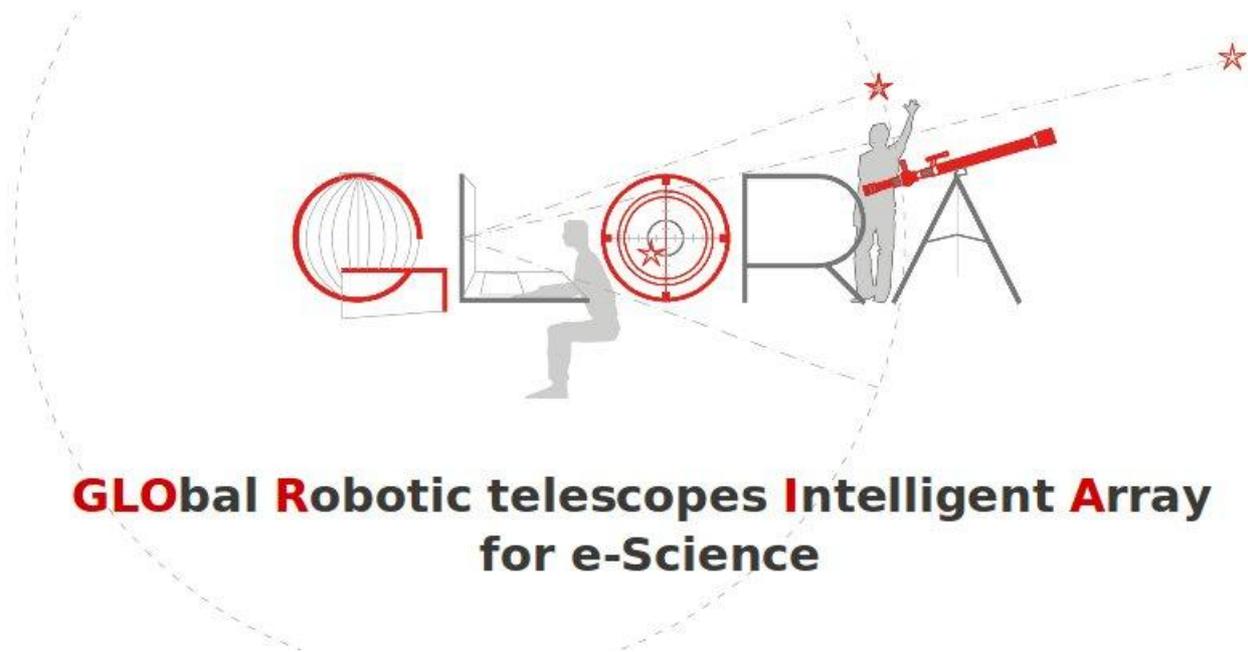




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## Astronomy of the Incas (Total Lunar Eclipse 2014)

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**Reference Documents**

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## 1. Objectives of the activity

In this activity, we highlight the culture and knowledge of pre-Columbian cultures in South America, mainly in the fields of mathematics and astronomy, with a particular focus on the Inca civilization. A group of GLORIA astronomers and an archaeoastronomy expert, traveling to Cusco to observe the total lunar eclipse in April 2014, will provide daily video diaries and blog entries to the GLORIA website.

The objectives of this activity are to:

- Raise awareness of the different cultures of the South American continent before the arrival of Europeans.
- Gain insight into the Inca culture, focusing on their knowledge in the fields of mathematics and astronomy.
- Connect scientific and historical storytelling to build respect and understanding for other cultures and races, some of which are already extinct.

