SIGNIFICANCE OF CONSTELLATIONS IN CAROLINIAN NAVIGATION

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SIGNIFICANCE OF CONSTELLATIONS IN CAROLINIAN NAVIGATION

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The seafaring peoples of Micronesia employ practical astronomy for oceanic canoe travel. The navigational demands of reaching small islands after days of open-water sailing have shaped their practical astronomy into a pragmatic system used to determine directions much as we use our modern compass. Micronesian methods of celestial navigation are well understood and documented for east-west travel. Ethnographers have attempted to apply these east-west navigational tools to north-south travel, but close examination indicates that this approach fails to incorporate methods reported to be used by the Micronesians. Alternative methods of north-south navigation can be postulated by recognising the distinctive characteristics of circumpolar star behaviour.

Star Lane Navigation

Goodenough established much of the framework upon which later ethnographers have based statements on Micronesian astronomy. His work (1953) represents the first comprehensive presentation of native astronomy in the Caroline Islands. He published the "Carolinian Star Compass" (Figure 1) which he composed from reports of similar compasses used by master navigators throughout the Carolines to teach apprentices. The 32 points on this compass represent directions analogous, but not equivalent, to points on European magnetic compasses (Gladwin 1970:148). He made each compass point correspond to the rising or setting point of a particular star. The rising or setting point of a star can only be determined at one instant in each 24-hour period, and then only if the horizon is clear of haze. Consequently, the Caroline navigators use several more subtle variations when applying the star compass.

The star compass can be applied to east and west travel simply and rigorously. Here stars nominally ascend and descend in straight lines perpendicular to the horizon. Only the altitude of the stars changes; the azimuth or bearing of each star remains constant. Thus, each star may be used to locate a unique azimuth, i.e., a point along the horizon, for six hours each night. Memorising many stars rising near the same azimuth forms a practical means to locate that easterly or westerly direction at night. This group of stars, called a star lane, has members that rise at different times throughout the night, minimising the time each compass point lacks an identifiable star. Practical considerations increase the need for many stars at each point. Observers located 8 °N of the equator (the central

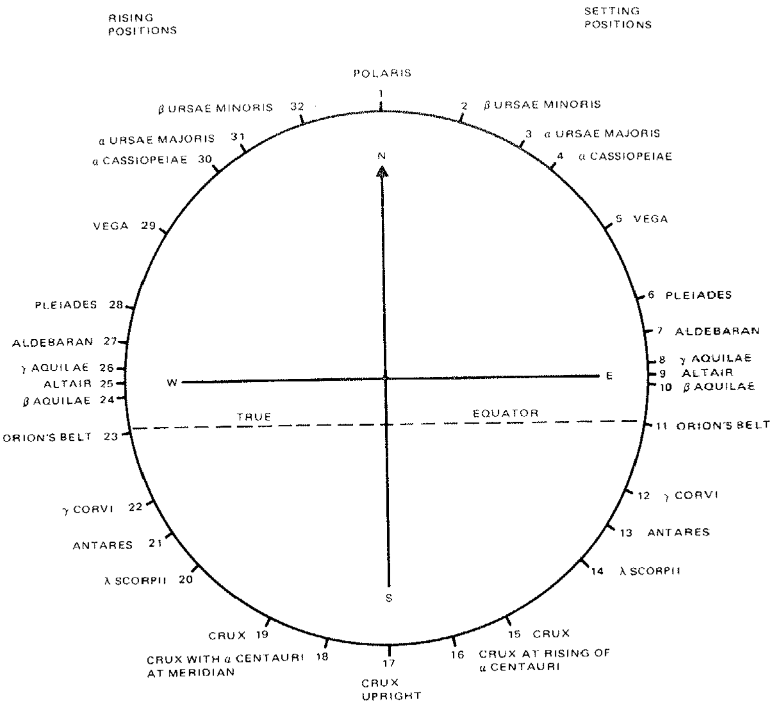

FIGURE 1. Carolinian Star Compass from Goodenough (1953).

latitude of the Caroline Islands) see the vertical star trails tilt 8°. Also, stars north or south of due east travel on increasingly carved paths, creating an additional shift in azimuth as the night progresses. In Carolinian astronomy, the relationship of stars which "follow the same path" is recognised by using the name of a single star to refer to all stars on the path (Goodenough 1953:5).

The determination of latitude is a valuable navigational tool. However, only circumstantial evidence, some found on the star compass, supports that such capability did exist with the South Pacific navigators. On Goodenough's compass, the east-west line is drawn between the rising and setting points of Altair, in response to the Caroline practice of calling the rising Altair "east". However, sailing towards Altair "east" then returning along Altair "west" will cause the canoe to finish north of its departure point. The only star lane pair that would bring the canoe back are those for Orion's Belt, because Orion's Belt lies on the celestial equator which uniquely intersects the horizon at due east and due west. The special significance of Altair's star lane, defined as the strip of sky along declination 8°44″N, is that it contains the zenith at the Carolines' 8°N latitude. The interest Caroline peoples have in Altair, calling it east and naming a month in their calendar after it (Goodenough 1953:12), can best be interpreted as an awareness and interest in the zenith. Latitude may be determined directly from the zenith by simply noting in which star lane the zenith lies. The Carolinian compass contains a notable concentration of five star lanes between declinations 1°S and 16°N, providing the capability to accurately distinguish the zenith, and thus latitude, from anywhere in Micronesia.

Gladwin (1970:150) recognised a discrepancy between the northern quadrant of Goodenough's compass and the practice of Caroline navigators. Goodenough represented compass points 2, 3, 4, 30, 31 and 32 with stars, but the navigators did not agree on the use of these stars as navigational tools. Gladwin found that Puluwat navigators use constellations in this region, and the stars Goodenough included were merely arbitrary choices which eliminated overlap and spaced the compass points evenly (Gladwin 1970:150, Goodenough 1953:9). Goodenough noted that since he drew all his material from published sources: "it follows that many of the conclusions presented here are tentative. They need validation in the field, and that soon, before the lore is forever lost" (Goodenough 1953:1). Gladwin's close working relationships with navigators of Puluwat Atoll identified this problem. After discovering the discrepancy, Gladwin questioned Hipour, his principal informant, and later another master navigator, Ikuliman, about which stars in the northern constellations were the actual ones used. In particular, were the stars Goodenough chose used for navigation? He wrote of the responses:

> . . . they not only disagreed that they were the correct stars to use, but they did not agree between themselves on which stars were the actual ones used for sighting a course. I even had the feeling that they were groping with an unfamiliar question when I demanded the identification (Gladwin 1970:150).

Apparently Goodenough's compass and actual navigational methods become unreconcilable near the north celestial pole. Gladwin was deeply disturbed by the apparent use of constellations in this part of the sky. He wrote of the Big Dipper and Cassiopeia:

> How then with their great extent and their overlap can they provide the navigator with clearly defined bearings distinct one from the next? The answer appears to be that they do not (Gladwin 1970:150).

Gladwin identified the problem but could not find an acceptable solution. One argument has been that a pragmatic people on an archipelago with east-west geography did not need to develop an accurate north-south navigation system. Lewis (1972:223) refuted this idea when he had Hipour navigate his yacht, without modern navigational aid, 450 miles north to Saipan and back. Landfall was made to within a few miles, unquestionably demonstrating that the proper navigational tools exist. To uncover these tools, the principles of practical astronomy must be examined to determine what type of system will overcome the shortcomings of star-lane navigation at northern compass points.

Two factors render the previously discussed star-lane navigation system useless near the celestial poles. First, the relative scarcity of circumpolar stars makes it difficult to find replacement stars rising on the eastern horizon. By geometry, the area available for stars between due north and north-east is just 40 percent of the area between north-east and east. At due north, no stars ever rise or set. Second, circumpolar stars experience constant angular motion around the pole which swings them quickly away from their point of rising. This is in contrast with stars near the celestial equator which travel in nearly straight lines above their point of rising and experience little angular motion until near the meridian overhead. Stellar motion near the poles becomes too pronounced for star-lane navigation to succeed, but by being so prominent this motion can itself be exploited to obtain accurate north-south navigation.

North-South Navigation

Two navigational methods can be imagined which permit north-south direction finding. Both necessarily require some en route observations and calculations to account for stellar motion and thus are best learned by young navigators during ocean voyages and not from land-based pedagogical star compasses most readily observed by ethnographers. One possible method resembles the techniques developed by European mariners. The second proposed method takes a more novel approach not previously identified.

The European type of celestial navigation requires that precise measurements be collected on a chosen star and then processed using spherical mathematics based on "astronomical triangles". An ancient system in the South Pacific would necessarily replace tables with memory and experience, replace instruments with naked-eye estimations, and replace analytical algebraic math with the intuitive math of geometry.

Certain astronomical triangles could make effective tools even under these restrictions. Imagine a right triangle having the line segment between Polaris and another star as the hypotenuse and the altitude of the star above Polaris as one leg; then the azimuth will be the remaining leg. Similarly, using the angle at which the hypotenuse intersects the horizon as a measure of elapsed time and the length of the hypotenuse (the star's declination) as a known length, the azimuth can be determined. For example, four hours (60° of rotation) after a star rises above the altitude of Polaris, its azimuth would be half of its distance from Polaris.

The second possible north-south navigational system, which has not been previously recognised, is suggested by the fact that, at a given instant, any object requires two sets of co-ordinates to define its placement in space. The first set of co-ordinates defines the displacement, or absolute position, of some point on the object. The second set of co-ordinates defines the orientation, or relative position, of the object about that point. For the celestial sphere, these two co-ordinates are constrained by the equations which govern solid-body rotation. The result of this constraint is that azimuth may be determined redundantly from both the absolute position and the orientation of an object. European navigation considers only the absolute position of solitary stars. Considering only the orientation of a constellation also permits determination of azimuth.

As constellations move across the sky, they also rotate about themselves. Thus, a time-lapse video recording centred on a particular star in a constellation would capture the constellation spinning about the star. Viewed from the equator, Ursa Major performs a back flip, rising nose first, crossing due north six hours later on her back, and setting west of north after six more hours with her nose pointing down. Throughout the night, the azimuth to which the constellation has moved may be judged from the position to which it has rotated. Knowing the bearing from the orientation of the constellation tells one the bearing of all constituent stars. The example below demonstrates how the orientation of the Southern Cross is enough to specify its azimuth.

Assume that on the returning oceanic canoe trip from Puluwat to Saipan, master navigator Hipour checks if he has drifted from his desired course, what we call 18 ° east of south. He looks directly ahead of the canoe and sees through an overcast sky the two stars in Figure 2a. From the southern position, colours and magnitudes of these stars, he unmistakably identifies the stars as the top and right cross stars of the Southern Cross. Assuming he has an image similar to Figure 2c stored in his mind from land-based observations, he uses the sightings to determine his precise heading.

Hipour notes that the right cross star lies slightly below the top cross star. As shown in Figure 2c, the right cross star lies slightly above the top cross star at the position marked "rising at 45 °" and the right cross star lies to the lower right of the top cross star in the upright position. It follows that the cross is slightly west of the 45 ° position or about 18 ° east of south.

The alternative approach of determing azimuth is the European method in

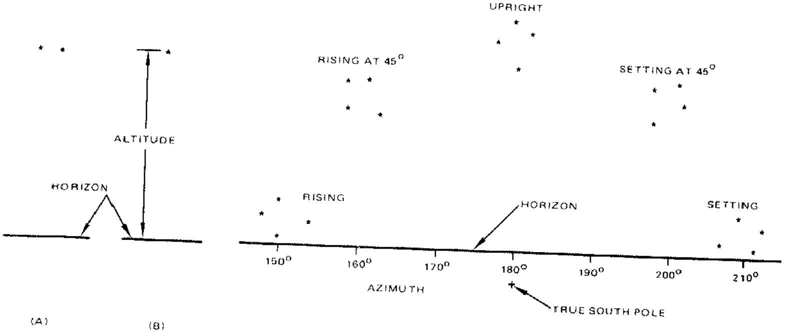

FIGURE 2. Examples of the orientation and altitude navigational methods using the Southern Cross constellation at its five most prominenet locations.

which Hipour notes the altitude of the star above the horizon as shown in Figure 2b. Assuming that his latitude is near 8 °N, comparing the altitude with Figure 2c gives the heading at 18 ° east of south. However, were he at a latitude of 10°N the star's altitude would be lower and the course thus determined inaccurate.

Both methods indicate to Hipour that his course is correct. However, several factors make constellation orientation easier and more precise to use than stellar altitude. The naked eye can judge degree-of-rotation less subjectively and therefore more accurately than it can judge altitude. A constellation of six stars contains 15 line segments connecting its constituent stars, providing a total of 60 reference positions where one star is slightly lower or higher than another, or just to the left or right of the other. By comparison, the only reference available to judge stellar altitudes is the horizon. Moreover, as noted above, changes in latitude significantly affect the altitude to which a star must rise to reach a specific azimuth, but will have no effect on the necessary degree of rotation. Thus, the relative orientation of a constellation provides an accurate measure of azimuth insensitive to latitude.

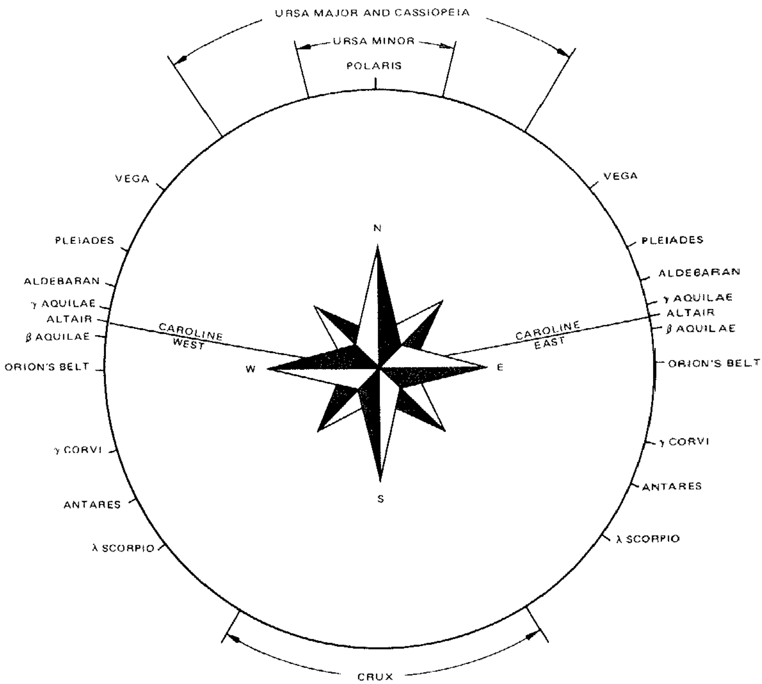

FIGURE 3. Carolinian star compass showing constellation ranges for navigation and star lanes at their true horizon locations.

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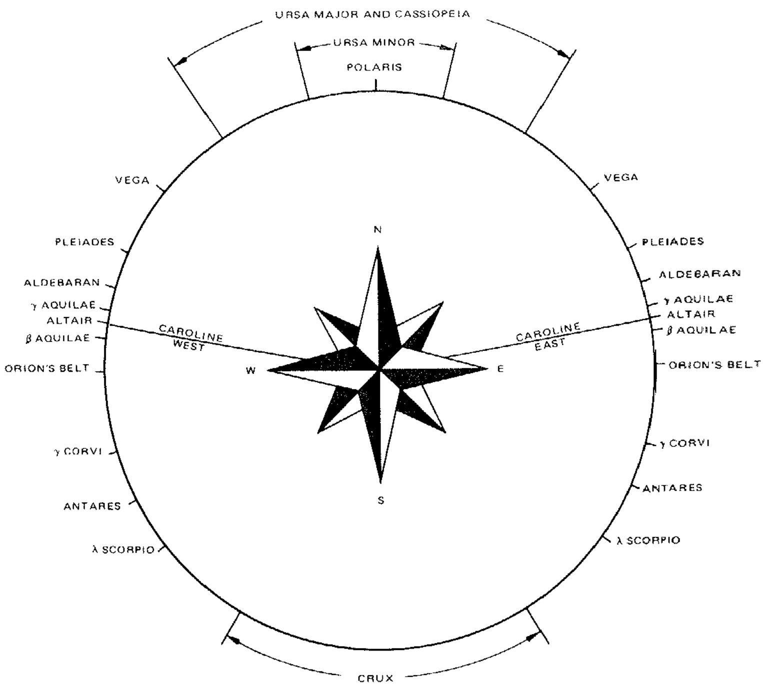

FIGURE 3. Carolinian star compass showing constellation ranges for navigation and star lanes at their true horizon locations.

A modified version of the Carolinian star compass which shows the navigational range of prominent northern and southern constellations is shown in Figure 3. Also, the star lanes have been shifted to reflect their astronomically correct rising positions with the compass perimeter considered to be the local horizon.

* * * *

Without the instruction manuals, charts and tables that a modern navigator studies to predict stellar positions, a traditional navigator studies the sky itself. A traditional navigator becomes intimately familiar with the appearance of each constellation and the relative positions of constellations to each other. With one glimpse of the sky, he knows the positions of the stars he cannot see, including those soon to rise above the horizon. How much the navigators rely on self-taught familiarity with the sky as opposed to learning specific positions as part of the oral tradition is unknown. Furthermore, since the European-style and constellation systems coexist in the sky, the navigators may augment the constellation system with aspects of the other. Based on their first-hand experience, Lewis and Gladwin acquired a feeling for Carolinian techniques that supports the conclusions drawn here but adds nothing to the detail. Lewis wrote:

> Gladwin (1970:150–1) has drawn attention to the fact that the more northerly points of the Carolinian compass are marked by constellations rather than by individual stars (Little Bear, Great Bear, and Cassiopeia) . . . Drawing on his own experience at sea in Hipour's canoe, he concludes that in both northerly and southerly courses the configuration of the stars is sufficiently distinctive that one can estimate a course with considerable ease and accuracy (pp.152–3). This seems to be the correct interpretation of steering by large constellations and was borne out by the experience of our long north-south passages when Hipour was always aware of the precise horizon position of his star points — even when only one heavenly body was available for orientation (Lewis 1972: 65–6).

Both authors express the notion that the navigators use the "configuration of the stars" for guidance. Lewis' last remark — that only one heavenly body is sufficient — suggests the navigators use the specific orientation of any constellation at any time of night to obtain their precise bearing.

Micronesian navigation towards northern and southern destinations is very different from that for eastern and western targets, yet is possible and effective. Of the two methods considered for north-south travel, navigation by constellation appears better suited to navigators without equipment and is best supported by statements from Carolinian navigators. However, additional direct inquiry is necessary to establish the details and innovations used in a navigator's functional system.

REFERENCES

Gladwin, Thomas, 1970. *East is a Big Bird: Navigation and Logic on Puluwat Atoll.* Cambridge, Harvard University Press.

Goodenough, Ward H., 1953. *Native Astronomy in the Central Carolines.* Museum Monographs. Philadelphia, The University Museum, University of Pennsylvania.

Lewis, David, 1972. *We, the Navigators: The Ancient Art of Landfinding in the Pacific.* Honolulu, The University Press of Hawaii.

Nassau, Jason J., 1948. *Practical Astronomy.* 2nd ed. New York, McGraw-Hill.