British Astronomical Association
Supporting amateur astronomers since 1890

Infinite Worlds

Artist's depiction of a possible image from a Solar Gravitational Lens (SGL) telescope. Credit Slava Turyshev

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

Issue 10 2021 April

Contents

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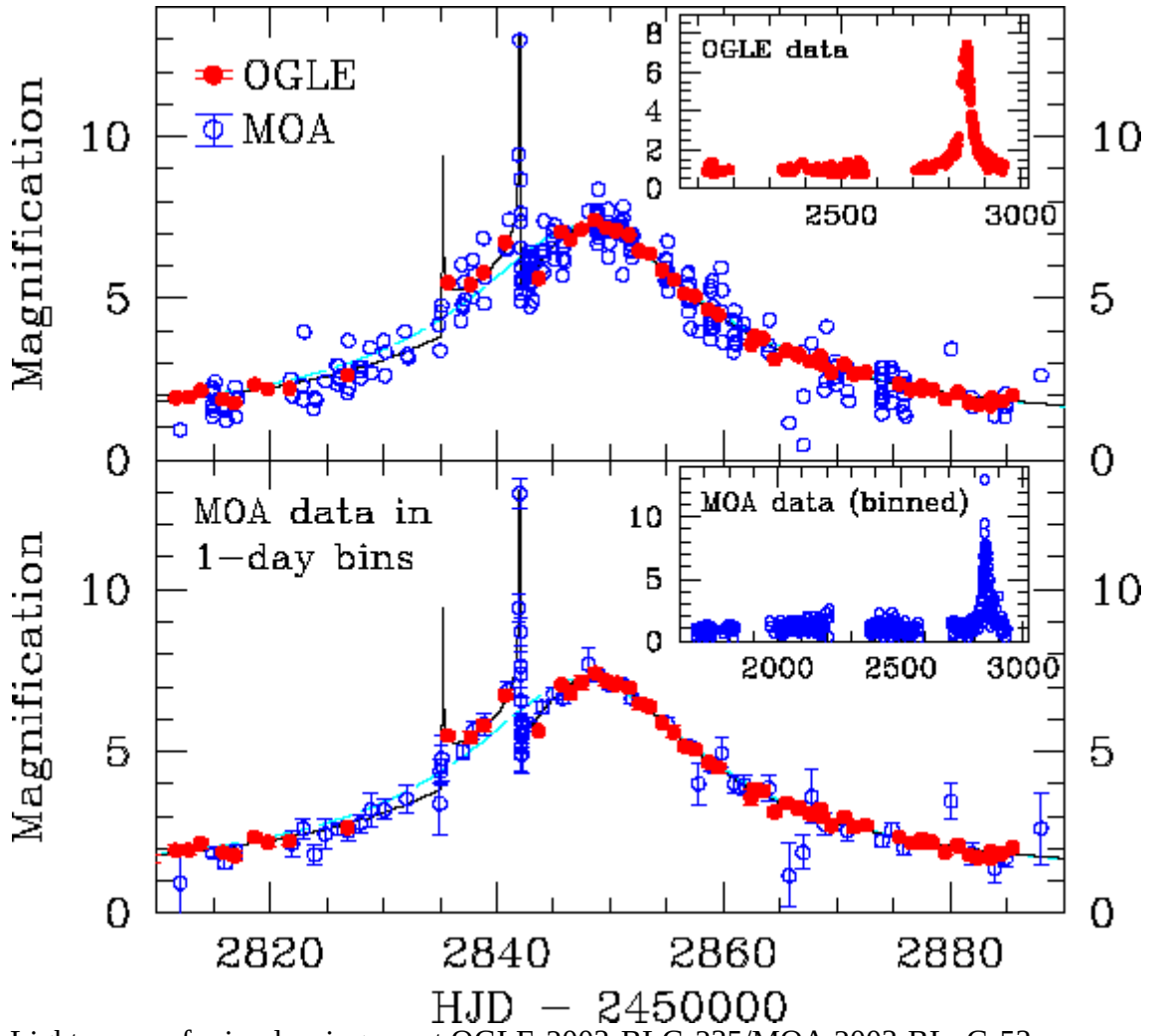
Microlensing Search for Exoplanets – potential new pro-am project

A draft of this project has been circulated to members of the Exoplanet Division for comment. The required frequency of observations is, typically, daily so it should quite easily fit with any other observing program you may be following. There are likely to be just a handful of targets available at any on time and possibly only one or two which have the potential to detect exoplanets so the amount of observing time that needs to be devoted to this project should not unduly impinge on other observing activities. The advantage over comet and supernovae hunting is that we do know where to look.

Typical light curves, see below, may have a base magnitude of between 12 and 18, vary by 1 to 2 magnitudes with 'exoplanet spikes' ranging from 0.2 to 0.7 magnitudes. A precision of +/- 0.05 magnitudes would seem appropriate which approximately equates to an SNR of 20. Such measurements should be well within the capabilities of a reasonably competent imager.



Light curve of microlensing event OGLE-2003-BLG-235/MOA 2003-BL~G-53

News

Direct Multipixel Imaging and Spectroscopy of an Exoplanet with a Solar Gravitational Lens Mission

The solar gravitational lens (SGL) is characterized by remarkable properties: it offers brightness amplification of up to a factor of ~1e11 (at 1 um) and extreme angular resolution (~1e-10 arcsec). As such, it allows for extraordinary observational capabilities for direct high-resolution imaging and spectroscopy of Earth-like exoplanets. Under a Phase II NIAC program, we confirmed that a mission to the strong interference region of the SGL (beyond 547.6 AU) carrying a meter-class telescope with a solar coronagraph would directly image a habitable Earth-like exoplanet within our stellar neighbourhood. For an exo-Earth at 30 pc, the telescope could measure the brightness of the Einstein ring formed by the exoplanet's light around the Sun. Even in the presence of the solar corona, the SNR is high enough that in 6 months of integration time one can reconstruct the exoplanet image with ~25 km-scale surface resolution, enough to see surface features and signs of habitability.
Video 'Using the Sun to Image Alien Planets' thanks to Steve Knight, HAG

A SETI signal from Proxima Centauri?

