



Magnetometría SQUID

José Ángel de Toro Sánchez

joseangel.toro@uclm.es

SQUID: Superconducting QUantum Interference Device

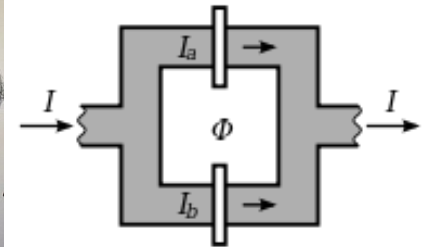
Historia

Efecto *Josephson* (premio Nobel 1973)

Possible new effects in superconductive tunneling
[B. D. Josephson, *Physics Letters* (1962)]

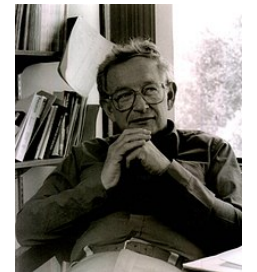


Sensor SQUID DC



P. W. Anderson (premio Nobel 1977, junto a Van Vleck)

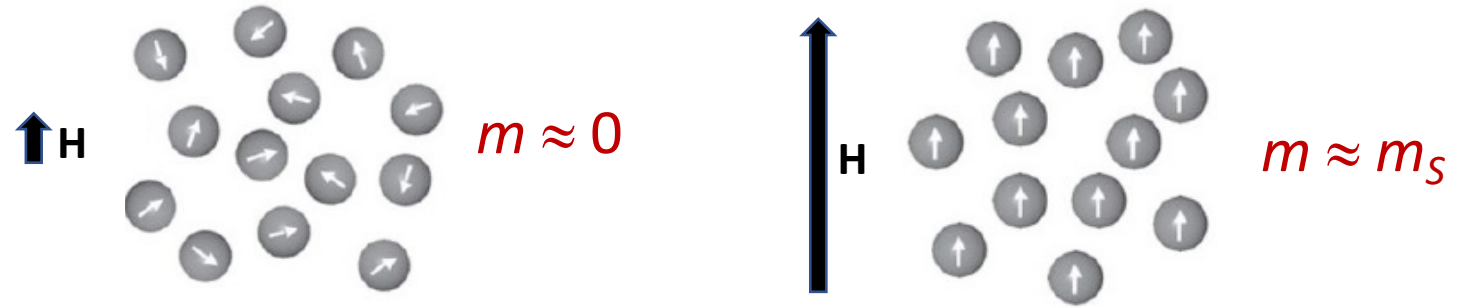
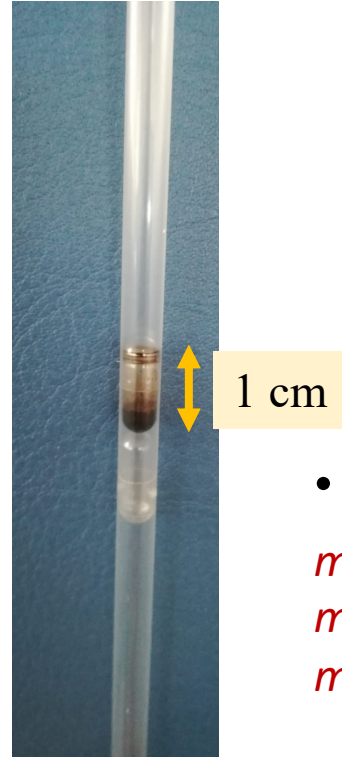
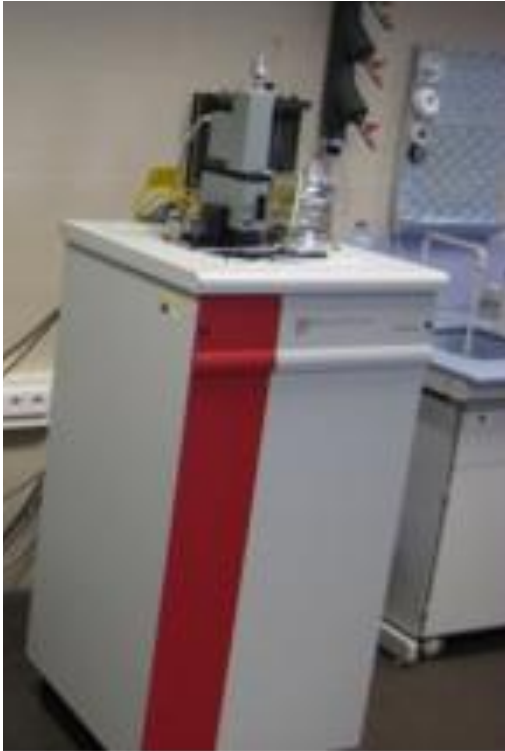
Probable Observation of the Josephson Superconducting Tunneling Effect
[P. W. Anderson and J. M. Rowell, *Physical Review Letters* (1963)]



• ¿Qué mide el SQUID?

