



TRANSIT

The December 2013 Newsletter of



NEXT TWO MEETINGS, each at 7.15 pm at Wynyard Planetarium

Friday 13 December 2013

Astronomy at the end of the rainbow

Prof. Paula Chadwick, Reader, Dept. of Physics, Durham University

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Friday 10 January 2014

Your first telescope

Dr Jürgen Schmoll, Chairman of CaDAS



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Editorial

Rod Cuff



First, a warm welcome to new members Trish & Rebecca Watkins!

A nice mix of articles this month (well, I think so, anyway!). Ray Brown continues with his series on gravity, looking at how it dictates the escape velocity from various bodies, and how *that* dictates what happens to atmospheres and even light. Ray also has another article, looking back at Comet ISON and side-swiping the BBC in the process. Talking of comets, there's a splendid image from Jürgen of the more long-lasting comet currently in our skies – Comet Lovejoy.

Picking up the astrophotography theme, I've written a piece about some recently acquired kit, along with some first-light images from it; and there's an article from Phil Plait of Bad Astronomy fame, discussing the newish development of building up a deep image from contributors across the world.

Finally, Barry Hetherington (and see the letter below!) has supplied a list (also published in the most recent issue of the *Journal of the British Astronomical Association*) of astronomical anniversaries in 2014 – AND has supplied a great reference work, which is attached as an Appendix, containing full details of how and when all the known planets and satellites were discovered. This should give Neil questions for Yorkshire Astromind for the next few years ...

Many thanks to all contributors. Please let me have articles for January's *Transit* by the end of 2013.

And finally: I hope you have an excellent festive season and will have a 2014 that is memorable for all the right reasons. And clear skies!

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Letter

To: Barry Hetherington

from the BAA

Dear Mr Hetherington,

Honorary Membership to [sic] The British Astronomical Association

I am pleased to inform you that this year was the last time we will be asking you for renewal of your subscription to the British Astronomical Association.

According to our records you were elected to the Association on **26th February 1964** and therefore your anniversary will fall within the 2013/14 session having been a member for a continuous period of fifty years.

You will become eligible for Honorary membership at the start of the new session when it begins on 1st August 2014.

Kind regards,

Madeleine Crow



Congratulations to Barry, until recently our chairman of many years' standing! – Ed.

OBSERVATION REPORTS AND PLANNING

Websites – December 2013

Here are some suggestions for websites that will highlight some of what to look out for in the night sky in December.

- **HubbleSite:** a video of things to see each month:
http://hubblesite.org/explore_astronomy/tonights_sky
- **Night Sky Info's** comprehensive coverage of the current night sky:
www.nightskyinfo.com
- **Jodrell Bank Centre for Astrophysics** – The night sky:
www.jodrellbank.manchester.ac.uk/astronomy/nightsky
- **Telescope House** monthly sky guide:
<http://tinyurl.com/pzzpmsx>
- **Orion's** What's in the Sky – November:
www.telescope.com/content.jsp?pageName=In-the-Sky-this-Month
- **Society for Popular Astronomy's** monthly Sky Diary:
www.popastro.com/documents/SkyDiary.pdf



Comet Lovejoy

Jürgen Schmoll

[We showcased a couple of Keith Johnson's recent astrophotos last month. Not to be outdone, here's a smashing one that Jürgen took recently of [Comet Lovejoy C/2013 R1](#), currently showing well in the pre-dawn skies (so I'm told!). – Ed.]



Hardware:

250mm [Ritchey–Crétien](#) reduced to $f = 1.34\text{m}$ focal length
NEQ6 Pro mount, guided on the comet
Canon EOS 40D modified (i.e. with its normal infra-red filter removed)
[Astronomik CLS filter](#)

Software and procedure:

Five 4-minute exposures
[Darks, flats and biases](#) taken
[DeepSkyStacker](#) for combining the above
Further manual stacking using [Fitswork](#)



Less 'scope, more scope

Rod Cuff

Increasingly these cold nights, I find I'm reluctant to contemplate astrophotography sessions involving lugging out and setting up a heavy telescope and tripod, taking out a table for a laptop and setting *that* up, linking everything to a heavy power tank, fixing a dew heater strip and connecting it to a second power tank – and then looking up and finding the clouds have rolled in. Yes, I could take the smart route and drill/wire up a remote and/or wireless observatory from my dining room, but I ain't gonna do that.

So I've been in the market for an additional and alternative slant on astrophotography. I wanted to get into DSLR usage, for wide-field views as well as through a telescope (which would involve most of the stuff already mentioned), and had taken the first step by visiting the [UK Astronomy Buy & Sell](#) website and buying a Canon 100D camera body, suitably astromodded (that is, having had its infrared filter removed) and with a remote shutter release. But what next?

June's issue of *Sky at Night Magazine* contained a positive review of a piece of kit that has turned out to suit me very well. It's the iOptron SkyTracker camera mount (Figure 1), described as 'A lightweight tracking camera mount that has been designed with travel in mind' – ideal for me, as it also opens up the possibility of taking it with me when going on holiday to countries with much darker skies than in most of the UK. I looked for other reviews, finding no negative ones and a very positive test-out in



Figure 1. iOptron SkyTracker V2 mount

alignment when used with free special-purpose smartphone software (see below).

There are a couple of other features that are useful but not essential:

- The tracking can be switched between sidereal rate (tracking at the same rate as the stars) and half that speed. The idea of the latter is that, provided the magnification is not too high, you can take a relatively long exposure of both the sky and terrestrial objects at the same time without significant blur from either. I've not experimented with this yet, but it could have its uses for capturing the Milky Way against a distant building or trees, for instance, although of course there are other ways of achieving the same effect by multiple exposures.
- There's an integrated compass (quite useful for improving the rough alignment to north before using the polarscope) and spirit level (useless).

Polar alignment

Looking through the polarscope in the daytime, you would see something like the reticle dial in the left-hand section of Figure 2; at night, when the SkyTracker is switched on, the dial is illuminated in red. The dial is divided into 12 hours, with a tick-mark every half-hour. For the moment, ignore the outermost set of circles. The inner set correspond to the marked number of minutes of arc away from the true celestial north pole.

When you have roughly (not too roughly!) aligned the mount facing north towards Polaris and with your latitude set more or less correctly, Polaris should be visible somewhere in the field of view of the polarscope. If you now open up the iPhone app (there's now one for Android systems too), you'll see something like the screen-grab shown in the right-hand section of Figure 2. Your phone will have set your latitude, longitude and local time automatically, and the app will have a green dot indicating where Polaris would appear if the mount were exactly aligned on the north celestial pole. All you have to do is to fine-tune the latitude adjustment screw on the mount while looking through the

Sky and Telescope, so I took the plunge and bought it (and a matching ball-head for camera/mount connection) from [Altair Astro](#).

For me the major points going for it are as follows.

- Small (the main block is about 6" × 4" × 2") and lightweight (about 1.1kg). The whole package fits neatly into a supplied padded case suitable for taking as hand luggage.
- Takes a camera load of up to 3kg, easily enough for the Canon plus my 18–135mm lens.
- Powered by 4 AA batteries, which the manufacturer claims will give up to 24 hours of use (presumably less in very cold weather), or by an external DC power supply such as a portable power tank.
- Suitable for both north and south hemispheres.
- Easily settable and lockable latitude adjustment.
- Illuminated polarscope for accurate polar

polarscope, which will bring the image of Polaris up/down to the right level, and horizontally rotate the mount itself slightly to bring Polaris across to the exact position shown in the app. You then lock both settings in place – and alignment is complete. It all takes just a few minutes, and alignment should be accurate to within at most a couple of minutes of arc, totally adequate for imaging.

The outer set of circles is for use in the southern hemisphere, using the star Sigma Octantis instead of Polaris. I hope one day to be able to check that out ...

