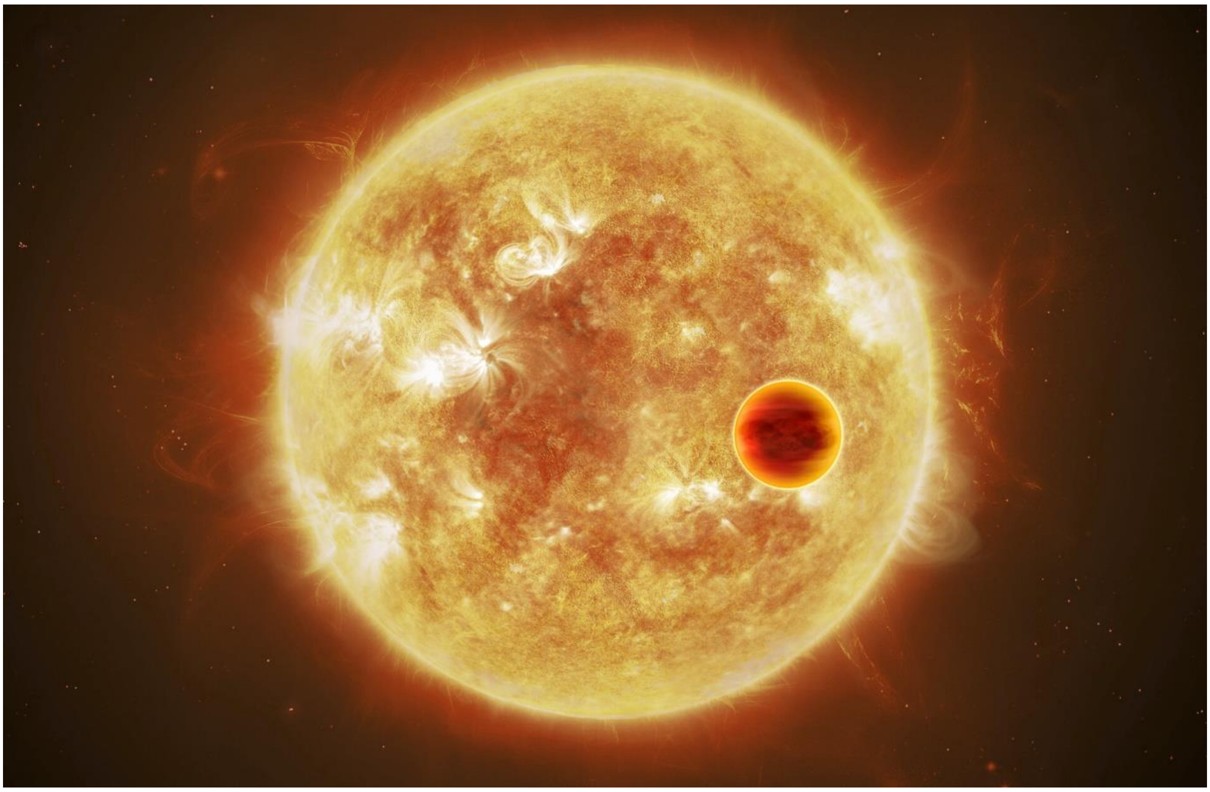
British Astronomical Association
Supporting amateur astronomers since 1890

Infinite Worlds



ARIEL moves from blueprint to reality Credit ESA

The e-magazine of the Exoplanets Division Of the Asteroids and Remote Planets Section

Issue 9 2021 January

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Section officers

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Assistant Director (Astrometry)	Peter Birtwhistle
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Assistant Director (Exoplanets)	Roger Dymock

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Peta Bosley, Simon Downs, Steve Futcher, Paul Leyland, David Pulley, Mark Salisbury, Americo Watkins

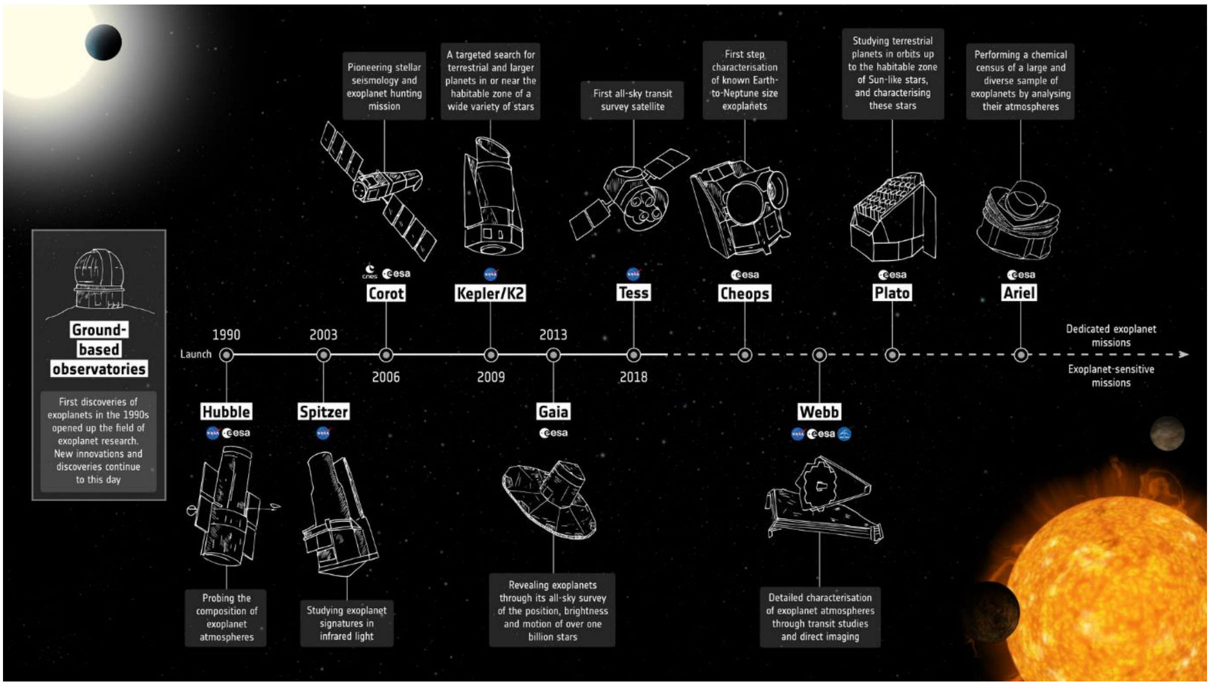
News

Atmospheric Remote-sensing Infrared Exoplanet Large-Survey (ARIEL)

ARIEL was selected in 2018 as the fourth medium-class science mission in ESA's Cosmic Vision plan. It was 'adopted' by ESA during the Agency's Science Programme Committee meeting on 12 November, paving the way towards construction.

