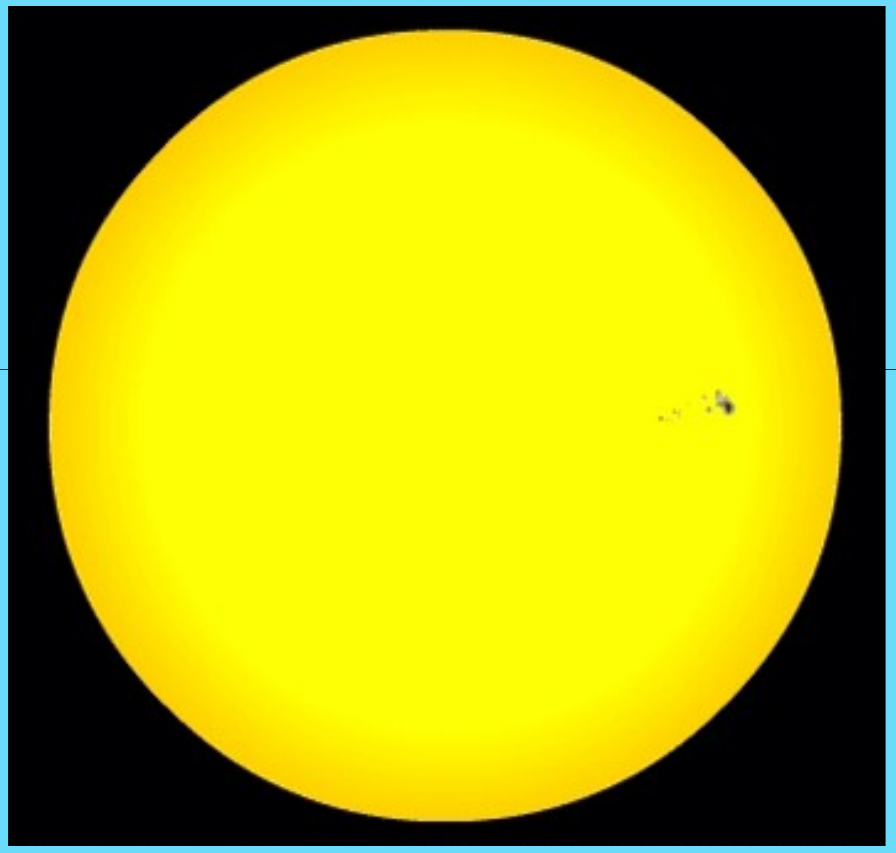
Abergavenny Astronomy Society

Topics for this month?

November 2019



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Topics for this month?

Potential topics for our "chat round table".

Items from the news etc over the last month

Suggested Topics:-

1) Transits. There are three bodies that provide us with solar transits, Mercury, Venus and the Moon. We also have exo-planet transits to investigate now.

2) The Solar System. Looking at the earliest written record of an aurora and the news that Voyager 2, launched in 1977, has now crossed into interstellar space.

3) Our galaxy, the Milky Way. The discovery of the first confirmed inter stellar comet to enter the solar system.

4) The Cosmos. Including a claim that the agreed shape of the universe is wrong, another suggestion that wormholes exist, heavy elements from neutron stars, a new gravitational wave detector and how big, or small, can a black hole be?

5) Dark Energy. More claims but few conclusions on dark energy.

November 2019

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Topics for this month?

November 2019

Transits

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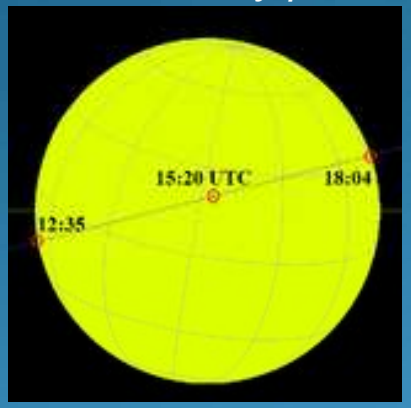
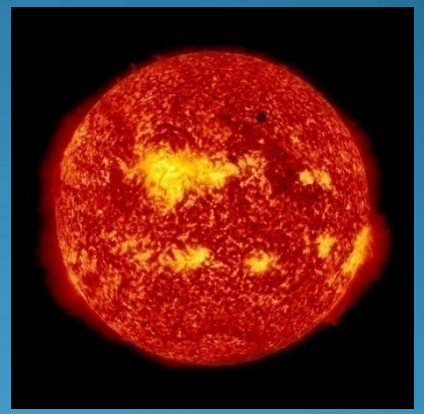
Topics for this month?

1) Transits : Solar

The definition of an astronomical transit, from Wikipedia, is *"a phenomenon when a celestial body passes directly between a larger body and the observer"*.



A couple of weeks ago there was a transit of Mercury, see the website posting, when the planet crossed the surface of the sun.



Transits of the sun also occur when Venus passes between us and the sun.

The next Mercury transit will be on the 13th Nov., 2032 with Venus following on on the 10th Dec., 2117. Venus may be a bit late for AAS members although some may be around for Mercury in 2032!!

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Topics for this month?

1) Transits : Solar

James Cook, who mapped the coasts of New Zealand and East Australia, was commissioned to observe the transits of Venus and Mercury in 1769.

He observed Venus from Tahiti and then Mercury from Mercury Bay in NZ.

His observations of Venus, along with other observations, helped to determine the distance of the earth from the sun.

It was hoped that the observation of Mercury could give a more precise longitude for the observation point. However, the success of that goal has been challenged.

Examples of the scientific investigations based on transits of Mercury are:
- -Investigations of the variability of the Earth's rotation and of the tidal acceleration of the Moon.
- -Measuring the mass of Venus from secular variations in Mercury's orbit.
- -Looking for long term variations in the solar radius.
- -Assessing the likely drop in light level in an exoplanet transit.

Venus transits
- -were used to gain the first realistic estimates of the size of the Solar System.
- -the 1639 transit, combined with the principle of parallax, provided an estimate of the distance between the Sun and the Earth that was more accurate than any other up to that time.
- -The 2012 transit was used to refine techniques to be used in the search for exo-planets.

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Topics for this month?

1) Transits : exo-planets

There are a number of methods used to detect exo-plants, that is planets orbiting other stars. These include:-

Radial Velocity

Microlensing

Astrometry

Direct imaging

and

Transit Photometry.

November 2019

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Topics for this month?

November 2019

1) Transits : exo-planets

The Methods

Radial Velocity
Detecting a orbiting body by it's red/blue shift as it orbits it's star. Can detect velocities of 3m/s.

Microlensing
Relies on lensing effects where an orbiting planet contributes to the lensing effect.
Whereas radial velocity searches look for planets in our immediate galactic neighbourhood, up to 100 light years from Earth microlensing can find planets orbiting stars near the centre of the galaxy.

Astrometry
Astrometry is the science of precision measurement of stars' locations in the sky. When planet hunters use astrometry, they look for a minute but regular wobble in a star's position. If such a periodic shift is detected, it is almost certain that the star is being orbited by a companion planet.

Direct Imaging
Direct imaging of exoplanets is extremely difficult, and in most cases impossible. Being small and dim planets are easily lost in the brilliant glare of the giant stars they orbit.

Transit Photometry

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Topics for this month?

1) Transits : exo-planets

The Kepler Space Telescope Mission used transit photometry to identify exo-plants.

It was launched in 2009 and was deactivated a year ago in 2018.

The telescope only covered 0.25% of the sky.

Kepler has discovered over 6,000 exo-planets

In 2018 a replacement for Kepler was launched; TESS (Transiting Exoplanet Survey Satellite). Its orbit is expected to be stable for at least 10 years.

TESS is fitted with 4 wide angle telescopes and is designed as an all sky telescope.

In its first year of operation TESS identified 1,000 "Objects of Interest" including 20 earth size planets, ie <4 Earth radii.

Following TESS identifying an object ground based telescopes can then investigate them in more detail.

