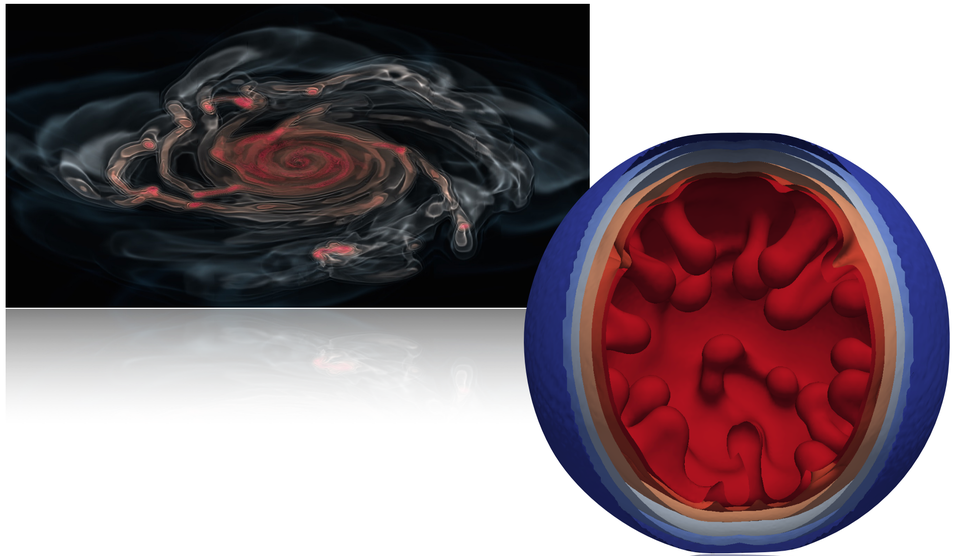
Geophysical evolution of forming rocky planets

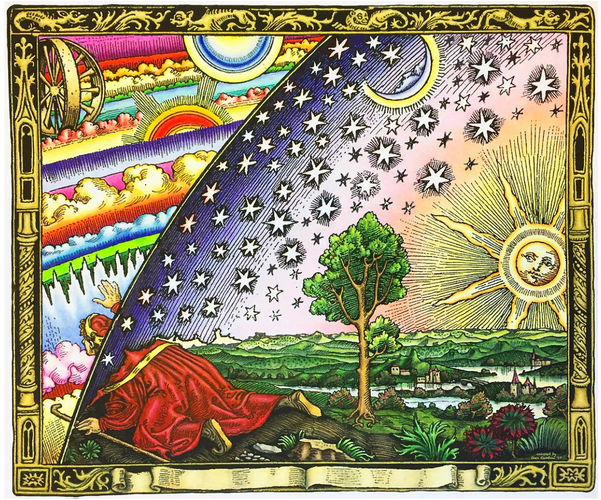
Tim Lichtenberg

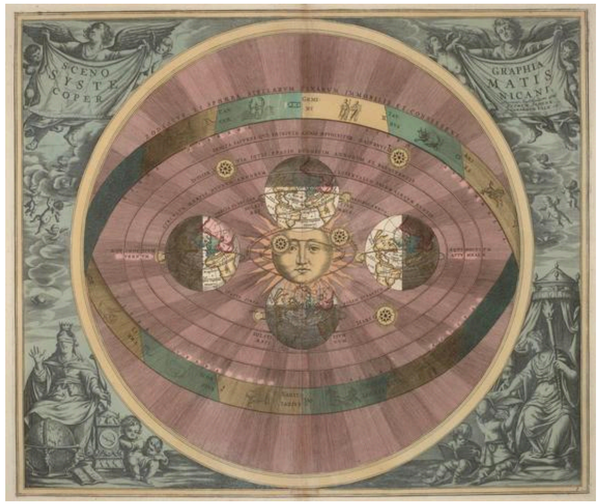


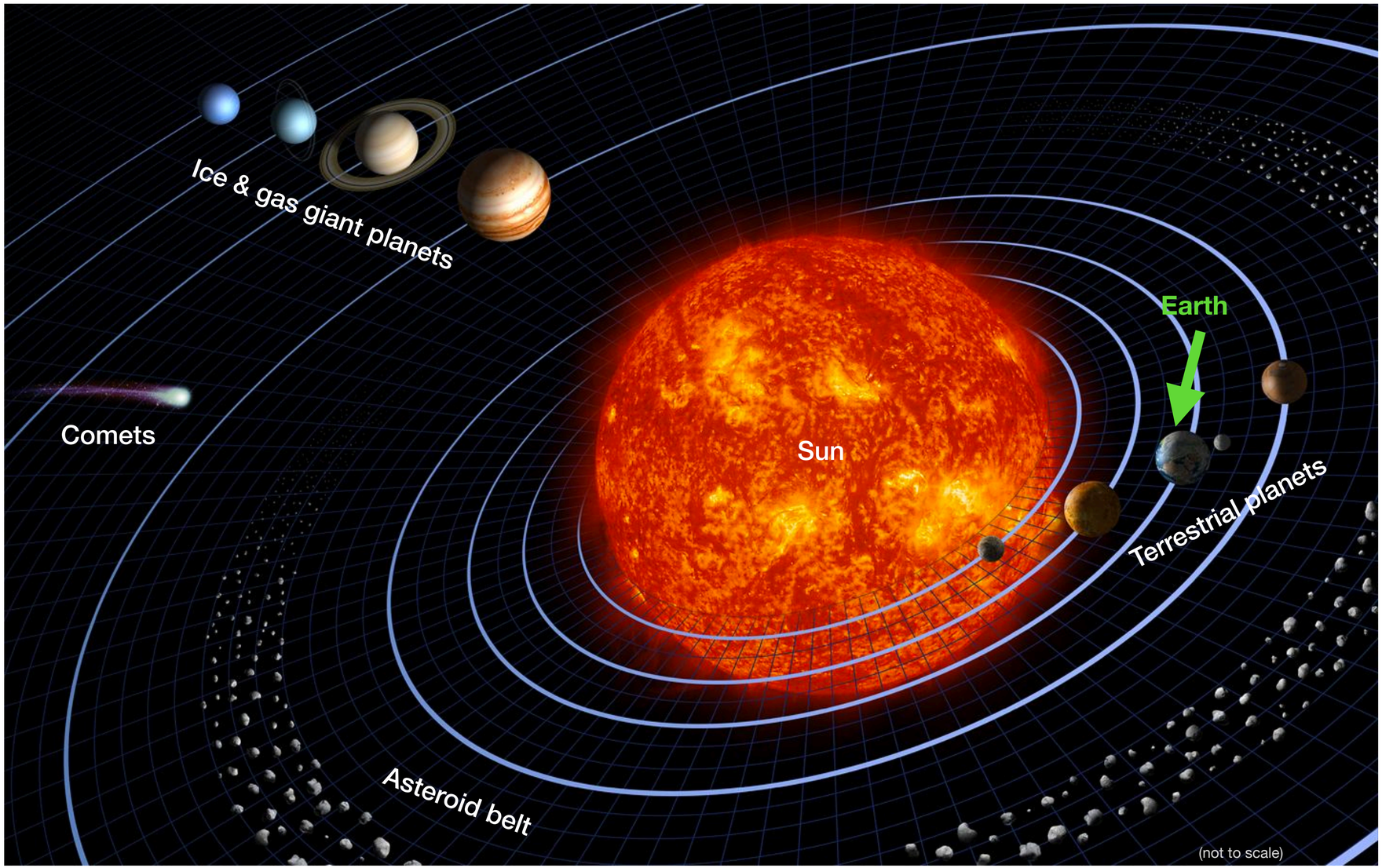
UNIVERSITY OF OXFORD

FNSNF
Swiss National Science Foundation

The Solar system: exceptional or ordinary?



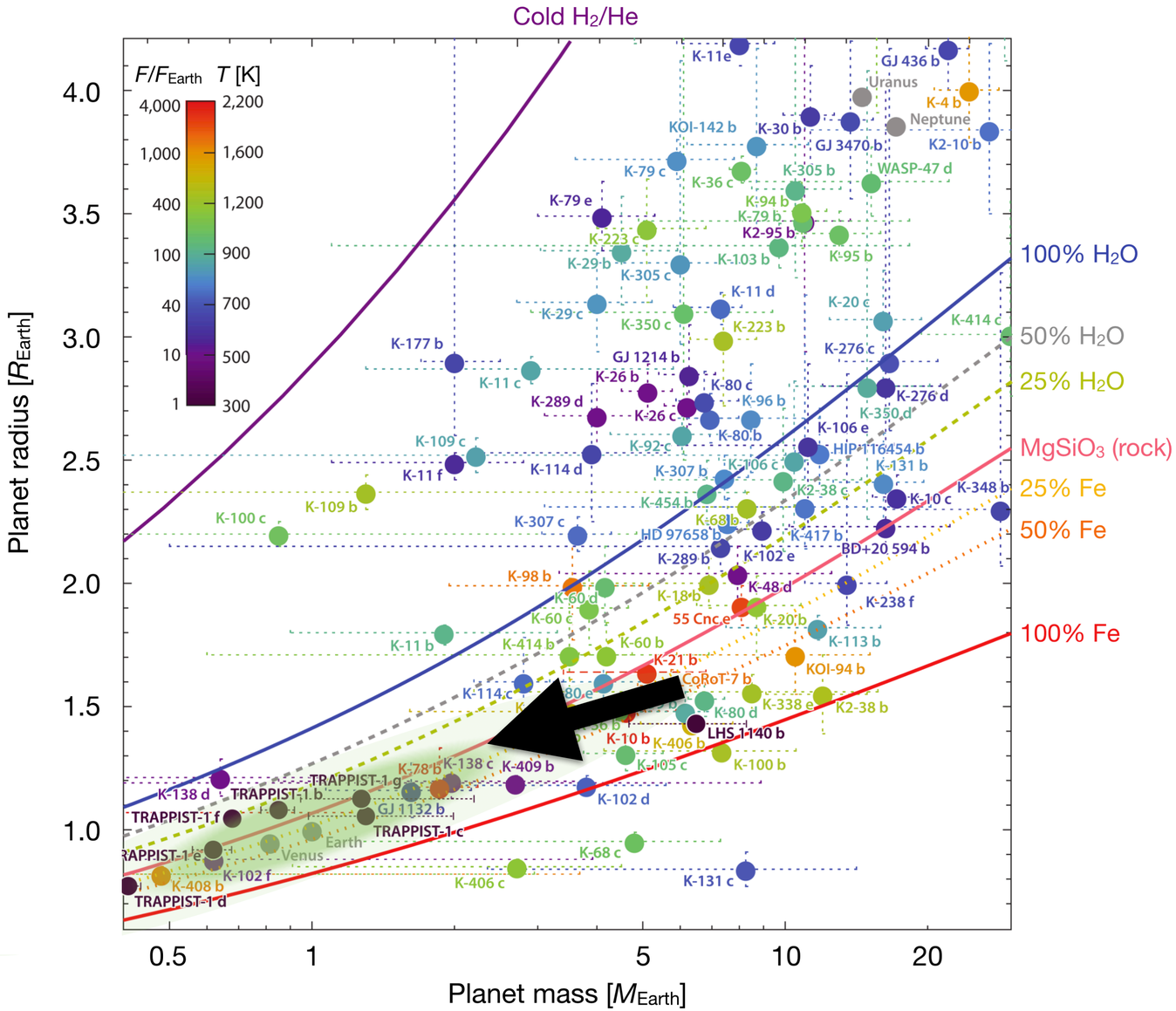




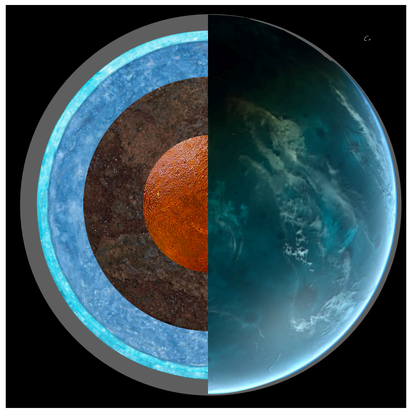
Harmonia Macrocosmica; L'atmosphère: météorologie populaire

NASA/JPL-Caltech

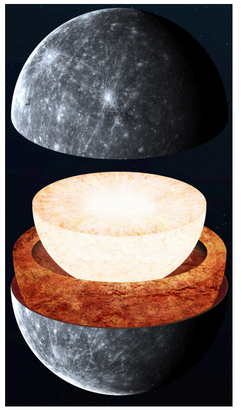
Exoplanetary diversity



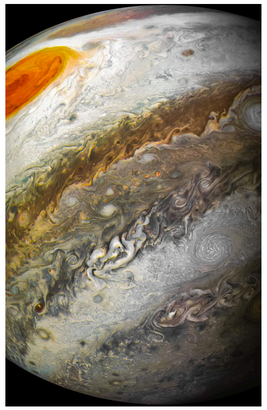
Modified from Kaltenegger 17



H_2O



Fe

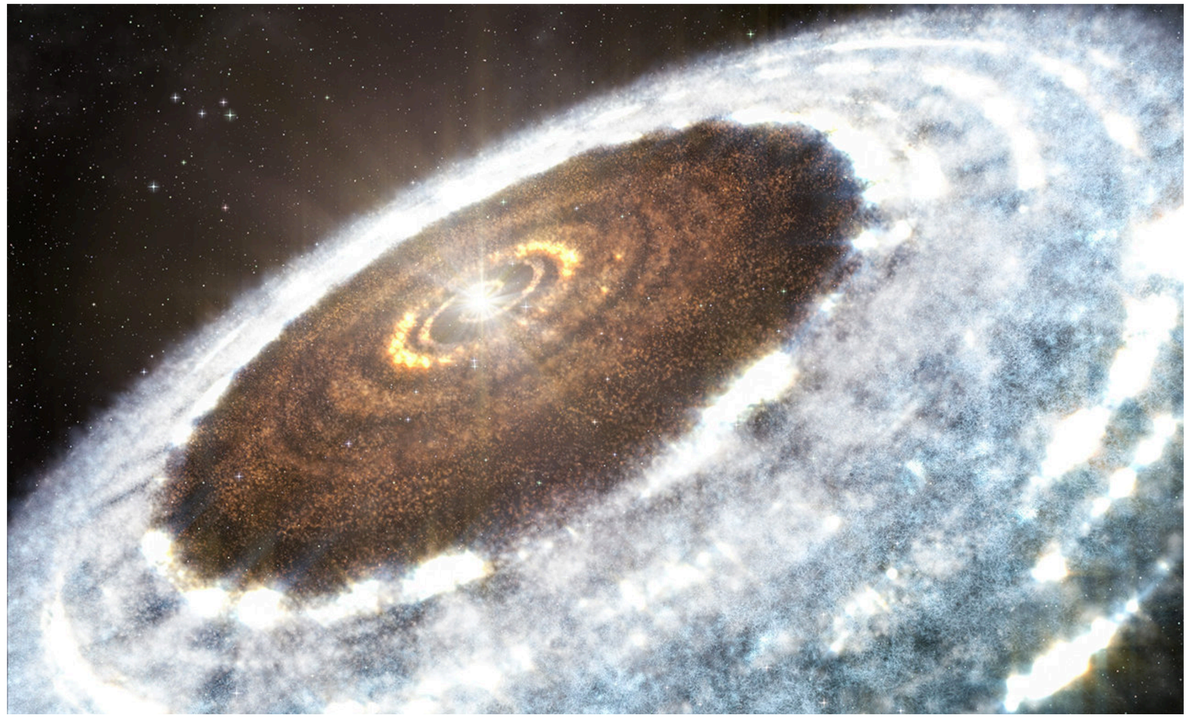


H_2/He

‘Earth-like’?

