

Approaching Skyscape Archaeology: A Note on Method and Fieldwork for the Case Study of Pompeii

The urban layout of Pompeii presents several orientations, possibly due to an uneven bare ground plateau. However, its main east-west axes have the same orientation of Herculaneum ones, suggesting that not only geomorphological constraints can explain the urban plan. Starting from a hypothesis by Nissen (1906), the method of skyscape archaeology was applied to Pompeii urban grid and temples, testing digital models with fieldwork measurements. The results show that the main east-west axes aligned with the rising summer solstice sun above the local horizon. Furthermore, the Doric Temple was orientated with the sunset on the same day of the year, suggesting an intentional design in the foundation ritual.

1. Introduction: Aims and Rationale of Skyscape Archaeology

The discipline of archaeoastronomy is more than one century old. This field of study is part of a wider etiquette called cultural astronomy, the study of the relationships between cultures and the sky. Though, due to its hybrid nature, for a long time archaeoastronomy could not find its proper place within academia, at least in Europe.¹ In the past, archaeoastronomers, often professional astronomers, archaeologists, anthropologists or architects, have been debating between two extreme methodological tendencies in order to prove celestial alignments: one side rigorous statistics was applied on a large number of similar sites as possible, on the other side the evidence was drawn upon records from anthropological history and archaeology.² This led to the so-called “green” and “brown” archaeoastronomy as reflected in the colour of two monographic volumes.³ Certainly, a midway method between the two approaches became evident. In the last decade, with the work by Liz Henty and Fabio Silva, archaeoastronomy was referred to as skyscape archaeology, in the attempt to fully affirm its identity within the discipline of archaeology, by starting from the material records towards a historically contextualised inter-

1 Campion 2015.

2 Ruggles 2011.

3 Ruggles 2011, 2.

pretation, and to be placed alongside landscape and maritime archaeology.⁴ The aim of archaeoastronomy, or skyscape archaeology, is to contextualise an archaeological site within the wider cosmos by reconstructing the ancient celestial vault and, possibly, its cultural value. Any potentially significant directions in archaeological structures, for instance the main axis, is geometrically extended and projected on the celestial sphere just above the profile of the local horizon: at that sightline horizon astronomy questions which celestial events might have been seen looking in that given direction as defined by the archaeological structure. Astronomical orientations are not just ones that reflect cardinal directions, as it often has been taken for granted.⁵ Important celestial orientations are many on the horizon: they can range from solstitial alignments, following the rising and setting positions of the sun across the year, lunar standstills which are similar to solar solstices but have a longer period of 18.6 years, significant rising and setting of brightest stars and planets, and to Milky Way alignments.⁶ Celestial bodies are the world time keepers, as well as the main tool for human groups to navigate within a wider landscape: in ancient times the sky was a fundamental point of reference for ordering time and space. More than practical uses, the celestial dome was also a realm of divinities and of the sacred. For instance, in many cases solar light was manipulated within the darkness of sacred architectures: precisely orientated structures channelled sunlight to illuminate statues or paintings at a specific time of the year with predictable hierophanies.⁷ In conclusion, by analysing monuments orientations the research aim is to find evidence of intentionality in order to establish if human groups built their architectonic environment in accordance to specific celestial patterns. This complex issue of intentionality will be dealt with further on in this paper. The aim of this contribution is to provide a brief methodological note on the application of skyscape archaeology techniques to an ancient site by presenting a recent analysis in regard to the urban grid of Pompeii and its temples.⁸

2. The Site: Pompeii and its Urban Layout

Any skyscape archaeological investigation should start from an understanding of the cultural and environmental features specific to the site, since the choice of observational points constrains the identification of alignments and interpretations.

4 Henty 2014, 13; Silva 2015.

5 Sommella 1988, 231; De Caro 1992, 81, n. 69.

6 Ruggles 2014a, 463-470; Connolly 2016, 13-15.

7 Ruggles 2014b, 380-381; Incerti 2001.

8 This preliminary note is related to the beginning of a doctoral project on the orientation of temples and urban grids in ancient Campania, from the 8th to the 3rd century BC. The project is carried out at Capys Laboratory at Università degli Studi della Campania *Luigi Vanvitelli* under the coordination of Prof. Carlo Rescigno, with the collaboration of Dr. Frank Prendergast and Dr. Georg Zotti.

Establishing which directions might have been considered potentially meaningful is the preliminary step of this approach.⁹ In regard to a temple, the main axis in either direction is usually taken as the most important line,¹⁰ but the diverging orientation of associated altars can be meaningful as well. For an urban orthogonal settlement, directions of main streets should additionally be considered, if no hints are given otherwise.¹¹ In the case of Pompeii, the urban plan presents several orientations, often not orthogonal to each other (fig. 1), and it is not clear if any diachronic orientation reassessments happened.¹² Indeed, detailed knowledge of the development of the city from its Archaic foundation at the end of the 7th century or beginning of the 6th century BC until the Hellenistic restructuring is doubtful and still in debate.¹³ One of the reasons is that the Archaic findings and structures remains too scattered to get a full understanding of the Archaic urban grid.¹⁴ The differences in height above sea level of the plateau, with *Via Stabiana* following the contours of a natural canyon, should be considered as a constraint causing the

