

Broad-band spectroscopy of electronuclear spin qudits based on vanadyl porphyrin molecules

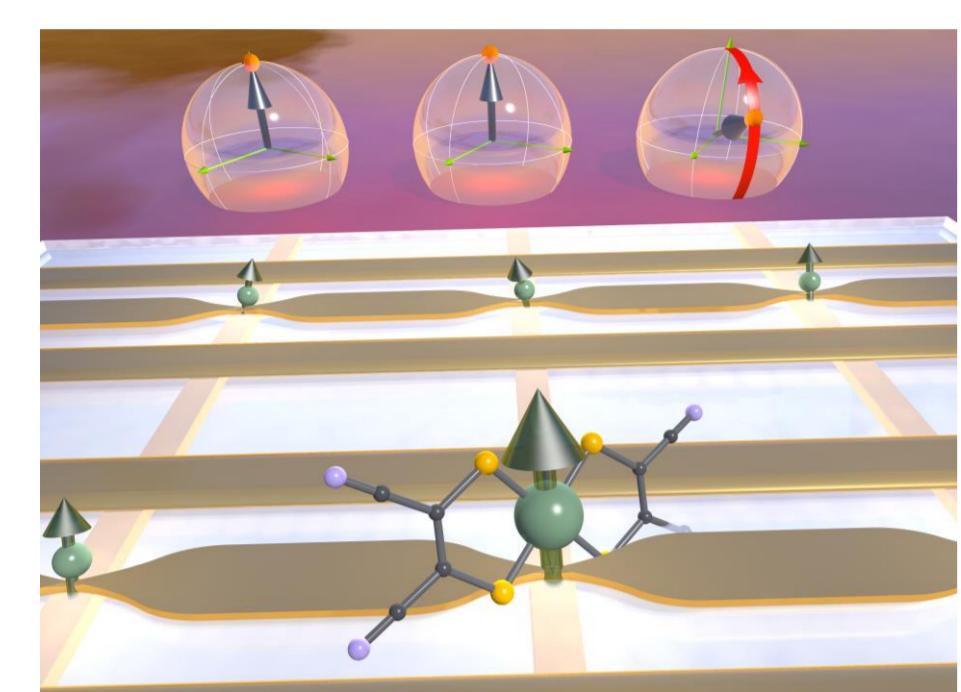
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Long-term goal:



Quantum computation with molecular spins [1]

