Contrasting g-factor anisotropy in easy-plane and easy-axis van der Waals CrX_3 (X =Cl, Br, I) magnetic materials

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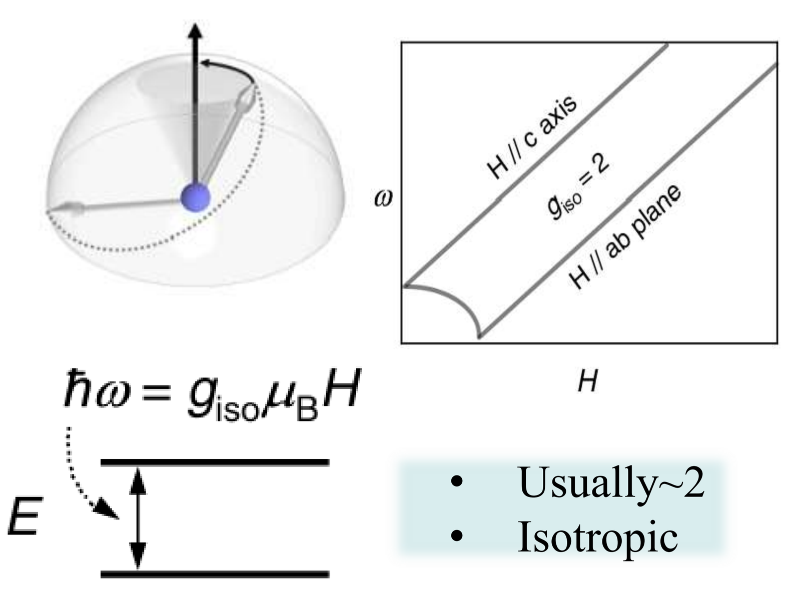
Motivation

g factor of free electron

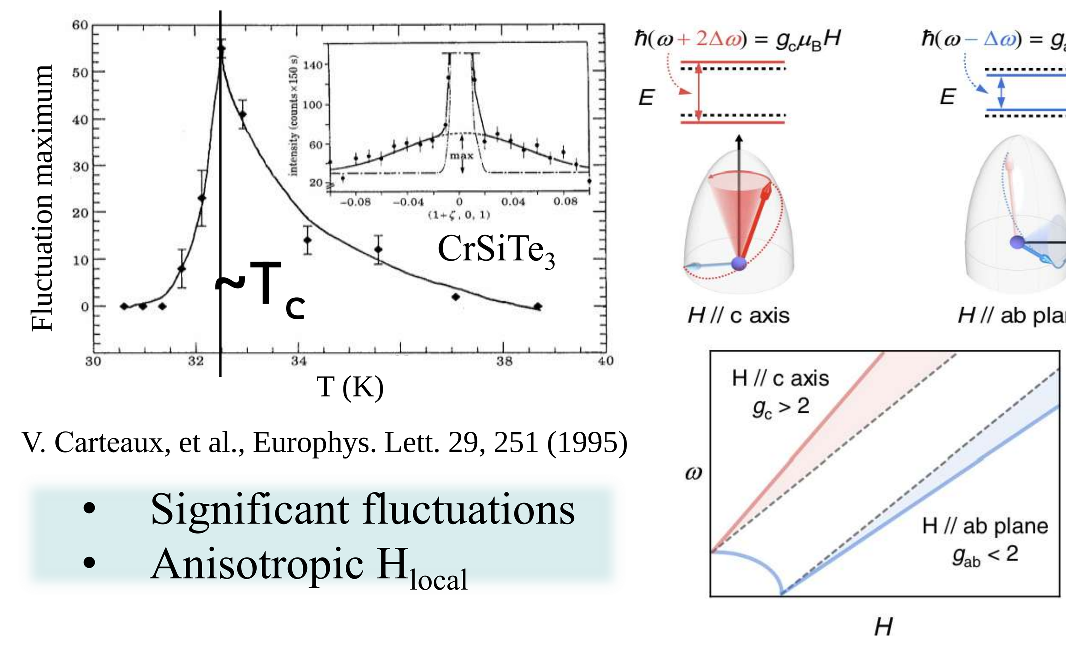


- Usually~2
- Isotropic

Li, Xu, *et al.*, Phys. Rev. B **106**, 054427 (2022)

