

Exoplanets

系外行星

Ing-Guey Jiang

Institute of Astronomy, National Tsing Hua University

江瑛貴

國立清華大學

天文研究所

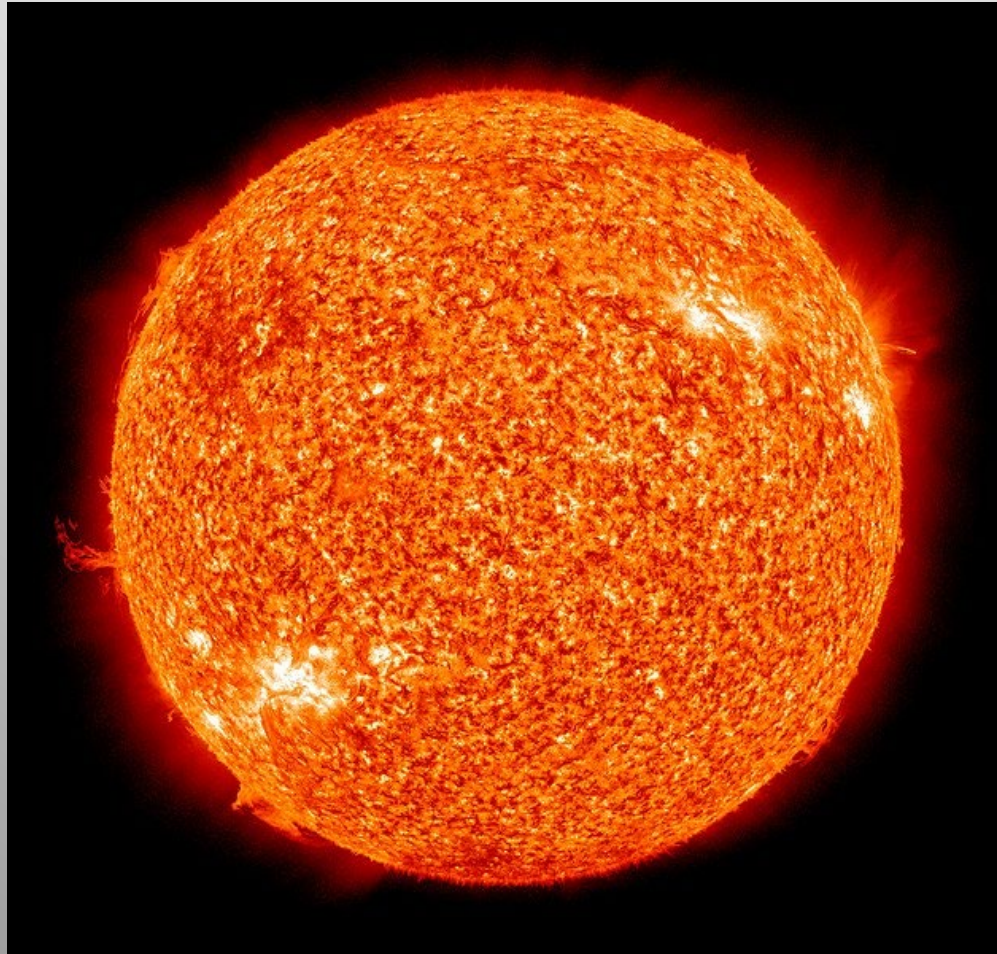
Outline 大綱

- Searching for a Rule of Planet Motion
- The Discoveries of Exoplanets
- Exoplanet Properties
- Planet Formation
- Exolife ?
- Possible Research Projects

The Earth 我們的地球



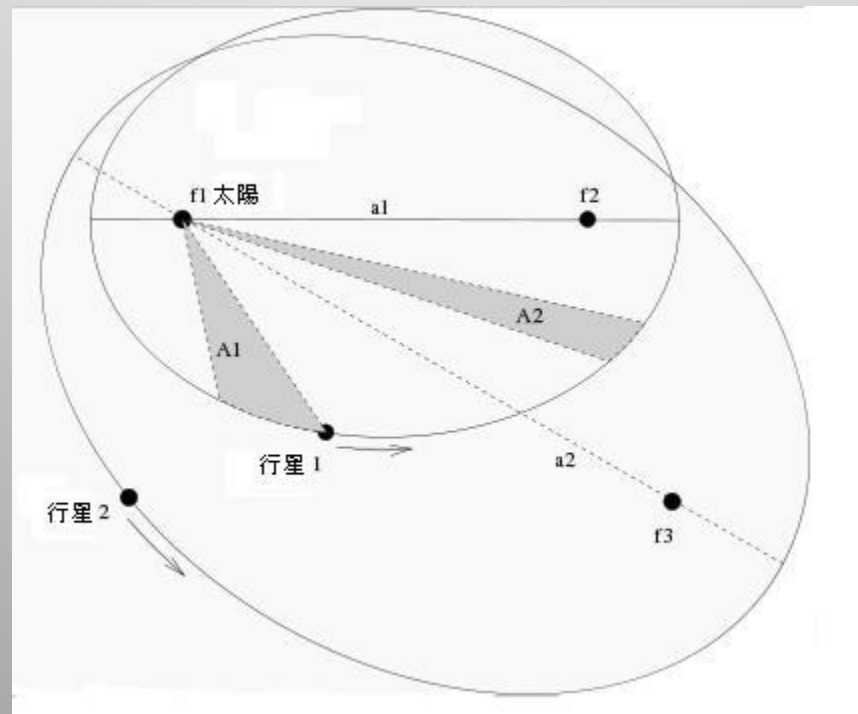
The Sun 我們的太陽



Copernicus哥白尼

- A model of the universe
- Placing the Sun rather than Earth at its center
- Heliocentrism 日心說
- Publishing: On the Revolutions of the Celestial Spheres 《天體運行論》 before his death
- Triggering the Copernican Revolution
- Making the Scientific Revolution

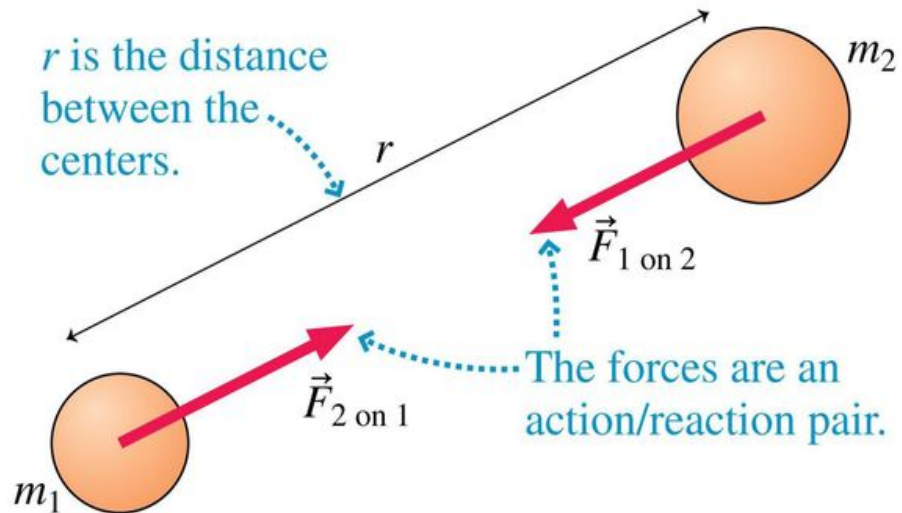
Kepler 克卜勒



Newton 牛頓

Gravity Obeys an Inverse-Square Law

- Gravity is a universal force that affects all objects in the universe.
- Newton proposed that the force of gravity has the following properties:



1. The force is inversely proportional to the square of the distance between the objects.
2. The force is directly proportional to the product of the masses of the two objects.