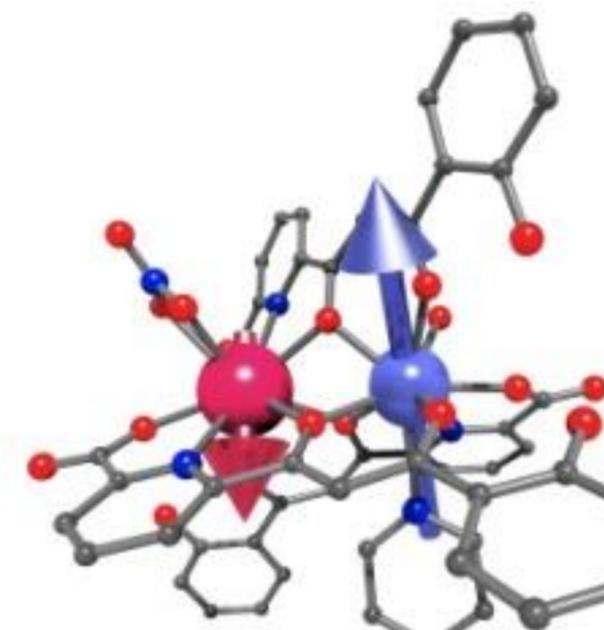
Building blocks



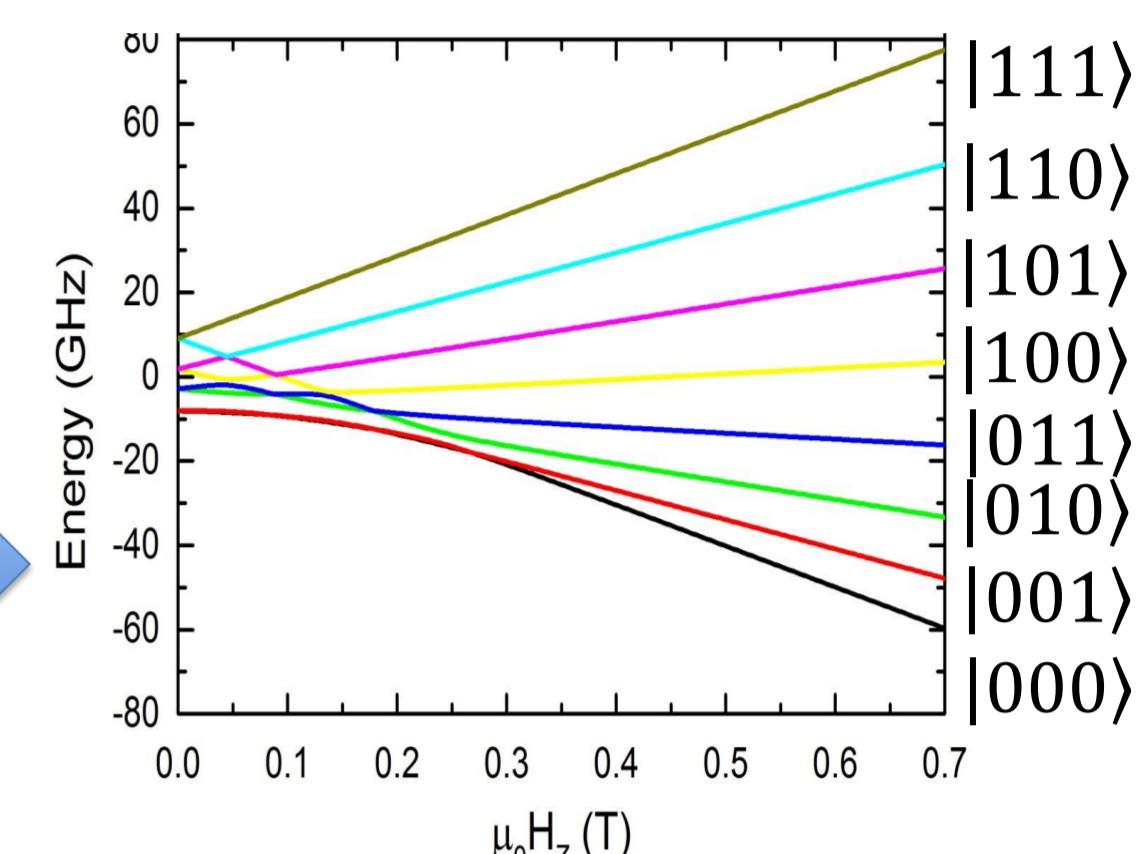
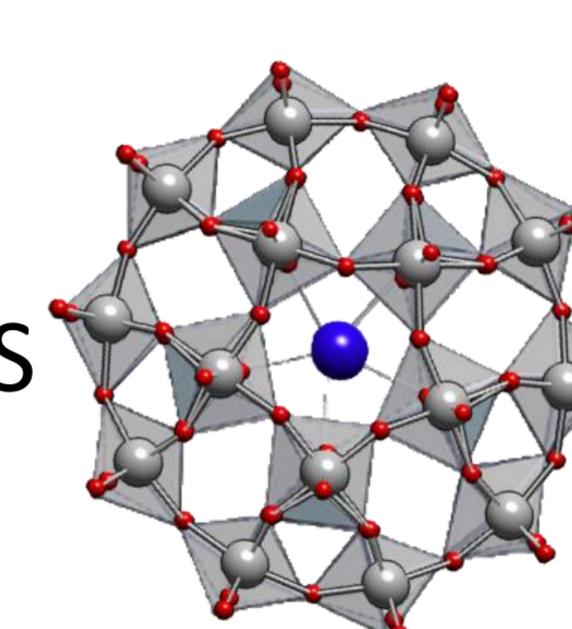
Molecules hosting d-dimensional qudits [2-3]

