A water budget dichotomy of rocky protoplanets from ^{26}Al-heating

Tim Lichtenberg

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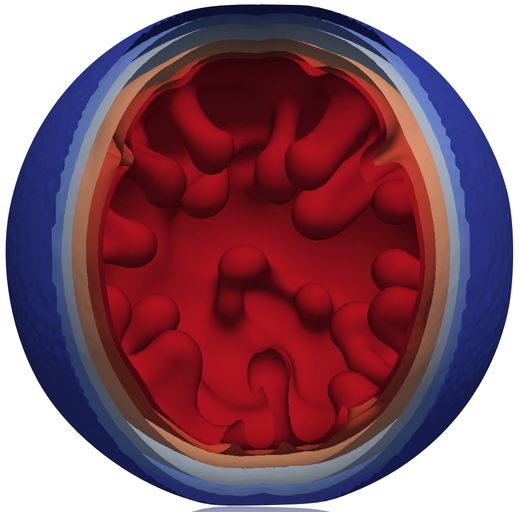
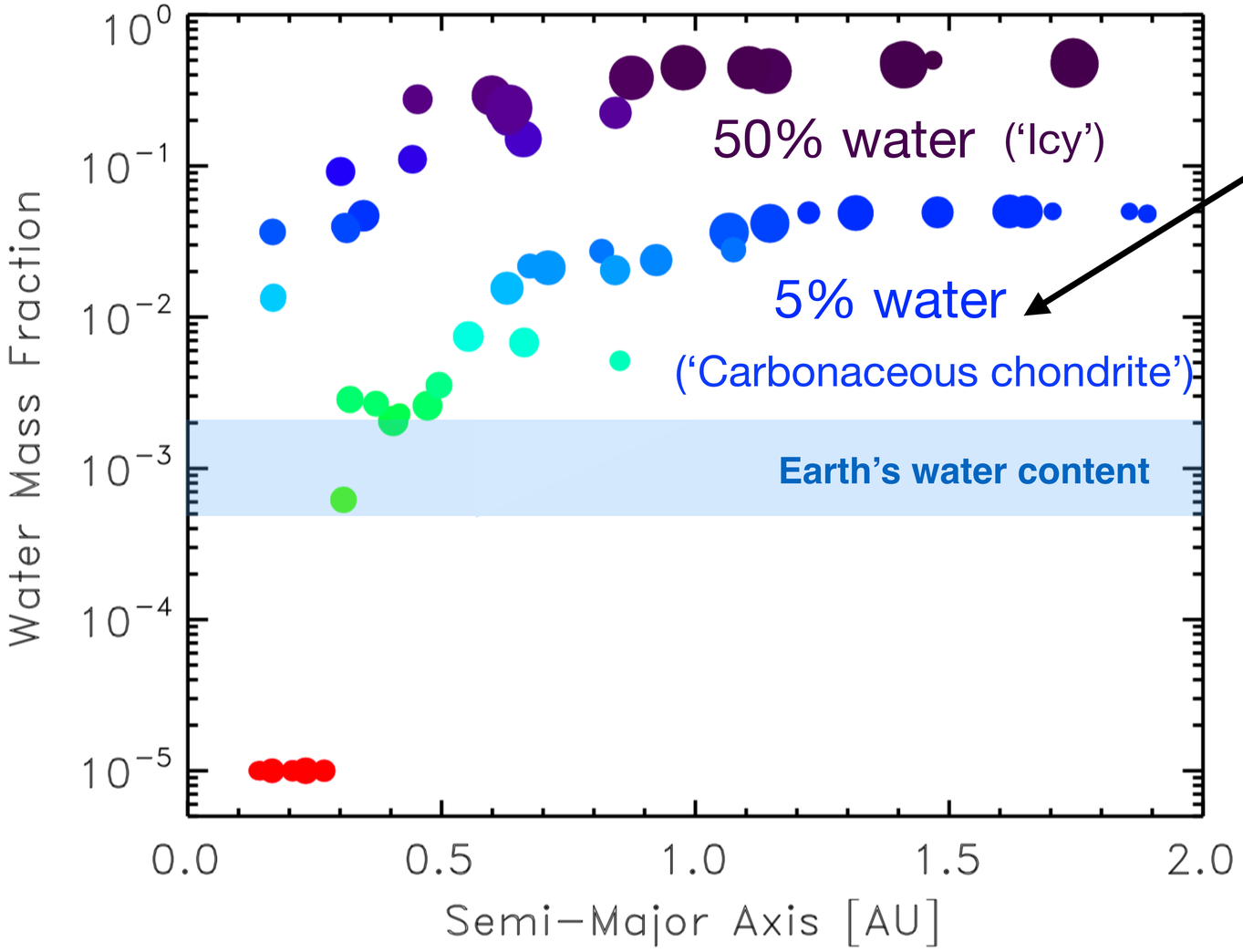
Taras Gerya (ETH Zürich)
Remo Burn (U Bern)
Yann Alibert (U Bern / CSH)
Christoph Mordasini (U Bern / CSH)

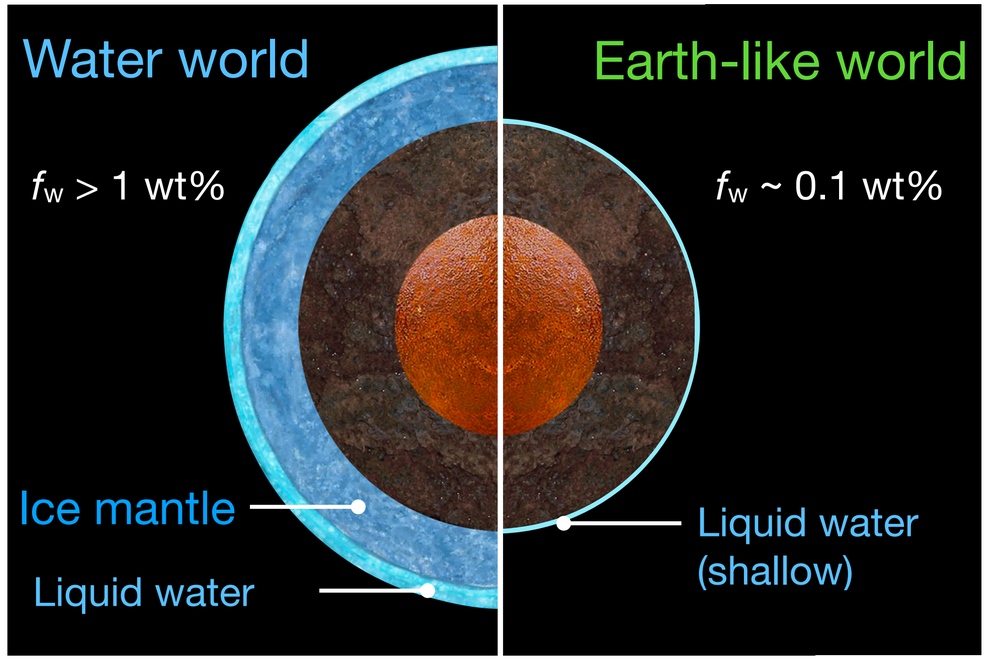


Nature Astronomy (2019), ***arXiv:1902.04026***

Plethora of water worlds



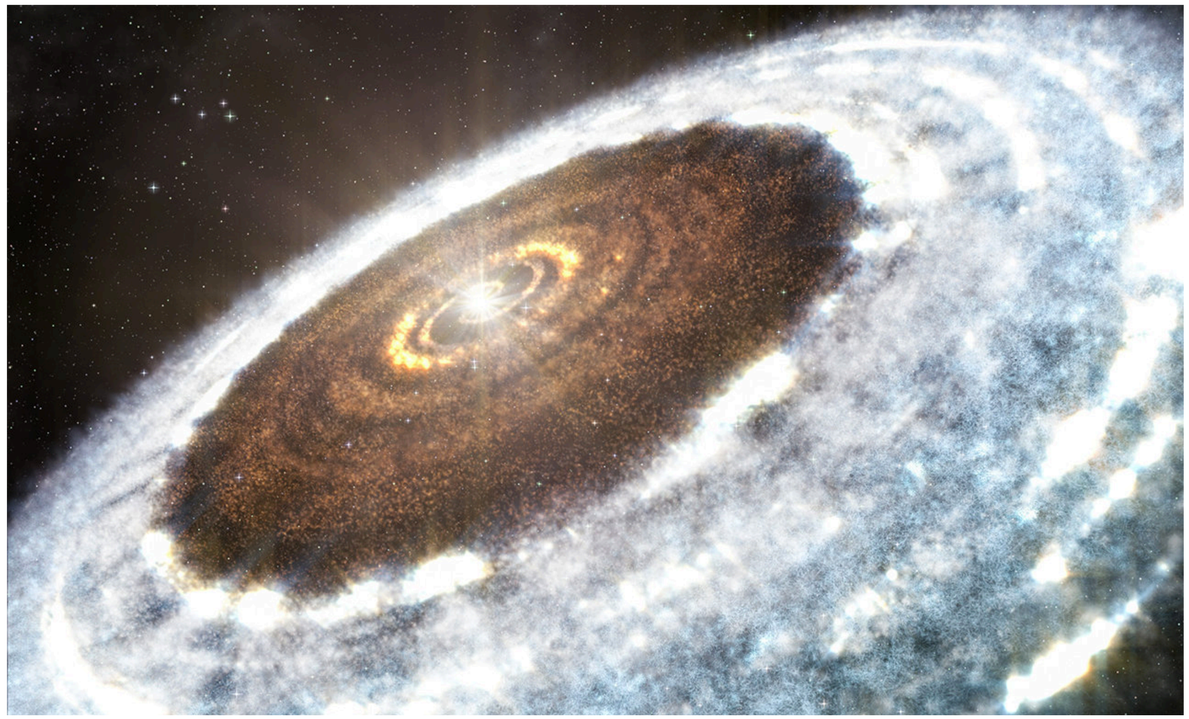
Planetesimal water content [wt%]

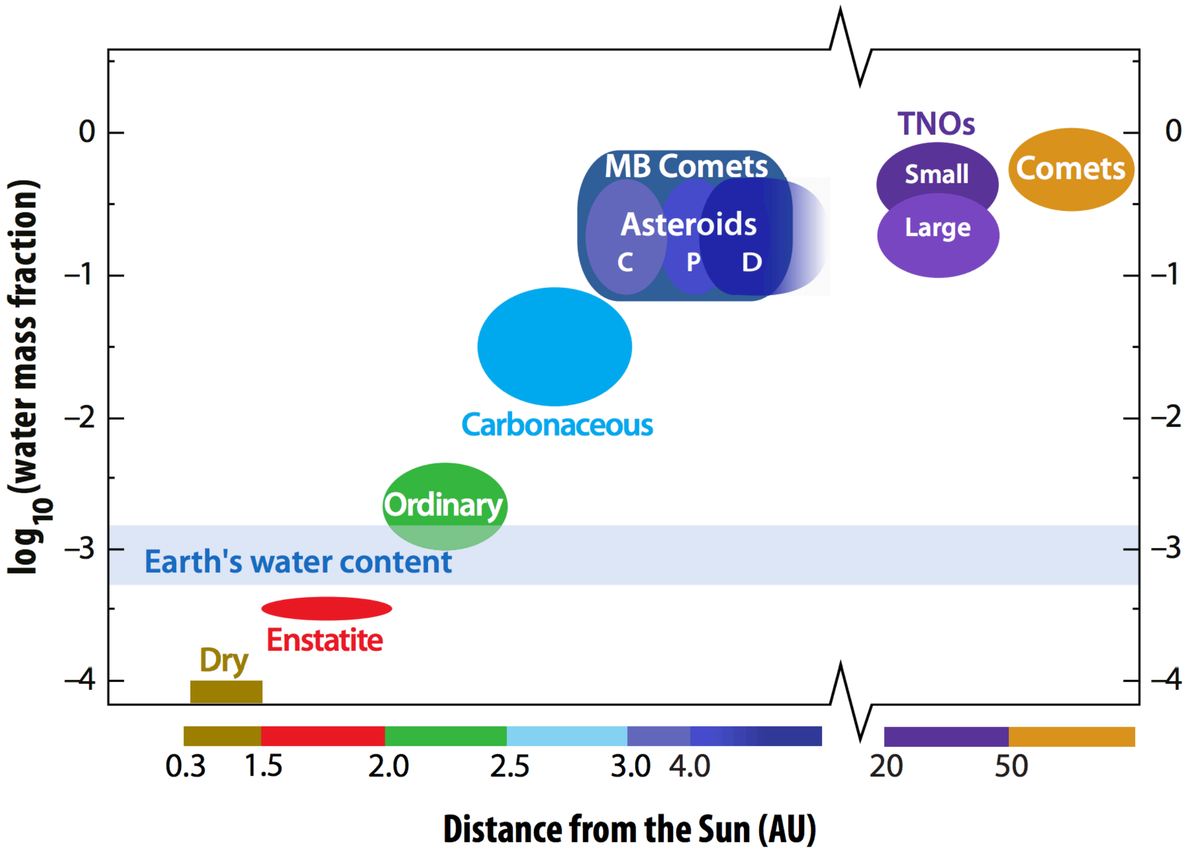


Ciesla+ 15, Mulders+ 15

e.g., Kuchner 03, Leger+ 04, Sotin+ 07, Tian & Ida 15, Noack+ 16/17, Alibert & Benz 17, Simpson 17, Ramirez & Levi 18, Zain+ 18, Izidoro+ 19

Water carrier during accretion?