Response to the local magnetic field H_{local}

Critical fluctuations in 2D materials



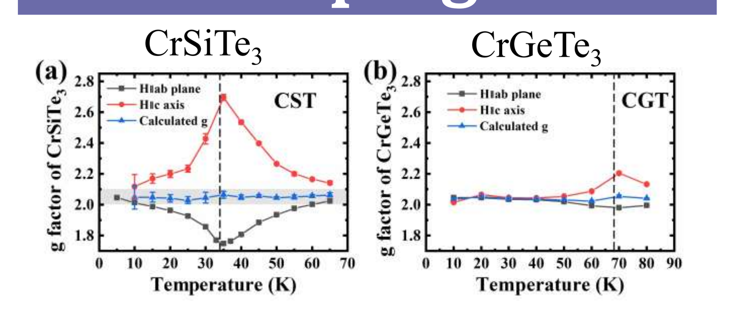
V. Carteaux, et al., Europhys. Lett. 29, 251 (1995)

- Significant fluctuations
- Anisotropic H_{local}

Li, Xu, *et al.*, Phys. Rev. B **106**, 054427 (2022)

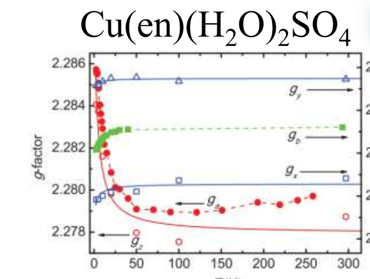
Anisotropic fluctuations

Anisotropic g factor



Li, Xu, *et al.*, Phys. Rev. B **106**, 054427 (2022)

$Cu(en)(H_2O)_2SO_4$ ✓ $g_{ab} \neq g_c$



$g_{ab} > g_c$ or $g_{ab} < g_c$?

R. Tarasenko, **et al.**, Phys. Rev. B **87**, 174401 (2013)

Temperature dependent anisotropic g factor

Factors affecting the g factor

$$g_c(T) = g_0\left[1 + \frac{S(S+1)}{3(T-Tc)}\cdot\frac{K_z}{k_B}\right]$$

$$g_{ab}(T) = g_0\left[1 - \frac{S(S+1)}{6(T-Tc)}\cdot\frac{K_z}{k_B}\right]$$

R. Tarasenko, **et al.**, Phys. Rev. B **87**, 174401 (2013)

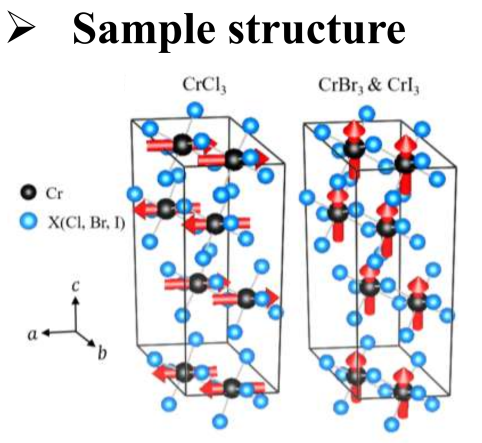
✓ Temperature

? Magnetic anisotropy

What is the correlation between magnetic anisotropy and the g-factor anisotropy?