Introduction

Molecules with several magnetic metal centres [2]



Molecules with one magnetic molecule with S or I > 1/2 (qudits) [4-6]



Molecular size NISQs

Molecular design: spin levels and coherence time

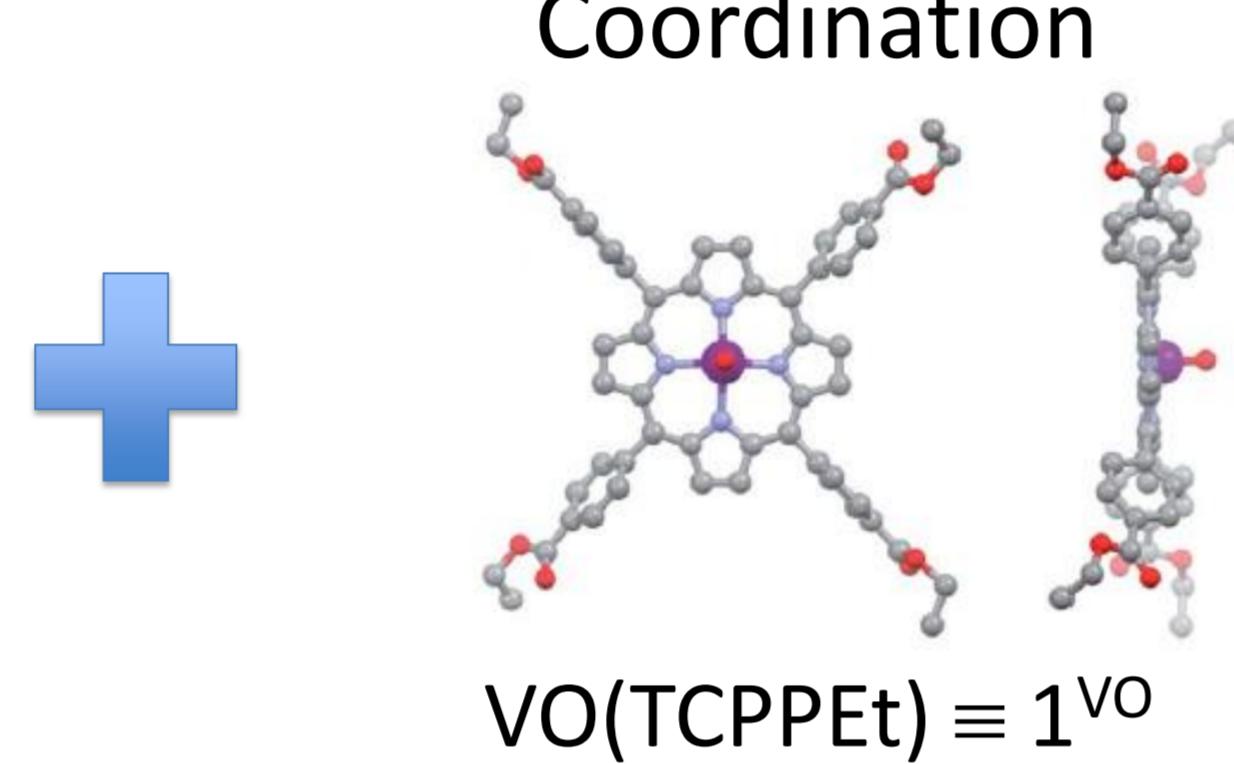
Group \ Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	² He
2	Li	Be																
3	Na	Mg																
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ge	As	In	Sb	Te	Ar
5	Rb	Sr	Y	Zr	Dy	Mo	Fe	Ru	Rh	Pd	Ag	Ge	As	Sn	Br	Kr		
6	Cs	Ba	Lu	Hf	Ta	W	Ts	Os	Ir	Pt	Au	Si	Pb	Bi	Po	At	Rn	Xe
7	Fm	Ra	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
	*	*	57	58	59	60	61	62	63	64	65	66	67	68	69	70		
	*	*	89	90	91	92	93	94	95	96	97	98	99	100	101	102		
	*	*	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No		

