

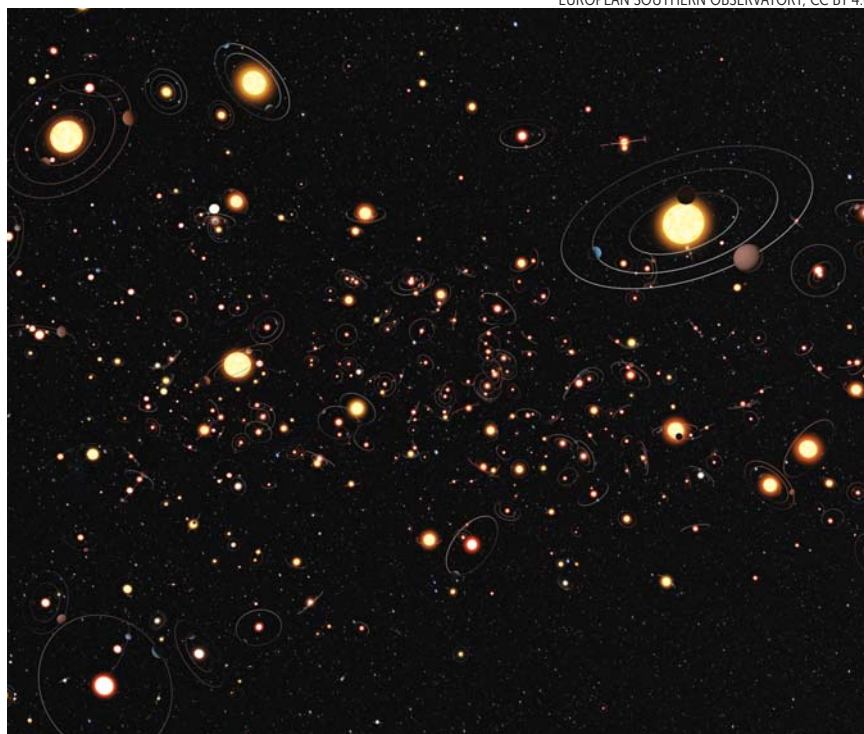
deeply into a certain area of complex adaptive systems are likely to find *An Introduction to Complex Systems* a bit thin. However, it is not meant to be an in-depth guide, but rather a survey of the field.

What makes *An Introduction to Complex Systems* stand out is its thoroughness. The book is basically an encyclopedia of complex-systems studies. Need to quickly reference the equation for the first law of thermodynamics? Section

7.1.3. How about measures of information? Section 6.1.4. A reader can find information quickly and efficiently—that is, in my opinion, the book’s greatest value. If Tranquillo’s text ends up on your shelf, you’ll find that you thumb through it regularly for a pithy description of a particular complex-systems approach.

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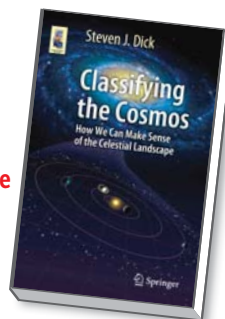


A Linnaean system for the stars

In 1735 Swedish botanist, zoologist, and physician Carl Linnaeus published his 12-page tract *Systema Naturae*. In it, he laid out a system for organizing life forms into a helpful hierarchy of categories—the roots of our modern kingdoms, phyla, families, and species. Astronomy, however, did not benefit from such a definitive moment; its systems for naming and classifying objects developed in fits and starts as new technologies revealed ever more marvelous denizens of the universe. In *Classifying the Cosmos: How We Can Make Sense of the Celestial Landscape*, astronomer and former NASA historian Steven Dick endeavors to bring

Classifying the Cosmos
How We Can Make Sense of the Celestial Landscape

Steven J. Dick
Springer, 2019.
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some order to the cosmic menagerie as we know it today. The result is an important and revelatory work that can be used by researchers, educators, and enthusiasts alike.

In one sense, *Classifying the Cosmos* offers a comprehensive encyclopedia of celestial objects. Dick adds greater value, however, by providing a thematic architecture for the known inhabitants of the cosmos. His celestial empire consists of three kingdoms—planets, stars, and galaxies—broken down into 18 families, 82 classes, and unnumbered types. Gravity, the key organizing principle, weaves everything together. The more speculative topics of dark matter and dark energy are left to others.

