I. INTRODUCTION

High-temperature unconventional superconductivity in the iron pnictides has led to numerous studies of isostructural materials incorporating other transition metals. While many noniron-based pnictogen compounds do indeed superconduct, it is clear that the presence of iron (even if partially substituted) is necessary to achieve a high transition temperature \(T_c\). For example, \(T_c\) in the Ni-based system Ba\((\text{Ni}_{1-x}\text{Co})_2\text{As}_2\) has a maximum just above 2 K \([1]\), but can exceed 35 K in Ba\(_{1-x}\)K\(_x\)Fe\(_2\)As\(_2\) \([2]\). In most cases, metal pnictides require chemical substitution or pressure to suppress a competing antiferromagnetic/structural transition and stabilize a superconducting ground state. However, exceptions are found in materials containing an alkali element \(A = \text{K}, \text{Rb}, \text{or Cs}\), as the AFe\(_2\)As\(_2\) \([3,4]\), ACr\(_3\)As\(_5\) \([5]\), A\(_2\)Cr\(_3\)As\(_5\) \([6]\), and A\(_2\)Mo\(_3\)As\(_3\) \([7]\) parent compounds are all superconductors, with a maximum \(T_c\) of about 11 K for Cs\(_2\)Mo\(_3\)As\(_3\) \([8]\).

Tangential to the work done exploring superconductivity in the Fe-, Ni-, and Cr-based pnictides, there has been a fair amount of study of the alkaline earth \((E = \text{Ca, Sr, Ba})\), whose members crystallize in the same ThCr\(_2\)Si\(_2\) structure as the iron- and nickel-based superconducting systems \([9–11]\). The Ba- and Sr-containing ECo\(_2\)As\(_2\) compounds do not exhibit any magnetic order down to 2 K, but have been shown to exhibit ferromagnetic (FM) and antiferromagnetic (AFM) spin correlations, respectively, through NMR and neutron measurements \([12–15]\). SrCo\(_2\)As\(_2\) in particular exhibits both FM and AFM fluctuations at 5 K, and their competition impedes the formation of long-range order \([16,17]\). CaCo\(_2\)As\(_2\), on the other hand, has an antiferromagnetic transition \([10]\) at 52 K. The difference lies in the fact that CaCo\(_2\)As\(_2\) crystallizes in a collapsed ThCr\(_2\)Si\(_2\) structure, with a much shorter \(c\) axis and therefore smaller separation between layers; it is also nonstoichiometric, with about 7% Co vacancy in the CoAs layers. These two factors weaken the electronic structure and cause stronger interlayer interactions, which helps to stabilize A-type collinear antiferromagnetic order \([18]\). Overall, the key difference with the presence of cobalt is the unit increase in electron filling \([19]\). Through many different studies, this has been shown to move the system away from the electronic instabilities leading to superconductivity in the iron-based system and toward competing magnetic interactions \([9,20–23]\).

To that end, to push a Co-based system closer to the electronic structure and electron filling observed in the iron-based superconducting pnictides, the oxidation state of ions in the CoAs layers should be increased. In the case of KFe\(_2\)As\(_2\), Fe has a nominal oxidation state of Fe\(^{2.5+}\) \((d^{5.5})\). In order to lower the electron count of Co\(^{2+}\) \((d^7)\) we can replace the alkaline earth metal with an alkali metal to yield Co\(^{3.5+}\) \((d^{6.5})\) and determine if it then behaves similarly to iron. KCo\(_2\)As\(_2\) is a good choice for this, and is the only Co-based alkali pnictide...
that has been synthesized to date. However, the previous reports were room temperature structural measurements [24], or low temperature magnetization measurements [25, 26] where significant amounts of unwanted phases in powder samples seem to have affected the data. Another reason to look at KCo$_2$As$_2$ is because KFe$_2$As$_2$ differs even from the other iron-based superconductors as a result of strong electron-electron interactions, leading to heavy fermion-like behavior at low temperatures [27]. We have found a reliable method for producing KCo$_2$As$_2$ single crystals with millimeter-scale dimensions that are stable in air. As a result, we have been able to measure magnetic, electrical, and thermodynamic properties at low temperatures, as well as directly image the band structure through angle-resolved photoemission spectroscopy (ARPES). We find no long range magnetic order or superconductivity above 100 mK. Our measurements offer a comparison to the iron-based materials that was previously restricted to theory [28], and contribute to the understanding of the relationship between electron distribution, magnetism, and superconductivity in pnictide materials.

