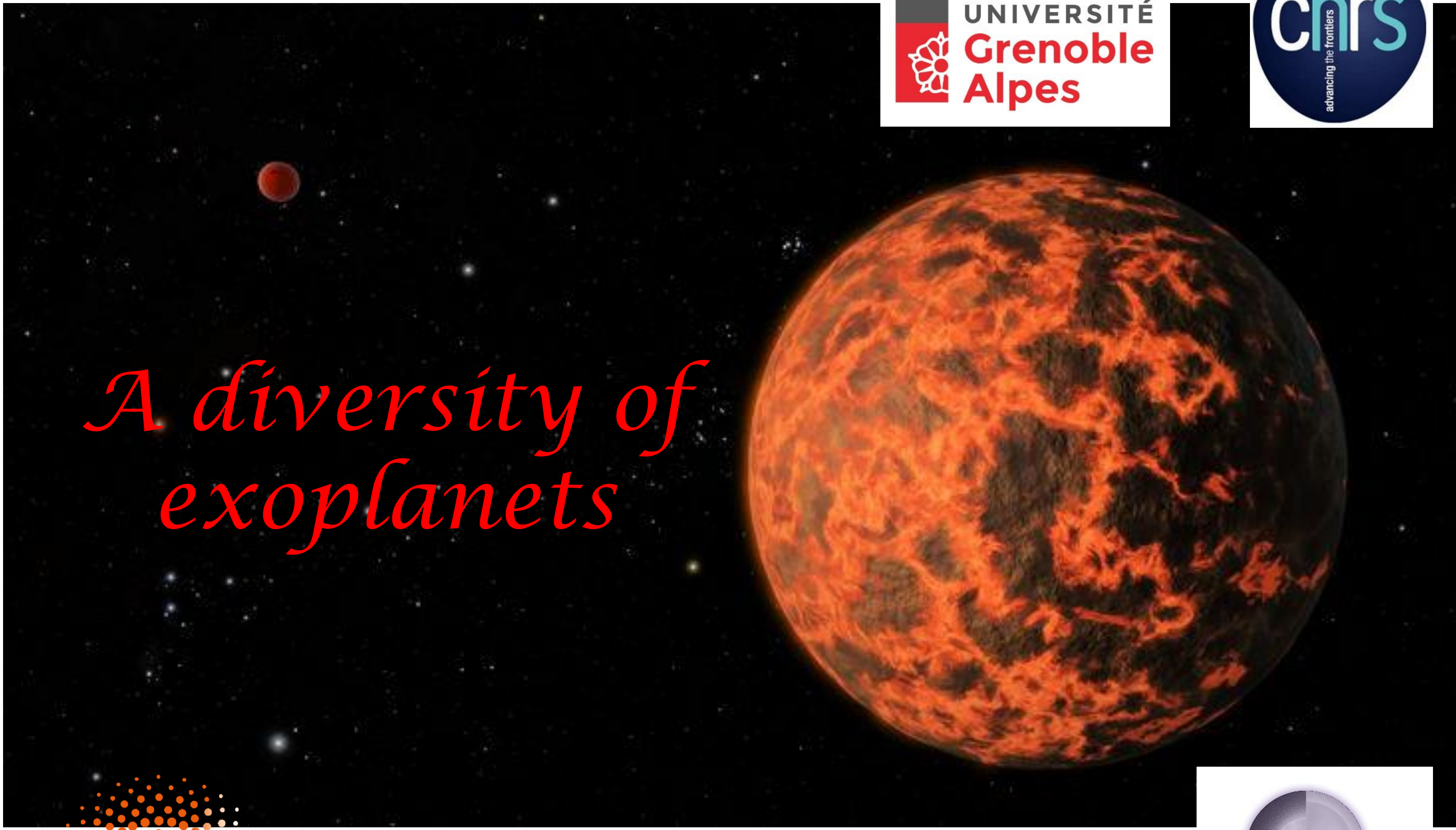
Guillaume MORARD

A diversity of exoplanets



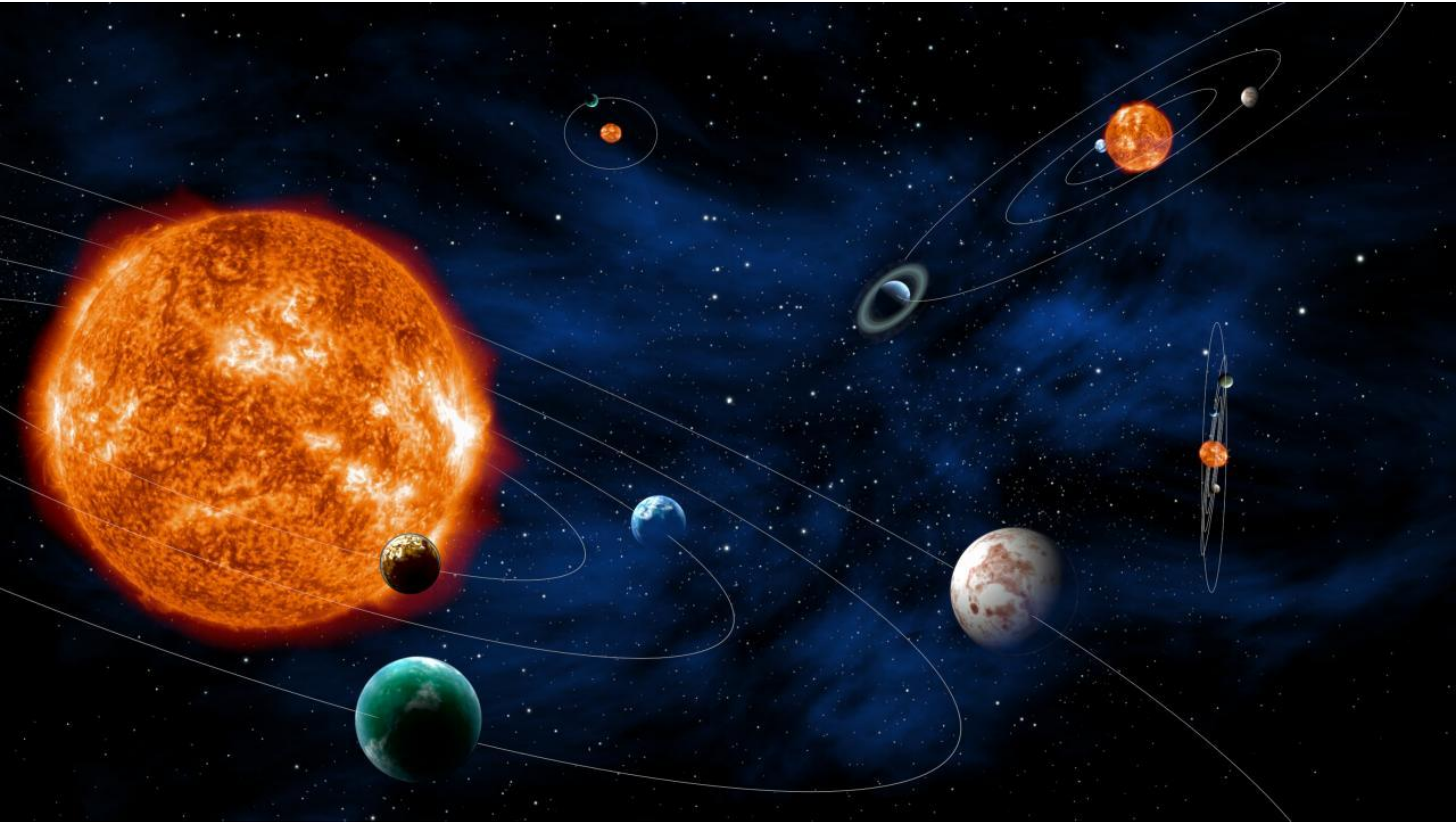
Université Grenoble Alpes

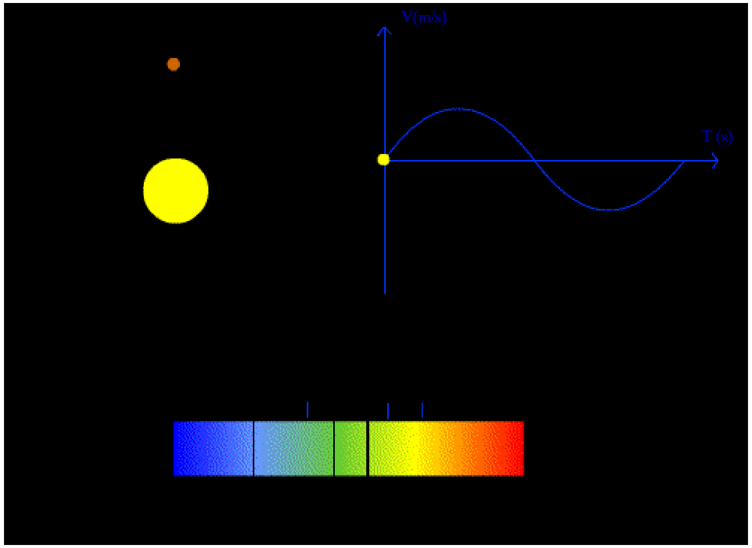
cnrs

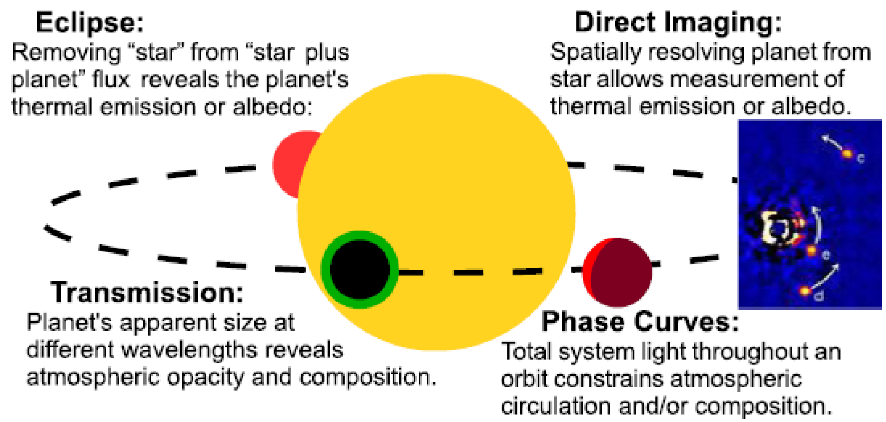
erc

Géodynamo

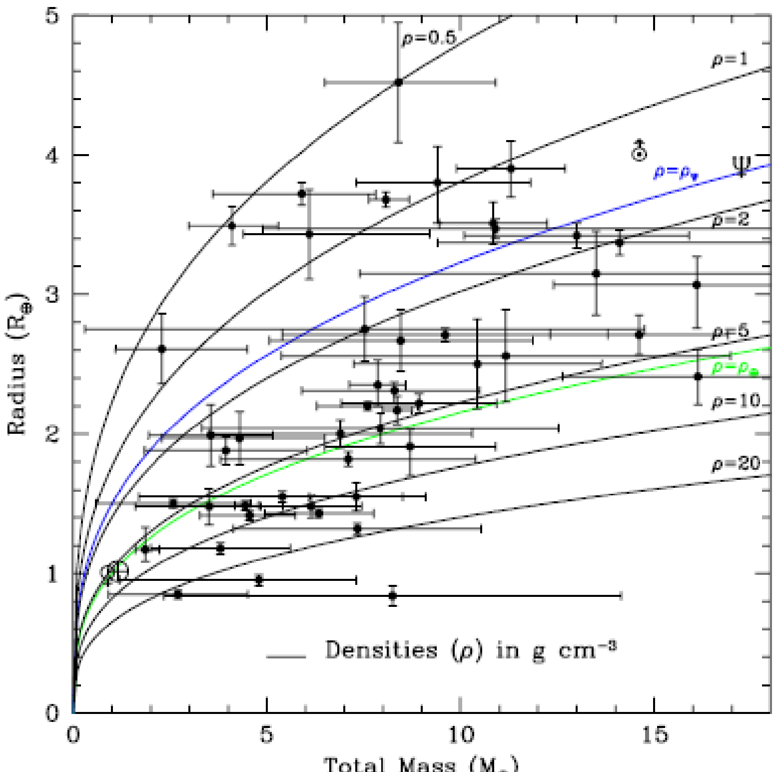
Planetary Diversity







Crossfield, PASP, 2015



Howe et al, The Astr. J., 2014

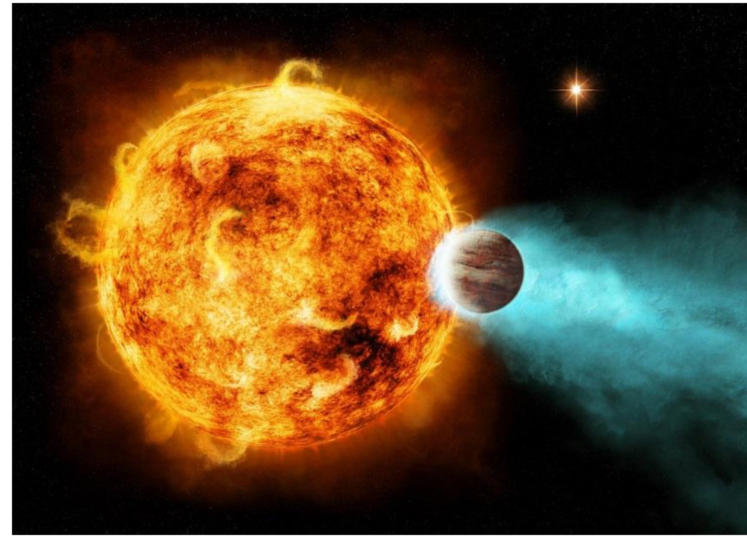
Information on the mass, the radius, the atmosphere composition, the star composition, etc ..

A planetary system around the millisecond pulsar PSR1257+12

A. Wolszczan* & D. A. Frail†

* National Astronomy and Ionosphere Center, Arecibo Observatory, Arecibo, Puerto Rico 00613, USA
† National Radio Astronomy Observatory, Socorro, New Mexico 87801, USA

NATURE · VOL 355 · 9 JANUARY 1992



A Jupiter-mass companion to a solar-type star

Michel Mayor & Didier Queloz

Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

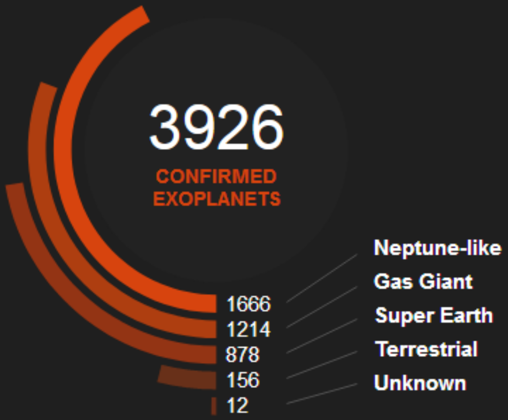
The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.

NATURE · VOL 378 · 23 NOVEMBER 1995

Exoplanet Discoveries

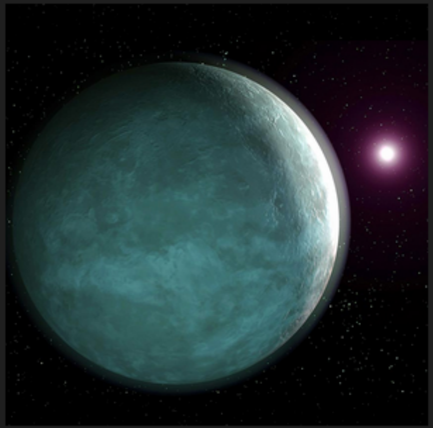
Latest Data from NASA's Exoplanet Archive

Planet Types



This chart tracks the current number of known planet discoveries beyond our solar system, sorted by type. Confirmed exoplanets have been validated by multiple observations. Kepler candidates have an 80-90% probability to be actual discoveries but have yet to be verified.

New Discovery



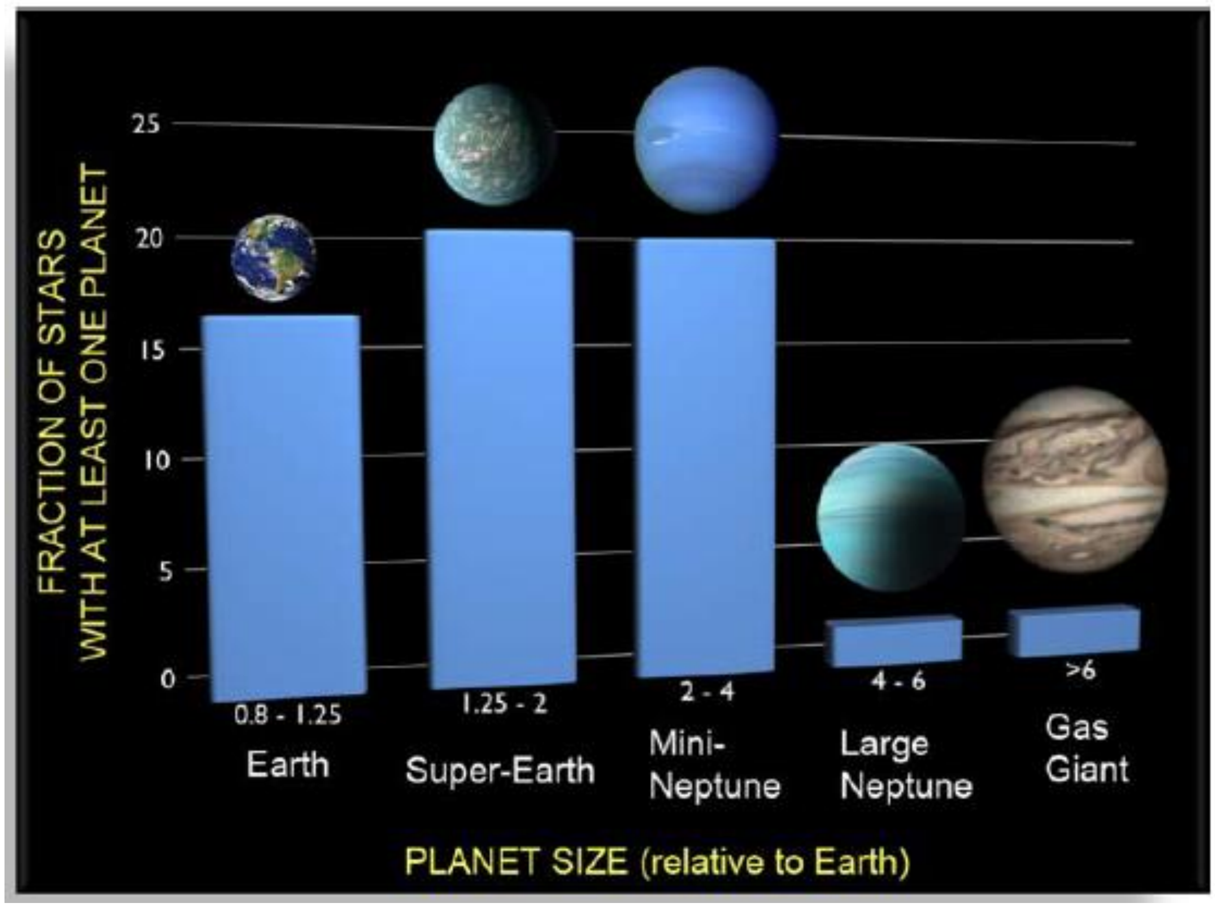
PLANET NAME	PLANET TYPE
Gl 686 b	Neptune-like
DISCOVERY DATE	DETECTION METHOD
2018	Radial Velocity

