

Urban Planning in the First Unfortified Spanish Colonial Town: The Orientation of the Historic Churches of San Cristóbal de La Laguna

Alejandro Gangui

Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales
CONICET – Universidad de Buenos Aires, Instituto de Astronomía y Física del Espacio (IAFE)
gangui@iafe.uba.ar

Juan Antonio Belmonte

Instituto de Astrofísica de Canarias
jba@iac.es

Abstract: The city of San Cristóbal de La Laguna in the Canary Island of Tenerife (Spain) is of exceptional value as the first unfortified colonial city to follow regular plan – a grid, outlined by straight streets that form squares – in the overseas European expansion. It constitutes a historical example of the so-called “Town of Peace”, the archetype of a city-republic in a new land that employed its own natural boundaries to delimit and defend itself. Founded in 1496, the historical centre of the old city was declared a World Heritage Site by UNESCO in 1999. We analyse the exact spatial orientation of 21 historic Christian churches currently existing in the old part of La Laguna, which we take as a good indicator of the original layout of the urban lattice. We find a clear orientation pattern that, if correlated with the rising or setting Sun, singles out an absolute-value astronomical declination slightly below 20° , which, within the margin of error of our study, might be associated with the 25th July feast day of San Cristóbal de Licia, the saint to whom the town was originally dedicated. We also discuss at some length some recent proposals which invoke somewhat far-fetched hypotheses for the planimetry of the old city and conclude with some comments on one of its outstanding features, namely its *Latin-cross* structure, which is apparent in the combined layout of some of its most emblematic churches.

Keywords: archaeoastronomy; Christian churches; La Laguna; urban planning

Introduction

Before the Castilian conquest of Tenerife, the area that today contains the city San Cristóbal de La Laguna was known as Aguere, an important fertile plain between the kingdoms (or *menceyatos*) of Tegueste, Anaga, Güímar and Tacoronte that was used communally by the aboriginal inhabitants – the Guanches – for seasonal cattle grazing (Tejera 1991). In November 1494, Aguere was the location of the most important battle between the Castilian troops, under the command of Don Alonso Fernández de Lugo, and the aborigines, under the command of Bencomo, *mencey* [king] of Taoro. The final victory in the summer of 1496 led to the annexation of Tenerife to the Crown of Castile; according to historical sources, this occurred close to 25th July, the feast day of San Cristóbal, and this gave the city its founding name and patronage.

The location of the old town was chosen with strategic reasons in mind: its elevated terrain, away from the sea, connects the north and south slopes of the island, thus giving its inhabitants control of the surrounding region and protecting the city against possible pirate attacks. It was also unique on the island in being surrounded by mountains, with abundant water courses, and a small lagoon (in fact, the aboriginal toponym “Aguere” meant “lagoon”).

The first feast of Corpus Christi following the conquest was celebrated in the primitive and newly built parish church of Our Lady of the Immaculate Conception (*Nuestra Señora de La Concepción*). Located near the present building, the feast was considered to be the first foundation of the city. Soldiers and civilians began building the first modest huts at the foot of the church; a few houses of rough stone, covered with straw that gave shape to a small hamlet. Settlement in this initial nucleus – in course known as the Upper Town (*Villa de Arriba*) – was irregular and unplanned, and it was located some distance from the lagoon that extended towards the north (and that would finally disappear in 1837, when it was drained) (Municipalidad de San Cristóbal de La Laguna 1998, 105).

However, the definitive foundation of the city came after Fernández de Lugo returned to the island in 1500 after having made an agreement with the Crown of Castile regarding how the conquered island would be administered. He obtained from the Catholic Monarchs (i.e. Isabella I of Castile and Ferdinand II of Aragon) the title of Adelantado (captain general), and the governorship of the territories. As such, he had the full right to administer justice, appoint the various administrative, judicial and military positions, adjudicate land disputes, dictate ordinances and represent the head of the town council (*cabildo*). The first meeting of this institution had taken place on 20th October, 1497, and for a long time it was the principal and only governing body of the island (Aznar Vallejo 2008, 191).

A new nucleus was now established about a kilometre to the southeast of the first settlement: an area now known as Adelantado’s Square (*Plaza del Adelantado*), around which grew an ordered grid, based on the classical template and in time forming the Lower Town (*Villa de Abajo*). This was a pattern already used in some older cities, such as those located in lower Andalucía like Puerto Real and Santa Fe de Granada. However, San Cristóbal de La Laguna was a city without walls founded under different circumstances in conquered distant land, and as such it had to respond to new political, economic and social

needs. In the long term, this new city design would serve as a model for the colonising process that would later take place in the new American territories (Navarro Segura 2006).

On 24th April, 1500, the Adelantado issued a decree by which the sale or construction of new houses in the old “Upper” town was no longer allowed, and he determined that new construction should be carried out “desde el l’espital de Santespiritus hazia el logar de Abaxo” – towards the southeast of the Hospital of the Holy Spirit or the Convent of San Agustín (Alemán de Armas 1986, 15). Meanwhile, new arrivals intensified, especially from the coasts of western Andalucía. The migratory current that accompanied the first conquerors began to adapt to the new lands, although the origins of these people was undoubtedly decisive in the different architectural models that emerged in the newly created settlements (Corbella Gualupe 2000). The historical centre of the city of San Cristóbal de La Laguna was practically defined towards the end of the sixteenth century, as is shown in one of the earliest surviving maps of the city (Figure 1). This map was drawn in 1588 by Leonardo Torriani, an Italian engineer, who had been sent by order of King Philip II to study the military defence of the archipelago (Torriani 1978). Over the years, the two population centres, the upper and lower *villas*, combined into one.



FIGURE 1. Map of the city of San Cristóbal de La Laguna towards the end of the sixteenth century, drawn by the Italian engineer Leonardo Torriani. On this map, the north is approximately to the left, an orientation that locates the Upper Town below the Lower Town.

Although on the Old Continent one can still find many cities with well-preserved historical centres which are much older than La Laguna, this city is of outstanding

historical value in that its “Lower Town” was conceived as a distinct project from the very beginning, established in a virgin, unpopulated and remote location that from the European perspective was without history, and that its precise original design, together with the morphology of the city and its remarkable urban profile, has remained practically unchanged since the days of Torriani, more than 400 years ago. The current city is not the result of centuries of interactions, modifications and reconstructions.