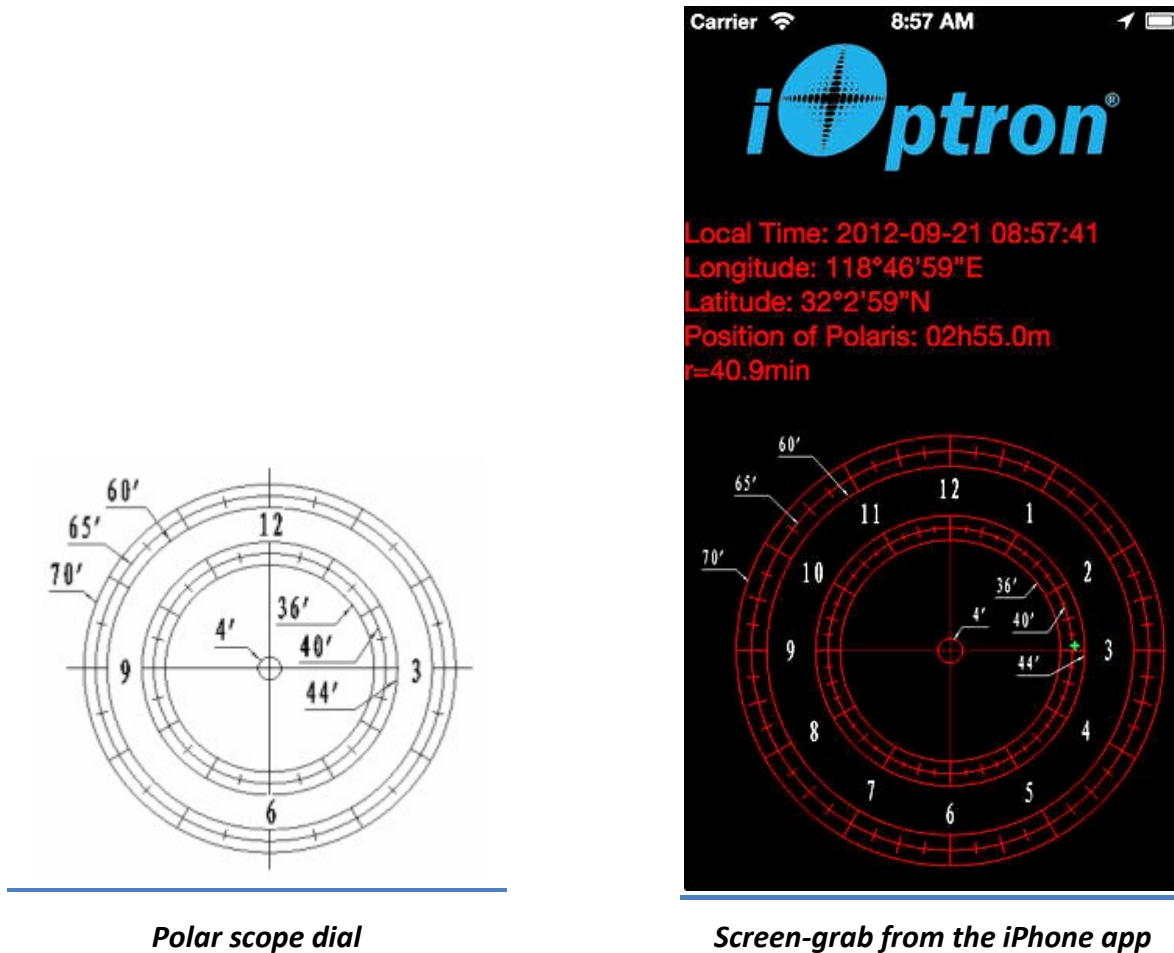


Figure 1. Setting the correct polar alignment

First light

So far I've used the kit for just one session, learning the relevant bells & whistles on the DSLR at the same time, so making mistakes as I went along and discovering a few things to be fixed with my set-up. In particular, my current birding/camera tripod is not easy to adjust smoothly and delicately when levelling the mount, and it's not as solid as I would like for normal use (although it will do very nicely for packing in my suitcase to take abroad). I also need a lower-profile 'trapezium' connector between DSLR and ball-head to enable a fuller and smoother fit, otherwise the struggle to secure the camera tends to disturb the alignment slightly.

The first results have been encouraging. The polar alignment was easy (though it would have helped to be only 3 feet tall or lying in a deckchair when peering through the polarscope) and very effective in ensuring good tracking.

Figure 3 is a 2-minute single exposure of Orion, post-processed in Photoshop to remove the considerable sky-glow and to brighten the stars slightly. The stars are pin-sharp, despite the slight breeze that was ruffling the leaves in the tree at the left.

Figure 4 showing the Hyades (bottom left) and Pleiades (top right) has had essentially the same settings, exposure and post-capture treatment. The existence and wide range of colours of the fainter stars in the image, I was surprised to find by checking a sample with [SkyTools](#), are real – at first I had assumed that little red flecks were due to noise and/or bad pixels, as they often have been with exposures I've taken with a CCD camera through a telescope.

Of course, both images would have benefited hugely from my taking multiple exposures and stacking them, then taking darks, flats and so forth – the usual things to make a more impressive image.



Figure 2. Orion, 10 Nov 2013, 01:41 UT -- Canon 100D, 2 mins at f/11.3, 42mm focal length, ISO 1600



Figure 3. The Hyades (bottom left) and Pleiades (top right), 10 Nov 2013, 01:34 UT -- Canon 100D, 2 mins at f/11, 47mm focal length, ISO 1600

GENERAL ARTICLES

Some thoughts on gravity and tides

Part 3: Escape velocities, planetary atmospheres and black holes

Ray Brown



Imagine a relatively small body of mass m , positioned a distance r_0 from a much larger mass M . Of particular interest is the case where mass m is an object located on the surface of a non-rotating, spherically symmetrical object of radius r_0 and mass M . Our considerations will effectively include examples where the sphere *is* rotating, but sufficiently slowly so that the centripetal force affecting m is an insignificant part of the gravitational attraction between M and m . For instance, for any object on the surface of Earth the gravitation force exceeds its centripetal part by the huge factor 5×10^{10} , so for our present purpose the Earth can be considered non-rotating.

The **escape velocity** of mass m is the minimum velocity v_0 in the direction radially away from M to which it would need to be impelled in order that m would be ejected into space to become completely free from the gravitational influence of M . As the distance r between the centres of m and M increases, the force of attraction F between them will decrease. We recall from Part 2 that the attractive force between masses M and m separated by a distance R was given by

$$F = GmM/R^2 \quad (i)$$

It is easily shown by mathematical integration of equation (i) that the minimum energy U needed for m to escape from M is

$$U = mMG/r_0$$

But the kinetic energy of a mass m moving with a velocity v is $\frac{1}{2}mv^2$.

So
$$mMG/r_0 = \frac{1}{2}mv_0^2 \quad (ii)$$

Rearranging this equation, we see that the escape velocity v_0 is $\sqrt{2MG/r_0}$.

So the escape velocity from the surface of mass M does not depend on the value of m . The **escape velocity from Earth**, v_0 , is calculated to be 11.2 km/sec.

Individual gas molecules in Earth's atmosphere have average speeds that are lower than 11.2 km/sec by at least one order of magnitude. The speeds of gas molecules increase with temperature and are highest for lightweight molecules. Fortunately, molecules of oxygen, nitrogen, water vapour and carbon dioxide, which constitute our atmosphere and are all essential for complex life, move too slowly to escape Earth's gravity. However molecules of hydrogen and helium, being of lower mass, do move fast enough to find their way gradually from Earth into outer space and so are almost entirely absent from our atmosphere.

An alternative rearrangement of the equation (ii) gives: $M/r_0 = \frac{1}{2}v_0^2/G$.

We conclude that planets with values of M/r_0 much smaller than that of Earth will allow lower escape velocities and so cannot retain atmospheres and consequently cannot develop and sustain complex life forms.

As expected, hot, small **Mercury** has essentially no atmosphere. By contrast the cold, massive **gas giants** can hold on to all gases and so have atmospheres rich in hydrogen and helium. Despite being colder than Earth, **Mars** has a lower mass and so can retain only a thin atmosphere of the relatively heavy gas carbon dioxide. Although hotter than Earth, **Venus** has a dense atmosphere of heavy gas molecules.

It should be mentioned that a planet's mass and temperature are not the only factors that determine its ability to retain an atmosphere. Energy acquired from the **solar wind** increases the speeds of gas molecules, so atmospheres are lost ('blown away') from planets insufficiently protected from the solar wind by their own, or nearby, magnetic fields. The magnitudes of the mass, temperature and magnetic field of our planet Earth are some of several 'Goldilocks' factors that allow it to host life.

The maximum possible value for escape velocity v_0 , or indeed for any velocity, is equal to the speed of light in a vacuum, $c = 3 \times 10^8$ m/sec, so if the value of M/r_0 exceeds $\frac{1}{2}c^2/G$ (6.7×10^{26} kg/m) then even light cannot escape from mass M . For any **black hole**,

$$M/r_0 > 6.7 \times 10^{26} \text{ kg m}^{-1}$$

where r_0 is the **Schwarzschild radius** of the **event horizon** around the central mass M of the black hole. Although here we have calculated the Schwarzschild radius using the simple Newtonian model of gravity, Schwarzschild obtained the same result by solving Einstein's field equations of relativity theory.

*Next month: Part 4 will discuss **Lagrangian points**.*



Power of multiple amateur telescopes, UNITE!

*Phil Plait, **Bad Astronomy***

Taking pictures of astronomical objects is a lot like collecting rainwater in buckets. Photons from your target are the rain, and your telescope is the bucket. The bigger the bucket, the more rain you collect. You get more water if you leave the bucket out longer, too.

So astronomers like to use big telescopes and long exposure times to get faint detail in their cosmic portraits. However, there's a third option: Use more than one bucket.

With that in mind, let me show you this fantastic picture of Jones-Emberson 1 (JE1), the gas shed by a dying star. Mind you: This is not a Hubble photo! (*See next page.*)





The planetary nebula Jones-Emberson 1, a dying star 1600 light years from Earth. This image was taken using six different small telescopes, with their power combined into one beautiful picture. Photo by Michael Stauning, Michael Rask, Torben Taustrop, Flemming R. Ovesen, Morten la Cour, Paul Christiansen, and Morten Balling. Used by permission.

