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PLATO Spacecraft Credit OHB Systems

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

Issue 6 2020 April

Contents

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Comment

'You are not alone' shouted the two-inch-high headline in my daily paper. Had ET become aware of our plight and was offering help? Was it a threat of invasion now that we were on the back foot? None of those – merely help for those self-isolating and trying to find new ways of making life bearable.

SETI@home will stop distributing tasks soon due to the amount of data becoming available exceeding that which can be processed over the internet.

Stay safe.

Meetings

The bad news as I am sure you know, unless you have been self-isolating on some distant exoplanet, is that the BAA Winchester Weekend, including the Exoplanet Division meeting on the Saturday afternoon, was cancelled. The good news is that the meeting will feature on the Saturday of next year's weekend which takes place 2021 April 9-11.

Discoveries – latest news

NASA Exoplanet Archive

March 19, 2020

This week's update includes data for six new planets, including the first ever planet in the Galactic thick disk, discovered by TESS, and transmission spectroscopy for three known planets. The new planets are: OGLE-2013-BLG-0911L b, KMT-2016-BLG-1836L b, OGLE-2016-BLG-1227L b, NGTS-10 b, MASCARA-4 b, and LHS 1815 b (TESS discovery).

To view the new planet and stellar parameters, use the Confirmed Planets, Composite Planet Data, and Extended Planet Data interactive tables. Or, check out the alpha release of our Planetary Systems table to browse ALL the planet and host star solutions.

The new transmission spectroscopy data are for K2-18 b, KELT-9 b, and HAT-P-41 b, all of which are browsable in the Transmission Spectroscopy interactive table.

Exoplanet.eu

Total planets;	4228
Planetary systems;	3129
Multiple planet systems;	691

On-line videos

Professor Charles Cockell, responsible for the on-line course Astrobiology and the Search for Extra-terrestrial Life, has posted a number of videos on YouTube described as the 'Life in the Universe Pandemic Series – Short fireside lectures of interest for the isolated'. They are;

1) Are Viruses alive?
2) Is there life on Mars?
3) Will samples from Mars cause a pandemic?
4) Why didn't the dinosaurs build a space program?
5) Will I ever meet aliens?
6) Do I really want to live on Mars?
7) How did life begin?
8) Will space be full of tyrannies?
9) Why is everyone so excited about Europa?
10) Can prisons help us explore space?
11) Do viruses have rights

Web sites of interest

The Open Exoplanet Catalogue is a database of all discovered extrasolar planets. It is still 'under development' and not all the listed pages are available as yet.

Publications

Papers

Utilizing Small Telescopes Operated by Citizen Scientists for Transiting Exoplanet Follow-up

Books (recently added to the Exoplanet website at https://britastro.org/node/15633)

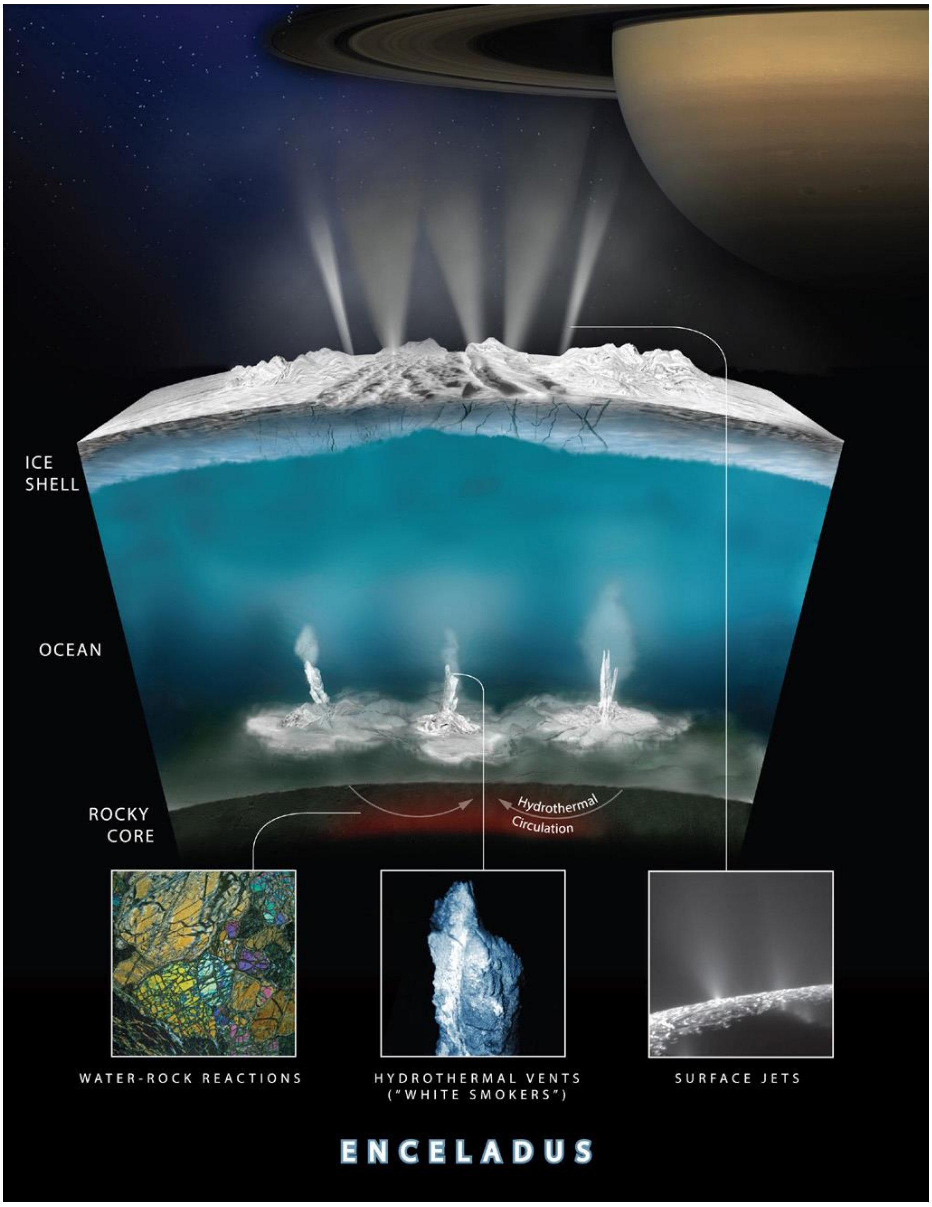
Our Cosmic Ancestry in the Stars by Chandra and Kamala Wickramasinghe and Gensuke Tokoro, Published by Inner Traditions, £9.01 (Paperback)

