The initial abundance of niobium-92 in the outer solar system.

Y. Hibiya[1, 2], T. Iizuka[2] and H. Enomoto[2], [1]JAMSTEC, Japan (hibiyuki@jamstec.go.jp), [2]University of Tokyo.

Introduction: The *p*-process radionuclide niobium-92 (^{92}Nb) decays to zirconium-92 (^{92}Zr) by electron capture with a half-life of 37 Myr. The system is a promising chronometer for addressing the early solar system evolution and planetary differentiation [1, 2]. The initial abundance of ^{92}Nb and its distribution in the early solar system provide valuable constraints on the time-scale of our solar system evolution, and on the origin of *p*-process nuclides. Previously, the initial ^{92}Nb abundance at the solar system formation was determined to be $(^{92}\text{Nb}/^{93}\text{Nb})_0 = (1.7 \pm 0.6) \times 10^{-5}$ by applying the internal isochron approach to the NWA 4590 angrite (U–Pb age: 4557.93 ± 0.36 Ma) [2]. This value is consistent with those obtained from internal Nb-Zr isochrons of eucrites, ordinary chondrites, and mesosiderites [1, 3], indicating that ^{92}Nb was homogeneously distributed among their source regions. Yet, all samples previously studied for ^{92}Nb are thought to have originated from the inner solar system. Here we report internal Nb-Zr isochron dating of the NWA 6704 achondrite that is considered to have originated from the outer solar system.

Sample and Methods: NWA 6704 is a primitive achondrite having a fresh igneous texture [4] with a U–Pb age of 4562.76 ± 0.30 Ma [5]. The mineralogy and petrography indicate that this meteorite underwent melting above liquidus temperature and subsequent rapid cooling ($> 10^{-1}$ °C/yr; [4]), making the effect of differing closure temperatures between the U-Pb and Nb-Zr systems insignificant. Furthermore, this meteorite has Δ^{17}O, ε^{50}Ti, ε^{54}Cr and ε^{84}Sr values similar to those of carbonaceous chondrites [4-6], indicating that it samples the same reservoirs in the solar nebula as the carbonaceous chondrite parent bodies (i.e., the outer solar system). Thus, NWA 6704 enables us to evaluate the distribution of ^{92}Nb between the inner and outer solar system for the first time.

We prepared mineral and whole rock fractions from five fragments of NWA 6704. The Nb/Zr ratios were obtained using a *Thermo Fisher Scientific*™ *iCAP Q*™ ICP–MS at the University of Tokyo without chemical separation. Zr was separated and purified from samples using a protocol modified from [2]. The Zr isotopic compositions were measured using a *Thermo Fisher Scientific Neptune Plus* MC-ICP-MS interfaced to a *Cetac Aridus II* desolvating nebulizer at the University of Tokyo.

Results & Discussion: The isochron defines an initial ^{92}Nb/^{93}Nb of $(2.8 \pm 0.3) \times 10^{-5}$ at the time of NWA 6704 formation. By combining this value with the U–Pb age of NWA 6704, an initial ^{92}Nb/^{93}Nb of $(3.0 \pm 0.3) \times 10^{-5}$ at the time of solar system formation is derived. The obtained value is distinctly higher than the initial value in the inner solar system of $(1.7 \pm 0.6) \times 10^{-5}$ [2]. This indicates that ^{92}Nb was heterogeneously distributed in the protoplanetary disk before the formation of NWA 6704, and was relatively enriched in the outer solar system. The difference between these two initial values causes the apparent Nb-Zr age difference of ~30 Myr, demonstrating that the current canonical value of $(^{92}\text{Nb}/^{93}\text{Nb})_0 = (1.7 \pm 0.6) \times 10^{-5}$ should not be used for the Nb–Zr dating of planetary materials from the outer solar system. The newly obtained initial ^{92}Nb/^{93}Nb value is clearly higher than the expected value in the model of ^{92}Nb synthesis by Type Ia supernova (SNIa) [7]. Thus, our results require another production site to be invoked for selectively producing ^{92}Nb. At the moment, only the *v*-process in Type II supernova (SNII) [8] satisfies such requirement. If so, our finding suggests that the time-interval from the last SNII explosion to the formation of our solar system needs be <100 My and that nuclides synthesized by the last SNII were preferentially implanted or preserved in the outer solar system. Such enrichment of the last SNII components in the outer solar system may account for the isotopic dichotomy between carbonaceous and non-carbonaceous meteorites [e.g., 9].

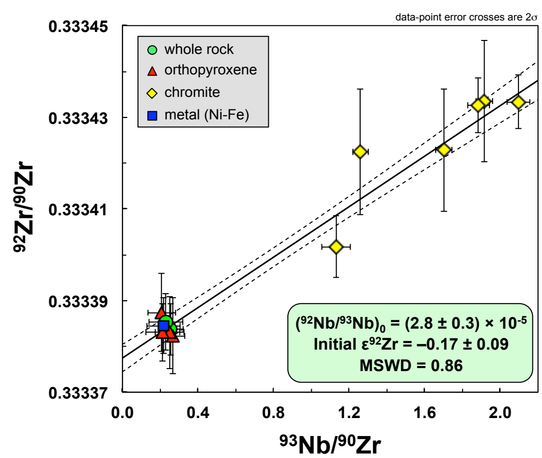

Figure 1. Nb-Zr isochron diagram for NWA 6704.

References: [1] Schönbächler et al. (2002) *Science*, 295: 1705–1708., [2] Iizuka et al. (2016) *Earth and Planetary Science Letters*, 439: 172–181., [3] Haba et al. (2017) *LPS XLVIII*, Abstract #1739. [4] Hibiya et al. (2019) *Geochimica et Cosmochimica Acta*, 245: 597–627., [5] Amelin et al. (2019) *Geochimica et Cosmochimica Acta*, 245: 628–642., [6] Hibiya et al. (2019) *Geostandards and Geoanalytical Research*, 43: 133–145., [7] Lugaro M. et al. (2016) *Proceedings of the National Academy of Sciences*, 113: 907–912., [8] Hayakawa et al. (2013) *The Astrophysical Journal*, 779: 9–13., [9] Warren (2011) *Earth and Planetary Science Letters*, 311: 93–100.