Exoplanets

Lecture 5

20 October 2023

Outline

- Data archives of space missions
- Tools to detect exoplanets
- Exoplanet family

Ondrejov OES spectrograph

- Tour of Perek telescope facilities

MAST archive

- https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html
- https://exo.mast.stsci.edu
- http://archive.stsci.edu/searches.html#missions
- http://simbad.u-strasbg.fr/simbad/

ExoMast

MAST Home

Select a collection...

MAST Observations by Object Name or RA/Dec

About Collections...

and enter target:

Enter object name or RA and Dec to cone search

Search

Show Examples... Random Search Advanced Search

anonymous

Login...

Account Info...

Upload Target Li...

My Download Basket: 0 fil...

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Home Page

MAST FTP Service Change

On 25 Oct 2021, the MAST FTP server archive.stsci.edu will no longer support unencrypted FTP connections. Only encrypted FTPS will be supported. Read more about this change and some related FAQ on the MAST FTP Service page.

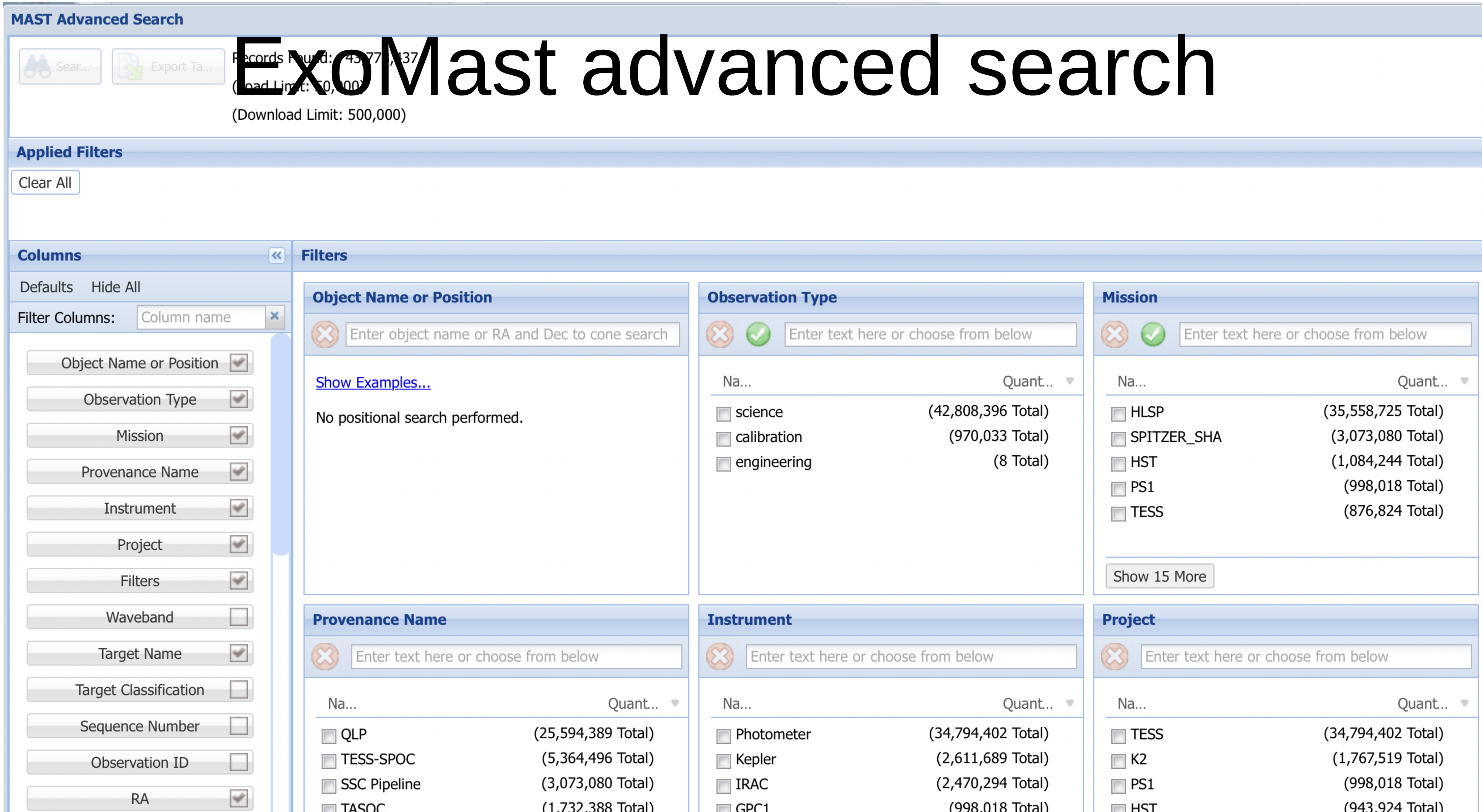
Our apologies for the inconvenience.

MAST: Barbara A. Mikulski Archive for Space Telescopes

The MAST Portal lets you search multiple collections of astronomical datasets all in one place. Use this tool to find astronomical data, publications, and images.

Note: This site uses cookies in order to monitor feature usage, track user preferences, and provide authentication for some services. By using this site you consent to the use of cookies for such purposes.

ExoMast advanced search



Lightcurve manipulation tools

- Downloading of the LC
- Performing photometry on the TESS LC
- Checking the cut-offs
- Creating own photometric masks
- https://docs.lightkurve.org - lightkurve 2.0
- https://github.com/afeinstein20/eleanor - eleanor
- https://arxiv.org/abs/1903.09152

How to recover the first TESS planet candidate with *Lightkurve*?

Data from the TESS mission are available from the data archive at MAST. This tutorial demonstrates how the Lightkurve Python package can be used to read in these data and create your own TESS light curves with different aperture masks.

Below is a quick tutorial on how to get started using *Lightkurve* and TESS data. We'll use the nearby, bright target Pi Mensae (ID 261136679), around which the mission team recently discovered a short period planet candidate on a 6.27 day orbit. See the pre-print paper by Huang et al (2018) for more details.

TESS data is stored in a binary file format which is documented in the TESS Science Data Products Description Document. *Lightkurve* provides a TessTargetPixelFile class which allows you to interact with the data easily.

[1]:
```
import lightkurve as lk
```

[2]:
```
search_result = lk.search_targetpixelfile('Pi Mensae', mission='TESS', sector=1)
```

[3]:
```
search_result
```

[3]: SearchResult containing 2 data products.