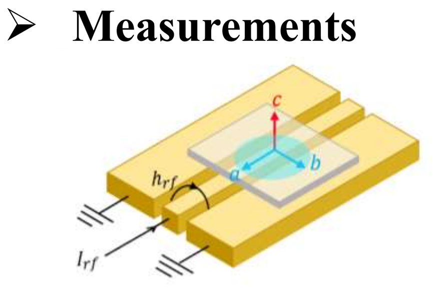
Samples and measurements

➢ **Sample structure**



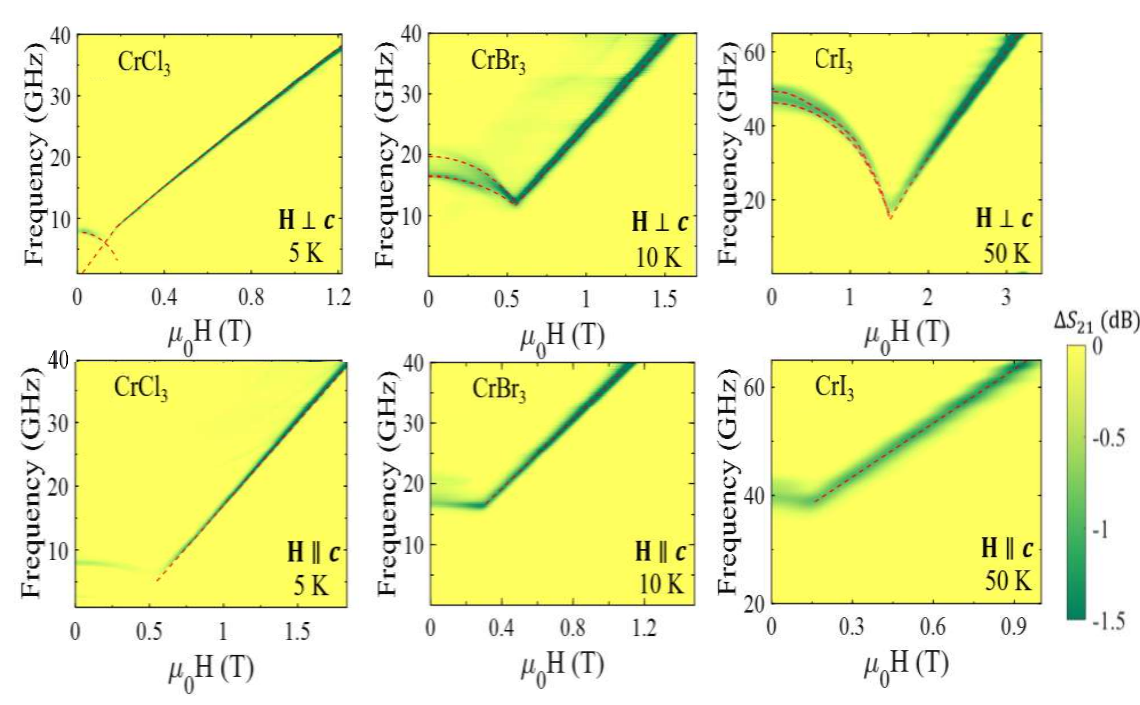
Similar lattice structure & Different magnetic anisotropy