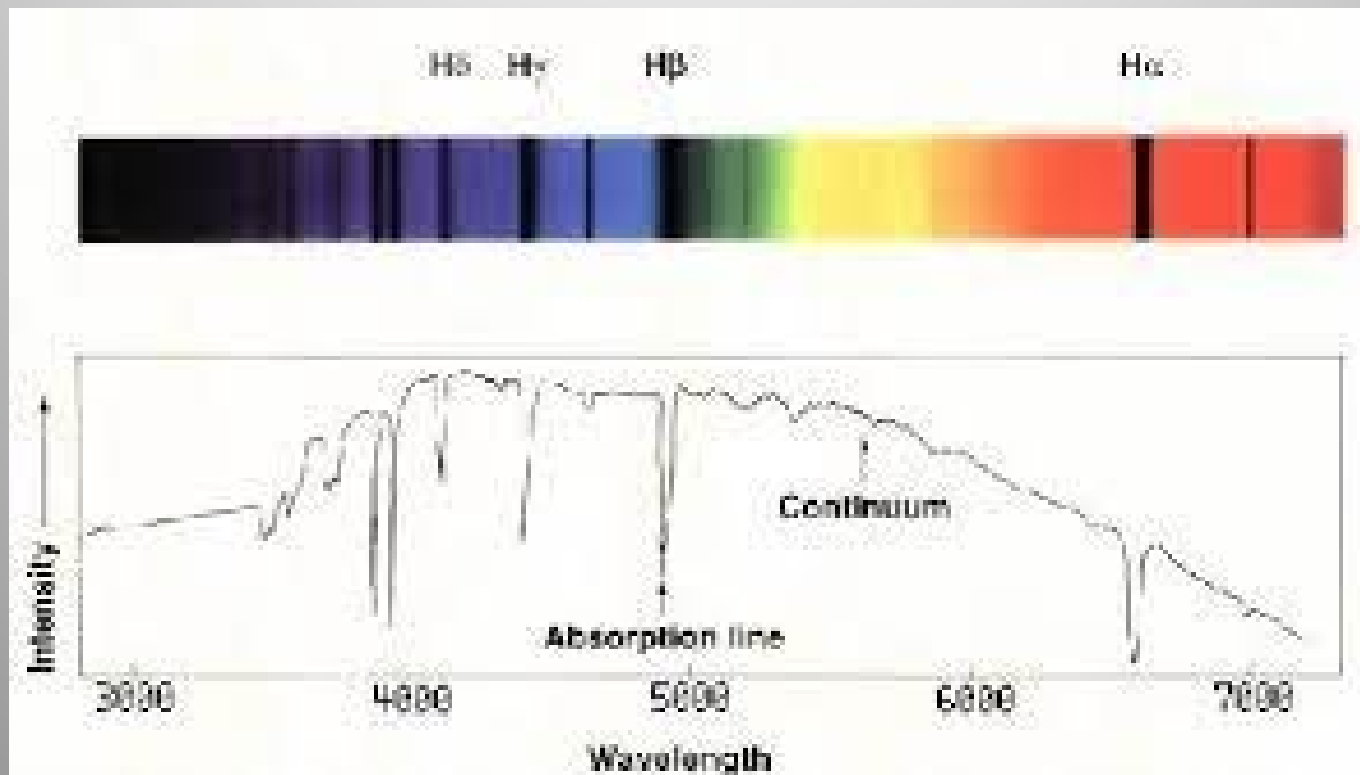
Celestial Mechanics

- Hypothesis
- Data Analysis → Kepler's Law
- Kepler's Law can be derived/proved by Newton's Gravity Theory
- Establishing Physics Law
- The Origin of Physics
- The Foundation of Science

