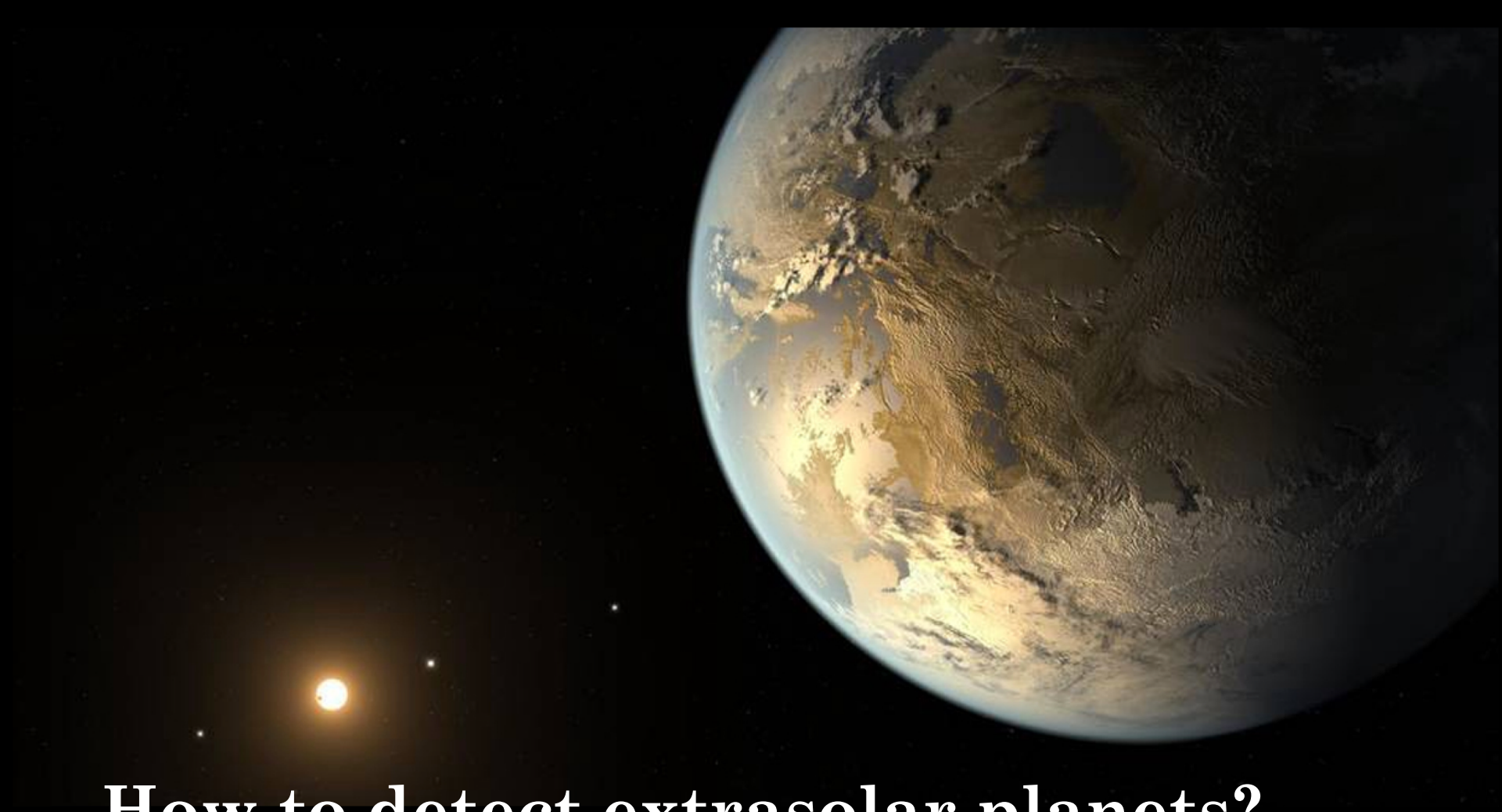


How to detect extrasolar planets?
(= planets outside of our solar system)

