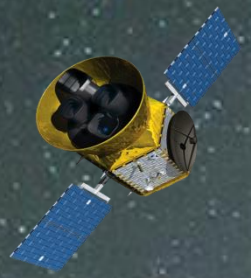


Exoplanet studies from space: an Australian perspective

Brad Carter, on behalf of the

Centre for Astrophysics, Institute for Advanced Engineering and Space Sciences

astrophysics.unisq.edu.au

University of Southern Queensland

iLAuNCH

Overview

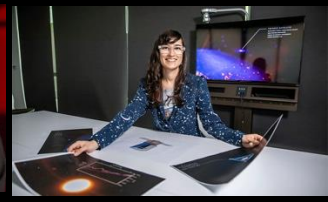
- The University of Southern Queensland is focused on the combination of astronomy and space to advance research, research training, education, and technology
- Our staff and students are using ground- and space-based facilities for exoplanet science and related stellar astrophysics
- The University operates Mt Kent Observatory on Queensland's Darling Downs to support space-based astronomy and space research
- We are also involved in several planned space astronomy missions
- Within the context of the iLAuNCH space program, we are exploring how small satellites can deliver precision pointing for space-based astronomy

Centre for Astrophysics
(10 core staff, ~20 PhD students)

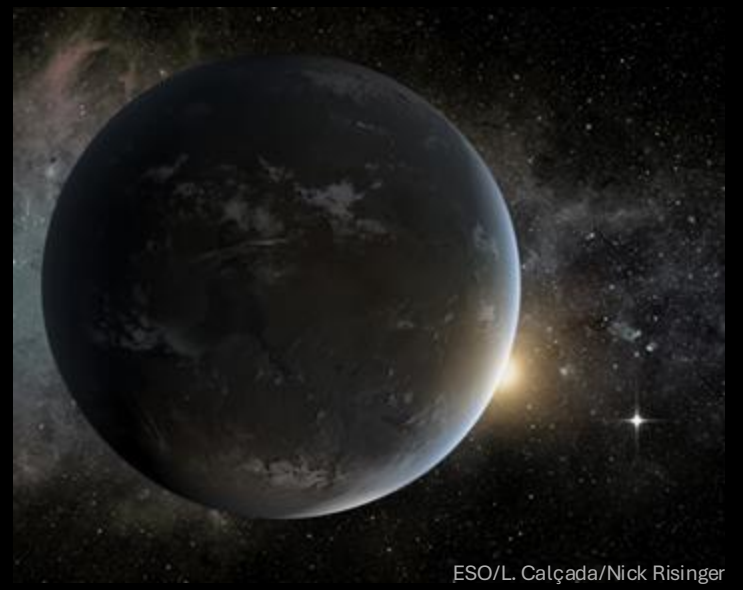






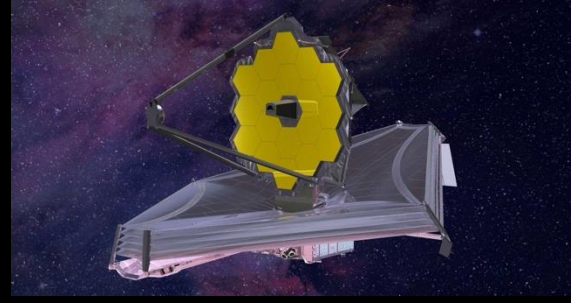
- Our main focus is on the shared evolution of stars and their planetary systems
- There are thus two major complementary research themes:
  - Exoplanet studies (discovery, characterization)
  - Stellar magnetism (activity, dynamos, winds, space weather)
- Combined star + planet studies enable:
  - Improved discovery & characterization of planets despite stellar activity
  - Exoplanetary space weather surveys to reference back to Solar forecasting
  - Improved observation and modelling of stellar effects on planetary evolution
  - Informing the search for habitable worlds beyond the Solar system
- We combine the analysis of ground- and space-based observations:
  - Mt Kent Observatory (Queensland), Siding Spring (NSW), international facilities, etc.
  - NASA's, TESS, JWST, HST, ESA's CHEOPS etc.
- We welcome collaborations here (and in other areas - extragalactic astronomy etc.)


ESO/L. Calçada/Nick Risinger

Know the star, know the planet: "We're now entering this era of really trying to understand the structure and composition of the planets, trying to understand what kinds of systems planets can exist … The star is the most dominant part of a solar system; it has the most mass, the most energy influence. We're studying these systems holistically… Everything we derive with regard to the characteristics of the planet — the size of the planet, the mass, the atmosphere — is all done relative to the star…You need to know the star in order to know the planet."

David Ciardi *NASA Exoplanet Science Institute*

Operational research facilities



GROUND-BASED
Mt Kent (MINERVA-Australis etc.)
Siding Spring (AAT, 2.3m)
Kitt Peak (WIYN telescope, NEID spectrograph)
ESO Paranal (VLT, ESPRESSO, CRIRES+)
Las Campanas (Magellan, PFS)
Mauna Kea (Gemini North, MAROON-X)
Cerro-Tololo (1.5m, CHIRON)
Las Cumbres Observatory network
Pic du Midi (Télescope Bernard Lyot, NARVAL)
MWA + ATCA (CSIRO collaboration)

SPACE-BASED
NASA/MIT TESS
NASA JWST
NASA HST
ESA CHEOPS
ESA Gaia
ISS NICER (GSFC collaboration)

Mt Kent Observatory

A Queensland astronomy & space facility:

MINERVA-Australis – exoplanet spectroscopy, photometry (telescope array + spectrograph)

Shared Skies Partnership– exoplanet photometry, widefield imaging (3 telescopes)

SONG – stellar spectroscopy, asteroseismology (telescope array + spectrograph)

DLR SMARTnet – imaging geostationary space debris (1 telescope, 2 optical tube assemblies)

Global Fireball Observatory camera (Desert Fireball Network)

also: Danish education telescope "FUT" – remote, robotic imaging and photometry (1 telescope)