II. CRYSTAL GROWTH AND CHARACTERIZATION

Crystals were grown from prereacted CoAs (Co powder, Alfa Aesar, 99.8%; As lump, Alfa Aesar, 99.999%) and K (cubes, Sigma Aldrich, 99.5%) in a 2:3 ratio. The excess K acts as a flux at high temperatures, similar to what has been done for KFe$_2$As$_2$ [29]. The combination was placed in an alumina crucible and sealed inside a stainless steel (grade 316 austenitic) pipe in argon atmosphere. The mixture of CoAs and K was heated to 900 °C at 50 °C/hour and held at that temperature for 12 hours to achieve a congruent melt, before being cooled to 650 °C at 2 °C/hour, at which point the temperature control was turned off and the furnace was allowed to cool to room temperature (roughly 20 °C). The reaction vessel was then cut open in an argon glove box and the growth material harvested from the alumina crucibles. This process resulted in a mixture of polycrystalline material and single crystals. The latter had dimensions that could exceed 1 × 1 × 0.5 mm$^3$ [Fig. 1(c)], with the shortest axis universally being the c axis, typical for layered tetragonal systems.

Despite previous reports of the material being moisture sensitive in powder form [25, 26], we found our KCo$_2$As$_2$ crystals to be air stable. After being left in ambient conditions for several days, there was no noticeable change in the x-ray diffraction (XRD) pattern, electrical transport results, or appearance of samples. However, the powder obtained directly from growths can decompose within an hour to CoAs and even ignite in air, likely because of unreacted K in the remaining flux. Thorough washing with anhydrous ethanol removes excess potassium arsenide fluxes and the remaining material is air stable. Similarly, crystals can have residual flux on their surface that will absorb water and decompose, but which can readily be removed with anhydrous solvents.

X-ray measurements were conducted on individual single crystals and a powder obtained from single crystals. Single crystal diffraction was performed on a Bruker Smart Apex II CCD diffractometer at both 300 K and 150 K. The integral intensity was corrected for absorption with the SADABS software [30] using the multiscan method. The structure was solved with the ShelXT-2014 [31] program and refined with the ShelXL-2015 [32] program and least-square minimization using the ShelX software package [32]. Powder diffraction was done with a Bruker D8 x-ray diffractometer with Cu K$_\alpha$ radiation, $\lambda = 1.5406$ Å (step size = 0.020°). Rietveld refinements on powder diffraction data were carried out using the TOPAS 4.2 software [33].

