JANUS
THE NEWSLETTER OF EWELL ASTRONOMICAL SOCIETY

NOVEMBER 2024

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Important Reminder:

To allow sufficient time to compile Janus and place it on the EAS Website by the 1st of the month any submissions for publication are required at least 3 days before the end of the month. Any items received after this date will be held over until the following month.

Editorial

Welcome to the November edition of Janus – the last one before our AGM in December.

Having edited Janus since January 2019 – nearly 6 years ago now (really?!) – I have begun to wonder whether it might be time to explore options for changing the format. As a first step, I have moved things around a little this month – nothing major, mainly giving myself more flexibility in the editorial section where I have increasingly struggled to fit (or not) my words into the constrained space I had allocated myself. Looking forward, I would appreciate any member's thoughts on other changes/improvements/additions they would like to see. I can't promise to accommodate everyone's ideas, but I'm open to any (reasonable) suggestions. Please email them to me at the editor's email address. Remember: It's your Newsletter, not mine!

Our lecture this month, entitled "Looking for Life on Mars and Habitability on Icy Moons", will be given by Professor Andrew Coates from the Mullard Space Science Lab (MSSL). It will be the last one of 2024, as we have no lecture in December.

October was another notable month for astronomical observations. As well as the widely predicted arrival of Comet C/2023 A3 Tsuchinshan-ATLAS, continuing high solar activity led to further sightings of Aurora further south than is usual. EAS members took the opportunity to image both comet and Aurora, and I intend to include a selection of their images in next month's edition. I had hoped to include them this month but, with so many to look at, I have struggled to find the necessary time to assess them sufficiently to assemble a representative collection.

With the Autumn equinox behind us, we're back on GMT (also known as Universal Time (UT) or Zulu (Z)). The days are getting shorter which, of course, means the nights are getting longer. By early December, there will be more than 16 hours between sunset one day and sunrise the next, meaning longer observing evenings. Let's hope for some clear nights to take advantage of them!

Finally, a reminder. Nominations for committee membership are required in time for voting at the AGM in December. Currently, there are 8 committee members (Chair, Secretary, Treasurer, Janus Editor, 4 others). If you wish to nominate someone for any of the posts, please complete a nomination form – a copy was attached to last month's edition of Janus, and copies will be available at the November meeting.

John

skyUpdate
What's up this month?

The Solar System November

MERCURY: recently passed behind the Sun at superior solar conjunction. It begins the month not readily observable, since it is very close to the Sun, at a separation of only 1° from it. Visibility remains poor throughout the month until, by the end of the month, soon to pass in front of the Sun at inferior solar conjunction, it remains difficult to see, reaching its highest point in the sky during daytime and being 3° below the horizon at dusk.

VENUS: is emerging into the evening sky as it approaches greatest elongation E. It begins the month difficult to see, reaching its highest point in the sky during daytime and being no higher than 6° above the horizon at dusk. By the end of the month, it will become visible at around 16:19, 12° above the S horizon, as dusk fades to darkness. It will then sink towards the horizon, setting 2 hours and 47 minutes after the Sun at 18:42.

MARS: begins the month visible in the morning sky, becoming accessible around 22:35, when it reaches an altitude of 10° above the NE horizon. It will then reach its highest point in the sky at 05:20, 60° above the S horizon, and will be lost to dawn twilight around 06:15, 58° above the SW horizon. By the end of the month, approaching opposition, it will be visible in the morning sky, becoming accessible around 21:06, when it reaches an altitude of 8° above the NE horizon. Reaching its highest point in the sky at 03:56, 59° above the S horizon, it will be lost to dawn twilight around 07:08, 42° above the W horizon.

JUPITER: is currently approaching opposition and is visible as a morning object. It begins the month visible in the morning sky, becoming accessible around 19:31, when it reaches an altitude of 7° above the NE horizon. Reaching its highest point in the sky at 02:34, 61° above the S horizon, it will be lost to dawn twilight around 06:30, 36° above the W horizon. By the end of the month, still visible in the morning sky, it becomes accessible around 17:24, when it reaches an altitude of 7° above the NER horizon. It will then reach its highest point in the sky at 00:26, 60° above the S horizon, before being lost to dawn twilight around 07:15, 9° above the NW horizon.

SATURN: is currently an early evening object, and begins the month visible in the evening sky, becoming accessible around 17:16, 18° above the SE horizon, as dusk fades to darkness. It will then reach its highest point in the sky at 20:13, 29° above the S horizon, and will continue to be observable until around 00:10, when it sinks below 11° above the SW horizon. By the end of the month, now receding into evening twilight, it is visible in the evening sky, becoming accessible around 16:45, 26° above the SE horizon, as dusk fades to darkness. Reaching its highest point in the sky at 18:19, 29° above the S horizon, it will continue to be observable until around 22:15, when it sinks below 11° above the SW horizon.