Email dated 2020 November 12 received from the ExoClock Team
Dear all,
We are very excited to share some wonderful news with you! The Ariel mission has been adopted by ESA and has entered the final phase of implementation. We are very happy to be part of the mission and even more happy that you are also working with us to increase the mission efficiency. Looking forward to continuing our collaboration until the mission launch in 2029! You can read the press release here:
http://www.esa.int/Science_Exploration/Space_Science/Ariel_moves_from_blueprint_to_reality

Best Regards,
Anastasia & Angelos



Exoplanet mission timeline Credit ESA

First ExoClock paper published
From the ExoClock team

We are pleased to inform you that the final version of the ExoClock paper has been accepted for publication and it is now available on the arXiv through the following link: https://arxiv.org/abs/2012.07478 All the data are included and available through this link: https://www.exoclock.space/dra

We already have enough observations to start working on the second publication! In order to organise it, we need to set a deadline for the data that will be included. We decided this to be the 30th of December and all observations submitted until that day will be part of this.

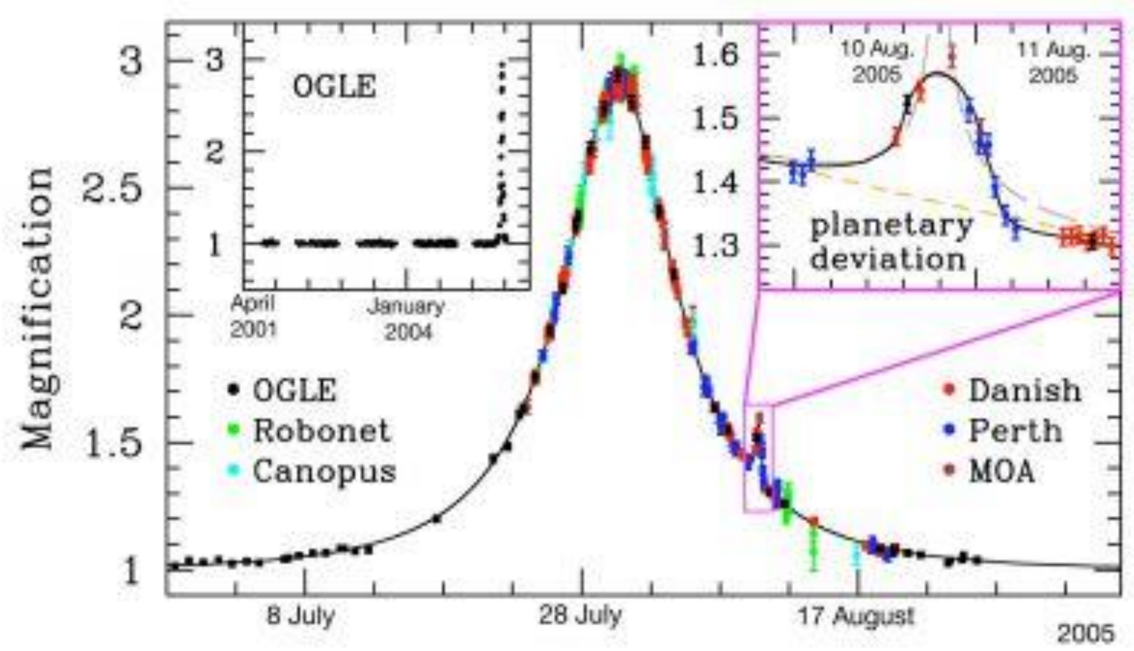
Congratulations again to everyone, looking forward to the next releases! Feel free to share the news with anyone interested!

Best
Anastasia & Angelos

BAA members made a significant contribution to the paper and continue to do so.

If you haven't participated as yet then, as Matt Prior the former England wicket keeper was fond of saying (and my wife when she wants a job done), 'Get on that'.

Gravitation micro-lensing detection of exoplanets
Dr. Siegfried Vanaverbeke has contacted us with a view to a possible collaboration with Cambridge University. More to follow as soon as I understand project requirements.



[OGLE](#) detection of an exoplanet Credit University of Cambridge

<u>Conferences/Meetings/Seminars/Webinars</u>

BAA Christmas meeting
[Fantastic Planets and How To Find them](#). Recording of the talk by Dr. Emily Brunsden. During this talk mention was made of Rogue Planets – free floating bodies not part of a stellar system. Visit [here](#) for more info.

EGU2021 PS1.1: [“Earths around other stars – bulk, interiors and atmospheres”](#)
2021 April 19-30. (EGU is the European Geosciences Union). Fee for non-EGU members is 210 Euros.

Interactions between the interior and atmosphere of terrestrial planets are modulated by the planets’ bulk composition, which in turn is linked to the chemical properties of their host stars. As stellar photosphere and planetary atmosphere can be directly probed, compositional properties of the rocky interior can only be inferred from other data. What constraints can be placed on the range of possible compositions of terrestrial exoplanets? How do surface-interior interactions shape atmospheric properties of rocky worlds around other stars? How diverse is the physical and chemical parameter space of these exo-worlds? We invite contributions - from geodynamics, geochemistry, cosmochemistry as well as astrophysics - that explore physical and chemical links between stars and planets and between rocky interior and atmosphere, and their implications for planet long-term evolution

'Virtual' Winchester (non) Weekend - BAA Winchester Meeting 2021
Saturday April 10 - https://britastro.org/winchester2021

Afternoon session
14.00 Introduction – Alan Dowdell
14.05 Pete and Paul's Astronomical Challenges 2021
Dr Paul Abel & Pete Lawrence (BAA & Sky at Night)
15.00 Break
15.15 BAA Exoplanets Division
Organiser: Roger Dymock (ARPS Assistant Director, Exoplanets)
15.30 Characterising ExOplanets Satellite mission – CHEOPS
Dr David Brown (University of Warwick Research Fellow)
16.30 Close meeting
Evening Session – The Alfred Curtis Lecture
19.30 Introduction – Alan Lorrain (BAA President)
On an Exoplanet Far, Far Away
Dr Jessie Christiansen
(NASA Exoplanet Science Institute, California Institute of Technology)

