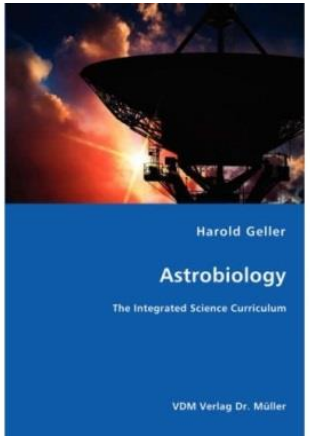


The Search for Exoplanets: Classroom Activities

By
Dr. Harold A. Geller
@AstroBioProf
Associate Professor
Observatory Director
George Mason University
NASA/JPL Solar System Ambassador

Abstract

I will demonstrate classroom activities focused on the search for exoplanets, especially linked to the Transiting Exoplanet Survey Satellite (TESS) spacecraft launched by NASA on April 18, 2018. This will include demonstration of both the transit method of detection and the radial velocity method of detection of planets orbiting stars other than our Sun.

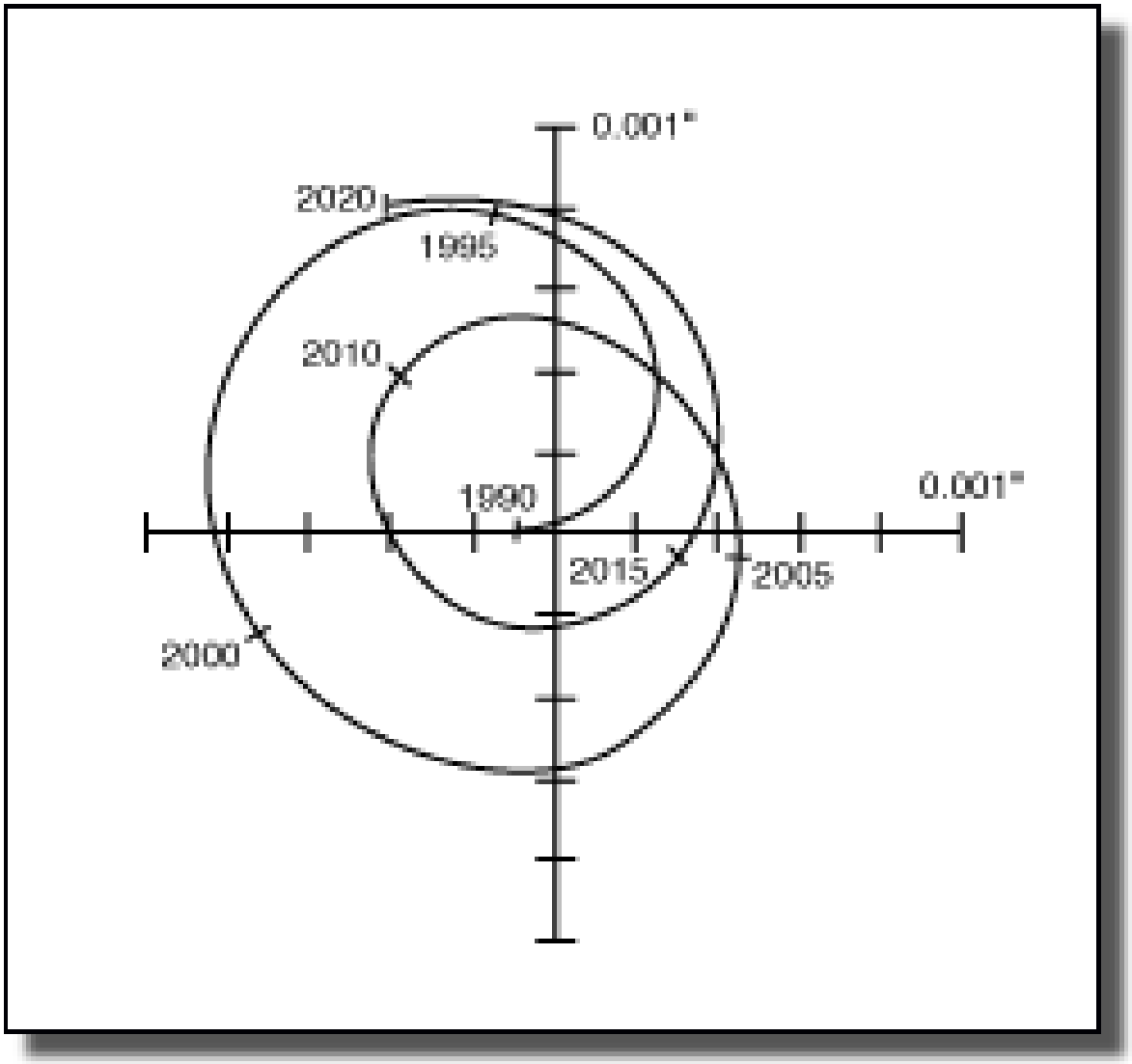
How to Find an Extrasolar Planet

- Think about how a planet effects the star around which it orbits
  - light seen from star
  - gravitational effects
    - translate into visual effects
  - spectroscopic effects
    - translate into observed spectroscopic observations
    - remember Doppler Effect

Four Main Ways to Find an Extrasolar Planet

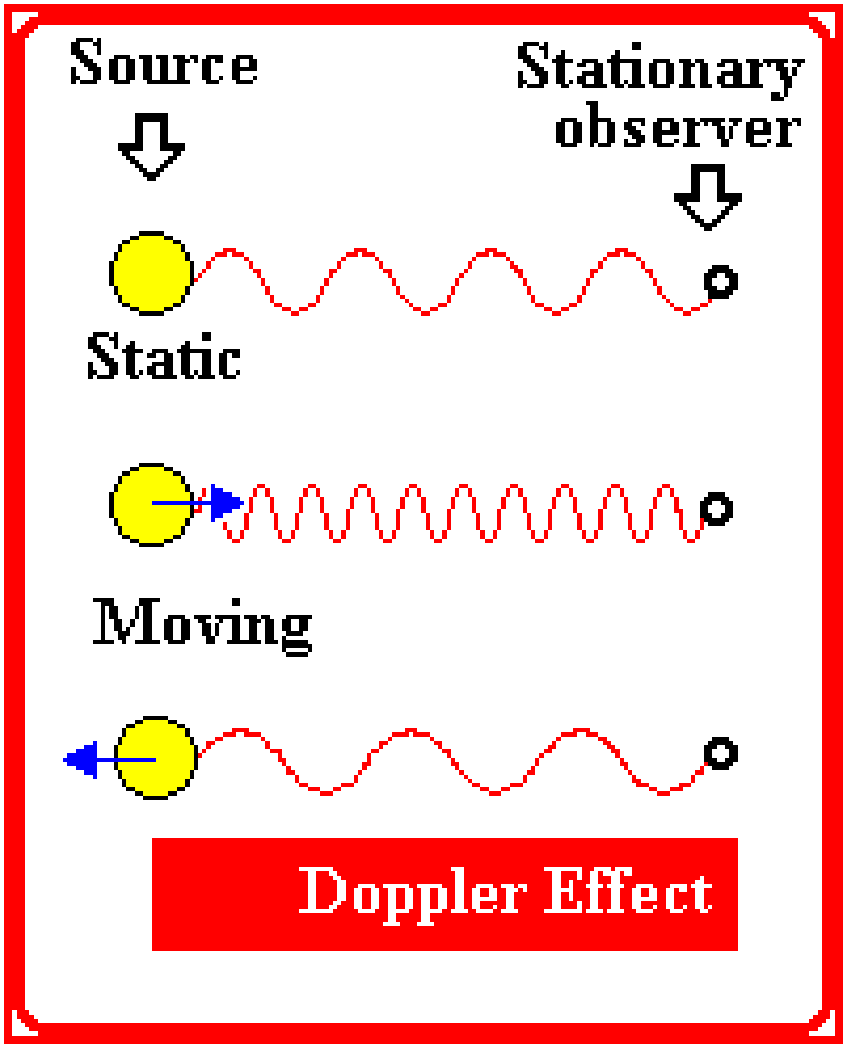
- Astrometrically
  - change in position caused by "dance with planet"
- Spectroscopically
  - Doppler Effect on spectral lines due to "dance with planet"
- Photometrically detected transit
  - light from star blocked by planet decreasing light seen from star in concert with orbit
- Gravitational Microlensing
  - large gravitational force effecting light path

