly visible in the lower image.

On the evening of June 20th I began another night of supernova hunting and went out to town for tea with other supernova hunters from Aussie that I had just met. I collected my images and went on holiday. That next day I checked my images and was really surprised to see an object in NGC134, a magnitude 10.4 barred spiral galaxy in the constellation of Sculptor located about 60 million light-years away. The image was taken at 5:30 am. I wasn't really sure but I thought it was worth checking out. I was away from home so I had to get to a net connection and sent my image to Peter in Aussie to see what he thought. We had to make sure it wasn't a minor planet or variable star first. That night I managed to get a conformation image from Geoff Wingham's observatory in Milton where I was staying and my colleagues in Aussie also got some images to confirm the object. By this stage I was getting quite excited and we got all the details together with extra help from Colin Drescher who did all the astrometry work that we needed. We then sent a report to Dan Green at Central Bureau for Astronomical Telegrams. Dan confirmed the discovery and in an Astronomical Telegram said that I was the sole discoverer of SN2009gj a 15.9 mag Supernova which was 82" east and 102" north of the centre of the nucleus of NGC 134.

I was so pleased that after all this time I managed to bag my first discovery. I was especially pleased that it was in a bright galaxy. I managed to get back to my observatory that next night and did a longer exposure image showing more detail. That night R. J. Foley of the Harvard-Smithsonian Center for Astrophysics reported that a CCD spectrum (range 305-1000 nm), obtained with the 6.5-m Magellan Clay telescope (+ MagE), shows that 2009gj is a type-IIb supernova. And is about three weeks after explosion. Adopting a redshift of 1750 km/s (measured from Na D absorption), the H-alpha P-Cyg absorption minimum is blueshifted by 13000 km/s. Type IIb supernovae are likely massive stars which have lost most, but not all, of their hydrogen envelopes through tidal stripping by a companion star. As the ejecta of a Type IIb expands, the hydrogen layer quickly becomes optically thin and reveals the deeper layers.

I hope that this will be the start of many more discoveries and goes to shows that even with amateur equipment we can still keep up with the big observatories that scan thousands of galaxies per night.

Planet Watching

The Solar System in July and August

by Brian Loader

Sunrise, transit and sunset times for Christchurch. At transit the Sun is due north and at its highest. It is the time of local solar midday.

Date	Jul 11	Jul 18	Jul 25
Rise	08:00	07:56	07:50
Transit	12:34	12:35	12:35
Set	17:09	17:15	17:21
Date	Aug 1	Aug 8	Aug 15
Rise	07:43	07:34	07:24
Transit	12:35	12:35	12:33
Set	17:28	17:36	17:43

The southern winter solstice with its shortest day is on June 21 with the Sun at its furthest north at about 5 pm. The day of earliest sunset is June 15, that of latest sunrise June 28, although the times vary by only 1 or 2 seconds for a day or 2 either side of these dates. And day-to-day variations in atmospheric refraction are likely to upset the calculations.

Lunar phenomena, mid July to mid August

July

4 92% lit Moon just over half a degree from Antares, mag 1.1
5 Moon furthest south and highest in NZ skies
7 Full Moon 9:21 pm, partial penumbral eclipse
8 At apogee, furthest from Earth, 406 224 km
10/11 Moon 4° from Jupiter and Neptune, closest in morning sky
14 Moon 7° from Uranus, morning sky
15 Last Quarter 9:53 pm
19 Crescent Moon 8° from Venus and Mars, morning sky
20 Furthest north and lowest in southern skies
22 At perigee, closest to Earth, 357 467 km
22 New Moon 14:35, solar eclipse not visible in New Zealand
24 Crescent Moon 3° from Regulus, mag 1.4
25 Crescent Moon 6° left of Saturn
28 43% lit Moon 4.5° from Spica, mag 1.1
29 First Quarter 22:00 pm
31 76% lit Moon within 3° of Antares, mag 1.1

August

1 early morning Moon within 1.5° of Antares
2 Moon furthest south and highest in NZ skies
4 at apogee, furthest from Earth, 406 024 km
6 Full Moon 12:55 pm; partial penumbral

eclipse not visible from New Zealand
6/7 Full Moon 4 deg from Jupiter and Neptune
9/10 89% lit Moon 5.5° from Uranus
14 Last Quarter 6:55 am
16 28% lit waning Moon 6° from Mars, morning sky
18 10% lit crescent Moon 3° from Venus, morning sky

The path of the total eclipse of the Sun on July 22 starts at sunrise on the coast of India close to Mumbai. It crosses northern India and central China, including Shanghai, before heading out to sea passing just south of the main islands of Japan. It then heads to the southeast across the Pacific to end at sunset some 3000 km northeast of New Zealand. No part of the eclipse is visible from NZ, although the edge of the partial eclipse passes close to North Cape and East Cape.

