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IS ŚIVA ICONOGRAPHY INSPIRED BY THE STARS?

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High resolution digital images of the many forms of Hindu God Śiva have been obtained from the 7th century Kailāśanātha Temple at Kanchipuram. Objective criteria have been defined for comparing digital images of nine sculptures, with naked eye star positions. A 50° x 50° region of the sky centred on ε Orionis of the same epoch, as well as a control field of the same area centred on γ Geminorum have been compared with the sculptures after establishing objective criteria for the matching of the sculpture and star fields. In the case of every sculpture, the stars of the Orion field match with the contours and features of the sculpture significantly better than with the stars of the comparison field. This result shows that the stars of the Orion region not only formed the inspiration for Śiva imagery but also a template for Śiva iconography.

Remarkably for the Orion star field, every sculpture is consistently aligned with the RA of the epoch. Thus the *Pallava* sculptors had access to star positions the Orion region and were also familiar with the equatorial coordinate system. Quantitative measurement of the displacement of the stars from the contour or features of each sculpture shows that, the rms value of the displacement is only 8 minutes of arc. This must clearly be the lower limit of the accuracy of the star positions used by the sculptors. The star catalogue of Ptolemy is less accurate than this and could not therefore have served as the basis for these sculptures. The star position-icon design connection appears to be part of the continuing tradition in India of archiving astronomical data in religious ritual, art and architecture.

Key words: Bhīksatana myth, Crab supernova (1054 AD), Gaṅgādhara myth, Kailāśanātha temple, Kālarimūrti myth, Kirāta myth, Naṭarāja form, Naṭarāja myth, Orion star field, Śiva and Nandī myth, Sculpture & Star fields.

MOTIVATION FOR THE STUDY

The Cola bronze of *Naṭarāja* cosmic dancer is one of the most widely known images of Indian art. This form of *Naṭarāja* is restricted both in geogra-

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phy and time. It is found only in south India and attained a canonical form in the eleventh century AD. Venkatram[1] and some others have suggested that this form of the Hindu God *Śiva* can be visualised in the stars of the Orion and neighbouring constellations. Although such a procedure is the basis for all constellation figure visualisation, it is a subjective procedure. Any set of dots representing the stars can be rotated, scaled and skewed to achieve a semblance of a match. It is necessary to establish an objective set of criteria for comparing star patterns with the *Ananda Tāṇḍava* icon of *Naṭarāja.* This involves understanding the relevant aspects of both Hindu iconography and celestial cartography as they have evolved over millennia.

Early investigations showed a very high spatial correlation between the canonical features of the *Ananda Tāṇḍava* icon listed by Zvelebil[2] and positions of the stars of the Orion region. The match was so dramatic that it strongly suggested that the sculptor had access to accurate star positions of the epoch. It therefore appeared that the icon design had a definite astronomical purpose. The orientation of the matched star region with respect to the icon, taken along with the fact of the proliferation of the images in the tenth and eleventh century AD led to the possibility that the astrononical purpose may have been to record the position of the crab supernova of 1054 AD (Raghavan[3]). The support for this possibility will be presented in a subsequent paper. However two important aspects have to be considered carefully before examining the above hypothesis in depth.

1. *Śiva* is known in many forms. Why should star positions have been used only in the design of *Natarāja* form? Do the icons of other forms also follow star positions?
2. If star positions have been used in the icon design what is the accuracy of the star positions? What is the source of this data?
3. Is there any textual support for the use of star positions in icon design?

Background for this Study

The Hindu God *Śiva* is an ancient and multifaceted deity. While the mythology of *Śiva* may be traced back to the *Vedic* times (~ 2000 BC), that he is a powerful sectarian God, is well established only in the epic *Mahābhārata*

(O'Flaherty[4]). In each myth associated with him, he takes a different form and has different attributes ! As Master of Time he acts as a destroyer. He is a wanderer in the burial grounds, a naked mendicant in the forest, and the cosmic dancer. He disguises himself as a hunter some times and is patient teacher at others. Over millennia, these myths have inspired poets to compose hymns on his exploits, in many major languages of India. What is the source of all or some of these colorful myths?

Orion is a Hunter in Greek mythology and *Śiva* disguises himself as the hunter *Kirāta* to test *Arjuna,* in a story narrated in the *Mahābhārata* ! We know that even today, that *Ārdrā* or α Orionis (Betelgeuse) is designated as *Śiva's* star. The Orion constellation is also known as *Kālpuruṣa* in India or the Man of Time. On the other hand *Śiva* is described in Tamil as *Kālarimūrti* and *Kālasaṃhāramūrti* in Sanskrit -the divinity who destroys time - a typical astronomical function. Thus the Orion constellation with *Śiva*'s star *Ārdrā*/ Betelgeuse on the shoulder of the hunter Orion could be the celestial representation of *Śiva.*

Such identification conforms to the way in which constellations were visualized by all cultures. The ancient residents of the sub-continent may well have identified the prominent constellation known as Orion the hunter today as a representation of their *Śiva* as hunter. In other cultures too the information available on earliest constellation shapes is from their description found in literature rather than as a visual representation. This work examines if the connection between the Orion constellation and *Śiva* extends beyond the three facts mentioned above.

Methodology

In order to conclusively identify *Śiva* with the Orion constellation, it is necessary to establish an objective methodology. This task is made complex by the fact that each myth has been embellished over time, as shown by versions of the same myth in texts of different epochs. So in each myth selected, the core characters alone are identified for comparison with the sky. This is appropriate, as the visual sky representation would most likely be that of the core characters.

As a next step the star patterns can be compared with actual sculptures of the different forms of *Śiva.* This requires a careful selection of both the myths and the sculptures. The following procedure has been followed.

1. To list and examine how many characters in the well known myths of *Śiva* can be identified with modern designations of constellations in the sky.
2. To select the earliest available homogeneous set of icons of the multi-forms of *Śiva.*
3. To establish a standard procedure for comparison of icon with star field, using historical and literary references wherever available.
4. To compare the Orion region with each of the selected sculptures as per standard procedure.
5. To make an identical comparison of the sculptures with a randomly selected test star field.

Characters in the Selected Śiva Based Myths

Seven forms of *Śiva* have been selected and the associate myths have been examined.

Appendix I gives a short description of each myth and the sky parallel. The following characters have been identified as being important in each myth.

