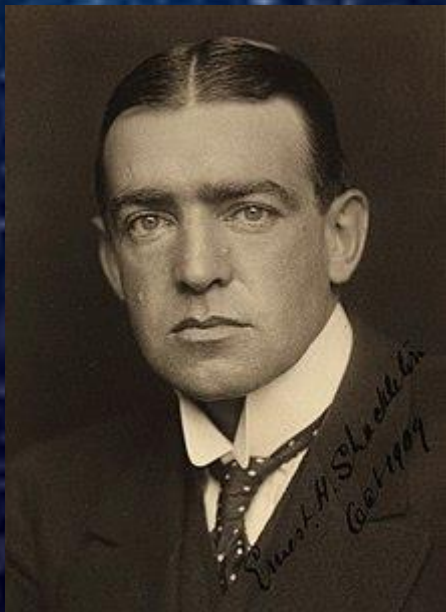


EXPLORE NEEDS EXPLORERS

EXoPLanet Orbit ResearchERS

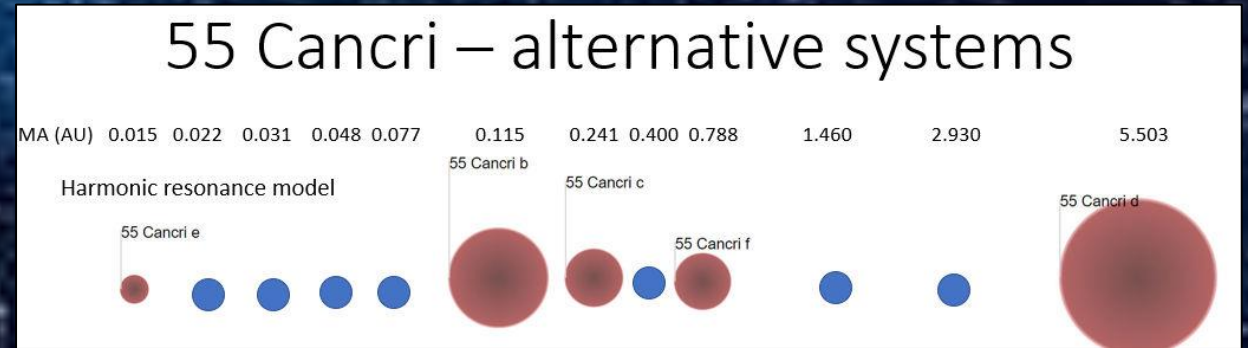
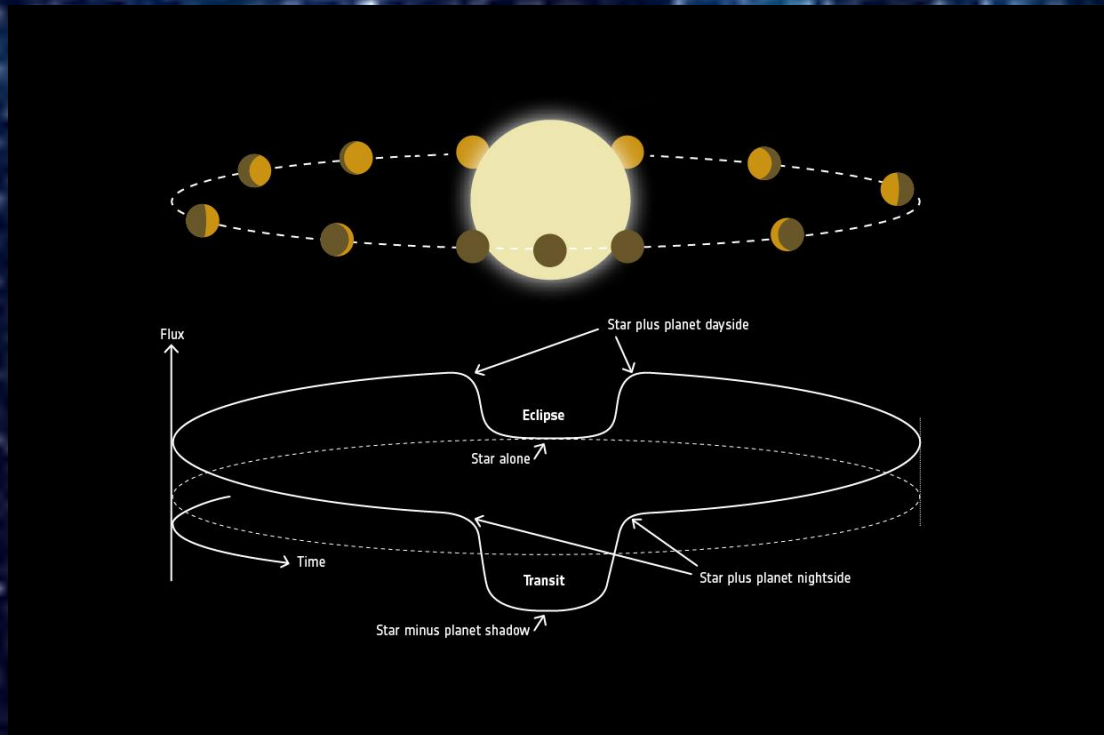


