

MACARTHUR ASTRONOMICAL SOCIETY Inc.

Journal



# PRIME FOCUS

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## President's Report

### It happened last month!

Our special guest speaker last month was Michael West from the Mars Society of Australia. It was a great night with a whole download of info about Mars, from the Marskin mechanical counter pressure suits to corporate signage on the deployed airbags.

Michael also spoke about the ESA tracking station in New Norcia Western Australia and the effects of isolation that future astronauts must endure. Also he spoke about his developments in the heads up computer displays and his own research projects being hoisted aloft on a satellite.

I am sure everyone enjoyed his very professional presentation and later that night he sought my permission to visit us again. Michael said he would love to give a talk on space exploration in general and subsequent updates on the discoveries ensuing from the Martian landers.

It's very satisfying for me to bring to the club the array of speakers that we have had over time, and I am ever mindful of maintaining the astronomical flavour so to speak.

Unfortunately I have declined Michael's request for another visit due to the fact that he is "over qualified." Also he forgot to invite me to lunch with Apollo 17 astronaut, Harrison Schmidt.

### That old chestnut

We finally made our way to the Oaks on Saturday 20/9. It's been a while since a telescope has hit the ground out there and a hearty band of souls braved some rather cold weather that night.

The cloud cover was extensive and only allowed limited viewing. However, the conditions were just the most perfect for detailed viewings of Mars we have seen in a long time.

Several of us employed magnification up to 300x and I managed to hit the juice to a

whopping big 400x. The benefits of a good polar alignment and reliable tracking meant I could sustain a still image for a long time. It's strange but the waning and waxing of the cloud cover would bring out detail. The air must have been forgiving enough to allow the big powers.

It's been a number of years since I have had the conditions just right to bump it up and see detail. Quite a while ago now Peter Druery boosted Jupiter to about 600x and we saw the planet the size of a tennis ball in the eyepiece. Sadly no detail at all, just a big fat disk.

However, down at the Oaks I experienced excellent views of that pesky little varmint, but it was a juggling act. When the planet brightened through the clouds I would lose the resolution, when it dimmed the clarity was superb. The polar caps and dark markings were clearly shown. It was at this point that it dawned on me that I was actually seeing the surface of another planet - how cool is that?

We had a mention of an Oaks night on 18/10. However, we had to transfer the night to support a star party for the girl guides at Kentlyn. We tried to get in touch with as many members as we could to advise of this. Please accept our apologies for any inconvenience due to the late re-shuffle.

### **Yet again it's the Gremlins**

It was time for a few members to leave the Oaks air field. With scopes packed it was time to start the engines and wizz off into the night. It's a dreaded sound really, the flatish battery trying its hardest to crank over a near frozen engine.

With jumper leads to the rescue and advice from an auto electrician (a handy potential member) all was well. The same could not be said about the recent forest night. The downside of that night was the constant blackouts in the cabin, not normally a problem for us astronomers who thrive in the darkness.

Unfortunately there was a fridge full of food to consider and hot water was in desperate short supply. The culprit appears to be a very suspect urn. The night was still a success, however, when leaving in the morning yours truly misjudged the distance between his car and a ditch. Steadfastly stuck, I was able to use that fantastic invention, the mobile phone.

Ned, Lloyd and Paul came to my rescue and witnessed my stupidity first hand. The idea of a tow rope seemed a good one, until it snapped. A robust push from the rear, courtesy of 3 strapping lads saw me on my way.

The sound of my son's voice still echoes in my ears, "Dad, call the Police... call the police."

### **Coming Up!**

20/10/03	General Meeting
25/10/03	The Forest
01/11/03	Observatory Public Night
17/11/03	General Meeting
22/11/03	The Forest
29/11/03	The Oaks

**Very Important:** check with Lloyd, John or myself to confirm the above dates, rain, storm or the unavoidable may creep in...my mobile is 0410 445 041

I think that's about it from me. Please travel safely and all the best.

