

The Astronomy of Indian Cities, Temples, and Pilgrimage Centers

J. McKim Malville

Department of Astrophysical and Planetary Sciences
University of Colorado, Boulder

Abstract

Throughout the Indian sub-continent, there are regions where culture and geography to create a landscape that is infused with meaning and power. These sites are often tirthas, places of extensive mythological associations where many believe that spirit can cross between different realms. Tirthas may be important fords of rivers, summits of hills where the heaven and the earth seem unusually close, or locations where Hindu deities have entered the world. Many contain a symbolic cosmology or visual astronomical sightlines, primarily to the solstices. The tirthas discussed in this paper are Chitrakut, Gaya, Varanasi, and Vijayanagara.

Chitrakut

Lying 125 km southwest of Allahabad, Chitrakut consists of a large network of sacred sites interconnected by pilgrimage routes, myth, and tradition. Traveling on foot, pilgrims may take five days visiting its many sacred hills, caves, and pools. The importance of the area as a pilgrimage destination probably goes back to the 3rd or 4th centuries BC when the *Ramayana* and the *Mahabharata* were being written. As described in the Ramayana, the area is associated with Lord Rama, his wife Sita, and his brother Laksmana who spent the first stage of their exile in the vicinity. Even before the exile of Rama, the forest and caves of the area contained habitations for sages and ascetics (Dubey et al. 2000). It is an example of a pilgrimage center in which, over the millennia, features of the natural landscape were selected to establish mythologically and astronomically significant patterns. The natural landscape contains three series of sub-tirthas, each of which establishes an isosceles triangle. Because of the special relationship between Rama and the region of Chitrakut, these triangles appear to represent the arrow and bow that are the identifying icons of Rama and Laksmana. The arrow that bisects the largest triangle is established by eight sites, extending more than 30 km toward Valmiki Ashram. (Valmiki is legendary author of the Ramayana.) Looking toward Valmiki Ashrama, the regression line has an azimuth of 63.5° . The arrow aligns with the direction of sunrise on June 21, which on a flat horizon in the Chitrakut area occurs at an azimuth of approximately 64° . The line contains Sphatikashila, a limestone rock in the Madakini River, set in a forest of considerable beauty. Footprints of Rama are reputedly visible on the rock. Another site on the line is Banke- Sidda, a large natural cave 100 m above the floor of the remote valley, the home of a recluse today, and, reportedly, of many similarly reclusive saints in the past.

The second line of sub-tirthas extends from the great well of Bharatkupa to Hanumandhara, where a perpetual stream falls on a large carved image of Hanuman. As described in the

Ramayana, after Hanuman set fire to Lanka, he was unable to cool himself until he reached this spring. The regression line of the five points has an azimuth of 296.2° . The "arrow" of that triangle is in line with the sun when it sets at summer solstice, which on a flat horizon occurs at an azimuth of approximately 296° . The two solstice lines intersect on the hill above Hanumandhara at a site known Sitarasoi (the kitchen of Sita), where an observer would see the sun at summer solstice rise in the vicinity of Valmiki Ashram and set above Kamadagiri hill, two important hills of the territory. Kamadagiri is especially revered because it is the hill on which Rama built his hut during exile, and it has a bow shape. In addition to the symbolism of the bow and arrow, the sun was an important icon for Rama and Lakshmana, who were son of the solar dynasty of Ayodhya. This second isosceles triangle is also remarkable in its symmetries. Two sides have lengths of 9.3 km and 9.6 km. The line from Bharatkupa to Hanumandhara bisects the central angle at better than 1%, i.e., the line to Balaji is 11.66° to the north and to Sphatikashila is 11.45° to the south.

At the smallest level, a third isosceles triangle is formed by Kamadagiri, Balaji and Sphatikashila; the longest sides have lengths of 2.4 km and 2.7 km, respectively. An individual on the summit of Kamadagiri would see the summer solstice sun rise near Balaji and the winter solstice sun rise near Hanumandhara-Sitarasoi.

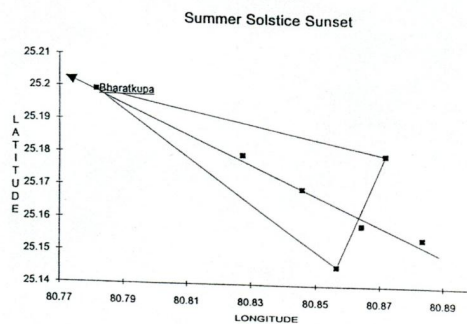
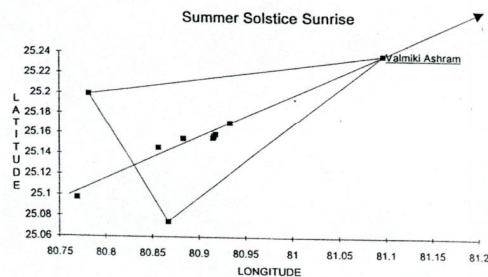
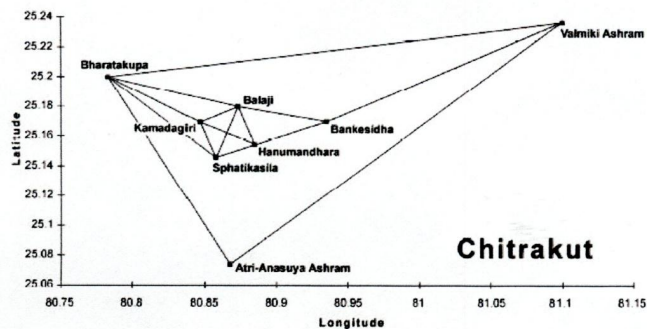


Figure 1: Chitrakut Tirthas



Figure 2 Sphatickashila (Crystal Rock) on the Madakini River

The two other major Hindu pilgrimage centers of northern India are Gaya (Singh et al. 2009) and Varanasi. Today Gaya, located 100 km south of Patna in the state of Bihar, is predominately a place to perform the *shraddha* ceremony for ancestors. Rama reportedly performed that ceremony for his father Dasharatha at Gaya. Judging from the number of sun temples and solar images in the area, *Surya* (sun) worship may have been the dominant activity in the past. The area is generally flat with four hills to the north, west, and south. The Phalgu River is on the east. It is the second largest city of Bihar. Before its urbanization the rocky hills and the Phalgu River would have been impressive sights for pilgrims. The major temple of Vishnupad, containing a foot print of Vishnu, is the center of sightlines to winter solstice sunrise, summer solstice sunset and winter solstice sunset, which occur over important shrines. A north-south axis passes through Vishnupad temple, from the Bodhi Tree of Bodh-Gaya, 9 km to south, to the temple of Rama-Shila, 4 km to the north.

Varanasi

The sun is one of the most ancient objects of devotion in India, first as a natural feature of the celestial hemisphere and later as an icon within temples (Srivastava 1986; Pandey 1971). Every morning of the year, the power and significance of the sun is revealed on the banks of the Ganga at Varanasi. At special days of the solar-lunar calendar, the rising sun, accompanied by chanting of mantras, oil lamps, bells, and ritual bathing, commands the attention of multitudes on the ghats (Singh 1994). Among the forested hills and lakes of the west bank of the Ganga, fourteen sun temples were built. Each was razed starting in AD 1191 during the centuries of Mughal occupation. The remnants of these temples have been mapped and located by Malville and Singh

(1995). Today, these temples are marked by a variety of features such as carved sun disks, carved lotus, or images of Surya.