URANUS: begins the month approaching opposition. It is visible from around 19:33, when it reaches an altitude of 21° above the E horizon. Reaching its highest point in the sky at 00:50, 57° above the S horizon, it will be lost to dawn twilight around 05:30, 26° above the W horizon. By the end of the month, having recently passed opposition, it will become accessible at around 17:32, when it rises to an altitude of 21° above the E horizon. It will reach its highest point in the sky at 22:47, 57° above the S horizon, and will become inaccessible at around 04:03 when it sinks below 21° above the W horizon.

NEPTUNE: is currently an early evening object, and begins the month visible in the evening sky, becoming accessible around 17:54, 22° above the SE horizon, as dusk fades to darkness. Reaching its highest point in the sky at 21:05, 36° above the S horizon, it will continue to be observable until around 00:23, when it sinks below 21° above the SW horizon. By the end of the month, still an early evening object, but now receding into evening twilight, it becomes accessible around 17:23, 31° above the SE horizon, as dusk fades to darkness. It reaches its highest point in the sky at 19:10, 36° above the S horizon, and will continue to be observable until around 22:27, when it sinks below 21° above the SW horizon.

Notable Events:

Some observations will require a telescope, others will be visible with the naked eye. More information at https://in-the-sky.org

November

1 New Moon
3 Conjunction of the Moon and Mercury
The Moon at perihelion
4 Lunar occultation of Antares
Close approach of the Moon and Venus
8 First Quarter Moon
11 Close approach of the Moon and Saturn
Lunar occultation of Saturn
12 Lunar occultation of Neptune
Northern Taurid meteor shower 2024
13 Asteroid 11 Parthenope at opposition
14 The Moon at aphelion
The Moon at perigee
15 Full Moon
Saturn ends retrograde motion
16 Close approach of the Moon and M45
Mercury at greatest elongation east
17 Uranus at opposition
Leonid meteor shower 2024
Close approach of the Moon and Jupiter
Lunar occultation of Beta Tauri
The Pleiades cluster is well placed
20 Close approach of the Moon and Mars
21 Mercury at dichotomy
α-Monocerotid meteor shower 2024
22 Mercury at highest altitude in evening sky
23 Third Quarter Moon
26 The Moon at apogee
27 Lunar occultation of Spica
The Hyades cluster is well placed
28 November Orionid meteor shower 2024
29 Comet 333P/LINEAR passes perihelion

December

1 New Moon
2 Pheonicid meteor shower 2024
The Moon at perihelion
4 Close approach of the Moon and Venus
5 Conjunction of Ceres and Pluto
December φ-Cassiopeid meteor shower 2024
6 Mercury at inferior solar conjunction
Jupiter at perigee
Mercury at perihelion
Puppid-Velid meteor shower 2024
Mars enters retrograde motion
7 Conjunction of Venus and Pluto
Jupiter at opposition
Neptune ends retrograde motion
8 First Quarter Moon
Close approach of the Moon and Saturn
Lunar occultation of Saturn
Conjunction of Venus and Ceres
Monocerotid meteor shower 2024
11 σ-Hydrid meteor shower 2024
12 The Moon at perigee
The Large Magellanic Cloud is well placed
13 Close approach of the Moon and M45
14 Geminid meteor shower 2024
The Moon at aphelion
Close approach of the Moon and Jupiter
Asteroid 15 Eunomia at opposition
The Running Man cluster is well placed
The Orion Nebula is well placed
15 Full Moon
Lunar occultation of Beta Tauri
Comae Berenicid meteor shower 2024
18 Close approach of the Moon and Mars
Lunar occultation of Mars
19 December Leonis Minorid meteor shower 2024
20 Mercury at dichotomy
Mercury at highest altitude in morning sky
21 December solstice
22 Third Quarter Moon
Ursid meteor shower 2024
24 The Moon at apogee
Lunar occultation of Spica
25 Mercury at greatest elongation west
28 Lunar occultation of Antares
The cluster NGC 2232 is well placed
29 Conjunction of the Moon and Mercury
The Rosette Nebula is well placed
30 New Moon
The Moon at perihelion

Collected Observations (and thoughts) – Gary Walker

The Northern Lights Again – Posted 11 October

Yesterday evening, just as on 10 May, (now exactly 5 months ago), I saw posts on my phone from local people, including Society members, showing images of the Aurora.