Isn't that gorgeous? It's even cooler than you think, too, because it's actually the combined result from six separate telescopes... not one of which has a mirror bigger than 35 centimetres (14")! Not only that, but it represents a total exposure time of 125 hours – more than five days.

It was created by observations from amateur astronomers Michael Stauning, Michael Rask, Torben Taustrop, Flemming R. Ovesen, Morten la Cour, Paul Christiansen and Morten Balling. It was Balling who contacted me about it – he and the other astronomers organized their efforts through the Danish bulletin board Astro-Forum.dk. Balling collected the data and combined them into the image above. Incredibly, some of the observations were done not far from the heavily light-polluted city of Copenhagen. However, the use of narrow filters (that is, filters that let through a very small range of colours) cut way back on the amount of light from the city, while still letting the nebular light pass through. The exposure times of individual images ran from 300–1800 seconds (5–30 minutes).

I was not familiar with the object when Balling sent me the image, so I was surprised by it; I've studied planetary nebulae and love them, so there aren't many I haven't seen before! JE1, it turns out, is a very large and exceedingly faint object, and not as popular a target as some smaller, brighter nebulae.

Located about 1600 light years away, JE1 is shaped by the winds from a dying star. I've described how this all works in many previous posts (notably for [the Cat's Eye nebula](#), [NGC 7026](#) and [NGC 1514](#), which has to be seen to be believed). In the image above, red is light from hydrogen, and blue from oxygen. Thousands of years ago, the star in the middle of JE1 started blowing a dense, slow wind that

compressed the material around it, forming the outer shell. Eventually, a faster wind started up that then pushed into the slower wind, carving the more evacuated region in the middle.

I'll note that it looks like all the oxygen in the nebula is in the middle, but that's an illusion. The filter used here (called an [OIII] filter) selects a particular colour emitted by oxygen when it's had two electrons stripped from the atoms. This type of atom strongly emits light, but is also fragile; in too dense an environment the remaining electrons get jostled and the atoms won't emit this kind of light. That means if you use an [OIII] filter you only see oxygen from the less dense regions – there's still oxygen all over the place, but it's not emitting this light. Hydrogen, on the other hand, is everywhere, so if you see less light from it that means there's less of it around.

Also, the odd waist you can see inside the nebula is probably due to the winds being shaped by rotation of the central star as it blew them off. The star was a red giant when that happened, having expanded from a Sun-like star to a bloated ruddy monster a hundred times its original size. When it did so, it may have literally consumed any planets close by. The planets would have sped the star up as they orbited inside it like a chef whipping up eggs, increasing its spin and leaving behind their legacy in the shape of the planetary nebula we see today.

I found several other lovely pictures of the nebula online; I quite like [this one by J-P Metsävainio](#) (who also created [this stunning 3D rotating nebula animation](#)), [this one by Bob Franke](#) which uses different colours, and [this unusual one](#) created using images from the Sloan Digital Sky Survey.

As a last note, I was reading [an article by the British Astronomical Association](#) when I saw that this object is nicknamed the Headphone Nebula. I laughed when I read that; it really does look like a pair of headphones.

I hope this is the beginning of more collaboration between amateur astronomers. It shows that with cooperation and effort really beautiful images can be made. I also think a lot more science can be done as well; a smaller bucket can be more than made up for by calling your friends, borrowing theirs, and leaving them all out in the photon rain for a bit longer.

[Ed: This content distributed by the [AAVSO Writer's Bureau](#). I've used a few of their articles before – free-of-charge material by excellent writers. I like this recent one not only because of its coverage of planetary nebulae, which I find some of the most beautiful things in the sky, but also because of the idea of amateur astrophotographers across the world combining data in this way. Anyone in CaDAS interested in pursuing this?]



That was the comet, that was

Ray Brown

More than once *Transit* has published letters from Neil reporting examples of the ignorance of basic knowledge shown by members of the public. In my view an incomparably more worrying phenomenon in BBC science programmes is the ignorance of scientists in subjects where they claim expertise. What are BBC editors paid for? Ash trays and motor cycles come to mind.

Comet ISON was billed as 'the comet of the century' and indeed that was the title of the BBC2 TV programme on comets broadcast during November. The programme ended with the statement that 'we never know when one is going to come around', so I presume that its title referred to the past 100 years, not to the 21st century!

The programme touched upon two fascinating questions:

1. Was **water** mainly brought to our planet by comets colliding with the young Earth?
2. Were the **amino acids** which are essential components of terrestrial life brought here by impacting comets, were they synthesised from other chemicals at the moments of comet impacts or did they simply form on our planet, say in black smokers?

The first issue has been tackled by comparing the heavy-water content in Earth's water with that fraction present in comets and in space dust. Water consists of molecules of H_2O – i.e. two hydrogen atoms bonded to a single oxygen atom. Both hydrogen and oxygen can exist as various stable isotopes. On Earth, for every million hydrogen nuclei that contain only a proton ${}_1\text{H}^1$ there are 156 hydrogen nuclei that also contain a neutron, and this rarer isotope ${}_1\text{H}^2$ is commonly also known as **deuterium**, ${}_1\text{D}^2$. So, for every ten million or so molecules of water on Earth, about 3120 are HDO and only one is D_2O . The term **heavy water** originally referred to almost pure D_2O , but 'heavy water' has also come to refer to any water that contains more than the natural amount of deuterium. Such water is marginally denser than natural water.

If the isotopic composition of Earth's water is similar to that of comets, this will provide strong evidence in favour of the theory that our water arrived by comet, rather than being already present when our planet initially formed or at least following the formation of the Earth–Moon system.

Dr Melissa Morris of Arizona State University, the supposed heavy-water expert featured in the BBC programme, pronounced that 'deuterium is a form of hydrogen that contains an extra *proton*' (sic!). No, Melissa, deuterium differs from hydrogen by containing a *neutron*. Next, Melissa performed a demonstration where 'an ordinary glass stopper', which sank in ordinary water (density 1.0 g cm^{-3}), was seen to float on water in which she claimed 'the heavy water content had been doubled and so had a density of 1.15 g cm^{-3} '. Wrong again, Melissa – here she had confused the two uses of the phrase 'heavy water' mentioned above. It is *pure* D_2O that has high density (actually 1.11 g cm^{-3}); a mere doubling of the amount of D from 156 to 312 ppm would have caused an insignificant and immeasurable increase in density above 1.0 g cm^{-3} . So Melissa didn't even know what she had in her flask! Furthermore, Melissa might have given some viewers the impression that such deuterium-enriched water is denser than glass! Of course, the 'glass stopper' was not *solid* glass but hollow, containing mainly air. But nobody at the BBC appears to have spotted these howlers. What do facts matter when viewing figures and hype are paramount?

The **Roche limit** or Roche radius is the centre-to-centre distance within which a celestial body such as a comet, held together only by its own **gravity**, will disintegrate due to the tidal forces caused by a second celestial body exceeding the first body's gravitational self-attraction. I described tidal forces in last month's issue of *Transit*. Inside the Roche limit, **orbiting** material will tend to disperse and form rings, while outside the limit, material will tend to **coalesce**. In this case

$$d = 2.45 R (\rho_s / \rho_c)^{1/3}$$

where ρ_c is the comet density, ρ_s the density of the Sun and R its radius.

We were looking forward to 3 December or earlier for Comet ISON to emerge from behind the Sun, but a few days beforehand we were told that it had fragmented as it grazed the Sun. Sun-grazing comets that approach closer to the star than the Roche limit are always likely to break up. They can survive only if the particles of the comet are held together by forces other than gravity – i.e. the

comet needs to be a solid body rather than a clump of dust and ice crystals. Comet ISON was expected to pass within about a million miles of the solar surface, but the Roche limit corresponds to a separation of about 1.5 million miles. The break-up suggests that Comet ISON was a relatively loose agglomeration of material.



Centenaries for 2014

Barry Hetherington

- 414 A comet appeared in the Pleiades; recorded from China.
- 714 In July large meteors flew northwest; seen from China.
- 1014 The Sun and Moon and other stars gave sad signs; seen from Europe.
- 1114 Gherardo of Cremona born; translated the *Almagest* and the *Toletan Tables* into Latin.
Bhaskara born; a Hindu astronomer; believed in a spherical earth.
The astronomical hydraulic clock tower built by Su Sung destroyed by barbarians.
- 1214 Roger Bacon born; an English philosopher; wrote on the theory and construction of the telescope.
- 1514 George Joachim (Rheticus) born; a student and disciple of Copernicus; wrote *Narratio Prima* (First Account) of the Copernican system.
Erasmus Flock born; a German astronomer and mathematician; wrote on comets.
- 1614 John Wilkins born; Bishop of Chester; wrote *Discourse concerning a New Planet*, tending to prove that it is probable our Earth is one of the planets.
Marcus Welser died; a German scholar; a friend of Galileo who wrote on astronomy.
Mundus Jovialis anno 1609 detectus ope perspicilli Belgici by Simon Marius, February, containing his research on Jupiter in which he claimed to have seen Jupiter's moons as early as late November 1609.
Christopher Scheiner produced a map of the Moon and drew Saturn as a planet with two handle-like extensions.
- 1714 Giovanni Battista Audiffredi born; an Italian Dominican astronomer; built a small observatory at the top of the Monastery of Santa Maria sopra Minerva; wrote on astronomy.
Cesar Francois Cassini de Thury born; a French astronomer; appointed Director of the Paris Observatory in 1771; undertook and completed the trigonometrical survey of France.
Walter Pope died on 25 June; in 1660 he was elected Gresham professor of astronomy.
John Radcliffe died; bequeathed funds for the building of the Radcliffe Observatory, Oxford.
William Romaine born; an English Evangelical Divine; appointed professor of astronomy at Gresham College, London.
Alexander Wilson born; the first professor of practical astronomy at Glasgow; in November 1769 he observed a very large sunspot and discovered that sunspots are cavities in the luminous matter surrounding the Sun.
Thomas Zebrowski born; a Lithuanian Jesuit mathematician and astronomer; designed an observatory on the roof of the university building in Vilnius; he observed the Moon and the satellites of Jupiter.

