

PAUL SCHERRER INSTITUT



Abhishek Nag:: Post Doctoral Fellow :: Paul Scherrer Institute

Quadrupolar magnetic excitations in an isotropic spin-1 antiferromagnet

12th International Conference on Inelastic X-ray Scattering 2022, 24.08.2022

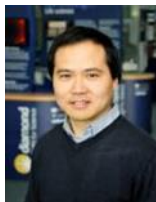
Magnetic excitations in Y_2BaNiO_5 using RIXS



RUTGERS



Stewart Blusson
Quantum Matter Institute
THE UNIVERSITY OF BRITISH COLUMBIA



K.-J. Zhou



S. Agrestini



S.-W. Cheong



A. Nocera



S. Johnston



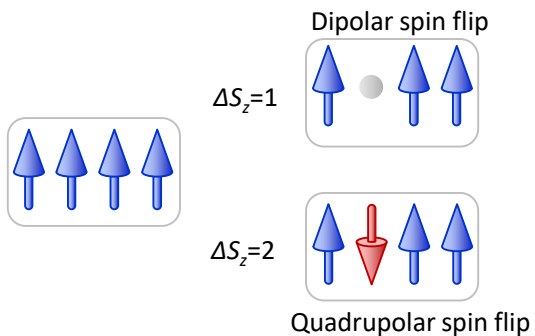
M. G.-Fernández



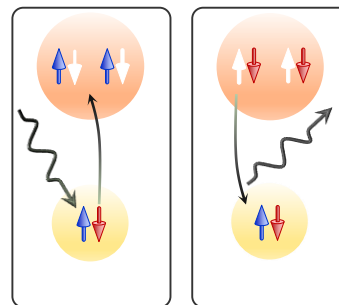
A. C. Walters

Outline of the talk

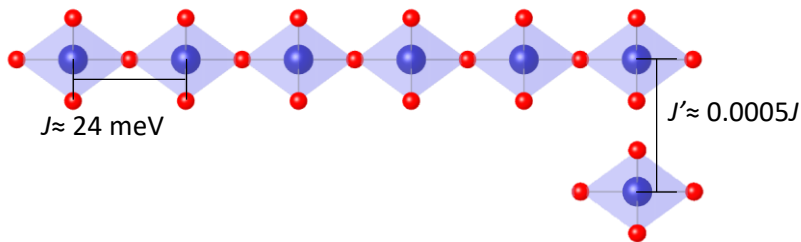
Quadrupolar spin excitations in $S=1$ systems



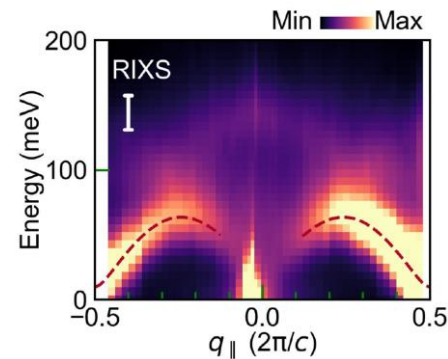
RIXS process of exciting double spin-flips



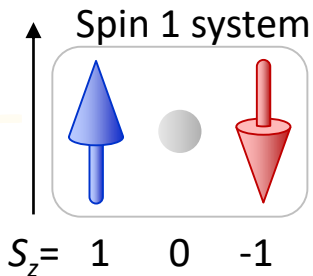
Y_2BaNiO_5



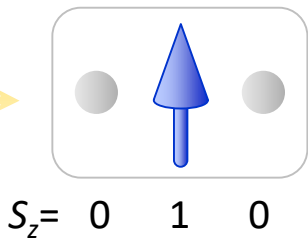
RIXS of Y_2BaNiO_5



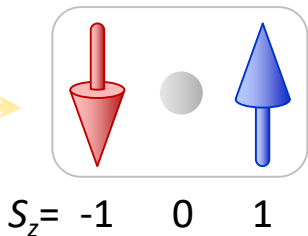
Quadrupolar spin excitations in $S=1$ systems



Dipolar spin flip
 $\Delta S_z = 1$



Quadrupolar spin flip
 $\Delta S_z = 2$



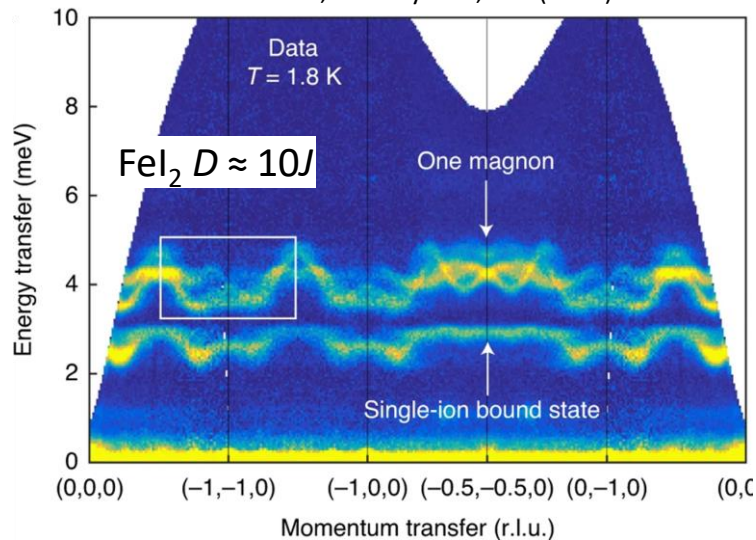
Elementary excitations of high-degree pair interactions: The two-spin-deviation spectra for a spin-1 ferromagnet

