Observing other worlds: Exoplanetary Systems

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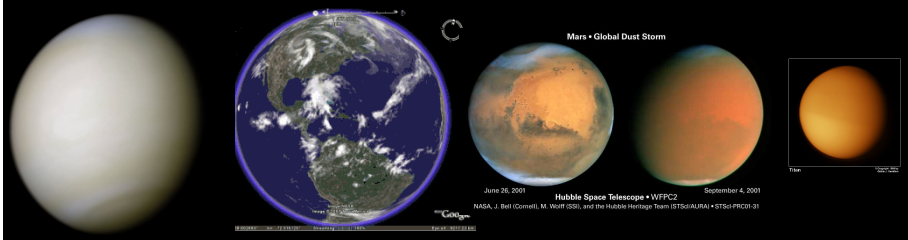
How 'normal' is our solar system?

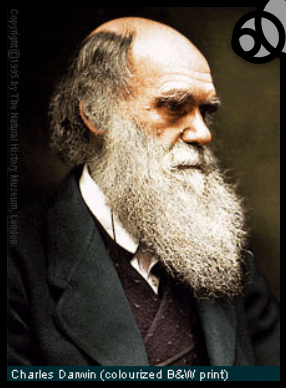
How unique is the Earth?

Solar system planets show an immense complexity and diversity



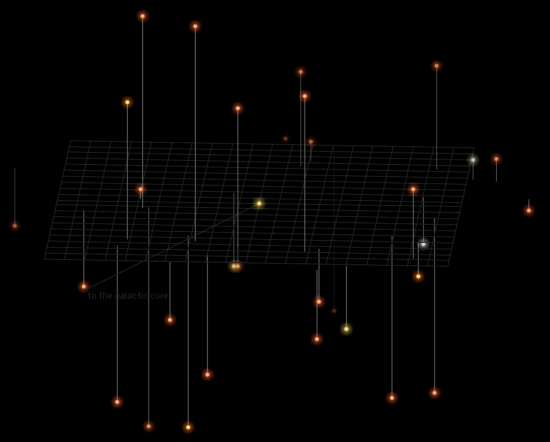
Venus	Earth	Mars	Titan
Super-rotating, CO2-based Opaque sulfuric acid clouds	**Partially clear, N2-based biotic oxygen**	**Tenous CO2 varying trace-amount of methane**	**Very cold, N2-based, opaque methane/ethane clouds**

Solar System:



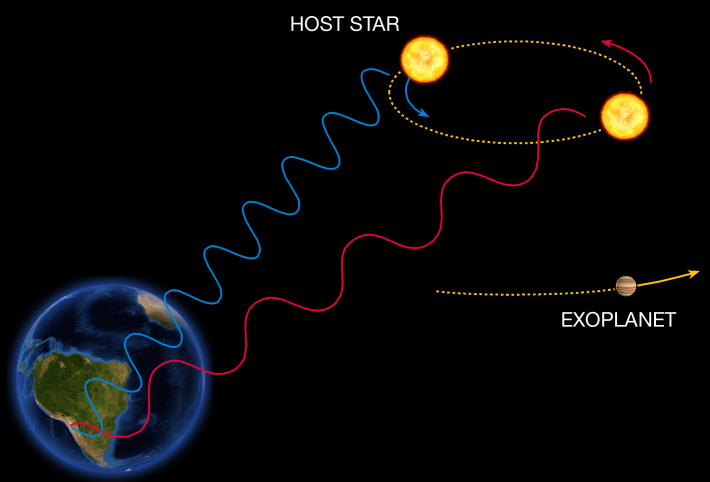
Trying to comprehend **Tree of Life** using three animals"