#	mission	year	author	exptime	target_name	distance
				s		arcsec
0	TESS Sector 01	2018	SPOC	120	261136679	0.0
1	TESS Sector 01	2018	TESS-SPOC	1800	261136679	0.0

ExoFop

- https://exofop.ipac.caltech.edu

TIC ID
186812530

In CTL?	Yes
TIC Contamination Ratio	0.006396
Number of Contamination Sources	80

Jump to

Open Observing Notes (6)

Download

7 nearby targets within 1 arcmin:
view | csv | pipe | text

149 Files: tar | zip
File List: csv | pipe

Text file of this page

Basic Information

Star Name & Aliases	Confirmed Planet Name(s)	RA/Dec (J2000, epoch 20
TIC 186812530, 2MASS J08171689+1236049, APASS 41707956, Gaia DR2 650254479499119232, TYC 0802-00751-1, UCAC4 514-046693, WISE J081716.89+123604.7	N/A	08:17:16.89 12:36:04.76 124.320365° +12.601322°

TESS Objects of Interest (1)

TOI	TIC	Master priority	SG1A priority	SG1B priority	SG2 priority	SG3 priority	SG4 priority	SG5 priority	ACWG ESM	ACWG TSM	TESS Dispositi
TOI 503.01	TIC 186812530.01	4	5	5	4	4	4	5	58	223	CP

Community TESS Objects of Interest (0)

+ Create new   CTOI Guidelines

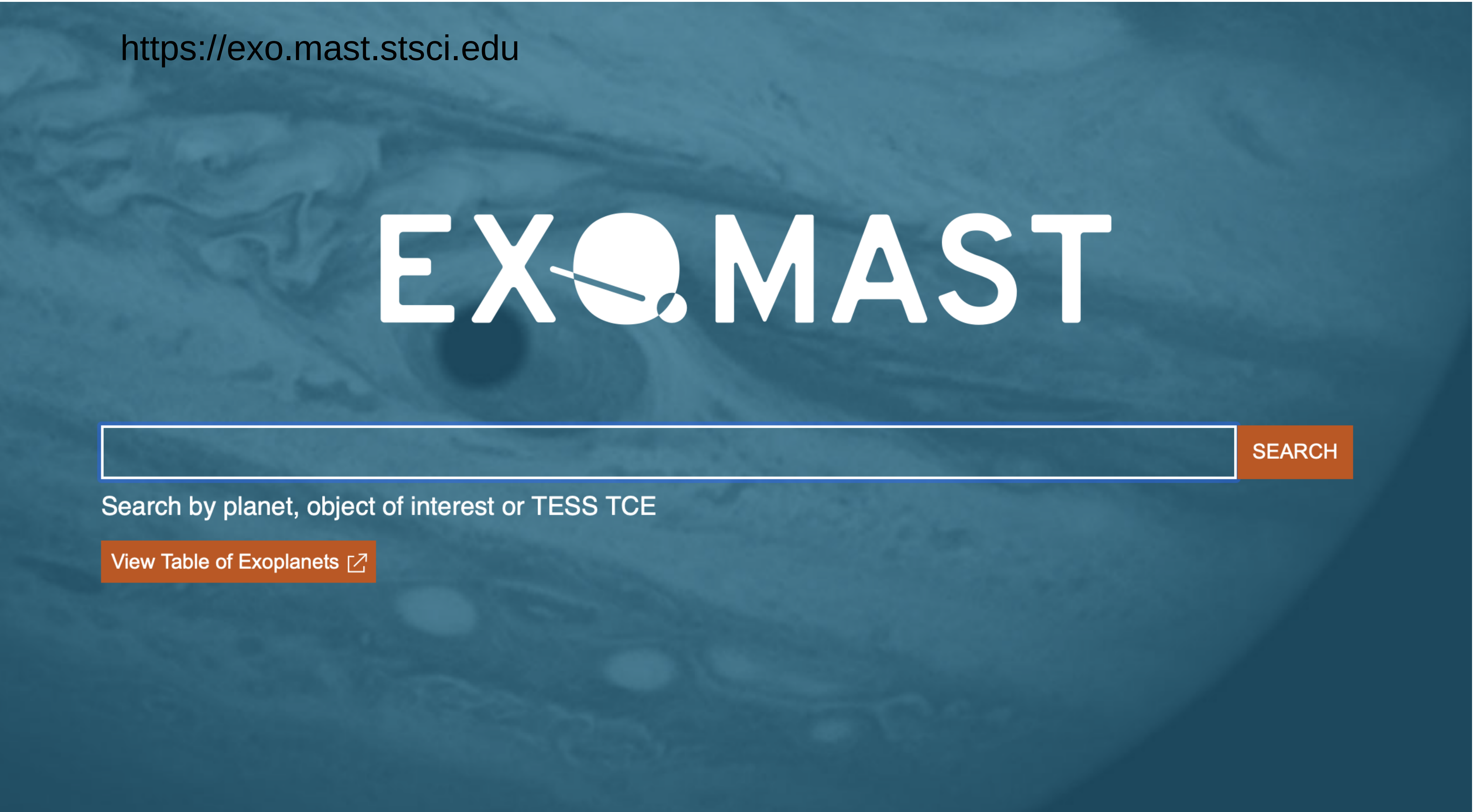
CTOI	Master priority	SG1A priority	SG1B priority	SG2 priority	SG3 priority	SG4 priority	SG5 priority	Initial Community Disposition

Planet Parameters (2)

+ Add new

Name	TOI	Disposition	Epoch BJD	Period days	Depth mmag	Depth ppm	Duration hrs	Inclination deg	Impact Parameter *b*	Rad_p/Rad_s	a/Rad_s	Radius R_Earth	Mass M_Earth
TESS Object of Interest (TESS Project) (1)													
TIC 186812530.01	TOI 503.01		2459249.58908 ± .0003773	3.6773569 ± .0000029	4.29715 ± .007766	3950 ± 7.15246	1.531 ± .33					11.5082 ± .623437	

https://exo.mast.stsci.edu



Exoplanet Utilities

https://astroutils.astronomy.osu.edu/exofast/

For recent news, follow me on twitter. You can also discuss with me and other users on Reddit.

This applet, and the instructions below, are for EXOFASTv1. For any research grade analysis, EXOFASTv2 is strongly recommended.

Online Applets

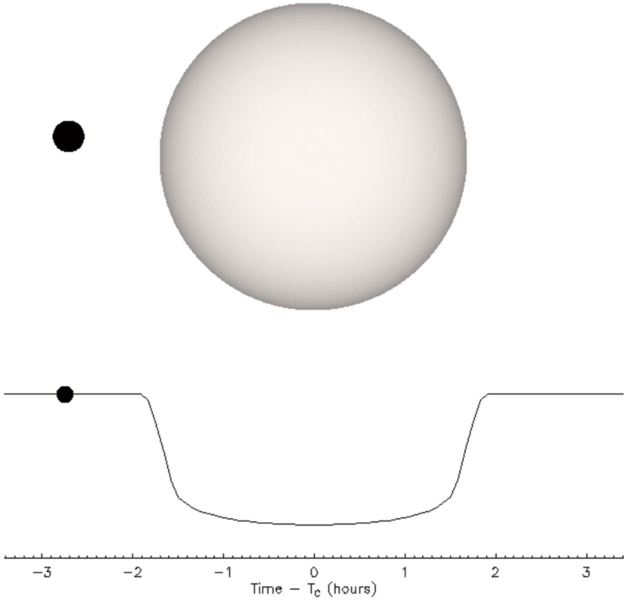
- EXOFAST -- Fits transit and/or RV data
- Ephemerides -- Calcuates transit/eclipse ephemerides
- Limb-darkening -- Calculates the quadratic limb-darkening parameters
- Barycentric Correction -- Calculates the barycentric velocity correction

Documentation

- README -- Installation instructions
- Documentation -- Documentation for all EXOFAST routines
- Release Notes -- Summary of changes/updates
- Limitations - Warnings about limitations of EXOFAST

Other

- barycorrpy -- A pure Python code written by Shubham Kanodia that does time conversion and barycentric velocity corrections
- barycorr.py -- A Python interface written by René Tronsgaard (Aarhus University) that uses the online API for utc2bjd, bjd2utc, and barycorr
- occultquad.py -- Python implementation of exofast_occultquad
- occultquad.f -- Fortran implementation of exofast_occultquad
- occultquad_extern -- IDL wrapper for fortran version of occultquad



HAT-P-3b in true color, created with TRANSITGIF.

