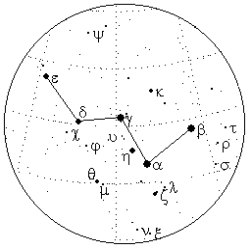


Wadhurst Astronomical Society Newsletter May 2014

INTERNATIONAL ASTRONOMY SHOW 2014

We have been requested by UK Astro Show Ltd to mention this year's International Astronomy Show 2014 after their successful show last year.

This year it will be held at the Warwickshire Exhibition Centre, The Fosse Way, Near Leamington Spa, Warwickshire CV31 1XN on Saturday the 7th and Sunday the 8th of June.

There will be over 60 vendors from the UK, Europe and the USA in the enlarged hall and there is a new 250 seat lecture marquee with a full programme by some popular speakers from television and astronomy publications such as Will Gater, Dr Lucie Green, Pete Lawrence and Nik Szymanek. The IAS 2014 show is the largest astro-show in the UK.

Tickets are Adults £7.50 (Advanced on-line tickets) Children £5.75 (Advanced on-line). Lectures £6.00 – only 250 seats per lecture, so they say book early to avoid disappointment. There is plenty of free parking and there is an on-site restaurant.

For further information, they have a website at: www.ukastroshow.com

SAGAS SUMMER EVENT 2014

The Committee have been trying to arrange an outing to Greenwich Observatory but after trying to find dates that were available and convenient it has been decided to postpone it until next year. But in the meantime, we have received a note from SAGAS.

SAGAS, the Southern Area Group of Astronomical Societies is holding their 2014 Summer Convention on Saturday the 19th of July. Again it is being held at the South Downs Planetarium & Science Centre, Chichester. There are talks on "Going to the Ends of the Earth to Prove Einstein Wrong", "History of the Greenwich Time Ball", "What Happened to Comet ISON?", "The UK Meteor Observation Network" and more. In previous years the event has been well worth going to.

The cost is £10 for members of Wadhurst Astronomical Society or £12 for non-members and there is free car parking. Times and further details of the day's events together with an application form can be downloaded from:
www.sagasonline.org/

There are limited places so it is worth reserving them as soon as possible, naming all people on the list as name badges will be provided on the day.

MEETINGS

The April meeting was introduced by John Vale-Taylor who greeted members and welcomed a number of visitors.

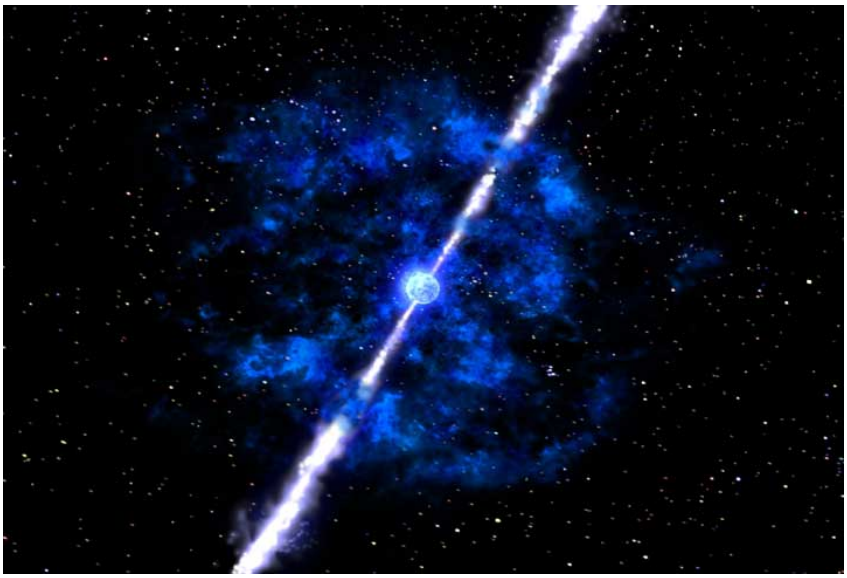
Last Saturday John spent hosting a Wadhurst Astronomical Society table with a few telescopes at an event called "Come and Meet Us" organised by Wadhurst council. It was a way in which various societies, clubs and groups could let local people know what was on offer. He said it was a successful and interesting day.

He then introduced our speaker for the evening, Stephen Tonkin who last October gave us an in depth introduction to binoculars, their care and use in astronomy. John told the meeting that Stephen had been a teacher for 30 years and is also well known through his articles in the "Sky at Night" magazine. He also thanked Stephen for coping with a very hectic journey to us tonight because of the closure of the M26 due to a serious road accident and the resultant chaos in the surrounding roads.

Ten Ways the Universe Tries to Kill You
Stephen Tonkin FRAS

To begin, Stephen said that there are at least 10 ways that life on Earth could be wiped out although one event he had left out occurred just before the 2012 Olympic Games in London. If the Mass Ejection from the Sun that had been observed had happened just eight days later, it would have come this way and affected the Earth and the Games would not have taken place.

The first candidate of the ten Stephen was going to talk about were Gamma Ray Bursts (GRBs) which are the consequence probably of a super-massive star collapsing and then releasing in a few seconds the same amount of energy that our Sun will release in its entire lifetime, but fortunately for us the energy is released in two extremely narrow beams.



An impression of a Gamma Ray Burst generation NASA

If one were to exist in our galaxy and we were in the direct line of the beam, it would wipe out the ozone layer, there would be mass extinction and starvation and life as we know it would cease but the chance of our being in line with a beam is extremely remote indeed. Stephen said that it is thought that there is perhaps one a day being created in the entire Universe so we are relatively safe which is just as well because he went on to say there is nothing to prevent them.

The second candidate is Magentars. These are relatively slowly rotating neutron stars with huge magnetic fields. They have a mass greater than the Sun but we were told that they are perhaps the size of Tunbridge Wells! The enormous magnetic field is so great it is capable of generating gamma and x-rays which are radiated out in all directions.

Apart from the harmful radiations, the magnetic pulse would wipe out satellites; emails would stop working and GPS systems would fail amongst other things and there would be no warning. We have been hit three times recently, in 1979, 1998 and 2004 and they can come from as far away as 20,000 light years.

