The Search for Life in Exoplanetary Systems

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(LRP 2010 Toronto Town Hall, March 17, 2010)

Astrobiology- the search for life

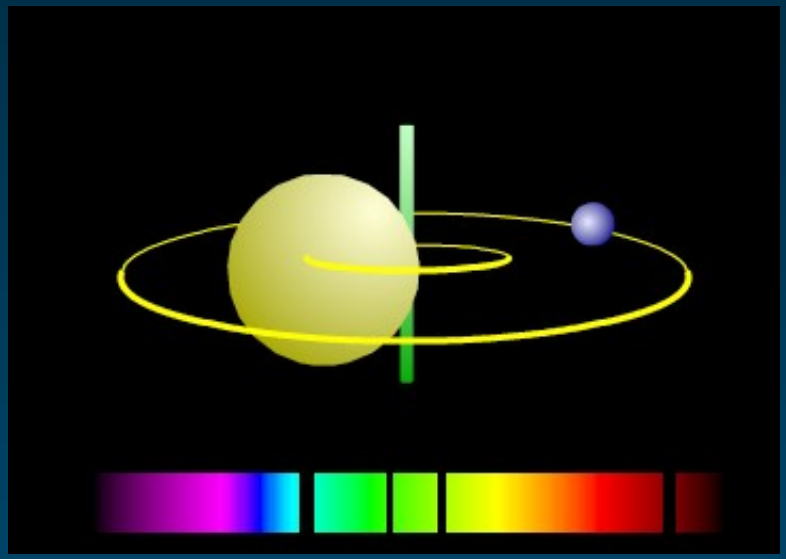
- Three scientific revolutions driving the search for life:
  - extreme microbial life on Earth
  - robotic exploration of Mars and Moons in solar system
  - exoplanets (over 400) – including SuperEarths

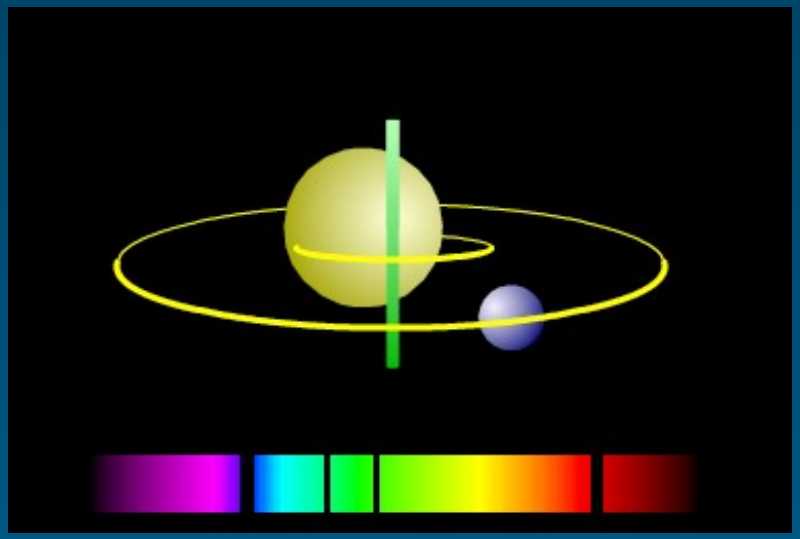
- Astrophysics determines planetary properties: composition, water content – and habitability, early atmosphere, and major biomolecular complement?

