Spoken text and written symbol: the use of layout and notation in Sanskrit scientific manuscripts

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Because of the traditional reverence for oral composition and recitation in Sanskrit literature, most Classical Sanskrit treatises, including scientific ones, were composed in verse and intended (at least in theory) for memorization. Written versions of Sanskrit texts are often presented in imitation of their ideal oral form, as an almost continuous and unformatted stream of syllables. Manuscripts of technical works on subjects such as mathematics and astronomy, however, had to combine this "one-dimensional" text stream with graphical and notational features generally requiring two-dimensional layout, such as tables, diagrams, and equations. The ways in which this synthesis could be achieved posed several significant challenges for Sanskrit scribes.

In fact, the notion of a Sanskrit scientific manuscript is in some respects almost a contradiction in terms. The following quote illustrates a longstanding attitude of skepticism towards written texts in the Sanskrit intellectual tradition:

> *pustakasthā tu yā vidyā parahastagataṃ dhanaṃ* |
>
> *kāryakāle samutpanne na sā vidyā na tad dhanam* ||
>
> Knowledge which is in a book, money in someone else's hand: when the time comes to use it, that knowledge or that money is not there. (*Cāṇakya-nīti-śāstra* 16.20)

The earliest surviving form of Sanskrit is venerated as a divine speech in which the ancient Indian sacred texts called the Veda were (and still are) recited and transmitted. Most of them are composed in metrical verse, and pandits developed a complicated system of mnemonic cues and memory training to ensure that they were preserved in an oral tradition with every syllable and accent intact. This focus on orality also seems to have inspired the early Indian interest in phonetics and grammar, and the very sophisticated analyses of these subjects dating back to the late first millennium BCE.

At the same time, Indian literature developed a strong dependence on the written word. The traditional oral instruction and explanation that had routinely accompanied the teaching of memorized texts crystallized into written prose commentaries that were disseminated along with, and sometimes instead of, the original verse compositions. The spread of

literacy and of intellectual addiction to literacy is thus far familiar in other ancient cultures as well. But the Sanskrit tradition was unique in its persistence in venerating and preserving the ideal of an oral intellectual tradition, even after it had become inseparable from written documents. Sanskrit manuscripts, especially in the sciences, thus represent a paradox: they are a testimony in writing to the supremacy of speech, and this dual nature is reflected in many of their characteristic features.

Some helpful guidance for the modern reader exploring the world of Sanskrit scientific manuscripts can be found in the words of an earlier "Western" scholar confronting these documents in light of his own culturally defined notion of what a book ought to be. Although he lived nearly a thousand years ago, many of his reactions are easy for moderns to empathize with, coming to a large extent from a shared intellectual tradition. He was Abū Rayḥān Muḥammad ibn Aḥmad al-Bīrūnī, the great eleventh-century polymath from Khwarezm in what is now Uzbekistan, who lived many years as part hostage, part protégé of the Ghaznavid sultans at their court in northwest India. While there, he learned some Sanskrit, and learned more of Sanskrit literature in translation, after which he composed a comprehensive work in Arabic called *Kitāb fī Taḥqīq mā li'l-Hind* or *Investigation of what is in India*. Many of his remarks on Indian customs and literature touch on the topic of books:

> The scientific books of the Hindus are composed in various favourite metres, by which they intend, considering that the books soon become corrupted by additions and omissions, to preserve them exactly as they are, in order to facilitate their being learned by heart, because they consider as canonical only that which is known by heart, not that which exists in writing. [Sachau, p. 19]
>
> They do not allow the Veda to be committed to writing, because it is recited according to certain modulations, and they therefore avoid the use of the pen, since it is liable to cause some error, and may occasion an addition or a defect in the written text. [Sachau, pp. 125–126]
>
> By composing their books in metres they intend to facilitate their being learned by heart, and to prevent people in all questions of science ever recurring to a *written* text, save in a case of bare necessity. . . They do not want prose compositions, although it is much easier to understand them. [Sachau, pp. 136-137]

Despite the official preference for memorized texts, the Indic manuscript tradition expanded prodigiously. It constitutes at the present time the largest group of handwritten documents in the world: over thirty million Sanskrit manuscripts were estimated in the late twentieth century to be extant in collections in India and elsewhere.[1] Perhaps as much as one-tenth of the total contains material in the traditional exact sciences such as mathematics, astronomy and astrology.

[1] Thirty million was the total estimated by David Pingree [Calder and Heilen, p. 522]; a more conservative figure of approximately five million manuscripts in India alone is suggested in [Goswamy].