Suitably encouraged, I went outside but couldn't see anything with the naked eye. So, I took photos to the North and NW, leaving my camera shutter open for some seconds, but no Aurora showed up on them! However, I took some images to the West, and picked up the edge of a pinkish glow, at the edge of one of the images.

Then I took some more of the SW sky and, this time, I managed to get something! My images showed a pink glowing "pillar" shaped light in the SW sky. This was not visible to my naked eye, nor with binoculars. It was around 11:30pm.

The Aurora glow was to the West of Pegasus and to the South of Cygnus, probably in the constellations of Delphinus, Equuleus, or Aquarius.
The Sun has, of course, been active over the last few weeks, with lots of Sunspots. Some Aurora was predicted a few nights ago, and on 9 October (although it was overcast that night).

I also saw a photo of Aurora on the front page of the Times newspaper of 9 October, showing Aurora from Scotland. Clearly, the Media is still interested in them!

On looking again, however, at about midnight, I COULD see the Aurora with the naked eye, and even the pink colour was quite clear! I realised, having taken more images, that the Auroral display was much more extensive than I first thought, and then I could see it with the naked eye. The pink glow was also, over the Western sky, and high up in the Northern sky!

Not only could I now see the pink colour (quite delicate, but clearly there), I also saw at least 4 long rays. One was in the West, close to Vega, pointing W-E and there were 3 more, parallel to each other, high up in the Northern sky, orientated N- S! I have NEVER previously seen the Aurora with my own eyes, (even on 10 May, I didn't see them by eye, but only on my images!)

The Northern Lights are notoriously fickle, and about as difficult to predict as the magnitude of a comet! In fairness though, they are only very rarely seen this far South, as they usually live up in the far Northern skies, although Scotland sees quite a few of them.

Once before, on 25 January 1938, a display was seen in the South, and some people feared that London was on fire, as this Aurora, too, had a strong pink glow! Probably, on this occasion, its proximity to the outbreak of the Second World War may have influenced people's minds!

I saw the Aurora from around midnight to about 12:30am, but I found that it had disappeared by 1am! I think that it had suddenly brightened up by around about midnight, as I couldn't see it with the naked eye around 11:30pm, but I could do so, by midnight!

As is frequently the case, social media "blew up" over the Aurora, with loads of images online. This is perhaps one of the more positive benefits of social media, as it can quickly alert people (like me, last night!), about an ongoing display. Before that, unless you were in touch with an astronomical friend, or fellow Aurora spotter, it was very difficult to see when an Auroral display was on, until it was too late. Astronomical magazines can't predict them in advance as, unlike events such as eclipses, or the motion of the Sun, Moon, and the Planets, etc, they are not predictable!

The Coronal Mass Ejections which give rise to Aurora cannot be predicted far in advance, either, apart from about a two-day warning, which is the time that they take to reach Earth. Even then, it is difficult to predict how intense any given Auroral display will be; just as bad as predicting exactly when, and how, Notilucent Clouds will pan out, or meteor showers. There were big Auroral displays in 1989, and 2003, but I missed them, as I didn't have the information that we do now.

The display was mentioned on the BBC News, but only at the end, and then, in conjunction with the weather forecast (predicting winds of 14,000 mph!?) – perhaps fair enough, as Aurora can be classified as "Space Weather"!

The main media remain interested in them, especially since last May's display, and has often been announcing possible displays, ever since!

At the October Society meeting, members were showing the images that they had captured and exchanging "war stories". Of course, mobile phones are now good enough to capture some excellent images of them. They don't always require a camera set up on a tripod!

The New Comet – Posted 12 October

The new comet is called C/2023 A3 Tsuchinshan-ATLAS which is, to say the least, rather a mouthful, so in future I will refer to it as Comet T-ATLAS.

I managed to see the new comet this evening, but I had to go over the fields at the back of my house, being as it was going to be low down in the sky. It was a deep twilight in perfect conditions, with virtually no clouds (for a change). Through my 11X80 binoculars, I saw the Coma, or "False Nucleus", appearing as a small disk of light, yellowish in colour, and a short tail extending up from it. I found that I could also pick it out with my naked eye, where it appeared as a fairly obvious "star", but I couldn't see the tail!

I observed it for half an hour between about 7pm and 7:30pm, and I saw it set into the distant treeline!

This is now, the 47th comet that I have seen. It appeared similar to the Comet McNaught of January 2007, again observed from the same place as tonight! That, too, was visible to the naked eye as an obvious "star".

Astronomers will note that this is yet another ATLAS comet, discovered by the robotic telescope set up of ATLAS (as well as the Chinese discoverer, too). This robotic telescope finds a lot of comets, which is why there are so many comets known as ATLAS – something that can actually be confusing to amateur astronomers!