Noel Sharpe  
President

## Telescope for Sale

### Tasco, 4½-inch reflector

500 mm focal length; 5x24 finder scope.  
20 mm & 4 mm eyepieces; barlow 3x.  
equatorial mount; tripod, accessory tray.  
instruction booklet; star wheel.  
original packaging;  
2 yrs old, like-new condition

**Price : \$300**

Contact: Henry. tel. 9829 6098



## The Forest Daniel

I asked my son to recount the last forest night we went on - this is the second time I took him. I asked him to jot down a few words. I have mixed in the conversations and happenings and it goes something like this. By the way the title is as Daniel wrote.

"Dad there was a freezed wombat on the road." "Daniel there's no such word as freezed, what do you mean?" "You know dad, like this." Daniel now extends his arms, falls on his back, puts legs in the air and tells me, "like you freeze." This now makes sense as he is describing road kill.

"I saw ice on the grass and ate it." Yes, there was a lot of frost that morning and Daniel has never seen it before, its not something one would eat though. Up at the crack of dawn we went for a walk. "Dad! Lots of kangaroos, I'll chase them." Now it was a bit of a tough night due to the power disruptions, Daniel got a bit scared and wanted a night light on, also he fell out of the top bunk whilst searching for the toilet.

I'm not an early riser and a walk in the morning glow does not inspire. However seeing a huge fox...I didn't know they came that big... shoot out in front of us was amazing. The kangaroos as Daniel would say were in the hundreds, not a good idea to bound up to one. I explained that they were wild kangaroos, not friendly and could punch your lights out in a flash.

"Would you like to see my drawings?" I was very proud of my son when without any prompting he showed several of the guys his drawings of Jupiter, Saturn, Mars and the magic mushrooms in the forest. Stupid me used a red light to highlight the drawings in the dark - they disappeared. "Dad, what did you do?" Wisely Ian placed the drawings in his car boot and with a white light all became clear.

The next morning Daniel was on the trail again to show his drawings. This time he bit off more than he could chew. Ned had

painstakingly drawn many pictures of Mars as seen through his telescope, very detailed and very professional and certainly a tribute to ones patience and passion. Daniel was seen comparing his pictures to Ned's, pictures filled with wonder and lopsided shapes, of colour and innocence and a fantastic stick figure that looked just like his dad!

A proud father

NS

### **The little spacecraft that could.**

In October 1989 a plutonium powered space probe was launched from the cargo bay of the space shuttle Atlantis. The probe was called Galileo. The spacecraft was of course named in honour of Galileo Galilei, the 17th century Renaissance scientist who discovered Jupiter's moons.

The project was approved by NASA back in 1977, however it took another 12 years to come to fruition, and a further 6 years travel time to reach the planet Jupiter. Galileo ended its travels by being deliberately driven into Jupiter's vast atmosphere. Over 4.5 billion kilometers has been put on the clock in 14 years of buzzing around Jupiter and its moons, well past the warranty period one would think

Without doubt Galileo has changed the way we think about our solar system. Over 14,000 photographs and measurements have been beamed back to the Earth. Imagine what further discoveries might have been forthcoming if its main antenna didn't fail on deployment.

### **Mission Accomplishments.**

3 of Jupiter's moons, Callisto, Europa and Ganymede have suggested oceans.

The most active volcano in the solar system belongs to a Jovian moon called Io. An extensive lava plume was photographed in all its glory.

A flyby of an asteroid revealed an orbiting moon.

Direct observations of the impact of the Shoemaker-Levy comet which smashed into Jupiter's atmosphere causing an explosion the size of the Earth.

Establishing that Jupiter and its moons represent a solar system in itself and subsequently establishing models for extra solar, solar systems.

I was reading up that at the time Galileo was photographing and taking readings of Io's volcanic explosions NASA's Infrared telescope on top of Mauna Kea, Hawaii was also able to take readings. The combined data has given scientists a wealth of information. How impressive is that little moon, not a great place for the holidays though, a tad hot.

The fact that Galileo has survived way passed its use by date is amazing. The intense radiation exposure more than twice its design parameters has created some problems though, but none that could not be overcome.