The architecture of a new city under Catholic rule was always, in one way or another, tied to the economy of the Catholic Church. In locations where ecclesiastical bodies had sufficient means, religious constructions were endowed with arches and ogival forms. However, where parishes were poor, or just beginning their collective life – as in the case of the Canaries, and, in particular, the island of Tenerife – options were limited. Religious art had to be a popular art: simple, quick to create and economical (Figure 2). These needs were adequately met by the Mudejar style (Fraga González 1977).



FIGURE 2. Two of the oldest constructions of the city. The San Miguel de los Ángeles chapel (left) was founded in 1506 by the Adelantado Fernández de Lugo, who expressed his wish to be laid to rest there. The Royal Sanctuary of the Holy Christ of La Laguna (right), known as Saint Francis or El Cristo, was also founded early in the sixteenth century and suffered several major mishaps during its long history, such as floods and fires (photographs by the authors).

The orientation of old churches has been of academic interest for a long time and has recently received new impetus in the literature, as it has been recognised that orientation represents a key feature of the architecture of these churches. According to early Christian texts, the symmetrical axes of religious buildings and churches’ apses should lie so that the priest would stand facing eastward during services (McCluskey 2015, 1704).

North Africa, in spite of Roman dominance, is an exception to this rule. In many regions, such as Proconsularis and Tripolitania, a number of old churches with orientations towards the west are found (Esteban *et al.* 2001, 81; Belmonte *et al.* 2007, 79). These regions are relevant to our study as the possible homelands of the Canarian aboriginal population. It should also be noted that most of these North African churches were oriented roughly within the solar range, with orientations between the winter

and summer solstices and noticeable clustering around the equinoxes and solstices (González-García 2015, 272).

In this work, we analyse the spatial orientation of most of the historic Christian churches currently existing in the old part of La Laguna. Our approach is based on the proposal that the alignment of churches can be considered a good indicator of the orientation of the original urban lattice. In our study, we also include a couple of religious constructions lying close to the borders of the city, as depicted by Torriani in Figure 1, due to the fact that these churches have old dates and, presumably, could be following the same general orientation as the rest.

Our main aim is to confirm whether a clear orientation pattern exists for the sample of churches (and therefore, according to our hypothesis, also for the layout of the city), and if this pattern can be correlated with the rising or setting Sun on particular dates throughout the year. As we will see, our results single out a broad interval, centred approximately on 25th July, which, although nowadays corresponding to the feast day of Saint James, in La Laguna is still celebrated as the feast day of San Cristóbal de Licia, the original patron saint of the city.

Before presenting our detailed analysis, in the next section we briefly discuss alternative ideas that assume a geometric origin for the planning of the city. Although we do not support this perspective, essentially because it has no adequate historical support in the documentary sources of the time, its introduction here is useful for contextualising our project and showing that a simpler explanation for the particular layout of the city is worth pursuing.

A City Inspired by Greek Philosophical Principles?

As noted above, La Laguna is exceptional for being the earliest documented instance of an unfortified colonial city with a regular plan – a square grid – in the European expansion overseas. As such, it constitutes a case study of the archetype of a city-territory that took advantage of its own natural boundaries to delimit and defend itself. In this instance, the natural defensive systems have always been the Chamarta ravine to the southwest and the Gonzaliánes ravine towards the east border, at the foot of the slopes of San Roque, as well as the prominent lagoon towards the north, and the mountains by which it is surrounded (Municipalidad de San Cristóbal de La Laguna 1998).

However, according to a popular modern tradition discussed by Navarro Segura (1999), La Laguna is also remarkable as the material realisation of a city built according to “a precise geometric plan” derived from the navigational science of the time, and with a symbolic structure that can be interpreted in a manner similar to a marine chart or even the well-known constellations of the sky (Navarro Segura 1999, 121). This plan, it is suggested, expresses the idea of a new social order inspired by the Christian concept of the Millennium – and its manifestation through the urban design – that arose around 1500 and that was encouraged by the Catholic Monarchs themselves for the foundation of new cities in conquered lands (Navarro Segura 1999, 79).

These characteristics can be attributed to Fernández de Lugo himself, as a result of his stay at court between August and October 1499, which at that time was residing in

the city of Granada. During those months, when the Adelantado was preparing his future campaign in Barbary (North Africa), the court supposedly dictated rules on how the new foundation in La Laguna was to be carried out (Navarro Segura 1999, 204), in accordance with ideas rooted in humanism and the prevailing religious renewal. From a comparative analysis between the future design of the actual city and the ideal city outlined in Plato's *Laws*, it is thought that the Catholic Monarchs agreed with the Adelantado "the application of the principles contained in the work [*Laws*] as part of an experimentation project of a new model of a city to be developed in the newly pacified territories incorporated to the Crown of Castile" (Navarro Segura 1999, 166).

On the basis of the literary tradition in the Iberian Peninsula at the time, Navarro Segura speculates that Fernández de Lugo would have had Plato's book in his hands and that from his careful reading of the text he would have considered seriously the philosopher's ideas – and the eventual application of them to La Laguna – with respect to the city of Magnesia discussed in Plato's dialogues (Navarro Segura 1999, 186; 2006). In collaboration with Antonio de Torres, overseer of the African campaign and versed in mathematics and navigation, and with the Sevillian Pedro de Vergara, mayor of the city of La Laguna for several years, the Adelantado would have carried out his design during the first two decades of the new century: a design that supposedly relied on ancient concepts based on mathematical formulas and that delineated its streets through the use of nautical astrolabes and other navigational tools (Navarro Segura 1999, 121). From then on, Platonic and Renaissance concepts overlapped in the configuration of the original urban layout; a utopian and symbolic city, a projection of the sky on the earth that was oriented by the compass rose, having the convent of San Agustín (the old limit of the Upper Town, Figure 3) as its exact geometric centre. However, with the premature death of Torres in a shipwreck in 1502 and the Adelantado's own disappearance in 1525, the ideas and symbolism behind this urban experiment would have been lost to oblivion in the years that followed during the foundation of Spain's American colonies (Navarro Segura 1999, 144).

Navarro Segura further suggests that the design of the city was also based on the application of instructions contained in Vitruvius's treatise *On Architecture* (c. 15 BC). These rules would have been straightforward to apply, due to the common use of navigation-bearing guidance instruments and familiarity with the notion of eight main winds, which Vitruvius identifies with eight regions of the horizon (Navarro Segura 1999, 204) – in his discussion on the foundation of cities, Vitruvius focuses on the winds as a key factor for the health of a location. In particular, Vitruvius prescribes inscribing the proposed circumference, which should then be divided into eight parts – the "Vitruvian octagon" – to calculate the position of the eight winds. The streets should be placed along directions intermediate to these winds (Vitruvius 1.6), which, in the plain of Aguere, were always particularly intense.