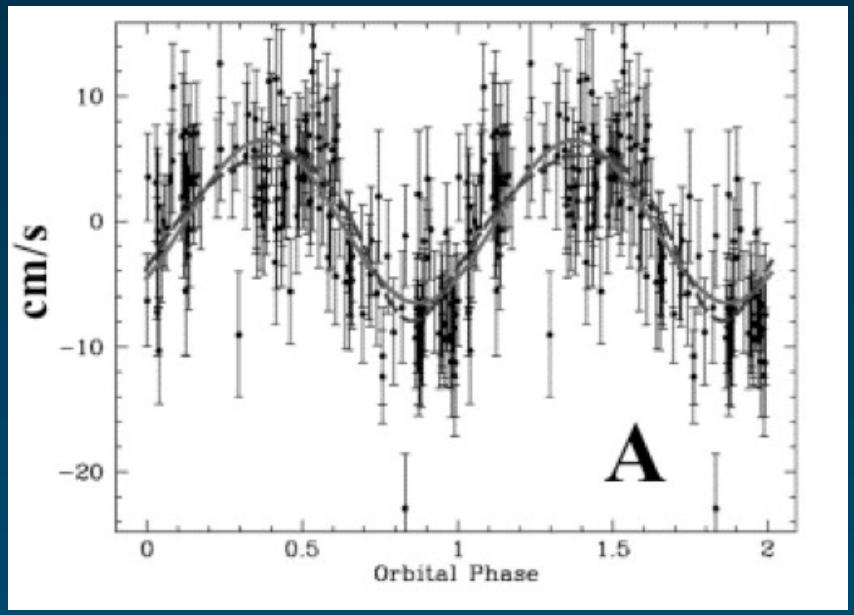
"The discovery of life on another planet is potentially one of the most important scientific advances of this century, let alone this decade, and it would have enormous philosophical implications."

U.S. 2001 Decadal Survey – National Research Council

Canadian contributions: 1. Radial velocity method







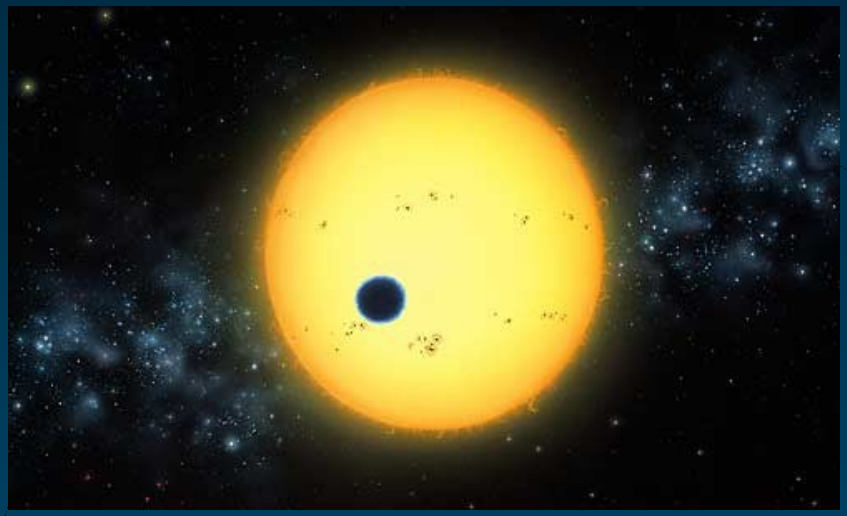
R-V method:

Pioneered by Campbell, Walker, & Yang 1988

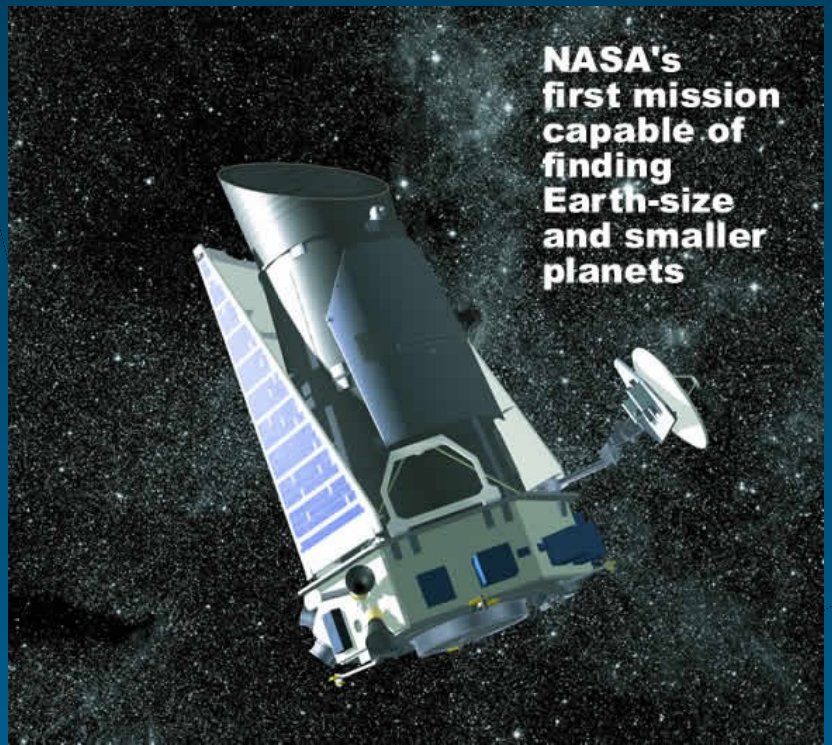
- Current precision 1m/s (Mayor et al 2009)