S. T. Chiu-Tsao, Peter M. Levy, and C. Paulson
Phys. Rev. B **12**, 1819 - Published 1 September 1975

Elementary excitations in $S = 1$ quadrupolar systems

J. Sivardiere
J. Magn. Magn. Mater. **1**, 23 - Published October 1975

X. Bai et al., Nat. Phys. **17**, 467 (2021)



Quadrupolar spin flips using RIXS

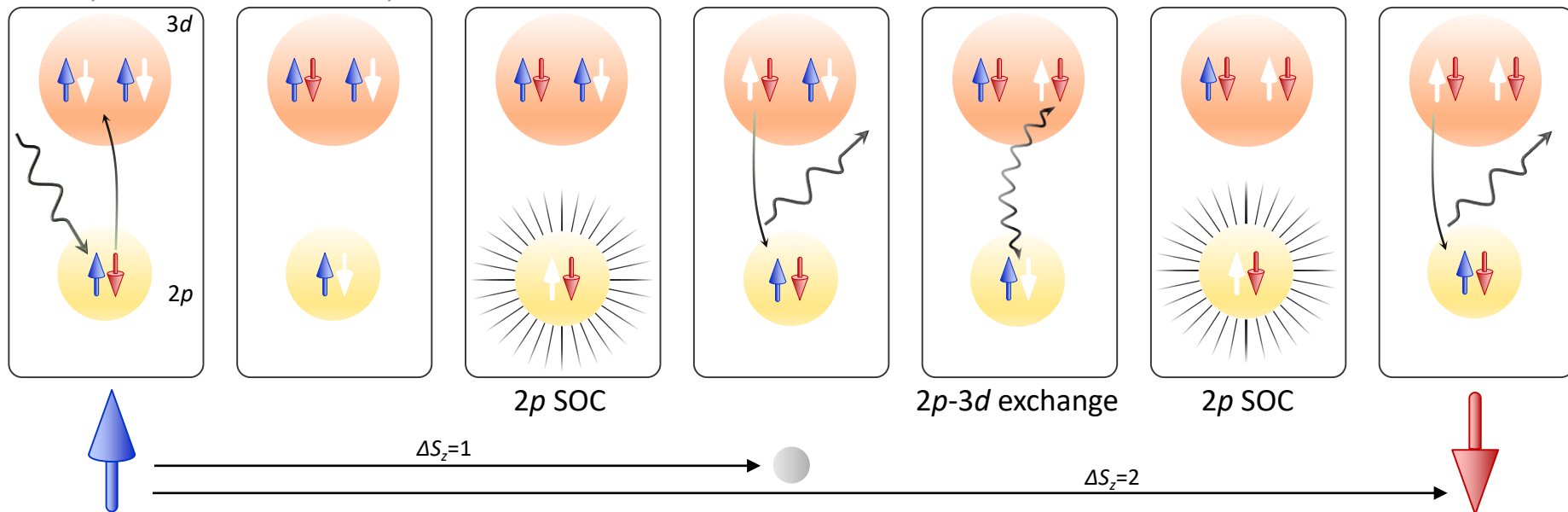
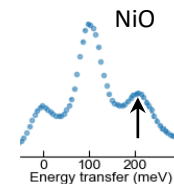
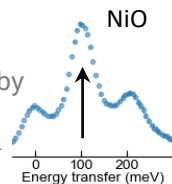
Local spin-flip spectral distribution obtained by resonant x-ray Raman scattering

