



# Kepler/K2, TESS, and Opportunities for Australia

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5<sup>th</sup> Australian Exoplanet Workshop University of New South Wales, December 9<sup>th</sup> 2015



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### Exoplanet Missions

"Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars."

Hubble

Spitzer

Ground-based Observatories



Kepler

2001 Decadal Survey

TESS

New Worlds, New Horizons

Book sname

JWST



New Worlds Telescope

WFIRST-

AFTA

Credit: nasa.gov



#### **Designing Kepler**



Kepler was optimized to measure n<sub>Earth</sub>; for finding terrestrial planets (0.5 to 10 Earth masses) in the habitable zone (out to 1 AU) of stars like the Sun
Continuously, simultaneously monitored nearly 200,000 stars, 1m Schmidt telescope, 30min integrations, field-of-view of >100 sq deg with 42 CCDs
Photometric precision of 20 ppm in 6.5 hours on Vmag = 12 solar-like star
Bandpass is 4300 - 8900 Å, plate scale is 3.98"/pixel





#### The Transit Method



# Mercury (0.002%) Earth (0.01%) Jupiter (1%)



#### **Transiting Planets**







- Transiting planets are *extremely* informative
  - You can obtain bulk properties radius, mass, density
  - You can measure atmospheric properties emission, absorption
- But! Not every star with planets will show transits
  - Requires a geometric alignment that goes as Rp/a = 0.5% for Earth at 1AU
- Therefore, in a discovery survey, need to observe many stars
  - Go narrow/deep (Kepler)
  - Go wide/shallow (TESS, Plato)



#### The story so far...







#### Determining $\eta_{Earth}$



We need to calculate both:

- N<sub>measured</sub>: the number of real Earth-like planets in the Kepler sample (i.e. understanding the reliability, or false positive rate)
- N<sub>detectable</sub>: the number of stars around which the Kepler pipeline would have detected such planets (i.e. understanding the completeness)

(The aim of my research has been to characterise P<sub>i,SNR</sub> for the Kepler pipeline, which we can then use to calculate the pipeline detection efficiency (Christiansen+2013,2015)









- There IS a Q1-Q17 catalogue (full Kepler observing baseline Coughlin+2015), but there was a processing issue and we are not recommending people use that catalogue for occurrence rate calculations
- Q1-Q16 catalogue (Mullally+2015):







- Using the method described by Youdin 2011; Burke, Christiansen et al. (2015) parametric occurrence rate (best fit = broken power law in radius and power law in period)
- 50-200 days, 1-2Re planets, using Q1-Q16 catalogue (Mullally et al. 2015):







- Second (of four) reactions wheels failed in 2013 no more precision pointing at the original Kepler field → K2!
- Slightly more than four years of data in total
- Final version of the pipeline (re)running now (or just finished early this week!)
- Full TCE list expected at the NASA Exoplanet Archive early next year
- Including fully automated dispositions (planet candidate, false positive no more humans making decisions!) and fully characterised detection efficiency

 We hope and expect the community to continue to produce many excellent analyses using the available data (pixels, light curves, TCE reliability products)



## K2: Extending Kepler's Power to the Ecliptic

Kepler







#### K2: Extending Kepler's Power to the Ecliptic



- Proposal cycle, every six months up to cycle 4 (C11, C12, C13)
- Two-step process:
  - Step 1 deadline: Feb 5, 2016
  - Step 2 deadline: Mar 4, 2016
  - C11 start date: Sep 24, 2016
- No proprietary period! Pixels and aperture photometry light curves available
- There is money! (But only if you have a US affiliation...)





#### K2: Extending Kepler's Power to the **Ecliptic**



- **Exoplanet** results coming in incredibly quickly - wild west of space-based precision photometry!
- Exploring exoplanet population variances stellar type, Galactic latitude, ...
- (Other areas of transient astronomy: white dwarfs, flares, asteroseismology, ...)



period.



Page 13



#### TESS – Transiting Exoplanet Survey Satellite



- Four 10cm telescopes, each with 24x24deg field of view
- 600-1000nm bandpass (enough different from Kepler for interesting degeneracy-breaking!)
- Eccentric high Earth orbit 17-59 Earth radii
- Two year mission one year northern sky, one year southern sky





#### TESS – Transiting Exoplanet Survey Satellite



- 200,000 stars, 1-minute cadence (!!!) postage stamps around targets, not all pixels come down
- Main sequence dwarfs (FGKM) 4-12<sup>th</sup> magnitude
- Full frame images every 30 minutes (!!!)





#### TESS – Transiting Exoplanet Survey Satellite



- Prime mission goal to measure masses of 50 nearby planets some funded follow-up – focus on Earths and super-Earths
- The real goal is to find the best targets for the next 100+ years of characterisation with Hubble, JWST, etc
- No proprietary period (!!!)
- TESS Guest Investigator Program – still taking shape, but something like 25,000 targets reserved for guest proposals
- One round of proposals (maybe two), a year before launch (next year!)
- Taking feedback now...