Astronomers with the Breakthrough Listen Project – the comprehensive radio SETI search being run out of the University of California at Berkeley – has detected radio emissions from

the direction of Proxima Centauri. That's the closest star system to us, a mere 4.2 light-years away, and it's known to be accompanied by at least two planets.

Hyperlinks
I was asked if it was possible to return to the same point in an issue after selecting a hyperlink. My suggestion is to right click on the link and then select 'Open link in new tab'. The emagazine stays where it was and you can have as many links open as you want. There were some other suggestions on the WWW but they didn't work for me.

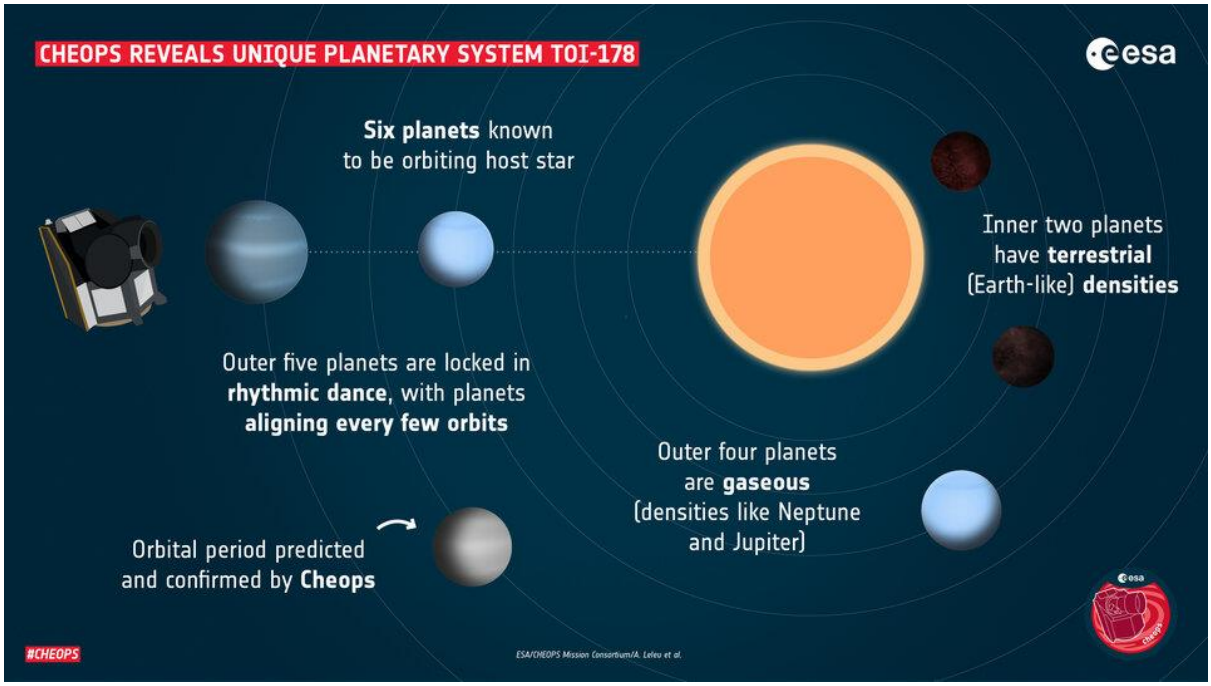
MicroObservatory
The project webpage has been updated to reflect the changes to the MicroObservatory Telescope Network

ARIEL ExoClock project~
The ExoClock Project page has been updated to reflect HOPS Version 3 and to include instructions as to how to submit observations to the Exoplanet Transit Database (ETD)

Recent discoveries
2021 April 1
Eight new planets added including two detected by gravitational microlensing. All examples of microlensing detection can be found in the NASA Exoplanet Archive's Microlensing Table. Total of confirmed exoplanets now stands at 4375

Check out the new planetary data in the Planetary Systems Table (gamma) (http://bit.ly/2Pt0tM1) and its companion table, Planetary Systems Composite Parameters (beta) (https://bit.ly/2Fer9NU), which offers a more complete table of planet parameters combined from multiple references and calculations. The Confirmed Planets, Composite Planet Data, and Extended Planet Data interactive tables are also currently updated with new planetary and stellar data, but will be retired in late March 2021. See this Transition document (https://bit.ly/3jLgrhl and the Archive 2.0 Release Notes (https://bit.ly/3rVQPTx for more information. Download/Website: https://exoplanetarchive.ipac.caltech.edu

ESA's exoplanet mission Cheops has revealed a unique planetary system consisting of six exoplanets, five of which are locked in a rare rhythmic dance as they orbit their central star. The sizes and masses of the planets, however, don't follow such an orderly pattern. This finding challenges current theories of planet formation.



Paper - [Co-orbital exoplanets from close-period candidates: the TOI-178 case]

Conferences/Meetings/Seminars/Webinars

Winchester 2021
The videos of the meeting are available at;
[Exoplanets– the future, Roger Dymock followed by CHEOPS Characterising ExOPlanets Satellite, Dr David Brown]
[On an Exoplanet Far, Far Away, Jessie Christiansen]

[The Institutions of Extraterrestrial Liberty – 2021 June 8-11]
The establishment of a permanent human presence beyond the Earth raises questions on what freedoms people can expect. On the one hand, space offers escape from entrenched views on Earth. On the other hand, the control of oxygen, food, and water production in isolated populations presents opportunities for extensive forms of tyranny. Investigating the institutional arrangements for liberty in space constitutes a fascinating problem in political philosophy and one of the most profound new challenges for democracy in the 21st century.