I saw an article about the comet in the Daily Mail today, and it was also mentioned on the BBC evening News. The Daily Mail was headlining it as being "last spotted in Neanderthal times". This is because its orbit is about 80,000 years long!

The disadvantage of this comet is that it is brightest when near the Sun, and low down in the West, just when it is harder to pick it out! When it gets higher in the sky, it will be better, but it will then start to fade - a typical "Catch 22" situation, or yet another manifestation of Murphy's Law! It reached its closest point to the Earth, tonight, being about 42 million miles away.

I could also see Venus appearing very bright, low down, well over to the South of the comet. This is the first time that I have seen Venus with the naked eye for a long time, because it has been "badly placed" for so long!

The Media on Comet T-ATLAS - Posted 15 October

The media have continued to occasionally mention the Comet in some newspapers, as well as on the BBC News!

On the BBC News today, they claimed that tonight would be the last opportunity to see the comet! This is, of course, not true, as it will be progressively rising higher in the sky! At the same time, however, it will be steadily fading.

Ever since 12 October, we have been stuck in a cloudy spell, so I count myself lucky to have seen it when I did!

The Comet again, and a SpaceX chain! – Posted 17 October

The weather has been atrocious for observing since 12 October, and only tonight was I able to see the comet again. We have been stuck with a frustrating cycle of either cloud or rain for 4 nights in succession!

Yesterday evening, the weather played its typical dirty trick of staying reasonably clear until the early evening but clouding over before dark!

Today, the comet appeared the same, with a yellowish coma disk, and a prominent tail of about 3 degrees in length, as seen through my 11x80 binoculars. I couldn't see it with my naked eyes, so it must have faded a bit since I last saw it.

Frustratingly, I only caught a glimpse of it with my 8" SCT, as it was still too low down to see well from my garden, but the view that I did see of it was little different from that of my binoculars!

So, I had to go over the fields at the back of my house, again, to see it, but the flipside is that I couldn't take my big telescope over there, so I was again restricted to binoculars. However, for bright comets like this one, binoculars give a superior view to a telescope, as you can fit the tail in, and see the entire comet, as it is! A telescope will only enlarge the Coma, but not fit much of the tail in.

I think that this comet is similar in manner to Comet NEOWISE, of 2020, although I think that NEOWISE was brighter!

As I said, in an earlier post, the BBC News made the absurd claim that last night would be the last chance to see the comet, but that, of course, is not the case, as it is steadily gaining altitude in the sky, although, of course, it will fade as it does so!

Whilst I was seeing this, I saw a chain of SpaceX satellites, obviously recently launched, as they were close together! They were visible to my naked eye, showing up as 2 chains of lights, separated by a gap between them, but all on the same path! This was approximately around 8pm, or a bit earlier.

In the first set of satellites there were 7 satellites, but the second chain had a total of 14 satellites, making a total of 21. Again, they were blue in colour, (which is done by SpaceX to dim them), but they were still quite bright. As they reached the zenith, I saw them all fade into the Earth's shadow!

Rising in the East was the Full Moon, which the media were making a meal of, as it was the 3rd "SuperMoon"! It was also the" Hunters Moon ". On the 6pm BBC News, they were trying to show a live image of it, but only one arc of it was visible, as it disappeared into clouds!

Comet T-ATLAS again! – Posted 19 October

This evening, as it is now higher up in the sky, I had a splendid view of the Comet, observing it from my back garden, rather than having to trek over the fields at the back of my house. In my 8' SCT, the coma appeared larger than in binoculars, surrounded by a larger fuzzy haze, and some of the tail. However, with a bright comet like this, the best view was, again, through my 11x80 binoculars! Tonight, the comet was framed by several stars, making a really beautiful scene.

Again, the tail extended for about 3 degrees, with the bright Coma at its head. Nonetheless, I still couldn't see it with the naked eye!

Latest Observations – Posted 22 October

Yesterday, I observed Mars. It is still very small in my scope, even at 300X, as it is still only 8.6' arcseconds in size, but I think that I could just about detect a dark feature upon it. On checking the Sky & Telescope Mars Finder, it showed that one of the most prominent dark features on Mars, Mare Acidalium, was on the face of Mars, at this time.

I saw the Comet again tonight. It may have been a bit fainter, (officially it has now faded to magnitude 5), but in my binoculars, the tail was still long, up to about 4 degrees in length, which almost filled the field of view of my 11x80 binoculars!

It still appeared the same as before, through my telescope. The comet has now risen higher in the SW sky, so at least, it is now visible for longer, and I can observe it from my own garden, and not have to traipse over the fields at the back of my house to do so!