Again, there is nothing we can do to prepare for or prevent them.

Thirdly, Stephen mentioned Cosmic Rays. These are very high energy particles that come from hyper-novae. We were told that they are millions of times more powerful than the Large Hadron Collider at CERN, although it is the secondary effect such as deletion of part of the DNA code that would affect us and they can also affect microchips. One of the results of this is that on the International Space Station, they have to reboot their computers every few hours.

They are there all the time, even reaching underground. What can we do about them? We can do something to help as Stephen said; we can live at low altitudes…

Next, we were introduced to Hypervelocity Stars.

Globular clusters are thought to be groups of very old stars but just occasionally blue stars called Blue Stragglers are discovered in them. It is thought that these are created when a black hole swallows a star causing two adjacent stars to merge making a Blue Straggler that is ejected and travels through space. If one was to come this way, it would have the same gravitational effect as the Sun and would disturb the Oort cloud sending debris towards us.

Artists impression of a travelling Hypervelocity Star Harvard-Smithsonian

Already several are known to exist but fortunately none are coming this way. If one was found to be coming this way, we would have something like half a millennium's warning. But again there is nothing we could do about them.

Rogue Black Holes came next in Stephen's list. These are black holes travelling through space. They would not have an Event Horizon so would be virtually invisible, and then only detectable through lensing effects. They would cause incredible gravitational destruction to the Solar System. We were told that the gravitational gradient would be so very great that we would all be "spagettified"! Again, there is nothing we could do about them.

Rogue Planets are objects the size of planets wandering through space. Again they could disturb the Oort cloud, causing debris to fall this way.

There is known to be one about 130 light years away. Once again, Stephen said there is nothing we can do about them but the risk to us is negligible.

Number seven on Stephen's list of how the Universe tries to kill us are Verneshots. These are hypothetical volcanic eruptions on Earth. It would be a volcano with a huge built up of carbon dioxide and magma deep beneath the Earth's crust at enormous pressure. The pressure could build up to such a degree that eventually when released, a huge plug of material would be ejected into a sub-orbital trajectory and the resultant shock wave would be similar to 6-million Hiroshimas at one go. We were told that the material could be the size of a large asteroid. There would be only a few minutes warning, although the velocity would be much lower than the impact with a real asteroid but would cause a dramatic effect.

Geologists think they occur about every hundred million years or so, although direct evidence is hard to find.

Stephen thinks the risk is negligible. Once again there is nothing we can do to prepare for them.

Galactic Collisions came next. They are occurring somewhere in the Universe all the time and in fact the Andromeda Galaxy is coming our way and will begin to pass through the Milky Way in about 4.5 billion years. Stars from Andromeda would probably pass through our galaxy without little interaction but if one came near it would disturb star positions.

We moved on to an Asteroid Strike. As time is progressing scientists are discovering more and more asteroids, many of them crossing the Earth's orbit. It is thought that the Tunguska event in Siberia in 1908 was the result of an asteroid impacting with the power of about 1,000 Hiroshimas. We were shown a photograph taken shortly afterwards and it is clear that the trees blown down all radiated out from one central point.

A black and white photograph of the area near Tunguska taken in 1908

In 2013 something landed at Chelyabinsk in Russia. It was thought to be an object about 17 metres wide with the power of about 500 kilotons of TNT. There were a number of resulting injuries but they were caused as people watched through their windows and the resulting delayed blast broke the glass.

If an approaching asteroid is identified Stephen said that the worst thing to do would be to try and break it up, which would result in many smaller impacts over a bigger area. If it were possible to deflect it, that might work but the only thing left would be to evacuate the area of expected impact.

The last of Stephen's killers is Solar Expansion.

Eventually our Sun is predicted to become a Red Giant with a diameter of something like 2 Astronomical Units! (one Astronomical Unit is the distance between the centre of the Sun and the Earth. Presently we are 1 AU from the centre of the Sun! This is certainly going to happen but not for approximately 5.4 billion years, possibly during the interaction between the Milky Way and the Andromeda Galaxy.

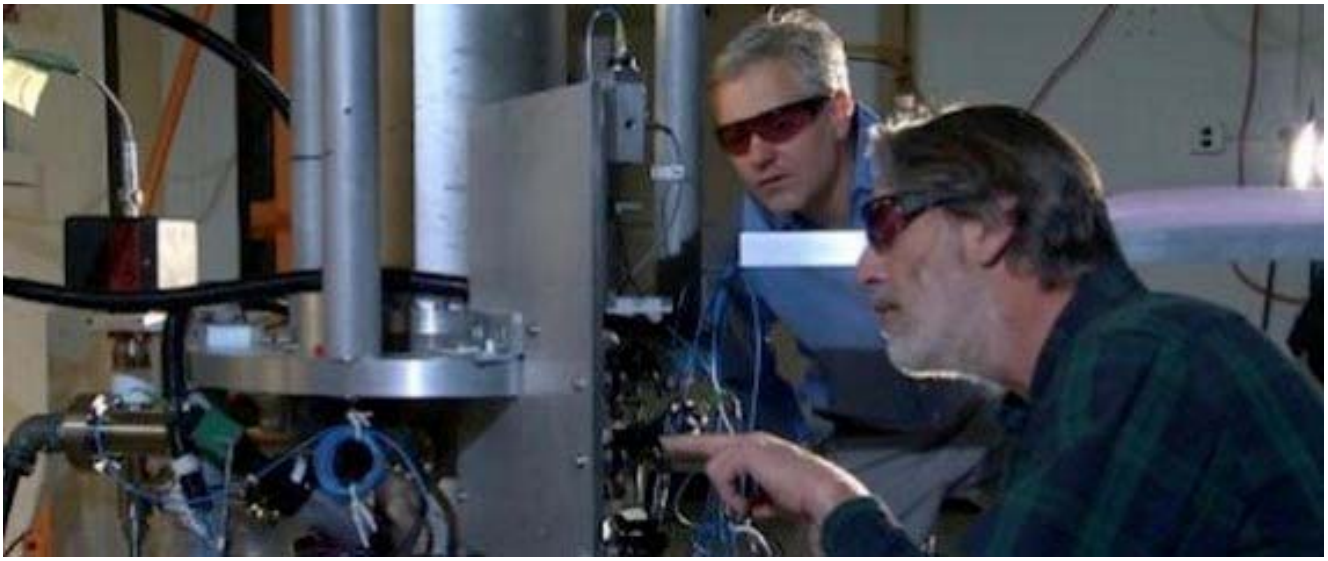
We were told that the Sun will begin to collapse and then expand, throwing off a lot of its mass. This will mean that the Earth's orbit will increase and will be outside the Sun's 2 AU diameter but the Earth will become very hot with the oceans boiling off and the atmosphere vanishing. Again, there is nothing we can do about it.