The Contact Paradox by Keith Cooper, Published by Bloomsbury Sigma, £13.29 hard back

The Search for our Cosmic Ancestry by Chandra Wickramasinghe, Published by World Scientific, £34.46 (Hardback)

Astrobiology

Could life exist in the ocean on Saturn's moon Enceladus? https://www.astrobio.net/news-exclusive/how-friendly-is-enceladus-ocean-to-life/



Processes in Enceladus's ocean Credit NASA JPL, Cal Tech

Space

CHEOPS

The CHEOPS (Characterising ExOPlanet Satellite) spacecraft was launched on 2019 December 18. The goal of the CHEOPS mission is to characterize the structure of exoplanets with typical sizes ranging from Neptune down to Earth diameters orbiting bright stars. This will be achieved by measuring high precision photometric sequences to detect a variation in the stellar brightness induced by a transiting planet. CHEOPS is built to achieve a photometric precision similar to Kepler while observing much brighter stars located anywhere on the sky.

The Moon
Space X aims to land its Starship on the lunar surface in 2022. See;
https://www.space.com/spacex-starship-moon-missions-2022.html and
https://www.spacex.com/starship

Intuitive Machines, based in Houston, Texas, is developing a Lunar Payload and Data Service (LPDS), Nova C spacecraft, which provides transit to lunar orbit, intact payload delivery to the lunar surface, and data communications and power services to assets both in lunar orbit and on the surface.

Mars
Sample return missions – three spacecraft will be required to accomplish collecting and storing samples and returning them to Earth. With the exception of the Mars 2020 mission the rest of the program is not exactly set in stone.

NASA – Mars 2020 will launch in August and the Perseverance rover will seek signs of ancient life and collect rock and soil samples for possible return to Earth.

NASA - Sample Retrieval Lander will launch in 2020 July and land near the Mars 2020 site and the Sample Fetch Rover will retrieve the samples collected and cached by the Perseverance rover. Having done so it will return to the lander where they will be loaded on to the Mars Ascent Vehicle which will carry them in to Mars orbit.

ESA – Earth Return Orbiter will also launch in 2026 September capture the container in Mars orbit and return the samples to Earth in 2031.

Titan
NASA has announced that its next destination in the solar system is the unique, richly organic world Titan. Advancing the search for the building blocks of life, the Dragonfly mission will fly multiple sorties to sample and examine sites around Saturn's icy moon.

Dragonfly rotorcraft-lander on Titan Credit NASA/JHU-APL

Dragonfly will launch in 2026 and arrive in 2034. The rotorcraft will fly to dozens of promising locations on Titan looking for prebiotic chemical processes common on both Titan and Earth. Dragonfly marks the first time NASA will fly a multi-rotor vehicle for science on another planet; it has eight rotors and flies like a large drone. It will take advantage of Titan's dense atmosphere – four times denser than Earth's – to become the first vehicle ever to fly its entire science payload to new places for repeatable and targeted access to surface materials.

The Solar System

NASA has selected four possible missions to explore the Solar System.

Trident - explore Neptune's moon Triton

VERITAS – map the surface of Venus

DAVINCI+ - analyse Venus' atmosphere

IVO – explore Jupiter's moon Io

Pro-am projects

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

See https://britastro.org/sites/default/files/ARIEL%20Space%20Mission%20V2.pdf for a full description and I do urge you to take part.

Observations are listed at https://www.exoclock.space/database/observations and include 34 by BAA members – a significant contribution much appreciated by the ARIEL team.

Presentations made at the Open Conference that took place in 2020 January are available at https://www.cosmos.esa.int/web/ariel/conference-2020

Planetary Transit and Oscillations of stars (PLATO)

At the BAA Meeting held on 2019 December 7, what a long time ago that seems, Mark Kidger gave a presentation on the PLATO mission which can be viewed at https://www.youtube.com/watch?v=A8a_BsPN5uw Amateur astronomers will be able to play a part in this mission by helping to confirm PLATO observations. The story so far (this section will eventually morph into a project document similar to the one available for ARIEL - https://britastro.org/sites/default/files/ARIEL%20Space%20Mission%20V2.pdf).

Contents

1.0 The PLATO space mission

1.1 Introduction to PLATO

PLAnetary Transits and Oscillations of stars (PLATO) is one of three ESA missions searching for Earth-like habitable exoplanets, the other two being ARIEL and CHEOPS. Its objective is to find and study a large number of extrasolar planetary systems, with emphasis on the properties of terrestrial planets in the habitable zone around solar-like stars. PLATO has also been designed to investigate seismic activity in stars, enabling the precise characterisation of the planet's host star, including its age. Scheduled launch date is 2026, such dates always slip I am advised, so should appeal to younger members!!!

PLATO will photometrically monitor a large number of bright stars for the detection of planetary transits and the determination of the planetary radii (around 3% accuracy). PLATO measures the ratio of planetary radii to that of its host star.

Identification of bright targets for spectroscopic and photometric follow-up observations of planetary atmospheres with other ground and space facilities. Asteroseismology for the determination of stellar masses, radii, and ages (up to 10% of the main sequence lifetime).

Radial velocity follow-up observations for the determination of the planetary masses (around 10% accuracy). Radial velocity signals for different kinds of planets orbiting a solar-mass star are given in Table 1.1.

