6th French Ariel school in Baronnies Lessons to learn from Solar System studies for exoplanets

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Adapted from a course given at the Les Houches school in 2022

Lessons to learn from Solar System

1. Transits and occultations in the Solar System
2. Complexities in radiative transfer of planets : inhomogeneities, aeronomy of upper atmospheres
3. Difficulties and errors in planetary spectroscopy
4. An unusual journey in the Solar System

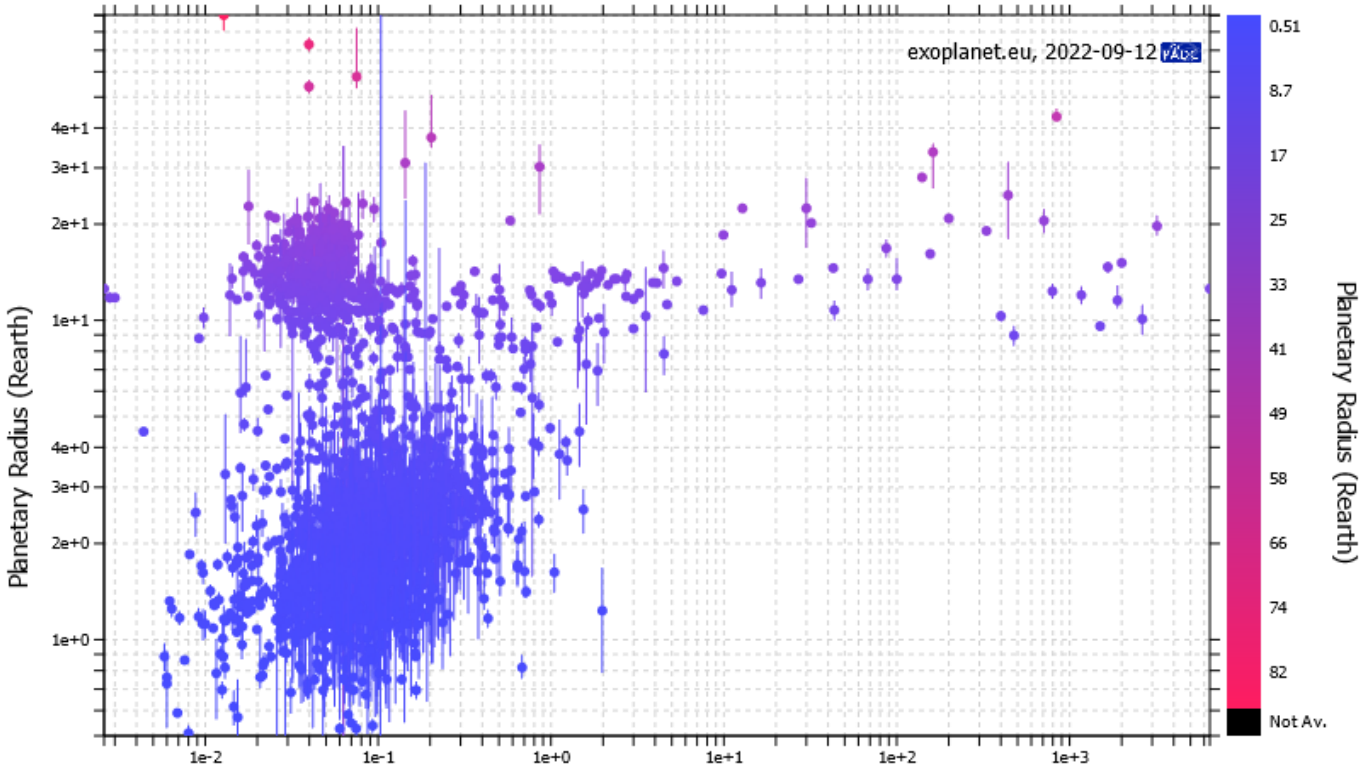
Objectives of the course

After decades of space exploration, the Solar System objects are today known with high accuracy, to the point that Earth sciences are dominent in the study of planets, more than astronomy !

This knowledge can be translated to exoplanets only if we extrapolate from the physical mechanisms, even if average parameters of exoplanets are NOT similar to our planets !

