

Introduction

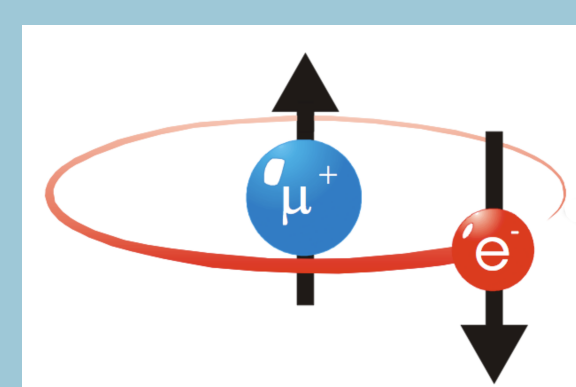
- The rapid development of organic materials has led to the point where they are now available in commercial products.
- The spin degree of freedom has not yet been used in organic materials in a commercial setting.
- Fundamental questions with respect to the mechanisms for electron spin relaxation in organic molecules remain.



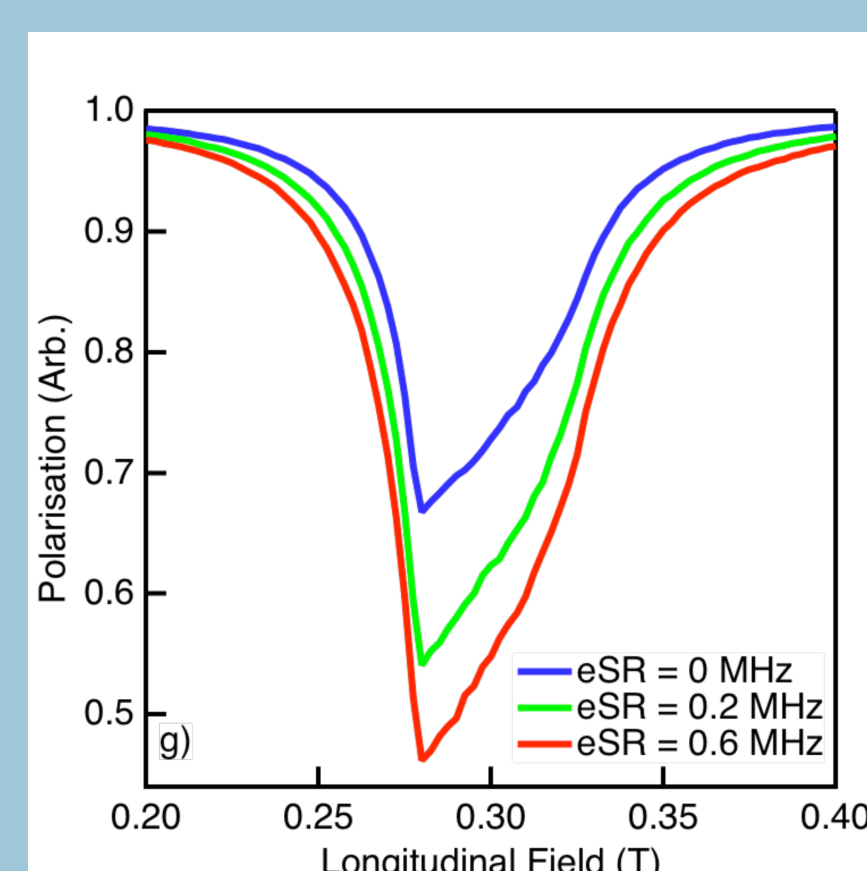
- A technique is needed that can differentiate between intrinsic and extrinsic effects.
- Muons used as a microscopic spin probe and localized to a single molecule can access this information.
- There are 4 muon facilities:- ISIS, PSI, TRIUMF and JPARC

Muon Spectroscopy: ALC Muon Technique

- Spin polarised muons are implanted into the sample and a magnetic field is applied along the initial direction of spin polarisation.
- The muon decays into a positron, whose emission direction is related to the muon's spin at the time of decay.
- The time evolution of the muon spin ensemble is measured by tracking the angular distribution of the decay positrons.
- The muon's spin is coupled to an electron spin. By tracking the muon's spin as a function of time, we can study the dynamics of the electron's spin.



Muonium: a coupled muon and electron

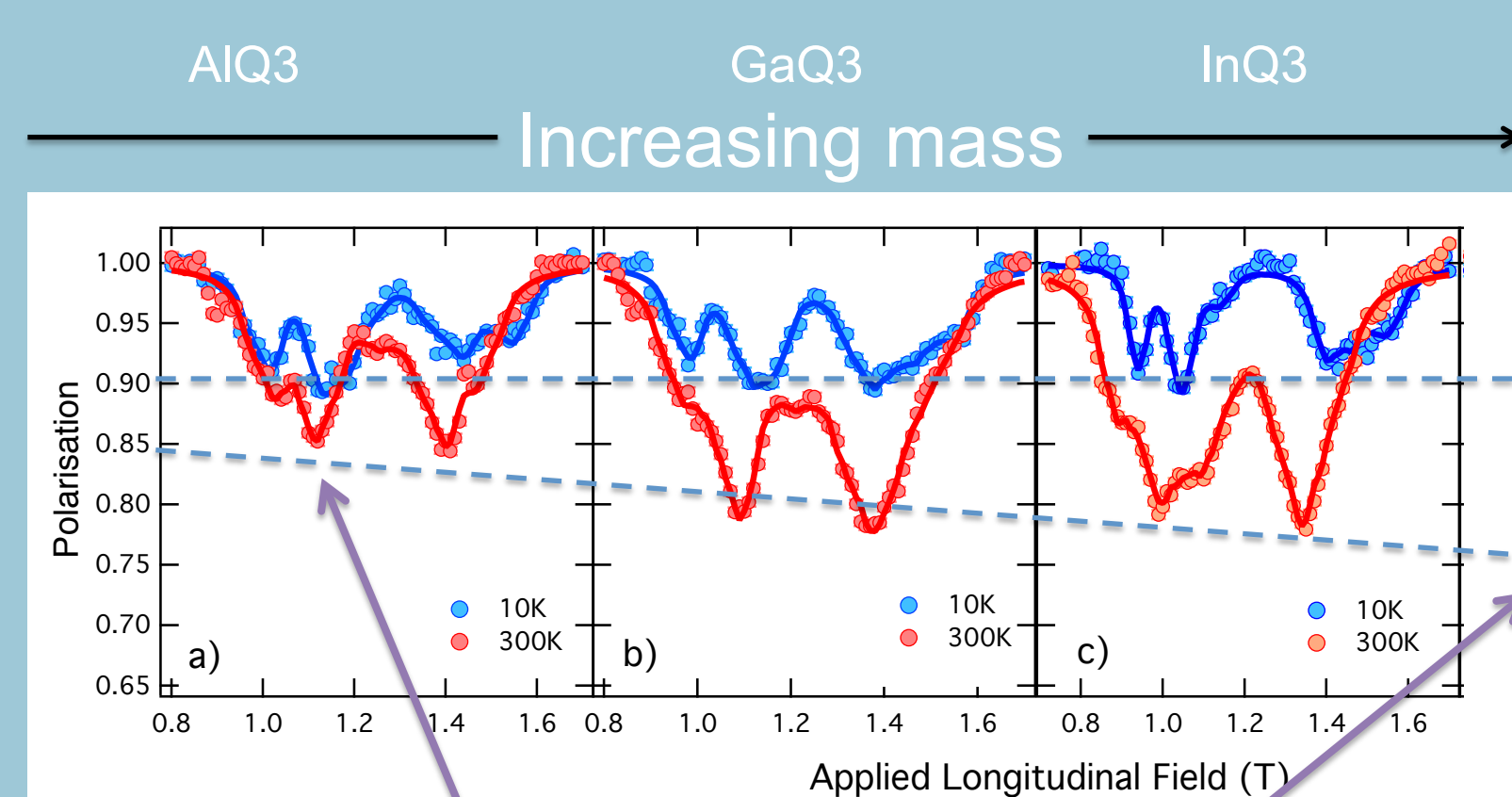


Increasing electron spin relaxation = increased ALC amplitude (in the <1MHz limit)

