s-wave superconductivity in the noncentrosymmetric W$_3$Al$_2$C superconductor: an NMR study

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Abstract
We report on a microscopic study of the noncentrosymmetric superconductor W$_3$Al$_2$C (with $T_c = 7.6$ K), mostly by means of $^{27}$Al- and $^{13}$C nuclear magnetic resonance (NMR). Since in this material the density of states at the Fermi level is dominated by the tungsten’s 5$d$ orbitals, we expect a sizeable spin–orbit coupling (SOC) effect. The normal-state electronic properties of W$_3$Al$_2$C resemble those of a standard metal, but with a Korringa product $1/(T_1 T)$ significantly smaller than that of metallic Al, reflecting the marginal role played by $s$-electrons. In the superconducting state, we observe a reduction of the Knight shift and an exponential decrease of the NMR relaxation rate $1/T_1$, typical of $s$-wave superconductivity (SC). This is further supported by the observation of a small but distinct coherence peak just below $T_c$ in the $^{13}$C NMR relaxation-rate, in agreement with the fully-gapped superconducting state inferred from the electronic specific-heat data well below $T_c$. The above features are compared to those of members of the same family, in particular, Mo$_3$Al$_2$C, often claimed to exhibit unconventional SC. We discuss why, despite the enhanced SOC, W$_3$Al$_2$C does not show spin-triplet features in its superconducting state and consider the broader consequences of our results for noncentrosymmetric superconductors in general.

Keywords: noncentrosymmetric superconductors, electronic correlations, $s$-wave superconductivity, NMR

(Some figures may appear in colour only in the online journal)

1. Introduction
Noncentrosymmetric superconductors (NCSCs) belong to a class of materials that miss a key symmetry, such as parity

[1]. In NCSCs, the lack of inversion symmetry of the crystal lattice often induces an antisymmetric spin–orbit coupling (ASOC), which lifts the degeneracy of the conduction-electron bands and splits the Fermi surface. Consequently, both intra- and inter-band Cooper pairs can be formed and an admixture
A particular NCSC family, which exhibits unconventional superconducting properties, is that of $M_3X_2Y$ compounds. For the definition of ‘unconventional’ superconductor (basically one that does not conform to $s$-wave pairing), we follow the definition put forward in reference [7]. Here, $M = \text{Mo, Pd, W, Pt}; X = \text{Li, Al};$ and $Y = \text{B, C, N}$. Five members of this family have already been studied and, in ascending order of atomic number $Z$ of the metal atom $M$, they are: Rh$_2$Mo$_3$N, Mo$_3$Al$_2$C, Li$_2$Pt$_3$B, W$_3$Al$_2$C, and Li$_2$Pd$_3$B. From general principles, it is expected that as $Z$ increases, the ASOC strength increases as well. Consequently, a superconductor of an unconventional type is more likely to appear in metals with a higher atomic number. Indeed, from the existing literature, it is known that, while Li$_2$Pd$_3$B is a conventional superconductor [8], its high-$Z$ Pt counterpart, Li$_2$Pt$_3$B, exhibits unconventional SC [9], here identified by the presence of gap nodes [10]. The superconducting properties of the isostructural Mo$_3$Al$_2$C vs W$_3$Al$_2$C compounds are, however, still under study, with various groups reporting contradictory types of SC, either conventional [11–17] or unconventional [18, 19], even for the single compound. Thus, in Mo$_3$Al$_2$C, a power-law behaviour of the $^{27}$Al nuclear magnetic resonance (NMR) spin–lattice relaxation rates possibly suggests superconducting gap nodes [18], while the exponential temperature dependence of the magnetic penetration depth and the absence of TRS breaking are more consistent with conventional nodeless SC [16, 20]. More experimental data is required to fully establish the true nature of these systems.

In this paper, we explore the electronic properties of W$_3$Al$_2$C, in both the normal- and the superconducting states. Our results indicate that this system is only weakly correlated. Most importantly, based on our NMR experiments, we provide evidence of BCS-type $s$-wave pairing in the noncentrosymmetric W$_3$Al$_2$C superconductor. It is surprising that unconventional SC is not observed, even though W has a higher atomic number than Mo (and, hence, a larger ASOC). We argue why, despite the presence of the heavier element, W$_3$Al$_2$C exhibits only conventional SC behaviour.