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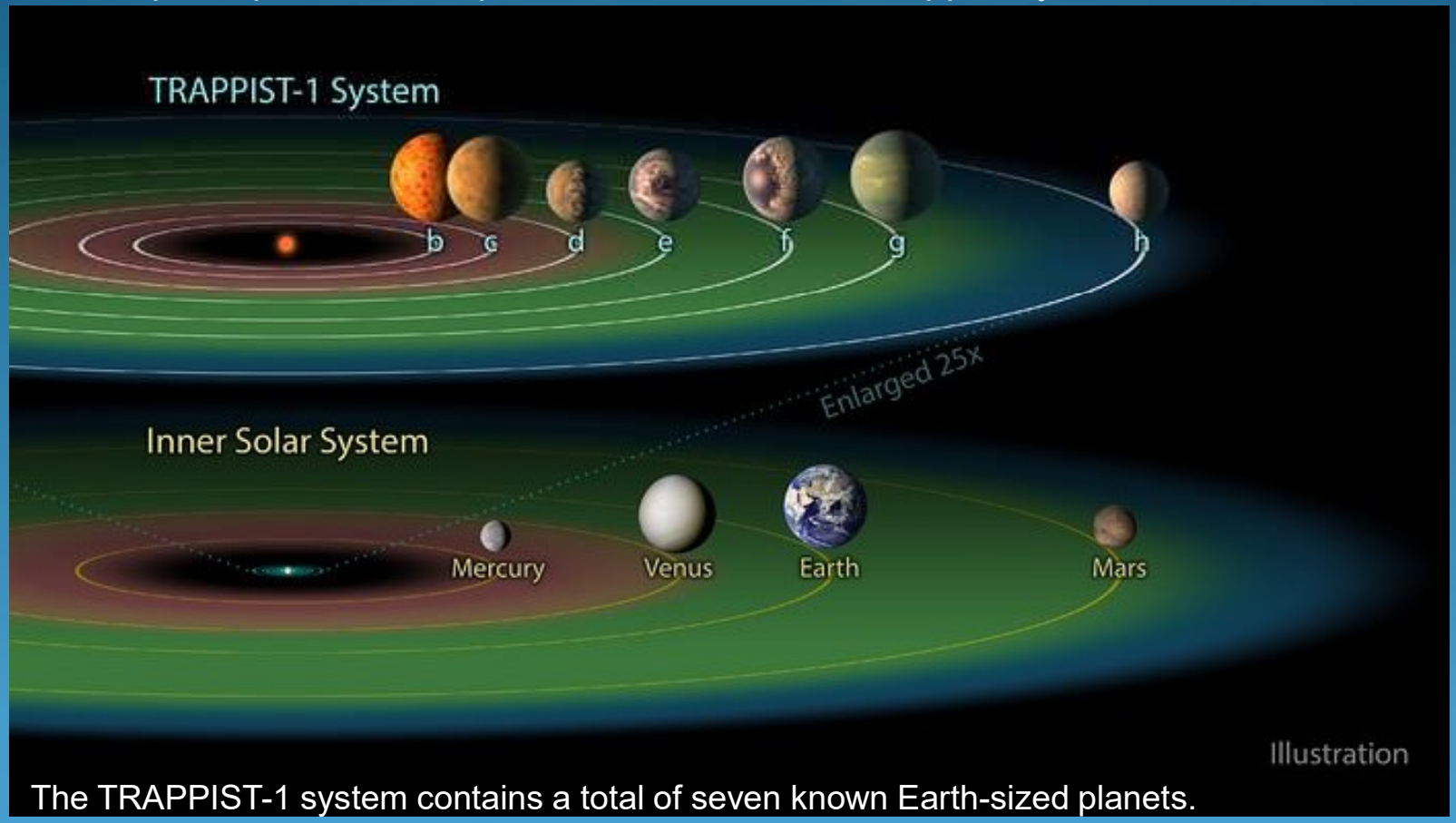
Topics for this month?

1) Transits : exo-planets

The Kepler Space Telescope Mission view of the Trappist system



The TRAPPIST-1 system contains a total of seven known Earth-sized planets.
Three of them are located in the habitable zone of the star (shown in green in this artist's impression), where temperatures are just right for liquid water to exist on the surface.

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Topics for this month?

2) The Solar System

November 2019

Voyager 2 reaches interstellar space

Abergavenny Astronomy Society

November 2019

Topics for this month?

2) The Solar System **Voyager 2 reaches interstellar space**

November 4, 2019, University of Iowa

Researchers report the spacecraft Voyager 2, launched in 1977, has reached interstellar space. It entered the interstellar medium at 119.7 AU, or more than 11 billion miles (17.7 billion km) from the sun.

Voyager 1's passed over the boundary six years ago. It had to travel 10 AU further than Voyager 2 in order to reach the heliopause.

In the study, the researchers note a jump in plasma density detected by a plasma wave instrument on the spacecraft as evidence Voyager 2 has entered interstellar space.

"In a historical sense, the old idea that the solar wind will just be gradually whittled away as you go further into interstellar space is simply not true," says Iowa's Don Gurnett, corresponding author on the study, published in “Nature – Astronomy”.

"We show with Voyager 2 -- and previously with Voyager 1 -- that there's a distinct boundary out there. It's just astonishing how fluids, including plasmas, form boundaries."

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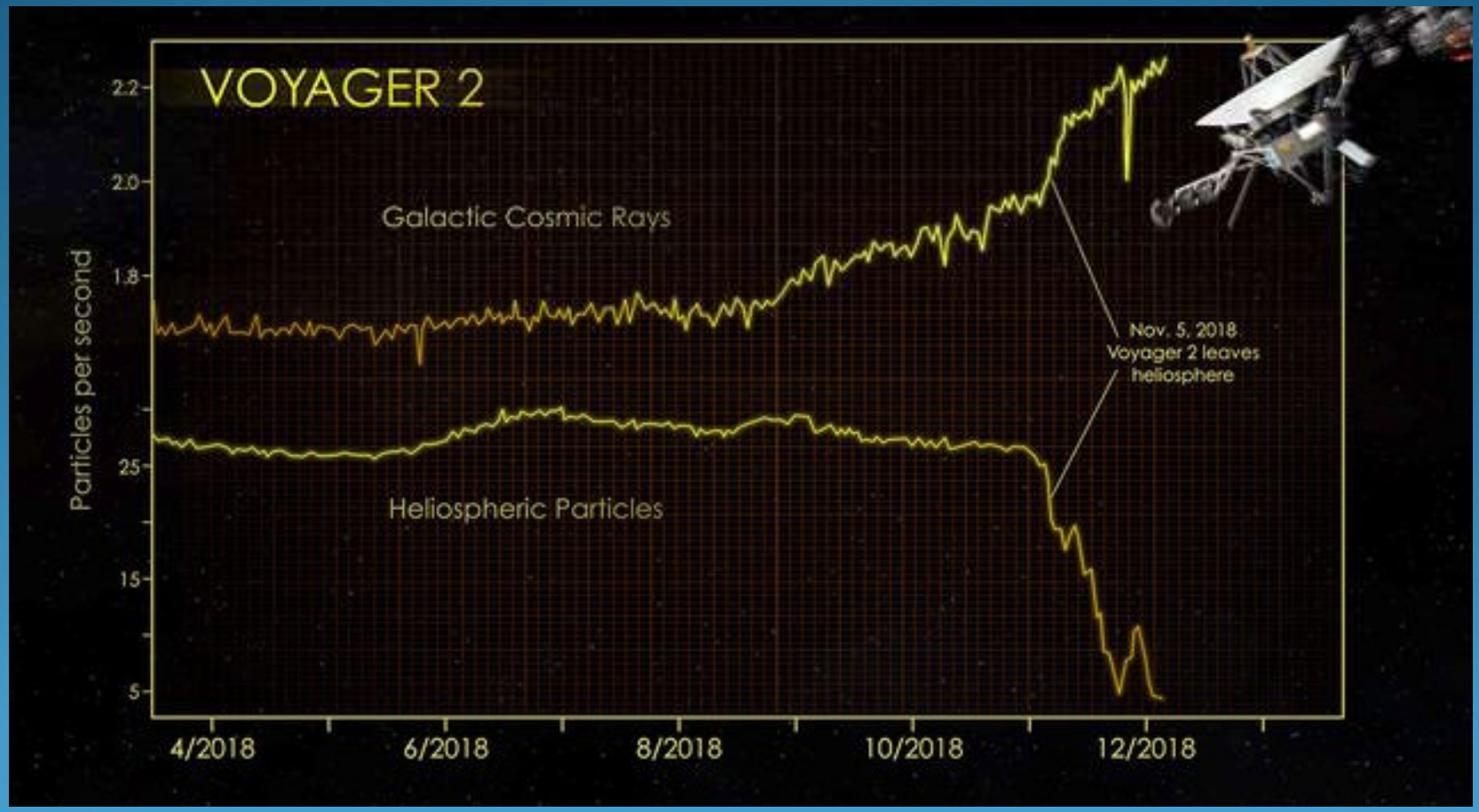
Topics for this month?