› More about this planet

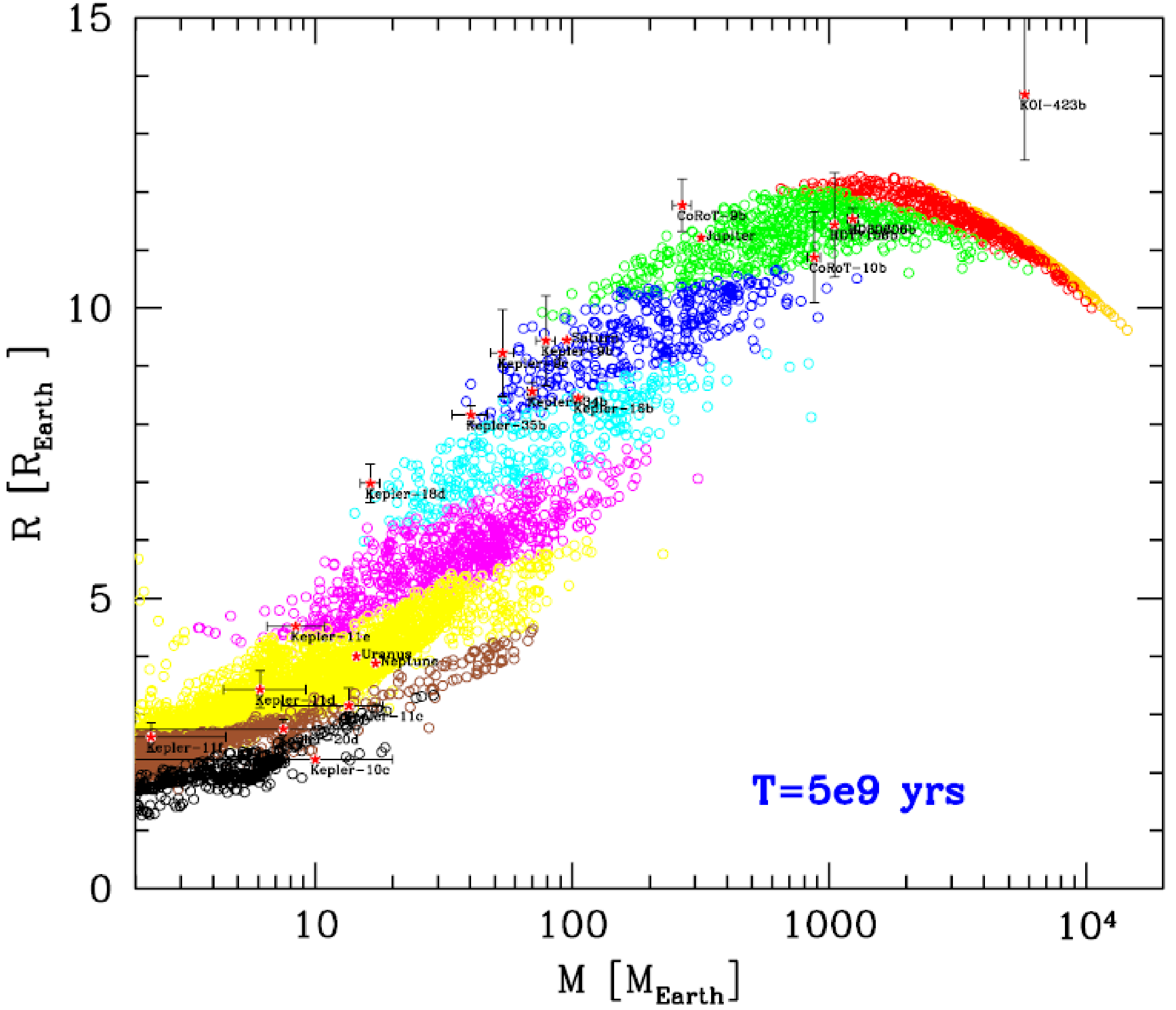
An abundance of small exoplanets around stars with a wide range of metallicities

Lars A. Buchhave[1,2], David W. Latham[3], Anders Johansen[4], Martin Bizzarro[2], Guillermo Torres[3], Jason F. Rowe[5], Natalie M. Batalha[6], William J. Borucki[7], Erik Brugamyer[8], Caroline Caldwell[8], Stephen T. Bryson[7], David R. Ciardi[9], William D. Cochran[8], Michael Endl[8], Gilbert A. Esquerdo[3], Eric B. Ford[10], John C. Geary[3], Ronald L. Gilliland[11], Terese Hansen[1], Howard Isaacson[12], John B. Laird[13], Philip W. Lucas[14], Geoffrey W. Marcy[12], Jon A. Morse[15], Paul Robertson[8], Avi Shporer[16,17], Robert P. Stefanik[3], Martin Still[18] & Samuel N. Quinn[3]

21 JUNE 2012 | VOL 486 | NATURE | 375



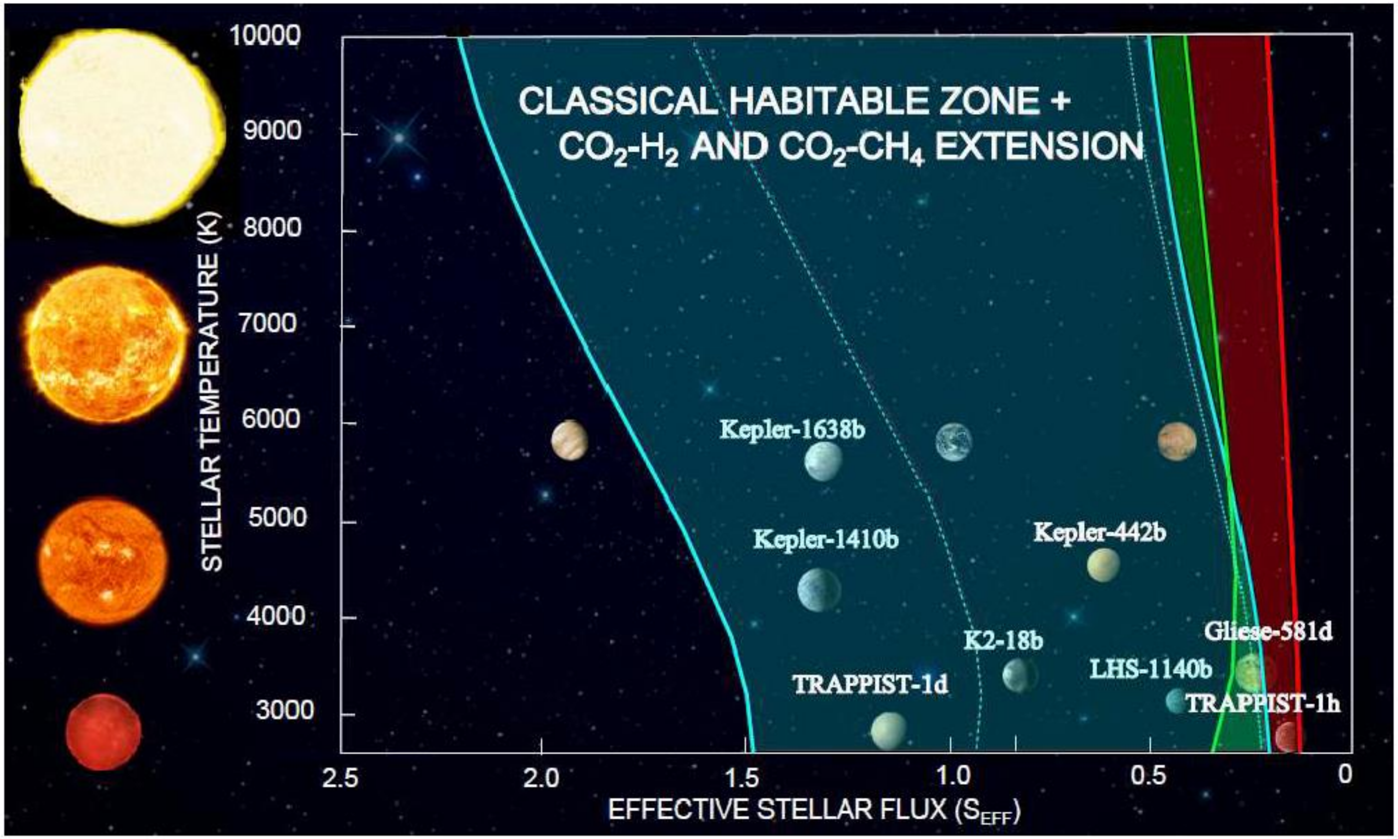
Fressin et al, 2013



Nature of exoplanets defined from the mass radius plots

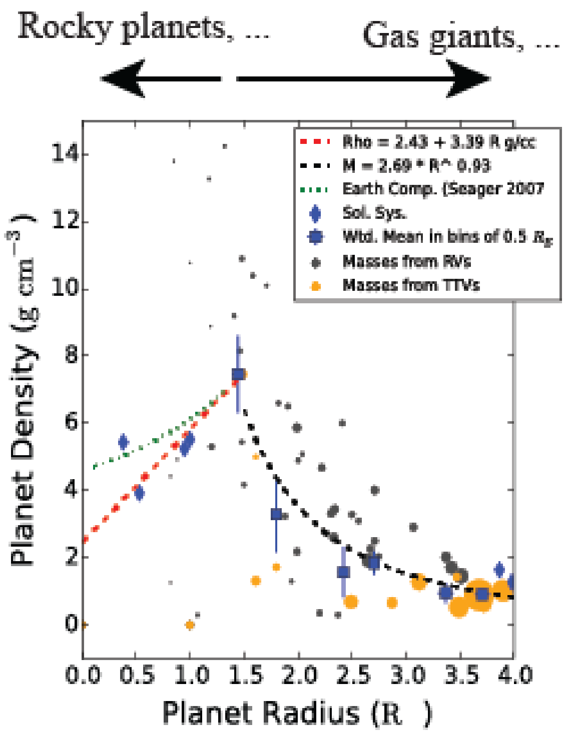
Mordasani et al, A & A, 2012

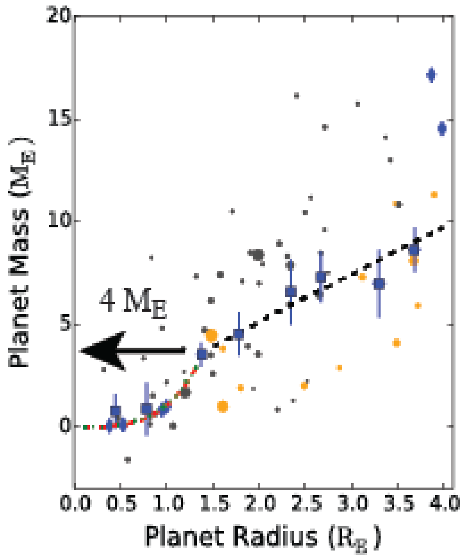
Definition of an habitable zone : water is required for life