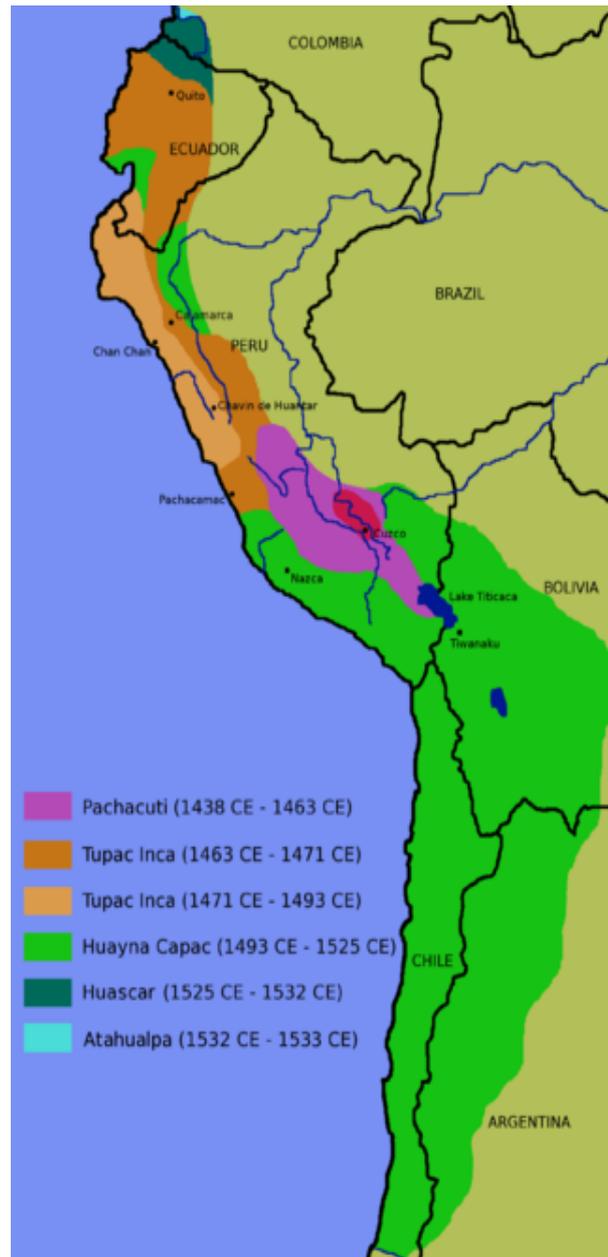
## 2. A little bit of history

### 2.1 The empire of the Incas

The Incas created a centralized state in South America, the last and most advanced of the so-called “pre-Columbian empires”. That territory was called Tahuantinsuyu (from the Quechua Tawantin Suyu “the four regions”). Its period of greatest splendour in the Andean region was between the XV and XVI centuries, coinciding with the apogee of the Inca civilization. It covered about 2 million km<sup>2</sup> between the Pacific Ocean and the Amazonian jungle, from near San Juan de Pasto in the north to the Maule river in the south. Thus, it became the largest state in pre-Columbian America.

The creation of the Empire of the Four Regions began during the reign of the Inca Viracocha, the eighth successor of the founder of the dynasty and founder of Cusco, Manco Capac. His son Pachacutec (1438-1471) conquered the highlands, but the real creator of the empire was Tupac Inca Yupanqui (1471-1493) who led the Inca armies from Ecuador to the Maipú River in Chile, an expansion that covered more than 35° of latitude. He divided the state into four administrative districts or ‘suyus’ - the *Collasuyu*, *Cuntisuyu*, *Chinchasuyu* and *Antisuyu*. The *Collasuyu*, to the southeast, was inhabited by the Quechua and Aymara indigenous peoples. It was the region of the sacred ‘Lake Titicaca’ and home of the city Tihuanacu, where Inti, the Sun God, and his sister/wife, Mama Quilla, the Moon Mother, originated. The *Cuntisuyu*, to the southwest, includes the regions populated by some of the most ancient cultures of Peru, including the Paracas and the Nazca. The *Chinchasuyu*, to the northeast, followed the coast, and included lands conquered by the Chimú empire and the sacred places of Pachacamac and Chavín de Huantar. Finally, the *Antisuyu*, located in the northwest, contained the sacred valleys of the Vilcanota River or Urumbamba. The strength of the empire lay here and was ultimately the seat of the strongest resistance, which subsequently expanded to the borders of the Amazon jungle.

After this golden period (Figure 1), the empire entered into a terminal decline due to several factors. The most significant of these was the competition for the throne among the sons of Huayna Capac. After the war, which led to a civil war, Atahualpa emerged victorious in 1532. However, his rise coincided with the arrival of the Spanish troops under the command of Francisco Pizarro, who captured him and then executed him in 1533. With Atahualpa’s death the Inca Empire ended. A vestige of independent states remained, created by rebels to the crown known as the “Incas of Vilcabamba”. These rebels battled in the following decades until this period ended in 1572 with the beheading of the last one, Tupac Amaru.



