Ancient Maps and Celestial Navigation

By Daniel Fisher
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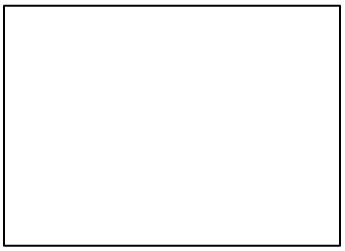

Introduction:

Five years ago I read an interesting and controversial book about a Chinese mariner and explorer by the name of Zheng He. It challenged what I had learned about world history, and peaked my interest in a couple areas. The first was Ancient maps. The second was Celestial Navigation. This book was followed by many others, and I've spent lots of time researching these and related subjects on the Internet.

During my research, I have learned that there are ancient maps in existence that show details of places, in which famous explorers claimed discovery, after the maps were made. How could this be? Also, about the possibility that the Chinese may have led the world in global exploration before Columbus ever set sail. But this is in direct conflict with what I have learned, and so I wonder, what is the real story? I have a lot of questions. Many of them still unanswered.

I want to invite you to join me on a journey of exploration. I am still on the journey and will likely be studying these subjects for some time. And as with most things, the more I learn, the dumber I get. It's been a curious journey.

The title of my presentation is "Ancient Maps & Celestial Navigation".

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Historical Truth:

Written history is influenced or biased by many things. For example, facts and opinions, nationality and ethnic background, religion and politics, pride or covering up things we are embarrassed to talk about, and it's certainly influenced by the voice of the victor.

So what then is historical truth?

Was the earth created 6,000 years ago as literal biblical history might suggest, or 4.5 billion years ago as science and physical evidence would suggest. What influences

what we believe as the historic truth in this matter? In spite of overwhelming physical evidence that the earth is 4.5 Billion years old, a significant percentage of the US population totally discount this evidence as it contradicts their religious beliefs.

So, what is historical truth? Is it what we want to believe?

If I were to ask a local high school class, or the people in this room, how many were killed by the Germans in the Holocaust, most could tell us about 6,000,000 people.

If I were to ask the High School class how many Chinese were killed by the Japanese during the occupation in China, I would likely get a bunch of blank stares. The Japanese were in China? When? Why? Really? The answer of about 30,000,000 people would likely surprise most people.

Why would we know so well about 6 million people in Europe, but the 30 million in China would be a great surprise? Well, look around this room. How many of us are of Chinese or Asian decent? How many of us are of European decent?

The history we are most familiar with, was likely written by people like us, who are mostly of European decent. If this room were filled with Asians, my guess is that our world historical view might be very different.

Why does American History typically start in 1492? Why do we say that Christopher Columbus discovered America, when we all know that there were already tens of millions of people in the Americas before he arrived? And they were here for thousands of years. And there were very advanced civilizations. The Christopher Columbus story is a very European-centric accounting of American history.

Have our European centric biases clouded important historic truths?

Actually, I'm not here to discuss or debate what is or what isn't historical truth. I only bring this up to open up your mind to the fact that what we have learned, from histories written by people mostly of European decent, may not be the whole story. And just ask that you be open to consider other possibilities.

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Explorers & Explorations:

We are all very familiar with famous maritime explorers like Columbus, Magellan, Da Gama, Balboa, etc.

Let's look at who are the important historical maritime explorers. I'll go to my most reliable and unbiased source of information. Wikipedia.

Looking down the list, the explorers seem to be mostly European. It now apparent to me that my reliable and unbiased sources of information, just might be unreliable and biased. Unless, of course, you really believe that there were no important Arabic, African, Asian, Muslim, Buddhist, Hindu, or other native explorers of any consequence.

Let's take one more look at the list. Hidden among the mostly Portuguese and English explorers, is a single name not from Europe. The name is Zheng He from China. Who is Zheng He?

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Zheng He's exploration of the world:

Zheng He is the greatest and most well known maritime explorer in the history of China. He was born in the Ming Dynasty in 1371 and died in 1433. He was a Chinese Muslim, eunuch, mariner, explorer, diplomat and fleet admiral.

From 1405 to 1433 Zheng He commanded expeditionary voyages to South East Asia, India, Middle East, East Africa. Some believe his explorations went well beyond those boundaries.

During the early 1420's, he led fleets of so called "Treasure Ships". These ships were enormous and if historical accounts are taken as factual, the ships measured 450 feet long and180 feet wide.

Here is a depiction of what a treasure ship looked like compared to a European Carrack.

Here is a photo of a model of a treasure Ship that I took at the Maritime Museum in Macau last month.

Fleets under Zheng He's command had more than 300 ships. These including 62 treasure ships. Also, horse ships, supply vessels, troop ships, war ships, patrol boars and water tankers. The fleets had more than 28,000 people including navigators, explorers, sailors, doctors, workers and soldiers.