This intentionality in the geometric layout of La Laguna is said to be reinforced by some axes that cross the city, establishing particular distance relationships between representative sixteenth-century religious buildings. Thus the geometric centre at San Agustín is equidistant from four old churches, taken in pairs: the church of San Juan



FIGURE 3. Main facade and walls of the church of San Agustín, next to the old convent of the same order, in its present state after a fire in 1964 consumed its interior and collapsed the roof. Its location marked the southeastern boundary of the old town, until the Lower Town was built (photographs by the authors).

Bautista and the church of El Cristo de La Laguna on the one hand, and the chapels of San Roque and San Cristóbal on the other (Navarro Segura 1999, 223). In addition, the religious axis linking the church of San Benito Abad (also of the sixteenth century) with the centre of the city plan at San Agustín is arranged precisely in an east–west direction, dividing the city-octagon into two parts. Finally, the distance separating the centre from the first two churches would be the same as that separating it from the two ends of the street that was once called Water Street (*Calle del Agua*), now Nava y Grimón back street and the eastern boundary of the city (Figure 4).

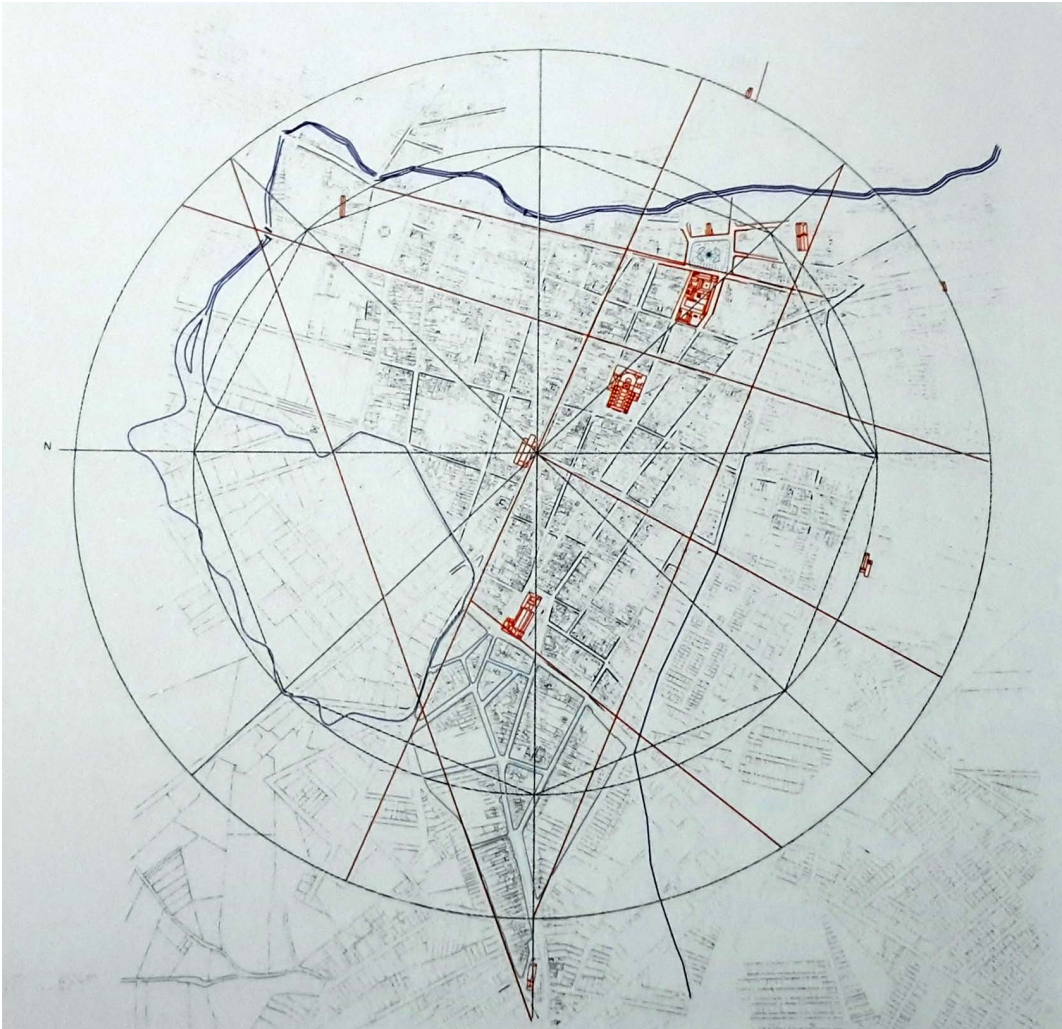


FIGURE 4. Map drawn by Navarro Segura with the distribution of the streets of San Cristóbal de La Laguna adjusted to a Vitruvian octagon (Vitruvius 1.6) inscribed in the circumference and related to the main winds. Supposedly centred in the church of San Agustín, it shows the location of several religious buildings as symbolic references to the geometric layout. In this map, north is to the left (adapted from Navarro Segura 1999, 233).

However, some years since Navarro Segura's proposal, other ideas concerning the design of the city have emerged, which, although they concurred with the idea of a geometric origin, differed in some of their details. For example, it was noted that the map of the historic centre did not show clear traces of a design based on the radius of a circumference. This was evidenced by the morphological aspect of the city, the layout of the streets and the location of the most representative old buildings, as noted by Herráiz Sánchez (2007, 61). Furthermore, once the alignment of three prominent constructions (the tower of La Concepción in the old town, the Cathedral Nuestra Señora de Los

Remedios and the chapel of San Miguel) was verified, Herráiz Sánchez hypothesised that there existed a new orientation axis for the city, which would be parallel to the axis of symmetry of La Concepción. This direction indicates roughly the solstitial line. It was also suggested that the relevance of the east–west (equinoctial) axis emphasised by Navarro Segura did not find an adequate justification in a city that, supposedly, was oriented towards a solstitial direction (we will see more details on this point in the next section). Herráiz Sánchez further suggested that the angle that forms the symmetry axis of La Concepción with respect to cardinal east, that he estimated to be approximately 26.5° , represented the minor angle of a “golden triangle”. From this, it was proposed that

the contours of the city, the location of religious buildings and the orientation and dimensions of the main streets are the result of adapting to the orography of the place the geometrical principles of the Golden Section, which coincide in the latitude of La Laguna with the most relevant solar movements. (Herráiz Sánchez 2007, 85)

To conclude this section, it should be borne in mind that one of the outstanding subjects for the readers of *On Architecture* was the Vitruvian reflection on the theory of proportions based on the human figure. In the urban planning for San Cristóbal de La Laguna proposed by Navarro Segura, the idea of the anthropomorphisation of the city is also present: the human figure has its “head” in the Adelantado’s Square, located to the east. The heart of the body would then be in the centre, occupied by the Church of Nuestra Señora de los Remedios, later converted into the main parish church and then into the cathedral. Finally, at the other end of the city, to the west, in the original nucleus of the Upper Town, the feet of the body would be located, in an agricultural area which formed the base and sustenance of the community (Navarro Segura 1999, 82).