**Figure 1:** Expansion of the Incan empire.

## 2.2 The Incas and astronomy

The Inca Empire was the most geographically dominant in South America. It was also the pre-Columbian culture that devoted a lot of time to the study of the sky.

The sky in the southern hemisphere is amazingly beautiful. The Milky Way and its two satellite galaxies, the Magellanic Clouds, put on a great display. The ancient inhabitants of the Incan Empire must have thought the same. Like the ancient civilizations of the Mediterranean (Greeks, Egyptians, Romans...), the Incans connected the bright stars in the sky into groups that they identified as "constellations". For example, the Milky Way was for them the great Rio Mayu, so bright that it clearly stood out from neighbouring areas. The Incas were also interested in the dark regions we now know to be interstellar dust. They noted the Coalsack, an especially dark region very close to the Chakana, or the Southern Cross, also known as Yutu, or the Partridge. The region of dark clouds between Sagittarius and Centaurus was known as the Black Llama whose shining eyes are the bright stars Alpha and Beta Centauri. Hanp'ata, the Toad, and Machacuay, the Snake, occupy areas of the Milky Way near a

large southern constellation formerly called 'Argo Navis'. Most important of all, the constellation we know as the Pleiades, was Collca (meaning Storehouse) to the Incas. (Confusingly, "Collca" was also the word used for the stars in the tail of the constellation Scorpio). Collca was the central reference for the calendar of the Peruvian highlands, and was one of the most important cosmological references for the Empire of the Four Regions, Tahuantinsuyu.

Astronomy received special attention because it was relevant for farming. The Incas patiently observed the Sun and determined the solstices and equinoxes, using specific instruments and methods such as *ceques* and *Intihuatanas*, which were common in several cities of the Empire. In Cusco, documents from the Spanish colonizers describe the Temple of the Sun, with forty-one axes, called *ceques*, radiating from it. Their arrangement involved topographic or astronomical alignments, defining a total of about 328 huacas, or sacred places, in the Cusco valley, which may have fulfilled both ritual and political functions.

The *sucancas* marked the points of the rising and setting sun at the solstices of June and December. A special case was the Huaca Quincalla which marked the passage of the sun through the zenith (i.e. when a vertical stick casts no shadow at noon), or the positions of the rising and setting of the Pleiades. The rising of the Pleiades was especially significant around the year 1500 as the heliacal rise (first appearance of a star on the eastern horizon just before sunrise, after its period of invisibility) on the 13th or 14th May (Julian calendar), was used as a calendrical reference.

We highlight some terms that refer to elements, buildings, or places of interest, that are scattered in various locations in the Old Inca Empire:

Quipus: System of knotted strings that were used for the administration of the Empire and also used as a mathematical device for counting, with calendrical or predictive purposes.

Intihuatanas: From Quechua: inti watana, "(location) where the sun is tied." These were monolithic sculptures carved in stone, with variable dimensions, but typically around 1-2 meters high and 2 meters in diameter. The standard shape consisted of a base with different levels. In some of them there was a ledge on top with a cubic aspect, each of the faces suggesting one of the major geographical directions: north, east, south and west. These were almost ubiquitous elements in the Inca cultural centres. It is thought that one of the purposes of the Intihuatanas was in the determination of the dates of the zenith passage of the sun.

Huacas: According to the pre-Columbian traditions, the huacas were elements possessing their own personalities (building, mountain, sculpture, etc..). They are a crucial part of the Incan and pre-Incan pantheon of ancient Peru, along with other "higher" Andean divinities such as Wiracocha or Pachacamac. The close relationship between the Andean people and the huacas is attested to by the large number of them that are scattered throughout the territory of Tahuantinsuyu. They were so important that, in some cases, they remain objects of veneration, even today.



**Figure 2:** Possible huaca at Chinchero. Jupiter can be seen low down in the background. Image: M. Serra-Ricart/shelios.org

As places of worship, the huacas are also famous for being sites where offerings were made. For this reason they were systematically looted and destroyed during the early years of the conquest of Peru (XVI century).