Momento Magnético, m [μ_B , emu, Am^2]

Sensibilidad $\sim 10^{-7}$ emu \rightarrow 1 ng de Fe



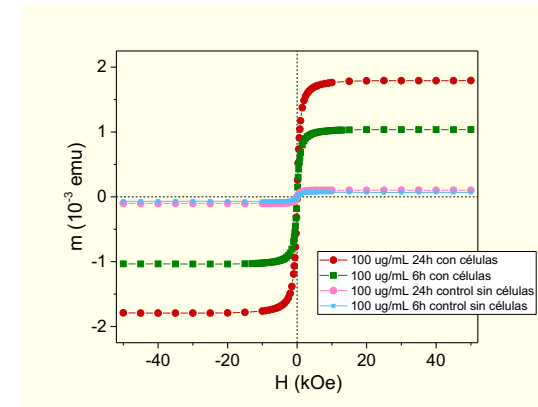
• ¿Frente a qué parámetros?

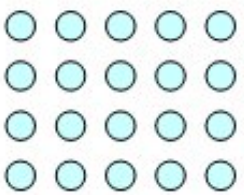
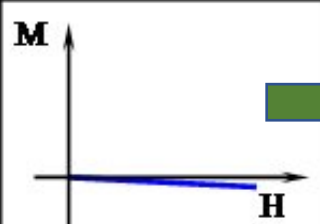


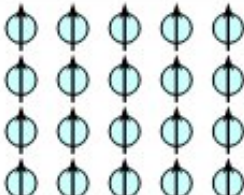
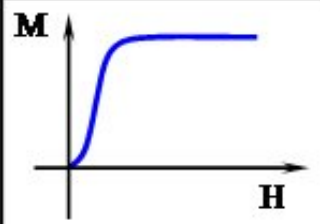
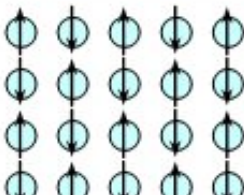
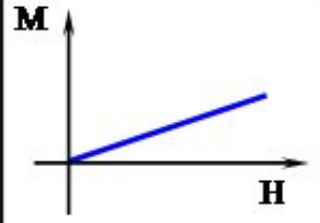
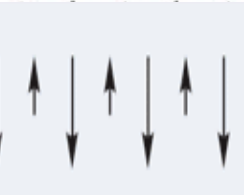
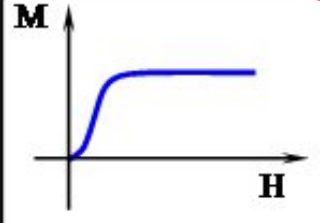
$m(H) \rightarrow$ Ciclos de histéresis; *campo magnético* H hasta 5 Tesla

$m(T) \rightarrow$ Transiciones de fase, bloqueo de NPs, ... ; *temperatura*: 3-400 K

$m(f) \rightarrow$ Dinámica de (macro)espines [0.001 – 10 s]

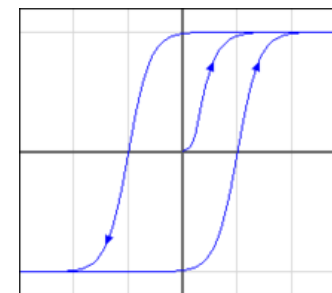
\rightarrow Dependencia con historia termomagnética



Type	Atomic / Magnetic Behaviour	
Dia-magnetism	 <p>Atoms have no magnetic moment</p>	
Para-magnetism	 <p>Atoms have randomly oriented magnetic moments Fluctuando!</p>	
Ferro-magnetism	 <p>Atoms have parallel aligned magnetic moments</p>	
Antiferro-magnetism	 <p>Atoms have anti-parallel aligned magnetic moments</p>	
Ferri-magnetism	 <p>Atoms have mixed parallel and anti-parallel aligned magnetic moments</p>	

Cuando el momento de la muestra es muy bajo, el diamagnetismo del sustrato y portamuestras domina la señal medida → esta contribución se resta fácilmente.