2. Experimental details

Polycrystalline samples of W$_3$Al$_2$C were prepared via high-temperature, high-pressure solid-state reaction. To achieve a homogeneous mixture, high-purity W, Al, and C powders in a quasi-stoichiometric ratio 3:1.8:0.8 were ball-milled for two days in a glove box under Ar atmosphere. The mixture was then pressed into a pellet and placed in an $h$-BN capsule, where the sample was heated up to 2173 K under 5 GPa for 24 h. Room-temperature x-ray powder diffraction (XRD) measurements were performed in a Bruker D8 diffractometer with Cu Kα radiation. Rietveld refinements via the FullProf suite confirm the cubic structure of W$_3$Al$_2$C, with a space group P4$_3$2 (No. 213) [22]. Magnetic susceptibility and heat-capacity measurements were performed on, respectively, a vibrating sample magnetometer and a physical property measurement system, both by Quantum Design. Further details on sample preparation and characterization have been reported in [11].

The $^{27}$Al NMR measurements, including lineshapes and spin–lattice relaxation times, were performed on W$_3$Al$_2$C in powder form at different applied magnetic fields (4–7 T). To cover the 1.8 to 300 K temperature range we used a continuous-flow CF-1200 cryostat by Oxford instruments, with temperatures below 4.2 K being achieved under pumped $^4$He conditions. Preliminary resonance detuning experiments confirmed a $T_c$ of 7.6 K at 0 T (5.3 K at 5 T). The $^{27}$Al NMR signal was detected by means of a standard spin-echo sequence, consisting of $\pi/2$ and $\pi$ pulses of 3 and 6 $\mu$s, with recycling delays ranging from 1 to 60 s, in the 1.8–300 K temperature range. Despite an echo delay of 100 $\mu$s, 2 to 32 scans were sufficient to acquire a good-quality signal. The lineshapes were obtained via fast Fourier transform of the echo signal. Spin–lattice relaxation times $T_1$ were measured via the inversion recovery method, using a $\pi–\pi/2–\pi$ pulse sequence. Subsequently, the $T_1$ values for the central transition of the spin-$\frac{1}{2}$ $^{27}$Al nucleus were obtained by using the relevant formula for the relaxation of quadrupole nuclei [23].

3. Results and discussion

3.1. $^{27}$Al NMR in the normal- and superconducting phases

NMR is a powerful local technique for investigating the electronic properties of materials, in particular, their electronic correlations, magnetic order, and SC [24]. Although the magnetic field reduces the $T_c$ value, a high upper critical field (here above 50 T [12]), still allows us to explore the superconducting behaviour of W$_3$Al$_2$C. In addition, we also investigated the NMR response in the normal state. The $^{27}$Al NMR measurements were performed in different external magnetic fields, from 4 to 7 T, corresponding to $T_c$ values between 5.9 and 4.6 K. In all cases, the $^{27}$Al NMR reference frequency $\nu_0$ was calculated with respect to a standard Al(NO$_3$)$_3$ reference. The $T_1$ relaxation times were calculated by using a stretched-exponential relaxation model [23, 25], whereby disorder is modelled by a stretching coefficient $\beta$:

$$M_2(t)/M_2^0 = 1 - f \left[ \frac{1}{35} e^{-t/(T_1)^\beta} + \frac{8}{45} e^{-6t/(T_1)^\beta} + \frac{50}{63} e^{-6t/(T_1)^\beta} \right].$$