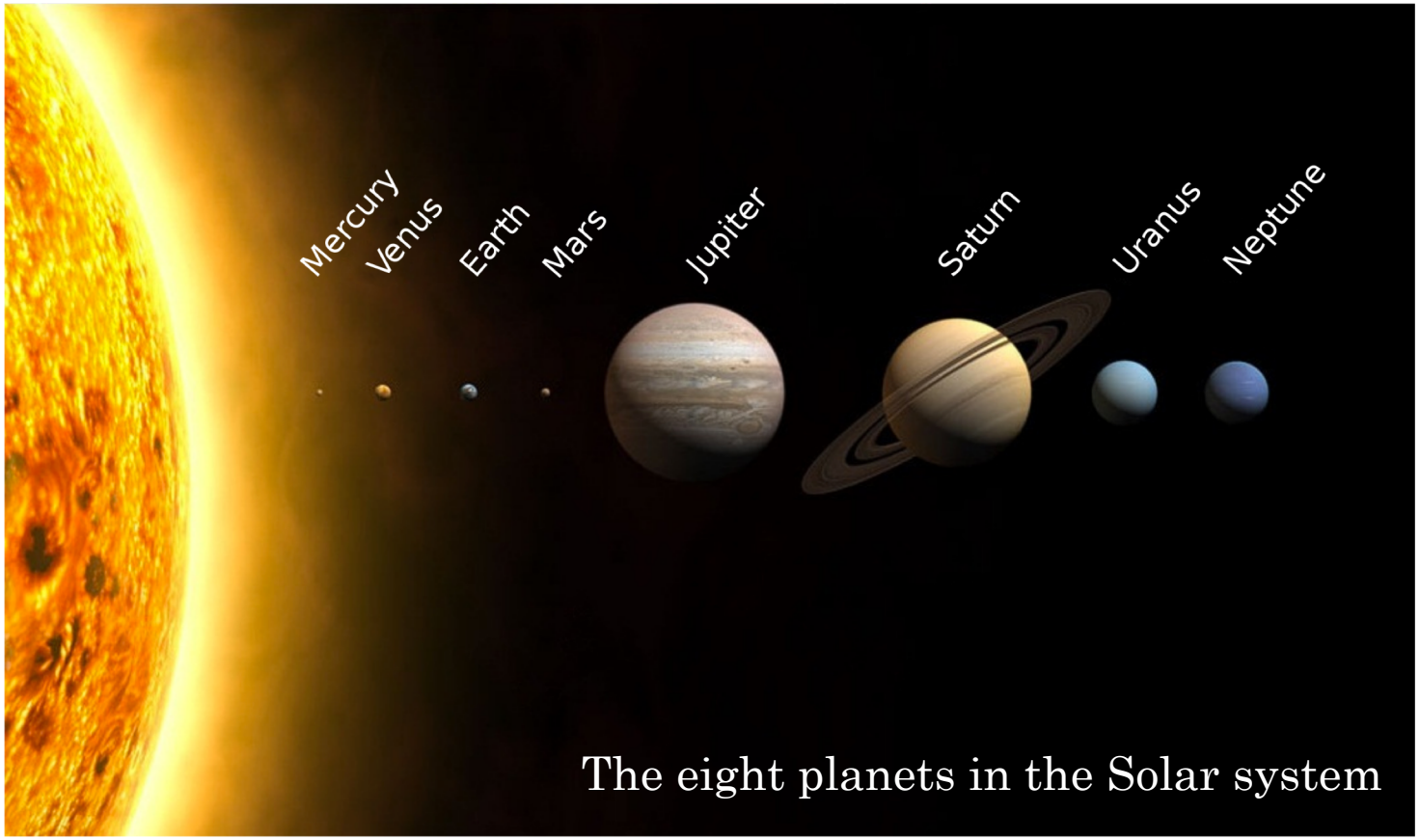
Dr. Denis Defrère

Inleiding tot de Sterrenkunde -- KUL (March 10th 2020)

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.