Fitting with juliet

- Will be shown on a dedicated jupyter notebook

- https://juliet.readthedocs.io/en/latest/

Exoplanets families

- Which types of exoplanets do we know?
- Statistics of exoplanets
- Evolution of exoplanetary systems and Solar system

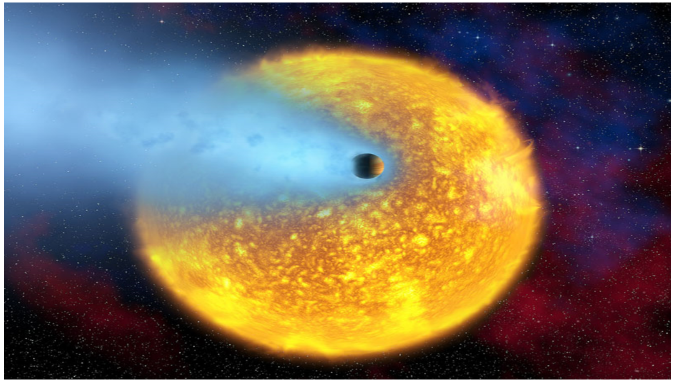
State of the art in 2006

- Hot Jupiters – gas planets
- Super Earths – small terrestrial planets

Types of planets (2006)

Giant planets (hot Jupiters)

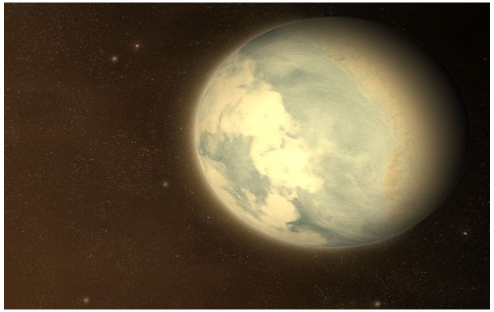
- close-in orbits
- short orbital periods (a few days)
- Jupiter-sized
- In transit with intensity decrease of a few %
- 1995 first detection 51 Peg (Mayor & Queloz 1995)



Vidal-Madjar et al. (2004)

Super Earths

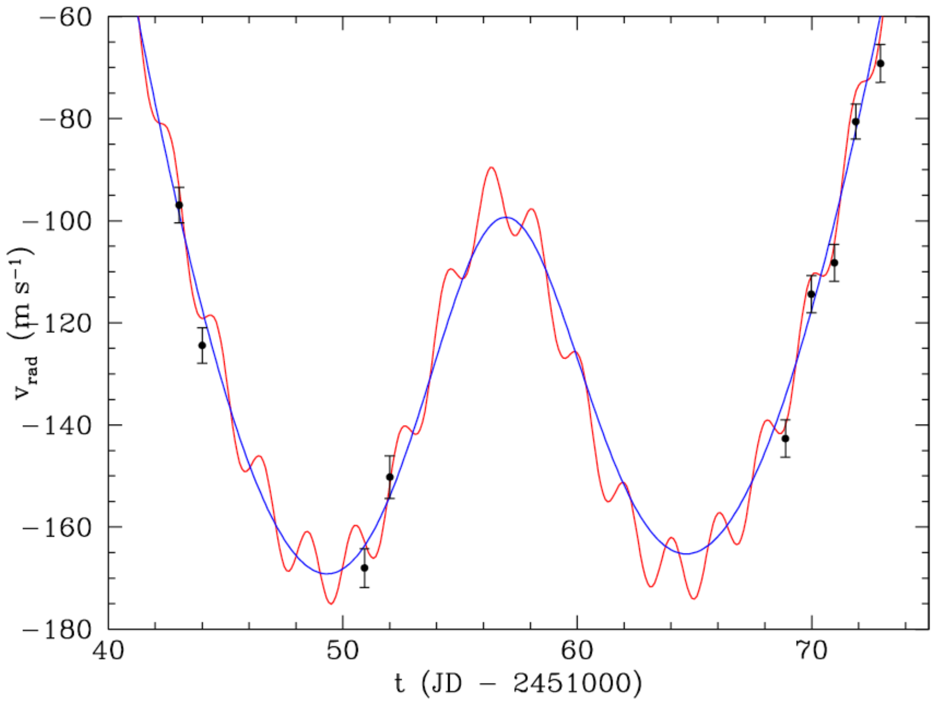
- masses up to 10 M_{Earth} (Valencia 2007)
- constraint on radius: 10 M_{Earth} – max 1.9 R_{Earth} (Valencia 2007)
- consist of rocks and iron & planetary ice (Fortney 2007)
- Gliese 581 system (Mayor, Udry 2009)

