# Discussion

*Clive Ruggles*

At any potential World Heritage site relating to astronomy, we have to consider what are the core values and their potential OUV. This leads to a suggested statement of OUV and suggested criteria that support the statement. In most cases not all the core values with potential OUV will be astronomical.

The extended case studies chosen for this volume represent attempts to develop methodologies most likely to provide a demonstration of potential OUV in relation to astronomy. While the case study authors have attempted to define potential OUV in each case, final statements of OUV can only result from the development of nomination dossiers by national authorities, their evaluation by the advisory bodies, and the successful inscription of the property concerned on the World Heritage List (WHL).

The extended case studies chosen for this volume do not in any sense constitute a "pre-listing", despite being structured as segments of nomination dossiers. In other words, the choice of case studies does not reflect any judgement about the likelihood of success if the properties concerned were to be nominated for the WHL.

In this concluding chapter we examine some of the main themes and issues of importance relating to astronomy that are raised by the case studies.

## Relating the tangible and the intangible

From a heritage perspective it is clear that astronomy must always be considered in its social context: all astronomy is ultimately cultural astronomy. The significance of astronomical perceptions and knowledge as intangible heritage is that they reinforce or deepen broader cultural understandings. Such knowledge may well be considered "scientific" in a broad sense (see TS1: 6–7) and it can also have (what a Western commentator, at least, would consider) practical benefits, such as in navigation; however, many other types of astronomical knowledge may also have strong cultural value, for example in the realm of religious beliefs and practices, or when used for astrological prognostications.

Since all tangible astronomical heritage must relate to the intangible heritage of astronomical knowledge itself,[1] a general issue running inevitably through all of the case studies, either explicitly or implicitly, is how to assess the relative strength of the attributes of value of the tangible and intangible heritage, and which combination might best demonstrate the potential OUV of the whole. (The same issue arises for all forms of science heritage.) This, of course, concerns the potential application of criterion (vi) but it also raises the question of whether a nomination under UNESCO's Convention for the Safeguarding of Intangible Cultural Heritage, rather than under the World Heritage Convention, or a linked nomination under both conventions, might be more appropriate in particular cases.

Tangible heritage itself comprises two distinct subcategories: fixed ("immovable") and movable, of which only the first is covered directly by the World Heritage Convention. The meaninglessness, on a conceptual level, of separating astronomical heritage by category—tangible immovable, tangible movable and intangible—is an issue discussed at length in TS1.

The Paris Observatory and Royal Observatory, Cape of Good Hope, South Africa case studies strongly underline the interconnectivity of different heritage objects. They also illustrate

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[1] Space technology heritage is slightly different in this regard, since it does not necessarily relate to the business of "doing astronomy".

ways in which science heritage sites with strong associations both to movable and intangible heritage items (and more specifically, observatories and similar institutions from the 17th century onwards) could be presented in the context of a nomination dossier.

The balance of tangible and intangible values at a classical observatory site is particularly well illustrated in the case of the Cape Observatory. Architecturally, the Greek Revival Main Building is almost unique among observatories worldwide and is slightly older than the Cambridge University Observatory whose style is somewhat similar. In terms of Cape colonial architecture, only the St Andrews Presbyterian Church in Cape Town is stylistically similar. Another building with exceptional architectural appeal is the McClean or Victoria building of 1896, designed by the famous colonial architect Sir Herbert Baker. This is in the unique style developed by him, with elements of stone, oval windows, varnished wood and pebble-dashed walls. Apart from the architecture, the site is replete with many of the telescopes, instruments and paraphernalia of the working 19th century observatory. The case of the Cape Observatory illustrates the indistinct boundaries between fixed ("immovable") and movable elements—thus, fixed observatory buildings have rotating domes and can have movable floors, and telescopes have movable parts but fixed mounts—as well as the importance of portable instruments and objects. The intangible heritage of scientific achievement, resulting in particular from its location in the southern hemisphere, also contributes significantly to the value of the site.

A stronger weighting towards the intangible is evident in the case of the sun- and star clocks of Oman. Here the actual sky-watching devices are of an ad-hoc nature, often insubstantial, relatively short-lived and constantly being replaced. For example, in the Mudhaybi area, indicator stars are watched from simple markers on walls, rising or setting above or below a second horizontal marker, often on the top of the wall; in many places the natural horizon is used. On the other hand, the use of sun and star observations for timing shares of irrigation water in Oman represents an impressive example of how observations and understanding of the celestial bodies can help human communities adapt to and survive in harsh environments. The practice of night-time star observation also demonstrates a direct cultural connection between subsistence ecology and the dark night sky that may well be unique in surviving to the present day, although it is threatened with extinction. Related practices of solar observation that apply the same astronomical system of time apportionment during daylight hours continue in perhaps as many as a hundred separate communities. Together, they represent vestiges of once-widespread practices relating astronomical timing to subsistence ecology that have continued uninterrupted for hundreds, if not thousands, of years.