Sadly on the 22nd of September a directive was given to dive bomb Jupiter - the little spacecraft would not survive this one. Low on

fuel and if left alone there was a chance of losing control, with over 2.5 tonnes of spacecraft together with a plutonium power pack smacking into a pristine Jovian moon would not be the act of a good neighbour.

Jupiter handled a full blown bombardment by a comet with great ease, Galileo's last task was to transmit data on the composition of Jupiter's atmosphere. We await the findings as a last testament, to the little spacecraft that could!

Noel Sharpe

### What IC This Month

October 20 – November 16

### Overhead at 8.30 pm

Looking north west, bright stars are Antares, the Scorpion's Stinger, the Teapot, planet Mars, Altair the Eagle, Job's Coffin, the Water-jar, and the square of Pegasus. Low on north horizon will be Vega and Deneb. To the southwest are Crux and the Pointers, Grus, Fomalhaut, Achernar, the Small Magellanic Cloud and low beyond the SCP is Canopus.

### The Moon Diary

20/10 Last Quarter

25/10 New Moon

1/11 First Quarter

9/11 Full Moon

17/11 Last Quarter

### Evening Sky Planets

**Mercury** is in the glare of the sunset with Virgo till 1/11 when it will be just visible till 30 mins after sunset. Each day it will climb further out of the glare till it sets one hour after the Sun by the 17<sup>th</sup>. Between 10-16 Nov. Mercury will still be low on the western horizon with Venus 12° above, but will rise up to meet each night. Mercury will come within 3° of Antares on the 18/11.

**Venus** is in Libra this month and will set in the twilight about 7.30 pm. Between 27-29/10 it will be low on western horizon near a thin crescent moon, but will then climb higher away from the sun setting about 2 hours after. On 11/11 it will be 4° below Antares, and 5° from Mercury on 17/11.

**Neptune** remains distant and cool in Capricornus 3.5° left of delta Cap. while to the east **Mars** is in Aquarius setting about 2-3 am. On 20/10 Mars will be 4° from **Uranus** and you should be able to capture the red and green planets in the one binocular field. Mars has a decidedly smaller and egg-shaped disk now, and it is difficult to make out much surface detail. The brightness has also diminished as the big show of 2003 slides to its end. A 10 day old moon will place itself 2° above Mars on the 2<sup>nd</sup> November.

### Morning Sky

**Jupiter** will rise in Leo after 3 am gradually increasing in size over the next few months. On 22/10 a last sliver of moon will be 6° below and to the left one hour before sunrise.

## Comets

Comet **2P/Encke** as mentioned last month is in Andromeda and on 25/10 will be just  $2^\circ$  from M31. It is expected to get brighter than 8<sup>th</sup> magnitude during November but will be closer to the west.

**2002/O7** is just west of Eta Carinae in mid October at 7<sup>th</sup> magnitude but will fade a little as it passes through Octans, Indus and on to Grus

## Meteors

**Alpha Monocerotids** can be seen 15-25 November with a peak on 22/11. They are a bit erratic but known for late evening short bursts of 5 to 400 per hour

## PORTRAITS IN THE SKY

### TRIANGULUM

Triangulum lies just to the north of Aries and passes the meridian 20 October. In ancient times its distinctive shape of three stars was called *Deltoton*. It contains one of Messier's objects, a faint face-on spiral galaxy. Triangulum's stars are quite faint but are easy to find next to Andromeda.

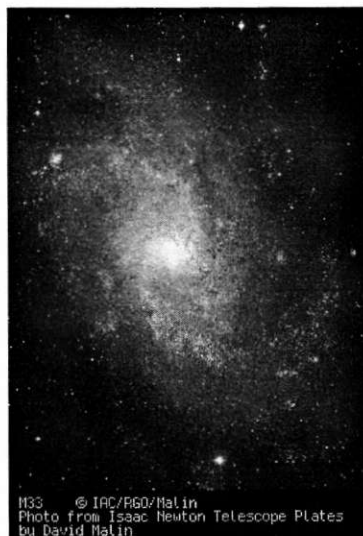
#### Double stars:

**6 Trianguli** also called *iota Tri*, is an attractive binary with colour contrast, yellow and blue: 5.3, 6.9; separation 3.9".

