# Incommensurate magnetic modulations of the 2D-layered Ho3Co described by superspace symmetry

## S. Goswani,1,2 V. Petříček,1 P.D. Babu,2 M. S. Henriques1

### 1FZU - Institute of Physics of the Czech Academy of Sciences, Prague, Czechia

### 2 UGC-DAE Consortium for Scientific Research, Mumbai Centre, Mumbai, India

### henriques@fzu.cz

The rich rare-earth (*R*) intermetallic compounds *R*3Co exhibit varied physical properties originating from the competition between exchange interactions and crystal field [1,2]. Their complex magnetic behavior, high spin ordering temperatures, magnetocaloric effect, giant magnetoresistance are naturally of fundamental interest, but also of great potential for technological applications such as cryocoolers and magnetoresistive devices [3]. They crystallize in the orthorhombic Fe3C-type structure (space group *Pnma*). This structure is 2-dimensional, consisting of *R*3Co sheets oriented along (001), with the *R* atoms located at two inequivalent positions. Surprisingly, most of the *R*3Co magnetic structures are yet poorly described. The Ho3Co compound remains probably the least studied compound of this isostructural series. It exhibits two antiferromagnetic transitions – one below the Néel temperature *T*N (=21 K) and another at *T*T (=9 K) previously identified as a spin re-orientation [4-6]. Single crystal magnetization and neutron diffraction performed on Ho3Co (powder and single crystal) did not provide any clear magnetic model [4,7]. Here we present the description of the incommensurate modulated magnetic structures in terms of magnetic superpace formalism as refined from neutron powder data in Jana2020 [8]. In the temperature range 3 K≤*T*<*T*N, the magnetic structure is described by an incommensurate propagation vector **k**=(*α*,0,0) with 0.1605<*α*< 0.1585 and a commensurate component **k**0 = (0,0,0). For *T*T<*T*≤ *T*N the spin arrangement consists of fan-like (Ho) and cycloidal (Co) modulations. Below *T*T, the presence of 3**k** and 5**k** harmonics results in an anharmonic ground state with the squaring of the modulation. The evolution of the magnetic modulations in Ho3Co for 3 K≤*T*< *T*N, is explained by two active irreducible representations under the *Pnm′a*(*α*00)000 magnetic superspace group, which allows the change of the structure with no further symmetry breaking. A significant moment contribution was detected in Co. The realized magnetic model will be discussed within the superspace symmetry approach, showing how it describes the complex modulations in a simple and robust form that is fully consistent with the macroscopic properties.

|  |
| --- |
| A diagram of a molecule  Description automatically generated with medium confidence |
| **Figure 1**. Spin modulation of Ho3Co at 18 K for Ho (blue) and Co (red) represented in a 5×1×1 supercell of the parent orthorhombic unit cell. The modulation of Ho1 and Ho2 is described as fanlike, with a fan spanning of 100°. The fan plane of Ho1 is parallel to (101), whereas Ho2 spins are at an angle of 57° away from the *a*-axis. The modulation of the Co spins is a circular cycloidal restricted to be parallel to (101). |

[1] N.V Baranov *et al*., *Eur. Phys. J. B* **16**, 67 (2000); [2] N.V. Baranov *et al*., *Physica B* **324**,179 (2002); [3] X. Zheng, B. Shen, *Chin. Phys. B* 26, 017501 (2017); [4] A. Podlesnyak *et al*., *J. Magn. Magn. Mater*. **272–276**, 565 (2004); [5] J. Shen *et al*., *J. Appl. Phys*. **109**, 07A931 (2011); [6] N.V. Baranov *et al*., *J. Phys.: Condens. Matter* **17**, 3445 (2005); [7] T. Palewski *et al*., *J. Magn. Magn. Mater*. **258–259**, 561 (2003); [8] V. Petricek *et al*., *Z. fur Krist. – Cryst. Mater*. **238**, 271 (2023)

This work was co-funded by the European Union and the Czech Ministry of Education, Youth and Sports (Project TERAFIT, CZ.02.01.01/00/22\_008/0004594).