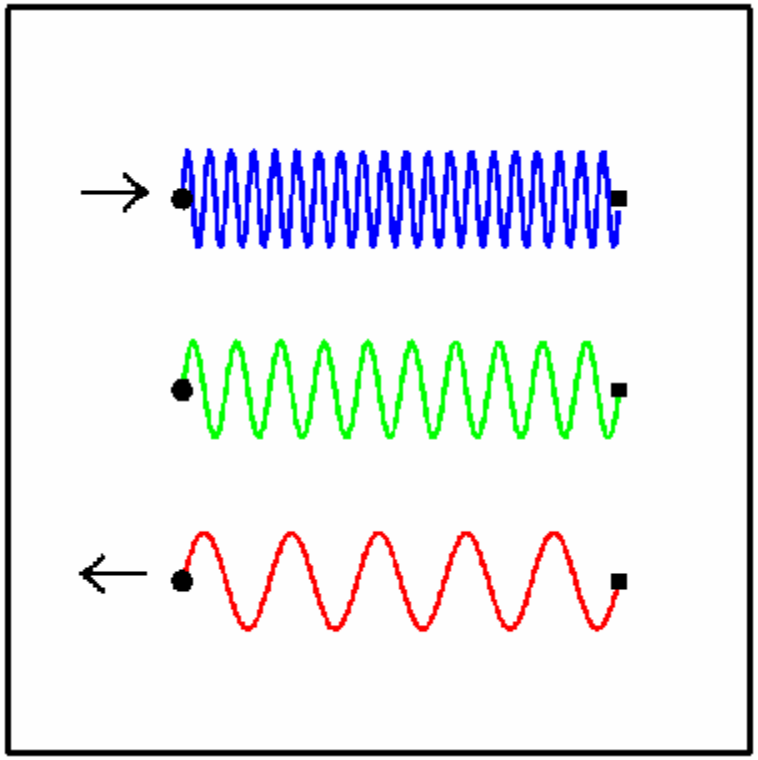
Astrometric change in position of Sun due to Jupiter as seen from 10 parsecs distant



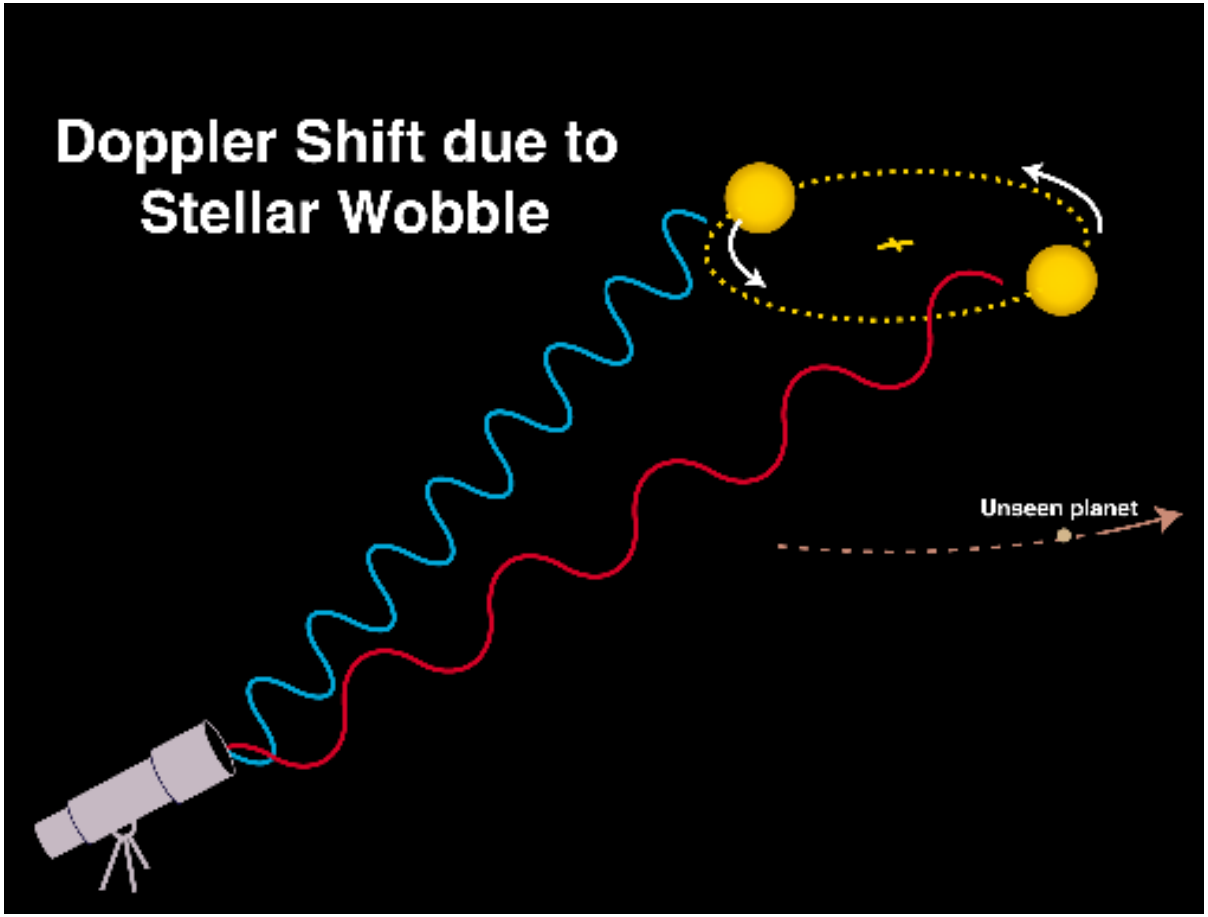
Astrometric displacement of the Sun due to Jupiter as seen from 10 parsecs.

