

Indian Physics: Outline of Early History

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1 Introduction

Historians of science are generally unaware of the contributions of Indians to physics. The main reason for this is that very little research has been done on the subject since Seal's *The Positive Sciences of the Hindus* appeared in 1915, a consequence of the fact that there are few history of science departments in Indian universities. Work relevant to the history of Indian physics has been done in philosophy departments but this is generally inaccessible to historians of physics. Some other work concerning history of ideas in physics has been published by historians of astronomy.

The objective of this paper is to present a preliminary outline of early history of physics in India. The focus here are the schools of Vaiśeṣika and Sāṃkhya that were interested in general principles of atomic theory and cosmology. Physical ideas in these and other schools were applied to technology as we can see for a much later period in Dharampal's book [4].

This paper should be read in conjunction with the papers on history of early Indian science and astronomy by the author [14-18, 22, 23], where the relevant Vedic ideas on cosmology are presented. To summarize this background context, the Vedic texts present a tripartite and recursive world view. The universe is viewed as three regions of earth, space, and sky which in the human being are mirrored in the physical body, the breath, and mind. The processes in the sky, on earth, and within the mind are taken to be connected. The universe is mirrored in the cognitive system, leading to the idea that introspection can yield knowledge.

2 On classification

The Vedic seers speak of ṛta, the laws underlying the universe. They also assert that all descriptions are limited, and outside their normal context they lead to logical paradox. The notable features of this world view are:

- An infinitely old, cyclic universe
- An atomic world and the subject/object dichotomy
- Relativity of time and space
- Evolution of life
- A science of mind
- Computable laws
- Language theory

As one would expect, these conceptions of evolution of life, relativity of space and time, and science of mind are not quite on the same lines as that of contemporary science. But that is precisely what makes Indian science especially interesting to the historian.

The first step in the development of any science is the naming of objects and categories. Then come the questions of change and transformation and the recognition that a certain essence of reality is unaffected by change. Having named objects and events, one turns to the relationships between them. The enumeration of categories in groups and their relationship with other such groups comes later. The question of the nature of the cognitive process by which the knowledge of the universe is obtained also comes at the end.

During the Ṛgvedic period itself, it had come to be recognized that although nature follows laws, a certain freedom characterizes human behaviour. The fundamental unity of reality is thus split into two distinct categories related to innate nature and cognition. The universe not only exists outside of ourselves, but a copy of it, howsoever imperfect, exists within each one of us. The enumeration of categories as they arise in the space of the mind is the concern of Sāṃkhya. The stated objective is to obtain discriminative knowledge of the manifest (*vyakta*), the unmanifest (*avyakta*) and the knower (*puruṣa*).¹ On the other hand, Vaiśeṣika deals with

the goal attributed to Kaṇāda, the mythical founder of the system, *yad iha bhāvarūpam, tat sarvaṃ mayāupasamkhyātavyam*, “I shall enumerate everything [in this world] that has the character of being.”

The two systems have differing focus. Sāṃkhya addresses evolution at the cosmic and the psychological levels; Vaiśeṣika delves deeper into the nature of substances and its scope includes both physics as well as metaphysics.

The emphasis in Indian thought on knowing the outside through an analysis of cognitive categories was far in advance of the concepts used by historians of science until the rise of modern physics. As a result, the six *darśanas* were often misrepresented in the commentaries that were written with the rise of Indian studies in the nineteenth century. These mistakes have been repeated in more recent works because this commentatorial tradition still operates within the framework of reductionist physics and analysis. With the rise of relativity and quantum mechanics, the subject has become central in the understanding of the physical universe. The outer world exists because there is someone to perceive it; likewise the mind is characterized by the associations between various objects and processes of the outer world.²An examination of the physical world in terms of categories of the mind or of “being” constitutes a perfectly legitimate way of approaching the outer world, albeit it is different from the manner in which Western science developed.

Sāṃkhya and Vaiśeṣika are generally paired with Yoga and Nyāya, respectively. The reason behind such a pairing is that the paired system provides the student with the ability to make further progress in his understanding. The focus in Sāṃkhya is the inner world and, therefore, an experiential or meditative attitude complements it. The insights of Yoga validate the categories of Sāṃkhya, indeed the two could proceed in a complementary fashion, which is why the two are considered the same system sometimes. In Vaiśeṣika, the focus is more on an enumeration of the categories of being, perceived apart from oneself. Since the categories are very many, the use of formal logic is essential to draw inferences, and in this respect Nyāya is its sister system.

Actually, Nyāya (logic) provides the analytical basis for all Indian sciences. Naiyāyikas say *astitva jñeyatva abhidheyatva*, “whatever exists, is knowable and nameable.” But it is also stated that speech has four forms, of which one kind, the *parā*, is unmanifest.³So all description and analysis is ultimately limited by paradox.

The categories of Sāṃkhya and Vaiśeṣika describe the physical and the psychological worlds. A comprehensive theory, integrating the insentient

and the sentient, is offered.

We first provide a brief review of the the Sāṃkhya and the Vaiśeṣika categories and then examine the significance of their physical concepts. The beginnings of these concepts can be traced back to the Vedic literature.

3 Overview and early development

We first begin with a few remarks on the chronology of the Indian texts. New results in archaeology have shown that the Indian tradition can be traced back in a series of unbroken phases to at least 8000 B.C.E. Archaeologists and geologists also believe that the Sarasvatī, the preeminent river of the Ṛgvedic age, dried up around 1900 B.C.E., leading to the collapse of the towns of the Harappan era that were primarily distributed in the Sarasvatī region. There is increasing acceptance of the view that the Ṛgveda should be earlier than 1900 B.C.E. The early Brāhmaṇas and the Upaniṣads then belong to the second millennium B.C.E.⁴

The Vedic hymns speak of ideas that are later described at greater length in the *darśanas*. Nature has an order that is expressed as *ṛta*.⁵ This order is behind the regularity in the movements of the planets, the seasons, and cycles on earth. *Ṛta* defines an inflexible law of harmony which offers a basis for its comprehension through the mind. The principle of order is sometimes represented by the pillar (*skambha*) as in the Atharvaveda⁶ and anthropomorphized as Brahmaṇaspati.⁷

The Ṛgvedic hymn 10.129 describes how prior to a separation between the subject and the object neither space or time existed. It goes on to say:

In the beginning desire arose, born of the mind, it was the primal seed. The seers who have searched their hearts with wisdom know the connection (*bandhu*) between being and non-being.

A cord stretched across them; what was above, and what was below? Seminal powers made mighty forces, below was strength and above was impulse.⁸

The connections (*bandhu*) between the outer and the inner are affirmed. Next, there is mention of the dichotomy between *puruṣa* and *prkṛti*, the impulse and the strength.

In Ṛgveda 10.90, *puruṣa*, is the cosmic person out of whose dismembered body the living and the inanimate worlds emerge. Here too a dichotomy,

expressed through the symbols of male and female, marks the paradoxical beginning of empirical existence. Puruṣa is born out of *virāj*, “the shining one,” and she out of him. This marks a distinction between puruṣa as transcendent reality and its manifestation in terms of individual consciousness.

Further on in the same hymn, several categories related to existence, such as space, sky, earth, directions, wind, metres and so on are created. Such an enumeration is described at greater length in the dialogue in the Bṛhadāraṇyaka Upaniṣad between Yājñavalkya and Maitreyī where seventeen of the twenty-three categories of classical Sāṃkhya are noted:

As all waters find their goal in the sea, so all touches in the skin, all smells in the nose, all taste in the tongue, all forms in the eye, all sounds in the ear, all deliberations in the mind, all knowledge in the intellect, all actions in the hands, all enjoyment in sex, all elimination in the excretory organs, all movement in the feet, and all the Vedas in speech.