Here $M_2^0$ is the magnetization value at thermal equilibrium, while $f$ reflects the efficiency of population inversion (ideally 2). In general, the experimental NMR data—shifts and relaxation rates—clearly reflect the two phases of W$_3$Al$_2$C: a normal metallic phase above $T_c$ and a BCS-type superconducting phase below it.
3.1. Metallic behaviour in the normal phase. In the normal phase, we observe an almost ideal metallic behaviour for all the applied magnetic fields (see figures 1(a) and 2(b)). For instance, the relaxation-rate data in figure 1(a) are well described by a power-law function with a scaling exponent of 1.0(1), i.e., the relaxation rate is perfectly proportional to temperature. We can also compute the Korringa product $\frac{1}{T_1 T}$ (here, only 0.017 s$^{-1}$ K$^{-1}$), which is proportional to the electronic density of states (DOS) at the Fermi level, $N(E_F)$ (see figure 1(b)). As expected for an ideal metal, in the normal phase of W$_3$Al$_2$C, $N(E_F)$ is practically constant with temperature and independent of the applied magnetic field, but approximately thirty times smaller than the Korringa product in metallic Al (0.54 s$^{-1}$ K$^{-1}$) [26, 27]. These widely differing relaxation rates are partly reflected also in the different Knight shifts: 450 ppm in W$_3$Al$_2$C vs 1636 ppm in metallic Al [28], resulting in a $T_1 T K^2$ of $1.19 \times 10^{-5}$ and $4.98 \times 10^{-6}$ sK in W$_3$Al$_2$C and in metallic Al, respectively. The different $T_1 T K^2$ values suggest that, although W$_3$Al$_2$C is an ordinary metal in its normal phase, it could still exhibit weak electronic correlations. The strong reduction in shift in W$_3$Al$_2$C suggests a very small contribution of $s$-electrons (responsible for the contact hyperfine interaction) at the Fermi energy. This is consistent with previous NMR studies of Al-based alloys [29] and with the electronic structure calculations of W$_3$Al$_2$C [11]. Indeed, the latter indicate that the $s$-electron band is shifted to higher energies, whereas the valence $d$-electron band of the W transition metal is prominent at the Fermi level.

3.1.2. NMR evidence of BCS SC in W$_3$Al$_2$C. In the superconducting phase, the electronic properties of the system can be described by the standard BCS theory, which predicts a gap ratio $2\Delta_0/k_B T_c = 3.53$ (see figure 2(a)) and a reduction of the NMR shift at low temperatures (see figure 2(b)).
Here, the reduced shift reflects the electron pairing into spin-compensated (typically s-wave) Cooper pairs. This result is consistent with a recent μSR study of W₃Al₂C [12], where s-wave SC with the same gap ratio was reported. The superconducting gap value we find in W₃Al₂C is intermediate to the SC gaps reported in Mo₃Al₂C, where an NMR study claimed a $2\Delta_0/k_BT_c$ ratio of 2.8(2) [14], while specific-heat measurements implied a ratio of 4.03 [13].

3.1.3. Detection of the Hebel–Slichter peak via $^{13}$C NMR.

According to the Korringa relation [30], $T_1$ in metals depends strongly on $N(E_F)$. Hence, upon entering the superconducting state, we expect an exponential decay of $T_1$. Yet, preceding this decay, just below $T_c$, the spin–lattice relaxation rate first increases above its normal-state Korringa value, showing a so-called coherence (or Hebel–Slichter-HS) peak [31, 32]. Such increase in relaxation rate results partly from the enhanced density of electronic states, which pile up near the SC gap edges [33, 34]. Considering its key role in the experimental confirmation of the BCS theory, the observation of a Hebel–Slichter peak is recognized as a clear indication of BCS-type s-wave SC.

However, its absence does not necessarily rule out the possibility of a standard s-wave pairing. This seems to be also the case for W₃Al₂C where, as illustrated in figure 1(a), we do not observe such peak in the $^{27}$Al NMR relaxation rates below $T_c$. Several hypotheses can be put forward to explain this experimental result.

One possibility, relevant to type-II superconductors, was suggested by Goldberg et al [35]. Here, the total nuclear spin-relaxation rate consists of the sum of two terms, the first of which describes the relaxation in the normal-state vortex cores, while the other captures the relaxation in the remaining superconducting volume. This theory predicts that the contribution from the normal-state cores is proportional to the external magnetic field $H$. To test it, we measured the relaxation rates at different magnetic fields, in the range from 4 to 7 T. As can be seen in figure 2(a), the (scaled) relaxation times generally fall on the same exponential curve, indicating that no field-dependent term arises from vortex cores. Consequently, this hypothesis cannot explain the absence of an HS peak.

Another possibility is that the HS peak is suppressed by disorder, caused by intrinsic defects and/or magnetic impurities. To investigate the role of disorder, we studied the linewidths and the stretching coefficient $\beta$. As shown in figure 3, $\beta$ decreases continuously as the temperature is lowered, while remaining always smaller than 1. This indicates a distribution of relaxation rates, reflecting the inequivalence of NMR sites, in turn due to the intrinsic disorder (see, for instance, references [36, 37]). However, we find that both parameters depend only weakly on temperature and show no discontinuities or an unusual behaviour near $T_c$. Thus, we can rule out the possibility that disorder, although present, is affecting the HS peak.