Kirāta myth – *Śiva* as *Kirāta, Arjuna* and the boar
Śiva and *Nandī* myth – *Śiva* and *Nandī*
Gaṅgādhara myth – *Śiva* as *Gaṅgādhara, Ākgś'agaṅgā, Bhagīratha*
Kālarimūrti myth – *Śiva* as *Kālarimūrti*
Bhīksatana myth – *Śiva* as *Bhīksatana, Kṛttikās, Saptarṣi*
Naṭarāja myth – *Śiva* as *Naṭarāja, Akāś'agaṅgā, Apasmāra/Muyalaka*

Fig. 1 shows a map of the Orion region of the sky with all stars visible to the naked eye (6th magnitude and brighter) marked. The area of this region is $60^{\circ} \times 60^{\circ}$ square degrees. All the constellations/parts of constellations identified as characters in *Śiva* based myths listed above are labeled. It is seen that in the neighboring constellation of Orion, at least 6 can be identified with main characters in these myths. In addition *Saptarṣi* i.e. Ursa Major lies north east of

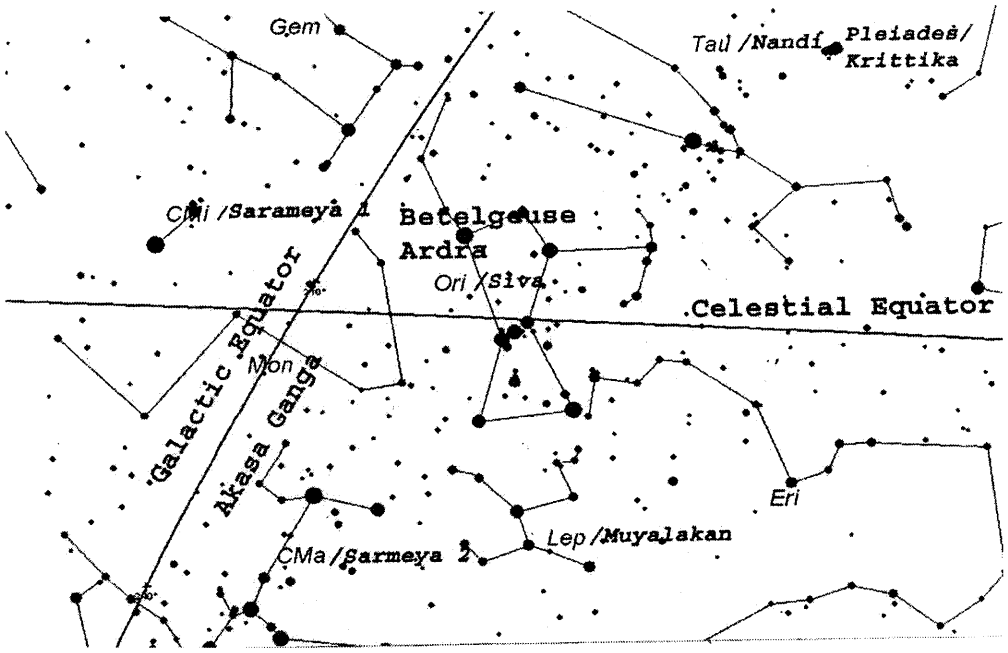


Fig. 1: Orion Region of the Sky – Current Epoch

Orion. This strengthens the identification of the stars of the Orion constellation as being the inspiration for the *Śiva* visualized by ancient Indians. This identification is interesting but not extraordinary. Often an astronomical event that has been observed is presented as a myth involving the celestial characters. Eclipse myths are well known examples of myths constructed by all cultures to explain and assimilate an extraordinary celestial event. It is entirely natural that the stars of the Orion region which are so prominent in the sky and so strategically located near the intersection of the celestial equator and the Milkyway, encouraged the visualisation of *Śiva,* an important God in the Hindu pantheon. How were so many different forms of *Śiva,* visualized from the same set of stars? This may be done in the following way. Let a basic set comprising of some of the most prominent stars, define some distinctive features. These are constant for every mythological form. From among the rest, a different set of stars of the same region outlines the other features and characters of the form and the associated myth. In what follows we will examine the above hypothesis by comparing different iconographic forms of *Śiva* with the same star field centred on Orion.

Selection of Multiforms of Śiva – Kailāśanātha Temple

There is an abundance of iconographic forms of *Śiva* in stone, which are distributed throughout South Asia. Each one is sculpted at a different epoch, the whole effort spanning more than two millennia. The early versions of the myths themselves go back four millennia! For an objective study it is necessary to select a homogeneous set of sculptures made at the same epoch and compared with the Orion star field of that epoch.

The *Kailāśanātha* Temple in Kanchipuram, India (Fig.2) is a remarkable temple for more reasons than one. Located in the out-skirts of the temple town that boasts of 108 temples, it is not a large temple. But as you drive down the dusty road, its elegance accentuated by a lonely palm tree, immediately strikes you. Built by the *Pallava* king Rājasiṃha in the late seventh century AD, it is the first structural temple in South India which has a distinctive style for its temples. All existing temples predating it are cave temples or monolithic ones carved out of rock as in Mahabalipuram, India. It has an original architectural style that has influenced later south Indian temples. The shear size and exuberance of the numerous sculptures takes your breath away. Srinivasan[5], using archaeometallurgical techniques, has shown that the *Naṭarāja* bronze in the Victoria Albert museum belongs to the *Pallava* era. Thus selecting sculptures in the first structural temple of south India built by a *Pallava* king is appropriate. The temple is dedicated to *Śiva* as *Kailāśanātha.* The technique of

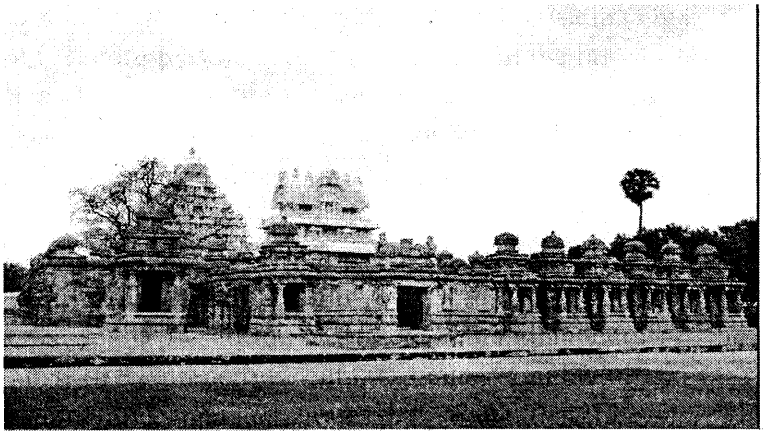


Fig. 2. *Kailāśanātha* Temple, Kanchipuram

placing slab upon slab of sand stone in place to achieve larger than life sizes and then sculpting the sand stone is unique. The delicate detail in the end product shows that the skill and effort must have been of a high order. The theme that runs through the temple is *Śiva Līlā* – 'the games of *Śiva*'. Almost all the major forms of *Śiva* are sculpted in the main and/ or 58 sub-shrines that form the temple. The sculptures in this seventh century *Pallava* temple will form a homogeneous set of sculptures for comparison with the Orion star field.