Stephen's final comment was that only the last threat is certainly going to get us. So; Humanity 9: Universe 1…

Snippets from the World of Science
John Wayte

Time

The world's most accurate clock is now officially ticking. It is accurate to less than 1 second in 300 million years. The clock will be used by cell-phones, GPS and the finance industry…



Currently the World's most accurate clock

Occultations

We often hear about occultations and the even more interesting graze-occultations of the Moon in front a star or object. I have been on one observing session where we had a graze occultation and it was quite interesting to see the plot to demonstrate the slope of our moon's craters.

Just to remind you, the next graze-occultation is on the 5th of May. See Brian Mills for more details.

Well, here is an occultation I hadn't heard about before.

On the 29th of April last at 2314 UTC there was an occultation in South Africa. (any guesses as to what UTC means? It is the co-ordinated Universal Time – the successor to GMT)

But what makes this one very interesting is that Asteroid 10199 Chariklo passes in front of a star and by using a number of powerful telescopes in the region, they hope to calculate the size of the asteroid and maybe even some hints as to its composition.

They say that at least the sky should be clear.

Planets

A question for you boffins. And I am sure that you know the answer – perhaps.

How many planets are there in our solar system? There were nine until Pluto got itself demoted to a dwarf planet. So that makes 8 – right? (Wait until Brian Mills' talk later)

Yes, possibly. However, a new dwarf planet with the romantic name of 2012 VP113 has been located at 80 AU. The previous record holder was Sedna at 78 AU. For the record, Pluto was supposed to be the furthest planet in our system varying between 30 and 50 AU from the Sun. While this find is interesting enough in its own right, this and some 10 other objects found in the Kuiper Belt are strangely aligned.

One possible explanation for this alignment could be that a further large planet exists at a distance of 250 AU. This planet could be rocky based and up to 10 times the size of Earth.

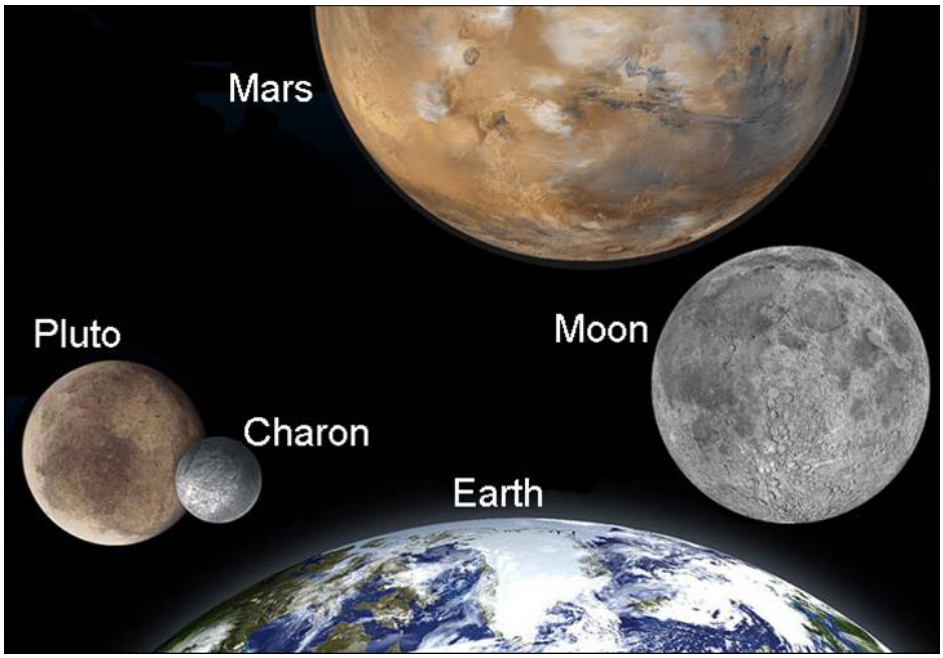
For the record, Voyager 1 is 127 AU from the Sun and Voyager 2 is at 104 AU.

Beginner's Talk – Pluto and Everything Else
Brian Mills

This month Brian reaches the limit of the Solar planets and a bit more…

Before Brian began he said that neither he nor John Wayte knew their talks were going to be so closely related.

Until recently, Pluto was regarded as the ninth planet of our Solar System, but in 1978, Pluto's moon, Charon was discovered and this made it very easy to work out the mass of Pluto and it was realised that it was much less massive than astronomers had thought. In fact Brian said it wasn't even the mass of our Moon.



Once Charon was discovered, it was realized just how small Pluto really was

As time progressed, more objects were discovered beyond the orbit of Neptune, one even bigger than Pluto. This was presenting a bit of a problem as to how to classify a planet or we were going to end up with a host of solar planets. So, as Brian said, this prompted the IAU, the International Astronomical Union to spring into action and form a committee in 2006 to set the criterion for what a planet should be.

After 10 days of deliberation they came up with a working idea. A planet must orbit the Sun, which Pluto does. A planet must be massive enough to become spherical which Pluto is, and a planet must have cleared the neighbourhood of material around its orbit which Pluto hasn't achieved. So Pluto is NOT a planet.

So what is it then? The proposal was for there to be a new classification, and this they called "Dwarf Planets" which permits it not to have cleared its orbit and also it must not be a satellite. The IAU went on to decide that all other objects were in yet a new category called "Small Solar System Bodies", SSSBs.