All projects are international collaborations

- Hill-top site (28S 153E, under 3 hrs drive from Brisbane, 30 mins from Toowoomba)
- Remote-access and robotic facility with:
  - Southern sky access, eastern longitude and time-zone
  - Relatively dark skies
  - High-speed communications
- Compared to Siding Spring:
  - Only 600m altitude, less windy!
  - Similar but more consistent typical seeing (1-2 arcsec)
  - Similar clear skies though more seasonal (winter is better)
  - Some low-altitude light pollution
  - Convenient access by road and air

MINERVA-Australis: exoplanet spectroscopy

NASA's Transiting Exoplanet Survey Satellite (TESS)

- MINERVA-Australis includes an array of 0.7m CDK700 telescopes that can observe multiple targets at once or combine their light-gathering abilities to put light via optical fibres into a spectrograph
- MINERVA-Australis provides dedicated southern-hemisphere radial velocity spectroscopic (and some photometric) follow-up for the **NASA TESS mission** to confirm and characterize planet candidates
- The project is run by a consortium of international and Australian universities and has gained philanthropic, Australian Research Council and the NASA/NSF NN-EXPLORE program support

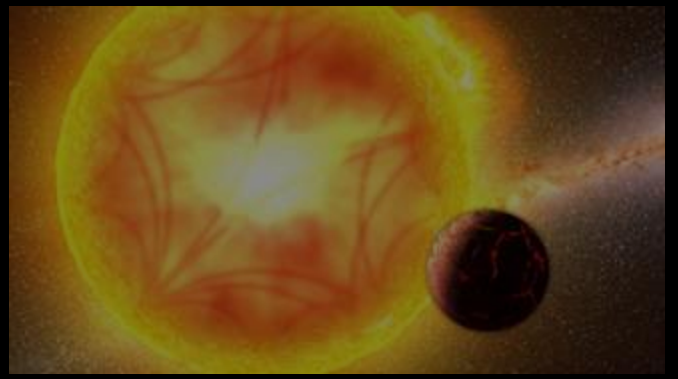
(Includes the newly installed 0.8m RAPTOR telescope)

Shared Skies Partnership: exoplanet photometry

- Three southern-hemisphere, eastern longitude telescopes at Mt Kent Observatory and US telescopes in Arizona and Kentucky enable all-sky astronomy; remote observers can observe during local daylight hours
- Telescopes are primarily used for the **NASA TESS Follow-up Program** transit photometry to discover exoplanets
- Shared Skies is a partnership between the University of Louisville and UniSQ
- Also supports student research training, education, and outreach.

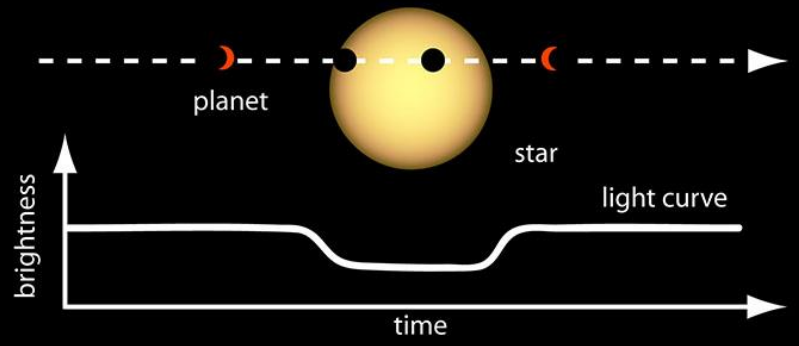
SONG: stellar seismology & exoplanets

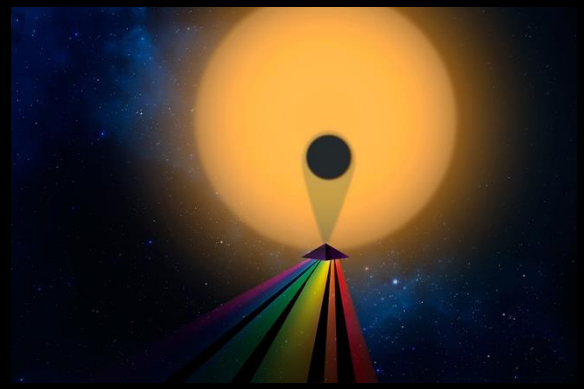
- Mt Kent hosts the Australian node of the global Stellar Observations Network Group (SONG) telescope network, an Australian collaboration with Danish astronomers
- SONG observations enable seismology of stellar interiors, complementing the work of MINERVA-Australis to deliver knowledge of the physics and evolution of stars (and hence their exoplanets)
- A similar approach to MINERVA-Australis is used to feed light by optical fibres from CDK700 telescopes to a dedicated SONG spectrograph
- Prospective ground-based complement to the planned **STEP: STars and ExoPlanets space telescope mission**



(Mt Kent also hosts the Danish "FUT" remote-access education telescope)

Overview of our space-based exoplanet research





Transiting planet photometry:

- NASA/TESS
- ESA/CHEOPS

Exoplanet atmospheres:

- HST - Hydrogen escape
- JWST – Scaled down Solar systems

Stars and planets:

- JWST
- TESS
- HST

Future missions

- STEP Danish space telescope
- NASA JPL/EVE proposed telescope
- China's Earth 2.0 space telescope
- iLAuNCH space technology
- Twinkle – sub-Saturns
- Mauve - stellar activity
- STEP - asteroseismology

