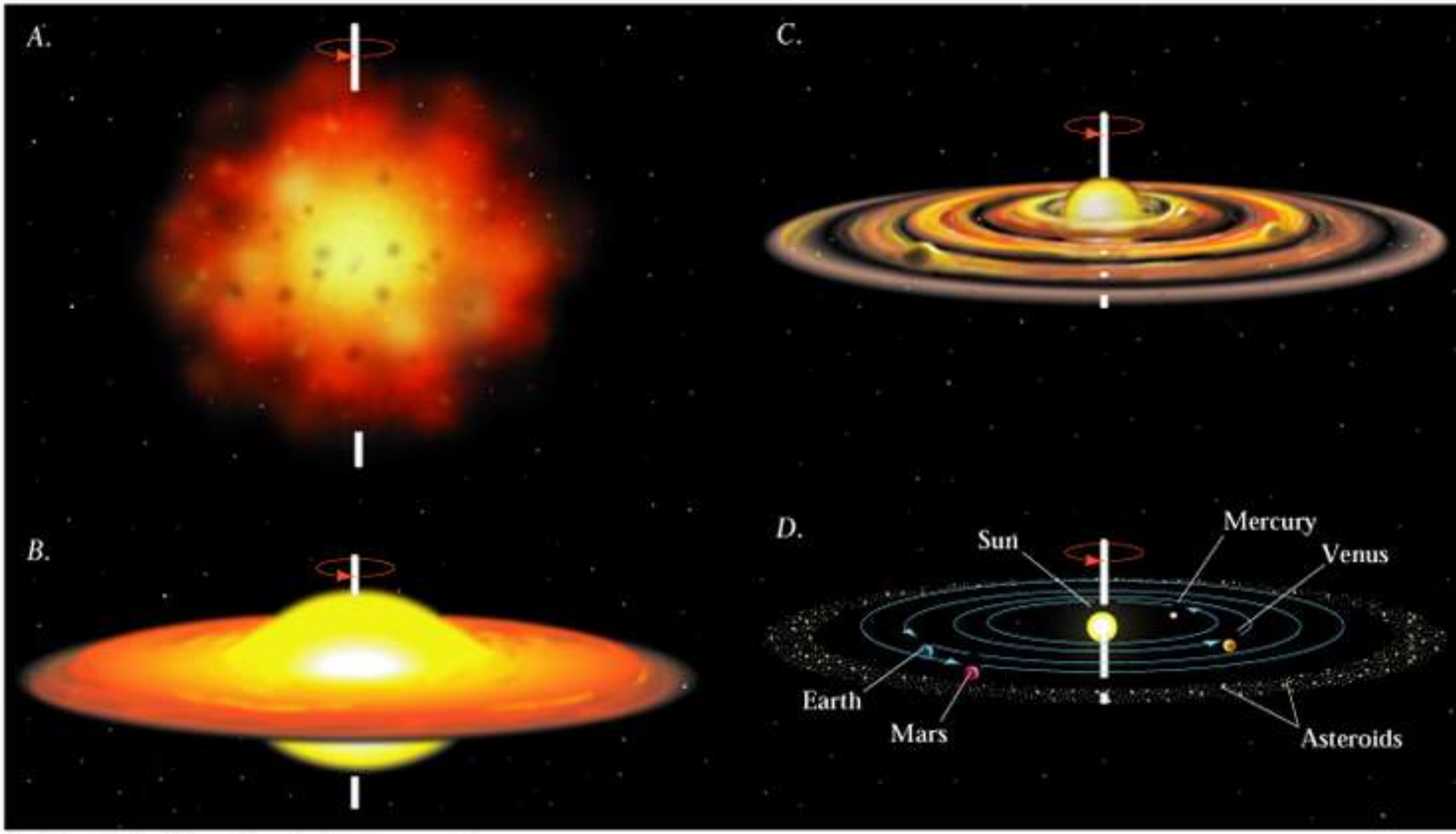
Exoplanets: Distinct worlds from the Solar system

THE 1ST SPACE SCIENCE SCHOOL

Shashanka R. Gurumath
Department of Physics,
VIT University,
Vellore – 632014
India

Supervisors:
Prof. K. M. Hiremath
Indian Institute of Astrophysics (IIA),
Bengaluru – 560034
&
Prof. V. Ramasubramanian
Department of Physics
VIT University
Vellore – 632014

