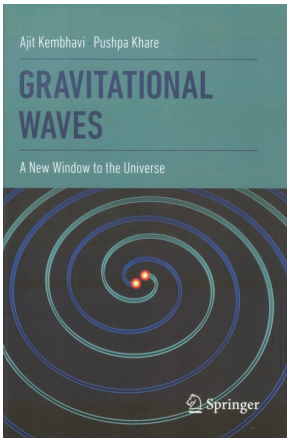


Gravitational Waves: A New Window to the Universe. Ajit Kembhavi and Pushpa Khare. Springer Nature Singapore Pte Ltd, 152 Beach Road, No. 21-01/04 Gateway East, Singapore 189721, Singapore. 2020. xxvi + 161 pages. Price: €27.99.

The study of cosmology has now found a new avenue – gravitational waves (GWs). The surprising results achieved by this technique surpass those offered by the introduction of radio astronomy or UV astronomy decades ago. This is because the new probe provides direct access to a phenomenon which remained within the realm of theoreticians. The method uses GWs, which can be considered as an analogue of the electromagnetic (EM) waves. The conceptualization of these waves takes us back to beyond a century, when Einstein predicted it with his general theory of relativity (GTR), although the detection remained elusive. From 1916 to 2016 was indeed a long wait. Now that the idea has been proved without any room for suspicion, it has aroused curiosity of people of all ages as a key for exploring the Universe.

It is important to understand the basics that led to this prediction. The book under review provides an excellent foundation for students and teachers who aspire to learn more about GWs. It can be broadly divided into two parts – the first six chapters concentrate on the physics with a brief historical introduction. The second chapter starts with EM waves, though elementary, perhaps to help the readers brush-up the ideas already known to them as physics students. The essence of GWs starts with chapter 3, which introduces gravity in a different perspective – as the curvature of space–time. This takes the reader to the approach of Einstein to GTR.

The chronological development of the concept of gravity starts from Newton offering a comfortable opening to the reader. The limitations of the logic of Newton and the emergence of novel ideas of Einstein are introduced as a lucid narrative. The precession of the perihelion of Mercury and the bending of starlight through the curvature of gravity of the Sun are explained in great detail, since they form the basis to understand the production of GWs.

Chapter 4 describes GWs in great detail without the aid of tensors and equations. Although this seems appropriate, a brief mathematical treatment as an Appendix would have satisfied the inquisitive minds. The processes responsible for the emission of GWs are described along with the early attempts to detect them. This leads the readers to appreciate the fact that we do not get to 'see' GWs in our surroundings as easily as EM waves. So we need to look at the sky, far beyond, where the order of magnitude of interactions for the production of GWs is feasible.

Chapter 5 takes us to the possible sources of GWs. Here again, a brief introduction to the compact massive objects like the white dwarf (WD), neutron star (NS) or black hole (BH) is essential. The structure of the stars and evolution leading to the formation of these compact objects are dealt with briefly. It is heartening to see that the evolution scenarios treat stars with masses less than 8 solar mass as potential progenitors of WD (most of the popular texts mention this as 1.4 $M_{\odot}$). Similarly, the range 8–25 solar masses for NS would also perhaps be noted by future textbooks.

GWs can be sourced by energetic events of supernova (SN) and gamma-ray bursts (GRBs). Although the mass lost for the production is extremely small – just a fraction 10^{-10}, the weak waves are detectable. Pulsars and mergers of binary NS and BH are also potential sources of GWs. The evidence of the existence of GWs realized through binary pulsars is explained in chapter 6. This is a turning point for understanding the shrinking orbit of the binary, which led to developing the detection techniques. The principle of Michelson interferometer was extended to GWs, so that the effect of the passage of the wave would be recognizable as a pulse. The challenge was in the design of the detector, which can sense a change of the order of 10^{-19} m.