Single crystal XRD of one of the recovered samples verified that KCo$_2$As$_2$ forms in the ThCr$_2$Si$_2$ structure expected from previous reports [24–26], the same one as the “122” iron pnictides [34], illustrated in Fig. 1(b). Lattice parameters were $a = 3.805(2)$ Å and $c = 13.573(8)$ Å at 300 K, and $a = 3.809(2)$ Å and $c = 13.580(8)$ Å at 150 K. Further details for both data sets are given in Table I, and more extensive parameters of the 150 K refinement are in Table II. The 300 K lattice parameters are similar to those found previously [24,25]. We note also that the $c$-axis length and $c/a$ ratio are both similar to KFe$_2$As$_2$ [24] and BaCo$_2$As$_2$ [25] and...
substantially higher than those of CaCo$_2$As$_2$ [23], i.e., the material does not form in “precollapsed” tetragonal structure. The slight negative thermal expansion (or, at least, the lack of positive thermal expansion) could be associated with the presence of Co and subtle changes in magnetism, as was noted for the spin glass CoSe [35]. Refinement of the single crystal pattern verified full elemental occupation of all structural sites. Room temperature (about 295 K) powder diffraction gave similar values of lattice parameters for KCo$_2$As$_2$ from single crystal data at 150 K. Previous magnetic measurements of KCo$_2$As$_2$ performed on powder samples [25,26] yielded contradictory results: One study reported a ferromagnetic transition [25] at 15 K, while the other found no long range ordering [26]. Band structure calculations predicted a lack of order in this system, and an overall weaker magnetic response than KFe$_2$As$_2$ [28]. This would be consistent with what we can infer from being in the uncollapsed tetragonal state, which in Co-based 122s typically inhibits long range order [10]. We conducted measurements on several single crystals of KCo$_2$As$_2$ that were thoroughly washed inside a glovebox and received minimal air exposure; representative magnetic susceptibility ($\chi$) data for one of the crystals are shown in Fig. 2 for field both parallel and perpendicular to the $ab$ plane. A 1-T field was used due to the fear of being in the uncollapsed tetragonal state, which in Co-based 122s typically inhibits long range order [10]. We conducted measurements on several single crystals of KCo$_2$As$_2$ that were thoroughly washed inside a glovebox and received minimal air exposure; representative magnetic susceptibility ($\chi$) data for one of the crystals are shown in Fig. 2 for field both parallel and perpendicular to the $ab$ plane. A 1-T field was used due to the small signal of the crystal (which weighed roughly 1 mg), but measurements in lower field were similar, though with worse signal/noise. We also saw no difference between field-cooled and zero-field-cooled data, and indeed no sign of any magnetic order in our samples, as $\chi$ was relatively constant with temperature above about 50 K (Fig. 2), indicative of Pauli paramagnetism. The magnitude of $\chi$ in both planes, about $10^{-3}$ emu/Oe mol Co, is about the size expected for a Pauli paramagnet, and an order of magnitude smaller than might be expected if there were a higher temperature antiferromagnetic transition. It is similar, for example, to the values measured for BaFe$_2$As$_2$ at room temperature where it is in the paramagnetic state [36]. Below 50 K the value increases sharply, likely due to a small amount of paramagnetic impurities. There is no indication of any sort of transition, and field sweeps on other samples at 2 K showed no hysteresis within the resolution of the measurement system. It seems possible that alternate phases may have been the source of low temperature ferromagnetism identified in previous paper [25], and powders would be more susceptible to these sorts of impurities. Co$_2$As, for example, has a low temperature ferromagnetic transition [37] at a temperature close to the $T_C$ = 15 K previously reported for KCo$_2$As$_2$.

### III. MAGNETIC PROPERTIES

Electrical resistance was measured as a function of temperatures between 1.8 and 300 K and fields up to 14 T. Samples were shaped into rectangular bars with current in the $ab$ plane, using gold wires attached to the samples with silver paste. There were no distinct features in the resistivity as a function of temperature, which has an initial linear decrease from room temperature before becoming flat below about 30 K [Fig. 3(a)]. The qualitative temperature dependence is similar to a previous resistance measurement on pressed pellets [26], but with a lower resistivity, which is to be expected for single crystals in comparison to polycrystals. The residual resistivity ratio, $\rho(1.8 \text{ K})/\rho(300 \text{ K})$, is typically over 100 and as high as

**TABLE I.** Single crystal x-ray diffraction data for KCo$_2$As$_2$.

| T (K)   | 150(2) | 301(2) |
|---------|--------|--------|
| Space group       | $I4/mmm$ | $I4/mmm$ |
| Crystal system    | tetragonal | tetragonal |
| $a$ (Å)           | 3.809(2) | 3.805(2) |
| $c$ (Å)           | 13.580(8) | 13.573(8) |
| Volume (Å$^3$)    | 197.0(2) | 196.5(3) |
| Z                 | 2       | 2       |
| Calculated density (g/cm$^3$) | 5.172 | 5.185 |
| $\lambda$, $\text{Mo K}\alpha$ (Å) | 0.71073 | 0.71073 |
| No. reflections collected | 2307 | 2220 |
| No. independent reflections | 184 | 184 |
| $F(000)$          | 278.0   | 278.0   |
| $R_1$, $wR_2$     | 0.0285, 0.0552 | 0.0264, 0.0538 |