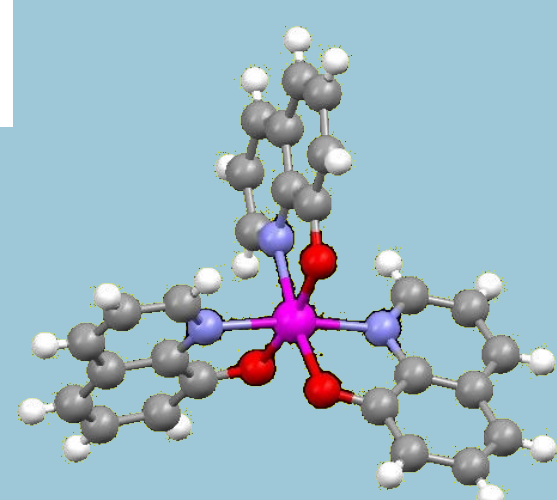
- The magnetic field is tuned through a resonance field, where the energy levels of the singlet and triplet muon/electron system are degenerate.
- At this resonance field, the muon's spin is a **highly sensitive probe of electron spin relaxation**. In the intermediate region (up to 1MHz), the main effect on the ALC is an amplitude change.

Further information can be found in:
S. Blundell, *Contemp. Phys.* **40**, 175 (1999)
I. McKenzie, *Naturewissenschaften* **96**, 873 (2010)
R. Kiefl, *Hyperfine Interactions* **32**, 707 (1986)

