a compound of composition [$IrCl_3$, $3R_2S$] isolated in two isomeric forms differing in colour and in solubility in organic solvents (published in 1932 and 1933). The more soluble isomer is orange yellow in colour while the less soluble isomer is red. On the basis of composition, stability and non-electrolytic nature of the yellow isomer in acetone solution, Prafulla Chandra concluded that it is a hexa-coordinated compound [$IrCl_3(Et_2S)_3$] and suggested that the red isomer is of similarly composition. He assigned *cis* (*fac*) and *trans* (*mer*) geometries for the yellow and red isomers respectively. Subsequent NMR and other physical studies, however, confirmed that the yellow species is actually the trans isomer and the red one was actually a dimerization isomer. Though this early assignment of Ray was discarded, it is Ray's original synthetic work that generated interest in these compounds. Ray's iridium work was indeed pioneering and finally led to the highly interesting family [$MX_3(R_2S)_3$] where M = Ru, Os, Rh or Ir and X = Cl or Br. Ray was active till the end of his life and continued to publish papers. Just a few years before his death in 1944, physicist (K. S. Krishnan, Van Vleck) started applying magnetic measurements and quantum mechanical theory to inorganic compounds.

I recall that in the IUPAC meeting held at Puerto Rico in 2011, the IUPAC President proposed that each country should celebrate the International Year of Chemistry, not only for the centenary of Madame Curie's chemistry Nobel, but also for a National Hero in Chemistry. Some of us suggested to the RSC representative that whether India and UK may jointly celebrate the 150th birth year of PC Ray honouring his strong UK connection. This was immediately approved by RSC President Professor Yellowless, who was a Professor of Inorganic Chemistry at Edinburgh, Ray's alma mater. On 31 January 2012, RSC installed an International Chemical Landmark Plaque at Presidency College 'To commemorate the life and achievements of Acharya P. C. Ray, father of Indian Chemistry, philanthropist and entrepreneur who founded modern chemistry teaching and research in India.' Interestingly, this was the first RSC Plaque outside Europe and USA.

In summary, the reader of this book will have a first-hand report from a top modern inorganic chemist about Ray's research contribution. This book is not blank hero worship. It is a dispassionate analysis of Ray's contribution to a wide area of inorganic chemistry and how it impacted later research.

I recommend this book to all college and university library as a dispassionate analysis of Ray's chemistry.

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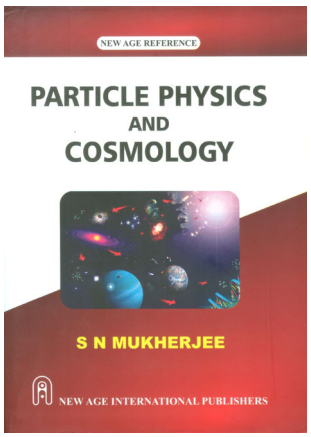

Particle Physics and Cosmology. S. N. Mukherjee. New Age International (P) Ltd Publishers, 7/30A, Daryaganj, New Delhi 110 002. 2019. x + 480 pages. Price: Rs 999.

This is a handy book of less than five hundred pages for the beginning student, published by New Age International. It introduces the basics of the topics, mentioned in the title, aimed at the advanced undergraduate and the starting graduate student. It is an admirable attempt since, though there are quite a few tomes covering Particle Physics and Cosmology separately and in more detail, it is hard to find one combining these two subjects at this level.

The first chapter, entitled 'Synthesis of micro- and macro-cosmos' and introducing some fundamental notions as well as defining several basic quantities in both areas, is quite readable. I especially liked the six tables at the end. There are, however, a couple of minor glitches. The expression for Planck time is given without defining it as $L_{Pl}c^{-1}$ and that for the Planck temperature (with a c^2 missing from the numerator) is given without explaining anywhere that k is not the space-time curvature index, used in chapter 8, but rather the Boltzmann constant. Also, a short section on Feynman diagrams (with which students at this level may not be familiar) is sorely missed here since these are drawn in several parts of the book later without any explanation.

The second chapter provides a clear and useful summary of basic elastic and deep inelastic lepton–hadron processes and also touches upon different types of colliders used in high energy physics. Unfortunately, accelerators with fixed targets as well as e^+e^- colliders are mentioned only cursorily. I also wish that the Further Reading list here were more extensive. It is sad to see Feynman's 'Photon–Hadron Interactions' omitted. Moreover, Close's 'Quarks and Partons' should have been included here rather than at the end of chapter 1.

Chapter 3, covering beta decay within the Fermi theory, is beautifully written. It sets the right historical perspective and covers all pertinent experiments – clearly showing the author's mastery over the subject. The V–A theory is properly developed while the neutrino sections are nicely presented and include discussions of all relevant past, recent as well as current experiments. I wish, though, that the author had clarified the distinction between a Dirac and a Majorana mass of a neutrino. While the tritium beta decay spectrum can measure either, neutrinoless double beta decay can only provide information on the latter.

Chapter 4, entitled 'Fundamental Interactions', is somewhat misnamed; it should have been called 'Gauge Theories of Strong, Electromagnetic and Weak Interactions' since it deals with only those theories. Gravitational interactions, though fundamental, are excluded here. I think that quantum chromodynamics merited a longer discussion. In particular, confinement is just mentioned briefly; the linear rise of the quark potential at large distances is shown in a graph but not explained. Also, no mention is made of lattice-based efforts. Otherwise, the coverage is good, I would say. The reader's imagination is tickled with brief mentions of GUTs and string theory.