Roger Dymock



2022 November 12

To boldly go...but where and what?

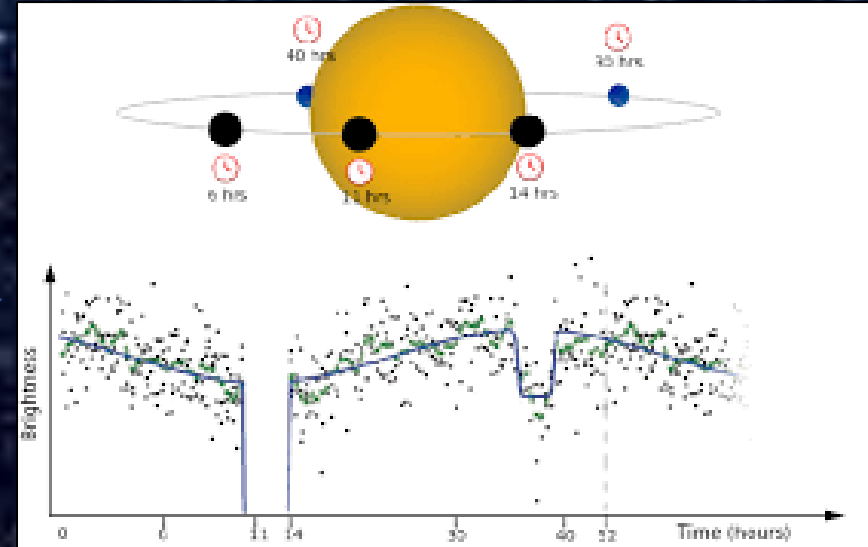
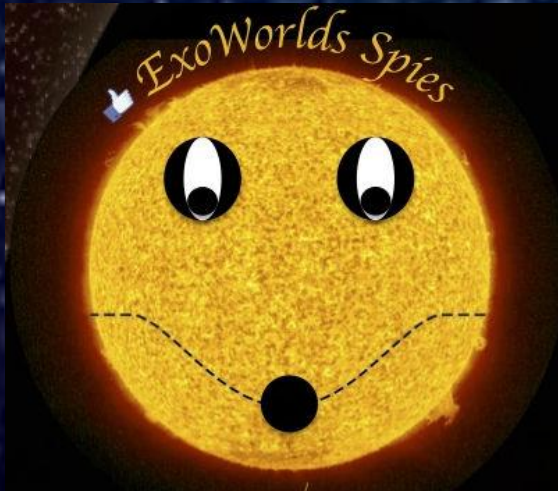


Under starters orders



Route 1

Route 2



HOPS

**** Extras ****

AstrolmageJ

Under starters orders Extras

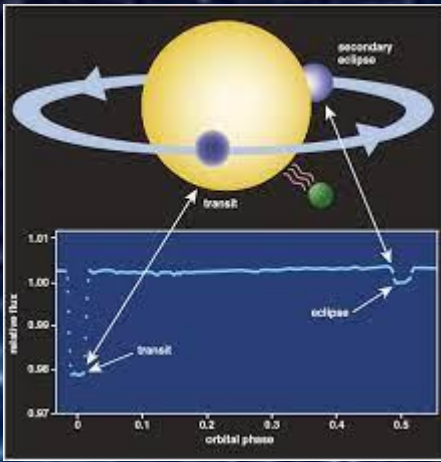
- Exoplanet Division websites;
- ARIEL ExoClock pro-am project - https://britastro.org/section_information/exoplanets-section-overview/ariel-exoclock-pro-am-project
- The ExoClock Project - <https://www.exoclock.space/project>
- ExoWorld Spies - <https://www.exoworldsspies.com/en/>