http://science.howstuffworks.com/planet-hunting.htm/printable

2. Transit Method



Lynnette Cook



Canada's MOST satellite

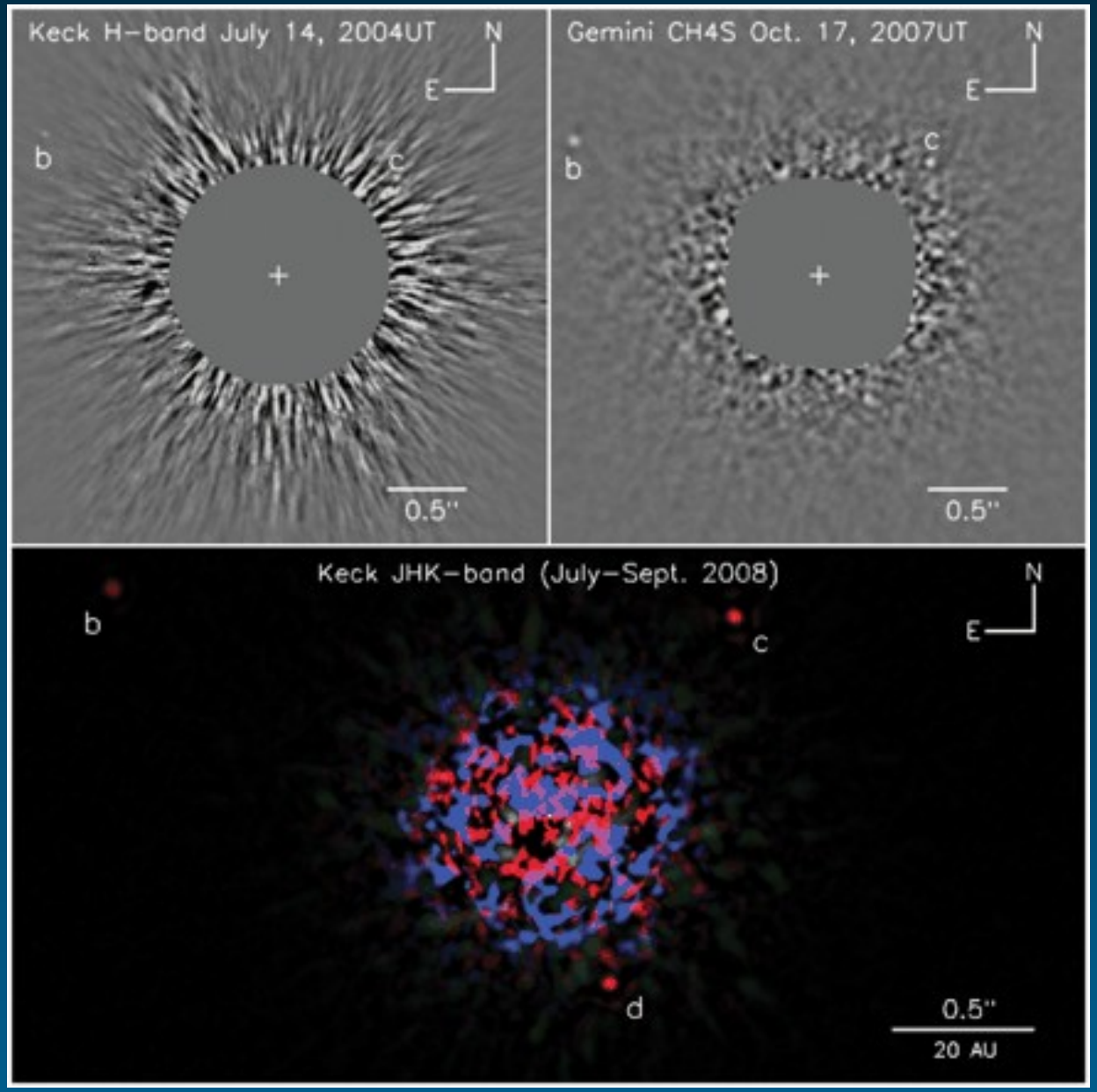
Kepler satellite, launched March 2009

3. Direct imaging of exoplanets
(eg. Marois et al 2008, Nature)

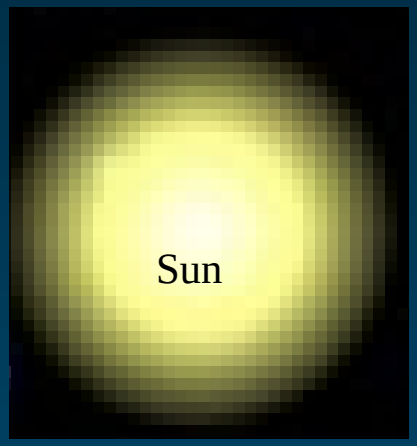
- Images of 3 planets with orbits at 24, 38, and 68 AU – planetary masses between 5-14 M_J
- Tip of the iceberg… many young systems with disks to look at..