Raman scattering

F. M. F. de Groot, P. Kuiper, and G. A. Sawatzky
Phys. Rev. B 57, 14584 - Published 15 June 1998

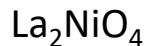
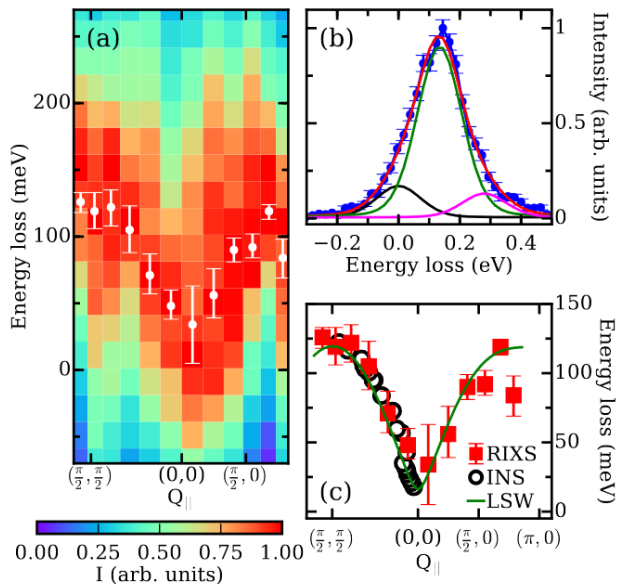
Observation of Two Nondispersive Magnetic Excitations in NiO by Resonant Inelastic Soft-X-Ray Scattering

G. Ghiringhelli, A. Piazzalunga, C. Dallera, T. Schmitt, V. N. Strocov, J. Schlappa, L. Patthey, X. Wang, H. Berger, and M. Grioni
Phys. Rev. Lett. 102, 027401 - Published 12 January 2009

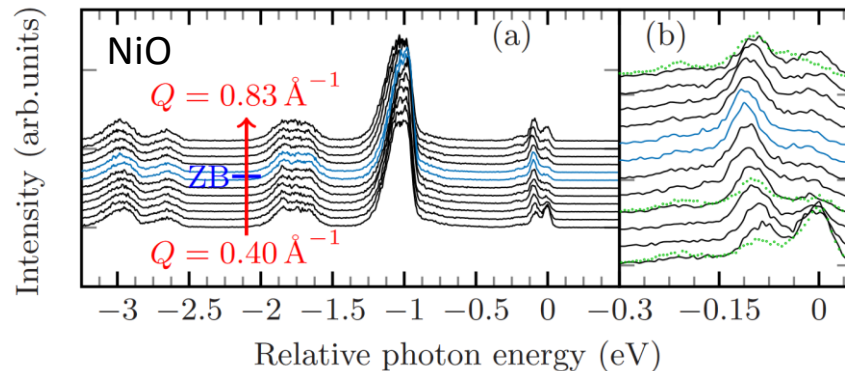


Collective magnetic excitations in $S=1$ systems

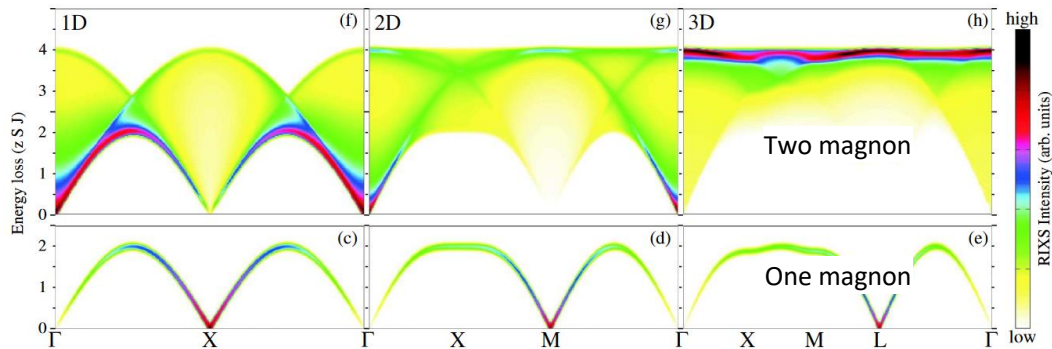
G. Fabbris et al., Phys. Rev. Lett. **118**, 156402 (2017)



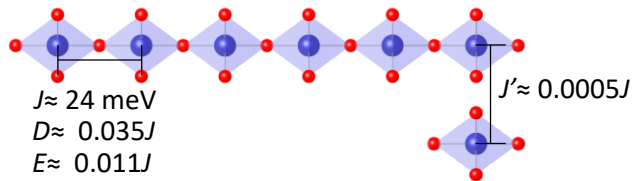
D. Betto et al., Phys. Rev. B **96**, 020409(R) (2017)



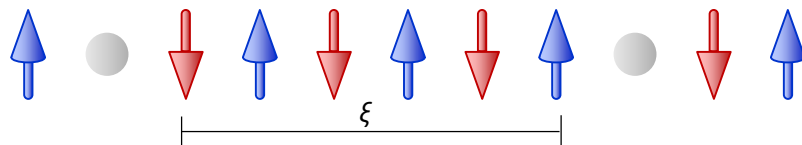
M. W. Haverkort, Phys. Rev. Lett. **105**, 167404 (2010)