Planet	Semi-major axis (AU)	Radial velocity (m/sec)
Jupiter	0.1	89.8
Jupiter	1.0	28.4
Jupiter	5.0	12.7
Neptune	0.1	4.8
Neptune	1.0	1.5
Super-Earth (5 Earth masses)	0.1	1.4
Super-Earth (5 Earth masses)	1.0	0.45
Earth	0.1	0.28
Earth	1.0	0.09

Table 1.1. Radial velocity signals

Links;
- ESA PLATO website - https://sci.esa.int/web/plato/
- PLATO Definition Study Report - https://sci.esa.int/documents/33240/36096/1567260308850-PLATO_Definition_Study_Report_1_2.pdf
- presentation by Mark Kidger at the BAA meeting held on 2019 December 7 - https://www.youtube.com/watch?v=A8a_BsPN5uw The video shows the whole of the meeting and this presentation runs from approximately 13mins to 1hr 18 mins.

2.0 Exoplanet characterisation

2.1 Earth II

Requirements for an exoplanet to be Earth-like and capable of supporting human life (from Mark Kidger's presentation to the BAA 2020 December 7);
- gravity =< 3g
- within the Goldilocks zone where liquid water can exist on the surface. In theory this is quite broad but if the Earth were 3% closer to the Sun it would tend to a runaway

greenhouse and if it were 3% further away it would tend to an iceball

To date;

- only 32 known exoplanets (4%) are < 3 Earth masses
- only 16 known exoplanets (0.9%) could support liquid water
- only 3 known exoplanets are both < 3 Earth masses and could support liquid water
- 2 of them are much hotter than Earth and are likely runaway greenhouse planets
- 1 is smaller and cooler than Earth and is more likely to be an iceball

In conclusion;

- our statistics are not good enough to say how many Earth-sized planets may exist around Sun-like stars
- only a very small number of them may be suitable candidates to be Earth !!

2.2 Mass-radius relationships

Knowing the radius and mass of an exoplanet enables its density to be determined which gives an indication of its composition – Figures 2.2.1 and 2.2.2

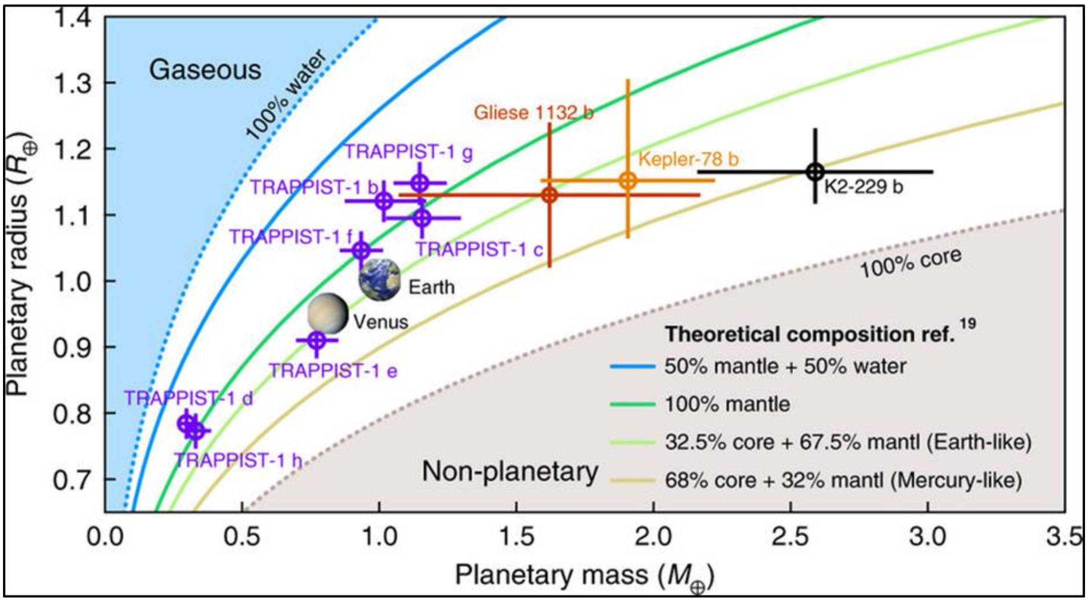


Figure 2.2.1. Mass-radius diagram of known Earth-sized planets

Figure 2.2.1 obtained from the paper 'An Earth-sized exoplanet with a Mercury-like composition' by Alexandre Santerne and others.