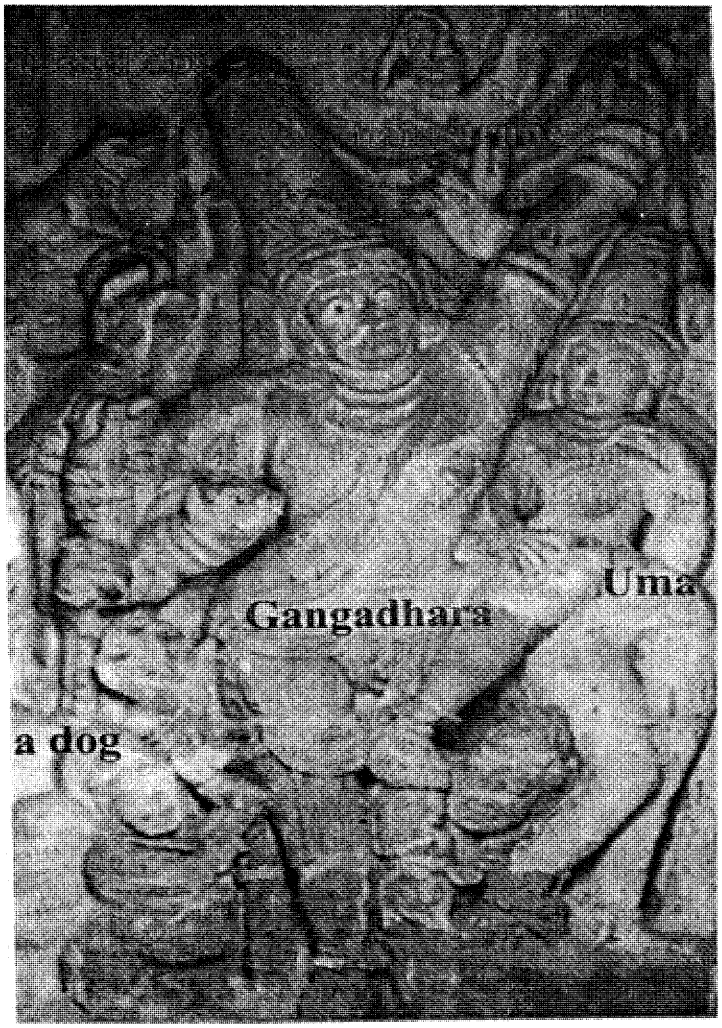


Fig.3. *Gaṅgādhara* (WL), *Kailāśanātha* Temple; notice the two dogs in the Panel

One of the dramatic sculptures in this temple is that of *Gaṅgādhara* displayed in the west lateral niche of the main shrine. Fig. 3 shows the main panel of this sculpture. The main protagonists of the myth *Gaṅgādhara, Pārvatī* and *Gaṅgā* are clearly shown. In addition two dogs that are part of the *Bhairava* myth are also shown. This feature was first noted by Lockwood et al[6] in many *Pallava-Gaṅgādhara* sculptures. Recall that Canis major and Canis minor flank the celestial equator and the Milky way in the sky. This correspondence has also been proposed by Venkatram[7]. This is a direct pointer: to the influence of celestial cartography in the sculpture. There are three other *Gaṅgādhara* panels in this temple, but none of them shows the two dogs, being narrower panels. The sculptures associated with this myth have therefore been taken for study first. Table 1 lists all the sculpture panels selected for study. Some forms other than *Gaṅgādhara* are also repeated in more than one panel. Only the best preserved one is selected in this study. The one in the north subshrine no.48 is in very poor condition.

Sculptures and Star Fields selected for Comparison

Each of the selected sculptures has been photographed with a high resolution digital camera. Care has been taken to avoid distortion in the image due to perspective effects. The digital image is corrected for the remaining small distortion, using the image processing software, Adobe Photoshop. These 2 D digital images form the basic set of sculptures to be compared with the star field which also is a 2 D projection of the stars on the celestial sphere. The beautiful scale drawings of Rea[8] has been used to identify the *Kirāta* and *Bhairava* forms of *Śiva* sculptures in the temple.

The star map for the Orion region for the seventh century AD is generated using the software package SkyMap Pro. This package has a very accurate data base, taken from the Tycho catalogue compiled by the HIPPORCOS satellite. A $50^{o} \times 50^{o}$ region of the sky, centred on the star ε Orionis in the belt is selected. The limiting magnitude in the maps generated is 6, the standard limit of naked eye visibility. The galactic equator which passes through the central part of the Milkyway band and the celestial equator are marked.

A star field centred on γ Geminorum of the same epoch is selected as a test field. This field has stars of nearly equal brightness, approximately in a

Table 1: *Kailāśanātha* Sculptures Selected for the Study

No.	Description	Location	Size of Panel in m	Resolution
1	*Gaṅgādhara*	sub shrine 23	1.20 × 0.60	65 pixels/degree
2	*Gaṅgādhara*	main shrine west	2.95 × 2.05	50 pixels/degree
3	*Gaṅgādhara*	main shrine north	1.48 × 0.59	80pixels/degree
4	*Gaṅgādhara*	sub shrine 48	1.20 × 0.75	62pixels/degree
5	*Kālarimūrti*	main shrine north	1.50 × 0.59	83pixels/degree
6	*Bhīksatana*	main shrine south	1.48 × 0.60	80pixels/degree
7	*Nātarāja*	main shrine west	1.48 × 0.60	40pixels/degree
8	*Kirāta*	sub shrine 15	1.20 × 0.80	60pixels/degree
9	*Bhairava*	sub shrine 14	1.20 × 0.60	59pixels/degree

line. These could be assumed to represent the belt of *Śiva*. Both the Orion and test star fields are matched with the sculpture using an identical procedure. This would help in assessing the uniqueness or otherwise of the match between the sculpture and the Orion field. Table 1 lists the size and the resolution of the digital image in pixels/degree. This has been calculated after scaling the Orion star field to match the sculpture.

Scaling Procedure

All cultures that have contributed to celestial cartography (Allen[9]) have uniformaly identified the position of five stars in the Orion constellation with respect to the figure of Orion. Betelgeuse (α Orionis) is always placed in the right shoulder or armpit while γ Orionis in the left arm pit/ shoulder. The three belt stars are precisely that they form the belt or midriff of the figure. So this is the basic set of stars that have to be matched with the shape of *Śiva* in every selected sculptural form.

