

**10 years of pressure tuning the two-dimensional transition metal
phosphorous trichalcogenides (MPX₃): review and outlook**

W Pik and C R S Haines*

Physics, University of East Anglia, UK

(Dated: May 8, 2026)

Abstract

Pressure has been used as a highly effective tuning parameter in the study of the many various phenomenon found in the family of materials given by the formula MPX_3 where M is a divalent transition metal and X is sulphur or selenium. The use of pressure has been gaining prominence since the first pressure study was reported ten years ago, in 2016. Here we present a review that collects the main results to come from pressure studies on the structural, magnetic, electronic and superconducting properties of this diverse family of materials. We also highlight the areas where pressure could play a crucial role in addressing key remaining mysteries.

6 I. INTRODUCTION

7 The MPX_3 family is a large and diverse group of materials - the 'M' can be Fe, Ni, Mn,
8 Co, Cd, Pb, Sn, V and it is quite likely that there are more possibilities. The 'X' so far is
9 limited to Se and S.. There have been a number of excellent review articles that focus on
10 the MPX_3 family and we do not seek to address all of the various observations from such a
11 large group of materials. In 2002 Scilipigni and Grasso [1] published a very comprehensive
12 work that we highly recommend. There has been a lot of progress since then and we will
13 confine ourselves to the discussion of experiments that use pressure as the primary tuning
14 parameter. A recent comprehensive review of the state of pressure work on these systems by
15 Matsuoka et al. [2] is worthy of note. In our present work we seek to update the field with
16 some of the most recent advances and a different perspective on the interpretation of some of
17 the most crucial experimental results. This review will proceed with an introduction into the
18 beginnings of the use of pressure to explore the properties of the MPX_3 family of materials
19 before then moving onto four sections addressing the progress made in understanding the
20 structural, magnetic, electronic and superconducting properties of the MPX_3 family that
21 has come from pressure studies.

22 Pressure studies began in 2016 with a report from Wang et al. [3] detailing the insulator to
23 metal transition in $MnPS_3$ and $MnPSe_3$. This was followed up with three articles published
24 in 2018 by independent groups across the world. First came reports of pressure induced
25 superconductivity by Wang et al. [4] in a paper that also reported some powder x-ray

* Contact author: c.haines@uea.ac.uk

26 diffraction and x-ray emission spectroscopy results. Wang et al. showed the continuous
 27 metallisation of both FePS_3 and FePSe_3 with applied pressure and the onset of a zero
 28 resistance state in FePSe_3 . Shortly after this Tsurubayashi et al. [5] reported the pressure
 29 and temperature dependence of resistivity in FePS_3 broadly in agreement with Wang et al.
 30 Next came the paper by Haines et al. [6]. This paper was focussed on FePS_3 and presented
 31 pressure dependent resistivity data and a comprehensive structural study under pressure.
 32 These four papers established the potential of pressure as a technique that could be used
 33 to make substantial progress in understanding the origins and potential applications of the
 34 diverse magnetic, electronic and superconducting properties of this material family.

35 II. STRUCTURAL EVOLUTION WITH PRESSURE

36 The sulphur containing members of the family all share a similar structure with most
 37 adopting the space group $C2/m$. Silipigni and Grasso [1] give a clear and thorough descrip-
 38 tion of this structure. This structure is a weak distortion from the trigonal type of structure
 39 one would expect from the observed ABC type stacking of the sulphur layers, Fig 1. The
 40 selenides adopt an AB stacking and this manifests in the $R\bar{3}H$ space group [7–9]. In this
 41 structure the metal ions have one nearest neighbour in the layers above and below that is
 42 another metal and one that is a P-P pair.

43 The first report of a structural transition was by Wang et al. in 2016 [3]. In this work
 44 it was not possible to solve the high pressure structures and structureless fitting was used
 45 to attempt to discern the evolution of the unit cell with applied pressure. It is important
 46 to point out that the important (001) peak falls outside the range that was accessible in
 47 this study. Without this peak there are many closely related space groups and unit cells
 48 that can be used to index the peaks - this makes it easy to be led astray. On the basis
 49 of this information a lattice collapse that comes from a dramatic reduction of the a lattice
 50 parameter was suggested. This intra planar volume collapse is certainly striking. A similar
 51 collapse was reported in FePS_3 and FePSe_3 in 2018 [4].

52 In the paper of 2018, Haines et al. [6] presented powder XRD data over a large range
 53 of d-spacing with high signal to noise. This allowed the authors to complete full Rietveld
 54 [11] refinements of the structure up to 18.1 GPa. With the benefit of the extra peaks it was
 55 shown that, for FePS_3 , the structural evolution is characterised by two phase transitions.