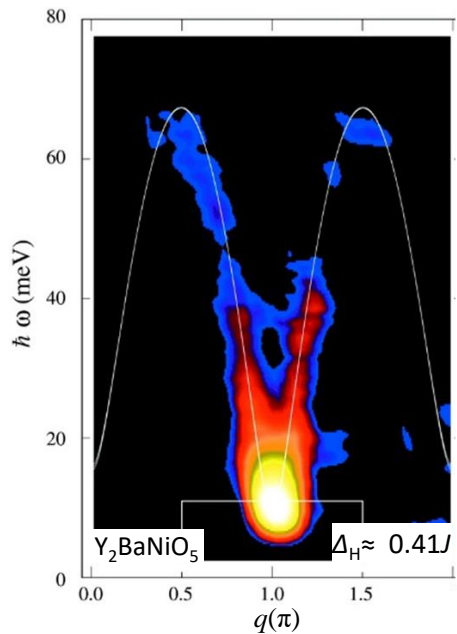
Haldane spin system Y_2BaNiO_5



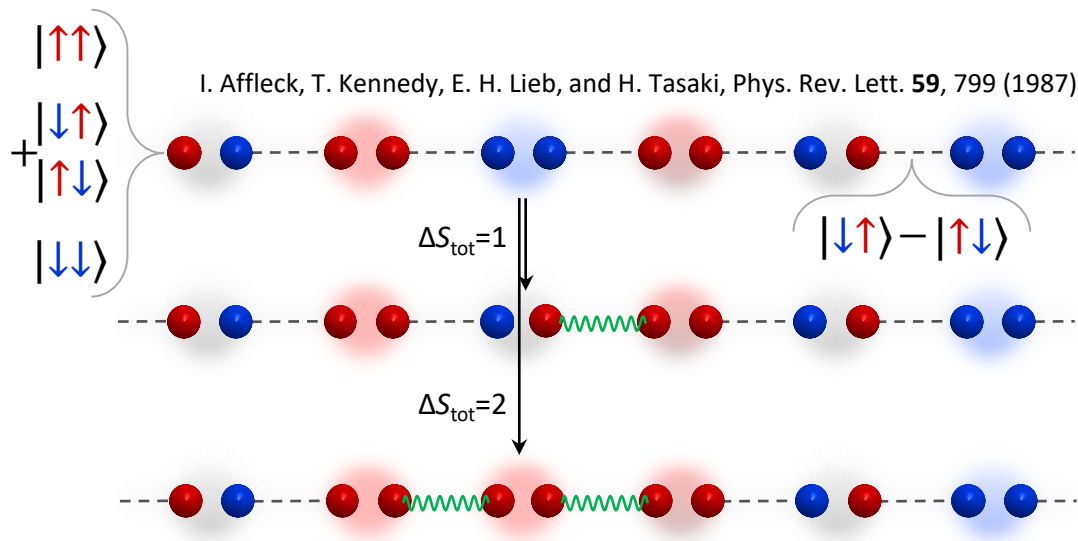
F. D. M. Haldane, Phys. Lett. A **93**, 464 (1983)



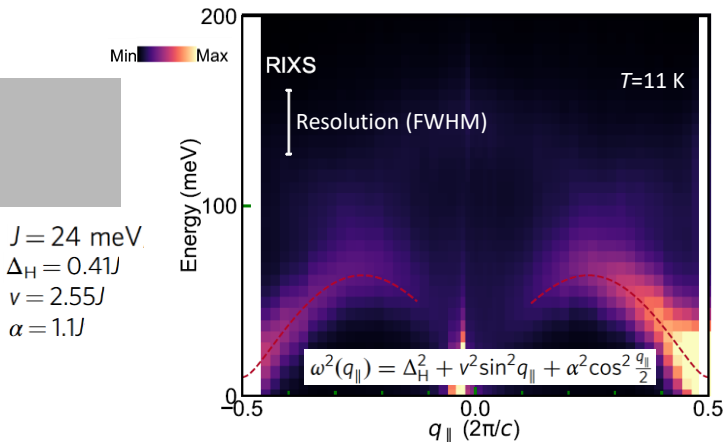
G. Xu et al., Science **317**, 1049 (2007)



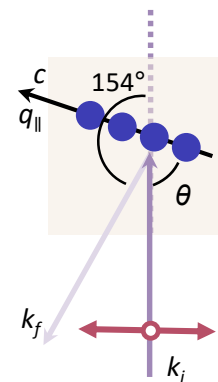
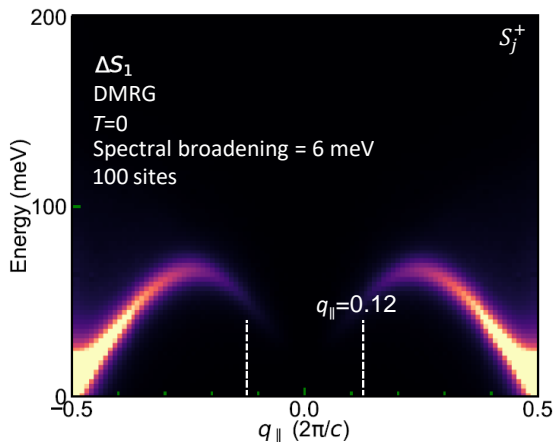
I. Affleck, T. Kennedy, E. H. Lieb, and H. Tasaki, Phys. Rev. Lett. **59**, 799 (1987)