#### Deep Sky Objects:

**M33 (NGC 598)** is a very large but quite faint face-on spiral galaxy sometimes known under the name "Pinwheel Galaxy".

Located just about midpoint between alpha Arietis and Beta Andromeda but slightly closer to Beta And, it is estimated to be from 2.5 to 3.5 million light years away. Because of its slow rotation it makes just one complete turn every 200 million years.



M33

Low power scopes, or even binoculars, work best on this.

Jumping now from the north to the southern sky we pick up another scientific instrument.

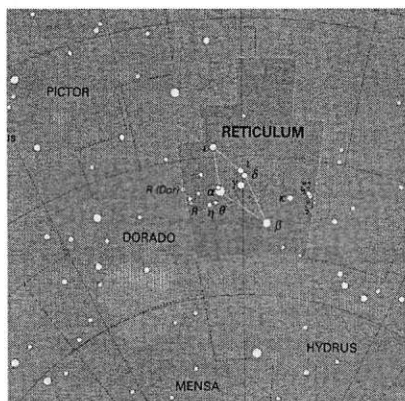
### RETICULUM – "The Net"

Lacaille's original intention was to recognise the device he used to plot the position of stars from others. In fact we still use something like it to describe the angle position of double stars – a reticulated eyepiece.

The system of lines marking angles around a circle resulted in the very scientific name

Reticulum Rhomboidalis. Some of that has been lost with shortening to:  
Reticulum – The Net.

Located halfway between Canopus and Achernar, this is an attractive binocular object grouped around a flattened diamond shape.



The **alpha** star is a yellow giant only 3.4 magnitude with **beta** further south. Across to the right from  $\alpha$ , is a group of deep orange stars  $\gamma$   $\delta$   $\epsilon$ .

Further to the right  $5^\circ$  from **delta** and a little to the south are some naked eye doubles.  $\zeta_1$  and  $\zeta_2$  are identical yellow stars similar to our Sun.

Just to the left of  $\alpha$  is  $\theta$  Del, a double yellow star 6.2, 8.2 separated by a close  $3''$ .

## ORION

Orion is the master of the summer skies. He lords over the heavens from late spring to early autumn, with his hunting dog Sirius trailing at his feet.

One story from the Hitties who flourished from 2000 to 1200 BC. gives an interesting account of Orion's death.

Here he is called Aqhat, and was a handsome and famous hunter. The Battle-Goddess Anat fell in love with Aqhat, but when he refused to lend her his bow, she sent another man to steal it. This chap bungled the job, and accidentally killed Aqhat and dropped the bow into the sea.

The Greeks knew Orion as the "dweller of the mountain", a great hunter and a great lover as well. But when he boasted that he would rid the earth of all wild animals, he may have sealed his own doom.

Whether the Earth Goddess herself heard of this boast or it was Apollo, who did not welcome Orion's designs on his sister Artemis, who told her, is not clear. In any case, the Earth Goddess sent the deadly scorpion on a mission to kill the mighty hunter.

Some stories have the scorpion killing Orion with its sting. However the general consensus is that he engaged the scorpion in battle but realising its armour was impervious to any mortal's attack, he jumped into the sea and swam toward Delos.

But Apollo had witnessed Orion's struggle with the scorpion and would not let him escape so easily. He challenged his huntress sister Artemis, to shoot that small black object far away in the sea, the head, he told her, of a treacherous villain.

Artemis was an excellent shot and struck the object with her first arrow. She then swam out to retrieve her trophy only to discover she had killed Orion her lover. Distraught she

implored the gods to restore his life, but Zeus objected, so Artemis put Orion's image in the heavens.

In his eternal hunting, Orion is careful to keep well ahead of the scorpion by disappearing over the horizon before Scorpius rises in the east. One rules the summer the other the winter evening sky.

Finding Orion should be no problem. Its stars are some of the most familiar in all the heavens.