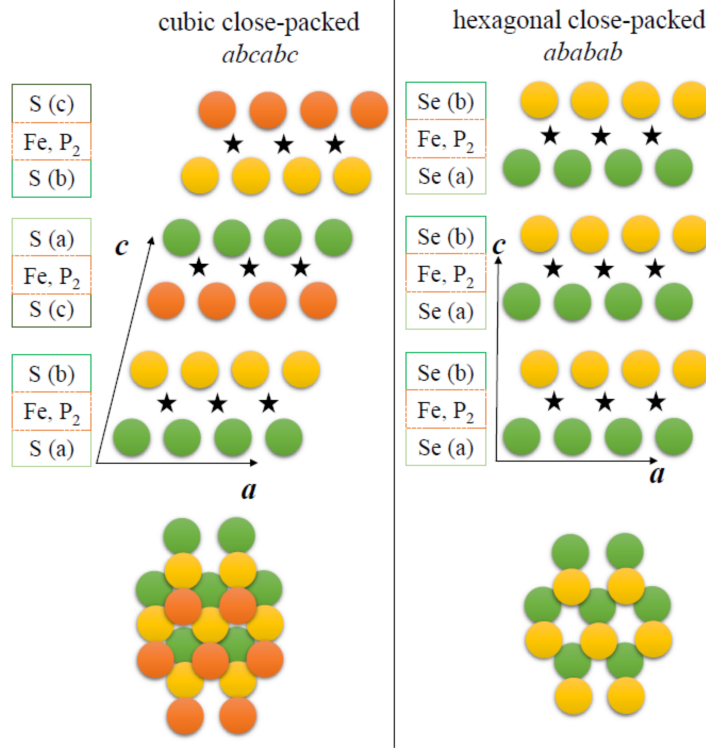


FIG. 1. Reproduced, with permission, from ref. [10].

First, at around 4GPa, a sliding transition in which the layers shear along the a axis by $\sim a/3$ and maintain the $C2/m$ space group. Then at ~ 10 GPa a collapse in the c^* and a change of space group from $C2/m$ to $P\bar{3}1m$. These transitions make chemical sense as the main changes are occurring in the weakly bonded van der Waals gap rather than in the primary bonds of the layers. In 2023, Jarvis et al. [12] used a combined single crystal and powder diffraction study to confirm this sequence of structural transitions in FePS₃. Taking the high pressure, high symmetry $P\bar{3}1m$ structure as the parent, the transitions, first to the $C2/m$ structure with $\beta \sim 90^\circ$ and then to the ambient pressure $C2/m$ structure with decreasing pressure can be described by a single gamma point distortion, Γ_3^+ . The atomic displacements are relatively small but the strain mode associated with Γ_3^+ is what gives the sliding transition and this is significant. The sliding transition is seen in $V_{1-x}PS_3$ [13] and no further higher pressure transitions have been reported.

Recent work [14] has shown that FePSe₃ is strikingly different to FePS₃. There is no sliding transition. The ambient structure has the space group $R\bar{3}$ and in this structure the stacking of the selenium atoms is AB. There is one high pressure structural transition into

the non-centrosymmetric $R3$ space group. This transition includes the characteristic collapse along the c^* direction. It is from this structure that superconductivity in this compound is emergent. The inversion centre is lost due to buckling of the Fe honeycomb and an associated splitting of the single selenium Wyckoff site into two. This change suggests the intriguing possibility that FePSe_3 could be a pressure tuned polar metal with an instability to superconductivity.

Reports on NiPSe_3 [15] show the exact same structural sequence with applied pressure as reported by Haines et al. [6] for FePS_3 . This is somewhat surprising as the selenides do not usually have the ABC packing of the Se atoms that leads to the $C2/m$ structure seen in the sulphides. An extensive study on NiPS_3 by Harms et al. in 2022 [16] provided evidence for a number of pressure induced phase transitions. The suggested sequence with increasing pressure is $C2/m \rightarrow P\bar{3} \rightarrow P\bar{3}1m \rightarrow P3m1 \rightarrow P3$. The evidence for this sequence came from Raman scattering, single crystal X-ray diffraction and DFT calculations. It is worth pointing out that difficulties with the single crystal X-ray data analysis precluded any full refinements of the data. Full refinements were possible for the study on $\text{V}_{0.9}\text{PS}_3$ by Coak et al. [13] in which a single transition was observed that corresponds to the sliding transition seen in FePS_3 [6].