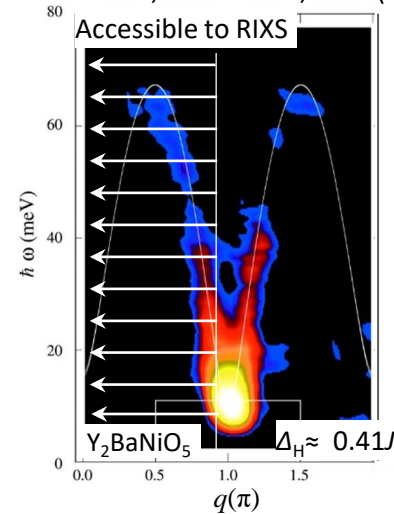
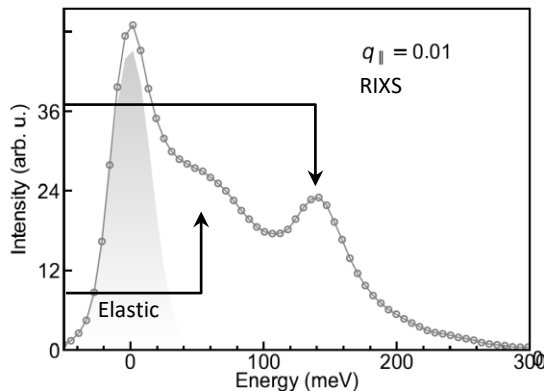
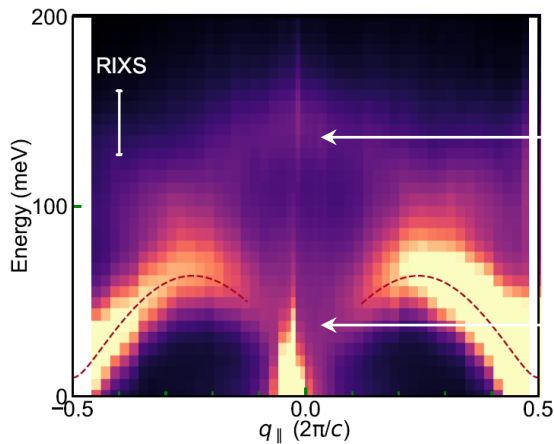
Ni L_3 RIXS on Y_2BaNiO_5



$J = 24$ meV
 $\Delta_H = 0.41J$
 $v = 2.55J$
 $\alpha = 1.1J$

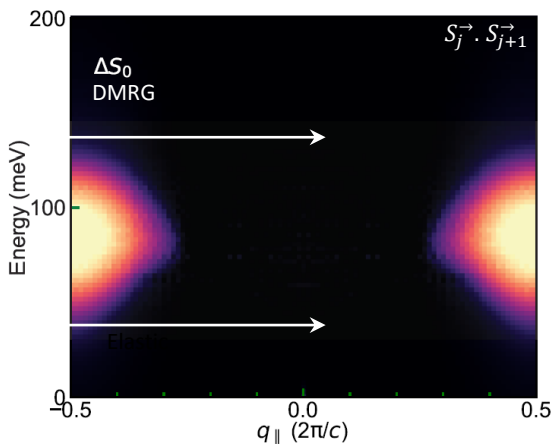
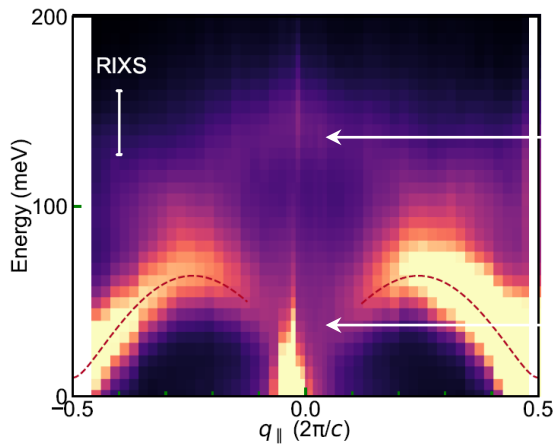
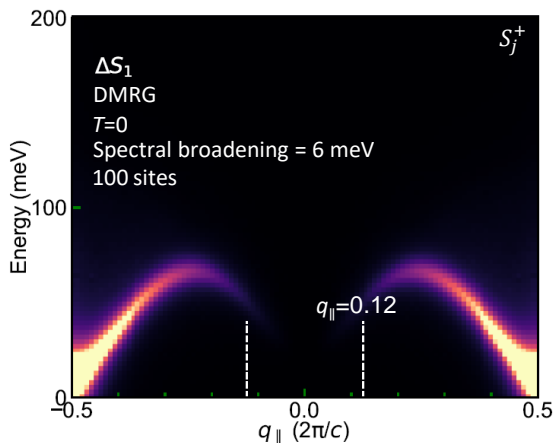
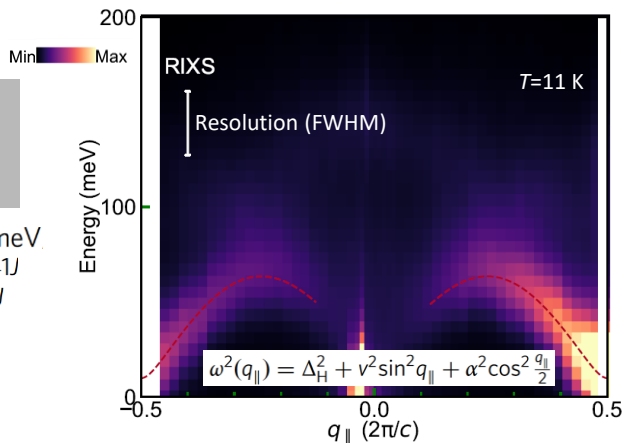


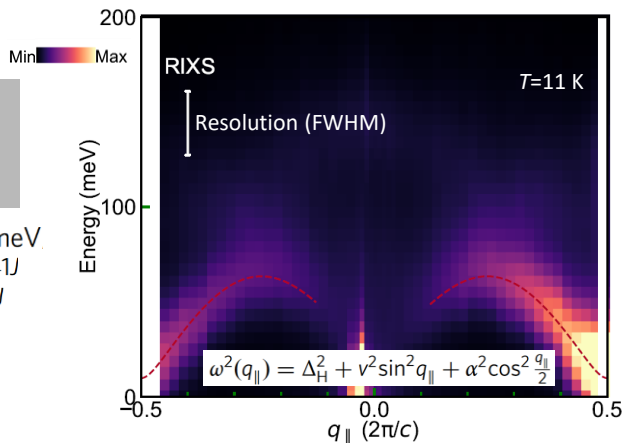
G. Xu et al., Science **317**, 1049 (2007)



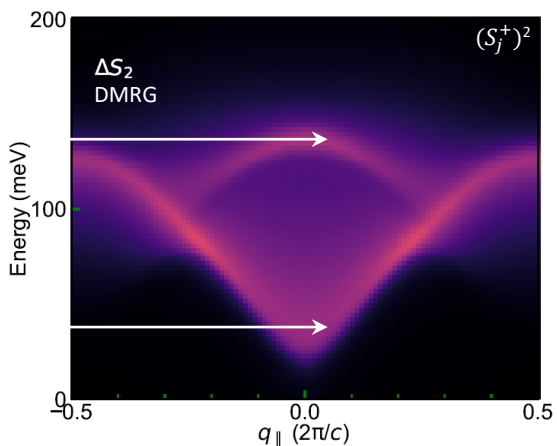
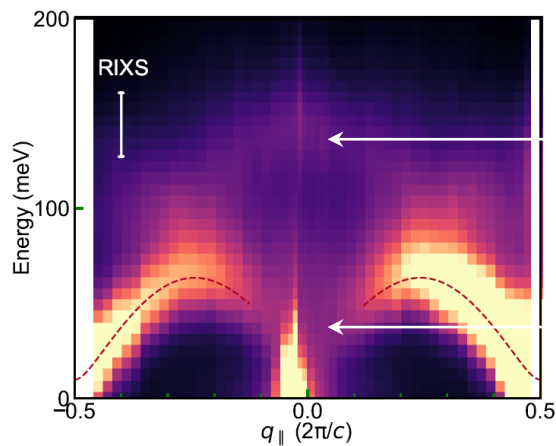
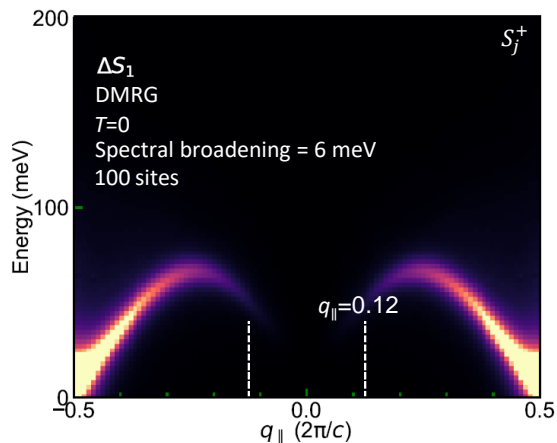
Ni L_3 RIXS on Y_2BaNiO_5

$J = 24 \text{ meV}$
 $\Delta_H = 0.41J$
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 $\alpha = 1.1J$