Figure 3: Sunrise over the Ganga

Between 1998 and 2000 a joint project by the University of Colorado (Malville) and Benares Hindu University (Rana Singh) was carried out at Assi Ghat, the southern-most ghat of Varanasi. Visitors were counted daily between 5 am and 9 am for a total of 600 days. The survey documented some 890,000 visitors, recording both gender and estimated age. The total number of celebrants on all the ghats of Varanasi may exceed that at Assi Ghat by a factor of eight.

The power of the solar-lunar calendar in Hindu India is demonstrated in the precision by which pilgrims gather on the ghats on the mornings of special festivals. One of the largest festivals is *Makara Sankranti* on January 14-15, celebrated in south India as Pongal, when the sun enters the constellation of Capricorn (Makara). This festival is the only fixed-date, solar event of the major festivals; the others have variable dates based upon the phases of the moon. One major festival that does not attract pilgrims and bathers is Holi, celebrated on the full moon of March/April. Activity on the ghats on the day of this festival is probably too raucous for traditional pilgrims.

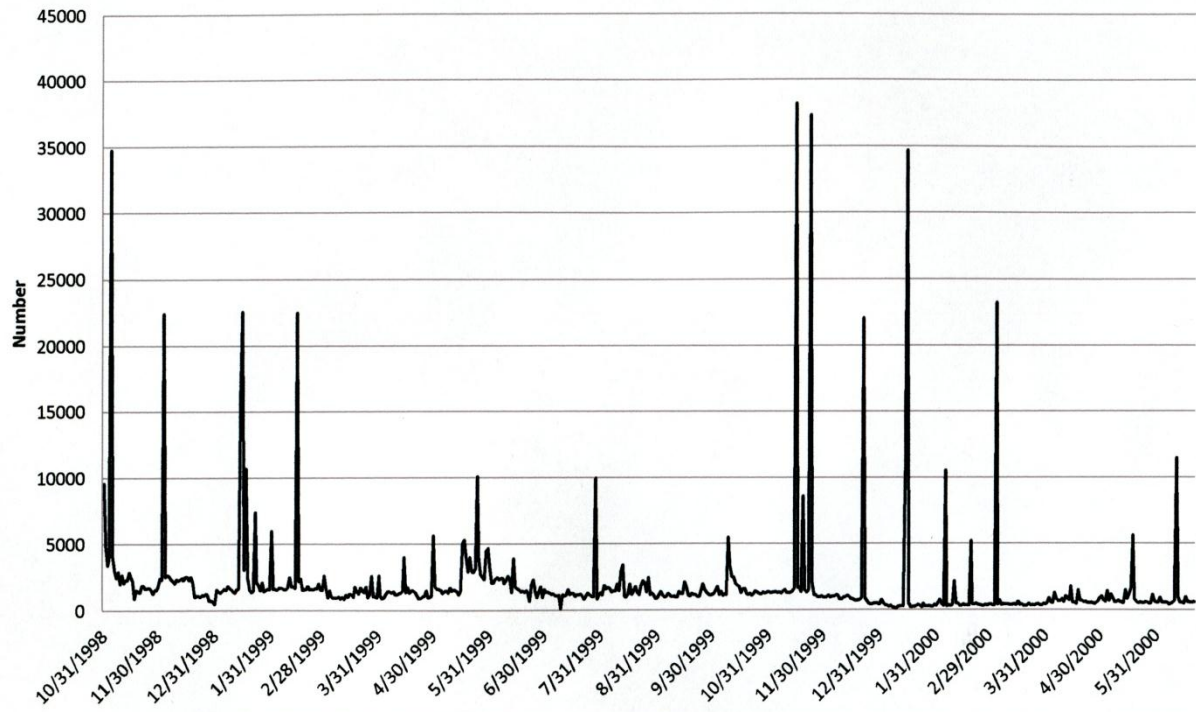


Figure 4 Daily counts of visitors to Assi Ghat

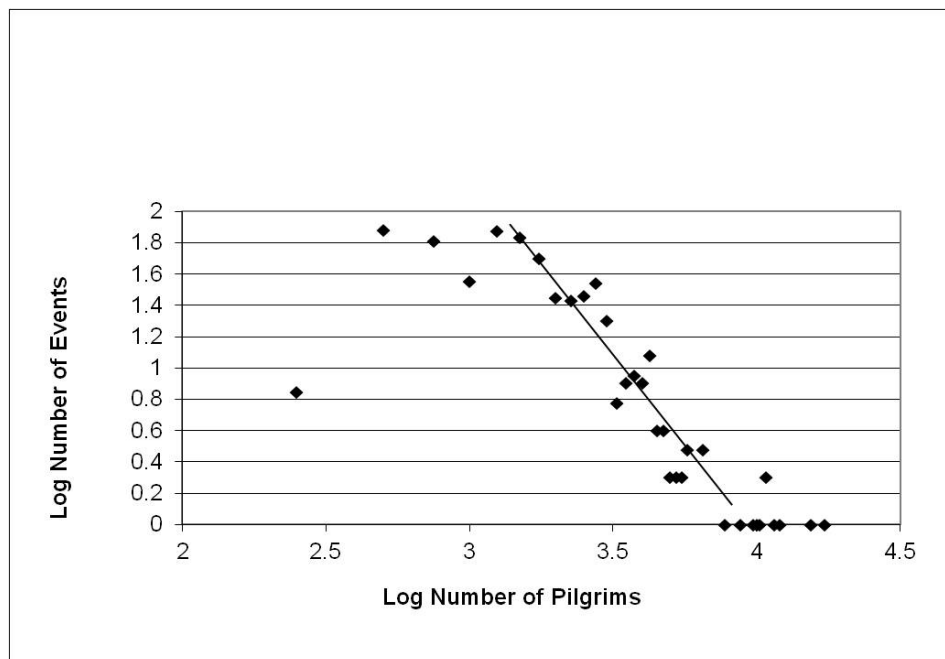


Figure 5 Distribution of Numbers of Visitors to Assi Ghat

In addition to the major pilgrimage festivals demonstrated in Figure 4 and Table 1, there is a background of pilgrimage activity on the ghats, which show a power law distribution in their