Stars 夜空中的星點



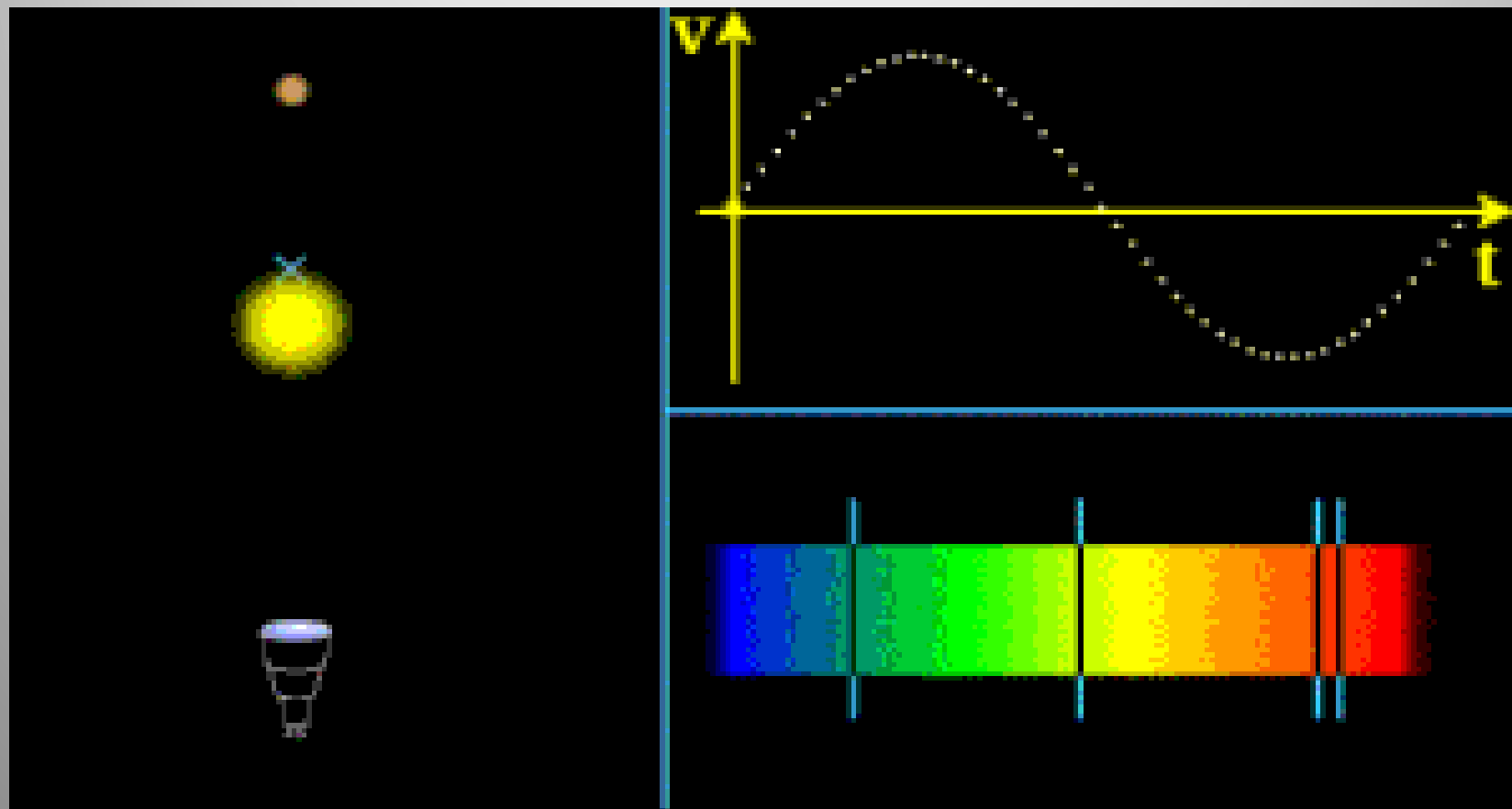
Stellar Spectrum 恆星光譜



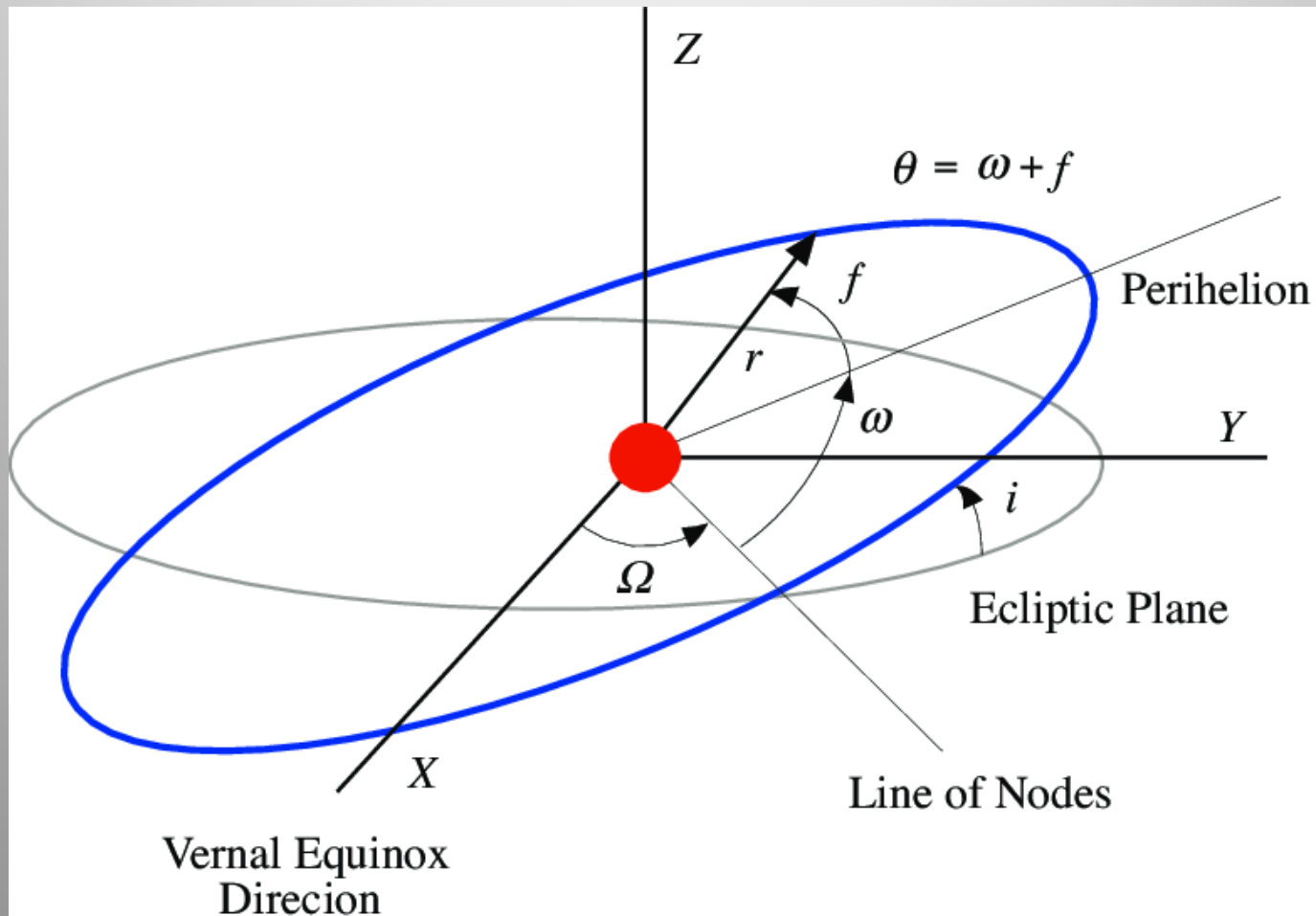
Doppler Effect 都卜勒效應



Radial Velocity 徑向速度法

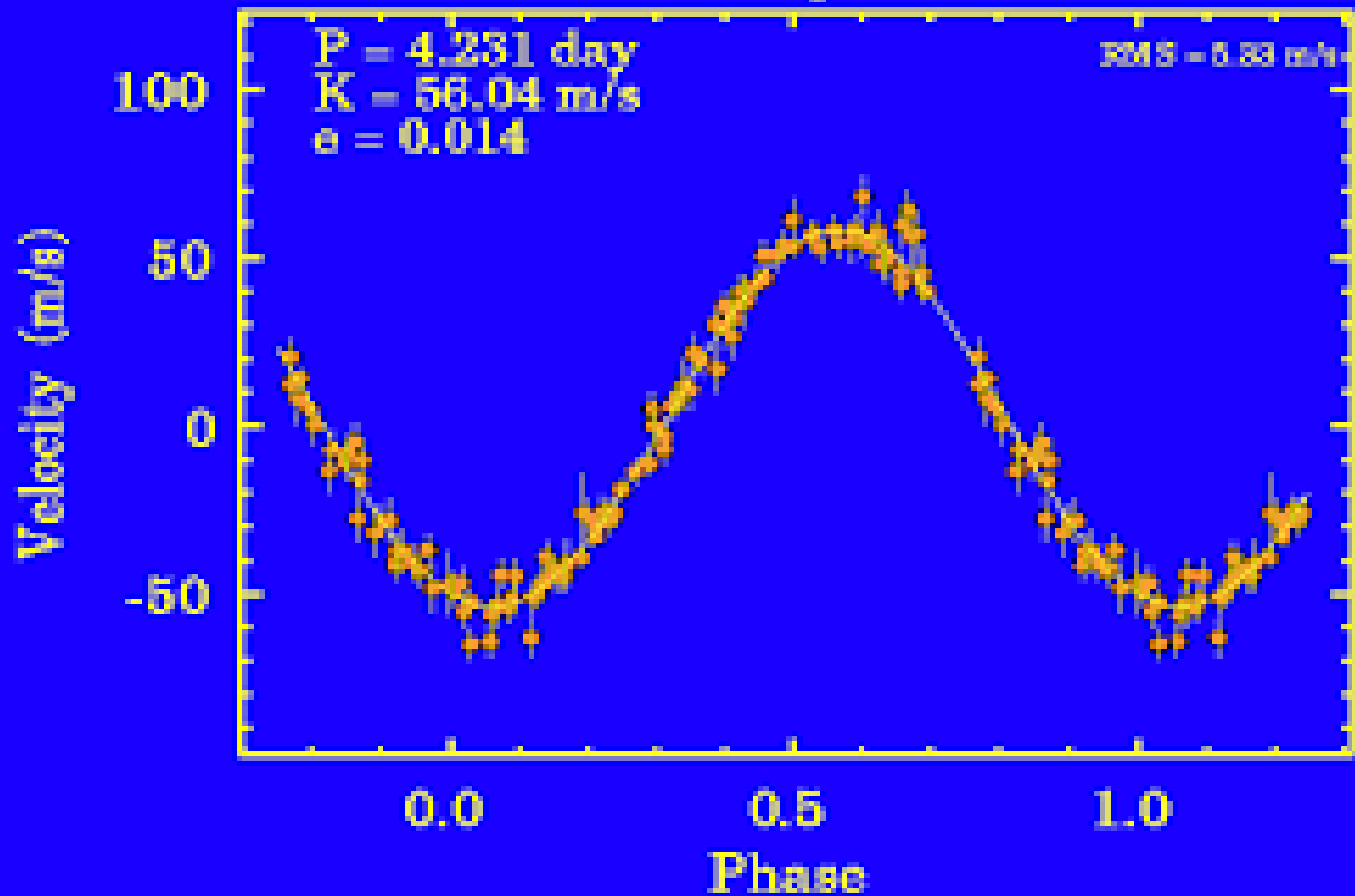