M13, a globular cluster in Hercules, discovered by Edmund Halley.

An Act of Parliament *for Providing a Publick Reward for Such Person or Persons as shall discover Longitude at Sea* received the Royal Assent of Queen Anne

- 1814 Anders Jonas Angström born; a Swedish physicist; studied the solar spectrum; discovered hydrogen in the Sun in 1862 and was the first person to investigate the spectrum of the aurora borealis.

Gaetano Cacciatores born; a Sicilian astronomer; in 1860 he was appointed Director of the Palermo Observatory; wrote on astronomy.

William Fishburn Donkin born; Savilian professor of astronomy at Oxford 1842–69; wrote *The Secular Acceleration of the Moon's Mean Motion*, 1861.

Herve Auguste Etienne Albans Faye born; a French astronomer; studied comets, stellar and planetary movements, parallaxes and solar physics.

Robert Grant born; professor of astronomy and Director of Glasgow University Observatory; wrote *History of Physical Astronomy*, 1852, and *Popular Treatise on Comets*, 1861.

Adolph Gottfried Kinau born; a German priest and selenographer; studied lunar rilles.

Daniel Kirkwood born; an American astronomer; studied the orbits of the asteroids; discovered the Kirkwood Gaps in the asteroid belt; wrote on comets, meteorites and asteroids.

Wolfgang Ludwig Krafft died; an astronomer and physicist of German origin who worked all his life in St Petersburg.

Erasmus Ommanney born; an English Admiral in the Royal Navy; observed the 1874 transit of Venus from Luxor; made observations of the aurora borealis.

Charles Frederick Alexander Shadwell born; a British admiral; wrote on nautical astronomy.

George Williams born; architect; erected an observatory near Dolgelly which contained a 5-inch telescope by Cooke; observed sunspots by day and the Moon by night.

A new catalogue of 7646 stars from the Palermo Observatory published by Giuseppe Piazzi, for which he received the prize of the French Académie des Sciences.

- 1914 William Andrews died; an English amateur astronomer.

John Caister Bennett born; a South African astronomer; observed and studied comets.

Adriaan Blaauw born; a Dutch astronomer; Director of the European Southern Observatory 1970–74; professor at the Leiden Observatory 1975–81; studied the structure of the galaxy.

Lorant Dezso born; a Hungarian astronomer; devoted his studies to solar physics; he established the solar department of the Budapest Observatory.

Yoshio Dohmoto born; a Japanese astronomer; head of the Asahikawa Observatory in Hokkaido; an observer of sunspots, comets, occultations and artificial satellites.

Nils Christofer Duner died; a pioneer of astrophotography in Sweden; worked at Lund Observatory.

Charles Fehrenbach born; a French astronomer; Director of the Observatoire de Haute Provence.

Mario Girolamo Fracastoro born; an Italian astronomer; Director of the Catania Observatory 1956–68; Director of the Pinto Torinese observatory; studied solar physics.

David Gill died; a Scottish astronomer; assistant at the Dun Echt observatory; appointed Her Majesty's Astronomer at the Cape of Good Hope in 1879; studied the parallax of stars in the southern hemisphere.

Takeo Hatanaka born; professor of astrophysics at Tokyo University and a staff member of the Tokyo Astronomical Observatory; studied planetary nebulae, the solar atmosphere, stellar evolution and radio astronomy.

George William Hill died; an American mathematician and astronomer; worked on celestial mechanics; worked at the Nautical Almanac Office, Cambridge, Massachusetts.

William Albert Hiltner born; Director of the Yerkes Observatory; Director of the University of Michigan's observatory; discoverer of the interstellar polarisation of starlight.

Edward Singleton Holden died; an American astronomer; director of the Washburn Observatory of the University of Wisconsin; first director of the Lick Observatory; founder of the Astronomical Society of the Pacific.

Hermann Joseph Klein died; a German selenographer; built a private observatory in Cologne.

Zdeněk Kopal born; a Czech-born astronomer; chairman of the astronomy department of Victoria University, Manchester; an authority on eclipsing variables, the terrestrial planets and the Moon.

Giuseppe Lorenzoni died; an Italian astronomer; Director of Padua Observatory; studied the solar spectrum.

Heinz von Lude born; astronomical computer; worked at the Astronomisches Rechen-Institut; calculated the orbits of asteroids.

Paul Ledoux born; a Belgian astronomer; awarded the Eddington Medal of the Royal Astronomical Society in 1972 for investigations into problems of stellar stability and variable stars.

José Mateo born; Director of the La Plata Observatory.

Lyman Strong Spitzer born; an American theoretical physicist, astronomer and mountaineer; director of Princeton University Observatory; worked on star formation and plasma physics.

Eduard Suess died; an Austrian geologist and selenologist; advocated a cosmic origin of tektites.

James Alfred Van Allen born; an American space scientist at the University of Iowa; instrumental in establishing the field of magnetospheric research in space.

Mary Helen Wright Greuter born; an American historian of astronomy; worked as an assistant at Vassar astronomy department; worked at Mount Wilson, the United States Naval Observatory and the Maria Mitchell Observatory.

Yakov Borisovich Zel'dovich born; a Soviet astrophysicist; constructed a theory of the structure of supermassive stars and compact stellar systems.

Sinope (Jupiter IX) discovered by Seth Barnes Nicholson on photographs taken with the 36-inch Crossley reflector of the Lick Observatory.

A transit of Mercury on 6 November.

An occultation of Jupiter I [Io] by Jupiter II [Europa] observed by Fauth on 12 October.

Walter Sydney Adams and Ernst Arnold Kohlschutter discovered the existence of small but significant differences between the spectra of giant and dwarf stars of the same spectral class.

Cepheid variable pulsations studied by Harlow Shapley.

A meteorite fell on 13 October at Appleby Bridge, Wigan, Lancashire.

During World War 1, near the Polish village of Morasko, an iron meteorite was discovered half a meter underground; the Polish government declared the region of the Morasko meteorite fall to be a natural sanctuary.

A 65-cm refractor by Carl Zeiss Jena delivered to the Neubabalsberg Observatory, Berlin.

Harlow Shapley became an astronomer at Mount Wilson Observatory.

The *Cordoba Durchmusterung* published, containing 580,000 stars.

THE TRANSIT QUIZ

Answers to November's quiz

Every answer starts with the letter J. The questions are in very rough order of increasing difficulty.

1. NASA's centre of excellence for deep-space systems, in Pasadena, California. [JPL](#) – the **Jet Propulsion Laboratory**.
2. The planned future successor to the Hubble Space Telescope. [JWST](#) – the **James Webb Space Telescope**.
3. Asteroid number 3, discovered in 1804. [Juno](#).
4. The largest facility in the world designed specifically to operate at submillimeter wavelengths, and situated on Mauna Kea, Hawaii. [JCMT](#) – the **James Clerk Maxwell Telescope**.
5. The tenth Astronomer Royal, who arranged the move of Greenwich Observatory to Herstmonceux in Sussex. [Sir Harold Spencer Jones](#) (1890–1960, and [Astronomer Royal](#) from 1933–55).
6. The name given by John Herschel to the brilliant open cluster NGC 4755 in the constellation Crux. [Jewel Box](#).
7. The international unit of flux density, equal to 10^{-26} watts per square metre per hertz. **Jansky (Jy)**, after the pioneering American radio astronomer [Karl Jansky](#) (1905–50).
8. The number of days that have passed since noon GMT on 1 January 4713 BC. [Julian Date](#). **Strictly speaking, that's the Julian Day Number (JDN), with the Julian Date being the previous day's JDN plus the fraction of a day that's passed since the previous noon – but hey, it's Christmas, right?!**
9. The French inventor of the spectrohelioscope. [Pierre-Jules-César Janssen](#) (1824–1907), who also **discovered helium, from its signature in the Sun's spectral lines**. You may read elsewhere that **George Ellery Hale, who seems to get everywhere, especially into quiz questions, invented the spectrohelioscope in 1924; but Janssen proved the principle with a makeshift set-up in 1868.**
10. The size of a nucleon (essentially a hydrogen atom) is defined as 1 fermi, and is equal to 10^{-13} cm. What name has been suggested (by [Richard Tolman](#)) for the time required for light to travel a distance of 1 fermi? [A jiffy](#). **I love that.**

December's quiz

Every answer starts with the letter K. The questions are in very rough order of increasing difficulty.