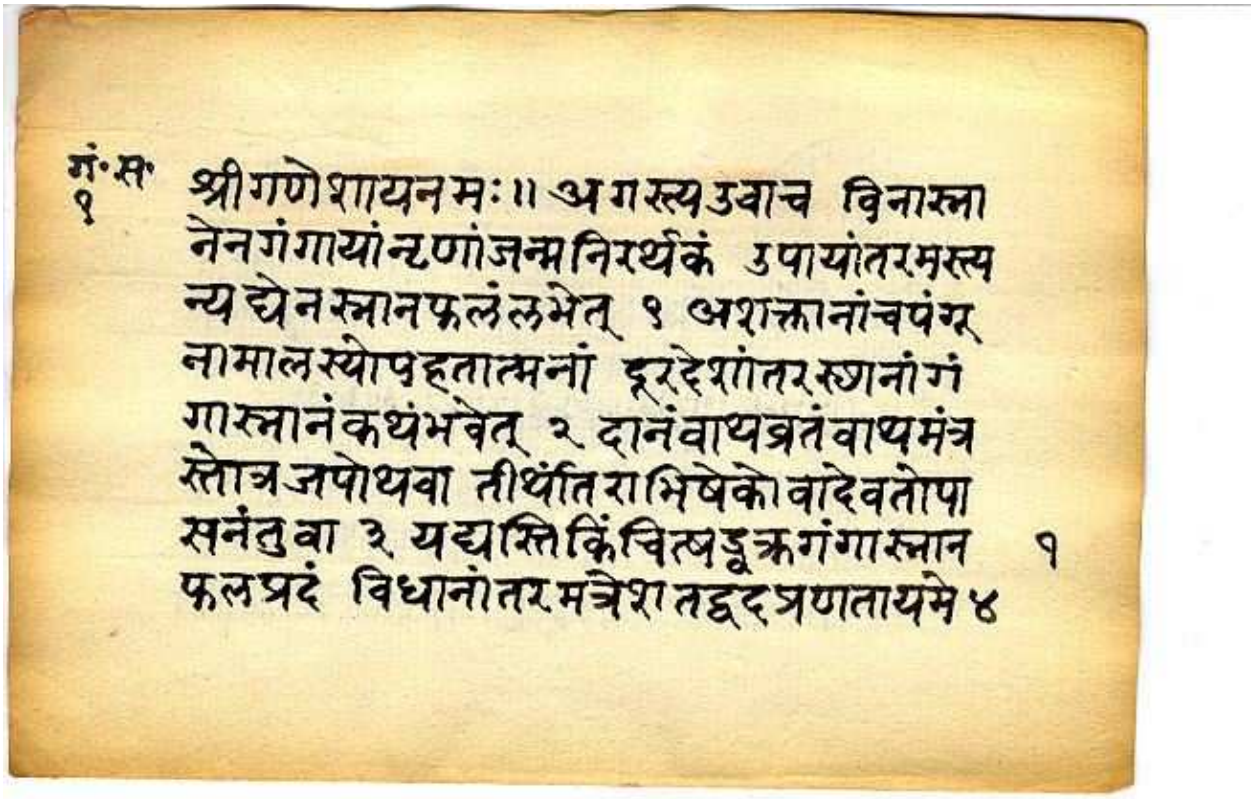

गं॰स॰ १
श्रीगणेशायनमः॥ अगस्त्यउवाच विनास्ना
नेनगंगायांनृणांजन्मनिरर्थकं उपायांतरमस्त्य
न्यद्येनस्नानफलंलभेत् १ अशक्तानांचपंगू
नामालस्योपहतात्मनां दूरदेशांतरस्थानांगं
गास्नानंकथंभवेत् २ दानंवाथव्रतंवाथमंत्र
स्तोत्रजपोथवा तीर्थंतराभिषेकोवादेवतोपा
सनंतुवा ३ यद्यस्तिकिंचित्तदुक्तंगंगास्नान १
फलप्रदं विधानोतरमत्रेश तद्वदप्रणतायमे ४

Figure 1: First page (folio 1v) of the Purāṇa text *Gaṅgā-sahasra* (Philadelphia, University of Pennsylvania Libraries, Penniman-Gribell Collection, no. 2332)

The physical form of these books whose users traditionally sought to avoid books was conservative in its development. Over the period it took the Western manuscript to morph from a parchment or papyrus roll into a codex, the Sanskrit manuscript seems to have persisted in its original form as a collection of unbound pieces of palm-leaf or birch-bark. As al-Bīrūnī reported,

> They bind a book of these leaves together by a cord on which they are arranged, the cord going through all the leaves by a hole in the middle of each. . . The proper order of the single leaves is marked by numbers. The whole book is wrapped up in a piece of cloth and fastened between two tablets of the same size. [Sachau, p. 171]

The oblong shape (with the horizontal dimension larger than the vertical) was determined by the longitudinal veins of the palm leaves, and was conventionally preserved in birch-bark and later in paper manuscripts as well.