Next Brian mentioned some objects that were now classified as Dwarf Planets. Ceres is in the Asteroid belt, and there are several in the Kuiper Belt such as Pluto, Haumea and the bizarrely named Makemake and others.

The Kuiper Belt is the torus space at between 20 and 30 Astronomical Units from the Sun. We were told that objects in this belt fall into one of two groups. One of these groups is not affected by the gravity of Neptune and the others are locked in resonance with Neptune, either "Plutinos" of which Pluto is the instigator and is in resonance. The others are called Twotinos and are in a two-to-one resonance with Neptune.

Also it is thought that short period comets such as Halley's comet come from the Kuiper Belt.

Another Dwarf Planet Brian mentioned was Eris which is also known as a Scattered Disk Object. These have highly eccentric orbits whose orbital plane can be greatly inclined by up to about 40° and some can even be affected by the gravity of Neptune. At present about 200 of these are known to exist.

And beyond the Kuiper Belt at about a light year away is the Oort Cloud. Not a great deal is know about this hypothetical disk, thought to be made up of objects likely to be composed of water, ammonia and methane ices. Yet one object is believed to originate from there and that is the long-period comet known as "Hale-Bopp".

Facts and Figures

	Distance from the Sun (AU)	Orbital eccentricity	"Year"	"Day"	Diameter (km)	Mag.
Ceres	2.7	0.075	4.6 yrs	9 hrs	940	6.64 to 9.34
Pluto	48.8 to 29.6	0.248	247 yrs	6.3 days	2,368	13.6 to 16.3
Haumea	51.5 to 34.7	0.195	283 yrs	3.9 hrs	2,000 x 1,000	17.3
Makemake	53.0 to 38.5	0.159	310 yrs	7.7 hrs	1,430	16.7
Eris	97.6 to 38.2	0.437	560 yrs	26 hrs	2,400	18.7

Brian then gave the Sky Notes which appear later in the Newsletter.

MAY MEETING

Wednesday 21st May 2014 – Our own Eric Gibson is talking about "Messier" and his work.
Meetings begin at 1930 although members are invited to arrive anytime after 1900 as this is a good time to exchange ideas and discuss problems and also relax before the meeting starts.

The venue as always is the Upper Room of the Methodist Church at the east end of Wadhurst Lower High Street, almost opposite the entrance to Uplands College. (For those with SatNav – the post code is TN5 6AT)
Anyone is welcome but non-members are asked if they wouldn't mind contributing £3 towards costs.

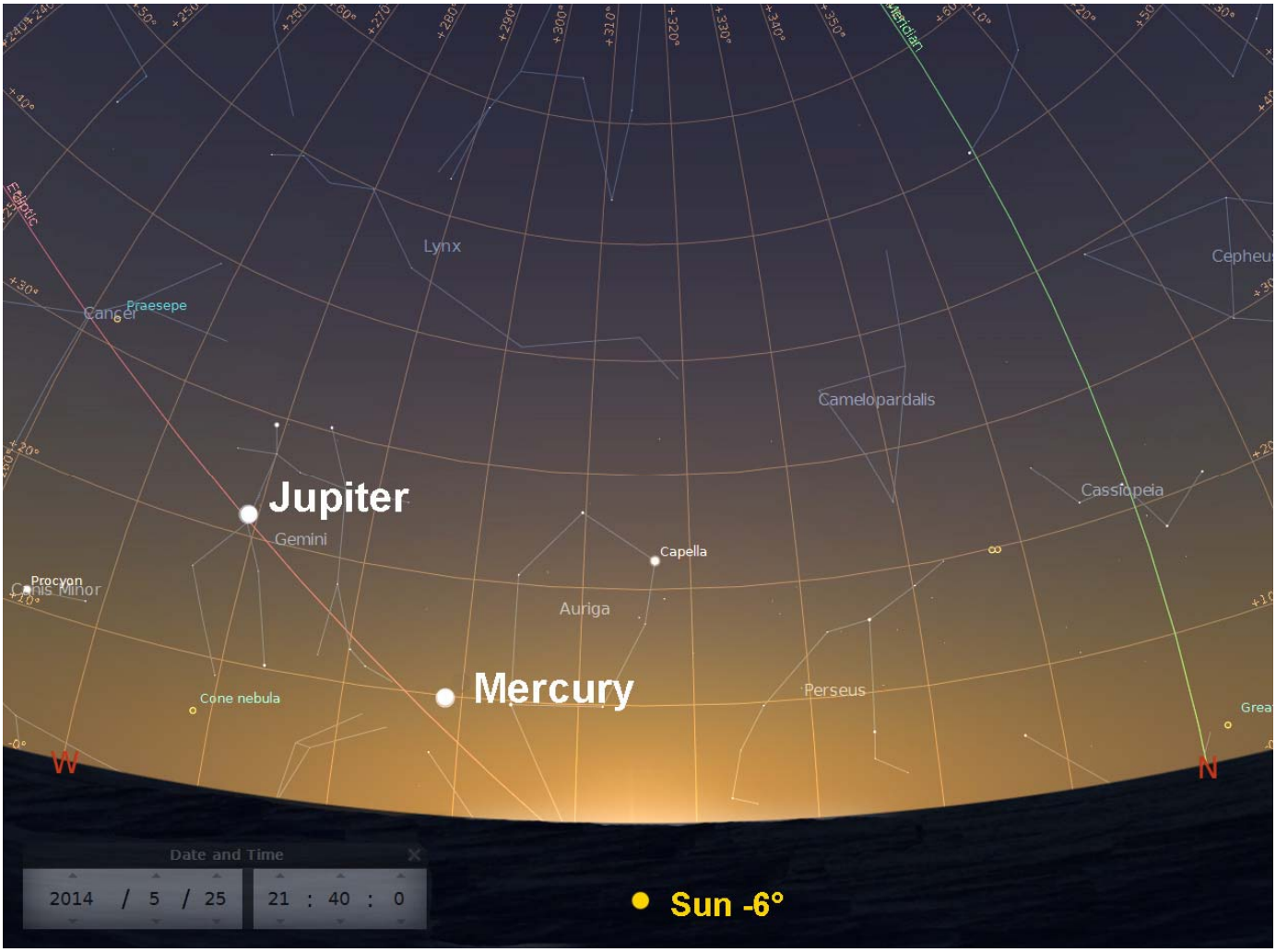
FUTURE MEETINGS

Wednesday 18th June 2014 – The Society's Open Evening which is open to visitors as well as members to bring along telescopes and other astronomical equipment to show others or have explained if there are problems.
Wednesday 16th July – Our Chairman John Vale-Taylor is giving a talk he calls "Cameras to Telescopes"
Late August we will be holding our annual barbecue. Details to follow.