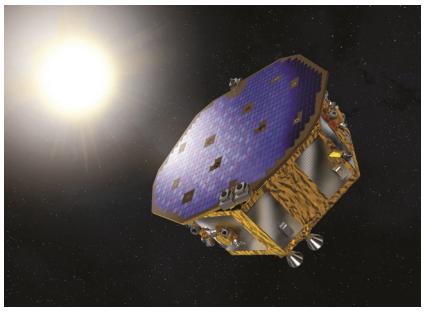
Chapter 7 describes the earliest attempts to detect GW in the 60s by Joseph Weber. Understanding this chapter is the key for exploring the new avenue opened up by GWs. The need for the long arms of the interferometer is explained in a lucid style. LIGO extending its arms to 4 km, its installation and operation are all described with details of the mirrors, mechanical arrangements to hold them, the detectors, the source of light and finally the sensitivity. The coverage on LIGO-India project is helpful to youngsters to participate in the international campaigns.

The success of the programme is reflected in the inflow of results. One important marker is the number of publications, while the other more important outcome is the international collaborative efforts which are essential for such large endeavours.

The September 2015 detection of GWs thus created history by paving the way for new astronomy. Many GW sources were detected in quick succession, which led to the capability of distinguishing BH and NS mergers. The masses of the components participating in the event and the final mass could also be calculated – all of which are covered in chapter 8. Theoreticians now have to worry about scenarios for the formations of binaries with both components as either BHs or NS. The evolution of stars in a binary system, reaching the end phase, and the subsequent evolution of the binary itself – are all topics of re-investigation.

The impact of the new window for the study of the Universe will be apparent from the distances of these sources. Our vision extended beyond the visible light, first by the radio waves in the early 60s, and later by the IR and UV probes in spaceships. A distance of 130 million light years was achieved – but only for large entities like galaxies. Here we have a binary with components of multiples of solar mass, located at that distance and communicating to us their merger.

Further, the strength of the signal hints at the possible mechanism of GW emission. SN as the most suitable candidates for these energetics and associated spectral features satisfy the demand on numbers. However,



Artist's impression of LISA Pathfinder. (Courtesy: The European Space Agency.)

of late, 'kilonova' candidates have also entered the list, as in the case of GW170817.

Thus, GWs have opened up a promising future for astrophysics. Details of 2G, and the promise of 3G GW detectors are discussed in the last chapter. This will also serve as a guide to those aspiring to enter this field of research.

The book has a glossary to help beginners, who may need to read and re-read it. Some mathematical details as appendices would have probably helped the students. The brief biographical sketches in boxes amidst the chapters provide some personal details, which seem irrelevant to the content of the book. A couple of more sentences on their scientific study would have been more appropriate. I was looking for the name of Prof. C. V. Vishveshwara or his books, considering his study of quasi-normal mode oscillations in the early 70s.

Ajit Kembhavi, well known for his contribution to the field of cosmology and leading India for fruitful international collaborations, and Pushpa Khare with her experience in the field of gravitational lensing and quasar studies, have done a commendable job in bringing out this book at a time when GWs are emerging as the new trend for researchers in astrophysics. With an excellent portrayal of the efforts, excitement and joy of the scientists involved in GW research, this book serves as a good introduction to astrophysics in general and GWs in particular. It is a useful guide for students and teachers to keep track of further research in the field, which promises many surprises.

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A Monograph on Potential Geoparks of India. D. Rajasekhar Reddy (ed.). Indian National Trust for Art and Cultural Heritage, New Delhi. 2021. 266 pages. Price: Not mentioned. ISBN: 978-93-82343-45-5.

Geological diversity in India with diverse rock types of different ages is of paramount significance. Various rock types exposed in the interesting landforms of the country's various physiographic regions are of immense scientific and aesthetic value. Despite a rich geological and cultural heritage, there is no geopark in this country. Specific laws to protect the archaeological sites exist in the country while the geological heritage sites remain unprotected.