Potential Pilot Projects

- PPP 1 Detecting secondary transits
- PPP 2 Monotransits/duotransits – confirmation of exoplanet discoveries
- PPP 3 TTVs/TDVs research which may lead to the discovery of additional exoplanets in known systems
- PPP 4 Phase curve photometry
- PPP 5 Detecting exomoons
- PPP 6 Detecting exocomets

PPP 1

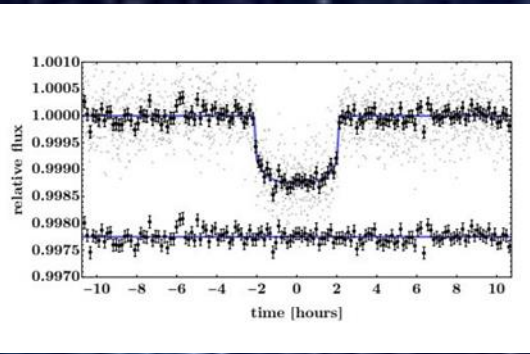
Secondary transits



- Objective – detect secondary transits (or eclipses) of known exoplanets
- A secondary transit or eclipse occurs when the exoplanet passes behind its host star as observed from Earth. Note that the secondary transit depth is much less than that of the primary transit
- Eclipses usually occur midway between primary transits and thus can be calculated using the ExoWorlds Spies Transit Scheduler at <https://www.exoworldsspies.com/en/scheduler/> plus Ephemeris data on the ExoClock website at <https://www.exoclock.space/database/planets>

PPP 2

Monotransits and Duotransits



- Objective – confirm presence of exoplanets by observing target star at predicted times. Opportunity for amateurs to be co-discoverers
- Numerous observations of mono/duotransits have been observed by TESS, Kepler, K2 and CHEOPS space telescopes
- Transit depth from above obs should indicate whether within capabilities of amateurs
- Confirmation requires three transits to be observed
- The orbital period can be calculated if the host star's mass and radius are known
- Mean Motion Resonance systems and Laplace resonant chains may indicate presence of additional planets and define their orbits

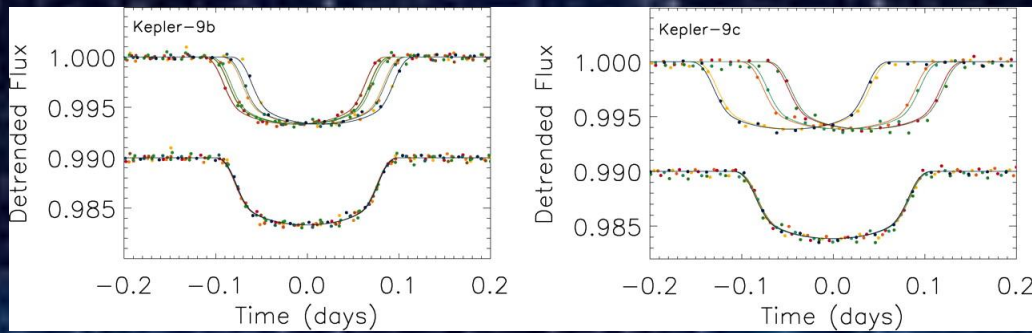
**** Extras ****

PPP 2 Extras

- MonoTools: a python package for planets of uncertain period - <https://pypi.org/project/MonoTools/>
- Single Transit Candidates from K2: Detection and Period Estimation - <https://arxiv.org/pdf/1512.03722.pdf>
- Hugh Osborn's Monotransits website - <https://hposborn.github.io/about.html>
- Amy Tuson's website (search for long-period exoplanets) - <https://amytuson.wordpress.com/>
- Mean motion resonances in exoplanet systems - <https://arxiv.org/pdf/1211.3078.pdf>
- Six transiting planets and a chain of Laplace resonances in TOI-178 - https://www.aanda.org/articles/aa/full_html/2021/05/aa39767-20/aa39767-20.html
- CHaracterising ExOplanet Satellite (CHEOPS) <https://cheops.unibe.ch/>
CHEOPS observations of TESS primary mission monotransits - <https://academic.oup.com/mnras/article/494/1/736/5809375>
Possible pro-am collaboration under investigation
- Kepler and K2 https://www.nasa.gov/mission_pages/kepler/main/index.html
- Transiting Exoplanet Survey Satellite (TESS) <https://www.nasa.gov/tess-transiting-exoplanet-survey-satellite>