Of course, the Space Weather website has been full of people's images of the comet, in their gallery. Unfortunately, I haven't been able to photograph it myself!

Latest Observations – Posted 27 October

I was still seeing the comet today, but I thought that it appeared fainter in my 11x80 binoculars, just as a fuzzy patch, with a short tail. However, I am not sure if this is a real effect, or down to the thin cirrus clouds, which were in the sky! In my telescope, though, the Coma was still quite bright, with part of the tail still visible. A couple of nights earlier, the tail was still fairly long in the binoculars!

Again, as on 17 October, at about 6.40pm, I saw a succession of satellites rising from the West, which were obviously SpaceX, again (there have been a couple of launches of them in the past few days). They were not nearly as close together as the last time, so they had obviously had time to spread out! Most were solitary, but at least one came up as a "pair" of satellites about 4-5 degrees apart. They all appeared white/yellowish when lower down, but turned blue when higher up, before fading into the Earth's shadow!

I saw that the star, Mira, the most famous variable star in Cetus, must have been at its minimum magnitude of about 9, as it was roughly equal to the adjacent star, very close to it, immediately to the left. I always use this "companion star" as a marker of magnitude, because it stays at the same magnitude 9.

Object of the month – Saturn and its Rings – Martin Howe

The gas giant Saturn reached opposition on 8 September 2024. An outer planet, such as Saturn, is said to be in opposition when the Sun, Earth, and that planet are in a straight line. In other words, the Sun and the planet are in opposite parts of the sky (180^{o} apart), and as a such, the planet crosses the meridian (due south) at midnight. I personally find that the planets are better observed a month or two after opposition, simply because they then cross the meridian (which is when they are at their highest elevation above the horizon) earlier in the evening and so at more sociable hours! For example, on the 1st of November, Saturn passes due south a little after 8pm at an altitude of exactly 30^{o}.

Saturn is famous for its system of rings, and although we now know that all the gas and ice giant planets have ring systems, Saturn's is the only one visible in binoculars or a small telescope. Discovered in 1610 by Galileo, the rings were initially thought to be solid structures, although Galileo was puzzled by how they changed size or even disappeared altogether over time. Subsequent observations revealed their true nature as a complex system of countless individual particles, each orbiting the planet independently, and that their inclination changed over time, thus solving Galileo's puzzlement. Composed primarily of ice particles, along with rocky debris and dust, Saturn's rings stretch out for thousands of kilometres but are very thin - less than a kilometre in thickness. It is their icy composition that make them so clearly visible from Earth.

Saturn's rings are divided into several distinct sections, including the A, B, and C rings, each characterized by varying density and composition. The A ring, the outermost and brightest, is separated from the B ring by the Cassini Division (named after Giovanni Cassini who discovered it in 1675) and is a gap caused by the gravitational influence of Saturn's moons. It is believed that Saturn's rings are likely to be remnants of comets, asteroids, or moons that ventured too close to the planet and were torn apart by its strong gravity.

Saturn's rings largely orbit Saturn in its equatorial plane, however, very similar to the Earth which is tilted by 23.5^{o}, Saturn and its rings are tilted relative to the orbital plane by about 27 degrees. This tilt causes the rings to appear dramatically different depending on the time of year as Saturn orbits the Sun. For example, during the equinoxes, the rings are nearly edge-on to the Sun, making them appear much thinner and less visible from certain angles. Conversely, at solstices, the rings are fully illuminated, showing a much larger extent of their beauty. As the equinoxes occur twice every orbital period (29.4 years for Saturn) then Saturn's rings appear edge on about every 15 years.

Saturn’s next equinox is in May 2025, although the rings will “dance around” the edge-on phase for a few months either side of this because of the impact of the Earth’s more rapid orbital period creating fleeting differences in our perspective of the rings.

An interesting long-term project is to image the differing inclinations of the rings over time. The composite image below shows this over a period of about 5 years.

"Cosmic inflation": Did the early cosmos balloon in size? A mirror universe going backwards in time may be a simpler explanation

Acknowledgement: This article was written by Neil Turok, Higgs Chair of Theoretical Physics, University of Edinburgh, and was first published in THE CONVERSATION on 24th October 2024. It is republished in full under a Creative Commons Licence. The original article, with additional links and images can be found here: *https://theconversation.com/cosmic-inflation-did-the-early-cosmos-balloon-in-size-a-mirror-universe-going-backwards-in-time-may-be-a-simpler-explanation-238343*

We live in a golden age for learning about the universe. Our most powerful telescopes have revealed that the cosmos is surprisingly simple on the largest visible scales. Likewise, our most powerful "microscope", the Large Hadron Collider, has found no deviations from known physics on the tiniest scales.

