THE CURIOUS CASE OF MARS' FORMATION

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Introduction: Recent data from terrestrial samples and martian meteorites suggest that Mars' isotopic and thus bulk composition is distinct from that of Earth, and therefore it likely grew further from the Sun [1]. Mars shows distinct signatures in the nucleosynthetic isotopes $\Delta^{17}O$, $\varepsilon^{48}Ca$, $\varepsilon^{50}Ti$, $\varepsilon^{54}Cr$, $\varepsilon^{62}Ni$ and $\varepsilon^{92}Mo$ [2,3,4,5]. This compositional difference has been attributed to Mars accreting a higher fraction of material akin to ordinary chondrite than Earth, which is thought to have formed mostly from material akin to enstatite chondrite [6], though this is still actively debated. Nevertheless these distinct isotopic signatures should be reproduced with modern N-body planet formation models.

Method and results: We ran 672 N-body simulations in total with two different planet formation models: the Classical model, in which Jupiter and Saturn are kept on their current orbits, and the Grand Tack model, wherein Jupiter and Saturn migrate through the primordial asteroid belt inward and then outward. Our results show that both models tend to yield Earth and Mars analogues with overlapping accretion zones. We also estimate the average percentage of primitive chondrite assembled into Earth and Mars by assuming that the initial solid disk consists of only enstatite chondrite in the inner region, and ordinary chondrite in the outer region. Our results show that a change in composition of the initial disk could have occurred near 1.3 AU. We further report that the Classical model fares better than the Grand Tack model for forming Mars with its documented compositions (29–68% enstatite chondrite plus 32–67% ordinary chondrite [7]) though the Mars analogues are generally too massive in the Classical case. We further calculate the predicted isotopic composition of ^{17}O, ^{50}Ti, ^{54}Cr, ^{142}Nd, ^{64}Ni and ^{92}Mo in the martian mantle from the Grand Tack simulations. We find that it is possible to match the measured isotopic composition of all the elements, but the resulting uncertainities are too large to place restriction on the dynamical evolution and birth place of Mars.

Future prospect: Our results show that increasing the resolution of dynamical simulation and higher precision isotopic measurements from the martian meteorites, especially for modrate and highly siderophile elements, are required to solve the mystery of Mars' formation. Combining planetary dynamics and cosmochemistry should be the future in tackling problems related to planet formation.

References: :[1] Brasser et al. (2017) EPSL, 468, 85 [2] Lodders & Fegley (1997) Icarus, 126, 373 [3] Sanloup et al (1999) Phys. Earth Planet In. 112, 43 [4] Tang & Dauphas (2014) EPSL, 390, 264 [5] Warren (2011) EPSL, 311, 93 [6] Javoy et al. (2010) EPSL, 293, 259 [7] Brasser et al. (2018) GRL, 45, 5908-5917.