The partial penumbral eclipse of the Moon on August 6 will not cause any significant change in the brightness of the full Moon. In any case it takes place round midday NZ, with the Moon below the horizon.

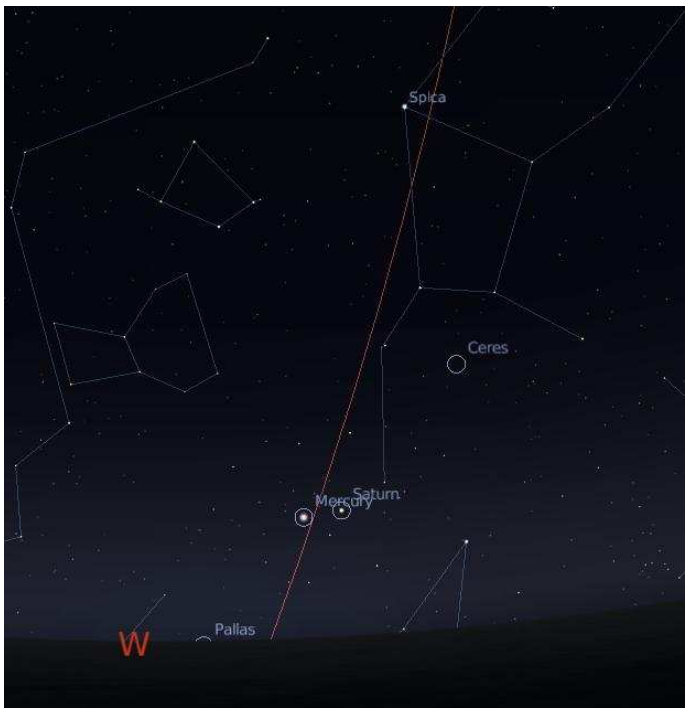
The Planets, mid July to August 2009

SATURN will be visible in the early evening, best seen as the sky darkens following sunset. By mid August the planet will set by about 8:30 pm, so will be low to the northwest early evening. The rings are going to close further during July and August as seen from the Earth. They are edge on to the Sun on August 10, making it very difficult to see anything of them from the Earth.

After August 10 the Sun will be shining, very obliquely, on the northern face of the rings. From the Earth the now un-illuminated southern face of the rings will still be in view, again likely to make them difficult to see. But the shadow of the rings may be visible as a think dark line on the face of Saturn. A modest telescope will be needed to see any effects. Since the rings of Saturn are edge on only once every 15 years, it will be worth taking the opportunity to look for any effects.

MERCURY, having been at inferior conjunction with the Sun on July 14, will move into the evening sky, setting after the Sun. It will move fairly quickly up into the evening sky, so that by the beginning of August it will set about 90 minutes after the Sun. By August 1, it should be fairly easy to see 45 minutes after sunset, but will be only 7º above the horizon, and 3º below the star Regulus. Mercury will be about 2 magnitudes brighter. Two evenings later the planet and star will be less than a degree apart.

The planet will get easier to see in the evening during the rest of August. By mid month it will set over two hours after the Sun and be 16 degrees up, 45 minutes after sunset, between west and northwest. On August 16 and 17, Mercury will be 3º to the left of Saturn, with Mercury brighter by a magnitude.



Mercury and Saturn as seen from Christchurch on the evening of 16 August.

JUPITER is at opposition on August 15, so by then will rise at the time of sunset and set at sunrise. In mid July it will rise a couple of hours after sunset, so will be best viewed in the late evening. It will remain quite close to Neptune, although the distance between them will increase to 3º.

For Galilean Satellite watchers, the series of mutual events, occultations and eclipses will continue in August. For the most part eclipses are partial and there is only a small drop in light, making them difficult to detect visually. However during an occultation one satellite moves in front of another. These events are quite easy to watch through a small telescope. Over the course of, usually, ten or twenty minutes the pair of satellites will be seen to merge and then separate again.

Dates and times of mutual occultations and deeper eclipses visible from NZ during July and August are below. Unfortunately almost all of them occur after midnight, only those on August 14 are during the evening.