These findings were not what most theorists expected. Today, the dominant theoretical approach combines string theory, a powerful mathematical framework with no successful physical predictions as yet, and "cosmic inflation" – the idea that, at a very early stage, the universe ballooned wildly in size. In combination, string theory and inflation predict the cosmos to be incredibly complex on tiny scales and completely chaotic on very large scales.

The nature of the expected complexity could take a bewildering variety of forms. On this basis, and despite the absence of observational evidence, many theorists promote the idea of a "multiverse": an uncontrolled and unpredictable cosmos consisting of many universes, each with totally different physical properties and laws.

So far, the observations indicate exactly the opposite. What should we make of the discrepancy? One possibility is that the apparent simplicity of the universe is merely an accident of the limited range of scales we can probe today, and that when observations and experiments reach small enough or large enough scales, the asserted complexity will be revealed.

The other possibility is that the universe really ***is*** very simple and predictable on both the largest and smallest scales. I believe this possibility should be taken far more seriously. For, if it is true, we may be closer than we imagined to understanding the universe's most basic puzzles. And some of the answers may already be staring us in the face.

The trouble with string theory and inflation

The current orthodoxy is the culmination of decades of effort by thousands of serious theorists. According to string theory, the basic building blocks of the universe are miniscule, vibrating loops and pieces of sub-atomic string. As currently understood, the theory only works if there are more dimensions of space than the three we experience. So, string theorists assume that the reason we don't detect them is that they are tiny and curled up.

Unfortunately, this makes string theory hard to test, since there are an almost unimaginable number of ways in which the small dimensions can be curled up, with each giving a different set of physical laws in the remaining, large dimensions.

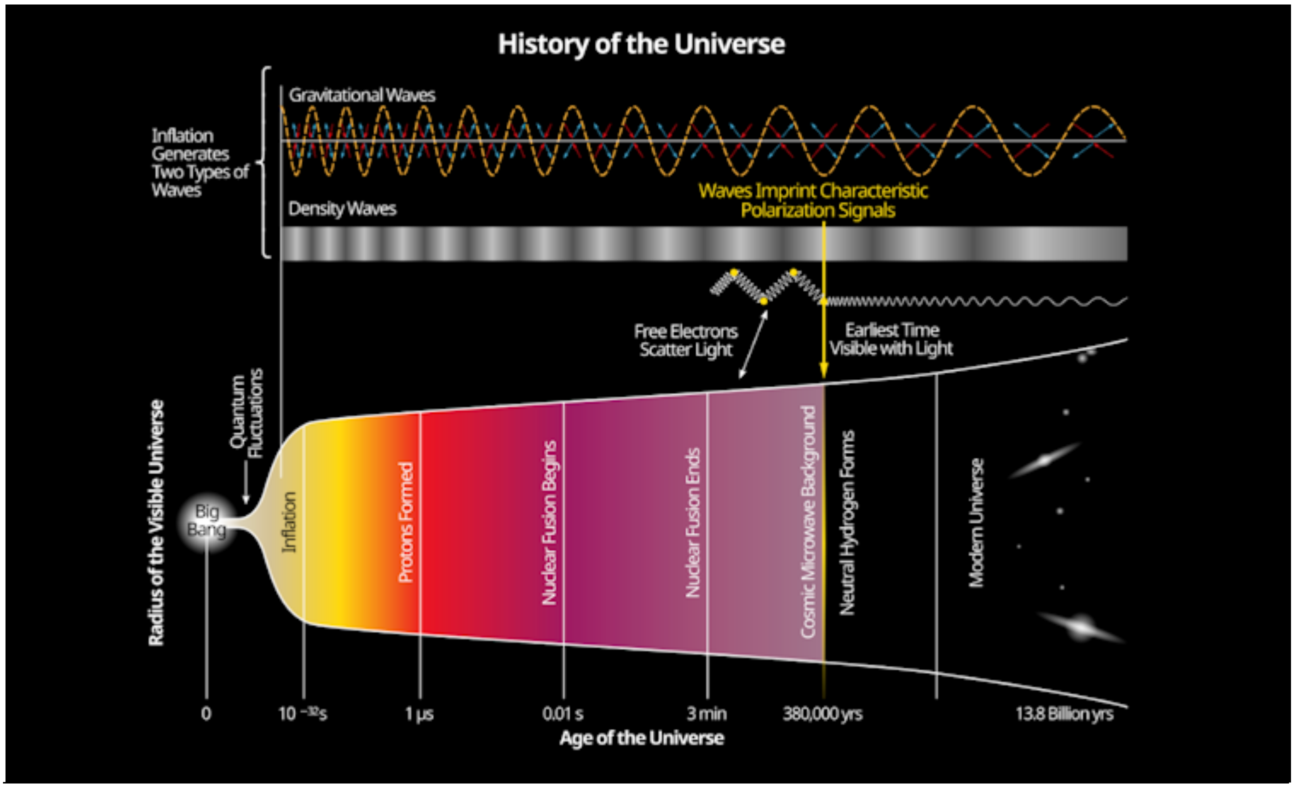
Meanwhile, cosmic inflation is a scenario proposed in the 1980s to explain why the universe is so smooth and flat on the largest scales we can see. The idea is that the infant universe was small and lumpy, but an extreme burst of ultra-rapid expansion blew it up vastly in size, smoothing it out and flattening it to be consistent with what we see today.