SKY NOTES FOR MAY 2014

Planets

Mercury passed through superior conjunction on April 26th and then moved east of the Sun to become an evening object. It reaches greatest eastern elongation on May 25th when, in angular terms, it will appear to be 23° from the Sun. This is the best evening apparition of Mercury as seen from the UK this year. Although in September its elongation will be greater at 26°, the position of the ecliptic will mean that the innermost planet will set only half an hour after the Sun making meaningful observations virtually impossible.

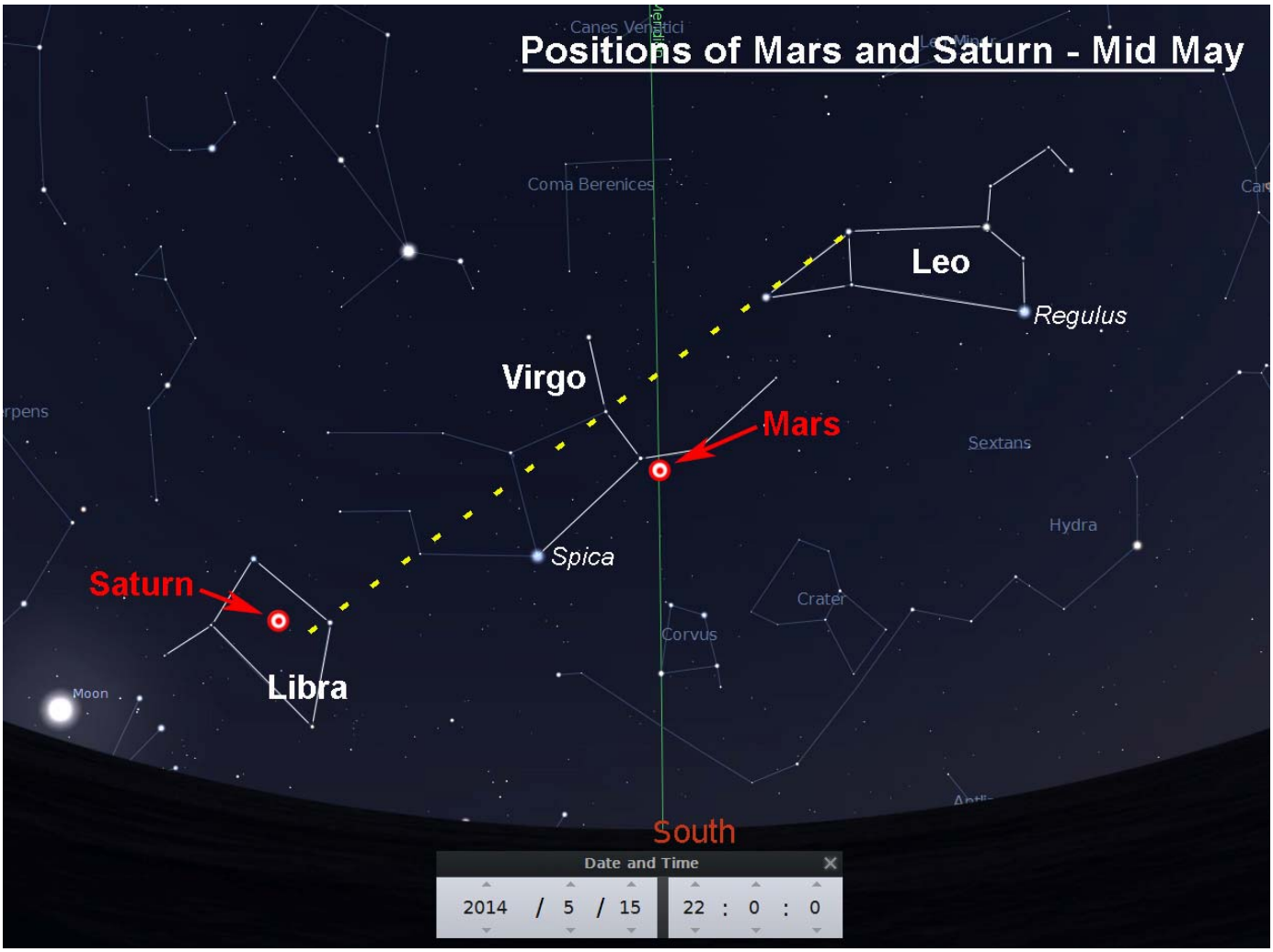


The map above shows the position of the planet on the evening of May 25th with the Sun 6° below the horizon, which marks the end of civil twilight and the beginning of nautical twilight. Jupiter is nearby and may be used as a guide, being that it is so much brighter than Mercury. It is unfortunate that its time of maximum brightness does not coincide with greatest elongation, in fact it has faded considerably by the time it has reached that point in its orbit. Mercury is brightest around May 8th when it will be magnitude -1.1 at an elevation of just 5.5°, dwindling to -0.7 on the 13th with an altitude of 8.5° By the time elongation is reached it is only just in negative figures at -0.2 although it is now 10° above the horizon. Its proximity to the Sun means that we can never see it in truly dark skies and it will always be apparently close even when seen at elongation.
Mercury is somewhat unique in the solar system. It is the smallest planet, having a diameter of 4,878 km, whilst it is also closest to the Sun. Besides that it has the highest orbital eccentricity at 0.21, as well as having the smallest axial tilt at just 0.03°.

Please remember that if you are "sweeping" for Mercury with optical aid, you must make sure the Sun has set first. If you don't, you risk losing your eyesight if you inadvertently look at the Sun.