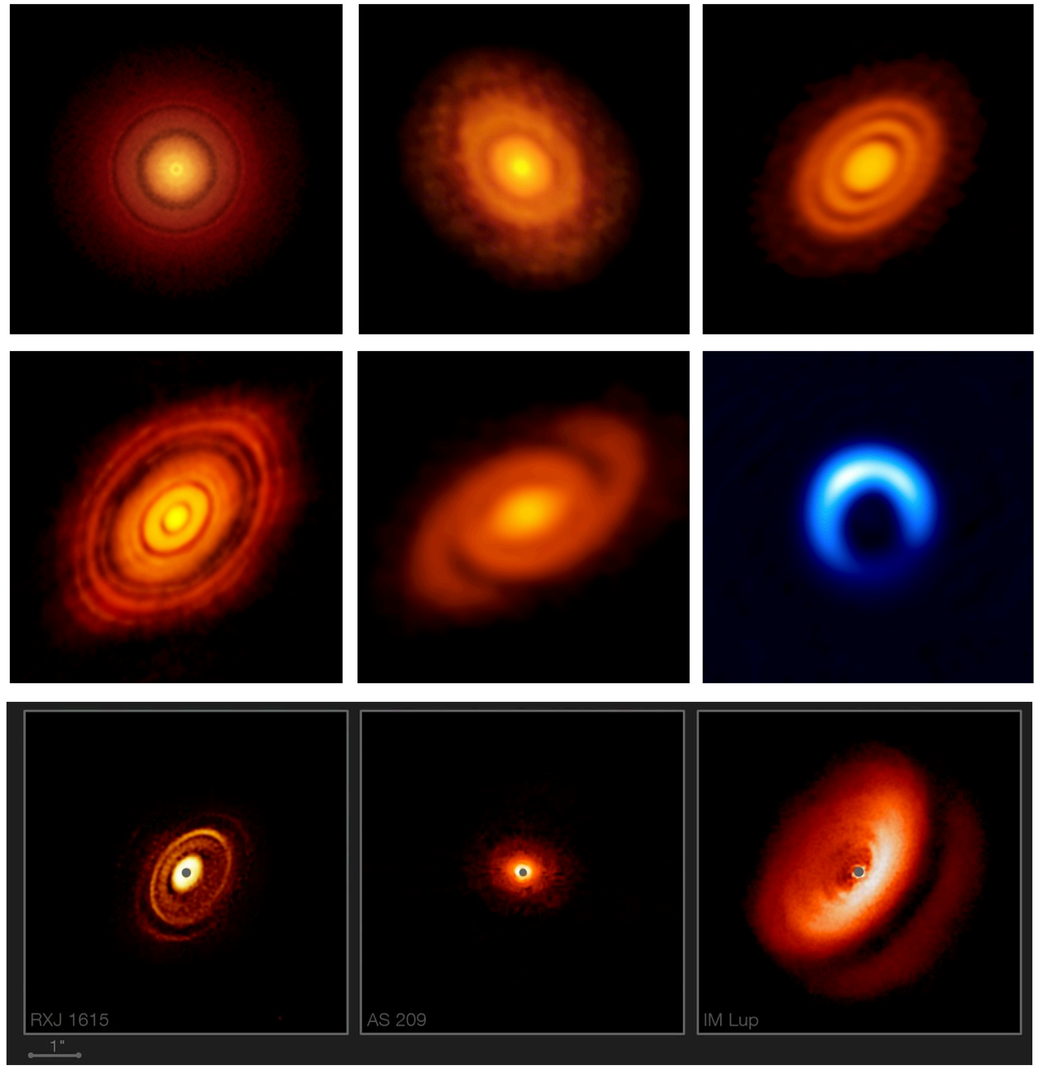
Meyer+ 08; Vadim Sadovski; NASA/JPL-Caltech

Composition rooted in formation



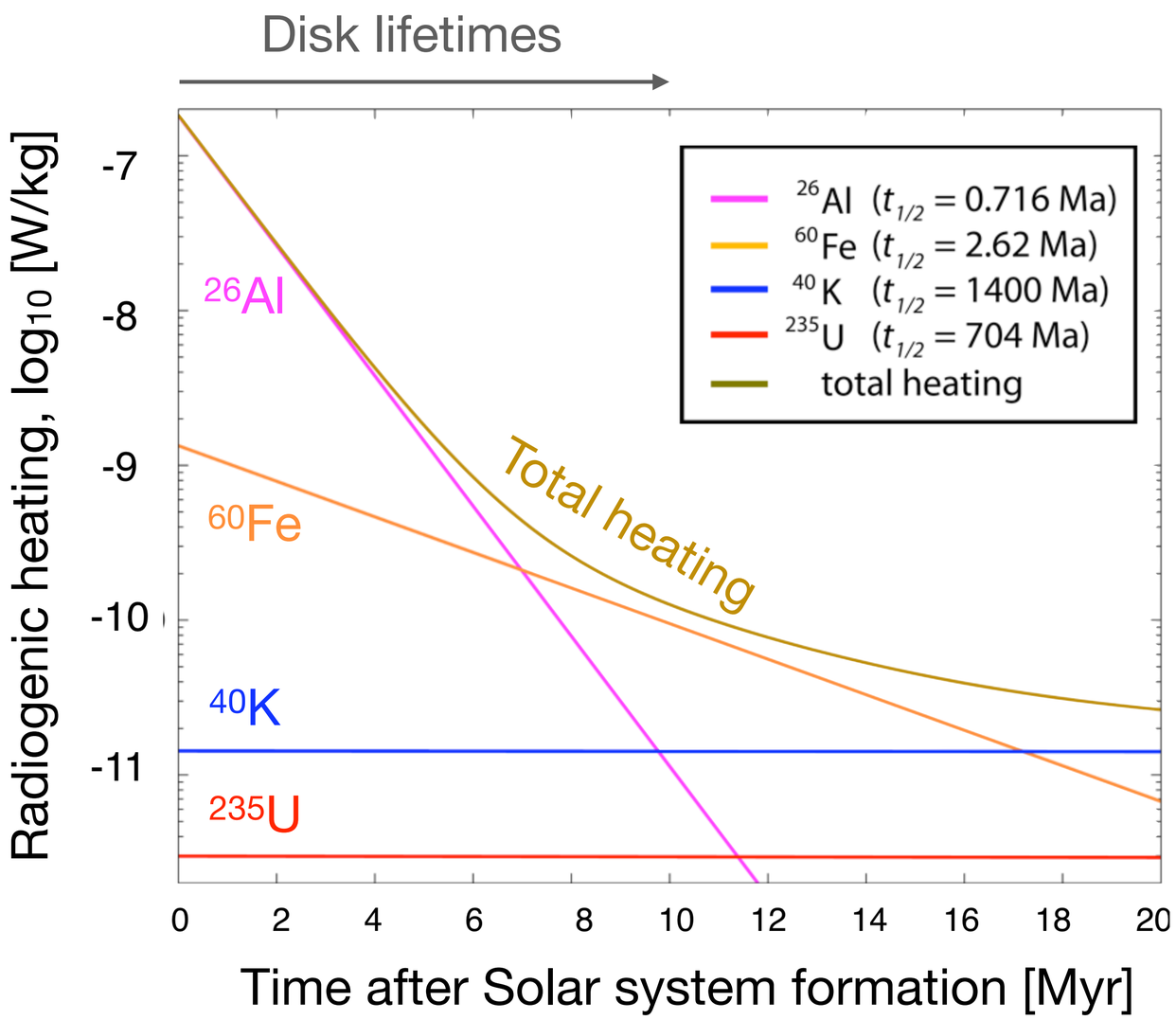
ESO / L. Calçada

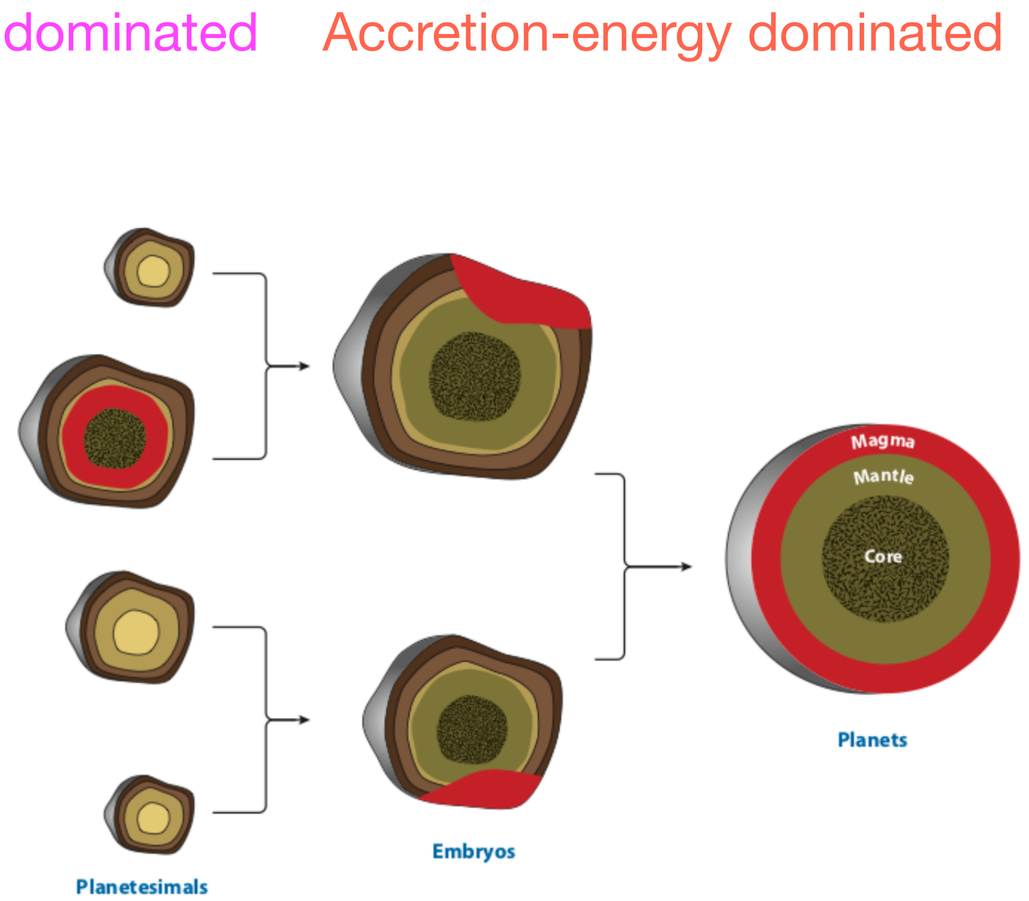
S. Andrews, L. Cieza, A. Isella, A. Kataoka, B. Saxton (NRAO/AUI/NSF), ALMA (ESO/NAOJ/NRAO)