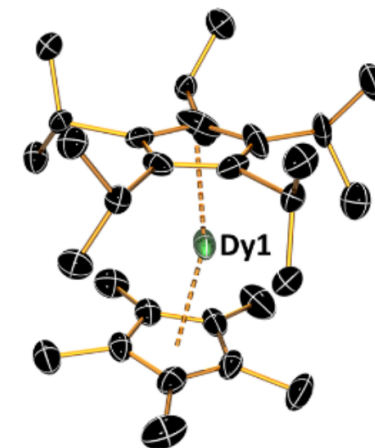
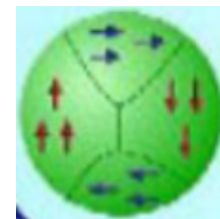
- Muchas sales y complejos organometálicos de metales *d* y *f*
- Líquidos con iones diluidos ... **vino?**



Fe, Co, Ni, Gd, NiFe, NdFeB, MnBi, CrO₂ ...

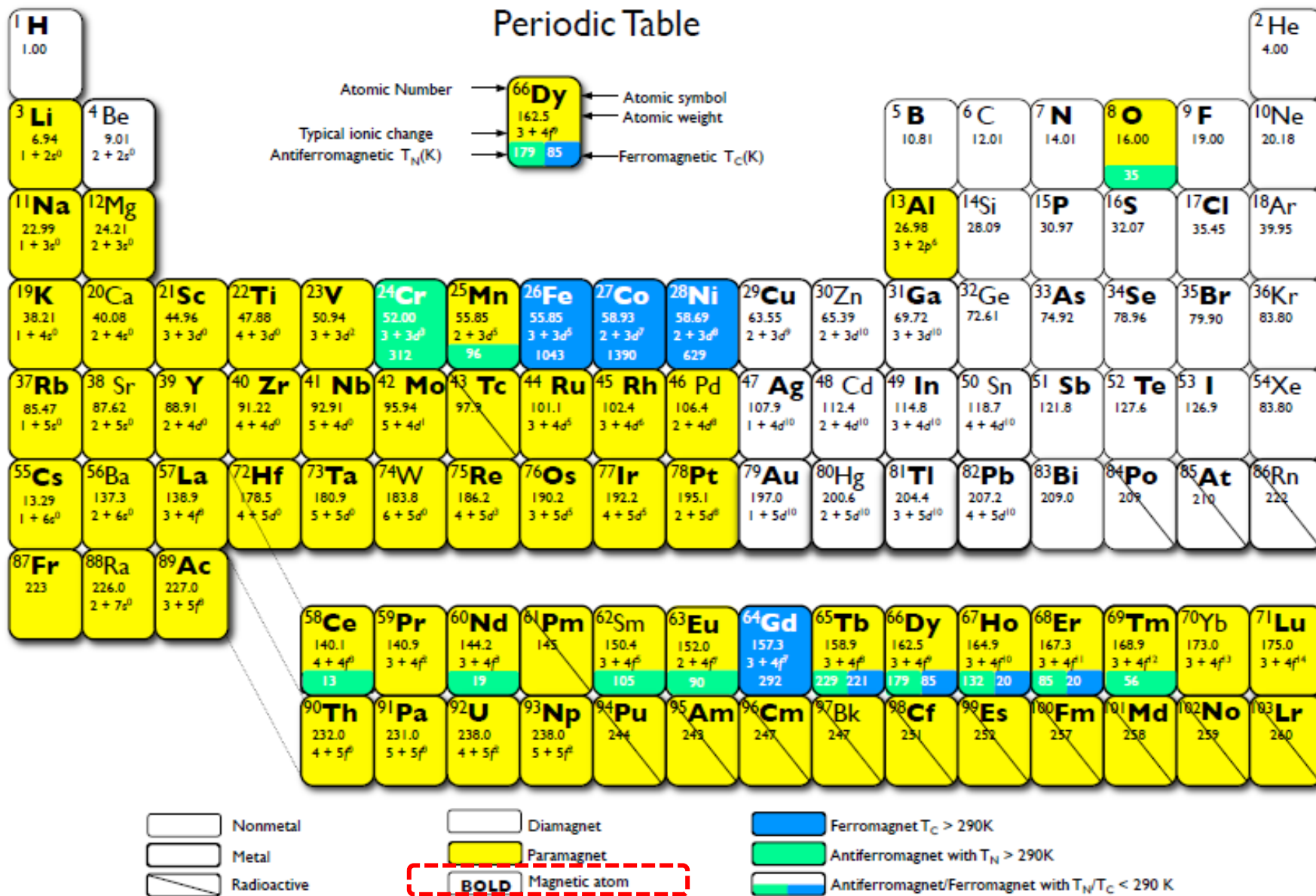
SMM (single-molecule magnets) → Guo et al., *Science* 21 Dec 2018

