MIAO-ALMA: Shocks and Protostellar Outflows in 70 μm-dark clumps with $L/M < 1\ L_{\odot}/M_{\odot}$

○Shuting Lin[1, 2] Siyi Feng[2] Junzhi Wang[3] Shanghuo Li[4, 5] Dan Miao[2] Zhi-Yu Zhang[4, 5] Sheng-yuan Liu[7] Nami Sakai[6] Fengwei Xu[8] Hauyu Baobab Liu[9, 10] Henrik Beuther[8] Di Li[11] Qizhou Zhang[13] Tie Liu[14] Patricio Sanhueza[1] Olli Sipilä[12] Ken'ichi Tatematsu[15, 16] Jaime E. Pineda[17] Xing Lu[14, 18] (1.Department of Astronomy, School of Science, The University of Tokyo 2.Department of Astronomy, Xiamen University 3.School of Physical Science and Technology, Guangxi University 4.School of Astronomy and Space Science, Nanjing University 5.Key Laboratory of Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education 6.RIKEN Cluster for Pioneering Research 7.Institute of Astronomy and Astrophysics, Academia Sinica 8.Max Planck Institute for Astronomy 9.Department of Physics, National Sun Yat-Sen University 10.Center of Astronomy and Gravitation, National Taiwan Normal University 11.New Cornerstone Science Laboratory, Department of Astronomy, Tsinghua University 12.Max-Planck-Institut für Extraterrestrische Physik 13.Center for Astrophysics | Harvard & Smithsonian 14.Shanghai Astronomical Observatory, Chinese Academy of Sciences 15.Nobeyama Radio Observatory, National Astronomical Observatory of Japan 16.Astronomical Science Program, Graduate Institute for Advanced Studies, SOKENDAI 17.Max Planck Institute for Extraterrestrial Physics 18.State Key Laboratory of Radio Astronomy and Technology)

To investigate the initial conditions of high-mass star-forming regions, we use SiO (2–1) emission to trace early shock-related kinematics toward sixteen 70μm-dark and massive clumps with luminosity-to-mass ratios (L/M) < 1 $L_{\odot}/M_{\odot}$, as part of the Multiwavelength Line-Imaging Survey of the 70 μm-dark and bright clouds (MIAO) project.

Using ALMA observations at a spatial resolution of ~ 0.06 pc and a velocity resolution of 0.21 km s^{-1}, we identify a total of thirty-seven outflows with a variety of morphologies. Outflow parameters were derived by integrating the HCO^{+} (1–0) line wings, excluding the quiescent dense core component traced by $H^{13}CO^{+}$(1–0). We find that outflow masses and velocities show moderate positive correlations with the masses of their driving cores. The derived outflow dynamical ages span ~ 10^{3}–10^{5} yr. We detect six narrow-linewidth (0.6–1.4 km s^{-1}) and three broad (> 2 km s^{-1}) SiO (2-1) features not associated with outflows driven by clearly identified protostars. Lacking coincident 3 mm dust continuum cores, their origins may be young outflows from undetected low-mass protostars, dissipating shocks, cloud–cloud collisions, or projection effects when the outflows lie close to the plane of the sky. The detection of these shocks and outflows in such extremely young environments demonstrates that protostellar activity has already begun.