Avenhaus+ 18

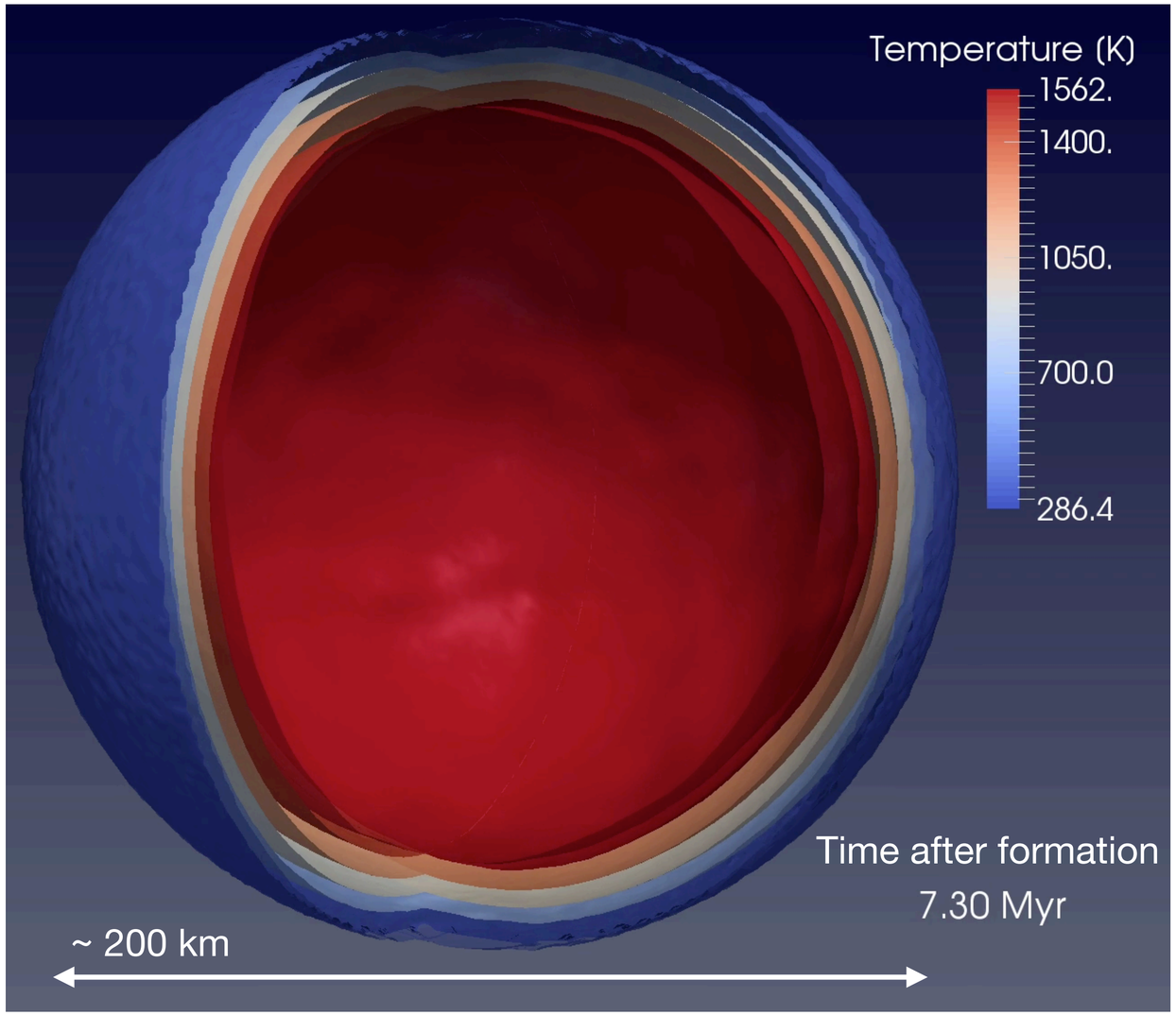
Geophysical evolution during accretion



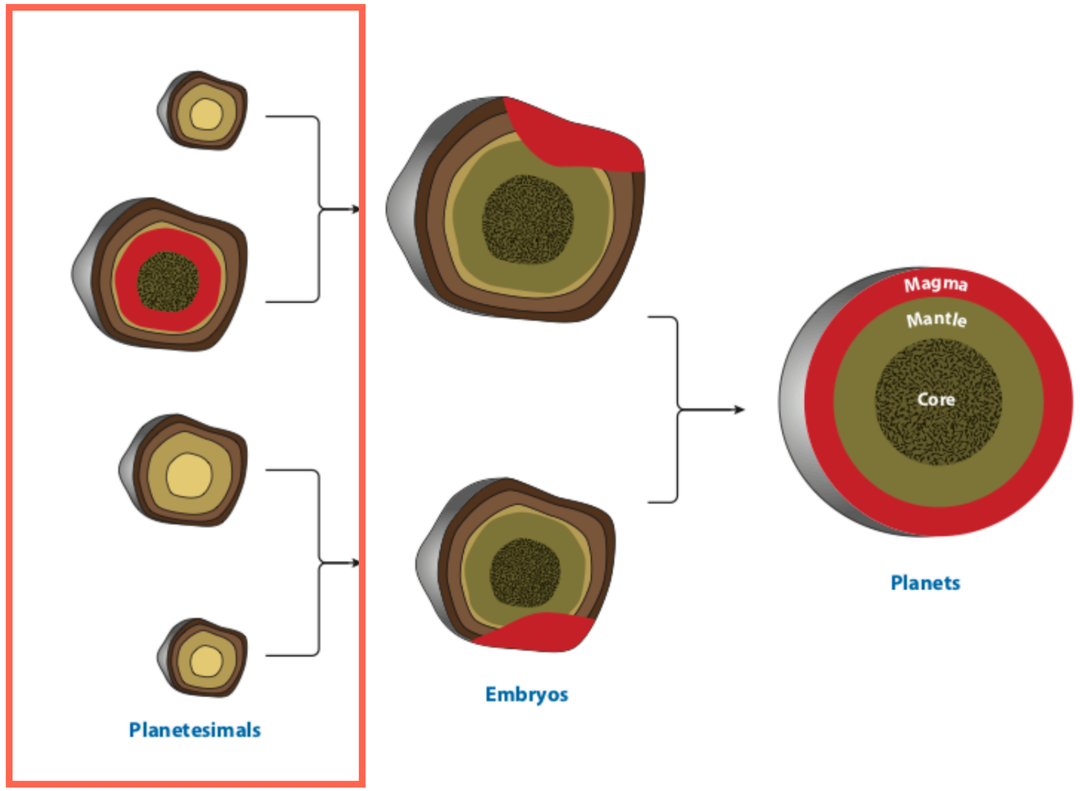


Elkins-Tanton 10, Weiss & Elkins-Tanton 17

Thermal evolution of planetesimals



^{26}Al dominated Accretion-energy dominated

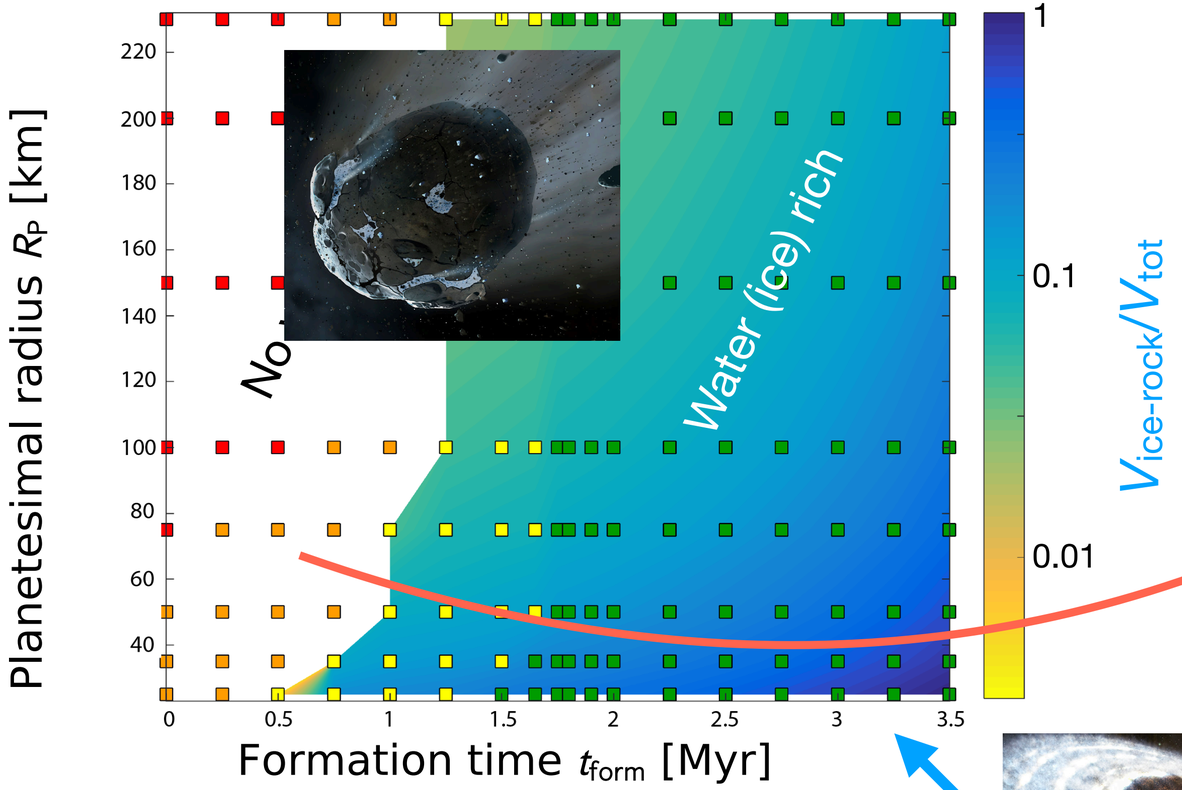


Lichtenberg+ 16a

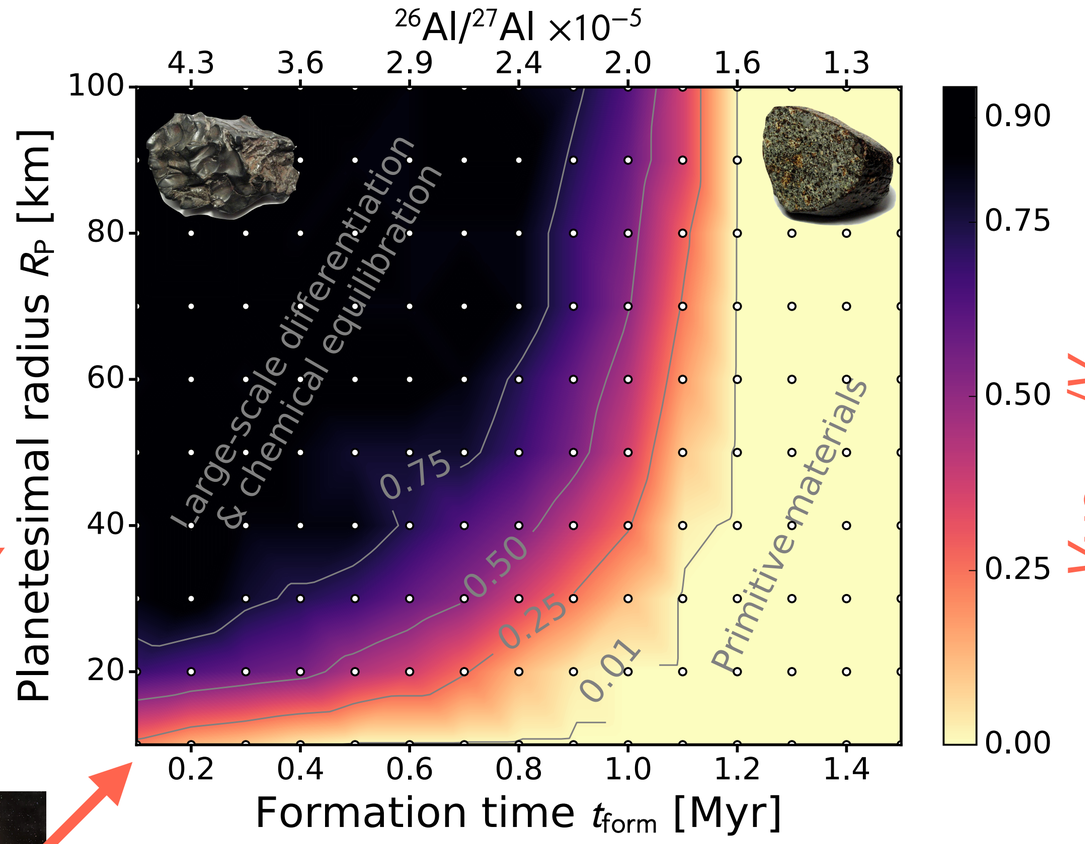
Elkins-Tanton 10, Weiss & Elkins-Tanton 17

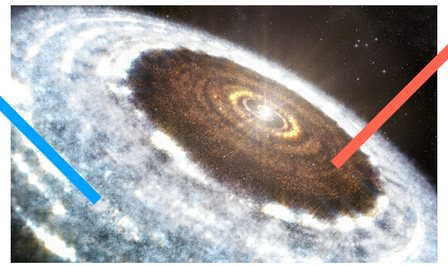
Volatile loss & chemical differentiation

Degassing



Magmatism & Differentiation



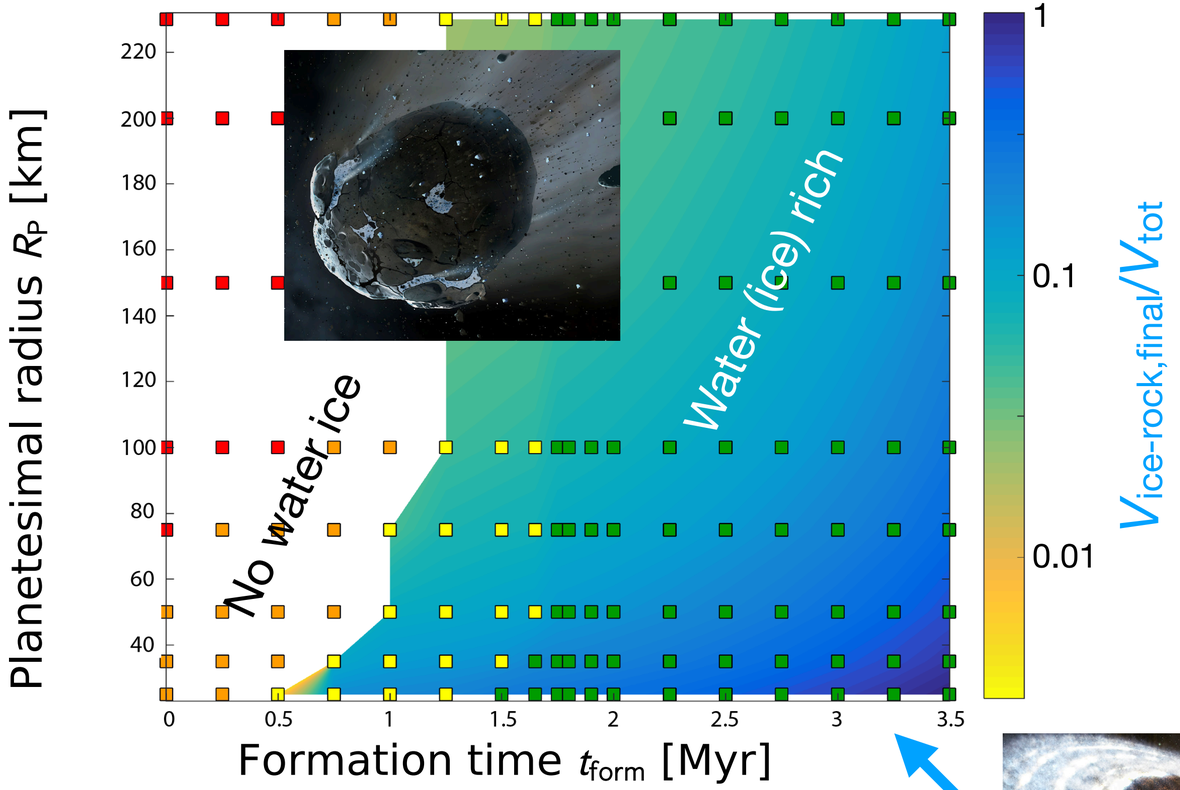


Monteux+ 18

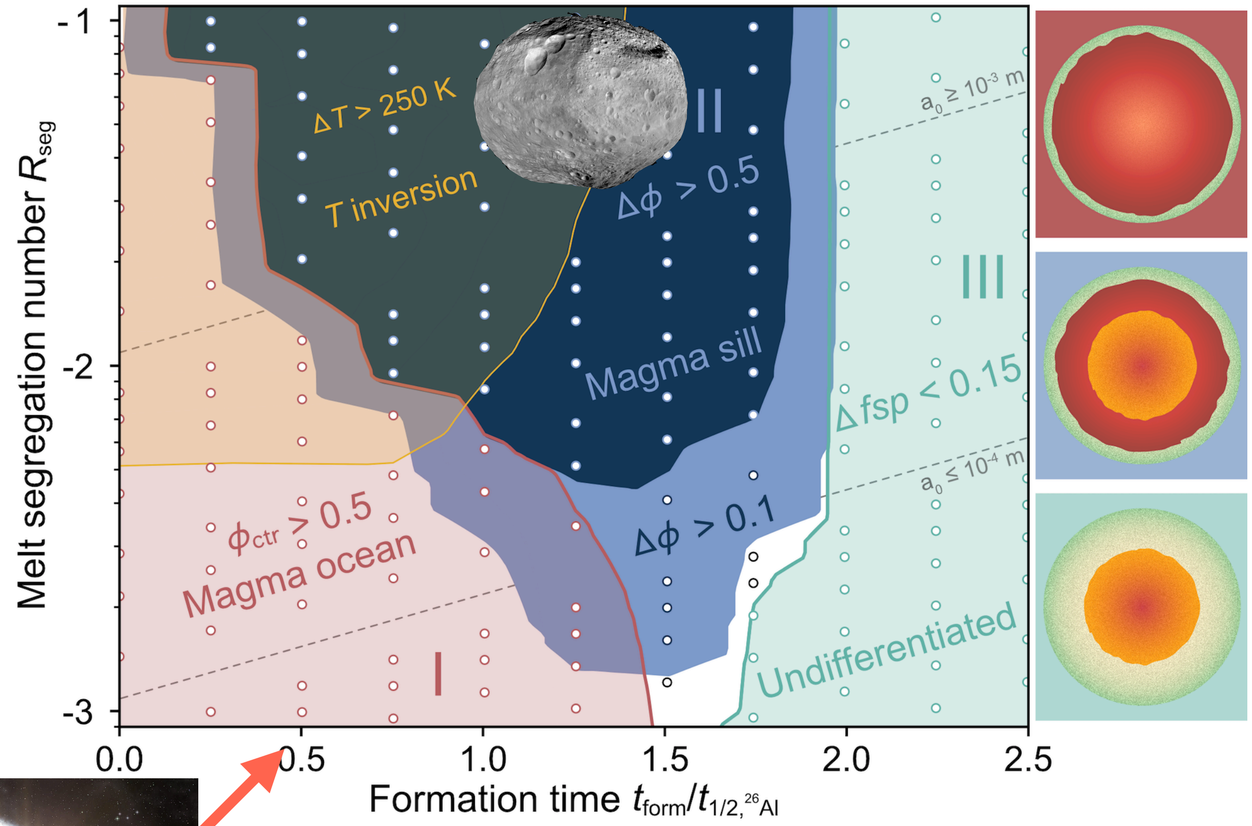
Lichtenberg+ 18

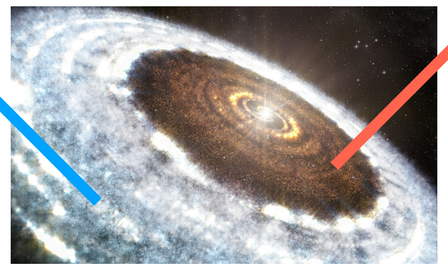
Volatile loss & chemical differentiation