Space technology heritage raises further complexities. Baikonur Cosmodrome, examined by Marov in Ch. 13, is recognized worldwide as the foremost operational base for the Soviet/Russian space programme. But, as Marov points out, instruments operating in space are themselves material artefacts of great significance, as are space vehicles (TS1, pp. 234–6) and landing sites on the moon, Mars or elsewhere (TS1, p. 264). Some of the juridical and practical issues raised by this type of heritage—such as what could be considered "fixed" or "movable"—were considered in TS1 (pp. 264–5) and will not be repeated here. The fact that much of the tangible heritage exists beyond the sovereign territory of member states—e.g. on the moon or other bodies in the solar system, in earth orbit or further away in space—may not represent an insurmountable problem in the future. A recent UNESCO report (Freestone *et al.* 2016) raises parallel issues with respect to marine heritage under the high seas. As pointed out there (p. 10), an independent external audit in 2011 recommended that the World Heritage Committee should reflect on appropriate means to preserve sites that correspond to conditions of OUV but are not dependent upon the sovereignty of States. It may be that similar considerations can eventually be applied to off-planet heritage.

The heritage of space exploration is a topic whose investigation has been officially recommended by the World Heritage Committee (36th session, St. Petersburg, 2012) and there is interest from a number of partners in participating, together with ICOMOS and the IAU, in the development of a thematic study devoted entirely to this topic. The organizations concerned include the Committee on Space Research (COSPAR), NASA, the European Space Agency (ESA), and the International Astronautical Foundation (IAF).

***Integrity and authenticity issues in relation to places of science***

Change is inevitable in a functioning place of science, and tends to increase rather than decrease its value. The same is true for technology heritage, because of the necessity for continual innovation and modification. This implies very careful consideration of integrity and authenticity issues (see TS1: 10–11; 267). The requirements of authenticity (how well the attributes reflect the OUV) and integrity (the completeness or intactness of the attributes that carry OUV) dictate that there should be sufficient genuine and comprehensible evidence remaining from the most significant periods in the history of the place in an adequate state of conservation. On the other hand, observatory directors do not wish to restrict their ability to continue to undertake cutting-edge science and are rarely able to see clearly how future developments might need to impact upon the existing components of their "monument of science" such as particular buildings and instruments.

Science itself can be viewed as a "living" cultural practice, and the importance and the inevitability of change, as science moves forward, is a feature it shares in common with indigenous knowledge and practices that could be recognized either as living components of a site or cultural landscape or in themselves as valuable intangible heritage worthy of potential recognition under the Convention for the Safeguarding of Intangible Cultural Heritage (CICH) (UNESCO 2003). In this case, the intangible heritage is related to a living community and not to a place. Such knowledge and practices are never static but are subject to continual modification and change—a fact that is well known, for example, to cultural astronomers (López 2014)—and is especially true for science and modern technology. In cases where indigenous and modern scientific values both have legitimacy, there is an absolute need to find an expression of value that encompasses both aspects and ensures locally sustainable accordance before proposing international recognition.

In practice, the OUV of a World Heritage Property must be clearly understandable by everyone, and enough tangible components, of sufficient quality, must be protected in order to ensure that this continues to be the case. Individual meanings (attributes of value) must remain clearly identifiable and represented. If the OUV is defined in a series of historical steps, each of them must remain clearly identifiable and represented. In the case of a serial inscription, each historical step must be present in the series as a whole. The details in any particular case could be explored by upstream process missions.

***Recommendations***

Given that only tangible, immovable heritage can contribute directly to the OUV but that movable objects and intangible evidence can constitute important additional value, it is good practice to present the inventory of attributes in the following order: (1) tangible evidence such as immovable features of the property; (2) visual links between tangible evidence and landscape features or qualities; (3) movable evidence such as small instruments and archives; and (4) intangible evidence and understanding of the place. Intangible evidence also contributes to the section on "history and development" in a nomination dossier.

## Protecting dark skies

The discussion of dark sky values in Ch. 2 concludes that, while dark sky places cannot, in themselves, be recognized as specific types or categories of World Heritage property, either cultural or natural (cf. TS1: 266), dark sky values can certainly enhance either the natural or cultural value of a place (or both), and in this sense contribute to potential OUV. Five of the case studies relate directly or indirectly to dark skies issues, reflecting the IAU's particular concerns about such matters. They explore various ways in which dark skies and light pollution issues could be raised in nomination dossiers.

***Dark sky reserves***

The Dark Sky in itself is an important natural feature of a given place. The Aoraki-Mackenzie region in New Zealand, one of the first to be recognized by the International Dark-Sky Association (IDA) as a gold-tier International Dark Sky Reserve, provides an example where an exceptional pristine dark sky is a vital component of the beauty of the open natural landscape. The Dark Sky Reserve already overlaps with part of the existing Te Wāhipounamu (South-west New Zealand) World Heritage Site (whc.unesco.org/en/list/551), listed under criteria (vii)–(x), and extending the boundary of the latter to include the Mackenzie area, as discussed in the case study, could provide a possible path towards achieving World Heritage recognition, including the dark sky value in close relationship with other natural features of exceptional value.