As a mass of salt has neither inside nor outside, but is altogether a mass of taste, thus indeed has that Self neither inside nor outside, but is altogether a mass of knowledge; and having risen from these elements, vanishes again in them.⁹

These include the five material elements, the five organs of sense, the five organs of action, the *buddhi*, in the form of *vijñāna*, *ahaṃkāra*,¹⁰ and mind. The only categories of the late Sāṃkhya which are not explicitly mentioned in the Bṛhadāraṇyaka Upaniṣad are the *tanmātras*, but the *bandhu* between the gross and the subtle, which is emphasized again and again in the Ṛgveda, indicates the implicit recognition of the corresponding subtle *tanmātra* for the five gross elements. This subtle representation of the outer in terms of *mātrā* is described explicitly in the Kauṣītaki Brāhmaṇa Upaniṣad where the specific abstract correspondences for certain outer functions, such as speech, breath, order, and so on, are listed in terms of *bhūtamātrā*.¹¹ The word *mātrā* here refers to the essence in the same manner as in the notion of *tanmātra*. *Ahaṃkāra* is described in the Chandogya Upaniṣad as the one who sees the universe.¹²

In other words, all the elements of Sāṃkhya seem to be in place in the Vedic literature. We also have a proper scientific system with its cosmic order and corresponding laws (*ṛta*), entities and relationships. Even the workings of the human mind are subjected to logical analysis.

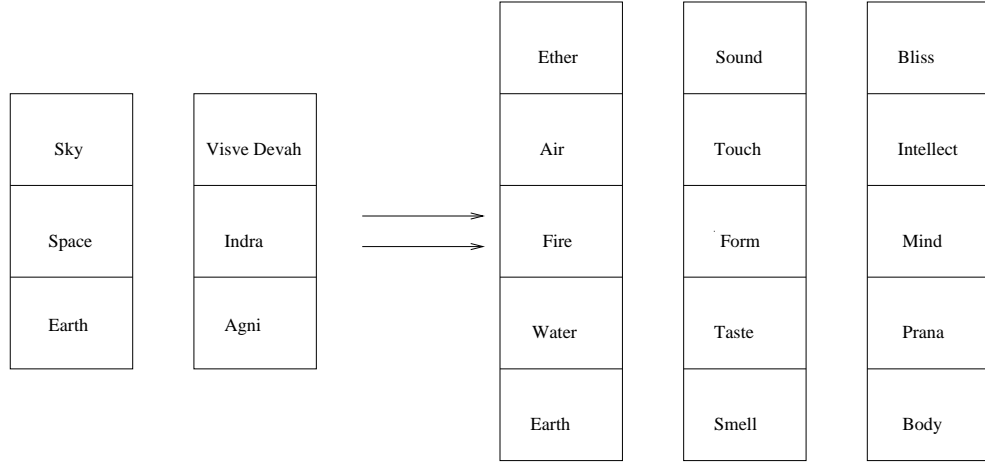


Figure 1: Five-layered universe

The Vedic system is a tripartite and recursive world view. At the most basic level, the universe is viewed as three regions of earth, space, and sky with the corresponding entities of Agni, Indra, and Viśve Devah (all gods). These three regions are represented in the Vedic ritual as three different altars. There is a mapping of these regions within the human body as well. The Chāndogya Upaniṣad speaks of a tripartite manifestation of reality, expressed as fire (red), water (white), and food (black) correlated with speech, breath, and mind.¹³ Śvetāśvatara Upaniṣad also describes the red, white, and black aspects of the One.¹⁴ In Āyurveda, the three *doṣas* (humours), *vāta*, *pitta*, and *kapha*, likewise define a tripartite model.

Counting separately the joining regions leads to a total of five categories where, as we see in Figure 1, water separates earth and fire, and air separates fire and ether.¹⁵ This counting in groups of five is seen in a variety of contexts as in the five directions, five senses, five seasons, five metres, five chants, five peoples, five breaths, and so on.

Although the processes in the sky, on earth, and within the mind are connected, all descriptions of the universe lead to logical paradox. The one category transcending all oppositions is *brahman*. Vedic ritual is a symbolic representation of this world view.

The complementarity between the mind and the outer world is of fundamental significance. Knowledge is classified in two ways: the lower (*aparā*) or dual; and the higher (*parā*) or unified. Knowledge is superficially dual and paradoxical but at a deeper level it has a unity. The material and the conscious are aspects of the same transcendental reality.

In the Chāndogya Upaniṣad, Uddālaka Āruṇi describes the unity behind the apparent duality as *sadvidyā*. Being (*sat*) provides both the origin and the unity:

In the beginning, my dear, this world was just Being, one only, without a second. Others say: “In the beginning this world was just Nonbeing (*asat*), one only, without a second; from that Nonbeing Being was produced.” But, my dear, how could this be? How from Nonbeing could Being be produced? No, my dear, in the beginning this world was just Being, one only, without a second.¹⁶

In the Taittirīya Upaniṣad, the individual is represented in terms of five different sheaths or levels that enclose the individual’s self.¹⁷ This represents another instance of expanded tripartite model. These levels, shown in an ascending order, are:

- The physical body (*annamaya kośa*)
- The energy sheath (*prāṇamaya kośa*)
- The mental sheath (*manomaya kośa*)
- The intellect sheath (*vijñānamaya kośa*)
- The bliss sheath (*ānandamaya kośa*)

These sheaths are defined at increasingly finer levels. At the highest level, above the bliss sheath, is the self. Intellect is placed below bliss, which is a recognition of the fact that eventually meaning is communicated not by associations, but rather by a synthesizing vision expressed by the notion of bliss.

Prāṇa is the energy coursing through the physical and mental processes. If one looked at the individual in the three fundamental levels, then at the lowest level is the physical body, at the next higher level is the energy systems at work, and at the next higher level are the thoughts. Since the

three levels are interrelated, the energy situation may be changed by inputs either at the physical level or at the mental level.

The key notion is that each higher level represents characteristics that are emergent on the ground of the previous level. In this theory mind is an emergent entity, but this emergence requires the presence of the self.

The mind may be viewed in a five-fold way: *manas*, *ahaṃkāra*, *citta*, *buddhi*, and *ātman*. Again these categories parallel those of Figure 1.

The notions of enumeration and indivisibility are so pervasive in Vedic thought that it is impossible to put a date on the rise of Sāṃkhya and Vaiśeṣika. But there developed specific schools where a particular manner of defining the attributes was taken; these schools trace their lineage to specific individuals, often starting with a mythical ṛṣi.

Classical Sāṃkhya

The notions of Sāṃkhya form a part of the earliest Vedic texts. As a system called by its formal name, it is described in the Mokṣadharmā and the Bhagavad Gītā as well as in the Upaniṣads. Its legendary founder was the sage Kapila who used to be dated to around 7th century B.C.E., but in light of the new findings related to Indian antiquity, is likely to have lived much earlier than that. The texts speak of at least twenty-six teachers including Āsuri, Pañcaśikha, Vindhyavāsa, Vārṣaganya, Jaigīṣavya, and Īśvarakṛṣṇa. By “classical Sāṃkhya” we mean the *Sāṃkhya-Kārikā* (SK) of Īśvarakṛṣṇa. The Sāṃkhya-Kārikā claims to be the summary of an earlier, more comprehensive treatise, the *Ṣaṣṭitantra*.

According to Sāṃkhya, reality is composed of a number of basic principles (*tattva*), which are taken to be twenty-five in the classical system. But since the heart of the system is its hierarchical framework, the exact number of the principles varies, especially in the earliest writings. But such a variation is of no fundamental importance.