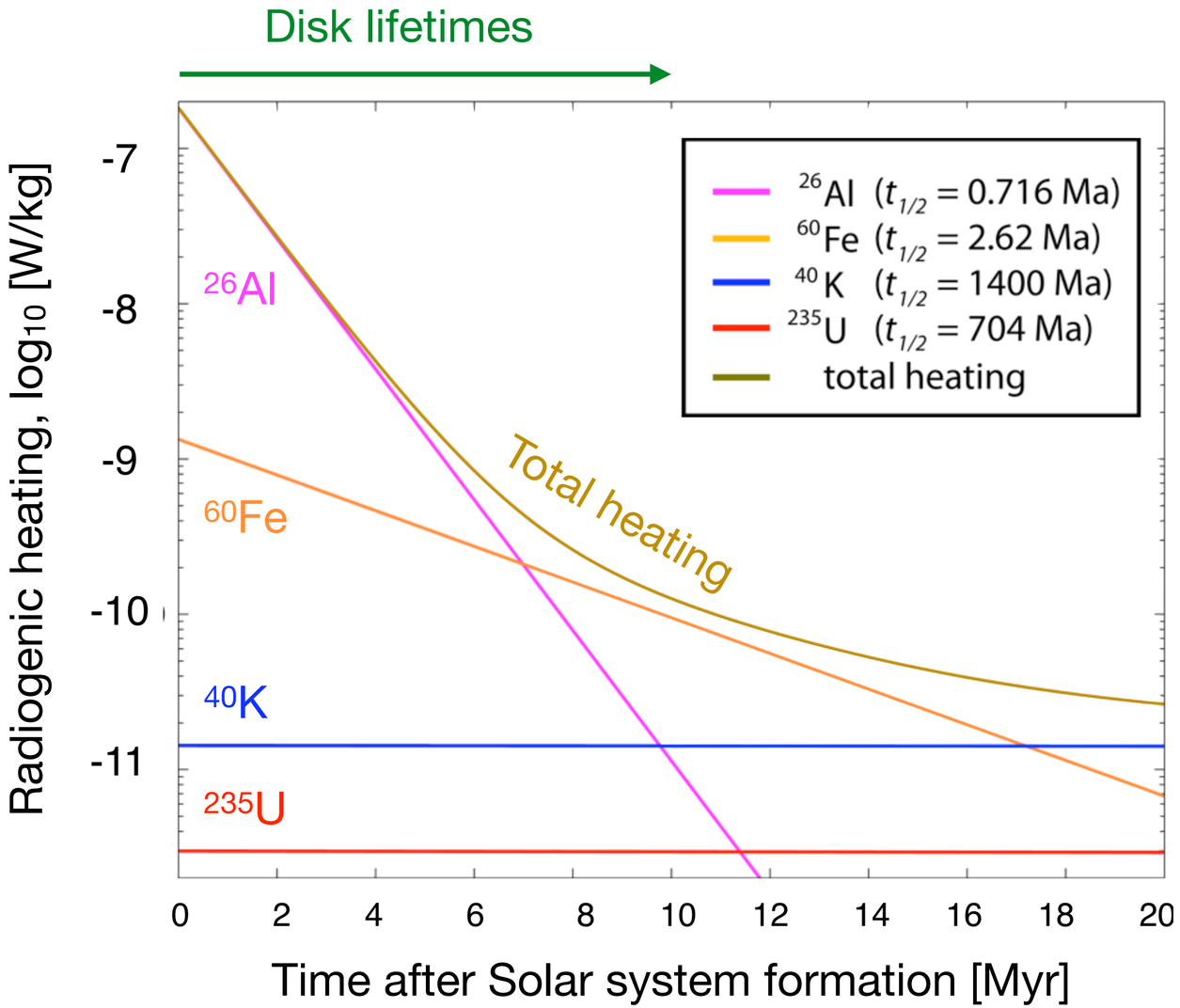


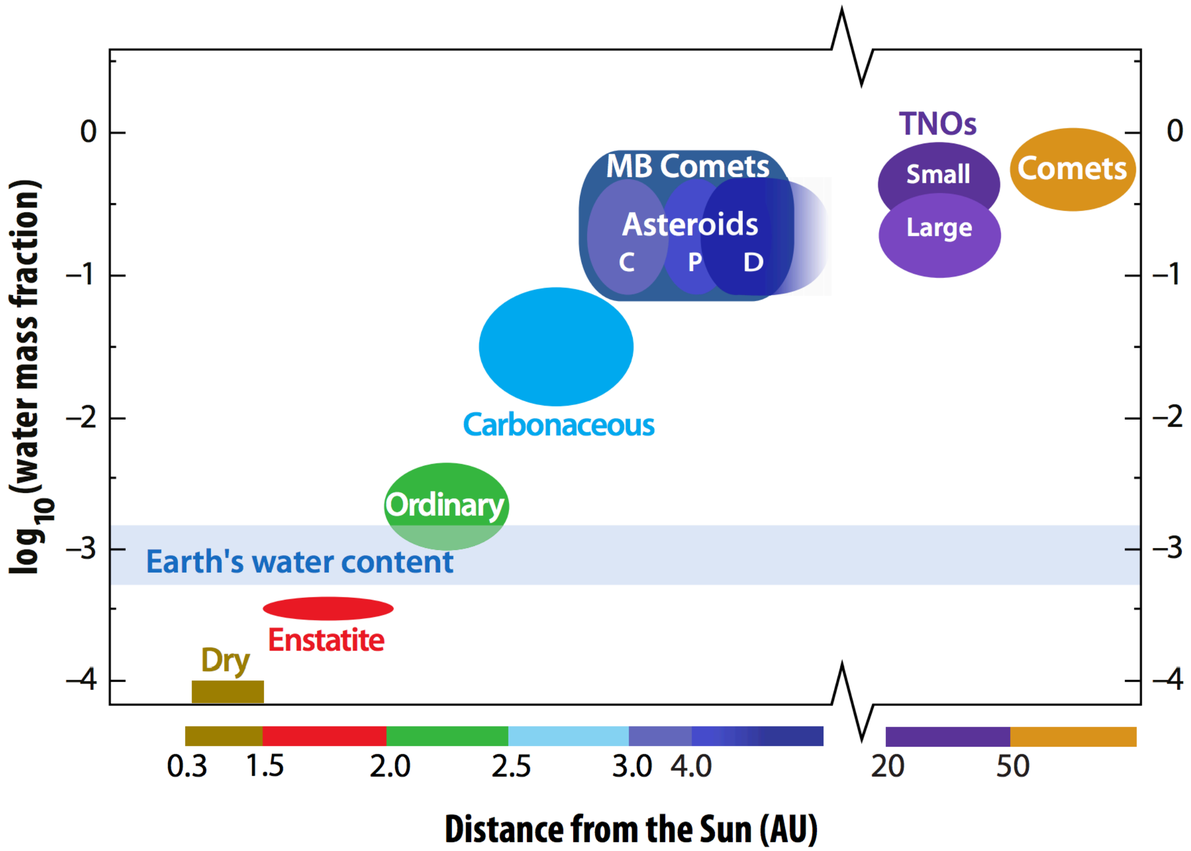


A. Angelich (NRAO/AUI/NSF)/ALMA (ESO/NAOJ/NRAO)

van Dishoeck+ 14, PPVI

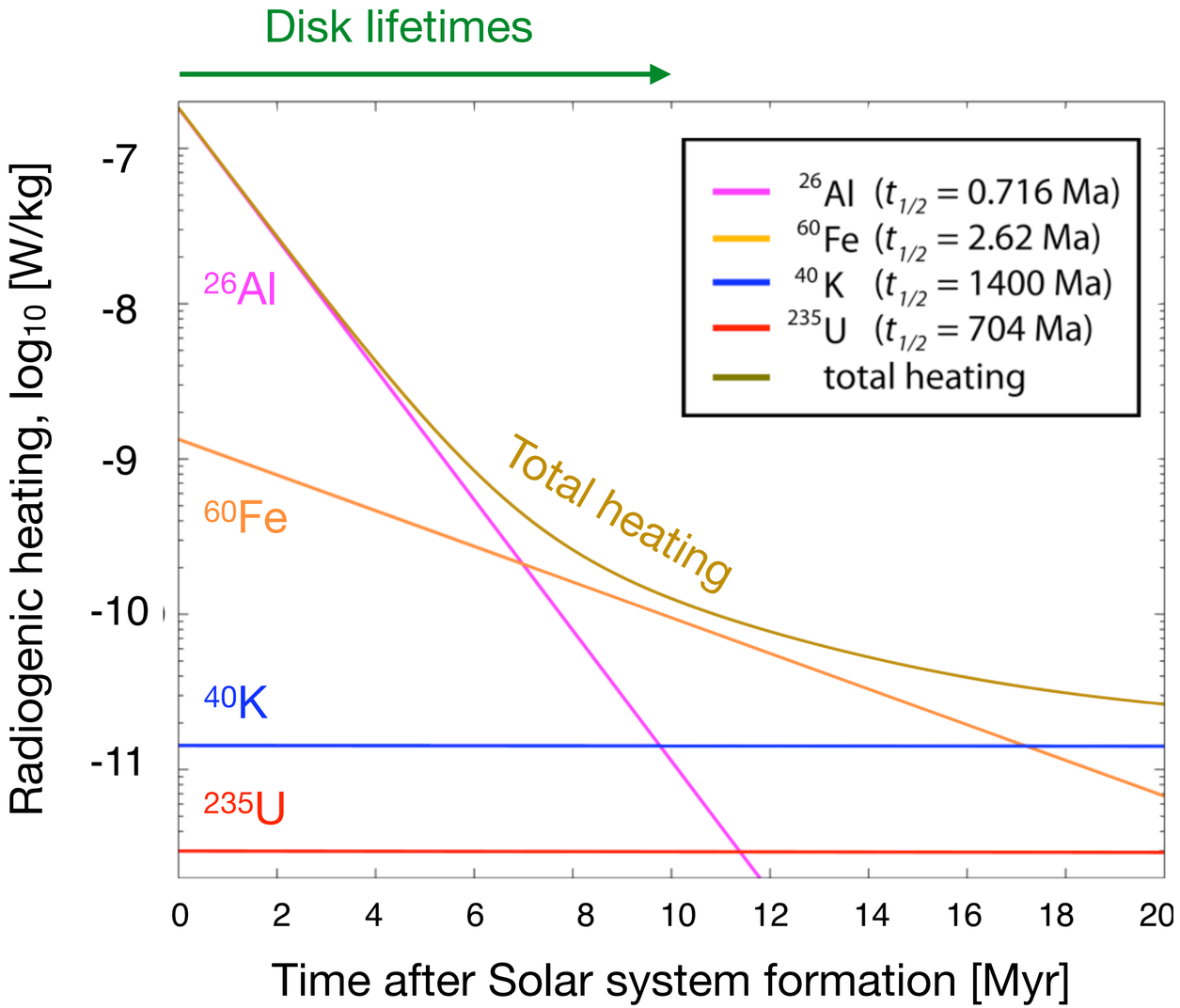
Radiogenic heating in early Solar System