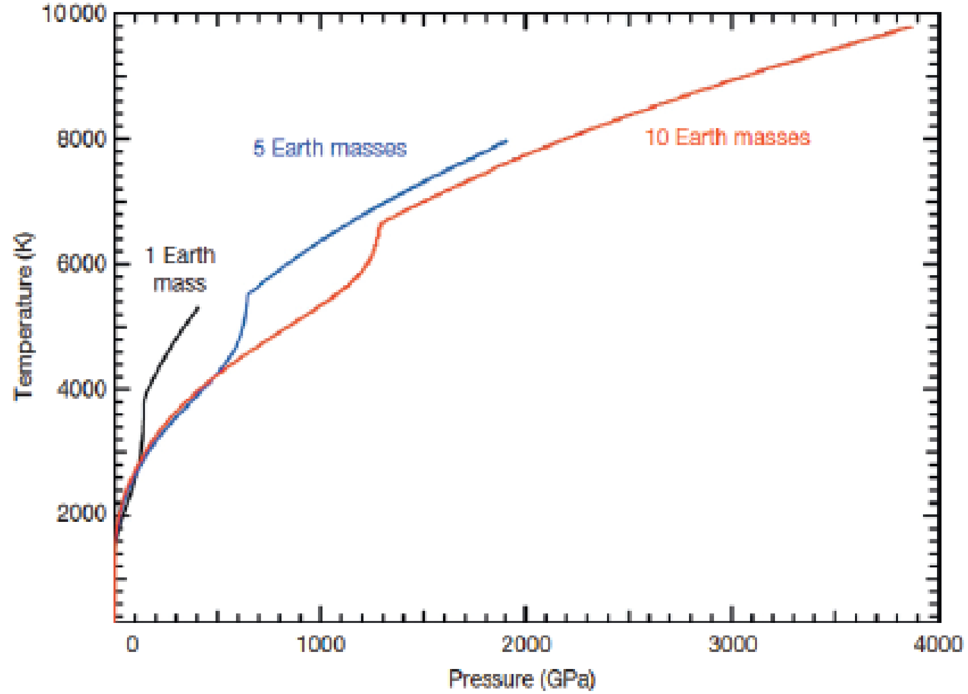
Ramirez, Geosciences, 2018

Pertinent P-T conditions to study the interior of rocky exoplanets





Weiss and Marcy, The Astr. Joun. Lett., 2014

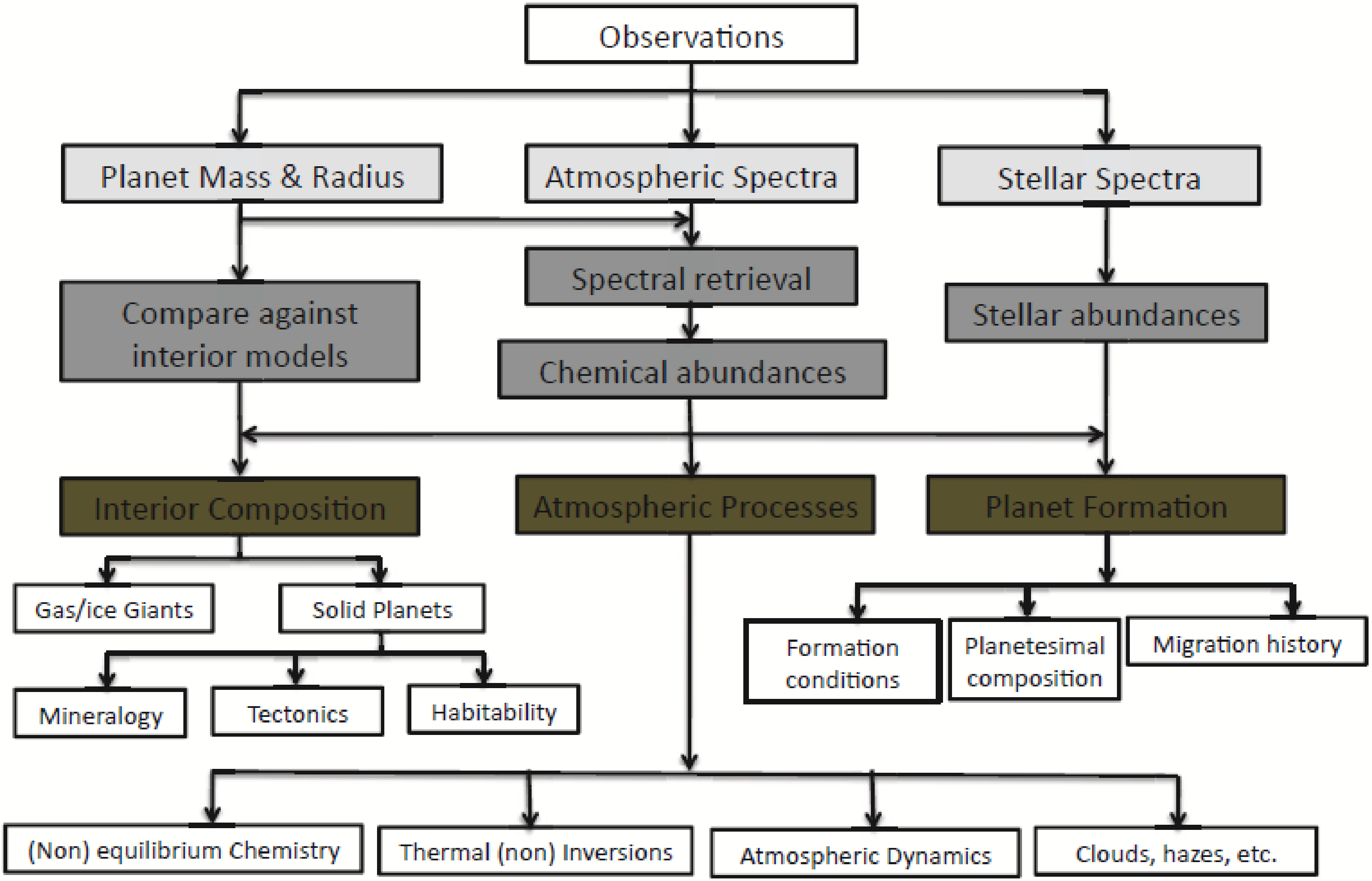


Duffy et al, 2015

CMB max : ~600 GPa

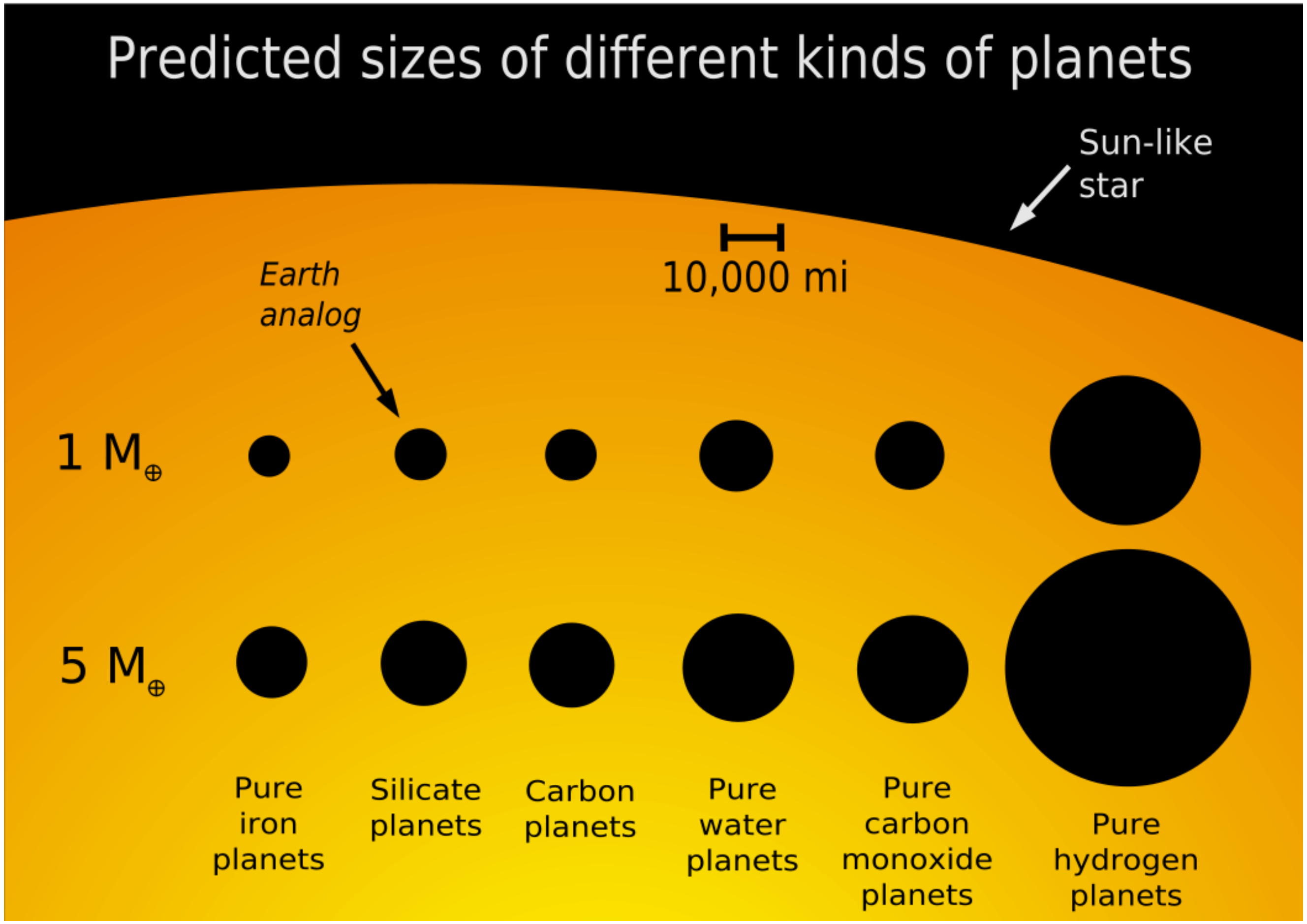
ICB max : ~1500 GPa

Relating Mineral Physics and observables



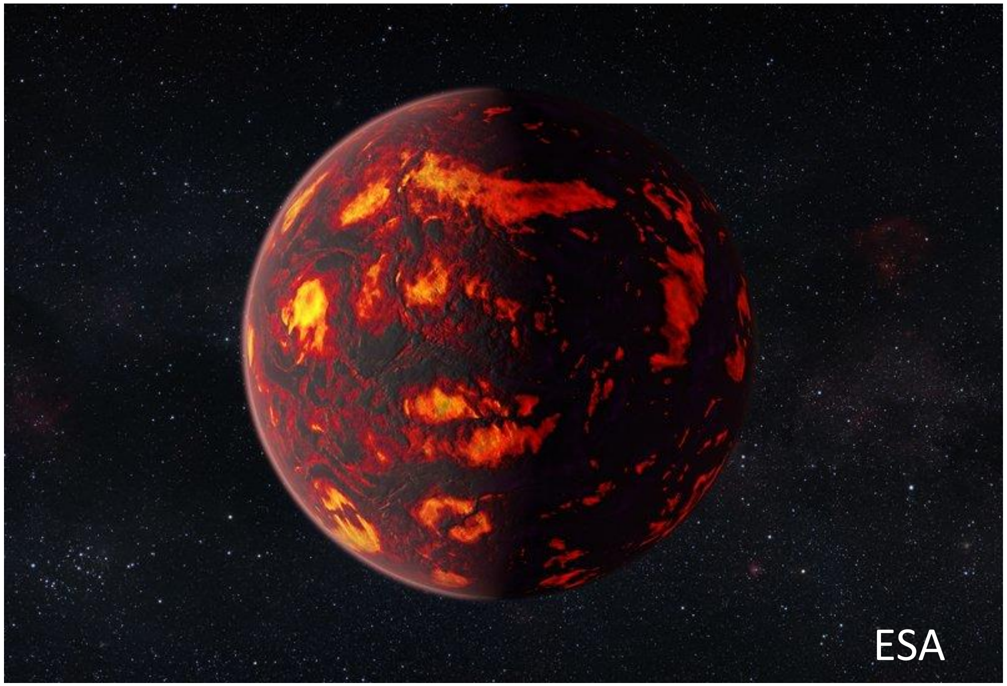
Madhusadhan et al, 2014

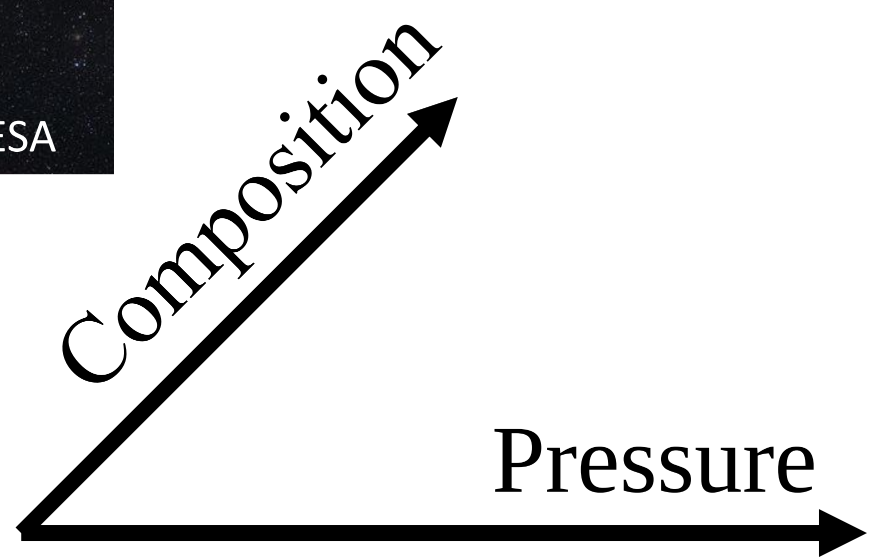
Large diversity of potential exoplanets



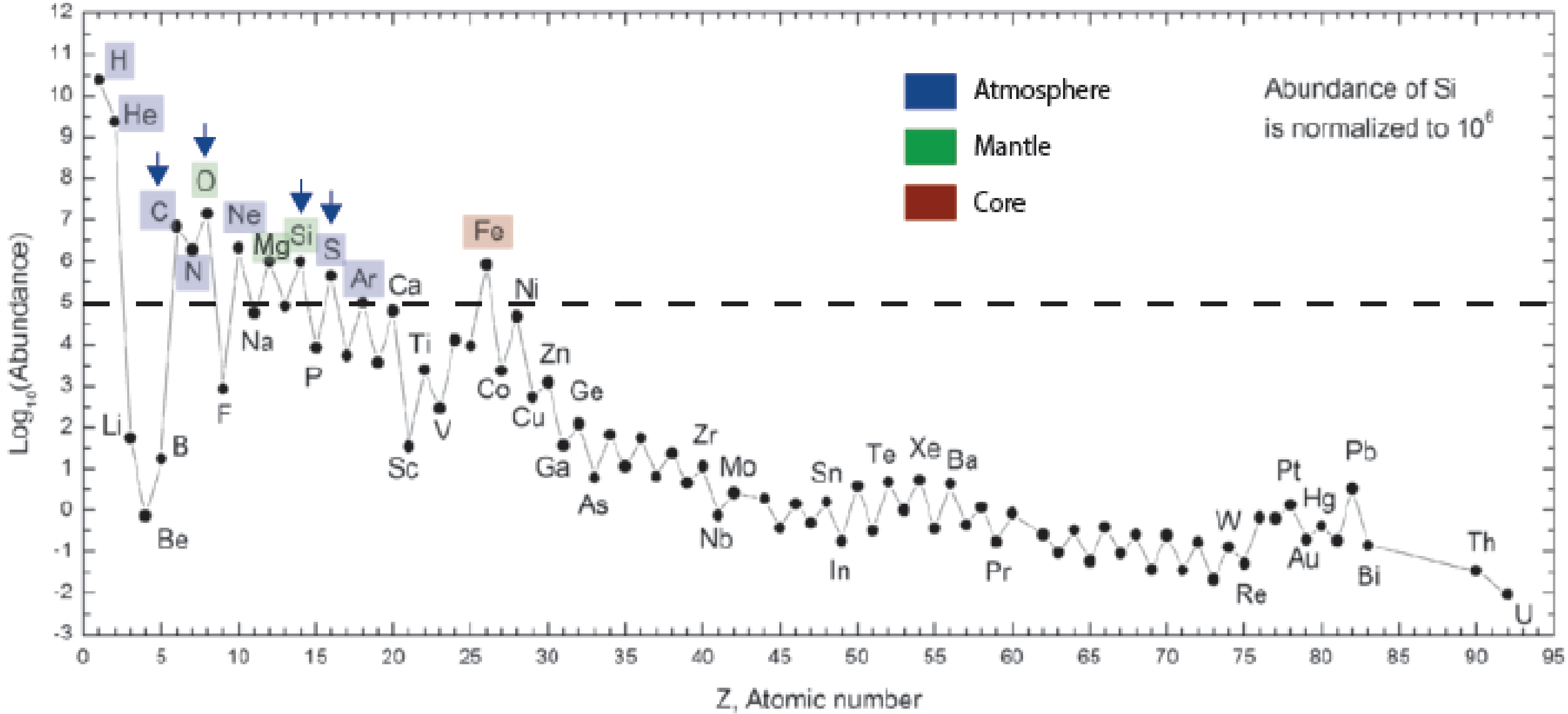
We need to refine the Mass/Radius ratio with Mineral Physics tools

Exoplanets' interiors





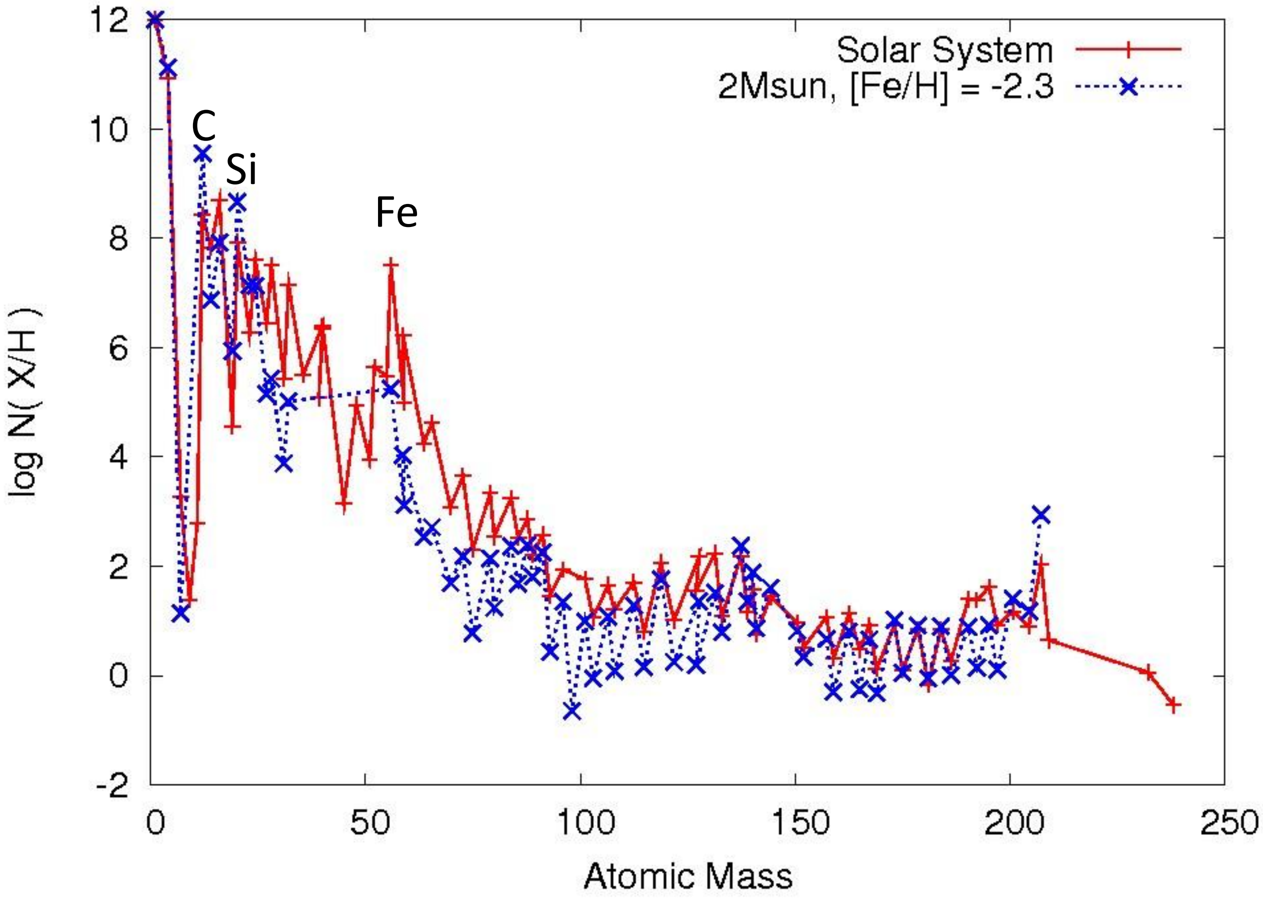
Nucleosynthesis sequence



Composition of the solar system

└──→ Composition of planet's envellopes

Different star : different nucleosynthesis sequence

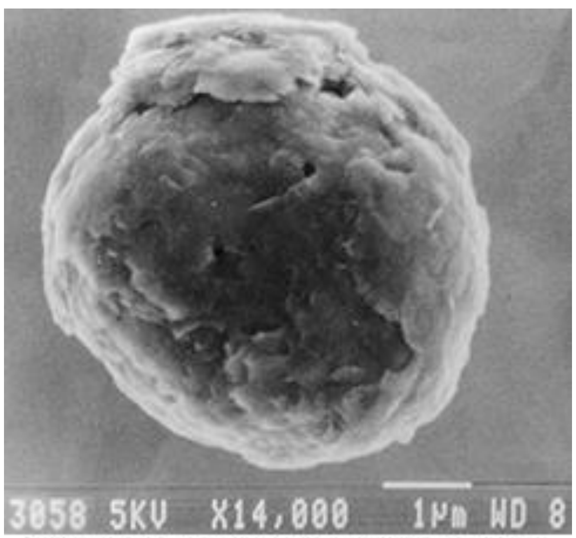


Karakas et al, CoALa program, 2010

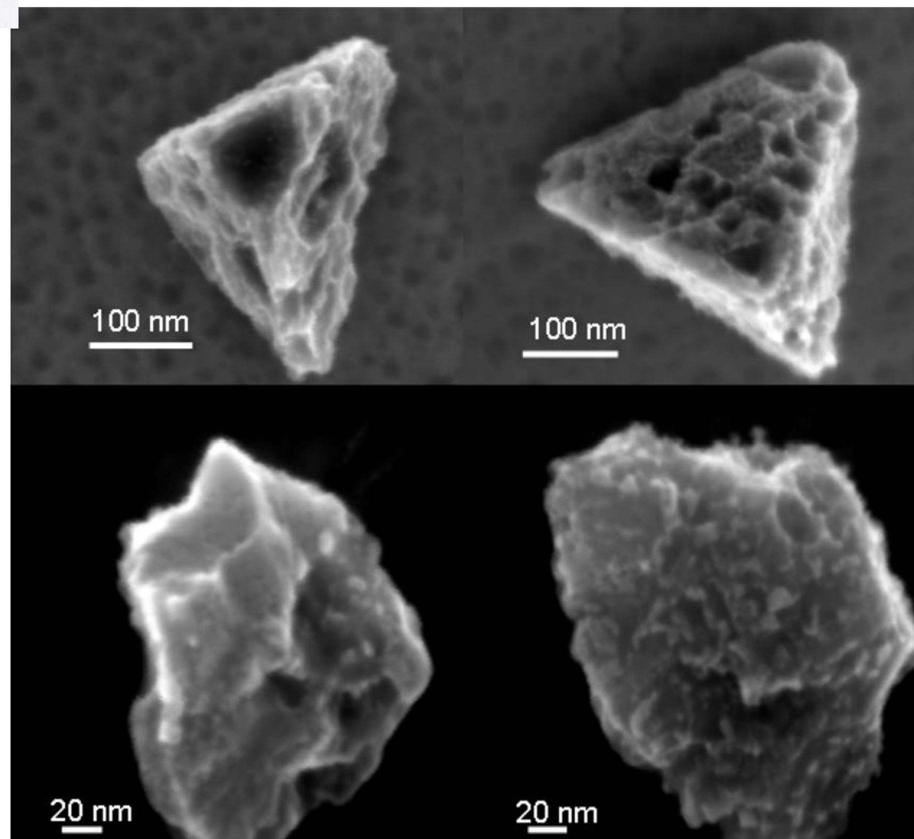
Presolar grains in the Murchinson meteorite

Silicon carbide

Graphite

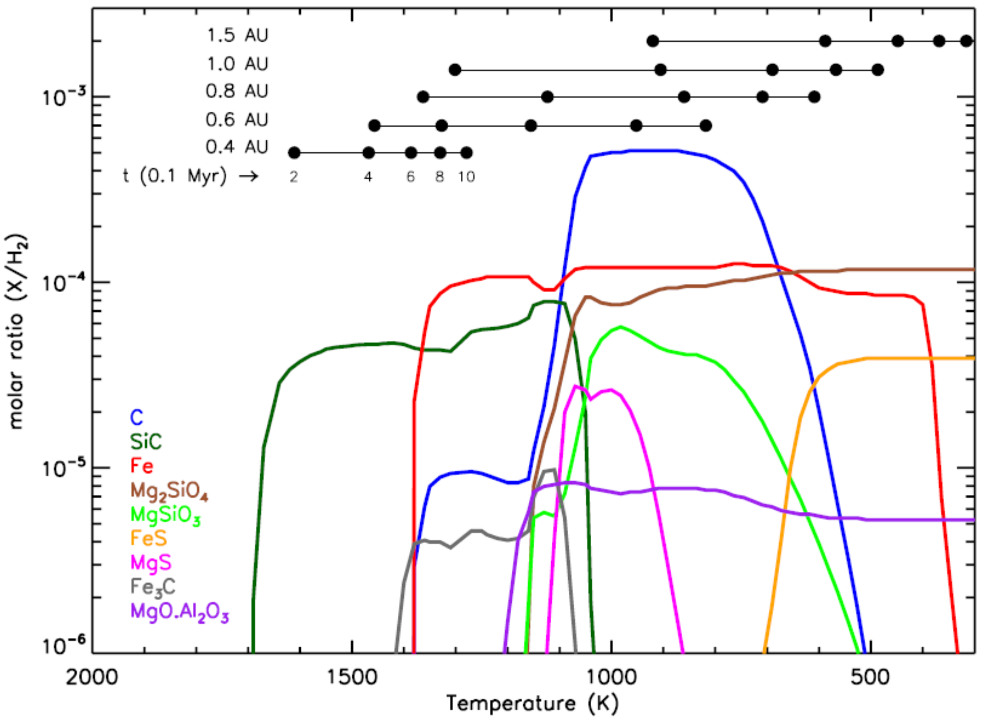


(Scale bar is 1µm.) Photo courtesy of S. Amari.

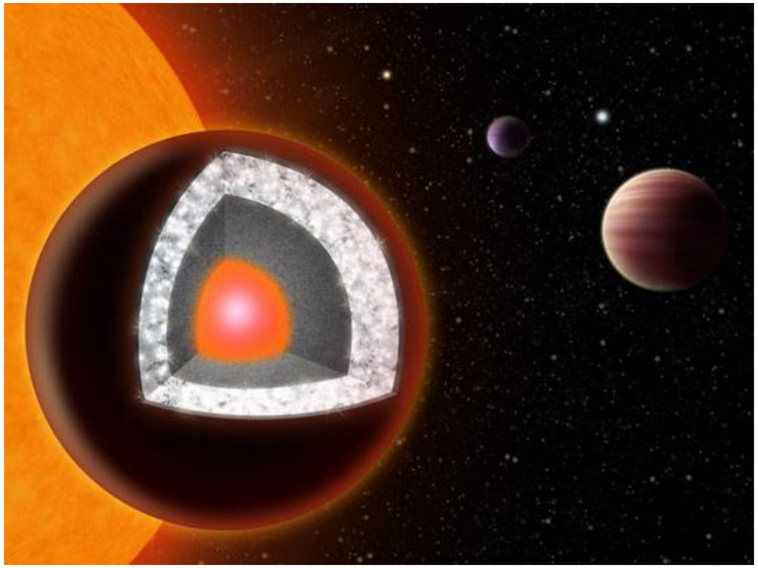


Hoppe et al, The Astroph. Journal, 2010

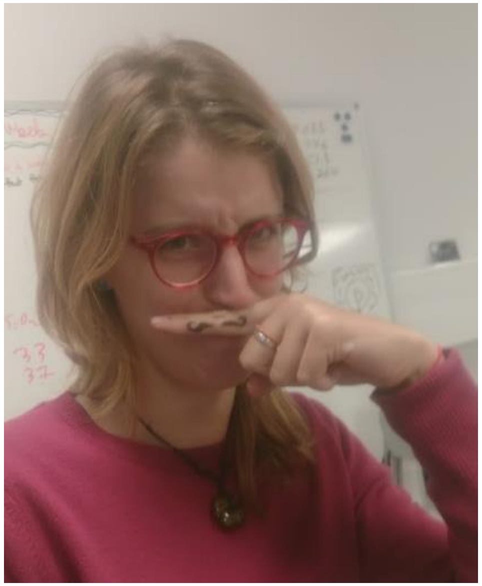
Possibility of high C/O ratio with different condensation sequences