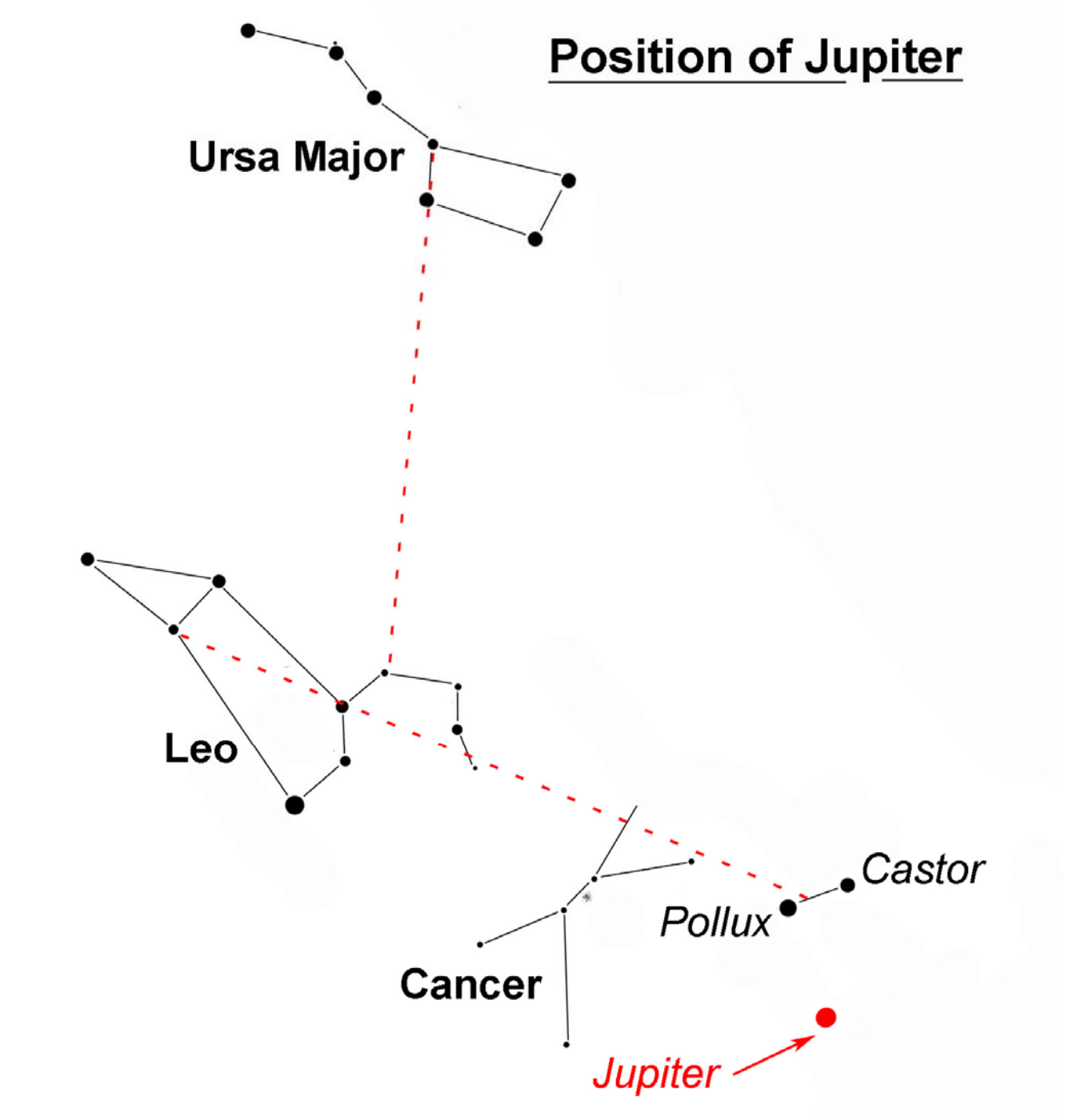
Venus is still a brilliant morning object although it is relatively low in the eastern sky just before sunrise. It is past its best and is gradually moving closer to the Sun although superior conjunction will not occur until late October. On the first of the month the planet is just 4° in altitude with the Sun 6° below the horizon, and by the end of May this figure has improved only fractionally. Strangely although it is moving closer to the Sun, it will become better placed for observation later in the year. On July 1st it will be 8° high whilst on August 1st its altitude will have risen to 10° thanks to the change in the angle the ecliptic makes with the horizon. See last month's Newsletter for more information on that subject.

Mars is nearly a month past opposition but is unmistakable in the late evening sky once darkness has fallen, mainly due to its obvious red hue. Despite that it is decreasing both in apparent diameter and brightness as the distance between us increases. In the middle of May at 22.00 BST the planet lies on the meridian, due south at an altitude of 35° as shown in the diagram. It begins the month moving retrograde (east to west) but reaches its second stationary point on the 20th and thereafter resumes direct motion once more.



Jupiter is nearing the end of this apparition as it closes in on the Sun ready for a July conjunction. It is visible in the west as soon as twilight falls although this becomes more difficult later in the month as the apparent distance between the planet and the Sun decreases despite Jupiter now moving direct (west to east). By the end of May Jupiter will set before midnight BST. An indication of it's position is given in the map for Mercury, but if you need extra guidance then the map below shows you how to find it using Ursa Major and Leo now that Orion is no longer available.

The cloud belts and moons can be seen with a small telescope, in fact the latter can be seen with just a pair of binoculars providing that you can keep them still. This can be done most successfully by mounting them on a camera tripod, but If that isn't an option then prop them, or yourself against a wall or fence. Once you can keep them steady details such as the four Galilean moons become so much easier to see. Jupiter does in fact have 67 moons varying in size from the huge Ganymede which is 5,200 km in diameter (considerably larger than our Moon) down to bodies possibly only a kilometre or so in size. There are also a number of moons recently discovered that have yet to be formally named by the International Astronomical Union.