Yet another possibility is that, for quadrupolar nuclei such as the spin-$\frac{5}{2}$ $^{27}$Al, also the quadrupole interaction contributes to the spin–lattice relaxation, tending to smear out the HS peak [38]. To test this possibility, we measured the $^{13}$C NMR relaxation rate in W₃Al₂C. Since $^{13}$C is a spin-$\frac{1}{2}$ nucleus, it represents a purely dipolar probe, not undergoing any quadrupole interaction. As can be seen in figure 4(a), we indeed observe a small feature just below $T_c$. Here, the exact $T_c$ value at 5 T was determined by means of a standard resonance-detuning experiment (data not shown).
To model the feature near $T_c$, we begin with the usual expression for the HS peak [33]:

$$\frac{R_s}{R_n} = \frac{2}{k_B} \int_\Delta^\infty \left[ N_s^2(E) + M_s^2(E) \right] f(E)[1 - f(E)] dE. \tag{1}$$

Here, $R_s$ and $R_n$ are the relaxation rates in the superconducting and the normal state, respectively, $M_s(E) = N_0 \Delta / \sqrt{E^2 - \Delta^2}$ is the anomalous DOS due to the coherence factor [33], and $N_s(E) = N_0 E / \sqrt{E^2 - \Delta^2}$ is the DOS in the superconducting state.

In our case, two modifications were made. Firstly, we chose $M_s(E)$ and $N_s(E)$ with a triangular broadening function $B(E)$, characterized by a width $2 \delta$ and a height $1/\delta$, with $\delta = 0.2 \Delta$. Secondly, we model the degree of coherence by the parameter $c$, by making the substitution $\Delta \rightarrow c \Delta$. The conventional BCS theory [39] predicts that, depending on the details of the scattering operator, the scattering matrix element can adopt a positive or a negative sign. The modelling of the HS peak typically requires a positive sign, but in other situations, e.g., in ultrasound absorption, the negative sign has to be used. Here, by setting $c$ as an adjustable parameter, one can model the case where the scattering matrix consists of both positive and negative components, which may cause a (partly) suppression of the HS peak. After these two modifications, $N_s(E)$ and $M_s(E)$ can be written as [40]:

$$N_s(E) = \int B(E' - E) \frac{E'}{(E'^2 - \Delta^2)^{1/2}} dE', \tag{2}$$

$$M_s(E) = \int B(E' - E) \frac{c \Delta}{(E'^2 - \Delta^2)^{1/2}} dE'. \tag{3}$$

The fit results are shown in figure 4(b). We find that the fit obtained by fixing $c = 1$ drastically overestimates the relaxation rates below $T_c$. On the other hand, the fit obtained by fixing $c = 0$ reproduces adequately the feature near $T_c$, although with a slightly overestimated relaxation below $T_c$.

From the $^{13}$C NMR relaxation rates in the superconducting state and the above analysis we infer with some confidence that W$_3$Al$_2$C indeed exhibits s-wave SC, as evidenced by the observation of an (albeit reduced) HS peak. Yet, it appears that there are some decoherence effects, both at and below $T_c$, most likely due to a strong electron–phonon coupling in this material (see reference [41] and the section below). In general, the exact mechanism of such decoherence effects is yet to be understood.

### 3.2. Electronic specific heat

To get further insight into the superconducting state of W$_3$Al$_2$C, the temperature dependence of its electronic specific heat was evaluated and analysed using different models. After subtracting the phonon contribution from the measured specific heat (see inset in figure 5), the electronic specific heat divided by the electronic specific-heat term, i.e., $C_e / \gamma T$, is obtained and presented in figure 5. The temperature-dependent superconducting-phase contribution to the entropy was calculated by means of the expression [42]:

$$S(T) = -\frac{\gamma_n}{\pi^2 k_B} \int_0^\infty \left[ \ln f + (1 - f) \ln(1 - f) \right] d\epsilon, \tag{4}$$

where $\gamma_n$ is the normal-state electronic specific-heat coefficient, $f = (1 + e^{\epsilon/T})^{-1}$ is the Fermi function and $E(\epsilon) = \sqrt{\epsilon^2 + \Delta^2(T)}$ is the excitation energy of quasiparticles, with $\epsilon$ the electron energies measured relative to the chemical potential (Fermi energy) [42, 47]. Here, $\Delta(T)$ is the temperature dependent gap function, which in the BCS s-wave model can be written as $\Delta(T) = \Delta_0 \tanh(1.82[1.018(T_c/T - 1)]^{0.51})$ [48], with $\Delta_0$ the gap value at zero temperature. In case of $p$- and $d$-wave pairings, the temperature-dependent gap functions are $\Delta(T) \sin \theta$, and $\Delta(T) \cos 2\phi$, respectively, exhibiting point- and line nodes in the respective gap function. The temperature-dependent electronic specific heat in the superconducting state can be calculated from $C_e = T \frac{dS}{dT}$.

