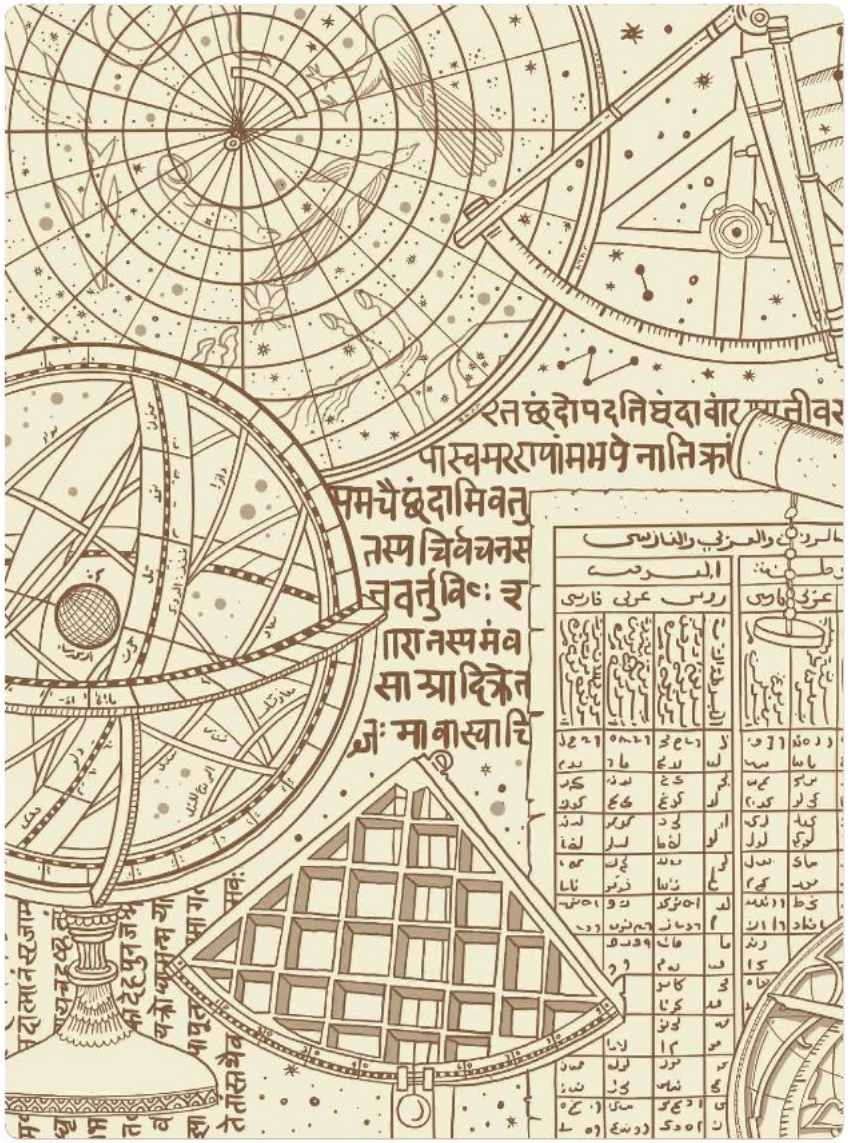

Communication Design Project II (2021)

The Astronomical Endeavours of Jai Singh

A Graphic Novel on Jantar Mantar

By

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Guided By

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INDUSTRIAL DESIGN CENTRE

Indian Institute of Technology, Bombay

2021

List of Contents

Introduction

During my childhood, we were often asked, “What do you want to be when you grow up?” and I remember answering with a confident, “I want to be an astronaut.” I must confess this was majorly due to the discussions we had about Kalpana Chawla at school, that my inner self wanted to emulate, like a literal interpretation of ‘shoot for the stars’. It felt exciting, scary and almost unbelievable to even imagine going to space and living there. Mysteries of the universe and speculations about the great unknowns truly fascinated me as a child.

But the biggest moment of wonder was the time I learnt of our ‘Cosmic Address’. It was is almost unimaginable to grasp how infinitesimally tiny we are in this huge cosmos, especially considering how the universe is still growing larger everyday. Other questions like how does the planet remain suspended in space? Will I fall from the face of the Earth if I am standing at the Equator? All of this only made me more excited and grateful about this planet that we live on. Eventually I learned about the planetary laws of motions, gravity, rotations, revolutions and many more astronomical and scientific concepts, but there something missing from that entire experience.

As I began revisiting this topic through the opportunity given to us by ASI, I realized that space has always been astonishing to me, but over the years in high school that magic faded away. It simply remained a subject, distant, cold and forgotten, much like Pluto. At no point were we given the idea that developments in science or mathematics, affected the world around us, socially, politically, religiously in any tangible way. The amazement and magic was lost and the impersonal words in the textbooks reflected none of its true mystique.

As I began reading about the History of Indian Astronomy, the evolutionary nature of scientific thinking seemed truly remarkable. To imagine that we went from living in caves, discovering fire and hunting animals for food to now travelling to the moon and making incredible discoveries about space, just seems unbelievable. Advancements and discoveries were made even during the most difficult times. One of the darkest periods in Indian History is towards the end of the 17th century as the decline of the Mughal Empire, led to complete anarchy and unrest in the nation. Even at this time a young Rajput king, decided to pursue astronomy, as he understood that creating a secular calendar based on logical reasoning and observations, would unify the people.

He may have lived in the medieval era but his outlook was highly modern. But the question still remains, why did he actually do all of this? What prompted him to do so? What were his early childhood influences that shaped him? And moreoever what other discoveries did he make?

This book attempts to understand the early influences, adversities and triumphs of an 18th century ruler, who just might have intended to bring to India its own Renaissance.

Context

The target audience for this project would be high school students from Grade V and above. These students from the state and central boards would have a uniform curriculum and syllabus, ensuring that they have some basic concepts in place, which are required to begin understanding this subject. Currently, the story would be written and conceptualized in English. Eventually, a translator's assistance would be required to effectively translate for multi-lingual audiences.

Design Objectives

The primary reason for creating this book was to bring together the information in textbooks and present it in an engaging manner so that one doesn't feel like one is studying. Concepts of the Earth, Sky and celestial bodies, would be addressed from the perspective of making naked-eye observations, as anyone could do these. The information would be woven as a story, offering not just astronomical information, but historical, political and logical perspectives as well. The final outcome as a graphic novel is intended to be informative and fun, just like reading a comic book.

With respect to the medium of a graphic novel, the framing, sequence and flow of the story would determine the interest with which a reader decides to devour the book. As it's pretty common to read the text and visuals together and finish it in one sitting. This poses an exciting challenge in terms of deciding the visual language and executing it.

Secondary Research

To get an idea of what is being taught to students,
I decided to look at three media of learning:

1. School Textbooks: Mandatory Reading
2. Books, Encylopedias: Voluntary
3. Shows, Series, Videos: Voluntary

Within the category of school textbooks, we reviewed SSC (Mahararashtra State Board) and NCERT textbooks. They helped to decide the pre-requisite information needed within the students to then understand the final content.

The Books and Encyclopedias around Astronomy are highly visual in nature with multiple photographs, diagrams, and vivid imagery of stars & galaxies. They have engaging layouts and a unique way of narrating facts, which generate a sense of wonder in the user.

The format of audio-video information is one of the most engaging sources of learning. As the subject requires one to understand the ‘Movement’ of the sun, planets, moon, stars and time, this medium is capable of helping students visualize the exact information. Following are some of the sources listed for learning astronomy.

Sources of Learning (For Children)

SSC (Maharashtra State Board) Textbooks, Pune
Lower Primary (I-V) Upper Primary (VI-VIII)

Age	Std.	Subject	Chapter	Keywords
8	III	EVS	Direction and Maps	Identifying our Address
			Understanding Time	Ways to measure time
			Changes in our Surroundings	Physical changes in sky and temperature
9	IV	EVS	Day and Night	Connection of the Earth's rotation with seasons
10	V	EVS (Part 1)	Our Earth and Our Solar System	Stars, Planets, Solar System, Satellites, Dwarf Planets, Asteroids, Gravity
			Motions of the Earth	Earth's Rotation, Sunrise & Sunset, Year, Leap Year, Phases of the Moon, Lunar Month & Tithis
		EVS (Part 2)	History and Concept of Time	Division of Time & Timeline, BCE (BC), CE (AD), Prehistoric/Historic, Carbon Dating
11	VI	Geography	The Earth and The Graticule	Angular Distance, Parallels of Latitudes, Meridians of Longitudes, Equator, Graticule
			Let us use the Graticule	Familiarizing with the Graticule, Importance of Tropic of Cancer & Tropic of Capricorn
		Science	Light and the Formation of Shadows	Reflection of Light, Pinhole Camera, Formation of Shadow, Sundial, Newton's Disc
			The Universe	Milky Way, Types of Galaxies & Stars, Facts & Figures about our Planets, Comet, Meteor

Sources of Learning (For Children)

SSC (Maharashtra State Board) Textbooks, Pune
Upper Primary (VI-VIII) High School (VIII-X)

Age	Std.	Subject	Chapter	Keywords
12	VII	Geography	How Seasons Occur - Part 1	Measuring Sunrise, Sunset, Duration of Day & Night (During June - Summer Solstice)
			The Sun, the Moon and the Earth	Motions & Phases of the Moon, Solar Eclipse, Lunar Eclipse, Occultation, Transit
			Tides	Centrifugal & Gravitational Force, Occurence & Effects of Tides, Timings of Tides
			How Seasons Occur - Part 2	Apparent Movement of Sun, Uttarayan, Dakshinayan, Vernal & Autumnal Equinox, Cycle of the Seasons
		Science	Effects of Light	Scattering of Light, Formation of Shadows, Solar Eclipse, Lunar Eclipse, Zero Shadow Day
			In the World of Stars	Lifecycle of Stars, Horizon, Zenith, Nadir, Celestial Poles, Celestial Equator, Constellations, Zodiac Signs, Nakshatras
13	VIII	Geography	Local Time and Standard Time	Local Time, Indian Standard Time, GMT, Universal Standard Time, Jantar Mantar
		Science	Life Cycle of Stars	Birth of Stars, their properties, Stability & Evolution of Stars, End-stages of stars (3)
14	IX	Science	Observing Space: Telescopes	Scientists, Different Forms of Light, Optical (Refracting) Telescope, Reflecting Telescopes, Radio Telescope, Telescopes in Space, ISRO
15	X	Science	Space Missions	Need & Importance of Space Missions, Artificial Satellites & their types, HEO, MEO, LEO, SLVs; Missions to Moon, Mars, other planets; Space Debris & their management

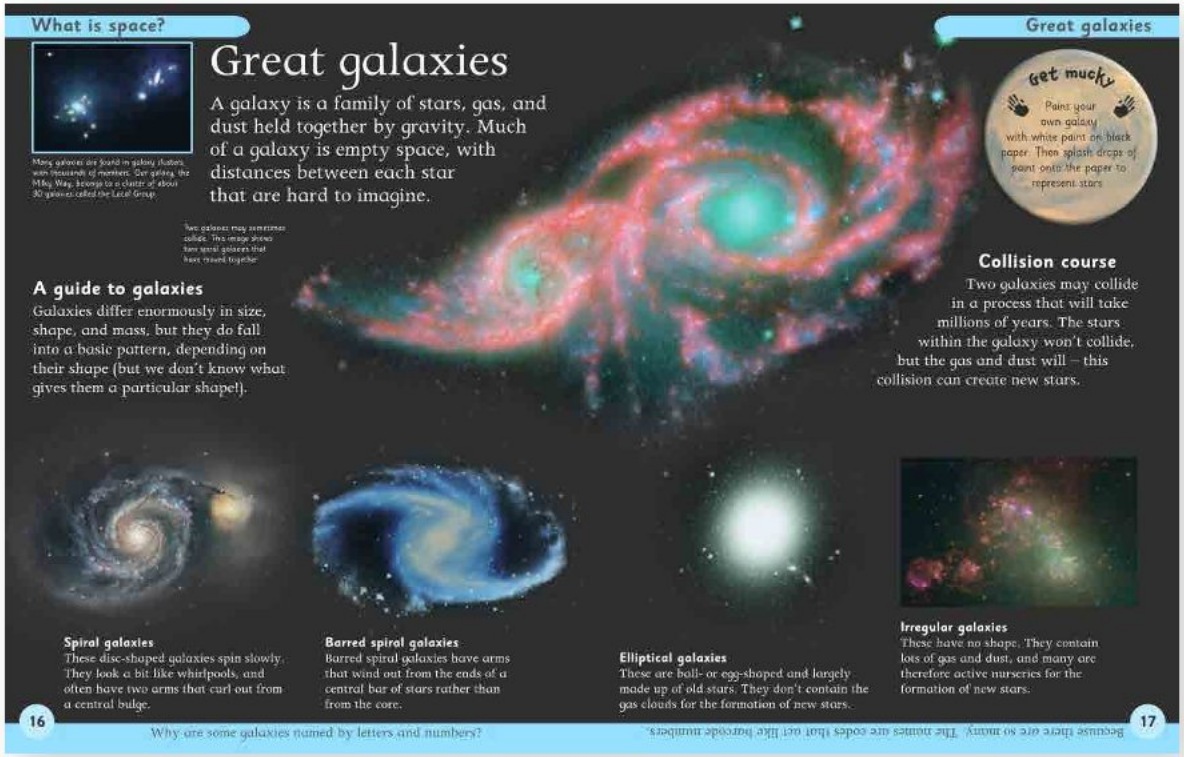
Sources of Learning (For Children)

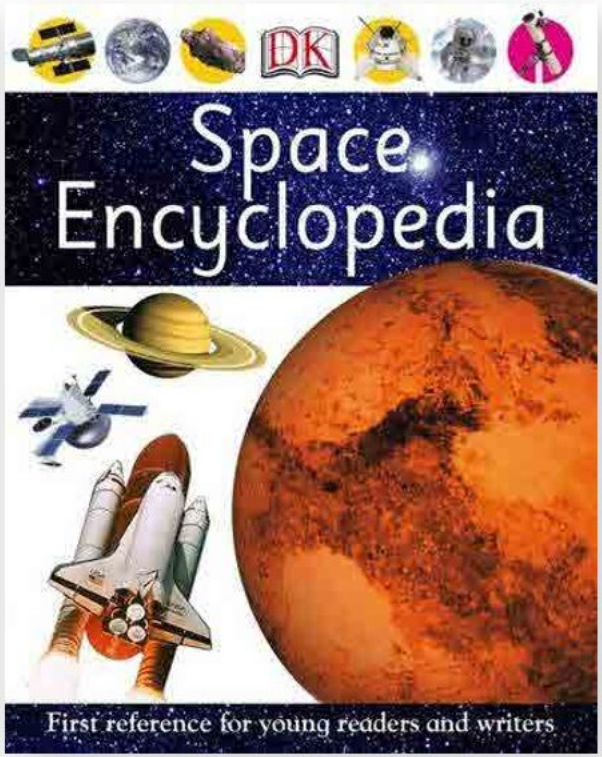
NCERT (National Council of Educational Research & Training)
Standard V - IX

Age	Std.	Subject	Chapter	Keywords
10	V	EVS	Sunita in Space	Globe, 3-D structure of Earth, Space missions (national, international) 3-d structure of Moon, Sun, Gravity.
11	VI	Social Science	The Earth in the solar system	Self, Earth, Solar system, Milky way galazy, the universe. Longitude/ Latitude, Motions of earth, landforms, climate (Vegetation& wildlife), concept of countries.
12	VII	Science	Motion and Time	Speed, Measurement of Time, Jantar Mantar, Oscillation, Unit of time
			Light	Light as a cocncept, Laws of reflection
13	VII	Science	Sound	Vibration, medium of propogation, amplitude
			Stars and the solar system	Positions of moon, Surface of moon, Stars (sun, pole, etc), Light year, Constellations, Solar system and all planets, Astronomy in ancient India, Meteroites and Meteors, Superstitions about comets, Meteor showers, Artificial satelites.
14	VIII	Science	Sound	Sound Production, Propagation, Waves, Speed of sound in different mediums, ultrasound, sonar.
			Matter in Our surroundings	Particles and their charachteristics, states of matter.
			Atoms and Molecules	Atom, Atomic mass
			Structure of atom	Different models of atom, Neutrons
			Gravitaion	Universal Law of Gravitation, mass, weight, Relation between gravity and mass.
15	IX	Science	The Human Eye and the colourful world	Atmospheric Refraction, Twinkling of stars, Advance sunrise and delayed sunset, etc.