### Can you name the three stars that make up Orion's Belt?

Above the belt, slightly to the left, is *Betelgeuse*, the right arm (or "armpit"), which glows with a dull red. Labelled *alpha Orionis*, it is less bright than *beta Orionis - Rigel*, in the opposite corner to the southwest. Also much larger, estimated at around 250 times the Sun. If one were to replace our Sun with Betelgeuse, its size would completely engulf the Earth and extend as far as the orbit of Mars.

As the brightest star in Orion, *Rigel* ranks as the seventh brightest star in all the heavens, just behind Capella.

The other corners of the constellation are formed by *Saiph* (*kappa Orionis*) and *Bellatrix* (*gamma Orionis*).

All women born under the sign of Bellatrix are supposed to have a gift for public speaking. The star's name is often translated as Female Warrior meaning Amazon, and another name for Bellatrix is "Amazon Star".

The constellation's main feature is the three stars which form the "belt" across the middle. From west to east they are: *Mintaka*, *Alnilam*, and *Alnitak*. Even the Bible makes reference to this famous group. God, while pointing out how all-powerful he was to Job, is reported to have said, He was able to "loose the bands of Orion" (*Job 38.31*).

*Alnitak* is also known as *zeta Orionis*, and is a well known triple star system. The primary is a blue-white star, and its companion (165°, 2.3") is a dull red.

Just to the south, is the Horsehead Nebula, a so-called dark nebula that is not visible in small scopes but quite spectacular in long-exposure photographs.

### Binary stars in Orion:

There are many double stars in this constellation visible in small telescopes.

*Beta Orionis (Rigel)* has a 10.4 magnitude companion (PA 202°), at a wide 9.5" separation. It is a visual binary; the companion much fainter but visible if you persist.



9

**Lambda Orionis** (between Betelgeuse and Bellatrix) is a fixed binary, with a 5.5 companion at 4.4" away.

**Theta<sup>1</sup>** is a complex system of fixed stars. The four brightest form The Trapezium, an outstanding multiple system for small telescopes. AB is at a separation of 8.8", AC: 12.7", and AD: 21.5".

**Theta<sup>2</sup>** is also a fine binary, a triple system to the southeast of The Trapezium. Component B is a binocular object: 6.4 magnitude at a separation 52.5". Component C (8.5) is even wider at separation 128.7".

**Sigma Orionis** is one of the few orbiting binaries found in Orion. Component B has an orbit of 158 years and is one of a few binary components that trace a not-quite-perfect circle. We see it nearly face on, as a wheel spinning around its hub, but at a distance of only 0.2", it is beyond all but 300mm scopes. Much easier to resolve is component E, with a visual magnitude of 6.7, this is a binocular object at a separation of 42".

**Zeta Orionis** (1.9, 4.0) has a very slow orbit of 1509 years, and is currently at 165° and 2.3" separation.

### Deep Sky Objects in Orion:

**M42, The Orion Nebula** is perhaps the most photographed deep sky object in the heavens, a vast nebula of gas and dust exquisitely lit by surrounding stars. This is a celestial nursery; which in several hundred million years will produce young stars from this wealth of cosmic matter.

Inside the nebula visible in medium sized telescopes is the fascinating four-star system

known as **The Trapezium**: (theta 1A, 1B, 1C, and 1D); four stars held together by common gravity. There are at least two other stars E and F which are part of this complex system. These stars and the nebula, form one of the most beautiful binary systems in the heavens.

**M43 (NGC 1982)** is a detached part of the Orion Nebula, with a ninth magnitude central star. A dark lane of gas separates M43 from M42, although the two are actually part of the same vast cloud.

**M78 (NGC 2068)** is a faint reflection nebula NE of Alnitak (zeta Ori), that is difficult to find. It looks best in long-exposure photographs, sort of like the mask of the Phantom of the Opera.