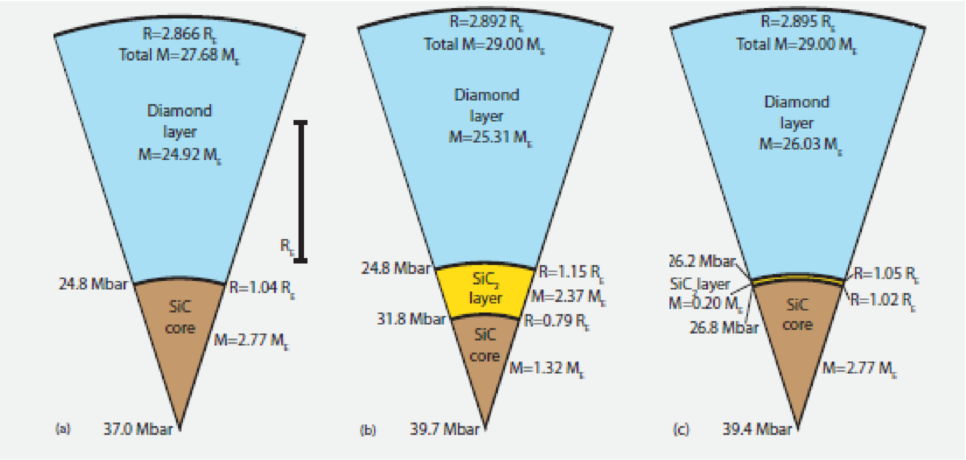
Madhusudhan et al., 2012



Carbon-rich exoplanets

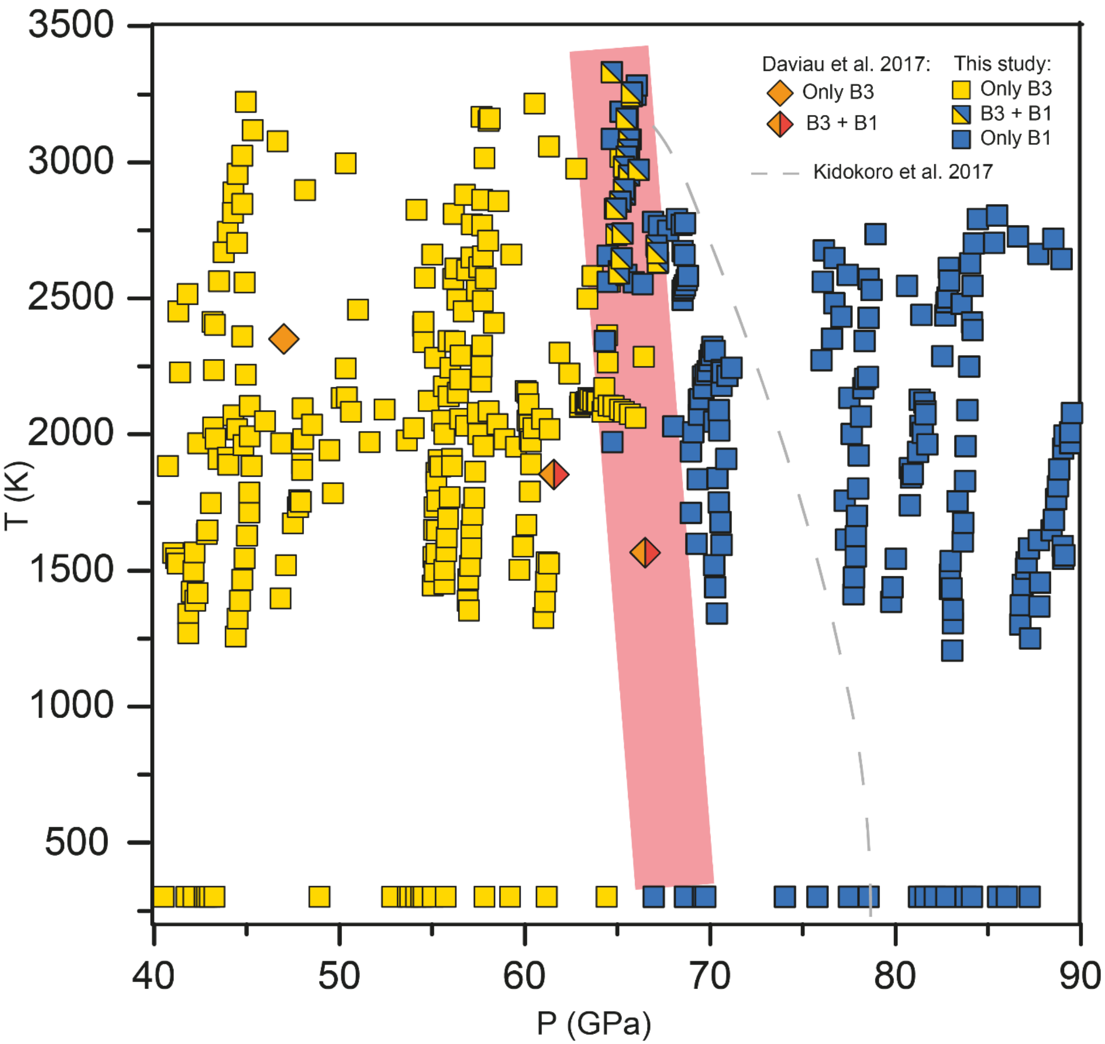


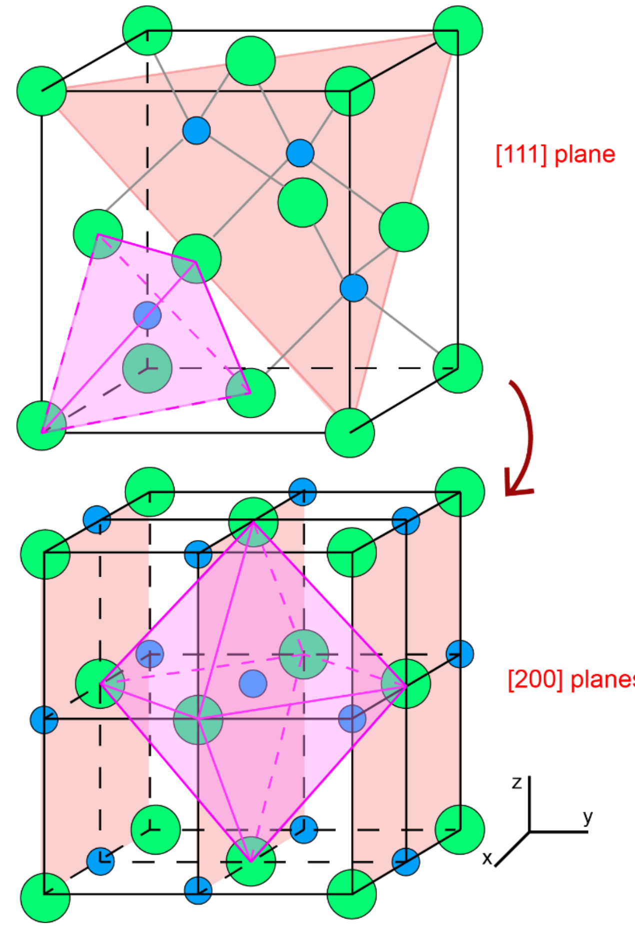
Francesca Miozzi
PhD in ERC PlanetDive program



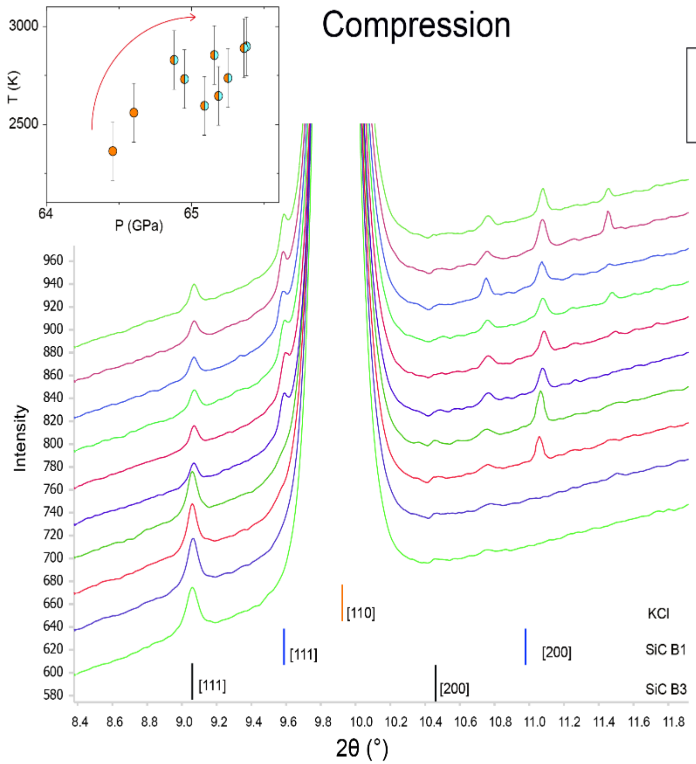
Wilson et al, The Astro. Journal, 2014

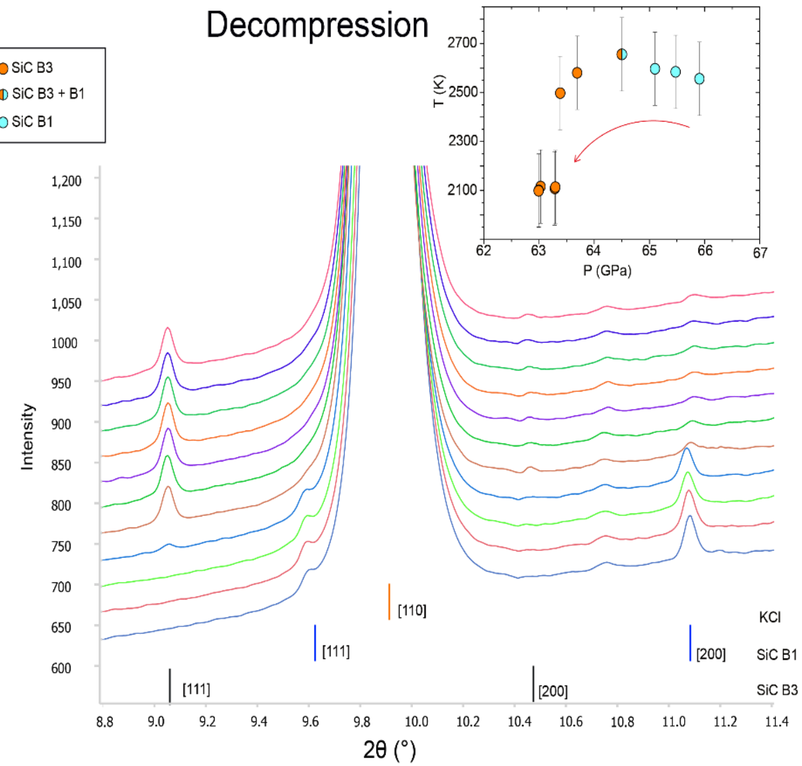
Phase diagram of SiC

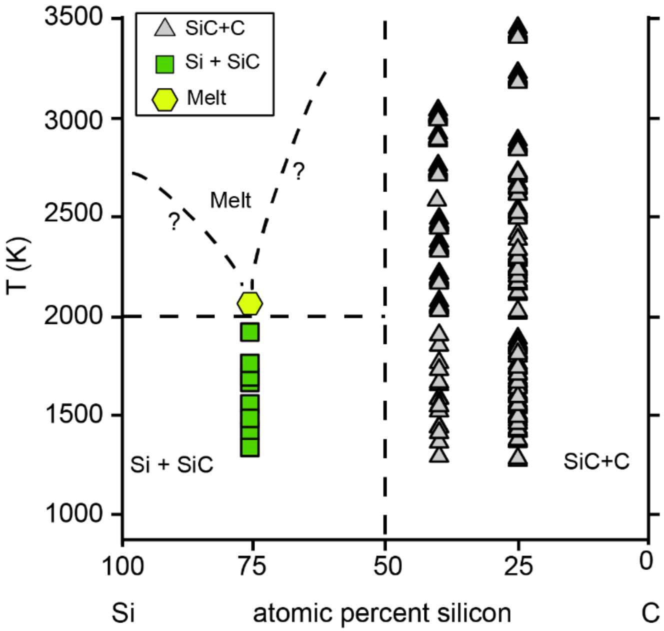




Miozzi et al, JGR Planets, 2018

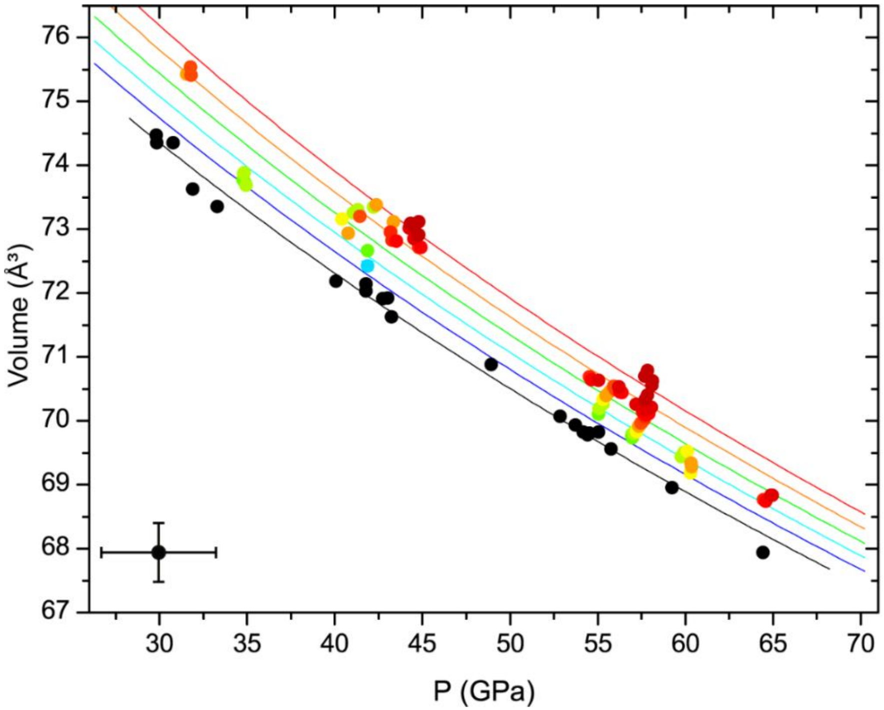


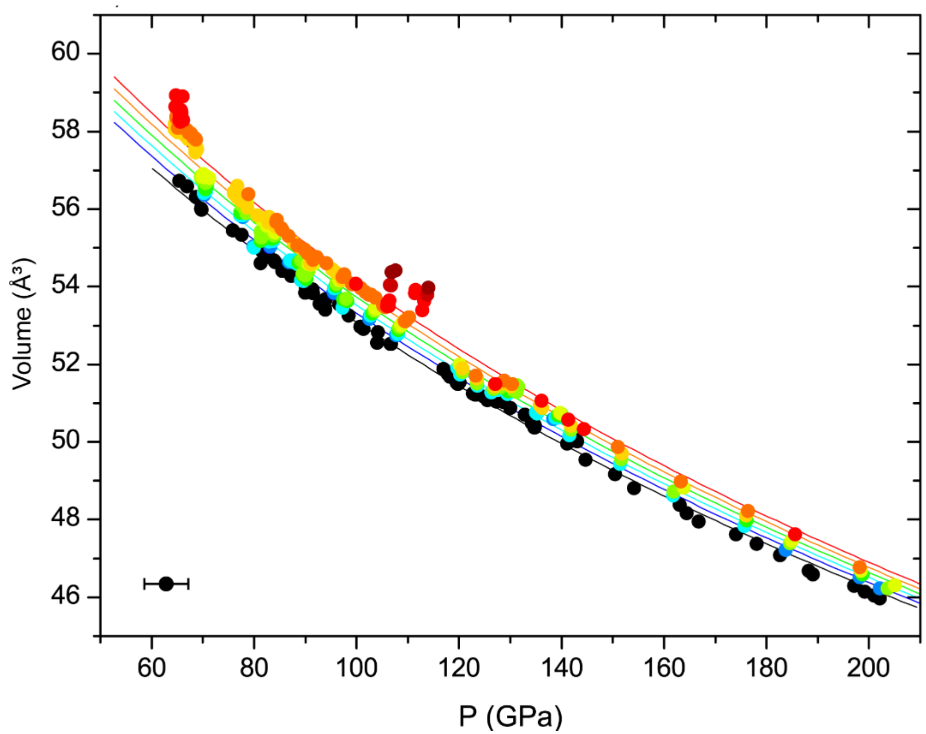




Phase diagram of Si-C binary system

Thermal equation of state of of SiC

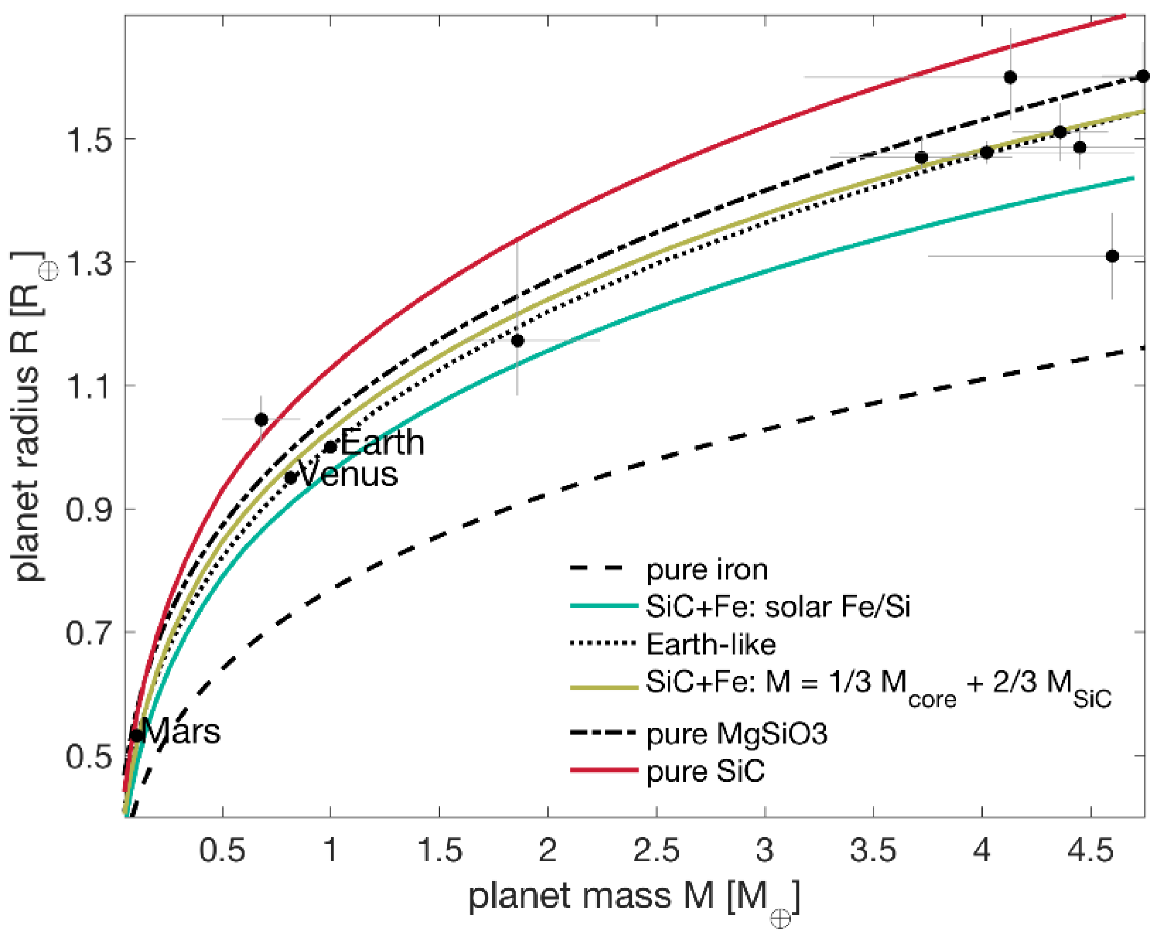




Possibility to reconstruct an hypothetic SiC based exoplanet

Miozzi et al, JGR Planets, 2018

Mass-radius relation for SiC-based planets



Earth-like and C-rich planets present similar M/R ratio

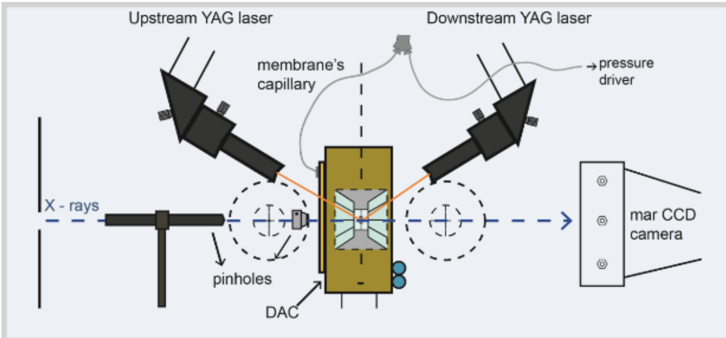
↓

M/R plots are not sufficient to discuss the potential diversity of internal exoplanets properties

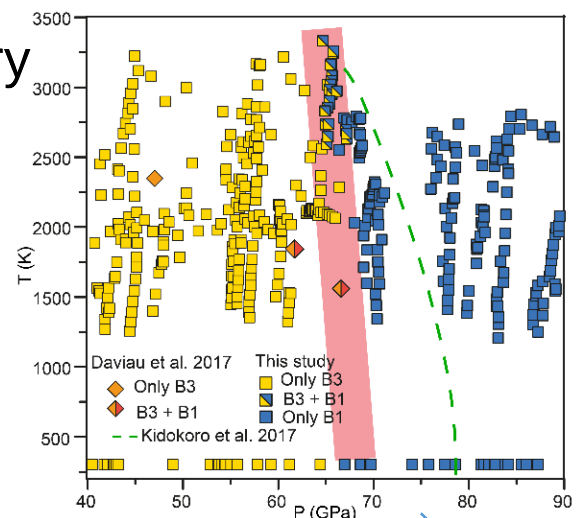
Miozzi et al, JGR Planets, 2018

Mineral physics approach

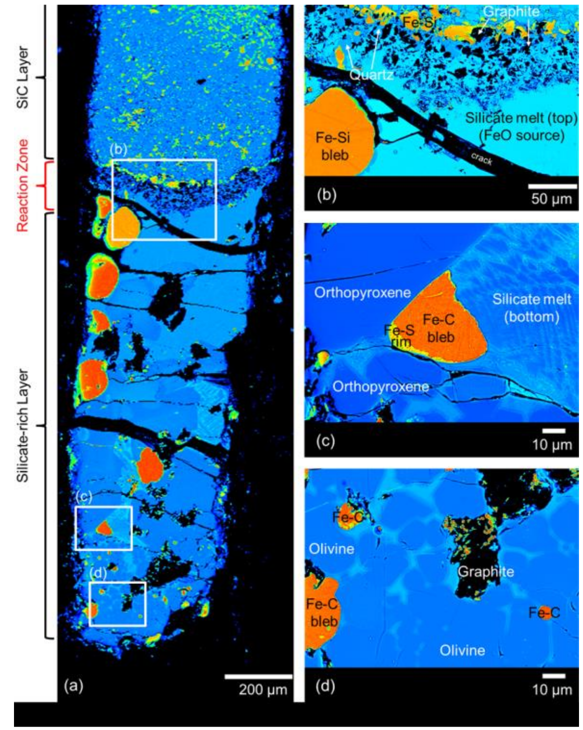
Experimental petrology approach



Binary/ternary systems. Study of the physical properties in wide P-T range.



