# ExoPlanet News
An Electronic Newsletter

*No. 145, 13 July 2021*



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## Contents

# 1 Editorial

Dear readers,

Welcome to Edition 145 of the ExoPlanet News!

In this issue you will find abstracts of scientific papers, Exoplanet Archive updates, a job advertisement, announcements for conferences, the latest exoplanet talks, and an overview of exoplanet-related articles on astro-ph. Also included is a contribution on the theme of music from exoplanet orbital motion.

We remind you of some **guidelines for using our templates**. If you follow these guidelines, you will make our job easier:

- Please rename the *.tex* file you send from *abstract_template* to something with your last name, like *jobs_smith* or *announcement_miller*
- Avoid using hyperlinks, the newsletter template cannot yet handle the package *hyperref*.
- Do not use any defined command or additional packages
- Abstract: should occupy maximum one page of the pdf without figure. If the list of authors is too large for this, please cut the list of authors, add "et al." followed by "(a complete list of authors can be found on the publication)".
- Figure: attach it to the e-mail without large white margins. It should be one single pdf file per abstract.
- Prior to submission, please remember to comment the three lines which start the tex document and the last line which ends the document.
- Please remember to fill the brackets {} after the title with author names.

For the next month we look forward to your paper abstracts, job ads or meeting announcements. Also special announcements are welcome. As always, we would also be happy to receive feedback concerning the newsletter. The Latex template for submitting contributions, as well as all previous editions of ExoPlanet News, can be found on the ExoPlanet News webpage (http://nccr-planets.ch/exoplanetnews/).

The next issue will appear on August 10, 2021.

Lokesh Mishra
Holly Capelo
Daniel Angerhausen
Julia Venturini
Timm-Emanuel Riesen

# 2 Abstracts of refereed papers

## Molecular mapping of the PDS70 system: No molecular absorption signatures from the forming planet PDS70 b

*G.Cugno[1], P. Patapis[1], T. Stolker[2], S. P. Quanz[1], A. Boehle[1], H. J. Hoeijmakers[3], G.-D. Marleau[4,5,6], P. Mollière[6], E. Nasedkin[6], I. A. G. Snellen[2]*

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*Astronomy & Astrophysics, https://arxiv.org/abs/2106.03615*

Determining the chemical properties of the atmosphere of young forming gas giants might shed light on the location in which their formation occurred and the mechanisms involved. We aim to detect molecules in the atmosphere of the young forming companion PDS70 b by searching for atmospheric absorption features typical of substellar objects. We obtained medium-resolution (R≈5075) spectra of the PDS70 planetary system with the SINFONI integral field spectrograph at the Very Large Telescope. We applied molecular mapping, based on cross-correlation with synthetic spectra, to identify signatures of molecular species in the atmosphere of the planet. Although the planet emission is clearly detected when resampling the data to lower resolution, no molecular species could be identified with the cross-correlation technique. We estimated upper limits on the abundances of $H_2O$, CO and $CH_4$ ($\log(X_{\rm mol}) < -4.0$, $-4.1$ and $-4.9$, respectively) assuming a clear atmosphere, and we explored the impact of clouds, which increase the upper limits by a factor up to 0.7 dex. Assuming that the observations directly probe the planet's atmosphere, we found a lack of molecular species compared to other directly imaged companions or field objects (see left panel of the Figure). Under the assumption that the planet atmosphere presents similar characteristics to other directly imaged planets, we conclude that a dusty environment surrounds the planet, effectively obscuring any feature generated in its atmosphere. We quantify the extinction necessary to impede the detection ($A_V \approx 16-17$ mag, right panel of the Figure), pointing to the possibility of higher optical thickness than previously estimated from other studies. Finally, the non-detection of molecular species conflicts with atmospheric models previously proposed to describe the forming planet. To unveil how giant planets form, a comprehensive approach that includes constraints from multiple techniques needs to be undertaken. Molecular mapping emerges as an alternative to more classical techniques like SED fitting. Specifically, tuned atmospheric models are likely required to describe faithfully the atmospheres of forming protoplanet, and higher spectral resolution data may reveal molecular absorption lines despite the dusty environment enshrouding PDS70 b.

*Download/Website:* `https://arxiv.org/abs/2106.03615`

*Contact:* `gabriele.cugno@phys.ethz.ch`

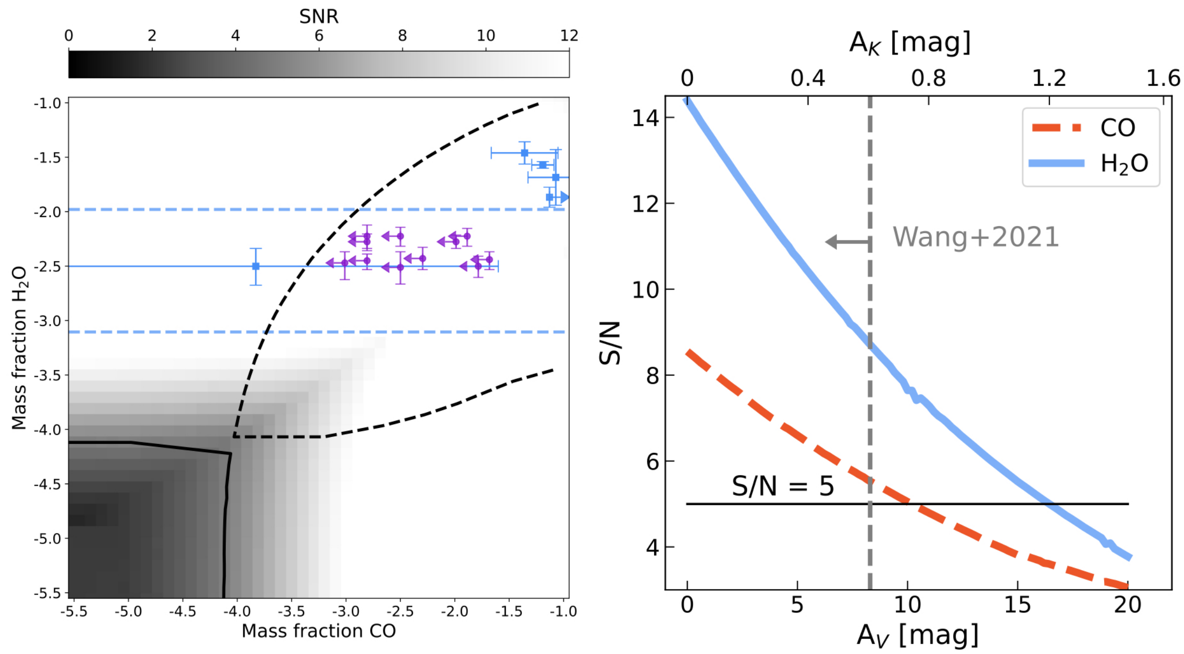


Figure 1: `Left:` Comparison of the detectability of molecules in the SINFONI data with measured abundances from substellar objects. Blue squares represent directly imaged companions HR8799 bce, $\beta$ Pic b and 51 Eri b while blue lines show the measured range for $H_2O$ in $\kappa$ And b. The blue arrow indicates the measured value was higher than the range of abundances shown in the plot. Violet circles represent a sample of T-dwarfs analyzed in Line et al, 2017. In this case arrows refer to upper limits. The solid black line represents the region where no molecule would have been detected in our SINFONI data because of too low mass fractions. Conversely, the dashed black line encloses the region where both molecules would have been detected. Assuming that the observations directly probe the planet's atmosphere, we find a lack of molecular species compared to other directly imaged companions or field objects.
`Right:` Signal to noise ratio of the detection of $H_2O$ and CO as a function of extinction affecting the emission spectrum of the planet. Assuming PDS70 b has the same chemical composition as HR8799 c, an additional extinction with $A_V \approx 16 - 17$ mag ($A_K \approx 1.2$ mag) is required in order not to detect molecules with S/N¿5. The vertical dashed line shows the maximum value obtained by SED fitting from Wang et al, 2021. Such an extinction would have revealed molecules in the planet atmosphere with S/N$\sim$7-9.

