Modern Astronomical Optics - Observing Exoplanets

2. Spectroscopic detection and characterization

Olivier Guyon - guyon@naoj.org

– *Jim Burge, Phil Hinz*

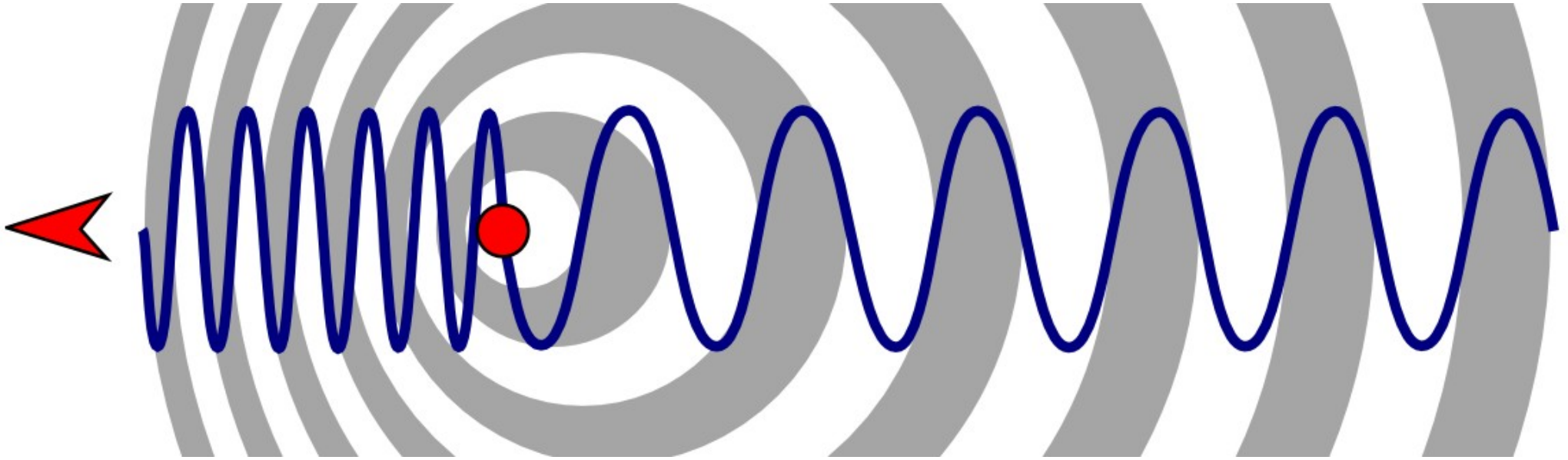
WEBSITE:

*www.naoj.org**/staff/guyon***

→ *Astronomical Optics Course*

→ *Observing Exoplanets (2012)*

Radial velocity – principle
Doppler effect



Radial velocity

Speed of light (3e8 m/s)

$f = (1-v/c)\, f_0$

emission frequency

Observed frequency

Light frequency $f = c/\lambda$

Visible light ~ 500 THz

Radial velocity – principle
Orbital motion

$V_{star} = V_{pl} \times M_{pl}/M_{star}$ ***[1]***

With:

V_{star} = star velocity

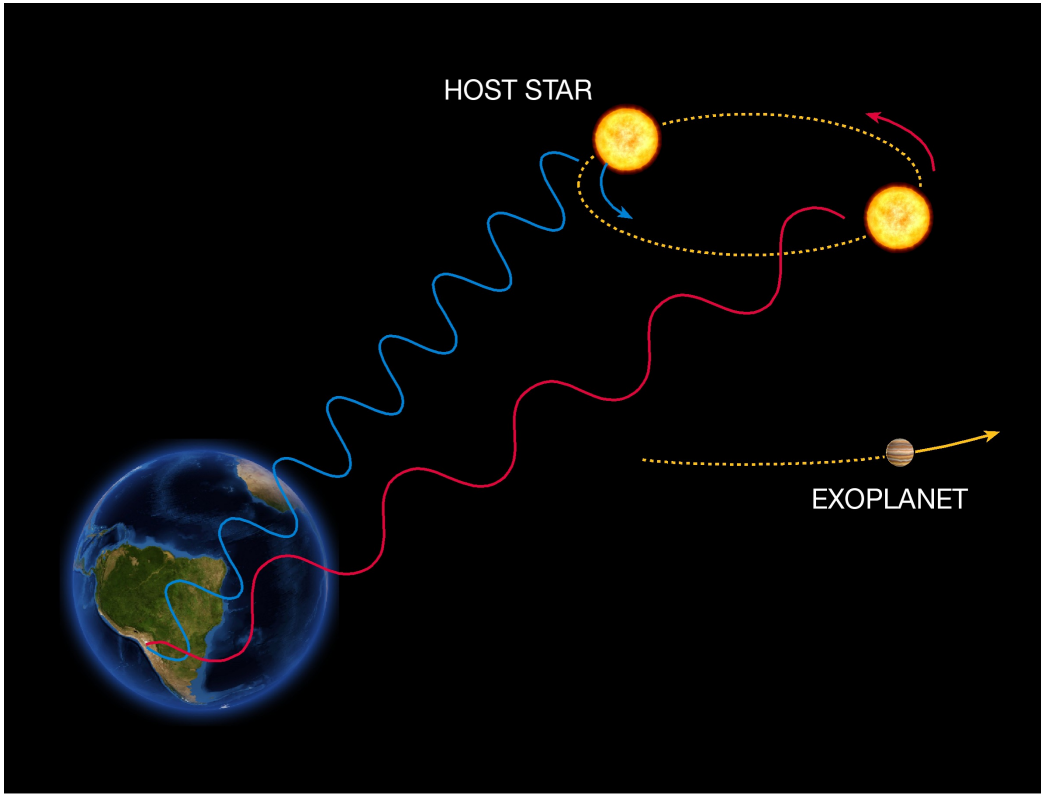
V_{pl} = planet velocity

M_{pl} = planet mass

M_{star} = star mass

Observed quantity = V_{star} sin(i)

With i=inclination



The Radial Velocity Method

ESO Press Photo 22e/07 (25 April 2007)

Kepler's third law:

$R^3 = P^2 GM_{star}/(4 \pi^2)$ ***[2]***

R = star to planet distance (semi-major axis)

P = orbital period

G = gravitational constant

Radial velocity observation = <u>orbital period P</u> and <u>V_{star} sin(i)</u>

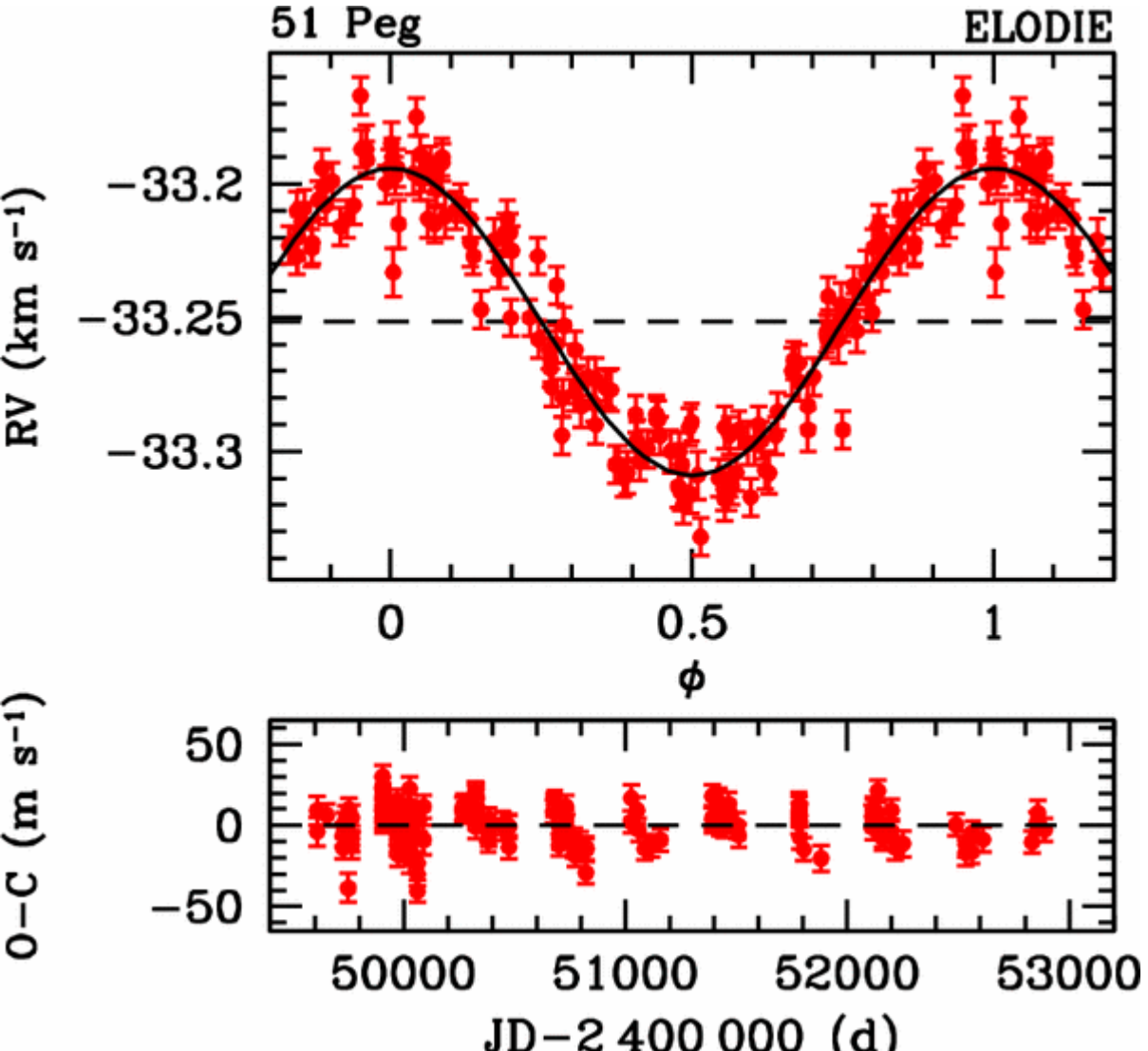
P → semi-major axis R *(using equ. [2] and stellar mass)* → $V_{pl} = 2\pi R/P$