Each treasure ship had multiple sealed compartments of which 2 could be damaged and flooded without sinking the ship. The rudder measured 36 feet in height. The ship could carry 2,000 tons of cargo and sail for long periods of time in very rough seas. They were armed with gunpowder weapons including cannon, mortars and exploding shells. These were by far the largest most powerful deep ocean fleets the world has ever known.

Although the scale of Zhen He's explorations was unprecedented, the routes he was traveling were not. Zheng He was following well-established, well-mapped routes of trade between China and the Arabian Peninsula and other locations, which had been traveled since the Han Dynasty hundreds of years before.

The Chinese Emperor had launched voyages of the treasure ships for a variety of reasons. One was to establish a strong, and impressive Chinese maritime presence. Also, to impress foreign people and return heads of state to China to pay tribute and kow-tow to the empire. And to extend the empires tributary system beyond the seas collecting tribute from barbarians. Also, as important, was the wish of the Emperor to send his fleets on a global manhunt to find his predecessor.

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Gavin Menzies - 1421:

It is pretty well known about Zheng He's voyages to India, Arabia, Africa and other places in the Indian Ocean. A book titled 1421, by Gavin Menzies, who was a British Naval Officer, offers compelling, and controversial evidence, that Zheng He not only traveled these routes, but 4 fleets under his command, traveled to and explored many parts of the world before the Europeans did.

More specifically, he charts how the Chinese fleets crossed the Cape of Good Hope in southern Africa, explored the west coast of Africa, the Atlantic coasts of North and South America. Traveled through the Strait of Magellan and on to explore the West coast of South and North America. Also, they explored Greenland, Australia and Antarctica.

Menzies describes the routes that these ships would have taken based on the seasons, current, and winds. Then presents evidence from places all over the world to prove the Chinese presence during these times. And evidence that European explores actually made use of maps and navigation information developed by Chinese.

Here is a 1418 Map said to be in Zheng He's possession as he and his Admirals set sail on epic journeys with the Treasure Ships staring in 1421.
You can clearly see China, but also Europe, Africa, the Bearing Strait, North and South America, Australia and Antarctica.

One of many key links for the Europeans acquiring Chinese maps and information was a Venetian by the name of Niccolo da Conti. He was a well-connected trader who moved to Alexandria, learned Arabic, married a Muslim woman and converted to Islam. At the time, the Islamic rulers of Egypt did not allow Christians to travel south of Cairo. But as a Muslim, da Conti journeyed to India, where based on his

writings, is likely to have met up with and traveled with fleets of Zheng He starting in 1421.

Later, after his return to Europe, and as penance for his renunciation of Christianity, he relayed his journeys to the papal secretary. In his description of Chinese Junks, he said" They have ten or twelve sails and great cisterns of water within….the lower part is constructed with triple planks. But some ships are built in compartments so that should one part be shattered, the other part remaining entire, they may accomplish the voyage. "

He also informed the papal secretary that he landed in Greater Java on a Chinese junk and had spent nine months there with his wife. He had many accounts of his journeys.

It is believed that de Conti passed on Chinese maps and information regarding his voyages, to Dom Pedro of Portugal, Henry the Navigators brother. This is just one of many key links or paths of information and knowledge sharing described by Menzies.

Menzies provides his evidence of both Chinese maps and knowledge of science, engineering, astronomy and navigation coming from China to Europe before the start of the European explorations and discoveries. And just before the advent of the Renaissance.

There are different schools of thought regarding Menzie's research and theories.

- First, that Menzies work is brilliant and he should get the Nobel Prize.
- Second, that he's totally off base, or even a quack, and should leave history to the historians.

I don't agree with all I've read by Menzies. Some if it is just flat out wrong. But I don't totally discount his theories either. From what I have learned from Menzies and other sources, I do think that that there is compelling evidence of early Chinese presence and influence around the world. And, that it deserves to be looked at more carefully.

Two key things to keep in mind. One, mastering the ability to determine longitude would be the only way to effectively map continents around the world. It seems that the Chinese may have mastered Celestial Navigation and the ability to determine longitude long before the Europeans could do it. Secondly, many of the early European maps included pretty accurate details of locations that no Europeans had explored by that time.

How could the Europeans get such detailed map information before their own explorations? Could it be from the China 1418 World Map, or other Chinese maps and information, or even from other sources?

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Ancient Chinese Travelers to North and South America:

There are ancient Chinese writings and maps that indicate Chinese knowledge of North and South America long before Zheng He even made his explorations. There is an ancient map discovered in the year 2000 in Korea, known as the Harris Map, believed to be of Chinese origin that shows and describes the Americas. It is also supposedly consistent with the ancient Chinese writing called the Shan Hai Jing (meaning Beautiful land to the east of China). It's a famous Chinese classic reportedly written around 2200B.C. Both the map and the writings describe a land to the east called FuSang where America is today. Some consider both the Shan Hai Jing and the Harris Map to be historical, but including mythological components as well.