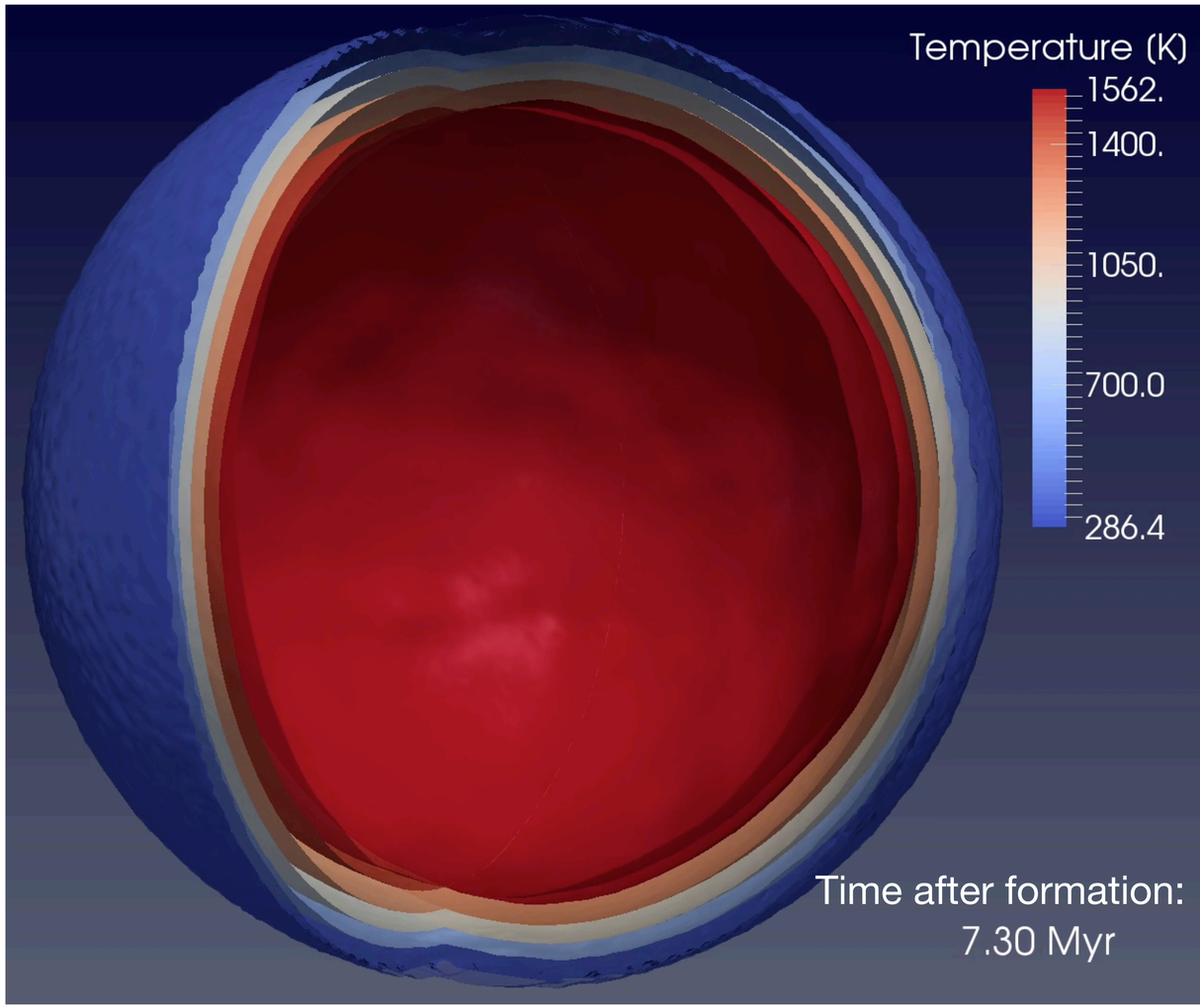




van Dishoeck+ 14, PPVI

Geodynamic evolution of planetesimal interiors

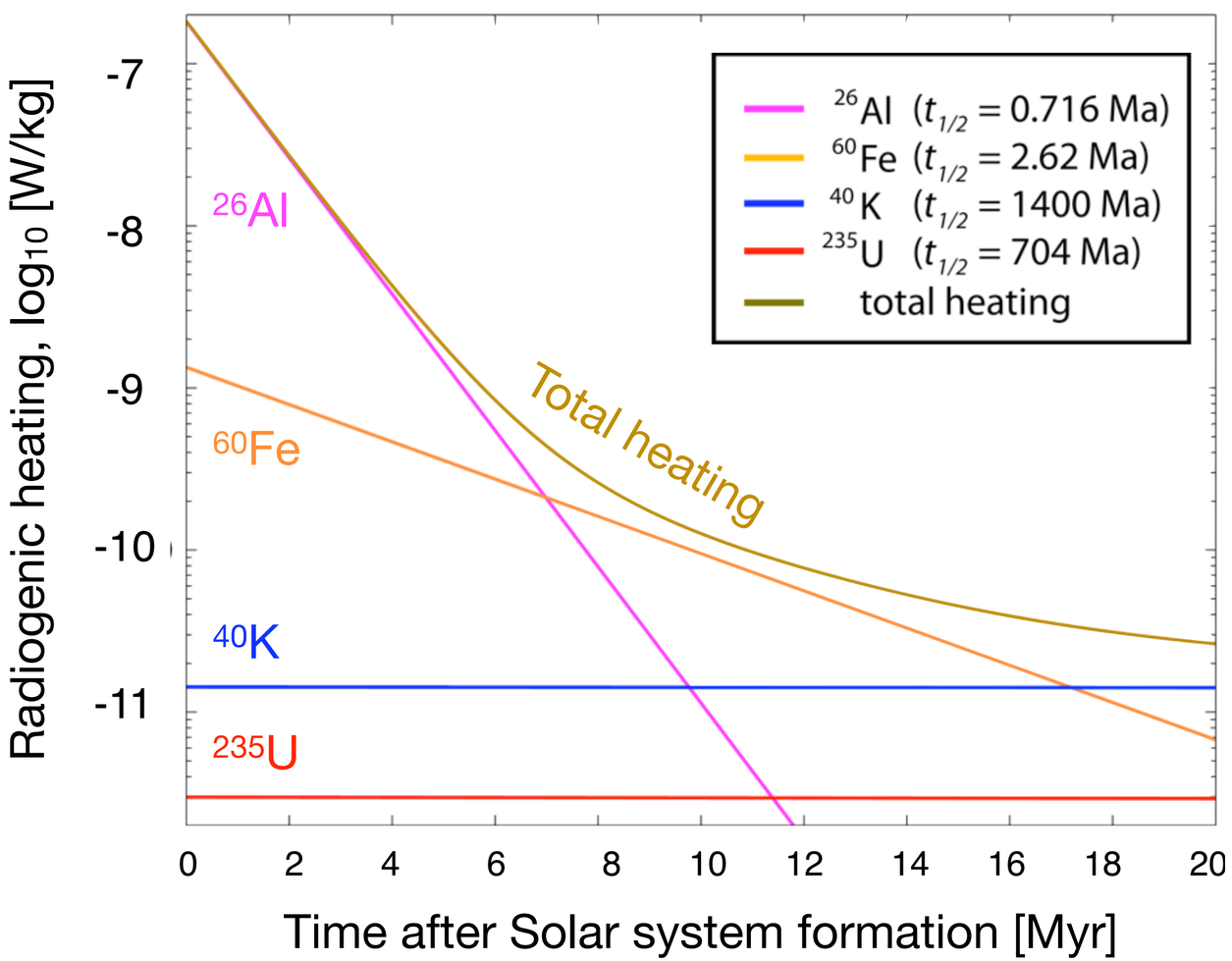




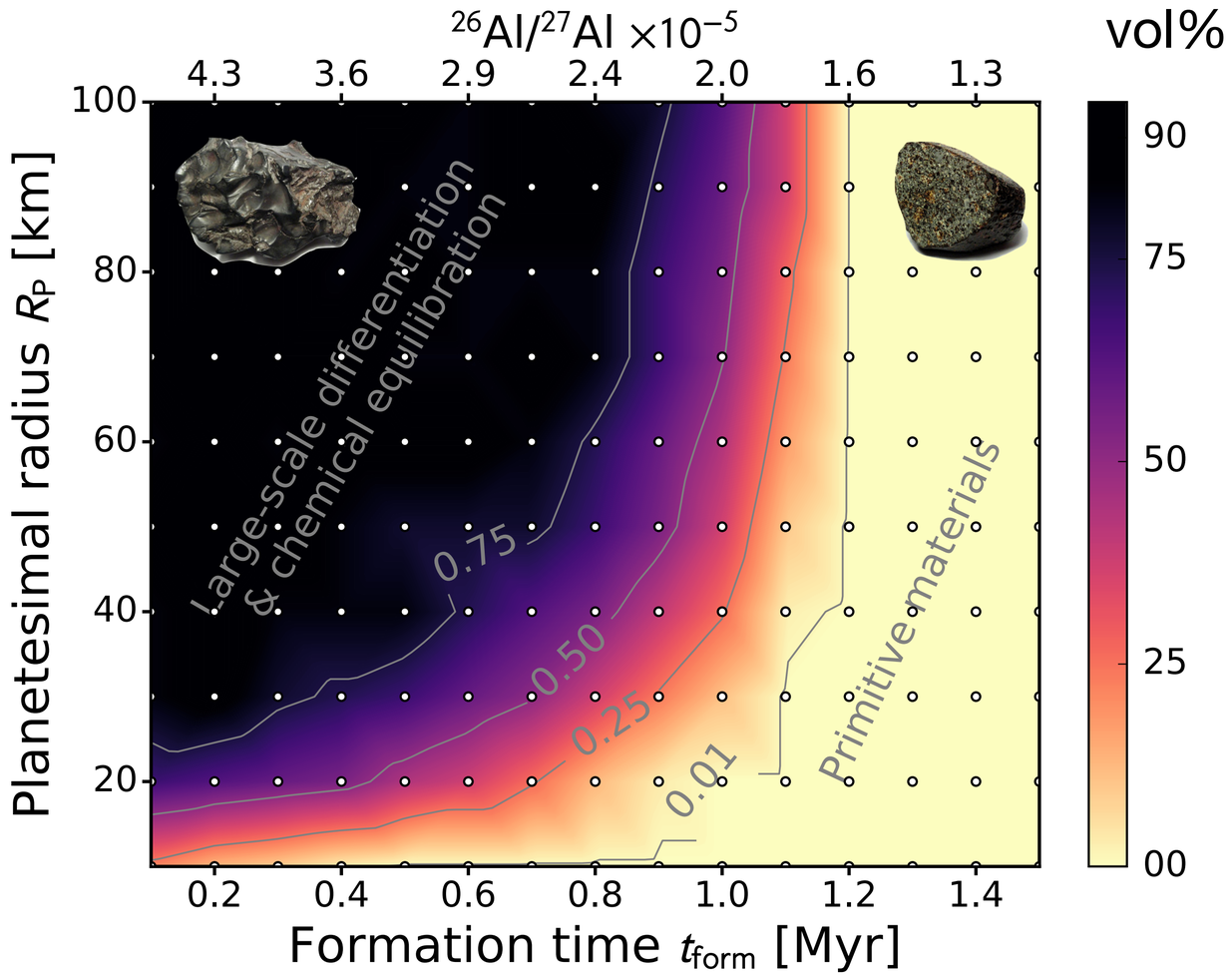
Lichtenberg+ 16a,18,19a,b

Geodynamic evolution of planetesimal interiors

Disk lifetimes

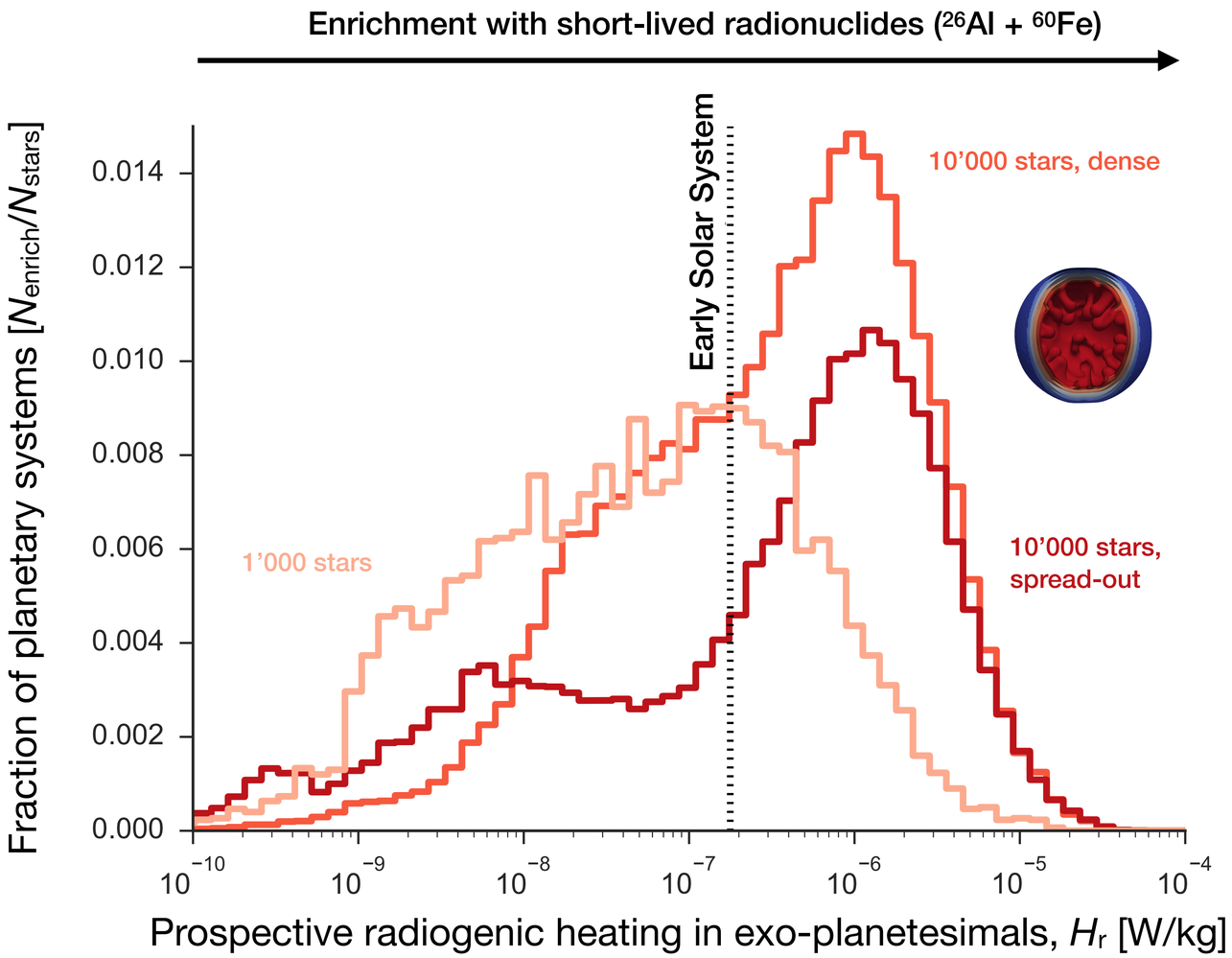


Magma generation



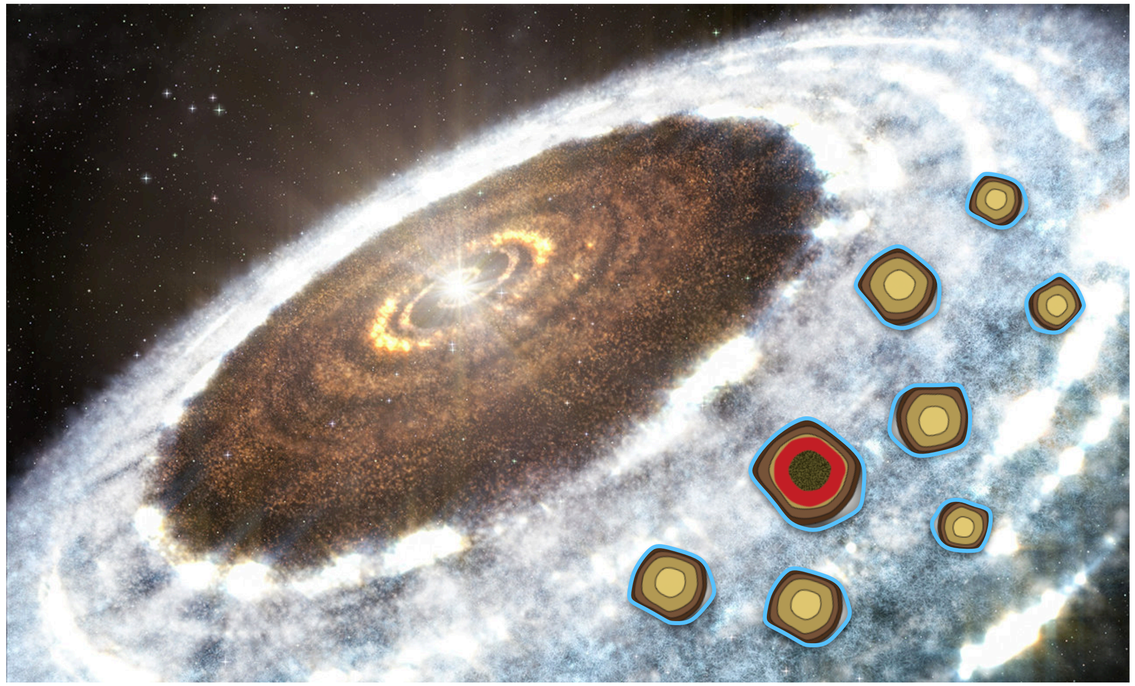
Lichtenberg+ 18, 19a

Planet accretion altered by ^{26}Al



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