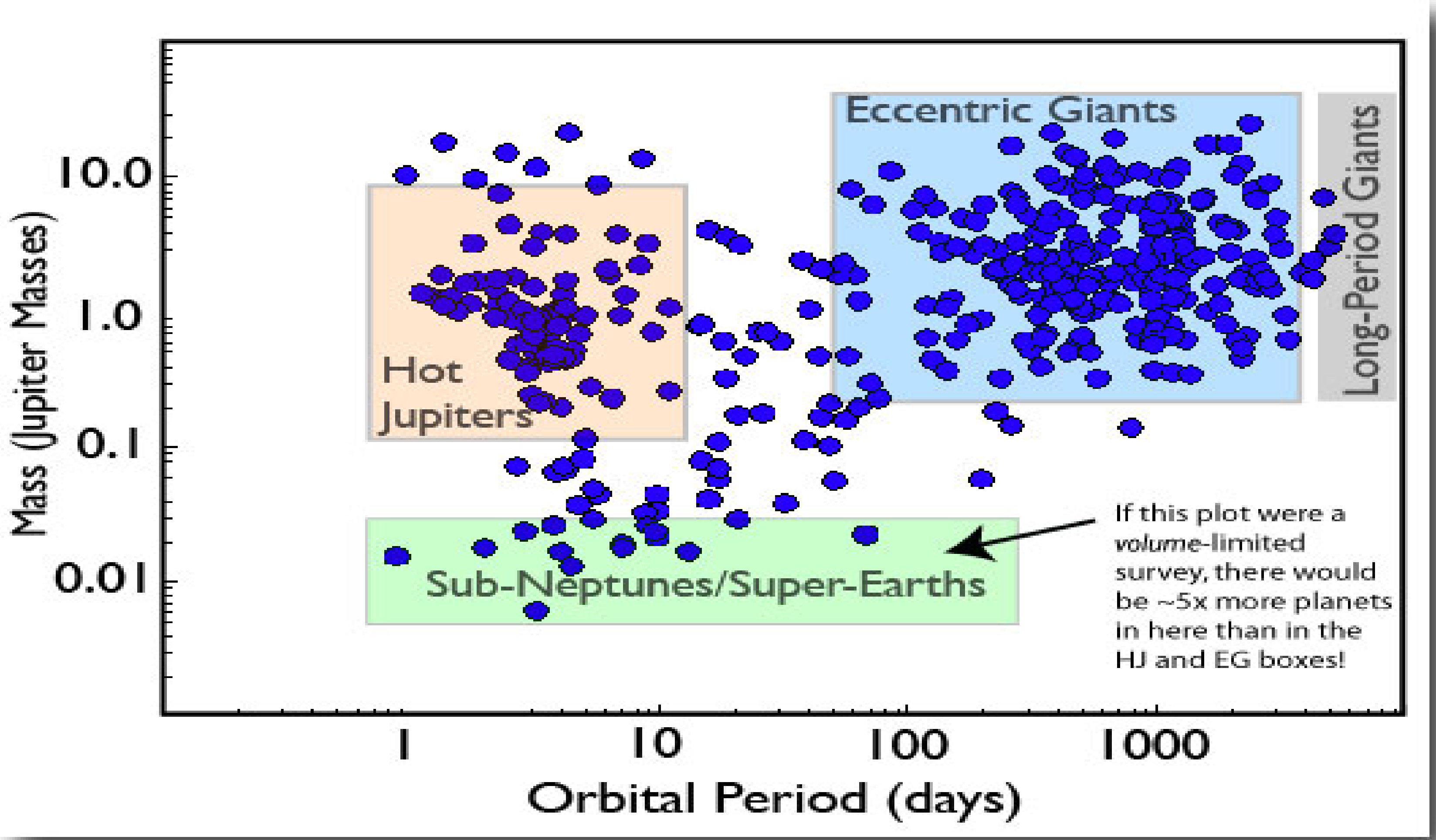


The first Super Earth

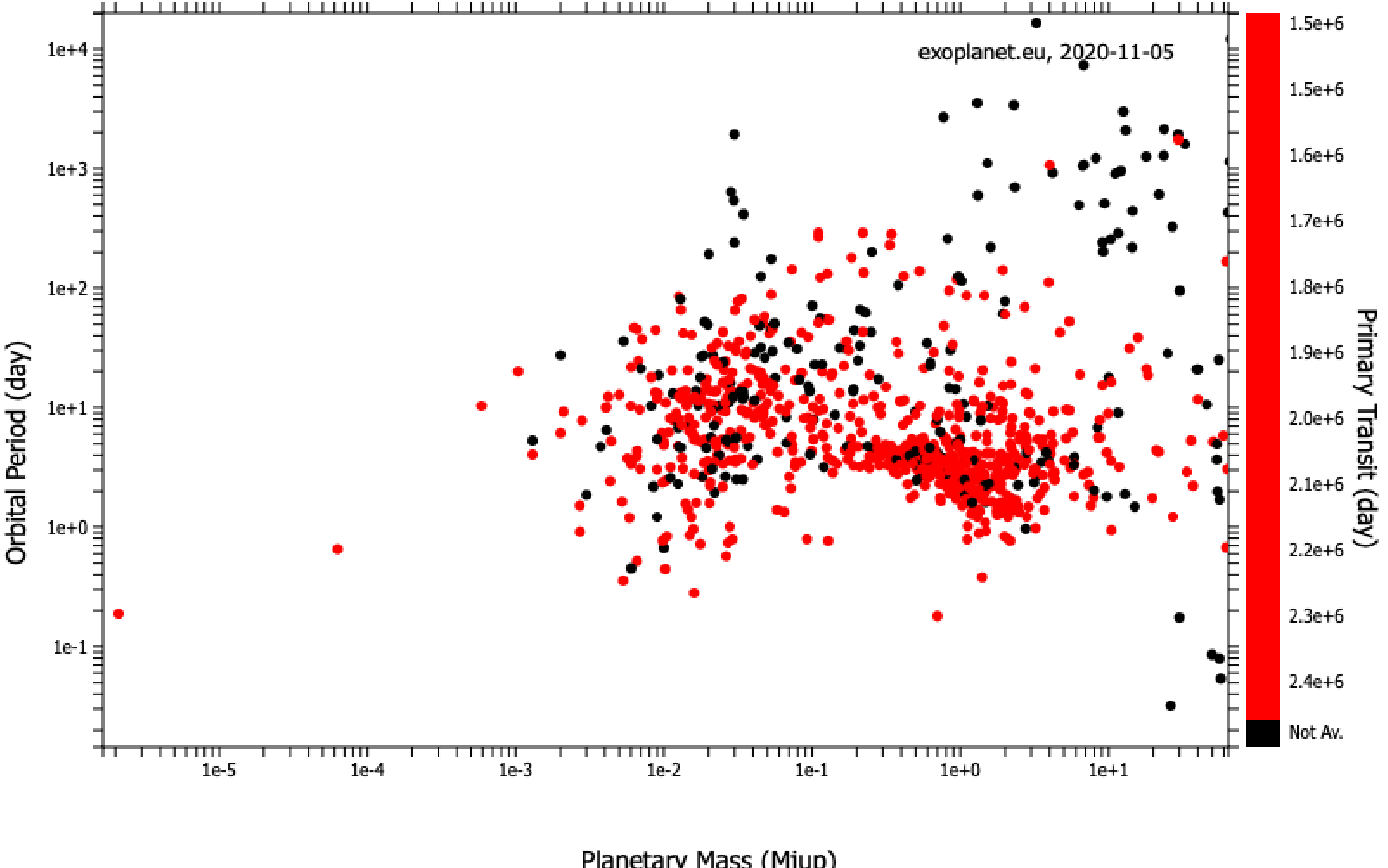
- GJ 876d Rivera et al. 2005 (Figure with RVs) https://arxiv.org/pdf/astro-ph/0510508.pdf
- M=7.5Mearth
- The first model
- - Valencia et al. 2006