PPP3

TTV and TDV research



- Objectives;
 - to discover additional exoplanets in known systems by examining Transit Timing and Transit Duration Variations in transit light curves
- - to discover examples of orbital decay
- References
 - Transit timing and duration variations...;
<https://arxiv.org/pdf/1706.09849.pdf>
 - Transit duration variations in multi planet systems;
<https://arxiv.org/pdf/2003.11590.pdf>
 - The Apparently Decaying Orbit of WASP-12;
<https://arxiv.org/abs/1703.06582>

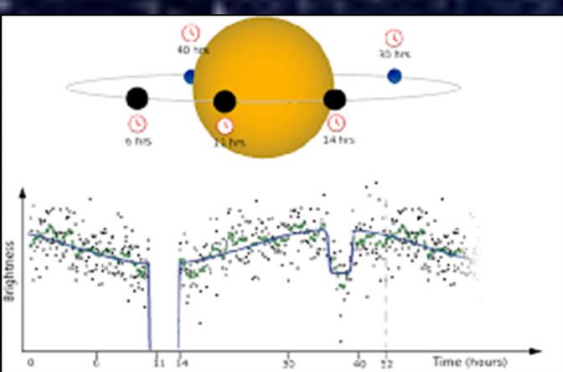
PPP 3 Extras

- Databases

- ExoClock; <https://www.exoclock.space/project>
 - Exoplanet Transit Database; <http://var2.astro.cz/ETD/archive.php>
 - BAA Exoplanet Division website under Web links/Data;
<https://britastro.org/sections/exoplanets>
 - Extrasolar Planets Encyclopaedia, Planet TrES-1b –
http://exoplanet.eu/catalog/tres-1_b/
- Several papers relating to Transit Timing Variations are listed

PPP 4

Phase curve photometry



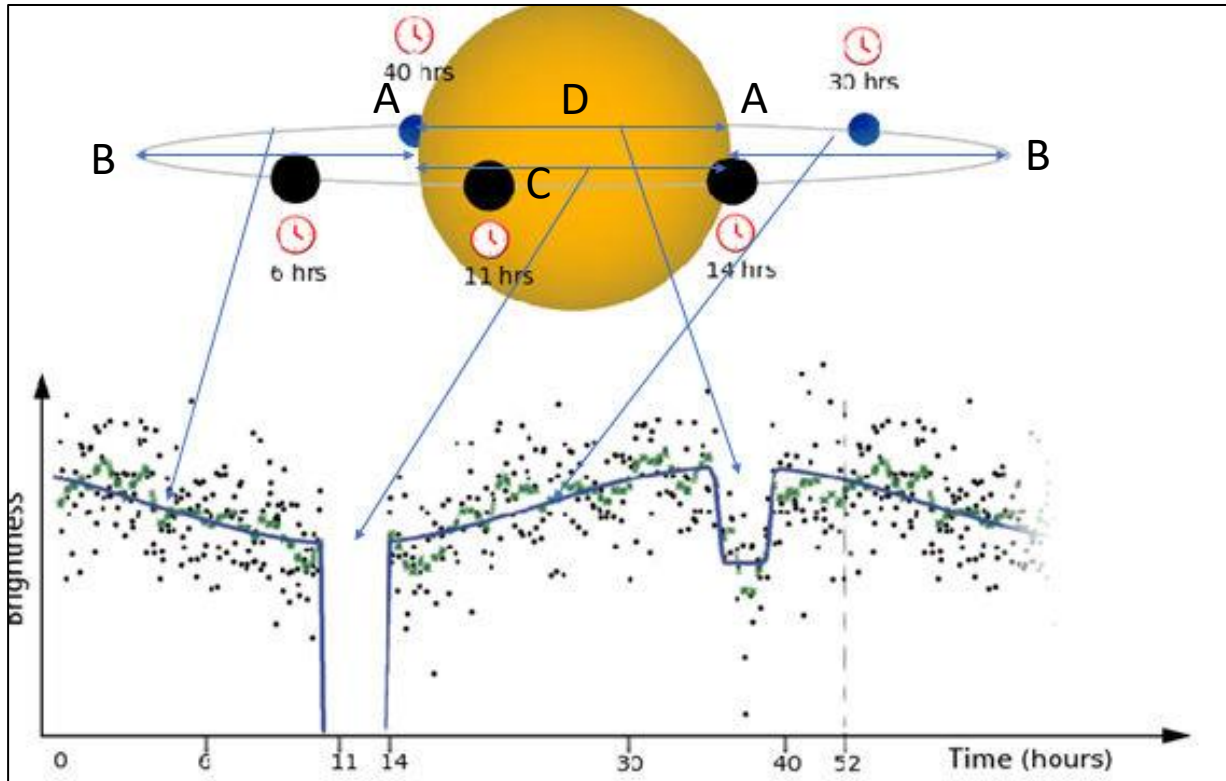
- Objective – image a complete orbit to determine the shape of the phase curve.
- From the phase curve;
 - the amount of cloud or haze can be determined
 - the shape of the phase curve can indicate the size of the particles in the planets atmosphere – the smaller the particles the flatter the curve
 - for small planets bright and dark features on the surface may be detected
 - for large planets changes in the phase curve can show changes in cloud cover