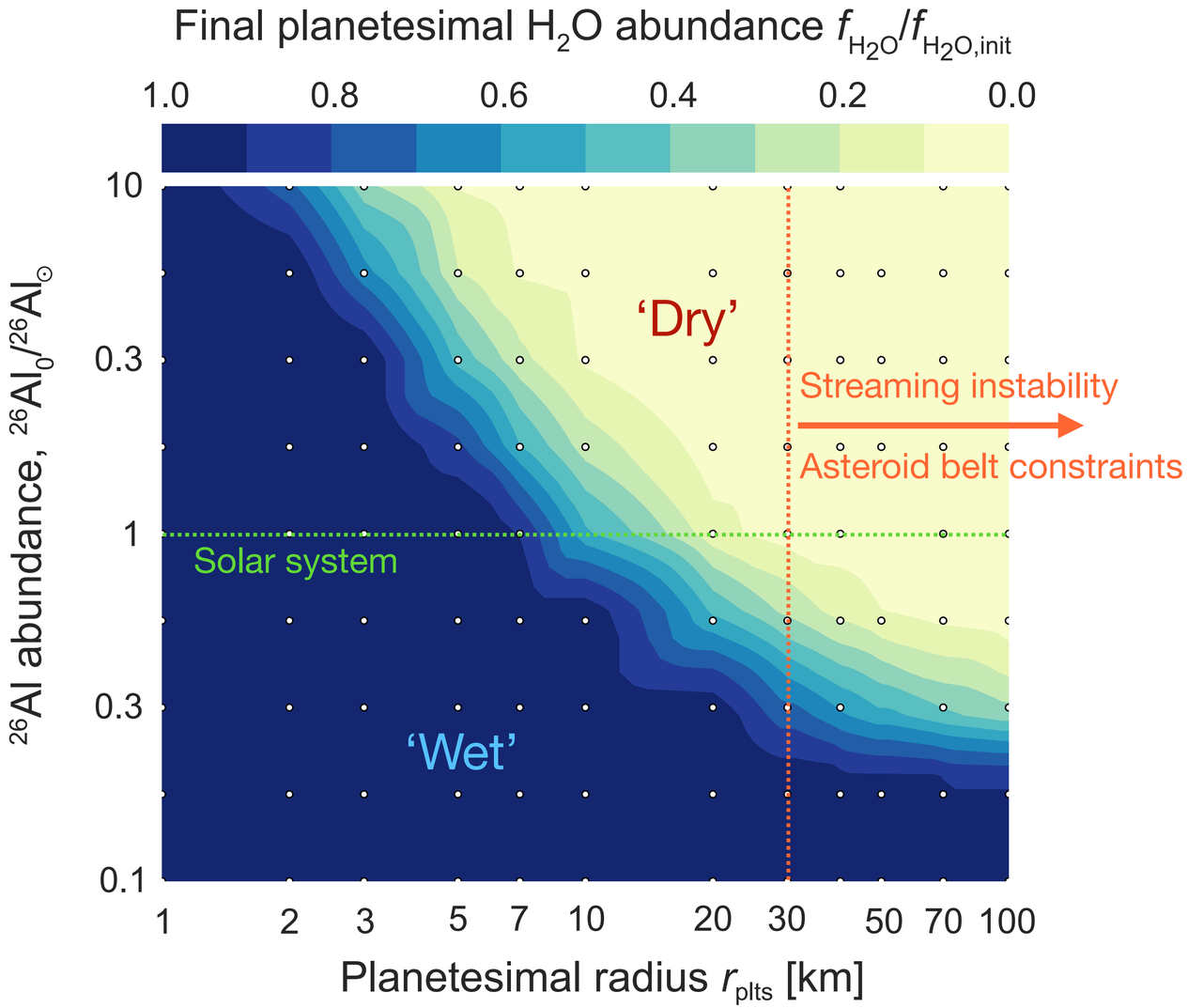
^{26}Al-heated icy planetesimals forming planets



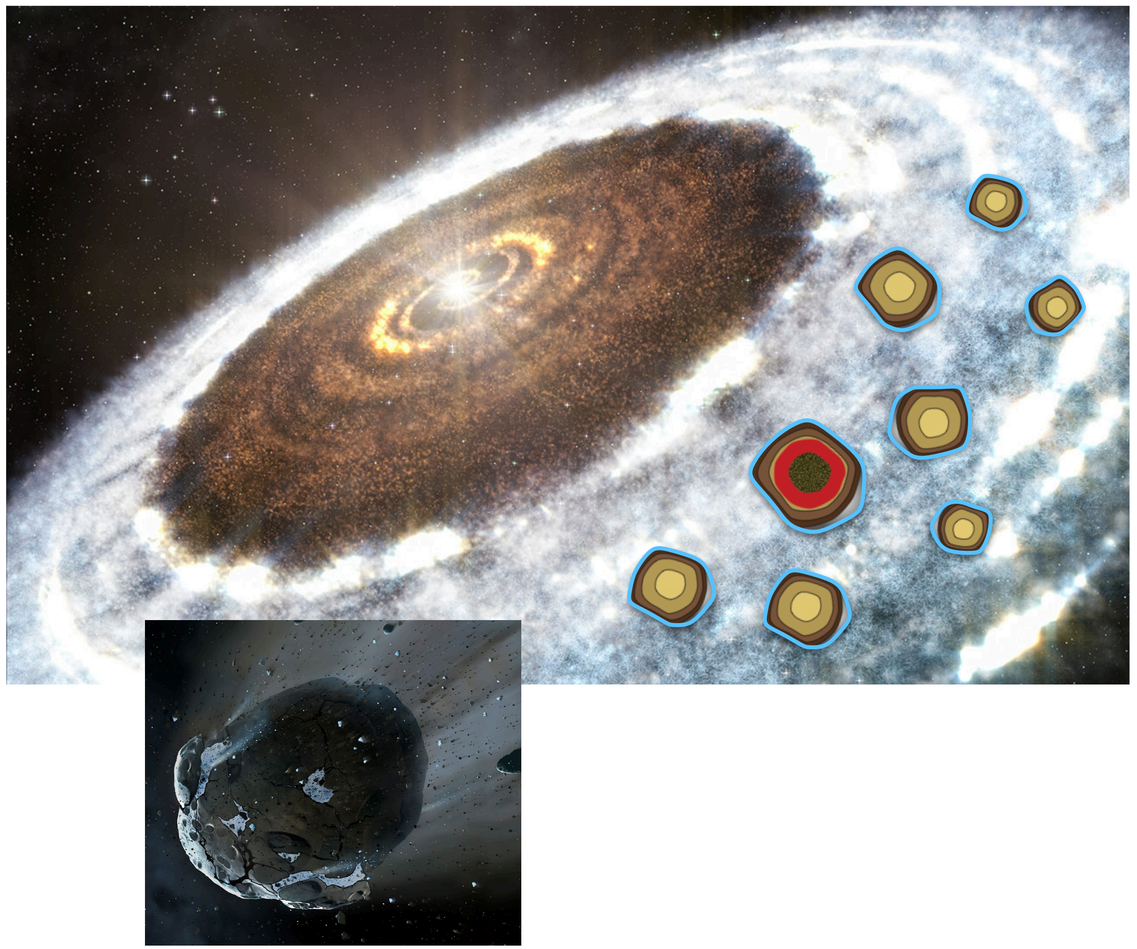
Lichtenberg, Parker, Meyer 16, Parker+14,15, Nicholson & Parker 17, Pfalzner+15, Kuffmeier+16

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

Rapid dehydration of water-rich planetesimals



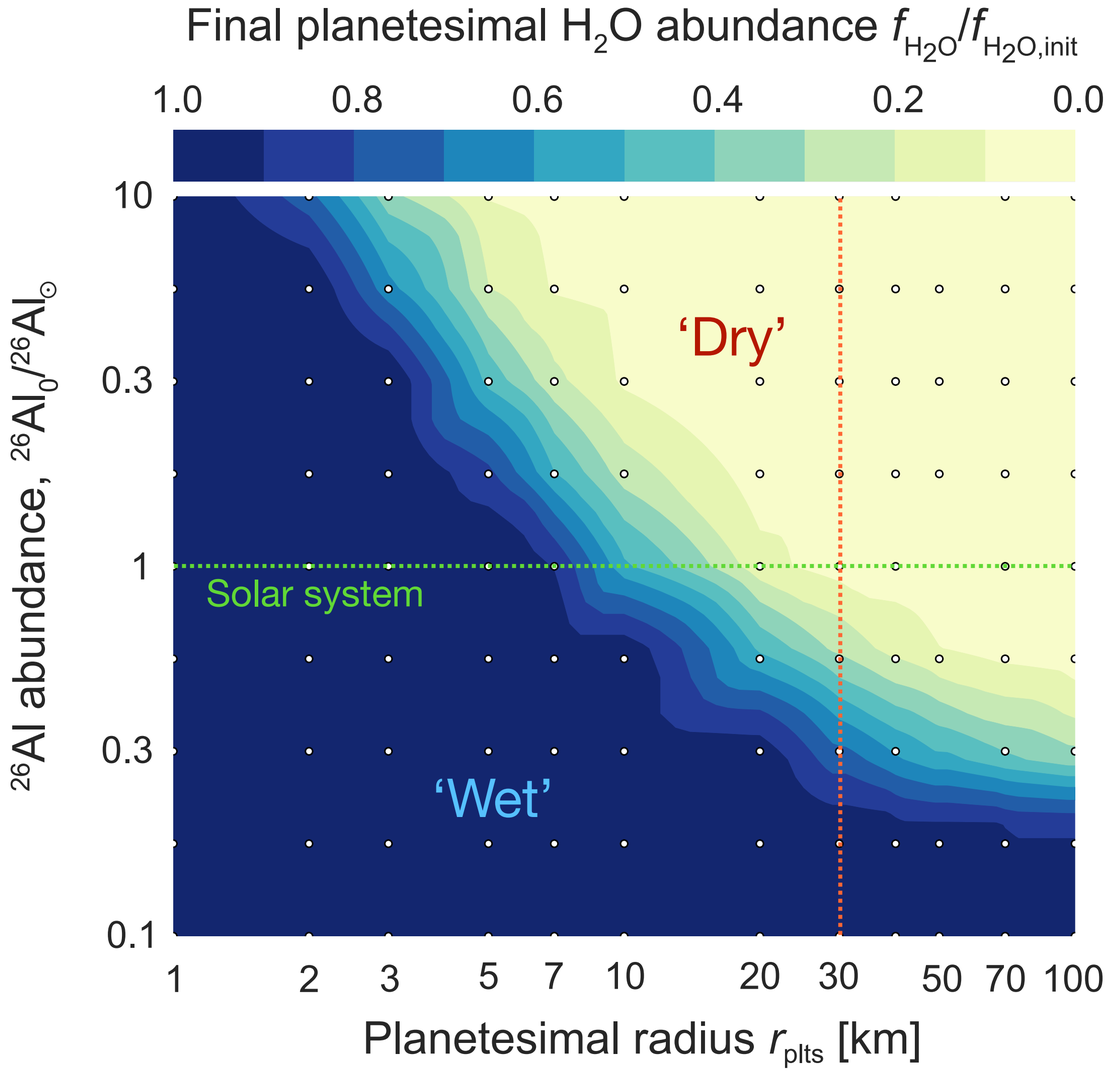
^{26}Al-heated icy planetesimals forming planets



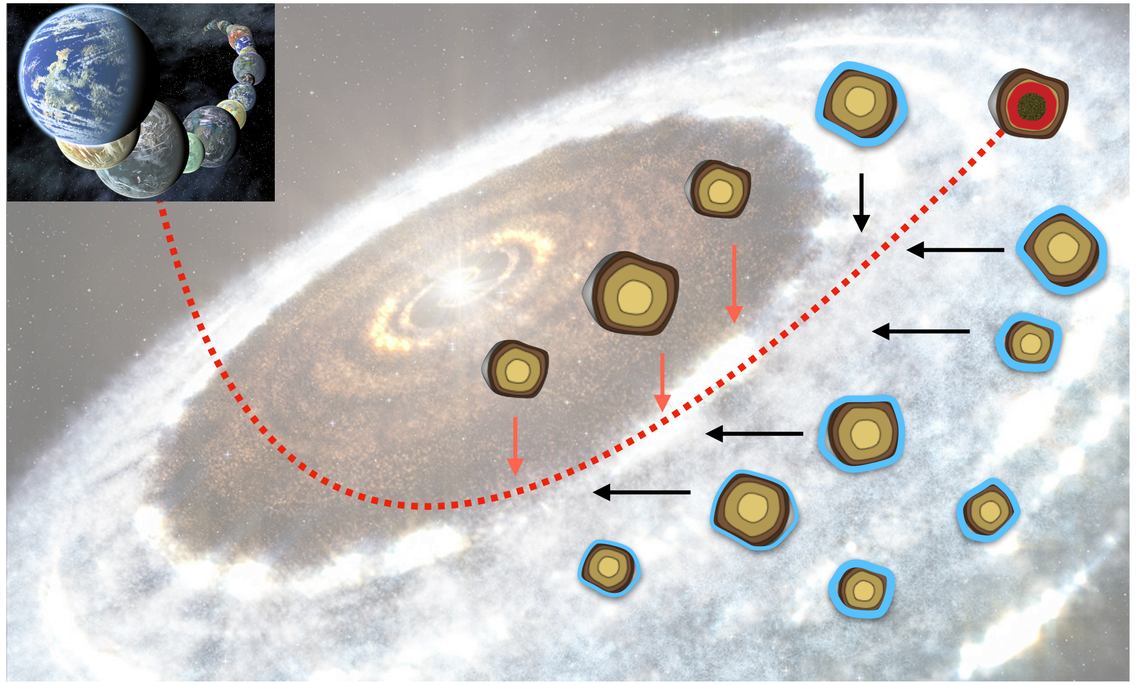
A. Angelich (NRAO/AUI/NSF)/ALMA (ESO/NAOJ/NRAO); ESA/NASA/M.A.Garlick