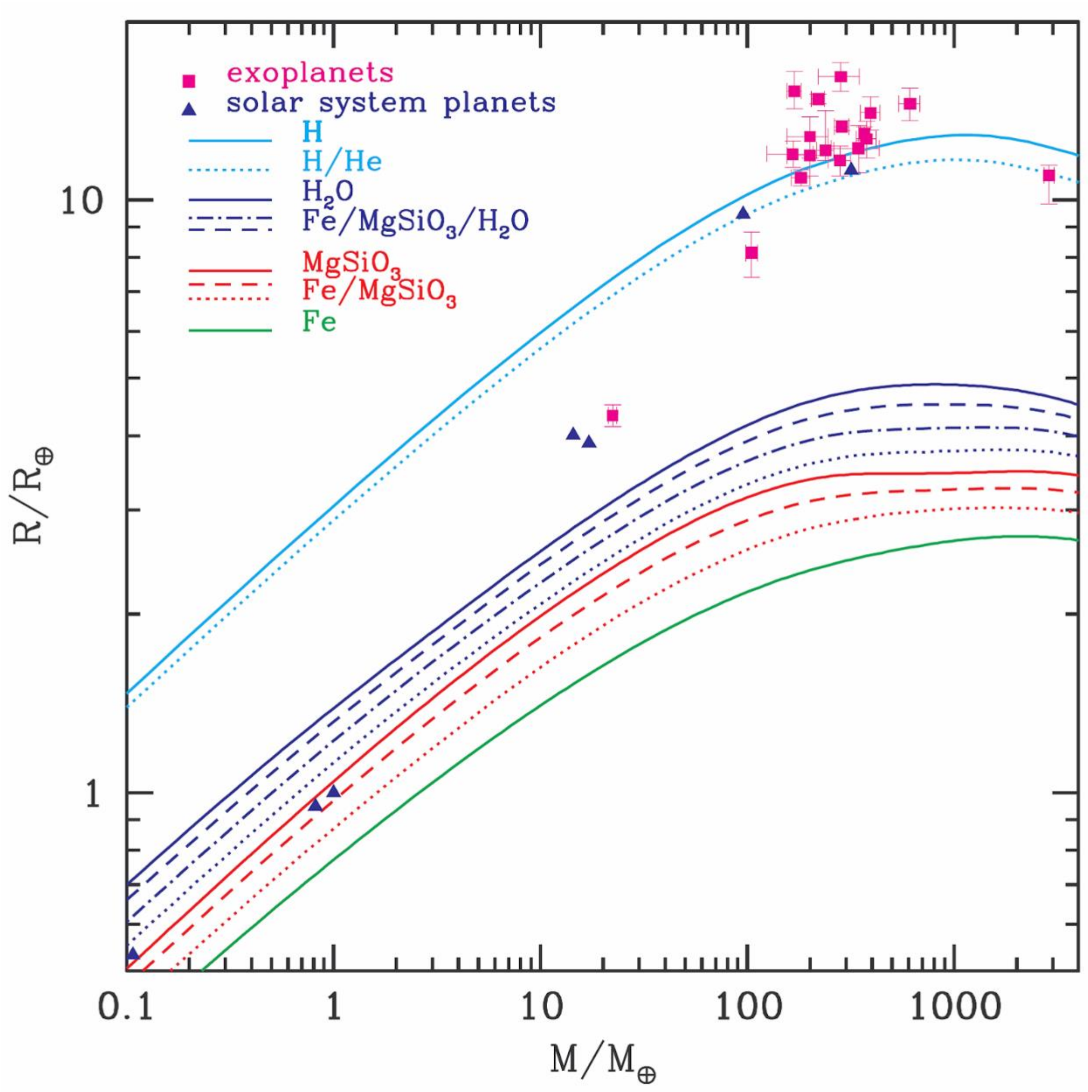


Figure 2.2.2. Mass-radius relationship indicating composition of known exoplanets

Figure 2.2.2 obtained from the Bruce Murray Space Image Library via the Planetary Society.