The dark skies of the Eastern Alpine and Großmugl starlight areas in Austria are not in themselves exceptional on a global scale. Data on sky brightness, irradiance, and night-sky emission set out in the case study do, however, indicate that the Eastern Alpine Starlight Reserve is an area whose dark skies are amongst the darkest in Europe, while the dark skies of the Großmugl "starlight oasis" (covering about 30 × 40km) are exceptional for a location so close to a large city. In the Eastern Alpine case, a possible way forward might be to focus upon other natural values such as the primeval beech forests similar to those whose outstanding value has already been recognised in Slovakia, Ukraine and Germany (whc.unesco.org/en/list/1133), and whose connection to dark skies might be established through links such as sustainable ecosystems. However, dark sky values cannot stand alone and other natural features must be shown to be really exceptional or unique.

Of course, a pristine dark-sky area with natural values may manifest other broad cultural connections. For example, the early Māori inhabitants of the Aoraki-Mackenzie region had strong cultural connections to the sky, stemming from the Polynesian tradition of night-time navigation by the stars that first brought them to Aotearoa (New Zealand). In some cases a better approach could be to consider the contribution of a dark sky to a cultural landscape, which, being a "combined work of nature and of man", can embrace both cultural and natural features. The astronomical timing of irrigation in Oman is a good example of this, being a modern indigenous cultural landscape with cultural practices of star observation, linked to other environmental issues (in this case, water management), that are threatened by the erosion of dark skies.

Cultural landscapes may also contain archaeological sites significant from the historical, aesthetic, ethnological or anthropological points of view. The Großmugl starlight oasis contains the largest and best preserved example of the large tumuli of the region which are characteristic of the Hallstatt period in Lower Austria. However, neither this specific monument nor this class of monument as a whole have any demonstrable connection with astronomy yet identified by archaeoastronomers. The area also contains two older circular ring-ditch enclosures (Kreisgrabenanlage), dating from the Neolithic period, mostly visible only as crop markings seen from the air. Monuments of this type are found over a wide region extending into several countries, and the entrance orientations of such monuments have been claimed to have an astronomical connection. However, this remains unproven, and systematic studies suggest that the principal factors defining the entrance orientation were in fact topographic. The most striking example of a solstitially oriented entrance that might have been intentional is found at Pranhartsberg 2, an enclosure well outside the Großmugl area. Thus, even if potential OUV could be demonstrated for the Großmugl area as a cultural landscape containing important archaeological sites—either alone, as part of a serial nomination, or as an extension to an existing World Heritage property such as Hallstatt-Dachstein/Salzkammergut (whc.unesco.org/en/list/806)—the lack of an explicit material connection between the archaeological remains and the sky would be a problem if one were trying to construct a case for OUV integrating both the cultural and dark sky aspects.

Another approach would be to include the dark sky as one among a wider set of natural features that enhance the cultural value of a place: thus both a mountain landscape and an exceptional sky may contribute to the value of a modern observatory site, as is the case at Pic du Midi. It is less clear, however, whether dark skies could be the only natural attribute of potential OUV (under criterion (vii)) at an otherwise cultural site. It is also conceivable that criterion (vii) could operate in conjunction with criterion (vi), but, again, demonstrating potential OUV under criterion (vi), if based only upon astronomical cognisance, could present a considerable challenge where there are few or no tangible remains with a clear direct cultural connection to the dark night sky. These latter cases would, of course, imply a mixed inscription.

The Hortobágy National Park in Hungary offers another possible approach: here, cultural OUV has been established under criteria (iv) and (v) (whc.unesco.org/en/list/474), while the dark sky value is recognised by the IDA as an International Dark Sky Park. It is also a UNESCO–MAB Biosphere reserve.

A case based on the cultural values could still include a general argument for maintaining a prehistoric cultural landscape in its "authentic light", including preserving dark starry skies at night. Thus at Stonehenge World Heritage Property in the United Kingdom, it is considered important to try and preserve the dark-sky setting for the monuments within the WHP, as this is how they would have originally been viewed (see case study). This is despite the fact that the astronomical connections recognized by UNESCO in the 2011 retrospective statement of OUV (also see case study) are with the sunrise and sunset, so dark sky values do not directly reinforce the cultural values. Rather, the dark sky serves in a general way to enhance a visitor's broad sense of the connection between the place and the sky.

### *Modern observatory sites and their dark skies*

The world's leading optical observatories symbolize, and are responsible for many of, the extraordinary advances made by astronomy since approximately the beginning of the 20th century. This value is innately cultural: however, of necessity, these observatories occupy exceptional places on our planet where a unique combination of environmental and natural circumstances occurs, resulting in incomparable sky quality (purity, stability, high average of cloud-free days, etc.) and, in particular, pristine dark skies. Preserving these skies is part of maintaining their heritage value.