In this way, the Adelantado would have applied to La Laguna the project of a city as defined in the *Laws*, Plato’s last and unfinished work (Navarro Segura 1999, 166). Thus, the new foundation would have been related to an ideal, mythical city, circular like the soul and the universe, which had been imagined eighteen centuries before by the great philosopher, and characteristic of a utopian human society where disloyalty is banished, which has no external walls and which is formed by concentric circles and endowed with economic, social and political structures, as had been suggested according to Plato’s text.

Methods and Results

In this section, we attempt to falsify the boldest hypotheses of Navarro Segura and Herráiz Sánchez, which, as mentioned above, we consider doubtful due to its absence in the available historical documentation. We will show that a simpler interpretation of the present design of the city might be possible, and that the city’s plan is actually based on the orientations of its churches. Because of this, and since the city of La Laguna has several characteristics that make it unique (mentioned in the Introduction), in this section we will develop a complete study of the orientation of the ensemble of its old churches and chapels. This archeoastronomical approach will shed light on the layout of the city as a whole and, perhaps, allow us to extract new elements that will reveal the main ideas in the origin of its design.

Our present analysis is the continuation of a large-scale project we are carrying out in the Iberian Peninsula and the Canary Islands. In the latter location, we have already focused on the precise orientation of the colonial churches on the island of Lanzarote, and the reader can find some of our methods of analysis in a prior study (Gangui *et al.* 2014). In the present work, we undertake the first systematic study of the religious constructions of the city of San Cristóbal de La Laguna. Our main interest now is to measure their precise orientations, as this can provide us with an indication of the layout of the city. Moreover, it can also provide us with unique archaeoastronomical data comprising a compact set of old churches whence we can search for pre-European and Catholic religious traditions, including astronomical ones, or a mix of both. As with previous works, this could offer us a broader understanding of a key aspect of Canarian culture (Gangui *et al.* 2016).

We present our data in Table 1, which shows the results of our fieldwork. The identification of the churches is presented, along with their geographical location in coordinates and orientation (archaeoastronomical data): the measured azimuth (rounded to 0.5° approximation) and the angular height of the point of the horizon towards which the altar or the narthex of the church is facing, as well as the derived computed declination corresponding to the central point of the solar disc. The measured height of the horizon was appropriately corrected for atmospheric refraction (Schaefer 1993, 314), and when the horizon was blocked we employed the digital elevation model based on the Shuttle Radar Topographic Mission (SRTM) available at HeyWhatsThat (Kosowsky 2017), which gives angular heights within a 0.5° approximation.

We obtained our measurements using a tandem instrument Suunto 360PC/360R, which incorporates a clinometer and a compass with a precision of 0.5°, and also by analysing the surroundings (landscape) of each of the buildings. We then corrected the azimuth data according to the local magnetic declination (Natural Resources Canada 2015), getting values always close to 5°08' W for different sites of the city. Our data is the result of several on-site measurements with a single instrument, taking the axes of the churches, from the back of the buildings towards the altars, as our main guide. In some cases, although not in all, as many churches are surrounded by modern buildings, we could verify that the lateral walls were parallel to their axes. By performing a simple error propagation, we estimate the error of our measurements to be around $\pm 3/4^\circ$ for the resulting declination. However, given the nature of the measurements, some of them done in the middle of the town and thus taken while surrounded by asphalt, metal and wires, we prefer to be more conservative and take our estimated error to be $\pm 1^\circ$ (upper bound). We consider our data is suitable for a statistical study of the monuments' orientations.

In Figure 5, we show the orientation diagram for the churches and chapels. The diagonal lines on the graph indicate, in the eastern quadrant, the extreme values of the corresponding azimuth for the Sun (azimuths of 62.7° and 116.6° – continuous lines – which are equivalent to the northern hemisphere summer and winter solstices, respectively) and for the Moon (azimuths of 56.6° and 123.6° – dotted lines – which are equivalent to the position of the major lunistics or lunar standstills).

TABLE 1. Orientations for the churches and chapels of the city of La Laguna. For each we show: the identification (name and most likely date of construction of the building itself); the geographical latitude and longitude (L and I); the astronomical azimuth (a) taken along the axis of the building towards the altar or – for some of them – towards the narthex (rounded to 0.5° approximation); the angular height of the horizon (h) in that direction (including the correction due to atmospheric refraction, and also rounded to 0.5° approximation); and the corresponding resultant declination (δ). Angular heights of the horizon for directions towards the narthex of the buildings were obtained from numerical terrain models. The final column for the declination shows a combination of both δ (altar) and δ (narthex) in order to emphasise its absolute value, as explained in the text. Finally, the Orientation column is computed by estimating the dates (taking into account the year of the construction of each church) when the final declination of the Sun is the one indicated.

NAME (DATE)	L (°) North	I (°) West	a (°) (altar)	h (°) (altar)	δ (°) (altar)	a (°) (narthex)	h (°) (narthex)	δ (°) (narthex)	δ (°) (final)	Patron saint date / Orientation
Cruz de los Herreros (19th cent.)	28.4929	16.3155	3	2	63.5				63.5	3rd May / ----
Cruz de Rodríguez Moure (18th cent.)	28.4912	16.3181	17	4	60.5				60.5	3rd May / ----
Sto. Domingo de Guzmán (1602)	28.4860	16.3134	88.5	4.5	3.5	268.5	1.5	-1	-1	8th Aug / 18th Mar–25th Sep
San Miguel (1506)	28.4875	16.3131	89	11.5	6.5	269	1	-0.5	-0.5	29th Sep / 9th Mar–15th Sep
Ntra. Sra. de Gracia (1540)	28.4751	16.3057	104	-1	-13	284	4.5	14	14	1st Sunday Aug / 18th Apr–5th Aug
San Roque (18th cent.)	28.4869	16.3102	104	-0.5	-13	284	2	13	13	16th Aug / 24th Apr–18th Aug
Ntra. Sra. de los Remedios (1515)	28.4891	16.3166	109	3.5	-15	289	2.5	17.5	17.5	8th Sep / 1st May–25th Jul
Ntra. Sra. de los Dolores (18th cent.)	28.4901	16.3168	110	4.5	-15	290	6	20	20	15th Sep / 20th May–23rd Jul
Convento Sta. Clara de Asís y San Juan Bautista (1577)	28.4896	16.3139	113	10.5	-14.5	293	4	22	22	11th Aug / 21st May–2nd Jul

