Prospecting for Habitable Worlds

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All the Known Planets In 1994
NASA’s 1995 ExNPS Report

Transit Photometry not Recommended!
What fraction of sun-like stars in our galaxy host potentially habitable Earth-size planets?
A Search for Earth-size Planets

Radii estimated for non-transiting exoplanets
Discovery data dithered slightly

Exoplanet Discoveries Over Time*

*According to https://exoplanetarchive.ipac.caltech.edu as of 8/29/17
Enabling *Kepler*

- Back illuminated CCDs (20 ppm photometric precision)
- Sophisticated algorithms
- Computational infrastructure
How Hard is it to Find Good Planets?

- Jupiter (~1%) with $Rp = 9.7 \text{Re}$ and $P = 331.6 \text{d}$
- Earth (~0.01%) with $Rp = 0.87 \text{Re}$ and $P = 19.58 \text{d}$
A Search for Earth-size Planets

First Light Image

Launched March 7 2009
First Light Image

Launched March 7 2009
Inset – Stellar oscillation Detections before Kepler.

Main: Kepler’s 4 years of study show the stars amplitudes (ppm) as color coded points. Extended study provides –

• Stellar ages and radii
• Internal differential rotation
• Convection zone depths ages
• Rotation axis orientation
• Heliophysics-like results

…for 15000+ stars

Asteroseismology with Kepler

Huber 2016
Kepler-452b
A Search for Earth-size Planets

Kepler-452 System

Kepler-186 System

Kepler-452b

Kepler-186f

Mercury, Venus, Earth, Mars

Solar System

ARTISTIC CONCEPT
Correcting Systematic Errors

Original Flux

Systematic Error-Corrected Flux
The Search Problem
Solar Variability

A Search for Earth-size Planets
Sophisticated Signal Processing Algorithms

An overcomplete, shift-invariant dyadic wavelet decomposition
The Search Problem
The Search Problem
Keeping Up with the Data
64 hosts, 712 CPUs,
3.7 TB of RAM,
148 TB of raw disk storage
Hardware Architecture: NAS Pleiades Supercomputer

- 7.25 Pflop/s peak cluster
- 246,048 cores
- 938 TB of memory
- 15 PB of storage
Kepler taught us that planets are ubiquitous:

What Next?
The View from Proxima b
NASA’s TESS Mission

Slated for launch by mid 2018
Transiting planets provide opportunities to determine the bulk planetary density and to characterize their atmospheres.
Exoplanet Missions

- Kepler
- Spitzer
- JWST
- New Worlds Telescope
- Hubble
- Ground-based Observatories

+ ESA's CHEOPS (2018)
+ ESA's PLATO Mission (2026)