## Radioactive Planet Formation

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*Astrophysical Journal, in press*

Young stellar objects are observed to have large X-ray and are thought to produce commensurate luminosities in energetic particles (cosmic rays). This particle radiation, in turn, can synthesize short-lived radioactive nuclei through spallation. With a focus on $^{26}$Al, this paper estimates the expected abundances of radioactive nulcei produced by spallation during the epoch of planet formation. In this model, cosmic rays are accelerated near the inner truncation radii of circumstellar disks, $r_X \approx 0.1$ AU, where intense magnetic activity takes place. For planets forming in this region, radioactive abundances can be enhanced over the values inferred for the early solar system (from meteoritic measurements) by factors of $\sim 10 - 20$. These short-lived radioactive nuclei influence the process of planet formation and the properties of planets in several ways. The minimum size required for planetesimals to become fully molten decreases with increasing levels of radioactive enrichment, and such melting leads to loss of volatile components including water. Planets produced with an enhanced radioactive inventory have significant internal luminosity which can be comparable to that provided by the host star; this additional heating affects both atmospheric mass loss and chemical composition. Finally, the habitable zone of red dwarf stars is coincident with the magnetic reconnection region, so that planets forming at those locations will experience maximum exposure to particle radiation, and subsequent depletion of volatiles.

*Download/Website:* `https://arxiv.org/abs/2107.03329`

*Contact:* `fca@umich.edu`

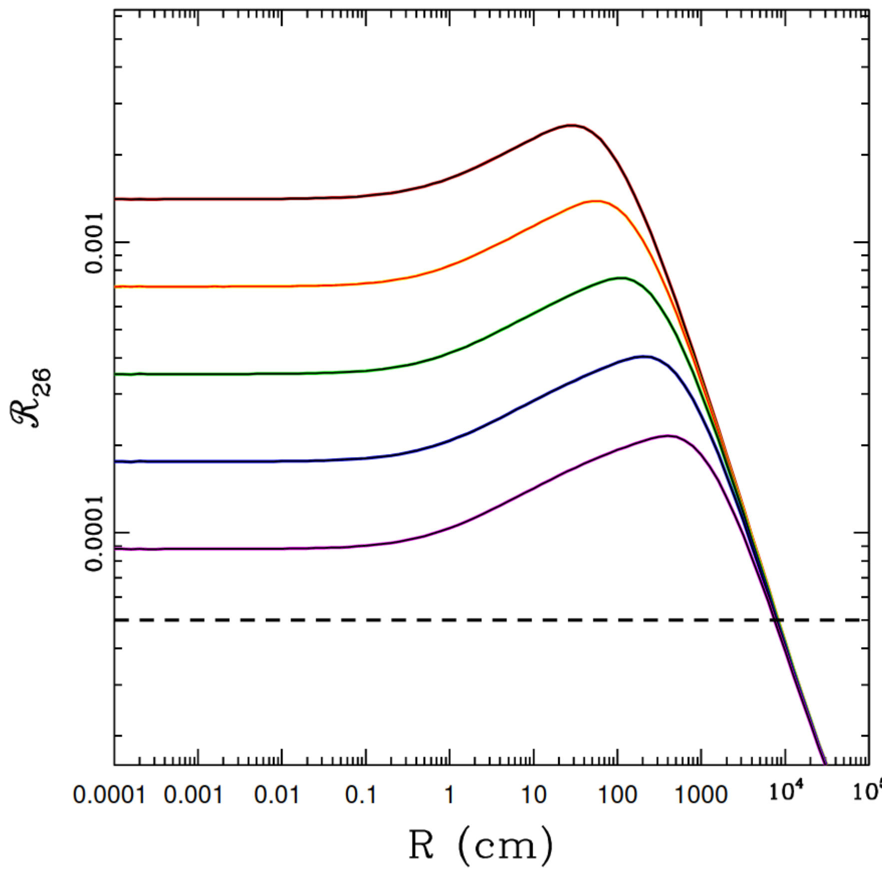


Figure 2: Estimated abundance ratio $\mathcal{R}_{26}$ (for $^{26}$Al/$^{27}$Al) as a function of the radius $R$ of the rocky bodies exposed to the cosmic radiation. Results are shown for different total amounts of rocky material in the reconnection annulus. The curves correspond to increasing total mass from top to bottom: $M_R/M_\oplus$ = 1/2 (red), 1 (orange), 2 (green), 4 (blue), and 8 (magenta). The lower dashed line marks the abundance ratio inferred for our solar system.

## Transmission spectroscopy with VLT FORS2: a featureless spectrum for the low-density transiting exoplanet WASP-88b

*P. Spyratos*[1], *N. Nikolov*[2], *J. Southworth*[1], *S. Constantinou*[3], *N. Madhusudhan*[3], *A. L. Carter*[4], *E. J. W. de Mooij*[5], *J. J. Fortney*[4], *N. P. Gibson*[6], *J. M. Goyal*[7], *C. Helling*[8], *N. J. Mayne*[9], *T. Mikal-Evans*[10]

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*Monthly Notices of the Royal Astronomical Society, in press (arXiv:2106.14808)*

We present ground-based optical transmission spectroscopy of the low-density hot Jupiter WASP-88b covering the wavelength range $4413 - 8333$ Å with the FORS2 spectrograph on the Very Large Telescope. The FORS2 white light curves exhibit a significant time-correlated noise which we model using a Gaussian Process and remove as a wavelength-independent component from the spectroscopic light curves. We analyse complementary photometric observations from the Transiting Exoplanet Survey Satellite and refine the system properties and ephemeris. We find a featureless transmission spectrum with increased absorption towards shorter wavelengths. We perform an atmospheric retrieval analysis with the AURA code, finding tentative evidence for haze in the upper atmospheric layers and a lower likelihood for a dense cloud deck. Whilst our retrieval analysis results point toward clouds and hazes, further evidence is needed to definitively reject a clear-sky scenario.

*Download/Website:* `https://arxiv.org/abs/2106.14808`

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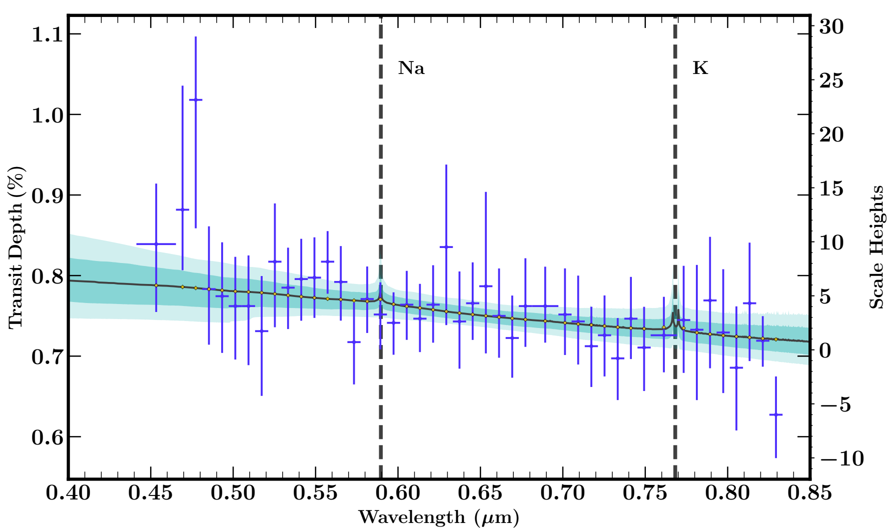


Figure 3: The median retrieved transmission spectrum of our AURA retrieval (black) and corresponding 1- and 2-$\sigma$ contours (dark and light turquoise, respectively). Vertical dashed lines denote the locations of the Na and K absorption peaks.

## Generic Models for Disk-Resolved and Disk-Integrated Phase Dependent Linear Polarization of Light Reflected from Exoplanets

*Aritra Chakrabarty*[1,2], *Sujan Sengupta*[1]

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*The Astrophysical Journal, in press (arXiv:2106.09434)*

Similar to the case of solar system planets, reflected starlight from exoplanets is expected to be polarized due to atmospheric scattering and the net disk integrated polarization should be non-zero owing to the asymmetrical illumination of the planetary disk. The computation of the disk-integrated reflected flux and its state of polarization involves techniques for the calculation of the local reflection matrices as well as the numerical recipes for integration over the planetary disks. In this paper, we present a novel approach to calculate the azimuth-dependent reflected intensity vectors at each location on the planetary disk divided into grids. We achieve this by solving the vector radiative transfer equations that describe linear polarization. Our calculations incorporate self-consistent atmospheric models of exoplanets over a wide range of equilibrium temperature, surface gravity, atmospheric composition, and cloud structure. A comparison of the flux and the amount of polarization calculated by considering both single and multiple scattering exhibits the effect of depolarization due to multiple scattering of light depending on the scattering albedo of the atmosphere. We have benchmarked our basic calculations against some of the existing models. We have also presented our models for the hot Jupiter HD 189733 b, indicating the level of precision required by future observations to detect the polarization of this planet in the optical and near-infrared wavelength region. The generic nature and the accuracy offered by our models make them an effective tool for modeling the future observations of the polarized light reflected from exoplanets.