daily numbers as shown in Figure 5. Virtually all of India serves as the pilgrimage catchment basin for Varanasi, and most devout Hindus plan to visit Varanasi at least once in a lifetime. The tradition of pilgrimage to Varanasi appears to be so powerful, deeply ingrained, and coherent across India that it has reached a state of self-organized criticality, i.e. the system is maintained near a critical point and characterized by system-wide cooperative behavior. In such a state the distribution of events follows a power law (Bak et al. 1988, Malville 2009; Turcotte 1997). A well-known example of self-organized criticality is a sand pile maintained at the angle of repose. Another example of SOC involves the energy of solar flares which follows a power law distribution, due to the metastable state of twisted magnetic fields and storage of energy.

Table 1: Major pilgrimage festivals of Varanasi.

Festival	Meaning	Date 1998	N	Date 1999	N	Date 2000	N
Makara Sankranti	Entry of the sun into Makara (Capricorn)			January 14 Jan 15	16,600 22,600	Jan 14 15 Jan	10,600 34,700
Mauni Amayasya	New Moon (Khumbu Mehla)			17 Jan	10,900	5 Feb	10,600
Basant Pachami	5 day waxing moon			22 Jan	7,400	10 Feb	2,200
Magha Purnima	Full moon			31 Jan	6,000	19 Feb	5,200
Shivaratri	14 days of waning moon			14 Feb	22,500	4 March	23,300
Buddha Purnima	Full moon			30 April	5,700	18 May	5,700
Ganga Dasharhra	10 days of waxing			24 May	10,100	11 June	11,500
Guru Purnima	Full moon			28 July	10,000		
Pitri Visarjan	New moon			9 Oct	5,500		
Chhatha Surya Shashti	6 days of waxing moon			15 Nov	38,300		
Prabodhini Ekadashi	11 days of waxing moon	31 Oct	9,600	19 Nov	8600		
Kartika Purnima	Full moon	4 Nov	34,800	23 Nov	37,400		
Agahana Purnima	Full moon	3 Dec	22,500	22 Dec	22,100		