References;

- Exoplanet phase curves: observation and theory;
<https://arxiv.org/pdf/1711.07696.pdf>

• **** Extras ****

PPP 4 Extras



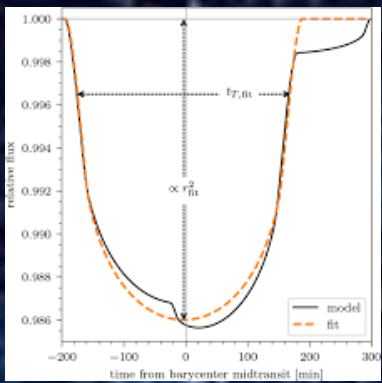
THE MEASURED BRIGHTNESS VARIES DEPENDING ON THE RELATIVE POSITIONS OF PLANET AND HOST STAR. MAXIMUM BRIGHTNESS IS AT TIMES WHEN THE PLANET IS ABOUT TO MOVE BEHIND AND EMERGE FROM THE HOST STAR (ITS DAY SIDE), A, AS WE ARE SEEING BOTH THE LIGHT FROM THE STAR AND REFLECTED LIGHT FROM THE PLANET (EQUIVALENT TO A FULL MOON).

AS THE PLANET REACHES MAXIMUM ELONGATION WE SEE 50% OF THE REFLECTED LIGHT (EQUIVALENT TO A 1ST OR 3RD QUARTER MOON), B.

MINIMUM BRIGHTNESS IS WHEN THE PLANET IS TRANSITING THE STAR AND WE SEE THE PLANET'S NIGHT SIDE, C, – A PRIMARY TRANSIT. A SECONDARY TRANSIT IS WHEN THE PLANET PASSES BEHIND THE STAR, D.

PPP 5

Detecting exomoons



- Objective – analyse transit light curves to see if the presence of an exomoon is indicated. For databases see PPP3
- The presence of an exomoon may show as variations in the transit light curve as may be seen in the example at top right
- References;
 - Exomoon indicators in high-precision transit light curves;
<https://arxiv.org/pdf/2004.02259.pdf>
 - Transit light curves for exomoons...
<https://iopscience.iop.org/article/10.3847/1538-4357/ac85a9/pdf>
- Review literature and report

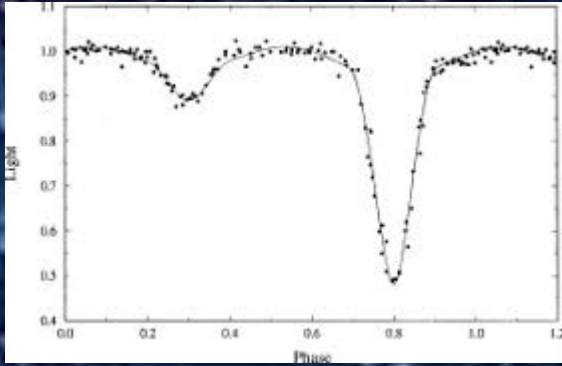


PPP 6

Detecting exocomets

- Objective - analyse transit light curves to see if the presence of an exocomet is indicated
- Analysis of light curves obtained by TESS, the Transiting Exoplanet Survey Satellite, have indicated the presence of what may be exocomets
- References;
 - New exocomets of beta Pic;
<https://www.aanda.org/component/article?access=doi&doi=10.1051/0004-6361/202142111>
- PhD opportunities;
 - Unusual transit observations with PLATO;
https://warwick.ac.uk/fac/sci/physics/research/astro/people/paulwilson/phd_opportunities/
- Review literature and report

What else might be lurking in your images ?



