

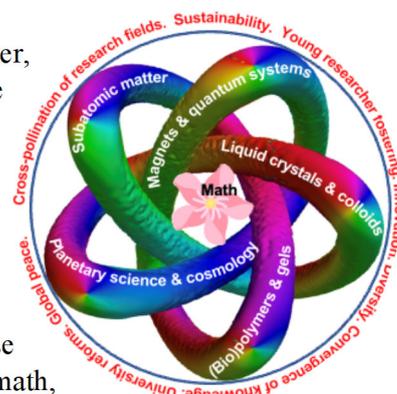
Vision of the prospective director, Prof. Ivan Smalyukh

Everything, ourselves included, is made of molecules and atoms, which are made of electrons, protons & neutrons, which are made of quarks and leptons... Researchers revealed smaller and smaller building blocks of matter, classified them, & detected their “fingerprint” signals coming from far riches of the Universe and its history. With each breakthrough, we felt “touching the depths of nature with bare hands”, though we have been playing by nature’s rules all along, uncovering just tiny fragments of its vast unknown. Feynman’s words “What I cannot create, I do not understand” resonate with my vision to develop new building blocks of matter, analogs of nature’s quarks, protons, atoms & molecules, which would boost our understanding of nature’s inner workings and allow for making new forms of matter by design. I have been introducing such building blocks [*Nature* 2013, *Science* 2019, *Nature* 2019] & phases of matter [*Science* 2018, *Science* 2019, *Nature* 2021] that so far have no direct analogs in natural systems. I now seek to establish an entire research paradigm of **knotted chiral meta matter (KCM²)**, with knots in fields as building blocks, through cross-pollinating topology with chirality knowledge across disciplines & scales & through fostering technological innovation to solve the most challenging global problems. The WPI program of MEXT is the only one in the World uniquely adequate for these ambitious goals, with the excitement & support at Hiroshima University (HU) creating a fertile ground.

Each time I returned from my visits to Japan, I brought Mizuhiki presents for my family and friends. Within this artform, many beautiful things can be made from a humble building block, the rice paper cord. When giving public lectures, I explain my research motto by drawing parallels with this art. What nature did not give us, I want to make by knotting and knitting physical fields, molecules and colloids. I want to understand nature’s inner workings at the subatomic-to-cosmological scales by exploring the fabric of spacetime and recreating it in observable physical fields, by understanding & controlling tangles of biological molecules like proteins & RNA. A Mizuhiki artist’s hand can create almost anything. In our designs of building blocks of matter, “knot chirality” can play the role of the artist’s hand by enabling the stability of knots in physical fields and polymer strands. This may help understand how nature uses different types of broadly defined chirality within the entire hierarchy of length and time scales, like charge-parity (CP) violation to prevail existence of matter over anti-matter and molecular chirality to control conformations of biopolymer strands essential for life. Learning and mastering such nature-inspired skills can endow us with the abilities to create new materials, cure diseases, & understand nature’s inner workings.

The tradition of Mizuhiki is said to have brought people together throughout the millennia of history. The dream of establishing a new interdisciplinary field of science brings together my team of PIs. We will interknit together mathematical knot theory and subatomic and cosmological physics with creations of knotted fields in magnets, liquid crystals and colloids, and with observations of knotted strands of proteins, RNA of coronavirus genome, and so on. Our center will tie together basic science with reforming graduate-level education in Japan and globally, dedicated both to expanding the bulk of scientific knowledge & to enabling a sustainable future. We dream about a large international scientific network with a **central mission to identify the organizing principles for emergent KCM² phenomena**.

Our interest in chirality relates to its emergent co-creation power, stabilizing particle-like solitons and knots in phenomena across the entire hierarchy of length and time scales, from subatomic to biological and cosmic systems. Promising significant discovery & differing from simpler disciplinary definitions of chirality, like in chemistry, this knot chirality requires dealing with a hierarchy of length and time scales & creation of entirely new concepts, laws & generalizations, which is only possible within a research effort uninhibited by disciplinary boundaries. Our “knot chirality” is a “poster child” for emergence, motivating us to cross-pollinate and fuse diverse research fields, defining the **identity** of our WPI. Our **KCM²** is not a branch of math, physics, chemistry, biology, material science, or engineering, but rather is an intrinsically interdisciplinary mixture of these, a pursuit in which progress is made simultaneously in the context of all these fields. Our WPI will holistically explore the role of knot chirality at subatomic-to-cosmic scales, with a focus on tabletop fundamental research, leading to a new field of the **emergent KCM² science**.