A quick look at the North Pacific Ocean currents will clearly show that it is an easy journey to travel from east Asia to North America. In fact, just getting caught in the ocean current can take you to North America on a small raft. And this has been done in modern times just to prove how easy it is. And, the currents can take you back home as well.

A look at the Harris map shows a large landmass at the center of the map. This is considered to be Asia, Africa and Europe. There is also a landmass to the east and one to the west. A description of the area to the east, Fu Sang, is consistent with a description of the Americas. A Chinese writing in 200BC described FuSang as 10,000 li (3000 miles) wide and having huge trees.

This map shows a modern day interpretation of what the Harris Map represents.

There have been several books published providing compelling evidence found in North and South America that in fact the Chinese (East Asians), have been traveling to the Americas for maybe thousands of years by boat. Evidence including ship wrecks, Chinese artifacts, Asian plants, Chinese characters carved in stone, South American names of places using Chinese words, DNA, construction methods, rituals, Asian animals, and much more. The evidence seems to support the idea that both the Harris map and the Shan Hai Jing writings provide historical, rather than mythological, accounts regarding the ancient Chinese knowledge of the Americas.

There seems to be growing body of evidence that there was in fact a much larger Chinese global presence and influence than what we had known.

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Ancient Maps:

In ancient times, making a map of large land area could be done quite accurately as shown by this stone-carved Song Dynasty map of 1137 A.D. This map shows precise details of China's coastal outlines, river systems and locations of over 500 settlements. The map extends as far a Korea and India.

It was not an easy map to make and likely took many years and thousands of trained people to identify reference points, place markers, take the measurements, and consolidate and analyze data. Of all the countries I can think of at that time, China is the only one with the power, capacity and skill to take on such an undertaking. It's pretty clear from this map that they knew both the latitude and longitude of the whole country. Keep in mind that these are the people who made the great wall and the Grand Canal.

But how does one make a map when traveling by sea. It would be extremely difficult to make a reasonably accurate map of continents separated by oceans unless one could determine longitude. And this couldn't be done until the invention of the marine chronometer, or timepiece, in the 18th century.

OK, lets take a look at some Ancient Maps and see what they can tell us:

Let me start by saying that I have now been thru over 100 ancient maps. A couple of observations:

- Many of the maps of old times have just recently surfaced in the last 10 – 100 years.
- Some of the maps are copies made of the original maps
- There are many maps that are suspect of being faked or forgeries, including some of the ones I show today.
- Maps were often kept secret because of the strategic importance.
- Maps were usually made as a collection of information acquired from other people, and often made by people with no maritime experience.
- Some maps that were previously photographed and evaluated have now disappeared.

There are so many ways to look at Ancient maps. For example:

- The historical time period the map was made.
- The region it was produced. Europe, China, etc.
- By the Cartographer or map maker
- Confidence of Authenticity
- By the projection: T-O, Mercator, Rose, etc.

- Technical accuracy
- The artistic beauty. And there are many very beautiful maps.
- Message it is try to convey.
- And many other ways.

I am going to focus on maps that display information about a particular region, where the map was made before that region was discovered.

So, we'll look at a few different regions including the Bering Strait, Australia, the Strait of Magellan, the Cape of Hood Hope and Antarctica.

Bearing Strait:

What does Wikipedia say about the Bearing Strait discovery? In 1648, a Russian named Semyon Dezhnoyov probably passed through the strait, but his report did not reach Europe. Danish born navigator Vitus Bearing entered it in 1728 and is the one who gets credit for it's discovery.

Let's look at a few maps.

This is a map from the Doge's Palace map room in Venice. The map has a long history but credited at before 1428, which was the inauguration of the palace. It doesn't really look like much does it?

But turn it upside down and you can clearly see East Asia, North America and the Bering Strait between them. There are a couple things of interest here.

First, the Europeans had not explored the bearing strait until 1728. In fact Christopher Columbus would reach America 64 years after this map. There is also remarkable detail of North America's West coast that was not fully explored until the 18th Century.

Second, A very cool thing about this map is that credit is given on the map, on the roundels, for information used to develop this map.

The first is about Niccolo da Conti, who we talked about earlier, after his travels to China. The inscription relating to Da Conti reads "Oriental India (China in fifteenth century terminology) as drawn in this way is clearly a result of the foreign travels and illustrated writings not the least the narratives of the merchant, Niccolo da Conti. Publication of this itinerary shed new light on the travels of mariners."

This other roundel is about Marco Polo after his travels to China.