Sources of Learning (For Children)

Books, Encyclopedias
on General Astronomy



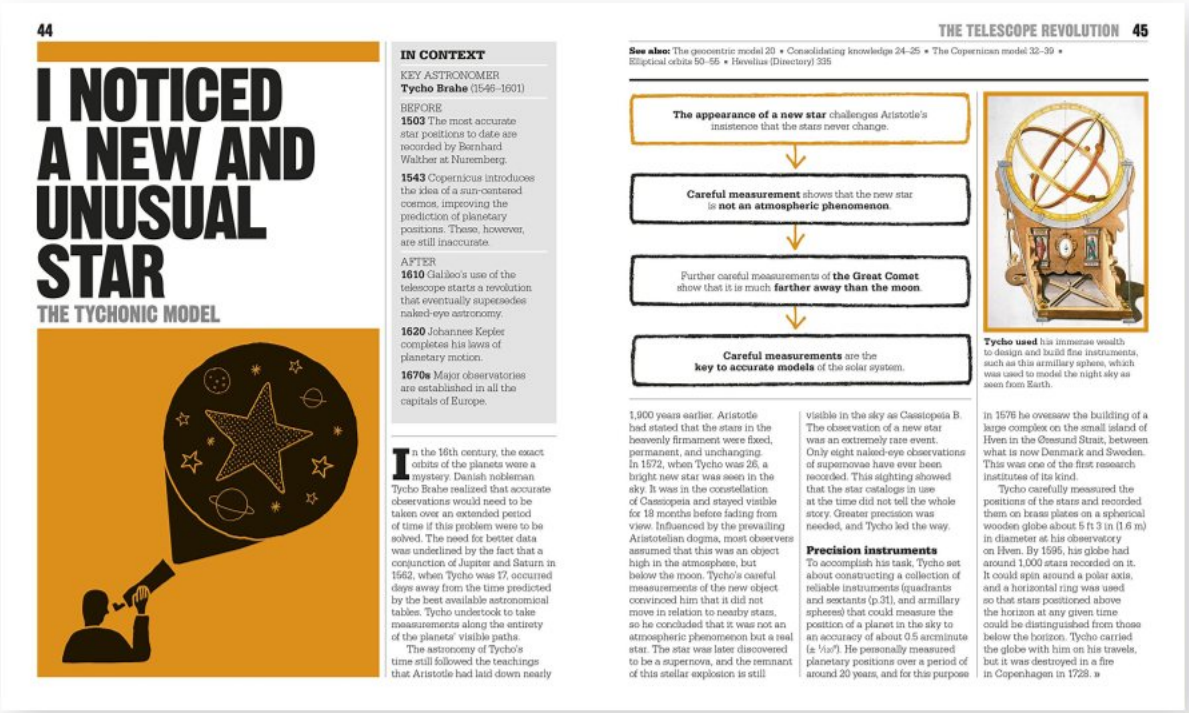


It consists of bite-sized information, interesting facts, quizzes, diagrams and multiple photographs and visual content. Every spread of a page explains one topic, to a decent amount of detail.

For ages 5 and above
Beginners

Sources of Learning (For Children)

Books, Encyclopedias
on General Astronomy



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I NOTICED A NEW AND UNUSUAL STAR

THE TYCHONIC MODEL

IN CONTEXT

KEY ASTRONOMER
Tycho Brahe (1546–1601)

BEFORE
1503 The most accurate star positions to date are recorded by Bernhard Walther at Nuremberg.

1543 Copernicus introduces the idea of a sun-centered cosmos, improving the prediction of planetary positions. These, however, are still inaccurate.

AFTER
1610 Galileo's use of the telescope starts a revolution that eventually supersedes naked-eye astronomy.

1620 Johannes Kepler completes his laws of planetary motion.

1670s Major observatories are established in all the capitals of Europe.

In the 16th century, the exact orbits of the planets were a mystery. Danish nobleman Tycho Brahe realized that accurate observations would need to be taken over an extended period of time if this problem were to be solved. The need for better data was underlined by the fact that a conjunction of Jupiter and Saturn in 1562, when Tycho was 17, occurred days away from the time predicted by the best available astronomical tables. Tycho undertook to take measurements along the entirety of the planets' visible paths.

The astronomy of Tycho's time still followed the teachings that Aristotle had laid down nearly

THE TELESCOPE REVOLUTION 45

See also: The geocentric model 20 • Consolidating knowledge 24–25 • The Copernican model 32–39 • Elliptical orbits 50–55 • Hevelius (Directory) 335

The appearance of a new star challenges Aristotle's insistence that the stars never change.

Careful measurement shows that the new star is **not an atmospheric phenomenon**.

Further careful measurements of **the Great Comet** show that it is much **farther away than the moon**.

Careful measurements are the **key to accurate models** of the solar system.

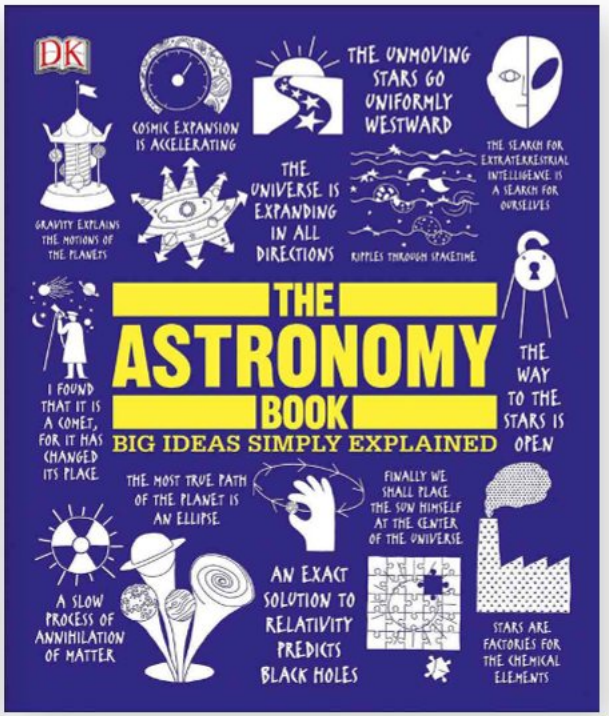
Tycho used his immense wealth to design and build fine instruments, such as this armillary sphere, which was used to model the night sky as seen from Earth.

1,900 years earlier. Aristotle had stated that the stars in the heavenly firmament were fixed, permanent, and unchanging. In 1572, when Tycho was 26, a bright new star was seen in the sky. It was in the constellation of Cassiopeia and stayed visible for 18 months before fading from view. Influenced by the prevailing Aristotelian dogma, most observers assumed that this was an object high in the atmosphere, but below the moon. Tycho's careful measurements of the new object convinced him that it did not move in relation to nearby stars, so he concluded that it was not an atmospheric phenomenon but a real star. The star was later discovered to be a supernova, and the remnant of this stellar explosion is still visible in the sky as Cassiopeia B. The observation of a new star was an extremely rare event. Only eight naked-eye observations of supernovae have ever been recorded. This sighting showed that the star catalogs in use at the time did not tell the whole story. Greater precision was needed, and Tycho led the way.

Precision instruments

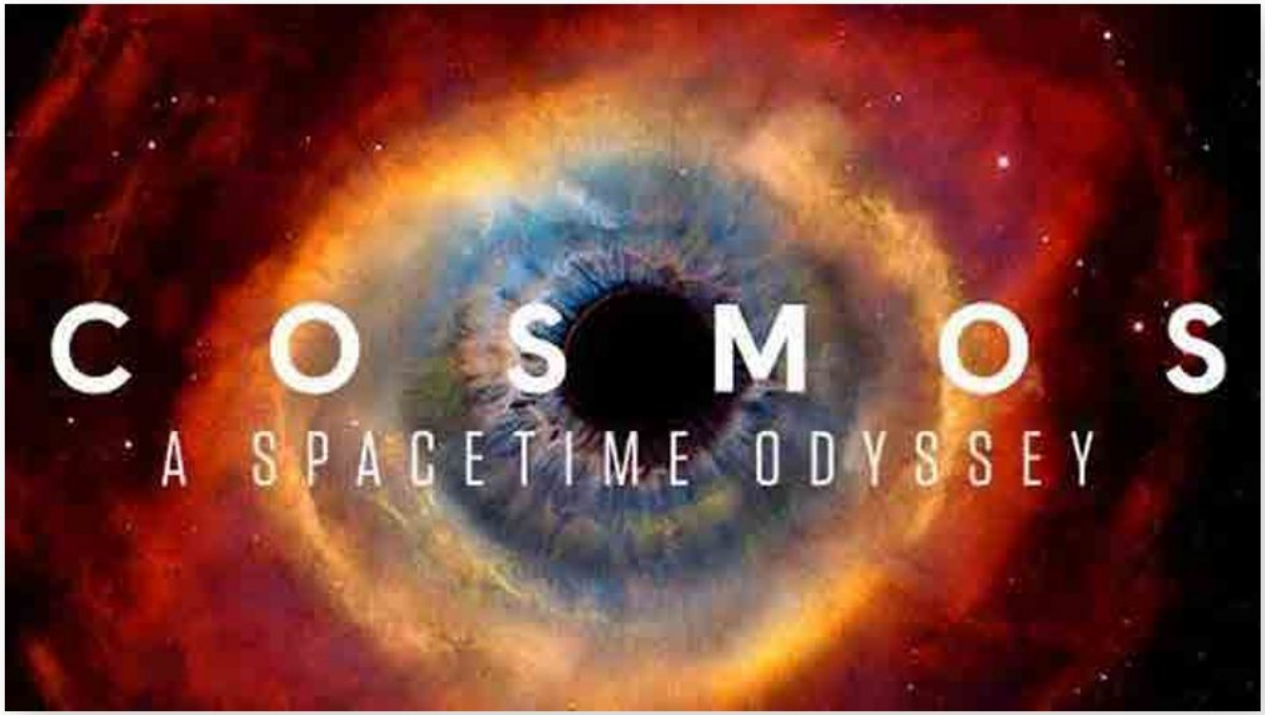
To accomplish his task, Tycho set about constructing a collection of reliable instruments (quadrants and sextants (p.31), and armillary spheres) that could measure the position of a planet in the sky to an accuracy of about 0.5 arcminute (± 1/120°). He personally measured planetary positions over a period of around 20 years, and for this purpose in 1576 he oversaw the building of a large complex on the small island of Hven in the Øresund Strait, between what is now Denmark and Sweden. This was one of the first research institutes of its kind.

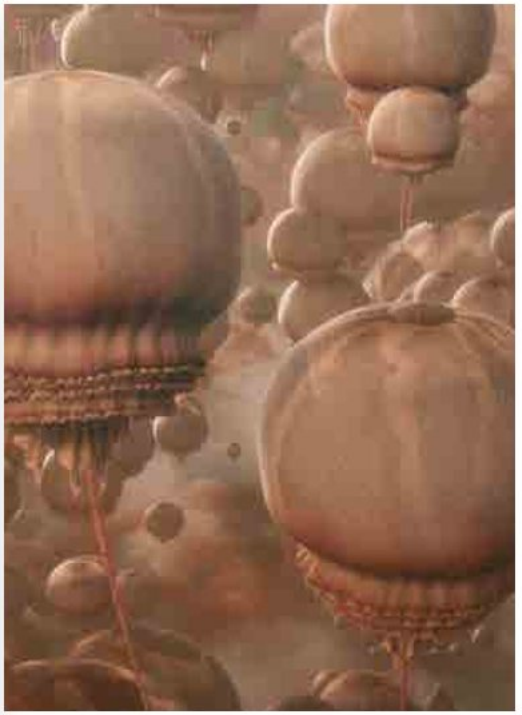
Tycho carefully measured the positions of the stars and recorded them on brass plates on a spherical wooden globe about 5 ft 3 in (1.6 m) in diameter at his observatory on Hven. By 1595, his globe had around 1,000 stars recorded on it. It could spin around a polar axis, and a horizontal ring was used so that stars positioned above the horizon at any given time could be distinguished from those below the horizon. Tycho carried the globe with him on his travels, but it was destroyed in a fire in Copenhagen in 1728. »



The book is mainly divided into 7 large sections by didviding the timeline. It follows a linear sequence of narrating the discoveries from past to present. This book appears to be intended for interested children in a higher age group, since it involves more textual content as compared to visuals. Every section is introduced with a concise timeline, explaining the discoveries in a single sentence and brief paragraphs explaining them.

Sources of Learning (For Children)





The series does an excellent job of creating a sense of wonder and magic in the viewer, as one is engaged auditorily and visually. The narrative is beautifully woven bringing up the past in the present and diving back millenniums ago. In doing so, it does not follow the linear narration of the universe's timeline. It appears to be highly engaging as one simply hops onto the journey of discovering the answers to some of the biggest questions.

Sources of Learning (For Children)

Shows / Series on
General Astronomy

Let's understand Equinox

509 views •
Streamed 2 days ago

The sunspot AR-2770: Myths and reality of solar...

271 views •
Streamed 1 week ago

Fantastic Bursts and How to Find Them

276 views •
Streamed 2 weeks ago

Discover the Night Sky! August 28, 2021

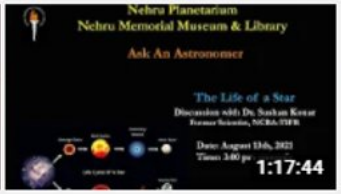
129 views • 3 weeks ago

"Sky Watch: being friends with stars".

366 views •
Streamed 3 weeks ago

Exploring Stellar Remnants in the Multi Messenger Era...