*Temples of the Sun:* Inti, the sun god, was a deity worshipped by the ancient Incas. In several cities of the ancient empire (Cusco, Vilcashuamán, Pisac and Ollantaytambo, among others) there is a shrine erected in his honor. The Quechua, who were the dominant people in the Incan Empire, had Inti on the first rung of the heavenly ladder. Temples of the Sun were founded in any place where the power of the Incan Empire was manifest, the most important of which was called Coricancha, in Cusco. Inti was married to his sister, the moon goddess, Mama Quilla, who shared equal rank in the heavenly court.

### 3. The expedition

The expedition to Cusco to observe the total eclipse of the moon on April 15th, 2014 will make a tour of various places of importance to Inca culture. The main monuments and buildings (related to astronomy) that are on these sites, and their relevance to the Incas, are described below. During the expedition Dr. Juan Antonio Belmonte, an archeoastronomy expert, will provide explanations. Daily videos and images of the places visited will be posted on the GLORIA website.

#### 3.1 Cusco

Capital of the Inca Empire, two legends attribute the foundation of Cusco to the first Inca, a legendary character named Manco Capac and his sister and consort Mama Oclo. In both stories the place was revealed by the sun god (Inti) to the founders after a pilgrimage from the south of the Sacred Valley of the Incas.

*Temple of the Sun (Coricancha):* One of the most revered and respected temples of the city of Cusco, this was the most important sanctuary dedicated to the sun god, Inti, in the Inca Empire. The front was a beautiful wall with the finest stonework, decorated by a continuous band of pure gold three feet off the ground, and a ceiling of fine and delicately cut straw.

All the important elements in the cosmology of the ancient Inca people were represented on the altar, including: Chasca, the morning and evening star; Collca, the Pleiades; the lightning god, Illapa; the Rainbow, the Earth and the Pachamama. Inti and Mama Quilla were placed on either side of the sublime gods Viracocha and Pachacamac. Some of the Coricancha's structures were aligned astronomically, possibly to the Pleiades, among other celestial bodies. A huge topographical "quipu" with a system of 41 ceques, or lines, radiating out from Coricancha, through 328 sacred sites, or huacas, was used for the creation of the complex Inca calendar.

*Quenko:* A few miles to the north of Cusco is the archaeological site of Quenko. A formidable huaca carved into rock, numerous sacred ritual elements like stairs, gutters, cups and other styled elements, can be seen. In some places, notable effects of light and shade are created on special dates in the calendar, such as solstices.

#### 3.2 Urubamba's Valley and Urubamba's Village

One of the most important places to the Incas was the Urubamba Valley or Vilcanota, also known as the Sacred Valley of the Incas. It was on the border with the forest jungle, called by them Antisuyo. The river that crosses the valley was called Willka Mayu or Sun's River. The snowy region whose ice feeds the river where it rises was called Willka Uta or Sun's House. With so many references to the Sun, it is no surprise that this valley was closely linked to the worship of this divinity. The word Willka is even more important in reference to the sun god than Inti.

The majority of the main towns where the Incas were established lie in this vast and fertile valley. The province of Urubamba consists of the districts where the main monuments and archaeological sites of the Inca territory lie: Urubamba, Ollantaytambo, Chinchero, Pisac, Machu Picchu, Maras or Yucay.

It is believed that there were 16 pillars of the sun in this valley, of which only 3 remain. One is 35 km from Cusco at the top a cliff in the town of Urubamba, and the remains of two others are in the "Isla del Sol" on Lake Titicaca. The Pillars of Urubamba are believed to have marked sunrise on the June solstice, when viewed from the patio of Quespiwanka, the palace of Huayna Capac, several hundred feet below in the valley. Sunrise could be seen during the solstice in June outside the north and south walls of the palace of Quespiwanka.

### 3.3. Pisac

These ruins are located on the highest hill above the current city, on a dry, rocky surface. The word Pisac comes from "Pisaca" meaning partridge, a bird species that lives in this area of Peru and can often be seen flying at dusk.