Vijayanagara



Figure 6 Matanga Hill as viewed from north in the Tungabhadra River

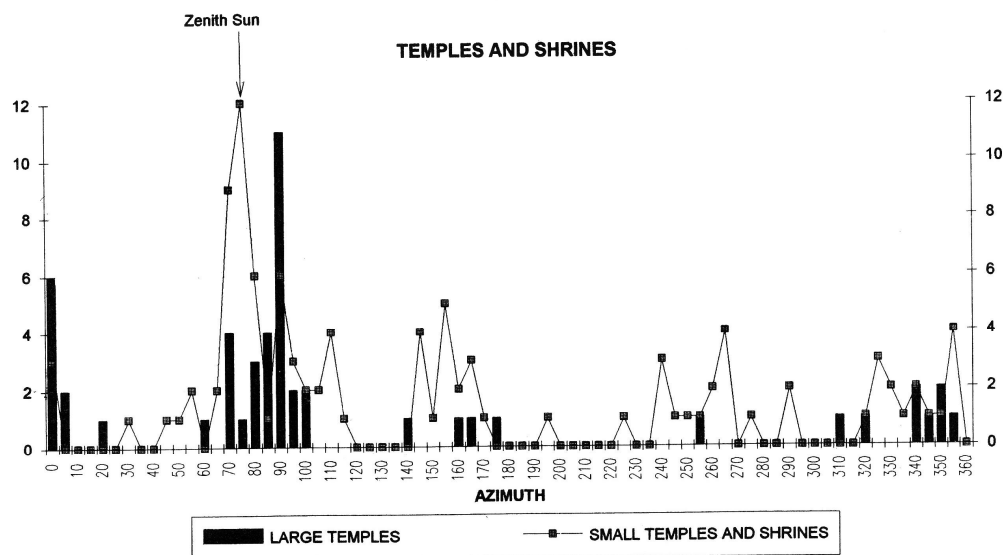


Figure 7 Orientations of the Temples and Shrines of Vijayanagara

With a population which may have reached 500,000 just before its destruction in 1565 AD, Vijayanagara was the greatest imperial city of medieval India, controlling the lower third of the sub-continent (Fritz 1985). The earliest historical reference to the site is 689-690 AD, when the most important deity was the river goddess, Pampa. Her cult and that of her father, Matanga, reveal the ancient importance and sacredness of the local river and its adjacent hill with its extensive caves. The founding of the capital city at this location was partly motivated by a desire to enhance the authority of the kings by the site's ritual power.

The major north-south axis of the city passes across the summit of Matanga Hill, the Royal Center contains on its western side the palaces of the queen and on the east the king's 100-column audience hall and the great truncated pyramid of the Mahanavami Dibbha from which the king would review the parades of subject people coming to express obeisance and pay tribute (Fritz, 1985; Fritz and Malville 1993; Malville and Fritz 1993, Malville 2001). The accuracy with which the north-south line divides the Royal Center is impressive and reveals the importance attached to the form of symmetry of king and queen in a Hindu empire. Sun sights obtained with a T-2 theodolite established that the spire of Virabhadra temple on the summit of Matanga hill lies 0.8 minutes of arc from true north as seen from the center of the major ceremonial gateway in the Royal Center. The accuracy of this axis was further confirmed by differential GPS measurements (Malville 2000, 2001). The Indian techniques for determining true north using shadow casting by a gnomon had been perfected for centuries, culminating in the work of Sripati in the 11th century (Malville 2000). It appears that the architects and astronomers of Vijayanagara, just 50 years before the dawn of telescopic astronomy, were able to obtain accuracies that were the highest achievable with the unaided human eye.