2nd major other Canadian contribution:

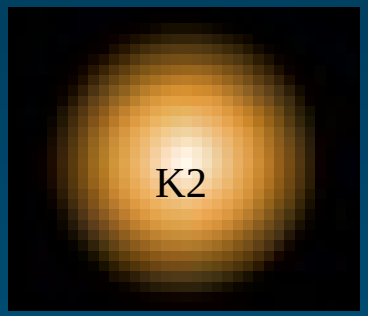
Lafreniere et al 2008)



Search for life-supporting planets: Earths in habitable zones – the M star strategy.



Probability = 1/200
P = 365 days
Transit depth = 10^{-4}



Probability = 1/140
P = 177 days
Transit depth = 1.25 x10^{-4}

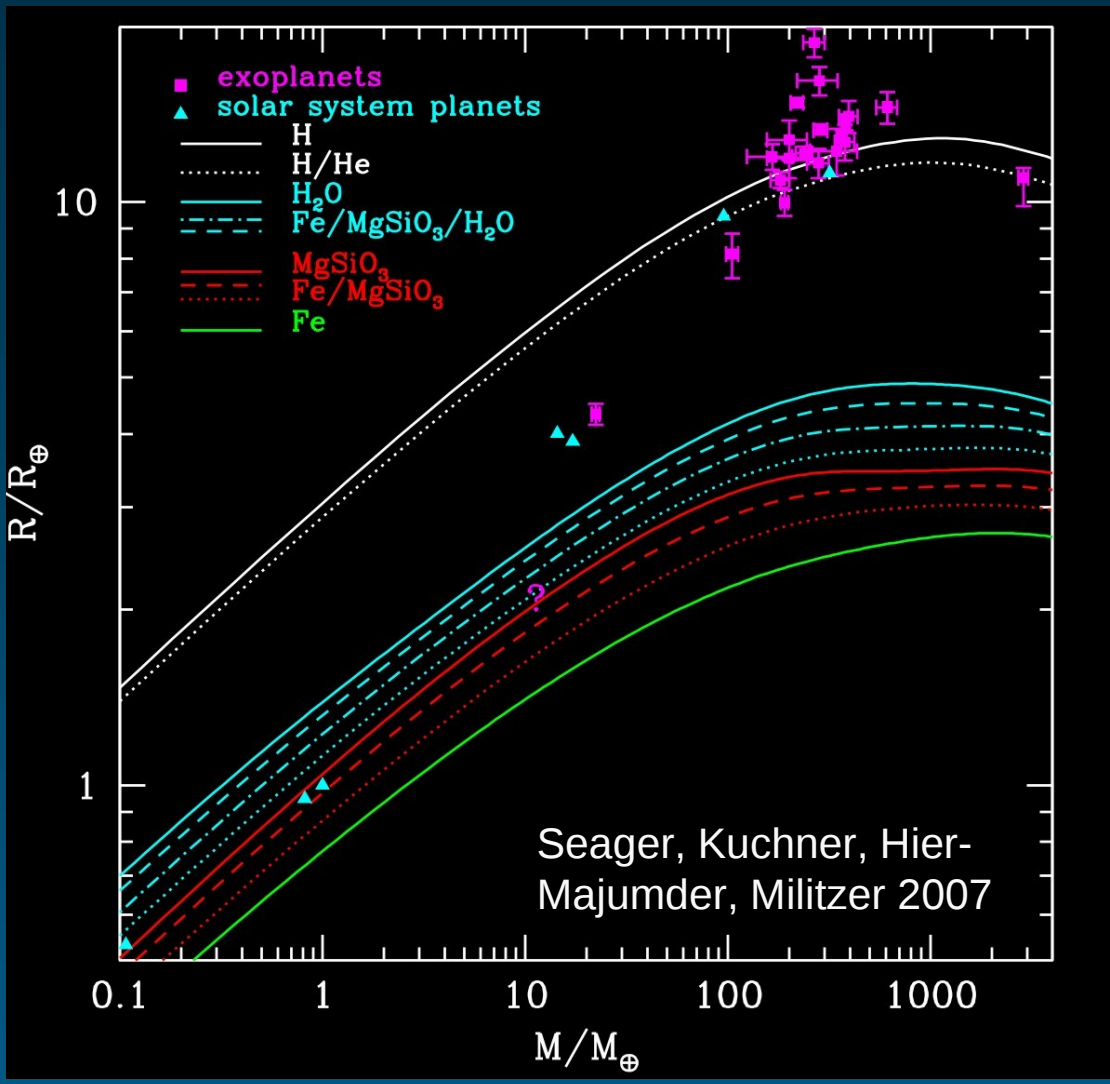
Probability = 1/50
P = 13 days
Transit depth = 0.001
Tidally-locked