Al-Bīrūnī commented on other characteristics that he evidently found unfamiliar or noteworthy:

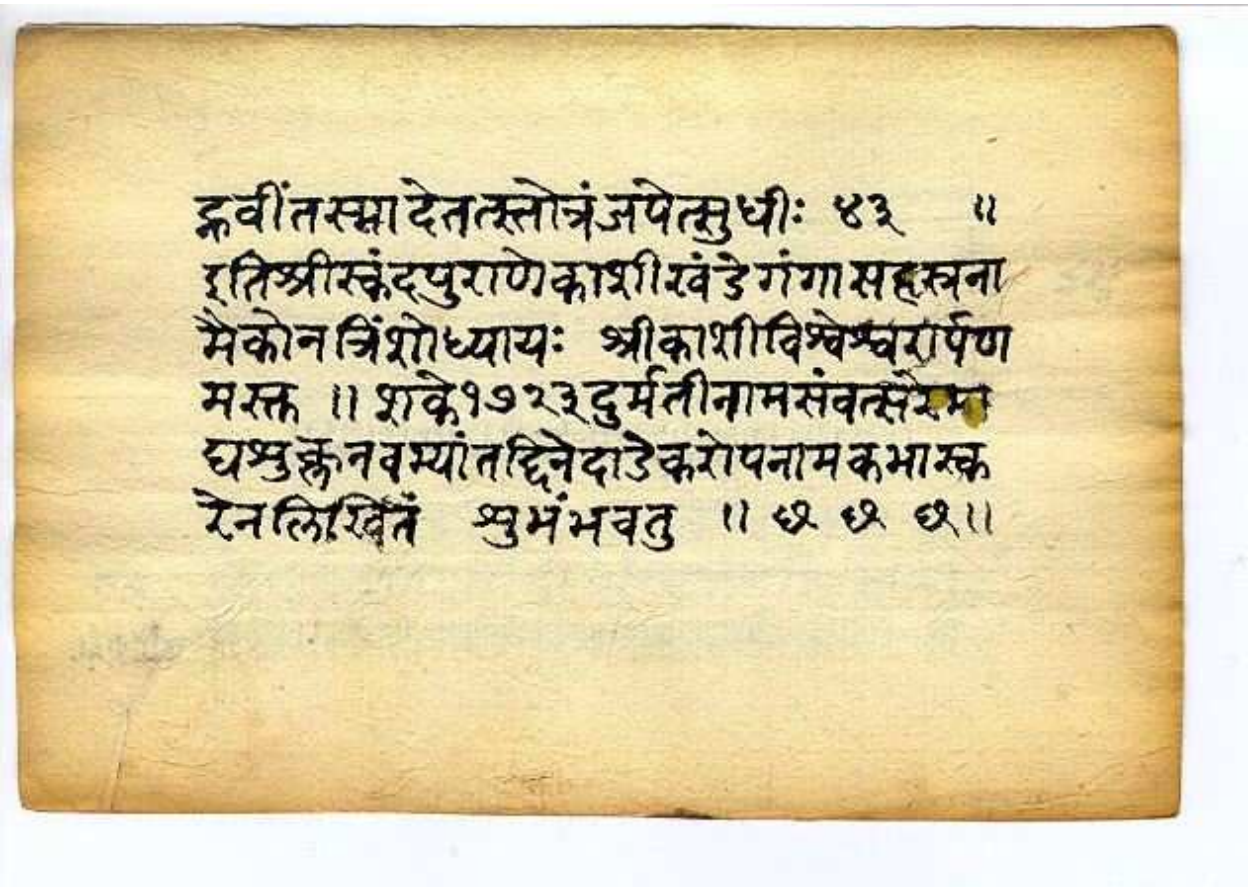


Figure 2: Final page (folio 28r) of the *Gaṅgā-sahasra* (Philadelphia, University of Pennsylvania Libraries, Penniman-Gribell Collection, no. 2332)

> Indian scribes are careless, and do not take pains to produce correct and well-collated copies. . . [an author's] book becomes already in the first or second copy so full of faults, that the text appears as something entirely new. [Sachau, p. 18]
>
> The Hindus begin their books with *Om*, the word of creation. [Sachau, p. 173]
>
> They write the title of a book at the end of it, not at the beginning. [Sachau, p. 182]

We cannot test al-Bīrūnī's assertions on Sanskrit manuscripts contemporary with his own experience of them. Due to the rigors of climate, very few Indian manuscripts predating the past three or four centuries have survived to the present. But many later examples attest to the conservatism of the tradition, as well as to its gradual modification. For example, the manuscript leaf shown in figure 1, a Purāṇa text in the collection of the University of Pennsylvania, omits the central hole for a binding-cord, but retains the classic oblong shape. It commences not with the sacred syllable *om* but with another standard

introductory invocation, *śrīgaṇeśāya namaḥ*, or "Homage to [the deity of beginnings,] Lord Gaṇeśa". After that, it is just a continuous transcription of the verses of the text.

The writing shows the few standard notational marks of the typical Sanskrit manuscript: the folio number in the upper left and lower right margins; the verse numbers punctuating the sequence of verses; and (in the first line) the double vertical bars or *daṇḍas* that serve as a generic punctuation mark. (The diagonal pattern in the verse numbers reflects the fact that in Sanskrit, the phonetic unit of writing is the syllable rather than the individual vowel or consonant. Verses with the same number of syllables tend to take up about the same amount of linear space to write out, and thus tend to fall into periodic-looking patterns when written.) Other than that, the text is not formatted in any way, but rather reproduced on the page as a stream of syllables, just as it would be recited orally.