1. He proposed what might have been the Thomson scale.
2. The distance at which a star would subtend a parallax of 0.001 arcsec.
3. Tycho Brahe's even more famous assistant.
4. Popular type of eyepiece with large eye relief – essentially, a modified Ramsden design.
5. Popular name for the shape marked out by ϵ , ζ , η and π Herculis.
6. A group of comets with similar orbits and a perihelion distance within 0.01 AU (about a million miles).
7. Essentially empty regions of the asteroid belt at 2.5, 2.95 and 3.3 AU, caused by resonances due to Jupiter's gravity. (The answer is in an article earlier in this issue ...)
8. The US national research facility for ground-based optical astronomy. It has the most diverse collection on Earth of telescopes for optical and infrared astronomy and daytime solar studies.
9. German physicist who, with Robert Bunsen (1811–99), developed the principles and techniques of astronomical spectroscopy.
10. Inventor of the term 'contact binary'; director of Yerkes Observatory; and discoverer of Titan's atmosphere, carbon dioxide in Mars' atmosphere, and methane in the atmospheres of Uranus and Neptune. But you'll probably know his name for another reason ...



APPENDIX: Discovering the Planets and Satellites of the Solar System

Barry Hetherington, September 2013

The discovery of the planets and moons of the solar system falls into five main categories. The first phase is naked-eye observations by the ancients. This is followed by discoveries made at the telescope by direct vision. Subsequent discoveries depend on recording images on photographs or CCDs from ground-based instruments. The third phase is by space probes, and the final phase is again by ground-based telescopes but using advanced imaging techniques.

The object of the first entry does not exist but figures in the history of astronomy.

1859 Mar 26 **Vulcan**, a planet orbiting the sun within the orbit of Mercury, discovered by Edmond Modeste Lescarbault from Orgères, near Orléans, France, with his 3.75-inch refractor – not verified.

Mercury, a planet known to the ancients – no known moons.

Venus, a planet known to the ancients – no known moons

Moon, the only satellite of the Earth – known to the ancients.

Mars, a planet known to the ancients.

1877 Aug 11 **Deimos** (Mars II) discovered by Asaph Hall working at the United States Naval Observatory, Washington DC, using the 26-inch, 32-foot focal length refractor.

1877 Aug 17 **Phobos** (Mars I) discovered by Asaph Hall working at the United States Naval Observatory, Washington DC, using the 26-inch, 32-foot focal length refractor.

1801 Jan 1 **Ceres**, a dwarf planet, discovered by Giuseppe Piazzi using the 5-foot vertical circle made by Jesse Ramsden for the Palermo Observatory, Sicily – no known moons – re-designated from an asteroid to a dwarf planet on 24 August 2006.

Jupiter, a planet known to the ancients

1610 Jan 7 **Ganymede** (Jupiter III) discovered by Galileo Galilei using a 1.5-inch refractor at the university of Padua, Italy.

1610 Jan 7	Callisto (Jupiter IV) discovered by Galileo Galilei using a 1.5-inch refractor at the university of Padua, Italy.
1610 Jan 8	Io (Jupiter I) discovered by Galileo Galilei using a 1.5-inch refractor at the university of Padua, Italy.
1610 Jan 8	Europa (Jupiter II) discovered by Galileo Galilei using a 1.5-inch refractor at the university of Padua, Italy. Simon Marius claimed to have seen all four satellites on 28 December 1609.
1892 Sep 9	Amalthea (Jupiter V), discovered by Edward Emerson Barnard using the 36-inch refractor by Alvan Clark at the Lick Observatory on Mount Hamilton, California.
1904 Dec 4	Himalia (Jupiter VI), discovered by Charles Dillon Perrine in photographs taken with the Crossley 36-inch reflector of the Lick Observatory on Mount Hamilton, California.
1905 Jan 3	Elara (Jupiter VII) discovered by Charles Dillon Perrine in photographs taken with the Crossley 36-inch reflector of the Lick Observatory on Mount Hamilton, California.
1908 Jan 27	Pasiphae (Jupiter VIII) discovered by Philibert Jacques Melotte on a photographic plate taken with the 30-inch Cassegrain telescope by Howard Grubb at the Royal Greenwich Observatory, London.
1914 Jul 21	Sinope (Jupiter IX) discovered by Seth Barnes Nicholson with the 36-inch Crossley reflector at the Lick Observatory, Mount Hamilton, California.
1938 Jul 6	Lysithea (Jupiter X) discovered by Seth Barnes Nicholson using the 100-inch Hooker reflector at the Mount Wilson Observatory, California.
1938 Jul 30	Carme (Jupiter XI) discovered by Seth Barnes Nicholson using the 100-inch Hooker reflector at the Mount Wilson Observatory, California.
1951 Sep 28	Ananke (Jupiter XII) discovered by Seth Barnes Nicholson with the 100-inch Hooker reflector at the Mount Wilson Observatory, California.

- 1974 Sep 11 **Leda** (Jupiter XIII) discovered by Charles Thomas Kowal on photographs taken with the 48-inch Schmidt Telescope at the Mount Palomar Observatory, California.
- 1975 Sep 30 **Themisto** (Jupiter XVIII) discovered from Mount Palomar Observatory, California, by Charles Thomas Kowal and Elizabeth Romer using the 48-inch Schmidt telescope – rediscovered on 21-11-2000 by Scott Sander Sheppard, David C Jewitt, Yanga Roland Fernandez, Eugene A Magnier, M Holman, Brian G Marsden and G V Williams from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 1979 Mar 4 **Metis** (Jupiter XVI) discovered by Stephen P Synnott from Voyager 1 images.
- 1979 March 5 **Thebe** (Jupiter XIV) discovered by Stephen P Synnott from Voyager 1 images.
- 1979 July 8 **Adrastea** (Jupiter XV) discovered by David C Jewitt and G Edward Danielson from Voyager 2 images.
- 1999 Oct 19 **Callirrhoe** (Jupiter XVII) discovered by Timothy B Sphar, Jim V Scotti, Robert S McMillan, Jeffrey A Larson, Joe Montani, Arianna E Gleason and Tom Gehrels using the 36-inch telescope on Kitt Peak, Arizona.
- 2000 Nov 23 **Harpalyke** (Jupiter XXII) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2000 Nov 23 **Kalyke** (Jupiter XXIII) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2000 Nov 23 **Iocaste** (Jupiter XXIV) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2000 Nov 23 **Erinome** (Jupiter XXV) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.

- 2000 Nov 23 **Isonoe** (Jupiter XXVI) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2000 Nov 23 **Praxidike** (Jupiter XXVII) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2000 Nov 25 **Megaclite** (Jupiter XIX) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2000 Nov 25 **Taygete** (Jupiter XX) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2000 Nov 26 **Chaldene** (Jupiter XXI) discovered by Scott Sander Sheppard, David C Jewitt, Yanga R Fernandez and Eugene Magnier from Mauna Kea Observatory, Hawaii, using the 88-inch reflector.
- 2001 Dec 9 **Hermippe** (Jupiter XXX) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea, Observatory, Hawaii.
- 2001 Dec 9 **Aitne** (Jupiter XXXI) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
- 2001 Dec 9 **Eurydome** (Jupiter XXXII) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
- 2001 Dec 9 **Sponde** (Jupiter XXXVI) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.

2001 Dec 9	Kale (Jupiter XXXVII) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2001 Dec 10	Autonoe (Jupiter XXVIII) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2001 Dec 11	Thyone (Jupiter XXIX) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2001 Dec 11	Euanthe (Jupiter XXXIII) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2001 Dec 11	Euporie (Jupiter XXXIV) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2001 Dec 11	Orthosie (Jupiter XXXV) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2001 Dec 11	Pasithee (Jupiter XXXVIII) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2001	S/2000J11, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt and Y Fernandez and G Magnier using the 88-inch telescope at Mauna Kea Observatory, Hawaii. Re-discovered by Scott Sander Sheppard in images obtained at the 256-inch Magellan Telescope, Las Campanas Observatory, Chile, in 2010 and 2011.
2002 Oct 31	Arche (Jupiter XLII) discovered by Scott Sander Sheppard using the 88-inch telescope from Mauna Kea Observatory, Hawaii.
2003 Feb 5	Eukelade (Jupiter XLVII) discovered by Scott Sander Sheppard using the 323-inch Subaru telescope, Mauna Kea Observatory, Hawaii.