Date	Mid time	Event	Duration (mm:ss)	Magnitude drop
15 Jul	01:24	Ganymede occults Europa	03:36	
21 Jul	00:08	Io occults Europa	06:54	
22 Jul	04:31	Ganymede occults Europa	04:36	
28 Jul	02:19	Io occults Europa	07:54	
29 Jul	06:08	Ganymede eclipses Europa	14:06	1.2
4 Aug	03:58	Io eclipses Europa	09:24	0.9
4 Aug	04:31	Io occults Europa	09:00	
11 Aug	06:33	Io eclipses Europa	10:54	0.8
11 Aug	06:45	Io occults Europa	10:24	
14 Aug	19:53	Io eclipses Europa	12:00	0.8
14 Aug	19:55	Io occults Europa	11:18	
17 Aug	05:14	Io occults Ganymede	35:18	

The occultation and eclipse of Europa by Io on the evening of August 14 in fact occur simultaneously, so while the eclipse is taking place, Io will also hide Europa from view. The 14th is the day Jupiter is at opposition, so Sun, Earth and Jupiter are all in line.

The eclipses listed should produce a noticeable fading of the moon being eclipsed, especially if it is compared to the moon causing the eclipse, which will remain bright.

These events need to be viewed through a small telescope. For an occultation start watching at least 3 times the duration before the event is due, when the two satellites should be visible very close together. Over the next few minutes they will merge and then separate again.

VENUS and **MARS** will remain easily visible in the morning sky, with Venus getting lower during the month. The two planets will be in Taurus in July. Mars will be directly between the Pleiades and Aldebaran, the brightest star in Taurus, on the morning of August 19. Aldebaran and Mars will be about the same brightness and colour. Also on the 19th the crescent Moon will be about 8º from both Mars and Venus. The Moon, planets and Aldebaran will form a kite shape with the Moon at the lower left and sharp end and Aldebaran to the upper right at the blunt end. Look for them about 7 am when Moon and Venus will be obvious in a direction between north and northeast.

On the last day of July, Venus will move into the most northerly part of Orion, but will move on into Gemini two days later. Mars will remain in Taurus for most of August. The Moon again passes Mars on the morning of August 16, when it will be 6º to the left of the planet. Two mornings later the Moon, now a very thin crescent, will be 3º to the lower left of Venus.

Stargazing 101

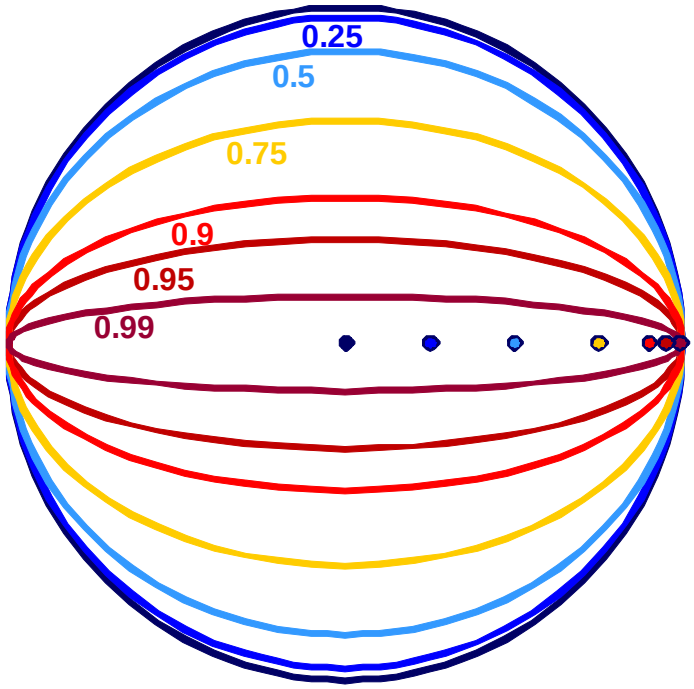
Keplerian Orbits

Kepler's first law – stating that "The orbit of every planet is an ellipse with the Sun at a focus" – may be one of the best known laws in the history of science. It is simpler to understand than Einstein's E = mc2, easy to visualise, and universal in its application. It is not limited to planets orbiting the Sun, and applies to any situation where a small body orbits a more massive one under the sole influence of their mutual gravitational attraction. Like many such laws it is an idealisation, and is true only to the extent that the mass of the orbiting body is too small to have any measurable impact on the central body. And it also assumes that the two bodies are in an otherwise empty universe, or at least one in which other bodies are so far away that their gravitational influences can be ignored. Still, it remains the starting point for virtually any calculation involving solar system dynamics, regardless of whether we wish to describe a planet orbiting the Sun, a moon orbiting its host planet, an artificial satellite orbiting the earth, a

spacecraft en route to an outer planet during the long silences when its motors are switched off, or a comet falling in from the distant Oort cloud.