For the purposes of a World Heritage application one would need to focus both upon truly exceptional advances in human knowledge and the most outstanding places that represent and symbolize them. One approach (*A*) could be to focus primarily upon the fundamental transformations in humankind's conception of the cosmos that have been achieved at some of the most exceptional observing places on the planet. For example, at the beginning of the 20th century the Milky Way galaxy was generally believed to constitute the entire universe; at its end, humankind knew of the existence of countless millions of other galaxies; of exotic objects such as quasars, pulsars, and black holes; and of cosmic expansion and the Big Bang—concepts that are now part of our collective culture. Broadly speaking, this transformation of ideas happened between 1920 and 1970. To the list of concepts that are now part of our collective culture one could conceivably add dark matter and dark energy, thus extending the period concerned up to the end of the 20th century. Other developments in 20th-century astrophysics, though plentiful, are likely to seem too narrowly focused from a heritage perspective.

A rather different approach (*B*) would be to emphasize an ensemble of places, structures and technologies as a step in the developments that have enabled fundamental advances to be made in astronomical knowledge during the course of human history. By constructing observatories on mountain summits, astronomers could not only minimize light pollution but also benefit from exceptional atmospheric quality and stability. During most of the 20th century, high mountaintop locations in particularly favourable regions of the planet were unsurpassed for making astronomical observations in optical as well as infrared and millimetre/sub-millimetre wavelengths.[2] This era could be chronologically located as a stage in a historical progression that had started with observatories being built within cities and later being located outside cities to avoid light pollution. This implies a start date in the late 19th century. In 1993, when the Hubble space telescope became operational, such ground-based observatories were complemented for the first time by space telescopes, although these will be unable to exceed what can be achieved from the surface of the planet for many decades to come (because we can build much larger receivers on the ground, and given the success of laser technology in countering the effects of atmospheric turbulence).

Most scientists and historians of science would probably follow approach (*A*), while (*B*) is more in line with the thinking of most heritage professionals. (*B*) could lead to a clear statement of potential OUV under criterion (iv) (an ensemble of the best examples) or (i) (a single outstanding case) with possible supporting values under criteria (ii) and (vi), while approach (*A*) might emphasize pristine skies as a natural value, perhaps to be considered under criterion (vii), strongly supported by criterion (vi). A combined approach could well provide the strongest demonstration of potential OUV, bearing in mind that (as already noted) it is unclear whether dark skies would be acceptable as the only natural attribute of potential OUV among an otherwise cultural nomination. Also, criterion (vi) is normally used in conjunction with other cultural criteria, following the *Operational Guidelines*, rather than natural ones.

Methodologies for assessing science heritage developed in TS1 attempt to combine relevant aspects of both approaches and these are further developed here in the case studies of the AURA Observatory (Chile), Canarian Observatories (Spain) and Mauna Kea Observatory, Hawai‘i (USA), as well as the Pic du Midi de Bigorre Observatory (France). In particular, Chapter 2 develops the "Windows to the Universe" concept in the context of the World Heritage Convention.

Many modern observatory sites, including the AURA Observatory, ORM La Palma (Canaries) and Mauna Kea, are emblematic of international technological cooperation on a grand scale from the 1960s onwards, which enables a wide range of technological developments at the cutting edge. This suggests the possibility of demonstrating attributes of potential OUV under criterion (ii).

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2 This ignores Antarctica, parts of which also has exceptional atmospheric conditions, and where the South Pole Observatory was founded in 1957. While there does exist an international convention relating to Antarctica (the Antarctic Treaty, signed by 12 countries), its land does not constitute the sovereign territory of any one State Party. Thus WHL recognition could only follow changes to the operation of the World Heritage Convention, as is suggested for marine heritage under the high seas (Freestone *et al.* 2016) and would be needed for space technology heritage beyond the surface of the planet, as already discussed.

While the case studies also refer to broader cultural associations such as rock art sites, none of them is closely associated with cultural sites that manifest a direct tangible connection with astronomy, although Mauna Kea in Hawai‘i, like the Aoraki-Mackenzie region in New Zealand discussed above, is connected with a cultural tradition emanating from the ancient Polynesians in which star knowledge is deeply embedded and respected. Ironically, instead of reinforcing the case for heritage recognition of the Mauna Kea Observatory, such associations cause potential conflict in that some indigenous groups regard the telescopes as encroaching upon land that is, for them, sacred and should not be used for such purposes. A recent meeting that formed part of the IUCN World Conservation Congress held in Honolulu in 2016, seeking ways in which the conflict might be resolved, drew attention to the unique relationship that exists in the Hawaiian Islands between cutting-edge science and technology and indigenous culture, through the medium of the sky and astronomy, and to their common concern to preserve dark starry skies.

An additional issue with regard to modern observatory sites and their dark skies is whether they are more appropriately considered sites or cultural landscapes (in the World Heritage sense),[3] in that they typically comprise collections of buildings and telescopes scattered over a considerable area, including perhaps more than one adjacent mountain peak (as at AURA). The obvious attraction of the cultural landscapes option is that these are “combined works of nature and of man" which raises the possibility of including of both the observatory and its dark sky in an integrated way. Cultural landscapes also embody both tangible and intangible heritage; they result from cultural and natural processes that began in the past and will continue into the future; and change is inherent in living landscapes, something that also applies to working observatory sites. On the other hand, we can recall the concept of a “monument of science” developed in TS1 (p. 267), which encapsulates the idea that an astronomical observatory is an integrated system linking fixed, movable and intangible heritage, and where change and development is inevitable.