The next map is called “Map with Ship” from Marco Polo in the 13th Century. You can clearly see the Bering Strait, Aleutian Islands and the coast of North America in his map. Where did Marco Polo get this information? From his Chinese friends during his visit?

Also, there is the Ortelius World Map of 1570 by Abraham Ortelius of Belgium. It clearly shows a strait between North America and Asia and shows details of North America that had not been explored yet. And the information is absolutely correct. Where did the information come from long before the discovery of the Bering Strait?

Australia:

Dutch explorers first discovered Australia in 1606. James Cook claimed the East coast for Britain in 1770.

Let’s start with the Di Virga Map made around 1411 – 1415. That map made by Venetian cartographer Albertinus de Virga clearly shows Australia almost 200 years before the official discovery. The map has incredible detail and accuracy of places in Siberia, East Africa, West Africa, the Gulf of Guinea and places the Portuguese and other Europeans had not started to explore for many decades. The map also shows Australia’s northern coast in correct position relative to Asia and Africa more than 300 years before Captain Cook charted it.

Jean Rotz, a French artist cartographer shows us Australia on his 1542 World map. He depicts details indicating knowledge of Australia and New Zealand.

And back to the Ortelius World Map of 1570, we again see what is clearly Australia shown 36 years before the first Dutch Exploration.

Tip of South America and the Strait of Magellan:

Let’s look at the tip of South America and the Strait of Magellan. What does Wikipedia say? Magellan’s ships entered the strait on November 1, 1520.

What is known as the “Green Globe”, located in Paris was made by unknown people in 1515. It is the oldest known cartographical document naming both North and South America as America. In this globe, made 5 years before Magellan, we can clearly see the tip of South America and the Strait of Magellan accurately depicted.

Johann Schoner of Nurmberg, Germany, also had a map and globe in 1515. It also shown is the tip of South America and the Strait of Magellan. It is probable that they both used the same source of information, as their depiction is very similar.

Schoner also produced a map and globe in 1520 showing the tip of South America before any word of Magellan's discovery could have got back to Europe after entering the strait on Nov. 1, 1520.

Here is a picture of Schooners 1520 globe.

The maps and globes clearly show the southern tip of South America and the "Strait of Magellan" before Magellan's exploration took place. Portuguese historian Antonio Galvao wrote that the king of Portugal had a map showing the Strait of Magellan. "In the year 1428 it is written that Dom Pedro, the King of Portugal's eldest son, was a great traveler. He went to England, France, Almaine and from thence into the Holy Land and to other places; and came home by Italy, taking Rome and Venice in his way: from whence he brought a map of the world which had all the parts of the world and earth described. The Strait of Magellan was called in it the Dragon's tail."

Also, the contract between the king of Spain and Magellan uses the phrase "go in search of the strait". How did they know there was a Strait?

A historian aboard Magellan's ship tells what happened after a mutiny broke out when they could find no sign of the Pacific. "We all believed that it was a cul-de-sac: but the captain knew that he had to navigate through a very well concealed strait, having seen it in a chart preserved in the treasury of the king of Portugal."

So, where did this information come from?

Cape of Good Hope:

Let's look at the Cape of Good Hope in Southern Africa. The first European to reach the cape was the Portuguese explorer Bartolomeu Dias in 1488.

What do the maps tell us?

Let's start with the Di Virga map. On this map, all of Africa and the Cape of Good Hope are clearly depicted some 70 years before Dias set sail. How could they have produced such details of the Africa coastline before it was ever explored?

Next we look at the Fra Mauro's Map made in 1459. Fra Mauro was a cartographer in Venice but worked for Dom Pedro of Portugal, Henry the Navigators brother. What's interesting about his map? Several things:

- Fra Mauro correctly drew the Cape of Good Hope some 30 years before Bartolomeu Dias round the Cape.
- Fra himself noted on the map that, "Around the year 1421, a ship or junk coming from India on a non-stop crossing of the Indian Ocean past the "Isles

of Men and Women" was driven beyond the Cap de Diab (Cape of Good Hope) and through the Isole Verde and obscured islands towards the west and south west for 40 days, found nothing but sea and sky. In their estimation, they ran for 2,000 miles and fortune deserted them. They made their return to the said Cap de Diab in 70 days.

- Fra Mauro had also drawn a picture of a Chines junk on the map.
- And also noted in the India ocean, "the ships or junks that navigate these seas carry four masts or more, some of which can be raised or lowered, and have 40 – 60 cabins for merchants.
- So, 60 years before Dias, there is a European accounting of a Chinese ship passing the Cape of Good Hope?

This a Chinese map made in 1389 showing most of Asia, Africa and parts of Europe. The details on this map are outstanding.