To specify an orbit in a form that can be used to calculate the position of the orbiting body at any point in time, we need to specify six *orbital elements*. It takes two numbers to specify the size and shape of the ellipse: one obvious way is to specify the longest and shortest axes, known since classical Greece as the *major axis* and *minor axis*, respectively. Astronomers prefer to use the semi-major axis – which is analogous to the radius of a circle – and the eccentricity, which measures the shape. The eccentricity of an ellipse is a number between 0 (in which case the major and minor axes are equal, and the ellipse becomes a circle), and 1 (in which case the ellipse becomes a parabola and the orbit is unclosed.

All of the planets except Mercury have nearly circular orbits, with eccentricities (*e*) ranging from 0.00677 (Venus) to 0.09340 (Mars). These appear near enough to circular at first glance, and you would be hard pressed to distinguish between a circle and an ellipse of equivalent size drawn to represent the orbit of, say, Jupiter (*e* = 0.04849). However, the extent to which the Sun is offset from the centre of a circular orbit is directly proportional to the eccentricity, and becomes noticeable even for *e* as small as 1-2%.



The eccentricity of an ellipse measures the amount by which it deviates from a circle, and the offset from the centre to each of its foci (only one of which is shown).

Orbital eccentricities have very significant and obvious effects for observing the planets. When Mars passes Earth on the outside lane every two years – at which time it is said to be in *opposition* – its distance from us can vary by almost a factor of two over a period of about sixteen years, from 55.5 million km to just over 100 million km. The August 2003 opposition made headlines because it was unusually close, but at closest approach the 2018 opposition (57.3 million km) is only slightly less favourable. This variation in separation makes a big difference to Mar's brightness at opposition, and to its maximum disc size. The next opposition in January 2010 is relatively distant, with Mars appearing much smaller and fainter (14 arc-sec, mag -1.28) than it did in 2003 (25 arc-sec, mag -2.88).

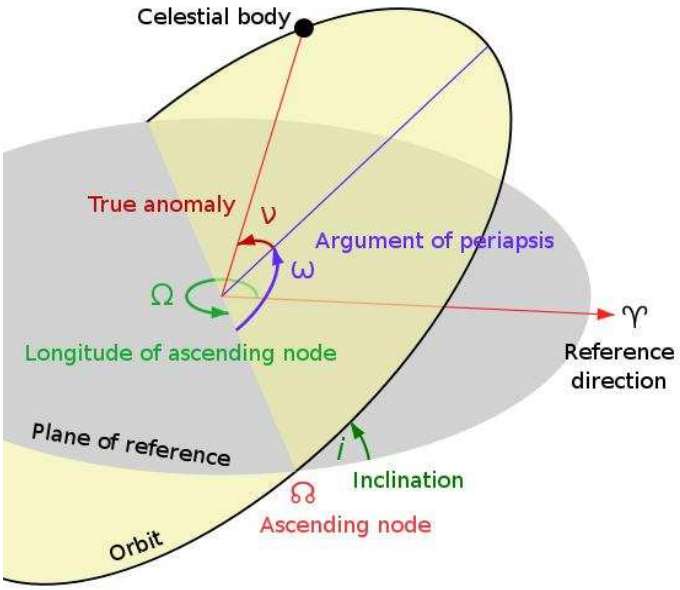
Mercury has by far the most eccentric orbit (e = 0.20563). This has a big effect on how it appears when viewed from Earth, determining how far it rises away from the Sun and how rapidly it travels from night to night, and is the reason why some apparitions are so much more favourable than others. For our own Moon *e* = 0.054, causing its apparent diameter to vary from 29.3 to 34.1 arc-min, and determining whether we see a partial or annular eclipse of the Sun should it pass directly in front of us.

Given the size and shape of an elliptical orbit, three more orbital elements – each of which measures an angle – are needed to tell us how it is oriented in space. Two angles tell us the direction in which the major axis is pointing; for example we could use the declination and right ascension of the point where the axis would intercept the celestial sphere if extended indefinitely. The third angle measures rotation about the major axis: if we were to sight directly along this axis towards the central body at the focus, this angle effectively tells us the direction in which the minor axis is pointing. These angles are always specified with respect to a fixed reference plane, such as the Earth's orbital plane (i.e., the ecliptic) for solar system bodies, or the Earth's equatorial plane for orbiting satellites.