*Download/Website:* `https://arxiv.org/abs/2106.09434`

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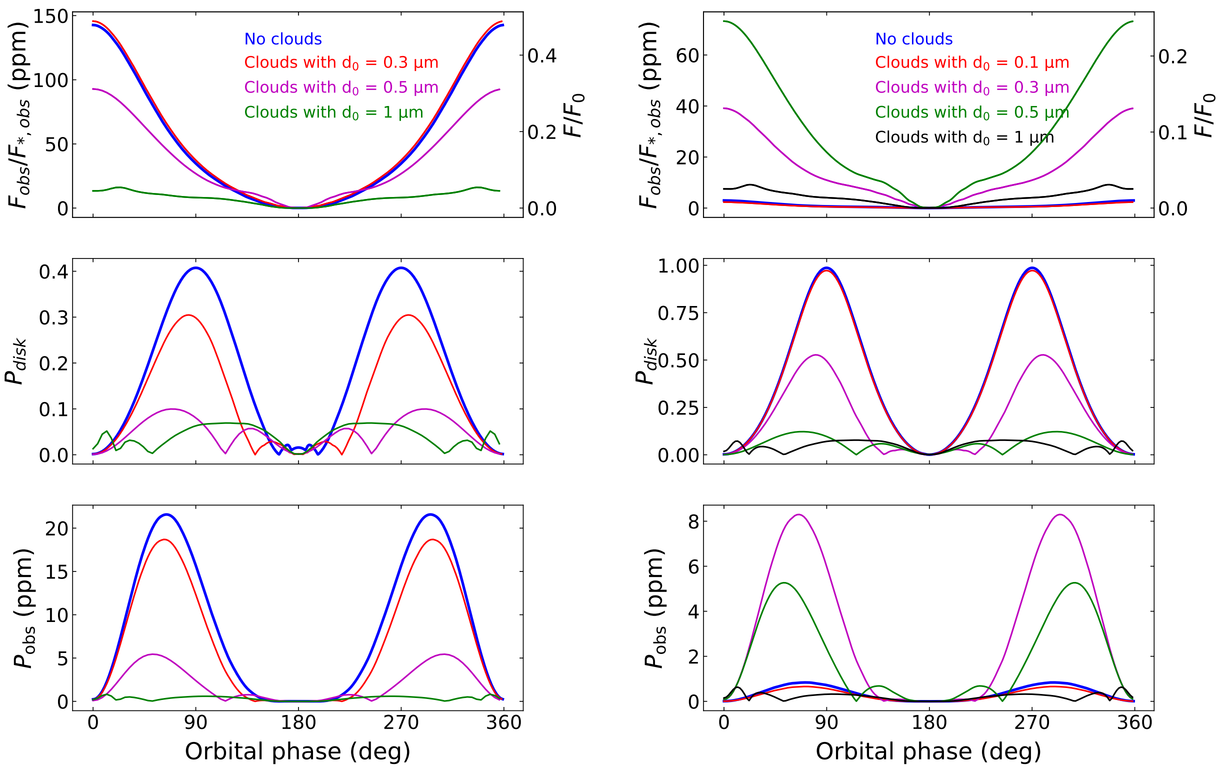


Figure 4: Models for the phase curves of the observable reflected flux and polarization from the hot Jupiter HD 189733 b at $\lambda = 0.55\ \mu$m. Top: Albedo ($F/F_0$) of the planet shown on the right axis and observed contrast of the reflected flux with respect to the host star flux ($F_{obs}/F_{*,obs} = F/F_* \frac{R_P^2}{R_*^2}$) shown on the left axis. Center: Disk-integrated polarization of the planet ignoring the flux from the host star. Bottom: Observable degree of polarization ($P_{obs}$) of the unresolvable star-planet pair. Left: Models without the presence of the atomic absorbers such as Na and K in the atmosphere. Right: Models in the presence of Na and K in the atmosphere, indicating lower degree of observable polarization than the left models.

## Evidence for TiO in the atmosphere of the hot Jupiter HAT-P-65 b

*G. Chen*[1,2], *E. Pallé*[3,4], *H. Parviainen*[3,4], *F. Murgas*[3,4], *F. Yan*[5]
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*Astrophysical Journal Letters, published (2021ApJ...913L..16C)*

We present the low-resolution transmission spectra of the puffy hot Jupiter HAT-P-65b (0.53 $\mathrm{M_{Jup}}$, 1.89 $\mathrm{R_{Jup}}$, $T_{\mathrm{eq}} = 1930$ K), based on two transits observed using the OSIRIS spectrograph on the 10.4 m Gran Telescopio CANARIAS (GTC). The transmission spectra of the two nights are consistent, covering the wavelength range 517–938 nm and consisting of mostly 5 nm spectral bins. We perform equilibrium-chemistry spectral retrieval analyses on the jointly fitted transmission spectrum and obtain an equilibrium temperature of $1645^{+255}_{-244}$ K and a cloud coverage of $36^{+23}_{-17}\%$, revealing a relatively clear planetary atmosphere. Based on free-chemistry retrieval, we report strong evidence for TiO. Additional individual analyses in each night reveal weak-to-moderate evidence for TiO in both nights, but moderate evidence for Na or VO only in one of the nights. Future high-resolution Doppler spectroscopy as well as emission observations will help confirm the presence of TiO and constrain its role in shaping the vertical thermal structure of HAT-P-65b's atmosphere.

*Download/Website:* `https://ui.adsabs.harvard.edu/abs/2021ApJ...913L..16C/abstract`

*Contact:* `guochen@pmo.ac.cn`

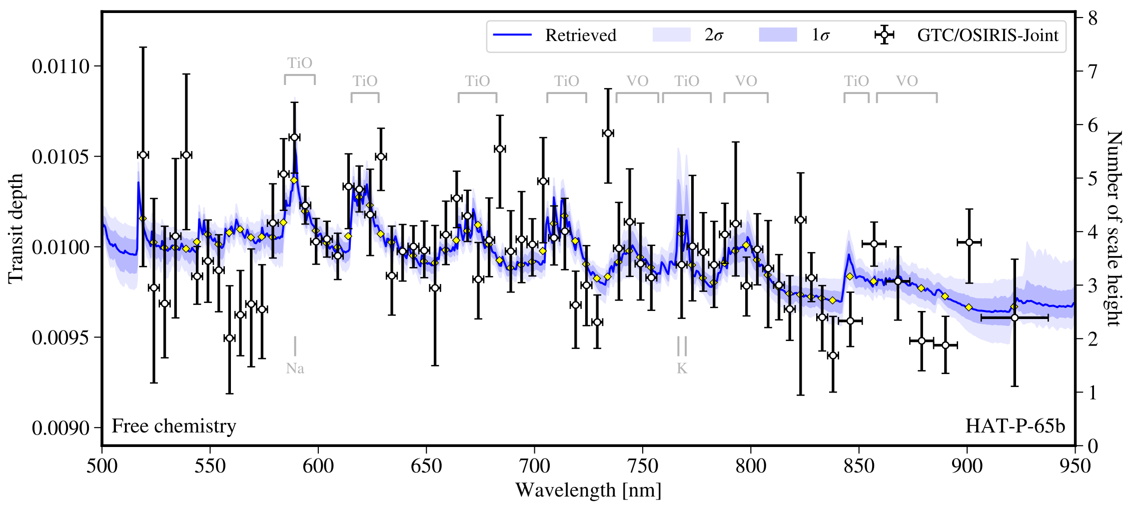


Figure 5: Transmission spectrum of HAT-P-65b jointly derived from two transits observed with GTC/OSIRIS (white circles with error bars) and retrieved atmospheric models assuming free chemistry (blue line and shaded areas).