Metal ion

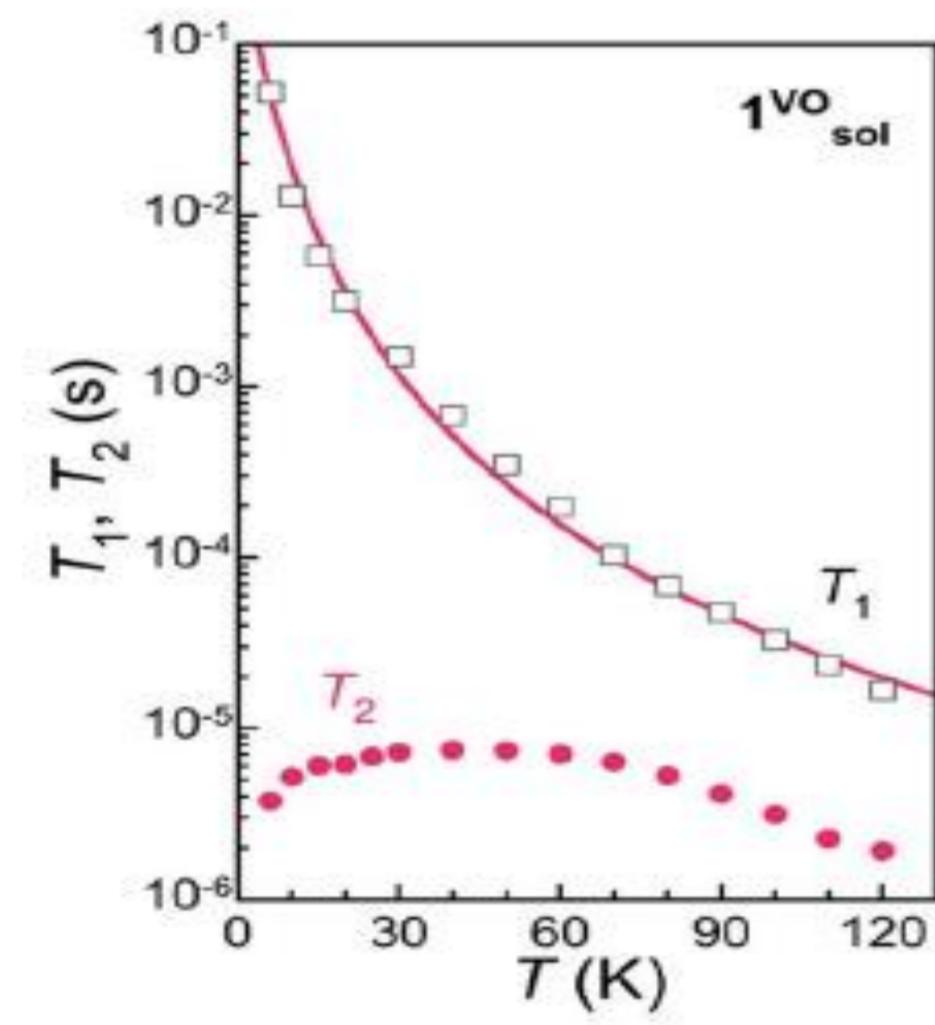
$$V^{4+} : [\text{Ar}] 4s^1$$

$$H = \mu_B g \vec{H} \vec{J} + \vec{S} \cdot \vec{A} \vec{I}$$

$$S = 1/2 ; I = 7/2$$



2D MOF with long coherence times [7]



- Long T_1 and T_2 that can be increased
- Fully characterised molecule as a $d=16$ electronuclear spin qudit