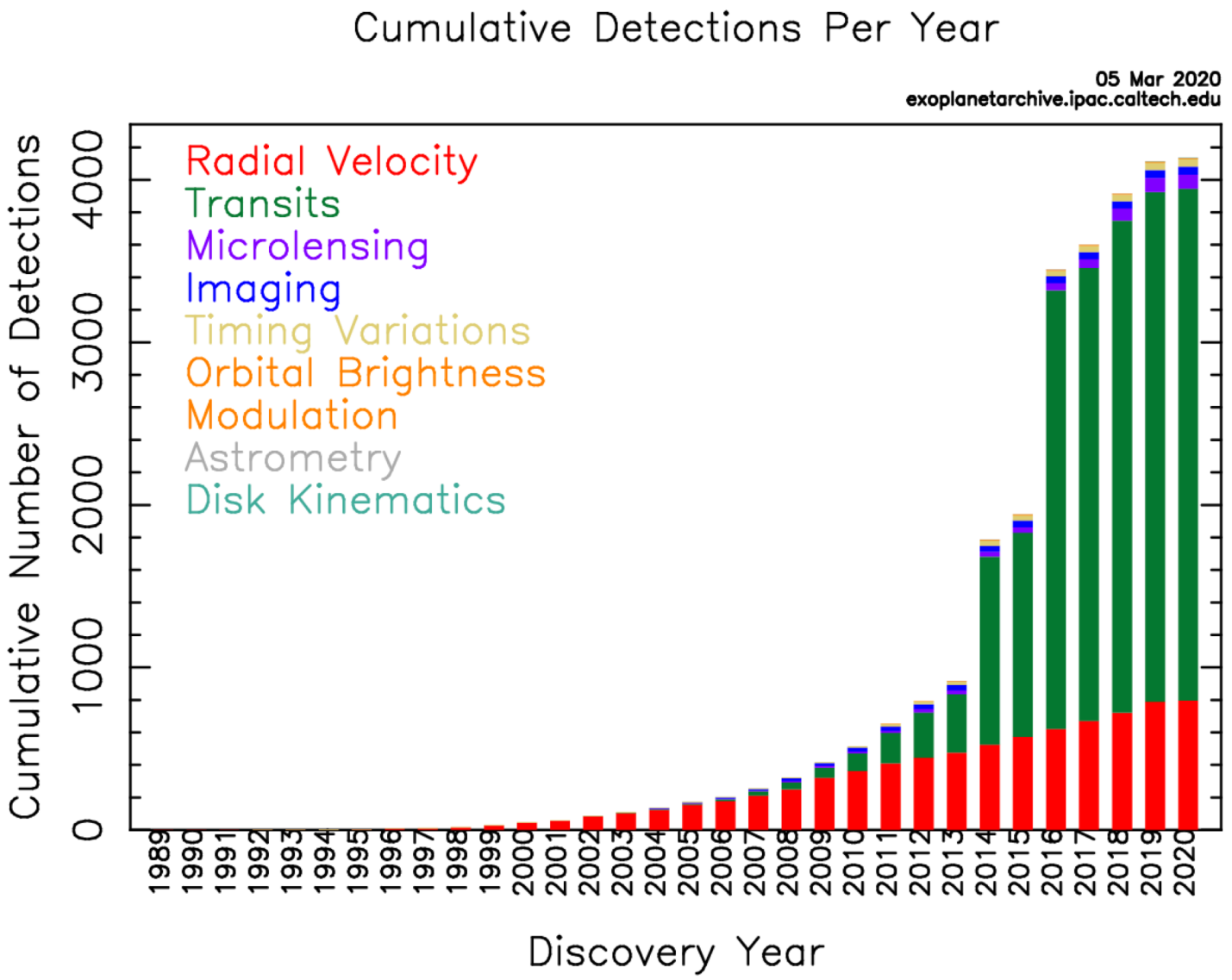


The eight planets in the Solar system

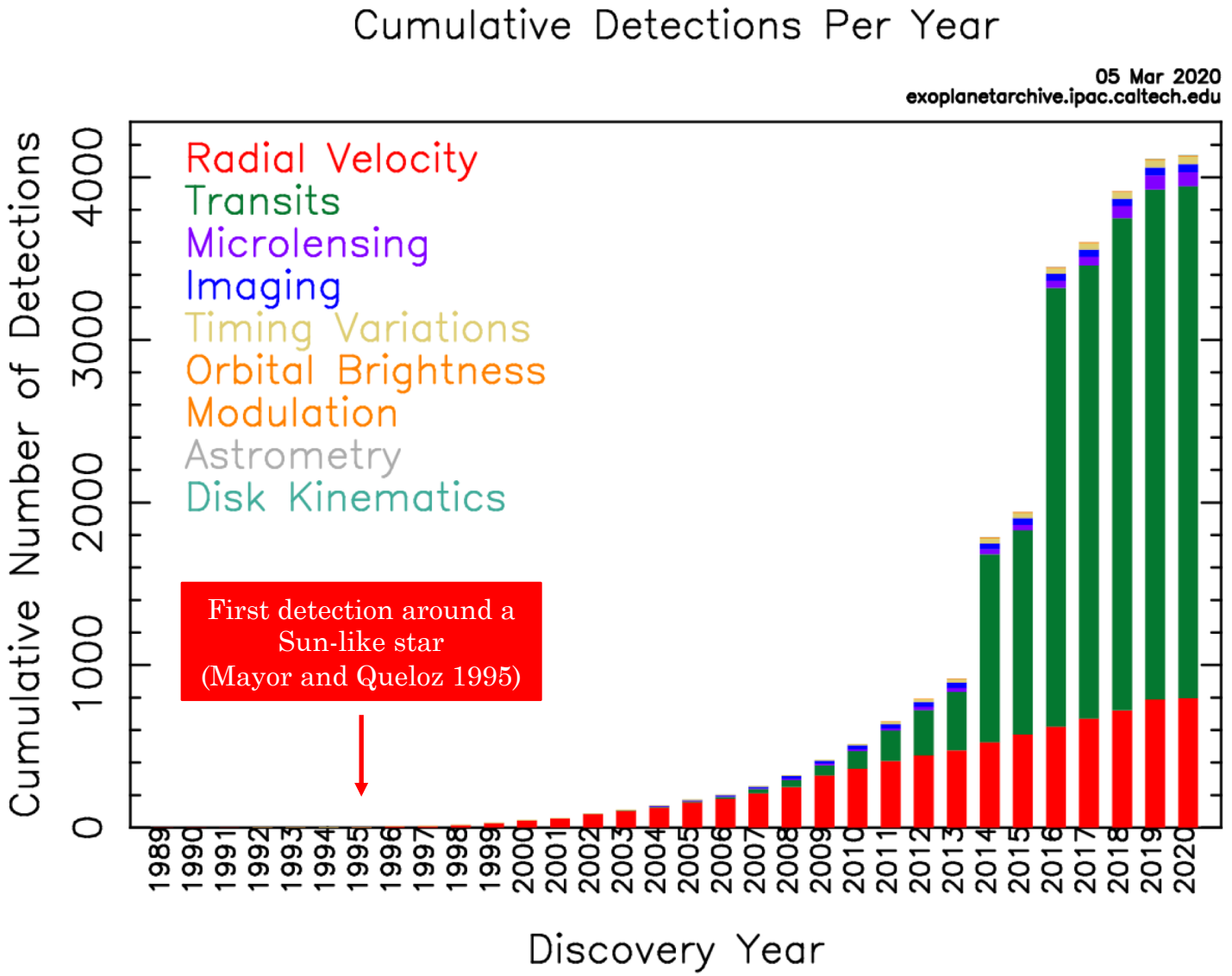
Questions:

Do you know how many extrasolar planets have been detected and how?

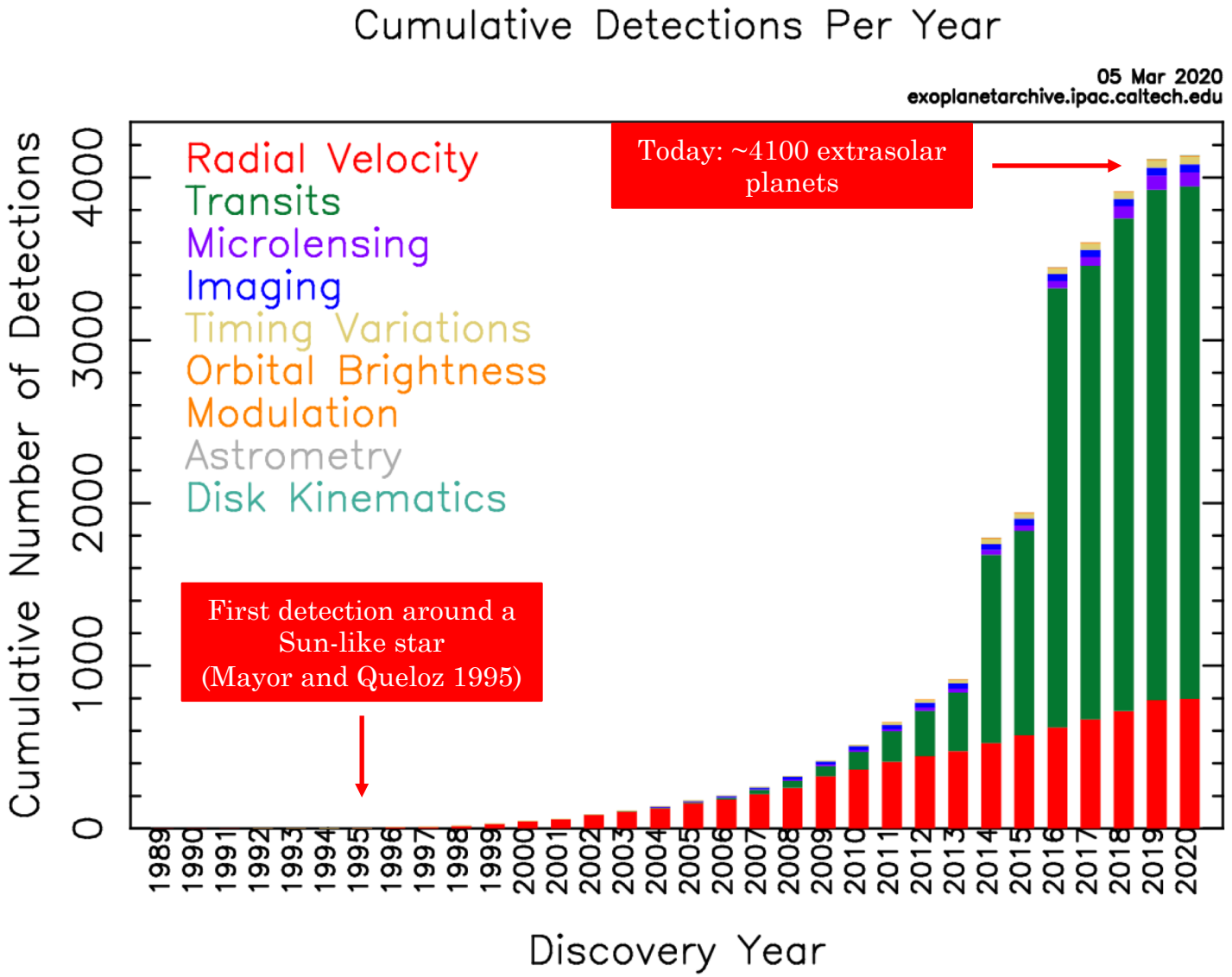
Lots of extrasolar planets!