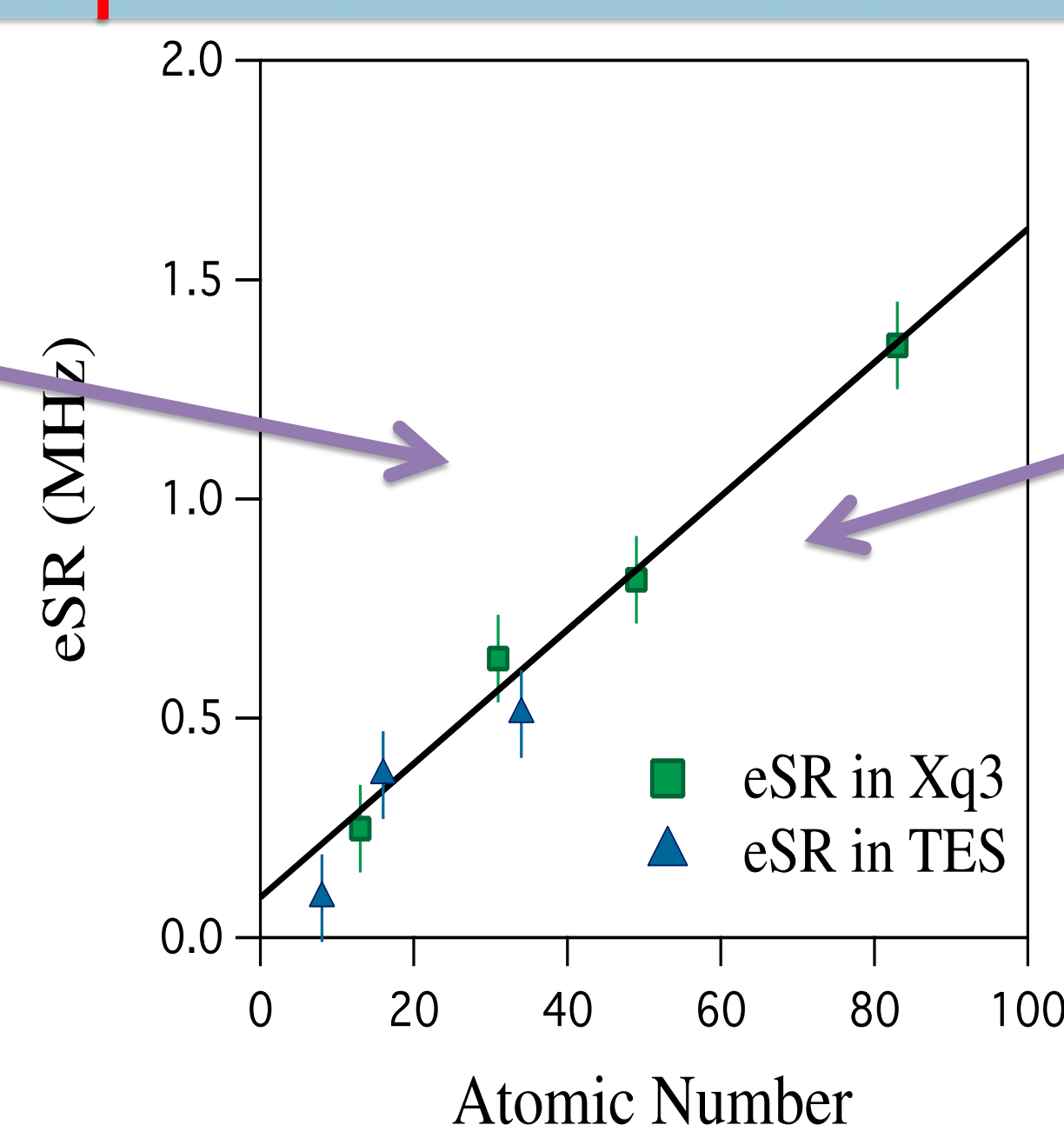
ESR In Quinolate Series