Also? Venus as an exoplanet: VADER

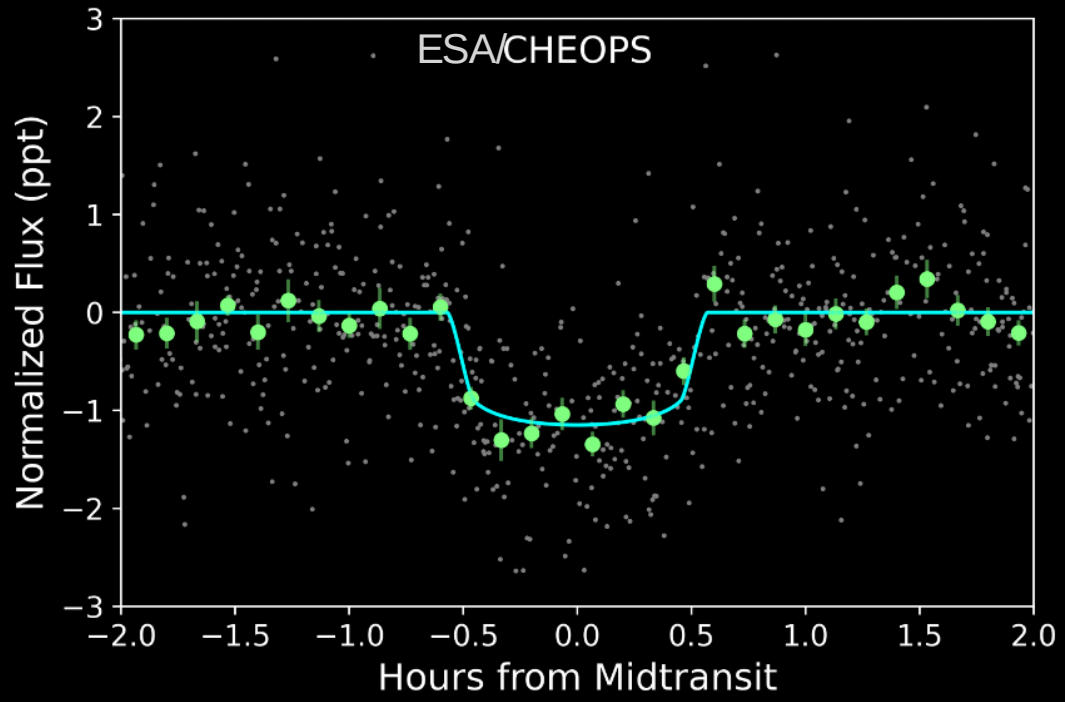
IN PROGRESS

Earth Twin or Evil Twin

GJ 12 b, the closest temporal Earth sized planet (12 pc)

Shishir Dholakia

UniSQ PhD student



More than 300 hours across 5+ programs awarded to UniSQ PIs

Dholakia, Palethorp et al, MNRAS (2024)

https://www.unisq.edu.au/news/2024/05/new-planet-discovery

PL ED RESTRICTED!

NASA JPL/EVE – UV/Optical Photometry (proposed SMEX mission concept)