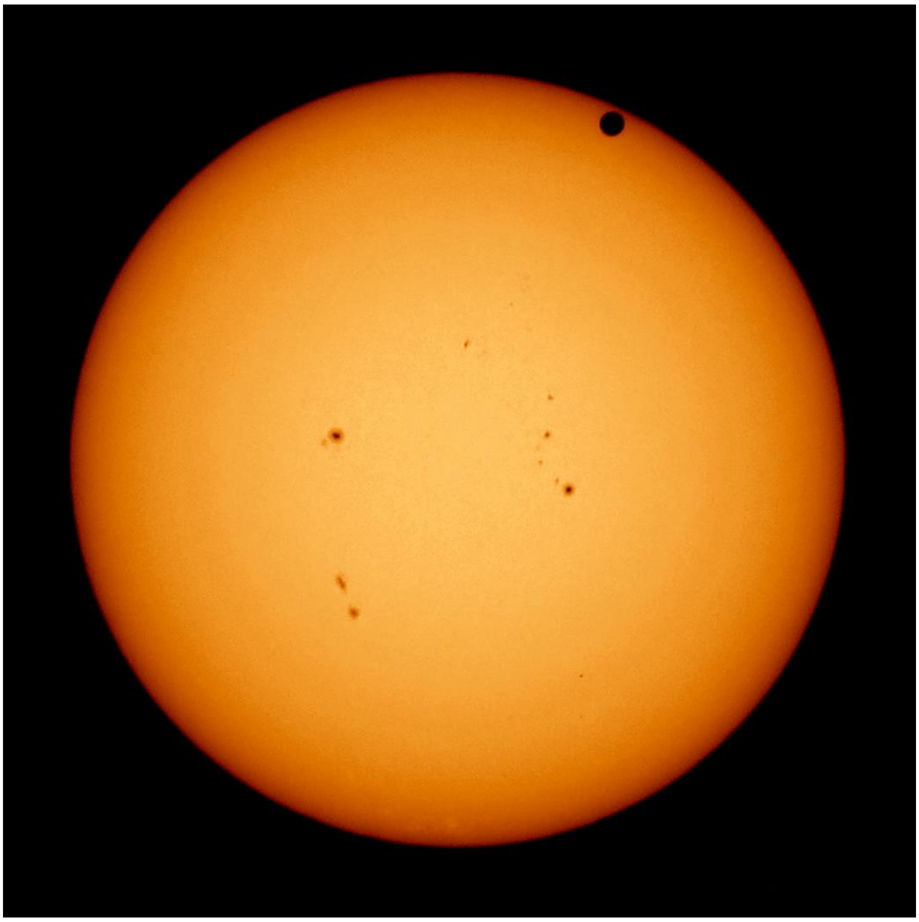
AAS Topical Conference:
Habitable Worlds; on-line, 2021 February 22-26 https://aas.org/meetings/aastcs8/habitable
There is a fee of $75 and you will need to create an AAS account before registering for this meeting.

Transit topics - Limb darkening

It has been suggested that this emagazine should include more topics of a technical nature. I hope you find this first article of interest. Submissions from members will be welcome.

What is it?
How is it calculated?
How does it affect transit light curves?

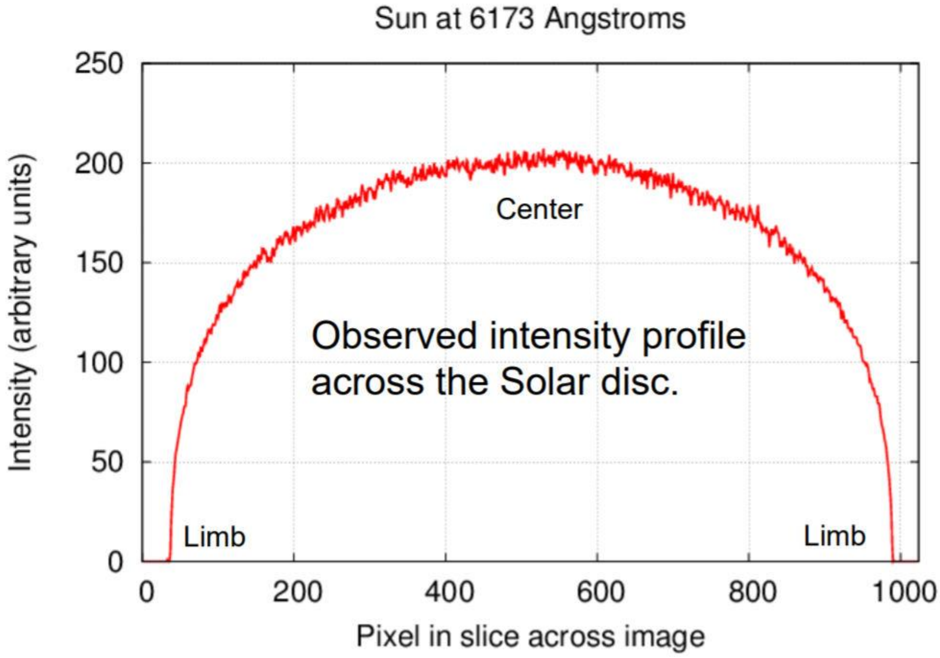
What is it?



As this image of our Sun shows it appears to be darker around the limb than at the centre. This is due to the light from the limb having further to travel towards Earth than those at the centre.

How is it calculated?

'Transit Exoplanet: Light Curve Analysis and Limb Darkening effect', slides 18-34 gives a very good description of the limb darkening effect and how it is calculated. The following is taken from those slides. An observed intensity profile of the Sun is shown below.



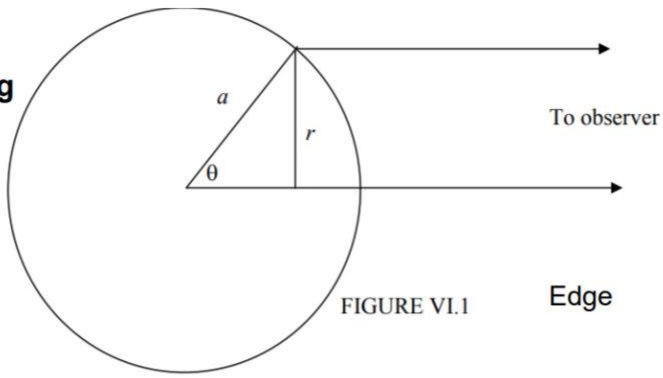
Limb darkening effect equation should be able to produce profiles like this one.

Solar Intensity profile Credit University of Toronto

Let's consider this geometry and define **the limb darkening coefficient** (u) as

u = [I(centre) - I(limb)]/I(centre)

which is a normalized differential intensity between the center and the limb.



The simplest known way to parameterize the limb darkening effect is

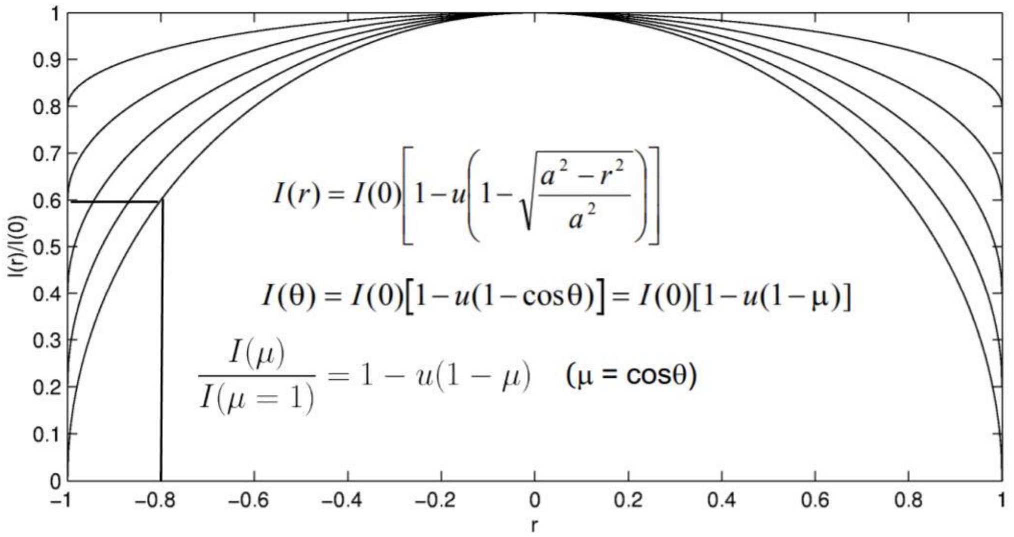
$$I(r) = I(0)\left[1 - u\left(1 - \sqrt{\frac{a^2 - r^2}{a^2}}\right)\right]$$

r : projected distance to the surface (= radial distance from the observed center of the disc)

$$I(\theta) = I(0)\left[1 - u(1-\cos\theta)\right] = I(0)[1 - u(1-\mu)] \quad (\mu = \cos\theta)$$

and this is known as "linear case" of limb darkening effect.