# 3 Jobs and Positions

## Investigating the interaction between life and the atmosphere on the early Earth and on Earth-like planets

*DLR*

*Berlin, Deadline 31.08.2021*

This position is concerned with basic scientific research investigating the interaction between life and the atmosphere on the early Earth and on Earth-like planets. During the evolution of the Earth, cycles linking the geophysics of the planetary interior and surface with the atmosphere likely played an important role. This study involves the implementation of these processes as well as the analysis of exoplanet scenarios with the Coupled Atmosphere Biogeochemistry (CAB) model and validation of model results via the use of an M-dwarf star lamp at DLR laboratories. The department *Extrasolar Planets and Atmospheres* (EPA) at the Institute of Planetary Research of DLR deals with the detection of extrasolar planets as well as the numerical modeling of habitability and atmospheric biosignatures on terrestrial planets. On the subject of planetary structure and interior, it works closely with the *Planetary Physics* department. EPA is a leading participant in the European satellite missions for the search and characterization of extrasolar planets (*CHEOPS, PLATO*) as well as in ground-based instruments/telescopes.
Modelers in the PF-EPA group are developing a radiative-convective climate model with coupled photochemistry to study the atmospheric temperature structure and chemical composition of rocky exoplanets and gas-rich sub-Neptunes. In particular, the work focuses on modeling small exoplanets in the habitable zone around cooler central stars. Such stars are particularly common in the solar neighborhood and are favorable targets for exoplanet observations with missions such as *CHEOPS* and *PLATO*.
Your tasks:

- Implementation of carbon (C)-nitrogen (N)-sulfur (S) biogeochemistry cycles in the coupled Atmosphere Biogeochemistry (CAB) model available at EPA
- validation of the implementation with laboratory data
- analysis of exoplanet scenarios with the model, use of the M-dwarf star lamp at the DLR laboratory

You can find the required qualification and the application procedure under the following link
https://www.dlr.de/dlr/jobs/en/desktopdefault.aspx/tabid-10596/1003_read-46360/1003

*Download/Website:*
`https://www.dlr.de/dlr/jobs/en/desktopdefault.aspx/tabid-10596/1003_read-46360/`

# 4 Announcements

## Petition for Codes of Social Conduct in Astronomy Collaborations

*Clémence Fontanive[1], Cassandra Hall[2], Richard Alexander[3], Shawn Domagal-Goldman[4], René Doyon[5], B. Scott Gaudi[6], Michael R. Meyer[7], John O'Meara[8], Ken Rice[9], Aki Roberge[4]*

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[2] University of Georgia, USA
[3] University of Leicester, UK
[4] NASA Goddard Space Flight Center, USA
[5] Université de Montréal, Canada
[6] The Ohio State University, USA
[7] The University of Michigan, USA
[8] W. M. Keck Observatory, USA
[9] University of Edinburgh, UK

*Open Letter to the Community, online*

Many official collaborations in astronomy lack Codes of Social Conduct, with policies in place to deal with cases of behavioural misconduct. We believe Codes of Conduct to be important tools to make academia a safe, respectful and inclusive environment. We have therefore written an Open Letter to the Community soliciting their introduction in all astronomy collaborations, consortia and science teams, with the hope to encourage and normalise their implementation.

You can read and sign the Letter at the following links:

- View Petition: http://bit.ly/AstroCodesOfConduct
- Sign Petition: http://bit.ly/SignCodesOfConduct

Please consider adding your name to ours and sharing the petition with your colleagues. Thank you very much for your support.

*Download/Website:* `http://bit.ly/AstroCodesOfConduct`
*Contact:* `clemence.fontanive@unibe.ch`

## Atmospheres, Atmospheres! Do I look like I care about atmospheres?

*Conference Chair(s): Eleonora Alei[1], Henri Boffin[2], Nuria Casasayas Barris[3], Stella Chasiotis-Klingner[2], Camilla Danielski[4], Chloe Fisher[5], Siddharth Gandhi[6] Ryan MacDonald[7], Emily Rickman[8], Elyar Sedaghati[2], Jiri Zak[2]*

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[2] ESO
[3] Leiden Observatory, Netherlands
[4] IAA Granada, Spain
[5] University of Bern, Switzerland
[6] Warwick Univeristy, UK
[7] Cornell University, USA
[8] ESA, STScI, Baltimore, USA

*Online Conference, 23-27 August 2021*

ESO is pleased to announce the conference "Atmospheres, Atmospheres! Do I look like I care about atmospheres?" that will take place online from 23 to 27 August 2021. The conference is scheduled to take place online (as a Zoom meeting), for 5 hours each day of the program. We anticipate the live program to start at 1 pm CEST and finish at 6 pm CEST.

*Important Dates*:
25 July 2021: Abstract and lecture registration deadline
15 August 2021: Conference registration deadline
23-27 August 2021: Conference dates

*Rationale*:
This conference will bring together the community working theoretically and observationally on understanding exoplanet atmospheres by transmission and emission spectroscopy, with an emphasis on using ground-based facilities. It aims also to bring together those working on the atmospheres of close-in exoplanets and those studying the atmospheres of giant planets in our Solar System, in order to compare methodologies and see where synergies exist or could be made. The conference has as further goal to prepare the next generation of astronomers to embark on this exciting and essential area of astrophysics, which is technically very challenging. Therefore, the conference is split into two separate events: the first two days are devoted to lectures and hands-on sessions and are aimed primarily at students (including master students) and other astronomers wishing to start in the field. The number of participants to this part of the conference will be limited to ensure the highest interaction possible, and if needed a selection of participants will be done by the organisers. The last three days of the conference will consist in a series of invited and contributed talks. In addition, the conference will include time allocated for discussions and social interactions. The conference will have dedicated breakout groups on Slack to foster discussions and post files. We anticipate discussion on Slack to start one week before the conference. The deadline for registration for the lectures and for abstract submission is 25 July 2021. Registration for the second part of the conference will be possible until 15 August 2021. To register please fill in the registration form available on the website. Registration is free. Please act responsibly and attend the conference if you register. To cancel your registration, please email atmo2021@eso.org. Details will be emailed to registered participants closer to the conference dates.

*Download/Website:* `https://www.eso.org/sci/meetings/2021/Atmo2021.html`

*Contact:* `atmo2021@eso.org`

## AGU 2021 Session P003 - Atmospheric Dynamics and Astro/geo-physical Modeling Studies of Habitable Ocean Worlds, Moons, and Atmospheres Near and Far

*Conveners: J.J. Fortney[1], Y. Kaspi[2], T.D. Komacek[3], and K.M. Sayanagi[4]*

[1] University of California Santa Cruz
[3] Weizmann Institute of Science
[3] University of Chicago
[4] Hampton University

*New Orleans, USA & Online Everywhere, 13-17 December 2021*

The realm of Geophysical and Astrophysical Fluid Dynamics (GAFD) has significantly expanded in phase space to include a wide variety of physical regimes. Models originally developed for phenomena on Earth and across the solar system are now being applied to exoplanets across vast parameter regimes. Atmospheric circulation models are being tested against new observational constraints, as from the Juno Mission. On the other extreme of the Reynolds number, modeling convection in ice shells offer explanations for many geological features on the surfaces of potentially habitable ocean worlds across the solar system. In addition, tools from the astrophysical context are now being applied to planetary science problems. This session aims to bring together a wide cross-section of these diverse communities that use a variety of practices and state-of-the-art methods. We expect an engaging session that focuses on new results in exoplanetary and solar system science, as well as computational methodology.

*Download/Website:* `https://www.agu.org/Fall-Meeting`

*Contact:* `tkomacek@uchicago.edu`

## Multidisciplinary perspectives on the formation and early evolution of terrestrial worlds (AGU 2021 session)

*Conveners: Dongyang Huang[1], Rebecca A. Fischer[2], Tim Lichtenberg[3], Laura K. Schaefer[4],*

[1] Department of Earth Sciences, ETH Zurich, CH
[2] Department of Earth and Planetary Sciences, Harvard University, USA
[3] Atmospheric, Oceanic and Planetary Physics, University of Oxford, UK
[4] Department of Geological Sciences, Stanford University, USA

*New Orleans/USA & Online, 13–17 December 2021*

We invite contributions to the session *"Multidisciplinary perspectives on the formation and early evolution of terrestrial worlds"* at the AGU Fall Meeting from 13–17 December 2021, New Orleans, USA & Online. Contributions from different perspectives are encouraged to address the early history of rocky planets, including, but not limited to, geochemistry, cosmochemistry, astronomy, mineral physics, petrology, and planetary sciences. The deadline for submissions is *Wednesday, 4 August 2021*. We look forward to seeing you in New Orleans and online!