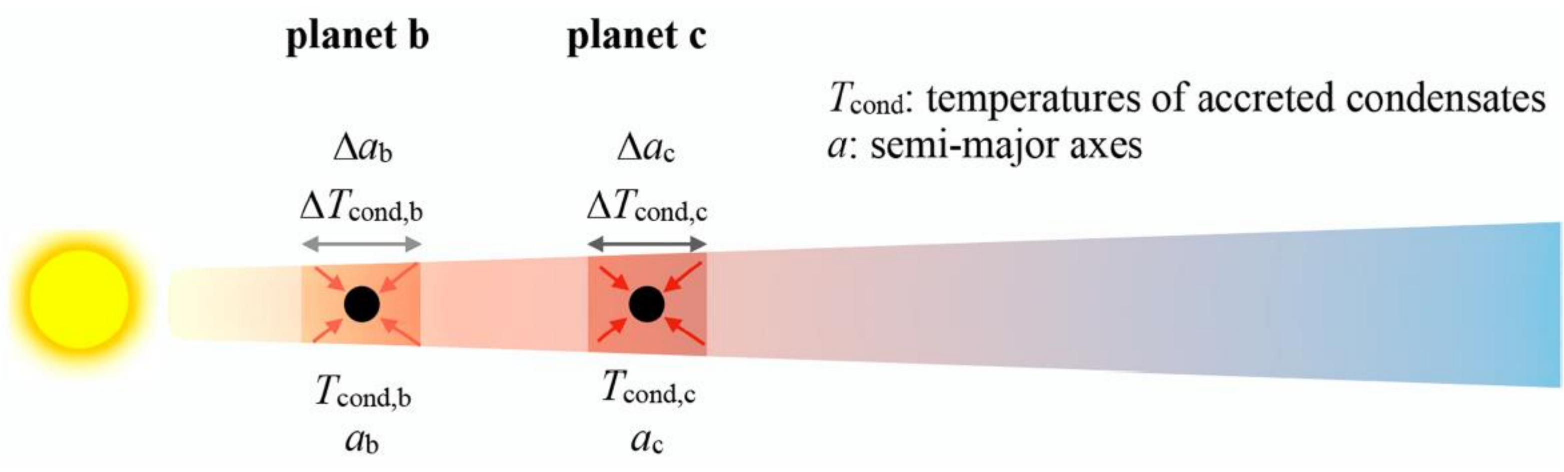
Miozzi et al. (2018)

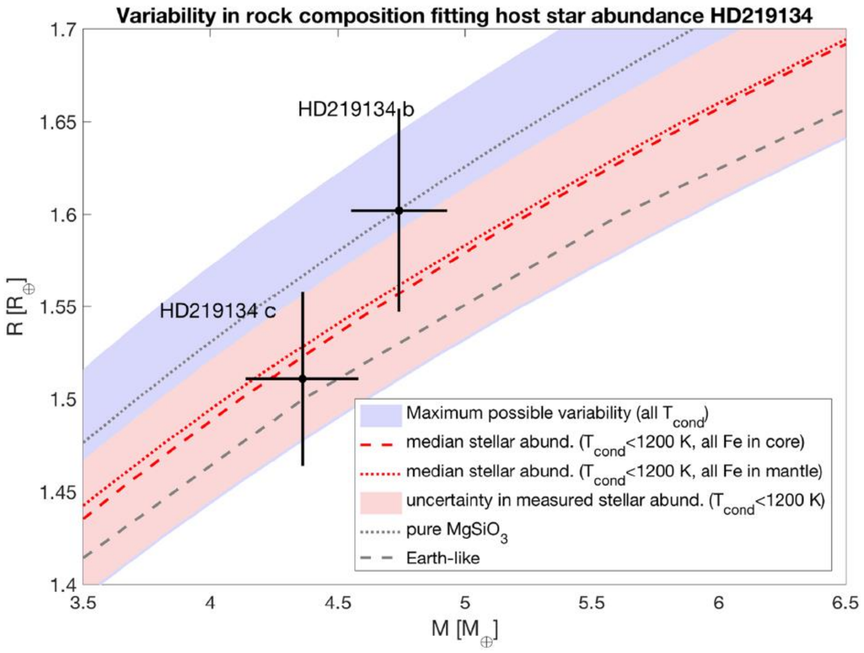


Hakim et al. (2018)

Complex multi-phases systems. Multiple mineral phases at specific P-T conditions.

INTEGRATIVE MODELS FOR EXOPLANETS INTERIORS

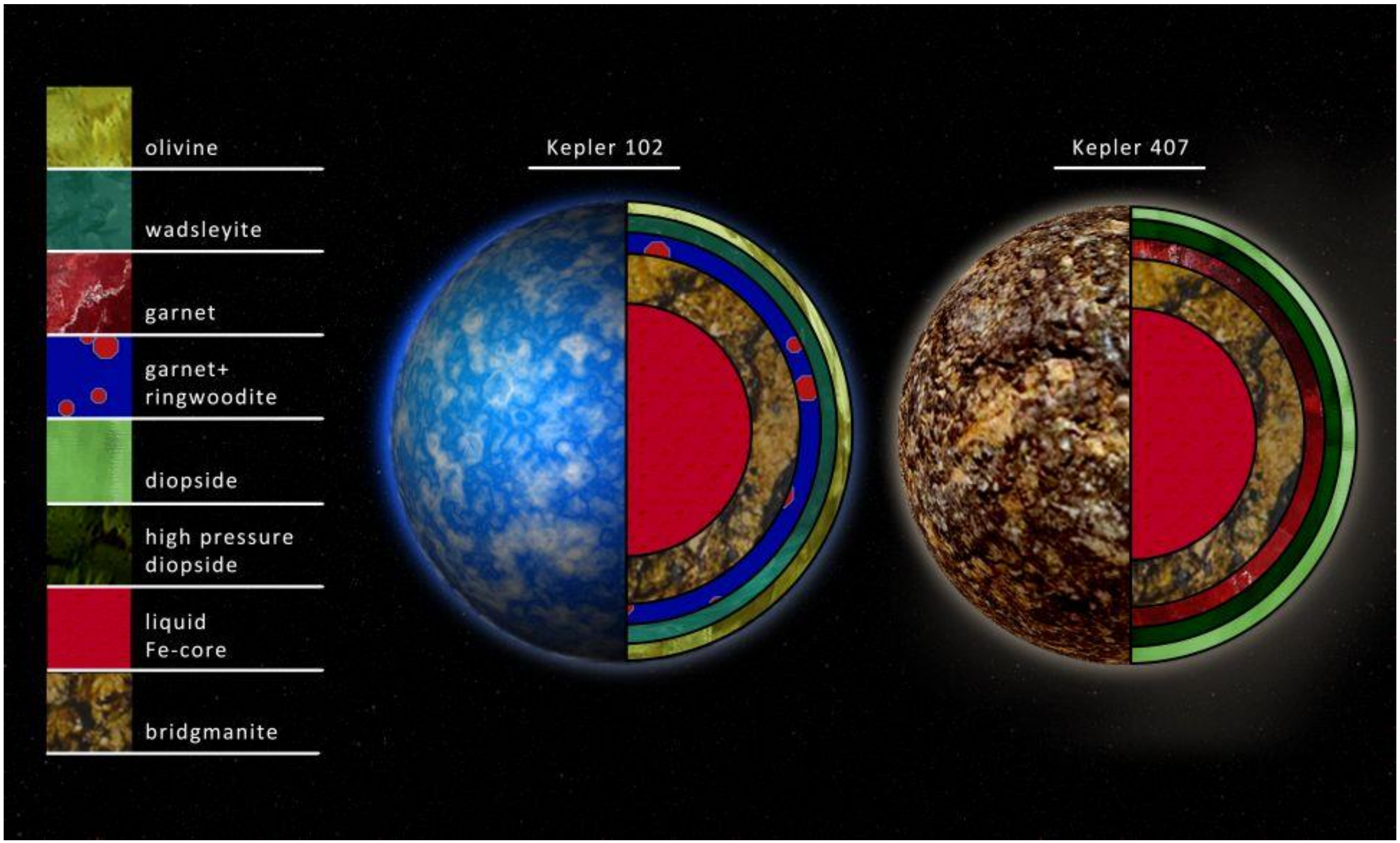




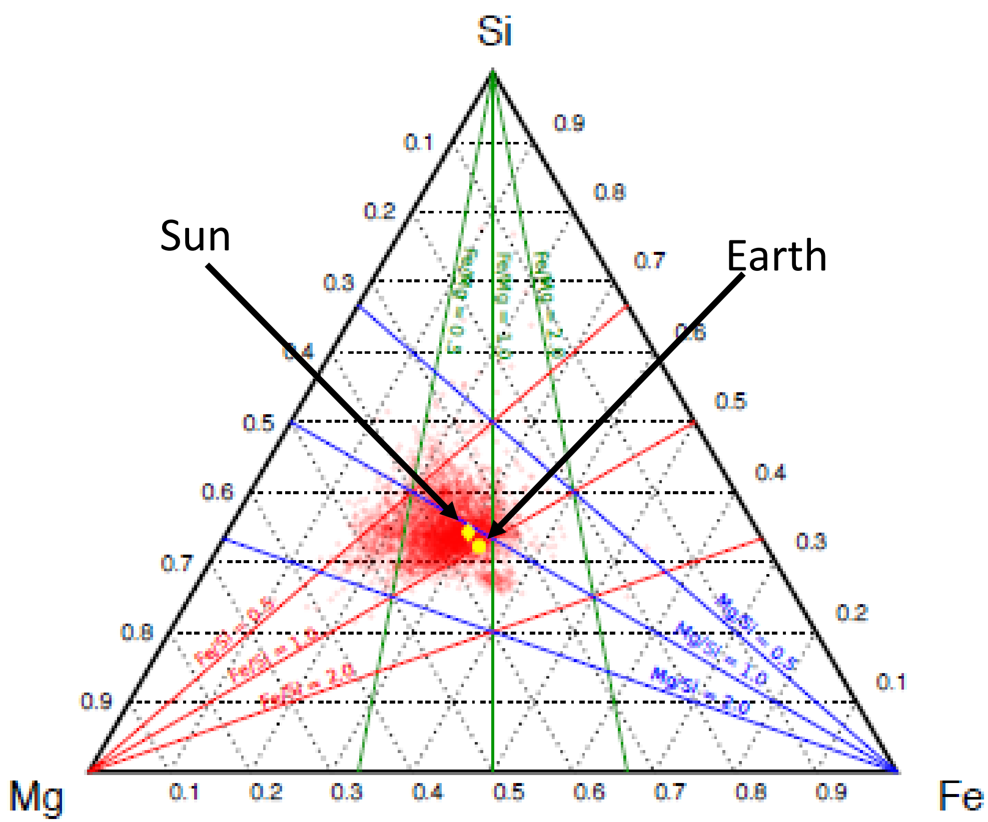
High Ca and Al planets formed close to their stars
Planets without core

Dorn et al, 2019

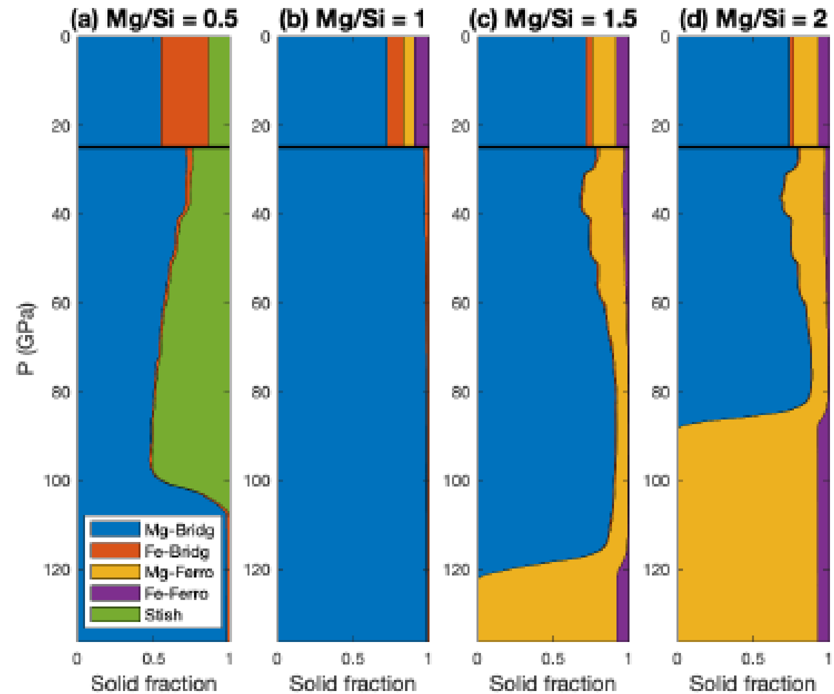
Garnet planets ????