Equation for the limb darkening coefficient Credit University of Toronto



Comparisons of the expected limb darkening profiles from the linear case with u = 1.0, 0.8, 0.6, 0.4 and 0.2 (from lowest curve upwards). The curve for u = 1 is a circle. The radius of the disc is taken to be 1, r = 0 is the centre of the disc and r = ± 1 is the limb.

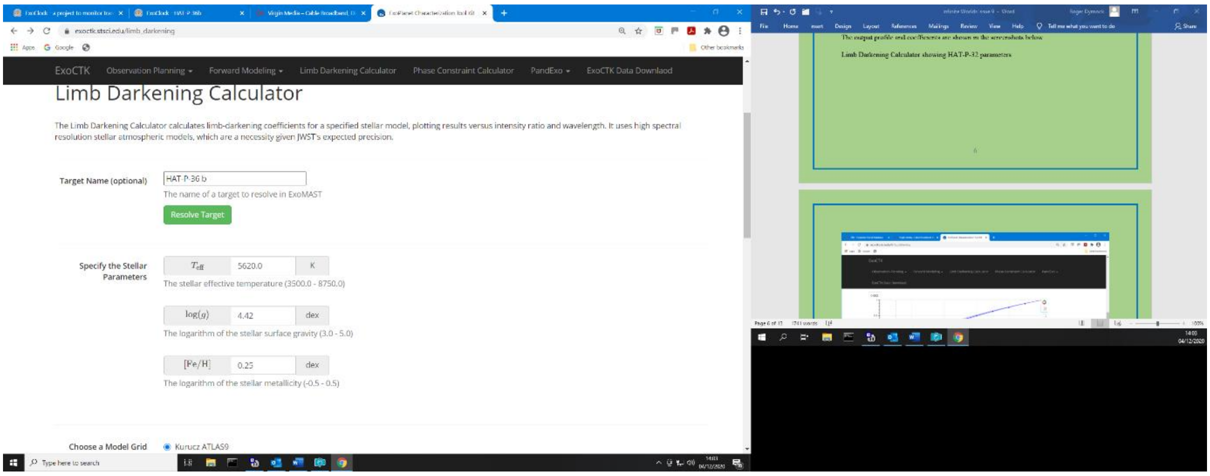
There are a number of equations for calculating the limb darkening effects including;

Linear (as above); I(μ)/I(1) = 1 – u(1 - μ)
Quadratic; I(μ)/I(1) = 1 – a(1 - μ) – b(1 - μ^2) Note that in the screenshot below a = c1 and b = c2

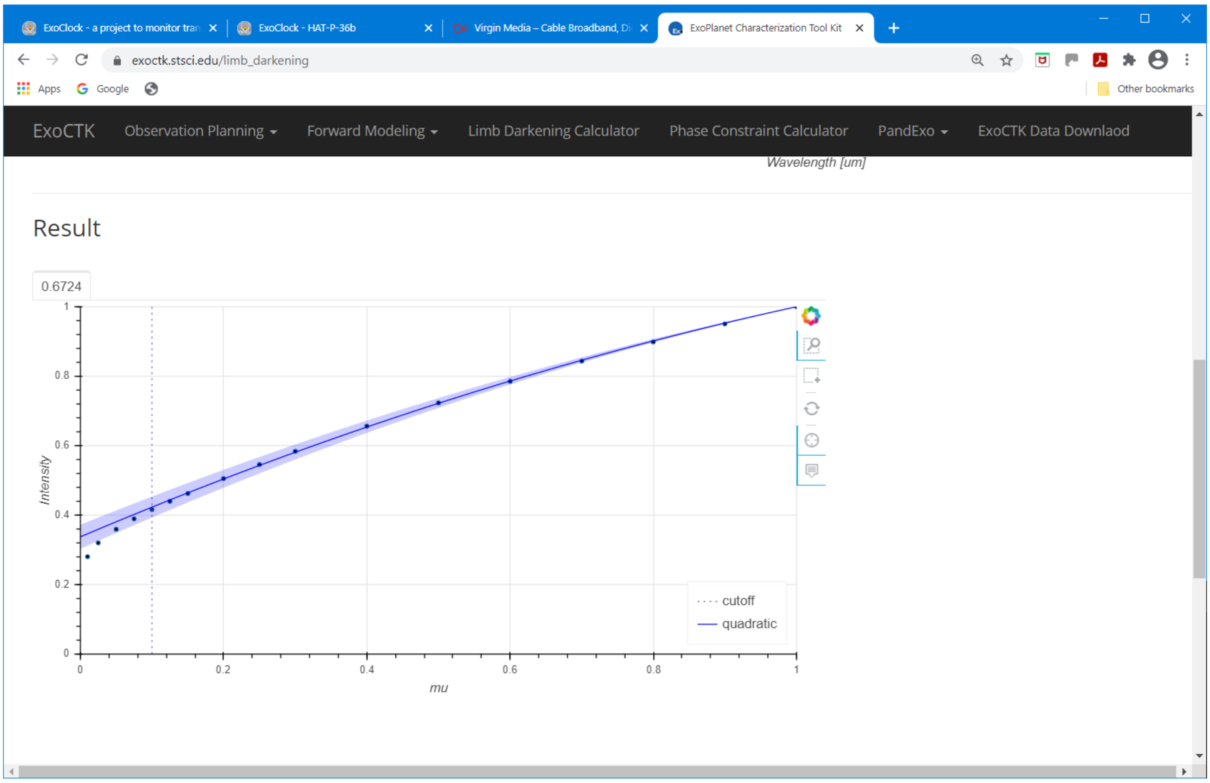
An example using the linear equation;
u = 1 (Intensity at centre of disk = 1 and at the limb = 0)
r = 0.8 therefore θ = 53° and cos 53° (μ) = 0.6
Intensity at 53° = 1 – 1(1 – 0.6) = 0.6 as shown in the diagram above

An example, HAT-P-36b, using the quadratic equation.
The ExoCTK Limb Darkening calculator calculates coefficient for the various limb darkening profiles. Entering the Target Name and clicking on Resolve Target specifies the Stellar Parameters as in the screen shot below. Then choose the Bandpass, Cousins R, and Limb Darkening Profile, quadratic in this case, and then Submit. The Limb Darkening Parameters are also shown on the ExoClock database for the specific target.