A sequence of digital filters is applied to all the 2-D digital images used in the study. This facilitates outlining the sculpture within the niche clearly and defining the region within which the coincidences of star positions and features are to be examined. The star field of Orion for the epoch of 700 AD is superposed on the 2D digital image of the selected image. The star map's scale is adjusted so that the five stars mentioned above are over the two shoulders/arm pits and the belt/midriff of the image. No rotation or skewing was used. The left panel in Fig. 4a shows the result of such a superposition for the *Gaṅgādhara*

sculpture in the north lateral niche, the best preserved *Gaṅgādhara.* Notice that only one scale factor is used in this matching procedure. For fine tuning the match, the map is then moved pixel by pixel both in the vertical (Dec) and horizontal (RA) directions to obtain the optimum superposition of the stars over prominent features in the sculpture. A remarkable feature of this matching is that the three star cluster of ϕ_1, ϕ_2 and λ Orionis is placed at the dangling left earring of *Gaṅgādhara.* Tamil hymns to *Śiva* always high light *Śiva* as the one with earrings. The most famous of these hymns is ascribed to a seventh century AD Tamil poet *Thirugnanasambandar*[10], when he sang about *Śiva* as "Thodudaya Sevian" meaning "the one who has an earring"! Taking this as an additional clue to the matching procedure this set of three stars was also added to the basic set mentioned earlier. Since the earring is a smaller feature in the sculpture than the shoulder/the armpit it provides a more accurate constraint in the scaling and matching procedure. The star field overlapping the image of the sculpture extends from RA $3^h\,45^m$ to $5^h\,25^m$ spanning 25°east to west in the sky. In the direction of declination the sculpture extends from 28°S to 22°N spanning 50° in the north – south direction. Notice how the sculpture is aligned in the vertical with the Right Ascension line.

Significantly, the artistic representation of Orion in the first star map by Bayer[11] to the map by Goldbach[12] spanning nearly two centuries, the star group consisting of ϕ_1, ϕ_2 and λ is shown in the ear lobe!(Fig. 4b).

The test star field centred on γ Geminorum is also matched with the same *Gaṅgādhara* sculpture. The star field has to be rotated by more than 25° to align the four stars with the midriff. There is however no second criterion that can be used to scale the star field. It is therefore scaled so that the area of the map in square degrees to cover the sculpture is the same as that of the Orion field. Once again the map is moved pixel by pixel so that the maximum number of stars fall on the outline or feature of the sculpture.

Comparison Procedure

The star fields and the sculpture have been compared at four levels:

Level 1: After the superposition and scaling of the star field to the sculpture, the matching stars are connected by straight lines to obtain the equivalent of an outline of the sculpture. The best fit figure is drawn for stars

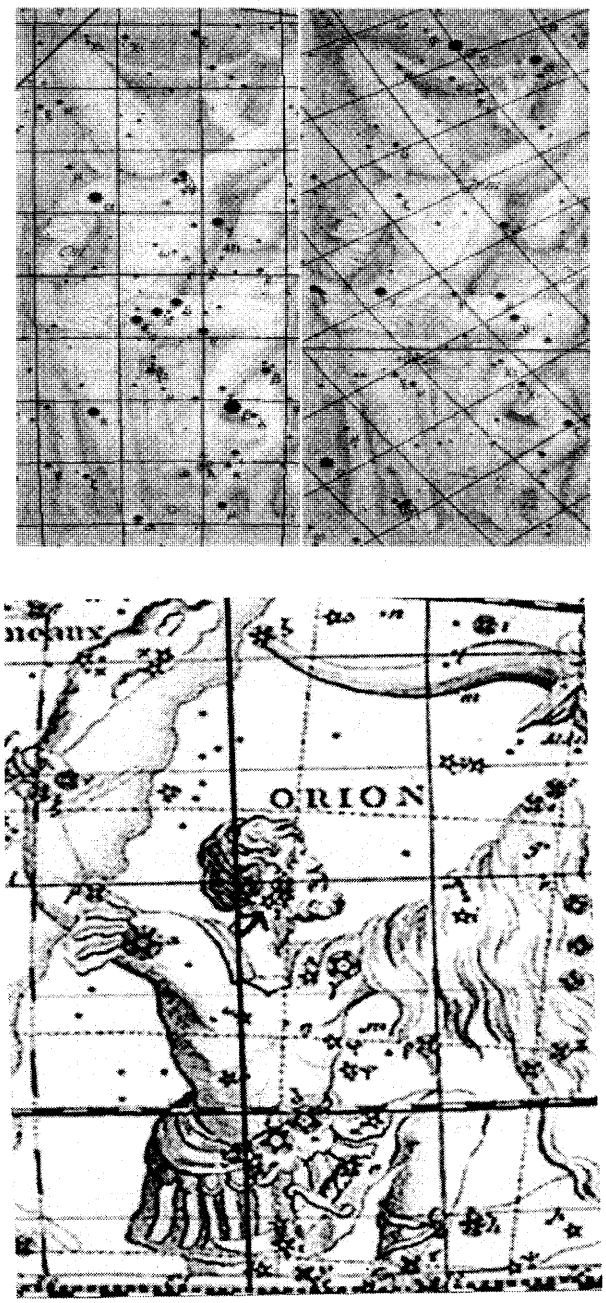


Fig. 4 (a) *Gaṅgādhara* Sculpture scaled with stars of Orion Field (left) and Random comparison field centred on γ geminorum (right); (b) Orion in French Edition of Atlas Celeste of Flamsteed (1776). Notice the star group formed by (ϕ_1,ϕ_2 and λ) at the ear lobe of the figure.

brighter than 4th, 5th and 6th magnitude successively. This is done for both the Orion and the test field. Although this is only a qualitative assessment it illustrates the difference between the match with the Orion and the test field very clearly.

Level 2: The number of stars that match features in the sculpture is counted. A star is counted as a match with the sculpture if it satisfies one of the categories given below with a displacement less than 0.75°. The number of matches and mismatches of all the stars in the area is counted separately for stars brighter than 4th, 5th and 6th magnitude. This count is made in both the Orion and test field as a percentage of the total number of stars falling within each sculpture. The criteria for deciding star-sculpture match are listed below:-

1. If a star lies with in 0.75° of a physical feature or accessory

2. If a star outlines the form i.e. the edge of the figure. Some times a star is in the middle of the thigh or fore arm. This is counted as a match only and only if it helps to define the posture of the sculpture as is often the case.

3. If the star shows the beginning of a change in direction that defines a posture or a gesture and lies with in 0.75°.

All stars with in the defined field that do not fit any of the above are counted as mismatches.

Level 3: A 1° × 1° grid is superposed on 2-d images of selected sculptures. The outline of these sculptures has been extracted by passing the images through numerical filters. A large number of squares have the outline/feature of the sculpture passing through them. Some fall on interspaces. The number of squares which are free of features or outline as defined above is counted as a fraction of the total number of squares that cover the sculpture. This fraction is the mismatch that would be obtained when a random set of dots is superposed on the sculpture image. This fraction can be compared with the fractional mismatches for both the Orion and test star fields measured in the level 2 analysis.

Level 4: The measure tool in Adobe Photoshop has been used to measure the displacement of a star from the nearest feature/outline of the images of the sculpture. The displacements of all the stars of the Orion field that lie with in the area of the sculpture have been measured. The distribution of the number of stars as a function of displacement has been obtained for the selected sculptures. This gives the lower limit of the accuracy of the star positions that underlie the design of the sculpture.