III. INSULATOR TO METAL TRANSITION

Insulator to metal transitions (IMTs) were first reported by Wang et al. in 2016 in MnPS_3 and MnPSe_3 at around 30 GPa and 25 GPa respectively. Tsurabayashi et al., Wang et al. and Haines et al. in 2018 [4–6] are the earliest reports of a pressure induced insulator-to-metal transition in the iron containing members of the family. These early papers report transport data from FePS_3 and FePSe_3 . Since then insulator-to-metal transitions have been reported in many members of this family including CoPS_3 [17], $\text{V}_{1-x}\text{PS}_3$ [13], NiPS_3 [16], NiPSe_3 [15], SnPS_3 [18], SnPSe_3 [19–21] and PbPS_3 [22]. In most cases the ITM takes place concomitantly with the structural transition in which the interlayer separation collapses. The notable exception is in the case of $\text{V}_{1-x}\text{PS}_3$ [13] in which there is a gradual change in the monoclinic angle β but no change in space group during the ITM transition.

The metallic state is perhaps the least well understood part of the general MPX_3 phase diagram. Some reports of magnetoresistance, in CoPS_3 [17] make a start on characterising

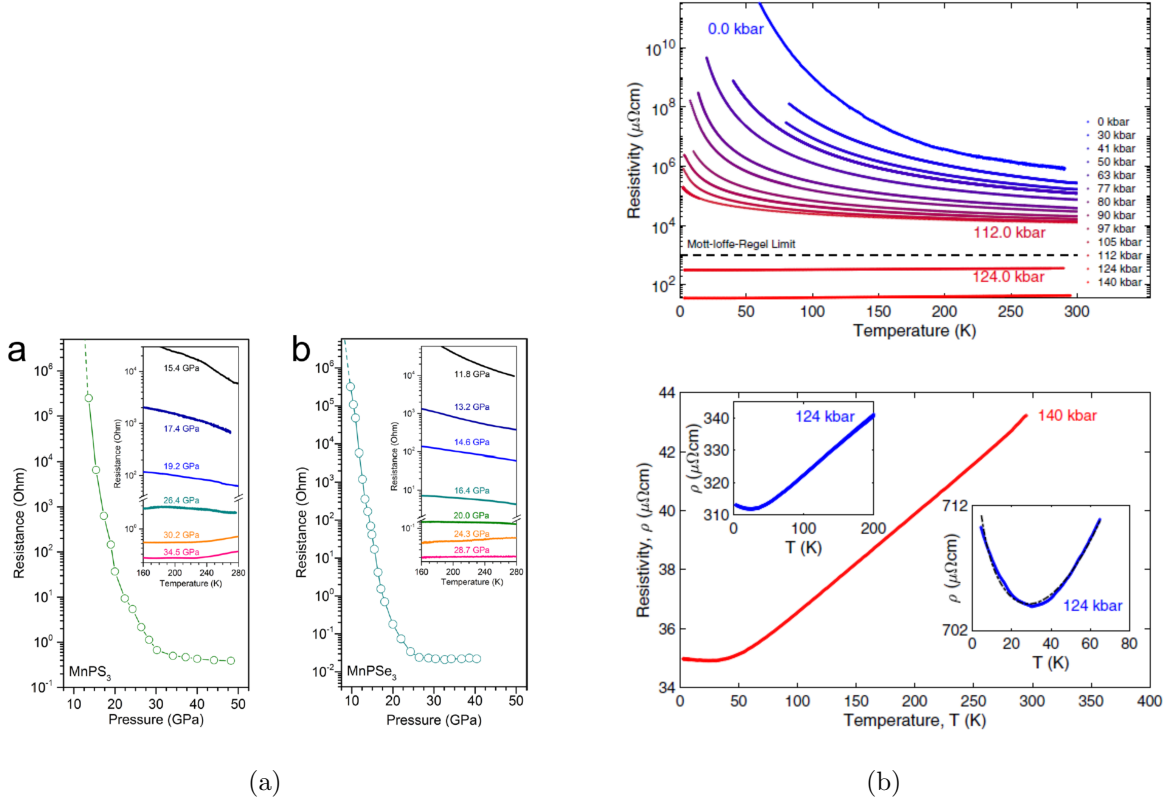


FIG. 2. Resistivity is the most direct probe of the IMT. Here we see examples from (a) MnPS₃ and MnPSw₃ (figure taken from Wang et al. [3]) and (b) V_{0.9}PS₃ (from [13])

the state but many questions remain

IV. MAGNETISM

We will not discuss the ambient pressure magnetic structure or properties of the MPX₃ family here as this has been done so well elsewhere [1, 23, 24]. Wang et al. [3] use X-ray emission spectroscopy (XES) to argue that the metallisation of MnPS₃ and MnPSe₃ is accompanied by a high spin to low spin transition. The spin associated with the Mn atom drops from 5/2 to 1/2 at the same pressure as the temperature dependence of the resistivity swaps from insulating to metallic. A similar high spin to low spin transition was suggested in FePS₃ and FePSe₃ in 2018 [4]. Neutron diffraction experiments on these materials have been reported by Coak et al. and Deng et al. [14, 25]. Both studies were carried out on D20 at the Institut Laue-Langevin (ILL) using Paris-Edinburgh type pressure cells. The results are, once again, strikingly different between the two sister materials. FePS₃ shows strong