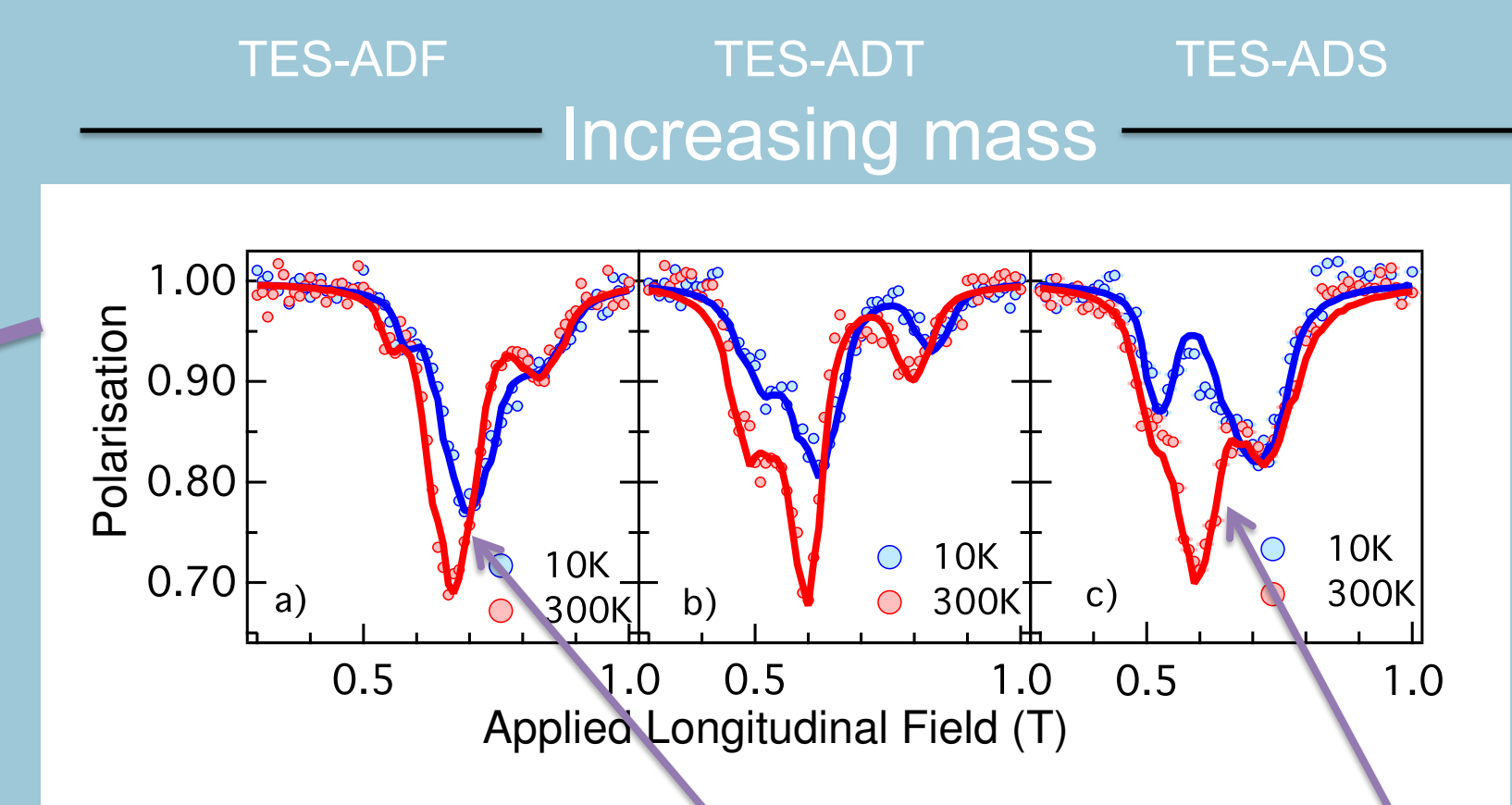
Increase in Δ with mass = Increase in ESR=spin orbit