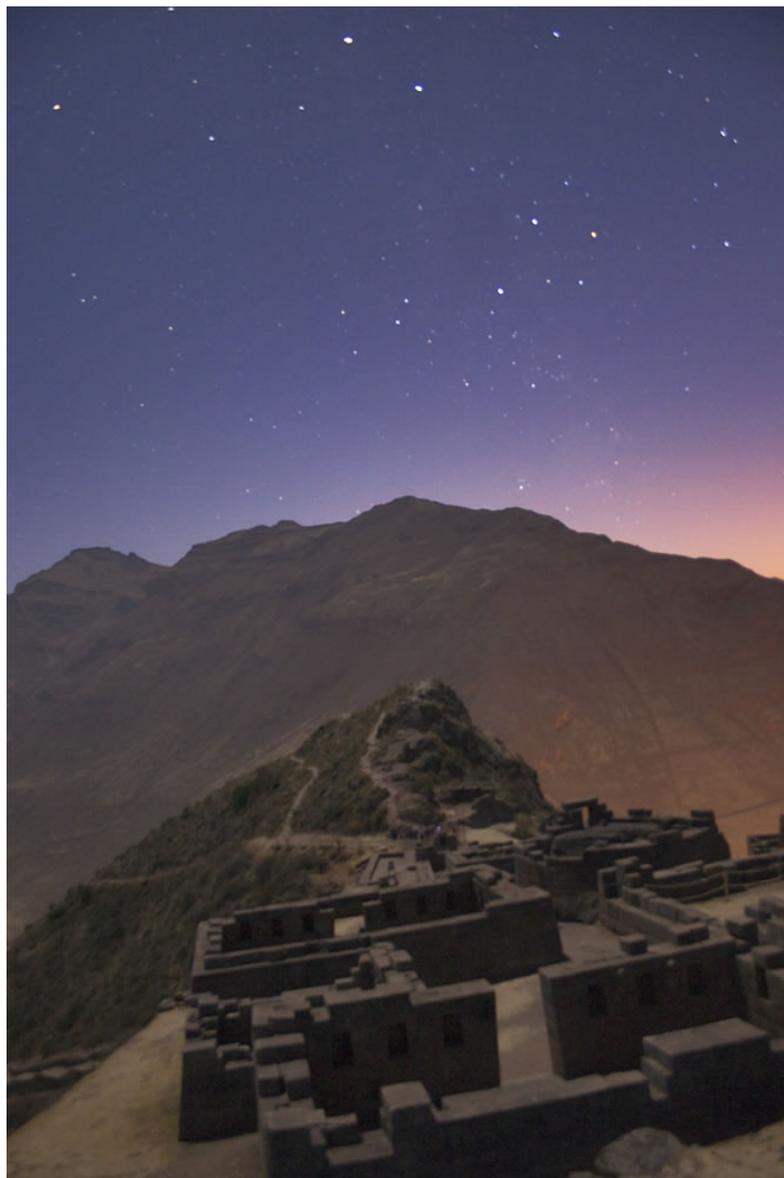
As with other Inca constructions, some studies report that this was not a fortress, but an estate owned by the Inca Pachacutec, composed of terraces, ceremonial and domestic structures, and aqueducts that provided water. Some buildings distributed along the Pisac Pueblo Viejo or Archaeological Pisac are:

*The Inca cemetery:* Located in front of the archaeological complex, separated from it by the creek Quitamayu. This cemetery is known as Tankanamarka and would have contained about 10,000 graves.

*City of the Towers:* Pisac is also known as the "City of Towers" because it has more than twenty towers built on the leading edge of the mountain. They are of perfect finish, very similar to the construction of Sacsayhuaman. Their purpose is unclear but a few seem to have been associated with water provision.

*The Intihuatana:* This is one of the most important ceremonial monuments in Pisac. Its location, at the top of the mountain, dominates much of the valley. Its sides are carved in the form of hands that are enclosed in a semicircle, so it is regarded as the *Pisac Temple of the Sun*. At the center of the building there is an altar carved in stone, which might have been used to observe solar movements, to celebrate religious rites worshipping the sun god, or for animal sacrifices. To the west of the altar there is a carved stone that could have been used for astronomical observations. The D-shaped altar is perfectly oriented to sunrise on the June solstice. The only other site with a similar altar is at Machu Picchu. This rock may represent the three Andean phases of the religious world: sky, world and underworld. The quality of its carving suggests that it served purely religious purposes.