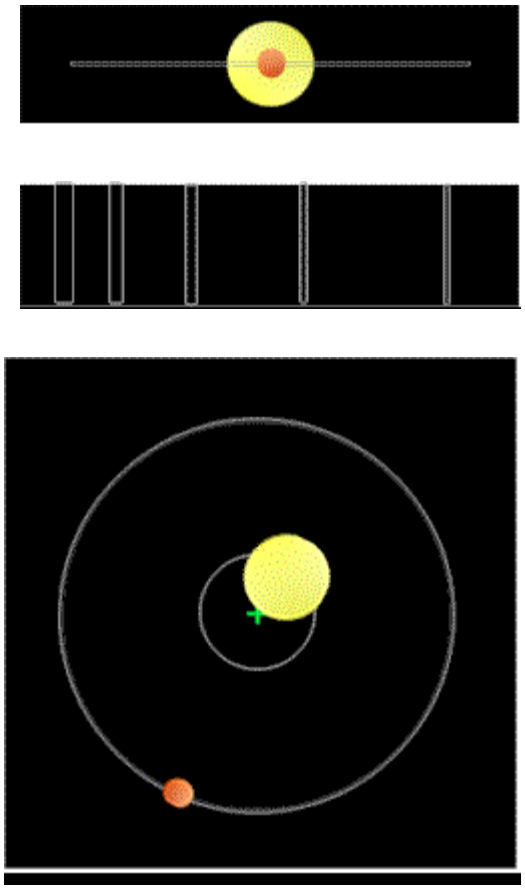
Remember Doppler



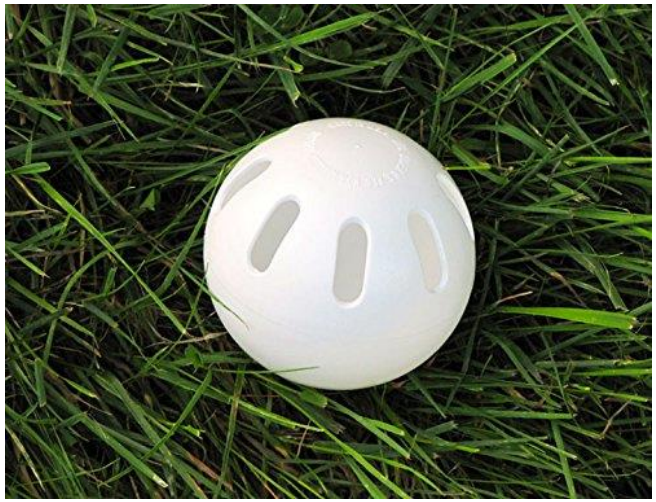


Applying Doppler



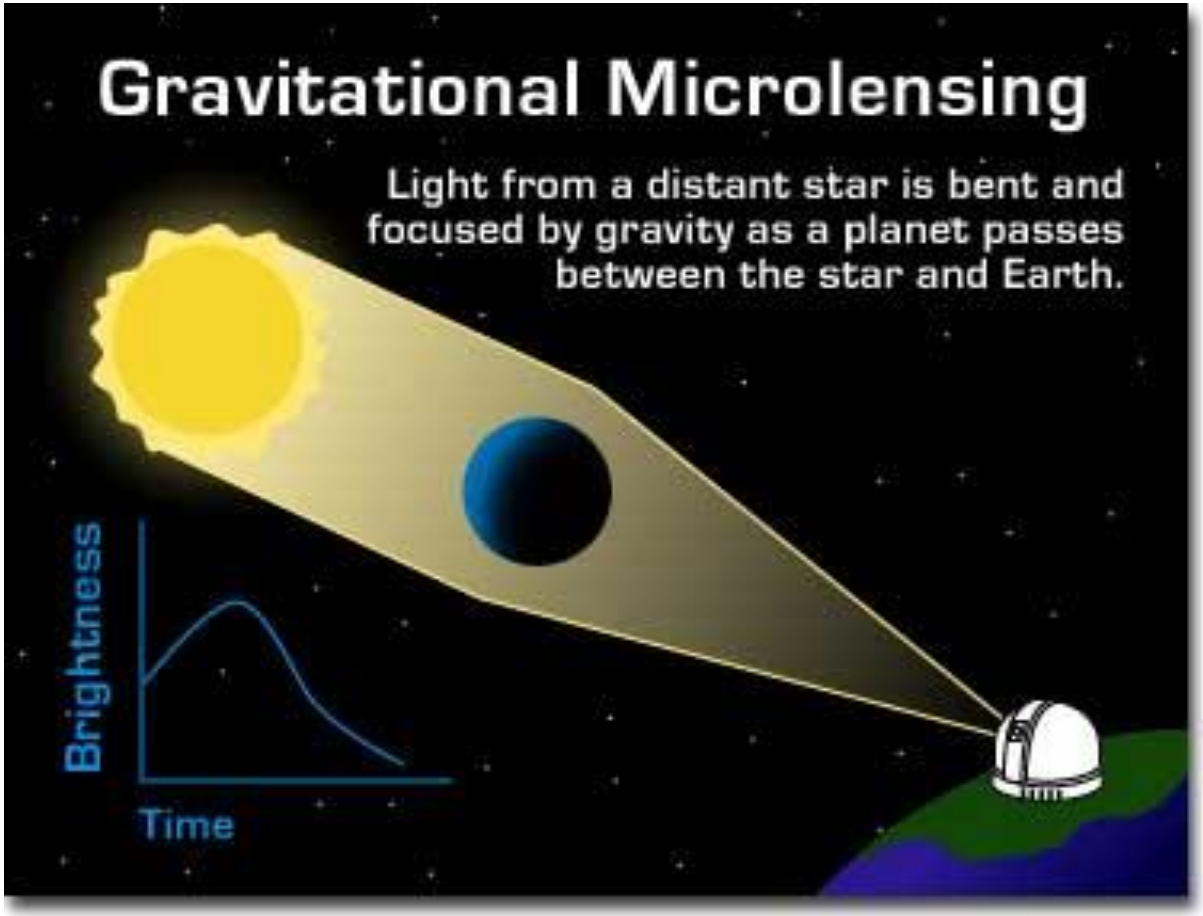


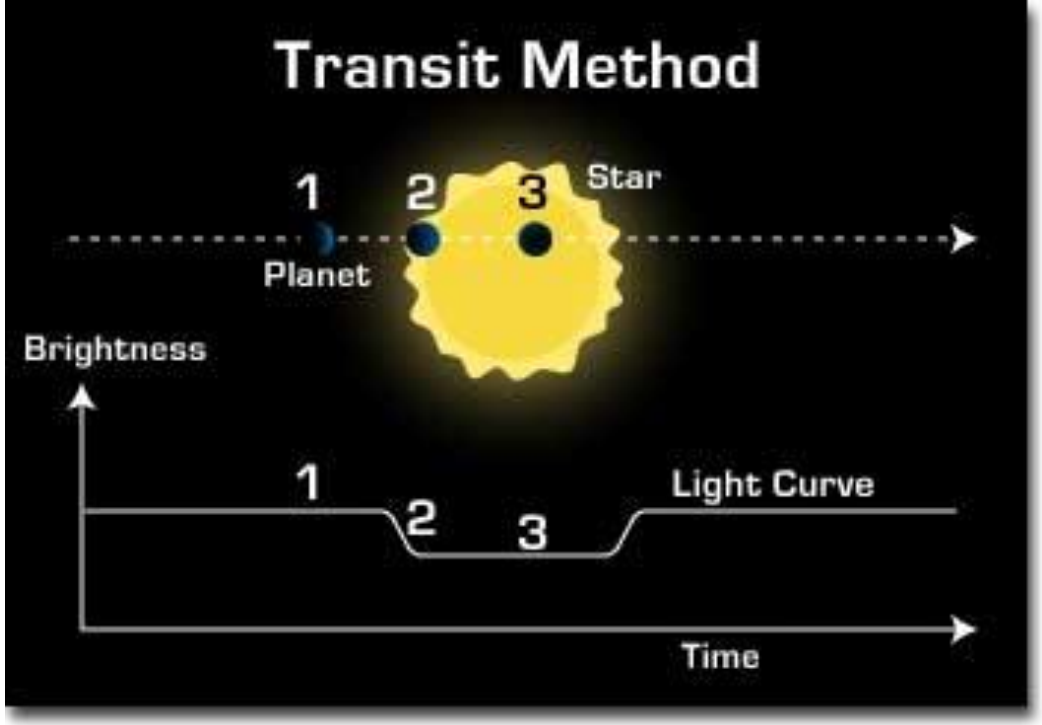
Demo With This



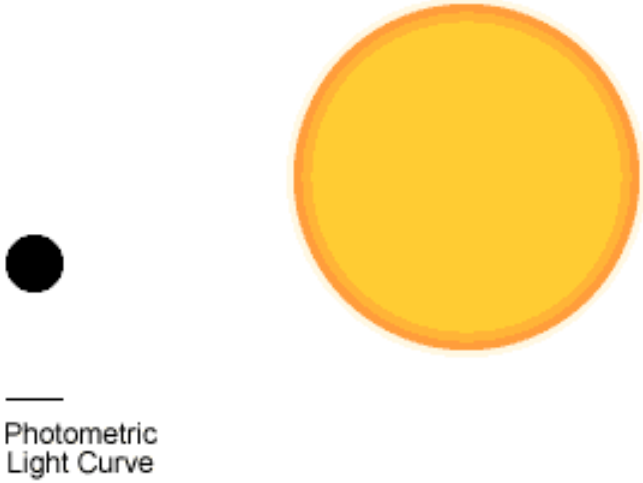
Demo With This

Applying Einstein

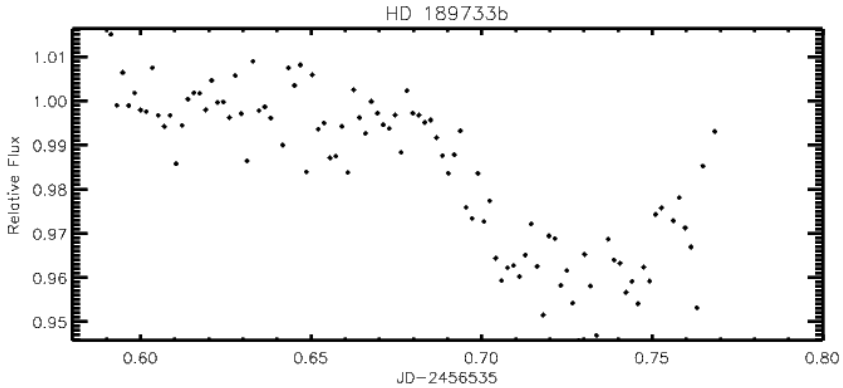




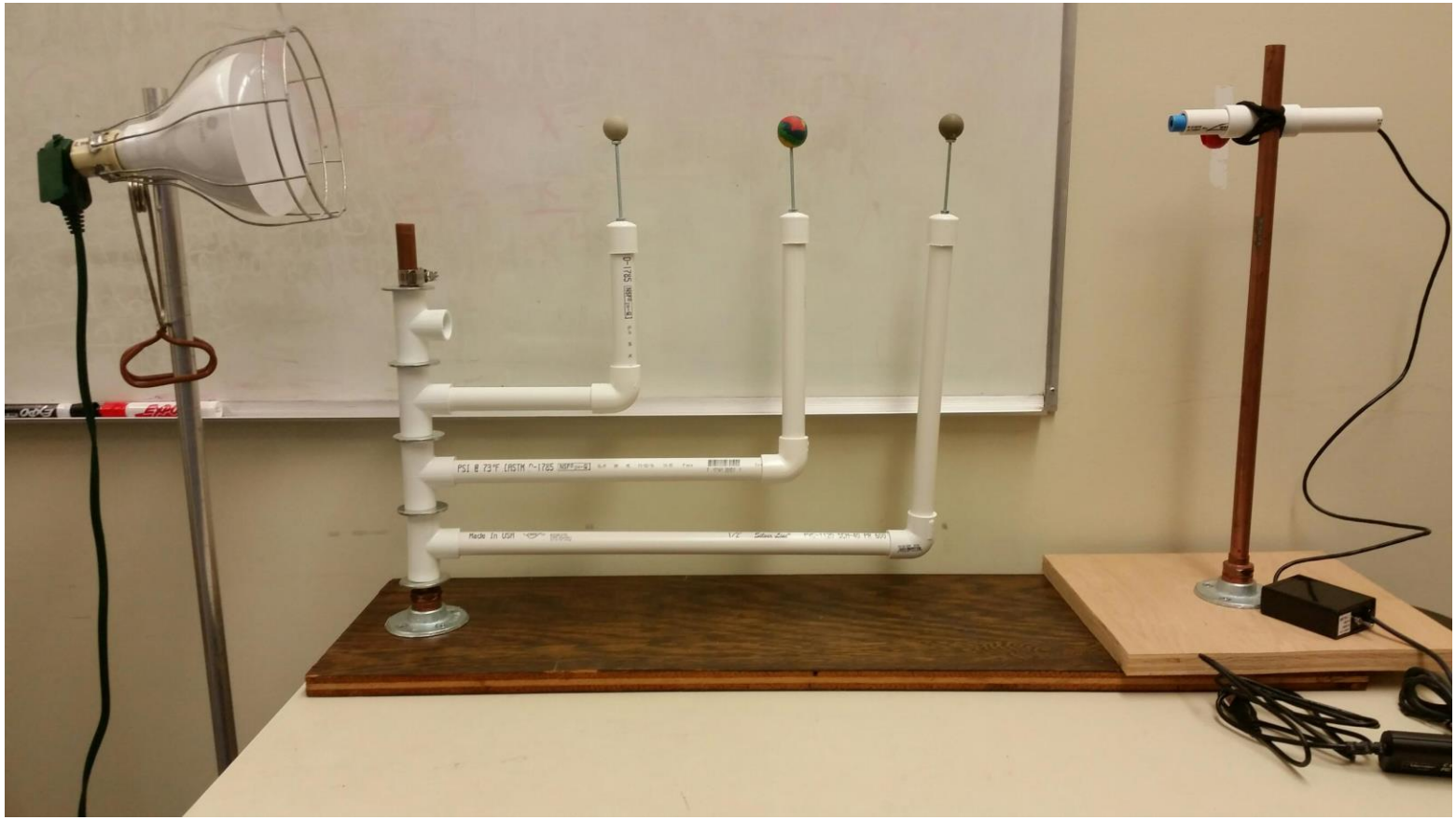
