

Colonial Churches as Astronomical Instruments
in San Cristóbal de las Casas
Informe Preliminár—Archivos de la Catedral

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In 1375, Toscanelli placed a hole in the lantern of the cathedral of S. M. del Fiore in order to study whether the earth's axis changes over time from the path of the sun's light. We do not know whether it functioned. His work was likely based on restudied classic Greek and Arabic manuscripts. In 1475, the Dominican astronomer Dante produced the first of many successful meridian lines in Italian churches by knocking holes in the roofs of churches (Heilbron, 299:70). By 1673, non-ecclesiastical meridian lines for astronomical research had been constructed in England (Amson 2008).

Hilbron (1999) discusses how these lines and others were used to measure the date of the equinox, the sun's altitude on the day of the summer solstice, the earth's annual motion, its obliquity, and other topics of interest to astronomers. Later holes in cathedrals were more effective and some used lenses to better focus the light (Hilbron 1999:225), but advances in telescope lenses ended their construction in Europe by the 1820s. Today, surviving European examples are of interest primarily to historians of the Catholic Church (e.g. Heyd 2003) and tourists. No published instances of these astronomical uses of churches have been found for in Latin America.

We report here a new finding, that meridian lines were also constructed in the Americas, in 17th and 18th century churches in Chiapas, Mexico. They traced the principle aisle of the church. Incredibly, although the lines continue to provide a spectacular light show, their meaning has been lost.

Even more astonishing is the finding that these 17th and 18th century churches were designed to produce these impressive light shows. As noted above, the Old World, churches were retrofitted for Meridian lines by breaking holes in the roof or cutting them into stained glass installations. Four of the churches studied in San Cristóbal de las Casas, were designed from the ground up to cast equinoctial and solstitial beams of light.

Side windows were also constructed to cast windows of lights on entryways and images. Images and windows also had to be aligned perfectly in order to be lighted on special dates by these light beams from domes of the church. This practice has been discovered in Franciscan missions on the northern frontier of New Spain by Mendoza (2005), who associated them with eschatological architecture as well as ecclesiastical iconography. In addition, Mendoza argues that the syncretic adoption of Cristo-Heilios was still present in the late 18th and early 19th century missions built by Franciscan and Ohlone Casanoan, Indians, in California.

These uses of windows of light in a number of missions in the northern frontier of New Spain have been only recently rediscovered (Mendoza 2005:2-5). Often lacking the domes of colonial churches, these churches used windows, which illuminated points of

ecclesiastical interest. I have found similar examples of the use of windows to illuminate images in the older churches of San Christóbal de las Casas, Chiapas, Mexico. In addition, I have observed solstitial orientations of a nave and also of a convent in two early 17th century churches in the countryside. In this report, we present the newly rediscovered Meridian lines here along with solstitial lights from the same churches in San Cristóbal de las Casas. I will briefly discuss saints and altars being lighted by these sources.

I divide the discussion into equinoctial and solstitial phenomena, and I provide series of photographs for the churches of Santo Domingo, la Caridad, and Santa Lucía with some additional information for the churches of Guadalupe and San Nickolas. This is a preliminary report, and a great deal of work remains to be done in documenting these phenomena. Understanding of details of their construction and finding the time when the knowledge of their meaning was lost requires archival study.

Astronomical Events of Importance for which the casting of light in churches is reported in this Report

1. The spring equinox occurred at 00:48 CST in the morning of March 20, 2008.
2. The spring cross-quarter moment (crossing day for the Maya), the midpoint between the solstice and equinox, happened at 21:55 CST on May 4, 2008.
3. The summer solstice occurred at 18:59 CST on June 20, 2008.

Equinoctial Meridian Lines

In 2007, my wife invited me to attend a mass at la Caridad. I was surprised to see a spot of light moving down the retablo. Since I was aware of Mendoza's findings in the missions of California, I resolved to return the following year to make a fuller study. Having read the important work by Heilbrun (1999), I was aware of Meridian lines. However, since none had been reported in the Americas, I did not expect to find them. To my great surprise, I found that there were beams of light that passed from the rear to the front of the aisle on the day of the equinox of the churches described below.

1. La Caridad. La Caridad, a Dominican church, is known by all as La Caridad, but is actually dedicated to San Juan de Dios. Its date of construction is 1739. After noting a spot of light moving down the retablo in 2007, I returned later to take a picture, which shows San Jose illuminated (see attached figure). A few weeks later, the saint below San Jose (Saint Dominic?) is illuminated and finally, before the equinox, the Virgin Mary would be illuminated except for a modification in the installation which impedes its shining on her.