Evolution of Solar system



Solar system

Name of Planetary Body	Mass (grams)	Semimajor Axis (AU)	Eccentricity	Orbital Period (years)	Mass in terms of Jupiter (Mj)	Distance from Sun in AU	Rotation rate
Mercury	3.30194E+26	0.387099	0.20564	0.240847	0.000174	0.387	58.646 days
Venus	4.86897E+27	0.723336	0.00678	0.615197	0.002564	0.732	243.01 days
Earth	5.9742E+27	1.000003	0.01671	1.000017	0.003146	1.000	23.9345 hours
Mars	6.41928E+26	1.52371	0.09339	1.880816	0.000338	1.524	24hr 37min
Jupiter	1.89878E+30	5.2029	0.0484	11.86262	1	5.203	9hr 50min
Saturn	5.68499E+29	9.537	0.0539	29.4475	0.299402	9.537	10hr 13min
Uranus	8.66259E+28	19.189	0.04726	84.01685	0.045622	19.191	17.2 hrs
Neptune	1.0278E+29	30.0699	0.00859	164.7913	0.05413	30.069	16.11 hrs

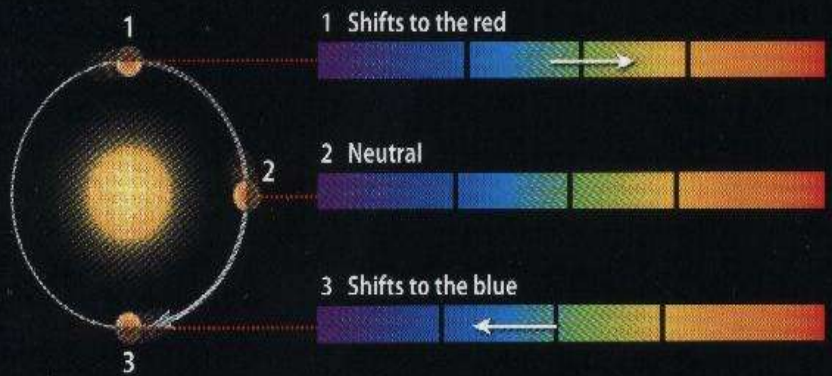
What are Exoplanets?

- Planets orbiting around the other Stars
- Discovery of first Exoplanets

  D. A. Frail & A. Wolszczan (1992) – pulsar 1257 + 12

  Mayer & Queloz (1995) – 51 Pegasi (main sequence star)
- 2900 confirmed planets (http://exoplanet.eu/)

Exoplanets detection methods



Radial-velocity method

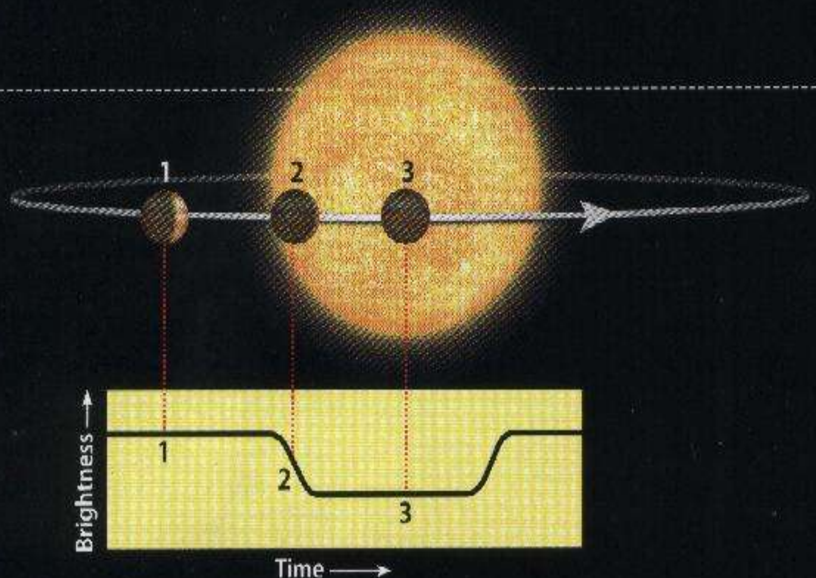
A planet's gravity tugs on its parent star, inducing a wobble in the star's motion. As the star moves closer to Earth, the star's spectral lines shift toward the blue; as the star moves away, the lines shift to the red. These changes allow astronomers to deduce a planet's minimum mass. A variation on this technique — in which a planet alters the timing of a pulsar's signal — has led to the discovery of four planets.

Pros

This is now the leading method — about 90 percent of known exoplanets were found with this technique. It's great at finding heavy planets, which cause bigger changes in radial velocity.

Cons

This method yields only a minimum mass unless astronomers can determine the planet's orbital inclination. Observations must stretch over a long period to find planets in large orbits.