Saturn is an evening object in Libra rising at 21.00 BST at the beginning of the month, though by the end this will have become 19.00. The ringed planet, currently moving retrograde, will reach opposition on May 10th when it will shine at magnitude +0.1. The easiest way to find Saturn is to use the back of Leo (the lion) to draw an imaginary line south eastwards. The line will pass close to Mars in Virgo before reaching Saturn, as shown on the "Mars and Saturn" map above. If you are unsure about finding Leo then refer to the "Position of Jupiter" diagram. The north pole of the planet is tilted towards us at an angle of 21°, providing us with excellent views of the ring system, something that will improve later this year and into next year.

Lunar Occultations

In the table below I've listed events for stars down to magnitude 7.0 that occur before midnight although there are many others that are either of fainter stars or occur at more unsociable hours. DD = **d**isappearance at the **d**ark limb. The column headed "mm" (millimetres) shows the minimum aperture telescope required for each event. **Times are in BST.** Please remember that the Society has telescopes that members can borrow, all of which are suitable for the following events.

May	Time	Star	Mag	Ph	Alt °	% illum.	mm
2nd	19.26	ZC 832	4.3	DD	37	13	140
4th	21.19	ZC 1106	3.6	DD	33	29	40
4th	22.18	SAO 96786	6.9	DD	24	29	50
11th	20.37	ZC1843	7.0	DD	26	90	180

Phases of the Moon for May

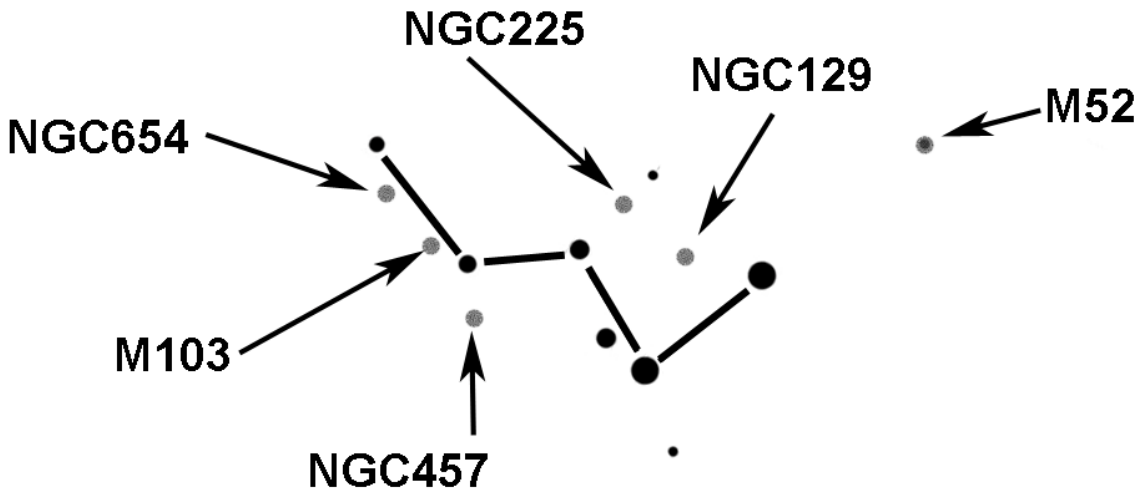
First ¼	Full	Last ¼	New
7th	15th	22nd	29th

ISS
There are no particularly bright evening passes of the International Space Station this month that are visible from the South East. The details of all passes, including those visible after midnight, can be found at www.heavens-above.com

Iridium Flares
The flares that I've listed are magnitude -2.0 or brighter although there are a lot more that are fainter or occur after midnight. If you wish to see a complete list, or obtain timings for somewhere other than Wadhurst, go to www.heavens-above.com . Remember that when one of these events is due it is sometimes possible to see the satellite before and after the "flare", although of course it will be much fainter at those times. **Times are in BST.**

May	Time	Mag.	Alt°	Az.°		May	Time	Mag.	Alt°	Az.°
2nd	19.30	-6.9	73	88 (N)		15th	21.49	-6.8	28	36 (NE)
6th	22.10	-4.0	10	18 (NNE)		18th	21.40	-4.4	33	39 (NE)
7th	22.08	-2.1	12	21 (NNE)		22nd	21.25	-2.1	41	42 (NE)
9th	20.42	-3.4	53	57 (ENE)		23rd	21.19	-3.6	40	44 (NE)
9th	22.06	-5.2	16	25 (NNE)		27th	21.04	-5.3	48	46 (NE)
12th	21.57	-5.1	23	32 (NNE)		30th	22.19	-3.8	15	20 (NNE)

The Night Sky in May (Written for 22.00hrs BST mid month)
In the north Ursa Major is close to the zenith with his smaller namesake pointing vertically towards him, whilst the head of Draco looks eastward towards neighbouring Hercules. The familiar "W" of Cassiopeia lies on the meridian below the celestial pole with her collection of open clusters. These include NGC654, 457, 129 and 225 plus M103 and M52 which are Charles Messier's contribution to the area's clusters. Their locations are shown below.



Nearby Camelopardalis also contains one such moderately bright amalgamation of stars in NGC1502 at magnitude 5.7. The double cluster in the sword handle of Perseus is at an altitude of 20° and still a fine sight in binoculars.
As we look east the bright star Vega, in Lyra, is making its presence felt, although of its two fainter companions in the Summer Triangle, only Deneb is currently above the horizon. The faint summer constellations of Hercules, Corona Borealis and Ophiuchus are all now visible but are in stark contrast to the winter groups that have now vacated the evening skies for another year.
Towards the south the faint constellations of Canes Venatici and Coma Berenices are high up on the meridian whist below them lies Virgo which contains a large number of faint galaxies. A little lower than Virgo, and on the meridian, is the southern end of the sprawling line of stars that make up Hydra. Corvus (the crow) and Crater (the cup) appear to be riding on the back of the celestial sea serpent. Delta Corvi is a telescopic double with a yellow primary (mag. 3.0) and a pale blue secondary (mag. 8.5) that have a 24" separation.
Turning to the west the hunter and his entourage have gone although Gemini and Auriga remain, whilst Cancer with the lovely open cluster M44 is at a respectable 35° altitude. Leo will be on view for some time to come so have a look at the double, gamma Leonis, at the base of the Lion's neck. A small aperture is all that is required to see this pair with magnitudes of 2.4 and 3.6 that lie 4.3" apart.