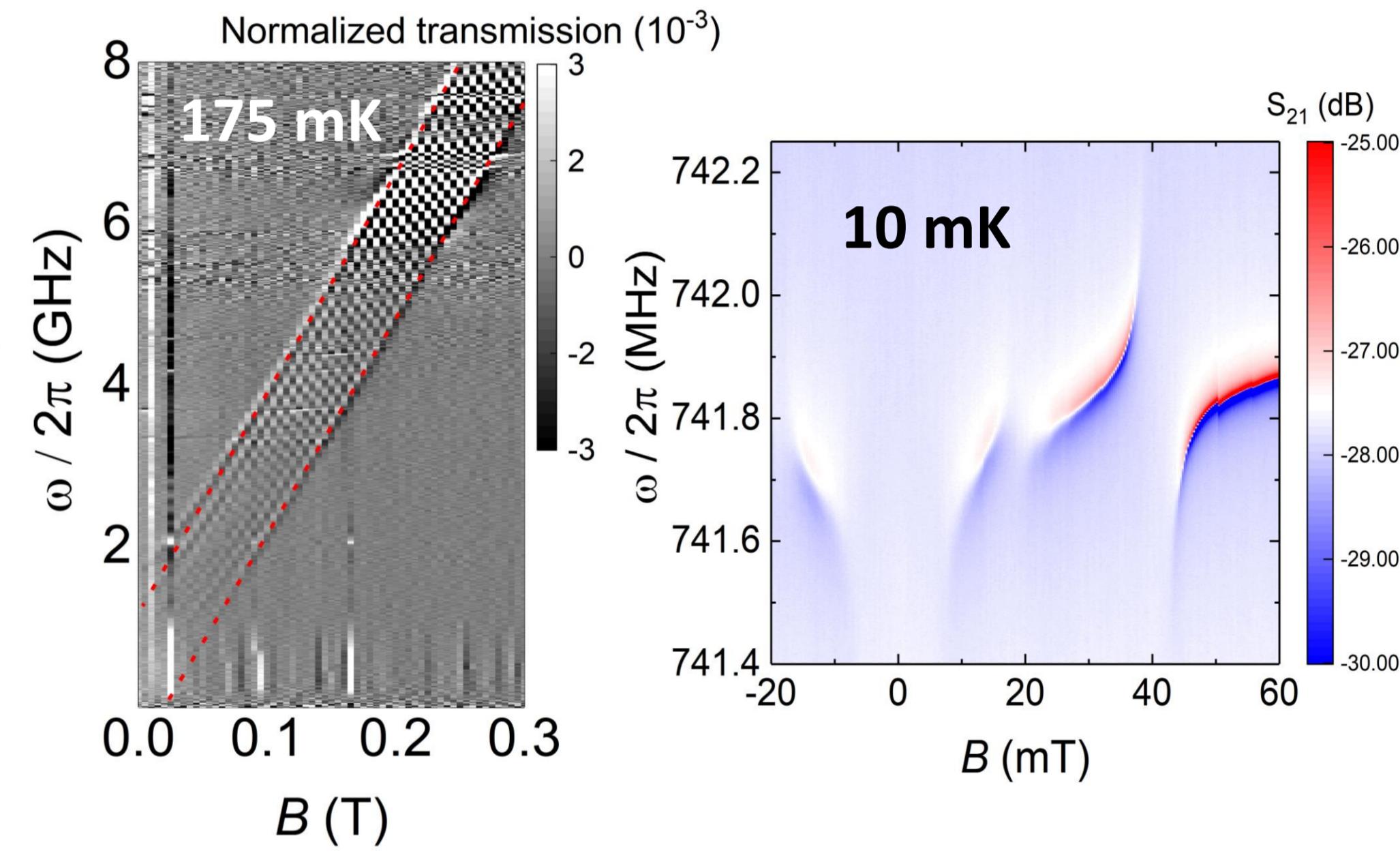