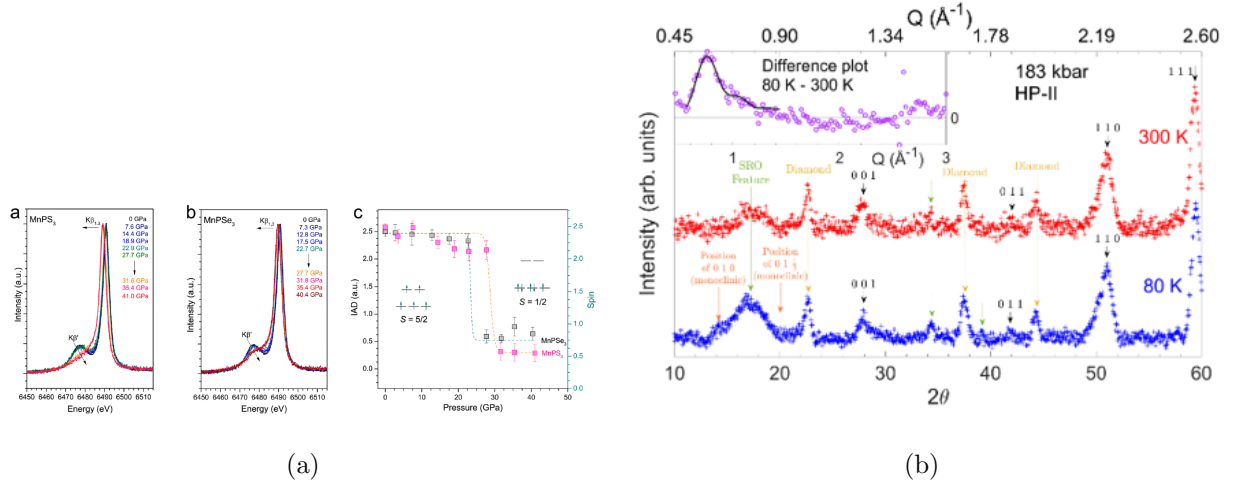


FIG. 3. (a) XES has been used to show a change in the spin state of a number of the MPX₃ materials. Here we reproduce results from Wang et al. [3] on MnPS₃ and MnPSe₃. Similar results have been reported for FePS₃ and FePSe₃. (b) SRO persists even up to room temperature (from [25])

113 evidence of iron remaining in the high spin state and contributing to significant magnetic
 114 scattering intensity characteristic of short range magnetic order. This is difficult to explain
 115 if there is indeed a high spin to low spin crossover. In FePSe₃ there is no evidence of coherent
 116 magnetic scattering above the critical pressure for the $R\bar{3}$ to $R3$ transition. This is consistent
 117 with the high spin to low spin cross over.

118 A combination of neutron diffraction data and SQUID magnetometry at high pressures
 119 [25] show that the antiferromagnetic Néel temperature increases slowly with increasing pres-
 120 sure, from 118K at ambient pressure to just over 160K at 10GPa. After the ITM transition
 121 there are no longer any observable magnetic Bragg peaks but a large broad feature at low
 122 Q characteristic of SRO is observed.

123 V. SUPERCONDUCTIVITY

124 There have currently been 7 reports of superconductivity in the MPX₃ family, FePSe₃ [4],
 125 NiPSe₃[15], SnPS₃[18], PbPS₃[22], and SnPSe₃ [19–21], with one of the reports in SnPSe₃
 126 being on the layered form, rather than the 3D form. There has also been a report of “possible
 127 superconductivity” in CrPSe₃[26]. We will split the discussion into the layered compounds
 128 and 3D compounds, starting off with the layered.

129 FePSe₃, NiPSe₃, and SnPSe₃, form layered compounds, in space groups $R\bar{3}H$, $C2/m$,
 130 and $P2_1/c$ respectively [7, 8]. With the difference between the layered and 3D SnPSe₃ being
 131 differences in unit cell parameters [20].