Transit Detection of Exoplanets



From GMU Observatory

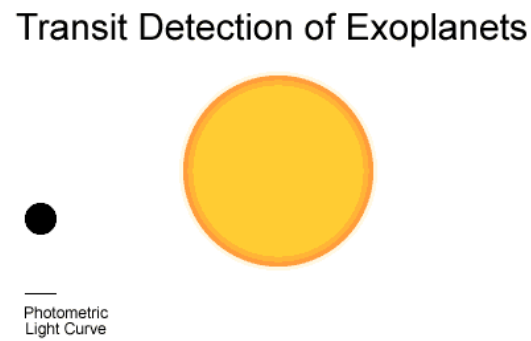


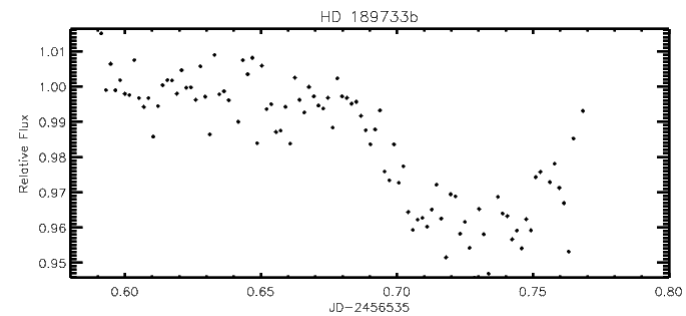
Rhett to Demo This



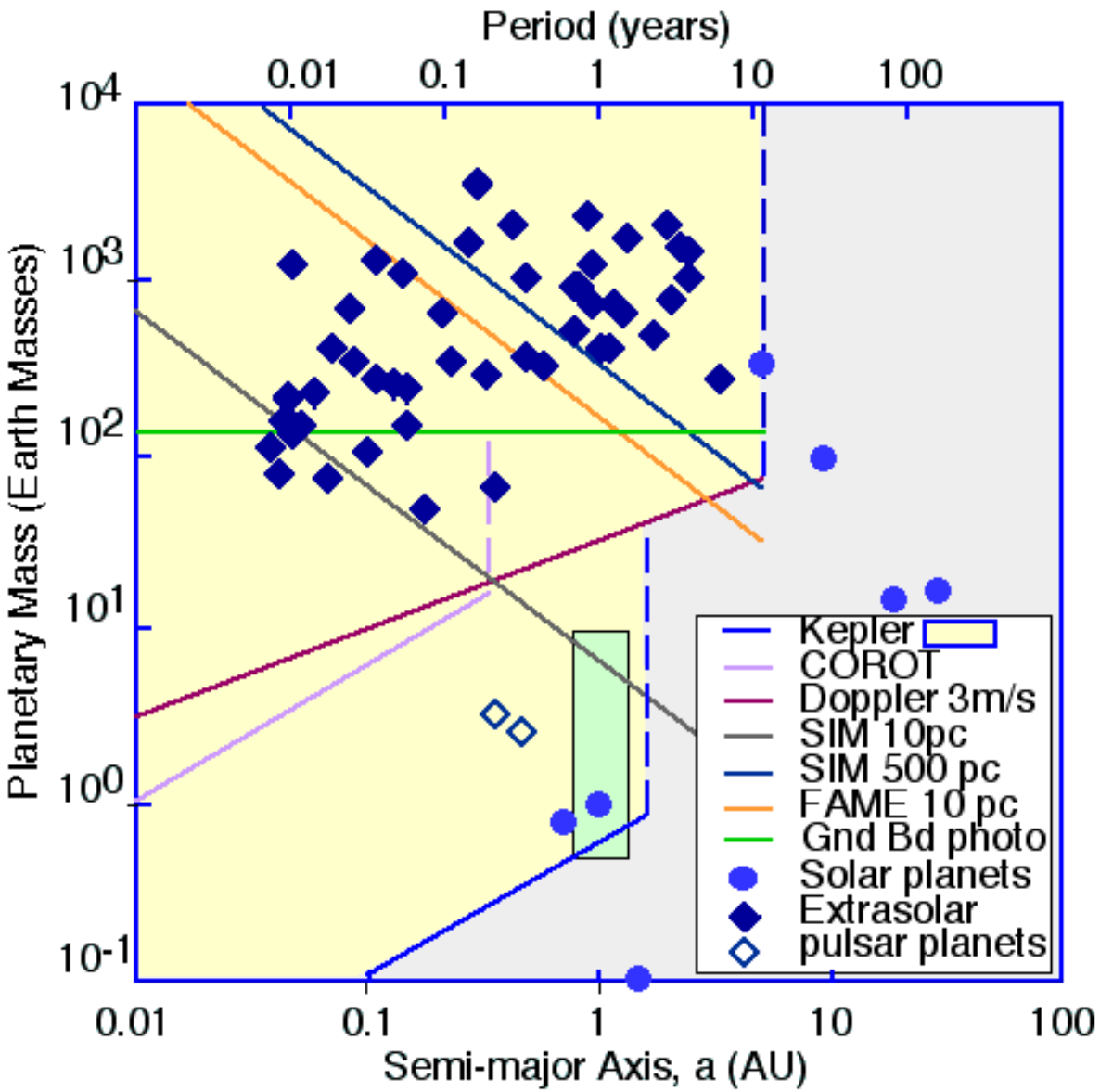
Possible Student Research Projects with Observatory

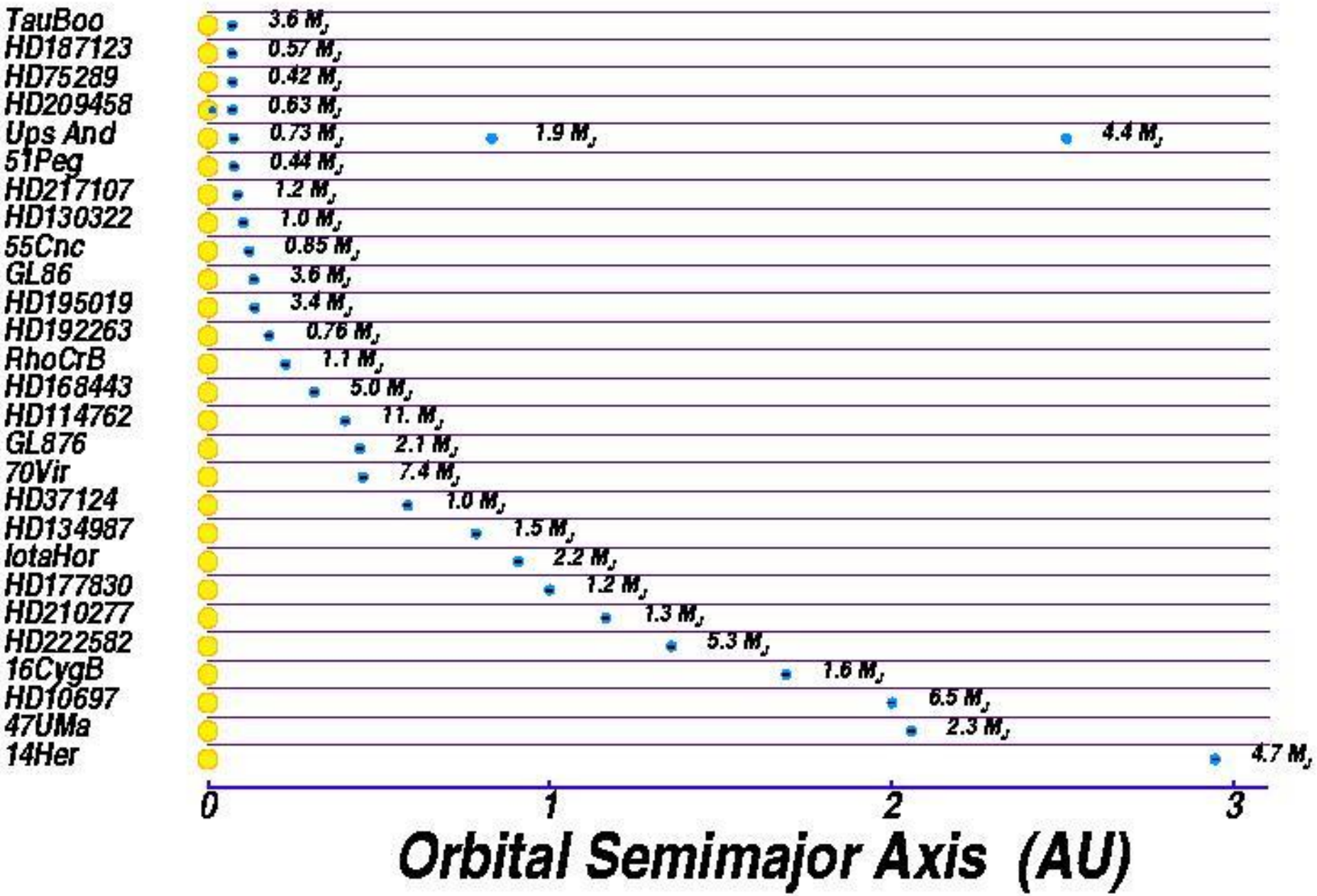
- Even within the light-polluted skies of Fairfax, the technology will allow us to
  - Search for extrasolar planets (planets beyond our solar system)
  - Conduct astroseismology studies (characteristics of stellar surfaces and interiors) with a high resolution spectrograph (requires separate purchase)
  - Search for supernovae (stars which have exploded in our galaxy and other galaxies)
  - Conduct studies of planetary atmospheres with a high resolution spectrograph