Water sources and waterways were also characteristic of this area. The main water source is located 20 meters from the main door of the complex. Two notches in the door were probably handles, with the door itself possibly leading to ceremonial baths.



**Figure 3:** The Southern Cross with the ruins of Pisac. Image: J.C. Casado/shelios.org

In Inca times the Urubamba River was channeled from Pisac to Ollantaytambo for agricultural purposes. Currently there are many vestiges of the side walls of the channel, and the Urubamba River flows in a straight line approximately 3.3 kilometers from the city.

### 3.3 Ollantaytambo

At the opposite end of the paved valley from Písac, 80 kilometers from the city of Cusco, lies the village of Ollantaytambo. At an altitude of 2700 meters, this complex was founded by Pachacutec and is believed to have had strategic military, religious and agricultural purposes. Among the elements are:

*The ceremonial sector:* This was mainly dedicated to the worship of Unu or Yaku, both water deities, and a number of water sources were used for this purpose. The bathing place of Ñusta was a font carved from a single piece of granite, 1.30 meters high and 2.50 meters wide and water still flows from it. The site is dominated by a

plain that leads to a huge hill on whose sides many monuments are located. The most significant, known as La Fortaleza, lies at the summit of this hill.

*La Fortaleza or Casa Real del Sol:* This unique building, and Ollantaytambo in general, retains evidence of urban planning by the Incas. The fortress, or shrine, consists of seventeen superimposed terraces, built on large stones carved of pink granite, in some cases measuring more than four meters high by two meters wide by two meters deep. The wall on the southeast edge of the Casa Real has an approximate azimuthal direction of  $43^\circ$ . The remains of the structure are not rectangular but adjacent monoliths are oriented at an azimuth of  $60^\circ$ , which is about the direction of sunrise on the June solstice, when it appears over the hill, Pinkuylluna, located directly in front of it.



**Figure 4:** Archeological site of Ollantaytambo. Image: J.C. Casado/shelios.org

*Inticahuarina (or Incamisama):* Located to the east of the Temple of the Sun in Ollana Valley, this consists of a large vertical rock surface tiled where some elements could act as seasonal markers. In particular, one of them seems to have indicated the passage of the sun through the zenith during the December solstice, when the festival of Capac Raymi was celebrated.

### 3.4 Aguas Calientes (Hot Waters)

This district is located about 110 kilometers from Cusco. Aguas Calientes is the home of one of the wonders of the world: the archaeological site of Machu Picchu.

#### ***Historic Sanctuary of Machu Picchu:***

Machu Picchu (from Quechua *machu pikchu*, "Old Mountain") is the contemporary name given to a *llaqta* (old Andean village) built by the Incas in the middle of the XV century, 2490 m above sea level, on the rocky promontory that connects the mountains of Machu Picchu and Huayna Picchu on the eastern slope of the Central Cordillera. Its original name is unknown although there are several hypotheses about it. According to documents from the mid XVI century, Machu Picchu would have been one of the vacation places of Pachacutec (ninth Inca of Tawantinsuyu, who reigned from 1438 to 1470) and perhaps one of the places where people worshipped after his death.

The area built in Machu Picchu is 530 meters long and 200 meters wide and includes at least 172 enclosures. The complex is clearly divided into two main areas. The agricultural zone, made up of sets of agricultural terraces is located to the south. The urban area was where the occupants lived and where the main civil and religious activities took place. Both zones are separated by a wall, a moat and a staircase, elements that run parallel down the slope east of the mountain. Among the elements worth noting are:

*The Intihuatana*: This special site was a magnificent marker of the zenith passage of the sun and of sunset at the December solstice. It is a small-scale replica of Huayna Picchu itself and is one of the most important huacas in the enclosure.