In the classical system, the first principle is (1) *prakṛti*, which is taken to be the cause of evolution. From *prakṛti* develops (2) intelligence (*buddhi*, also called *mahat*), and thereafter (3) self-consciousness (*ahaṃkāra*). From self-consciousness emerge the five subtle elements (*tanmātra*): (4) ether (*ākāśa*), (5) air, (6) light, (7) water, and (8) earth. From the subtle elements emerge the five (9-13) material elements (*mahābhūta*). Next emerge the five organs of sense (*jñānendriya*): (14) hearing, (15) touch, (16) sight, (17) taste, and (18) smell, and five organs of action (*karmendriya*): (19) speech, (20) grasping, (21) walking, (22) evacuation, and (23) procreation.

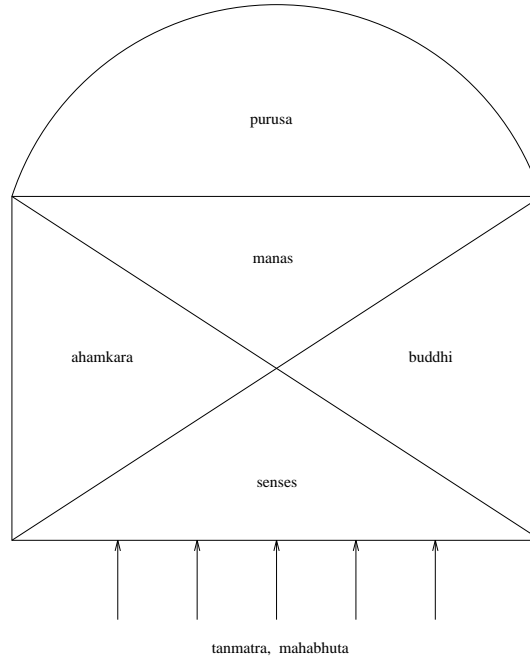


Figure 2: The cognitive system

Finally, self-consciousness produces the twenty-fourth of the basic elements: (24) mind (*manas*), which, as a sixth sense, mediates between the ten organs and the outside world. The last, twenty-fifth, tattva is (25) *puruṣa*.

The emergence from prakṛti of intelligence and, later, of subtle and gross elements, mind and consciousness, appears to mirror the stages through which a newly-conceived individual will pass. Here intelligence, as the second tattva, is what endows the newly fertilized cell the ability to organize and grow; self-consciousness represents the stage which allows the organism to sense the environment, and so on. The thesis that the world is connected, allows one to see the same process at the cosmic and the psychological levels.

The doctrine of the three constituent qualities (*guṇa*): *sattva*, *rajas*, and *tamas*, plays a very important role in the Sāṃkhya physics and metaphysics. These *guṇas* are described in the Upaniṣads. In its undeveloped state, cosmic

matter has these *guṇas* in equilibrium. As the world evolves, one or the other of these become preponderant in different objects or beings, giving specific character to each. The quality of *sattva*, which stands for virtue or transparency, inheres in all things tending to truth, wisdom, beauty or goodness; the quality of *rajas*, or activity, energy or passion, is present in all that is fierce, forceful or active; the quality of *tamas*, which stands for inertia, is to be found in all that is stupid or dull. The *guṇas* can be viewed as the three constituent strands of materiality.

Sāṃkhya can also be seen as having three basic dimensions:

1. The constitutive (*tattva*) dimension, dealing with form (*rūpa*), the principle or the essential core (*liṅga*);
2. The projective (*bhāva*) dimension, concerning the projective or the intentional (*pravṛtti*), the predispositional, or cause-effect (*naimittanaimittika*); and
3. The consequent (*phala*) dimension, dealing with what has come to pass (*bhūta*) or the phenomenal creation (*pratyayasarga*).

They *guṇas* can also be viewed as the threads that tie together the three realms of the *tattvas*, the *bhāvas*, and the *bhūtas*.

Vaiśeṣika

This school of “individual characteristics” is supposed to have been founded by Kaṇāda, the son of Ulūka. Other important sages associated with this tradition include Candramati, Praśastapāda, Vyomaśiva and Udayana. Kaṇāda’s Vaiśeṣika Sūtras (VS) describe a system of physics and metaphysics. Its physics is an atomic theory of nature, where the atoms are distinct from the soul, of which they are the instruments. Each element has individual characteristics (*viśeṣas*), which distinguish it from the other non-atomic substances (*dravyas*): time, space, soul, and mind. The atoms are considered to be eternal.

There are six fundamental categories (*padārtha*) associated with reality: substance (*dravya*), quality (*guṇa*), motion (*karman*), universal (*sāmānya*), particularity (*viśeṣa*), and inherence (*samavāya*). The first three of these have a real objective existence and the last three are products of intellectual discrimination. Each of these categories is further subdivided as follows.

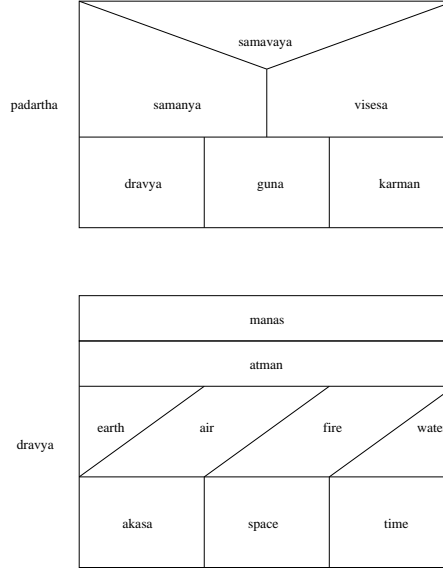


Figure 3: The categories of Vaisesika

There are nine classes of substances (*dravya*), some of which are nonatomic, some atomic, and others all-pervasive. The nonatomic ground is provided by the three substances ether (*ākāśa*), space (*dis*), and time (*kāla*), which are unitary and indestructible; a further four, earth (*pṛthivī*), water (*āpas*), fire (*tejas*), and air (*vāyu*) are atomic composed of indivisible, and indestructible atoms (*aṇu*, *paramāṇu*); self (*ātman*), which is the eighth, is omnipresent and eternal; and, lastly, the ninth, is the mind (*manas*), which is also eternal but of atomic dimensions, that is, infinitely small.

There are seventeen qualities (*guṇa*), listed in no particular order as colour or form (*rūpa*), taste (*rasa*), smell (*gandha*), and touch (*sparsā*); number (*saṃkhyā*), size or dimension (*parimāṇa*), separateness (*pṛthaktva*), conjunction (*saṃyoga*), and disjunction (*vibhāga*); remoteness (*paratva*) and nearness (*aparatva*); judgment (*buddhi*), pleasure (*sukha*), pain (*duḥkha*), desire (*icchā*), aversion (*dveṣa*), and effort (*prayatna*). These qualities are either physical or psychological. Remoteness and nearness are interpreted in two different ways: temporally or spatially. This list is not taken to be

comprehensive because later sound is also described as a quality. But there is a fundamental difference between sound and light. Sound is carried by the non-atomic ākāśa, whereas light, implied by rūpa, is carried by tejas atoms. But even sound is sometimes seen as a specific characteristic of atoms.

There are five different types of motion (*karman*) that are associated with material particles or the organs of the mind: ejection, falling (attraction), contraction, expansion, and composite motion.

Universals (*sāmānya*) are recurrent generic properties in substances, qualities, and motions. Particularities (*viśeṣa*) reside exclusively in the eternal, non-composite substances, that is, in the individual atoms, souls, and minds, and in the unitary substances ether, space, and time.

Inherence (*samavāya*) is the relationship between entities that occur at the same time. This provides the binding that we see in the various categories so that we are able to synthesize our experience.