The symbolism of separation of space into eastern and western halves by the north-south axis is further elaborated by the symmetric placement of the king's 100-column audience hall and the queen's large palace. The center of the major room of the palace lies 92.8 m to the west of the axis while the center of the 100-column hall lies 89 m to the east.

At the southern base of Matanga hill are found the remains of a lake, an important element of the symbolism connected with the cosmic mountain, Mt. Meru. If one stands at night inside the ceremonial gateway facing Matanga hill, one can observe that the pivot of the heavens lies immediately above it. The visual conjunction of celestial pole and sacred mountain could not be more clearly presented. The ritual significance of Matanga hill is indicated by three monumental staircases constructed of great slabs of granite, and a pradakshina path around its base. Within the mountain are two sets of caves. The massive lower cave crosses the mountain from west to east, starting with a carved image of Ganesh.

Malville and colleagues measured the locations orientations and geometries of more than 150 temples, shrines, and palaces of Vijayanagara using differential GPS and sun sights with a theodolite. The major temples suggest a bow shaped pattern, iconic of Rama, and similar to those of Chitrakut and the majority (72%) of them open to either the east or north. Those temples that demonstrate the use of high precision techniques in establishing an axis with an accuracy of better than 1° are listed in Table 2.

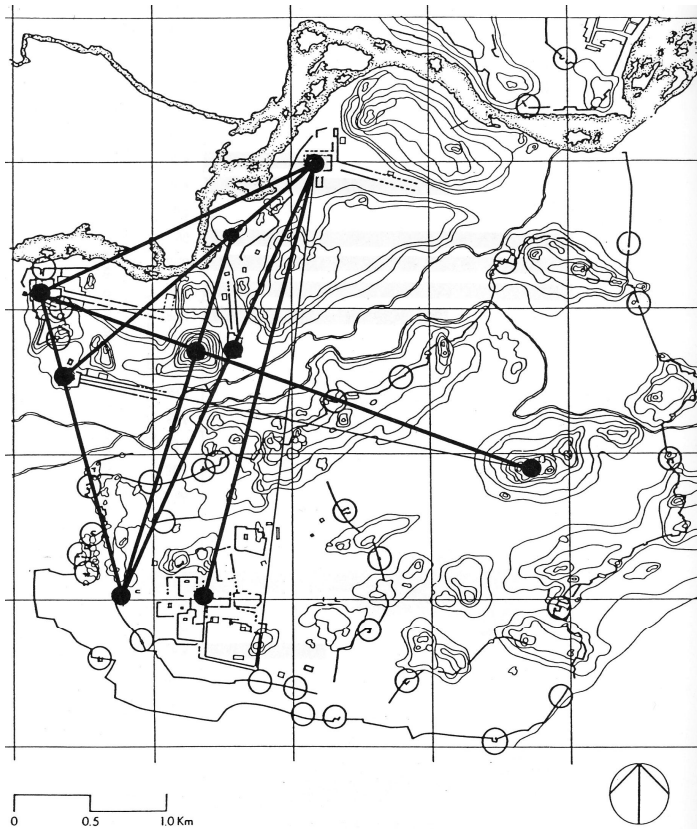


Figure 8. Bow-like Pattern of the Major Temples of Vijanagara

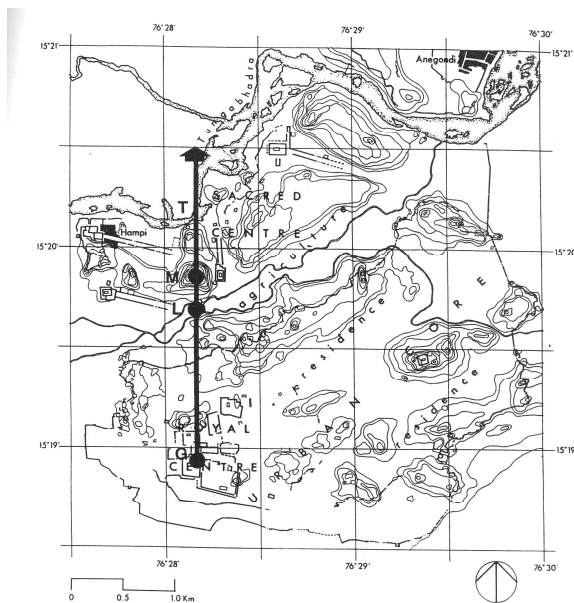


Figure 9. North-South Axis of Vijanagara (T, Tungabhadra River; M, Matanga Hill; L, Lake; G Ceremonial Gate of the Royal Center)

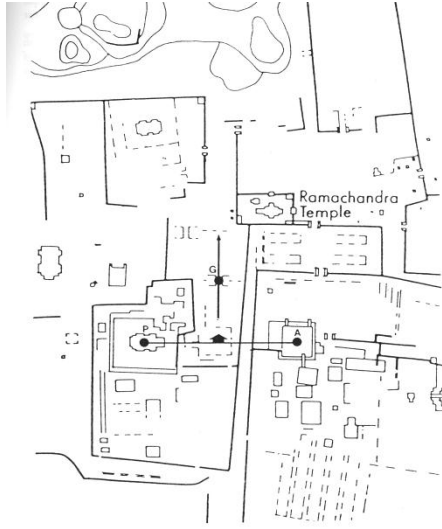


Figure 10; Royal Center showing the Ceremonial Gate G, Queen's Palace, P, and King's Audience Hall, A.

Table 2 Orientations of the Major Temples

TEMPLE	AXIAL LENGTH (m)	ORIENTATION
Virabhadra	10	0°13'
Chandrasekhara	29	89°46'
Tirumangai Alvar	24	89°55'
Vitthala	71	89°40'
Pattabhirama	70	90°42'
Krishna	47	90°47'