NAME (DATE)	L (°) North	I (°) West	a (°) (altar)	h (°) (altar)	δ (°) (altar)	a (°) (narthex)	h (°) (narthex)	δ (°) (narthex)	δ (°) (final)	Patron saint date / Orientation
San Agustín (1506)	28.4906	16.3176	114.5	3	-19.5	294.5	4.5	23.5	23.5	28 Aug / 12 Jun
Ntra. Sra. de la Concepción (1515)	28.4903	16.3205	115.5	1	-22	295.5	4	24	24	8th Dec / 12th Jun
Conv Sta. Catalina de Siena (1606), dedic. Virgen del Rosario	28.4877	16.3138	190	-0.5	-61	10	3.5	63	63	7th Oct / ----
San Cristóbal (1552)	28.4838	16.3139	251	3.5	-15	71	0.5	16.5	16.5	25th Jul / 26th Apr–28th Jul
El Cristo (San Francisco) (1580)	28.4934	16.3124	273	2.5	3.5	93	8.5	1.5	1.5	14th Sep / 14th Mar–9th Sep
San Benito Abad (1554)	28.4902	16.3261	278.5	3	9			9	9	11th Jul / 3rd Apr–21st Aug
San Juan Bautista (1582)	28.4851	16.3190	286	2.5	15			15	15	24th Jun / 21st Apr–2nd Aug
Cruz de los Plateros (18th cent.)	28.4872	16.3177	288	2	16.5			16.5	16.5	3rd May / 6th May–7th Aug
Santísima Trinidad (casa Peraza y Ayala) (1769)	28.4872	16.3159	291	2.5	19.5			19.5	19.5	Mobile / 17th May–25th Jul
Cruz de San Francisco o Cruz de los Álamos (19th cent.)	28.4928	16.3141	292	4.5	21			21	21	3rd May / 25th May–18th Jul
San Diego del Monte (1672)	28.5008	16.3279	316	12	45.5			45.5	45.5	13th Nov / ----
Cruz Verde (1761)	28.4857	16.3146	338	3.5	57			57	57	3rd May / ----

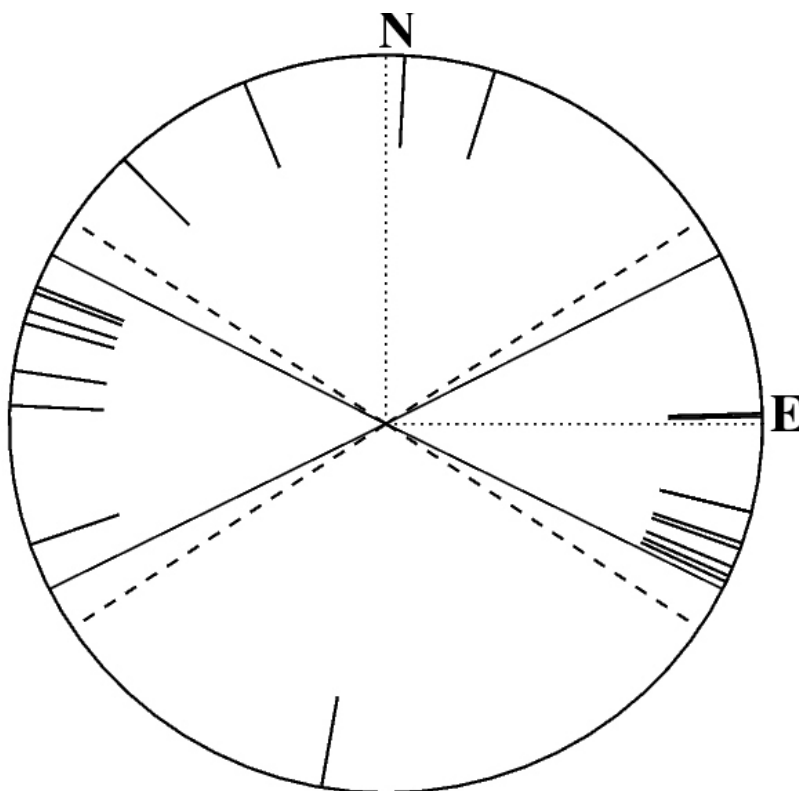


FIGURE 5. Orientation diagram of the churches and chapels of San Cristóbal de La Laguna, obtained from the data of azimuths in Table 1, considering the direction towards the altar. The majority of the monuments follow the canonical orientation pattern in the solar range, while a few small private chapels concentrate in the northern quadrant and the one of the convent of Santa Catalina de Siena points within 10° from the south (although its door opens up in the eastward direction).

If we consider the direction, going from the front towards the apse of the churches, of the 21 buildings we measured, seven are oriented in the western quadrant, while nine point towards the eastern quadrant (all of them within the solar range). There are also four which are oriented in the northern quadrant (between 315° and 45°) and only one in the southern quadrant, as shown in Figure 5. Apart from the few small private chapels that are roughly oriented to the north, in general the vast majority of the constructions are oriented within the solar range.

While there might be different underlying causal factors for this orientation pattern, the idea that the churches may be astronomically oriented is suggestive. Regarding the solar range, there are a few peculiarities. On the one hand, two of the oldest churches (Santo Domingo and San Miguel) are, to a high degree, oriented towards the equinox. On the other hand, we find two important buildings apparently oriented close to the northern hemisphere winter solstice rising Sun, namely the churches of San Agustín and of Nuestra Señora de La Concepción. However, such an orientation was a very rare objective in the Iberian Christian world (González-García and Belmonte 2015), and it is

more likely that the orientation is actually towards the setting Sun during the opposite (summer) solstice. This would be a reasonable (namely, political and social) solution for the Church to indulge the original population that inhabited these lands and the first colonists coming to Tenerife from nearby Gran Canaria, for whom the summer solstice, contemporary to the time of harvest, was a much more relevant temporal milestone (Belmonte 2015, 1121).

To better understand what we have discussed so far, in Figure 6 we present a declination histogram, corresponding to measurements taken towards the altars, which is independent of geographical location and local topography. This figure shows the astronomical declination versus the normalised relative frequency (to be defined below), which enables a clear and more accurate determination of the structure of the peaks.