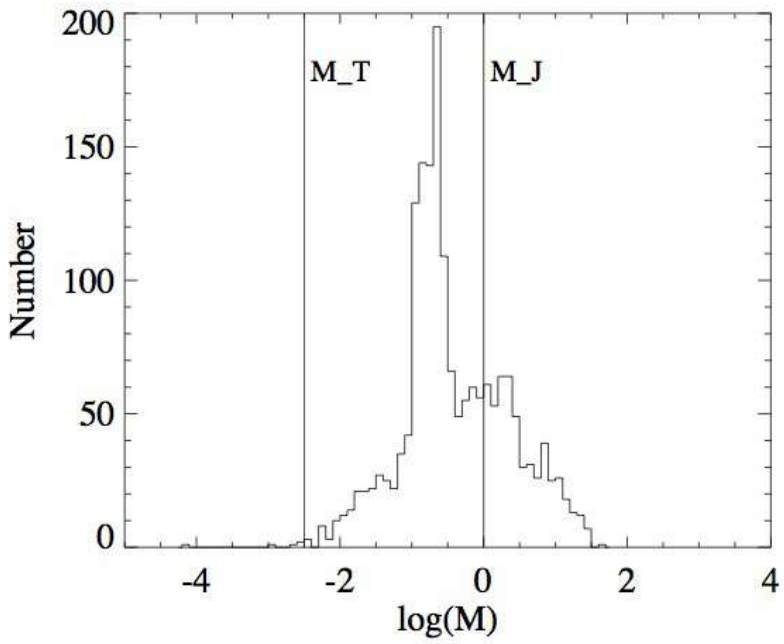
The main objective of the course will also to remember all the errors made in planetology during decades, to try not to repeat them in exoplanets study

Exoplanet demography : current status



Exoplanets.eu – 09/12/2022 planets 5168 (2207 represented)

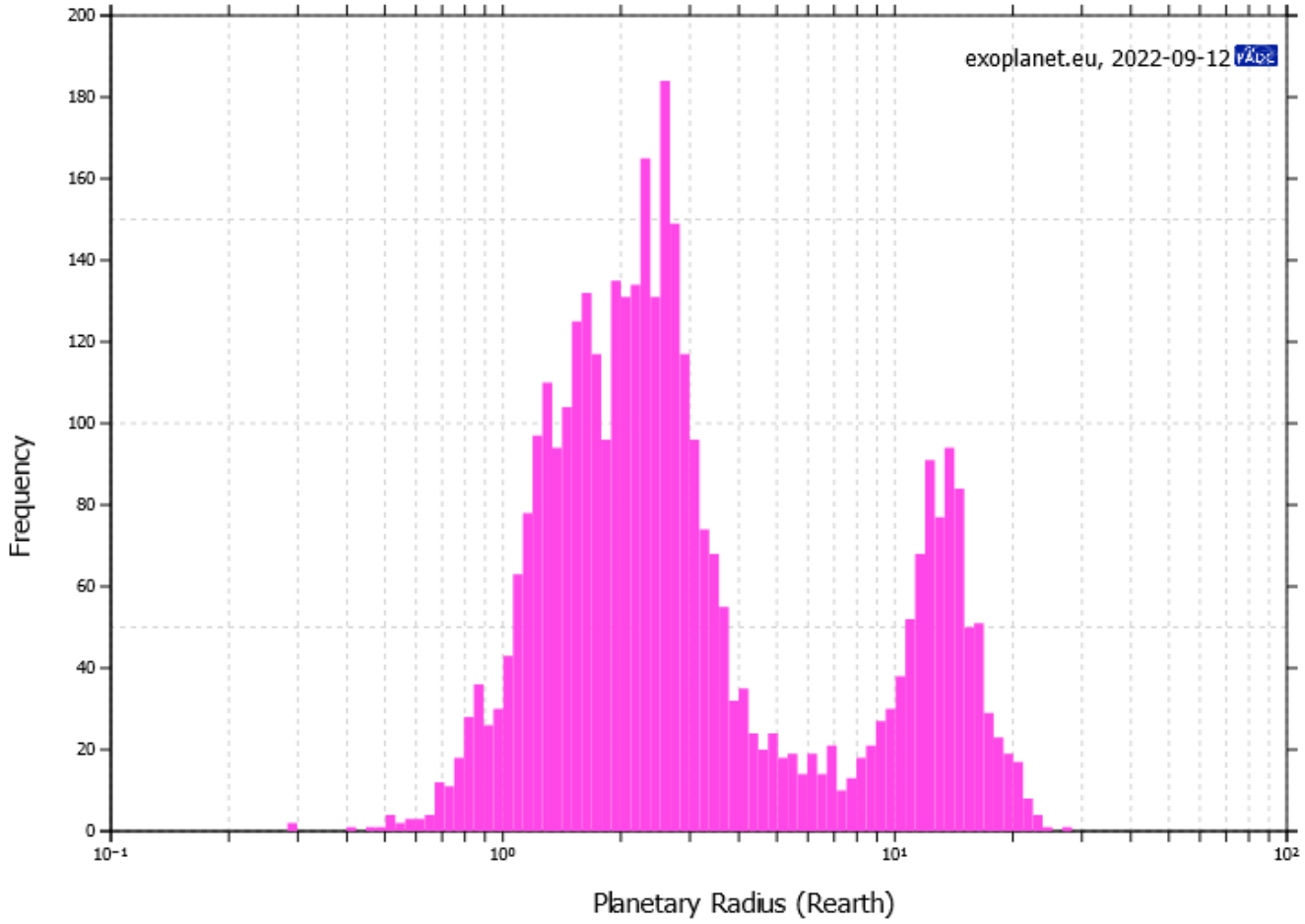
Histogram of exoplanets mass



G. Tinetti, priv. comm.

Today, known planets plotted as a function of distance to the star (up to 20 au) and planetary radii (in Earth masses). Temperature of the host stars is given through the color grid