Transit method

If a planet's orbital plane lies along or near our line of sight, the planet will pass in front of the star once each orbit. The planet's black disk causes a small dip in the star's brightness. If the dips occur regularly and produce the same dimming each time, and the star shows no sign of being a periodic variable, the culprit should be a planet. Radial-velocity measurements can confirm the planet's existence.

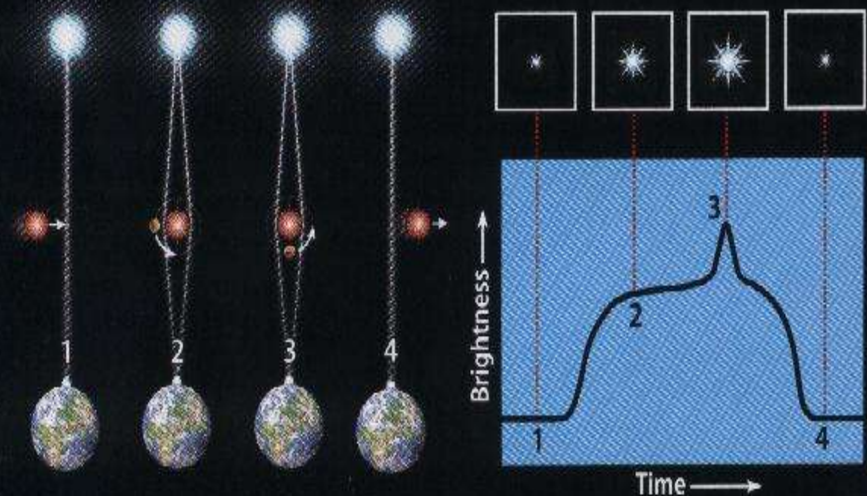
Pros

Because the orbital inclination is known, astronomers can use radial-velocity measurements to calculate the planet's exact mass.

Cons

Only a small fraction of all planets transit their parent star's disk, because most planets don't orbit along our line of sight.

Exoplanets detection methods



Microlensing method

If a star or planet passes in front of a more distant star, general relativity says the intervening object's gravity will act as a lens, causing the distant star to brighten. Using robotic telescopes, scientists monitor a large number of background stars, looking for microlensing events. A smooth rise and fall in brightness indicates a dim star as the intervening culprit; a blip on a smooth light curve signifies an orbiting planet.

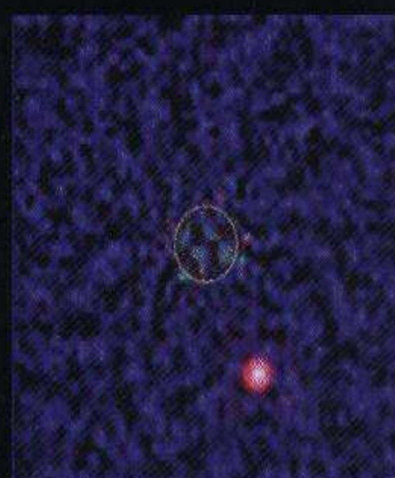
Pros

This method is capable of finding Earth-mass planets with existing technology.

Cons

The microlensing events result from chance alignments, so they can never repeat.

A POSSIBLE PLANET orbits the brown dwarf 2M1207. In this Hubble Space Telescope image, the brown dwarf's light has been subtracted to reveal the companion, which has a minimum mass of 5 Jupiters. NASA/ESA/ G. SCHNEIDER (STEWARD OBSERVATORY), ET AL.



Direct-imaging method

As the name implies, this technique requires taking a planet's image. Because a planet shines by reflecting starlight (or emitting its own infrared radiation), it pales in comparison to its parent star. Viewing a planet in a star's glare is a little like seeing a firefly next to a powerful lighthouse beacon. Still, big telescopes on the ground and in space have found a few promising planet candidates.