Degassing



Chemical segregation

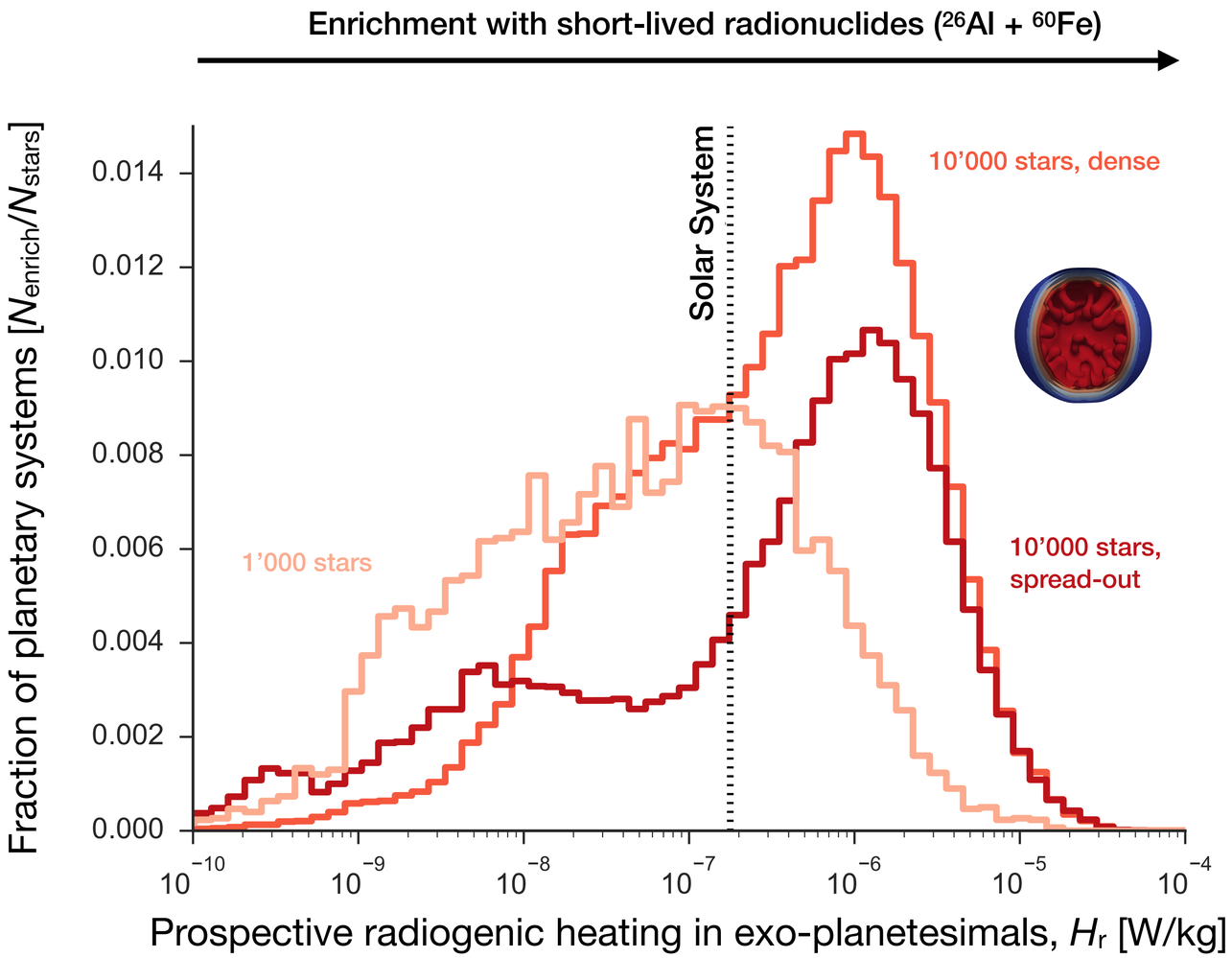




Monteux+ 18

Lichtenberg, Keller, Katz+ 19

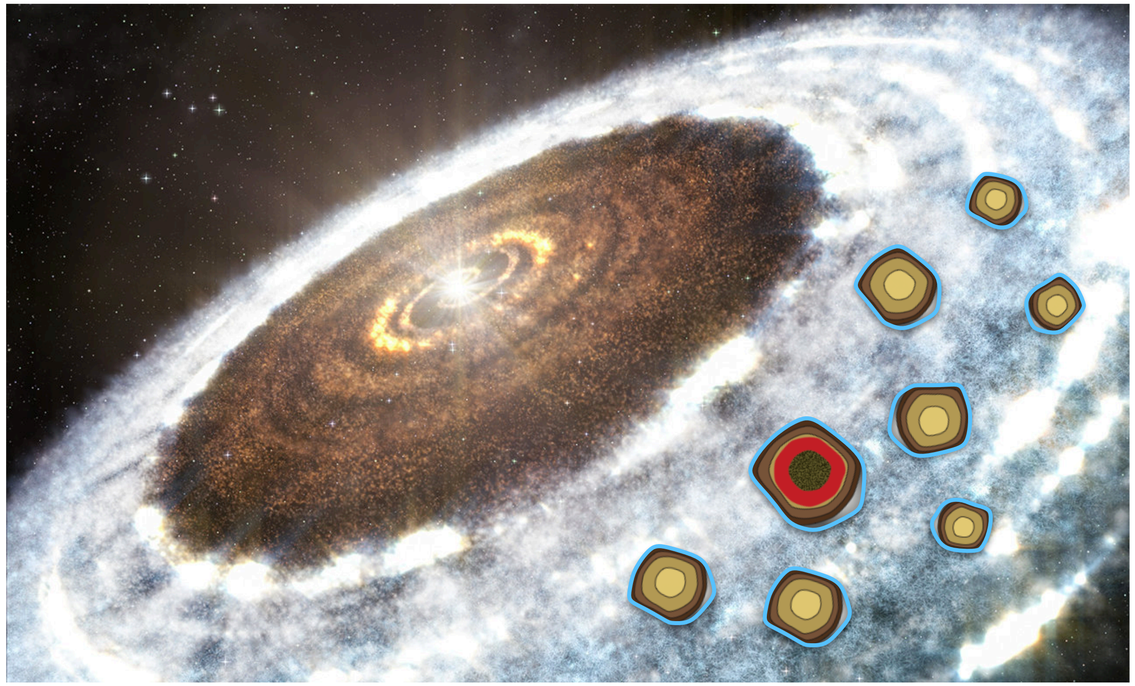
Planetary accretion altered by ^{26}Al



~ 10^2—10^8 × Earth's present-day interior radiogenic heating

Lichtenberg+ 16b

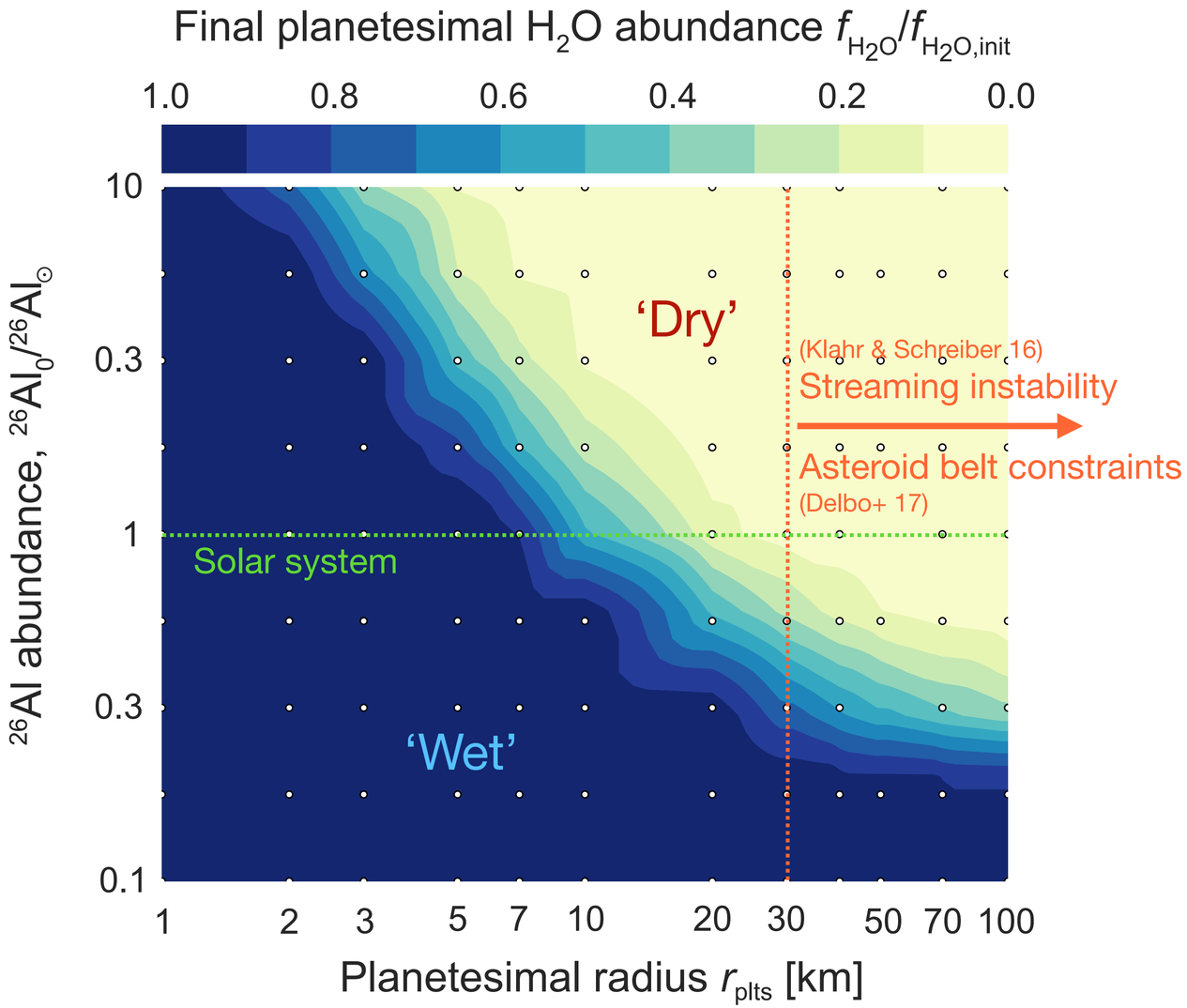
^{26}Al-heated icy planetesimals forming planets



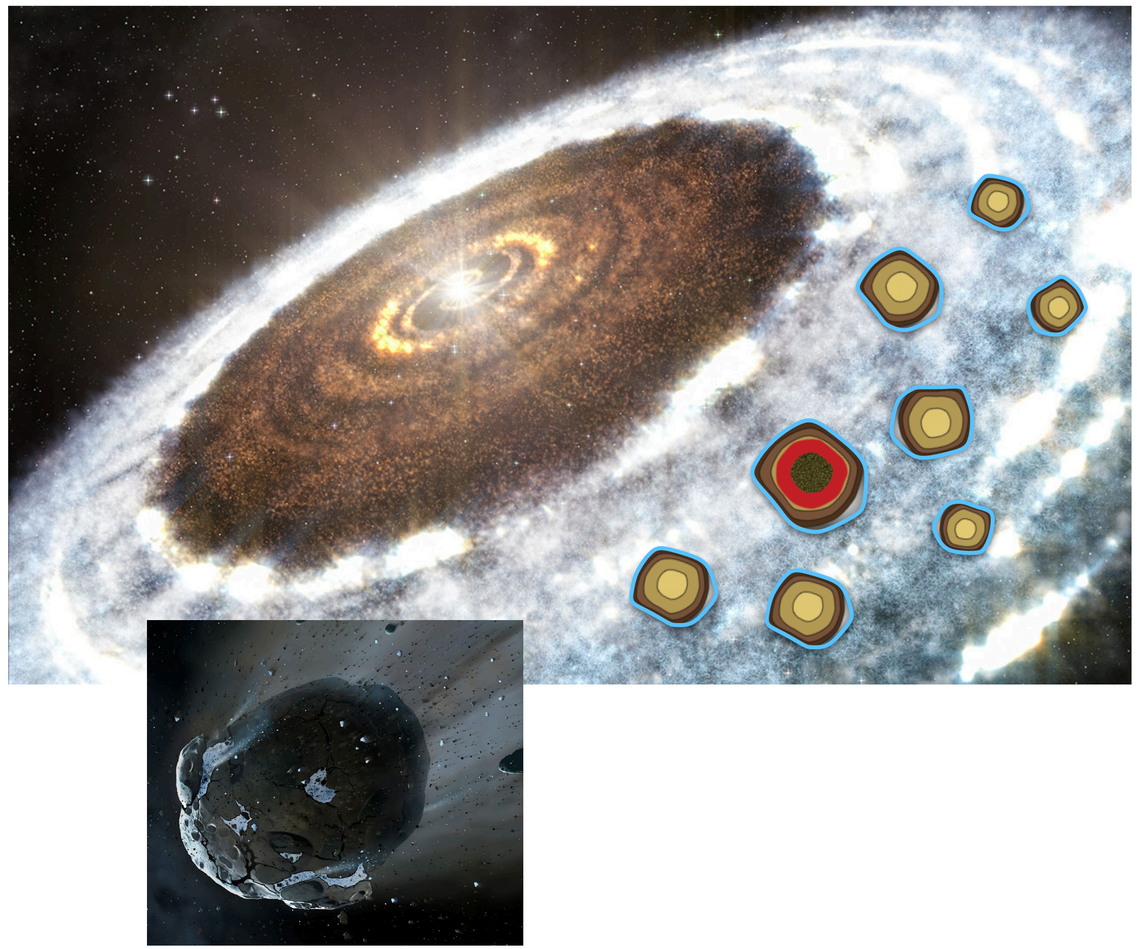
A. Angelich (NRAO/AUI/NSF)/ALMA (ESO/NAOJ/NRAO)