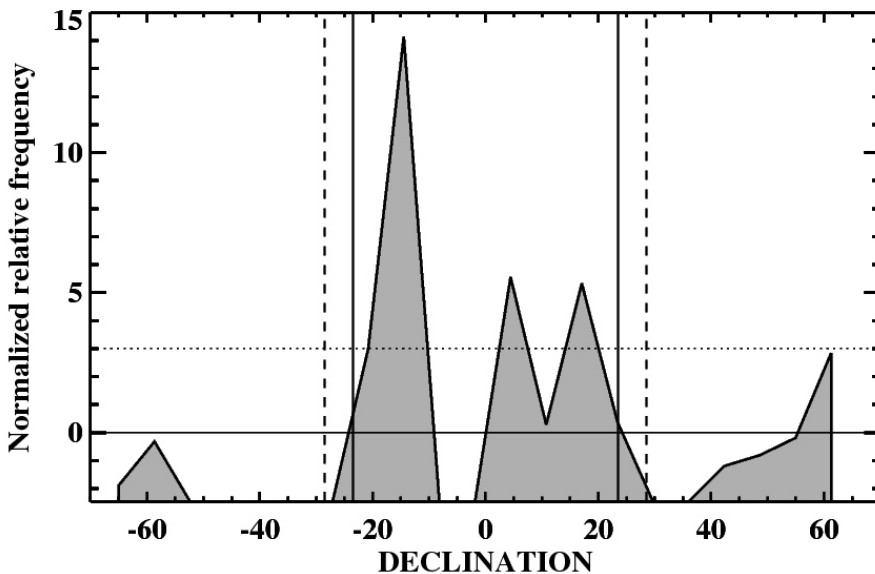


FIGURE 6. Declination histogram (or curvigram), corresponding to the measurements taken along the axes of the churches towards the altars, showing the estimated “normalised relative frequency” as detailed in the main text. There are three peaks above the 3σ level (dotted horizontal line), with the middle one related to the near-equinoctial direction of some of the buildings. The other two main peaks, although different in height, are symmetrical and worth further exploration (see the main text). The continuous vertical lines represent the declinations corresponding to the extreme positions of the Sun at the solstices, while the dashed vertical lines represent the same for the Moon in major lunar standstills. In addition to the main peaks, we see two other minor peaks. Both are found close to declination $\pm 60^\circ$ and might be associated with accumulation peaks due to orientations near the meridian line.

In our analysis, we are using an appropriate smoothing of the declination histogram by a function called “kernel” to generate the kernel density estimate (KDE). For each entry in declination in Table 1, we multiply the value of the number of occurrences by the kernel function with a given passband or bandwidth (González-García and Belmonte 2014, 100). We have employed an Epanechnikov kernel with a width of twice our estimated error in declination.

Following González-García and Sprajc (2016, 192), to ensure that a concentration of values for the declination is significant we compared the distribution of our measured data against the result expected from a uniform distribution, where the orientations are homogeneously distributed to each possible point in the horizon (the null hypothesis). This comparison will quantify the significance of our results.

Hence, we employ the quantity $(f(\text{obs})-f(\text{unif}))/\sigma(\text{unif})$ for our comparison of declinations, where $f(\text{obs})$ is the frequency of the observed event, $f(\text{unif})$ is the frequency of the uniform event (namely, the frequency of the declinations arising from a sample with uniformly distributed orientations), and $\sigma(\text{unif})$ is the standard deviation of the uniform distribution. Using this “normalised relative frequency” is equivalent to comparing our data with the results of a uniform distribution of the same size as our data sample, and with a mean value equal to the mean of our data (González-García and Sprajc 2016, 195).

Obtaining a KDE-smoothed histogram (a curvigram) scaled with respect to the uniform distribution allows us to see whether our actual data departs significantly from that distribution. The scale is given by the standard deviation of such uniform distribution: for example, if our data has a maximum that reaches the value 3, this means that it is three times larger than the standard deviation and is expressed as 3σ . We take this as the standard criterion to indicate whether our obtained values in declination are significant or not.

In Figure 6, there appear three statistically significant peaks (above the 3σ horizontal line), the middle one of which is located very close to declination zero and probably associated with the equinoctial directions of some of the churches that have been previously mentioned.

However, the other two main peaks of the declination histogram are located at roughly symmetrical positions with respect to the zero-declination equinoctial point, which suggests that these peaks might be related somehow. From the figure, we clearly see they do not respond to solstitial orientations, so we ought to look for a different explanation. For example, can we be sure the builders of these churches always oriented their constructions in the direction of the rising Sun? What would we find if, due to the orography of the site or for other reasons, they allowed orientations towards *both* the rising Sun and the setting Sun?

To check the plausibility of this last hypothesis, we included some measurements of the buildings’ axes in the opposite direction to the canonical one, namely towards the narthex of the churches. We show this in the second set of data presented in the seventh to ninth columns of Table 1 (a, h, δ), of which the “h” data was computed from the digital elevation model based on the SRTM available through HeyWhatsThat (Kosowsky 2017). As we have indicated, although in these kinds of studies, in general, the measurements towards the altar are privileged, the orography of the city and the declination histogram of Figure 6 prompted us test the opposite direction for a few constructions.

In Figure 7, we have constructed a new declination histogram, which allows the possibility of both the rising and setting Sun as orientation targets. The figure shows the astronomical declination (now in absolute value) versus the normalised relative frequency and allows us to see a new structure for the histogram: there appears one

outstanding peak dominating the chart which, although hard to identify with a single preferred date due to the spread in the data as reflected in the width of the curve, might be associated with a date close to the feast day of San Cristóbal de Licia – as noted above, the saint to whom La Laguna was originally dedicated.