2) The Solar System **Voyager 2 reaches interstellar space**



https://www.jpl.nasa.gov/images/voyager/20181210/PIA22924-16.gif

November 2019

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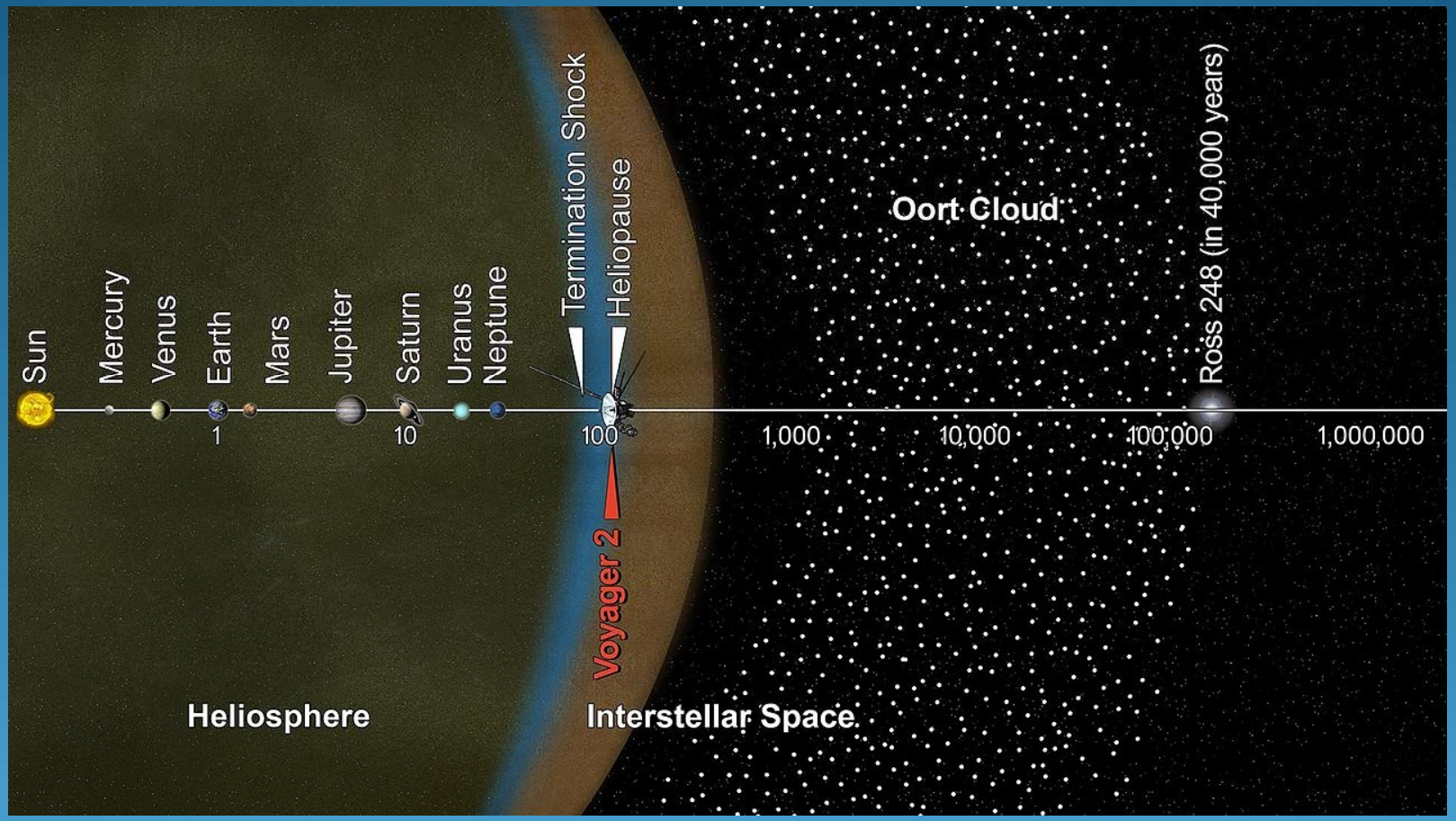
Topics for this month?

November 2019

2) The Solar System

Voyager 2 reaches interstellar space



The current position of Voyager 2 December 2018, around 120 AU from the Sun
Earth is 1 astronomical unit (AU) from the Sun;
Neptune is 30.1 AU from the Sun;
Thus Voyager 2 is around four times as far from the Sun as the last planet.

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Topics for this month?

2) The Solar System **Voyager 2 reaches interstellar space**

November 2019

Terminations and future of the Voyager spacecraft *(from Wikipedia)*

Neither Voyager is headed to any particular star.

Voyager 1:-

expected to reach the Oort cloud in about 300 years and take about 30,000 years to pass through it,
in about 40,000 years, provided it is not retrieved, it will pass within 1.6 light-years of the star Gliese 445,
in 2018 it was travelling at 17kms/sec.

Voyager 2:-

In 42,000 years it will pass 1.7 light-years from the star Ross 248.
Then in 296,000 years it should pass by Sirius at a distance of 4.3 light-years.
Voyager 2 is expected to keep transmitting weak radio messages until at least the mid 2020s.

As the power from the thermoelectric generators (RTG) slowly reduces, various items of equipment have been turned off on both spacecraft.

Year	End of specific capabilities as a result of the available electrical power limitations
1998	Termination of scan platform and UVS observations
2007	Termination of *Digital Tape Recorder* (DTR) operations (It was no longer needed due to a failure on the *High Waveform Receiver* on the *Plasma Wave Subsystem* (PWS) on June 30, 2002.)
2008	Power off *Planetary Radio Astronomy Experiment* (PRA)
2016 approx	Termination of gyroscopic operations?
2019	CRS heater turned off.
2020 approx	Initiate instrument power sharing
2025 or so	Can no longer power any single instrument

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Topics for this month?

2) The Solar System

November 2019

Ancient Aurorae
Assyrian and Babylonian Astrologers
Recorded the Oldest-Known Solar Storms

astrobites.org

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November 2019

Topics for this month?

2) The Solar System Ancient Aurorae

Hisashi Hayakawa, Yasuyuki Mitsuma, Yusuke Ebihara and Fusa Miyake
Graduate School of Letters, Osaka University, Japan
Published in The Astrophysical Journal Letters,

For dates before the first telescopic sunspot observations in 1610 auroral records in historical archives have proved of great use.

These space weather events constitute a significant threat to a modern civilization, because of its increasing dependency on an electronic infrastructure.

Recent studies have identified multiple extreme space weather events derived from solar energetic particles in natural archives, such as the event in 660 BCE.

While the level of solar activity around 660 BCE is of great interest, this had not been within the coverage of the hitherto-known datable auroral records in historical documents that extend back to the 6th century BCE.

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Topics for this month?

2) The Solar System Ancient Aurorae_ Assyrian and Babylonian Astrologers Recorded the Oldest-Known Solar Storms

The Osaka team have examined Assyrian astrological reports in the 8th and 7th centuries BCE

They identified three observational reports of candidate aurorae, and dated these reports to approximately 680 BCE -- 650 BCE.

The Assyrian cuneiform tablets let us extend the history of auroral records and solar activity by a century.

These cuneiform reports are considered to be the earliest datable records of candidate aurorae

They support the concept of enhanced solar activity suggested by the cosmogenic isotopes from natural archives.