The end of the manuscript, as al-Bīrūnī remarks, is where the identification of its content appears. The end of the abovementioned manuscript is shown in figure 2. After the final verse number (43), the text concludes:

> Thus the twenty-ninth chapter called *Gaṅgā-sahasra* in the *Kāśī-khaṇḍa* in the revered *Skanda-purāṇa*. May it be an offering to Kāśī-Viśveśvara [Śiva]. In the year Śaka 1723 [1801 CE], called Durmatī [in the sixty-year Jupiter cycle], on the ninth [lunar] day of the waxing fortnight of [the month] Māgha, [it was] written [copied] by Bhāskara surnamed Dāṃḍekara. May it be auspicious.

Here the text of the work is primarily a spoken composition, with what might be called a lapse into conscious literacy at the end.

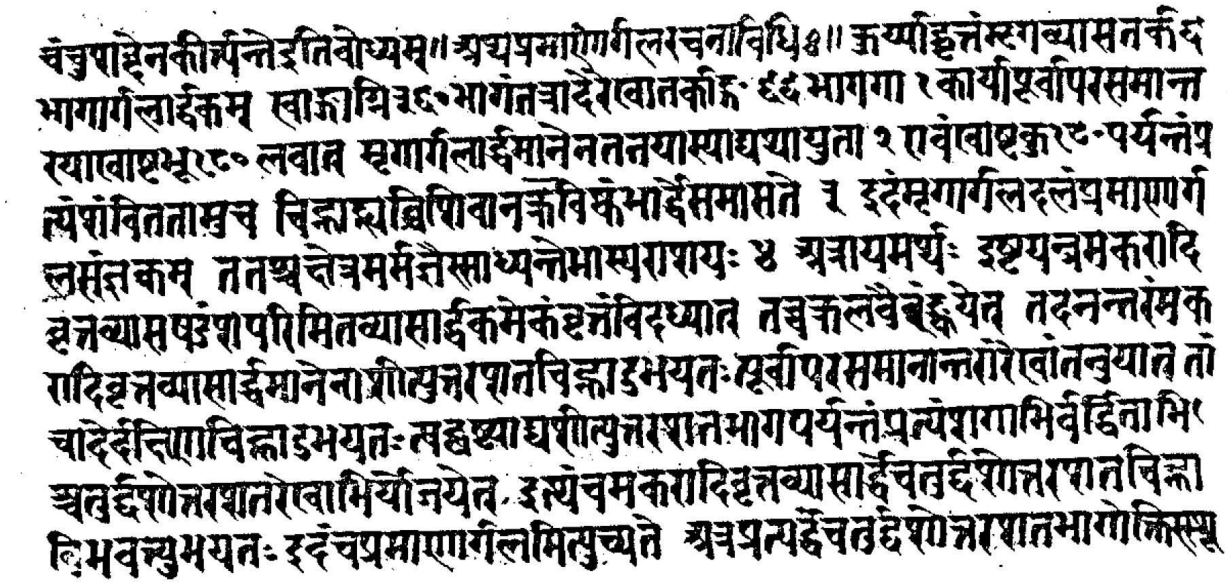


Figure 3: Versified number words and numerals in an astronomical manuscript (Varanasi, Sampurnanand Sanskrit University, no. 35245)

The purely oral format is not ideally suited to scientific texts, especially to their expository apparatus of commentary, worked examples, tables and figures, and in particular, numerical values. Number-words are notoriously difficult to fit into a metrical verse structure, since they are so rigid in their meaning and format. Indian scientists around the first few centuries of this era circumvented this problem in writing scientific verse by means of the so-called *bhūta-saṅkhyā* or "object number" system [Sarma, pp. 38–41], described by al-Bīrūnī as follows:

> For each number they have appropriated quite a great quantity of words. Hence, if one word does not suit the metre, you may easily exchange it for a synonym which suits. [Pseudo]-Brahmagupta says: "If you want to write *one*, express it by everything which is unique, as *the earth*, *the moon*; *two* by everything which is double, as, *e.g.*, *black* and *white*; *three* by everything which is threefold; the *nought* by *heaven*, the *twelve* by the names of the sun." [Sachau, p. 177]

In manuscripts, such "concrete numbers" were generally accompanied by their written numeral equivalents, as in the examples seen in figure 3, which shows a page from an 1820 copy of an astronomical treatise composed a few decades earlier. Near the start of the second line is the compound *kha-aṅga-agni*, "void-limb-fire", immediately followed by the numerals "360". "Void" signifies zero, "limb" six (from the conventional six limbs or supporting disciplines of the sacred Veda), and "fire" three (from the three fires used in worship rituals). Concrete numbers and original Sanskrit number-words could be mixed in such compounds, as in the first word of line 3, *kha-aṣṭa-bhū*, "void-eight-earth", "180".