474 views •
Streamed 1 month ago



The Life of a Star" by Dr. Sushan Konar

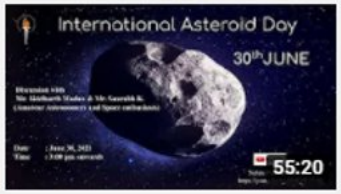
475 views •
Streamed 1 month ago

Sky at the Night Perseid meteor shower 2021

482 views •
Streamed 1 month ago

Conjunction: Mars-Venus-Moon

2.8K views •
Streamed 2 months ago



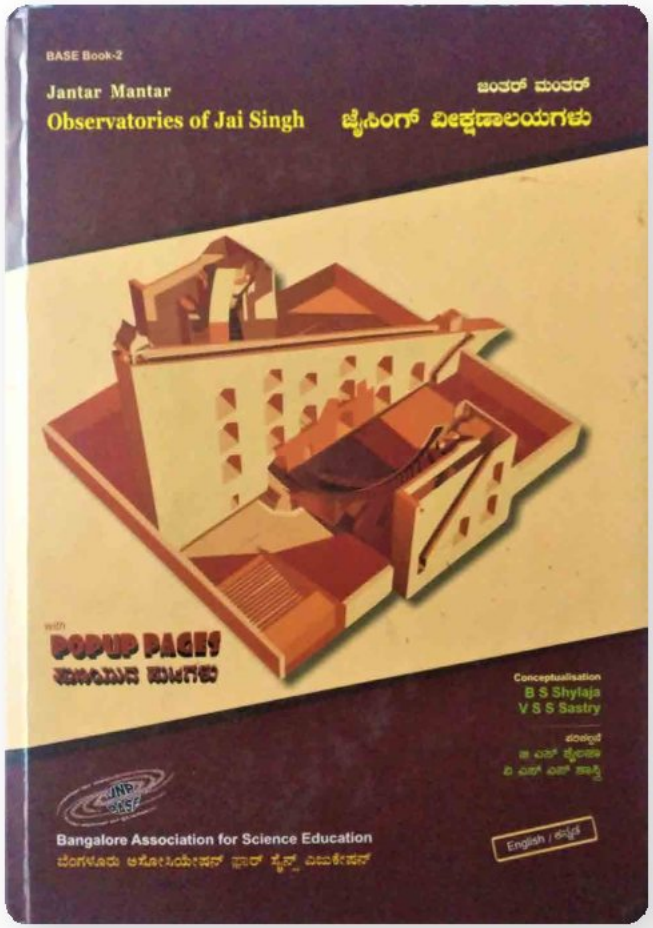
International Asteroid Day

3.4K views •
Streamed 2 months ago

Youtube has a large community of educators who create engaging and precise content explaining complex concepts. Though majority of the information revolves around world astronomy and universal concepts, organizations such as Nehru Planetarium have multiple videos on their channel as a part of their outreach program on educating young people. They also have some content centered around Indian Astronomy.

Sources of Learning (For Children)

Books, Encyclopedias
on the specific topic



From the collection of Prof. Aniket Sule

Jantar Mantar: Observatories of Jai Singh

The Bangalore Association for Science Education (BASE) published this **pop-up book** explaining the astronomical structures at Jantar Mantar.

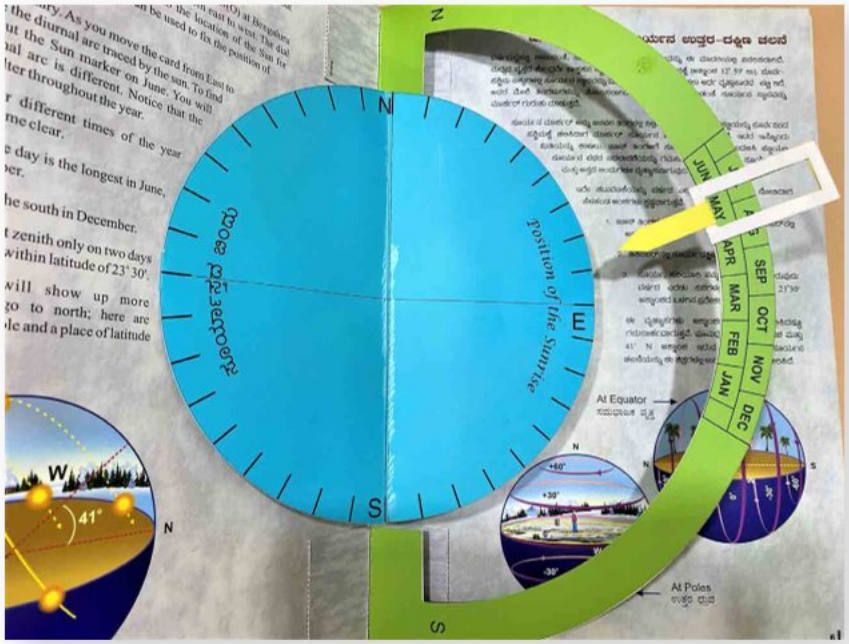
The book starts with an explanation of the terms that form the vocabulary to understand the following structures such as, celestial sphere, azimuth, altitude, zenith, nadir and more. The introduction tries its best to explain these terms in a very simple and lucid language. It immediately plunges into the instruments one by one, as each spread carries a pop-up model of that particular structure. Instruments such as Samrat Yantra, Dakshinottara Bhitti, Sastamsa Yantra, Nadi Valaya, Ram Yantra, Digamsa Yantra, Chakra Yantra, Jaiprakash Yantra, Unnatamsa Yantra, Misra Yantra & a few more, have been covered in this book.

At the very end a paragraph is dedicated to the astronomer king Sawai Jai Singh who designed and built these instruments, explains his reason for building the huge masonry instruments.

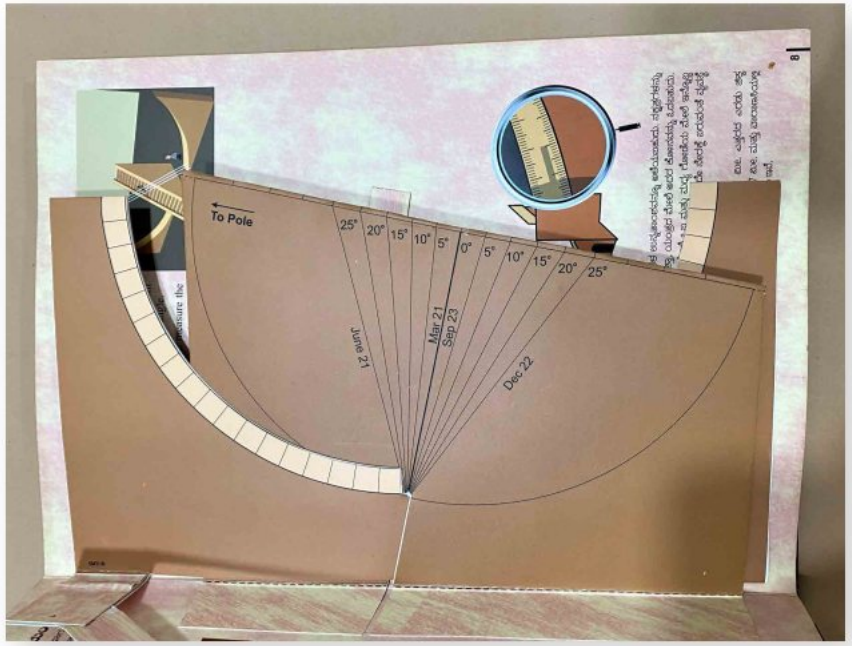
Sources of Learning (For Children)

Books, Encyclopedias
on the specific topic

For high school students



The model explaining the North-South motion of the Sun



Samrat Yantra - Sun Dial

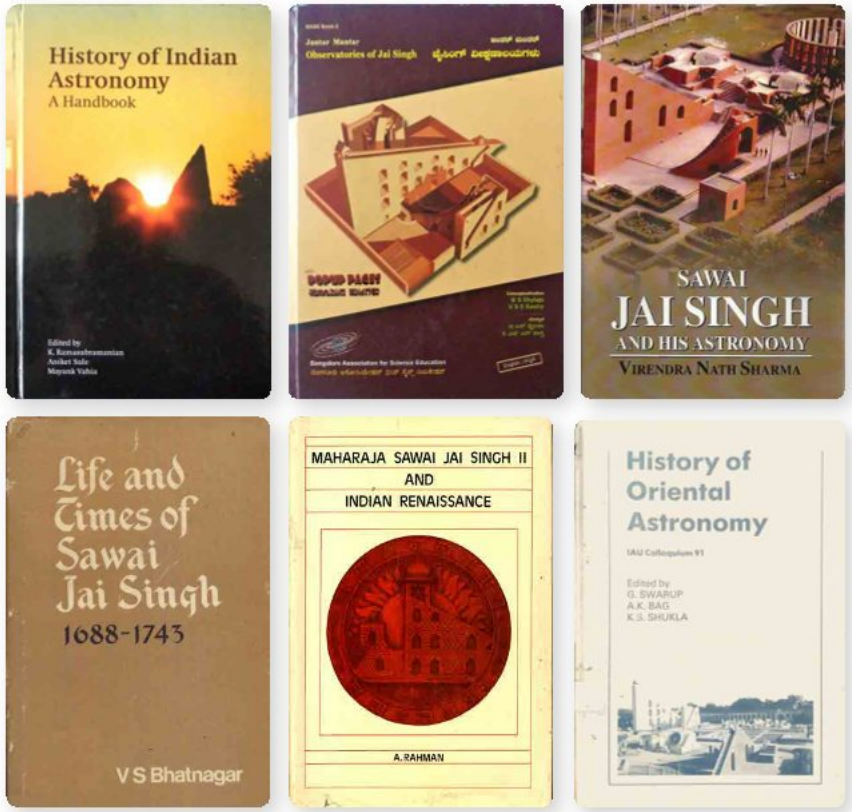
The book tries its best to explain with 3D recreations, but the need for an additonal explanantion is felt, in terms of how to operate the book. One must be clear with the concepts prior to reading the book or else one would have to go back and forth. As a teaching aid in classrooms, the teachers can use this format to help the students visualize the monumental scale of the cosmic structures.

Reference Books

The following books are extensively detailed accounts in all aspects. The book ‘History of Indian Astronomy’ is a compilation of multiple articles that help one to understand the origin and development of astronomy in India. It explains in a great amount of detail every important phase of Indian Astronomy. Particularly the article by Dr. N. Rathnasree on the Jantar Mantar observatories is eye-opening to say the very least.

‘Life and Times of Sawai Jai Singh’ mainly talks about the political climate during that period, while also highlighting the role of Jai Singh within it. The other two books offer an in-depth understanding of his intellectual and astronomical capabilities. V.N. Sharma’s in depth account of ‘Sawai Jai Singh and His Astronomy’ gives a detailed explanation of all the instruments present at all the five observatories, alongwith the influences on Jai Singh which led him to creating these inventions.

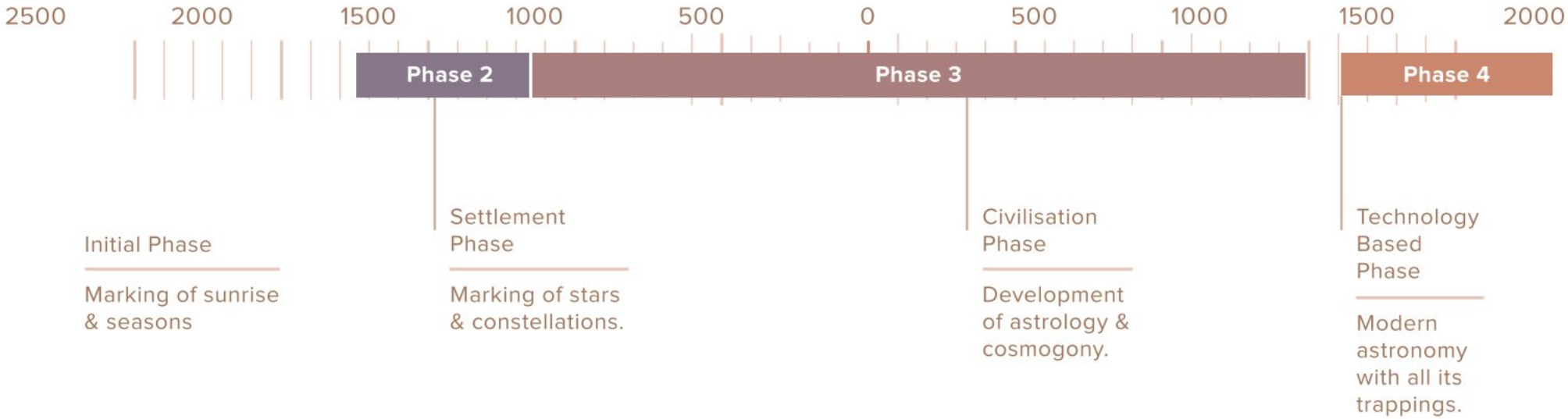
A. Rahman’s book ‘Maharaja Sawai Jai Singh and The Indian Renaissance’ poses highly intuitive questions and then investigates the reasons behind them. It proves itself to be a short, precise and highly informative read on Jai Singh and his environment.



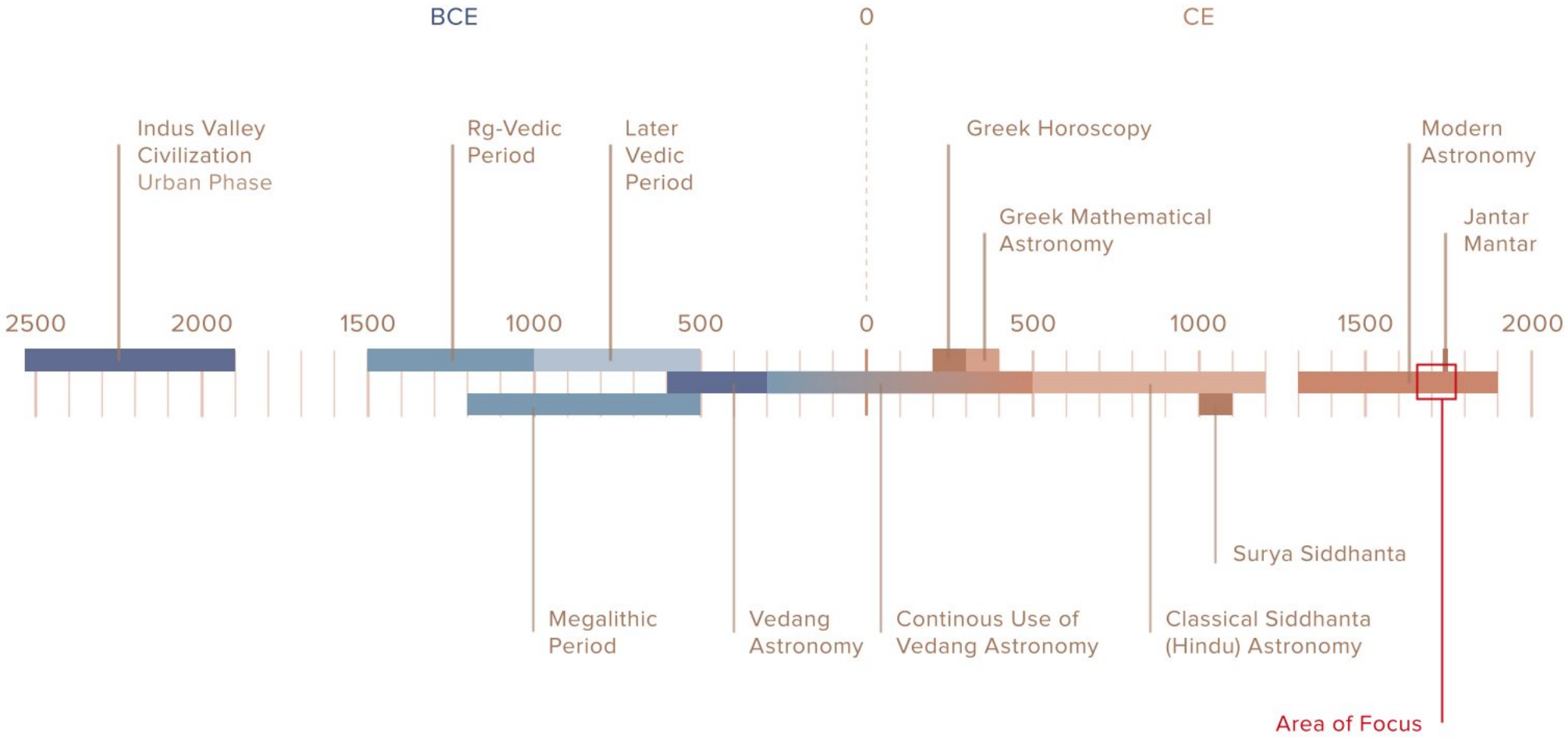
Timeline of Indian Astronomy

A timeline emerged from the book 'History of Indian Astronomy' which helped to understand the patterns within the broad timeframe.