2.3 Summary

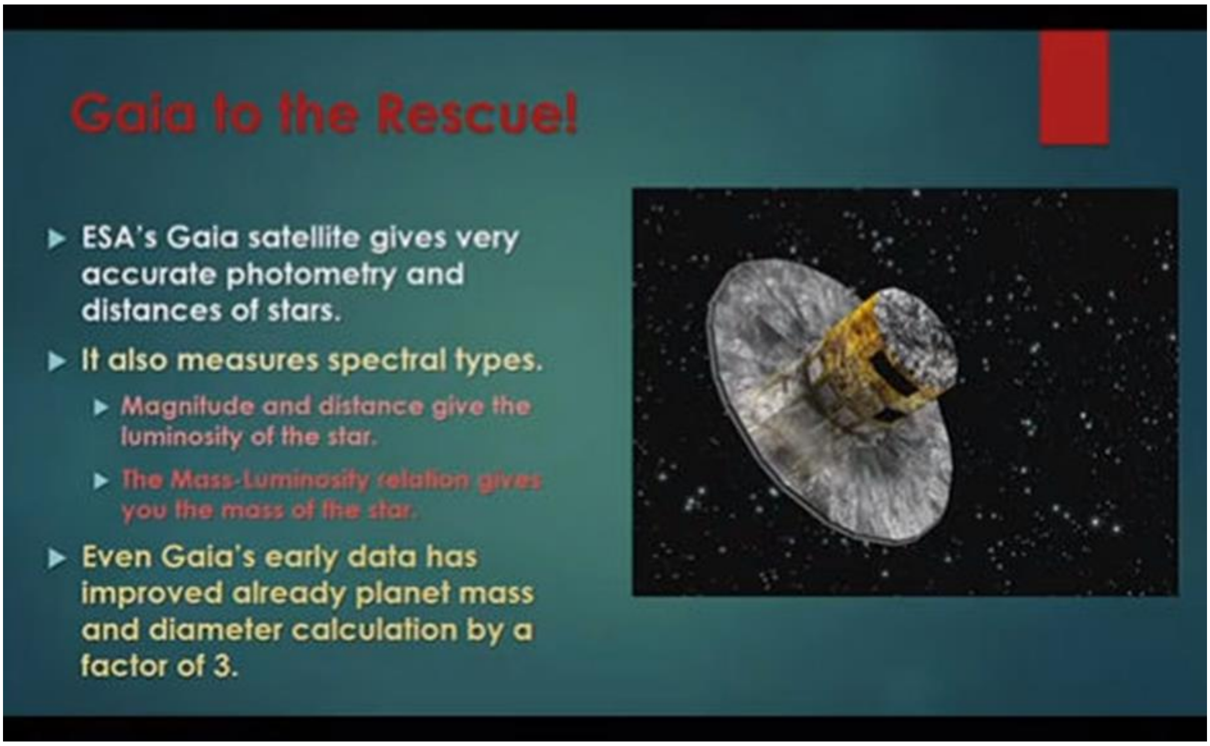


Figure 2.3.1. Gaia data Credit Mark Kidger

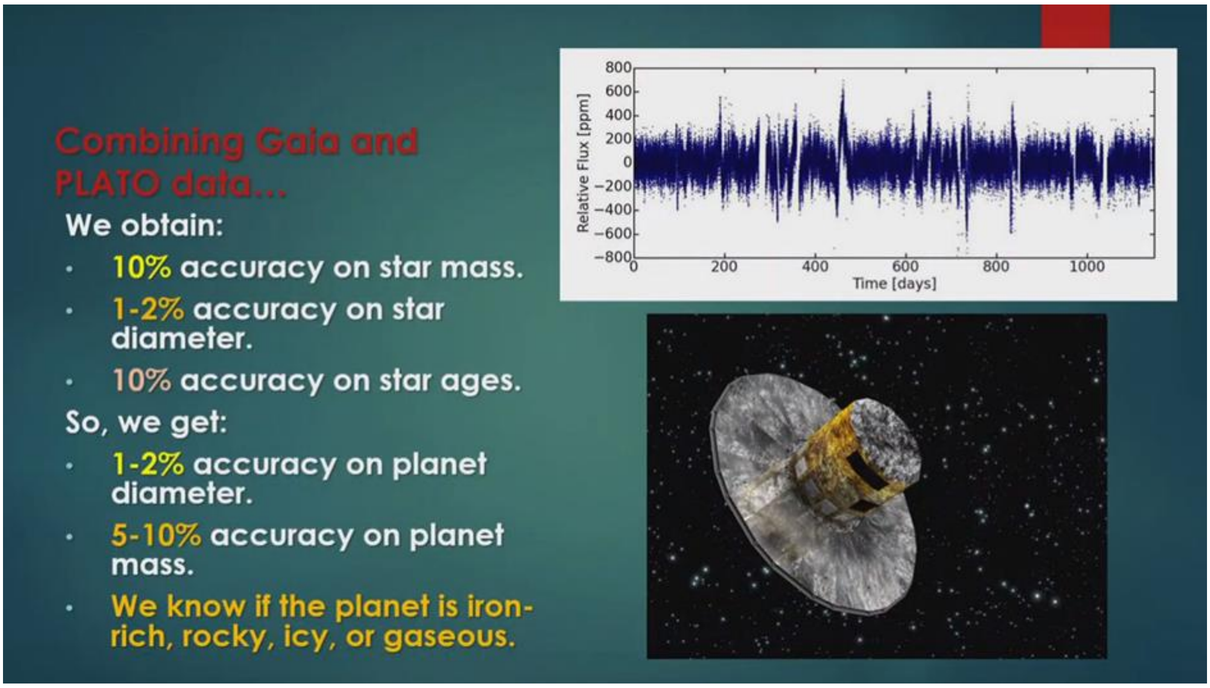


Figure 2.3.2. Exoplanet characterisation using Gaia and PLATO data. Credit Mark Kidger

3.0 Ground-based Confirmation

PLATO Ground-based Observation - https://platomission.com/2018/05/14/ground-based-observation-programme/ -

A considerable amount of help will be needed from both professional and amateur astronomers to confirm PLATO exoplanet observations. This will normally be done spectroscopically on an 8-metre telescope. An agreement has been negotiated with the

3.1 Professional collaboration

European Southern Observatory (ESO) for 50 nights per year on an 8 metre over the course of the mission.

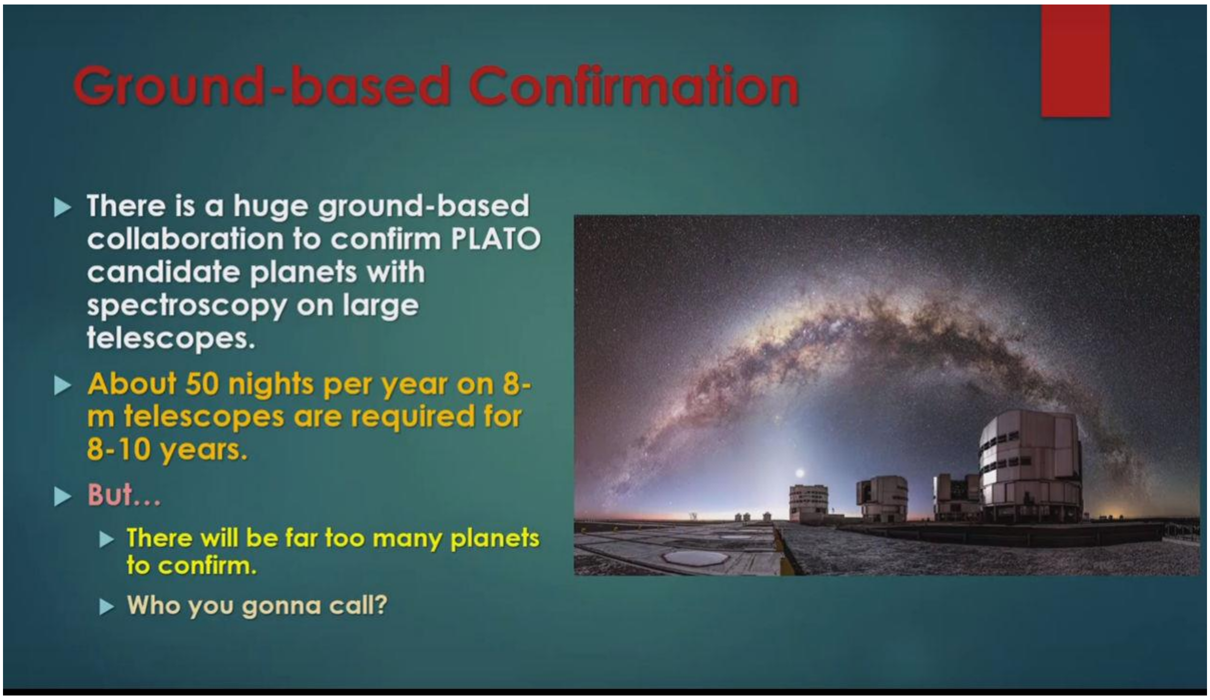


Figure 3.1.1. Ground based confirmation program Credit Mark Kidger

3.2 Amateur collaboration

The coordinator for amateur participation is Gunther Wuchtterl, gwuchterl@kuffner-sternwarte.at