The Vaiśeṣika atomic structure characterizes four of the five Sāṃkhyan mahābhūtas; the fifth, ether, is non-atomic and all-pervasive. Some of the Vaiśeṣika guṇas correspond to the Sāṃkhyan tanmātras. In Sāṃkhya the tanmātras come first, in Vaiśeṣika atoms are primary.

Each of the two schools has had a very long history.¹⁸This included many variations to the classical formulation given above. There has also been considerable difference in interpretation. In the sections that follow, I present an eclectic summary from this mass of material to communicate their main physical ideas.

4 Physical concepts

The Vaiśeṣika categories appear to provide a convenient starting point to examine the physical concepts inherent in these two systems.

The ground layer consists of indivisible, invisible and indestructible atoms (*aṇu*, *paramāṇu*). It is the aggregation of these atoms that give rise to different destructible compound substances. These atoms are ideals, representing unities of fundamental attributes. In this sense, they are quite similar to the concept of such elementary particles of modern physics which are proposed on theoretical grounds.

It is useful to consider the modern atomic doctrine for the sake of reference. Here the elementary particles are characterized by various attributes, each of which has a numerical value. These attributes include mass, charge, angular momentum, energy, and so on. The properties of bulk matter is, in

principle, obtainable from those of its constituents, but at each higher level of aggregation of atoms, new properties emerge.

Philosophically, there are two main approaches, *positivism* and *realism*, for the understanding of physics. According to the positivist, the only scientific knowledge is the one that can be expressed in logical statements. Since our logic and our language is a result of the observations of the world, this presupposes that the observer is central to this knowledge. This is essentially the same as the Nyāya position. The realist believes that there exists an independent reality which is probed through observation and experiment. Put differently, the positivists believe that knowledge is subjective, whereas realists believe that it is objective.

A positivist accepts that there are elements of an empirical reality which science uncovers, but points out that the realist view involves a logical contradiction, since there is no way of observing an observer-independent reality and hence we cannot verify that such a reality exists.

A weaker form of objectivity is sometimes identified with the positivist position. Here we speak of an empirical reality which is not independent of the observer, but is the same for all observers. Such weak objectivity characterizes relativity theory.

Atoms and their combinations

According to the Vaiśeṣika Sūtras, “Earth possesses colour, taste, smell, and touch. Waters possess colour, taste, and touch, and are fluid and viscid. Fire possesses colour and touch. Air possesses touch. These (preceding characteristics) are not in ether.”¹⁹ This indicates how the qualities are seen as being built out of elementary entities. Such a unitary picture is even more clearly spelt out for the atoms and the tanmātras. As mentioned before, Sāṃkhya provides a slightly different focus, where the abstract tanmātras are considered to be the building blocks for the gross atoms.

The Vaiśeṣika atomic substances are defined in a matrix of four non-atomic substances (*dravyas*)—time, space, soul and mind. In other words, the physical universe has an objective existence and mind and soul do not simply emerge from the material ground and disappear when the material structure disintegrates.

The objective elements of the physical world are characterized by *dravya*, *guṇa*, and *karman*, or substance, quality, and action. There is a further characterization in terms of non-reactive and reactive properties.

Two atoms combine to form a binary molecule (*dvyāṇuka*). Two, three,

four or more dvyaṅukas combine into grosser molecules of tryaṅuka, caturaṅuka, and so on. The other view is that atoms form dyads and triads directly to form molecules of different substances. Atoms possess an incessant vibratory motion. The activity of the atoms and their combinations are not arbitrary but according to laws that are expressed as the adṛṣṭa.

Molecules can also break up under the influence of heat (*pākajotpatti*). In this doctrine of *pīlupāka* (heating of atoms), the impact of heat particles decomposes a molecule.

Heat and light rays are taken to consist of very small particles of high velocity. Being particles, their velocity is finite. This is also apparent from the fact that motion is contingent upon time as one of the dravyas. The particles of heat and light can be endowed with different characteristics and so heat and light can be of different kinds.

Elsewhere it is said that there is no difference between the atom of a barley seed and paddy seed, since these are but atoms of earth. Under the impact of heat particles, atoms can exhibit new characteristics.

A bhūta-atom evolves out of integration from the corresponding tanmātra. This indicates a primacy of the abstract over the material. On the other hand, the atoms may be taken to be unitary objects and their combinations seen as generating various tanmātras. One may further assume that rudiment-matter (*bhūtādi*) leads to its more specific forms. Brajendranath Seal summarizes some views on the relationship between atoms and tanmātras as follows:

The rudiment-matter (bhūtādi) acted on by rajas (energy) produces the sound-potential (vibration-potential).

The vibration-potential, as a radicle, with accretion of atoms, condensing and collocating, generates the touch-potential which is impingent as well as vibratory.

The impact-potential, as a radicle, with a similar accretion of atoms generates the heat-and-light-potential which radiates light and heat in addition to being impingent as well as vibratory.

The light-and-heat-potential, as a radicle, with further accretion of atoms generates the taste-potential.

The taste-potential, as a radicle, with further accretion of atoms, generates the smell-potential.²⁰

The order of the formation of the bhūta-paramāṇu is seen according to the following hierarchical scheme:

1. The sound-potential, subtle matter, with accretion of rudiment-matter generates the ākāśa atom.
2. The touch-potential combines with vibratory particles (sound-potential) to generate the vāyu atom.
3. The light-and-hear-potentials combine with touch and sound-potentials to produce the tejas atom.
4. The taste-potential combines with the foregoing three to produce the āpas atom.
5. The smell-potential combines with the foregoing four to generate the earth atom.²¹

In summary, all these views see matter as being of a unitary nature which when excited to different states produces potential of different kinds that correspond to the tanmātras and then constitutes different elements.

The *Padārthadharmasaṃgraha* of Praśastapāda deals with the question of ultimate substances. Earth, fire, water, and ether are here taken to be the basic material substances. But their existence is taken to be contingent on the presence of someone who knows of them, namely Brahman. Praśastapāda's commentary and exposition of the relevant sūtras of VS, with sūtra numbers shown in parentheses, is as follows:

Ākāśa (ether), time and space have no lower constituents. (VS 2.1.27, 29-31)

Of ākāśa the qualities are—sound, number, dimension, separateness, conjunction and disjunction. (VS 7.1.22)

Thus, then, being endowed with qualities, and not being located in anything else, it is regarded as a substance. And in as much as it has no cause, either homogeneous or heterogeneous, it is eternal. (VS 2.1.18)

Time is the cause of the [relative] notions of “priority,” “posteriority,” or “simultaneity” and “succession,” and of “late” and

“soon.” In as much as there is no other cause or basis for these notions, as appearing with regard to these objects,—notions which differ in character from all notions described before,—we conclude “time” to be the basis of these. (VS 2.2.6)

Time is the cause or basis of the production, persistence and destruction (or cessation) of all produced things; as all these are spoken of in terms of time... (VS 2.2.9)

Though from the uniformity of the distinguishing character of time, time is directly by itself, one only, yet, it is indirectly, or figuratively, spoken of as manifold, on account of the diversity among the conditions afforded by the production, persistence and cessation of all produced things...