V_{star} sin(i), V_{pl} → M_{pl} sin(i) *(using equ. [1] and stellar mass)*

Radial velocity = measurement of planet's orbit (except inclination) and M_{pl} sin(i)

Radial velocity – Signal amplitude

Jupiter → 12.7 m/s
Earth → 9 cm/s



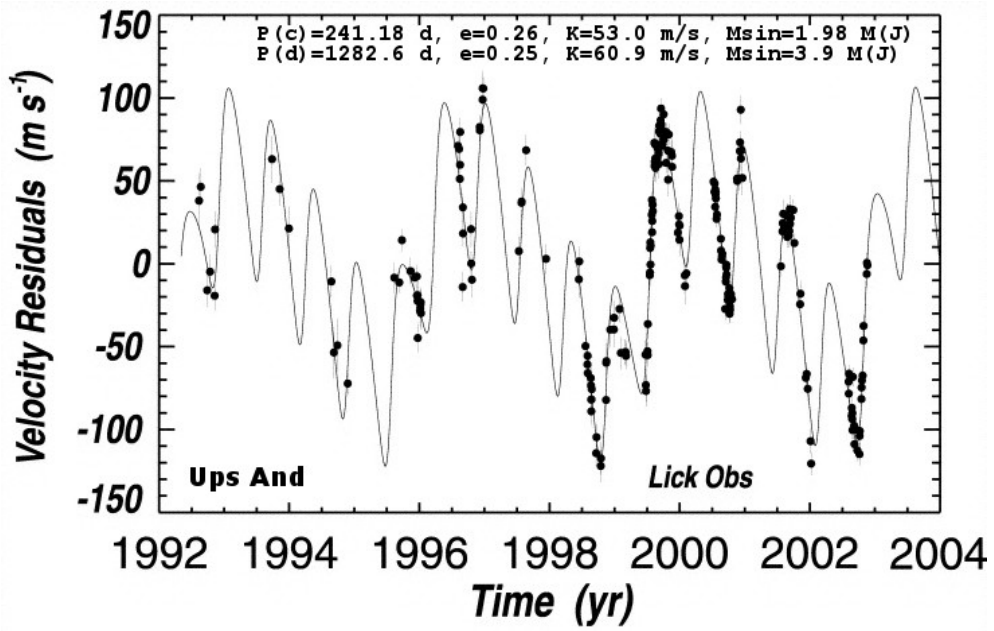
51 Peg b : first exoplanet identified around Sun-like star (1995)

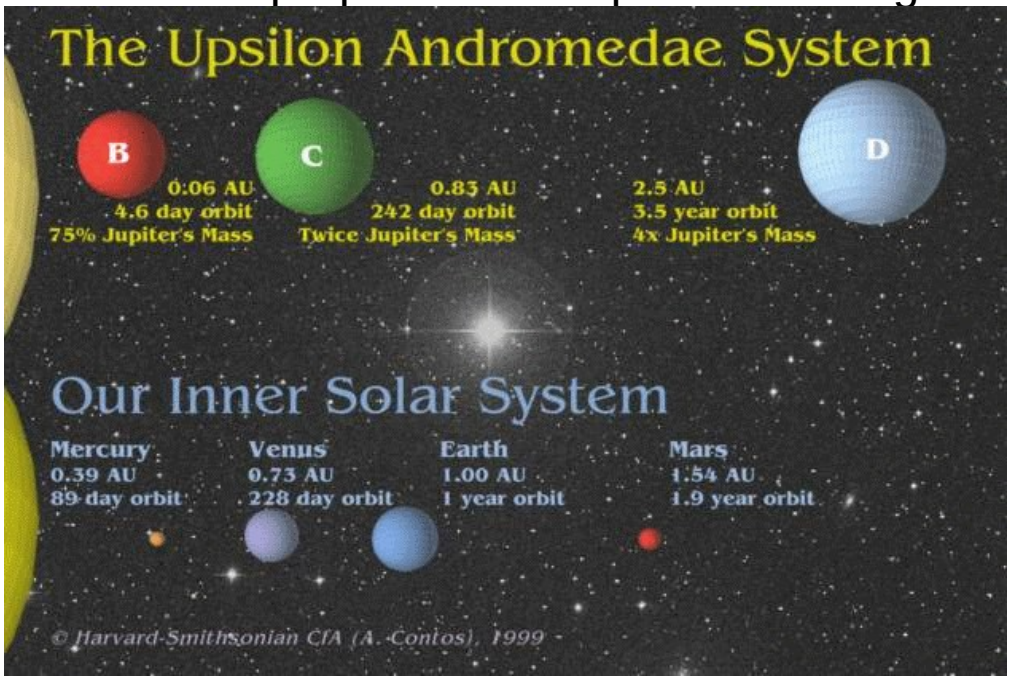
Period = 4.23 day
Mass sin(i) = 0.47 MJ
Eccentricity = 0