[CHEOPS Science Workshop VI – 2021 July 13-16]
The CHEOPS workshop VI will be held 13-16 July, 2021, some 15 months after the beginning of CHEOPS science operations. The workshop will be the occasion for the planetary science community at large to discuss and share the first main results of CHEOPS in different fields, from the planetary internal structure to atmospheric characterization, etc. Participants are invited to propose contributed talks and posters on all scientific aspects linked to CHEOPS, including CHEOPS based-results as well as proposals for future observations and synergies with other facilities.

[TESS (Transiting Exoplanet Survey Satellite) Conference II – 2021 August 2-6]
This conference will occur at the beginning of the 2nd year of the extended mission, and

during TESS's 4th year overall. The conference will be dedicated to all aspects of the TESS mission, including data analysis of 20-second and 2-minute pixel stamps and the 10-minute and 30-minute full frame images, in addition to the wide range of science done with TESS data. The conference is being designed to run entirely online. A final decision on whether the conference will have any in-person activities is expected to be made by the end of March. The conference has no registration fee. However, registration is mandatory for all participants through the online registration form here. We ask that you submit your registration by July 1st so the LOC can make sure the conference online tools will be able to support the number of participants.

Transit topics

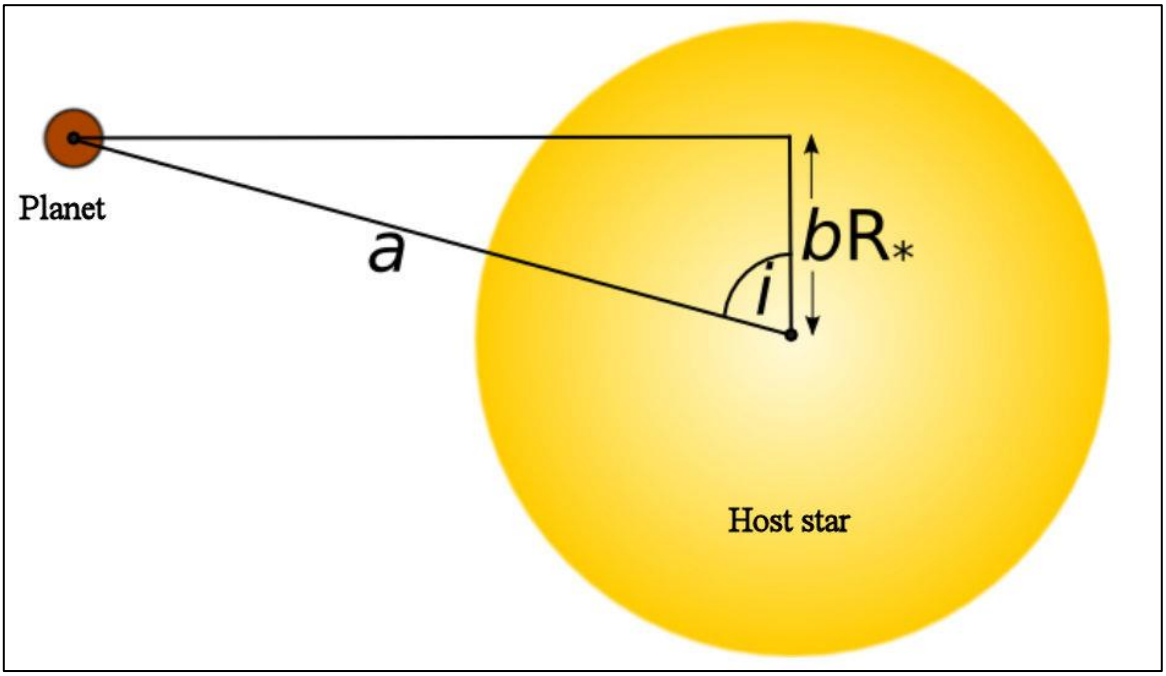
Correction to Limb Darkening article in last issue – thanks to Robin Leadbetter.

On page 10 I said "Limb darkening causes the ingress, 1-2, and egress, 3-4, to be gradual rather than instantaneous" This is not correct. Ingress and egress would not be instantaneous even in the absence of limb darkening. There is a significant effect due to the diameter of the planet relative to the Star (In the case of XO-1b shown there the diameter of the planet is approximately 1/10 of that of the star so the time between 1st and 2nd contact and 3rd and 4th contact would be approximately 1/10th of the transit time for an equatorial transit even in the absence of limb darkening). A Bruce Gary explains in his book, the smooth variation between contacts 2 and 3 is produced by stellar limb darkening.

Transit Topics - Impact parameter

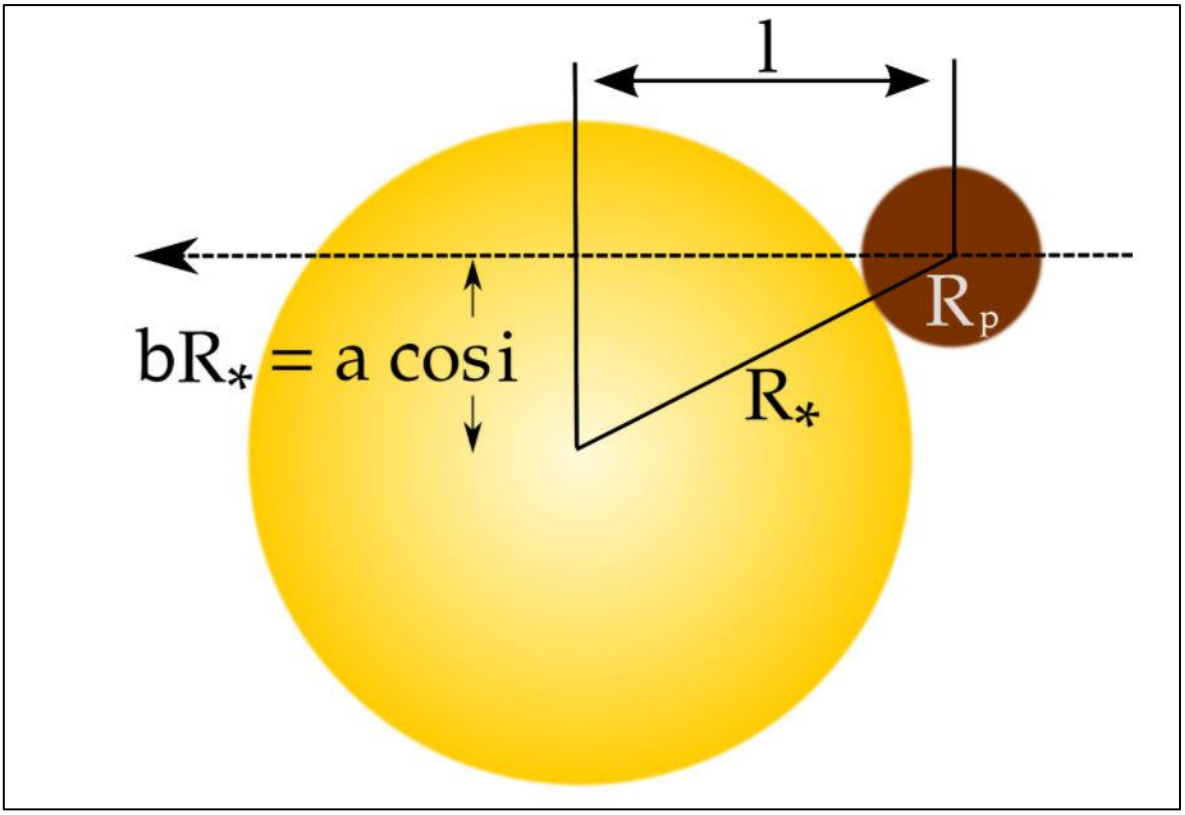
What is it?
How does it relate to the exoplanet orbital parameters?
How does it affect the shape of the transit light curve?