Space is the cause of the notions of east, west, below and above, and so on, with regard to one material object considered with reference to another material object as the starting point or limit. Specially so, as there is no other cause for these notions. (VS .2.12; 2.1.31; 7.1.24; 7.2.22)²²

The nature of sound

The underlying physical ideas of our systems are presented well in the discussion of sound. According to Praśastapāda:

Sound is the quality of ākāśa, perceptible by the auditory organ. It is momentary. It can be produced by contact, by disjunction, or by another sound. There are two kinds of sound: *varṇa* (syllables) and *dhvani*. The production of the syllables is a result of the contact of the internal organ and self when influenced by memory. First, one desires to produce the sound and then makes an effort. The moving air strikes the throat, producing a contact with the ākāśa, and resulting in the sound. Sounds are always produced in a series, like a series of ripples in water and when these waves reach the ear we hear them.²³

Sound energy is viewed as a wave. The waves impinge on the hearing organ and are recognized through associations. Praśastapāda’s *dhvani* is considered to be noise. But it appears that its role is similar to the *dhvani* defined by Ānandavardhana and Abhinavagupta as the power of suggestion in its purest form that plays a significant part in the recall of the conscious and unconscious associations.

Evolution

With the background of the bandhu between the outer and the inner in mind, it is clear that the evolution of the tattvas can also be viewed as an evolution of the universe. Buddhi or mahat arises before space and matter. This presumes that with buddhi also emerges the cognition of time. And further, that space and matter, which constitute the physical universe, are contingent on the existence of intelligence. The working of the nature's intelligence is seen as soon as the notions of prior and posterior, related to the change associated with a physical process, become real.

The Sāṃkhya system also presupposes a universe which comes into being and then is absorbed back in the ground-stuff of reality. This is what we see in the Purāṇic cyclic universe also. Within each cycle, a gradual development of intelligent life is assumed. It is postulated that the plants arose first, followed by animals of various kinds, and lastly by man. Such a creation and destruction may be viewed to be taking place at various levels, including the psychological level related to the creation and destruction of thoughts.

5 Analysis, causality

The choice of the basic categories in both Sāṃkhya and Vaiśeṣika is dictated by considerations of economy. This parallels a similar emphasis on economy in the Indian grammatical tradition. The fundamental bandhu between language, thought and empirical reality make it possible to analyze the processes of nature.

The Sāṃkhya Kārikās present the question of *pramāṇa*, the method of validation, thus:

Perception, inference, and reliable authority are considered the three means for this purpose. Perception is the selective ascertainment of particular sense-objects. Inference, which is of three kinds, depends upon a characteristic mark and that which bears that mark (association). Reliable authority is trustworthy verbal testimony. The understanding of things beyond the senses is inferred by analogy.²⁴

The Vaiśeṣika Sūtras also clearly present the principle of cause (*kāraṇa*) and effect (*kārya*).²⁵ Praśastapāda describes time and space as *nimittakāraṇa*,

efficient cause, for all phenomena. This indicates position in space and change in time are fundamental to all reality.

Causality is expressed in Sāṃkhya as *satkārya*, “the doctrine of the existence of the effect (in the cause).”

The effect exists due to: (a) the non-productivity of non-being; (b) the need for an appropriate material cause; (c) impossibility of all things coming from all things; (d) things producing only according to their nature; (e) the nature of the cause.²⁶

There is no *ex nihilo* creation in the Sāṃkhya but only a progressive manifestation.

The guṇas provide the necessary ingredient for the universe (be it physical or psychological) to evolve. They make it possible to distinguish between the prior and the posterior. The action of guṇas is essential to the definition of time and to the workings of causality.

But guṇas are really not objective constituents of nature. Rather, they represent a relative property. This is explained most clearly in *Gauḍapādabhāṣya* in the relativity inherent in “the beautiful and virtuous woman who is a source of delight but cause of pain to her co-wives and of delusion in the passionate.”²⁷ In physical terms, one may speak of a separation between two extremes by activity in the middle. Or, the guṇas may be viewed as the potential whose gradients set up the process of ceaseless change. The activity in the middle, characterized by rajas, separates the two poles of puruṣa and undifferentiated prakṛti, or those of sattva and tamas.

6 How does the mind make sense?

The observer has become a part of physics since the advent of relativity and quantum mechanics; the observer also plays a central role in Indian philosophical systems. The question of observation in Sāṃkhya and Vaiśeṣika is considered at two levels: at the level of the mind, which is seen as an instrument; and at the level of the awareness ground-stuff, puruṣa.

The Sāṃkhya model of the mind was shown in Figure 2. In it intellect (buddhi), self-consciousness (ahaṃkāra) and mind (manas) are the three inner instruments that process the sense impressions.

Since the buddhi together with the other internal organs (ahaṃkāra and manas) comprehends every object; therefore, the three-fold

instrument is the doorkeeper and the remaining (ten) are the doors.²⁸

Memory is seen to arise due to associations and the traces left by past cognitions; this involves a contact between the self and the internal organ. The traces are stored by repetitions and by selective interest in the objects of the past cognitions. A recalled memory may become the cause of recollection of a part of the previous cognition, desire or aversion, and of further association of ideas.²⁹

Ordinary language is limited in its capacity to describe all nature, likewise memories are inadequate in their remembrance of the past. But *ātman*, by virtue of its linkages with brahman, does have access to the hidden memories. This means that a part of the mind is unconscious, inaccessible to the empirical self.

Prāśastapāda calls memory as a form of true knowledge (*vidyā*) but does not count it as a *pramāṇa*. The objection to memory being considered as true knowledge is that it is just a trace. A memory does not represent an object completely; it leaves out some of the properties previously present and adds others that were not initially there. In other words, memories are reconstructions of reality.

Cognition cannot be taken to arise out of the sense-organs.

These (organs, namely, *ahaṅkāra*, *manas* and the ten senses) which are different from one another and which are distinct specifications of the *guṇas*, present the whole to the *buddhi*, illuminating it for the *puruṣa* like a lamp.³⁰

The question of the seat of intelligence is analyzed::

In the cognitions of sound, etc, we infer a “cognizer.” This character cannot belong to the body, or to the sense-organs, or to the mind; because all these are unintelligent or unconscious. Consciousness cannot belong to the body, as it is a material product, like the jar; and also as no consciousness is found in dead bodies.

Nor can consciousness belong to the sense-organs; because these are mere instruments, and also because we have remembrances of objects even after the sense-organ has been destroyed, and even when the object is not in contact with the organ.

Nor can it belong to the mind; because if the mind be regarded as functioning independently of the sense organs, then we would have perception and remembrance simultaneously presenting themselves; and because the mind itself is a mere instrument.

And thus the only thing to which consciousness could belong is the self, which thus is cognized by this consciousness.

As from the motion of the chariot we infer the existence of an intelligent guiding agent in the shape of the charioteer, so also we infer an intelligent guiding agent for the body, from the activity appearing in the body, which have the capacity of acquiring the desirable and avoiding the undesirable.³¹

Coming to the question of puruṣa, it is stated *na prakṛtir na vikṛtiḥ puruṣaḥ*, that it is neither *prakṛti* (creative) not *vikṛti* (created).³² Puruṣa transcends vyakta and avyakta, it is discriminating, subjective, specific, conscious and non-productive.³³ Puruṣa is a witness, free, indifferent, watchful, and inactive.³⁴

The puruṣa, in this characterization, does not interfere with prakṛti and its manifestations. It is transcendent and completely free (*kaivalya*).

What are the reasons that puruṣa must exist?

*saṃghātaparārthatvāt
triguṇādiviparyayād adhiṣṭhānāt,
puruṣo'sti bhoktrbhāvāt
kaivalyārtham pravṛttes ca.*

The puruṣa exists because aggregations exist for another; because there must be the opposite to the three guṇas; because there must be superintending power; because there must be an enjoyer; because there is activity for the sake of freedom.³⁵

We see that this conception of the “enjoyer” or “observer” parallels the manner in which the observer enters the picture in modern physics.³⁶ The physical laws are immutable; nevertheless, the universe appears to require that observers be present.