Dick’s explanation of planets exemplifies how the classification system works: Planets are fully described in the planets kingdom section, but are also cited as circumstellar objects in the stars kingdom section. Stars, in turn, have their own kingdom but also play key roles in the galaxies kingdom. That sort of overlap makes explicit the hierarchy of matter in our universe. From planets, to stars with planetary systems, to galaxies and their groupings on ever grander scales, Dick unfolds our observable cosmos like the nested, connected, and evolving ecosystem it is.

The author also provides fascinating historical backstories to many of the classes and how they were discovered. For example, he recounts how the ice giant planet Uranus was observed several times in the century that preceded William Herschel’s written account in 1781 and how Herschel first described it as a comet rather than a planet. Even more amazing, Galileo Galilei accidentally observed Neptune a whopping 234 years before its official discovery by Urbain Jean Joseph Leverrier in 1846. It then took *Voyager 2*’s flybys of Uranus in 1986 and Neptune in 1989 to generate sufficient data for astronomers to conclude that those two planets belonged to a new class of ice giants that differ in size and composition from the gas giants of Jupiter and Saturn.

Dick also wades into continuing controversies, such as the kerfuffle surrounding Pluto’s demotion to dwarf planet. He notes the proposal to designate Pluto’s similarly massive kinfolk in the Kuiper belt as “Plutoids,” a classification that I have been championing in my own writings but, alas, has yet to catch on. Consequently, Dick places Pluto in the dwarf planet class as part of the subplanetary family that includes meteoroids, asteroids, comets, and other small bodies of the solar system.

The author admits that classification does not necessarily imply understanding. Nevertheless, he provides ample descriptions of each class so that the reader can gain a decent understanding of the phenomena associated with them. *Classifying the Cosmos* focuses on the physical nature of each object, rather than on qualities such as appearance or means of observing. For example, he favors differentiating stars not by their colors and corresponding surface temperatures, but

by their luminosity classes, as determined by their spectroscopically derived surface gravities and corresponding sizes. The resulting stellar classes of dwarf, subdwarf, subgiant, giant, bright giant, supergiant, and hypergiant make sense in that taxonomic architecture.

Dick's classification system constrains main-sequence stars, also called dwarf stars, to a single class because of their key physical similarity, namely core hydrogen fusion. Thus, 90% of all extant stars

fall into just one of his 36 stellar classes. The author then characterizes their wide-ranging masses, luminosities, temperatures, energy-transfer mechanisms, and other properties in only eight pages. I do not wish to complain here, but I do want to note that his treatment favors key physical differences over quantitative demographics.

My biggest concern lies in the galaxy family of the galaxies kingdom. Elliptical, lenticular, spiral, and irregular galaxies all constitute classes in the normal subfamily, and Seyfert galaxies, radio galaxies, quasars, and blazars are classes in the active subfamily. I was surprised by the lack of a comparable starburst galaxy subfamily or class despite numerous mentions; surely such a categorization would be justified based on their unique physical properties. Dick instead discusses starburst galaxies in other classes under the galaxy, intergalactic medium, and galactic systems families.

That minor gripe aside, I found *Classifying the Cosmos* to be thoroughly researched and engaging. It includes ample references to original peer-reviewed articles, the latest mission websites, and well-written general-interest articles by respected science writers. Although the author's tone is mostly informative, he sometimes waxes more lyrical. I especially liked the passage in which he notes that Herschel "likened the heavens to a luxuriant garden, where we see in succession 'the germination, foliage, fecundity, fading, withering, and corruption' of plants, except that in the heavens, we see all stages at once. Whether plants or planets, sunflowers or stars, we see the lifecycle of nature's creations spread before us, awaiting understanding."

The excellent scientific content, beautiful color images, and high-quality printing of this book make it a winner. In the introduction, Dick expresses the hope that his classification effort will be of educational use, "helping students and astronomy enthusiasts understand the place of these objects in the celestial landscape." I would say that he has succeeded most admirably. I would also add that the book will be a handy reference for researchers and communicators of astronomy.

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