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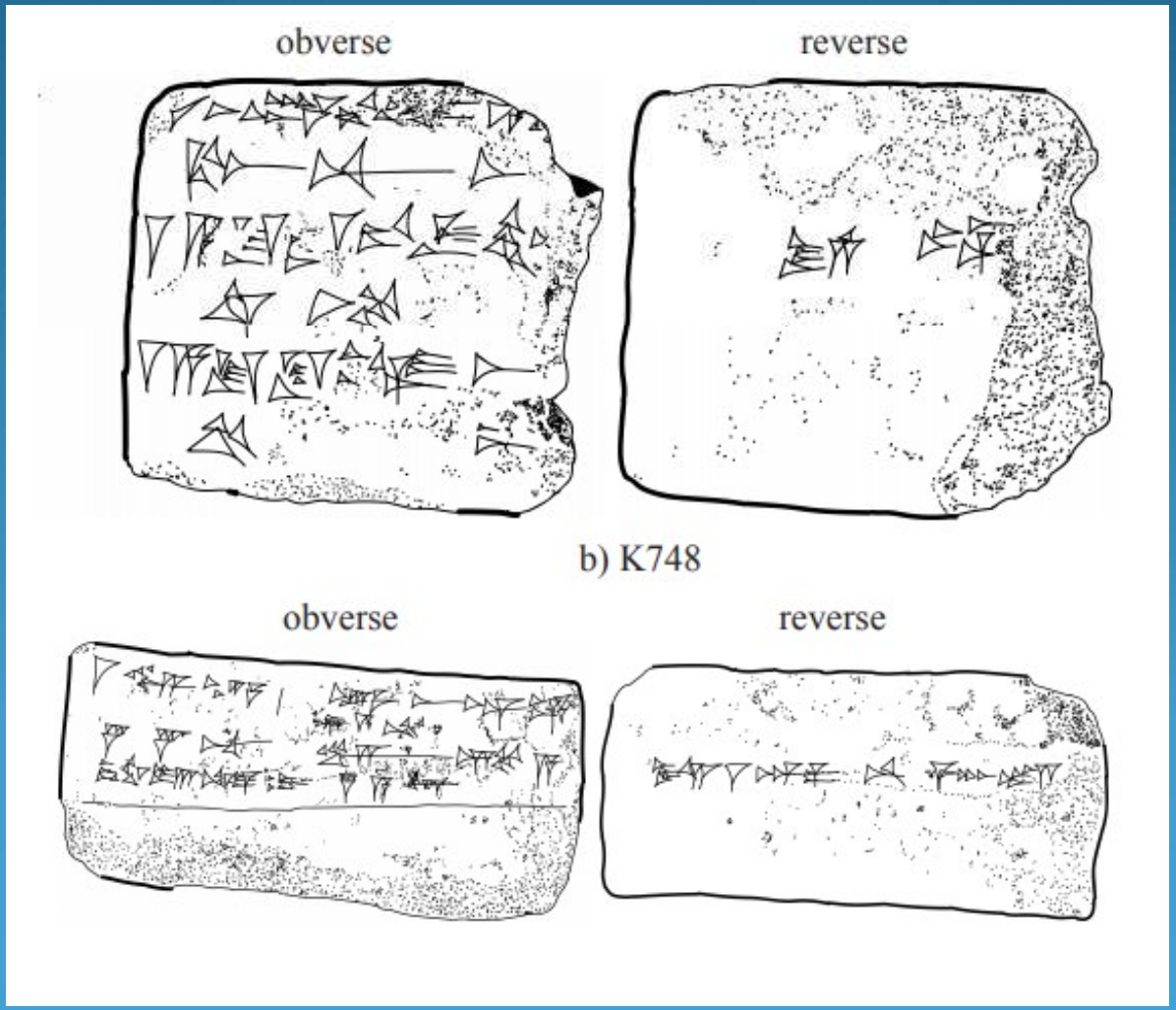
Topics for this month?

2) The Solar System

Ancient Aurorae



November 2019

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Topics for this month?

2) The Solar System

November 2019

The discovery of the first confirmed inter stellar comet to enter the solar system

www.sciencedaily.com

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Topics for this month?

3) Our galaxy: The first confirmed inter stellar comet to enter the solar system

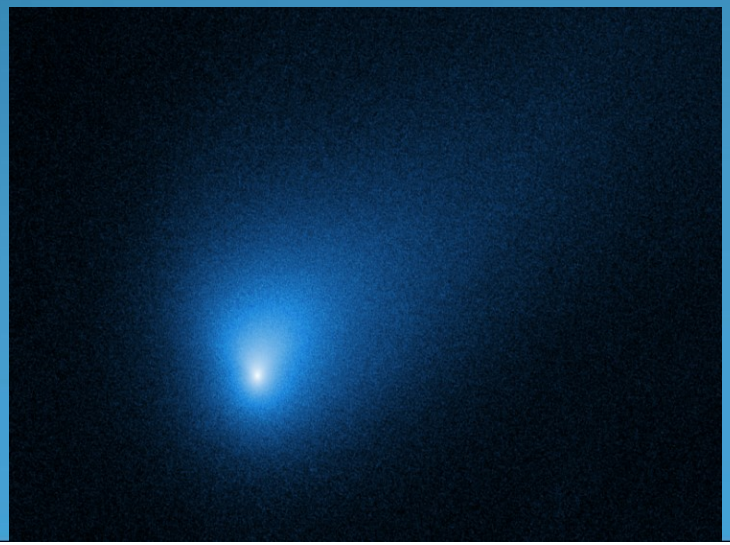
October 16, 2019 : NASA/Goddard Space Flight Center

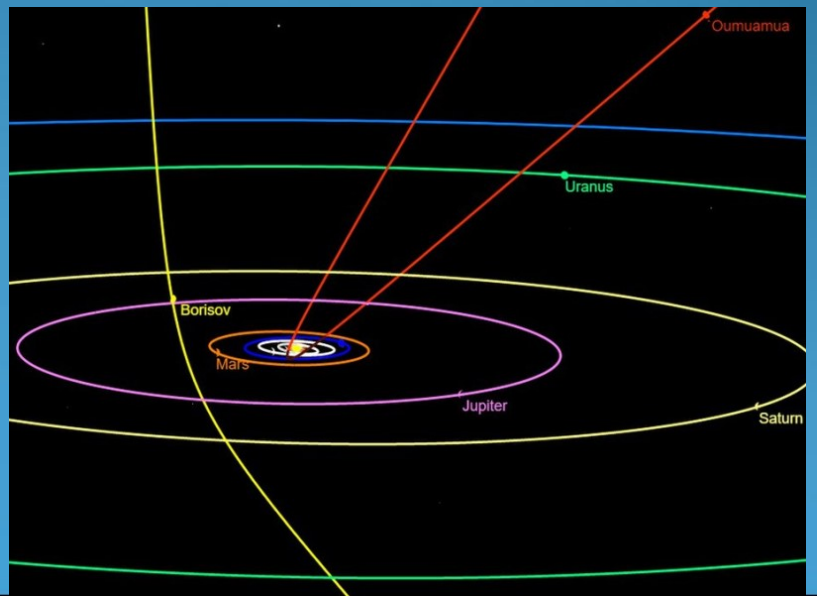
Hubble has given astronomers their best look yet at an interstellar visitor.

Comet 2I/Borisov, its speed (110,000 mph) and trajectory indicate it has come from beyond our solar system.

Crimean amateur Gennady Borisov discovered the comet on Aug. 30, 2019.

It is only the second such interstellar object, after Oumuamua, known to have passed through the solar system





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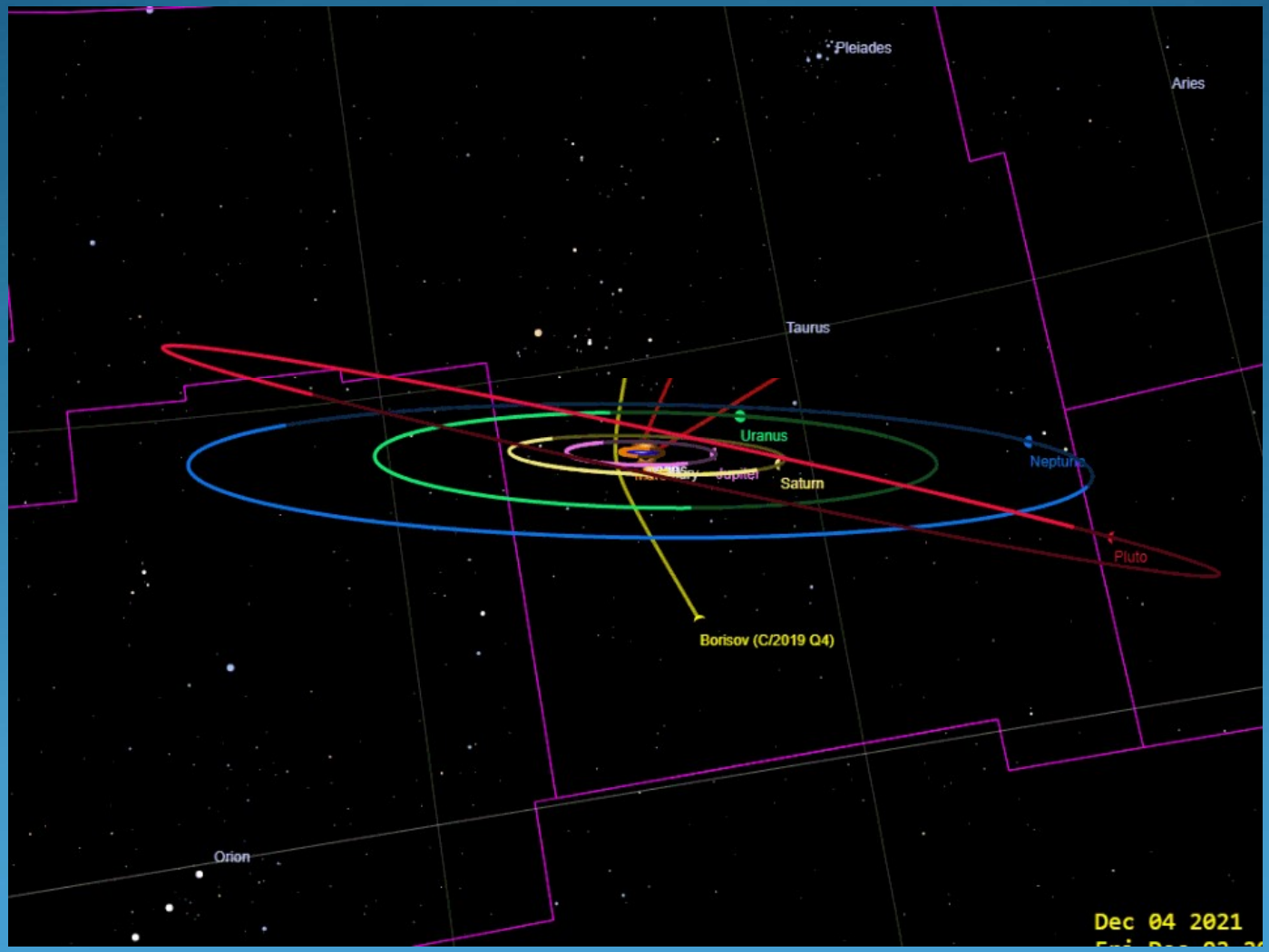
Topics for this month?

3) Our galaxy: The first confirmed inter stellar comet to enter the solar system



https://upload.wikimedia.org/wikipedia/commons/5/58/A_comparison_of_two_interstellar_objects_passing_through_our_solar_system.gif : ***Author*** *Tony873004*

November 2019

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Topics for this month?

4) The Cosmos

November 2019

What Shape Is the Universe
Closed or Flat?

www.quantamagazine.org

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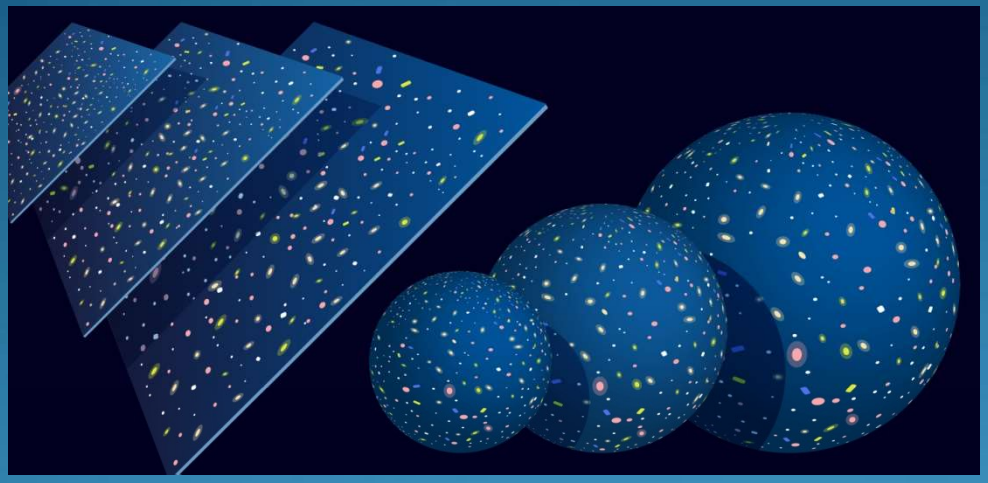
November 2019

Topics for this month?

4) The Cosmos : What Shape Is the Universe — Closed or Flat



In a flat universe, as seen on the left, a straight line will extend out to infinity.

A closed universe, right, is curled up like the surface of a sphere. In it, a straight line will eventually return to its starting point.

Quanta Magazine

The leading theory of the universe's birth, known as cosmic inflation, yields pristine flatness. And observations since the early 2000s have shown that our universe is very nearly flat and must therefore come within a hair of the critical density — calculated to be about 5.7 H atoms' worth of stuff/m^3 of space, much of it invisible.

According to the new analysis, the large amount of lensing of the CMB suggests that the universe may be about 5% denser than the critical density, averaging something like 6 H atoms/m^3.
So gravity wins and the cosmos closes in on itself. This new investigation "clearly points towards a closed model," according to Alessandro Melchiorri of Sapienza University of Rome.

A member of the Planck team who worked on the CMB analysis, said the simplest explanation for the specific feature in the CMB data that Rome team interpreted as evidence for a closed universe "is that it is just a statistical fluke."

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Topics for this month?

4) The Cosmos

November 2019

Could wormholes actually exist?

www.zmescience.com

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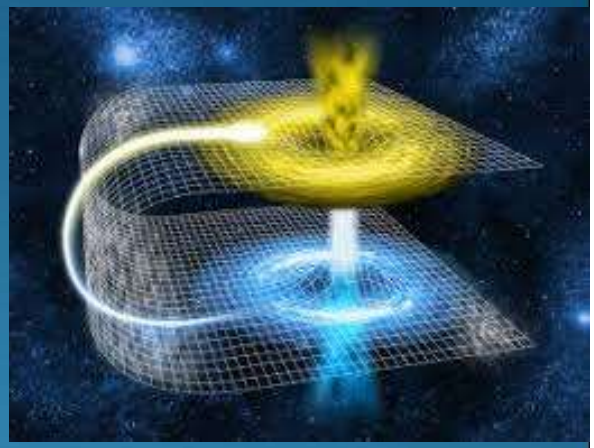
Topics for this month?

November 2019

4) The Cosmos : Could wormholes actually exist?



Wormholes are often a staple of sci-fi stories.

Intertwining dimensions by bending space and time can be quite handy.

Unfortunately, they've never been proven to actually exist.

Now a new study out of the University of Buffalo (UB) has attempted to take a look at what they would look like if they were real and have been looking at Sagittarius A*.

"If you have two stars, one on each side of the wormhole, the star on our side should feel the gravitational influence of the star that's on the other side. The gravitational flux will go through the wormhole," says Dejan Stojkovic, cosmologist and professor of physics. So mapping the expected orbit of a star, like S2, around Sagittarius A*, could show deviations from that orbit if there is a wormhole there with a star on the other side.

Current surveying techniques are not yet precise enough to reveal the presence of a wormhole.

Sufficient advances in precision may occur in the next one or two decades - or not.