There is also the paradox that while corresponding to prakṛti there exists a single puruṣa, or a single root consciousness, in reality there are many observers.

*jananamaraṇakaraṇānāṃ
pratiniyamād ayugapatpravṛttest ca,
puruṣabahutvaṃ siddhaṃ
traiguṇyaviparyayāc cai'va.*

The plurality of puruṣas arises from: the diversity of births, deaths, and faculties; actions or functions at different times; difference in the proportion of guṇas in different individuals.³⁷

The proximity between prakṛti and puruṣa makes it appear that the unconscious is endowed with awareness.³⁸

In other words, the language of the kārīkās does acknowledge with great clarity, and in a manner perfectly consistent with modern insights, that the question of consciousness represents a paradox. The mind is taken to operate in a causal fashion, just as the physical world does. The sensory input is transformed by the associations of different kinds that lie in the memory and the predispositions (as determined by the guṇas) to reach judgments.

7 Qualities, motions, universals

Kaṇāda lists seventeen qualities and says there are more. Candramati, in *Daśapadārthaśāstra*, adds the following seven to this list: mass (*gurutva*), fluidity (*dravatva*), viscosity (*sneha*), disposition (*saṃskāra*), merit (*dharma*), demerit (*adharmā*), and sound (*śabda*).

Mass inheres in earth and water and causes a substances to fall down. Fluidity inheres in earth, water and fire and causes the flowing of a substance. Viscidity inheres in water and causes coherence with a substance such as earth. Disposition can either be physical, in relation to a motion, or mental. Merit and demerit are psychological qualities related to pleasure and pain. Merit is of two kinds, viz., activity (*pravṛtti*) and inactivity (*nivṛtti*).

In physical terms, four states of matter are described: ākāśa or ether, which is non-atomic and, therefore, by itself represents vacuum; gas, as in tejas; liquid, as in water; and solid, as in earth. Since the aggregate substances have size, the question of the manner in which their qualities inhere arises.

A distinction was made between qualities which pervade their loci and those which do not. Candramati lists the following as locus-pervading:

color	taste	smell
touch	number	dimension
separateness	farness	nearness
contact	disjunction	fluidity
viscosity	weight	velocity

These are the ones of significance for physical objects. Sometimes, a few additional qualities are said to be locus-pervading.

Praśastapāda describes qualities related to objects somewhat differently than Candramati. He offers weight, fluidity, viscosity and saṃskāra (disposition); this last quality is further subdivided into inertia (*vega*), elasticity (*sthitisthāpaka*), and trace (*bhāvanā*).³⁹

Fluidity is of two varieties: natural and instrumental. It is a natural quality of water and an instrumental quality of earth and fire. When water freezes into ice, the natural fluidity of water is seen to be counteracted by the fire of the sky, so that the atoms combine to form a solid. Water, earth, and fire all have fluidity. However, water's fluidity is held to be primary, while that of the other two substances is secondary. Viscidity is responsible for cohesion and smoothness.

Kaṇāda defines motion into five varieties: ejection (*utkṣepaṇa*), attraction (*avakṣepaṇa*), contraction (*ākuñcana*), expansion (*prasaraṇa*), and composite movement (*gamana*).⁴⁰In the case of gamana there is contact with points of space in various directions, or there are many loci.⁴¹Motion by gravity is discussed. "Weight causes falling; it is imperceptible and known by inference."⁴²Motion is produced by mass, which is the same as a motion due to gravitational attraction.⁴³

Inertia is the quality of a moving object which is responsible for its continuing in its motion. The Vaiśeṣika position is that inertia is countered by other forces, leading to energy loss, which is why the moving object slowly loses its speed.

That motion cannot take place instantaneously, was well understood. Vyomaśīva in his Vyomavatī speaks of how a motion has several parts that will take increments of time. Likewise, motions produced in cooking will take time to produce the new quality associated with the process, where time, in this context, is equivalent to energy. This is a statement of the empirical fact that a minimum energy needs to be expended before a state change occurs. With water the temperature must reach the boiling point before steam will be obtained. This observation expresses an understanding of the quantum effect in daily processes.

It is stated that there are two kinds of universals: higher and lower.⁴⁴The

higher universal here is Being, which encompasses everything. Lower universals exclude as well as include. This means that the universals could be defined in a hierarchical fashion. The higher universal is akin to a superposition of all possibilities and so it anticipates the essence of the quantum theory.

8 Cosmology, astronomy

We now consider how the ideas of Sāṃkhya and Vaiśeṣika are intertwined with the development of Indian science. Since Sāṃkhya, in one of its many forms, has been a part of Indian thinking going back to the remotest times, one may be certain that it played an important role. This is most easy to see for astronomy for which the extant texts provide enough information in terms of layers of material, and thereby allow us to see a gradual development of various ideas. This evolution of astronomy may be taken to be a prototype for the development of other sciences.

Ideal forms play a role in Vaiśeṣika. For example, sphericity (*pārimaṇḍalya*) is considered a basic shape. Candramati speaks of two kinds of sphericity: when it is minute, it resides in an atom, and when it is absolutely large (infinite), it resides in ākāśa, time, place, and self. In between the very large (cosmos) and the very small (atom) are the objects of the observable universe which will not conform to the ideal shape. So in astronomy, which represents this middle ground, one must consider deviations from spherical or circular shapes and orbits.

Since only the cosmos as a whole may be considered to be perfect, space as a dravya will not have any absolute properties. This reasoning sets Indian physical science apart from the tradition of Greek science which took space to be absolute and the observer on the earth to have a privileged position. In Indian physics, space and time are considered to be relative.

Considering Indian astronomy, it should be noted that its understanding is undergoing a major shift. More than a hundred years ago, it was believed⁴⁵ that the Indians were the originators of many of the notions that led to the Greek astronomical flowering. This view slowly lost support and then it was believed that Indian astronomy was essentially derivative and it owed all its basic ideas to the Babylonians and the Greeks. It was even claimed that there was no tradition of reliable observational astronomy in India.

Billard,⁴⁶ using statistical analysis of the parameters used in the many

Siddhāntas, showed that these texts were based on precise observations and so the theory that there was no observational tradition in India was wrong. Seidenberg showed that the altars of the Brāhmaṇas already knew considerable geometry. He saw the development of the mathematical ideas going through the sequence of equivalence by number followed by an equivalence by area.⁴⁷ Further work showed that these altars represented astronomical knowledge. Since then it has been found that the Vedic books are according to an astronomical plan.⁴⁸ The texts themselves mimic the tripartite connections of nature!

On the non-uniform motion in the sky

We first consider the sun. With respect to an observer on the earth, the sun has two motions. First, is the daily motion across the sky. Second, is the shifting of the rising and setting directions. It is this second motion which defines the seasons. Its two extreme points are the solstices, and the points where the sun's orbit crosses the equator or when the nights equal the days are the equinoxes.

The Aitareya Brāhmaṇa describes how the sun reaches the highest point on the day called viṣuvant and how it stays still for a total of 21 days with the viṣuvant being the middle day of this period. In the Pañcaviṃśa Br. several year-long rites are described where the viṣuvant day is preceded and followed by three-day periods called svarasāman days. This suggests that the sun was now taken to be more or less still in the heavens for a total period of 7 days. So it was clearly understood that the shifting of the rising and the setting directions had an irregular motion.

The year-long rites list a total of 180 days before the solstice and another 180 days following the solstice. Since this is reckoning by solar days, it is not clear stated how the remaining 4 or 5 days of the year were assigned. But this can be easily inferred.