**TABLE II.** Structural, lattice, and anisotropic displacement parameters for $I4/mmm$ KCo$_2$As$_2$ from single crystal data at 150 K. All off-diagonal terms are equal to zero.

| Atom | Wyckoff site | x    | y    | z    | $U_{11}(\text{Å}^2)$ = $U_{22}(\text{Å}^2)$ | $U_{33}(\text{Å}^2)$ |
|------|--------------|------|------|------|----------------------------------------------|----------------------|
| K    | 2a           | 0    | 0    | 0.5  | 0.0115(5)                                    | 0.0199(9)            |
| Co   | 4d           | 0.5  | 0.5  | 0.75 | 0.0065(2)                                    | 0.0176(4)            |
| As   | 4e           | 0.5  | 0.5  | 0.65040(5) | 0.00728(19) | 0.0171(3) |

**FIG. 2.** Field-cooled magnetic susceptibility of a KCo$_2$As$_2$ single crystal as a function of temperature, with 1 T field applied both parallel (blue) and perpendicular (red) to the $ab$ plane of the crystals. The background signal from the quartz holder was more than an order of magnitude smaller than the sample signal in both cases, and has been subtracted.
FIG. 3. (a) Resistivity as a function of temperature in zero field with current in the $ab$ plane. The inset shows the resistance of two other samples measured down to 100 mK, showing a lack of any low temperature transitions. (b) The magnetoresistance $\Delta \rho / \rho = (\rho(B) - \rho(0 \text{T})) / \rho(0 \text{T})$ of a different KCo$_2$As$_2$ sample at various temperatures, with the field again applied along the $c$ axis perpendicular to current. The inset compares temperature sweeps at 0 T [the same data as (a)] and 9 T. (c) The Hall coefficient $R_H$ based on field sweeps at constant temperature. The inset shows the $\rho_{xy}$ data at 2, 45, and 250 K. All other field sweeps were also linear. (d) The low temperature specific heat data. The purple dotted line is a linear fit based on the Debye low temperature model of the electron and phonon contribution.

Measurements of the Hall coefficient $R_H$ were made by sweeping field between $-14$ T and $+14$ T at constant temperature over the range 2–300 K [Fig. 3(c)]. Positive and negative field data were antisymmetrized to remove the longitudinal MR signal. The extracted even component was linear for all temperatures, as demonstrated by the Fig. 3(c) inset. The fitted slopes were used to calculate $R_H$. While the overall change is small, it is interesting to note the minimum near 50 K, before $R_H$ moves back toward zero as temperature is further decreased.

Heat capacity measurements were performed below 25 K on a 3.8 mg single crystal. Data from 3–7 K (10–50 K$^2$) fit well to the low temperature Debye specific heat model, $C/T = \gamma + \beta T^2$ [Fig. 3(d)]. The Sommerfeld coefficient $\gamma = 7.3 \pm 0.2$ mJ/K$^2$ mol, and phonon term $\beta = 0.89 \pm 0.02$ mJ/K$^4$ mol can be used to solve for a Debye temperature of $\theta_D = 220 \pm 4$ K. These values, especially $\gamma$, are much closer to those of BaCo$_2$As$_2$ ($\gamma = 8.2$ mJ/K$^2$ mol, $\theta_D = 250$ K) [20] than KFe$_2$As$_2$ (90 mJ/K$^2$ mol and 160 K) [39].
The quasiparticle dispersion, shown in yellow and red-solid lines for the zone-center and zone-corner pockets, respectively. The momentum-distribution curves with Lorentzian line-shapes; the Fermi wave vectors \([\text{white dashed lines in (a)}]\). The quasiparticle dispersion (black markers) along the different cuts in momentum space is determined from fitting the momentum-distribution curves with Lorentzian line-shapes; the Fermi wave vectors \(k_F\) and velocities \(v_F\) are determined from a linear fit of the quasiparticle dispersion, shown in yellow and red-solid lines for the zone-center and zone-corner pockets, respectively.