Planets around other stars are very difficult to observe

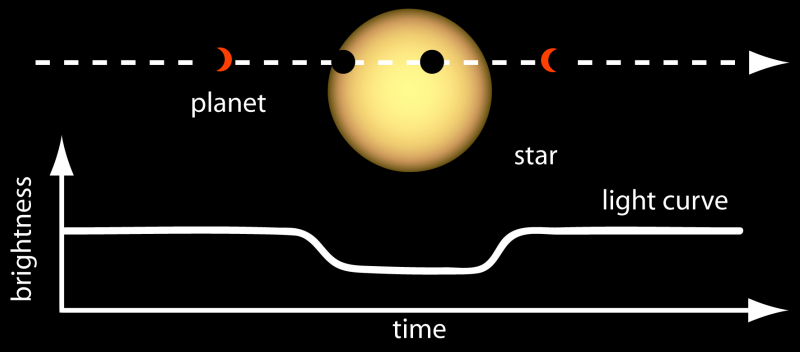


Majewski

Indirect methods

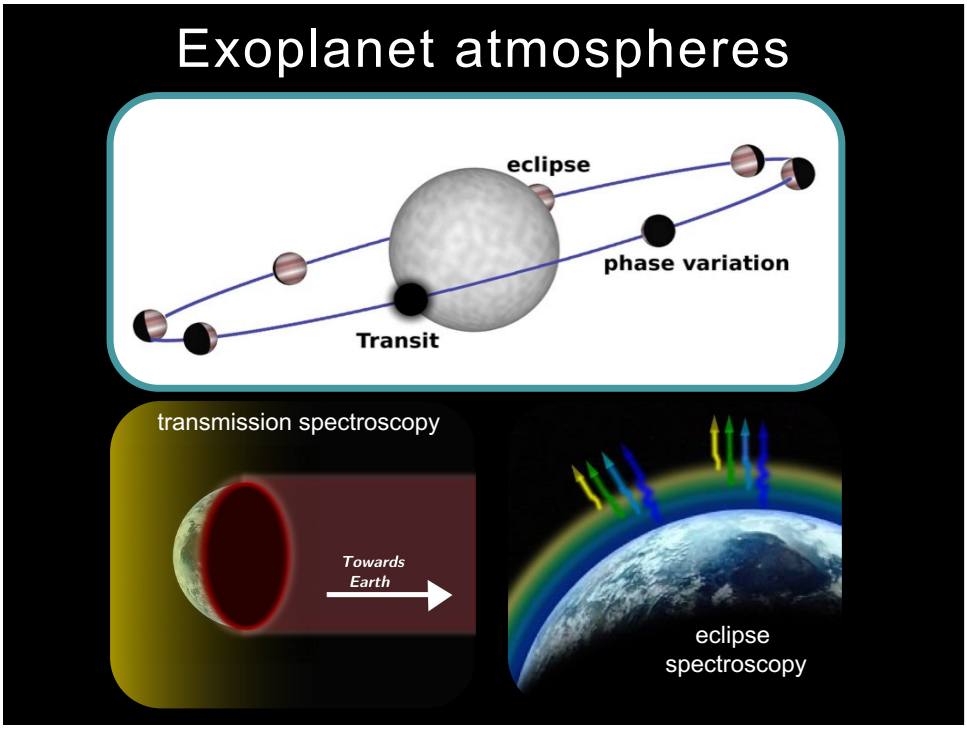


Indirect methods



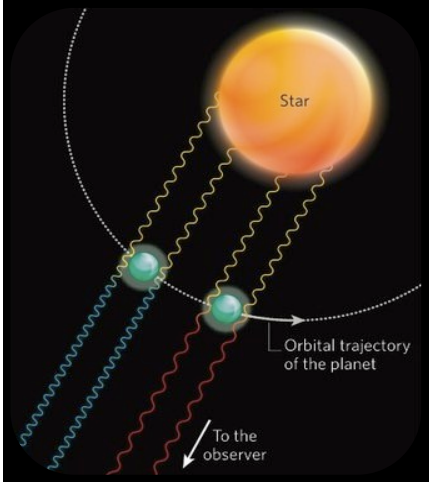
25 years of exoplanets studies

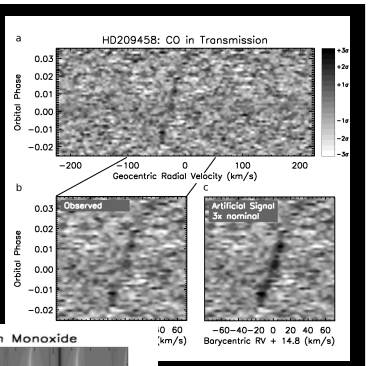
- Thousands of exoplanets found
- Diversity even larger than in Solar System
  - Hot Jupiters on close-in orbits
  - Super-Earths/mini-Neptunes
  - Super-Jupiters at very large distances
- 1:10 stars host Jupiter-mass planets
- 1:5 stars host Neptune-mass planets
- Most stars host Earth-mass planets

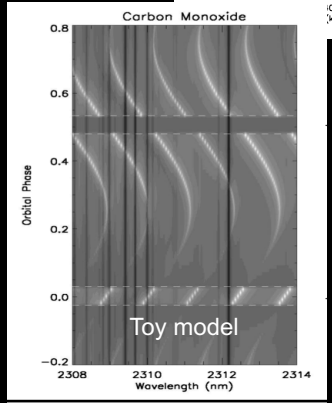

Exoplanet atmospheres
eclipse
phase variation
Transit
transmission spectroscopy
Towards
Earth
eclipse
spectroscopy