  https://iopscience.iop.org/
- article/10.1086/509800/pdf

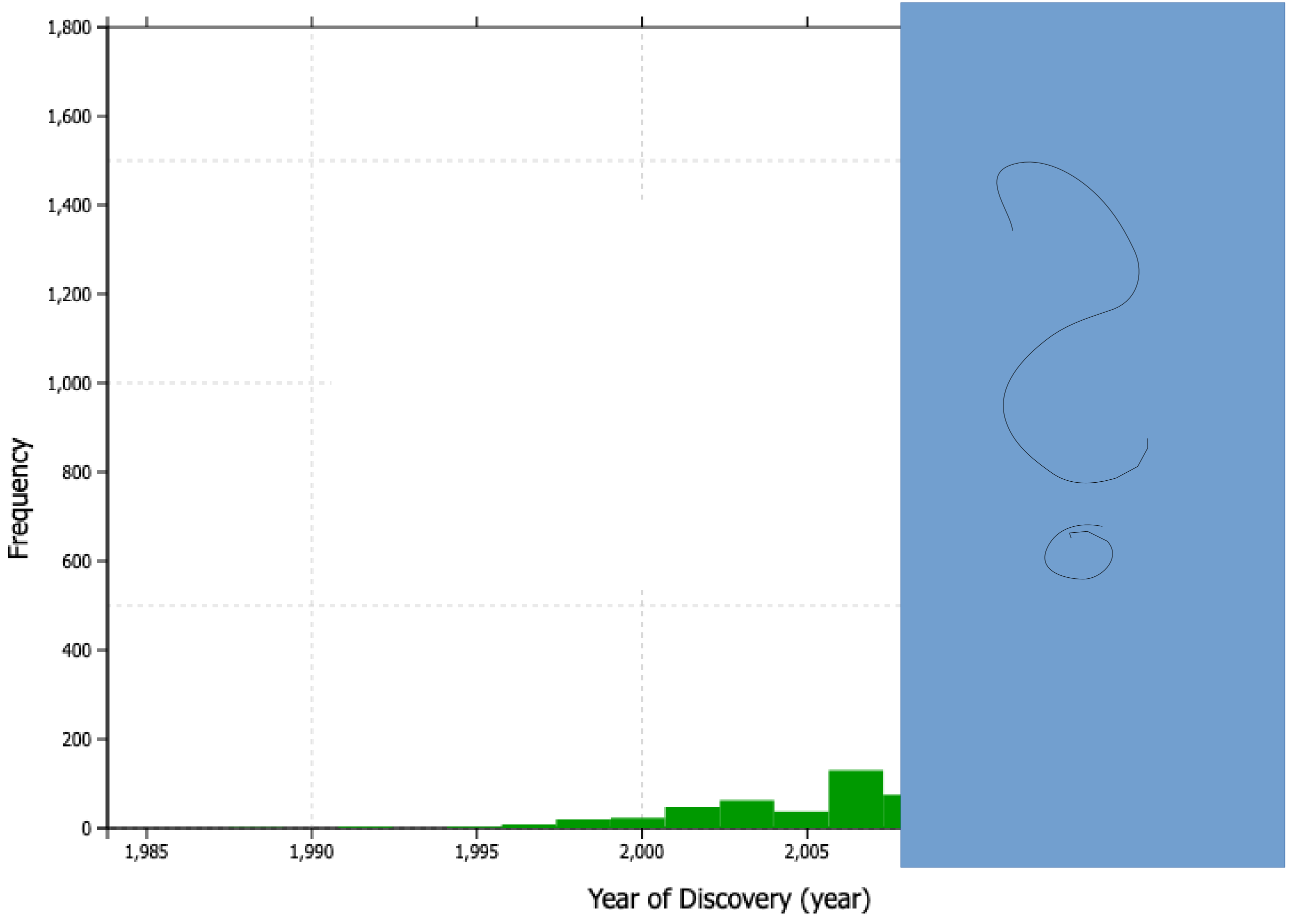



Eccentric Giants
Long-Period Giants
Hot Jupiters
Sub-Neptunes/Super-Earths
If this plot were a *volume*-limited survey, there would be ~5x more planets in here than in the HJ and EG boxes!
Mass (Jupiter Masses)
10.0
1.0
0.1
0.01
1
10
100
1000
Orbital Period (days)

Mass vs. Period

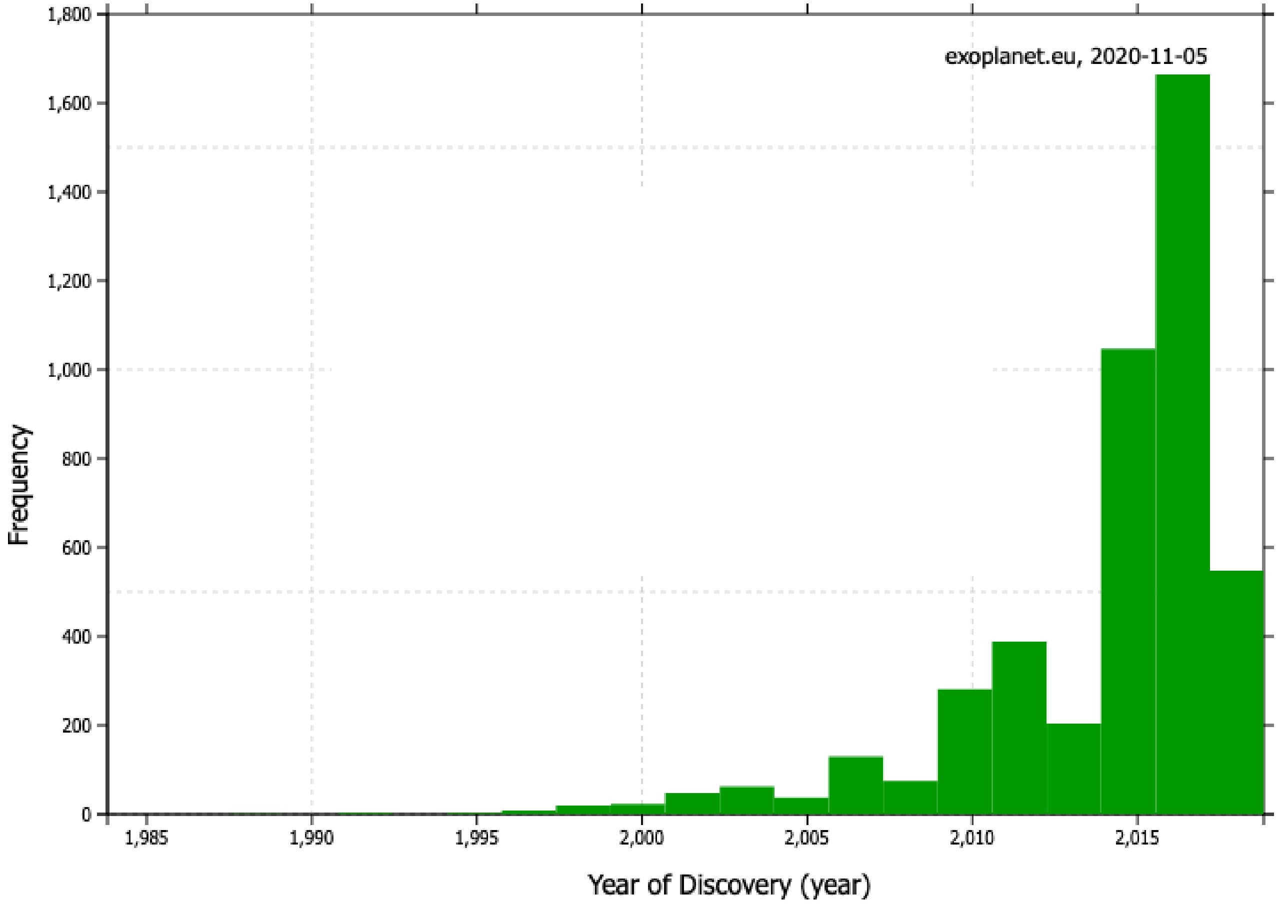


Status 2006



1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Frequency
1,985
1,990
1,995
2,000
2,005
Year of Discovery (year)

How is the status today?



