**Supplementary Information**

**Observation of roton-like dispersion relations in acoustic metamaterials**

Zhenxiao Zhu1,#, Zhen Gao1,# \*, Gui-Geng Liu2#, Yong Ge3, Yin Wang3, Xiang Xi1, Bei Yan1, Fujia Chen4, Perry Ping Shum1, Hongxiang Sun3,\*, Yihao Yang4,\*

1Department of Electrical and Electronic Engineering, Southern University of Science and Technology, Shenzhen 518055, China.

2Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, 21 Nanyang Link, Singapore 637371, Singapore.

3School of Physics and Electronic Engineering, Jiangsu University, Zhenjiang, 212013, China.

4Interdisciplinary Center for Quantum Information, State Key Laboratory of Modern Optical Instrumentation, ZJU-Hangzhou Global Science and Technology Innovation Center, Zhejiang University, Hangzhou 310027, China.

#These authors contributed equally to this work.

\*E-mail: gaoz@sustech.edu.cn (Z.G.); jsdxshx@ujs.edu.cn (H.S); yangyihao@zju.edu.cn (Y.Y.);



**Supplementary Figure S1 The fitted curve (green line) of the measured dispersion (red colour) with third-nearest-neighbour interactions using the 1D toy model.**



**Supplementary Figure S2 Calculated roton-like dispersion relations for four 1D toy models with beyond-nearest-neighbour interactions.** The dispersion relations for four 1D toy models with *N* = 2 (red curves), 3 (green curves), 4 (blue curves), 5 (purple curves), respectively. The parameters are *KN*/*K*1 = 3 with *N* = 2, 3, 4, 5 and , respectively.



**Supplementary Figure** **S3 The mean energy fluxes of different eigenmodes at the same frequency of 1.35 kHz for (a) *N* = 2, (b) N = 4 and (c) N = 5, respectively.**