Advance warning for June
26th June - Moon occults Mercury 12.53 BST.

Graze Occultation Event
Following the disappointingly cloudy outcome of our last graze occultation event, there is a chance for members to take part in another graze this time of a magnitude 7.8 star. As shown on the map, the mean graze track passes across Ashdown Forest during the evening of 5th May. Please contact me if you wish to take part and haven't yet added your name to the list that was circulated at the April meeting. The society has telescopes and electronic stopwatches that members can use. The line indicates the mean northern limb, so the shadow of the Moon is below the line. With luck we hope to be able to time the disappearances and

reappearances of the star between the mountains and valleys at the limb of the Moon. This information is used for, amongst other things, calculating fluctuations in the solar diameter by predicting the appearance of “Baily’s Beads” during total eclipses of the Sun.

Details of the event are as follows:

Date ……. 5th May 2014
Time ……. 22.08 BST
Star ……. SAO 97580
Magnitude ……. 7.8
Altitude …….. 30°
Azimuth ……. 256° (west)
Altitude of Sun……... -13°
Moon % illuminated…….. 38%
Cusp angle ……. 4.6°
Min. aperture …… 100mm

Brian Mills

NASA SPACE PLACE

The Power of the Sun's Engines
By Dr. Ethan Siegel

Here on Earth, the sun provides us with the vast majority of our energy, striking the top of the atmosphere with up to 1,000 Watts of power per square meter, albeit highly dependent on the sunlight's angle-of-incidence. But remember that the sun is a whopping 150 million kilometres away, and sends an equal amount of radiation in all directions; the Earth-facing direction is nothing special. Even considering sunspots, solar flares, and long-and-short term variations in solar irradiance, the sun's energy output is always constant to about one-part-in-1,000. All told, our parent star consistently outputs an estimated 4×10^{26} Watts of power; one *second* of the sun's emissions could power all the world's energy needs for over 700,000 years.

That's a literally astronomical amount of energy, and it comes about thanks to the hugeness of the sun. With a radius of 700,000 kilometres, it would take 109 Earths, lined up from end-to-end, just to go across the diameter of the sun once. Unlike our Earth, however, the sun is made up of around 70% hydrogen by mass, and it's the individual protons — or the nuclei of hydrogen atoms — that fuse together, eventually becoming helium-4 and releasing a tremendous amount of energy. All told, for every four protons that wind up becoming helium-4, a tiny bit of mass — just 0.7% of the original amount — gets converted into energy by $E=mc^2$, and that's where the sun's power originates.

You'd be correct in thinking that fusing ~4 × 10^{38} protons-per-second gives off a tremendous amount of energy, but remember that nuclear fusion occurs in a *huge* region of the sun: about the innermost quarter (in radius) is where 99% of it is actively taking place. So there might be 4 × 10^{26} Watts of power put out, but that's spread out over 2.2 × 10^{25} cubic meters, meaning the sun's energy output *per-unit-volume* is just 18 W / m^3. Compare this to the average human being, whose basal metabolic rate is equivalent to around 100 Watts, yet takes up just 0.06 cubic meters of space. In other words, **you emit 100 times as much energy-per-unit-volume as the sun**! It's only because the sun is so large and massive that its power is so great.

It's this slow process, releasing huge amounts of energy *per reaction* over an incredibly large volume, that has powered life on our world throughout its entire history. It may not appear so impressive if you look at just a tiny region, but — at least for our sun — that huge size really adds up!

Check out these "10 Need-to-Know Things About the Sun": http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun

Kids can learn more about an intriguing solar mystery at NASA's Space Place: http://spaceplace.nasa.gov/sun-corona

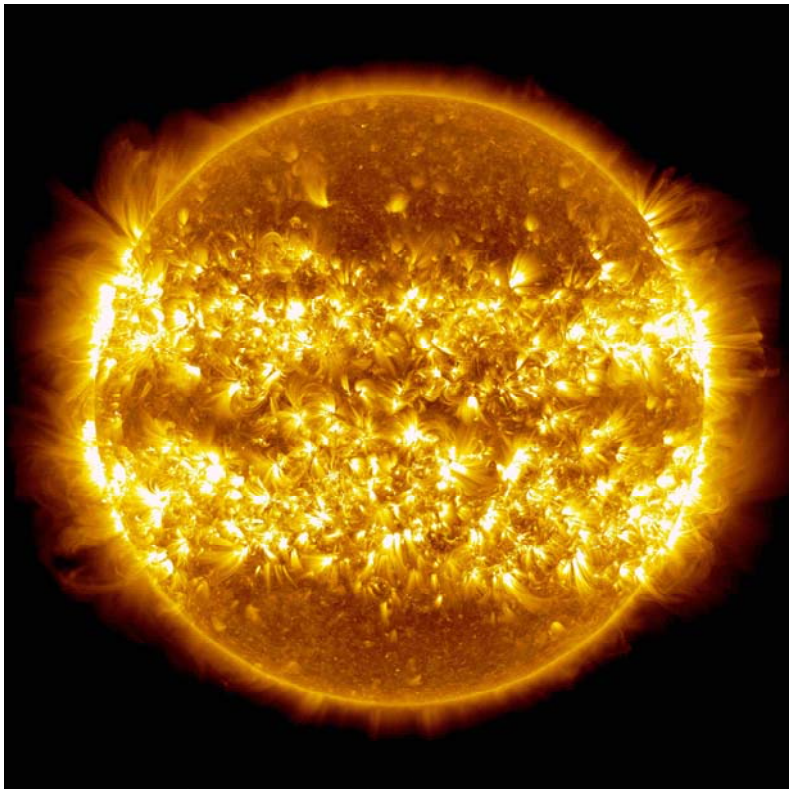


Image credit: composite of 25 images of the sun, showing solar outburst/activity over a 365 day period; NASA / Solar Dynamics Observatory / Atmospheric Imaging Assembly / S. Wiessinger; post-processing by E. Siegel.

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