Elliptical Orbit 橢圓軌道

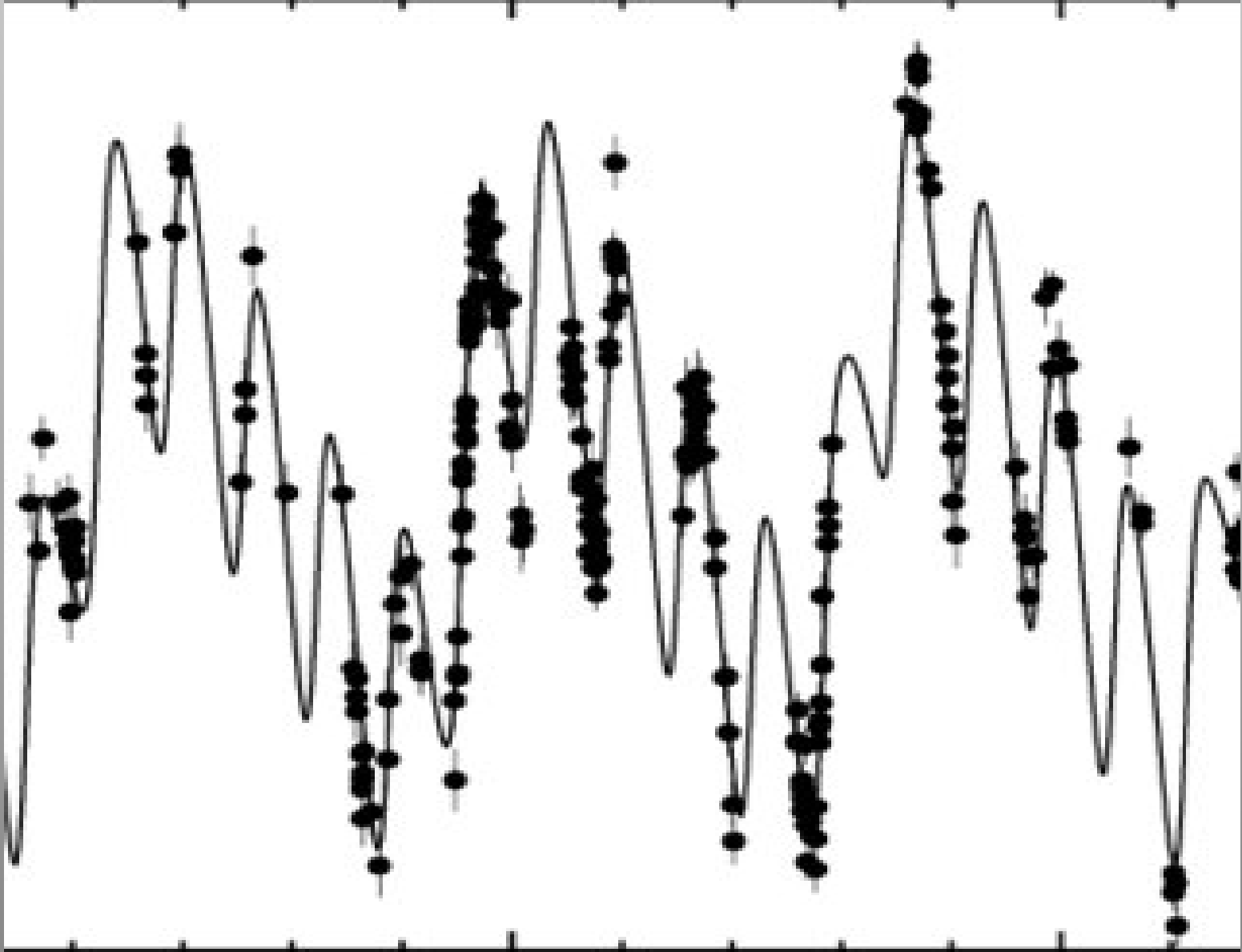


Single Planet 單一行星

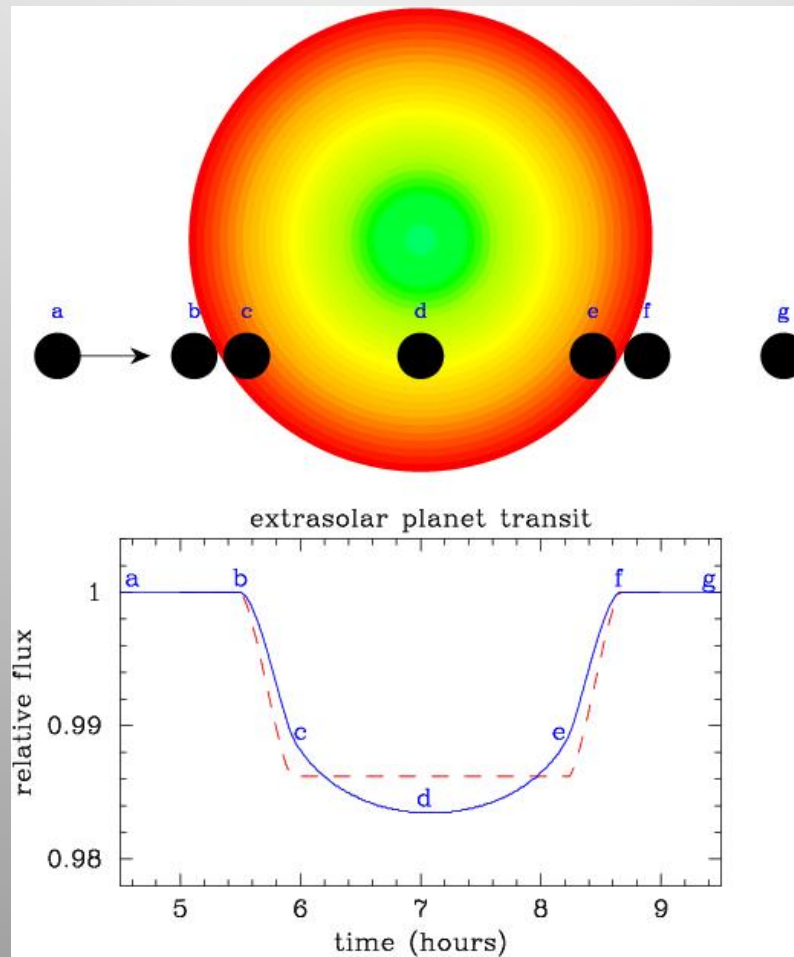
51 Pegasi



Multiple Planets 多行星

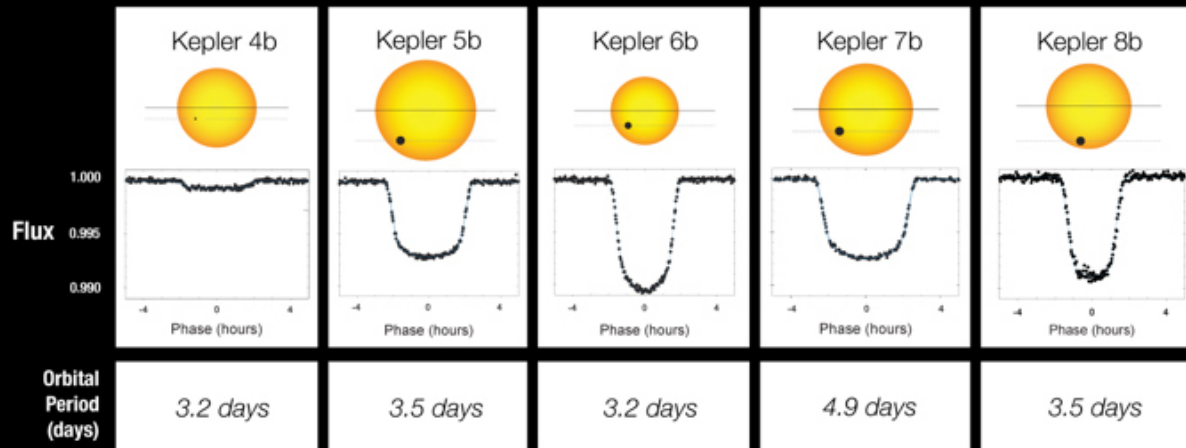


Transit 凌星法