The change in transition metal seems much more relevant to material properties than the change from alkali to alkaline earth, most notably in the correlation strength or effective mass, as indicated by \(\gamma\). Combining the heat capacity and magnetization results, we can calculate the Wilson ratio \(R_W = \frac{\Delta T_0}{3\mu_0\gamma}\), where \(\mu_0\) is the vacuum permeability, \(k_B\) the Boltzmann constant, and \(g_e\) the electron \(g\) factor. The closer a material is to long range magnetic order, the higher \(R_W\) will be (\(R_W = 1\) for a free electron gas). For \(\text{KCo}_2\text{As}_2\) we get a value of about 2, much lower than \(\text{BaCo}_2\text{As}_2\) where it is 7–10, depending on orientation \([20]\), reinforcing the weak magnetism seen in susceptibility data. It also shows that the substitution of alkali (K) for alkaline earth (Ba) does lead to some degree of change.

V. ARPES

Angle-resolved photoemission spectroscopy (ARPES) measurements were carried out to quantitatively describe the \(\text{KCo}_2\text{As}_2\) band structure and determine electron density. Single crystals were cleaved in the UHV environment at 11 K, exposing the plane perpendicular to the \([001]\) direction. We performed photoemission using 120 eV photons in both linear-vertical and linear-horizontal polarizations, and summed the resulting ARPES intensity to produce the images in Fig. 4. These measurements were taken with an R-4000 Scienta hemispherical analyzer at the Quantum Materials Spectroscopy Centre endstation of the Canadian Light Source.

The Fermi surface [Fig. 4(a)] is obtained by averaging the spectral intensity within a range of the Fermi energy \((E_F)\) defined by the energy resolution \((\pm 12\text{ meV})\), and consists of two pockets. The first (in yellow) is located at the Brillouin zone (BZ) center \([k^F = (0, 0)]\), and the second pocket (in red) is located at the BZ corner, \([k^X = (2\pi/a, 2\pi/a)]\). The BZ is indicated by solid-black lines, using a value of \(a = 3.809\text{ Å}\) from the 150 K XRD results (Table II). We take three cuts across the Fermi surface, shown in panels (b)–(d). From these ARPES spectra, we see that both the \(\Gamma\) and \(X\) pockets are electron like.

We extract the quasiparticle dispersion \(E(k)\) from the momentum distribution curves (MDCs), which are given by the photoemission intensity at constant binding energy. As long as the self-energy is momentum-independent, the MDCs can be described by Lorentzian peaks centered at the quasiparticle momenta. We apply this Lorentzian fit (plus a constant background) to MDCs exhibiting sharp features; the extracted electronic dispersion \(E(k)\) is shown as black markers in Figs. 4(b)–4(d). Remarkably, \(E(k)\) is well described by a linear dispersion down to about 0.4 eV below the Fermi energy, as shown in yellow and red for the pockets at the BZ center and corner, respectively. We determine the Fermi velocity of the zone-corner pocket to be \(v_F^X = 2.4 \pm 0.3 \text{ eV Å}\) from the linear fit of the bands shown in Figs. 4(b) and 4(d), with no observed variation between the \(\Gamma - \Gamma\) and \(\Gamma - X\) directions within uncertainty. Likewise, \(v_F^X = 1.8 \pm 0.2 \text{ eV Å}\) is obtained from the \(\Gamma_0\) and \(\Gamma_1\) pocket in both high symmetry directions. The minimum of the \(X_0\) pocket (extracted from a hyperbolic model of the dispersion) is located at \(E_m^X = -0.62 \pm 0.06 \text{ eV}\). However, this hyperbolic model underestimates the band minimum at \(\Gamma_0\), so the energy-distribution curve is used in combination with an extrapolation of the linear dispersion to determine \(E_F^X = -0.15 \pm 0.05 \text{ eV}\).