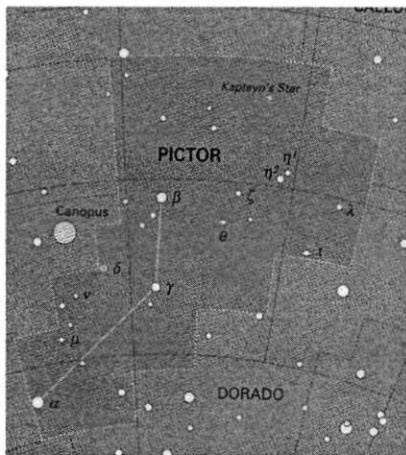
M78

**The Horsehead Nebula** is an intriguing and devilishly difficult dark nebula found just between zeta Orionis and sigma Orionis. Visible only in very good conditions with medium to large telescopes and a H-Beta filter.

## PICTOR - "The Painter's Easel"

Passing the meridian at 12 am on 2<sup>nd</sup> January, Pictor is an invention of Nicolas Louis de Lacaille, who originally called the constellation "Le Chevalet et la Palette" (The Painter's Easel and Palette).

It's stars are quite faint, nevertheless there are several objects of interest, including the second fastest moving star.



### Double stars:

**Theta Pictoris** is a multiple system but AB although 7<sup>th</sup> magnitude are only separated by 0.2". C: 7.0; is more possible with separation 38".

**Iota Pictoris** is a wide binary: 5.5, 6.5; separation 12.3".

**Mu Pictoris** has a relatively faint component: 6.0, 9.0; separation 2.4".

### Deep Sky Objects:

**Kapteyn's Star** is a fairly faint (8.8) red dwarf discovered in 1897, by Professor Jacobus Cornelius Kapteyn of the University of Groningen in Holland, known for its large proper motion. He found that all stars which have a measurable proper motion, belong to one of two star streams moving in different directions at different speeds.

Kapteyn's Star is moving at a radial velocity of 242 km/s at a distance of 12.73 light years. This makes it second only to the fast moving Barnard's Star in Ophiuchus.

The star has a luminosity absolute magnitude of 10.85 which is far less than our own Sun (-26), and is found roughly 8.5° NW of Beta Pictoris. Burnham has a finder's chart p1463.

Go see the Great Hunter, catch some stars in The Net and watch for changing colours in the Painter's palette this month.

Good seeing

IC



**(Editor's acknowledgment:** The charts for Reticulum and Pictor are from Ian Ridpath and Wil Tirion's book "*Collins Pocket Guide – Stars and Planets*" – 3<sup>rd</sup> edition. It's a "must have" book for amateur astronomers.)

### Shakespeare on Astronomers:

I came across a great paraphrase of Shakespeare the other day (relating to astronomers) while reading up for my presentation tonight. It went: "The fault is not in the stars, but in their theories." Does anyone know what the original quotation was and where?

Bob Bee



## News Bites

### A Tiny Asteroid Whizzes By

On Saturday, September 27th, a very small asteroid plunged past Earth well inside the Moon's orbit. Unseen, it passed just 78,000 kilometers (a fifth the Moon's distance) above Earth's surface before racing back into interplanetary space. Judging by its faintness, 18th magnitude when first picked up the next day, it can't be any larger than 3 to 6 meters across. That's "room size," notes Edward L. Bowell, principal investigator for the Lowell Observatory Near-Earth Object Search (LONEOS) at Anderson Mesa, Arizona, where the first images were taken.

LONEOS collaborates with Minor Planet Research, Inc., where Robert A. Cash used the Pinpoint Detection Software to discover the object's faint trails on three LONEOS images. He immediately sent his measurements to the Minor Planet Center in Cambridge, Massachusetts, which alerted astrometric observers around the world.

More images of the rapidly receding, fading object were acquired on the 29th by LONEOS, and also by amateur astronomer Peter Birtwhistle in Berkshire, England, using a Meade 12-inch Schmidt-Cassegrain telescope. The Minor Planet Center announced the find on October 1st, dubbing it 2003 SQ222. Brian G. Marsden's orbital elements, refined on October 3rd, indicate that the tiny planetoid is traveling in a low-inclination orbit that takes it to well out beyond Mars's distance from the Sun, then inward as close as Venus, in a period of 1 year 10 months.