In 2008, I found that on the vernal equinox, light from the southwestern window of the four windows in the domes of La Caridad cast a light that moves up the center aisle of the church. Later, I found that the summer solstice light illuminates the south entryway to the church (see figures).

The domes over each wing of the transept have 16 architectural lines emanating from them, presumably to mark the original 16 Dominican friars when the order first applied to the Pope for recognition. A small opening in the top points to the 13th ray in each on the equinox, counting 1 as the ray pointing to the north.

2. Santo Domingo. Palm Sunday occurred five days before the equinox in 2008. Fortunately, I was in the church of Santo Domingo for that service on March 16, 2008, with a camera and tripod, not really knowing what to expect. The figures show that a bright beam of light appeared from a window in the southwest of the dome. At first it shone on the west end of the principle aisle, on the north side. It traveled down the north side of the aisle, stopping in front of the pulpit, before fading. Pictures taken a week later on Easter show a beam now moving towards the pulpit but along the pews on the south side. Interpolation with pictures taken on Easter day makes clear that on the equinox the spot of light must have traveled the center of the aisle on the equinox. In later years, I observed that the beam does travel the center; however it begins somewhat to the south and ends somewhat to the north of the centerline. The center of the aisle, by measurement, is equidistant from each wall. The original floor is now covered by at least a later wooden one, so research is needed to determine whether the line was marked on the original tile floor as a Meridian line. The church was constructed over a period of time with many subsequent rebuilding episodes. However, the original construction probably dates from around 1560 (Markman 1984).

3. Santa Lucía. The date of construction of the church of Santa Lucía is not secure. Although Antiguas (1991:86) suggests late 19th century, an INAH report notes a letter specifying that the muebles of the church had been stolen in 1819 (Anonymous 1999: 469), suggesting early 19th century or earlier.

A figure attached shows the light moving up to stop on the altar on the 30th of March. I was not there to observe its behavior on the equinox, but since the sun had risen further by the time of these photographs, it seems probable that the beam of light traveled up the aisle on the day of the equinox.

4. Guadalupe. I have minimal data on Guadalupe. A sign at the church states that it was constructed in 1835. Unlike the churches above, it is not oriented perfectly east-west; it is 10° off by Brunton compass on April 23, 2008; however, magnetic north is $3^\circ 7'$ to the east by declination, so the actual deviation is 7° . It is possible that the church was laid out by compass when the deviation was 7° . With a latitude of $16^\circ 45' 0''$ N and longitude of $92^\circ 37' 60''$ W (DMS), as recently as 1900, the declination at San Cristóbal was almost 7° to the east. Calculation of declination by year might help establish the date of construction by making the assumption that it was laid out by magnetic north. Later investigation showed that in the single dome window that has not been covered up, a light did move down the center of the aisle on the equinox; however, I have never been able to be in the church to observe the full travel of it down the aisle.

5. Saint Nickolás lacks a dome. Since it is oriented precisely east-west, windows on the east side would, only on the equinox, frame the windows on the west. I did not photograph nor observe this phenomena on the equinox, although the windows of light were approaching their opposite windows a week before.

A meridian line of light was also observed at Guadalupe, although after the equinox (figures not presented). Because the sun was higher in the sky when the observation was made on April 8, three weeks after the solstice and almost a month before the crossing-day, a pair of lights was observed to the north of the aisle. They may have divided the church on May 4 but observation was not possible on that day. Less well studied are the times when both western windows in the domes of Sto. Domingo, La Caridad, and Santa Lucía entered the nave.

On February 8, 2007, I observed the top of the pulpit, covered in gold, illuminated by a shaft of light, which turned the normally dark roof, a spectacular light. This is close to the cross-quarter day, and is a time still when Tojolabal Maya peoples in the area cluster festivals (Louanna Furbee, personal communication).

Why did the architects of these four domed churches in Chiapas, place the windows so that a beam of light on the equinox would trace the aisle of the church so that on the solstice, the south entry way or an installation would be illuminated? Recall that these churches were constructed in the 17th, 18th, and possibly early 19th centuries. One obvious reason for the equinoctial line tracing the aisle would be to alert that Easter should be observed on the next Sunday that occurred after the next full moon. But would this be necessary? With the widespread diffusion of the printing press, cheap calendars noting Easter day were easily distributed to churches in Europe.