Inflation is also popular because it potentially explains why the energy density in the early universe varied slightly from place to place. This is important because the denser regions would have later collapsed under their own gravity, seeding the formation of galaxies.

Over the past three decades, the density variations have been measured more and more accurately both by mapping the cosmic microwave background - the radiation from the big bang - and by mapping the three-dimensional distribution of galaxies.

In most models of inflation, the early extreme burst of expansion which smoothed and flattened the universe also generated long-wavelength gravitational waves - ripples in the fabric of space-time. Such waves, if observed, would be a “smoking gun” signal confirming that inflation actually took place. However, so far, the observations have failed to detect any such signal. Instead, as the experiments have steadily improved, more and more models of inflation have been ruled out.

Furthermore, during inflation, different regions of space can experience very different amounts of expansion. On very large scales, this produces a multiverse of post-inflationary universes, each with different physical properties.



The history of the universe according to the model of cosmic inflation. wikipedia, CC BY-SA

The inflation scenario is based on assumptions about the forms of energy present and the initial conditions. While these assumptions solve some puzzles, they create others. String and inflation theorists hope that somewhere in the vast inflationary multiverse, a region of space and time exists with just the right properties to match the universe we see.

However, even if this is true (and not one such model has yet been found), a fair comparison of theories should include an “Occam factor”, quantifying Occam’s razor, which penalises theories with many parameters and possibilities over simpler and more predictive ones. Ignoring the Occam factor amounts to assuming that there is no alternative to the complex, unpredictive hypothesis – a claim I believe has little foundation.

Over the past several decades, there have been many opportunities for experiments and observations to reveal specific signals of string theory or inflation. But none have been seen. Again and again, the observations turned out simpler and more minimal than anticipated.

It is high time, I believe, to acknowledge and learn from these failures, and to start looking seriously for better alternatives.

A simpler alternative

Recently, my colleague Latham Boyle and I have tried to build simpler and more testable theories that do away with inflation and string theory. Taking our cue from the observations, we have attempted to tackle some of the most profound cosmic puzzles with a bare minimum of theoretical assumptions.

Our first attempts succeeded beyond our most optimistic hopes. Time will tell whether they survive further scrutiny. However, the progress we have already made convinces me that, in all likelihood, there are alternatives to the standard orthodoxy – which has become a straitjacket we need to break out of.

I hope our experience encourages others, especially younger researchers, to explore novel approaches guided strongly by the simplicity of the observations – and to be more sceptical about their elders' preconceptions. Ultimately, we must learn from the universe and adapt our theories to it rather than vice versa.

Boyle and I started out by tackling one of cosmology's greatest paradoxes. If we follow the expanding universe backward in time, using Einstein's theory of gravity and the known laws of physics, space shrinks away to a single point, the "initial singularity".

In trying to make sense of this infinitely dense, hot beginning, theorists including Nobel laureate Roger Penrose pointed to a deep symmetry in the basic laws governing light and massless particles. This symmetry, called "conformal" symmetry, means that neither light nor massless particles actually experience the shrinking away of space at the big bang.

By exploiting this symmetry, one can follow light and particles all the way back to the beginning. Doing so, Boyle and I found we could describe the initial singularity as a "mirror": a reflecting boundary in time (with time moving forward on one side, and backward on the other).

Picturing the big bang as a mirror neatly explains many features of the universe which might otherwise appear to conflict with the most basic laws of physics. For example, for every physical process, quantum theory allows a "mirror" process in which space is inverted, time is reversed and every particle is replaced with its anti-particle (a particle similar to it in almost all respects, but with the opposite electric charge).

According to this powerful symmetry, called CPT symmetry, the "mirror" process should occur at precisely the same rate as the original one. One of the most basic puzzles about the universe is that it appears to [violate CPT symmetry] because time always runs forward and there are more particles than anti-particles.