The design of this concrete-number system, a post-literate development in Sanskrit verse, seems to have been inspired specifically by the written form of numerals in decimal place-value notation: "zero-six-three" rather than the traditional verbal presentation "three hundred and sixty". It is not clear why the digit-stream of a concrete number was ordered from the least significant to the most significant digit, rather than the other way around. A decimal place-value numeral would naturally have been written in left-to-right Indic scripts with its most significant digit first. Whatever its origin, this least-to-most-significant ordering seems to have been fixed in the concrete-number notation before its earliest recorded use. And of course, an absolutely rigid ordering convention would be necessary for the notation to be useful, as there is no way to tell from the strings of verbally encoded digits themselves whether the first or the last is supposed to represent the units place.

As seen in the examples in figure 3, numerals accompanying concrete-number words in manuscripts were simply inserted into the text stream, not graphically distinguished in any way from verse numbers. Moreover, the verse numbers themselves might temporarily disappear from the text stream (as in the page shown in the figure, where the diagonal pattern of verse numbers 1-2-3-4 is not continued by a 5) because the sequence of numbered verses in the base-text was interrupted by a patch of commentary in prose. The written text is thus a sometimes confusing mix of oral and visual features, maintaining a linear flow.

The strong strain of orality persisting in this manuscript tradition may have exciting implications for the study of pedagogical methods in Sanskrit science. The late David

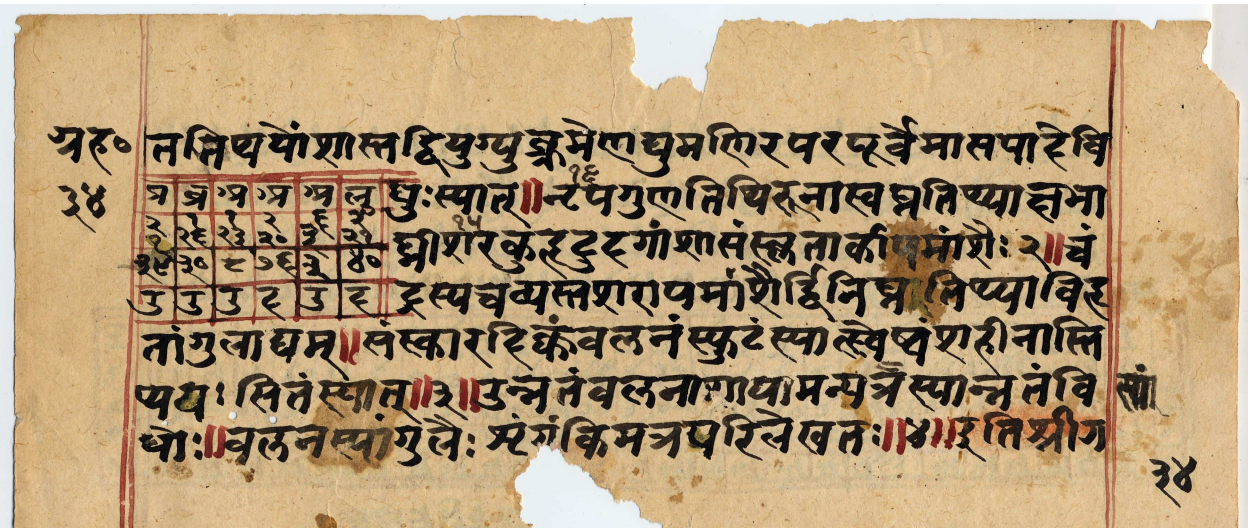


Figure 4: Numerical tables and decoded numerals in an astronomical handbook (commentary on *Graha-lāghava* of Gaṇeśa, f. 34r; manuscript in private collection)

Pingree maintained that the style of certain astronomical commentaries strongly suggests that they were essentially verbatim transcriptions of oral instruction: class lecture notes, as it were [Pingree "Schools"]. We are used to thinking of a commentary as a writer's engagement with a written text; what we may have in addition within the Sanskrit scientific tradition is the alternative concept of a commentary as a written record of a spoken lecture.

We cannot infer too much from this possibility, however, since we also frequently see scientific manuscripts that are clearly not continuous verbal productions but contain more temporal layers, as illustrated in figure 4. This manuscript of a sixteenth-century astronomical handbook shows a purely visual feature, a table placed in a box display to one side of the text stream. As is usual in Sanskrit scientific manuscripts but less so in Western ones, the table is not referenced or described in the text itself: it is literally a silent accompaniment to the words of the book.

We can also see evidence of a scribe's or reader's choices in the addition of numerals above the corresponding number words occurring in the verses as originally copied. In line 2 there is a small "16" inserted above the word *nṛpa* or "ruler", a conventional concrete number for sixteen. In the line below, "15" is similarly written in above the concrete number *śara-ku*, "arrow-earth" (where "arrow" stands for the metaphorical five arrows of the love-god Kāma).