- 2003 Feb 6 **Kallichore** (Jupiter XLIV) discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
- 2003 Feb 6 **Helike** (Jupiter XLV) discovered by Scott Sander Sheppard, David C. Jewitt, Jan T Kleyna, Yanga R. Fernandez and Henry H. Hsieh using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
- 2003 Feb 8 **Hegemone** (Jupiter XXXIX) discovered by Scott Sander Sheppard, David C. Jewitt, Jan T. Kleyna, Yanga R. Fernandez, and Henry H. Hsieh using the 323-inch Subaru telescope, Mauna Kea Observatory, Hawaii.
- 2003 Feb 8 **Aoede** (Jupiter XLI) discovered by Scott S. Sheppard, David C. Jewitt, Jan T. Kleyna, Yanga R. Fernandez, and Henry H. Hsieh using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
- 2003 Feb 8 **Kore** (Jupiter XLIX) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 323-inch Subaru telescope, Mauna Kea Observatory, Hawaii.
- 2003 Feb 9 **Mneme** (Jupiter XL) discovered by Scott S. Sheppard, Brett Joseph Gladman and L Allen with the 323-inch Subaru telescope and 141-inch Canada–France–Hawaii telescope at the Mauna Kea Observatory, Hawaii.
- 2003 Feb 9 **Thelxinoe** (Jupiter XLII) discovered by Scott Sander Sheppard and Brett Joseph Gladman using the 141-inch Canada–France–Hawaii telescope and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
- 2003 Feb 9 **Cyllene** (Jupiter XLVIII) discovered by Scott Sander Sheppard with the 323-inch Subaru telescope, Mauna Kea Observatory, Hawaii.
- 2003 Feb 26 **Carpo** (Jupiter XLVI) discovered by Scott S. Sheppard and others from the University of Hawaii's Institute for Astronomy using the 141-inch Canada–France–Hawaii telescope at the Mauna Kea Observatory, Hawaii.

2003 Feb 27	Herse (Jupiter L) discovered by Brett J. Gladman, John J. Kavelaars, Jean-Marc Petit, and Lynne Allen with the 141-inch Canada–France–Hawaii telescope, Mauna Kea Observatory, Hawaii.
2003 Feb/Mar	S/2003J2, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez, and Henry H. Hsieh using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2003 Feb/Mar	S/2003J4, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez, and Henry H. Hsieh using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2003 Feb/Mar	S/2003J5, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez, and Henry H. Hsieh using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2003	S/2003J9, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2003	S/2003J10, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2003 Mar	S/2003J12, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2003 Feb/Mar	S/2003J3, a satellite of Jupiter, discovered by Scott Sander Sheppard, David C Jewitt, Jan T. Kleyna, Yanga R. Fernandez, and Henry H. Hsieh using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope, and the 88-inch reflector at Mauna Kea Observatory, Hawaii.

2003 Apr	S/2003J15, a satellite of Jupiter, discovered by Scott Sander Sheppard et al using the 323-inch Subaru Telescope at the Mauna Kea Observatory, Hawaii.
2003 Apr	S/2003J16), a satellite of Jupiter, discovered by Brett Joseph Gladman and others, with the 141-inch Canada–France–Hawaii telescope and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2003 Apr	S/2003J18, a satellite of Jupiter, discovered by Brett Joseph Gladman and others with the 141-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2003 Feb	S/2003J19, a satellite of Jupiter, discovered by Brett Joseph Gladman and others with the 141-inch Canada–France–Hawaii telescope and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2004 Feb	S/2003J23, a satellite of Jupiter, discovered by Scott Sander Sheppard and others using the 323-inch Subaru Telescope, the 141-inch Canada–France–Hawaii telescope and the 88-inch reflector at Mauna Kea Observatory, Hawaii.
2010 Sep 7	S/2010J1, a satellite of Jupiter, discovered by Robert Jacobson, Marina Brozovic, B Gladman, and Mike Alexandersen with the 200-inch Hale telescope, Palomar Observatory, California.
2010 Sep 8	S/2010J2, a satellite of Jupiter, discovered by Christian Veillet with the 141-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
2011	S/2011J1, a satellite of Jupiter, discovered by Scott Sander Sheppard and others using the 256-inch Magellan Telescope at Las Campanas Observatory, Chile.
2011	S/2011J2, a satellite of Jupiter, discovered by Scott Sander Sheppard and others. using the 256-inch Magellan Telescope at Las Campanas Observatory, Chile.

Saturn, a planet known to the ancients.

1655 Mar 25	Titan (Saturn VI) discovered by Christiaan Huygens observing from The Hague, Netherlands, with a telescope 12 feet long of 10½ feet focal length, 2 inches in diameter with a magnification of 50×.
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1671 Oct 25	Iapetus (Saturn VIII) discovered by Giovanni Domenico Cassini from the Royal Observatory, Paris, with a 17-foot telescope by Joseph Campani.
1672 Dec 23	Rhea (Saturn V) discovered by Giovanni Domenico Cassini from the Royal Observatory, Paris, with a 34-foot telescope by Joseph Campani.
1684 Mar 21	Tethys (Saturn III) discovered by Giovanni Domenico Cassini from the Royal Observatory, Paris, with telescopes made by Joseph Campani of 100 and 136 feet focal lengths.
1684 Mar 21	Dione (Saturn IV) discovered by Giovanni Domenico Cassini from the Royal Observatory, Paris, with telescopes made by Joseph Campani of 100 and 136 feet focal lengths.
1789 Aug 28	Mimas (Saturn I) discovered by William Herschel at Slough, England, using his 40-foot focal length telescope with a 4-foot diameter mirror and a magnification of 189×
1789 Sep 17	Enceladus (Saturn II) discovered by William Herschel at Slough, England, using his 20-foot reflector and confirmed with his new 40-foot focal length telescope with a 4-foot diameter mirror.
1848 Sep 16	Hyperion (Saturn VII) discovered by George Phillips Bond using the 15-inch equatorial refractor by Merz and Mahler of the Harvard Observatory, Cambridge, Massachusetts, USA. Independently discovered by William Lassell from his observatory at Starfield, Liverpool, England, on 18 September using his 20-foot equatorial reflector.
1898 Aug 16	Phoebe (Saturn IX) discovered by William Henry Pickering on photographic plates taken by Delisle Stewart at Harvard Observatories southern station, the Boyden Observatory, at Arequipa, Peru, using the 24-inch aperture, 160-inch focal length Bruce Astrograph.
1966 Dec 15	Janus (Saturn X) discovered by Audouin Charles Dollfus at the Pic du Midi Observatory, France, with the 42-inch telescope. Confirmed on 1980 Feb 19 by Dan Pascu from Washington.

1966 Dec 18	Epimetheus (Saturn XI) discovered by Richard Walker with the 61-inch reflector at the United States Naval Observatory, Flagstaff. The satellite had an orbit similar to that of Janus and the two were assumed to be one body. In 1978 October John W Fountain and Stephen M Larson at Tucson realised that there were two bodies involved. Confirmed on 1980 Feb 26 by D Cruikshank at Mauna Kea Observatory.
1980 Feb 29	Helene (Saturn XII) discovered by Pierre Laques, Raymond Despiau and Jean Lecacheux with the 42-inch telescope at the Pic du Midi Observatory, France.
1980 Mar 13	Calypso (Saturn XIV) discovered by Dan Pascu, P Kenneth Seidelmann, William A Baum and Douglas G Currie at the United States Naval Observatory at Flagstaff, Arizona, with the 61-inch Kaj Strand Astrometric Reflector.
1980 Apr 8	Telesto (Saturn XIII) discovered by Bradford A Smith, Harold Reitsema, Stephen M Larson and John Fountain with the 61-inch reflector at the Lunar and Planetary Laboratory, Tucson, Arizona.
1980 Oct	Atlas (Saturn XV) discovered by Richard John Terrile and the Voyager 1 Science Team.
1980 Oct	Prometheus (Saturn XVI) discovered by Stewart Collins and the Voyager 1 Science Team.
1980 Oct	Pandora (Saturn XVII) discovered by Stewart Collins and the Voyager 1 Science Team.
1990	Pan (Saturn XVIII) discovered by Mark R Showalter on 11 Voyager 2 photographs taken in 1981.
2000 Aug 7	Ymir (Saturn XIX) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 86-inch telescope at the European Southern Observatory, La Silla, Chile.
2000 Aug 7	Paaliaq (Saturn XX) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 86-inch telescope at the European Southern Observatory, La Silla, Chile.

- 2000 Aug 7 **Kiviuq** (Saturn XXIV) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 86-inch telescope at the European Southern Observatory, La Scilla, Chile.
- 2000 Sep 23 **Tarvos** (Saturn XXI) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.
- 2000 Sep 23 **Ijiraq** (Saturn XXII) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.
- 2000 Sep 23 **Suttungr** (Saturn XXIII) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.
- 2000 Sep 23 **Mundilfari** (Saturn XXV) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.
- 2000 Sep 23 **Skathi** (Saturn XXVII) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.
- 2000 Sep 23 **Erriapus** (Saturn XXVIII) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.
- 2000 Sep 23 **Siarnaq** (Saturn XXIX) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.