“Materiales Magnéticos”



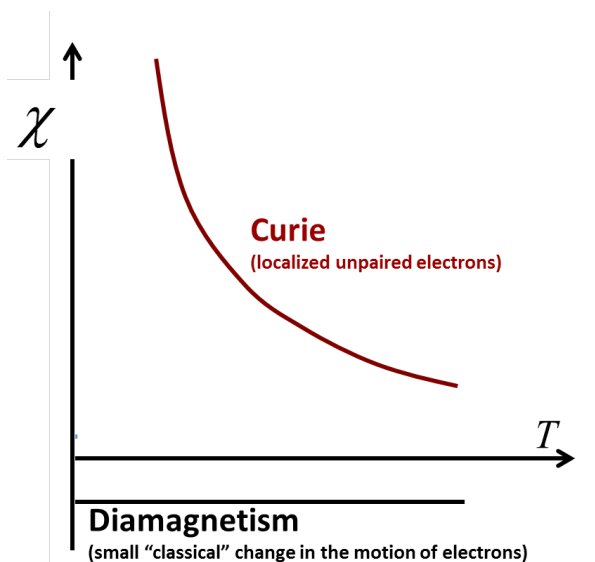
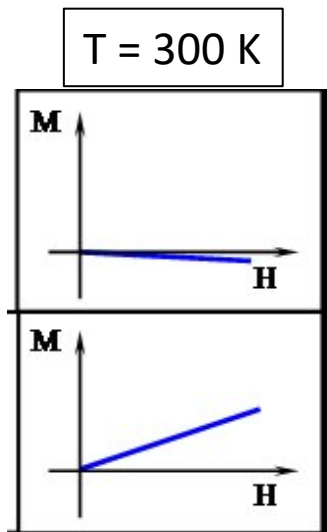
CoO, NiO, IrCr, MnS, FeCl₃, ...

Ferritas, Fe₃O₄ → MFe₂O₄, maghemita (γ-Fe₂O₃)