The insertion of numerals as an artifact of the scribal process is also attested by careless placement of them where they are not appropriate. For example, a scribe will sometimes encounter the word "earth" or "moon" and write the numeral "1" following it, even when the word in the text as originally composed is meant solely in its physical sense and not as a number.

This blurring of the roles of word and numeral can have repercussions in scribal prac-

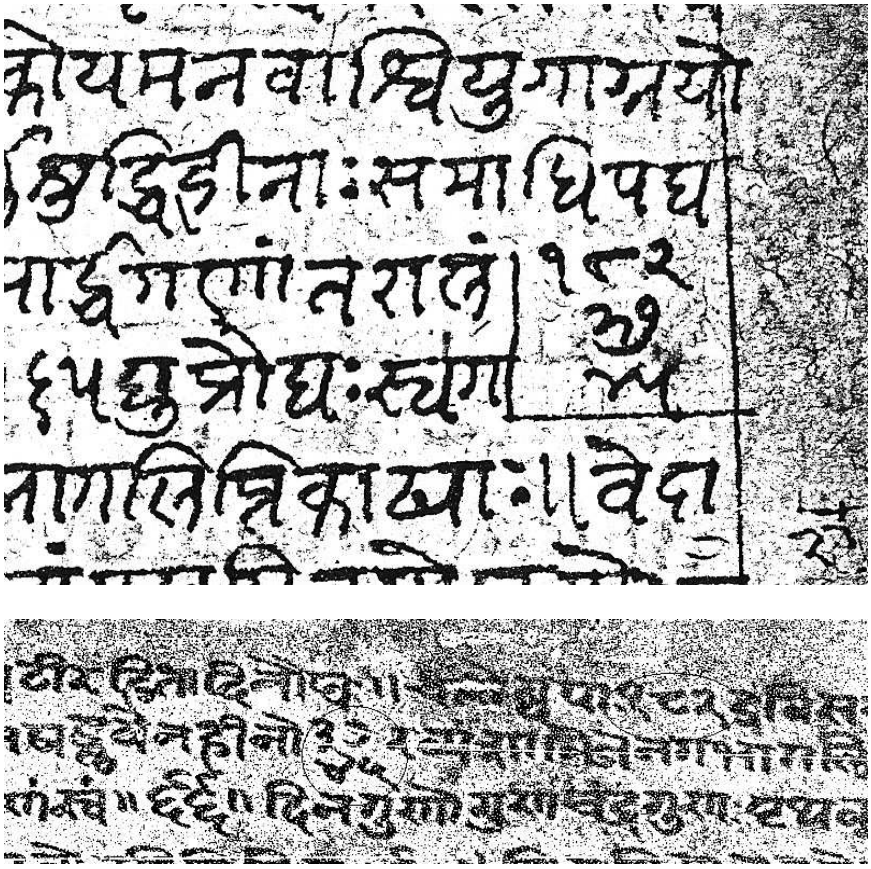
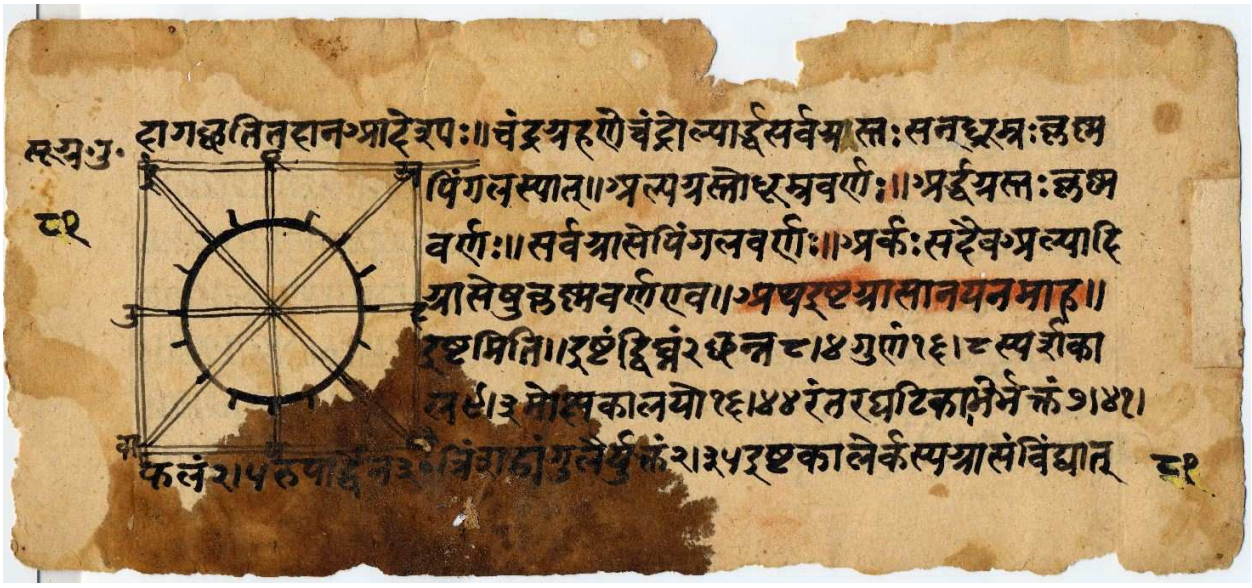