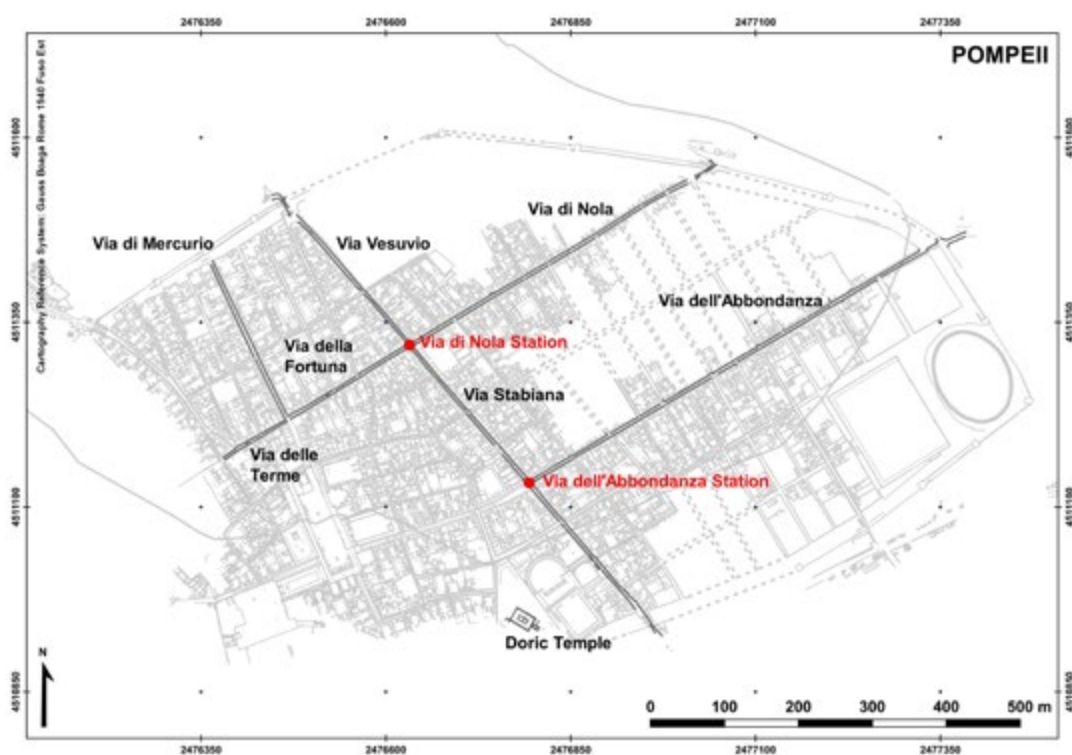


Figure 1. Pompeii's plan with the urban references mentioned in the text (adapted from Morichi et al. 2018 by Michele Silani).

9 Ruggles 2014b, 376.

10 Boutsikas 2007–2008; Pernigotti 2019.

11 González-García et al. 2019.

12 Bonghi Jovino 2011, 10.

13 Bonghi Jovino 2011; Giglio 2016.

14 Avagliano 2018.

layout to diverge from a geometrical form, if ever one was intended.¹⁵ Thus, scholars have explained orientation as defined by geomorphological causes;¹⁶ however, the independence of Pompeii east-west axes in respect to altimetric conditions is confirmed by its comparison with Herculaneum, whose *decumani*, or east-west axes, have the same azimuths as in Pompeii i.e. c. 60°/240°.

In questioning the diachronic layout of Pompeii, it may be useful to test astronomical hypotheses of orientation. In the Sarno Valley, a strong Etruscan characterisation of the social indigenous communities preceded the foundation of Pompeii,¹⁷ and the *Etrusca Disciplina* of setting boundaries was based on the observation of the sky, at least as far as the Latin legacy can testify.¹⁸ At the beginning of the 20th century, Heinrich Nissen proposed that *Via di Nola* pointed towards the rising sun at summer solstice, but mentioning an error evident by the fact that the south side

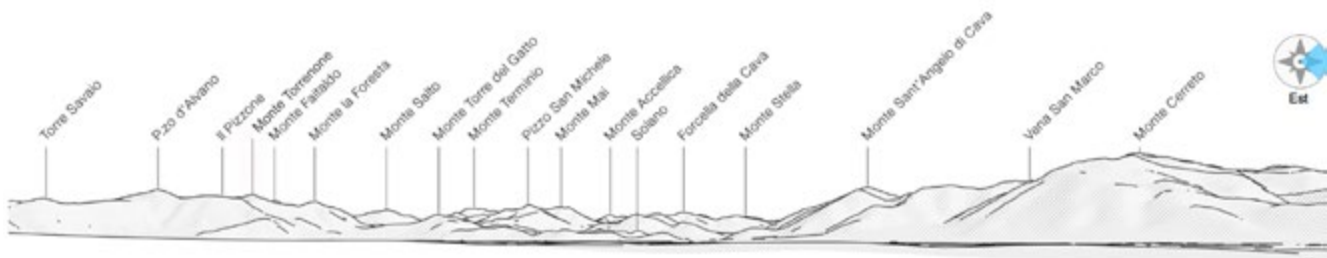


Figure 2. Horizon profile as seen from Pompeii looking East (PeakFinder 2020).

of the street was not illuminated.¹⁹ Stefano De Caro suggested, instead, that the same road was intended to point towards Monte Torrenone (fig. 2), a triangular shape mountain on the north-eastern side and location of Sarno river springs.²⁰ In order to test these and other hypotheses, a digital landscape and skyscape model were first reconstructed; secondly, site fieldwork was undertaken in order to check the accuracy of the virtual reconstructions; third, some considerations on a possible interpretation are suggested. Due to the doubts regarding how the urban grid was planned and developed, it was necessary to progress by enabling more possibilities, testing all directions and starting from the most central routes, including *Via di Mercurio*, *Via delle Terme*, *Via della Fortuna*, *Via Marina*, *Via di Nola*, *Via dell'Abbondanza*, and so on (fig. 4).²¹ In particular, for the specific task of questioning Nissen's hypothesis, the focus is on the North-East horizon where *Via dell'Abbon-*

15 Holappa and Viitanen 2011, 182.

16 Holappa and Viitanen 2011, 182; Giglio 2016.

17 Cristofani 2009.

18 Briquel 2008, 44.

19 Nissen 1906, 105-107.

20 De Caro 1992, 82.

21 Ruggles 2014b, 376; Ruggles 2014a, 414.

danza, *Via di Nola*, and *Via delle Terme* are pointing at (fig. 3) in comparison to the position of the rising sun at summer solstice.

3. Projecting the Pompeian Streets on the Celestial Sphere: Azimuth, Altitude and Declination

The aim of this section is to analyse data from the available digital models to test Nissen's observation with more sophisticated tools. For this scope, the direction of each road should be geometrically projected on the celestial sphere,²² in a point described by two celestial coordinates, azimuth and altitude. Therefore, the first step for applying skyscape archaeology is to measure the azimuth values of the selected axial directions for structures of interest. The azimuth of a given direction is here regarded as the clockwise angle from the True North.²³ A recent geo-referenced cartography of Pompeii was used within GIS software for this task.²⁴ For each route, the geometrical line running midway between the two lateral side walls of the street was considered as the main axis of orientation of a route.²⁵ This was not always possible since streets are not fully straight,²⁶ due to the nature of the architectonic components.²⁷ The modifications in the different phases of urban development might have affected