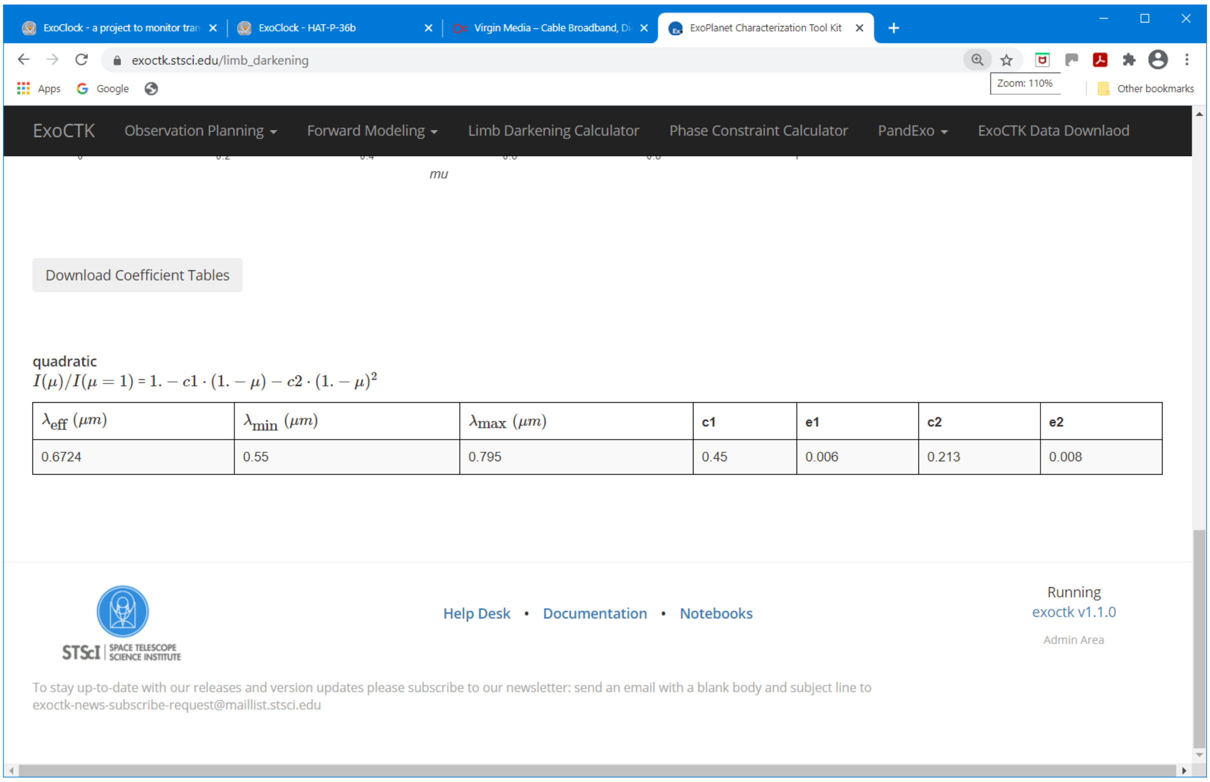
The output profile and coefficients are shown in the screenshots below.



Limb Darkening Calculator showing HAT-P-36 parameters



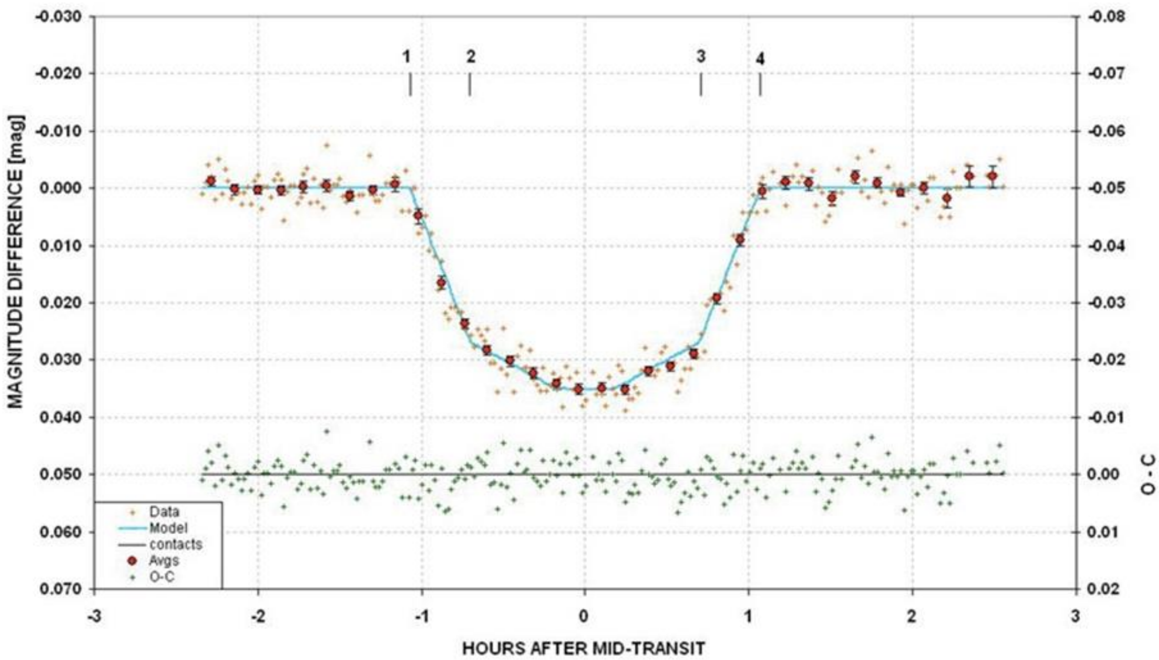
Limb Darkening profile for HAT-P-32



Limb Darkening coefficients

How does it affect transit light-curves?

The effect of limb darkening can be seen in exoplanet transit light-curves – example below taken from Bruce Gary's book Exoplanet Observing for Amateurs (Second Edition (Plus) available in paperback format) Limb darkening causes the ingress, 1-2, and egress, 3-4, to be gradual rather than instantaneous and the part of the light-curve, 2-3, to be curved rather than flat.