This is the Kangnido World Map made in Korea in 1402 but looking much like the Chinese map. Both of these maps predate both Columbus and Zheng He. Although not to scale and Korea has been grossly enlarged, the map does clearly shows the Cape of Good Hope and the coast of East, South and West Africa some 60 years before Dias set sail.

Did the Chinese have detailed information about Africa that was passed onto Di Virga and Fra Mauro? The Europeans clearly had knowledge of Chinese ships sailing the Atlantic before 1459 as indicated on the Fra Mauro map.

Antarctica:

Alright, now let's get down to some really fun stuff. In 1820, several expeditions claimed to have been the first to have sighted Antarctica, with the very first being a Russian expedition. The first landing was probably just over a year later when American Captain John Davis, a sealer, set foot on the ice.

1820?? Really? What do the maps tell us?

In 1929, historians found a map, which was later proven to be made in 1513 by Piri Reis, an Ottoman Admiral and Cartographer. In his personal notes, he claims to have made this remarkable map from many earlier documents he had seen, some dating back to the 4th century B.C. The map shows West Africa, Eastern America and the coastline of Antarctica without the ice.

What's remarkable about this map is the precision in which latitude and longitude was shown. What can we say about this map?

Well, first of all, it shows details of Antarctica 300 years before Antarctica was discovered. It was about 250 years before the means of accurately calculating

longitude was invented. And, according to modern geographers, the land mass could not have been seen without sonar and seismic instruments for 6,000 years before that. The map shows what Antarctica looks like without ice.

When this map was evaluated by US Cartographers the following evaluation was provided:

"The geographical detail shown in the lower part of the map agrees very remarkably with the results of the seismic profile made across the top of the ice-cap by the Swedish-British Antarctic Expedition of 1949. This indicates the coastline had been mapped before it was covered by the ice-cap. This part of Antarctica ice free. The ice-cap in this region is now about a mile thick. We have no idea how the data on this map can be reconciled with the supposed state of geographical knowledge in 1513."
—Harold Z. Ohlmeyer Lt. Colonel, USAF Commander

Let's take a look at the Italian Astronomer and Geographer Oronteus Finaeus's map of 1531. It clearly shows great details of all of Antarctica but with an unusual Cordiform Projection. At this projection, the details are remarkable.

But when the projection is redrawn on a modern polar projection, it is remarkably similar to the modern projection of Antarctica. This map was drawn almost 300 years before Antarctica was discovered.

Evaluation of this map by US Air Force Cartographers say the following:
"Oronteus Fineaus Map (1531) suggests, beyond a doubt, that it also was compiled from accurate source maps of Antarctica, but in this case of the entire continent. Close examination has proved the original source maps must have been compiled at a time when the land mass and inland waterways of the continent were relatively free of ice." It also goes on to say "The Cordiform Projection used by Oronteus Fineaus suggests the use of advanced mathematics. Further, the shape given to the Antarctic continent suggests the possibility, if not the probability, that the original source maps were compiled on a stereographic or gnomic type of projection (involving the use of spherical trigonometry). We are convinced that the findings made by you and your associates are valid, and that they raise extremely important questions affecting geology and ancient history, questions which certainly require further investigation."

Just one other map called the Gilt Globe of 1528 also shows considerable details of Antarctica. Almost 300 years before it was discovered.

We could have similar discussion about the West Coast of North America, and maps as early as 1424 showing places Columbus discovered in 1492. But I think you get the point.

So, where did this information come from? Could it have come from Zheng He's expeditions? Could it have come from other explorers before the Europeans and others laid claim to their discoveries?

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Navigation:

In ancient times, making a map of something on land could be done quite accurately as we saw on the stone carved Song Dynasty map of 1137 A.D
But how does one make a map when traveling by sea. Let's start by looking at some basic navigation tools for setting a course.

First, for a skilled ancient navigator, one had to have good knowledge of ocean currents, winds, and seasonal weather patterns and to use them to your advantage. Unskilled navigators could find themselves in a perilous situation.

Second, the sun will always rise in the east, and set in the west. General directions can be estimated by observing the sun.

Third is the North Star. By identifying Polaris in the night sky, one can quickly determine the direction of true north.

Last is a compass, if you are lucky enough to have one. First records of the compass go back the Han Dynasty around 2000 years ago. It was a loadstone spoon placed on a cast bronze plate. By the 7-8th Century, the Chinese figured out a way to magnetize iron needles and made other refinements making it useful for sea navigation. Also, as Polaris is due north, the difference between the magnetic compass readings, and true north, can be determined and the compass adjusted or calibrated.

By using wind and currents, the setting and rising of the sun, the North Star and a magnetic compass if available, and one could tell direction of travel and set a course. By the 7th century, Chinese mariners could set a course within 2 degrees. However, these tools do not tell you your location on the earth. They can only help set your heading.