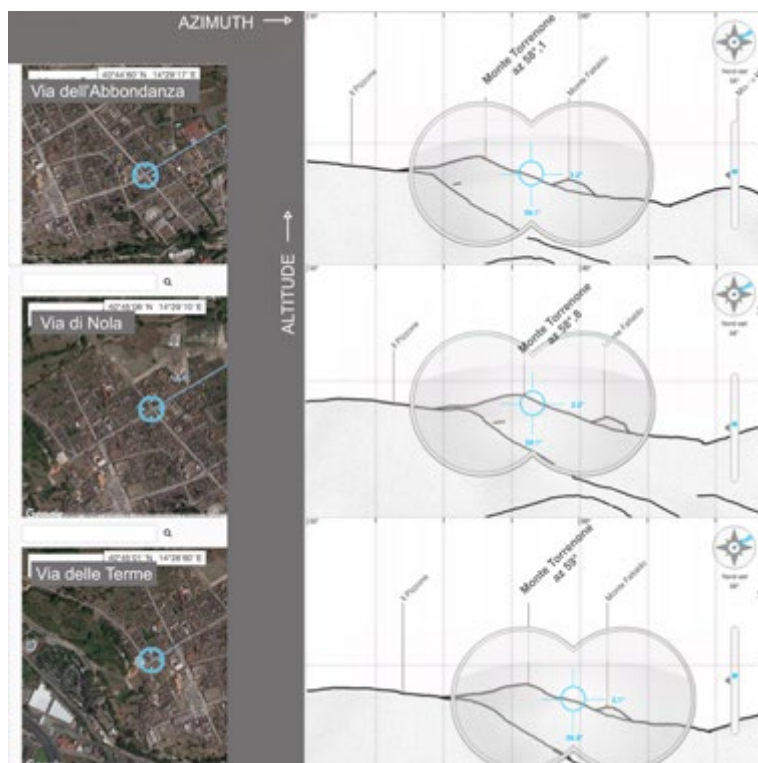


Figure 3. Orientation of Pompeian streets projected on the celestial sphere just above the local horizon. The skyline looking north-east from *Via dell'Abbondanza*, *Via di Nola*, *Via delle Terme* is characterised by *Monte Torrenone* and *Monte Faitaldo*. Note how the apparent position of the landscape, for instance the azimuth of *Monte Torrenone* peak, varies accordingly to the view point. The street azimuth values are derived from QGIS after Morichi et al. 2018. (adapted from PeakFinder 2020 by Ilaria Cristofaro).

22 Karttunen et al. 2003, 14.

23 Karttunen et al. 2003, 15; Zotti and Wolf 2020, 218.

24 Morichi et al. 2018; The meridian convergence value $\gamma = -0.34^\circ$ was determined on the medium value indicated on the regional technical cartography CTR from *Regione Campania*. Within the software QGIS, used for cartographic analysis, some plug-ins allow to directly measure azimuth values of a given direction with consideration of the meridian convergence. In alternative, azimuth values can be measured in satellite imagery within Google Earth by using the ruler tool.

25 Prendergast 2014, 391.

26 For example *Via di Nola* presents a slight curvature at its end.

27 Ruggles 2014b, 375-380.

Direction towards	Road/Archaeological structure	Azimuth (GIS)	Altitude (PeakFinder)	Latitude (Morichi et al. 2018)	Road/Archaeological structure Computed Declination (A)	Target in the LANDSCAPE	Target in the SKYSCAPE	Celestial Body Declination 600 BC (for the sun: Laskar 1985; others: Stellarium) (B)	Difference between (A) and (B)
EAST	Via di Nola (midway line)	59,10	3,3	40,751	25,212	Monte Terranone	summer solstice sunrise	23,757	1,445
	Via dell'Abbondanza (midway line from its cross-road with Via Stabiana until Porta Sarno)	59,15	3,2	40,750	25,107	Monte Terranone-Monte Falzaido	summer solstice sunrise	23,757	1,339
	Forum X Via dell'Abbondanza (midway line until via dei Teatr)	72,46	1,9	40,750	14,467	Monte Torre del Gallo	sun rising 60 days before and after summer solstice?		
	Via delle Terme (midway line from Via Consolare until Via del Foro)	59,83	3,1	40,751	24,513	Monte Terranone-Monte Falzaido	summer solstice sunrise	23,757	0,745
	Tempio della Fortuna, north wall	60,17	3	40,751	24,235	Monte Falzaido's North slope	summer solstice sunrise	23,757	0,467
	Tempio della Fortuna, south wall	59,19	3,4	40,751	25,217	Monte Terranone	summer solstice sunrise	23,757	1,449
	Via della Fortuna (midway line)	58,56	3,3	40,751	25,599	Monte Terranone's North Slope	Arcturus (star)?	27,035	-1,436
		58,56	3,3	40,751	25,599	Monte Terranone's North Slope	summer solstice sunrise	23,757	1,831
	Vicolo degli Scheletri (from Vicolo di Ecurachia until Vicolo del Lupanare)	75,04	2,4	40,750	12,899	Monte Terminio	Delphinus (constellation)?	11,900	0,969
	Via Marina (Resilica's north side wall)	66,31	2,3	40,751	17,815	Monte Saito	Minor Lunar Standstill?	18,800	-0,985
	Temple of Apollo, transversal axis	64,66	2,5	40,749	20,634	South's slope Monte la Foresta	sun rising 30 days before and after the summer solstice?		
	Temple of Isis, central axis	59,47	3,2	40,749	24,877	Monte Falzaido peak	summer solstice sunrise	23,757	1,110

Figure 4. Skyscape archaeology database with values shown in decimal degrees. All the landscape and skyscape targets of structures orientation data are kept for completeness, but it is not presumed these were intended by the builders. These are orientations but not necessarily alignments (see last section). Here, only the east direction is shown. The altitude values were measured with PeakFinder 2020 and, due to the different software programs used, there are divergences (± 0.1) in respect to altitude values in fig. 6 (elaborated by Ilaria Cristofaro).

the orientation of the Archaic structures, such as the original delimitation of the blocks used as foundations.²⁸ Therefore, the most correct methodology is to define an average orientation of the block fronts and, in the case of significant differences, to take into consideration the topographical reasons for such deviations and any archaeological data available to explain these variations. All data were recorded within an excel file (fig. 4). All azimuth values for streets were measured on GIS software using the “Azimuth Measurement” plug-in v. 0.2.2 with a precision of 0.01° , on the basis of Morichi’s vectoral cartography.²⁹

28 On this aspect of continuity of orientations and discontinuity of occupation see Coarelli 2008, 174–175 and the extensive discussion in the same volume *Nuove ricerche archeologiche nell'area vesuviana (scavi 2003–2006)*, 508 ff. However, it has been shown how the alignments underlying the planning of the urban layout of Pompeii were drawn in the 6th century BC, taken up and respected in later periods, see Giglio 2016, 29–30.

