Book Review

Planets: Ours and Others: From Earth to Exoplanets by **Thérèse Encrenaz** (World Scientific Publishing Company, Singapore, 2013)

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The exploration of worlds beyond our fragile home planet has fired the imaginations of humankind for generations, and we are privileged to live in a time when robotic planetary spacecraft and sophisticated telescopes are revealing landscapes and environments that have, until now, been hidden away from human perception. The central quest of planetary science is to find our place in the cosmos — was the complex blend of circumstance that allowed the evolution of our civilization somehow unique, or are we but one of a plethora of inhabited worlds stretching across our galaxy? We stand on the brink of answering this question, and this new book by Thérèse Encrenaz captures the breath-taking pace of planetary exploration, both within our solar system and around other stars, that has brought us to this point in our history.

Thérèse Encrenaz is well placed to capture the excitement of this field, having served at the center of world-leading missions to Venus, Mars, Jupiter and comets over the past five decades. An Emeritus Senior Scientist of the CNRS (Centre National de la Recherche Scientifique), Dr. Encrenaz works at the Observatoire de Paris using an array of observatories and space missions to explore the inner workings of planetary atmospheres. In creating this new book, her challenge was to introduce the essential ingredients of planetology for a general audience, using just a few short chapters to share both a passion for discovery and the breadth of our unanswered questions about our Solar System. Dr. Encrenaz has met this challenge with a book that reveals how alien worlds form and evolve, why the types of planet and conditions might vary from world to world, and speculates on what sort of planets might still be out there waiting to be discovered.

The breathless pace of discovery is captured in the very first chapter on how we study other worlds, where the essence of a whole scientific discipline involving years of research from hundreds of scientists is distilled into a few short paragraphs. Dr. Encrenaz explains the history of exploration from hand drawings to photographic plates and ultimately multi-spectral remote sensing across the entire electromagnetic spectrum. Planetary science is a study in patience given the long gestation times for developing, launching and operating new missions to distant targets. Each new generation of planetary scientists shares this burden, passing concepts and skills from one to the next, such that an individual may only see one grand mission during a research career (examples include Voyager, Galileo, Cassini, and hopefully the JUICE mission to explore the Galilean satellites in the 2030s). The long gaps are filled by remote observations from a collection of giant observatories spread around the globe, and the opening chapter makes the case for combining both exploration and Earth-based observation to understand our neighboring planets. Despite many challenges along the way, including failures at launch, this chapter highlights just how extraordinarily reliable instrumentation and spacecraft can be once a probe is en route — the Cassini probe, for example, is still operating flawlessly some 18 years after launch; and Mars Rovers typically exceed their expected lifetimes many times over. If one forgets the incredible science for just one moment, then this is a wonderful testament

to the skills and labors of the engineers on Earth tasked with developing these “chance of a lifetime” missions. Many of the scientific results described in this book stand on their shoulders.

The next chapter explores the formation of planets, the general structure of our solar system, and the uniqueness of our home. Dr. Encrenaz describes how planets form from debris discs surrounding newly ignited stars; how metals, rocks and ices accrete to form the building blocks of planets; how these building blocks are violently re-distributed by powerful gravitational forces as they struggle to form planets; and how these complex interactions have shaped the solar system as we see it today — rocky inner planets, an asteroid belt, gaseous giant planets, a Kuiper belt of ice worlds, and the Oort cloud of comets. We also look ahead to the aging of our Sun and the changes we might expect, from the ultimate vaporizing of the Earth, sublimation of the Kuiper belt and the Sun’s final demise as a white dwarf. The point is not to instill fear, but to explain that we see other planetary systems at all stages in their evolution, from the formation of clearings in planetary discs to the demise of planets, so that looking outwards can also teach us about our home.

We make a brief excursion into geophysics as we begin to explore the terrestrial worlds, reviewing the basic physical parameters that shape a world, from the mass and orbital properties, the presence or absence of magnetic fields (and therefore the influence of the solar wind on the shifting balance of atmospheric composition, particularly the loss of water), and the importance of material recycling via plate tectonics and volcanism. Via a comparison of the past and present climates of Venus, Earth and Mars, we see how the cycles of atmospheric gases (notably water) can shape planetary climate and habitability, and a continuing theme is the fragility of our climate system when compared to the extremes witnessed on Venus and Mars. This delicate balance is both striking and sobering, with our planetary neighbors showing how easily a different set of starting conditions, or quirks of planetary evolution, can yield vastly divergent fates. The climate archives preserved within Earth’s crust reveal that we have enjoyed a relatively stable climate for a remarkably long time, with the Earth serving as a lifeboat in this unforgiving sea of space. Given the unprecedented influence of human activity on this delicate climate system, these worlds offer a stark and serious warning that urgent action is required to avoid such an extreme fate.