Extrasolar Planet Detection Capability

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HD209458
Ups And
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HD217107
HD130322
55Cnc
GL86
HD195019
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RhoCrB
HD168443
HD114762
GL876
70Vir
HD37124
HD134987
IotaHor
HD177830
HD210277
HD222582
16CygB
HD10697
47UMa
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3.6 M_J
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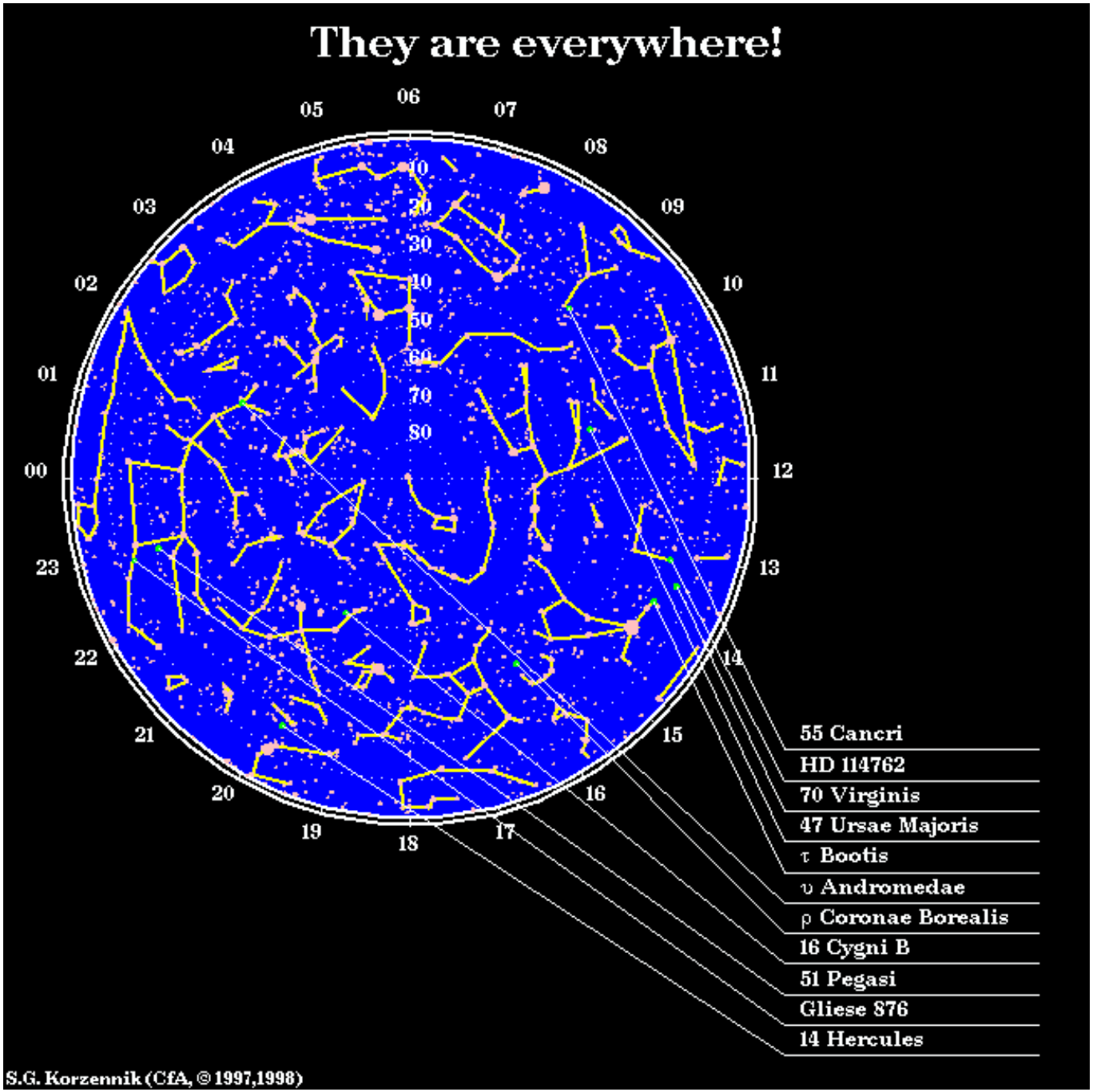
Orbital Semimajor Axis (AU)


They are everywhere!
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30
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50
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70
80
55 Cancri
HD 114762
70 Virginis
47 Ursae Majoris
τ Bootis
υ Andromedae
ρ Coronae Borealis
16 Cygni B
51 Pegasi
Gliese 876
14 Hercules
S.G. Korzennik (CfA, © 1997,1998)

National Aeronautics and Space Administration

NASAfacts

TESS

Transiting Exoplanet Survey Satellite

DISCOVERING NEW EARTHS AND SUPER-EARTHS IN THE SOLAR NEIGHBORHOOD

The Transiting Exoplanet Survey Satellite (TESS) is an Explorer-class planet finder. In the first-ever spaceborne all-sky transit survey, TESS will identify planets ranging from Earth-sized to gas giants, orbiting a wide range of stellar types and orbital distances. The principal goal of the TESS mission is to detect small planets with bright host stars in the solar neighborhood, so that detailed characterizations of the planets and their atmospheres can be performed.

TESS will monitor the brightnesses of more than 500,000 stars during a two year mission, searching for temporary drops in brightness caused by planetary transits. Transits occur when a planet's orbit carries it directly in front of its parent star as viewed from Earth. TESS is expected to catalog more than 3000 transiting exoplanet candidates, including a sample of ~500 Earth-sized and 'Super Earth' planets, with radii less than twice that of the Earth. TESS will detect small rock-and-ice planets orbiting a diverse range of stellar types and covering a wide span of orbital periods, including rocky worlds in the habitable zones of their host stars.

TESS stars will be 30-100 times brighter than those surveyed by the Kepler satellite; thus,TESS planets should be far easier to characterize with follow-up observations. These follow-up observations will provide refined measurements of the planet masses, sizes, densities, and atmospheric properties.

TESS will provide prime targets for further, more detailed characterization with the James Webb Space Telescope (JWST), as well as other large ground-based and space-based telescopes of the future. TESS's legacy will be a catalog of the nearest and brightest stars hosting transiting exoplanets, which will comprise the most favorable targets for detailed investigations in the coming decades.

TESS team partners include the Massachusetts Institute of Technology (MIT) Kavli Institute for Astrophysics and Space Research (MKI), NASA's Goddard Space Flight Center (GSFC); MIT Lincoln Laboratory (LL); Orbital ATK (OA); NASA's Ames Research Center (ARC); the Harvard-Smithsonian Center for Astrophysics (SAO); and the Space Telescope Science Institute (STScI).

TESS has been selected by NASA for launch in 2017 as an Astrophysics Explorer mission.

TESS SCIENCE OBJECTIVES

DISCOVER TRANSITING EXOPLANETS ORBITING NEARBY, BRIGHT STARS

The NASA Kepler Mission showed that planets are abundant throughout the Galaxy, but most of the Kepler planets orbit stars too distant for further study. The NASA TESS Mission will find exoplanets transiting nearby, bright stars: the best targets for followup characterization with large ground telescopes, the Hubble Space Telescope, and the James Webb Space Telescope.