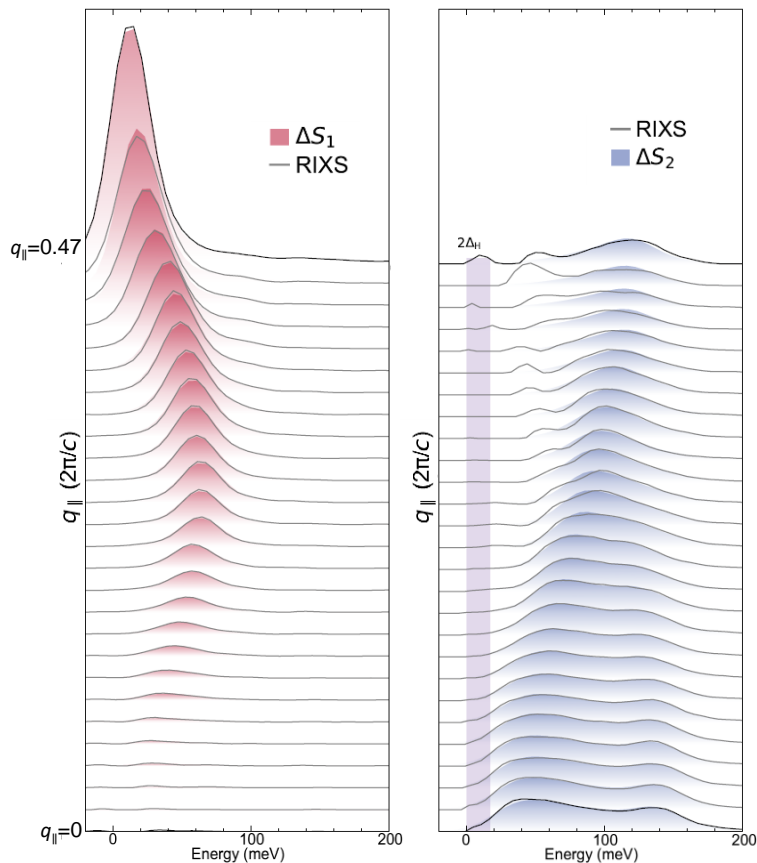
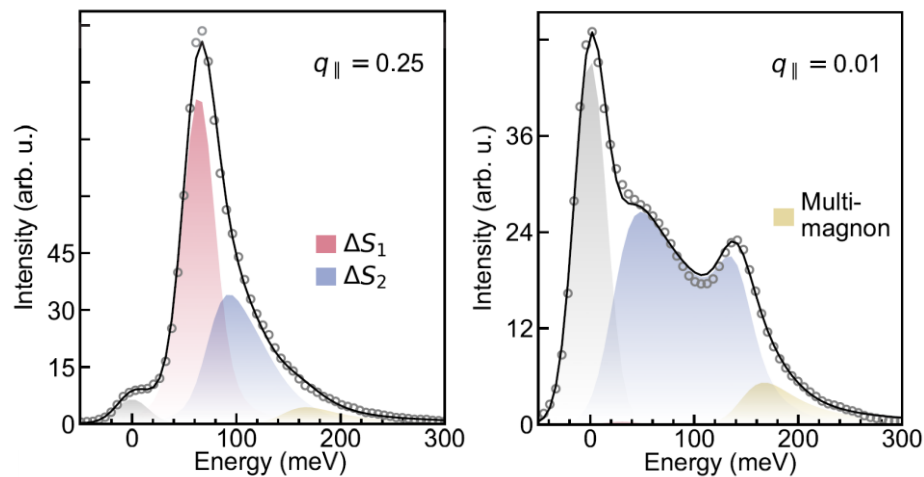
Ni L_3 RIXS on Y_2BaNiO_5 

$J = 24$ meV
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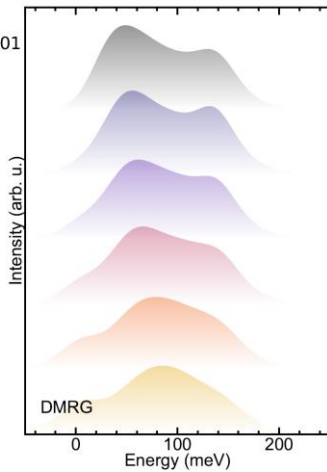
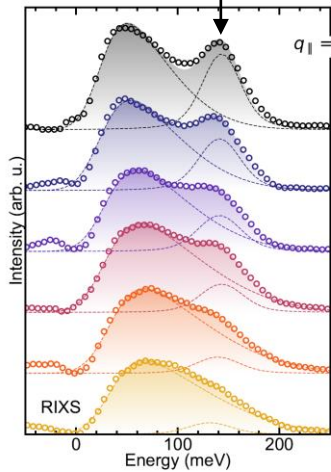
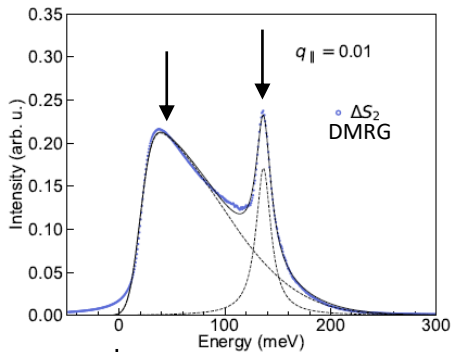