29 Morichi et al. 2018.

For each road direction, the second step is to measure the skyline altitude defined as the angular distance above the mathematical horizon, or astronomical horizon.³⁰ The local horizon profile is the visible line where ground and sky meet: indeed, mountains and hills can alter the visibility of a celestial body's rising and setting in comparison to where it would rise if the horizon had an altitude of 0°. When the horizon profile is uneven (see fig. 2), the skyline altitude varies accordingly. Altitude values were measured from digital terrain models based on Shuttle Radar Topography Mission 90m (SRTM 3") resolution datasets, and converted into a horizon profile.³¹ For such resolution datasets and for horizon distances larger than c. 10 km, as in the case of Monte Torrenone and Faitaldo which are c. 18 km faraway from Pompeii, the accuracy is c. 0.1°.³² It is important to notice that for a vast area, such as the 66 hectares plateau of Pompeii, the skyline profile is dependent on a perspective related to a precise observation point. Indeed, mountains seen from different locations appear positioned differently in respect to the azimuth grid: for example, the azimuth of Monte Torrenone peak stands at 58.8° from *Via di Nola*, but at 58.1° if seen from *Via dell'Abbondanza* (fig. 3). Therefore, for each observation point, generally by standing at the beginning of the road (fig. 3), the correct panorama was reconstructed. In summary, for each street azimuth value (az), its relative skyline altitude value (h) was measured: this results in a precise point on the celestial sphere, based on the two coordinates of the "horizontal system".³³

The third step is to convert data into astronomical declination values in order to identify possible astronomical events for a specific sightline, such as an urban road or temple axis. Declination is a celestial coordinate of the "equatorial coordinate system" not measurable on site but calculated by converting the coordinates from the horizontal system (azimuth/altitude).³⁴ Thus, having the latitude (φ) of the site, the declination (δ) is determined as followed:³⁵

$$\sin \delta = (\sin \varphi \times \sin h) + (\cos \varphi \times \cos h \times \cos az)$$

Declination is a coordinate fixed on the celestial sphere and ideal to identify celestial objects since these generally move along precise declination lines.³⁶ An overview of all possible astronomical alignments can be achieved by numerically com-

30 Karttunen *et al.* 2003, 14; Zotti and Wolf 2020, 218.

31 To convert DTM into horizon profile we used the software programs HeyWhatsThat at <https://www.heywhatsthat.com/>, PeakFinder at <https://www.peakfinder.org/>, and Horizon (© 1998–2020 Andrew Smith) available at <http://www.agksmith.net/horizon>.

32 Patat 2011. For shorter distances, resolution can be enhanced with a DTM from IGM data each 20m.

33 Karttunen *et al.* 2003, 14–15; Ruggles 2014a, 460.

34 Karttunen *et al.* 2003, 15–17; Ruggles 2014a, 460–463.

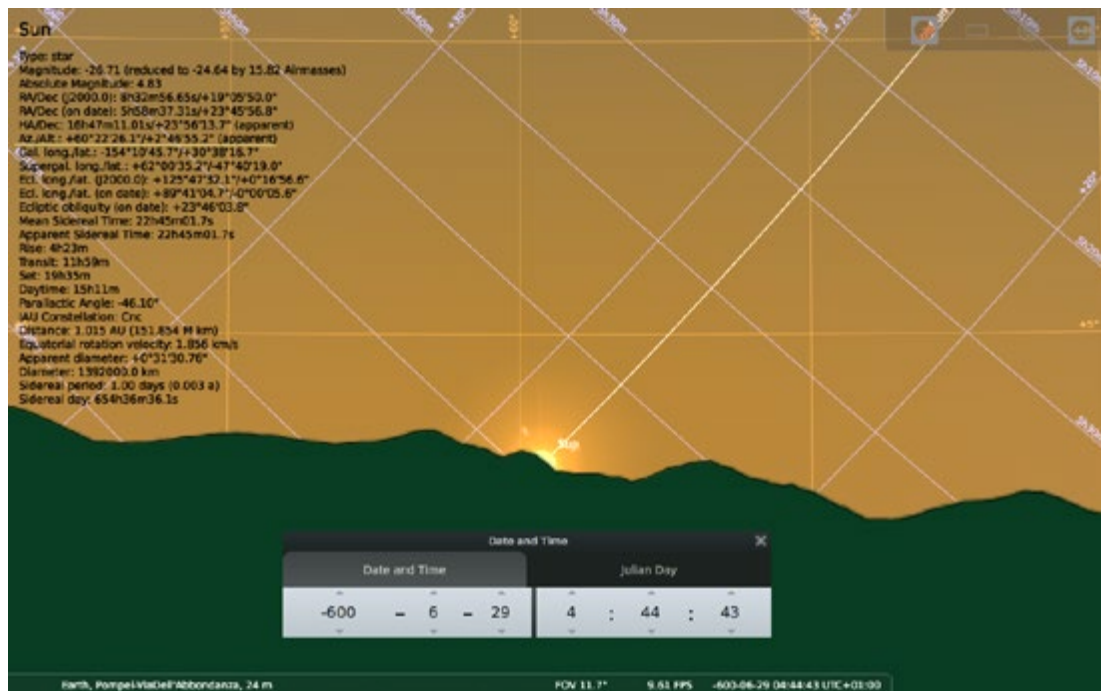
35 Ruggles 2014a, 461; a convertor is available at <https://www3.cleveruggles.com/index.php/tools/declination-calculator>.

36 Ruggles 2014a, 460.

paring the calculated declinations, resulting from projecting the Pompeian streets into the celestial sphere, with the list of main solar and lunar declinations, as well as stellar ones, in a chosen epoch.³⁷ A declination value can correspond to one or more celestial body visible at a different time or season, and all matching values should be recorded in the database for completeness purposes (fig. 4).³⁸ The difference between the street sightline declination and the celestial body declination should have a margin of error within 1°–2° maximum, depending by the structural conditions of the archaeological site.

The fourth step is to bring all previous information together and further test possible astronomical orientations with a virtual reconstruction of ancient skies with software programs, moving from a numerical to a visual comparison. For the present research, Stellarium which is an open-source planetarium software program, was used to go back in time to visualise the Pompeian sky of the 7th–6th century BC.³⁹ An artificial polygonal panorama was also added within the astronomical software to virtually recreate the local DTM horizon profile within the skyscape (fig. 5).⁴⁰ Celestial coordinates resulting from Pompeii streets sightlines were visually compared with the position of main sky events such as the sun's course at summer solstice. This can be visually plotted using "archaeolines" within Stellarium.⁴¹ One outcome from this analysis was that a number of streets and templar structures

Figure 5. Rising of the sun at summer solstice behind Monte Faitaldo in the 6th century BC as seen from "Via dell'Abbondanza Station", Pompeii. In orange the horizontal coordinate system (altitude/azimuth); in violet the equatorial coordinate system (right ascension/declination). The fieldwork computed measurements of the sun's azimuth 60°:374 (60° 22' 27") for summer solstice in 600 BC corresponds to the value of the Stellarium digital reconstruction (60° 22' 26"). Horizon profile after SRTM 3" computed with software Horizon (©Andrew Smith) and Stellarium 2020.