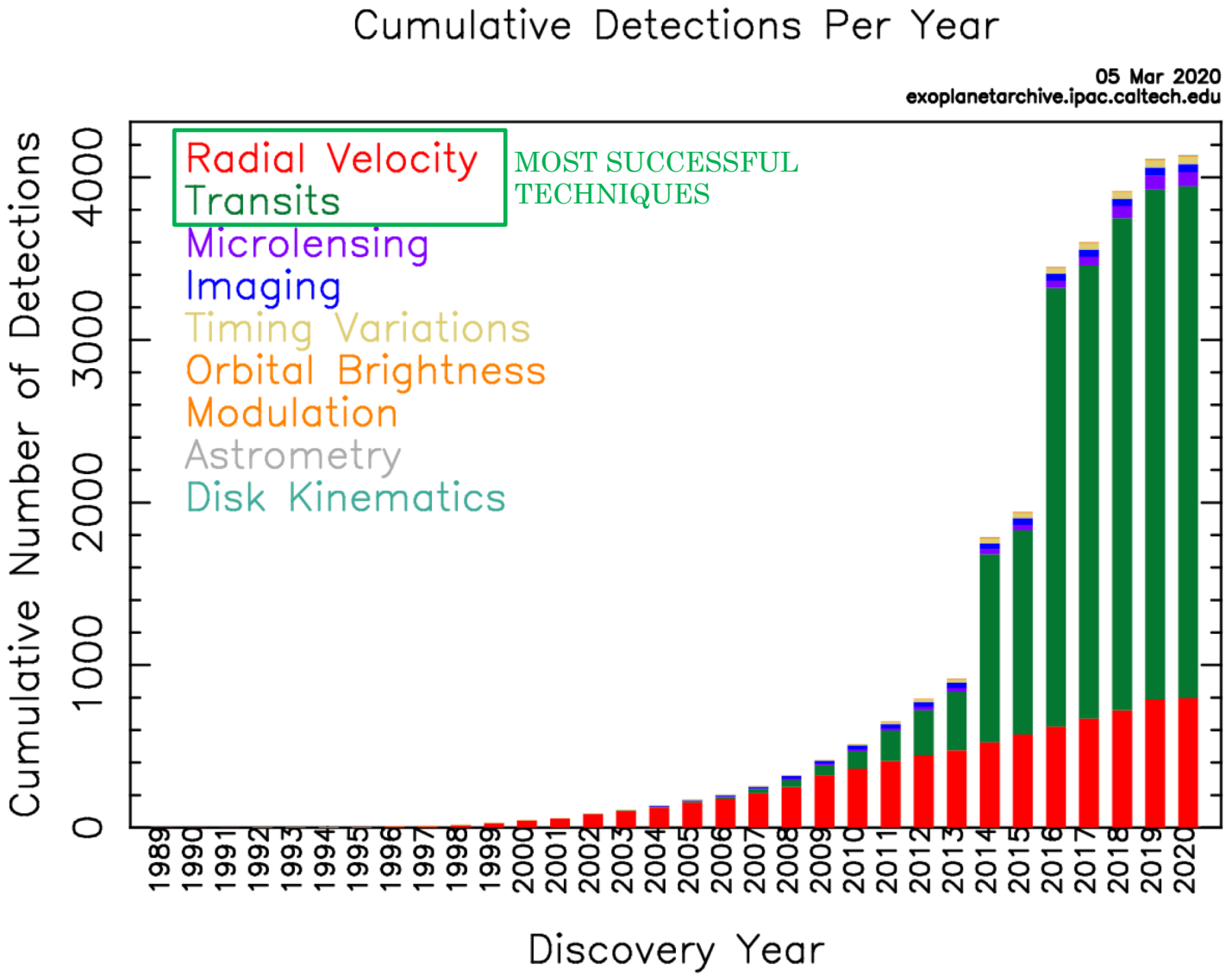
Lots of extrasolar planets!



Lots of extrasolar planets!