What is it?
The following diagrams and associated explanation are taken from Paul Anthony's website at https://www.paulanthonywilson.com/exoplanets/exoplanet-detection-techniques/the-exoplanet-transit-method/ As Paul mentions The figures and derivations are adapted from "Transiting Exoplanets", by Carole A. Haswell.



Impact parameter definition Credit P A Wilson

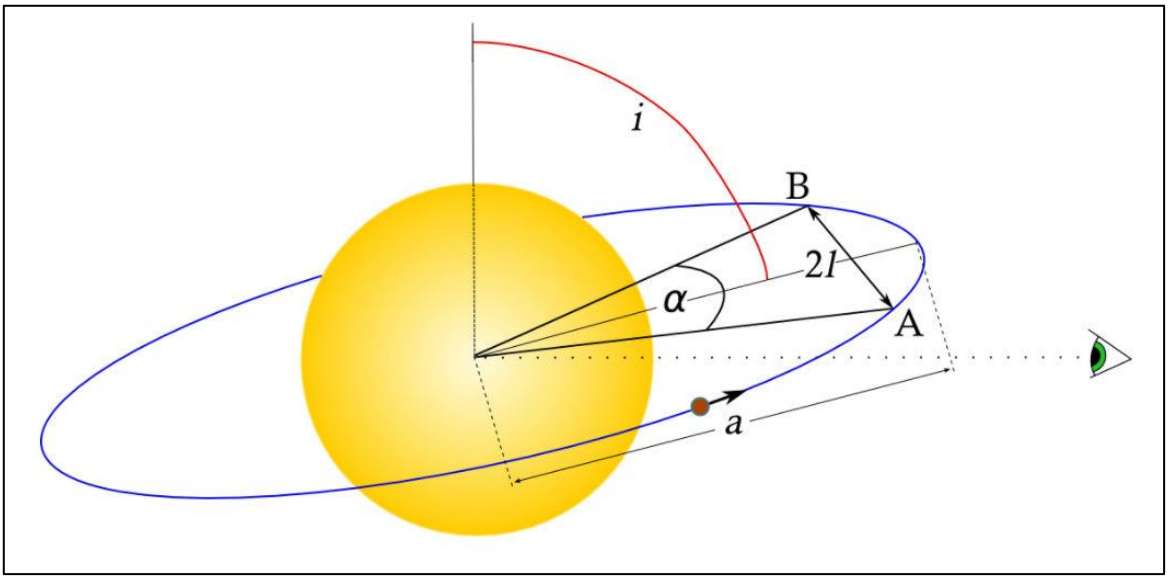
The impact parameter, b, is the sky-projected distance between the centre of the stellar disk and the centre of the planetary disk when the planet is in the mid-point of its transit across its host star.



Transit chord length Credit Paul Anthony Wilson

The distance that the planet has to travel to complete a transit is $2l = 2\sqrt{((R_* + Rp)^2 - (bR_*)^2)}$

How does it relate to the exoplanet orbital parameters?