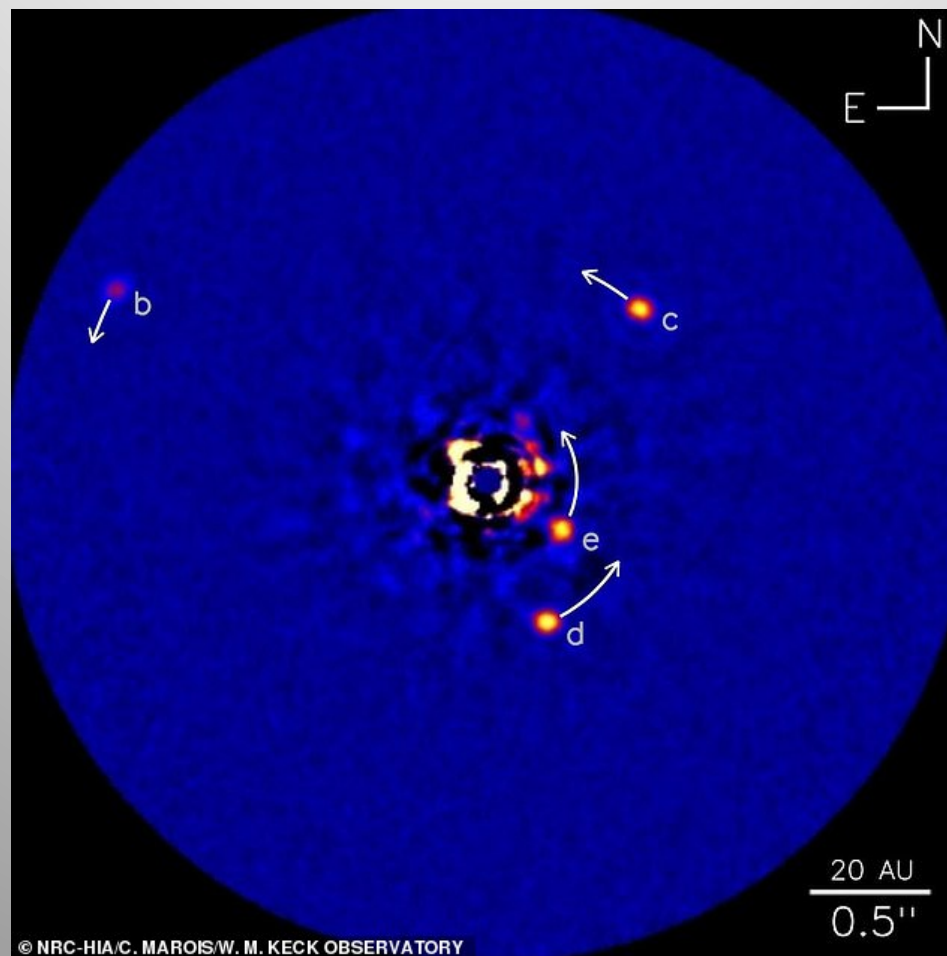


Transit Data 凌星觀測資料

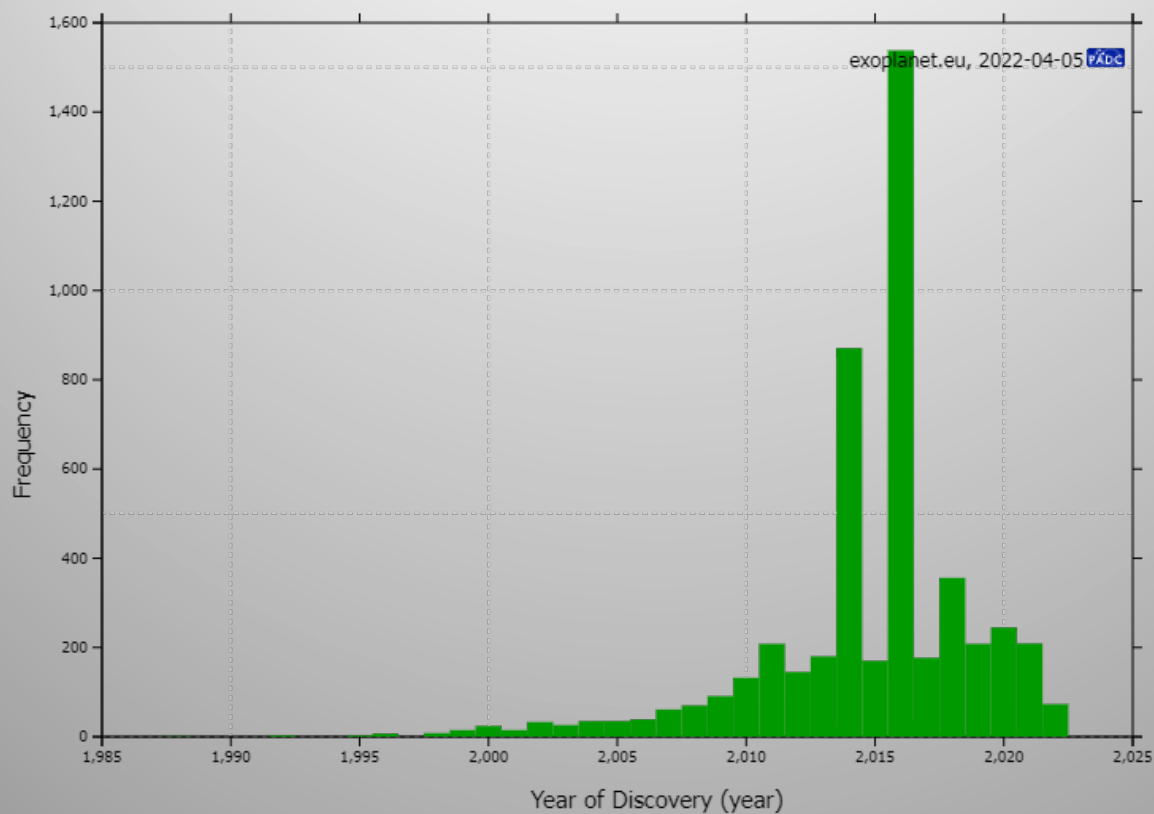
Transit Light Curves



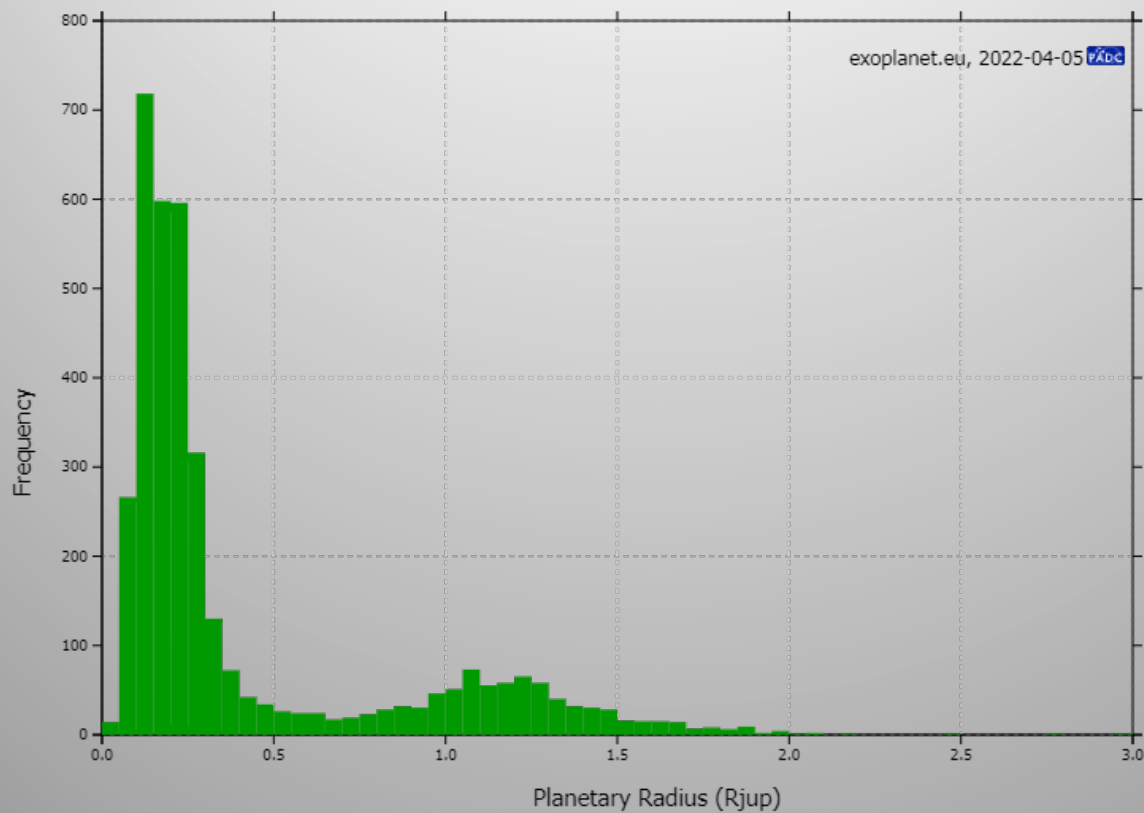
Direct Imaging 直接成像法



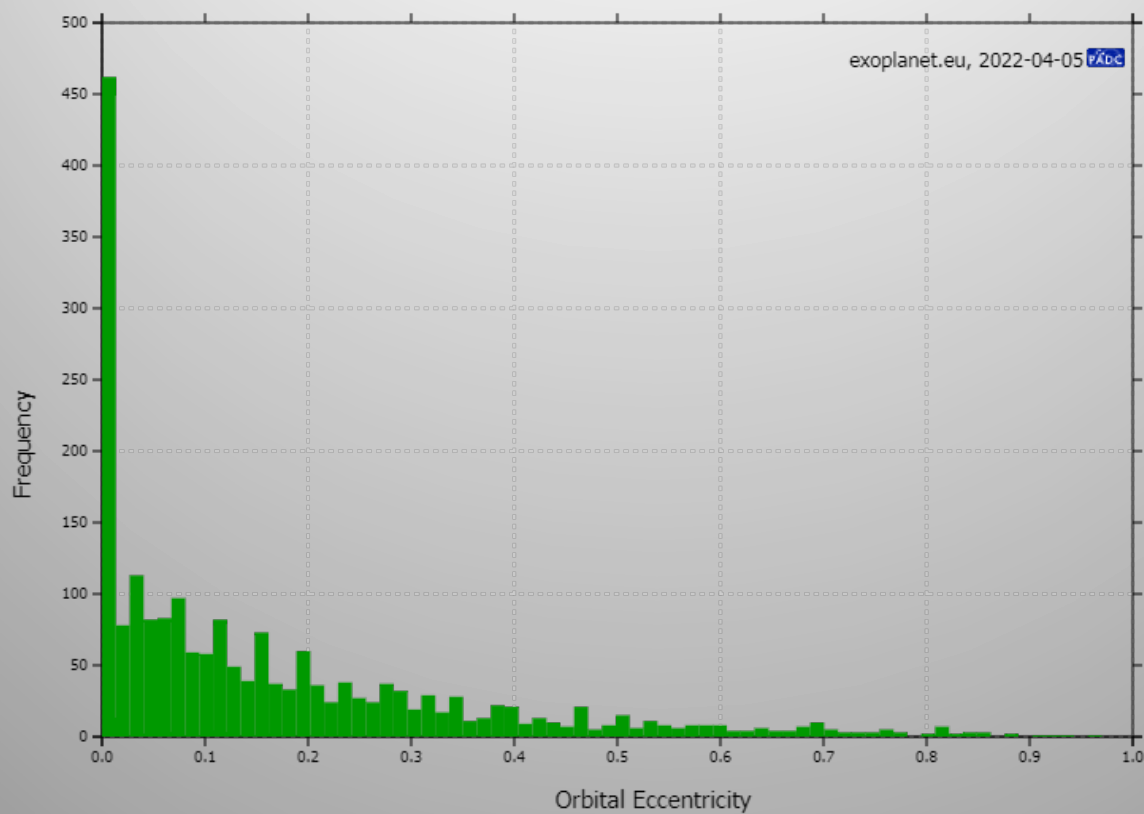