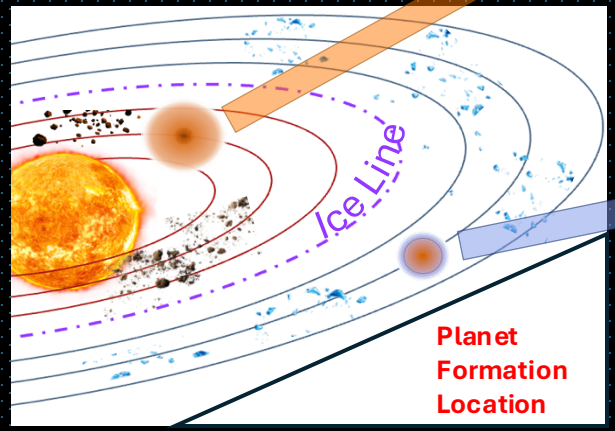
Preliminary Survey Strategy

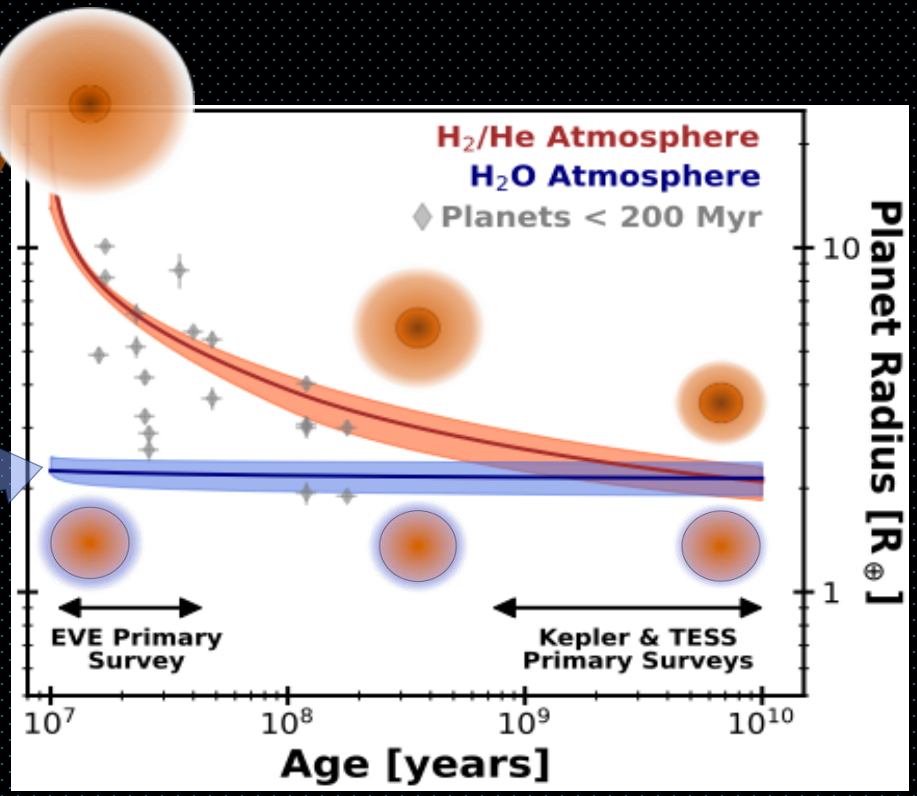
22cm aperture

30-day stare

18 fields

25deg^2 FOV

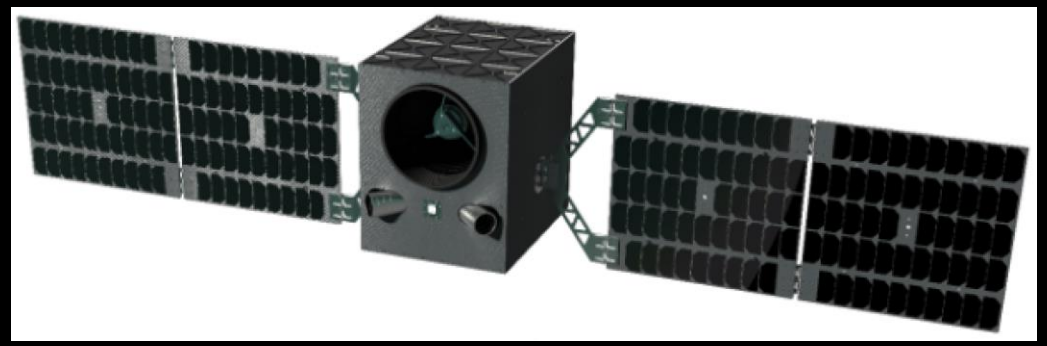




EVE Exoplanet Science team member
Associate Professor George Zhou
ARC Future Fellow

EVE Exoplanet Science team member
Sydney Vach
UniSQ PhD student

STEP: STars and ExoPlanets



- UV imaging (280-380 nm)
- 0.5 x 0.5 sq. deg. FOV
- 25-cm diameter
- Low-Earth orbit (550 km)
- Launch June 2025

STEP Science team member
Associate Professor Simon Murphy
ARC Future Fellow

Initial development funded by the Danish Ministry of Higher Education and Science

AARHUS UNIVERSITY

SpaCe – Aarhus Space Centre

PL ED

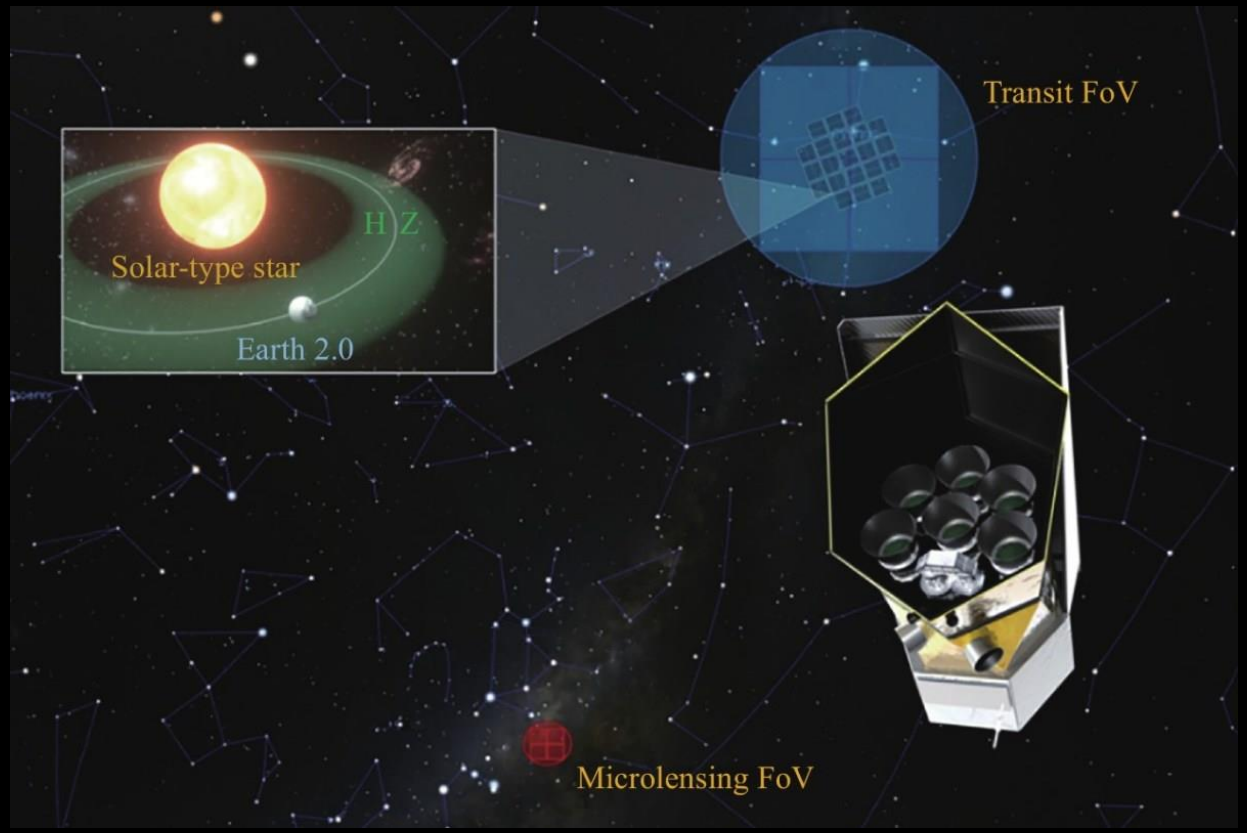
Innovation Academy for Microsatellites of CAS