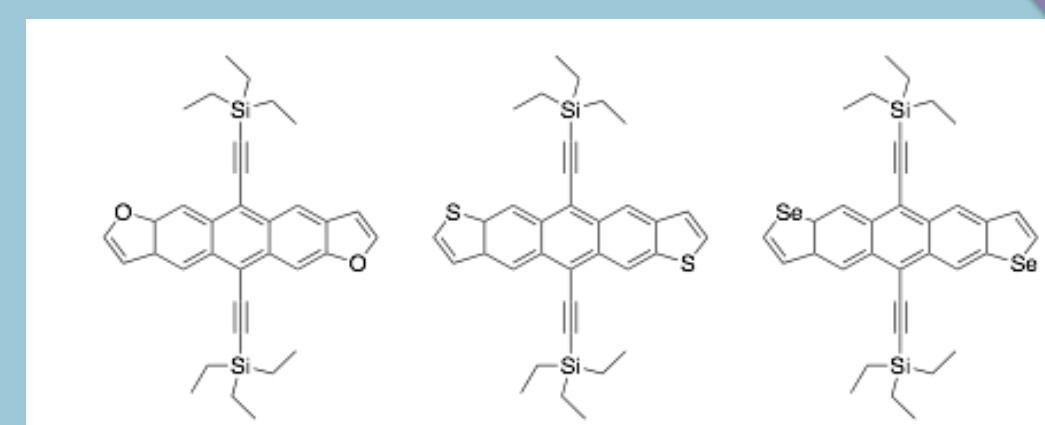
Spin Orbit Interaction



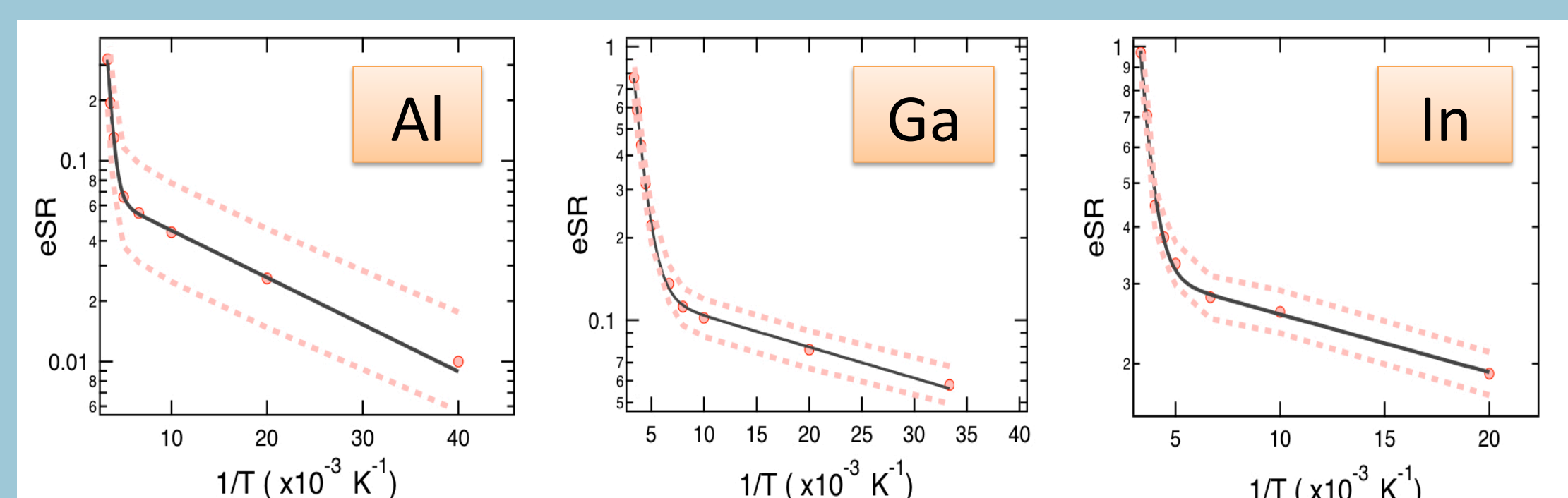
ESR In TES Series



Same Increase with mass = Increase in ESR=spin orbit

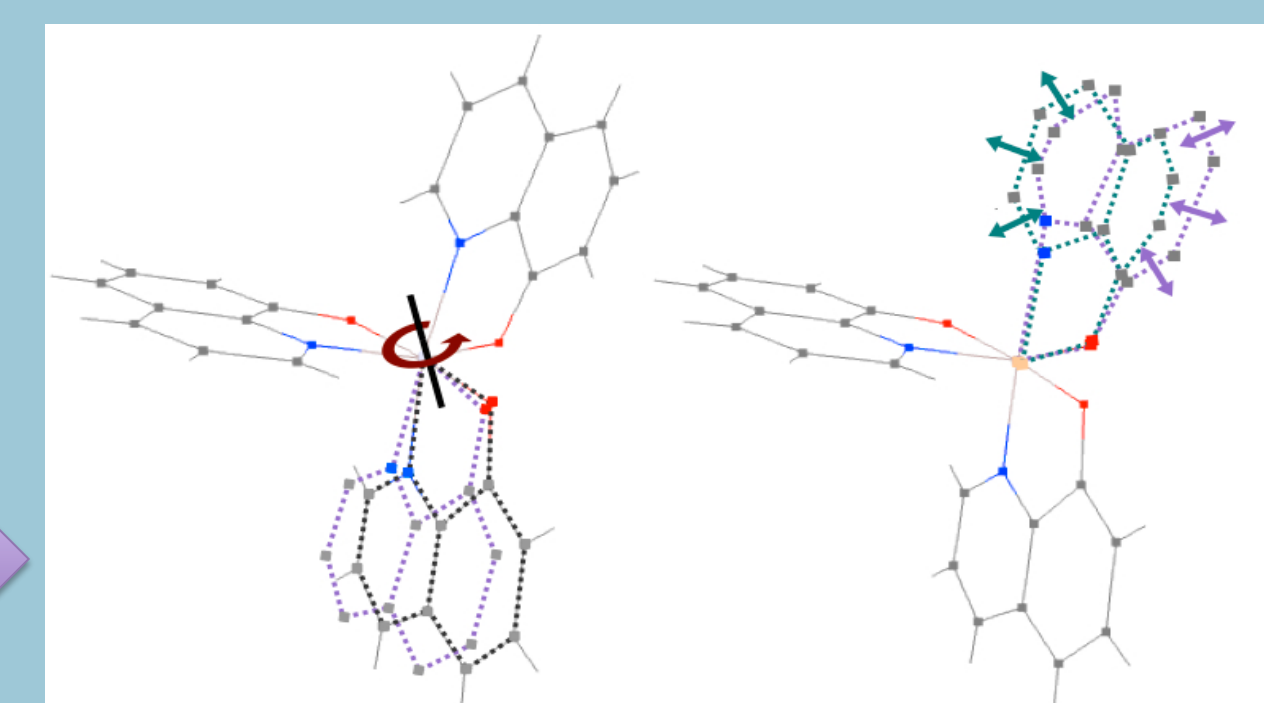