1

AU

Exoplanet Bulk Composition

- Masses and radii can be measured for transiting exoplanets (magenta points)
- Infer an exoplanet's bulk composition from its mass and radius
- Major components of terrestrial planets: iron, silicates, water.



Equipping planets for life: origin of water and biomolecules on planets

- Water carried by asteroids beyond snow-line (eg. Raymond 2004)?
- Where are biomolecules primarily made?
  - early reducing planetary atmosphere (Miller-Urey)?
  - hydrothermal vents in deep ocean?
  - icy grains in protostellar disks? meteorite parent bodies?

The challenge:

- Find Earth-like planets in habitable zones
  - over next 3 years - Kepler could find a few dozen?
  - major revolution in science…
- Characterize their atmospheres – search for oxygen, signatures of chlorophyll (“red edge”):
- Image these planets – continents, oceans, cloud, etc. -
- Chart early planetary evolution: early “Earths” around young stars

- Collaborate with microbiologists, geochemists, geophysicists, in designing tests for specific biosignatures of life - connecting with Astrobiology programs

  eg. how much oxygen needs to be present in atmosphere for good evidence for life?

Next major observatory: Terrestrial Planet Finder

- (top) TPF visible-light coronograph
- (below) TPF flying formation IR interferometer
- Interferometric nulling by 10^5 allows direct imaging of Earths.
- 4 x 3.5 m telescopes

http://planetquest.jpl.nasa.gov/TPF/tpf_book/

Where Canadian community stands

- In U.S., NASA strongly supports Astrobiology research – eg. Kepler mission
- 14 funded NASA/university centres – National Astrobiology Institute
- Astrobiology annual science conference – nearly 300 *grad students* among nearly 1000 participants….
- Strong connections between astro / planetary science / astrobiology communities

- Canada:

  - Analogue sites: "CARN" network supported by CSA

  - NSERC CREATE program (2009-): McGill, McMaster (OI), Toronto, Western Ontario: 70 HQP over 6 years.

  - first CIFAR Astrobiology workshop (2009) – 2nd being planned

  - McMaster Origins Institute: Astrobiology program

  - JWST / SKA / TMT (spectroscopy) coming …

Proposal to LRP 2010

- Exoplanetary science as a key area for Canadian astronomy and astrophysics (cf several white papers)
- Search for life on terrestrial exoplanets and SuperEarths as a key science problem in this decade.
- Support for JWST / TMT / SKA– and investigation of TPF concept as a major new observatory for imaging to complement TMT.
- Ensure that TPF can play role as general purpose observatory as well.