National Space Science Center, CAS

China to launch "Earth 2.0" exoplanet observatory in 2028

Andrew Jones August 22, 2024

Spacenews.com



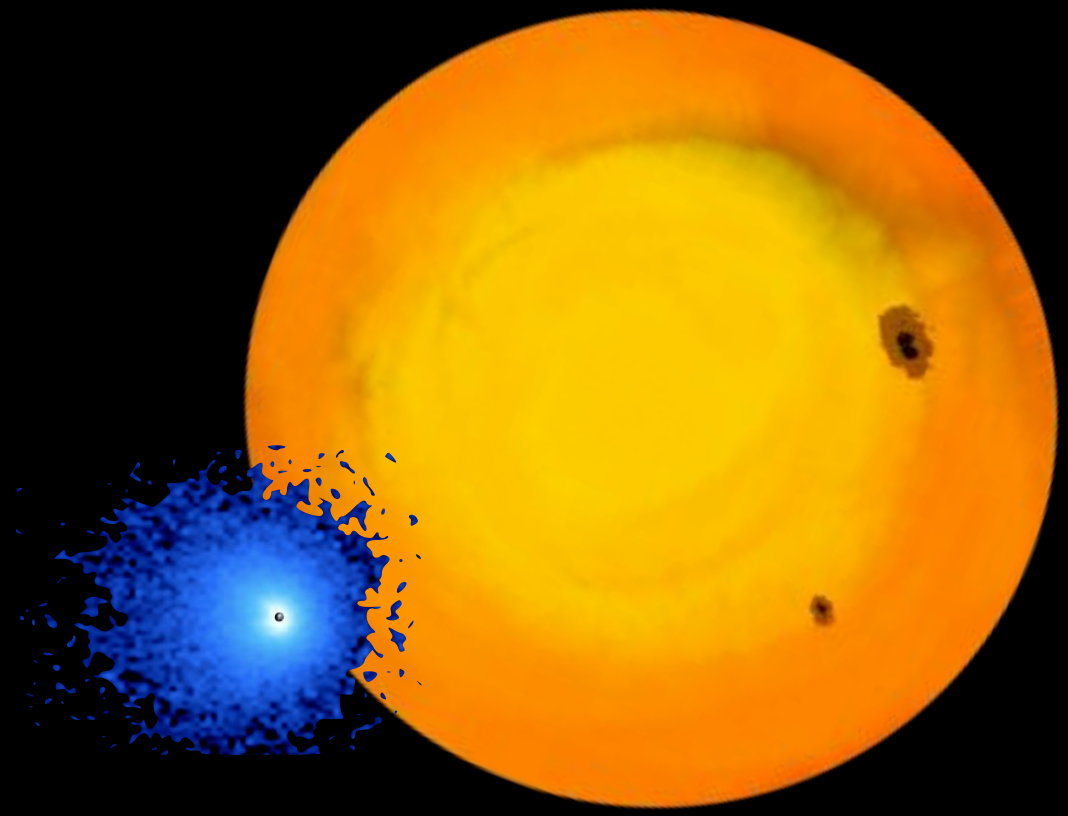
Started Engineering Phase Aug 2024

- Halo Orbit at L2
- 500 sq. deg. FOV (transit)
- 4 sq. deg. FOV (microlensing)
- 30-cm diameter x 7 (6+1)
- 4 year survey of 1.2 million stars

Simulated Mission Yield
Ge, … Huang et al (2022)

IN PROGRESS

HST Programs for Hydrogen escape in young exoplanets



Lead Principal Investigator
Associate Professor George Zhou
ARC Future Fellow

CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

DARTMOUTH

https://georgezhouastro.wordpress.com/

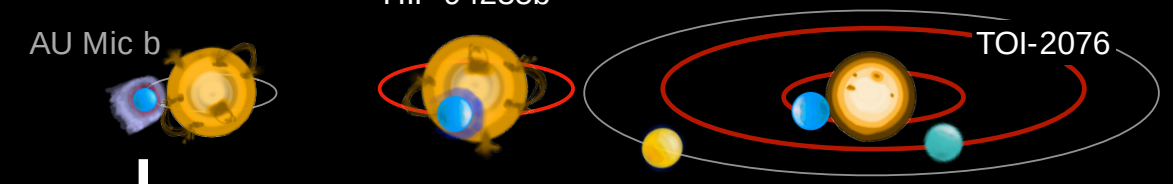
IN PROGRESS

HST Programs for Hydrogen escape in young exoplanets (continued)