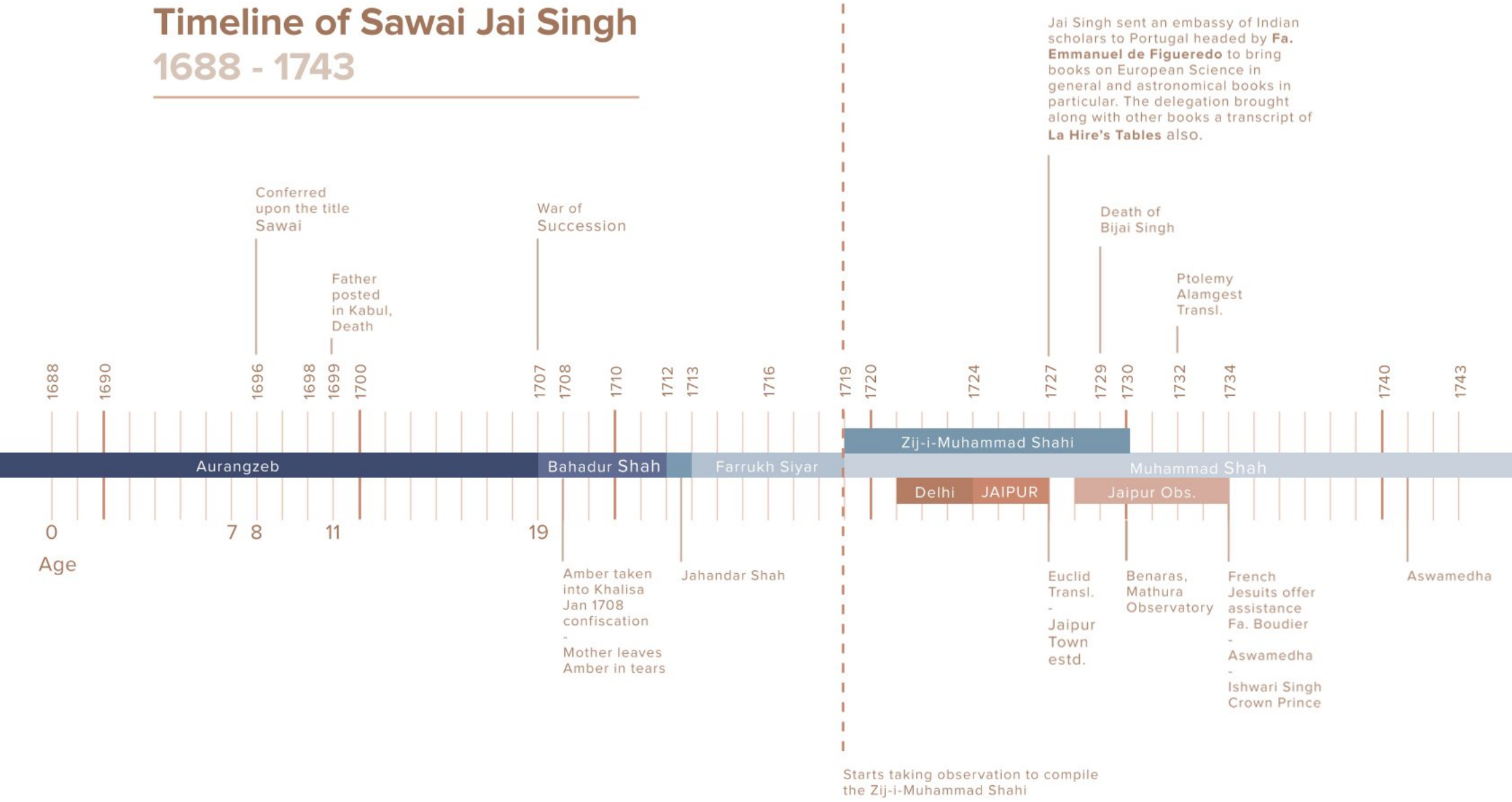
Unfortunately, at the current level of knowledge, it is not possible to say anything about the state of astronomy in the Harappan times that preceded the Vedic Age (Phase 2).



Timeline of Indian Astronomy



Timeline of Sawai Jai Singh
1688 - 1743

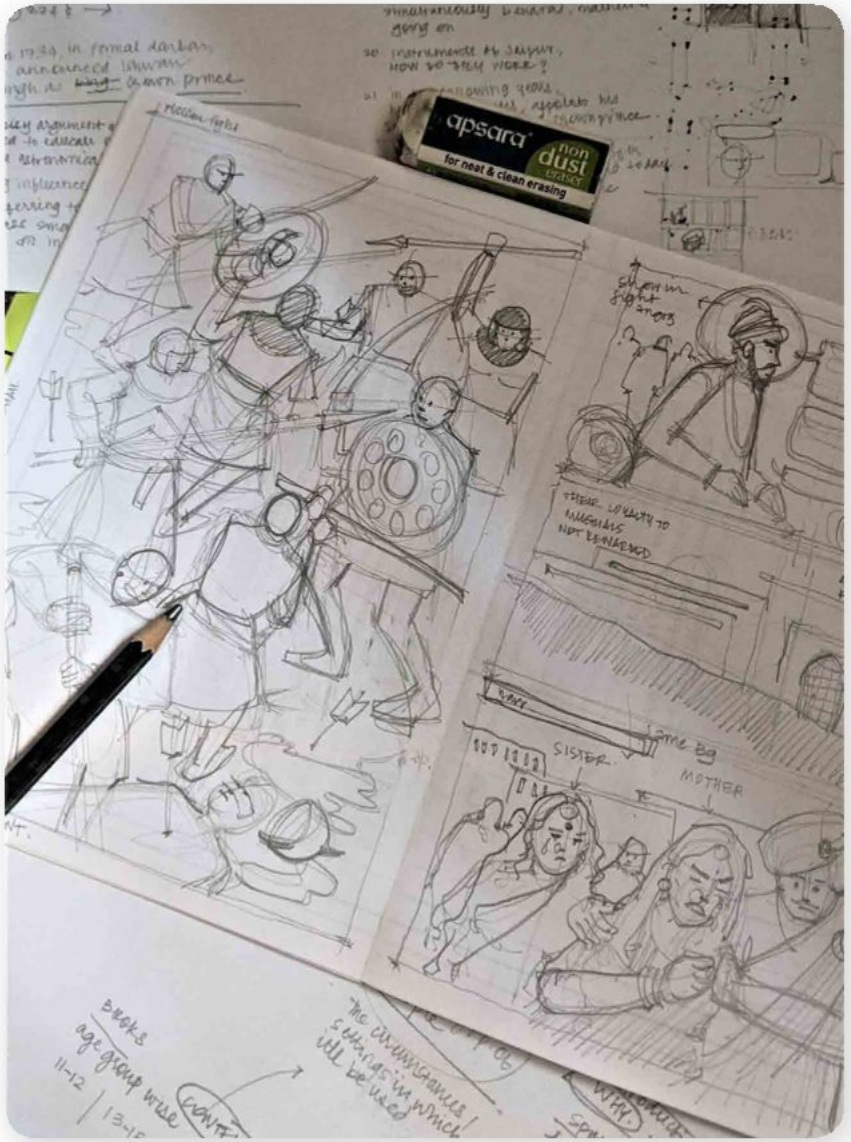


Process of Writing & Drawing

The process of writing began with firstly analysing the timeline, to establish a sequence of events. The historical accounts provided in books led to the understanding of Sawai Jai Singh as a person, his characteristics, personality traits and behaviour. The resulting character sketches were firstly explored within the storyline and then through visuals.

As I began writing the script for each panel, I quickly realized that it would be easier for me to draw the storyboards thereby understanding the framing and sequencing of the panels which would very directly affect the pace of the story. Storyboarding proved realy helpful in deciding the pace that I wish to set for a particular scene and moments where I can build up tension so that the reader is compelled to turn the page and continue reading it.

A book that proved extremely helpful in this process was Will Eisner's 'Comics and Sequential Art' which gave a detailed break-up of the process and wonderful insight into the types of layouts, frames, typography and their effect on the reader.



List of Scenes

Scene 1: Jai and Bijai pursuing studies, aged 7 and 5 years respectively.

Scene 2: Studies interrupted when Father sends him to court; conferred upon the title Sawai.

Scene 3: Resumes Studying, sending progress letters to father in Kabul

Scene 4: Receives news of Father's Death, at 11 years old crowned as the King

Scene 5: Aurangzeb's Death, The War of Succession, the battle between the brothers

Scene 6: Bahadur threatens to take away his home, policy against Rajputs

Scene 7: Forced to leave Amber, Mother crying

Scene 8: The times under Jahandar and Farrukh Siyar continue to be tumultuous with continued clashes against Marathas, Jats, Saiyids.

Scene 9: 1719, in the court of the new emperor, Muhammad Shah, noisy debate regarding disagreement in the calendrical dates. Decides to undertake the task of creating a secular calendar.

Starts Zij observations with Mirza Khairullah

Scene 10: Starts referring to different tables for calculations, Tables of Ulugh Beg, makes small brass instruments, points out inaccuracy of telescope.

Scene 11: Delhi Observatory under construction, how is it accurate in calcs its design. Samrat Yantra.

Scene 12: Entry of Vidyadhar Bhattacharya to discuss town planning of Jaipur

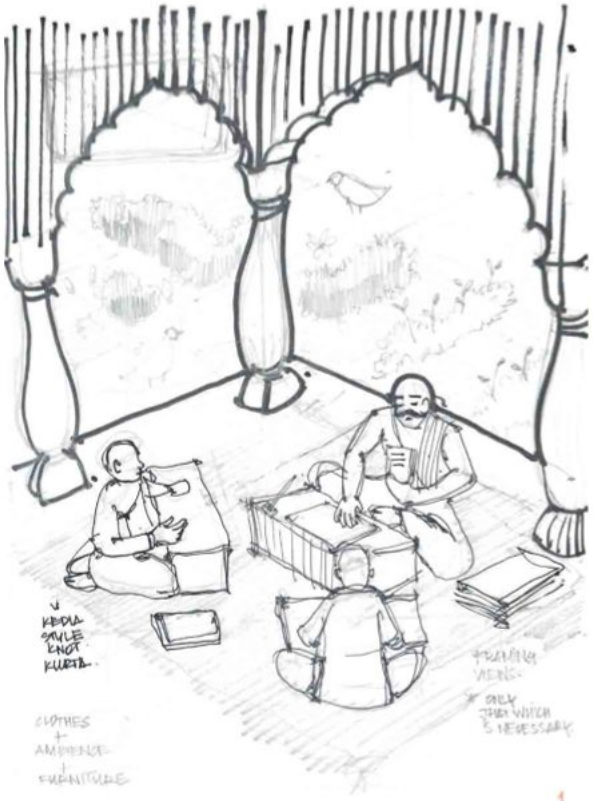
Scene 13: At City Palace, Jaipur continues to pursue astronomy. The Bureau of Translation, a huge library of translated works. Sends people to collect books on European Science. The Jesuits dont introduce him to Heliocentrism (Copernicus and Galelei)

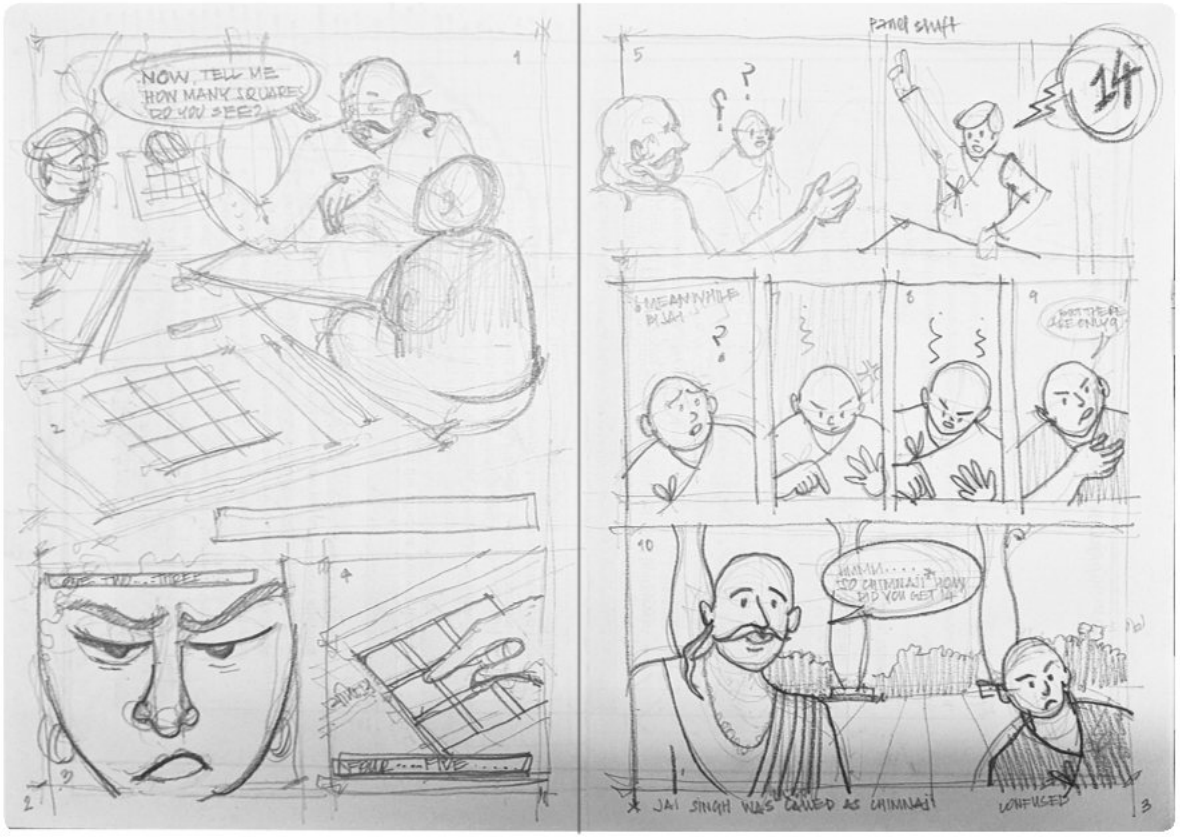
Scene 14: Jaipur Observatory underway (simultaneously Benaras, Ujjain and Mathura too), The Instruments of Jaipur (How do they work?)