Lichtenberg+ 19b

^{26}Al controls bulk water content



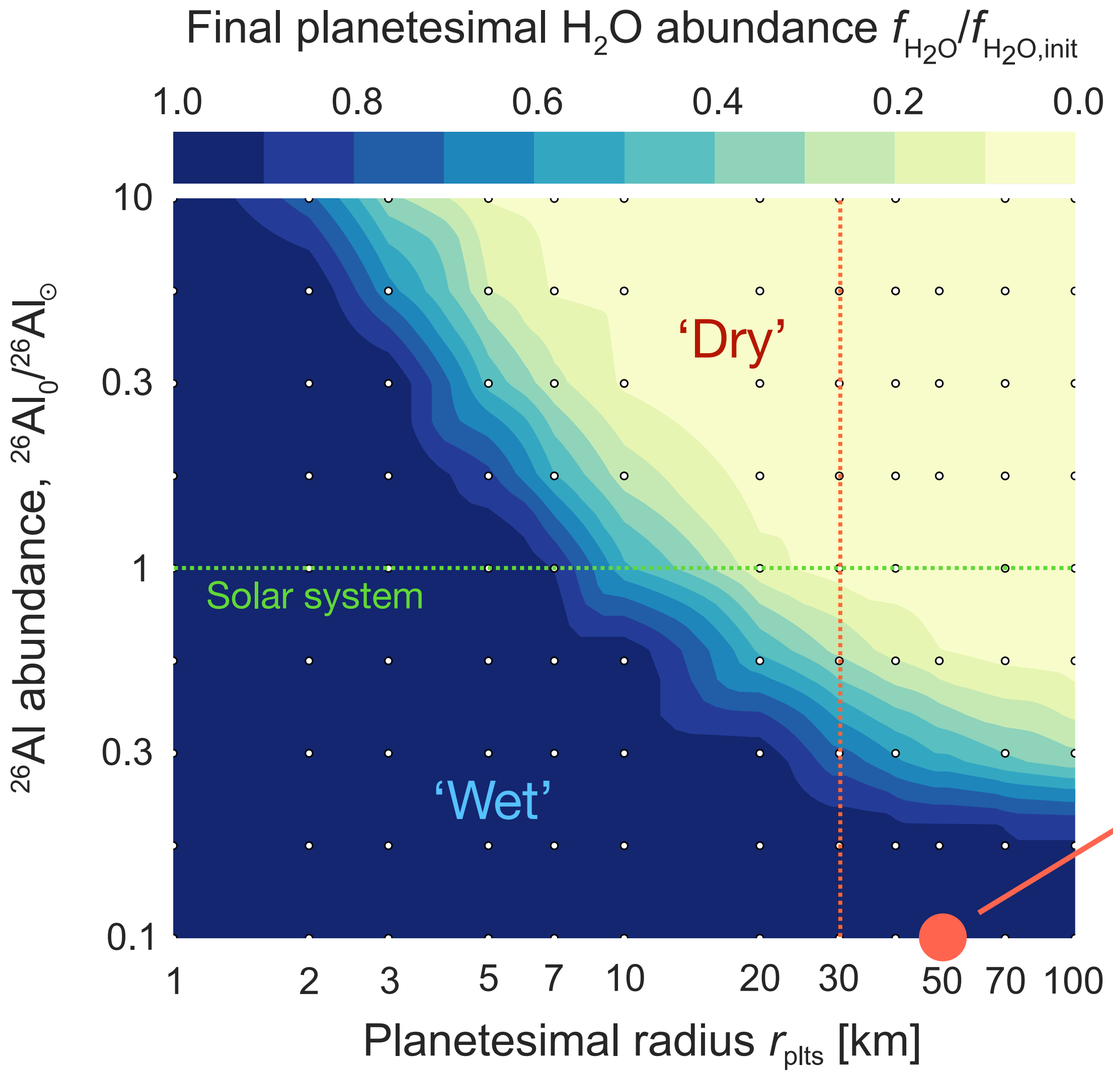
Synthetic exoplanet populations

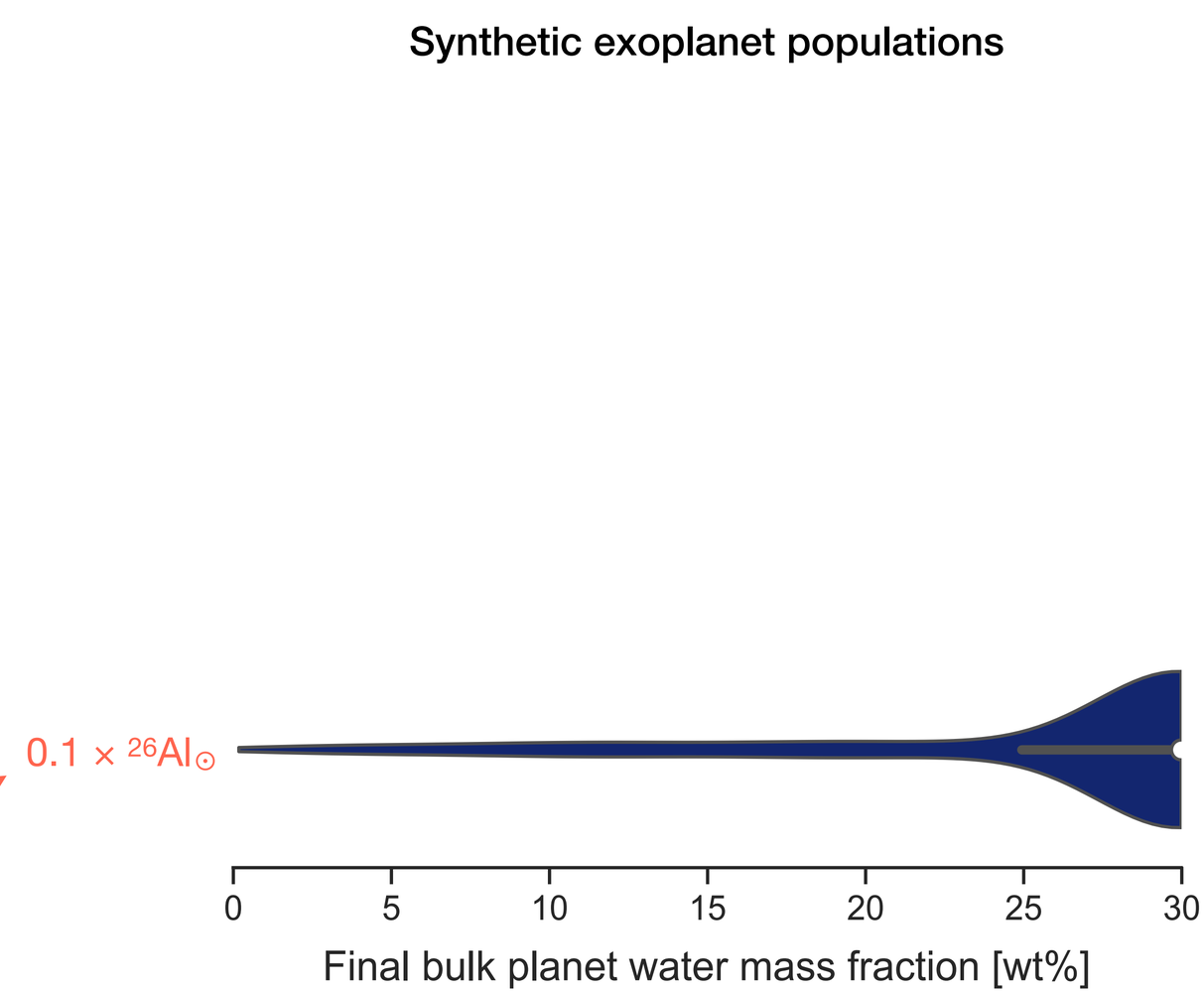


Accretion & decreasing water abundance in planetesimals

Lichtenberg+ 19b

^{26}Al controls bulk water content

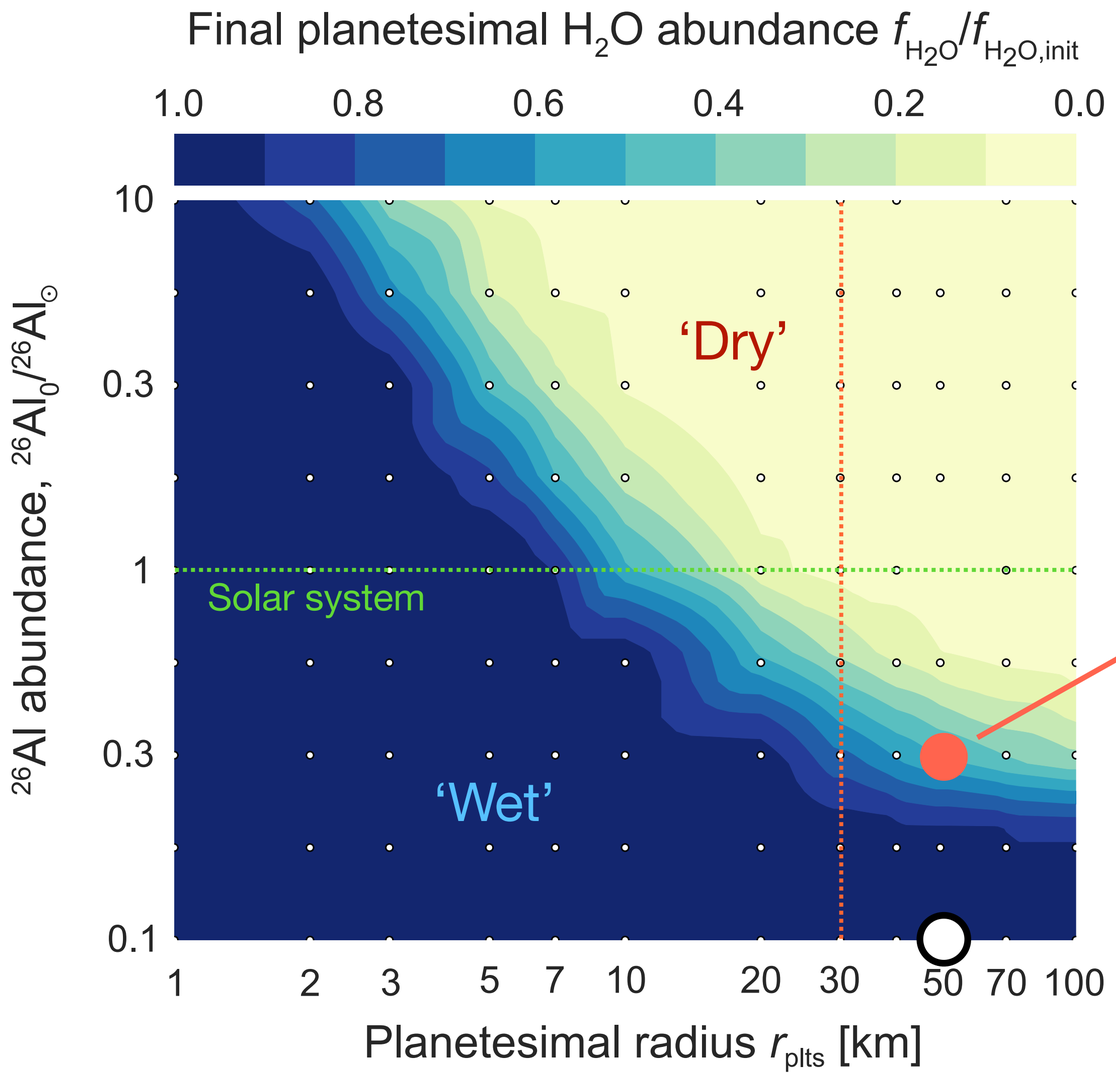


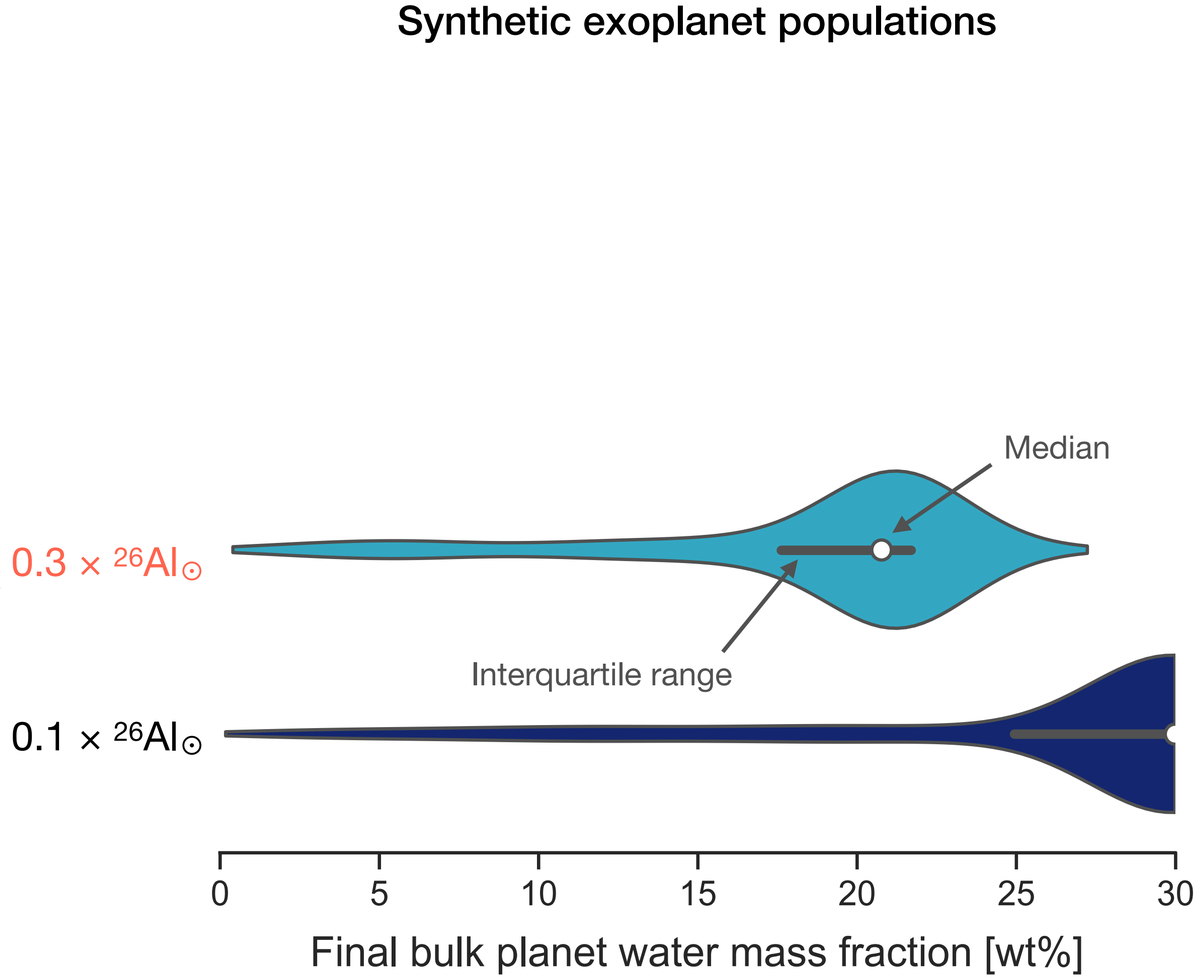


$f_w > 0$, $M_P < 10$ M_{Earth}, G stars

Lichtenberg+ 19b

^{26}Al controls bulk water content





Lichtenberg+ 19b

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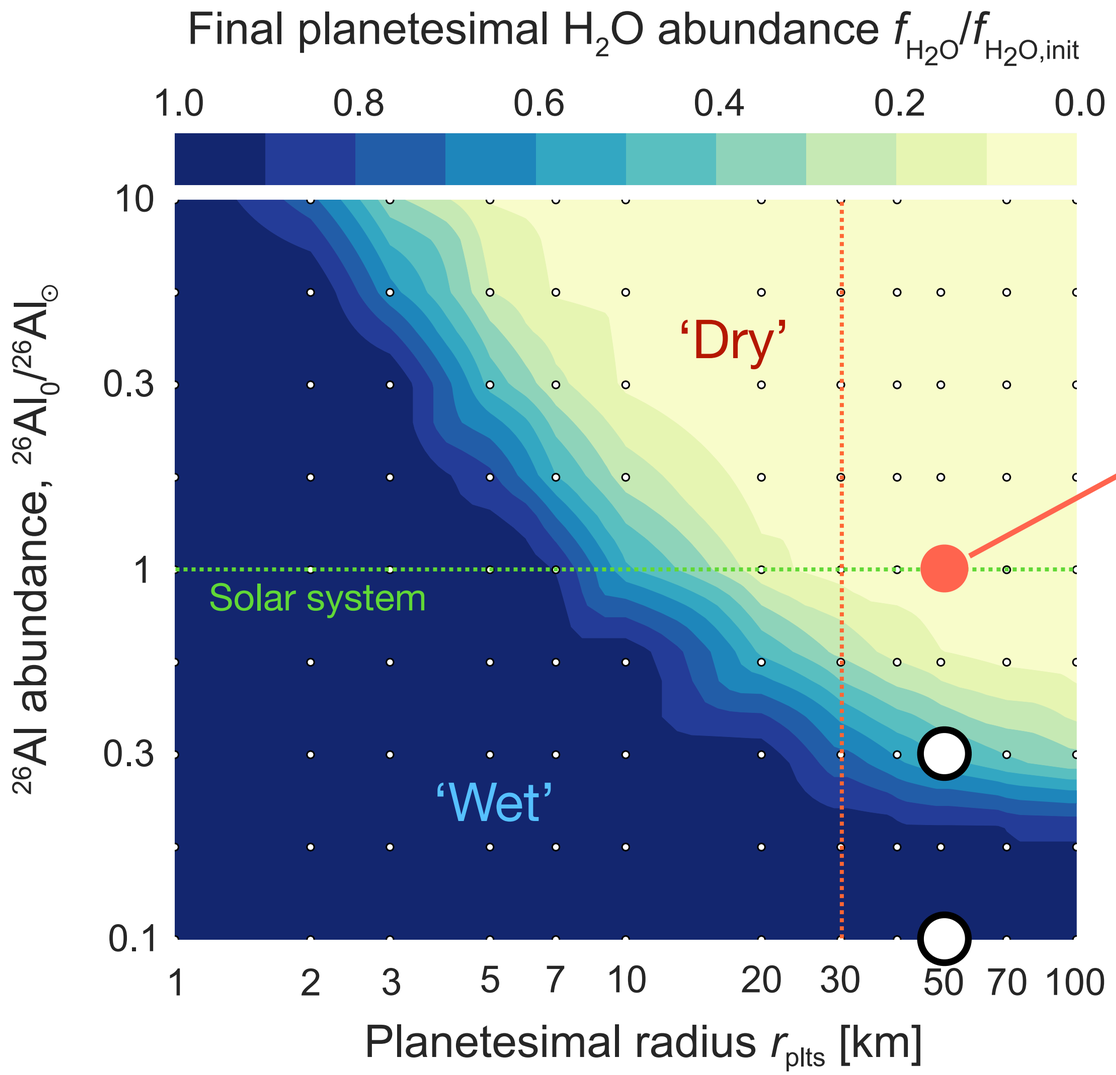

