Sub-Kelvin scanning tunneling spectroscopy (STS) in the Chevrel phases SnMo$_6$S$_8$ and PbMo$_6$S$_8$ reveals two distinct superconducting gaps with $\Delta_1 = 3$ meV, $\Delta_2 \sim 1.0$ meV and $\Delta_1 = 3.1$ meV, $\Delta_2 \sim 1.4$ meV respectively. The gap distribution is strongly anisotropic, with $\Delta_2$ predominantly seen when scanning across unit-cell steps on the (001) sample surface. The spectra are well fitted by an anisotropic two-band BCS s-wave gap function. Our spectroscopic data are confirmed by electronic heat capacity (HC) measurements, which also provide evidence for a twin-gap scenario. Our finding can explain the extraordinary high upper critical field in this family of superconductors and may provide clues on how to enhance the critical fields of novel superconductors.

(a) Scanning tunneling spectroscopic zero-field 35 nm trace on SnMo$_6$S$_8$ taken at $T=0.4$ K with junction resistance $R_T = 0.03$ GΩ.
(i) Topography showing steps two unit cells high;
(ii) spectroscopic trace;
(iii), (iv) raw spectra taken on a flat terrace (1) and above a topographic step (2).

(b) Zero-field 40 nm trace on PbMo$_6$S$_8$ taken at $T=0.5$ K, $R_T = 0.015$ GΩ. (i) Spectroscopic trace; (ii) average spectrum from entire trace; (iii) topographic variation.

Temperature variation of the large gap $\Delta_1(T)$ in (a) SnMo$_6$S$_8$ and (b) PbMo$_6$S$_8$, measured by STS. The gap value was determined by fitting spectra acquired on a flat terrace (i.e., with a negligible $\Delta_2$ component) using a BCS singleband anisotropic s-wave model.

(a),(b) $C_{\text{eiss}}/T$ with two-band-model fits [H. Padamsee et al., J. Low Temp. Phys. 12, 387 (1973)]. Insets: $C/T$ at 0 and 28 T. (c),(d) Field-dependent contributions to $C_{\text{eiss}}$ at $T=0.35$ K with linear fits above and below a 2 gap crossover field $H_x$: In a single-band BCS s-wave superconductor, $\gamma(H)$ should be linear. However, at $T=0.35$ K we observe bends in $C_{\text{eiss}}$ at $H_x = 2.8$ T and $3.4$ T in SnMo$_6$S$_8$ and PbMo$_6$S$_8$, respectively.

Scanning tunneling spectra taken on the steps between terraces consistently display additional kinks corresponding to a second superconducting gap at low energy:

(a)–(c) SnMo$_6$S$_8$ STS spectra and fits: $T=0.4$ K, $R_T = 0.03$ GΩ.
(d)–(e) PbMo$_6$S$_8$ STS spectra and fits: $T=0.5$ K, $R_T = 0.015$ GΩ.
(f) PbMo$_6$S$_8$ spectrum from [C. Dubois et al., Phys. Rev. B 75, 104501 (2007)]: $T=1.9$ K, $R_T = 0.025$ GΩ. The second gap was hidden in the broadening of the data.

Together, our spectroscopic and thermodynamic data provide compelling evidence for a multiband order parameter in Chevrel Phase superconductors. In both SnMo$_6$S$_8$ and PbMo$_6$S$_8$, a strongly coupled quasi-isotropic band (contributing the majority of the DOS at $E_F$) coexists with a highly anisotropic weakly coupled minority band. Looking ahead, we postulate that understanding and manipulating the interplay between two or more such bands may hold the secret to realizing high values for $H_{c2}$ in future superconducting materials.