The first printing press arrived in Mexico City in the 16th century; however, the first in Chiapas was in the late 18th century (Castañada 1940). For churches built in the 16th, 17th and 18th centuries, a Meridian line announcing Easter would have been valuable. Builders of these early churches might have placed these lines there for that reason. However, other reasons are possible. Mendoza (2005:90-91) notes the importance of church architecture manipulating light in missions in the north of New Spain. He suggests their relation to the impending apocalypse. However, he is writing of Franciscan traditions and the setting of the San Cristóbal churches requires equally dedicated investigation of Dominican sources.

Mendoza found midwinter solstice illuminations by windows of light of various images and architectural features in the Mission San Juan Bautista (Mendoza 2005:88). As will be described below, such illuminations of images may be more characteristic of equinoctial light in Chiapas. Solstice beams of light announced the summer solstice (the winter has not been observed) by being directed in two cases (Sto. Domingo and la Caridad) to south entryways.

Summer Solsticial Beams of Light

The light cast from the opening in the dome to the south entryway of the nave of Santo Domingo and La Caridad was centered on the south door at the summer solstice. Therefore, the doors must have been set just so to receive the light, given that the window also has to be placed perfectly in order to project a Meridian line.

Sta. Lucía lacks a south entrance, but there is a solstice ray of light, which impacts the base of an obviously more recent glass-enclosed painting of the virgin. The solstice light would have struck an image placed about a meter from the floor. I did not study Guadalupe at the time solstice.

The symbolism of a beam of light illuminating the entrance to the south of the church must be important and further archival and library study will be needed to understand that importance in the minds of the architects of these churches.

Windows of Lights on Images

The meridian lines and solstice beams are phenomena of the morning. Constraints of time for the single investigator prevented a full study of the beautiful lights that illuminate especially images of saints, in the afternoons, at the churches. A few examples are given in the photographs, enough to suggest that more research is warranted. Further, some minor changes by the church would permit the light to paint these images into especially beautiful figures. The Virgin Mary in the south transept of Sto. Domingo is only partially illuminated, as shown in the figure, because her sculpture is placed too far back into the niche. The Virgin Mary in la Caridad cannot receive the beam of light before the equinox that previously illuminated in turn the two saints above her, because of an impeding superstructure that appears to have been remodeled, as mentioned above.

Churches Outside of San Cristóbal de las Casas

San Jose. Time did not permit study of any but one other domed standing church, that of San Jose outside of San Cristóbal, that in Comitán Domínguez. The church, like the surrounding streets, is oriented to approximately 318°; streets to the north and south are not parallel. At 10:00 am on April 18, almost a month after the equinox, there was a strong light coming from the upper left window in the dome that was split by pillars of the principal arch. It is possible that the beam would have described a Meridian line on March 21, but future research is necessary to confirm this hypothesis. On February 12, a spot from the first window north of the center of the dome traveled from the south wall to die just to the south of the center line; it might stop there on the cross-quarter day, but this hypothesis remains to be tested.

Two churches in ruins were briefly studied. Coapa and Coneta, which both date from the 1630s, were not aligned in the traditional east-west orientation.

Coneta: The Church. The church faces does face in the general direction of the winter solstice, to the west (with an Brunton compass I observed an azimuth of approximately 233.5°, which, when corrected for modern declination, is actually about

233°). The December 21 solstice sunset on December 21, 1630, would have been seen at 241° at 11° elevations, just to the left of the peak of the hill to the east. Coneta does have two intact windows, one on the southwest side, the other on the northwest that should be investigated for their alignment.

Coneta has a spherical aperture in the facade that would have permitted light to have impacted the back of the church. From the back of the church, looking through the aperture, one sees the peak of the nearby hill in the center of vision. Pedestrian reconnaissance is necessary to investigate whether this was a “water hill” for the indigenous inhabitants, who might have left some archaeological evidence in the form of remains of a shrine.

Coneta: The Convent. The convent is hafted to the church at an angle of about 66° instead of the more typical 90°. A published map by Markman (1984:Fig. 188) permits a declination-adjusted azimuth of 291° to be estimated for the only end of the convent that might have had a window—the other end abutting the church. This is very close to what would have been seen looking from the convent to the west in 1630, where the solstice sun would have set with an azimuth of 291°6' at 1° elevation over the flat horizon to the right of the hill.