132 These layered compounds all exhibit a structural phase transition at pressures close to
 133 the onset of the superconducting state. NiPSe₃ exhibits a sliding transition at ~ 4 GPa, with
 134 the β angle becoming close to 90° . FePSe₃ reports a sudden collapse of a and b , indicating a
 135 shrinkage of the Fe honeycomb lattice at ~ 8 GPa. SnPSe₃ does not undergo an isostructural
 136 phase transition like the other two, but instead a transition from $P2_1/c \rightarrow P2_1$ at ~ 13.6 GPa,
 137 with a coexistence of the two being reported at higher pressures. Layered SnPSe₃ is also
 138 reported to amorphize at higher pressures, with superconductivity persisting through the
 139 amorphous phase[21].

140 These structural phase transitions are all concomitant with the onset of superconductivity.
 141 FePSe₃ exhibits the onset of superconductivity at ~ 9 GPa, with a T_c of ~ 2.5 K, NiPSe₃ at
 142 ~ 8 GPa, with a T_c of ~ 4.2 K and finally SnPSe₃ at ~ 16 GPa, with a T_c of ~ 3.5 K. Layered
 143 SnPSe₃ and to a lesser degree FePSe₃ exhibit a two stage superconductivity seemingly,
 144 whereas NiPSe₃ seems to exhibit the typical superconductivity 'hump'. For SnPSe₃ the
 145 peak T_c in superconductivity coincides with the pressure in which SnPSe₃ is reported to go
 146 amorphous. The amorphous state, or possibly $Cmcm$ space group that was reported in the
 147 3D version [20], which have similar forms.

148 The onset of superconductivity being concomitant with a structural phase transition
 149 implies that the structural transition aids the formation of the superconducting state, likely
 150 through the enhancement of the IMT. All three of these phase transitions are associated
 151 with an interplanar collapse, this brings the systems closer to a 3-dimensional system, which
 152 could be a more favourable system for a superconducting state to form in.

153 The other materials in the family that have been reported superconducting are all in
 154 a 3D form in their ambient conditions, with space group $P2_1/c$ [27]. With the exception
 155 of SnPS₃ which exists in the monoclinic Pc at ambient conditions, and undergoes a phase
 156 transition to $P2_1/c$ at ~ 0.2 GPa [28].

157 Like the layered materials, SnPS₃ and the 3D SnPSe₃ have their onset of superconductiv-
 158 ity nearly concomitant with a structural phase transition. SnPS₃ exhibits the first signs of
 159 superconductivity at ~ 31.7 GPa, with a $T_c \sim 2.2$ K [18]. SnPSe₃ exhibits superconductivity
 160 at ~ 15.3 GPa, at a $T_c \sim 2.2$ K [19], or ~ 18.9 GPa, with a $T_c \sim 3.1$ K [20]. These all increase

monotonously up to the highest pressures recorded in those experiments. The structural transitions in these systems is reported to occur at ~ 32.5 GPa for SnPS_3 and ~ 22 GPa or between 15.3 and 30 GPa for SnPSe_3 .

PbPS_3 is unique in that the onset of superconductivity does not occur near a structural phase transition. There is in fact, no structural phase transition reported up to 54 GPa for PbPS_3 [22]. The onset of superconductivity in PbPS_3 is seen at ~ 39 GPa, with $T_c \sim 3.2$ K. This leads to PbPS_3 being the only compound which doesn't have a structural transition at the core of the superconducting transition.

In these compounds, there is the possibility that the superconductivity seen is due to superconducting nature of the individual elements like selenium, tin and lead [29, 30]. Zhang et al considered this with SnPSe_3 [19], but concluded that due to being able to recover their Raman signal, which ruled out pressure induced disproportionation, the superconductivity would not be contributed from elemental selenium. Then it is possible to be true for the other compounds too.

With the other compounds all having their superconductivity in the proximity of a structural phase transition, it is useful to look at their behaviour of T_c v P, centred at their individual structural phase transitions, and see any similarities in their behaviour.

One obvious difference in these materials we haven't brought up is the chalcogen species, sulphur and selenium. Only SnPS_3 and PbPS_3 are sulphur species, and both have a 3D structure. It is very clear however, that the sulphur species take much more pressure, to tune the system into a superconducting state. This shows that the chalcogen species has a vital role in the formation of the superconducting state.

The suppression of the superconducting state via application of magnetic field was seen in all of these systems. All of them exhibited behaviour consistent with the Ginzburg-Landau equation [31], with the exception of FePSe_3 . An upturn was observed in the behaviour, which would be consistent with a field being applied parallel to the layers of this compound [31], but due to the nature of a DAC, and not being stated otherwise, we assume the field applied to FePSe_3 was perpendicular to the plane, and as such, this is unusual behaviour. This upturn was attributed to multiband superconductivity [4].