*Session description*: Accretionary processes are fundamental to our understanding of the thermal and compositional evolution of rocky planets in the solar system and beyond. Advances in experiments under extreme $P$-$T$ conditions, theoretical modelling across atomic and planetary scales, and observations at a system-level are key to unravelling the early history of rocky, potentially habitable worlds. In particular, processes related to planetary accretion and evolution, such as condensation, impacts, (de-)volatilization, atmosphere formation, core-mantle differentiation, and climate diversity have been increasingly constrained by planetary sample analysis, laboratory experiments, theoretical simulations, and astronomical observations of extrasolar planetary systems. In this session, we invite interdisciplinary contributions that address the various physical and chemical aspects of planetary accretion and differentiation, including geochemistry, cosmochemistry, astronomy, mineral physics, petrology, and planetary sciences. *Session mentee: Gabriel Nathan*

*Invited Speakers*: Asmaa Boujibar (Carnegie), Jie Li (U Michigan)
*Sections*: Study of Earth's Deep Interior, Mineral and Rock Physics, Planetary Science
*Themes*: Origin and evolution, Planetary atmospheres, Interiors, Planetary Geochemistry

*Download/Website:* `https://agu.confex.com/agu/fm21/prelim.cgi/Session/123642`

## Call for NASA Keck Key Strategic Mission (KSMS) Support Proposals for 2022A

*Dr. Dawn M. Gelino, NASA Exoplanet Science Institute*

*KSMS NOIs Due: August 16, 2021 at 4 pm PDT,*

*Proposals Due: September 16, 2021 at 4 pm PDT,*

NASA is a 1/6 partner in the W. M. Keck telescopes and allocates 47 nights per semester. For the upcoming 2022A proposal cycle, in addition to General Observing and Mission Support proposals, NASA is also soliciting proposals for large Key Strategic Mission Support (KSMS) programs. Also starting in 2022A, the NASA Keck proposal review will use the Dual Anonymous Proposal Review (DAPR) process.

The opportunity to propose as Principal Investigators (PIs) for the NASA time on the Keck Telescopes is open to all U.S.-based astronomers, i.e., those with their principal affiliation at a U.S. institution. Astronomers at non-U.S.-based institutions may serve as Co-Is.

KSMS projects may support past, present, and/or future missions, now including JWST. Between 10 - 60 nights total over two years (2022A-2023B) will be allocated between one or more KSMS projects with a maximum of 15 nights per semester. An important element of the KSMS programs is a plan for timely release of processed data in a form suitable for use by the broader community as a contributed dataset through the Keck Observatory Archive (KOA).

Proposers planning to submit a KSMS proposal must submit a required but non-binding Notice of Intent (NOI) by August 16, 2021. The NOI should contain the PI and co-I names and affiliations, the program title, a short abstract, and identify the supported mission(s).

For more information on KSMS proposals, please see full announcement here: https://nexsci.caltech.edu/missions/KSA/22A_KSMS.pdf

Important Dates:

- July 30, 2021: Call for Proposals and NOI submission site available
- August 16, 2021: KSMS NOIs due to NExScI by 4 pm Pacific
- September 2, 2021: Deadline to request a written letter of endorsement from NASA Headquarters
- September 16, 2021: All proposals and letters of support due to NExScI by 4 pm Pacific

*Contact:* `keckcfp@ipac.caltech.edu`

## The sonification of exoplanetary motions using Kepler's original algorithm

*Frederic V. Hessman*[1]
[1] Institut für Astrophysik, Univ. Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

*Göttingen, July 9, 2021*

In 1619, Johannes Kepler published his theory for planetary motion: he assumed the proper motions of the planets as seen from the central host are proportional to the frequency of virtual planetary tones and that, together, these tones form cosmic musical chords. He was sure of the divine origin of the motion because the planets known to him occasionally form harmonious major or minor chords.

Exoplanetary systems offer a whole new universe of cosmic chords. The systems with mean-motion resonances are particularly interesting because resonant orbits result in harmonious Pythagorean chords: 2:1 is a musical octave, 3:2 a fifth, 4:3 a fourth, 5:4 a major third, 6:5 a minor third, etc. Most systems are not in perfect resonance, so they sound ”out-of-tune” (see and hear the wonderful sonification of Trappist-1 by Russo et al. at https://www.system-sounds.com) but Kepler could only conceive of the distinct tones expressed in Western music notation and played by nearly all Western musicians, so he intended us to round the planetary frequencies to the nearest musical note. These notes – expressing the relative motions of the planets – can then be printed in the form of a musical score and given to any band, choir, or orchestra to play. Because the tonal range of planetary systems is larger than that of a choir or orchestra, the notes often have to be shifted up or down by one or more octaves, fortunately leaving the underlying harmony relatively unaffected.

I have produced sonifications (MP3) and scores (PDF) for most of the known exoplanetary systems with 4 or more planets (more will be added as I get to them): they are available for public use at the URL given below. License for scientific use (e.g. public talks) is given, permission for performance is gladly given upon request.

**Editorial Note:**
**To visit the webpage given below, please replace the 'tilde' character (before "hessman") in the url address with an actual tilde character (from your keyboard). The inconvenience is regretted.**

*Download/Website:*
`http://www.astro.physik.uni-goettingen.de/~hessman/TheMusicOfTheExoplanets/`

*Contact:* `hessman@astro.physik.uni-goettingen.de`


Figure 6: Part of a Keplerian score for Kepler-11.

# 5 Exoplanet Archive Updates

## June Updates at the NASA Exoplanet Archive

*The NASA Exoplanet Archive team*
Caltech/IPAC-NASA Exoplanet Science Institute, MC 100-22 Pasadena CA 91125

*Pasadena CA USA, July 13, 2021*

**Note:** Unless otherwise noted, all planetary and stellar data mentioned in the news are in the Planetary Systems Table (`http://bit.ly/2Pt0tM1`), which provides a single location for all self-consistent planetary solutions, and its companion table the Planetary Systems Composite Parameters (`https://bit.ly/2Fer9NU`), which offers a more complete table of parameters combined from multiple references and calculations. Data can also be found in the Microlensing Planets Table (`https://bit.ly/3urUyZU`) or Direct Imaging Planets Table (`http://bit.ly/3ayD185`).

**June 17, 2021**

**21 New Planets Include Two Found by Citizen Scientists**
We've added 21 planets this week, two of which were discovered by citizen scientists participating in the Zooniverse Planet Hunters TESS project (`https://bit.ly/3AIlVlW`). See the System Overview page for HD 152843 (`https://bit.ly/36jGG9E`) and NASA's news release featuring some of the co-authors (`https://go.nasa.gov/3AJqhZR`).

The other new planets this week are WASP-110 b, Kepler-1703 b (KOI-3503.01), Kepler-1703 c (KOI-3503.02), Kepler-324 d (KOI-1831.03), Kepler-968 d (KOI-1833.02), HD 107148 c, HD 136925 b, HD 141004 b, HD 145675 c, HD 156668 c, HD 164922 e, HD 168009 b, HD 213472 b, HD 24040 c, HD 26161 b, HD 3765 b, HD 66428 c, HD 68988 c, and HD 95735 c.

**New Spitzer Kepler Survey (SpiKeS) Contributed Data**
This latest contributed data set by Werner et al. 2021 (https://bit.ly/2UCNyfO) provides the highest-precision infrared photometry of 200,000 Kepler field stars to help identify Kepler targets that may be blended binaries or have dusty material orbiting the stars. The data file can be downloaded from the SpiKeS documentation page (`https://bit.ly/3hr0caD`).

**June 3, 2021**

**12 New Planets, Including Rare Neptune-sized Gas World**
This week's crop of exoplanets includes TOI-1231 b, a Neptune-sized gas world that orbits a very bright red-dwarf star—a rare occurrence that may provide opportunities for atmospheric data observations for exoplanet characterization. Read NASA's Discovery Alert (`https://go.nasa.gov/36jIdwq`) for details.