AU Mic b

HIP 94235b

TOI-2076



20 Myr

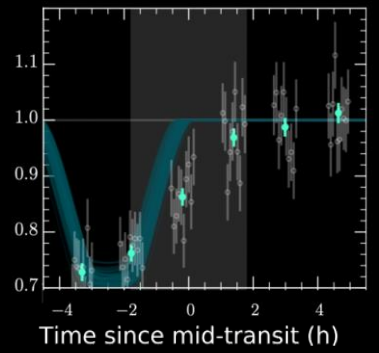
100 Myr

HST 17151 PI Zhou

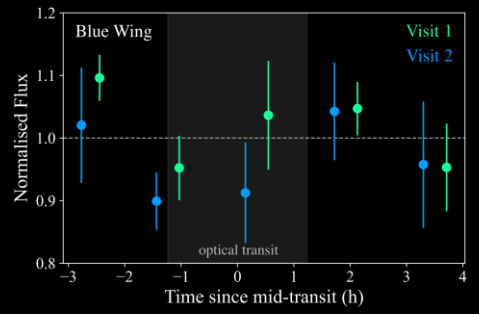
200 Myr

HST 17482 PI Zhou

New HST Program



Rockcliffe+ 23

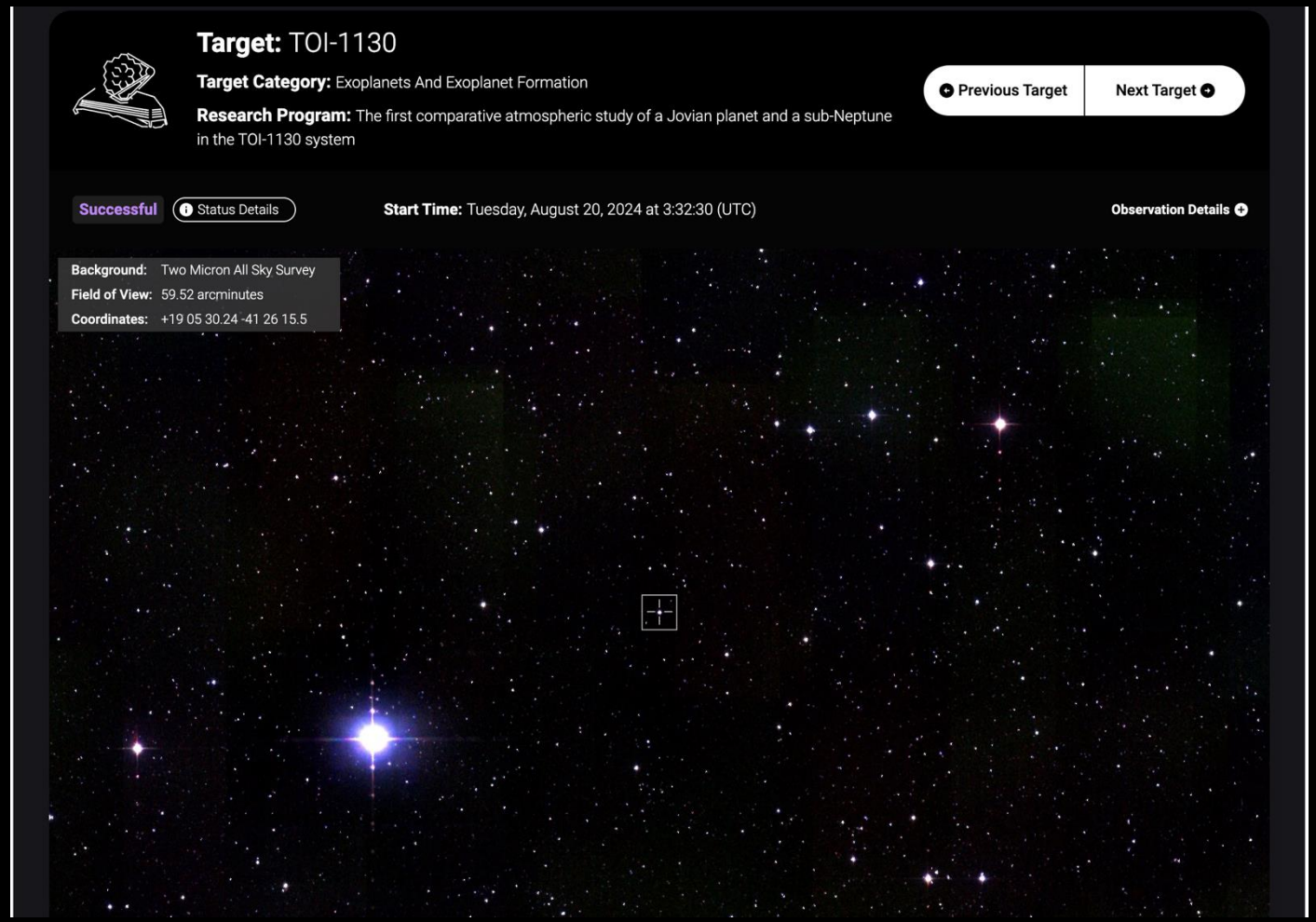


Morrissey, Zhou+ 2024

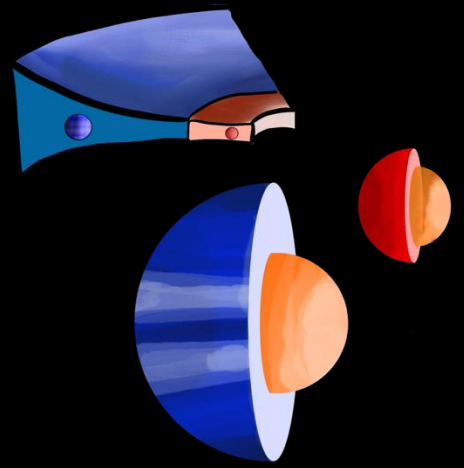
https://georgezhouastro.wordpress.com/

IN PROGRESS

Atmospheres of scaled-down Solar Systems with JWST



GO 3385 (30 hours)
Lead Principal Investigator
Senior Lecturer Chelsea Huang
ARC Future Fellow



https://chelseahuangexoplanets.com/

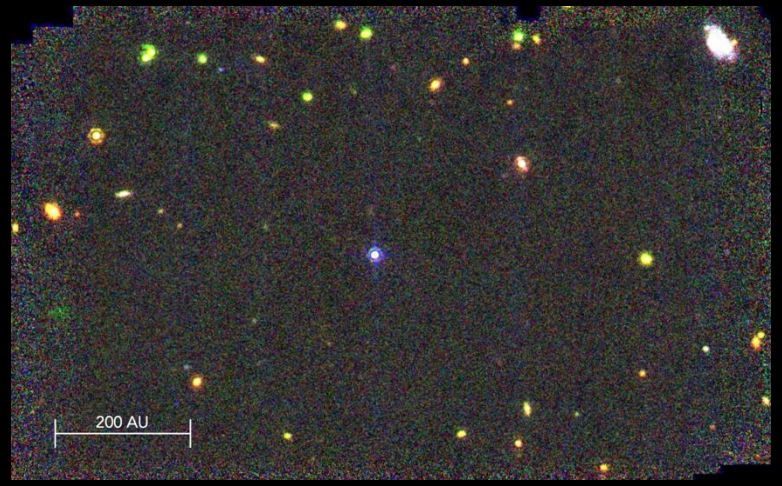
MIT KAVLI INSTITUTE

IN PROGRESS

The MIRI Exoplanets Orbiting White Dwarfs (MEOW) Survey

Limbach, Vanderburg, Venner et al (2024)