10

Rapidly dehydrated icy planetesimals



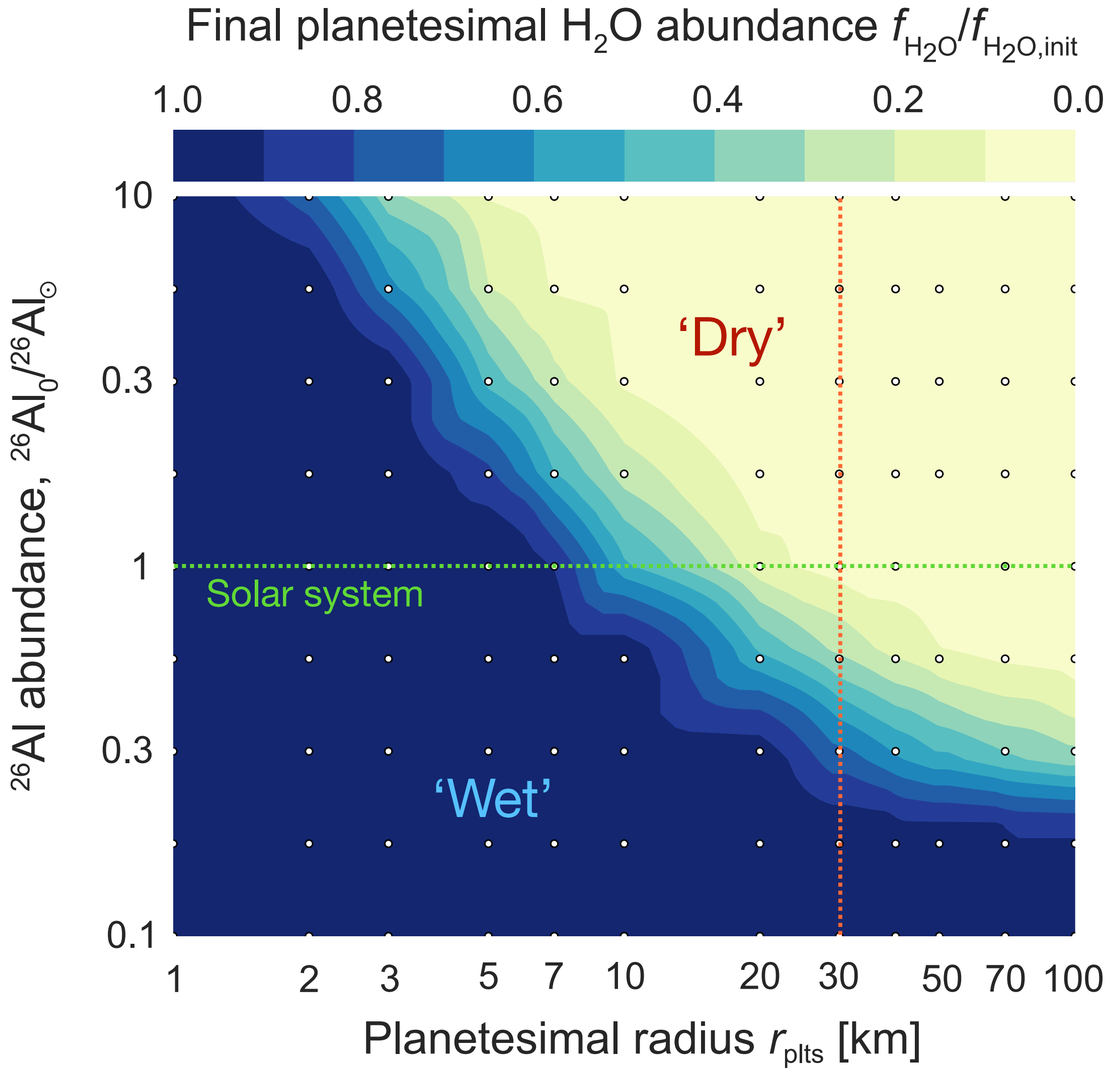
^{26}Al-heated icy planetesimals forming planets



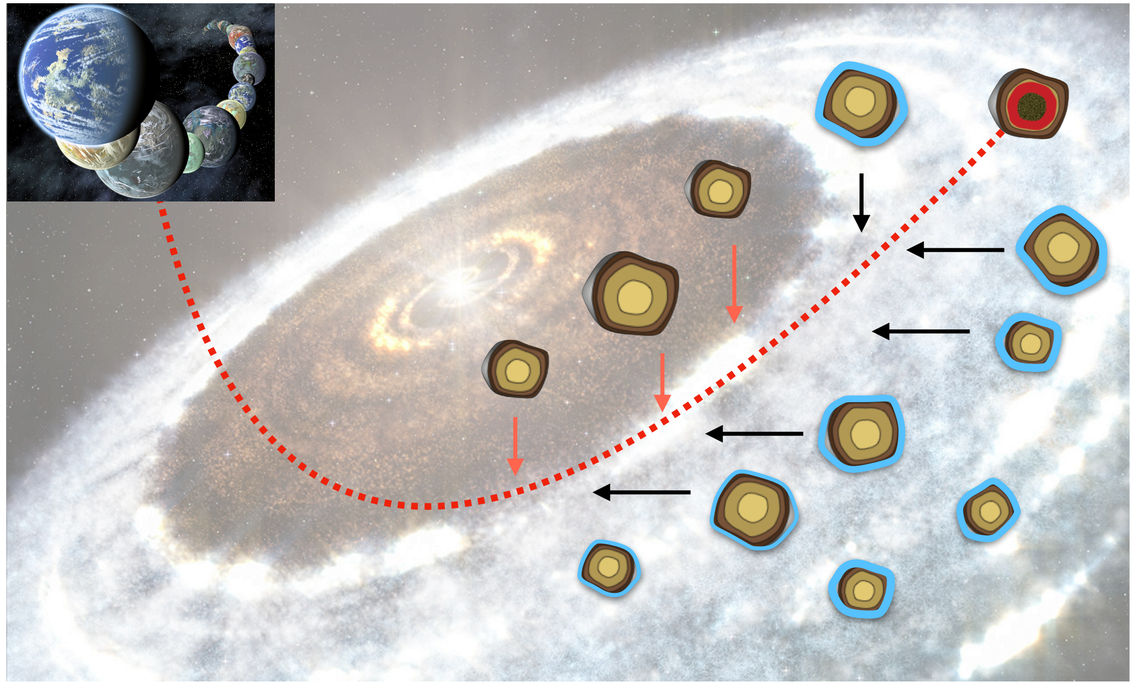
A. Angelich (NRAO/AUI/NSF)/ALMA (ESO/NAOJ/NRAO); ESA/NASA/M.A.Garlick

Lichtenberg+ 19b

^{26}Al controls bulk water content



Synthetic exoplanet populations

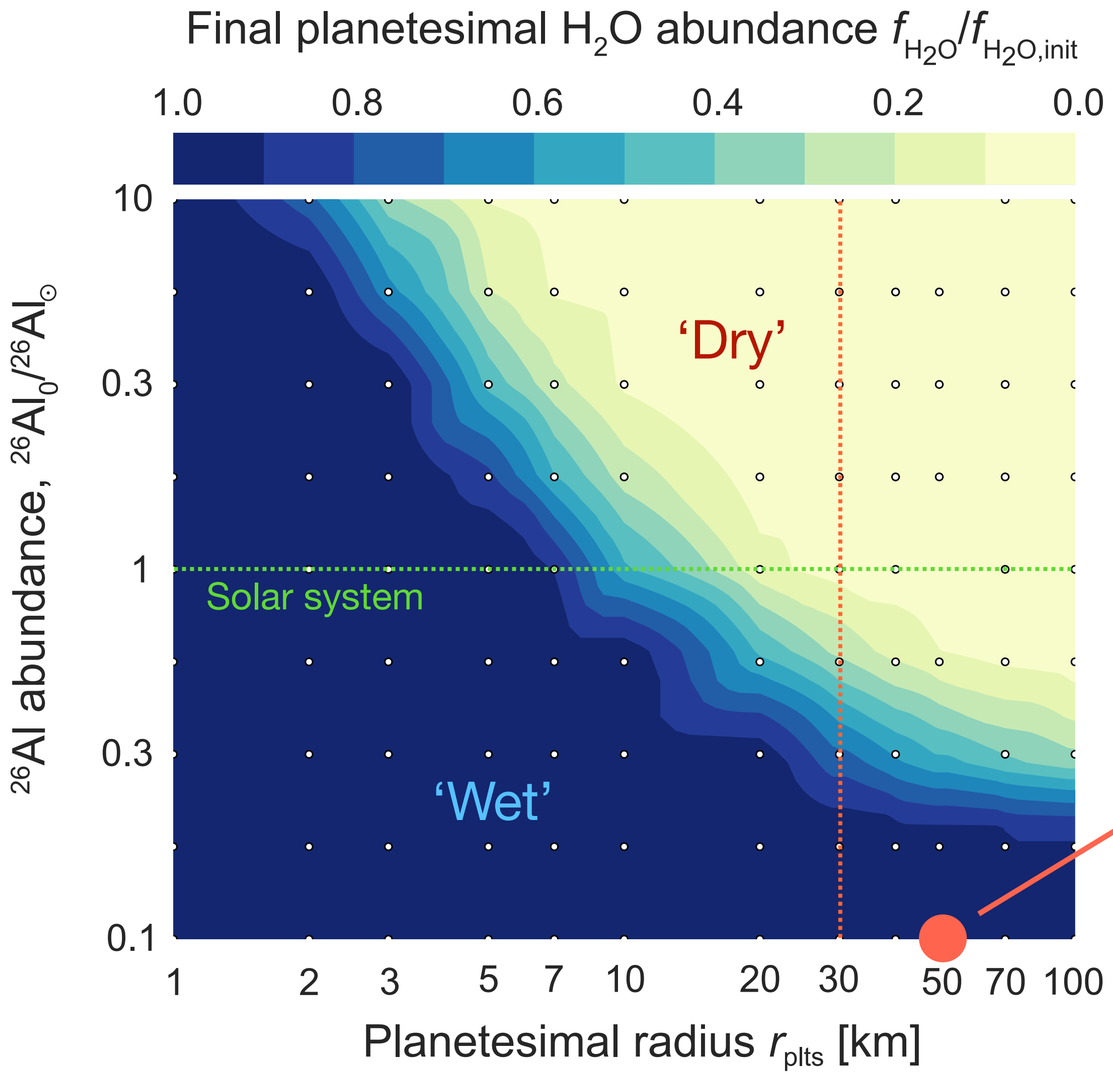


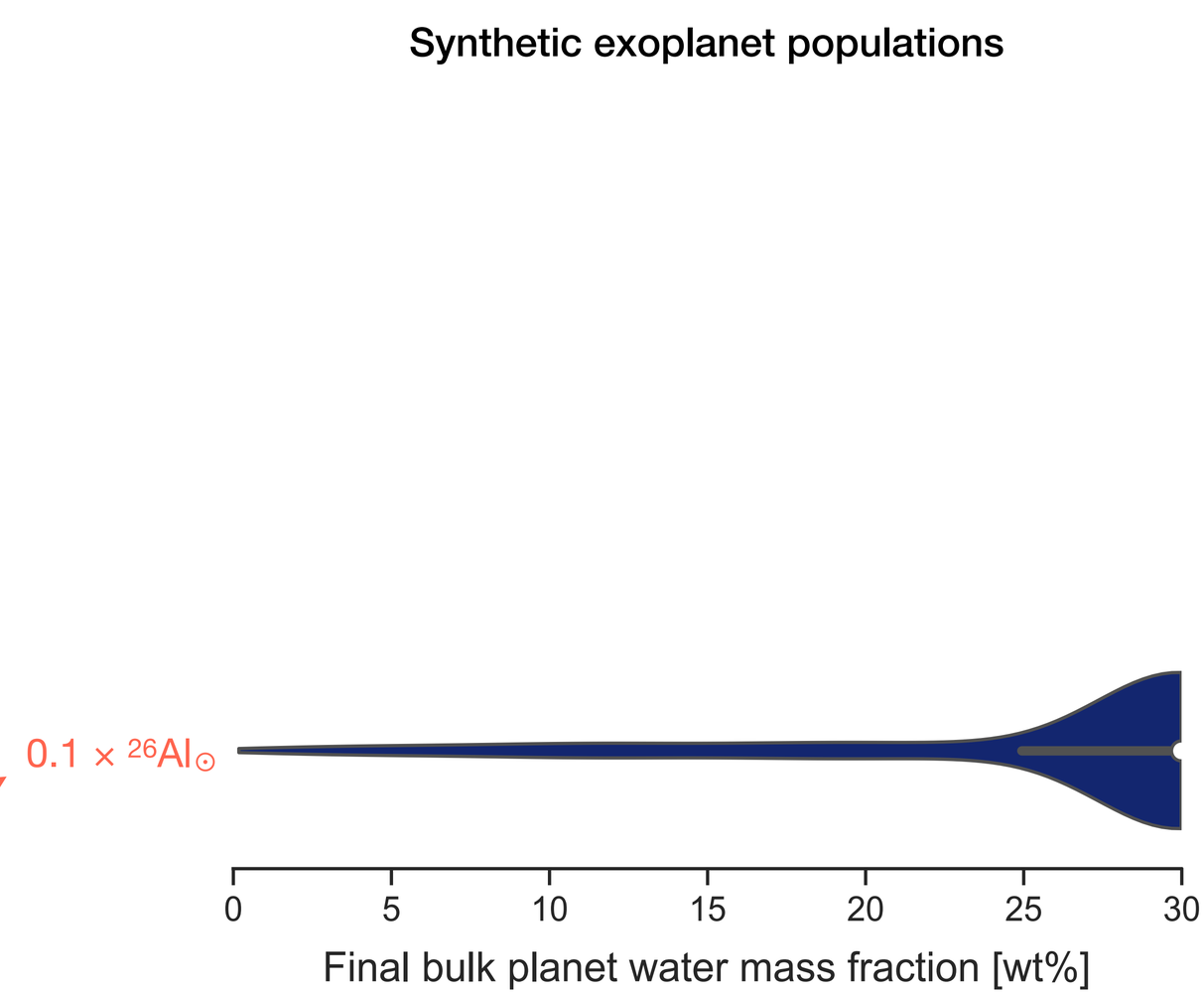
Accretion & decreasing water abundance in planetesimals