Table 2: Summary of Matching between Star Field and Sculpture Image Level II Results

Name	Orion Field			Ramdom Test Field		
	<4th mag	<5th mag	<6th mag	<4th mag	<5th mag	<6th mag
1. Gaṅgādhara						
Total stars	21	63	174	15	52	146
%mismatch	**0**	**1.6**	**1.7**	**13.2**	**9.6**	**6.8**
2. Gaṅgādhara 2						
Total number of stars	16	44	103	7	19	58
%mismatch	**0**	**2.3**	**1.9**	**14.2**	**31.6**	**13.8**
3. Kālarimūrti						
Total number of stars	24	67	165	14	42	124
%mismatch	**0**	**0**	**3.6**	**28.6**	**13.6**	**10.5**
4. Nāgarāja						
Total number of stars	18	60	151	–	–	–
%mismatch	**0**	**1.7**	**1.3**			
5. Bhīksatana						
Total number of stars	24	59	173	–	–	–
%mismatch	**0**	**0**	**0**			
6. Kirāta						
Total number of stars	23	73	173	–	–	–
%mismatch	**0**	**1.4**	**1.7**			
7. Bhairava						
Total number of stars	27	74	190	–	–	–
%mismatch	**0**	**1.4**	**4.2**			

Results of the Comparison between Sculpture and Star Fields

Level I comparison: Seven of the nine sculptures listed in Table 1 have been compared at this level. Two *Gaṅgādhara* sculptures that have deteriorated considerably have been excluded from further comparison. For each sculpture the stars superposed on the sculpture have been joined to form an outline of the sculpture at each category of limiting brightness. This has

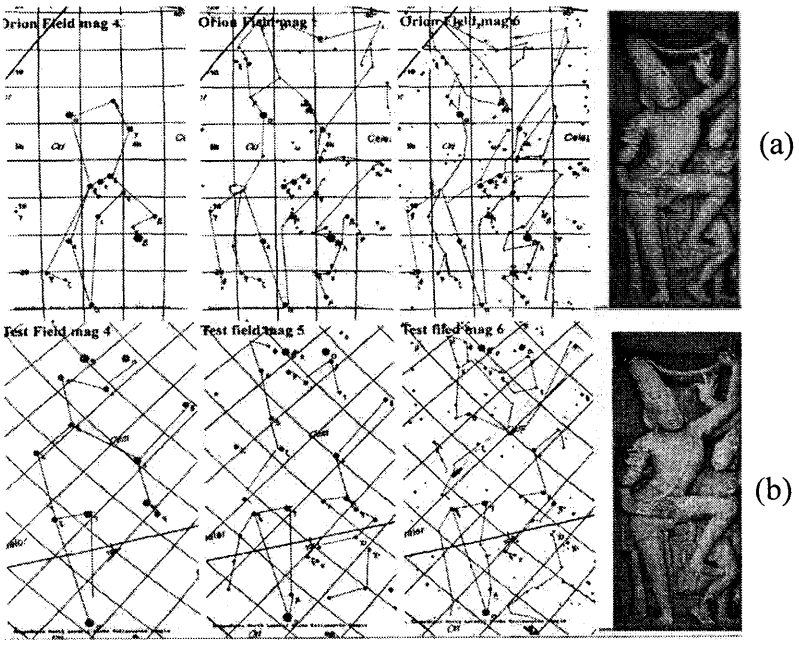


Fig. 5: Comparison with Gaṅgādhara – Outlines formed by stars of progressively fainter limiting magnitudes: (a) Field Centred on ε Orionis , (b) Field Centred on γ Geminorum

been done for both the Orion field and test field stars. Fig.5 shows the outlines formed when the stars brighter than 4th, 5th and 6th magnitude stars of both fields are superposed on the *Gaṅgādhara* sculpture in the north lateral niche of the main shrine. This sculpture is the best preserved one. It is very clear that the

Table 3: Summary of Matching between Star Field and Sculpture Image - Level III Results

Name	Orion Field	Test Field
1. Gaṅgādhara (WL)		
%measured mismatch	1.7	6.8
% of random mismatch	7.6	7.6
2. Gaṅgādhara (NL)		
% of measured mismatch	1.9	13.8
% of random mismatch	10.2	10.2
3. Kālarimūrti		
% measured mismatch	3.8	10.5
% of random mismatch	10.9	10.9

Orion stars outline the form of the sculpture in a progressive fashion as fainter stars are included. All the stars together outline the form very well indeed. The stars of the test field do not show a clear trend at all. At every stage the outlines form a poor reproduction of the sculpture form. Every sculpture examined shows the same pattern of progressive and excellent reproduction of the form by the Orion stars. In contrast, stars of the test field produce poor and sometimes grotesque outlines.

Level II comparison: All seven sculptures have been used at this level. The procedure will be given in detail for the *Gaṅgādhara* sculpture in the west lateral niche, the largest panel under study. Since the sculpture has deteriorated in some places, the scale drawings of Rea[14] have also been used to make unambiguous identification of features.

A total of 174 stars of naked eye visibility overlap with the sculpture. Only stars with in the outline of the sculpture are used in the comparison. Stars that do not fall directly on a feature are identified and the angular distance of these stars from the nearest feature is measured using the measure tool in Adobe Photo Shop. Of these stars 98.3% of them have a displacement of less than 0.75° from an identifiable feature. Only three stars of sixth magnitude and brighter and 1 star of 5th magnitude and brighter are not a match. They are counted as mismatches. All the stars 4th magnitude and brighter, can be classified in one of the categories defined above. Only 1.7% of the stars visible to the naked eye in the region are not matches.

The image of the sculpture superposed with the star field has also been independently assessed for mismatches between the sculpture and star positions by Dr. Sounderrajaperumal. He was not given the drawings by Rea. He counted 4 mismatches instead of 3, the extra mismatch falling in the deteriorated part of the sculpture. Thus essentially identical results have been obtained by two independent researchers. Clearly the distribution of stars in this region of the sky has served as a template to the seventh century sculptor of the *Gaṅgādhara* panel.

Interestingly the stars which match with the two dogs in the panel are not those of modern Canis Major and Canis Minor! They are stars in modern Monoceros and Orion constellation respectively . Yet they straddle both the galactic and celestial equators consistent with their mythical representation.

The same procedure is adopted for the test field. There are a total of 146 naked eye stars overlying the sculpture. The largest mismatch is in the category of brightest stars compared to 0% for the Orion field. For stars brighter than 5th and 6th magnitudes the mismatched stars are fewer at 9.6% and 6.8% respectively. Even this is significantly higher than that for the Orion field. Independent counts yielded identical results. This implies that the design is influenced by the faintest and not the brightest stars, a finding that is the very opposite of the principles of constellation visualization! On the other hand, in the case of the Orion field, features appear to have been sculpted deliberately to match 100% of the bright stars up to 4th magnitude. The 5th and 6th magnitude stars also play an important but secondary role with a match figure 99%.

The following is especially noteworthy as shown in Fig.6.

1. The stars used to depict the single strand of hair to trap the *Gaṅgā*
2. The stars used to depict the fingers that are holding up the strand
3. The stars used to depict *Gaṅgā* at the entry point located in the Milkyway
4. The stars used to depict droplets of *Gaṅgā* after being tamed flowing out of the *Gaṅgādhara's* locks. These again follow the Milkyway.