Then came mini-Neptunes

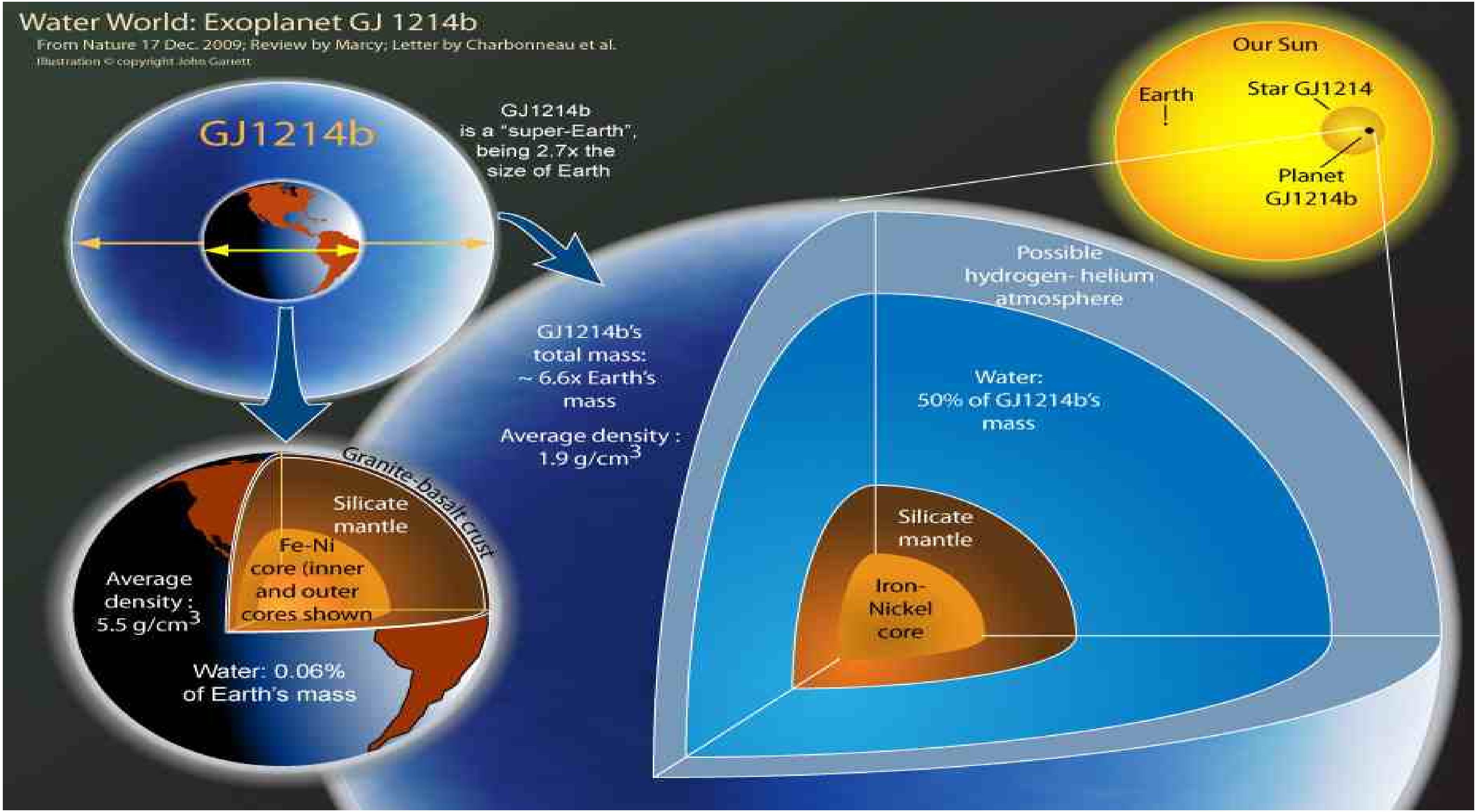
GJ1214b

- **Super-Earth-sized planet detected in 2010**

  Charbonneau et al. 2010, Nature

<u>PARAMETERS</u>

- **Orbiting M dwarf star (V=14.71 mag) in 1.58 days**
- **Only 14pc distance**
- **M=0.02Mj**
- **R=0.245Rj**
- **Mysterious atmosphere?**


Water World: Exoplanet GJ 1214b
From Nature 17 Dec. 2009; Review by Marcy; Letter by Charbonneau et al.
Illustration © copyright John Garrett
GJ1214b
GJ1214b is a "super-Earth", being 2.7x the size of Earth
Our Sun
Earth
Star GJ1214
Planet GJ1214b
Possible hydrogen- helium atmosphere
GJ1214b's total mass: ~ 6.6x Earth's mass
Average density : 1.9 g/cm3
Water: 50% of GJ1214b's mass
Silicate mantle
Iron-Nickel core
Granite-basalt crust
Silicate mantle
Fe-Ni core (inner and outer cores shown
Average density : 5.5 g/cm3
Water: 0.06% of Earth's mass

Super Earths and Rocky planets

- Super Earths < 10 M Earth (Valencia et al. 2006)
- Planets with a solid surface
- Sub-group of SupearEarths
- They can have an atmosphere or not
- Kepler discovered the most of them