Lichtenberg+ 19b

Benz+ 14, PPVI

^{26}Al controls bulk water content

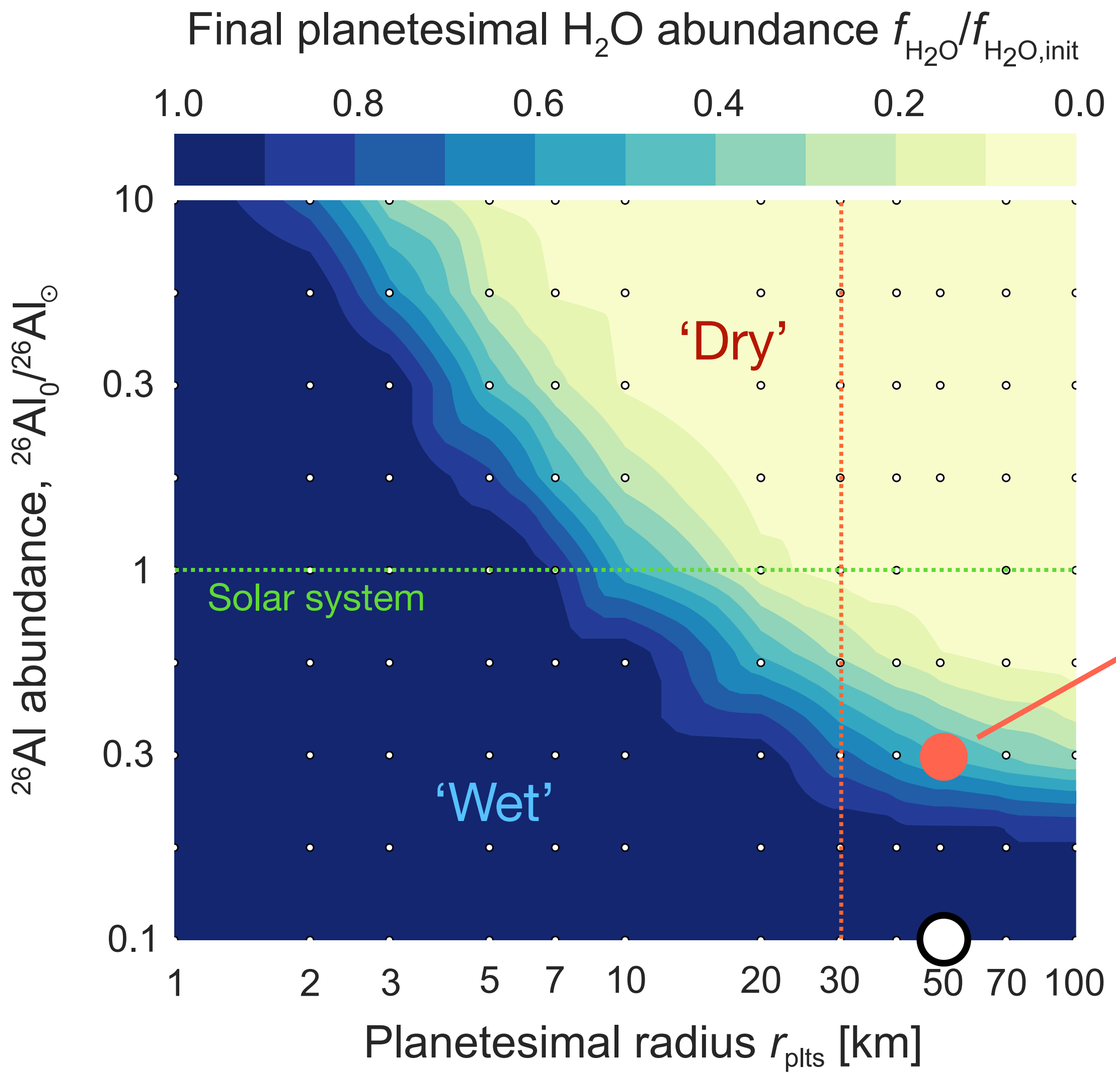


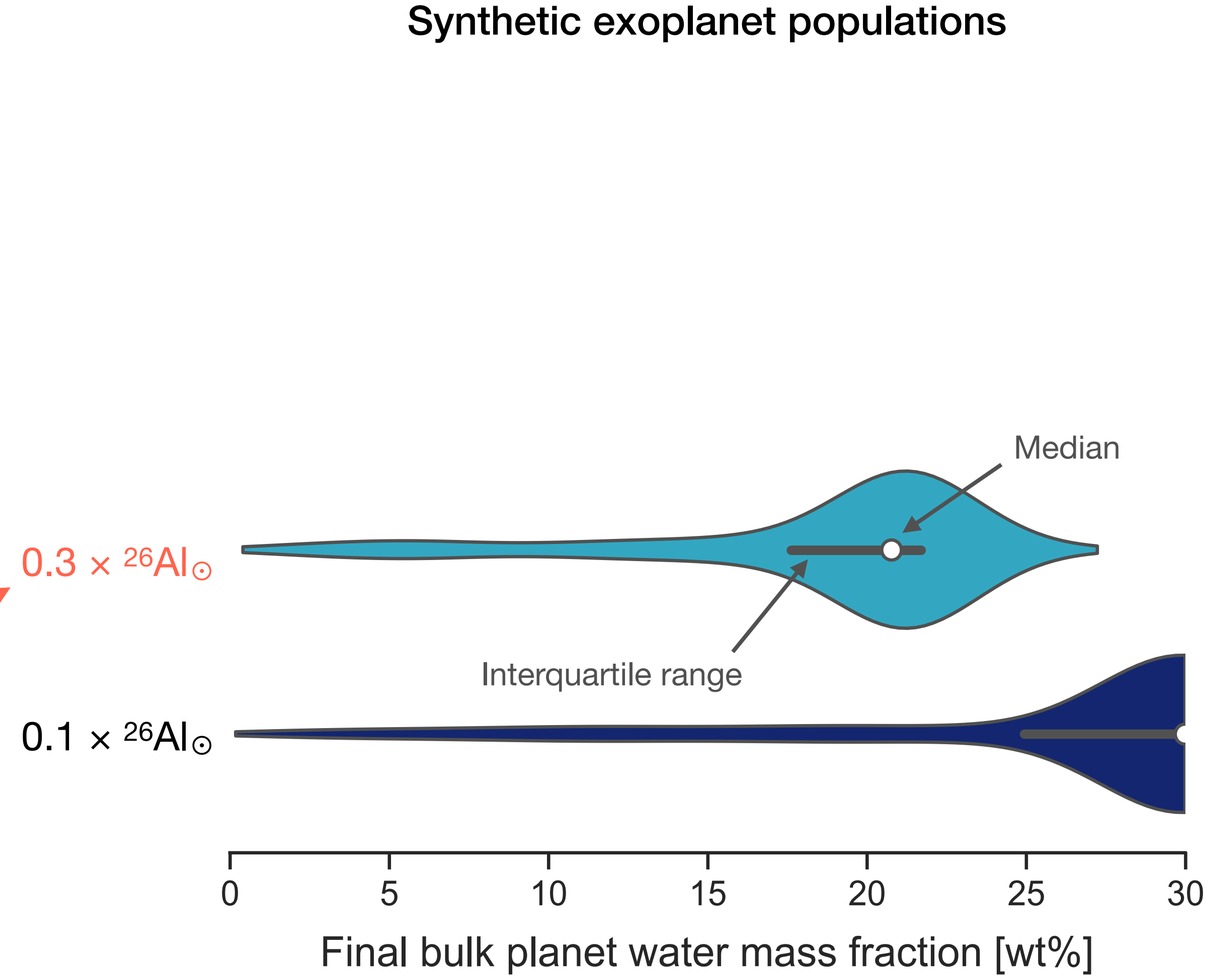


Lichtenberg+ 19b

$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

^{26}Al controls bulk water content

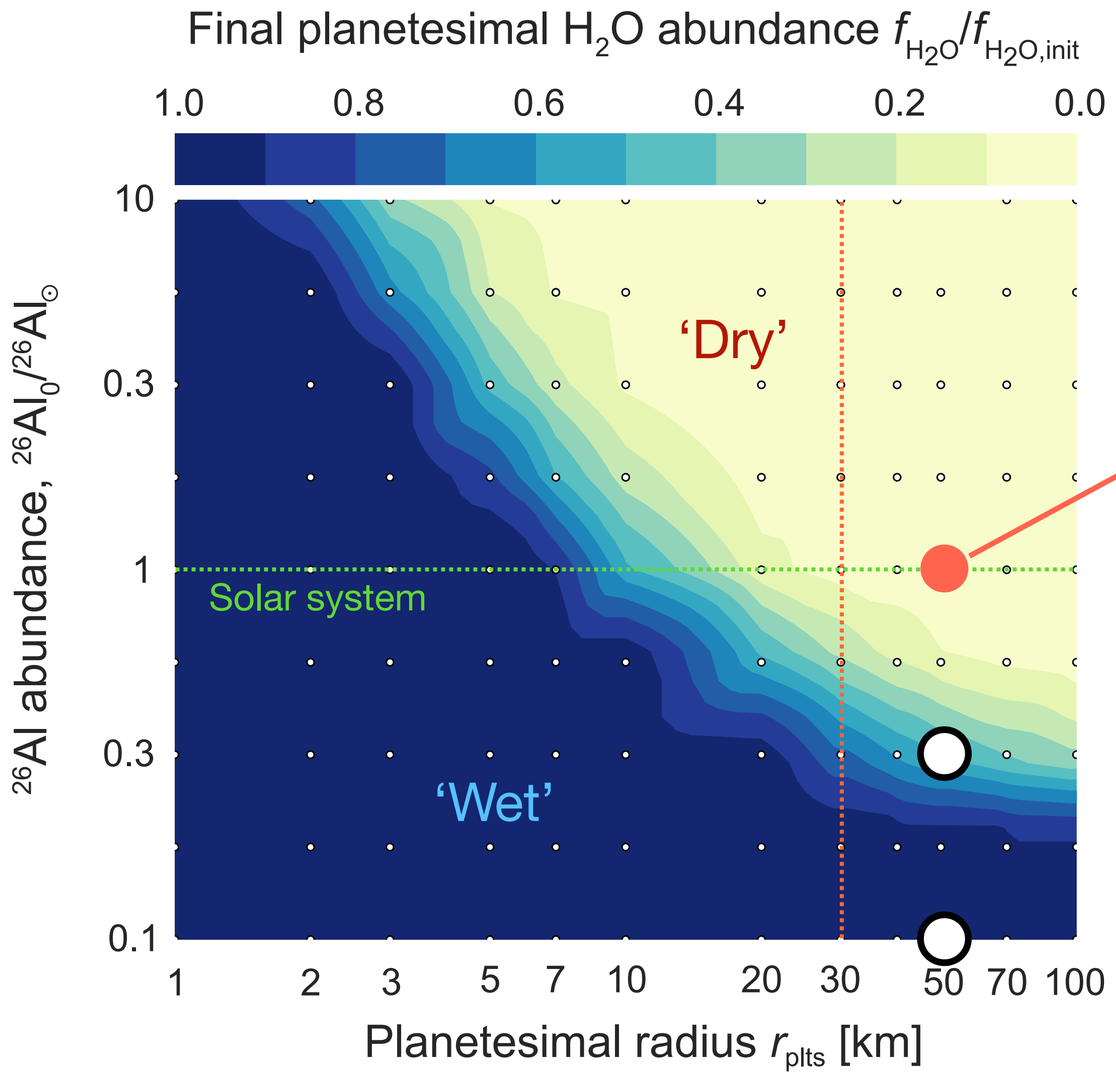


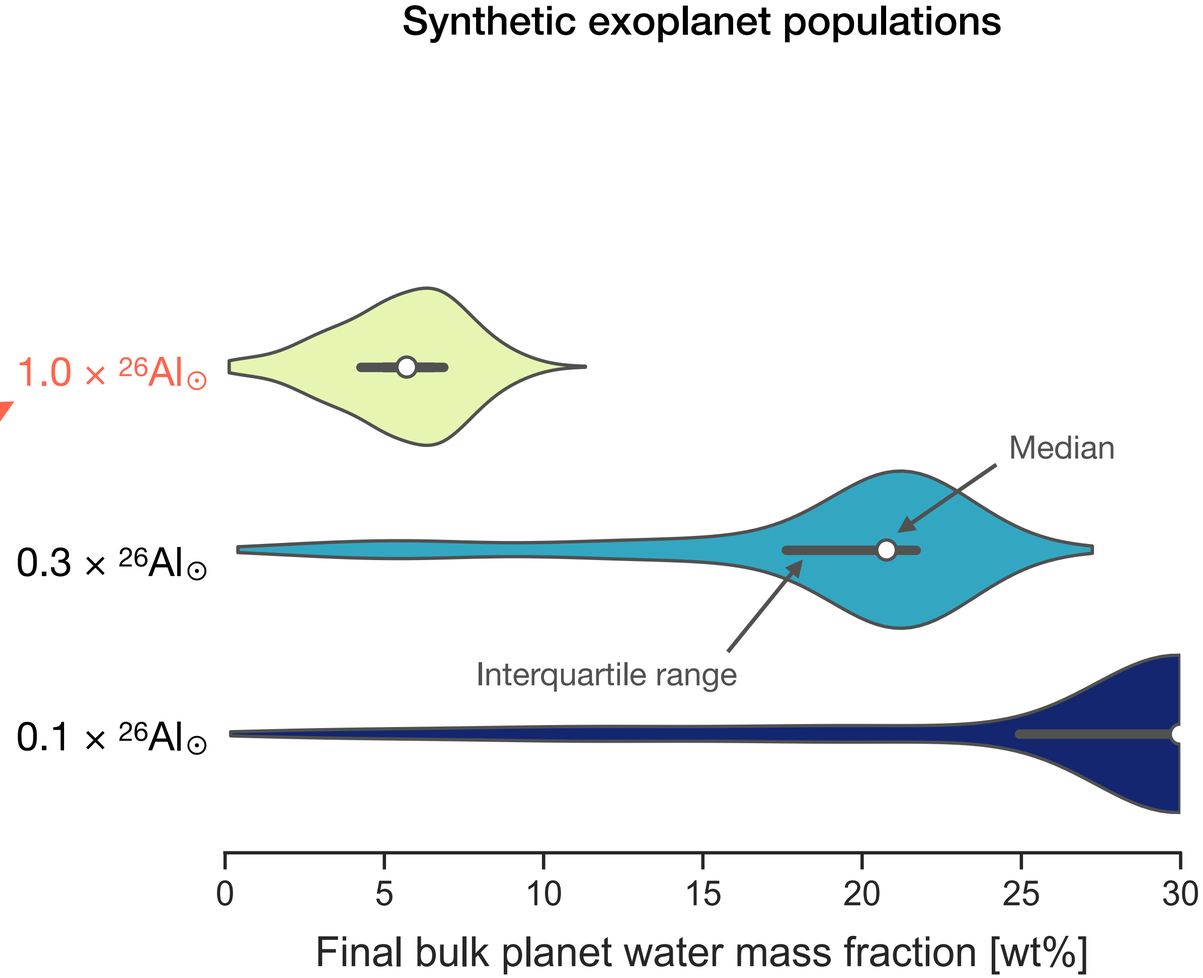


Lichtenberg+ 19b

$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

^{26}Al controls bulk water content

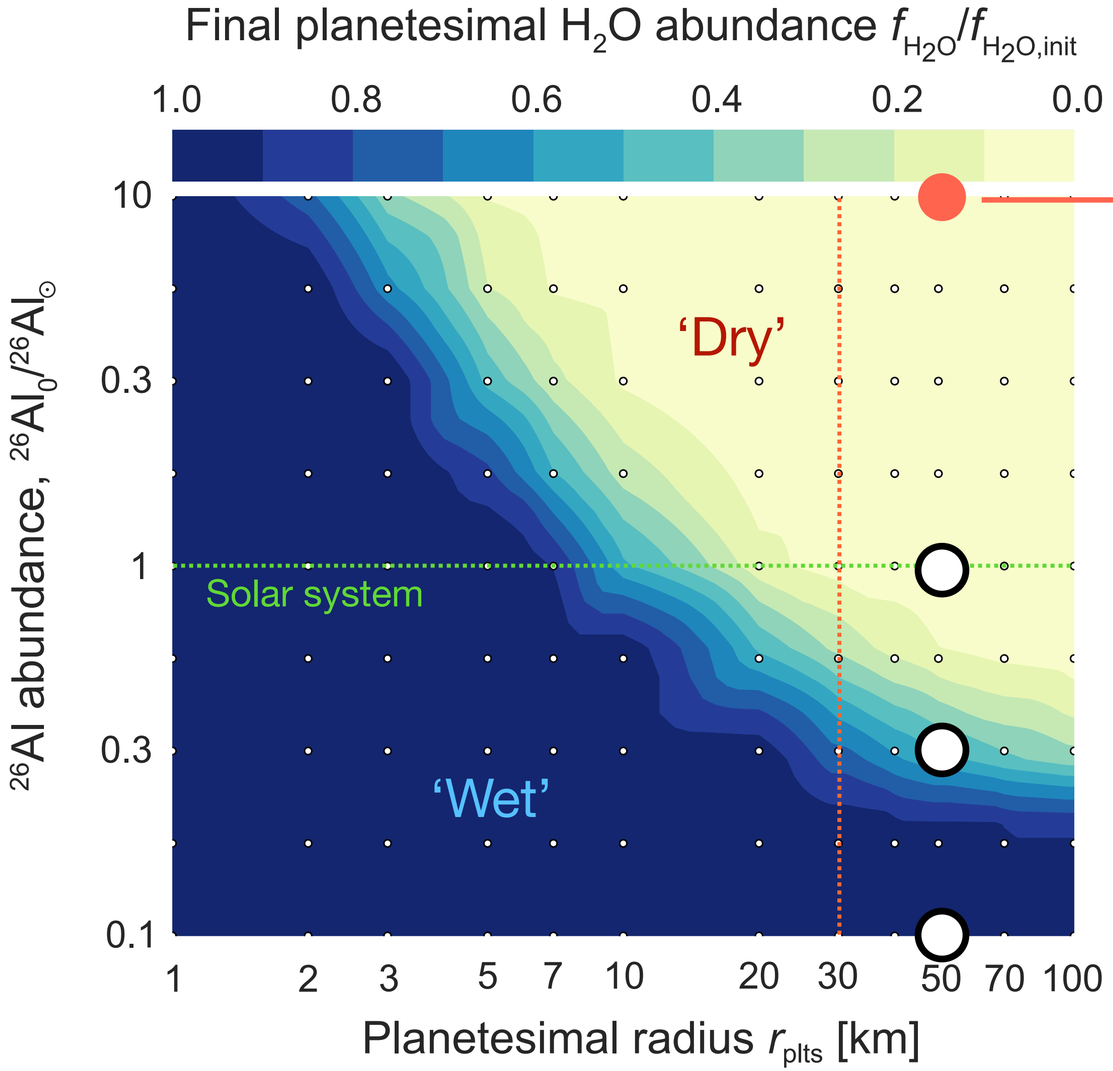


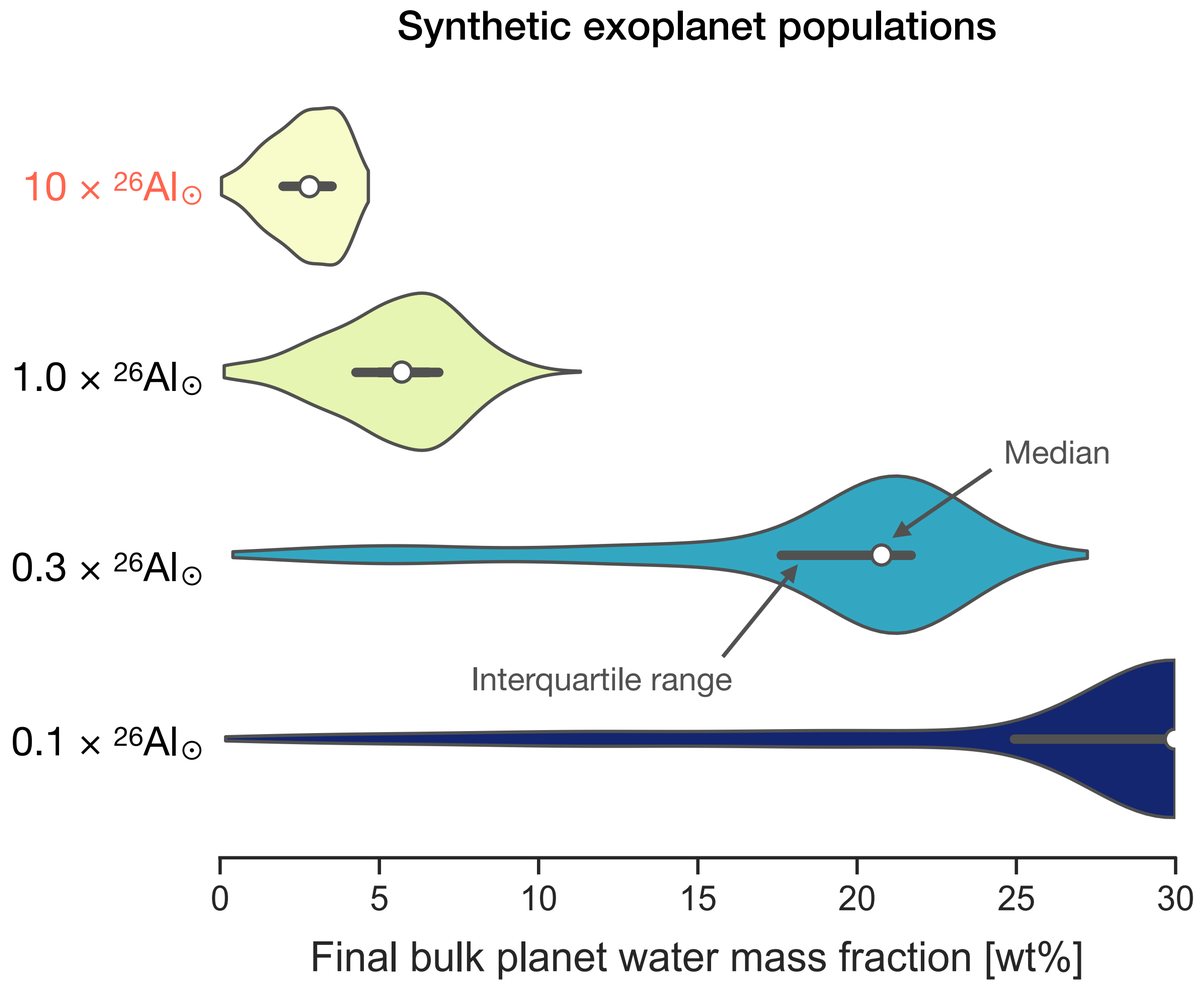


Lichtenberg+ 19b

$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

^{26}Al controls bulk water content

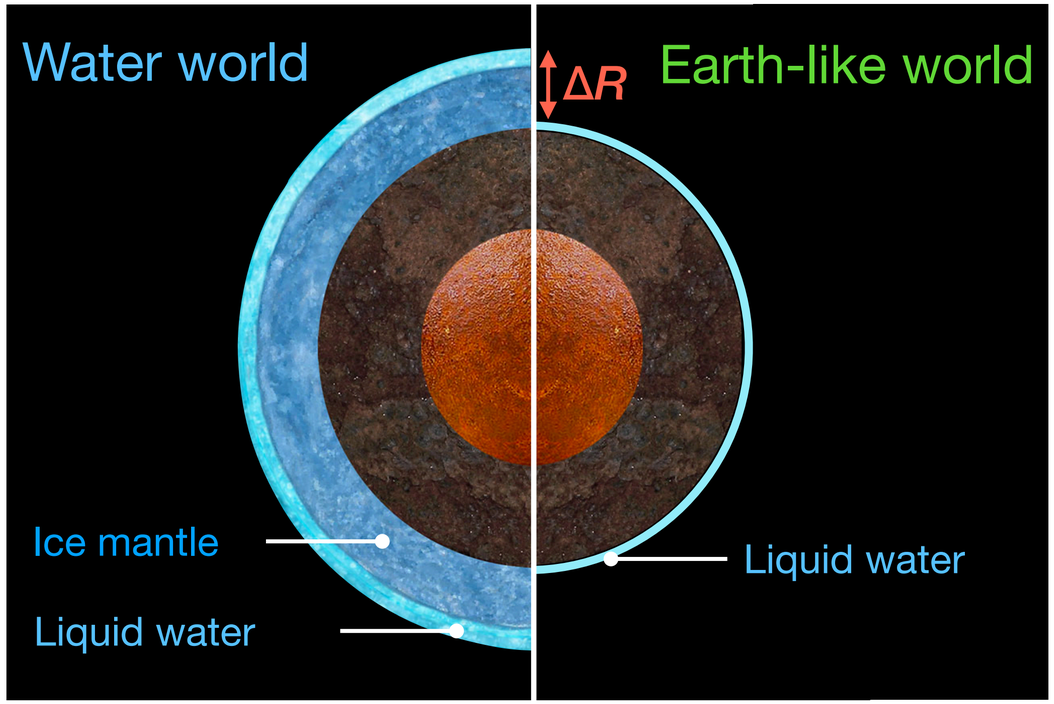