Earth's twins and cousins



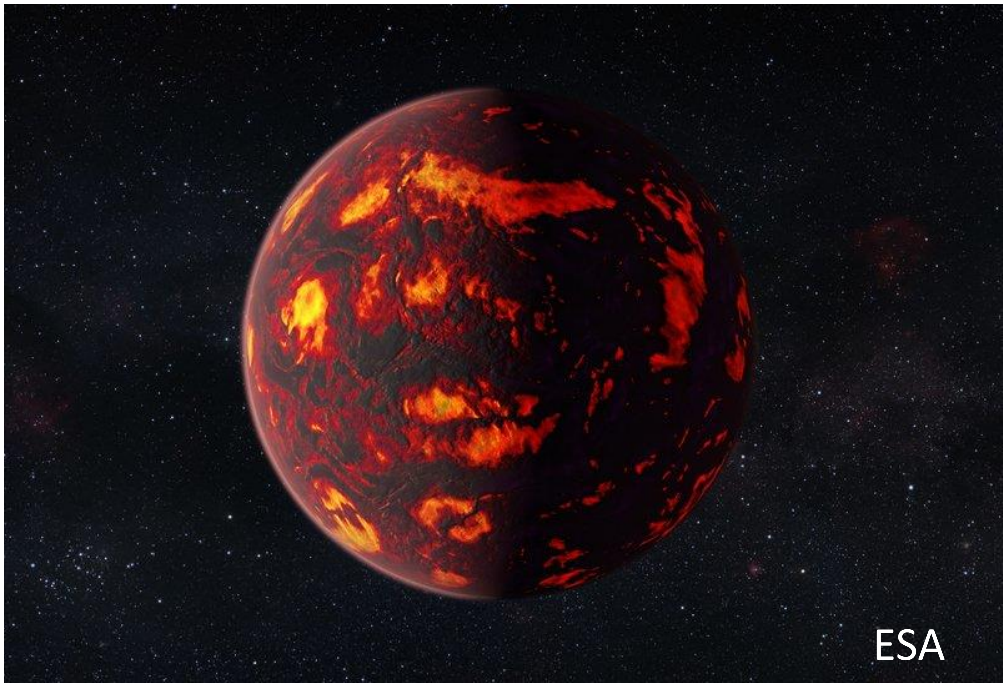
Composition from the Hypatia Catalog

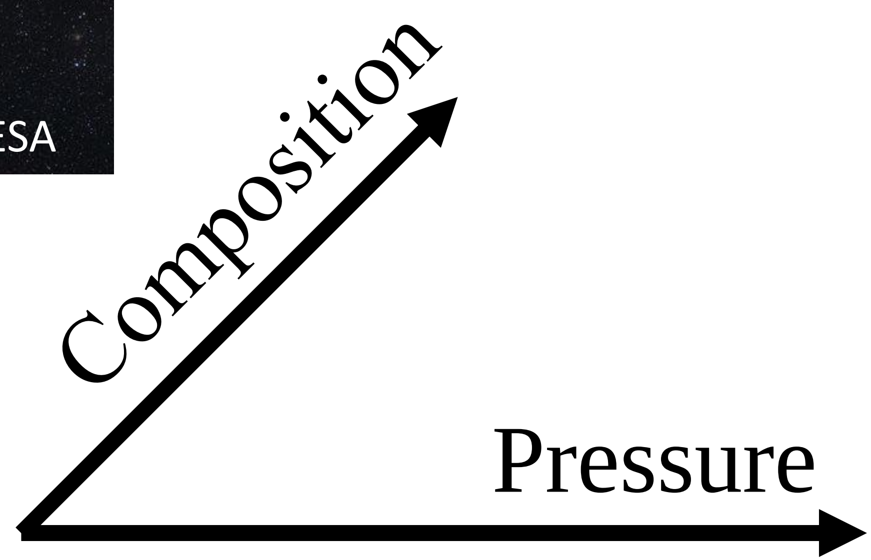


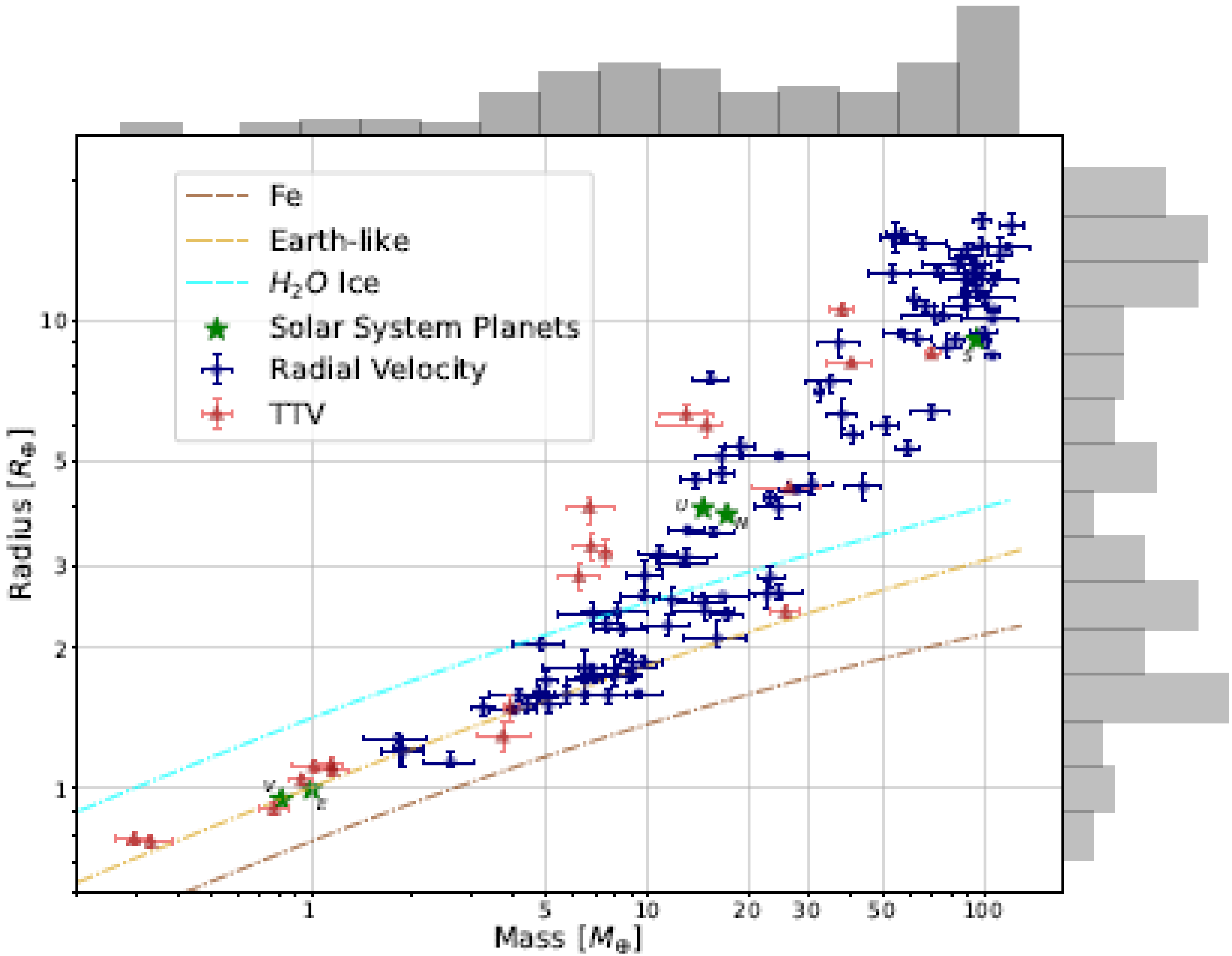
Resulting internal structure

After Spaargaren et al, Ast. & Ast., 2020

Exoplanets' interiors

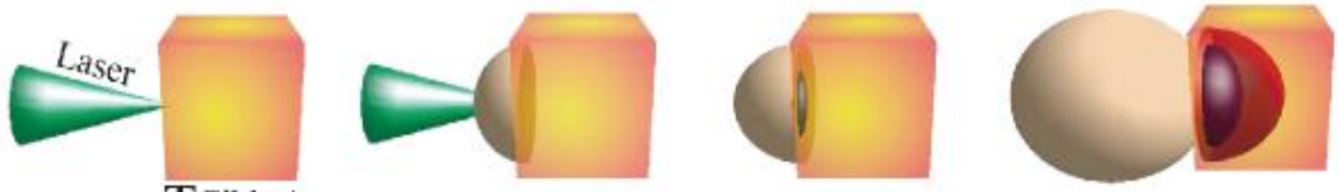




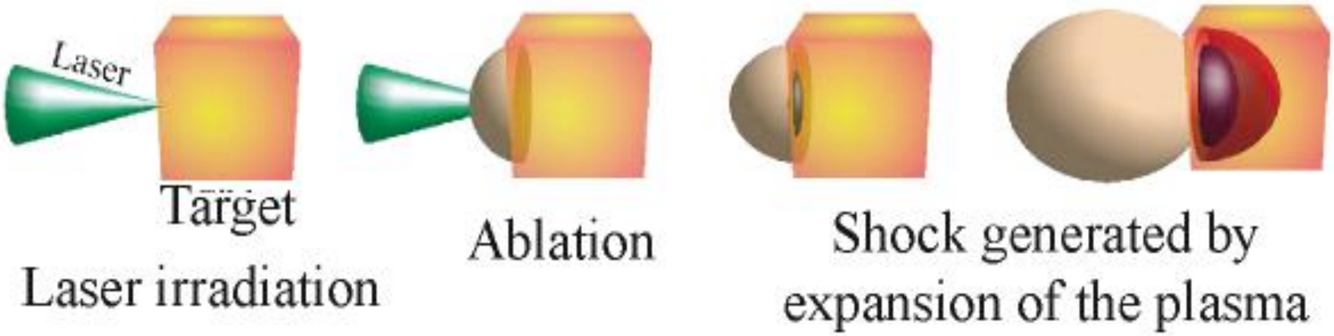


Otegi et al, 2019

Laser shock experiments



Laser shock experiments



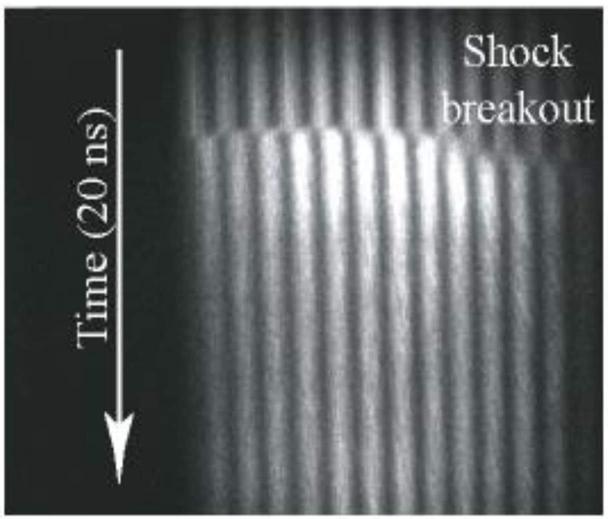


Image of interferometry of the rear face (VISAR)

Related to the pressure

Laser shock experiments

Laser irradiation

Ablation

Shock generated by expansion of the plasma

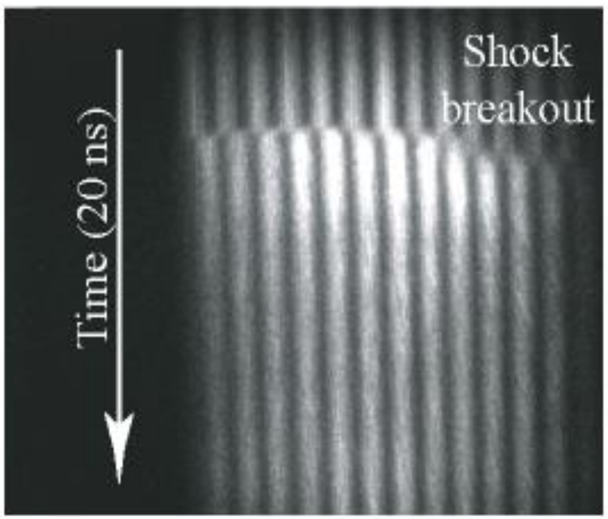
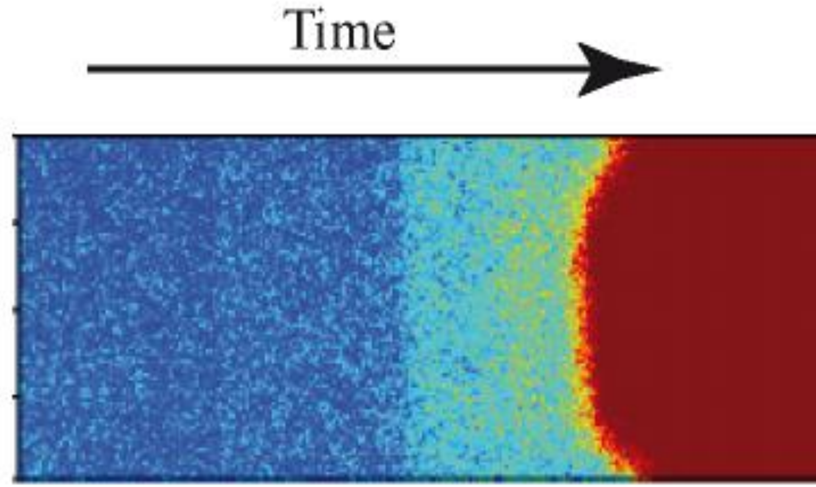


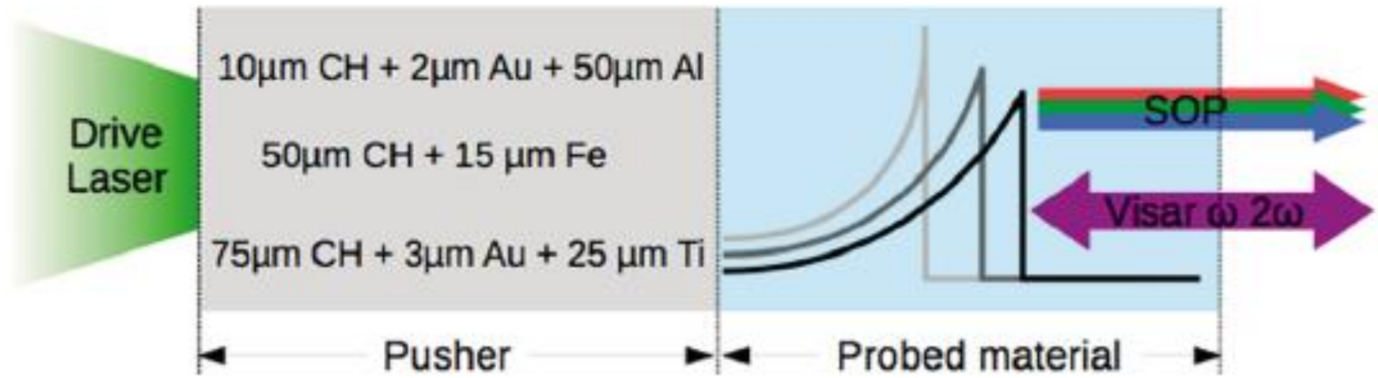
Image of interferometry of the rear face (VISAR)

Related to the pressure

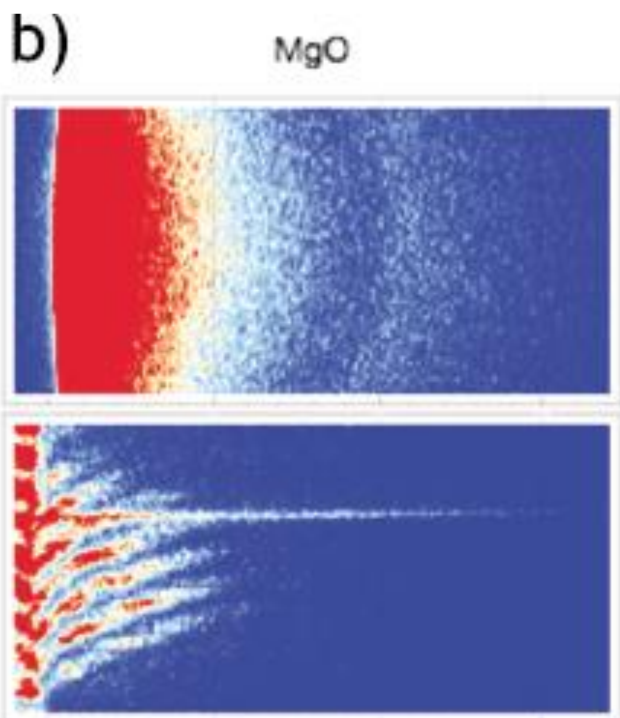


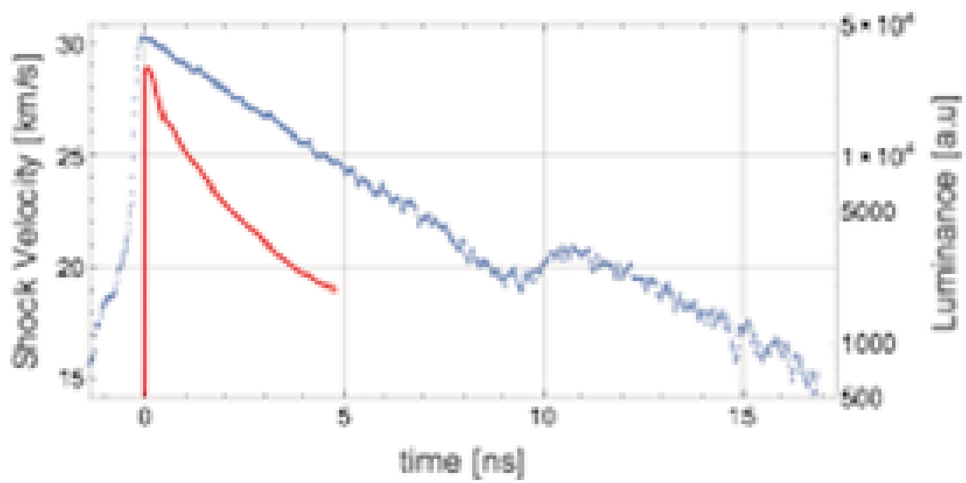
Streaked Optical Pyrometer

Related to the temperature



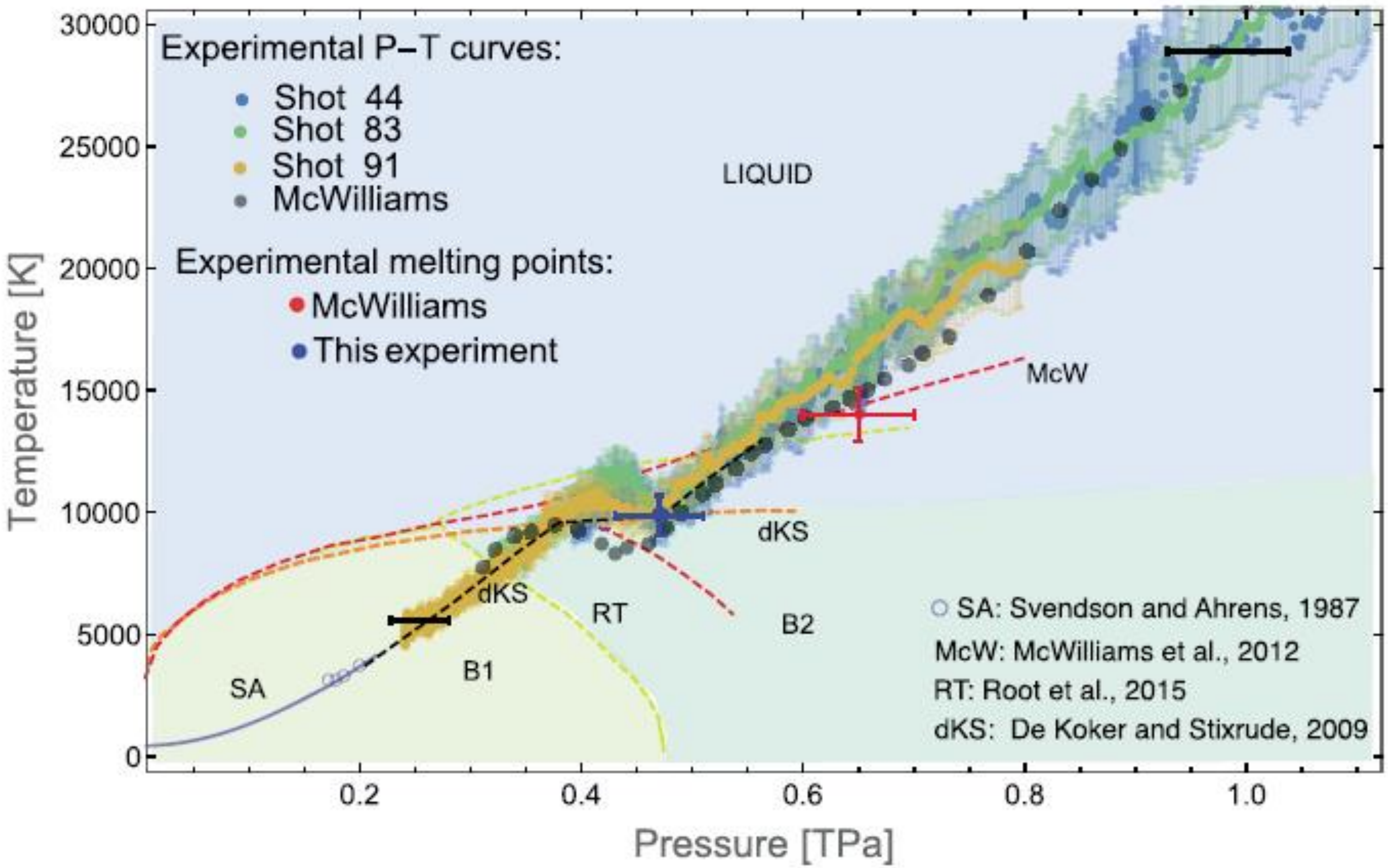
Decaying shock experiments on MgO





Bolis et al, GRL, 2016

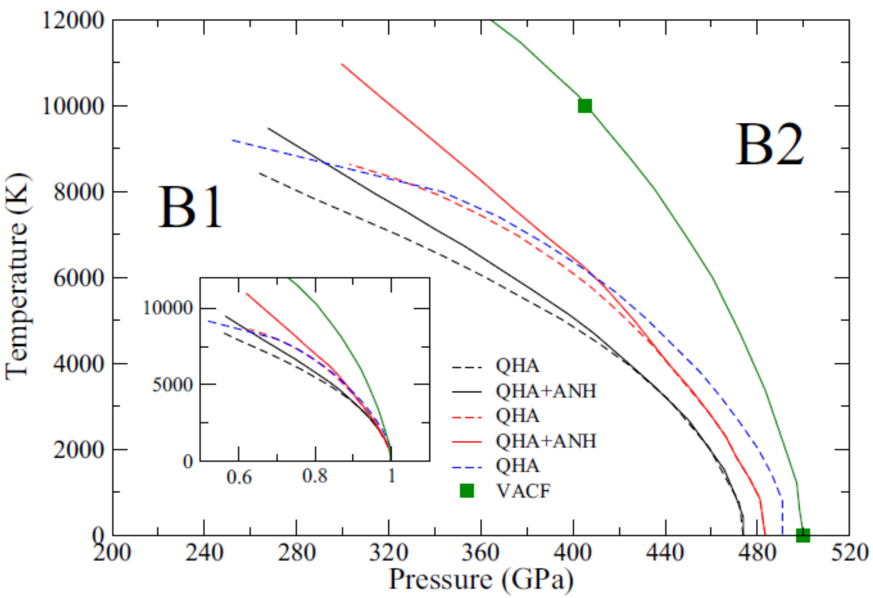
Reconstruire le diagramme de phase du MgO

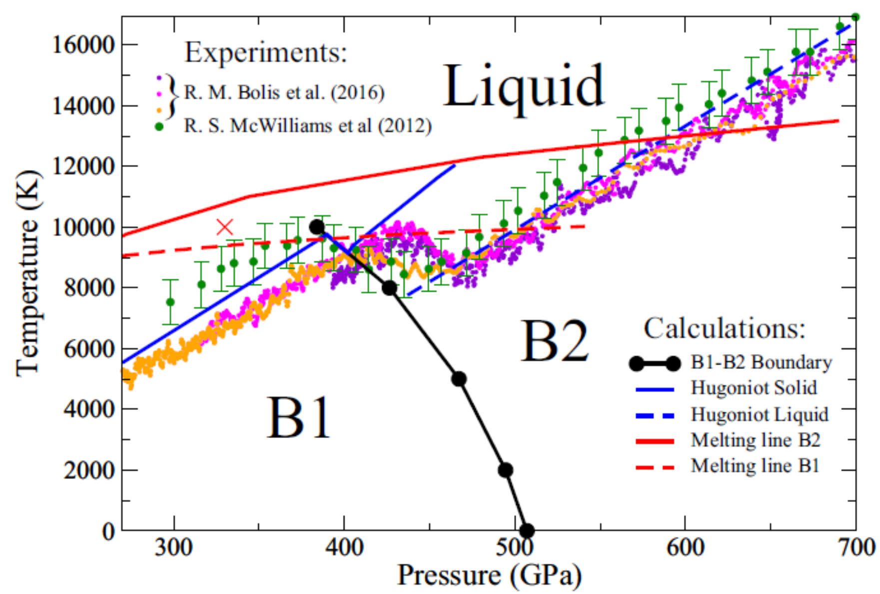


Bolis et al, GRL, 2016

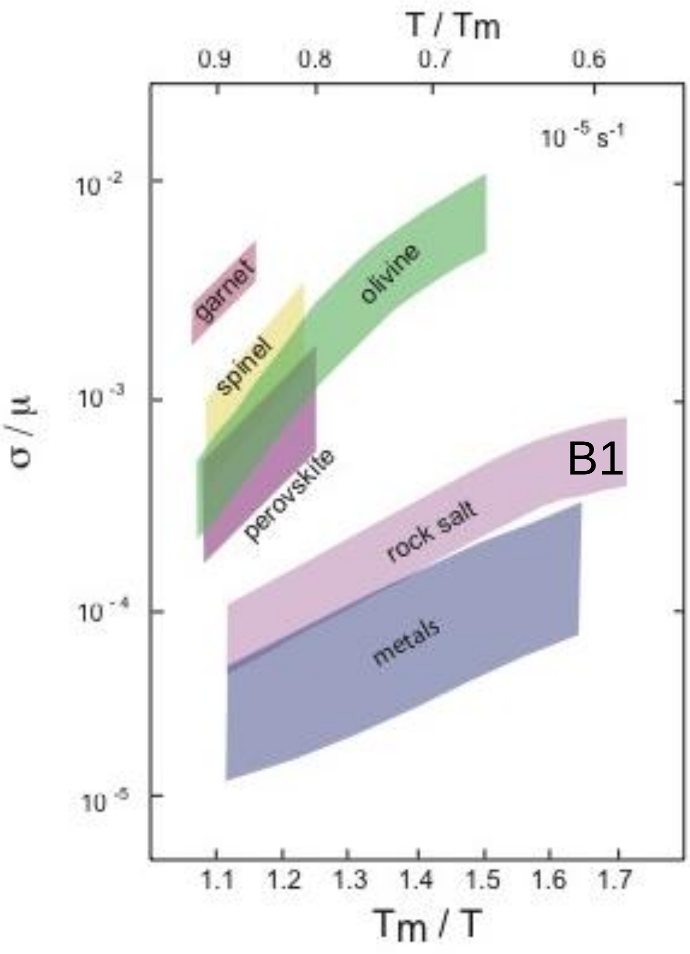
Ab initio calculations of the B1-B2 phase transition in MgO