- 2000 Sep 23 **Thrymr** (Saturn XXX) discovered by Brett J Gladman, John J Kavelaars, Jean-Marc Petit, Hans Scholl, Matthew J Holman, Brian G Marsden, Phillip D Nicholson and Joseph A Burns using the 140-inch Canada–France–Hawaii reflector from Mauna Kea Observatory, Hawaii, with adaptive optics.
- 2000 Nov 9 **Albiorix** (Saturn XXVI) discovered by Matthew J Holman and Timothy B Spahr using the 256-inch reflector telescope at the Fred Lawrence Whipple Observatory on Mt. Hopkins, near Amado, Arizona.
- 2003 Feb 5 **Narvi** (Saturn XXXI) discovered by Scott Sander Sheppard, David C Jewitt and Jan T Kleyna using the 323-inch Subaru telescope, Mauna Kea Observatory, Hawaii.
- 2004 Jun 1 **Methone** (Saturn XXXII) discovered by the Cassini Imaging Science Team – Joe Burns, Torrence Johnson, Alfred McEwen, Carl Murray, Bob West, Joe Veverka, Peter Thomas, Andre Brahic, Tony DelGenio, Andy Ingersoll, Carolyn Porco, Steve Squyres, Luke Dones and Gerhard Neukum.
- 2004 Jun 1 **Pallene** (Saturn XXXIII) discovered by the Cassini Imaging Science Team – Joe Burns, Torrence Johnson, Alfred McEwen, Carl Murray, Bob West, Joe Veverka, Peter Thomas, Andre Brahic, Tony DelGenio, Andy Ingersoll, Carolyn Porco, Steve Squyres, Luke Dones and Gerhard Neukum.
- 2004 Oct 21 **Polydeuces** (Saturn XXXIV) discovered by the Cassini Imaging Science Team – Joe Burns, Torrence Johnson, Alfred McEwen, Carl Murray, Bob West, Joe Veverka, Peter Thomas, Andre Brahic, Tony DelGenio, Andy Ingersoll, Carolyn Porco, Steve Squyres, Luke Dones and Gerhard Neukum.
- 2004 Dec 12 **Aegir** (Saturn XXXVI) discovered by Scott S Sheppard, David L Jewitt and Jan T Kleyna, using a wide-field camera on the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2004 Dec 12 **Bebhionn** (Saturn XXXVII) discovered by Scott S Sheppard, David L Jewitt and Jan T Kleyna, using the wide-field camera on the 323-inch Subaru telescope from Mauna Kea Observatory, Hawaii.
- 2004 Dec 12 **Bergelmir** (Saturn XXXVIII) discovered by Scott S Sheppard, David L Jewitt and Jan T Kleyna, using wide-field camera on the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.

- 2004 Dec 12 **Farbauti** (Saturn XL) discovered by Scott S Sheppard, David L Jewitt and Jan T Kleyna, using wide-field camera on the Subaru 323-inch reflector telescope from Mauna Kea \observatory, Hawaii.
- 2004 Dec 12 **Fornjot** (Saturn XLII) discovered by Scott S Sheppard, David L Jewitt and Jan T Kleyna, using a wide-field camera on the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2004 Dec 12 **Hati** (Saturn XLIII) discovered by Scott S Sheppard, David L Jewitt and Jan T Kleyna, using a wide-field camera on the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2004 Dec 12 **Hyrrokkin** (Saturn XLIV) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna using the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2004 Dec 13 **Bestla** (Saturn XXXIX) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna, using wide-field camera on the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2004 Dec 13 **Fenrir** (Saturn XLI) discovered by Scott S Sheppard, David L Jewitt and Jan T Kleyna, using a wide-field camera on the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2005 May 1 **Daphnis** (Saturn XXXV) discovered by the Cassini Imaging Science Team – Joe Burns, Torrence Johnson, Alfred McEwen, Carl Murray, Bob West, Joe Veverka, Peter Thomas, Andre Brahic, Tony DelGenio, Andy Ingersoll, Carolyn Porco, Steve Squyres, Luke Dones and Gerhard Neukum.
- 2006 Jan 4 **Kari** (Saturn XLV) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna, based on data obtained with the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2006 Jan 5 **Loge** (Saturn XLVI) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna using the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.

- 2006 Jan 5 **Skoll** (Saturn XLVII) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna using the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2006 Jan 5 **Surtur** (Saturn XLVIII) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna using the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2006 Jan 5 **Jarnsaxa** (Saturn (L)) discovered by Scott S Sheppard, David C Jewitt and Jan Kleyna using the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2006 Jan 5 **Greip** (Saturn LI) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna using the Subaru 323-inch reflector telescope from Mauna Kea Observatory, Hawaii.
- 2007 Jan 16 **Tarqeq** (Saturn LII) discovered by Scott S Sheppard, David C Jewitt and Jan T Kleyna at the Subaru 323-inch reflector at the Mauna Kea Observatory in Hawaii.
- 2007 May 30 **Anthe** (Saturn XLIX) discovered by the Cassini Imaging Science Team – Joe Burns, Torrence Johnson, Alfred McEwen, Carl Murray, Bob West, Joe Veverka, Peter Thomas, Andre Brahic, Tony DelGenio, Andy Ingersoll, Carolyn Porco, Steve Squyres, Luke Dones and Gerhard Neukum.
- 2008 Aug 15 **Aegaeon** (Saturn LIII) discovered by the Cassini Imaging Science Team – Joe Burns, Torrence Johnson, Alfred McEwen, Carl Murray, Bob West, Joe Veverka, Peter Thomas, Andre Brahic, Tony DelGenio, Andy Ingersoll, Carolyn Porco, Steve Squyres, Luke Dones and Gerhard Neukum.
- 1781 Mar 3 **Uranus**, a planet discovered by William Herschel while living in Bath, England, using a 6.2-inch speculum mirror mounted in a 7-foot tube giving a magnification of 227×. It was observed by John Flamsteed on 23 December 1690 and on five other occasions (once in 1712 and four times in 1715), cataloguing it as the star 34 [Tauri](#). It was seen by James Bradley in 1748, 1750 and 1753, and observed by Tobias Mayer in 1756. Pierre Charles Le Monnier observed it on ten occasions between 1764 and 1771 including on four consecutive nights.
- 1787 Jan 11 **Titania** (Uranus III) discovered by William Herschel from Slough, England, with a 20-foot reflector with an aperture of 18.7 inches.

1787 Jan 11	Oberon (Uranus IV) discovered by William Herschel from Slough, England, with a 20-foot reflector with an aperture of 18.7 inches.
1851 Oct 24	Ariel (Uranus I) discovered by William Lassell from Starfield, near Liverpool, England, with his 24-inch mirror of 20 feet focal length.
1851 Oct 24	Umbriel (Uranus II) discovered by William Lassell from Starfield, near Liverpool, England, with his 24-inch mirror of 20 feet focal length.
1948 Feb 16	Miranda (Uranus V) discovered by Gerard Peter Kuiper on photographic plates taken on 1948 February 16 at the Cassegrain focus of the 82-inch Otto Struve reflector of the McDonald Observatory on Mount Locke, Texas.
1985 Dec 30	Puck (Uranus XV) discovered by Stephen Synnott and the Voyager 2 Science Team.
1986 Jan 3	Juliet (Uranus XI) discovered by the Voyager 2 Science Team.
1986 Jan 3	Portia (Uranus XII) discovered by the Voyager 2 Science Team.
1986 Jan 9	Cressida (Uranus IX) discovered by the Voyager 2 Science Team.
1986 Jan 13	Desdemona (Uranus X) discovered by the Voyager 2 Science Team.
1986 Jan 13	Rosalind (Uranus XIII) discovered by the Voyager 2 Science Team.
1986 Jan 13	Belinda (Uranus XIV) discovered by the Voyager 2 Science Team.
1986 Jan 20	Cordelia (Uranus VI) discovered by the Voyager 2 Science Team.
1986 Jan 20	Ophelia (Uranus VII) discovered by the Voyager 2 Science Team.
1986 Jan 23	Bianca (Uranus VIII) discovered by the Voyager 2 Science Team.

1986 Jan 18	Perdita (Uranus XXV) discovered by Erich Karkoschka from Voyager 2 images.
1997 Sep 6	Caliban (Uranus XVI) discovered by Brett J Gladman, Phillip D Nicholson, Joseph A Burns and John J Kavelaars with the 200-inch Hale telescope at Palomar Observatory, California..
1997 Sep 6	Sycorax (Uranus XVII) discovered by Phillip D Nicholson, Brett J Gladman, Joseph A Burns and John J Kavelaars using the 200-inch Hale telescope at Palomar Observatory, California.
1999 Jul 18	Prospero (Uranus XVIII) discovered by Matthew J Holman, John J Kavelaars, Brett J Gladman, Jean-Marc Petit and Hans Scholl using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
1999 Jul 18	Setebos (Uranus XIX) discovered by John J Kavelaars, Brett J Gladman, Matthew J Holman, Jean-Marc Petit and Hans Scholl using the 140-inch Canada–France–Hawaii telescope at Mauna Kea Observatory, Hawaii.
1999 Jul 18	Stephano (Uranus XX) discovered by Brett J Gladman, Matthew J Holman, John J Kavelaars, Jean-Marc Petit and Hans Scholl using the 140-inch Canada–France–Hawaii telescope from Mauna Kea Observatory, Hawaii.
2001 Aug 13	Trinculo (Uranus XXI) discovered by John J Kavelaars, Matthew J Holman, and Dan Milisavljevic at the Dominion Astrophysical Observatory in Victoria, British Columbia, by using the 158-inch reflector at the Cerro Tololo Inter-American Observatory in Chile.
2001 Aug 13	Francisco (Uranus XXII) discovered by John J Kavelaars, Matthew J Holman, Dan Milisavljevic and Tommy Grav at the Dominion Astrophysical Observatory in Victoria, British Columbia, by using the 158-inch reflector at the Cerro Tololo Inter-American Observatory in Chile.
2001 Aug 13	Ferdinand (Uranus XXIV) discovered by Dan Milisavljevic, Matthew J Holman, John J Kavelaars and Tommy Grav at the Dominion Astrophysical Observatory in Victoria, British Columbia, and by using the 158-inch reflector at the Cerro Tololo Inter-American Observatory in Chile.