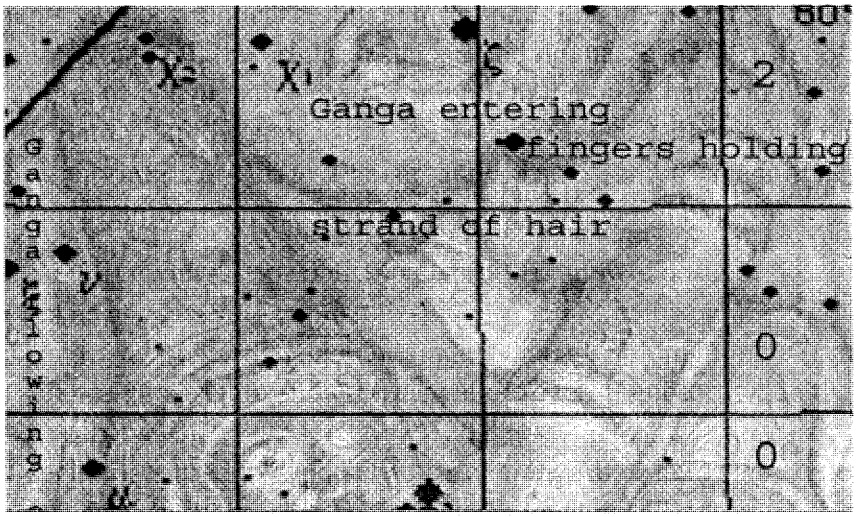
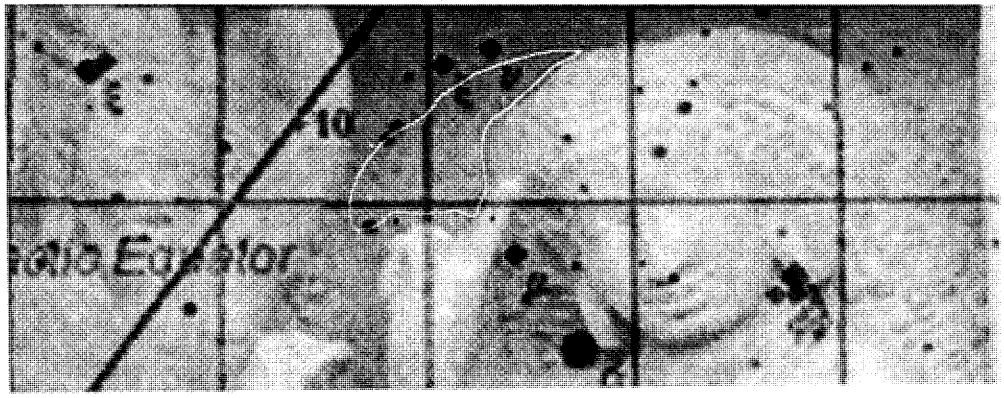


Fig. 6 : Section of *Gaṅgādhara* Sculpture superposed with star map

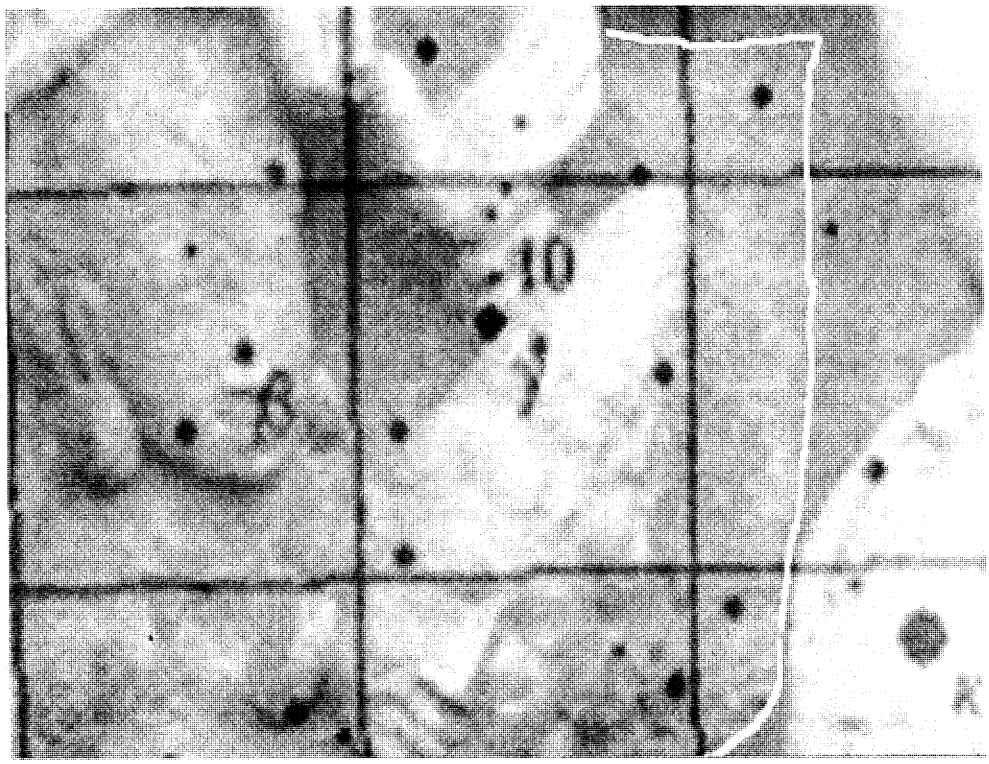
Level 2 comparison has been made for the rest of the seven selected sculptures. As in the case of *Gaṅgādhara* (WL), for the Orion region all the sculptures are aligned with the RA lines. The RA lines of the test field have to be rotated by more than 25° for matching the sculptures. The level 2 comparison of all the sculptures leads to the same conclusions as for *Gaṅgādhara* (WL), only more emphatically so. The brightest stars have no mismatch for the Orion field. In direct contrast, these stars have the maximum mismatch in the test field. For all values of brightness the mismatch in the test field is an order of magnitude of higher than for the Orion field. Table 2 sets out the results of level 2 comparison for all sculptures.

In the case of every sculpture studied the mismatch with the positions of stars of 4th magnitude and brighter is 0% for the Orion field. For fainter stars of the same region, the correspondence is also excellent, the mismatch never going above 4.2% in any sculpture. In contrast, the mismatch for positions of stars in a random field is maximum for the brightest stars, always higher than 13%. For fainter stars in the same field also, the mismatch is never below 6%. We also obtain the anomalous result of the match being better for fainter stars than for brighter ones, for stars from the randomly selected field. This contradicts the principle of constellation visualization. Any degree of match obtained between the stars of the test field and the sculptures is by chance. On the other hand, the high degree and progressive nature of the matches of the *Śiva* sculptures with the Orion region star positions is by design and not by chance.

The overlap of all stars with important features and shape is 100% for *Bhīksatana!* Initially 8 stars were found to deviate by more than 0.75° from any identifiable feature in the *Bhīksatana* panel. However on close examination it was found that the star positions matched with faint features shown in Fig.7. These features are the back-hair of *Bhīksatana* Fig(7a) and the multiple figures of *Ṛṣi Patnīs* carved delicately in the background as if to suggest depth in the scene (Fig. 7b)! This ingenious way in which the star positions are put to use in the most aesthetic way is strong additional proof for the premise of this paper. Remarkably it has allowed us to visualize the aesthetic sensibilities of a sculptor who lived 1300 years ago. This discovery makes the match between positions of naked eye stars and the features of the sculpture of *Bhīksatana* 100%.



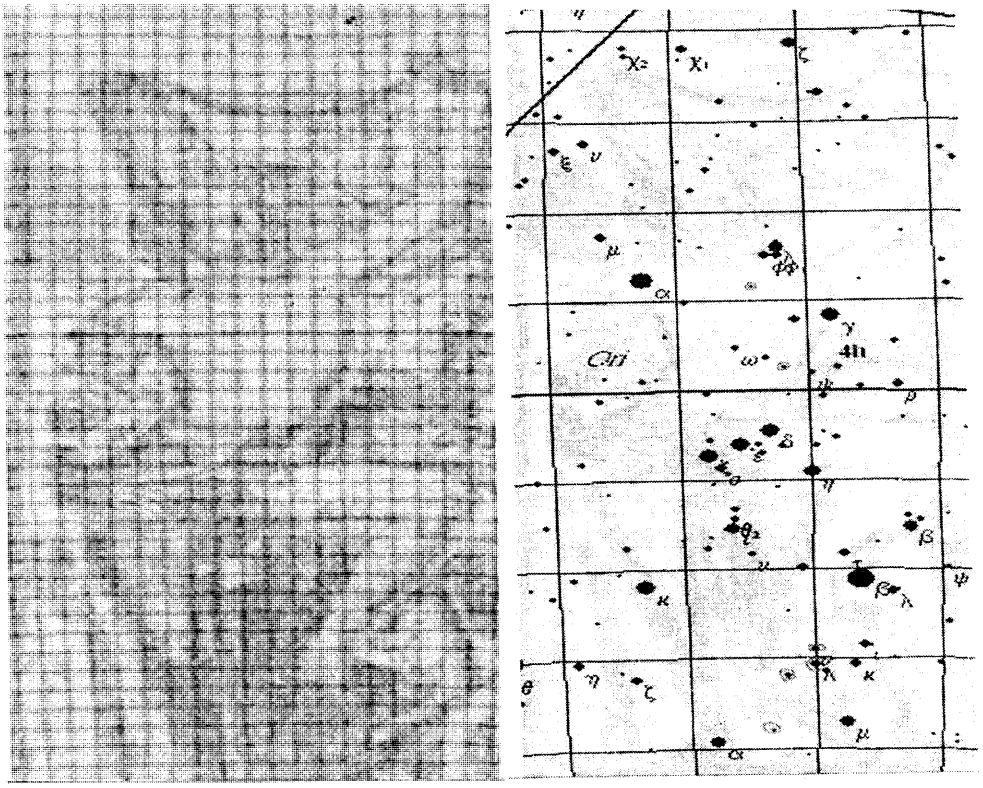
(a)



(b)

Fig. 7: Section of *Bhīksatana* Sculpture superposed with star map, (a) The four stars originally counted as not falling on any feature, delineate the faintly sculpted and erased, back hair of *Bhīksatana* outlined in white; (b) The three stars originally counted as not falling on any feature, delineate the faintly sculpted forms of *Ṛṣi Patnis* lining up behind the first one.

III Level 3 comparison: The sculptures *of Gaṅgādhara* (WL), *Gaṅgādhara* (NL) and Kālarimūrti are included in level 3 analysis. The images of the selected sculptures are passed through a sequence of digital filters to extract the outline of the sculpture and its features. A 1° × 1° grid is superposed on the extracted image (Fig. 8a). The total number of squares N covering the entire sculpture is counted. The number n of squares not occupied by any feature or outline of the sculpture is also counted. The ratio n/N gives the fraction of the total number of stars that will not fall with in 0.75° of a feature or outline of the sculpture, when a random set of stars is overlaid on the sculpture. For the *Gaṅgādhara* (WL) sculpture 7.6% or the squares are empty. So we should find a mismatch figure of 7.6% of a random set of stars. For the test field the mismatch figure is 6.8% close to the figure for a random set. The mismatch for the



(a) (b)

Fig.8. (a) Contour of *Gaṅgādhara* sculpture with a 1° grid superposed; (b) Contour of *Gaṅgādhara* sculpture scaled and matched with stars of Orion

Orion field is an order of magnitude less than the value for a random match. Table 3 sets out the results for all the three sculptures so analysed. In every sculpture, the mismatch for the Orion field in column 2 is one order of magnitude lower than the mismatch expected for a random set. In the case of the test field the mismatch figures agree closely with that calculated for the random set. This gives statistically significant support for the hypothesis that star positions underlie the icon design (Fig. 8b).

IV Level 4 comparison: If the star positions have formed a template for designing the sculptures, it is reasonable to ask if their accuracy can be estimated from the sculptures. The displacement of the stars from the nearest contour/feature has been measured with the measure tool of Adobe Photoshop for the Orion field. This measurement is made with accuracy between 1.5′-2.5′ of arc on the image. The cumulative percentage of stars that fall with in a certain angular displacement is plotted as a function of that displacement (Fig.9). 50% of the stars in *Gaṅgādhara* and *Bhīksatana* sculptures fall with in 0.075° or 4.5′ of arc. For *Kālarimūrti* this figure is 0.125° or 8′ of arc. 95% of all the stars fall with in 0.75° of a feature/outline. This latter result is identical with the results obtained in the level 2 analysis. This figure for the accuracy of star positions includes the random and systematic errors inherent in converting the star positions into an aesthetic sculpture. It must therefore represent the lower limit of the accuracy of the star positions used. It is reasonable to state that that the star positions of the Orion region were available to the sculptor with accuracy better than 8' of arc. Compare this with the 10' of arc accuracy of Ptolemy's 2nd century AD catalogue. There are 103 stars visible to the naked eye in the region of the sky matched by the sculpture of *Gaṅgādhara* (NL). A comparison of these stars with stars in Ptolemy's catalogue shows that nearly 1/3rd of them (34) are not listed in it. A further examination shows that 26 of these 34 are placed very accurately on the extracted contour. 5 others follow the outline, but less accurately. Only 2 of these are not essential to the design. Ptolemy catalogue, therefore, is not the source of these star positions. This conclusion is also indicated by the higher accuracy of the star positions derived from the sculptures themselves. Even as it is clear that the sculptors had access to accurate naked eye star positions, their source is an open question.