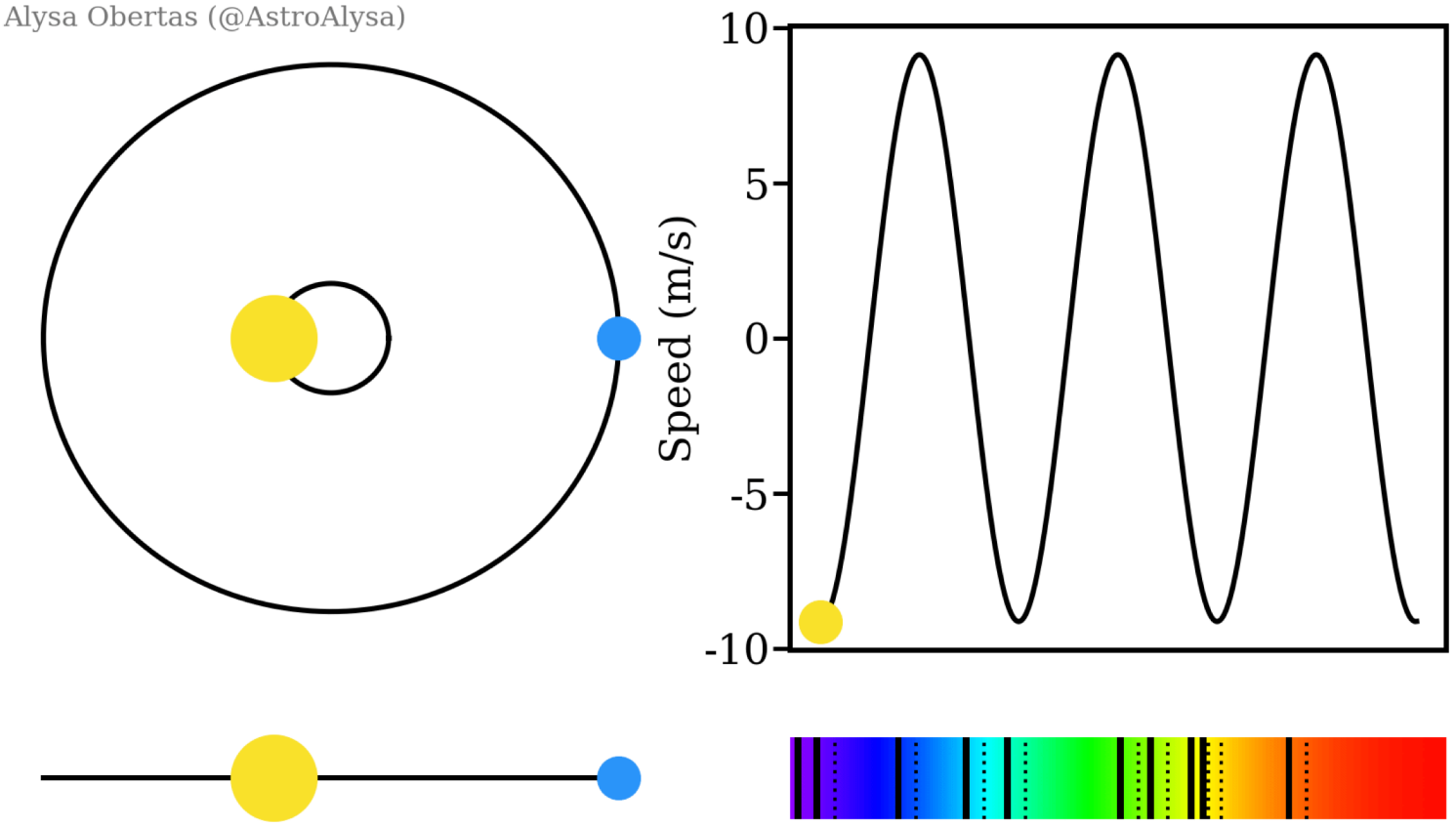


Lots of extrasolar planets!



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:

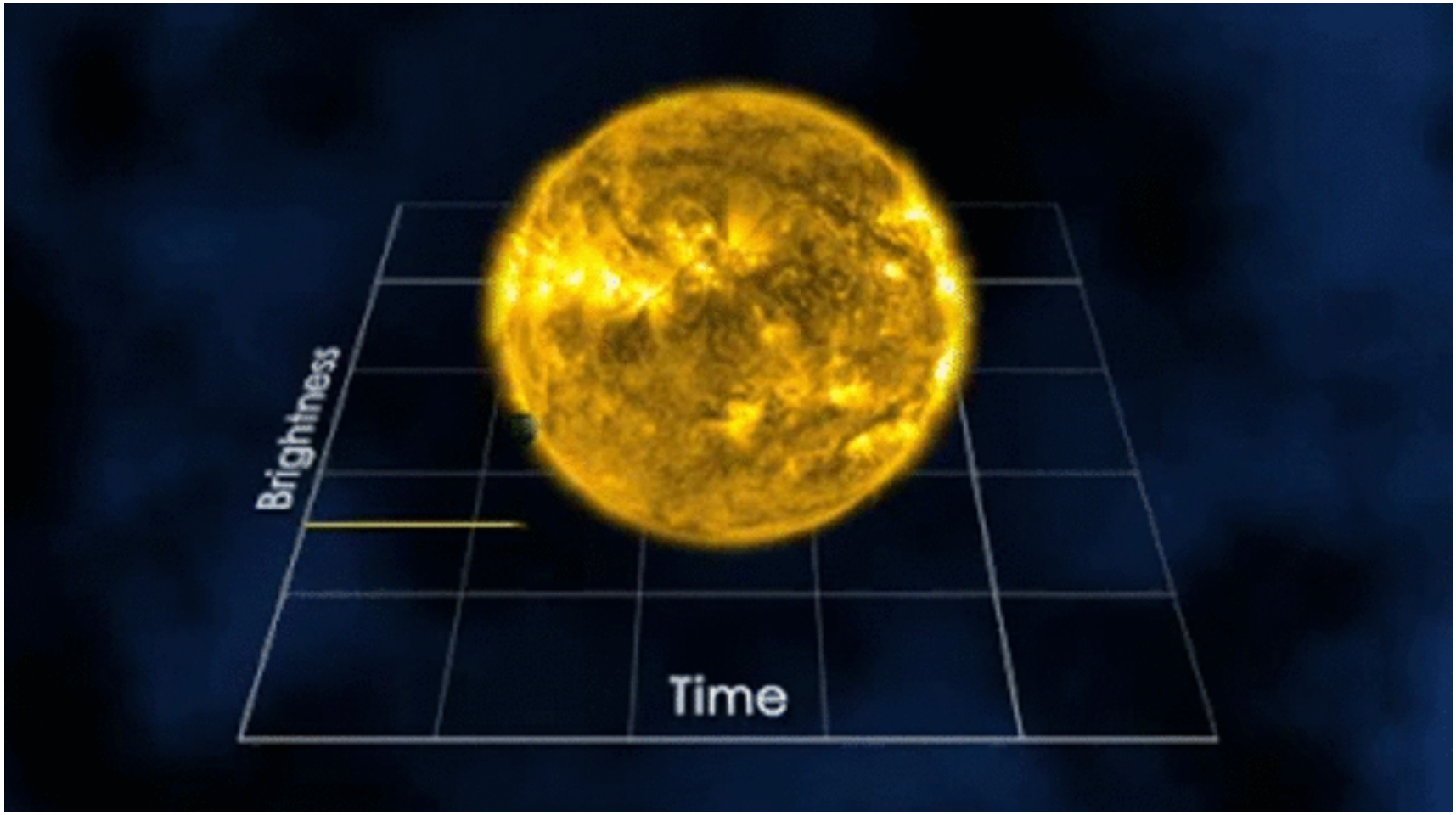
$$K = \left(\frac{2\pi G}{P_{orb}}\right)^{1/3} \frac{M_p sini}{(M_* + M_p)} \frac{1}{\sqrt{1-e^2}}$$

*measured
*derived

  - P_{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

Technique 2: transit

- Low probability but simple observation
- Good for large planets close to the star

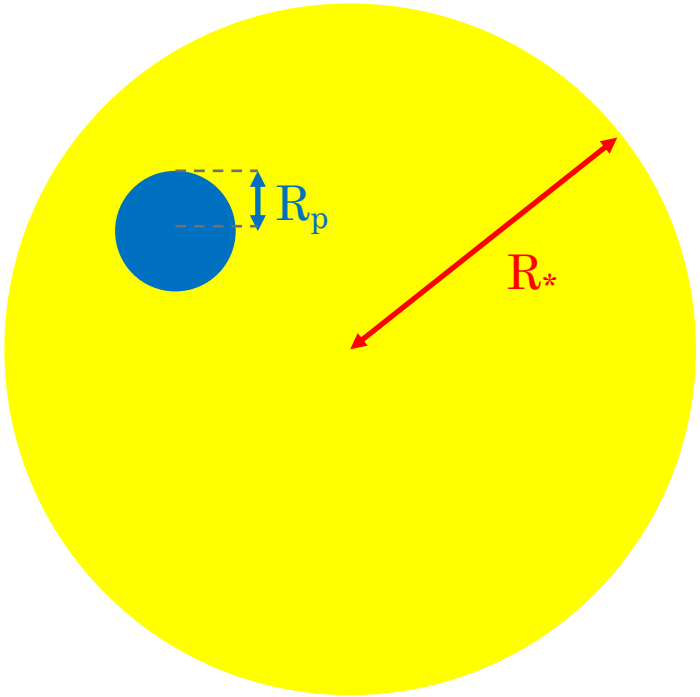


Technique 2: transit signal

- Intensity signal:

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

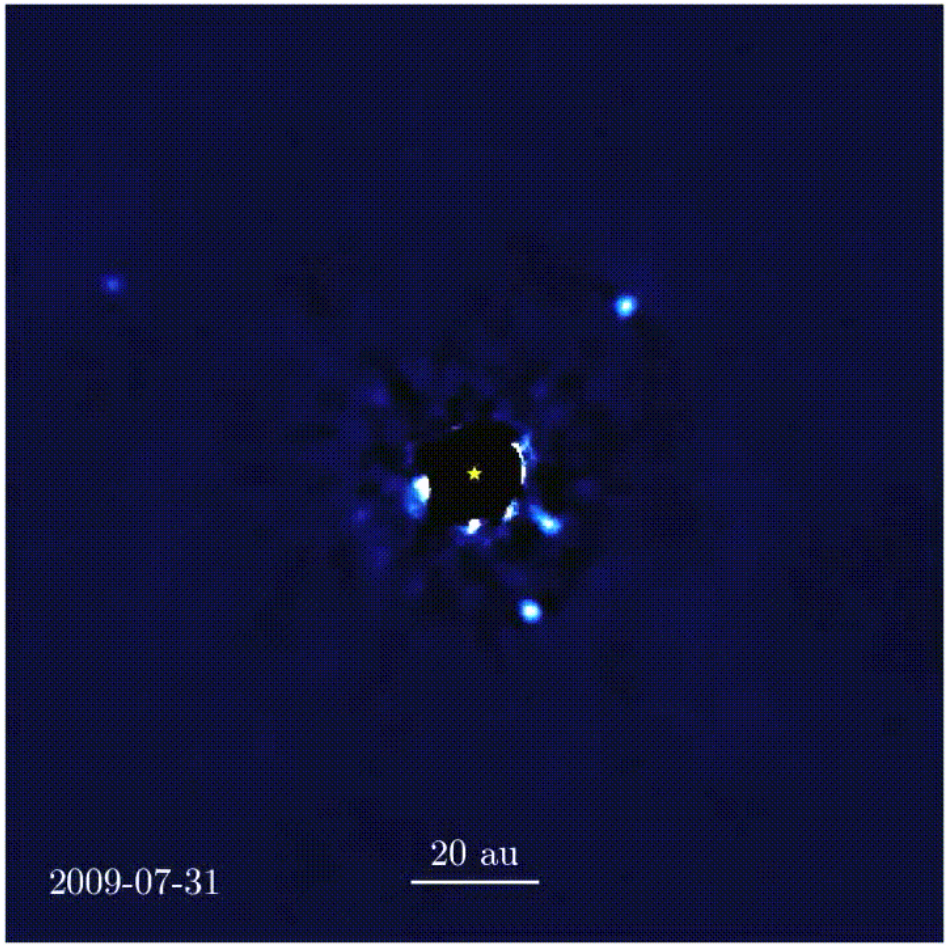
*measured
*derived



  - R_* : stellar radius
  - R_p : planet radius
  - About 1% for Jupiter and Sun
  - Transit duration proportional to $(P_{orb})^{1/3}\ R_* \ /\ (M_*)^{1/3}$
  - 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