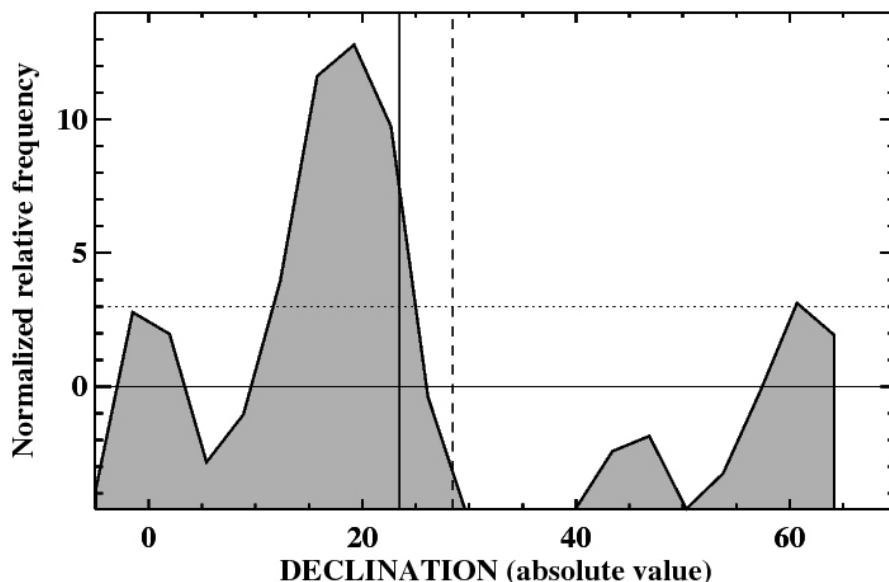


FIGURE 7. Absolute value declination histogram for the chapels and churches of La Laguna. Only one prominent peak slightly below c. 20° is found above the 3 σ level (dotted horizontal line) and may be associated with the Catholic Church feast day of San Cristóbal on 25th July (or 10th July, both dates being relevant), closely corresponding to the Sun's declination on that day at the time of the founding of the city. As before, the continuous (dashed) vertical line represents the absolute value declination corresponding to the extreme position of the Sun (Moon) at the solstice (at major lunar standstill). In addition to the main peak, we see two barely statistically significant minor peaks. One is found around the equinox, pointing to a canonical orientation pattern, while the other – corresponding to a declination around 60° – as noted before, might be associated with an accumulation peak due to orientations near the meridian line.

The two declination histograms presented here show that those orientations close to the equinoctial direction are not preferred by our measured church data. In the same way, solstitial orientations are also largely absent in these plots. Both these results go against the orientation proposals of the previous authors we reviewed in the last section.

As a last note, one truly outstanding feature of the city we are studying is its *Latin-cross* layout, which includes indications of a crucified figure. This is apparent in the combined layout of some of La Laguna's most emblematic churches when one sees the city from above (Figure 8). A group of five of the oldest churches – still standing today – are so distributed on the land as to suggest the form of a cross, with the crucified figure's head (i.e. the inclined head of the crucified Christ) placed in the San Miguel de los Ángeles chapel (just in front of the Adelantado's Square in the Lower Town) and its feet located in the church of La Concepción, in the old part of the city.



FIGURE 8. Map of the city of San Cristóbal de La Laguna in Tenerife with the location of five notable religious constructions which display an inclined Latin-cross, generally interpreted as representing a crucified person with the head tilted towards the south. On the map, we can see the church, Nuestra Señora de La Concepción (LC), at the foot of the cross, Nuestra Señora de Los Remedios (LR), the main cathedral of the city in the middle and the San Miguel chapel (SM), located in the Adelantado's Square at the head of the crucified figure. On both sides of this head, we find El Cristo (EC, the Saint Francis church, in the north) and the San Cristóbal chapel (SC) in the south (image based on a map courtesy of Google Earth).

The relevance of this singular feature is not clear for the time being, as there are no historical sources documenting it. We therefore take it as an interesting subject for further research, which we plan to pursue in the near future, given that we do know the characteristics and coordinates of all the relevant buildings. Future work should quantify the statistical significance of the particular alignment of these five emblematic churches, as well as the actual metric of the cross and the involved angles. It is interesting to recall that years before the two recent and challenging proposals advanced by the studies of Navarro Segura and of Herráiz Sánchez, which we briefly discussed above, a majority of the inhabitants of La Laguna thought that this obvious *cross* structure was the one underlying the general plan of the city and, hence, it was another reason (or even the *main* reason) for the inclusion of the city as a World Heritage Site by UNESCO.

Discussion

This study has considered the spatial orientation of 21 historic Christian churches currently existing in the old part of San Cristóbal de La Laguna, in order to provide new insights into the city's urban planning. According to the UNESCO declaration confirming La Laguna's World Heritage Status, the city exhibits the signs of an interchange of influences between European and Hispano-Portuguese and American cultures (UNESCO World Heritage Committee 2018). This feature is apparent not only in its grid plan, but also in its churches, chapels and cloisters and in the civil architecture, which are closely

related to Spanish examples in the Americas. La Laguna was the first unfortified Spanish colonial town with a regular plan, and it is thought that its layout provided the model for many colonial towns in the Americas. Designed virtually single-handedly by the Adelantado, Don Alonso Fernández de Lugo, with the favour and support of the Catholic Monarchs, it is outstanding in its planning as a city, supposedly built as a complete and self-contained project and as a space for the organisation of a new social order (UNESCO World Heritage Committee 2018). However, as we have also described in this paper, current popular beliefs suggest that the layout of La Laguna may have been designed according to utopian assumptions for an ideal town inspired by Greek philosophical principles.

In our approach to the problem, we took a more pragmatic path towards the study of the actual layout of the city, by analysing the exact orientation of its old churches and chapels. We were able to determine that a definite orientation pattern might have been followed, and this suggests that the reasons for the actual layout of the city might be simpler than imagined by previous authors. The measured archaeoastronomical data as presented, for example, in the declination histogram of Figure 7, shows a representative pattern which, within certain limits imposed by the limited sample of measured constructions and the resulting width of the main peak, suggests there exists some privileged date which is close to the feast day of San Cristóbal de Licia.

We can also see that the prominent, albeit broad, peak of Figure 7 is located around the same declination as that characterising the orientation of the principal church, Nuestra Señora de Los Remedios (declination 17.5°), if one accepts that the main alignment of this construction was directed towards the setting Sun. As this church became the main cathedral of the city, located close to the joining line of the upper and lower *villas*, its actual orientation could have served as a model for the other churches constructed afterwards. However, in the absence of documentary sources, this hypothesis is difficult to test.

Apart from this, we also found a couple of emblematic churches oriented in the canonical way, namely towards the equinoxes, and another small group aligned with the summer solstice, a characteristic time-mark of the island's aboriginal population before the conquest. However, neither of these two orientations is dominant in the measured sample. This suggests that, given our hypothesis that churches' orientations indicate the original city grid, solstitial or equinoctial directions were not the main target of the builders of the city, contrary to what has been proposed in previous investigations of this subject.