被發現的系外行星個數



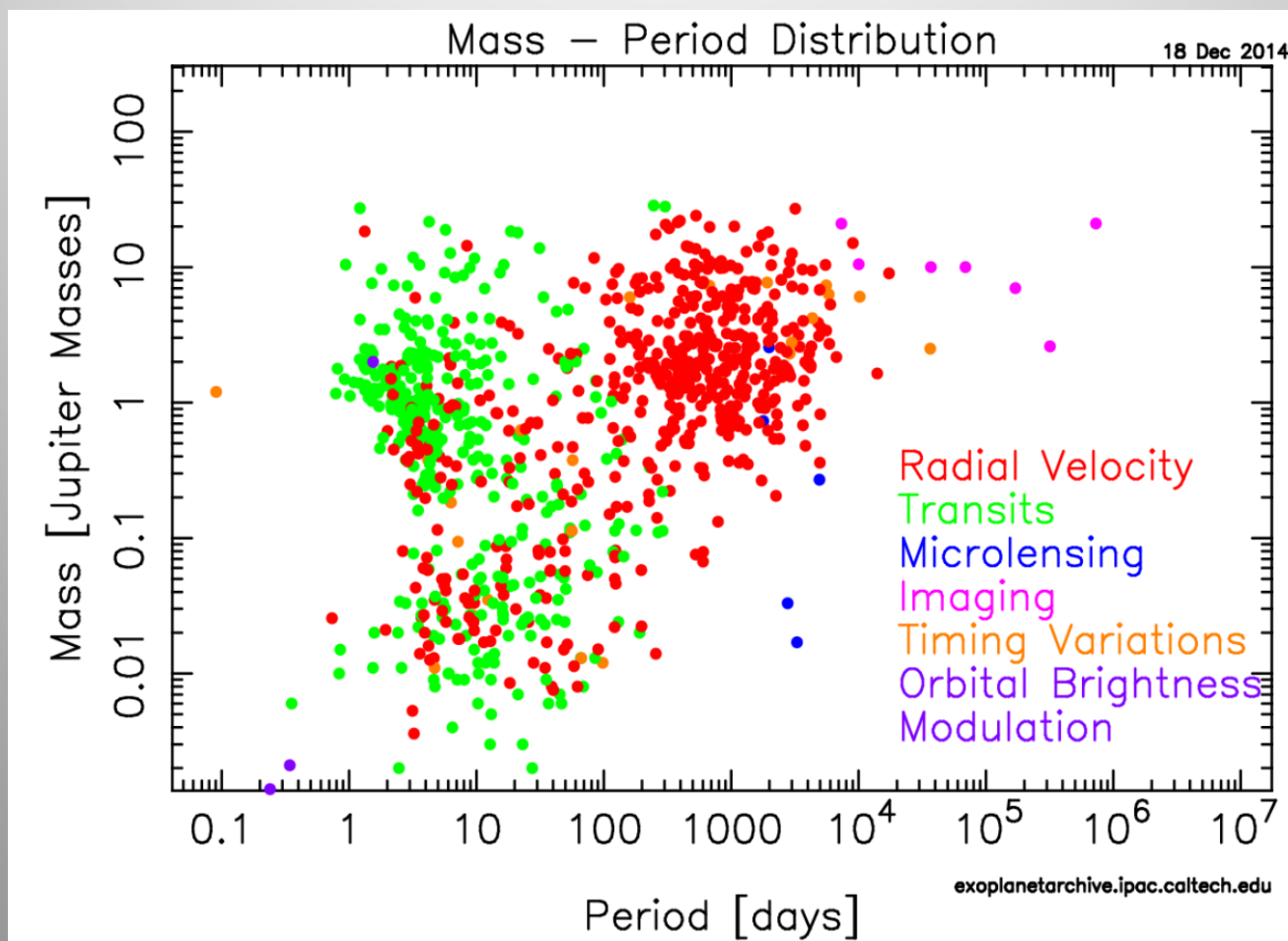
系外行星的大小



系外行星軌道曲率

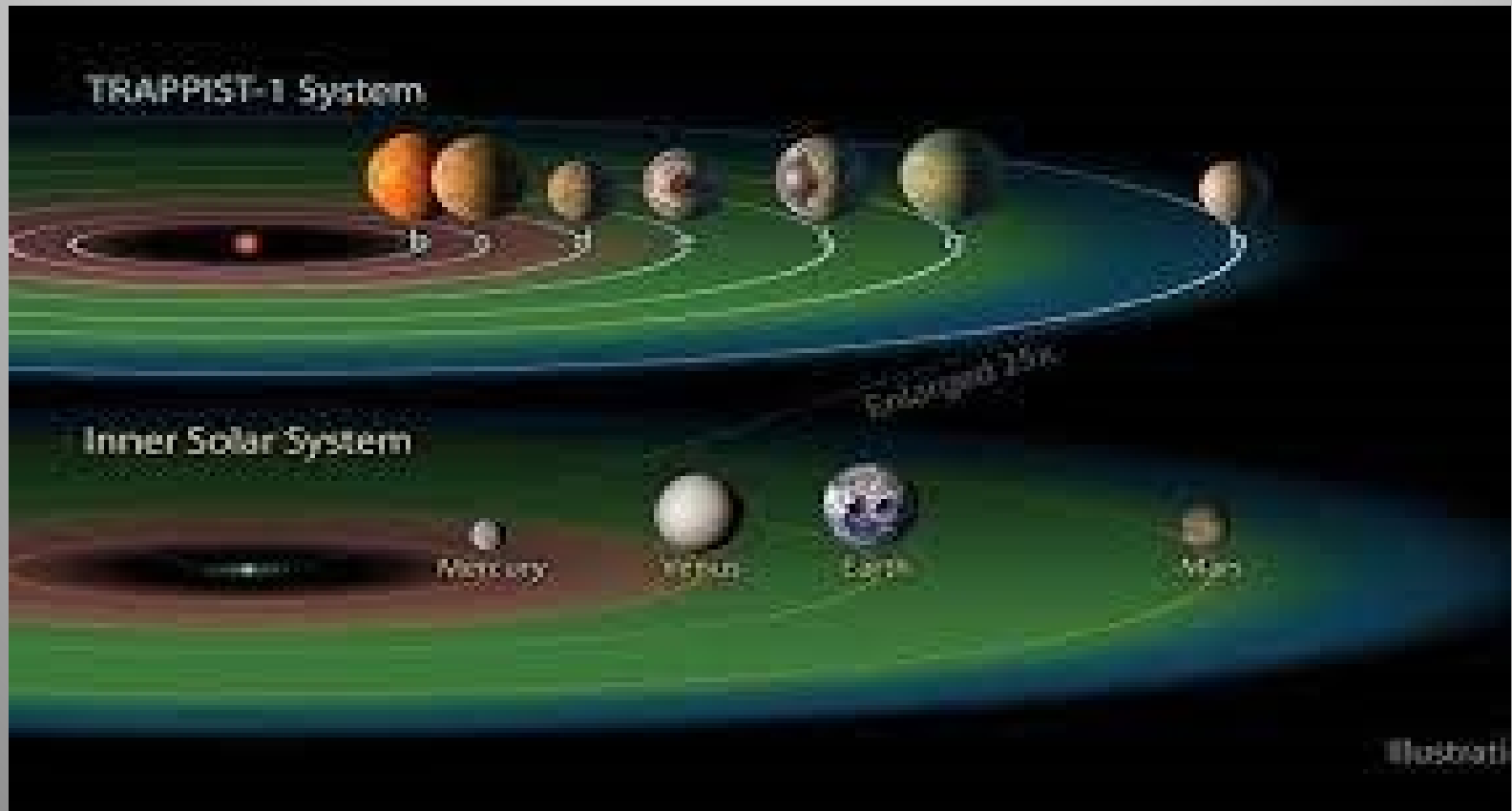


分佈圖



Multi-Planet System 多行星系統

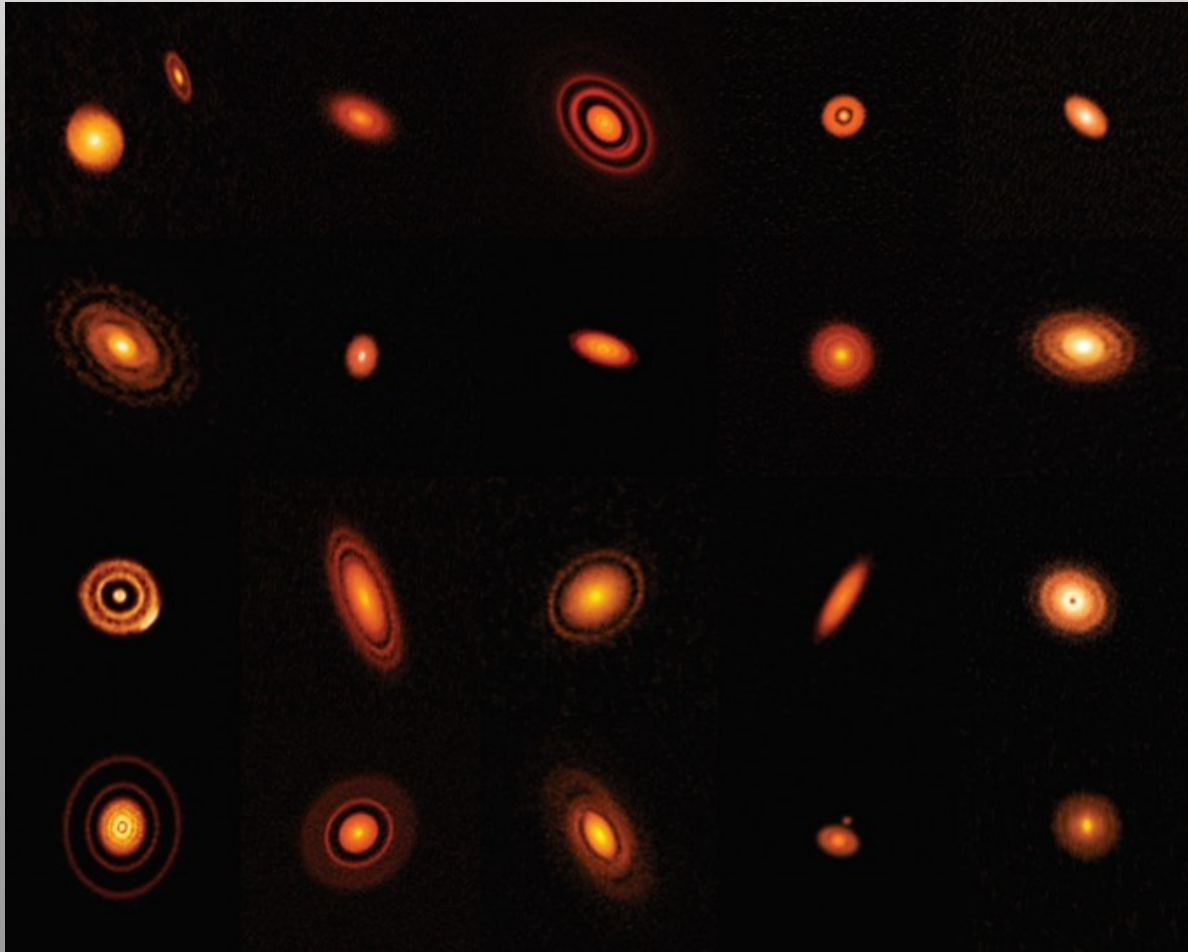
TRAPPIST-1 System