Check out TOI-1231 b's System Overview page (`https://bit.ly/3hICrcY`), as well as those for the other 11 planets: YSES-2 b, TOI-220 b, TOI-1444 b & c, BD+45 564 b, BD+55 362 b, BD+63 1405 b, HD 124330 b, HD 155193 b, HD 331093 b, and BD-00 4475 b.

*Download/Website:* `https://exoplanetarchive.ipac.caltech.edu`

*Contact:* `mharbut@caltech.edu`

# 6 As seen on Exoplanet-talks.org

*Download/Website:* `http://exoplanet-talks.org`
*Contact:* `info@exoplanet-talks.org`

*Instruction video:* http://exoplanet-talks.org/talk/164

**A Stellar Mass Dependence of Structured Disks: A Possible Link with Exoplanet Demographics** by *Nienke van der Marel* – talk/375
**TESS Legacy: the brightest, closest transiting planets for atmospheric studies** by *Rafael Luque* = talk/376

**JWST ERS Pre-Launch Data Hackaton:**
**How do we study the atmospheres of transiting exoplanets?** by *David Sing* – talk/361
**How do we get started working with JWST data during this hackathon?** by *Zach Berta-Thompson* – talk/363
**Welcome and Overview of the ERS Program** by *Natalie Batalha* – talk/364
**JWST Data: What does it look like? How to calibrate it? What to expect?** by *Néstor Espinoza* – talk/365
**Introduction to git and GitHub** by *Christina Hedges* – talk/366
**How do we go from detector pixels to extracted stellar spectra?** by *Nicolas Crouzet* – talk/367
**What lessons have we learned?** by *Laura Kreidberg* – talk/368
**How to engage with the JWST Calibration Pipeline?** by *Nestor Espinoza* – talk/369
**Eureka Tutorial** by *Laura Kreidberg* – talk/370
**Challenges in Exoplanet Timeseries Observations** by *Hannah Wakeford* – talk/371
**Physical Models for Transiting Planets** by *Kevin Stevenson* – talk/372
**Hannah Wakeford, Munazza Alam, Neale Gibson, Laura Kreidberg, Bjorn Benneke: Panel Discussion on Instrumental Systematics** by *Zach Berta-Thompson* – talk/373
**Tutorial on Fitting a Transit with Gaussian Processes** by *Neil Gibson* – talk/374

# 7 As seen on astro-ph

The following list contains exoplanet related entries appearing on astro-ph in June 2021.

**June 2021**

astro-ph/2106.00079: **Fundamental Challenges to Remote Sensing of Exo-Earths** by *Adiv Paradise et al.*
astro-ph/2106.00441: **Accretion of tidally disrupted asteroids onto white dwarfs: direct accretion versus disk processing** by *Daohai Li, Alexander J. Mustill, Melvyn B. Davies*
astro-ph/2106.00493: **Biosignatures of the Earth I. Airborne spectropolarimetric detection of photosynthetic life** by *C.H. Lucas Patty et al.*
astro-ph/2106.00584: **Chaotic diffusion of the fundamental frequencies in the Solar System** by *Nam H. Hoang, Federico Mogavero, Jacques Laskar*
astro-ph/2106.00685: **L 98-59: a Benchmark System of Small Planets for Future Atmospheric Characterization** by *Daria Pidhorodetska et al.*
astro-ph/2106.00688: **Quantifying the Similarity of Planetary System Architectures** by *Dolev Bashi, Shay Zucker*
astro-ph/2106.00713: **J-PLUS: A first glimpse at spectrophotometry of asteroids – The MOOJa catalog** by *David Morate et al.*
astro-ph/2106.00972: **Predicting exoplanet mass from radius and incident flux: A Bayesian mixture model** by *Qi Ma, Sujit K Ghosh*
astro-ph/2106.01081: **Observation of bottom-up formation for charged grain aggregates related to pre-planetary evolution beyond the bouncing barrier** by *Felix Jungmann, Gerhard Wurm*
astro-ph/2106.01159: **Observability of the Vertical Shear Instability in protoplanetary disk CO kinematics** by *Marcelo Barraza-Alfaro et al.*
astro-ph/2106.01246: **TOI-674b: an oasis in the desert of exo-Neptunes transiting a nearby M dwarf** by *F. Murgas et al.*
astro-ph/2106.01365: **Testing whether a signal is strictly periodic. Application to disentangling planets and stellar activity in radial velocities** by *Nathan C. Hara et al.*
astro-ph/2106.01531: **Chiral Selection, Isotopic Abundance Shifts, and Autocatalysis of Meteoritic Amino Acids** by *Michael A. Famiano et al.*
astro-ph/2106.01533: **Matters Arising on "Breakup of a long-period comet as the origin of the dinosaur extinction" by Siraj Loeb** by *Steven J. Desch et al.*
astro-ph/2106.01558: **The Growth of Protoplanets via the Accretion of Small Bodies in Disks Perturbed by the Planetary Gravity** by *Tatsuya Okamura, Hiroshi Kobayashi*
astro-ph/2106.01753: **On the stability of planetary orbits in binary star systems I. The S-type orbits** by *G. De Cesare, R. Capuzzo-Dolcetta*
astro-ph/2106.01911: **Detection of Dynamical Instability in Titan's Thermospheric Jet** by *M. A. Cordiner et al.*
astro-ph/2106.02061: **How Deep Is the Ocean? Exploring the phase structure of water-rich sub-Neptunes** by *Matthew C. Nixon, Nikku Madhusudhan*
astro-ph/2106.02079: **The orbit and density of the Jupiter Trojan satellite system Eurybates-Queta** by *M.E. Brown et al.*
astro-ph/2106.02188: **A differentiable N-body code for transit timing and dynamical modeling. I. Algorithm and derivatives** by *Eric Agol, David M. Hernandez, Zachary Langford*
astro-ph/2106.02276: **Relativistic Dynamical Stability Criterion of Multi-Planet Systems with a Distant Companion** by *Lingfeng Wei et al.*
astro-ph/2106.02610: **Visible-light Phase Curves from the Second Year of the TESS Primary Mission** by *Ian Wong et al.*
astro-ph/2106.02659: **Recurring Planetary Debris Transits and Circumstellar Gas around White Dwarf ZTF J03281219** by *Zachary P. Vanderbosch et al.*