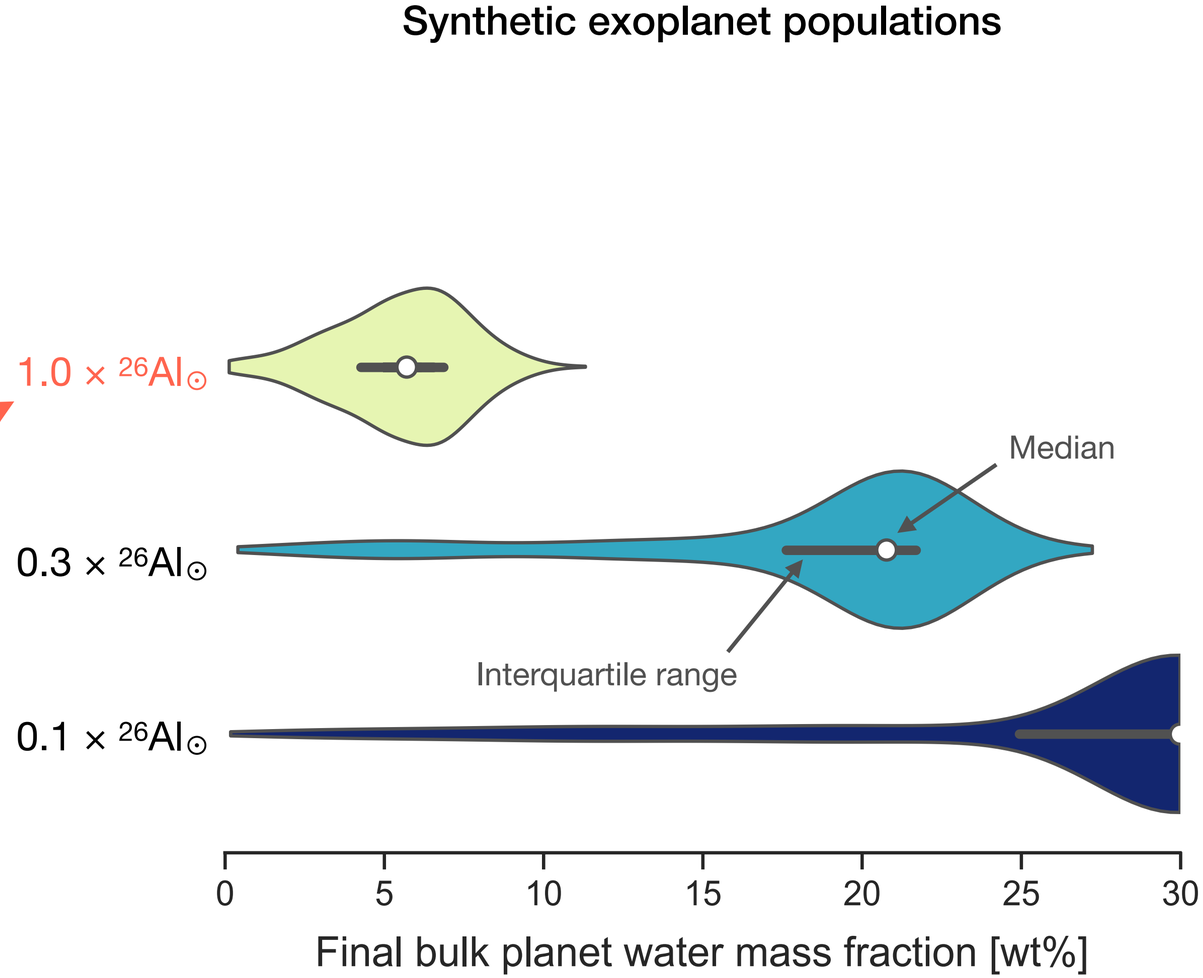

Lichtenberg+ 19b

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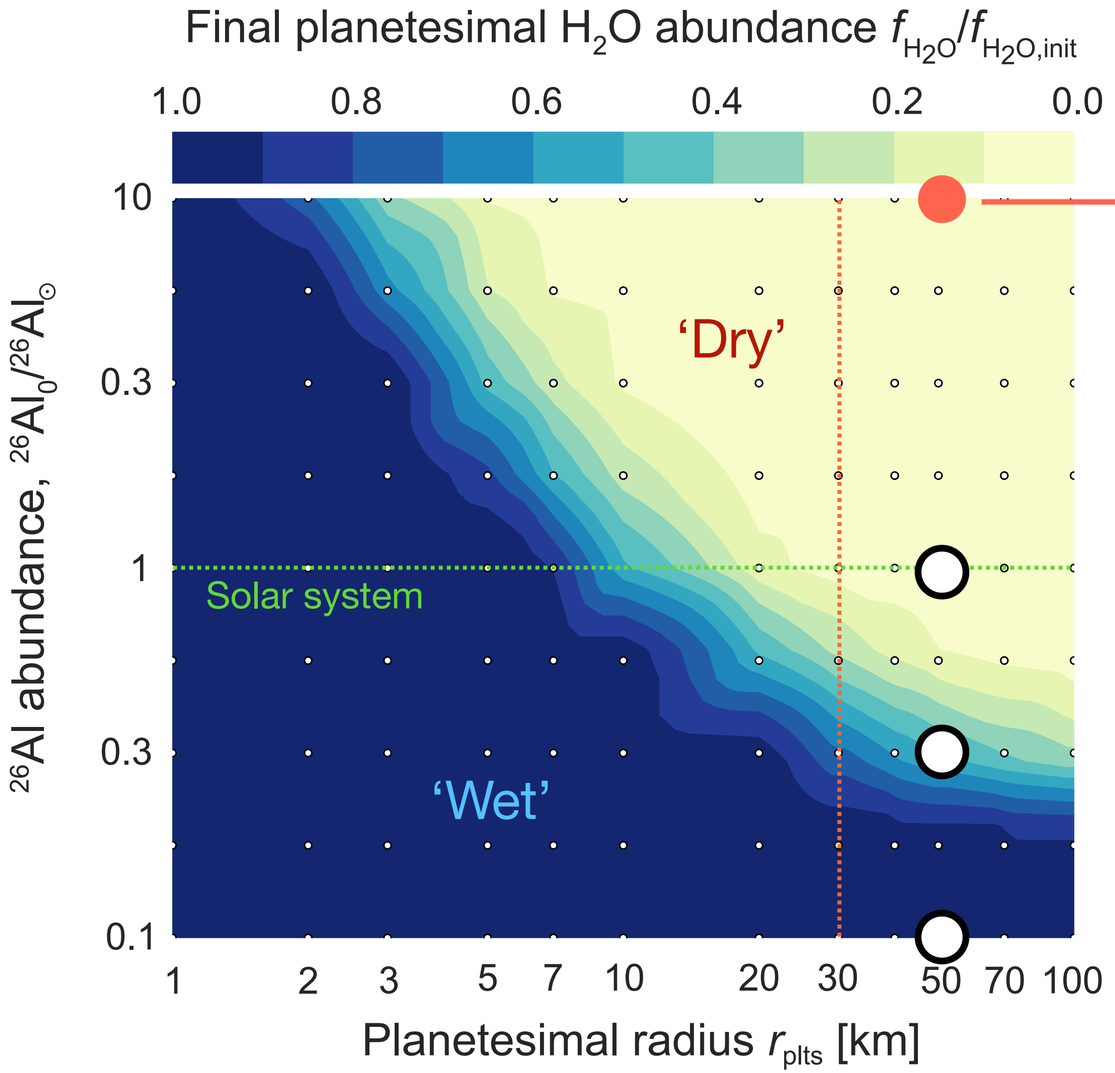
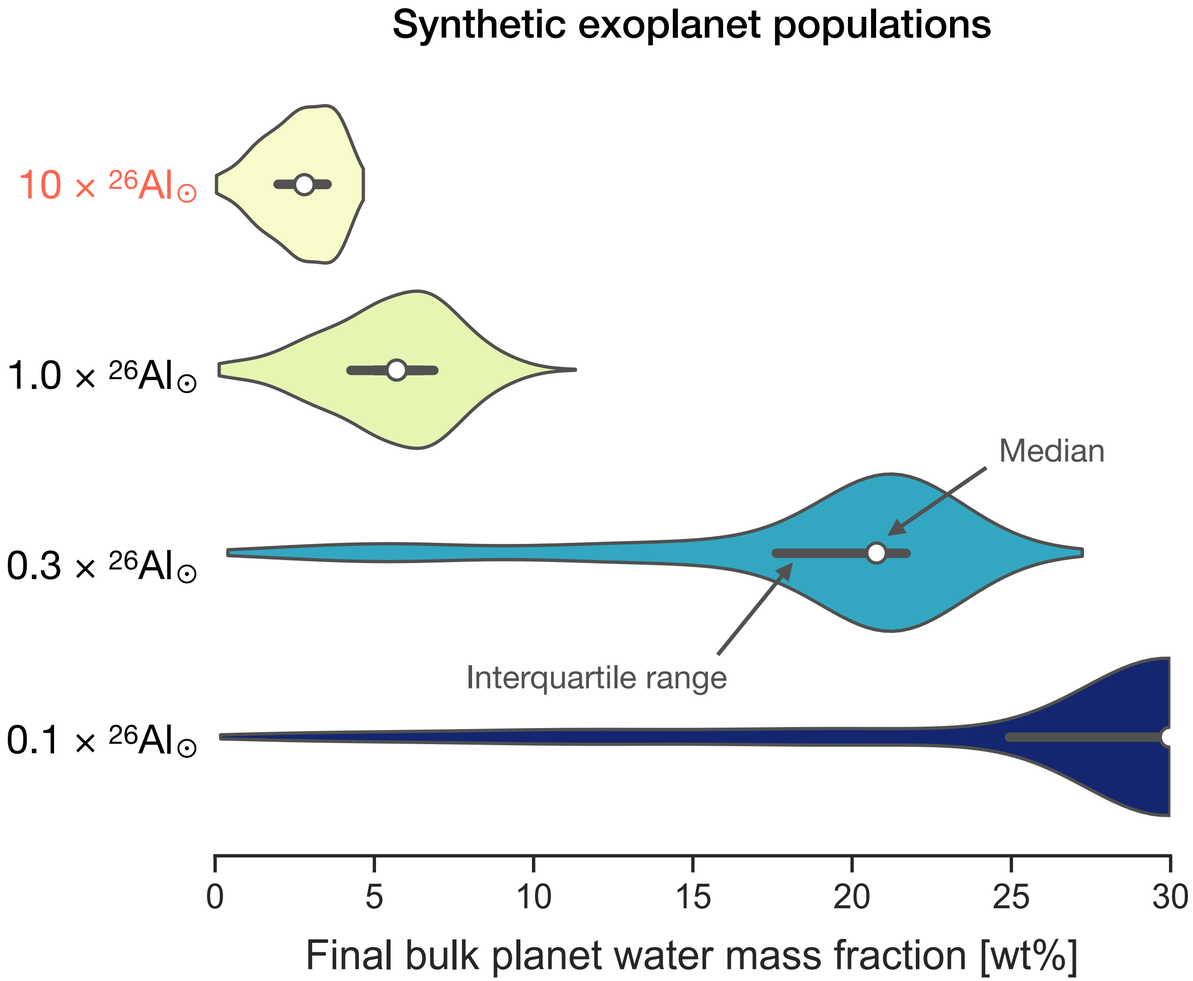
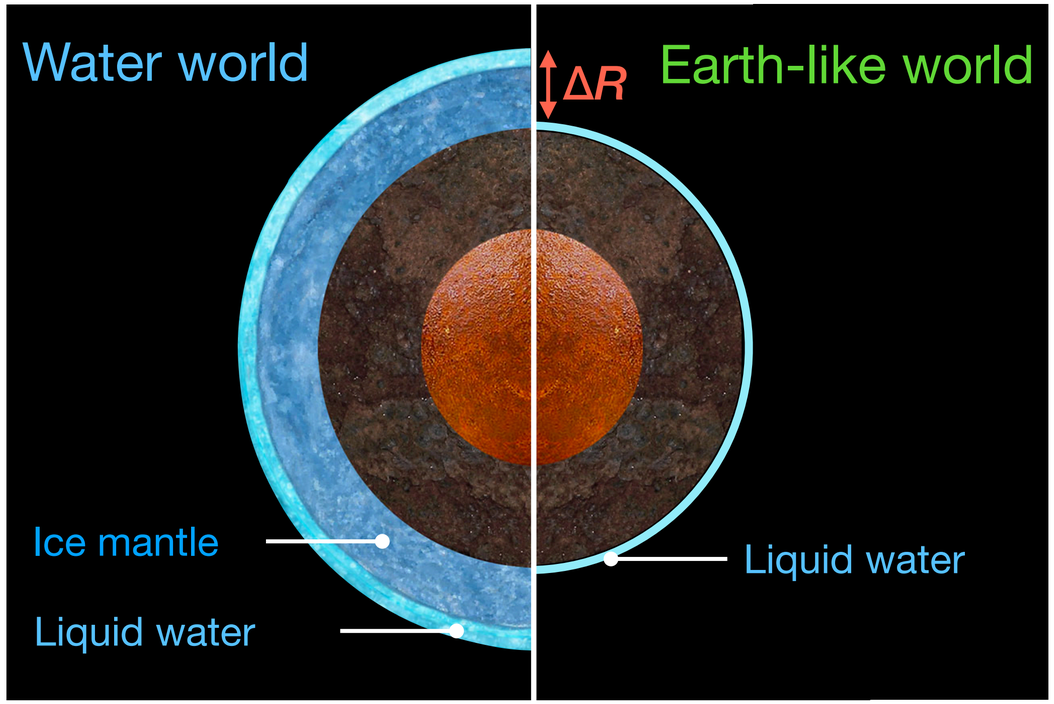