Transit duration Credit Paul Anthony Wilson

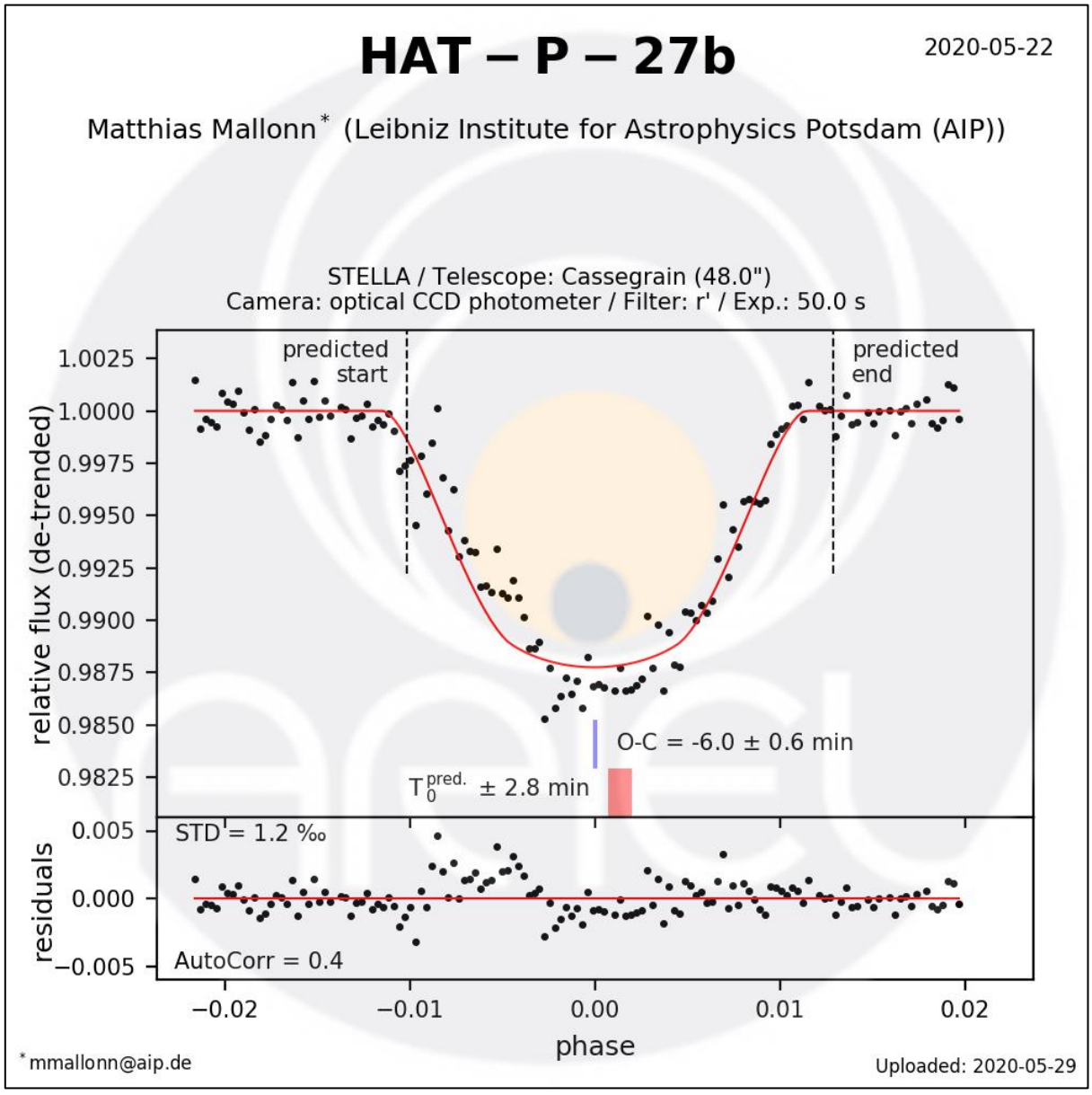
While transiting the host star the planet moves from A to B around its (assumed circular) orbit. Note that the inclination, i, is measured relative to the plane of the sky and, if it is 90° b b = 0 and, if 0° then b = 1.

The distance travelled by the planet when completing one revolution of its orbit = 2πa, the distance travelled between A and B = αa (α is in radians) and the straight-line distance between A and B (the transit length) = 2l. Also sin(α/2) = l/a

The equation for the transit time, T, is;
$T = P(\alpha/2\pi) = (P/\pi)\sin^{-1}(l/a) = (P/\pi)\sin\text{-}1(\sqrt{((R_* + Rp)^2 - (bR_*)^2)})/a)$

How does it affect the shape of the transit light curve?

Examples of light curves with different impact parameters. Note that the larger the Impact parameter the narrower is the light curve as shown by that for HAT-P-27b below.



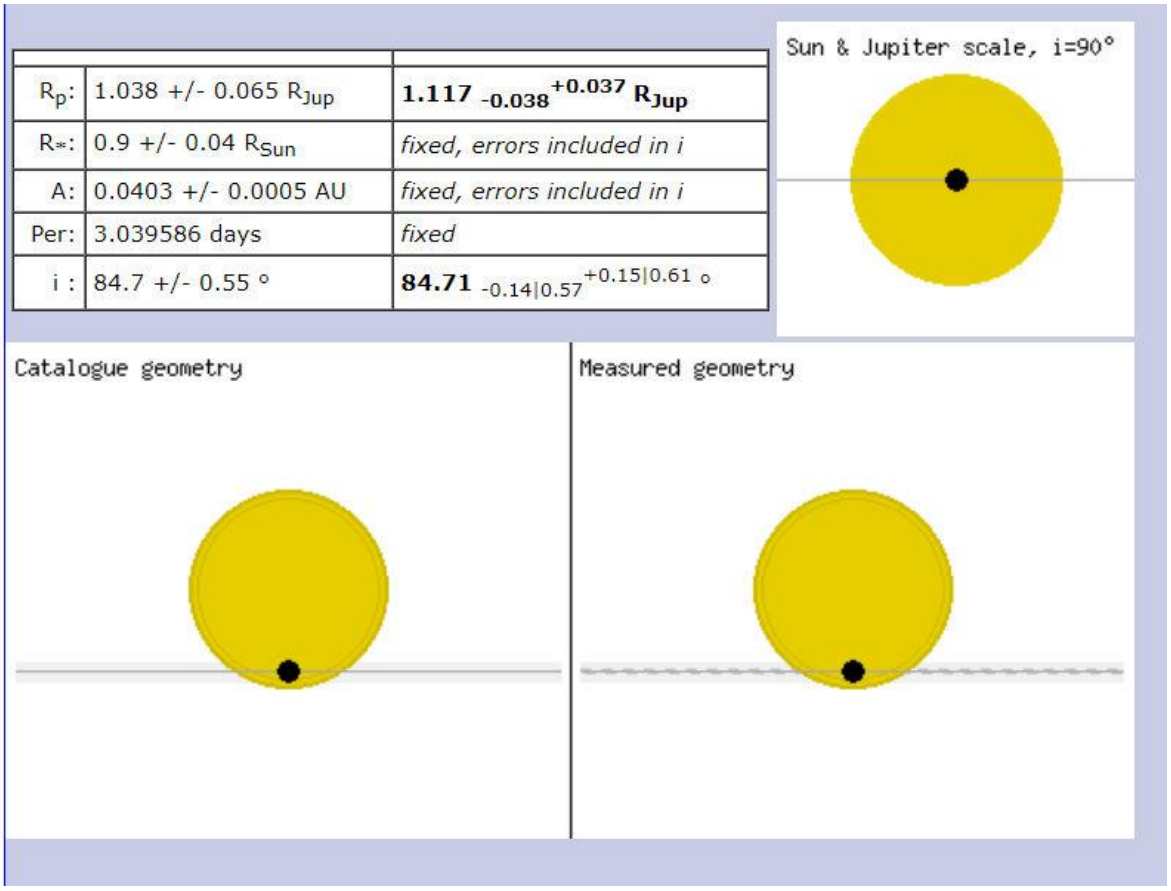
Transit light curve for HAT-P-27b Credit M Mallonn, ExoClock