Figure 5: Displayed numbers correctly and incorrectly copied in two manuscripts of the same work (top: Varanasi, Sampurnanand Sanskrit University, no. 35566, f. 39v; bottom: Pune, Bhandarkar Oriental Research Institute, no. 860 of 1887–91, f. 5v)

tice where it is not completely clear which numbers accompany specific words in a text and which are standalone displays. Figure 5 shows partial images of leaves from two manuscripts of the same text, which display the same group of numbers: 182, 37, 45. But in the second manuscript, the scribe has mistakenly perceived these numbers in his source as belonging with different words on different lines of the text rather than grouped separately in a display. So he has copied them in different places, on the first and second lines of the excerpt.[2] This sort of misreading is not uncommon, and can render the role of the copied numerals incomprehensible in one or two iterations of miscopying. The scribal "carelessness" that al-Bīrūnī grumbled about seems in this case to signify a lesser importance attributed to these appended numerals; they are carried along with the text stream, but are not really seen as part of its structure, and their inclusion and placement are not crucial to the correctness of the words of the text.

[2]The same example is more briefly described in [Plofker, p. 533].



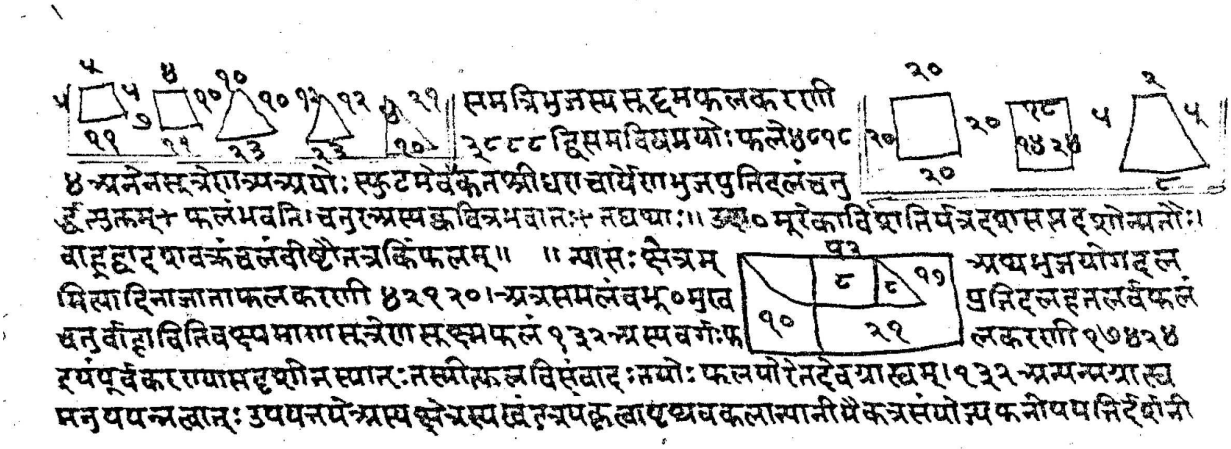


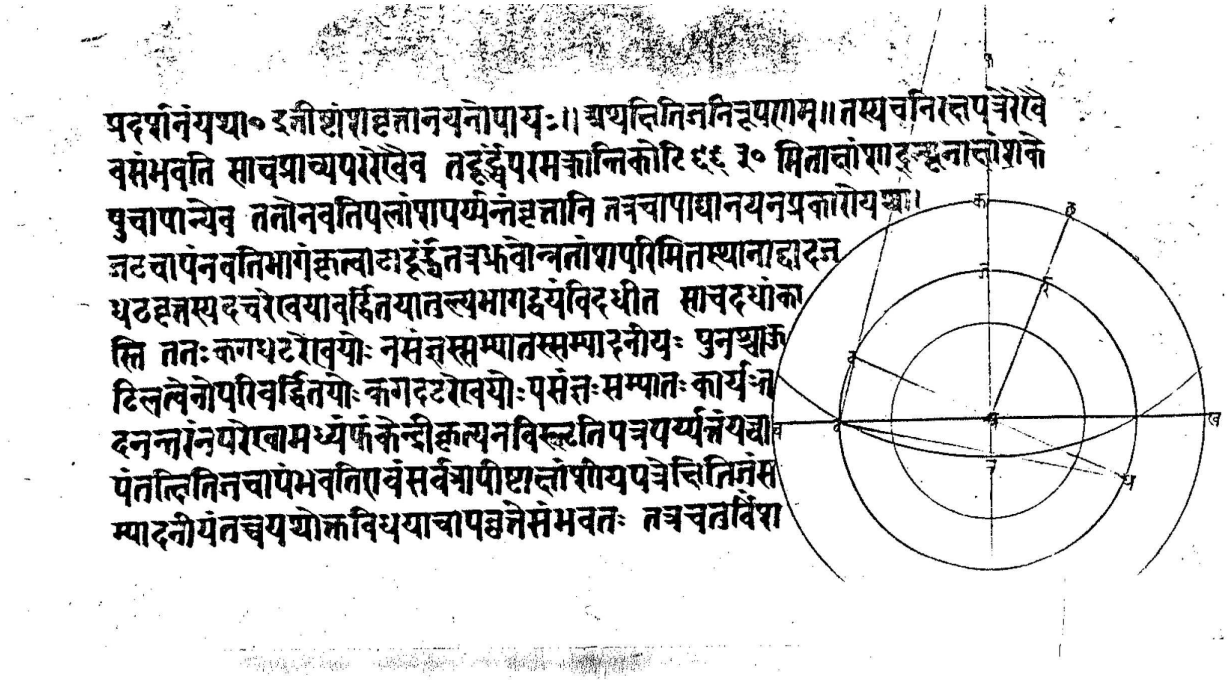
Figure 6: Diagrams in an astronomical manuscript (f. 81v in the MS of Figure 4) and a mathematical one (Varanasi, Sampurnanand Sanskrit University, no. 104595, f. 58v)