European Southern Observatory
Very Large Telescope (4x8m telescopes)

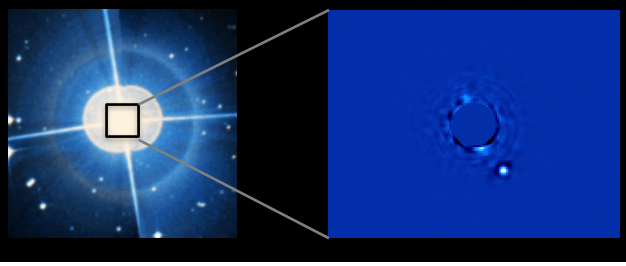
High-dispersion spectroscopy

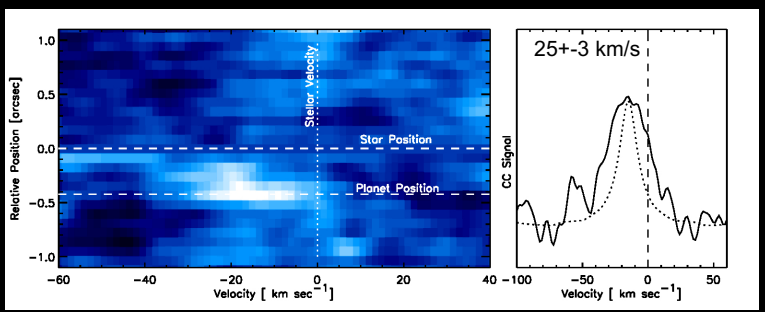




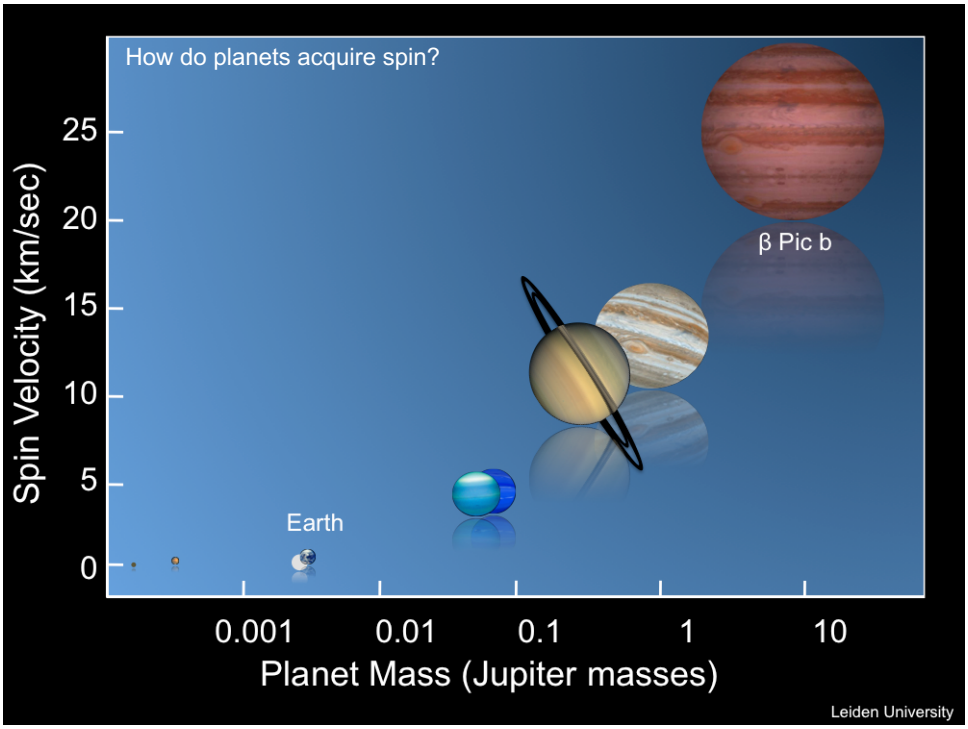


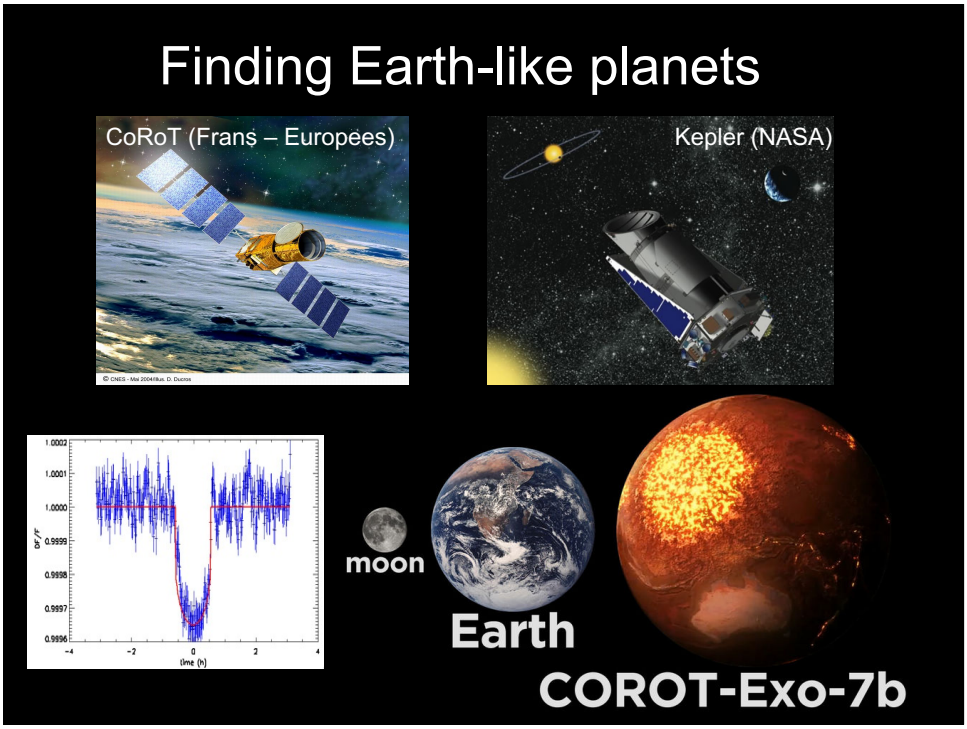
High Dispersion Spectroscopy + high-contrast imaging