Given Impact parameter = 0.86

Calculated Impact parameter
b = a x cos(i)/R* where;

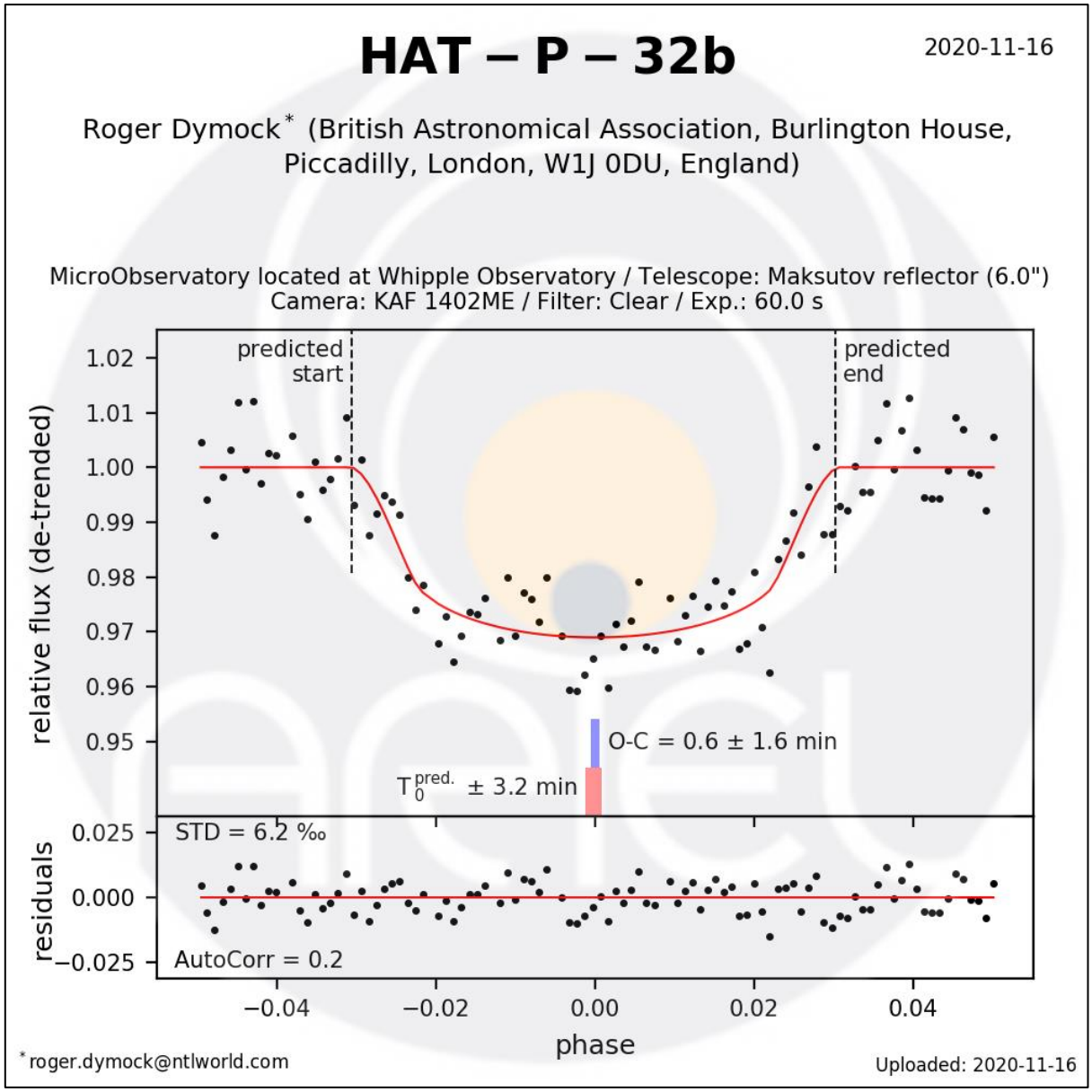
a = semi major axis = 0.04 au = 0.04 x 149597870 = 5983915 km
I = orbital inclination = 85 degrees
R* = radius of star = 0.898 Rsun = 0.898 x 696265 = 625246 km
Therefore b = 0.83 which is close to the given value and indicates that the transit is close to the edge of the stellar disk where b = 1 – see diagram below.