Mathematical concepts, like the ones of knot and homotopy theories, will aid us with generalization of findings. While we will focus on systems like liquid crystals (LCs), colloids, magnets and (bio)polymers, our findings will provide insights into related phenomena in experimentally less accessible systems, like black holes, elementary particles & origins of life in the pre-biotic world. Conversely, theories of subatomic physics and cosmology will inspire us to deepen our understanding of related phenomena in these highly accessible condensed matter systems. For example, mathematical solitons can materialize in open crystal lattices of the heliknotons found in chiral LCs & in ones formed by bioderived cellulose nanocrystals & in configurations within cuticles of *Chrysina resplendens*, the gold scarab beetle. Porous thermally super-insulating materials with interknitted molecules & designable reflectivity can be used in building envelopes (cumulatively responsible for 40% of all generated energy) to reduce the energy demand. From the biomedical standpoint, mis-knotting in proteins can cause diseases, such as Alzheimer's, so the control of these processes may aid in treating diseases. Our fundamental science can aid in solving the most challenging problems by enabling technologies that reduce the energy demand to slow down climate change, a threat bigger than that of a nuclear war. Knowledge traditionally took decades to “diffuse” across disciplines. We will reduce this time 100-fold by removing disciplinary boundaries & building on Japan/HU's strengths while developing our new paradigm.

Our WPI will sponsor exchanges of students and postdocs between HU, Japanese institutions, and those of foreign PIs, circulating young talent between our global network's nodes. Combined with recruiting efforts, we will hold annual meetings with subsidized participation for young researchers, building on my experience of organizing annual inter-continental advanced materials for photonics schools (iCAMPs). PhD training will define a context for the formation of a community of graduate researchers, built around activities designed to broaden the education base, foster scientific growth and expand global perspectives. By team-teaching courses and drawing students from different preparation backgrounds, our WPI will become a focal point for interdisciplinary training, enabling students to learn by performing projects in a collaborative environment. We will partner with HU's existing programs to support young researchers ranging from students to professors. The new WPI will become a magnet attracting & a knot inter-connecting young talent globally. It will create a testbed for research-based education reforms within & beyond Japan. Young researchers face big challenges in the early stages of their careers, some of which are specific to Japan. There is a strong intention to introduce changes, but the process is slow. Our WPI will reform this system profoundly and expeditiously, not through “writing and reading the air”, adopting the best practices of US & UK PhD programs while “customizing” them to Japan and making them even better.

WPIs funded so far seem to strengthen elite Japanese institutions that are already well-funded research centers. For HU, the WPI would be a game-changer, a chance of attracting many outstanding international researchers while working hand-in-hand with top research centers in Japan and globally by fostering research exchanges. Strongly committed to gender diversity, our WPI would help HU with recruiting talented leading researchers with very high global recognition & visibility, as well as talented postdocs & students from other countries & premier research centers globally, whom HU cannot attract otherwise. For MEXT, this is an opportunity to truly co-create a center of research excellence. Our WPI would help foster research excellence by bringing together top international leaders in the emerging *KCM²* field/paradigm under one roof of the WPI building at HU for interdisciplinary collaborations, potentially enabling future Nobel Prizes & Fields Medals.

Meetings with other current US-based WPI directors convinced me that it will be possible for me to focus on science and the “big picture” while directing the WPI. I will approach this endeavor creatively, like research and everything I do, but I will need help in running the WPI. The support of President Ochi is amazing: he offered a new building & his administrative “right hand”, Administrative Director Abe, to help implement reforms. Also important will be the support of my scientific soulmates, with whom we share the vision to create our WPI dedicated not only to expanding the bulk of scientific knowledge but also to enabling a sustainable future. We will interknit natural & social sciences through science-based fostering of young researchers and engagement of female students to interest them in academic careers, as well as through university-public-industry-Government relations & outreach, strengthening the public support for science that promotes sustainability & peace. A beautiful chiral object, the Oleander flower is a symbol of the rebirth of Hiroshima, & a symbol of our passion to create the new WPI and the paradigm of *KCM²* – **IT WILL BLOSSOM!**