➢ **Measurements**



Vector Network Analyzer (VNA) : 100 MHz ~ 67 GHz

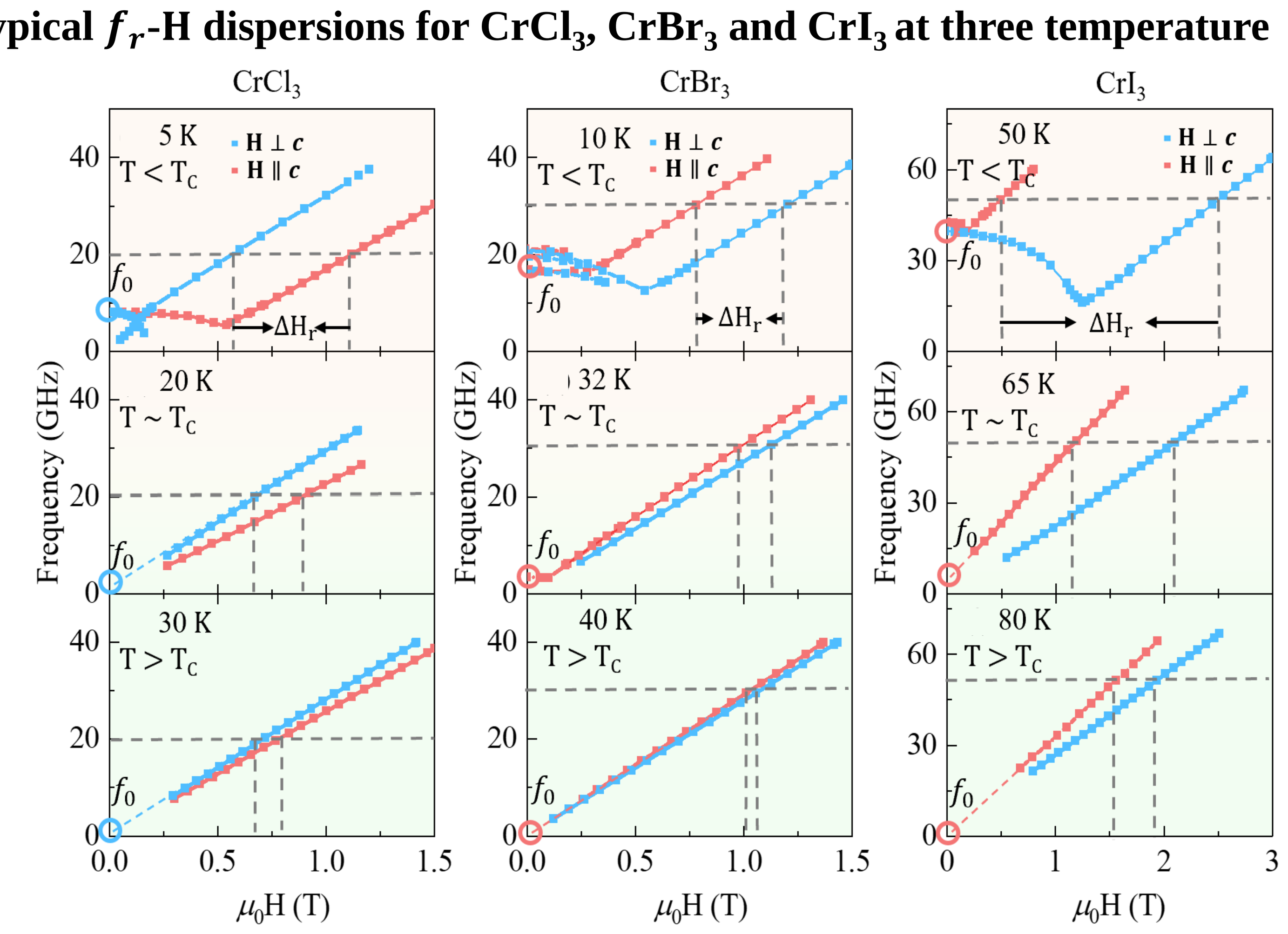
➢ **Typical absorption spectra**



AFM easy-plane anisotropy | FM easy-axis anisotropy | FM easy-axis anisotropy

Determine the critic temperature T_c

➢ **Typical f_r-H dispersions for $CrCl_3$, $CrBr_3$ and CrI_3 at three temperature**



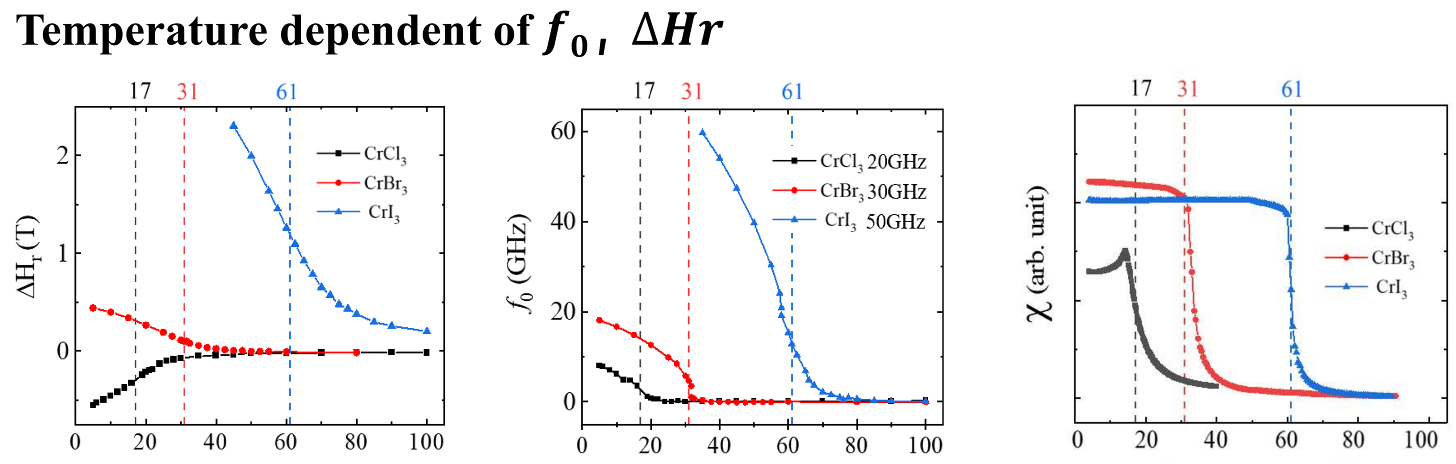
For $H \perp c$, $f_r = \frac{g\mu_B}{h}\sqrt{H(H+H_{eff})}$