There is no simple theoretical solution as to which approach—sites (groups of buildings) or cultural landscapes—would be more appropriate for modern observatories. But the answer could effect dark sky considerations. If the dark sky were viewed as a characteristic of a cultural landscape, its definition—and regulation—would be more complex than for a cultural site (set of buildings and/or monuments). It would also affect the choice of buffer zone. If a property was nominated as a cultural or natural landscape with the dark skies as an additional value, a large buffer zone would need to be considered for regulation, up to and including the skyline.

### ***Conclusions***

The dark sky does not constitute a part of a property in the juridical sense: it is not a tangible feature specific to a location, nor is it an immovable attribute of the place. Yet it can clearly be viewed as a natural attribute that can add to the natural value of a property. In certain cases it can also support important historical and social values; in such cases it could (also) be seen as an intangible cultural attribute. In other words, the dark-sky characteristics of a place can feature

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3 According to UNESCO’s *Operational Guidelines*, a World Heritage cultural property may comprise sites (“works of man”) or cultural landscapes (“combined works of nature and man”). A site may comprise groups of buildings or monuments, for example “groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of Outstanding Universal Value from the point of view of history, art or science.” A cultural landscape is an area “of Outstanding Universal Value from the historical, aesthetic, ethnological or anthropological points of view” which is “illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal.”

among a set of attributes of value, cultural or natural, that could together justify OUV. In this case, maintaining those dark skies would become an important management issue. In any case, the quality of the sky can be regarded as a quality of the global landscape, and its conservation (for example, by regulations to control light pollution) as an aspect of good management of the property.

For modern observatory sites and their dark skies, potential OUV is likely to rely mainly upon presenting a site or ensemble of sites

- as technological and scientific implementations leading to major contributions to the history of astronomy [WH criteria (iv) and (vi)];
- as technological and scientific masterpieces [WH criterion (i)];
- as some of the best places on the planet for sky transparency and atmospheric stability [WH criterion (vii)];
- as outstanding examples of international cooperation for human progress in knowledge and science, forming part of a long-standing and ongoing tradition among the community of astronomers [WH criterion (ii)];

and/or

- as peaceful and sustainable examples of the use of exceptional natural locations for human progress in knowledge and science [WH criterion (iv)].

The cultural landscape concept may merit consideration in some cases. This is because it not only encapsulates the interaction between people and their environment but also represents a category of heritage that is intrinsically evolving. The same is true of places of science, and in particular of still-functioning observatories and their dark skies: concepts such as sustainability—the need to preserve cultural and/or natural values in a context that is inevitably changing—apply equally to both.

## Issues relating to serial nominations

Paris Observatory is without doubt a place of the foremost importance for the history of astronomy within the history of European civilization. It demonstrates strong integrity and authenticity, is well conserved, and has a good collection of instruments and outstanding archives. Potential OUV might be demonstrated in various ways, just as the OUV of the Royal Observatory Greenwich, UK, is already recognised in terms of navigation and the measurement of longitude (as part of the Maritime Greenwich WHP, whc.unesco.org/en/list/373) and that of Pulkovo Observatory, Russia, as part of an architectural ensemble (the Historic Centre of St Petersburg and Related Groups of Monuments WHP, whc.unesco.org/en/list/540).

It is also clear that Paris Observatory it is one of a family—classical observatories of the Western world, built both within Europe and in the colonies—that, collectively, are very significant in the history of humankind. This group might well include Greenwich, Pulkovo and the Cape Observatory, South Africa, as well as many others. This suggests that a serial nomination might be an appropriate way forward. What are the relative strengths of the individual and the serial approaches?

### *General considerations*

Taking account of the *Operational Guidelines*, of WH Committee decisions and recommendations, and of the reports of the advisory bodies governing evaluations, we can identify the following general considerations concerning serial nominations:

- The group must comprise those places that best demonstrate the potential OUV of the whole ensemble. Various attributes might demonstrate potential OUV under one or more of

UNESCO's criteria, and not all attributes of value have to be demonstrated at every component property in the series. However, each component must contribute significantly to some facet of the overall OUV, otherwise a serial property could represent little more than a catalogue. The comparative analysis, which forms a crucial part of the nomination dossier, must ensure not only that all properties that best support the statement of OUV are included in the sample but also that no equally important sites are excluded, from a global perspective.