37 Ruggles 1999, 57; Ruggles 2014c, 475–480.

38 Ruggles 2014b, 376.

39 Available at <https://stellarium.org/>; Zotti and Wolf 2020.

40 Zotti and Wolf 2020, 66.

41 Zotti 2016.



Figure 6. Eastern horizon profiles as seen from different cross-roads at Pompeii, comparing the direction of Pompeian streets with position of the rising sun at solstices at the beginning of the 6th century BC. Created with the software Horizon (©Andrew Smith), with processed DTM data from the Shuttle Radar Topography Mission 90m (SRTM 3"). The red circles represent the sightline of the roads with an apparent diameter or error of $\pm 1^\circ$. The yellow line on the left is the course of the sun at summer solstice in 600 BC, and the right one is the winter solstice sun's path (adapted by Ilaria Cristofaro).

seemed to be directed towards the position of the rising sun at summer solstice in the Archaic period, with a variable divergence of 1° - 2° (fig. 4). In order to test the accuracy of the digital models, and to document the occurrence of the celestial event on site, the investigation progressed with the acquisition and analysis of field data as discussed in the next section.

I.C

4. Fieldwork and Data Analysis: The Position of the Sun Rising above the Mountains

On site autoptic perception and fieldwork are crucial elements in any skyscape archaeology investigation. The precision of digital models and the virtual reconstructions proposed in the previous section are here tested according to direct evi-

dence measured in the field. For this task, a fieldwork campaign for observation and measurement at the site of Pompeii for the day of summer solstice, 21st June 2020 was planned. To test the hypothesis of the orientation of the eastern sector of the urban grid with the rising summer solstice sun, two observation points were defined by dividing our working team into two groups:⁴² the first group was standing at the crossroad between *Via Stabiana* and *Via dell'Abbondanza*, named "*Via dell'Abbondanza Station*"; the second, at the intersection between *Via Stabiana* and *Via di Nola*, named "*Via di Nola Station*" (fig.1). At the first crossroad, the sun rose on the right slope of Monte Faitaldo; whereas, at the second observation point, the position of the rising sun appeared on the top peak of the same mountain. We recorded the position of rising sun in respect to the local landscape with photographic documentations (fig. 9).

In order to measure the sun position on the celestial sphere, from "*Via dell'Abbondanza Station*" a survey was carried out by using the shadow projection of a gnomon on the ground, technique used since antiquity for orientation in respect to

the sun.⁴³ For use as a gnomon, a 1.65 m long telescopic pole with a prism was fixed on the planking level and kept in a vertical position by using the in-built spherical bubble level. With a Leica TS16 Total Station, with an angular precision of 1", three points were measured: the gnomonic pole base (B) and top (C), and its shadow projection on the ground (A). Measurements were done 5 minutes after the first visible ray of the rising of the sun. The same procedure was repeated 35 minutes after the sun rising in order to have control data for comparison. In order to geo-reference the survey with the local cartographic

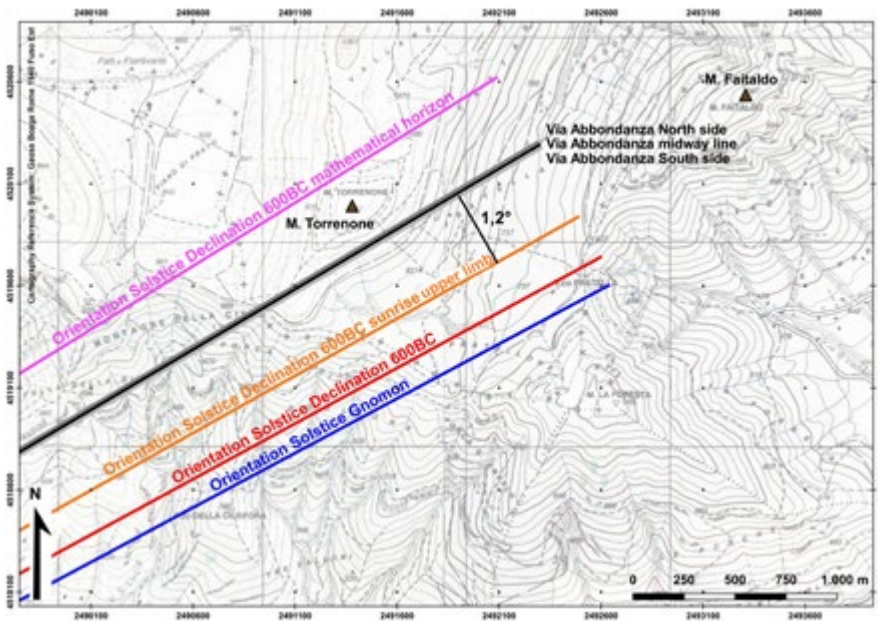


Figure 7. Orientation of the sun according to fieldwork measurements and calculations in relation to the position of Monte Torrenone and Faitaldo (c. 18 km from Pompeii). "Orientation Solstice Gnomon" (in blue) is the direction of the gnomon shadow on 21/06/2020, 5 minutes after the sun rising. "Orientation Solstice Declination 600BC" (in red) is the previous measurement with the correction for ecliptic obliquity in 600 BC. "Orientation Solstice Declination 600BC sunrise upper limb" (orange) is the orientation of the sun at the exact moment of its upper limb rising in the Archaic period and represents the final direction to be compared with *Via dell'Abbondanza* midway line (black). Finally, "Orientation Solstice Declination 600 BC mathematical horizon" (pink) is a test applying the suggestion by Hyginus to sight the sun as if above an ideal zero-horizon (elaborated by Michele Silani).

42 We would like to thank Prof. Carlo Rescigno and Prof.ssa Carmela Capaldi for assisting the observations.

43 Herodotus, *Histories* II 109.

projection system, from “Via dell’Abbondanza Station” three anchorage points from the *Parco Archeologico di Pompei* topographical grid were rigorously measured.⁴⁴ Thanks to the acquisition of these data, it was possible to determine the position of the sun 5 minutes after its local rising on 21/06/2020 and to display its orientation on the map (“orientation solstice gnomon” on fig. 7). Indeed, as mentioned in the previous section, the parameters necessary to determine the position of any points on the celestial sphere are azimuth and altitude: in this case, the sun position was calculated with the direction of the gnomon shadow (az) and the angle $B\hat{A}C$ (h). The results of the fieldwork have given an azimuth value of 61.55° in the line between the gnomon and its shadow projection and reported on the site plan with the correction given by the meridian convergence inherent to the georeferenced cartography used (“orientation solstice gnomon” on fig. 7).⁴⁵ The angle $B\hat{A}C$ gave the altitude value of 3.277° , also considering the penumbra ambiguity.⁴⁶