For $H \parallel c$, $f_r = \frac{g\mu_B}{h}\sqrt{H(H+H_{eff})}$

➡ g_{ab}, g_c and H_{eff}

Large difference between the slopes of H//c and H⊥c near T_c

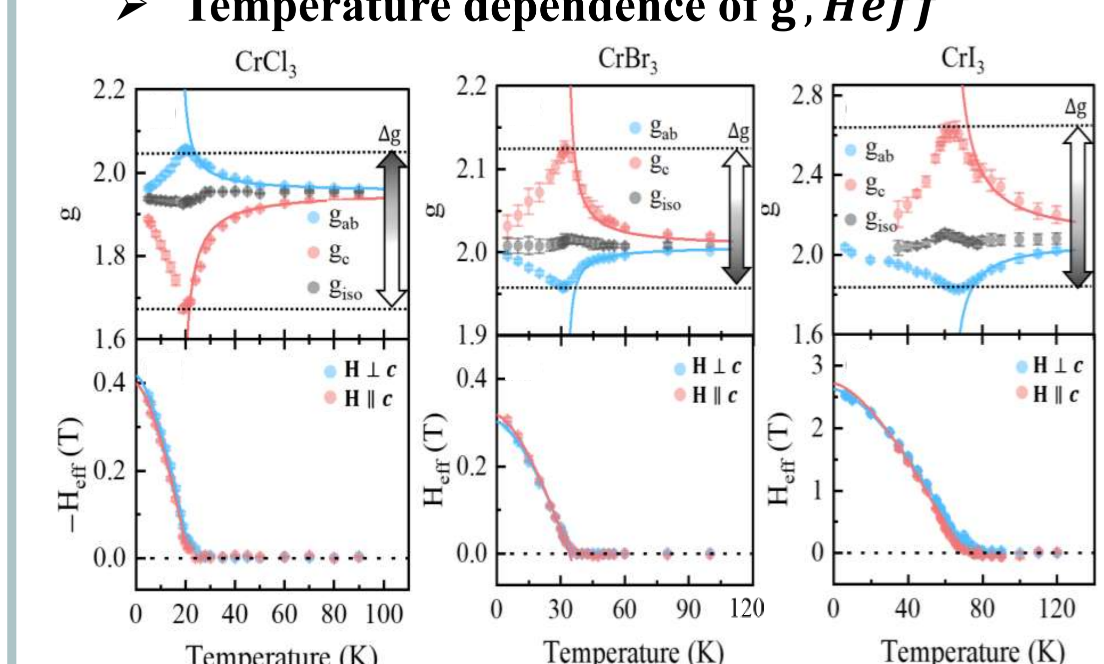
➢ **Temperature dependent of f_0, ΔHr**



$CrCl_3$ (T_c~17 K), $CrBr_3$ (T_c~31 K), CrI_3 (T_c~61 K).

Temperature dependent g factor

➢ **Temperature dependence of g, H_{eff}**



Anisotropic g-factor can be fitted by:

For $H \parallel c$, $g_c(T) = g_0\left[1 + \frac{S(S+1)}{3(T-Tc)}\cdot\frac{K_z}{k_B}\right]$

For $H \perp c$, $g_{ab}(T) = g_0\left[1 - \frac{S(S+1)}{6(T-Tc)}\cdot\frac{K_z}{k_B}\right]$