TESS is designed to:

- Monitor 500,000 nearby stars for planets
- Focus on Earth and Super-Earth size planets
- Cover 400X larger sky area than Kepler
- Span stellar spectral types of F5 to M5

Transiting exoplanets allow us to observe the following for those planets that transit nearby bright stars:

- Fundamental properties: mass, radius, orbit
- Dynamics: planet-planet interactions, mutual inclinations, moons, tides
- Atmospheric composition + structure: transmission spectrum, emission spectrum, albedo, phase function, clouds, winds

TESS MISSION OVERVIEW

ALL-SKY, TWO YEAR PHOTOMETRIC EXOPLANET DISCOVERY MISSION

TESS will tile the sky with 26 observation sectors:

- At least 27 days staring at each 24° x 96° sector
- Brightest 100,000 stars at 1-minute cadence
- Full frame images with 30-minute cadence
- Map Northern hemisphere in first year
- Map Southern hemisphere in second year
- Sectors overlap at ecliptic poles for sensitivity to smaller and longer period planets in JWST Continuous Viewing Zone (CVZ)

TESS observes from unique High Earth Orbit (HEO):

- Unobstructed view for continuous light curves
- Two 13.7 day orbits per observation sector
- Stable 2:1 resonance with Moon's orbit
- Thermally stable and low-radiation

TESS SCIENCE INSTRUMENT

FOUR WIDE FIELD-OF-VIEW CCD CAMERAS

Each of the four cameras has:

- 24° x 24° Field-of-View
- 100 mm effective pupil diameter
- Lens assembly with 7 optical elements
- Athermal design
- 600nm – 1000nm bandpass
- 16.8 Megapixel, low-noise, low-power, MIT Lincoln Lab CCID-80 detector

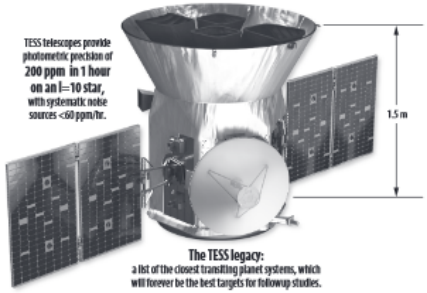
TESS SPACECRAFT

DESIGNED FOR PHOTOMETRIC STABILITY

Heritage Orbital LEOStar-2 spacecraft bus:

- 3-axis stabilized pointing, with ≤3 arc-sec performance
- Two-headed star tracker; 4 wheel zero-momentum system
- 400W single-axis articulating solar array
- Passive thermal control
- Mono-propellant propulsion system
- Ka-band 100 Mbps science downlink

TESS will launch in 2017, in time to find planets for JWST to observe.



For more information, please visit our web site:
http://tess.gsfc.nasa.gov

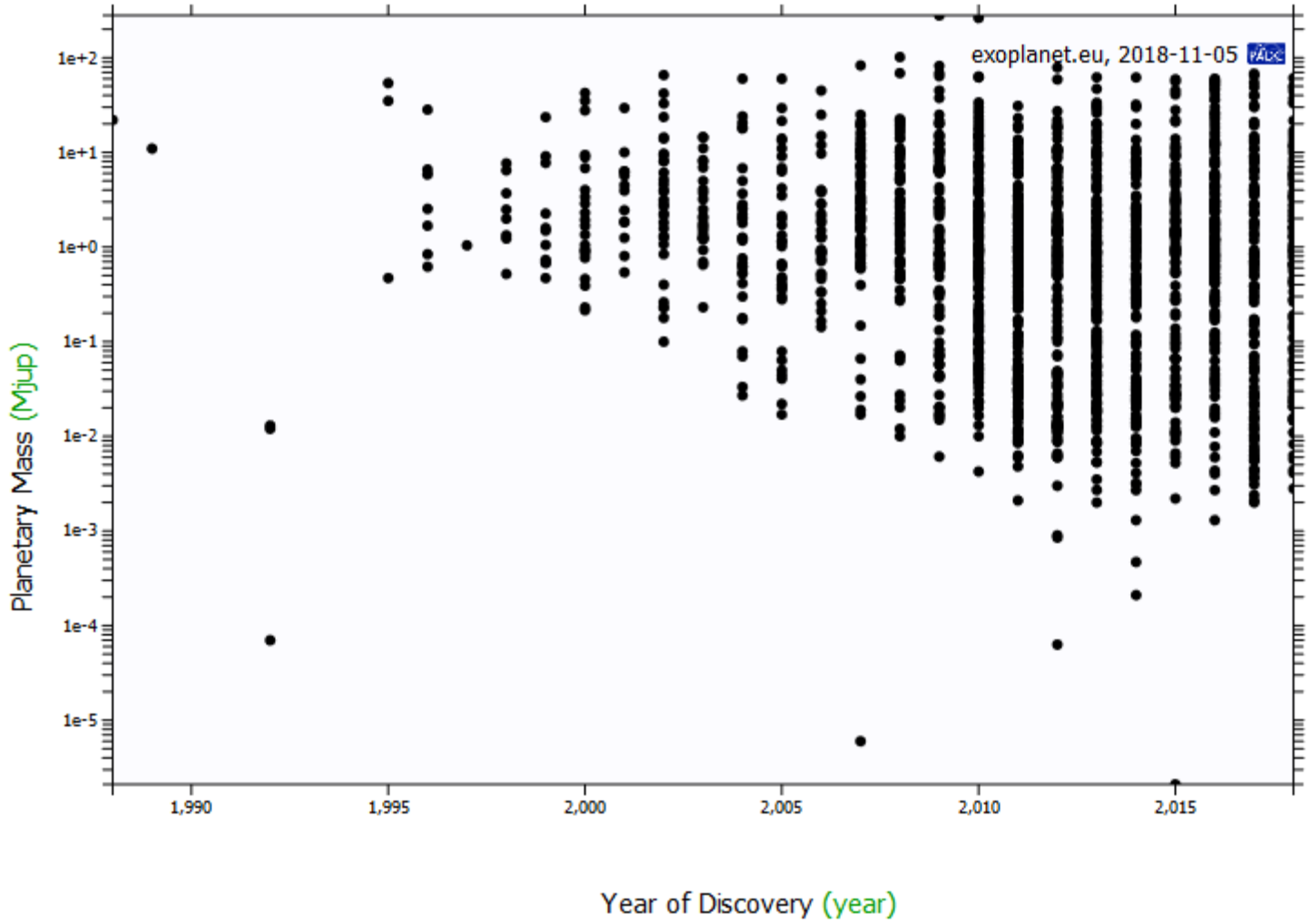
National Aeronautics and Space Administration