The fit results using the above-mentioned models are shown by solid lines in the main panel of figure 5. We find that, while the s-wave model fits the electronic specific heat data...
The superconducting properties of the $M_3X_2C$ family of NCSCs are summarized in table 1. The data are somewhat challenging to interpret, because of the lack of a clear trend when arranged in order of increasing atomic number $Z(M)$. Most likely this reflects the fact that the superconducting behaviour of the $M_3X_2C$ compounds is highly dependent on the details of their band structures, which differ widely between members of the same family. Despite this difficulty, we can still draw some conclusions.

First, we note that the SC gap values $2\Delta/k_B T_c$ seem to differ, depending on whether they were determined by means of NMR, $\mu$SR, or $C_p$ measurements. In general, the gaps estimated via NMR and $\mu$SR, which are both local-probe techniques, tend to be in good agreement. Conversely, the SC gaps determined from $C_p$ data tend to be higher than those calculated from NMR and $\mu$SR data, and systematically indicate a strong electron–phonon coupling across the entire family of $M_3X_2Y$ compounds.

Secondly, we note that the $(T_1T)^{-1}$ values of $W_3Al_2C$ are consistent with those of the analog compound $Mo_3Al_2C$ obtained by Bauer et al [18]. Since $Mo_3Al_2C$ adopts the same structure as $W_3Al_2C$, the only differences being that $W$ is less electronegative than Mo (1.7 vs 2.16 on the Pauling scale) and marginally larger atomic covalent radius compared to Mo (150 vs 145 pm), we expect the $N(E_F)$ of $Mo_3Al_2C$ and $W_3Al_2C$ to be of a similar magnitude and, consequently, their $(T_1T)^{-1}$ values to be comparable. Considering that the actual $N(E_F)$ of $Mo_3Al_2C$ is twice as large as that of $W_3Al_2C$ (5.48 vs 2.37, see table 1), this implies an approximately fourfold increase in relaxation rate $[(T_1T)^{-1} = 0.075 \text{ vs } 0.017 \text{ (sK)}^{-1}]$, see table 1). On the other hand, the $(T_1T)^{-1}$ values obtained by Kuo et al [19] and Koyama et al [14] are wildly different (see figure 6). Recently, it was shown that the deliberate introduction of vacancies (here Al) in $M_3X_2Y$ by soft chemical etching does not significantly influence the DOS (as from DFT calculations and heat-capacity data), yet it dramatically alters the strength of electron–phonon coupling [41]. Hence, the presence of vacancies might justify the different $(T_1T)^{-1}$ values obtained by the different groups. Furthermore, since $W_3Al_2C$ intrinsically contains more Al-vacancies than its Mo counterpart [41], this might explain the BCS-type character of the former.

Thirdly, our results in table 1 support the observation made by Bauer and Sigrist [1] that, in case of phonon-mediated superconductors, although a noncentrosymmetric crystalline structure is required for the occurrence of unconventional SC, it does not necessarily imply it. Another remarkable example

3.3. Comparison with other members of the $M_3X_2Y$ family

The superconducting properties of the $M_3X_2Y$ family of NCSCs are summarized in table 1. The data are somewhat challenging to interpret, because of the lack of a clear trend when arranged in order of increasing atomic number $Z(M)$. Most likely this reflects the fact that the superconducting behaviour of the $M_3X_2C$ compounds is highly dependent on the details of their band structures, which differ widely between members of the same family. Despite this difficulty, we can still draw some conclusions.