UniSQ PhD student
Alex Venner

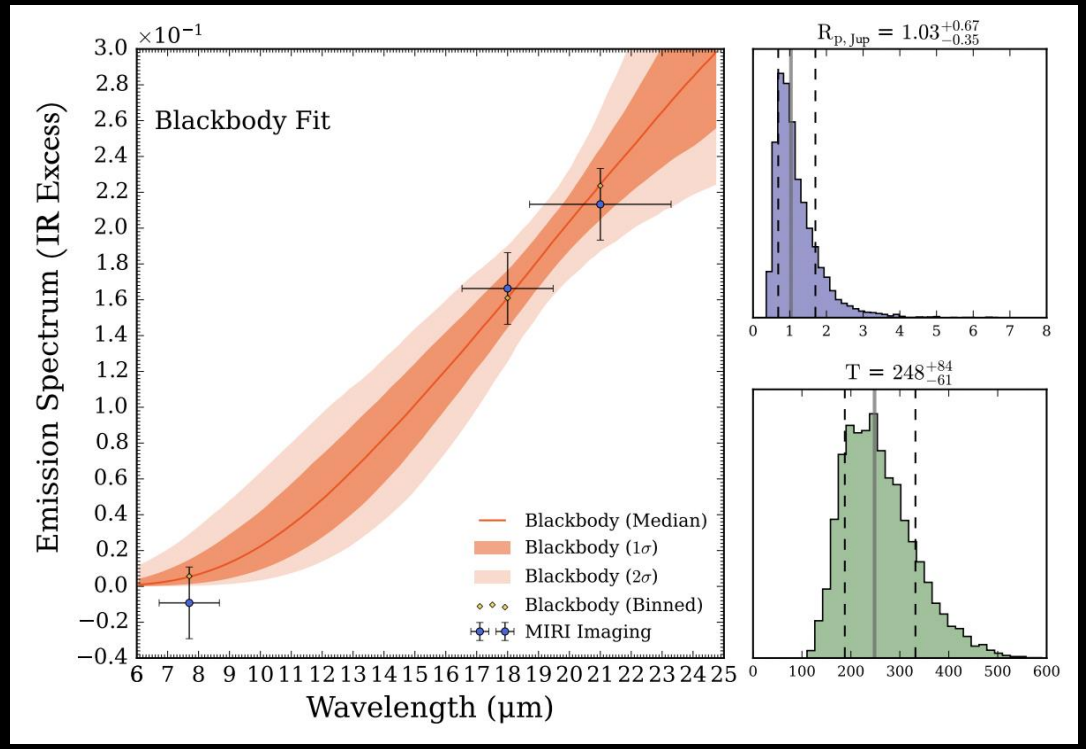


GO 3621
Lead Principal Investigator
GO 3652
Co-Lead Principal Investigator
GO 4403 (113 hours)
Co Investigator

https://chelseahuangexoplanets.com/

LSA ASTRONOMY
UNIVERSITY OF MICHIGAN

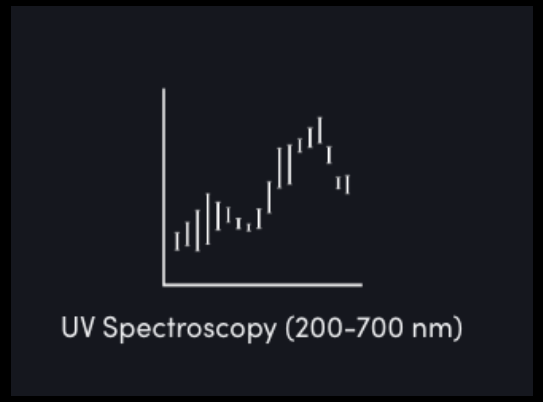
MIT KAVLI INSTITUTE



Mauve spectroscopy of stellar flares driving exoplanetary storms

UniSQ Mauve Science Team
Duncan Wright & Brad Carter

- 13-cm diameter
- R~65
- Launch in October 2025



https://bssl.space/mauve/

PL ED

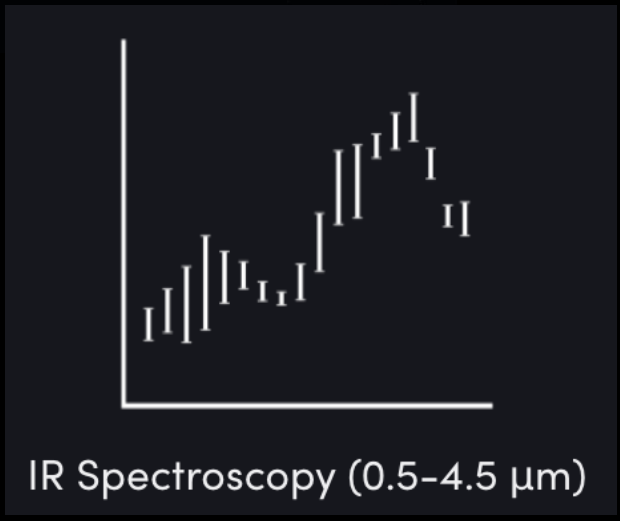
Atmospheres of super-Neptunes/Sub-Saturns with Twinkle

UniSQ Twinkle Science Team Lead
Duncan Wright

Nataliea Lawson
Former UniSQ PhD student
Annie Jump Cannon Fellow,
University of Delaware

BLUE SKIES SPACE

- 45-cm diameter
- R~70
- Launching in 2027

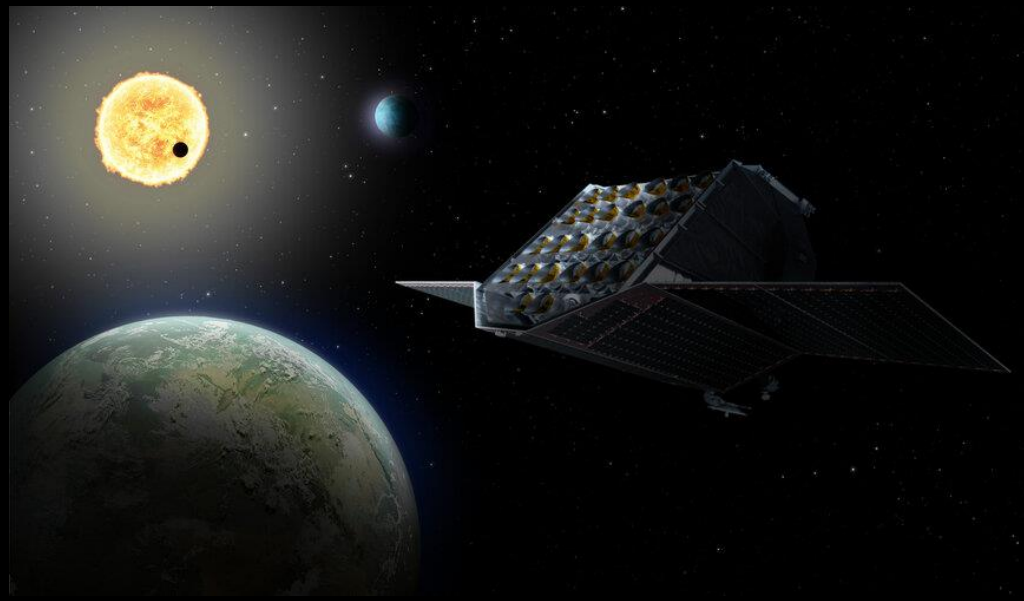


https://bssl.space/twinkle/

IN PROGRESS PLANNED

PLATO mission support

- Magnetic field detections and models for interpreting PLATO observations – finding planets despite the presence of stellar spots, modelling the impacts of stellar magnetism on asteroseismology
- Spectropolarimetry of targets ahead of the 2026 launch
- Post-launch follow-up observations