We note that density functional theory (DFT) calculations of the dispersion near the \(X\) point show the presence of two bands, while we observe only one: Given that the dispersion of the two bands is very close \((\Delta k_F \approx 0.05 \text{ Å}^{-1})\), and matrix-element effects suppress the intensity of one of the bands in the high-symmetry cuts shown in Fig. 4, we are not able to distinguish them within the broad features of the Fermi surface. Therefore, detailed modeling of the photoemission matrix elements and higher quality data is needed to confirm the dispersion of this second band.

To determine the electron concentration, we extract the Fermi wave vector \((k_F)\) of the electron pocket at \(\Gamma\) and \(X\). The tetragonal symmetry of the crystal lattice requires a fourfold
symmetric in-plane Fermi surface. The simplest model satisfying this symmetry consists of a Fermi wave vector with the following angle dependence:

$$\mathbf{k}_F - \mathbf{k}_{FS} = k_r + k_4 \cos(4\phi),$$  \hspace{1cm} (1)$$

where $\phi$ is the angle along the Fermi surface with respect to the $\Gamma - \Gamma$ direction, $k_r$ and $k_4$ are parameters which define the radius and the warping of the Fermi surface, and $\mathbf{k}_{FS}$ is the momentum of the high-symmetry point at $\Gamma$ and $K$ for their respective electron pockets. The values for $k_r$ and $k_4$ are determined from the extracted $k_F$ values across the high symmetry directions $\Gamma - \Gamma$ and $\Gamma - X$.

We average the $k_F$ extracted from several cuts for each high-symmetry direction, and each pocket. $X_{00}$ is used for the analysis of the zone-corner pocket. Along the $\Gamma - X$ direction, we find the Fermi wave vector $k_F - k_{X} = 0.38 \pm 0.02$ Å$^{-1}$. Similarly, along the $\Gamma - \Gamma$ direction [Fig. 4(d)], we obtain $k_F - k_{\Gamma} = 0.40 \pm 0.02$ Å$^{-1}$. This gives $k_r = 0.39 \pm 0.03$ Å$^{-1}$ and $k_4 = 0.012 \pm 0.002$ Å$^{-1}$, which results in an electron concentration of $0.35 \pm 0.05$ electrons per BZ (note that this electron concentration would be doubled by the presence of the additional band at $X$). The same analysis performed on the $\Gamma_{00}$ pocket at the zone center results in Fermi wave vectors described by $k_F - k_{\Gamma} = 0.16 \pm 0.02$ Å$^{-1}$ along the $\Gamma - X$ direction, and $0.14 \pm 0.02$ Å$^{-1}$ along the $\Gamma - \Gamma$ direction. This results in $k_r = 0.15 \pm 0.01$ Å$^{-1}$ and $k_4 = -0.010 \pm 0.002$ Å$^{-1}$, where the negative sign accounts for the 45 degree phase shift between the warping of the zone-center and zone-corner pockets. We calculate the electron concentration of the zone-center pocket to be $0.052 \pm 0.007$ electrons per BZ. When added together, the volume of all the Fermi surface sheets (including the additional pocket at $X$ predicted by DFT, that we cannot distinguish) corresponds to a total carrier counting of about $0.75 \pm 0.01$ electrons per BZ, or about $3.8 \times 10^{21}$ electrons per cm$^3$.