The remaining major type of non-verbal feature in a scientific manuscript is, of course, the technical diagram. In the indigenous Sanskrit scientific tradition, diagrams tend to be few in number, and they do not interact with the text content in the way that, say, the geometric figures of Euclid do. As illustrated in the examples in Figure 6, they are occasional visual reinforcements for verbal explanations and rules, and they are generally roughly schematic rather than precisely traced. The figure in the first manuscript represents the beginnings of an eclipse diagram (which the scribe apparently never completed), while those in the second are modeling various geometry formulas. As with displayed numbers, a chunk of the page's area is set aside for diagrams in apparently random segments, and the

text-stream with its own incidental numbers flows beside and around those spaces. Again as with numbers, the occasional unfinished or misrepresented form of a figure seems to be considered a tolerable omission.

The same casualness about the role of figures is still observed, though to a lesser extent (see figure 7), in a manuscript of a late work, the same previously shown in figure 3. In this late eighteenth-century text describing and explaining the Islamic astrolabe, although most of the style and layout is typical of traditional Sanskrit manuscripts, elements of Islamic influence can be seen in the drawings. They are carefully formed with compass and straightedge, not casually sketched freehand. And the key points in the first figure are labeled with letters of the alphabet, a practice that Arabic and Persian authors picked up from Greek geometry texts but that Sanskrit scholars did not use until they encountered it in Islamic texts. Note that the diagram in the second leaf is blank; Indian scribes still frequently failed to fill in spaces left for features like tables and figures.

The tradition of the Indian scientific manuscript was by this time within a century and a half of its end. As colonial administrators strove to foster modern Western education and technology, and as Indian scientists sought recognition in European and eventually global institutions, the Sanskrit scientific manuscript fell out of favor as a way to preserve and transmit technical learning. While certain works (primarily sacred texts) were and in some cases still are printed in traditional format on oblong pages, the Western-style book soon superseded manuscripts in all other genres, including the exact sciences. Fittingly, after their long cooperation, memorized oral learning and written manuscripts in the sciences faded from the scene together.



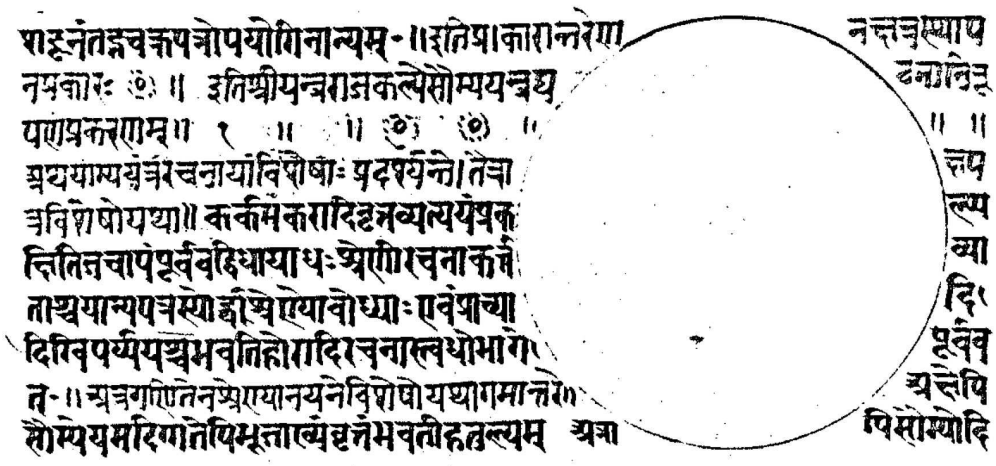


Figure 7: Diagrams in a late work (the MS of figure 3), showing Islamic influence (first: f. 4r, second: f. 26r)

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