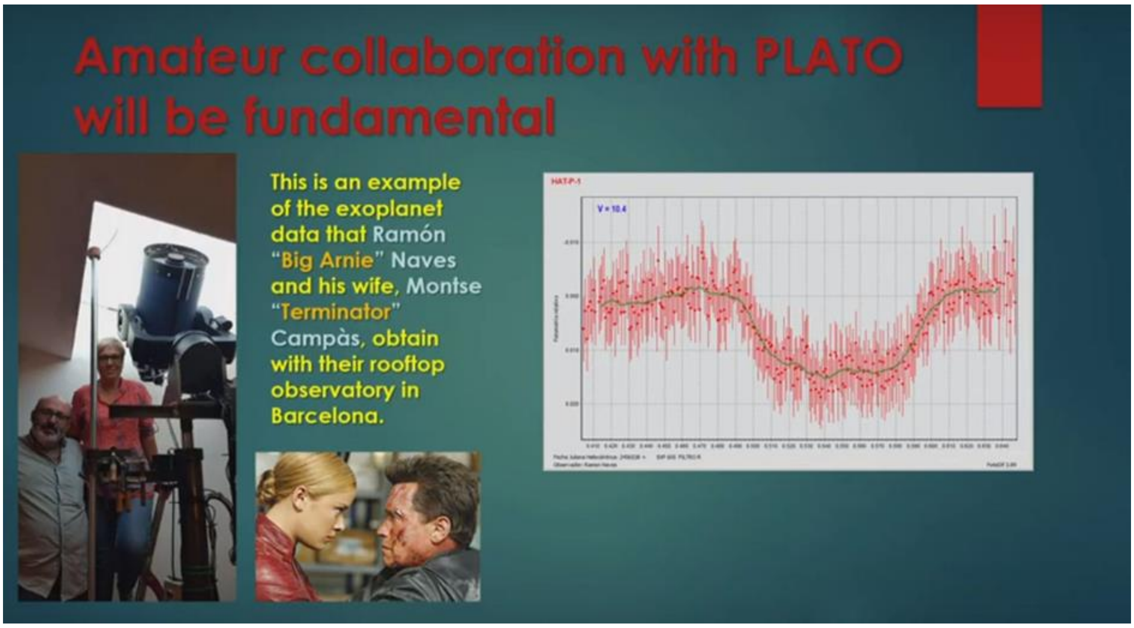


Figure 3.2.1. Example of Jupiter-size exoplanet transit light curve Credit Mark Kidger

And now for quite a coincidence. In 2006 I attended the Meteors, Asteroids and Comets in Europe (MACE) meeting at the Kuffner Observatory in Vienna. Who am I sitting next to in Figure 3.2.1? None other than Gunther Wuchtterl!!!

Figure 3.2.2. Günther Wuchterl, Roger Dymock, Robin Lauryssen-Mitchell, Richard Miles, r Pravec, Korado Korlevic

There are several stellar processes which can mimic exoplanet transits, some of which are shown in Figure 3.2.2, which is why transit candidates require confirmation.

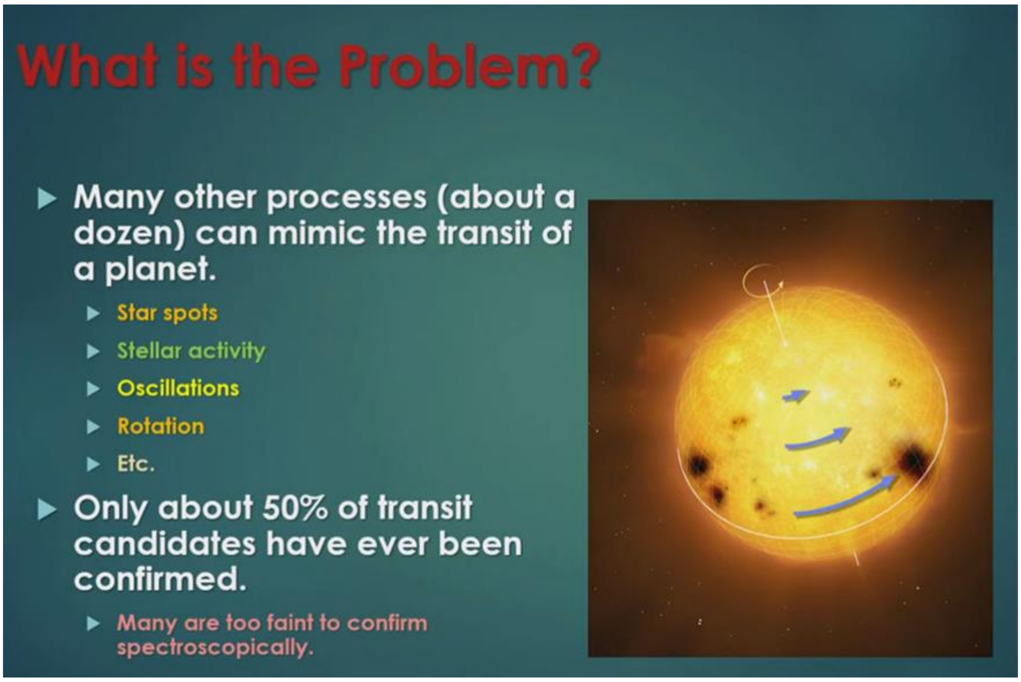


Figure 3.2.2. Transit mimics. Credit Mark Kidger

Unlike ARIEL, which will be observing known exoplanets, PLATO is a discovery mission. It is estimated that 2% of stars listed in the first version of their input catalogue which will be observed will show transits. Which 2% is as yet unknown and PLATO will give alerts for each batch of new transit candidates. Amateurs will be able to tap into these alerts and assist in confirming, by transit photometry, the presence of an exoplanet or not as the case may be and their participation will be a fundamental part of the mission. Figure 3.2.3 shows a typical transit light-curve. A 20-30 cms/8-12 ins telescope suggested