*The Tower or Temple of the Sun*: This is accessed by a cover, which shows the remains of a security mechanism. The main building is known as the *Tower*, with a semicircular structure and finely carved blocks. Its two windows were designed to look at Collca rising, providing a fairly accurate marker of the June solstice heralding the beginning of *Inti Raymi* (the biggest festival of the Tahuantisuyu), respectively. One of its windows shows signs of having had encrusted ornaments that were ripped out at some point in the history of Machu Picchu, destroying part of its structure.



**Figure 5:** The Temple of the Sun at Machu Picchu. Built just above a large natural rock, this was used by the Incas as an astronomical calendar. The sun can be seen entering through a window at dawn on June 21st (winter solstice in the southern hemisphere) in the upper left of the photo.

*Intimachay*: A window-box excavated from rock, barely a square inch in area and more than two meters deep, allows the Sun's rays to penetrate only very near the December solstice, the date of the second most important festival of the Inca calendar, *Capac Raymi*.

*The Sacred Precinct or Great Temple*: This group of buildings is arranged around a square courtyard. All evidence indicates that the site was used for various rituals and includes two of the most magnificent buildings of Machu Picchu: the *Temple of the Three Windows*, where the walls of large polygonal blocks were assembled like a puzzle, and the *Main Temple*, made of more regular blocks, that might have been the main ceremonial precinct of the city containing the "priests' house", "sacristy" or "chamber of ornaments." The western perimeter wall of the group includes a semicircular section which seems to be astronomically oriented to the sun at the December solstice. There is evidence suggesting that construction of the general assembly area, which includes several carved stones and huacas, not was finished.

### 3.5 Chinchero

Strategically located at the junction of three roads connecting Cusco, Yucay and Pumamarca, this town was a staging post to Machu Picchu at the time of Tawantinsuyu. This route started in Carmenca's district (present district of Santa Ana, in Cusco), following the foothills of Senca, passing near lake Piuray and Chinchero, continuing to Maras.

*The Sun Temple:* Located in the main square, this stands on the ruins of the palace of Inca Túpac Inca Yupanqui. The dimensions of the temple are a testament to the importance of the chiefs of the city, both in pre- and post-colonial times. This is also an excellent example of the wealth of the churches in the cusqueños villages. Nearby lies a splendid huaca carved into the rock with a number of seats that may serve to mark important directions to the horizon, including astronomical ones.

### 3.6 Maras

Maras has no astronomical significance but it is an important cultural reference. The present town was founded in colonial times by Pedro Ortiz de Orué. When many Inca citizens of Cusco's palaces were removed from the city, they had to migrate to other small towns such as San Sebastián and Maras. Although a very important town in the past, today Maras is an isolated village and lacks modern structures. In the main square (Plaza de Armas) there is a monument with a set of statues depicting a peasant couple and a donkey. The pedestal of the monument contains images of the three major tourist attractions in the locality: the ruins of Moray, the colonial church of San Francisco and the Saltworks of Maras.

*The ruins of Moray:* About 7 km east of Maras are the ruins of what was supposed to be the center of Moray Inca agricultural research (see below).

*Tiobamba Sanctuary:* This is a colonial church made of adobe in the typical Cusco religious architectural style. It contains paintings of The Last Supper.

*Las Salinas de Maras (The Saltmines of Maras):* These lie to the northwest of the village. They are made up of about 3000 small settling pockets, each with an area of about 5 m<sup>2</sup>. In the dry season these are filled with salt water from a natural spring and when the water evaporates the salt crystallizes. When the salt reaches a thickness of about 10 cm it is removed and then packaged and shipped to markets in the region.

### 3.7 Moray

Moray is a formidable archaeological complex, consisting of impressive systems of platforms and enormous overlapping terraces, taking the shape of a giant amphitheater. These beautiful terraces formed a large agricultural laboratory with different microclimates, allowing the ancient Peruvians to improve their crops. Significant progress was made in agriculture, which the basis of their economic development. It is possible that the word Moray comes from the term "amoray" in reference to the corn crop, or "moraya" or "morbid" which was the word for dehydrated potatoes.