A: Global Markers: Latitude and Longitude

When one is traveling by sea, there are no markers, road signs and few reference points. So, in order to navigate, one must come up with a system of reference points across the land and oceans to accurately pinpoint their location on the earth.

The system of markers used by mariners for a long time is latitude and longitude.

Latitude lines, for example can extend from the equator at 0 degrees to the North Pole at 90 degrees. Longitude lines extend East or West from a reference point for a total of 360 degrees around the globe.

With such a system, ship A and ship B, who are out discovering new lands, can identify point C with the same coordinates of latitude and longitude.

But this is all theoretical. In Ancient times, how does one actually know where you are on this global grid when you are in the middle of an ocean? Or even on land? This is the hard part, and knowledge of several difficult sciences and well as construction of precision instruments are necessary to accurately fix a position at sea.

Determination of Latitude:

The first challenge was the determination of latitude at any point. This was actually a relatively simple task. Standing at the North Pole, Polaris would be directly overhead at 90 degrees latitude. Standing at the equator, the star would measure directly horizontal at 0 degrees latitude. So, by measuring the angle of Polaris relative to the horizon at your location, one could determine their latitude anywhere in the Northern Hemisphere. Other reference stars can be used in the Southern Hemisphere. There are several means for making this measurement including the astrolabe.

Determination of Longitude

People at different latitudes will see the stars positioned differently as described. But at any give latitude, people at different longitudes around the world all the same thing. So, everybody at the equator, for example, will see essentially the same night sky no matter where they are in the world.

But to know your location on the earth, one must be able to determine their longitude or the position east or west of a known point.

Longitude can been roughly estimated at sea, for example, by sailing in an westerly direction, dropping a Log-line in the water and measuring how much rope is let out over a given period of time. So, if it takes 1 minute to let out 200 feet of rope, then in 1 hour one would have traveled about 2.3 miles.

However, this is a crude method and does not take into account variances in direction of travel, variance in wind speed, and of ocean currents. If the ocean current were moving 1 mile and hour the other way, the actual distance traveled would only be 1.3 miles. Or if the current were moving 2 miles an hour in the same direction, the distance traveled would be 4.3 miles. These are huge variance and the navigator would have no idea. So, it's not very reliable.

In 1761 when John Harrison invented the marine chronometer, the task of determining longitude became very simple. The chronometer was a reliable timepiece that would maintain the time at a reference point like Greenwich UK. Here's how you could have calculated longitude in 1763 after you bought your first marine chronometer.

- First, you determine 12 o'clock noon at your unknown location, based on the suns position of shortest shadow.
- At that local time, your chronometer tells you that it's 6:23pm at Greenwich, UK, which is the location of the Prime Meridian or zero longitude line.
- The local time of 12:00 o'clock noon is 6:23 hours earlier than GMT of 6:23pm.
- So, your longitude is easily calculated at 97.75 degrees west longitude based on a 6 hour 23 minute difference.

With a chronometer, it's very easy to determine longitude. But without the ability to know a standard time at a fixed location, it is a seemingly an impossible task.

So, I wanted to understand what techniques the Chinese could have used to determine how to calculate longitude. Here is some of what I learned.

Calculation of longitude is a very complex and difficult task and people worked on a solution for centuries. The successful determination would require deep knowledge of several things creating the foundation for Celestial Navigation. These include the following:

An accurate calendar: In 1276, Kublai Khan, the first emperor of the Yan dynasty, assigned the task of compiling a new calendar to astronomer Guo Shou Jing so the empire would have a unified calendar. Guo Shou Jing started by developing 12 astronomical devices that were far better in function and accuracy than previous devices. He set up a program of astronomical observations in 27 locations throughout China. The items of observation included the length of the shadow of a gnomon, the angle of the North Star from the ground surface, and the beginning times of day and night on the vernal equinox and the autumnal equinox. He also examined over 900 years of astronomical records from 462 – 1278. Guo Shou Jing and other astronomers worked for four years and completed the calendar in 1280.

The calendar was made based on celestial observations and its accuracy was unprecedented. It calculated the length of a year at 365.2425 day. Extreme accuracy was required in order to predict future positions of the moon, stars, planets, eclipses and comets. The calendar was officially adopted in 1384 and would have been the calendar used by Zheng Hu.

An earth grid system including the size of the earth: We have already seen the common use of a grid system including latitude and longitude, which the Chinese used. But such a system would be useless unless one knew the actual size of the earth. We have also seen how Guo Shou Jin set up 27 locations throughout China for astronomical observations. And we have also seen the stone map of China with a measured grid pattern. These observation locations could easily be identified on the stone map or other maps of that time. By knowing these locations, and the angle to Polaris at each, one can easily calculate the diameter and circumference of the earth.