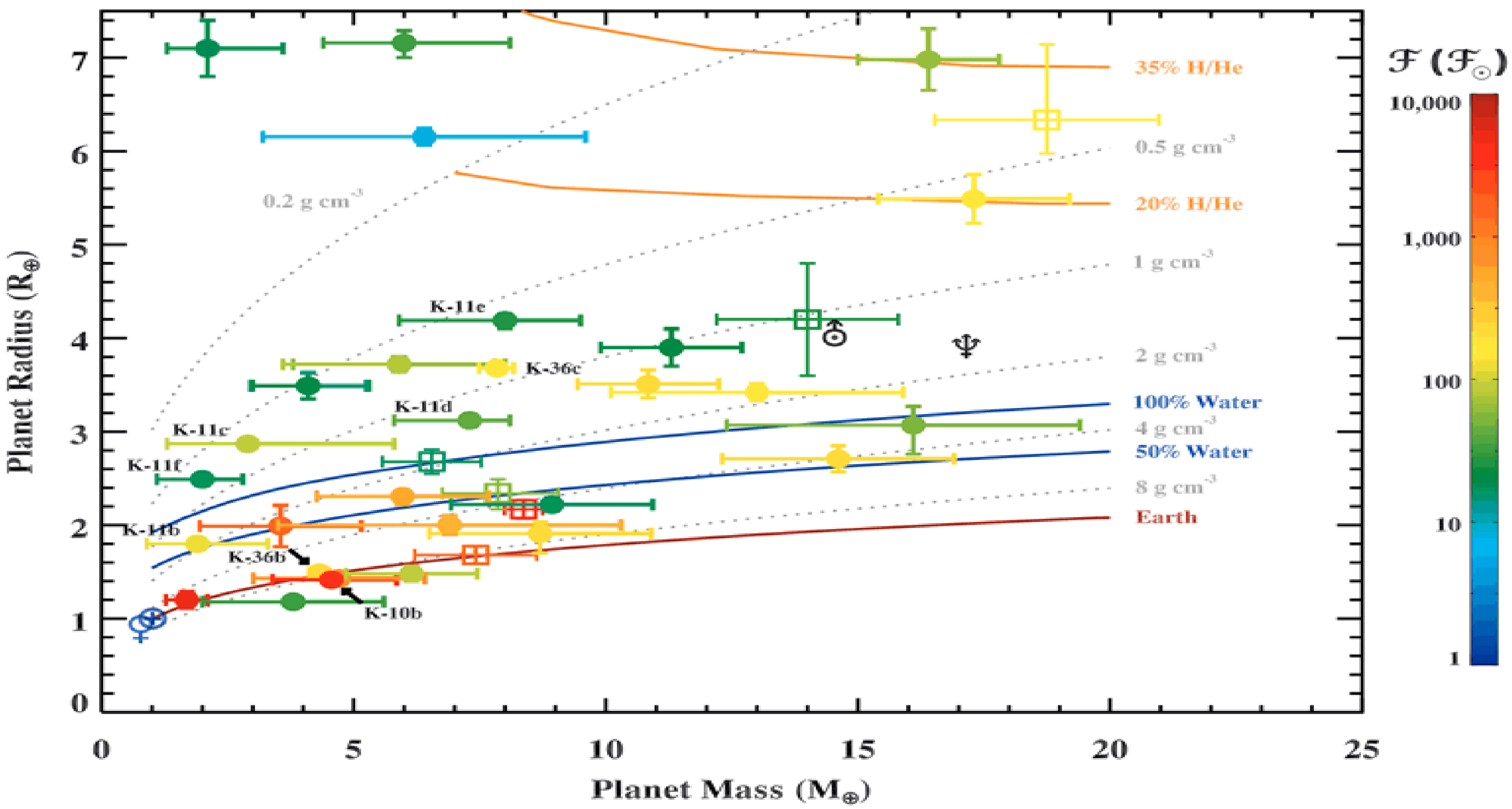
Super Earths mass limits

- 1-10 Mearth
- Ida et al. 2004, ApJ, https://iopscience.iop.org/article/10.1086/381724/fulltext/58801.text.html

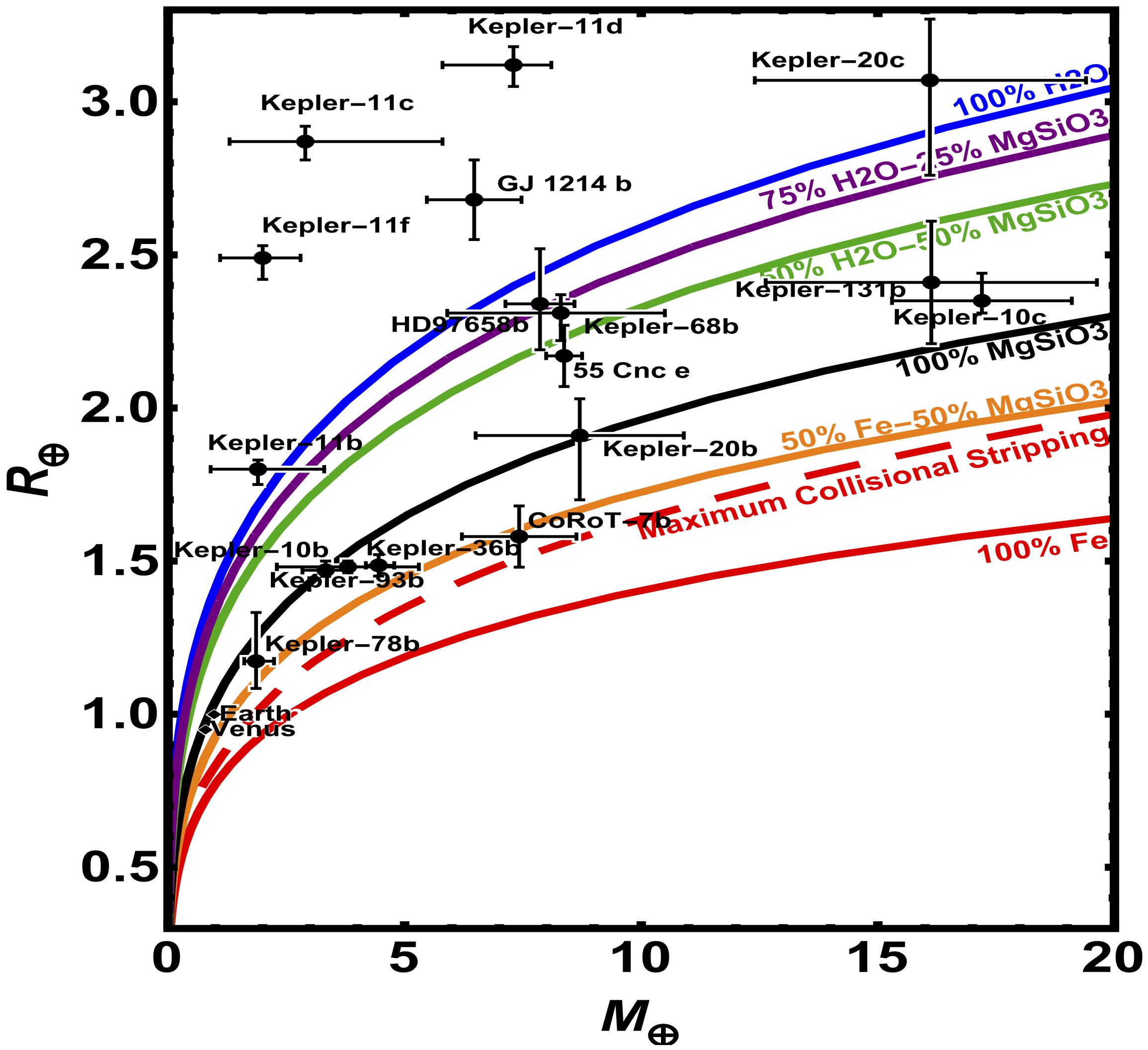
  - 10MEarth is the limit where H. He gas can be retained

  - lower bound is for historical reasons
- In this group belong planets with oceans, rocky and massive Earths planets