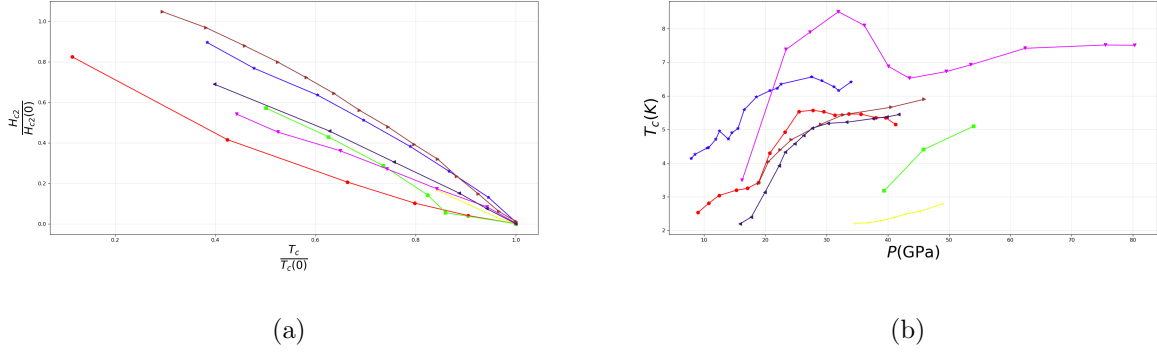


FIG. 4. (a) Collection of applied field vs T_c , normalised by upper critical field at 0K, and T_c at 0 field. An upper critical field for FePSe₃ was yielded by fitting a polynomial to the data presented in [4], as it didn't fit the GL equation. (b) A global collection of the T_c versus pressure curved of the MPX₃ compounds. Legend: Red Circles - FePSe₃ [4], Brown triangles - SnPSe₃[20], Blue stars - NiPSe₃ [15], Dark blue triangles - SnPSe₃ [19], Pink triangles - Layered SnPSe₃ [21], Green squares - PbPS₃ [22], Yellow plus - SnPS₃ [18].

VI. FUTURE DIRECTIONS AND OPEN QUESTIONS

Despite the considerable effort put into pressure studies on the MPX₃ compounds there are many open questions. Experiments at extreme pressure are difficult and time consuming. The pressure evolution of the structural phase transitions is still unknown or in need of additional studies for most of the family.

The ITM transition has been observed broadly across the family but detailed measurements of the nature of the metallic state are lacking. Some of the family are predicted to be Mott insulators and the metallised Mott insulator is a state of much interest. The Mott insulating state is characterised by a band gap at the Fermi energy that is opened up because of strong electron-electron repulsion. This state exists for a narrow range of electron density and can be metallised by self-doping (band structure changes) or extrinsic doping to move the system out of this range. The resulting metallic state would, therefore, still be likely to feel some effect of the on-site repulsion leading to strongly correlated metallic states. This has been explored in specific cases in 3D [32] but no examples are reported in 2D materials. Low-temperature upturns in the resistivity are common [6, 13, 33] and are somewhat reminiscent of Kondo physics, though at this point this is very speculative.

Measurements to determine the type of superconductivity in this family have revealed

much but we still do not know the symmetry of the pairing interaction or much of the phenomenology of this state. For example we have no estimates for the correlation length, penetration depth or critical currents associated with the superconductivity that has been observed.