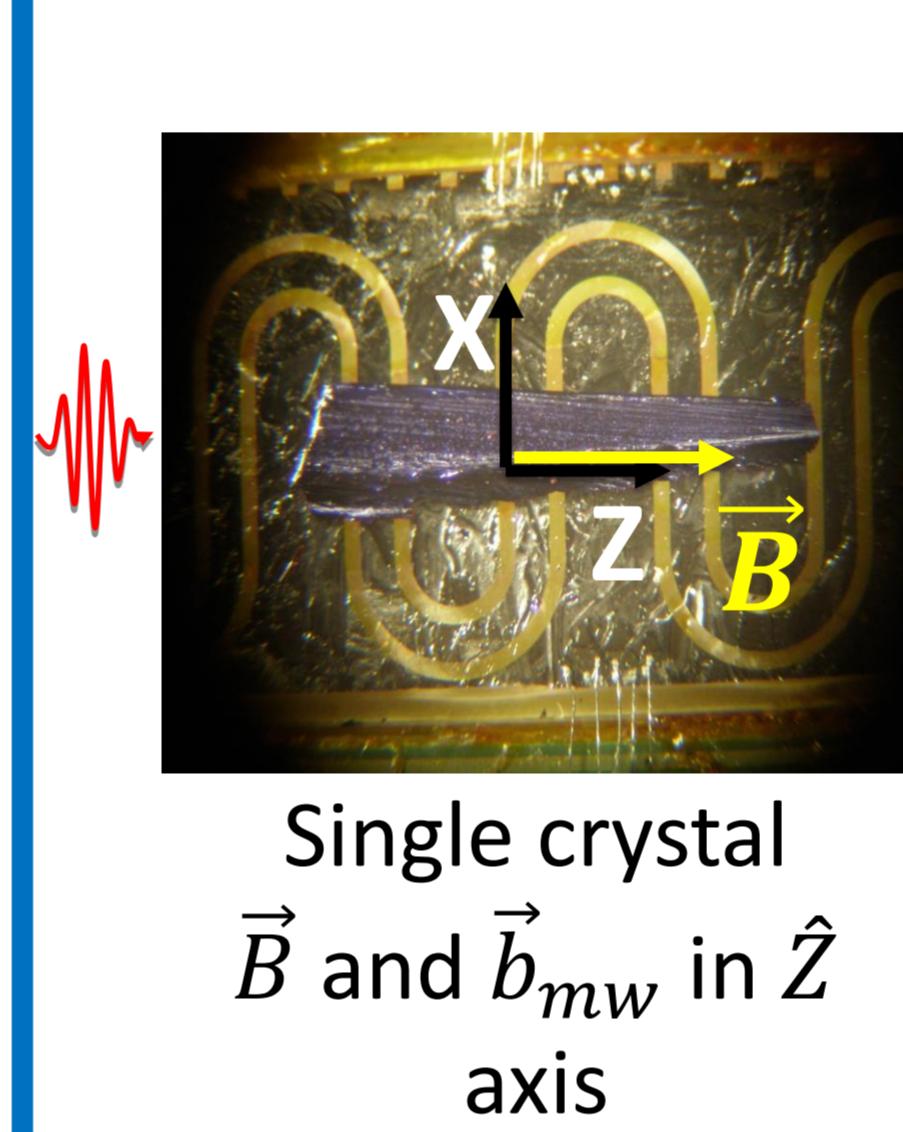
Conclusions