From these values, at the latitude of 40.75° that is precisely “Via dell’Abbondanza Station”,⁴⁷ the calculated declination of the sun is 23.43° .⁴⁸ This declination value corresponds to the expected value of the obliquity of the ecliptic ϵ for 21st June 2020, confirming the consistency of the fieldwork

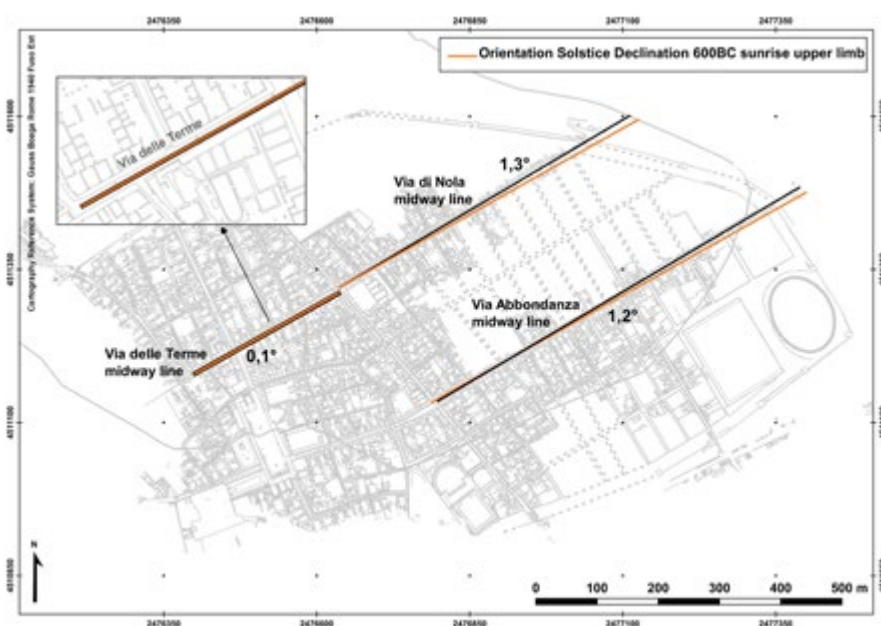


Figure 8. Comparing the orientation of street centrelines (black) with the direction of the sunrise upper limb rising on summer solstice in 600 BC (orange lines). All orange lines are created parallel to each other's starting from the one at Via dell'Abbondanza, obtained after fieldwork measurements and data analysis for the sun position. The geometrical translation is possible due to the sun infinite distance in respect to the urban dimensions, since at that precise moment the sun has the same azimuth (60.37°) for the whole plateau of Pompei (elaborated by Michele Silani).

44 Other control measurements were done on archaeological structures visible both on site and on Pompeii topographical reference basis from Morichi *et al.* 2018.

45 See note 24.

46 The fuzziness of the gnomon shadow is due to the fact that the sun is not a point source of light but has an apparent diameter of 0.5° ; therefore, we added a penumbra error of $\pm 0.25^\circ$ to the value of the altitude.

47 For the conversion of the latitude value in geographic coordinates WGS84 starting from cartographic coordinates with Gauss Boaga Fuso Est Roma 1940, the national IGM software Verto 3k was used.

48 Ruggles 2014a, 460-462.



Figure 9. Top: Rising of the sun at summer solstice from "Via dell'Abbondanza Station", Pompeii, 21st June 2020. Consider that the position of the sun in the 7th -6th cent. BC was half a degree on the left than nowadays (photo by Ilaria Cristofaro). Below: Panorama image of the rising of the sun at summer solstice from "Via di Nola Station", with Via Vesuvio on the left and Via Stabiana on the right, Pompeii, 21st June 2020 (photo by Carlo Rescigno).

on site measurements.⁴⁹ Furthermore, it was necessary to consider the exact moment when the sun was rising, since field measurements have a delay of 5 minutes in respect to it. For this reason a reassessment of the bearings was carried out, considering that the hour angle of the sun does not flow at an even rate, the sun in those 5 minutes was running 1.096° along the declination line, which is inclined in respect to the astronomical horizon to an angle corresponding to the co-latitude.⁵⁰ After having subtracting those 5 minutes, the new computed values are 60.83° for the azimuth and 2.45° for altitude for

the upper limb of the sun rising on 21/06/2020. To calculate the position of the sun at its rising in the 7th-6th century BC, the small variation in the oscillation of the obliquity of the ecliptic ϵ should be added.⁵¹ Even if the year 600 BC was used as a reference date for the urban foundation, not much variation in the ecliptic ϵ and the sun position would exist for few centuries of difference. Therefore, we substituted the sun obliquity of the ecliptic ϵ value for AD 2020 to the one for 600 BC: in particular, the solstitial declination of the sun has a difference in declination of $+0.33^\circ$.⁵² Finally, from the sun's Archaic declination value, it was possible to calculate back the value of the sun azimuth in the Archaic period,⁵³ in order to compare it with the orientation of the urban grid of Pompeii: keeping unchanged the altitude and the latitude, in 600 BC the summer solstice rising sun azimuth value of

49 Ruggles 1999, 57; Ruggles 2014a, 465; Data for ϵ are derived from Laskar (1986) using the calculator provided by PH Science Labs at http://www.neoprogrammics.com/obliquity_of_the_ecliptic/

50 Karttunen *et al.* 2003, 31-32.

51 Ruggles 2014c, 479-480.

52 Ruggles 2014c, 479-481; Data for ϵ are derived from Laskar (1986) using the calculator provided by PH Science Labs at http://www.neoprogrammics.com/obliquity_of_the_ecliptic/

53 Karttunen *et al.* 2003, 31-32.

60.37° (60° 22' 27") was obtained ("orientation solstice declination 600 BC sunrise upper limb" on fig. 7). Due to the progressive decrease of the ecliptic obliquity over two and half millennia, the sun now rises half a degree, which corresponds to the width of the sun diameter, south of its rising position in 600 BC.⁵⁴ This result is fully compatible with Stellarium data for summer solstice on 29/06/-600 at 4:44:43 from "Via dell'Abbondanza Station" and the SRTM 3" horizon profile by Horizon software (fig. 5). The wider error on the altitude 2.45° (2° 26' 46") in respect to 2° 46' 55" by Stellarium derives from the fuzziness of the penumbra ambiguity in the gnomon shadow.