Figure 7 gives the measurements of temples and shrines. Instead of a preference for east and north or for the solstices, the small temples primarily have azimuths of 70° - 80°. At the latitude of Vijayanagara, on a flat horizon, sunrises on those two days of summer and winter solstice occur at azimuths of 65.5° and 114.4°. The average orientation of the 35 structures in the north-east sector is 75.02°. The three other clusters are open to azimuths that average 159°, 257°, and 341°, and are approximately separated by 90° from each other. The average rotation away from cardinality for the four directions is 17°. Similar to the small temples and shrines, the palaces do not show a preference for cardinal directions but show a preference for 75.5°, close to that of the small temples and shrines.

The 15° - 17° rotation of the small temples, shrines, and palaces may identify an indigenous ceremonialism involving the zenith sun. The position of the rising sun on the morning when it

crosses the zenith may have served as the ordering principle. At Vijayanagara, on the morning of May 3 and July 27, the sun reaches the zenith at noon, when it rises on a flat horizon at an azimuth of 74° . Although the day of the zenith sun is celebrated in other tropical cultures, this is the first time it has been noted in the archaeological record of India. Many religious traditions were present in the capital, and it is unknown which considered the zenith sun important (Malville 1993, 1994). Attention to that event is not surprising considering the visual drama of the disappearance of shadows from superstructures of Hindu temples.

Concluding Remarks

All of the sites considered in this paper started out as tirthas. Chitrakut has continued as a relatively natural landscape. Gaya has been urbanized. Varanasi, where in the past, travelers would have camped on either bank before crossing over to the other side of the Ganga, has been transformed into the major tirtha of India. Vijayanagara became the capital of a major empire. The survey of bathers at Assi ghat demonstrates the power and precision of the solar-lunar calendar and suggests the condition of self-organized criticality in the pilgrimage tradition centered on Varanasi.

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