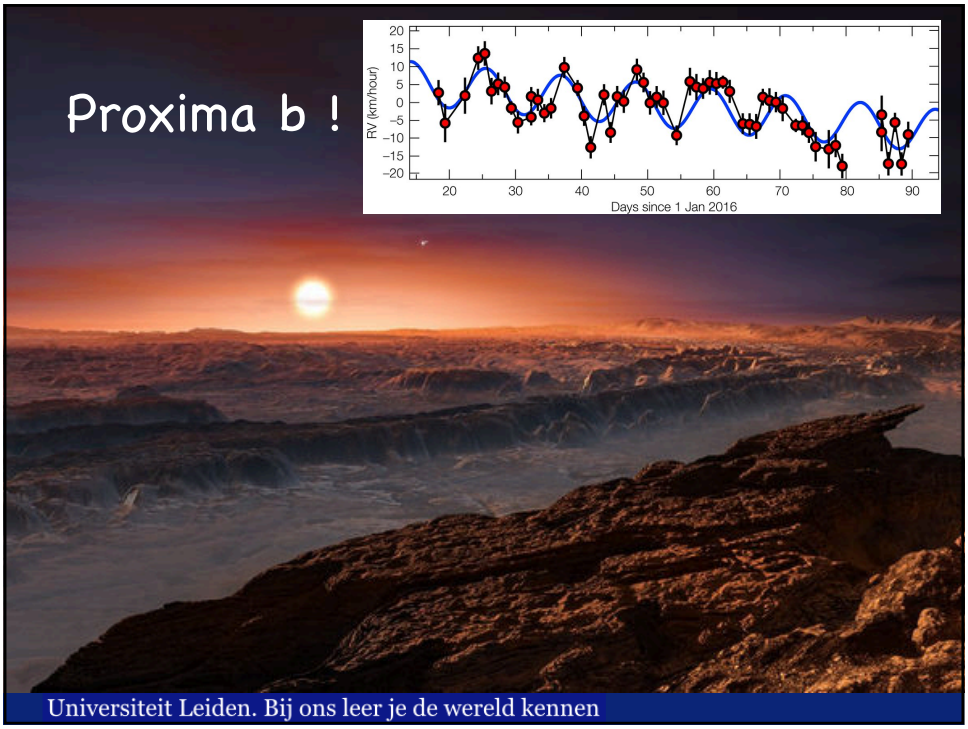




Length of Day on Beta Pictoris b ~8 hours

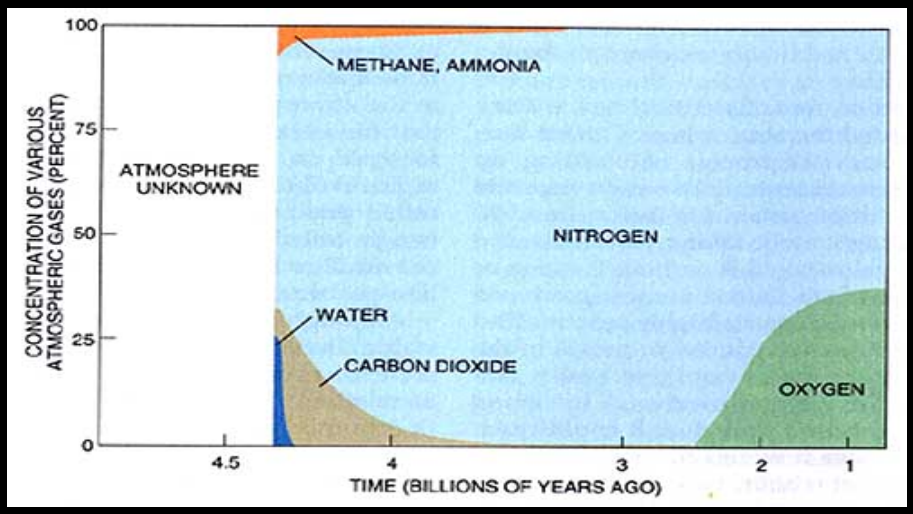

How do planets acquire spin?
Spin Velocity (km/sec)
25
20
15
10
5
0
β Pic b
Earth
0.001
0.01
0.1
1
10
Planet Mass (Jupiter masses)
Leiden University

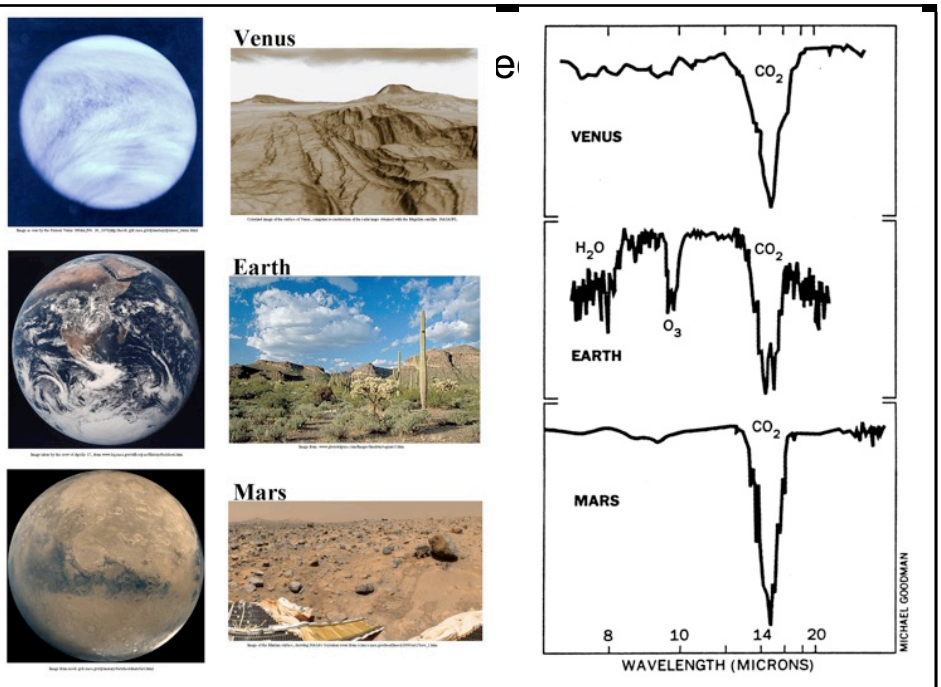

Finding Earth-like planets
CoRoT (Frans – Europees)
Kepler (NASA)
moon
Earth
COROT-Exo-7b


Proxima b !
RV (km/hour)
Days since 1 Jan 2016
Universiteit Leiden. Bij ons leer je de wereld kennen


European Extremely Large Telescope - 2024
Universiteit Leiden. Bij ons leer je de wereld kennen

Finding evidence for Life





How common is extraterrestrial life?

Philosofy for astronomers

1. The Copernican Principe:

We do not observe the universe from a special place → the Earth is a common planet

2. The Antropic Principe:

Our place in the universe needs to be able to sustain life → the Earth is special