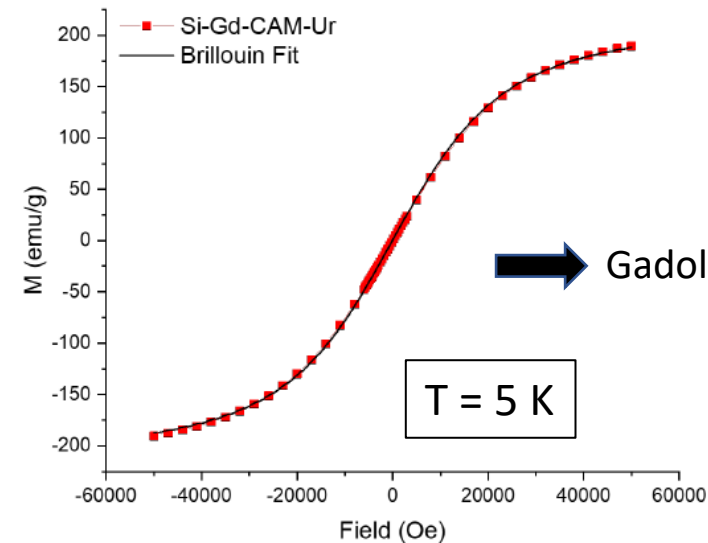


Diamagnetismo

Paramagnetismo



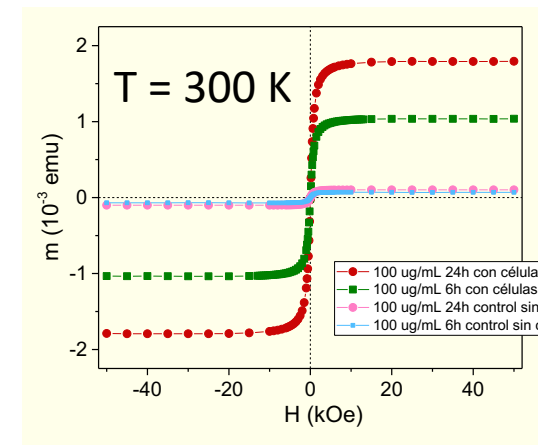
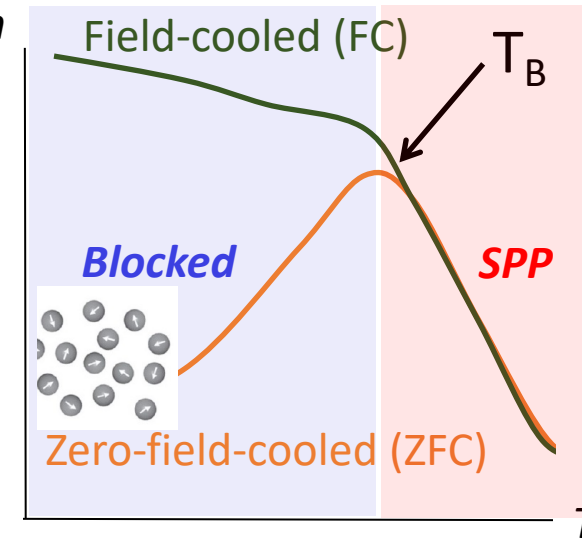
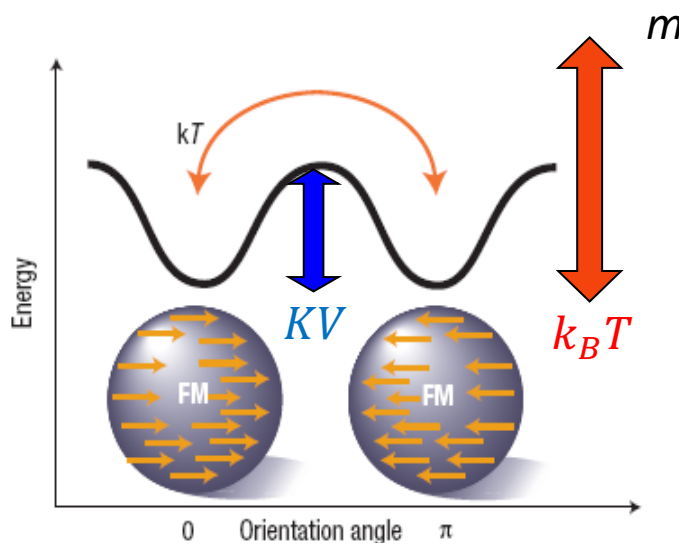
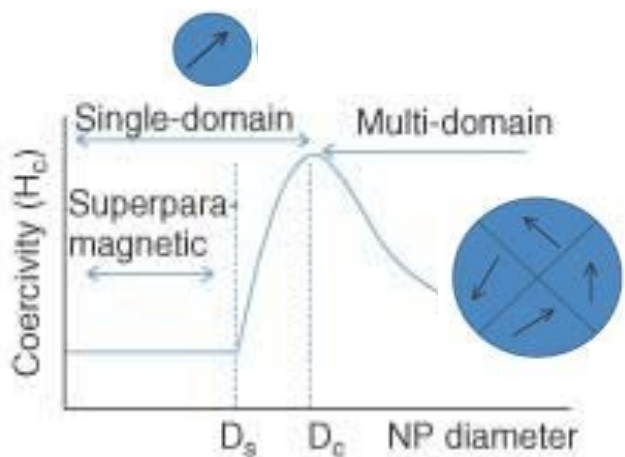
TFM Chiara Olla: carbon dots + Gd (Mayo/2019)



$$\mu \approx 7 \mu_B$$

Gadolinio iónico, bien diluido

Superparamagnetismo



- Si sospechas que tu material es (al menos) paramagnético, el SQUID tal vez pueda:
- *Cuantificar la concentración de los iones responsables*
 - *Determinar el estado de agregación de dichos iones*

Gracias