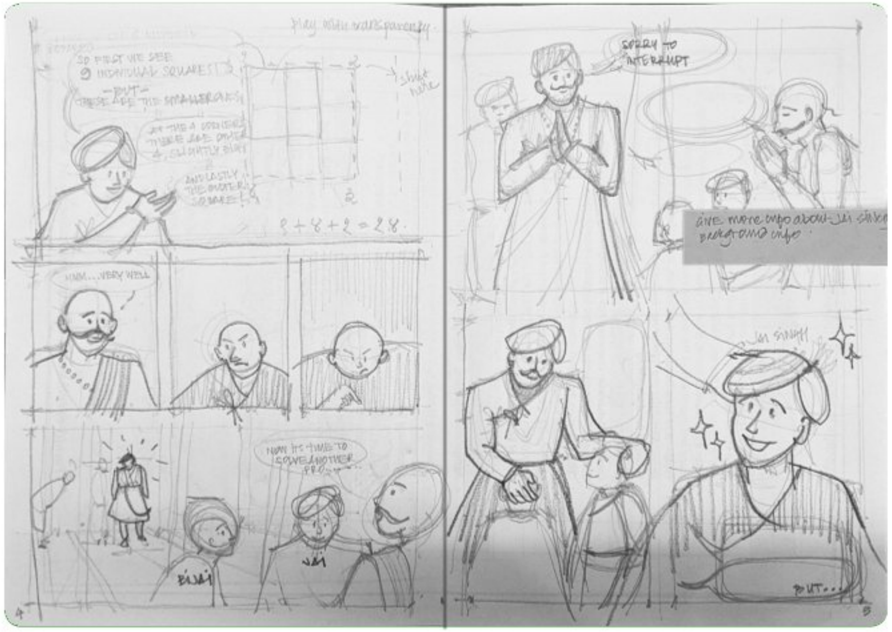
Scene 15: Deterioration of Health, Ishwari Singh as Crown Prince, Death in September 1743 before completing his 55th year.

Scene 16: Conclusion, the current state.

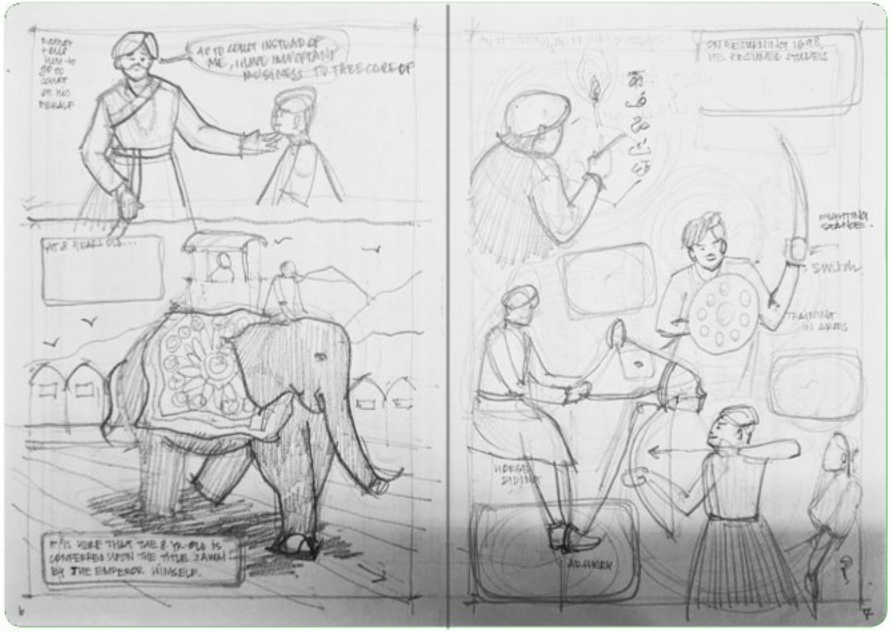
Storyboards





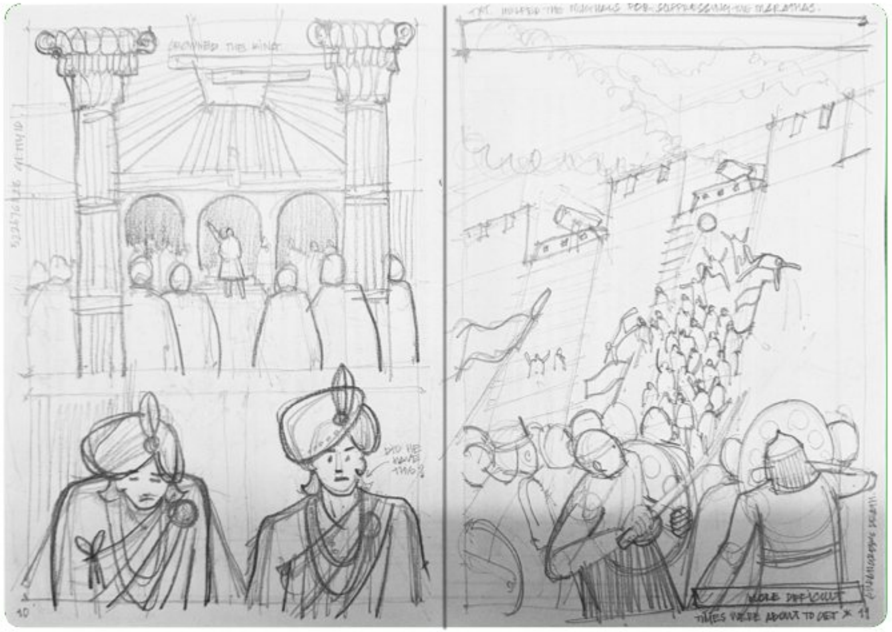


SORRY TO INTERRUPT
give more info about Jai Singh background info
HMM... VERY WELL
JAI SINGH
BUT...

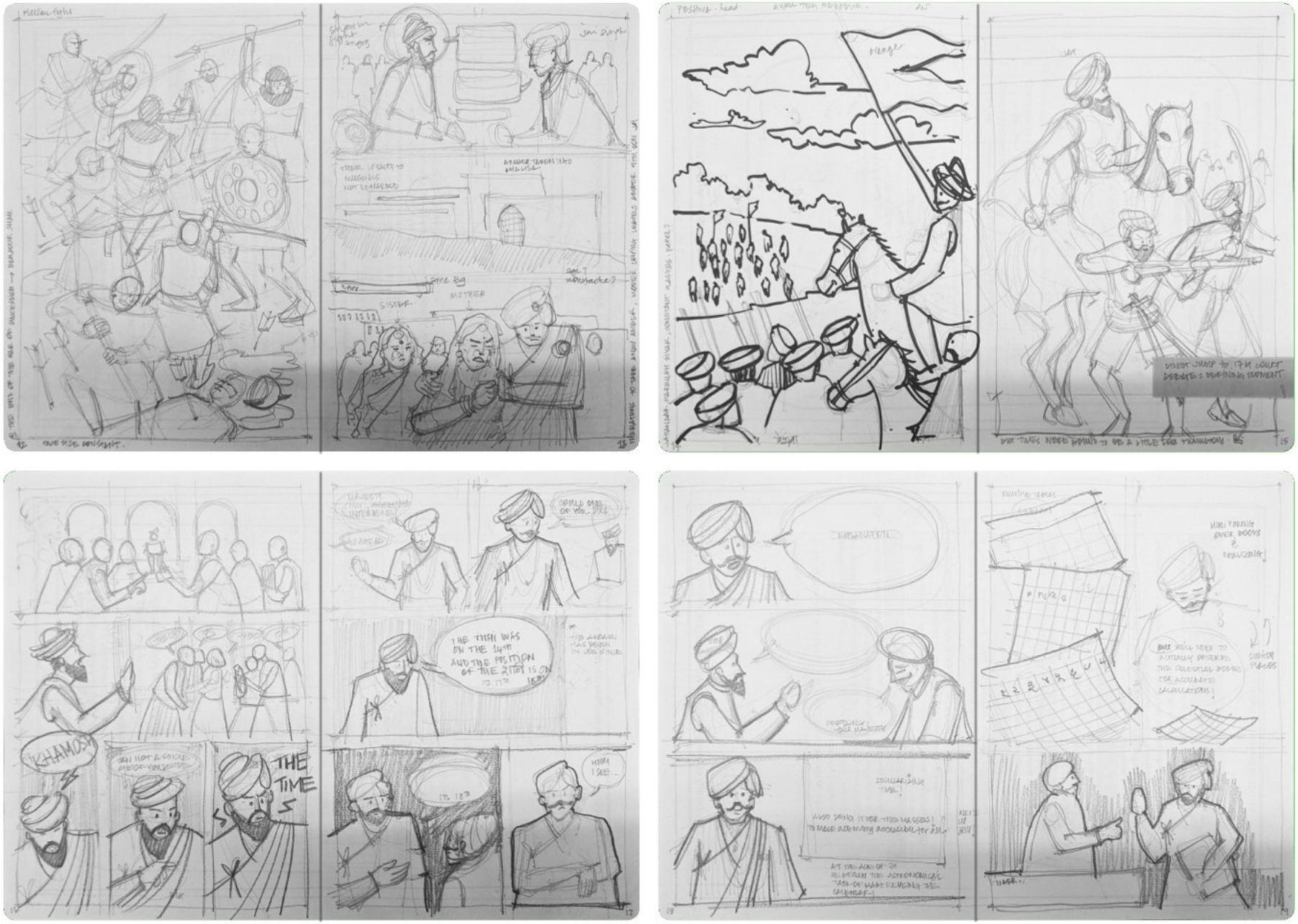


AS TO COURT INSTEAD OF ME, I HAVE IMPORTANT BUSINESS TO TAKE CARE OF
AT 8 YEARS OLD...
IT IS HERE THAT THE 8 YR OLD IS CONFERRED UPON THE TITLE SAWAI BY THE EMPEROR HIMSELF.
TRAINING IN ARMS

father, everyone is doing well here at home. we're studying well.
OH! father's letter!



DID HE KNOW THIS?
MORE DIFFICULT
TIMES WERE ABOUT TO GET


SISTER
MOTHER
THE TITHI WAS ON THE 14TH AND THE POSITION OF THE SUN IS ON
KHAMOSH!
THE TIME
HMM I SEE...


LIBRARY STUDY AREA
FACT FINDING MISSION + LATEST ADVANCES
HINDU
WE FULLY UNDERSTAND HOW IMP THIS IS
WE SHALL RETURN WITH LATEST MANUSCRIPTS
AND SO THEY SET ON THE JOURNEY

In the year 1696, on a quiet morning at Amer Fort, two young princes, Jai Singh and Bijai Singh, were receiving lessons from their tutor in the pavilion. They were learning the subject of mathematics, a favourite of Jai Singh. As their tutor introduced a new problem, both immediately began solving it. Within no time Jai Singh squealed the answer with excitement, while Bijai was still hunched over counting. The tutor was pleased with Jai Singh's aptitude and quick response. As they continued solving more math problems, the tutor was interrupted.

The king, Bishan Singh, father of Jai and Bijai, visited the pavilion to enquire about their progress. Bishan Singh then informed Jai that he must visit the royal court on his behalf as he had other matters to attend to. The obedient prince, at once sets for the Court. Little did he know that his studies would be temporarily halted, and he would gain the title 'Sawai' from the Emperor Aurangzeb himself. He then proceeded to stay at the court for two more years, after which he returned back home in 1698, and resumed his studies. Being a Rajput prince, he was taught archery, horse-riding, training-in-arms and so much more. He was also proficient in Dingal, Sanskrit, Persian, as well as Arabic and Turki. In 1698, the two princes' father was posted in Kabul so they would write letters to keep him updated on their progress. Matters of the state, the position of crops, the water levels in the state, all matters were informed to the King. Jai Singh continued his studies under the care of his mother and learned tutors. The stories of his ancestors, incidents of the Mughal Court, the numerous Emperors and their Begums and princes, as well as the battles and sieges in distant lands, kept him thrilled and engaged to learn more. One fine morning he was interrupted from his studies by a minister. The minister bowed low, with his shoulders drooping and revealed a scroll from the fold of his garments. He handed over the scroll to the young prince and retreated. As Jai Singh read the letter, his curiosity was replaced by grief, for the letter held the news of his father's death.

At only 11 years of age Jai Singh was crowned to be the King. The Diwan-I-Aam, filled with ministers and courtiers, hailed the new king with chants and cheers. Jai Singh now bore the burden of the heavy crown, metaphorically and literally as he ascended the throne of Amber. Over the next few years he continued to assist the Mughals, to suppress the Maratha and Jat rebellions primarily in the Deccan. He was met with victories, but he remained unaware of

the chaos that lay ahead. With the death of Aurangzeb in 1707, a terrible war of succession broke out between the three sons, Bahadur Shah, Azam Shah and Kam Baksh. The bloody battles resulted in Bahadur Shah acquiring the Mughal throne. He then forgave Jai Singh and other rulers who sided with his opponents. But his policy towards the Rajputs did not reflect that. He soon ordered the Fort of Amber to be taken under Khalisa (when a high revenue yielding land is directly placed under the Imperial Revenue Department). Jai Singh, his mother and sister were forced to leave their ancestral home of more than seven centuries and shift to another fort, as Bahadur Shah confiscated it.

As the Mughal seat crumbled slowly, uprisings of the Marathas, Jats and Saiyids continued with renewed vigour. After the death of Bahadur Shah in 1712, the next two emperors, Jahandhar Shah and Farrukh Siyar, paved the way for the Emperor Muhammad Shah in 1719. It is during this period, that he witnessed a noisy debate at the court of the Emperor. Two visibly distinct groups of nujumis (court astrologers) were arguing over the auspicious date for the Emperor to begin an important journey. Unable to help himself, Jai Singh intervened to get a grasp of the situation. He realised the importance of having one secular calendar to unify the people of the land. This would only be possible with accurate astronomical tables based on observing natural phenomena. He requested the Emperor to grant him permission for revising the tables. The Emperor respectfully allowed him to do so citing his deep knowledge and love for the subject of astronomy. This was the event that marked the beginning of his astronomical journey.

Act 2

Surrounded by multiple calendars, the Gurgani (Tusi), Ilkhani (Ulugh Beg), Ilahi (by Mulla Chand during the reign of Akbar) and Hijra calendar (re-introduced by Aurangzeb) he found certain discrepancies between them. The observed and calculated values differed. The time of rising and setting of the planets, the beginning and end of seasons, and the timing of eclipses of the sun and moon, varied in all of them. Even the length of the day varied as per the sun, and it would not fit into the predefined equal day and night division. He very soon realised the importance of observations and employable methods to begin this task. But how could he achieve accurate measurements? With this question he turned to **Mirza Khairullah**, a fellow astronomer, who would then go on to author the Zij-I-Muhammad-Shahi along with Jai Singh himself. He was also introduced to the work of Ulugh Beg- his astronomical tables as well as the instruments designed by him. **Sultan Mirza Ulugh Beg** was a secular king and was trying to develop secular policies, but was murdered at the

hands of his own narrow-minded people, who felt threatened by his policies. Despite this hatred, his own broad attitude to science was evident from the following statement: “Religion disperses like mist, kingdoms are destroyed, but the works of scientists remain forever.” Jai Singh truly admired Ulugh Beg for this reason and closely studied the Samarkand Observatory, and decided that he too might need to build such structures. But before embarking on that monumental task, he continued working with small brass instruments and even a telescope! The telescope according to Jai Singh allowed him to see distant stars in the day as well. He recorded the oval shape of Saturn, which tells us that he was actually using a faulty telescope. Because at that point in time, the telescopes invented were mainly for observing the night sky and were not accurate enough for measuring. The wood and brass instruments did not measure up to his expectations. With increased use, their axes underwent severe wear and tear and consequently gave inaccurate data. He wanted to achieve the highest level of accuracy possible to naked eye observations! Determined by this ordeal, he ordered for gallons of wax, and began sculpting models of his own instruments. As he built them with his own hands, slicing and measuring every angle and surface, the wax models proved helpful in resolving the designs. But what did he design? And how accurate were they?