To conclude, and based on the foregoing discussion, we think that the city planning as revealed by the spatial layout of the studied religious buildings could be better understood from simple, well-tested, principles, such as those employed in this paper, which are ubiquitous in archaeoastronomical research. These include canonical examples of monument orientations, the by-product of Christianisation, and a marked preference for aligning religious buildings according to the old town patron saint date. Our findings, at least momentarily, put aside the need for additional hard-to-verify philosophical hypotheses that aim to explain the layout of San Cristóbal de La Laguna.

References

- Alemán de Armas, A., 1986. *Guía de La Laguna*. La Laguna, Spain: Librería El Águila.
- Aznar Vallejo, E., 2008. "La época fundacional y su influjo en el patrimonio histórico de San Cristóbal de La Laguna". *Anuario de Estudios Atlánticos* 54 (1): 169–205.
- Belmonte, J. A., 2015. "Pre-Hispanic Sanctuaries in the Canary Islands". In *The Handbook of Archaeoastronomy and Ethnoastronomy*, edited by C. L. N. Ruggles, 1115–1124. New York: Springer. https://doi.org/10.1007/978-1-4614-6141-8_106
- Belmonte J. A., A. Tejera, M. A. Perera and R. Marrero, 2007. "On the Orientation of Pre-Islamic Temples of North-West Africa: A Reappraisal. New Data in Africa Proconsularis". *Mediterranean Archaeology and Archaeometry* 6 (3): 77–85.
- Corbella Gualupe, D., 2000. "La arquitectura de las ermitas del siglo XVI, en el municipio de La Laguna". In *III Coloquio de Historia Canario-Americana. VIII Congreso Internacional de Historia de América*, edited by F. Morales Padrón, 2833–2846. Gran Canaria, Spain: Cabildo de Gran Canaria.
- Esteban C., J. A. Belmonte, M. A. Perera Betancort, R. Marrero and J. J. Jiménez González, 2001. "Orientations of Pre-Islamic Temples of North-West Africa". *Archaeoastronomy* 26: S65–S84.
- Fraga González, M. C., 1977. *La arquitectura mudéjar en Canarias*. Santa Cruz de Tenerife, Spain: Aula de Cultura de Tenerife.
- Gangui, A., A. C. González-García, M. A. Perera Betancort and J. A. Belmonte, 2014. "La orientación como una seña de identidad cultural: las iglesias históricas de Lanzarote". *Tabona: Revista de Prehistoria y Arqueología* 20: 105–128.
- Gangui, A., A. C. González-García, M. A. Perera Betancort and J. A. Belmonte, 2016. "On the Orientation of the Historic Churches of Lanzarote: When Human Necessity Dominates over Canonical Prescriptions". In *The Materiality of the Sky: Proceedings of the 22nd Annual SEAC Conference 2014, Malta*, edited F. Silva, K. Malville, T. Lomsdalen and F. Ventura, 125–134. Lampeter: Sophia Centre Press.
- González-García, A. C., 2015. "A Voyage of Christian Medieval Astronomy: Symbolic, Ritual and Political Orientation of Churches". In *Stars and Stones: Voyages in Archaeoastronomy and Cultural Astronomy. Proceedings of the SEAC 2011 Conference*, edited by F. Pimenta, N. Ribeiro, F. Silva, N. Champion and A. Joaquinito. British Archaeology Reports, International Series 2720: 268–275. Oxford: Archaeopress.
- González-García, A. C. and J. A. Belmonte, 2014. "Sacred Architecture Orientation across the Mediterranean: A Comparative Statistical Analysis". *Mediterranean Archaeology and Archaeometry* 14 (2): 95–113.
- González-García, A. C. and J. A. Belmonte, 2015. "The Orientation of Pre-Romanesque Churches in the Iberian Peninsula". *Nexus Network Journal* 17 (2): 353–377. <https://doi.org/10.1007/s00004-014-0231-7>
- González-García, A. C. and I. Sprajc, 2016. "Astronomical Significance of Architectural Orientations in the Maya Lowlands: A Statistical Approach". *Journal of Archaeological Science: Reports* 9: 191–202. <https://doi.org/10.1016/j.jasrep.2016.07.020>
- Herráiz Sánchez, F., 2007. *La Laguna oculta. El cielo y la piedra*. Santa Cruz de Tenerife, Spain: Ediciones Idea.
- Kosowsky, M., 2017. *HeyWhatsThat* [online]. Accessed January 2017, <http://www.heywhatsthat.com/>
- McCluskey, S. C., 2015. "Orientation of Christian Churches". In *Handbook of Archaeoastronomy and Ethnoastronomy*, edited by C. L. N. Ruggles, 1703–1710. New York: Springer. https://doi.org/10.1007/978-1-4614-6141-8_173
- Municipalité de San Cristóbal de La Laguna, 1998. *Ensemble historique de San Cristóbal de La Laguna. Proposition d'inscription comme bien culturel dans la liste du patrimoine mondial*, vol. 1 [online]. Accessed July 2017, <http://whc.unesco.org/uploads/nominations/929.pdf>
- Natural Resources Canada, 2015. *Magnetic Declination Calculator* [online]. Accessed January 2017, <http://geomag.nrcan.gc.ca/calc/mdcal-en.php>
- Navarro Segura, M. I., 1999. *La Laguna 1500: la ciudad-república. Una utopía insular según "Las leyes" de Platón*. San Cristóbal de La Laguna, Spain: Ayuntamiento de San Cristóbal de La Laguna.
- Navarro Segura, M. I., 2006. "Las fundaciones de ciudades y el pensamiento urbanístico hispano en la era del Descubrimiento". *Scripta Nova. Revista electrónica de geografía y ciencias sociales* 10 (218): Art. 43. [online] Accessed December 2017, <http://www.ub.edu/geocrit/sn/sn-218-43.htm>

- Schaefer, B.E., 1993. "Astronomy and the Limits of Vision". *Vistas in Astronomy* 36 (4): 311–361. [https://doi.org/10.1016/0083-6656\(93\)90113-X](https://doi.org/10.1016/0083-6656(93)90113-X)
- Tejera, A., 1991. *La prehistoria de Canarias. Tenerife y los guanches*. La Laguna, Spain: Centro de la Cultura Popular Canaria.
- Torriani, L., 1978. *Descripción de las Islas Canarias*. Santa Cruz de Tenerife, Spain: Goya Ediciones.
- UNESCO World Heritage Committee, 2018. "San Cristóbal de La Laguna" [online]. Accessed 22 March 2018, <http://whc.unesco.org/en/list/929>
- Vitruvius, 1931. *On Architecture*, vol. 1: *Books 1–5*, trans. F. Granger. Loeb Classical Library 251. Cambridge, Massachusetts: Harvard University Press.