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Terrestrial planet accretion constrained by isotopes: Implications for Earth-like habitats

Helmut Lammer[1], Manuel Scherf[1], and Nikolai V. Erkaev[2,3]
[1]Austrian Academy of Sciences, Space Research Institute, Graz, Austria
[2]Institute of Computational Modelling SB RAS, Krasnoyarsk, Russian Federation
[3]Siberian Federal University, Krasnoyarsk, Russian Federation

Here we discuss terrestrial planet formation by using Earth and our knowledge from various isotope data such as ^{182}Hf-^{182}W, U-Pb, lithophile-siderophile elements, atmospheric ^{36}Ar/^{38}Ar, ^{20}Ne/^{22}Ne, ^{36}Ar/^{22}Ne isotope ratios, the expected solar ^{3}He abundance in Earth's deep mantle and Earth's D/H sea water ratios as an example. By analyzing the available isotopic data one finds that, the bulk of Earth's mass most likely accreted within 10 to 30 million years after the formation of the solar system. Proto-Earth most likely accreted a mass of 0.5 to 0.6 M_{Earth} during the disk lifetime of 3 to 4.5 million years and the rest after the disk evaporated (see also Lammer et al. 2021; DOI: 10.1007/s11214-020-00778-4). We also show that particular accretion scenarios of involved planetary building blocks, large planetesimals and planetary embryos that lose also volatiles and moderate volatile rock-forming elements such as the radioactive decaying isotope ^{40}K determine if a terrestrial planet in a habitable zone of a Sun-like star later evolves to an Earth-like habitat or not. Our findings indicate that one can expect a large diversity of exoplanets with the size and mass of Earth inside habitable zones of their host stars but only a tiny number may have formed to the right conditions that they could potentially evolve to an Earth-like habitat. Finally, we also discuss how future ground- and space-based telescopes that can characterize atmospheres of terrestrial exoplanets can be used to validate this hypothesis.