FM 18:
Scale-free processes in the universe

https://doi.org/10.1017/S1743921316006360 Published online by Cambridge University Press

Astronomy in Focus, XXIXB, Focus Meeting 18
XXIXth IAU General Assembly, August 2015
Piero Benvenuti, ed.

doi:10.1017/S1743921316006360

Foreword

Most of the distribution functions in the universe, including those for mass, energy, and structure of components like dark matter, galaxy clusters, galaxies, magnetic fields, cosmic rays, star clusters, and stars, have power-law shapes suggesting a lack of definite scales in their formation processes. As these scale-free behaviors are obtained without fine-tuning, they are by definition self-organized, which raises fascinating questions regarding the respective roles of long-range (gravity) and short-range (collisional) interactions. These questions touch on the interaction between dark matter, baryons, cosmic rays and magnetic fields, the importance of scales where the power-laws break down, the observed deviations from power-laws, and the range of scales that are truly coupled. Computer simulations now include a large enough range of scales to reproduce some of these power-laws, and recent theoretical analyses attempt to unify them.

The main objective of this Focus Meeting was to gather cosmologists, astrophysicists and statistical physicists, whether they are observers, theoreticians or numericists. It was viewed as an opportunity to exchange ideas from different horizons and plan the next steps in this global investigation. The meeting succeeded in being truly trans-disciplinary and focused. Several key topics included: the universality of power-law probability distribution functions, their breaks and deviations, the coupling between cosmic rays, magnetic fields, turbulence, and gravity, the interplay of dark matter and baryons in hierarchical systems, the transitions from cosmological to baryonic physics, the insights from the physics of critical phenomena, and self-organized criticality.

The conference consisted of 14 invited talks, 21 contributed talks, and 17 posters. We are grateful to all of our presenters for making this an interesting and timely meeting. We learned that a variety of mechanisms involving physical processes that do not have a characteristic length, mass, or energy can produce power-law distributions, including self-similar geometrical effects like hierarchical fragmentation, turbulent cascades, and self-organized criticality. Moreover, the superposition of distributions that individually are not power laws may also produce something like a power law. Because power laws tend to appear on scales that are well removed from boundary and initial conditions, the processes that break or terminate the range of a power law are important also for our understanding of the physical phenomena. We concluded that a full description of the physical processes characterized by a power-law distribution requires both the identification of these processes and an explanation of what terminates its range. We hope to organize a continuation meeting with this perspective in the near future.

Edith Falgarone, Bruce Elmegreen, and Enrique Vázquez-Semadeni, November 2015