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Topics for this month?

4) The Cosmos

Hidden monster or spooky cosmological coincidence??

The Two LIGO/Virgo Binary Black Hole Mergers on 2019 August 28 Were Not Strongly Lensed

Authors: Leo P. Singer, Daniel A. Goldstein, and Joshua S. Bloom

Status: open access on arXiv

First Author's Institution: Astroparticle Physics Laboratory, NASA Goddard Space Flight Center

November 2019

astrobites.org

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Topics for this month?

4) The Cosmos : Hidden monster or cosmological coincidence?

The LIGO/Virgo collaborations went public in April of this year.

This means that live alerts are sent out when their detectors find something significant so that other teams with telescopes that are sensitive to different types of radiation can point their antennae in the direction of the gravitational radiation.

If something luminous was involved in the gravitational wave production, then they'll hope to see any radiation given off at other frequencies, like x-rays, or radio waves.

This paper focuses on an unusual alert from LIGO/Virgo, a detection of black holes merging, so there was no electromagnetic counterpart to be found.

However, what caught today's author's eyes was that there was not one, but two merger events within 20 minutes of each other, and seemingly from similar places in the sky.

However, it is estimated that observing independent black hole mergers within 20 minutes of each other should only happen roughly once every 16 years.

Could this actually just have been one black hole merger which had been gravitationally lensed and then detected twice?

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Topics for this month?

4) The Cosmos : Hidden monster or cosmological coincidence?

So, if this was just one black hole merger event, there needs to be a monstrous object hiding somewhere that we are yet to discover, and

we also need the black holes and the lens to have been in a particular alignment so that the time delay is much smaller than would normally be predicted for such a large lens.

Despite the fact that it was super unlikely for two mergers to be detected within 20 minutes of each other, today's authors argue that the other possible explanation is even more unlikely.

It looks as though it was indeed just a spooky cosmological coincidence.

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Topics for this month?

4) The Cosmos

November 2019

Japanese gravitational wave detector to join LIGO and Virgo

newatlas.com/physics

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November 2019

Topics for this month?

4) The Cosmos : Japanese GW detector to join LIGO and Virgo

The four gravitational wave facilities,

LIGO Hanford (top left),

KAGRA (top right),

Virgo (bottom left) and

LIGO Livingston (bottom right)

ICRR, Univ. of Tokyo
LIGO Lab
Caltech
MIT
Virgo Collaboration

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Topics for this month?

4) The Cosmos

November 2019

Strontium detection confirms heavy elements form in neutron star mergers

physicsworld.com

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Topics for this month?

4) The Cosmos : Strontium detection confirms heavy elements form in neutron star mergers

The "Big Bang", that marked the origin of the universe, resulted in the formation of Hydrogen followed by Helium and a small amount of Lithium.

Most of the other "light" elements, up to Iron, were formed in cataclysmic explosions like supernova.

It had been proposed that heavier elements were formed in even larger explosions like merging neutron stars, so called kilo nova.

Now the first spectroscopic evidence that heavy elements are created by the merger of two neutron stars has been found by an international team of scientists.

By analysing light captured by the Very Large Telescope in Chile, the team has shown that strontium was produced in a huge "kilonova" explosion that followed such a merger.

As well as confirming that neutron-star mergers are a significant source of heavy elements, the study also provides the first spectroscopic evidence that neutron stars comprise neutron-rich matter.

November 2019

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Topics for this month?

4) The Cosmos

New class of black holes smaller than thought possible discovered
The Independent

Possible Detection of a Black Hole So Big It 'Should Not Exist'
Quanta Magazine

November 2019

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Topics for this month?

4) The Cosmos : How big or Small can a stellar black hole be?

Theory was that high mass stars with a mass between 1.4 & 3 M⊙ should be neutron stars.

Beyond 10 M⊙ gravitational collapse will usually occur to produce a black hole, though the smallest observed mass of a stellar black hole was about 5 M⊙.

November 2019

Abergavenny Astronomy Society

Topics for this month?

4) The Cosmos : How big or Small can a stellar black hole be?

Now scientists have discovered a new class of black holes that are smaller than thought possible.

A black hole has been discovered that is 3.3 M⊙, making it by far the smallest known.

So it seems there is a lower mass population of black holes.

Todd Thompson, of Ohio State University, said “people are trying to understand supernova explosions, how supermassive black stars explode, how the elements were formed in supermassive stars.

“So if we could reveal a new population of black holes, it would tell us more about which stars explode, which don’t, which form black holes, which form neutron stars.”

November 2019

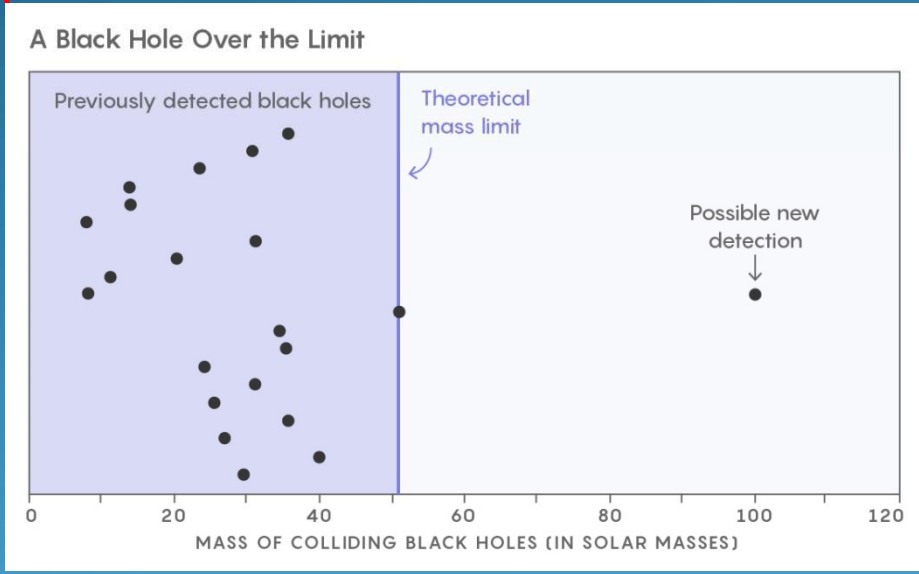
Abergavenny Astronomy Society

November 2019

Topics for this month?

4) The Cosmos : How big or Small can a stellar black hole be?

At the other end of the scale black hole physicists have been excitedly discussing reports that the LIGO and Virgo gravitational-wave detectors recently picked up the signal of an unexpectedly enormous black hole, 100 M⊙, one with a mass that was thought to be physically impossible, between 65 & 130 M⊙.



A pair-instability supernova happens when the core grows so hot that light begins to spontaneously convert into electron-positron pairs. The light's radiation pressure had kept the star's core intact;
when the light transforms into matter, the resulting pressure drop causes the core to rapidly shrink and become even hotter, further accelerating pair production and causing a runaway effect.
Eventually the core gets so hot that oxygen ignites, fully reversing the core's implosion, so that it explodes instead.

For cores with a mass between about 65 and 130 times that of our sun (according to current estimates), the star is completely obliterated. Cores between about 50 and 65 solar masses pulsate, shedding mass in a series of explosions until they drop below the range where pair instability occurs.
Thus there should be no black holes with masses in the 50-to-130-solar-mass range.

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Topics for this month?

5) Dark Energy

November 2019

Dark energy debate reignited by controversial analysis of supernovae data

physicsworld.com

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Topics for this month?

2) The Cosmos : Is Dark Energy merely an artefact of our movement ?

Cosmic acceleration is a central element of the Standard Model of cosmology and has been corroborated by other types of observational evidence, including data from the cosmic microwave background (CMB).

Dark energy, the name given to the force thought to be pushing the universe apart at ever greater speeds, may be nothing more than an artefact of our acceleration through a local patch of the universe.

That is the controversial claim of a group of physicists who reckon they have found flaws in the evidence underpinning the concept of cosmic acceleration. The dispute centres on type Ia supernovae, used by researchers to calculate cosmic distances and rates of expansion.

In 2015 Oxford University physicist Subir Sarkar and two colleagues at the Niels Bohr Institute wrote a paper to claiming that the evidence for cosmic acceleration was not as watertight as generally supposed.