Coapa. Like Coneta, the church at Coapa does not face due west, but instead faces towards the east at 117° as read from the map in Lee and Markman (1977: Fig. 12.2). Since the map was made in 1976, and the declination then was 5°55 E, the actual orientation of the church is approximately 111°. On December 21, 1630 AD, the sun would have risen at 110°41' at 0.5° over the relatively flat horizon. Tom Lee, who took me to these churches, and I did not study the convent orientation for lack of time.

The most interesting feature of Coapa is that the church is not oriented east-west nor is it oriented to the grid of the streets of the town, which Lee and Markman (1979) found to be towards the intercardinal directions, that is 45° and 135°, rather than 0° and 90° from north. These directions along with the solstices were used by the prehistoric Maya to organize space. Even today, the “crossing-days” between the solstice and equinox are celebrated by clusters of fiestas among Tojolabal Maya and probably other groups (Louanna Furbee, personal communication). Rice (2005:33) among others had noticed the importance of the intercardinal directions along with the solstices in Maya sites such as Dos Pilas.

Preliminary conclusions

The light beams are predicted to trace meridian lines up the center of the aisle on the equinox; however, for 3-5 days before and after, they can be seen moving up one side or the other of the aisle. The solstice light rays can be observed over about 10 days, owing to the apparent slowing of the movement of the sun as it approaches and then leaves the apex of its orbit. This phenomenon could best be observed between about June 15 to June 27. Temporary removal of the barrier on the inside of the south entry to Sto. Domingo might permit the spot of light to actually enter the entryway on those days,

although it is possible that a supporting pillar would impede that. The figures attached will help explain the discussion above. They will also show the beauty of the figures illuminated and the pleasure that can be had from knowing this was the gift of the architects of the church. It is a pity they have been forgotten. I hope their recognition can lead to their appreciation by those who enter these churches on these special days of light.

Respectfully submitted,

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Preliminary Bibliography

Amson, John Ceres 2008 Gregory's meridian line of 1673-74: A St. Andrews detective story, *Journal of the British Society for the History of Mathematics*: 23:58-72.

Anonymous Catálogo Nacional de monumentos Históricos Inmuebles, Vol. VI.
(CONACULTA• INAH, Estado de Chiapas, Mexico, 1999).

Atigas, Juan B. 1991 *La Arquitectura de San Christóbal de las Casas*. Gobierno del Estado de Chiapas, UNAM.

Benavides, Antonio 1984 La arqueología histórica Maya de Chiapas: un inicio. *XVII Mesa Redonda de la Sociedad Mexicana de Antropología*, II: 195-205. Mexico.

Castañeda, Carlos E. 1940 The beginning of printing in America *The Hispanic American Historical Review*, 20: 671-685.

Evans, Robin 1995 *The Projective Cast: Architecture and Its Three Geometries* (MIT Press).

Heyd, Michael 2003 The discourse of pious science, *Cambridge University Press Online Journals*, 16.

Heilbron, J.L. 1999 *The Sun in the Church: Cathedrals as Solar Observatories*
(Cambridge Mass: Harvard University Press).

Lee, Thomas Arvol and Sidney D. Markman 1977 *The Coxoh Colonial Project and Coneta, Chiapas, Mexico: A Provincial Maya Village under the Spanish*

Conquest. *Historical Archaeology*, Vol. II, pp. 56-66. Society for Historical Archaeology.

Markman, Sidney 1984 *Architecture and Urbanization in Colonial Chiapas, Mexico*. Philadelphia, American Philosophical Society

Mendoza, Rubén G. 2005 Sacrament of the sun: Eschatological architecture and solar geometry in a California mission. 22, 87-110, *The Journal of the California Mission Studies Association*.

Ortiz Herrera, Rocío 2003 *Pueblos Indios, Iglesia Católica y Élités Políticas en Chiapas (1824-1901). Una perspectiva comparativa*. CONECULTA-El Colegio de Michoacán.

Peraza Guzmán, Marco 2000 *Arquitectura y urbanismo virreinal (Coordinador)*, Universidad Autónoma de Yucatán, Facultad de Arquitectura.

Rice, Prudence M. 2005 *Maya Calendar Origins: Monuments, Mythistory, and the Materialization of Time*. UT Press.