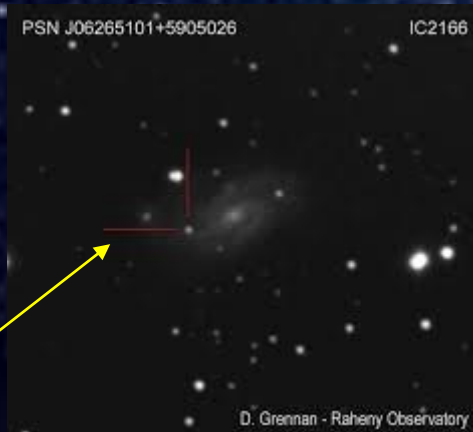
Eclipsing binary star



Asteroid



Comet



Supernova



Tumbling satellite



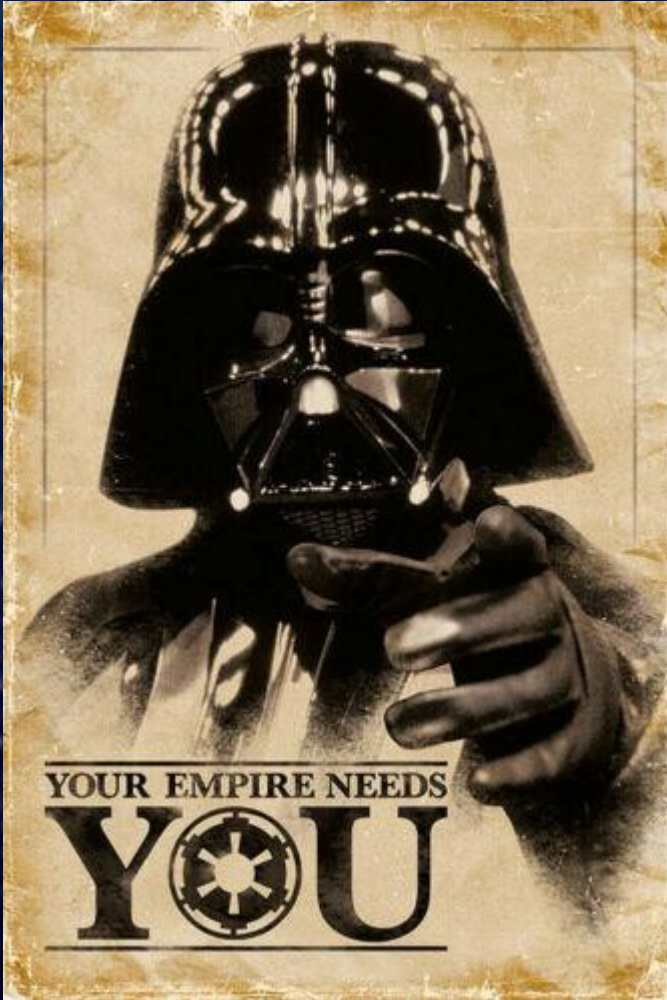
JWST



Until the time comes when we can actually build a star ship, as shown here, and visit exoplanets then we will have to rely on astronomers, professional and amateur, to tease out their secrets

We have outlined some of the things we can do. What next?

We need you



If you are interested in coordinating or participating in one of the projects presented at this meeting or would like to suggest others then please contact;

Roger Dymock - roger.dymock@ntlworld.com

or

Rodney Buckland – rodney.buckland@open.ac.uk

A very important part of all of this is to report to us whatever it is you find or conclude. A follow-up meeting to review progress is under consideration.

Carpe diem!!!

And finally.....

- The BAA Exoplanet website will be updated with EXPLORE material
- Monthly email to all Exoplanet Division members including;
 highlights
 project progress
 links to relevant material on Exoplanet Division website and elsewhere
- If you wish to be added to the Exoplanet Division mailing list then please send email to roger.dymock@ntlworld.com
- Follow-up mtg under consideration