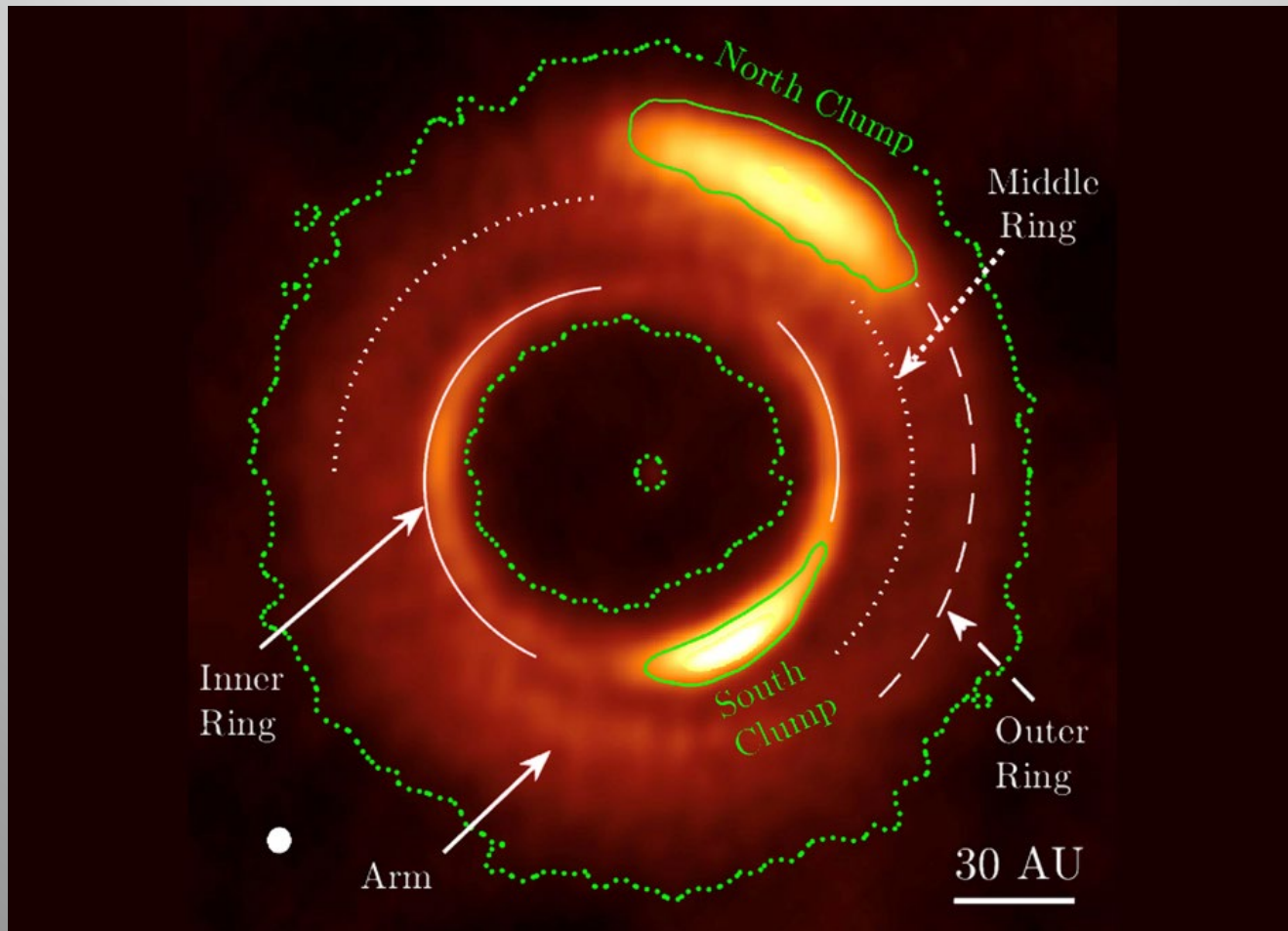
Planet Formation 行星形成

- 核心吸積 core accretion
- 灰塵粒子 dust grain
- 星子 planetesimal
- 盤不穩定 disk instability
- 原行星盤 proto-planetary disk
- 類地行星 terrestrial planet
- 類木行星 Jovian planet