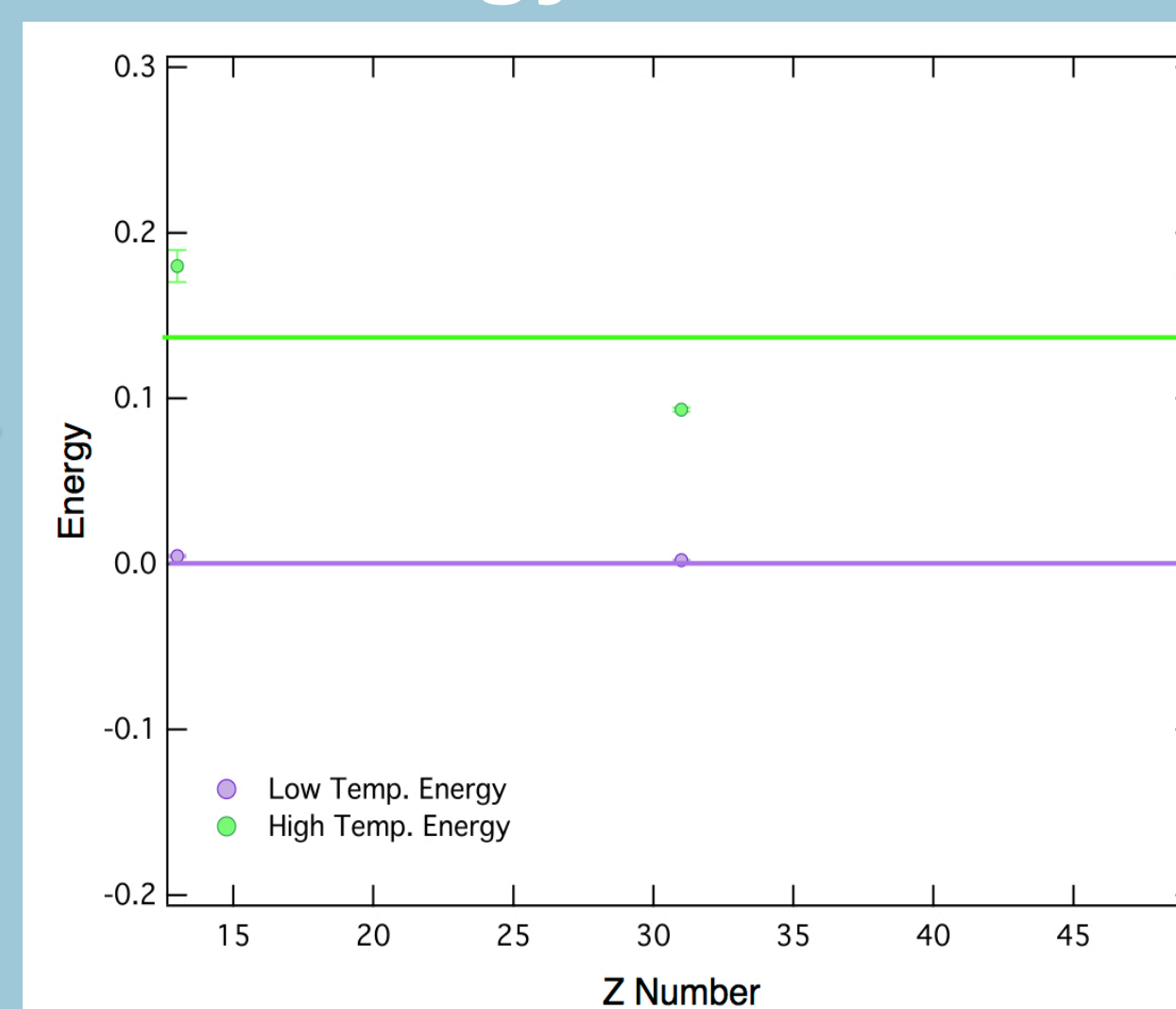


Temperature Dependence



No change in activation E with Z-number = Indirect Hyperfine not dominant

Energy Scales



$E=37.4 \text{ cm}^{-1}$

$E=1450.3 \text{ cm}^{-1}$

Vibrational Coupling = Enhanced Spin Orbit