Dr. Encrenaz’s tour through the solar system continues at a rapid pace, highlighting some of the weird and wonderful environments that have been revealed through half a century of planetary exploration. We are offered brief glimpses into the past history of Mars, with a potentially wet and warm climate that has today been replaced by cold, arid conditions. Destinations that scientists study for their whole careers are covered in just a few lines — the icy crusts of Jupiter’s most fascinating moon, Europa; the thick chemical smog enshrouding Titan; the enormous watery jets of Enceladus; the gigantic collision that could have tilted the ice giant Uranus onto its side. This rogues gallery of exciting targets is necessarily brief given the length of this book, but is accompanied by a wealth of images acquired in recent years. More focus is given to the processes shaping the overarching structures — why, for example, do Jupiter and Uranus have a host of large satellites, whereas Saturn has one main satellite (Titan) and Neptune’s largest satellite, Triton, appears to be a captured object from the Kuiper Belt? How could the migration of these planets within the early solar system have influenced their subsequent evolution? By doing so, Dr. Encrenaz avoids losing the reader in the details and highlights the general principles and lessons that we can apply to other planetary systems.

The final chapters exemplify this theme, which take us to the realm of planets around other stars. Given their great distance, and the immense challenge in measuring their physical and chemical properties, our understanding of worlds beyond our solar system is in its infancy. But this field has exploded in recent years, with the discovery of almost 2000 new planets in the past two decades, allowing us to explore the probability of stars hosting planetary systems and, potentially, Earth-like worlds. Encrenaz uses the lessons of our solar system to develop a planetary taxonomy that depends on basic parameters — planetary mass, the distance to the star, and the spectral type of the star. Depending on these fundamental processes, we could find that small worlds are rocky with Mars/Venus-like atmospheres; icy with Titan-like atmospheres rich in nitrogen and methane; or, if we are lucky, Earth-like with nitrogen, oxygen and water-rich atmospheres. Similar arguments can be made to distinguish the cold and gaseous Jupiter-class worlds in our solar system from the “hot Jupiters” commonly found around other stars — planets so close to their parent stars that their atmospheres are heated to thousands of degrees. Hot Jupiters, warm Neptunes, Super Earths and worlds of magma oceans offer environments unlike anything observed in our solar system and take comparative

planetology to a whole new level. Through sophisticated exoplanetary observations we are beginning to understand the diversity of planetary evolution, placing our own fragile world into a much broader context. Indeed, the discussion of exoplanets ends by highlighting the extreme challenge of exoplanetary science today — to move beyond the current era of discovery and into the era of climate characterization, which will require the ability to directly measure the spectra of these distant worlds and potentially signatures for benign environments and possible life. This endeavor is rightly described as the “*first priority for the astronomical community*”.

Throughout this book, we are constantly reminded of both the difficulties associated with comparative planetology and of the range of unsolved mysteries. The book reveals the questions at the cutting edge of our field today, and how quickly our understanding can evolve. The book was finished in 2013, and since then we have had further exploration of Mercury, Venus, Mars, Saturn, the asteroids Vesta and Ceres, the first ever encounter with Pluto and the first landing on a comet, to name but a few. Both the European Space Agency and NASA have targeted Jupiter and its diverse collection of satellites for large missions in the next decade. With each new mission will come new discoveries, new insights, answers to old questions and new mysteries to solve. As Dr. Encrenaz points out, “*Other discoveries are in front of us, and the frontiers of the solar system keep moving further and further away.*” The region of the icy giants Uranus and Neptune, in particular, has been visited only once by a planetary explorer and represents a tantalizing destination for future exploration. Will the foundations of planetology that have been introduced in this book stand the test of these new discoveries? Or will a new paradigm, or a new planetary taxonomy, emerge from the latest raft of missions? It is certainly an exciting time to be a part of this rapidly growing and fresh field.

Dr. Encrenaz’s wide-ranging experience shines through the pages of this book, producing a rich introduction to planetary science that whets the appetite for future discovery. The principles of planetary formation, evolution, astronomy, geophysics and climate science are all intermingled to paint a picture of modern planetology and the fragility of our own world, standing on the shoulders of the fleet of sophisticated interplanetary explorers launched over the past several decades. The book should capture the imagination of educated non-specialists, whilst providing professionals with a welcome reminder of the big questions facing the next generation: both looking outward into the cosmos, and looking inward to the climate challenges faced here on planet Earth.

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