J. Bouchet,[1] F. Bottin,[1] V. Recoules,[1] F. Remus,[1] G. Morard,[2] R. M. Bolis,[3,4] and A. Benuzzi-Mounaix[3,4]
[1]*CEA, DAM, DIF, F-91297 Arpajon, France*
[2]*Sorbonne Université, Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, IMPMC, Museum National d'Histoire Naturelle, UMR CNRS 7590, Paris, France*
[3]*LULI-CNRS, Ecole Polytechnique, CEA, Université Paris-Saclay, Palaiseau cedex, F-91128, France*
[4]*Sorbonne Université, UPMC Univ Paris 06, CNRS, Laboratoire d'utilisation des lasers intenses (LULI), place Jussieu, Paris cedex 05, 75252, France*

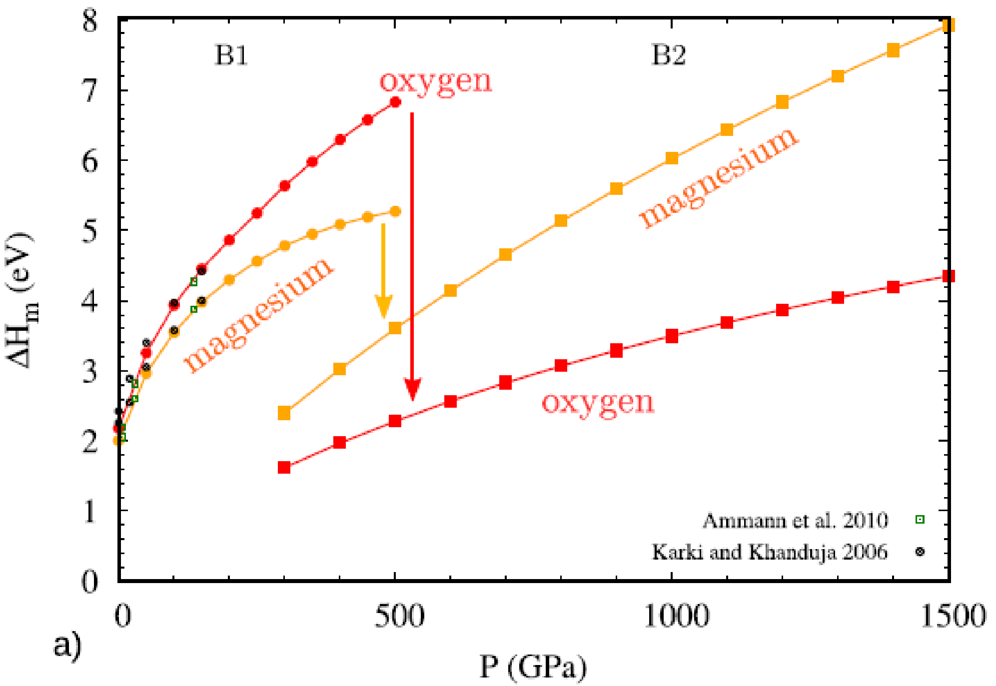




Change of migration enthalpy of vacancies : Change of viscosity in B2 structure?