The Indian National Trust for Art and Cultural Heritage (INTACH) protects the archaeological and historical sites, the geological heritage sites do not fall under its purview. This monograph, highlighting the need for a formal body for such protection, has earned enormous praise from the geological fraternity. The monograph has been meticulously edited by Rajashekhar Reddy and it contains 14 chapters. They describe the significant geoscientific features of specific areas that fulfill UNESCO's conditions for giving them Geoparks status. The curtain-raiser chapter by the editor lists intrinsic characters of a geopark and the criteria to be fulfilled before one can request UNESCO to accord geopark status to a specific area.

In the first article, Biswas and Chauhan make a case for the Kutch rift basin as a potential geopark. They have identified 70 geosites under 9 geostations, namely Bhuj, Mandvi, Naliya, Narayan Sarovar, Lakhpat, Matanomadh, Nakhrana, Kavda and Rapar. Each of these sites has been meticulously tabulated and supported with good quality illustrations. Apart from these, Dholavira Archaeological Museum, Wood Fossil Park, Gangtabet Temple and Banjara Hills could be additional components in this geopark site. Kutch basin is well known for its extensive exposures of Jurassic fossiliferous beds, Cenozoic beds, salt flats (Rann) and numerous tectonic features. Geological heritage sites discussed in this chapter indicate that the area of the Kachchh basin is *de facto* a natural textbook for teaching, learning and researching any discipline of geology.

In the following article, Bhargava *et al.* present the details of wetlands between Renuka Lake to Koti-Dhaman-Sataun in the Himachal Himalaya. Rock exposures in this area range from 1800 Ma old Rampur Group of rocks to 16–2.6 Ma old Cenozoic sediments. These rocks represent shallow marine, subtidal, glaciomarine and fluvial sedimentation. This proposed geopark site exposes the geomorphological, cultural and architectural features listed in table 1 and figure 2 of the article. Explanations for the figures could have been a little more elaborate. What element of these outcrops could be of interest to the visitors is also not stated clearly. The Renuka Lake in the area is of great tourist attraction. Several cultural and religious institutions in this area are significant.

Vaddadi and Vaddadi highlighting the geological potentials of the Pune Ahmednagar tract, proposed a geopark in this part of the world-renowned Deccan Flood Basalt Volcanic Province. This province tells us the story of a unique, catastrophic and episodic volcanic eruption that took place ca. 65 million years ago. Lava caves, lava channels, and vesicular and amygdaloidal flows represent the ancient volcanic eruptions. In addition, there are 75 ka old volcanic ash-beds derived from Toba Volcano of Indonesia. Multi-storied potholes and ornamental zeolite crystal-bearing rock cavities are significant features of this area. Furthermore, several archaeological and historical sites in this belt increase the potential of this site to be a geopark. The article is well illustrated, although the description of individual figures should have been a bit more elaborate.

Jaisalmer basin of Jurassic age in Thar Desert of Rajasthan deserves a geopark status, argues Wadhawan. He lists several geologically significant features of this terrain, including an existing fossil-wood park, well-preserved dinosaur footprints, excellent scenic scarp sections, cuesta landscape, stony pavements, inland Rann with ephemeral playas, and highly photogenic sand dunes in support of his argument. Apart from these, an ancient abandoned village at Kuldhara, several historical monuments, traditional water harvesting structures of Rajasthan, and unique desert animals increase the potential of this site for being declared as a geopark.

Reddy and Karadu present the case of Vishakhapatnam as a potential geopark site. The most important geological and geomorphological sites include Erra Matti Dibbalu, where very picturesque coastal red-sand dunes occupy a large tract. Deep gully erosion in the stabilized aeolian sands, the natural arch formed by marine erosion, cliff faces, platforms and benches formed by wave action, volcanic ash deposits, famous Borra caves and Arku valley, bauxite deposits with characteristic pisolites are noteworthy geological features. In addition, numerous archaeological and historical sites of great cultural significance and a wildlife sanctuary add to this area's credit and increase its potential as one of the first geoparks in India. This article includes well-documented, nice pictures and maps.