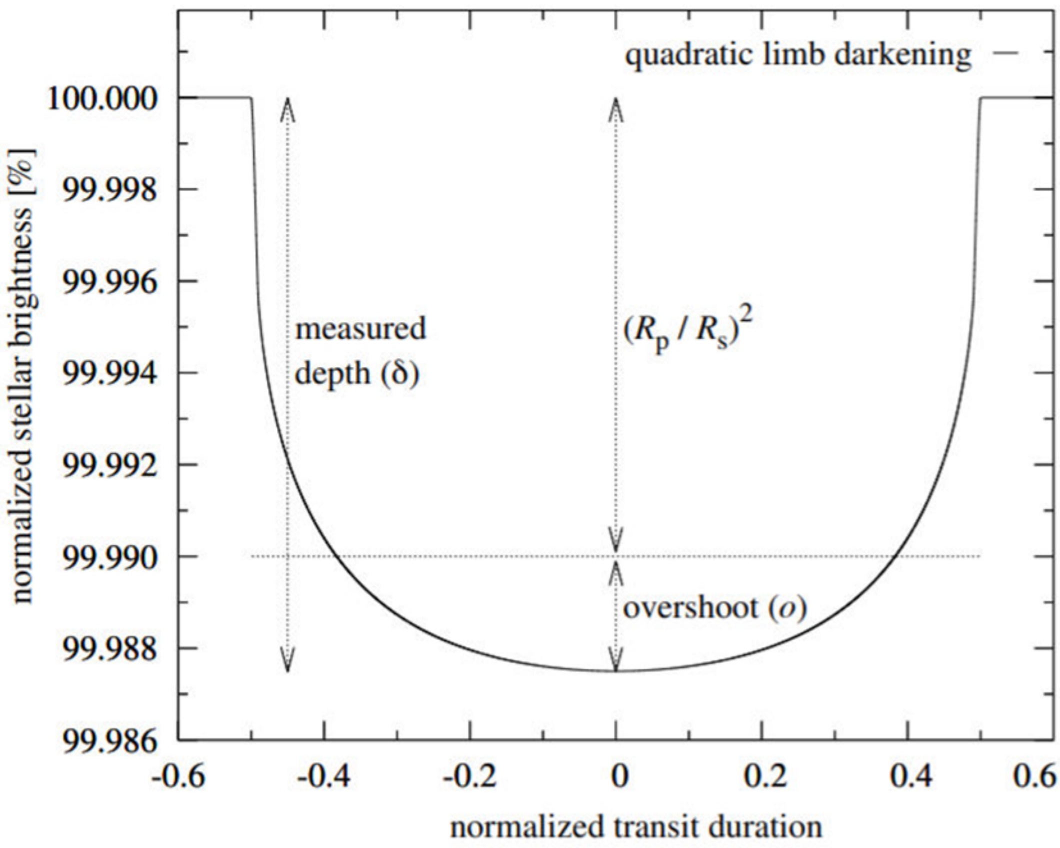


Exoplanet XO-1b transit light-curve Credit Bruce Gary

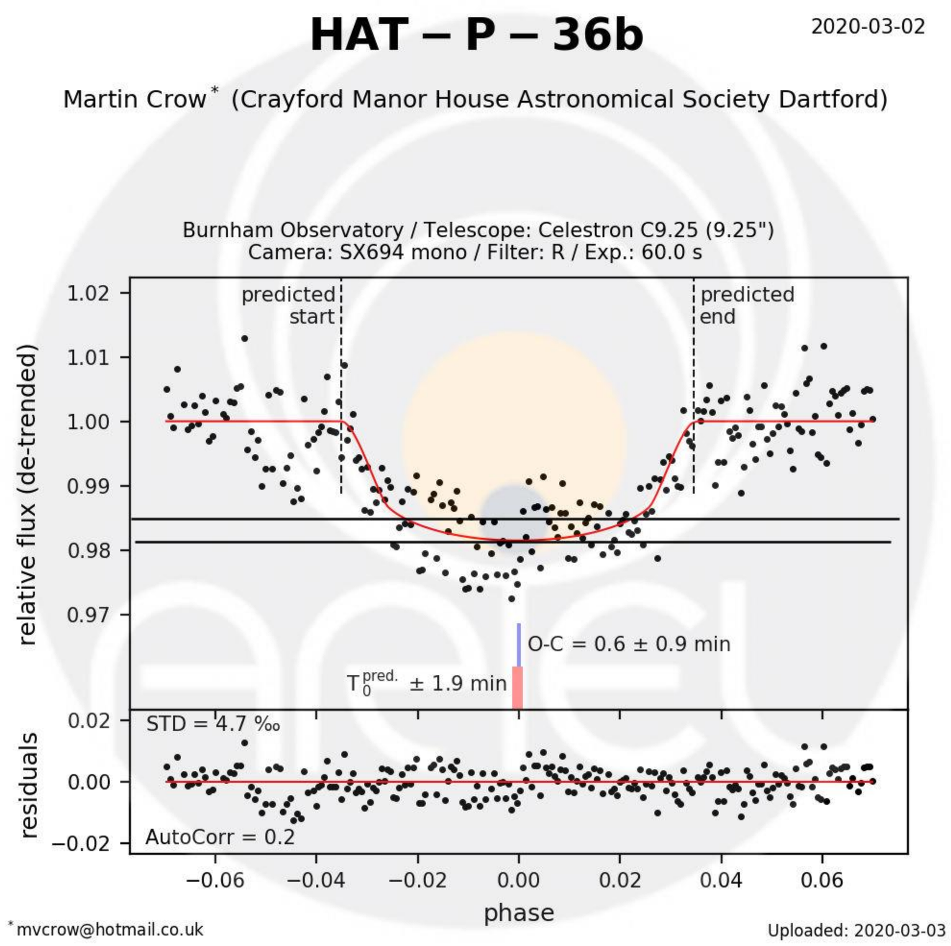
The paper ‘Analytic solutions to the maximum and average exoplanet transit depth for common stellar limb darkening laws’ by René Heller at https://arxiv.org/pdf/1901.01730.pdf explains how stellar limb darkening can result in deeper transits than if the stellar disk was considered to be of uniform brightness and thus produce errors in the calculation of planetary radii. The following equations are taken from that paper.

The planetary radius is one of the properties that can be derived from a transit light curve. If the star’s appearance is considered to be a circle with uniform brightness then the ratio of the planetary radius (Rp) and stellar radius (Rs) can be estimated from the constant transit depth D measured in flux, where $(Rp/Rs)^2 = D/F$ and F equals stellar flux out-of-transit. However, stars show centre-to-limb brightness variations that affect the estimated planet-to-star radius ratio.

The ‘overshoot’ due to limb darkening is shown in the diagram below and this leads to a larger value for the transit depth and hence a larger value for the radius, Rp, of the exoplanet. The out-of-transit measurement (100 in the diagram below) is a disk average value whereas during transit the exoplanet is blotting out light of a greater and then lesser intensity as it moves towards and away from the centre of the disk.



Effect of limb darkening Credit René Heller



For HAT-P-36b, Rp/Rs = 0.126 and therefore the maximum transit depth should be $0.126^2 = 0.016$. This is shown by the upper horizontal line in the diagram above at 0.984 relative flux.

However, the maximum transit depth is 0.019 (lower horizontal line) which give Rp/Rs = 0.138 and thus a larger (incorrect) value for the planet diameter.

The next step is to calculate the overshoot and apply that in order to obtain the corrected value of Rp/Rs. This example will use the quadratic limb darkening equation.

The stellar disk averaged intensity (using the values for HAT-P-36b as above), Ida = 1 - 0.45/3 - 0.213/6 = 0.815 (for simplicity the intensity, Io, at the centre of the stellar disk is set to one).

The planetary radius can be calculated from the equation; (Rp/Rs) = $\sqrt{\delta(Ida/Ip)} = \sqrt{(0.019(0.815/1)} = 0.124$ (assuming the transit crosses the stellar disk centre where the intensity, Ip = Io = 1) and as can be seen this is close to the correct answer.