The construction of the **Jantar Mantar observatory in Delhi** was completed during 1721-1724. These huge buildings were intended to tell 2 important things; the time and position, specifically, the angular measurements of the sun, moon and other celestial bodies, as these recorded observations would then help in revising the astronomical tables. The time would govern daily activities, matters of the state, festivals etc.

The huge **Samrat Yantra** is a symmetrical instrument built in stone, with a right-angled triangle in the centre and two arcs on either side of it. The hypotenuse of this triangle is actually a flight of stairs. Stairs that lead to the observing deck. As one climbs up the flight of stairs, one can see certain markings. Also, the two arcs on either side of the stairs carry similar markings. But what do they say? Well... they tell the time! As the shadow of this hypotenuse, also known as the gnomon, falls on the arc, using the markings one can precisely tell the time of the day. The markings go from 6 in the morning to 6 in the evening. As the sun travels from East to West we can tell the time, just by looking at the shadow. But how did Jai Singh arrive at the measurements of this ginormous triangle?

Imagine placing a vertical rod at the north pole. Now let us place vertical rods all over the Earth’s surface. We know that due to gravity they would all stand perfectly perpendicular to the ground, and if we could zoom out and enlarge these rods they would look like spikes sticking out of a ball. But for us to get uniform time measurements throughout all locations, we

decided that this vertical rod would have to be parallel to the Earths' rotational axis. Now, all these rods are parallel to the axis no matter where you are on Earth! The next thing that we need to pay attention to is the latitude of our particular region, for it will determine the acute angle at which the gnomon should be placed with respect to the ground! If you are in Mumbai, the latitude is 19°, so the angle would be 19°! So on and so forth.

The markings on this instrument go from one hour to the accuracy of 20 seconds. The one at Jaipur, the world's largest sundial, is accurate up to 2 seconds. One can actually see the shadow move on the scale. But... wait! Was this the only way one could tell the time? No, there was a water clock, which could tell the time! This water bowl (ghati/ghatika) was actually a hemispherical copper bowl with a very fine perforation at the bottom. When placed on the surface of water in a larger basin, the water would enter it from below the perforation. Once full, the bowl would sink to the bottom of the basin. The weight of the bowl was so carefully designed that the sinking would take place in precisely 24 minutes, and this immersion would happen 60 times in a day. Only now we have 60 minutes, 24 times a day, and this method was the standard unit of time measurement in India.

The second thing required for the astronomical tables were the locations of the stars and celestial bodies. But how did they actually manage to take these angular measurements? As the celestial bodies are too far away from us, back then we were unable to calculate their accurate distance from the Earth, while standing on Earth. So making Earth as our point of reference, and specifically our latitude, we started to map celestial bodies in the sky. The **altitude** of a celestial body would mean the height at which it is seen in the sky with respect to the horizon. It's the vertical angular distance. The highest altitude would be 90 °, which is also called the **Zenith,** when it's directly above our head. The **Azimuth** is calculated facing the North as we horizontally sweep the ground in a clockwise manner over East, South, West and back to North. It is the horizontal angular distance between the celestial body and pure North. These simple concepts were employed while building these instruments for a layperson as well.

The **Rama Yantra** is an instrument that helps in determining exactly this, the altitude and azimuth of celestial bodies. It is divided into 2 complementary instruments, which when combined become one whole. These cylindrical structures carry a vertical rod (gnomon) at the centre and as the tip of the shadow falls on the graduated scales one can mark the azimuth and altitude from it. If the shadow falls in between two scales, it means that the other instrument should be used for measurements. But if one were to take measurements at night, how would they be possible? Questions like these lead to the practical working of the instruments. But what

makes these instruments so special?

The fact that most of these were the first of their kind in scale and accuracy in naked-eye observations. Any amateur astronomer or even a layperson could easily take readings from these instruments, once the calibrations and basic logic were clear. Most of the instruments were designed by him, based on carefully calculated and deduced values. Apart from being aesthetic architectural buildings, they were actually trigonometry brought to life!

Sawai Jai Singh employed various Hindu astronomers to take readings at the Delhi observatory. He was unable to give most of his time here as another important task lay in front of him. Discussions with **Vidyadhar Bhattacharya,** the town planner, revealed his plans for building a new town in the plains away from the hilly Amber Fort, the town of Jaipur. The two would extensively discuss matters of military needs, rainwater harvesting, and the grid-like pattern of the town allowing for town squares, bazaars and chaupars. He had identified many craftsmen, artisans, and scholars in Jaipur and had offered them residences in the affluent sectors of Jaipur.

As he shifted from Amber Fort to the City Palace of Jaipur he brought together a school of scientists. They were talented mathematicians, astronomers, and town planners. Since, in those days there were no specialists, each one of them was well versed in science as a whole, including subjects such as medicine. In addition, their understanding of and contribution to literature and poetry, history and other subjects, as we now know them, was also considerable. At the royal library, a happening and divinely spacious environment is created by the various scholars of that time. **Keval Ram** wrote on mathematics and astronomy. **Samrat Jagannath** translated Almagest and Tahrir-i-uqlidas, i.e. Plotemy's text on astronomy and geometry of Euclides and other books. **Mohammad Huzoor Allahi** was the author of the first Indian book on logarithms, and the translator of the work of Ulugh Beg. Vidyadhar Bhattacharya assisted the others as he was proficient in Persian. Mirza Khairullah too worked on the Zij. Maharaja Jai Singh overlooked the translation of many important texts in the field of mathematics, astronomy, spherical trigonometry from Middle East Asia and Europe. His library would soon expand to house hundreds of important texts. As the Maharaja was examining one such work of translation he was interrupted by **Father Emmanuel de Figuerado and Padre Manuel.** He informed the two European scientists of his desire to acquire the latest books and advancements in the field of science and astronomy from the West. He stressed the importance of this fact-finding mission to them, as his own Hindu astronomers refused to cross the sea and go to Europe, citing reasons that their caste will get washed off if they cross the sea. Father Figuerado

and Padre Manuel seemed to understand the importance of this mission and reassured the Maharaja that they would return with success. The two of them along with a few other assistants and students set out to Portugal in 1727.

Act 3

With amicable relations between the Marathas, the Maharaja now began to focus on the Jaipur observatory. The instruments to tell the time (Samrat Yantra) and local or ecliptic coordinates (Ram Yantra) were repeated in the Jaipur observatory. The Samrat Yantra at Jaipur was built to be the largest sundial in the world and offered an accuracy of up to 2 seconds. But at noon one could not tell the location of the sun even with the Ram Yantra. Considering that to understand the passage of the sun from East to West over the North and South, one needed a special instrument. The Dakshinotra Bhitti Yantra was capable of recording the position of the Sun at noon. By recording the location of the Sun over an entire year, one could identify the equinoxes and solstices. The onset of seasons, festivals and the celebration of New Year in different cultures was tied to this. The Jaiprakash Yanta, Nadivalaya Yantra and Sastamsa Yantra are equally striking and ingeniously designed instruments. (Visual description follows) Multiple other instruments were constructed at the Jaipur observatory, and astronomers of different parts of the country and world seemed to frequent them.

While the Maharaja was inspecting and discussing the Zij with Samrat Jagannatha and Mirza Khairullah, he was greeted by Father Figuerado and Padre Manuel. The Maharaja, excited to know about the latest developments in astronomy in the West enquired about their travels and findings. They presented a copy of the Tabulae Astronomicae (Astronomical Tables) of Philippe de la Hire, a French mathematician and astronomer. But they did not carry with them the works of Kepler, Newton, Galileo or even Copernicus, for the Jesuits themselves did not believe that the Sun was at the center of our universe. They continued to blindly believe in the Ptolemaic model as well as the canons of Hindu Astronomy blindly. Hence the information fed to Jai Singh by them was heavily outdated. Even though Jai Singh was detached from the latest knowledge in astronomy he continued to build more observatories as he understood the importance of taking multiple readings from different latitudes to then make more accurate tables. He continued to persevere for knowledge and gain assistance from the French Jesuits too. He invited Father Boudier from Chandernagar, a French Jesuit, who came with his telescope to Jaipur.

One day as Jai Singh was walking in the Jaipur observatory at noon, and examining the instruments, he faltered and

fainted. His attendants quickly rushed to him and carried him to his royal chambers. Prince Ishwari Singh rushed over and tended to his father. On recovering, Jai Singh told his son that he wished for him to take up the royal duties and matters of the state, as he was no longer in a condition to handle both the political duties and astronomical pursuits.

With Ishwari Singh now declared as the crown prince, the Maharaja continued to invite scholars, astronomers, and mathematicians from the West. Andreas Strobl and Anton Gabelsberger, Bavarian Jesuits and astroonomers, worked with him from 1740 to 1743, at Jaipur. The Maharaja desired to find more accurate instruments from the West, even after he had built his own observatories. He also planned to send a second fact-finding mission under the guidance of Strobl to Rome. He kept himself occupied with finding newer accurate tables and designing a new instrument, a perpetual motion machine, but in the year 1743 he breathed his last. Ishwari Singh ascended the throne at a difficult time, much like his father. Forced by the fear of an upcoming war, he diverted all his resources to raising an army. With these worries that threatened his own inheritance, he could not continue his father's astronomical tradition. In 1750, seven years after Jai Singh's death, his second son, Madho Singh, ascended the throne and revived the astronomical interests of his father. He built the Miśra yantra of Delhi and had some brass instruments fabricated, which now are in storage at Jaipur. In Madho Singh's own lifetime the Delhi observatory ceased to operate, and its instruments were vandalized for their material.' After Madho Singh, astronomical activities at Jai Singh's other observatories declined tremendously, to the point that the astronomers employed there had no choice but to look for work elsewhere.

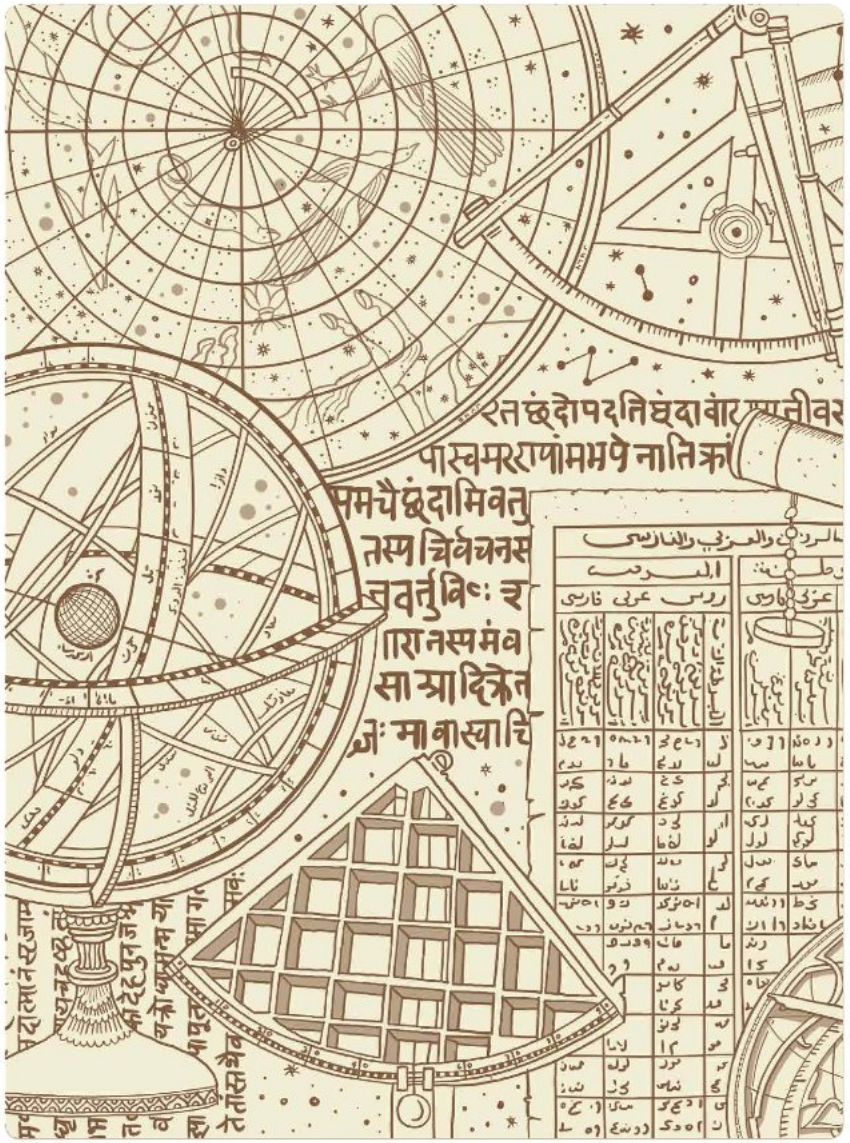
But to live in the times of Jai Singh, times of social and religious intolerance, political clashes and bigotry, he managed to bring together scholars, astronomers, mathematicians of different faiths to work together towards one goal, ushering in a new age of science. Because science had no religion, no nationality. He displayed foresight and immense vigour, as is evident from his astronomical journey and the instruments that stood the test of time.

Currently, the Jaipur observatory functions the best out of all the other ones. Restoration efforts over time, have only sometimes proven helpful. The use of marble on the surfaces was done in one such restoration that was a poor choice. Albeit marble looks very grand and worthy of being used in such a grand structure, the shadow on marble is not as sharp as compared to the shadow on a lime plastered surface. Collaborative efforts between the Archaeological Society of India and Nehru Planetarium, offer hope in terms of restoration efforts. Apart from this, the Jantar Mantar observatories can benefit greatly from regular visits by school

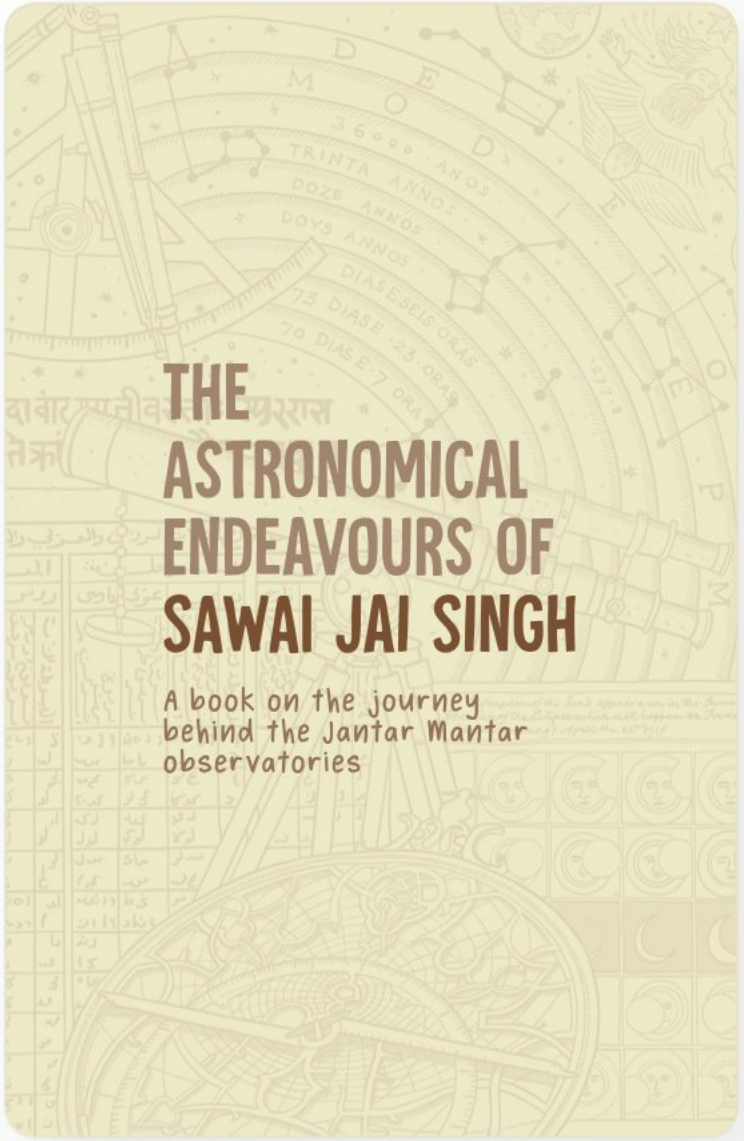
and college students. They can still serve the purpose of open-air laboratories for students and amateur astronomers. And probably the best thing that one can do is discuss and learn about the stars, sun and moon which were worth risking one's life for.

