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### **Spinel in CV chondrules: Insights into chondrule thermal histories.**

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We performed a survey of spinel within two CV3 chondrites and found out that spinel within chondrules are systematically spinel *stricto sensu* (i.e.,  $\text{MgAl}_2\text{O}_4$ ). These Mg-spinel grains display oxygen isotopic signature similar to other minerals within chondrules ( $\Delta^{17}\text{O}$  ranges from -6 to -2 ‰). Moreover, textural considerations strongly suggest that Mg-spinel and olivine are co-magmatic.

We therefore apply a geothermometer based on Al-Cr distribution between spinel and olivine [1] for determining their crystallization temperatures. The calculated temperatures range from 1200 to 1640 °C, which is lower than the liquidus temperature usually estimated for porphyritic chondrules (~1600 °C). Our results then suggest that chondrules must have undergone relatively low cooling rates in order to crystallized such minerals and textures, which is in agreement with non-linear and two-stage cooling rate models of chondrule formation [2].

[1] Coogan, L. A. et al. (2014) *ChemGeo* 368, 1–10.

[2] Jones, R. H. et al. (2018) *Chondrules and the Protoplanetary Disk*, 57–90, Cambridge University Press

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