Carrying out statistical tests on a sample of 740 type Ia supernovae, they investigated the empirical procedure used to adjust absolute brightness to account for variations in emission between supernovae as well as absorption of their light by intervening dust.

They claimed to have found “only marginal” evidence for cosmic acceleration, calculating a statistical significance for such acceleration of less than 3σ. Normally, 5σ is seen as the gold standard for a discovery.

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Topics for this month?

2) The Cosmos

Meanwhile in Arizona

New dark energy experiment may solve one of the universe's greatest mysteries

November 2019

www.zmescience.com

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Topics for this month?

5) Dark Energy : the Dark Energy Spectroscopic Instrument (DESI)

November 2019

On October 22, the Dark Energy Spectroscopic Instrument (DESI) on the Mayall Telescope in Arizona achieved first light.

This is a huge leap in our ability to measure galaxy distances – enabling a new era of mapping the structures in the universe.

As its name indicates, it may also be key to solving one of the biggest questions in physics: what is the mysterious force dubbed “dark energy” that makes up the 70% of the universe?

The first maps of the universe were produced by the Centre for Astrophysics Redshift Survey, 1977 to ~1989, using redshifts to measure the distance of a galaxy.

These assumptions were tested with new observations, including, from 2000, the Sloan Digital Sky Survey (SDSS), a dedicated redshift survey telescope mapping the large scale structure in the universe to unprecedented detail.

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November 2019

Topics for this month?

5) Dark Energy : the Dark Energy Spectroscopic Instrument (DESI)

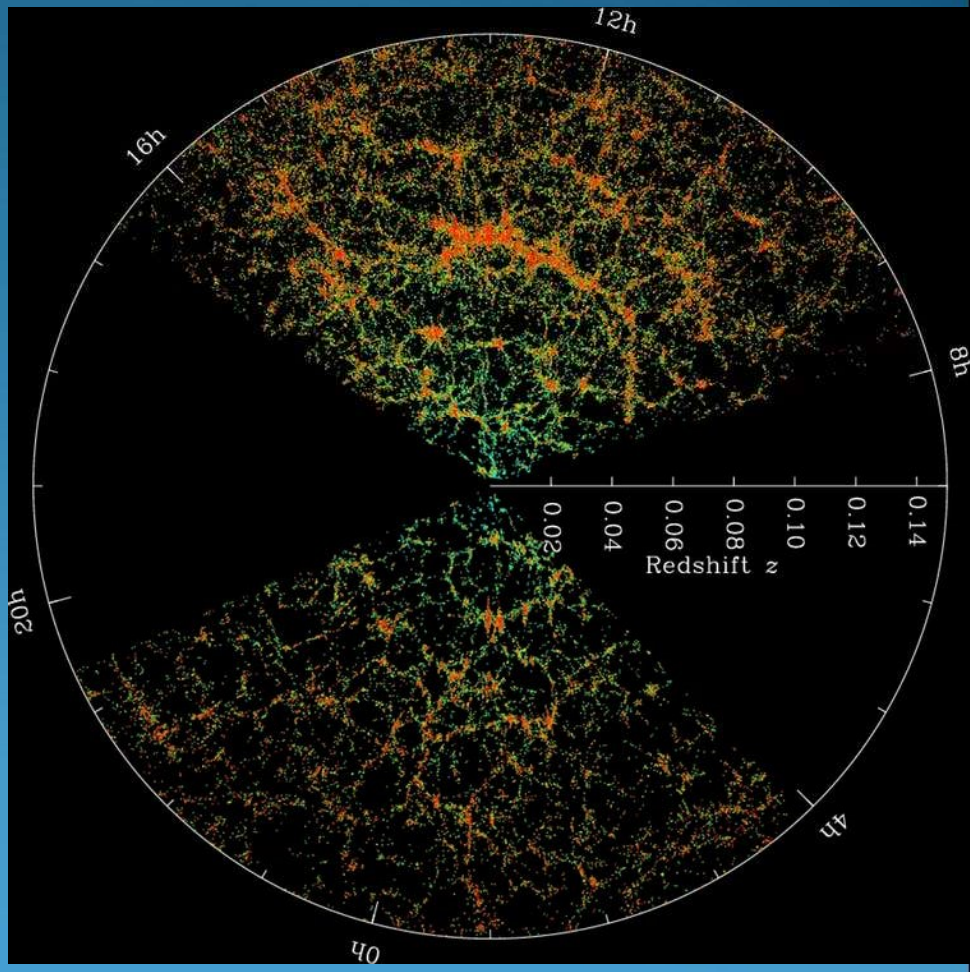
The combination of all these observations heralded a new era of cosmological understanding with a universe consisting of 30% matter and 70% dark energy.

But despite the fact that **most** physicists have now accepted that there is such a thing as dark energy, we still do not know its exact form.

So, 2 alternatives:-

1) **DE is just an illusion caused by our passage through the local universe, or**

2) **There really really is something out there – but what???**



SDSS map. Each dot is a galaxy; M. Blanton and SDSS, CC BY-SA

Abergavenny Astronomy Society

Topics for this month?

November 2019

Topics - summary

AAS : Notes for Discussion 25th November, 2019

Potential topics for our Discussion Group

Topic 1

Transits:-
The definition of an astronomical transit, from Wikipedia, is *"a phenomenon when a celestial body passes directly between a larger body and the observer"*.
A couple of weeks ago there was a transit of Mercury, see the website posting, when the planet crossed the surface of the sun.

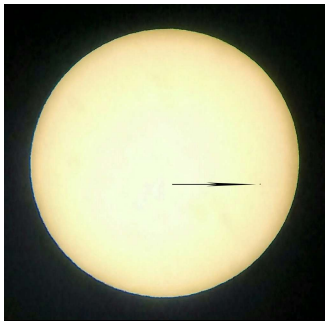


Photo taken with a mobile phone through a telescope.

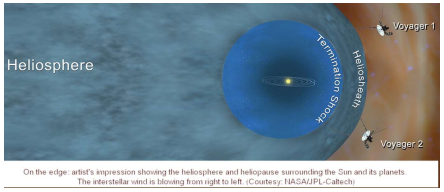
The arrow points at Mercury

Nick Busby

Transits of the sun also occur when Venus passes between us and the sun. The next Mercury transit will be on the 13th Nov., 2032 with Venus following on on the 10th Dec., 2117. Venus may be a bit late for AAS members although some may be around for Mercury in 2032!!
Transits have also proved useful for finding exo-planets and also trying to get a spectrum of the planet's potential atmosphere as the star light passes through it.
In our discussion we can also explore what solar transits have revealed to us and also the latest details on exo-planet transits.

Topic 2 : The Solar System
Aurora : when was the first written record of an auroral event. You may be surprised to hear that it is thought, by an Osaka University team, to be 587BC.

Voyager : Has Voyager 2 finally crossed into interstellar space? According to plasma density measurements it has.



On the edge: artist's impression showing the heliosphere and heliopause surrounding the Sun and its planets. The interstellar wind is blowing from right to left. (Courtesy: NASA/JPL-Caltech)

Topic 3 : Milky Way
The Hubble Space telescope has spotted the first confirmed inter stellar comet. Comet 2I/Borisov will be at its closest approach, about twice as far as the earth from the sun, on the 19th December.

Topic 3 : The Cosmos
What shape is the Cosmos. It is currently thought to be almost flat. However, one team from Rome, have published what is called a provocative paper in Nature claiming that analysis of the Planck CMB (Cosmic Microwave Background) data shows that the cosmos is in fact is closed, curled up like a ball. The Planck Team are sticking to their interpretation. Is this code for baloney??

Another non-standard claim, this time from a US university, is that there may well be wormholes around our own supermassive black hole, Sagittarius A*. They say that we should be able to detect them in the next couple of decades. Bit too far out for me, ignoring the fact that it's 26,000 light years from us.

The Japanese Gravity Wave Detector is due to join the 2 US and the Italian detectors before the end of the current detecting run. It is expected to improve precision 3 fold. Still with GWs a NASA researcher, trawling through recently released data, thinks they have found 2 events, in the same part of the sky within 20 mins of each other. So, is this an example of lensing, like with light, or just coincidence?

