This workshop was the fourth in what has become a biannual series on a topic central to several cosmological and astrophysical issues, including the formation of large scale structure, the evolution of galaxies within cluster environments and the nature of very hot and very low density plasmas. The first two of these workshops were held at the University of Michigan in Ann Arbor (UMi), while the third was at the Niels Bohr International Academy (NBIA), in Copenhagen. FTPI sponsored this one, which was quite timely, and provided most of the financial support. NBIA and UMi also contributed financial support and members to the SOC. The FTPI was an ideal setting for this workshop, and it was considered a great success by all involved.

The focus of these workshops is well expressed in the title; namely, to advance understanding of the physics of the hot, diffuse plasma that fills galaxy clusters (and constitutes something like 90% of their baryonic mass) and how that physics depends on and reveals the formation dynamics of cosmic hierarchical structure. Galaxy clusters are the largest (spanning millions of light years) and most massive ($10^{14}-10^{15}$ $M_{\odot}$) bound structures in the universe. The talks are mostly built on theory and simulation, although about 1/4 of the presentations are observation-based. So, in fact, the topics and the discussion at this workshop were quite broad. There were 31 invited talks. In addition nine poster presentations were included. (This was the first workshop in this series to include posters.) All together there were 54 registered participants coming from North America, Europe, East Asia and South Asia.

It was very rewarding at this workshop to see evidence of rapid progress since the previous, 2014, workshop towards developing a practical understanding of these environments. One important distinction of this workshop series from others with analogous topical focus is the effort to understand ICM physics at a fundamental level on all scales, spanning “microscales”, where particle kinetics and plasma instabilities dominate to cluster-sized “macroscales”. There are multiple critical questions about the proper way to model ICM dynamics and thermodynamics that depend on a full understanding of these media as plasmas. That is a major challenge because of the fact that, because of their very high temperatures and very low densities, the “plasma character” of ICMs is very different from plasmas that can be made in terrestrial laboratories or that can be studied directly in the solar system. One of the challenges that these workshops try to address is how to bridge those differences and, accordingly, how to test which models are most appropriate in ICMs. The talks and especially the discussions at this,
FTPI, workshop demonstrated very significant progress in this direction and also an increased appreciation among both theorists and observers that these issues must be resolved to make further progress.

One very special feature of this workshop was a presentation and then extensive discussion of unique results from the Japanese “Hitomi” X-ray satellite (also known as “Astro-H”). Hitomi was the first X-ray astronomical satellite to include a spectrometer with sufficient spectral resolution to measure Doppler broadening of X-ray atomic emission lines (so, in effect, measurements of plasma motions). The satellite met an untimely death last February, only a few months after launch, but did manage to obtain beautiful spectral measurements of one galaxy cluster in the constellation Perseus. Those measurements demonstrated that the Perseus cluster ICM is turbulent and quantified the turbulence properties. Those two results add fundamental information about cluster formation and ICM physics. The next X-ray satellite scheduled for launch that can do anything similar is not due until 2028. Almost ½ day in this workshop was devoted to presentation and discussion of these results. Since the Hitomi results were “quarantined” until very recently, these discussions were not possible until now.

Comments from participants were uniformly very positive about both the science at the meeting and the high quality organization and support from FTPI.

Summary by Tom Jones

Workshop website: