Book Review

“An Introduction to Planetary Atmospheres” by Agustín Sánchez-Lavega, CRC Press, 2011;
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The science about planetary atmospheres is an interdisciplinary field that combines several branches of knowledge including atmospheric science, geophysical and astrophysical fluid mechanics and planetology. This discipline has a relatively short history and can trace its roots from Challis’s paper in 1863 (On the Indications by Phenomena of Atmospheres to the Sun, Moon and Planets, MNRAS, vol. 23, 1863, pp 231–238). Although atmospheres surrounding planets have been investigated since the 19th century, the real progress in their study is connected with the use of giant ground-based and space telescopes as well as with the orbiting and landing spacecrafts.

An Introduction to Planetary Atmospheres is an excellently written introductory book that presents the state-of-the-art of planetary atmospheric science. Designed to serve as a textbook for undergraduate and graduate courses on the topic, the book includes nine chapters and a useful appendix. The large number of problems (with solutions or hints) provides a good supplement to the main text. Moreover, the book contains a list of tables and a list of symbols (12 pages).

The first chapter of this book gives an overview of planets and planetary systems. It begins with concise presentations of extrasolar planets and solar system planets. Then, orbital motion under the action of (Newtonian) gravity, Kepler’s laws of planetary motion, and two-body and restricted three-body problems are described. Another group of questions is

related to gravitational field of planets, including tidal force and torque and Roche’s limit. The notions of the sidereal and synodic periods are introduced and explained also. The following section covers the nature of the primary energy sources that are involved in atmospheric processes, i.e., the rotational mechanical energy and the internal and external energy sources. Discussed are radioactive decay, gravitational energy, tidal heating and irradiation, with particular attention paid to insolation, albedo and the internal and external energy sources relationship. The last three sections deal with the internal structures of planetary bodies, the origin and nature of planetary magnetic fields and the classification of planets (somewhat controversial).

Chapter 2 concentrates on origin and evolution of planetary atmospheres. The so-called standard model for solar system formation and the thermal evolution of the planets are described first. Subsequently, the sources for the atmospheric gases with the main mechanisms by which the atmospheres of the planets form (outgassing during accretion phase, capture processes, etc.) are indicated. The basic processes affecting the evolution of atmospheres are then recapitulated, including thermal evaporation (Jeans escape), non-thermal escape, hydrodynamic escape (blowoff), geometrical blowoff escape and impact erosion. The main factors influencing on long-term atmospheric evolution are also enumerated. The remainder of the chapter focuses on the paleoclimatology of the Earth’s atmosphere and presents some remarks on observed atmospheric changes on other planets (Venus, Mars, Titan, etc).

Spectroscopy is defined as the study of the interaction between electromagnetic radiation and matter.

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Chapter 2 concerns atmospheric spectroscopy which plays a crucial role in determining the composition of atmospheres. Planetary spectrum is analysed with the reflected spectrum and the thermal part of a planet spectrum. Next, the atomic spectrum is described in the framework of Bohr semi-classical atomic theory. Then, a detailed exposition of the molecular signatures in planetary spectra is presented. Lastly, three useful tables summarizing the measured atmospheric composition of planets and satellites are inserted and discussed.

In chapter 4, devoted to thermal structure of planetary atmospheres, emphasis is given to the massive bodies with dry atmosphere. Hydrostatic equilibrium conditions are derived first, and concise information on the observed temperature structure on Venus, Earth, Mars, Titan, Jupiter, Saturn, Uranus, and Neptune are presented. Thereafter, the elements of radiative transfer theory in a purely gaseous atmosphere are sketched and the radiative equilibrium in atmospheres is considered. The theory is then applied to a variety of atmospheric problems such as greenhouse effect, heating rates. Some useful indicators of atmospheric thermal state (radiative time constant and radiative temperature) are also introduced. In this context, thermal oscillations in atmospheres (known as thermal tides) are explored in some detail. The chapter ends with some elements of thermodynamics applied to densest layers of the atmospheres. Eight tables, including planets' and satellites' vertical temperature profile, are placed in the appendix.