The two basic days in this count are the viṣuvant (summer solstice) and the mahāvratā day (winter solstice) which precedes it by 181 days in the above counts. Therefore, even though the count of the latter part of the year stops with an additional 180 days, it is clear that one needs another 4 or 5 days to reach the mahāvratā day in the winter. This establishes that the division of the year was in the two halves of 181 and 184 or 185 days. Corroboration of this is suggested by evidence related to an altar design from Śatapatha Brāhmaṇa as shown in Fig 4. This figure shows that the four quarters of the year were not taken to be equal.⁴⁹

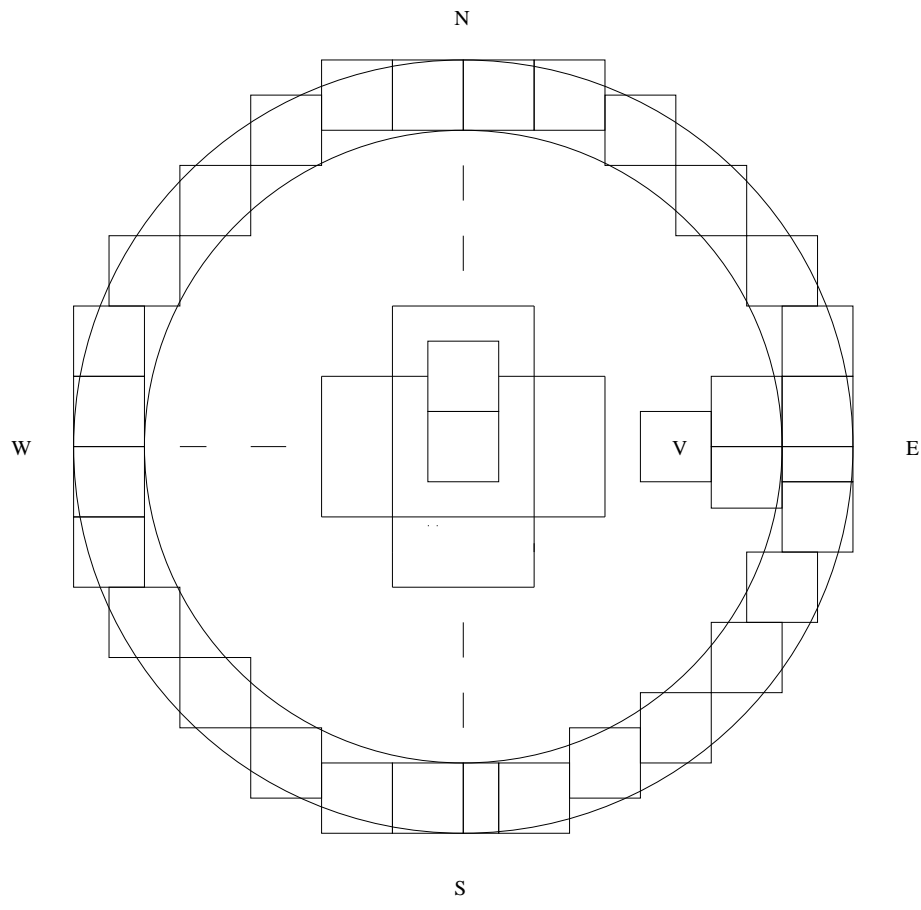


Figure 4: The non-uniform circuit of the Sun

Likewise, the motions of the planets were known to be non-uniform. The ideal orbits were considered to be circular. But the actual motion deviated from the ideal, represented in terms of the struggle between the devas and the asuras of the Vedic mythology.⁵⁰

By the time of the Siddhāntas, the planet orbits were represented with respect to the sun. Not only did Āryabhaṭa (c. 500 C.E.) believe that the earth rotates, but there are glimmerings in his system (and other similar Indian systems) of a possible underlying theory in which the earth (and the planets) orbits the sun, rather than the sun orbiting the earth. The evidence is that the period provided is the śīghrocca, which is the time taken by the planet to orbit the sun relative to the sun. For the outer planets this is not significant: both earth and sun are inside their orbits and so the time taken to go round the earth and the time taken to go round the sun are the same. But this becomes significant for the inner planets.

The motion of the earth

Only an ideal body will be at complete rest in the Vaiśeṣika system. So it is not surprising to see Āryabhaṭa take the earth to rotate on its axis. It appears that the rotation of the earth is inherent in the notion that the sun never sets that we find in the Aitareya Brāhmaṇa:

The [sun] never really sets or rises. In that they think of him “He is setting,” having reached the end of the day, he inverts himself; thus he makes evening below, day above. Again in that they think of him “He is rising in the morning,” having reached the end of the night he inverts himself; thus he makes day below, night above. He never sets; indeed he never sets.⁵¹

One way to visualize it is to see the universe as the hollow of a sphere so that the inversion of the sun now shines the light on the world above ours. But this is impossible since the sun does move across the sky during the day and if the sun doesn’t set or rise it doesn’t move either. Clearly, the idea of “inversion” denotes nothing but a movement of the earth.

By our study of the early Vedic sources, we are now able to understand the stages of the development of the earliest astronomy. After the Ṛgvedic stage comes the period of the Brāhmaṇas. This is followed by Lagadha’s astronomy. The last stage is early Siddhāntic and early Purāṇic astronomy.

Ancient Indian astronomy may be described in terms of three broad stages which mirror the development of the corresponding philosophical ideas.

- *Stage 1.* This is primarily Ṛgvedic astronomy. Here we speak of the motion of the sun and the moon, nakṣatras, and the planets and their orbits are not according to the ideal cyclic motions. We are not certain when this period began but we have many references of astronomical events in the mythology, like the destruction of the sacrifice of Dakṣa by Śiva, which indicates the era of the fourth millennium B.C.E.,⁵² but note that this story belongs to a later stratum of the Vedic myths. The ritual of this period was done according to the Vedāṅga Jyotiṣa of Lagadha (c. 1300 B.C.E.). Being the standard manual for determination of the Vedic rites, Lagadha's work must have served as a "living" book which is why the language of the extant text shows later linguistic usage. The objective of the Vedāṅga Jyotiṣa is to do the astronomical calculations for the daily rites. The calculations use forms that may be unrelated to observational processes as in the case of the mean positions of the sun and the moon. The day is defined with respect to the risings of the sun, the stars, and the moon. This indicates that the idea of relativity with respect to time processes was well understood. The orbits of the sun and the moon are considered with respect to their mean positions, suggesting the non-uniform nature of their motions was well known.
- *Stage 2.* This is the astronomy of the Brāhmaṇas associated with names like those of Yājñavalkya and Śāṅḍilya. Although the rites of the Brāhmaṇas appear to be very ancient, the texts appear to belong to the second millennium B.C.E. Their astronomy is represented by means of geometric altars and deals with the non-uniform motion of the sun and the moon and intercalation for the lunar year. There is also the beginnings of an understanding of universal attraction in terms of "strings of wind joined to the sun." This astronomy corresponds to the Sāṃkhya of the Bṛhadāraṇyaka Upaniṣad.
- *Stage 3.* This concerns mainly with the early Siddhāntic and Purāṇic periods. Here our main sources are the Śulbasūtras, the Mahābhārata, the early Purāṇas, Sūryasiddhānta and other texts. This stage saw the development of the śīghrocca and mandocca cycles and the concept of the kalpa, the large period associated with creation at the cosmic level.

At the end of these stages stands the classical Siddhāntic period inaugurated by Āryabhaṭa. The concepts of the śīghrocca and mandocca cycles indicate that the motion of the planets was taken to be fundamentally around the sun, which, in turn, was taken to go around the earth. We can see the development of these ideas as an explication of the notion of a non-ideal motion in terms of several stages of underlying ideal motions. This is analogous to how the ideal shapes of the atoms, when combined, lead to the non-ideal shapes of the gross elements.