If it ever hits Earth it should break up in the upper atmosphere, causing virtually no harm — much like the slightly smaller Park Forest

meteorite that dropped fragments on a Chicago suburb last March.

Asteroid 2003 SQ222 now tops the Minor Planet Center's list of the closest known approaches by asteroids outside the Earth's atmosphere. But larger objects have come even closer. Meteor Crater near Flagstaff, Arizona, was produced by the prehistoric impact of an asteroid perhaps 1,000 times more massive than 2003 SQ222. The meteoroid that exploded over Tunguska, Siberia, in 1908 may have been 30 times wider than 2003 SQ222. When hundreds of tourists saw the great Grand Teton National Park fireball of August 10, 1972, they were witnessing the atmospheric graze of an object about twice the size of 2003 SQ222 before it skipped back into space.

(From Sky & Telescope)

### Uranian Moons Aplenty

Planetary moon hunters have found a new trove of objects orbiting Uranus. In the past month, astronomers have confirmed five new moons around the distant gas giant. The members of the quintet are all rather small — each around 10 kilometers across. With these additions, Uranus now sports 27 moons total, ranking it behind Jupiter and Saturn at third place. (S&T)

### Einstein's Still Right... for now.

If it was ever in doubt, Einstein still rules. His 1915 theory of gravity, the General Theory of Gravitation, has just passed its most stringent test by far. Extremely precise measurements of the radio link between Earth and NASA's Cassini spacecraft, bound for Saturn, match General Relativity's predictions extraordinarily closely.

However, physicists suspect that even more refined experiments, planned for the near future, could tune up the first deviations – pointing the way to a new and more complete theory of the basic forces of nature and the fundamental makeup of space-time.

The Cassini experiment was carried out in June 2002, when the spacecraft passed just 9 arcminutes from the Sun's southern rim as seen from Earth. Using NASA's Deep Space Network, scientists sent radio carrier waves to Cassini for a couple of weeks and precisely measured the minute frequency shifts in the returned signal.

Due to the warping of space-time by the Sun's gravity, the round trip to the spacecraft was a trace longer that it would have been without the relativistic curvature. The result: a tiny extra frequency shift in Cassini's radio signals.

So far Einstein has been vindicated. But future space probes, such as NASA's Gravity Probe B (due to be launched on December 6<sup>th</sup> 2003) and the European astrometry mission GAIA (due for launch in 2010) could finally take physics to the next step beyond. (S&T)

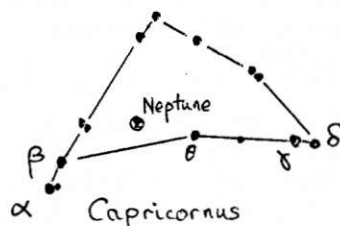
### One Lap Around the Pool for Neptune

Here's an interesting bit of trivia for you, brought to you via Australia's Greg Bryant writing for Sky & Telescope.

The planet Neptune was discovered near the border of Aquarius and Capricornus in September 1846, 157 years ago. Now Neptune takes 166 years to complete one orbit around the Sun. This means that Neptune has returned to the area (if not the

exact place) of its discovery. (I suppose in 2012 it will be closer to its discovery point.)

So why not give yourself a historical buzz and try to locate Neptune as Adams and Le Verrier found it. *Astronomy 2003* has a handy finder chart on p118 and gives its positions for any date you choose. At the moment, since it's not quite a full orbit, Neptune finds itself still within Capricornus at RA 20 hrs 51 min, Declination  $-17^{\circ} 39'$ . I have provided a rough sketch below to give the general location.



### Identifying Dark Matter

Although we do not yet know what dark matter is, particle physics has provided three compelling candidates. The first is the *neutrino*. Neutrinos are much less massive than the other elementary particles and until recently it appeared that they were massless, like the photon. However, three experiments have now established that neutrinos are not massless. While their masses have not been precisely determined, neutrinos left over from the Big Bang must contribute somewhere between 0.1 and 5.0% of the critical density, a contribution similar to that made by the stars.

The other two candidates are *axions* and *neutralinos* – but more about them another time – they're another (dark) matter. ■