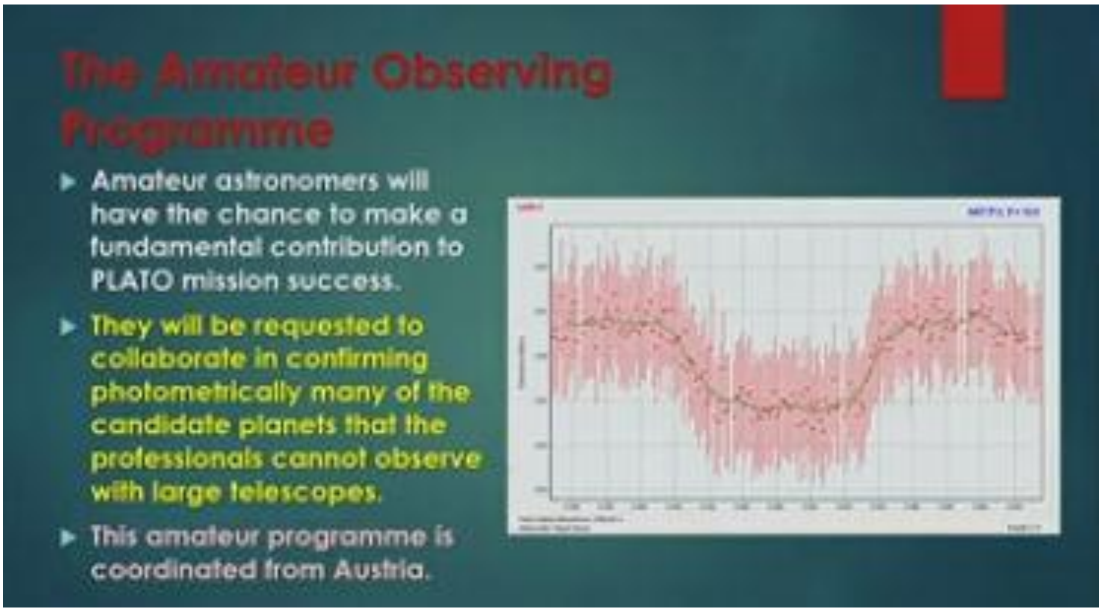


Figure 3.2.3. Amateur observing program Credit Mark Kidger

4.0 Imaging and analysis process

To be added

5.0 PLATO targets

Mark Kidger comments;

PLATO is a very different case to ARIEL as regards follow-up. ARIEL, needs a target list of 1000+, known exoplanets to characterise. Obviously, Kepler, TESS and other programmes have already supplied them with a number of targets of interest, although they are still well short of the 1000 envisaged. ARIEL's problem is the exact inverse of PLATO: while we will ask observers to go out and confirm new candidate planets that were previously unknown, ARIEL will characterise previously discovered planets that have been confirmed by observers. We cannot give a target list (yet) because we do not know which of our 270000 candidate stars will turn out to have planets. ARIEL, in contrast, cannot observe many of its target stars because the ephemeris for the planet transit is so hopelessly inaccurate and so it needs people to do the hard yards to observe a transit that may have timing that is uncertain by a number of days, in order to correct the ephemeris and tell ARIEL when to point at that star. PLATO will sit on each of its 270000 candidates for a minimum of 2 years, hoping to see something happen sometime, while, for ARIEL to be efficient, it must hop to a star, observe the transit and then hop straight to the next, without waiting around for something to happen. All this means that in terms of ground-based follow-up, it is so much easier for ARIEL to define what it needs well in advance than for PLATO to do the same.

Figure 5.1 lists potential targets in order of priority.

Figure 5.1. PLATO targets

Appendix A – Calculating the radius of a star

The distances to the host stars will be provided by the Gaia spacecraft measuring the parallax of stars.

Ref; Sloan Digital Sky Survey

Calculating a star's radius is a somewhat lengthy process. Even the largest star is so far away that it appears as a single point from the surface of the Earth - its radius cannot be measured directly. Fortunately, understanding a star's luminosity provides you with the tools necessary to calculate its radius from easily measured quantities.

A star's luminosity, or total power given off, is related to two of its properties: its temperature and surface area. If two stars have the same surface area, the hotter one will give off more radiation. If two stars have the same temperature, the one with more surface area will give off more radiation. The surface area of a star is directly related to the square of its radius (assuming a spherical star).

The luminosity of a star is given by the equation

$L = 4\pi R^2 s\, T^4$,

Where L is the luminosity in Watts, R is the radius in meters, s is the Stefan-Boltzmann constant ($5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$), and T is the star's surface temperature in Kelvin.

The temperature of a star is related to its B-V magnitude. Table A1 below can help you find the temperature of the star based on its B-V magnitude.

B-V	Surface Temperature (Kelvin)
-0.31	34,000
-0.24	23,000
-0.20	18,500
-0.12	13,000
0.0	9500
0.15	8500
0.29	7300
0.42	6600
0.58	5900
0.69	5600
0.85	5100
1.16	4200
1.42	3700
1.61	3000

Table A.1 Colour surface temperature relationship

The calculation is actually somewhat easier if we try to find the ratio of another star's radius to that of our Sun. Let L_s be the luminosity of the Sun, L be the luminosity of another star, T_s be the temperature of the Sun, T be the temperature of the other star, R_s be the radius of the Sun, and R be the radius of the other star.

We can then write the ratio of their luminosities as;
$L/L_s = (4\pi R^2 sT^4)/(4\pi R_s 2sT_s 4) = (R/R_s)^2(T/T_s)^4$

Solving for the ratio R/R_s yields;
$R/R_s = (T_s/T)^2(L/L_s)^{1/2}$

The temperatures can be found approximately from the table above by looking at the B-V values. To find the ratio L/L_s, we can use the absolute magnitudes of the stars. The magnitude scale is a logarithmic scale. For every decrease in brightness of 1 magnitude, the star is 2.51 times as bright. Therefore, L/L_s can be found from the equation

$L/L_s = 2.51^{Dm}$, where $Dm = m_s - m$

Let's look at the star Sirius. It has visual magnitude of -1.44, B-V of .009, and a parallax, p, of 379.21 milli arc seconds. Finding its distance from its parallax yields

One parsec is the distance, d, at which one AU subtends an angle of one second of arc therefore d = 1/p = 1/.37921 = 2.63 parsecs.

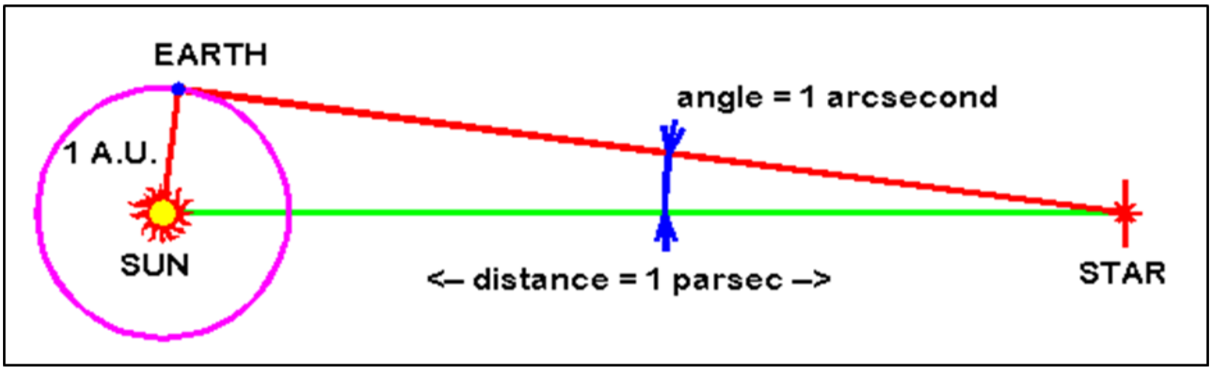


Figure A.2. Distance measurement

Knowing the distance, the absolute magnitude can be calculated from the equation;
Absolute magnitude (M) = Apparent magnitude (m) – 5 x log(d = distance in parsecs) + 5