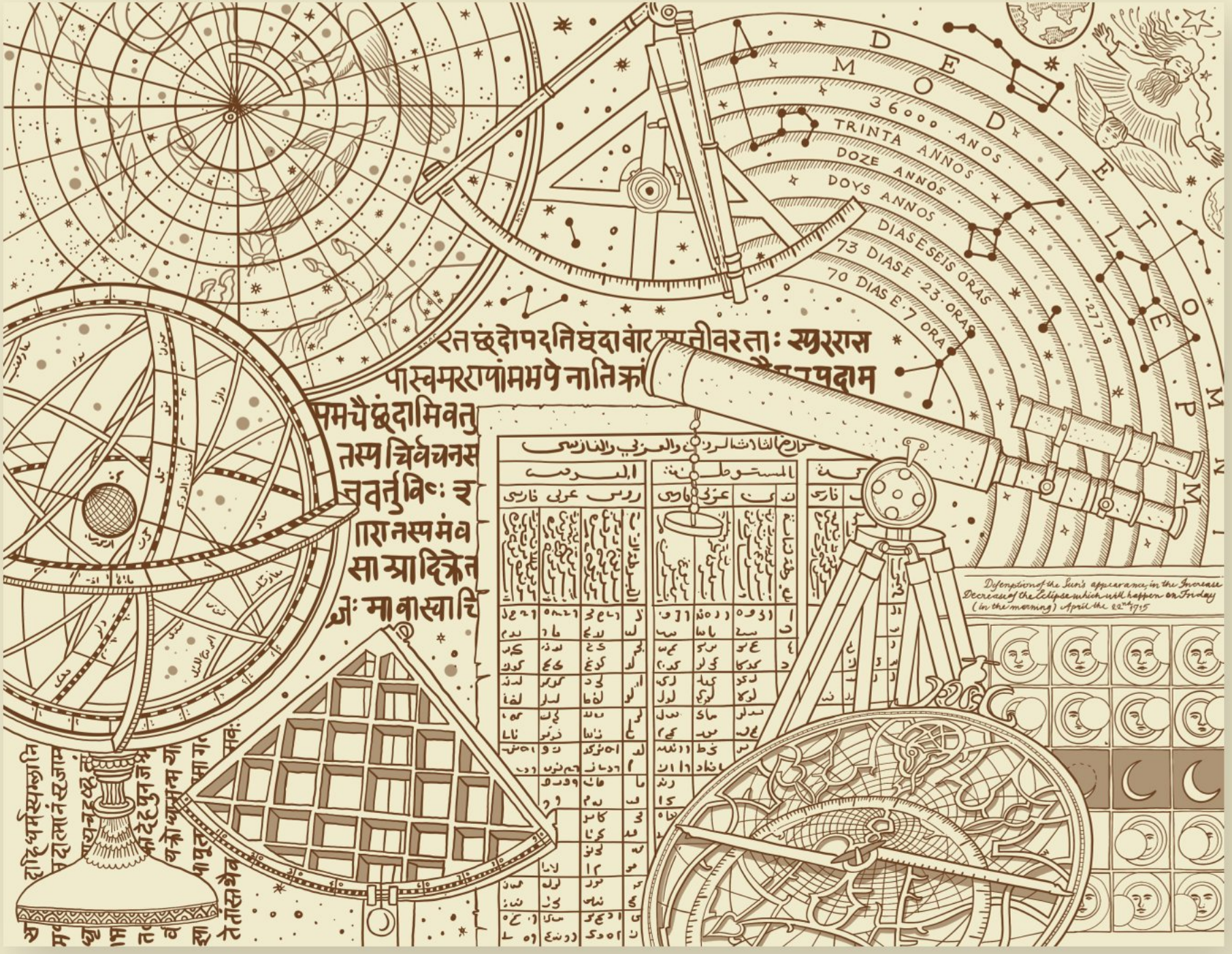
The Visuals: Illustration Style

Similar to the sketches in the storyboards, the illustrations would be outlined and filled, as shown in the adjoining image. The colour palette is kept monochromatic as it allows us to absorb the details of the artwork without the hindrance of multiple colours.

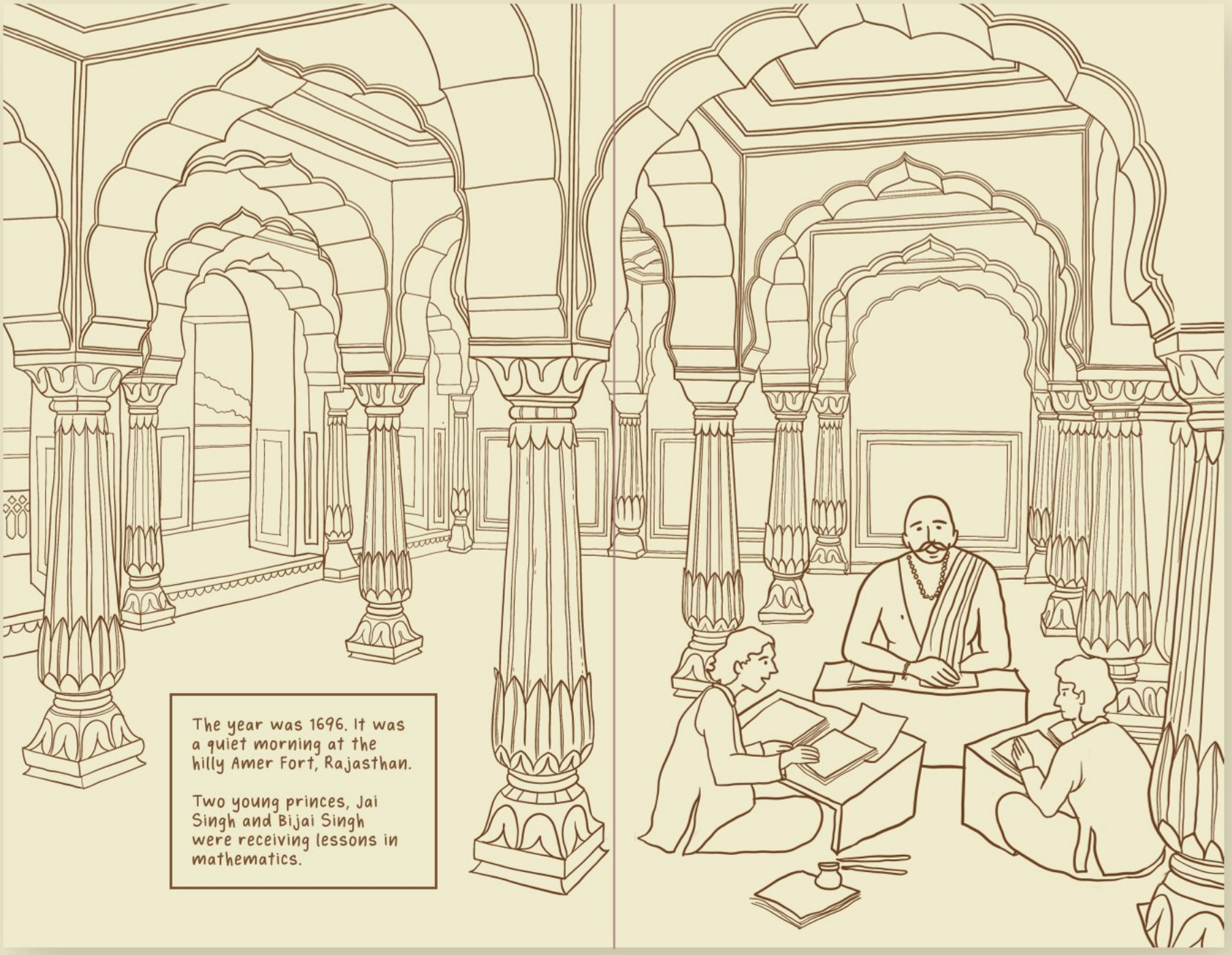


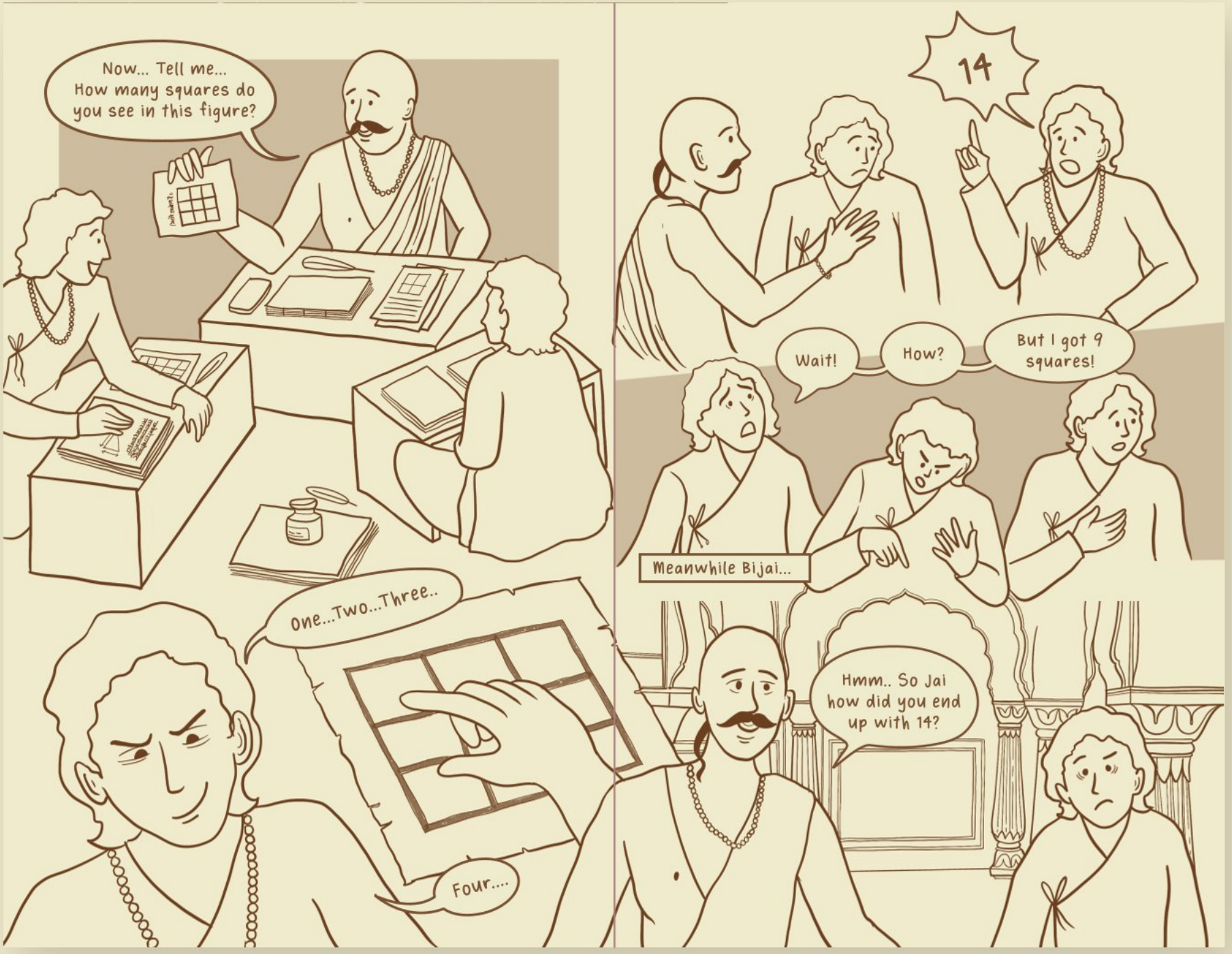
Excerpts from the Final Book

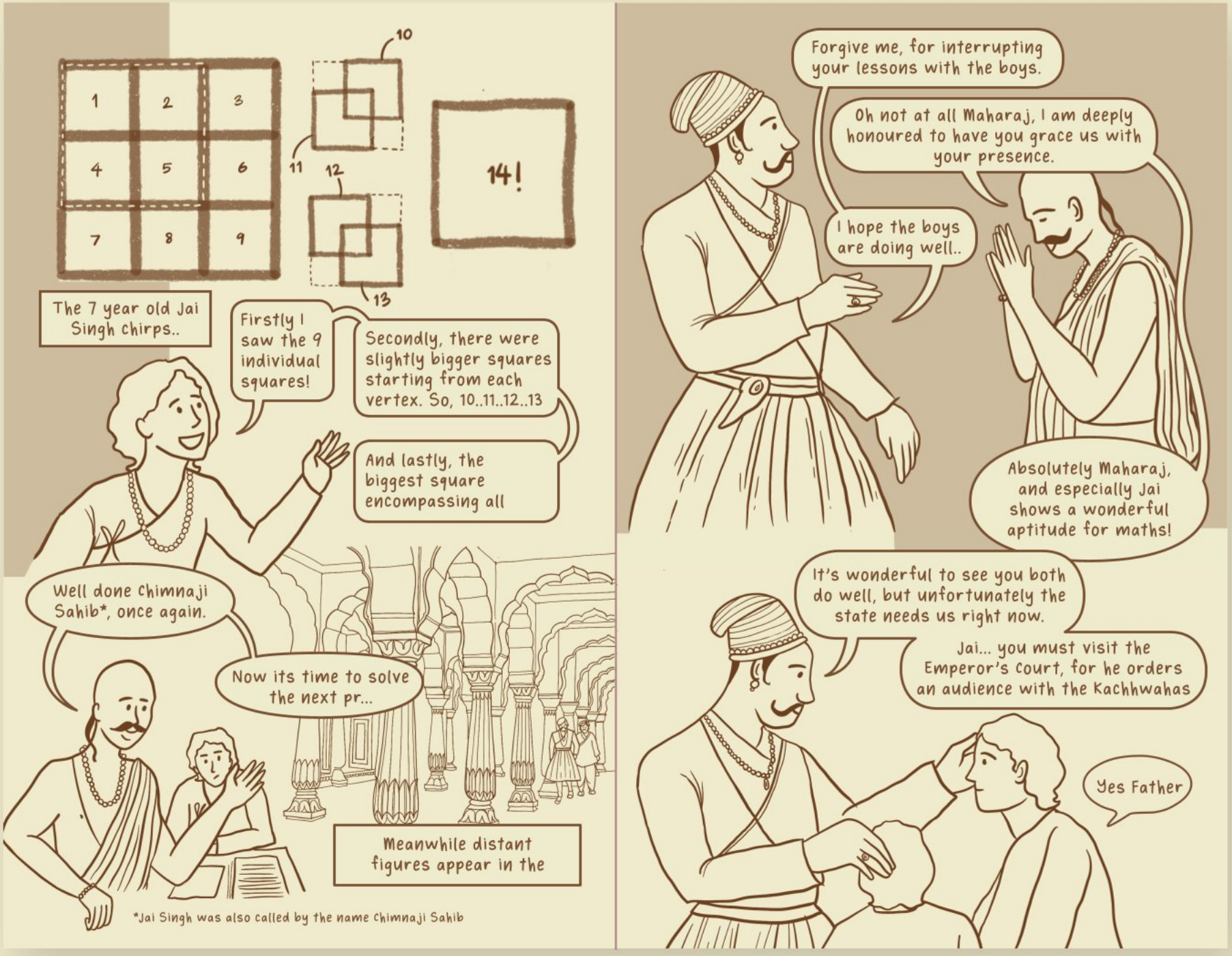



DE MODO DITTEOPM
36000 ANOS
TRINTA ANNOS
DOZE ANNOS
DOYS ANNOS
DIASESEIS ORAS
73 DIASE 23 ORAS
70 DIAS E 7 ORA
277.8
Description of the Sun's appearance, in the Increase
Decrease of the Eclipse which will happen on Friday
(in the morning) April the 22nd 1715

CHAPTER I
THE BIRTH OF A CURIOUS MIND


The year was 1696. It was a quiet morning at the hilly Amer Fort, Rajasthan.
Two young princes, Jai Singh and Bijai Singh were receiving lessons in mathematics.