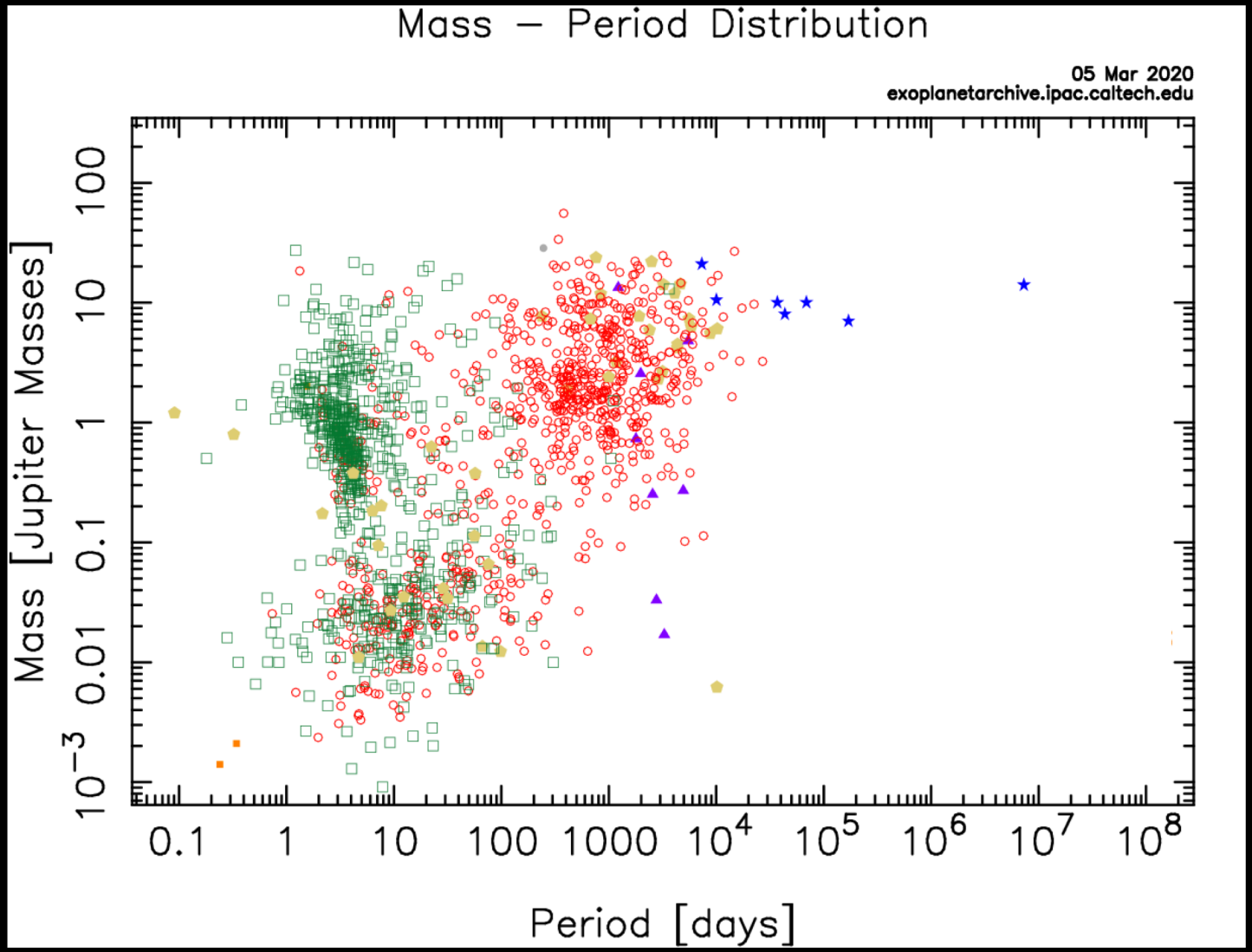


HR 8799 surrounded by 4 giants extrasolar planets

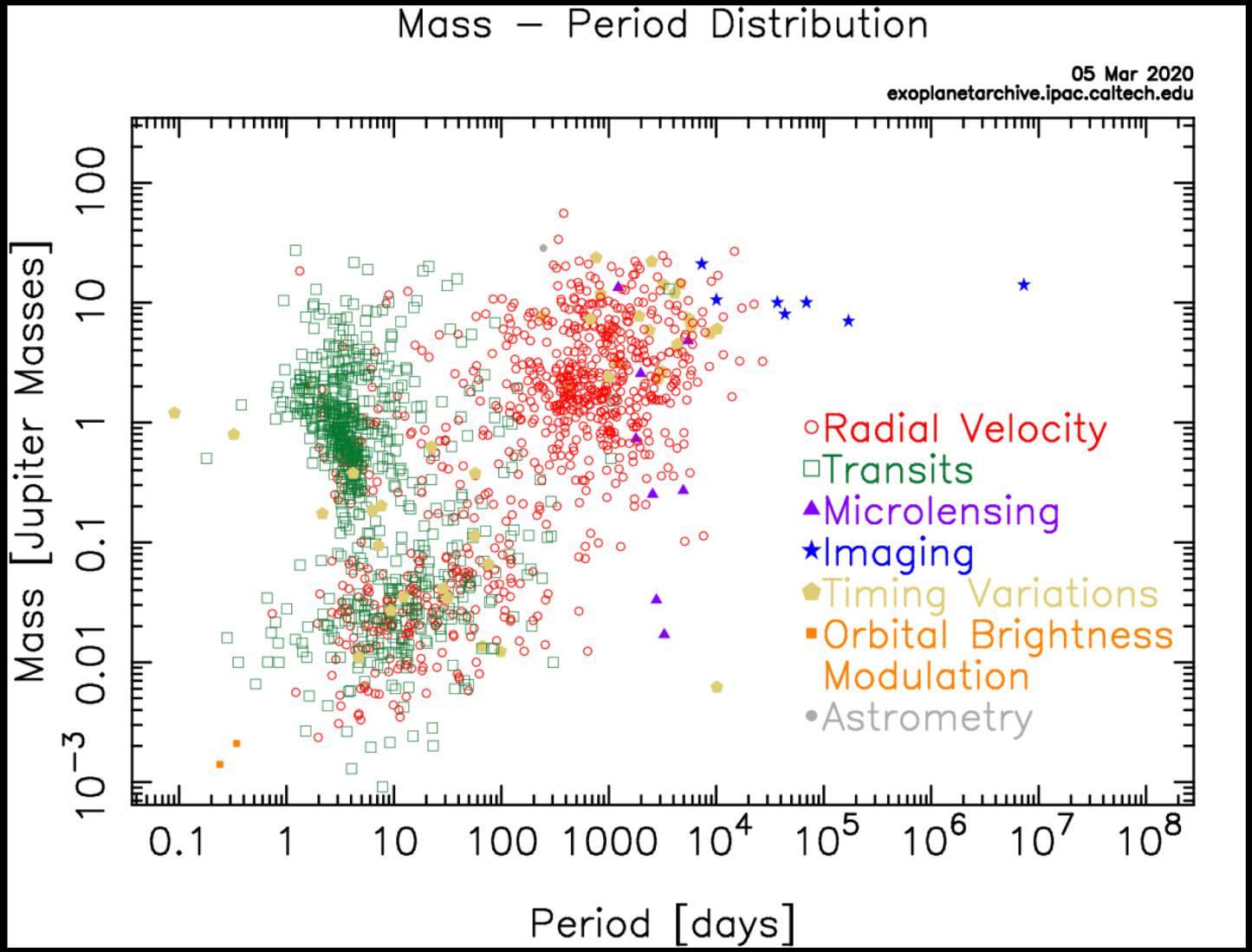
Technique 3: direct imaging

Technique 3: direct imaging

Questions: What kind of extrasolar planets can we detect today?