astro-ph/2106.02660: **Chemical signatures of a warped protoplanetary disc** by *Alison K. Young et al.*
astro-ph/2106.03570: **Evidence for a sublimated water atmosphere on Ganymede from Hubble Space Telescope observations** by *Lorenz Roth et al.*
astro-ph/2106.03607: **Gravito-turbulence and dynamo in poorly ionised protostellar discs. I. Zero-net-flux case** by *A. Riols et al.*
astro-ph/2106.03615: **Molecular mapping of the PDS70 system: No molecular absorption signatures from the forming planet PDS70 b** by *G. Cugno et al.*
astro-ph/2106.03657: **The Total Solar Irradiance variability in the Evolutionary Timescale and its Impact on the Mean Earth's Surface Temperature** by *N.T. Shukure, S.B Tessema, N. Gopalswamy*
astro-ph/2106.03848: **How planets grow by pebble accretion IV: Envelope opacity trends from sedimenting dust and pebbles** by *M. G. Brouwers et al.*
astro-ph/2106.03863: **Re-evaluation of Lunar X-ray observations by Apollo 15 16** by *Anniek J. Gloudemans et al.*
astro-ph/2106.03999: **How much water was delivered from the asteroid belt to the Earth after its formation?** by *Rebecca G. Martin, Mario Livio*
astro-ph/2106.04431: **The similarity of the interstellar comet 2I/Borisov to solar system comets from high resolution optical spectroscopy** by *C. Opitom et al.*
astro-ph/2106.04601: **The entry geometry and velocity of planetary debris into the Roche sphere of a white dwarf** by *Dimitri Veras et al.*
astro-ph/2106.04603: **Planet Hunters TESS III: two transiting planets around the bright G dwarf HD 152843** by *Nora L. Eisner et al.*
astro-ph/2106.04617: **A minimal model for vertical shear instability in protoplanetary accretion disks** by *Ron Yellin-Bergovoy, Eyal Heifetz, Orkan M. Umurhan*
astro-ph/2106.04637: **Constraining the effect of convective inhibition on the thermal evolution of Uranus and Neptune** by *Steve Markham, Dave Stevenson*
astro-ph/2106.04648: **Possible evidence of p-modes in Cassini measurements of Saturn's gravity field** by *Steve Markham et al.*
astro-ph/2106.04701: **Atomic iron and nickel in the coma of C/1996 B2 (Hyakutake): production rates, emission mechanisms, and possible parents** by *Steven Bromley et al.*
astro-ph/2106.04736: **Analysis of Hybrid Gas-Dust Outbursts Observed at 67P/Churyumov-Gerasimenko** by *John W. Noonan et al.*
astro-ph/2106.04737: **Spatial Distribution of Ultraviolet Emission from Cometary Activity at 67P/Churyumov-Gerasimenko** by *John W. Noonan et al.*
astro-ph/2106.05011: **Uncovering the ultimate planet impostor. An eclipsing brown dwarf in a hierarchical triple with two evolved stars** by *J. Lillo-Box et al.*
astro-ph/2106.05045: **Searching for Saturn's X-rays during a rare Jupiter Magnetotail Crossing using Chandra** by *D. M. Weigt et al.*
astro-ph/2106.05273: **Detection of Ongoing Mass Loss from HD 63433c, a Young Mini Neptune** by *Michael Zhang et al.*
astro-ph/2106.05276: **The early instability scenario: Mars' mass explained by Jupiter's orbit** by *Matthew S. Clement et al.*
astro-ph/2106.05362: **The general applicability of self-similar solutions for thermal disc winds** by *Andrew D. Sellek, Cathie J. Clarke, Richard A. Booth*
astro-ph/2106.05975: **High resolution ALMA and HST images of q1 Eri: an asymmetric debris disc with an eccentric Jupiter** by *J. B. Lovell et al.*
astro-ph/2106.06156: **The TESS-Keck Survey: Science Goals and Target Selection** by *Ashley Chontos et al.*
astro-ph/2106.06240: **Planetesimal Dynamics in the Presence of a Giant Planet** by *Kangrou Guo, Eiichiro Kokubo*
astro-ph/2106.06523: **Recovery of Meteorites Using an Autonomous Drone and Machine Learning** by *Robert*

*I. Citron et al.*
astro-ph/2106.06550: **Planetary Systems Around White Dwarfs** by *Dimitri Veras*
astro-ph/2106.06686: **Systematic KMTNet Planetary Anomaly Search, Paper II: Five New q¡2104 Mass-ratio Planets** by *Kyu-Ha Hwang et al.*
astro-ph/2106.07058: **The architecture of multi-planet systems as a tracer of their formation mechanisms** by *Udit Arora, Yasuhiro Hasegawa*
astro-ph/2106.07301: **YARARA: Significant improvement of RV precision through post-processing of spectral time-series** by *M. Cretignier et al.*
astro-ph/2106.07403: **Meteor colorimetry with CMOS cameras** by *B. E. Zhilyaev et al.*
astro-ph/2106.07443: **CHEOPS Precision Phase Curve of the Super-Earth 55 Cnc e** by *B.M. Morris et al.*
astro-ph/2106.07648: **LBT Reveals Large Dust Particles and a High Mass Loss Rate for K2-22 b** by *Everett Schlawin et al.*
astro-ph/2106.07659: **Constraining Saturn's interior with ring seismology: effects of differential rotation and stable stratification** by *Janosz W. Dewberry et al.*
astro-ph/2106.07680: **The Effect of Inefficient Accretion on Planetary Differentiation** by *Saverio Cambioni et al.*
astro-ph/2106.07729: **Possibilities for an Aerial Biosphere in Temperate Sub Neptune-Sized Exoplanet Atmospheres** by *Sara Seager et al.*
astro-ph/2106.07757: **ALMA 870 $\mu$m continuum observations of HD 100546. Evidence of a giant planet on a wide orbit** by *D. Fedele et al.*
astro-ph/2106.07809: **The aftermath of convective events near Jupiter's fastest prograde jet: implications for clouds, dynamics and vertical wind shear** by *Ramanakumar Sankar, Chloe Klare, Csaba Palotai*
astro-ph/2106.08249: **GRAVITY K-band spectroscopy of HD 206893 B: brown dwarf or exoplanet** by *J. Kammerer et al.*
astro-ph/2106.08349: **Presence of water on exomoons orbiting free-floating planets: a case study** by *Patricio Javier Ávila et al.*
astro-ph/2106.08369: **Peculiar orbits and asymmetries in extreme trans-Neptunian space** by *C. de la Fuente Marcos, R. de la Fuente Marcos*
astro-ph/2106.08538: **Waterworlds Probably Do Not Experience Magmatic Outgassing** by *Joshua Krissansen-Totton et al.*
astro-ph/2106.08660: **Discovery of an inflated hot Jupiter around a slightly evolved star TOI-1789** by *Akanksha Khandelwal et al.*
astro-ph/2106.08842: **Idealised 3D simulations of diabatically-forced Ledoux convection. Application to the atmosphere of hot rocky exoplanets** by *Simon Daley-Yates et al.*
astro-ph/2106.09025: **Collisions in a gas-rich white dwarf planetary debris disc** by *Andrew Swan et al.*
astro-ph/2106.09084: **Jupiter's "Cold" Formation in the Protosolar Disk Shadow: An Explanation for the Planet's Uniformly Enriched Atmosphere** by *Kazumasa Ohno, Takahiro Ueda*
astro-ph/2106.09091: **Rare Event Sampling Improves Mercury Instability Statistics** by *Dorian S. Abbot et al.*
astro-ph/2106.09189: **An Automated Bolide Detection Pipeline for GOES GLM** by *Jeffrey C. Smith et al.*
astro-ph/2106.09434: **Generic Models for Disk-Resolved and Disk-Integrated Phase Dependent Linear Polarization of Light Reflected from Exoplanets** by *Aritra Chakrabarty, Sujan Sengupta*
astro-ph/2106.09525: **Impact of magneto-rotational instability on grain growth in protoplanetary disks: II. Increased grain collisional velocities** by *Munan Gong et al.*
astro-ph/2106.09725: **The Occurrence-weighted Median Planets Discovered by Transit Surveys Orbiting Solar-type Stars and Their Implications for Planet Formation and Evolution** by *Kevin C. Schlaufman, Noah D. Halpern*
astro-ph/2106.09739: **A Lopsided Outer Solar System** by *Alexander Zderic et al.*
astro-ph/2106.10099: **Polarimetric signature of the oceans as detected by near-infrared Earthshine observations** by *J. Takahashi et al.*

astro-ph/2106.10167: **Global Three-Dimensional Simulations of Outer Protoplanetary Disks with Ambipolar Diffusion** by *Can Cui, Xue-Ning Bai*

astro-ph/2106.10186: **An analytical model for tidal evolution in co-orbital systems I. Application to exoplanets** by *Jérémy Couturier, Philippe Robutel, Alexandre C. M. Correia*

astro-ph/2106.10292: **Detection of Aerosols at Microbar Pressures in an Exoplanet Atmosphere** by *Raissa Estrela et al.*

astro-ph/2106.10293: **Planetary magnetosphere evolution around post-main-sequence stars** by *Dimitri Veras, Aline A. Vidotto*

astro-ph/2106.10294: **Irradiation-driven escape of primordial planetary atmospheres I. The ATES photoionization hydrodynamics code** by *Andrea Caldiroli et al.*

astro-ph/2106.10565: **The Geographic Distribution of Dense-phase O2 on Ganymede** by *Samantha K. Trumbo, Michael E. Brown, Danica Adams*

astro-ph/2106.10754: **A SOPHIE RV search for giant planets around young nearby stars (YNS). A combination with the HARPS YNS survey** by *A. Grandjean et al.*

astro-ph/2106.10794: **Secular resonance of inner test particles in hierarchical planetary systems** by *Hanlun Lei*

astro-ph/2106.10878: **An analytic solution for evaluating the magnetic field induced from an arbitrary, asymmetric ocean world** by *Marshall J. Styczinski et al.*

astro-ph/2106.11207: **Formulation and Resolutions of the Red Sky Paradox** by *David Kipping*

astro-ph/2106.11241: **Precautionary Planetary Defence** by *Aaron C. Boley, Michael Byers*

astro-ph/2106.11263: **Non-local thermodynamic equilibrium effects determine the upper atmospheric temperature structure of the ultra-hot Jupiter KELT-9b** by *L. Fossati et al.*