Histogram of planetary radii



Philosophical context

1) The Earth is **not** at the center of the (planetary) universe

Paradigm : Earth-like planets around Sun-like stars are not the most common planets…

2) The Solar System planets are **not** the representative templates for exoplanets study : superEarths/subNeptunes are the most common (and we don’t know much about them) !

3) Why do we need to study Solar System planets ? Not as templates, but for the physical mechanisms which are universal

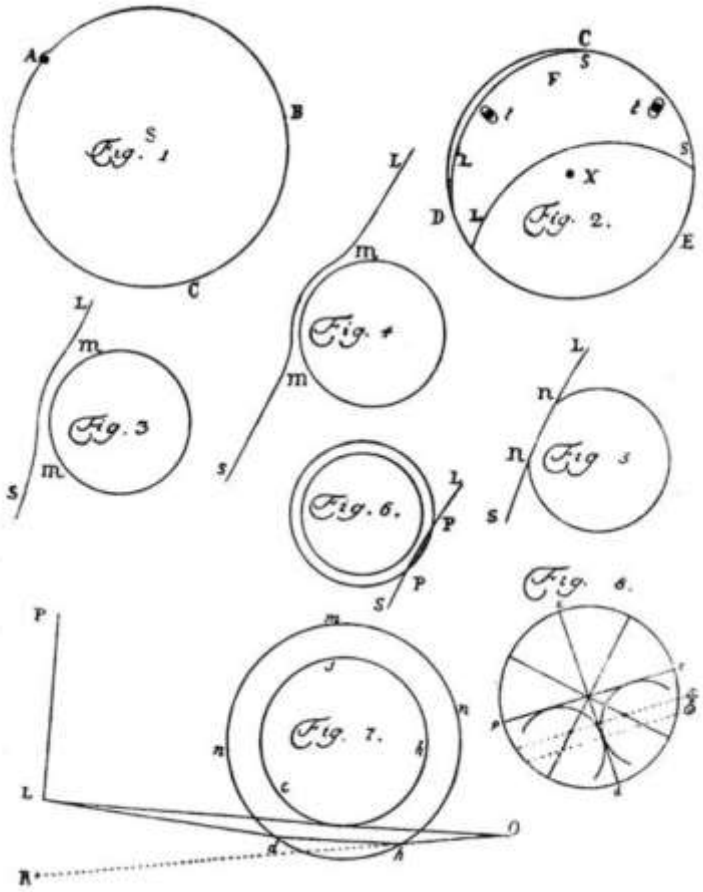
Transits and eclipses in the Solar System

- Transit observable from Earth only for inner planets ! Mercury & Venus transits

Lomonosov discovery of the atmosphere of Venus (1761)

Note: this was 8 years before the Cook observations in Tahiti

Lomonosov's drawing of Venus transit across the Sun's disc



1. Entering the solar disk in B
2. Colors caused by refraction
3. & 4. Bulge as Venus leaves the Sun

Marov, 2004, IAU proceedings

Future transits of Venus

Date(s) of transit	Time (UTC)			Notes[8]
	Start	Mid	End	
10–11 December 2117	23:58	02:48	05:38	Visible in entirety in eastern China, Korea, Japan, south of Russian Far East, Taiwan, Indonesia, the Philippines, and Australia. Partly visible in Central Asia, the Middle East, south part of Russia, in India, most of Africa, and on extreme West Coast of North America.
8 December 2125	13:15	16:01	18:48	Visible in entirety in South America and the eastern North America. Partly visible in Western North America, Europe, Africa, and Oceania.

Future transits of Mercury[15]

Date of mid-transit	Time (UTC)			
	Start	Mid	End	
2032 Nov 13	06:41	08:54	11:07	
2039 Nov 7	07:17	08:46	10:15	
2049 May 7	11:03	14:24	17:44	
2052 Nov 8–9	23:53	02:29	05:06	
2062 May 10–11	18:16	21:36	00:57	
2065 Nov 11–12	17:24	20:06	22:48	
2078 Nov 14	11:42	13:41	15:39	

Transits and eclipses in the Solar System

- Transit observable from Earth only for inner planets ! Mercury & Venus transits

- For any planets (and small bodies…), a powerful tool for investigation is the star occultation

An interesting example: the Jupiter spectral occultation in 1999 by HIP9369