How to detect extrasolar planets?
(= planets outside of our solar system)

Dr. Denis Defrère
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What is a planet?

A planet is a celestial body which, in the Solar System,
- is in **orbit around the Sun**;
- has sufficient mass to assume **hydrostatic equilibrium** (a nearly round shape);
- has "**cleared the neighborhood**" around its orbit.

The eight planets in the Solar system
Questions:

Do you know how many extrasolar planets have been detected and how?
Lots of extrasolar planets!
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First detection around a Sun-like star (Mayor and Queloz 1995)
Lots of extrasolar planets!

First detection around a Sun-like star (Mayor and Queloz 1995)

Today: ~4100 extrasolar planets
Lots of extrasolar planets!

Cumulative Detections Per Year

- Radial Velocity
- Transits
- Microlensing
- Imaging
- Timing Variations
- Orbital Brightness
- Modulation
- Astrometry
- Disk Kinematics

MOST SUCCESSFUL TECHNIQUES
Technique 1: Radial velocity

- Star, planet move around common center of mass
- Doppler effect moves spectral lines
- Look for periodic variations in stellar velocity
Technique 1: RV signal

- Semi-amplitude of radial velocity given by:

\[ K = \left( \frac{2\pi G}{P_{\text{orb}}} \right)^{1/3} \frac{M_p \sin i}{(M_* + M_p)} \frac{1}{\sqrt{1-e^2}} \]

- \( P_{\text{orb}} \): orbital period
- \( M_* \): mass of star
- \( M_p \): mass of planet
- \( i \): inclination, angle between normal to orbital plane and line of sight
- \( e \): eccentricity

*measured
*derived
Technique 2: transit

- Low probability but simple observation
- Good for large planets close to the star
Technique 2: transit signal

- Intensity signal:

\[ \frac{\Delta I}{I} = \left( \frac{R_p}{R_*} \right)^2 \]

- \( R_* \): stellar radius
- \( R_p \): planet radius
- About 1% for Jupiter and Sun
- Transit duration proportional to \((P_{orb})^{1/3} \frac{R_*}{(M_*)^{1/3}}\)
- Transit duration: also estimate of stellar radius
- Intensity change then provides planetary radius
Technique 3: direct imaging

- Equivalent to taking a picture of the planetary system
- Require good sensitivity and high angular resolution => large telescope

HR 8799 surrounded by 4 giants extrasolar planets
Technique 3: direct imaging
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Questions: What kind of extrasolar planets can we detect today?
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What we have learned today

- First extrasolar planet around a Sun-like star detected in 1995

- More than 4100 extrasolar planets detected today

- Different detection techniques (radial velocity, transit, direct imaging, ...)

- What we can learn: presence, mass, radius, orbit

- Next: how to characterize them? (i.e. chemical composition)
Some perspectives
Some perspectives

Zone searched for exoplanets
Further readings


• NASA exoplanet archive for up-to-date plots and latest results: https://exoplanetarchive.ipac.caltech.edu/

• Extrasolar planet encyclopedia for news and catalog: http://exoplanet.eu/

• Slides of this presentation: www.biosignatures.ulg.ac.be/ddefrere/teaching.php

• Contact: ddefrere@uliege.be