2003 Aug 25	Mab (Uranus XXVI) discovered by Mark R Showalter and Jack J Lissauer with the Hubble Space Telescope's Advanced Camera for Surveys.
2003 Aug 25	Cupid (Uranus XXVII) discovered by Mark R Showalter and Jack J Lissauer with the Hubble Space Telescope's Advanced Camera for Surveys.
2003 Aug 29	Margaret (Uranus XXIII) discovered by Scott Sander Sheppard and David C Jewitt with the Subaru 323-inch reflector at the Mauna Kea Observatory, Hawaii.
1846 Sept 23	Neptune , a planet discovered by Johann Gottfried Galle and Heinrich Louis D'Arrest from the Berlin Observatory with a 9.6-inch equatorial-mounted achromatic refractor by Merz and Mahler using calculations provided by Urbain Jean Joseph Le Verrier. Galileo observed it on 28 December 1612 and again in 1613. Astronomers at the Paris Observatory observed it on 8 and 10 May 1795. John Herschel saw it on 14 July 1830 and John Lamont observed it in 1845 and 1846.
1846 Oct 10	Triton (Neptune I) discovered by William Lassell from Starfield, near Liverpool, England, with his 24-inch mirror of 20 feet focal length.
1949 May 1	Neried (Neptune II) discovered by Gerard Peter Kuiper on photographic plates taken with the 82-inch Otto Struve reflector of the McDonald Observatory, Texas.
1989 Jun	Proteus (Neptune VIII) discovered by the Voyager 2 Science Team
1989 Jul	Despina (Neptune V) discovered by the Voyager 2 Science Team
1989 Jul	Galatea (Neptune VI) discovered by the Voyager 2 Science Team.
1989 Jul	Larissa (Neptune VII) discovered by the Voyager 2 Science Team. An occultation of a star by this moon was observed on 24 May 1981 by Harold J Reitsema, William B Hubbard, Larry A Lebofsky and David J Tholen while trying to observe an occultation of the planet's ring system using the 61-inch reflector at the Catalina station, Arizona, and the 40-inch reflector on Mt. Lemmon, Arizona.
1989 Aug	Naiad (Neptune III) discovered by the Voyager 2 Science Team.

1989 Aug	Thalassa (Neptune IV) discovered by the Voyager 2 Science Team.
2002 Aug 13	Laomedeia (Neptune XII) discovered by Matthew J. Holman, John J. Kavelaars, Tommy Grav, Wesley C. Fraser and Dan Milisavljevic using images taken by the 158-inch Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile and the 141-inch Canada–France–Hawaii Telescope, Mauna Kea Observatory, Hawaii.
2002 Aug 14	Halimede (Neptune IX) discovered by Matthew J. Holman, John J. Kavelaars, Tommy Grav, Wesley C. Fraser and Dan Milisavljevic using images taken by the 158-inch Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile and the 141-inch Canada–France–Hawaii Telescope, Mauna Kea Observatory, Hawaii.
2002 Aug 14	Sao (Neptune XI) discovered by Tommy Grav, Matthew J. Holman, John J. Kavelaars, Wesley C. Fraser and Dan Milisavljevic using images taken by the 158-inch Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile and the 141-inch Canada–France–Hawaii Telescope, Mauna Kea Observatory, Hawaii.
2002 Aug 14	Neso (Neptune XIII) discovered by Matthew J. Holman, John J. Kavelaars, Tommy Grav, Wesley C. Fraser and Dan Milisavljevic using the 158-inch Blanco telescope at Cerro Tololo Inter-American Observatory in Chile.
2003 Aug 29	Psamathe (Neptune X) discovered by Scott Sander Sheppard, David C. Jewitt and Jan T. Kleyna using the 327-inch Subaru reflector at the Mauna Kea Observatory, Hawaii.
2013 Jul 1	S/2004 N 1, a satellite of Neptune, discovered by Mark Showalter of the SETI Institute in Mountain View, California, with the Hubble Space Telescope.
1930 Feb 18	Pluto , a dwarf planet discovered by Clive Tombaugh on photographic plates taken on 23 and 29 January with the 13-inch astrograph at the Lowell Observatory – re-designated from a planet to a dwarf planet on 24 August 2006.
1978 Apr 13	Charon (Pluto I) discovered by James Walter Christy from the United States Naval Observatory at Flagstaff, Arizona using the 61-inch Kaj Strand Astrometric Reflector.

- 2005 May 15 **Nix** (Pluto II) discovered by Hal A Weaver, S Alan Stern, Max J Mutchler, Andrew J Steffl, Marc W Buie, William J Merline, John R Spencer, Eliot F Young and Leslie A Young using the Hubble Space Telescope.
- 2005 May 15 **Hydra** (Pluto III) discovered by Hal A Weaver, S Alan Stern, Max J Mutchler, Andrew J Steffl, Marc W Buie, William J Merline, John R Spencer, Eliot F Young and Leslie A Young using the Hubble Space Telescope.
- 2002 Jun 5 **Quaoar** a dwarf planet discovered by Michael Brown and Chadwick Trujillo of the California Institute of Technology, Pasadena, using the 48-inch Schmidt (Samuel Oschin Telescope) at the Palomar Observatory, California.
- 2003 Oct 21 **Eris**, a dwarf planet discovered by Mike Brown, a professor of planetary astronomy at the California Institute of Technology; Chad Trujillo of the Gemini Observatory; and David Rabinowitz of Yale University at the Palomar Observatory, California, using the 48-inch Samuel Oschin Schmidt telescope at Mount Palomar Observatory. The discovery was confirmed in January 2005.
- 2005 Sep 10 **Dysnomia** (Eris I) discovered by the 394-inch Keck II refractor using the Keck Observatory Laser Guide Star Adaptive Optics (LGSAO) system, Mauna Kea Observatory, Hawaii, by M E Brown, M A van Dam, A H Bouchez, D Le Mignant, R D Campbell, J C Y Chin, A Conrad, S K Hartman, E M Johansson, R E Lafon, D L Rabinowitz, P J Stomski, Jr, D M Summers, C A Trujillo, and P L Wizinowich.
- 2003 Nov 14 **Sedna**, a dwarf planet discovered by Mike Brown, Chad Trujillo and David Rabinowitz using the 48-inch Schmidt (Samuel Oschin Telescope) at Palomar Observatory and Yale's 160-megapixel Palomar Quest Camera.
- 2004 Feb 17 **Orcus**, a dwarf planet discovered by Michael Brown, Chad Trujillo and David Rabinowitz using an automated sky survey telescope in California
- 2005 Nov 13 **Vanth** (Orcus I) discovered by Mike Brown and T A Suer using the Hubble Space Telescope.
- 2004 Dec 28 **Haumea**, a dwarf planet discovered by Mike Brown and his team at Caltech on images taken on May 6 2004 with the 48-inch Schmidt (Samuel Oschin

Telescope) at the Palomar Observatory, California. José Luis Ortiz Moreno and his team at the Instituto de Astrofísica de Andalucía at Sierra Nevada Observatory in Spain found Haumea on images taken on March 7–10, 2003.

- 2005 Jan 26 **Hi'iaka** (Haumea I) discovered by the Keck Observatory Laser Guide Star Adaptive Optics (LGSAO) system, Mauna Kea Observatory, Hawaii - M E Brown, M A van Dam, A H Bouchez, D Le Mignant, R D Campbell, J C Y Chin, A Conrad, S K Hartman, E M Johansson, R E Lafon, D L Rabinowitz, P J Stomski, Jr, D M Summers, C A Trujillo and P L Wizinowich.
- 2005 Nov 7 **Namaka** (Haumea II) discovered by the Keck Observatory Laser Guide Star Adaptive Optics (LGSAO) system, Mauna Kea Observatory, Hawaii - Michael E Brown, M A van Dam, A H Bouchez, D Le Mignant, R D Campbell, J C Y Chin, A Conrad, S K Hartman, E M Johansson, R E Lafon, David L Rabinowitz, P J Stomski, Jr, D M Summers, Chad A Trujillo and P L. Wizinowich.
- 2005 Mar 31 **Makemake**, a dwarf planet discovered by Michael E Brown, Chad A. Trujillo and David L. Rabinowitz at the Keck Observatory, Mauna Kea Observatory, Hawaii.