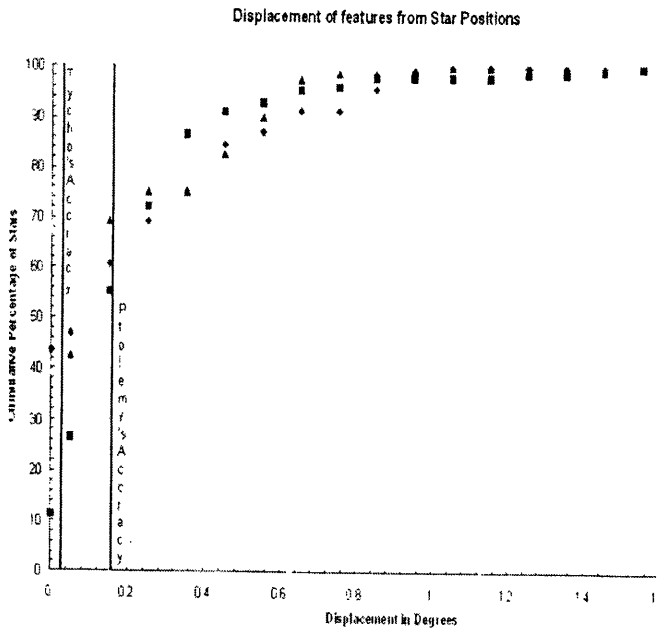


Fig. 9: Cumulative percentage of stars falling with in a prescribed value of angular displacement from the feature as function of the displacement. Diamonds - *Gaṅgādhara*; Squares - *Kālarimūrti*; Squares - *Bhīkasatana*. The accuracies of the Ptolemy and Tyco catalogues are shown on the plot for reference

Search for Textual Support

The earliest statement that is in support of the idea of stars being the inspiration for icons of deities is the *Ṛg* vedic description of deities as 'men in the sky' (Bannerjea[16]). The earliest extant text that states specific rules for iconometry is *Bṛhatsaṃhitā* [17] by Varāhamihira. This text mentions another book by Nagnajit as containing the rules of Dravidian iconometry. This book is now lost. The extant texts of iconometry date from twelfth century AD onwards. Although there is no dearth of texts, very little quantitative work appears to have been done to corroborate the rules contained in these texts with actual measurements on existing sculptures. Siromoney et al[18] have used statistical methods to analyse the facial proportions of south Indian sculptures. The study is based on measurements with anthropometric instruments on 39 well preserved carvings from the *Kailāśanātha* temple, Kanchipuram. The average values found for the facial proportions are quite different from the proportions prescribed by later canonical texts. They conclude that there is no basis to be-

lieve that the sculptors followed the rules prescribed in any extant iconometry text. The statement by Nagasamy[19] that the establishment of canonical texts followed the *Pallava* sculptures rather than precede them supports this finding.

Although explicit textual corroboration for the star position-icon design has not been found, the visual evidence presented in the paper is very strong and must be accepted. It is relevant to point out that Schaefer[20] found that the Hipparchus' lost star catalogue is archived as a sculpture in the Farnese Atlas. So preserving star positions in the form of sculpture is a known practice. Again Kak[21,22,23] has shown how rules given in Vedic texts for constructing sacrificial altars contain astronomical data. Thus in south Asia there is a continuing tradition of coding astronomical data in religious ritual, art and architecture. The star position -icon design connection fits well into this method of archiving or using astronomical data.

Conclusions

1. *Pallava* sculptors of *Kailāśanātha* temple, Kanchipuram used the Orion region star positions to design their sculptures of *Śiva* in his various forms. This is an extension of continuing tradition of associating Betelgeuse *(Ārdrā)* as *Śiva's* star.

2. The sculptures are all aligned with the RA lines showing that they were familiar with the equatorial system of coordinates.

3. They had access to a star catalogue of the Orion region with accuracy better than 8′ of arc.

4. The sculptors had the ability to transform essentially 2-d template into an aesthetic 3-d sculpture.

5. The use of star positions to design icons follows a tradition of archiving astronomical data in religious ritual, art and architecture.

6. Although textual support has so far not been found, the strong visual proof for the connection between icon design and star position must be recognized.

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APPENDIX I

a. *Kirāta* Myth: - *Śiva* as *Kirāta* the Hunter parallels Orion. Other than *Kirāta,* the other main characters are the boar *Varāha* and the warrior *Arjuna.* In the neighborhood of Orion these two characters cannot be identified from the current names of constellations.

b. *Nandī* Myth: *Nandī* the Bull is ever present with *Śiva,* especially in *Śiva* temples. Here it is portrayed always as a bull facing *Śiva* in a seated position with its face turned to one side. Taurus the bull as represented in modern constellation figures is a bull with the head turned towards the body and feet tucked in. With *Śiva* identified as Orion, *Nandī* can therefore be easily identified as Taurus facing Orion the hunter or *Śiva* as *Kirāta.*

c. *Gaṅgādhara* Myth: In this myth Bhagīratha prays that *Ākāśagaṅgā* the river in the sky descended down to the earth. As *Gaṅgā* descends ferociously it is feared that there will be a deluge on earth. *Śiva as Gaṅgādhara* comes to the rescue. He snares *Gaṅgā* in his locks and slows her descent to the earth. Milky way is known as *Ākāśagaṅgā* in India. The Milkyway passes down from above the head of Orion in the right location to have inspired the *Gaṅgādhara* myth. Bhagīratha cannot be readily identified, from the modern constellation forms and names.

d. *Bhairava Myth:* The imagery invoked by the myth of *Śiva* as *Bhairava* is of a terrible form of *Śiva* wandering with the severed head of *Brahmā* in the cremation grounds. Two black hounds follow him to lick the oozing blood so that none of the poisonous blood falls on the ground. The two dogs are also

sometimes referred to as guarding the entry gates of heaven. With Orion as *Bhairava,* Canis Major and Canis Minor are the dogs of *Bhairava!* According to tradition *Deva loga* or heaven is north of the celestial equator and *Daitya loga* or hell is south of it. Notice that the figure of Orion/*Śiva* is neatly divided by the celestial equator, appropriate to visualizing the location as a cremation ground. The Milkyway also ascends to the northern half here, so the twin dogs are watch dogs at the Milkyway as well (Allen[9]).

e. *Naṭarāja* Myth: *Śiva* as *Naṭarāja* is most well known for the *Ananda Tāṇḍava.* The other significant character in the episode is *Muyalaka,* also known *Apasmāra. Muyalaka* literally means hare-like in Tamil. *Naṭarāja* dances on this hare-like creature crushing it. With *Orion/Śiva* as *Naṭarāja,* the constellation Lupus the Hare that lies below Orion can be assigned to represent *Muyalaka* in the myth. Additionally *Gaṅgā* one of the canonical features of the *Ananda Tāṇḍava* bronzes and the Milkyway/*Ākāśagaṅgā* passes down from above the head of Orion.

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