- It is possible to include a place already on the WHL within a subsequent serial nomination. Precedents include the Frontiers of the Roman Empire WHP (whc.unesco.org/en/list/430), inscribed in 2008, which includes the pre-existing Hadrian's Wall WHP (UK), inscribed in 1987. Whatever its existing recognized values, as a component of a new ensemble the place must contribute significantly to the OUV of that ensemble as explained above.
- The components of a serial nomination need to be defined in a common way, with an overall management plan and a global conservation policy. This implies, for example, that no serial property could comprise a mixture of "sites" (collections of buildings, monuments) and cultural landscapes. In practice, there are very few WH serial properties that are sets of extended landscapes, an exception being the two mining areas in Slovenia and Spain that form the Heritage of Mercury WHP (whc.unesco.org/en/list/1313).
- Ideally, all the components of a potential serial inscription will be nominated together, as happened in the case of the Struve Geodetic Arc WHP (whc.unesco.org/en/list/1187). However, where this is not practicable (for example, given the complexities of developing transnational nominations), it is possible to adopt a staged approach in which, although the complete set of components is specified at the outset, only a subset of the component properties is nominated in each stage. For inscription, the set of components proposed at the first stage must demonstrate OUV in itself, and the remaining components need to add to that OUV.
- Integrity considerations dictate that a threat to the OUV of any individual component is a threat to the OUV of the serial property as a whole. Thus, if one component is at risk then the whole serial property will be considered at risk and put on UNESCO's list of World Heritage in Danger.

Ultimately, State Parties must make the decision as to whether a single outstanding example or an ensemble would provide a better demonstration of potential OUV (see TS1: 267–268).

### *Classical observatories*

As regards the classical observatories, there are various possibilities of a serial nomination demonstrating a significant advance in science.

A case could perhaps be made for including *all* observatories from the 17th to the early 20th centuries that might wish to be included, as a serial nomination. They were established for similar reasons and very often were the first research institutions in their various countries. The remarkable number of such establishments and their basic similarity is conveyed by the study *Astronomical Observatories: from Classical Astronomy to Modern Astrophysics* (Wolfschmidt 2009).

If a few such observatories were to be chosen, one would have to ask which ones stand out among the generality. Tangible features might include the architecture, the presence of the first instruments of a particular kind, and so on. Intangible factors might include major discoveries made from the site and the public perception of the ranking of an observatory as a whole among other institutions or historical buildings.

A serial nomination could be considered for several observatories within a given country. For example, within South Africa there are two large optical observatories other than the Cape Observatory: the Boyden Observatory of the University of the Free State (formerly a part of Harvard University) and the Republic Observatory in Johannesburg (no longer doing active astronomical research). Both these institutions have campuses, old instruments and buildings, and are associated with some important discoveries (e.g., of the first dwarf galaxies at Boyden, and of the nearest star, Proxima Centauri, at the Republic Observatory). One might therefore consider these three institutions as an ensemble representing foreign observing stations of northern hemisphere institutions. However, one must identify a strong enough thematic linkage to demonstrate potential OUV as an ensemble, otherwise one faces the danger of producing what is essentially no more than a catalogue of sites (TS1:269–270).

Another relevant issue in relation to observatories is the question of whether outlying meridian marks and other peripheral structures in separate locations should be recognised as part of a thematic ensemble. In the case of the Cape Observatory, for example, there remains a north meridian mark on the hill known as Blaauberg, about 20km away across Table Bay. The observatory was also involved with pioneering geodetic surveys. About 75 km to the north are two pyramids that define the end of a geodetic baseline set out by Thomas Maclear in the mid-19th century, and about 140 km to the north is a monument marking Maclear's efforts to verify the geodetic surveys of N-L de la Caille in 1752. These sites already enjoy protection as National Monuments.

On a related issue, there has also been some interest in promoting as global heritage a geodetic arc following the 30°E meridian down through Africa from Egypt to Port Elizabeth in South Africa. This "30th Meridian Arc", initiated in 1883 but only eventually completed in 1954 (Braun 2003; Smith 2006), has been connected to the more famous Struve Arc (whc.unesco.org/en/list/1187), already a serial World Heritage property spanning 10 countries, and suggested as a possible extension to the existing Struve Arc inscription. Aside from the need to establish heritage value that would add to the existing OUV, the administrative complexities of adding a further 10 countries or so to an existing ensemble of 10 countries would be considerable.

### *Modern observatory sites and their dark skies*

The discussion above suggests that some or all of the modern observatory sites and their dark skies included as case studies in this volume could constitute part of a potential serial nomination. Whichever way potential OUV is to be demonstrated, however, the comparative analysis could raise complex issues. For example, not all high-elevation observatories are on mountain summits, an example being the Observatorio Astronómico Nacional (Colombia), constructed in 1803 at an elevation of approximately 2600m but within the city of Bogotá; places with the most exceptional atmospheric quality on the planet are not necessarily on mountains but may (according to some astronomers) also exist in locations where no observatories have been built, e.g. within Turkmenistan and Uzbekistan; and other high mountain summits around the world—including some where major observatories were built before the second half of the 20th century, such as California (USA) and the Pyrenees (France)—do not have the exceptionally high sky transparency and atmospheric stability that marks out such locations in the Canary Islands, the Hawaiian Islands, or northern Chile.

A productive approach may be to adopt a "chronological differentiation" methodology identifying distinct phases of development with different characteristics, while recognizing a particular ensemble of (late-19th and) 20th-century observatories built on high mountains, as a whole, as an outstanding heritage landmark representing the revolution in humanity's understanding of the cosmos that has taken place through scientific and technological cooperation and achievement at some of the most exceptional locations on the planet. For example, one could identify three phases as follows:

- Phase I (1880–1910): Pioneers first conquer high mountains to set up astrophysical observatories.
- Phase II (1910–1960): Such observatories are responsible for discoveries that revolutionized humanity's perception of the cosmos (e.g. the existence of other galaxies; the expansion of the universe).
- Phase III (1960–2000): Technological masterpieces achieved by international cooperation are constructed at the very best places on the planet, leading the way to even greater discoveries and expansion of the boundaries of human knowledge (e.g. cosmic acceleration and dark energy).