$M = m - 5 \log d + 5 = -1.44 - 5 \log (2.63) + 5 = 1.46$

We know the temperature of the Sun is 5800K. From the chart, the temperature of Sirius is about 9500K. Our Sun has an absolute magnitude of 4.83. The difference in magnitude is 3.37. Putting everything together yields

$R/R_s = (5800/9500)^2(2.512^{3.37})^{1/2} = 1.76$ therefore Sirius has a radius approximately 1.76 times that of our Sun

Appendix B Measuring the surface temperature of a star by spectroscopy
In 1900, physicist Max Planck worked out the mathematical details for how to exactly predict a body's spectrum once its temperature is known. The curve is therefore called a Planck 'black body' curve. It represents the brightness at different wavelengths of the light emitted from a perfectly absorbing 'black' body at a particular temperature. From the mathematical properties of the Planck Curve, Figure B.1, it is possible to determine a relationship between the temperature of the body and the wavelength where most of its light occurs - the peak in the curve. This relationship is called the Wein Displacement Law and is;

Temperature = 2897000 Kelvins/Wavelength where the temperature is in units of Kelvin and the wavelength is in units of nanometers.

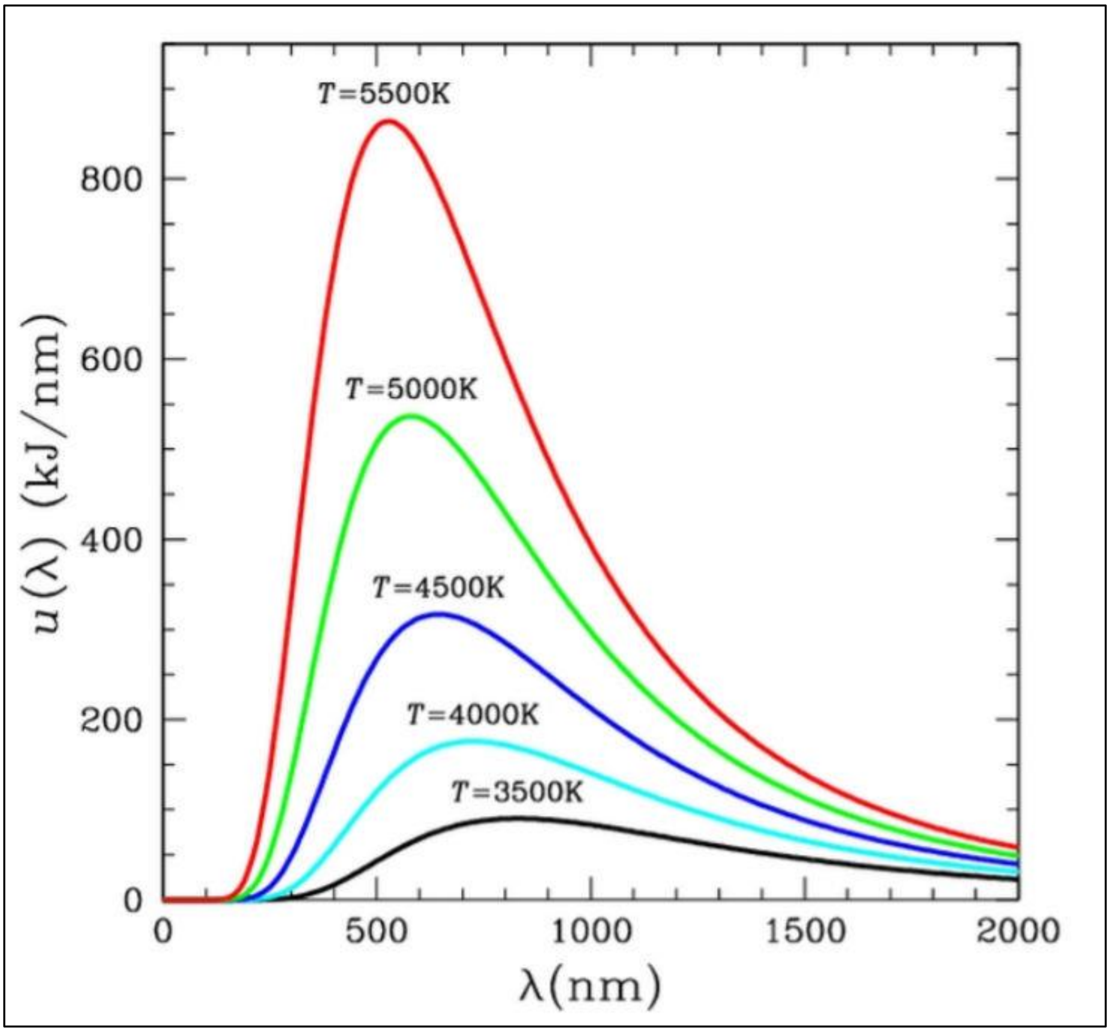


Figure B.1. Planck black body curve

For a full description of how the surface temperature of a star can be determined from spectroscopy see https://www.shelyak.com/measure-star-temperature/?lang=en

Appendix C Asteroseismology

Asteroseismology can be used to determine stellar masses, radii, and ages (up to 10% of the main sequence lifetime). Papers on the subject;

- https://arxiv.org/abs/0909.0506
- https://www.aanda.org/articles/aa/pdf/2014/06/aa23408-14.pdf

Oscillations measured by Gaia can give age of stars accurate to +/- 10%. Can also determine how evolved a star is e.g. is it about to leave the main sequence (useful information if looking for a new home for mankind). Also tells us if a planet is very old or very young and therefore recently formed.

Roger Dymock
ARPS Assistant Director Exoplanets
2019 September 13