VI. DISCUSSION

The major themes of the iron pnictides are absent in KCo$_2$As$_2$. KFe$_2$As$_2$ shows clear evidence of strong correlations at low temperatures: It has a very large Sommerfeld coefficient, a steep drop in resistance at low temperature marking a coherent-incoherent crossover, and magnetic susceptibility reminiscent of heavy fermion compounds [27]. The Co version instead features a $\gamma$ typical of metallic compounds, a resistance linearly proportional to temperature over most of the measured range, and a small Wilson ratio that is evidence for weaker magnetic interactions in KCo$_2$As$_2$ than nearly ferromagnetic BaCo$_2$As$_2$. The correlated behavior in KFe$_2$As$_2$ is attributed to coupling that places it close to a Mott transition [27]. In fact, it has been shown that in general the six 3$d$ electrons result in the Fe pnictide parent compounds being close enough to half-filling of $d$ orbitals that correlation effects have significant influence, especially when chemical substitution or applied pressure are incorporated [40]. Electron doping via Co moves it further away and, just as expected, signatures of correlated behavior vanish. Of course, as noted in analysis of band structure calculations, at the most basic level the addition of an electron changes the position of the Fermi energy and would have an effect even before considering correlations [28], as has been demonstrated already in comparisons of BaFe$_2$As$_2$ and BaCo$_2$As$_2$ [41]. Still, while the loss of an electron through K-Ba substitution would seem to balance Co-Fe replacement, we do not see anything like the magnetic and structural transitions of BaFe$_2$As$_2$. This is because correlations in these compounds stem from the 3$d$ orbitals of the transition metal specifically, so doping on different sites does not cancel out. The presence of at least some iron is crucial, and cobalt cannot replicate its effects because its seventh electron disrupts the orbital order iron takes on, regardless of the other elements present.

A Fermi surface comparison again reveals parallels and key differences. In the nonmagnetic, tetragonal states of KFe$_2$As$_2$, BaFe$_2$As$_2$, and KCo$_2$As$_2$, ARPES data show pockets at the zone center and corner [42,43]. The first two in fact have several concentric pockets, with those at $\Gamma$ being of hole character. In contrast, KCo$_2$As$_2$ and the ECo$_2$As$_2$ compounds [19,41] only have electron pockets. The K compound presents some differences even from the ECo$_2$As$_2$ series. Its $\Gamma$ pocket is circular, in contrast to the rhombo found at the zone center for the other materials [19]. This fits with calculations calling for cylindrical pockets [28].

The minimum in the Hall coefficient just below 50 K is unexpected for a single carrier type material. A “turn on” temperature in a similar range, featuring changes in both the MR and Hall coefficient, is seen in many extreme magnetoresistance materials, but typically involves changes in carrier concentration and mobility of multiple bands of differing sign [44]. ARPES also indicated that one band has a carrier concentration an order of magnitude higher, in which case it should dominate transport. However, the emergence of a significant MR and the change in zero field $\rho_{xx}$ in this same temperature range (from linear to roughly quadratic, before plateauing at even lower $T$) are signs for an overall change in scattering mechanism that would affect transport. It would not be detectable in our ARPES measurements since they were only done at a single, far lower temperature. There is also a difference between the carrier concentrations derived from ARPES and Hall effect measurements: for the former it is about $3.8 \times 10^{21}$ cm$^{-3}$, while the latter is approximately $1.3 \times 10^{22}$ cm$^{-3}$ at low temperatures. Whether this discrepancy is attributable to lack of experimental resolution or indicates something more profound is a question to be resolved with continued study.

VII. SUMMARY

A reliable method for the production of air stable KCo$_2$As$_2$ single crystals has been provided and the properties from ambient to liquid helium temperatures summarized. This crystal growth technique opens up a route to potential synthesis of Rb- and Cs-based counterparts, where the incorporation of a heavier alkali metal would offer an interesting comparison. KCo$_2$As$_2$ does not exhibit any signatures akin to the highly correlated state of KFe$_2$As$_2$, and shows many differences from the general properties of other iron pnictide superconductors. This results from the extra electron of cobalt, which significantly alters 3$d$ orbital interactions and inhibits the same correlated effects seen in the iron equivalent, whose bands are closer to half filling. But KCo$_2$As$_2$ merits interest
on its own. The observation of linear magnetoresistance and nonparabolic band dispersions are motivation for future investigation of possibly interesting physics in this system.

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