- Tunable electronuclear spin entanglement introduces additional operations
- Universal quantum operations can be performed with this molecule
- No quadrupolar term is required in order to preserve universality, only a not fully uniaxial nor fully isotropic hyperfine interaction
- 1^{VO} molecules provide promising realisations of either a 4-qubit processor or a $d = 16$ qudit

References

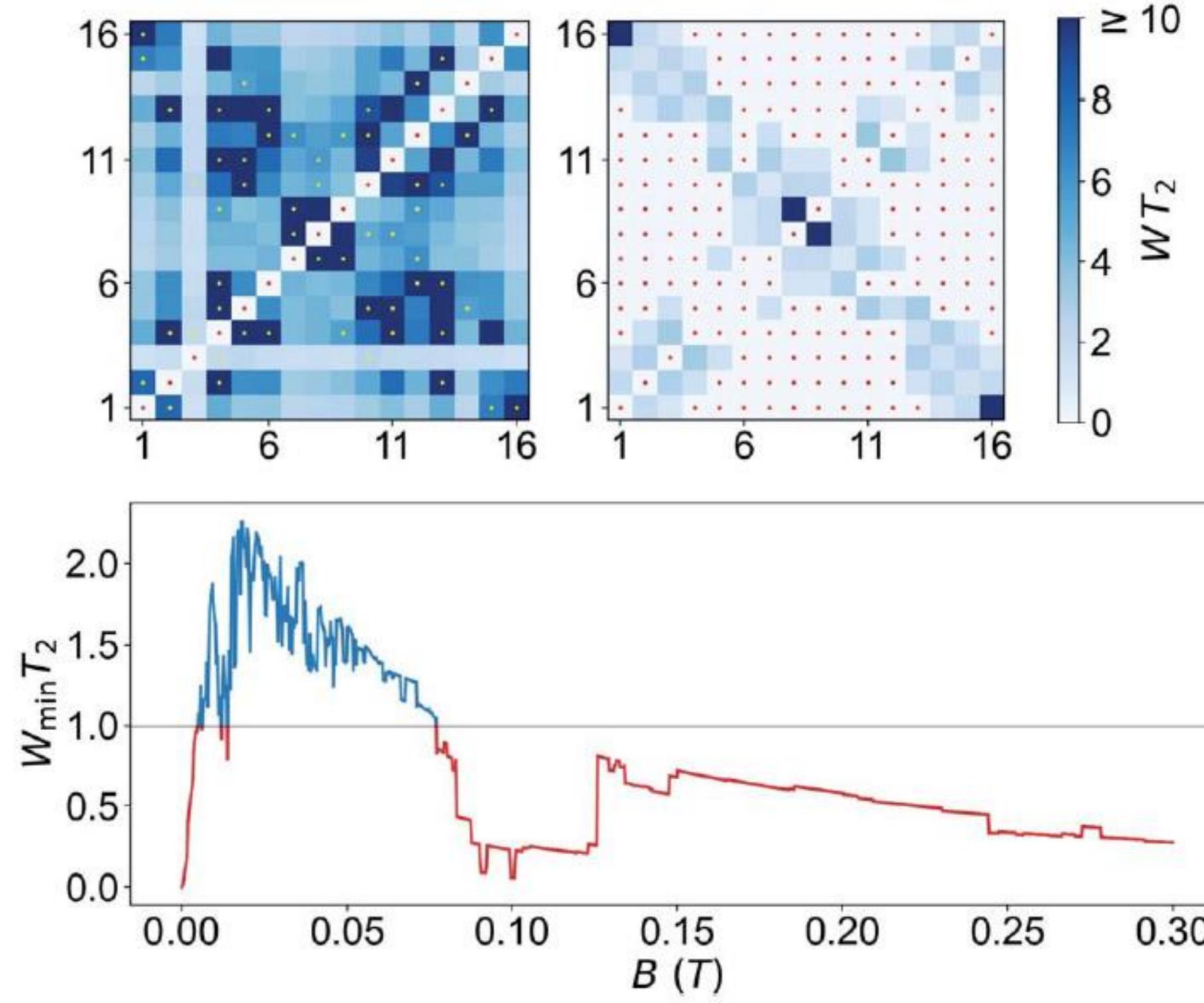
- [1] M. D. Jenkins et al., *Dalton Trans.* **45**, 16682-16693 (2016)
- [2] G. Aromí et al., *Chem. Soc. Rev.* **41**, 537 (2012)
- [3] F. Luis et al., *Phys. Rev. Lett.* **107**, 117203 (2011)
- [4] E. Moreno-Pineda et al., *Chem. Soc. Rev.* **47**, 501-513 (2018)
- [5] R. Hussain et al., *J. Am. Chem. Soc.* **140**, 9814-9818 (2018)
- [6] E. Moreno-Pineda et al., *Angew. Chem.* **56**, 9915-9919 (2017)
- [7] A. Urtizberea et al., *Mater. Horiz.* **7**, 885 (2020)

Broad-band spectroscopy at very low temperature



- Non linear dependence of energy levels at low magnetic fields
- Level anharmonicity \Rightarrow operations addressing & control
- Strong spin-photon coupling \Rightarrow read-out

Universality of 1^{VO} -based molecular spin qudit



- Universal operations at sufficiently low magnetic fields
- Improving T_2 the universal magnetic field region can be widened
- At high magnetic fields, disconnected pairs of states arise

Support and funding