### 3.8 Sacsayhuamán

Sacsayhuaman (Quechua: "the place where the hawk is satisfied") is an Inca "ceremonial fortress" located one mile northwest of Cusco. Although construction began during the rule of Pachacuti, in the XV century, it was his grandson, Huayna Capac, who put the final touches to it in the XVI century. The "ceremonial fortress" of Sacsayhuaman, with its megalithic walls, is the largest architectural work that the Incas built. From the fortress, the viewer is treated to a panoramic view of the surroundings, including the city of Cusco and Ausangate, one of the most important "huacas" in the Inca Empire. The peaks such as Ausangate, the Pachatusán and Cinca, visible from the fortress, were believed to be inhabited by apus, or powerful spirits, that govern the mountains.

The fact that the Incas would build a fortress is notable, since at the time of its construction they did not face major external threats. Its shape and location are perhaps guided by other principles, such as harmony between architecture and landscape. Current research suggests that it was a temple dedicated to the worship of the sun, in which case both construction and the surrounding environment were important.

The architectural complex covers the edge of the north side of the city. The south side of the building was surrounded by a wall of carved polished stones almost 400 meters long. The limits of the temple, east and west, were marked by walls and other platforms. The main front of the building faces north and is protected by a formidable system of three platforms. These are supported by zigzagging walls, made of large stones, which astonished the first visitors and, even now, continue to astound. The Inca Garcilaso states that these walls were made to demonstrate the might of the Inca. Among the architectural elements we highlight the following:

*Casa Real del Sol (Royal House of the Sun)*: Sacsayhuaman is one of the great stone monuments of Inca architecture, and was possibly a sanctuary. There are abundant descriptions of the richness of the interiors. Further evidence, such as the high quality and abundance of the objects stored in the rooms, strongly suggests that this was a temple dedicated to sun worship, appropriately called "Cieza de León", a "Real Casa del Sol". Garcilaso de la Vega left a testimony, in his Royal Commentaries, that the cusqueños knew that this architectural complex was actually a Royal House of the Sun, and not a fortress as conquerors named the complex.

*The doors of Sacsayhuaman*: There were several doors leading through different levels of stairs. Garcilaso left the names of three of them. On the wall of larger stones there was the door Punco Tiu (tiu means sand), the second was called Acahuana Puncu and third Huiracocha Puncu (after the god Viracocha).

*The towers of Sacsayhuaman*: The main campus consists of three large terraces, whose lands were raided and leveled. On the east side was the Paucar Brand (Lovely Complex); in the center Sallac Brand (Enclosure with Water) and west, Muyu Brand (Round enclosure).

*Muyu Marca tower or Cahuide tower*: This was a cylindrical tower. Thanks to information contained in the chronicles and later excavations, we know it was a building of four superposed parts, reaching a total height of 20 meters.

*Terraces*: Very little remains of the old buildings built on the terraces of the complex. Between the towers of Muyu Marca and Sallac Marca there was an elongated square. In the highest terrace of the set there is a circular pool, which could have been a water reservoir, and a rectangular building with a single door. At the southeast end of the complex, curved platforms can be seen and two barns (or colcas).

*Huacas*: The set includes numerous formations carved into the rock, including the famous "Silla del Inca" (Chair of the Inca). Some of these are of a ceremonial character while others are related to astronomical events.

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|    | <b>CSIC</b><br>Consejo Superior de Investigaciones Científicas<br>SPAIN                                   |
|    | <b>CTU</b><br>Czech Technical University in Prague<br>CZECH REPUBLIC                                      |
|    | <b>FZU-CAS</b><br>Institute of Physics of the Academy of Sciences of the Czech Republic<br>CZECH REPUBLIC |
|    | <b>IAC</b><br>Instituto de Astrofísica de Canarias<br>SPAIN   |
|  | <b>INAF</b><br>Istituto Nazionale di Astrofisica<br>ITALY   |
|  | <b>SAO</b><br>Special Astrophysical Observatory of Russian Academy of Sciences<br>RUSSIA                  |
|  | <b>UCD</b><br>University College Dublin<br>IRELAND  |
|  | <b>UCH</b><br>University of Chile<br>CHILE  |
|  | <b>UMA</b><br>University of Malaga<br>SPAIN   |
|  | <b>UOX</b><br>University of Oxford<br>UNITED KINGDOM  |
|  | <b>UWAR</b><br>Uniwersytet Warszawski<br>POLAND   |