This obtained result is diverging from 1.2° in respect to the mean orientation of *Via dell'Abbondanza* (figs. 7-8) and this is compatible with the accuracy expected for the determination of an astronomical orientation in antiquity. Irregularities in the urban modifications following the moment of the city foundation until AD 79 have clearly conditioned our determination of the mean orientation of *Via dell'Abbondanza*.⁵⁵ However, results show that *Via delle Terme* has the most precise orientation to the rising summer solstice sun among the roads surveyed (fig. 8); therefore, from that street autoptic observations and photographic documentation will be produced during the next solstice. Moreover, the altitude value obtained (2.45°) is referred to the center of the solar disk and compatible with the presence of Monte Faitaldo on the horizon. The mountain would have partially covered the sun, whose upper limb would have been visible, exactly at its rising. The importance of the landscape and the local skyline was already considered in antiquity, as confirmed by the writing of ancient Gromatics, or Roman agrimensores,⁵⁶ in particular Hyginus, when he questioned:

*et si kardo a monte non longe nascatur siue decumanus, quomodo potest cursus comprehendi recte, cum ferramento sol occiderit et trans montern sol adhuc luceat et eisdem ipsis adhuc campis in ulteriore parte resplendeat?*⁵⁷

*If the kardo or decumanus originates not far from the mountain, how can the course (of the sun) be sighted properly, if the sun has set on the ferramentum, but is still shining beyond the mountain and beaming down on the very same plain in the more distant area?*⁵⁸

In the case of Pompeii, the presence of Monte Torrenone and Monte Faitaldo seems to have been considered in the ancient planning of the town. As a confirmation, we tested the possibility of having a zero horizon, by sighting the solstitial sun

54 Ruggles 1999, 57.

55 Prendergast 2014, 391.

56 For recent evidence of Gromatics in Pompeii see Ferro, Magli, and Osanna 2020.

57 Hyg. *const. limit.* 12-16 Th.; see the illustration from the codexes of the Gromatics (Rome, Vat. Pal. Lat. 1564, fol. 92r), fig. 98a Th., 98 C. in Dilke 1967, pl. 4.

58 Campbell 2000, 146-147.

rising above an ideal flat horizon with no mountains according to the suggestion by Hyginus: this orientation does not conform with the urban layout (“orientation solstice declination 600 BC mathematical horizon” on fig. 7). More appropriate to the present analysis are the words of the agrimensor Frontinus, who wrote that

*multi mobilem solis ortum et occasum secuti uariarunt hanc rationem. sic uti[que] effectum est, ut decumani spectarent ex qua parte sol eo tempore, quo mensura acta est, oriebatur*⁵⁹

*many have followed the variable rising and setting of the sun and altered this principle.⁶⁰ Indeed they have arranged so that the decumani faced from the part (of the heavens) where the sun was rising at the time when the survey was carried out.*⁶¹

The definition of the visible horizon profile from a specified point is a central issue for investigations relating the relationship between astronomical and on-site orientations. For this reason, more data have been acquired, still in elaboration, for other relevant positions of Pompeii topography, corresponding to the two urban Archaic sanctuaries, the Apollo Temple and the Doric Temple, as well as at the crossroad nearby the Temple of Fortuna Augusta. Horizon profiles, together with archaeological structures survey, will be inserted within the software Stellarium in order to refine the accuracy of the reconstructions and realize new cases study, since the solutions acquired on site fieldwork just discussed resulted fully compatible with the digital models.

M.S.

5. Preliminary Considerations towards a Possible Interpretation: Orientation versus Alignment in Foundation Rituals

Different conventions exist in relation to use of the term orientation and alignment.⁶² If orientation is meant to be “the measured direction of a structure’s façade or axis with respect to the local meridian (azimuth)”, the idea of alignment implies the original intention of directing a monument façade or axis towards a determinate target beyond any coincidence.⁶³ The question of intentionality is, therefore, a central issue. Efrosyni Boutsikas and Clive Ruggles pointed out that the “fundamental methodological problem” in archaeoastronomy consists in the fact that a determinate architectonic orientation must point somewhere – in the land or

59 Frontino *de limit.* 14, 14–17 Th.

60 The principle of directing *decumani* from east to west.

61 Campbell 2000, 11.

62 Prendergast 2014, 389.

63 Prendergast 2014, 391.

skyscape (fig. 4).⁶⁴ Moreover, whereas the landscape changes only over long time periods, the sky's movement provides a wide range of astronomical possibilities for one single orientation. Thus, any claims for a particular intentional orientation, or alignment, should be supported by archaeological evidence and culturally contextualized. Bradley E. Schaefer (2006) proposed a useful manner to proceed.⁶⁵ He argued that for claiming intentionality three or more conditions should be satisfied: first, the orientation should be statistically significant (3σ or better); second, there should be archaeological evidence for the orientation intentionality; third, there should be ethnographical or anthropological evidence on the symbolic value of the alignment, which means that any archaeoastronomical orientation needs to be explained within the specific cultural context in order to give sense to a particular interpretation. As Stanisław Iwaniszewski considered, the skyscape's experience is related to particular cultural, social, technological and environmental conditions; hence, it became essential to intertwine several disciplines in order to justify the fieldwork's measurements within a contextualized interpretation.⁶⁶

According to Schaefer, to calculate the statistical significance in respect to the null hypothesis, which implies that an orientation is accidental, the probability that a single orientation within a single site corresponds within 1° (± 1) to a solar direction, cardinal or solstitial, is $1/22.5$.⁶⁷ This is due to considering that the eight main solar rising and setting positions (four cardinal and four solstitial) occupies an azimuth value $\pm 1^\circ$ for a whole circle of 360° : in total they cover 16° , or 2° each 8 directions, that is 4.4% of the whole circle of the horizon. In a gaussian statistic this probability corresponds to 2.08σ . Thus, quoting Vito Francesco Polcaro, the probability that an orientation found in "one of the eight fundamental solar directions is due to chance is significantly high", therefore its factual presence "does not prove itself that it was intended by builders".⁶⁸ In the case of Pompei, apart from the urban fabric and all the monuments oriented accordingly to it, there is another relevant archaic structure oriented towards summer solstice: the Doric Temple, situated on a promontory on the southern limit of the city (fig. 1). This has its main axis with an azimuth of 300.25° , pointing towards the city plateau, with the altitude of the local bare ground horizon of 1.7° . Its own very peculiar orientation was not affected by the topographical contexts: in particular, looking towards the cella, the temple's prolonged axis pointed within an approximation of 1° towards the position of the setting sun at summer solstice in the 7th-6th century BC (fig. 10). The same cannot be true for the reverse view, looking south-east with the back at the temple entrance. At the time of winter solstice, a mountain delays the sunrise