The terminology for these angles borders on the arcane, reflecting the long and distinguished history of orbital theory. The *inclination* (*i*) is easy enough to understand and remember, measuring the tilt of the orbital plane relative to the reference plane. It is small (less than 4º) for all the planets except Mercury (7º), but – simply by virtue of being non-zero – is enough to ensure that Venus and Mercury usually lie

north or south of the Sun whenever they overtake us on the inside lane. Were this not the case, transits of both planets would occur much more often than they do.

The *argument of periapsis* (ω) measures the direction towards which the semi major axis points, in the opposite direction to the Sun. This turns out to be Gemini for Earth, Aquarius for Mars, and Pisces for Jupiter; but has few if any observable consequences. The *longitude of the ascending node* (Ω) defines the orientation of the *line of nodes*, and is relevant to events such as transits of Venus and Mercury. Finally, having determined the precise shape and orientation of the orbit, it remains only to specify where the orbiting body is at some specific time. The *mean anomaly* – another term with a strong historical flavour – provides this information, and is also expressed as an angle. Given these six elements, together with an agreed but arbitrary time zero (the *epoch*), the position of the orbiting body can be calculated exactly.



The orbital plane (yellow) intersects a reference plane (gray). The two planes intersect in the line of nodes, which connects the centre of mass with the ascending and descending nodes. This plane, together with the Vernal Point ♈, establishes a reference frame. Source: Wikipedia.

In practice, few if any orbits attain the Keplerian ideal. Orbits change with time in response to effects such as the gravitational pull of other bodies, the nonsphericity of the primary, relativistic effects, and tidal friction. If we want to describe the motion of the Moon with sufficient accuracy to predict the time of lunar occultations to within a few seconds – to within a few arc seconds in RA and declination – we have to allow for sixty such effects. To measure the Earth-Moon separation to within a few mm, as is required for subtle tests of general relativity using laser reflectors left in place by the Apollo astronauts, many hundreds of terms are required. But all such calculations start with Kepler's laws.

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Cloudy nights

Constellation Quiz

Think you know your way around the constellations? Try your hand at the following quiz, to see how well you know your Canis from your Canes. Answers at bottom of page 15.

1. Crux (the Southern Cross) is the smallest constellation. Which is the second smallest?
   (α) Circinus; (β) Equuleus; (γ) Sagitta; (δ) Scutum

2. One of the following constellations is spelt incorrectly. Which one?
   (α) Canes Venatici; (β) Scorpio; (γ) Sagittarius; (δ) Piscis Austrinus

3. How many of the following statements about the constellation Mensa are true?
   - It is the only constellation named after a geographical feature.
   - It contains two stars brighter than magnitude 5.

- No part of it can be seen from north of the Tropic of Cancer.
- It contains part of the Greater Magellanic Cloud.

(α) 1; (β) 2, (γ) 3; (δ) 4

4. Which one of the following constellations is not crossed by the celestial equator?
   (α) Aquarius; (β) Eridanus; (γ) Libra; (δ) Canis Minor

5. One of the following constellations does not share a common border with Carina. Which one?
   (α) Centaurus; (β) Pictor; (γ) Volans; (δ) Dorado

6. How many constellations contain no Messier objects?
   (α) 35; (β) 47; (γ) 53; (δ) 58

7. The centre of which constellation culminates at midnight on 1 January?
   (α) Canis Major; (β) Lepus; (γ) Columba; (δ) Cancer

8. Which is the smallest zodiacal constellation?
   (α) Cancer; (β) Aries; (γ) Capricornus; (δ) Gemini

9. Which constellation lies immediately south of Piscis Austrinus?
   (α) Grus; (β) Indus; (γ) Phoenix; (δ) Microscopium

10. How many constellations are named after birds?
    (α) 6; (β) 7; (γ) 8; (δ) 9

The spectacularly coloured nebulosity around Antares and rho Ophiuchi, imaged by Jason Jennings in a mosaic spanning nearly 10 degrees (20 full Moons). Source: http://apod.nasa.gov/apod/ap090708.html .

Answers: 1 β; 2 β; 3 γ; 4 γ; 5 δ; 6 γ; 7 α; 8 γ; 9 α; 10 δ

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