Chapter 5 pertains to cloud thermodynamics and cloud particle physics (microphysics). The first section deals with elements of chemical thermodynamics, discussing the surface–troposphere cycles of condensable gases and aerosols on Venus, Earth, Mars and Titan. Next, the basic properties of clouds are systematized using the Clausius–Clapeyron equation. Subsequently, is material concerning microphysical processes. Included are: nucleation, diffusion, collision and coalescence, and sedimentation. A more advanced topic pertaining to radiative transfer theory in an atmosphere containing suspended particles are presented next. Finally, observed properties of clouds in planetary atmospheres are overviewed.

The current state of knowledge regarding the structure of low-density atmospheres of the bodies is

provided in chapter 6. Two cases are taken into account: the upper areas of the massive atmospheres of planets and satellites until now described, and the objects with tenuous atmospheres. Generally acceptable nomenclature of atmospheric regions, based on terrestrial analogies, is presented first. A brief review of photochemistry, which plays the crucial role in the determination of the physico-chemical state of planetary atmospheres, comes next. Comparison of the measured and modeled vertical composition of the terrestrial and giant planets, Titan, Triton and Pluto is another theme. A valuable information concerning internal processes in planetary ionospheres is included also. Two sections deal with heating balance in the troposphere and diffusion processes in the upper atmospheres. Thereafter, is a description of the phenomena of the exceptional beauty, airglow and aurora (there are radiation emission processes that differ in the excitation source). The two final sections cover the topics of gas production mechanisms, atmospheric composition, surface temperatures of planets, dwarf planets, and satellites with tenuous atmospheres.

The last three chapters of the book constitute, in some sense, a compendium of the basics of atmospheric dynamics.

Chapter 7 is focused on the terse description of the large-scale motions that characterize the planetary atmospheres. Local and total derivatives are defined, and the continuity, Navier–Stokes, and thermodynamic energy equations are presented. The momentum equation (rather complicated) is written for Cartesian and spherical coordinate systems. Two approximations are considered (i.e., f -plane and β -plane), and equations for the geostrophic balance, cyclostrophic balance and gradient wind balance are submitted. The basic philosophy of Boussinesq and anelastic approximation together with thermal wind conception is considered also. Specialized topics such as vorticity, the planetary boundary layer and planetary turbulence are also treated. The observed large-scale motions in the planets and the general circulation models of planetary atmospheres are the subject of the rest this chapter.

The wave motions are of great importance in atmospheres. Waves manifest in all sizes and forms, depending on the restoring force mechanisms acting on the medium. Chapter 8 offers a brief overview of

linear wave theory. It includes the acoustic waves, gravity waves, Rossby waves, planetary waves and the dynamics of thermal tides. In addition, the large-scale and long-term oscillations, a spectacular wave-like phenomena observed on Earth, Mars, Jupiter and Saturn, are reported briefly.

The concept of stability and the nature of instability of motions of fluids is an essential part of hydrodynamic considerations. Chapter 9 classifies the main kinds of instabilities encountered in the planetary atmospheres. The notion of the Richardson number is introduced and the following atmospheric instabilities are considered briefly: vertical instability, Kelvin–Helmholtz instability, inertial instability, barotropic instability and baroclinic instability. Firstly, what is known about the convective processes in the planets with massive atmospheres is recapitulated. Secondly, the vortices and vorticity dynamics are outlined in the context of flow instabilities. Types of hydrodynamic instabilities are described in systematic way. The observational aspects of vortices in the giant planets together with the other dynamical phenomena that

occur in planetary atmospheres are presented also. Included are, among others, dust devils, earth's tornado, von Karman streets, tropical cyclones, etc. The topics of last two sections are somewhat more special. These include the polar dynamics in the planets and the atmospheric effects of the impact of comet with Jupiter.

An appendix consists of terse information concerning methods of exploring planetary atmospheres.

In sum, I have found *An Introduction to Planetary Atmospheres* to be a very interesting and valuable book. In my opinion this book will be useful not only for researchers working in the field, but also for the Earth sciences community who possess a relatively high level of mathematical skills and some knowledge of physics.

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