A Star Map: The Chinese have been making and recording astronomical observations for many centuries. They developed a way to map the stars by using Polaris as the key reference point. They then divided the sky into 28 sections called mansions, and fixed positions of the upper stars relative to Polaris within each mansion. Lower stars were fixed relative to upper stars. They entered 1,461 stars in their tables. So, for the star map, they used basically the same system of measurement as they did the earth based on latitude and longitude. This was called the equatorial system and was eventually adopted by the Europeans. To measure each star, they built instrumentations with sighting tubes and calibrated scales to precisely measure both the number of degrees below Polaris (declination) and horizontally the number of degrees from Nanjing (ascension).

A typical star map would have looked like this.

Means of measuring elapsed time:

So we have a calendar, an earth grid and a star map. Next is measurement of elapsed time.

Records show that the Chinese measured elapsed time by measurement of the suns shadow. The most famous observatory, the Zhou Gong Tower, still stands. It includes a 40-foot metal measuring pole called a gnomon, with 125 feet of flat stones laid in a northerly direction and a large water clock. They measured the suns noon shadow of the gnomon cast on the stones (the shortest shadow). The longest shadows are cast at sunrise and sunset, and the length of the shadows between those points determines the precise time at that location. As early as 721AD, they realized that the shadow not only varied by the time of day, but also by the day of the year, and the latitude of the measuring point.

So, for measuring the time of day by the suns shadow, they were able to correct for the day of the year as well as the latitude. They also made adjustments due to the irregular motion of the earth around the sun due to the eccentricity of the earth's orbit, and the difference between the equator and the ecliptic, or the great circle of the suns apparent path.

Measurements after dark where done by a large water clock which was calibrated during the day against a gnomon. With these tools, the Chinese were able to tell precisely the time by the minute, both day and night.

The outstanding accuracy of their measurement of time is illustrated by their measurement of the lunar cycle at 29.530591 days producing an error of less than one second a month.

Motion of the heavens relative to time.

The development of an accurate calendar, a sky map, and centuries of astronomical observations, and means to measure elapsed time, combined with high levels of mathematics provided the ability to accurately predict the motion of the sun, moon, stars, planets, comets and eclipses over long periods of time. These were logged into what are called Ephemeris tables.

So, basically, the Ephemeris tables combine elements of both time and space. For example, on November 15, 2013, at 8:40pm, at Holland, Michigan's longitude, you could determine, from the tables, exactly which stars would be crossing our local meridian overhead.

Inventive ways to put these things together to measure longitude.

Using these tools, there were several inventive ways the Chinese came up with to measure longitude. The first was with a Lunar Eclipse.

In order to determine longitude, one would need to have a standard measure of time relative to a known point. A lunar eclipse, where the earth's shadow covers the moon, is a key celestial event that can be seen by people across half the globe at the same time. Being able to accurately predict a lunar eclipse like the Chinese were able to do, provided a unique opportunity to take simultaneous measurements from different locations on the earth at the exact same time.

From key strategic points on the earth, observation stations were established employing many of the tools we have just discussed. First, they could predict when a lunar eclipse would occur by consulting the ephemeris tables. Then by setting up a local meridian line, they could then identify the star crossing the local meridian at the exact time the earth's shadow enters or exits one or more of the phases of the lunar eclipse.

For example, at day 141, at 10:23p.m at an observation station in Calicut, the eclipse entered it's first phase. At that time, the star ALPHA was crossing the local meridian. Further measurements could be taken at different phases to increase accuracy.

The observation data could then be returned back to Nanjing along with data from all observation posts. Since the star at the Nanjing meridian was observed at the beginning of the eclipse, the precise longitude could be calculated and maps calibrated for all the observation posts relative to Nanjing. In this case, the lunar eclipses acted as the standard world clock with Nanjing being the location of the prime meridian.

Although incredibly useful and accurate, it could only be accomplished during a lunar eclipse, and from a fixed point on land. But you can see how it would be very useful for establishing exact longitudes for key points of exploration or discovery.

A second way to calculate longitude is useful because it is not dependent on a periodic lunar eclipse. It can be done any time weather conditions allow observations of the sun and stars. It's a little tricky, so let me explain.

Siderial Time: I always thought that it took 24 hours for the earth to make a 360-degree rotation about its axis. I was wrong. It actually takes 23 hours, 56 minutes and 4 seconds to make one 360-degree rotation relative to the stars. This is called sidereal time. It takes 24 hours for one rotation relative to the sun, which is about 361 degrees of rotation. This is solar time.

So, there is about a 4-minute gap between sidereal time and solar time. How does this happen.

Well, since the earth is traveling in an elliptical orbit around the sun, it travels about 1 degree around the ecliptic orbit each day. So, the direction of the sun at noon changes by one degree each day as the earth travels around the sun. Relative to the stars, it will travel an extra 1-degree to line up with the sun the next day.