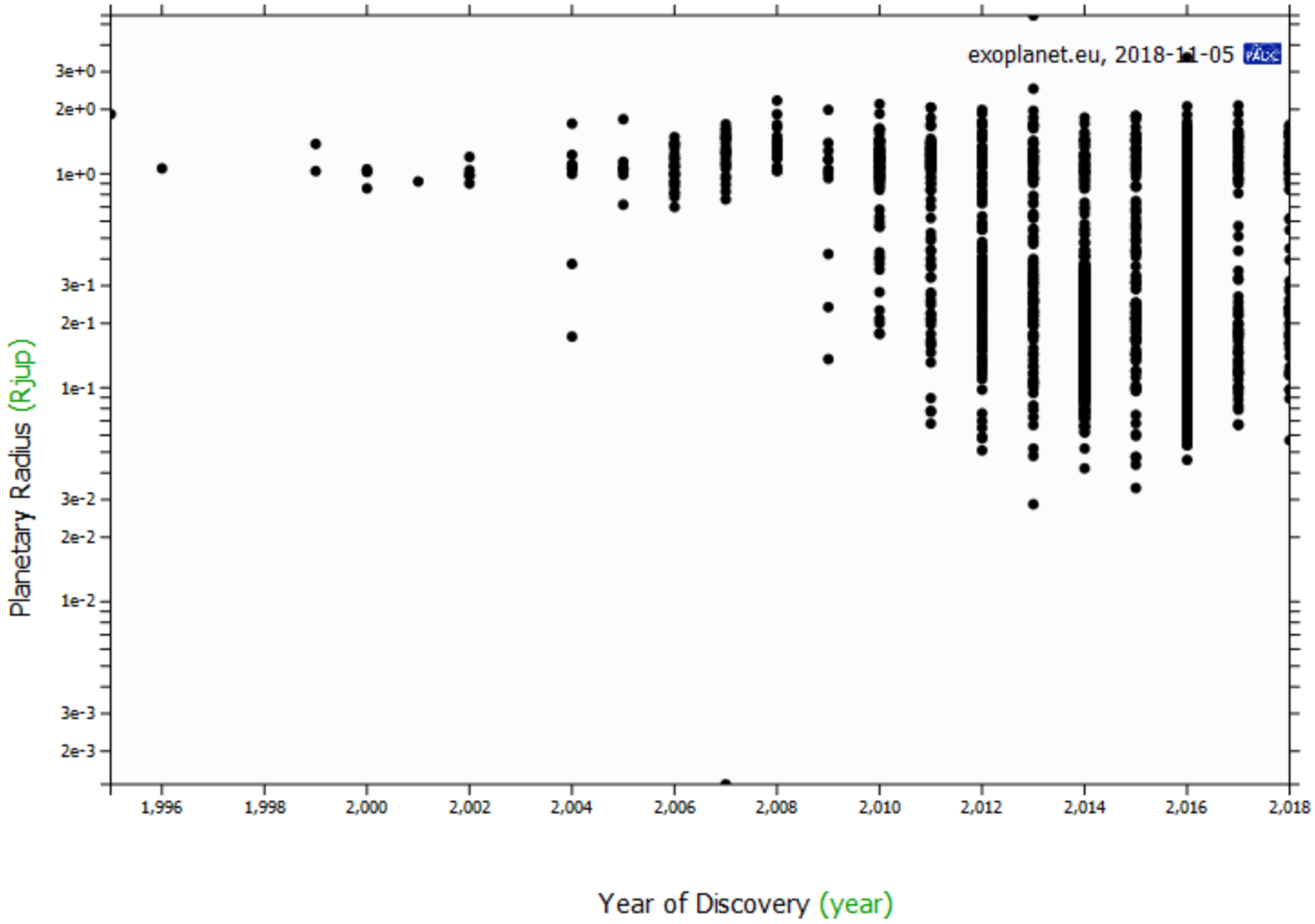
Goddard Space Flight Center
8800 Greenbelt Road
Greenbelt, MD 20771

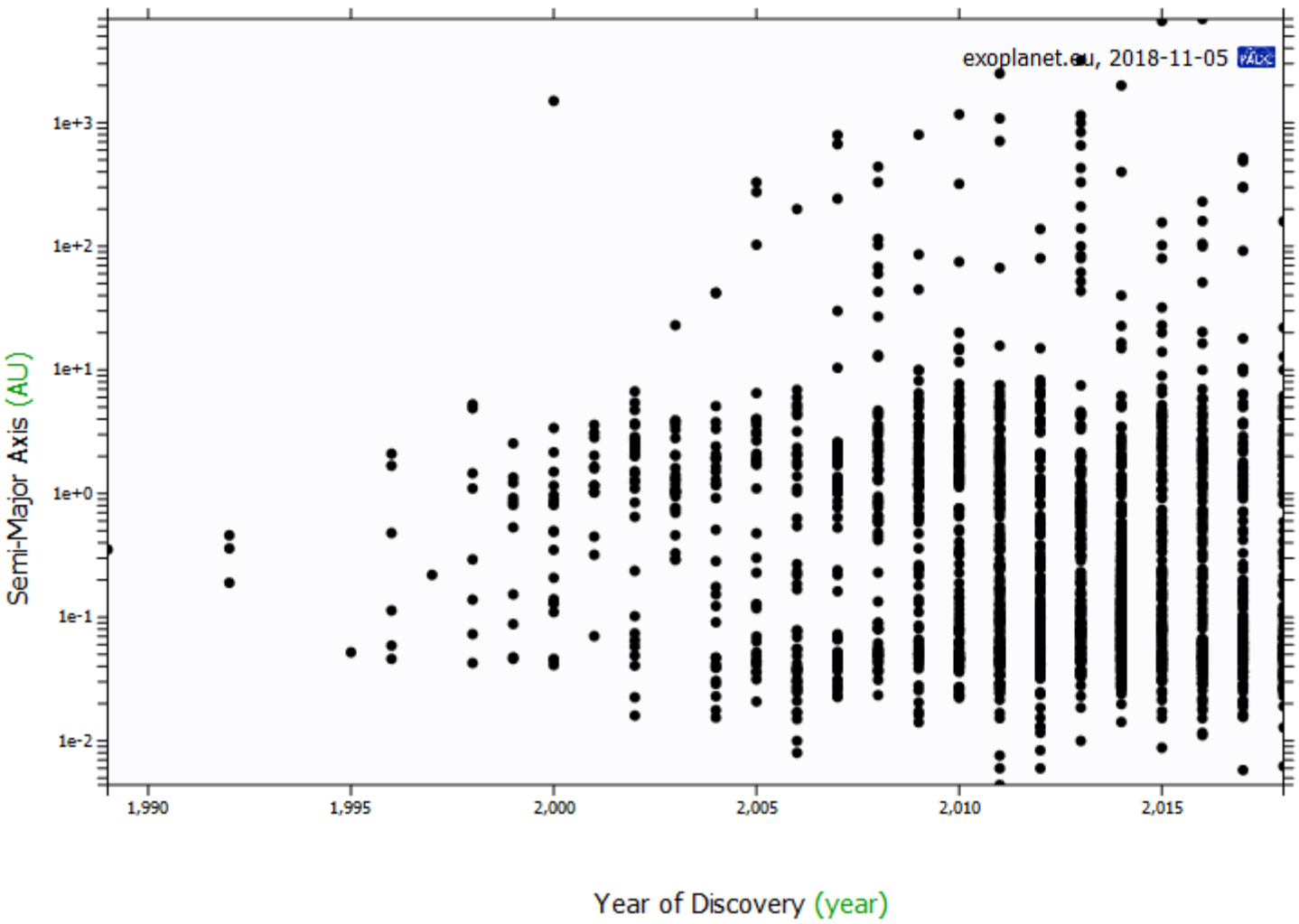
www.nasa.gov

Latest Exoplanet Data

Last update:
5 November 2018
3,875 planets


exoplanet.eu, 2018-11-05
Planetary Mass (Mjup)
1e+2
1e+1
1e+0
1e-1
1e-2
1e-3
1e-4
1e-5
1,990
1,995
2,000
2,005
2,010
2,015
Year of Discovery (year)


exoplanet.eu, 2018-11-05
Planetary Radius (Rjup)
3e+0
2e+0
1e+0
3e-1
2e-1
1e-1
3e-2
2e-2
1e-2
3e-3
2e-3
1,996
1,998
2,000
2,002
2,004
2,006
2,008
2,010
2,012
2,014
2,016
2,018
Year of Discovery (year)


exoplanet.eu, 2018-11-05
Semi-Major Axis (AU)
1e+3
1e+2
1e+1
1e+0
1e-1
1e-2
1,990
1,995
2,000
2,005
2,010
2,015
Year of Discovery (year)

Using the prolific planet hunting Kepler spacecraft, astronomers have discovered 4,496 planet candidates orbiting other suns since the Kepler mission's search for Earth-like worlds began in 2009. To find them, Kepler monitors a rich star field to identify planetary transits by the slight dimming of starlight caused by a planet crossing the face of its parent star.