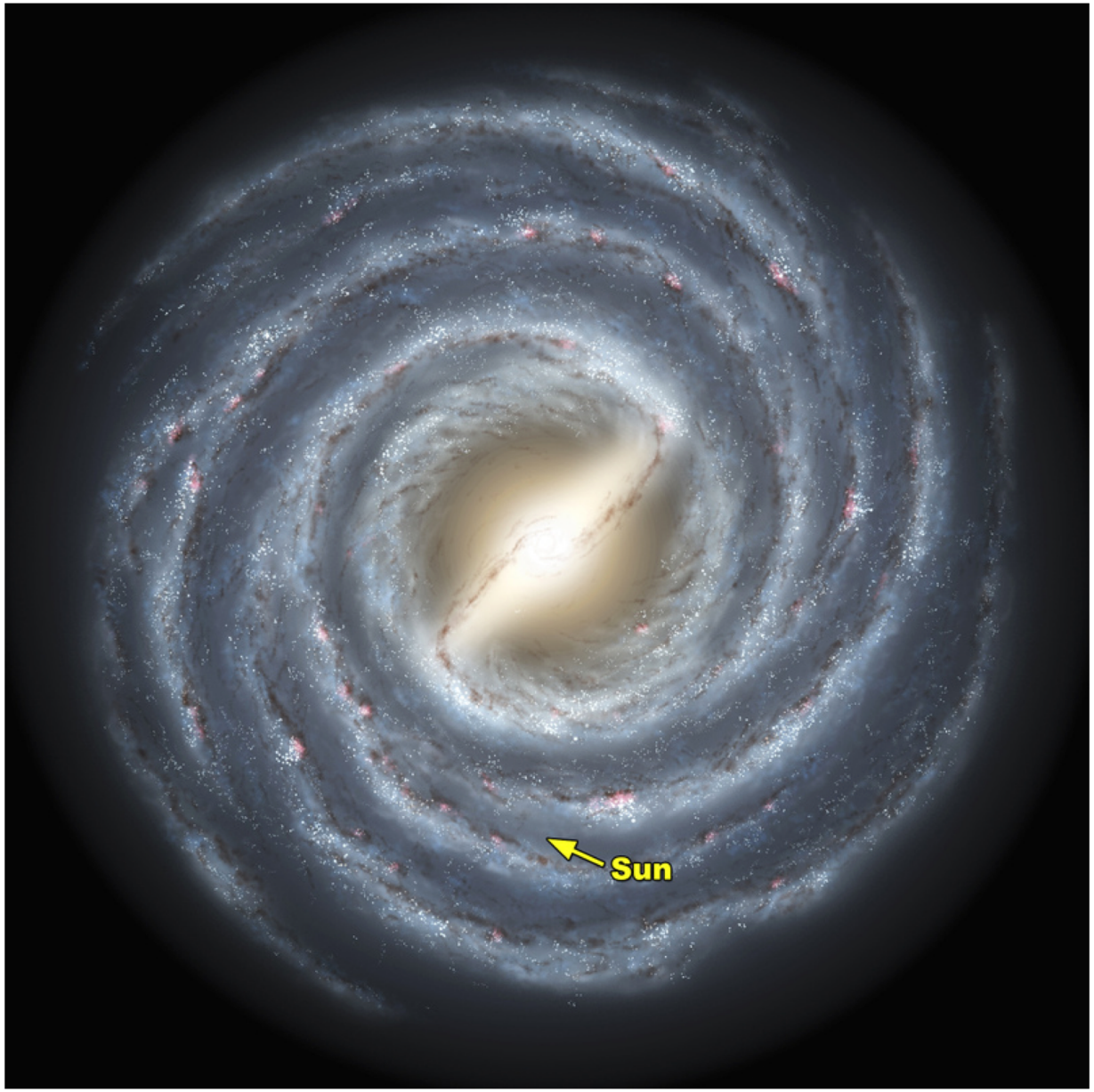
Questions: What kind of extrasolar planets can we detect today?



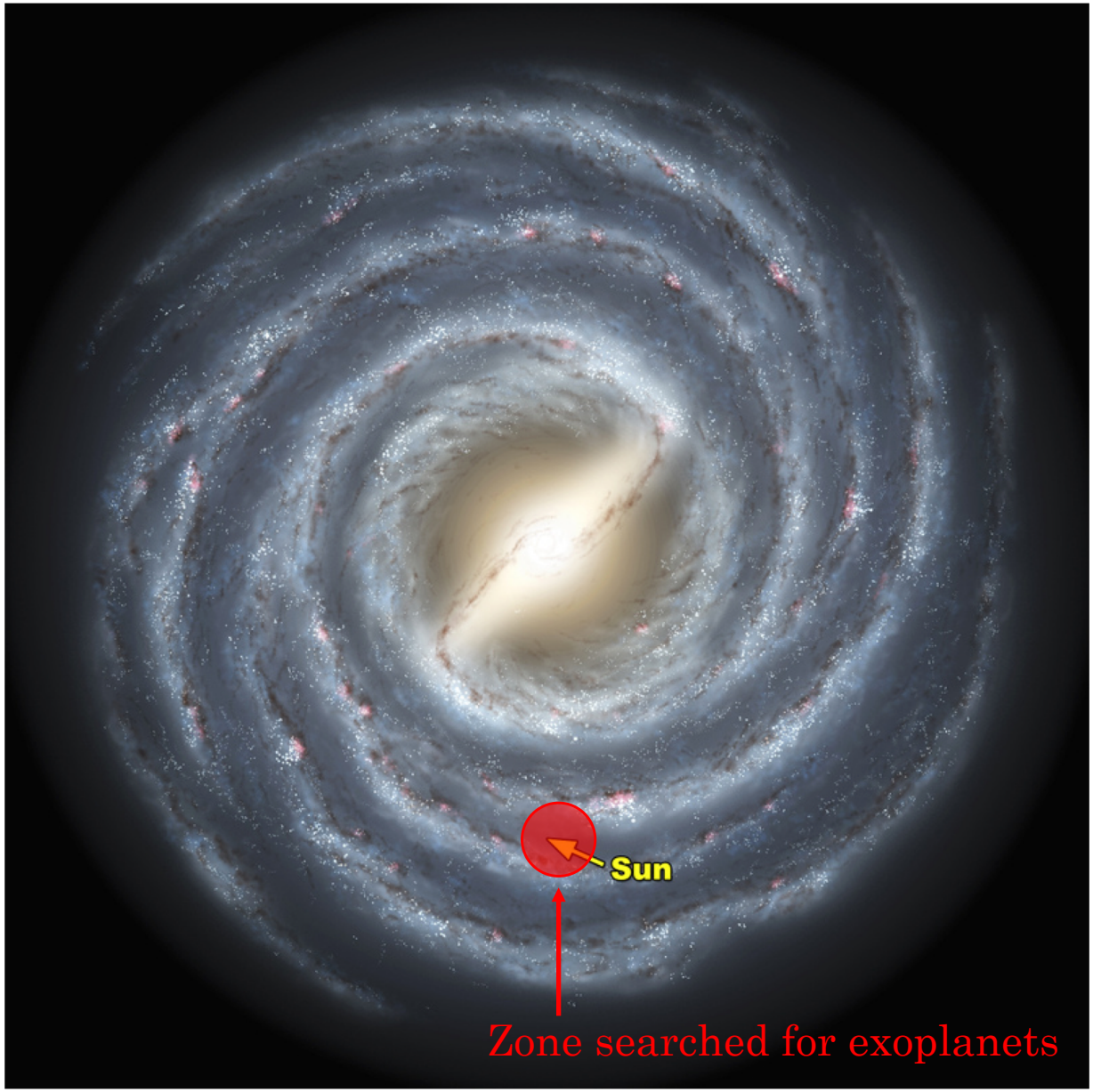
What we have learned today

- 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 perpsectives



Some perpsectives



Further readings

- A survey of exoplanet detection techniques: https://arxiv.org/pdf/1805.02771.pdf
- 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