Collective quadrupolar magnetic excitations

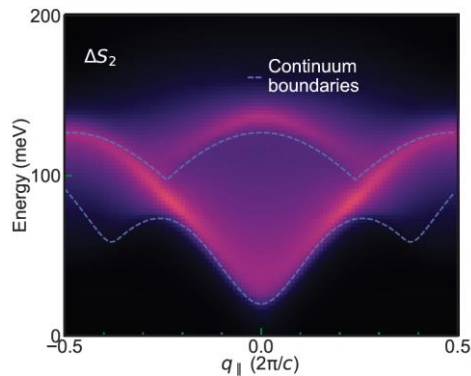
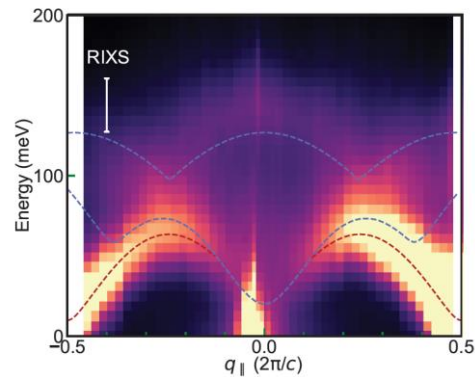
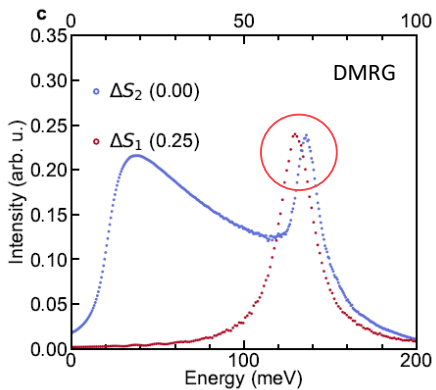
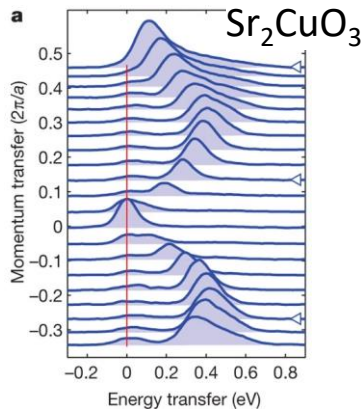
$$I_{\text{RIXS}}(q_{\parallel}, \omega) = C_0(q_{\parallel})S_0(q_{\parallel}, \omega) + C_1(q_{\parallel})S_1(q_{\parallel}, \omega) + C_2(q_{\parallel})S_2(q_{\parallel}, \omega)$$



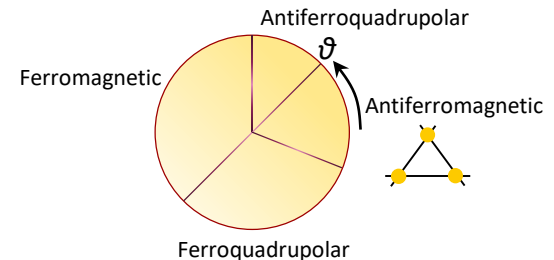
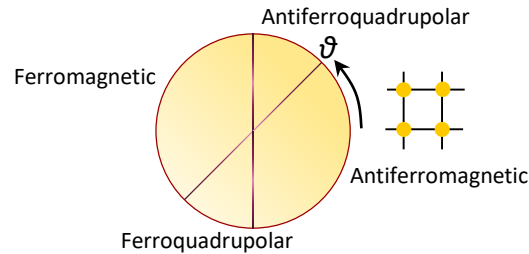
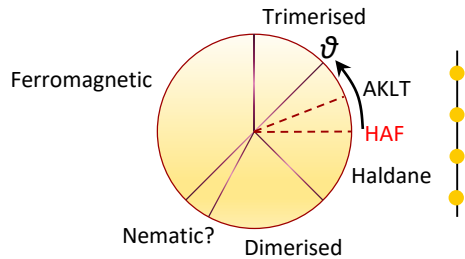
Dual behaviour of the quadrupolar excitations



J. Schlappa et al., Nature **485**, 82 (2012)



- *L*-edge RIXS: *Collective* $\Delta S=2$ quadrupolar excitations in spin-1 systems.
- No anisotropy/dipolar-quadrupolar interactions needed.
- Dual nature of quadrupolar excitations in Y_2BaNiO_5 .
- Bound states: highly sensitive to thermal fluctuations.
- Weak repulsion in the dispersing bound states.



$$\mathcal{H} = \sum_i \mathcal{H}_{i,i+1} = \sum_i [\cos \theta (\mathbf{S}_i \cdot \mathbf{S}_{i+1}) + \sin \theta (\mathbf{S}_i \cdot \mathbf{S}_{i+1})^2]$$