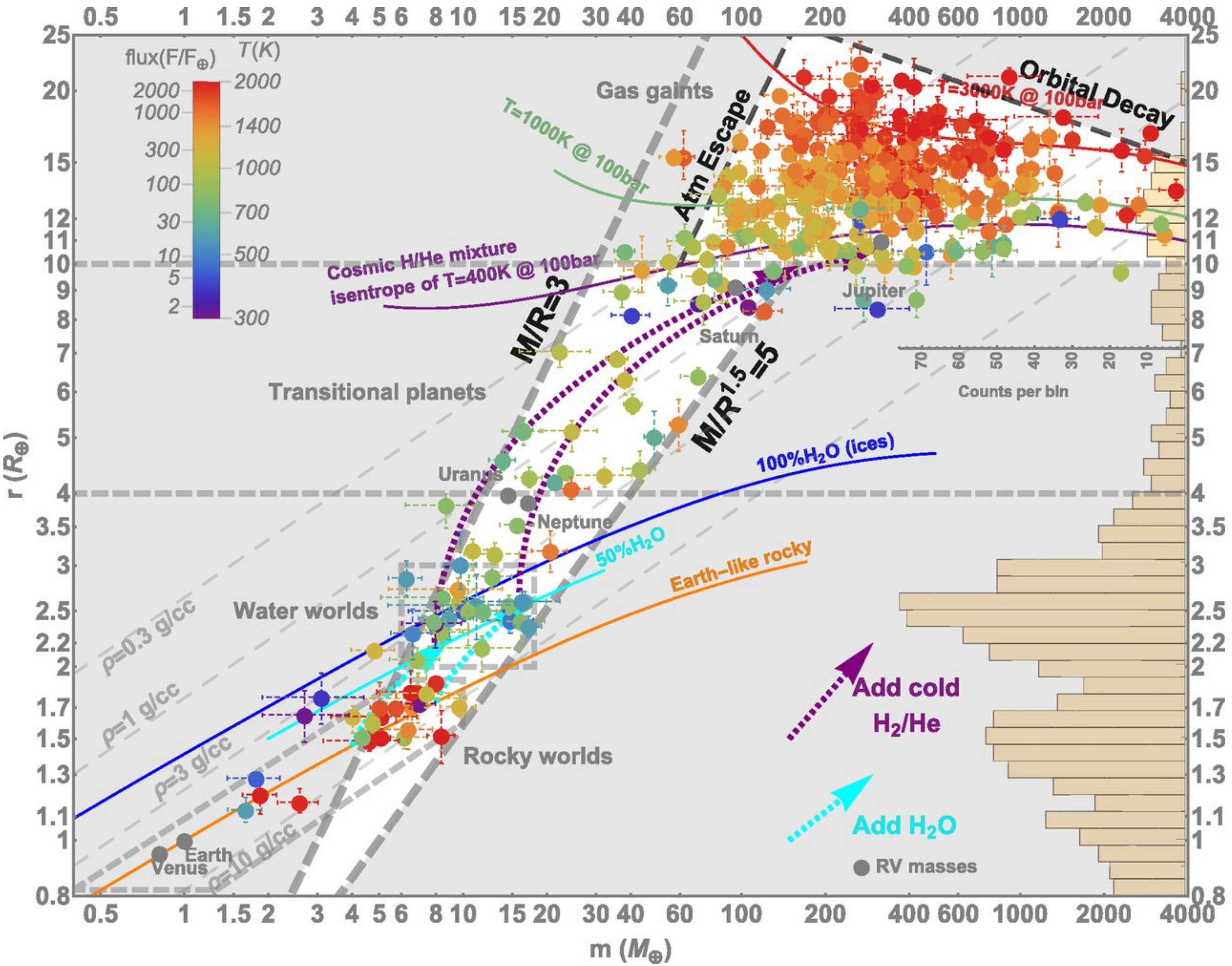
Mass radius diagrams



http://arxiv.org/abs/1409.1595

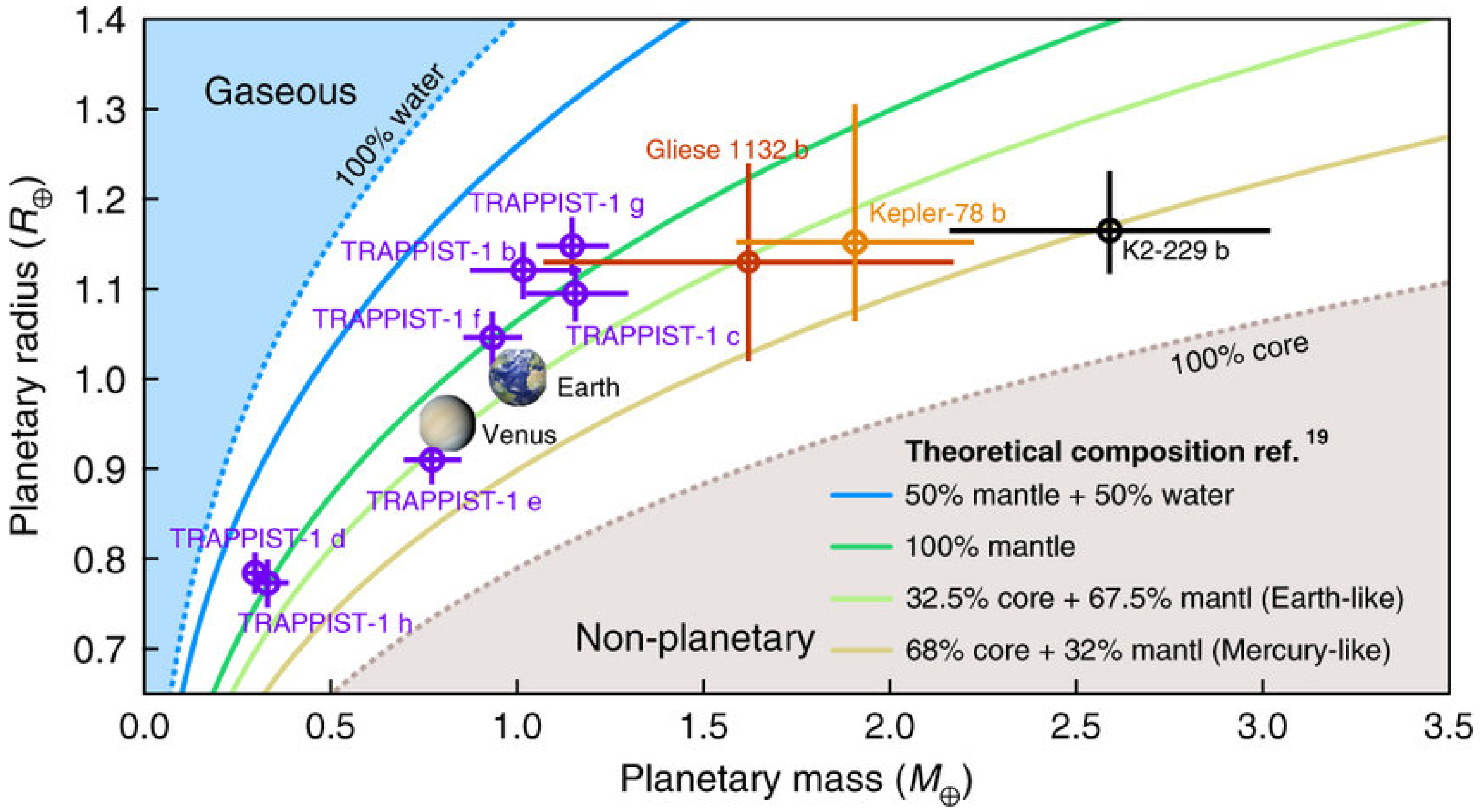


https://www.cfa.harvard.edu/~lzeng/Exoplanet%20Models.html



Zeng et al. 2019, PNAS, https://doi.org/10.1073/pnas.1812905116

Getting closer to the Earth-like



Santerne et al. 2018, https://www.nature.com/articles/s41550-018-0420-5

Next week

- Evolution of our Solar System
- Evolution of exoplanetary systems
- The place of our Solar system in the Universe