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Table 1. Comparison of the superconducting parameters of selected noncentrosymmetric superconductors with the chemical formula $M_3X_2Y$, where $M$ is a metal. In all the cited references, $N(E_F)$ includes the contribution from SOC.

| Parameter | $\text{Rh}_2\text{Mo}_3\text{N}$ | $\text{Mo}_3\text{Al}_2\text{C}$ | $\text{Li}_2\text{Pd}_3\text{B}$ | $\text{W}_3\text{Al}_2\text{C}$ | $\text{Li}_2\text{Pt}_3\text{B}$ |
|-----------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| $Z(M)$    | 42                              | 42                              | 46                              | 74                              | 78                              |
| $T_c$ (K) | 4.3 [43]                        | 9.0 [18]                        | 7.2 [44]                        | 7.6 [11]                        | 2.6 [44]                        |
| $\gamma$ (mJ mol$^{-1}$ K$^{-2}$) | 24.15 [43]                      | 17.8 [18]                      | 9.5 [44]                        | 10                               | 9.6 [44]                        |
| $\Delta C_p/\gamma T_c$ | 1.5                             | 2.28 [18]                       | 1.75 [44]                       | 2.3                              | 0.75 [44]                       |
| $\xi$ (nm) | 6.77 [43]                       | 4.6 [18]                        | 7.6 [44]                        | $<5.7$ [11]                       | 11.8 [44]                       |
| $N(E_F)$ (states eV$^{-1}$ f.u.$^{-1}$) | —                               | 5.48 [18]                       | 2.24 [45]                       | 2.37 [11]                        | 2.9 [45]                        |
| $1/(T_1 T)$ ($\text{s} \cdot \text{K}$)$^{-1}$ | —                               | 0.34[27Al] [14]                 | 0.045[11B] [21]                  | 0.017[27Al]                      | 0.034[11B] [21]                  |
| $2\Delta/\kappa_0 T_c(C_p)$ | 3.62 [43]                       | 4.03 [13]                       | —                              | 4.50                             | Non $s$-wave                     |
| $2\Delta/\kappa_0 T_c$(NMR) | —                               | 2.8 [14]                        | 2.2 [8]                         | 3.5                              | Non $s$-wave                     |
| $2\Delta/\kappa_0 T_c(\mu\text{SR})$ | 3.46 (dirty) [46]               | 2.59 [20]                       | —                              | 3.5 [12]                         | Non $s$-wave                     |
| (3.84 (clean) [46] |                                  |                                 |                                 |                                  |                                 |

Figure 6. $1/T_1 T$ vs temperature for $\text{Mo}_3\text{Al}_2\text{C}$ as obtained from Koyama et al [14], Bauer et al [18] and Kuo et al [19].

of this is $\text{Mo}_3\text{P}$ [50] which, as $\text{W}_3\text{Al}_2\text{C}$ reported here, is a normal BCS-type superconductor, despite being an NCSC. Further, even within the same family, isostructural compounds can display a different superconducting behaviour. For instance, $\text{CePt}_3\text{Si}$ and $\text{LaPt}_3\text{Si}$ are isostructural ($P\overline{4}mm$ space group) and both display a large spin–orbit coupling (SOC). However, while $\text{CePt}_3\text{Si}$ exhibits unconventional SC [51, 52], $\text{LaPt}_3\text{Si}$ does not [52]. Future studies could shed more light on this issue and clarify the link between unconventional SC and the lack of a structural inversion centre.

4. Conclusion

Extensive NMR- and specific-heat measurements in the noncentrosymmetric $\text{W}_3\text{Al}_2\text{C}$ superconductor, provide ample evidence about its weak electron correlation, yet with a strong electron–phonon coupling. Most importantly, we establish that $\text{W}_3\text{Al}_2\text{C}$ shows a conventional BCS-type $s$-wave SC. This, apparently unnoteworthy result, is surprising in view of the enhanced SOC of W atoms, whose 5$d$ orbitals dominate the DOS at the Fermi level. This is all the more remarkable, if one considers that the analogous $\text{Mo}_3\text{Al}_2\text{C}$ compound, hosting the much lighter Mo atoms, is claimed to be an unconventional superconductor. Such a counterintuitive outcome may be explained with the subtle role played by SOC, as well as its competition with the electron bandwidth in the $M_3X_2Y$ family. Finally, by considering the similar case of $\text{Mo}_3\text{P}$, we show that $\text{W}_3\text{Al}_2\text{C}$ represents yet another example of a noncentrosymmetric material with conventional normal-state- and superconducting properties, thus emphasizing the role of a noncentrosymmetric structure as a beneficial (but not sufficient) condition in achieving unconventional SC.
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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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