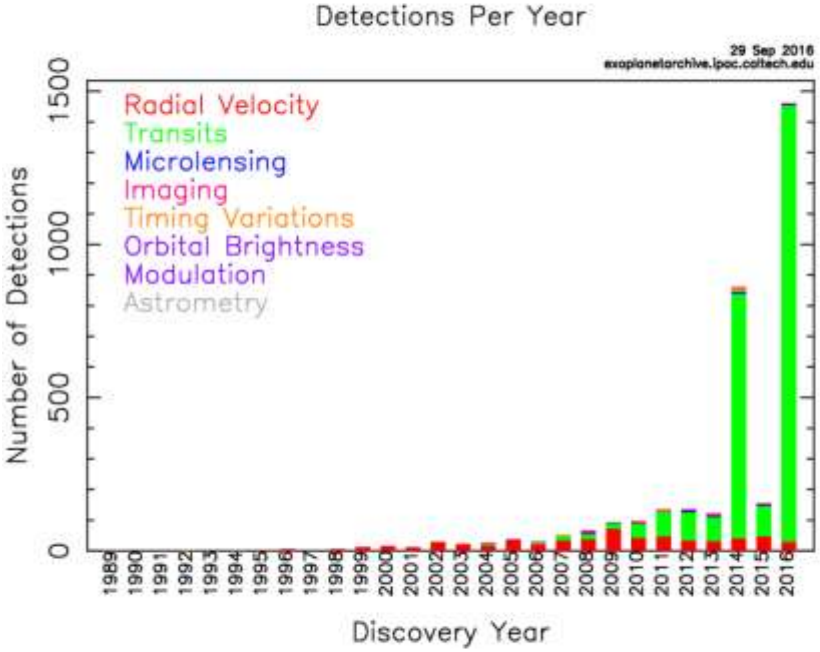
Pros

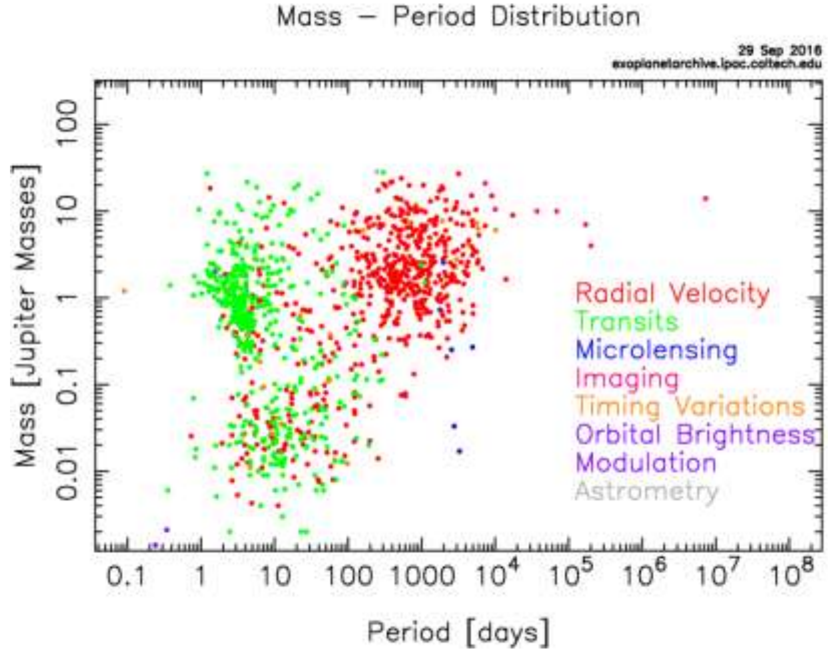
A detailed spectrum of the planet can reveal its physical characteristics.

Cons

In most cases, the planet turns up through luck — on an image taken for another purpose.

Current status:





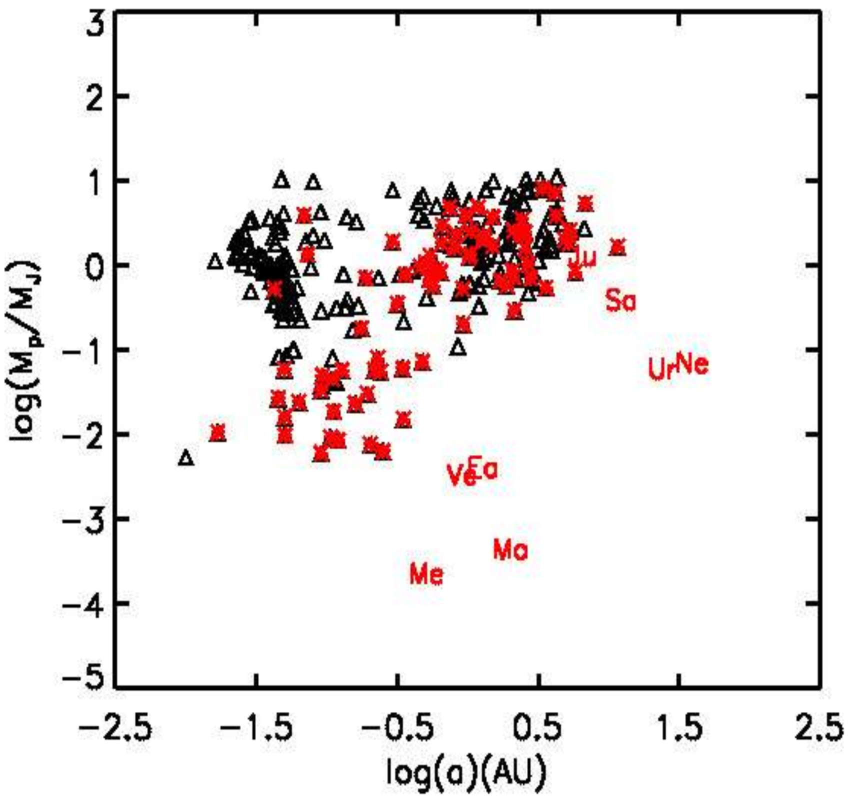
Current status:

- Smallest radius – Kepler-37b – R_J
- First terrestrial planet – Kepler-10b
- Lowest mass – PSR B1257+12 – 0.02 M_{earth}
- Closest orbit – PSR J1719-1438 – 0.004 AU
- Hottest – Kepler-70b – 7143K
- Youngest – K2-33b – 5 to 10 Myrs

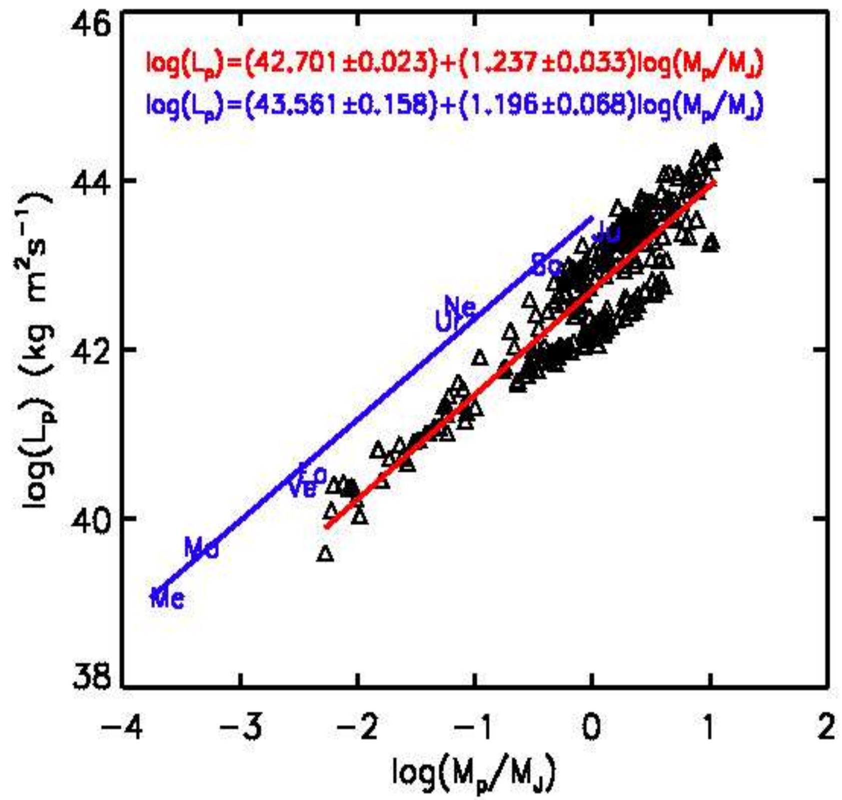
Few problems in solar system

- Why most of terrestrial planets in solar system have less mass.?
- Why sun rotates on its axis slowly compare to planets.? (i.e., most of the angular momentum of solar system is distributed among planetary body rather than sun)
- Why eccentricity of mercury is more compare to other terrestrial planets.?
- There is regularity in orbits of the planets (Titius – Bode law) i.e., the spacing of orbits increases more or less geometrically as we move away from the Sun.
  - Is all planetary system in the universe obey this property.?

Results



log(M_p/M_J)
log(a)(AU)
Ju
Sa
Ur
Ne
Ve
Ea
Ma
Me



log(L_p)=(42.701±0.023)+(1.237±0.033)log(M_p/M_J)
log(L_p)=(43.561±0.158)+(1.196±0.068)log(M_p/M_J)
log(L_p) (kg m^2s^-1)
log(M_p/M_J)
Ju
Sa
Ne
Ur
Ea
Ve
Ma
Me

Previous and present projects

- CoRoT – Planet search & Asteroseismology
- Kepler & K2 – Earth-size transiting exoplanets
- Gaia – Astrometry of exoplanetary hosts
- HARPS – Radial velocity
- MEarth
- TrES
- WASP

Planned projects

- CHEOPS – examine transiting exoplanets
- TESS – All sky survey, small planets around brightest star
- JWST – Direct imaging of exoplanets
- PLATO – Rocky planets and stellar evolution
- WFIRST – Microlensing and cosmology

THANK YOU