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

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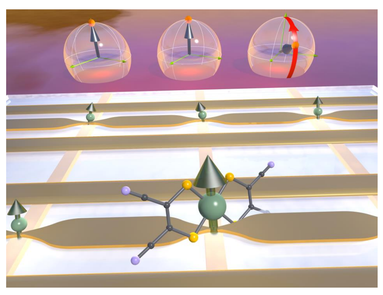
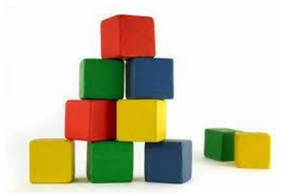
Introduction

Long-term goal:



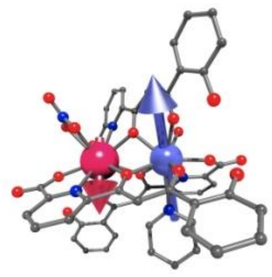
Quantum computation with molecular spins [1]

Building blocks

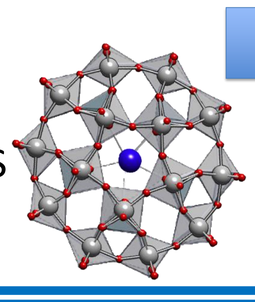


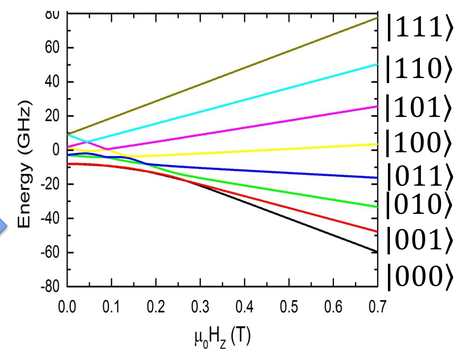
Molecules hosting d-dimensional qudits [2-3]

Molecules with several magnetic metal centres [2]



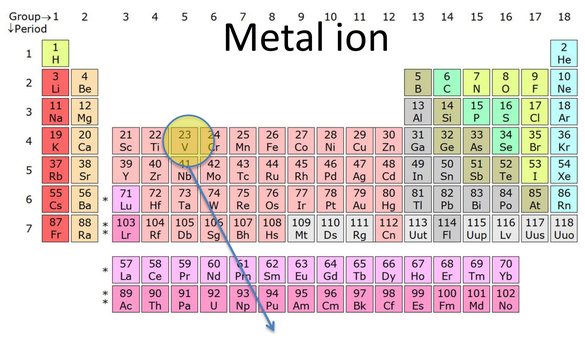
Molecules with one magnetic molecule with S or I > ½ (qudits) [4-6]





Molecular size NISQs

Molecular design: spin levels and coherence time

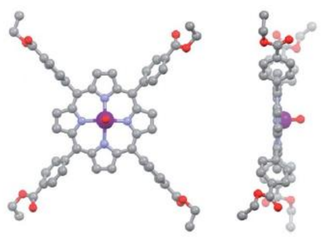


V^{4+} : [Ar] $4s^1$

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

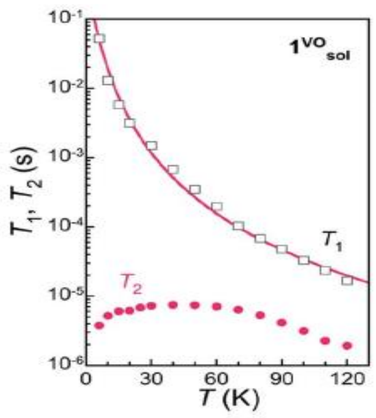
$$S = 1/2\,;\, I = 7/2$$

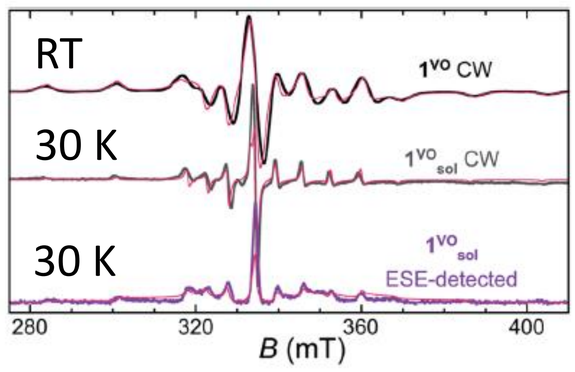
Coordination



VO(TCPPEt) ≡ 1^{VO}

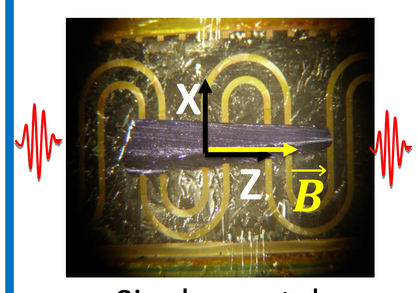
2D MOF with long coherence times [7]