The result of this is that the stars are in a different position at any given time than they were the night before. So, the star you saw at the local meridian at midnight yesterday will show up about 4 minutes before midnight tonight. This information was provided to the navigators on ephemeris tables.

To the naked eye, I wanted to see how far a star travels in that four minutes, so I set up my camera and took a time exposure of a star. You can see the distance of travel.

So, if you are at the Prime Meridian in Nanjing, and star ALPHA crossed the prime meridian at 12:00 midnight, tomorrow at 12:00 midnight it will have shifted by this amount. This distance is about one degree of arc. And actually, you will see the star moving to the right, but ending up to the left 24 hours later.

To get a getter idea of what this gap looks like, I have superimposed a photo of the moon, which has an arc of ½ of a degree. So you can see the 4-minute time gap relative to the moons diameter.

For ancient mariners, here is what you do to determine the longitude.

- Wait for a clear day and clear night.
- Calculate which day it is by counting the number of days since leaving China and correlating that to the standard calendar.
- Next, you would consult the ephemeris star tables to determine which star would be in line with the meridian in Nanjing at midnight of that day. Let's say it's day 35 of the calendar and star ALPHA is listed above the meridian in Nanjing at midnight. This illustration shows ALPHA at Nanjing and also shows where ALPHA would be 24 hours later after is has made one rotation the earth.
- Then, with the use of the gnomon, you would identify exactly noon time for your location by the measurement of the shortest sun shadow, then use the calibrated water clock to measure 12 hours to midnight.
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- At exactly midnight, you would identify the location of the reference star ALPHA relative to the local meridian line. Or, in this case, you would calculate the time after midnight that ALPHA crosses the meridian.
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- Let's say that ALPHA crosses our local meridian at 1 minute and 19 seconds after midnight. Then you would have observed a 1 minute and 19 second shift relative to what the observer in Nanjing saw.
- You would then calculate that you are 1/3 through the 3 minute and 56 second sidereal time gap, which means that you are 120 degree around the world relative to Nanjing or at a longitude of 120 degrees from the Chinese prime meridian.

This is an amazing way to calculate longitude. However, small measurement errors could miscalculate longitude by a long distance. The measurement errors could include things like:

- The exact time estimation of the shortest shadow at noon.
- The water clocks ability to measure 12 hours exactly to midnight.
- Identifying the target stars position at midnight relative to local meridian reference line you have set up.

A cumulative error of only 8 seconds among these variables would create an error of 850 miles of longitude. It is reported that this could be calculated with an error of just 2 seconds or just over 200 miles. By making multiple measurements, the level of accuracy could also be increased.

There is also a method likely used by the Chinese, which could measure longitude from a vessel instead of on land. This method uses the equation of time and the angular distance between the moon and a selected star or plants. I have not yet

studied the specific mathematics and calculations of how this is done. But I do think the Chinese may have had the scientific understanding and the precision instrumentation capable of making such measurements. And to successfully navigate the world.

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Conclusion:

From the collapse of the Roman Empire to the start of the Renaissance in the 15th century, Europe went through the dark ages and a thousand years of stagnant technology development. During that time, China was by far the most advanced and developed country in the world and experienced an explosion in technological and scientific innovation and development. China, with a Pacific coastline longer than the entire Mediterranean coast, has been building ships for thousands of years, has a long history of deep ocean sailing building knowledge of ocean currents and seasonal winds. They developed high level mathematics and were doing centuries of precision astronomical observations which would have been necessary to understand the motion of the sun, stars and planets. This was needed to navigate, determine latitude and longitude and to create accurate maps. The very peak of this development was during the days of Zheng He's explorations.

But also during Zheng He's time of exploration, China itself started into it's own dark ages. There was great political upheaval. As leadership changed, records and history were intentionally destroyed including records of Zheng He's voyages. There was a permanent halt to further explorations and the country withdrew inward and cut contact with the outside world. Zheng He's achievements were minimized, important technological innovations came to an end and from that time on, China fell far behind the rest of the world. At the same time, Europe's Renaissance started which was the beginning of an explosion in technological and scientific innovations and discoveries.

Did China explore the world before European explorers? Did they develop information that ended up on European maps? Perhaps the mark the Chinese left on the world was different that what the Europeans left and not as easy to see. The Chinese during their voyages focused on exploration, trade, influence and relationships. They were also very focused on their own internal development.

The Europeans, competing with each other, usually pursued conquest, exploitation, domination or plunder. These leave a more permanent mark and legacy. In the last 600 years, the Europeans clearly have been the victors in terms of world exploration. And the historical narrative is usually told from the perspective of the victor.

Thank You!

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