⇩ K_z

The effective magnetic field extrapolated to 0 K can be obtained through:

$$H_{eff}(T) = H_{eff0}\left(1 - aT^{\frac{3}{2}}\right)$$

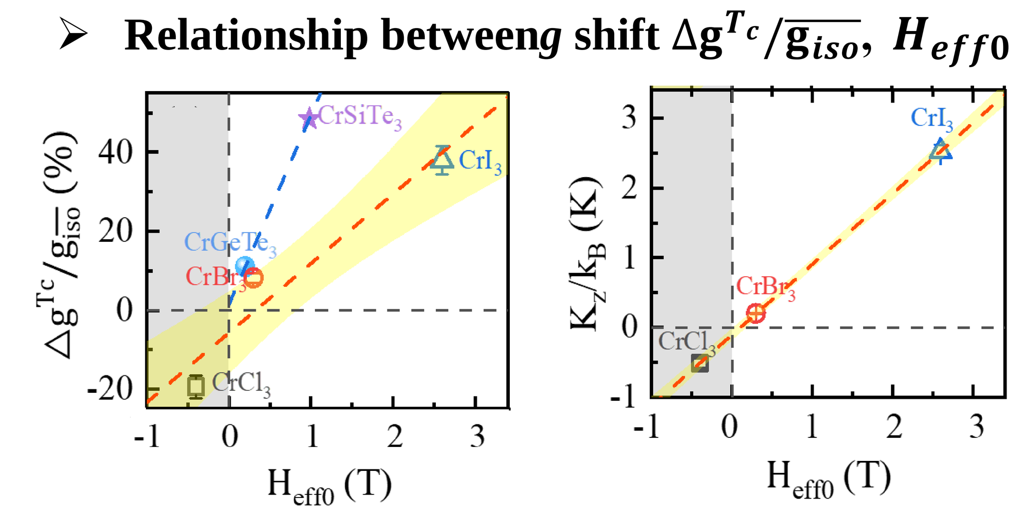
⇩ H_{eff0}

✓ Anisotropic g factor in CrX_3 ($g_{ab} \neq g_c$)

✓ A distinct anisotropy in $CrCl_3$ compared to $CrBr_3$ and CrI_3

Magnetic anisotropy dependent g factor

➢ **Relationship betweeng shift $\Delta g^{T_c}/\overline{g_{iso}}$, H_{eff0} and K_z**



The maximum anisotropic g factor at T_c: $\Delta g^{T_c}/\overline{g_{iso}} = (g_c^{T_c} - g_{ab}^{T_c})/\overline{g_{iso}}$

A positive linear correlation

➢ **Summary of $\overline{g_{iso}}$ and g shift $\Delta g^{T_c}/\overline{g_{iso}}$ for typical 2D and quasi-2D ferromagnets**

Sample	$\overline{g_{iso}}$	$\Delta g^{T_c}/\overline{g_{iso}}$ (%)	T_c	easy axis (plane)	Reference
$CrCl_3$	1.943	-19.4	17 K(AFM)	ab plane	This work
$CrBr_3$	2.010	8.2	31 K(FM)	c axis	This work
CrI_3	2.071	38.0	61 K(FM)	c axis	This work
$Cu(en)(H_2O)_2SO_4$	~ 2	~ -10.0	0.91 K(AFM)	a axis	[1]
$BaCu_3V_2O_8(OH)_2$	~ 2	~ 9.0	9 K(AFM)	c axis	[2]
$CrGeTe_3$(CGT)	2.039	~ 14.7	68 K(FM)	c axis	[3]
$CrSiTe_3$(CST)	2.050	~ 47.8	34 K(FM)	c axis	[3]

g factor anisotropy is correlated to the magnetic anisotropy

[1] R. Tarasenko, **et al.**, Phys. Rev. B **87**, 174401 (2013)
[2] F. Bert , **et al.**, Phys. Rev. B **88**, 144419 (2013).
[3] Li, Xu, *et al.*, Phys. Rev. B **106**, 054427 (2022)

Conclusion

✓ We observed the variation of the g-factor with temperature in 2D materials CrX_3, and also detected the anisotropic g-factor when the external magnetic field is applied along different crystal axes.

✓ We observe a distinct g-factor anisotropy in easy-plane anisotropic $CrCl_3$ compared to the easy-axis anisotropic materials $CrBr_3$ and CrI_3.

✓ Our analysis establishes a positive linear correlation between g-factor shifts and effective fields, connecting the g-factor anisotropy to magnetic anisotropy.