Now... Tell me... How many squares do you see in this figure?
One...Two...Three..
Four....
14
Wait!
How?
But I got 9 squares!
Meanwhile Bijai...
Hmm.. So Jai how did you end up with 14?


1
2
3
4
5
6
7
8
9
10
11
12
13
14!
The 7 year old Jai Singh chirps..
Firstly I saw the 9 individual squares!
Secondly, there were slightly bigger squares starting from each vertex. So, 10..11..12..13
And lastly, the biggest square encompassing all
Well done Chimnaji Sahib*, once again.
Now its time to solve the next pr...
Meanwhile distant figures appear in the
*Jai Singh was also called by the name Chimnaji Sahib
Forgive me, for interrupting your lessons with the boys.
Oh not at all Maharaj, I am deeply honoured to have you grace us with your presence.
I hope the boys are doing well..
Absolutely Maharaj, and especially Jai shows a wonderful aptitude for maths!
It's wonderful to see you both do well, but unfortunately the state needs us right now.
Jai... you must visit the Emperor's court, for he orders an audience with the Kachhwahas
Yes Father

The obedient prince, at once set for the court. Little did he know that though his studies would be temporarily halted, he would gain the title 'Sawai' from the Emperor Aurangzeb himself.

Sawai literally means a quarter over one in strength and / or intelligence.

He then proceeded to stay at the court for two more years, learning about the administration of state affairs.

On returning home in 1698, he resumed his studies. As a Rajput Prince he was trained in multiple aspects. Cultural Arts, Literature, Martial Arts, and so much more...

He learnt languages like Dingal, Sanskrit, and Persian, as well as Arabic and Turki.

Horse-riding...

Sword Fighting...

And archery were a must for any Rajput

In 1698, their father, Bishan Singh was posted in Kabul, so Jai would write letters to keep him updated on their progress.

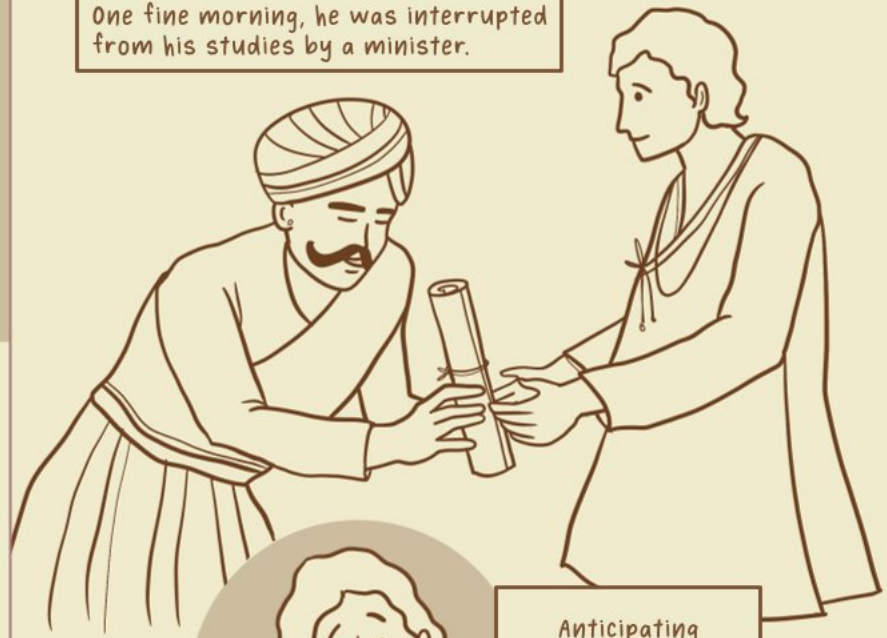
Matters of the state, the position of crops, the water levels in the state, all matters were informed to the King.

In return, his father would keep them updated with the developments in Kabul with the Mughal Empire.

Jai Singh continued his studies under the care of his mother and learned tutors.

The stories of his ancestors, incidents of the Mughal Court, the numerous Emperors & their Begums and princes, as well as the battles & sieges in distant lands, kept him thrilled & engaged to learn more.

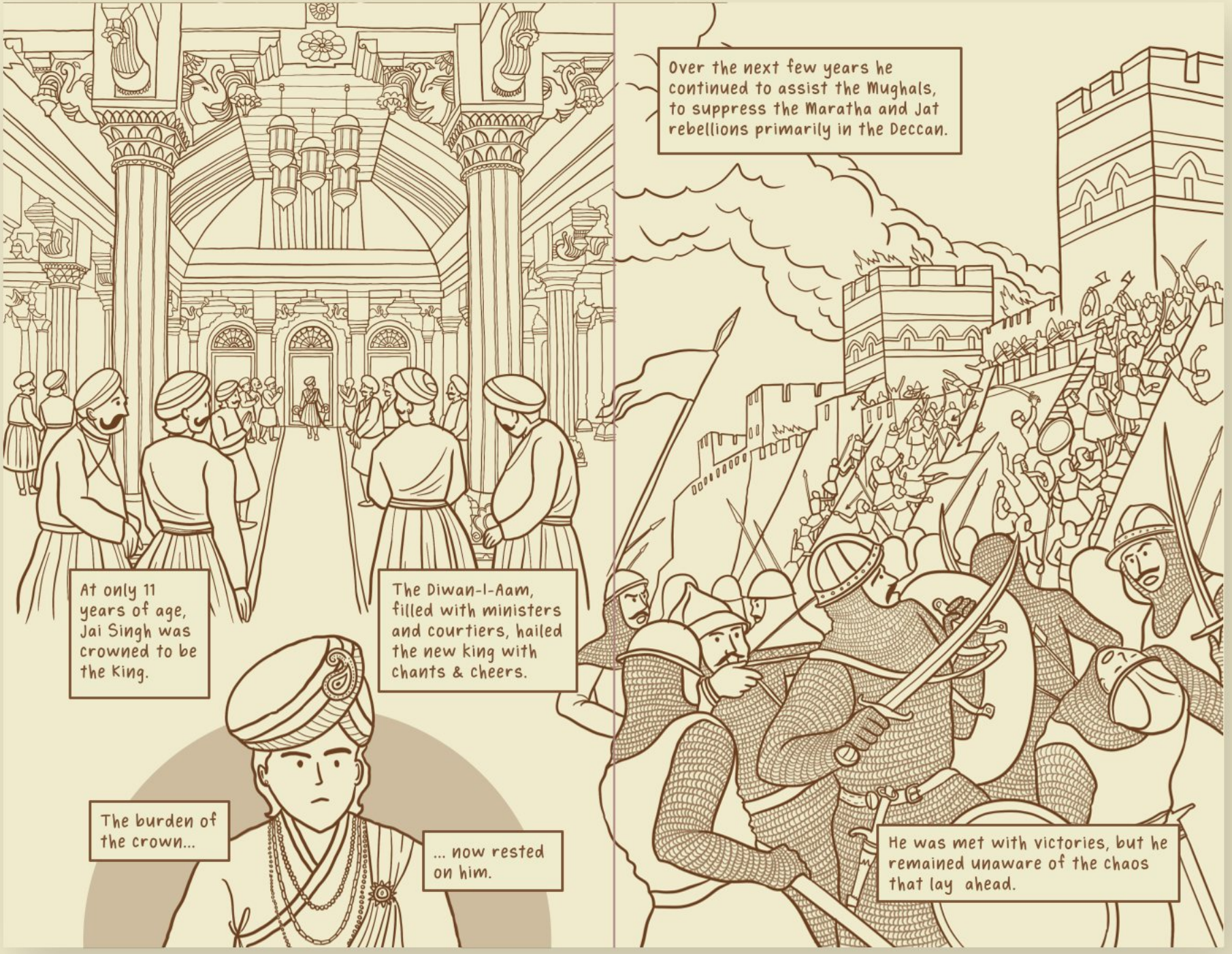
One fine morning, he was interrupted from his studies by a minister.

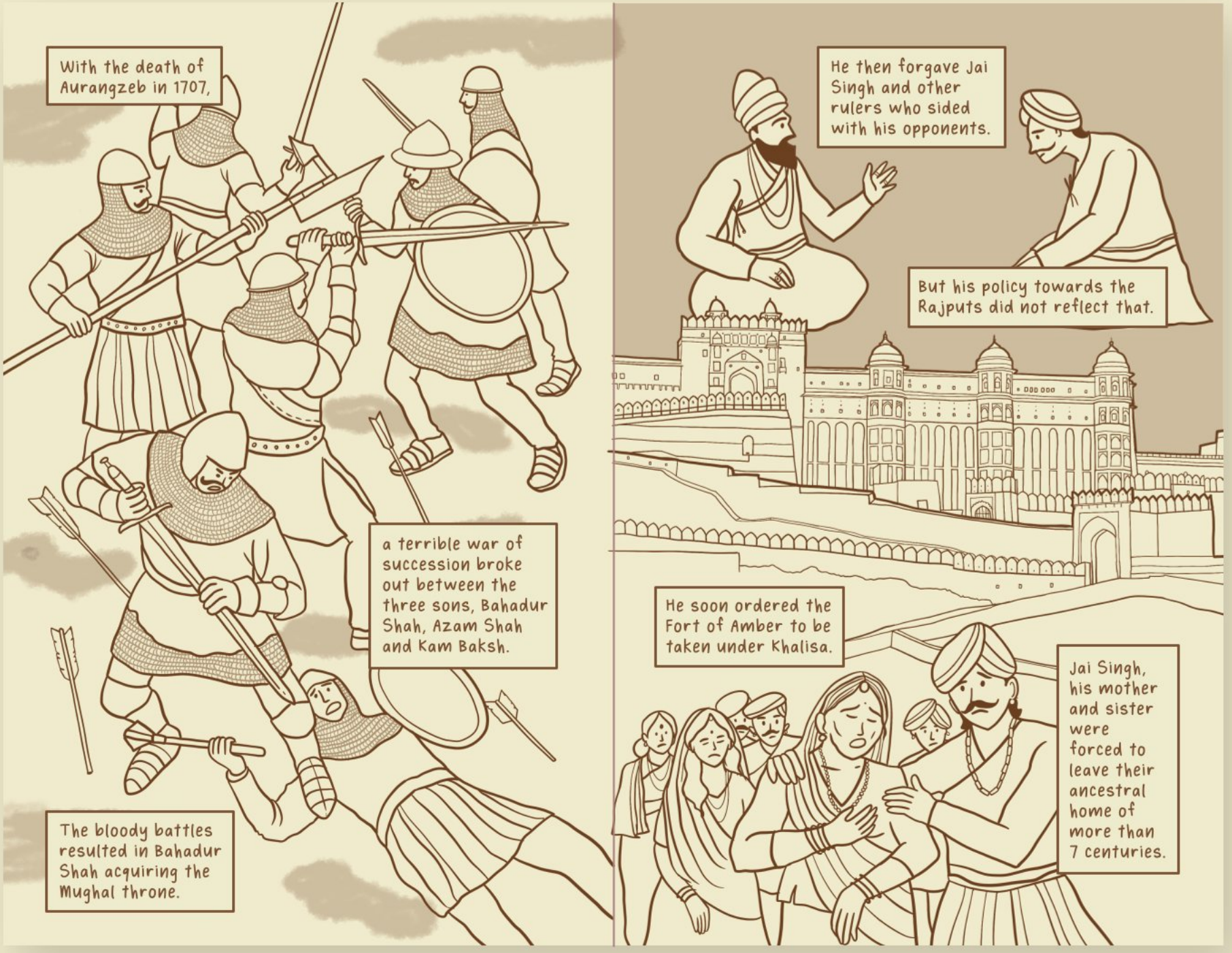


Anticipating a letter from his father, he promptly started to read it.

But alas...

The letter carried the news of his father's death...


At only 11 years of age, Jai Singh was crowned to be the King.
The Diwan-I-Aam, filled with ministers and courtiers, hailed the new king with chants & cheers.
The burden of the crown...
... now rested on him.
Over the next few years he continued to assist the Mughals, to suppress the Maratha and Jat rebellions primarily in the Deccan.
He was met with victories, but he remained unaware of the chaos that lay ahead.


With the death of Aurangzeb in 1707,
a terrible war of succession broke out between the three sons, Bahadur Shah, Azam Shah and Kam Baksh.
The bloody battles resulted in Bahadur Shah acquiring the Mughal throne.
He then forgave Jai Singh and other rulers who sided with his opponents.
But his policy towards the Rajputs did not reflect that.
He soon ordered the Fort of Amber to be taken under Khalisa.
Jai Singh, his mother and sister were forced to leave their ancestral home of more than 7 centuries.


%#!
$#&
@!#
@!#
As things slowly began to settle down, Jai Singh continued to be a frequent visitor at the court.
But one day, a noisy debate broke out...
ENOUGH!!
Two distinct groups of nujumis were arguing on fixing an auspicious date, for the Emperor to begin an important journey.
Jai Singh quickly realized that the two groups were following 2 different calendars!
Your Majesty, these two calendars confuse the best of us? What about the common people?!
We ought to build an accurate calendar, which can be followed across our land!
Since you who are learned in mysteries of science and have a perfect knowledge of this matter,
would be doing a great service in correcting the differences between the calendars!
It would be an honour.
And so began the journey of building the celestial observatories...

Learnings

While working on this project, I had the opportunity to be amazed by the subject of astronomy. Not only was I able to work on the visualization of these concepts, but I was also able to weave together history, politics and science through a story. Before arriving at this topic, the material read prior to it, was equally riveting and exciting. This is probably the main reason, why it was hard for me to focus on one topic and it poses a wonderful opportunity for me to try and work on them as separate graphic novels. Stories of the past and how they shape the future is a theme that I always wished to explore.

The challenge in this project was to actually first understand how these instruments work in principle and then begin explaining them, with the help of words and visuals. It was attempted as an amalgamation of a comic book and textbook, which would educate the children as they grow curious about what happens next. I also learnt the nuances of framing a sequence and trying to communicate them in an effective way. From reading multiple books on the subject to finalizing a story and shaping it up to be a concise narrative of the topic, as well as understanding the medium of a graphic novel, this project has truly been very special.

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