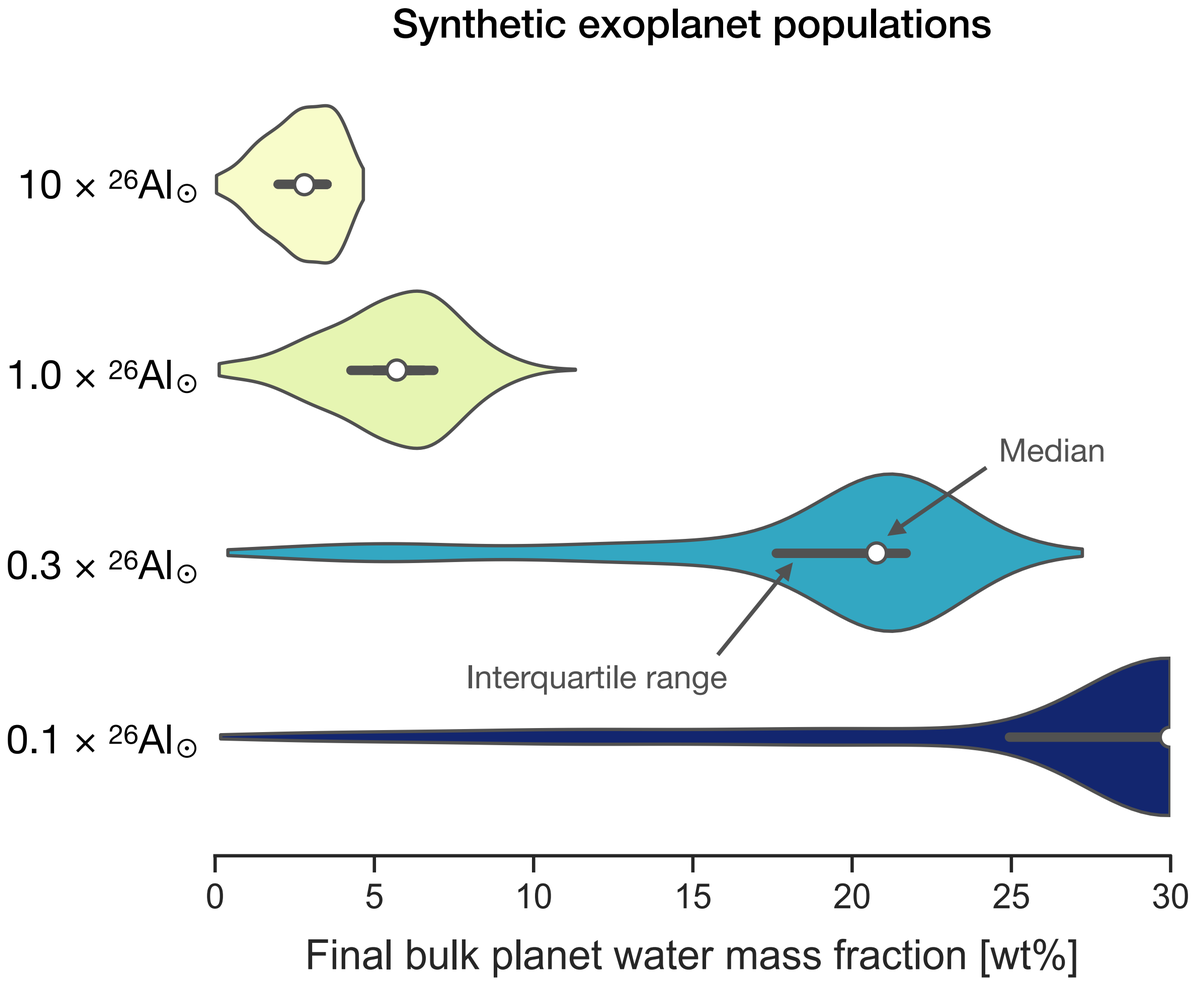


Lichtenberg+ 19b

$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

^{26}Al controls bulk water content

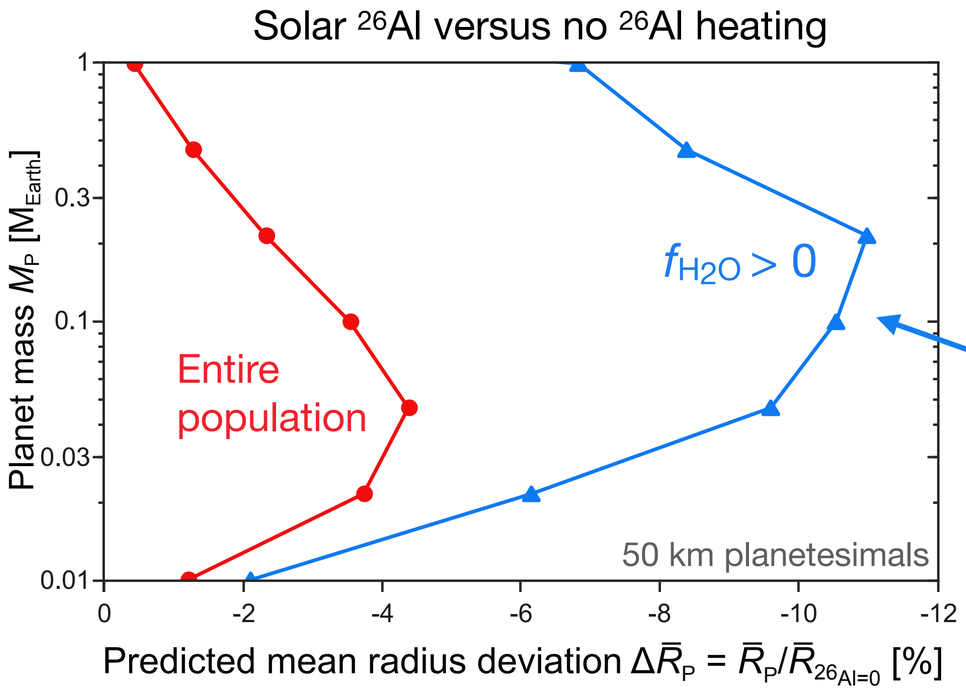


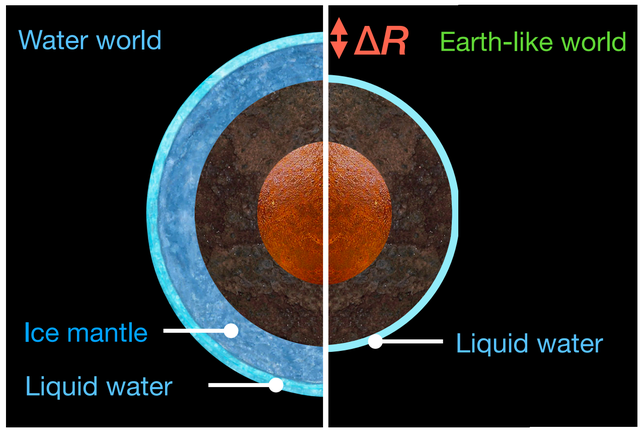


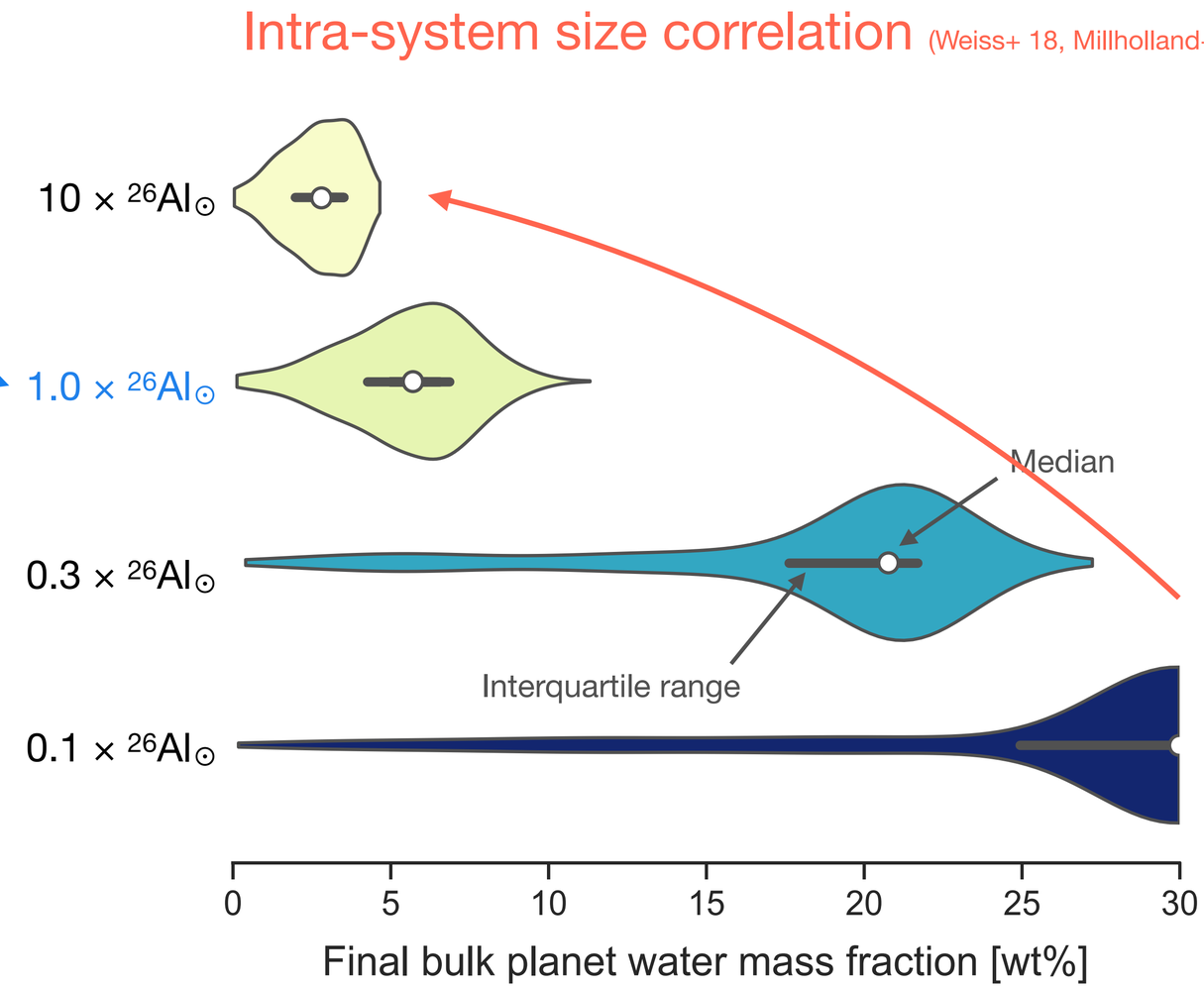
Leger+ 04, Sotin+ 07, Alibert 14, Noack+ 16/17

$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

^{26}Al alters exoplanet structure

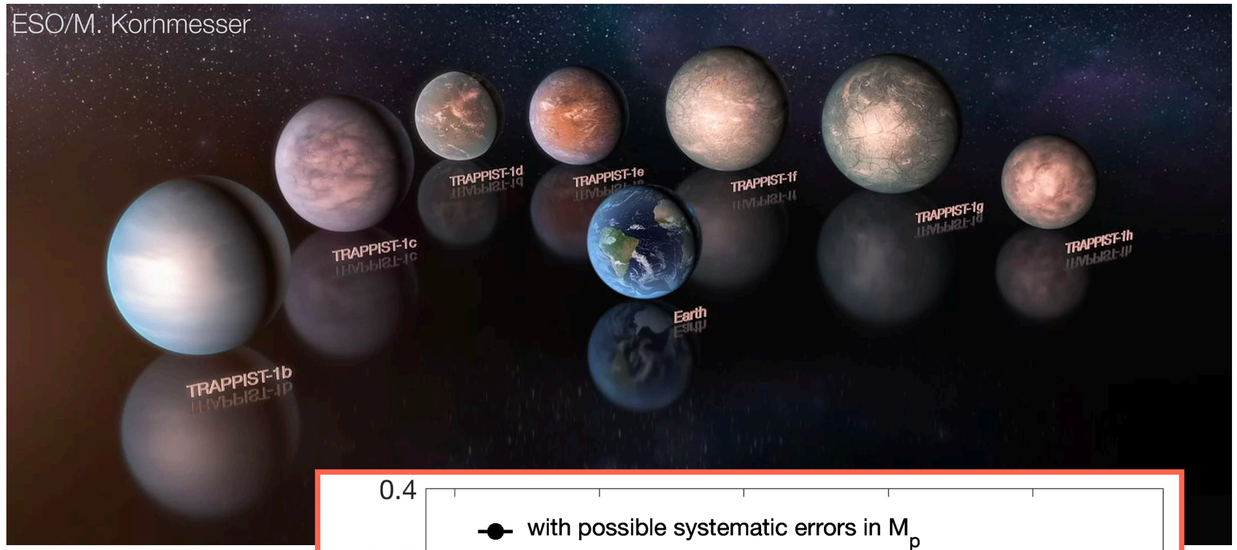


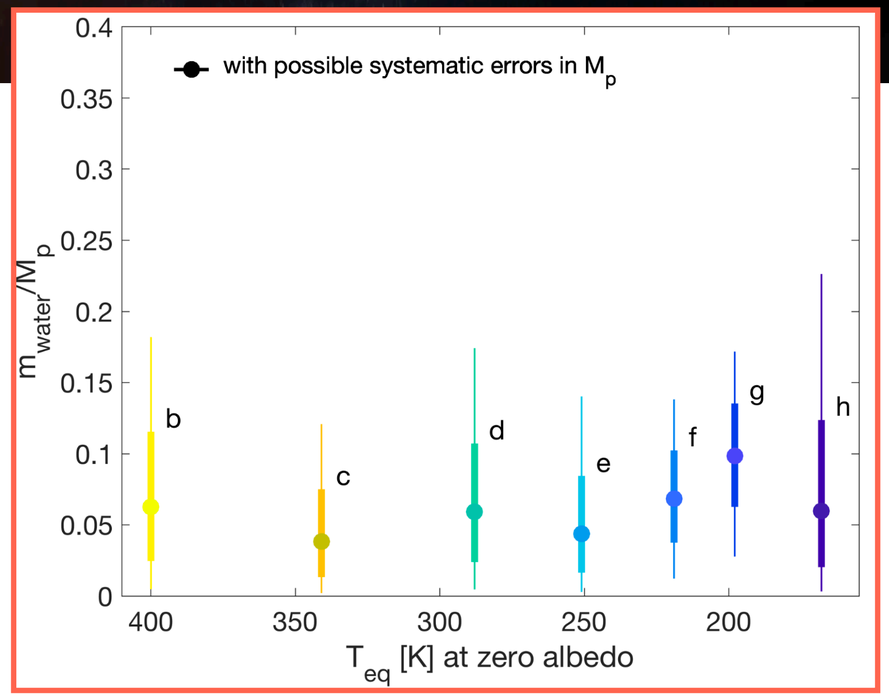




$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

^{26}Al shapes distribution systematics

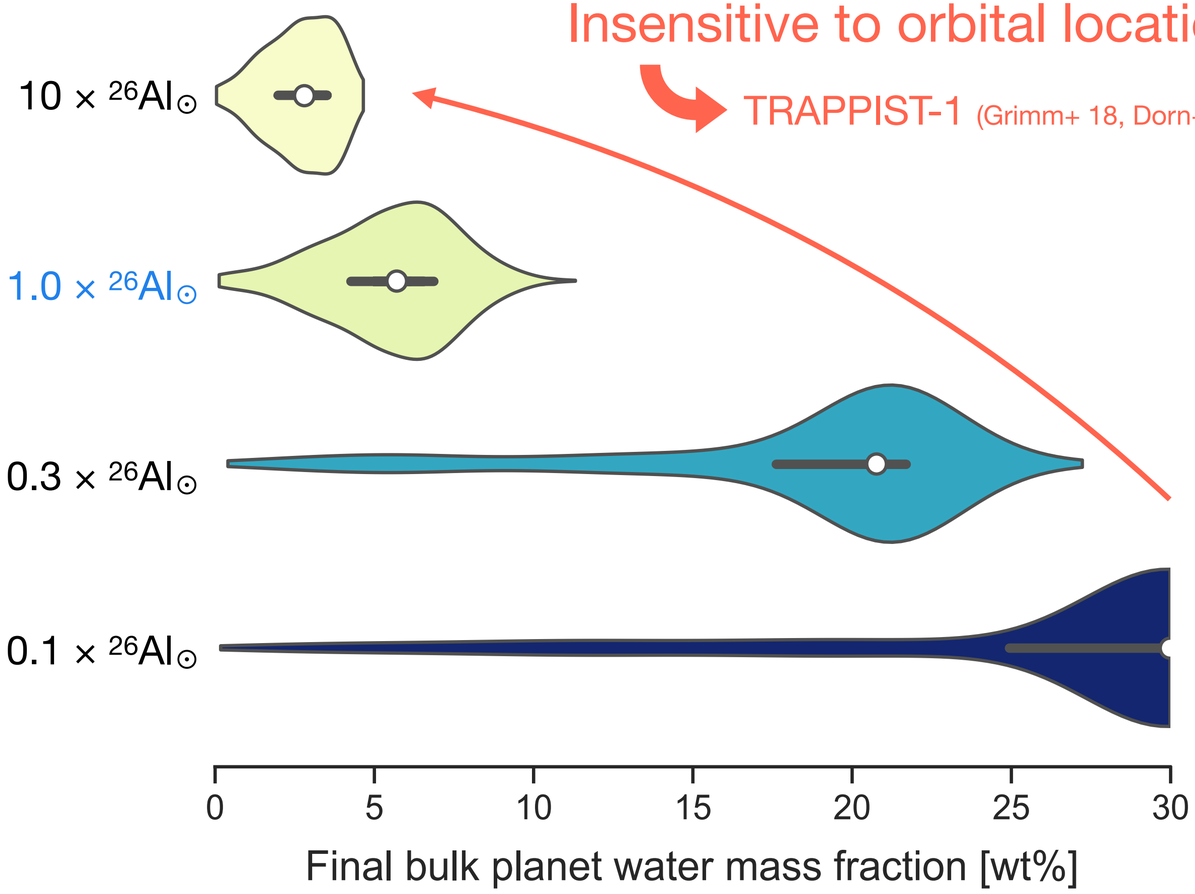




Intra-system size correlation (Weiss+ 18, Millholland+ 18)

Insensitive to orbital location