Our mirror hypothesis restores the symmetry of the universe. When you look in a mirror, you see your mirror image behind it: if you are left-handed, the image is right-handed and vice versa. The combination of you and your mirror image are more symmetrical than you are alone.

Likewise, when Boyle and I extrapolated our universe back through the big bang, we found its mirror image, a pre-bang universe in which (relative to us) time runs backward and antiparticles outnumber particles. For this picture to be true, we don't need the mirror universe to be real in the classical sense (just as your image in a mirror isn't real). Quantum theory, which rules the microcosmos of atoms and particles, challenges our intuition so at this point the best we can do is think of the mirror universe as a mathematical device which ensures that the initial condition for the universe does not violate CPT symmetry.

Surprisingly, this new picture provided an important clue to the nature of the unknown cosmic substance called dark matter. Neutrinos are very light, ghostly particles which, typically, move at close to the speed of light and which spin as they move along, like tiny tops. If you point the thumb of your left hand in the direction the neutrino moves, then your four fingers indicate the direction in which it spins. The observed, light neutrinos are called "left-handed" neutrinos.

Heavy "right-handed" neutrinos have never been seen directly, but their existence has been inferred from the observed properties of light, left-handed neutrinos. Stable, right-handed neutrinos would be the perfect candidate for dark matter because they don't couple to any of the known forces except gravity. Before our work, it was unknown how they might have been produced in the hot early universe.

Our mirror hypothesis allowed us to calculate exactly how many would form, and to show they could explain the cosmic dark matter.

A testable prediction followed: if the dark matter consists of stable, right-handed neutrinos, then one of three light neutrinos that we know of must be exactly massless. Remarkably, this prediction is now being tested using observations of the gravitational clustering of matter made by large-scale galaxy surveys.

The entropy of universes

Encouraged by this result, we set about tackling another big puzzle: why is the universe so uniform and spatially flat, not curved, on the largest visible scales? The cosmic inflation scenario was, after all, invented by theorists to solve this problem.

Entropy is a concept which quantifies the number of different ways a physical system can be arranged. For example, if we put some air molecules in a box, the most likely configurations are those which maximise the entropy – with the molecules more or less smoothly spread throughout space and sharing the total energy more or less equally. These kinds of arguments are used in statistical physics, the field which underlies our understanding of heat, work and thermodynamics.

The late physicist Stephen Hawking and collaborators famously generalised statistical physics to include gravity. Using an elegant argument, they calculated the temperature and the entropy of black holes. Using our "mirror" hypothesis, Boyle and I managed to extend their arguments to cosmology and to calculate the entropy of entire universes.

To our surprise, the universe with the highest entropy (meaning it is the most likely, just like the atoms spread out in the box) is flat and expands at an accelerated rate, just like the real one. So statistical arguments explain why the universe is flat and smooth and has a small positive accelerated expansion, with no need for cosmic inflation.

How would the primordial density variations, usually attributed to inflation, have been generated in our symmetrical mirror universe? Recently, we showed that a specific type of quantum field (a dimension zero field) generates exactly the type of density variations we observe, without inflation. Importantly, these density variations aren't accompanied by the long wavelength gravitational waves which inflation predicts – and which haven't been seen.

These results are very encouraging. But more work is needed to show that our new theory is both mathematically sound and physically realistic.

Even if our new theory fails, it has taught us a valuable lesson. There may well be simpler, more powerful and more testable explanations for the basic properties of the universe than those the standard orthodoxy provides.

By facing up to cosmology's deep puzzles, guided by the observations and exploring directions as yet unexplored, we may be able to lay more secure foundations for both fundamental physics and our understanding of the universe.

Up Next:

NEXT MEETING: 8pm Friday 8 November – Nonsuch High School

Professor Andrew Coates from the Mullard Space Science Lab (MSSL) will talk about "Looking for Life on Mars and Habitability on Icy Moons".

There will also give a presentation on the sky at night for the coming month.

AGM: 8pm Friday 13 December – Nonsuch High School

NEXT USER GROUP:

Suspended until further notice.

NEXT DENBIES OBSERVING SESSION:

The next sessions, allowing for moon rise & set times and cloud conditions, should be sometime around the new moon which is on 1 November and 30 November.

The precise date and timings of any session will be advised by email and WhatsApp a few days in advance but should be within the period 28 October to 7 November and 25 November to 6 December.

AD HOC OBSERVING AT WARREN FARM:

These will be at short notice when the weather is favourable, and may replace, or be additional to, sessions at Denbies. Please watch our WhatsApp feed for alerts.