You may recall that it was claimed, at the time of the GW detections that heavy elements are formed in the collisions of neutron stars. This has now been confirmed with the detection of strontium.

Theory dictates how small of large a black hole can be. From 5 times the mass of the sun and, although theory allows for sizes above 130 solar masses there should be none between 50 and 130. Now a black hole has been discovered with a size of 3.3 solar masses and another with 100.

5 : Dark Energy (DE)
DE was discovered in 1998 when it was found that the expansion of the universe, rather than slowing down was actually increasing. So, there had to be a negative energy force that was overcoming the attractive force of gravity. This was called Dark Energy and it comprises 70% of the universe. Now a couple of papers from a team at Oxford, the Niels Bohr Institute and Paris claim that cosmic acceleration does not exist – hence no dark energy.

Meanwhile, the Dark Energy Spectroscopic Instrument (DESI) went live on the 22nd October. With this instrument they are hoping to help solve the nature of DE.

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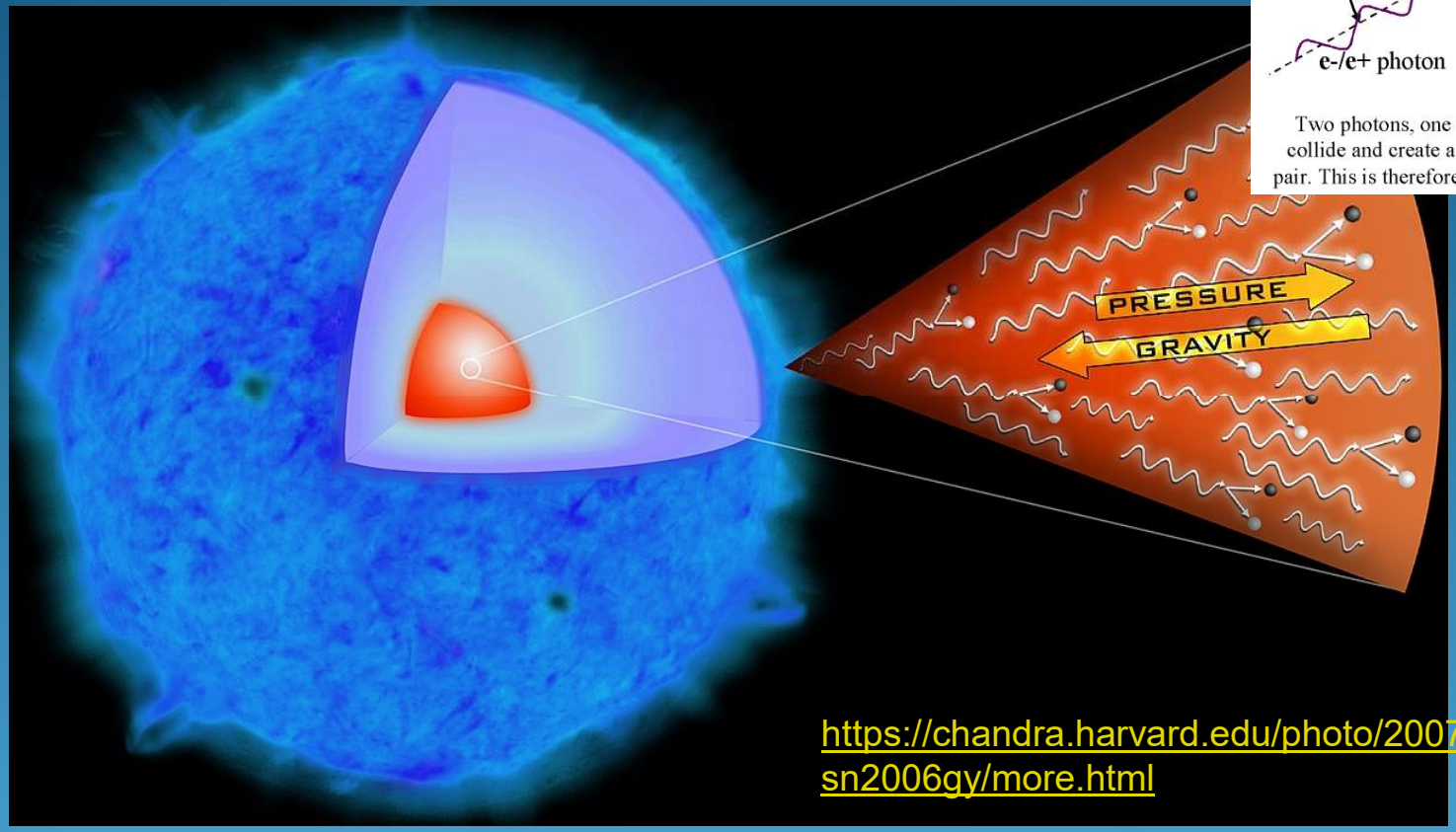
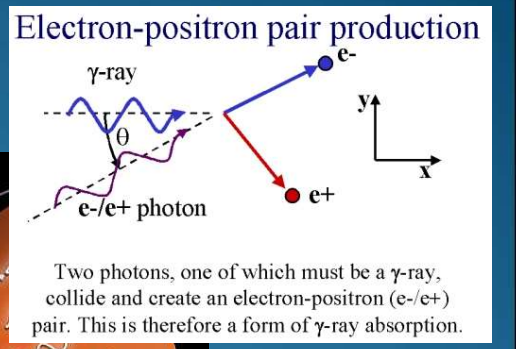
Topics for this month?

Topics – pair instability supernova process



https://chandra.harvard.edu/photo/2007/sn2006gy/more.html



This illustration shows the process that astronomers think triggered the explosion in SN 2006gy. When a star is very massive, (>130 x solar mass) the gamma rays produced in its core can become so energetic that some of their energy is drained away into production of particle and antiparticle pairs. The resulting drop in pressure causes the star to partially collapse under its own huge gravity. After this violent collapse, runaway thermonuclear reactions ensue and the star explodes, spewing the remains into space.

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Other Topics File Listing

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Name

- 01a Mercury with a mobile.jpg
- 02a Voyager 2 reaches interstellar space_ Instrument detects plasma density jump -- ScienceDaily.pdf
- 02a Voyager 2 spacecraft crosses barrier into interstellar space_ZMEScience.pdf
- 02a Voyager 2 spacecraft goes interstellar as it leaves the solar bubble – Physics World.pdf
- 02a Voyager 2's Interstellar Arrival Was Kind of Familiar. That's Surprising - Eos.pdf
- 02a Voyagers-Heliosphere.jpg
- 02a Voyagers-Heliosphere-01.jpg
- 02b Ancient Aurorae_ Assyrian and Babylonian Astrologers Recorded the Oldest-Known Solar Storms _ astrobites.pdf
- 03a Hubble observes first confirmed interstellar comet -- ScienceDaily.pdf
- 04a What Shape Is the Universe — Closed or Flat_ _ Quanta Magazine.pdf
- 04b Could wormholes actually exist_ZMEScience.pdf
- 04c Hidden monster or spooky cosmological coincidence_ _ astrobites 1910.03601.pdf
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- 04c Japanese gravitational wave detector to join LIGO and Virgo.pdf
- 04d Astronomers confirm heavy elements are born from neutron star collisions_ZMEScience.pdf
- 04d Strontium detection confirms heavy elements form in neutron star mergers – Physics World.pdf
- 04h 1742px-Sn2006gy_collapse_ill.jpg
- 04h New class of black holes smaller than thought possible discovered_ The Independent.pdf
- 04h Pair-instability supernova - Wikipedia.pdf
- 04h Possible Detection of a Black Hole So Big It 'Should Not Exist' _ Quanta Magazine.pdf
- 04h sn2006gy_ill.tif
- 05a Dark energy debate reignited by controversial analysis of supernovae data – Physics World.pdf
- 05b New dark energy experiment may solve one of the universe's greatest mysteries_ZMEScience.pdf
- 09e A Discovery of a Triple AGN System _ astrobites.pdf
- 09f Cosmologists Debate How Fast the Universe Is Expanding _ Quanta Magazine.pdf
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