In such a scheme, one can simultaneously recognize the importance of Pic du Midi de Bigorre (established—at first as a meteorological observatory—in 1881, becoming an astronomical observatory in 1908) as a pioneering achievement in Phase I, particularly in terms of its elevation (2900m); that of Mt Wilson (case study TS1:206–208), which is not at a particularly high elevation and where the dark sky has been obliterated by light pollution, in terms of its fundamental contribution to cosmology in the first half of the 20th century; and the three "Windows to the Universe" observatories where extraordinary international technological and scientific cooperation maintain the cutting edge at some of the most exceptional locations on the planet.

***Archaeoastronomical sites***

The potential for a serial nomination of archaeoastronomical sites is explored below with reference to the case study on seven-stone antas (Portugal and Spain).

***Intangible heritage***

Serial nominations are also possible under the Convention for the Safeguarding of Intangible Cultural Heritage (CICH), raising the possibility of international nominations relating to key intangible themes such as ocean navigation.

## The recognition and management of astronomical values at archaeological sites

While ancient sites may have a strong connection to astronomy, in no cases do the astronomical values exist in isolation. So-called "observatories" (Belmonte 2014) are, if anything[4], invariably temples, tombs or other buildings with connections to the sky manifested in features such as their orientation. Thus while Chankillo in Peru presents a unique example of “landscape timekeeping”, as the case study puts it—a monumental device that enabled the calendar to be regulated against the horizon rising and setting positions of the sun throughout the year—this existed as part of a ritual complex evidently devoted to a cult that linked warfare, calendrical regulation, sun worship and social hierarchy. Appreciating the social and religious context is vital to the interpretation of the site and the assessment of its value as a whole. Thus, while the potential OUV may be supported mainly by the astronomy, it is essential to take account of the secondary attributes deriving from this broader context.

Similarly, the seven-stone antas of Portugal and Spain represent the remains of tombs which, by being consistently oriented upon points within the solar rising arc on the horizon, manifest a conceptual connection between death, ancestors or ancestral spirits and the rising sun that prevailed over a remarkably wide area during the 4th millennium BC. Their unique importance, astronomically speaking, derives from the fact they provide the earliest examples of a custom of sunrise orientation that is statistically defensible — in contrast, for example, to the

[4] On the question of the credibility of archaeoastronomical evidence see TS1:270–271.

famous solstitial orientation of Newgrange passage tomb in Ireland (part of the Brú na Bóinne World Heritage Property, whc.unesco.org/ en/list/659), which is a "one-off". But any potential World Heritage nomination would also need to acknowledge the broader archaeological context of these monuments, for instance the remarkable consistency in their architectural design.

The existence of solstitial orientations at several monuments within the Stonehenge World Heritage Property (see case study) reinforces their intentionality, although not at the level of formal statistical support. At Stonehenge, in contrast to the other examples, the astronomical attributes of OUV were only recognised retrospectively, after Stonehenge had already been inscribed on the World Heritage List for over 25 years[5] (as part of the Stonehenge, Avebury and Associated Sites WHP whc.unesco.org/ en/list/373). The case study focuses on the management issues that arise as a consequence.

Given that the Chankillo ritual complex as a whole represents the cultural transformation of a natural landscape covering more than 17 $km^2$, containing not only the thirteen towers that provide the foresights for the solar observation device but also an extraordinary triple-walled fortified temple and various other monumental constructions, both a site and a cultural landscape approach are open as possibilities here.

In contrast, the seven-stone antas are much more modest constructions scattered over many hundreds of kilometres within a developed landscape, which suggests a serial approach. Indeed, such an approach is necessary since the astronomical significance is only evident from the group as a whole (cf. TS1: 269). While the orientation of any particular monument in the group could have arisen through factors quite unrelated to astronomy, it is the fact that all 177 measured sites face within the arc of sunrise that proves this was intentional. The fact that the monuments are, in the main, situated in a flat landscape lacking prominent topographic landmarks demonstrates beyond doubt not only that orientation was a key architectural consideration in the design and constructions of these tombs but that the correct orientation could only have been achieved by reference to the sky. On the other hand, it is clear that not all of the 177 sites (and perhaps no more than a select few) could contribute significantly to the potential OUV, most obviously because of their poor state of conservation and lack of integrity.

## Breaking new ground

World Heritage concepts, definitions and processes are not fixed for all time. Indeed, UNESCO's *Operational Guidelines for the Implementation of the World Heritage Convention* (whc.unesco.org/ en/guidelines/) are continually updated to take account of changing concepts and new experience. A good example is the introduction of the concept of cultural landscapes in 1994. Expert workshops are an essential part of this process, an example being that on serial nominations held in Switzerland in 2010 (whc.unesco.org/document/124861), Thematic Studies and other publications, and nomination proposals that raise new issues, periodically motivate and inform revisions to the overall vision of World Heritage.