https://www.esa.int/Science_Exploration/Space_Science/Plato

BCool Collaboration co-leader
Associate Professor Stephen Marsden

IN PROGRESS

The iLAuNCH space program

- **i**nnovative **L**aunch, **A**utomation, **N**ovel materials, **C**ommunications, and **H**ypersonics
- UniSQ + ANU + UniSA
- $180M industry collaboration
- Australia & international industry
- Technology R&D
- Commercialization
- Space technology degree

https://ilaunch.space/

IN PROGRESS

Technology for space-based astronomy

- In collaboration with iLAuNCH we now have an added interest in space technology
- Our current focus is on precision SmallSat pointing/imaging for stellar/exoplanet research by building upon the success of the NASA ASTERIA (Arcsecond Space Telescope Enabling Research in Astrophysics) mission
- We are also now part of a Queensland's quantum and advanced technology research network and so exploring the potential for "quantum meets space"

https://www.jpl.nasa.gov/missions/arcsecond-space-telescope-enabling-research-in-astrophysics-asteria/

PL ED

RESTRICTED!

UniSQ iLaunch project

Lead: Professor Duncan Wright

- 20 cm aperture
- ~ 10 U satellite
- Photometric imaging in Optical
- Half a degree field of view
- Similar to NASA JPL/ASTERIA
- 10 hours of continuous observation per two weeks

VADER - Stephen Kane, UCR/UniSQ adjunct

Venus Atmospheric Dynamics and Exoplanet Reconnaissance (VADER) mission

Specific science objectives of VADER include the following:

- Monitoring of Venus atmospheric and climate dynamics for various atmospheric species, probing different depths into the atmosphere.
- Phase and wavelength dependent atmospheric reflection and scattering.
- Latitudinal dependent rotation rates.
- Convolved data for exoplanet direct imaging emulation.
- Extraction of atmospheric dynamics and rotation for convolved data.
- Filling the gap left by the JAXA Akatsuki mission that recently concluded.
- Synergy with the NASA DAVINCI and VERITAS mission deployments, and the ESA EnVision mission deployment, all scheduled for early 2030s.

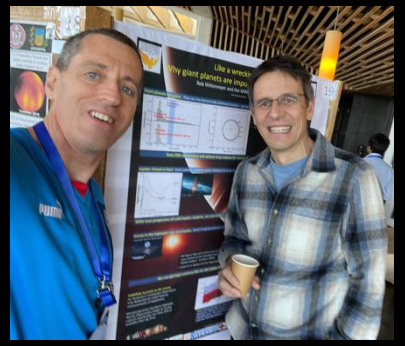
These objectives will be achieved via the following:

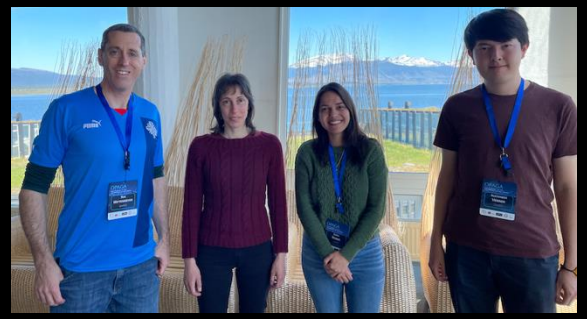
- Continuous full disk images of Venus through phase variations.
- 10 narrow passbands from UV to NIR.
- 30-60 minute cadence.

astrophysics.unisq.edu.au

Thank you … ANY QUESTIONS?

Chelsea Huang TESS launch *Cape Canaveral* April 2018





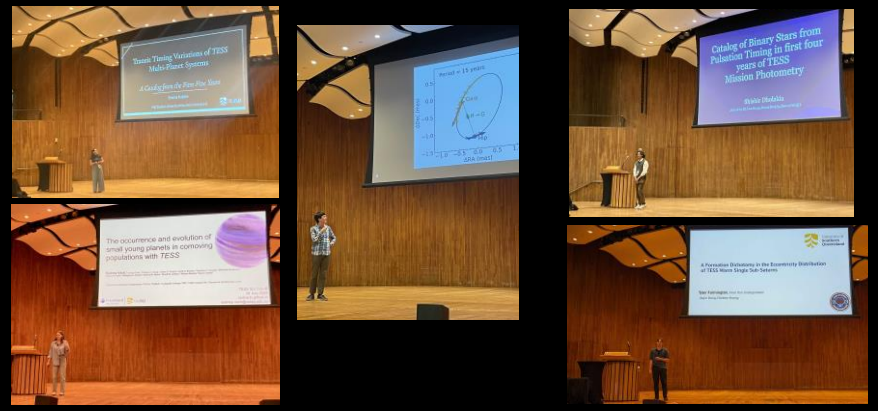
Rob Wittenmyer (+D. Queloz); Rob with Adriana Errico (external PhD student), Emma Nabbie, Alex Venner, at *Open Problems in the Astrophysics of Gas Giants*, Chile, December 2023

(Our staff & students out and about…)

Exoplanets V, Leiden

Ava Morrisey *Exoplanets V* Leiden June 2024

UniSQ@TESS Science Conference III (2024 August, MIT)



Emma Nabbie, Sydney Vach, Alex Venner, Shishir Dholakia, Tyler Fairnington. *Exoplanets TESS Science Conference II* August 2024

Shishir Dholakia *Know Thy Star Know Thy Planet 2* Caltech Feb 2025