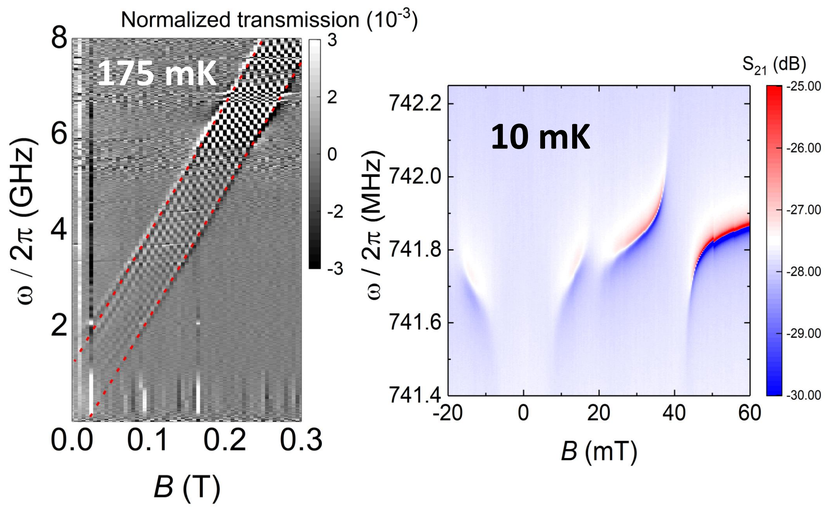


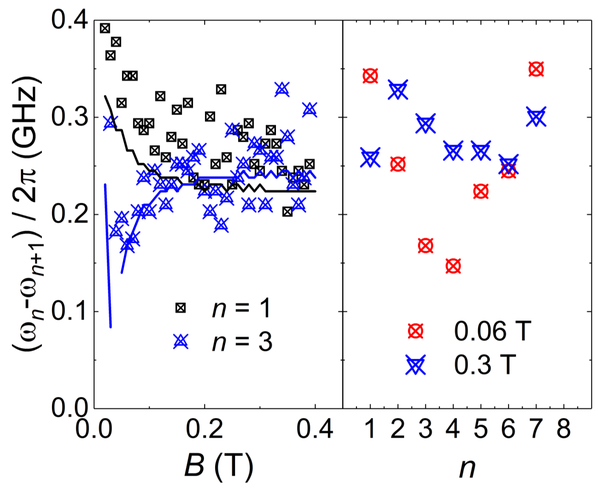
- **Long T_1 and T_2** that can be increased
- Fully characterised molecule as a **d=16 electronuclear spin qudit**

Broad-band spectroscopy at very low temperature



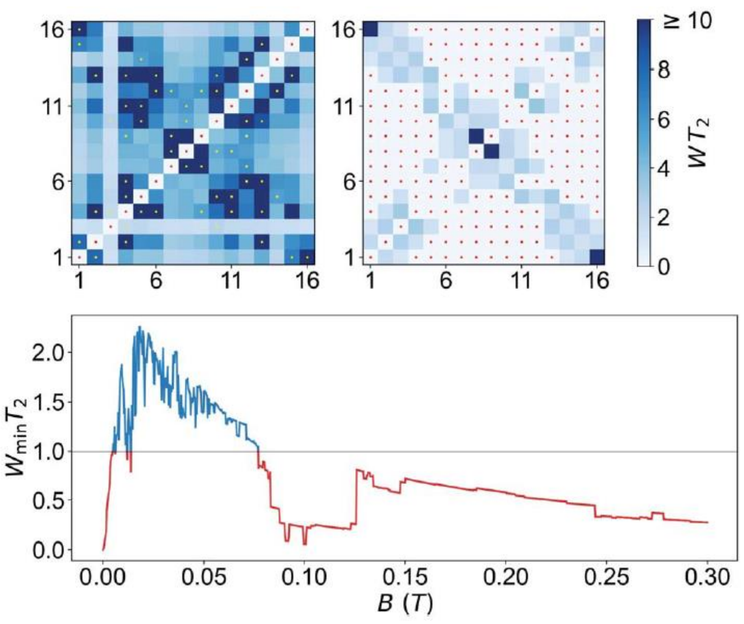
Single crystal $\vec{B}$ and $\vec{b}_{mw}$ in $\hat{Z}$ axis





- **Non linear dependence** of **energy levels** at low magnetic fields
- Level anharmonicity ⇒ **operations addressing & control**
- Strong spin-photon coupling ⇒ **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**

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)

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