All above data from [NASA Exoplanet Archive]



R_p:	1.038 +/- 0.065 R_{Jup}	**1.117** $^{+0.037}_{-0.038}$ **R_{Jup}**
R_*:	0.9 +/- 0.04 R_{Sun}	*fixed, errors included in i*
A:	0.0403 +/- 0.0005 AU	*fixed, errors included in i*
Per:	3.039586 days	*fixed*
i :	84.7 +/- 0.55 °	**84.71** $^{+0.15\|0.61}_{-0.14\|0.57}$ °

Geometry [Credit Ramon Naves, TRESCA]

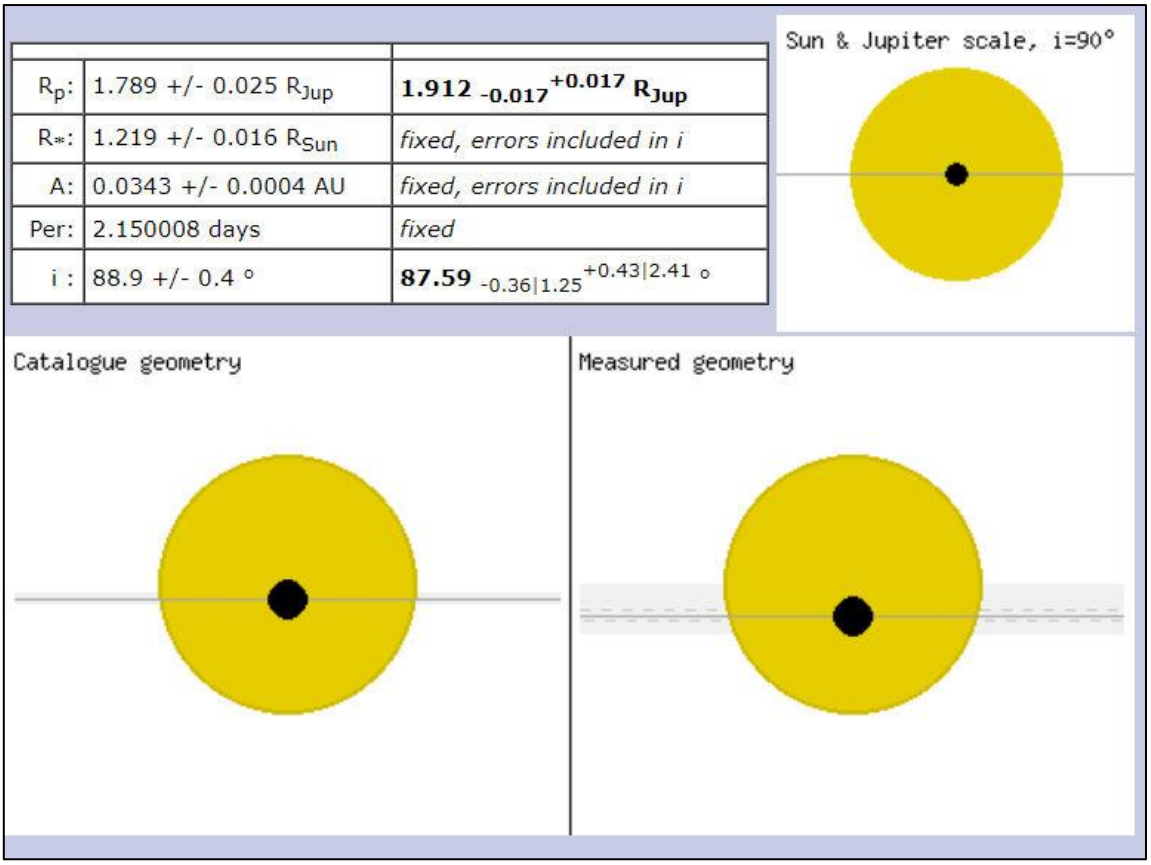


Transit light curve for HAT-P-32b Credit Roger Dymock, ExoClock

Given Impact parameter = 0.09

Calculated Impact parameter
b = a x cos(i)/R* where;
a = semi major axis = 0.034 au = 0.034 x 149597870 = 5086328 km
I = orbital inclination = 89 degrees
R* = radius of star = 1.367 Rsun = 1.367 x 696265 = 951794 km
Therefore b = 0.09 which indicates that the transit is close to the centre of the stellar disk where b = 0 – see diagram below.

All above data from NASA Exoplanet Archive



R_p:	1.789 +/- 0.025 R_{Jup}	**1.912** $^{+0.017}_{-0.017}$ **R_{Jup}**
R_*:	1.219 +/- 0.016 R_{Sun}	*fixed, errors included in i*
A:	0.0343 +/- 0.0004 AU	*fixed, errors included in i*
Per:	2.150008 days	*fixed*
i :	88.9 +/- 0.4 °	**87.59** $^{+0.43\|2.41}_{-0.36\|1.25}$ °

Geometry Credit Yves Jongen, TRESCA

Orbital and stellar parameters are derived from both transit light curve and radial velocity measurements but that is for a future edition (probably editions) of Infinite Worlds.

Web sites of interest

Yale University 100 Earths Project

The search for 100 Earths in the solar neighbourhood is a grand quest. Nothing quite like this has been done before. The detection of 100 Earths would provide a sample size that is large enough to place constraints on the occurrence of exobiology. This project will launch humankind's exploration of other worlds in our Galaxy.

Are there other Earths: The odds of life around nearby stars Video - thanks to Steve Knight, HAG, for this link. Quite interesting and not too hard on the brain cells. Earth Similarity Index is mentioned – explanations at the Planetary Habitability Laboratory and its Wikipedia entry.

Space missions

James Webb Space Telescope

The General Observer scientific observations for the NASA/ESA/CSA James Webb Space Telescope's first year of operation have been selected. Proposals from ESA member states comprise 33% of the total number of selected proposals and correspond to 30% of the available telescope time on Webb. Exoplanets and Disks observations forming part of General Observer Programs in Cycle 1 are listed here.