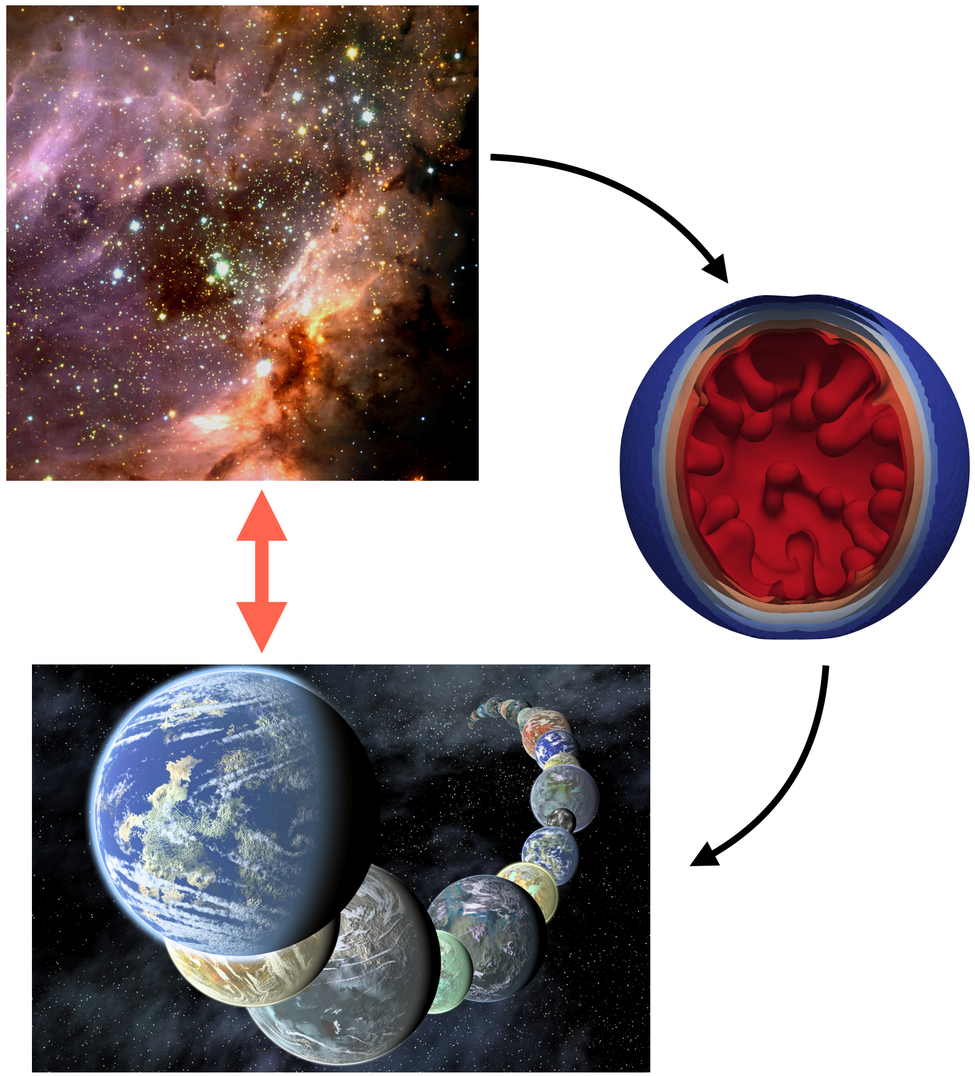
TRAPPIST-1 (Grimm+ 18, Dorn+ 18)



Dorn+ 18

$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

Geophysical evolution of forming rocky planets



- Geophysical evolution links studies of early solar system and accretion to exoplanets
  - ➡ Volatile loss & differentiation in planetesimals
  - ➡ Systematically shapes planet composition
- Planetary system water budget dichotomy from ^{26}Al:
  - ➡ Not-enriched systems form ocean worlds
  - ➡ Enriched systems form water-poor planets
- ◉ Statistically traceable with future transit missions?

A water budget dichotomy of rocky protoplanets from ^{26}Al-heating
Lichtenberg, Golabek, Burn, Meyer, Alibert, Gerya, Mordasini (2019)