Sūrya Siddhānta describes a “mechanistic” model for the planetary motions which is like the mechanistic physical models of the Vaiśeṣika:

Forms of time, of invisible shape, stationed in the zodaic, called the śīghrocca, mandocca, and node (pāta), are causes of the motion of the planets. The planets, attached to these points by cords of air, are drawn away by them, with the right and left hand, forward or backward, according to nearness, toward their own place. A wind, called *pravaha*, impels them toward their own uccas, being drawn away forward and backward.⁵³

The antecedents of this system can be seen in the earlier texts. Ṛgveda speaks of the stars of the Ursa Major (the Seven Sages) having ropes of wind, (*munayo vāta raśanāḥ*).⁵⁴ Śatapatha Br. describes the sun as *puṣkaramādityo*, “the lotus of the sky.” It also says:

tadasāvāditya imāṃlokāntsūtre samāvayate, tadyattatsūtraṃ vāyuh..

The sun strings these worlds [the earth, the planets, the atmosphere] to himself on a thread. This thread is the same as the wind...⁵⁵

This suggests a central role to the sun in defining the motions of the planets and ideas such as these must have ultimately led to the theory of the śīghrocca and the mandocca cycles.

The sun’s central role implies that the basic functioning of gravitation was understood. This action was visualized in terms of “ropes of wind,” which, in modern terminology, would be called a field.

Relativity of time and space

To summarize, the first descriptions were non-uniform motions of “mean” objects. Later models shift the centre from the earth, first by considering

that earth spins on its axis, and then representing the non-circular motion of the planets with respect to the sun.

The parallel speculative thought in the Purāṇas takes space and time to be relative in a variety of ways. Time can flow at different rates for different observers. Time and space are not absolute. There exist countless universes with their own Brahmā, Viṣṇu, and Maheṣa.

To appreciate the background for this thought, consider that in Vaiśeṣika the universal is taken to be timeless and ubiquitous. Whatever can be defined with respect to space and time cannot be a universal. The processes that mark the passage of time on an object would thus be relative. It is only the universals which are of the highest form, i.e. true for all time and space, that are absolute. And the only such universal is the Being.

These ideas are elaborated in the Purāṇas, the Āgamic and the Tāntric literature, and in books like the Yoga-Vāsiṣṭha.

9 Concluding remarks

We have shown that the physical concepts underlying Sāṃkhya and Vaiśeṣika represent a sophisticated materialist framework for the laws of nature. This physics was based on general observations on the various physical processes. Since an element of the two philosophical systems was metaphysical, the reasoning was often validated based on psychological arguments. Both systems emphasized causality and so were capable of elucidating nature's laws. The basic categories are ideals and the modifications of these ideas provide endless structure.

There is also a complementarity between Sāṃkhya and Vaiśeṣika. By considering the evolution of tattvas, Sāṃkhya emphasizes genesis both at the cosmic as well as the psychological levels. More details related to the constitution of the physical world are provided by Vaiśeṣika. These structures are paralleled in Indian grammatical philosophy with production based on a small set of axioms.

There is also a recognition that new enumerative categories are needed in the characterization of empirical world. It is recognized that the description of the physical world requires categories that go beyond the basic 25 of the Sāṃkhya system. Some of them are described in Vaiśeṣika, but there the emphasis is on atoms and their mutual relationships. For example, new categories are necessary to characterize the motion of planets. Driven by the requirement of reconciling the cyclic ideal motions of the planets to the

actual ones, more complex orbits were introduced. This complexity was seen as being engendered by the workings of gravity-like forces.

Speaking of one of these philosophies, the historian of thought Karl Potter says:

Nyāya-Vaiśeṣika offers one of the most vigorous efforts at the construction of a substantialist, realist ontology that the world has ever seen. It provides an extended critique of event-ontologies and idealist metaphysics. It starts from a unique basis for ontology that incorporates several of the most recent Western insights into the question of how to defend realism most successfully. This ontology is “Platonistic” (it admits repeatable properties as Plato’s did), realistic (it builds the world from “timeless” individuals as well as spatio-temporal points or events), but neither exclusively physicalistic nor phenomenalist (it admits as basic individuals entities both directly known and inferred from scientific investigations). Though the system has many quaint and archaic features from a modern point of view, as a philosophical base for accommodating scientific insights it has advantages: its authors developed an atomic theory, came to treat numbers very much in the spirit of modern mathematics, argued for a wave theory of sound transmission, and adapted an empiricist view of causality to their own uses.⁵⁶

In reality, the scope of Sāṃkhya and Vaiśeṣika is even greater than this, because they reconcile the observer to the frame of a materialist physics, leading to subtle insights that have been validated by modern physics. Consider, for example, the notion that one may take the tanmātras to be composed of bhūtādi or the other way round. The tanmātras are an abstract potential whereas bhūtādi are the elementary atoms which is somewhat like the quantum wavefunction and material particles. Sāṃkhya, where the observer is central, considers tanmātras to emerge first. On the other hand, Vaiśeṣika, with its focus on atoms and their combinations, does not speak of tanmātras although some of the guṇas are like the tanmātras. In other words, we have something akin to the concept of wave-particle duality of quantum physics.

The assumption that all observed world emerges out of prakṛti implies that the material substratum of all substances is the same. The qualities of Vaiśeṣika emerge as material atoms combine in different ways. These

emergent properties are not limited to inanimate matter but also to the instruments of cognition where actual cognition requires the self to be the activating agent.

This paper presents only two of the many currents of the Indian physical thought. One needs also to consider texts on architecture, astronomy as well as the traditions related to crafts and military science for additional insight.

Abbreviations

AB	Aitareya Brāhmaṇa
AV	Atharvaveda
BU	Bṛhadāraṇyaka Upaniṣad
CU	Chāndogya Upaniṣad
KBU	Kauṣītaki Brāhmaṇa Upaniṣad
PP	Padārthadharmasaṃgraha of Praśastapāda
RV	Ṛgveda
ŚB	Śatapatha Brāhmaṇa
SK	Sāṃkhya Kārikā
ŚU	Śvetāśvatara Upaniṣad
TU	Taittirīya Upaniṣad
VS	Vaiśeṣika Sūtra

Notes

1. SK 2.
2. Heisenberg [5], Kak [9,14,16-18,21].
3. RV 1.164.45.
4. See, for example, Kak [7,8,10-15,20].
5. RV 4.23; 10.85; 10.190.
6. AV 10.
7. RV 2.25; 10.121.
8. RV 10.129.4-5.
9. BU 4.5.12-13.

10. BU 1.4.1.
11. KBU 3.5.
12. CU 7.25.1.
13. CU 6.2-5.
14. ŚU 4.5.
15. TU 2.1.
16. CU 6.2.1-2.
17. TU 3.2-6.
18. See, for example, Dasgupta [3], Matilal [28], Potter [29], Hulin [6], Larson [26], Larson and Bhattacharya [27].
19. VS 2.1
20. Seal [31], pages 37-38.
21. Seal [31], pages 38-39.
22. PP 5.41-3.
23. PP 137.
24. SK 4-7.
25. SK 7.
26. SK 9.
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28. SK 35.
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31. PP 5.44s; see also VS 3.1.19.
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33. SK 11.
34. SK 19.
35. SK 17.
36. Heisenberg [5], Kak [9].
37. SK 18.
38. SK 20.
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40. VS 10.
41. PP 143.
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45. Burgess [2].
46. Billard [1].
47. Seidenberg [32].
48. Kak [15-20,22-25].
49. The figure is from ŚB 8.5; see also Kak [15].
50. Kak [15].
51. AB 4.18.
52. Kramrisch [25], pages 42-43.
53. Sūrya Siddhānta 2.1-5.
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