The impact parameter, the distance of the transit from the disk centre, needs to be considered but that is another story.

Recent discoveries

As of 2021 January 11 the total number of confirmed exoplanets stood at 4331 – NASA Exoplanet Archive. The Planetary Systems page is replacing the Confirmed Planets page.

Web sites of interest

Zooniverse - Disk Detective

Somewhere out there, new planets are forming. Planets form from vast clouds of gas, dust, and chunks of rock---clouds in the shape of disks, with baby stars in the center. You can help professional astronomers find where planets are forming by searching for stars that are surrounded by these disks.

Publications

The Scientific Context for Exploration of the Moon

Because of the Moon's unique place in the evolution of rocky worlds, it is a prime focus of NASA's space exploration vision. Currently NASA is defining and implementing a series of robotic orbital and landed missions to the Moon as the initial phase of this vision. To realize the benefits of this activity, NASA needs a comprehensive, well-validated, and prioritized set of scientific research objectives. To help establish those objectives, NASA asked the NRC to provide guidance on the scientific challenges and opportunities enabled by sustained robotic and human exploration of the Moon during the period 2008-2023 and beyond. This final report presents a review of the current understanding of the early earth and moon; the identification of key science concepts and goals for moon exploration; an assessment of implementation options; and a set of prioritized lunar science concepts, goals, and recommendations.

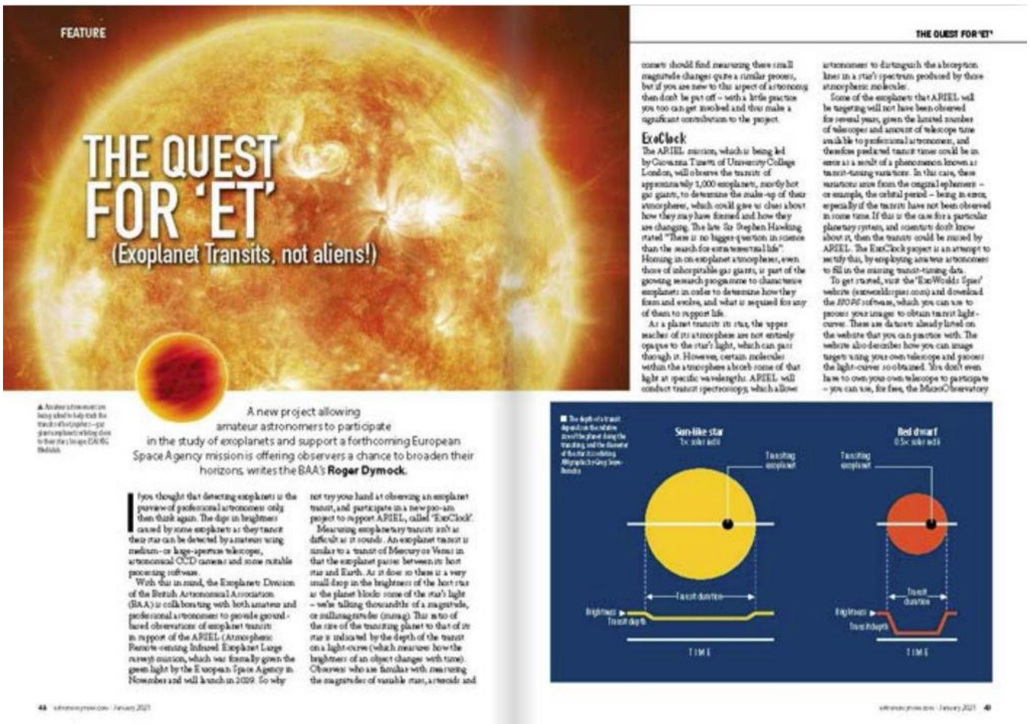
Eclipse time variations and the continued search for companions to short period eclipsing binary systems

Paper by G. Faillace, David Pulley, John Mallett, Americo Watkins, Ian Sharp and Xinyu Mai published in the JBAA 2020 December Sadly George Faillace passed away on 2020 March 19. His obituary, by David Pulley, appears in the above mentioned JBAA.

Spacefarers: How Humans Will Settle the Moon, Mars and beyond

While many books have speculated on the possibility of living beyond the Earth, few have delved into the practical challenges or plausible motives for leaving the safe confines of our home planet. Christopher Wanjek argues that there is little doubt we will be returning to the Moon and exploring Mars in the coming decades, given the potential scientific and commercial bonanza. Private industry is already taking a leading role and earning profits from human space activity. This can be, Wanjek suggests, a sustainable venture and a natural extension of earthbound science, business, and leisure. He envisions hotels in low-earth orbit and mining, tourism, and science on the Moon. He also proposes the slow, steady development of science bases on Mars, to be followed by settlements if Martian gravity will permit reproduction and healthy child development.

[Astronomy Now, 2021 January issue](#)



The Quest for 'ET' (Exoplanet Transits, not Aliens) Credit Astronomy Now

Software

AIP4Win is now available for free with no requirement for a registration code – see https://www.aavso.org/aip4win-no-longer-requires-registration. My thanks to Steve Futcher for this information.

Astrobiology

BBC's A Perfect Planet

A guide to what is needed for life to exist. A Perfect Planet is a 2021 five-part earth science series presented by David Attenborough. The first episode premiered on 3 January 2021 on BBC One. Filming took place over four years, across 31 countries, with crew navigating difficulties in extreme temperatures and remote locations. The editing process was affected by the COVID-19 pandemic. The series covers volcanoes, the sun, weather and oceans, with the final episode focusing on human impact on the environment.

Life survives on Earth by chance

Chance played a role in determining whether Earth stayed habitable

Earth's climate has remained continuously habitable throughout 3 or 4 billion years. This presents a puzzle (the 'habitability problem') because loss of habitability appears to have been more likely. Solar luminosity has increased by 30% over this time, which would, if not counteracted, have caused sterility. Furthermore, Earth's climate is precariously balanced, potentially able to deteriorate to deep-frozen conditions within as little as 1 million years. Here I present results from a novel simulation in which thousands of planets were assigned randomly generated climate feedbacks. Each planetary set-up was tested to see if it remained habitable over a period of 3 billion years. The conventional view attributes Earth's extended habitability solely to stabilising mechanisms. The simulation results shown here reveal instead that chance also plays a role in habitability outcomes. Earth's long-lasting habitability was therefore most likely a contingent rather than an inevitable outcome.

Artificial Gravity
32 minute Youtube video **-** Artificial gravity is a concept that is ubiquitous in our science fiction yet elusive in our space program. Why is this? And how could we develop artificial gravity soon? In a Cool Worlds special, this video essay goes in depth on the topic discussing why centrifuges are the most plausible. Thanks to Steve Knight, HAG, for this link.