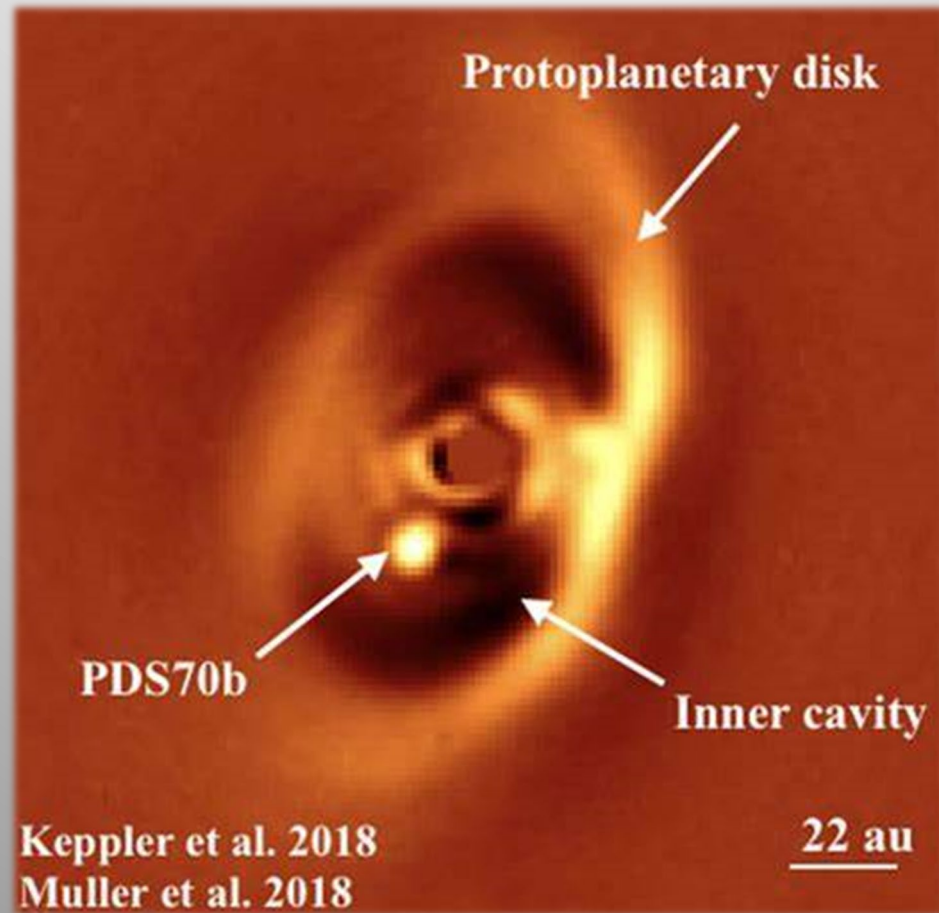
Proto-Planetary Disk 原行星盤



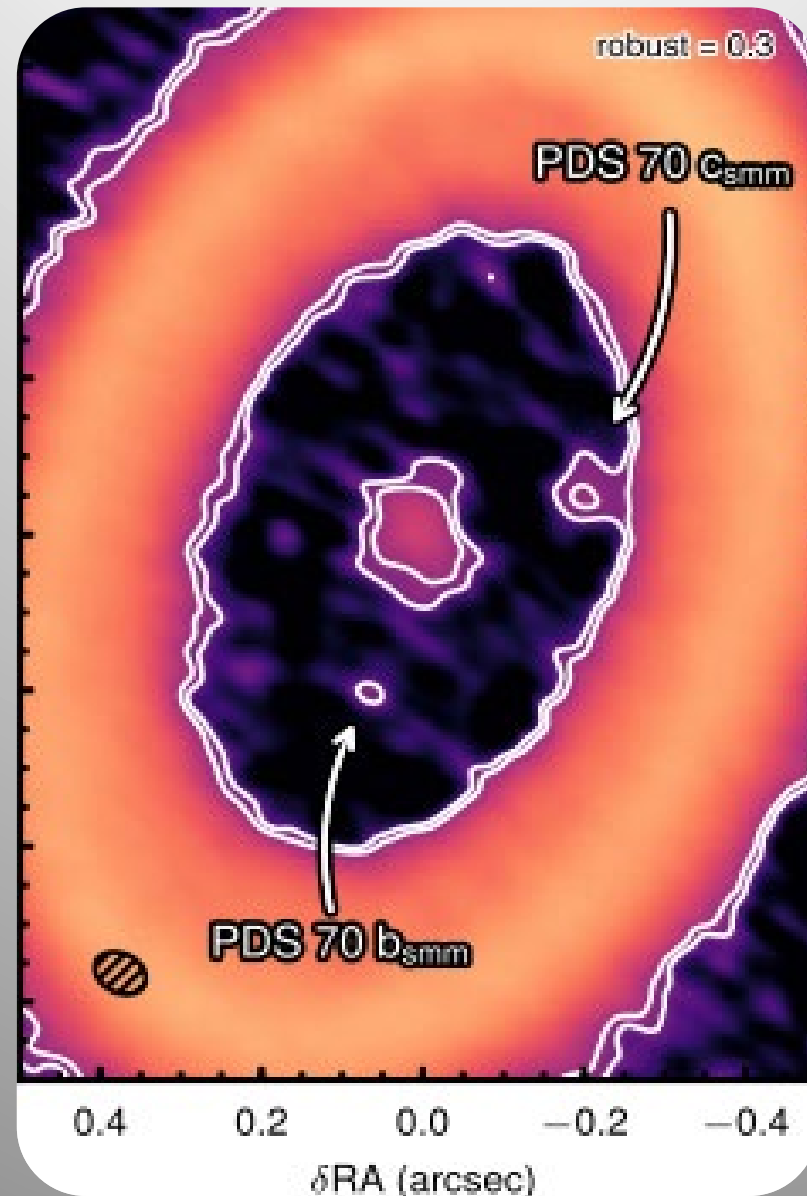
Fragment Structure 塊狀結構



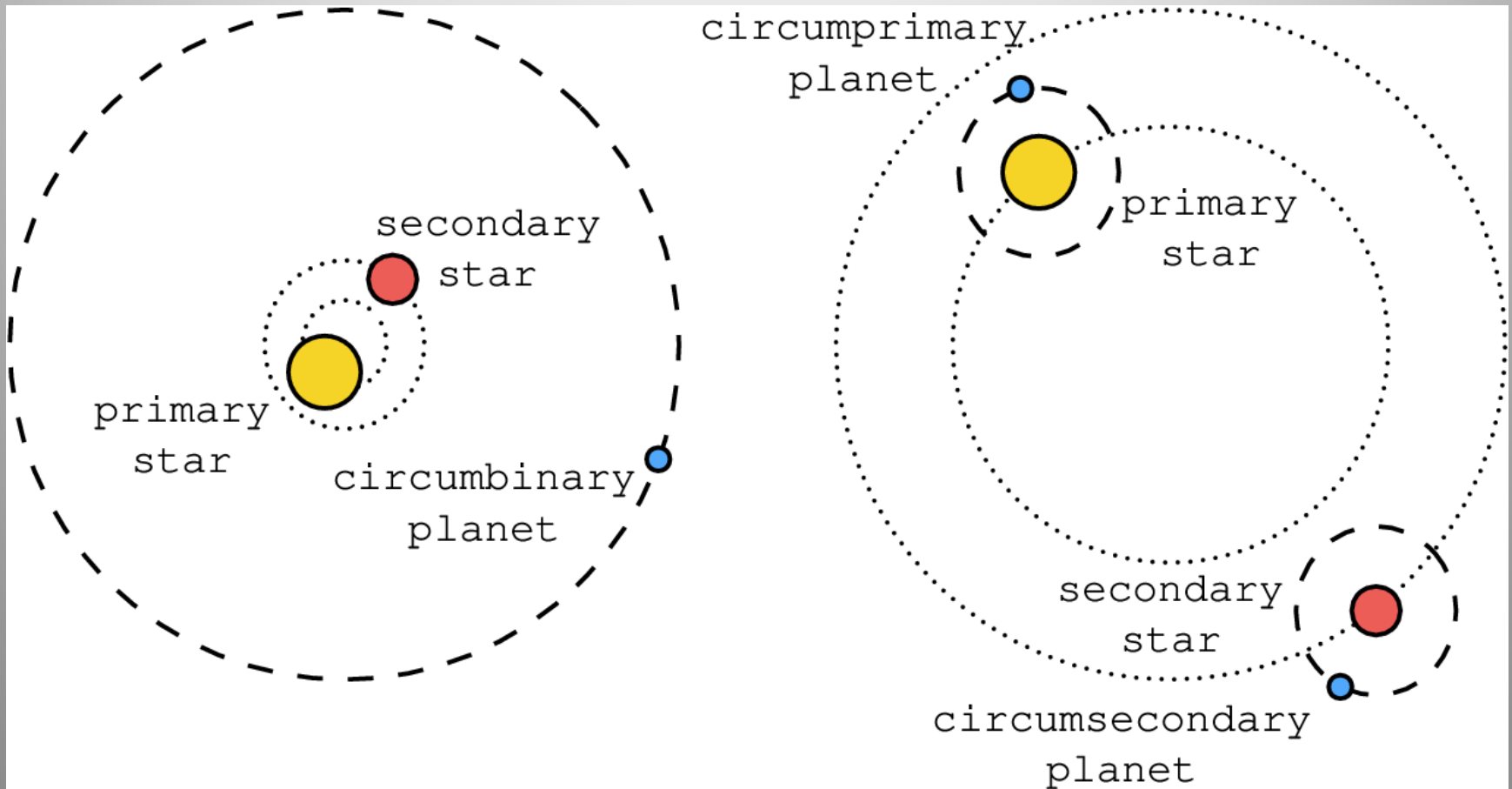
PDS 70b



PDS 70b and PDS 70c



Planet with Binary Stars 雙星行星



More Suns 后羿射日



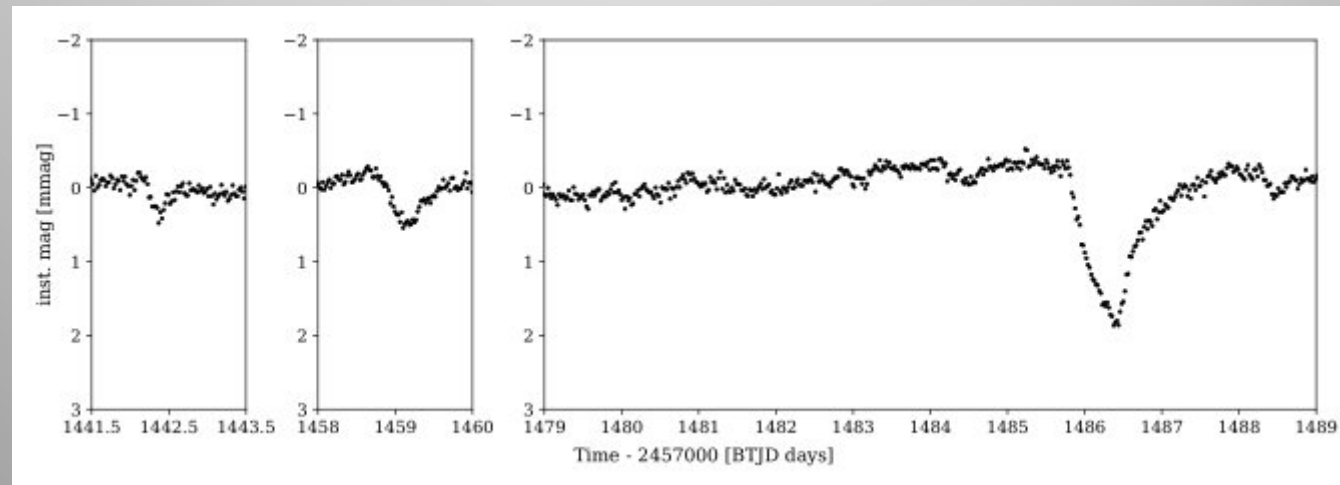
Exomoon 系外月球



Exomoon Light Curve 光變曲線



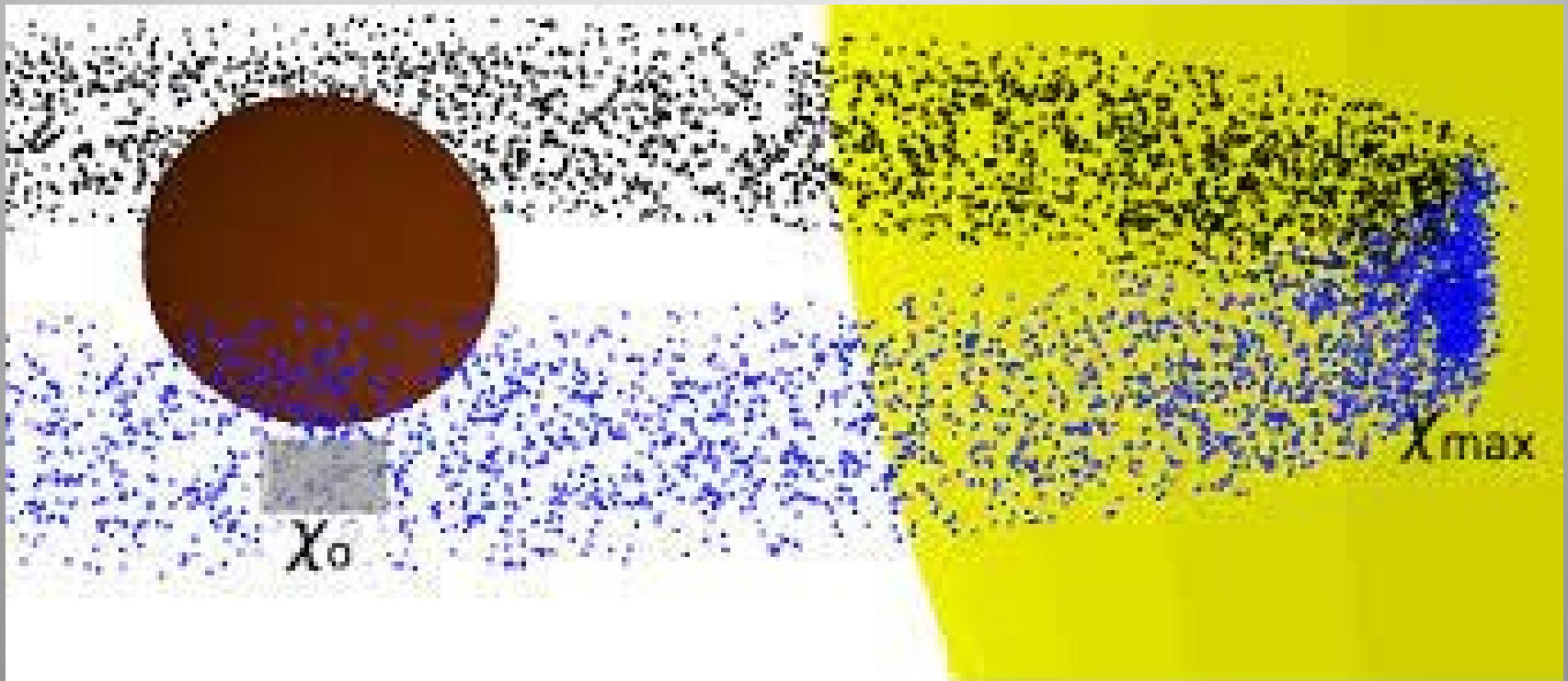
Exocomet 系外彗星



Exolife 外星生命

- Organic Molecular 有機分子
- Habitable Zone 適居帶
- Exoplanet Atmosphere 系外行星大氣:
Na, H₂O , CO, CO₂, CH₄
- Extraterrestrial Intelligence 高智慧生物？
- Artificial Satellites on Exoplanets
系外行星上的人造衛星？

Clarke Exobelt



ExoFarm

- Evidence of farming on exoplanets ?
- Extraterrestrial techno-signature ?
- Industrial-scale agriculture has changed the make up of our atmosphere
- The signature of an ExoFarm
- Is it visible on Earth-like planets orbiting other stars ?

Possible Research Projects

- Observing Orbital Evolution
- Simulating Orbital Evolution
- Observing Exoplanet Atmosphere
- Modeling Exoplanet Atmosphere
- Determining Structures of Planetary Systems
- Studying the Stability of Planetary Systems
- Observing Proto-Planetary Disks
- Simulating Proto-Planetary Disks