Publications
A survey of exoplanet phase curves with Ariel - https://arxiv.org/abs/2102.06523

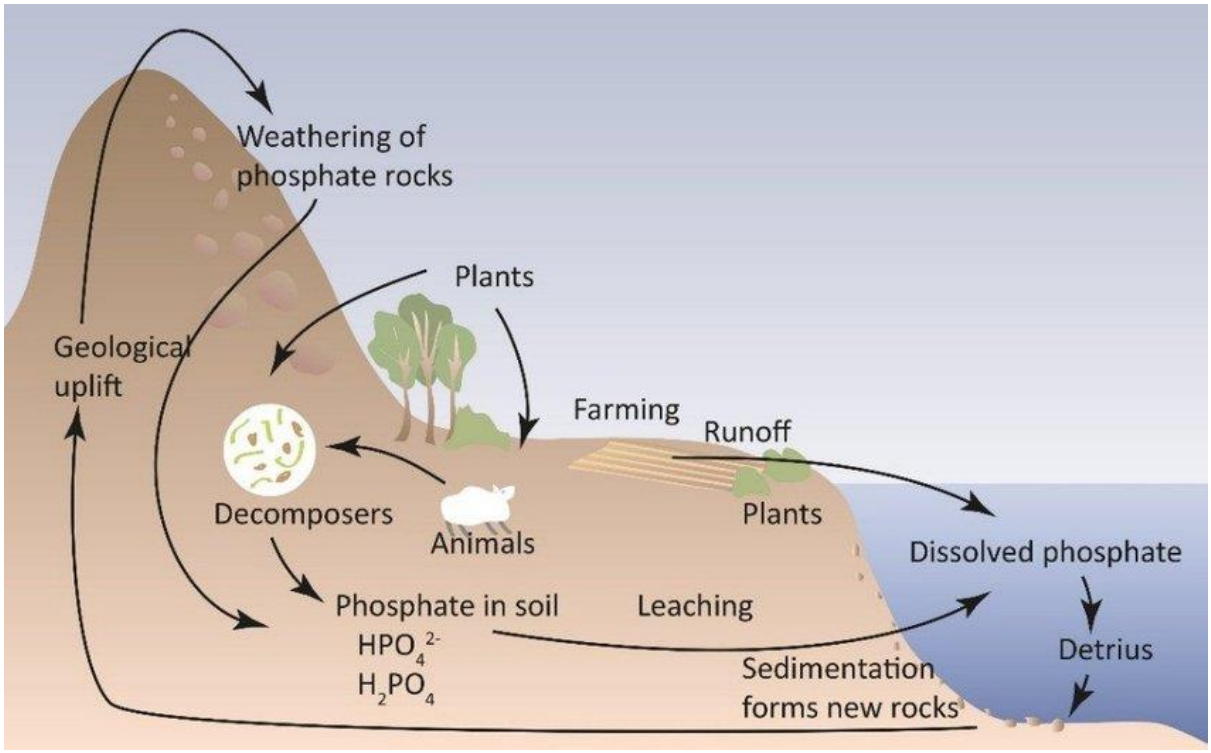
Software
HOPS Version 3, the software used to analyse ExoClock observations, is now available together with a manual.

Astrobiology
Asteroids vs microbes
The University of Edinburgh's 'BioAsteroid' payload is one of multiple experiments running simultaneously aboard ESA's Kubik – Russian for cube – facility aboard Europe's Columbus module of the International Space Station. It found its way to orbit via the new commercial Bioreactor Express Service. The experimenters want to see how BioAsteroid's combination of bacteria and fungi interact with the rock in reduced gravity, including to observe whether characteristic 'biofilms' will be grown on rock surfaces, comparable to dental plaque on teeth.

A New Test for Life on Other Planets
A simple chemistry method could vastly enhance how scientists search for signs of life on other planets. The test uses a liquid-based technique known as capillary electrophoresis to separate a mixture of organic molecules into its components. It was designed specifically to analyze for amino acids, the structural building blocks of all life on Earth. The method is 10,000 times more sensitive than current methods employed by spacecraft like NASA's Mars Curiosity rover, according to a new study published in Analytical Chemistry. The study was carried out by researchers from NASA's Jet Propulsion Laboratory, Pasadena, California.

What are the chemical signs of life beyond Earth?
To look for molecules that point to life, scientists seek to understand what makes biochemistry different from everything else**.**

Lightning strikes may have started life on Earth
A new study published in Nature Communications suggests lightning may have been a key component in making phosphorus available for organisms to use when life on Earth first appeared by about 3.5 billion years ago. Phosphorus is an essential nutrient for animals and plants. It plays a critical role in cell development and is a key component of molecules that store energy, such as ATP (adenosine triphosphate), DNA and lipids (fats and oils). Read more at The phosphorous cycle.



The phosphorous cycle

Organic materials and water from asteroid Itokawa

New research led by Dr Queenie Chan from Royal Holloway, University of London, has found water and organic matter on the surface of an asteroid sample returned from the inner Solar System. This is the first time that organic materials, which could have provided chemical precursors for the origin of life on Earth, have been found to be intrinsic to asteroid Itokawa and not terrestrial contamination. The single grain sample was returned to Earth from asteroid 'Itokawa' by JAXA's first Hayabusa mission in 2010. The sample shows that water and organic matter that originate from the asteroid itself have evolved chemically through time.

Space – stepping stones to other star systems

Leaving Earth

SPACE X Starship

No it isn't science fiction but two SpaceX Starships, SN9 and SN10, on their launch pads at the company's base near Boca Chica in Texas. With its Super Heavy first stage rocket attached it has Mars in its sights. However, all did not go according to plan.

SN9 exploded during landing

SN10 take off, flight and landing appeared to be satisfactory but then it exploded after a fire

Space elevators
Are Space Elevators Possible? If you like maths and engineering then this is for you. My thanks to Steve Knight, HAG, for this link.

The Moon
NASA's Artemis mission
The Lunar Exploration Program Overview can be found here -
https://www.nasa.gov/sites/default/files/atoms/files/artemis_plan-20200921.pdf

NASA is getting ready to send astronauts to explore more of the Moon as part of the Artemis program, and the agency has selected SpaceX to continue development of the first commercial human lander that will safely carry the next two American astronauts to the lunar surface. The agency's Space Launch System rocket will launch four astronauts aboard the Orion spacecraft for their multi-day journey to lunar orbit. There, two crew members will transfer to the SpaceX human landing system for the final leg of their journey to the surface of the Moon. After approximately a week exploring the surface, they will board the lander for

their short trip back to orbit where they will return to Orion and their colleagues before heading back to Earth.

Illustration of SpaceX Starship that will carry the first NASA astronauts to the surface of the Moon under the Artemis program. Credit SpaceX

Roger Dymock
ARPS Assistant Director Exoplanets