astro-ph/2106.11322: **Image simulation for space applications with the SurRender software** by *Jérémy Lebreton et al.*

astro-ph/2106.11331: **Exploiting timing capabilities of the CHEOPS mission with warm-Jupiter planets** by *Borsato L et al.*

astro-ph/2106.11444: **Non-detection of Helium in the upper atmospheres of TRAPPIST-1b, e and f** by *Vigneshwaran Krishnamurthy et al.*

astro-ph/2106.11470: **Knowledge Gaps in the Cometary Spectra of Oxygen-Bearing Molecular Cations** by *Ryan Fortenberry, Dennis Bodewits, Donna Pierce*

astro-ph/2106.11527: **Four new PLanetesimals Around TYpical and Pre-main seqUence Stars (PLATYPUS) Debris Discs at 8.8mm** by *Brodie J. Norfolk et al.*

astro-ph/2106.11664: **Simulating gas giant exoplanet atmospheres with Exo-FMS: Comparing semi-grey, picket fence and correlated-k radiative-transfer schemes** by *Elspeth K.H. Lee et al.*

astro-ph/2106.12003: **Global 3D Radiation Hydrodynamic Simulations of Proto-Jupiter's Convective Envelope** by *Zhaohuan Zhu et al.*

astro-ph/2106.12084: **Complex Water Ice Mixtures on NII Nereid: Constraints from NIR Reflectance** by *Benjamin N. L. Sharkey et al.*

astro-ph/2106.12358: **Understanding the Effects of Systematics in Exoplanetary Atmospheric Retrievals** by *Jegug Ih, Eliza M.-R. Kempton*

astro-ph/2106.12448: **Radiative Rayleigh-Taylor Instability and the structure of clouds in planetary atmospheres** by *P. Tremblin et al.*

astro-ph/2106.12947: **First MATISSE L-band observations of HD 179218. Is the inner 10 au region rich in carbon dust particles?** by *E.Kokoulina et al.*

astro-ph/2106.13094: **Dust environment of active asteroids P/2019 A4 (PANSTARRS) and P/2021 A5 (PANSTARRS)** by *Fernando Moreno et al.*

astro-ph/2106.13242: **Searching For Transiting Planets Around Halo Stars. II. Constraining the Occurrence Rate of Hot Jupiters** by *Kiersten M. Boley et al.*

astro-ph/2106.13251: **Searching For Transiting Planets Around Halo Stars. I. Sample Selection and Valida-**

**tion** by *Jared R. Kolecki et al.*

astro-ph/2106.13421: **The Exomoon Corridor for Multiple Moon Systems** by *Alex Teachey*

astro-ph/2106.13558: **The planar two-body problem for spheroids and disks** by *M. Wold, J. T. Conway*

astro-ph/2106.13782: **The formation of planetary systems with SPICA** by *I. Kamp et al.*

astro-ph/2106.14047: **Self-Sustaining Vortices in Protoplanetary Disks: Setting the Stage for Planetary System Formation** by *Zsolt Regaly, Kundan Kadam, Cornelis P. Dullemond*

astro-ph/2106.14491: **Transit detection of the long-period volatile-rich super-Earth $\nu$2 Lupi d with CHEOPS** by *Laetitia Delrez et al.*

astro-ph/2106.14550: **Exoplanet X-ray irradiation and evaporation rates with eROSITA** by *G. Foster et al.*

astro-ph/2106.14808: **Transmission spectroscopy with VLT FORS2: a featureless spectrum for the low-density transiting exoplanet WASP-88b** by *Petros Spyratos et al.*

astro-ph/2106.14810: **Revisiting the averaged problem in the case of mean-motion resonances of the restricted three-body problem. Global rigorous treatment and application to the co-orbital motion** by *Alexandre Pousse, Elisa Maria Alessi*

astro-ph/2106.14852: **The Temporal Onset of Habitability For Earth-Like Planets** by *Johnny Seales, Adrian Lenardic*

astro-ph/2106.14863: **A Criterion for the Onset of Chaos in Compact, Eccentric Multiplanet Systems** by *Daniel Tamayo et al.*

astro-ph/2106.14890: **High-contrast observations of brown dwarf companion HR 2562 B with the vector Apodizing Phase Plate coronagraph** by *Ben J. Sutlieff et al.*

astro-ph/2106.14968: **TOI-942b: A Prograde Neptune in a 60 Myr old Multi-transiting System** by *Christopher P. Wirth et al.*

astro-ph/2106.14991: **Discovery of two TNO-like bodies in the asteroid belt** by *Sunao Hasegawa et al.*

astro-ph/2106.14994: **A Pilot Radio Search for Magnetic Activity in Directly Imaged Exoplanets** by *Yvette Cendes, Peter K. G. Williams, Edo Berger*

astro-ph/2106.15039: **Breakup of the Synchronous State of Binary Asteroid Systems** by *Hai-Shuo Wang, Xi-Yun Hou*

astro-ph/2106.15246: **GMRT observations of the exoplanetary systems Boötis and 55 Cancri** by *Mayank Narang et al.*

astro-ph/2106.15302: **Streaming instability of multiple particle species II – Numerical convergence with increasing particle number** by *Noemi Schaffer, Anders Johansen, Michiel Lambrechts*

astro-ph/2106.15394: **An inventory of atomic species in the atmosphere of WASP-121b using UVES high-resolution spectroscopy** by *Stephanie R. Merritt et al.*

astro-ph/2106.15589: **Evidence for a Non-Dichotomous Solution to the Kepler Dichotomy: Mutual Inclinations of Kepler Planetary Systems from Transit Duration Variations** by *Sarah C. Millholland et al.*

astro-ph/2106.15687: **Constraining mornings evenings on distant worlds: a new semi-analytical approach and prospects with transmission spectroscopy** by *Néstor Espinoza, Kathryn Jones*

astro-ph/2106.16066: **Discovery of Super-Slow Rotating Asteroids with ATLAS and ZTF photometry** by *N. Erasmus et al.*

astro-ph/2106.16113: **Hydrodynamic Model of H$\alpha$ Emission from Accretion Shocks of Proto-Giant Planet and Circumplanetary Disk** by *Shinsuke Takasao, Yuhiko Aoyama, Masahiro Ikoma*

astro-ph/2106.16208: **The near-UV transit of HD 189733b with the XMM-Newton Optical Monitor** by *George W. King et al.*

astro-ph/2106.00476: **Wavelength Dependence of Activity-Induced Photometric Variations for Young Cool Stars in Hyades** by *Kohei Miyakawa et al.*

astro-ph/2106.00582: **Rapid expansion of red giant stars during core helium flash by waves propagation to the envelope and implications to exoplanets** by *Ealeal Bear et al.*

astro-ph/2106.00781: **Following the Lithium: Tracing Li-bearing Molecules Across Age, Mass, and Gravity in Brown Dwarfs** by *Ehsan Gharib-Nezhad et al.*

astro-ph/2106.01363: **Using artificial neural networks to improve photometric modeling in airless bodies** by *J. L. Rizos et al.*

astro-ph/2106.01387: **New Candidate Extreme T Subdwarfs from the Backyard Worlds: Planet 9 Citizen Science Project** by *Aaron M. Meisner et al.*

astro-ph/2106.01661: **A MUSE view of the asymmetric jet from HD 163296** by *C. Xie et al.*

astro-ph/2106.02430: **H2S observations in young stellar disks in Taurus** by *P. Rivière-Marichalar et al.*

astro-ph/2106.04536: **TOI-1278 B: SPIRou unveils a rare Brown Dwarf Companion in Close-In Orbit around an M dwarf** by *Étienne Artigau et al.*

astro-ph/2106.04666: **Possible routes for the Formation of Prebiotic Molecules in the Horsehead Nebula** by *Luciene da Silva Coelho, Amâncio César dos Santos Friaça, Edgar Mendoza*

astro-ph/2106.05060: **Guest Editorial: Overview of the Special Issue and a Dialog on Starshades** by *Jonathan Arenberg, Anthony Harness, Rebecca Jensen-Clem*

astro-ph/2106.05247: **Disk Masses and Dust Evolution of Protoplanetary Disks Around Brown Dwarfs** by *Anneliese M. Rilinger, Catherine C. Espaillat*

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