-
- [1] V. Grasso, L. Silipigni, and Dipartimento, Low-dimensional materials: The mpx3 family, physical features and potential future applications, *Rivista Del Nuovo Cimento* **25**, 1 (2002).
- [2] T. Matsuoka, H.-S. Kim, S. Samanta, J. L. Musfeldt, and D. G. Mandrus, Mpx3 van der waals magnets under pressure (m = mn, ni, v, fe, co, cd; x = s, se), *Frontiers in Materials* **Volume 11 - 2024**, 10.3389/fmats.2024.1362744 (2024).
- [3] Y. Wang, Z. Zhou, T. Wen, Y. Zhou, N. Li, F. Han, Y. Xiao, P. Chow, J. Sun, M. Pravica, A. L. Cornelius, W. Yang, and Y. Zhao, Pressure-driven cooperative spin-crossover, large-volume collapse, and semiconductor-to-metal transition in manganese(ii) honeycomb lattices, *Journal of the American Chemical Society* **138**, 15751 (2016), pMID: 27934025, <https://doi.org/10.1021/jacs.6b10225>.
- [4] Y. Wang, J. Ying, Z. Zhou, J. Sun, T. Wen, Y. Zhou, N. Li, Q. Zhang, F. Han, Y. Xiao, P. Chow, W. Yang, V. V. Struzhkin, Y. Zhao, and H. kwang Mao, Emergent superconductivity in an iron-based honeycomb lattice initiated by pressure-driven spin-crossover, *Nature Communications* **9**, 10.1038/s41467-018-04326-1 (2018).
- [5] M. Tsurubayashi, K. Kodama, M. Kano, K. Ishigaki, Y. Uwatoko, T. Watanabe, K. Takase, and Y. Takano, Metal-insulator transition in mott-insulator feps3, *AIP Advances* **8**, 2016 (2018).
- [6] C. R. Haines, M. J. Coak, A. R. Wildes, G. I. Lampronti, C. Liu, P. Nahai-Williamson, H. Hamidov, D. Daisenberger, and S. S. Saxena, Pressure-induced electronic and structural phase evolution in the van der waals compound feps3, *Physical Review Letters* **121**, 10.1103/PhysRevLett.121.266801 (2018).
- [7] W. Klinge, R. Ott, and H. Hahn, Über die darstellung und eigenschaften von hexathio- und hexaselenohypodiphosphaten, *ZAAC - Journal of Inorganic and General Chemistry* **396**, 271 (1973).
- [8] B. R. O. G. L. A. R. J, FrenchProprietes structurales de phases miipx3 (x=s, se), *ANN.*

CHIM.; FRA; DA. 1980; VOL. 5; NO 6; PP. 499-512; ABS. ENG; BIBL. 15 REF. (1980).

- [9] A. Wiedenmann, J. Rossat-Mignod, A. Louisy, R. Brec, and J. Rouxel, Neutron diffraction study of the layered compounds mnpse3 and fepse3, Solid State Communications **40**, 1067 (1981).

- [10] S. Deng, *Emergent Critical Phases in Strongly Correlated Low-Dimensional Magnetic Systems*, Ph.D. thesis, Apollo - University of Cambridge Repository (2023).

- [11] H. M. Rietveld, A profile refinement method for nuclear and magnetic structures, Journal of Applied Crystallography **2**, 65 (1969).

- [12] D. M. Jarvis, M. J. Coak, H. Hamidov, C. R. S. Haines, G. I. Lampronti, C. Liu, S. Deng, D. Daisenberger, D. R. Allan, M. R. Warren, A. R. Wildes, and S. S. Saxena, Comparative structural evolution under pressure of powder and single crystals of the layered antiferromagnet feps₃, Phys. Rev. B **107**, 054106 (2023).

- [13] M. J. Coak, S. Son, D. Daisenberger, H. Hamidov, C. R. Haines, P. L. Alireza, A. R. Wildes, C. Liu, S. S. Saxena, and J. G. Park, Isostructural mott transition in 2d honeycomb antiferromagnet v0.9ps3, npj Quantum Materials **4**, 10.1038/s41535-019-0178-8 (2019).

- [14] S. Deng, M. J. Coak, C. R. S. Haines, H. Hamidov, G. I. Lampronti, D. M. Jarvis, X. Zhang, C. Liu, D. Daisenberger, M. R. Warren, T. C. Hansen, S. Klotz, C. Kim, P. Yang, B. Wang, J. Cheng, J.-G. Park, A. R. Wildes, and S. S. Saxena, Emergent polar metal phase in a van der waals mott magnet (2026), arXiv:2501.13635 [cond-mat.str-el].

- [15] H. Sun, L. Qiu, Y. Han, E. Yi, J. Li, M. Huo, C. Huang, H. Liu, M. Li, W. Wang, D.-X. Yao, B. A. Frandsen, B. Shen, Y. Hou, and M. Wang, Coexistence of zigzag antiferromagnetic order and superconductivity in compressed nipse3, Materials Today Physics **36**, 101188 (2023).

- [16] N. C. Harms, T. Matsuoka, S. Samanta, A. J. Clune, K. A. Smith, A. V. Haglund, E. Feng, H. Cao, J. S. Smith, D. G. Mandrus, H. S. Kim, Z. Liu, and J. L. Musfeldt, Symmetry progression and possible polar metallicity in nips3 under pressure, npj 2D Materials and Applications **6**, 10.1038/s41699-022-00313-9 (2022).

- [17] T. Matsuoka, R. Rao, M. A. Susner, B. S. Conner, D. Zhang, and D. Mandrus, Pressure-induced insulator-to-metal transition in the van der waals compound cops3, Physical Review B **107**, 1 (2023).

- [18] B. Yue, W. Zhong, T. Wen, Y. Wang, H. Yu, X. Yu, C. Chen, J.-T. Wang, and F. Hong, Pressure-induced ferroelectric-to-superconductor transition in snps3, Physical Review B **107**,

L140501 (2023).