The next two chapters (5 and 6) are somewhat technical in nature – dealing respectively, with neutrino experiments in general and the specific phenomenon of neutrino oscillations. First, different

sources of non-accelerator neutrinos, as discovered, are properly enumerated. However, I was disappointed to see no mention of the discovery of atmospheric neutrinos at the Kolar Gold Fields in India. Then the author provides a survey of the global landscape of neutrino oscillation experiments. There is no mention of T2K/T2HK and DUNE, but otherwise the survey is adequate. Coming to neutrino oscillations themselves, the phenomenon is nicely explained, first with two and then with three neutrino flavours. Theoretical topics, such as the neutrino mass hierarchy and the TBM matrix, are also touched upon. Unfortunately, the TBM discussion is outdated since Daya Bay and other experiments have since established that θ_{13} is nonzero and ~8°, thereby ruling out TBM. There is also a nice, compact treatment of neutrino oscillations in matter including the MSW effect. The discussion ends with a short summary of long-term perspectives.

The rest of the book is devoted to an introductory presentation of modern cosmology. Chapter 7 introduces the basics of Big Bang Cosmology and the subsequent chapter 8 presents the elements of the Standard Cosmological Model. In chapter 7 the Hubble expansion constant H and the Doppler redshift z as well as Hubble's law are illustrated. I wish the author had given the full relativistic expression for z in terms of c and the velocity of recession v. Also, it is unfortunate that the contribution of George Gamow to the Big Bang origin of the Universe is omitted, though his role in formulating Big Bang Nucleosynthesis (BBN) is mentioned. Following the Big Bang, the onset of initial radiation domination and the subsequent transition to matter domination are briefly but satisfactorily explained and the steady state model debunked. It is alright to quote, as done here, standard formulae without derivation in an elementary text such as this, but at least proper references to sources with such derivations should have been given in appropriate places. BBN is compactly but adequately treated in one section; I particularly enjoyed reading the box on the Saha equation in this context. Then the author discusses the thermodynamics of the Early Universe, nicely sketching its evolution from its Big Bang origin to the formation of atoms and molecules. This is followed by a section on the Cosmic Microwave Background Radiation (CMBR). I was pleasantly surprised at the fairly detailed nature of the discussion of the CMBR anisotropy alongside COBE and WMAP results and the mention of the Sachs–Wolfe effect. However, data from the later and more current PLANCK satellite are unfortunately not mentioned. The section ends with a short discussion of the number of effective neutrino species probed by CMBR.

In the rest of chapter 7, the author proceeds to treat the subject of nuclear astrophysics to lay the setting for a subsequent discussion of supernovae. The discussion is naturally focused on the behaviour of a collapsing star. After elucidating the competing roles of gravity and electron degeneracy pressure (I wish it were mentioned that the latter originated from the Pauli Exclusion Principle), the Chandrasekhar Limit is derived. Then the author treats the topic of stellar structure in order to deal with the sequence of star formation – from Red Giants to White Dwarfs – including our Sun. A serious omission here is the absence of any illustration with the Hertzspring–Russell diagram. Turning then to nuclear reactions, the author discusses the formation of nuclear elements in stars in a surprisingly detailed way that is highly welcome. Finally, supernovae explosions and different supernovae relics are covered. However, the premier diagnostic role of type 1a supernovae in the discovery of the acceleration of the Universe is postponed to a later discussion in the next chapter. Chapter 7 ends with a fairly detailed discussion of the information on neutrinos that could be extracted from supernovae data.

The final chapter 8 on the Standard Cosmological Model aims quite high – trying to cover a wide span of topics. To start with, a lightning review of GR and the FRW Universe (including the cosmological constant and inflation) is presented. This is followed by an overview of the important aspects of observational cosmology. I liked the table containing information on various satellite missions and ground-based efforts currently in progress. Turning to large scale structure, the author provides rapid fire treatments of gamma ray bursts, neutron stars and white dwarfs. These are followed by a somewhat more ambitious coverage of black holes and their connection to a quantum theory of gravity, as gleaned by Hawking. Next, the author discusses the evidence for and the possible nature of Dark Matter, briefly mentioning current searches including both space- and ground-based efforts. This is followed by a quick coverage of critical issues in the standard cosmological model. These include the horizon and flatness problems (though I wish that the success of inflation in tackling these were emphasized a bit more here). There is also a brief mention of Dark Energy. The next section contains a compact introduction to gravitational waves including their detection and a reference to their origin. Then comes the last section 8.4 where the author truly comes into his element as a researcher in relativistic heavy ion collisions. He provides the reader with the picture (in the temperature-baryon density plane) of a possible synthesis between the physics of the Early Universe and the formation of Quark–Gluon Plasma (QGP) in RHIC and ALICE experiments. Finally, the reader's imagination is tickled by brief mentions of M-theory and the search for earthlike planets.

Three appendices appear at the end, containing elementary expositions of theoretical and statistical tools used in the study of these areas.

Occasional grammatical lapses appear in this book – with singulars and plurals as well as articles. There are also several printer's devils, e.g. Fred Hoyle's name is misspelt on p. 277. In case there is another edition, a more careful proofreading will help. I also think that 'Majorana' and 'Dark Energy' should be included in the Glossary. Otherwise, this book is a praiseworthy effort. It is not supposed to compete with the more detailed Particle Physics book by Palash Pal or the two extensive volumes on the Early Universe by Gorbunov and Rubakov. Those books would be needed to develop a more thorough knowledge of the mentioned subjects. However, Prof. Mukherjee has written an excellent introduction to these current areas, which are in the limelight, for advanced undergraduate and beginning graduate students – especially in India. This work is evidently a labour of love and the author deserves kudos for his effort.

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