64 Boutsikas and Ruggles 2011, 59.

65 Schaefer 2006.

66 Iwaniszewski, 2014, 323.

67 Schaefer 2006.

68 Polcaro 2016, 2.



Figure 10. The top yellow line shows the direction of the Doric Temple's main axis with an azimuth of $300^{\circ}.25$ (towards north-west): considering the altitude of $1^{\circ}.7$, this direction points at the summer solstice sunset in the Archaic period ($\pm 1^{\circ}$). The bottom yellow line is the direction of summer solstice sunrise in line with Via delle Terme. At the cross-road between Via delle Terme and the last trait of Via Consolare, the angle of c. 120° of the two solstitial diagonals is still visible in the viability (adapted from Google Earth 2020 by Ilaria Cristofaro).

and this shifts the azimuth of the rising sun so as not to correspond with the temple's axis, therefore excluding the possibility of alignment.⁶⁹ Thus, it is possible to calculate the null hypothesis that the summer solstitial coexistence of the peculiar orientation of the Doric temple, together with the urban grid, is due to chance, assuming they are statistically independent. This corresponds to the composite probability that two orientations within a single site points at the eight fundamental solar directions is due to chance is $1/506.25$, or 0.2% . In conclusion, the probability that two orientations in a single site pointing at relevant solar directions is not coincidental is 99.8% , which corresponds to 3.5σ and is therefore statistically significant. Thus, the first test is successfully passed.

The direct archaeological evidence may give some hints to confirm the solstitial alignments. The extended axis of the Doric Temple, as well as the facing *heroon*, is diagonally crossing the middle of the Forum, to unite and align with the very last part of *Via Consolare* (fig. 10). This association was already noted by Filippo Coarelli, stating that there might have been an old track connecting the road coming

from the *Salinae Herculeae*, called *viu Sarinu*, to the Doric Temple, in a cult dedicated to Hercules in relation to the salt market.⁷⁰ From the present analysis new data can be added to this theory, since *Via delle Terme* represents the best fit to the rising midsummer sun among the streets surveyed (figs. 6 and 8). Between *via Consolare* and *Via delle Terme* the angle of 120° might reflect the intersection of the two solstitial directions at midsummer time, one sightline coming from the Doric Temple towards the sunset, the other pointing at sunrise above Monte Faitaldo-Torrenone (fig. 10). If the summer solstice played a part in the ritual temporality and spatiality of the city foundation, and if the Doric Temple preserved such a memory with its

69 For this reason we excluded the possible orientation to winter solstice sunset for the urban grid (on the opposite geometrical side of summer solstice sunrise), but further analysis is needed.

70 Coarelli 2001, 98.

orientation, the data here analysed highlight the cross-road between *Via Consolare* and *Via delle Terme* as the central point of the urban planning. Few centuries after, by the end of the 1st century BC, the Temple of Fortuna Augusta was built nearby: its orientation does not seem casual since the sanctuary appears as an intrusion on existing nearby buildings, also obstructing the viability of *Via della Fortuna*. This anomaly may find an explanation if the direction of the sun rising at summer solstice was the target of the temple axis. Indeed, according to Jacqueline Champeaux, in the Roman world at the day of summer solstice a festivity dedicated to Fortuna was celebrated.⁷¹

There are many advantages of using the sun as a point of reference in urban planning in preference to sighting a mountain, as De Caro suggested.⁷² Due to the sun's infinite distance with respect to Earth, orientation to the sun was possible in many sectors of a site, even where distant from each other, its rays always appearing parallel at multiple places (fig. 8). In comparison, sighting a nearby mountain from different distant points on a site would introduce parallax errors causing streets not to be parallel (fig. 3): in the case of Pompeii, although *Via di Nola* is oriented towards Monte Torrenone, this is not true for *Via dell'Abbondanza* or *Via delle Terme*. Furthermore, solar and topographical (mountain and relative river springs) solutions need not be mutually exclusive, if considering that the Roman festivity dedicated to Fortuna was celebrated at summer solstice at the local fluvial divinity and known as the *Tiberina descensio*.⁷³ Therefore, De Caro's hypothesis will be further scrutinised by testing the nearby urban layout of Nuceria Alfaterna, whose orientation was suggested to point at the same mountain peak.⁷⁴

How such archaeological evidence might be related to the temporality of foundation rituals will be the topic of analysis in future research. Finally, apart for calendric purposes more proper to temple rituality, other possible interpretations of such specific orientation in the urban grid include the function of guaranteeing the right solar irradiation across the year to all houses façades.⁷⁵ This intention might explain the greater error attested for the eastern part of the grid. This and other interpretations will be further explored in the future advancement of this research by comparing other urban settlements to better understand the role of the sky within foundation rituals.

I.C.

71 Champeaux 1982, 207-234.

72 De Caro 1992, 81-83.

73 Champeaux 1982, 207-224; De Caro 1992, 82-85.

74 De Caro 1992, tav. 7.

75 Vinaccia 1939, 210-215.

6. Conclusion

Skyscape archaeology explores meanings and functions attributed to celestial phenomena by human groups within the specificity of each cultural perspective. The interrelationship between the skyscape, the horizon profile and the geomorphological landscape creates a wider understanding of the site in examination. For the case study of Pompeii, a starting hypothesis by Nissen was tested by employing digital reconstruction of the land- and skyscape. The fieldwork has proven the compatibility of direct data with the digital models. The orientations of *Via dell'Abbondanza*, *Via di Nola*, and *Via delle Terme* were compared to the position of the rising sun at summer solstice in the Archaic period above Monte Torrenone and Faitaldo. The best fit result was for *Via delle Terme*, orientated towards the solstitial sun within 0.5° , in respect to *Via dell'Abbondanza* with 1.2° of error, whereas *Via di Nola* has a divergence error of 1.3° (fig. 8). The sighting of the sun above the local horizon for orientating the *decumanus* is textually attested by Frontinus, whereas Hyginus suggested a zero-horizon practice not compatible with Pompeii urban grid. In order to confirm the intentionality of such astronomical alignment, a statistical test was carried out: considering the co-existence on site of two important solar directions, one in the urban grid and the other at the Doric Temple, the probability that this is coincidental is 0.2%. Moreover, archaeological evidence in relation to the cult of Heracles at the Doric Temple and the position of *Via Consolare* proposed by Coarelli will be further scrutinised with the additional evidence of the alignment to the direction of the summer solstice sunset. The intention of assuring equal solar irradiation all year could be one explanation for the urban grid and this needs further testing. These preliminary results will be contextualised by applying the method of skyscape archaeology to other Campanian cities in order to compare data. Meanwhile other evidence is brought to light, it is possible to conclude by suggesting the hypothesis that summer solstice had temporal and spatial significance for the planning of ancient Pompeii, as inferred from the orientation of the urban grid and the Doric Temple.

I.C., M.S.

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