- [19] H. Zhang, W. Zhong, X. Yu, B. Yue, and F. Hong, Electronic phase transitions and superconductivity in ferroelectric $\text{Sn}_2\text{P}_2\text{S}_6$ under pressure, *Physical Review B* **109**, 214517 (2024).
- [20] J. Wang, X. Liu, L. Zhang, J.-g. Guo, and T. Ying, Influence of dimensionality on superconductivity in pressurized 3D SnPSe_3 single crystal, *Physical Review Materials* **8**, 074803 (2024).
- [21] M. Qi, W. Chen, Y. Huang, H. Song, X. Lv, M. Wu, W. Zhao, L. Zhang, and T. Cui, Pressure-induced superconductivity in van der Waals layered semiconductor SnPSe_3 , *Journal of Materials Chemistry C* **12**, 5108 (2024).
- [22] X. He, Z. Zhang, Z. Ding, S. Wang, C. Chen, X. Chen, Y. Zhou, C. An, M. Zhang, Y. Zhou, X. Yang, and Z. Yang, Pressure-induced superconductivity in the metal thiophosphate $\text{Pb}_2\text{P}_2\text{S}_6$, *Physical Review Materials* **7**, 054801 (2023).
- [23] G. le Flem, Magnetic interactions in the layer compounds $\text{M}_2\text{P}_2\text{S}_6$ ($\text{M} = \text{Fe}, \text{Co}, \text{Ni}$), *Solid State Communications* **42**, iv (1982).
- [24] R. Brec, Review on structural and chemical properties of transition metal phosphorous trisulfides $\text{M}_2\text{P}_2\text{S}_6$, *Solid State Ionics* **22**, 3 (1986).
- [25] M. J. Coak, D. M. Jarvis, H. Hamidov, A. R. Wildes, J. A. Paddison, C. Liu, C. R. Haines, N. T. Dang, S. E. Kichanov, B. N. Savenko, S. Lee, M. Kratochvílová, S. Klotz, T. C. Hansen, D. P. Kozlenko, J. G. Park, and S. S. Saxena, Emergent magnetic phases in pressure-tuned van der waals antiferromagnet FeP_2S_6 , *Physical Review X* **11**, 10.1103/PhysRevX.11.011024 (2021).
- [26] C. Li, C. Li, Z. Tang, K. Liu, E. Chen, Y. Wang, Y. Zhou, J. Guo, and Y. Wang, Superconductivity in Honeycomb Antiferromagnet CrPSe_3 via Irreversible Pressure-Mediated Interlayer Sliding, *ACS Nano* **20**, 5072 (2026).
- [27] C. D. Carpentier and R. Nitsche, Vapour growth and crystal data of the thio(seleno)-hypodiphosphates $\text{Sn}_2\text{P}_2\text{S}_6$, $\text{Sn}_2\text{P}_2\text{Se}_6$, $\text{Pb}_2\text{P}_2\text{Se}_6$ and their mixed crystals, *Materials Research Bulletin* **9**, 401 (1974).
- [28] Y. Tyagur and I. Tyagur, Influence of high pressure on the electrical resistance of $\text{Sn}_2\text{P}_2\text{S}_6$ ferroelectric crystals, *High Pressure Research* **28**, 607 (2008).
- [29] Y. Akahama, M. Kobayashi, and H. Kawamura, Pressure-induced superconductivity and phase transition in selenium and tellurium, *Solid State Communications* **84**, 803 (1992).

- 298 [30] J. Eisenstein, Superconducting Elements, Reviews of Modern Physics **26**, 277 (1954).
- 299 [31] J. A. Woollam, R. B. Somoano, and P. O'Connor, Positive Curvature of the $h c_2$ vs $t c$ Bound-
300 aries in Layered Superconductors, Physical Review Letters **32**, 712 (1974).
- 301 [32] S. Friedemann, H. Chang, M. B. Gamza, P. Reiss, X. Chen, P. Alireza, W. A. Coniglio,
302 D. Graf, S. Tozer, and F. M. Grosche, Large fermi surface of heavy electrons at the border of
303 mott insulating state in NiS_2 , Scientific Reports **6**, 25335 (2016).
- 304 [33] T. Matsuoka, A. Haglund, R. Xue, J. S. Smith, M. Lang, A. M. dos Santos, and D. Man-
305 drus, Pressure-induced insulator-metal transition in two-dimensional mott insulator NiPS_2 ,
306 arXiv:2103.12470 , Journal of the Physical Society of Japan **90**, 10.7566/JPSJ.90.124706 (2021).