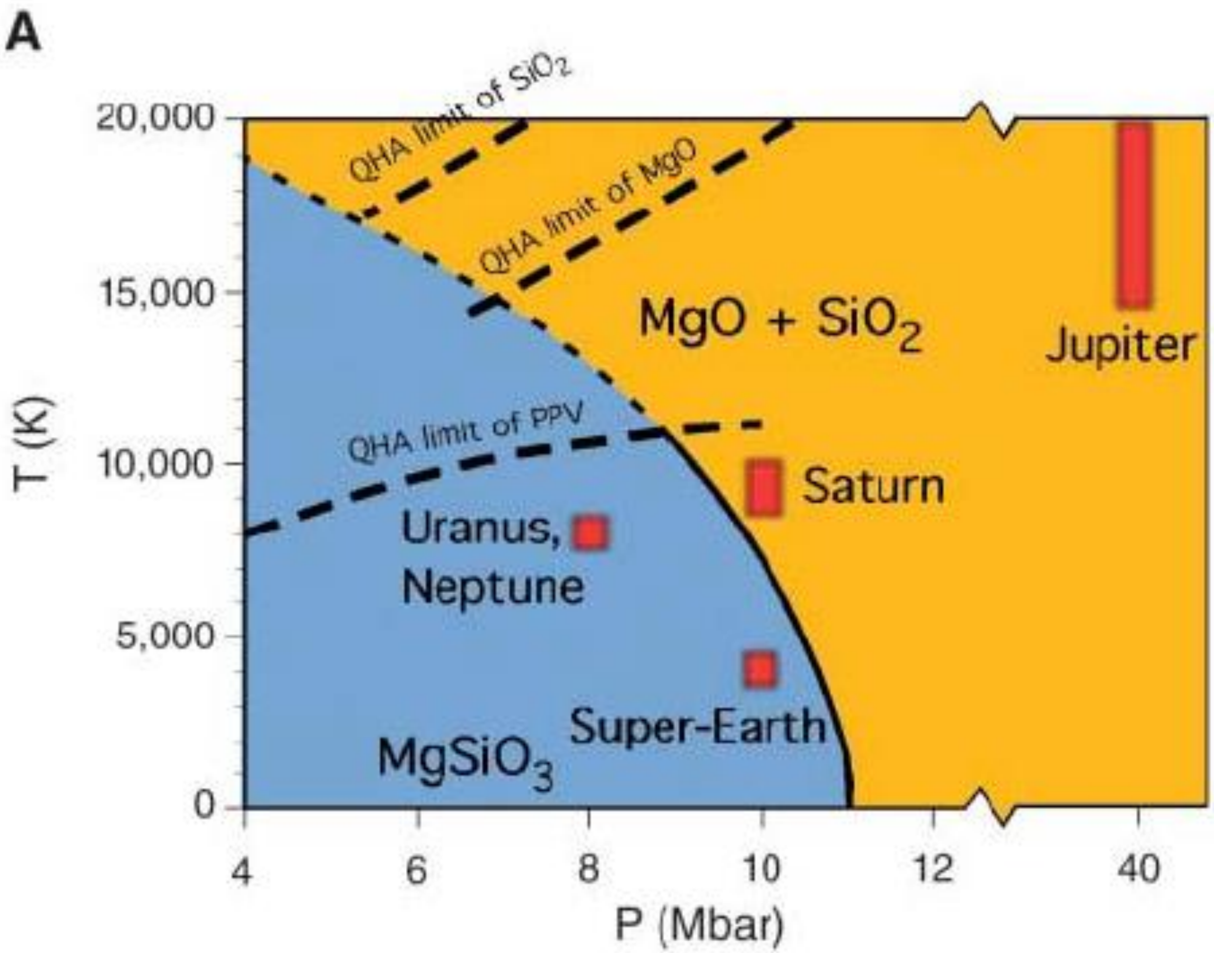


Karato, 1989

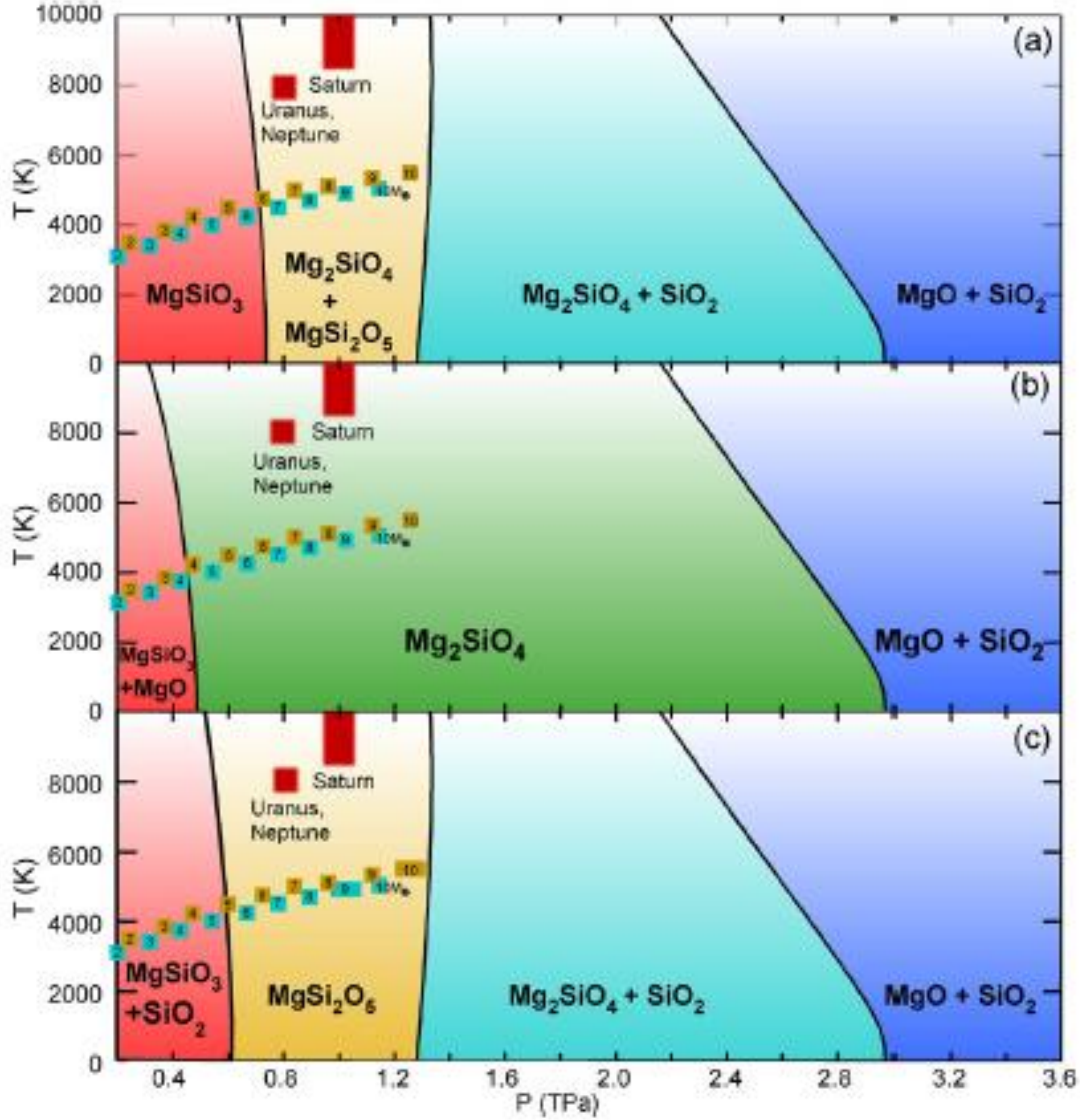


Ritterbex et al, Icarus, 2018

MgSiO3 dissociation

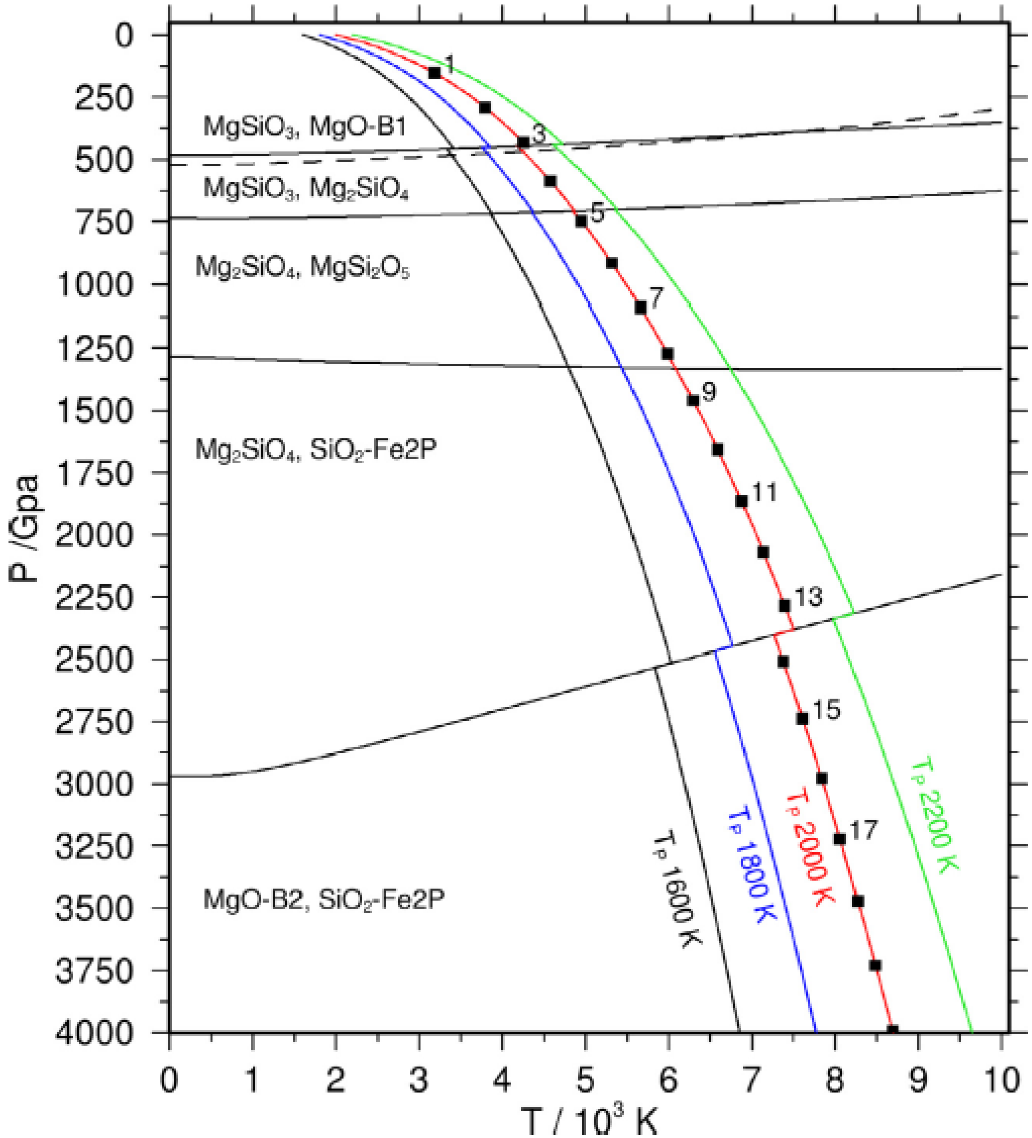


Umemoto et al, Science, 2006



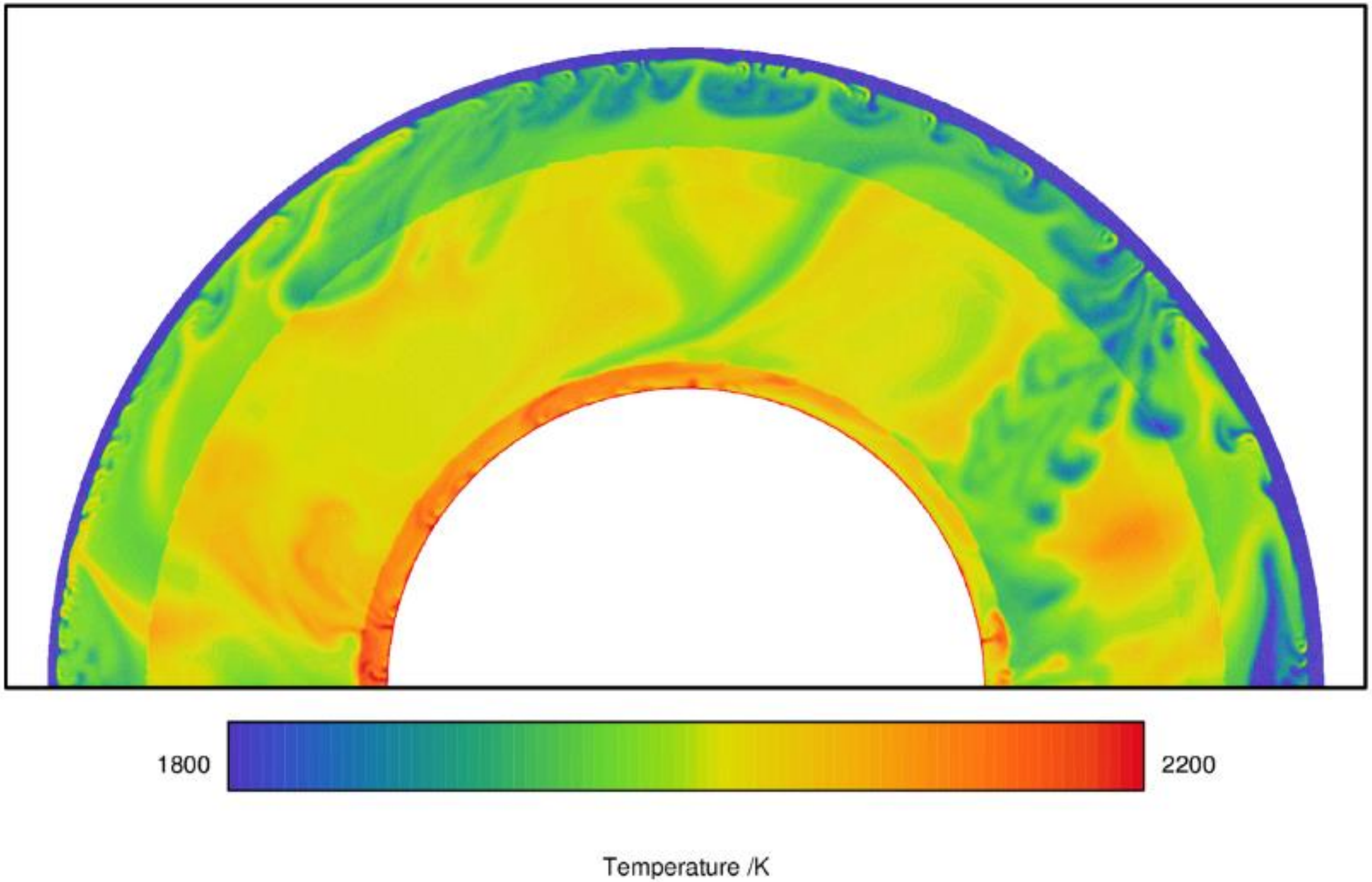
But even more complicated

Umemoto et al, EPSL, 2017



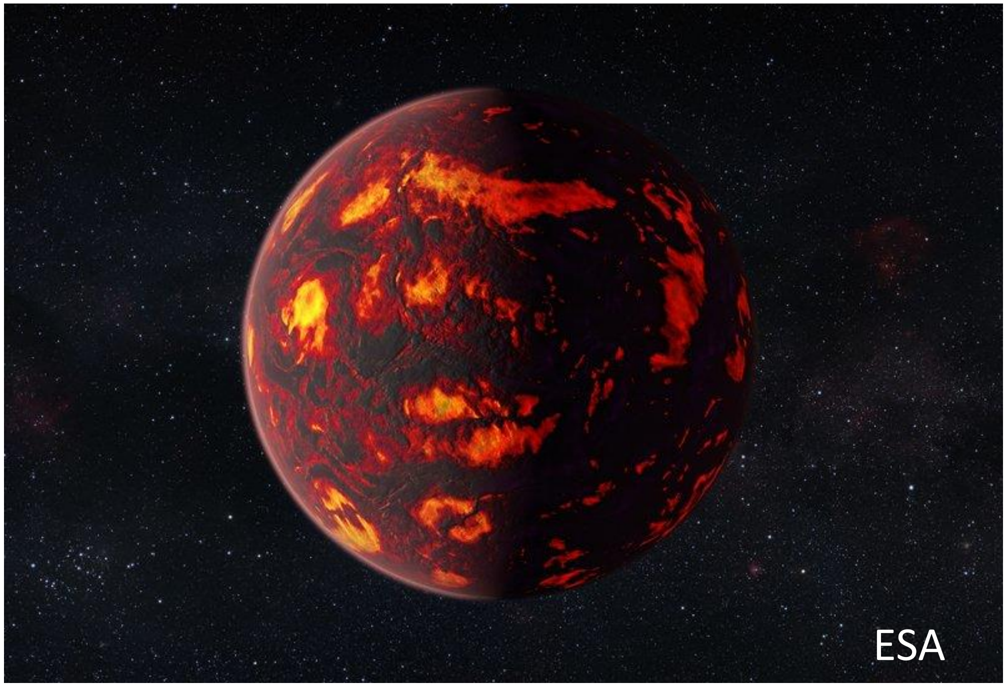
Van den Berg et al, Icarus, 2019

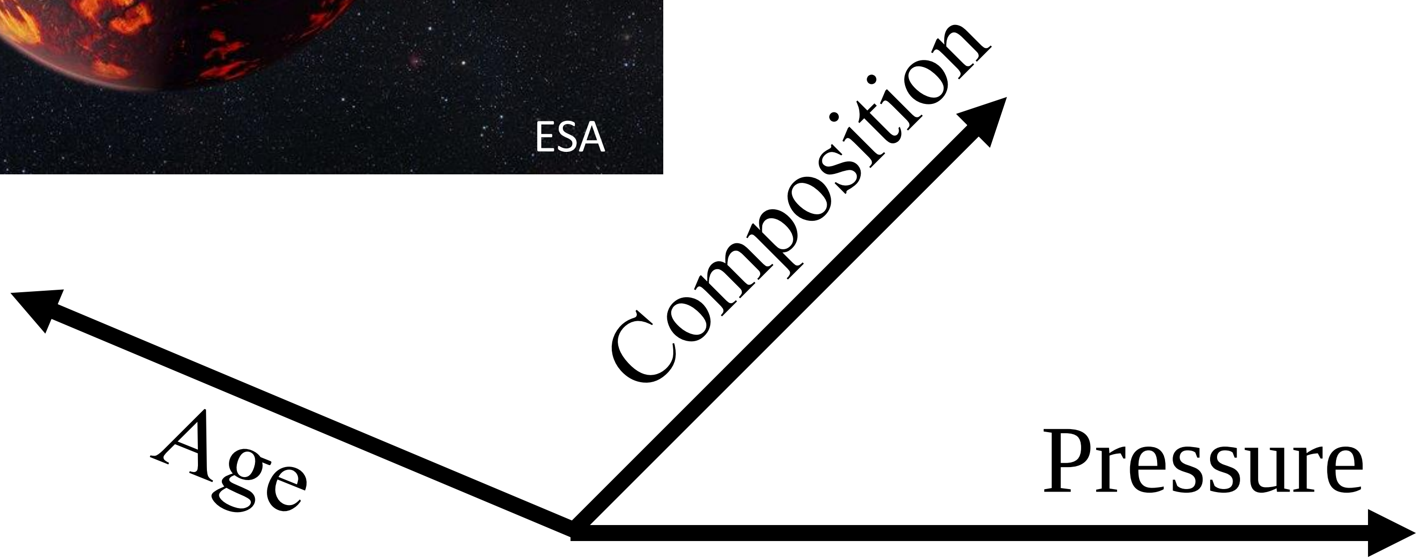
Internal dynamic of a 15 Mearth planet



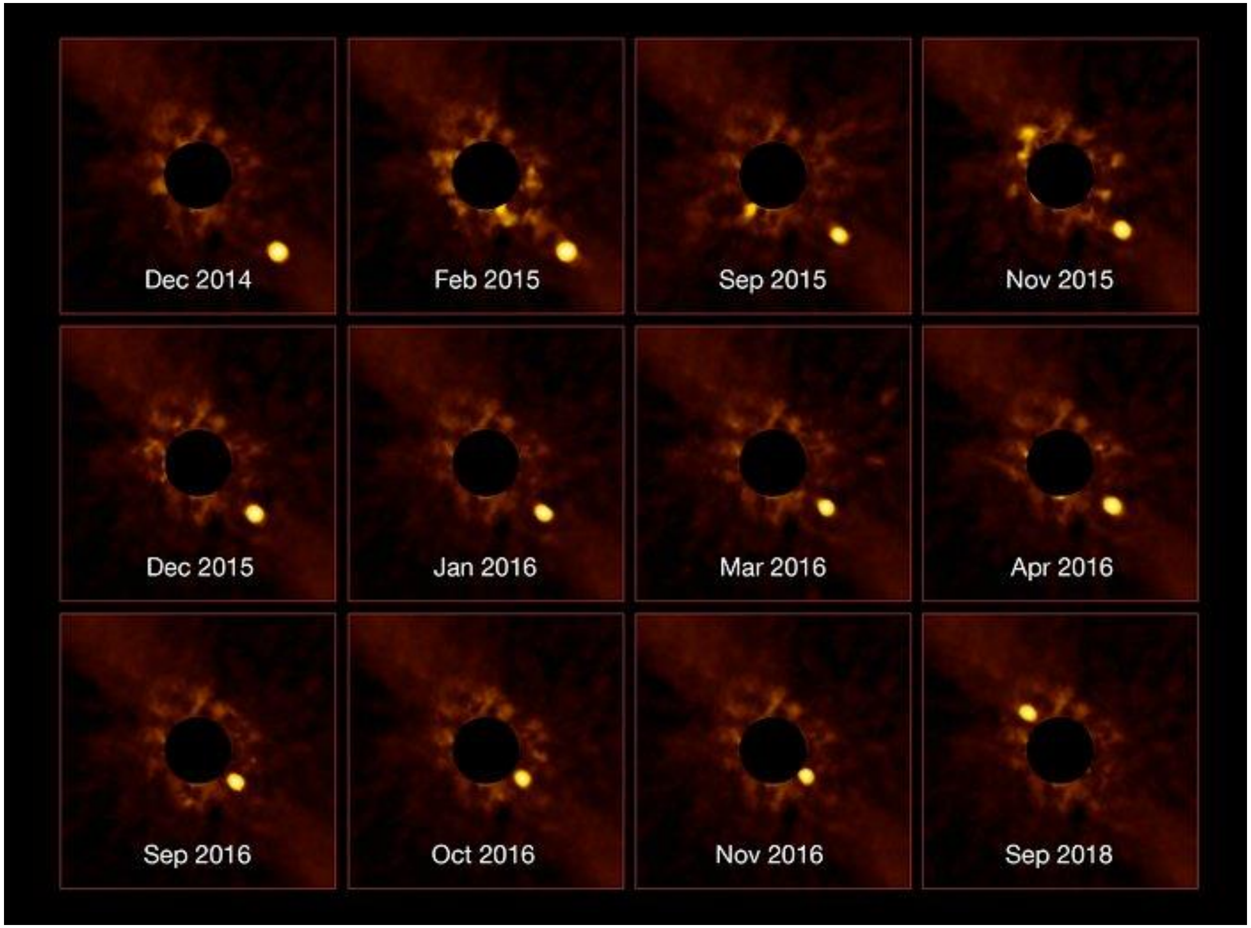
Van den Berg et al, Icarus, 2019

Exoplanets' interiors

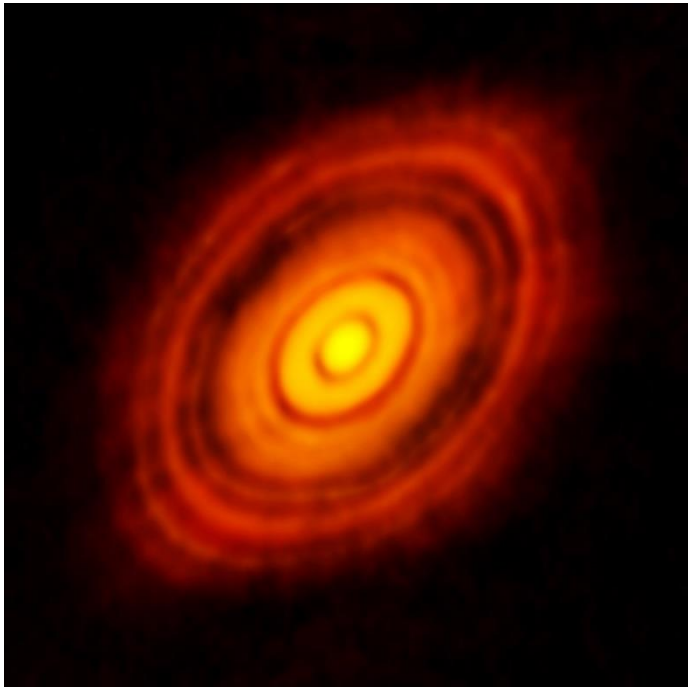




Beta-pictoris: direct imaging

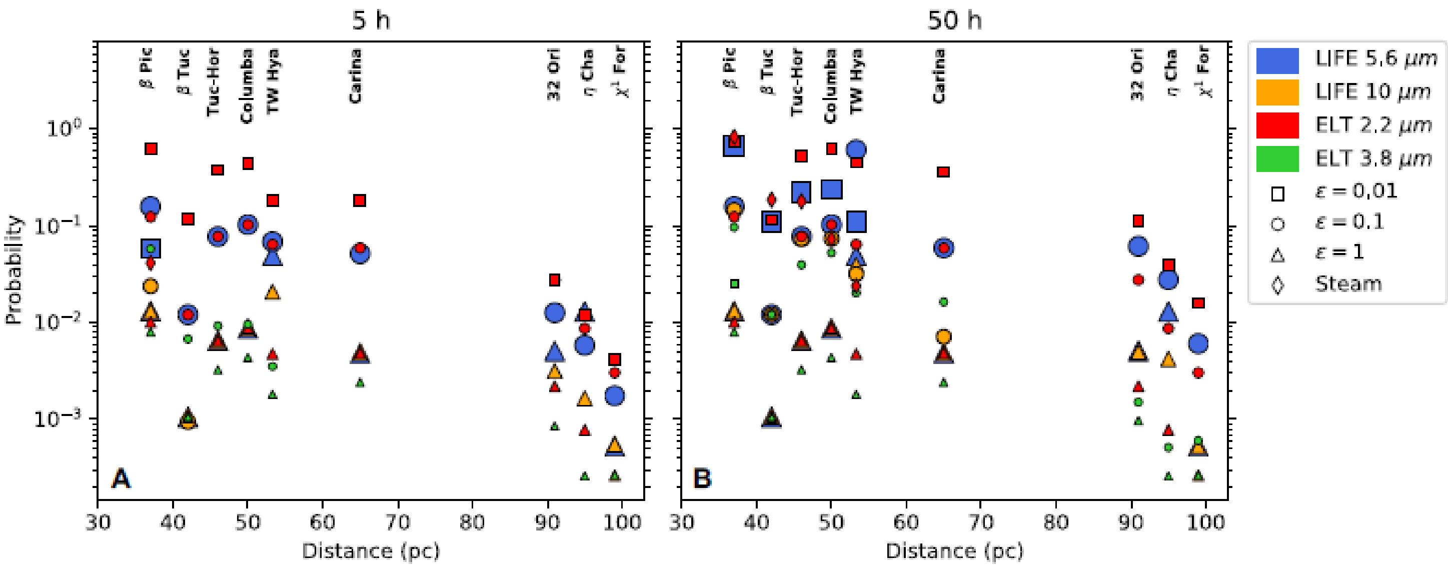


Young planets

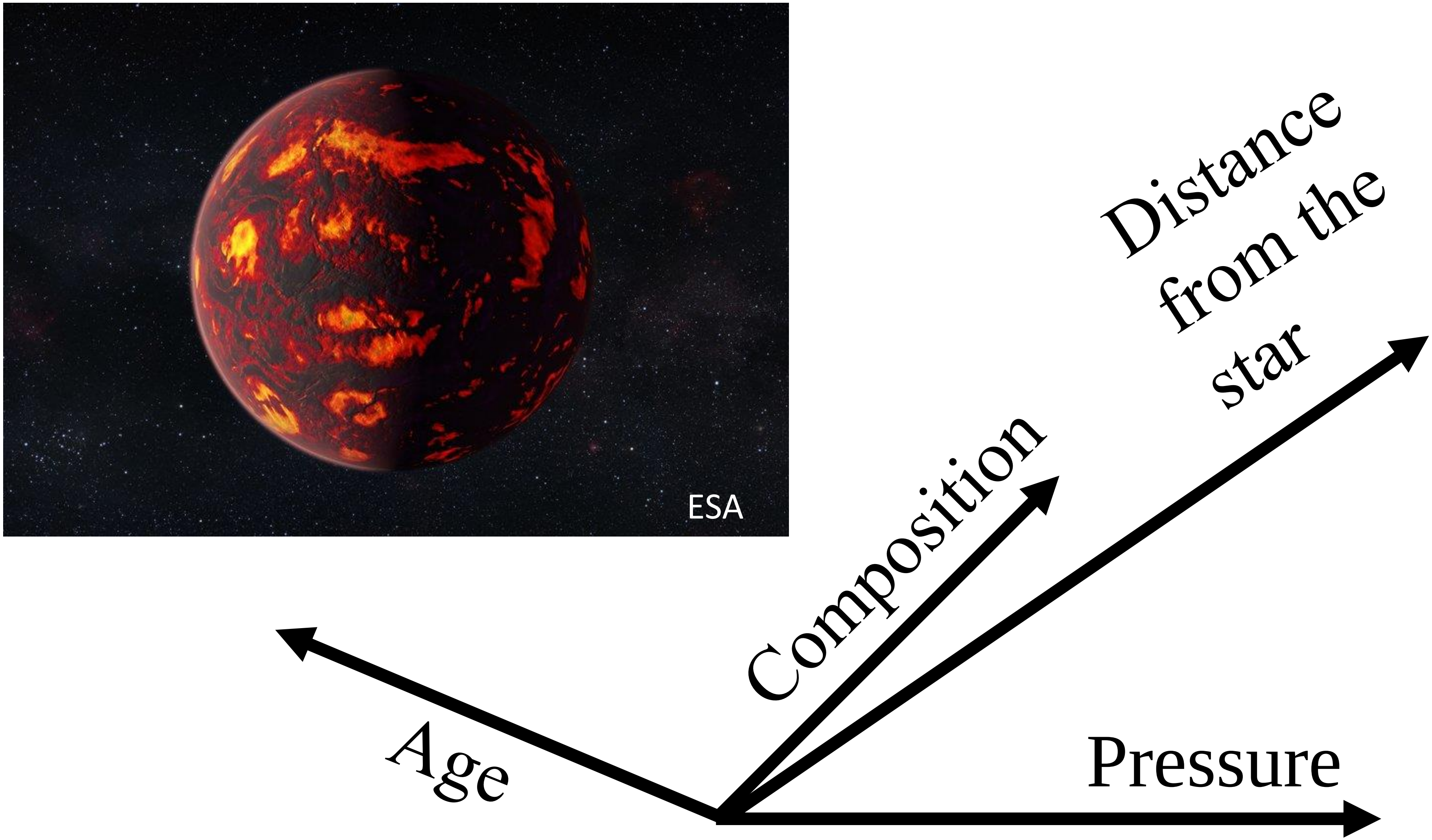


Direct imaging of molten protoplanets in nearby young stellar associations

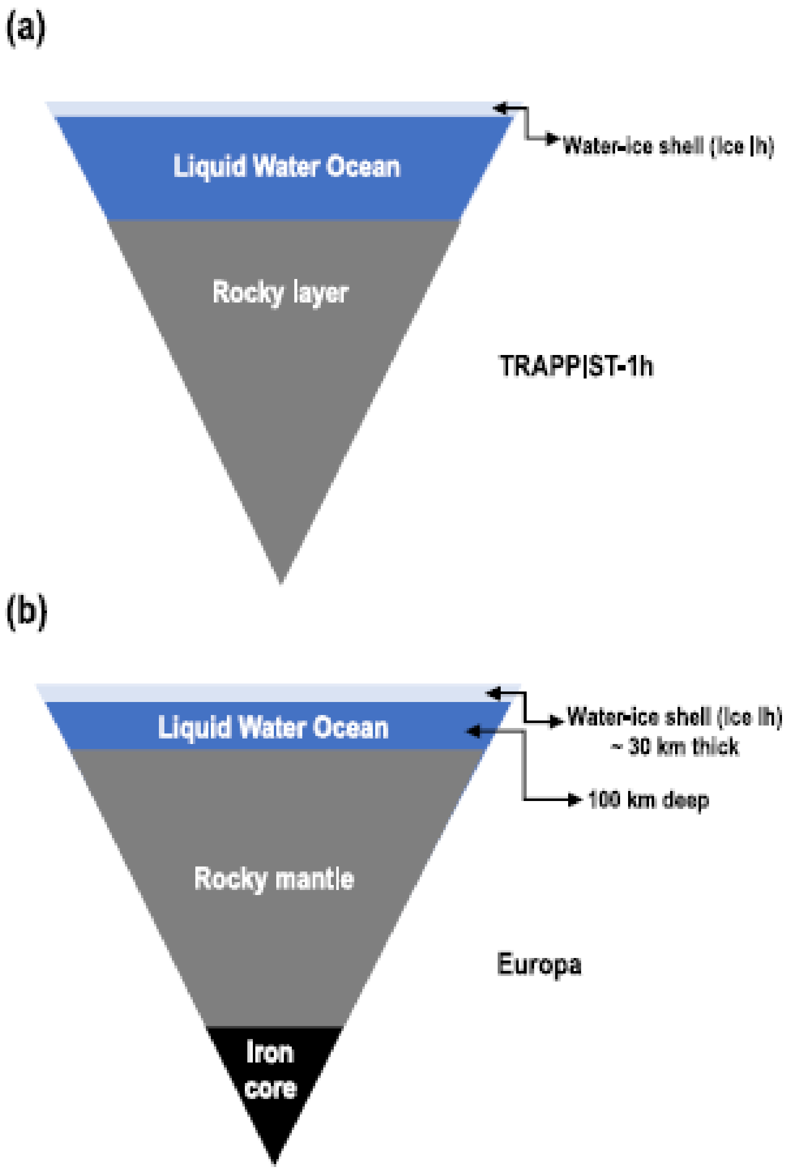
Irene Bonati[1,2], Tim Lichtenberg[2,3], Dan J. Bower[4], Miles L. Timpe[5] and Sascha P. Quanz[6]

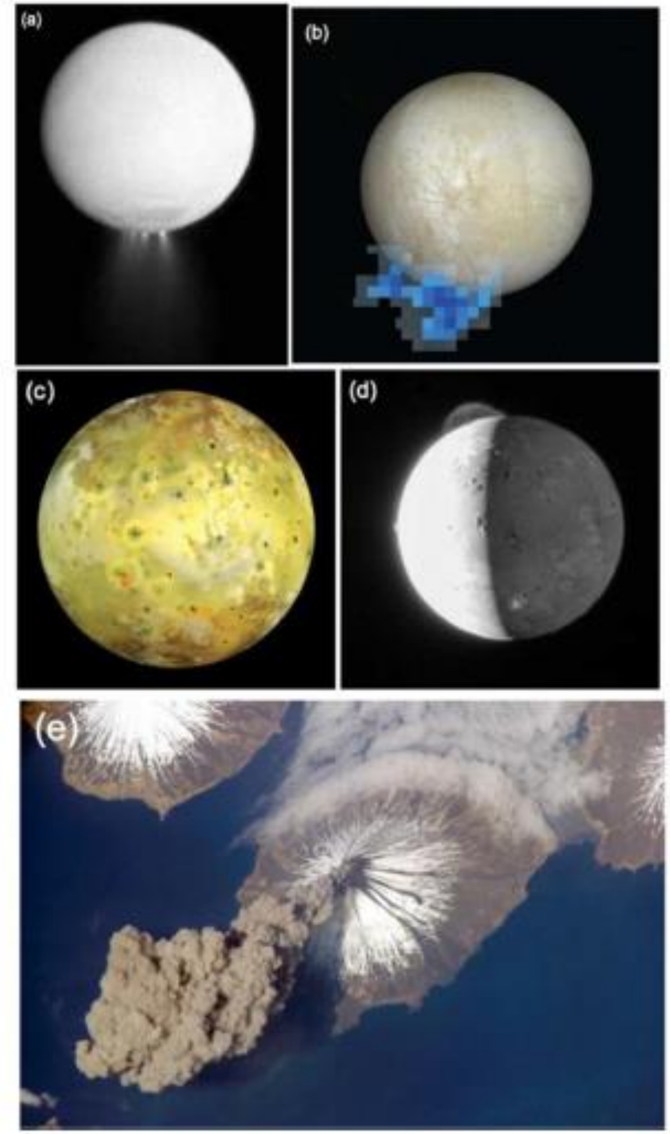


Exoplanets' interiors



Ocean's worlds





Future characterization of cryo-volcanism?

Quick et al, 2020

Final feeling for conclusion