RV ampl = 57 m/s

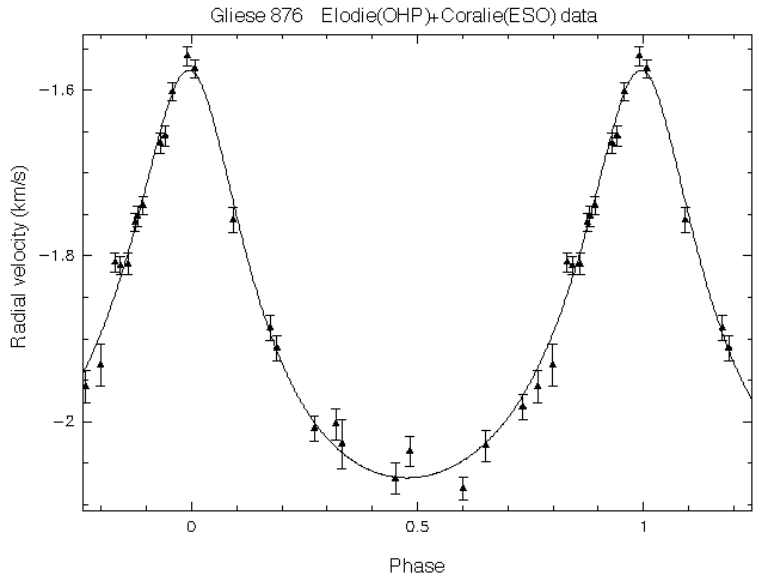
Radial velocity – examples

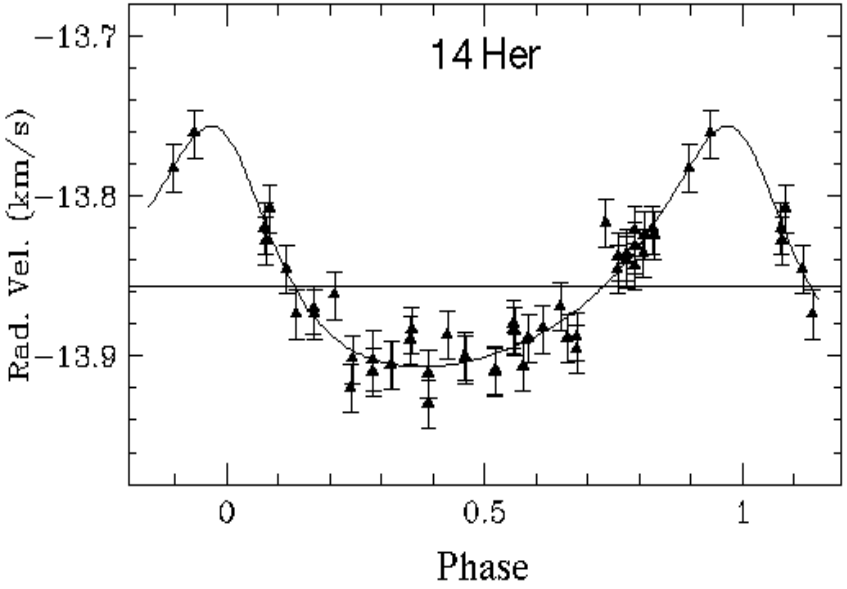
Ups And : planetary system
Shows superposition of 3 planets RV signals





Non-circular orbits (Gl 876 b & 14 Her)





Exoplanet spectroscopy

Direct imaging spectroscopy: planet light is isolated

Transit spectroscopy: planet + star light. Planet seen in transmission or reflection

Figure on the right shows Earthshine spectra (Woolf & Smith 2001)