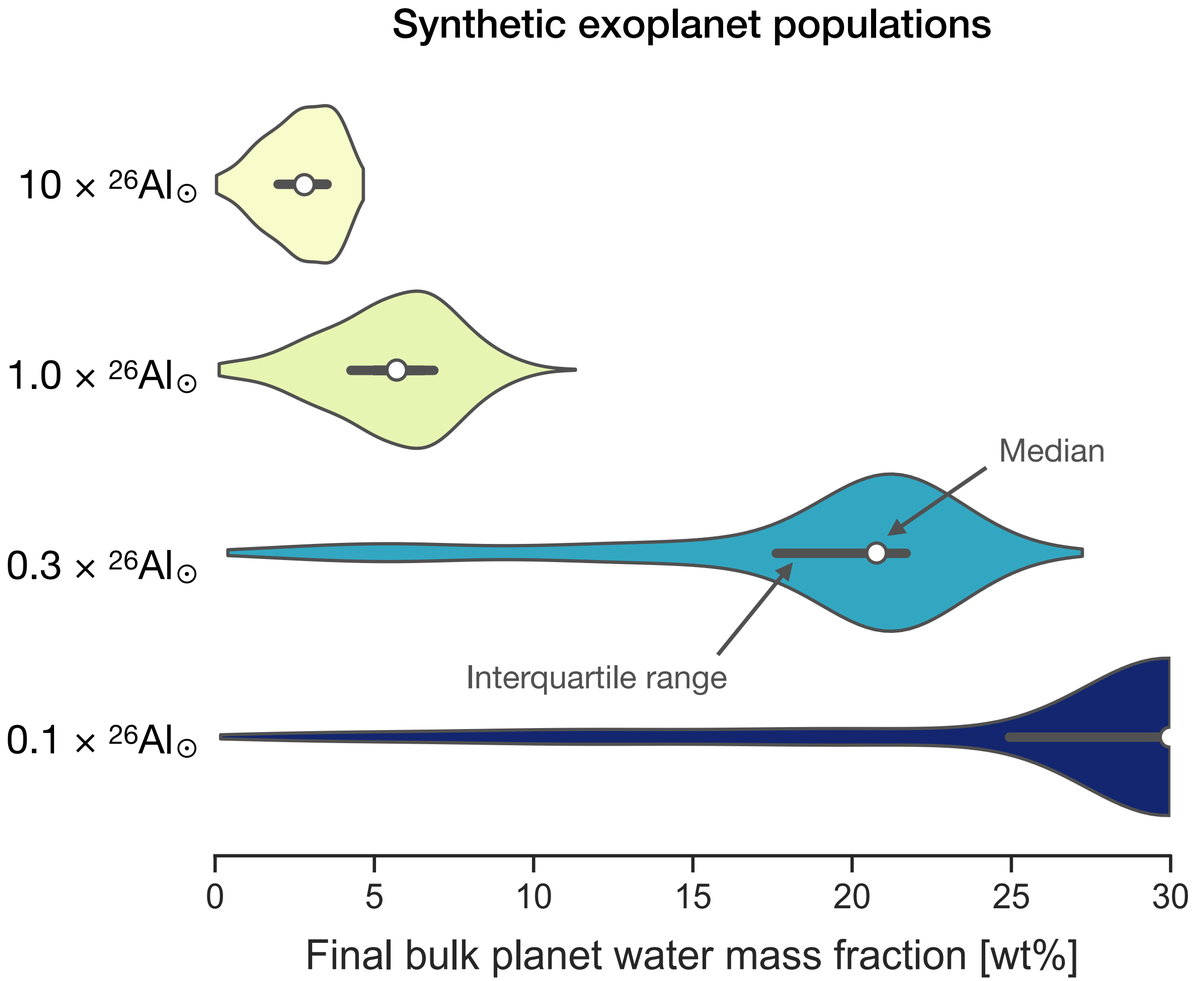


Lichtenberg+ 19b

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

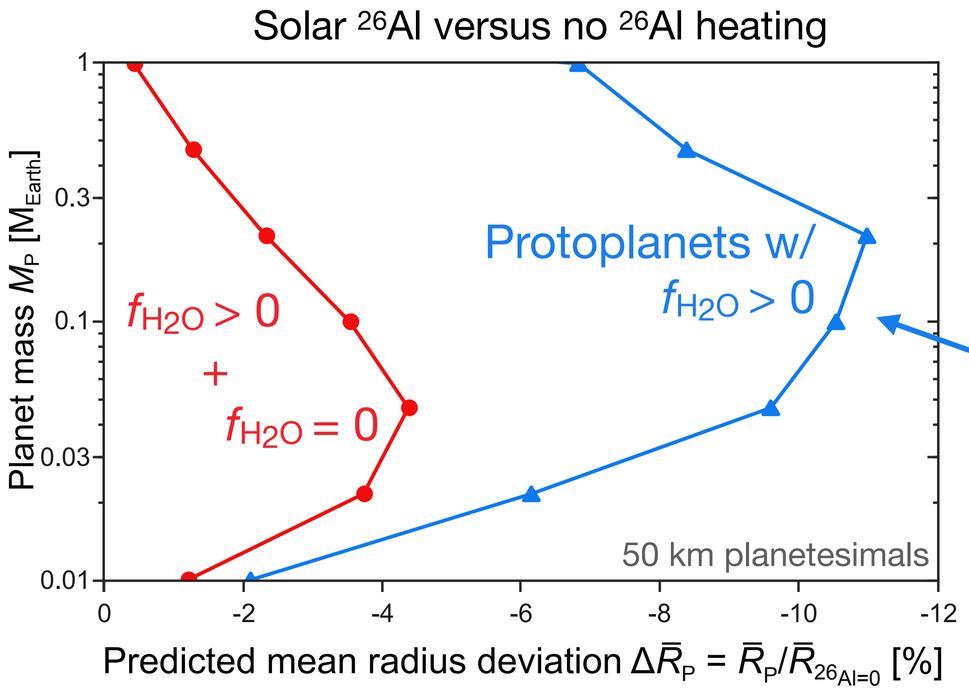
^{26}Al controls bulk water content

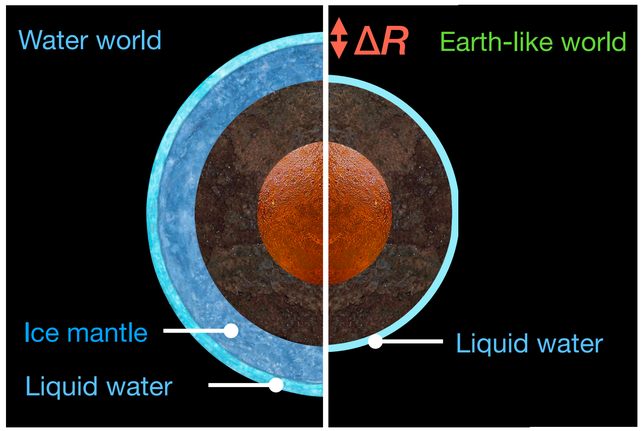




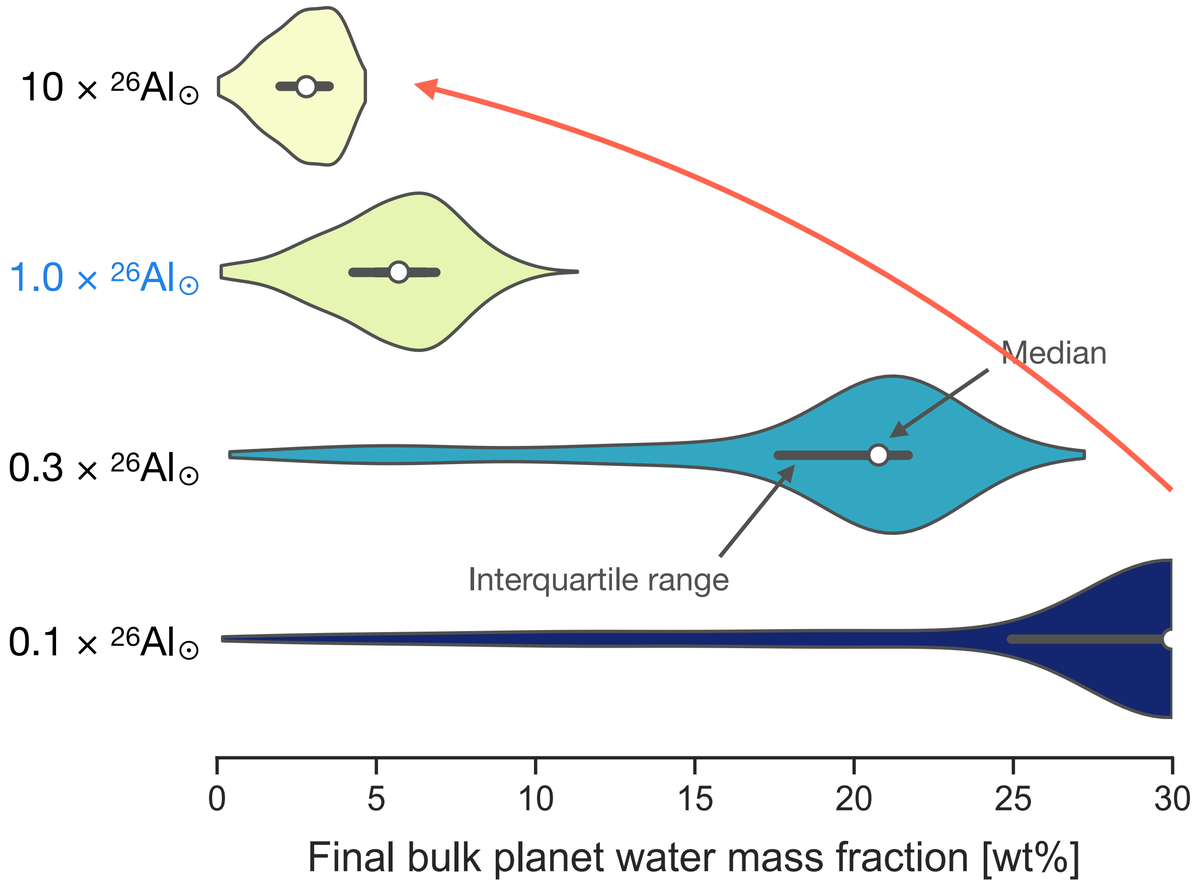
Leger+ 04, Sotin+ 07, Alibert 14, Noack+ 16/17

^{26}Al shapes exoplanet structure





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

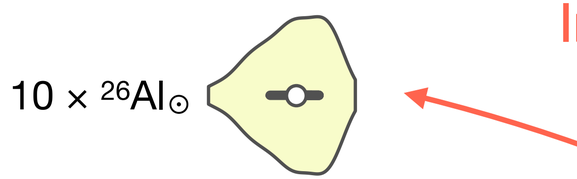


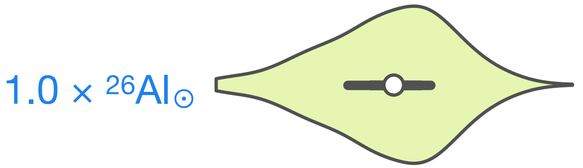
^{26}Al shapes distribution systematics

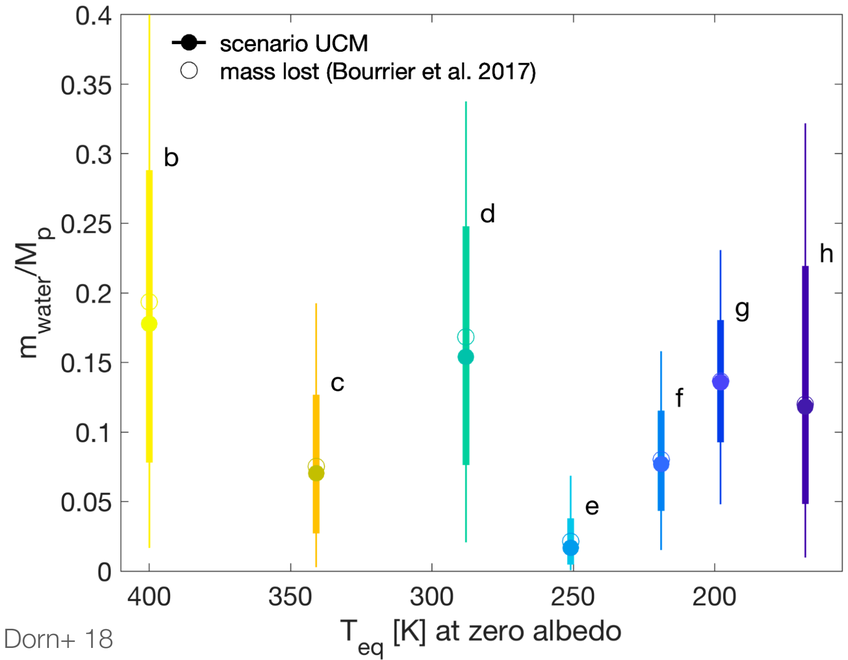
Intra-system size correlation (Weiss+ 18, Millholland+ 18)

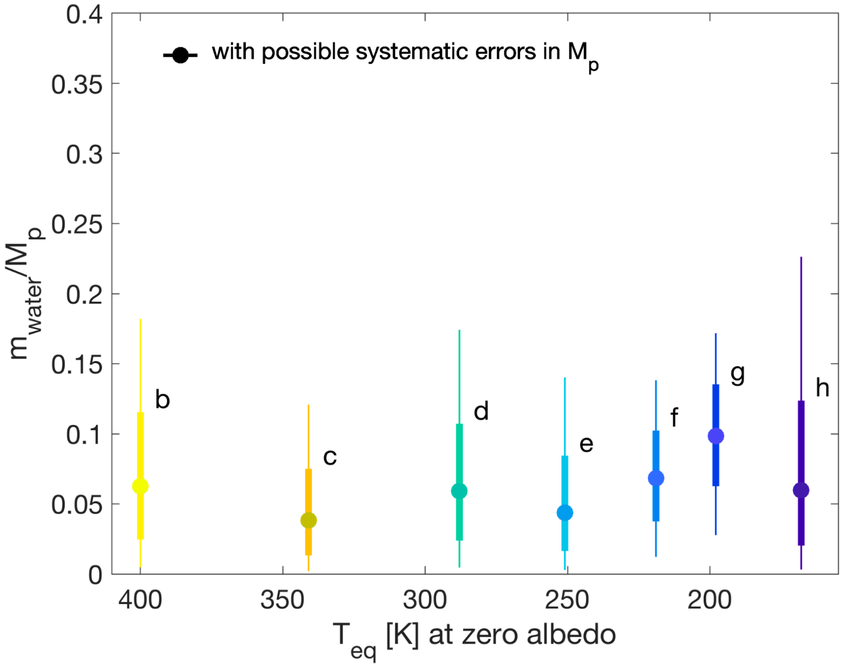
Insensitive to orbital location

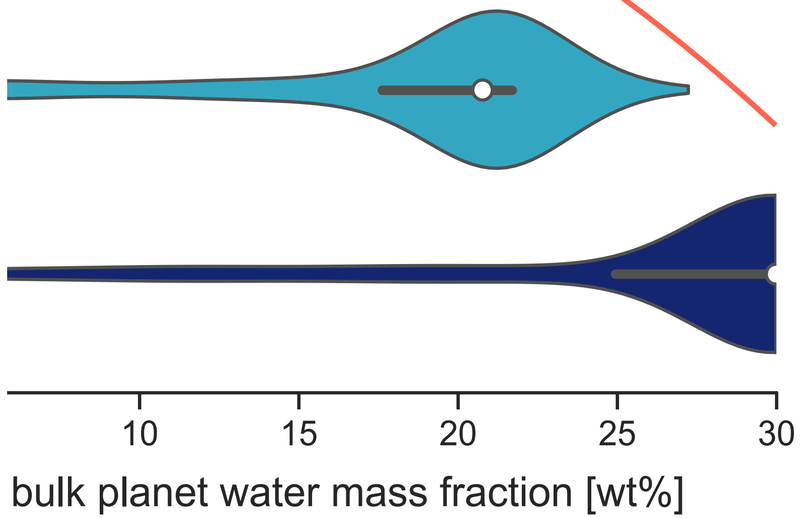
TRAPPIST-1 (Grimm+ 18, Dorn+ 18)





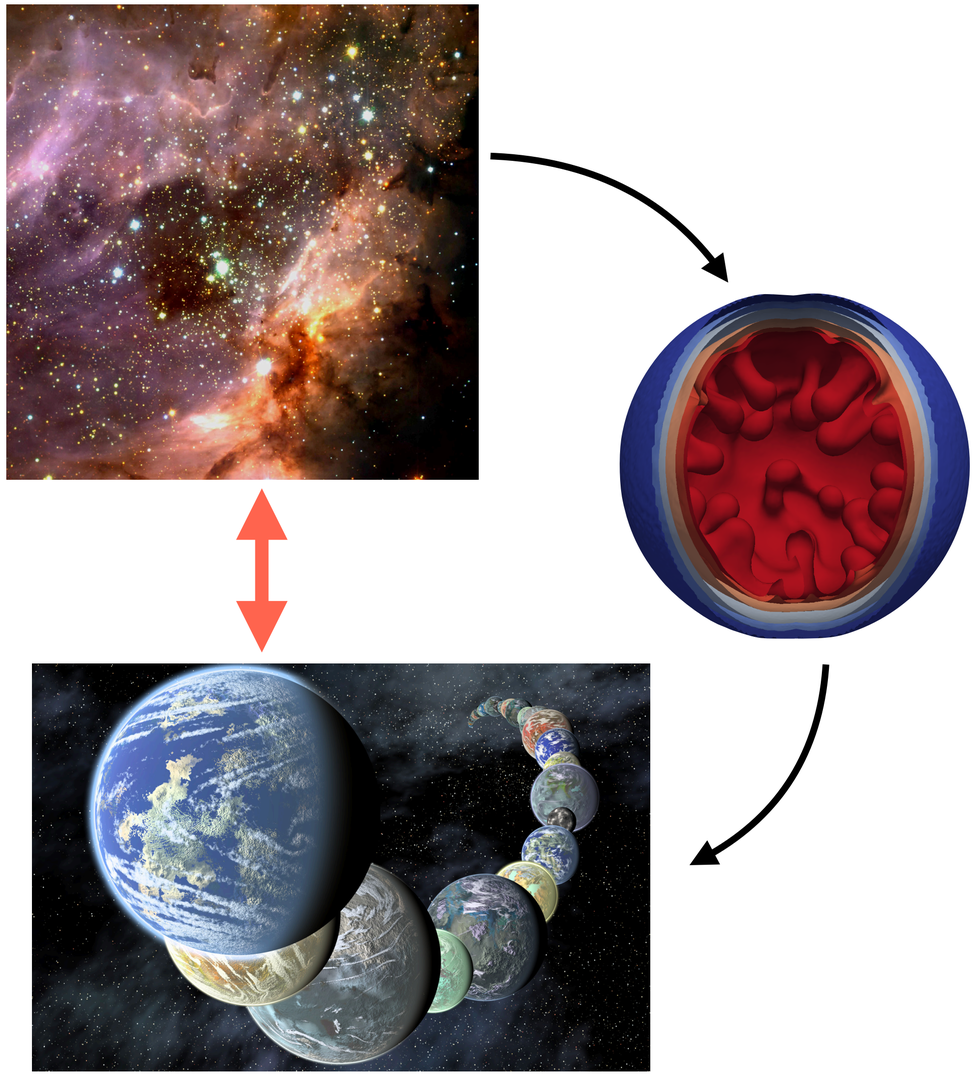






Dorn+ 18

^{26}Al dehydration – open questions



- Earth dry thanks to ^{26}Al?
  - **Timing of snowline migration *vs* planetesimal formation *vs* proto-Jupiter gap opening (~1 Myr) *vs* nature of meteorite/chondrite parent bodies** *—> Lichtenberg+18*
- Influence of pebble accretion
  - Earth's water not predominantly pebble-inherited
  - Embryo formation planetesimal-supported
- Successive episodes of planetesimal accretion
  - Embryos formed earlier than ~ 1 Myr after CAIs
- Planetesimal birth size frequency distribution?
- Heterogeneous ^{26}Al distribution in Solar PPD?

^{26}Al key control on planet composition

- Fraction of planetary systems polluted with ^{26}Al

  ➡ Volatile loss & differentiation in planetesimals

- Systemic dichotomy:

  ➡ Enriched systems form water-poor (proto-)planets

  ➡ Not-enriched systems tend to form ocean worlds

◉ Statistically traceable w/ future transit missions?

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Lichtenberg, Golabek, Burn, Meyer, Alibert, Gerya, Mordasini (*Nature Astronomy, 2019*)