SETI signal from Proxima Centauri?
Scientists working as part of Breakthrough Listen – the 10-year, $100 million SETI project to find evidence of intelligent life in the Universe – have detected an anomalous radio signal apparently in the direction of Proxima Centauri, the closest star to our Solar System - https://21stcenturyseti.com/2020/12/30/have-we-detected-a-seti-signal-coming-from-proxima-centauri/

Building blocks of life can form before stars
An international team of scientists, led by Dr Sergio from Queen Mary University of London, have shown that glycine, the simplest amino acid and an important building block of life, can form under the harsh conditions that govern chemistry in space. The results suggest that glycine, and very likely other amino acids, form in dense interstellar clouds well before they transform into new stars and planets.

Biomining
Rare Earth elements are present on the Moon and Mars, but they are embedded within the rock and soil, making it difficult to use them. Bringing mining equipment would, again, be too heavy and expensive to bring from Earth, and the machinery would have to be completely redesigned for use in such an inhospitable environment. ESA's BioRock project has been working on a solution: biomining in space. Bringing the world's tiniest miners to do the extraction for us. Biomining uses microbes to leach off the rocks and "eat" the rare Earth elements. The metals can then be extracted from the microbes, and used for further processing. This method has been used successfully on Earth for years. But could this work in space?

See also;
https://www.astrobiology.ac.uk/research/space-missions/biorock
https://www.nasa.gov/mission_pages/station/research/news/biorock-iss-research-microbes-space

ISS experiment - Genes in space 6
Deoxyribonucleic acid (DNA) damage caused by increased exposure to radiation can affect the long-term health of astronauts. Genes in Space-6 determines the optimal DNA repair mechanisms that cells use in the spaceflight environment. The investigation evaluates the entire process in space for the first time by inducing DNA damage in cells and assessing mutation and repair at the molecular level using the miniPCR and the Biomolecule Sequencer tools aboard the space station.

Space travel can adversely impact energy production in a sell
Studies of both mice and humans who have travelled into space reveal that critical parts of a cell's energy production machinery, the mitochondria, can be made dysfunctional due to changes in gravity, radiation exposure and other factors, according to investigators at Georgetown Lombardi Comprehensive Cancer Center. These findings are part of an extensive research effort across many scientific disciplines to look at the health effects of travel into space. The research has implications for future space travel as well as how metabolic changes due to space travel could inform medical science on Earth

Life beyond: Chapter 1. Alien life, deep time and our place in cosmic history
Life beyond: Chapter II: The Museum of Alien Life

Space – stepping stones to other star systems

Sub-orbital flight and on to Mars
A video summarising new advanced spacecraft for space tourism, space exploration and other space missions, manufactured by SpaceX, Blue Origin, Virgin Galactic, Boeing and others.

SpaceX Starship Serial Number 8 (SN8) test flight

Up, down, Ooops!!! Thanks to Steve Knight, HAG, for the above two links.

The Moon
"Forward to the Moon Together: NASA's Plan for Lunar Exploration" hosted by Institute of Physics. Recording of conference on 6th October – 1hr 33mins. Thanks to Steve Futcher, HAG, for this link.

Agenda:
Introduction from Professor Paul Hardaker, Institute of Physics
Talk by Dr Douglas Terrier, NASA
Q&A / In conversation with Dr Terrier, Paul Hardaker and Sue Horne, UK SPACE Agency

Moon Village habitat
Renowned architectural firm Skidmore, Owings & Merrill, originator of many of the world's tallest skyscrapers, has been working on an even more challenging design: a habitat for a future Moon Village. Their proposal has undergone rigorous examination by ESA experts at the Agency's mission-evaluating Concurrent Design Facility.


Multiple lunar habitats making up a Moon Village Credit ESA

Extracting oxygen from lunar dust

British engineers are fine-tuning a process that will be used to extract oxygen from lunar dust, leaving behind metal powders that could be 3D printed into construction materials for a Moon base. It could be an early step to establishing an extra-terrestrial oxygen extraction plant. This would help to enable exploration and sustain life on the Moon while avoiding the enormous cost of sending materials from Earth.

Science priorities for first crewed Artemis landing on the Moon

Activities related to field geology, sample collection and return, and deployed experiments all are part of the necessary mix of work to advance a science program at the Moon. Collectively, this candidate set of activities will address the highest science priorities that can be achieved at the lunar South Pole. The priorities and a candidate set of activities are included in a new NASA report. See also Lunar living - Artemis Base Camp concept.

Lunar resources

An international team of scientists led by the Center for Astrophysics | Harvard & Smithsonian, has identified a problem with the growing interest in extractable resources on the moon: there aren't enough of them to go around. With no international policies or agreements to decide "who gets what from where," scientists believe tensions, overcrowding, and quick exhaustion of resources to be one possible future for moon mining projects

NASA's SOFIA discovers water on the Sunlit surface of the Moon

NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) has confirmed, for the first time, water on the sunlit surface of the Moon. This discovery indicates that water may be distributed across the lunar surface, and not limited to cold, shadowed places. SOFIA has detected water molecules (H2O) in Clavius Crater, one of the largest craters visible from Earth, located in the Moon's southern hemisphere. Previous observations of the Moon's surface detected some form of hydrogen, but were unable to distinguish between water and its close chemical relative, hydroxyl (OH). Data from this location reveal water in concentrations of 100 to 412 parts per million – roughly equivalent to a 12-ounce bottle of water – trapped in a cubic meter of soil spread across the lunar surface. The results are published in the latest issue of Nature Astronomy.

Mars

[Travelling to Mars and hibernating like a brown bear]

In the longer term, to destinations further afield than Mars, missions could take years. During the long coasts between destinations, with automatic systems in control, astronauts would face the challenge of living in a confined space with not much to do for an extremely long period. "Might as well sleep it off!" Studies initiated by ESA's Advanced Concepts Team have gone one step further. Wouldn't it be nice if astronauts could hibernate!

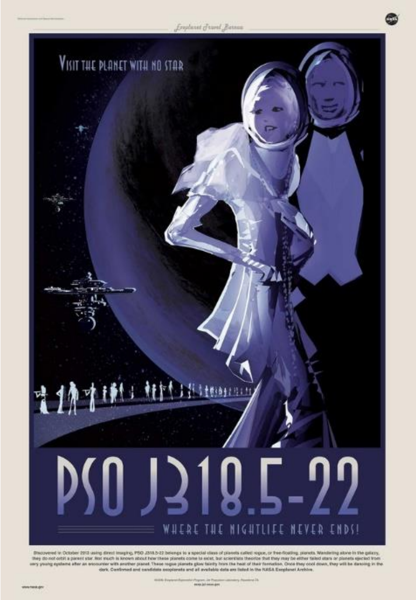
ESA/NASA sample return missions

The Mars Sample Return campaign foresees NASA and ESA launching multiple missions to the Red Planet to collect samples, launch them into space and return them safely to Earth.

Incredible Mars Discoveries that show this Planet is not your Average Planet – 41 mins video thanks to Steve Knight.

And finally…

Want to go where there are no Covid restrictions? Try the NASA Exoplanet Travel Bureau



How about this place where the nightlife never ends?

Wishing you all a much better 2021
Roger Dymock
ARPS Assistant Director Exoplanets