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5 Amanda Chadburn writes: "There are a number of reasons for this. Firstly, archaeoastronomy has developed significantly as a discipline since the 1980s. In parallel, the discipline of landscape archaeology has also developed, gained in importance and become more recognised. This means that our understanding of ancient sites of archaeoastronomy in their landscape context has altered. Secondly, our understanding of the Stonehenge landscape has dramatically changed in the last 25 years, after years of research that has been particularly intensive since 2000 (Darvill 2005). Some new sites of astronomical importance have been discovered. Thirdly, an appreciation of the settings of sites, buildings and monuments has considerably altered in the UK since the 1980s (see, for example, English Heritage 2011), and finally, and management of WHPs has radically changed and developed, for example through UNESCO's *Operational Guidelines for the World Heritage Convention*."

A number of the case studies discussed in this volume break new ground, or at least push beyond existing boundaries, in various respects. For example, the "Windows to the Universe" observatory sites, dating from 1959 onwards, are more recent than any already currently on the World Heritage List. While there is no "time limit" from a World Heritage perspective—indeed, cultural landscapes can include living (intangible) heritage—it is clear that telescopes still under construction could not be considered as tangible heritage, because their potential (in terms of technological achievement and scientific discovery) has not yet been fulfilled. As regards precedents, there are very few historical observatories on the World Heritage List and no observatories from the 20th century (whether or not still undertaking active science). The most recent example on a National Tentative List at the time of writing is Jodrell Bank (UK), founded in the late 1940s. UNESCO has a Modern Heritage Programme (whc.unesco.org/en/modernheritage/) to promote 19th- and 20th-century architectural heritage: cities and urban planning, monuments and palaces, industrial heritage, etc. Examples on the World Heritage List include Brasilia, created in the late 1950s, and several from the early 20th century (whc.unesco.org/document/117571). Potential value under criterion (vi) is not limited in any absolute sense by time, but the value of recent scientific discoveries as intangible heritage must still be recognized and defined by established World Heritage recommendations and practice.

Even at existing World Heritage Properties, OUV is a living issue: it is not defined for eternity, and the revision of OUV is normal. This raises the possibility of modifying the statements of OUV for existing World Heritage Sites so as to include more explicit recognition of their astronomical values: for example, by altering boundaries and/or the buffer zone, by the inclusion of environmental aspects such as dark sky protection, and adding measures to manage and preserve significant sightlines to horizons. The Stonehenge case study explicitly addresses the last of these issues.

The case study of the sun- and star clocks of Oman describes possible refinements or extensions of existing criteria of OUV at an existing World Heritage Property. The *aflaj* (irrigation channels) of Oman were inscribed in 2006 under criterion (v) and the ICOMOS evaluation on p.51 of the nomination file (whc.unesco.org/en/list/1207/documents) recognises that criteria (ii) and (iv) might also be justified on the basis of further information. One could also envisage enhancements of the value under criterion (v). The collection of *aflaj* irrigation systems represents some 3,000 still functioning systems in Oman. Ancient engineering technologies demonstrate long-standing, sustainable use of water resources for the cultivation of palms and other produce in extremely arid desert lands. Such systems reflect the former total dependence of communities on this irrigation, and the astronomical timing of the apportionment of water represents a time-honoured, fair and effective management and sharing of water resources, underpinned by mutual dependence and communal values.

The need to balance the World Heritage List so as to better represent the heritage of human achievements in the fields of science and technology has been clearly recognized for well over a decade, for example in the establishment of the Astronomy and World Heritage Initiative itself in 2003 (whc.unesco.org/en/astronomy/). Yet such heritage raises fundamental issues and demands innovative approaches to familiar concepts such as integrity and authenticity. Additionally, dark-sky recognition has long been problematic in the World Heritage context. This creates difficulties for State Parties and challenges for UNESCO's advisory bodies.

This Thematic Study demonstrates the feasibility of such nominations on a technical level. Astronomy has a place on the World Heritage List, but not every site considered important by astronomers has a place on this list. At the time of writing, the International Astronomical Union has resolved to establish its own "outstanding astronomical heritage" certification to be attributed to astronomical sites and institutions that had a significant role in the history of astronomy. This will help establish the credibility of the site from a global heritage perspective and, potentially, provide an important step towards World Heritage List nomination in appropriate cases.

Since January 2015, it has been possible for State Parties to request advisory missions as part of the "upstream processes" whereby UNESCO's advisory bodies can provide advice and assistance to governments who are considering potential nominations. (In the case of properties with a connection to astronomy, the IAU understands that it might also be called upon to provide upstream advice alongside the advisory bodies in its capacity as a Partner Organization to UNESCO.) It seems clear that an early upstream involvement from the advisory bodies could be especially important in the development of nomination dossiers in this challenging but hugely important and underrepresented area of human heritage.

## Acknowledgements

I am most grateful to Michel Cotte for his comments and suggestions on earlier drafts of this discussion.

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